Appendix H
Support Documentation: Flood Retention Facility Long-term Impacts and Mitigation

FLOOD RETENTION FACILITY LONG-TERM IMPACTS AND MITIGATION

Purpose of this Support Documentation

During scoping and development of the Draft Chehalis Basin Strategy Programmatic Environment Impact Statement (EIS), a number of questions and comments were raised regarding specific operational details and associated impacts from the long-term operation of the Flood Retention Facility (e.g., dam and associated reservoir). Though Chapter 4 of the EIS provides a succinct summary of the significant impacts associated with this action element, this appendix provides a more detailed assessment of the range of impacts that could occur. Details on the operations of the Flood Retention Facility are included in the *Draft Operations Plan for Flood Retention Facilities* (Anchor QEA 2016a).

Background

Two different Flood Retention Facility types (a dam with and without a permanent reservoir) are being considered, as described in Chapter 2 of the EIS. The Flood Retention Facility would not protect communities from all flooding; however, it is intended to substantially reduce damages during major floods. Major floods are described as flows exceeding 38,800 cubic feet per second (cfs) at the Grand Mound gage located along the Chehalis River in Thurston County. This magnitude of flood has a 15% probability of occurrence in any year, which equates to a 7-year recurrence interval on average. The Flood Retention Facility would operate at and above the major flood stage in order to realize the most flood damage reduction benefit, while minimizing impacts on streamflow in the Chehalis River.

The proposed Flood Retention Facility would be located on Weyerhaeuser property, south of State Route 6 in Lewis County, on the mainstem Chehalis River about 1 mile south of Pe Ell. Ownership, operations, and maintenance of the Flood Retention Facility have not been determined at this planning-level stage of the process. Property acquisition within the Flood Retention Facility footprint and reservoir would be required, and the land would no longer be managed as commercial forestland.

The Flood Retention Only (FRO) facility consists of a dam that does not maintain a permanent reservoir. The dam would temporarily retain water in the event a major flood is predicted (once every 7 years; 15% probability of occurring in any given year). The Flood Retention Flow Augmentation (FRFA) facility consists of a dam with a permanent reservoir pool, which would include additional capacity to retain floodwaters in the event a major flood is predicted. Water stored in the permanent reservoir during winter would be released as needed (typically during spring through summer) to augment flows and reduce water temperatures in portions of the mainstem Chehalis River. Further details about each type of dam are provided in Chapter 2 of the EIS.

Impacts and Mitigation by Element of the Environment

Water Resources

Floodwaters would be retained in the reservoir when flows are predicted to exceed a threshold level of 38,800 cfs near Grand Mound (a major flood). The FRO facility would allow the Chehalis River to pass through unimpeded, except during a major flood or greater. Flows would be retained in the FRO reservoir during a major flood and emptied over a period of up to 32 days after the flood peak. The FRFA facility would maintain a permanent reservoir with extra capacity for flood retention when major floods occur. Flood Retention Facility flows and reservoir elevations modeled for a typical year, floods, and a dry year are illustrated in Figures H-1 through H-3.

The FRO facility would be designed to hold water back when major floods are predicted to occur. Figure F-1 shows the pool would be empty at 425 feet elevation (green line), and outflow (orange line) would be equal to inflow (blue line), except when flooding is predicted. When flooding is predicted (as shown in Figure H-1, Inset 1), outflow would be reduced to capture increasing inflow, thereby increasing the pool elevation. The reduction in flow would be 200 cfs per hour, a rate of change which would minimize fish stranding downstream of the dam. After the flood passes and inflow decreases, the reservoir outflow would be increased to draw down the pool at a rate that minimizes the landslide potential—while allowing higher flows to be discharged from the reservoir with the purpose of maintaining geomorphic processes to the Chehalis River downstream of the dam. When the pool is about 100 feet deep, outflow would be reduced to decrease the drawdown rate for debris management operations. After debris management operations have completed (approximately 2 weeks), outflow would be increased to resume the normal drawdown rate until the reservoir is empty.

The FRFA facility would be designed to augment flows and decrease water temperatures in the Chehalis River from the late spring to early fall, in addition to holding water during major floods. The FRFA has a conservation pool for flow augmentation that has up to a 40-foot range in depth (from elevation 627 to 587 feet [160 to 200 feet deep]) in a typical year. Flows vary from year to year, but, in general, outflows would be reduced in the late fall and early winter to refill the reservoir. Once the conservation pool was full, outflow would equal inflow. When inflow dropped below minimum releases, the outflow would maintain the minimum release and the conservation pool drawdown (see Figure H-1, Inset 3). As with the FRO, outflow is reduced to capture major floods using the flood pool of the FRFA reservoir (above 627 feet in elevation). If a frequently occurring flood (below the major flood level) occurs when the conservation pool is not full (see Figure H-1, Inset 2), the outflow would increase to equal the inflow, in order to allow these floods to maintain river processes (sediment movement and other channel-forming processes) downstream of the dam.

Figure H-1

Flood Retention Facility Flows and Reservoir Elevations in a Typical Year

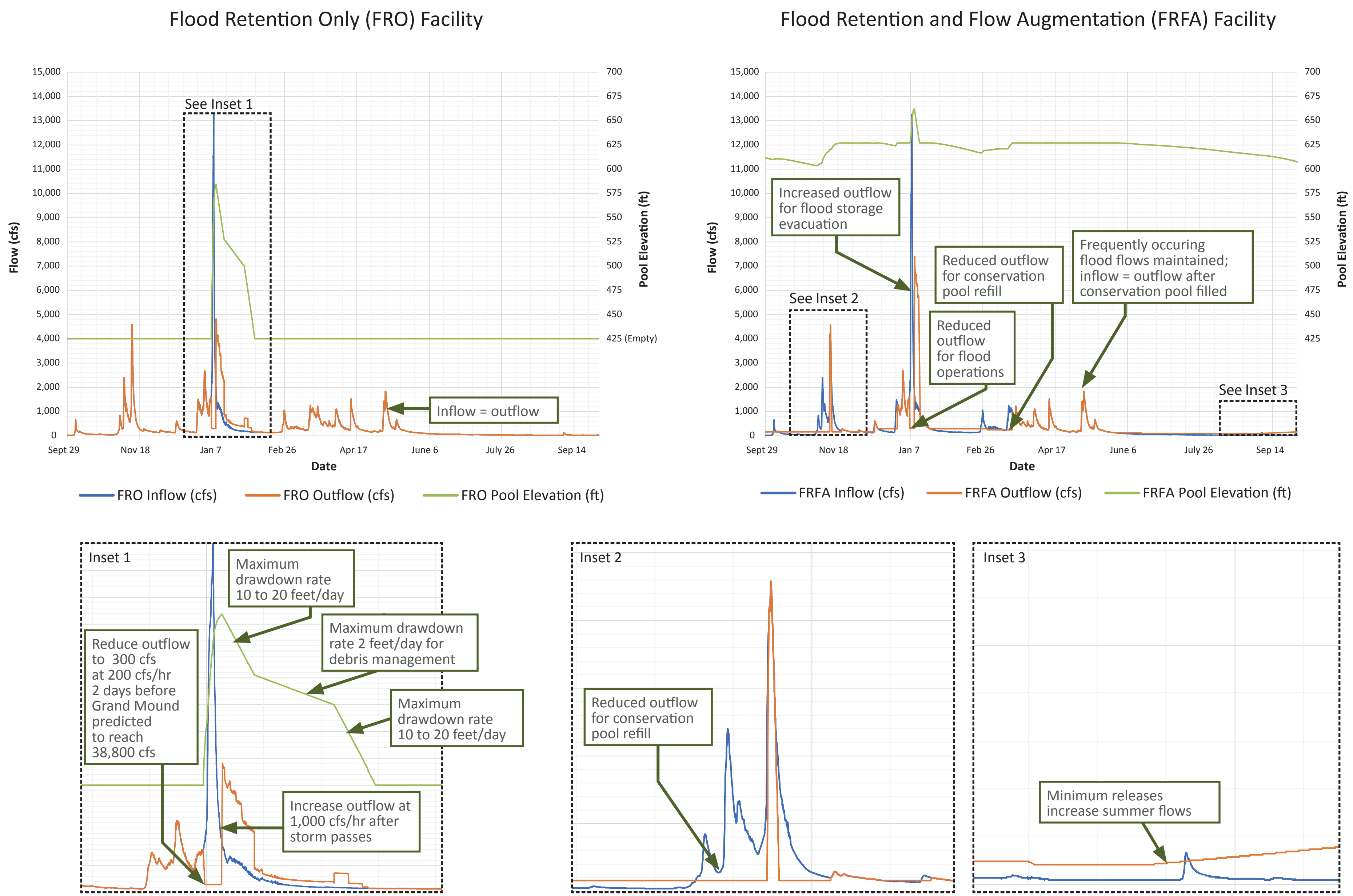
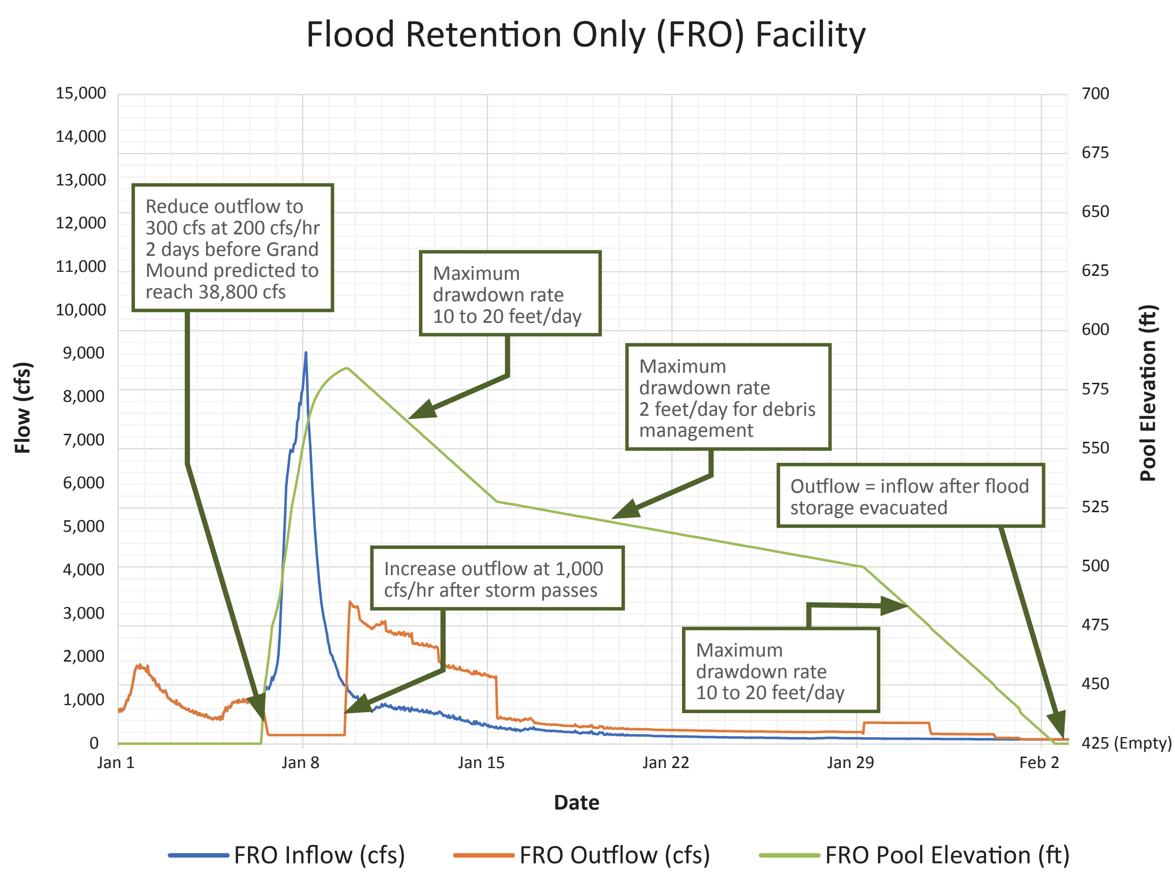


Figure H-2

Flood Retention Facility Flows and Reservoir Elevations in a Flood Event



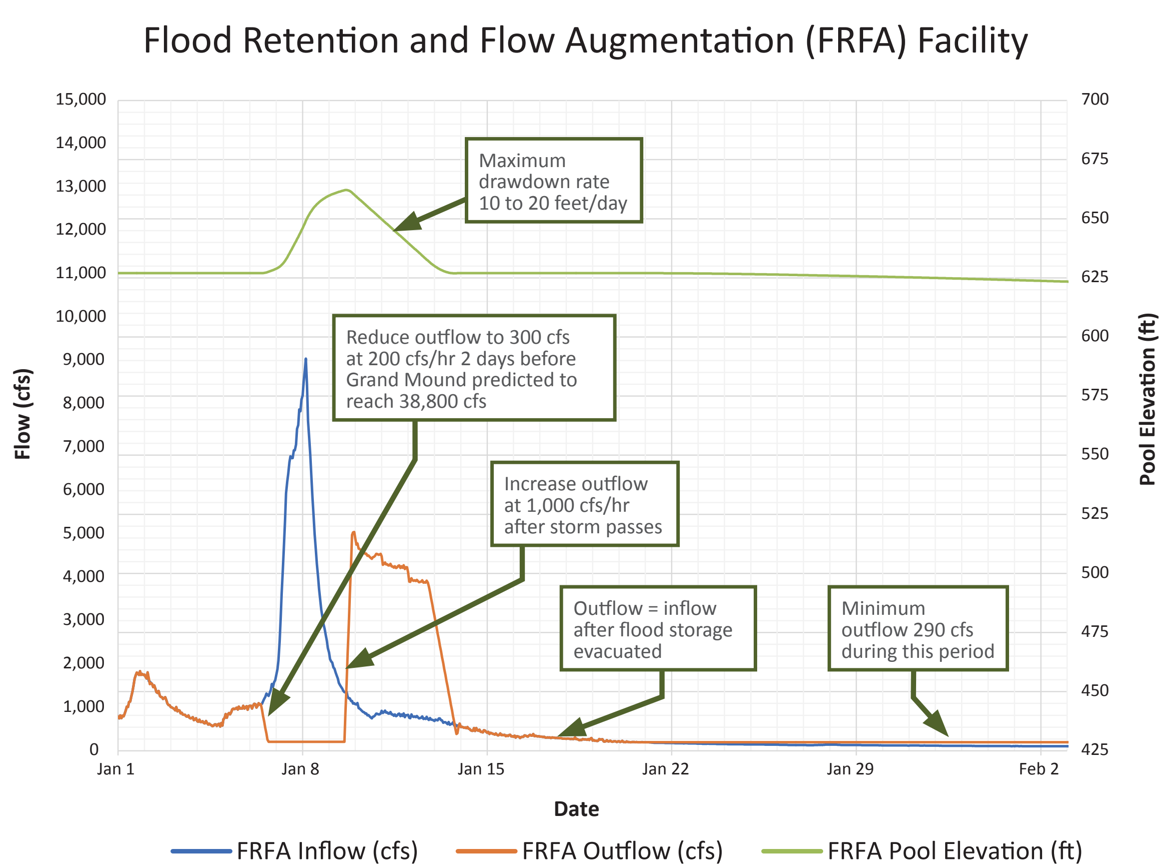
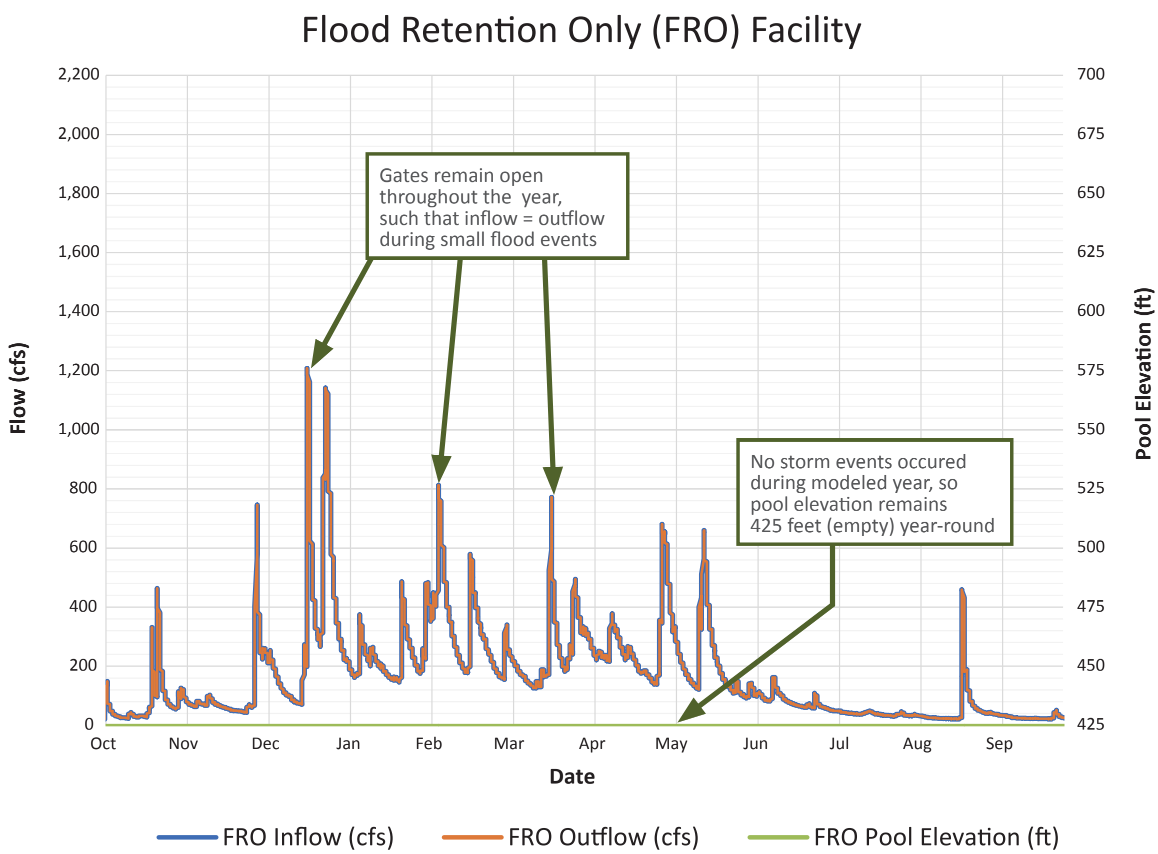
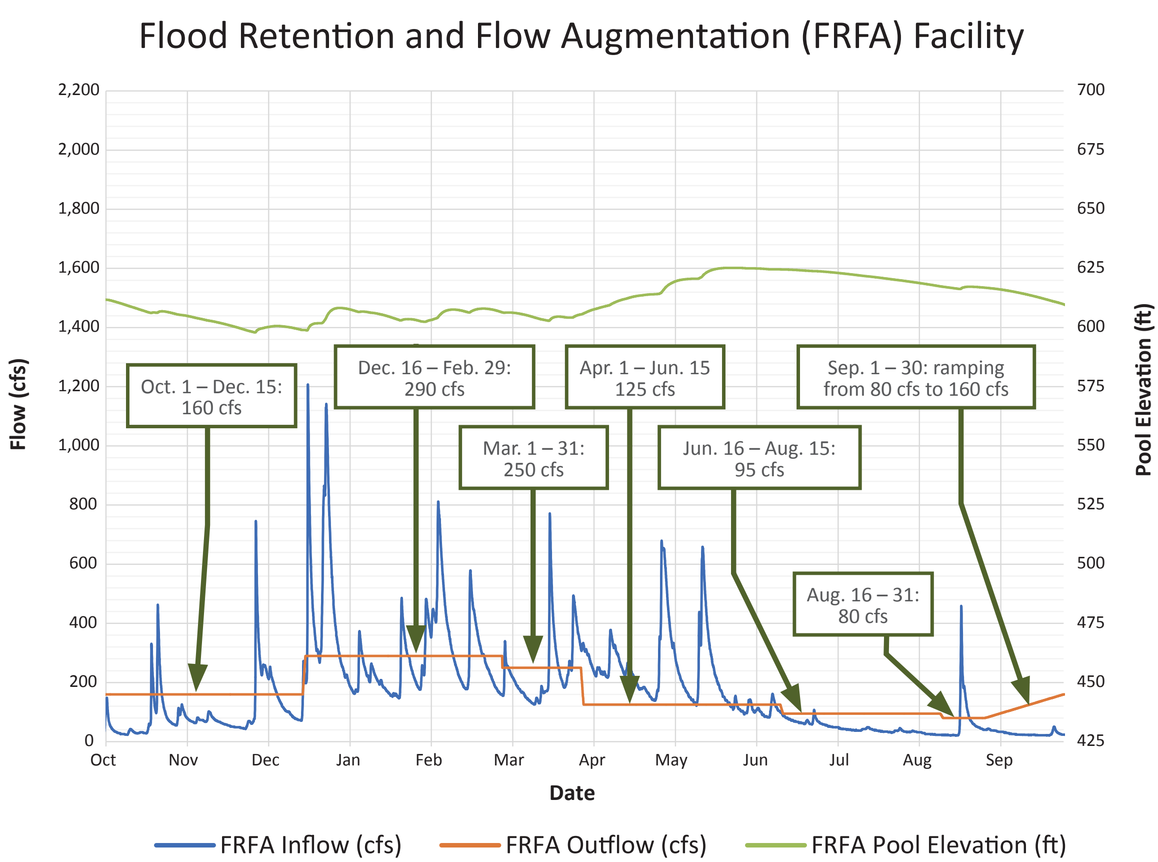


Figure H-3

Flood Retention Facility Flows and Reservoir Elevations in a Dry Year





Sediment and Turbidity

For both the FRO and FRFA facility, sediment could be generated by surface runoff from exposed slopes along the reservoir footprint, along the shoreline from erosion at the reservoir waterline, and within the segment of the Chehalis River upstream of the reservoir where dynamic channel conditions would result from the fluctuating reservoir elevations. The area within the conservation pool of the FRFA reservoir and areas within the reservoir footprint of the FRO dam would be cleared, and fluctuating reservoir levels would expose bare soils to erosion. Vegetation in the flood storage pool of the FRFA and FRO facilities would be managed to create different zones—the makeup of which would depend on the frequency and duration of inundation. Fine sediment previously deposited in the reservoir area could be resuspended when reservoir water levels rise or fall, increasing suspended sediment and turbidity in the reservoir pool.

Higher levels of sediment (than existing conditions) could be delivered to a temporary or permanent reservoir area from potential landslides triggered by water retention. For the FRFA facility, the conservation pool would permanently trap some fine sediment, which would settle on the bed of the reservoir.

For both the FRO and FRFA facilities, the potential exists for prolonged, controlled releases of turbid water as the reservoir draws down after a major flood (occurrence once every 7 years on average). That drawdown period could last up to 32 days (Anchor QEA 2016a). However, for both configurations, some fine sediment would be trapped during the flood retention period, and would reduce the overall quantity of suspended sediment released downstream during periods of major floods compared to existing conditions. For the FRO facility, high flows that occur outside of flood retention periods could erode previously deposited fine sediment in the reservoir. This could cause higher rates of suspended sediment to be released than under existing conditions, which could create more frequently occurring turbid conditions in the Chehalis River. The rate of suspended sediment releases from the reservoir would be greater in the years immediately following flood operations and the removal of vegetation.

For the FRFA facility, sediment would not likely be resuspended because the reservoir would not be drawn down to its previous bed level. This would reduce the amount of suspended sediment released from the reservoir outside of the flood retention period. The average residence time of water in the FRFA facility would be 84.6 days (Anchor QEA 2016b).

Turbidity in the nearby Skookumchuck River below the Skookumchuck Reservoir has been identified by the Washington Department of Fish and Wildlife (WDFW) as an issue because it impairs the ability to conduct adult fish spawning and fish snorkel surveys. The average residence time of water in the Skookumchuck Reservoir is 64 days, which indicates that the FRFA reservoir may produce less turbidity in the Chehalis River than is experienced in the Skookumchuck River because of the longer predicted residence time in the FRFA reservoir.

Temperature, Dissolved Oxygen, and Nutrients

Reservoir Area

Within the reservoir areas of the Flood Retention Facility, streamside vegetation that could not withstand periodic inundation (such as conifers) would be removed along the Chehalis River and its tributaries. Remaining streamside vegetation (tree canopy as well as understory vegetation) around the shoreline may not provide effective shade to reduce solar radiation and heat loading to the stream and reservoir surfaces. Increases in water temperature could occur upstream of the Flood Retention Facility during the spring, summer, and fall.

The reach of the Chehalis River upstream of the FRO facility would continue to flow unimpeded outside of major floods and the associated inundation period. However, the potential exists for increased sedimentation within the inundation footprint to cause the river channel to become wider and shallower, leading to an increased rate of heating compared to current conditions. Upstream of the FRO dam, water temperature in the Chehalis River would be expected to increase in late spring, summer, and early fall because increased solar radiation would heat water that flows through the reservoir area where riparian vegetation had been removed. Increases in water temperature are predicted along the mainstem Chehalis River and in the tributary areas cleared as part of the vegetation removal for FRO dam operations. In the mainstem Chehalis River, temperatures are predicted to be 2 to 4˚C higher than baseline conditions at the dam location (river mile [RM] 108.6), and 1˚C higher than baseline upstream at RM 114 (see Figures H-4 to H-9). These figures present the temperature results as the 7-DADMax. State water quality criteria apply to the 7-DADMax, which is defined (per Washington Administrative Code 173-201) as the arithmetic average of seven consecutive measures of daily maximum temperatures. The 7-DADMax for any individual day is calculated by averaging that day's daily maximum temperature with the daily maximum temperatures of the 3 days prior to and the 3 days after that date (Ecology 2012).

In the tributaries that flow into the reservoir area, temperatures are predicted to increase by up to 5˚C in Crim Creek (see Figure H-10). As with the mainstem Chehalis River, temperature effects diminish farther upstream in Crim Creek to an increase of 2˚C at Crim Creek (see Figures H-10 to H-12). Increases in water temperature would cause dissolved oxygen (DO) concentrations to decline in the Chehalis River during summer and fall because warmer water has a lower capacity to hold oxygen.

When the FRO facility is operational, the potential exists for warming within the reservoir. Model-predicted FRO reservoir temperatures are shown in Figures H-13 and H-14 for an approximately 10-year flood during fall and spring, respectively. Modeling results show that waters in the reservoir could warm if the reservoir is used during spring because of the duration water is retained (approximately 1 month). There is a potential for a decline in DO in the reservoir during flood retention periods from decaying vegetation. However, flood retention would typically occur from November to March (when flooding typically occurs) when air temperatures are cooler, which limits the potential water temperature increase. This is anticipated to limit the potential for DO impacts with FRO operations (Anchor QEA 2016c)

Figure H-4

FRO Facility Footprint Model 7-DADmax Temperature Predictions – Dam Location (RM 108.6)

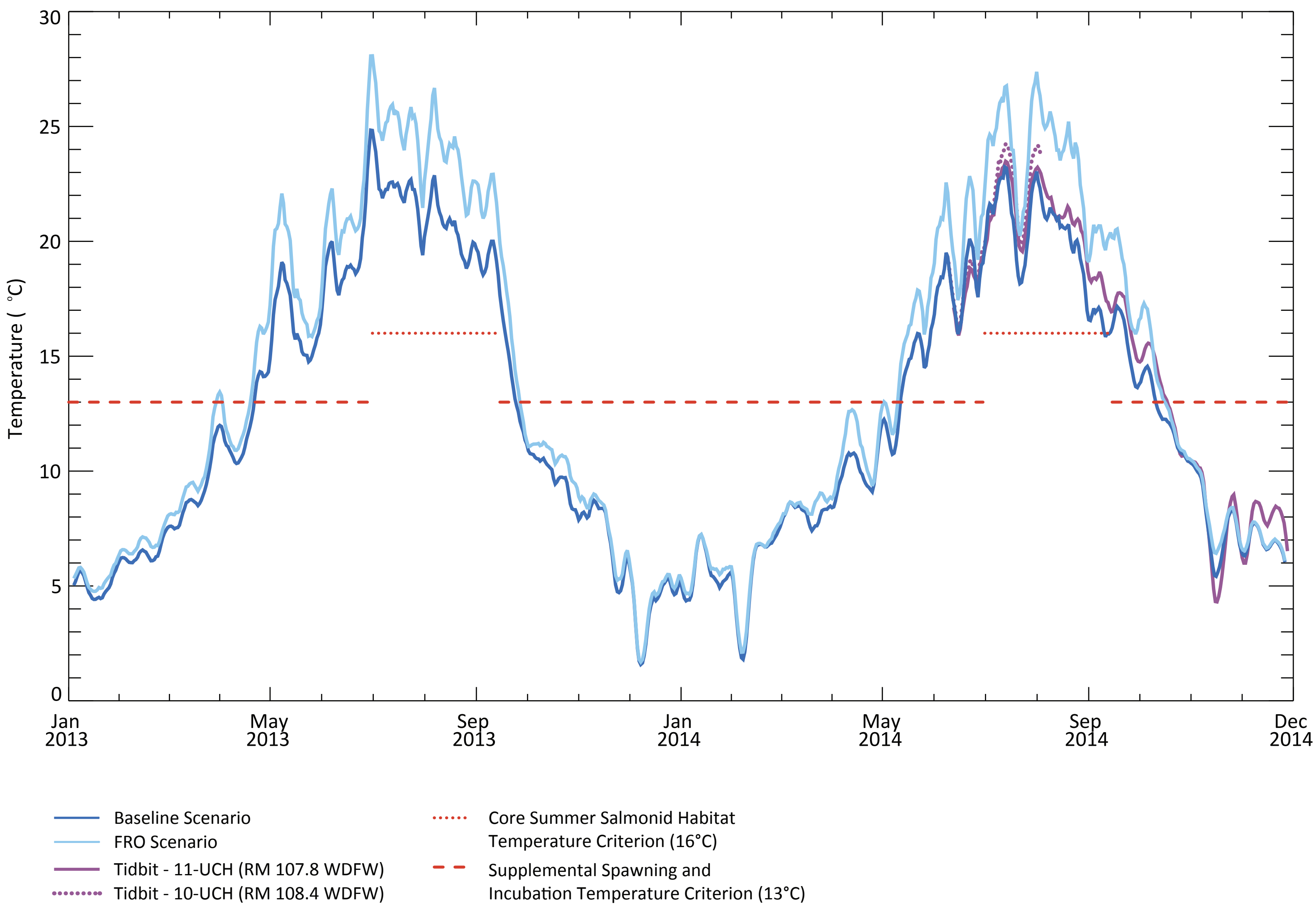


Figure H-5

FRO Facility Footprint Model 7-DADmax Temperature Predictions – RM 110.5

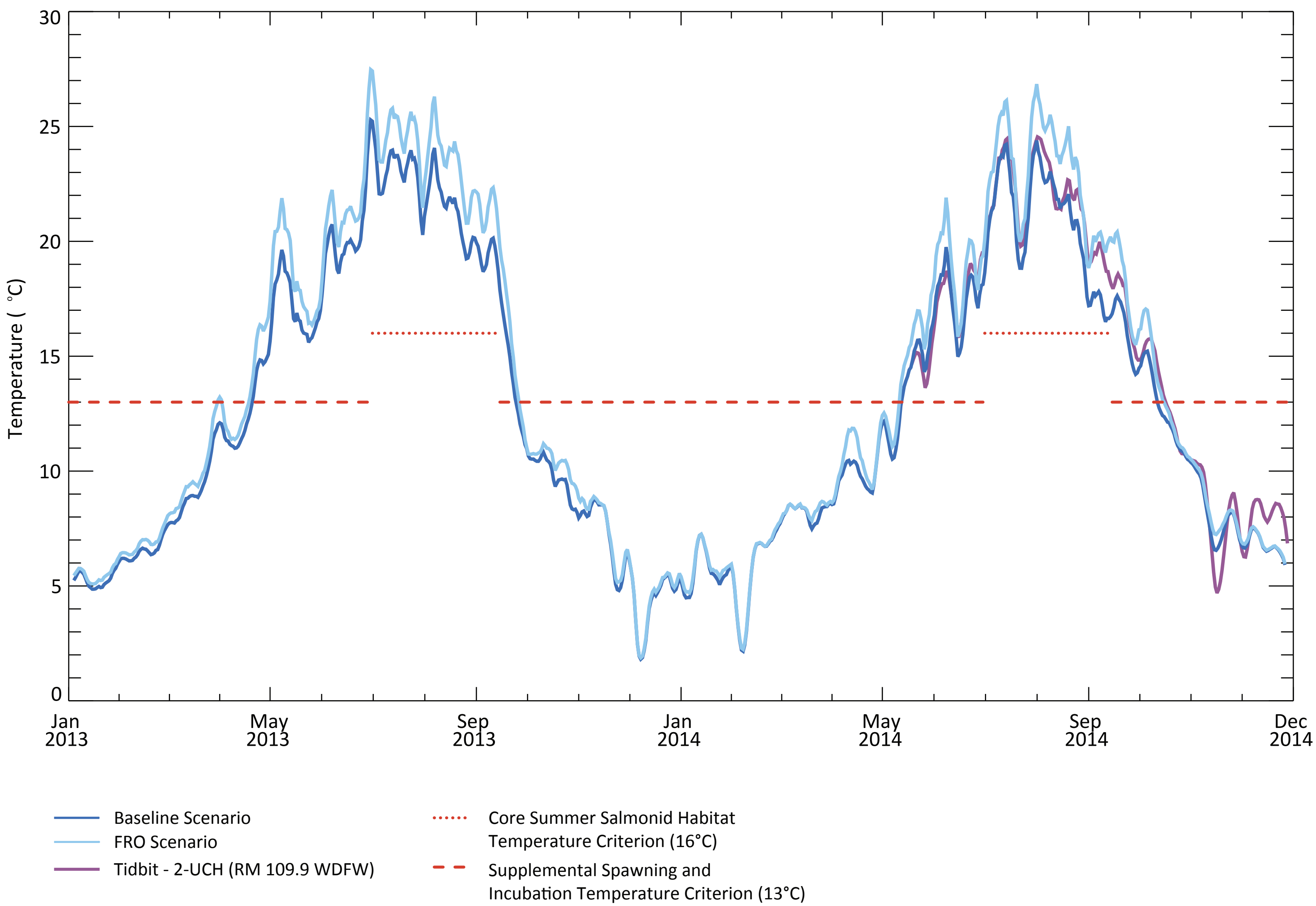


Figure H-6

FRO Facility Footprint Model 7-DADmax Temperature Predictions – RM 110.9

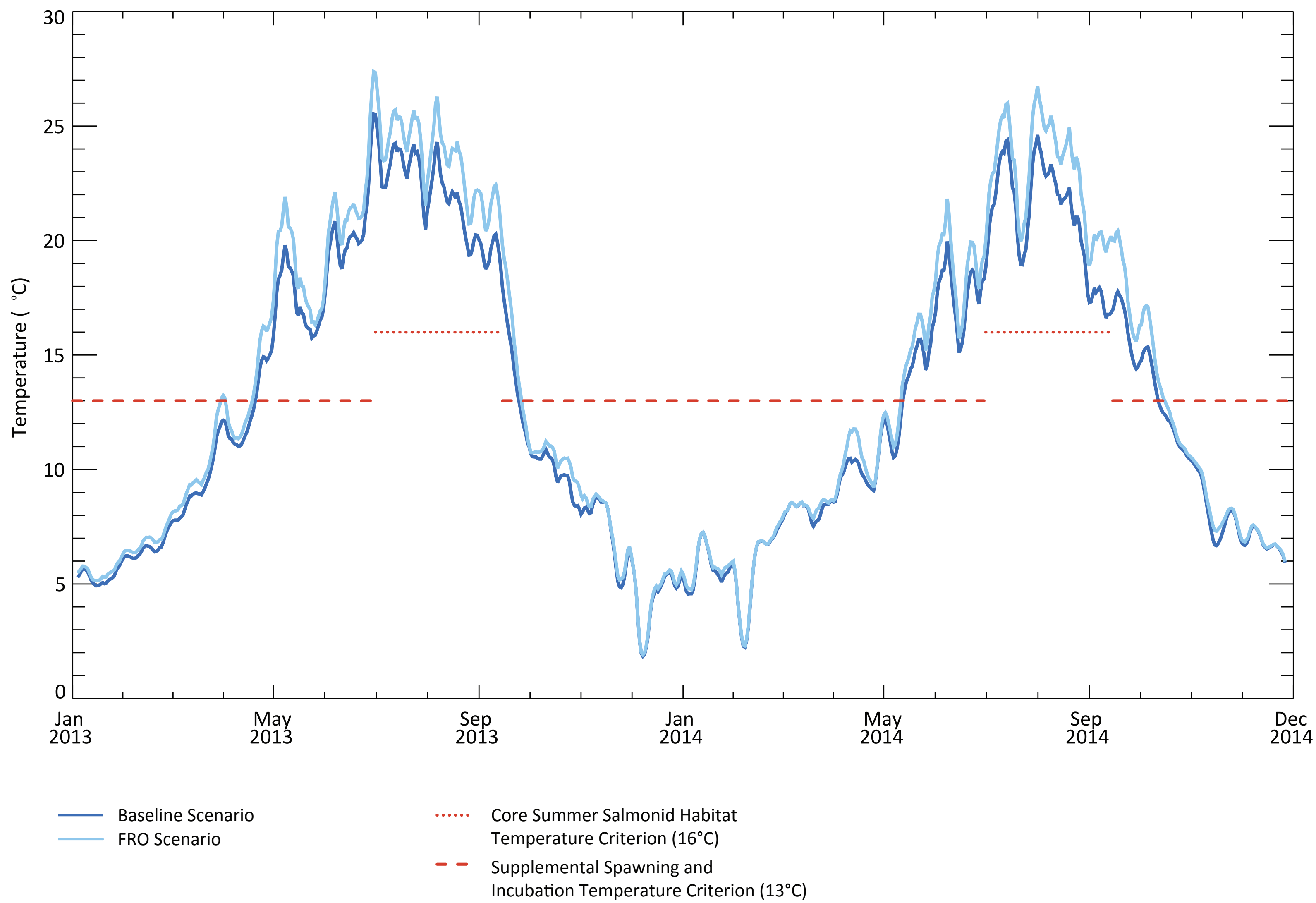


Figure H-7

FRO Facility Footprint Model 7-DADmax Temperature Predictions – RM 112.8

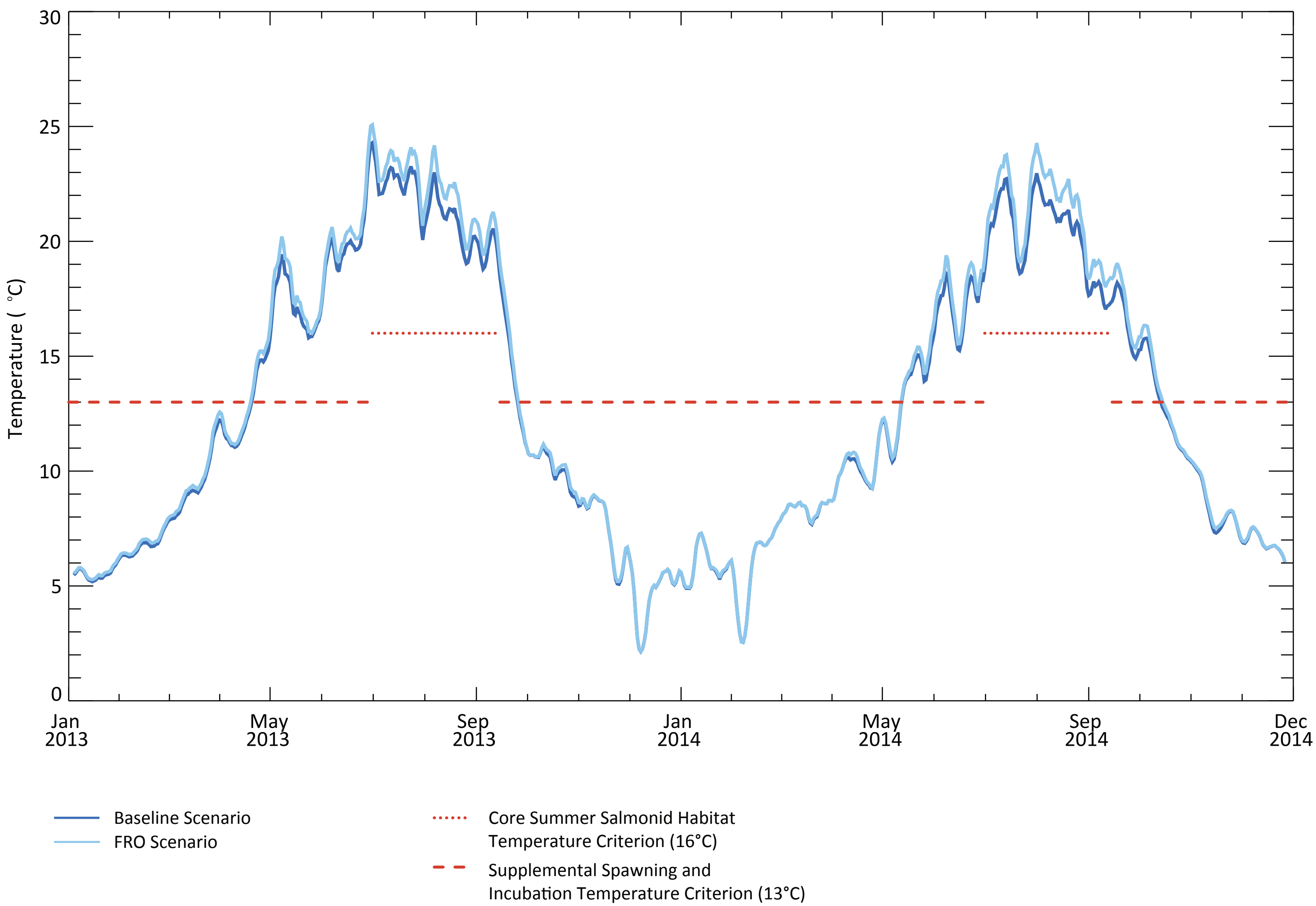


Figure H-8

FRO Facility Footprint Model 7-DADmax Temperature Predictions – RM 113.3

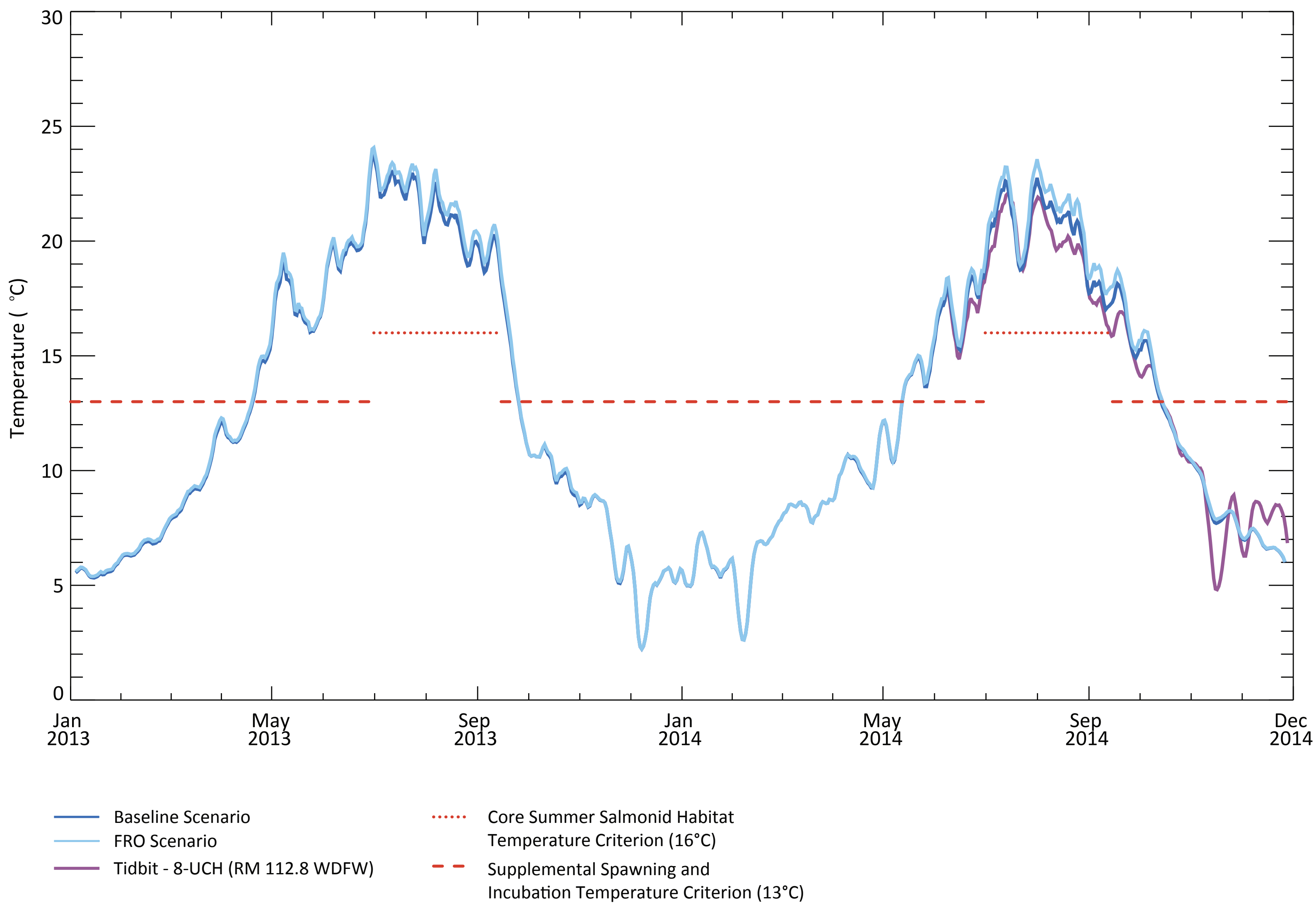


Figure H-9

FRO Facility Footprint Model 7-DADmax Temperature Predictions – RM 114.0

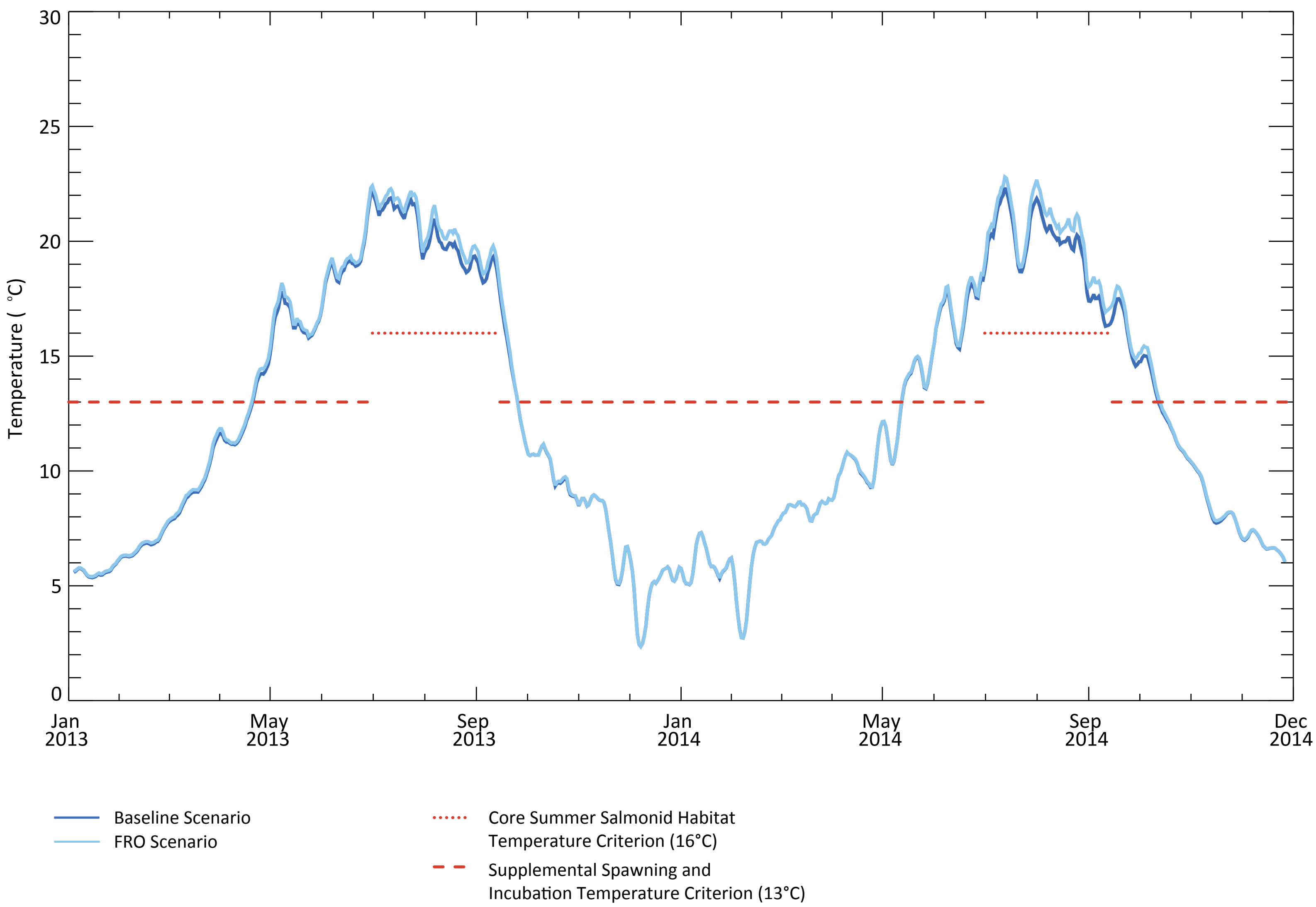


Figure H-10

FRO Facility Footprint Model 7-DADmax Temperature Predictions – 9.3 mile on Crim Creek Branch

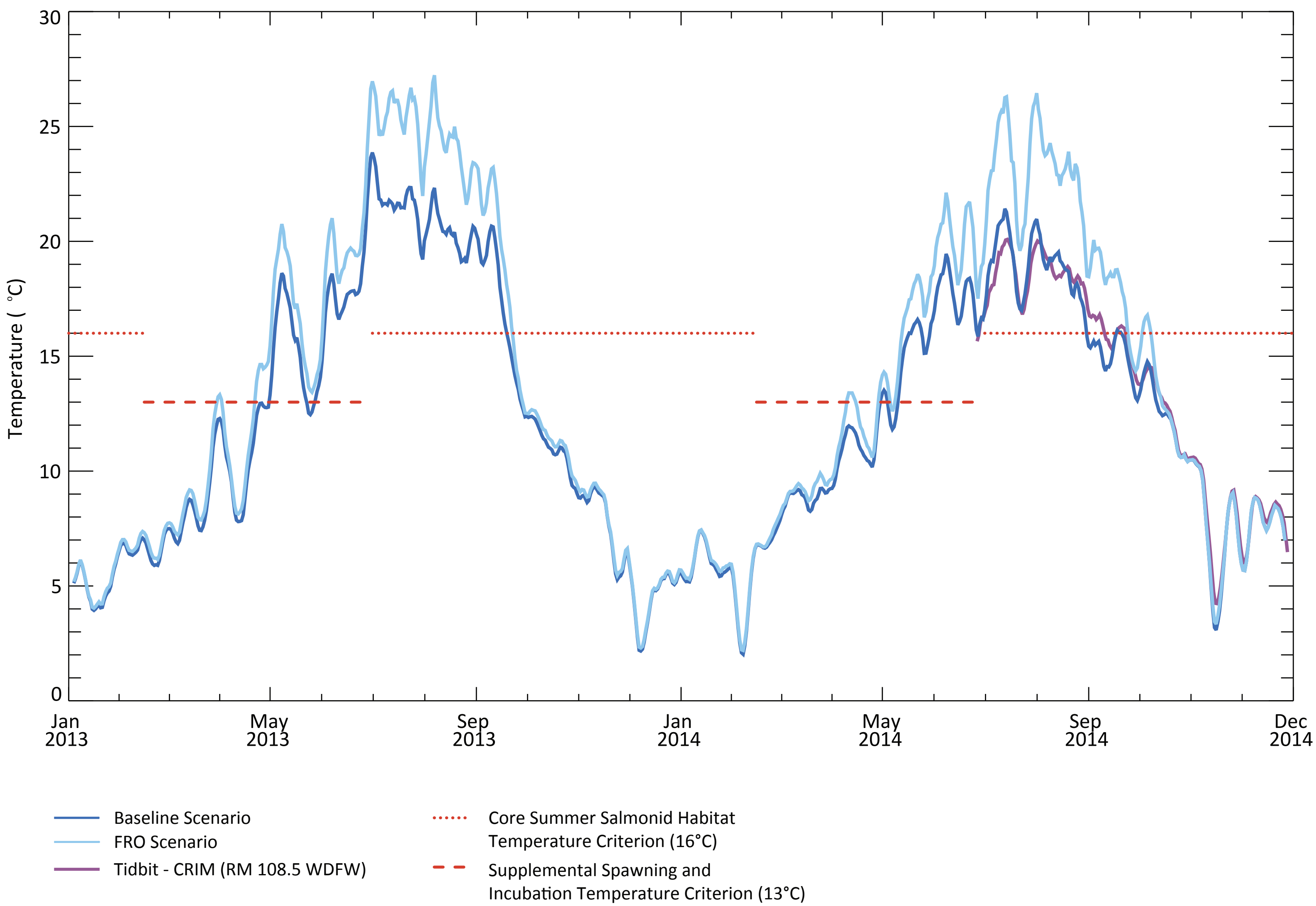


Figure H-11

FRO Facility Footprint Model 7-DADmax Temperature Predictions – 7.8 mile on Crim Creek Branch

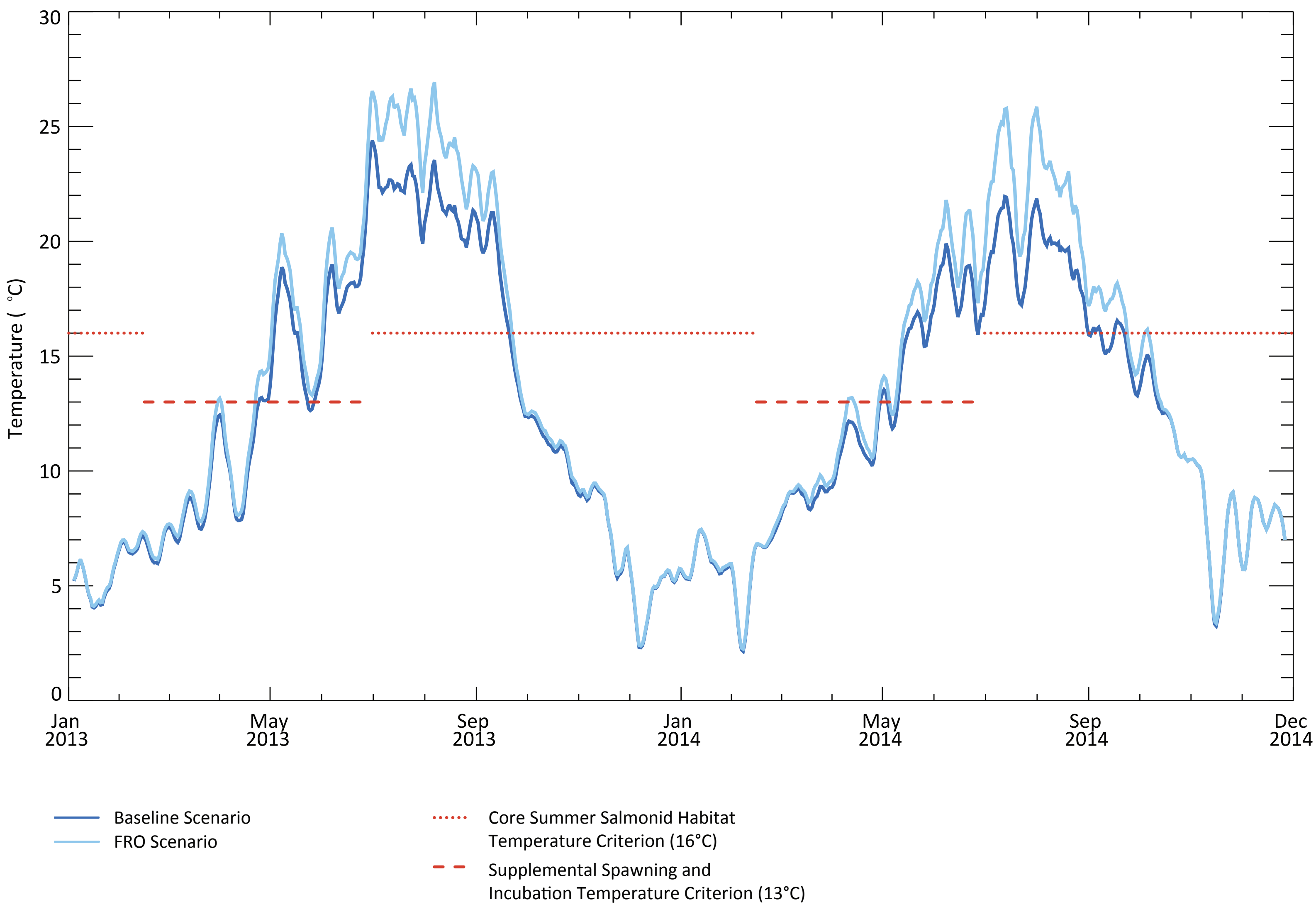


Figure H-12

FRO Facility Footprint Model 7-DADmax Temperature Predictions – 4.3 mile on Crim Creek Branch

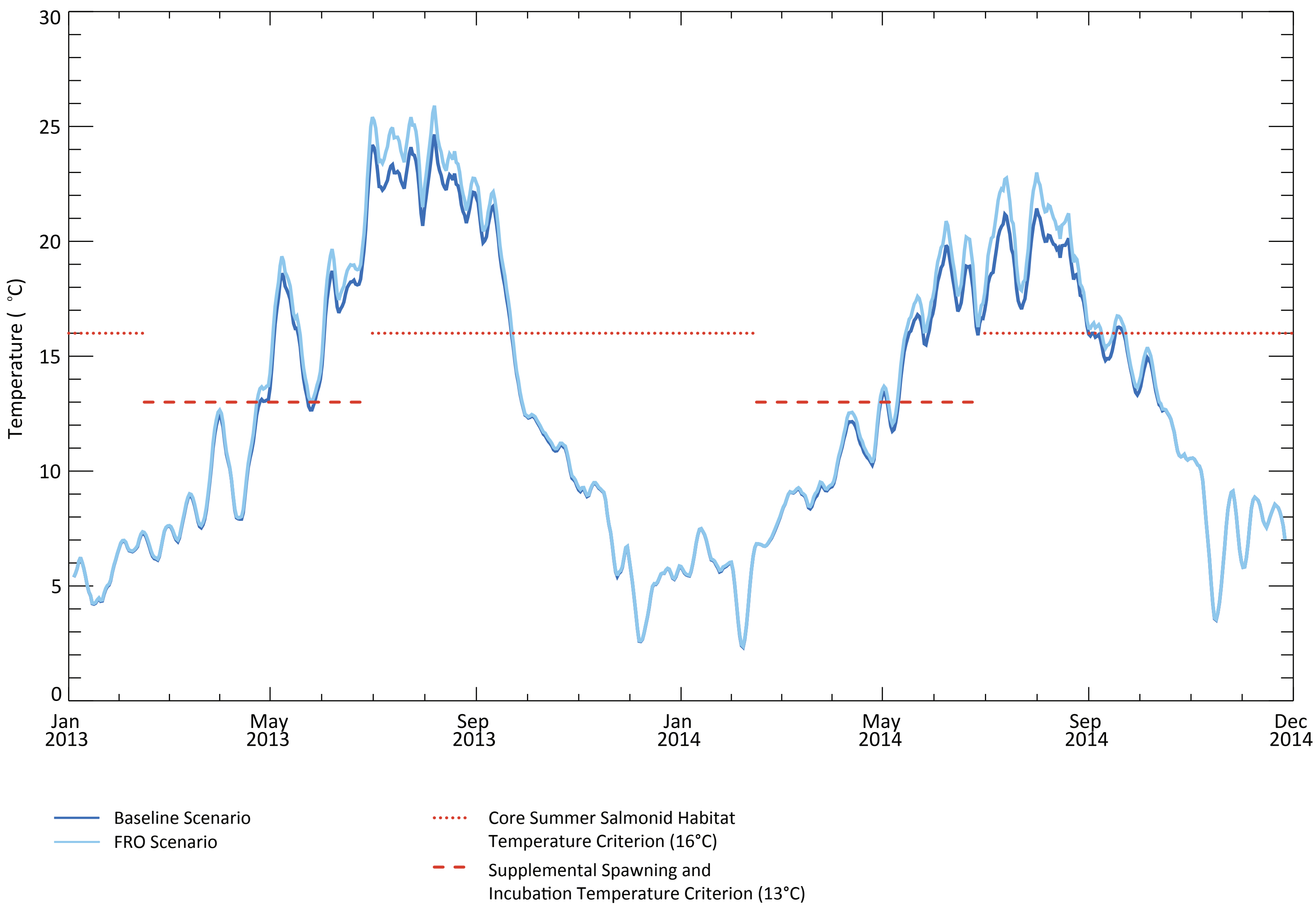


Figure H-13

Modeled Fall 7-DADmax Temperature Profile Within FRO Reservoir For a 10-year Flood

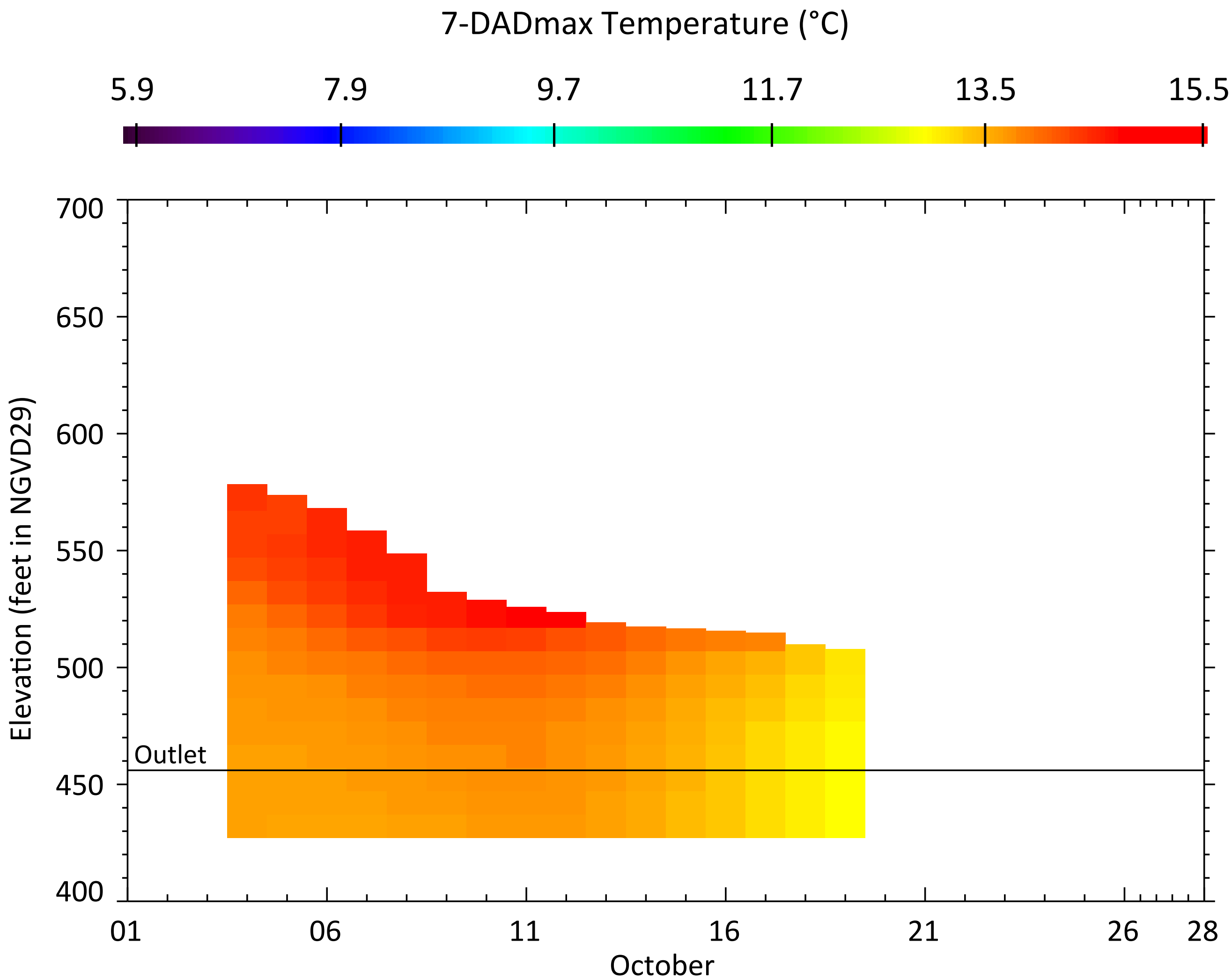
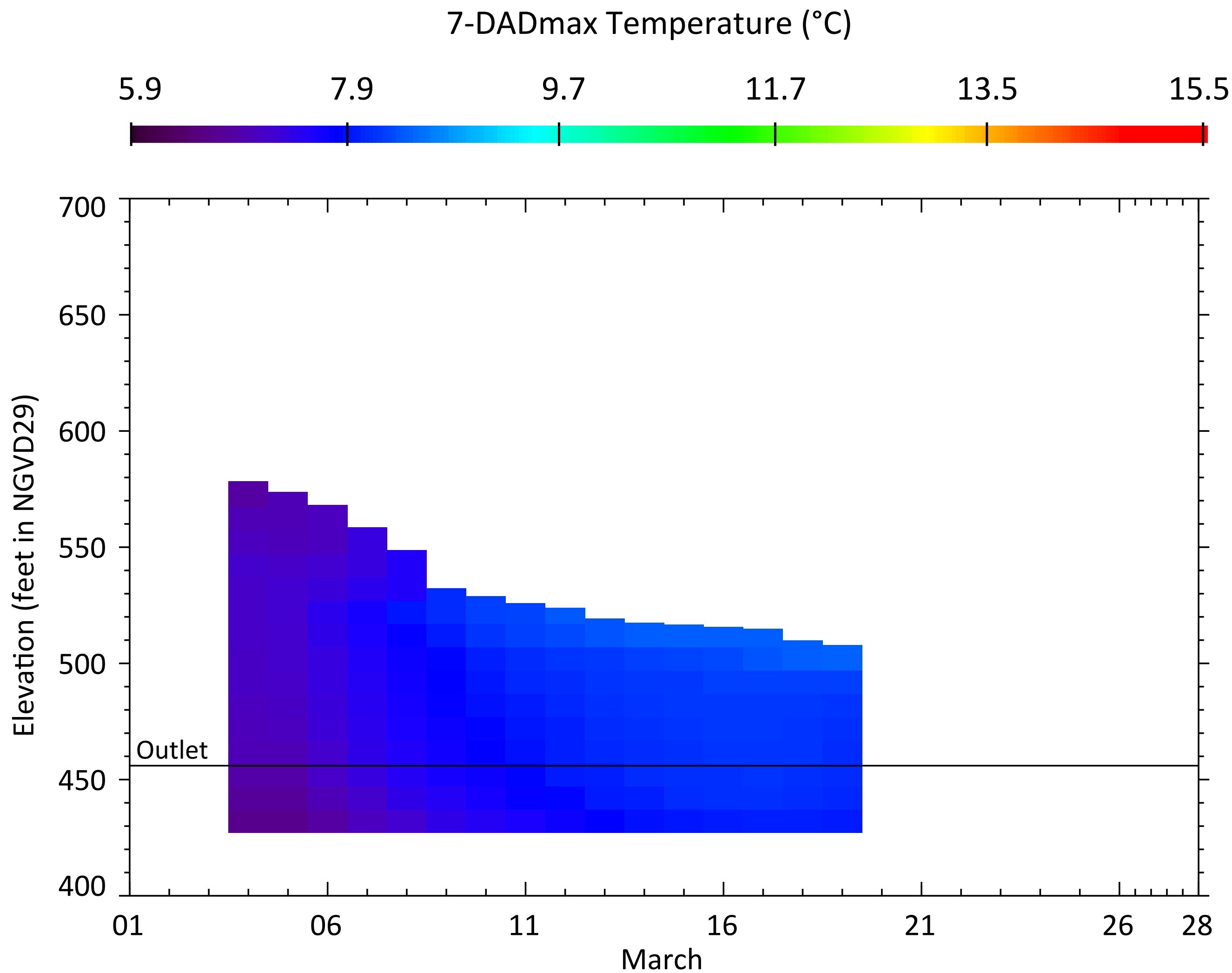


Figure H-14

Modeled Spring 7-DADmax Temperature Profile Within FRO Reservoir For a 10-year Flood



In the FRFA reservoir, the temperature of the conservation pool would vary depending on the season and depth in the reservoir. Temperatures on the surface of the conservation pool would be higher during the summer and fall due to the increased surface area of water exposed to solar radiation than the existing free-flowing, river condition. Vegetation around the shoreline would also not provide effective shade to reduce solar radiation (heat loading) to the reservoir surface. Temperatures in the conservation pool would cool with depth; the coldest temperature would occur at the bottom of the conservation pool near the dam (see Figure 4.2-2 in the EIS). The most pronounced stratification in the conservation pool would occur in summer, with warm water on the surface and much cooler water at the bottom. During fall, cooling of the conservation pool's surface would lead to a turnover within the reservoir, mixing the surface and bottom layers and creating more uniform temperature conditions throughout the reservoir.

In the FRFA conservation pool, thermal stratification and lack of mixing during summer would potentially lead to lower DO conditions in the lower elevations (deeper depths) of the reservoir (see Figure 4.2-3 in the EIS). Additionally, the potential exists for nutrient loading in the conservation pool from decaying vegetation that would be trapped in the reservoir. This decaying vegetation could contribute to decreased oxygen levels deep in the reservoir.

Downstream of the Reservoir

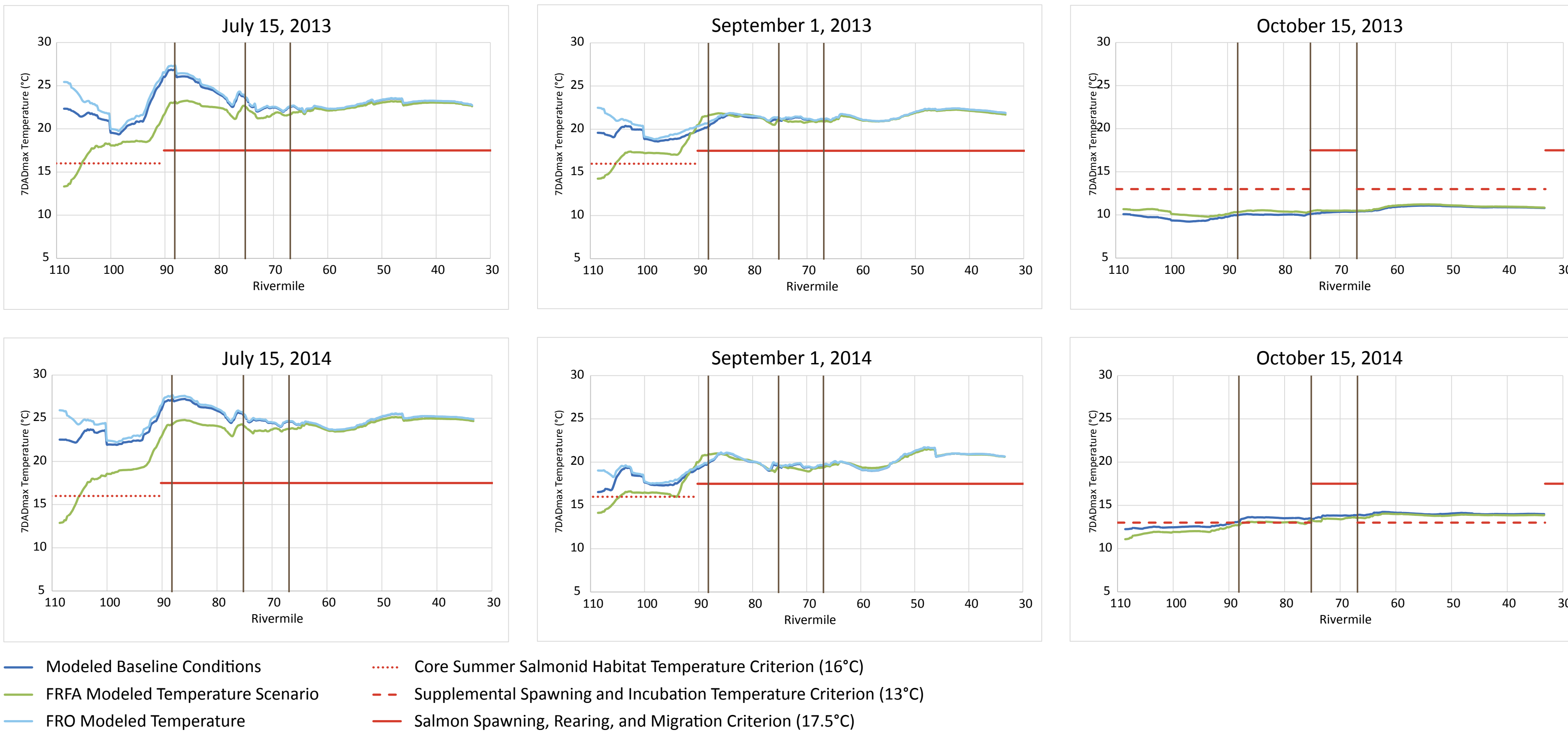
For the FRO facility (non-flood conditions) predicted downstream mainstem water temperatures are presented in Figure H-15. Slight increases in water temperature would occur downstream of the proposed dam, but would approach background conditions near the confluence of the South Fork Chehalis River (near RM 88). During a flood, if ambient atmospheric conditions are warmer than the water flowing into to the reservoir during a flood, and the stored water is heated while in the reservoir, the potential exists for an increase in water temperature in and downstream when the reservoir is emptied (see Figures H-16a and H-16b). Temperature conditions for major floods (FRO operations) were modeled for both fall and spring conditions. The model predicted increases in downstream water temperature (over baseline) with releases during fall conditions (Figure H-16a) by 1 to 2˚C. The model predicts cooler water releases during spring floods downstream of the FRO dam, which would be cooler than the downstream river temperatures (Figure H-16b). The potential also exists for reduced DO concentrations in FRO facility discharges as a result of any water temperature warming (fall conditions), decay of organic material, and periodic sediment inputs at and upstream of the FRO facility. The downstream effect is likely to be limited because flood retention operations would occur in cool months and the retention time would be short for the FRO operations (Anchor QEA 2016a).

In the FRFA scenario, controlled releases of cooler waters from deeper parts of the reservoir during the spring, summer, and early fall would reduce water temperatures in the Chehalis River, and reduction could extend downstream to RM 65 (see Figure H-15). However, during fall, warmer water could be released downstream if cooler water is not available from deeper parts of the reservoir once it turns over (where warmer water occurs at depth once the reservoir experiences fall turnover). The effect of cool-water releases during spring and summer diminishes progressively downriver. As the Chehalis River equilibrates to ambient atmospheric temperature conditions, warmer tributary inflows begin to dominate instream conditions and lack of shade along the river allows solar radiation to heat the water. At all times during the year, the effect of the outflow water temperature from the FRFA facility would be negligible below RM 65 (see Figure H-15). Potential releases of warmer water from the reservoir during the fall months could result in reduced DO levels downstream of the FRFA facility. The conceptual design and operations plan for the FRFA dam minimizes the potential downstream increase in water temperature in fall, as well as DO impacts, through the following measures:

- Maintaining a large enough conservation pool to keep cool water in the reservoir throughout the summer and early fall
- Releasing flow in a multi-outlet tower to enable mixing of flow from different levels in the reservoir
- Releasing flows from above the bottom of the reservoir to reduce the potential DO impact
- Providing an aeration structure to increase DO when flow is released

As a result of controlled releases of cooler water in late summer and early fall, water quality standards may be attained at some times and in some reaches of the Chehalis River downstream of the FRFA reservoir where temperature and DO do not presently meet applicable numeric criteria. Conversely, at other times, the water quality standards may not be attained in areas where criteria are presently met (see Figure H-15). The cooler water releases from the FRFA reservoir may help protect designated uses downstream of the FRFA dam, where water temperatures do not meet applicable criteria during the summer and fall.

Figure H-15
Modeled Temperatures Downstream of Flood Retention Facility



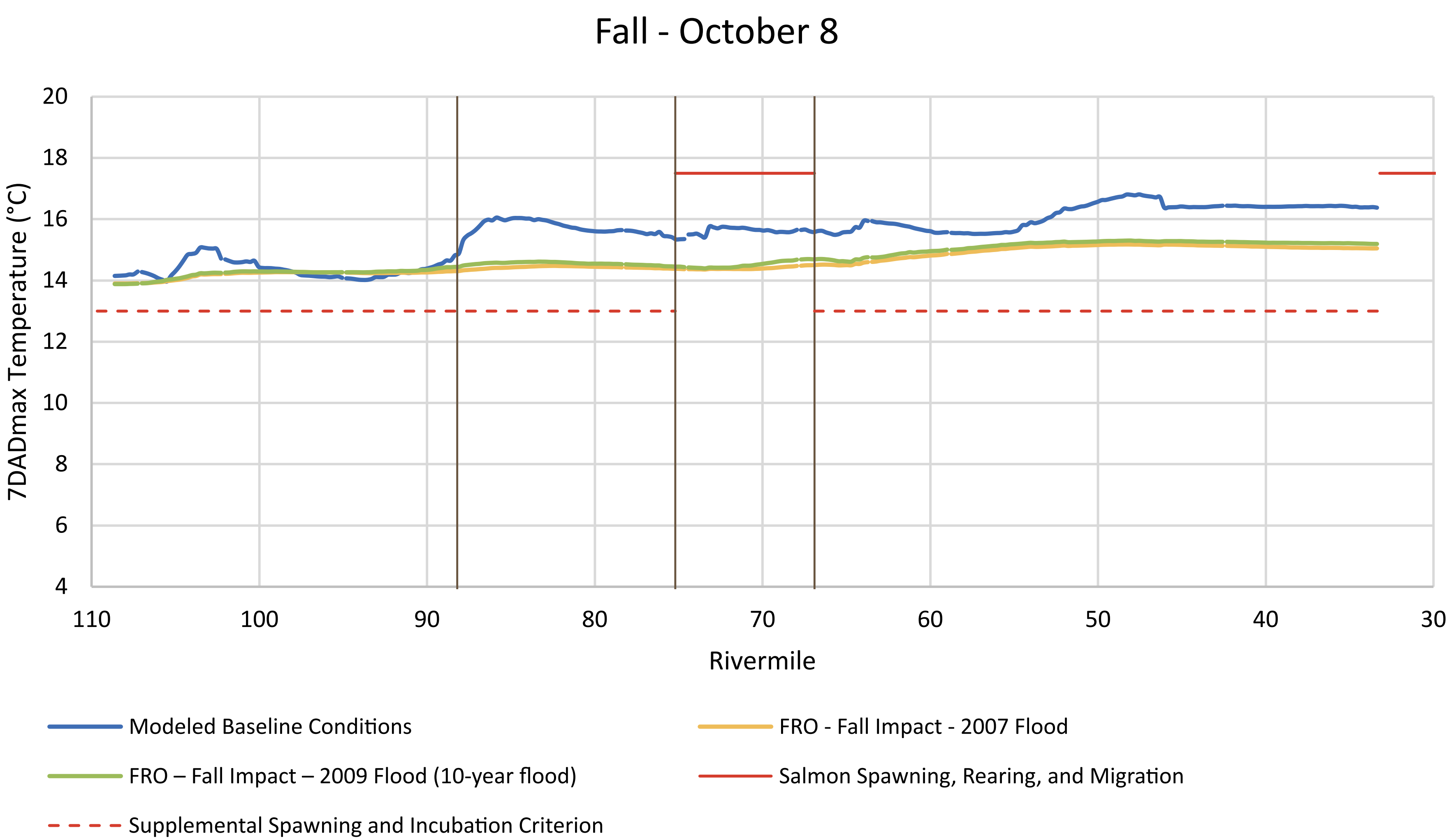
Notes:

South Fork Chehalis River confluence = RM88
Newaukum River confluence = RM75
Skookumchuck River confluence = RM67

7DADmax: 7-day average of the daily maximum temperatures is the arithmetic average of 7 consecutive measures of daily maximum temperatures.

Figure H-16a

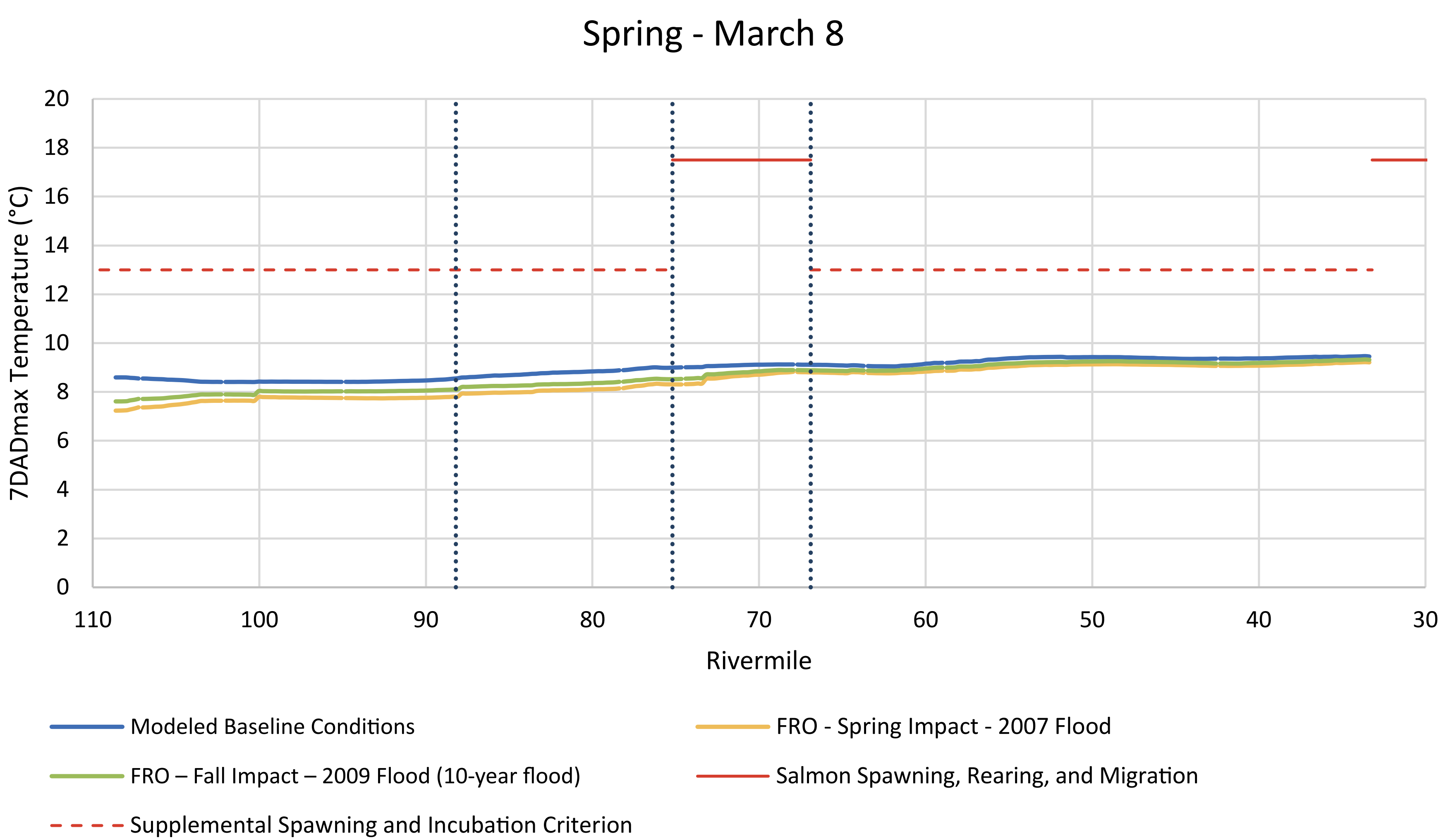
Modeled Downstream 7-DADmax Temperature with FRO Facility Operations During Fall Flood Conditions



Note:
7DADmax: 7-day average of the daily maximum temperatures is the arithmetic average of 7 consecutive measures of daily maximum temperatures.

Figure H-16b

Modeled Downstream 7-DADmax Temperature with FRO Facility Operations During Spring Flood Conditions



Note:

7DADmax: 7-day average of the daily maximum temperatures is the arithmetic average of 7 consecutive measures of daily maximum temperatures.

Surface Water Quantity

The FRO facility reservoir would retain water for up to 32 days during flood operations to allow for capture of floodwater, controlled release of reservoir contents, and management of debris and wood as the reservoir is emptied. The proposed FRO facility operations are as follows:

- Impoundment of floodwater when a threshold flow of 38,800 cfs is forecasted at the Grand Mound gage
- Outflow from the FRO reservoir would be reduced at a rate of 200 cfs per hour until 300 cfs outflow is reached
  - The 200 cfs per hour reduction rate is designed to reduce the potential for fish stranding in downstream areas
  - The 300 cfs outflow is designed to maintain a flow typically experienced by fish downstream of the reservoir in the winter (under existing non-flood conditions)
- When the flood storage pool is emptied, the drawdown rate would be limited to between 10 to 20 feet per day to reduce the potential for landslides in the reservoir area
- For debris management, the reservoir would be drawn down to about 100 feet deep
  - Over a 2-week period, the reservoir drawdown rate would be reduced so that debris management may occur (2 feet per day for debris management; Anchor QEA 2016a)
  - At the end of the 2-week period, the remaining water in the reservoir would be discharged at a rate of 10 feet per day (Anchor QEA 2016a)

For the FRO facility, it is estimated that water would be impounded in the reservoir 2% of the time on average (based on the previous 27-year period of flow records in the Chehalis River).

The FRFA facility includes a conservation pool of 65,000 acre-feet, and additional flood pool above that level for flood retention. During a flood, reservoir operations would be similar to the FRO facility, with the exception that no time would be needed for debris management; a conservation pool would be permanently maintained and floodwater could be released more quickly than from the FRO facility. Outside of flood operations, the FRFA reservoir level would fluctuate in response to inflow and outflow. The planned operation is to operate the reservoir within a maximum 40-foot range in pool surface elevation, which is much less than the approximate 200-foot depth of the conservation pool at the FRFA facility. The limited drawdown would provide flexibility in releasing cool water in the summer and provide better downstream passage conditions for juvenile fish from flow augmentation in the late summer and early fall.

Downstream of the Flood Retention Facility, flows would be reduced during floods in order to decrease downstream flooding (see Figure H-2); a minimum flow of 300 cfs discharge would be maintained during floods. Following flood operations when the flood pool was emptied, flows would be increased in the Chehalis River from 300 cfs at a rate of approximately 1,000 cfs per hour. The maximum flow released from the reservoir would be approximately 6,000 cfs from the FRO facility or 11,000 cfs from the FRFA facility.

With the FRFA facility, reduction in flow downstream would occur in the winter because of filling the conservation pool; however, during frequently occurring high-flow events (events that do not cause major floods), the flows downstream would not be reduced. This would help to offset any reduction in flows during times when the conservation pool is filling. Part of the storage in the conservation pool would be used to increase summer instream flows and reduce temperature for the benefit of fish habitat in the Chehalis River (see Figures H-1 and H-3). See additional discussion in the Fish and Wildlife section.

Geology and Geomorphology

Geology

In the reservoir area, fluctuating water levels and bare soils resulting from the removal of trees during construction could trigger shallow landslides and a deep-seated landslide around the reservoir footprint (RM 108 to RM 114; see Figure H-1). Shallow landslides have the potential to occur around the reservoir perimeter, with impacts isolated to local reservoir areas. Landslides could increase sediment delivery to the reservoir and increase turbidity, either slowly and incrementally or quickly and catastrophically. Seiche waves after sudden landslides could cause damage to the Flood Retention Facility when the reservoir is full.

Over the long term, erosion would periodically occur along the FRO or FRFA facility reservoir perimeter, especially in areas of dynamic water-level fluctuations, releasing fine-grained sediment and woody material into the reservoir. In the FRFA reservoir, minor wave action could lead to shoreline erosion along the perimeter of the pool, causing temporary local turbidity increases. The potential for increased turbidity and suspended sediments from slope erosion in the reservoir is greater for the FRFA facility than the FRO facility because the slopes within the permanent reservoir pool would be bare and have less resistance to erosion. The amount of erosion would depend on the steepness of the slope and whether bedrock is present (bedrock would not erode).

The FRFA facility reservoir could induce low-level seismicity by the weight of the water in the reservoir pool. This has the potential to damage the Flood Retention Facility and appurtenant structures, and cause concern among local residents. For the FRFA facility, the proposed reservoir depth would be shallower than reservoirs that have incurred seismicity from the weight of water. Induced seismicity elsewhere has been mostly associated with active faults (Gupta 1992), whereas the faults that may exist in the Flood Retention Facility and reservoir area are thought to be millions of years old and not active.

Geomorphology

The Flood Retention Facility would create areas of sediment deposition where sediment conveyed by the Chehalis River or a tributary meets a reservoir pool. The deposition locations would change because of fluctuating pool elevations in relation to the timing of sediment input. Areas of deposition would be subject to erosion when subsequent high flows occur. The length of streams where these conditions would occur would be much greater for the FRO facility than the FRFA facility, because the FRO facility would not have a permanent pool and would have a greater range of water level fluctuations between operational periods. The reservoir for the FRO facility would extend 5.7 miles upstream of the dam along the Chehalis River (during a major flood). Most of that reservoir length has the potential for sedimentation during flood retention operations, as do the tributaries that are inundated (major tributaries include Crim [including a segment of Lester Creek], Hull, Browns, Big, Roger, and Smith creeks). When subjected to high flows, deposited sediment would be eroded when the reservoir is not operating. Fine sediments would be readily eroded and coarser (bedload) sediments, such as gravel, would take longer to move, but would likely be eroded and transported downstream during high flows (flows that occur every 2 to 5 years; Dubé 2016).

With the FRFA facility, most of the sedimentation would occur in the upper reaches of the conservation pool (7.6 miles long) and in the areas subject to flooding during flood operations (1.0 to 1.3 miles long). This also includes the areas of the tributaries that are subject to water-level fluctuations during reservoir operations, and includes Crim Creek, and the lower segments of Lester, Hull, Browns, Big, Roger, Smith, and Alder creeks. There would be less opportunity for sediment to be eroded and transported downstream of the dam in the Chehalis River because of the permanent reservoir.

The increased water level fluctuations with the either the permanent (FRFA) or temporary reservoir (FRO) would create more dynamic geomorphic conditions that would have an effect on sediment conditions within the reservoir. In addition, the thinning or clearing of vegetation in the reservoir footprint area would expose more ground subject to wave action and surface erosion. For the FRFA facility, there would be more wave action and erosion along the reservoir shoreline, which would result in direct delivery of sediment to the impoundment area (Dubé 2016).

Lower peak flows in the Chehalis River downstream of the Flood Retention Facility could affect the sediment deposition dynamics at the tributary confluences, such as alluvial fan extents, sediment deposition timing, and grain size distribution. As a result of reducing peak flows and associated water velocities, the potential exists for a decrease in the rate and frequency of bank erosion that could occur on outside meander bends downstream of the reservoir. Floodplain and off-channel connections would not change for floods with recurrence intervals of less than 7 years, as the Flood Retention Facility would not alter peak events for small floods. During a 100-year flood, 4,480 acres of the floodplain area would not be inundated.

Vegetation

The reduction or removal of vegetation from the riparian zone of the river and its tributaries during construction of the Flood Retention Facility, or the subsequent die-off of non-flood-tolerant vegetation by extended inundation during the operation of the reservoir, could adversely affect the ability of these zones to provide important ecological functions. Such actions could reduce the ability of riparian areas to remove sediments and regulate natural erosion processes by reducing or removing understory herbs and shrubs that intercept and filter overland flows that help stabilize the streambank. The removal or death of large trees along river and streambanks could reduce the area of streamside shading, leading to higher instream water temperatures during the summer months. Reduction in the extent of streamside vegetation could also reduce the amount and variety of leaf litter, organic debris, and woody material entering the stream system, affecting nutrient cycles and instream habitat-forming processes further downstream. Furthermore, changing the composition or removing vegetation from riparian areas could reduce or eliminate wildlife habitat and fragment wildlife travel corridors used by amphibians, reptiles, birds, and various mammals.

Over the long term, the structure and composition of riparian vegetation communities in the reservoir footprint would change in response to reservoir operation activities (e.g., retention and release of floodwater). Species that are less flood-tolerant (e.g., Douglas fir) would likely die off following extended inundation events, leaving those that can handle longer periods of prolonged inundation (e.g., western red cedar, red alder). The overall result would be a shift from a riparian zone dominated by coniferous trees to one dominated by smaller deciduous trees and shrubs with a smaller coniferous component (i.e., western red cedar). Table H-1 and Figures H-17 and H-18 describe the anticipated vegetation impacts within the Flood Retention Facility reservoirs based on pre-construction management actions and inundation of the reservoir. In addition to direct die-off from flooding, riparian vegetation could also be affected by the alteration of the soil structure and composition due to varying depths and frequencies of inundation, sediment deposition from retained floodwaters, and the increased potential for landslides from fluctuating water levels in the reservoir.

Table H-1
Expected Vegetation Community Types by Inundation Zone for the Flood Retention Facility

ZONE	ELEVATION RANGE[1] (FEET)	ANTICIPATED INUNDATION FREQUENCY/LENGTH	PRE-CONSTRUCTION MANAGEMENT ACTIONS[2]	VEGETATED AREA[3] (ACRES)	EXPECTED POST-CONSTRUCTION VEGETATION COMMUNITY TYPE AND TYPICAL VEGETATION
FRO FACILITY					
1	424 – 567	• 10% chance of being flooded in a year (10-year flood) • Under water up to 32 days when flooded	Selectively harvested to remove non-flood-tolerant species[3]	405	Deciduous riparian shrubland: various willows, red-osier dogwood, potential emergent/scrub-shrub wetlands
2	567 – 584	• 5% chance of being flooded in a year (20-year flood) • Under water for 4 days when flooded	No harvest	80	Deciduous riparian forest with some conifers: red alder, western red cedar, Oregon ash, black cottonwood, willows, elderberry, snowberry
3	584 – 612	• 1% chance of being flooded in a year (100-year flood) • Under water for 1 day when flooded	No harvest	136	Mixed coniferous/ deciduous transitional forest: Douglas fir (young), red alder, big-leaf maple
4	612 – 627	• <1% chance of being flooded in a year (>100-year flood)	No harvest	90	Coniferous forest: Douglas fir
FRFA FACILITY					
1	424 – 627	• Flooded every year • Under water on average greater than 83 days per year when flooded	Clear-cut	711	Aquatic: largely unvegetated
2	627 – 653	• 10% chance of being flooded in a year (10-year flood) • Under water for 25 days when flooded	Selectively harvested to remove non-flood-tolerant species[3]	178	Deciduous riparian shrubland: various willows, red-osier dogwood, potential emergent/scrub-shrub wetlands
3	653 – 661	• 5% chance of being flooded in a year (20-year flood) • Under water for 4 days when flooded	No harvest	56	Deciduous riparian forest with some conifers: red alder, western red cedar, Oregon ash, black cottonwood, willows, elderberry, snowberry

ZONE	ELEVATION RANGE[1] (FEET)	ANTICIPATED INUNDATION FREQUENCY/LENGTH	PRE-CONSTRUCTION MANAGEMENT ACTIONS[2]	VEGETATED AREA[3] (ACRES)	EXPECTED POST-CONSTRUCTION VEGETATION COMMUNITY TYPE AND TYPICAL VEGETATION
4	661 – 678	• 1% chance of being flooded in a year (100-year flood) • Under water for 1 day when flooded	No harvest	134	Mixed coniferous/ deciduous transitional forest: Douglas fir (young), red alder, big-leaf maple
5	678 – 687	• <1% chance of being flooded in a year (>100-year flood)	No harvest	72	Coniferous forest: Douglas fir

Notes:
1. North American Vertical Datum of 1988
2. May be either periodically repeated on a regular management cycle (e.g., every 20 years) or as needed
3. Vegetated area extents are only those areas that are currently vegetated and do not include roads or non-vegetated land (e.g., stream channels)

Both types of flood retention facilities would modify seasonal peak flows in the Chehalis River and reduce the extent of major floods in areas downstream. These changes could reduce the transport of water and nutrients to the outer edges of the Chehalis River floodplain, which could affect the vegetation of those areas. Potential effects include plant desiccation (i.e., extreme drying), reduced growth, competitive exclusion, ineffective seed dispersal, or failure of seeding establishment (Poff et al. 1997). All of these could affect plant growth and survivorship and could eventually lead to a gradual change in riparian vegetation composition in the outer portions of the Chehalis River floodplain, with flood-tolerant tree species giving way to a forest more characteristic of unflooded areas (Décamps et al. 1988; Nilsson and Berggren 2000). For example, cottonwood, a common riparian and floodplain tree species along the Chehalis River, is a disturbance species that establishes after winter-spring flooding during the brief period when competition-free alluvial substrates and wet soils are available for germination (Poff et al. 1997). Seedling germination is further dependent on a certain rate of floodwater recession because seedling roots must remain connected to a receding water table as they grow downward (Rood and Mahoney 1990). Reduction of flooding in these areas could reduce or remove the conditions required for cottonwood germination, and constrain the future establishment of new cottonwood forests in the floodplain. In addition to these changes, a reduction in the downstream flooding extents could also limit the establishment of invasive species that are spread by flood flows, as certain areas of the floodplain would receive floodwaters less frequently.

The reduction in flood extents downstream of the Flood Retention Facility would also reduce the episodic disturbance of downstream riparian areas and wetlands by major or larger floods. This could result in a reduction in the occurrence of major channel avulsions and large-scale channel migrations, allowing the adjacent riparian forest to become more mature as the occurrence of periodic disturbance decreases.

Figure H-17

Expected Vegetation Community Type in the FRO Facility Reservoir

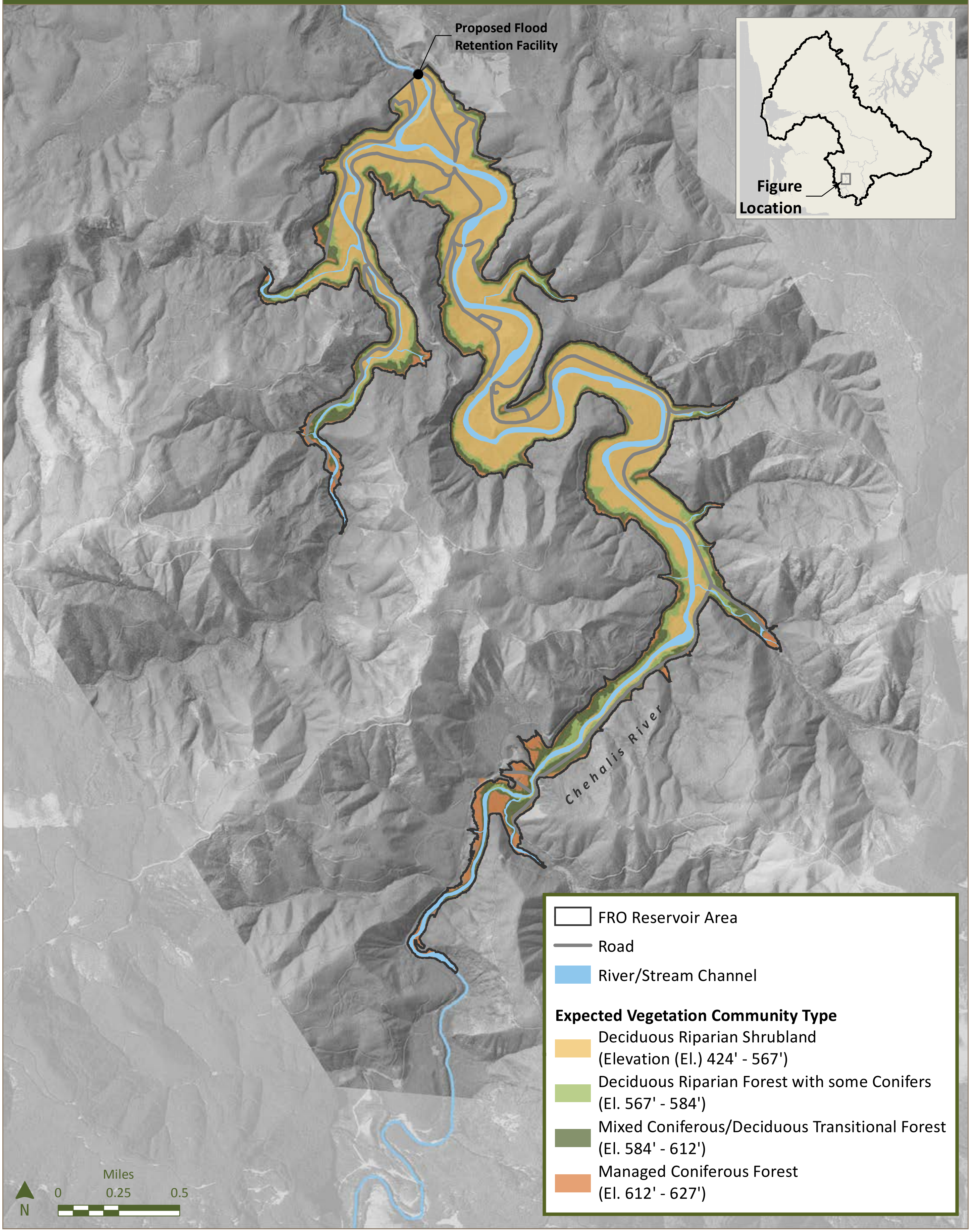
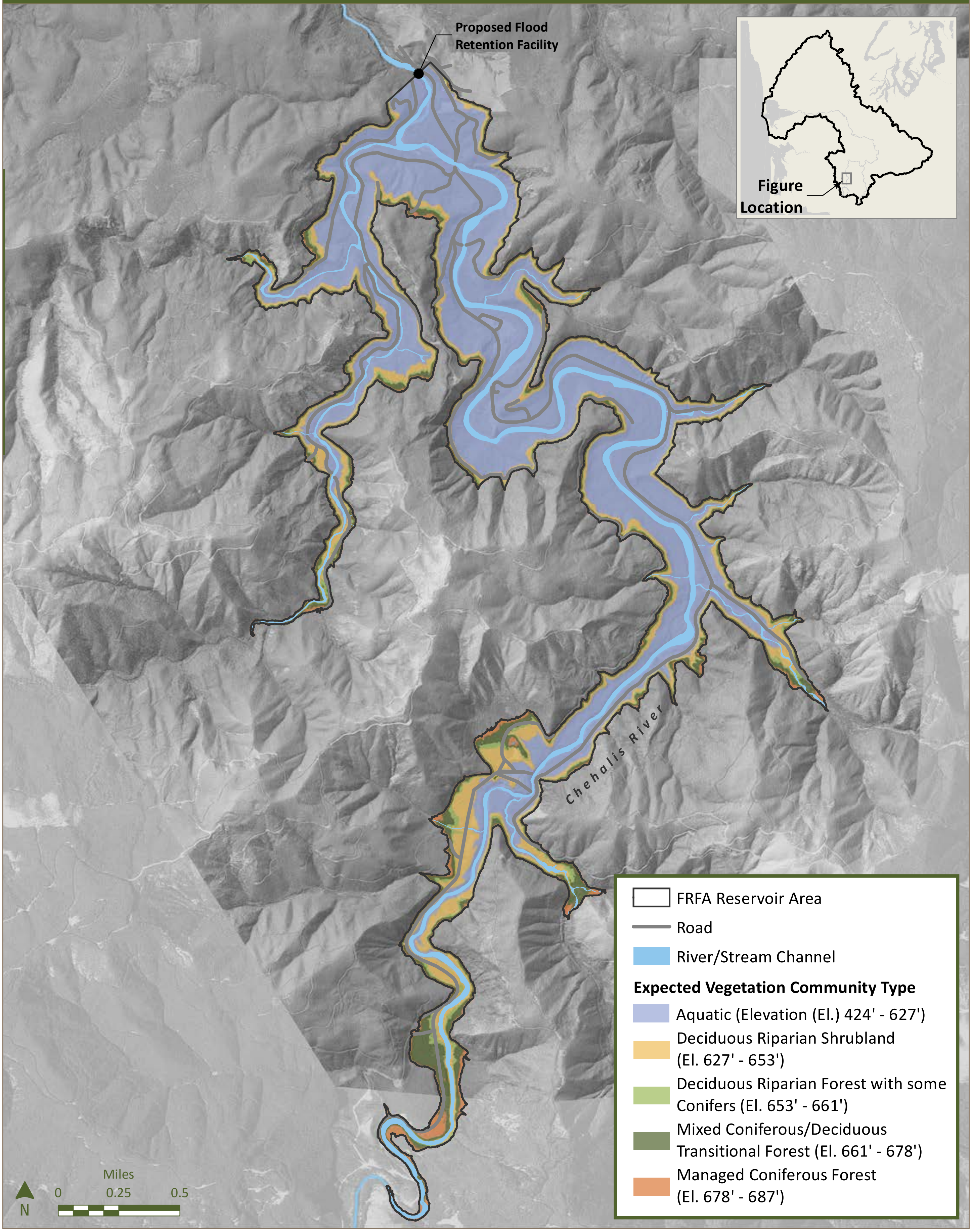


Figure H-18

Expected Vegetation Community Type in the FRFA Facility Reservoir



Fish and Wildlife

Fish

The effects of dams on aquatic systems in the Pacific Northwest have been widely studied, with the literature generally showing far-reaching negative impacts for aquatic systems. The dam types proposed for the upper Chehalis River would be uniquely designed for the purpose of flood retention, with added measures intended to reduce the adverse impacts on fish. It is important to evaluate the impacts of the proposed dams in context of historical impacts of dams throughout the Pacific Northwest; however, because the dams and flood control operations being proposed are unique to this site, it is equally important to evaluate the impacts of each dam to fish independent from the known effects of other dams.

The potential long-term impacts on fish are primarily related to the following changes in physical attributes of the environment created by the Flood Retention Facility:

- Periodic or permanent inundation of the area upstream of the dam
- Introduction of an obstacle or complete barrier to fish migration from dam and fish passage infrastructure
- Reduction in the magnitude of high-flow events downstream of the dam that drive habitat-forming processes
- Potential benefit from the FRFA facility resulting from a decrease in temperatures downstream

Anticipated long-term adverse impacts of the Flood Retention Facility on fish populations in the mainstem Chehalis River above and immediately below the dam are primarily due to changes in habitat functions and reduced access to habitat or survival from the following:

- Loss of habitat function within the reach of the Chehalis River inundated upstream of the dam for cool, swift-water associated fish species, including loss of salmon spawning habitat
- Partial reduction in fish survival and potential interruptions to migration due to passage impediments, including salmon and lamprey spawning migrations
- Changes to fish habitat-forming processes and water quality downstream of the dam
- Exposure of juvenile salmonids that use the FRFA reservoir for rearing to predators that may thrive in the reservoir

The potential long-term benefits to fish are primarily related to the following changes in physical attributes of the environment created by the FRFA facility:

- Creation of reservoir habitat that some species and life stages that currently exist in the area could utilize for rearing or foraging, such as coho salmon, steelhead, largescale sucker, mountain whitefish, or sculpin; however, uses in summer may be limited due to high water temperatures

- Flow augmentation and temperature reduction downstream of the FRFA facility

It is important to consider that any impact on adult salmonid passage, spawning success, and cohort productivity in 1 year will also result in reduced adult returns 3 and 4 years after the event.

Loss of Habitat Function Upstream of the Flood Retention Facility

The extent of inundation and, therefore, the amount of habitat and number of fish affected by the inundation would vary with the size of the flood. On average, the FRO facility would inundate up to 5.3 miles of river channel, while the largest floods (100-year floods and greater) would inundate up to 6.2 miles of the river channel (778 acres). The FRFA facility reservoir would permanently convert 6.3 miles of stream habitat to lake-type habitat, with inundation of up to 7.6 miles of stream habitat (1,264 acres at full pool) during the largest floods.

As stated in the Water Resources section, the FRO facility would allow the river to pass through the dam unimpeded most of the time. Flood retention would be temporary and would occur, on average, once every 7 years with a 15% probability of occurrence. From 1989 to 2015, seven events would have triggered flood retention (flows greater than 38,000 cfs at Grand Mound; Anchor QEA 2016a). Closure of the FRO tunnels would have lasted for 26 to 34 days for each period of retention. Flows that exceed the capacity of the FRO facility tunnels to pass water could have caused some water to pool upstream of the facility in 20 of 27 years over the same time period, lasting for a few hours up to 5 days for each event. Note that this period of record included a higher frequency of flooding than the overall historical record dating back to the 1880s, described in Chapter 2 of the EIS.

The adverse effects of inundation of salmon redds varies by species. Spring-run and fall-run Chinook salmon tend to spawn in shallow reaches of the mainstem Chehalis River and entirely within the potential maximum inundation area (Ashcraft et al. 2016). Based on WDFW surveys from 2013 to 2015 of redds found upstream of the proposed dam site to the headwaters of the river, many would be affected by inundation, including nearly all of the spring-run Chinook salmon (99%), the majority of fall-run Chinook salmon (72% to 100%), and, to a lesser extent, coho salmon (28% to 67%) and steelhead (35% to 37%), with the remainder found upstream of the predicted inundation area (Ashcraft et al. 2016). As many as 115 spring-run (46 redds) and 313 fall-run Chinook salmon (125 redds) have been observed in the maximum inundation area in recent years. While many coho salmon and steelhead spawn in headwater tributaries above the maximum inundation area, many have also been observed spawning within the inundation area. As many as 1,552 coho salmon (776 redds) and 2,016 winter-run steelhead (1,016 redds) have been observed spawning in approximately 52 to 53 river miles in and above the inundation area (Ashcraft et al. 2016). With an FRO facility, a single, temporary inundation event is expected to result in a complete loss of any incubating salmon embryos that are in the inundation area at the time of the flood, eliminating this proportion of the annual cohort of salmon originating from the upper Chehalis Basin. Permanent inundation of stream habitat with an FRFA facility represents a permanent loss of spawning habitat for salmonids that require flowing water to oxygenate eggs. See Chapter 3 of the EIS for more details on fish use upstream of the Flood Retention Facility.

Inundation of the reach of the Chehalis River upstream of the Flood Retention Facility would affect other fish species that have been observed in the vicinity, including resident rainbow and cutthroat trout, mountain whitefish, largescale sucker, longnose dace, speckled dace, redside shiner, various freshwater sculpin, Pacific lamprey (adult and larval), and Western brook lamprey (Winkowski 2015; Zimmerman and Winkowski 2016). Flood retention with an FRO dam would occur during the rainy season (fall and winter), and therefore is unlikely to affect spawning of most non-salmonid fish, which occurs in the spring and summer, with the exception of mountain whitefish that spawn in the fall. Flood retention with an FRO dam would affect rearing and behaviors, such as foraging and local-scale movements of these non-salmonid fish over the winter. With an FRFA facility, permanent inundation of habitat would eliminate areas of fast-moving streams with well-aerated gravel required by many of the existing species in this area. Pacific lamprey require such habitat for spawning and larval rearing, and would rely on the remaining stream habitat upstream of the permanent pool for these functions. If spawning habitat is limited upstream of the reservoir or lamprey are unable to pass efficiently through the reservoir, the abundance of Pacific lamprey above the dam will decline. Pacific lamprey are widely distributed in the mainstem Chehalis River below the proposed dam site (NPLCC 2016; USFWS 2016) and in other major tributaries of the Chehalis River that will not be affected by the proposed dam and reservoir (Jolley et al. 2016). However, the magnitude of the impact that the loss of lamprey upstream of the FRFA dam presents to the whole Chehalis Basin population remains an uncertainty. Predicted responses of various species to stream inundation are based on known life history preferences; however, major uncertainties exist around actual fish responses because of limited data on abundance at the basin, or even sub-basin scale.

The creation of a reservoir environment would change the distribution of fish that currently occupy the Chehalis River above the Flood Retention Facility. Fish would no longer be confined to the river channel; instead, they would redistribute themselves in or around the pool environment (FRFA). Adult salmon and other fish in search of suitable spawning areas could move upstream of their current spawning grounds or attempt to move downstream below the dam. If the capacity of tributary reaches above the reservoir inundation footprint to support salmon is limited (e.g., due to limited area with suitable gravel for spawning or limited area and food resources for rearing juveniles), the addition of more spawners to areas above the reservoir could, over time, reduce the abundance of the population that originates from above the dam once density-dependent factors become an effect.

The hydrologically dynamic area that becomes inundated and dewatered during flood storage with either the FRO or FRFA dam may create an area where fish may take temporary residence, then become stranded due to the drawdown of stored water if it occurs too rapidly. Use of the hydrologically dynamic area by spawning salmon could pose risks for redds at the margins of the inundated area that are subsequently dewatered during drawdown. Planned drawdown rates would be 10 to 20 feet per day to minimize risk of landslides and erosion. Stranding could occur at any drawdown rate; however, the likelihood of stranding for salmon would be highly variable depending on age and size of the fish, species, substrate, and channel configuration (Hunter 1992). Immobile life stages, such as lamprey ammocoetes or developing salmon embryos, in newly built redds would be most at risk.

For the FRFA, some fish and life stages would adapt to the changes and utilize lake-type habitat, some would not, and habitat function would be reduced for some species, reducing survival of those species in the area. Some species and life stages, such as adult salmon, steelhead, and lamprey, may only use the pool as a migratory corridor as they move into stream environments upstream of the reservoir, while other species and life stages may be more adaptable to residing in lake or reservoir environments. Some juvenile salmon that emerge from tributaries upstream may move downstream and utilize reservoir habitat for varying periods in the fall, winter, or early spring, depending on the species and their life history. However, water would heat and stratify during the summer months, exceeding the core summer salmonid habitat criterion (16°C), and the temperature range for optimal growth of juvenile salmon (10 to 15°C; McCullough 1999) in the upper elevations (shallower depths) of the reservoir. Immediately upstream of the FRFA dam, water temperatures may reach close to 24°C in July and August, which would be stressful, increase risk of disease outbreak, and would be detrimental to growth of juvenile salmon because their ability to feed cannot meet their metabolic requirements at these temperatures. Water temperatures could be directly lethal to salmon (26°C) near the surface for short periods of the summer in some years (McCullough 1999).

Warmer waters in the FRFA reservoir would also hold lower DO; however, reductions in DO are not expected to reach levels considered lethal for juvenile salmon near the surface. In addition, decaying vegetation and lack of mixing could contribute to low DO levels deep in the reservoir, though the potential use of these depths by fish species in uncertain. Reduced water quality in shallower layers of the reservoir could force juvenile salmon to seek thermal refugia in deeper water, limiting their foraging opportunities and reducing the effectiveness of juvenile fish collection facilities, or could cause them to emigrate from the reservoir early in the summer. The reservoir environment may favor predatory fishes, such as Northern pikeminnow, which are highly adaptable and thrive in reservoirs of the Columbia River where they prey heavily on juvenile salmon (Zimmerman 1999). Warmer reservoir temperatures are also known to exacerbate predator feeding on juvenile salmonids (Petersen and Kitchell 2001).

Northern pikeminnow were observed immediately downstream of the Flood Retention Facility site during recent fish surveys, and other predatory warm water, non-native species were observed farther downstream (Zimmerman and Winkowski 2016). A permanent reservoir may create an environment that could favor adaptable non-native species (e.g., largemouth bass) to expand their range in the upper Chehalis Basin if artificially introduced by humans or the fish migrate upstream that far; however, public access to the reservoir is not anticipated, reducing the likelihood of human introductions.

Permanent loss and selective harvest of large trees and vegetation would occur above the Flood Retention Facility: (see the Wetlands and Vegetation section). Removal of trees and vegetation would permanently eliminate benefits to fish provided by a riparian buffer zone by disrupting the associated physical, chemical, and biotic processes. Insects that fall from trees overhanging the water are an important direct food source for fishes rearing in streams. Food and nutrient inputs from riparian vegetation that directly and indirectly feed fish would be reduced (Allan et al. 2003). Riparian plants supply dissolved nutrients to the water, supporting growth of primary producers that aquatic invertebrates and some fish feed on. Fish habitat-forming processes in the Chehalis River system are already impaired by a lack of large wood, and the supply of large wood to the stream from this stretch of river would be further reduced due to the removal of large trees from the inundation area. However, some wood could be delivered to the stream channel with landslides. Large wood is necessary to maintain fish habitat-forming processes, such as the creation of pools and side-channel habitat. Fish may also be affected by the development of new roads and utilities that would be necessary to support the Flood Retention Facility. Increased impervious surfaces and road densities could potentially increase fine sediment and pollutant delivery to the stream via stormwater runoff, which are hazardous to fish.

During flooding of an FRO reservoir, a transient reduction in DO in the reservoir to levels that affect fish behavior could occur during longer periods of flood retention due to processes that consume oxygen, including decomposition of submerged plants and algae growth driven by nutrient inputs from newly inundated soil. During summer, shading by riparian trees would be reduced or eliminated around stream reaches that flow through the reservoir footprint, resulting in increased water temperatures of up to 5°C compared to current conditions in some areas (e.g., Crim Creek). Increased temperatures would persist for approximately 22 miles on the Chehalis River downstream of the FRO dam. Water temperatures in the reach immediately below the FRO facility are predicted to increase by approximately 2 to 3°C in summer, an area which already has summer water temperatures that exceed optimal limits for salmon and other cool-water fish species (Beschta 1997). Impacts of the FRO facility on water temperature would be negligible below the confluence with the South Fork Chehalis River (RM 85).

Deposition and re-mobilization of fine sediment would occur in hydrologically dynamic areas in the FRO inundation footprint and in the upper reaches of the FRFA reservoir, causing increased turbidity in the pool downstream areas. When flow velocity decreases in upper reaches of the reservoir, mobilized sediments would be deposited and accumulate in the non-flowing reservoir area. Sediment deposition in this scenario would have the greatest impact on benthic species and immobile life stages. Fine sediments could reduce incubation survival for fish that use the riverbed for spawning and change habitat use for species that rely on larger bed materials. In particular, salmon embryos incubating in redds require constant flow of oxygenated water through the gravel and would suffocate if located in stream reaches that become temporarily inundated and covered in newly deposited sediment. With the FRO facility, fine sediment would be remobilized during drawdown or during subsequent rain events, which would increase turbidity in the stream reaches upstream and downstream of the Flood Retention

Facility. Turbidity could affect fish directly by causing gill abrasion and impairing vision used for foraging and avoiding predators. Disturbance of the substrate due to flood retention would alter food webs that support fish by resetting the standing crop of algae and aquatic invertebrates that feed fish (Power 2006), approximately once every 7 years.

Fish Passage

For both the FRO and FRFA facilities, the passage of upstream migrating adult and juvenile salmonids is being incorporated into the design of passage facilities. For downstream migrating juvenile salmonids, passage facilities are also being designed for both types of dams. The passage of upstream migrating adult Pacific lamprey is also being incorporated into the design of passage facilities for both types of dams and the downstream passage of juvenile lamprey is being incorporated into the FRO outlet tunnels. Quantitative estimates of fish passage efficiency and survival for salmon and lamprey have been provided based on observations at existing dams for various methods of passage being proposed for each dam type.

With an FRO dam, passage for all fishes would be provided upstream and downstream through tunnels at the base of the dam. The FRO tunnel outlets are being designed to match the current grade and hydraulic characteristics of the river. When tunnels are open (during non-flood conditions), passage survival would range from 59% to 96% for salmon, steelhead, and lamprey depending on species and life stage (both adult and juvenile fish will access and utilize the tunnels). Fish passage through the structure would be blocked when flood retention occurs, and during flow events that are high enough to cause high flow velocity or submerge the tunnels (greater than 2,000 cfs) but not high enough to trigger flood retention. During a flood retention event, fish that enter the reservoir would have no outlet for downstream fish passage until the tunnels are reopened. Modeling of the annual hydraulic conditions from 1989 through 2015 indicates fish passage would have been impaired by high flows in 26 out of 27 water years modeled, and fish passage in these years would have been blocked during one to three separate events in a given water year. Fish passage would have been impaired or blocked anywhere from a total of 22 hours (in 1992/1993) up to a total of nearly 59 days (in 1989/1990 and 1990/1991).

During a major flood when tunnels would be closed, a trap and transport system is under consideration for providing upstream fish passage past the FRO. For salmonids, adult upstream passage under trap and transport is estimated to be reduced slightly compared to tunnel passage (from 94% to 96% down to 91%), whereas for juvenile salmonids migrating upstream, passage by a specially designed low-flow entrance at the trap and transport facility is estimated to be reduced somewhat compared to tunnel passage (from 59% to 79% down to 54%). For Pacific lamprey, adult passage into the low-flow entrance at the trap and transport facility is estimated to enable 54% of the adults migrating upstream to pass the dam.

Fish passage through the FRO dam would be impaired or blocked only during the rainy season (November to February). Four out of the five salmonid species present (fall-run Chinook salmon, coho salmon, early hatchery-origin winter-run steelhead, and coastal cutthroat trout), and potentially Pacific lamprey, migrate upstream to spawn during this period, although lamprey typically migrate later during spring and early summer. Salmon spawning success could be reduced when adults that are delayed from moving upstream attempt to spawn in less optimal habitat below the reservoir, or mature adults become stressed and suffer from pre-spawn mortality if they expend their energy stores prior to finding upstream habitat. The fate of juvenile migratory fish trapped upstream of the FRO dam during flood retention remains unknown. In coastal streams, juvenile salmon tend to redistribute into small tributary or off-channel pool habitat during fall and winter (Hance et al. 2016; Bustard and Narver 1975) in response to increasing stream discharge or floods to find refuge from high-velocity flows (Peterson 1982; Bell et al. 2001) and potentially continue foraging when food is scarce in the mainstem (Giannico and Hinch 2003). The FRO dam may adversely affect juvenile salmon by preventing their normal movements up or downstream to seek refuge during flood conditions and forage in winter; alternatively, the FRO reservoir could provide a stable pool-type habitat during flood retention and reduce displacement of juvenile salmonids downstream of the FRO due to reduced peak-flow events. Juvenile Pacific lamprey movement downstream could also become impaired during a flood retention event in winter and early spring as they begin their migration to the ocean. The impact of draining the temporary reservoir on fishes is undetermined; however, a risk of stranding in dewatered areas and injury exists for fish that pass through the tunnels at the base of the dam after a flood retention event due to high-velocity flows and debris.

At the FRFA facility, two potential upstream passage facilities are being evaluated: a fish ladder and a trap and transport system. Passage facilities for fish migrating upstream are expected to perform well for adult salmonids and mediocore for adult lamprey and juvenile salmonids. Juvenile salmon would not be able to climb a fish ladder; therefore, upstream juvenile fish passage would have to be provided by a specially designed low-flow entrance at the trap and haul facility. It is estimated that 54% of the adult Pacific lamprey that approach the dam would pass through the ladder or trap and transport facility. This is based on the estimated performance of a specially designed entrance, weir designs, flumes, resting pools, attachment surfaces, and flow conditions that would be incorporated into the ladder and trap and transport facility designs to accommodate adult lamprey passage. Lamprey, which have been observed upstream of the Flood Retention Facility site (Winkowski 2015), have difficulty moving through structures engineered for upstream migrating salmon because of the unique way they use their mouth parts to attach to the substrate while progressing upstream, rather than swimming through the water column (Moser et al. 2002).

For downstream-migrating fish at the FRFA facility, two potential passage facilities are being evaluated: a floating surface collector located in the reservoir near the dam and a multi-port outlet system. Juvenile fish collected at the floating collector would be transferred into trucks, transported, and released downstream. Juvenile fish that enter one of the outlets in the multi-port systems would pass through downstream without artificial transport. While it is uncertain how either downstream passage system would perform for lamprey in the Chehalis River, it is possible their effectiveness will be low given that salmonids are surface oriented, juvenile lamprey are bottom oriented, and the systems would be located to collect juvenile salmon and steelhead and adult steelhead at the surface. Over the long term, the challenge of passing lamprey downstream around an FRFA dam could prevent lamprey from migrating to the ocean, leading to local reductions in the population and possibly elimination of lamprey upstream of the dam.

Upstream passage of juvenile salmonids, adult lamprey, and other resident fish through either Flood Retention Facility is expected to be reduced compared to the baseline. Upstream passage of juvenile salmonids and adult lamprey past the FRFA will be limited to those fish that can enter the adult ladder or trap and transport system alternatives under design. A low-velocity, low-level entrance for adult lamprey and juvenile fish attraction is being incorporated into the ladder and trap and transport designs next to the main (adult salmon) entrances, which provide attraction flow for the low velocity entrance. These systems are under design and the current estimate is that 54% of the juvenile fish approaching the base of the FRFA might pass the dam. The upstream passage of juvenile salmonids, adult lamprey, and resident fish is also being incorporated into the design of the FRO outlet tunnels. The grade of the tunnels will match the grade of the current river channel at the dam site and velocities within the tunnels are being designed (reduced) to accommodate the upstream migration requirements of these fishes and life stages. The tunnels are estimated to pass from 59% to 79% of the juvenile salmonids migrating upstream. Upstream and downstream passage is an important consideration for juvenile salmonids, which actively travel throughout the area during the summer, presumably to forage and find refuge (Winkowski and Zimmerman, in prep). If the tunnels do not perform as expected, juvenile salmonids could become concentrated below the Flood Retention Facility, potentially increasing the density of juveniles in downstream areas that may have a limited productivity to support juvenile rearing in these populations.

All fish passage elements that involve holding or movement of fish around the river, such as trap and transport or a floating surface collector, would involve crowding, delays, and human handling, which could cause fish stress, disease, and death (Clements et al. 2002; Specker and Schreck 1980; Murauskas et al. 2014).

Changes to Habitat-forming Processes and Water Quality Downstream of the Flood Retention Facility

Flood Retention Facility operations would affect fish by reducing the volume and amplitude of very large floods that produce the forces that drive habitat-building processes (Poff and Zimmerman 2010). For example, high-energy floods transport gravels important for salmon spawning and large wood that creates logjams, which is important for slowing flows and creating pools used by rearing juvenile salmon, holding adult salmon, and other fish species. High-energy floods also cause avulsions of the river, which ultimately result in the creation of complex off-channel habitat important for juvenile coho salmon and other fish species. These processes can be partially maintained and the impact on fish habitat reduced by allowing lower-magnitude floods to pass downstream of the Flood Retention Facility

(Poff and Zimmerman 2010), as would be the case for both the FRO and FRFA. With an FRFA dam, large wood and sediment would be prevented from moving downstream, resulting in a greater impact on downstream habitat-building processes than an FRO dam that could pass some large wood and sediment; however, large wood and sediment would be withheld during flood retention with an FRO dam.

The FRO facility would allow all floods that do not exceed the major flood threshold to pass through, maintaining fish habitat-forming processes until a large flood occurs. Temporary flood retention would change the timing and rate of sediment transport, and potentially the rate and occurrence of channel migration, representing a change in forces that shape habitat complexity for fish downstream. Similarly, the FRFA facility would retain floods above the same retention threshold and would pass more moderate floods. However, in order to maintain a conservation pool, floods in the fall and early winter may be retained during a period of reservoir re-filling. The FRFA facility would retain almost all sediment, reducing delivery of sediment to downstream reaches that is important for fish habitat, including gravels used by salmon for spawning. The result would be that the existing substrate below the FRFA facility would become coarser over time as smaller bedload is scoured and transported downstream, but is not replaced by materials recruited from sources above the dam.

An additional impact of a prolonged period of high turbidity during drawdown could include interruption of spawner surveys that require biologists to visually spot fish and redds in the river, impairing the ability for biologists to assess the size of the salmon run each year. Turbidity in the nearby Skookumchuck River below the Skookumchuck Reservoir is known to impair WDFW's ability to sight redds and spawners during stock assessment surveys. The average residence time of water in the Skookumchuck Reservoir is 64 days. In comparison, the average residence time of water in the FRFA facility reservoir would be 83 days, suggesting the FRFA facility may cause less turbidity downstream than is currently experienced from the Skookumchuck River.

Flood control operations would reduce floodplain inundation by 10% (4,480 acres), eliminating some connections between the Chehalis River and off-channel or floodplain areas during and after floods that are large enough to trigger flood retention, resulting in an impact on fish and wildlife habitat function. Floodplain areas that are ephemerally connected to the mainstem river can be important rearing habitat for fish, juvenile coho salmon in particular. Off-channel habitat could also be inhabited by non-native species that appear to benefit when off-channel habitats become disconnected from the mainstem. In a survey of off-channel habitats adjacent to the mainstem Chehalis River, more frequent connection and seasonal flooding of the habitat was associated with more native and fewer non-native fish and amphibian species in off-channel habitats (Ashcraft et al. 2016). Most of the floodplain area (90%) would still experience flooding most of the time as moderate floods would continue to pass downstream, and the hydrologic influence of other major tributaries to the Chehalis River would not be impeded.

A reduction in flooding below the Flood Retention Facility could lead to land use change by humans, such as more development or agricultural uses that may affect water quality and water quantity for fish and aquatic wildlife. However, substantial new development in areas where inundation from floodwaters is reduced by the Flood Retention Facility is not anticipated because the extent of flooding is not expected to change considerably with either facility, as it would primarily reduce flooding depths (see Appendix L). Reducing flooding of urban areas could create a minor benefit to fish and aquatic wildlife by reducing exposure of fish to concentrated levels of pollutants typically mobilized during floods from roads, gas stations, and storage facilities.

Flow Augmentation and Temperature Reduction with the FRFA Facility

The FRFA facility would regulate flows and temperature for fish, particularly salmon, downstream of the FRFA facility. The FRFA facility would be designed and operated to optimize conditions for spring-run Chinook salmon by increasing the amount of habitat below the FRFA facility that meets temperature suitability criteria for pre-spawning salmon, spawning salmon, and incubating embryos. The increase in habitat area provided by increased flow and decreased temperature is also estimated to increase the amount of suitable habitat available to native, non-salmonid fish species below the dam. Mid-summer operations would be designed to reduce water temperature and improve DO by releasing water from specific elevations in the reservoir and by augmenting flow downstream of the FRFA facility. Low summer flows would be augmented to meet minimum instream flow targets for fish. During August, when water temperatures are highest and DO is lowest, water released from the FRFA facility would be approximately 10°C cooler than existing conditions and DO would be slightly elevated, with the greatest effect in the reaches immediately below the dam up to the confluence with the South Fork Chehalis River, and attenuating by the confluence with the Skookumchuck River (RM 65; PSU 2016). Reduction in water temperature would be targeted to increase usable habitat during the summer for spring-run Chinook salmon holding in the river prior to spawning under existing conditions, and is expected to help address the anticipated rise in water temperature that would likely occur with climate change (see the Climate Change section). Recent efforts to track adult spring-run Chinook salmon movements indicate that in the Chehalis Basin, these fish have adapted to surviving in a naturally warm, rain-driven system. They have adapted by either by moving in to cooler headwater tributaries early in the summer, before temperatures in the mainstem Chehalis River become stressful, or by pausing in cool-water refugia near the confluences of major tributaries from July to September (Liedtke et al. 2016).

There is uncertainty around the magnitude of water temperature reduction and flow augmentation benefits provided by the FRFA facility for a species that has adapted behaviorally to a warm river, especially relative to the losses predicted to other species resulting from the FRFA facility. An increase in the proportion of juvenile salmonids residing in the area just below the Flood Retention Facility would be possible with an artificial reduction in temperature; however, other habitat characteristics (e.g., pool number, substrate size, and channel complexity) are also important determinants of juvenile salmonid distribution. The stream reaches that are closest to the potential Flood Retention Facility occur in a "transitional" zone for the summer fish community, from one dominated by juvenile salmonids to one dominated by warm-water associated species like redside shiner and dace (e.g., speckled, longnose).

The occurrence of these groups of species is related to an increase in water temperature and change in habitat characteristics moving from upstream to downstream (Zimmerman and Winkowski 2016). The change in flow and temperature could have the unintended effect of altering the timing and intensity of biological cues for fishes downstream of the Flood Retention Facility by providing cool-water pulses earlier in the year than under natural conditions (Young et al. 2011).

Effects to hyporheic flows downstream of the Flood Retention Facility may occur (Arntzen et al. 2006), though the changes would be complex and have not been quantified. Hyporheic zones where the river gains cool, oxygenated water provide high-quality spawning habitat for salmon (Geist et al. 2002) and lamprey, and can provide refugia when temperatures in the water column are higher than is optimal for other cool-water associated fish species currently observed near the potential dam site (juvenile trout and salmon, prickly sculpin, riffle sculpin, torrent sculpin).

Modeled Effects to Salmon

The predicted changes to the physical environment that shape salmon habitat resulting from the FRO and FRFA facilities were applied in a salmon habitat model (Ecosystem Diagnosis & Treatment [EDT]) to evaluate the impact of changes in habitat to salmon populations. Physical changes for each Flood Retention Facility type are summarized in Table H-2 (ICF 2016).

Table H-2
Summary of Environmental Changes for the Flood Retention Facility

AREA	FRFA	FRO
Tributaries above reservoir footprint	No change	No change
Reservoir footprint	• Approximately 7 miles of riverine reaches converted to reservoir habitat • Reservoir will be used by some species and life stages, including some juvenile salmon in the shoreline areas	• Riverine reaches converted to glides • Riparian area function reduced • Temperature increased • Large wood decreased in 50% or 100% of inundation footprint length
Dam	• Adult salmonid passage survival: 79% to 91% • Juvenile salmonid collection at dam: 64% survival • Upstream juvenile passage: 54% • Adult lamprey passage survival: 54% • Juvenile lamprey collection at dam: <1%	• Adult salmonid passage survival: 94% to 96% (91% during floods) • Juvenile salmonid passage survival: – 85% to 95% downstream – 59% to 79% upstream • Adult lamprey passage survival: 96% (54% during floods) • Juvenile lamprey passage survival: 95%

AREA	FRFA	FRO
Dam to South Fork Chehalis River	• Increased summer flow, decreased winter flow • Decreased summer temperature, increased fall temperature • Reduced wood, coarsening of sediment • Reduced bed scour • Changes in floodplain inundation	• Reduced wood • Reduced bed scour • Changes in floodplain inundation
South Fork Chehalis River to Newaukum River	Changes from upstream reach attenuate to the confluence with the Newaukum River	Changes from upstream reach attenuate to the confluence with the Newaukum River
Newaukum River to Black River	Reduction in flood peaks and floodplain inundation	No change
Black River to Grays Harbor	No change	No change

The collective impacts of the FRO facility on salmon habitat were analyzed using the EDT model. This included loss of function of temporarily inundated riparian habitat upstream of the structure, reduced fish survival while passing through the structure, and changes to habitat-building processes downstream (ICF 2016). To analyze the effects of the FRO facility on fish, two scenarios—FRO 50 and FRO 100—were evaluated. These scenarios represent the assumption that 50% or 100% of the habitat upstream of the FRO dam would be degraded by impounding flood flows. The effect of an FRO 50 scenario may represent a more likely scenario because habitat would be disturbed only when floods are retained, approximately once every 7 years, and a Pre-construction Vegetation Management Plan would prevent total loss of riparian vegetation and riparian area function for fish. Though inundation associated with an FRO facility is anticipated to occur infrequently, a precise projection of the highest extent of impacts on upstream habitat degradation is difficult to project given uncertainties related to the extent of potential water temperature increase, reduction of food and nutrient inputs from riparian habitat loss and fine sediment deposition, spawning gravel changes in the reach between retention events, channel widening, mass wasting sediment input, and other factors. Therefore, it is appropriate to evaluate both 50% and 100% upstream habitat loss to capture the range of potential outcomes. The assumed downstream changes in habitat included reduced large wood, reduced bed scour, increased water temperature, and changes in floodplain inundation. Results suggest that all four salmon species would experience some decline in abundance. The decline in abundance reflects the adverse impact of the Flood Retention Facility on population productivity and population life history diversity, both of which are measures of population resiliency (McElhany et al. 2000).

The collective habitat impacts from the FRFA facility on salmonids were also modeled, including the conversion of complex river habitat to reservoir (ICF 2016). Downstream of the FRFA facility, the assumed impacts modeled were reductions in large wood, lower bed scour, coarsening of sediment to a higher degree than the FRO, with the added increase in summer flow, decrease in winter flow, decrease in summer temperature, and increase in fall temperatures. The FRFA facility in the Chehalis River is a new design in a previously un-dammed river and uncertainty surrounds the actual response of spring-run Chinook salmon to flow and temperature modulation below the FRFA facility (see Appendix K).

Wildlife

Permanent alterations to riparian areas could result from changes to the flows upstream and downstream of a Flood Retention Facility, potentially disrupting physical, chemical, and biotic processes associated with riparian areas, reducing or eliminating many of the important functions (Knutson and Naef 1997) provided by these riparian areas. Potential changes to habitat resulting from alteration of riparian areas could include the following:

- Reduction, elimination, or fragmentation of habitat and travel corridors for wildlife, including amphibians, reptiles, birds, and various mammals
- Reduction in the contribution of the riparian area to suitable water quality for wildlife, especially stream-associated amphibian species, including filtration and purification of runoff, shading and thermoregulation of water, and stabilization of fine sediment and turbidity from streambank erosion that could lead to filling of interstitial spaces in stream substrate used by amphibians for breeding and foraging (Leonard et al. 1993)
- Reduction in the amount of leaf litter, organic debris, and other nutrient inputs that support species at the base of the food chain, reducing forage for wildlife species in aquatic habitats
- Reduction in the amount and variety of woody material contributed to the system, affecting nutrient cycles and limiting instream habitat-forming processes that support stream-associated amphibians
  - Riparian woody material is a habitat feature used by amphibians, like the state-candidate species Van Dyke’s salamander, for breeding and foraging
  - Instream woody material provides stable steps within stream systems used by stream-breeding amphibians for breeding and refuge
- Reduction in ecosystem complexity (habitats with diverse features support a greater variety of wildlife species)

Impacts on wildlife and habitat would occur upstream of the dam, resulting from clearing of vegetation within the temporary FRO reservoir or FRFA conservation pool from fluctuating water levels that would cause frequent disturbance in these areas.

Long-term impacts on wildlife habitat would occur with the clearing of mixed coniferous and deciduous upland forest vegetation of varying sizes and age classes, as well as some scattered wetland communities in the structural and inundation footprint for the Flood Retention Facility, as described in the Vegetation section. Conversion of forested upland, riparian, and wetland wildlife habitats to those dominated by herbaceous and shrub vegetation species would result in loss of some types of riparian habitat used by wildlife, and may represent a gain of useful habitat for others. The loss of trees could directly affect feeding and nesting by bird and mammal species, and possibly for the federally Endangered Species Act-listed species marbled murrelet. The loss of riparian cover impairs habitat conditions for many amphibians, especially by reducing adequate surface moisture and appropriate temperature conditions for terrestrial stages of stream-associated amphibians, such as the state-candidate species Van Dyke's salamander (Hallock et al. 2005). Conversely, brushy vegetation exposed in the impoundment area during dry periods could provide additional foraging habitat for deer, elk, and birds of prey (Link 2004).

Disturbances to habitats of native species provide opportunities for the invasion of non-native wildlife species, such as the European starling and American bullfrog, that could prey on or out-compete native wildlife species for resources (Knutson and Naef 1997). The temporary stillwater habitat created by the FRO facility may provide more habitat for warm, stillwater-associated wildlife species like the American bullfrog than currently exists in the Chehalis Basin, though this concern is substantially greater for the permanent pool of the FRFA facility reservoir.

Long-term impacts would also occur due to periodic or permanent inundation of the current forest, riparian, or stream habitats. Inundation could affect wildlife currently using these areas by changing the types of habitat available for wildlife in this area over the long term. The diversity and composition of wildlife species that currently use specific existing habitats to breed, forage, rest, and overwinter could change as a result of modifications to wildlife habitat. Species that rely on aquatic systems for life cycle stages (e.g., amphibians, western pond turtle, and North American beaver) would be particularly vulnerable to impacts on aquatic habitat (ASEPTC 2014). Songbirds, raptors, and large and small mammals would be less vulnerable and more adaptable to changes in aquatic habitat because they generally are not as reliant on specific aquatic habitat features.

Impacts on physical processes due to the drawdown of the FRO or the FRFA flood pool may result in long-term impacts on wildlife. Mobilization of previously deposited sediment would occur as stream channels become re-established, and during vegetation removal performed as part of ongoing maintenance. Further, potential landslides in the reservoir footprint would result in changes in sedimentation to downstream aquatic habitats. A prolonged flood pulse due to controlled reservoir drawdown could change habitat-building processes downstream for semi-aquatic wildlife species, altering aquatic habitat conditions used for breeding and foraging.

Temporary inundation of the FRO reservoir would impact wildlife and wildlife habitat in the stream reach within the boundaries of the inundation area. Though flooding would be infrequent and temporary, the flooded area would be relatively large, up to 778 acres. During floods, river flows would be retained in the reservoir, with filling and draining of the reservoir lasting up to 32 days. Longer inundation events present an adverse impact on wetlands and riparian habitat where vegetation would die, resulting in a larger extent of unvegetated or sparsely vegetated mudflats. Inundation of riparian habitat used by amphibians and other wildlife species would directly displace animals or result in mortality for species unable to disperse or relocate to other suitable habitats (Knutson and Naef 1997). Increased deposition of coarse sediment and some fraction of fine sediment upstream of the Flood Retention Facility would negatively affect water quality (increased turbidity and low DO) and aquatic habitat for stream invertebrates and stream-associated amphibians for breeding and foraging. Temporary inundation and sedimentation of the stream channel would alter its structure from pools and riffles (to sedimented, then eroded) and replace stable aquatic habitat with dynamic habitat, affecting habitat preferred by aquatic amphibians.

Permanent inundation of the FRFA facility reservoir would convert stream and riparian habitats to a pool (lacustrine) habitat for which many stream-dwelling wildlife species, especially native amphibians, are not well adapted, presenting a loss of functional habitat for these species. For instance, conversion of stream habitat to reservoir habitat represents a direct loss of breeding habitat for the state-endangered western pond turtle, and has the potential to contribute to the local or regional extirpation of the species (ASEPTC 2014). Most wildlife species would not adapt to the changes from stream, riparian, and terrestrial habitats to a lacustrine habitat, forcing these species to attempt to relocate to other suitable habitat (Knutson and Naef 1997). Some species would successfully relocate to other suitable habitat and some species would be unsuccessful in relocating to other habitats and would perish (Knutson and Naef 1997).

Specific species that would be adversely affected by temporary (FRO reservoir) and permanent (FRFA reservoir) water retention include the western toad and western pond turtle. Breeding habitat for the western toad in the Chehalis Basin is concentrated in the Chehalis River mainstem and larger tributaries within the proposed reservoir footprint (Hayes et al. 2016). Temporary inundation of these areas by the FRO reservoir during flood retention events and permanent inundation in the FRFA conservation pool would eliminate this habitat, potentially contributing to the extirpation of the western toad from this portion of the Chehalis Basin. Although western toads are known to breed in stillwater reservoirs, the potential for this to occur in the FRFA conservation pool is uncertain due to the magnitude and timing of water fluctuations in the reservoir due to dam operations. The western pond turtle, a state-endangered species that is potentially present in the Chehalis Basin, would also be affected by the direct loss of potential breeding habitat from the conversion of stream habitat to reservoir habitat (ASEPTC 2014). Such losses would contribute to the local or regional extirpation of that species.

Both flood storage reservoir scenarios would change water quality by increasing temperature, with possible declines in DO and elevated turbidity conditions. This would result in an impact on amphibian species that prefer to breed and forage in stream-fed systems with cooler water temperatures. Warmer stillwater conditions could favor warm-water, non-native species that compete with and prey on native species, especially the American bullfrog. Some long-term impacts of a permanent reservoir could be beneficial to native species. For instance, the reservoir area would provide additional foraging habitat for certain fish-eating raptor species, such as eagles and osprey, and waterfowl species breed and forage in inundated areas.

Downstream of the Flood Retention Facility, flood control would cause a substantial reduction in the magnitude of peak floods, which would translate to reductions in habitat-forming processes. While flooding of the magnitude that would trigger flood retention would be infrequent (approximately once every 7 years), it is the largest floods that have the greatest ability to shape aquatic species habitat. Habitat-building processes downstream would also be affected by the retention of much of the sediment and large wood load by the Flood Retention Facility. Coarse sediment and large wood are features that provide habitat for amphibians for breeding and foraging. The following habitat-building processes would be impaired by flood control:

- The likelihood for some floodplain and off-channel habitats to become inundated would be greatly reduced, altering the existing hydrological habitat conditions
- Sediment deposition and routing would change compared to current patterns
- Interactions between high flows and large wood that create avulsions would be reduced, leading to less creation of new off-channel habitats
- Connections between the river and off-channel habitat may be reduced, which would reduce the ability of semiaquatic species, especially amphibians, to access other aquatic habitats
- A reduction in flood disturbances would provide more stable habitat conditions that would benefit wildlife species that currently breed, forage, and overwinter under existing aquatic and riparian habitat conditions that could be disturbed by flooding events (Knutson and Naef 1997)
- Less fluctuation in water levels in off-channel habitats is associated with increased likelihood that warm-water, non-native species, such as American bullfrogs, could become established

Changes in the structure and composition of downstream riparian habitat and the services provided may be altered gradually over time due to better growth and survivorship of the riparian vegetation with the reduction in the scouring effect of high flows on plant roots, saplings, and seeds along the riverbank during major floods (Williams and Wolman 1984; Friedman et al. 1998). Additionally, the Flood Retention Facility itself could become a barrier to the dispersal of riparian plant species, which could limit the diversity of riparian plant species downstream for semi-aquatic wildlife habitat, thus reducing the quality of wildlife habitat. Changes to the structure and composition of downstream riparian habitats could result in the following:

- A decrease in suitable areas for species that use unvegetated areas for nesting, such as the state-endangered western pond turtle, or for emerging after metamorphosis, such as the state-candidate western toad (Nussbaum et al. 1983)

- An increase in the extent of maturing/mature riparian forests tending toward older, less productive successional states, and reduced extents of young riparian habitats, affecting the quality of wildlife habitat in riparian areas (Nilsson and Berggren 2000)
- Changes in dispersal of riparian plant species, as well as species composition and diversity of riparian plant species downstream of the Flood Retention Facility, as a result of flow modification
- Transition of riparian areas and floodplain vegetation from flood-tolerant tree species to forest types more characteristic of unflooded upland areas (Décamps et al. 1988; Nilsson and Berggren 2000), which could affect the type and quality of wildlife habitat available in these areas
- Reduced area affected by invasive plant species spread by flooding, which may maintain higher quality habitat for native species

Flood control with the FRFA dam would allow for the modulation of flows downstream of the dam year-round, with the intention of providing higher base flows and cooler water during the summer months to improve downstream habitat for salmon. The potential effects of these higher flows and cooler water temperatures on stream-breeding and stream-associated terrestrial amphibians is uncertain. An increase in low summer instream flows downstream of the FRFA dam could benefit certain amphibian species by providing sufficient water levels in off-channel habitats that dry up under existing conditions. Although many amphibian species could also benefit from cooler stream temperatures, such changes could interfere with the seasonal environmental cues (e.g., increased water temperature; decreased flow and water depth) used by these species to trigger the initiation of metamorphic processes. An increase in summer base flows and reduction in temperatures has the potential to delay or eliminate breeding habitat for the instream-breeding western toad, which appears to prefer warm shallow open water areas in the stream channel for breeding (Hayes et al. 2016). To evaluate this potential, the change in usable downstream habitat for western toads based on the proposed changes in flow and temperature that would occur with an FRFA dam was modeled using a Physical Habitat Simulation (PHABSIM) model for the six consecutive river reaches below the proposed dam. The results of this modeling effort indicate that there would be no change in the area of usable habitat for western toad in the river reach immediately below the proposed dam, but a reduction in area of usable habitat for all subsequent reaches. Overall, although flows from the FRFA dam could be regulated to maximize available instream habitat for salmon below the dam, targeted flows could conflict with those that are optimal for amphibians (ASEPTC 2014).

Table H-3

Change in Instream Habitat Area for Western Toad with FRFA Facility Flow Release

CHEHALIS RIVER REACH	CHANGE IN INSTREAM HABITAT AREA FOR WESTERN TOAD (ALL LIFE STAGES)
Pe Ell to Elk Creek	0%
Elk Creek to South Fork Chehalis	-21%
South Fork Chehalis to Newaukum	-15%
Newaukum River to Skookumchuck River	-2%
Skookumchuck River to Black River	-2%
Black River to Porter	-2%

Note: Data are the sum of the monthly averages of the change in Weightable Usable Area from May through September
Source: Beecher 2015

Climate Change

The evaluation of impacts related to climate change is considered from two perspectives, based on Washington State Department of Ecology guidance: adverse impacts that contribute to the effects of climate change (e.g., new sources of greenhouse gas [GHG] emissions) and effects of climate change on the proposed action element (e.g., increased sea levels, reduced snowpack, changes in water availability, changes in streamflow timing, increased forest fires, more extreme precipitation events, flooding).

Greenhouse Gases in Brief

GHG emissions adversely affect the environment by contributing to global climate change. In turn, global climate change results in environmental impacts in Washington such as rising sea levels and changes in water supply. GHGs include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), nitrogen trifluoride (NF_3), hydrofluorcarbons (HFCs), perflurocarbons (PFCs), and sulfur hexafluoride (SF_6). In a very simple sense, GHG emissions are air pollutants. However, there are distinctive features about these emissions that make them different from other air pollutants.

GHGs, and in particular carbon dioxide, are emitted by a vast number of sources, both natural and human-caused, in amounts ranging from trivial to massive. These emissions mix rapidly and uniformly in the atmosphere. They contribute equally to global concentrations no matter where they are emitted. A ton of CO_2 emitted in Seattle has the same effect on global concentrations as a ton emitted in Clarkston. Unlike many conventional air pollutants, local concentrations of GHGs are not greater near large sources than they are in areas far away.

Carbon dioxide equivalent (CO_2e) in metric tons (MT) is the preferred measure for determining GHG emissions rates for any combination of these GHGs. GHG emissions are typically expressed in a common metric so their impacts can be compared directly, because some gases have a higher global warming potential than others.

Source: (Ecology 2011)

Effects of the Flood Retention Facility Contributing to Climate Change

Adverse impacts contributing to climate change are not anticipated from operation and maintenance of the Flood Retention Facility, as these activities would generate relatively few GHG emissions. GHG emissions would occur from truck trips and electricity use for activities, such as sediment and debris management, vegetation management, and operation and maintenance of gate and outlet structures and fish passage facilities; however, these emissions are expected to be below the threshold for qualitatively disclosing emissions (10,000 MT CO_2e per year).

Effects of Climate Change on the Flood Retention Facility

The effects of climate change predicted with climate change forecasts include changes in precipitation, increased flooding, and drought conditions. Increased extents of flooding in downstream areas from more intense winter rains anticipated with climate change would be moderated with the Flood Retention Facility. In addition, the FRFA facility could help to moderate predicted increases in instream temperatures resulting from climate change by releasing cool water into the Chehalis River during spring through early fall.

The Flood Retention Facility is designed to address predicted patterns of climate change and could accommodate more intense precipitation and the corresponding more frequent needs for flood storage. The increased use of the Flood Retention Facility over time in response to climate change may magnify other effects of the facilities on elements of the environment, including increased potential impacts on geology, geomorphology, wetlands and vegetation, fish and wildlife (including possible delay in downstream juvenile migration and blocked upstream passage for juvenile fish), and tribal resources, as a result of increased frequency and duration of reservoir inundation periods.

Land Use

Construction of the permanent pool of the FRFA facility reservoir would create a new shoreline area, subject to regulation under the state Shoreline Management Act (SMA). The reservoir is anticipated to be a maximum of 1,264 acres if used to its full capacity. Because it is larger than 1,000 acres, it could become a Shoreline of Statewide Significance, with accompanying regulatory requirements. The FRO facility may also create a new shoreline area, but only in the event that the reservoir was full long enough to establish an ordinary high water mark, which defines SMA jurisdiction.

Construction of the FRFA facility could result in potential changes to riparian management zone (RMZ) designations under Forest Practices Rules, changing the area protected by RMZs along tributaries entering the FRFA facility reservoir. The permanent reservoir may result in differences in fish distribution and forest practices water typing upstream of the reservoir and resulting changes to RMZs would alter potential land uses or forestry operations within that zone.

References

Allan, J.D., M.S. Wipfli, J.P. Caouette, A. Prussian, and J. Rodgers, 2003. Influence of Streamside Vegetation on Inputs of Terrestrial Invertebrates to Salmonid Food Webs*. Canadian Journal of Fisheries and Aquatic Sciences* 60(3):309-20.

Anchor QEA, 2016a. *Draft Operations Plan for Flood Retention Facilities.* Prepared for the Chehalis Basin Work Group. September.

Anchor QEA, 2016b. *Flood Retention Flow Augmentation (FRFA) Reservoir Residence Times*. Memorandum from A. Hill (Anchor QEA) to R. Montgomery (Anchor QEA). July 5.

Anchor QEA, 2016c. *Draft Reservoir Water Quality Model*. Prepared for the Chehalis Basin Work Group. September.

Arntzen, E.V., D.R. Geist, and P.E. Dresel, 2006. Effects of fluctuating river flow on groundwater/surface water mixing in the hyporheic zone of a regulated, large cobble bed river. *River Research and Applications* 22:937-946.

ASEPTC, 2014. *Effects of Flood Retention Alternatives and Climate Change on Aquatic Species*. Prepared for the Chehalis Basin Work Group. 153 pp.

Ashcraft, S., C. Holt, M. Zimmerman, M. Scharf, and A. Weiss, 2016. *Upper Chehalis Salmonid Spawner Abundance and Distribution: 2013-2015 Interim Report*. Draft report prepared for EIS development. Fish Program, Aquatic Research Section, Washington Department of Fish and Wildlife. July.

Beecher, H. (Washington Department of Fish and Wildlife), 2015. Email to Robert Montgomery (Anchor QEA) regarding Weighted Usable Area for species. November 5.

Bell, E., W.G. Duffy, and T.D. Roelofs, 2001. Fidelity and Survival of Juvenile Coho Salmon in Response to a Flood. *Transactions of the American Fisheries Society* 130:450-458.

Beschta, R.L., 1997. Riparian Shade and Stream Temperature: an alternative perspective. *Rangelands* 19:25-28.

Bustard, D.R., and D.W. Narver, 1975. Aspects of the winter ecology of juvenile Coho Salmon (*Oncorhynchus kisutch*) and steelhead trout (*Salmo gairdneri*). *Journal of the Fisheries Research Board of Canada* 32:667-680.

Clements, S.P., B.J. Hicks, J.F. Carragher, and M. Dedual, 2002. The effect of a trapping procedure on the stress response of wild Rainbow Trout. *North American Journal of Fisheries Management* 22:907-916.

Connor, W.P., J.G. Sneva, K.F. Tiffan, R.K. Steinhorst, and D. Ross, 2005. Two alternative juvenile life history types for fall Chinook salmon in the Snake River basin. *Transactions of the American Fisheries Society* 134:291-304.

Décamps H, M. Fortuné, F. Gazelle, G. Pautou, 1988. Historical influence of man on the riparian dynamics of a fluvial landscape. *Landscape Ecology* 1(3):163-173.

Dubé, K. (Watershed GeoDynamics), 2016. Personal communication with J. Goldsmith (Anchor QEA) regarding sediment transport modeling and shoreline erosion. May 24.

Ecology (Washington State Department of Ecology), 2011. *Guidance for Ecology Including Greenhouse Gas Emissions in SEPA Reviews.* June 3. Available from: http://www.portolympia.com/DocumentCenter/View/1919.

Ecology, 2012. *Water Quality Standards for Surface Waters of the State of Washington*. Publication No. 06-10-091. Amended May 2011. Revised January 2012.

Friedman, J.M., W.R. Osterkamp, M.L. Scott, and G.T. Auble, 1998. Downstream Effects of Dams on Channel Geometry and Bottomland Vegetation: Regional Patterns in the Great Plains. *Wetlands* 14(4):619-633.

Geist, D.R., T.P. Hanrahan, E.V. Arntzen, G.A. McMichael, C.J. Murray, and Y.J. Chien, 2002. Physicochemical Characteristics of the Hyporheic Zone Affect Redd Site Selection by Chum Salmon and Fall Chinook Salmon in the Columbia River. *North American Journal of Fisheries Management* 22(4):1077-1085.

Giannico, G.R., and S.G. Hinch, 2003. The effect of wood and temperature on juvenile coho salmon winter movement, growth, density and survival in side-channels. *River Research and Applications* 19(3):219-231.

Gupta, H.K., 1992. *Reservoir-Induced Earthquakes*. New York: Elsevier Science, 364.

Hallock, L.A., and K.R. McAllister, 2005. Van Dyke's Salamander. Washington Herp Atlas. Updated October 2011. Available from: http://www1.dnr.wa.gov/nhp/refdesk/herp/speciesmain.html.

Hance, D.J., L.M. Ganio, K.M. Burnett, and J.L. Ebersole, 2016. Basin-Scale Variation in the Spatial Pattern of Fall Movement of Juvenile Coho Salmon in the West Fork Smith River, Oregon. *Transactions of the American Fisheries Society* 145(5):1018-1034.

Hayes, M., J. Tyson, and K. Douville, 2016. *2016 Chehalis ASRP Instream Amphibian Survey Report: 3rd Progress Report for Post-Feasibility Efforts*. Draft report prepared for EIS development. Habitat Program Science Division, Aquatic Research Section, Washington Department of Fish and Wildlife.

Hunter, M.A., 1992. *Hydropower flow fluctuations and salmonids: a review of the biological effects, mechanical causes, and options for mitigation*. State of Washington Department of Fisheries Technical Report No. 119. September. Available from: http://wdfw.wa.gov/publications/01085/wdfw01085.pdf.

ICF (ICF International), 2016. Draft EDT modeling results for Chehalis Basin Strategy Programmatic EIS. Prepared for the Washington State Department of Ecology.

Jolley, J.C., G.S. Silver, J.E. Harris, E.C. Butts, and C. Cook-Tabor, 2016. *Occupancy and Distribution of Larval Pacific Lamprey and Lampetra spp. in Wadeable Streams of the Pacific Northwest.* Vancouver: U.S. Fish and Wildlife Service, Columbia River Fish and Wildlife Conservation Office.

Knutson, K.L., and V.L. Naef., 1997. *Management recommendations for Washington's Priority Habitats: Riparian*. Olympia: Washington Department of Fish and Wildlife, 181. December. Available from: http://wdfw.wa.gov/publications/00029/wdfw00029.pdf

Leonard, W.P., H.A. Brown, L.L.C. Jones, K.R. McAllister, and R.M. Storm, 1993. *Amphibians of Washington and Oregon*. Seattle: Seattle Audubon Society.

Liedtke, T.L, M.S. Zimmerman, R.G. Tomka, C. Holt., and L. Jennings, 2016. *Behavior and movements of adult spring Chinook salmon* (Oncorhynchus tshawytscha) *in the Chehalis River Basin, southwestern Washington, 2015.* U.S. Geological Survey Open-File Report 2016-1158. Prepared in cooperation with the Washington Department of Fish and Wildlife. September. Available from: https://pubs.er.usgs.gov/publication/ofr20161158.

Link, R., 2004. *Living with Wildlife in the Pacific Northwest*. Seattle: University of Washington Press.

McCullough, D.A., 1999. *A Review and Synthesis of Effects of Alterations to the Water Temperature Regime on Freshwater Life Stages of Salmonids, with Special Reference to Chinook Salmon*. Seattle: U.S. Environmental Protection Agency, Region 10.

McElhany, P., M.H. Rucklelshaus, M.I. Ford, T.C. Wainwright, and E.P. Bjorkstedt, 2000. *Viable salmonid populations and the recovery of evolutionary significant units*. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-42. June.

Moser, M.L., P.A. Ocker, L.C. Stuehrenberg, and T.C. Bjornn, 2002. Passage Efficiency of Adult Pacific Lampreys at Hydropower Dams on the Lower Columbia River, USA. *Transactions of the American Fisheries Society* 131(5):956-965.

Murauskas, J.G., J.K. Fryer, B. Nordlund, and J.L. Miller, 2014. Trapping Effects and Fisheries Research: A Case Study of Sockeye Salmon in the Wenatchee River, USA. *Fisheries* 39(9):408-14.

Nilsson, C. and K. Berggren, 2000. Alterations of Riparian Ecosystems Caused by River Regulation. *BioScience* 50(9): 783-792.

NPLCC (North Pacific Landscape Conservation Cooperative), 2016. Pacific Lamprey Nature Serve Rankings. Updated June 12, 2015. Cited September 1, 2016. Available from: https://nplcc.databasin.org/datasets/fb4c6a49a017424b8c78e81ec55a1927

Nussbaum, R.A., E.D. Brodie Jr., and R.M. Storm, 1983. *Amphibians and Reptiles of the Pacific Northwest*. Moscow: University of Idaho Press.

Petersen, J.H., and J.F. Kitchell, 2001. Climate regimes and water temperature changes in the Columbia River: Bioenergetic Implications for predators of juvenile salmon. *Canadian Journal of Fisheries and Aquatic Sciences* 58:1831-1841.

Peterson, N.P., 1982. Immigration of Juvenile Coho Salmon (*Oncorhynchus kisutch*) into Riverine Ponds. *Canadian Journal of Fisheries and Aquatic Sciences* 39:1308-1310.

Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegaard, B.D. Richter, R.E. Sparks, and J.C. Stromberg, 1997. The Natural Flow Regime: A Paradigm for River Conservation and Restoration. *BioScience* 47(11):769-784.

Poff, N.L., and J.K.H. Zimmerman, 2010. Ecological responses to altered flow regimes: a literature review to inform environmental flows science and management. *Freshwater Biology* 55:194-20.

Power, M.E., 2006. Environmental controls on food web regimes: A fluvial perspective. *Progress in Oceanography* 68:125-133.

PSU (Portland State University), 2016. *Draft Development and Calibration of the Chehalis River CE-QUAL-W2 Water Quality Model.*

Rood, S.B., and J.M. Mahoney, 1990. Collapse of riparian poplar forests downstream from dams in western prairies: probable causes and prospects for mitigation. *Environmental Management* 14(4): 451-464.

Specker, J.L., and C.B. Schreck, 1980. Stress Responses to Transportation and Fitness for Marine Survival in Coho Salmon (*Oncorhynchus kisutch*) Smolts. *Canadian Journal of Fisheries and Aquatic Science* 37:765-769.

USFWS (U.S. Fish and Wildlife Service), 2016. The Fish Files: Pacific Lamprey Redd Surveys in the Chehalis and Willapa River Basins. Updated June 2, 2011. Cited August 31, 2016. Available from: http://the-fish-files.blogspot.com/2011/06/pacific-lamprey-redd-surveys-in.html.

Williams, G.P., and M.G. Wolman, 1984. *Downstream Effects of Dams on Alluvial Rivers*. Geological Survey Professional Paper 1286. U.S. Department of the Interior. U.S. Government Printing Office, Washington, D.C.

Winkowski, M., 2015. *Upper Chehalis Instream Fish Study 2015*. Draft report prepared for EIS development. Fish Program, Aquatic Research Section, Washington Department of Fish and Wildlife. November.

Winkowski, J., and M. Zimmerman, in prep. Summer habitat and movements of juvenile anadromous salmonids in a coastal river in Washington State. To be submitted to *Ecology of Freshwater Fish*.

Young, P.S., J.J. Cech Jr., and L.C. Thompson, 2011. Hydropower-related pulsed-flow impacts on stream fishes: a brief review, conceptual model, knowledge gaps, and research needs. *Reviews in Fish Biology and Fisheries* 21:713–731.

Zimmerman, M.P., 1999. Food Habits of Smallmouth Bass, Walleyes, and Northern Pikeminnow in the Lower Columbia River Basin during Outmigration of Juvenile Anadromous Salmonids. *Transactions of the American Fisheries Society* 128 (6):1036-54.

Zimmerman, M., and J. Winkowski, 2016. *Riverscape Surveys of In-stream Fish Assemblages and Habitat in the Chehalis River*. Draft report prepared for EIS development. Fish Program, Aquatic Research Section, Washington Department of Fish and Wildlife. January.