February 2020
Proposed Chehalis River Basin Flood Damage Reduction Project
SEPA Draft Environmental Impact Statement

Appendix E
Fish Species and Habitats Discipline Report

Publication No.: 20-06-002

DEPARTMENT OF
ECOLOGY
State of Washington

About this Document

This discipline report has been prepared as part of the Washington Department of Ecology's (Ecology's) State Environmental Policy Act (SEPA) Environmental Impact Statement (EIS) to evaluate a proposal from the Chehalis River Basin Flood Control Zone District (Applicant).

Proposed Action

The Applicant seeks to construct a new flood retention facility and temporary reservoir near Pe Ell, Washington, and make changes to the Chehalis-Centralia Airport levee in Chehalis, Washington. The purpose of the Applicant's proposal is to reduce flooding originating in the Willapa Hills and improve levee integrity at the Chehalis-Centralia Airport to reduce flood damage in the Chehalis-Centralia area.

Time Frames for Evaluation

If permitted, the Applicant expects Flood Retention Expandable (FRE) facility construction would begin in 2025 and operations in 2030, and the Airport Levee Changes construction would occur over a 1-year period between 2025 and 2030. The EIS analyzes probable impacts from the Proposed Action and alternatives for construction during the years 2025 to 2030 and for operations from 2030 to 2080. For purposes of analysis, the term "mid-century" applies to the operational period from approximately 2030 to 2060. The term "late-century" applies to the operational period from approximately 2060 to 2080.

Scenarios Evaluated in the Discipline Report

This report analyzes probable significant environmental impacts from the Proposed Action, the Local Actions Alternative, and the No Action Alternative under the following three flooding scenarios (flow rate is measured at the Grand Mound gage):

- **Major flood:** Water flow rate of 38,800 cubic feet per second (cfs) or greater
- **Catastrophic flood:** Water flow rate of 75,100 cfs
- **Recurring flood:** A major flood or greater that occurs in each of 3 consecutive years

The general area of analysis includes the area in the vicinity of the FRE facility and temporary reservoir; the area in the vicinity of the Airport Levee Changes; and downstream areas of the Chehalis River to approximately river mile 9, just west of Montesano.

Local Actions Alternative

The Local Actions Alternative represents a local and nonstructural approach to reduce flood damage in the Chehalis-Centralia area. It considers a variety of local-scale actions that approximate the Applicant's purpose through improving floodplain function, land use management actions, buying out at-risk properties or structures, improving flood emergency response actions, and increasing water storage from Pe Ell to Centralia. No flood retention facility or Airport Levee Changes would be constructed.

No Action

Under the No Action Alternative, no flood retention facility or Airport Levee Changes would be constructed. Basin-wide large and small scale efforts would continue as part of the Chehalis Basin Strategy work, and local flood damage reduction efforts would continue based on local planning and regulatory actions.

SUMMARY

Aquatic resources include the fish, shellfish, aquatic macroinvertebrates, and marine mammal species in the study area. Attributes of native species that are evaluated include their ecological role, federal and state special status, and their role in fisheries. Non-native fish species are managed in the Chehalis River for recreational fishing and are analyzed in terms of their role in recreational fisheries and their effects on native fish species. Freshwater aquatic macroinvertebrates are also evaluated as a key fish prey item and indicator of aquatic habitat health. Finally, indirect impacts to marine mammals and fish-eating birds are identified because they depend on fish prey (such as Chinook salmon [*Oncorhynchus tshawytscha*]) likely to be affected by the Proposed Action and the No Action Alternative.

The aquatic habitat resources analyzed include instream habitat and nearby freshwater floodplain wetlands that are hydraulically connected to the Chehalis River and allow fish to access the habitat from the river.

The primary study area for aquatic species and habitats includes areas that could be affected by the Proposed Action, including the following three specific areas (Figures E-1a and E-1b):

- Area of the proposed FRE facility and associated access, construction, and maintenance areas
- Area of proposed maximum inundation extent for the temporary reservoir on the mainstem upper Chehalis River and upstream tributaries
- Area downstream of the proposed FRE facility including reaches near the airport levee

The primary study area for the analysis of impacts to fish and shellfish ranges from the headwaters of the Chehalis River to the modeled extent of potential late-century catastrophic flooding, about river mile (RM) 9, west of Montesano (Figure E-1a). This includes the lower portions of major Chehalis River tributaries including the South Fork Chehalis, Newaukum, and Skookumchuck rivers. Within the primary study area, impacts to aquatic habitat are addressed for three areas that have distinct physical, biological, and chemical attributes needed for fish and shellfish species:

- Headwaters and upper mainstem Chehalis River
- Middle and lower mainstem Chehalis River
- Off-channel and emergent wetland habitats

The salmon and steelhead (*Oncorhynchus* spp.) and Pacific lamprey that originate from the Chehalis Basin are migratory and anadromous, meaning they spend part of their life cycles migrating through the mainstem Chehalis River, to access other major tributary rivers, and part in Grays Harbor estuary and the ocean. To characterize direct impacts within the study area and to evaluate the indirect effect of migratory fish on larger food webs and communities, this evaluation also considers a broader study area. The broader study area includes Grays Harbor estuary and the Pacific Ocean where communities and food webs may be affected by changes in anadromous species abundance.

Resources used to develop the analyses include records and reports developed by the State of Washington Department of Fish and Wildlife for the Chehalis Basin and quantitative fish population and habitat modeling of areas that will be affected in the Chehalis Basin. An integrated modeling approach using the Ecosystem Diagnosis and Treatment (EDT) Life-Cycle Model (LCM) was used to identify the potential impacts on coho salmon, steelhead, and spring-run and fall-run Chinook salmon from the Proposed Action. For other, non-salmon native fish, the Physical Habitat Simulation (PHABSIM) model was used to estimate changes in usable habitat area. Other estimate of change in habitat or species abundance are based on observational studies in the Chehalis Basin and comparisons to similar scenarios in published literature where quantitative information is lacking. In addition, the Proposed Action analysis incorporates changes over time habitat potential due to projected effects of a changing environmental baseline.

Several other discipline reports prepared for the project provide detailed information on resources that influence fish and other aquatic species and habitats in the study area. Information about vegetation and wildlife that may interact with fish can be found in the *Wildlife Species and Habitats Discipline Report* (Anchor QEA 2020a). The *Water Discipline Report* (ESA 2020a) describes surface waters and groundwater, water uses, water rights, and streamflows that affect aquatic habitat. More detailed information on wetlands and regulatory waterbodies in the study area is available in the *Wetlands Discipline Report* (Anchor QEA 2020b). The *Earth Discipline Report* describes geologic and geomorphic conditions that influence habitat for aquatic species in the study area (Shannon & Wilson and Watershed Geodynamics 2020). Finally, recreational and tribal fisheries are discussed in the *Recreation Discipline Report* and *Tribal Discipline Report* (ESA 2020b, Anchor QEA 2020c), respectively.

Table E-1 summarizes the impacts identified and mitigation proposed for the aquatic habitats and species addressed.

Table E-1
Summary of Fish Species and Habitats Impacts from the Proposed Action

IMPACT	IMPACT FINDING	MITIGATION PROPOSED (SUMMARIZED, SEE SECTION 3.2.6)	SIGNIFICANT AND UNAVOIDABLE ADVERSE IMPACT
PROPOSED ACTION (FRE FACILITY AND AIRPORT LEVEE CHANGES) – CONSTRUCTION			
Headwaters and Upper Chehalis River (including FRE facility and temporary reservoir): Impacts to fish, aquatic species, and aquatic habitat function from: temporary dewatering of the river at the FRE facility site, in-water work, reduced fish passage, permanent elimination of 0.32 acre of reduced instream aquatic habitat, degraded riparian function, reduced nutrient availability, and removal of large trees in 600 acres of the temporary reservoir area. Increases in temperature 2°C to 3°C in summer and decrease in dissolved oxygen due to loss of vegetation in the FRE facility and temporary reservoir area.	**Significant:** - Aquatic habitat - Spring-run and fall-run Chinook salmon, coho salmon, and steelhead in the Above Crim Creek Subbasin - Non-salmon native fish - Freshwater mussels **Significant** to moderate: - Macroinvertebrates	**FISH-1:** Develop and implement a Fish and Aquatic Species and Habitat Plan. **EARTH-3:** Develop and implement a Large Woody Material Management Plan. **WATER-1:** Develop and implement a Surface Water Quality Mitigation Plan. **WET-1:** Develop and implement a Wetland and Wetland Buffer Mitigation Plan. **WET-2:** Develop and implement a Stream and Stream Buffer Mitigation Plan. **WILDLIFE-1:** Develop and implement a Vegetation Management Plan. **WILDLIFE-2:** Develop and implement a Wildlife Species and Habitat Management Plan. **WILDLIFE-3:** Develop and implement a Riparian Habitat Mitigation Plan.	**Yes, unless mitigation is feasible**
Upper and Middle Chehalis River (downstream of FRE facility): Impacts to species and aquatic habitat function from construction activities, in-water work, and reduced fish passage. A 2°C to 3°C temperature increase in summer due to loss of vegetation in the temporary reservoir area going downstream from the FRE facility site to the confluence with the South Fork Chehalis River.	**Significant** - Aquatic habitat - Salmon and steelhead in the Rainbow Falls to Crim Creek sub-basin - Migratory non-salmon native fish - Freshwater mussels **Significant** to moderate -Macroinvertebrates Moderate - Non-migratory native fish	Same as above	**Yes, unless mitigation is feasible**

IMPACT	IMPACT FINDING	MITIGATION PROPOSED (SUMMARIZED, SEE SECTION 3.2.6)	SIGNIFICANT AND UNAVOIDABLE ADVERSE IMPACT
Impacts to Southern Resident killer whales from the reduction of salmonids from the Chehalis River, especially Chinook salmon.	Moderate	Same as above	No
Noise and vibration at the FRE facility site may injure or disturb fish.	Moderate	None	No
Impacts to marine mammals (other than Southern Resident killer whales) from reduction in salmonids.	Minor	None	No
Impacts to fish-eating birds from reduction in salmonids.	Moderate to Minor	None	No
No impacts to aquatic species in Floodplain Off-Channel and Emergent Wetland Habitats.	No impact	None	No
No impacts from airport levee construction on fish and aquatic habitat because no work would occur below the ordinary high water mark.	No impact	None	No
PROPOSED ACTION (FRE FACILITY AND AIRPORT LEVEE CHANGES) – OPERATIONS			
Upper Chehalis River (including FRE facility and temporary reservoir): Impacts to fish, aquatic species and aquatic habitat function from: increase in temperature (2°C to 3°C increases in summer) due to lack of large trees in the temporary reservoir, degraded riparian function, recurring inundation events affecting up to 847 acres of vegetation, reduced fish passage, bed scour affecting spawning grounds, degraded habitat, reduction in channel-forming flows and large woody material, and reduced nutrient contributions to the river.	**Significant** - Aquatic habitat - Spring-run and fall-run Chinook salmon, coho salmon, and steelhead in the Above Crim Creek sub--basin - Non-salmon native fish - Freshwater mussels **Significant** to moderate - Macroinvertebrates	**FISH-1:** Develop and implement a Fish and Aquatic Species and Habitat Plan. **EARTH-3:** Develop and implement a Large Woody Material Management Plan. **WATER-1:** Develop and implement a Surface Water Quality Mitigation Plan. **WET-1:** Develop and implement a Wetland and Wetland Buffer Mitigation Plan. **WET-2:** Develop and implement a Stream and Stream Buffer Mitigation Plan. **WILDLIFE-1:** Develop and implement a Vegetation Management Plan. **WILDLIFE-2:** Develop and implement a Wildlife Species and Habitat Management Plan.	**Yes, unless mitigation is feasible**

IMPACT	IMPACT FINDING	MITIGATION PROPOSED (SUMMARIZED, SEE SECTION 3.2.6)	SIGNIFICANT AND UNAVOIDABLE ADVERSE IMPACT
		WILDLIFE-3: Develop and implement a Riparian Habitat Mitigation Plan.	
Upper and Middle Chehalis River (downstream of FRE facility): Impacts to species and aquatic habitat function from: change in substrate transport process, reduced large woody material, reduced channel-forming flows, increase in temperature (2°C to 3°C increases in summer) due to lack of large trees in the temporary reservoir down to confluence with South Fork, increased turbidity from reservoir releases.	**Significant** - Aquatic habitat in the temporary reservoir area to the confluence South Fork Chehalis River - Spring-run and fall-run Chinook salmon, coho salmon, and steelhead in the Rainbow Falls to Crim Creek sub--basin - Non-salmon native fish - Freshwater mussels **Significant** to moderate - Macroinvertebrates Moderate - Aquatic habitat downstream to the South Fork Chehalis River	Same as above	**Yes, unless mitigation is feasible**
Changes to floodplain inundation extents downstream of the FRE facility and creation of new habitat from reduction in peak flows from FRE facility operations.	**Significant**	Same as above	**Yes, unless mitigation is feasible**
Impacts to Southern Resident killer whales from the reduction of salmonids, especially Chinook salmon.	Moderate	Same as above	No
Impacts to aquatic habitat above the temporary reservoir extent to the headwaters.	Moderate	Same as above	No
Impacts to marine mammals (other than Southern Resident killer whales) from reduction in salmonids.	Minor	None	No

IMPACT	IMPACT FINDING	MITIGATION PROPOSED (SUMMARIZED, SEE SECTION 3.2.6)	SIGNIFICANT AND UNAVOIDABLE ADVERSE IMPACT
Impacts to fish-eating birds from reduction in salmonids.	Moderate to Minor	Impacts to fish-eating birds from reduction in salmonids.	No
Short-term impacts on in-river and floodplain conditions from airport levee operations.	No impact	None	No

Table E-2
Summary of Fish Species and Habitats Impacts from Alternatives

IMPACT	IMPACT FINDING
LOCAL ACTIONS ALTERNATIVE	
Construction: Floodplain storage improvements and channel migration protection would result in sporadic, localized construction activity affecting fish habitat, with individual projects occurring over a long time.	Minor
Operation: Floodplain storage improvement activities and channel migration protection may impact fish, shellfish, and aquatic habitat if they occur in the river channel or adjacent floodplain areas.	Minor
Flood severity and frequency are expected to increase in the future.	**Continuing substantial flood risks**
NO ACTION ALTERNATIVE	
Aquatic habitats and species will be affected by increased flooding and climate change that would reduce habitat suitability and likely restrict native species abundance and distribution. The quality and quantity of habitat available to aquatic species will be impacted and the productivity of aquatic salmonid species throughout the study area will be reduced. Increased water temperatures and decreases in summer flows will substantially affect multiple cold-water adapted aquatic species. The distribution of warm-water adapted species could expand including invasive species.	**Continuing substantial flood risks**

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1 INTRODUCTION

This report describes aquatic species and habitats within the study area. This report evaluates potential impacts associated with the Chehalis River Basin Flood Control Zone District's (Applicant's) Proposed Action as well as the Local Actions and No Action alternatives.

1.1 Resource Description

Aquatic resources include the fish, shellfish, aquatic macroinvertebrates, marine mammal and fish-eating bird species in the study area. Attributes of native species that are evaluated include their ecological role, federal and state special status, and their role in fisheries. Non-native fish species are managed in the Chehalis River for recreational fishing and are analyzed in terms of their role in recreational fisheries and their effects on native fish species. Freshwater aquatic macroinvertebrates are also evaluated as a key fish prey item and indicator of aquatic habitat health. Finally, indirect impacts to marine mammals and fish-eating birds are identified because they depend on fish prey (such as Chinook salmon [*Oncorhynchus tshawytscha*]) that are likely to be affected by the Proposed Action and the No Action Alternative. Lists of fish and shellfish species that occur in the study area, aquatic macroinvertebrate types, and marine mammals that may be affected by the Proposed Action or alternatives are provided in Attachment E-1.

The aquatic habitat resources analyzed include instream habitat and nearby freshwater floodplain wetlands that are hydraulically connected to the Chehalis River and allow fish to access the habitat from the river. To evaluate the variety of the habitat types along the Chehalis River, habitats are divided into three types that are analyzed separately:

- Headwaters and upper mainstem Chehalis River
- Middle and lower mainstem Chehalis River
- Off-channel and emergent wetland habitat

Fish habitat resources are described in terms of the key physical, biological, and chemical attributes needed for fish and shellfish species within each habitat type. Each of the major habitat types is also described in terms of its function for supporting different species guilds and life stages.

The effects of the Proposed Action are analyzed quantitatively and qualitatively for anadromous salmon and steelhead and qualitatively for representative freshwater species including Pacific lamprey (*Entosphenus tridentata*), speckled dace (*Rhinichthys osculus*), largescale sucker (*Catostomus macrocheilus*), mountain whitefish (*Prosopium williamsoni*), largemouth bass (*Micropterus salmoides*; a key non-native predator), and smallmouth bass (*Micropterus dolomieu)* based on observational studies in the Chehalis Basin and comparisons to similar scenarios in published literature.

Several other discipline reports prepared for the project provide detailed information on resources that influence fish and other aquatic species and habitats in the study area. Information about vegetation and wildlife that may interact with fish can be found in the *Wildlife Species and Habitats Discipline Report* (Anchor QEA 2020a). The *Water Discipline Report* (ESA 2020a) describes surface waters and groundwater, water uses, water rights, and streamflows that affect aquatic habitat. More detailed information on wetlands and regulatory waterbodies in the study area is available in the *Wetlands Discipline Report* (Anchor QEA 2020b). The *Earth Discipline Report* describes geologic and geomorphic conditions that influence habitat for aquatic species in the study area (Shannon & Wilson and Watershed Geodynamics 2020). Finally, recreational and tribal fisheries are discussed in the *Recreation Discipline Report* and *Tribal Discipline Report* (ESA 2020b; Anchor QEA 2020c), respectively.

1.2 Regulatory Context

The jurisdictional authorities and regulations, statutes, and guidance relevant to impacts on fish species and habitats are summarized in Table E-3.

Table E-3
Regulations, Statutes, and Guidelines for Fish Species and Habitat

REGULATION, STATUTE, GUIDELINE	DESCRIPTION
FEDERAL	
Clean Water Act (33 United States Code [USC] 1251 et seq.)	Protects water quality in surface water and groundwater.
Section 404 of the Clean Water Act	Regulates the placement of dredged or fill material into waters of the U.S.
Section 401 of the Clean Water Act	Requires that a water quality certificate be obtained for any activity within waters of the U.S. that needs a federal permit.
Section 303(d) of the Clean Water Act	Requires that all states restore their waters to be "fishable and swimmable." Section 303(d) of the Clean Water Act establishes a process to identify and clean up polluted waters.
Endangered Species Act (16 USC 1531 et seq.)	Section 7 requires consultation with the U.S. Fish and Wildlife Service (USFWS) and/or the National Oceanic and Atmospheric Administration (NOAA) Fisheries when undertaking a federal action to ensure the conservation of any listed animal species and critical habitat so as not to jeopardize the continued existence of any listed species; NOAA Fisheries manages listed marine species while USFWS manages listed terrestrial and freshwater species.
Magnuson-Stevens Fishery Conservation and Management Act Provisions; Essential Fish Habitat (67 Federal Regulations 2343)	Governs marine fisheries management in U.S. federal waters; federal agencies are required to consult with NOAA Fisheries on activities that may affect essential fish habitat.

REGULATION, STATUTE, GUIDELINE	DESCRIPTION
Section 10 of the Rivers and Harbors Appropriation Act (33 USC 403)	The U.S. Army Corps of Engineers (Corps) regulates the obstruction or alteration of navigable waters of the U.S. below the ordinary high water mark; tributaries and backwater areas associated with navigable waters of the U.S. are also regulated under Section 10. The Corps navigable determination for the Chehalis River states: *"Project mileage begins at Union Pacific Railway bridge at Aberdeen, WA. Navigable to 68.5 miles above mouth, near Chehalis, WA."*
Fish and Wildlife Coordination Act (16 USC 661)	Requires equal consideration and coordination of wildlife conservation with other water resources development programs and provides authority to USFWS and NOAA Fisheries to evaluate impacts on fish and wildlife from federal actions that result in modifications to waterbodies.
STATE	
Forests and Fish Law (ESHB 2019)	Provides direction on how to implement the Forest Practices Act. These rules apply to both fish- and non-fish-bearing streams on timber-managed landscapes. Forest Practices Habitat Conservation Plan implemented in 2006.
Forest Practices Act (Revised Code of Washington [RCW] 76.09) and Forest Practices Rules Title 222 Washington Administrative Code (WAC)	The Washington Department of Natural Resources administers rules that govern forest practices activities on non-federal and non-tribal forestland in Washington state.
Washington State Hydraulic Code (220-660 WAC)	Serves to protect fish, shellfish, and their habitats by requiring all actions that use, divert, obstruct, or change the natural flow or bed of salt or fresh state waters to obtain a Hydraulic Project Approval from the Washington Department of Fish and Wildlife (WDFW).
WDFW State and Protected Species (220-610 WAC)	WDFW oversees the listing and recovery of state endangered, threatened, or sensitive species to ensure their survival as free-ranging populations in the state.
Washington Department of Fish and Wildlife Fish Passage Inventory, Assessment, and Prioritization Manual; 2019	The WDFW Fish Passage Inventory, Assessment, and Prioritization Manual provides standardized guidance for assessing structures that potentially block adult salmonid passage and identifying surface water diversion deficiencies, and an established protocol for prioritizing barrier corrections.
Washington State Shoreline Management Act (90.58 RCW)	Requires all local jurisdictions with Shorelines of the State to adopt Shoreline Master Programs consistent with the Shoreline Management Act, which emphasizes appropriate shoreline land use, protection of shoreline environmental resources, and protection of the public's right to access and use state shorelines.
Growth Management Act (RCW 36.70A)	Requires all cities and counties in Washington to adopt development regulations, according to the best available science, that protect critical areas as defined in RCW 36.70A.030(5), including fish and wildlife habitat conservation areas.

REGULATION, STATUTE, GUIDELINE	DESCRIPTION
Water Resources Act of 1971 (RCW 90.54)	Provides fundamentals of water resource policy for the state to ensure that waters of the state are protected and fully utilized for the greatest benefit to the people of the state of Washington; provides direction to state and local governments in carrying out water and related resources programs.
Washington State Wildlife Action Plan	Comprehensive plan for conserving the state's fish and wildlife and its natural habitats as part of the State and Tribal Wildlife Grants Program. Identifies the Species of Greatest Conservation Need and Priority Habitats and Species list, WDFW's catalog of habitats and species considered to be priorities for conservation and management. The Priority Habitats and Species list is intended to be used by local governments that are responsible for the protection of fish and wildlife habitat under the Growth Management Act, Shoreline Management Act, SEPA, and the Forest Practices Act.
Fish and Wildlife (Title 77 RCW)	Fish, shellfish, and wildlife species are managed under WDFW's authority; the following chapters are relevant to impacts on fish species and habitats: • **77.44:** Warmwater game fish enhancement program • **77.55:** Construction projects in state waters • **77.57:** Fishways, flow, and screening • **77.85:** Salmon recovery • **77.95:** Salmon enhancement program • **77.105:** Recreational salmon and marine fish enhancement program • **77.110:** Salmon and steelhead trout – Management of resources • **77.135:** Invasive species
Invasive/Non-Native Species (220-640 WAC)	Classifies prohibited and regulated species, and regulates the introduction or possession of non-native and invasive aquatic species.
Rivers and Habitat Open Space Program (222-23 WAC)	Policy on the permanent acquisition of conservation easements on forestlands and channel migration zones containing critical habitat for threatened and endangered species.
Washington Department of Natural Resources Natural Heritage Program	The Natural Heritage Program has no direct regulatory authority and is advisory only; conservation status assigned to species and habitats are used to support federal, state, and local land management policies and listing decisions.
LOCAL	
Lewis County Municipal Code Chapter 17.38 (Critical Areas); Chapter 17.25 (Shoreline Management)	Lewis County Code Title 17 (Land Use and Development Regulations) classifies and designates critical areas in Lewis County in Chapter 17.38 (Lewis County 2019); this chapter establishes regulations for the protection of ecological functions and values of critical areas outside of lands within the jurisdiction of the Shoreline Management Act.
Grays Harbor County Municipal Code Chapter 18.06 (Critical Areas Protection Ordinance)	Grays Harbor County Code Title 18 (Environment) identifies and regulates environmentally critical areas under Chapter 18.06 (Grays Harbor 2017); this chapter supplements development requirements in zoning classifications to provide additional controls consistent with best available science for the protection of environmentally critical areas.

REGULATION, STATUTE, GUIDELINE	DESCRIPTION
Thurston County Municipal Code Title 24 (Critical Areas); Title 19 (Shoreline Master Program)	Thurston County Code Title 24 establishes regulations and enforcement processes for the protection of critical areas (Thurston County 2018); the chapter considers the best available science in the designation, protection, and management of critical areas; Title 19 establishes regulations for the protection of shorelines.
Pacific County Ordinance No. 180 (Critical Areas and Resource Land); Ordinance No. 183 (Shoreline Master Program)	Pacific County Ordinance No. 180 implements the Growth Management Act and environment goals of the Pacific County Comprehensive Plan through protecting the functions and values of ecologically sensitive areas (Pacific County 2017); Ordinance No. 183 establishes the Shoreline Master Program to manage and protect shorelines.
City of Chehalis Municipal Code Chapters 17.21 to 17.27 (Critical Areas); Chapter 17.18 (Shoreline Substantial Development Permit)	Chehalis Municipal Code Chapter 17 (Uniform Development Regulations) establishes regulations pertaining to the development of critical areas to protect the environmentally sensitive resources of Chehalis and regulates development within the shoreline zone (City of Chehalis 2019).
City of Centralia Municipal Code Chapters 16.16 to 16.21 (Critical Areas); Chapter 16.08 (Shoreline Master Program)	Centralia Municipal Code Chapter 16 (Environment) regulates the use of land in and around critical areas, wildlife habitat, and natural hazard areas within the city and implements the Shoreline Master Program (City of Centralia 2019).

2 METHODOLOGY

2.1 Study Area

The primary study area for aquatic species and habitats includes areas that could be affected by the Proposed Action, including the following three specific areas (Figures E-1a and E-1b):

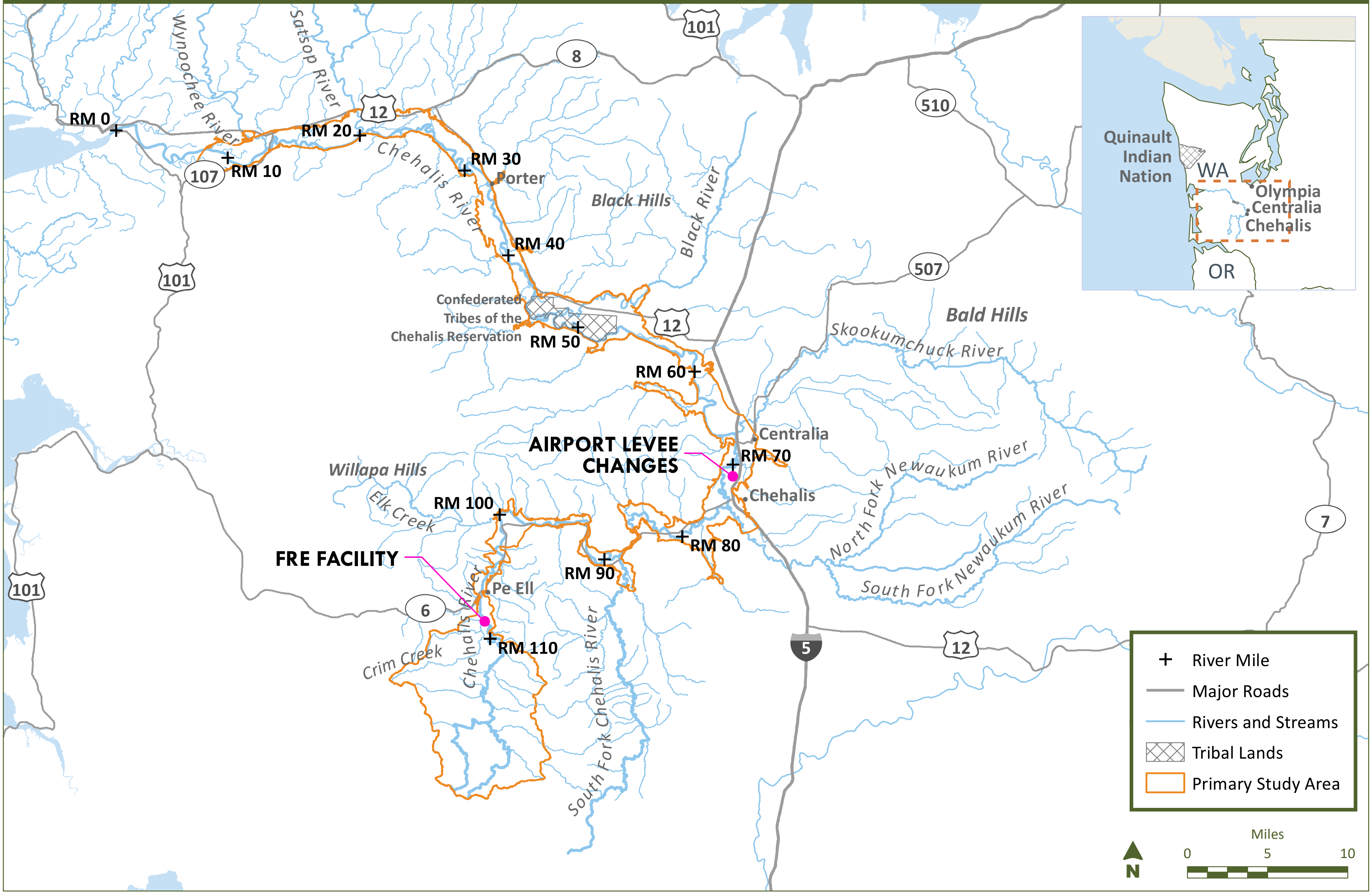
- Area of the proposed Flood Retention Expandable (FRE) facility and associated access, construction, and maintenance areas
- Area of proposed maximum inundation extent for the temporary reservoir on the mainstem upper Chehalis River and upstream tributaries
- Area downstream of the proposed FRE facility including reaches near the airport levee

The primary study area for the analysis of impacts to fish and shellfish ranges from the headwaters of the Chehalis River to the modeled extent of potential late-century catastrophic flooding, RM 9, west of Montesano, Washington (Figure E-1a). This includes the lower portions of major Chehalis River tributaries including the South Fork Chehalis, Newaukum, and Skookumchuck rivers.

The hydrologic effects of the Proposed Action are predicted to occur across more than 100 miles of the Chehalis River and its floodplain, extending from approximately 6 miles upstream of the proposed FRE facility to RM 9 west of Montesano, where the effects on fish would be most noticeable. Hydraulic changes caused by the Proposed Action would be small in magnitude downstream of the confluence with the Black River (RM 47), on the order of 0.5 to 1.5 feet in reduction in water surface elevation during flood retention (details available in the *Water Resources Discipline Report* [ESA 2020a]). For other potential impacts on fish and habitat, the downstream areas that could be affected by geomorphic and water quality effects of the FRE facility extend to just downstream of the confluence with the South Fork Chehalis River (RM 85; *Earth Discipline Report* [Shannon & Wilson and Watershed GeoDynamics 2020; Van Glubt et al. 2017]).

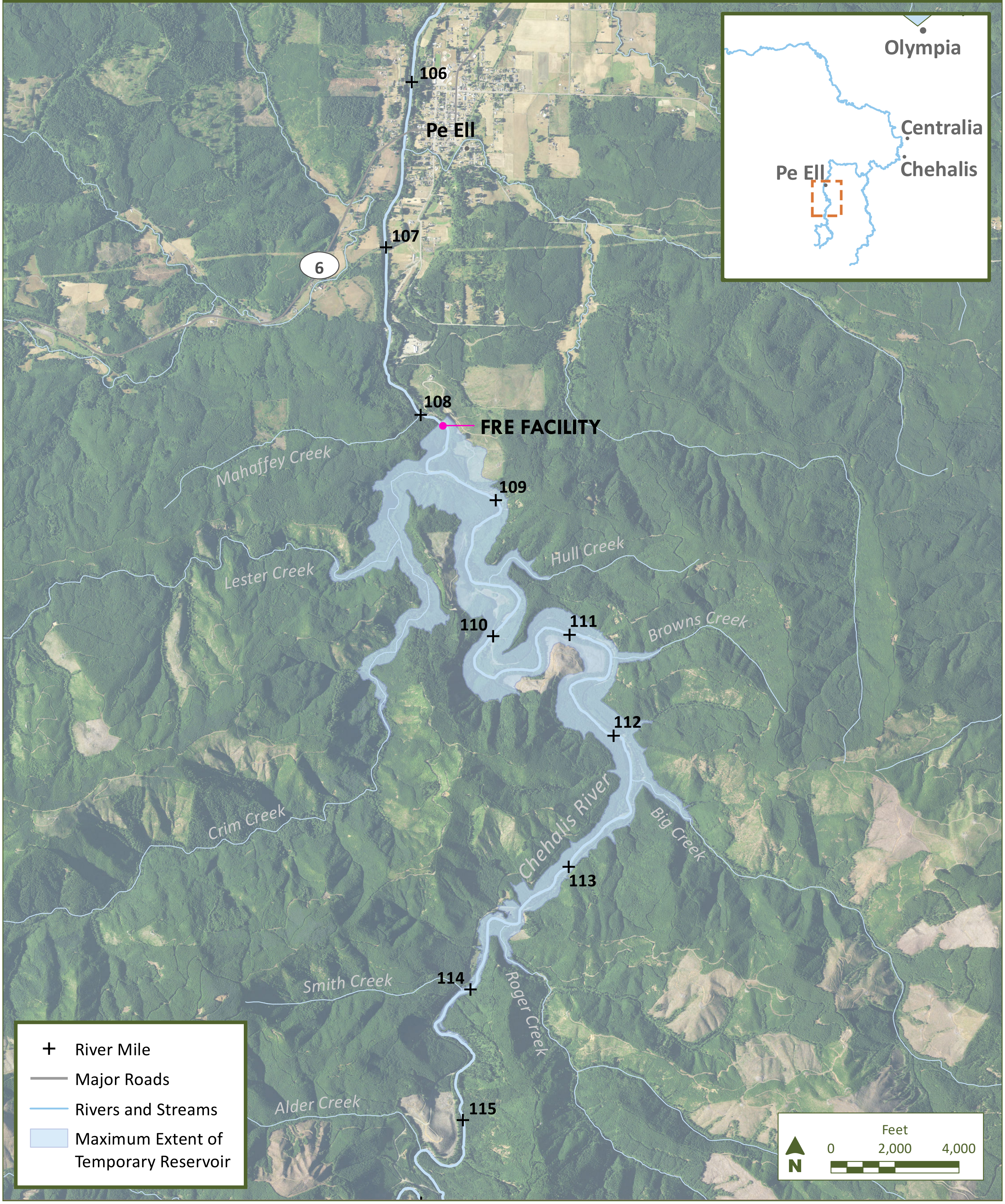
Salmon and steelhead (*Oncorhynchus* spp.) and Pacific lamprey that originate from the Chehalis Basin are migratory and anadromous, meaning they spend part of their life cycles migrating through the mainstem Chehalis River to access other major tributary rivers, and part in Grays Harbor estuary and the ocean. To characterize direct impacts within the study area and to evaluate the indirect effect of migratory fish on larger food webs and communities, this evaluation also considers a broader study area. The broader study area includes the tidally-influenced section of the Chehalis River downstream of RM 9, Grays Harbor estuary and the Pacific Ocean where communities and food webs may be affected by changes in anadromous species abundance.

Figure E-1a
Fish Species and Habitats Study Area



+	River Mile
—	Major Roads
—	Rivers and Streams
▨	Tribal Lands
☐	Primary Study Area

Figure E-1b
Fish Species and Habitats Study Area Near the Temporary Reservoir



Within the primary and broader study areas, discrete focus units (subbasins) were identified for modeling and analysis of impacts. More information on these subbasins and their use in impact analysis is described in Section 2.4.2.1.

If permitted, the Applicant expects FRE facility construction would begin in 2025 and operations in 2030, and construction of the Airport Levee Changes would occur over a 1-year period between 2025 and 2030. The EIS analyzes probable impacts from the Proposed Action and alternatives for construction during the years 2025 to 2030 and for operations from 2030 to 2080.

For operations, the effects of the following four types of flow conditions are analyzed (flow rate is measured at the Grand Mound gage):

- Major flooding with water flow rate of 38,800 cubic feet per second (cfs; FRE facility outlets closed)
- Catastrophic flooding with water flow rate of 75,100 cfs (FRE facility outlets closed)
- Recurring major or greater flood that triggers flood retention at the FRE facility in 3 consecutive years (FRE facility outlets closed)
- Periods when the FRE facility outlets are open, including typical seasonal flows that are not large enough to trigger flood retention by the FRE facility and summer low flows

2.2 Affected Environment

The following sections describe the types of fish, shellfish, aquatic macroinvertebrates, fish-eating marine mammals and birds, and habitats found within the study areas, with a focus on State Priority Habitats and Species. The discussion is divided into two sections, Aquatic Habitats and Aquatic Species. The habitats section describes the two Priority Habitats for fish, aquatic macroinvertebrates, and shellfish, known to be present in the primary study area: instream and floodplain habitat. The species sections describe those species known or likely to be present in the instream and freshwater wetland habitat within the primary study area based on recent research; these include freshwater fish (Section 2.2.2.1 and 2.2.2.2), shellfish (Section 2.2.2.3), and macroinvertebrates (Section 2.2.2.4).

Several freshwater species that occur in most reaches downstream of the primary study area are addressed qualitatively, including some with federal special status, because these species and habitats are downstream of the area that would be significantly impacted by the Proposed Action. The remaining sections describe two additional species groups of special concern: common riverine aquatic macroinvertebrates that are the prey for freshwater fish in the primary study area (Section 2.2.2.4), and marine mammal and bird predators in the broader study area that depend upon fish that originate from coastal rivers, including salmon (Section 2.2.2.5). See Attachment E-1 for a complete list of species in the primary and broader study areas and details on species status.

The Chehalis Basin is one of the few watersheds in Washington that does not have salmonid species (with the exception of bull trout) listed under the Endangered Species Act (ESA). Additionally, the watershed still retains some connectivity with its floodplain, an essential component for the life cycles of many aquatic species. Although salmon runs have had many good returns during the last 30 years, average runs display a long-term decline, and poor returns of one or more species of salmon in most years have significantly limited tribal and non-tribal harvest to protect the most vulnerable species. Some estimates indicate that the potential of existing habitat to produce salmon has been reduced by as much as 80% (ASEPTC 2014) due to the loss or degradation of aquatic habitats.

Human actions have had considerable impact on watershed processes in the Chehalis Basin. Aquatic habitat throughout the Chehalis Basin has been extensively altered by humans since the 1850s through a variety of activities including agriculture, logging, gravel mining, dredging, dams, water diversions, transportation infrastructure, and point and non-point source pollution. Degradation of aquatic habitats is of particular concern because the salmonid species that are negatively impacted by this degradation have particular significance to tribal cultures, communities, and economies.

2.2.1 Aquatic Habitats

The Chehalis River is in a large coastal watershed that supports a diversity of aquatic habitats. Variation in physical conditions from the upper reaches to the mouth of the river has created four major fish habitat types observed in the primary study area that would be affected by the Proposed Action: headwaters and upper mainstem, middle and lower mainstem, off-channel habitat, and emergent floodplain wetlands (see text box). The locations of these habitats within the study area are shown in Figures E-2a, E-2b, and E-2c.

The State of Washington Priority Habitat types that would be affected by the Proposed Action are instream habitat and freshwater wetlands (WDFW 2019a). Instream habitat is defined as the combination of physical, biological, and chemical processes and conditions that interact to provide functional life-history requirements for instream fish and wildlife resources. Freshwater wetlands are defined as transitional lands between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water at some time during the growing season of each year.

Instream habitat and freshwater wetlands can be further subdivided by the predominate conditions in different areas and accessibility of the habitat to fish. In this report, four primary fish habitat types are identified for the Chehalis River (see text box). Three types of instream habitat exist that are home to different fish communities: the headwaters and upper mainstem, middle and lower mainstem and off-channel habitat. A fourth habitat type, the emergent floodplain wetlands or simply "floodplain wetland habitat", is also important to fish. It describes areas that are not considered in-stream habitat but are but are hydraulically connected to the Chehalis River for several weeks to months of the wet season, allowing fish to access them for at least part of the year.

The instream and floodplain wetland habitat features are shaped by a combination of hydrologic and geophysical conditions, and human uses of the land around the river or human uses of the river itself.

Water temperatures throughout the Chehalis River are relatively warm due to the low elevation and low gradient of the river, that ranges from about 800 feet in elevation at the confluence of the East and West Forks (RM 118) to 22 feet at the downstream end of the study area at RM 9. Solar heating is the primary driver of water temperatures, and elevated stream temperatures in the Chehalis River are attributed to a lack of stream shading, with some heating attributed to the loss of shade that was historically provided by mature riparian vegetation. The water frequently exceeds maximum temperature thresholds in summer that salmon and steelhead prefer.

Primary Fish Habitat Types of the Chehalis River

Headwaters and Upper Mainstem: Characterized by steeper gradients, confined stream channel, coarser substrate and bedrock, and cooler water temperatures; provides spawning and rearing habitat for salmonids and other cold-water adapted species.

Middle and Lower Mainstem: The mainstream channel below the convergence of headwater tributaries; may be connected to off-channel or floodplain habitats; provides migratory and rearing habitat for salmonids and rearing and foraging habitat for warm-water adapted species.

Off-Channel: Low-gradient, low-velocity network of side channels that provide rearing habitat and refuge from mainstem flows for cold-water adapted species in winter and rearing habitat for warm-water adapted species in summer.

Emergent Floodplain Wetlands: Seasonally flooded areas of the floodplain with adequate connection to the mainstem for fish access; provide temporary but highly productive rearing habitat.

Figure E-2a

Map of Aquatic Habitat Locations

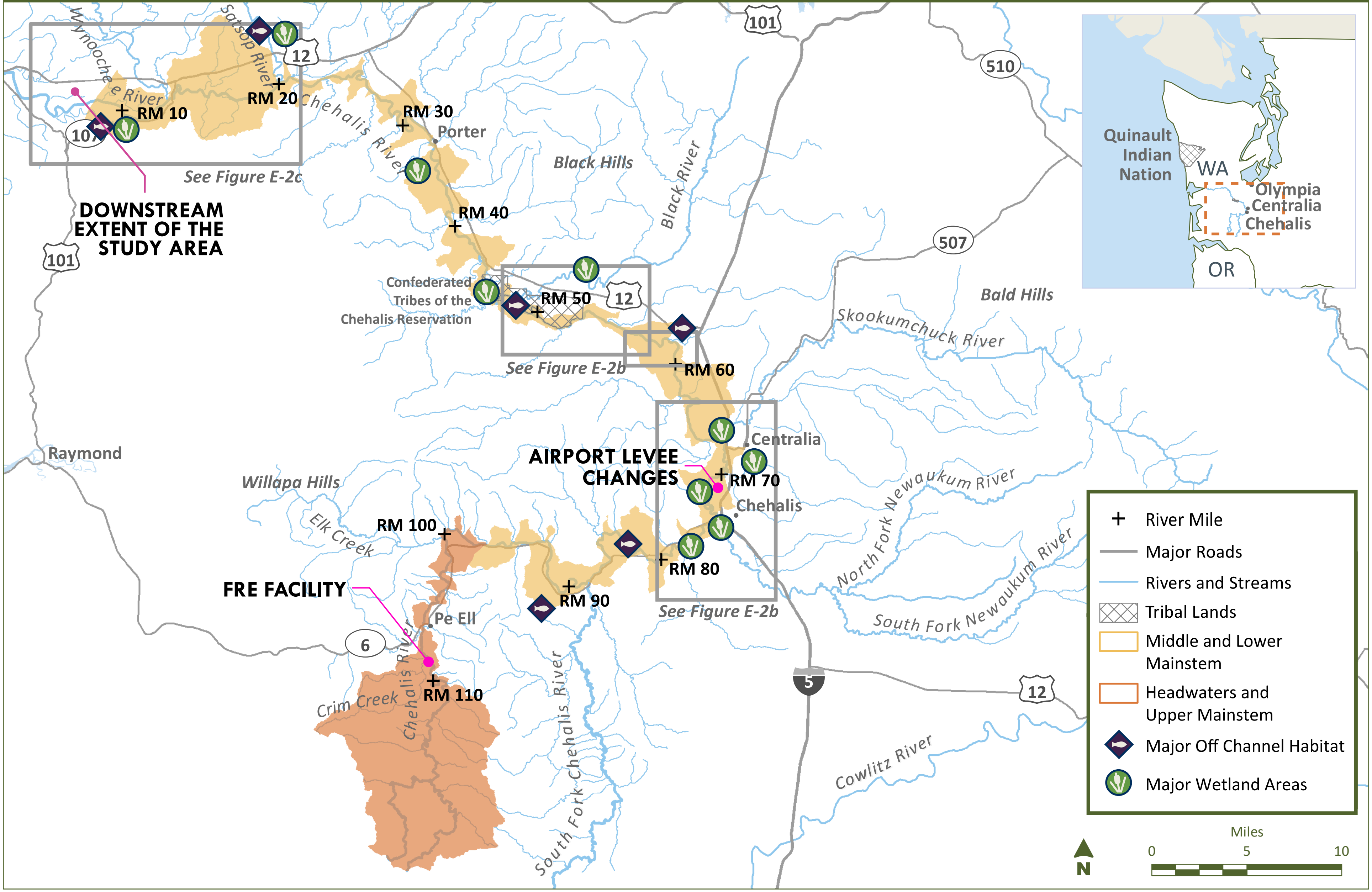


Figure E-2b
Detail of Major Floodplain Off-channel and Wetland Habitats

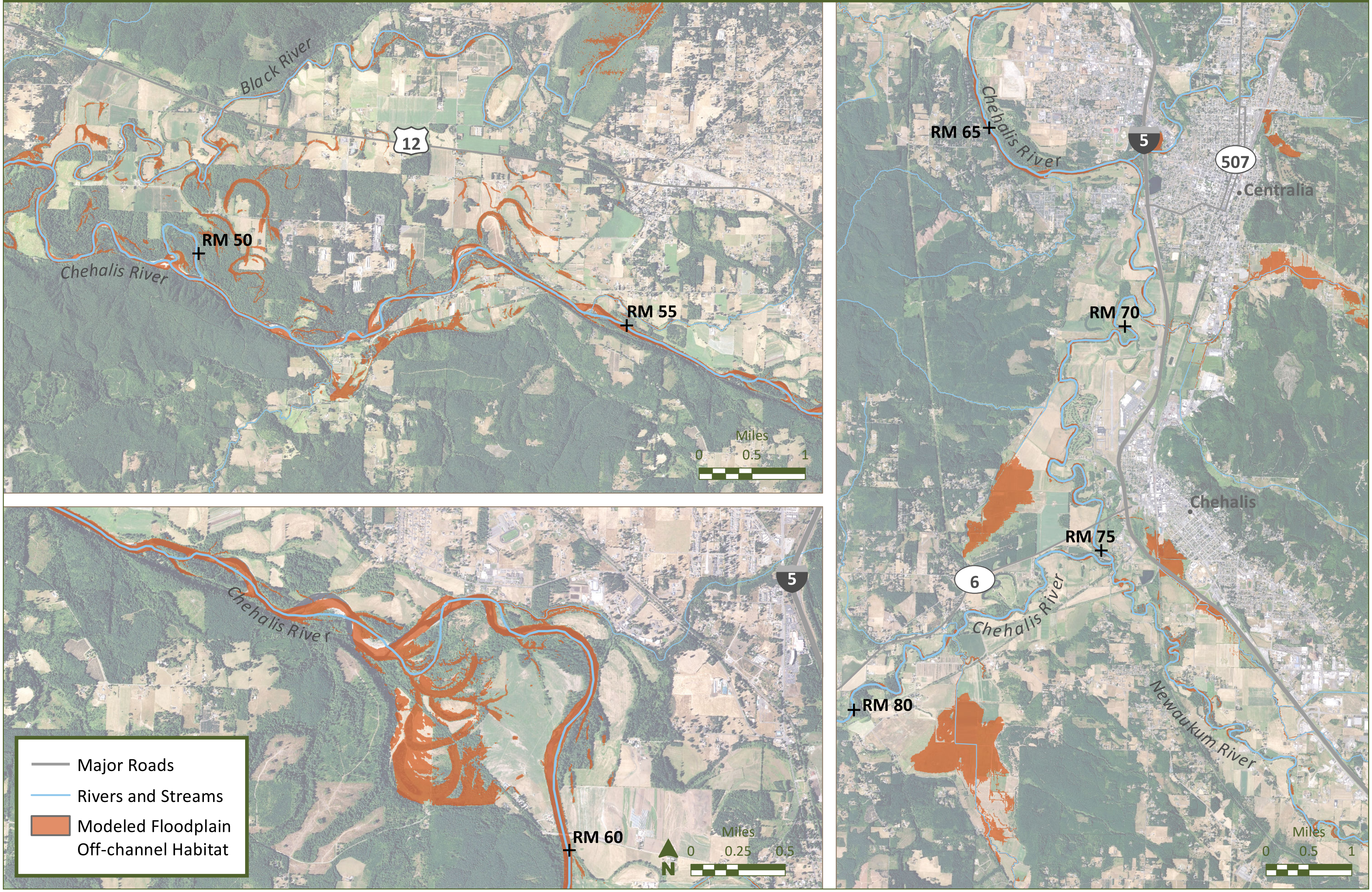
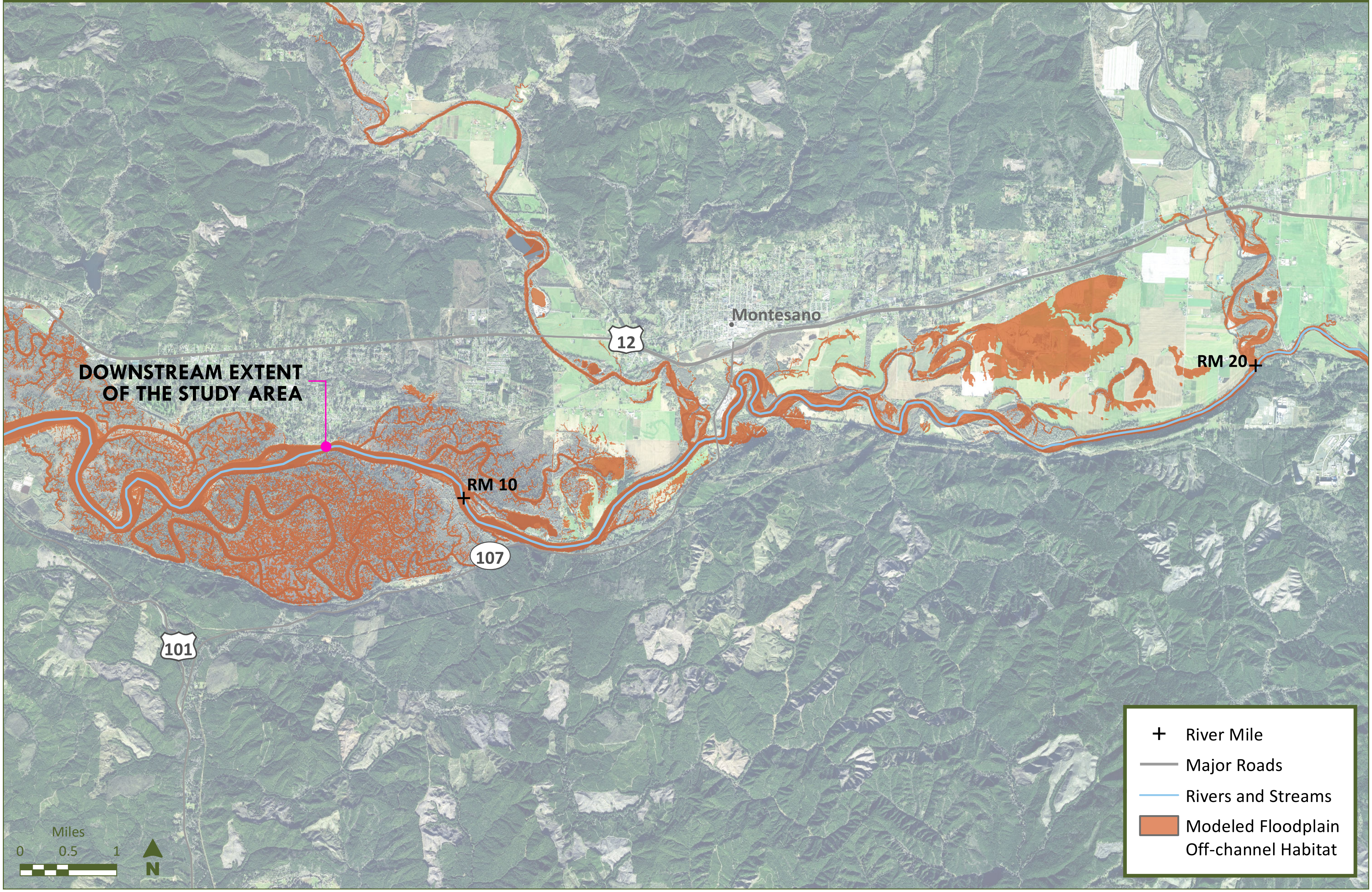


Figure E-2c
Detail of Major Floodplain Off-channel and Wetland Habitats



The State of Washington has developed extensive water quality standards for surface waters consistent with public health and public enjoyment of the waters and the propagation and protection of fish, shellfish, and wildlife (Washington Administrative Code [WAC] Chapter 173-201A). The applicable temperature criteria for select stream segments in the study area are summarized in Table E-4 and in the text following the table.

Table E-4
Designated Aquatic Life Uses and Temperature Criteria for Select Chehalis Basin Streams

STREAM SEGMENT	DESIGNATED AQUATIC LIFE USES	CRITERIA (7-DADMax)
Chehalis River downstream of RM 90.2	Spawning, rearing, and migration	17.5°C*
	Supplemental spawning and incubation (Oct. 1 to May 15)	13°C
Chehalis River upstream of RM 90.2	Core summer salmonid habitat	16°C*
	Supplemental spawning and incubation (Sept 15 to July 1)	13°C
Elk Creek	Core summer salmonid habitat	16°C *
	Supplemental spawning and incubation (Sept. 15 to July 1)	13°C
South Fork Chehalis River mouth to 0.4 mile upstream	Spawning, rearing, and migration	17.5°C *
	Supplemental spawning and incubation (Sept. 15 to July 1)	13°C
Newaukum River	Core summer salmonid habitat	16°C*
	Supplemental spawning and incubation (Sept. 15 to July 1)	13°C
Skookumchuck River mouth to Hanaford Creek	Core summer salmonid habitat	16°C*
	Supplemental spawning and incubation (Sept. 15 to July 1)	13°C
Lincoln Creek	Spawning, rearing, and migration	17.5°C*
	Supplemental spawning and incubation (Sept. 15 to July 1)	13°C
Black River	Spawning, rearing, and migration	17.5°C**
	Supplemental spawning and incubation (Sept. 15 to July 1)	13°C

Source: WAC 173-201A-200
Notes:
7-DADMax: 7-day average of daily maximum temperature
* Applies year-round except when superseded by supplemental spawning and incubation criteria
** Applies year-round

In addition to the numeric temperature criteria shown in Table E-4, Ecology's surface water quality standards contain other narrative criteria and guidelines relating to temperature, including the following:

- Moderately acclimated (16°C to 20°C) adult and juvenile salmonids will generally be protected from acute lethality by discrete human actions maintaining the 7-day average of daily maximum (7-DADMax) temperature at or below 22°C and the 1-day maximum (1-DMax) temperature at or below 23°C (WAC 173-201A-200(1)(c)(vii)(A)).
- When a waterbody's temperature is warmer than the criteria (or within 0.3°C of the criteria) and that condition is due to natural causes, then human actions considered cumulatively may not cause the 7-DADMax temperature of that waterbody to increase more than 0.3°C (WAC 173-201A-200).

Anchor QEA conducted continuous temperature monitoring in 2013 and 2014 to characterize conditions in the upper Chehalis Basin (Anchor QEA 2014). Automated temperature data were collected from 12 Chehalis River sites, from upstream of Pe Ell (RM 107), downstream to near Oakville (RM 42), and from tributaries like Elk and Lincoln creeks and the Newaukum, Skookumchuck, and Black rivers. The approximately 1-year temperature monitoring period extended from late July 2013 through July 2014. In general, all stations in stream reaches designated as core summer salmonid habitat in WAC 173-201A-602 exceeded the criterion upstream of RM 90.2 (16°C 7-DADMax) in August and September 2013 and July 2014. Stations in stream reaches with supplemental spawning/incubation criteria applied in the September 15 to July 1 range showed exceedances of the 13°C criteria in late September and again from late May through June. The data for the station on the Chehalis River above Pe Ell (RM 107) shows that the 7-DADMax was approximately 21°C in August 2013 and 23°C in July 2014. The July 2014 data show acute impairment that exceeds Washington's lethality guidelines.

Longer-term temperature monitoring carried out by Ecology suggests that the summers of 2013 and 2014 were not unusually warm. Table E-5 shows the frequency of other recent temperature exceedances in the Chehalis River.

The Chehalis River is also shaped by human uses including timber harvest, historical log drives and splash damming, agriculture, and development. Timber harvesting dating back to the earliest European settlement reduced shading by riparian vegetation and reduced the availability of large wood log jams in the river that force large pool development, settling of fine sediments, and braiding of the river channel. In addition, historical splash damming and intentional straightening of the river channel around agricultural and residential areas throughout the Chehalis Basin have resulted in a stream channel that is more simplified (predominantly single-thread) compared to historic conditions.

Table E-5

Recent Temperature Exceedances in the Chehalis River

WATER QUALITY MONITORING LOCATION	RELEVANT DESIGNATED AQUATIC LIFE USES AND CRITERIA (7-DADMAX)	YEARS WITH EXCEEDANCES IN MONTHLY SAMPLES	MAXIMUM TEMPERATURE IN MONTHLY SAMPLES	YEARS WITH EXCEEDANCES IN CONTINUOUS SUMMER SAMPLING (7 DAD MAX)	MAXIMUM CONTINUOUS TEMPERATURE (7-DAD MAX)
Porter	Spawning, rearing and migration (18°C prior to 2009; 17.5°C after 2009)	1997, 1998, 2001 to 2014, 2016, 2017	25.4°C (7/24/2006)	2001 to 2014, 2016	24.3°C (8/17/2016)
	Salmonid spawning and incubation (13°C)	2011, 2014, 2015	14.5°C (10/21/2014)	No Data	No Data
Centralia	Spawning, rearing and migration (17.5°C)	2016, 2017, 2018	21.7°C (7/19/2017)	No Data	No Data
Dryad	Core Summer Salmonid Habitat (16°C)	2001 to 2014, 2016, 2017	21.9°C (8/18/2009)	2001 to 2014	26.0°C (7/30/2009)
	Salmonid spawning and incubation (13°C)	2009 to 2014, 2016, 2017, 2018	17.6°C (9/22/2014)	No Data	No Data
Near Pe Ell	Salmonid spawning and incubation (13°C)	2017, 2018	14.3°C (7/19/2017)	No Data	No Data

Note: Includes data collected in Ecology’s monthly monitoring program from 2009 through 2018, except for the station near Pe Ell that has only been operational since 2016. The 7-day average of daily maximum temperature (7-DADMax) is calculated from continuous temperature data that are collected at 30-minute intervals from June through September at long-term monitoring stations at Porter and Dryad only. Temperature criteria are described in WAC 173-201A.

Other historical and current conditions that contribute to habitat-limiting factors for fish are described in greater detail in the *Wetlands Discipline Report* (Anchor QEA 2020b) and several other resources (Smith and Wenger 2001; GHLE 2011; CBS 2017a; ICF 2016; Beechie 2018) and were recently synthesized by ecoregion to support the Chehalis Basin Strategy's Aquatic Species Restoration Plan (ASRPSC 2019).

In addition to these general trends in habitat conditions that are observed throughout the Chehalis Basin, fish habitat varies as the river flows from the mountainous headwaters in the Willapa Hills to the broad, low-elevation floodplains of the middle and lower reaches of the mainstem river. The differences in major fish habitat types observed along the river's path are described in subsequent sections.

2.2.1.1 Headwaters and Upper Mainstem Chehalis River

In the analyses presented here, references to the headwaters habitats include any fish-accessible tributary streams that converge to create the Chehalis River upstream of the FRE facility site, including the East and West forks of the Chehalis River, George Creek, Cinnabar Creek, Mack Creek, Thrash Creek, Alder Creek, Roger Creek, Big Creek, Browns Creek, Hull Creek, Crim Creek and Lester Creek. The upper Chehalis River refers to the mainstem Chehalis River from the convergence of the East and West forks (RM 118) to Rainbow Falls (RM 97). See Figure E-2a for the portion of the river included in headwaters and upper mainstem Chehalis River for this analysis.

The headwaters of the Chehalis River and its tributaries originate in the Willapa Hills, a low-elevation mountain range with rain-dominated hydrology. The East and West forks of the Chehalis River drain from the headwaters to form the upper mainstem Chehalis River where the proposed FRE facility would be located, at approximately RM 108. The hydrograph in the upper Chehalis Basin reflects the seasonal trends in precipitation, with peak flows during rain events in the fall, winter, and early spring, and seasonal low flows during the summer in July through September. The headwater reaches and tributaries have higher gradients than the middle and lower mainstem reaches; however, gradients are lower than observed in other Pacific Northwest rivers, resulting predominantly in a pool-riffle channel type in the upper mainstem Chehalis River (J. Winkowski et al. 2018).

Compared to other Chehalis Basin tributaries, the upper Chehalis River also has a relatively high proportion of reaches with bedrock substrate and canyons that confine the stream channel and restrict channel migration. In the area between the confluence of the East and West forks (RM 118) to just upstream of Rainbow Falls (RM 98), bedrock is the predominate substrate in 13.9% of river segments; however, gravel is one of the predominant substrates throughout this area, with cobble and boulder more common upstream of RM 113 and sand more common downstream of RM 110 (J. Winkowski et al. 2018). The upper mainstem Chehalis River is more linear and simplified compared to historic conditions, particularly downstream of Crim Creek (RM 108).

Timber harvest in headwater areas and the upper Chehalis Basin has increased the frequency of landslides and reduced the availability of large wood that contributes to channel complexity. Current Forest Practices Rules protect riparian areas to promote development of riparian forest and the processes for recruiting large woody material. While not all riparian tree stands are fully functioning, they are on a trajectory to becoming mature trees and a source of large wood in the future.

The upper Chehalis River is relatively warm compared to the headwaters of other tributaries that have been extensively surveyed (the East Fork Satsop, West Fork Humptulips, and South and North Fork Newaukum rivers) with maximum temperatures exceeding 20°C from mid-July through August (J. Winkowski et al. 2018; J. Winkowski and Zimmerman 2019). Water quality is impaired primarily with respect to temperature for cool-water-associated species such as salmonids, but also due to low dissolved oxygen (DO) as a result of high water temperatures and bacteria that affect all aquatic species. Monthly sampling by Ecology in 2016, 2017, and 2018 identified DO levels in samples collected from the Chehalis River above Pe Ell to be below the 9.5 milligrams per liter (mg/L) criteria on August 31, 2016 (8.9 mg/L) and August 15, 2018 (8.9 mg/L). Monitoring data collected by Anchor QEA showed DO below 9.5 mg/L downstream of Pe Ell in August and September 2013 and in July 2014 (Anchor QEA 2014).

Despite degradation, the upper Chehalis River supports salmon and steelhead, lamprey, and other native fishes. Summer stream temperatures in headwaters and the upper mainstem Chehalis River are cooler than downstream areas and support a cold-water fish assemblage dominated by salmonids compared to downstream reaches that are dominated by native cyprinids (minnows) and non-native species such as bass, sunfish, and bluegill (J. Winkowski et al. 2018). The upper Chehalis River is used for spawning by spring-run Chinook salmon, fall-run Chinook salmon, coho salmon (*Oncorhynchus kisutch*), and steelhead (*Oncorhynchus mykiss*; abundance and distribution summarized by Ashcraft et al. 2017). The upper mainstem Chehalis River habitats are also heavily used by juvenile salmonids for rearing (J. Winkowski et al. 2018).

Fish passage is partially blocked for some resident fish to the uppermost reaches of the East and West forks of the Chehalis River by Fisk Falls, a natural barrier between RM 113 and 113.6. However, modification of the falls in 1970 improved fish passage for Chinook and coho salmon, steelhead, and resident trout compared to historical conditions (WDF 1975; WDFW 2019f). A blockage on the West Fork Chehalis River has developed more recently at RM 4.2.

2.2.1.2 Middle and Lower Mainstem Chehalis River

In the analyses presented here, the middle mainstem Chehalis River refers to the portion of the river from Rainbow Falls (RM 97) to the confluence with the Skookumchuck River (RM 67). The lower mainstem Chehalis River refers to the portion from the confluence with the Skookumchuk River to the downstream extent of the study area near RM 9. See Figure E-2a for the portion of the river included in the middle and lower mainstem Chehalis River for this analysis.

The Chehalis Basin is a rainfall-dominated system and, as such, streamflow varies considerably across seasons, with high fall and winter flows and relatively low summer baseflows. During summer low-flow periods, the Chehalis River is recharged by groundwater from aquifers. Groundwater levels are deep in the Chehalis Basin, with less groundwater and surface water exchange in the lower Chehalis River. More interaction between surface water and groundwater occurs in the middle and upper Chehalis River, upstream of Grand Mound at RM 58.8 (Ely et al. 2008). For some fish, especially salmon and other cool-water species, river reaches that gain groundwater from aquifers in the middle Chehalis River are likely to provide important summer refugia, with more stable water levels and cooler temperatures relative to other river reaches with less groundwater input.

Downstream of Rainbow Falls (RM 97), the middle and lower mainstem habitat is mainly shaped by the low-elevation alluvial valley and rain-driven hydrology. Sediments are mostly slightly silty fine sand, gravelly sand, and sandy gravel (*Earth Discipline Report*).

In the middle Chehalis River, historical splash damming and intentional straightening of the river channel around agricultural and residential settlements has, over time, allowed the force of high river flows to scour and incise the stream channel in the middle and lower Chehalis River. Much of the channel downstream of the confluence with the South Fork Chehalis River has essentially stayed in place since the 1940s. The mainstem fish habitat is largely impaired compared to historical conditions, lacking the features like braided channels, deep pools, log jams, and overhanging vegetation commonly used by fish for foraging, rearing, and finding refuge from warm temperatures or predators. The result for fish habitat is a stream channel that is predominantly single-thread, incised, and largely disconnected from floodplain habitat, with higher fine sediments and higher water temperatures than historical conditions.

Historically, wide riparian cottonwood stands may have fringed the river channel; however, historical accounts of the natural riparian areas are lacking and riparian conditions are currently considered moderately to significantly impaired.

Low base flows below the state’s instream flow requirements for fish in the late summer have resulted in impacts to water for many years. Junior water rights have been curtailed for the past five summers due to low-flow conditions in the Chehalis River (Ecology 2019a), and in summer 2019 the Chehalis River and its tributaries were closed for fishing (WDFW 2019g). Water temperature impairments occur throughout the middle and lower Chehalis River as previously described. The portion of the Chehalis River upstream of the Black River (identified in state rule as Water Resource Inventory Area (WRIA) 23, or the Upper Chehalis River) is also identified on Ecology’s most recent 303(d) list as water quality limited for DO, based on exceedances that fell below the criteria of 9.5 mg/L from 2004 to 2009 monitoring data from Ecology’s Dryad station (RM 98, near Rainbow Falls; Ecology 2016). Between 2010 and 2016, the lowest monthly DO sampling result from Dryad was 8.5 mg/L (Ecology 2019b). At the long-term monitoring station at Porter (RM 33), monthly sampling data show that the daily minimum DO criterion of 8.0 mg/L is typically met, with one exceedance (at 7.9 mg/L) since 2001 (Ecology 2019a).

A fecal coliform bacteria total maximum daily load (TMDL) for the Chehalis River in WRIA 23 was completed in 2004 based on standard exceedances, and instream levels have generally been decreasing over time after implementing and improving best management practices (BMPs) for non-point-source pollutants, and replacing failing on-site sewage treatment systems. Monitoring data from Ecology's long-term monitoring station at Dryad show only one monthly sample exceedance of the fecal coliform standard since 2004. Farther downstream, the monitoring station at Porter shows four exceedances of the water quality standard since 2004 (Ecology 2019b, 2019c). The lower Chehalis River is covered by the Grays Harbor/Chehalis Watershed Fecal Coliform Bacteria TMDL that was completed in 2002. Ecology's 303d list documents dioxins and polychlorinated biphenyls (PCBs) found in fish tissue samples in the Chehalis River in the Centralia area (Ecology 2016).

The fish community found in this habitat reflects the physical conditions of the mainstem river. As shown in Figures E-3a and E-3b, the river becomes dominated downstream by native cyprinid species and non-native species (e.g., sunfishes, basses) that have a higher tolerance for warm water temperatures and fine sediments compared to cold-water species such as salmonids (J. Winkowski et al. 2018). The mainstem is used by juvenile salmonids for rearing during all stages of development and as a migration corridor for adult salmon accessing spawning habitat in the upper reaches or tributaries.

2.2.1.3 Floodplain Off-Channel and Emergent Wetland

The Chehalis River is low gradient and slow moving with off-channel areas that historically migrated due to frequent flooding. The river channel is increasingly unconfined moving from upstream to downstream reaches. Historically, the resulting aquatic habitat was an extensive off-channel network characterized by oxbows, sloughs, beaver ponds, and side channels with diversity in water velocity, substrate, and cover.

Human uses in the Chehalis Basin have led to channelization and incision of the river, and intentional filling of depressional wetlands leading to degradation and disconnection of the river from much of the historically abundant off-channel habitat. Today, however, remnants of several meanders still exist. The low-gradient reaches of the middle and lower Chehalis River and tributary confluence areas (where the channel conditions permit) are also connected to nearby floodplain areas that experience seasonal flooding in the winter through spring to create emergent wetlands. These ephemeral habitats gradually warm in temperature as spring and summer progress, contracting or becoming completely desiccated by late summer. This ephemeral habitat in the floodplain of the lower Chehalis River has been identified as important overwintering habitat for fish (Henning et al. 2007; see Section 2.2.2 for details by species).

Exotic species make up half of the vertebrate species in extensive surveys of floodplain off-channel habitats and commonly include species that prefer slow-moving water (e.g., basses, bullhead catfish, yellow perch and common carp).

Figure E-3a

Summer Distribution of Juvenile Salmonid Fish Species

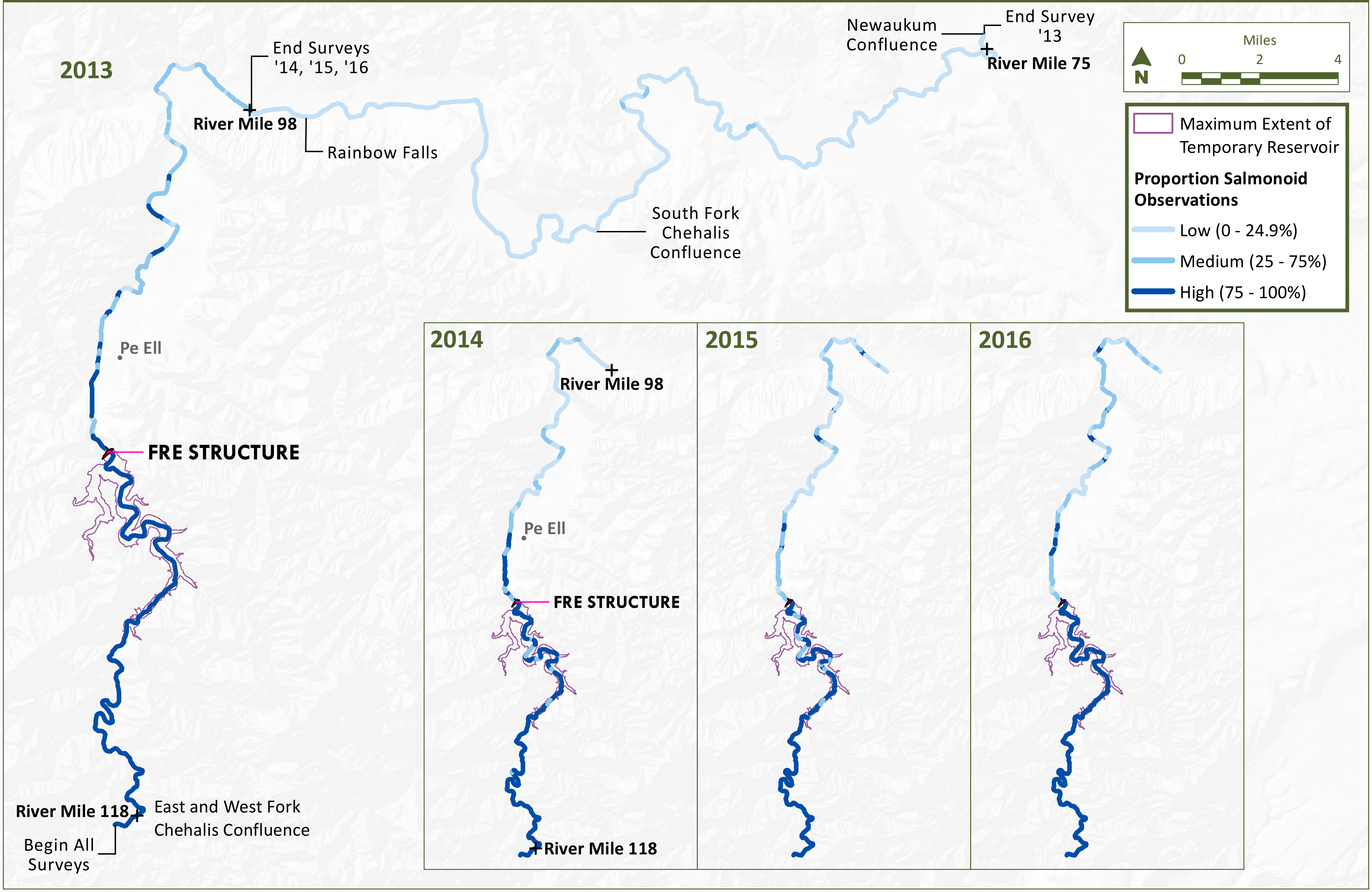
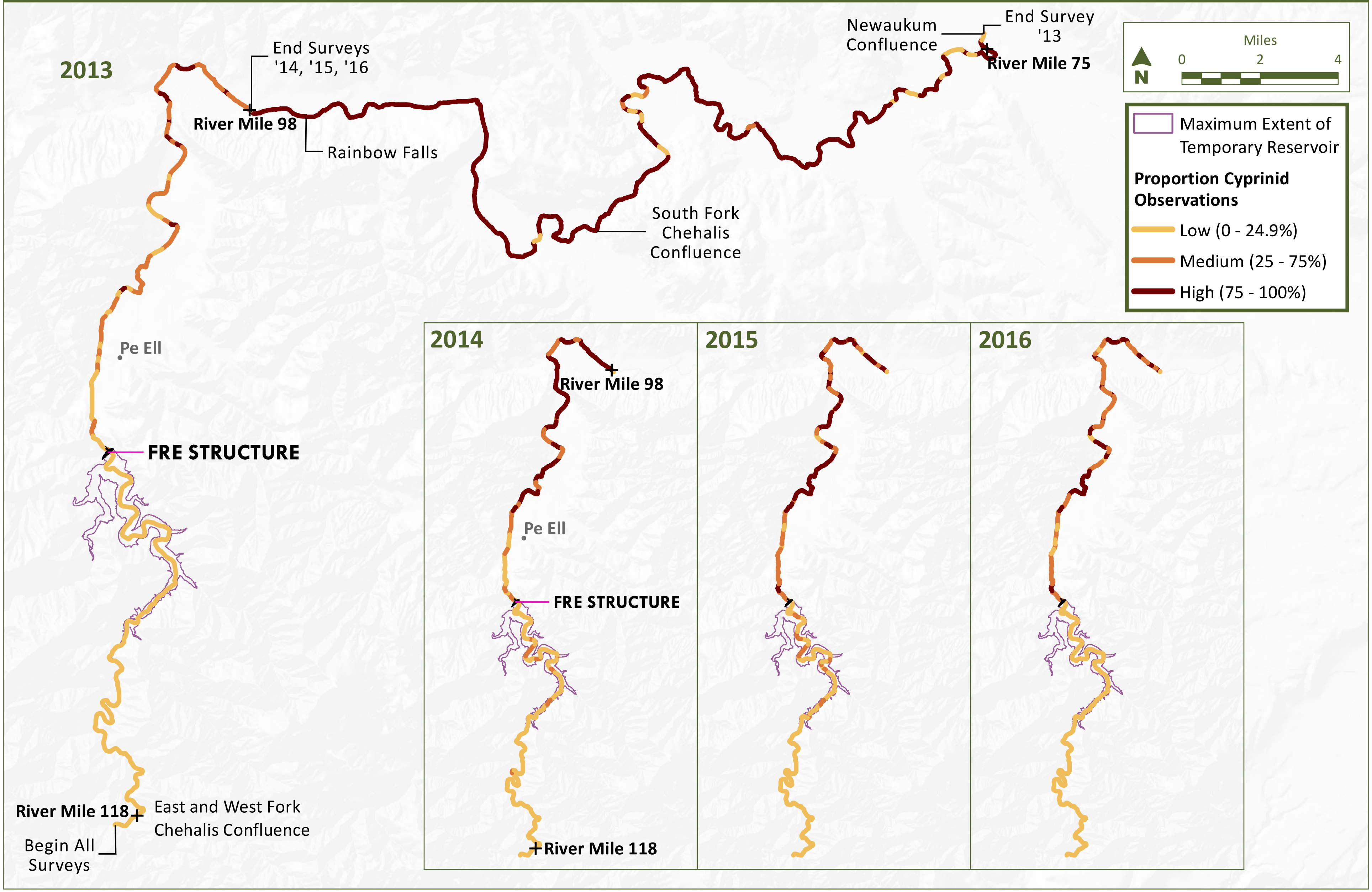


Figure E-3b
Summer Distribution of Cyprinid Fish Species



Today, approximately 1,939 acres (3%) of the Chehalis River floodplain consists of wetlands or off-channel aquatic habitats that exist year-round (Pierce et al. 2017). Nearly two-thirds of wetlands in the entire Chehalis River floodplain occur in the lower river reaches, in particular, between the confluences of the Wynoochee River at the downstream end of the primary study area and the Black River (RM 13 to 47), and especially between the Satsop River and Porter Creek (RM 20 to 33). Across the entire Chehalis Basin (all of the Chehalis River and its tributaries), it is estimated that over 7,300 acres of floodplain habitat currently exists in the form of side channels, ponds, lakes, and marshes that are accessible by fish and could be used by species like coho salmon that are adapted for off-channel rearing.

It is estimated that historic floodplain habitat has been significantly reduced across the entire Chehalis Basin; for instance it is estimated that approximately 80% of off-channel floodplain rearing habitat for coho salmon has been lost compared to historic conditions recorded at the turn of the 20th century (CBS 2017b). Within the study area it is estimated that approximately 3,094 acres of floodplain habitat exists adjacent to the mainstem Chehalis River that is accessible by juvenile salmonids and is inundated for at least 4 months of the year, providing consistent rearing habitat for juvenile coho salmon (McMullen 2019).

Portions of the Chehalis River experience prominent lateral migrations resulting in significant off-channel habitats in the study area, especially at major confluences with the South Fork Chehalis River, Bunker Creek, and the Black River (locations within the study area are shown in Figure E-2a; substantial off-channel habitats also exist downstream of the primary study area).

Ephemeral wetlands can be even more productive for foraging and rearing than off-channel habitat because they provide emergent vegetation, stagnant water, and have high decomposition rates. However, they may become seasonally disconnected from the main channel (Henning 2004). The contribution of these habitats to total productivity of aquatic habitats in the Chehalis Basin varies from year to year, depending on flooding extents in winter and spring as well as the rate and degree of desiccation and water temperatures in summer. Overwintering juvenile coho salmon are commonly observed in floodplain rearing areas where they feed and grow over several months, migrating back to the mainstem and out to sea as the floodplains desiccate and water temperatures increase in spring (Henning et al. 2006).

Modeling conducted by Ecology (Ecology 2011) indicates relatively large wetland areas in the following locations within the primary study area (detailed maps available in the *Wetlands Discipline Report*):

- North and south of the Chehalis River, upstream of the Newaukum River confluence (RM 75)
- Around lower Salzer Creek (RM 70) within the floodplain
- West of the Chehalis River and in the lower Scheuber Ditch area (near RM 68 to RM 69)
- At the confluence of the Chehalis and Skookumchuck rivers (RM 67)
- In the floodplain around lower Roundtree and Davis creeks (RM 42)
- In much of the floodplain south of the confluence of the Chehalis River and Porter Creek (RM 34)

Within the primary study area, in areas downstream of Crim Creek (RM 108) to RM 9, it is estimated that approximately 1933 acres of accessible floodplain winter rearing habitat currently exists for coho salmon, which is also highly productive habitat for various other native and non-native fish species. Some of the most complex off-channel and floodplain wetland areas that are estimated to flood annually and provide winter rearing habitat for fish are shown in detail in Figure E-2b.

The number of fish species (species richness) tends to increase in the downstream direction in the off-channel habitats (Hayes et al. 2015, 2019). Several native fish species have been observed in off-channel and floodplain wetland habitats, including juvenile coho salmon, juvenile Chinook salmon, cutthroat trout (*Oncorhynchus clarkii*), largescale sucker, northern pikeminnow (*Ptychocheilus oregonensis*), Olympic mudminnow (*Novumbra hubbsi*), Pacific lamprey, sculpin species (*Cottus* spp.), redside shiner (*Richardsonius balteatus*), speckled dace, three-spined stickleback (*Gasterosteus aculeatus*), and western brook lamprey (*Lampetra richardsonii*; Hayes et al. 2019; Henning et al. 2007). These habitats are highly productive sites for some native fish species like Olympic mudminnow (a floodplain off-channel specialist) and three-spined stickleback and, when adequately connected to the mainstem or with long hydroperiods, serve as refuge and high-quality rearing habitat for other species like juvenile coho salmon, particularly during winter.

Non-native fish species also thrive in many off-channel habitats, becoming more abundant as water temperatures warm in the summer, and in those that experience a year-round hydroperiod compared to those that desiccate seasonally (Hayes et al. 2019; see Section 2.2.2.2 and Attachment E-1 for non-native species associated with floodplain habitats). Some exotics, such as largemouth bass, are known to occur in both mainstem and off-channel habitats (Hughes and Herlihy 2012; Hayes 2019), but any movement dynamic that may exist between those areas is not understood.

2.2.2 Aquatic Species

Fish community composition varies depending on distance from the mouth of the river, a result of the diversity of physical habitat conditions from the headwaters to the delta. Habitat preferences, species distribution, and key life-history traits for fish in the study area are described in the following sections. Species are grouped by family and shared characteristics, with special focus given to species listed in the State of Washington Priority Habitats and Species list that also occur near the proposed FRE facility site. Additional detail is provided for salmonids that have been the focus of intensive study in the upper Chehalis Basin.

A complete list of species known to occur in the study area is provided in Attachment E-1. Freshwater and anadromous State of Washington priority fish species are listed in Table E1-1. Unlisted freshwater fish and shellfish species, including non-native fish species, are listed in Table E1-2. Marine mammals that prey upon salmon and steelhead from the Chehalis Basin are listed in Table E1-3.

2.2.2.1 Anadromous Salmonids

Chinook salmon, chum salmon, coho salmon, steelhead, and coastal cutthroat trout are widespread in the Chehalis River and its associated off-channel and floodplain habitats. Throughout all adult and juvenile life-history phases, salmon and trout require cool, clean water (Bjornn and Reiser 1991).

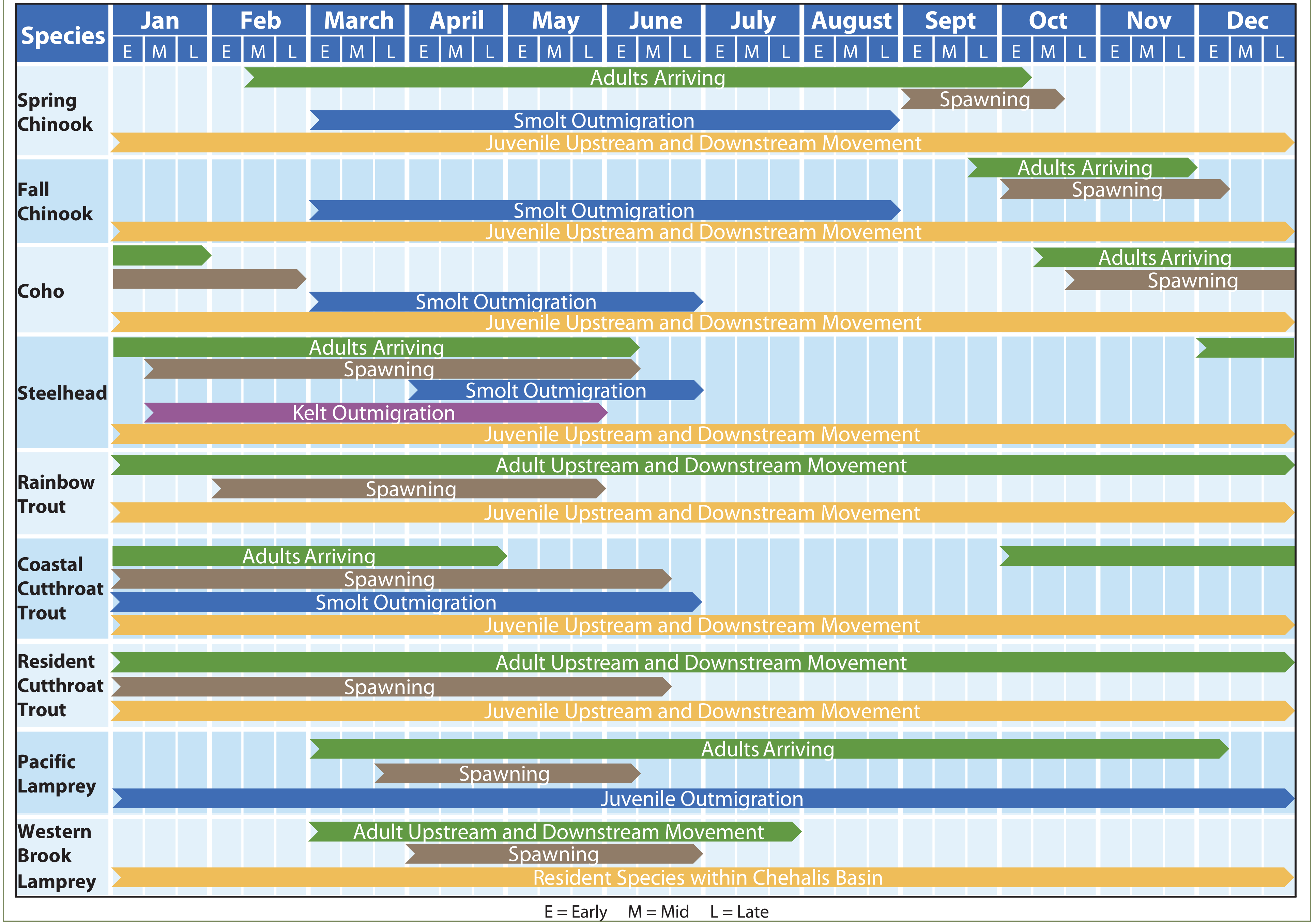
Adults migrating to spawning habitats also need barrier-free passage corridors with enough water depth and flow to provide unimpeded access to spawning areas. The state of Washington has also developed criteria for designing fish passage improvement structures to facilitate the passage of fish through or around a barrier and restore upstream and downstream access to habitats (WAC 220-660-200). Salmonid and lamprey migration and movement periods for the upper Chehalis River are shown in Figure E-4.

Spawning adults require specific flow conditions, cover, and access to spawning gravels to deposit eggs. Once deposited, fertilized eggs need to incubate in stable substrates that are free of excessive fine sediment and porous enough to allow oxygenated water to flow past the developing embryos. When incubation is complete and juveniles emerge from spawning gravels, they need access to food, cover, and space to rear. After rearing for a period of several days to several years, depending on the species, juvenile salmon need adequate flows and barrier-free conditions to migrate downstream to marine habitats. Depending on the species, some juveniles migrate to the ocean in their first spring or summer, while others overwinter in freshwater. While residing in freshwater during summer months, juvenile salmon and trout actively migrate upstream and downstream relatively short distances, usually less than 1 mile, but in some cases several miles—as observed in the upper Chehalis River and South Fork Newaukum River (J. Winkowski et al. 2018).

The fish community in the upper Chehalis River and accessible tributaries is dominated by Chinook salmon, coho salmon, and steelhead, and resident rainbow trout (*O. mykiss*) and resident and potentially sea-run cutthroat trout species. For salmon and steelhead populations, the distribution and spawning habitat of adults has been documented over many years to quantify run size, set harvest quotas, and estimate escapement (the number of fish returning to spawn). For coastal cutthroat trout, detailed life-history, distribution, and abundance information in the Chehalis Basin is limited (ASEPTC 2014). For Chinook salmon, coho salmon, and steelhead, management data have been used to characterize trends in abundance. The population run sizes are summarized in Table E-6.

Figure E-4

Anticipated Migration Periods of Selected Fish Species and Life Stages



Source: Data from Wydoski and Whitney 2003 and Holt 2019; figure adapted from Figure 2-1 in CBS 2018b.

Table E-6

Estimated Historical Adult Salmon and Steelhead Abundance

SPECIES	**DATA AVAILABLE**	**TOTAL CHEHALIS BASIN RUN SIZE**[1]			**ABUNDANCE IN STUDY AREA**[2]			**ABUNDANCE UPSTREAM OF CRIM CREEK**[3]		
		AVERAGE	**HIGH (YEAR)**	**LOW (YEAR)**	**AVERAGE**	**HIGH (YEAR)**	**LOW (YEAR)**	**AVERAGE**	**HIGH (YEAR)**	**LOW (YEAR)**
Spring-run Chinook salmon	1991 to 2018	2,250	5,153 (2004)	528 (2018)	2,095	5,034 (2004)	496 (2018)	23	65 (2014)	3 (2015)
Fall-run Chinook salmon	1971 to 2018	15,641	40,149 (1989)	5,183 (1983)	5,352	9,951 (2018)	2,862 (1994)	320	424 (2015)	239 (2017)
Coho salmon	1987 to 2017	55,624	128,525 (2014)	12,228 (1994)	24,190	46,398 (2010)	8,966 (2007)	858	1,590 (2014)	174 (2013)
Winter-run steelhead	1983 to 2018	10,221	19,000 (2004)	5,622 (2017)	2,650	4,604 (2004)	1,164 (2011)	1,283	1,850 (2014)	942 (2017)

Notes:

1. Sources: Scharpf 2019, WDFW 2019c. Describes total estimated number of fish that returned to all tributaries of Grays Harbor excluding the South Bay Rivers.
2. Sources: Scharpf 2019, WDFW 2019c. Describes total estimated number of fish that were spawned naturally; excludes fish caught in downstream fisheries.
3. Source: Ashcraft et al. 2017. Data were collected from return years 2013 through 2018. Includes winter-run steelhead that spawn before and after the March 15 date used for discerning hatchery-origin “early” stock from the wild “late” stock.

Chinook salmon, coho salmon, and steelhead spawn in the Chehalis River, both in the mainstem and in tributaries, with variable distributions among the two habitat types depending on the species.

Thousands of salmon and steelhead spawn in the areas that would be affected by the FRE-facility, including areas directly affected in the portion of the mainstem Chehalis River downstream and upstream of the proposed FRE facility location (RM 108.2), and within the temporary reservoir inundation area. Many of those salmon spawn in headwater tributary streams upstream of the temporary reservoir inundation area, including Crim Creek, Roger Creek, Thrash Creek, Cinnabar Creek, George Creek, and the East and West forks of the Chehalis River (Ashcraft et al. 2017). Above the proposed FRE facility location, spring-run Chinook salmon spawn only in the mainstem Chehalis River and their upstream distribution is the most limited. Fall-run Chinook salmon spawn primarily in the mainstem with some spawning in the lower reaches of tributaries, and steelhead and coho salmon have the broadest spawning distribution in large areas in both the mainstem and tributaries. The distribution of adult spawning salmon and steelhead observed in the study area from RM 80 to RM 130 during fall 2013 to spring 2017 is shown in Figures E-5 to E-8 for each species.

Juvenile coho salmon, Chinook salmon, and steelhead are abundant in the headwaters of the upper Chehalis River (J. Winkowski et al. 2018). Almost every reach of the upper mainstem and every accessible tributary upstream of Crim Creek are consistently occupied by juvenile salmonids in annual surveys (M. Winkowski et al. 2016; J. Winkowski et al. 2018; J. Winkowski and Zimmerman 2017). Juvenile salmon and steelhead can be highly mobile during the summer low-flow period in the upper mainstem Chehalis River. An intensive study of juvenile salmonid movement found that subyearling juvenile Chinook salmon rear in the upper Chehalis River above the proposed FRE facility during their first spring and summer but move downstream by late August. 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 (J. Winkowski and Zimmerman 2017).

In summer 2015, juvenile salmon distributions were surveyed more extensively 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 (M. 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. During the August survey, juvenile Chinook salmon were observed both upstream and downstream of the proposed FRE facility site (J. Winkowski and Zimmerman 2017; J. Winkowski et al. 2018). J. Winkowski and Zimmerman (2017) found that the juvenile Chinook salmon outmigration from the upper Chehalis Basin was generally complete by August.

It is probable that many juvenile salmon and steelhead migrate downstream from the headwaters to overwinter in other freshwater habitats in the lower mainstem, off-channel, or floodplain wetlands prior to migrating to the ocean, as has been observed in other coastal rivers, but this behavior is not well defined for the Chehalis River populations. Access to upstream and downstream habitats provides foraging opportunities as well as refuge from predators and other environmental stressors, such as refuge provided by off-channel habitat during high winter flows or sources of cool groundwater during low summer flows.

Off-channel and emergent wetland habitat in the floodplain of the lower Chehalis River has also been identified as important low velocity refugia and overwintering rearing habitat for juvenile salmonids, especially coho salmon (Henning et al. 2007).

The Washington Department of Fish and Wildlife (WDFW) recognizes nine populations of Chinook salmon, including spring-run and fall-run life-history types within the Chehalis Basin.

2.2.2.1.1 Spring-Run Chinook Salmon (Affected Environment)

Within the primary study area, spring-run Chinook salmon are found in the mainstem Chehalis River (Figures E-5a and E-5b). Compared to other species, spring-run Chinook salmon spend a relatively long period of time holding in the Chehalis River and some of its large tributaries, including the Skookumchuck and Newaukum rivers, prior to spawning. Most enter the Chehalis River in the late winter and spring and spawn in the fall. During summer months, spring-run Chinook salmon can be observed holding in cool-water refugia, including major tributaries such as the Skookumchuck and Newaukum rivers and areas where tributaries converge with the mainstem Chehalis River such as below the Newaukum River. In the mainstem Chehalis River, spring-run Chinook salmon spawning occurs from near Porter (RM 33.3) to near the confluence with the Skookumchuck River (RM 67.0), and near Adna (RM 81.3) to the upper Chehalis River (RM 113.4).

Spring-run Chinook salmon spawning in the upper Chehalis River is assumed to occur between September and mid-October, peaking in early October. Intensive surveys conducted between 2013 and 2017 in reaches immediately upstream and downstream of the proposed FRE facility site found that all of the spring-run Chinook salmon redds observed were in the mainstem Chehalis River and none were in the tributaries. Approximately 99% of spring-run Chinook salmon redds above the proposed FRE facility location were within the proposed temporary reservoir area (Figure E-5b; Ashcraft et al. 2017). Between 2013 and 2017, it is estimated that an average of 27 spring-run Chinook salmon spawned above the proposed dam site annually (Table E-6; Ashcraft et al. 2017). Run timing assignments (spring or fall) for Chinook salmon in the upper Chehalis River are based on timing of redd building, redd condition, and phenotypic characteristics, behavior, and condition of the fish associated with the redd.

Several recent studies have examined the relatedness of Chinook salmon across the Chehalis Basin, and the traits that separate spring-run from fall-run Chinook salmon in the Chehalis Basin.

Figure E-5a
Spring Chinook Salmon EDT-Modeled Fish Distribution for the Upper Chehalis Basin

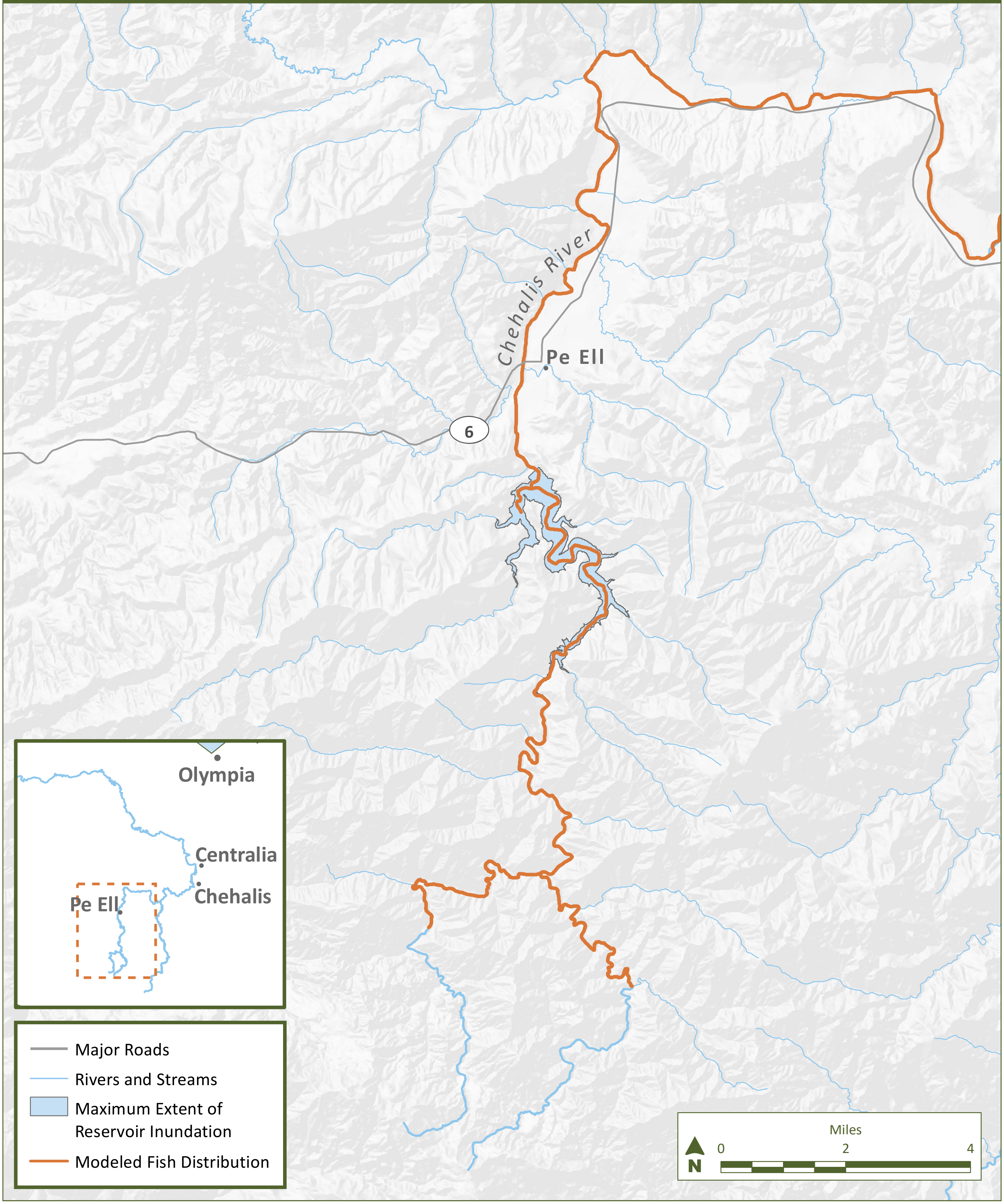
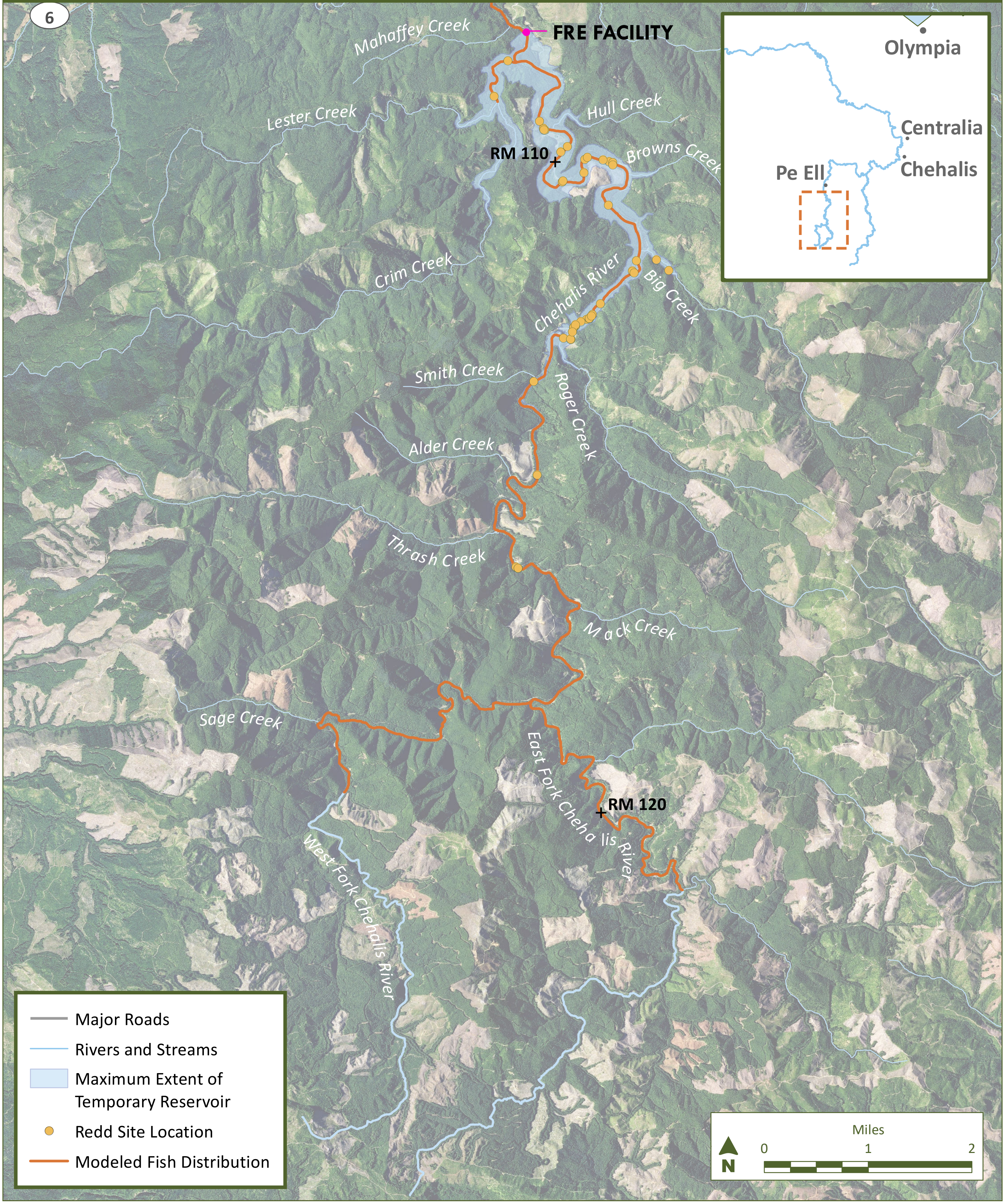


Figure E-5b

Spring Chinook Salmon Redd Site Locations Upstream of Crim Creek (2013-2017)



Source: Redd location data from Ashcraft et al. (2017); modeled fish distribution data from WDFW SWIFD and ICF.

The population genetic structure of Chehalis spring-run Chinook salmon was examined by Brown et al. (2017), who used carcass samples collected from throughout the basin over many years but not using a sampling regime designed specifically for their study. They found weak genetic structure among spawning tributaries and patterns consistent with isolation by distance (i.e., genetic distance was correlated with geographic distance). No genetic distinction was found among carcasses called fall-run in the field and those called spring-run in the field, likely in part due to mistaken identity of the run-type in the field (see below).

Spring- and fall-run timing was assigned to adult female Chinook salmon carcasses using otolith chemistry by Campbell et al. (2017), to inform previous run timing designations that were based on spawning date or body degradation criteria. The authors found that field carcass identification of spring-run Chinook salmon corresponded weakly with otolith results in 2015 (33% agreement) and moderately in 2016 (approximately 50% agreement), while the identification of fall-run Chinook salmon agreed with otolith determinations 93% and 99% of the time in 2015 and 2016, respectively. Their results were complicated by high levels of background strontium:calcium (chemicals used in the determination of run timing) in three out of the four areas where samples were collected, which may have interfered with the ability to use chemistry to assign spring- or fall-run type.

Genetic markers known to distinguish spring- and fall-run Chinook salmon in coastal lineages (Thompson, Bellinger et al. 2019) were also used in an analysis of Chehalis Basin Chinook salmon by Thompson, O'Rourke et al. (2019). The dataset included some of the samples analyzed by Campbell et al. (2017), all samples analyzed by Brown et al. (2017), and an additional set of "well-phenotyped" samples of known run timing to be used to test the genetic markers' ability to distinguish the runs. Using these well-phenotyped samples, they established that the markers distinguished spring- and fall-run Chinook salmon in the Chehalis Basin. They had several additional important findings.

First, similar to Campbell et al. (2017), they found that field and genetic identification of fall-run Chinook salmon carcasses agreed in almost all cases (i.e., low error rate), but results of the two identification methods disagreed extensively for spring-run Chinook salmon (i.e., high error rate). Second, error rates were spatially biased. Specifically, all carcasses sampled downstream of the Skookumchuck River with a spring-run field identification had the fall-run genotype as did many, but not all, of the field identified spring-run fish upstream of the confluence with the Skookumchuck River. This corroborates the high error rate in field identification by Campbell et al. (2017) and demonstrates the importance of the upper Chehalis Basin to spring-run Chinook. Third, as with Brown et al. (2017), Thompson, O'Rourke et al. (2019) found spatial population structure and structure associated with run type. Structure was strongest between Newaukum River spring-run Chinook salmon and other collections. Genomic analysis showed that unlike the Newaukum River spring-run Chinook salmon, Skookumchuck and upper Chehalis River spring-run Chinook salmon were introgressed with fall-run Chinook salmon. However, most spring-run (by genotype) samples were 15 to 20 years old, limiting the interpretation for current conditions and highlighting the need for additional research designed specifically to elucidate spatial and temporal distributions of spring- and fall-run Chinook salmon in the Chehalis River and tributaries from the Skookumchuck River upstream.

Chehalis River spring-run Chinook salmon typically have a subyearling freshwater life history and return to spawn at 3 to 6 years of age, with most returning at age 4. The number of spring-run Chinook salmon harvested annually is not discerned from fall-run Chinook salmon catches in salt-water harvest and freshwater sport-catch records and spring-run Chinook salmon are not supplemented by hatchery production. There is a great deal of concern over the future of spring-run Chinook salmon in the basin. The distribution of the species in the Chehalis Basin is limited, and key populations exist in the Skookumchuck and Newaukum rivers along with smaller production areas in the South Fork and upper Chehalis River. Throughout the basin, the abundance of spring-run Chinook salmon has been declining in recent years (Lestelle et al. 2019).

2.2.2.1.2 Fall-Run Chinook Salmon (Affected Environment)

Fall-run Chinook salmon enter the river just weeks prior to spawning from August through November, with peak numbers in September, and spawn throughout the Chehalis River and major tributaries (Figures E-6a and E-6b). Spawning habitats include the mainstem Chehalis River upstream of the confluence with the Satsop River near Elma (RM 28) to near the confluence with the Skookumchuck River (RM 67), and from the confluence with the South Fork Chehalis River (RM 88) to areas upstream of Pe Ell (RM 108). Between 2013 and 2017, it is estimated that an average of 340 fall-run Chinook salmon spawned above the proposed FRE facility site annually, with approximately 83% of redds located within the temporary reservoir (Table E-6; Ashcraft et al. 2017).

Chehalis River fall-run Chinook salmon have a subyearling freshwater life history and typically outmigrate to marine habitats in their first spring. Adults typically return to spawn at 4 to 6 years of age, with most returning at age 5. This species is heavily harvested in ocean fisheries. Hatchery production contributes to annual returns to the Grays Harbor and lower Chehalis River tributaries (Humptulips, Wishkah, Satsop, and Wynoochee rivers; WDFW 2019c).

Fall-run Chinook salmon spawning in the upper Chehalis River occurs in October through early December and peaks in late October. October 15 is used as a threshold date for differentiating the earlier spawning spring-run Chinook salmon from fall-run Chinook salmon (Ashcraft et al. 2017).

Genetic markers known to distinguish fall-run Chinook salmon in coastal lineages (Thompson, O’Rourke et al. 2019) and used in analyses of Chehalis Basin Chinook salmon (Thompson, Bellinger et al. 2019) are discussed earlier under spring-run Chinook salmon.

Figure E-6a

Fall Chinook Salmon EDT-Modeled Fish Distribution for the Upper Chehalis Basin

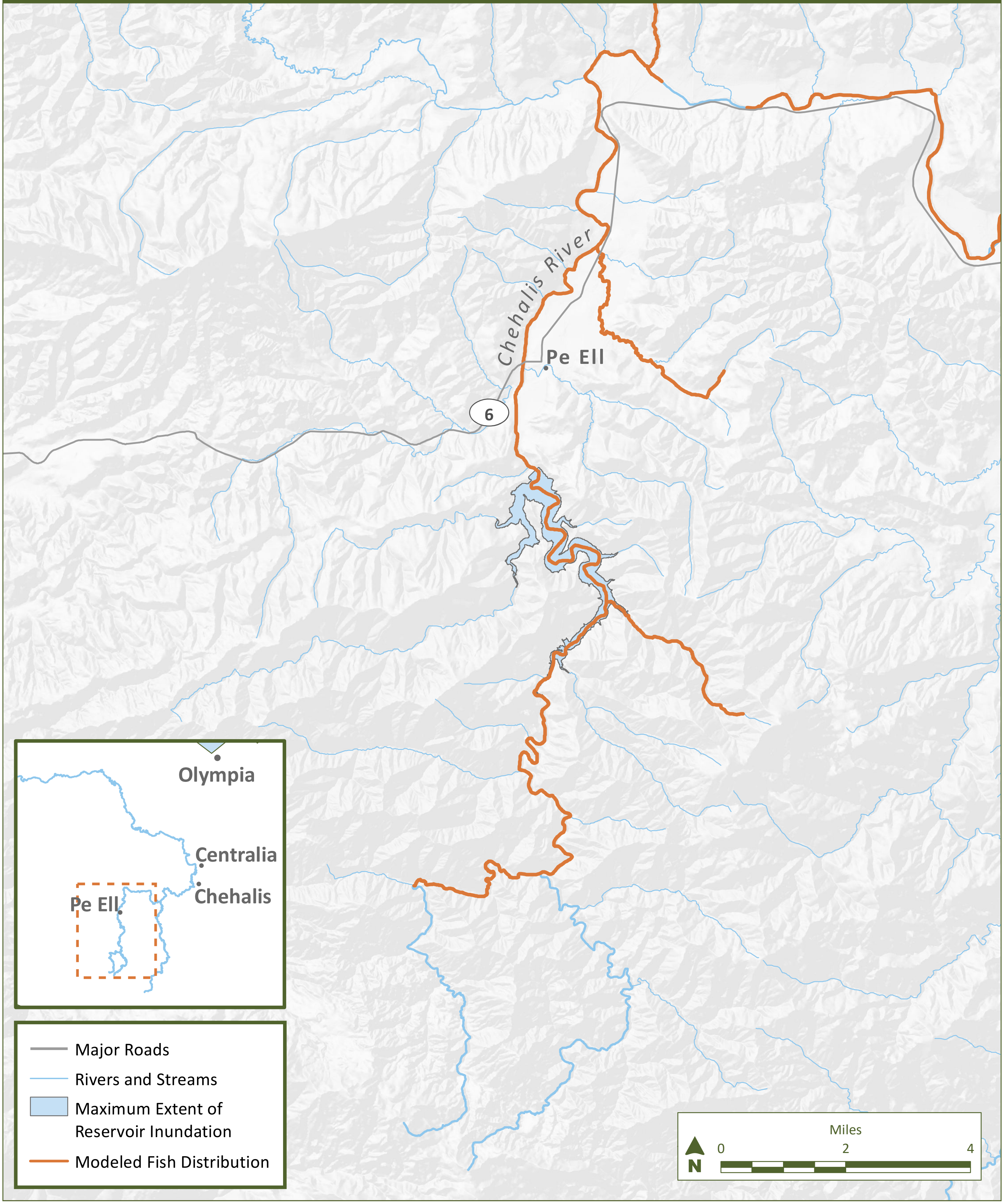
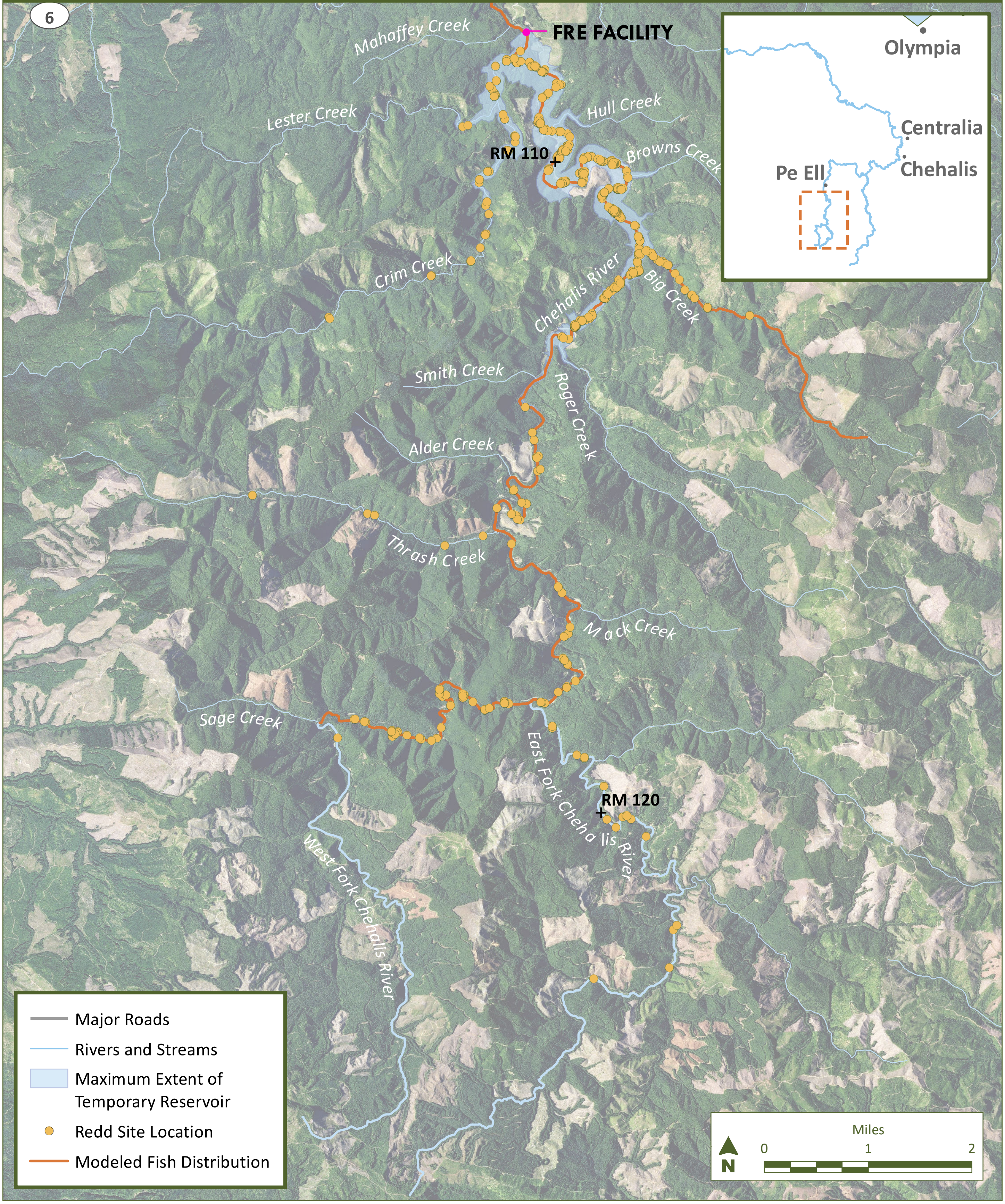


Figure E-6b
Fall Chinook Salmon Redd Site Locations Upstream of Crim Creek (2013-2017)



Source: Redd location data from Ashcraft et al. (2017); modeled fish distribution data from WDFW SWIFD and ICF.

2.2.2.1.3 Coho Salmon (Affected Environment)

Coho salmon are present throughout the Chehalis River basin, including the upper reaches of the mainstem Chehalis River (downstream and upstream of Pe Ell) and in the major tributaries to the upper Chehalis River (Figures E-7a and E-7b). Between 2013 and 2017, it is estimated that an average of 764 coho salmon spawned above the proposed FRE facility site annually, with approximately 41% of redds occurring within the temporary reservoir (Table E-6; Ashcraft et al. 2017).

Chehalis River coho salmon spend their first year of life in freshwater and migrate to the Pacific Ocean as yearling smolts and return to spawn at (total) age 2 (jacks) or 3 (adults). Coho salmon are targeted in commercial and sport fisheries, and extensive hatchery production contributes to annual returns in the Grays Harbor tributaries, lower Chehalis Basin tributaries, Newaukum River, Elk Creek, and the Skookumchuck River (WDFW 2019c). Two broad populations of coho salmon are recognized in the Chehalis Basin: early and late return and spawn timing. Early coho salmon return and spawn from August to late November, and late coho salmon are recognized as those returning and spawning in early December through January. The fourth week of November is used as a threshold date for differentiating early coho from late coho salmon (Ashcraft et al. 2017).

Coho salmon spawning in the upper Chehalis River occurs from November to January, with a broad peak of activity throughout December.

A recent study found extensive population genetic structure in Chehalis Basin coho salmon (Seamons et al. 2019). Genetic differences were found between cohorts of coho salmon from the same spawning location, among spawning tributaries, and based on run timing (early and late). Consistent with previous genetic studies, coho salmon in the upper Chehalis Basin (i.e., upstream of the proposed FRE facility site) were genetically distinct from coho salmon spawning in other locations. Coho salmon in the South Fork Chehalis and Newaukum rivers were also genetically distinct from coho salmon from other areas of the Chehalis Basin. Elk Creek receives late-run coho salmon from the Skookumchuck Hatchery. Skookumchuck late-run coho salmon are genetically the same as Satsop late-run coho salmon, from which they were recently derived. Few hatchery-produced coho salmon are found upstream of Elk Creek and there was no genetic signal from Skookumchuck late-run coho salmon in fish collected in the upper Chehalis or South Fork Chehalis rivers.

Figure E-7a

Coho Salmon EDT-Modeled Fish Distribution for the Upper Chehalis Basin

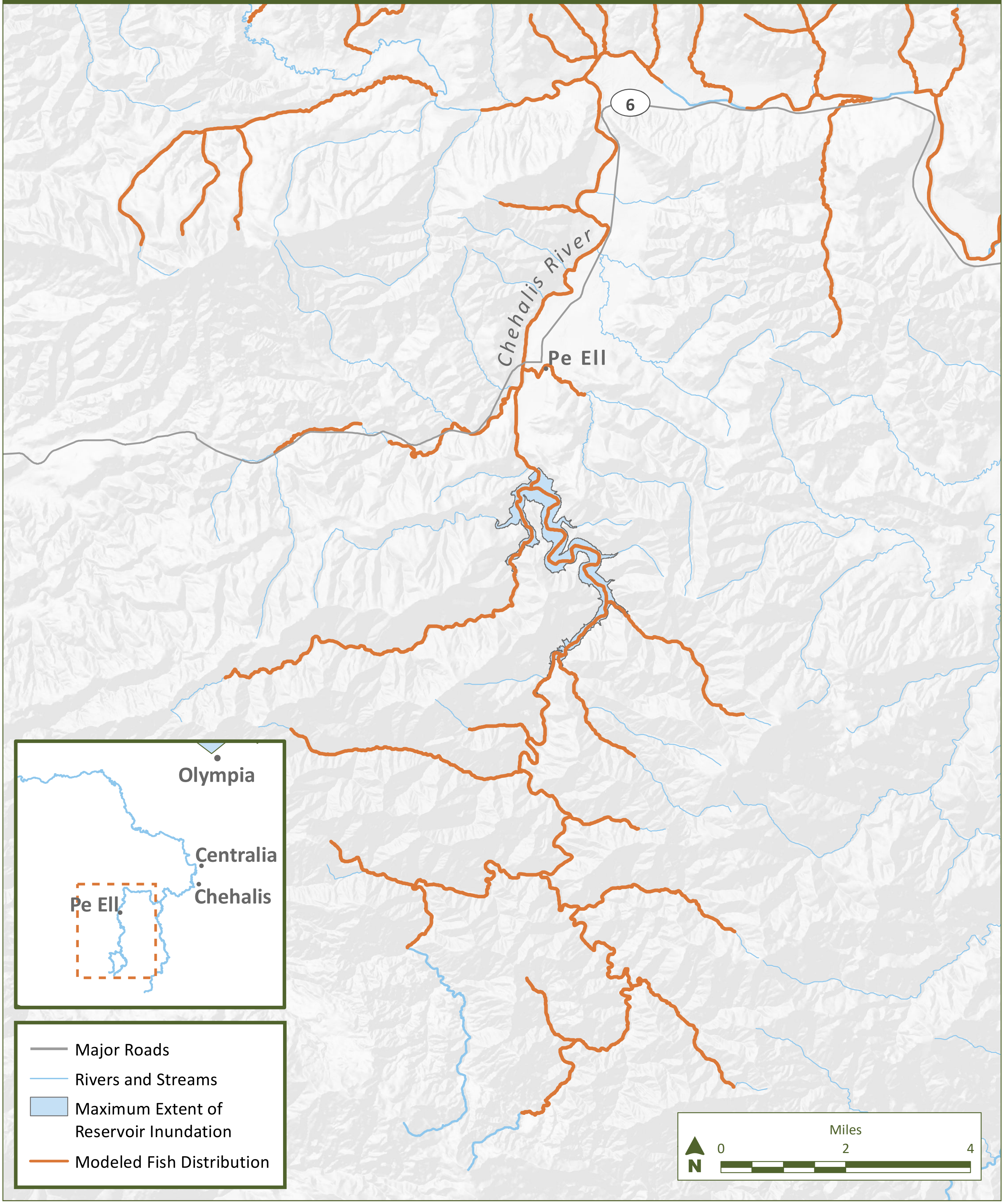
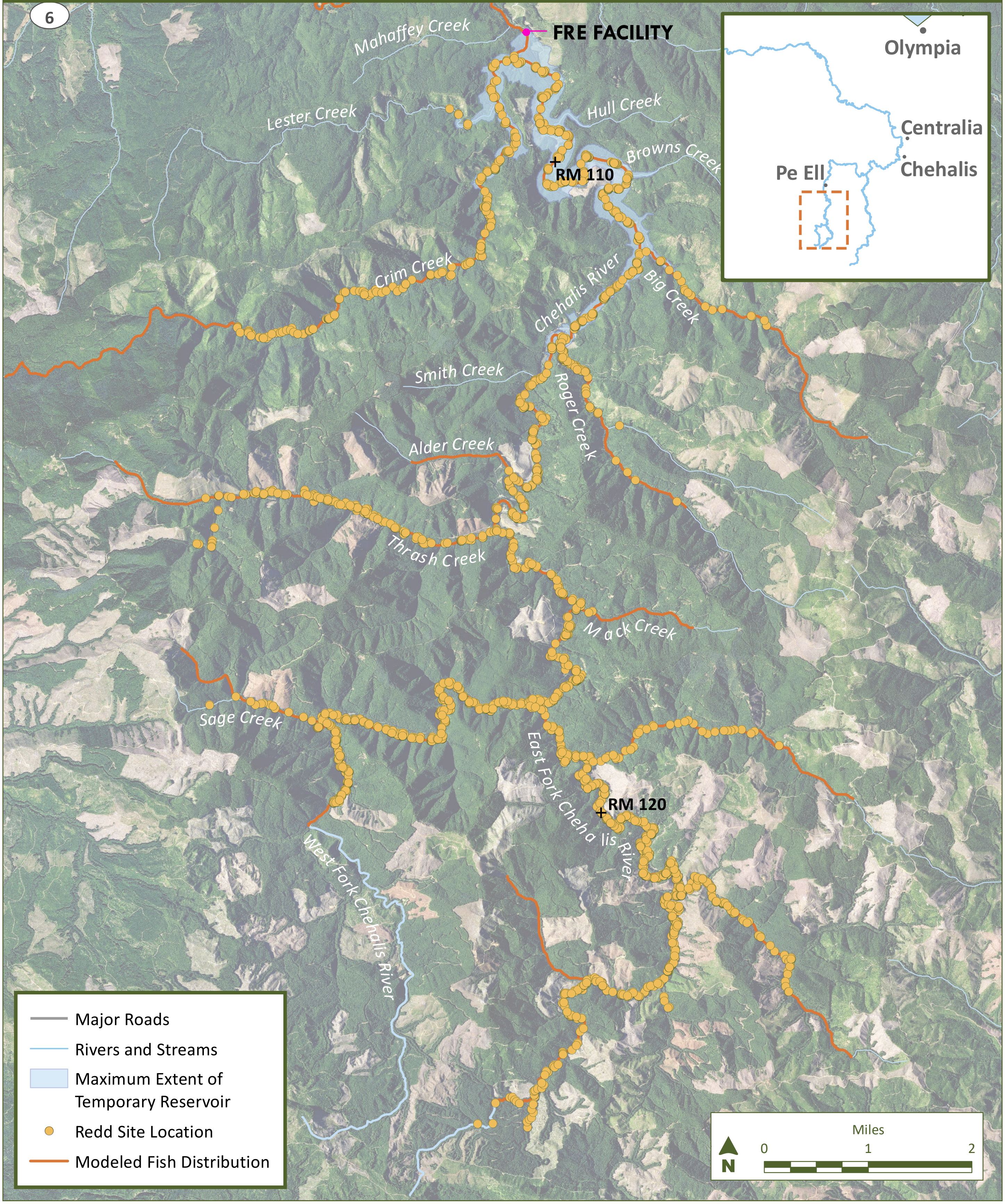


Figure E-7b
Coho Salmon Redd Site Locations Upstream of Crim Creek (2013-2017)



Source: Redd location data from Ashcraft et al. (2017); modeled fish distribution data from WDFW SWIFD and ICF.

2.2.2.1.4 Steelhead (Affected Environment)

Winter-run steelhead are present throughout the Chehalis River (Figures E-8a and E-8b). Summer-run steelhead are present in the lower basin but not in the study area. In the upper Chehalis River, most spawning takes place in the mainstem Chehalis, East Fork Chehalis, and West Fork Chehalis rivers as well as in medium and small tributaries. Between 2013 and 2017, it is estimated that an average of 1,369 steelhead spawned above the proposed FRE facility site annually, with approximately 35% of redds occurring within the temporary reservoir (Table E-6; Ashcraft et al. 2017).

Winter-run steelhead typically migrate to the Pacific Ocean after spending 2 to 3 years rearing in freshwater habitats. As adults, most return to spawn at 4 or 5 years of age. Hatchery production has contributed significantly to winter-run steelhead returns to the Grays Harbor tributaries, lower Chehalis Basin tributaries, Newaukum River, Elk Creek, and the Skookumchuck River (WDFW 2019c). There are summer run steelhead hatcheries on the Humptulips River and Wynoochee River. Hatchery winter-run steelhead are regularly harvested in sport fisheries, and hatchery and wild steelhead are harvested by both Quinault Indian Nation and Chehalis Tribe commercial fisheries but are not targeted in state-managed commercial fisheries.

Wild steelhead spawning in the upper Chehalis River occurs from mid-March through May, with a broad range in peak activity from late March to late April. Skookumchuck Hatchery steelhead are released in Elk Creek annually. Skookumchuck steelhead spawn earlier than other wild steelhead in the basin, but later than the non-local Chambers Creek early hatchery winter stock. All hatchery steelhead are externally marked by removing the adipose fin. Snorkel surveys conducted each winter since 2014 indicate minimal to no observations of hatchery-origin steelhead in the upper Chehalis River Subbasin. March 15 is used throughout the basin as a threshold date for differentiating redds made by the earlier spawning hatchery steelhead and later spawning wild steelhead.

A recent study found extensive genetic structure in *O. mykiss* in the Chehalis Basin (Seamons et al. 2017). Most analyzed samples were from anadromous adult steelhead, but juvenile *O. mykiss* were sampled for two collections, and thus could have comprised steelhead and resident rainbow trout. At its most inclusive level, genetic structure was spatially organized into the following three groups corresponding with headwater geography: tributaries draining the Olympic Mountain Range, tributaries draining the Cascade Mountain Range, and tributaries draining the Willapa Hills. Willapa Hills tissue collections analyzed included samples from upstream of the proposed FRE facility site (i.e., upper Chehalis River) and the South Fork Chehalis River. Steelhead in the Skookumchuck River were found to be genetically distinct and had low diversity, likely due to hatchery program activities. The collection of samples taken in the Newaukum River did not appear to be from a single spawning population and instead appeared to be composed of individuals from the lower, middle, and upper Chehalis River. Thus, the genetic status of *O. mykiss* in the Newaukum River remains unknown.

Figure E-8a
Steelhead EDT-Modeled Fish Distribution for the Upper Chehalis Basin

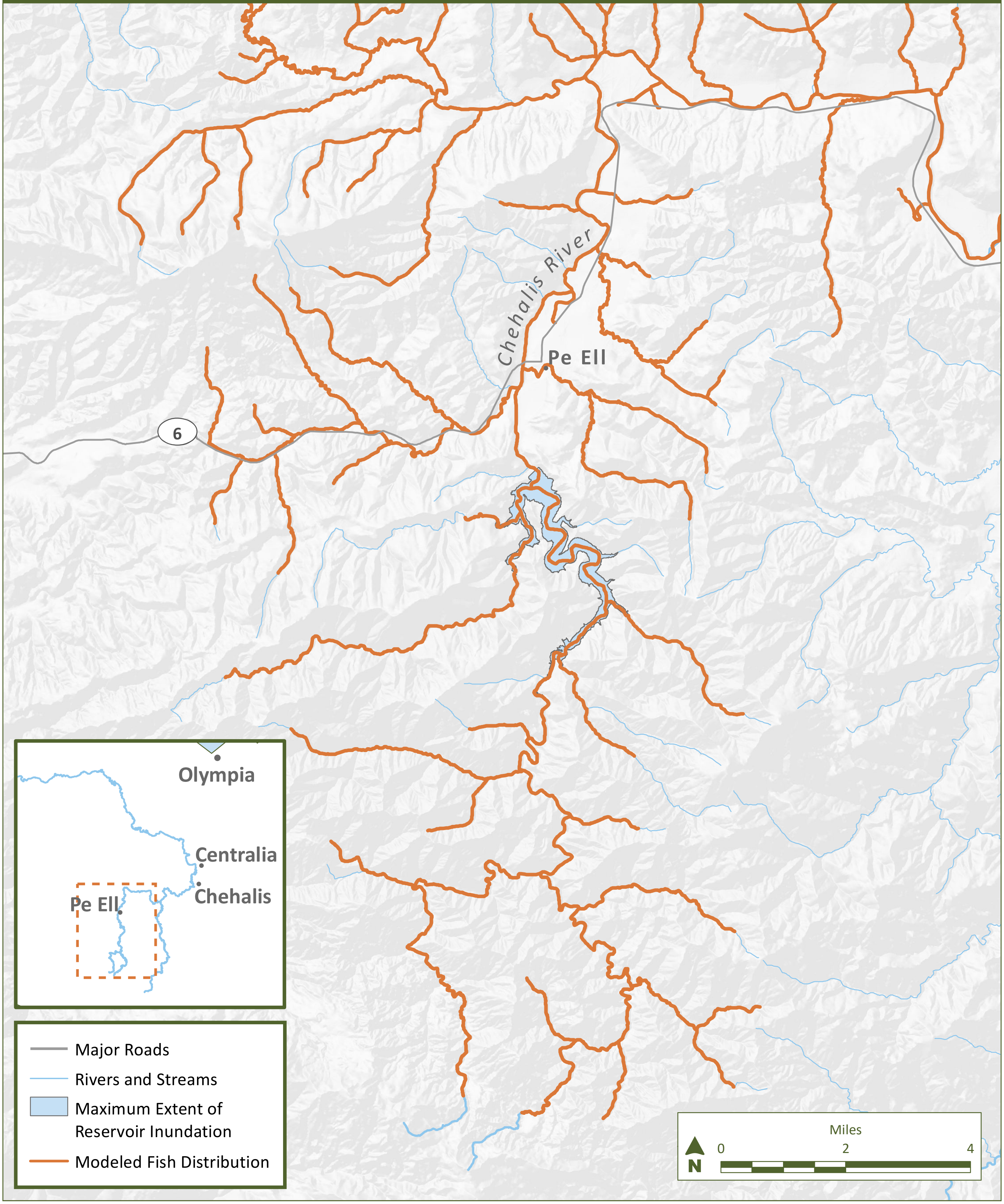
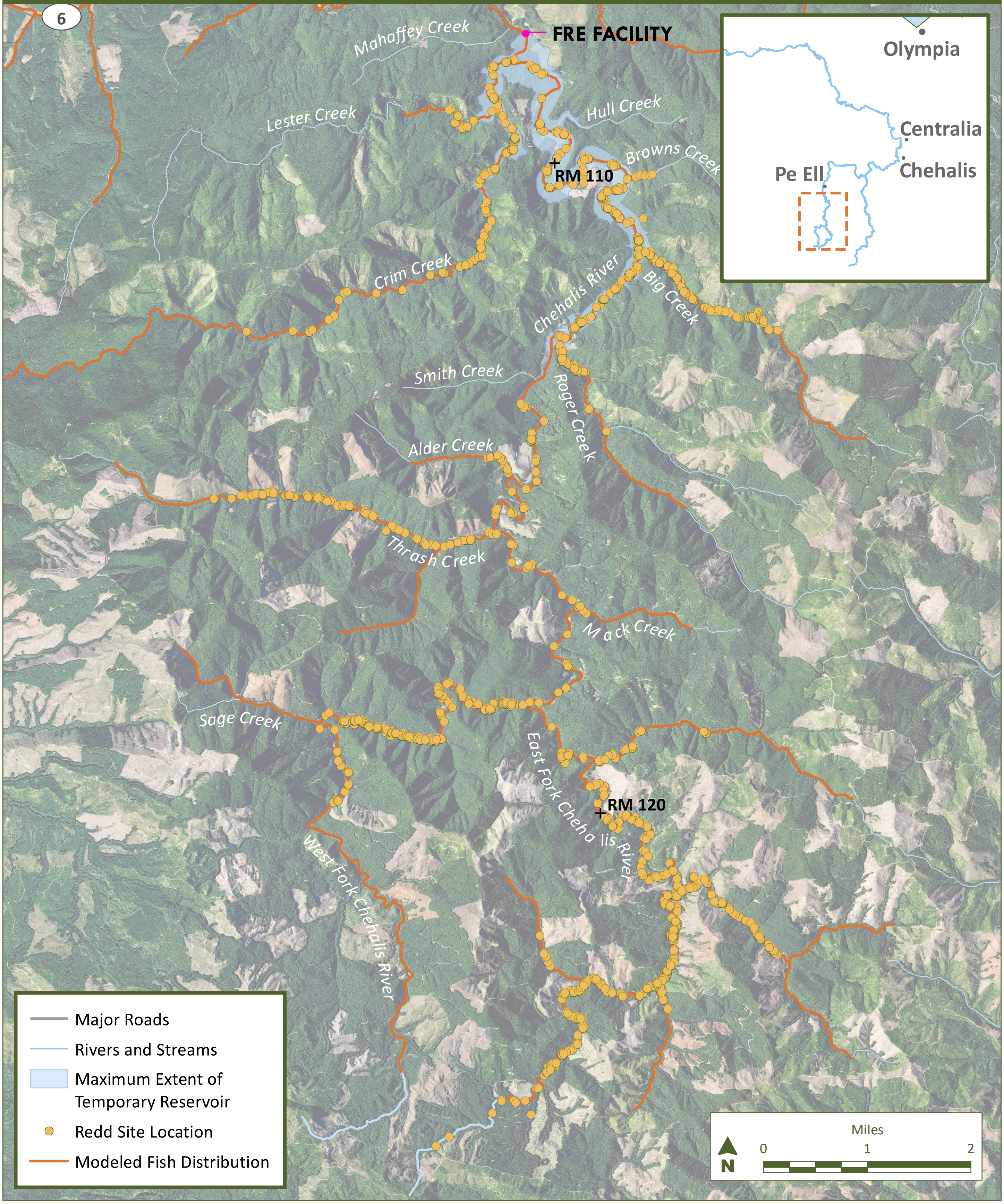


Figure E-8b
Steelhead Redd Site Locations Upstream of Crim Creek (2013-2017)



Source: Redd location data from Ashcraft et al. (2017); modeled fish distribution data from WDFW SWIFD and ICF.

2.2.2.2 Other Native and Non-Native Fish Species (Affected Environment)

Lamprey

The Pacific lamprey (*Lampetra tridentata*) is anadromous, completing the freshwater phase of its life cycle in streams and rivers from Baja California, Mexico, to Hokkaido, Japan (Moyle 2002). In the Pacific Northwest, Pacific lamprey spawn in low-gradient streams in the basins of large rivers in Oregon, Washington, Idaho, and British Columbia, and spend more than half of their 6- to 10-year life span as filter-feeding larvae burrowing in fine sediments of streams (Torgersen and Close 2004). After an extended time (4 to 6 years), larvae (ammocoetes) go through a metamorphosis that includes major morphological and physiological changes in preparation for their downstream migration and life in marine environments.

Juveniles (macropthalmia) migrate downstream during spring freshets and feed in the ocean for 1 to 3 years before returning as adults for reproduction (Close et al. 2002). Pacific lamprey likely do not return to natal streams (Hatch and Whiteaker 2009) but are guided to spawning locations by other factors such as an attraction to odors emanating from ammocoetes (Yun et al. 2011). Levels of genetic differentiation among Pacific lamprey from different areas are low, likely due to a lack of population differentiation that would occur with natal homing (Docker 2010).

Pacific lamprey is included as a Species of Greatest Conservation Need in the Washington State Wildlife Action Plan and is a Species of Tribal Importance. The population structure of Pacific lamprey in the Chehalis River is not known. Adults typically return to rivers the year before they spawn, which occurs during spring (late March through early June). Lamprey have extremely high fecundity rates and are semelparous, meaning they die after one spawning season. Late maturity, semelparity, and high fecundity suggest that Pacific lamprey capitalize on infrequent opportunities for reproduction in highly variable environments (Clemens et al. 2013).

Pacific lamprey appear to be broadly distributed in the mainstem Chehalis River and major tributaries. Pacific lamprey have been found in the mainstem Chehalis River above and below the proposed FRE facility site (USFWS 2011) and occupied every subbasin sampled in the Chehalis Basin in a recent study (e.g., Newaukum, Skookumchuck, Black rivers; Jolley et al. 2016). In a total of 59 reaches surveyed during July, August, and September near the proposed FRE facility site and within the temporary reservoir, lamprey ammocoetes not identified to species occupied 49% of surveyed reaches, while ammocoetes identified as Pacific lamprey occupied 41% of the reaches (M. Winkowski et al. 2016). Pacific lamprey ammocoetes are also numerous downstream of the proposed FRE facility site where the area has been surveyed to Rainbow Falls (M. Winkowski, Cropper et al. 2019). Generally, lamprey ammocoetes have been found throughout the upper Chehalis River; however, identifying the species is difficult at sizes less than 70 millimeters.

Western brook lamprey (*Lampetra richardsonii*) normally resides in freshwater and thus is not anadromous (Wydoski and Whitney 2003). Western brook lamprey are found in smaller streams with a lower gradient than Pacific lamprey, and Wydoski and Whitney (2003) report they are present along the southern and western boundaries of the Olympic Peninsula at lower elevations. Spawning occurs from April through June. Mature adult western brook lamprey do not feed, as their only function is to reproduce. Thus, this species is non-parasitic and does not feed on other fish; the larva are filter feeders that consume microscopic plant and animal matter (Wydoski and Whitney 2003). Newly metamorphosed and adult western brook lamprey occupy gravel beds in suitable spawning streams, and the larvae inhabit silty-bottomed backwater habitats (Wydoski and Whitney 2003).

Western river lamprey (*Lampetra ayresii*) is included as a state of Washington Species of Greatest Conservation Need and Candidate for the state of Washington Priority Habitats and Species list. Detailed distribution records are not available for river lamprey, although (Wydoski and Whitney 2003) state they are likely present in major coastal rivers. Similar to Pacific lamprey, Western river lamprey spawning occurs primarily in May but can occur from April through June. Larvae occupy silty substrates in backwater habitats and quiet eddies of coldwater streams (Wydoski and Whitney 2003). Similar to Pacific lamprey, Western river lamprey migrate to the ocean as they transform from the larval stage into juveniles (macrophthalmia) and finally into adults. Unlike Pacific lamprey, Western river lamprey remove the flesh of their prey rather than fluids (Wydoski and Whitney 2003).

Lamprey ammocoetes have also been encountered in surveys designed to detect amphibians and still-water associated fishes of the middle and lower Chehalis River floodplain off-channel habitats and stream-associated side-channel habitat (Hayes et al. 2015), though the ammocoetes were not identified to the species level.

Lamprey habitat limiting factors have not been identified for the Chehalis Basin. However, Close (2000) identified the following principal conditions associated with the decline of Pacific lamprey populations in the Columbia River Basin:

- Poor passage conditions for adult and juvenile lamprey at mainstem hydroelectric dams
- Poor habitat conditions in tributaries due to reduced instream flows in many tributaries that have greatly affected the natural production potential of Pacific lamprey
- Dewatering or low flows in late spring and summer that affect adult upstream migration into tributaries
- Low flows, poor riparian conditions, and resultant high water temperatures that have reduced the quality and quantity of adult spawning and juvenile rearing areas

Additionally, predation by non-native species is identified as a general threat to Pacific lamprey by the U.S. Fish and Wildlife Service (USFWS; Streif 2007), including bass and sunfish that have become established in the Chehalis River.

Chum Salmon

Fall chum salmon are the second most abundant anadromous salmonid present in the Chehalis Basin. Most chum salmon spawn in the mainstem Humptulips, Hoquiam, Wishkah, Wynoochee, and Satsop rivers and their tributaries, but additional spawning is observed as far upstream as the Black River, Cloquallum Creek, and other smaller mainstem tributaries (Edwards and Zimmerman 2018; Ashcraft et al. 2017).

Chum salmon juveniles spend little time in rivers, migrating to estuaries as subyearlings, but spend relatively more time in estuaries prior to migrating to the Pacific Ocean. Chum salmon return to spawn at 3, 4, and 5 years of age. Chum salmon are targeted in commercial and sport fisheries, and extensive hatchery production contributes to annual returns in the Grays Harbor tributaries and lower Chehalis Basin tributaries. Chum salmon return and spawn from October to late November.

A recent study found minimal population genetic structure in Chehalis Basin chum salmon (Small et al. 2019). Chehalis Basin chum salmon clustered with other coastal chum salmon populations. Humptulips River chum salmon were slightly differentiated from other Chehalis Basin chum salmon populations, and there was some evidence for isolation by distance.

Resident Rainbow Trout, Cutthroat Trout, and Mountain Whitefish

Similar to the anadromous salmonids, resident trout also prefer clean, cold-water habitat with habitat features including riffles and pools, especially key for spawning. Adults require barrier-free passage corridors with enough water depth and flow to provide unimpeded access to spawning areas. Spawning adults require specific flow conditions, cover, and access to spawning gravels to deposit eggs.

Resident trout (rainbow and cutthroat) are widely distributed throughout the upper mainstem Chehalis River and in the larger tributaries off the mainstem (J. Winkowski et al. 2018). In general, both cutthroat trout and resident rainbow trout are broadly distributed throughout the proposed FRE inundation area (M. Winkowski et al. 2016); however, the abundance of these species has not been estimated for the upper Chehalis Basin. Cutthroat trout have been observed using more upstream, headwater portions of tributaries.

Where studied, there is no genetic difference between resident and anadromous forms of *O. mykiss* in the anadromous zone, and each life-history form may produce offspring of the other (e.g., Courter et al. 2013). Thus, genetic structure found in steelhead (described earlier) likely represents structure found in resident rainbow trout. Genetic analysis of Chehalis Basin coastal cutthroat has not been done. Where evaluated, genetic structure has been found within watersheds where natural and human-made migration barriers exist (e.g., Wofford et al. 2005), among independent spawning tributaries leading directly to marine waters (e.g., Losee et al. 2017), and among spawning tributaries of a large river system (e.g., Bohling et al. 2018). Thus, it is likely that genetic structure among Chehalis Basin spawning tributaries for coastal cutthroat also exists.

In summer, adult mountain whitefish tend to occur in groups in pools and in upstream, cooler locations. Little is known regarding juvenile mountain whitefish spatial distribution in the Chehalis River (J. Winkowski et al. 2018). Mountain whitefish spawning occurs in September through January (Wydoski and Whitney 2003). For rearing, mountain whitefish specifically have been found to prefer deep (greater than 5 feet) medium or large rivers with minimal flow (M. Winkowski and Kendall 2018). Adult mountain whitefish distribution is not thoroughly documented in the Chehalis River; however, they have been found to undergo seasonal long-distance movements (up to 185 river kilometers; M. Winkowski, Kendall et al. 2019).

Within the proposed temporary reservoir area, juvenile rainbow trout or steelhead surveyed in summer were present in 92% of reaches in the mainstem and tributary areas, whereas cutthroat trout were observed only in tributary portions of the temporary reservoir in Lester, Hull, Browns, Big, and Roger creeks and mainly upstream of presumed anadromous fish barriers (M. Winkowski et al. 2016). Mountain whitefish were documented upstream of the confluence of Browns Creek, and at the confluence of Crim Creek and the mainstem Chehalis River (M. Winkowski et al. 2016). In surveys conducted in the upper Chehalis River from 2013 to 2016, mountain whitefish were distributed throughout approximately 6.2 RM and 9.3 RM (10 river kilometers [rkm] and 15 rkm) upstream and downstream of the proposed FRE facility location, respectively (J. Winkowski et al. 2018). Genetic analysis of Chehalis Basin mountain whitefish has not been performed. Where evaluated, mountain whitefish show very little genetic structure within and among major river basins (e.g., Whiteley et al. 2006).

Freshwater Sculpins

Sculpins are benthic species widely distributed in the mainstem Chehalis River and tributaries. Freshwater sculpins are known to seek out woody material and other shelter-forming structures for spawning. Adult sculpins prefer mainstem, medium or small rivers with gravel or cobble substrate. The species also commonly use side channels and tolerate warm or cool water. Generally, sculpins are not highly mobile, with a range of a few hundred meters or less.

Torrent sculpins have been documented throughout the mainstem and tributary portion of the temporary reservoir inundation area in 93% of surveyed reaches (M. Winkowski et al. 2016). Riffle and reticulate sculpins are less common and usually prefer small streams and backwaters. Reticulate sculpins were observed in 41% of surveyed reaches, limited to the mainstem. Some sculpin taxa show clear geographic patterns within the stream network (Young et al. 2017).

Sculpins are also widely observed in off-channel floodplain and emergent floodplain wetland habitats of the middle and lower Chehalis River, including the torrent sculpin, riffle sculpin, reticulate sculpin, and prickly sculpin (Hayes et al. 2016, 2019; Henning et al. 2007). Prickly sculpin is the dominant sculpin species in off-channel and emergent floodplain wetland habitats, whereas other sculpin taxa use these habitats where they are connected to the stream network (Hayes 2019a). Genetic analysis of sculpins from off-channel habitats and the upper Chehalis Basin has revealed that at least five different taxa are represented, including at least two that do not closely match any currently described species (Young et al. 2017; Marshall 2018).

Minnows

As the river transitions from colder upstream headwaters to slower moving, warmer downstream areas beginning around Pe Ell, redside shiner, longnose and speckled dace, and northern pikeminnow dominate the reaches (J. Winkowski et al. 2018). While spawning, minnows prefer gravel substrate in relatively shallow water with a range of velocities; for rearing, the species prefer larger structure and boulders in slightly deeper water (M. Winkowski and Kendall 2018). Dace and shiner are small-bodied fishes that grow to approximately 6 inches as adults, whereas northern pikeminnow and peamouth (*Mylocheilus caurinus*) are relatively fast growing and long lived, growing up to 12 inches. Adult northern pikeminnow are aggressive predators and they may consume large numbers of juvenile salmonids. A study carried out between 1988 and 1989 in the Chehalis River suggested northern pikeminnow did not appear to account for unusually high levels of mortality that coho salmon smolts were experiencing during this time frame (Schroder and Fresh 1992).

Within the proposed temporary reservoir area, redside shiners were documented primarily using the mainstem Chehalis River downstream of the confluence with Browns Creek. Speckled and longnose dace (*Rhinichthys cataractae*) are widely distributed, occurring in 59% and 44% of reaches surveyed, respectively. Longnose dace have been documented using the river farther upstream to the confluence with Roger Creek, and speckled dace above Fisk Falls up to the headwaters (M. Winkowski et al. 2016). Northern pikeminnow were not documented using surveyed reaches upstream of RM 108.

Minnows are also commonly found in off-channel and emergent floodplain wetland habitats; speckled dace, redside shiner, northern pikeminnow, and, less commonly, peamouth have been observed (Hayes et al. 2015, 2016, 2019; Henning et al. 2007). Northern pikeminnow are one of the most widely distributed native fish species in off-channel habitats.

Suckers

Adult largescale suckers are relatively abundant in the upper Chehalis River (J. Winkowski et al. 2018). These species prefer deep-water habitats during the day and move closer to the shoreline at night (Wydoski and Whitney 2003). Suckers tolerate high water velocities, though juveniles prefer shallower water, pools, and backwaters. Suckers prefer gravel substrate and riffle habitat for spawning, which occurs in the spring. Adult largescale suckers undertake spawning migrations in spring, but their distribution in the Chehalis River is not well characterized. Largescale suckers general spawn between April and July, depending on location (Wydoski and Whitney 2003).

Largescale suckers were documented within the temporary reservoir inundation area, downstream of RM 111 in the upper Chehalis River (M. Winkowski et al. 2016). Largescale suckers are also common in off-channel and emergent floodplain wetland habitats (Hayes et al. 2019; Henning et al. 2007).

Olympic Mudminnow

The Olympic mudminnow was designated as a state-listed sensitive species in Washington in 1999. Olympic mudminnow are highly unique to the coastal lowlands of Western Washington, occurring nowhere else in the world, and the majority of the population occurs within the Chehalis Basin with few sightings in other drainages (Mongillo and Hallock 1999). Olympic mudminnow only occur in habitats where there is little or no flow, such as streams, wetlands, and ponds. They require habitats with a muddy bottom and typically occur in areas with aquatic vegetation and where large predatory fish, such as bass, are absent.

The species is wholly dependent on temporarily flooded wetland habitats and is sensitive to changes in hydrology, including changes in flow (WDFW 2013). Olympic mudminnows fertilize only one to two eggs at a time, usually migrating to shallow areas protected from predators (Kuehne and Olden 2014).

The historical range of Olympic mudminnow in the Chehalis Basin has been reduced significantly as key wetland habitats have been affected by human development (Mongillo and Hallock 1999; see the discussion of habitat loss in Section 2.2.1.3). During intensive off-channel habitat surveying in 2015 and 2016, Olympic mudminnow was observed in off-channel habitat adjacent to the Chehalis River mainly between the confluences of Porter Creek and the Black River (RM 33 to 47). They also occurred in low densities upstream of the confluence with the Black River to the South Fork Chehalis River (RM 47 to 88; Hayes et al. 2016; Hayes 2019b). The life history and status of this species is described in more detail in *Threatened and Endangered Wildlife in Washington: 2012 Annual Report* (WDFW 2013).

Bull Trout

Coastal/Puget Sound bull trout are ESA-listed as threatened (64 Federal Register 58909). Bull trout are documented to occur in lower Chehalis River and Grays Harbor tributaries and are presumed to occur in the lower mainstem Chehalis River, which is part of the species' designated critical habitat upstream to RM 43 (near Oakville) (75 Federal Register 63898).

Eulachon

The southern Distinct Population Segment (DPS) of eulachon smelt, which includes Washington state, is ESA-listed as threatened (75 Federal Register 13012). Eulachon spawning has been documented in the Chehalis Basin, as indicated by the consistent presence of larvae across several years (Mallette 2014; Langness et al. 2018). Eulachon were documented in surveys for downstream-drifting larvae in the lower Chehalis River in 2012 and in 2015 to 2017 near Friends Landing Boat Ramp (RM 10) and immediately downstream of the confluence with the Wynoochee River (RM 13).

The Chehalis Basin is not currently included in the designation of rivers included as Critical Habitat (76 Federal Register 65323), since it was reported historically that eulachon were found in low numbers in Grays Harbor. However, recent surveys suggest that a relatively large estimated annual spawning stock biomass exists, as high as 62,330 pounds in 2016 (Langness et al. 2018). Environmental DNA (eDNA) surveys confirm the identify of larvae and eggs captured in surveys to be eulachon and longfin smelt that have similar morphology but occur slightly earlier in the season (Langness et al. 2018).

Adult Eulachon enter freshwater to spawn in January through April in the Chehalis River (Langness et al. 2018). Spawning occurs over coarse sand and pea-size gravel. Adults die shortly after spawning and larval eulachon drift downstream to rear in saltwater (Wydoski and Whitney 2003).

Eulachon are generally observed migrating short distances upstream to spawn in nearshore areas of coastal rivers (Gustafson et al. 2010; Wydoski and Whitney 2003). The spatial extent of surveys in the Chehalis River have been limited to areas downstream of the primary study area; however, it is likely that eulachon distribution extends upstream of the confluence with the Wynoochee River (Langness et al. 2018). Several historical reports suggest that eulachon can migrate many miles upstream in other large rivers (e.g., in the Columbia River as far as the town of Hood River at RM 169; Gustafson et al. 2010).

Green and White Sturgeon

The southern DPS of the green sturgeon is ESA-listed as threatened (71 Federal Register 17757). Green sturgeon have been observed in the lower Chehalis River, and while their current documented spawning habitat does not include the Chehalis River, suitable spawning habitat may exist there (NMFS 2005, 2015). White sturgeon are not federally listed. A recreational fishery and commercial tribal fishery exists for white sturgeon in Grays Harbor and a recreational catch and release fishery exists in the lower and middle Chehalis River. The distribution of white sturgeon is not well characterized; however, it has been reported that white sturgeon have been caught upstream of the Black River (Holt 2019).

Non-Native Fish Species

Non-native fish species have been introduced to the Chehalis River and other habitats within the Chehalis Basin. The major groups of introduced non-native species include those in the centrarchid or sunfish family, and those in the carp or bullhead family. Non-native fish species observed in the lower and middle Chehalis River and adjacent off-channel or floodplain habitats are listed in Attachment E-1, Table E1-2.

Ten exotic fish species have been observed in off-channel habitats: rock bass (*Ambloplites rupestris*), brown bullhead (*Ameiurus nebulosus*), common carp (*Cyprinus carpio*), goldfish (*Carassius auratus*), pumpkinseed (*Lepomis gibbosus*), bluegill (*L. macrochirus*), smallmouth bass (*Micropterus dolomieu*), largemouth bass (*M. salmoides*), black crappie (*Pomoxis nigromaculatus*), and yellow perch (*Perca flavescens*). Of this assemblage, five of the six centrarchid fishes, rock bass, pumpkinseed, bluegill, largemouth bass, and black crappie, were common and widespread, with largemouth bass, bluegill, and pumpkinseed the most common, in that order (Henning et al. 2007; Hayes et al. 2015, 2016, 2019). Non-native predators like largemouth bass, smallmouth bass, and yellow perch are found in at least 40%

of the mainstem Chehalis River (Hughes and Herlihy 2012). Common carp and goldfish occur with more limited distributions (Hayes et al. 2015, 2016, 2019).

Invasive bass thrive in the warmer reaches and slow-moving off-channel habitat of the lower and middle Chehalis River. While both largemouth and smallmouth bass inhabit mainstem and side-channel habitats, largemouth bass are generally assumed to be more associated with side-channel habitat, such as oxbow lakes and side-channel marshes, and smallmouth bass are more river oriented (Wydoski and Whitney 2003). A float survey conducted in fall 2018 from Fort Borst Park in Centralia (RM 67; at the Skookumchuck River) on the mainstem Chehalis River to the Galvin Road Bridge (RM 64) revealed that both smallmouth and largemouth bass commonly occur. Smallmouth bass in excess of 30 centimeters were frequently observed, and largemouth bass in excess of 35 centimeters were not uncommon in lobes of the mainstem river where water velocities were reduced. Based on dozens of observations of large bass of both species, surveyors conclude that exotic bass abundance in the mainstem is greater than previously assumed (Hayes 2019c).

The upstream extents of bass invasion into salmonid-dominated river habitats are associated with warm water temperatures above 50°F and is projected to increase under future climate scenarios (Wydoski and Whitney 2003; Lawrence et al. 2012; Rubenson and Olden 2019). Temperature preferences of largemouth and smallmouth bass are similar, but the upstream extents of their range may differ as largemouth bass may tolerate slightly cooler temperatures for rearing and prefer slightly warmer temperatures for spawning (Wydoski and Whitney 2003).

Bass are opportunistic predators and large individuals can prey on heavily on juvenile salmon where their distributions overlap (Wydoski and Whitney 2003). The presence of invasive predators, including bass, is named as a potential limiting factor for the sustainability of some salmon populations in the Chehalis Basin (GHLE 2011).

Largemouth bass distribution in Chehalis River off-channel habitat extends at least as far upriver as the confluence with the South Fork Chehalis River (Hayes et al. 2016; J. Winkowski et al. 2018). In the mainstem Chehalis River, the non-native sunfish and bass distribution extends as far upstream as Rainbow Falls in the Chehalis River (J. Winkowski et al. 2018).

2.2.2.3 Freshwater Shellfish (Affected Environment)

Three species of freshwater mussels have been documented in the Chehalis River: western floater (*Anodonta* spp.), western pearlshell (*Margaritifera falcata*), and western ridged mussel (*Gonidea angulata*; Waterstrat 2013). Nedeau et al. (2009) provides a review of basic host life-history and habitat information for these species, summarized here.

Freshwater mussel species have a parasitic larval stage that requires a host that is most often a specific fish species; their distribution reflects movement and colonization of their host species (Jepsen 2009). Western floaters are known to parasitize prickly sculpin, three-spined stickleback, and trout. Western pearlshell tend to prefer cold, clean rivers and creeks up to mountain headwaters like their host fish, salmon and trout.

Physical habitat affects the life history of mussels by influencing flow-habitat relationships, reproductive onset and water temperature, glochidial release and host-fish interactions, juvenile settlement and flow magnitude, and growth and water temperature (Blevins 2018). Freshwater mussels are long-lived and slow growing; western pearlshell can live for 100 years and western ridged mussels for 20 to 30 years.

Mussels tend to cluster together in beds that may have been continuously occupied for hundreds of years. Long-standing mussel bed sites are often important for population persistence. Adult freshwater mussels live within, or on the bottom of, river or stream habitats and tend to concentrate in areas with consistent flows and substrate conditions, reflecting portions of the riverbed that are stable even during high flow events. These are also places where near-bed hydrodynamics are optimal for mussel feeding and filtering, and that allow for overlap with fish hosts during reproductive periods. Western ridged mussels co-occur with the western pearlshell, but tend to occur more frequently in depositional reaches with finer sediments. Western ridged mussels are found along bank edges, in areas with stabilizing boulders, clay substrate, and areas with fine sediments as well as gravels (Blevins 2018).

Freshwater mussels have a significant role in filtering and cleaning the water. An average adult mussel can clear 15 to 45 liters (4 to 12 gallons) of water per day (Strayer 2008). In mussel beds, this water filtering removes bacteria, algae, and fine sediment from the water column. Some of the material ingested is bound and released to the riverbed where it becomes food for other organisms including aquatic macroinvertebrates and larval fish.

Freshwater mussel species are vulnerable to decline because they require good water quality, and they cannot evade rapidly changing environmental conditions. They are slow growing, very slow to recolonize, and their habitat is not easily replicated outside of natural processes. The specific parasite-host relationships of the larvae can be disrupted if the host fish is no longer present; mussel recruitment fails when host species do not physically overlap with mussel beds during the appropriate time of the year (Nedeau et al. 2009).

Freshwater mussels have been observed throughout the upper and middle Chehalis River; however, little is known about their distribution and habitat use. They appear to be more common between Rainbow Falls (RM 97) and the confluence with the Newaukum River than reaches upstream of Rainbow Falls.

In a WDFW survey, freshwater mussels were numerous in the mainstem Chehalis River from Elk Creek (at Doty) to the Newaukum River confluence, and mussel densities in some reaches were so high that they were the major substrate (J. Winkowski et al. 2018). These surveys likely covered only a fraction of the mussel distribution in the Chehalis Basin, and species composition was not determined. Eight very localized beds of western ridged mussels have been documented in the Chehalis River downstream of the confluence with the Newaukum River (Blevins 2018). Western ridged mussels co-occur with western pearlshell in six of the known beds and with western floaters in three of the known beds.

2.2.2.4 Aquatic Macroinvertebrates (Affected Environment)

A large diversity of aquatic macroinvertebrate species exists in Pacific Northwest streams (summarized by Hershey and Lamberti 1998; see the list of major taxonomic groups in Attachment E-1). Aquatic macroinvertebrates are categorized into functional feeding groups, including scrapers or grazers that feed on periphyton and algae, collector-filterers and collector-gatherers that capture drifting organic material, shredders that tear and feed on larger material such as leaves, and predators that prey on other invertebrates.

The aquatic macroinvertebrate community includes the larval stages of multiple types of stream-associated insects including but not limited to species that are aquatic during both immature and adult stages; aquatic insects that are aquatic during immature but not mature stages, and non-insect arthropods, snails, crayfish, and aquatic worms. Diversity in life-history patterns among species contributes to a community that changes over the entire year. Life-cycle duration and frequency of new generations within a given year is one trait that is affected by environmental constraints, especially temperature and nutrition. Emergence of a cohort is often synchronized to cues such as temperature or photoperiod, allowing the adult forms to maximize reproductive success.

Macroinvertebrates play a crucial role in the decomposition of organic materials and are a critical link in the flow of energy through the food web, from primary producers to vertebrate predators. Emerging adult macroinvertebrates have an important role as food subsidies to terrestrial organisms such as arachnids and birds. Macroinvertebrates are the primary food source for most stream fishes; the diversity of species and life-history types ensures that various food types are available to many fish species over the entire annual cycle.

Carcasses of spawning salmon are an important food resource for stream macroinvertebrates in the Pacific Northwest. In this way, macroinvertebrates are a major link for the distribution of marine-derived nutrients throughout the stream ecosystem, an important subsidy brought from the ocean by returning salmon (Hershey and Lamberti 1998).

Off-channel and floodplain wetlands often function as areas where macroinvertebrates accumulate and find refuge from extreme flows (Negishi et al. 2002). Floodplain production of invertebrates can be orders of magnitude greater than that produced in the river channel (Gladden and Smock 1990) and result in enhanced growth and survival of salmonids using the floodplain habitat (Sommer et al. 2001).

Aquatic macroinvertebrate communities respond to changes in water quality, water quantity and flow velocity, food abundance, and other habitat parameters (Hershey and Lamberti 1998).

Macroinvertebrates tend to respond to changes in water quality (temperature, dissolved oxygen, and water chemistry) in well documented and predicable ways (Mackay 1992) such that they are used as indicators of stream condition. Macroinvertebrate abundance and community composition are one target of biological monitoring of stream health by Ecology (Ecology 2010) as part of a program to evaluate, restore, and maintain the chemical, physical, and biological integrity of the nation's waters, mandated by the Federal Clean Water Act (33 USC §1251 Sec. 101(a)).

At the site scale, flow velocity, substrate, and food supply determine types of taxa present (Hershey and Lamberti 1998). Riparian canopy has a strong influence on community structure by providing leaves and woody material for shredders. Channel geomorphology affects the macroinvertebrate productivity, which is highest in broad, alluviated channels and lowest in narrow, bedrock, or sediment-depleted reaches. Macroinvertebrates colonize large wood, using it as substrate and as a food resource. Large wood has a strong indirect effect on macroinvertebrate community by slowing stream velocity and stabilizing the substrate. Stream fish populations tend to increase with large wood volume in part because of the associated invertebrate food resources.

Variation in flow (floods and desiccation) is the major source of natural disturbance and temporary reductions in the macroinvertebrate community (Lamberti et al. 1991; Resh et al. 1988). Floods cause substantial reductions in invertebrate diversity and density to only 2% to 10% compared to pre-flood conditions (Lepori and Hjerdt 2006). During floods, algae and mosses are removed from streams by scour or abrasion, and leaves and other detritus are fragmented and flushed downstream.

The response of the invertebrate community to a flood is modulated by the following: 1) the predictability of the flood; 2) the severity of the flood; and 3) the availability of food resources (Lepori and Hjert 2006). Aquatic macroinvertebrates are adapted to respond to intermediate levels of disturbance that occur with natural flood regimes (Ward and Standford 1983; Poff et al. 1997). Recovery of macroinvertebrate communities from intermediate levels of flooding is typically relatively rapid, occurring within weeks to months of the flood event, following largely predictable patterns (Niemi et al. 1990; Mackay 1992; Resh et al. 1988). Recovery occurs by several mechanisms: drift from upstream reaches, oviposition, and migration from undersurfaces of rocks and hyporheic zone that provide refugia during floods (Stanford and Ward 1988).

Under extreme flood conditions, benthic biomass can be significantly reduced. Changes in channel morphology from severe floods with debris flows (i.e., 1 in 2,000 years) may have much longer lasting effects on invertebrate community density and productivity and recovery can vary by functional feeding group (Lamberti et al. 1991; Snyder and Johnson 2006). As the severity of floods increases, the effectiveness of small-scale flow refugia decreases (Sedell et al. 1990) and the sources of colonizers that support recovery become farther apart. Delayed reductions in abundance can also follow major floods (Lamberti et al. 1991). The macroinvertebrate community may take years to recover following a catastrophic flood (more than 5 years; Mundahl and Hunt 2011), and the macroinvertebrate community can be altered over the long term to a new post-flood state (Lamberti et al. 1991).

Chronic human impacts, including climate change, pollutants, increases in temperature, and removal of riparian vegetation, tend to preclude recovery to pre-disturbance conditions (Hershey and Lamberti 1998). Dams that have modified the natural flow regime of streams and rivers remove the structuring influence of floods on invertebrate communities, in some cases leading to dramatic, often deleterious, shifts in community composition (Poff et al. 1997). This is one reason a number of ecologists advocate for the return or maintenance of natural flood regimes to regulated rivers.

2.2.2.5 Marine Mammals and Birds (Affected Environment)

A number of marine fish, bird, and mammal species prey upon Chehalis Basin salmon and steelhead in the ocean. This discipline report focuses on the marine mammal predators whose range brings them to the coastal areas near or within Grays Harbor, and whose diet can be largely made up of salmon species, including killer whale (*Orcinus orca*), California sea lion (*Zalophus californianus*), Steller sea lion (*Eumetopias jubatus*), northern fur seal (*Callorhinus ursinus*), and harbor seal (*Phoca vitulina*). In addition, piscivorous birds that rely on Grays Harbor are included.

Within Grays Harbor, harbor seals are numerous with haulouts located on intertidal mudflats and sandbars. Smaller numbers of California sea lions may occur within Grays Harbor (Jeffries et al. 2000) and their numbers have increased in recent years just outside of Grays Harbor at Westport (Mittan 2015). The eastern DPS of Steller sea lions in Washington mainly occurs on the outer coast (Wiles 2015). Northern fur seals are pelagic, spending most of their lives in the open ocean.

All marine mammals are protected by the Marine Mammal Protection Act of 1972, amended in 1994, with jurisdiction shared between the National Oceanic and Atmospheric Administration (NOAA) Fisheries and USFWS. Steller sea lions were removed from the endangered species list in December 2013. The Southern Resident DPS killer whale population was federally listed as endangered in 2005 and updated in 2014 (70 Federal Register 69903; 79 Federal Register 20802). Grays Harbor and the coast of Washington lie outside the designated critical habitat for Southern Resident killer whales (71 Federal Register 69054).

Killer whales occur broadly around the world. They are divided into distinct ecotypes that may represent subpopulations or subspecies based on their range, appearance, diet, habitat, genetics, and behavior. Two ecotypes of killer whales occur along the inshore areas of the Washington coast west of Grays Harbor: residents and transients. Although their range overlaps at certain times of the year, they are not known to interbreed. Resident killer whales prey upon fish, whereas transient killer whales prey upon other marine mammals and squid.

The Southern Resident killer whales inhabit coastal waters from Southeast Alaska to Southern California, but spend the majority of spring, summer, and fall in the inland waters of Puget Sound and Strait of Juan de Fuca. In summer, salmonids make up the majority of the Southern Resident killer whale diet (more than 98%), with Chinook salmon from the Fraser River and Puget Sound composing most of their summer diet (Hanson et al. 2010; Ford et al. 2016). The winter range and feeding habits of the Southern Resident killer whale are not as well studied; however, they have been observed frequently outside of Grays Harbor near Westport between January and June, presumably following and preying upon large runs of returning Columbia River Chinook salmon (Hanson et al. 2013).

Southern Resident killer whales were listed as endangered in 2005 under the ESA and a recovery plan was completed in 2008. In March 2018, Governor Inslee issued an executive order directing state agencies to take immediate actions to help the struggling killer whale population and establishing the Southern Resident Orca Task Force to develop a long-term plan for recovering killer whales (Office of the Governor 2018). The task force's recommendations support overarching goals to benefit killer whales, including increasing the abundance of Chinook salmon, decreasing disturbance and other risks posed by vessel traffic and noise, reducing exposure to toxic pollutants for killer whales and their prey, and ensuring adequate funding, information and accountability measures are in place to support effective recovery efforts moving forward.

NOAA Fisheries and WDFW developed a prioritized list of West Coast Chinook salmon stocks that are important to the recovery of endangered Southern Resident killer whales (NOAA Fisheries and WDFW 2018). Biologists cautioned that this priority list should not be viewed as a definitive ranking, but rather as a relative and dynamic picture of which West Coast Chinook salmon populations are currently supporting the Southern Resident killer whales. The Southern Resident killer whales prefer Chinook salmon as prey, although they also feed on chum salmon, coho salmon, steelhead, and other species such as halibut (*Hippoglossus stenolepsis*) and lingcod (*Ophiodon elongatus*). The stocks from the Puget Sound, Columbia River, Strait of Georgia, Fraser River, and Snake River were found to be highest priority. The Washington Coast stocks includes spring-run and fall-run Chinook salmon from the Chehalis River and were rated in the next category in priority.

The population of Chinook salmon that originates from the upper Chehalis River is one of several subpopulations originating from Chehalis River and Grays Harbor tributaries that contribute to the Grays Harbor population overall. The Southern Resident killer whales depend on spring-run Chinook salmon as a food source. The number of these fish has been decreasing throughout the region, and several Chinook populations (outside of the Chehalis Basin) that are preyed upon by Southern Resident killer whales are designated as threatened or endangered (70 Federal Register 37160, 79 Federal Register 20802).

In addition, Grays Harbor is one of the five largest estuaries within the Pacific Flyway (Buchanan et al. 2001) and is home to numerous piscivorous waterbirds, waterfowl, and shorebirds. These include the priority species great blue heron (*Ardea herodias*), hooded merganser (*Lophodytes cucullatus*), red-throated loon (*Gavia stellata*), Pacific loon (*Gavia pacifica*), Caspian tern (*Sterna caspia*), double-crested cormorant (*Phalacrocorax auritus*), sooty shearwaters (*Puffinus griseus*), greater yellowlegs (*Tringa melanoleuca*) and red-necked grebe (*Podiceps grisegena*; WDFW 2019a), as well as the Species of Greatest Conservation Need (SCGN) brown pelicans (*Pelecanus occidentalis*), Clark's grebe (*Aechmophorus clarkia*), and common loon (*Gavia immer*). State endangered marbled murrelet (*Brachyramphus marmoratus;* federally threatened) and tufted puffin (*Fratercula cirrhata*) also utilize coastal areas of Washington. Additional piscivorus birds that rely on Grays Harbor include Western gull (*Larus occidentalis*), glaucous-winged gull (*Larus glaucescens*), Heermann's gulls (*Larus heermanni*), and osprey (*Pandion haliaetus;* Wahl et al. 2005).

2.2.3 Climate Change

Worldwide, there is increasing evidence that climate change is impacting biodiversity and that species and populations are responding in a variety of ways (Carter et al. 2018). Crozier et al. (2019) report that major ecological realignments are already occurring in response to climate change. Shifts in dominant physical attributes associated with climate change are typically reported for freshwater flow and temperature, estuarine conditions, sea level rise, and ocean productivity and acidification. Each is discussed in the context of the Chehalis Basin in the following paragraphs as they are likely to impact the life cycles of migratory fish in the study area.

The Chehalis Basin is a rain-dominated watershed that is expected to experience more intense precipitation events and possible shifts in the timing of the most intense rainfall (Mauger et al. 2016). The Pacific Northwest warmed about +1.3°F during the past century (1895 to 2011; DNR 2018). Increases in annual air temperature of 3.3°F to 9.7°F by 2070 to 2099 (compared to the period 1970 to 1999) are projected, with the largest increases projected to occur during summer (Mote et al. 2014).

Because watershed processes are directly tied to climate attributes, a change in climate can affect where and how fish live (e.g., food production, availability, and use of water). Therefore, all aquatic species in the Chehalis Basin are potentially susceptible to environmental changes associated with climate change. For example, higher temperatures throughout the year may impact the abundance and composition of macroinvertebrate communities (Durance and Ormerod 2007). For Pacific salmon, all life stages (early life history, juvenile freshwater, estuary, marine, and adult freshwater) are sensitive to different exposure attributes associated with climate change (Crozier et al. 2019).

In the Chehalis Basin, annual precipitation is projected to increase in both frequency and intensity in the winter, and peak flows are expected to increase on average by 12% by 2040 (mid-century) and by 26% by 2080 (end-of-century; WSE 2019). Summer precipitation is projected to decrease in magnitude by as much as 30% (Mote et al. 2014).

Increased frequency and intensity of streamflow is likely to increase channel scour locally, which has a number of secondary effects (e.g., patterns of wood recruitment, stream substrate material distribution). This could also disrupt salmon spawning behavior and timing, scour salmon redds, displace juveniles, and change sediment deposition patterns in the riverbed. Changes in peak flows could also affect migrations of fish that migrate during high-flow periods, such as coho salmon and steelhead (NWFSC 2015). Ward et al. (2015) evaluated 21 Chinook salmon populations from the Pacific Northwest and found support for the impact of increased flows on salmon, where increased variability in freshwater flows had a more negative effect on population growth than any other climate variable in their model, which included environmental covariates that are major indicators of ocean productivity (Pacific Decadal Oscillation and North Pacific Upwelling indices) along with hydrologic covariates (mean winter flow, flow variability, and date of peak flow events). Changes in habitat associated with climate change may result in direct effects such as mortality from heat stress, changes in growth and development rates, and disease resistance; indirect effects on salmon mortality, growth rates and movement behavior could occur from changes in the freshwater habitat structure and the invertebrate and vertebrate community, which governs food supply and predation risk (NWFSC 2015).

Summer stream water temperatures are expected to increase under climate change scenarios (Isaak et al. 2017, McConnaha 2018) because of increases in air temperatures and lower summer flows, which is represented specifically in the Chehalis Basin in the Chehalis Thermalscape model (J. Winkowski and Zimmerman 2019). The increase in stream water temperatures would reduce the quality and quantity of freshwater habitat, especially for salmonid species that become stressed from high water temperatures (Mantua et al. 2010), and negatively impact freshwater productivity (DNR 2018, Ohlberger et al. 2018, J. Winkowski and Zimmerman 2019).

Higher temperatures in the summer could increase susceptibility to disease, parasites, and predators. They could also affect a species' ability to find suitable microhabitats to reduce effects of increased temperature if the microhabitats are eliminated or reduced in extent and are no longer accessible to the species given its distribution. Changes in summer temperature and flow could affect both juvenile and adult salmon stages in some populations, especially those with yearling life histories and summer migration patterns (Quinn 2005; Crozier and Zabel 2006; Crozier et al. 2010). Adults that migrate or hold during peak summer temperatures can experience high mortality in unusually warm years, especially if trapped and transported above barrier dams (Keefer et al. 2010). Higher temperatures in the winter could increase fry growth or reduce incubation times (NMFS 2016).

Extensive research in the Pacific Northwest has been conducted on the invasion and expansion of non-native species under future climate change scenarios (Lawrence et al. 2012, Lawrence et al. 2014, Rubenson and Olden 2019). This research is highly relevant to the Chehalis Basin given that it is a low-elevation, rain-dominated system that currently supports a diverse assemblage of non-native species. Warmer stream temperatures in the future may positively impact non-native species currently present in the Chehalis Basin; this would cause additional stresses for native species due to increased predation by non-native species (J. Winkowski and Zimmerman 2019).

Salmon and steelhead physiology and behavior are adapted to local environmental conditions, including flow magnitude and timing and temperature. These adaptations vary systematically among populations and are demonstrated in traits such as age and timing of juvenile and adult migrations (Quinn 2005). Expected differences in behavioral responses from climate change include shifts in seasonal timing of important life-history events, such as the adult migration, spawn timing, fry emergence timing, and juvenile migration (NWFSC 2015).

Summarizing the potential effects on freshwater life stages of salmon and steelhead, Mantua et al. (2010) concluded that the combined effects of warming summertime stream temperatures and altered streamflows will likely reduce the reproductive success for many Washington salmon populations, with impacts varying for different life-history types and watershed types.

Overall, it is likely that climate change has already affected salmon and fish species and aquatic habitat in the study area, and impacts are expected to increase in the future.

The life cycles of migratory fish are also affected by estuary and ocean conditions beyond the primary study area. Estuarine habitat such as in Grays Harbor could be affected by higher sea levels and warmer water temperatures. This could reduce the availability of accessible habitat such as wetlands, cause thermal stress, and increase susceptibility to disease, parasites, and predators (NMFS 2016). Eelgrass beds are highly critical biodiversity hotspots that may be vulnerable to ocean acidification and temperature changes (DNR 2019).

Changes in sea level would affect the extent of tidal influence and associated low-elevation areas. Sea level rise could result in the decline (in quality and extent) of coastal wetlands, tidal flats, and beaches (Mote et al. 2014). By 2025, sea level rise is predicted to result in habitat transitions from forested freshwater tidal swamp to brackish and freshwater marsh in lower river surge plain areas, where rising water levels and increased saltwater intrusion would cause trees to die. In the inner estuary and greater Grays Harbor areas, there would be a loss of low-elevation tidal mud and sand flats from sea level rise (ASEPTC 2014).

Environmental conditions in both fresh and marine waters inhabited by Pacific Northwest salmon are influenced, in large part, by two ocean-basin scale drivers, the Pacific Decadal Oscillation (PDO) and the El Niño-Southern Oscillation (ENSO; NWFSC 2015). Marine habitat could be affected by increased water temperatures, changes in the timing and intensity of upwelling, and ocean acidification (Wainwright and Weitkamp 2013). Trends in warming and ocean acidification are highly likely to continue during the next century (IPCC 2013). Higher temperatures could cause thermal stress, shifts in migration or range of fish, and susceptibility to disease, parasites, and predators. Ecosystems could shift or stratification could change, affecting habitat structure and food supply. Ocean acidification could disrupt the food supply system and shift ecosystems (NMFS 2016). West Coast salmon entering the ocean in 2016 were expected to encounter subtropical food webs that do not promote high survival (NMFS 2016). Ocean acidification, lower summer freshwater flows, and higher winter freshwater flows (from creeks and streams) may alter water chemistry and reduce key ecosystem components, especially shell-forming organisms such as oysters, clams, mussels, pteropods, phytoplankton, and zooplankton, or species that depend upon them in coastal and marine waters (DNR 2019).

The full implications of ocean acidification on salmon are not known at this time. Some high-quality salmon prey (e.g., krill) might be negatively affected by ocean acidification, but there are several possible pathways by which higher trophic levels might compensate for changes at a lower trophic level (NWFSC 2015). Migration patterns of fish in the ocean could be affected by climate-induced contraction of thermally suitable habitat. Abdul-Aziz et al. (2011) modeled changes for summer thermal ranges in the open ocean for Pacific salmon. For coho salmon and steelhead, they predicted contractions in suitable marine habitat of 30% to 50% by the 2080s, and for Chinook salmon an even larger contraction of from 86% to 88% (NWFSC 2015).

Finally, climate impacts to one life stage of salmon generally affect body size or timing in the next life stage. For this reason, the life-cycle effects of climate change from spawning adult to spawning adult must be considered to fully identify the scope of risk to a given population. Even without interactions among salmon life stages, the total impacts of climate change in many stages will have cumulative effects on population dynamics, and climate effects tend to be negative across multiple life stages (Healey 2011; Wade et al. 2013; Wainwright and Weitkamp 2013). Any stressors, such as predation, in combination with climate impacts will present pressures of much greater concern than they would individually.

2.3 Studies and Reports Referenced/Used

The following studies, reports, and models were used to identify and evaluate potential fish and fish habitat impacts:

- *Chehalis Basin Strategy Programmatic EIS* (Ecology 2017)
- *Water, Earth, Wetlands,* and *Wildlife Species and Habitats Discipline Reports* (ESA 2020a; Shannon & Wilson and Watershed GeoDynamics 2020; Anchor QEA 2020a, 2020b)
- WDFW Fish Program research and monitoring for the Chehalis Basin Strategy (various authors, including non-WDFW collaborators 2013 to present)
- WDFW Habitat Program research and monitoring for the Chehalis Basin Strategy (various authors 2014 to present)
- WDFW fish abundance records
- WDFW Priority Habitats and Species maps (WDFW 2019b)
- WDFW Priority Habitats and Species list (WDFW 2019a)
- Salmon SCoRE (WDFW 2019c)

- Personal communications for unpublished data (cited at the topic discussed and listed as references)
- Salmon and Steelhead Population Response: Joint Ecosystem Diagnosis and Treatment and NOAA Fisheries' Ecosystem Diagnosis and Treatment (EDT) Life-Cycle Model (LCM) outputs
- Inputs and parameters of the prior 2016 Chehalis EDT model were described in *Chehalis Basin Strategy Analysis of Salmonid Habitat Potential to Support the Chehalis Basin Programmatic Environmental Impact Statement* (McConnaha et al. 2017)
- Physical Habitat Simulation (PHABSIM) study of changes in fish habitat with changes in flow, temperature (Normandeau 2012; Beecher 2015; Pacheco 2019a, 2019b)
- State and federal fish passage design guidelines (NMFS 2011; Barnard et al. 2013)
- *Combined Dam and Fish Passage Conceptual Design Report; Reducing Flood Damage and Restoring Aquatic Species Habitat* (CBS 2017c)
- *Combined Dam and Fish Passage - Supplemental Design Report - FRX Dam Alternative; Reducing Flood Damage and Restoring Aquatic Species Habitat* (CBS 2017d)

2.4 Technical Approach

Potential direct impacts are identified for each of the aquatic habitats and species known to occur in the primary study area and increases in water temperatures as a result of large tree removal in the temporary reservoir inundation area.

When floodwaters are retained under the first three scenarios listed above, the river channel would be turned into a reservoir. Under these conditions, spawning conditions would be eliminated in the temporary reservoir area. For a major flood, 5.3 miles of the river channel and 188 acres would be inundated. For a catastrophic flood based on modeling for future conditions with climate change in late-century, 6.4 miles and 847 acres would be inundated. Based on salmonid spawning locations discussed in Section 2.2.2.1, spawning of fall-run Chinook salmon, coho salmon, and steelhead would be impacted by both major and catastrophic flood retention events, whereas spring-run Chinook salmon would be impacted by major flood retentions due to their spawning distribution occurring predominantly within the 5.3 miles of river channel directly above the FRE dam.

The Proposed Action could affect many fish species. Effects on fish would depend on location and each species' unique life-history and habitat preferences. The magnitude or frequency of flood reduction in any one location would not affect all fish species the same way. Therefore, impacts are assessed based on location relative to the FRE facility site and timing (construction, post-construction non-flood conditions, and flood retention operations). Table E-7 presents a framework of the various factors that were considered when analyzing impacts. For each habitat type and species grouping, impacts are identified for the key locations and timing of different activities and/or flow and flood scenarios.

Table E-7

Parameters Used for Impact Analysis for Fish Species and Habitats Affected by the Proposed Action

LOCATION	TIMING	HABITAT TYPES	SPECIES GROUPS	TOPIC OF ANALYSIS
PRIMARY STUDY AREA FOR DIRECT IMPACTS				
• At the FRE facility • Within the temporary reservoir extent • Subbasins upstream of the temporary reservoir extent • Chehalis River downstream of the FRE facility to RM 9 (west of Montesano)	• During construction • During operation, non-flood retention conditions • During flood retention: – Major flood – Catastrophic flood – Recurring major floods	• Mainstem and headwaters – Above Crim Creek Subbasin • Mainstem – Rainbow Falls to Crim Creek Subbasin • Floodplain off-channel • Emergent floodplain wetland	• Salmon and steelhead • Non-salmon native fish • Non-native fish • Freshwater shellfish • Aquatic macroinvertebrates	• Reduction in fish passage • Elevated noise and vibration • Change in habitat function • Change in aquatic community composition • Change in prey availability • Modeled salmon and steelhead response • Modeled non-salmon native fish response
BROADER STUDY AREA FOR INDIRECT IMPACTS				
• Chehalis River • Estuary and ocean	• Post-construction, long-term trends	• Mainstem – Downstream of RM 9 • Marine	• Salmon and steelhead, including chum salmon • Eulachon, bull trout, green sturgeon, white sturgeon • Marine Mammals • Marine birds	• Change in prey availability • General impacts to salmon and steelhead life cycle

Impacts were assessed quantitatively, whenever possible, by relying on firsthand surveys of fish species and habitats in the Chehalis Basin and modeled predictions for the changes that could occur with the Proposed Action. When quantitative information was lacking, impacts were estimated qualitatively based on comparisons to similar aquatic systems. Data and assumptions used for salmonid impact modeling are detailed in Attachment E-2. Fish passage assumptions used for the EIS are detailed in Attachment E-3.

Sources of quantitative information include results of fish and fish habitat studies conducted since 2012, other published literature or white papers describing fish and habitat specifically in the Chehalis Basin, and modeled fish habitat and fish population responses. For salmon and steelhead, an integrated EDT-LCM approach was used to estimate population-level impacts. For other, non-salmon native fish, the PHABSIM model was used to estimate changes in usable habitat area due to the proposed FRE facility. The integrated EDT-LCM and PHABSIM models are described in further detail in Section 2.4.2.

2.4.1 Aquatic Habitats

Impacts on fish, shellfish, and freshwater fish habitat were identified by evaluating changes in habitat area, habitat function, and aquatic community composition in each of the key aquatic habitats that occur in the study area (headwaters, mainstem, off-channel, and emergent floodplain wetlands).

Fish habitat function considers the following five major factors:

- Hydrology: seasonal habitat inundation patterns, changes in stream flow and dewatering, and temporary reservoir inundation and drawdown
- Water quality: temperature, chemistry, pollutants and turbidity limits as described in Washington State water quality standards for salmonid spawning rearing and migration (WAC 173-201A)
- Geomorphic habitat-shaping processes: substrate type, stream channel dynamics, and large wood
- Riparian area function: vegetation composition, shading, contribution of nutrients, and delivery of large wood to the stream channel
- Fish habitat connectivity: vertically along the mainstem stream channels and horizontally to off-channel areas and wetlands

Aquatic community composition focuses on the food web and competitors for native fish, specifically the aquatic macroinvertebrate prey base for native fish, anadromous fish as the prey base for marine mammal predators, and non-native fish species as predators of native fish.

The analysis also considered the effects of noise and vibration generated during construction. Underwater noise and vibration thresholds are used by the Washington State Department of Transportation (WSDOT) to protect fish from underwater sound originating from activities such as pile driving, and other vibratory work transmitted through open water. Thresholds exist for sound predicted to affect behavior and for sound predicted to cause injury (WSDOT 2016; Hastings 2002; Fisheries Hydroacoustic Working Group 2008).

However, while sound and vibration exposure criteria have been developed to prevent injuries from impulsive sound in open water, they are not applicable for construction activity adjacent to rivers. Effectively measuring transmitted construction sound and vibration in a small river like the Chehalis River may not be possible. Therefore, monitoring fish behavior will likely be necessary to observe effects of sound created by construction as a permit condition of the Hydraulic Project Approval (HPA).

2.4.2 Aquatic Species

Changes to salmon and steelhead population metrics are modeled by integrating the effect of changes in fish habitat function throughout the study area and fish passage through the FRE facility using the integrated EDT-LCM approach (Attachment E-2). Changes in usable habitat area for other key fish species are modeled by integrating changes in water temperature and known habitat suitability criteria using PHABSIM. The effects of changes in aquatic community composition on target species are mostly assessed qualitatively; however, the effect of non-native fish species and food availability on salmonids is considered in EDT.

Impacts are analyzed on the scale of the entire study area or by site, when the site scale varies depending life-history traits of the target species being analyzed. The analysis for impacts on fish and habitat considered the following:

- Temporary, repeated, or permanent change in habitat function
- Temporary, repeated, or permanent reduction in fish passage efficiency and survival
- Temporary, repeated, or permanent change in aquatic community composition, including Chehalis River fish species, their prey, and their predators
- Modeled change in salmon and steelhead population metrics
- Modeled change in usable instream fish habitat area

2.4.2.1 Salmon and Steelhead Impact Assessment

Although Chehalis Basin salmon or steelhead populations are not listed under the ESA, thresholds for significance were determined using a weight of evidence approach and NOAA’s Viable Salmonid Population (VSP) criteria used in ESA listing and recovery plans (McElhaney et al. 2000). These VSP criteria include abundance, productivity, diversity, and spatial structure.

The integrated EDT-LCM modeling approach was used to identify the potential impacts on coho salmon, steelhead, and spring-run and fall-run Chinook salmon from the Proposed Action. The EDT model was used to compute the effect of the Proposed Action on the modeled species at points in time. Life-stage and reach-specific productivity and capacity outputs from EDT based on changes in habitat were then input into NOAA LCM for each species to evaluate stochastic effects of the alternatives on anadromous salmonid population dynamics over time. The integrated approach takes advantage of the strengths of both models, where EDT estimates the effects of an action on habitat, and the life-cycle models incorporate the effects of environmental variability and sequential flood retention events into the analyses.

The Proposed Action analysis incorporates changes over time in salmonid habitat potential due to projected effects of a changing environmental baseline. The modeling of future conditions (mid- and late-century) accounts for projected changes in hydrology (Hill and Karpack 2019) and temperature due to climate change (Van Glubt et al. 2017) and several additional factors. The model also considered land use changes including areas of potential future development, funded and planned culvert removals, tree growth in managed forests, and implementation of five Aquatic Species Restoration Plan (ASRP) early actions. Additional detail on the EDT-LCM integrated model and data and assumptions used is described further in this section and in detail in Attachments E-2 and E-3.

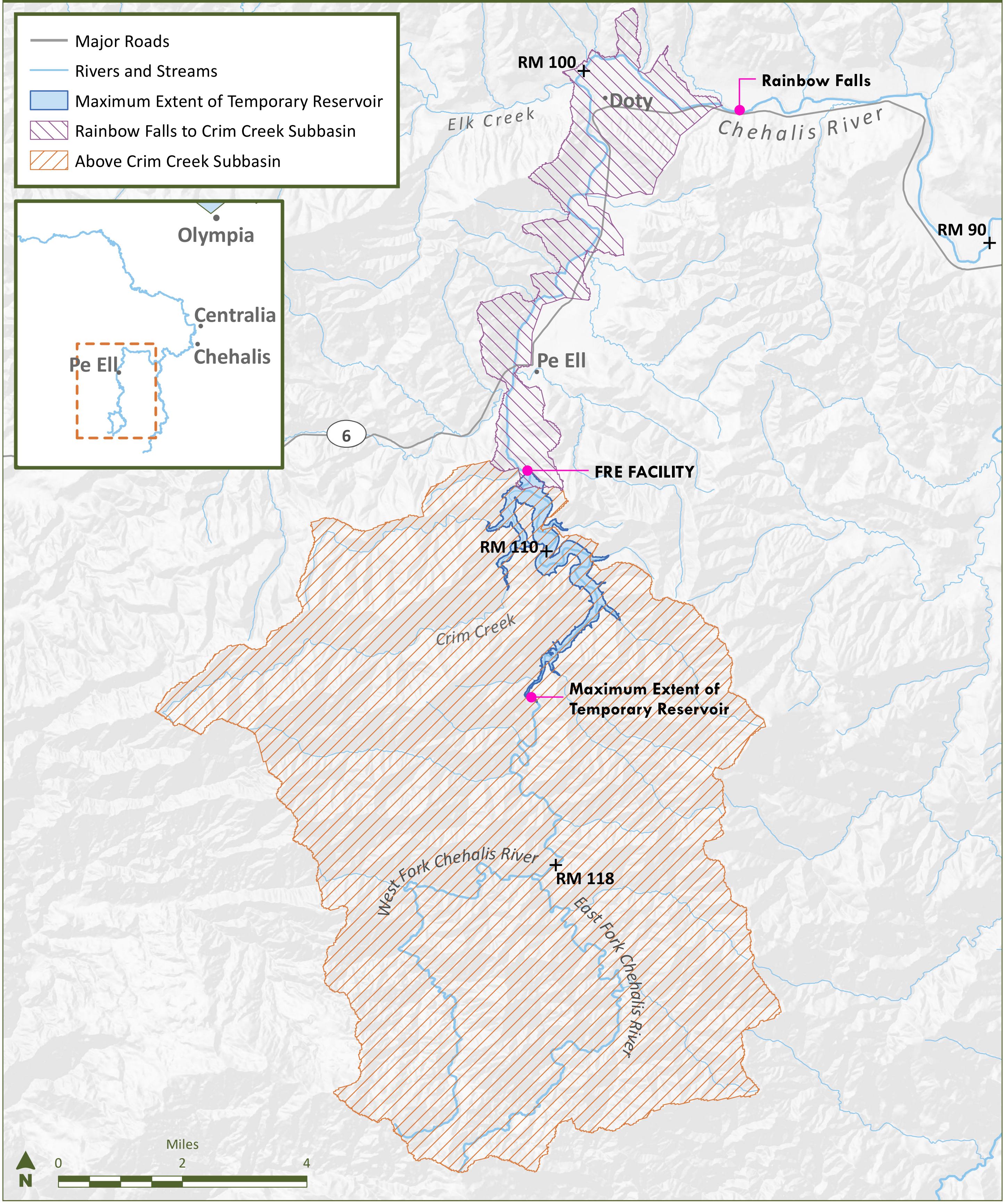
The integrated model evaluates impacts during the construction time period, and during the operations time period under non-flood conditions where the river flows through the FRE outlets, using a 2-year flow level. This interval was selected because it represents normal winter flood conditions that fish in the upper Chehalis Basin would be exposed to during frequent (1- to 5-year recurrence) flows and where FRE facility conduits would remain open. The 10-year flow recurrence interval was selected to represent a major flood scenario because a water flow rate of 38,800 cfs at the Grand Mound gage is reached under this recurrence interval, triggering a flood retention event where the FRE facility conduits are closed. Similarly, the 100-year flow recurrence interval was selected to represent the catastrophic flood scenario because a high water flow rate of 75,100 cfs at the Grand Mound gage is reached, triggering a retention event where the FRE facility conduits are closed. The models used a simulation period (2001 to 2100) for analysis of the Proposed Action. The 2031 to 2063 time frame represents the mid-century period, and the 2064 to 2100 time frame represents the late-century time period in this EIS and overlaps with the operational time frame for the Proposed Action.

Fall-run and spring-run Chinook salmon, coho salmon, and steelhead were modeled using the integrated EDT-LCM approach. Effects on each species are assessed at the following spatial scales (Figure E-9):

- Above Crim Creek Subbasin
- Rainbow Falls to Crim Creek Subbasin

The two focal spatial scales address those parts of the primary study area that would be most affected by the FRE facility. The Above Crim Creek Subbasin includes the area of the mainstem Chehalis River and its tributaries within the temporary reservoir inundation area. This subbasin would be directly affected by flood retention events. The Rainbow Falls to Crim Creek Subbasin includes the FRE facility and the mainstem Chehalis River immediately downstream from the proposed facility and its tributaries. This subbasin would be directly affected by reductions in flow during flood retention events and dam operations. Effects of floods and flood retention, habitat degradation in the temporary reservoir area, fish passage through the FRE facility, and changes in mainstem river habitat below the FRE facility are incorporated into the EDT model and assessed in the Above Crim Creek and Rainbow Falls to Crim Creek Subbasins.

Figure E-9
Salmonid Impact Modeling Units



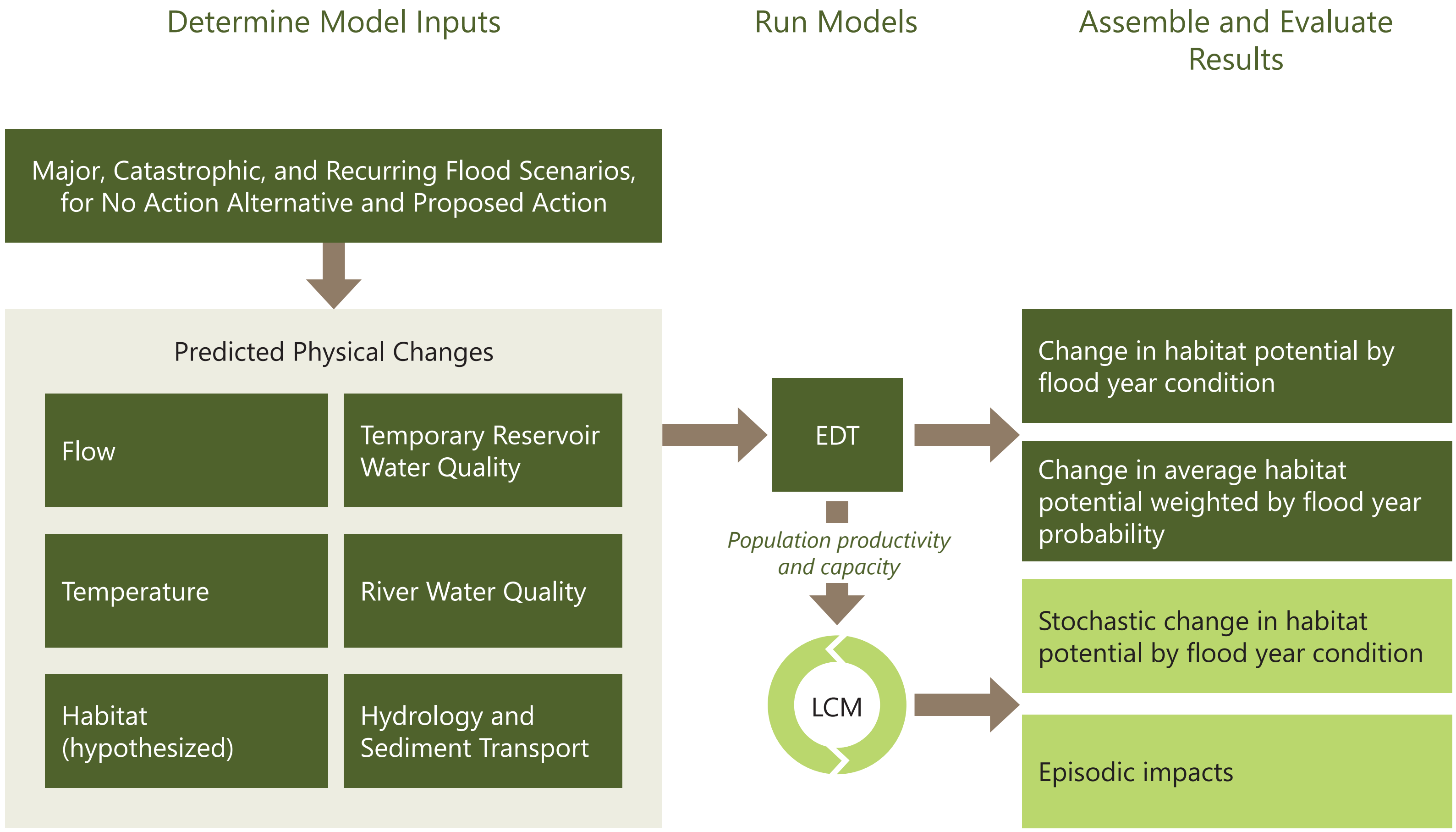
Chum salmon were not modeled because the Proposed Action is not likely to have significant impacts on spawning or rearing chum salmon in the study area. Chum salmon are documented to occur in the mainstem Chehalis River upstream to approximately the confluence with the Black River (RM 47), as well as in lower Chehalis River and Grays Harbor tributaries (WDFW 2019c). Chum salmon spawn in tributaries of the Chehalis River from the Black River (upstream) to the Hoquiam River (downstream) and do not typically spawn in the mainstem Chehalis River (Zimmerman and Holt 2016; Edwards and Zimmerman 2018).

Species distributions in EDT were based on the Statewide Washington Integrated Fish Distribution (SWIFD) system developed by WDFW and through extensive discussions with members of the ASRP Science and Review Team. Separately, Walther et al. (2019) estimated the upper limit of occurrence of coho salmon, steelhead, and chum salmon in the Chehalis Basin using empirical relationships between occurrence data and landscape attributes. Walther et al. (2019) plan to continue to apply the modeling approach to estimate the range of occurrence for each species using a final regression model. When this information is available, the current fish distributions in EDT could be updated and used in future analyses.

Key Model Assumptions

Information used to characterize the Proposed Action and the No Action Alternative in the EDT-LCM integrated model comes from quantitative models and published literature. This information was used to develop assumptions about flow scenarios and habitat conditions with and without the FRE facility and above and below the facility along with fish passage through the FRE facility during construction (2025 to 2030) and operations (2030 to 2080). Construction impacts are based on typical seasonal flows and do not account for the potential of a major or larger flood occurring during construction and backwater effects that could temporarily inundate area upstream of the diversion dam. Future hydrologic conditions, incorporating climate change predictions, are modeled that represent projected mid-century and late-century conditions. In cases where no quantitative information was available to support assumptions, hypotheses were posed based on first principles, professional knowledge, and published literature. The sources of quantitative information and professional hypotheses used to develop the assumptions used in the EDT model are explained in Attachment E-2. The scenarios that are analyzed for the Proposed Action and the No Action Alternative are shown in Figure E-10. Additional information on model inputs and assumptions is provided in Section 2.4.2.1.

Figure E-10
EDT and LCM Modeling Process and Integration



2.4.2.1.1 Ecosystem Diagnosis and Treatment Model

The EDT model aims to capture the physical features and environmental impact of the proposed project and characterizes the change in performance of modeled salmonid species. Potential fish population performance is evaluated based on the following viable salmonid population (VSP) metrics (defined by McElhany et al. 2000):

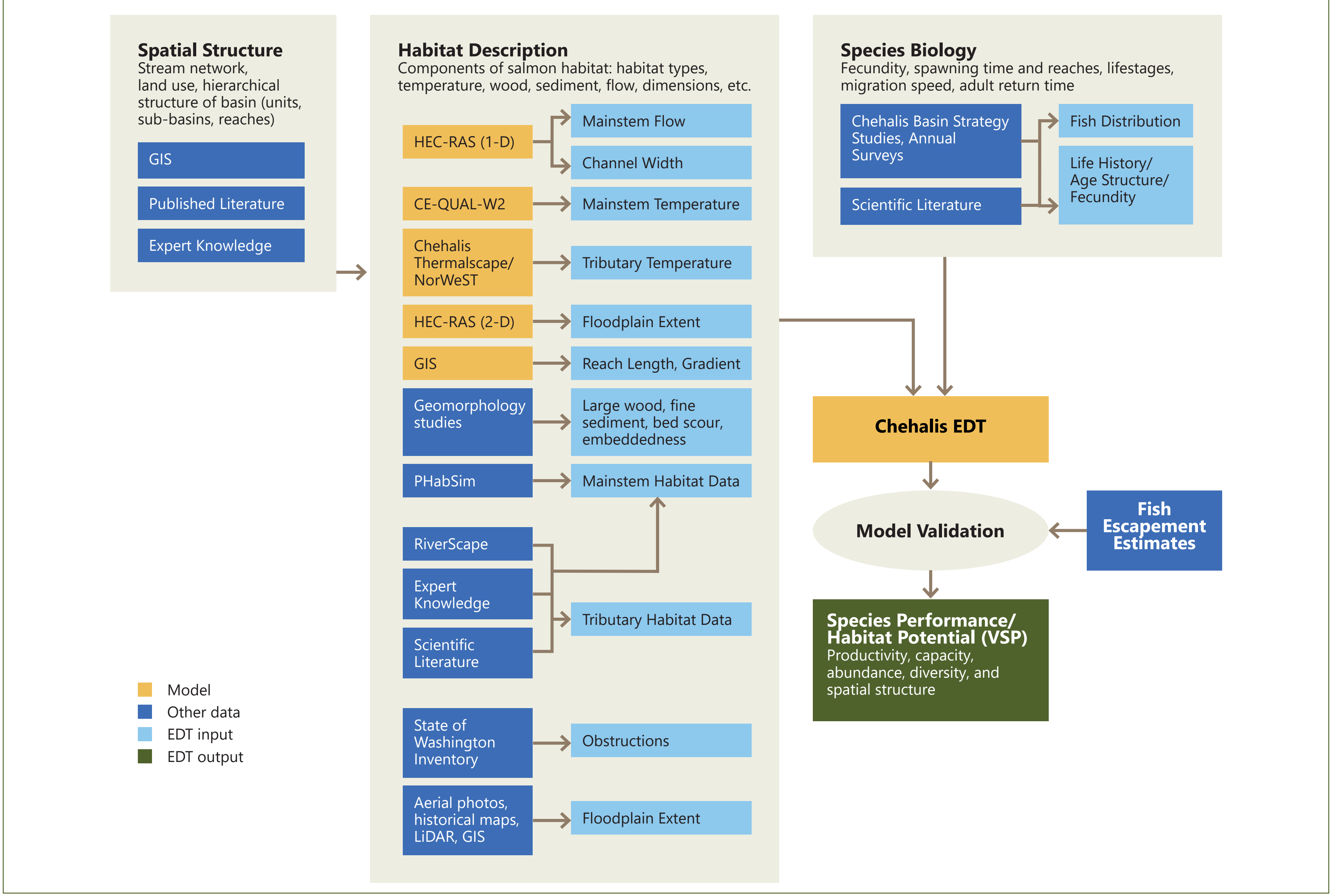
- Abundance: the number of adult fish returning to the basin in the absence of harvest; number of naturally spawning fish needed to ensure that the population persists over time
- Productivity: the density-independent survival rate from spawner to progeny (returns per spawner and how well the population replaces itself)
- Population spatial structure: the pattern of estimated fish abundance across the Chehalis Basin; the geographic distribution of fish at all life stages, needed to protect against a catastrophic loss in one location
- Diversity: the variation in genetic, physiological, morphological, and behavioral attributes (providing the fish with flexibility to adjust to changing environments), the breadth of potential fish performance across the modeled life-history variation

A viable salmon or steelhead Distinct Independent Population (DIP) within an Evolutionarily Significant Unit (ESU; for salmon) or Distinct Population Segment (DPS; for steelhead) is a naturally self-sustaining, demographically distinct unit (based on geographic distance, river structure, ecology, and life-history characteristics) and has a low risk of extinction. Population viability is defined based on a specified probability (e.g., 0.95) of persistence in 100 years.

The EDT model evaluates habitat for species life stages at a reach level along multiple life-history pathways that represent variations in fish life history. Life-stage performance is then aggregated across the species' life history to compute population-level performance. Species performance is assessed in terms of the potential capacity, productivity, abundance, life-history diversity, and spatial structure of the species under the modeled habitat condition.

The EDT model is constructed of three major components (shown in Figure E-11): a spatial structure based on a network of connected stream reaches, a habitat description of the physical and biological conditions at a reach scale, and the species' biology consisting of information describing life history, distribution, and habitat requirements.

Figure E-11
Structure and Major Components of Chehalis EDT Model



The spatial structure of EDT is constructed using a geographic information system (GIS), incorporating geomorphic, topographical, and other physical features to define a network of linked stream reaches. This spatial structure is used to organize the reach-level habitat description that addresses physical conditions in the reaches across months within a year. Information on physical structure (e.g., large wood), hydrology (e.g., high flow, low flow, annual shape), habitat types (e.g., riffles, pools, glides), and channel form (e.g., bed scour, confinement) is collected from multiple sources, including empirical habitat surveys, hydraulic models (e.g., HEC-RAS) and geomorphologic information. Biological information relating to predation, introduced species, and hatcheries is also included because it affects the potential performance of species using the habitat. This information was used to develop assumptions for the EDT model as described in Attachment E-2.

The potential performance of the species under the modeled habitat condition depends on the length of exposure of life stages to the conditions and their biological requirements (e.g., temperature tolerances). Exposure is determined by the location, timing, and migration speed of the life stages that define the life-history pathways within the model. This information is assembled from published literature, reports, and knowledge of local experts. Habitat requirements for each species' life stage are developed to create a generalized set of life-stage survival and density relationships. The life-stage-habitat relationships are used to evaluate habitat conditions for modeled species at a population scale.

During the process of running the EDT model for the integrated approach, quality assurance and control measures were conducted. For example, corrections were made to sediment ratings in the EDT model for mainstem Chehalis River reaches upstream of the Newaukum River due to an error found in the ratings. In this case, updated EDT model outputs were reviewed but were not incorporated into the LCM because the LCM modeling had been completed and differences between the EDT model runs were judged to be small and did not change the results in any meaningful way.

The model was first used to estimate fish performance under the current habitat condition, which was then compared to future performance resulting from restoration projects, flood control projects, or future climate conditions by altering the underlying habitat description.

2.4.2.1.2 Integration of EDT and NOAA Life-Cycle Model

The integrated modeling approach combines the EDT equilibrium-state habitat model with the NOAA life-cycle model (a component of the entire NOAA Model). This approach uses EDT modeling to estimate impacts to salmonid habitat conditions from proposed flood control actions in years with differing flood magnitudes, and life-stage productivities and capacities derived from that analysis are fed into the dynamic NOAA LCM to produce a time series of spawner abundance. The EDT modeling reflects the steady-state equilibrium response to the sets of environmental conditions that vary with water flow level and flood magnitude, and the integrated EDT-LCM illustrates the dynamic population response to changes in the flood event using stochastic year-to-year variation in flood magnitudes based on their recurrence intervals. NOAA developed these life-cycle models for spring- and fall-run Chinook salmon, coho salmon, and steelhead to simulate effects from the Proposed Action. The purpose of the integrated EDT-LCM is to examine time trends in spawner abundance generated by the LCM using the EDT-generated estimates of annual life stage productivities and capacities under several flood conditions and proposed flood control actions.

2.4.2.1.3 NOAA Life-Cycle Model

The NOAA LCM incorporates the population capacity and productivity from EDT into a stochastic (i.e., random process) analysis of fish population performance in the context of variable environmental conditions over time with and without the FRE facility in place. The NOAA LCM also assesses generational effects on salmonid abundance and evaluates the effects of sequential flood conditions on salmon populations by modeling major flood scenarios in 3 consecutive years.

The NOAA LCM is a population dynamics model driven by demographic rates—specifically, life-stage-specific productivities and capacities. In the model, cohorts of fish move through time and space in an age-structured, life-stage-based approach. Life stages include spawning adult returns, eggs deposited in and incubated in streambed gravels, juveniles rearing in freshwater, and the marine phase (including smolt migrants to the bay and ocean). The freshwater spatial extent of the NOAA LCM is identical to EDT. The NOAA LCM tracks cohorts of fish through time, and, because fish spend a variable number of years in the ocean, the LCM includes mixed ages of adults returning to spawn. This age-based, temporal modeling approach allows the potential effects of the loss or significant degradation of cohorts through time as a consequence of FRE facility operation to be estimated at the subpopulation and overall population level.

The NOAA LCM uses the population capacity and productivity outputs from EDT for the estimated conditions during current, mid-century, and late-century time periods, with and without the FRE facility, under conditions for the three representative flow events selected (typical seasonal flows, major flood, and catastrophic flood events). It also evaluates the scenario with major floods in 3 consecutive years.

Results are reported as estimated mean equilibrium abundance of returning adults within a population over time. The year-to-year variability in modeled abundance is shown in response to variation in estimated habitat conditions associated with the different flow scenarios and water years modeled (i.e., from the typical seasonal flows, major flood, and catastrophic flood conditions with and without the Proposed Action). Annual ocean productivity in the LCM is treated as a density independent function, where there is no limit in capacity and productivity is held constant among the flood scenarios modeled. Therefore, effects of variability in marine environmental conditions are not included in the model and have no effect on estimated adult survival or abundance. This was done to focus the analysis on effects of changes in freshwater habitat productivity associated with the Proposed Action and No Action alternatives, and not mask any freshwater effects observed by incorporating marine environment variability into the analysis.

The process of checking the behavior and results of the integrated EDT-LCM model involved two parts: comparisons of EDT-LCM adult spawner abundance with EDT-generated equilibrium spawner abundance; and inspection of changes in adult spawners across all of the model iterations through the different time periods and scenarios. Initially, NOAA ran the model under a fixed scenario (climate, flood, action combination), and verified that the EDT-LCM adult spawner abundance matched the EDT-generated equilibrium abundance. Once it was verified that the two models would produce the same results under fixed conditions, NOAA began running the model under varying conditions. NOAA then examined the dynamics of the spawner abundance results (the spread, if any, of the model iterations and the changes across climate periods and between scenarios) in response to changes between mid- and late-century climate periods.

NOAA checked that the EDT-LCM results fell roughly within the range of the three EDT flood scenarios for a given climate-action analysis combination. The EDT-LCM results could fall outside of the EDT results for two main reasons: 1) the EDT-LCM stochastically uses EDT-generated productivities, so a fish may experience juvenile rearing under one flow condition and adult holding under another, thus producing deviation from the EDT results which report equilibrium abundance under constant conditions; and 2) the effects of mixed age of adult returns in the EDT-LCM means more than one brood year contributes to the spawning adults each model year, creating further deviation from the static conditions of the EDT results.

2.4.2.1.4 Modeling Limitations, Uncertainty, and Variability

There is uncertainty associated with any forecast based on model studies. Uncertainty in the salmonid modeling conducted for this EIS is described in Attachment E-2, and the areas of uncertainty are summarized as follows:

- The biological status of spring-run Chinook salmon in the Chehalis basin, including current and historic distribution and pre-spawning behavior.
- Difficulty in distinguishing spring-run Chinook salmon in the Chehalis Basin from fall-run Chinook salmon.
- How habitat conditions above and below the FRE facility during construction and operation will change.
- Uncertainty associated with 10- or 100-year floods occurring during FRE facility construction (rather than 2-year floods, which is what is currently modeled). A 10- or 100-year flood during this period could have major impacts on fish species and habitat.
- Uncertainty associated with fish passage estimates.
- The effect of climate change on conditions in Grays Harbor and the ocean.
- Uncertainty in mid- and late-century conditions for peak flows, low flows, and stream temperature.
- Common model uncertainties (life-stage representation, capacity estimates, survival estimates, changes in parameters due to habitat change, etc.).

- Uncertainty associated with conditions above the proposed FRE facility or in any tributary of the Chehalis River because the HEC-RAS model could not be used to evaluate these areas.
- Uncertainty in flooding impacts to flow and channel width because the EDT model is structured based on monthly (not daily) increments of time. The impacts of the flood events are diminished when daily flows are incorporated into a monthly time step in the analysis.
- Uncertainties associated with lack of variation in timing and duration of the flood events in 2-, 10-, and 100-year flood years; no variation in flow conditions at other, non-flood event, times of the year; and no variation in the life stage of the salmon and steelhead being affected by the flood event. Additionally, uncertainties due to actual differences in 2-, 10-, and 100-year flood conditions in the future have not been captured since specific water years were chosen as representative in the models.
- Uncertainties associated with the impacts of bed scour on salmon and steelhead survival in tributaries of the two modeled reaches because this was not included in the models (only impacts to the mainstem were included).
- Uncertainty associated with the fact that changes in hydrology associated with the 3 water years modeled were not modeled in the reach above the proposed FRE facility.
- Impacts due to changes in mainstem river water temperature associated with 2-, 10-, and 100-year flow recurrence intervals are uncertain because these data were not available.

The following impacts are evaluated in the *Earth Discipline Report* and *Water Discipline Report* and in the habitat sections below but were not considered in the modeling approach for areas downstream of the FRE facility:

- Broad, long-term effects of a lack of channel-forming flows downstream of the FRE during floods
- How a lack of flooding would impact channel width, fine sediment levels, floodplain maintenance and formation, and riparian structure and function

Variability refers to natural variability in habitat conditions or life-stage parameters. Annual variation in habitat conditions affected by peak flows was incorporated into the modeling approach. The integrated model results reflect the influence of these factors on variation in annual abundance and equilibrium population size. Variability associated with ocean conditions and marine survival, freshwater life-stage survival (e.g., egg-to-fry survival), and FRE facility passage survival would be expected to increase the variability around median abundance estimates. These were not incorporated into the modeling approach.

2.4.2.2 Non-Salmon Fish Impact Assessment

The change in usable habitat that would occur with the FRE facility is evaluated for a representative suite of fish species using Weighted Usable Area (WUA) calculated with the Chehalis PHABSIM model. The PHABSIM model was prepared based on direct measurements in the Chehalis Basin in conjunction with WDFW to model relationships between flow and WUA, or the usable habitat in units of square feet per 1,000 feet of river channel (Normandeau 2012; Caldwell et al. 2004). Thus, WUA is an index of habitat availability, at varying river flow levels. The area from the upper Chehalis River near the FRE facility to Elk Creek is the focus for estimating change in WUA with the Proposed Action and No Action alternatives.

The PHABSIM model uses Habitat Suitability Criteria that were developed to characterize the microhabitat preferences of six species during spawning and rearing life stages in terms of water depth, water current velocity, and substrate preference. Habitat Suitability Criteria were updated with recent observations made in the Chehalis Basin to improve specificity of the criteria (M. Winkowski and Kendall 2018) for Pacific lamprey, speckled dace, largescale sucker, and mountain whitefish. In addition, the relationships between flow and WUA were adjusted to show the effect of temperature on different life stages of key fish species (with input from WDFW provided in Beecher 2015; Pacheco 2019a, 2019b; M. Winkowski 2019). It should be noted that temperature ranges occupied by these species were based on observations in published literature about other rivers; species-specific temperature tolerances have not been identified for the Chehalis River and, therefore, may not adequately represent the true range of temperatures occupied by these fishes.

WUA was calculated for the range of average temperature and average stream flow conditions that typically occur across the year, within various reaches of the mainstem Chehalis River, for a selected set of species. The selected species are representatives of guilds (a group of species that use the same resources) defined by their presence in different areas of the river and life histories, including species that occur in more upstream reaches of the river with cooler water and downstream reaches with warmer water; spring, summer, and fall spawners; and migratory and resident species. The species analyzed included four native fish species (largescale sucker, Pacific lamprey, mountain whitefish, and speckled dace) and two non-native, fish predator species (largemouth bass and smallmouth bass; Table E-8).

Table E-8
Representative Fish Species Analyzed for Weighted Usable Area

REPRESENTATIVE SPECIES	OCCUPANCY	SPAWN TIMING	RANGE
Largescale Sucker	Downstream/warmer[1]	Spring	Resident and migratory (within freshwater)
Mountain Whitefish	Upstream/cooler[1]	Fall/Winter	Migratory (within freshwater)
Pacific Lamprey	Broadly distributed[2]	Spring/Summer	Migratory (anadromous)
Speckled Dace	Downstream/warmer[1]	Summer	Resident
Largemouth Bass	Downstream/warmer[1]	Spring/Summer	Resident
Smallmouth Bass	Downstream/warmer[1]	Spring	Resident

Note: Weighted Usable Area is an index of habitat availability, at varying river flow levels.
Sources:
1. J. Winkowski et al. 2018
2. M. Winkowksi, Cropper et al. 2019

The effects of the Proposed Action and No Action Alternative were estimated by calculating the change in WUA that would result from the change in average flow and average water temperature projected to occur due to climate change and the FRE facility by mid-century (2040) and late-century (2080).

The monthly averages of average daily flows from water years 2013 and 2014 were used to represent the baseline condition. For evaluating the effect of the FRE facility, it was assumed that typical flow conditions would be unaffected and water temperatures would increase due to the removal of vegetation in the temporary reservoir inundation area. Future conditions were modeled based on predicted changes in precipitation and air temperature due to climate change (Mauger et al. 2016) and resulting changes to surface flows (Hill and Karpack 2019) and surface water temperature with a temporary flood storage facility, accounting for the loss of shading due to removal of vegetation in the temporary reservoir inundation area (Van Glubt et al. 2017). By late-century, average monthly flows would increase slightly in fall, winter, and spring (3% to 7%) and would be reduced in summer (16%), and daily average water temperature would increase year-round, with greatest increases of up to 2°C to 3°C in mid- to late-summer in the temporary reservoir inundation area, as discussed in greater detail in the *Water Discipline Report*.

The change in WUA by mid-century and late-century was calculated for each species and life stage in the reaches that would experience changes in temperature due to the FRE facility: one site in the upper Chehalis River upstream of Crim Creek (at RM 110.9) and the reach of the river from Pe Ell to the confluence of Elk Creek.

The PHABSIM model was not developed to evaluate the effects of high-flow events and daily temperature extremes (minimums and maximums). Rather, it is useful for examining the change in the average amount of habitat available under typical flow conditions and average temperatures as they vary across the year. In addition, the WUA estimated by the PHABSIM model varies with the amount of fine substrate in a given reach, and substrate composition is predicted to change in the reaches just above and below the FRE facility as a result of flood retention (discussed in detail in the *Earth Discipline Report*). However, substrate was not included as a factor in this analysis because the increase in fine sediment due to the FRE facility would be less than 3%, which is below the sensitivity threshold for PHABSIM. Given these limitations, the changes to WUA may underestimate impacts for smallmouth bass.

2.4.2.3 Fish Passage

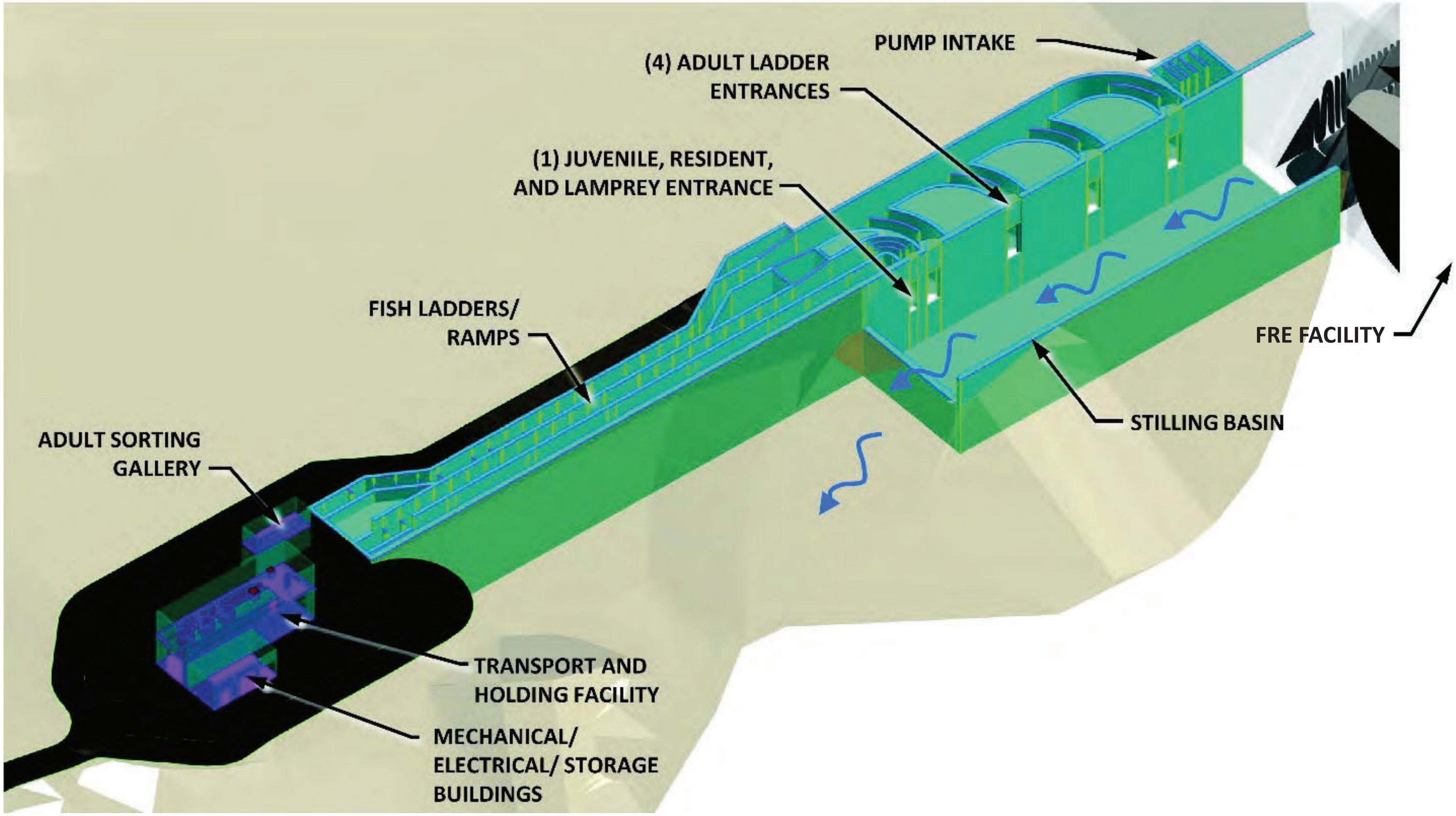
Fish passage performance is the combination of passage efficiency and survival. These were estimated for passage through a temporary flow diversion tunnel and temporary trap-and-transport during FRE facility construction, and through use of a specialized fish collection, handle, transfer, and release (CHTR) system during operation (Figure E-12).

The Applicant's fish passage design for the FRE facility must meet state and federal regulations and optimize fish passage during construction and during operation, including non-flood conditions and during flood retention events. NOAA Fisheries requires fish passage to be provided between the 95% and 5% exceedance flow values, or in other words the middle 90% of the streamflow of record when migrating fish are normally present at a site (NMFS 2011). The Revised Code of Washington (RCW) 77.57.030 requires provision for passage of all fish and fish life stages believed to be present in the system.

The Applicant's project description uses elements of the fish passage design that were reviewed by the Chehalis Basin Strategy's Fish Passage Technical Subcommittee (Subcommittee) of the Flood Damage Reduction Technical Committee in 2016 (CBS, 2017c; Appendix G, Attachment A). Subcommittee participants included representatives from WDFW, USFWS, National Marine Fisheries Service (NMFS), Washington Department of Ecology (Ecology), Quinault Indian Nation, and the State of Washington Consultant Study Team (HDR and Anchor QEA). Attachment E-3 provides details of the process used to review the design. Detailed design information is not available from the Applicant at this time but would be required for the permitting process. Information used for the EIS analysis is described in the *Proposed Project Description and Alternatives* (Anchor QEA 2020d) in Appendix 1 of the EIS.

To estimate the fish passage efficiency associated with temporary trap-and-transport methods to be provided during FRE facility construction, estimated performance of similar temporary systems for adult salmonids used in western Washington were reviewed. Information on the design details used to develop the fish passage survival values are provided in Attachment E-3.

Figure E-12
Isometric View of the CHTR Fish Passage Facility



Source: HDR 2018

The effects of the proposed FRE facility on fish passage performance are evaluated for spring-run and fall-run Chinook salmon, coho salmon, steelhead, coastal cutthroat, Pacific lamprey, and western brook lamprey in various life stages. The information used for the life stages is derived from field-specific data obtained by WDFW in 2015 and 2016 and historical documentation developed for the Chehalis Basin. These fish are known to be present near the FRE facility, in the inundation area of the associated temporary reservoir, and upstream of the reservoir for both upstream and downstream passage (Table E-9). Anticipated migration periods of selected fish species are shown in Figure E-4.

Fish passage survival estimates for spring-run and fall-run Chinook salmon, coho salmon, and steelhead during FRE facility operation are used in the EDT model to inform the population response using the integrated EDT-LCM approach (Table E-9). The effects of changes to fish passage through the FRE facility reach on salmon and steelhead population responses were quantified by incorporating the estimates of fish passage survival for target salmon and steelhead species and life stages into the EDT model for the project alternatives (No Action and Proposed Action), time frames (construction and operation), and flow scenarios (typical seasonal flows, major and catastrophic floods, and recurring floods). The effect of reduced fish passage survival during construction (a duration of up to 5 years) is also included in the EDT-LCM. No variation in fish passage survival rates was incorporated into the models.

Specific information on fish passage performance for coastal cutthroat, Pacific lamprey, and western brook lamprey was not available. Assumptions for estimated fish passage survival for these species was based on discussions with experts and were used qualitatively to assess fish passage impacts (Table E-9).

Fish passage survival rates were determined for selected species for the scenarios analyzed for construction and operation of the proposed FRE facility site (Table E-9). One survival value was developed for both the major and catastrophic flood retention events because fish passage would be equivalent for the two flood scenarios. Adults and juveniles migrating downstream would have to reside temporarily in the temporary reservoir under both a major and catastrophic flood, and the effectiveness of the CHTR facility for adults and juveniles migrating upstream would be similar between all flood scenarios (major or catastrophic floods).

Table E-9

Estimated Fish Passage Survival Rates for the FRE Facility[1]

LIFE STAGE	DIRECTION	DURING CONSTRUCTION	NON-FLOOD RETENTION	FLOOD RETENTION
SPRING-RUN CHINOOK SALMON				
Adult	Upstream	61%	94%	91%
Juvenile	Upstream	0%	64%	50%
Juvenile	Downstream	85%	85%	0%
FALL-RUN CHINOOK SALMON				
Adult	Upstream	65%	94%	91%
Juvenile	Upstream	0%	64%	50%
Juvenile	Downstream	85%	85%	0%
COHO SALMON				
Adult	Upstream	32%	94%	91%
Juvenile[2]	Upstream	0%	64%	50%
Juvenile[2]	Downstream	85%	85%	0%
STEELHEAD				
Adult	Upstream	45%	96%	91%
Adult	Downstream	49%	75%	0%
Juvenile	Upstream	0%	79%	54%
Juvenile	Downstream	95%	95%	0%
COASTAL CUTTHROAT				
Adult	Upstream	9%	92%	54%
Adult	Downstream	Not estimated	78%	0%
Juvenile	Upstream	0%	64%	45%
Juvenile	Downstream	85%	95%	0%
PACIFIC LAMPREY				
Adult	Upstream	Not estimated	96%	Not estimated[4]
Juvenile[3]	Downstream	0%	95%	0%
WESTERN BROOK LAMPREY				
Adult	Upstream	Not estimated	96%	Not estimated[4]
Juvenile[3]	Downstream	0%	95%	0%

Notes:

1. 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.
2. Includes coho salmon fry, transitional and smolt life stages.
3. Includes ammocoetes and macrophthalmia.
4. Pending more information being provided by the Applicant regarding the low velocity CHTR entrance; the proposed design is a prototype, the design has not been developed beyond the 30% level, nor has the prototype been installed or evaluated.

FRE Facility Construction Period

Fish migrating downstream through the FRE facility during construction, including actively migrating juvenile salmon and steelhead in the smolt life stage, would pass the site using a temporary flow diversion tunnel. A conservative approach was used to determine the downstream passage survival estimates for juvenile salmonids through the flow diversion tunnel. Factors considered included the following:

- Estimated passage efficiency through the diversion tunnel
- Potential effects of vegetation removal in the temporary reservoir area during construction
- Water ponding upstream of the diversion tunnel during high-flow events
- Debris accumulation at the entrance to the flow diversion tunnel

Upstream passage of adult salmonids would be provided during construction through temporary trap-and-transport methods, using temporary picket weirs downstream of the FRE facility construction site to guide fish a ladder entrance. Adult salmon would then be transported around the FRE facility construction site using live boxes and transport trucks. The estimated total survival values for temporary trap-and-transport operations (Table E-9) are based on the combination of estimated trapping efficiency and survival during the transfer to trucks, transport, release, and post-release.

For upstream passage during construction, the Applicant's project description states "juvenile salmonids, resident fish, and lamprey that are captured and collected will be considered incidental to the collection of adult target salmonid species" (Martin 2019). Due to the uncertainty of fish passage survival and feasibility of passage for these species and life stages with the temporary trapand-transport system, the EIS assumes upstream fish passage survival is 0% during construction (Table E-9).

As described in Attachment 3, juvenile salmonid movement upstream through the diversion tunnel was judged unlikely to occur for three reasons. First, it was assumed that juvenile salmonid parr would be hesitant to move upstream against the current through a 1,680 foot-long, dark tunnel. Second, the temporary picket weir installed downstream of the FRE facility during construction may act as a visual or behavioral barrier that inhibits the upstream movement of salmonid parr. Finally, if not mitigated by BMPs, construction activities could create a behavioral deterrent for upstream migrating fish if vibration created by construction activities reaches levels that exceed background levels in the water column or water quality is affected by releases of turbid water.

Assumptions regarding operation of the temporary trap-and-transport operations that were incorporated into the estimated survival values are discussed in Attachment E-3. These include assumptions that transported fish would move downstream after release, steelhead adults (kelts) migrating downstream through the bypass tunnel would approach the picket weir from an upstream direction, the design of the picket weir would provide a slot or "vee" to allow steelhead or other species migrating downstream to pass the weir, and flow events would occur at a magnitude that overtops (lays down) the pickets.

The Applicant's project description does not include plans to light the diversion tunnel for fish passage. However, fish move throughout the diel period, and juvenile steelhead in the upper Chehalis River show a clear pattern of upstream movement near dawn and downstream movement during early evening

(J. Winkowski and Zimmerman 2017). For this EIS, it was assumed that no juvenile salmonids would migrate upstream through the diversion tunnel during construction due to its length, the dark conditions, and vibration associated with construction activities (Table E-9).

Upstream passage for juvenile salmonids or other fishes during construction will need to be addressed during permitting during which three options may be considered: 1) juvenile salmonids may pass upstream through the temporary flow diversion tunnel; 2) passage may occur through incidental catch during operation of the temporary trap-and-transport facilities designed for adult salmonids; and 3) a facility or program designed specifically to capture these species and life stages may be designed and operated.

FRE Facility Operations

Non-Flood Conditions

The impact assessment included the following assumptions during non-flood conditions:

- Fish would enter and pass through the 310-foot-long, unlit tunnels in the base of the FRE facility.
- The design of FRE facility outlet tunnels would be required to meet federal and state regulations for upstream and downstream passage for migrating adult and juvenile salmon and steelhead, resident fish, and lamprey for the full range of flow conditions, up to the high fish passage design flow threshold, as required by NOAA Fisheries' flow exceedance criteria (NMFS 2011; CBS 2017a).
- A 2-year flow event (typical seasonal flow) would pass through the low-level outlets without surcharging. Surcharging is a condition where the water level at the upstream entrance of a conduit is above the top (crown) of the conduit. Flows up to 8,500 cfs would pass through the low-level outlets without surcharging. Above this river flow, surcharging could occur, and water could back up at the (upstream) entrance to the tunnel.
- The FRE facility would typically allow water from all flow events up to about 8,500 cfs to pass through the facility with the outlet gates fully open and with no surcharging. The outlet conduits have been designed to provide sufficient capacity to prevent a backwater condition from developing upstream of the outlets for flows up to and above a required high fish passage flow (2,200 cfs; CBS 2018a). However, as river flow increases, surcharging occurs, and water backs up at the entrances to the outlets. Flow at the entrances under these conditions transitions to a submerged inlet and orifice flow when the river elevation is between 445 feet mean sea level (msl) and 449 feet msl (CBS 2017c, Appendix B).
- The FRE design incorporates flow velocity and depth through the outlet conduits that mimic the flow velocity and depth occurring through the existing river channel in this reach, although the length of the FRE outlet tunnels is longer than the existing bedrock canyon.

Flood Retention Periods

The FRE facility would impound water when the river is forecasted to rise above 38,800 cfs within 48 hours at the downstream river monitoring gage at Grand Mound, Washington. After flood operations have been initiated and the conduit gates begin regulating outflows, fish passage through the conduits would no longer be available and operation of the CHTR facility for fish passage would begin (CBS 2018b). The exact details of how fish passage would transition from open outlet conduits to closed conduits and operation of the CHTR facility have not been identified by the Applicant. The impact assessment included the following assumptions during flood retention periods based on the current operating plan (CBS 2017e):

- The FRE facility outflow would be reduced at a rate of 200 cfs per hour 2 days prior to the predicted start of major flooding.
- Gates for the FRE outlets would be closed to upstream migrating fish. A minimum of 300 cfs would continue to flow through the lowest FRE outlet at all times.
- Juvenile and adult salmonids and other fishes migrating downstream would reside in the temporary reservoir for up to 35 days.
- Flow releases during and after flood retention would vary according to the Reservoir Operations and Management Plan (detailed in Appendix 1, *Proposed Project Description and Alternatives*). During drawdown fish would exit the temporary reservoir through the FRE outlets.
- A maximum rate of change in reservoir outflow of 200 cfs per hour would be used to minimize the potential for fish stranding downstream of the temporary reservoir.
- Upstream migrating adult and juvenile fish would be collected at the CHTR facility, transported, and released upstream of the FRE facility.

2.4.2.4 Shellfish, Aquatic Macroinvertebrates, Marine Mammals and Birds

The effects of the proposed actions on freshwater shellfish and aquatic macroinvertebrates are evaluated qualitatively because of a lack of documentation of their distribution in the primary study area, particularly in the areas that will be most affected in the temporary reservoir inundation area and the reaches immediately downstream of the proposed FRE site. Generalizations and assumptions have been made based on known habitat preferences, and projected changes in the key habitat elements that support these species.

Potential indirect impacts on marine mammals and birds that prey upon salmon and steelhead are identified based on the potential change in this element of their prey base.

2.4.2.5 Related Impact Assessment Information

The U.S. Army Corps of Engineers (Corps) is conducting a review of the Proposed Action under the National Environmental Policy Act, as the lead federal agency, and is responsible for addressing federal requirements such as the ESA in consultation with the USFWS and NOAA Fisheries. The USFWS and NOAA Fisheries work in cooperation with tribes and other federal, state, and local agencies to implement the ESA. The federal agencies follow federal regulations for protecting threatened or endangered species and for adding a species to the threatened or endangered list. If it is determined that the ongoing survival of a species or isolated population is at risk, additional measures may be identified under these processes that could further reduce potential impacts on fish and habitat.

Salmonid production from the Chehalis River is an important contributor to ocean fisheries and is essential for supporting in-river fisheries such as ceremonial, subsistence, commercial and non-commercial tribal harvest and recreational fisheries. Decreased abundance and productivity in salmonid species associated with the Proposed Action could affect harvest allocations. However, multiple factors are considered when setting harvest allocations, and no assessment is made of how co-managers might adjust harvest regulations and allocations in the future due to any reductions in abundance and population productivity associated with the Proposed Action.

3 TECHNICAL ANALYSIS AND RESULTS

3.1 Overview

This section describes the probable impacts on aquatic and fish species and habitats from the Proposed Action (Section 3.2), Local Actions Alternative (Section 3.3), and No Action Alternative (Section 3.4). This section also evaluates required permit conditions and planning document requirements that could address the impacts identified (Section 3.2.5). When probable significant adverse environmental impacts remain after considering these, the report identifies mitigation measures that could avoid, minimize, or reduce the identified impact below the level of significance, if possible (Section 3.2.6).

3.2 Proposed Action

Potential effects of the Proposed Action are described for periods of construction (2025 to 2030) and operation (2030 to 2080). Although Chehalis Basin salmon or steelhead populations are not listed under the ESA, thresholds for significance were determined using a weight of evidence approach and NOAA's Viable Salmonid Population (VSP) criteria used in ESA listing and recovery plans (McElhaney et al. 2000). These VSP criteria include abundance, productivity, diversity, and spatial structure.

Section 3.2.1 presents model results for spring-run and fall-run Chinook salmon, coho salmon, and steelhead for both construction and operation periods. The modeling results are then incorporated into the discussion of construction impacts (Section 3.2.2) and operation impacts (Section 3.2.3) of the Proposed Action in terms of changes in salmonid abundance. Impacts on fish species due to construction and operation of the FRE facility, including changes in landscape and habitat functions, as well as impacts associated with climate change were evaluated.

3.2.1 Modeling Results for Impacts of Construction and Operations of the Proposed Action on Salmonids

Modeling results for the construction and operational periods of the Proposed Action are described in the following sections. Integrated model results are presented as the median value followed by the range in estimated abundance (minimum-maximum) for each species once the population stabilized within each time period analyzed (construction, operations mid-century, and operations late-century). Next, the relative change in estimated abundance is presented.

The relative change (percentage) values provide information about the direction and magnitude of any changes in abundance. The models were used primarily to inform relative changes in abundance associated with the Proposed Action rather than predict absolute population sizes. The integrated model approach used only a subset of conditions, listed below, that potentially affect fish production in the Chehalis Basin. As a result, the models can be used to evaluate relative changes in production between current and future conditions.

As described in Attachment E-2, the EDT-based population productivity and capacity estimates for each species and model scenario were input into the NOAA LCM in the integrated model approach. Results of the EDT and integrated EDT-LCM modeling are presented in Figures E-13 to E-24. Results for EDT are presented first for each species modeled followed by integrated EDT-LCM model results. Differences in estimated change in abundance for each species among the typical seasonal flow, major flood, and catastrophic flood scenarios modeled based on EDT are presented in Figures E-13, E-16, E-19, and E-22. Results for salmonid impacts during construction are described in Section 3.2.2.2 and results for operations impacts are described in Section 3.2.3.2.

The time frame for constructing the FRE facility is 5 years. Because it takes time for a population to stabilize and reach equilibrium abundance in the integrated model, estimated equilibrium abundance of all species based on the integrated model is lower than that estimated by EDT for the 5-year construction period. If the construction period was longer, it is expected that integrated model and EDT model results would converge, similar to the operations modeled. To accurately present impacts to salmonids during construction, both EDT and integrated model results are presented and described in Section 3.2.2.2, with the expectation that EDT results best represent estimated changes in future abundance. Because the simulation period into mid-century and late-century is long enough for estimated equilibrium abundance to stabilize using the integrated model, impacts from operating the Proposed Action are described in Section 3.2.3.2 based on integrated model results alone.

In addition to impacts on salmon and steelhead abundance, there are also impacts to salmon and steelhead productivity, diversity, and spatial structure associated with the Proposed Action, which includes both constructing and operating the FRE facility. These are discussed in Section 3.2.3.2 in a summary of the effects of the Proposed Action on salmonids from pre-construction through late-century.

Format for EDT Modeling Results Figures

The EDT model result figures (E-13, E-16, E-19, and E-22) present results for a single species and both subbasins. For example, Figure E-13 presents the estimated abundance of spring-run Chinook salmon in the Above Crim Creek and Rainbow Falls to Crim Creek Subbasins.

The percent change in estimated fish abundance is shown as vertical bars relative to the left y-axis scale, and the numeric change in abundance is shown as dots with the actual value of the change presented above each dot based on the right y-axis scale.

Three time periods are displayed (project construction, mid-century, and late-century), along with changes in abundance associated with typical seasonal flows, major floods, and catastrophic floods. Note that the right-hand y-axis scales vary among species in the EDT-only figures.

Format for Integrated Modeling Results Figures

Results of the integrated modeling approach used to estimate effects of the Proposed Action on salmon and steelhead are presented in Figures E-14 through E-24. Each figure based on the integrated model approach presents results for a single species and subbasin. For example, Figure E-14 presents the estimated abundance of spring-run Chinook salmon in the Above Crim Creek Subbasin. Fish abundance is represented in the y-axis and the simulation time frame is shown in the x-axis. Each figure consists of four panels.

In the Chinook and coho salmon figures, the upper left panel displays the trend in estimated abundance with typical seasonal flow, major floods, and catastrophic floods incorporated into the integrated model, but without recurring flood events. The upper right, lower left, and lower right panels present the trends in estimated abundance when major floods occur 3 years in a row (i.e., recurring flood events early [2033 to 2035], mid [2050 to 2052], and late [2080 to 2082] in the simulation periods).

In the steelhead figures, the left panels display the trend in estimated abundance with typical seasonal flow, major floods, and catastrophic floods incorporated into the integrated model, but without recurring flood events. The right panels present the trends in estimated abundance when major floods occurred 3 years in a row in the middle of the simulation period (2050 to 2052). The effects of recurring floods occurring early and late in the simulation period on steelhead were not modeled because there was no effect of recurring floods in the middle of the simulation period and simulating early and late recurring floods would have the same result.

Each panel is divided into four key time periods: initialization of the model (2001 to 2024; white), project construction (2025 to 2030; gray), mid-century (2031 to 2063; light green; represented by 2040 conditions) and late-century (2064 to 2100; dark green; represented by 2080 conditions). In each panel the solid black line represents the median values of all model iterations and the light gray lines represent the range in individual iterations through the time series that resulted from variability in estimated abundance associated with the typical seasonal flow, major flood, and catastrophic flood scenarios that were modeled stochastically. Note that gray lines that fall to zero indicate model runs where the species is projected to have no adults retuning that year, and if the pattern continued, the population would be extirpated from the subbasin.

Estimated median abundance is reduced sharply when transitioning between time periods due to the changing environmental baseline (increased water temperature). These transition periods are blocked out because these reductions are an artifact of the modeling approach and are not meaningful.

Dashed vertical lines depict the recurring flood scenarios. Initial population abundance in the integrated model reflects the estimated starting population abundance based on EDT model results.

Figure E-13
Change in Spring Chinook Salmon Abundance Under Proposed Action

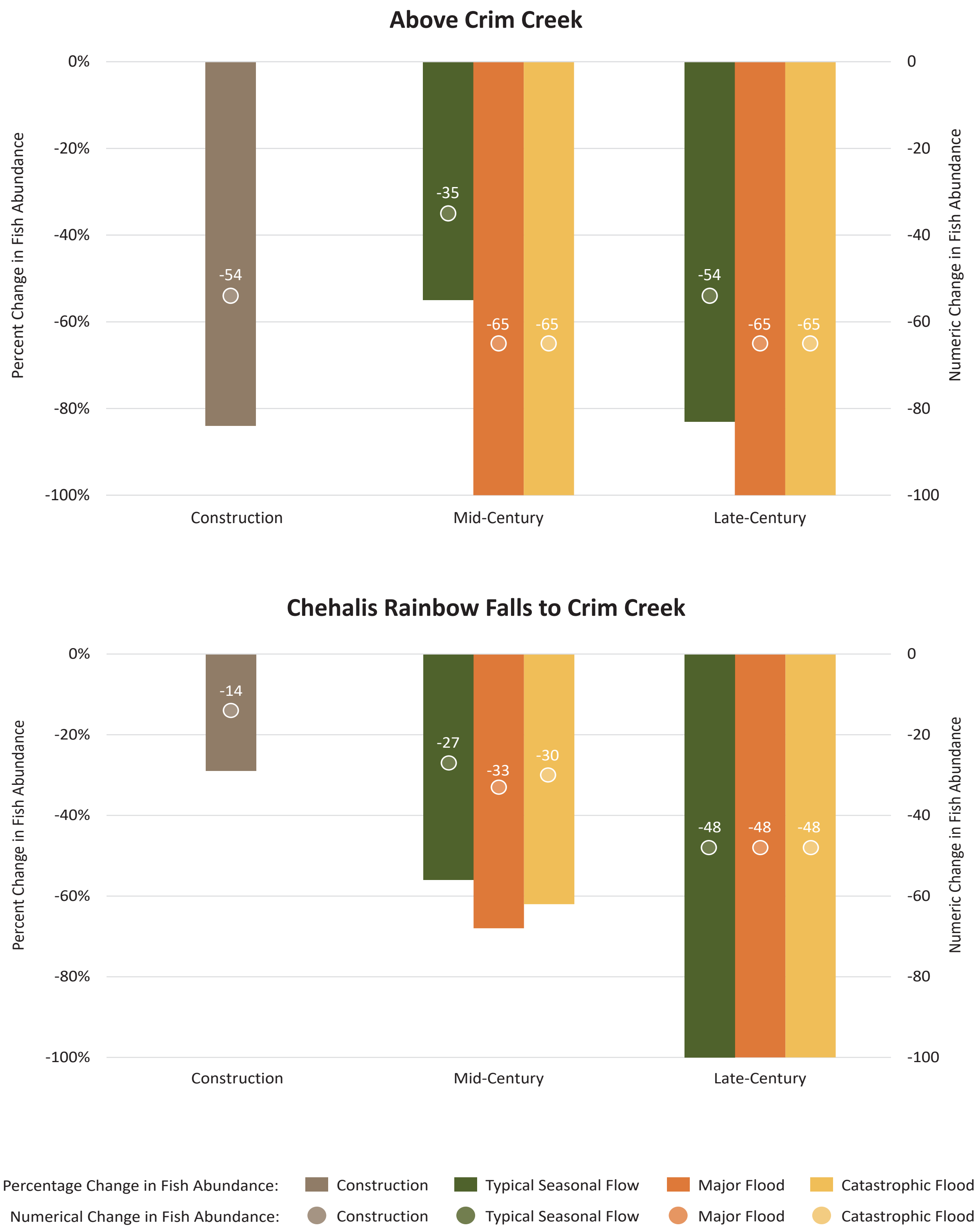
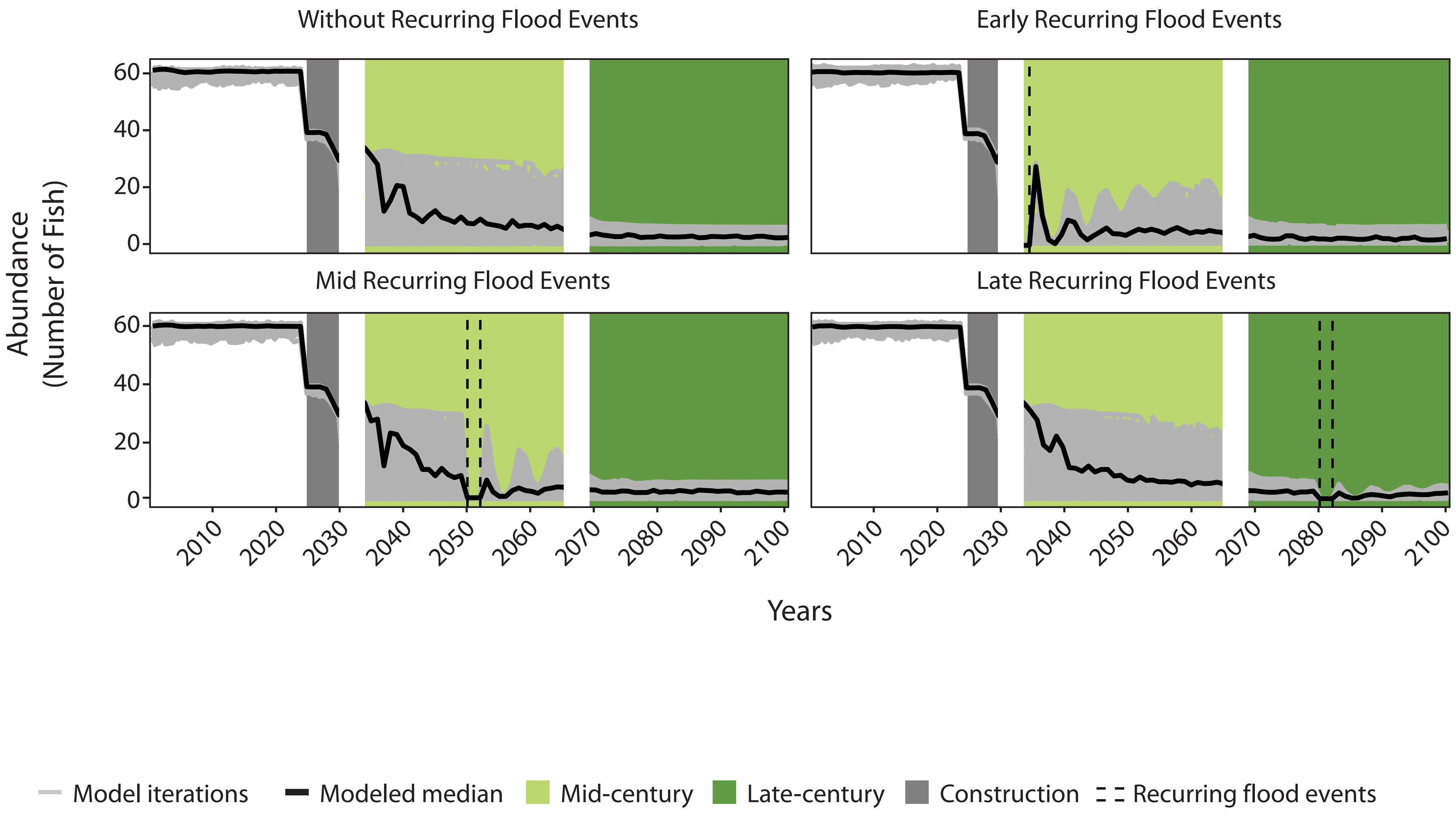
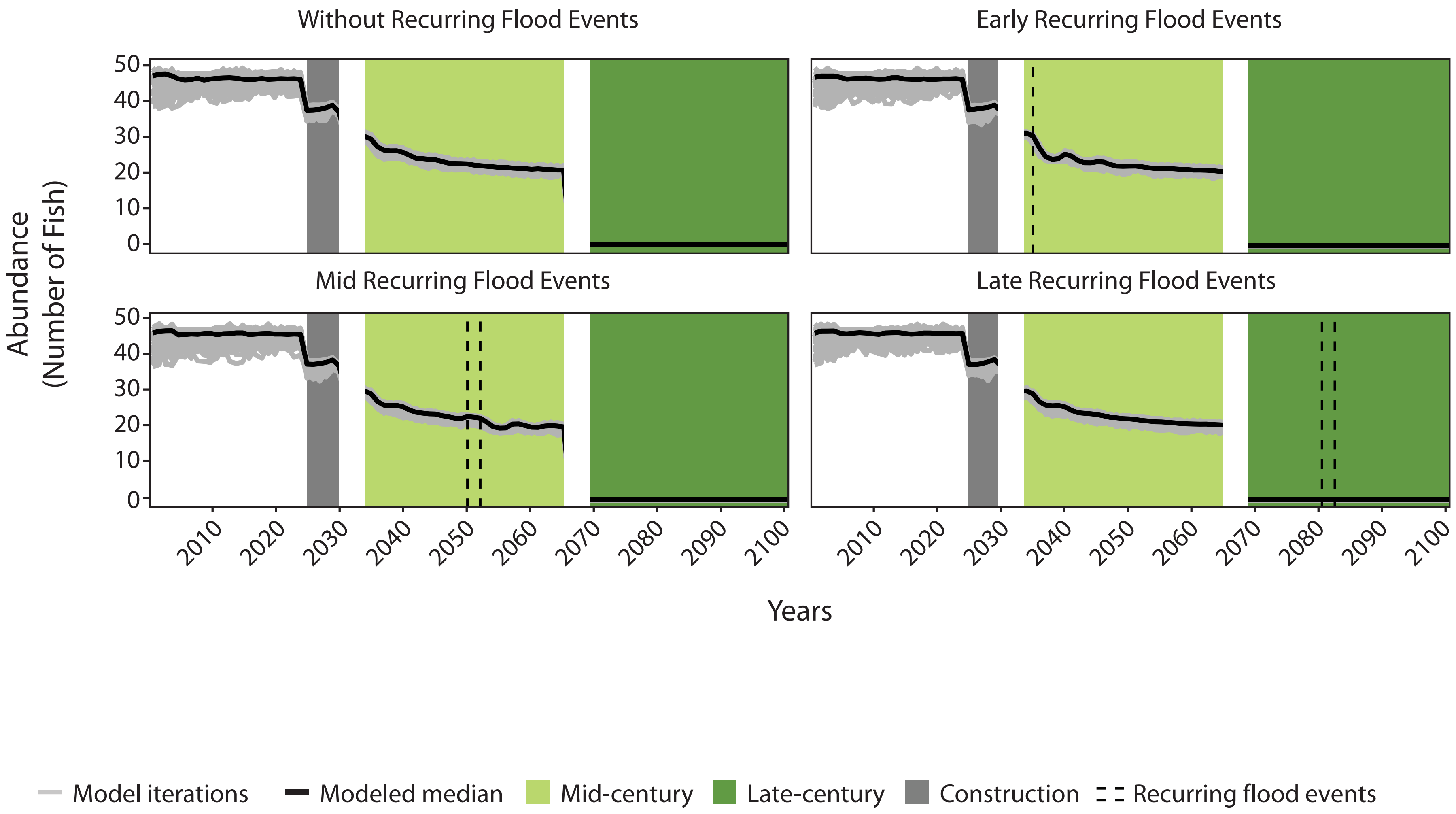


Figure E-14
LCM Results for Spring Chinook Salmon Above Crim Creek Subbasin Under Proposed Action



Source: NOAA 2019

Figure E-15
LCM Results for Spring Chinook Salmon Rainbow Falls to Crim Creek Subbasin Under Proposed Action



Source: NOAA 2019

Figure E-16
Change in Fall Chinook Salmon Abundance Under Proposed Action

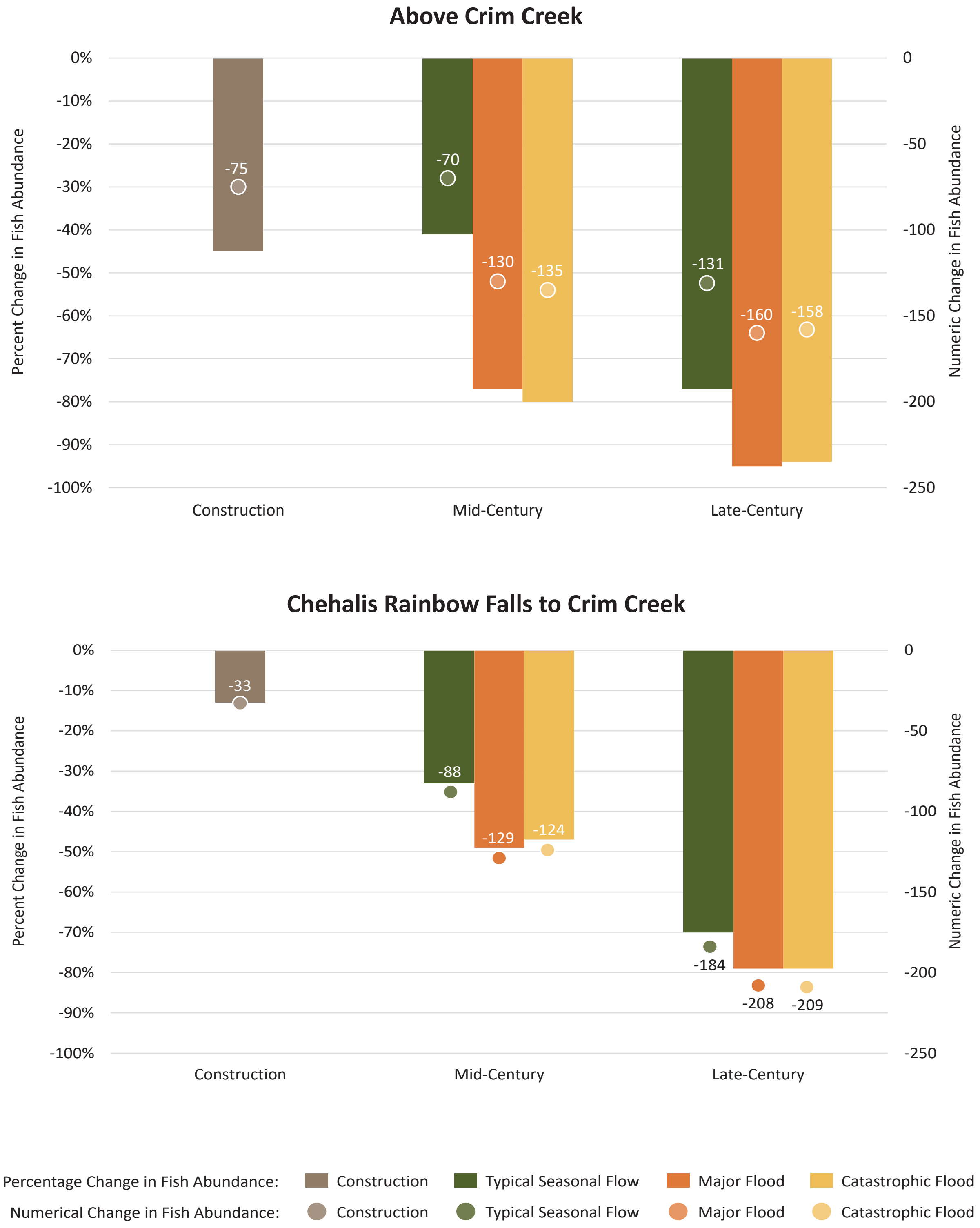
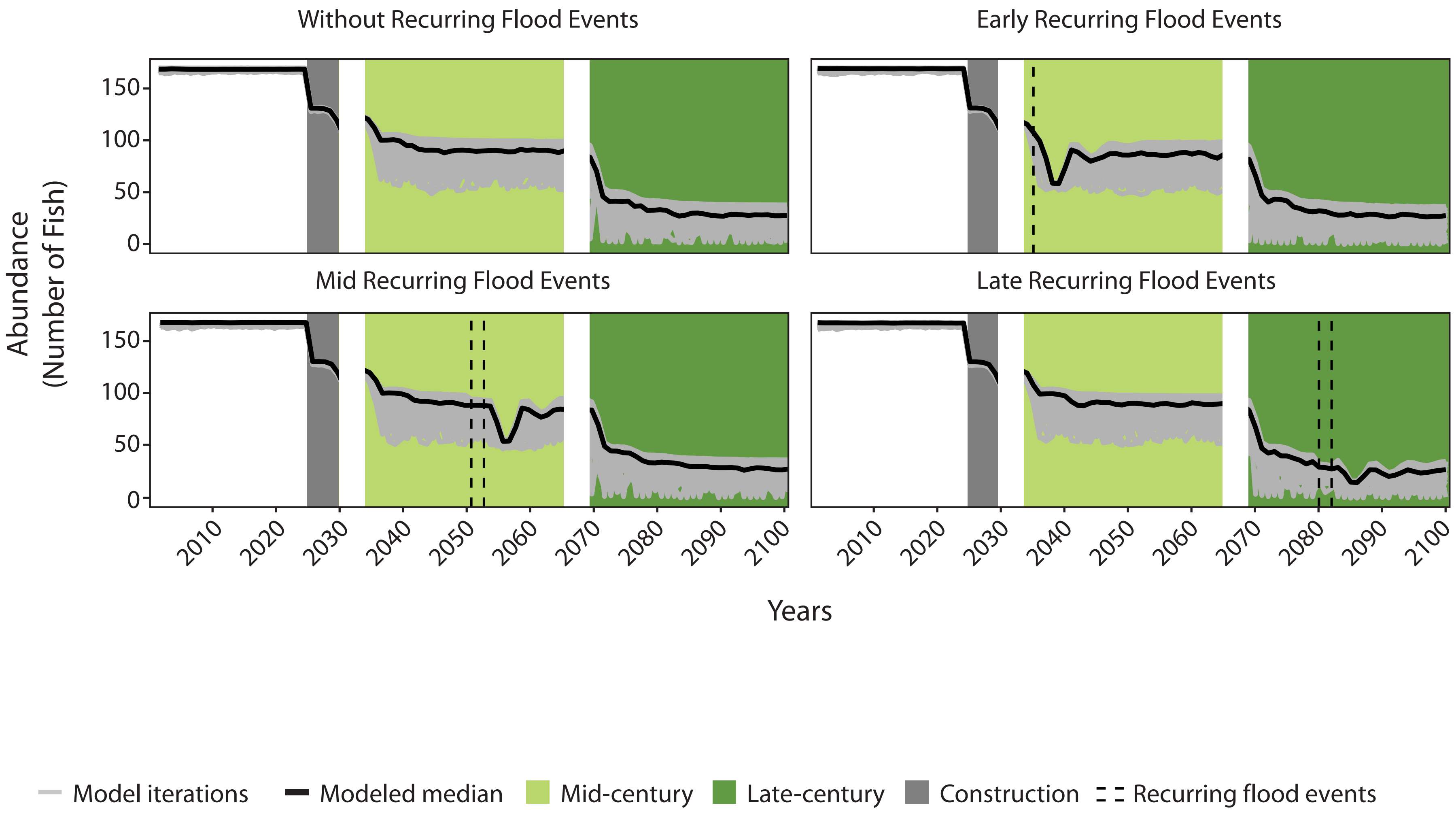


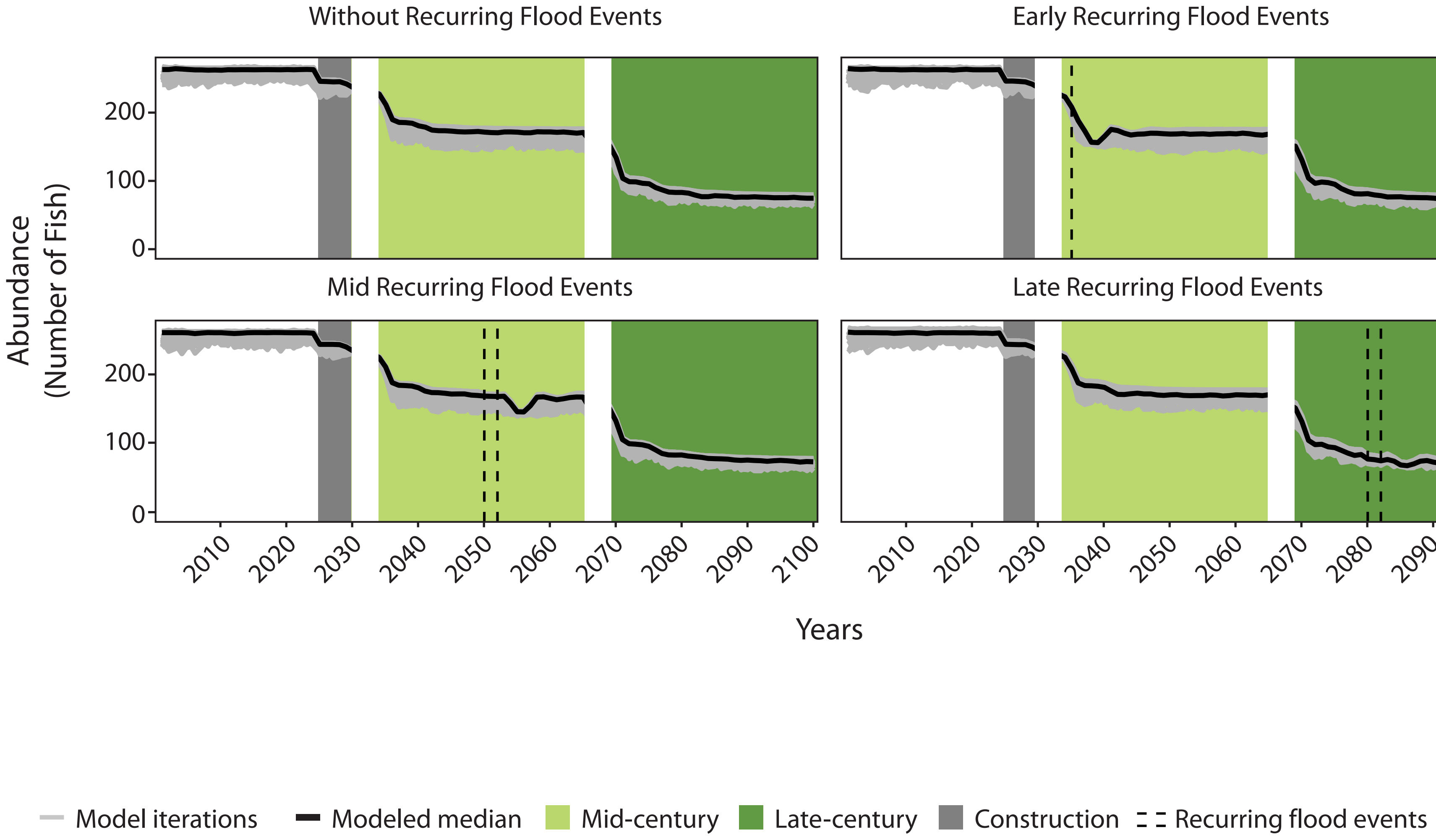
Figure E-17
LCM Results for Fall Chinook Salmon Above Crim Creek Subbasin Under Proposed Action



Source: NOAA 2019

Figure E-18

LCM Results for Fall Chinook Salmon Rainbow Falls to Crim Creek Subbasin Under Proposed Action



Source: NOAA 2019

Figure E-19
Change in Coho Salmon Abundance Under Proposed Action

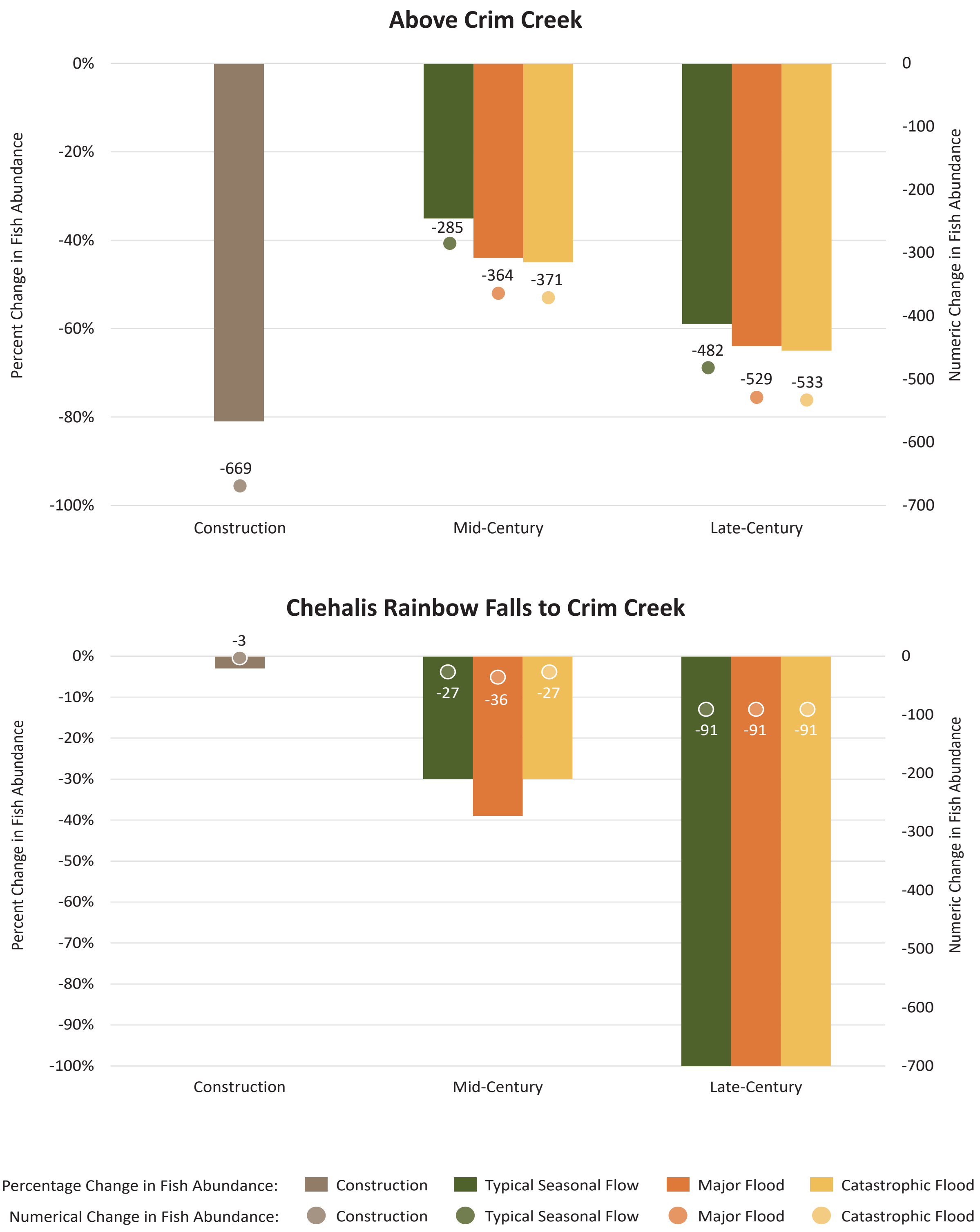
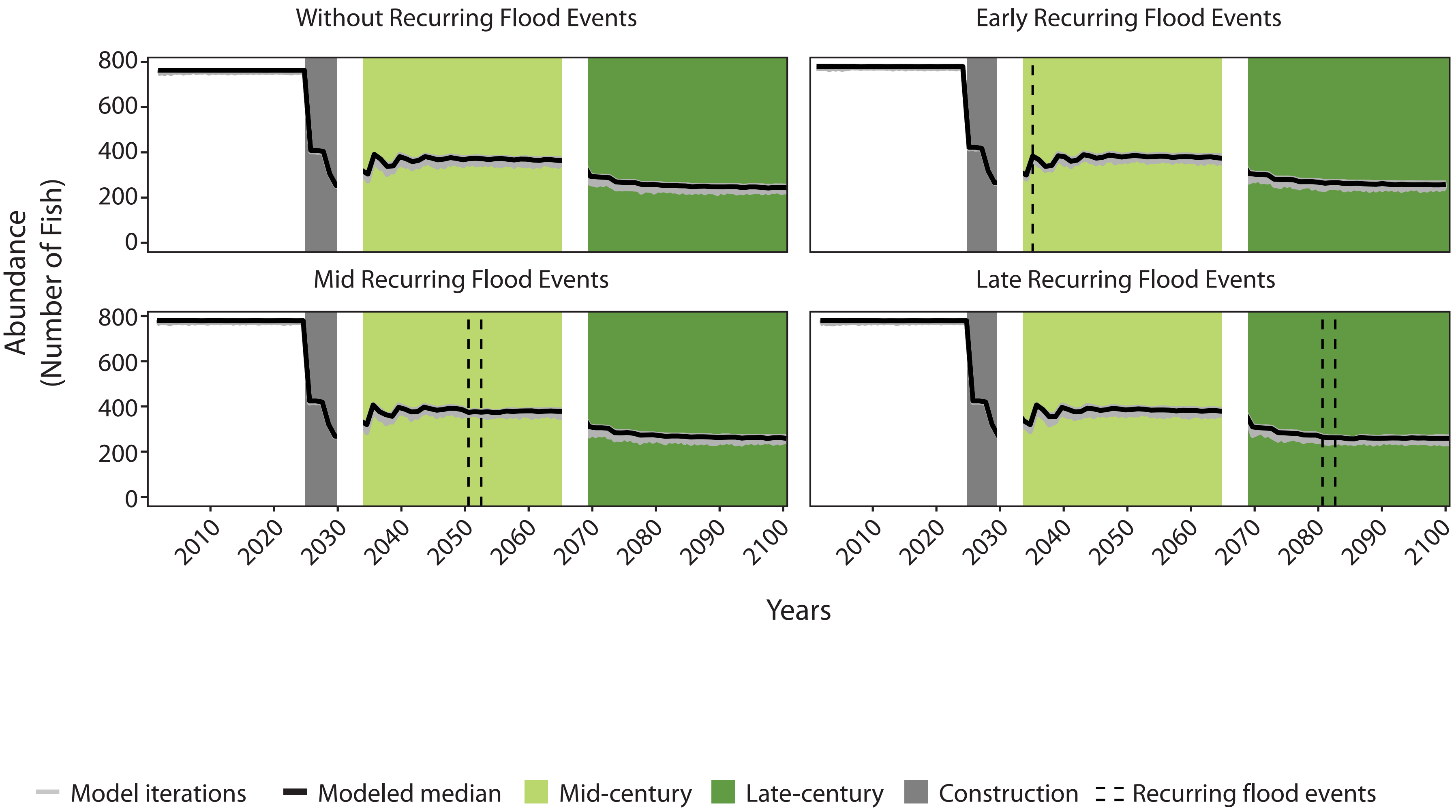


Figure E-20

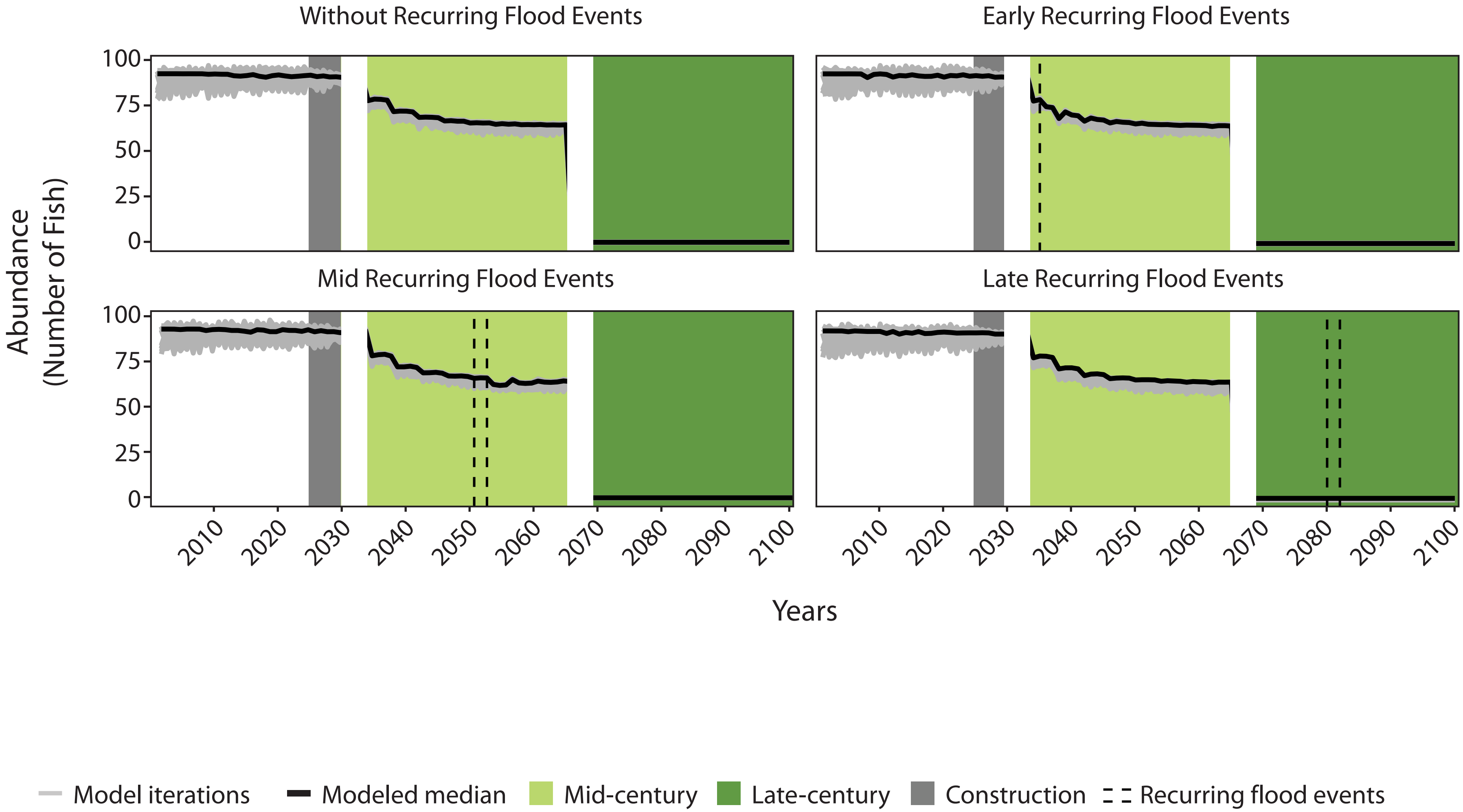
LCM Results for Coho Salmon Above Crim Creek Subbasin Under Proposed Action



Source: NOAA 2019

Figure E-21

LCM Results for Coho Salmon Rainbow Falls to Crim Creek Subbasin Under Proposed Action



Source: NOAA 2019

Figure E-22

Change in Steelhead Abundance Under Proposed Action

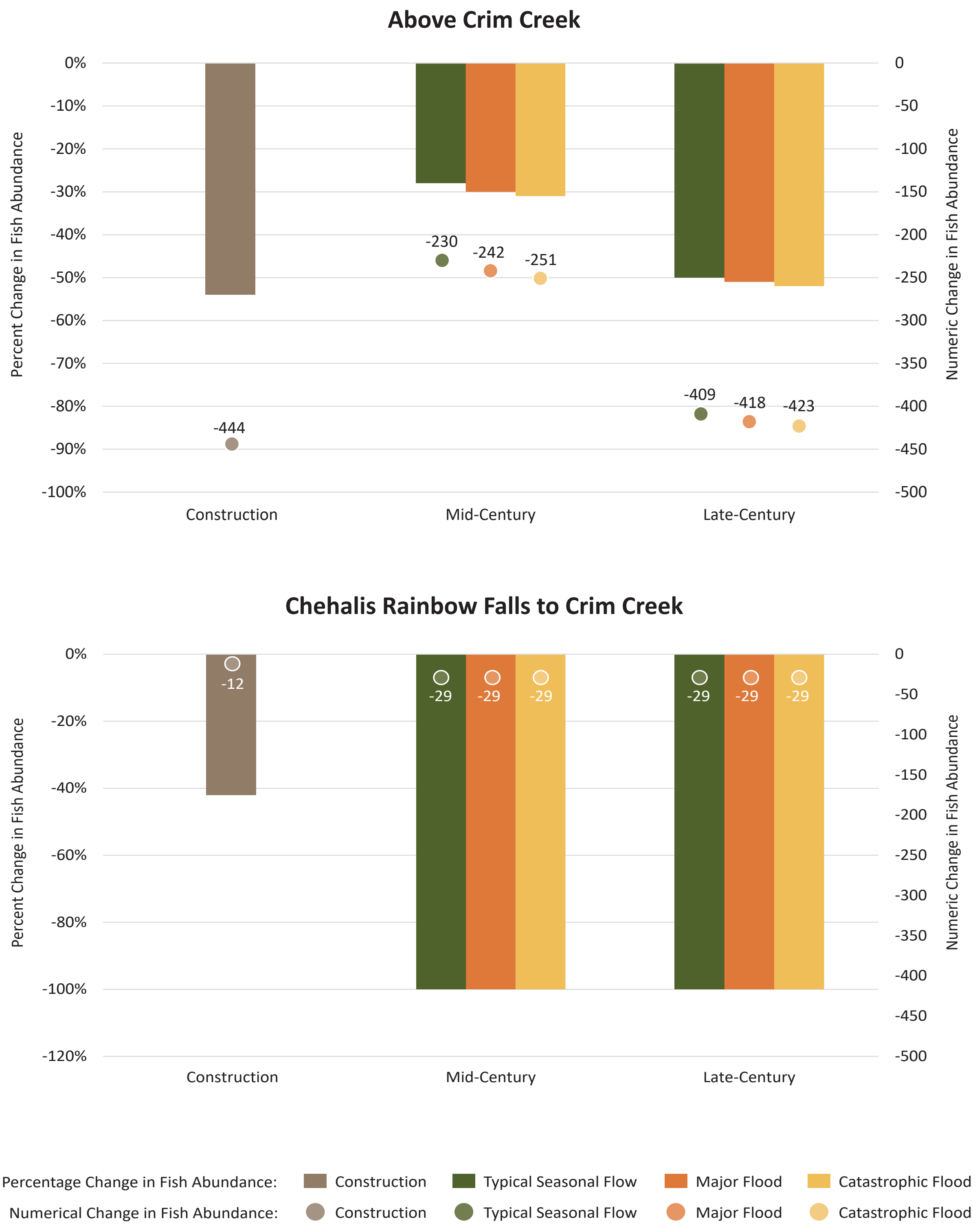


Figure E-23
LCM Results for Steelhead Above Crim Creek Subbasin Under Proposed Action

Source: NOAA 2019

Figure E-24

LCM Results for Steelhead Rainbow Falls to Crim Creek Subbasin Under Proposed Action

Source: NOAA 2019

3.2.2 Impacts from Construction

Construction of the FRE-facility element of the Proposed Action would affect fish, shellfish and aquatic macroinvertebrates as a result of the construction of the FRE facility in the stream channel, reduced fish passage around and through the construction site, and vegetation and large wood removal in the temporary reservoir inundation area.

Construction of the FRE facility would indirectly affect marine mammals and piscivorous birds as a result of the reductions in fish abundance, specifically anadromous salmon and steelhead that are a key prey resource.

Constructing raised airport levees would have minimal direct impacts on fish and fish habitat since the activities would occur above the ordinary high water mark (OHWM). Permits and BMPs that would prevent impacts to the aquatic environment during construction activities near water and discussed further in the sections below.

If permitted, the Applicant expects FRE facility construction would occur between 2025 and 2030 and would last approximately 5 years (Martin 2019b). The primary FRE construction activities would include constructing the diversion tunnel, FRE foundation, and FRE structure in Year 2 to Year 5 of the construction period. These activities would involve the blasting of rock, foundation drilling, vibratory roller-compacted concrete placement, and construction truck activity.

Construction of the FRE facility is expected to require three separate in-water work periods lasting from July 1 through September 30 each year. Regulatory agencies establish timing for the in-water work and windows are timed for the lowest flows of the year to minimize impacts to the river and for the period when spawning salmon are least likely to be in the area. WDFW has established an in-water work window for the upper Chehalis from August 1 to August 31. The Corps in-water work window is from July 1 to August 31. The Applicant would be required to request extensions from WDFW and the Corps to allow in-water work outside of these periods to meet their planned 5-year construction time.

In-water work for construction of the FRE facility would include site clearing, construction of temporary fish passage facilities, placement of the cofferdams, and installation of upstream and downstream diversion tunnel portals. Cofferdam construction would occur in Year 1, temporary trap-and-transport facility construction in Year 2, and removal of cofferdams to allow the river to return to the channel in Year 5. Construction of the temporary trap-and-transport facility in Years 1 and 2 would require work below the OHWM to complete the passage barrier, fish ladder entrance, and attraction water intake.

Work schedules for most elements of the FRE facility would be 10 hours per day, 5 to 7 days per week. Roller-compacted concrete operations for the FRE construction would require work for 20 hours per day, 7 days per week. Blasting for the FRE foundation and temporary river bypass tunnel construction would occur as often as one to four times per week over a period of about 12 months, then blasting in the interior of the tunnel would continue once or twice per day over a period of approximately 9 months.

For fish passage around the FRE facility site during construction, the Chehalis River and fish would continue to flow through the proposed FRE site in the natural river channel until a temporary trap-and-transport facility is constructed and operating for upstream passage, which is projected to occur during the Year 2 in-water work window. After the temporary trap-and-transport facility is operating successfully for migrating fish, the Chehalis River would be diverted through the diversion tunnel that would provide downstream fish passage starting in Year 3.

In the case of a flood event that could result in the cofferdam being overtopped during construction, the Applicant will prepare a pre-flood preparation plan. Cofferdams would be built to protect against 3-year return flood events. If a greater then 3-year return flood event is predicted, the pre-flood preparation plan would be implemented. Flood preparation measures may include moving equipment, cleaning the site, and avoiding concrete pours in preceding days. If flood water overtops the cofferdam and fish enter the construction area, they would be removed when the area is accessible again for workers. Fish salvage would be required to be carried out by properly trained individuals, following recommended fish exclusion, capture, handling, and electroshocking protocols and standards developed by USFWS and WDFW (2012) to minimize this impact.

Overall, construction of the FRE facility would likely have the following effects on fish species and habitat (these are discussed in the following sections in more detail):

- Degradation of fish habitat in the dam footprint area and construction reach due to construction activities in the existing river channel
- Degradation of fish habitat in the temporary reservoir inundation area due to vegetation removal
- Increased water temperature above and below the FRE facility construction site due to the removal of vegetation from the temporary reservoir inundation area
- Elevated turbidity levels due to excavation and earthwork involving soil disturbance in the Chehalis River channel
- Sound pressure waves generated from rock blasting for foundation work and construction of the diversion tunnel that could affect fish directly (see discussion of noise and vibration in Section 3.2.2.2)
- Vibration from placement of roller-compacted concrete for the coffer dams and FRE facility and from construction truck activity that may be transmitted through earth into water and affect fish behavior (see Section 3.2.2.2), particularly for adult and juvenile life stages attempting to move upstream around the construction site
- Decreased fish passage effectiveness past the FRE facility construction site (discussed in Section 2.4.2.3; Table E-9)

Estimated construction impacts of the FRE facility are based on typical seasonal flows and do not account for the potential of a major or larger flood occurring during construction and backwater effects that could temporarily inundate area upstream of the diversion dam. Additional information on construction methods is provided in Appendix 1 of the EIS, *Proposed Project Description and Alternatives*. Appendix 1 of the EIS also includes preliminary plans from the Applicant that would be required to be finalized and implemented prior to construction to minimize impacts to aquatic habitats, fish, and shellfish include the following:

- Fish Passage Plans for FRE facility construction that meet WDFW and NOAA Fisheries criteria
- Temporary Erosion Control Plan
- Stormwater Pollution Prevention Plan that meets requirements in Ecology's *Stormwater Management Manual for Western Washington*
- Spill Prevention and Control Plan
- Pre-Construction Vegetation Management Plan

3.2.2.1 Aquatic Habitats

Impacts to aquatic habitat would result from construction of the FRE facility and temporary trap-and-transport facility as well as removal of vegetation and wood in the temporary reservoir area. Impacts on aquatic habitat will likely occur if the changes to habitat function and connectivity of the Chehalis River lead to changes in aquatic communities in upstream tributary subbasins.

Changes to the physical conditions during construction are described in the *Water Discipline Report* (ESA 2020a) and *Earth Discipline Report* (Shannon & Wilson and Watershed GeoDynamics 2020), and changes to riparian area vegetation and wetlands are described in the *Wildlife Species and Habitats Discipline Report* and *Wetlands Discipline Report* (Anchor QEA 2020a, 2020b), respectively. Sedimentation from excavation and erosion is identified in the *Earth Discipline Report,* and resulting risk of turbidity is identified in the *Water Discipline Report* as a minor to moderate impact, to be controlled by BMPs. Removal of vegetation in the temporary reservoir extent is identified as having a significant impact to ecological function in over 600 acres of upland, riparian, and wetland areas in the *Wildlife Species and Habitats Discipline Report*.

The ways in which the physical changes to the environment would affect fish habitats are summarized below for each habitat type and area of the Chehalis River relative to the FRE facility and temporary reservoir area.

3.2.2.1.1 Headwaters and Upper Mainstem Chehalis River Habitat, Including the FRE Facility and Temporary Reservoir (Impacts from Construction)

Construction of the FRE facility would occur in the riverbed of the upper mainstem Chehalis River in an area that is a migration corridor for salmon and steelhead. The headwaters and upper mainstem Chehalis River at the FRE site and upstream of the FRE site are considered together as one geographic area for the analysis of construction impacts. This includes the 6.4 miles of Chehalis River in the temporary reservoir area.

The FRE facility construction area would occupy 8 acres of the stream channel that, along with adjacent areas isolated by cofferdams, would be temporarily dewatered when the river is rerouted through the diversion tunnel. The FRE structure would permanently remove 0.32 acre of riverbed.

The aquatic habitat impacts at the FRE site would result from permanent loss of instream habitat due to the concrete FRE structure footing, temporary dewatering and diversion of the river around the construction site, and potential effects on water quality and impairments of fish passage during construction (discussed in greater detail below).

The habitat affected by construction is habitat for many resident and anadromous fish species (M. Winkowki et al. 2016; impacts to Aquatic Species are discussed in detail in Section 3.2.2.2). Salmon and steelhead spawn less than 0.5 river mile upstream of the FRE site (Ashcraft et al. 2017) and less than 1.5 miles downstream of the FRE site (Ashcraft et al. 2017). Juvenile salmon, steelhead and resident trout currently rear within and migrate through the potential FRE site in upstream and downstream directions (J Winkowski and Zimmerman 2017; J. Winkowski et al. 2018). If mussel beds die in the construction area, they may not easily recolonize disturbed areas and some mussel habitat would be permanently lost in the FRE structure footprint.

Degraded Riparian Function

In the temporary reservoir inundation area, large trees (greater than 6 inches diameter at breast height) and all non-flood-tolerant trees would be removed in accordance with the Applicant's project description in areas with greater than a 5% chance of being flooded in a given year. Large trees and all non-flood-tolerant trees and wood would also be actively removed from the FRE construction area, affecting over 600 acres of upland, riparian, and wetland areas (see the *Wildlife Species and Habitats Discipline Report* for details) during construction. The loss of trees in the riparian areas and removal of large wood would impair the aquatic habitat throughout the 6.4-river-mile maximum reservoir extent.

Since no large trees would be allowed to grow to provide shade and other habitat benefits in riparian areas, this impact would continue through operations. Flood retention with FRE-operations would result in the loss of large and non-flood tolerant trees across a total of 847 acres of forest with a catastrophic flood, described further in Section 3.2.3. Specific impacts within the temporary reservoir area would include the following:

- Riparian area function would be degraded due to the removal of large trees that provide structure to the riparian forest, shade to the stream channel, and nutrient and wood inputs to the stream.

- Daily maximum water temperatures would increase 0.5°C to 3°C, depending on time of year, from lack of shading, with the greatest impact in June through mid-September (Van Glubt et al. 2017, described in the *Water Discipline Report*).
- A reduction in large wood due to active removal would result in reduced aquatic habitat complexity, a reduction in the amount of certain microhabitat types, such as pool-riffle complexes, and reduced substrate retention. Areas where channel features are controlled by the natural bedrock geology and channel constraints would experience less change than unconfined areas with gravel substrate. Large wood is a key element to channel structure and complexity in areas that are not bedrock controlled.
- Large wood also helps slow water velocities and contributes to the development of pools that provide cooler stream temperature, decreases fine sediment transport, provides refuge for juvenile fishes from predation, and enables successful feeding (Wohl et al. 2015; Poff et al. 1997; Wald 2009).
- The food supply for fish would be reduced or change in composition as a result of less leaf litter input to streams from riparian vegetation (aquatic macroinvertebrates use leaves as a food source), a reduction in benthic macroinvertebrates that colonize large wood, and fewer terrestrial insects falling from riparian vegetation.

Vegetation survival and riparian area function is likely to be reduced completely in areas of the temporary reservoir that are more frequently disturbed, such as the pool that would form just upstream of the outlet gates during backwatering events.

Reduced Nutrient Availability in Aquatic Habitat

Impacts of reduced fish passage survival on salmon and steelhead populations was incorporated into the integrated modeling approach, and the results show the abundance of migratory fish would be reduced (discussed in detail in Section 3.2.3.2.2). Summer movements of juvenile salmon and steelhead would be impaired as would fall redistributions and spring out-migrations of juvenile salmon and steelhead. These impacts were assessed qualitatively.

Reduced fish passage to the upper reaches of the mainstem Chehalis River and tributary streams has an indirect impact on habitat by reducing inputs of marine-derived nutrients from fish carcasses. Shellfish that depend on migratory fish hosts could also be reduced over time in this area.

Reduced Water Quality

During FRE facility construction, water diversion, placement of cofferdams to isolate the work area, and construction of the bypass channel to reroute the river would cause localized impacts on fish habitat from reduced water quality. Water quality permits will be required for construction activities to meet water quality standards. Releases of turbidity, pollutants, or stormwater with reduced quality are expected to be effectively minimized with the implementation of BMPs that would be required as part of the Construction National Pollutant Discharge Elimination System (NPDES) Stormwater Permit. The

NPDES permit would require the construction activities meet water quality criteria standards, including turbidity and pollutants.

When trees are removed from the riparian areas in the temporary reservoir during construction, the daily maximum water temperatures would increase 0.5°C to 3°C, depending on time of year, from lack of shading, with the greatest impact in June through mid-September. Daily maximum temperatures of the Chehalis River could increase by up to 2°C to 3°C in mid- to late-summer in the temporary reservoir, exceeding temperature water quality criteria (Van Glubt et al. 2017). The increase in water temperatures would result from the loss of tree cover and shading. Additionally, modeling for Crim Creek in the temporary reservoir showed that loss of riparian cover and stream shading associated with the FRE facility is predicted to result in temperature increases of between 2°C and 5°C, exceeding water quality criteria (Anchor QEA 2017).

Summary of Impacts to Aquatic Habitat in Upper Chehalis River from Construction

Combined, these actions would present a **significant** adverse impact to aquatic habitat in the Upper Chehalis River from construction of the Proposed Action. Mitigation is proposed for the Applicant to develop plans for Fish and Aquatic Species and Habitat, Vegetation Management, Riparian Habitat, Wetlands, Large Woody Material Management, Wetlands and Wetland Buffers, Stream and Stream Buffers, and Surface Water Quality to mitigate impacts to aquatic habitat in the upper mainstem Chehalis River. However, there is uncertainty if the implementation of the plans would be technically feasible and economically practicable. Therefore, the Proposed Action would have **significant and unavoidable** adverse environmental impacts on aquatic habitat, unless the Applicant develops plans as described above that meet regulatory requirements and for which implementation is feasible.

The Fish and Aquatic Species and Habitat Plan and Riparian Habitat Plan would require the Applicant to ensure no net loss for the aquatic and stream habitats impacted by construction and operational activities. The plans would need to ensure habitat is replaced, protected, maintained and monitored in areas outside of the temporary reservoir. The future potential contributions from riparian areas that are currently developing with protections under Forest Practices Rules would be lost, including the benefits from mature trees and sources of large wood. The Surface Water Quality Mitigation Plan would need to provide reasonable assurance that water quality standards and in-water designated uses are met.

3.2.2.1.2 Middle and Lower Mainstem Chehalis River Habitat (Impacts from Construction)

The function of the Chehalis River as a migratory corridor could be impaired by 2°C to 3°C increases in daily maximum summer water temperature that are propagated downstream from the FRE facility site. Water temperature impacts would attenuate downstream with inputs from tributaries such as Elk Creek to approximately the confluence with the South Fork Chehalis River. This would be a **significant** adverse impact on aquatic habitat in the middle Chehalis River. Other impacts to aquatic habitat at the FRE facility site would not extend downstream to affect the middle and lower mainstem reaches.

Mitigation is proposed for the Applicant to develop plans for Fish and Aquatic Species and Habitat, Vegetation Management, Riparian Habitat, Wetlands, Large Woody Material Management, Wetlands and Wetland Buffers, Stream and Stream Buffers, and Surface Water Quality to mitigate impacts to aquatic habitat in the middle mainstem Chehalis River. However, there is uncertainty if the implementation of the plans would be technically feasible and economically practicable. Therefore, the Proposed Action would have **significant and unavoidable** adverse environmental impacts on aquatic habitat, unless the Applicant develops plans as described above that meet regulatory requirements and for which implementation is feasible.

3.2.2.1.3 Floodplain Off-Channel and Emergent Wetland Habitats (Impacts from Construction)

No direct impacts to off-channel and floodplain wetland habitats would occur from construction of the FRE facility.

3.2.2.2 Aquatic Species

This section first discusses the impacts during construction that would affect fish, macroinvertebrate, and shellfish species. Some impacts resulting from in-water work and water diversion would affect species only within the construction area. Some impacts would extend to areas outside of the isolated FRE facility construction area, primarily resulting from impairments to riparian function, water quality, and construction noise. Indirect effects on aquatic species may occur if the changes to habitat function and connectivity of the Chehalis River lead to changes in aquatic communities in upstream tributary subbasins or extend to the marine environment.

Impacts to chum salmon, bull trout, eulachon, green sturgeon, and white sturgeon are not analyzed in detail since these species tend to occur downstream of areas that would experience significant impacts to hydraulics, water quality and substrate continuity. Eulachon have not been observed in the primary study area; however, eulachon are not precluded from being present in areas that could be directly impacted. Construction of the Proposed Action is not likely to have significant impacts on chum salmon, bull trout, eulachon, green sturgeon, and white sturgeon. However, it is expected that the Proposed Action, restoration, and climate change would all have some indirect impact on populations of these species that use the Chehalis River. The sections then discuss impacts to salmon and steelhead fish passage and quantitative changes in salmon and steelhead abundance. This is followed by a general discussion of impacts to non-salmon fish species, shellfish and macroinvertebrates, and marine mammals.

There are also impacts to salmon and steelhead productivity, diversity, and spatial structure associated with constructing the FRE facility. These are discussed in Section 3.2.3.2 under a summary of the effects of the Proposed Action on salmonids from construction through operations in late-century.

3.2.2.2.1 In-Water Work and Dewatering During Construction

Fish would be particularly vulnerable to impacts during in-water work, planned to occur during July through September, during Years 1, 2, and 5. In-water work to construct cofferdams, tunnel portals, and temporary trap-and-transport facilities would create the risk of direct mortality to fish and shellfish, for instance if they become impinged, stranded, or smothered by materials or equipment. Exclusion and removal of fish from in-water work areas may be required to minimize impacts of the in-water work.

In addition, the process of dewatering the construction area when the river is diverted through the diversion tunnel carries the risk of stranding fish. Supplemental construction information from the Applicant (Martin 2019b) states that direct impacts to fish would be minimized in the construction area by permit conditions that require the removal and relocation of aquatic species (including shellfish) from dewatered areas, and the observance of seasonal restrictions (in-water work windows and other seasonal restrictions) for protection of fish. Fish capture and transport carries the risk of causing mortality to fish and shellfish; however, the fish salvage would be required to be carried out by properly trained individuals, following recommended fish exclusion, capture, handling, and electroshocking protocols and standards developed by USFWS and WDFW (2012) to minimize this impact. In-water work and dewatering during construction would have **significant to moderate** impacts to fish species.

Mitigation is proposed for the Applicant to develop plans for Fish and Aquatic Species and Habitat, Vegetation Management, Riparian Habitat, Wetlands, Large Woody Material Management, Stream and Stream Buffers, and Surface Water Quality to mitigate impacts to aquatic species from in-water work and dewatering. However, there is uncertainty if the implementation of the plans would be technically feasible and economically practicable. Therefore, the Proposed Action would have **significant and unavoidable** adverse environmental impacts on aquatic species, unless the Applicant develops plans as described above that meet regulatory requirements and for which implementation is feasible.

3.2.2.2.2 Fish Passage During Construction

3.2.2.2.2.1 Salmonid Movement Upstream During Construction

Upstream passage of adult salmonids would be provided during construction through temporary trap-and-transport methods, using a temporary picket weir downstream of the FRE facility construction site to guide fish to a ladder entrance. Adult salmon and steelhead would then be transported around the FRE facility construction site using live boxes and transport trucks. Survival of adult salmonids during construction using temporary trap-and-transport operations is predicted to be low and range from 32% to 65% among species (Table E-9; discussed further in Attachment E-3). Survival would vary depending on the design of the picket weir and ladder entrance, water conditions experienced each year, the location selected for the temporary facility, and hydraulic conditions at the selected location.

J. Winkowski and Zimmerman (2017) investigated the summer ecology of juvenile steelhead and Chinook salmon near the FRE construction site. Juvenile steelhead underwent repeated upstream and downstream movements through the study area up to a distance of 7 km, and the majority (81%) of steelhead movements occurred between the hours of 04:00–07:00 and 18:00–21:00. Most juvenile Chinook salmon were detected just once moving in a downstream direction.

Juvenile salmonids migrating upstream from below the FRE facility would encounter a picket weir installed for the temporary trap-and-transport operation. These fish could be blocked at the picket weir from moving upstream due to a behavioral response to avoid the structure and move downstream, or they could pass through the temporary picket weir by swimming through gaps between the pickets. If juvenile salmonids pass upstream through the pickets, it is considered unlikely that these fish would move upstream into the diversion tunnel due to the length of the dark tunnel and their behavioral tendency to not enter dark passageways. Therefore, for juvenile salmonids moving upstream the survival rate is estimated to be 0% (Table E-9). This estimate was used qualitatively to assess impacts to salmonids; the upstream movement of this life stage is not a component of the Chehalis EDT model and therefore was not incorporated into quantitative analysis of impacts using the integrated modeling approach.

The Applicant states that juvenile salmonids, resident fish, and lamprey collected in the temporary trapping facility will be considered incidental to the collection of adult salmonid species target for collection, and that species and life stages that are incidentally captured will be transported upstream of the construction area and released back to the Chehalis River (Martin 2019b). WAC 220-660-200 provides that the Applicant should design the weir to ensure continued fish passage for all species present at all mobile life stages and compensatory mitigation may be required if a fish passage structure cannot pass all fish species present at all mobile life stages. Martin (2019b) also states that upstream and downstream passage of juvenile salmonids, resident fish, and lamprey during operation of the temporary passage facility will continue to be discussed with WDFW as the project progresses. WDFW has developed guidelines for adult salmonids migrating upstream (resident trout, sea run cutthroat trout, bull trout, steelhead, and sockeye, pink, chum, and Chinook salmon; WDFW 2019d). NMFS (2011) provides general criteria and guidelines for upstream juvenile salmonid passage. However, there are numerous native, non-salmonid species in the project area (Table E1-2, Attachment E-1).

3.2.2.2.2.2 Salmonid Movement Downstream During Construction

Fish migrating downstream through the FRE facility during construction, including adults, fry, parr, and actively migrating juvenile salmon and steelhead in the smolt life stage would pass the site using a temporary flow diversion tunnel. Estimated fish passage survival rates are presented in Table E-9. The temporary flow diversion tunnel would be dark within a short distance downstream from the entrance.

Hydraulic cues would be present as a result of streamflow through the tunnel for fish to use for orientation and would help guide fish into the tunnel and minimize delays in downstream passage. Factors that could impair downstream passage survival through the flow diversion tunnel include potential effects of vegetation removal in the temporary reservoir area during construction, debris accumulation at the entrance to the flow diversion tunnel, and the temporary backwatering of the diversion tunnel and partial filling of the reservoir during high-flow events.

For adult fish moving downstream, the survival rate for steelhead was estimated to be 49% (Table E-9) but was not estimated for other species. However, as discussed in Attachment E-3, this life stage is thought to be an important contributor to overall population productivity, but post-spawn steelhead migrate downstream in an extremely poor and weak condition. injury or mortality could occur if kelts have to pass through debris on diversion tunnel trash racks or become impinged on the temporary picket weir located downstream of tunnel (Attachment E-3). Temporary backwatering of the diversion tunnel and partial filling of the reservoir during high-flow events such a major or catastrophic flood would result in delays to downstream migrating adult steelhead.

Passing downstream migrating adult steelhead past the temporary picket weir would require incorporating a passage opening into the design, which may reduce the efficiency of the weir for collecting upstream migrating fish that is already estimated to be low. The cumulative fish passage effectiveness (survival) estimate of 49% for kelts migrating downstream (Table E-9) assumes some form of passage slot or system will be provided in the picket weir design for kelt passage. Collecting downstream migrating adult steelhead above the temporary picket weir is another potential alternative for reducing injury to these fish at the picket weir. This would include a secondary weir, trap, and holding facility. In addition, the spacing between the pickets (open area) would need to be sized to impede or allow passage of jack salmonids (precocious male salmon that have generally spent one winter in the ocean) or small native fishes, based on permit discussions. Therefore, there will be challenges in developing an effective picket weir design that balances weir efficiency for both upstream and downstream migrants along with maintenance requirements, because narrower spacings will result in increased maintenance to remove debris from the pickets.

Once a juvenile salmonid enters the lighted entrance to the diversion tunnel it could continue to move downstream through the tunnel if flow is at a level that provides a positive cue to move downstream and the fish decides to not reject the dark tunnel environment. However, the exact behavior of actively migrating juvenile salmonids through the diversion tunnel is unknown. For juvenile fish moving downstream, the survival rate for juvenile salmonids migrating through the tunnel was estimated to range from 85% to 95%. These estimates were used qualitatively to assess impacts to salmonids and are not a component of the EDT model used for analysis.

In the EDT model it was assumed that juvenile salmonids would pass downstream through the tunnel. If this assumption is incorrect and there is mortality to juvenile salmonids migrating downstream through the diversion tunnel, the reported modeled impacts to salmon and steelhead during construction would not capture this effect and would therefore underestimate of the true effect. Similarly, injury or mortality to downstream juvenile migrants passing through debris collected on the diversion tunnel trash racks at the inlet to the tunnel could occur, but this impact was not incorporated into the analytical approach.

3.2.2.2.2.3 Fish Passage Plan

Fish passage during construction would be required to meet requirements as part of the HPA process along with a fish passage plan to reduce impacts to aquatic species. Estimated impacts from fish passage are described in Table E-9 and Attachment E 3. The fish passage plan would also be included as part of the Fish and Aquatic Species and Habitat Plan. The fish passage plan would include the following measures:

- Implement the most efficient means for trapping and transport of all fish species present at all mobile life stages.
- Coordinate with WDFW on the location, design, and operation of the temporary trap-and-transport facilities and release locations.
- Monitor fish passage weekly and report on fish passage performance monthly to:
  - Evaluate passage effectiveness
  - Adaptively manage fish passage operations and implement changes to operations to address challenges such as weir failure due to debris or high flow, and fish holding below weir and not entering the fish ladder due to construction activities or conditions at the weir
  - Identify any unforeseen events and a clear pathway for addressing them through a contingency plan
- For both temporary (construction) and permanent (operation) periods, develop fish passage contingency plans that can be implemented if passage standards are not met.
- Ensure trash racks on the temporary construction diversion tunnel remain free of debris; any debris accumulations are to be removed promptly.
- Design the diversion channel with hydraulic conditions to ensure upstream and downstream fish passage during its use, including avoiding delay through adequate attraction to the bypass channel; monitor passage through the bypass channel for effectiveness.

Combined, reduced fish passage during construction would have **significant** impacts on fish both upstream and downstream of the FRE facility. Mitigation is proposed for the Applicant to develop a Fish and Aquatic Species and Habitat Plan to mitigate impacts to fish from reduced fish passage; however, there is uncertainty if implementation of the plan is technically feasible and economically practicable. Therefore, the Proposed Action would have **significant and unavoidable** adverse environmental impacts on fish species, unless the Applicant develops plans as described above that meet regulatory requirements and for which implementation is feasible. The proposed mitigation is described in more detail in Section 3.2.5. The Fish and Aquatic Species and Habitat Mitigation Plan would require the

Applicant to develop plans to provide no net loss for the fish species and habitats impacted by construction.

3.2.2.2.3 Water Quality During Construction

Water temperature would increase over time as trees and non-flood-tolerant species are removed from the temporary inundation area (*Water Discipline Report*). This would result in areas that exceed optimal temperatures in summer for cold-water-adapted fish like salmon, trout, and lamprey that currently occur in large numbers near the FRE facility site. The effects of temperature exceedances on fish can range from bioenergetic conditions requiring them to increase their foraging efforts and reducing their growth potential (e.g., temperatures that exceed state criteria for salmon and trout of 17.5°C), to potentially lethal conditions when temperatures exceed approximately 20°C.

When trees are removed from the riparian areas in the temporary reservoir, the daily maximum water temperatures would increase 0.5°C to 3°C, depending on time of year, from lack of shading, with the greatest impact in June through mid-September. Daily maximum temperatures of the Chehalis River could increase by up to 2°C to 3°C in mid- to late-summer in the temporary reservoir, exceeding temperature water quality criteria (Van Glubt et al. 2017). The increase in water temperatures would result from the loss of tree cover and shading. Additionally, modeling for Crim Creek in the temporary reservoir showed that loss of riparian cover and stream shading associated with the FRE facility is predicted to result in temperature increases of between 2°C and 5°C, exceeding water quality criteria (Anchor QEA 2017).

Table E-4 lists the temperature criteria for streams in the study area. Increased water temperatures were included in the modeling for salmonids and steelhead and evaluated for fish species described in this section. In addition to the impacts of increased water temperature on fish, similar impacts will affect macroinvertebrate and shellfish.

In-water construction presents the risk of reduced water quality in the area of the construction and downstream. Releases of turbidity, hazardous materials spills, and stormwater runoff into the river can directly affect fish. In particular, high turbidity can irritate and injure fish gills and can interfere with vision, impairing foraging and predator avoidance behaviors. High turbidity that settles may also smother macroinvertebrate and shellfish communities. Hazardous materials spilled into the water or carried by stormwater (such as petroleum products, metals, and low pH water from curing concrete) can be acutely toxic to fish. As is described in Section 3.2.2.2, impacts of releases of turbidity and other pollutants would be minimized with BMPs included in permit conditions and described in supplemental construction information (Martin 2019b). Water quality impacts of increased temperatures to aquatic species during construction of the FRE would be **significan**t adverse impacts.

Mitigation is proposed for the Applicant to develop plans for Fish and Aquatic Species and Habitat, Vegetation Management, Riparian Habitat, Wetlands, Large Woody Material Management, Wetlands and Wetland Buffers, Stream and Stream Buffers, and Surface Water Quality to mitigate impacts to fish species; however, there is uncertainty if the implementation of the plans would be technically feasible and economically practicable. Therefore, the Proposed Action would have **significant and unavoidable** adverse environmental impacts on fish species, unless the Applicant develops plans as described above that meet regulatory requirements and for which implementation is feasible. The Fish and Aquatic Species and Habitat Mitigation Plan would require the Applicant to develop plans to provide no net loss for the fish species and habitats impacted by construction.

3.2.2.2.4 Noise and Vibration During Construction

The in-water and out-of-water work for construction of the FRE has the potential to generate noise and vibration that can affect aquatic species. In-water work would generate noise and vibration that is likely to disturb fish behavior. However, high-energy sound that could be injurious or lethal to fish would not be generated in water. In-water work may occur continuously over three, 3-month periods for 10 hours per day, during periods when migrating adult spring-run Chinook salmon would present. Exclusion and removal of fish from in-water work areas may minimize impacts of noise generated by the in-water work.

Noise sources from out-of-water work would include vibration that could be transferred from the adjacent earth to the water as a result of site clearing construction equipment, use of vibratory rollers used for roller-compacted concrete placement, and construction truck activity. This could occur continuously for up to 20 hours a day, 7 days per week, over the 5 years of activities, presenting a constant risk of disturbing fish behavior near the construction area.

The detonation pressure from blasting forms a shock front resulting in rock fragmentation, displacement, ground vibration, air overpressure, and water overpressure. Overpressure is caused by a shock wave when the air or water pressure exceeds atmospheric pressure. Rapid gas expansion following the detonation creates a secondary pressure pulse that decays far more slowly than the detonation shock pulse (Kolden and Aimone-Martin 2013). The energy from blasting moves through the air, ground and water, and from the ground into water (ADFG 1991). Blasting in the dry moves energy waves through the earth and along the surface, impacting nearby bodies of water by the transfer of energy at the water-substrate interface (ADFG 1991; Kolden and Aimone-Martin 2013). Energy moving into a waterbody creates overpressure and a gas expansion pulse in the water column (Kolden and Aimone-Martin 2013).

Four parameters determine the amount of ground vibration and water overpressure: charge weight, distance from charge to waterbody, substrate type, and local topography. Energy travels through bedrock, saturated soil, unsaturated soil, ice, frozen soil, and water and the associated energy varies based on the material’s density and wave velocity. In addition, geology as well as topography plays a role in determining blast impacts (ADFG 1991; Kolden and Aimone-Martin 2013).

Water overpressure and ground vibration from blasting that is transferred to the water can kill or injure fish. Overpressure injury ranges from scale loss to ruptured internal organs. Although other organs may be affected, the most sensitive organ is the swim bladder. In addition to injuries, behavioral changes may also occur. Rearing juveniles and spawning adults in shallow water are at increased risk from overpressure impacts. Ground vibration can directly injure or kill embryos in the gravel. Embryos in early stages of development are sensitive to movement and the ground vibration from blasting are likely to kill embryos.

Blasting would occur intermittently and much of the work would occur within the diversion tunnel. However, blasting presents the highest risk of affecting fish because of the high-energy sound pressure waves created, and it may occur as frequently as daily over a period of approximately 2 years.

To reduce or eliminate effects to fish or to keep fish out of regions where blasting pressure waves are harmful, the selected contractor will be required to attenuate vibration transference when blasting close to the active flow in the Chehalis River or its tributaries. Water transmits shock waves more effectively than air, and isolating blasts from water is an effective means of reducing blasting effects. The Applicant’s supplemental construction information (Martin 2019b) states that no blasting would occur within the active river channel (with water flowing). Blasting for the FRE foundation excavation would occur “in the dry” after the river has been diverted to the diversion tunnel, with a minimum 25-foot-wide dry working space buffer between the blast site and the cofferdam that isolates the work area from active river flow.

Additional attenuation measures may be considered, such as maintaining a dry work area within this zone using sheetpiles as cofferdams, using bubble curtains directly waterward of blast locations, and selecting the minimum sized charge and type of explosives necessary to accomplish the excavation. The Applicant (Martin 2019b) also states that buffer distances between blasting charges and the actively flowing river would be used to determine when vibration attenuation measures must be employed.

Sound is also extremely important to fish and is used for communication, prey and predator detection, and navigation. Because of this, fish have highly developed sensory systems to detect sound pressure waves and water particle motion. Fish behavioral responses to sound are variable depending on the species’ sensitivity, frequency of the sound, and masking of the sound by background noise and vibration. Rough and irregular noise, such as that created by impact drilling or blasting, causes a greater impact on animal behavior than smoother, continuous noise (Popper et al. 2014). Impacts of sound on fish behavior may include masking of important sound signals, driving fish from preferred areas, disturbing foraging, spawning, or migration activities including entering the FRE temporary trap-and-transport facility, or exposing fish to predators.

Depending on the species, distance from the source, and the nature of the source, exposure to high levels of sound may result in the following injuries or effects on fish:

- Immediate or delayed death due to injury
- Injury including damage to the ear or swim bladder and other organs, internal or external bleeding, scale loss
- Changes in hearing sensitivity (temporary or permanent threshold shift) that may, or may not, reduce fitness and survival
- Masking that makes it difficult for fish to detect biologically meaningful sounds against the noise background
- Substantial changes in behavior

Guidelines for different sound sources that are likely to result in each of these effects have been developed (e.g., Popper et al. 2014) and can be used to assess potential effects from FRE facility construction during monitoring of blasting activities. As a conservative measure, NOAA Fisheries and USFWS have suggested 150 dB re 1 µPa root mean square (rms) as the threshold for behavioral effects to fish species that are listed as threatened or endangered. This criterion has been applied in many biological opinions evaluating percussive pile driving activities. The criterion was selected on the basis that sound pressure levels in excess of 150 dB re 1 µPa rms can cause temporary behavioral changes (startle and stress) that might decrease the ability of fish to avoid predators (Woodbury and Stadler 2008).

Sound pressure levels generated from blasting will have to be monitored to determine whether thresholds that can kill or injure fish are exceeded in the adjacent river. Martin (2019b) proposes to manually and safely remove fish from the areas to be dewatered during the second in-water work period when water flow is shifted from the natural river channel to the diversion tunnel. This may also be required to adequately protect fish during blasting conducted for preparation of the FRE facility foundation and diversion tunnel construction if monitoring indicates sound pressure levels in water are above threshold levels. Alaska Department of Fish and Game blasting standards (Timothy 2013) limit the instantaneous pressure rise in the water column in rearing habitat and migration corridors to no more than 7.3 pounds per square inch where fish are present. Peak particle velocities in spawning gravels are limited to no more than 2.0 inches per second during the early stages of embryo incubation (Timothy 2013).

Sound transmitted through the earth adjacent to the Chehalis River as particle motion may be detected by particle-motion-sensitive fishes, including salmon, potentially over long distances depending on substrate composition and frequency of the vibration. Noise and vibration can create an adverse impact on fish hearing and behavior that would vary in magnitude depending on the timing and intensity of activities, and sound transmission through the earth. The exact transmission distance of sound through the earth to the river channel and in-water levels are unknown at this time and will have to be monitored. Kolden and Aimone-Martin (2013) recommends measuring overpressures and velocities in a linear array for increasing charge sizes in the early stages of large-scale blasting activities and then using the site-specific attenuation models to predict ground vibration and overpressures to determine the range of impacts on fish. In addition to impacts from blasting, a major concern for regulatory agencies will be whether the construction activities affect fish behavior to such a degree that collection efficiency of the temporary trap-and-transport system is reduced.

The Applicant proposes to manually and safely remove fish from the areas to be dewatered during the second in-water work period when water flow is shifted from the natural river channel to the diversion tunnel (Martin 2019b). The Applicant also states that monitoring of blasting activities will be conducted, and other vibration mitigation measures will be implemented when blasting within a prescribed distance of waterbodies where fish are present, such as sheet pile walls and bubble curtains. The prescribed distance from waterbodies would be determined in coordination with the consulting agencies.

Permit requirements to minimize impacts related to noise and vibration include monitoring noise levels and fish behavior, removing fish from affected areas prior to blasting, limiting noise-generating work such as blasting to times when sensitive species are not migrating or rearing, following BMPs of initiating blasting slowly to allow fish to react and move away from sound sources, and implementing a blasting noise mitigation plan. The monitoring would also consider if the noise affects fish to such a degree that collection efficiency of the temporary trap-and-transport system is reduced. Monitoring of sound pressure levels generated from blasting would be required to determine whether thresholds that can kill or injure fish are exceeded in the adjacent river. If monitoring indicates sound pressure levels in water are above threshold levels, fish may need to be removed from the area to adequately protect fish during blasting conducted for preparation of the FRE facility foundation and diversion tunnel construction.

With the permit requirements described above and proposed mitigation, noise generated by blasting and vibration for construction of the FRE presents a **moderate** adverse impact to aquatic species.

3.2.2.2.5 Salmon and Steelhead Species (Impacts from Construction)

3.2.2.2.5.1 Spring-Run Chinook Salmon (Impacts from Construction)

Overall, the model results indicate that construction of the Proposed Action would have a **significant** impact on spring-run Chinook salmon.

Integrated model results indicate that estimated spring-run Chinook salmon abundance in the Above Crim Creek Subbasin would decline from a median of 60 fish (range 56-61 fish) prior to construction to 29 fish (28-29) during the 2025 to 2030 construction period, a 52% decrease (Figure E-14). Estimated spring-run Chinook salmon abundance in the Rainbow Falls to Crim Creek Subbasin would decline from 47 fish prior to construction (40-48) to 38 fish (36-38) during the 2025 to 2030 construction period, a 19% decrease (Figure E-15). EDT model results indicated that construction of the FRE facility would reduce estimated spring-run Chinook salmon abundance from 65 to 11 fish (84% decrease) in the Above

Crim Creek Subbasin and from 48 to 34 fish (29% decrease) in the Rainbow Falls to Crim Creek Subbasin compared to the pre-construction period (Figure E-13).

The decline in spring-run Chinook salmon in the Above Crim Creek Subbasin during construction would be due to reduced passage survival and degradation of habitat conditions within the temporary reservoir inundation area, which encompassed nearly all modeled production of spring-run Chinook salmon above the FRE facility site. The assumed habitat degradation above the FRE facility site included an increase in summer water temperature that decreased the survival of spring-run Chinook salmon during the adult holding period. The decline in the Rainbow Falls to Crim Creek Subbasin would be due to increased water temperature associated with vegetation removal within the temporary reservoir area above the FRE facility.

For spring-run Chinook salmon and the other salmon species and steelhead modeled, the EDT model results were similar in pattern to the integrated model but decreases in estimated abundance were higher than the integrated model. These differences are most likely due to adults in the integrated model returning during construction from earlier brood years, where adults from pre-construction brood years support the population through one generation.

3.2.2.2.5.2 Fall-Run Chinook Salmon *(Impacts from Construction)*

Overall, the model results indicate that construction of the Proposed Action would have a **significant** impact on fall-run Chinook salmon.

Integrated model results indicate that estimated fall-run Chinook salmon abundance in the Above Crim Creek Subbasin would decline from a median of 167 fish (range 164-168 fish) prior to construction to 106 fish (106-106) fish during the 2025 to 2030 construction period, a 37% decrease (Figure E-17). Estimated fall-run Chinook salmon abundance in the Rainbow Falls to Crim Creek Subbasin would decline from 261 fish (245-263) fish prior to construction to 235 fish (231-236) during the 2025 to 2030 construction period, a 10% decrease (Figure E-18). EDT model results indicate that construction of the FRE facility would reduce estimated fall-run Chinook salmon abundance from 169 to 94 fish (45% decrease) in the Above Crim Creek Subbasin and from 263 to 230 fish (13% decrease) in the Rainbow Falls to Crim Creek Subbasin compared to the pre-construction period (Figure E-16).

The decline in fall-run Chinook salmon in the Above Crim Creek Subbasin during construction would be due to reduced passage survival and degradation of habitat conditions within the temporary reservoir inundation area, which encompassed much but not all modeled production of fall-run Chinook salmon above the FRE. This run would be less impacted than spring-run Chinook salmon because production outside the temporary reservoir area would be unaffected during construction, and fall-run Chinook salmon lack the summer adult holding life stage of spring-run Chinook salmon.

3.2.2.2.5.3 Coho Salmon (Impacts from Construction)

Overall, the model results indicate that construction of the Proposed Action would have a **significant** impact on coho salmon.

Integrated model results indicate that estimated coho salmon abundance in the Above Crim Creek Subbasin would decline from a median of 782 fish (range 774-783 fish) prior to construction to 271 fish (269-272) fish during the 2025 to 2030 construction period, a 65% decrease (Figure E-20). Estimated coho salmon abundance in the Rainbow Falls to Crim Creek Subbasin would decline from a median of 90 fish (7994) prior to construction to 89 fish (84-91) during the 2025 to 2030 construction period, a 1% decrease (Figure E-21). EDT model results indicate that construction of the FRE facility would reduce estimated coho salmon abundance from 824 to 155 fish (81% decrease) in the Above Crim Creek Subbasin and from 91 to 88 fish (3% decrease) in the Rainbow Falls to Crim Creek Subbasin compared to the pre-construction period (Figure E-19).

The greatest impact on coho salmon from construction would occur in the Above Crim Creek Subbasin where fish would be affected by the clearing of vegetation in the temporary reservoir area and especially by the assumed low passage survival rate at the FRE site during construction. The small (2%) decline in habitat potential for coho salmon in the Rainbow Falls to Crim Creek Subbasin as estimated by the EDT model was due to increased water temperature associated with vegetation removal in the temporary reservoir inundation area.

3.2.2.2.5.4 Steelhead (Impacts from Construction)

Overall, the model results indicate that construction of the Proposed Action would have a **significant** impact on steelhead.

Integrated model results indicate that estimated steelhead abundance in the Above Crim Creek Subbasin would decline from a median of 742 fish (range 741-745) prior to construction to 361 fish (361-361) during the 2025 to 2030 construction period, a 51% decrease (Figure E-23). Estimated steelhead abundance in the Rainbow Falls to Crim Creek Subbasin would decline from a median of 16 fish (15-17) prior to construction to 13 fish (13-14) during the 2025 to 2030 construction period, a 19% decrease (Figure E-24). EDT model results indicate that construction of the FRE facility would reduce estimated steelhead abundance from 821 to 377 fish (54% decrease) in the Above Crim Creek Subbasin and from 29 to 17 fish (42% decrease) in the Rainbow Falls to Crim Creek Subbasin compared to the pre-construction period (Figure E-22).

The decline in steelhead in the Above Crim Creek Subbasin during construction would be due to reduced passage survival and degradation of habitat conditions within the temporary reservoir inundation area. The decline in the Rainbow Falls to Crim Creek Subbasin would result from increased water temperature associated with vegetation removal within the reservoir area.

3.2.2.2.5.5 Summary of the Impacts of the Proposed Action on Salmonids During Construction

Impacts during FRE facility construction for each species by subbasin are presented in Table E-10. A discussion of the estimated impacts of the FRE facility construction is included in Section 3.2.2.2, which summarizes the impacts of the Proposed Action (FRE construction and operation) on salmon and steelhead abundance, productivity, spatial structure and diversity, along with a discussion of effects of the flow scenarios and climate change.

Mitigation is proposed for the Applicant to develop plans for Fish and Aquatic Species and Habitat, Vegetation Management, Riparian Habitat, Wetlands, Large Woody Material Management, and Surface Water Quality to mitigate impacts to spring- and fall-run Chinook salmon, coho salmon, and steelhead in the two subbasins. However, there is uncertainty if the implementation of the plans would be technically feasible and economically practicable. Therefore, construction of the Proposed Action would have **significant and unavoidable** adverse environmental impacts on spring- and fall-run Chinook salmon, coho salmon, and steelhead, unless the Applicant develops plans as described above that meet regulatory requirements and for which implementation is feasible. The Fish and Aquatic Species and Habitat Mitigation Plan would require the Applicant to develop plans to provide no net loss for the fish species and habitats impacted by construction.

Table E-10
Change in Estimated Abundance of Salmon and Steelhead During Construction of the Proposed FRE Facility

	ABOVE CRIM CREEK		RAINBOW FALLS TO CRIM CREEK	
SPECIES	INTEGRATED MODEL	EDT	INTEGRATED MODEL	EDT
Spring-run Chinook salmon	-52%	-84%	-19%	-29%
Fall-run Chinook salmon	-37%	-45%	-10%	-13%
Coho salmon	-65%	-81%	-1%	-3%
Steelhead	-51%	-54%	-19%	-42%

3.2.2.2.6 Non-Salmon Native Fish (Impacts from Construction)

The effects of construction on resident, non-salmon fish were not quantitatively modeled and are described here qualitatively. The effects of dewatering and diversion of the river around the construction site, water quality impacts, removal of large trees in riparian areas within the temporary reservoir area, and the BMPs that aim to minimize adverse impacts are described generally in Section 3.2.2.2.

For native resident species such as sculpins and minnows, fish passage will be required and will need to be addressed during construction. However, there is a greater uncertainty associated with the passage of these species through the FRE facility diversion tunnel compared to salmonids due to a lack of basic information for most species on swimming capabilities and behavior through a structure of this length. Passage for non-salmon fish would be limited around the construction site. It is assumed that downstream passage would occur via the river diversion tunnel. Trap-and-transport structures for upstream passage around the construction site would not specifically target non-salmon species, and there is uncertainty associated with the ability of resident fish to migrate upstream through the diversion tunnel. A large reduction or elimination of upstream passage may occur, limiting the ability of non-salmon fishes to access habitat in upper portions of the watershed above the FRE facility during construction.

The Applicant has stated that juvenile salmonids, resident fish, and lamprey that are captured and collected will be considered incidental to the collection of adult target salmonid species, will be transported upstream of the construction area and released back to the Chehalis River, and that passage of juvenile salmonids, resident fish, and lamprey during operation of the temporary passage facility will continue to be discussed with WDFW as the project progresses.

The low efficiency of upstream fish passage during the construction period would adversely impact non-salmon fish, especially migratory fish such as Pacific lamprey and highly mobile fish such as resident trout, mountain whitefish, and largescale sucker. For less mobile resident fish such as minnows and sculpins, mobility around the site would also be limited, but the degree to which they would migrate past the construction site is considered small.

Overall, construction of the Proposed Action would have a **significant** adverse impact on migratory non-salmon fish such as Pacific lamprey, largescale sucker, and mountain whitefish because of blockage or uncertainty about transport to upstream habitat.

Mitigation is proposed for the Applicant to develop plans for Fish and Aquatic Species and Habitat, Vegetation Management, Riparian Habitat, Wetlands, Large Woody Material Management, and Surface Water Quality to mitigate impacts to migratory non-salmon fish from construction. However, there is uncertainty if the implementation of the plans would be technically feasible and economically practicable. Therefore, the Proposed Action would have **significant and unavoidable** adverse environmental impacts on migratory non-salmon fish from construction, unless the Applicant develops plans as described above that meet regulatory requirements and for which implementation is feasible. The Fish and Aquatic Species and Habitat Mitigation Plan would require the Applicant to develop plans to provide no net loss for the fish species and habitats impacted by construction.

Construction of the Proposed Action would have a **moderate** impact on non-migratory fish (e.g., minnows and sculpins) because they can continue to use habitat upstream or downstream of the construction site; however, all fish species would be affected by impacts to the aquatic habitat (e.g., decreased water quality from increased turbidity, loss of riparian habitat and function).

3.2.2.2.7 Freshwater Shellfish and Aquatic Macroinvertebrates (Impacts from Construction)

Freshwater shellfish and aquatic macroinvertebrates are vulnerable to in-water construction activities because of their inability to move away from the activity and their reliance on specific substrate types and water quality. Dewatering of 8 acres of the Chehalis River channel in the area of the FRE facility would create an adverse impact for shellfish and macroinvertebrates that is likely to persist after water returns to the channel because habitat degradation due to FRE facility operations would limit recolonization. As a condition of the HPA, larval lamprey and freshwater mussels would be moved. Mussels would be required to be moved to existing unimpacted mussel beds to increase the chance of survival from relocation.

Construction activities would affect water quality and substrate by causing elevated levels of turbidity and sedimentation, resulting in adverse impacts on shellfish and macroinvertebrates. However, releases of turbidity or stormwater with reduced quality are expected to be effectively minimized with the implementation of BMPs required as part of the Construction NPDES Stormwater Permit. The NPDES permit would require the construction activities to meet water quality criteria, including turbidity. More information is provided in the *Water Discipline Report*.

The distribution and species composition of shellfish and macroinvertebrates within the proposed FRE facility construction area have not been surveyed, and the magnitude of the construction-related impacts on these species is highly uncertain. Freshwater shellfish are common downstream of the expected ranges of construction impacts, but mussel beds may also occur in areas closer to the FRE facility site that could be affected by sedimentation. For shellfish, the construction of the FRE facility would create a barrier that may prevent mussel host fish from overlapping with upstream mussel beds, thus decreasing recruitment and preventing gene flow between populations above and below the FRE facility. If mussel beds die in the construction area, they may not easily recolonize disturbed areas and some habitat would be permanently lost in the FRE structure footprint.

Loss of habitat in the 0.32-acre footprint of the FRE facility and decreasing recruitment would create a permanent **significant** adverse impact on mussels. The spatial scale of the habitat loss and alteration would be a **significant to moderate** adverse impact on aquatic macroinvertebrates.

Mitigation is proposed for the Applicant to develop plans for Fish and Aquatic Species and Habitat, Vegetation Management, Riparian Habitat, Wetlands, Large Woody Material Management, and Surface Water Quality to mitigate impacts to mussels and aquatic macroinvertebrates from construction. However, there is uncertainty if the implementation of the plans would be technically feasible and economically practicable. Therefore, the Proposed Action would have **significant and unavoidable** adverse environmental impacts on mussels and aquatic macroinvertebrates from construction, unless the Applicant develops plans as described above that meet regulatory requirements and for which implementation is feasible.

3.2.2.2.8 Marine Mammals and Birds (Impacts from Construction)

The construction of the FRE facility would directly adversely affect fish in the upper Chehalis Basin, especially anadromous salmon and steelhead that are the prey of some marine mammals, birds and other wildlife (the range of predators and scavengers that rely on salmon is described in the *Wildlife Species and Habitats Discipline Report*). Anadromous salmon and steelhead would be less abundant due to poor fish passage survival during construction. Marine predators that prey on Chehalis Basin salmon, either the outmigrating smolts or the returning adults, may be indirectly affected by a change in salmon population sizes.

The population of Chinook salmon that originates from the upper Chehalis River is one of several subpopulations originating from Chehalis River and Grays Harbor tributaries that contribute to the Grays Harbor population overall. Southern Resident killer whales depend on spring-run Chinook salmon as a food source. The number of these fish has been decreasing throughout the region, and several Chinook salmon populations outside of the Chehalis Basin that are preyed upon by Southern Resident killer whales are designated as threatened or endangered (70 Federal Register 37160, 79 Federal Register 20802).

Southern Resident killer whales spend significant amounts of time foraging along Washington's coast at the mouth of the Columbia River and near Grays Harbor in the winter and spring (Hanson 2017). Body condition (Durban et al. 2017; Fearnbach et al. 2018) and diet (Hanson et al. 2010; Ford et al. 2016; Hanson 2017) information suggests that the killer whales are experiencing reduced body condition and are forced to diversify their diet at this time to eat other fish species in an attempt to meet their caloric needs. The degree to which a decline in the specific subpopulation of fish originating from the upper Chehalis River would affect the Southern Resident killer whale is unknown, and the magnitude of construction-related impacts on killer whales is highly uncertain.

The number of fish that would likely be impacted by the Proposed Action represents a small proportion of the overall diet of the Southern Resident killer whales. However, the loss of salmon and steelhead, and in particular spring-run Chinook salmon from the Chehalis River, would present a **moderate** adverse impact on Southern Resident killer whales. The loss of salmon and steelhead from the Proposed Action would have **minor** adverse impact on other marine mammals because they prey upon a more diverse set of fish species.

The species-specific dependence of each species of piscivorous birds on salmon and steelhead in Grays Harbor is unknown. Piscivorous birds that occur in Grays Harbor include loons, terns, gulls, cormorants, shearwaters, pelicans, osprey, grebes, puffin, marbled murrelets, great blue heron, mergansers, and yellowlegs. Individual avian species' use of fish is dependent on behavioral specialization and adaptation and abundance and availability of suitable fish resources, which in turn will be influenced by predator pressure, including the effects of predation by other bird species, fish species and marine mammals. With decreased salmon and steelhead, changes to the food web for these birds could occur; while some birds can likely adjust to prey on other fishes, more specialized species would be more highly affected. Construction of the Proposed Action would have **moderate to minor** impacts on birds due to uncertainty about the degree to which these birds rely on salmon and steelhead as prey.

3.2.3 Impacts from Operation

Operation of the Proposed Action would directly affect fish, shellfish, aquatic macroinvertebrates and their habitats as a result of the presence of the FRE facility in the stream channel. It would result in changes to streamflow and floodplain inundation with flood retention events, reduced fish passage around and through the FRE facility area, active maintenance of the vegetation and removal of wood in the temporary reservoir inundation area, and reduced channel-shaping forces downstream of the FRE facility that would normally occur during a major to catastrophic flood. It would indirectly affect marine mammals and piscivorous birds as a result of the reductions in fish abundance, specifically anadromous salmon and steelhead that are a key prey resource.

Raising the airport levee would affect in-river and floodplain conditions for short periods (days) during major or catastrophic flood events and have no lasting effect on fish, shellfish, or aquatic macroinvertebrate habitat or productivity.

Additional information on operation is provided in the EIS Appendix 1, *Proposed Project Description and Alternatives* (Anchor QEA 2020d). Appendix 1 of the EIS also includes preliminary plans from the Applicant to minimize impacts to aquatic habitat and species that would be required to be finalized and implemented prior to operations, including the following:

- Fish Passage Plans for FRE facility operation
- Reservoir Operations and Management Plan
- Post-Construction Vegetation Management Plan

3.2.3.1 Aquatic Habitats

Direct impacts on fish and shellfish habitat from operation of the Proposed Action would result from physical changes to river flows (including water quantity and timing), water quality, stream channel width, sediment transport, large wood inputs and transport, riparian area vegetation, and floodplain off-channel areas and wetlands. Significant impacts of operation were identified in the other discipline reports that will also affect fish. Changes to the physical conditions are described in the *Water Discipline Report* and *Earth Discipline Report*, and changes to riparian area vegetation and wetlands are described in the *Wildlife Species and Habitats Discipline Report* and *Wetlands Discipline Report*, respectively.

The *Earth Discipline Report* identifies changes to sediment transport and substrate in the river channel within the temporary reservoir, reduced large wood levels, and decreased channel formation downstream of the FRE facility from reduced large wood and sediment. The *Earth* and *Water Discipline Reports* identify water quality impacts due to higher turbidity levels caused by fluctuating water level, particularly when the temporary reservoir drains. In addition, the *Water Discipline Report* identifies increased temperatures exceeding water quality criteria in the Chehalis River in the temporary reservoir inundation area and downstream when the FRE facility is not storing water, due to loss of riparian vegetation cover and stream shading. The *Water Discipline Report* also discusses decreases in dissolved oxygen levels exceeding water quality criteria at the FRE facility site and temporary reservoir. The *Wetlands* and *Wildlife Species and Habitats Discipline Reports* identify the loss of ecological function across up to 847 acres of upland, wetland, and riparian vegetation communities from reoccurring inundation events that will result in sediment deposition, channel widening, channel migration, and future colonization by invasive vegetation.

The ways in which the physical changes to the environment would affect the quantity and functioning of fish habitats are summarized below for each habitat type and area of the Chehalis River relative to the FRE facility and temporary reservoir inundation area.

The EDT model was used to analyze the change in habitats caused by the FRE facility and estimate the effects on the abundance of salmonids that originate from areas upstream of Rainbow Falls. Tables E2-6 to E2-8 in Attachment E-2 summarize the assumptions about the changes in habitats that were incorporated into the EDT model with source material cited. The habitat effects incorporated by EDT included changes in micro-habitat types (such as pools and riffles), temperature, large wood, bed scour, flow, fine sediment, riparian function, and food production that are relevant to salmonids. These changes in physical habitat features would also be experienced by other non-salmon fish, shellfish and macroinvertebrate species. Therefore, the assumptions listed in Tables E2-6 to E2-8 were used as the basis for developing the following summary descriptions of impacts to aquatic habitats from operation of the Proposed Action.

3.2.3.1.1 Headwaters Upstream of the Temporary Reservoir Area Habitat (Impacts from Operation)

Between floods and during flood retention events, fish habitat upstream of the maximum extent of the temporary reservoir inundation would not be directly affected. Fish passage upstream to tributary streams would be impaired and integrated modeling results show that the abundance of migratory salmon and steelhead would be reduced. Shellfish that depend on migratory hosts could also be reduced over time. This would result in adverse impacts on habitat due to reduced inputs of marine-derived nutrients brought by salmon carcasses and the habitat benefits created by shellfish. During flood retention events, access to stream habitat would become temporarily disconnected by the reservoir that would act as a barrier to some species moving between habitats below, in, and above the temporary reservoir area.

For migratory species collected during a flood retention event by the CHTR facility below the FRE, held, and released into or above the temporary reservoir, access to habitats upstream of the temporary reservoir would be commensurate with the effectiveness of the CHTR facility, described in Section 2.4.2.3. Following the flood retention event, these species could redistribute themselves into headwater tributaries unless sediment deposited in the reservoir area during a flood retention event creates a barrier to fish movement.

Therefore, there would be **moderate** adverse impacts to aquatic habitat in the headwaters upstream of the temporary reservoir area from operations.

3.2.3.1.2 Upper Mainstem Chehalis River Habitat within the Temporary Reservoir Area (Impacts from Operation)

Between floods, habitat would be permanently degraded across 847 acres of upland, riparian, and wetland areas in the temporary reservoir area due to active removal of large trees (greater than 6 inches diameter at breast height), all non-flood-tolerant trees, and large wood, and due to the long-term effects of catastrophic inundation events (vegetation management impacts are described in greater detail in the *Wildlife Species and Habitats Discipline Report*). This loss of trees in the riparian areas and removal of large wood would impair the aquatic habitat throughout the 6.4-river-mile reservoir extent.

The future potential contributions from riparian areas that are currently developing with protections under Forest Practices Rules would be lost, including the benefits from mature trees and sources of large wood.

Specific impacts within the temporary reservoir area between floods would include the following:

- Riparian area function would be severely degraded due to the removal of large trees that provide structure to the riparian forest, shade to the stream channel, and nutrient and wood inputs to the stream.
- The daily maximum water temperatures would increase 0.5°C to 3°C, depending on time of year, from lack of shading, with the greatest impact in June through mid-September. Daily maximum temperatures of the Chehalis River could increase by up to 2°C to 3°C in mid- to late-summer in the temporary reservoir. The increase in water temperatures would result from the loss of tree cover and shading. Additionally, modeling for Crim Creek in the temporary reservoir showed that loss of riparian vegetation cover and stream shading associated with the FRE facility is predicted to result in temperature increases of between 2°C and 5°C. Table E-4 lists the temperature criteria for streams in the study area. The increased water temperatures would likely be lethal levels for some cold-water adapted species.
- A reduction in large wood (due to active removal and loss of large trees delivered to the stream by sloughing and landslides) would result in reduced aquatic habitat complexity, a reduction in

the amount of certain microhabitat types, such as pool-riffle complexes, and reduced substrate retention. Areas where channel features are controlled by the natural bedrock geology and channel constraints would experience less change than unconfined areas with gravel substrate. Large wood is a key element to channel structure and complexity in areas that are not bedrock controlled.

- Large wood also helps slow water velocities and contributes to development of pools that provide cooler stream temperature, decreases fine sediment transport, provides refuge for juvenile fishes from predation, provide habitat for macroinvertebrate communities, and enables successful feeding (Wohl et al. 2015; Poff et al. 1997; Wald 2009).
- Bed scour would increase due to the loss of large wood and large riparian trees that tend to reduce water velocity and stabilize the substrate, further reducing the substrate quality for salmon spawning.
- Fine sediment would be deposited in the inundated reaches, with erosion and redistribution of sediment causing variable substrate conditions; a reduction in substrate quality for salmon spawning would occur due to increases in fine sediment.
- The food supply for fish would be significantly reduced or change in composition as a result of frequent inundation, less leaf litter input to streams from riparian vegetation (aquatic macroinvertebrates use leaves as a food source), a reduction in benthic macroinvertebrates that colonize large wood, and fewer terrestrial insects falling from riparian vegetation (direct impacts of operations on aquatic macroinvertebrates is addressed in Section 3.2.3.2).
- A backwater pool would form extending approximately 300 feet upstream of the FRE facility when flows exceed 12,500 cfs at the open outlet gates, causing periodic inundation for a few hours at a time that would degrade the habitat more intensively in this area.

During flood retention events, a free-flowing section of the Chehalis River would become a temporary reservoir, inundating and degrading the habitat. Inundation would occur for up to 35 days, with a maximum depth of 195 feet, extending approximately 5.5 miles upstream during a major flood, or 6.4 miles upstream for larger floods by late-century. Specific impacts within the temporary reservoir area during flood retention events would include the following:

- Habitat would be rapidly converted from stream-type habitat to deep-water habitat, eliminating salmon spawning habitat during inundation.
- Erosion within temporary reservoir from changes to vegetation and reservoir deposition and subsequent erosion of deposited sediment (more detail is provided in the *Earth Discipline Report*).
- Changes to sediment transport rates and substrate grain size within the potential inundation area and downstream of FRE facility (more detail is provided in the *Earth Discipline Report*).
- Riparian area function, large wood availability, and typical riverine habitat types (such as pool-riffle complexes) would be degraded completely while the reservoir area is inundated.
- Turbidity would increase slightly due to resuspension of sediment which could smother redds.

Combined, there would be **significant** adverse impacts to aquatic habitat in the upper mainstem Chehalis River within the temporary reservoir area. Vegetation survival and riparian area function is likely to be reduced completely in areas of the temporary reservoir that are more frequently disturbed, such as the backwater pool near the outlet gates.

Mitigation is proposed for the Applicant to develop plans for Fish and Aquatic Species and Habitat, Vegetation Management, Riparian Habitat, Wetlands, Large Woody Material Management, Wetlands and Wetland Buffers, Streams and Stream Buffers, and Surface Water Quality to mitigate impacts to aquatic habitat in the upper mainstem Chehalis River; however, there is uncertainty if the implementation of the plans would be technically feasible and economically practicable. Therefore, the Proposed Action would have **significant and unavoidable** adverse environmental impacts on aquatic habitat, unless the Applicant develops plans as described above that meet regulatory requirements and for which implementation is feasible.

Some impacts that result from the active removal of large trees and large wood would be reduced by implementing the proposed Vegetation Management Plan that would limit disturbance of vegetation communities where possible and calls for revegetating cleared areas with flood-tolerant native plant species, and monitoring and maintaining planted areas to ensure the success of mitigation plantings. Vegetation survival and riparian area function is likely to be reduced completely in areas of the temporary reservoir that are more frequently disturbed, such as the backwater pool near the outlet gates. Some impacts that result from the active removal of large wood would be reduced by implementing the proposed Large Woody Material Management Plan that would require that the large woody material which accumulates in the reservoir to be used for habitat in other areas. Large woody materials could be placed within the river channel along the mainstem Chehalis River and in appropriately sized tributaries and upland habitats identified in the plan within 60 days of completing drawdown following each inundation event.

Some impacts that result from the degradation of riparian habitat would be reduced by implementing the proposed Riparian Habitat Mitigation Plan that includes options that provide no net loss for the riparian and stream habitats impacted by construction and operational activities. The proposed plan would require riparian habitat to be replaced, protected, maintained and monitored in areas outside of the temporary reservoir.

The Fish and Aquatic Species and Habitat Mitigation Plan would require the Applicant to include options that provide no net loss for the riparian and stream habitats impacted by construction and operational activities. The plan would need to ensure riparian habitat is replaced, protected, maintained and monitored in areas outside of the temporary reservoir. The future potential contributions from riparian areas that are currently developing with protections under Forest Practices Rules would be lost, including the benefits from mature trees and sources of large wood. The Surface Water Quality

Mitigation Plan would need to provide reasonable assurance that water quality standards and in-water designated uses are met.

3.2.3.1.3 Upper and Middle Mainstem Chehalis River Habitat Downstream of the FRE Facility Impacts from Operation)

Between flood retention events, removal of large trees and large wood to maintain the temporary inundation area would affect water temperature and supply of habitat-shaping features (sediment and wood) that are carried into areas downstream of the FRE facility. These downstream effects of the FRE facility would be moderated by inputs of water, sediment, and wood from major tributaries such as Elk Creek, the South Fork Chehalis River, and Newaukum River (though the supply of large wood is limited throughout the basin). Specific impacts downstream of the FRE facility between flood retention events over the long-term would include the following:

- Substrate transport processes would be affected from the FRE facility downstream to RM 85, with an overall net decrease in sediment storage in the area, particularly in the bedrock canyon for 0.5 mile downstream of the FRE facility. Changes in substrate grain size that are important to aquatic habitat would be minor downstream of the FRE facility.
- Large wood delivery to the channel would be eliminated in the temporary reservoir and reduced in reaches downstream of the FRE facility, reducing fish refugia and the structure necessary to form different habitat types. Large wood helps slow water velocities and contributes to development of pools that provide cooler stream temperature, decreases fine sediment transport, provides refuge for juvenile fishes from predation, and enables successful feeding (Wohl et al. 2015; Poff et al. 1997; Wald 2009).
- Daily maximum water temperatures would increase by 0.5°C to 3°C, depending on time of year, from lack of shading upstream, with the greatest impact in June through mid-September.
- Between flood retention events when flows are less than 38,000 cfs at Grand Mound, floodplain inundation extents and depths would not change.
- Temperature impacts would be moderated by colder tributary inputs, with no observable effect to water temperature downstream of the confluence with the South Fork Chehalis River.
- Channel forming flows would be reduced, affecting formation of aquatic habitat downstream of the FRE facility.

During flood retention events, habitat would be temporarily impacted by changes in flows. Effects would be moderated by inputs of major tributaries downstream of Elk Creek. Specific impacts downstream of the FRE facility during flood retention events would include the following:

- Flows would be reduced to winter minimums of 300 cfs from an average of 1,000 cfs for 2 to 3 days, resulting in a large contraction of winter habitat area for fish, and potentially stranding salmon and steelhead redds.

- Bed scour, transport of substrate, and transport of wood would be reduced, reducing habitat complexity and delivery of spawning gravels to downstream reaches that benefit fish habitat.
- Habitat-shaping forces associated with major or larger floods would be eliminated (see *Earth Discipline Report*).

Combined, there would be **significant** adverse impacts to aquatic habitat in the upper and middle Chehalis River mainstem downstream of the FRE facility to the confluence with the South Fork Chehalis River from the increase in temperature. Direct impacts of the FRE facility on downstream hydraulics and bed scour could be reduced by implementation of a Reservoir Operations and Management Plan in the Applicant's project description that sets limits for outflow to maintain minimum instream flows during flood retention and controls reservoir drawdown rates to limit bed scour.

Mitigation is proposed for the Applicant to develop plans for Fish and Aquatic Species and Habitat, Vegetation Management, Riparian Habitat, Wetlands, Large Woody Material Management, Wetlands and Wetland Buffers, Stream and Stream Buffers, and Surface Water Quality to mitigate impacts to aquatic habitat in the upper and middle mainstem Chehalis River; however, there is uncertainty if the implementation of the plans would be technically feasible and economically practicable. Therefore, the Proposed Action would have **significant and unavoidable** adverse environmental impacts on aquatic habitat, unless the Applicant develops plans as described above that meet regulatory requirements and for which implementation is feasible.

Impacts downstream of the confluence with the South Fork Chehalis River (RM 85) would be **moderate** because water temperature increases from FRE facility operation would be attenuated.

3.2.3.1.4 *Off-Channel and Floodplain Habitat Downstream of the FRE Facility (Impacts from Operation)*

Between flood retention events, off-channel and emergent floodplain habitat would be inundated and remain hydrologically connected to the mainstem Chehalis River at flows below the threshold for flood retention (38,000 cfs as measured at Grand Mound).

During flood retention events, off-channel and floodplain habitat inundation could be temporarily reduced as outflows from the FRE facility are limited to winter minimum levels for 2 to 3 days. After peak flows have subsided across the basin, the FRE outlet gates would be opened in a controlled manner to allow retained water to pass downstream over the course of several weeks. The reduction in water surface elevation during flood retention events downstream of the FRE facility during flood retention events was modeled for the entire study area, shown in Attachment N-1 of the *Water Discipline Report.*

Specific impacts to off-channel and floodplain habitat downstream of the FRE facility during operations would include the following:

- Floodplain inundation could be reduced to the mouth of the Chehalis River, with the affect attenuating downstream of the FRE facility. Flood depths would be reduced by less than 1 foot downstream of the confluence with the Black River. Floodplain inundation would be reduced to extents similar to typical seasonal maximums, resulting in no change to the typical amount overwintering fish habitat availability.
- Flushing of some off-channel and floodplain areas that currently occurs during major (or larger) floods would no longer occur.
- Channel forming and habitat-shaping forces associated with major (or larger) floods would be eliminated (see *Earth Discipline Report*). There is considerable uncertainty around the range and magnitude of impacts associated with a reduction in habitat-shaping flows on fish habitat in the floodplain.
- Changes to inundation extents and durations could impact access to wetlands or floodplain habitats, predator distributions and pressures, and food production for rearing fish.

Combined, these actions would be **significant** adverse impacts to aquatic habitat in off-channel and floodplain areas downstream of the FRE facility. Mitigation is proposed for the Applicant to develop plans for Fish and Aquatic Species and Habitat, Vegetation Management, Riparian Habitat, Large Woody Material Management, Wetlands and Wetland Buffers, Streams and Stream Buffers, and Surface Water Quality to mitigate impacts to aquatic habitat in the off-channel and floodplain areas downstream of the FRE facility. However, there is uncertainty if the implementation of the plans would be technically feasible and economically practicable. Therefore, the Proposed Action would have **significant and unavoidable** adverse environmental impacts on aquatic habitat, unless the Applicant develops plans as described above that meet regulatory requirements and for which implementation is feasible.

3.2.3.1.5 Impacts of Reducing the Magnitude of Floods on the Chehalis River (Impacts from Operation)

The effects of dams on downstream aquatic habitats have been widely studied, with the literature generally showing far-reaching negative impacts for aquatic systems. There are several broad syntheses that provide holistic overviews of documented effects of regulated flows (e.g., Bunn and Arthington 2002; Lytle and Poff 2004; Naiman et al. 2008; Poff and Zimmerman 2010). However, the FRE facility proposed for the upper Chehalis River is a flood retention facility that allows the river to flow through outlets most of the time, and the reservoir is retained only temporarily. Operation of the FRE facility will eliminate peak flows in downstream reaches; however, the long-term effects on fish habitat of allowing smaller magnitude floods pass through this unique design have not been well documented in the literature or fully quantified in the Chehalis Basin. Observations made in other systems with dams were used to inform the potential impacts of eliminating peak flows to habitat downstream of the FRE facility and are discussed here.

The loss of stream power associated with bed-mobilizing peak flows may simplify channel morphology by discouraging the formation of within-channel bars and islands and eroding existing ones (Ward et al. 2002; Poff et al. 1997; Ligon et al. 1995). Flow variability also affects the recruitment of large woody material into the channel, which in turn, affects local sediment erosion and deposition rates and creation of habitat (Wohl et al. 2015; Poff et al. 1997; Wald 2009; Naiman et al. 2008). Basic channel geometry (width and wetted perimeter) can be relatively unchanged at large scales if mean annual flows are similar to pre-dam periods (Burke et al. 2009); however, habitat complexity at smaller scales, such as creation of new pool-riffle complexes and connectivity with off-channel habitat, becomes reduced.

Loss of peak flows reduces the frequency and magnitude of disturbances to which riparian plants are adapted and encourages the encroachment of channel-stabilizing vegetation (Ligon et al. 1995). Flow regulation can impact species richness in riparian areas (Andersson et al. 2000), by reducing riparian plant dispersal by water, contributing to summer mortality resulting from groundwater depletion (Rood et al. 2003) and contributing to declines in native, flow-adapted taxa and subsequent colonization by invasive plant species (Lytle and Poff 2004). The type and intensity of flow regulation influences the level of impact to riparian vegetation communities (Jansson et al. 2000) and interacts with other habitat processes (e.g., water temperature and geomorphological processes) to shape riparian vegetation and fish community structure (Marchetti and Moyle 2001).

A reduction in the magnitude of flooding reduces the functional extent of the active floodplain (Nilsson and Berggren 2000). Altered hydrology downstream of dams reduces groundwater recharge in riparian areas and can result in a falling groundwater table (Nilsson and Berggren 2000). In floodplains, the main inputs of nutrients, sediment, and organic matter are mainly via surface flow from upstream (Pinay et al. 2002). Flooding distributes marine-derived nutrients from salmon carcasses and fertilizes terrestrial vegetation (Ben-David et al. 1998).

With the Proposed Action, changes to the inundation of wetlands and open water aquatic habitats downstream of the FRE facility due to flood retention during major and catastrophic floods were quantified in the *Wetlands Discipline Report* based on Ecology's Modeled Wetlands Inventory dataset (Ecology 2011) and the National Hydrology Dataset (USGS 2019). In the largest magnitude scenario analyzed, retention of a late-century catastrophic flood, up to 16 acres of open water and 17 river miles of stream-type habitat would no longer be inundated and would have potentially reduced depths and duration of flooding. Flood retention could result in 506 acres of wetlands that would no longer be inundated with a catastrophic flood. A large degree of uncertainty exists around the magnitude of this impact for fish and other aquatic organisms like macroinvertebrates that rely on wetland habitat, because it is estimated that 203 acres of the wetlands affected by retention of a catastrophic flood are potentially disturbed, no longer functioning as wetlands. No extensive assessment of the connectedness of affected wetlands has been carried out for accurately quantifying fish use.

Reductions in peak flows (energy), large wood, and sediment transport due to the FRE facility as described in the *Earth Discipline Report* would affect aquatic habitat over time through impacts to habitat-forming processes that move large amounts of material (sediment and wood) over short periods of time, such as during the 2007 flood of record. The cumulative effects of decreased large floods, reduced sediment supply, and limited large woody material downstream of the FRE facility would likely result in reduced major channel changes that occur during big floods over the long term downstream to the confluence with the South Fork (*Earth Discipline Report*).

Peak flows create in-channel and off-channel habitats for fish in multiple ways: by limiting habitat formation, changing the connectedness of off-channel areas for fish, and affecting the fish community structure in off-channel areas over time. For instance, major avulsions of the river that occur with large-magnitude floods are responsible for the long-term dynamic balance between the creation and elimination of off-channel habitats that are highly productive habitats when inundated, either year-round or during seasonal floods. Since 1945, channel migration rates in the Chehalis River mostly occurred as progressive, slow bank erosion on the outside of meander bends except for the period around 2007. The only avulsion since 1945 (rapid change to a new channel) noted occurred in the RM 104 to RM 105 area during the 2007 flood due to a channel-spanning log jam. The presence of an FRE facility would eliminate major channel avulsions that create off-channel habitat. In addition, it has been hypothesized that waterbodies that do not experience frequent flushing flows have heavier loads of non-native fish and amphibian species (such as bass and bullfrogs) known to prey on native fishes including juvenile salmon (Hayes et al. 2019).

In summary, elimination of peak flows would reduce channel migration to approximately the South Fork Chehalis River confluence (*Earth Discipline Report*), and the formation of floodplain habitats within the primary study area (*Wetlands Discipline Report*). Bankfull flooding that occurs on a 1.5- to 2-year recurrence interval would not trigger closure of the FRE facility, would still act on the river channel and floodplain, and is also considered important for channel-forming processes (*Earth Discipline Report*). The seasonal flushing of hydrologically connected off-channel habitats would still occur. However, limits to the creation of new habitats could adversely affect fish species like Olympic mudminnow, an obligate of floodplain wetland habitats, and species like coho salmon that use off-channel and floodplain habitats for part of their rearing phases.

Combined, these actions would be **significant** adverse impacts to aquatic habitat downstream of the FRE facility from reduction of the magnitude of floods. Mitigation is proposed for the Applicant to develop plans for Fish and Aquatic Species and Habitat, Vegetation Management, Riparian Habitat, Large Woody Material Management, Wetlands and Wetland Buffers, Streams and Stream Buffers, and Surface Water Quality to mitigate impacts to aquatic habitat downstream of the FRE facility. However, there is uncertainty if the implementation of the plans would be technically feasible and economically practicable. Therefore, the Proposed Action would have **significant and unavoidable** adverse environmental impacts on aquatic habitat, unless the Applicant develops plans as described above that meet regulatory requirements and for which implementation is feasible.

3.2.3.2 Aquatic Species

This section first discusses impacts to abundance, which includes the modeled operation impacts of the FRE facility for salmonids (spring-run and fall-run Chinook salmon, coho salmon, and steelhead), followed by impacts to productivity, diversity, and spatial structure. Fish passage impacts for salmonid species during operation are also discussed. Non-salmonid fish species are then addressed, including effects on their passage through the FRE facility site during operation. The section concludes with impacts for shellfish, macroinvertebrates, and marine mammals. Indirect effects on aquatic species may occur if the changes to habitat function and connectivity of the Chehalis River lead to changes in aquatic communities in upstream tributary subbasins or extend to the marine environment.

Impacts to chum salmon, bull trout, eulachon, green sturgeon, and white sturgeon are not analyzed in detail because these species occur only in areas downstream of major impacts to hydraulics, water quality, and substrate continuity. Eulachon have not been observed in the areas that would experience significant impacts to fish habitat; however, eulachon are not precluded from being present in those areas. Operation of the Proposed Action is not likely to have significant impacts on chum salmon, bull trout, eulachon, green sturgeon, and white sturgeon. However, it is expected that the Proposed Action, restoration, and climate change would all have some indirect impact on populations of these species that use the Chehalis River.

In the temporary reservoir area upstream of the FRE facility, fish, shellfish and macroinvertebrates would be directly affected by rapid inundation during flood retention events. Lake-type habitat would be unusable for many of the fish, all of the shellfish, and a majority of the macroinvertebrate species because they are adapted to flowing stream habitat. Fish may become redistributed out of the stream channel and into flooded areas and fish may become stranded as floodwaters are drawn down. Localized high turbidity will occur at levels that impair fish behaviors like migration and foraging. Deposition of sediment will smother incubating salmon embryos and sessile organisms like shellfish and lamprey ammocoetes. Salmon spawning habitat would be eliminated by inundation and deposition of fine sediment. The benthic macroinvertebrate community that provides food for fish would be eliminated during inundation (Lepori and Hjerdt 2006); since the reservoir would be retained temporarily, no lake-type invertebrate zooplankton would develop. Impacts of FRE facility operation (flood retention) would be reduced by the implementation of the Applicant's Reservoir Operations and Management Plan that controls drawdown rates to avoid stranding of mobile species such as fish.

Large wood would not be supplied to the river channel upstream of the FRE facility and large logs (greater than 30 feet in length) would not be passed below the FRE facility, eliminating a primary source of large wood supply in the upper Chehalis River. Large wood is essential for growth and survival of salmon and steelhead; it helps provide cooler stream temperature, decreases fine sediment, helps form and maintain many channel and floodplain features such as river bars and riffle-pool sequences, and provides refuge for juvenile fishes from predation and slower water to enable successful feeding (Wohl et al. 2015; Poff et al. 1997; Wald 2009). The dampening of channel-forming processes, reduction in terrestrial nutrients, and a loss of large woody material due to the FRE facility would have significant detrimental impacts to salmon and steelhead in the Chehalis Basin.

With the operation of the FRE facility, peak flows associated with high-water events would be greatly reduced. Variability in natural flow regimes is critical to ecosystem function (Ward et al. 2002). As discussed in Section 3.2.3.1, reductions in peak flows would impede processes that increase salmon and steelhead habitat complexity and create off-channel rearing habitats and viable spawning areas for these fishes over time. In addition, limiting high-water events that infiltrate the floodplain would also limit the input of terrestrial nutrients to the stream, which would have negative impacts on juvenile salmon and steelhead growth.

3.2.3.2.1 Fish Passage During Operations

For areas upstream of the FRE facility, fish passage survival rates for periods between flood retention events and during flood retention are shown in Section 2.4.2.3, Table E-9. Fish passage survival is estimated to vary depending on species and life stage. For adult salmonids moving upstream, fish passage survival is estimated to be 94% to 96% via FRE tunnels between flood retention periods, declining to 91% during flood retention using trap-and-transport methods. The major floods (or greater) that would trigger flood retention by the FRE facility tend to occur from November through February, affecting upstream migration for large numbers of fish (fall-run Chinook salmon, coho salmon, steelhead, and cutthroat trout).

3.2.3.2.1.1 Non-Flood Conditions

The FRE facility would have five outlets the Chehalis River would pass through: one outlet 12 feet wide by 20 feet high and four outlets 10 feet wide by 16 feet high. The outlets would be low gradient and exposed to daylight at both ends.

During non-flood conditions it is assumed fish would enter and pass through the 310-foot-long outlet tunnels in the base of the FRE facility. Passage in both upstream and downstream directions is volitional (i.e., no physical trapping or handling) and the conditions within the outlet tunnels would be designed to meet state and federal passage standards. Upstream migrants would enter the tunnel entrance under ambient lighting and pass upstream through the tunnels, unless blocked by a behavioral response to the darkened portion of the tunnels or poor hydraulic conditions within the tunnel that form temporarily at a specific location due to bedload deposition. Fish moving downstream would enter the tunnel entrance under ambient lighting and pass downstream through the tunnels by swimming with the flow. Fish movement could be interrupted by a behavioral response to the darkened portion of the outlet tunnels, although this response is not expected to occur.

Hydrologic modeling performed for the FRE facility (Anchor QEA 2019) indicates the low-level outlets (LLOs) can discharge up to approximately 12,500 cfs without surcharging; thus a typical seasonal flow would be passed through the outlet tunnels without surcharging. However, with increased river flow, surcharging could occur, and water could back up at the (upstream) entrance to the tunnel. The magnitude of the backwatered condition would depend on the magnitude of the storm event and would most likely be limited to short-duration periods (hours or days; Attachment E-3). Under these conditions, downstream migrating fish would hold in the backwatered area or pass through the outlet tunnels. For upstream migrating fish, water velocity through the outlet tunnels under a storm event would temporarily exceed fish passage standards, and fish would most likely reside below the FRE facility until flows subside and fish passage conditions improve.

3.2.3.2.1.2 Flood Retention Periods

For major floods or larger, the FRE outlets would be closed and water would be temporarily stored in the reservoir area for up to 35 days. During flood retention operations, gates for the outlet conduits would be closed to migrating fish. The FRE facility outflow would be reduced at a rate of 200 cfs per hour 2 days prior to the predicted start of major flooding. The Applicant proposes to use a maximum rate of change in reservoir outflow of 200 cfs per hour to minimize the potential for fish stranding downstream of the temporary reservoir. The 200-cfs-per-hour rate was determined by applying a 2-inch-per-hour decline in river stage downstream of the FRE facility. The flow rate used for that calculation was 1,000 cfs, the median flow for November to March during which most floods occur. That rate of change would be adjustable and could be adaptively managed during operations. An outlet flow of 300 cfs would be maintained during flood retention operations; fish residing upstream of the FRE facility would remain in the temporary reservoir and not move through the deep, low volume outlet discharge.

When the FRE outlet gates are opened after a flood retention event, flow releases would vary according to the operations plan developed for the FRO facility (CBS 2017c), and it is assumed that fish in the temporary reservoir would exit through the outlet conduits. During drawdown of the reservoir, the gates would open and increase outflow by 1,000 cfs per hour to a maximum outflow of from 5,000 to 6,500 cfs, which would limit the duration of the flow increases to about 5 hours. Reservoir drawdown rates would be limited to 10 feet per day (5 inches per hour depending on many factors, including localized hydraulic conditions at the entrances due to site conditions and the design of the CHTR).

The CHTR facility design includes a low-flow (low-volume, low-velocity) entrance for juvenile salmonids, resident fish, and adult lamprey, and separate ladders and holding facilities for these species and life stages apart from similar but high-flow components for adult salmonids (CBS 2018b). While the CHTR design incorporated this feature to support the passage of these species and life stages and the lamprey component of the design was based on the latest research information, the actual performance of the low-flow entrance for juvenile salmonid, resident fish, and lamprey is unknown because the design is an untested prototype. A more detailed design will be required during the permitting phase to ensure the CHTR meets the federal and state requirements for fish passage.

3.2.3.2.1.3 Fish Passage Plan

Estimated impacts from fish passage during operations are described in Table E-9 and Attachment E 3. The Fish Passage Plan would also be included as part of the Fish and Aquatic Species and Habitat Plan. The Fish Passage Plan would include the following measures:

- Implement the most efficient means for trapping and transport of all fish species present at all mobile life stages.
- Monitor fish passage weekly and report on fish passage performance monthly to:
  - Evaluate passage effectiveness of the FRE outlet conduits during non-flood conditions and the CHTR facility during flood retention events.
  - Adaptively manage fish passage operations and implement changes to operations to address challenges such as debris accumulations on outlet conduit trash racks and issues with the CHTR design or operation such as flow adjustments and fish behavior.
  - Identify any unforeseen events and a clear pathway for addressing them through a contingency plan.
- For both temporary (construction) and permanent (operation) periods, develop fish passage contingency plans that can be implemented if passage standards are not met.
- Ensure trash racks on the outlet tunnels remain free of debris; any debris accumulations are to be removed promptly.
- Design the outlet conduits with hydraulic conditions that ensure upstream and downstream fish passage and avoid fish delaying when migrating into and through the outlets.

Combined, the impacts to fish species from reduced fish passage would be **significant.** Mitigation is proposed for the Applicant to develop plans for Fish and Aquatic Species and Habitat, Vegetation Management, Riparian Habitat, Large Woody Material Management, Wetlands and Wetland Buffers, Streams and Stream Buffers, and Surface Water Quality to mitigate impacts to fish species from reduced fish passage. However, there is uncertainty if the implementation of the plans would be technically feasible and economically practicable. Therefore, the Proposed Action would have **significant and unavoidable** adverse environmental impacts on fish species, unless the Applicant develops plans as described above that meet regulatory requirements and for which implementation is feasible. The Fish and Aquatic Species and Habitat Mitigation Plan would require the Applicant to develop plans to provide no net loss for the fish species and habitats impacted by operations.

3.2.3.2.2 Salmon and Steelhead Species (Impacts from Operations)

3.2.3.2.2.1 Spring-Run Chinook Salmon (Impacts from Operations)

Overall, the model results indicate that operation of the Proposed Action would have a **significant** impact on spring-run Chinook salmon.

Estimated spring-run Chinook salmon abundance in the Above Crim Creek Subbasin would decline throughout the Proposed Action operational period (Figure E-14). In the mid-century period the decline would stabilize at a median value of 3 fish (range 0-15) compared to a median of 60 fish (56-61) prior to construction and 29 fish (28-29) during construction, a decrease in median estimated abundance of 95% and 90%, respectively. In the late-century period, the decline would stabilize at a median value of 2 fish (0-5), compared to a median of 60 fish prior to construction and 29 fish during construction, a decrease in median estimated abundance of 97% and 93%, respectively. Within both time periods, numerous model iterations estimated that abundance of spring-run Chinook salmon would be zero fish.

Recurring flood events would reduce estimated spring-run Chinook salmon abundance in the Above Crim Creek Subbasin initially, after which the population would stabilize (Figure E-15). Recurring floods early in the simulation period would influence equilibrium population abundance variability, and recurring floods in the middle of the simulation would reduce median estimated abundance from 7 to 3 fish compared to equilibrium abundance under non-recurring flood conditions.

Estimated spring-run Chinook salmon abundance in the Rainbow Falls to Crim Creek Subbasin would decline throughout the Proposed Action operational period. In the mid-century period, the decline would stabilize at a median value of 21 fish (range 19-22) compared to a median of 47 fish (40-48) prior to construction and 38 fish (36-38) fish during construction, a decrease in median estimated abundance of 55% and 45%, respectively. Within the mid-century period, no model iterations resulted in an estimated abundance of zero spring-run Chinook salmon. In the late-century period spring-run Chinook salmon would be eliminated from this subbasin.

Recurring flood events early and in the middle of the simulation period would reduce estimated spring-run Chinook salmon abundance in the Rainbow Falls to Crim Creek Subbasin initially, after which the population would continue a downward trend through the mid-century period. Recurring floods early and in the middle of the simulation periods would have no effect on median estimated abundance compared to equilibrium abundance under non-recurring flood conditions. Spring-run Chinook salmon abundance in this subbasin was estimated to be zero in late-century, and the late recurring flood would have no effect on the population.

Overall, construction of the FRE facility and its operation during the mid- and late-century periods, combined with increased water temperatures associated with the mid-century and late-century periods, would have a **significant** impact on estimated spring-run Chinook salmon abundance in both subbasins. The population below the FRE facility was small to begin with and would be extirpated by late-century.

The population above the FRE facility spawns almost exclusively in the temporary reservoir area and would reach equilibrium abundance at a very small population size of 2 fish (late-century) or 3 fish (mid-century). Numerous iterations of the integrated model resulted in an estimated abundance of zero fish in the Above Crim Creek Subbasin population in both analysis periods, suggesting that while technically present, the population may be functionally extirpated.

3.2.3.2.2.2 Fall-Run Chinook Salmon (Impacts from Operations)

Overall, the model results indicate that operation of the Proposed Action would have a **significant** impact on fall-run Chinook salmon.

Estimated fall-run Chinook salmon abundance in the Above Crim Creek Subbasin would decline throughout the Proposed Action operational period (Figure E-17). In the mid-century period the decline would stabilize at a median value of 82 fish (range 51-92) compared to a median of 167 fish (164-168) prior to construction and 106 fish (106-106) during construction, a decrease in median estimated abundance of 51% and 23%, respectively. In the late-century period the decline would stabilize at a median value of 28 fish (2-38) compared to a median of 167 fish prior to construction and 106 fish during construction, a decrease in median estimated abundance of 83% and 74%, respectively. Within the mid-century and late-century periods, no iterations of the integrated model produced estimates of zero fish.

Recurring flood events would reduce estimated fall-run Chinook salmon abundance in the Above Crim Creek Subbasin initially, after which the population would stabilize. Recurring floods in the middle of the simulation period would reduce median equilibrium abundance from 90 to 82 fish, while recurring floods early and late in the simulation would have no effect on median estimated equilibrium abundance.

Estimated fall-run Chinook salmon abundance in the Rainbow Falls to Crim Creek Subbasin would decline throughout the Proposed Action operational period (Figure E-18). In the mid-century period the decline would stabilize at a median value of 166 fish (range 144-172) compared to a median of 261 fish (245-263) prior to construction and 235 fish (231-236) during construction, a decrease in median estimated abundance of 36% and 29%, respectively. In the late-century period the decline would stabilize at a median value of 75 fish (65-80) compared to a median of 261 fish prior to construction and 235 fish during construction, a decrease in median estimated abundance of 71% and 68%, respectively. Within the mid-century and late-century periods, no iterations of the integrated model produced estimates of zero fish.

Recurring flood events early and in the middle of the simulation period would reduce estimated fall-run Chinook salmon abundance in the Rainbow Falls to Crim Creek Subbasin initially, after which the population would continue a downward trend through the mid-century period. Recurring floods in the middle of the simulation period would reduce median equilibrium abundance from 170 to 166 fish, while recurring floods early and late in the simulation would have no effect on median estimated equilibrium abundance.

Overall, construction of the FRE facility and its operation during the mid- and late-century period, combined with increased water temperatures associated with the mid-century and late-century periods, would have a **significan**t impact on fall-run Chinook salmon in both subbasins. Variability in estimated abundance based on the integrated model was greater in the Above Crim Creek Subbasin than the Rainbow Falls to Crim Creek Subbasin, with nearly zero fish produced in many model iterations. This was due to the impact of flood storage events on fall-run Chinook salmon above the proposed FRE facility that spawn predominantly within the temporary reservoir area. Estimated abundance in both subbasins would be large enough to allow the populations to persist but at reduced levels. By late-century, estimated abundance of fall-run Chinook salmon in both subbasins would decrease by approximately 70% to 80% under the Proposed Action. The population above the FRE facility would reach very low (i.e., 2) estimated equilibrium abundance in numerous model iterations. As described above, since this is a separate population, the persistence of the population may be at risk.

3.2.3.2.2.3 Coho Salmon (Impacts from Operations)

Overall, the model results indicate that operation of the Proposed Action would have a **significant** impact on coho salmon.

Estimated coho salmon abundance in the Above Crim Creek Subbasin would decline immediately during the construction period for the Proposed Action (Figure E-20). The decline would be a result of low estimated trapping efficiency for coho salmon associated with a temporary trap-and-transport system. This species migrates into the upper Chehalis River during fall and winter when flows can be high and turbid. This can result in the picket weir having to be removed due to high flow or debris accumulations and high turbidity levels, reducing ladder collection efficiency. In the mid-century period under FRE operations, the decline would stabilize at a median value of 382 fish (range 368-389) compared to a median of 782 fish (774-783) prior to construction and 271 fish (269-272) fish during construction, a decrease in median estimated abundance of 51% compared to the median initial abundance and an increase of 41% compared to the median abundance during construction. In the late-century period the decline would stabilize at a median value of 263 fish (240-271) compared to a median of 782 fish prior to construction and 271 fish during construction, a decrease in median estimated abundance of 66% and 3%, respectively. Within the mid-century and late-century periods, no iterations of the integrated model produced estimates of zero fish.

Recurring flood events early in the simulation period would reduce estimated coho salmon abundance in the Above Crim Creek Subbasin initially, after which the population would stabilize. Recurring floods in the middle of the simulation period would reduce median equilibrium abundance slightly (385 to 382 fish), while recurring floods early and late in the simulation would have no effect on median estimated equilibrium abundance.

Integrated model results indicate the Rainbow Falls to Crim Creek population of coho salmon would be smaller than the population above the proposed FRE facility. Estimated abundance of coho salmon in this subbasin would not decline during the construction period but would decline thereafter (Figure E-21). During mid-century the decline would stabilize around 62 fish (range 57-63) compared to a median of 90 fish (79-94) fish prior to construction and 89 fish (84-91) during construction, a decrease in median estimated abundance of 31% and 30%, respectively. Within the mid-century period, no iterations of the integrated model produced estimates of zero fish. In the late-century period coho salmon would be extirpated from this subbasin.

Recurring flood events early and in the middle of the simulation period would reduce estimated coho salmon abundance in the Rainbow Falls to Crim Creek Subbasin initially, after which the population would stabilize. Differences in median equilibrium abundance under recurring floods middle and late in the simulation period would be insignificant.

Overall, construction of the FRE facility and its operation during the mid- and late-century period, combined with increased water temperatures associated with the mid-century and late-century periods would have a **significant** impact on estimated coho salmon abundance in both subbasins. In the Above Crim Creek Subbasin, impacts to coho salmon from construction would be substantial and immediate, after which the population would recover somewhat during the mid-century period and then decline. Impacts would be smaller for coho salmon than spring-run and fall-run Chinook salmon because coho salmon are more widely distributed in the upper Chehalis River and utilize habitats both within and upstream of the temporary reservoir area.

Variability in estimated abundance based on the integrated model due to modeled project operations was also lower for coho salmon than spring-run and fall-run Chinook salmon in the Above Crim Creek Subbasin for the same reason. Based on integrated model results, estimated abundance of coho salmon above the proposed FRE facility would be reduced to less than half its initial population size. In the Rainbow Falls to Crim Creek Subbasin, the initial population size would be small (less than 100 fish) and the Proposed Action would extirpate coho salmon from this subbasin by late century.

3.2.3.2.2.4 Steelhead (Impacts from Operations)

Overall, the model results indicate that operation of the Proposed Action would have a **significant** impact on steelhead.

Estimated steelhead abundance in the Above Crim Creek Subbasin would decline immediately during the construction period for the Proposed Action (Figure E-23). The decline would be a result of low estimated trapping efficiency for steelhead associated with a temporary trap-and-transport system. This species migrates into the upper Chehalis River during winter when flows can be high and turbid, which can result in reduced ladder collection efficiency or the picket weir having to be removed due to high flow or debris accumulations and high turbidity levels.

In the mid-century period under FRE facility operations, the decline would stabilize at a median value of 545 fish (range 537-546) compared to a median of 742 fish (741-745) prior to construction and 361 fish (361-361) fish during construction, a decrease in median estimated abundance of 27% compared to the median initial abundance and an increase of 51% compared to the median abundance during construction. In the late-century period the decline would stabilize at a median value of 381 fish (378-384) compared to a median of 742 fish prior to construction and 361 fish during construction, a decrease in median estimated abundance of 49% compared to the median initial abundance and an increase of 6% compared to the median abundance during construction.

Habitat potential above the FRE facility would be least affected for steelhead of the four species modeled because much of the modeled production of steelhead in the Above Crim Creek Subbasin would occur outside the temporary reservoir and would therefore be unaffected by conditions within the reservoir. Additionally, in the EDT model flood effects occurred during October through February (see Tables E2-6, E2-7, and E2-8 in Attachment E-2) and steelhead spawning occurred during the non-flood season. Thus, there are no impacts due to eggs in redds suffocating. However, if a flood event that resulting in reservoir formation behind the FRE facility were to occur later in the year, when steelhead eggs are incubating in redds, the inundation impacts on steelhead would be greater than what is currently modeled.

Within the mid-century and late-century periods, no iterations of the integrated model produced estimates of zero fish. Recurring flood events had no effect on median abundance regardless of when they were inserted into the simulation period because, as discussed above, in the EDT model flood effects occurred during October through February and steelhead spawning occurred during the non-flood season.

Integrated model results indicate the Rainbow Falls to Crim Creek population of steelhead would be smaller than the population above the proposed FRE facility. Estimated abundance of steelhead in this subbasin would decline during the construction period from a median value of 16 fish (range 15-17) prior to construction to 13 fish (13-14) during construction (Figure E-24). In the mid-century and late-century periods, steelhead would be eliminated from this subbasin and therefore recurring flood events would have no effect on median estimated abundance. Steelhead population abundance in this subbasin is at a very low level currently and the population is estimated to be extirpated.

Overall, construction of the FRE facility and its operation during the mid- and late-century period, combined with increased water temperatures associated with the mid-century and late-century periods, would have a **significant** impact on estimated steelhead abundance in both subbasins. In the Above Crim Creek Subbasin, impacts to steelhead from construction would be substantial and immediate, after which the population would recover somewhat during the mid-century period and then decline in late century. Below the FRE facility in the Rainbow Falls to Crim Creek Subbasin, steelhead are modeled to be extirpated by mid-century due to increased temperatures and degraded environmental conditions.

3.2.3.2.2.5 Summary of Impacts from the Proposed Action on Salmonids (Construction Through Operations in Late-Century)

Operation of the proposed FRE facility would have **significant** impacts on salmon and steelhead in both subbasins, starting when construction is completed and continuing through late century. Integrated model results, summarized in Table E-11, indicate that estimated impacts to salmon and steelhead from the initial simulation period prior to construction, through construction, and during operation of the FRE facility through late-century would be significant to populations above and below the proposed FRE facility.

Mitigation is proposed for the Applicant to develop plans for Fish and Aquatic Species and Habitat, Vegetation Management, Riparian Habitat, Wetlands, Large Woody Material Management, and Surface Water Quality to mitigate impacts to spring-run and fall-run Chinook salmon, coho salmon, and steelhead in the two subbasins; however, there is uncertainty if the implementation of the plans would be technically feasible and economically practicable. Therefore, operation of the Proposed Action would have **significant and unavoidable** adverse environmental impacts on spring-run and fall-run Chinook salmon, coho salmon, and steelhead, unless the Applicant develops plans as described above that meet regulatory requirements and for which implementation is feasible. The Fish and Aquatic Species and Habitat Mitigation Plan would require the Applicant to develop plans to provide no net loss for the fish species and habitats impacted by operations.

In the Above Crim Creek Subbasin, impacts by late-century would be greatest for spring-run (97% decline) and fall-run Chinook salmon (83% decline) due to their propensity to spawn in the reservoir area and eggs being suffocated during flood retention events, followed by coho salmon (66% decline) and steelhead (49% decline). In the Rainbow Falls to Crim Creek Subbasin, spring-run Chinook salmon, coho salmon, and steelhead would be extirpated, while fall-run Chinook salmon abundance was estimated to decline by 71%. The added impact of increased temperature in the Rainbow Falls to Crim Creek Subbasin, differences in changes in estimated salmonid abundance among the typical seasonal flow and major and catastrophic flood scenarios modeled based on EDT are small. In this reach, bed scour is low due to the low gradient of the river and flood events being retained by the FRE facility during major and catastrophic floods, and differences among the flow scenarios modeled for all four species are primarily associated with changes in average flow based on the water year selected for modeling each flow scenario (Attachment E-2).

Table E-11
Change in Estimated Abundance of Salmon and Steelhead from Current to Late-Century from Constructing and Operating the FRE Facility

SPECIES	ABOVE CRIM CREEK		CRIM CREEK TO RAINBOW FALLS	
	MID-CENTURY	LATE-CENTURY	MID-CENTURY	LATE-CENTURY
Spring-run Chinook salmon	-95%	-97%	-55%	-100%
Fall-run Chinook salmon	-51%	-83%	-36%	-71%
Coho salmon	-51%	-66%	-31%	-100%
Steelhead	-27%	-49%	-100%	-100%

Recurring Floods: Recurring floods would result in small changes in median estimated abundance for spring-run and fall-run Chinook salmon and coho salmon in the Above Crim Creek Subbasin and fall-run Chinook salmon in the Rainbow Falls to Crim Creek Subbasin under the mid recurring flood scenario relative to median abundance under non-recurring flood conditions. Recurring floods would have no effect on steelhead abundance based on integrated model results.

Abundance: The recent 10-year total run abundance values of salmon and steelhead in the Chehalis Basin are already far below historical values from the early 1900s (Hiss and Knudsen 1993). Specifically, recent abundance vs. historical values range from 23% for spring-run Chinook salmon to 49% for steelhead. This indicates that current basin-wide populations are impaired. Recovery plans for Puget Sound Chinook salmon (NMFS 2006) and steelhead (NMFS 2018) state that population recovery goal targets for natural origin spawners are 70% of historical abundance values.

The salmon and steelhead in the two subbasins of the Chehalis River evaluated in this report represent only a fraction of the entire Chehalis Basin population (approximately 1.2% of spring-run Chinook salmon, 3.4% of fall-run Chinook salmon, 2.7% of coho salmon and 15.&% of steelhead; Ronne 2019). However, the expected declines in salmon and steelhead abundance in the two subbasins are significant in that they bring the total abundance even further below the recovery goal target of 70% of historical abundance.

Integrated model results also show increased variability in estimated salmonid abundance among model run iterations associated with the flow scenarios modeled, primarily for spring-run and fall-run Chinook salmon. Over the mid- and late-century time frames, spring-run Chinook salmon abundance was estimated to be zero and fall-run Chinook salmon abundance ranged as low as 2 fish in the Above Crim Creek Subbasin. This highlights the increased year-to-year variability and subsequent vulnerability of these species to stressors under the Proposed Action. Such variability also impacts access to fishing (economic and cultural consequences) and the ecology of the basin for numerous other species, including Southern Resident killer whales that depend on the presence of Chehalis Basin salmon and steelhead.

Additionally, as described above, studies have shown geographic and genetic differences in coho salmon and steelhead spawning in the upper Chehalis River (South Fork Chehalis River and upstream of Crim Creek) compared to downstream portions of the basin (Seamons et al. 2017; Seamons et al. 2019). These upper basin coho and steelhead likely represent populations (akin to a Demographically Independent Population [DIP] as defined by NOAA; Myers et al. 2015) that are separate from coho salmon and steelhead populations in other parts of the river. Utilizing existing information and NOAA's definition of a DIP, the predicted declines in coho salmon and steelhead in the two modeled subbasins under the Proposed Action would result in dramatic decreases in abundance further below the recovery goal target of 70% of historical abundance of these potential DIPs in the upper basin.

Productivity: Recent 10-year total run size (spawners plus fish harvested) of natural-origin spring-run and fall-run Chinook salmon, coho salmon and steelhead in the Chehalis Basin has declined or remained constant over time (PFMC 2019; WDFW steelhead run reconstruction database). Therefore, productivity for these populations appears to be declining in some cases. Given that abundance levels across species are significantly less than 70% of historical values, productivity values greater than 1 are needed to increase population abundance and reach sustainable levels. Recent and projected declines in ocean survival under climate change further increase impacts to population productivity.

In the EDT model, calculation of equilibrium abundance within the Beverton-Holt formulation requires a productivity of at least 1 (i.e., when the number of spawners equals the number of progeny produced). Life history trajectories with a productivity that is less than 1 are considered non-sustainable and do not enter into the calculation of abundance. Productivity values estimated by the EDT model for the three species and two life-history strategies for Chinook salmon and two subbasins modeled under current conditions are shown in Tables E-12 and E-13. The low abundance of spring-run Chinook salmon reflects low productivity compared to other species. These fish face a number of challenges that reduce survival (productivity) including the need to survive as adults during summer prior to spawning. In a warm system like the Chehalis River, this requires cool water refugia, which can be limiting. The low abundance and productivity of spring-run Chinook salmon, the need for summer holding habitat, as well as other issues related to genetics and introgression from fall-run Chinook salmon make spring-run Chinook salmon the most threatened of the four species modeled.

Productivity of fall-run Chinook salmon is appreciably greater than that of spring-run Chinook salmon (Table E-12) because fall-run Chinook salmon do not experience the impact on survival that occurs for spring-run Chinook salmon during the summer adult holding period. Fall-run Chinook salmon are most abundant and have the highest productivity of the four species in the Rainbow Falls to Crim Creek Subbasin below the site of the proposed FRE facility (Tables E-12 and E-13). The higher survival of fall-run Chinook salmon in this area compared to other species is because they do not have the adult summer holding stage while juveniles emigrate in their first spring and so do not experience the high summer water temperature that characterizes this section of the river.

Productivity of coho salmon in the Rainbow Falls to Crim Creek Subbasin, as estimated by the EDT model, is approximately 1.6 adult returns per spawner. The low productivity of coho salmon in this subbasin means that sustained production of coho salmon may not occur in this area during years of poor ocean survival when productivity could drop below 1.0. In addition, this species is estimated to be extirpated from this subbasin by late-century due to the limited quantity and quality of habitat for coho salmon in the reach (see Section 3.4.3.2.1.3).

For steelhead, based on EDT model results, approximately 6% of the basin-wide steelhead habitat potential was estimated to be above Rainbow Falls, and almost all of the current potential was in the Above Crim Creek Subbasin (only 3% of the potential above Rainbow Falls was in the Rainbow Falls to Crim Creek Subbasin). Steelhead potential in the Rainbow Falls to Crim Creek Subbasin is low compared to the other species as a result of steelhead life history. Winter steelhead spawn in late winter and juveniles emerge in spring and summer. The Rainbow Falls Crim Creek Subbasin has high summer water temperature that reduced the survival of fry produced in this area in the EDT model.

Table E-12
Estimated Spring-Run and Fall-Run Chinook Salmon Productivity (Returns per Spawner) by Subbasin under Current Conditions

FLOW SCENARIO	SPRING-RUN CHINOOK SALMON		FALL-RUN CHINOOK SALMON	
	RAINBOW FALLS TO CRIM CREEK	ABOVE CRIM CREEK	RAINBOW FALLS TO CRIM CREEK	ABOVE CRIM CREEK
Typical seasonal flood	1.78	2.10	4.48	3.81
Major flood	1.59	1.96	3.70	3.54
Catastrophic flood	1.45	1.85	3.10	3.29

Table E-13
Estimated Coho Salmon and Winter Steelhead Productivity (Returns per Spawner) by Subbasin under Current Conditions

FLOW SCENARIO	COHO SALMON		STEELHEAD	
	RAINBOW FALLS TO CRIM CREEK	ABOVE CRIM CREEK	RAINBOW FALLS TO CRIM CREEK	ABOVE CRIM CREEK
Typical seasonal flood	1.62	2.80	2.16	12.03
Major flood	1.60	2.77	1.92	12.04
Catastrophic flood	1.67	2.75	1.93	12.02

Productivity values estimated by the EDT model for the four species and two subbasins modeled under the Proposed Action are shown in Tables E-14 and E-15. The Proposed Action would result in decreases in estimated productivity of all four salmon and steelhead species in the Above Crim Creek Subbasin and fall-run Chinook salmon in the Rainbow Falls to Crim Creek Subbasin, and the extirpation of spring-run Chinook salmon, coho salmon, and steelhead in the Rainbow Falls to Crim Creek Subbasin compared to estimated current productivity. In addition, there is a significant effect of flood retention events (10-year and 100-year) on spring-run Chinook salmon in the Above Crim Creek Subbasin (Table E-14).

Table E-14
Estimated Spring-Run and Fall-Run Chinook Salmon Productivity (Returns per Spawner) by Subbasin under the Proposed Action

FLOW SCENARIO	SPRING-RUN CHINOOK SALMON		FALL-RUN CHINOOK SALMON	
	RAINBOW FALLS TO CRIM CREEK	ABOVE CRIM CREEK	RAINBOW FALLS TO CRIM CREEK	ABOVE CRIM CREEK
Typical seasonal flood	0.07	1.55	2.22	2.82
Major flood	0.08	0.14	2.56	1.73
Catastrophic flood	0.08	0.15	2.56	2.07

Table E-15
Estimated Coho Salmon and Winter Steelhead Productivity (Returns per Spawner) by Subbasin under the Proposed Action

FLOW SCENARIO	COHO SALMON		STEELHEAD	
	RAINBOW FALLS TO CRIM CREEK	ABOVE CRIM CREEK	RAINBOW FALLS TO CRIM CREEK	ABOVE CRIM CREEK
Typical seasonal flood	0.11	2.32	0.02	7.46
Major flood	0.14	2.28	0.02	7.43
Catastrophic flood	0.14	2.28	0.02	7.32

With respect to abundance and productivity, two key salmonid VSP parameters analyzed in this discipline report, it is important to recognize that abundance in EDT is calculated as a function of both stock productivity (returns per spawner at the intercept or zero abundance level of a spawner-recruit curve) and habitat capacity (abundance at the level where the spawner-recruit curve levels off). Habitat capacity is a function of stock productivity, food availability and the quantity (area) of key habitat available to the stock. In the EDT model productivity is independent of capacity because productivity is density-independent survival (at the zero-abundance level of a spawner-recruit curve there is zero abundance and hence no competition among individuals), and habitat capacity is dependent on productivity (along with food and habitat area).

Under the Proposed Action, in the EDT model the FRE facility affects both habitat capacity and stock productivity, and through these it therefore affects population abundance. In this analysis, the effect of the FRE facility on abundance is primarily due to changes in habitat capacity due to the removal of vegetation in the reservoir inundation area and the transformation of riverine habitat (with pools and riffles associated with a specific area [length and width]) in the inundation area into reservoir habitat (a large pool with very different habitat characteristics for salmonids and width compared to riverine habitat). While productivity does change as modeled using EDT with FRE facility construction and operation due to increased water temperature and changes in large wood inputs to the river channel, the biggest change in the EDT model is in habitat capacity. Therefore, when reviewing estimated changes in salmonid abundance and productivity associated with the Proposed Action, it is important to keep in mind that abundance is influenced by changes in productivity and habitat capacity, and much of the estimated change in abundance is from changes in habitat conditions in the FRE reservoir inundation area.

Diversity: The upper basin of the Chehalis is warmer and is geographically and hydrologically distinct from other regions of the Chehalis Basin. The reduction of spring-run and fall-run Chinook salmon, coho salmon, and steelhead from the upper basin due to the Proposed Action represents a significant impact to the genetic, physiological, morphological, and behavioral diversity of these salmon and steelhead in the Chehalis Basin.

As described above, coho salmon and steelhead found at and upstream of the proposed FRE facility are genetically distinct from coho salmon and steelhead in lower river areas. Additionally, Chinook salmon genetic structure within the Chehalis Basin indicates that there is population structure consisting of an upstream group (South Fork and upper Chehalis River, Newaukum River, and Skookumchuck River) and a downstream group (Wynoochee, Wishkah, Satsop, Black, and Chehalis mainstem rivers; Brown et al. 2017). Any decline of Chinook salmon, coho salmon, or steelhead in the upper basin due to the Proposed Action would be a significant loss of genetic diversity from Chehalis Basin populations.

Diversity is also calculated within the EDT model. It is defined as the proportion of sustainable life history trajectories (those with a productivity greater than 1) for a species that are used to calculate equilibrium abundance. In EDT, diversity relates to the breadth of suitable habitat within the spatial unit and variation in modeled life histories within the population being analyzed. As habitat is degraded, the proportion of trajectories with productivity greater than 1 decline, indicating that the calculated abundance relies on an increasingly narrow range of suitable habitat and life histories within the population. Populations with higher EDT diversity values are assumed to have greater resiliency to environmental perturbations compared to those with lower diversity values.

As habitat is projected to degrade in the future due to the Proposed Action, the diversity of salmonids would also decline because all of the life-history trajectories that start within the temporary reservoir area would be eliminated when the FRE outlets are closed during a flood retention event. This means the projected abundance and productivity of salmonids would be supported by a smaller array of life-history strategies.

Diversity values calculated in the EDT model for each species, flow scenario modeled and subbasin are presented in Tables E-16 and E-17. For example, EDT estimates that under the 2-year flow scenario in the Above Crim Creek Subbasin, 2% of the life history trajectories for spring-run Chinook salmon are sustainable and contributing to the productivity of the population and are being used in the model to estimate equilibrium abundance (Table E-16).

Table E-16
Estimated Spring-Run and Fall-Run Chinook Salmon Diversity (Proportion of Sustainable Life History Trajectories in the EDT Model by Subbasin) under the Proposed Action in Late-Century

FLOW SCENARIO	SPRING-RUN CHINOOK SALMON		FALL-RUN CHINOOK SALMON	
	RAINBOW FALLS TO CRIM CREEK	ABOVE CRIM CREEK	RAINBOW FALLS TO CRIM CREEK	ABOVE CRIM CREEK
Typical seasonal flood	0.00	0.02	0.09	0.04
Major flood	0.00	0.00	0.07	0.02
Catastrophic flood	0.00	0.00	0.07	0.02

Table E-17
Estimated Coho Salmon and Winter Steelhead Diversity (Proportion of Sustainable Life History Trajectories in the EDT Model by Subbasin) under the Proposed Action in Late-Century

FLOW SCENARIO	COHO SALMON		STEELHEAD	
	RAINBOW FALLS TO CRIM CREEK	ABOVE CRIM CREEK	RAINBOW FALLS TO CRIM CREEK	ABOVE CRIM CREEK
Typical seasonal flood	0.00	0.08	0.00	0.28
Major flood	0.00	0.09	0.00	0.28
Catastrophic flood	0.00	0.07	0.00	0.28

Spatial structure: The upper Chehalis Basin drains the Willapa Hills and is spatially distinct from the other portions of the Chehalis, which drain the Cascade and Olympic Mountains. Thus, the upper basin represents a unique spatial area of the basin, and losses of spring-run and fall-run Chinook salmon, coho salmon, and steelhead there would represent a significant loss of salmon and steelhead spatial structure across the Chehalis Basin.

As described above, coho salmon and steelhead spawning in the upper Chehalis Basin have been shown to be genetically distinct from coho salmon and steelhead spawning in all other portions of the Chehalis Basin (Seamons et al. 2017; Seamons et al. 2019). Upper basin Chinook salmon have also been shown to be genetically distinct from downstream fish (Brown et al. 2017). The section of the Chehalis River mainstem and anadromous tributaries in the Above Crim Creek Subbasin represents a significant proportion of the salmon and steelhead spawning in the upper basin. In addition, a large fraction of salmon and steelhead spawn in the proposed FRE facility inundation area. Specifically, between 2013 and 2017, 93%, 86%, 39%, and 33% of all spring-run Chinook salmon, fall-run Chinook salmon, coho salmon, and steelhead redds, respectively, surveyed in the Chehalis River above Crim Creek were located in the reservoir inundation area (Ashcroft et al. 2017). Therefore, impacts associated with the inundation area represent significant impacts to the spatial structure of salmon and steelhead, especially in the upper Chehalis Basin. The Proposed Action would decrease the spatial structure of populations in the basin by eliminating spring-run Chinook salmon, coho salmon, and steelhead populations in the Rainbow Falls to Crim Creek Subbasin and significantly impacting all species in the Above Crim Creek Subbasin by late-century.

Climate change: Predictions from climate change models show significant impacts of climate change on salmon and steelhead in the upper Chehalis Basin, including decreases in abundance due to increased temperature and decreased summer flow. The addition of the FRE facility would magnify those negative impacts during the summer months. With the predicted extirpation of spring-run Chinook salmon, coho salmon, and steelhead in the Rainbow Falls to Crim Creek Subbasin under the No Action Alternative, the need to maintain access to cooler water habitat and passage through or over the FRE facility into habitat above Crim Creek is important as a refuge for population persistence. The FRE facility, associated fish passage, and degraded habitat within the temporary inundation area upstream would limit access to cooler water habitats in the upper watershed and degrade habitat conditions upstream of Crim Creek, limiting the benefits of the upper area as a refuge from increased temperatures.

The increased variability in salmon and steelhead abundance estimated by the integrated model also highlights decreased resiliency of the salmon and steelhead to climate change stressors. Specifically, if salmon and steelhead abundance between years is already fluctuating, when additional stressors are added to the population (such as those associated with climate change), the population abundance may not be able to recover.

3.2.3.2.3 *Non-Salmon Native Fish (Impacts from Operations)*

The FRE facility outlet tunnels were designed to perform better than NOAA Fisheries' flow exceedance criteria for year-round, safe, volitional upstream and downstream passage for resident fish and lamprey for discharge and velocity conditions up to 4,000 cfs (CBS 2017a). Between impoundment events, it is assumed fish would readily enter and pass through the 310-foot-long outlet tunnels that would be low gradient and exposed to daylight at the entrances and exits. However, there is less certainty associated with passage estimates for resident fish compared to salmonids because fish passage design criteria were developed for anadromous salmonids.

During flood retention events, downstream passage would be delayed for the duration of the retention period (up to 35 days for a catastrophic event) and upstream passage would be provided by the CHTR facility. The CHTR facility will be designed to pass Pacific lamprey and resident fish through the use of high- and low-flow entrances and separate ladders and holding facilities for the target species and life stages. There is a high degree of uncertainty around the performance of the CHTR facility for non-salmonids, and fish passage survival has not been quantified for most of these species. Fish passage survival for resident trout using the CHTR is estimated to be 54% for upstream migrating adult cutthroat trout and 54% or 45% for upstream migrating juvenile rainbow trout (steelhead) and cutthroat trout, respectively (Section 2.4.2.3, Table E-9).

In summary, the FRE facility would create permanent and constant adverse impacts on native fish within the temporary reservoir inundation area and downstream from the FRE facility to Elk Creek because spawning habitat would be reduced or eliminated for most native species, summer rearing area would be greatly constricted, and non-native predators like largemouth bass may expand their range year-round due to warmer water temperatures. In addition, fish passage survival would be reduced through the FRE facility for mobile and migratory species.

Overall, operation of the Proposed Action would create a **significant** adverse impact on native fish within the temporary reservoir and reaches downstream of the FRE that are affected by the 0.5°C to 3°C increase in water temperature because spawning habitat would be reduced or eliminated for most native species, summer WUA would be greatly constricted, and a large degree of uncertainty surrounds the ability of native fish to take advantage of expanded habitat in winter.

The effects of the operations of the FRE facility were evaluated for a representative suite of species by estimating the change in habitat area with changes in flow, measured as Weighted Usable Area (WUA), that would occur with the FRE facility using the Chehalis PHABSIM model, as described in Section 2.4.2.2. The data reflect changes in WUA, with an additional adjustment to reflect species uses in context of the lower tolerances, upper tolerances, and optimal temperature conditions for each species. The WUA estimates are given for spawning and rearing habitat only. The effects of the FRE facility were evaluated for conditions that would occur with operations at mid-century and late-century. The effects of climate change on increasing water temperature and decreasing summer flows (see Section 2.2.3) were also included in the analysis.

It should be noted that the analysis of WUA for non-salmon fish did not include resident trout species such as rainbow and cutthroat trout. These species share many of the same habitat preferences as the salmon and steelhead modeled using EDT, and it is assumed that, in general, the populations that occurs in the upper Chehalis Basin would respond similarly to the impacts to productivity described for steelhead. Information on resident trout population sizes and distribution limits the ability to quantify their potential responses.

In these scenarios, the effects of the loss of shading in the temporary reservoir area would cause increased water temperatures upstream and downstream of the FRE facility. The change in WUA was calculated for one site upstream of the FRE facility (at RM 110.9) and one reach downstream of the FRE facility from Pe Ell to Elk Creek (Caldwell et al. 2004; Normandeau 2012). The reaches downstream of the confluence with Elk Creek were not evaluated because the temperature change associated with the FRE facility would be too small (less than 0.5°C) to show detectable changes in WUA in most cases.

The predicted change in monthly average flow and average temperature with mid-century and late-century climate conditions is shown in Table E-18. The change in monthly average WUA by mid-century and late-century compared to current conditions is shown in Tables E-19 and E-20, respectively, for the area upstream of Crim Creek and in Tables E-21 and E-22 for the area downstream of the FRE facility to the confluence with Elk Creek.

As was observed for salmon and steelhead, the FRE facility would add to the adverse effect of climate change on water temperatures, leading to habitat contraction for most native species and life stages in spring, summer, and fall. The change in habitat area progresses in a linear manner from mid-century to late-century, with greater impacts in late-century. For most native species, the projected increases in summer temperature combined with reductions in summer flows would reduce habitat area considerably for both spawning and rearing.

During periods of peak water temperatures in July and August, rearing habitat would be reduced by 32% to 55%, depending on the species, by mid-century, and by 68% to 89% by late-century upstream of Crim Creek. Rearing habitat would be reduced by 37% to 58% by mid-century and by 72% to 100% by late-century in the reach from Pe Ell to Elk Creek. Continued warming is likely to result in an upstream shift in available salmonid habitat in the summer, consistent with observations that the existing fish community tends to shift from a salmonid-dominated community in the cooler headwater areas to a cyprinid and non-native centrarchid-dominated community in the warmer middle and lower mainstem Chehalis River during the summer (J. Winkowski et al. 2018; J. Winkowski and Zimmerman 2019).

Table E-18

Projected Average Flows and Temperatures Upstream and Downstream of the FRE Facility Site in the Upper Chehalis River under Future Conditions

REACH	PERIOD	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
FLOW (cfs)													
Above Crim Creek	Mid-Century	492	719	792	501	210	78	36	22	148	255	446	503
	Late-Century	492	731	809	501	198	73	34	21	140	240	446	503
Pe Ell to Elk Creek	Mid-Century	746	1,090	1,200	759	318	118	55	34	224	386	675	762
	Late-Century	746	1,108	1,226	759	301	111	52	32	211	364	675	762
TEMPERATURE (°C)													
Above Crim Creek	Mid-Century	6.8	7.1	9.8	12.0	16.0	19.9	24.1	23.7	19.8	13.4	9.2	7.1
	Late-Century	9.1	8.8	11.4	13.0	17.0	21.7	26.9	26.9	23.1	16.7	11.6	10.2
Pe Ell to Elk Creek	Mid-Century	6.6	6.9	9.6	11.8	16.1	19.8	25.4	25.7	20.7	13.5	8.9	7.2
	Late-Century	9.0	8.8	11.6	13.3	17.7	22.2	28.8	29.3	24.1	16.9	11.1	10.3

Sources: Hill and Karpack 2019 for flow, Van Glubt et al. 2017 for temperature

Table E-19

Change in WUA Upstream of Crim Creek by Mid-Century with the Proposed Action

SPECIES	LIFE STAGE	MAY	JUN	JUL	AUG	SEP	OCT
Largescale Sucker	Rearing	-5%	-11%	-35%	-37%	-15%	-14%
Largescale Sucker	Spawning	-52%	-100%	NA	NA	NA	NA
Mountain Whitefish	Adult Rearing	-14%	-25%	-32%	-35%	-33%	-25%
Mountain Whitefish	Juvenile Rearing	-14%	-23%	-32%	-35%	-33%	-24%
Mountain Whitefish	Spawning	NA	NA	NA	NA	-100%	-56%
Pacific Lamprey	Rearing	-16%	-27%	-42%	-44%	-37%	-24%
Pacific Lamprey	Spawning	2%	-22%	-75%	NA	NA	NA
Speckled Dace	Adult Rearing	-4%	-5%	-51%	-55%	-10%	-4%
Speckled Dace	Juvenile Rearing	-6%	-6%	-51%	-55%	-12%	-6%
Speckled Dace	Spawning	NA	-100%	0%*	0%*	NA	NA

Notes:
The Chehalis PHABSIM model was calibrated for flow measurements that occur in summer only for the area above the confluence with Crim Creek (at RM 110.9). Months in which a given species does not use the habitat for spawning are noted by ‘NA’. Months in which no WUA currently exists for a given species are indicated with an asterisk. Habitat suitability for smallmouth bass and largemouth bass was not evaluated upstream of Crim Creek.
NA: Not applicable

Table E-20

Change in WUA Upstream of Crim Creek by Late-Century with the Proposed Action

SPECIES	LIFE STAGE	MAY	JUN	JUL	AUG	SEP	OCT
Largescale Sucker	Rearing	-11%	-36%	-73%	-75%	-52%	-31%
Largescale Sucker	Spawning	-77%	-100%	NA	NA	NA	NA
Mountain Whitefish	Adult Rearing	-28%	-51%	-69%	-70%	-62%	-53%
Mountain Whitefish	Juvenile Rearing	-27%	-48%	-69%	-70%	-62%	-51%
Mountain Whitefish	Spawning	NA	NA	NA	NA	-100%	-96%
Pacific Lamprey	Rearing	-29%	-54%	-88%	-89%	-69%	-45%
Pacific Lamprey	Spawning	-7%	-63%	-100%	NA	NA	NA
Speckled Dace	Adult Rearing	-8%	-26%	-73%	-76%	-62%	-23%
Speckled Dace	Juvenile Rearing	-11%	-27%	-73%	-76%	-64%	-26%
Speckled Dace	Spawning	NA	-100%	0%*	0%*	NA	NA

Notes:
The Chehalis PHABSIM model was calibrated for flow measurements that occur in summer only for the area above the confluence with Crim Creek (at RM 110.9). Months in which a given species does not use the habitat for spawning are noted by ‘NA’. Months in which no WUA currently exists for a given species are indicated with an asterisk. Habitat suitability for smallmouth bass and largemouth bass was not evaluated upstream of Crim Creek.
NA: Not applicable

Table E-21

Change in WUA from Pe Ell to Elk Creek by Mid-Century with the Proposed Action

SPECIES	STAGE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Largescale Sucker	Rearing	11%	6%	-4%	3%	-11%	-9%	-47%	-58%	-27%	-11%	0%	19%
Largescale Sucker	Spawning	NA	NA	NA	-30%	-46%	-100%	NA	NA	NA	NA	NA	NA
Mountain Whitefish	Adult Rearing	10%	6%	-8%	-10%	-22%	-39%	-43%	-54%	-40%	-19%	0%	7%
Mountain Whitefish	Juvenile Rearing	10%	6%	-12%	-13%	-20%	-34%	-43%	-55%	-36%	-19%	0%	3%
Mountain Whitefish	Spawning	NA	NA	NA	NA	NA	NA	NA	NA	0%*	-58%	0%	2%
Pacific Lamprey	Rearing	42%	20%	8%	-9%	-12%	-23%	-59%	-51%	-28%	-11%	9%	31%
Pacific Lamprey	Spawning	NA	NA	2%	-11%	9%	-35%	-89%	NA	NA	NA	NA	NA
Speckled Dace	Adult Rearing	14%	8%	-2%	-4%	5%	-10%	-38%	-37%	-4%	-5%	1%	10%
Speckled Dace	Juvenile Rearing	14%	8%	-4%	-6%	3%	-11%	-38%	-38%	-4%	-5%	1%	7%
Speckled Dace	Spawning	NA	NA	NA	NA	0%*	-100%	0%*	0%*	NA	NA	NA	NA
Largemouth Bass	Adult Rearing	0%*	0%*	100%*	19%	6%	2%	-16%	-4%	-6%	30%	100%*	0%*
Largemouth Bass	Spawning	NA	NA	NA	NA	195%	-2%	NA	NA	NA	NA	NA	NA
Smallmouth Bass	Adult Rearing	0%*	0%*	0%*	5%	-3%	7%	-26%	-29%	-4%	2%	0%*	0%*
Smallmouth Bass	Spawning	NA	NA	NA	69%	24%	-100%	NA	NA	NA	NA	NA	NA

Notes:
The Chehalis PHABSIM model was calibrated for flow measurements that occur in summer only for the area above the confluence with Crim Creek (at RM 110.9). Months in which a given species does not use the habitat for spawning are noted by ‘NA’. Months in which no WUA currently exists for a given species are indicated with an asterisk. Smallmouth bass and largemouth bass are not currently known to occur upstream of Elk Creek, but could expand their ranges upstream into suitable habitat in the future.
NA: Not applicable

Table E-22
Change in WUA from Pe Ell to Elk Creek by Late-Century with the Proposed Action

SPECIES	STAGE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Largescale Sucker	Rearing	18%	11%	-16%	-9%	-21%	-37%	-90%	-100%	-62%	-33%	-9%	16%
Largescale Sucker	Spawning	NA	NA	NA	-26%	-83%	-100%	NA	NA	NA	NA	NA	NA
Mountain Whitefish	Adult Rearing	17%	7%	-24%	-27%	-38%	-56%	-85%	-90%	-68%	-54%	-14%	-1%
Mountain Whitefish	Juvenile Rearing	17%	1%	-21%	-30%	-37%	-53%	-85%	-90%	-66%	-53%	-14%	-5%
Mountain Whitefish	Spawning	NA	NA	NA	NA	NA	NA	NA	NA	0%*	-97%	0%	2%
Pacific Lamprey	Rearing	87%	50%	11%	-19%	-22%	-50%	-100%	-100%	-70%	-34%	19%	68%
Pacific Lamprey	Spawning	NA	NA	8%	-11%	-10%	-73%	-100%	NA	NA	NA	NA	NA
Speckled Dace	Adult Rearing	24%	13%	-5%	-8%	-6%	-37%	-72%	-77%	-66%	-17%	-1%	14%
Speckled Dace	Juvenile Rearing	24%	11%	-6%	-11%	-8%	-38%	-73%	-78%	-66%	-18%	-1%	11%
Speckled Dace	Spawning	NA	NA	NA	NA	0%*	-100%	0%*	0%*	NA	NA	NA	NA
Largemouth Bass	Adult Rearing	100%*	100%*	100%*	55%	4%	-11%	-53%	-100%	-26%	59%	100%*	100%*
Largemouth Bass	Spawning	NA	NA	NA	NA	293%	-12%	NA	NA	NA	NA	NA	NA
Smallmouth Bass	Adult Rearing	0%*	0%*	100%*	7%	-5%	-5%	-100%	-100%	-25%	-2%	100%*	0%*
Smallmouth Bass	Spawning	NA	NA	NA	219%	24%	-100%	NA	NA	NA	NA	NA	NA

Notes:
The Chehalis PHABSIM model was calibrated for flow measurements that occur in summer only for the area above the confluence with Crim Creek (at RM 110.9). Months in which a given species does not use the habitat for spawning are noted by ‘NA’. Months in which no WUA currently exists for a given species are indicated with an asterisk. Smallmouth bass and largemouth bass are not currently known to occur upstream of Elk Creek, but could expand their ranges upstream into suitable habitat in the future.
NA: Not applicable

The modeling predicts that spawning habitat would be reduced to zero by mid-century in months that already have limited amounts of suitable habitat for largescale sucker (June), mountain whitefish (September), and speckled dace (June). By late-century, spawning habitat would be reduced significantly or completely for spawning activities that typically occur between May and October for all native species. Habitat area for all the representative species examined (cool-water-adapted and warm-water-adapted; spring spawners, summer spawners, and fall spawners) would be reduced in summer due to the reduction in flows.

The amount of rearing habitat available to native species may increase in winter due to slightly warmer water temperatures; however, fish responses to winter water temperatures have not been directly investigated in the Chehalis River.

Non-native largemouth and smallmouth bass, aggressive predators of juvenile salmonids, do not currently occur upstream of Rainbow Falls (RM 97; J. Winkowski et al. 2018). The WUA data show that the range of these invasive species in reaches upstream of Elk Creek is currently limited by cold water temperatures in fall, winter, and spring. These and other warmwater non-native species could see a large expansion of spawning habitat into upstream reaches with the future increase in temperatures. WUA is predicted to increase up to 293% for largemouth bass spawning in May and 219% for smallmouth bass spawning in April. By late-century, warmer water temperatures through the winter will reduce starvation periods for smallmouth bass and may allow largemouth bass to rear upstream of Elk Creek year-round if they are able to expand their distribution to those reaches.

Upstream expansion by bass may be limited by natural height and velocity barriers. Rainbow Falls may be a barrier to upstream movement; smallmouth bass were observed just downstream of Rainbow Falls (near the confluence with the South Fork Chehalis) yet stream temperatures appear suitable above Rainbow Falls. Rainbow Falls is a cascade waterfall measured to be 5 feet tall (WDFW 2019h) which exceeds the maximum jumping height for smallmouth bass, which is approximately 2 feet (Meixler et al. 2009).

Water temperature is a strong predictor of invading bass distributions in Pacific Northwest rivers (Sharma et al. 2009; Lawrence et al. 2012) and bass distributions are predicted to expand with climate change (Vander Zanden et al. 2004; Sharma et al. 2009). The thermal optima for rearing young-of-the-year smallmouth bass, a life stage that was not modeled, is quite high at 29°C (Shuter and Post 1990) compared to optimal temperatures for rearing adults that range from 20°C to 25°C (Wydoski and Whitney 2003). It is hypothesized that elevated water temperatures in summer and fall that contribute to fast growth may allow of the young-of-the-year juveniles to achieve the minimal size to survive the winter starvation period (Shuter et al. 1980; Lawrence et al. 2012). Water temperatures in the Chehalis River will exceed the thermal optima for adult bass and reach the upper lethal limits for smallmouth bass by late-century. Therefore, modeled changes in WUA indicate that habitats for rearing adults will be reduced or eliminated in the hottest months. However, adults that are able to find thermal refuge may find new opportunities to spawn and their offspring may find optimal conditions to expand their distribution.

The estimated change in WUA over time is based on average daily temperatures and does not account for daily extremes, nor can the analysis account for the ability of mobile fish to find temperature refugia in deep pools or areas of groundwater inputs. Increases in daily maximum temperatures may further limit fish distributions in summer unless cool-water refugia exist. Additional changes to habitat will occur that are not captured by the PHABSIM model, including changes to fine-sediment deposition in the inundation area upstream of the FRE facility, and bed scour downstream of the FRE facility that may be adverse or may benefit different species depending on their preferences. The ability for species to inhabit the temporary reservoir area in the long term depends upon their abilities to survive inundation or find refuge during floods, and to recolonize from tributaries or areas downstream, and the efficiency of the FRE fish passage facility.

The utility of the PHABSIM model outputs is limited to estimating change in habitat area based on changes in flow and temperature without consideration of other key habitat elements for species survival. The ways in which species will respond to the changes in habitat available to them are not predicted by the PHABSIM model. For the increase in rearing habitat in winter months to accrue as a benefit to fish, other habitat elements must be available such as adequate food supply and refugia from sporadic high-flow events. There must still be suitable amounts of spawning habitat to sustain a population that can seed the habitat with juveniles, and those juveniles must be able to survive the warmer summers. Some species may adapt to changes in water temperature by shifting spawn timing over time; for instance, mountain whitefish have been observed migrating in response to specific temperature cues in fall and winter that may also shift in time and space (M. Winkowski, Kendall et al. 2019). Thus, changes in WUA do not capture all impacts anticipated for non-salmon fish.

Mitigation is proposed for the Applicant to develop plans for Fish and Aquatic Species and Habitat, Vegetation Management, Riparian Habitat, Wetlands, Large Woody Material Management, and Surface Water Quality to mitigate impacts on native fish; however, there is uncertainty if the implementation of the plans would be technically feasible and economically practicable. Therefore, operation of the Proposed Action would have **significant and unavoidable** adverse environmental impacts to native fish, unless the Applicant develops plans as described above that meet regulatory requirements and for which implementation is feasible. The Fish and Aquatic Species and Habitat Mitigation Plan would require the Applicant to develop plans to provide no net loss for the fish species and habitats impacted by operations.

3.2.3.2.4 Freshwater Shellfish and Aquatic Macroinvertebrates (Impacts from Operations)

Freshwater shellfish and aquatic macroinvertebrates are vulnerable to rapid changes in flow and sedimentation that would occur with the FRE facility because of their immobility and reliance on specific substrate types, flows, and water quality to survive. Flood retention events would cause rapid changes in depth and reduced water velocity, creating a direct adverse impact for mussels and other invertebrates that rely upon flowing water to survive. In addition, sediment deposition events would be followed by erosion within the inundation area of the FRE facility that may temporarily bury and suffocate immobile invertebrates in sediments that settle out of the water column, or become disturbed later when the reservoir is drained and the streambed erodes (detailed analyses of sediment transport can be found in the *Earth Discipline Report*).

Over the long term by late-century, a net accumulation of sediment would occur in the inundation area, with a decrease in storage within 0.5 mile downstream of the FRE facility, with alternative areas of storage and transport downstream to RM 85 (near the confluence with the Newaukum River). Large variations in substrate grain size that are important to aquatic habitat would occur upstream of the FRE facility, with minor changes downstream of the FRE facility. The *Earth Discipline Report* provides additional detail on these topics (Shannon & Wilson and Watershed GeoDynamics 2020).

Changes in substrate storage and substrate size in the inundation area are predicted to be significant, and downstream of the FRE facility during non-flood conditions they are predicted to be moderate (detailed in the *Earth Discipline Report*). Flows and channel characteristics would remain unchanged during non-flood conditions. Changes immediately after major, catastrophic, and recurring flood retention events would create adverse impacts on the substrate and flows, and therefore aquatic invertebrates, both upstream and downstream of the FRE facility. The magnitude of impacts would be greatest following recurring floods within one season.

Within the temporary reservoir, the benthic macroinvertebrate community that provides food for fish would be substantially reduced following flood retention events due to the long duration of inundation, and deposition of fine sediment (Lepori and Hjerdt 2006).The macroinvertebrate community is not likely to recover to pre-flood conditions in the intervening years between flood retention events (Eveleens et al. 2019, Haghkerdar et al. 2019). Any recolonization would likely be by shorter-lived, more tolerant species that are not the same food for salmon.

The increase in water temperature in the inundation area and downstream of the FRE facility could affect the timing of key life-cycle events, in particular the release of glochidia (parasitic larvae of mussels) that occurs within specific temperature ranges in spring (from March through July in other rivers). However, there is uncertainty around the magnitude of this effect, with limited information about whether the mussel species and their fish hosts would be able to adjust to earlier increases in temperature and survive warmer temperatures in mid-summer. An indirect adverse effect on mussels could occur if there are long-term changes in host fish distribution (sculpin, trout, and salmon) that persist after a flood retention event, affecting mussel distribution and gene flow between colonies that occur upstream and downstream of the FRE facility.

For a short distance from the FRE facility downstream to the confluences with tributary streams, benthic organisms may experience dewatering along the margins of the river channel during flood retention events when flows are reduced from winter median levels of approximately 1,000 cfs to a minimum of 300 cfs. In addition, the release of water following flood retention events would increase bed scour downstream of the FRE facility to approximately RM 85, creating an adverse effect for shellfish and macroinvertebrates embedded or attached to substrates that become mobilized.

Downstream of the FRE facility, the magnitude of disturbances caused by catastrophic floods would be moderated and invertebrates may recolonize the river following flood retention events. However, invertebrate distributions, abundance, and species diversity may change based on a given species' preferences in response to the long-term change in sediment profiles and water temperature in the upper Chehalis River. In addition, the loss of peak flow events that tend to create new habitat and maintain channel width may reduce the amount of habitat available to macroinvertebrates over time.

The distribution and species composition of shellfish and macroinvertebrates within the proposed FRE facility inundation area have not been surveyed, so a high level of uncertainty surrounds the magnitude of the impact of disturbance due to flood retention. Freshwater mussels are common where they have been surveyed downstream of the proposed FRE facility site, and it can be conservatively assumed they are equally common upstream of the site. Western ridged mussel distributions are known to be localized in areas of specific habitat conditions which may make them vulnerable to changes in substrate composition and near-bed hydraulics.

Overall, the disturbance to habitat with flood retention events would be infrequent, but longer in duration than with natural flood events, and the magnitude of the impacts would depend upon species' abilities to survive each disturbance event or recolonize the disturbed areas in the temporary reservoir inundation area and downstream of the FRE facility after water is released.

Freshwater mussel beds that become inundated in the temporary reservoir are likely to become smothered by fine sediment that settles out of the water column. Recovery of disturbed freshwater mussel beds is not likely to occur due to loss of suitable habitat, changes in hydraulic conditions, impacts to host fish, and because of their slow growth and recolonization rates. Over the long term, the FRE facility would create a **significant** adverse impact to shellfish due to loss of habitat, changes in hydraulics that may affect long-standing mussel bed conditions, and changes in host fish abundance and distribution.

The existing macroinvertebrate community is not likely to become reestablished in the temporary inundation area. The macroinvertebrates that do recolonize disturbed areas are likely to differ from species composition prior to FRE facility construction, populated by shorter-lived species, especially in areas that experience more frequent inundation or bed scour. Over the long term, the FRE facility would create a **significant to moderate** adverse impact to aquatic macroinvertebrates due to direct loss of habitat, loss of organic matter inputs, and changes in hydraulics.

Mitigation is proposed for the Applicant to develop plans for Fish and Aquatic Species and Habitat, Vegetation Management, Riparian Habitat, Wetlands, Large Woody Material Management, and Surface Water Quality to mitigate impacts to mussels and aquatic macroinvertebrates; however, there is uncertainty if the implementation of the plans would be technically feasible and economically practicable. Therefore, operation of the Proposed Action would have **significant and unavoidable** adverse environmental impacts to mussels and aquatic macroinvertebrates, unless the Applicant develops plans as described above that meet regulatory requirements and for which implementation is feasible. The Fish and Aquatic Species and Habitat Mitigation Plan would require the Applicant to develop plans to provide no net loss for the fish species and habitats impacted by operations.

3.2.3.2.5 Marine Mammals and Birds (Impacts from Operations)

Operation of the FRE facility may indirectly affect marine mammals, birds and other wildlife that prey upon steelhead and salmon that originate from the upper Chehalis Basin. The range of predators and scavengers that rely on salmon is described in the *Wildlife Species and Habitats Discipline Report*. Marine predators that prey on Chehalis Basin salmon, either the outmigrating smolts or the returning adults, may be indirectly affected by a change in salmon population sizes.

The population of Chinook salmon that originates from the upper Chehalis River is one of several subpopulations originating from Chehalis River and Grays Harbor tributaries that contribute to the Grays Harbor population overall. Southern Resident killer whales depend on spring-run Chinook salmon as a food source, and the overall number of these fish has been decreasing throughout the region. Several Chinook salmon populations (outside of the Chehalis Basin) that are preyed upon by Southern Resident killer whales are designated as threatened or endangered (70 Federal Register 37160, 79 Federal Register 20802).

Southern Resident killer whales spend significant amounts of time foraging along Washington’s coast at the mouth of the Columbia River and near Grays Harbor in the winter and spring (Hanson 2017). Body condition (Durban et al. 2017; Fearnbach et al. 2018) and diet (Hanson et al. 2010; Ford et al. 2016; Hanson 2017) information suggests that the killer whales are experiencing reduced body condition and that they are forced to diversify their diet at this time to eat other fish species in an attempt to meet their caloric needs in late winter and spring.

The degree to which a decline in the specific subpopulations of salmon originating from the upper Chehalis River would affect the Southern Resident killer whales is unknown, and the magnitude of these impacts related to operation of the FRE facility on killer whales is highly uncertain. The number of fish that would likely be impacted by the Proposed Action represents a small proportion of the overall diet of the Southern Resident killer whales. However, the loss of salmon and steelhead, in particular spring-run Chinook salmon, from the Chehalis River would present a **moderate** adverse impact to Southern Resident killer whales. The loss of salmon and steelhead resulting from the Proposed Action would have **minor** adverse impact on other marine mammals because they prey upon a diversity of fish species.

The species-specific dependence of piscivorous birds on salmon and steelhead in Grays Harbor is unknown. Piscivorous birds that occur in Grays Harbor include loons, terns, gulls, cormorants, shearwaters, pelicans, osprey, grebes, puffin, marbled murrelets, great blue heron, mergansers, and yellowlegs. Individual avian species' use of fish is dependent on behavioral specialization and adaptation and abundance and availability of suitable fish resources, which in turn will be influenced by predator pressure, including the effects of predation by other bird species, fish species and marine mammals. With decreased salmon and steelhead, changes to the food web for these species could occur; while some birds can likely adjust to prey on other fishes, more specialized species would be more highly affected. Operation of the Proposed Action would have **moderate to minor** impacts on birds due to uncertainty about the degree to which these birds rely on salmon and steelhead as prey.

3.2.4 Required Permits

Potential permits related to aquatic habitats and species associated with the construction and operation of the Proposed Action include the following:

- **Aquatic Lands Lease and Use Authorization (Washington Department of Natural Resources [DNR]):** Construction of the FRE facility may require a lease from DNR and use authorization for construction and operation.
- **County and Local Shoreline Management Act and Critical Areas Review (Lewis County, Thurston County, Pacific County, Grays Harbor County, City of Centralia, City of Chehalis):** Construction and operation of the Proposed Action would require local shoreline and clearing and grading permits.
- **ESA Consultation (USFWS):** The Proposed Action could affect listed species or designated critical habitats. USFWS would evaluate the effects on listed and proposed species and critical habitats.
- **Fish Transport Permit (WDFW):** A permit is required to transfer live fish within the State of Washington.
- **Forest Practices Permit (DNR):** Timber harvest within the proposed reservoir pool would be subject to Washington Forest Practices regulations and permits.
- **Hydraulic Project Approval (WDFW):** The Proposed Action would use, divert, obstruct, and change the natural flow and bed of freshwaters of the state and therefore would require a Hydraulic Project Approval from WDFW under the state's hydraulic code rules. The Hydraulic

Project Approval would include conditions intended to minimize impacts on instream and riparian habitat and functions from construction of the Proposed Action.

- **NPDES Industrial Stormwater Permit (Ecology):** The Proposed Action would result in releases of water that require an industrial stormwater permit. All wastewater and stormwater generated from the Proposed Action and potentially discharged would be evaluated and characterized by the state. Once the water to be discharged has been accurately evaluated and characterized by the state, the specific standards for water discharged from the project area would be defined and the type of NPDES permit would be determined and issued.
- **Section 401 Clean Water Act Water Quality Certification (Ecology):** Because a federal (Corps Section 404) permit would be needed to construct the Proposed Action, a Section 401 Water Quality Certification from Ecology would be needed to document the state's review of the project and its concurrence that the Applicant has demonstrated that the Proposed Action will meet state water quality standards. This certification is intended to provide reasonable assurance that the Applicant's project will comply with state water quality standards and other requirements for protecting aquatic resources, and covers both construction and operation of the facility.
- **Section 402 Clean Water Act National Pollutant Discharge Elimination System (NPDES) Construction Stormwater Permit (Ecology):** The construction of the Proposed Action would require a construction stormwater permit. As part of the NPDES permit process, stormwater and wastewater generated on the site would be evaluated and characterized, after which the specific language and type of NPDES would be determined.
- **Section 404 Clean Water Act Permit (Corps):** Section 404 requires discharges of dredged/fill material to waters of the U.S. be done only under the authorization of a permit. Because construction of the FRE facility would involve excavation and fill placement in the Chehalis River, and construction of the Airport Levee Changes may involve fill placement in wetlands, the Proposed Action would require a Section 404 permit from the Corps. As part of this approval, Endangered Species Act consultation would also be required.
- **Scientific Collection Permit (WDFW):** Handling or collection of fish species may require a scientific collection permit.

3.2.5 Proposed Mitigation Measures

This section describes mitigation measures proposed for the Applicant to implement that would reduce impacts to fish and aquatic species and habitats from construction and operation of the Proposed Action. These mitigation measures would be implemented in addition to compliance with environmental permits, plans, and authorizations described in Section 3.2.4 that would be required for the Proposed Action.

- **FISH-1 (Fish and Aquatic Species and Habitat Plan)**: To mitigate the impacts to fish and aquatic species and habitats associated with construction and operation of the Proposed Action, mitigation is proposed for the Applicant to develop and implement a Fish and Aquatic Species and Habitat Plan. The plan must be developed in coordination with and approved by WDFW, tribes, and other applicable local, state, and federal agencies. The plan must include a range of options that provide no net loss of ecological function for the fish species and habitats impacted by construction and operational activities. Mitigation will be considered from the headwaters of the Chehalis River to the confluence of the Chehalis and Newaukum rivers. The mitigation will include, but is not limited to, the following:

- Mitigation for temporal loss of functions and values until the restored or created habitat addressing impacts is fully functional.
- Advance in-kind mitigation implemented prior to construction, such as replacement (restoration or creation), for the fish and aquatic habitat impacted by the Proposed Action.
- Protection of areas adjacent to the temporary reservoir area supporting connectivity between the restored or created habitat to replace the lost functions and values for impacted species.
- A Monitoring Plan identifying long-term actions to verify the implemented mitigation provides adequate compensation for impacts to functions and values provided by fish species and their habitats. Monitoring will be conducted over the life of the Proposed Action.
- An Adaptive Management Plan describing measures that will be taken should the mitigation not achieve performance standards set forth in the Monitoring Plan.
- A Maintenance Plan describing work that will be conducted over the life of the Proposed Action to maintain the functions and values provided by replacement habitat.
- Permanent protection measures via land acquisition or through a conservation easement in perpetuity that fully encumbers the restored fish and riparian habitat.
- This plan will be developed in conjunction with management and mitigation plans for vegetation, wetlands and wetland buffers, stream and stream buffers, wildlife species and habitat, riparian habitat, surface water quality, and large woody material.

Other Related Mitigation Plans:

- **EARTH-3 (Large Woody Material Management Plan)**: To mitigate the impacts of construction and operation of the Proposed Action on large woody material and habitat, mitigation is proposed for the Applicant to develop and implement a Large Woody Material Management Plan (for details, see *Earth Discipline Report*).
- **WATER-1 (Surface Water Quality Mitigation Plan):** To reduce impacts to surface water quality and designated aquatic life[1] uses of the Chehalis River and Crim Creek from construction and operation of the Proposed Action, mitigation is proposed for the Applicant to develop and implement a Surface Water Quality Mitigation Plan (for details, see *Water Discipline Report*).

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[1] Designate aquatic life uses for this reach of the Chehalis River are Core Summer Salmonid Habitat including year-round protection for salmon spawning, rearing, and migration, Chapter 173-201A-602 WAC.

- **WET-1 (Wetland and Wetland Buffer Mitigation Plan)**: To mitigate the impacts to wetlands and wetland buffers from construction and operation of the Proposed Action, mitigation is proposed for the Applicant to develop and implement a Wetland and Wetland Buffer Mitigation Plan (for details, see *Wetlands Discipline Report*).
- **WET-2 (Stream and Stream Buffer Mitigation Plan)**: To mitigate the impacts to streams and stream buffers from construction and operation of the Proposed Action, mitigation is proposed for the Applicant to develop and implement a Stream and Stream Buffer Mitigation Plan (for details, see *Wetlands Discipline Report*).
- **WILDLIFE-1 (Vegetation Management Plan)**: To mitigate the impacts to habitat from construction and operation of the FRE and temporary reservoir, mitigation is proposed for the Applicant to develop and implement a Vegetation Management Plan (for details, see *Wildlife Species and Habitats Discipline Report*).
- **WILDLIFE-2 (Wildlife Species and Habitat Management Plan):** To mitigate the impacts to wildlife species and habitat from construction and operation of the Proposed Action, the Applicant will prepare a Wildlife Species and Habitat Management Plan (for details, see *Wildlife Species and Habitats Discipline Report*).
- **WILDLIFE-3 (Riparian Habitat Mitigation Plan)**: To mitigate the impacts to riparian habitat from construction and operation of the Proposed Action, mitigation is proposed for the Applicant to develop and implement a Riparian Habitat Mitigation Plan (for details, see *Wildlife Species and Habitats Discipline Report*).

3.2.6 Significant and Unavoidable Adverse Environmental Impacts

There is uncertainty if mitigation is technically feasible or economically practicable; therefore, construction and operation of the Proposed Action would have **significant and unavoidable** adverse environmental impacts on fish and aquatic species and habitats, as follows:

- Aquatic habitat on the upper mainstem Chehalis River from permanent loss of 0.32 acre of riverbed habitat, loss of vegetative shade, degraded riparian function, reduced nutrient availability, and reduced water quality.
- Aquatic habitat on the middle and lower Chehalis River to the confluence with the South Fork from water quality impacts and reduction of channel-forming flows and large woody material.
- Spring-run Chinook salmon in the Above Crim Creek Subbasin and Crim Creek to Rainbow Falls Subbasin from degraded habitat and reduced fish passage.
- Fall-run Chinook salmon in the Above Crim Creek Subbasin and Crim Creek to Rainbow Falls Subbasin from degraded habitat and reduced fish passage.
- Coho salmon in the Above Crim Creek Subbasin and Crim Creek to Rainbow Falls Subbasin from degraded habitat and reduced fish passage.
- Steelhead in the Above Crim Creek Subbasin and Crim Creek to Rainbow Falls Subbasin from degraded habitat and reduced fish passage.

- Migratory non-salmon fish (Pacific lamprey, largescale sucker, and mountain whitefish) in the upper and middle Chehalis River from degraded habitat and reduced fish passage.
- Mussels at the FRE facility site and above and below the site from decreased recruitment and degraded or loss of habitat.
- Aquatic macroinvertebrates at the FRE facility site from degraded or loss of habitat.

The Applicant may provide mitigation plans as described above. If agencies determine the plans meet WDFW guidelines and regulatory requirements and the implementation is feasible, then the impacts would be addressed as part of the permitting processes.

3.3 Local Actions Alternative

Local action elements include land use management, floodproofing, buy-out of at-risk properties or structures, floodplain storage improvement (riparian restoration, afforestation, floodplain reconnection, water flow abatement), channel migration protection, and early flood warning systems. The EIS Appendix 1, *Proposed Project Description and Alternatives* (Anchor QEA 2020d), provides additional detail about these elements.

3.3.1 Impacts from Construction

Of the six local action measures identified under this alternative, two elements could result in the need for construction activities adjacent to or within the river channel and, therefore, could result in impacts on fish, shellfish, macroinvertebrates or aquatic habitat. Floodplain storage improvements and channel migration protection would be expected to result in sporadic, localized construction activity affecting aquatic habitat, with individual projects occurring over a long time.

Adverse direct impacts on fish, shellfish, macroinvertebrates, and aquatic habitat could result from activities that would occur below the OHWM such as floodplain storage improvements and channel migration protection, and potentially from actions above the OHWM associated with riparian restoration on bank and levee setbacks. There is also potential for these construction activities to change the characteristics and morphology of a waterbody or its OHWM and disconnect floodplain and off-channel habitat.

Freshwater fish, shellfish, and aquatic habitat within the river reach of the construction activity may be directly affected during any in-water work. Construction activities that involve water diversions, cut and fill, or vegetation disturbance have the potential to increase turbidity and sedimentation in the stream channels, disrupting fish behavior or causing injury to fish or fish eggs. Diversion of the river around construction sites for channel migration protection activities that require in-channel construction may also cause fish injury, stranding, passage obstruction, or impairments to foraging. Accidental releases of pollutants from construction equipment may cause temporary reductions in water quality. Elevated sound and vibration associated with construction activities may disturb fish behavior, or may cause injury to fish in the case of sharp-rise and high-energy activities such as pile driving (the effects of sound on fish are described in greater detail for the Proposed Action in Section 3.2.2.2).

Work below the OHWM would need to comply with federal, state, and local requirements to avoid, minimize, and mitigate for impacts on water quality, endangered species, and critical areas. Disturbed areas would be required to be restored to pre-construction status and/or ecological function following construction.

Overall, due to the limited scale and duration of construction of local actions, their likely location around developed areas, and that many activities would occur outside aquatic habitat, such impacts would likely be **minor** in the study area over the long term.

Construction associated with riparian restoration, stream constriction removal, and channel migration protection may have indirect impacts to areas downstream of project sites but would be required to meet water quality standards and have required state, local, and federal permits for water quality and work affecting in-water work. Indirect impacts of local actions construction are not anticipated to be significant.

3.3.2 Impacts from Operation

This section analyzes the potential impacts from operation and implementation of local actions. Of the six local action measures identified under this alternative, floodplain storage improvement activities and channel migration protection may have direct effects on fish, shellfish, and aquatic habitat if they occur in the river channel or adjacent floodplain areas.

Generally, the floodplain storage improvement element could increase habitat complexity and adjacent floodplain habitat availability, benefitting fish species and habitats. Increased floodplain inundation is likely to benefit fish if the floodplain areas are connected to the mainstem and increase usable rearing habitat during wet seasons. Restoration of riparian areas may improve habitat function by providing key habitat elements such as shading and nutrient regulation.

Channel migration protection activities, like the placement of large woody material, would immediately increase habitat complexity for fish species, but may have the potential to disrupt some benefits from natural channel migration processes and could result in loss of habitat complexity over the long term. Overall, channel migration protection projects that are designed to reverse incision processes that have resulted from historic land uses will benefit aquatic habitat on the larger scale.

The operation of local actions is likely to have **minor** impacts on fish, shellfish, and aquatic habitat.

Operation of land use management, floodproofing, and buy-out of at-risk properties and structures may indirectly affect fish, shellfish, and aquatic habitat by changing the interactions between developed properties and adjacent river and floodplain areas over the long term.

Local actions projects could have indirect impacts where flood levels may be decreased downstream of the installation. This has the potential to change hydrological regimes in floodplain habitat that could be beneficial or adverse.

Protection measures for structures in the floodplain, as part of the floodproofing element, would allow for continuation of activities in the floodplain that are harmful to fish and fish habitat, such as preventing restoration of riparian area vegetation or preventing the creation of off-channel habitat. Conversely, reducing human impacts in at-risk properties or structures would not have adverse impacts on habitat by allowing floodplain reconnection or restoration activities.

Indirect impacts may occur if unintended adverse consequences of restoration actions, constriction removal, and channel migration protection projects persist in the long term, such as a change in bank erosion rates or channel migration downstream of the project area. Channel migration protection measures could adversely affect fish habitat by permanently altering river hydraulics, velocities, and causing bank erosion in other areas. As noted previously, the cumulative effects from multiple channel migration protection measures could be more significant than those caused by single projects.

The indirect effects of operation of local actions are likely to be **minor** for fish, shellfish, and aquatic habitat.

3.4 No Action Alternative

The No Action Alternative activities that could affect fish, shellfish, and aquatic habitat are floodproofing efforts led by the Chehalis Basin Flood Authority, potential WSDOT programs including floodwalls and barriers to protect major roadways, and ongoing land uses including development and timber harvest. Stream and floodplain restoration efforts that will occur include the Chehalis Basin Strategy-led ASRP and USFWS Chehalis Fisheries Restoration Program, both of which may result in broad restoration efforts spread across the entire Chehalis Basin. ASRP early action habitat restoration measures were incorporated into EDT as part of the integrated modeling approach and include physical changes in habitat from restoration actions funded in the 2017 to 2019 biennium and are listed in the following paragraph).

The No Action Alternative scenario modeled using EDT to estimate impacts on salmon and steelhead includes the following assumptions about ongoing changes to environmental conditions, including climate change (see Section 2.2.3), in the Chehalis Basin:

- Changes in hydrology (Hill and Karpack 2019) and temperature (Van Glubt et al. 2017) due to climate change, projected based on conditions in mid-century and late-century
- Land use degradation due to population growth, projected for mid-century and late-century
- Removal of 24 culvert passage impediments by WSDOT called for in tribal injunction (12 were assumed to be replaced by mid-century and another 12 by late-century) and 12 culverts identified by the Chehalis Lead Entity as being removed during the 2017 to 2019 biennium
- ASRP early action habitat restoration actions funded in the 2017 to 2019 biennium at the following locations:
  - East Fork Satsop River, RM 8 to RM 10.5
  - Wynoochee River, RM 13.5 to RM 15
  - Skookumchuck River, RM 18.6 to RM 21.6
  - South Fork Newaukum River, RM 10.9 to RM 13
  - Stillman Creek, RM 0 to RM 2.5
- Continued tree growth in managed forests due to protections under the Forest Practices Act of 1974 (RCW 76.09), and its implementing provisions under the Forest Practices Rules (WAC 222) resulting in increased shade and cooler water

Population capacity and productivity estimates from EDT based on these assumptions were input into the LCM to assess any effects of the No Action Alternative on salmonid abundance over time.

3.4.1 Modeling Results for Impacts of the No Action Alternative on Salmonids

Modeling results for the No Action Alternative are described in the following sections. Similar to what was discussed under the Proposed Action in Section 3.2.1, integrated model results are presented as the median value followed by the range in estimated abundance (minimum-maximum) for each species once the population stabilized within each time period analyzed (mid-century and late-century). Next, the relative change in estimated abundance is presented. The relative change values are the most important because these provide information about the direction and magnitude of any changes in abundance. Results of the EDT and integrated EDT-LCM modeling for the No Action Alternative are presented in Figures E-25 to E-36.

Format for EDT Modeling Results Figures

The EDT model results for each species are presented in Figures E-25, E-28, E-31, and E-34. Each EDT-only figure presents results for a single species and both subbasins. For example, Figure E-25 presents the estimated abundance of spring-run Chinook salmon in the Above Crim Creek and Rainbow Falls to Crim Creek Subbasins.

The percent change in estimated fish abundance is shown as vertical bars relative to the left y-axis scale, and the numeric change in abundance is shown as dots with the actual value of the change presented above each dot based on the right y-axis scale. Two time periods are displayed (mid-century and late-century), along with changes in abundance associated with typical seasonal flows, major floods and catastrophic floods. Note that the right-hand y-axis scales vary among species in the EDT-only figures.

Format for Integrated Modeling Results Figures

Results of the integrated modeling approach used to estimate effects of the No Action Alternative on salmon and steelhead are presented in Figures E-26 through E-36. Each figure based on the integrated model approach presents results for a single species and subbasin starting with Figure E-26. For example, Figure E-26 presents the estimated abundance of spring-run Chinook salmon in the Above Crim Creek Subbasin. Fish abundance is represented in the y-axis and the simulation time frame is shown in the x-axis.

In the Chinook and coho salmon figures, each figure consists of four panels. The upper left panel displays the trend in estimated abundance with typical seasonal flow, major floods, and catastrophic floods incorporated into the integrated model, but without recurring flood events. The upper right, lower left, and lower right panels present the trends in estimated abundance when major floods occur 3 years in a row, a worst-case scenario. Recurring floods were modeled as early (2033 to 2035), mid (2050 to 2052), and late (2080 to 2082) in the simulation periods

In the steelhead figures, the left panels display the trend in estimated abundance with typical seasonal flow, major floods, and catastrophic floods incorporated into the integrated model, but without recurring flood events. The right panels present the trends in estimated abundance when major floods occurred 3 years in a row in the middle of the simulation period (2050 to 2052). The effects of recurring floods occurring early and late in the simulation period on steelhead were not modeled because there was no effect of recurring floods in the middle of the simulation period and simulating early and late recurring floods would have the same result.

Each recurring flood scenario was modeled with a companion non-recurring simulation. Differences in median estimated abundance between recurring and non-recurring scenarios were only observed during mid recurring floods and were small (ranged from 3 to 8 fish). To present the worst-case scenario where differences in median abundance were observed and reduce the number of figures, the upper left panel in each figure is the non-recurring simulation run for the mid recurring flood scenario.

Each panel is divided into three key time periods: initialization of the model (2001 to 2033; white), mid-century (2031 to 2063; light green; represented by 2040 conditions), and late-century (2064 to 2100; dark green; represented by 2080 conditions). In each panel the solid black line represents the median values of all model iterations, and the light gray lines represent the range in individual iterations through the time series that resulted from variability in estimated abundance associated with the typical seasonal flow, major flood, and catastrophic flood scenarios that were modeled stochastically.

Estimated median abundance is reduced sharply when transitioning between time periods due to the changing environmental baseline (increased water temperature). These transition periods are blocked out because these reductions are an artifact of the modeling approach and are not meaningful.

Dashed vertical lines depict the recurring flood scenarios. Initial population abundance in the integrated model reflects the estimated starting population abundance based on EDT model results.

Figure E-25
Change in Spring Chinook Salmon Abundance Under No Action Alternative

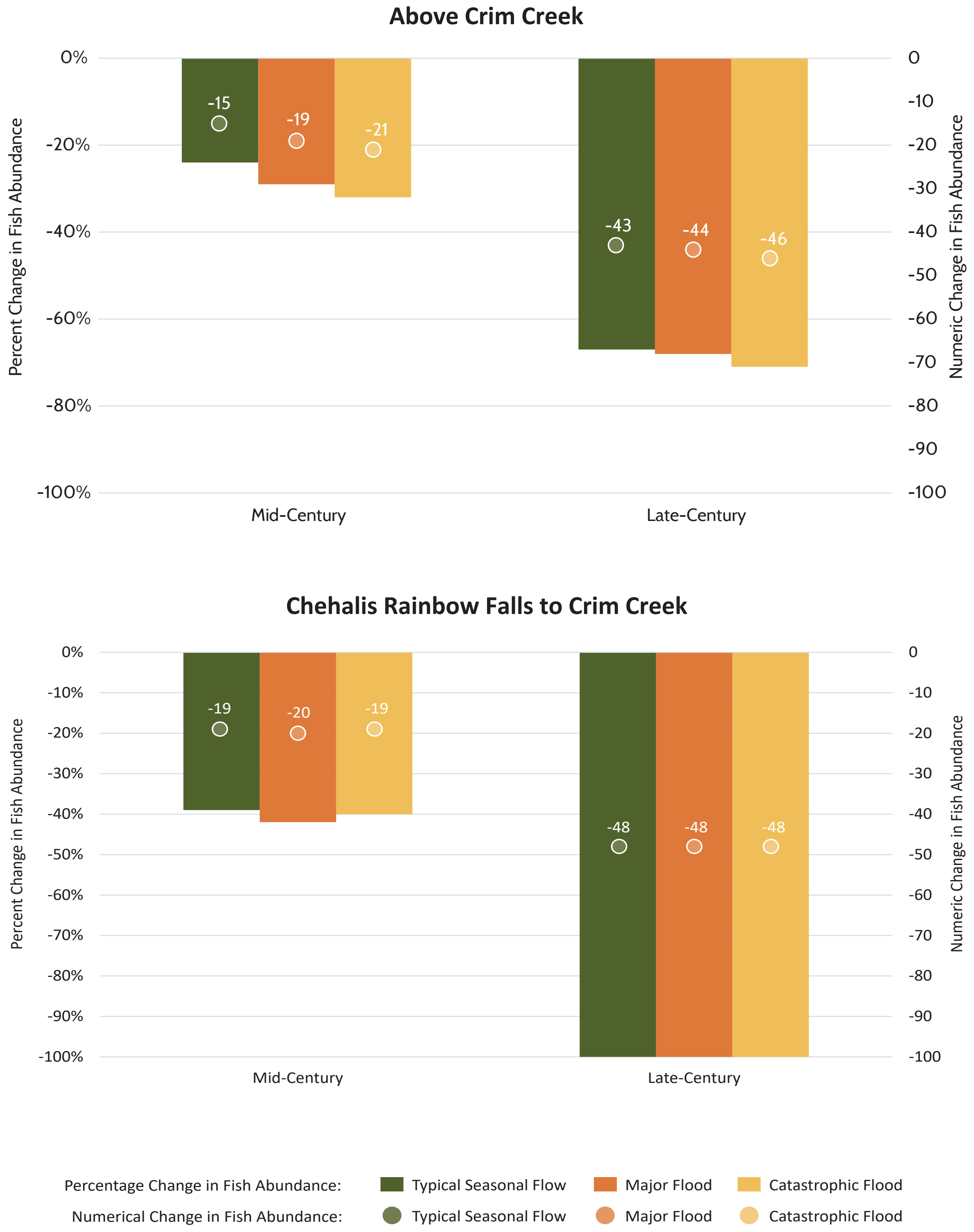
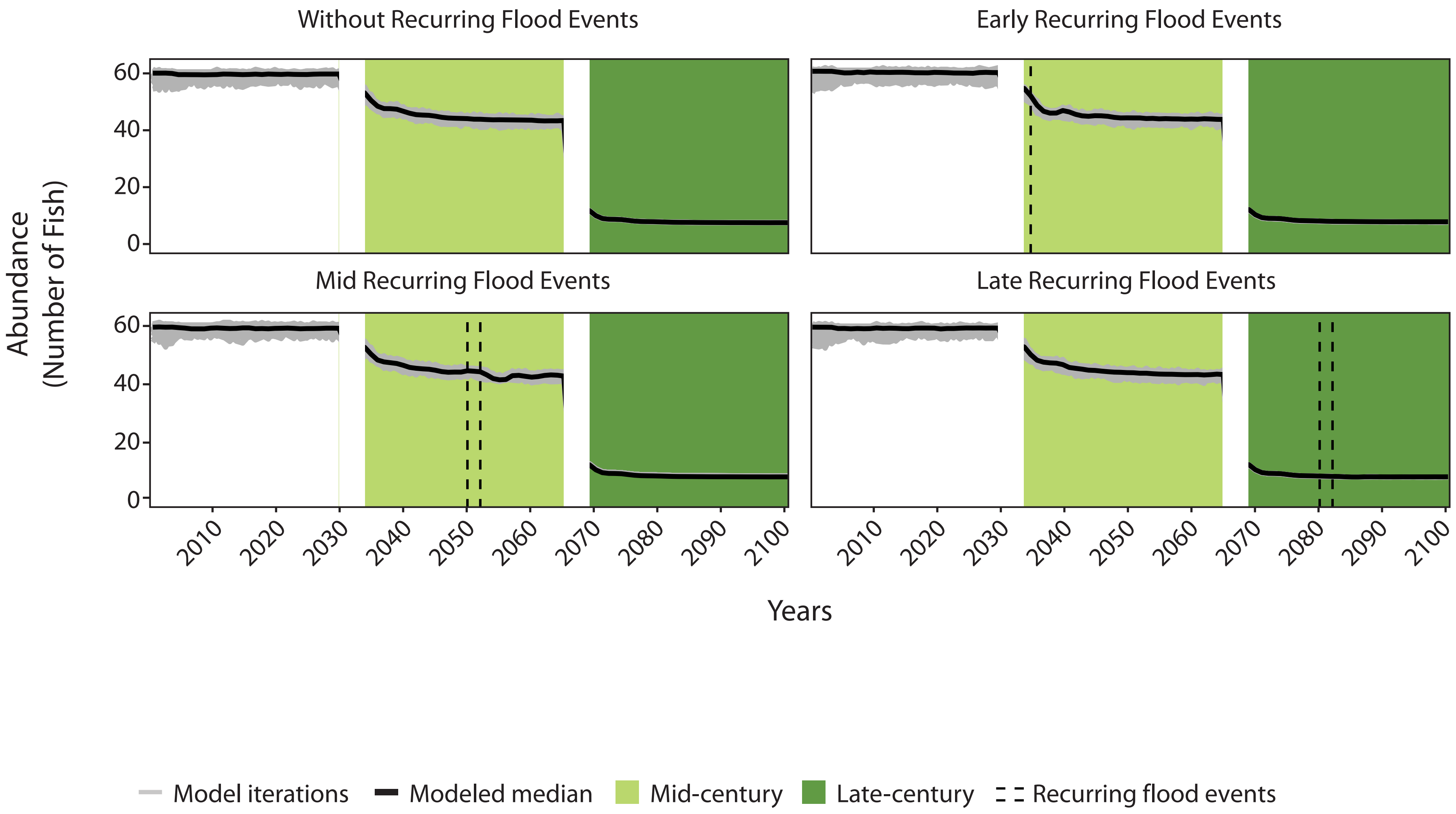
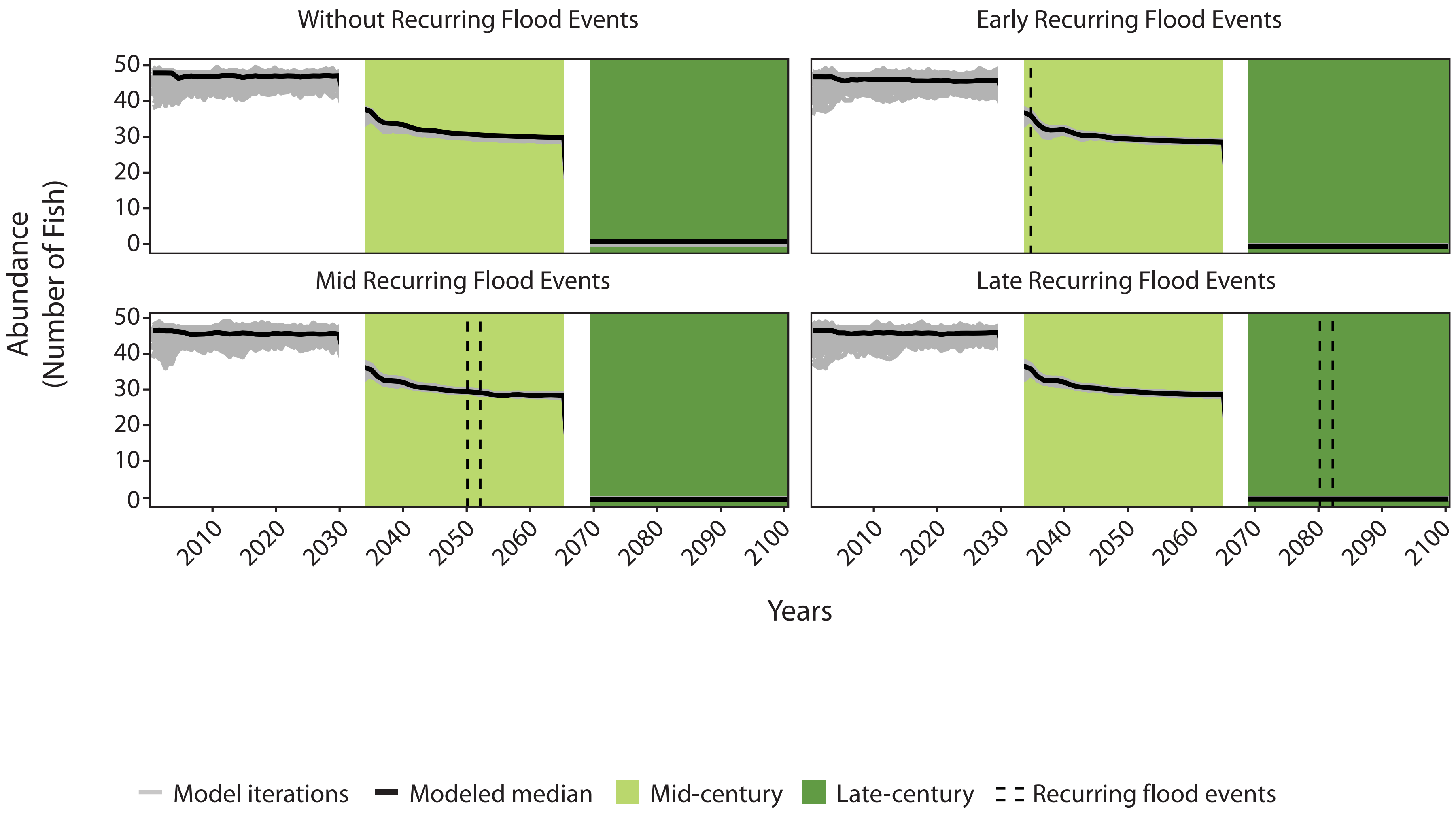


Figure E-26
LCM Results for Spring Chinook Salmon Above Crim Creek Subbasin Under No Action Alternative



Source: NOAA 2019

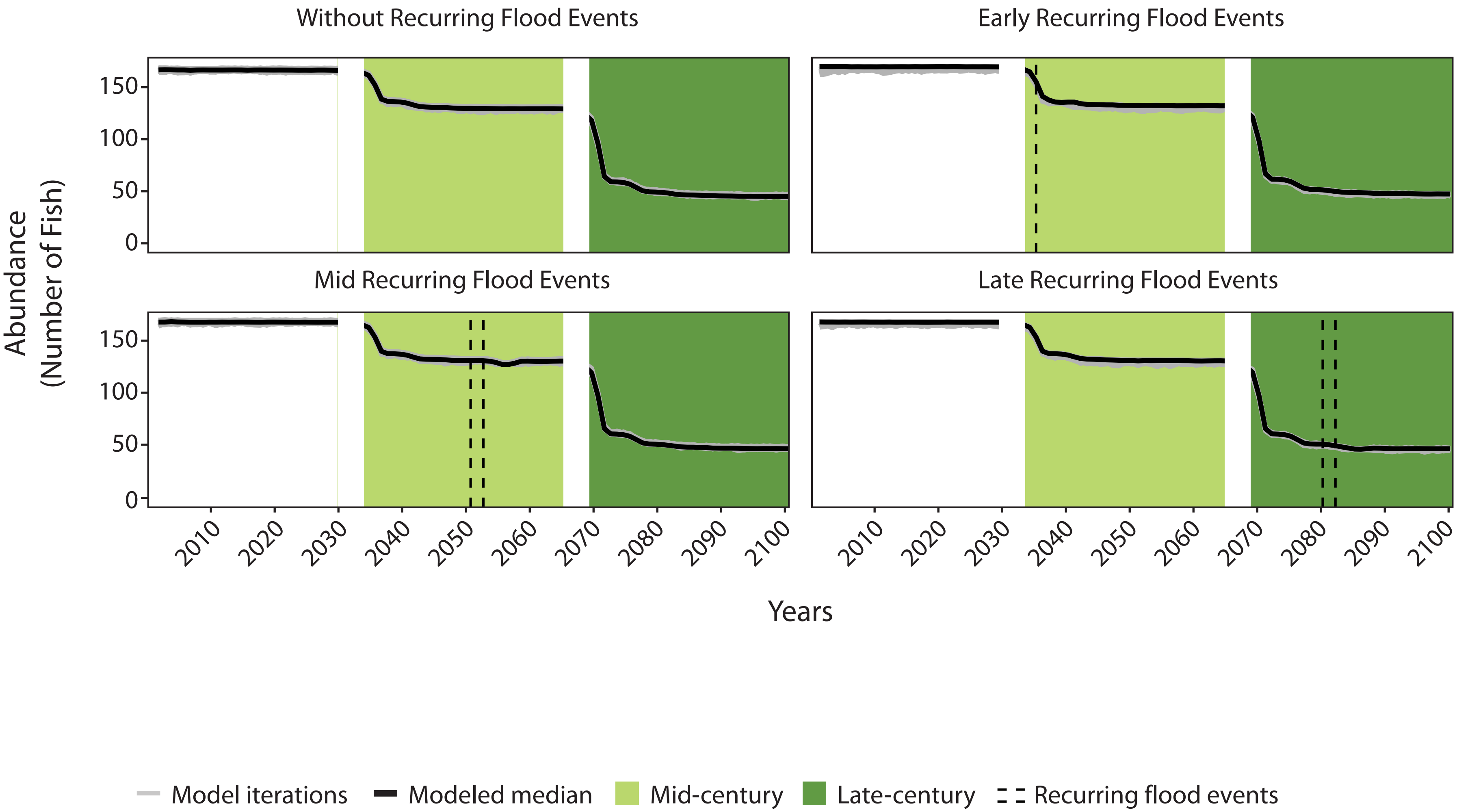
Figure E-27
LCM Results for Spring Chinook Salmon Rainbow Falls to Crim Creek Subbasin Under No Action Alternative



Source: NOAA 2019

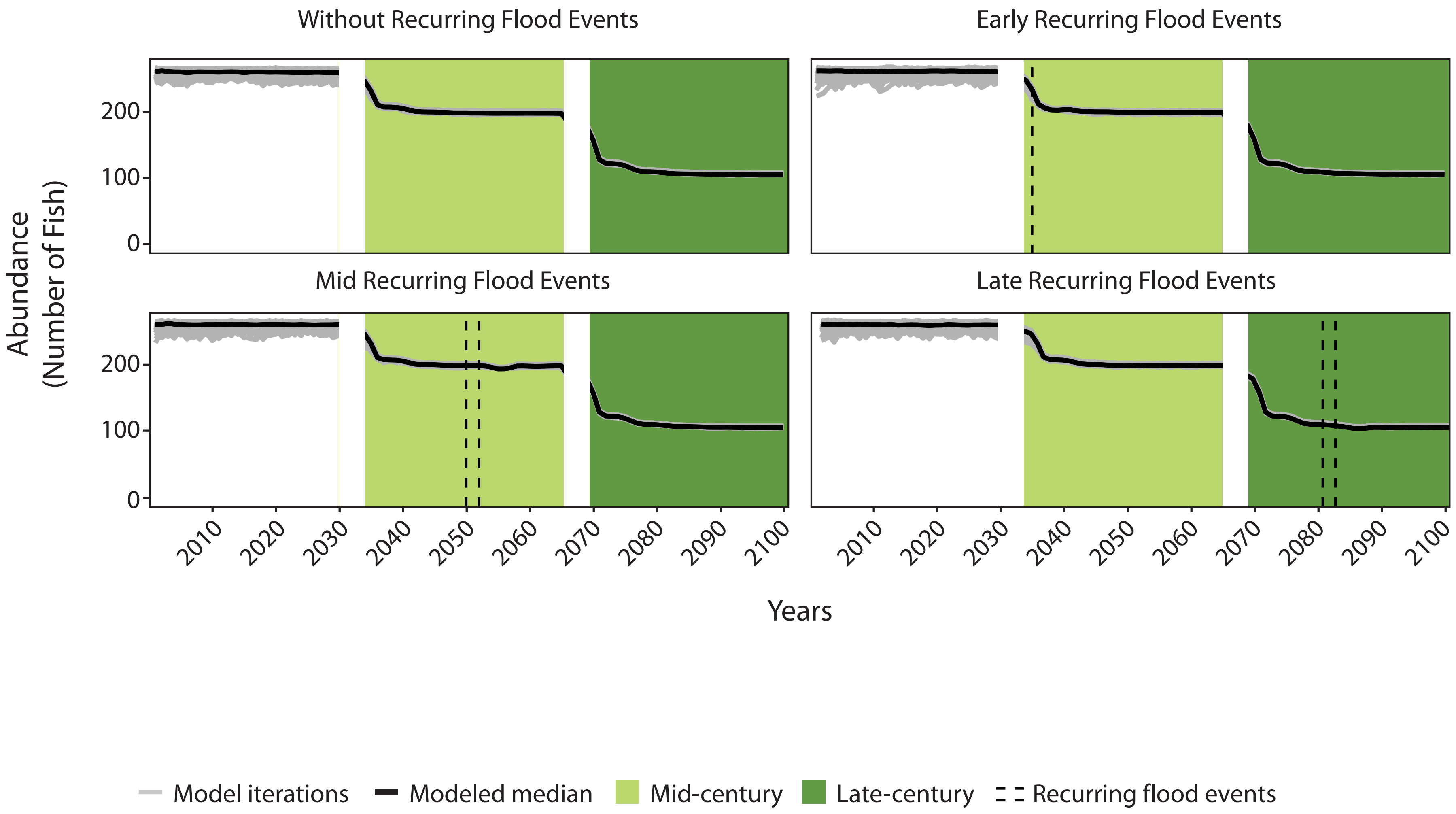
Figure E-28
Change in Fall Chinook Salmon Abundance Under No Action Alternative

Figure E-29
LCM Results for Fall Chinook Salmon Above Crim Creek Subbasin Under No Action Alternative



Source: NOAA 2019

Figure E-30
LCM Results for Fall Chinook Salmon Rainbow Falls to Crim Creek Subbasin Under No Action Alternative



Source: NOAA 2019

Figure E-31
Change in Coho Salmon Abundance Under No Action Alternative

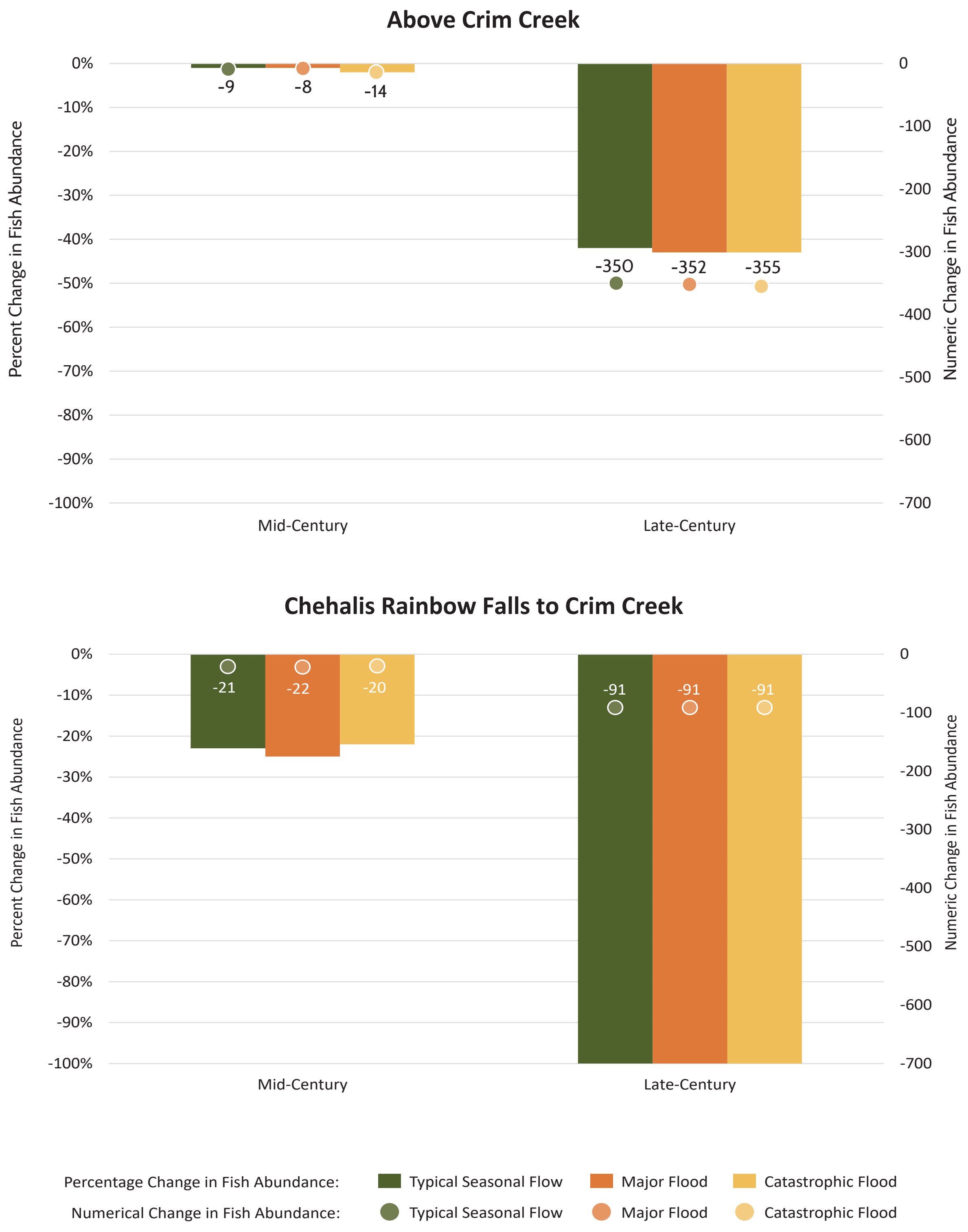
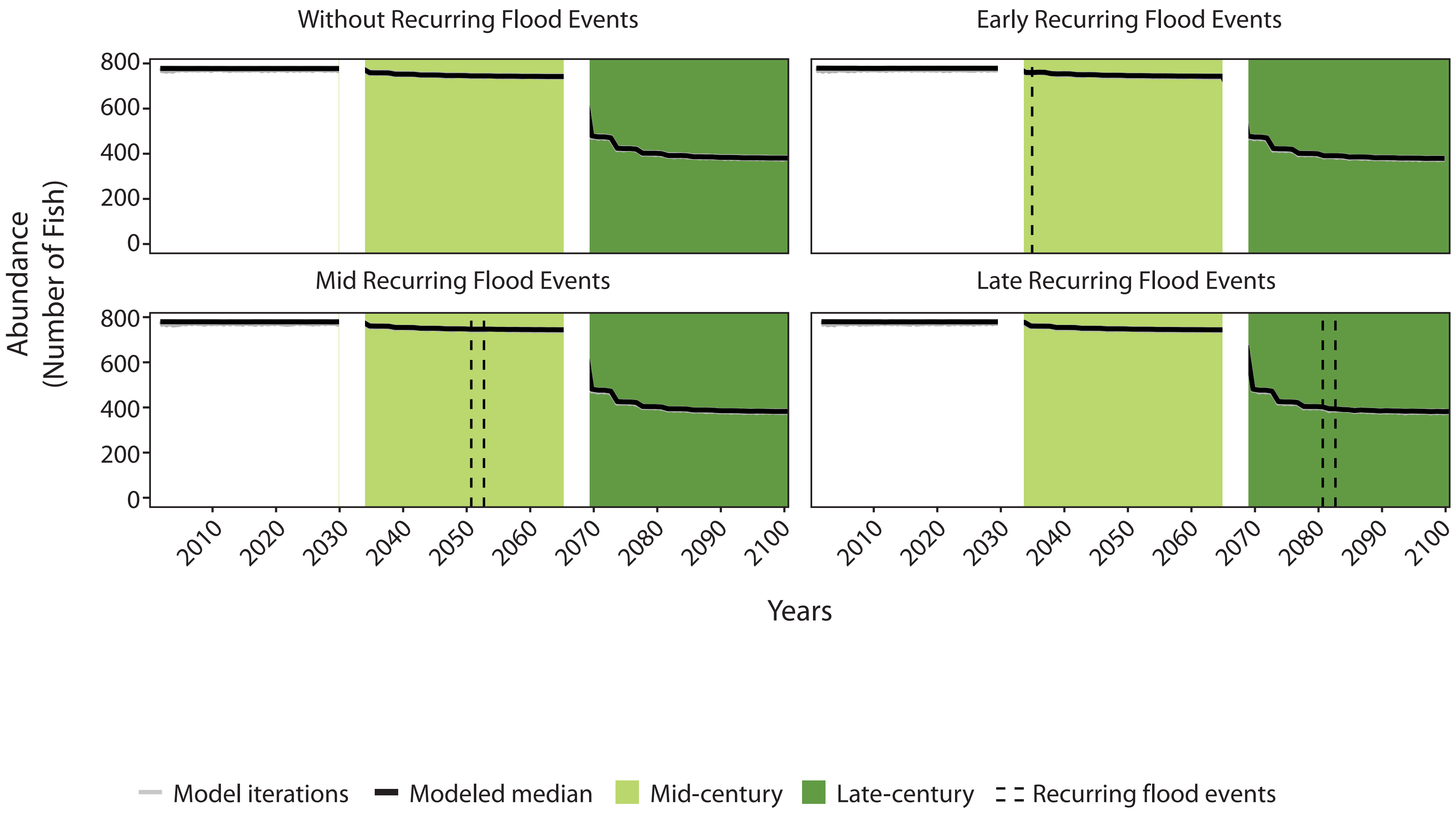


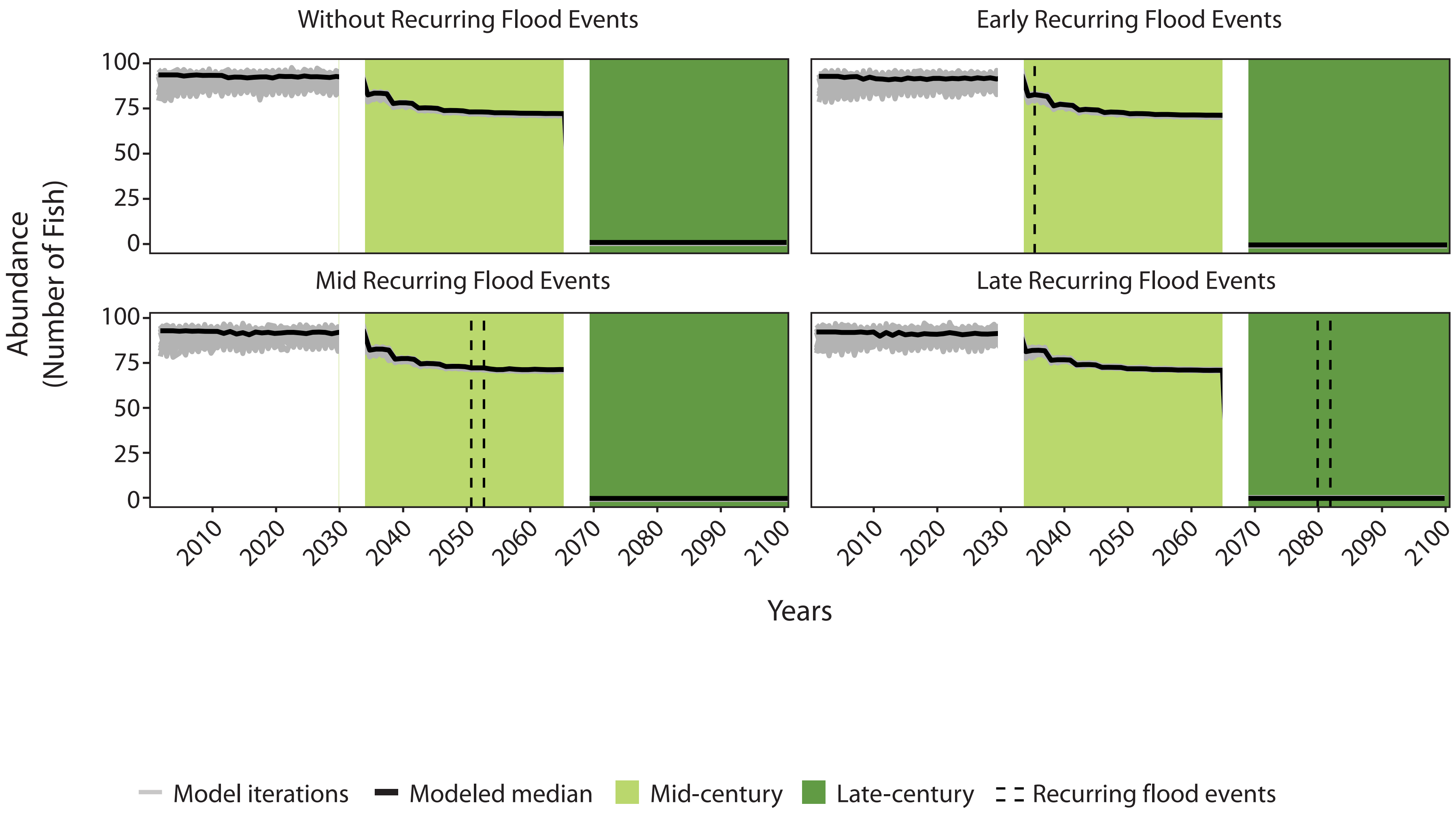
Figure E-32
LCM Results for Coho Salmon Above Crim Creek Subbasin Under No Action Alternative



Source: NOAA 2019

Figure E-33

LCM Results for Coho Salmon Rainbow Falls to Crim Creek Subbasin Under No Action Alternative

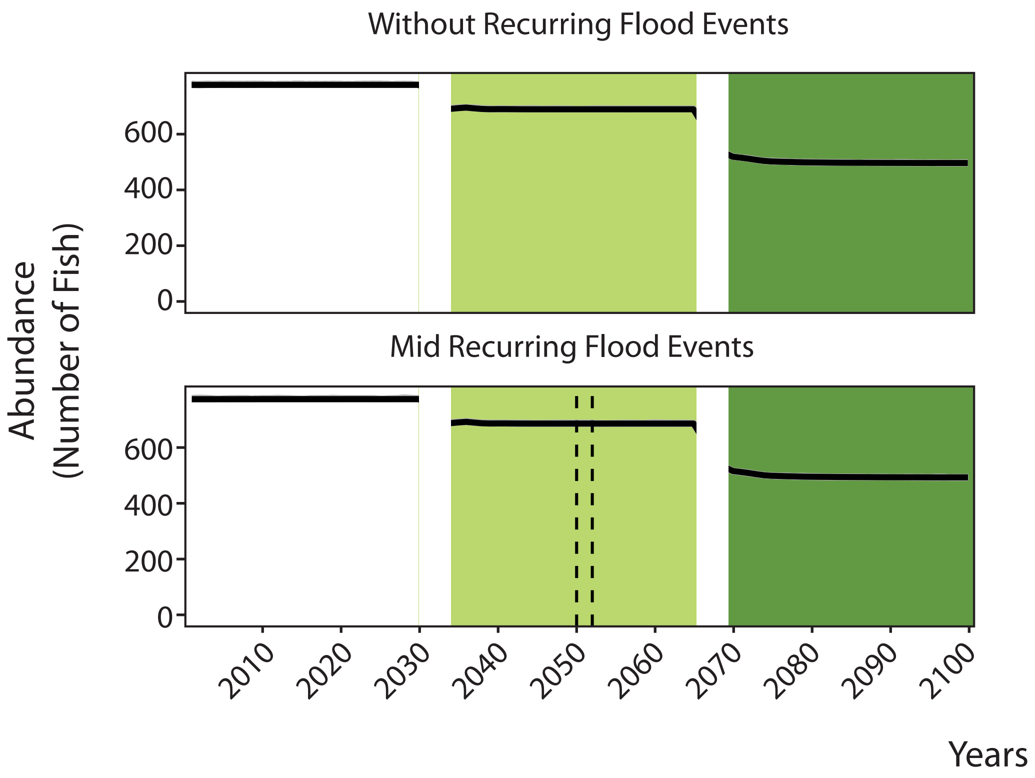


Source: NOAA 2019

Figure E-34
Change in Steelhead Abundance Under No Action Alternative

Figure E-35

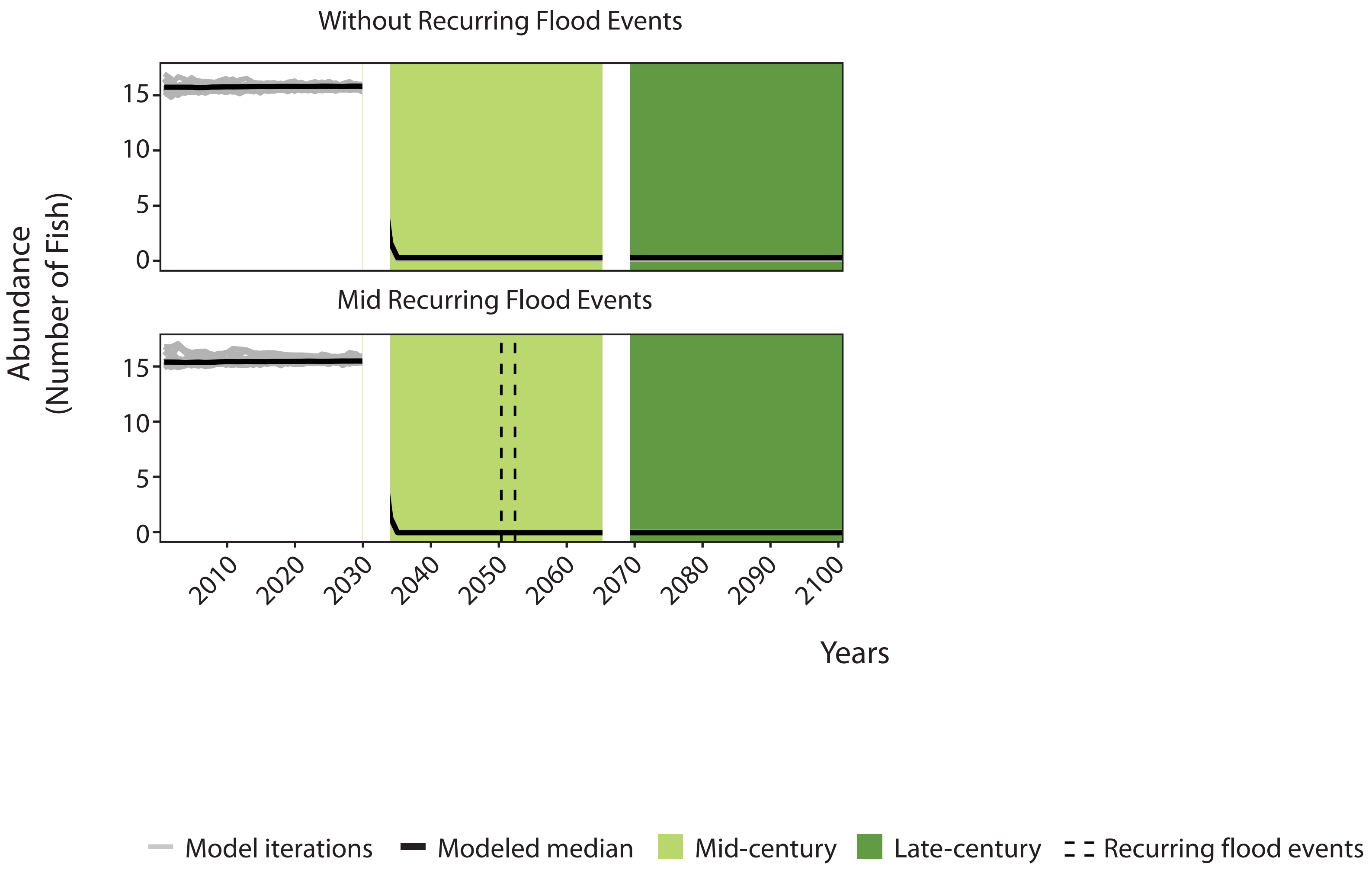
LCM Results for Steelhead Above Crim Creek Subbasin Under No Action Alternative



Source: NOAA 2019

Figure E-36

LCM Results for Steelhead Rainbow Falls to Crim Creek Subbasin Under No Action Alternative



Source: NOAA 2019

3.4.2 Impacts from Construction

Elements of the No Action Alternative that would require construction include Chehalis Basin Flood Authority (Flood Authority) projects that include a mix of in-water and out-of-water construction, WSDOT programs that require floodwalls or barriers, ongoing land use and development, floodproofing, timber harvest, and stream restoration and modifications.

Of the various construction needs identified under the No Action Alternative, elements that could result in activities adjacent to or within the river channel could result in impacts on fish or fish habitat. This could include in-water and floodplain projects currently identified including Flood Authority-sponsored culvert replacement and flood and habitat mitigation projects, as well as restoration and stream modification projects under the USFWS Chehalis Fisheries Restoration Program and the ASRP early action habitat restoration actions funded in the 2017 to 2019 biennium listed in Section 3.4. Construction activities would be expected to result in sporadic, localized impacts on fish habitat over a short time.

Freshwater fish, shellfish, and aquatic habitat within the river reach of the construction activity may be directly affected during any in-water work. Construction activities that involve water diversions, cut and fill, or vegetation disturbance have the potential to increase turbidity and sedimentation in the stream channels, disrupting fish behavior or causing injury to fish or fish eggs. Diversion of water around construction sites for channel migration protection activities that involve in-channel construction may also cause fish injury, stranding, passage obstruction, or impairments to foraging. Accidental releases of pollutants from construction equipment may cause temporary reductions in water quality. Elevated sound and vibration associated with construction activities may disturb fish behavior, or may cause injury to fish in the case of sharp-rise and high-energy activities such as pile driving (the effects of sound on fish are described in greater detail for the Proposed Action in Section 3.2.2.2).

Work below the OHWM would need to comply with federal, state, and local requirements to avoid, minimize, and mitigate for impacts on water quality, endangered species, and critical areas. Disturbed areas would be required to be restored to pre-construction status and/or ecological function following construction.

Overall, construction activities in the primary study area under the No Action Alternative are limited in duration, and many activities would occur in the dry. The stream restoration and barrier removal projects would benefit fish and shellfish in the long term.

Construction associated with elements of the No Action Alternative adjacent to or within the river channel may have indirect impacts to areas downstream of project sites if water quality is impaired by pollutants or elevated turbidity.

3.4.3 Impacts from Operation

The No Action Alternative would include a mix of regulatory programs intended to reduce flood impacts and protect critical areas, construction projects to floodproof structures and roads in the 100-year floodplain, projects intended to improve ecological functions of streams and floodplains, and ongoing land uses, development, and timber harvest.

3.4.3.1 Aquatic Habitats

Projects undertaken to restore aquatic habitat under the No Action Alternative are not predicted to have direct adverse impacts on habitat in the primary study area. Climate change is predicted to have numerous impacts to habitat, which are discussed in Section 2.2.3.

Operation of floodproofing projects, including Flood Authority projects for private properties and WSDOT's road protection projects, may have indirect impacts on fish, shellfish, and aquatic habitat by changing the interactions between developed properties and adjacent river and floodplain areas over the long term.

Protection measures for structures in the floodplain, as part of the floodproofing elements undertaken by the Flood Authority or WSDOT, would allow for continuation of activities in the floodplain that are harmful to fish and fish habitat. Pollution, habitat degradation, and habitat disconnection would continue associated with agriculture, residential and commercial development, and intensive transportation along the I-5 corridor. In addition, floodproofing for human uses would prevent restoration of riparian vegetation or floodplain habitat. Projects that have the potential to change hydrologic regimes in floodplain habitat could be beneficial or adverse where flood levels may be changed upstream or downstream of the installation. Projects in the floodplain must follow regulations intended to protect critical areas like aquatic habitat, and impacts would be mainly associated with changes to hydrology during major or catastrophic floods that occur infrequently.

Ongoing land use, development, and timber harvest will indirectly and adversely affect aquatic habitat by continuing to alter natural hydrologic processes. Tree growth in riparian areas will continue to be protected under the Forest Practices Act of 1974 and its implementing provisions under the Forest Practices Rules (WAC 222), resulting in improved shading and improved water temperatures, primarily in headwater areas of the Chehalis River and its tributaries. It was also assumed in the EDT model that large wood recruitment to the river from mature riparian areas would increase over time and would improve fish habitat by creating new pools, cool water refugia, off-channel low velocity habitat, and substrate for macroinvertebrates by mid- or late-century.

Of the projects proposed under the No Action Alternative, culvert removals and ASRP early action habitat restoration actions are specifically designed to benefit fish habitat by restoring fish passage between disconnected reaches and improving habitat function of mainstem tributary habitat. ASRP restoration activities will improve habitat complexity by adding large wood and gravels, and reconnecting floodplain and side-channel habitats, as well as reducing water temperature by restoring and protecting riparian vegetation and creating cool-water refugia. Currently, the effects are considered indirect because the ASRP early action habitat restoration actions funded in the 2017 to 2019 biennium and USFWS's Chehalis Fisheries Restoration Program actions are broadly dispersed across the Chehalis Basin and outside the primary study area, and most benefits are likely to be limited to the site scale, such as within the treated river reaches.

Adverse indirect impacts could occur as a result of floodproofing and land uses in the broader study area, as discussed earlier for the primary study area.

3.4.3.2 Aquatic Species

3.4.3.2.1 Salmon and Steelhead Species

3.4.3.2.1.1 Spring-Run Chinook Salmon

Estimated spring-run Chinook salmon abundance in the Above Crim Creek Subbasin would decline throughout the No Action Alternative simulation period (2031 to 2099; Figure E-26). In the mid-century period (2031 to 2063), the decline would stabilize at a median value of 44 fish (range 41-45) compared to a median initial population abundance of 61 fish (56-62) fish in simulation year 2030. In the late-century period (2064 to 2099), the decline would stabilize at a median value of 8 fish (8-8). Estimated median abundance compared to the initial abundance would decrease 28% and 87% in the mid- and late-century periods, respectively.

Recurring flood events would reduce estimated spring-run Chinook salmon abundance in the Above Crim Creek Subbasin initially, after which the population would stabilize. None of the recurring floods scenarios modeled affected median estimated equilibrium abundance compared to the non-recurring flood condition.

Estimated spring-run Chinook salmon abundance in the Rainbow Falls to Crim Creek Subbasin would decline through the mid-century period of the No Action Alternative simulation period (2031 to 2063) and would be extirpated from the subbasin in the late-century (Figure E-27). In the mid-century period (2031 to 2063), the decline would stabilize at a median value of 29 fish (range 29-29) compared to a median initial population abundance of 47 fish (42-48) in simulation year 2030, which is a 38% decrease in abundance.

Recurring flood events early (2035) and in the middle (2050) of the simulation period would reduce spring-run Chinook salmon in the Rainbow Falls to Crim Creek Subbasin initially, after which the population would continue a downward trend through mid-century. The early and mid-recurring flood scenarios would have no effect on median estimated equilibrium abundance compared to the non-recurring flood condition. Spring-run Chinook salmon abundance in this subbasin was estimated to be zero in late-century and the late (2080) recurring flood would have no effect on the population.

3.4.3.2.1.2 Fall-Run Chinook Salmon

Estimated fall-run Chinook salmon abundance in the Above Crim Creek Subbasin would decline throughout the No Action Alternative simulation period (2031 to 2099; Figure E-29). In the mid-century period (2031 to 2063), the decline would stabilize at a median value of 130 fish (range 126-131) compared to a median initial population abundance of 167 fish (164-168) in simulation year 2030. In the late-century period (2064-2099), the decline would stabilize at a median value of 48 fish (44-48). Estimated median abundance compared to the initial abundance would decrease 22% and 71% in the mid- and late-century periods, respectively.

Recurring flood events early (2035) in the simulation period would reduce fall-run Chinook salmon in the Above Crim Creek Subbasin initially, after which the population would stabilize. None of the recurring floods scenarios modeled affected median estimated equilibrium abundance compared to the non-recurring flood condition.

Estimated fall-run Chinook salmon abundance in the Rainbow Falls to Crim Creek Subbasin would decline through the mid- and late-century periods of the No Action Alternative simulation period (2031 to 2099; Figure E-30). In the mid-century period (2031 to 2063), the decline would stabilize at a median value of 199 fish (range 194-200) compared to a median initial population abundance of 260 fish (233-265) in simulation year 2030. In the late-century period (2064 to 2099), the decline would stabilize at a median value of 107 fish (104-107) fish. Estimated median abundance compared to the initial abundance would decrease 24% and 59% in the mid- and late-century periods, respectively.

Recurring flood events early (2035) in the simulation period would reduce fall-run Chinook salmon in the Rainbow Falls to Crim Creek Subbasin initially, after which the population would stabilize. None of the recurring floods scenarios modeled affected median estimated equilibrium abundance compared to the non-recurring flood condition.

3.4.3.2.1.3 Coho Salmon

Estimated coho salmon abundance in the Above Crim Creek Subbasin would decline throughout the No Action Alternative simulation period (2031 to 2099; Figure E-32). In the mid-century period (2031 to 2063), the decline would stabilize at a median value of 747 fish (range 742-748) fish compared to a median initial population abundance of 782 fish (770-783) in simulation year 2030. In the late-century (2064 to 2099), the decline would stabilize at a median value of 386 fish (380-387). Estimated median abundance compared to the initial abundance would decrease 4% and 51% in the mid- and late-century periods, respectively. Recurring flood events would have little effect on coho salmon in the Above Crim Creek Subbasin.

Estimated coho salmon abundance in the Rainbow Falls to Crim Creek Subbasin would decline through the mid-century period of the No Action Alternative simulation period (2031 to 2063) and coho salmon would be extirpated from the subbasin in the late-century (Figure E-33). In the mid-century (2031 to

2063), the decline would stabilize at a median value of 70 fish (range 69-70) compared to a median initial population abundance of 90 fish (81-94) in simulation year 2030, which is a 22% decrease in abundance. Recurring flood events early (2035) in the simulation period would reduce coho salmon in the Rainbow Falls to Crim Creek Subbasin initially, after which the population would continue a downward trend before stabilizing at the end of the mid-century period. None of the recurring floods scenarios modeled affected median estimated equilibrium abundance compared to the non-recurring flood condition.

3.4.3.2.1.4 Steelhead

Estimated steelhead abundance in the Above Crim Creek Subbasin would decline throughout the No Action Alternative simulation period (2031 to 2099; Figure E-35). In the mid-century period (2031 to 2063), the decline would stabilize at a median value of 658 fish (range 658-661) compared to a median initial population abundance of 742 fish (742-743) fish in simulation year 2030. In the late-century (2064 to 2099), the decline would stabilize at a median value of 474 fish (473-476). Estimated median abundance compared to the initial abundance would decrease 11% and 36% in the mid- and late-century periods, respectively. Recurring flood events would have no effect on steelhead abundance the Above Crim Creek Subbasin because the effects of flood events on bed scour and channel width were not modeled above RM 108 or in tributaries. Additionally, flood events were modeled only during periods of the year when steelhead eggs were not the ground.

Estimated steelhead abundance in the Rainbow Falls to Crim Creek Subbasin would decline to zero during mid- and late-century under the No Action Alternative (Figure E-36). The estimated steelhead population size was small initially (median of 16 fish, range 15-16 fish), and by mid-century the population is estimated to be extirpated from this subbasin due to increased temperatures and degraded environmental conditions.

3.4.3.2.1.5 Summary of Impacts from the No Action Alternative on Salmonids

Changes in estimated abundance are shown in Table E-23.

Table E-23
Overall Change in Estimated Abundance of Salmon and Steelhead under the No Action Alternative through Late-Century

SPECIES	ABOVE CRIM CREEK		RAINBOW FALLS TO CRIM CREEK	
	MID-CENTURY	LATE-CENTURY	MID-CENTURY	LATE-CENTURY
Spring-run Chinook salmon	-28%	-87%	-38%	-100%
Fall-run Chinook salmon	-22%	-71%	-24%	-59%
Coho salmon	-4%	-51%	-22%	-100%
Steelhead	-11%	-36%	-100%	-100%

Salmon and steelhead in the Chehalis Basin are harvested, and similar to the Proposed Action, the significant impacts noted above for spring-run and fall-run Chinook salmon, coho salmon, and steelhead associated with the No Action Alternative would result in decreased abundance. The decreased abundance would be considered by and factored into future fishery management decisions by the fishery co-managers.

Flood Scenarios: Differences in changes in estimated salmonid abundance among the typical seasonal flow and major and catastrophic flood scenarios modeled based on EDT are shown in Figures E-25, E-28, E-31, and E-34 for each species modeled. There was little variability in estimated salmonid abundance associated with the flood scenarios modeled under the No Action Alternative. The modeling approach was selected primarily to evaluate the effects of operating the FRE facility (outlets open versus closed) on salmonids and not the effects of various flood flows under the Proposed Action. The variation that did occur among the flood scenarios was due to increased bed scour. In the EDT model, current bed scour ratings were adjusted to reflect presumed conditions during major and catastrophic flood events. Adjustments were limited to mainstem Chehalis River reaches upstream of Elk Creek due to the low river gradient below Elk Creek.

Because of this, differences among flood events were greater in the Above Crim Creek Subbasin than in the Rainbow Falls to Crim Creek Subbasin. Among all three species and two life-history strategies of Chinook salmon, two subbasins, and two time periods modeled, differences in decreased estimated abundance between floods modeled under the No Action Alternative ranged from 0% to 8%. The largest difference was between the typical seasonal flow and the catastrophic flood for spring-run Chinook salmon in the Above Crim Creek Subbasin, where estimated abundance decreased 24% and 32%, respectively (Figure E-25).

The flow conditions modeled are the only stochastic aspect to the integrated modeling approach used in the analysis. Variability associated with ocean conditions and marine survival as well as other freshwater factors would be expected to increase the variability around median abundance estimates but were not incorporated into the modeling approach. These factors are discussed in Section 2.4.2.1.4. Also, evaluating effects of the No Action Alternative on salmon and steelhead quasi-extinction thresholds rather than zero as the lower bound was not a component of the SEPA EIS analysis.

Productivity, diversity, and spatial structure: Similar to the Proposed Action, among all species and spatial units, changes in estimated population productivity based on EDT model results track changes in the modeled equilibrium abundance results under the No Action Alternative because abundance is calculated from population productivity and habitat capacity.

Productivity values estimated by the EDT model for the three species and two life-history strategies for Chinook salmon and two subbasins modeled under current conditions are shown in Tables E-12 and E-13 in Section 3.2.3.2. Productivity values estimated by the EDT model for the three species and two life-history strategies for Chinook salmon and two subbasins modeled under the No Action Alternative in late-century are shown in Tables E-24 and E-25.

Table E-24
Estimated Spring-Run and Fall-Run Chinook Salmon Productivity (Returns per Spawner) by Subbasin under the No Action Alternative in Late-Century

FLOW SCENARIO	SPRING-RUN CHINOOK SALMON		FALL-RUN CHINOOK SALMON	
	RAINBOW FALLS TO CRIM CREEK	ABOVE CRIM CREEK	RAINBOW FALLS TO CRIM CREEK	ABOVE CRIM CREEK
Typical seasonal flood	0.10	2.01	3.39	3.18
Major flood	0.10	2.01	3.40	2.90
Catastrophic flood	0.10	2.01	3.40	2.68

Table E-25
Estimated Coho Salmon and Winter Steelhead Productivity (Returns per Spawner) by Subbasin under the No Action Alternative in Late-Century

FLOW SCENARIO	COHO SALMON		STEELHEAD	
	RAINBOW FALLS TO CRIM CREEK	ABOVE CRIM CREEK	RAINBOW FALLS TO CRIM CREEK	ABOVE CRIM CREEK
Typical seasonal flood	0.12	2.67	0.03	8.00
Major flood	0.12	2.67	0.03	7.98
Catastrophic flood	0.12	2.67	0.03	7.96

Productivity under the No Action Alternative in late-century compared to current conditions would decrease significantly for spring-run Chinook salmon, coho salmon, and steelhead in the Rainbow Falls to Crim Creek Subbasin, resulting in these species being extirpated from the subbasin. Fall-run Chinook salmon productivity in this subbasin in late-century compared to current conditions would decrease by approximately 8% to 24% among the three flow scenarios modeled.

In the Above Crim Creek Subbasin, fall-run Chinook salmon productivity in late-century compared to current conditions would decrease from 17% to 19% among the flow scenarios, and steelhead productivity would decrease from 33% to 34%. Estimated productivity for spring-run Chinook salmon and coho salmon would be relatively unchanged (a 1% decrease for coho salmon and a change of -4% to +9% for spring-run Chinook salmon in late-century compared to current conditions).

Under the No Action Alternative, the spatial structure of spring-run Chinook salmon and coho salmon and steelhead populations in the Chehalis Basin would decline due to the loss of these populations in the Rainbow Falls to Crim Creek Subbasin. The concern over the future of spring-run Chinook salmon discussed for the Proposed Action (Section 3.2) applies to the No Action Alternative as well. Along with the loss of spring-run Chinook salmon in the Rainbow Falls to Crim Creek Subbasin, the population in the Above Crim Creek Subbasin would decrease by 87% under the No Action Alternative from the current time period to late-century and have an estimated equilibrium abundance of 8 fish in late century based on integrated model results. In addition, fall-run Chinook salmon would decrease by 71% during this same time period in this subbasin and would have an estimated equilibrium abundance of 48 fish. Chinook salmon in the Above Crim Creek Subbasin spawn predominantly within the lower reaches of the Chehalis River in the Above Crim Creek Subbasin and are therefore more susceptible to increased water temperatures compared to the upper tributaries that coho salmon and steelhead also occupy.

3.4.3.2.2 Non-Salmon Native Fish

The effects of the No Action Alternative were evaluated for a select suite of species by estimating the change in habitat area, measured as WUA, that would occur using the Chehalis PHABSIM model. As described in Section 2.4.2.2, the data reflect changes in flow and temperature in the context of the lower and upper tolerances and optimal conditions preferred by each species during the rearing and spawning life stages. The No Action Alternative was evaluated for conditions that would occur at mid-century and late century, reflecting the effect of climate change on increasing water temperature and decreasing summer flows. The change in WUA was examined for areas with available channel morphology and flow measurements at one site upstream of the FRE facility, at RM 110.9, and downstream of the FRE facility, from Pe Ell to Elk Creek (Caldwell et al. 2004; Normandeau 2012).

The predicted change in monthly average flow and average temperature with mid-century and late-century climate conditions is shown in Table E-26. The average change in monthly average WUA by late-century compared to existing conditions is shown in Tables E-27 and E-28 for the area upstream of Crim Creek and in Tables E-29 and E-30 for the area from Pe Ell to the confluence with Elk Creek.

Table E-26

Predicted Average Flows and Temperatures in the Upper Chehalis River

REACH	PERIOD	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
FLOW (cfs)													
Above Crim Creek	Mid-Century	492	719	792	501	210	78	36	22	148	255	446	503
	Late-Century	492	731	809	501	198	73	34	21	140	240	446	503
Pe Ell to Elk Creek	Mid-Century	746	1,090	1,200	759	318	118	55	34	224	386	675	762
	Late-Century	746	1,108	1,226	759	301	111	52	32	211	364	675	762
TEMPERATURE (°C)													
Above Crim Creek	Mid-Century	6.8	7.0	9.7	11.9	15.8	19.6	23.8	23.4	19.5	13.2	9.2	7.2
	Late-Century	9.0	8.8	11.4	12.9	16.8	21.5	26.6	26.5	22.7	16.5	11.6	10.2
Pe Ell to Elk Creek	Mid-Century	6.5	6.9	9.6	11.6	15.8	19.4	24.9	25.2	20.4	13.3	8.8	7.3
	Late-Century	8.9	8.7	11.5	13.1	17.4	21.7	28.2	28.8	23.8	16.8	11.1	10.3

Table E-27

Change in WUA by Mid-Century with the No Action Alternative Upstream of Crim Creek

SPECIES	LIFE STAGE	MAY	JUN	JUL	AUG	SEP	OCT
Largescale Sucker	Rearing	-5%	-8%	-33%	-29%	-11%	-14%
Largescale Sucker	Spawning	-52%	-31%	NA	NA	NA	NA
Mountain Whitefish	Adult Rearing	-14%	-18%	-31%	-27%	-27%	-25%
Mountain Whitefish	Juvenile Rearing	-14%	-16%	-31%	-27%	-27%	-24%
Mountain Whitefish	Spawning	NA	NA	NA	NA	-100%	-56%
Pacific Lamprey	Rearing	-16%	-19%	-40%	-34%	-30%	-24%
Pacific Lamprey	Spawning	2%	-15%	-72%	NA	NA	NA
Speckled Dace	Adult Rearing	-4%	-2%	-50%	-51%	-6%	-4%
Speckled Dace	Juvenile Rearing	-6%	-3%	-50%	-51%	-9%	-6%
Speckled Dace	Spawning	NA	-55%	0%*	0%*	NA	NA

Sources: Pacheco 2019a, 2019b

Notes:

The Chehalis PHABSIM model was calibrated for flow measurements that occur in summer only for the area above the confluence with Crim Creek (at RM 100.9). Months in which a given species does not use the habitat for spawning are noted by 'NA'. Months in which no WUA currently exists for a given species are indicated with an asterisk. Habitat suitability for smallmouth bass and largemouth bass was not evaluated upstream of Crim Creek.

NA: Not applicable

Table E-28

Change in WUA by Late-Century with the No Action Alternative Upstream of Crim Creek

SPECIES	LIFE STAGE	MAY	JUN	JUL	AUG	SEP	OCT
Largescale Sucker	Rearing	-9%	-29%	-70%	-72%	-50%	-31%
Largescale Sucker	Spawning	-69%	-100%	NA	NA	NA	NA
Mountain Whitefish	Adult Rearing	-24%	-46%	-65%	-67%	-61%	-53%
Mountain Whitefish	Juvenile Rearing	-24%	-42%	-65%	-67%	-60%	-51%
Mountain Whitefish	Spawning	NA	NA	NA	NA	-100%	-96%
Pacific Lamprey	Rearing	-27%	-48%	-84%	-85%	-67%	-45%
Pacific Lamprey	Spawning	-3%	-48%	-100%	NA	NA	NA
Speckled Dace	Adult Rearing	-6%	-12%	-71%	-74%	-57%	-23%
Speckled Dace	Juvenile Rearing	-9%	-13%	-71%	-74%	-58%	-26%
Speckled Dace	Spawning	NA	-100%	0%*	0%*	NA	NA

Sources: Pacheco 2019a, 2019b

Notes:

The Chehalis PHABSIM model was calibrated for flow measurements that occur in summer only for the area above the confluence with Crim Creek (at RM 100.9). Months in which a given species does not use the habitat for spawning are noted by 'NA'. Months in which no WUA currently exists for a given species are indicated with an asterisk. Habitat suitability for smallmouth bass and largemouth bass was not evaluated upstream of Crim Creek.

NA: Not applicable

Table E-29

Change in WUA by Mid-Century with the No Action Alternative from Pe Ell to Elk Creek

SPECIES	LIFE STAGE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Largescale Sucker	Rearing	11%	6%	-4%	3%	-10%	-6%	-38%	-51%	-27%	-11%	0%	19%
Largescale Sucker	Spawning	NA	NA	NA	-30%	-43%	-68%	NA	NA	NA	NA	NA	NA
Mountain Whitefish	Adult Rearing	10%	6%	-8%	-10%	-21%	-33%	-35%	-47%	-40%	-19%	0%	7%
Mountain Whitefish	Juvenile Rearing	10%	6%	-12%	-13%	-19%	-28%	-35%	-48%	-36%	-19%	0%	3%
Mountain Whitefish	Spawning	NA	NA	NA	NA	NA	NA	NA	NA	0%*	-58%	0%	2%
Pacific Lamprey	Rearing	42%	20%	8%	-9%	-11%	-15%	-48%	-38%	-28%	-11%	9%	31%
Pacific Lamprey	Spawning	NA	NA	2%	-11%	10%	-29%	-75%	NA	NA	NA	NA	NA
Speckled Dace	Adult Rearing	14%	8%	-2%	-4%	6%	-7%	-30%	-29%	-4%	-5%	1%	10%
Speckled Dace	Juvenile Rearing	14%	8%	-4%	-6%	4%	-7%	-30%	-31%	-4%	-5%	1%	7%
Speckled Dace	Spawning	NA	NA	NA	NA	NA	-99%	0%*	0%*	NA	NA	NA	NA
Largemouth Bass	Adult Rearing	0%*	0%*	100%*	19%	6%	2%	-13%	0%	-6%	30%	100%*	0%*
Largemouth Bass	Spawning	NA	NA	NA	NA	175%	-2%	NA	NA	NA	NA	NA	NA
Smallmouth Bass	Adult Rearing	0%*	0%*	0%*	5%	-3%	9%	-13%	-17%	-4%	2%	0%*	0%*
Smallmouth Bass	Spawning	NA	NA	NA	69%	24%	-100%	NA	NA	NA	NA	NA	NA

Notes:
The Chehalis PHABSIM model was calibrated for flow measurements that occur in summer only for the area above the confluence with Crim Creek (at RM 100.9). Months in which a given species does not use the habitat for spawning are noted by ‘NA’. Months in which no WUA currently exists for a given species are indicated with an asterisk. Smallmouth bass and largemouth bass are not currently known to occur upstream of Elk Creek, but could expand their ranges upstream into suitable habitat in the future.
NA: Not applicable

Table E-30

Change in WUA by Late-Century with the No Action Alternative from Pe Ell to Elk Creek

SPECIES	LIFE STAGE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Largescale Sucker	Rearing	18%	11%	-16%	-6%	-18%	-33%	-85%	-92%	-61%	-32%	-9%	16%
Largescale Sucker	Spawning	NA	NA	NA	-25%	-75%	-100%	NA	NA	NA	NA	NA	NA
Mountain Whitefish	Adult Rearing	18%	7%	-24%	-24%	-33%	-54%	-80%	-86%	-68%	-51%	-14%	-1%
Mountain Whitefish	Juvenile Rearing	18%	1%	-27%	-27%	-32%	-50%	-80%	-86%	-66%	-50%	-14%	-5%
Mountain Whitefish	Spawning	NA	NA	NA	NA	NA	NA	NA	NA	0%*	-96%	0%	2%
Pacific Lamprey	Rearing	85%	50%	10%	-17%	-19%	-46%	-100%	-100%	-68%	-33%	19%	68%
Pacific Lamprey	Spawning	NA	NA	8%	-11%	-3%	-64%	-100%	NA	NA	NA	NA	NA
Speckled Dace	Adult Rearing	24%	13%	-5%	-6%	-3%	-30%	-67%	-72%	-65%	-15%	-1%	14%
Speckled Dace	Juvenile Rearing	24%	11%	-6%	-9%	-4%	-31%	-68%	-73%	-65%	-17%	-1%	11%
Speckled Dace	Spawning	NA	NA	NA	NA	NA	-100%	0%*	0%*	NA	NA	NA	NA
Largemouth Bass	Adult Rearing	100%*	100%*	100%*	48%	5%	-9%	-43%	-100%	-26%	60%	100%*	100%*
Largemouth Bass	Spawning	NA	NA	NA	NA	293%	-2%	NA	NA	NA	NA	NA	NA
Smallmouth Bass	Adult Rearing	0%*	0%*	100%*	7%	-4%	-3%	-100%	-100%	-24%	-1%	100%*	100%*
Smallmouth Bass	Spawning	NA	NA	NA	219%	24%	-100%	NA	NA	NA	NA	NA	NA

Notes:
The Chehalis PHABSIM model was calibrated for flow measurements that occur in summer only for the area above the confluence with Crim Creek (at RM 100.9). Months in which a given species does not use the habitat for spawning are noted by ‘NA’. Months in which no WUA currently exists for a given species are indicated with an asterisk. Smallmouth bass and largemouth bass are not currently known to occur upstream of Elk Creek, but could expand their ranges upstream into suitable habitat in the future.
NA: Not applicable

The change in habitat area progresses in a linear manner from mid-century to late-century, with greater impacts in late-century. The major effects of changes in WUA are discussed in greater detail in Section 3.2 in the analysis of the Proposed Action. Potential changes in WUA include, for most native species, the following effects:

- Major contraction or complete loss of summer spawning and rearing habitat due to lower flows and warmer temperatures
- Potential expansion of winter rearing habitat for native species due to warmer temperatures
- Potential expansion in spawning and rearing for non-native largemouth bass, an aggressive predator of juvenile salmonids due to warmer winter temperatures

There must still be suitable amounts of spawning habitat to sustain a population that can seed the habitat with juveniles, and those juveniles must be able to survive the warmer summers.

During periods of peak water temperatures in July and August, rearing habitat would be reduced by 27% to 51%, depending on the species, by mid-century, and by 65% to 85% by late-century upstream of Crim Creek. Rearing habitat would be reduced by 30% to 51% by mid-century and by 67% to 100% by late-century in the reach from Pe Ell to Elk Creek. The modeling predicts that spawning habitat would be reduced to zero by late-century in months that already have limited amounts of suitable habitat for largescale sucker (June), mountain whitefish (September), and speckled dace (June).

Habitat area for all the representative species examined (cool-water-adapted and warm-water-adapted; spring spawners, summer spawners, and fall spawners) would be reduced in summer due to the reduction in flows. The amount of rearing habitat available to native species may increase in winter due to warmer water temperatures. This trend is consistent with observations that the existing fish community tends to shift from a salmonid-dominated community in the cooler headwater areas to a cyprinid and non-native, centrarchid-dominated community in the warmer middle and lower mainstem Chehalis River (J. Winkowski and Zimmerman 2019).

Non-native largemouth and smallmouth bass, which are warm-water adapted, non-native predators of juvenile salmon, could see a large expansion of spawning habitat into upstream reaches with the future increase in temperatures. WUA is predicted to increase up to 293% for largemouth bass spawning in May and 219% for smallmouth bass spawning in April.

By late-century, warmer water temperatures through the winter will reduce starvation periods for smallmouth bass and may allow largemouth bass to rear upstream of Elk Creek year-round if they expand their distributions to those reaches. Modeled changes in WUA indicate that habitats for rearing adults will be reduced or eliminated in the hottest months; however, adults that are able to find thermal refuge may find new opportunities to spawn and their offspring may find optimal conditions to expand their distribution (discussed in greater detail in Section 3.2.3.2).

The utility of the PHABSIM model outputs is limited to estimating change in habitat area based on changes in flow and temperature without consideration of other key habitat elements for species survival. The ways in which species will respond to the changes in habitat available to them are not predicted by the PHABSIM model. Thus, changes in WUA do not capture all impacts anticipated for non-salmon fish, but provide a basis for understanding how the habitat availability may affect fish communities.

3.4.3.2.3 Freshwater Shellfish and Aquatic Macroinvertebrates

In-water work to remove fish passage barriers, address habitat mitigation requirements, ASRP early action restoration projects and USFWS's Chehalis Fisheries Restoration Program under the No Action Alternative are expected to benefit aquatic species, including shellfish and aquatic macroinvertebrates. BMPs that include salvage and relocation of mussels in accordance with regional guidance (Luzier and Miller 2009; Blevins et al. 2018) could minimize project impacts. Mussel-friendly stream restoration (Blevins et al. 2019) could benefit shellfish in the long run.

The impact of the changing environmental baseline due to climate change may adversely affect shellfish and aquatic macroinvertebrates, mainly due to contraction of wetted areas with lower flows in summer and warmer summer temperatures.

3.4.3.2.4 Marine Mammals and Birds

Marine predators that prey on Chehalis Basin salmon, either the outmigrating smolts or the returning adults, may be indirectly affected by a change in salmon population sizes.

The populations of Chinook salmon that originates from the upper Chehalis River are among several subpopulations originating from Chehalis River and Grays Harbor tributaries that contribute to the Grays Harbor population overall. Southern Resident killer whales depend on spring-run Chinook salmon as a food source, and the overall number of these fish has been decreasing throughout the region. Several Chinook salmon populations (outside of the Chehalis Basin) that are Southern Resident killer whale prey are designated as threatened or endangered (70 Federal Register 69903; 79 Federal Register 20802). While the degree to which a decline in the specific subpopulation of fish originating from the upper Chehalis River would affect the Southern Resident killer whale is unknown, and the magnitude of the impacts related specifically to the No Action Alternative is highly uncertain.

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Attachment E-1
Species Tables

Table E1-1

Freshwater and Anadromous Fish with Special Status in the Chehalis Basin

FAMILY GROUP	COMMON NAME	SCIENTIFIC NAME	STATE PRIORITY SPECIES STATUS	FEDERAL ENDANGERED SPECIES ACT STATUS	PRIORITY AREA[1]	HABITAT USE
Lampreys	Pacific lamprey	*Entosphenus tridentata*	Not Listed, Species of Tribal Importance[2]	Not Listed, Species of Concern	Any occurrence	Anadromous
Lampreys	Western river lamprey	*Lampetra ayresi*	Candidate[2]	Not Listed	Any occurrence	Anadromous
Mudminnows	Olympic mudminnow	*Novumbra hubbsi*	Sensitive[2]	Not Listed	Any occurrence	Freshwater
Salmonids	Chehalis fall-run Chinook salmon	*Oncorhynchus tshawytscha*	Candidate	Washington Coast ESU: Not Listed	Any occurrence	Anadromous
Salmonids	Chehalis spring-run Chinook salmon	*Oncorhynchus tshawytscha*	Candidate	Washington Coast ESU: Not Listed	Any occurrence	Anadromous
Salmonids	Grays Harbor fall-run Chum salmon	*Oncorhynchus keta*	Candidate	Pacific Coast ESU: Not Listed	Any occurrence	Anadromous
Salmonids	Coastal/Puget Sound bull trout	*Salvelinus confluentus*	Candidate[2]	Threatened	Any occurrence	Anadromous
Salmonids	Coastal resident-searun cutthroat trout	*Oncorhynchus clarkii*	Priority	Not listed	Any occurrence	Freshwater or anadromous
Salmonids	Chehalis coho salmon	*Oncorhynchus kisutch*	Priority	Southwest Washington ESU: Not Listed	Any occurrence	Anadromous
Salmonids	Steelhead	*Oncorhynchus mykiss*	Candidate (Steelhead)	Southwest Washington DPS: Not Listed	Any occurrence	Freshwater or anadromous
Smelt	Eulachon	*Thaleichthys pacificus*	Candidate[2]	Southern DPS: Threatened	Regular concentration	Anadromous
Smelt	Longfin smelt	*Spirinchus thaleichthys*	Priority	Under Review	Breeding areas and regular concentrations	Anadromous
Sturgeons	Green sturgeon[3]	*Acipenser medirostris*	Priority[2]	Southern DPS: Threatened	Any occurrence	Anadromous

FAMILY GROUP	COMMON NAME	SCIENTIFIC NAME	STATE PRIORITY SPECIES STATUS	FEDERAL ENDANGERED SPECIES ACT STATUS	PRIORITY AREA[1]	HABITAT USE
Sturgeons	White sturgeon	*Acipenser transmontanus*	Priority[2]	Not Listed	Any occurrence	Anadromous

Notes:

Sources: WDFW 2019a, 2019b

1. Species are considered a priority only when they occur within known limiting habitats or priority areas. If limiting habitats are unknown, or species are rare, the priority area is described as "any occurrence."
2. Included as a Species of Greatest Conservation Need in Washington's State Wildlife Action Plan.
3. No spawning populations of green sturgeon are known to occur in the Chehalis River.

DPS: distinct population segment

ESU: evolutionarily significant unit

Table E1-2

Unlisted Freshwater and Anadromous Fish and Freshwater Shellfish that Occur in the Chehalis River Basin

FAMILY GROUP	COMMON NAME	SCIENTIFIC NAME	HABITAT USE
NATIVE FISH SPECIES			
Lampreys	Western brook lamprey	*Lampetra richardsonii*	Freshwater
Minnows	Longnose dace	*Rhinichthys cataractae*	Freshwater
Minnows	Northern pikeminnow	*Ptychocheilus oregonensis*	Freshwater
Minnows	Peamouth	*Mylocheilus caurinus*	Freshwater
Minnows	Redside shiner	*Richardsonius balteatus*	Freshwater
Minnows	Speckled dace	*Rhinichthys osculus*	Freshwater
Salmonids	Mountain whitefish	*Prosopium williamsoni*	Freshwater
Salmonids	Rainbow trout	*Oncorhynchus mykiss*	Freshwater
Salmonids	Cutthroat trout	*Oncorhynchus clarkii*	Freshwater/Anadromous
Sculpins	Coast range sculpin	*Cottus aleuticus*	Freshwater/Brackish
Sculpins	Prickly sculpin	*Cottus asper*	Freshwater/Brackish
Sculpins	Reticulate sculpin	*Cottus perplexus*	Freshwater
Sculpins	Riffle sculpin	*Cottus gulosus*	Freshwater
Sculpins	Shorthead sculpin	*Cottus confusus*	Freshwater
Sculpins	Torrent sculpin	*Cottus rhotheus*	Freshwater
Sticklebacks	Three-spined stickleback[1]	*Gasterosteus aculeatus*	Freshwater/Brackish/ Anadromous
Suckers	Largescale sucker	*Catostomus macrocheilus*	Freshwater
NON-NATIVE FISH SPECIES			
Carps	Common carp	*Cyprinus carpio*	Freshwater
Carps	Goldfish	*Carassius auratus*	Freshwater
Catfishes	Brown bullhead	*Ameiurus nebulosus*	Freshwater
Perches	Yellow perch	*Perca flavescens*	Freshwater
River Herrings	American shad[1,2]	*Alosa sapidissima*	Anadromous
Sunfishes	Black crappie	*Pomoxis nigromaculatus*	Freshwater
Sunfishes	Bluegill	*Lepomis macrochirus*	Freshwater
Sunfishes	Largemouth bass	*Micropterus salmoides*	Freshwater
Sunfishes	Pumpkinseed	*Lepomis gibbosus*	Freshwater
Sunfishes	Rock bass	*Ambloplites rupestris*	Freshwater
Sunfishes	Smallmouth bass	*Micropterus dolomieu*	Freshwater
FRESHWATER SHELLFISH			
Freshwater Mussels	Western floaters	*Anodonta* spp.	Freshwater
Freshwater Mussels	Western pearlshell	*Margaritifera falcate*	Freshwater
Freshwater Mussels	Western ridged mussel	*Gonidea angulate*	Freshwater

Sources: Hiss and Knudsen 1993; Wydoski and Whitney 2003; Hughes and Herlihy 2012; Hayes et al. 2015; Small et al. 2017; Hayes et al. 2019; Nedeau et al. 2019.

Notes:

1. Indicates lower Chehalis River species.
2. No significant spawning populations of American shad are known to occur in the Chehalis River.

Table E1-3

Marine Mammal Predators of Anadromous Fish that Originate from the Chehalis Basin

COMMON NAME	SCIENTIFIC NAME	STATE PRIORITY SPECIES STATUS	FEDERAL ENDANGERED SPECIES ACT STATUS[2]	PRIORITY AREA[1]	HABITAT USE
Orca whale	*Orcinus orca*	Endangered	Southern Resident DPS: Endangered	Regular concentrations in foraging areas and in migration routes	Marine
California sea lion	*Zalophus californianus*	Priority	Not Listed	Haulouts	Marine, Freshwater, Terrestrial
Steller (Northern) sea lion	*Eumetopias jubatus*	Threatened	Eastern DPS: Delisted	Haulouts	Marine, Freshwater, Terrestrial
Northern fur seal	*Callorhinus ursinus*	Not Listed	Not Listed	Not applicable	Marine, Terrestrial
Harbor seal	*Phoca vitulina*	Not Listed	Not Listed	Haulouts	Marine, Terrestrial

Sources: WDFWa, NMFS 2019

Notes:
Includes marine mammals known to feed on the anadromous fish species that occur in the Chehalis Basin.

1. Species are considered a priority only when they occur within known limiting habitats or priority areas. If limiting habitats are unknown, or species are rare, the priority area is described as “any occurrence.”
2. All marine mammal species are federally protected throughout their range under the Marine Mammal Protection Act.

DPS: distinct population segment

Table E1-4
Example Freshwater Benthic Macroinvertebrate Taxa Likely to Occur in the Upper Chehalis Basin

COMMON NAME	SCIENTIFIC ORDER NAME
Beetles	*Coleoptera*[1]
Flies	*Diptera*[1]
Aquatic worms	*Haplotaxida*
Mites	*Trombidiformes*
True bugs	*Hemiptera*[1]
Stoneflies	*Plecoptera*[1]
Caddisflies	*Trichoptera*[1]
Mayflies	*Ephemeroptera*[1]
Aquatic snails	*Gastropoda*
Damselflies, dragonflies	*Odonata*
Dodsonflies, alderflies	*Megaloptera*
Crayfish	*Decapoda*
Amphipods	*Amphipoda*
Midges	*Chironomids*[1]
Backswimmers	*Notonectids*[1]
Springtails	*Collembola*[1]

Sources: Ecology 2019; Hershey and Lamberti 1998
Note: Several functional feeding groups may occur within a macroinvertebrate order.
Functional feeding groups include scrapers, collector-gatherers, collector-filterers, shredders, and predators.
1. Common food item in juvenile salmon diets while rearing in freshwater.

Table E1-5
Avian Predators of Anadromous Fish that Originate from the Chehalis Basin

COMMON NAME	SCIENTIFIC NAME	STATE PRIORITY SPECIES STATUS	FEDERAL ENDANGERED SPECIES ACT STATUS	PRIORITY AREA[1]	HABITAT USE
Marbled murrelet	*Brachyramphus marmoratus*	Endangered Priority: vulnerable aggregations	Federally Threatened	Any occurrence in suitable habitat	Marine, Terrestrial
Tufted puffin	*Fratercula cirrhata*	Endangered Priority: vulnerable aggregations and species of recreational, commercial, and/or tribal importance	Not Listed	Breeding areas, regular concentrations	Marine, Terrestrial
Hooded merganser	*Lophodytes cucullatus*	Priority: species of recreational, commercial, and/or tribal importance	Not Listed	Cavity-nesting ducks, breeding areas	Marine, Freshwater, Terrestrial
Great blue heron	*Ardea herodias*	Priority: vulnerable aggregations	Not Listed	Breeding areas	Marine, Freshwater, Terrestrial
Red-throated loon	*Gavia stellate*	Priority: vulnerable aggregations	Not Listed	Western Washington nonbreeding concentrations	Marine, Freshwater, Terrestrial
Pacific loon	*Gavia pacifica*	Priority: vulnerable aggregations	Not Listed	Western Washington nonbreeding concentrations	Marine, Freshwater, Terrestrial
Common loon	*Gavia immer*	Sensitive Priority: vulnerable aggregations	Not Listed	Breeding sites, migratory stopovers, and regular concentrations	Marine, Freshwater, Terrestrial

COMMON NAME	SCIENTIFIC NAME	STATE PRIORITY SPECIES STATUS	FEDERAL ENDANGERED SPECIES ACT STATUS	PRIORITY AREA[1]	HABITAT USE
Double-crested cormorant	*Phalacrocorax auritus*	Priority: vulnerable aggregations	Not Listed	Western Washington breeding concentrations; Western Washington nonbreeding concentrations	Marine, Freshwater, Terrestrial
Caspian tern	*Sterna caspia*	Priority: vulnerable aggregations	Not Listed	Western Washington breeding concentrations	Marine, Freshwater, Terrestrial
Sooty shearwater	*Puffinus griseus*	Priority: vulnerable aggregations	Not Listed	Western Washington nonbreeding concentrations	Marine, Terrestrial
Greater yellowlegs	*Tringa melanoleuca*	Priority: vulnerable aggregations	Not Listed	Western Washington nonbreeding concentrations	Freshwater, Terrestrial
Red-necked grebe	*Podiceps grisegena*	Priority: vulnerable aggregations	Not Listed	Western Washington nonbreeding concentrations	Marine, Freshwater, Terrestrial
Clark's grebe	*Aechmophorus clarkia*	State Candidate Species Priority: vulnerable aggregations	Not Listed	Breeding areas and regular concentrations	Marine, Freshwater, Terrestrial
Brown pelican	*Pelecanus occidentalis*	Priority: vulnerable aggregations	Not Listed	Regular concentrations in foraging and resting areas	Marine, Terrestrial
Western gull	*Larus occidentalis*	Not Listed	Not Listed	Not applicable	Marine, Terrestrial
Glacous-winged gull	*Larus glaucescens*	Not Listed	Not Listed	Not applicable	Marine, Freshwater, Terrestrial
Heermann's gull	*Larus heermanni*	Not Listed	Not Listed	Not applicable	Marine, Terrestrial

Source: WDFW 2019a
Notes:
Includes piscivorous waterbirds, waterfowl, and shorebirds known to feed on the anadromous fish species that occur in the Chehalis Basin.
1. Species are considered a priority only when they occur within known limiting habitats or priority areas. If limiting habitats are unknown, or species are rare, the priority area is described as "any occurrence."

Table E1-7
Unlisted Avian Predators of Fish that Originate from the Chehalis River Basin

COMMON NAME	SCIENTIFIC NAME	HABITAT USE
American dipper[1]	*Cinclus mexicanus*	Marine, Freshwater
Bald eagle[1]	*Haliaeetus leucocephalus*	Marine, Freshwater, Terrestrial
Belted kingfisher[1]	*Megaceryle alcyon*	Marine, Freshwater
Bonaparte's gull	*Chroicocephalus philadelphia*	Marine, Freshwater, Terrestrial
Brandt's cormorant	*Phalacrocorax penicillatus*	Marine
California gull	*Larus californicus*	Marine, Freshwater, Terrestrial
Common goldeneye[2]	*Bucephala clangula*	Marine, Freshwater
Common merganser[1,2]	*Mergus merganser*	Marine, Freshwater
Common murre	*Uria aalge*	Marine
Common raven[1]	*Corvus corax*	Freshwater, Terrestrial
Common tern	*Sterna hirundo*	Marine
Elegant tern	*Thalasseus elegans*	Marine
Great egret[2]	*Ardea alba*	Marine, Freshwater
Green heron[2]	*Butorides virescens*	Marine, Freshwater
Harlequin duck	*Histrionicus histrionicus*	Marine, Freshwater
Herring gull	*Larus argentatus*	Marine, Freshwater, Terrestrial
Osprey	*Pandion haliaetus*	Marine, Freshwater
Pelagic cormorant	*Phalacrocorax pelagicus*	Marine
Pied-billed grebe[2]	*Podilymbus podiceps*	Marine, Freshwater
Red-breasted merganser[2]	*Mergus serrator*	Marine, Freshwater
Rhinoceros auklet	*Cerorhinca monocerata*	Marine
Ring-billed gull	*Larus delawarensis*	Marine, Freshwater, Terrestrial

Sources:
[1] HMWSTS 2014
[2] Hamer et al. 2017
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Attachment E-2
Salmonid Impacts Modeling Methods

SALMONID IMPACTS MODELING METHODS

This attachment describes the modeling methods used to evaluate the effects of the Proposed Action and No Action alternatives on anadromous salmonid populations. The Local Actions Alternative was not modeled. The quantitative methods used to assess the effects of the No Action Alternative and the FRE facility component of the Proposed Action on salmonid passage and habitat quality involved several steps. The first step was to estimate fish passage survival through the FRE site and changes in habitat across the study area for target species and life stages. Attachment E-3 describes the estimates of fish passage performance used in the integrated salmonid impacts modeling approach. Second, the estimates were incorporated into the Ecosystem Diagnosis and Treatment (EDT) model and the EDT model was run for the Proposed Action and No Action alternatives at different time frames (construction, mid-century and late-century) and under various flow scenarios.

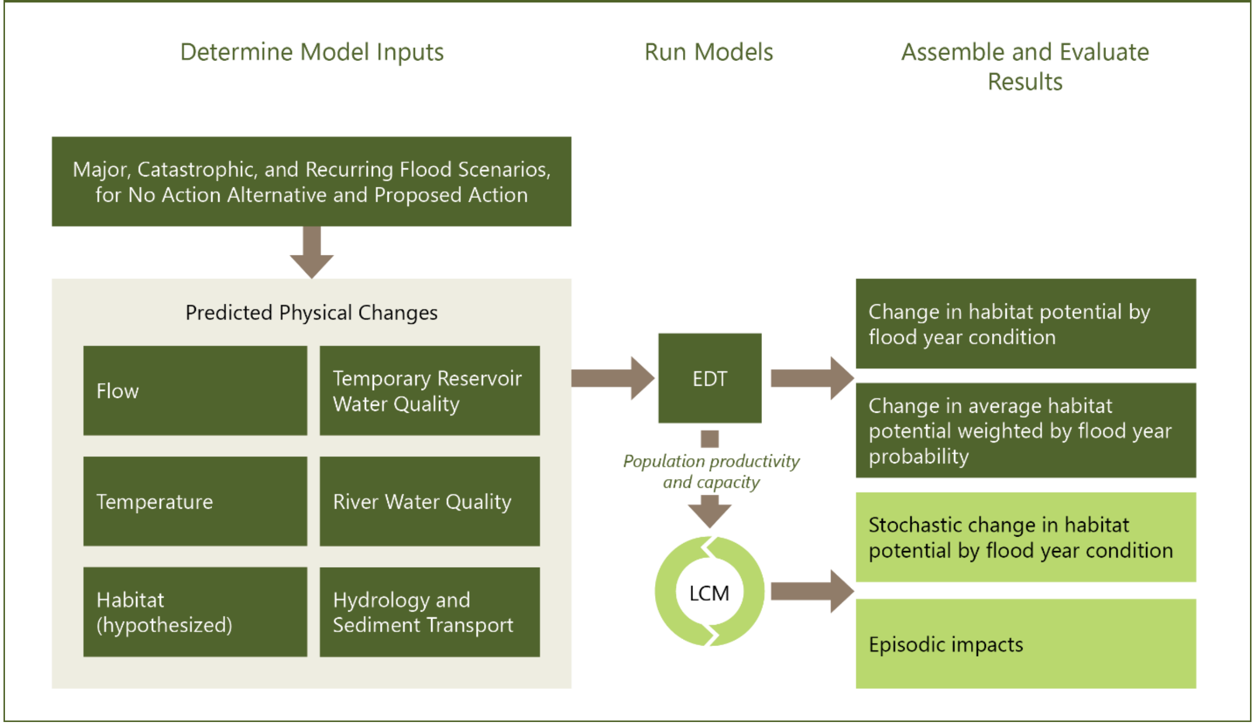
For operations of the Proposed Action, the effects of the following four types of flow conditions were analyzed (flow rate is measured at the Grand Mound gage):

- Major flooding with water flow rate of 38,800 cfs (FRE facility outlets closed)
- Catastrophic flooding with water flow rate of 75,100 cfs (FRE facility outlets closed)
- Recurring major or greater flood that triggers flood retention at the FRE facility in each of 3 consecutive years (FRE facility outlets closed)
- Periods when the FRE facility outlets are open, including normal river flows and flooding that is not large enough to trigger flood retention by the FRE facility

Finally, life-stage and reach-specific productivity and capacity outputs from EDT were then input into National Oceanic and Atmospheric Administration (NOAA) life-cycle models (LCM) for each species to evaluate stochastic effects of flow and flood retention events on anadromous salmonid population dynamics over time under the two alternatives modeled (Figure E2-1). Stochasticity in other factors, including FRE facility passage survival, freshwater life-stage survival (e.g., egg-to-fry survival), and marine survival, were not included in the LCM.

The main premise of the integrated (EDT-LCM) modeling approach is that habitat loss and degradation associated with the alternatives influence biological responses (salmon and steelhead abundance and life-cycle productivity). The modeling approach allowed effects of changes in habitat and habitat-forming processes associated with the No Action and Proposed Action alternatives to be estimated for different habitat conditions during three time periods (construction, mid-century and late-century), allowing effects on salmon populations over the long term to be quantified.

Figure E2-1
EDT and LCM Modeling Process and Integration



Ecosystem Diagnosis and Treatment Model

The EDT model estimates the potential performance of fish species under alternative habitat conditions. EDT is a deterministic, salmonid life-cycle model that evaluates potential performance of fish populations as a function of the physical features of the environment that characterize a model scenario. In EDT, a population is defined as fish production originating from spawning within a defined spatial area (e.g., the Chehalis River above the proposed FRE facility) as affected by habitat conditions across the species' life history. Performance of fish in a defined population under a modeled scenario is evaluated using the following Viable Salmonid Population (VSP) metrics used by NOAA Fisheries (McElhany et al. 2000):

- Abundance: the number of adult fish returning to the basin in the absence of harvest
- Productivity: the density-independent survival rate from spawner to progeny (returns per spawner)
- Diversity: the breadth of potential fish performance across the modeled life-history variation
- Spatial structure: the pattern of estimated fish abundance across the Chehalis basin

The EDT population metrics are compatible with the attributes of these VSP metrics. The EDT salmonid population metrics describe different aspects of habitat as it affects fish performance. Abundance in EDT is the long-term average expected number of fish that would be supported by the habitat condition. In

EDT, abundance is calculated from carrying capacity and productivity; capacity is a function of the quantity of suitable habitat for the species, while productivity reflects the quality of habitat and its effect on fish survival.

Productivity is defined as the survival rate of the population in a spatial analysis unit in the absence of competition (i.e., density-independent survival) based on the quality of the habitat in the unit. In the EDT model, productivity and habitat carrying capacity are used to calculate the equilibrium abundance of a fish population within a spatial unit. Productivity is independent of capacity, but productivity is one factor in the determination of capacity along with habitat area.

Productivity in EDT is the density-independent survival parameter of the Beverton-Holt production function and is the maximum survival rate (returns per spawner) in the absence of competition. EDT evaluates habitat against a range of life-history pathways that are generated by the model within windows that set the possible locations, timing, migration speed, and behavior of the species' life stages.

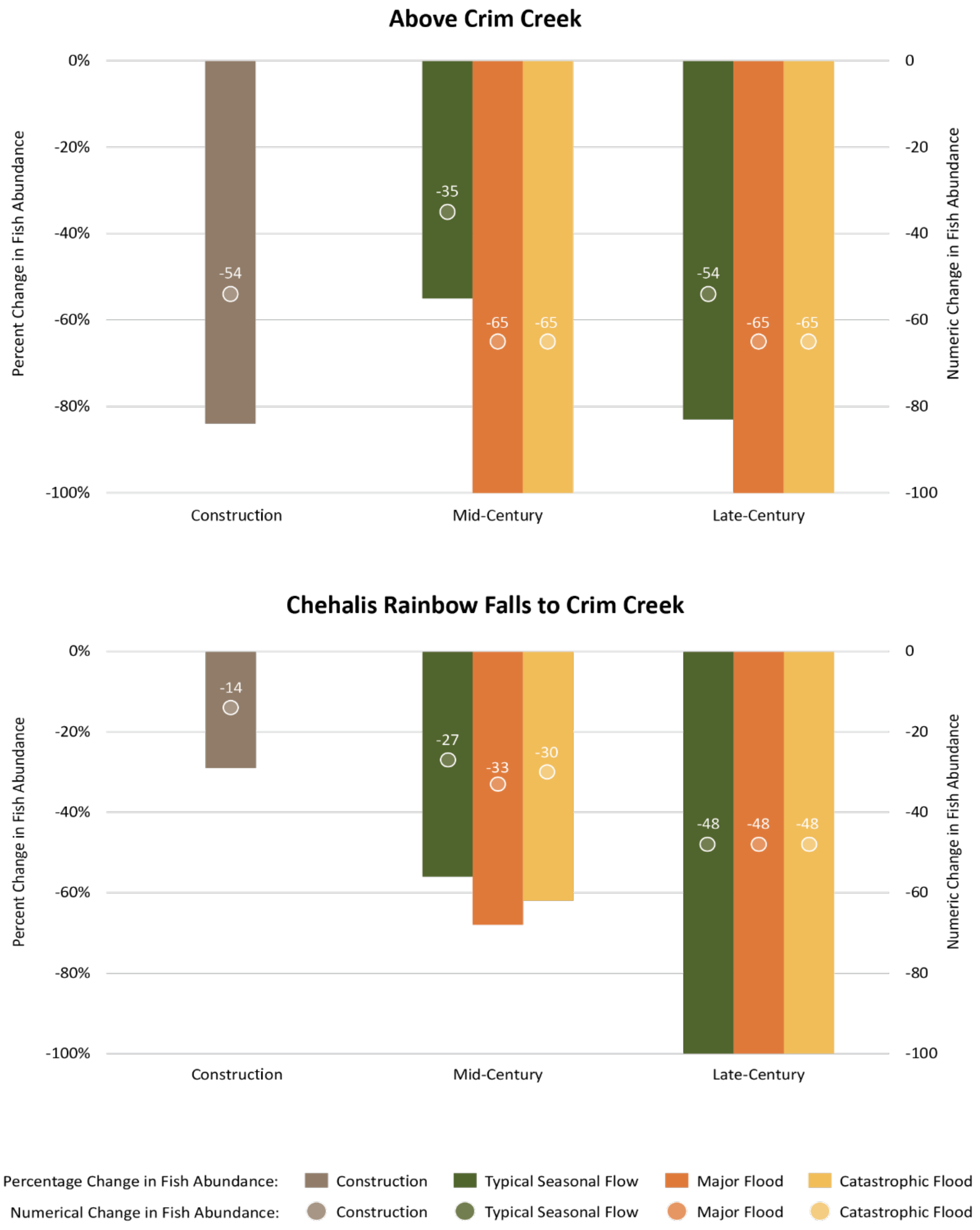
To assess diversity the EDT model evaluates habitat against an array of life-history strategies within defined life-history parameters. These strategies are not necessarily genetically linked but relate the variation in behavior within a population to how habitat is experienced by fish, with some fish spawning early, some late, and some juvenile fish dispersing downstream while others rear near their natal reaches prior to emigration. The EDT diversity metric is a measure of the breadth of suitable habitat and life-history strategies that can prevail: Good habitat conditions allow for success of a broad array of strategies, while poor conditions result in a reduced "window of opportunity" in which only a few strategies may be successful. Diversity in EDT is the proportion of life-history pathways that succeed (i.e., that result in productivity being greater than 1) and contribute to the estimates of abundance for the population. A higher proportion of successful pathways indicates greater breadth of suitable habitat; very low diversity in EDT indicates a narrow "window of opportunity" within which fish can potentially survive and is indicative of poorer habitat.

Spatial structure reflects the distribution of habitat conditions across the basin. It is evaluated outside of EDT as the distribution of potential abundance of fish between populations. Estimated abundance and productivity developed through EDT are reviewed and used to assess the spatial structure of populations within a species across the basin.

Each scenario modeled in EDT was characterized in terms of the potential abundance of fish that could be supported by the habitat condition. Changes in estimated population productivity based on EDT model results track changes in the modeled equilibrium abundance results because abundance is calculated from population productivity and habitat capacity. Estimates of fish population productivity and capacity for each species and model scenario developed through the EDT model were used as inputs in the NOAA LCM in the integrated model approach as described in the following section.

An example of the application of EDT is shown in Figure E2-2. The effect of the Proposed Action on spring-run Chinook salmon habitat potential is presented as the change in salmonid abundance from the current habitat condition to that under 2-, 10-, and 100-year flow conditions among two spatial units (populations). In Figure E2-2, the percent change in estimated fish abundance is shown as vertical bars relative to the left y-axis scale, and the numeric change in abundance is shown as dots with the actual value of the change presented above each dot relative to the right y-axis scale. The three time periods modeled are displayed along with changes in abundance associated with each flow condition modeled.

Figure E2-2
Change in Spring Chinook Salmon Abundance Under Proposed Action



NOAA Life-Cycle Model and the Integrated Model

The LCM incorporates population capacity and productivity estimates from EDT into a stochastic analysis of fish population performance to assess any generational effects of the two alternatives modeled on salmonid abundance over time. It was also used to evaluate the effects of sequential flood conditions on salmonid population abundance by inputting productivity and capacity data from EDT for the major flood scenario into the LCM for 3 consecutive years. To assess the effects of recurring floods on salmonids potentially occurring at different times in the simulation period, recurring floods were assessed in years 2033 to 2035, 2050 to 2052, and 2080 to 2082. Because this model incorporates EDT outputs into a stochastic LCM and is different from the models being developed by NOAA to assess Chehalis Basin Aquatic Species Restoration Plan (ASRP) scenarios, the combined EDT-LCM model is referred to as the "integrated model."

The integrated model is a population dynamics model for each salmonid species that is driven by demographic rates; specifically, life-stage-specific productivities and capacities derived from EDT. The integrated models track cohorts of fish through time and space in an age-structured, life-stage-based approach. Life stages tracked in the Chehalis River models include spawning adults, eggs deposited and incubated in streambed gravels, juveniles rearing in freshwater, and the marine phase that includes smolt migrants to the bay and ocean. The freshwater spatial extent of the integrated models includes the same Chehalis subbasins and subpopulations represented in EDT. Because the integrated models track cohorts of fish through time, and because fish spend a variable number of years in the ocean, the integrated models include mixed ages of adults returning to spawn each year. Age-based temporal modeling was used to estimate the potential effects at the subpopulation and overall population level through time resulting from the construction and operation of the Proposed Action and under the No Action Alternative.

Species Modeled

The integrated modeling approach assessed the effects of the Proposed Action and No Action alternatives on the following species:

- Spring-run Chinook salmon
- Fall-run Chinook salmon
- Coho salmon
- Steelhead

Physical effects of the Proposed Action are expected to occur in the mainstem Chehalis River. Chum salmon were not modeled because they do not typically spawn in the Chehalis River mainstem (Zimmerman and Holt 2016). Chum salmon spawn in tributaries of the lower part of the Chehalis Basin, and fry rapidly move out of freshwater to the ocean. Therefore, it was assumed the Proposed Action would have a negligible effect on chum salmon compared to the species listed above. In addition, while chum salmon are incorporated into the EDT model, this species has not been incorporated into the LCM and cannot be evaluated using the integrated modeling approach.

Spatial Extent

The focus of the analysis was on impacts to salmonid habitat in the Chehalis River upstream and downstream of the proposed FRE facility. Effects on each species were assessed at the following spatial scales:

- Above Crim Creek Subbasin (above the proposed FRE facility)
- Rainbow Falls to Crim Creek Subbasin (below the proposed FRE facility)

Sources of Information

Information used to characterize the Proposed Action in the EDT model comes from quantitative models (e.g., HEC-RAS), published literature, and professional knowledge and judgment. Temperature in the mainstem Chehalis River was derived from a CE-QUAL-W2 model developed by Portland State University (PSU) for the Washington Department of Ecology (Ecology; Van Glubt et al. 2017). Tributary temperatures were derived from modeling by WDFW (Winkowski 2019) and the U.S. Forest Service NorWeST system as described in McConnaha (2019). Flow and channel widths were estimated by Anchor QEA (Hill 2019) using a HEC-RAS model (Karpack and Butler 2019). Bed scour assumptions were based on hypotheses and published information as described in McConnaha and Ferguson (2019).

Where no quantitative means were available to predict impacts, hypotheses were posed based on first principles and published literature. Dr. Kathy Dube, the geomorphologist on the Anchor QEA SEPA EIS team, has conducted extensive work on sediment movement in the upper Chehalis Basin. Dr. Dube provided her professional judgment on the direction and amount of change in physical attributes in EDT associated with the FRE facility under different flow years and climate conditions in the form of an Excel spreadsheet (Dube 2019b).

Modeled Scenarios

The scenarios analyzed in the SEPA EIS for the Proposed Action and No Action alternatives focused on three FRE operational scenarios related to flow and two future climate time frames (Table E2-1).

Table E2-1
Scenarios Analyzed in the SEPA EIS to Evaluate Salmonid Impacts

FLOW RECURRENCE INTERVAL	MODELED FLOW YEAR	NO ACTION TIMELINE[1] (YEAR)			FRE FACILITY TIMELINE (YEAR)			
		CURRENT CLIMATE	FUTURE CLIMATE		CURRENT CLIMATE	CURRENT CLIMATE[3]	FUTURE CLIMATE	
2-year	2011	2020	2040	2080	Construction (2025)[2]	2030	2040	2080
10-year	2009	2020	2040	2080		2030	2040	2080
100-year	1996	2020	2040	2080		2030	2040	2080

Notes:
1. No Action includes the following elements:
   - Five habitat restoration projects in tributaries (2040 and 2080)
   - Tribal injunction culverts replaced (2040 and 2080)
   - Other implemented culvert replacements (2025)
2. Construction scenario is the same as the 2-year 2030 FRE facility except in regard to fish passage.
3. Assumes that construction conditions prevail for 5 years starting in 2025.

Only 2-year flows were modeled during construction, which is a limitation regarding the modeling approach and adds uncertainty to the model results. A worst-case scenario would be for a 10- or 100-year flood to occur during construction, which could impact fish species and habitat.

FRE Operational Scenarios

Alternative operations of the proposed project were based on 3 water year conditions designed to highlight the impact of the FRE facility on habitat conditions in the upper Chehalis River. The three flow recurrence intervals chosen represent typical seasonal flow (2-year) conditions, major flood (10-year), catastrophic flood (100-year), or recurring major flood scenarios (Table E2-2). The individual water years selected to represent these flow recurrence intervals were selected from water years 1989 to 2018 (October 1988 to September 2018) for which hourly data are available at the Doty gage (Hill and Karpack 2019).

The 3 water years were chosen to evaluate the impact of the proposed project on salmon and steelhead habitat conditions in the upper Chehalis River, and not to analyze the effects of flood conditions throughout the Chehalis Basin. The 2-year (seasonal) flow condition represented typical conditions that would occur during winter when the FRE gates would be open and no reservoir would be present. The major (10-year) and catastrophic (100-year) flood scenarios capture conditions under which the FRE gates would be closed and a reservoir formed above the FRE facility.

The hydrological conditions (flow and channel width) associated with the 3 water years were modeled using a Hydrologic Engineering Center - River Analysis System (HEC-RAS) model developed for the Chehalis Basin to evaluate river hydrology and flows associated with floods and flood retention. The Chehalis HEC-RAS model is based on the 30-year period of record (1989 to 2018) and represents the mainstem Chehalis River from the site of the proposed FRE facility (RM 108) downstream to the mouth of the Chehalis River. The HEC-RAS model could not be used to evaluate conditions above the proposed FRE facility or in any tributary of the Chehalis River because these areas are not part of the model. The EDT model is structured based on monthly (not daily) increments of time. Daily average flow and channel width data from the HEC-RAS model were converted into average monthly flow and channel width values for use in EDT. The implications of this are effects of the flood event, which is typically short in magnitude (approximately 1-3 days), are diminished when incorporated into a monthly time step in the analysis.

The 2-year flow recurrence interval represents normal winter flood conditions that fish in the upper Chehalis Basin would be exposed to during frequent (1- to 5-year recurrence) flows and where FRE facility conduits would remain open. Water year 2011 was selected to represent baseline conditions because there were numerous non-flood flow events that occurred during winter 2011 (Figure E2-3).

The 10-year flow recurrence interval represents a major flood scenario. Water year 2009 was selected to represent 10-year flood conditions because it contained one major flood (Figure E2-4) that would result in closure of the FRE facility and flood retention. Other years in the time series that contained a 10-year flood were not selected because there were two major flood events during those years, so those years were judged to be non-representative. Because of weather patterns in 2009, average monthly flow and channel width were less than that for 2011, the 2-year flow condition.

Water year 1996 was selected to represent 100-year flood conditions because it was the only 100-year flow recurrence interval year available from the hydrologic data set; it also contained one catastrophic flood (Figure E2-5) that would result in closure of the FRE facility and flood retention. Average monthly flow and channel width during the 1996 water year were higher than 2011 and 2009. Differences in average winter flow among the 3 water years modeled are shown in Figure E2-6 relative to the average winter flow for the 30-year period of hydrologic record.

The 3 flow years modeled do not represent a progression of increasing winter flow conditions but, rather, conditions that result in alternative operation of the FRE facility. The modeling approach, HEC-RAS model inputs, and water years used in the analysis were selected primarily to evaluate the effects of the Proposed Action (dam closed versus open) on salmonids. For example, 2009 was chosen to represent a condition that would trigger the closure of the FRE facility and result in the alteration of habitat conditions above and below the facility rather than its overall flow relative to other years. Water year selection affected average flow conditions. For example, average winter flow in 2009 used to represent a 10-year flood condition is lower than the average winter flow in 2011 chosen to represent the 2-year flood condition.

Because specific past year's water years were chosen to represent all 2-, 10-, and 100-year flood conditions, there is no variation in timing and duration of the flood events and no variation in flow conditions at other times of the year. The lack of variation in timing and duration of the flow events means that there is not variation in the life stage of the salmon and steelhead being affected by the flood event. In reality, in the future, variation in the timing and during of the flood events are very likely, which would result in different life stages of the salmon and steelhead being affected by the floods, which could result in greater or lesser impact to salmon and steelhead.

The water years selected are consistent with those used to develop streamflow and flooding estimates under future climate change conditions (Hill and Karpack 2019). Water year 2007 was not selected to represent 100-year flood conditions because that water year represented an approximately 250-year flow recurrence interval.

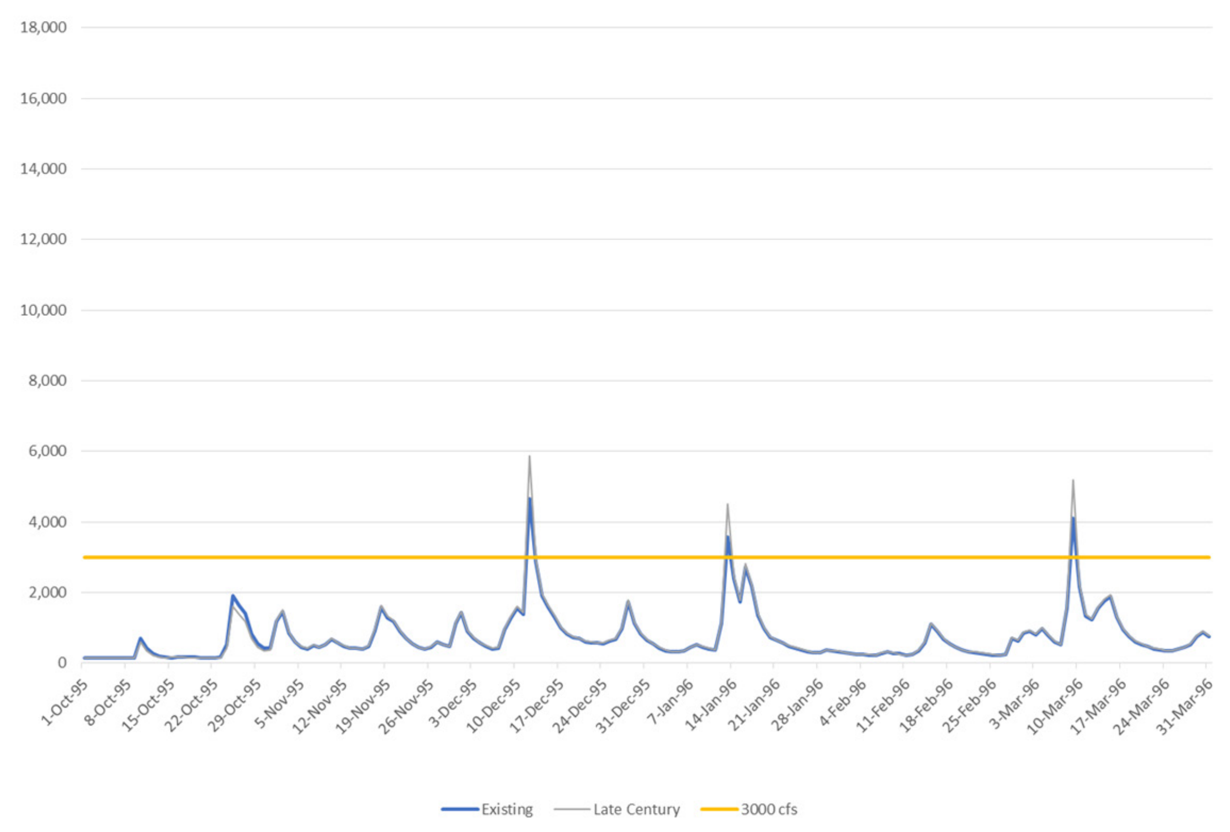
Table E2-2
Scenario Definitions Regarding Water Year and FRE Facility Operation[1]

SCENARIO	DEFINITION	RECURRENCE INTERVAL	MODELED WATER YEAR
Typical Seasonal flood	A high-flow condition that would not trigger an FRE facility closure	2-year	2011
Major flood	Water flow rate of 38,800 cfs or greater measured at the Grand Mound gage that would trigger an FRE facility closure	10-year	2009
Catastrophic flood	Water flow rate of 75,000 cfs or greater measured at the Grand Mound gage that would trigger an FRE facility closure	100-year	1996
Recurring flood	A major or catastrophic flood as measured at the Grand Mound gage that occurs 3 consecutive years in a row	3 consecutive 10-year floods	2009

Notes:
1. Under the Proposed Action it is assumed that a major high-water event eliminates the reproductive potential of populations spawning and rearing in the temporary reservoir area at that time.

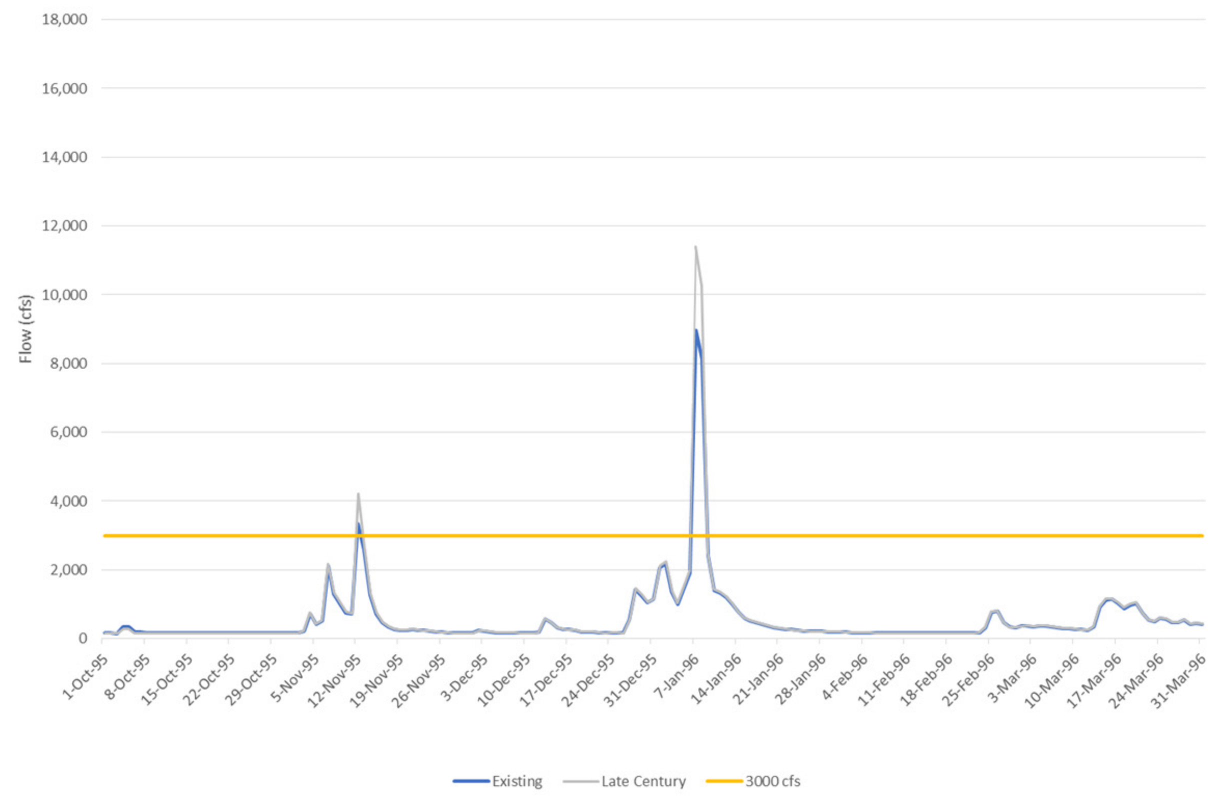
cfs: cubic feet per second

Figure E2-3
Daily Flow (cfs) for Water Year 2011 Representing a 2-Year Flow Condition



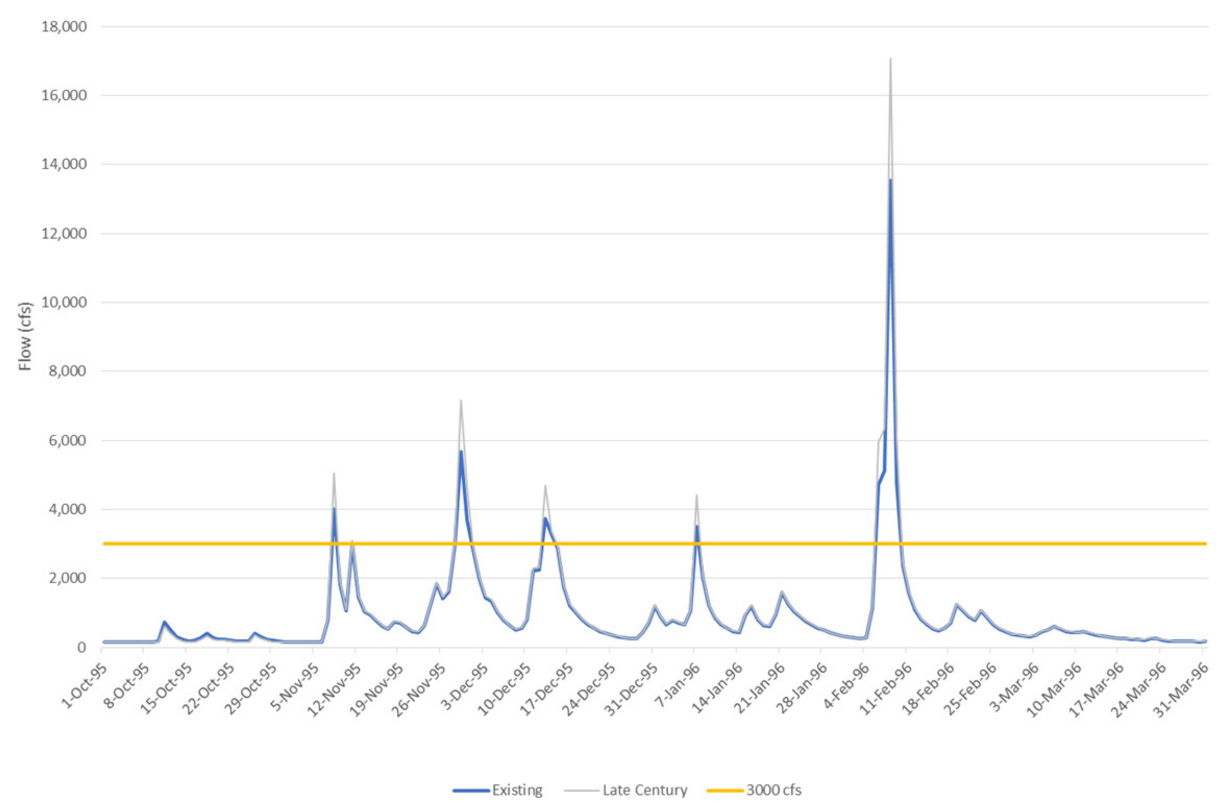
Note: The yellow reference line denotes the 3,000 cfs flow at which substrate mobilization resulting in bed scour occurs at the FRE facility location (3,000 cfs) (Dube 2019a).

Figure E2-4
Daily Flow (cfs) for Water Year 2009 Representing a 10-Year Flood Condition



Note: The yellow reference line denotes the 3,000 cfs flow at which substrate mobilization resulting in bed scour occurs at the FRE facility location (3,000 cfs) (Dube 2019a).

Figure E2-5
Daily Flow (cfs) for Water Year 1996 Representing a 100-Year Flood Condition



Note: The yellow reference line denotes the 3,000 cfs flow at which substrate mobilization resulting in bed scour occurs at the FRE facility location (3,000 cfs) (Dube 2019a).

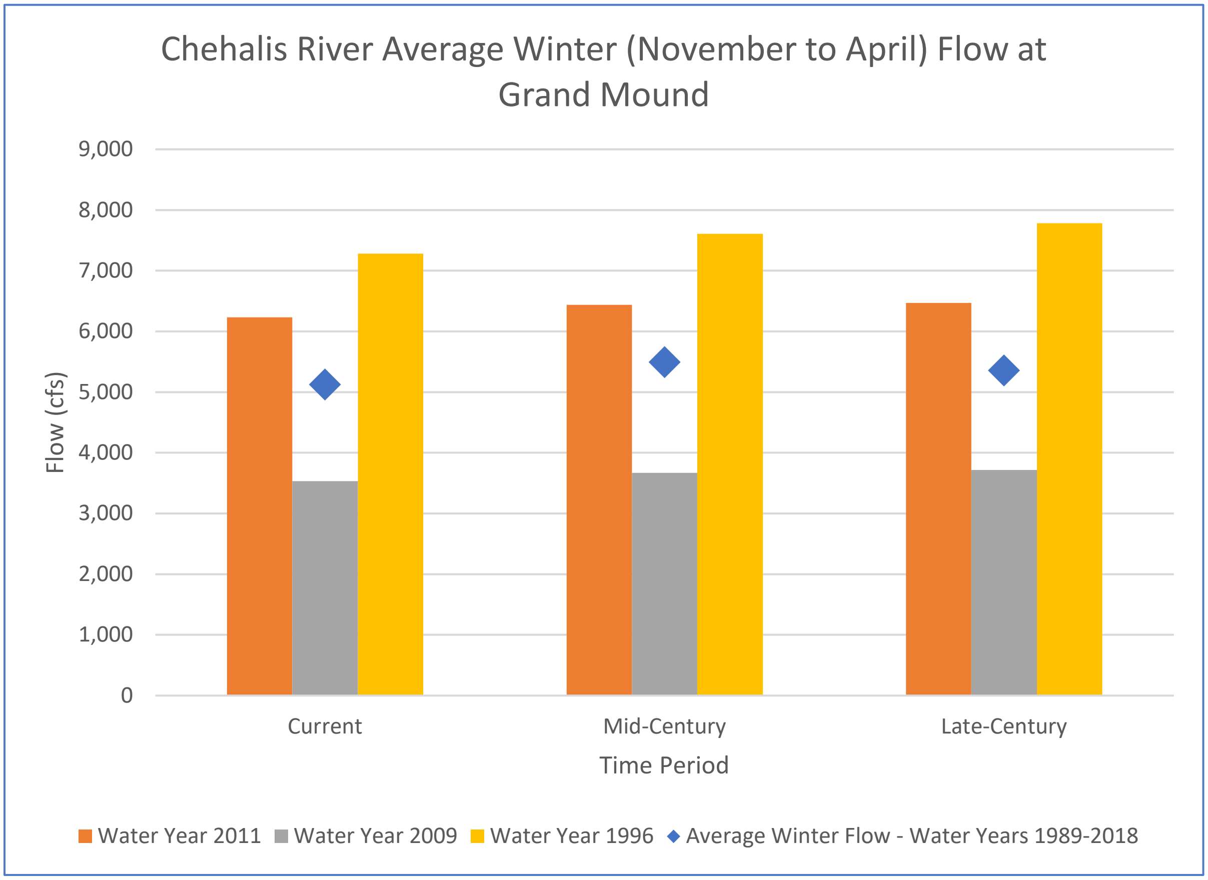
EDT model parameters in the two reaches above and below the proposed FRE facility were adjusted in response to changes in flow and dam operations (discussed below in the FRE Modeling Assumptions section; see Tables E2-6 to E2-8). An important difference between the three flow conditions modeled relates to the bed scour attribute in EDT that primarily affects the survival of eggs during the winter incubation period. While bed scour is recognized as an important issue affecting salmonid production (Goode et al. 2013) and is known to occur in the Chehalis Basin (Watershed Dynamics and Anchor QEA 2017), there are no scientific studies relating scour and fish survival in the Chehalis Basin. As a result, a hypothesis was developed to adjust current bed scour ratings in the EDT model to reflect presumed conditions in the major and catastrophic flood events (McConnaha and Ferguson 2019). Bed scour was assumed to increase with channel gradient and was increased in the Chehalis River above Elk Creek by 33% under the major flood scenario and 50% under the catastrophic flood scenario relative to the rating under a typical seasonal flow condition. These values were applied to the mainstem Chehalis River from Elk Creek to the confluence of the East Fork and West Fork Chehalis River because these reaches would be most affected by the Proposed Action and due to the increase in river gradient above Elk Creek. The bed scour values were not applied to the tributaries because the focus of the analysis was on the effects of the Proposed Action alternative in the mainstem Chehalis River. This significantly limits the overall impacts of floods on salmon and steelhead in the two modeled subbasins.

Analyses of changes in mainstem river water temperature associated with 2-, 10-, 100-year flow recurrence intervals were not available because this analysis was not conducted by Portland State University.

Overall, this analytical approach resulted in the following:

- Variation in precipitation patterns among water years analyzed, such as average flow during the 10-year flood being less than during the 2-year flow condition (Figure E2-6).
- Minor differences in average flows among the 3 water years modeled as a result of HEC-RAS model output having to be converted into monthly values for use in EDT and small differences in average channel width and thus salmonid habitat capacity among the water years analyzed.
- Effects of changes in flow being limited to the reach below the proposed dam (not the above-dam reach). Changes in hydrology associated with the 3 water years modeled were not available for tributaries in the Rainbow Falls to Crim Creek Subbasin or for the Above Crim Creek Subbasin.
- Bed scour associated with 10- and 100-year floods not being applied to the tributaries, which reduced impacts of flooding on salmon and steelhead.

Figure E2-6
Average Winter (November-April) Flow (cfs) Under Existing and Future Climate Conditions for the Three Water Years Modeled



Future Climate Conditions

Modeled future climate conditions represent projected conditions in mid- and late-century, which correspond to projected climate conditions in years 2031 to 2063 and years 2064 to 2099 in the integrated model, respectively (Table E2-1; Figure E2-7). In the EDT model these periods correspond to around 2040 and 2080, respectively. The term ‘around’ and the ranges in years modeled for the future climate periods are used because future climate predictions represent general periods of time, not specific years. Future climate conditions assumptions developed by the University of Washington Climate Impacts Group were incorporated into flow and temperature models to project changes to conditions in the Chehalis Basin (e.g., Van Glubt et al. 2017). The assumptions used to characterize conditions in mid- and late-century under future climate conditions are described later in the No Action Alternative section.

Changes in hydrology associated with future climate conditions were developed by Hill and Karpack (2019) for the mainstem Chehalis River from RM 108 to the mouth of the Chehalis River (as discussed above). The HEC-RAS model outputs are in the form of daily average flow and channel width for each year modeled. The daily flow and channel width data from HEC-RAS were entered into EDT as monthly averages. Estimated water temperatures associated with future climate are discussed below in the No Action Alternative section.

Future climate was assumed to increase bed scour as a result of stronger and more frequent winter storms. Bed scour was assumed to increase in all reaches of the Chehalis Basin with a gradient greater than 0.0017 by 8% by mid-century and by 21% by late-century (McConnaha and Ferguson 2019). The gradient criteria resulted in low-gradient mainstem reaches below Rainbow Falls and the lowermost reaches of major tributaries being excluded from increased effects of bed scour associated with climate change.

The approach outlined in Table E2-1 results in the following scenarios being modeled under current and future climate conditions:

- **No Action Alternative:** 2-year (water year 2011) hydrograph without the FRE facility but with current habitat conditions above and below the FRE facility as described in footnote 1 in Table E2-1.
- **No Action Alternative:** 10-year (water year 2009) hydrograph without the FRE facility but with current habitat conditions above and below the FRE facility as described in footnote 1 in Table E2-1.
- **No Action Alternative:** 100-year (water year 1996) hydrograph without the FRE facility but with current habitat conditions above and below the FRE facility as described in footnote 1 in Table E2-1.
- **FRE facility during construction:** 2-year (water year 2011) hydrograph without the FRE facility, with degraded 2-year conditions above FRE facility, and estimated fish passage survival through the FRE facility based on passage through the flow diversion tunnel. The flow diversion tunnel has been designed to provide sufficient capacity to prevent a backwater condition from developing upstream of the outlets for flows up to and above a required high fish passage flow (2,200 cfs) (CBS 2018). However, with increased river flow, surcharging would occur, and water would back up at the (upstream) entrance to the tunnel. Flow through the conduit is not regulated and the magnitude of the backwatered condition would depend on the storm event and would most likely be limited to hours or days. Velocity through the tunnel would exceed fish passage standards during flood events. This hydrograph was selected for modeling of the construction period because it contained no FRE facility closures or effects of a previous closure of the outlets. However, only considering the 2-year hydrograph is a limitation and uncertainty in the model as a worst-case scenario would be a 10- or 100-year flood, which could have impacts on fish species and habitat.

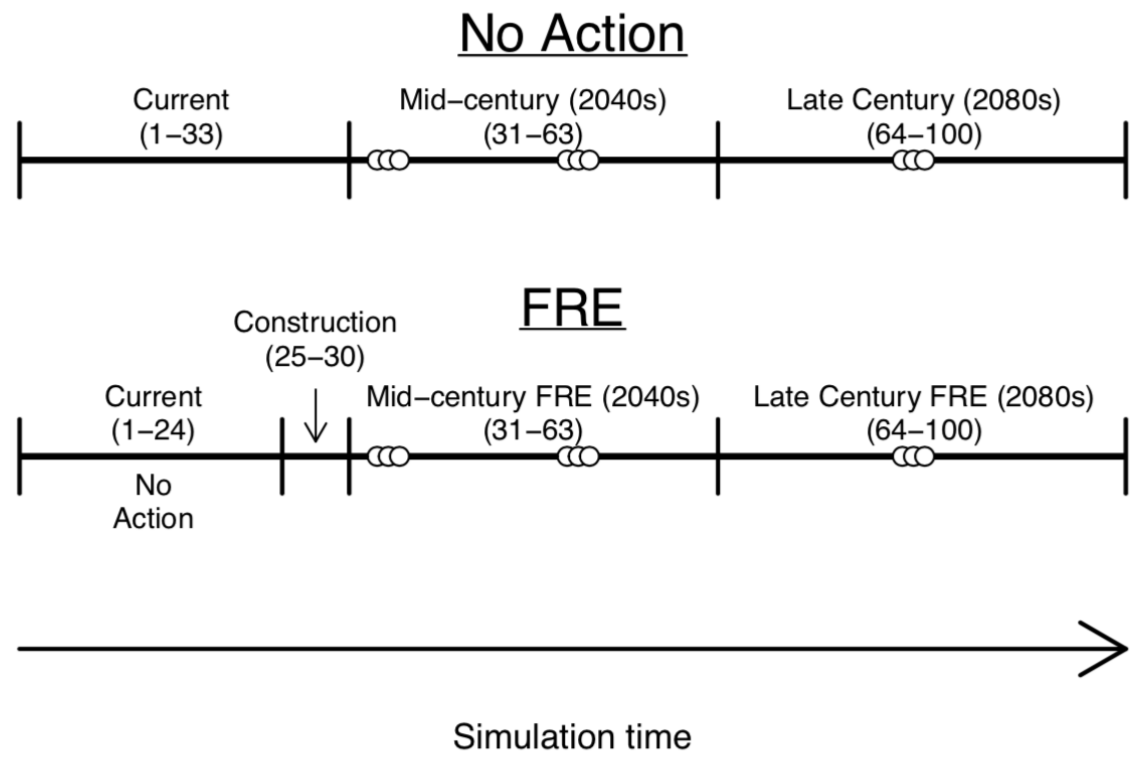
- **FRE during operation, 2-year flow baseline conditions:** 2-year (water year 2011) hydrograph with degraded 2-year conditions above and below FRE facility and with fish passage through FRE facility outlet conduits.
- **FRE facility during operation, major flood:** 10-year (water year 2009) hydrograph with degraded 10-year conditions above and below the FRE facility and with FRE facility fish passage via an adult salmon, juvenile salmon, lamprey, and resident fish facility.
- **FRE during operation, catastrophic flood:** 100-year (1996) hydrograph with degraded 100-year conditions above and below FRE facility and with FRE facility fish passage via an adult salmon, juvenile salmon, lamprey, and resident fish facility.
- **FRE facility during operation, recurring floods:** 10-year (2009) hydrograph with degraded 10-year conditions above and below FRE facility and with FRE facility fish passage via an adult salmon, juvenile salmon, lamprey, and resident fish facility repeated 3 years in a row; sensitivity runs conducted where the 3 years in a row occur early, middle, and late in the 2025 to 2080 period of analysis (LCM only).

Integrated Model Stochasticity

The integrated models use the outputs from EDT for the estimated conditions during current, mid-century, and late-century periods with and without the FRE facility. The EDT outputs, which consist of life-stage specific measures of productivity and capacity, were estimated under the conditions for the three representative flows (2-, 10-, 100-year events) and used as integrated model input parameters. As the integrated models were run, parameters were selected from either the 2-, 10-, or 100-year condition according to annually independent draws from their probabilities of recurrence. The probabilities of flow recurrence are the reciprocals of their expected frequencies (i.e., the 2- year flow recurrence probability was 1/2, or 0.50). The integrated models were run for 100 iterations for each scenario, where each iteration consisted of a 100-year simulation time sequence.

In each scenario that included the possibility of operation of an FRE facility, the construction period parameters estimated from the EDT model were applied in the integrated model to 5 sequential years to reflect the estimated construction period duration (2025 to 2030). The recurring flood scenario was applied near the early, midpoint, and endpoint of the simulation time sequence in each integrated model (Figure E2-7). The integrated model approach analyzed the Proposed Action and No Action alternatives with and without the recurring flood scenario. The alternatives modeled included current, mid-century (2040s), and late-century (2080s) climate conditions (Figure E2-7).

Figure E2-7
Time Series Modeled Using the Integrated Modeling Approach for the Chehalis Basin SEPA EIS Alternatives



By selecting future conditions probabilistically (i.e., based on the likelihood of a 2-, 10- or 100-year flood event occurring in any given year within the model run), the integrated model results display how variability in flow conditions through time affect the modeled abundance of salmon and steelhead associated with the Proposed Action and No Action alternatives. While the variability modeled is instructive in evaluating the effect of the alternatives, it incorporates only the variability associated with differences between the 2-, 10-, and 100-year flood events upstream and downstream of the dam site. This is only a portion of the total variability affecting the species. Variability due to changes in annual flows beyond the 3 water years modeled, freshwater life-stage survival, ocean survival, FRE facility passage survival, or other factors is not included in this analysis and may have additional effects on modeled fish performance.

No Action Alternative

The No Action Alternative (environmental baseline) scenario modeled using EDT included the following configuration:

- Changes to incorporate climate change in 2040 and 2080 were as follows:
  - New flow and channel widths in the mainstem Chehalis River were used based on hydraulic modeling conducted by Anchor QEA. Flows were adjusted in the HEC-RAS model based on the recommended adjustments in Hill and Karpack (2019) regarding reductions during dry months, increases during wet months, and large increases during high-flow events. The HEC-RAS model was re-run with the flow input changes from climate change, and channel widths were provided for the EDT model as an output of the HEC-RAS model based on the new flows.
  - Temperature for the mainstem Chehalis River used to represent current conditions was obtained from modeling conducted by PSU for 2013 and 2014 water year conditions (Van Glubt et al. 2017). Future mainstem temperature conditions were estimated in the PSU modeling by adjusting the PSU results for the 2014 water year by the projected change in air temperature between 2014 and the late 21st century based on Mauger et al. (2016).
  - Future temperature change for Chehalis River tributaries was identical to that used in the Phase I ASRP analysis (see McConnaha 2019). The Chehalis Thermalscape model (Winkowski 2019) was used to develop the information needed for the EDT ratings in the tributaries for the current scenario and was adjusted for future (2040 and 2080) temperature ratings using data from the NorWeST model (Isaak et al. 2017; McConnaha 2019).
- Land use degradation due to population growth in 2040 and 2080 as modeled in the ASRP was addressed as follows:
  - Estimated habitat degradation assumptions developed for ASRP for 2040 and 2080 were incorporated into the EDT model.
  - New areas of land use degradation identified by Ecology are small and insignificant in terms of their effect on EDT results; therefore, these new areas were not included in the analyses of the No Action Alternative.
- Removal of culvert passage impediments called for through the tribal injunction; these represent 24 culverts associated with state highways (12 were assumed to be removed by 2040 and another 12 by 2080); these were modeled similar to ASRP.
- Twelve culverts identified by the Chehalis Lead Entity as being removed during the 2017 to 2019 biennium that are within the spatial domain of the EDT model were removed in EDT by setting passage at these culverts to 100% in the model.

- ASRP early action habitat restoration measures funded in the 2017 to 2019 biennium were incorporated into EDT and include physical changes in habitat from the following restoration actions:
  - East Fork Satsop River, river mile (RM) 8.0 to RM 10.5
  - Wynoochee River, RM 13.5 to RM 15.0
  - Skookumchuck River, RM 18.6 to RM 21.6
  - South Fork Newaukum River, RM 10.9 to RM 13.0
  - Stillman Creek, RM 0.0 to RM 2.5
- Tree growth in managed forests is the same as what is being modeled for the ASRP for current and future (i.e., 2040 and 2080) conditions; this results in increased shade and decreased water temperature.
- Newly available information on the geomorphological characteristics of the upper Chehalis River for current and future (i.e., 2040 and 2080) conditions was incorporated into the EDT model for the following model attributes:
  - Bed scour (McConnaha and Ferguson 2019) in the mainstem Chehalis River only (not in tributaries)
  - Large wood (Dube 2019b)
  - Embeddedness of spawning gravels (Dube 2019b)
  - Fine (intra-gravel) sediments (Dube 2019b)
  - Maximum and minimum channel width (meters) from Anchor QEA HEC-RAS

FRE Modeling Assumptions

Fish Passage

Fish passage estimates incorporated into EDT to assess the Proposed Action are described in Attachment E-3. Juvenile and adult salmonid migrant survival estimates are shown in Table E2-3 and Table E2-4, respectively.

Table E2-3

Estimated Juvenile Salmonid Downstream Migrant Passage Effectiveness

SPECIES/RUN	CONSTRUCTION	OPERATIONS – NON-FLOOD RETENTION
Spring-run Chinook Salmon	0.85	0.85
Fall-run Chinook Salmon	0.85	0.85
Coho Salmon	0.85	0.85
Steelhead	0.95	0.95

Table E2-4
Estimated Adult Salmonid Upstream Passage Effectiveness During FRE Facility Operations (2030 to 2080)

SPECIES/RUN	NON-FLOOD RETENTION[1]	FLOOD RETENTION[2]
Spring-run Chinook Salmon	0.94	0.91
Fall-run Chinook Salmon	0.94	0.91
Coho Salmon	0.94	0.91
Steelhead	0.96	0.91

Notes:
1. Refers to conditions with FRE facility gates open and no flood storage. Data from Table 11-4 in CBS 2017.
2. Refers to conditions with FRE facility gates closed and with flood storage. Data from Table 11-5 in CBS 2017.

Adult fish passage effectiveness assumptions during construction were developed in coordination with WDFW based on information from picket weir installations and trap-and-transport operations used in Washington rivers of a similar size to the upper Chehalis River (Table E2-5).

Table E2-5
Estimated Adult Salmonid Upstream Passage Effectiveness during FRE Facility Construction (2025 to 2030)

SPECIES/RUN	TRAPPING EFFICIENCY*	HANDLING AND TRANSPORT TRUCK LOADING SURVIVAL	TRANSPORT, RELEASE, AND DELAYED MORTALITY	CUMULATIVE FISH PASSAGE EFFECTIVENESS (SURVIVAL)
Spring-run Chinook Salmon	0.85	0.90	0.80	0.61
Fall-run Chinook Salmon	0.80	0.95	0.85	0.65
Coho Salmon	0.35	0.95	0.95	0.32
Steelhead	0.50	0.95	0.95	0.45

Note:
* Including effects of fish moving downstream from weir.

FRE Dam Parameters

Tables E2-6 to E2-8 summarize assumptions incorporated into the EDT model to analyze the effects of the FRE facility on salmonids. Most physical habitat changes extend from the reaches including the temporary reservoir under the 10- and 100-year flood conditions downstream to Rainbow Falls. Changes to flow, channel width, and temperature extend downstream to an extent indicated by the hydrology models. Tables E2-6 to E2-8 summarize assumed conditions upstream and downstream from the proposed FRE facility during winter and the following summer when the FRE facility outlet gates are open (2-year flow recurrence interval), and during winter and the following summer in which the FRE facility gates are closed (10- and 100-year flood events).

The assumption was made that EDT is evaluating sustained, overwintering floodplain habitat that is accessible and available continually to juvenile salmonids for 4 months during winter. Episodic floods such as the 10- and 100-year events were assumed to have no effect on that sustained overwintering habitat. Habitat in EDT is characterized monthly across a year; habitat characteristics in the model describe the average or typical condition in each month. In the case of floodplain habitat, the need is to characterize the sustained winter habitat that supports juvenile salmonids. This was assumed to be the floodplain area that would be present and connected to the main channel (i.e., accessible by fish) across a 4-month winter period. As a result, episodic events such as a flood pulse that may last only a few days are not explicitly considered, although such a flood may change the average monthly flow and estimated channel width. The assumption is that a flood pulse may flood an expanded area for a few days but not provide sustained winter habitat needed to support juvenile salmonids.

Table E2-6

Assumed Winter (October to March) Conditions Affected by the Flood Retention Expandable Facility, Outlets in Open Position During 2-Year Flow

EDT ATTRIBUTE	HYPOTHESIS (RELATIVE TO CURRENT CONDITION)	ASSUMPTION	SOURCE	RATIONALE
ABOVE TEMPORARY RESERVOIR				
No change from current modeled condition for riverine reaches. Reaches assigned to riverine (no change) or affected by inundation determined by >50% of length in either category.				
WITHIN TEMPORARY RESERVOIR				
During a 2-year flow event we assume the FRE facility outlet gates would remain open and riverine conditions would be present above the proposed FRE facility. An area above the facility, delineated by the 10-year flood inundation extent, is assumed to be affected by the periodic inundations in other years during major and catastrophic floods. Within this area, habitat would be permanently degraded under the 2-year flow event condition at the start of the FRE facility construction: trees would be removed within the riparian zone and upslope—riparian function would be decreased and sediment would increase due to inundation during large floods.				
Spatial Extent		10-year flood inundation footprint		Riverine habitat would be degraded in the intervening years due to periodic inundation and permanent riparian removal. Assume 10-year flood inundation footprint.
Temperature	Modeled		PSU CE-QUAL-W2 modeling for PEIS FRO with reduced shading (Van Glubt et al. 2017)	Temperature conditions derived from modeling.
Channel Width	Unchanged for construction; changed for climate scenarios	Addresses channel area outside the small pool that can form upstream of FRE facility when high flows exceed the hydraulic capacity of the outlets when gates are open	Anchor QEA HEC-RAS modeling for: 2025: Existing-High-Flow-2-2011; 2040: Mid-Century FRE-High-Flow-2-2011; 2080: Late-Century FRE-High-Flow-2-2011	Modeled channel width varies with climate condition (mid- and late-century).

EDT ATTRIBUTE	HYPOTHESIS (RELATIVE TO CURRENT CONDITION)	ASSUMPTION	SOURCE	RATIONALE
Backwater Area at FRE Facility		Not included in FRE modeling	Montgomery 2019	Water is expected to briefly back up behind the FRE facility a short distance (less than 0.06 mile) for a duration of a few hours during peak 2-year flow events. Not analyzed.
Habitat Types	Unchanged		Hypothesis (Dube 2019b)	Dube advises that there would be little net change in habitat types above the FRE facility because habitat types in the reach are largely controlled by geology and natural channel constraints (rather than large wood).
Large Wood	Decreased	Decrease wood by 100%	Hypothesis. Based on *Proposed Flood Retention Facility Pre-Construction Vegetation Management Plan* (Ecology 2017, Appendix J)	Wood would be reduced 100%. The *Vegetation Management Plan* calls for removal of all wood within the temporary reservoir, even if it is derived from landslides. Based on this, all wood was assumed to be removed.
Bed Scour	Increased	Bed scour increased by 10%	Hypothesis	Large wood is a key attribute in reducing bed scour. Removal of large wood within the temporary reservoir should negatively affect bed scour. The exact amount of change is unclear, so scour was increased by 10%, but only in the mainstem (not in the tributaries).
Fine Sediment	Increased	Fine sediment rating within 10-year reservoir footprint increased by 10%	Hypothesis (Dube 2019b)	Dube advises little change in fine sediment above the FRE. While fine sediment will be deposited in the inundated reaches, redistribution of sediment will occur and result in little overall change. Assumed a 10% increase in fine sediment.

EDT ATTRIBUTE	HYPOTHESIS (RELATIVE TO CURRENT CONDITION)	ASSUMPTION	SOURCE	RATIONALE
Flow High Flow Low Flow Pattern	Modeled	Rate from Anchor QEA modeling	Anchor QEA HEC-RAS Modeling: 2025: Existing-High-Flow-2-2011; 2040: Mid-Century FRE-High-Flow-2-2011; 2080: Late-Century FRE-High-Flow-2-2011	Modeled flow pattern and ratings assumed. Likely little change from current conditions during free-flow periods with gates open.
Riparian Function	Decreased	Degrade Riparian Function rating within 10-year footprint by 75%.	Hypothesis. *Based on Proposed Flood Retention Facility Pre-Construction Vegetation Management Plan* (Ecology 2017, Appendix J)	According to the *Vegetation Management Plan*, all riparian forest would be eliminated along inundated reaches and upslope within the temporary reservoir; willows and shrub would develop. Resulting riparian will generally be young (less than 10 years old) willows and shrubs and emergent vegetation. Most or all woody vegetation likely to be killed during a 10-year inundation event and will reset to emergent after each event.
Food	Decreased	Degrade benthos ratings by 25%	Hypothesis	Benthic community would be disrupted by inundations, increased sedimentation, and increased temperature. Reduced input from riparian zone due to riparian changes. Young willows and emergent vegetation could supply some insects and leaf litter to stream.
BELOW FRE FACILITY				
Bed Scour	Unchanged		Hypothesis (Dube 2019b).	Dube advises no change in bed scour below the FRE facility in 2-year flood. FRE facility would have little effect on peak flows and bed scour during 2-year event.

EDT ATTRIBUTE	HYPOTHESIS (RELATIVE TO CURRENT CONDITION)	ASSUMPTION	SOURCE	RATIONALE
Large Wood	Decreased	Decreased by 10% down to Rainbow Falls	Hypothesis	Trash racks will block wood movement from upstream. Therefore, assumed a 10% decrease.
Riparian Function	Unchanged		Hypothesis	No modification to existing riparian is proposed below the FRE facility and no change was assumed.
Fine Sediment	Unchanged		Hypothesis (Dube 2019b).	Dube advises that while some fine sediment would settle out above the FRE facility and be mobilized during high winter flow, it would continue to be moved downstream and result in no net increase in fine sediment or embeddedness below the FRE facility.
Flow High Flow Low Flow Pattern	Modeled	Rate from Anchor QEA modeling	Anchor QEA HEC-RAS Modeling: 2025: Existing-High-Flow-2-2011; 2040: Mid-Century FRE-High-Flow-2-2011; 2080: Late-Century FRE-High-Flow-2-2011	Modeled flow pattern and amount is assumed. Likely little change from current conditions during free-flow periods with gates open.
Floodplain	Unchanged			Normal extent of sustained overwintering floodplain habitat that is modeled to assess salmonid productivity in EDT should not change with the FRE facility, which will only affect peak flows during winter floods.

Note:
These assumptions also apply to the construction period (2025 to 2030) during winter.

Table E2-7

Summer (April to September) for 2-Year, 10-Year, and 100-Year Flow Conditions, Outlets in Open Position

EDT ATTRIBUTE	HYPOTHESIS (RELATIVE TO CURRENT CONDITION)	ASSUMPTION	SOURCE	RATIONALE
ABOVE TEMPORARY RESERVOIR				
No change from current modeled condition for riverine reaches. Reaches assigned to riverine (no change) or affected by inundation determined by >50% of length in either category.				
WITHIN TEMPORARY RESERVOIR				
Summer conditions are assumed to be similar for the 2-year flow and 10- and 100-year flood events. Assumed that habitat within the temporary reservoir (defined by a 10- or 100-year flood) would be degraded due to the effects of periodic inundation, increased sedimentation, and removal of riparian forest due to vegetation management. Some recovery of habitat would occur in the intervening years. Summer conditions following a winter closure of the FRE facility (10- or 100-year event) are assumed to be the same as those for the 2-year flow event.				
Spatial Extent		All reaches encompassed by the 10-year inundation footprint for the 2- and 10-year scenarios and all reaches encompassed by the 100-year inundation footprint for the 100-year scenario		Summer habitat above the FRE facility would be degraded due to periodic inundation. Assume 10-year footprint extent for 2-year flow and 10-year flood conditions, and 100-year flood footprint extent for 100-year flood conditions.
Maximum Temperature	Increased		PSU CE-QUAL-W2 modeling for FRO with reduced shading (Van Glubt et al. 2017).	Temperature increased due to loss of riparian shade above FRE facility. Use PSU modeling of FRO for reduced shade. Same as used for the Programmatic EIS.
Channel Width	Modeled		Anchor QEA HEC-RAS modeling: 2025: Existing-High-Flow-2-2011; 2040: Mid-Century FRE-High-Flow-2-2011; 2080: Late-Century FRE-High-Flow-2-2011	Modeled channel width will not change with the climate scenario (mid- and late-century) because the spatial extent of the HEC-RAS model extended from the FRE downstream to the mouth of the Chehalis River and did not include the temporary reservoir.
Flow High Flow Low Flow Pattern	Modeled		Anchor QEA HEC-RAS modeling	Modeled flow conditions assumed.

EDT ATTRIBUTE	HYPOTHESIS (RELATIVE TO CURRENT CONDITION)	ASSUMPTION	SOURCE	RATIONALE
Riparian Function	Decreased	Decrease current riparian function by 75% within all impounded reaches	Hypothesis (based on input from Merri Martz and *Vegetation Management Plan*)	According to the *Vegetation Management Plan*, all riparian forest would be eliminated along inundated reaches, but willows and shrub would develop. Resulting riparian will generally be young (less 10 years old) willows and shrubs and emergent vegetation. Most or all woody vegetation likely to be killed during a 10-year or greater flood inundation event, so reset to emergent vegetation after each event.
Large Wood	Decreased	Degrade wood ratings by 100%	Hypothesis based on *Vegetation Management Plan* and WDFW	Wood would be reduced 100%. *Vegetation Management Plan* calls for removal of all large wood within the temporary reservoir, therefore assumed 100% degradation.
Fine Sediment	Increased	Fine sediment rating within 10-year reservoir footprint increased by 10%	Hypothesis	Dube advises no change in fine sediment above the FRE facility. While fine sediment will be deposited in the inundated reaches, some redistribution of sediment will occur and result in little overall change. Assumed small increase in fine sediment.
Habitat Types	No change	No change	Hypothesis (Dube 2019b)	Wood is not currently a dominant structural habitat element in the upper Chehalis River (habitat is mostly geologically formed). Hence, reduced riparian may not change summer habitats to the extent it is controlled by wood. Dube advises no change.
Food	Decreased	Degrade benthos ratings by 25%	Hypothesis	Benthic community would be disrupted by inundations plus increased fine sediment. Community composition may change due to loss of riparian function and increased

EDT ATTRIBUTE	HYPOTHESIS (RELATIVE TO CURRENT CONDITION)	ASSUMPTION	SOURCE	RATIONALE
				water temperatures. Reduced input from riparian zone due to riparian dominated by young willows and emergent vegetation that could supply insects and leaves to stream.
BELOW FRE FACILITY				
Below the FRE facility during a summer following a winter in which the FRE facility was not closed (i.e., 2-year flow event) conditions in the mainstem channel below the FRE facility would be affected by its presence and closures during other, high flow, winters.				
Maximum Temperature	Modeled (increased)		PSU CE-QUAL-W2 modeling for FRO with reduced shading (Van Glubt et al. 2017)	Removal of riparian forest above the FRE facility will decrease shade and increase summer temperature as captured in PSU modeling.
Flow High Flow Low Flow Pattern	Modeled		Anchor QEA HEC-RAS modeling	Modeled flow assumed. Likely little change from current flow pattern and amount during free-flow periods.
Channel Width	Modeled		Anchor QEA HEC-RAS modeling: 2025: Existing-High-Flow-2-2011; 2040: Mid-Century FRE-High-Flow-2-2011; 2080: Late-Century FRE-High-Flow-2-2011	Modeled channel width assumed.
Large Wood	Decreased	Decrease by 10% down to Rainbow Falls	Hypothesis	Trash racks will block wood movement from upstream, so a 10% decrease is assumed.
Fine Sediment	Unchanged		Hypothesis (Dube 2019b)	Dube advises no change to fine sediment. While some fine sediment would settle out above the FRE facility, it would be redistributed downstream with no net change.

Note:
These assumptions also apply to the construction period (2025 to 2030) during summer.

Table E2-8

Assumed Winter (October to March) Conditions above FRE Facility, Outlets in Closed Position During 10-Year and 100-Year Flood

EDT ATTRIBUTE	DIRECTION	ASSUMPTION	SOURCE	RATIONALE
ABOVE TEMPORARY RESERVOIR				
No change from current modeled condition for riverine reaches. Reaches assigned to riverine (no change) or affected by inundation determined by >50% of length in either category				
WITHIN TEMPORARY RESERVOIR (CLOSED POSITION): ASSUMED FOR ENTIRE PERIOD				
During winters in which the FRE facility gates would be closed to capture large storms (10- and 100-year floods), inundated stream and river areas would be converted to an inundation pool thereby eliminating all spawning within the inundated area. This condition will be assumed for the entire winter period.				
Spatial Extent		All reaches encompassed by the 10- or 100-year flood inundation footprint.		
Maximum Temperature	Modeled		PSU CE-QUAL-W2 modeling for Flood Retention and Flow Augmentation facility (Van Glubt et al. 2017)	Use PSU modeling for Flood Retention and Flow Augmentation reservoir.
Channel Width	Set by temporary reservoir to encompass littoral habitat area (less than 3 meters depth).		Anchor QEA HEC-RAS modeling: 2040, 10-Year: Mid-Century FRE-Major-10-2009; 2040, 100- Year: Mid-Century FRE- Catastrophic- 100- 1996; 2080, 10- Year: Late-Century FRE-Major- 10-2009; 2080, 100- year: Late-Century FRE- Catastrophic- 100- 1996	Useable reservoir area limited to area of littoral (less than 3 meters depth) to allow some downstream redistribution of juvenile salmon during inundation from upstream but limit the total extent of useful habitat.

EDT ATTRIBUTE	DIRECTION	ASSUMPTION	SOURCE	RATIONALE
Flow High Flow Low Flow Pattern	Modeled		Anchor QEA HEC-RAS modeling: 2040, 10 Year: Mid-Century FRE-Major-10-2009; 2040, 100 Year: Mid-Century FRE-Catastrophic- 100- 1996; 2080, 10 Year: Late-Century FRE-Major- 10-2009; 2080, 100 year: Late-Century FRE- Catastrophic- 100- 1996	
Riparian Function	Decreased	Decrease current riparian function by 100% within reservoir	Hypothesis	Riparian function eliminated within reservoir area.
Large Wood	Decreased	Decrease wood ratings by 100%	Hypothesis	Wood assumed to be eliminated from the reservoir and not have a riverine function.
Turbidity	Increased	Turbidity within temporary reservoir increased by 15%	Hypothesis	Turbidity within the inundation pool will increase due to resuspension of sediment.
Food	Decreased	Reduce food attributes by 75%	Hypothesis	No zooplankton would develop in the inundation pool; benthic food eliminated.
Habitat Types	Altered	All habitat types within inundated reaches shifted to littoral (less than 3 meters depth) and limnetic (greater than 3 meters depth) under an inundation scenario	Hypothesis	Assumption is that closure of FRE facility during 10- and 100-year events would eliminate all spawning within the temporary reservoir. Use of littoral allows movement across the inundated area and use by juveniles during winter but is not key habitat for spawning. Limnetic habitat assigned lower key habitat value for juvenile salmonids.

EDT ATTRIBUTE	DIRECTION	ASSUMPTION	SOURCE	RATIONALE
BELOW FRE FACILITY (CLOSED POSITION)				
Bed Scour	Decreased	Decrease by 33% down to Rainbow Falls	Hypothesis (Dube 2019b).	Dube advises a decrease in bed scour when FRE facility is used to capture peak storms.
Large Wood	Decreased	Decrease by 33% down to Rainbow Falls	Hypothesis (Dube 2019b)	Trash racks and active removal of all floating wood during drawdown will block wood movement.
Fine Sediment	Unchanged		Hypothesis (Dube 2019b)	Some fine sediment would settle out above the FRE facility but will be mobilized when winter flows are above 3,000 cfs when sediment begins to mobilize and the 10-year flood event when the FRE gates close and deposited below the FRE facility, which is not considered in the models
Flow Max Flow Low Flow Patten	Modeled	Rate from Anchor QEA modeling	Anchor QEA HEC-RAS modeling: 2040, 10 Year: Mid-Century FRE-Major-10-2009; 2040, 100 Year: Mid-Century FRE-Catastrophic- 100- 1996; 2080, 10 Year: Late-Century FRE-Major- 10-2009; 2080, 100 year: Late-Century FRE- Catastrophic- 100- 1996	FRE facility largely affects peak storm flow and has little effect on average maximum flow
Floodplain	Unchanged	Watershed Science and Engineering modeled floodplain for ASRP	Hypothesis	Normal extent of sustained overwintering floodplain habitat that is modeled to assess salmonid productivity in EDT should not change with the FRE facility, which will only affect peak flows during winter floods.

Modeling Uncertainties and Limitations

Two main types of uncertainty in the integrated EDT-LCM outputs include model uncertainty (accuracy of model form) and parameter uncertainty (accuracy of parameter estimates, including measurement error and extrapolation error). Sources of uncertainty in model structure include the following: 1) which aspects of life histories are represented or omitted; 2) which habitat effects are represented or omitted; and 3) the accuracy of equations used to represent habitat effects on life-stage parameters. Uncertainty in the parameter estimates used in the LCM can arise from natural spatial and temporal variation, extrapolation errors, and measurement errors, all of which influence the accuracy of parameters such as fish densities or productivity estimates. Thus, there is uncertainty associated with any forecast based on model studies.

The integrated model approach is intended to evaluate the effect of changes in habitat associated with the Proposed Action and No Action alternatives on potential fish production using only a subset of conditions that potentially affect fish production in the Chehalis Basin. As a result, the models are best used to evaluate relative changes in production between current and future conditions under the alternatives.

For the salmonid impacts modeling conducted for the SEPA EIS, the following limitations of the modeling approach and areas of uncertainty are acknowledged:

- The biological status of spring-run Chinook salmon in the Chehalis Basin, including current and historic distribution and pre-spawning behavior
- Uncertainties about spring-run Chinook salmon in the Chehalis Basin:
  - Spring-run Chinook salmon are difficult to distinguish from fall-run Chinook salmon in the field during abundance surveys. There is considerable uncertainty in recent abundance estimates for the species. Recent genetics studies suggest that spring-run Chinook salmon abundance in spawner surveys has likely been overestimated, making it difficult to gauge how well the integrated model is performing relative to empirical spawner counts.
- How habitat conditions above and below the FRE facility during construction and operation will change, including:
  - How fast will habitat recover from an FRE facility closure event?
  - What will habitat above the FRE facility look like through time?
  - How will downstream conditions change?
  - Will fish recolonize habitat after an FRE facility event, and if so, how quickly?
  - Will fish self-distribute downstream from the FRE facility during a closure and spawn successfully?
- Uncertainty associated with 10- or 100-year floods occurring during FRE facility construction (rather than 2-year floods, which is what is currently modeled). A 10- or 100-year flood during this period could have impacts on fish species and habitat.

- Uncertainty associated with fish passage estimates as noted in Attachment E-3.
- The effect of climate change on conditions in Grays Harbor and the ocean. Inclusion of these factors would affect the numeric estimates of fish performance under both alternatives. Annual variation in ocean conditions and ocean survival is a significant contributor to annual variation in spawner abundance for salmon and steelhead. It is not clear how climate change will affect salmon and steelhead survival in Grays Harbor and the ocean, although climate models suggest that ocean temperatures will likely increase in the future and increasing ocean temperatures may lead to reduced adult returns (Logerwell et al. 2003). For small or declining populations, this annual variation may result in populations going to very low numbers (or zero in some years), possibly resulting in earlier functional extirpation.
- In this analysis, effects of peak flow outside the project area were not modeled so that effects of the Proposed Action were easier to detect. This results in an underestimation of the functional extirpation of weak species, especially spring-run Chinook salmon. Inclusion of flood effects outside the project area may result in earlier functional extirpation of small populations (e.g., spring-run Chinook salmon) if that was to be modeled.
- Uncertainty in mid- and late-century conditions for peak flows, low flows, and stream temperature. There is considerable uncertainty in climate projections resulting from uncertainty in projected greenhouse gas emissions, as well as differences among climate models. While effect of this uncertainty can be evaluated in models (e.g., by using high and low estimates), this uncertainty cannot be reduced.
- Basic model uncertainties (life-stage representation, capacity estimates, survival estimates, changes in parameters due to habitat change, etc.), which are common modeling uncertainties.
- Uncertainty associated with conditions above the proposed FRE facility or in any tributary of the Chehalis River because the HEC-RAS model could not be used to evaluate these areas.
- Uncertainty in flooding impacts to flow and channel width because the EDT model is structured based on monthly (not daily) increments of time. The impacts of the flood events are diminished when daily flows are incorporated into a monthly time step in the analysis.
- Uncertainties associated with lack of variation in timing and duration of the flood events in 2-, 10-, and 100-year flood years; no variation in flow conditions at other, non-flood event, times of the year; and no variation in the life stage of the salmon and steelhead being affected by the flood event. Additionally, uncertainties due to actual differences in 2-, 10-, and 100-year flood conditions in the future have not been captured since specific water years were chosen as representative in the models.
- Uncertainty associated with the impacts of bed scour on salmon and steelhead survival in tributaries of the two modeled reaches as this was not include in the models (only impacts to the mainstem were included).
- Uncertainty associated with the fact that changes in hydrology associated with the 3 water years modeled were not modeled in the reach above the proposed FRE facility.

- Impacts due to changes in mainstem river water temperature associated with 2-, 10-, 100-year flow recurrence intervals are uncertain as these data were not available.
- Uncertainty associated with aspects of the project that were not considered in the modeling approach for areas downstream of the FRE facility:
  - Broad, long-term effects of a lack of channel-forming flows during floods
  - How a lack of flooding would impact channel width, fine sediment levels, floodplain maintenance and formation, and riparian structure and function

Modeled Variability

Variability refers to natural variability in habitat conditions or life-stage parameters, such as annual variation in flood magnitude and its effect on bed scour and incubation survival. Annual variation in habitat conditions affected by peak flows is currently incorporated into the model (e.g., the influence of annual variation in peak flow on incubation survival). Effects of the Proposed Action also vary as a function of peak flow (e.g., the dam is modeled as closed in years with 10-year and 100-year floods, but not the 2-year flow). Where such stochastic factors are included, such as these flow conditions, the integrated model results reflect the influence of these factors on variation in annual abundance and equilibrium population size and on the variation around the equilibrium population size. However, variability in other factors, including estimated FRE facility passage survival, freshwater life-stage survival (e.g., egg-to-fry survival), and varying ocean conditions affecting marine survival were not included in the models.

Results are reported as estimated mean equilibrium abundance of returning adults within a population over time. The year-to-year variability in modeled abundance is also shown in response to variation in estimated habitat conditions associated with the different flow scenarios and water years modeled (i.e., from the typical seasonal flows, major flood, and catastrophic flood conditions with and without the Proposed Action).

Airport Levee Changes

The proposed raising of the Chehalis-Centralia Airport levees was not evaluated using the integrated modeling approach. Analysis of the Proposed Action using EDT focused on the effects of the FRE facility on sustained habitat for modeled species that constitutes the normal winter habitat condition, not the conditions that exist under episodic flood events that inundate floodplain habitats and then quickly recede. Normal winter habitat in the model is that which exists for months at a time (4 months or more), at appropriate depths that juvenile salmonids can use (greater than 1 foot), and where access to floodplain habitat is maintained during the inundation period for access and egress. Raising the airport levee would affect in-river and floodplain conditions for a short period (days) during major or catastrophic flood events but would have no lasting effect on salmonid productivity using the analytical approach described above. This component of the Proposed Action was addressed qualitatively in the *Fish Species and Habitat Discipline Report*.

Local Actions Alternative

The Local Actions Alternative was not evaluated using the integrated modeling approach. This is because the actions being implemented have not been defined in enough detail to inform how they could be incorporated into EDT or where they would occur in the Chehalis Basin. This alternative was addressed qualitatively in the *Fish Species and Habitat Discipline Report*.

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Attachment E-3

Fish Passage Associated with the Proposed Action

FISH PASSAGE ASSOCIATED WITH THE PROPOSED ACTION (FRE FACILITY)

This attachment describes the estimates of salmonid fish passage performance that were incorporated into the Ecosystem Diagnosis and Treatment (EDT) model and the integrated modeling approach described in Attachment 2, along with a qualitative assessment of passage performance for additional fish species or life stages.

FRE Fish Passage Conditions and Criteria

The upper Chehalis River channel at the proposed FRE facility site is a rectangular channel incised in hard bedrock. At this location, river flow remains in the channel up to approximately 4,000 cubic feet per second (cfs); above that level, flow accesses a wider channel on an existing terrace. The narrow and deep rectangular rock channel currently creates river velocities well in excess of the 2-foot-per-second velocity guidelines for fish passage design (Barnard et al. 2013).

The FRE facility design incorporates flow velocity and depth through the outlet conduits that mimic the flow velocity and depth occurring through the existing river channel in this reach, although the length of the FRE outlet tunnels is longer than the existing bedrock canyon. Hydraulic modeling of the Flood Retention Only (FRO) facility's 240-foot-long outlet conduits conducted for the *Chehalis Basin Strategy Programmatic EIS* is assumed to result in (represent) the same effect of the FRE facility, and shows the outlet conduits would replicate the stream discharge and velocity rating curves of the current stream channel, even when flows exceed the high fish passage design flow of 2,200 cfs through river discharges of 4,000 cfs (CBS 2017a). Since the FRE outlet tunnels are longer than the FRO tunnels, these hydraulic conditions will need to be analyzed and verified. Differences in survival between large- and small-sized salmonids passing through the proposed FRE facility tunnels are expected to be minimal given the hydraulic conditions in the FRO conduits that were modeled and based on the literature that was reviewed.

NMFS (2011) provides recommended guidelines for upstream juvenile salmonid passage though fish ladders. For fish in the 45 to 65 mm size range, the guidelines include maintaining hydraulic drops below 0.13 foot at entrances and exits to passage facilities and water velocities between 1.5 and 2.5 foot per second (fps) for swim distance of less than 1 foot. For fish in the 80 to 100 mm size range, the guidelines include maintaining hydraulic drops below 0.33 foot at entrances and exits and water velocities between 3 and 4.5 fps for swim distance of less than 1 foot. The Washington Administrative Code for Fish Passage Improvement Structures (WAC 220-660-200) requires a maximum velocity of 2.0 fps through culverts greater than 200 feet in length.

During summer when juvenile salmonids move upstream and downstream through the site to access different rearing habitats (J. Winkowski and Zimmerman 2017), low river flow through the FRE facility sluice outlets would result in velocities within this recommended ranges for juveniles. The high fish passage design flow is 2,200 cfs. Hydraulic modeling conducted on the FRO design indicate the conduits replicate the natural stream discharge and velocity rating curves exhibited by the natural channel up through river discharges of 4,000 cfs. Additional hydraulic model analysis may be required during permitting to understand the effect of the increased length of the FRE facility tunnels compared to the FRO tunnels on hydraulic conditions within the tunnel, and relative to fish passage criteria over the full range of non-flood flows, to assess any impacts on the upstream passage of resident and salmonid fishes.

Quantitative Methods Used in the Analysis of the Proposed Action's Effects on Anadromous Salmonid Passage

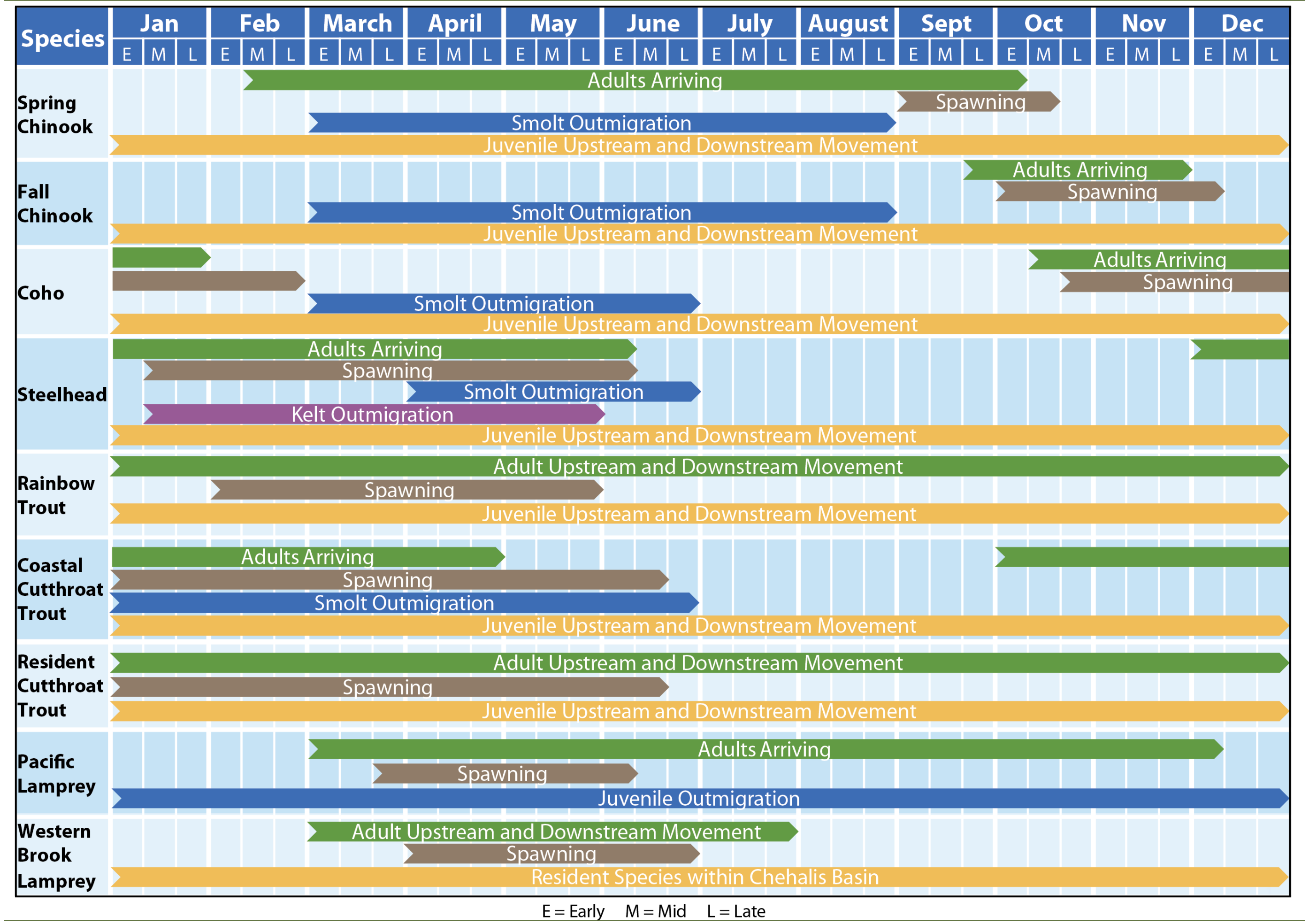
The quantitative methods used to assess the effects of the Proposed Action on salmonid passage through the project reach involved estimating fish passage survival for target species and life stages, incorporating the estimates into EDT, and running EDT under the alternatives (Proposed Action and No Action), time frames (Proposed Action construction and operation), and flow scenarios (2-, 10-, 100-year, and recurring) modeled. As described in Attachment E2, life-stage and reach-specific productivity and capacity outputs from EDT were input into NOAA life-cycle models (LCM) for spring-run and fall-run Chinook salmon, coho salmon, and winter steelhead to evaluate stochastic effects of the Proposed Action and flood retention events on salmonid population dynamics over time. . Anticipated migration periods of key fish species are shown in Figure E3-1.

Juvenile Salmonid Passage During FRE Facility Construction (2025 to 2030)

Downstream Passage Survival

Fish migrating downstream through the proposed FRE facility during construction would pass the site through a flow diversion tunnel. The tunnel is anticipated to be 20 foot wide and 20 foot high, horseshoe-shaped, and 1,630 feet long. It would be blasted through rock, lined with concrete, and designed to have a slope of approximately 1% that matches the grade of the existing channel at the FRE facility location (CBS 2018a).

Figure E3-1
Anticipated Migration Periods of the Targeted Species and Life Stages



Sources: Data from Wydoski and Whitney 2003, Holt 2019; figure adapted from Figure 2-1 in CBS (2018b). Figure depicts the potential range in the timing of migration and spawning events.

State and federal agencies require fish passage to be provided between the 95% and 5% exceedance flow values. This range was estimated to be from 16 cfs to 2,200 cfs at the FRE facility (CBS 2017a) and would result in water velocity within a smooth, hydraulically efficient tunnel ranging from 4 fps to 25 fps, respectively (CBS 2018a). While downstream fish passage through the diversion tunnel appears feasible, modifications to the tunnel design may be required to ensure flow velocities meet fish passage guidance and flow conveyance targets during construction (CBS 2018a).

Juvenile fish passage estimates developed for the FRO Alternative of the Programmatic EIS were reviewed. The Fish Passage Technical Subcommittee (Subcommittee) of the Flood Damage Reduction Committee reviewed fish passage information when developing the initial fish passage concepts for the FRO. Subcommittee participants included representatives from the Washington Department of Fish and Wildlife (WDFW), U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), Washington Department of Ecology (Ecology), Quinault Indian Nation, and the State of Washington Consultant Study Team (HDR and Anchor QEA). The Subcommittee met in 2017 to refine design criteria, obtain feedback on design modifications, and maintain agency concurrence on the preliminary design of fish passage facilities associated with the FRO dam alternative (CBS 2018b). The study included refinement of design criteria, preliminary level design development of a CHTR fish passage facility, and evaluation of costs for potential fish passage facilities that could accommodate passage of upstream migrating fish species, should a run-of-river-type dam be built. These activities were performed in collaboration with members of the Flood Damage Reduction Technical Committee, and in concert with numerous other physical and biological studies being performed as part of the Chehalis Basin Strategy to evaluate potential flood damage reduction and aquatic species habitat restoration strategies. The methods and meeting notes of the Subcommittee are documented in Appendix G of CBS (2017a); the conclusions of the Subcommittee are shown in Table E3-1. The Subcommittee did not estimate fish passage during FRO construction.

Fish passage facility performance estimates were made during development of the FRO facility alternative in the *Chehalis Basin Strategy Programmatic EIS* (CBS 2017d, Appendix G). The criteria used to design the FRO facility conduits were based on Washington State Water Crossings Design Guidelines (Barnard et al. 2013); NOAA Fisheries fish passage engineering criteria were also consulted (NMFS 2011). These estimates were developed for an operational FRO facility and were used when estimating passage through the FRE facility outlet tunnels because the FRE and FRO have similar outlet conduit design features and operation plans that would result in similar flows, water velocity, and gradients (CBS 2017a, 2017b, 2017c). One difference between the FRE and FRO facility outlets is their length: FRE outlet conduits are 310 feet long compared the FRO outlets, which are 240 feet long. Any effects on potential fish passage efficiencies associated with the longer FRE outlet conduits were not incorporated into the fish passage efficiency estimates for the FRE facility.

Table E3-1
Downstream Migrant Survival Estimates Developed by the Fish Passage Technical Subcommittee for the FRO and Adopted for the FRE Facility During Construction

SPECIES	OPERATIONS – NON-FLOOD RETENTION
Spring-run Chinook Salmon	85%
Fall-run Chinook Salmon	85%
Coho Salmon	85%
Steelhead	95%

NMFS (2011) states that water velocity in juvenile fish bypass conduits (i.e., channels and pipes) should be maintained between 6 and 12 fps for the entire operational range of bypass flow and must always be greater than 2 fps. If higher velocities are approved by NMFS, special attention to pipe and joint smoothness must be demonstrated by the design. NMFS expects that sediment deposits can accumulate within the bypass system when velocities are less than 2 fps.

Juvenile fish passage conditions and survival through the FRE facility diversion tunnel were discussed with a senior NMFS fish passage engineer (Ferguson 2019). The engineer stated that juvenile survival through such a tunnel would not be a concern to NMFS based on the low slope of the tunnel (1%), discharge from the tunnel directly reentering the river channel at grade without plunging into a stilling basin, and the assumption that there would be no protrusions into the tunnel or any pockets in the walls of the tunnels that developed as part of tunnel construction. To meet NMFS standards, any protrusions that formed during the concrete pour due to air pockets would have to be filled so the tunnel walls are smooth. The horseshoe-shaped configuration of the flow diversion tunnel eliminated NMFS's concerns over hydraulic discontinuities forming in the lower corners of a rectangular-shaped tunnel and the need to install fillets in the bottom corners of the channel.

The engineer also based NMFS's position on their experience with the Bonneville Dam Second Powerhouse Corner Collector (Corner Collector) on the Columbia River. In 2004, an ice and trash sluiceway at the powerhouse was reconfigured into a successful fish passage route that includes a 2,800-foot-long transportation channel flowing at 45 to 50 fps. The channel is concrete, rectangular in shape, and three sided. Flow from the forebay plunges over a leaf gate into the channel, and flow from the channel plunges into the dam tailrace. Ploskey et al. (2012) reported that survival through the Corner Collector was 97.5% (SE = 0.54%), 99.1% (SE = 0.46%), and 97.0% (SE = 0.01%) for acoustically tagged steelhead, yearling Chinook salmon, and subyearling Chinook salmon, respectively.

Survival rates selected for juvenile salmonids migrating downstream through the FRE facility during construction were identical to those developed by the Subcommittee and modeled for the FRO operation in the Programmatic EIS (CBS 2019a). This included 85% survival for spring-run and fall-run Chinook salmon and coho salmon, and 95% for steelhead (Table E3-1). These values are more conservative than the empirical estimates provided by Ploskey et al. (2012) for the Corner Collector because several additional factors during construction were considered. These included potential effects of vegetation removal in the reservoir footprint, water ponding upstream of the diversion tunnel during high-flow events, and debris accumulation at the entrance to the flow diversion tunnel.

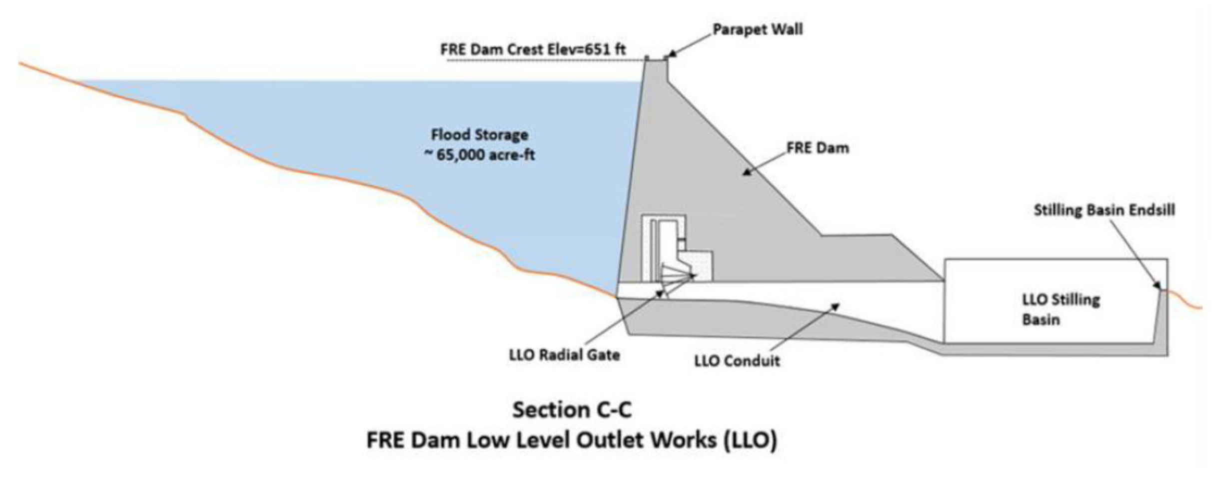
Although light conditions in the flow diversion tunnel will be dark a short distance downstream from the entrance, the survival values incorporate the assumption that juvenile fish will readily enter the diversion tunnel when migrating downstream with the current. This was based on the propensity for smolts to enter surface-oriented, high-velocity outlets at Columbia River dams (Johnson et al. 2005). Also, the FRE facility diversion tunnel would operate year-round and is run-of-the-river. This maintains hydraulic cues that help guide fish to the tunnel entrance and minimize passage delay for all life stages of downstream migrants, and it minimizes factors associated with mortality that commonly occur in impounded systems (Kock et al. 2019).

Juvenile Salmonid Passage During FRE Operation (2030 to 2080)

FRE Facility Outlet Design and Operation

The FRE facility outlet design is expected to include five low-level sluice outlets: a single 12-foot-wide by 20-foot-high sluice at invert elevation 408 feet, and two pairs of 10-foot-wide by 16-foot-high sluices with invert elevations of 411 feet located on each side of the larger center sluice (CBS 2018a). The sluice outlets are approximately 310 feet long (CBS 2017b; Attachment F, Appendix J). Two pairs of 10-foot by 16-foot sluice gates will control flow into parallel conduits separated by a center dividing wall terminating approximately 100 feet downstream of the gate seats. Downstream of the divider wall, the outflows from both gates combine into a 22-foot-wide by 16-foot-high single conduit. A parabolic drop of about 31 feet in the floor elevation of the sluice conduit transitions the discharge into the downstream stilling basin floor at an elevation of 377 feet (Figure E3-2).

Figure E3-2
FRE Facility Cross Section



Source: Figure 5-2 in CBS (2018a).

A full-height trash rack extending from the riverbed will prevent most large woody material from entering the sluice outlets. The larger sluice outlet in the center will be used to pass most of the bedload sediment in the river and most small debris. Some sediment is expected to pass through the smaller sluice outlets as well, but the center sluice with a lower invert elevation will intentionally receive the most wear from sediment passage over time (CBS 2018a).

The outlet conduits have been designed to provide sufficient capacity to prevent a backwater condition from developing upstream of the outlets for flows up to and above a required high fish passage flow (2,200 cfs) (CBS 2018a). However, as river flow increases, surcharging occurs, and water backs up at the entrances to the outlets. The FRE facility would typically allow water from all high-flow events up to about 12,500 cfs to pass through the facility without surcharging with the sluice gates fully open. When surcharging, flow at the entrances under these conditions transitions to a submerged inlet and orifice flow when the river elevation is between 445 feet mean sea level (msl) and 449 feet msl (CBS 2017a, Appendix B).

Anchor QEA hydrologists estimated the frequency and duration of pool-formation events for the FRE facility based on hourly flow data from 1989 to 2018 and projected changes in flow in mid- and late-century based on climate model downscaling analysis conducted by the University of Washington Climate Impacts Group (Table E3-2). The values shown in Table E3-2 are totals for each time period. The number of hours and proportion of time pools form by surcharging decreases from the current time period to 2040 and 2080 because the number of pools formed by flood retention increases as higher flows are increasingly captured (Anchor QEA 2019a, 2019b).

Table E3-2
Estimated FRE Facility Pool Formation Frequency and Duration, 1989 to 2018

	POOLS FORMED BY SURCHARGING ONLY		ALL POOLS (SURCHARGING AND FLOOD RETENTION)	
TIME PERIODS	HOURS OF POOL FORMATION	PROPORTION OF TIME (%)	NUMBER OF EVENTS	PROPORTION OF TIME (%)
Current	104	0.04	20	1.8
2040	87	0.03	27	3.8
2080	13	0.01	26	5.2

Estimated Downstream Passage Survival

Juvenile salmonid passage during FRE facility operations was assessed by reviewing juvenile fish passage estimates developed for the FRO in the Programmatic EIS (CBS 2017a), anticipated FRE facility operations, and relevant literature on fish passage through spillways and in laboratory studies under high-velocity conditions (CBS 2019a).

For the FRO, juvenile salmonids migrating downstream were expected to reside in the FRO reservoir during flood retention events for up to 32 days. Flow releases during the flood retention events would vary according to the operations plan developed for the FRO (CBS 2017c), and fish were expected to migrate out of the reservoir volitionally in flow discharged through the outlet conduits. The Subcommittee concluded that any temporary delay of the frequency expected was acceptable and providing temporary downstream passage during flood retention events was not required (CBS 2017a, Appendix G).

Operation plans have not been developed for the FRE facility and are assumed to be identical to FRO operations. Modeling efforts included climate change scenarios that are applicable to the Operations Plan, such as a maximum reservoir retention period of 35 days. During FRE facility impoundment events, flow releases are assumed to vary (CBS 2017c), and fish would migrate out of the reservoir volitionally in flow discharged through the outlet conduits. Between impoundment events, it was that assumed fish would readily enter and pass through the 310-foot-long FRE facility outlets set at grade and exposed to daylight at the entrance, similar to what was assumed for the 240-foot-long FRO sluice outlets and the 1,630-foot-long FRE facility flow diversion tunnel during construction.

Based upon the similarities between the FRO and FRE facility designs and the lack of a significant, compelling reason or basis to change from the previously developed estimates, downstream migrant survival estimates developed by the Subcommittee and used in the Programmatic EIS were incorporated into the EDT model to assess impacts associated with the proposed FRE facility during construction and periods between flood impoundment events (Table E3-3).

Table E3-3
Estimated Juvenile Salmonid Downstream Migrant Passage Effectiveness

SPECIES	CONSTRUCTION	OPERATIONS – NON-FLOOD RETENTION
Spring-run Chinook Salmon	85%	85%
Fall-run Chinook Salmon	85%	85%
Coho Salmon	85%	85%
Steelhead	95%	95%

Note:
The values represent fry (coho salmon) and actively migrating transitional or smolt life stages (Chinook salmon, coho salmon, and steelhead).

The values in Table E3-3 represent fry coho salmon and actively migrating transitional or smolt life stages of Chinook salmon, coho salmon, and steelhead. Most of the information on juvenile fish passage through conduits and over spillways comes from studies conducted at Columbia River dams where water velocities and shear forces are high. Typically, test fish used in laboratory or field experiments were yearling-sized fish than could be outfitted with radio or acoustic transmitters. More recently, with the downsizing of tags, the survival of subyearling Chinook salmon passing spillways has been evaluated; however, direct comparison of survival between these two size classes is not feasible due to different environmental conditions experienced during the spring (yearling) and summer (subyearling) passage seasons.

Differences in survival between large fish (parr and yearling smolts) and small fish (fry and subyearling smolts) through high-velocity passageways are difficult to quantify because several factors come into play: 1) smaller fish have less mass and do not have as much momentum when leaving a high-velocity jet; 2) smaller fish are less likely to be exposed to shear zones and impact objects due to their smaller size (R2 Resource Consultants 1998); and 3) the tissue of smaller fish is less developed and more likely to become injured, such as the operculum being caught in a jet and torn when the gill opens.

Differences in survival between large- and small-sized fish passing through the proposed FRE facility conduits are expected to be minimal given the hydraulic conditions in the conduits. Ruggles and Murray (1983) reviewed the literature on mechanical injuries to fish passing spillways and concluded that both small and large fish sustain some free-fall injuries if velocities exceed 52 fps. They noted that smaller fish are less likely to accelerate to velocities of this magnitude under free-fall conditions, and fish mortality in spillways and stilling basins is related to the form and concentration of energy dissipation. At large dams, structures are often placed in the path of spillway flow to dissipate energy and protect the foundation of the structure. Fish passing through the spillway flow are exposed to turbulence and high shear forces as energy is dissipated.

The FRE facility conduits would not be the same as spilling water over a spillway ogee, nor would flow pass over energy-dissipation baffles in the stilling basin. Rather, flow from the conduits would mimic the current river channel, and discharge from the conduits is expected to flow at grade through the FRE facility and enter a backwatered pool at the downstream base of the facility. Even if rapid deceleration conditions were present, fish injuries would not be a concern unless velocities were higher than has been estimated. R2 Resource Consultants (1998) reported that mortality rates were zero for larger-sized fish (20 centimeters in length) and smaller-sized fish (10 centimeters in length) when velocity was less than 66 and 58 fps, respectively. These data were developed in laboratory studies where juvenile coho salmon, Chinook salmon, and steelhead were ejected from a high-velocity jet into a static tank of water. Given this information, the proposed survival estimates in Table E3-3 were assumed to apply to all juvenile salmonid life stages.

Adult Salmonid Passage During FRE Facility Construction (2025 to 2030)

The CBS (2018a) report evaluated three alternatives for providing adult fish passage during construction. It ruled out constructing the permanent collect, handle, transfer, and release (CHTR) facility and using it to pass adult fish during FRE facility construction. Section 7.2.3 of the report described a temporary trap-and-transport facility that was analyzed as follows:

> *Temporary trap and transport (T&T) facilities are common to provide fish passage for projects that require extensive in-water work for long duration, such as what will be required for the FRE dam. The temporary T&T facility would be installed and begin operation prior to any other in-water work. The facility would be located far enough downstream of the diversion tunnel outlet such that river flow approaching the facility would be as calm and uniform as practicable. A temporary trap and transport facility would likely consist of a temporary barrier such as picket weirs or an inflatable dam with a fish ladder on the left bank that leads to holding ponds or holding tanks at the top of the bank where they could be easily accessed by transport trucks.*

The inflatable dam would require installing a concrete fish ladder and supplying the ladder with water at all times, making the inflatable dam option challenging from standpoint of both design and cost.

On March 21 and 29, 2019, representatives from Ecology, WDFW, and Anchor QEA met by phone to discuss and develop estimates for adult passage through the FRE facility during construction (CBS 2019b). The discussion focused on the effectiveness of temporary picket weirs because WDFW is familiar with this type of design and operates many of these facilities throughout the state, WDFW could provide data from these operations to inform the passage estimates, and WDFW would likely require this type of trapping system to be installed below the FRE facility to provide fish passage during construction.

The following assumptions regarding a picket weir operation associated with the FRE facility were identified:

- The trapping and transport operation will be conducted by WDFW or by an operator trained by WDFW who uses WDFW techniques and meets state standards.
- Access roads to the collection and release sites will be provided for truck and employee access and the transfer of fish from a live box to the transport truck.
- The trapping site has not been selected but is assumed to be located between the FRE facility site and the Weyerhaeuser office complex (within 1 mile of the site) next to Road 1000.
- To estimate total survival for the temporary trap-and-transport operation, the following components of survival were estimated, combined, and provided as one input to the EDT model:
  - Trapping efficiency
  - Transfer to trucks
  - Truck transport, release, and post-release survival
- The release site has not been selected but it is assumed that it will be located a short distance above the construction site (within 1 mile of the site).
- The following considerations were also assumed:
  - Transported fish will move downstream after release.
  - Steelhead kelts migrating downstream through the bypass tunnel will approach the picket weir from an upstream direction.
  - The weir design would provide a slot or "vee" to allow steelhead or other species migrating downstream to pass.
  - Flow events will occur at a magnitude that overtops (lays down) the pickets.
  - Fall-run Chinook salmon will move downstream after release and look for spawning habitat and will encounter the picket weir; therefore, the discussions also considered the availability of spawning habitat downstream of the picket weir.

Coordination call participants reviewed data from picket weir and trapping programs in the Baker River, Sunset Falls on the Skykomish River, Asotin Creek, North Fork Toutle River, White River, Cedar River, Elk Creek (Rogue River, Oregon), and various operations in southwestern Washington. Participants also discussed the available scientific literature on salmonid trapping and transportation.

Based on the assumptions identified above and a review of the effectiveness of existing trap-and-transport operations using picket weirs, the estimates of fish passage effectiveness shown in Table E3-4 were developed and provided as inputs to the EDT model.

Table E3-4
Estimated Passage Effectiveness for Adult Salmonids Upstream and Steelhead Kelts Downstream During FRE Facility Construction (2025 to 2030)

SPECIES/RUN	TRAPPING EFFICIENCY[1]	HANDLING AND TRANSPORT TRUCK LOADING SURVIVAL	TRANSPORT, RELEASE, AND DELAYED MORTALITY	CUMULATIVE FISH PASSAGE EFFECTIVENESS (SURVIVAL)[1]
Spring-run Chinook Salmon	0.85	0.90	0.80	0.61
Fall-run Chinook Salmon	0.80	0.95	0.85	0.65
Coho Salmon	0.35	0.95	0.95	0.32
Steelhead	0.50	0.95	0.95	0.45
Steelhead (kelts)	0.60	0.90	0.90	0.49
Cutthroat	0.10	0.95	0.95	0.09

Notes:
Cumulative fish passage effectiveness is the product of trapping efficiency, handling and transport survival, and release and delayed mortality.
1. Includes effects of fish moving downstream from weir.

It was noted that if not mitigated by best management practices, construction activities could create a behavioral deterrent for upstream migrating fish if vibration created by construction activities reaches levels that exceed background levels in the water column or water quality is affected by releases of turbid water.

Adult Salmonid Passage During FRE Facility Operations at Mid-Century (2030 to 2080)

In 2016 and 2017, the Subcommittee reviewed and discussed adult fish passage information when developing the initial fish passage concepts for the FRO alternative (CBS 2017a, Appendix G).

NMFS (2011) requires the high fish passage design flow to be the mean daily streamflow that is exceeded 5% of the time during periods when target fish species are migrating. WDFW (2000) suggests using a 10% exceedance flow as the high design flow. The 5% high exceedance flow was selected for use in designing the FRO conduits given that it is a more rigorous standard to meet. NMFS (2011) requires a low fish passage design flow equal to the mean daily streamflow that is exceeded 95% of the time during periods when migrating fish are typically present. WDFW (2000) recommends that a low flow should be established based upon site-specific conditions.

Non-Flood Retention Operations

The FRO conduit design was intended to provide year-round, safe, volitional upstream and downstream passage for migrating adult salmon and steelhead, resident fish, and lamprey for the full range of flow conditions up through the high fish passage design flow as required by the NMFS flow exceedance criteria (CBS 2017a). The criteria used to design the FRO conduits were based on Barnard et al. (2013), which suggests that a minimum hydraulic design target of 0.8 foot of water depth and a maximum flow velocity of 2 fps should be used for water crossing structures with lengths of approximately 200 feet. However, the Subcommittee determined that the natural flow characteristics in this river reach were more restrictive to passage than WDFW's guidelines, and concluded the proposed flow velocity and depth through the outlet conduits should mimic the flow velocity and depth occurring naturally through the existing river reach at the location of the dam. This premise influenced the overall approach toward designing and evaluating performance of upstream and downstream passage through the conduits.

Hydraulic modeling results indicated the FRO conduits replicate the natural stream discharge and velocity rating curves exhibited by the natural channel well above the high fish passage design flow of 2,200 cfs and up through river discharges of 4,000 cfs (CBS 2017a). The river at the proposed location of the FRE facility is a rectangular channel incised in hard rock. Flow stays in the channel up to approximately 4,000 cfs; above that level, flow accesses a wider channel on an existing terrace. The narrow and deep rectangular rock channel creates natural river velocities that are well in excess of the 2-fps fish passage velocity suggested by Barnard et al. (2013) for fish passage design. However, the Subcommittee agreed that mimicking the natural hydraulic conditions was the most appropriate approach for the design of the FRO conduits, in part because the incised rock channel would remain upstream and downstream of the dam after the dam is constructed.

Conditions in the FRE facility sluice outlets during non-flood retention periods would be designed to pass adult salmonids using the same approach and criteria used to design the FRO conduits. Therefore, estimates of adult salmonid passage effectiveness during non-flood retention FRE facility operations were assumed to be identical to those estimated by the Subcommittee for the FRO and used in the Programmatic EIS (Table E3-5).

Flood Retention Operations

The preliminary design of the CHTR facility fish passage alternative for collecting and passing upstream migrating fish is described in CBS (2018b). The facility was designed to pass adult salmonids, Pacific lamprey, resident fish, and juvenile salmonids through use of high- and low-flow entrances and separate ladders and holding facilities for the target species and life stages. Upstream fish passage facilities used during FRE facility operations would be identical to this design. Therefore, estimates of adult salmonid passage effectiveness during FRE facility operations were assumed to be identical to those developed by the Subcommittee for the FRO and used in the Programmatic EIS (Table E3-5).

Table E3-5
Estimated Adult Salmonid Upstream Passage Effectiveness
During FRE Facility Operations at Mid-Century (2030 to 2080)

SPECIES/RUN	NON-FLOOD RETENTION	FLOOD RETENTION
Spring-run Chinook Salmon	94%	91%
Fall-run Chinook Salmon	94%	91%
Coho Salmon	94%	91%
Steelhead	96%	91%

Source: Tables 11-4 and 11-5 (CBS 2017a).

Qualitative Assessments of Fish Passage

The post-spawn adult steelhead (kelt) life stage has not been incorporated into the EDT model, and therefore the effects of the Proposed Action on kelts was not modeled using the integrated modeling approach. Due to a lack of specific information on fish passage performance and quantitative models of fish passage for many resident fish, Pacific lamprey, and steelhead kelts, the effects of the Proposed Action on these species and life stages were estimated, and the estimates were used qualitatively to assess impacts of the FRE on these species.

Estimated Upstream Juvenile Salmonid Passage Survival During FRE Facility Construction and Non-Flood Retention Operation

The effects of upstream movements of salmonid parr through the FRE facility outlet conduits and into degraded habitat in the temporary reservoir inundation area were not addressed quantitatively using the EDT model. J. Winkowski and Zimmerman (2017) observed repeated upstream and downstream movements of tagged juvenile steelhead in the upper Chehalis River during summer within a 14.8-kilometer study reach that encompassed the proposed FRE facility site. The authors concluded that while home ranges for rearing salmonid parr during summer are often thought to be small, movements may be more prevalent than previously thought, and summer habitat should be defined by a network of suitable rearing reaches with connectivity available in both upstream and downstream directions. J. Winkowski and Zimmerman (2017) also observed that tagged juvenile Chinook salmon in the reach underwent a downstream migration and where most fish were detected once, and movement occurred on days with warmer stream temperature and higher flows.

Similar to the approach taken in designing the FRO conduits (Section 11.4.1.2; CBS 2017a), the FRE facility sluice outlets are expected to replicate the natural streamflow and velocities exhibited by the natural channel through which fish will pass at the FRE facility location, whether the dam is in place or not, up through river discharges of 4,000 cfs.

As described above, NMFS (2011) and the Washington Administrative Code for Fish Passage Improvement Structures (WAC 220-660-200) provide recommended guidelines for upstream juvenile salmonid passage though fish ladders. During summer when juvenile salmonids move upstream and downstream through the site to access different rearing habitats (J. Winkowski and Zimmerman 2017, low river flow through the FRE facility sluice outlets would result in velocities within these recommended ranges for juveniles. The high fish passage design flow is 2,200 cfs, and hydraulic modeling conducted on the FRO design indicates the conduits replicate the natural stream discharge and velocity rating curves exhibited by the natural channel up through river discharges of 4,000 cfs. Additional hydraulic model analysis may be required during permitting to understand the effect of the increased length of the FRE facility tunnels compared to the FRO tunnels on hydraulic conditions within the tunnel relative to fish passage criteria over the full range of non-flood flows to assess any impacts on the upstream passage of resident and salmonid fishes.

However, during construction it is unlikely that juvenile salmonids will move upstream into the 1,680-foot-long diversion tunnel. This conclusion is not based on empirical data but the assumption that juvenile salmonid parr would be hesitant to move upstream against the current into and through a long, dark tunnel, because the fish have had no exposure to this type of habitat in their evolutionary history. In addition, the installation and operation of a temporary picket weir installed in the river channel downstream of the FRE facility during construction to collect adult salmonids may act as a visual or behavioral barrier that inhibits the upstream movement of salmonid parr. The spacing between the pickets (open area) would need to be sized to impede, or allow, passage of jack salmonids (precocious male salmon that have generally spent one winter in the ocean) or small native fishes, based on permit discussions. There will be challenges in balancing weir efficiency and maintenance requirements because narrower spacings will result in increased maintenance requirements.

If not mitigated by best management practices, construction activities could create a behavioral deterrent for upstream migrating fish if vibration created by construction activities reaches levels that exceed background levels in the water column or water quality is affected by releases of turbid water.

If juvenile salmonid parr did move upstream through the dam construction site, they would access an area within the temporary reservoir inundation area where habitat quality has been degraded by tree clearing and vegetation removal as described in CBS (2016). J. Winkowski and Zimmerman (2017) reported that tagged juvenile steelhead underwent upstream and downstream movements up to 7 kilometers (4.3 miles). Therefore, it is unlikely that steelhead parr moving upstream through the FRE facility would move into habitats above the reservoir because the reservoir would extend on average 6.8 miles above the FRE facility site under a 100-year flood event in late-century with climate change (Anchor QEA 2019b). It is assumed that coho salmon parr rearing in the FRE facility construction reach would behave similarly. Therefore, for these species it was concluded that parr would be more likely to utilize habitats downstream from the construction reach (that are generally warmer) than upstream reaches.

During FRE facility non-flood retention operations, the 310-foot-long FRE facility outlet conduits would be partially lighted through ambient lighting at the entrances and exits to the conduits, they would be designed to pass juvenile salmonids, no construction activities would be occurring, and the temporary picket weir used during construction would be removed and replaced with a permanent CHTR facility. Based on professional judgment, the Subcommittee estimated that the overall performance (collection efficiency and survival to release) of juvenile salmonids moving upstream through the FRO conduits would be 64% for coastal cutthroat trout, spring-run and fall-run Chinook salmon, and coho salmon, and 79% for winter steelhead (Appendix G, Table 4-2; CBS 2017a). During FRE facility flood retention operations, a permanent CHTR located on the right bank would be operated. Most cutthroat trout observations within the project area have been in tributary areas, upstream of presumed anadromous fish barriers, and not within the vicinity of the proposed facility (M. Winkoski et al. 2016).

Based upon the similarities between the FRO and FRE facility outlet designs and the lack of a significant, compelling reason or basis to change from the previously developed estimates, upstream migrant survival estimates developed by the Subcommittee and used in the Programmatic EIS are assumed to represent conditions expected to occur in the FRE facility. However, additional hydraulic model analysis may be required during permitting to understand the effect of the increased length of the FRE facility tunnels compared to the FRO tunnels on hydraulic conditions within the tunnel relative to fish passage criteria over the full range of non-flood flows to assess any impacts of this change in the design on the upstream passage of resident and salmonid fishes.

In conclusion, construction of the FRE and its operation would **impact** the upstream movement of juvenile coho salmon and steelhead parr rearing in the FRE project area. This will impose some reduction in the productivity of coho salmon and steelhead parr rearing during summer in the project area due to reduced access to cooler, upstream habitats during construction and the occupation of lower quality rearing habitat below the FRE facility.

Estimated Upstream Juvenile Salmonid Passage Survival During FRE Facility Flood Retention

There would be no upstream movement of juvenile salmonids through the FRE facility outlet conduits during a flood retention event due to the closure of the gates. The conceptual design of the CHTR for the FRO/FRFA did not address the upstream migration of juvenile salmonids (CBS 2017a). However, the Subcommittee noted that juvenile salmonids will enter CHTR systems. Based on professional judgment, the Subcommittee estimated overall performance (collection efficiency and survival to release) for the CHTR would be 45% for coastal cutthroat trout, 50% for spring-run and fall-run Chinook salmon, and coho salmon, and 54% for steelhead (Appendix G, Table 4-4; CBS 2017a).

During development of the preliminary CHTR design, a juvenile fish, resident fish, and adult lamprey ladder entrance was incorporated into the CHTR to allow upstream passage of these life stages and species (CBS 2018b). The entrance was located adjacent to the northernmost adult salmonid entrance to the CHTR facility and at the downstream end of the stilling basin. It was located such that upstream migrating target species would encounter this entrance first and not have to swim past the three high-velocity entrances for adult salmonids to enter a low-velocity entrance.

The juvenile fish, resident fish, and adult lamprey ladder entrance was designed as a low-volume, low-velocity entrance for life stages and species with reduced sustained and burst swim speeds compared to adult salmonids. Inside the 6-foot-wide by 15-foot-high entrance would be a 33-foot-long by 21-foot-wide by 30-foot-high pool that connects the entrance to a juvenile fish ladder and two lamprey entrances. The juvenile ladder was designed to meet juvenile salmonid passage criteria. The lamprey entrances would allow adult lamprey to exit the pool and attach to the smooth surfaces of flumes and move up the flumes to holding tanks. This design incorporated the latest fish passage information and research from the Columbia River on lamprey passage facility design that provides lamprey with a surface to attach to, rest, and then detach and burst upstream and reattach to the smooth surface.

The Subcommittee did not update the estimated performance of the CHTR juvenile fish, resident fish, and adult lamprey based on the preliminary CHTR design (CBS 2018a). While a CHTR with a juvenile salmonid entrance would likely perform better than one without, there is little information on the actual performance of such an entrance. Rather than speculate as to its performance, it was assumed the performance was similar to that estimated by the Subcommittee for the original CHTR concept. This approach is conservative and increases confidence in the performance values selected, but also considers the uncertainties associated with how juvenile salmonids might use such a specially designed CHTR entrance below the FRE facility.

Passage is roughly 50% for these life stages and species, indicating upstream passage of juvenile fish during flood retention events would be adversely affected. However, these are low-frequency, episodic, and relatively short-duration events that occur during winter, a period of likely reduced parr and resident fish movements in an upstream direction compared to summer. Therefore, the overall adverse effect on the upstream movement of juvenile salmonids past the FRE facility during flood retention events would be **minor**.

Estimated Survival of Steelhead Kelt Migrating Downstream Through the FRE Facility

Steelhead are iteroparous and can migrate downstream as adults, re-mature in the ocean, and return to their natal stream to spawn again. Post-spawning migrations of steelhead are typically dominated by first-time kelts returning to the sea after their first spawning event and are thought to be more common in females (Nielsen et al. 2011). Despite the energetic costs associated with the post-spawn migrations, iteroparous fish are thought to contribute substantially to the genetic and demographic structure of some salmon populations (Nielsen et al. 2011).

The proportion of spawners that migrate downstream after spawning is relatively high. For example, Mayer et al. (2008) reported that approximately 54% of wild and hatchery pre-spawners were re-captured as kelts at a weir upon their out-migration following spawning in Asotin Creek in southeastern Washington. However, the proportion of kelts migrating downstream that survive to return and spawn again is low and varies across populations (Narum et al. 2008). Busby et al. (1996) reported that iteroparity (i.e., surviving to spawn again) is relatively uncommon in North American steelhead populations north of Oregon; results of scale analysis indicated that 91% of steelhead sampled in the Quillayute River were on their first spawning migration. The reason for the low survival is the energetic cost for fish of migrating upstream, spawning, and migrating downstream after feeding ceases upon entering freshwater. Penney and Moffitt (2014) found that between early freshwater entry and post-spawning (kelt) emigration, the lipid content of white muscle was reduced by 94% to levels less than 1% of wet tissue weight. They also state that lipid content was depleted more rapidly than protein during the reproductive cycle, and afterward provided the only remaining somatic energy source for the post-spawning migration downstream.

In general, few studies of kelt survival through dams have been conducted. However, Colotelo et al. (2014) captured a large number (n = 487) of steelhead kelts at Lower Granite Dam on the Snake River and implanted the fish with acoustic transmitters and passive integrated transponder tags. Survival through a 510-kilometer-long reach of seven dams and reservoirs and a portion of the Columbia River below Bonneville Dam was 38.4% (SE = 2.5%). Within individual river reaches, estimated survival per kilometer ranged from 95.8 to 99.9%. Overall, tagged fish passed through spillway passage routes at the dams in greater proportions and survived at higher rates compared to powerhouse routes composed of turbines and juvenile fish bypass systems. Estimated survival of tagged fish that passed via spillway weirs was 93.6% (SE = 1.6%) and 92.7% (SE = 1.8%) at Little Goose and Lower Monumental dams, respectively (Colotelo et al. 2014).

Given the relatively short length of the proposed FRE facility conduits compared to the spatial extent evaluated by the Colotelo et al. (2014) study, the generally high survival through spillways reported in that study, and the FRE facility sluice outlet design that mimics the existing river channel, kelt survival through the conduits is expected to be high.

However, three areas of concern exist regarding kelts passing the FRE facility when migrating downstream due to their depleted energetic state and overall poor condition: 1) injury or mortality if fish pass through debris collected on conduit trash racks; 2) kelts delaying in the temporary reservoir during flood retention events; and 3) fish approaching a temporary picket weir located downstream of the conduits installed during FRE facility construction to collect upstream migrating adult salmonids. The need to maintain clear trash racks during kelt migration periods will need to be discussed and evaluated in the future. The need to install slots to pass kelts migrating downstream through the pickets during late winter and spring after spawning was noted during discussions with WDFW staff on the effectiveness of picket weirs (CBS 2019b).

Based on the issues described above, the FRE facility would reduce the survival of post-spawn adult steelhead. The Subcommittee estimated that the survival of downstream migrating adult steelhead through the FRO conduits would be 75% (CBS 2017a). Overall, the effect would be reduced if debris collection on FRE facility sluice outlet trash racks is managed and not allowed to build up during the post-spawn migration period. Effects would be larger during FRE facility construction if impacts of construction on vibration and water quality are not adequately minimized, along with the potential effects of a temporary picket weir if not designed to pass kelts and due to the longer length of the flow diversion tunnel (1,630 feet) compared to the sluice outlets (310 feet). Overall, the FRE facility would have a **moderate impact** on the survival of downstream migrating steelhead kelts.

Upstream and Downstream Lamprey and Resident Fish Passage

The Subcommittee reviewed fish passage information when developing the initial fish passage concepts for the FRO (CBS 2017a; Appendix G). 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. The State of Washington interprets its regulatory authority (RCW 77.57.030) to require provision for passage of all fish and fish life stages believed to be present in the system. For the purposes of developing fish passage alternatives for the FRO, the Subcommittee selected anadromous and fluvial species known to be present within the influence of the FRE facility, in the inundation area of the associated reservoir, and upstream of the reservoir for both upstream and downstream passage (Table E3-6). These primary species and their known swimming and leaping abilities were used to influence fish passage technology selection and development of specific technical design criteria for the FRO.

Table E3-6
Target Fish Species and Life Stages Selected for FRO Design

SPECIES	UPSTREAM	DOWNSTREAM
Spring-run Chinook Salmon	Adult, Juvenile	Juvenile
Fall-run Chinook Salmon	Adult, Juvenile	Juvenile
Coho Salmon	Adult, Juvenile	Juvenile
Winter Steelhead	Adult, Juvenile	Adult, Juvenile
Coastal Cutthroat	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	Not applicable

Source: Table 11-1 (CBS 2017a)

The Subcommittee developed survival estimates for some resident fish species expected to pass through the FRO conduits (Table E3-7).

Table E3-7
Anticipated Fish Passage Performance of FRO Conduits

SPECIES	ADULT UPSTREAM	JUVENILE UPSTREAM	ADULT DOWNSTREAM	JUVENILE DOWNSTREAM
Coastal Cutthroat	92%	64%	78%	95%
Pacific Lamprey	96%	-	-	95%
Western Brook Lamprey	96%	-	-	95%

Source: Table 11-4 (CBS 2017a)
Note:
It was assumed that lamprey adults only migrate upstream, juveniles only downstream.

The Subcommittee estimated that the overall performance (collection efficiency and survival to release) for the CHTR would be 45% and 54% for juvenile and adult coastal cutthroat migrating upstream, respectively.

The Subcommittee, with support from the U.S. Fish and Wildlife Service representative, assembled relevant biological data for the target resident species as well as for lamprey and salmonids (CBS 2017a).

The Subcommittee was not able to find data on all target resident species. A summary of data compiled for each species is provided in Table 2-7 in CBS (2018b). The preliminary design of the CHTR facility accommodated the collection and transport of the resident species listed in Table 2-7 to the extent possible, without adversely affecting facility performance for listed priority species (salmonids, cutthroat trout, and lamprey). While information was collected on the swimming and leaping capabilities of the resident fish species listed in Table 2-7, information on the performance of resident species passing through FRO- or FRE-like structures was not located.

Given this background, the anticipated fish passage performance of the FRE facility conduits for fish migrating downstream was assumed to be similar to the FRO (Table E3-7). The entrances to the FRO and FRE facility conduits would be similar in terms of lighting, channel shape, and water velocity.

For resident fish migrating upstream through the FRE facility conduits, ambient light conditions at entrance to tunnels, and hydraulic conditions and sediment accumulations in the tunnels, should be similar between the FRO and FRE facility conduits. Any differences in resident fish passage performance between the FRO and FRE facility would result from the behavior of fish attempting to migrate through the longer FRE facility tunnels. This may alter behavior and cause fish attempting to migrate upstream to turn around, but the extent to which the additional length of the FRE facility outlet tunnels compared to the FRO outlet tunnels would cause this to occur is unknown. The difference is approximately 70 feet.

Uncertainty

The fish passage estimates reviewed and developed for SEPA EIS analysis are based on the most current regulatory guidance, scientific information, field experience, and best professional judgment available. However, uncertainties associated with the fish passage estimates described earlier include the following:

- In general, there is less uncertainty associated with passage estimates for salmonids than resident fish due to the greater amount of information available and design criteria developed for anadromous salmonids and their swimming capabilities.
- For anadromous salmonids, there is less uncertainty associated with estimates of the upstream passage of adults and downstream passage of juveniles through the FRE facility than with estimates of the upstream movements of juveniles through the FRE facility diversion tunnel or outlet conduits. This is primarily due to uncertainty regarding the behavior of fish moving against the current through the tunnel or outlet conduits.
- Overall, there is a high level of confidence that a CHTR facility would perform well for upstream migrating adult Chinook salmon, coho salmon, and steelhead (CBS 2017a). However, localized hydraulic conditions at the entrances due to site conditions may affect CHTR performance. Also, while the design of the low-velocity, low-flow entrance and interior ramps for lamprey, juvenile salmonids, and resident fish relies on the most current information available, the entrance

efficiencies of the design have not been tested and are based on information from other sites and professional judgment.

- The estimated performance of temporary trap-and-transport operations for adult salmonids during FRE facility construction is generally low. The observed performance would vary depending on flow conditions experienced each year, the location selected for the temporary trapping facility and hydraulic conditions at the selected location, the experience of facility operators, and effects of construction on the behavior of fish in the trap area.
- There is uncertainty associated with assumptions about how juvenile salmonids in the FRE facility reservoir would exit the reservoir after a flood retention event. The instinct of actively migrating fish is to continue to move downstream. Once they sense hydraulic cues associated with water exiting the reservoir, they are expected to sound and continue downstream (based on professional judgment).
- There is uncertainty associated with the passage of resident fish migrating upstream through the FRE facility diversion tunnel and outlet conduits due to a lack of basic information for many species on their swimming capabilities and behavior through these types of structures.

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