US Army Corps of Engineers ®
Portland District

Engineering Documentation Report

Foster Dam Downstream Fish Passage Alternatives

Foster Dam

June 2016 90% Draft Report

ABBREVIATIONS AND ACRONYMS

BiOp	Biological Opinion
cfs	cubic feet per second
COP	Configuration/Operation Plan
Corps	U.S. Army Corps of Engineers
DDR	Design Documentation Report
ER	Engineering Regulation
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
ft/s	feet per second
MW	megawatt(s)
NAVD88	North American Vertical Datum of 1988*
NGVD29	National Geodetic Vertical Datum of 1929*
NMFS	National Marine Fisheries Service
ODFW	Oregon Department of Fish and Wildlife
O&M	Operations and Maintenance
PDT	Project (or Product) Delivery Team
RM	river mile(s)
RM&E	Research, Monitoring, and Evaluation
RO	regulating outlet
RPA	Reasonable and Prudent Alternative
TDG	total dissolved gas
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Society
WATER	Willamette Action Team for Ecosystem Restoration
WVP	Willamette Valley Project

English to Metric Conversion Factors

To Convert From	To	Multiply by
feet (ft)	meters	0.3048
Miles	kilometers (km)	1.6093
Acres	hectares (ha)	0.4047
Acres	square meters (m^2)	4047
square miles (mi^2)	square kilometers (km^2)	2.590
acre-feet	hectare-meters	0.1234
acre-feet	cubic meters (m^3)	1234
cubic feet (ft^3)	cubic meters (m^3)	0.02832
feet/mile	meters/kilometer (m/km)	0.1894
cubic feet/second (cfs or ft^3/s)	cubic meters/second (m^3/s)	0.02832
degrees fahrenheit (°F)	degrees celsius (°C)	(Deg F - 32) x (5/9)

* Elevations in this report are presented in National Geodetic Vertical Datum of 1929 (NGVD29) unless otherwise shown. NGVD29 is 3.43 ft above the North American Vertical Datum of 1988 (NAVD88).

To convert NGVD29 to NAVD88 at Foster: [Elev ft NAVD88]=[Elev ft NGVD29 +3.43 ft]

EXECUTIVE SUMMARY

Executive Summary to be provided after ATR. ..

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Foster Dam Downstream Fish Passage Alternatives
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FOSTER DAM PROJECT PERTINENT DATA

1. General	
Stream	South Santiam
Drainage area, square miles	494
Project completion date	1968
2. Reservoir	
Length (maximum pool), miles	6.5
Full pool, acres	1,220
Full pool elevation, feet (NGVD29)*	641.2
Storage, acre-feet	
Total usable	33,600
Flood control	31,000
Power storage	3,600
Dead storage	27,400
Total storage	61,000
Minimum tailwater elevation	525.2
Normal flood tailwater elevation (@10,000 cfs release), feet	531.2
Standard project flood (Regulated), cfs	84,500
Maximum discharge (Dec. 1964), cfs	99,500
Minimum discharge, cfs	95
Mean annual run-off (1926-1964), acre-feet	1,852,090
* Flow rates depend on the height of the pool	
3. Dam	Rockfill
Type	4,800
Length, feet	126
Height (streambed to roadway deck), feet	97,600
Concrete volume, cubic yards	Approximately
Embankment fill, cubic yards	1,146,000
4. Spillway	Ogee crest, gate
Type	controlled
Gates (tainter)	Four – 45 x 46 feet
Crest elevation	596.8
Design discharge, cfs	195,000
Project design flood, cfs	214,000
5. Penstocks	
Number	
Diameter, feet	2
Length, feet	13.5
Emergency closure	235
	Bulkhead gate
6. Power Plant	
Type of turbines	Kaplan
Number of generating units	2
Rated capacity, kilowatts, total	20,000
Hydraulic capacity, cfs	2,200

1. INTRODUCTION

1.1. PURPOSE AND NEED

The U.S. Army Corps of Engineers (Corps) and Oregon Department of Fish and Wildlife (ODFW) developed a spill operation at Foster dam in 1983 for downstream juvenile fish passage by installing a fish weir (Figure 1-1) at the spillway, in Spill Bay 4, at elevation 613 NGVD. The fish weir is a modified, notched stop log with a discharge of approximately 250-300 cfs. Prior to 2013, the fish weir was normally operated for one month (15 April – 15 May) at a reservoir elevation of approximately 615 feet each year for downstream fish passage. The reservoir elevation for this operation required a partial draw down of the reservoir, after refill during spring (per the Rule Curve, refill begins on 1 February), to avoid excessive head pressure on the lower spillway stop logs. During 2009, the Corps acquired new and improved stop logs that could allow fish weir operation at a higher pool elevation (635 NGVD). This higher operating elevation of the fish weir reduced the impact of its operation on other project authorizations by maintaining a higher reservoir elevation; principally, water storage and recreation. This new fish weir could also decrease the percentage of fish that pass via the powerhouse because it could be operated for longer periods each year. Starting in 2013, the fish weir was operated for longer periods and fish passage studies were undertaken to inform potential long term operations for downstream fish passage (see Section 2.7.2.2?).

Figure 1-1 Foster Fish Weir (left) and View from Downstream (Weir in Spill Bay 4 on right; Spill Bay 3 on left).

Installation of the fish weir requires a crane to hoist and install. The weir is lowered through the road deck gatewell slot, and rests on top of existing stop logs in the spill bay. The stop logs are installed in the spill bay at elevation 612 feet prior to installing the weir. The weir sits on top of the stop logs. This installation work requires a complete closure of the Foster Dam road deck for one day because the crane and trucks block the road deck. Because Foster Dam road deck is generally open to the public, a road closure announcement is required and is released to the public prior to the road closure. After the fish weir is installed in Spill Bay 4, the tainter gate (spill bay gate) is raised to full open position and water flows over the surface of the weir and falls on the downstream side (Figure 1-1).

In July 2008, the National Marine Fisheries Service (NMFS) released a Biological Opinion (BiOp) of the effects of continued operations and maintenance of the 13 dams operated by the Corps in the

Willamette Valley for species listed for protection under the Endangered Species Act (ESA) (NMFS 2008). The NMFS found that the Proposed Action alone, as described in the Corps' 2007 Supplemental Biological Assessment, was not sufficient to avoid jeopardy or adverse modification of critical habitat for two fish species: Upper Willamette River (UWR) Chinook salmon (*Oncorhynchus tshawytscha*) and UWR Winter steelhead (*O. mykiss*).

The 2008 NMFS BiOp Reasonable and Prudent Alternative (RPA) includes that the Action Agencies assess and implement options for improving downstream fish passage at Foster Dam. RPA measure 2.8 of the BiOp recognizes the spillway configuration and operation at Foster dam could improve downstream fish passage. RPA measures 2.8, 2.10, 4.8, 4.11 and 4.13 of the BiOp require investigation of operational or structural alternatives at the dam to improve downstream fish passage (NMFS 2008). The RPA states that:

> *"The Action Agencies will evaluate the effectiveness of [the fish weir] operation on downstream fish passage as part of RM&E (RPA measure 2.10) and COP studies (RPA measure 4.13). Based on the results of these studies, the Action Agencies will recommend modifications to this spill operation or new downstream fish passage facilities or operations. If modified operations are warranted and can be carried out within existing physical and operational constraints, the Action Agencies will begin to carry out these operations consistent with RPA measure 4.8, Interim Downstream Fish Passage. If more extensive modifications are needed, the Action Agencies will follow the process described in the COP study, RPA measure 4.13."*

RPA measure 4.13 indicated the Action Agencies would carry out a Configuration/Operation Plan (COP), a multi-year, multi-level study process to evaluate a range of potentially beneficial actions for listed fish at Willamette system dams and reservoirs. Current evaluations of potential actions across several Corps' dams in the Willamette Valley include improvements to the Foster fish weir to improve downstream fish passage as part of a broader suite of actions to address NMFS RPA.

The purpose of the Foster Dam Downstream Passage Alternatives Engineering Documentation Report (EDR) is to determine a preferred alternative to improve fish passage to address NMFS 2008 RPA measures for downstream fish passage at Foster Dam. Fish passage studies conducted at Foster Dam and reservoir over the last several years indicated the current fish weir is not very effective as a surface outlet for downstream fish passage. However, these studies also indicated that behavior and route distribution of downstream migrants under various operations improved surface route of passage and could be effective. Additionally, the studies show juvenile and adult salmon and steelhead are migrating downstream beyond the typical one-month annual operation of the weir (15 April – 15 May). Results from the studies are discussed in Section 2.7 of this report. The fish weir has structural and hydraulic limitations on flows and hydraulic head. The weir could only be operated with a maximum of approximately 2.5 ft. of hydraulic head, with maximum flows of approximately 250 - 300 cfs. Because of these limitations, the weir cannot be operated if the reservoir elevation increases or fluctuates more than 2.5 ft. The spill gate must be closed until the reservoir elevation decreases to the required 616 ft. for weir operations. Considering the less than desired fish passage efficiency of the weir and the structural and hydraulic limitations for operations, it was determined that alternatives for improving downstream passage at Foster Dam should be investigated. The Foster Dam Downstream Passage Product Delivery Team (PDT) is charged to assess alternatives for improving downstream fish passage. The preferred alternative will be carried forward into a design documentation report (DDR) for detailed design and evaluation.

1.2. PROJECT AUTHORIZATION

The existing authorized purposes for Foster Dam include flood risk management, hydropower generation, recreation, fish and wildlife, irrigation, water quality, and navigation. There are no non-Federal sponsor Operation and Maintenance, Repair, Replacement and Rehabilitation (OMRR&R) responsibilities. Foster Dam is part of the general comprehensive plan for flood control and other purposes in the Willamette River Basin. Foster Project was authorized by the Flood Control Act of 1960 (Public Law 645, 86th Congress, H.R. 7634).

1.3. RELATIONSHIP TO BIOP OBJECTIVES AND PATH FORWARD

This Foster Dam Downstream Fish Passage Alternatives study is in response to the NMFS Biological Opinion (NMFS 2008), which requires evaluation and improvements to downstream fish passage at Foster Dam. Results from research, monitoring, and evaluation (RM&E) activities, the COP analysis of sub-basin priorities, and other BiOp-related studies are being used along with the results of the Foster Dam Downstream Fish Passage Alternatives report to inform the Action Agencies and the Willamette Action Team for Ecosystem Restoration (WATER) on the path forward toward meeting the objectives of the RPA measures of the BiOp. The preferred alternative identified in this report will move forward to a Design Documentation Report (DDR) phase pending funding approval.

2. FOSTER DAM PROJECT DESCRIPTION

2.1. GENERAL

2.1.1. Location

The Willamette River Basin, composed of 11 sub-basins, is located in northwestern Oregon, and is approximately 150 miles long and 75 miles wide (Figure 2-1). It covers 12 percent of the state, contains extensive, rich agricultural land and forests, and is home to approximately 70 percent of the state's residents. The Willamette River flows north and is a major tributary to the Columbia River. The Willamette River Basin supports two ESA listed anadromous fish species (UWR Chinook salmon and UWR winter steelhead) above Willamette Falls. Additionally, the Willamette River supports three ESA listed fish species (Lower Columbia River Chinook salmon, coho salmon, and steelhead) below Willamette Falls. These fish species have historical, economic, and cultural significance. Historically, the South Santiam sub-basin was a significant contributor to the UWR Chinook salmon and steelhead stocks; however, declines in population sizes for both species have been noted in recent years.

Foster Dam is located at river mile 37.9 on the South Santiam River at Foster, Oregon; 38.5 miles above the confluence of the North and South Santiam Rivers and approximately 25 miles southeast of Albany, Oregon (Figure 2-2). Foster provides regulation for Green Peter project, located 8 miles upstream on the Middle Santiam River. Features of Foster Dam include the main embankment dam, a concrete gravity spillway section south of the main dam, and an embankment wing dam south of the spillway.

Figure 2-1. The Willamette Valley River Basin

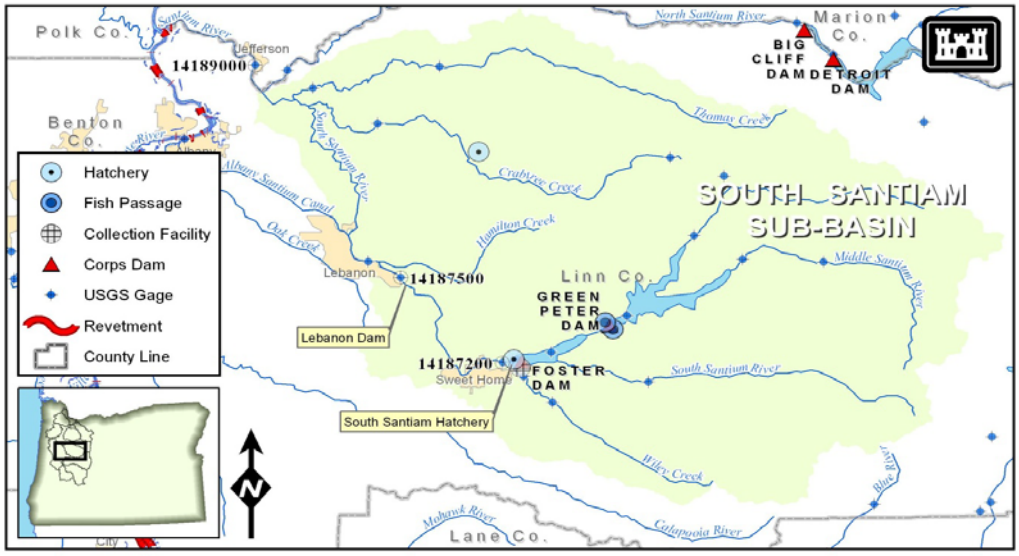


Figure 2-2. South Santiam Sub-Basin

2.1.2. **History**

During the last 50 years, 13 dams have been constructed and operated by the Corps in the Willamette River basin for a variety of purposes, including flood risk management, power generation, and supply of water for irrigation, navigation, improved water quality, recreation opportunities, and improved habitat conditions for fish and wildlife. Authorized individually, these 13 dams are collectively referred to as the Willamette System. Foster Dam was completed in 1968 and serves as a re-regulating dam for the upstream Green Peter Dam.

2.2. FOSTER DAM PROJECT FEATURES

Foster Dam (Figure 2-3) is a rockfill structure with a powerhouse and concrete spillway with 4 tainter gates, controls runoff from a drainage area of 494 square miles of mountainous and timbered land. The Foster Dam Project features are described in detail in the following sections.

Figure 2-3. Foster Dam and Reservoir Looking East (upstream)

2.2.1. **Foster Dam**

Foster Dam includes a 1,255 foot-long impervious core rock-fill main embankment dam, 126 foot high concrete gravity spillway section south of the main dam, and a 2,985 foot long embankment wing dam south of the spillway. The dam is approximately 90 feet high from average tailwater to the crest of the dam. The normal evacuation rate is 15,000 cfs. The maximum evacuation rate without exceeding downstream capacity is 18,000 cfs. The power plant has an installed capacity of 20,000 kW and is located at the toe of the rock-fill dam. Figure 2-3 shows the general plan of the embankment and the principle features of the project.

2.2.2. **Spillway**

The ogee-type spillway is 180 feet long and is equipped with four 45 foot x 44.6 foot tainter gates (Figure 2-4 and 7). The spillway crest (ogee) is at elevation 596.7 feet. The four spill bays are numbered 1-4, North to South, with bay number 4 closest to the turbine units The spillway has a discharge capacity of 200,000 cfs at maximum pool (El. 641.0 ft), with the gates fully open. The total capacity of one spill bay at minimum flood control pool (El. 613 ft) is 40,000 cfs. The spillway discharges into a stilling basin.

Figure 2-4. Foster Dam Spillway Downstream View – Spill Bays are Numbered From Left(N) to Right(S) With Spill Bay 4 Being Closest to the Turbine Intakes (right side of picture)

2.2.3. **Turbines**

The Foster Dam power facility consists of two Kaplan turbines, each with a 10 megawatt capacity. The hydraulic capacity of the powerhouse is between 1,600 and 3,600 cfs. Outflows above the maximum turbine capacity are released over the spillway and are generally limited to the 18,000 cfs downstream channel capacity. The minimum power pool is at elevation 609 feet. Penstocks (Figure 2-5) supply water to the turbines. The centerline for the turbine penstock intakes is 588 feet. Flows through the turbines at two typical reservoir elevations; low winter pool (613 ft) and high summer conservation pool (637 ft) are summarized in Table 2-1.

Table 2-1. Current Foster Dam Project Turbine Operating Capacities

	Minimum Discharge (cfs)	**Maximum Discharge (cfs)**	**Minimum Discharge (cfs)**	**Maximum Discharge (cfs)**
Reservoir Elevation (ft)	**613.0**	**613.0**	**637.0**	**637.0**
Single unit Operation				
1 x Turbine	525	1710	565	1330
Double unit Operation				
2 x Turbine	1040	3420	1130	2660

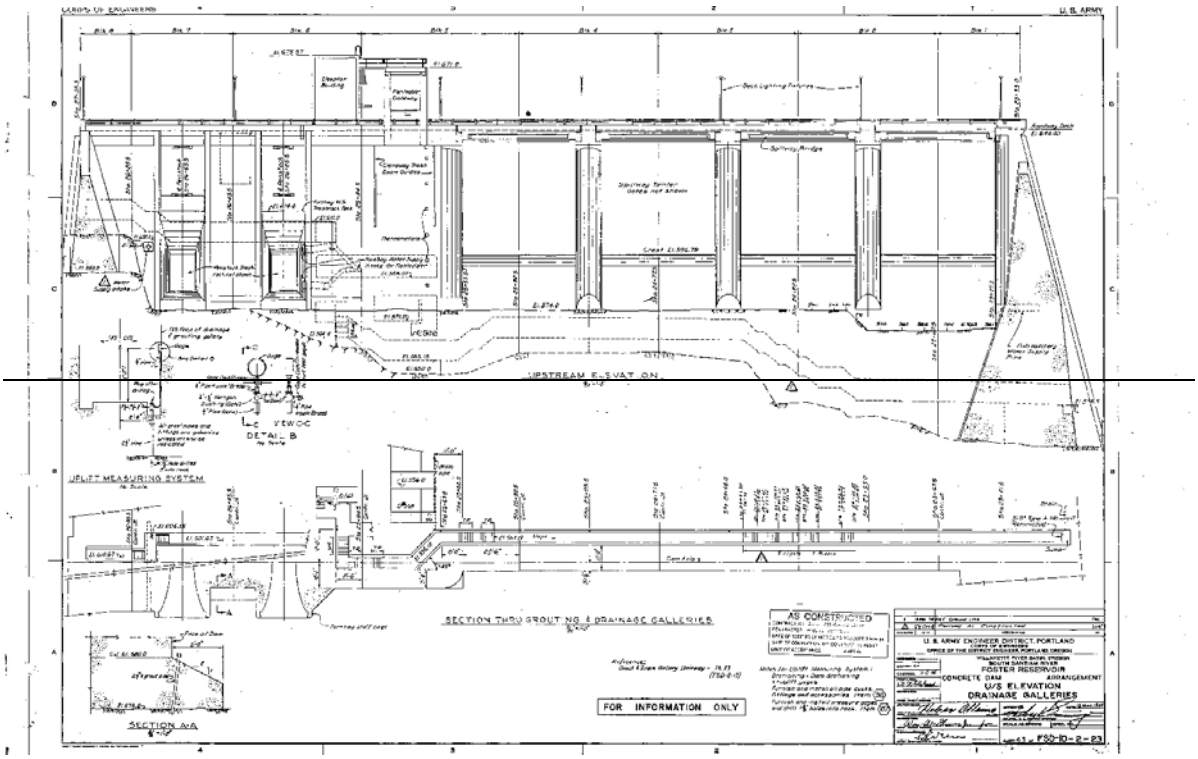


Figure 2-5. Upstream View of Foster Dam Showing the Turbine Penstock Intakes (Left) and Spillway (Right). Spill Bay Number 4 is Closest to the Turbine Intakes.

2.2.4. **Adult Fish Collection Facility**

A recent major upgrade to the Adult Fish Facility at Foster Dam was completed in April of 2014. The facility upgrade utilizes portions of the original Adult Fish Facility and provides modern fish collection, sorting, holding and truck transport feature. The facility also provides for broodstock holding and spawning capabilities for the South Santiam hatchery.

2.2.5. **Downstream Migrant Passage Facilities at Foster Dam**

Collection or transport facilities were not initially provided for downstream migrating juvenile salmonids at Foster Dam. Fish may pass the dam via the turbines or over the spillway during spill periods, and a fish weir in Spill Bay 4, when operated. The centerline of the turbine penstock intake is at elevation 588 feet, between 23 and 50 feet from the surface depending on reservoir level. This location was incorporated into the design of the dam to gain maximum attraction (commensurate with powerhouse operation) of juvenile salmon moving through the reservoir. The spillway is operated to pass excess water to maintain reservoir elevations. The downstream elevation drop from the spillway crest is approximately 75 to 90 feet. A fish weir, positioned as a surface outlet in Spill Bay 4 (Figure 1-1 and 2 6), was designed to pass downstream migrating winter steelhead moving near the water surface. The weir is typically operated at a reservoir elevation of 616 ft. for one month (15 April – 15 May) each year for fish passage. Steelhead kelts may also use the fish weir as a downstream passage route.

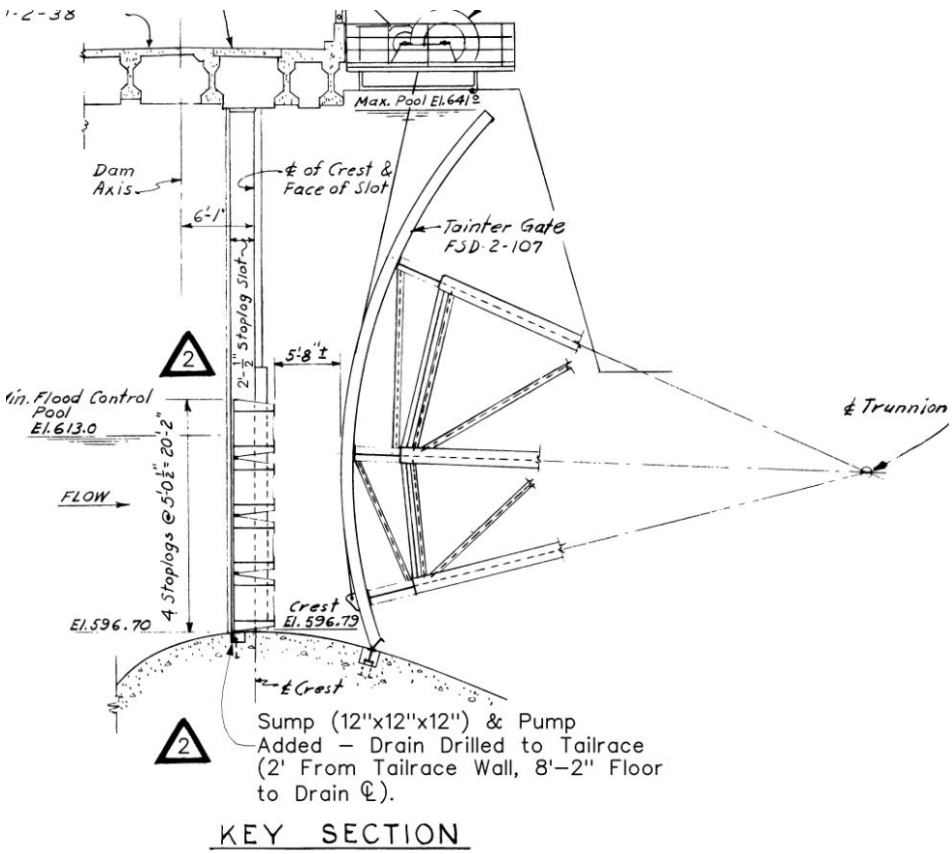


Figure 2-6. Cross Section of Foster Dam Spill Bay 4.

2.2.6. **Fish Weir**

In 1983 the Corps and ODFW developed a surface spill operation for juvenile fish passage by temporarily operating a fish weir in Spill Bay 4 at reservoir elevation 615 ft., with a discharge of approximately 250-300 cfs. The weir is typically operated each year between 15 April and 15 May to provide a surface route for downstream migrating juvenile Chinook salmon and steelhead. Refill of the Foster reservoir, after the winter flood control season, typically commences on 1 February (see Section 2.6 for a description of the Foster Water Control description). The reservoir must be lowered back to elevation 616 ft. for fish weir operation during mid-April to mid-May, then refilled to the summer conservation elevation (637 ft.). The configuration placed the weir on top of three 5 ft. high stop logs. The following chart (Table 2-2) was supplied to the operators as guidance:

Table 2-2. Original Foster Fish Weir Discharge Capacities

Forebay	CFS	Comments
613.00	18.30	0.1’ = 14.66 CFS
613.10	32.96	
613.20	47.62	
613.30	62.28	
613.40	76.94	
613.50	91.60	Lower Operating Limit
613.60	106.26	
613.70	120.92	
613.80	135.58	
613.90	150.24	
614.00	164.90	
614.10	179.56	
614.20	194.22	
614.30	208.88	
614.40	223.54	
614.50	238.20	Upper Operating Limit
614.60	252.86	
614.70	267.52	Maximum Weir Design
614.80	282.18	
614.90	296.84	
615.00	311.50	
615.10	326.16	
615.20	340.82	
615.30	355.48	
615.40	370.14	
615.50	384.80	

Six 4 ft. stop logs were fabricated during spillway gate rehabilitation in 2009. Once the spillway gate work was completed, the configuration of stop logs with the fish weir changed. The lowest stop log had to be stop log #1, which is a 4 ft stop log, the top stop log to mate with the fish weir had to be stop log #10, and all 5 ft stop logs had to be placed above the 4 ft stop logs. This configuration allowed the fish weir to be operated at two reservoir elevations; low pool (615 ft) and high pool (635 ft). Starting in the spring of 2013, the fish weir was operated year round for research of downstream passage of juvenile Chinook salmon and winter steelhead. Screw trapping efforts above and below the reservoir indicate that most juvenile steelhead emigrate in the later summer and fall (Romer et al. 2014). Because of the fish passage research, the Foster reservoir was maintained at two elevations; low pool el 615.5 to el 616.5 during fall-winter-spring and high summer conservation pool el 635 ft. The typical summer conservation elevation is 637 ft., however, because of stop log configuration and the restricted head on the weir, maximum pool elevation had to be maintained at el 635.0. This required a Special Operations Request (SOR) and significant discussions with stakeholders to change the summer pool level from 637 ft. to 635 ft. The SOR was approved. The following chart (Table 2-3) was supplied to the operators as guidance:

Table 2-3. Current Foster Dam Fish Weir Operating Capacities

	Fish Weir Crest ele			
	614.3	**633.2**		
Head on Weir (ft)	Forebay Ele (ft)	Forebay Ele (ft)	Discharge (cfs)	
3.90	618.2	637.1	460	Structural Maximum
3.70	618.0	636.9	420	
3.50	617.8	636.7	380	
3.30	617.6	636.5	350	
3.10	617.4	636.3	320	
2.90	617.2	636.1	290	Operational Maximum
2.70	617.0	635.9	260	
2.50	616.8	635.7	230	
2.30	616.6	635.5	200	
2.10	616.4	635.3	175	
1.90	616.2	635.1	150	Operational Mid-Point
1.70	616.0	634.9	125	
1.50	615.8	634.7	105	
1.30	615.6	634.5	85	
1.10	615.4	634.3	65	
0.90	615.2	634.1	50	Operational Minimum
0.70	615.0	633.9	35	
0.50	614.8	633.7	20	

Many considerations and planning are required prior to installing or removing the fish weir. Some of these include:

a. Coordinating road closure with local stakeholders (schools, emergency services, logging companies, etc.).
b. Services contract for trucks and trailers to move stop logs and lifting beam from the Foster compound to the roadway deck
c. Special Operations Request approval from local and USACE stakeholders (dam safety, water management, Linn County Parks and Recreation etc.)
d. Coordination with Foster maintenance crew and crane operator.

2.3. PROJECT OPERATIONS

Most inflow to Foster Dam comes from a combination of outflows from Green Peter Dam and the South Santiam River above Foster Lake. Foster Lake typically fluctuates about 1 to 2 feet daily as it receives flows that may vary hourly from the Green Peter Dam powerhouse. Key flow rates and ramp rate requirements for Foster Dam are listed below (cfs):

High Flow Period:	
Minimum Flow	Inflow up to 10,000
Normal Maximum Flow* (for evacuation of stored flood water)	18,000
Normal Rate of increase per hour	
100-1,000 cfs	500
1,000-3,000 cfs	1,000
3,000-18,000 cfs	1,500
Maximum Rate of Decrease per hour	20% of flow
Low Flow Period:	
Minimum Flow	
February 1 – March 15	800
March 16 – May 15 (winter steelhead spawning)	1,500
May 16 – June 30 (winter steelhead incubation)	1,100
July 1 – Aug 31 (rearing)	800
Sep 1 – Oct 15 (Chinook spawning)	1,500
Oct 16 – Jan 31 (Chinook incubation)	1,000
Rate of Change (Increase)	300/hr
Rate of Change (Decrease)	
Maximum rate of decrease (at outlet) – 0.1 ft/hr nighttime, 0.2 ft/hr daytime	

*Project outflows during major flood events may exceed these levels.

At higher flow events, Foster Dam passes inflow until an outflow of 10,000 cfs is reached. During this time, Green Peter Dam flows are typically reduced as needed to a minimum of 50 cfs, which is maintained at this level throughout the event, unless high storage levels at Green Peter Dam mandate higher flows. Once flows at Foster Dam reach 10,000 cfs, this release is held and the pool is allowed to fill. Outflows are not changed unless high storage levels at Foster Dam mandate higher releases, or the peak has passed and pool evacuation needs to begin. During evacuation, Foster Dam is drafted first with releases as high as 15,000 cfs, but more typically 12,000cfs. Drafting of stored water from Green Peter Dam is achieved by maintaining draft rates from Foster Dam and increasing Green Peter Dam as other inflows drop off. Under the spring spill operation at Foster Dam, about 92 to 238 cfs is typically spilled daily from 6 a.m. through 9 p.m. from April 15 through May 15 each year. This operation facilitates the passage of juvenile and kelt winter steelhead and juvenile Chinook salmon from the reservoir near its surface.

Ramping rates below Green Peter Dam are unrestricted and highly variable, causing water levels in Foster Dam Reservoir to change by 5 to 15 feet per day (USFWS 1961, Corps 1989). Up-ramping rates varied from 500 cfs per hour at initial flow between 500 and 1,000 cfs, to 2,500 cfs per hour when initial flows are higher than 18,000 cfs. Ramping operations at Foster Dam were modified in 2006 to reduce fishery impacts. Currently the Corps attempts to maintain ramping rates of 0.1 foot/hour at night and 0.2 foot/hour during daylight hours except during active flood risk management operations.

2.4. DAM SAFETY

2.4.1. Dam Safety Action Classification

The USACE dam safety program makes use of a risk classification system termed Dam Safety Action Classification (DSAC) to help guide key decisions within the program. This classification system portrays the need for urgency of action and the priority for responding to risk associated with USACE dams. The DSAC assignment is informed by the 'incremental risk'. The 'incremental risk' is the risk (likelihood and consequences) to the pool area and downstream floodplain occupants that can be attributed to the presence of the dam should the dam breach prior or subsequent to overtopping, or undergo component malfunction or miss-operation. The consequences typically are due to downstream inundation, but loss of the pool can result in significant consequences in the pool area upstream of the dam.

Foster Dam is rated as a DSAC III in October 2013. The DSAC rating was primarily driven by the inability to pass flows during an extreme event such as the PMF, which would cause overtopping and scour of the embankment dam. This rating is considered in the selection of any alternative to improve fish passage at Foster Dam. All DSAC ratings require no significant increase in risk at a project.

2.5. PROJECT HYDROLOGY

Foster Dam Reservoir is located at river mile 38.8 on the South Santiam River, 2 miles below the junction of the Middle Santiam and South Santiam Rivers. The South Santiam River Basin tributary to Foster Dam is located on the west slope of the Cascade Range about 30 miles east of Albany, Oregon. The South Santiam River Basin tributary to Foster Dam Reservoir is a fan-shaped area of 494 square miles. About one-half of the area above the dam site lies within the Willamette National Forest and the terrain is mountainous and heavily timbered. The mean elevation of the basin is 2,750 feet varying from 525 feet at the dam to 5,818 feet on the eastern boundary of the Middle Santiam watershed. Figure 2-2 shows the outline of the South Santiam River Basin.

2.5.1. Precipitation Records

Normal annual precipitation for the 494-square-mile watershed above Foster Dam is estimated to be 86 inches, varying from about 68 inches near the dam to more than 108 inches near Quartzville (USACE 1967). Normally, 68 percent of the annual precipitation falls in the 5-month period, November through March. July and August are normally the driest months of the year, with less than 2 percent of the annual precipitation occurring in those 2 months. Rainless periods of more than 30 days are not uncommon during the summer season

2.5.2. Streamflow Records

Mean monthly inflows for Foster Dam Reservoir for the Period of Record (POR) from Water Year (WY) 1969 through WY 2013 are shown in Table 2-4. The data sources and additional stream flow

statistics are described in Appendix B. A mean monthly inflow larger than 6,250 cfs has occurred in one or more years for each of the months November through June (see column labeled "Largest Occurrence"). The average of the mean monthly inflows is considerably lower from July through October compared to the remainder of the year.

Table 2-4. Mean Monthly Inflows

Month	Mean Monthly Inflows		
	Largest Occurrence (cfs)	**Average Occurrence (cfs)**	**Minimum Occurrence (cfs)**
October	5,237	1,614	244
November	12,156	3,997	482
December	13,396	5,698	781
January	14,136	5,155	599
February	14,665	2,911	520
March	12,157	2,747	460
April	10,108	2,786	662
May	6,771	2,542	605
June	6,250	1,569	521
July	1,833	792	373
August	1,668	777	338
September	2,594	1,237	338

Figure 2-8 shows the maximum, average, and minimum mean daily inflow for each day of the year. Maximum inflows occur when the target pool level is at Minimum Conservation Pool (El. 613)

during the winter flood risk management season. Additional information on inflow frequencies is provided in Appendix B.

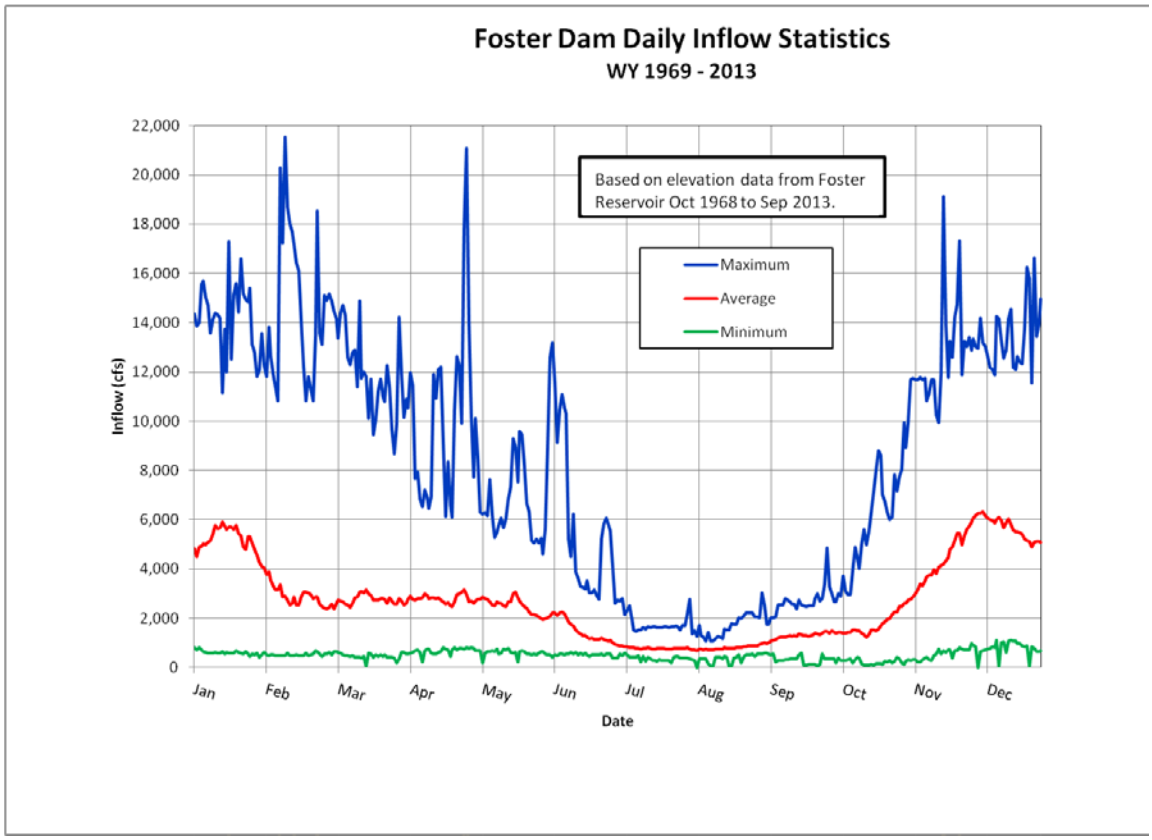


Figure 2-7 Foster Dam Mean Daily Inflows

Figure 2-9 shows the 5 through 95 percent chance exceedance values of the unregulated inflows, plotted by day of the year. In general, the inflow exceeds 1,500 to 6,000 ft^3/s about 50 percent of the time during the period from November through the middle of May (see "50 percent chance exceedance" curve). From late October through mid-June, the inflow is about 2,500 to 9,000 ft^3/s or greater 25 percent of the time (see "25 percent chance exceedance" curve). Only rarely (about 5 percent of the time for several days in November through January), does the inflow exceed 12,000 ft^3/s.

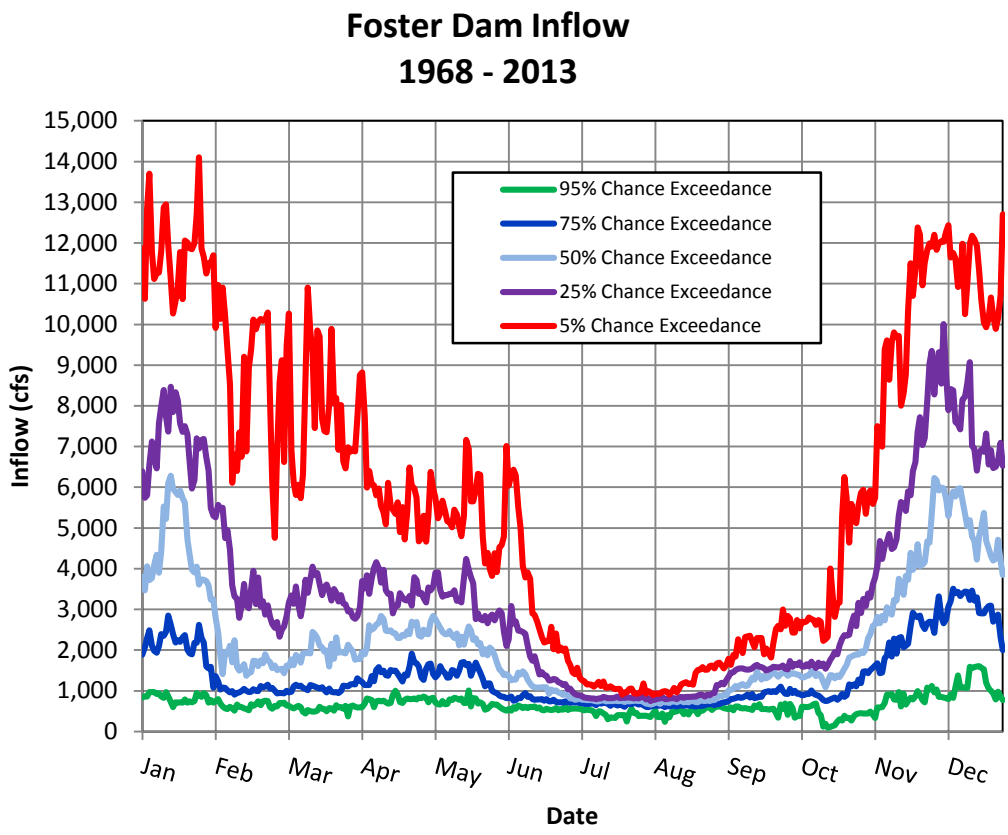


Figure 2-8. Foster Dam Daily Exceedance Inflows

2.5.3. **Fish Habitat Impacts Related to Hydrology/Channel Morphology**

According to Romer et al. (2015) it is suspected that scouring high flows (>10,000 ft3/s) during egg incubation in some years may limit juvenile production in the South Santiam River (Romer et al. 2013). The river above Foster Dam Reservoir has a deeply incised channel and most of the accessible spawning substrate is perched on bedrock. The South Santiam River has been in this condition since the 1930s, according to a Bureau of Fisheries stream habitat report (McIntosh et al. 1990), recently corroborated by a watershed assessment conducted in 2000 (South Santiam Watershed Council 2000) which states that:

> In 1856, a large fire in the watershed loaded the South Santiam stream channels with lots of wood which caused an aggradation of the channels. Most of this large wood component was removed by subsequent fires, flood events, and, more recently, timber salvage harvest. One result was downcutting in the channels and today many channels including the South Santiam River run mostly on bedrock. This creates high energy stream flows that affect the ability of juvenile fish to occupy the habitat. During high winter flows they suffer a greater risk of predation and can be washed out of the streams along with essential nutrients.

High flows that occur early in the year may displace redds, causing direct mortality to eggs and alevins residing in the interstitial spaces of the substrate. Peak flows >10,000 ft^3/s have occurred in mid-January (near estimated emergence timing) for three of the five years (2010-2014) that we have assessed juvenile production above Foster Dam Reservoir. Peak flows were <5000 ft^3/s in 2010 (BY2009) and 2013 (BY2012) and the year-class strength of returning adults from those brood years compared to other years may lend insight to the quality of spawning habitat above Foster Dam Reservoir and its effect on juvenile production.

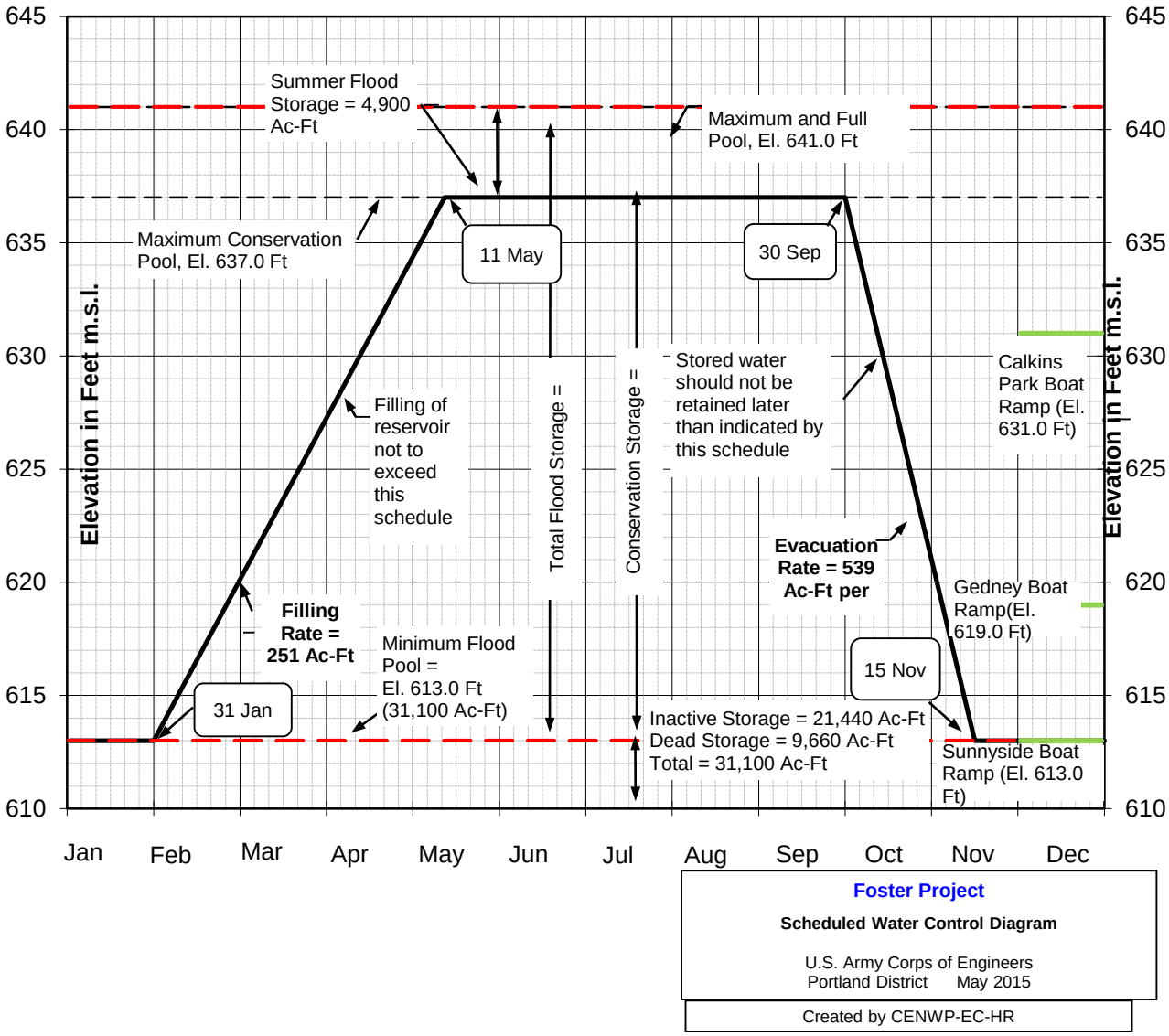
2.6. FOSTER DAM PROJECT HISTORIC OPERATIONS

The Foster Dam Project operations are controlled by operators located at the dam site. Relevant Foster Dam Project operations are described in the following sections.

2.6.1. Reservoir Storage

The original water control diagram is shown in Figure 2-10. In 1981 a fish weir was installed at Foster Reservoir and historical fish operations began. These operations were to fill the reservoir as normal starting in February, draw the reservoir back down in April for fish passage, then refill in May. The historical fish operations are shown as the dash line in Figure 2-11. In 2013, the historical fish operations was changed for an ongoing fish passage study. The current operation draw the reservoir down in the fall a keeps it there until refill in May. This research operations is shown as the solid line on Figure 2-11.

Figure 2-9 Water Control Diagram for Foster Dam and Reservoir



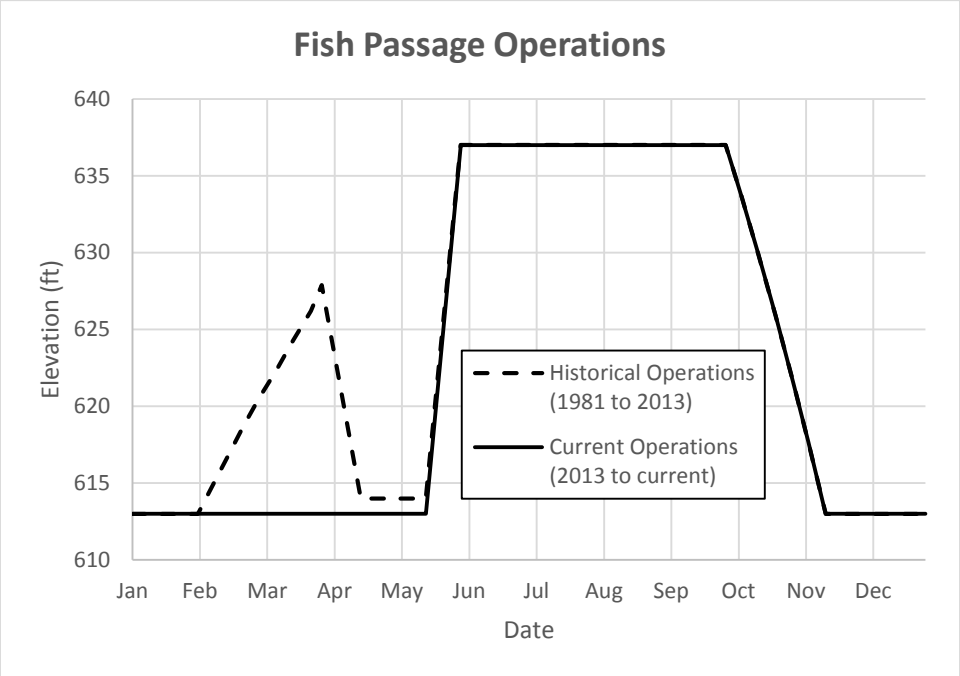


Figure 2-10 Fish Passage Operations

Mean monthly, 5%, and 95% non-exceedance elevations for Foster Reservoir for the POR from WY 1981 through WY 2013 are shown in Table 2-5. The data sources and additional streamflow statistics are described in Appendix B. The averages of the mean monthly elevations are the lowest from November through February, which corresponds with the flood season.

Plotted on Figure 2-11 are the average, 5%, and 95% non-exceedance mean daily elevation for each day of the year, plotted with the historical fish operations elevation. Additional information on inflow frequencies is provided in Appendix B.

Table 2-5 Mean Monthly Elevations

Month	Mean Monthly Elevations		
	95% Non-Exceedance (ft)	**Average (ft)**	**5% Non-Exceedance (ft)**
October	616.32	629.66	612.84
November	619.87	615.35	613.57
December	625.90	614.09	613.96
January	624.37	614.24	613.72
February	635.68	617.12	618.12
March	637.35	621.61	635.80
April	637.17	617.38	635.25
May	637.21	624.82	634.96
June	637.30	636.85	623.18
July	633.00	636.50	613.77
August	617.21	636.26	613.00
September	616.22	635.51	612.77

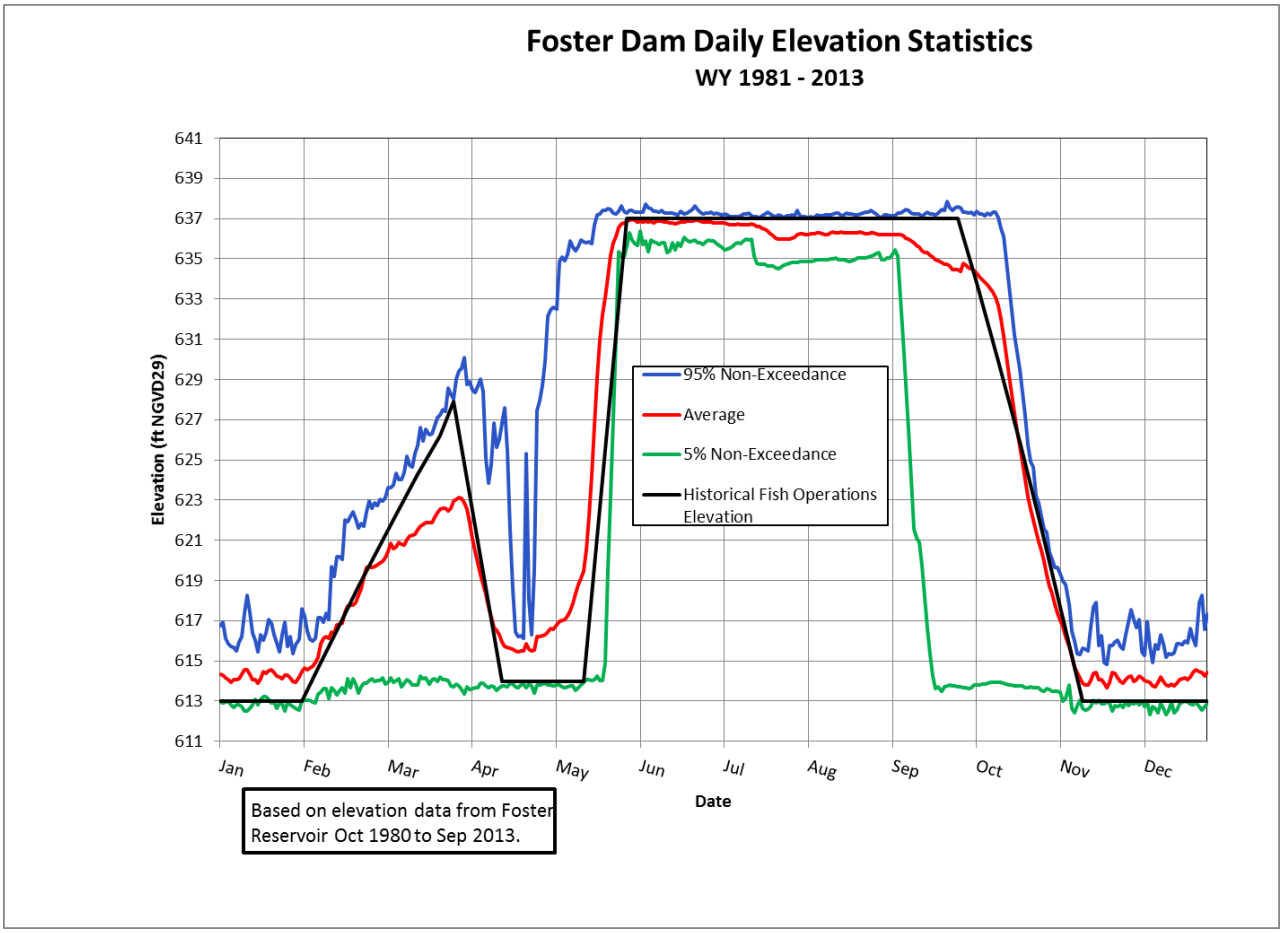


Figure 2-11 Foster Dam Mean Daily Elevations

2.6.2. **Project Outflows**

Mean monthly discharges for Foster Reservoir from WY 1981 through WY 2013 are shown in Table 2-6. The data sources and additional streamflow statistics are described in Appendix B. A mean monthly discharge larger than 5,500 cfs has occurred in one or more years for each of the months October through June (see column labeled "Maximum"). The average of the mean monthly discharges is considerably lower from June through October compared to the remainder of the year.

Plotted on Figure 2-12 are the maximum, average, and minimum mean daily discharge for each day of the year. Maximum discharges occur when the target pool level is at Minimum Conservation Pool (El. 613) during the winter flood risk management season. Additional information on discharge frequencies is provided in Appendix B.

Table 2-6 Mean Daily Discharges

Month	Mean Monthly Discharges		
	Maximum (cfs)	**Average (cfs)**	**Minimum (cfs)**
October	8,520	1,755	540
November	14,970	4,138	540
December	14,750	5,645	600
January	15,760	4,983	700
February	20,390	2,858	660
March	14,890	2,705	600
April	15,550	3,055	600
May	10,130	2,252	560
June	13,360	1,671	80
July	2,840	843	560
August	1,580	748	550
September	3,300	1,209	550

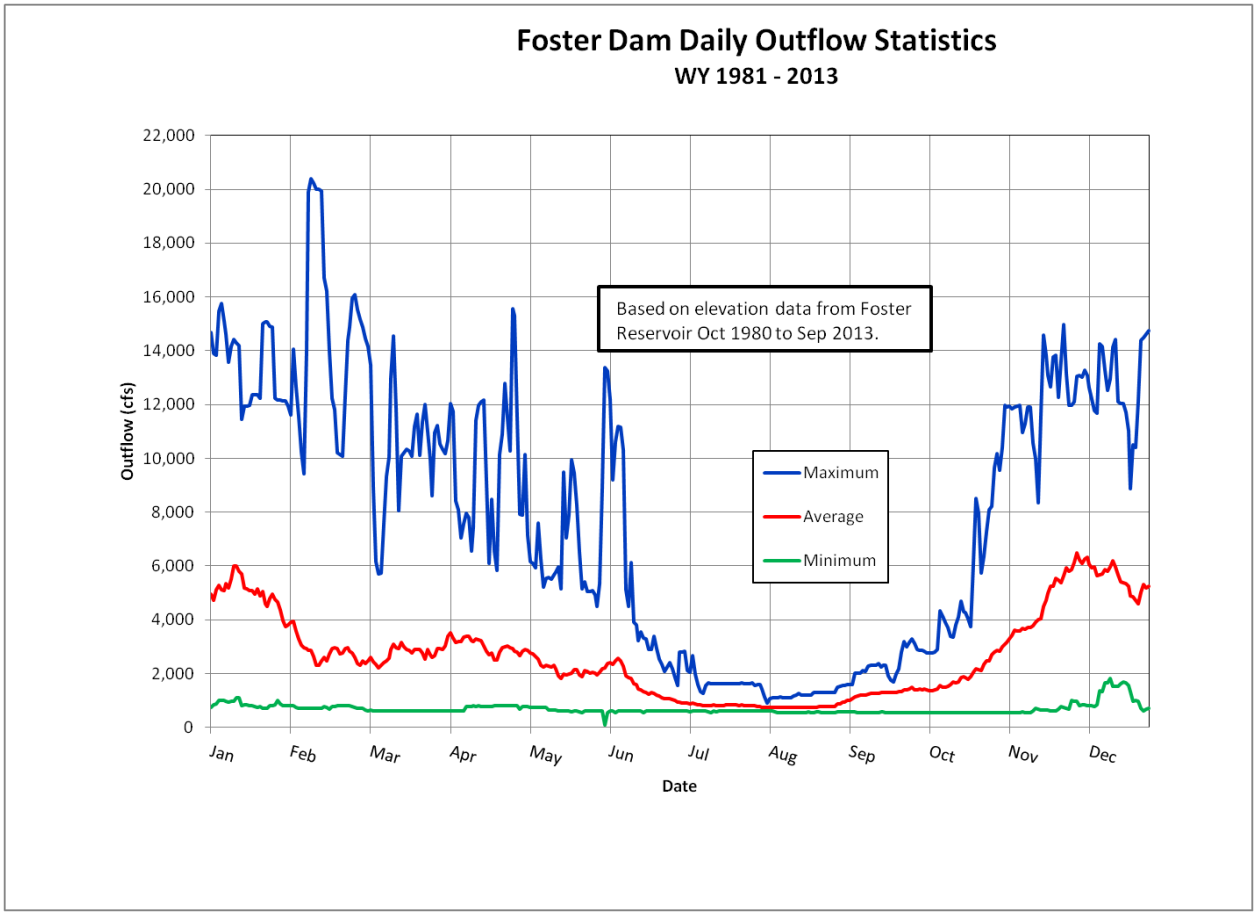


Figure 2-12 Foster Dam Mean Daily Discharges

2.7. PROJECT BIOLOGICAL BACKGROUND

2.7.1. Target Fish Species

The targeted fish species of interest for Foster Dam downstream fish passage alternatives are UWR Spring Chinook salmon and UWR Winter steelhead.

Spring Chinook salmon and winter steelhead are present in the South Santiam subbasin. Upstream passage is provided above Foster Dam for natural origin (unmarked) spring Chinook salmon and winter steelhead through trap and haul on the South Santiam River. Juvenile and adult downstream fish passage occurs at the spillway, through a fish weir or a regular spill bay, and the turbines. Downstream fish passage information (survival rates and passage efficiency) are summarized in Section 2.7.1.4.

2.7.1.1. UWR Spring Chinook salmon

The South Santiam sub-basin historically sustained high quality spawning habitat to support UWR Spring Chinook salmon populations, and in 1947 the returning Spring Chinook salmon to the sub-basin represented 35% of total escapement above Willamette Falls (Mattson 1948). However, in recent years monitoring results indicate returns of natural origin adults to the South Santiam River were much lower than those of hatchery fish.

Since 2009, only unmarked (presumed natural origin) adult Spring Chinook salmon are transported above Foster dam and allowed to spawn in the South Santiam subbasin upstream from the dam. Juvenile and adult downstream passage occurs through turbines or spillway at Foster Dam. Surface spill operation, using the fish weir in Spill Bay 4 during outmigration season to pass juvenile Chinook salmon downstream as an alternative to turbine passage.

Genetic pedigree analysis indicates the sub-population of spring Chinook salmon above Foster Dam has been naturally replacing itself (O'Malley et al. 2014 and 2015) under the existing fish passage program. Cohort replacement rate (CRR) for the 2007, 2008 and 2009 populations was estimated at 0.96, 1.16, and 1.55 respectively. However, the effective population size (Ne) of the reintroduced population was estimated at 100, 138, and 118 individuals in 2007, 2008 and 2009, respectively. The long term evolutionary potential of a population of < 500-1000 effective breeders may be at risk.

2.7.1.2. UWR Winter Steelhead

An estimated 63% of the potential winter steelhead spawning habitat in the South Santiam subbasin is currently located upstream of the Willamette Valley dams (R2 Resource 2009). Unmarked adult winter steelhead are trapped at the Foster Adult Fish Facility and transported above Foster dam and allowed to spawn in the South Santiam subbasin upstream from the dam. Juvenile and adult (kelts) downstream passage occurs through the turbines or spillway, including the fish weir when operated. Surface spill operation, using the fish weir in Spill Bay 4, during outmigration season to pass juvenile and adult (kelts) steelhead downstream is an alternative to turbine passage.

Winter steelhead historically spawned above Green Peter and Foster dams, but passage above Green Peter dam was abandoned after fish collection efficiency (adult and juvenile stages) was found to be inadequate. After the dams were constructed, Buchanan and others (1993) estimated 2,600 winter steelhead spawned in the entire South Santiam River basin, including the upper mainstem above the dams

and in Thomas, Crabtree, McDowell, Wiley, Canyon, Moose, and Soda Fork creeks (NMFS 2008). Abundance estimates provided by ODFW through spawning surveys and dam counts from 2000-2006 averaged 1,953 adults for the South Santiam River (NMFS 2008). About 40% of the winter steelhead entering the Willamette Basin spawn in the North and South Santiam subbasins (Jepson et al. 2015). Adult winter steelhead counts in the Willamette Basin at Willamette Falls have declined in recent years for unknown reasons.

2.7.2. Target Species Migration

2.7.2.1. Downstream Juvenile Chinook salmon and Steelhead Migration Timing

Head of reservoir sampling by ODFW indicate juvenile Chinook salmon enter the reservoir as fry in spring months (mainly between January and April) and peak downstream migration occurs during February and March (ODFW 2013). Juvenile steelhead (sub yearlings) are generally present in the head of reservoir throughout most of the year; with numbers peaking between August and November (ODFW 2013).

2.7.2.2. Downstream Juvenile Chinook salmon and Steelhead Dam Passage

Under current operations, the turbines are the primary route for passing water and fish at Foster Dam. The spillway is generally operated to pass excess water, especially during flood control season. The fish weir (in Spill Bay 4) of the spillway is typically (historically) operated for one month (April 15 – May 15) each year for downstream fish passage (mainly juvenile steelhead) at a low reservoir elevation (613 ft). Beginning in 2013, the Corps began operating the fish weir year-round at two reservoir elevations; low pool at 613 ft and high pool at 635 ft, for fish passage studies.

A direct injury and survival study, utilizing balloon tags, of juvenile steelhead was conducted at the Fish Weir and a turbine unit at Foster Dam during 2012 (Normandeau Associates Inc 2013). Results of this study indicate the 48-hour survival of steelhead passing through the turbine at low pool (613 ft el) ranged from 74% to 85% (Normandeau Associates Inc 2013). For the Fish Weir, steelhead survival was estimated at 99.5% and 94% for low and high pool (635 ft el), respectively (Normandeau Associates Inc 2013). A majority of steelhead experienced high injury after passage at the Fish Weir during the high pool test, while few injuries were observed during the low pool test (Normandeau Associates Inc 2013).

Recent fish passage studies by Pacific Northwest National Laboratory (PNNL)(hydroacoustics and active tag) and ODFW sampling in the reservoir and below the dam) show large numbers of juvenile salmon and steelhead present in the reservoir and passing the dam during periods of low pool (fall, winter, early spring) (Hughes el al 2013, 2016; Romer et al 2014). PNNL hydroacoustics study also indicated a larger proportion of juvenile fish passed the fish weir versus the turbines during summer operations (Hughes el al 2013). Additionally, the study indicated adult steelhead kelts out-migrate during spring and early summer (March through May) and a majority of these fish passed the dam via the fish weir (Hughes et al 2013).

During 2014 through 2015, PNNL conducted a radio telemetry study of juvenile Chinook salmon and steelhead behavior and passage at Foster Dam (Hughes et al 2016). Downstream passage and survival of juvenile Chinook salmon and steelhead were evaluated for two reservoir elevations (low winter pool (613 ft) and high summer pool (635 ft)). Chinook salmon more readily passed the dam during low pool periods than steelhead; 83% of the 694 fish released in the Foster reservoir passed the dam and migrated downstream at low pool (Tables 2-7 and 2-8). For steelhead passage during spring months (March through May; low and high pool periods), 63% of the 771 released into the Foster reservoir never passed

the dam (Tables 2-7 and 2-8). Instead, only 24% of 465 steelhead passed the dam during March and April and 4% of 94 passed in the fall and almost all fish passed via the fish weir (Hughes et al 2016). It appears a majority of steelhead stayed in the reservoir. During the high pool conditions (May-June), very few Chinook salmon and steelhead passed the dam (Hughes et al 2016). Passage distributions for both Chinook salmon and steelhead were weighted towards non-turbine routes of passage (Fish Weir and Spill Bays 1-3) and survival was highest through the Fish Weir and Spill Bays 1-3 for both species (61%-73%) (Table 2-8; Hughes et al 2016). Almost all steelhead passed the dam via the Fish Weir and for both species, most passed during the night time hours (Hughes et al 2016).

A spill versus turbine passage test was conducted during 2015 by PNNL to evaluate the efficacy of spill as a non-turbine passage route for juvenile salmon and steelhead. A block/treatment study design was used; "Spill+Weir" versus "Turbine+Weir" (Hughes et al 2016). Results indicate total passage rates for Chinook salmon were much higher during the "Spill+Weir" treatment at high pool, but not at low pool, relative to the "Turbine+Weir" treatment (Table 2-9). Passage at the Fish Weir was higher than turbines during the "Turbine+Weir" treatment for low and high pool (Table 2-9). Spill passage was higher than weir passage for low and high pool during the "Spill+Weir" treatment (Table 2-9). For steelhead passage rates, no difference was observed between the two treatments for low or high pool (Table 2-9).

Table 2-7 *Chinook salmon and Steelhead Released above Foster Dam and Subsequent Detections at the Forebay and Dam-Face Telemetry Array with Passage Proportions During 2015 (Hughes et al 2016).*

			Did Not Pass		**Dam Passage**	
	Location	**Released (n)**	**Proportion**	**n**	**Proportion**	**n**
Spring	**Yearling Chinook**					
	Low Pool	505	0.079	40	0.921	465
	High Pool	189	0.418	79	0.582	110
	Overall	694	0.171	119	**0.829**	**575**
	Steelhead					
	Low Pool	465	0.759	353	0.241	112
	High Pool	306	0.435	133	0.565	173
	Overall	771	0.630	486	**0.370**	**285**
Fall	**Subyearling Chinook**					
	Low Pool	1222	0.287	351	**0.713**	**871**
	Steelhead					
	Low Pool	94	0.957	90	**0.043**	**4**

Table 2-8 Dam Passage and Route Specific Survival Estimates of Chinook salmon and Steelhead Passage at Foster Dam in Spring 2015 (Hughes et al 2016).

	Chinook salmon		**Steelhead**	
Location	n	Estimates	n	Estimates
Low Pool – 613 ft				
Dam Passage Survival	465	0.64	112	0.63
Turbine Unit 1	149	0.51	16	0.56
Spill Bay 1-3	230	0.73	45	0.61
Fish Weir	78	0.63	46	0.67
High Pool – 635 ft				
Dam Passage Survival	110	0.77	123	0.63
Turbine Unit 1	2	--	1	--
Spill Bays 1-3	68	0.92	4	0.75
Fish Weir	39	0.52	166	0.62

Table 2-9 *Block/Treatment Spill Test Results of Chinook Salmon and Steelhead in 2015 by Study Period. Treatments include "Turbine+Weir" and "Spill+Weir."(Hughes et al 2016).*

		Total Passage (n)					
		Turbine+Weir		**Spill +Weir**			
		Turbine	**Weir**	**Spill**	**Weir**	**Significance**	***P* value**
Yearling Chinook	Low Pool (613 ft)	82	72	174	5	No	0.74
	High Pool (635 ft)	1	16	66	20	Yes	0.03
Steelhead	Low Pool (613 ft)	13	31	39	14	No	0.53
	High Pool (635 ft)	1	55	4	75	No	0.47
Subyearling Chinook	Low Pool (613 ft)	48	77	434	14	Yes	<0.01

2.8. PROJECT ENVIRONMENTAL BACKGROUND

2.8.1. Water Quality

2.8.1.1. Total Dissolved Gas

The Corps collected Total Dissolved Gas (TDG) data below Foster Dam in 2006, 2007 and 2008-2009. This information identified that spill discharges of greater than about 3,000 cfs produce near-field gas saturations above state water quality standards, though data collected during the 2008-2009 Foster Dam Spillway Gate Repair Study showed that spill discharges greater than 1,500 cfs, with no powerhouse discharge, can produce TDG levels above the 110% state water quality standard, monitored just 200 feet downstream of the dam. Also, TDG saturations in this area could exceed 130% when discharges exceed 12,000 cfs during high flow events when nearly 100% of discharge is passed as spill. In a January 2009 Foster Dam spill event of 13,000 cfs and greater, TDG measured 5 miles downstream of Foster Dam was still near 115% saturation. During this same time period, TDG levels measured at the county park at Waterloo, approximately 14.6 miles downstream of Foster Dam, were near saturation of 110%.

The Corps conducted a detailed TDG study in 2013, which included ten monitoring sites within the forebay and tailrace of Green Peter and Foster Dams, and further downstream of Foster Dam tailrace. The study began in August, 2013 and was completed in May, 2014. Continuous hourly TDG data was downloaded manually on a monthly cycle throughout this study period. Results are summarized in the Willamette Basin Annual Water Quality Report.

2.8.1.2. Temperature

The Corps has monitored stream temperatures in the South Santiam Basin since the early 1960s. Upstream water temperatures have been collected at the Corps-funded USGS gaging sites since the early 1960's. In-reservoir water temperatures have been collected by the Corps since 2010; and downstream water temperatures have been collected in the Foster Dam tailwater (14187200; Corps ID SSFO) since the 1970's, and in Green Peter Dam tailwater (USGS gages 14186200; Corps ID GPRO) since 2007. More recently the Corps and USGS collected water temperature data upstream, downstream, and within Green Peter and Foster reservoirs during 2013 as part of implementing the 2008 Biological Opinions from NMFS and USFWS. The Corps deployed thermistor strings in the reservoirs to understand the temperature dynamics within the reservoir. Upstream and downstream temperature data were collected at established USGS gaging stations.

The in-reservoir thermistor string data shows that Foster reservoir thermally stratifies in the summer with warmer water near the surface (Figure 2-13). The approximate depth of the thermocline (the vertical zone of rapid transition from warmer to cooler water) at Foster reservoir was 15 feet. Foster reservoir has a maximum depth of about 110 feet and a retention time of one month. It is a relatively shallow reservoir and hence has little storage of cold water. Temperatures near the surface reached the 72 ºF range by July and again in mid - August. The pattern of temperatures in Foster reservoir are influenced by the temperature released by Green Peter reservoir, temperatures of inflows from South Santiam River, and meteorological conditions.

Green Peter and Foster dams influence summer water temperatures in the lower South Santiam subbasin, below the two dams, by lowering water temperatures through deep, cold hypolimnetic releases. These projects have reduced average water temperatures below Foster Dam in the lower South Santiam by as much as 5.4°F (3°C) during late spring and as much as 12.6°F (7°C) during summer (NMFS 2008). Fall and early winter temperatures below Green Peter Dam on the Middle Santiam, on the other hand, have increased compared to natural (pre-dam) temperatures as the cold hypolimnetic water released during the summer months, leaving warmer water in the reservoir for fall releases. However, this warming is greatly moderated within Foster Reservoir by the colder inflow from the unregulated South Santiam River, and water temperatures are closer to the temperature targets below Foster Dam on the South Santiam River as compared to other drainages in the Willamette Basin Figure 2-13.

Foster Dam outflow temperatures in the summer were not as cold as Green Peter Dam outflows, due to the influence of unregulated inflows from the South Santiam River and Wiley Creek, heating of surface waters in Foster Reservoir, and release of warmer surface water (by 5 °F) frequently discharged from the spillway for Foster Dam fish weir tests. In late fall and early winter, Foster Dam outflow temperatures were moderated (cooled) by the influence of the colder, unregulated inflows from the South Santiam River and Wiley Creek. Foster Dam downstream temperatures have mostly met the Resource Agencies summer temperature targets since 1978, as shown in Figures 2-13 and 2-14.

Water temperatures measured in the tailwater of Green Peter and Foster Dams show dam discharges were typically cooler and less variable than the upstream mix conditions during spring and summer, and warmer than the targets during fall and early winter (Figure 2-15). The upstream mix conditions are based on a warming rate applied to inflow temperatures. Ideally, temperatures below these two projects should be warmer in the summer and cooler in the fall to better mimic the natural temperature regime.

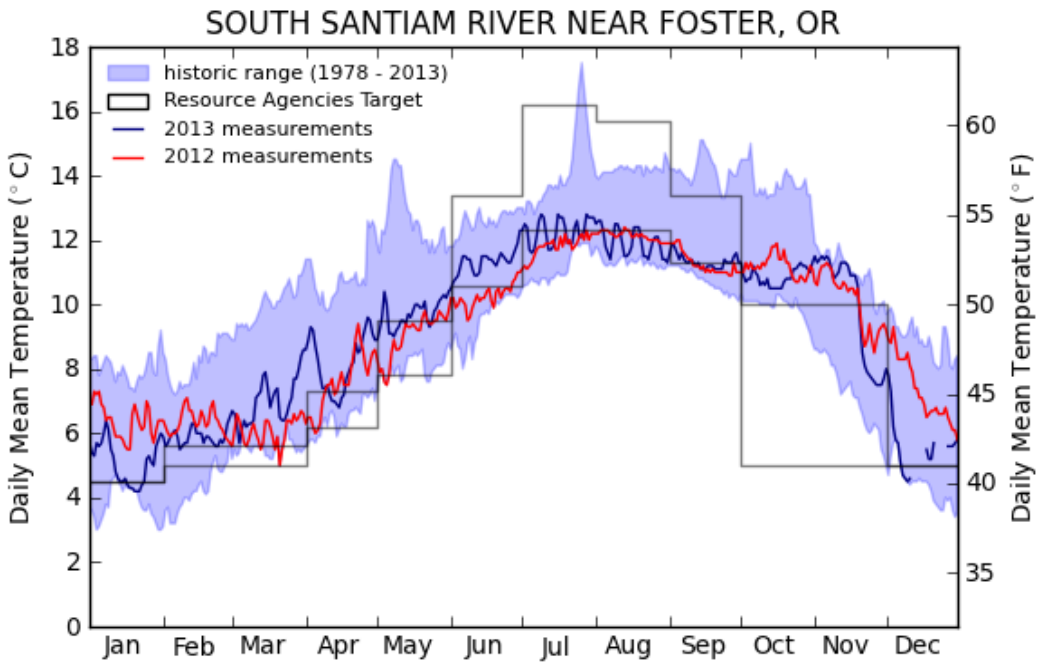
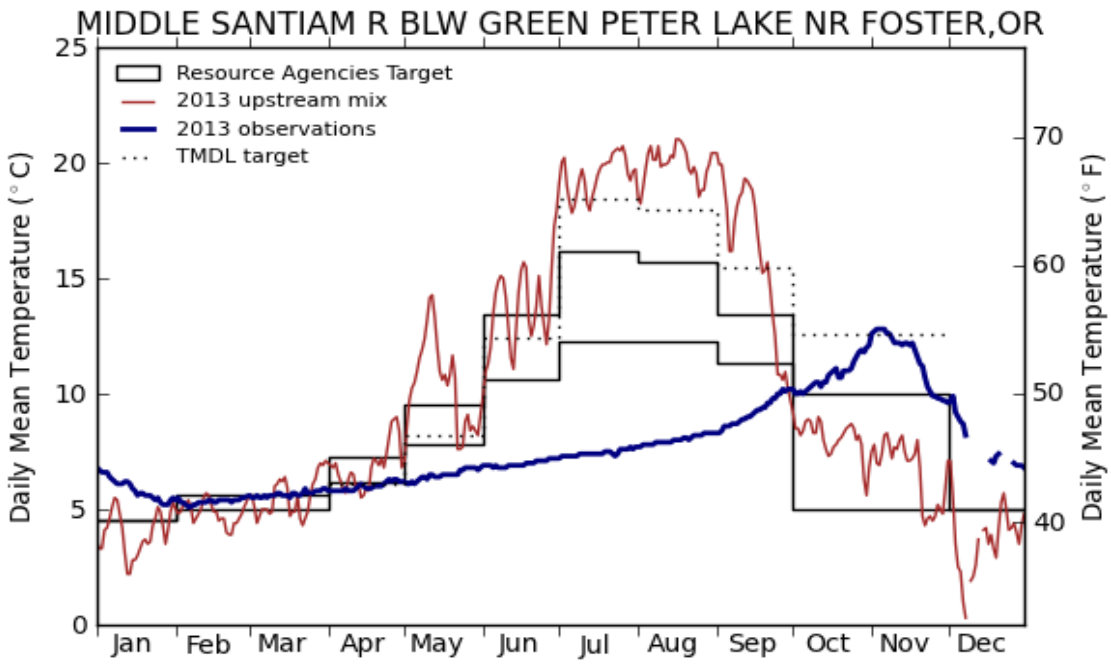


Figure 2-13 Foster Reservoir Daily Mean 2012 and 2013 Outflow Temperatures Compared to Resource Agencies Target Temperatures and Temperature Ranges during 1978 - 2013



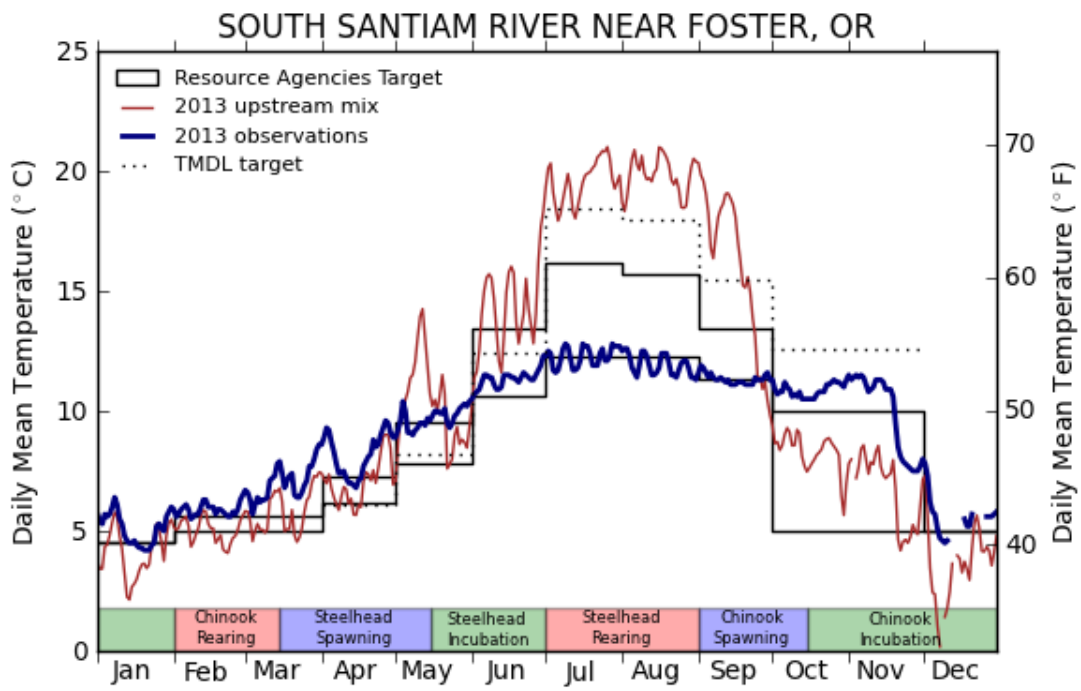


Figure 2-14 Green Peter and Foster Reservoirs Daily Mean Outflow Temperatures Measured in the Middle Santiam R. & South Santiam R. (near Cascadia) in 2013 Compared to Upstream Mix (including Quartzville Creek) and ODEQ's TMDL and Resource Agencies Target Temperatures & Primary Salmonid Life Stage of Concern.

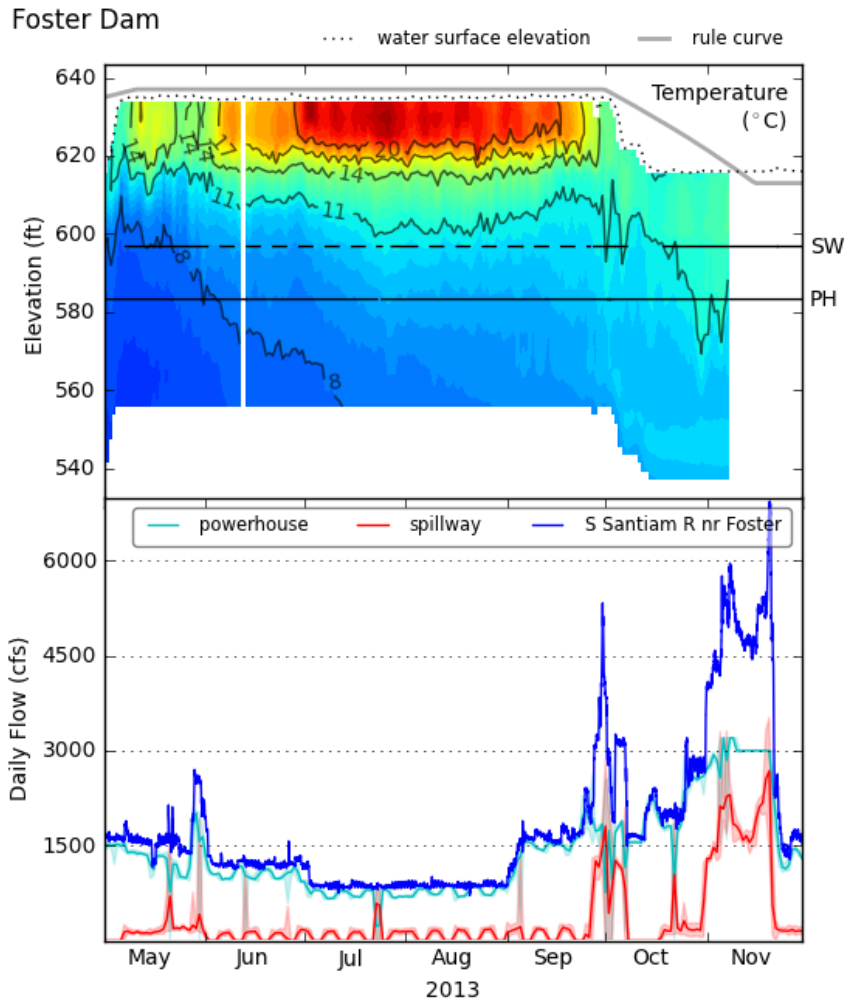


Figure 2-15 Foster Reservoir Thermal Structure, Operations and Hourly Outflow Temperatures, May through November, 2013. In the Upper Graph, the Outlet Elevation is Plotted When the Outlet is Active. The Shaded Areas are Minimum / Maximum Flow Ranges.

2.8.2. **Sediment Quality**

Sediments in Foster Reservoir were sampled on September 18, 2013 as part of the Synoptic Survey project for the Middle and South Santiam Rivers. Sample locations were selected to get a broad representative of reservoir sediment.

Two (2) box core samples were collected from surface sediments in Foster Reservoir. Both samples were submitted for physical and chemical testing, with data presented in Table 2-13.

The material ranged from 71.4% silt and clay to well graded silt and clay with sand (50.5 % silt + clay and 45.6 % sand). The total solids in the two samples ranged from 40.0 % to 42.1 %.

The two samples were also submitted for metals and pesticides testing, with data presented in Table 2.9. Ag, As, Cd, Cr, Cu, Ni, Pb, Sb, Hg and Zn metals were detected in both samples, but no levels approach the Sediment Evaluation Framework freshwater screening level. No pesticides (including DDT), were found at the MDL in either sample.

Table 2-9 Sediments in Foster Reservoir

Parameter	091813 FO-01	Data Qualifier	091813 FO-02	Data Qualifier	SEF Freshwater Screening Level
Conventional Parameters (%)					
Total Solids	40		42.1		--
Grain Size (%)					
Gravel	1		8		--
Sand	26.6		45.6		--
Silt + Clay	71.4		50.5		--
Metals (mg/kg)					
Antimony	0.117	J	0.232		--
Arsenic	3.12		3.43		20
Cadmium	0.115		0.141		1.1
Chromium	12.4		10.1		95
Copper	21.1		23.3		80
Lead	7.81		9.91		340
Mercury	0.054		0.054		0.28
Nickel	14.4		8.17		60
Silver	0.06		0.06		2
Zinc	44.3		57.4		130
Pesticides (ug/kg)					
4,4'-DDE	1.3	Ui	1.2	Ui	16
4,4'-DDD	1.3	U	1.2	U	9
4,4'-DDT	1.3	U	1.2	U	12
Aldrin	1.3	U	1.2	U	9.5
trans-Chlordane	1.3	U	1.2	U	--
cis-Chlordane	1.3	U	1.2	U	--
Total Chlordane		U		U	2.8
Dieldrin	1.3	U	1.2	U	1.9
Heptachlor	1.3	U	1.2	U	1.5
gamma-BHC (Lindane)	1.3	U	1.2	U	--

3. TECHNICAL DESIGN CRITERIA AND CONSIDERATIONS

3.1. GENERAL

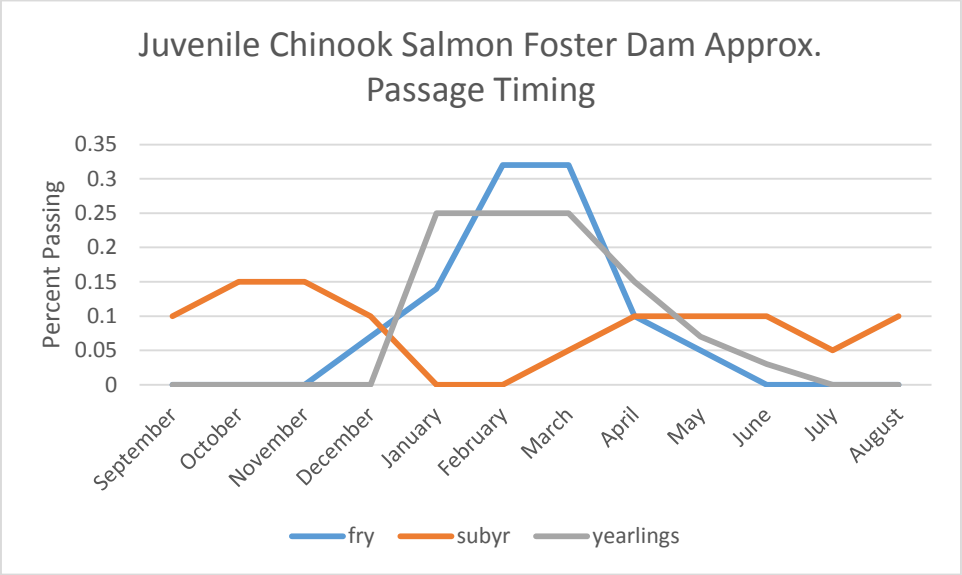
The purpose of this section is to describe the design criteria, considerations, and assumptions used to develop, evaluate, and determine feasibility of measures for improving downstream fish passage at Foster Dam. The criteria and considerations developed to date were based on consideration of project authorized purposes, operational limitations, and best engineering practices. These design criteria and considerations have been compiled as a means to develop

and evaluate alternatives for improving downstream passage at Foster Dam. The design criteria and considerations will be developed further as the chosen Alternative is studied in more detail throughout the Design Document Report (DDR) process.

3.2. CONSIDERATIONS FOR FISH

3.2.1. Target Species Migration Considerations

The timing of migration through daily and seasonal cycles; migration paths, including vertical and horizontal distribution of fish; and significant migration cues require consideration in the development and evaluation of alternatives. Annual and monthly timing of downstream migration for spring Chinook salmon and winter steelhead varies with environmental and Foster Dam operational conditions. Screwtraps have been operated for several years above and below Foster Reservoir (Romer et al. 2014). When summarized across years, juvenile spring Chinook salmon and winter steelhead are passing Foster Dam throughout the year, with peaks in spring and fall for steelhead, and spring fall and winter for Chinook salmon (Fred Monzyk, Pers. Comm., December, 2015). Additionally, the PNNL study (2013) indicated steelhead kelts are passing the dam during spring months.



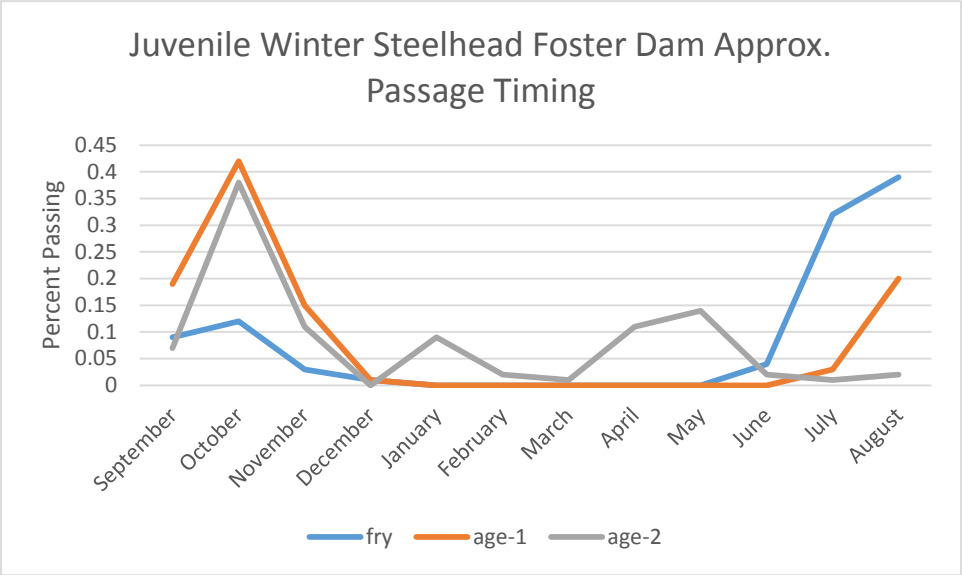


Figure 3-1 Approximate downstream passage timing of juvenile spring Chinook and winter steelhead at Foster Dam. Data provided by Fred Monzyk, ODFW (Pers. Comm., December 2015).

3.2.2. Target Species Swimming Speed Criteria and Considerations

The assumed design criteria for juvenile salmonid swimming speeds (*Bell, 1991, Jones et al 1974, Webb 1971)* are shown in Table 3-1.

Table 3-1. Juvenile Fish Swimming Speeds (Bell, 1991, Jones et al 1974, Webb 1971)

Species	**Speed (fps), Sustained**
Chinook salmon (2”)	0.5-1.2
Chinook salmon (>2”)	1.0-2.1
Steelhead	2.1-2.9

Three aspects of swimming speed are considered in the design criteria for fish facilities. They are:

- Cruising – a speed that can be maintained for long periods of time (hours).
- Sustained – a speed that can be maintained for minutes.
- Darting – a single effort burst of speed that is not sustainable.

3.2.3. Generalized Downstream Passage Considerations

- The design or operation of the fish passage device needs to accommodate all juvenile life stages of spring Chinook salmon and winter Steelhead, and adult winter Steelhead.
- The flownet created by the entrances should be of sufficient intensity to attract juveniles toward them, particularly in the absence of guidance nets or structures.

- Location: The entrance must be located so that it may easily be located by downstream migrating target fish species. (NMFS 2008, Section 11.9.1.1)
- Location: The fish passage device must permit passage of out-migrating salmonids with minimal injury or delay. (NMFS 2008, 11.9.1.1)
- Lighting: Ambient lighting conditions must be included upstream of the entrance and should extend to the flow control device. Where lighting transitions cannot be avoided, they should be gradual, or should occur at a point in the system where fish cannot escape the device. (NFMS, 2008, Section 11.9.2.3)
- Sampling: Sampling facilities installed in the system must not in any way impair operation of the facility during non-sampling operations. (NMFS 2007, Section 11.9.3.11)

3.3. CONSIDERATIONS FOR ENVIRONMENTAL COMPLIANCE AND CULTURAL RESOURCES

During the DDR, the environmental compliance document will be written (mostly likely a REC, Record of Environmental Compliance) to address potential environmental impacts and benefits. The REC will consider cultural resources, Endangered Species Act, 410/404 water quality, air quality, recreation, and various other laws and executive orders concerning the natural environment. Typically, the REC is written by the time the 90 percent DDR is complete. This ensures that selected alternative is moving forward and the environmental concerns addressed relate to the actual proposed project. Review of the draft proposed EDR has not raised any unusual concerns that cannot be addressed during the DDR phase of the project.

Regarding cultural resources there are two primary concerns for this project. The first involves potential operational changes to the Foster Reservoir pool levels. These operational changes may be permanent or temporary. Both may have an adverse impact to known or unknown archaeological resources. Changes may include holding the pool at specific elevation for a longer or shorter duration then the current operations, conducting a deep drawdown, or changing the overall timeframe of the drawdown and refill timeline. The second concern is any change or alteration work conducted on or to the dam and any of its components. The dam is eligible for the National Register of Historic Places the Corps Archeologist will need to complete an effects determination and initiate consultation with the Oregon State Historic Preservation Office and any interested Tribes.

3.4. OPERATIONAL AND MAINTENANCE CRITERIA AND CONSIDERATIONS

3.4.1. Project Authorized Purposes

The downstream passage system should consider and minimize impacts to the other missions of Foster Reservoir and the WVP; specifically flood risk management (FRM), power generation, recreation, and water conservation for downstream needs (fisheries, water quality, irrigation, water supply, etc.). The downstream passage system should not prevent operations (discharge rate or pool elevations) in such a way that operations for the critical FRM mission are impeded.

3.4.2. Operations Criteria and Considerations

Project operations to be maintained are described in Section 2.3

3.4.2.1. **Water Quality Operations**

The following are water quality consideration that will need to be addressed through the evaluation of the alternatives:

- The passage system should not impact water quality or limit the function of any existing equipment or operations designed to improve water quality.
- Total dissolved gas should not increase in the tailrace or downstream of Foster Dam with any operational or structural changes.
- The facility should not produce additional toxins to the water column due to the materials used.
- Screens should not be an additional source of algae.

3.4.3. **Maintenance Criteria and Considerations**

The following general maintenance criteria and considerations were applied to evaluation of the measures considered:

- Consideration should be given to the increased maintenance required by more frequent operation of any devices in conjunction with a fish passage system.
- Consideration should be given to the maintainability of any new equipment or component added to the project. All components that require regular inspection, adjustment, lubrication or periodic replacement should be readily and safely accessible or have a designed method of access. Because the project is remotely operated, required planned maintenance should be minimized to the extent possible.
- Bypass access: Access for inspection and debris removal must be provided at locations in the bypass system where debris accumulations may occur. (NMFS 2008, Section 11.9.1.5)
- Access: Bypass pipe or open channels must be designed to minimize debris clogging and sediment deposition and to facilitate inspection and cleaning as necessary. Access ports or other means of providing for inspection and cleaning may be acceptable. (NMFS 2008, Section 11.9.3.5)
- Debris Management:
    - Inspection and Maintenance: A reliable, ongoing inspection, preventative maintenance, and repair program is necessary to ensure facilities are kept free of debris and that screen media, seals, drive units, and other components are functioning correctly during the outmigration period. A written plan should be completed and submitted for approval with the screen design. (NMFS 2008, Section 11.10.1.1)
    - Screen cleaning (Active Screens): Active screens must be automatically cleaned to prevent debris accumulation. Timing for screen cleaning intervals is provided in NMFS 2008, Section 11.10.1.2.

3.5. HYDRAULIC CRITERIA AND CONSIDERATIONS

3.5.1. **Design References**

The following references were used to establish hydraulic criteria and considerations and perform design calculations to analyze the alternatives.

- NMFS (National Marine Fisheries Service), 2008. Anadromous Salmonid Passage Facility Design. NMFS, Northwest Region, Portland, Oregon.
- U.S. Army Corps of Engineers (USACE)/Bell, Milo C., 1991. Fisheries Handbook of Engineering Requirements and Biological Criteria.
- National Marine Fisheries Service (NMFS). 2008. Anadromous Salmonid Passage Facility Design. February.
- USACE EM 1110-2-1602 Hydraulic Design of Reservoir Outlet Works. 1980. October.
- Corps of Engineers Hydraulic Design Criteria. 1987. November.
- USACE Portland District. 1968. Water Control Manual for Foster Lake. December.
- Federal Emergency Management Agency (FEMA). 1986. Flood Study, Linn County, Oregon Community Number 410136. September.

3.5.2. **Hydraulic Design**

3.5.2.1. **General Criteria and Considerations**

The following general hydraulic considerations were applied to evaluation of the final alternatives considered:

- Civil Works: The civil works of the passage facilities must be designed in a manner that prevents undesirable hydraulic effects (such as eddies and stagnant flow zones) that may delay or injure fish or provide predator habitat or predator access. (NMFS 2008, Section 11.8.1.3)
- Trash racks: If trash racks are used, sufficient hydraulic gradient must be provided to route juvenile fish from between the trash rack and screens to the bypass. (NMFS 2008, Section 11.9.1.6)
- Inspection: The completed screen and bypass facility must be made available for inspection by NMFS, to verify that the screen is being operated consistent with the design criteria. (NMFS 2008, Section 11.10.1.5)
- Evaluation: Screen and bypass facilities may be evaluated for biological effectiveness and to verify that hydraulic design objectives are achieved. (NMFS 2008, Section 11.10.1.6) Consideration of the expected biological and hydraulic evaluations should be given in the design of the facility.
- The bypass entrance and all components of the bypass system must be of sufficient size and hydraulic capacity to minimize the potential for debris blockage. (NMFS 2008, Section 11.9.1.1)
- Bypass channel velocity: To ensure that fish move quickly through the bypass channel (i.e. the conveyance from the terminus of the screen to the bypass pipe), the rate of increase in velocity between any two points in the bypass channel should not decrease and should not exceed 0.2 ft/s per foot of travel. (NMFS 2008, Section 11.9.1.8)
- Minimum velocity: The minimum bypass entrance flow velocity should be greater than 110% of the maximum channel velocity upstream of the bypass entrance. At no point must flow decelerate along the screen face or in the bypass channel. (NMFS 2008, Section 11.9.2.2)
- Weirs: For diversions greater than 25 cfs, weirs used in bypass systems should maintain a weir depth of at least 1 foot throughout the smolt out-migration period. (NMFS 2008, Section 11.9.2.5)

- Dimensions: For diversions greater than 3 cfs, the bypass entrance must extend from the floor to the channel water surface, and should be a minimum of 18 inches wide. (NMFS 2008, Section 11.9.2.4)
- Flows and pressures: In general bypass flows in any type of conveyance structure should be open channel. If required by site conditions, pressures in the bypass pipe must be equal to or above atmospheric pressures. Pressurized to non-pressured (or vice-versa) transitions should be avoided within the pipe. Bypass pipes must be designed to allow trapped air to escape. (NMFS 2008, Section 11.9.3.3)
- Diameter/Geometry: The bypass pipe diameter or open channel bypass geometry should generally be a function of the bypass flow and slope, and should be chosen based on achieving the velocity and depth criteria. (NMFS 2008 Section 11.9.3.6)
- Design bypass flow: Design bypass flow should be about 5% of the total diverted flow amount, unless otherwise approved by NMFS. (NMFS 2008, Section 11.9.3.7)
- Location (NMFS 2008, Section 11.9.4.1):
    - Bypass outfalls must be located to minimize predation by selecting an outfall location free of eddies, reverse flow, or known predator habitat. The point of impact for bypass outfalls should be located where ambient river velocities are greater than 4.0 ft/s during the smolt out-migration.
    - Bypass outfalls must be located where the receiving water is of sufficient depth to endure that fish injuries are avoided at all river and bypass flows. The bypass flow must not impact the river bottom or other physical features at any stage of river flow.
- Impact velocity: Maximum bypass outfall impact velocity, including vertical and horizontal velocity components, should be less than 25.0 ft/s. (NMFS 2008, Section 11.9.4.2)
- Discharge and attraction of adult fish: The bypass outfall discharge into the receiving water must be designed to avoid attraction of adult fish thereby reducing the potential for jumping injuries and false attraction. (NMFS 2008, 11.9.4.3)
- Water quality: The outfall flow should not cause the total dissolved gas (TDG) at the project to exceed accepted standards (110% saturation).

3.6. STRUCTURAL CRITERIA AND CONSIDERATIONS

3.6.1. General

The structural features of the Foster Dam downstream fish passage system are described in this section. The new structural features will be constructed of concrete, steel, and possibly aluminum and will be designed as described in the following paragraphs. This section covers references, basic data, design loads, design earthquakes, a list of structures considered to be hydraulic structures, and structural design/analysis considerations for each component of the modifications.

3.6.2. Design References

The structural design will conform to the following reports, criteria, Engineering Manuals (EMs), Engineering Regulations (ERs), Engineering Technical Letters (ETLs), Technical Manuals (TMs), and industry codes.

- U.S. Army Corps of Engineers (USACE) /Bell, Milo C. 1991. Fisheries Handbook of Engineering Requirements and Biological Criteria.

- National Marine Fisheries Service, 2008. Anadromous Salmonid Passage Facility Design. February.
- USACE. 1995. ER 1110-2-1806, Earthquake Design and Analysis for Corps of Engineers Projects.
- USACE. 2001. EM 1110-2-2000, Standard Practice for Concrete.
- USACE. 1995. EM 1110-2-2007, Structural Design of Concrete Lined Flood Control Channels.
- USACE. 2005. EM 1110-2-2100, Stability Analysis of Concrete Structures.
- USACE. 2003. EM 1110-2-2104, Strength Design for Reinforced-Concrete Hydraulic Structures.
- USACE. 1995. EM 1110-2-2200, Gravity Dam Design.
- USACE. 2003. EM 1110-2-2400, Structural Design of Spillway and Outlet Works.
- USACE. 1989. EM 1110-2-2502, Retaining and Flood Walls.
- USACE. 1998. EM 1110-2-2902, Conduits, Culverts and Pipes.
- USACE. 1989. EM 1110-2-3104, Structural and Architectural Design of Pumping Stations.
- USACE. 2007. EM 1110-2-6053, Engineering and Design - Earthquake Design and Evaluation of Concrete Hydraulic Structures.
- USACE. 2014. ETL 1110-2-584, Design of Hydraulic Steel Structures.
- Aluminum Association (AA). 2010. Aluminum Design Manual.
- American Association of State and Highway Transportation Officials (AASHTO). 2012. Bridge Design Manual.
- American Concrete Institute (ACI).ACI 318-14, Building Code Requirements for Structural Concrete.
- ACI. ACI 350-06, Code Requirements for Environmental Engineering Concrete Structures.
- American Institute of Steel Construction (AISC). Steel Construction Manual (LRFD and ASD), 14th Edition.
- American Society of Concrete Contractors. Guide for Surface Finish of Formed Concrete.
- American Society of Civil Engineers (ASCE). ASCE 07-10, Minimum Design Loads for Buildings and Other Structures.
- American Welding Society (AWS). 2011. Structural Welding Codes for Steel and Aluminum.
- International Building Code (IBC). 2012, as supplemented by the 2014 Oregon Structural Specialty Code, Chapter 16, “SNOW LOADS” AND “WIND LOADS”
- Structural Engineers Association of Oregon. 2007. Snow Load Analysis for Oregon, revised by the State of Oregon Building Codes Division Statewide Alternate Methods No. 15-02 Electronic Snow Load Locator.
- U.S. Geological Survey (USGS). 2008. National Seismic Hazard Maps.
- AISC Steel Design Guide 27 - Structural Stainless Steel

3.6.3. **Engineering Properties of Construction Materials**

The engineering properties of construction materials are:

Concrete: All Cast-in-Place Structures
New concrete touching or containing water f'c=4,500 psi
Existing concrete f'c=4,000 psi
Modulus of elasticity (E) 3,600,000 psi
Poisson's ratio 0.2

Steel Reinforcement: All Structures
New: ASTM A615 Grade 60 fy=60,000 psi
Existing: ASTM A15 (replaced by A615) Grade 40 fy=40,000 psi

Structural carbon steel and structural stainless steel: Areas of use shown on drawings
ASTM A36 (carbon steel) fy=36,000 psi
ASTM A 992 (carbon steel) fy=50,000 psi
ASTM A240 (stainless steel) fy=30,000 psi
ASTM A276 (stainless steel) fy =30,000 psi to 45,000 psi depending on Type selected

Structural Aluminum: Areas of use shown on drawings
Type 6061-T6 fy=40,000 psi
Type 5052-H32 fy=28,000 psi

ASTM = American Society for Testing Materials
f'c = Specified compressive strength of concrete
fy = Specified yield strength

3.6.4. **Design Loads**

3.6.4.1. **Dead Loads**

Dead loads consist of the weight of concrete, metal, and fixed equipment. Concrete unit weight is assumed to be 150 pounds per cubic foot (lbs/ft^3). Steel unit weight of 0.283 pound per cubic inch (lb/in^3) is based upon AISC values for structural plates and shapes. Aluminum unit weight of 0.098 lb/in^3 is based on AA values for structural shapes and plates.

3.6.4.2. **Hydrostatic**

The hydrostatic loads against the structure include internal and external pressures for all design load conditions. The unit weight of water is assumed to be 62.4 lbs/ft^3.

3.6.4.3. **Uplift**

Uplift at the base of the hydraulic structures is assumed to be 100 percent of the adjacent river pressure over 100 percent of the base area. At internal planes, uplift is assumed to vary linearly from hydrostatic head at the external surface of a hydraulic structure to the hydrostatic head at any internal surface. Uplift pressures are assumed to remain unchanged during an earthquake.

3.6.4.4. **Live Loads**

The live loads are based on ASCE 7-11 Table 4.1. The live loads used for the design are summarized in Table 3-3. The Project crane maximum lift capacity for the weir and stop logs is 22000 lbs. based on the determined crane outrigger positions on the spillway bridge.

Table 3-2 Design Live Loads

Type	**Uniform Load (psf)**	**Concentrated Load (lbs)**
Catwalks for maintenance access	40	300
Walkways and elevated platforms (other than exist ways)	100	0
Stairways and exit ways	100	300

4. ALTERNATIVE SELECTION APPROACH AND EVALUATION CRITERIA

4.1. GENERAL

Corps Planning Guidance requires an upfront examination of project goals, objectives, and constraints. The process, criteria and methods that will be used to determine a preferred alternative are described below. This process involves:

1) Defining evaluation criteria
2) Estimating biological benefits, costs and impacts of alternatives
3) Completing a cost effectiveness analysis
4) Identifying a preferred alternative

4.2. DEFINE EVALUATION CRITERIA

The general approach to evaluate the actions includes: (1) biologically feasibility and benefit; (2) technically feasibility; and (3) cost effectiveness. Design criteria and considerations from Chapter 3 will be used to develop alternatives as described in Chapter 5. This Chapter describes how alternatives developed in Chapter 5 will be evaluated in order to select a preferred alternative. General definitions and approach follows:

1) Biological Benefits:
   i. Fish passage improvements must allow sufficient passage survival so that the above dam sub-population is able to replace itself on average over time (i.e., the ratio of adult spawners to returning adult progeny is approximately $\geq$ 1:1 over time). Therefore the downstream passage survival rate must be sufficiently high, when factoring in the productivity and survival of the population through its lifecycle, so adults are able to replace themselves. For alternatives expected to support spawner replacement, benefits will then be compared based on the estimated downstream passage survival.
2) Technically Feasible:
   ii. Design/performance assumptions for proposed actions can be achieved with reasonable certainty.
   iii. Willamette Project (WP) critical authorized purposes will not be impacted. These purposes include in particular flood risk reduction, and could also include other

missions (e.g. hydropower, water supply, and recreation) depending on the specific WP project and any pre-existing regulations, guidelines, or agreements.

iv. Dam safety is not compromised.

3) Cost Effective:

v. Feasible actions which achieve the necessary level of benefit for the least cost will be prioritized over others.

vi. Estimated action costs must include: cost to design and construct, costs to maintain, and cost impacts to hydropower production.

vii. Impacts to other purposes will be considered.

4.3. KEY CRITERIA TO ESTIMATE BIOLOGICAL BENEFITS AND IMPACTS

The specific criteria and assumptions to be used to evaluate Foster Dam downstream passage alternatives, and a summary of the methods to be applied to estimate benefits and impacts are summarized below:

1) ***Actions will meet dam safety requirements, and not result in a reduction to the Corps flood risk management mission.*** To assess and implement alternatives for BiOp implementation, it was assumed that the selected plan or suite of plans will not result in a reduction to the Corps flood risk management mission. If an alternative results in an increase in flood risk or flood impacts as analyzed, it will be flagged for further discussion to mitigate flood risk or dam safety concerns. Assessing changes to operational regimes will be necessary to meet Corps dam safety requirements.

   Flood risk management analyses will be conducted using the results of reservoir simulation modeling and regulation expertise. Measures will be modeled using ResSim. The results of these model runs will then be compared to the results of the baseline (current conditions) to identify changes to FRM operations. Within the ResSim model, downstream control point rules will be in place specifying regulation goals for key gage locations called control points. The Willamette projects operated to meet FRM goals at these control points individually and as a system. Therefore, when one project is modified in an operational scenario, another project was adjusted to try to meet the specified control point goal. With other projects able to compensate partially for a change in one project's operation, the impact to flooding will be assessed at the control point (i.e., was the system able to maintain flows at a control point below key thresholds). The FRM impact assessment procedure is shown below.

   1. Compare the number of occurrences that a control point flow is above the regulation goal under the operational scenario to the baseline values).

      a. The ResSim period of record output will be post-processed to count the number of days the regulation goals is exceeded each year and statistics will be computed on these counts.

      b. Compare the 95% non-exceedance counts. The 95% non-exceedance was selected because it represents a relatively infrequent occurrence. The 95% non-exceedance count is the value, in number of days (or more) a year, that the control point flow does not exceeded the regulation goal for

5% of the years in the POR (4 years of the 73-year POR). These 4 years may have more days above the regulation goal than reported in the 95% non-exceedance count.

c. The 95% non-exceedance should incorporate most of the large flow events. There may be occasion to use the 99% non-exceedance values.

2. Compare the 95% non-exceedance peak flow under the operational scenario to the baseline values.

   a. The 95% non-exceedance should incorporate most of the large flow events. There may be occasion to use the 99% non-exceedance peak flows.

   b. The ResSim flows are also daily averages and do not truly represent the instantaneous peak of the flood event. The focus will be on differences in peak flows between the baseline and operational scenario.

   c. Because there was both model error and potentially gage error, a difference of 5% in the peak flows was considered no change.

3. If either the duration a control point exceeded the regulation goal or the magnitude of the peak flow were higher under the alternative being simulated than the baseline, then the alternative will be flagged for further consideration of possible mitigation costs or acceptability.

4. If there is a strong biological support for retaining an alternative that was flagged for consideration, then a more detailed analysis would need to be conducted with individual flood events on an hourly time step.

There are concerns and limitations with the existing equipment at each Willamette system dam that must be considered with regard to operations and dam safety. Impacts to dam safety will be addressed during the work of the specific design teams (i.e., the teams will not design a structure that does not meet dam safety standards). In addition, dam safety requirements, such as the restrictions to spillway gate operations and minimum and maximum gate openings, will be incorporated into the operational alternative evaluations through ResSim to ensure that alternatives carried forward comply with dam safety requirements. Alternatives not meeting dam safety requirements will not be included in design team recommendations or brought forward for inclusion as alternatives for final design. Design teams will explore dam safety implications in more detail for those alternatives carried forward for final design. A Potential Failure Modes Analysis (ER 1110-2-1156) will be required to ensure that any dam modifications do not increase the overall incremental risk of the project to be greater than tolerable guidelines. The USACE Risk Management Center may have involvement if significant modifications are required. This will be determined by the Portland District Dam Safety Officer.

2) ***Any above-dam fish reintroduction efforts must reach "replacement."*** Fish passage improvements must allow sufficient passage survival so that the above dam sub-population is able to replace itself on average over time (i.e., the ratio of adult spawners to returning adult progeny is approximately $\geq$ 1:1 over time).

An analysis will be conducted using output from Species Lifecycle Analysis Module (SLAM) to estimate whether or not each fish population could successfully replace itself under the assumed fish passage alternatives. The SLAM model was developed and operated by NWFSC and parameterized with regional input. Several workshops (8) were conducted with WATER in 2014 to discuss model input assumptions and provide guidance on model results. Model documentation products were shared with the WATER during review by the Independent Scientific Advisory Board (ISAB). Development of the SLAM models and biological assumptions are documented in NWFSC (2015).

The Fish Benefit Workbook (FBW) spreadsheet tool was developed by the Corps and used to estimate annual dam passage survival for juvenile Chinook salmon and steelhead at each dam under existing and alternative reservoir, discharge, and passage route conditions (Corps 2015). The Fish Benefits Workbook methodology and input parameters were discussed at WATER Fish Passage Team (FPT) meetings and multiple regional workshops. FBW documentation was reviewed by the WATER and the model framework was reviewed by the ISAB. Additionally, model parameter assumptions were provided by WATER and used to test the FBW tool. Assumptions used in the FBW to evaluate Foster Dam downstream fish passage alternatives are documented in Chapter 6.

For the above dam population component, the replacement ratio was computed for each year using the current natural origin spawners (spawning adults) divided by the (natural origin + hatchery origin spawners) from 4 years prior (their parents). The 5-year running average was also computed to look at the replacement from the cohort perspective. The SLAM output provides estimates of hatchery origin spawners and natural origin spawners for each year from 1-105 in the simulation. To verify whether or not an alternative resulted in population replacement above a dam, multiple aspects were checked including:

- The average replacement ratio - above 90% (meets replacement) and above 85% (nearly meets replacement).
- The percent of time the 5-year running average was above 95% - more than 70% of the time (meets replacement) and more than 60% of the time (nearly meets replacement).

The replacement analysis using SLAM was used to estimate the minimum downstream passage survival rate needed at Foster Dam to achieve the population replacement criteria described above. Biological benefits of alternatives will then be compared using the estimated downstream survival rates prepared using the FBW to determine if they achieve or exceed this downstream passage survival rate to support population replacement.

3) ***Phased Approach is Preferred***. To reduce risks and apply information gained during the design and implementation steps, a phased approach will be considered where feasible, and appropriate, for each alternative. This approach provides important phased prototyping steps to help lower risks and improve chances of reaching biological goals.

4) ***Actions should be cost-effective, including consideration of hydropower impacts***. Some alternatives will provide similar levels of benefits, and the least expensive, feasible alternative should be prioritized. Implementation of the RPA will be costly and it must be done in a cost-effective manner. Development of a cost-effective plan, or suite of plans, is an opportunity for the region and nation to improve the probability of long-term survival of ESA-listed species, while using available resources wisely.

   Hydropower impacts will be jointly estimated by the Corps and BPA. To the extent power production in the Willamette Valley is already optimized as part of the federal power system, any change in operations resulting from the alternatives being evaluated may entail non-optimal power production. If an alternative is found to reduce the social value of hydropower production, then an estimate will be made of the losses in monetary terms. Bonneville Power Administration will estimate these losses. The monetary loss estimate will use the same underlying parameters and assumptions (discount rate, planning horizon, constant price levels) as the rest of the analysis. The hydropower losses will be present valued to a common point in time for each operational alternative.

   The BPA will use the Hydro System Simulation (HYDSIM) model, in conjunction with the ResSim model, to estimate hydropower impacts. The HYDSIM model simulates power production for the month-to-month operation of the Pacific Northwest hydropower system. The HYDSIM model will be used by BPA to post-process the ResSim modeling to capture hydropower impacts. The lost average megawatts (aMW) of generation will be combined with forecast market price estimates to estimate the lost hydropower by alternative. The lost aMW will also be used as input for the power value analysis, discussed below.

   A power value analysis (PVA) will be used by BPA to evaluate the financial impact of each alternative or combination of alternatives. Preliminary PVA analysis by BPA indicates that the Power Value will likely be negative. The PVA quantifies the costs and benefits of hydropower operations at each Corps Willamette power plant over a 20-year time horizon, given a set of assumptions about future investment and further operational restrictions at the facilities. Only the costs and benefits associated with hydropower production will be captured in the PVA. Monetized impacts of each alternative will then be compared to a baseline value in order to calculate the economic effect and the carbon dioxide emission rates for replacement generation for lost hydropower.

5) ***Risk assessment related to biological benefit assumptions.*** We believe risk of not meeting our assumptions for fish passage are moderate to low. Our fish model output (dam passage survival) is most sensitivity to downstream passage efficiency (DPE). Our assumptions for DPE are based on local study of radio-tagged juvenile Chinook salmon and winter steelhead, which indicates these juvenile fish generally prefer to pass through surface outlets (either the weir or spillway when available) rather than turbines, and DPE positively increased with the flow range tested. The proposed solution should improve DPE by providing a surface route of passage at higher flows than the existing weir, and would be operated when juveniles are passing. We recommended the weir be designed for operation at a range of flows, since fish passage response to flows under the range of environmental conditions that could occur has not been tested. Adding surface spill is a

feasible additional action that can be taken if goals are not achieved with the improved fish weir alone.

4.4. COMPLETE COST-EFFECTIVE ANALYSIS

After alternatives were filtered for those estimated to achieve the population replacement criteria, the biological benefits for baseline and alternatives were compared based on the estimated downstream fish passage survival rate. A cost-effectiveness analysis was conducted to compare costs and outputs of the alternative combinations for the system. An average survival rate among spring Chinook salmon and winter steelhead will be used when evaluating cost effectiveness of alternatives.

The costs of alternatives or combinations of alternatives will be in monetary terms. Project first costs including design, construction, supervision and administration, engineering during construction and O&M costs will be in monetary terms at a fixed price level (2014 dollars). If construction extended over a multiple-year period, interest during construction will be calculated and added. The costs will be present valued to the base year. The O&M costs will be estimated over the project life and present-valued back to the base year. The average annual equivalent values will be shown for these costs. The period of analysis will be the same for all alternatives, 2015 through 2064 where 2015 was the base year.

Opportunity costs such as forgone hydropower will be assessed for alternatives in comparison to the without-project condition, with hydropower in dollar terms. Hydropower impacts will be considered with stakeholder input from BPA, primarily as lost hydropower replacement costs. Recreation impacts will not be included in the total costs for the cost-effectiveness analysis but will be represented as other impacts for consideration.

The non-monetary fish benefits of each measure will be weighed against the costs of the measures. The analysis will generally follow the cost-effective analysis procedures laid out in *Cost Effectiveness Analysis for Environmental Planning: Nine Easy Steps* (Corps 1994). Cost effectiveness analysis identifies projects that minimize cost for a given level of output or maximize output for a given cost. Also, the focus will be on monetized costs—construction, O&M and hydropower impacts. The main analysis steps include:

- Display outputs and costs.
- Eliminate economically inefficient solutions. Re-order the list in ascending order and identify the least cost solution for each level of output, dropping the inefficient cases.
- Eliminate ineffective solutions. Conduct a pair-wise comparison of remaining outputs and monetary costs to identify and delete those solutions that will produce less output at equal or greater costs than subsequently ranked solutions.
- Calculate Average Costs. Divide cost by output to find average total cost and display output, total cost, and average cost for cost-effective solutions.
- Calculate cost-effectiveness as average cost per unit of output

4.5. IDENTIFY PREFERRED ALTERNATIVES

The most cost effective alternatives will be compared considering biological benefit, feasibility, and costs. Examples of how analysis results and other supporting information is summarized to support a decision are presented below. The preferred alternative is based on extent criteria are met, and confidence in the assumptions made.

5. DEVELOPMENT OF ALTERNATIVES

5.1. INITIAL DEVELOPMENT OF MEASURES

A preliminary list of creative ideas for downstream passage at Foster Dam was developed through brainstorming by the PDT in May 2014. These creative ideas were then shared and expanded with members of the FPT on June 11, 2014. The draft operational and structural ideas along with draft assessment criteria were shared at the monthly FPT meeting on September 30, 2014. These early creative ideas were the precursor to additional expanded ideas that were developed in a design charrette workshop in January 2015.

The design charrette was comprised of Corps employees with expertise in multiple subject matters. This workshop used a value methodology to approach the current concepts and measures under consideration for improvement to fish passage, and help clarify options for a path forward in the design phase. Most of the existing ideas for improvement were conceptual and provided significant opportunities for creative thinking. The team was specifically charged with analyzing the project to help bring new ideas and measures for improvement to downstream fish passage. Additionally, the team was asked to group the ideas (or measures) into more comprehensive alternatives that would provide a more complete solution for consideration by the PDT.

An expanded list was prepared in the charrette and grouped in the following categories: Operational Measures, Structural Measures, Minimize Predation, Minimize Injury, Entrain Fish, Match Timing, Simplify Operations and, Balance Authorization. This list of creative ideas was evaluated by the team, resulting in a reduced list consisting of 18 Measures, 8 Design Suggestions and 9 Universally Recommended Measures using the following set of evaluation criteria:

- Confidence in improving fish passage rate;
- Feasibility of funding;
- Track record of success;
- Simple design, operation and maintenance;
- Acceptable to stakeholders
- Minimal impacts to recreation, hydropower and flood mitigation

Combinations of these Measures, Design Suggestions, and Universally recommended Measures resulted in 5 viable project Alternatives to be developed further. The Measures and subsequent Alternatives are described below.

5.2. MEASURE DESCRIPTIONS

The measures for improving downstream fish passage at Foster Dam focus on operational measures or structural measures intended to attract and pass juvenile fish downstream of the project. The PDT did not advance options past the EDR phase that require a significant project configuration change. This section describes the measures at a conceptual level for the EDR. The following text and table shows the measures carried through the initial evaluation process. These measures are combined into the alternatives that are discussed in Section 6.

Table 5-1. Measures

Operational Measures	
O-2a	Use spill bays 2 and 3 at low and high pool
O-2b	Use spill bay 4 at low and high pool
O-5	Modify the temporal use of the fish weir – operate the weir year-round
MT-2	Operate spill bays and shut off turbines during peak run timing
Structural Measures	
S-4a	Modified fish weir crest shape
S-4c	Water cushion on spillway for fish passing a significant distance above the spillway crest
S-4e	Gate within the spillway gate
S-4f	Turbine Screens
EF-2	Bypass canal with floating orifice gate
EF-3	New fish weir with the capability to meet varying elevations or flow requirements. Either a fixed or floating crest weir.
Universally Recommended Measures	Recommended measures, or design suggestions regardless of alternative selected.
MP-3	Formalize an operational debris removal program
MI-6	Manage spill to minimize gas (TDG)
EF-14*	Install lighting at entrance inlet to attract fish on the upstream side
SO-5**	Build a permanent hoist over spill bay 4 to eliminate need for crane mobilization
SO-6**	Buy a mobile crane
SO-7	Buy a truck and trailer for stop log transportation
SO-15	Avoid disruption of operations of the Adult Fish Facility (AFF) including attraction to the fish ladder
SO-16	Install permanent fish study monitoring equipment to provide a system for ongoing research

*If further evidence shows it is effective, it can be added to any alternative.
**These alternatives are mutually exclusive and will work with any of the alternatives.

5.2.1. Operational Measures

Background: Currently, Foster Dam turbine unit 1 is the only turbine designed to be used for station service (provide power to Foster Dam). Because of this, unit 1 is operated exclusively when generation is only required from one unit (usually in the summertime during low flow operations). Foster Dam Electrical Reliability Upgrade (ERU) is in plans and specifications development which will allow both turbine units to be used for station service.

5.2.1.1. Measure No. 02a: Use Spill Bays 2 and 3 at Low and High Pool

Once the ERU construction is complete, turbine unit 2 will be operated exclusively during low flow, for single unit operations, and operate spill bays 2 and 3 for fish passage. This will be beneficial to fish operations in several ways. Turbine unit 2 is north of unit 1 and closer to the spillway. Operating unit 2, concurrently with spill bays 2 and 3 will increase flows near the spillway, therefore providing attraction flows to the spillway for fish. Additionally, the Forebay Water Supply (FWS) for the Adult Fish Facility is tapped from penstock 2. With unit 2 in operation, flow passing the FWS inlet piping prevents fish from entering the FWS piping, which could lead to entrainment and mortality. The fish weir will not be operated in this operational change; only spill bays 2 and 3 will be operated as surface flow outlets for fish passage.

The operational measure does not require any special deviations for spill bay operation. During spillway (bays 2 and 3) operations, the reservoir elevations will be maintained as prescribed in the Water Control

manual (the Rule Curve for reservoirs in the Willamette basin). The gate openings (minimum and maximum) for each spill bay will be determined by the Reservoir Regulators and the prescribed gate openings for river flows and reservoir elevations. Minimum and maximum gate openings are determined by the forebay elevation and flows. Additional spill bays and turbine unit 1 may be operated if river flows are higher than the maximum flows allowed to pass each of bays 2 and 3. This operational measure was analyzed in Reservoir Simulation (ResSim) and Fish Benefits Workbook (FBW) models for practicality.

5.2.1.2. **Measure No. O2b: Use Spill Bay 4 at Low and High Pool**

This measure is similar to O2a above but Spill Bay 4 would be operated instead of bays 2 and 3 for fish passage. Spill Bay 4 would be operated concurrently with turbine unit 2. Turbine unit 2 would provide the attraction flow for fish, but once the fish are in the flow net, they would be attracted to the surface flows at bay 4 and use that spill bay for passage. The fish weir will not be operated in this operational change. The reservoir elevations will be maintained as prescribed in the Water Control manual. Additional spill bays and turbine unit 1 may be operated if river flows are higher than the maximum flows allowed to pass Spill Bay 4. This operational measure was analyzed in ResSim and FBW models for practicality.

5.2.1.3. **Measure No. O5: Modify the Temporal Use of the Fish Weir**

Background: Traditional operation period of the fish weir is for one month each year, from 15 April to 15 May. This requires lowering of the Foster reservoir for one month after spring refill, then the reservoir is refilled to the summer levels after mid-May. This operation has two negative impacts on power production. First, a significant amount of potential power producing water is passed, via the spillway, at a rate faster than can be used by both turbines during drafting of the reservoir to prepare for the weir operation. Secondly, that same amount of water must be drawn from the Green Peter reservoir to rapidly fill the Foster reservoir, after weir operations in mid-May, prior to Memorial Day recreation activities. This operation is conducted at the end of spring when rainfall is less abundant. Given the results of recent fish passage studies, the majority of both juvenile and adult salmon and steelhead pass downstream at times other than the traditional 15 April to 15 May time period.

Operational Change: Maintain the Foster reservoir at the low winter pool elevation (615 ft.) until May (that is, maintain the low reservoir from October – May), then refill to the summer pool elevation. Operate the fish weir concurrent with turbine operations year round for fish passage. The weir would be operated during the low pool period (October – May), then raised and operated at the high, summer pool elevation (June – September). This operational change would provide a year-round surface outlet for downstream migrating fish and will conserve water in the Green Peter reservoir which could be used to quickly fill the Foster reservoir at the end of May. Although the fish weir is prioritized for surface flows, any or all spill bays may be operated if river flows are higher than the maximum flows allowed to pass the fish weir. The Reservoir Regulators and Foster Operators will determine the order of outlets (turbines, spill bays) for passing water at the dam if flows prevent operation of the fish weir. This operational measure was analyzed in ResSim and FBW models for practicality.

5.2.1.4. **Measure No. MT-2 Operate Spill Bays and Shut off Turbines During Peak Run Timing**

Background: Generally, the turbines are the primary route for passing water at Foster Dam. The spillway is used to pass excess water to maintain the reservoir and downstream flows.

Operational Change: This measure proposes to use the spillway as the primary route for passing water during peak run timing of downstream migrating fish (current results from studies indicate October

through May) and turning off the turbines (no power generation). This measure would allow all fish to pass the dam via the spillway. No passage would occur at the turbines because they will be off. The fish weir will not be operated. Any or all spill bays will be operated as the surface flow outlet for fish. No changes to the Rule Curve is required; the reservoir will be maintained as prescribed by the Water Control manual. The Reservoir Regulators and Foster Operators will determine the order of spill bays for passing water at the dam, depending on river flows. Additionally, if river flows exceed the capacity of the spillway, the turbine units may be operated to pass the excess water. This operational measure was analyzed in ResSim and FBW models for practicality.

5.2.1.5. **Measure No. MT-3: Flushing Flow**

Background: Current reservoir operations begin a slow refill of Foster Reservoir from February to May transitioning from winter flood control operations to spring/summer operations. During 2013, the refill operation timing was substantially shortened to about 9 days in early May. Concurrent fish passage data suggest an increase (pulse) in passage coinciding with the rapid inflow to Foster reservoir from Green Peter. This correlation would have to be vetted with more testing, but this measure could potentially assist downstream passage during the yearly Foster reservoir refill. Further research may indicate that multiple surges could be beneficial thereby increasing the temporal use of the Green Peter reservoir flow for downstream fish passage.

Operational Change: Utilize the stored water at Green Peter Dam to create a surge of flow into the Foster Reservoir during refill in an effort to influence Chinook salmon and steelhead to seek downstream passage during peak timing thereby reducing passage time. .

5.2.2. **Structural Measures**

5.2.2.1. **Measure No. S-4a: Modified Fish Weir Crest Shape**

Modify the shape of the fish weir crest such that trajectory of the flow more closely parallels the ogee surface. This would help to reduce stress and potential injury to juvenile fish caused by a larger angle of impact. Temporary or permanent top spill weirs, like those currently used at McNary and John Day dams create a similar water slide effect to allow safer contact with the ogee surface. Concepts could include an actual weir/slide shape downstream of the weir crest ending on the ogee surface or modification of the weir crest only, such that a flow trajectory similar to the slope of the ogee is created.

5.2.2.2. **Measure No. S-4c: Water Cushion on Spillway for Fish Passing a Significant Distance Above the Spillway Crest**

This alternative includes a modification to the lower stop logs to allow for flow in a location beneath the fish weir flow. This will provide a cushion for fish, minimizing damage from high velocity impact on the spillway. It will also serve to entrain and direct the fish flow in the horizontal direction. This modification could also increase the overall flow, improving attraction for juvenile fish in the upper column of the reservoir.

5.2.2.3. **Measure No. S-4e: Gate Within a Spill Bay Gate**

Retrofit an existing tainter gate or gates (or redesign a new gate) by adding an actuated mini-gate near the bottom of the gate's skin plate. This would allow for juvenile fish passage through the mini-gate while keeping the spillway gate in a closed position, allowing a minimal amount of flow for fish passage without adversely affecting the forebay elevation. Depending on the location of the entrance, attraction flow may simulate more of an orifice signature rather than surface flow. If the entrance is high, impact concerns would have to be addressed.

5.2.2.4. **Measure No. S-4f: Turbine Bypass Screens**

Install screens to penstock intakes to prevent fish from entering the turbines. Screens will meet NMFS screening criteria.

5.2.2.5. **Measure No. EF-2: Bypass Canal With Floating Orifice Gate**

Build a bypass canal on either side of the river. The north side canal would use the fish hatchery water supply line and would require fish screening. The south side canal would use a pipe through the dam, routing fish through a canal all the way to the tailrace.

5.2.2.6. **Measure No. EF-3: New Fish Weir with Capability to Meet Varying Elevations or Flow Requirements.**

The addition of a floating crest to a new fish weir or a larger weir with a fixed crest would allow the weir to maintain ideal hydraulic conditions (flow rate, velocity, etc.) over a range of forebay pool elevations. The floating weir would move in relation to the forebay elevation, providing optimal flow over the weir while the fixed weir would have a large enough opening to allow operation at multiple flow and pool elevation conditions.

All above structural measures were evaluated in the FBW model, using the operational measure results from ResSim models using that have the equivalent flow of each outlet, with a revised set of parameters in the FBW model.

5.2.3. Universally Recommended Measures

5.2.3.1. **MP-3: Formalize an operational debris removal program**

5.2.3.2. **MI-6: Manage spill to minimize gas (TDG)**

5.2.3.3. **EF-14*: Install lighting at entrance inlet to attract fish on the upstream side**

5.2.3.4. **SO-5**: Build a permanent hoist over spill bay 4 to eliminate need for crane mobilization**

5.2.3.5. **SO-6**: Buy a mobile crane**

5.2.3.6. **SO-7: Buy a truck and trailer for stop log transportation**

5.2.3.7. **SO-15: Avoid disruption of operations of the Adult Fish Facility- (AFF) including attraction to the fish ladder**

5.2.3.8. **SO-16: Install permanent fish study monitoring equipment to provide a system for ongoing research**

5.2.4. Measures Not Carried Forward

In building the alternatives, the team discovered a few existing measures that, upon further discussion, were similar in nature to other measures and thus, were deleted from further consideration.

- S4b – Modify fish weir – provide pool of water for fish passing over the weir utilizing tainter gate (discharge remains the same)
- S4d – Modify fish weir – fabricate additional stop logs
- S5 – Modify the ogee – extension of the ogee
- MP-4 – Team determined MP-3 and MP-4 had the same overall intent.

6. ALTERNATIVE DESCRIPTIONS

From the accepted measures the team compiled six project alternatives that provided a more complete strategy and suggestion for options to improve fish passage at Foster Dam. The alternatives are 1) New Fish Weir, 2) Operational Improvements, 3) Double Bypass Canal, 4) Single Bypass Canal and New Fish Weir, 5) Gate within a Gate, and 6) Turbine Screens. The Alternatives are described below, including a list of the accompanying combinations of measures recommended to be carried forward. These alternatives were analyzed using Res Sim and the Fish Benefit Workbook models. The results can be found in Chapter 7.

6.1. NO ACTION ALTERNATIVE (BASELINE)

No operational or structural modifications to existing fish weir system or project operations. This alternative would be to continue the current operations of the fish weir for one month each year (15 April – 15 May) for fish passage. The turbines would be the primary route for passing water and fish and the spillway would be used as needed to pass excess water. This simulation sets the baseline which will be used as the comparison for all FOS downstream passage alternative simulations. All templates set up for comparison use the Early Implementation results as the comparative values. This alternative is referred to as the **Baseline** in the analysis and results section. Figure 6.1 depict the operational conditions as modeled in RES-SIM and used in the downstream fish passage analysis of this alternative in the FBW.

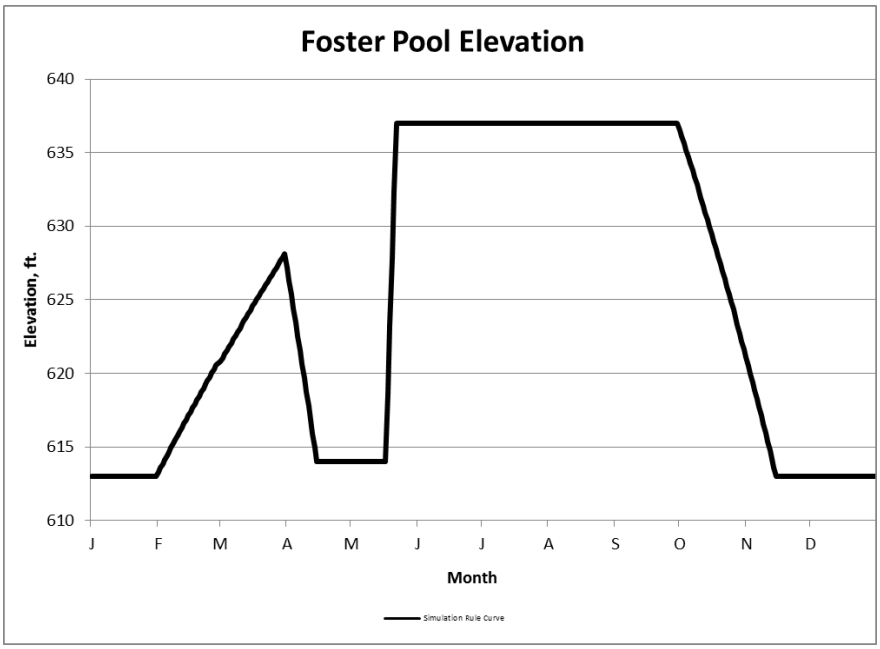


Figure 6-1 Rule Curve for the No Action Alternative (Baseline)

6.2. ALTERNATIVE 1: NEW FISH WEIR

Construct a new fish weir with a flow capacity that could vary between 300 to 860 cfs; a means of operating over multiple pool elevations, and the ability to operate year round in conjunction with or without the use of turbine flow (actual operations to be determined). The new fish weir would be used in Spill Bay 4 (or another bay TBD). Additionally, operate Spill Bays 2 and/or 3 during low pool or flood control season for fish attraction and passage. Operation of Spill Bay 2 or 3 will be river flows dependent (low flows may prevent operating these spill bays).

Alternative 1 combines any or all of the following seven measures:

O-2a	Use spill bays 2 and 3 at low and high pool
O-5	Modify the temporal use of the fish weir or other passage routes
MT-2	Operate spill bays and shut off turbines during peak run timing or longer
S-4a	Modified fish weir crest shape
S-4c	Water cushion on spillway for fish passing a significant distance above the spillway crest
EF-3	New fish weir with capability to meet varying elevations or flow requirements
MT-3	Flushing flow
BA-1	Power generation alternatives

The concept for a new fish weir is to reduce or replace flow through the turbines and operate the spillway to pass water and fish as a non-turbine route for downstream fish passage during peak fish passage run timing or year round. Surface outlets have been shown to be beneficial for downstream passage. The changes in the forebay elevation between flood control season (low pool) and summer (high pool) require the operations staff to remove the fish weir and either add or remove stop logs to operate the fish weir at the correct elevation related to the reservoir. This alternative would pursue the construction of a new fish weir (with flows of approximately 800 cfs) to be operated during peak fish passage timing, or year round, as the primary passage route. The concept is to construct a new fish weir with the ability to accommodate multiple reservoir elevations. The new weir would be designed such that it could be used with the current stoplogs and lifting beam. The Project crane maximum lift capacity for the weir and stop logs is 22000 lbs. based on the determined crane outrigger positions on the spillway bridge. A bridge load rating was performed for spillway bridges and the bridges are adequate for design and legal loadings. Copies of the load rating reports are in Appendix F. The figures below show sketches of the proposed fixed weir.

The new fish weir would be the primary means of passing water through Spill Bay 4 when installed. The tainter gate must be dogged fully open. If high flows are expected that require use of Spill Bay 4 the project would be required to remove the fish weir and stop logs to return the tainter gate and bay to normal flow control.

During the design process, the PDT would investigate incorporating all of the measures listed above into the final design, construction, and operation of the new weir. Safe passage for fish downstream of the weir is integral to this project. Measure S-4c would provide a water cushion for fish passing over the fish weir by utilizing an orifice through the lower stop log(s), or other means of protection such as modifying the crest shape to direct flow parallel to the slope of the ogee spillway.

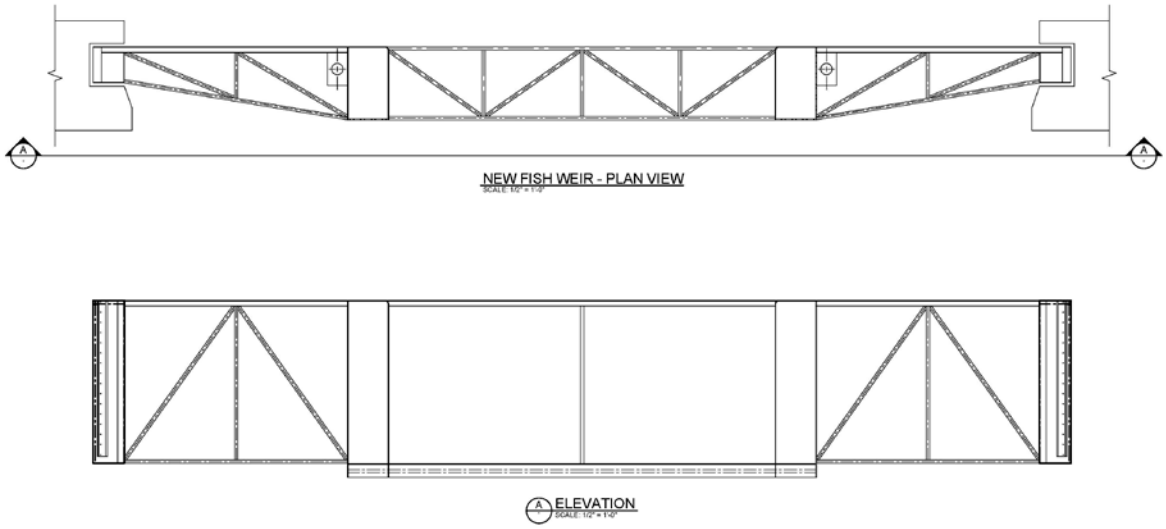
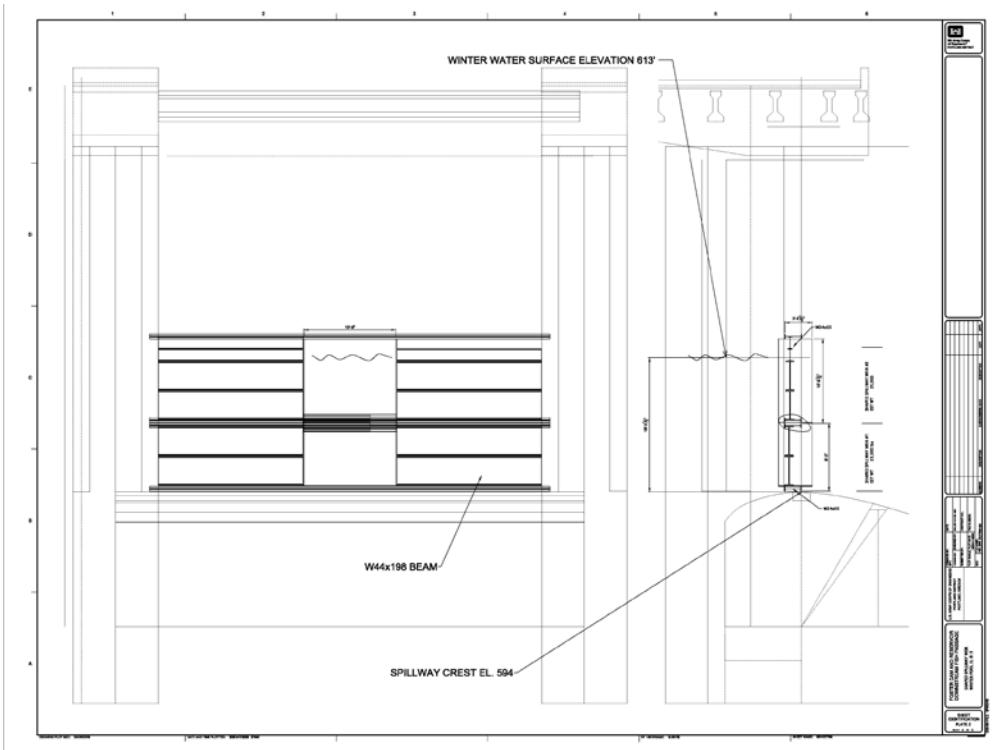


Figure 6-2 Fixed weir alternative sketch

The following drawings depict two elevations of a fixed fish weir to accommodate two water surface elevations: Winter water surface elevation EL 613 ft. and Summer water surface elevation EL 637 ft.



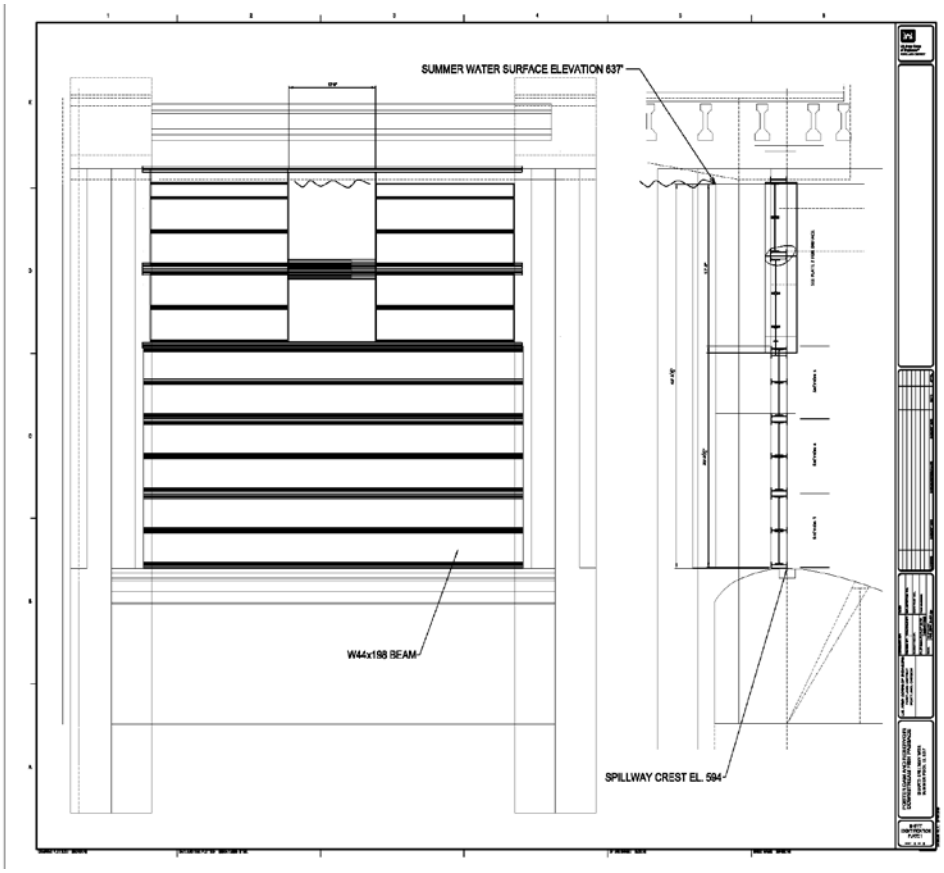


Figure 6-3 Fixed weir installed

Based on criteria and considerations from Chapter 3, and the measures described above, the following sub-alternatives were developed and carried forward for analysis. The graphics below depict the operational conditions as modeled in RES-SIM and used in the downstream fish passage analysis of this alternative in the FBW.

Alternative 1.1, Fish Weir 300 01 Oct – 15 May with use of powerhouse: This simulation draws down Foster Reservoir to elevation 613 ft by October 01 and tries to maintain this elevation until May 15. The fish weir, located in spillway number 4, is operated with a constant release of 300 cfs from October 01 until May 15. After May 15 the reservoir is refilled to elevation 637 ft. Any required outflow over 300 cfs is released through the powerhouse, if minimum powerhouse flows can be met. If minimum powerhouse flows cannot be met, the extra outflow above 300 cfs is release with the other spillways. If additional water besides the fish weir and powerhouse is required to be release, spillways number 1, 2, or 3 are used. Figure 6.2 depicts the operational conditions as modeled in RES-SIM and used in the downstream fish passage analysis of this alternative in the FBW.

The new fish weir would be the primary means of passing water through Spill Bay 4 when installed. The tainter gate must be dogged fully open. If high flows are expected that require use of Spill Bay 4 the project would be required to remove the fish weir to return the tainter gate and bay to normal flow control.

Alternative 1.2, Fish Weir 500 01 Oct – 15 May with use of powerhouse: This simulation draws down Foster Reservoir to elevation 613 ft by October 01 and tries to maintain this elevation until May 15. The fish weir, located in spillway number 4, is operated with a constant release of 500 cfs from October 01 until May 15. After May 15 the reservoir is refilled to elevation 637 ft. Any required outflow over 500 cfs is released through the powerhouse, if minimum powerhouse flows can be met. If minimum powerhouse flows cannot be met, the extra outflow above 500 cfs is release with the other spillways. If additional water besides the fish weir and powerhouse is required to be release, spillways number 1, 2, or 3 are used. Figure 6.2 depicts the operational conditions as modeled in RES-SIM and used in the downstream fish passage analysis of this alternative in the FBW.

The new fish weir would be the primary means of passing water through Spill Bay 4 when installed. The tainter gate must be dogged fully open. If high flows are expected that require use of Spill Bay 4 the project would be required to remove the fish weir to return the tainter gate and bay to normal flow control.

Alternative 1.3, Fish Weir 860 01 Oct – 15 May with use of powerhouse: This simulation draws down Foster Reservoir to elevation 613 ft by October 01 and tries to maintain this elevation until May 15. The fish weir, located in spillway number 4, is operated with a constant release of 860 cfs from October 01 until May 15. After May 15 the reservoir is refilled to elevation 637 ft. Any required outflow over 860 cfs is released through the powerhouse, if minimum powerhouse flows can be met. If minimum powerhouse flows cannot be met, the extra outflow above 860 cfs is release with the other spillways. If additional water besides the fish weir and powerhouse is required to be release, spillways number 1, 2, or 3 are used. Figure 6.2 depicts the operational conditions as modeled in RES-SIM and used in the downstream fish passage analysis of this alternative in the FBW.

The new fish weir would be the primary means of passing water through Spill Bay 4 when installed. The tainter gate must be dogged fully open. If high flows are expected that require use of Spill Bay 4 the project would be required to remove the fish weir and stop logs to return the tainter gate and bay to normal flow control.

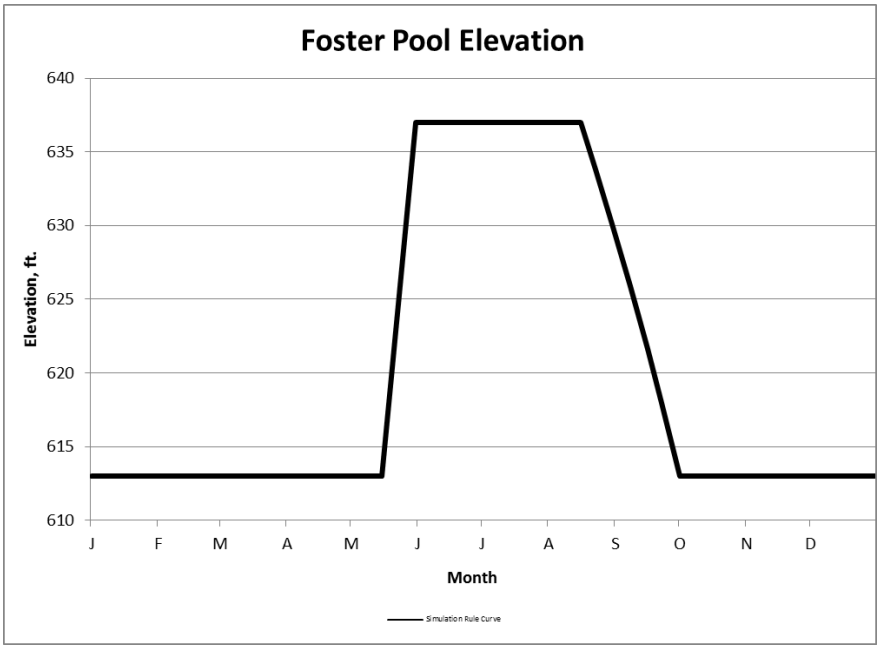


Figure 6-4 Rule Curve for Alternative 1.1, 1.2, and 1.3

Alternative 1.4, Fish Weir 500 Year round with use of powerhouse if can meet min flows: This simulation draws down Foster Reservoir to elevation 613 ft by November 15 and tries to maintain this elevation until January 31. The fish weir, located in spillway number 4, is operated with a constant release of 500 cfs all year, regardless of the pool elevation. After January 31 the reservoir is gradually refilled to elevation 637 ft by May 11. Any required outflow over 500 cfs is released through the powerhouse, if minimum powerhouse flows can be met. If minimum powerhouse flows cannot be met, the extra outflow above 500 cfs is release with the other spillways. If additional water besides the fish weir and powerhouse is required to be release, spillways number 1, 2, or 3 are used. Figure 6.3 depicts the operational conditions as modeled in RES-SIM and used in the downstream fish passage analysis of this alternative in the FBW.

The new fish weir would be the primary means of passing water through Spill Bay 4 when installed. The tainter gate must be dogged fully open. If high flows are expected that require use of Spill Bay 4 the project would be required to remove the fish weir and stop logs to return the tainter gate and bay to normal flow control.

Alternative 1.5, Fish Weir 860 Year round with use of powerhouse: This simulation draws down Foster Reservoir to elevation 613 ft by November 15 and tries to maintain this elevation until January 31. The fish weir, located in spillway number 4, is operated with a constant release of 860 cfs all year, regardless of the pool elevation. After January 31 the reservoir is gradually refilled to elevation 637 ft by May 11. Any required outflow over 860 cfs is released through the powerhouse, if minimum powerhouse flows can be met. If minimum powerhouse flows cannot be met, the extra outflow above 860 cfs is release with the other spillways. If additional water besides the fish weir and powerhouse is required to be release, spillways number 1, 2, or 3 are used. Figure 6.3 depicts the operational conditions as modeled in RES-SIM and used in the downstream fish passage analysis of this alternative in the FBW.

The new fish weir would be the primary means of passing water through Spill Bay 4 when installed. The tainter gate must be dogged fully open. If high flows are expected that require use of Spill Bay 4 the

project would be required to remove the fish weir and stop logs to return the tainter gate and bay to normal flow control.

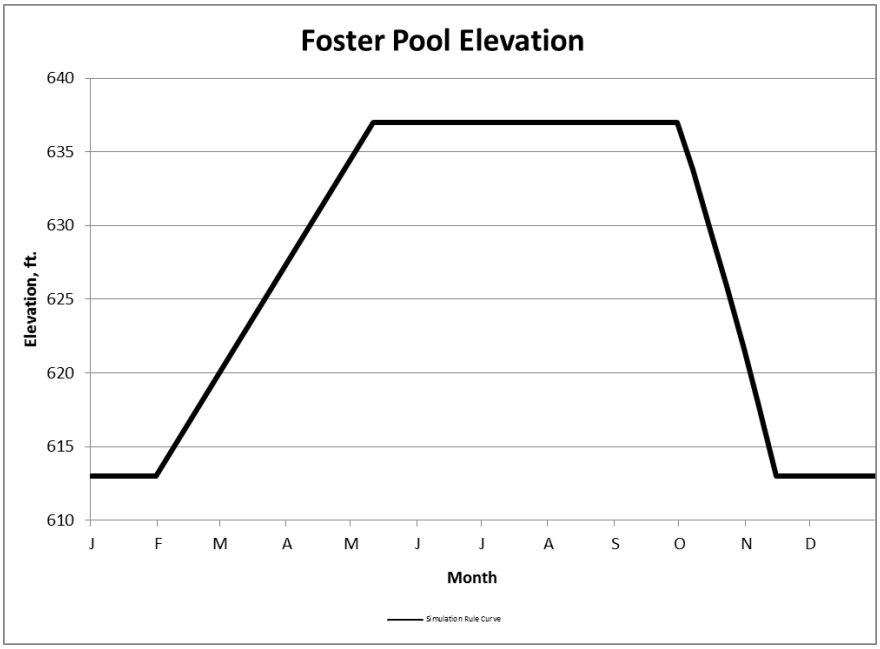


Figure 6-5 Rule Curve for Alternative 1.4 and 1.5

6.3. ALTERNATIVE 2: OPERATIONAL IMPROVEMENTS ONLY

Alternative 2 uses existing operational features (e.g. operate the spill bays) to provide fish passage, with no structural improvements required. The current fish weir will not be used. Instead, one or more spill bays would be open to operational capacity as a water and fish passage route. Alternative 2 combines all or some of the following five measures:

O-2a	Use spill bays 2 and 3 at low and high pool
O-2b	Use spillway 4 at low and high pool
MT-2	Operate spill bays and shut off turbines during peak run timing
MT-3	Flushing Flow
BA-1	Power Generation Alternatives

Based on criteria and considerations from Chapter 3, and the measures described above, the following sub-alternatives were developed and carried forward for analysis. The graphics below depict the operational conditions as modeled in RES-SIM and used in the downstream fish passage analysis of this alternative in the FBW.

Alternative 2.1 Operational Improvements, Spillbay 4 Low Pool. This simulation draws down Foster Reservoir to elevation 613 ft by November 15 and tries to maintain this elevation until April 30. Spillway number 4, without the fish weir, is operated to pass fish from November 1 through April 30. The spillway is operated with at least a minimum gate opening, which varies with the pool elevation, but is usually around 860 cfs at pool elevation 613 feet. After April 30 the reservoir is gradually refilled to elevation 637 ft by May 31. Any required outflow over minimum gate opening is released through the

powerhouse, if minimum powerhouse flows can be met. If minimum powerhouse flows cannot be met, the extra outflow will be released with the spillways. Figure 6.4 depicts the operational conditions as modeled in RES-SIM and used in the downstream fish passage analysis of this alternative in the FBW.

Alternative 2.2 Operational Improvements, Spillbay 4 High Pool. This simulation draws down Foster Reservoir to elevation 613 ft by November 15 and tries to maintain this elevation until April 30. Spillway number 4, without the fish weir, is operated to pass fish from May 01 through September 30. The spillway is operated with at least a minimum gate opening, which varies with the pool elevation, but is usually around 860 cfs at pool elevation 613 feet. After April 30 the reservoir is gradually refilled to elevation 637 ft by May 31. Any required outflow over minimum gate opening is released through the powerhouse, if minimum powerhouse flows can be met. If minimum powerhouse flows cannot be met, the extra outflow will be released with the spillways. Figure 6.4 depicts the operational conditions as modeled in RES-SIM and used in the downstream fish passage analysis of this alternative in the FBW.

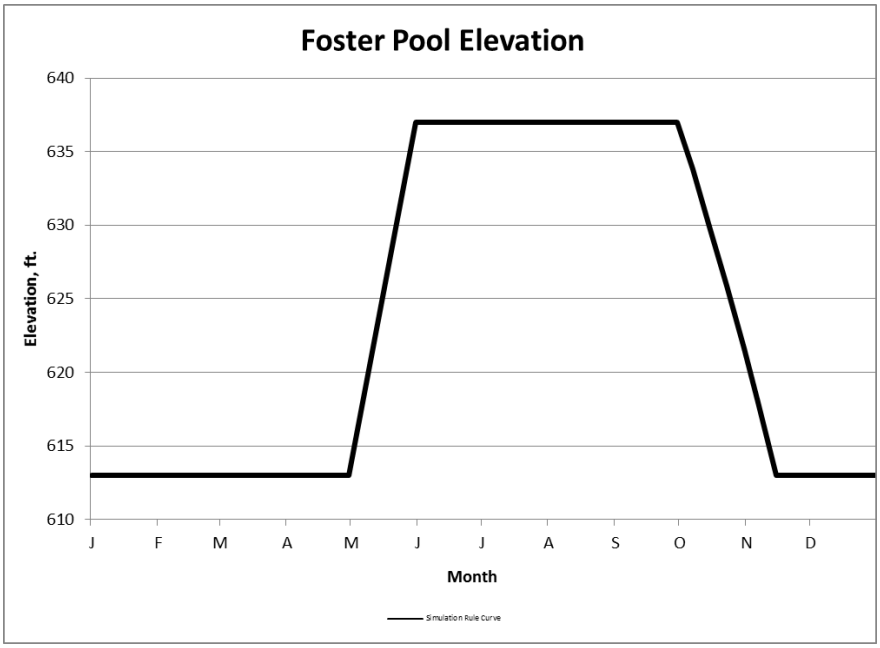


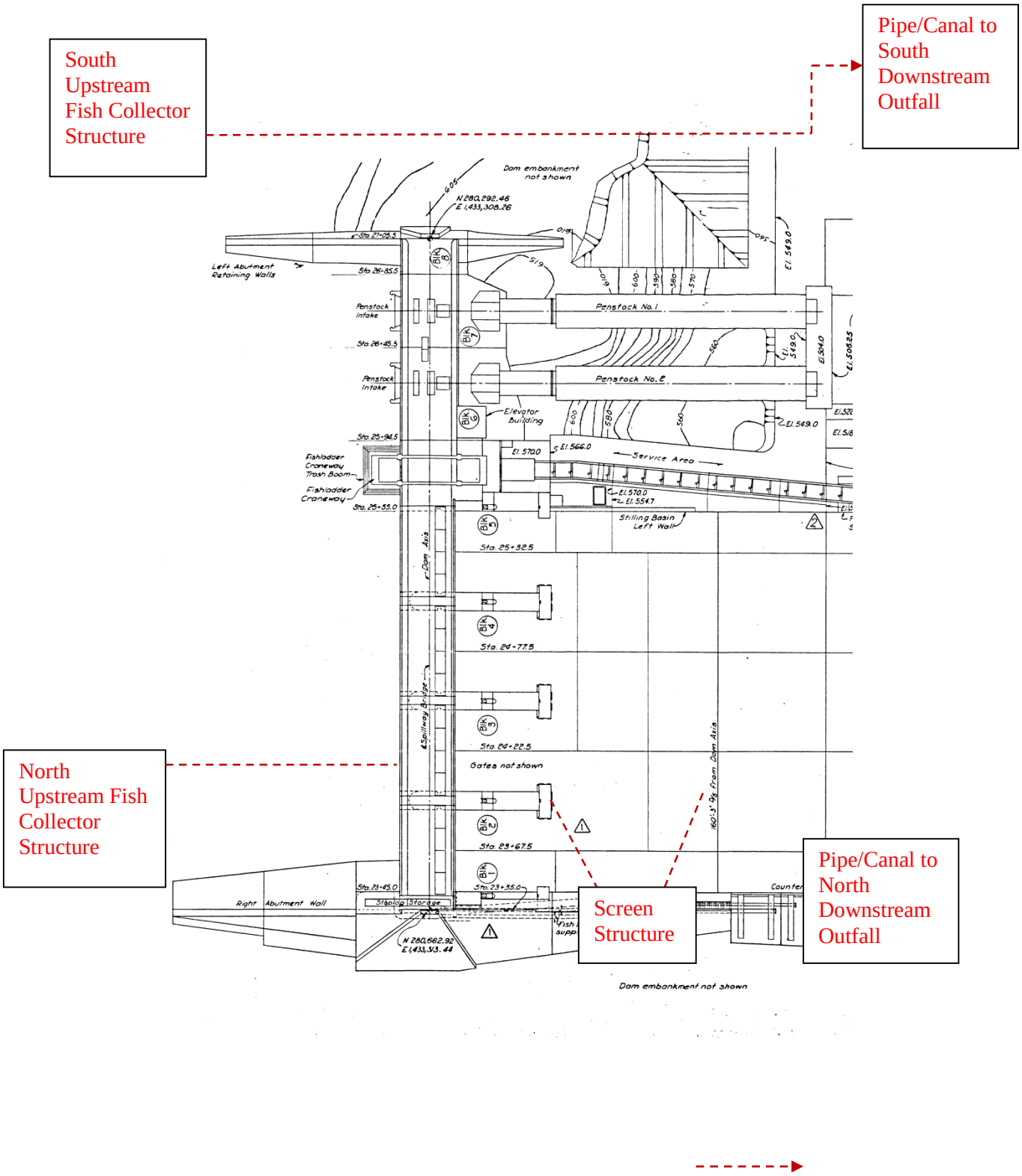
Figure 6-6 Rule Curve for Alternative 2.1 and 2.2

6.4. ALTERNATIVE 3: DOUBLE BYPASS CANAL

Alternative 3 includes building bypass canals on both sides of the river. The north side canal would use the fish hatchery water supply pipe and requires fish screening. The south side would run a pipe through the dam routing fish through a canal all the way to the tailrace. This alternative represents a significant structural and configuration change. Alternative 3 combines the following two measures:

EF-2	Bypass Canal With Floating Orifice Gate
MT-3	Flushing Flow

The concept is to construct fish collection structures in the Foster Dam forebay on both the north and south side of the approach (near each bank). The purpose of the collection structures is to provide attraction flow and openings to capture/entrain fish following the shorelines before nearing the dam and the turbines. This alternative would consist of constructing fish collection structures upstream of the spillway dam and powerhouse penstock intakes on the north and south shorelines and routing fish through pipes and/or canals to downstream locations, as shown in the following concept drawing.


South Upstream Fish Collector Structure
Pipe/Canal to South Downstream Outfall
North Upstream Fish Collector Structure
Screen Structure
Pipe/Canal to North Downstream Outfall
Dam embankment not shown
Left Abutment Retaining Walls
Penstock Intake
Penstock No. 1
Penstock No. 2
Elevator Building
Fishladder Craneway Trash Boom
Fishladder Craneway
Service Area
Stilling Basin Left Wall
Dam Axis
Spillway Bridge
Gates not shown
Right Abutment Wall
Staplog Storage
Dam embankment not shown

The upstream fish collector structures would incorporate floating orifice gates similar to those used at the Bonneville Project to control flow for fish passage and accommodate the changing pool elevations. Fish would travel in pipes through the dam and continue in a pipe, and/or canal, to outfalls downstream. The south pipeline/canal would be placed through the dam structure. The north pipeline/canal would use the fish hatchery water supply pipe for fish passage to a screen structure where fish would be directed to an outfall downstream and the hatchery water would be directed back to the hatchery supply pipeline.

Based on criteria and considerations from Chapter 3, and the measures described above, this alternatives was carried forward for analysis as **Alternative 3.1**. Figure 6.3 depict the operational conditions as modeled in RES-SIM and used in the downstream fish passage analysis of this alternative in the FBW.

6.5. ALTERNATIVE 4: SINGLE BYPASS CANAL AND NEW FISH WEIR

Alternative 4 combines the following eight measures:

O-2a	Use spill bays 2 and 3 at low and high pool
O-5	Modify the temporal use of the fish weir
S-4a	Modified fish weir crest shape
EF-3	New fish weir with capability to meet varying elevations
MT-2	Operate spill bays and shut off turbines during peak run timing or longer
MT-3	Flushing Flow
EF-2	Bypass canal with a floating orifice gate
BA-1	Power generation alternatives

The concept is to build a bypass canal on the south side between the left bank and before the turbines and a new weir in spill bay 2. The purpose of the collection structure is to provide attraction flow and openings to collect fish following the shoreline before nearing the dam. This alternative would consist of constructing a fish collection structure upstream of the powerhouse penstock intakes and spillway dam on the south shoreline and routing fish through pipelines and/or canals to downstream outfalls, as shown in the concept drawing for Alternative 3 – Double Bypass Canal.

The upstream fish collector structure would incorporate floating orifice gates similar to those used at the Bonneville Project to control flow for fish passage and accommodate the changing pool elevations. Fish would travel in pipes through the dam and continue in a pipe, and/or canal, to outfalls downstream. The south pipeline/canal would be placed through the dam structure.

Based on criteria and considerations from Chapter 3, and the measures described above, this alternatives was carried forward for analysis. Figure 6.3 depicts the operational conditions as modeled in RES-SIM and used in the downstream fish passage analysis of this alternative in the FBW.

6.6. ALTERNATIVE 5: GATE WITHIN A GATE

Alternative 5 would modify or replace a spill bay gate(s) to include weirs or ports that provide adjustable openings to accommodate varying water levels. Alternative 5 combines the following six measures:

S-4e	Gate within the spillway gate
MT-2	Operate spill bays and shut off turbines during peak run timing or longer
MT-3	Flushing Flow
BA-1	Power generation alternatives

This alternative would retrofit the existing tainter gate (or redesign a new gate) by adding an actuated mini-gate near the bottom of the gate's skin plate. This would allow for juvenile fish passage through the mini-gate while keeping the spillway gate in a closed position, allowing a minimal amount of flow for fish passage without adversely affecting the forebay elevation and reservoir management. The added gate would be designed to provide the proper flow trajectory for safe passage along the ogee. Operating equipment would be included to operate a slide gate to initiate and stop flow and possibly regulate flow. Depending on the location of the entrance, attraction flow may simulate more of an orifice signature rather than surface flow. If the entrance is high, impact concerns would have to be addressed.

This alternative would develop a concept implemented at the Santeetlah Dam located in North Carolina on the Cheoah River. The following figures are taken from a paper presented at the 29th Annual U.S. Society on Dams (USSD) Conference in 2009.

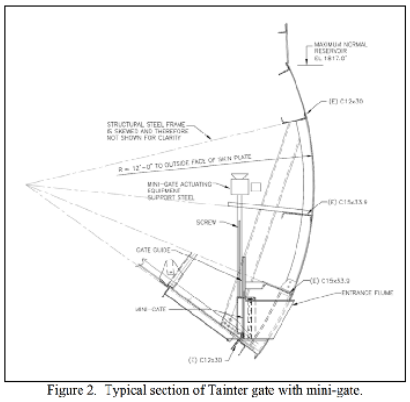


Figure 2. Typical section of Tainter gate with mini-gate.

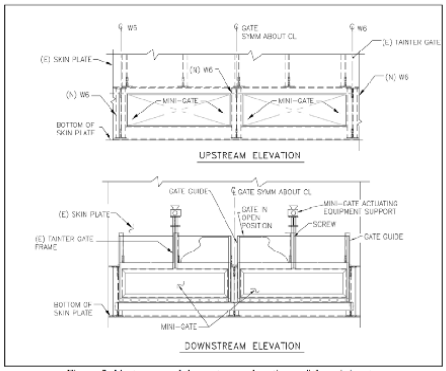
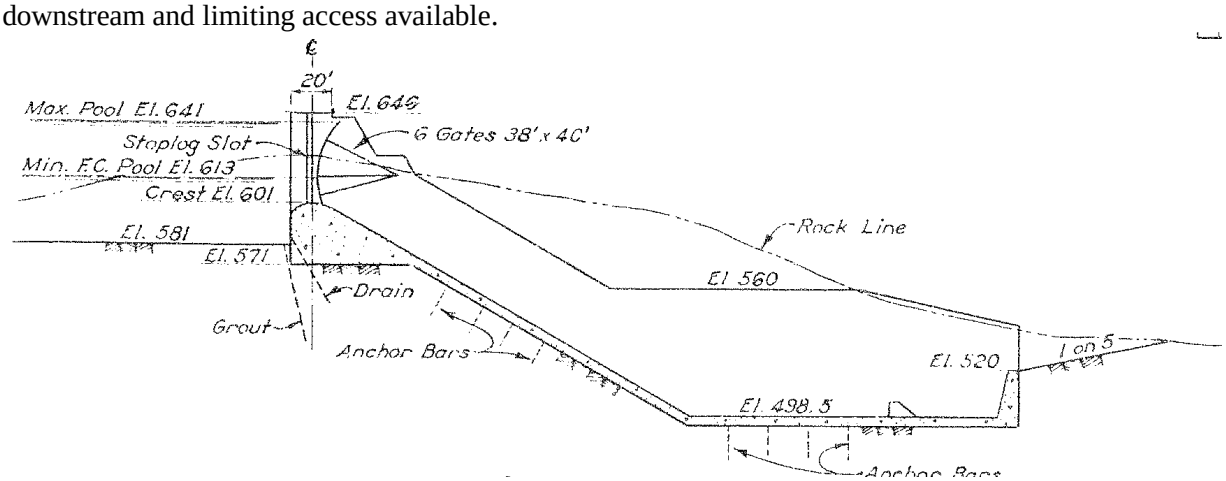


Figure 3. Upstream and downstream elevations of the mini-gate.

Engineering concerns were raised during follow on discussion of the concept indicating this alternative is likely not viable. The gates are mounted on the downstream side of the dam with the trunnions furthest downstream. Any components will be mounted on the downstream side of the gates which places them far downstream and limiting access available.



The gates have already been structurally reinforced to address loading concerns. The gate within a gate concept will require mounting a new opening on the downstream side of the gate where the hydraulic forces are largest. The entire gate would need to be replaced to provide the structural strength to support the mechanical equipment and flows through the gate. The weight of the combined components would

require replacement of all the newly installed hoisting equipment to provide the lifting capacity to operate the gate safely during high load conditions. Therefore, this alternative was not carried forward for further analysis.

6.7. ALTERNATIVE 6: TURBINE SCREENS

Alternative 6 includes one structural measure and multiple operational measures. The operational measures are similar to Alternative 2, but power generation would not be foregone as the penstocks would have screens installed to prevent fish from entering the penstocks. Screens would meet NMFS screening criteria. This alternative would make use of the existing weir structure with no modifications to it.

O-2a	Use spill bays 2 and 3 at low and high pool
O-2b	Use spillway 4 at low and high pool
MT-3	Flushing Flow

Based on criteria and considerations from Chapter 3, and the measures described above, this alternatives was carried forward for analysis as **Alternative 6.1**. Figure 6.3 depicts the operational conditions as modeled in RES-SIM and used in the downstream fish passage analysis of this alternative in the FBW.

6.8. DOWNSTREAM FISH PASSAGE ASSUMPTIONS USED IN THE FISH BENEFIT WORKBOOK

The Fish Benefit Workbook (FBW) was used to estimate and compare the biological benefit (downstream passage survival of juvenile spring Chinook and winter steelhead) of each alternative. To complete this analysis, fish passage parameters used in the FBW were estimated from field studies, related literature, and professional judgment. These parameter estimates, and their sources, are documented below. Description of the FBW and how these parameters are used in the FBW, are documented in the Fish Benefit Workbook Users Guide, Appendix C.

Dam Passage Efficiency (DPE), all life stages

Pool elev.	Baseline	1.1 New Fish Weir 300cfs	1.2 & 1.4 New Fish Weir 500cfs	1.3 & 1.5 New Fish Weir 860cfs	2.1 Spillbay 4 low pool	2.2 Spillbay 4 high pool	4.1 Single Bypass 300cfs	3.1 Double Bypass 860cfs	6.1 Turbine Exclusion Screens*
637.00	0.80	0.80	0.90	0.95	0.98	0.95	0.95	0.95	0.98
614.00	0.80	0.90	0.95	0.98	0.98	0.98	0.98	0.98	0.98
613.00	0.80	0.90	0.95	0.98	0.98	0.98	0.98	0.98	0.98
609.00	0.80	0.90	0.95	0.98	0.98	0.98	0.98	0.98	0.98
596.80	0.80	0.90	0.95	0.98	0.98	0.98	0.98	0.98	0.98
583.25	0.80	0.90	0.95	0.98	0.98	0.98	0.98	0.98	0.98

* This alternative assumes the turbine intake has exclusionary screens, with fish passage via the Fish Weir (300cfs) operated year round, or through the spillway when operated.

Information sources used to prepare *DPE* assumptions:

Scenario	Rationale	Source
1.1 New Fish Weir 300cfs	See Alden 2014a and 2014b	Alden 2014a and Alden 2014b
1.2 & 1.4 New Fish Weir 500cfs	PNNL reported as high 97%, and 98% of radio-tagged juveniles passed surface routes (spillway and/or fish weir during specific seasons and operations. PNNL radio telemetry study indicates existing surface routes are attractive to, and utilized by both species, and use of these routes is positively relates to flow and in some cases reservoir pool elevation. We assume DPE will improve over baseline with installation of an improved fish weir increasing attraction and collection efficiency with improved weir shape and operated with high flows. We assume the level of improvement proportionate with increase in surface flow provided.	PNNL 2015: Personal communication to Fenton Khan from James Hughes. See data tables and summary in Section 2.7.1.4 of this report.
1.3 & 1.5 New Fish Weir 860cfs		
2.1 Spillbay 4 low pool		
2.2 Spillbay 4 high pool		
4.1 Single Bypass 300cfs		
3.1 Double Bypass 860cfs		
6.1 Turbine Exclusion Screens		

Route Survival by lifestage, applied for both Chinook and Steelhead

Fry

	Baseline	1.1 New Fish Weir 300cfs	1.2 & 1.4 New Fish Weir 500cfs	1.3 & 1.5 New Fish Weir 860cfs	2.1 Spillbay 4 low pool	2.2 Spillbay 4 high pool	4.1 Single Bypass 300cfs	3.1 Double Bypass 860cfs	6.1 Turbine Exclusion Screens*
Spillway Survival	0.90	0.90	0.90	0.90	0.98	0.95	0.90	0.90	0.90
Turbine Survival	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Fish Passage Survival	0.90	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98

Sub-yearlings**

Spillway Survival	0.90	0.90	0.90	0.90	0.98	0.92	0.90	0.90	0.90
Turbine Survival	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Fish Passage Survival	0.75	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98

Yearlings**

Spillway Survival	0.82	0.82	0.82	0.82	0.98	0.90	0.82	0.82	0.82
Turbine Survival	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
Fish Passage Survival	0.65	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98

* This alternative assumes the turbine intake has exclusionary screens, with fish passage via the Fish Weir (300cfs) operated year round, or through the spillway when operated.

** Assume survival decreases with fish size (i.e. better for fry than subs). Updated values based on PNNL RT study presentation at FEB8, 2016 WFSR, and previous Normandeau injury and survival (balloon tag study) estimates.

Information sources used to prepare *route survival* assumptions:

- Hughes et al. 2016
- PNNL, 2014
- Normandeau, 2013
- John Day spillway route survival.

Scenario	Rationale	Source
Baseline	See Alden 2014a and 2014b	Alden 2014a and Alden 2014b
1.1 New Fish Weir 300cfs	See Alden 2014a and 2014b.	Alden 2014a and Alden 2014b
1.2 & 1.4 New Fish Weir 500cfs		

1.3 & 1.5 New Fish Weir 860cfs 2.1 Spillbay 4 low pool 2.2 Spillbay 4 high pool 4.1 Single Bypass 300cfs 3.1 Double Bypass 860cfs 6.1 Turbine Exclusion Screens	Survival data from Normandeau 2013 for juvenile steelhead was used to develop survival assumptions for both species. Weir/Spill: The steelhead survival data **c**ollected by Normandeau (2013) indicated that average survival ranged from ~82-100%; with lower mortality rates for fish considered malady-free. Turbines: Turbine survival rates from Normandeau 2013 for steelhead varied based on pool elevation, with higher survival rates occurring at lower pool elevation. The size of the test fish ranged from 123-274 mm and averaged 213 mm (total length). This about double the length of the Chinook salmon expected to migrate through Foster Dam. Assume new weir structure would be designed to achieve 98% survival. Up to 100% survival has been observed for TSW's at Columbia Dams (references as cited by Alden 2014a).	

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Percent Fish Approaching, all alternatives

Chinook salmon

fry		subyr		yearlings	
% Fish Approaching		% Fish Approaching		% Fish Approaching	
September	0.00	September	0.10	September	0.00
October	0.00	October	0.15	October	0.00
November	0.00	November	0.15	November	0.00
December	0.07	December	0.10	December	0.00
January	0.14	January	0.00	January	0.25
February	0.32	February	0.00	February	0.25
March	0.32	March	0.05	March	0.25
April	0.10	April	0.10	April	0.15
May	0.05	May	0.10	May	0.07
June	0.00	June	0.10	June	0.03
July	0.00	July	0.05	July	0.00
August	0.00	August	0.10	August	0.00

Steelhead

fry		Yearlings		Age-2	
% Fish Approaching		% Fish Approaching		% Fish Approaching	
September	0.09	September	0.19	September	0.07
October	0.12	October	0.42	October	0.38
November	0.03	November	0.15	November	0.11
December	0.01	December	0.01	December	0.00
January	0.00	January	0.00	January	0.09
February	0.00	February	0.00	February	0.02
March	0.00	March	0.00	March	0.01
April	0.00	April	0.00	April	0.11
May	0.00	May	0.00	May	0.14
June	0.04	June	0.00	June	0.02
July	0.32	July	0.03	July	0.01
August	0.39	August	0.20	August	0.02

Information sources used to prepare *% fish approaching* assumptions:

- Fred Monzyk, personal communication (email) to Fenton Khan, December, 2015. Passage timing developed from screwtrapping catch records, 2010 to 2015, for above the reservoir and below Foster Dam. See figures and summary in Section 2.7.1.3 of this report.
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Route Effectiveness

BASELINE & 1.1 Fish Weir 300 cfs – all life stages

Chinook					Steelhead				
Q Ratio	Spill	Fish Pass	RO*	Turb	**Q Ratio**	Spill	Fish Pass	RO*	Turb
0.10	0.37	4.18	0.00	0.05	**0.10**	0.10	5.92	0.00	0.05
0.20	0.73	2.59	0.00	0.10	**0.20**	0.20	4.58	0.00	0.09
0.30	1.10	2.86	0.00	0.14	**0.30**	2.25	3.82	0.00	0.14
0.40	1.13	2.86	0.00	0.19	**0.40**	0.41	3.82	0.00	0.19
0.50	1.15	2.86	0.00	0.24	**0.50**	0.51	3.82	0.00	0.23
0.60	1.19	2.86	0.00	0.34	**0.60**	0.61	3.82	0.00	0.28
0.70	1.22	2.86	0.00	0.44	**0.70**	0.72	3.82	0.00	0.33
0.80	1.13	2.86	0.00	0.62	**0.80**	0.57	3.82	0.00	0.36
0.90	1.09	2.86	0.00	0.56	**0.90**	0.55	3.82	0.00	0.55
1.00	1.00	2.86	0.00	0.77	**1.00**	0.56	3.82	0.00	0.58

*****RO = Regulating Outlet. Foster Dam does not have any Regulating Outlets

1.2 & 1.4 Fish Weir 500 cfs – all life stages

Chinook					Steelhead				
Q Ratio	Spill	Fish Pass	RO	Turb	**Q Ratio**	Spill	Fish Pass	RO	Turb
0.10	0.37	6.00	0.00	0.05	**0.10**	0.10	6.00	0.00	0.05
0.20	0.73	6.00	0.00	0.10	**0.20**	0.20	6.00	0.00	0.09
0.30	1.10	6.00	0.00	0.14	**0.30**	0.31	6.00	0.00	0.14
0.40	1.13	6.00	0.00	0.19	**0.40**	0.41	6.00	0.00	0.19
0.50	1.15	6.00	0.00	0.24	**0.50**	0.51	6.00	0.00	0.23
0.60	1.19	6.00	0.00	0.34	**0.60**	0.61	6.00	0.00	0.28
0.70	1.22	6.00	0.00	0.44	**0.70**	0.72	6.00	0.00	0.33
0.80	1.13	6.00	0.00	0.62	**0.80**	0.57	6.00	0.00	0.36
0.90	1.09	6.00	0.00	0.56	**0.90**	0.55	6.00	0.00	0.55
1.00	1.00	6.00	0.00	0.77	**1.00**	0.56	6.00	0.00	0.58

*RO = Regulating Outlet. Foster Dam does not have any Regulating Outlets

1.3 & 1.5 Fish Weir 860cfs – all life stages

Chinook					Steelhead				
Q Ratio	Spill	Fish Pass	RO	Turb	**Q Ratio**	Spill	Fish Pass	RO*	Turb
0.10	0.37	7.00	0.00	0.05	**0.10**	0.10	7.00	0.00	0.05
0.20	0.73	7.00	0.00	0.10	**0.20**	0.20	7.00	0.00	0.09
0.30	1.10	7.00	0.00	0.14	**0.30**	0.31	7.00	0.00	0.14
0.40	1.13	7.00	0.00	0.19	**0.40**	0.41	7.00	0.00	0.19
0.50	1.15	7.00	0.00	0.24	**0.50**	0.51	7.00	0.00	0.23
0.60	1.19	7.00	0.00	0.34	**0.60**	0.61	7.00	0.00	0.28
0.70	1.22	7.00	0.00	0.44	**0.70**	0.72	7.00	0.00	0.33
0.80	1.13	7.00	0.00	0.62	**0.80**	0.57	7.00	0.00	0.36
0.90	1.09	7.00	0.00	0.56	**0.90**	0.55	7.00	0.00	0.55
1.00	1.00	7.00	0.00	0.77	**1.00**	0.56	7.00	0.00	0.58

*RO = Regulating Outlet. Foster Dam does not have any Regulating Outlets

2.1 & 2.2 Spill bay 4 (low & high pool) – all life stages

Chinook					Steelhead				
Q Ratio	Spill	Fish Pass	RO	Turb	**Q Ratio**	Spill	Fish Pass	RO*	Turb
0.10	0.37	0.00	0.00	0.05	**0.10**	0.10	0.00	0.00	0.05
0.20	0.73	0.00	0.00	0.10	**0.20**	0.20	0.00	0.00	0.09
0.30	1.10	0.00	0.00	0.14	**0.30**	0.31	0.00	0.00	0.14
0.40	1.13	0.00	0.00	0.19	**0.40**	0.41	0.00	0.00	0.19
0.50	1.15	0.00	0.00	0.24	**0.50**	0.51	0.00	0.00	0.23
0.60	1.19	0.00	0.00	0.34	**0.60**	0.61	0.00	0.00	0.28
0.70	1.22	0.00	0.00	0.44	**0.70**	0.72	0.00	0.00	0.33
0.80	1.13	0.00	0.00	0.62	**0.80**	0.57	0.00	0.00	0.36
0.90	1.09	0.00	0.00	0.56	**0.90**	0.55	0.00	0.00	0.55
1.00	1.00	0.00	0.00	0.77	**1.00**	0.56	0.00	0.00	0.58

*RO = Regulating Outlet. Foster Dam does not have any Regulating Outlets

4.1 Single Bypass (300cfs) – all life stages

Chinook					Steelhead				
Q Ratio	Spill	Fish Pass	RO	Turb	**Q Ratio**	Spill	Fish Pass	RO*	Turb
0.10	0.37	7.00	0.00	0.05	**0.10**	0.10	7.00	0.00	0.05
0.20	0.73	7.00	0.00	0.10	**0.20**	0.20	7.00	0.00	0.09
0.30	1.10	7.00	0.00	0.14	**0.30**	0.31	7.00	0.00	0.25
0.40	1.13	7.00	0.00	0.19	**0.40**	0.41	7.00	0.00	0.19
0.50	1.15	7.00	0.00	0.24	**0.50**	0.51	7.00	0.00	0.23
0.60	1.19	7.00	0.00	0.34	**0.60**	0.61	7.00	0.00	0.28
0.70	1.22	7.00	0.00	0.44	**0.70**	0.72	7.00	0.00	0.33
0.80	1.13	7.00	0.00	0.62	**0.80**	0.57	7.00	0.00	0.36
0.90	1.09	7.00	0.00	0.56	**0.90**	0.55	7.00	0.00	0.55
1.00	1.00	7.00	0.00	0.77	**1.00**	0.56	7.00	0.00	0.58

Rational: single bypass will only be located along one shoreline and operated at 300cfs. Only fish approaching from shoreline where bypass canal is located will use the canal, and therefore used 7.0, as compared to 8.0 for the double bypass.

*RO = Regulating Outlet. Foster Dam does not have any Regulating Outlets

3.1 Double Bypass (860 cfs) – all life stages

Chinook					Steelhead				
Q Ratio	Spill	Fish Pass	RO	Turb	**Q Ratio**	Spill	Fish Pass	RO*	Turb
0.10	0.37	8.00	0.00	0.05	**0.10**	0.10	8.00	0.00	0.05
0.20	0.73	8.00	0.00	0.10	**0.20**	0.20	8.00	0.00	0.09
0.30	1.10	8.00	0.00	0.14	**0.30**	0.31	8.00	0.00	0.14
0.40	1.13	8.00	0.00	0.19	**0.40**	0.41	8.00	0.00	0.19
0.50	1.15	8.00	0.00	0.24	**0.50**	0.51	8.00	0.00	0.23
0.60	1.19	8.00	0.00	0.34	**0.60**	0.61	8.00	0.00	0.28
0.70	1.22	8.00	0.00	0.44	**0.70**	0.72	8.00	0.00	0.33

Rational: double bypass will have canals along both shorelines and each operated at 430cfs (860cfs total). Fish approaching from either shoreline could encounter the bypass canals, and therefore used 8.0, as compared to 7.0 for the single bypass.

*RO = Regulating Outlet. Foster Dam does not have any Regulating Outlets

6.1 Turbine Screen – all life stages

Chinook					Steelhead				
Q Ratio	Spill	Fish Pass	RO	Turb	**Q Ratio**	Spill	Fish Pass	RO*	Turb
0.10	0.37	0.00	0.00	0.05	**0.10**	0.10	0.00	0.00	0.05
0.20	0.73	0.00	0.00	0.10	**0.20**	0.20	0.00	0.00	0.09
0.30	1.10	0.00	0.00	0.14	**0.30**	0.31	0.00	0.00	0.14
0.40	1.13	0.00	0.00	0.19	**0.40**	0.41	0.00	0.00	0.19
0.50	1.15	0.00	0.00	0.24	**0.50**	0.51	0.00	0.00	0.23
0.60	1.19	0.00	0.00	0.34	**0.60**	0.61	0.00	0.00	0.28
0.70	1.22	0.00	0.00	0.44	**0.70**	0.72	0.00	0.00	0.33
0.80	1.13	0.00	0.00	0.62	**0.80**	0.57	0.00	0.00	0.36
0.90	1.09	0.00	0.00	0.56	**0.90**	0.55	0.00	0.00	0.55
1.00	1.00	0.00	0.00	0.77	**1.00**	0.56	0.00	0.00	0.58

*RO = Regulating Outlet. Foster Dam does not have any Regulating Outlets

Information sources used to prepare *RE* assumptions:

ALTERNATIVE	Parameter SOURCE
ALL, except those listed separate in this table	Passage effectiveness data (proportions of radio-tagged juvenile Chinook and steelhead) by route, season, pool elevations from 2015 field study was provided by James Hughes, Pers. Comm., January 2016 emailed to Khan and Piaskowski. Raw data included in Appendix C3 to this report.
Weir 500	Professional judgment, Corps. Adjusted from PNNL RT study data, assuming improved route effectiveness of: Weir 500 - RE values of 6, all flows. Weir 860 - RE values of 7, all flows. Single bypass - RE values of 7, all flows. Double bypass - RE values of 8, all flows
Weir 860	
Single Bypass	
Double Bypass	

7. RESULTS

7.1. RES SIM RESULTS

The Willamette River Basin Res Sim model simulates the operations of the 13 USACE Willamette River Basin dams. The inputs to this model comes from a dataset of unregulated daily discharges from WY 1936 to 2009. The model computes various outputs on a daily time step. A statistical analysis was done on these daily outputs and is presented below. See Appendix B for more details on the results.

7.1.1. No Action Alternative (Baseline)

Figure 7-1 shows the Res Sim results of the No Action Alternative. This alternative is the baseline that all other alternatives are compared to. The top graph is the Foster Reservoir pool elevation and also includes the rule curve used in the simulation. The bottom graph is the inflow and discharge from Foster Reservoir. The discharge is shown for each outlet. The gray scale shows the non-exceedance values. For example, in the Elevation graph, the white area is the 5% non-exceedance area. 5% of the time or less, the pool will not exceed this elevation. In the Flow graph, the dark gray area is the 95% non-exceedance area. 95% of the time the total discharge from Foster Reservoir will not be above that area. The gray scale will be shown on each of the result graphs for comparison of the alternative to the baseline.

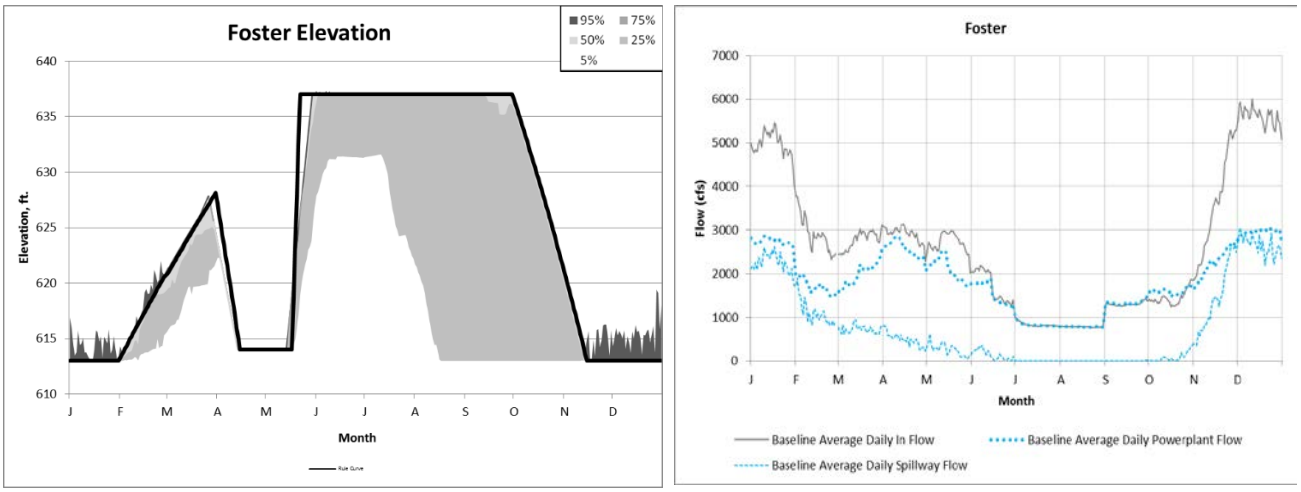


Figure 7-1 Res Sim Simulation Results for the No Action Alternative (Baseline)

7.1.2. **Alternative 1.1, Fish Weir 300 01 Oct – 15 May with use of powerhouse**

Figure 7-2 shows the Res Sim results of Alternative 1.1. This alternative only has a minor impact to the pool elevation. As can be seen in the discharge graph, the discharge from the powerhouse has decreased in this alternative.

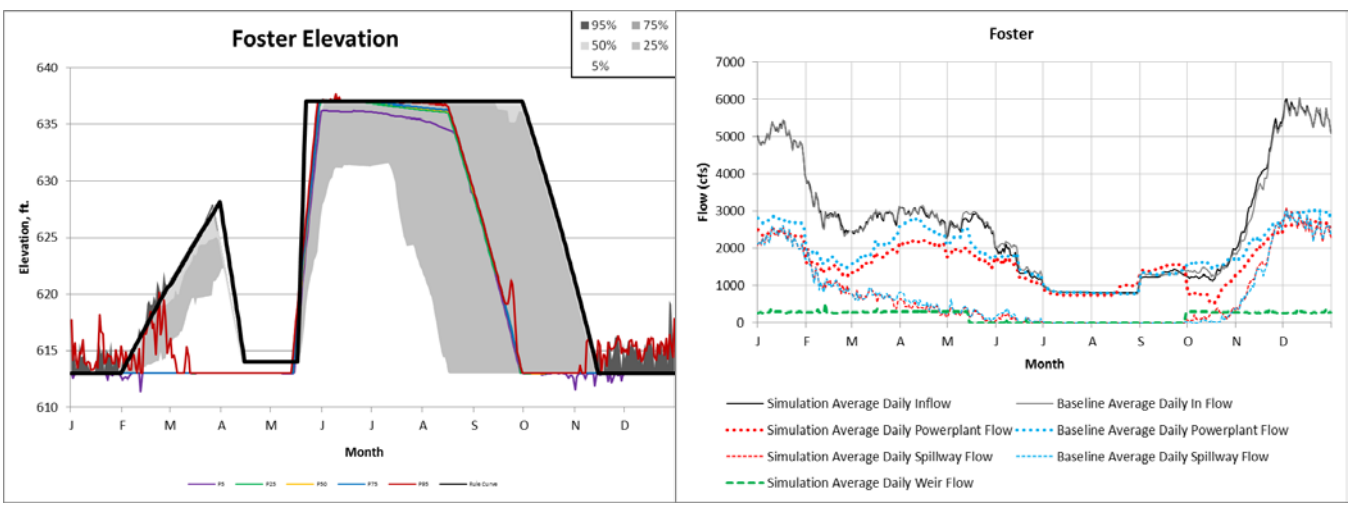


Figure 7-2 Res Sim Simulation Results for Alternative 1.1, Fish Weir 300 01 Oct – 15 May with use of powerhouse

7.1.3. **Alternative 1.2, Fish Weir 500 01 Oct – 15 May with use of powerhouse**

Figure 7-3 shows the Res Sim results of Alternative 1.2. This alternative only has a minor impact to the pool elevation; similar to Alternative 1.1. As can be seen in the discharge graph, the discharge from the powerhouse has decreased in this alternative.

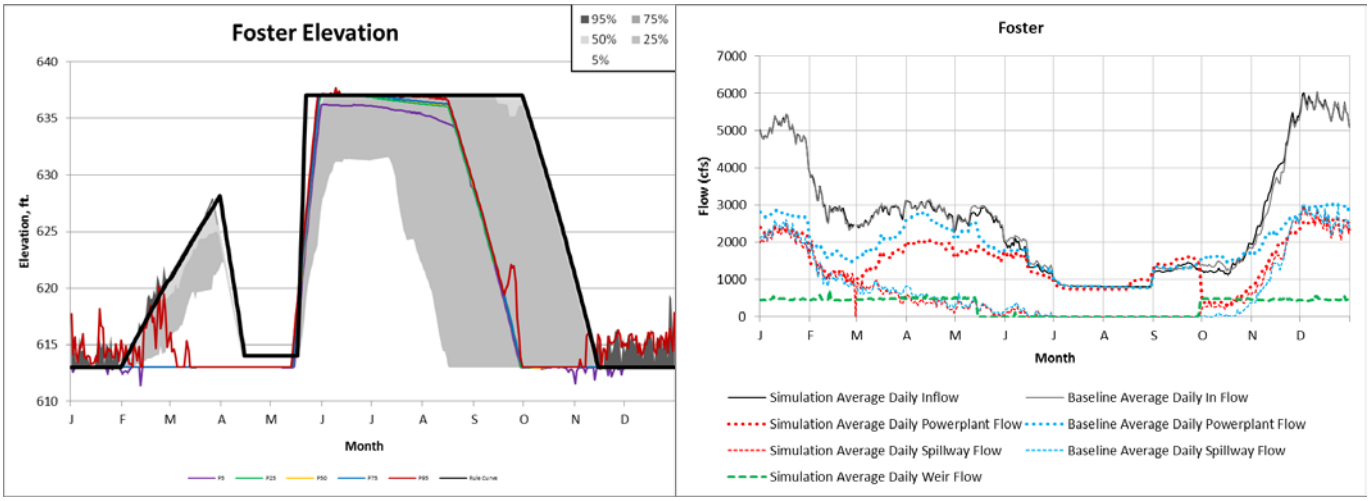


Figure 7-3. Res Sim Simulation Results for Alternative 1.2, Fish Weir 500 01 Oct – 15 May with use of powerhouse

7.1.4. Alternative 1.3, Fish Weir 860 01 Oct – 15 May with use of powerhouse

Figure 7-4 shows the Res Sim results of Alternative 1.3. This alternative only has a minor impact to the pool elevation; similar to Alternatives 1.1 and 1.2. The discharge from the powerhouse has decreased in this alternative, more than Alternatives 1.1 and 1.2.

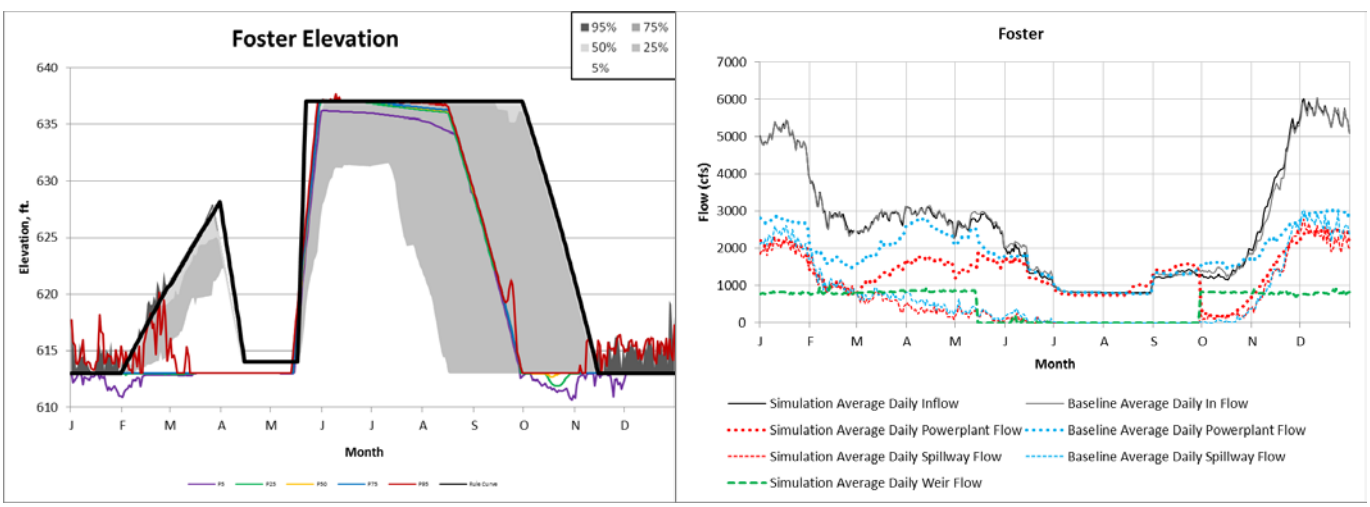


Figure 7-4. Res Sim Simulation Results for Alternative 1.3, Fish Weir 860 01 Oct – 15 May with use of powerhouse

7.1.5. Alternative 1.4, Fish Weir 500 Year Round with use of powerhouse

Figure 7-5 shows the Res Sim results of Alternative 1.4. This alternative only has a minor impact to the pool elevation. The discharge from the powerhouse has decreased in this alternative, similar to Alternative 1.3.

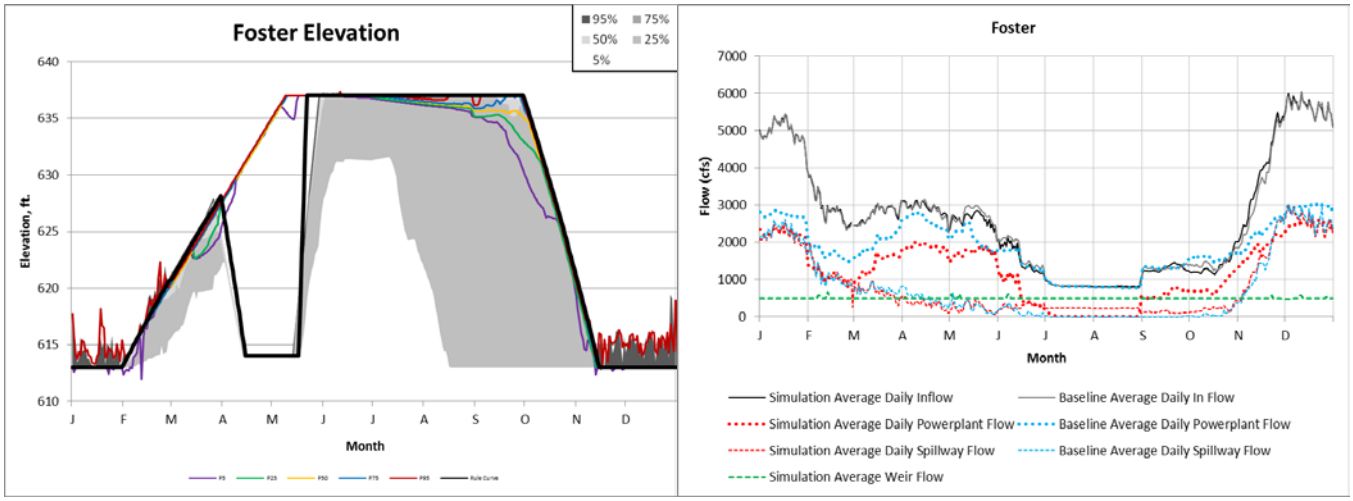


Figure 7-5. Res Sim Simulation Results for Alternative 1.4, Fish Weir 500 Year Round with use of powerhouse

7.1.6. Alternative 1.5, Fish Weir 860 Year Round with use of powerhouse

Figure 7-6 shows the Res Sim results of Alternative 1.5. This alternative has a major impact to the pool elevation. In the summer time, especially after July 01, the inflow into Green Peter Reservoir is well below the 940 cfs (860 cfs for the fish weir plus 80 cfs for the fish facility) being discharged from Foster Reservoir. The extra discharge lowers the pool elevation in both Green Peter and Foster Reservoirs. The discharge from the powerhouse has decreased in this alternative, similar to Alternative 1.3.

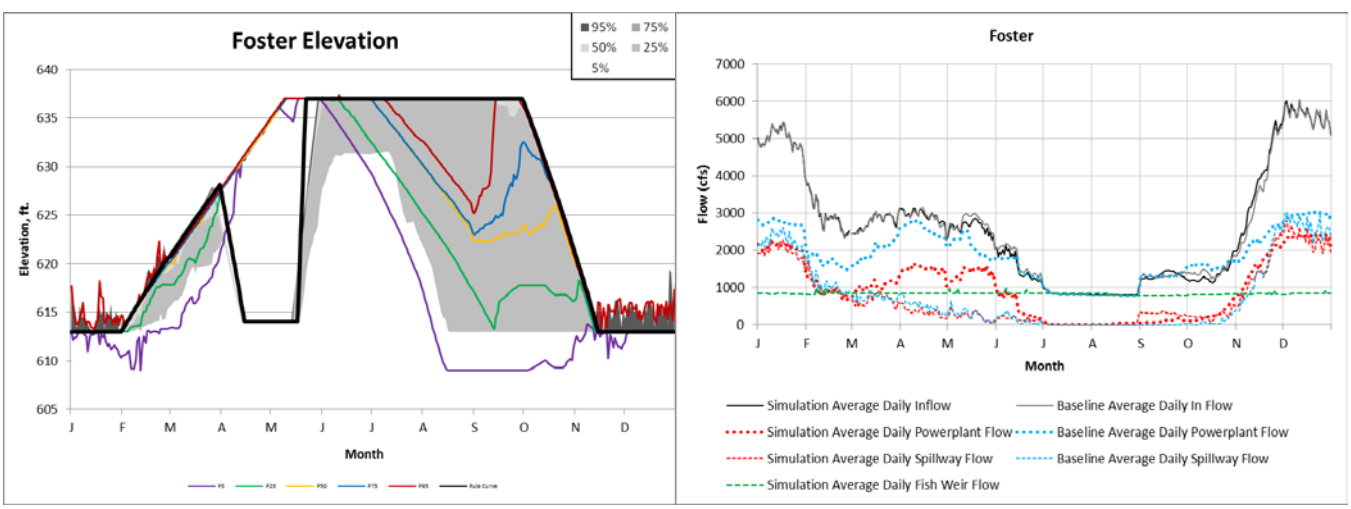


Figure 7-6. Res Sim Simulation Results for Alternative 1.5, Fish Weir 860 Year Round with use of powerhouse

7.1.7. **Alternative 2.1, Spillbay 4 Low Pool**

Figure 7-7 shows the Res Sim results of Alternative 2.1. This alternative has little impact to the pool elevation. The discharge from the powerhouse has decreased to almost zero during the time Spillbay 4 is used to pass fish.

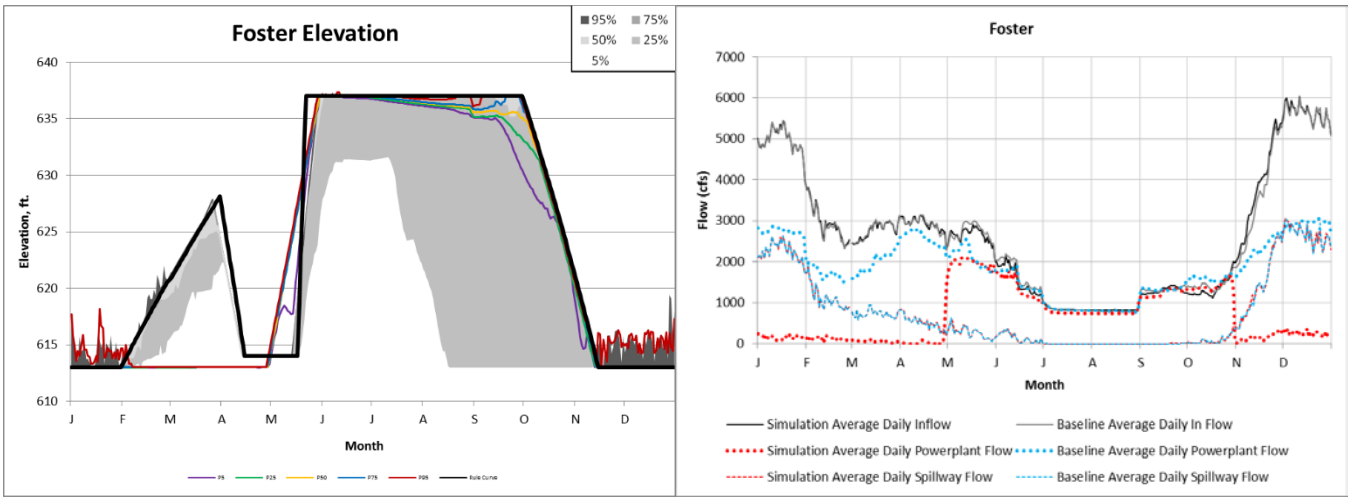


Figure 7-7. Res Sim Simulation Results for Alternative 2.1, Spillbay 4 Low Pool

7.1.8. **Alternative 2.2, Spillbay 4 High Pool**

Figure 7-8 shows the Res Sim results of Alternative 2.2. This alternative has a major impact to the pool elevation. The spillway gates have a minimum gate opening to avoid cavitation.
A minimum gate opening is required for spillway tainter gates to avoid conditions where vibrations (driven by flow conditions at small gate openings) could cause excessive wear and/or damage to the gate. During summer months when the pool is high, this minimum gate opening causes the outflow from Foster Reservoir to be greater than the inflow. This causes the pools in Foster and Green Peter Reservoirs to be much lower than the baseline (Green Peter Reservoir is releasing water to avoid draining Foster Reservoir). The discharge from the powerhouse has decreased to almost zero during the months the spillbay is used to pass fish.

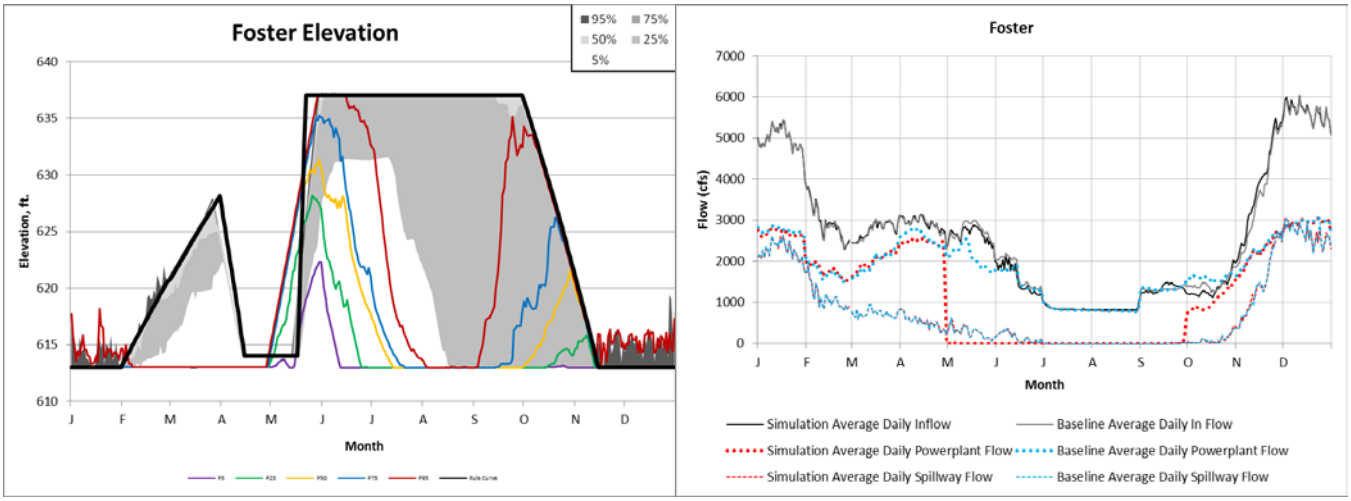


Figure 7-8. Res Sim Simulation Results for Alternative 2.2, Spillbay 4 High Pool

7.1.9. **Alternative 3, Double Bypass Canal**

Operationally, Alternative 3, Double Bypass Canal is very similar to Alternative 1.5, Fish Weir 860 Year Round with use of powerhouse. Because of this, Alternative 3 was not model using Res Sim. The Res Sim results from Alternative 1.5 were used for this alternative and can be found in Section 7.1.6.

7.1.10. **Alternative 4, Single Bypass Canal and New Fish Weir**

Figure 7-9 shows the Res Sim results of Alternative 4. This alternative has very little impact to the pool elevation. The discharge from the powerhouse is decreased somewhat throughout the year.

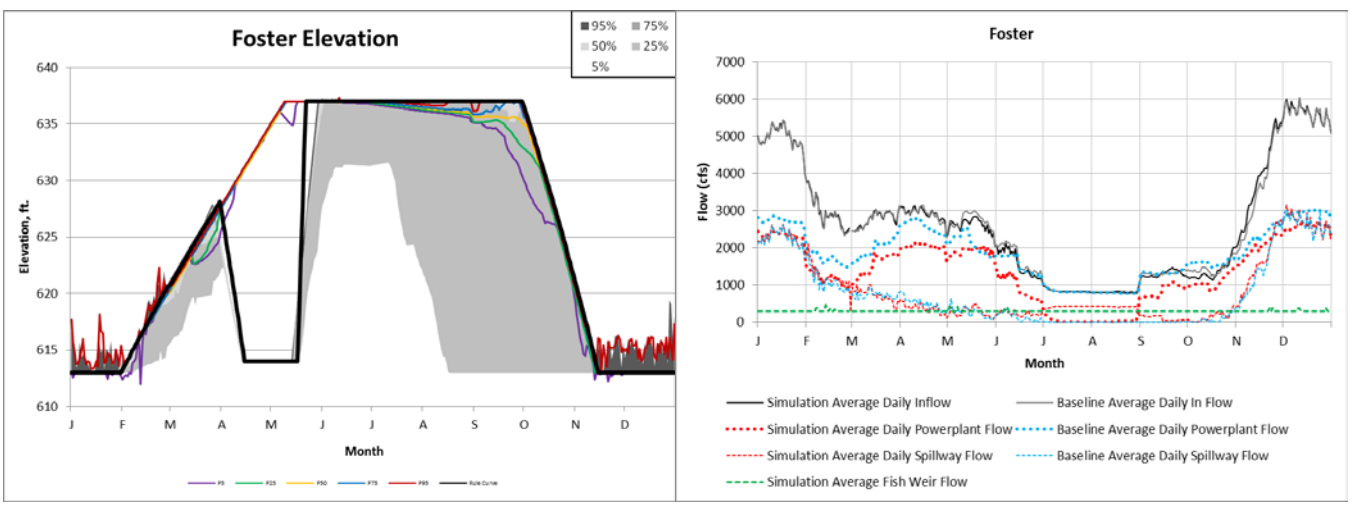


Figure 7-9. Res Sim Simulation Results for Alternative 4, Single Bypass Canal and New Fish Weir

7.1.11. **Alternative 6, Turbine Screens**

Operationally, Alternative 6, Turbine Screens is very similar to Alternative 4, Single Bypass Canal and New Fish Weir. Because of this, Alternative 6 was not model using Res Sim. The Res Sim results from Alternative 4 were used for this alternative and can be found in Section 7.1.10.

7.2. **BIOLOGICAL**

7.2.1. **Population Replacement Assessment**

As described in Section 4.3 (Key Criteria to Estimate Biological Benefits and Impacts), an analysis was conducted using output from SLAM to estimate whether or not a population could successfully replace itself under a range of fish passage alternatives. The SLAM output provided estimates of hatchery origin spawners and natural origin spawners for each year from 1-105 in the simulation. For the above dam population component, the replacement ratio was computed for each year using the current natural origin spawners (spawning adults) divided by the (natural origin + hatchery origin spawners) from 4 years prior (their parents). The 5-year running average was also computed to look at the replacement from the cohort perspective. To verify whether or not an alternative resulted in population replacement above a dam, multiple aspects were checked including:

- The average replacement ratio - above 90% (meets replacement) and above 85% (nearly meets replacement).
- The percent of time the 5-year running average was above 95% - more than 70% of the time (meets replacement) and more than 60% of the time (nearly meets replacement).

Table 7-1. Summary of Replacement Analysis for South Santiam Chinook salmon

Reach	SLAM Alternative	AVER	Count > 1	Median	Percent Time >1	Percent Time >.95	Ave of Running Ave	Replacement Status	FBW (overall) Estimated Survival
	FOS_Weir860	105%	68	104%	67%	84%	102%	Meets replacement criteria	73%
	FOS_FriendTurbine	105%	68	104%	67%	82%	102%	Meets replacement criteria	74%
	FOS_ContWeir	101%	49	99%	49%	64%	98%	Nearly meets replacement criteria	67%

Table 7-2. Summary of Replacement Analysis for South Santiam Steelhead

		AVER	Count > 1	Median	Percent Time >1	Percent Time >.95	Ave of Running Ave	Replacement Status	FBW (overall) Estimated Survival
Above FOS - Below GPR	Baseline	99%	52	100%	52%	82%	96%	Meets replacement criteria	49%
	FOS_ContWeir	101%	70	102%	70%	88%	98%	Meets replacement criteria	67%
	FOS_Weir860	102%	73	102%	72%	87%	99%	Meets replacement criteria	72%
	FOS_FriendTurbine	100%	58	101%	57%	88%	98%	Meets replacement criteria	55%
	FOS_Baseline	101%	59	101%	59%	86%	98%	Meets replacement criteria	67%

Results indicate that replacement was estimated for Chinook salmon at a FBW survival rate of 74%, and nearly met at a FBW survival rate of 67%. Therefore alternatives that do not achieve a downstream passage survival of at least 70% should not be carried forward for further analysis since they are unlikely to support population replacement for South Santiam spring Chinook salmon above Foster Dam.

For winter steelhead, results indicate that replacement was achieved at a FBW survival rate of 49%, under baseline conditions. However, there is less confidence in the model output for steelhead due to less empirical information available to parameterize the model at this time. Moreover, the abundance of winter steelhead adults returning to the South Santiam has declined in recent years. For these reasons, or until further analysis is completed, we believe a conservative approach should be taken; we assume a similar level of improvement is likely needed for steelhead as for Chinook salmon.

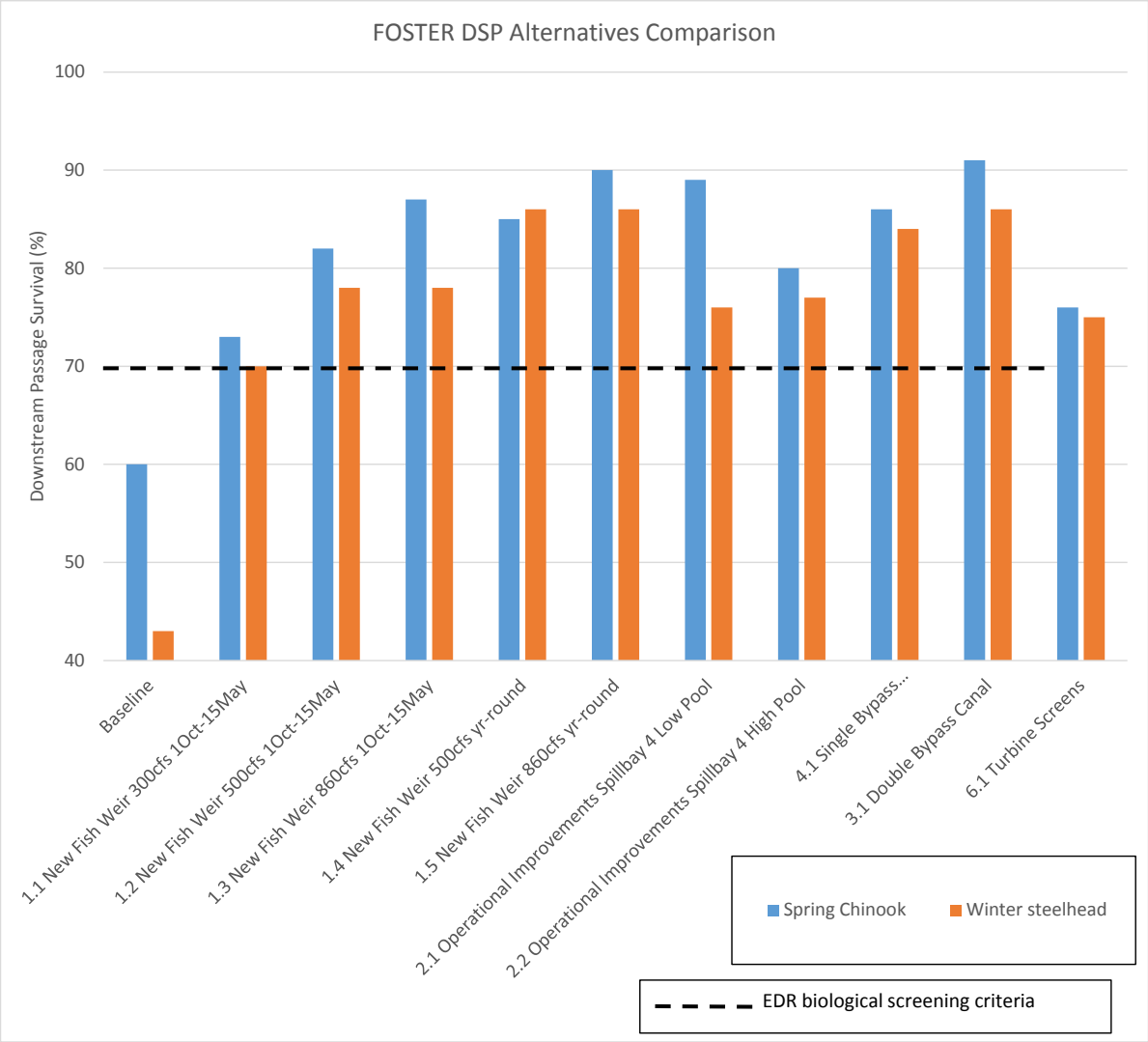
Therefore alternatives not achieving a downstream passage survival of at least 70% for both Chinook salmon and steelhead should not be carried forward for further analysis since they are unlikely to support population replacement for these populations South Santiam above Foster Dam.

7.2.2. **Downstream Passage Survival Estimates**

The population replacement analysis results indicated that baseline conditions (no action alternative) did not meet the biological alternative screening criteria for either spring Chinook salmon or winter steelhead (>70% downstream passage survival). However, all other alternatives met the replacement analysis alternative screening criteria, and therefore all the alternatives will be carried forward for further assessment considering costs, impacts and feasibility.

Downstream fish passage survival estimates from FBW ranged from about 70% to as high as 91% among the alternatives evaluated (Figure 7.10). Downstream passage survival estimates by life stage for each species are documented in Figures 7.11 and 7.12. The lowest benefit was estimated for alternative 1.1 (new fish weir operated at 300 cfs 1Oct to 15May). The highest estimated benefit (for both species) was similar across two alternatives, 1.5 (new fish weir operated at 860 cfs 1Oct to 15May) and 3.1 (Double bypass canal). Survival benefits among the alternatives, although similar among the two species, were consistently estimated higher for spring Chinook than for winter steelhead (except for alternative 1.4).

Figure 7.10. Comparison of estimated biological benefit of downstream passage alternatives for Foster Dam. Estimates were prepared using the Fish Benefit Workbook based on parameters documented in Section 6.8 (Downstream Fish Passage Assumptions Used in the Fish Benefit Workbook).


FOSTER DSP Alternatives Comparison
Downstream Passage Survival (%)
100
90
80
70
60
50
40
Baseline
1.1 New Fish Weir 300cfs 1Oct-15May
1.2 New Fish Weir 500cfs 1Oct-15May
1.3 New Fish Weir 860cfs 1Oct-15May
1.4 New Fish Weir 500cfs yr-round
1.5 New Fish Weir 860cfs yr-round
2.1 Operational Improvements Spillbay 4 Low Pool
2.2 Operational Improvements Spillbay 4 High Pool
4.1 Single Bypass...
3.1 Double Bypass Canal
6.1 Turbine Screens
Spring Chinook
Winter steelhead
EDR biological screening criteria

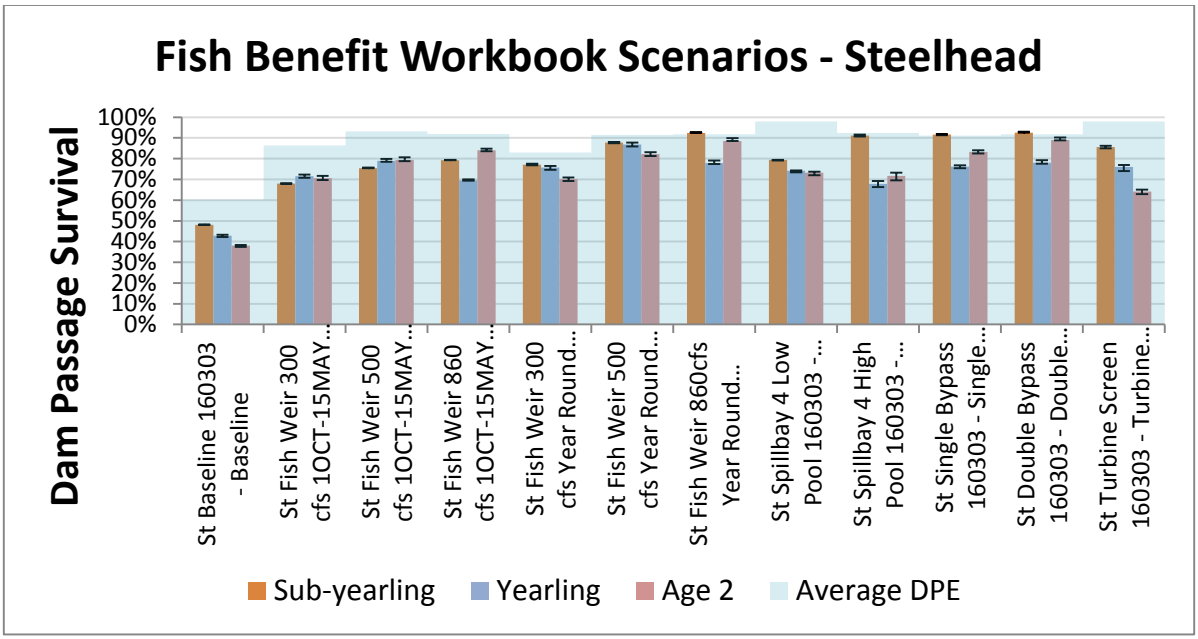


Figure 7-11 Downstream Fish Passage Survival Estimates: Steelhead

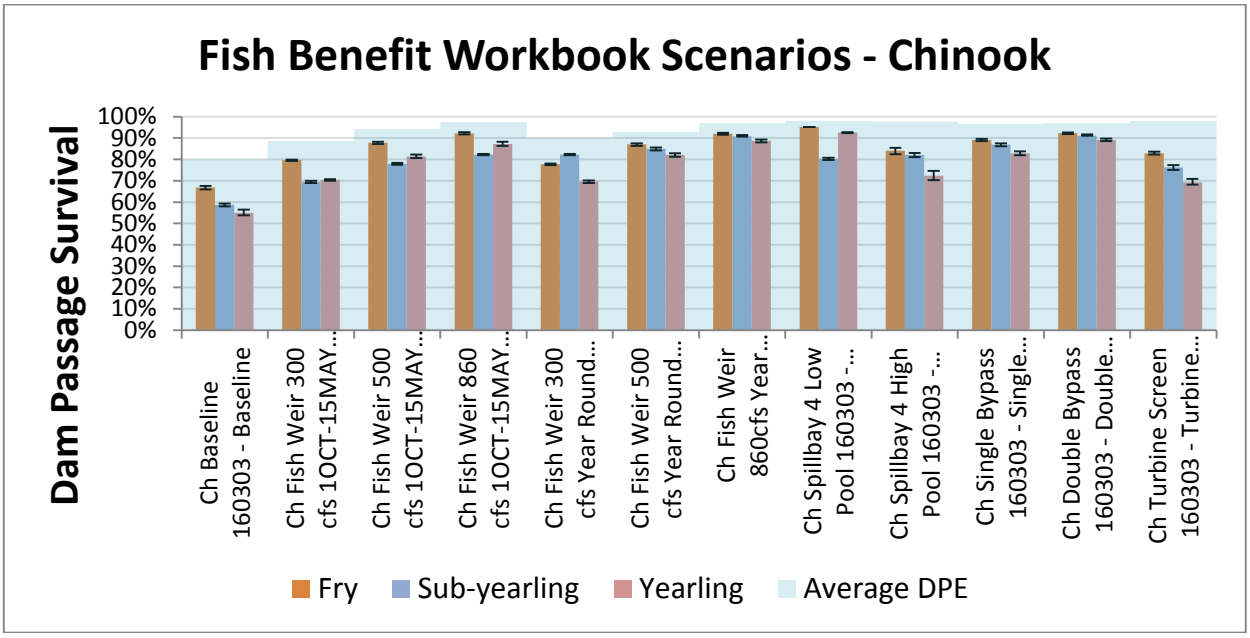


Figure 7-12 Downstream Fish Passage Survival Estimates: Chinook

7.3. CONSTRUCTION COSTS

7.3.1. Cost Methodology

Due to the level of design for the Foster downstream passage alternatives (approximately 5% level), these estimates fall into a Class 4 estimate: early concept designs, lacking detailed design and scope clarity resulting in major estimate assumptions in design and quantities, heavy reliance on cost engineering judgment, cost books, parametrics, and historical comparisons. Based on this, all costs were derived using corollary data from similar projects completed recently and scaled up or down to the projected design (size and cost). For the corollary cost data, recent projects in close geographic proximity with similar scope were used when possible to give the most reasonable similar costs. Those costs were then escalated to present time, present dollar values. Each of the projects and cost information used are presented below with the corresponding features.

7.3.2. New Fish Weir (Recommended Alternative 1.2)

The cost of a new fish weir is compared to the cost of spillway stoplogs. The new weir is estimated to weigh 16,700 pounds. At $6/pound the new weir would cost $100,000. The Portland District recently awarded a contract for bulkhead construction at $2.50/pound and another contract for intake gates at $7/pound. This alternative also includes a new truck and flatbed trailer. It is assumed that this equipment would be purchased with a separate supply contract. The truck is estimated to cost $150,000 and the trailer is estimated to cost $15,000. Including a 35.2% contingency and 3.8% escalation the total cost for supply contracts is estimated at $372,000.

Planning, engineering, and design is estimated to cost $504,000 including an 84.2% contingency and 4.9% escalation. Construction management is estimated to cost $28,000 including a 5% contingency and 7.4% escalation. The Total Project Cost is estimated at $904,000.

7.3.3. Operational Improvements

Operational improvements do not include any construction costs. This alternative is considered a low cost risk.

7.3.4. Single Bypass Canal

A single bypass canal is compared to the level of effort for a new upstream passage facility, which cost $20 to $40 million to design and construct. A single bypass would likely be more comparable to the lower end of this range. It could also be compared to the Bonneville Power House Two Juvenile Bypass System that was built in 1998 for $28.5 million ($47.9 million in 2016 dollars). The Bonneville JBS is about double the size of what would be required for Foster. This alternative is considered a high cost risk.

7.3.5. Double Bypass Canal

A double bypass canal is compared to the level of effort for a new upstream passage facility, which cost $20 to $40 million to design and construct. A double bypass would likely fall into the middle of this range. It could also be compared to the Bonneville Power House Two Juvenile Bypass System that was built in 1998 for $28.5 million ($47.9 million in 2016 dollars). The Bonneville JBS is about double the size of what would be required for Foster. This alternative is considered a high cost risk.

7.3.6. Turbine Exclusion Screens

Turbine exclusion screens would be challenging to install at Foster Dam. The estimate is based on professional judgment and is considered a high cost risk.

7.4. FEASIBILITY

All of the alternatives that were carried forward were determined to be technically feasible.

7.5. OTHER IMPACTS

7.5.1. Flood Risk Management

Flood risk management is one of the primary authorizations of the Willamette system. Potential changes to FRM could occur if potential alternatives to address the ESA modify project flows, modify the timing of flows, or require pool levels higher than a project's water control diagram. Thus, if results of reservoir modeling for a potential alternative showed a change from the benchmark operations that negatively impacted FRM, then that alternative was noted as having impacts to flood risk management.

Flood risk management analyses were conducted using the results of reservoir simulation modeling and regulation expertise. Measures were modeled using ResSim. The results of these model runs were compared to the results of the benchmark to identify changes to FRM operations. Within the ResSim model, downstream control point rules were in place specifying regulation goals for key gage locations called control points. The Willamette projects operated to meet FRM goals at these control points individually and as a system. Therefore, when one project was modified in an operational scenario, another project was adjusted to try to meet the specified control point goal. With other projects able to compensate partially for a change in one project's operation, the impact to flooding was assessed at the control point (i.e., was the system able to maintain flows at a control point below key thresholds). The FRM impact assessment procedure is shown below.

1. Compare the number of occurrences that a control point flow is above the regulation goal under the operational scenario to the Benchmark (see the Flood Damage Reduction Summary Tables in Appendix B for benchmark values).
    a. The ResSim period of record output will be post-processed to count the number of days the regulation goals is exceeded each year and statistics will be computed on these counts.
    b. Compare the 95% non-exceedance counts. The 95% non-exceedance was selected because it represents a relatively infrequent occurrence. The 95% non-exceedance count is the value, in number of days (or more) a year, that the control point flow does not exceeded the regulation goal for 5% of the years in the POR (4 years of the 73-year POR). These 4 years may have more days above the regulation goal than reported in the 95% non-exceedance count.
    c. The 95% non-exceedance should incorporate most of the large flow events. There may be occasion to use the 99% non-exceedance values.
2. If either the number of days a control point exceeded the flood stage under the alternative being simulated increase when compared to the Benchmark, then the alternative was noted as having flood risk management impacts.

7.5.1.1. **Flood Risk Management Impacts**

The impacts to flood risk management of each alternative are shown below in Table 7-1. Impacts are defined as an increase or decrease to the number of days above bankfull or flood stage when compared with the baseline. This information can be found in the Flood Damage Reduction Summary in Appendix B. Bankfull is when the river flow at the control point reaches the top of the bank but does not leave the channel. Flood stage is when the river flow at the control point exceeds the channel and impacts property.

Most alternatives increased the number of days a control point was at bankfull by one day. This is considered a minor impact, as defined in Section 7.5.1. Alternatives 2.1 and 2.2 increased the number of days a control point was above flood stage by one day. This is considered an impact to flood risk management, as defined in Section 7.5.1.

Table 7-2. Flood Risk Management Impacts

Alternative Number	Alternative Name	Changes to Days Above Flood Stage	Control Point of Change	Changes to Days Above Bankfull	Control Point of Change	Impact to Flood Risk Management?
1.1	New Fish Weir 300cfs 1Oct-15May	0 days	---	1 day	Willamette River near Goshen	No
1.2	New Fish Weir 500cfs 1Oct-15May	0 days	---	1 day	Willamette River near Goshen	No
1.3	New Fish Weir 860cfs 1Oct-15May	0 days	---	1 day	Willamette River near Goshen	No
1.4	New Fish Weir 500cfs Year Round	0 days	---	1 day	Willamette River near Goshen	No
1.5	New Fish Weir 860 cfs Year Round	-1 day	Willamette River at Albany	1 day	Willamette River near Goshen	No
2.1	Operational Improvements Spillbay 4 Low Pool	1 day	South Santiam River at Waterloo	1 day	Willamette River near Goshen	Yes
2.2	Operational Improvements Spillbay 4 High Pool	1 day	South Santiam River at Waterloo	1 day	Willamette River near Goshen	Yes
3	Single Bypass Canal	-1 day	Willamette River at Albany	1 day	Willamette River near Goshen	No
4	Double Bypass Canal	-1 day	Willamette River at Albany	1 day	Willamette River near Goshen	No

6	Turbine Exclusion Screens	-1 day	Willamette River at Albany	1 day	Willamette River near Goshen	No

7.5.2. **Hydropower**

To the extent power production in the Willamette Valley is already optimized as part of the federal power system, any change in operations at Foster resulting from the alternatives being evaluated in the study may entail non-optimal power production. If an alternative was found to reduce the value of hydropower production, then an estimate was made of the losses in monetary terms. Bonneville Power Administration (BPA) staff were responsible for making an estimate of these losses. The monetary loss estimate used the same underlying parameters and assumptions (discount rate, planning horizon, constant price levels) as the rest of the analysis. The cost to replace hydropower losses were present valued to a common point in time for each alternative. In this study, hydropower impacts were jointly estimated by the U.S. Army Corps of Engineers (Corps) and BPA.

Corps staff performed the Foster project operations simulations for each alternative and furnished the discharge and pool elevation data, formatted for BPA staff to simulate the hydropower generation. Table 7-3 lists the annual average monthly generation at Foster for each alternative.

Table 7-3 Monthly Generation for Alternatives

	FOS Downstream Passage-Alternatives-FOS Hydropower, aMW (extracted from BPA's OMET ALTERNATIVES.xls)															
Run Names (alternatives)	**Oct-15**	**Nov-15**	**Dec-15**	**Jan-16**	**Feb-15**	**Mar-16**	**Apr-16**	**Apr-16**	**May-16**	**Jun-16**	**Jul-16**	**Aug-16**	**Aug-16**	**Sep-16**	Annual	difference
hours per month	744	720	744	744	672	744	360	360	744	720	744	360	384	720		
Willamette IRRM - Base Case	12.247	15.425	19.479	18.014	11.726	14.342	18.986	16.151	15.589	12.712	7.014	6.699	6.589	11.192	13.502	---
FOS-Weir300-N-A	11.000	14.890	17.548	15.699	9.562	11.178	14.205	14.041	14.658	11.466	6.192	5.932	6.329	10.260	11.903	-1.599
FOS-Weir500-Nov-Apr	10.932	13.973	16.973	14.986	7.644	9.699	13.096	12.904	14.589	11.466	6.164	5.932	6.233	10.205	11.331	-2.172
FOS-Weir860-N-A	11.000	13.342	16.274	14.137	6.644	8.205	11.233	11.137	14.685	11.452	6.205	5.932	6.411	10.260	10.823	-2.679
FOS-Weir_300-01Oct-15May-withpower	5.397	13.082	17.712	15.904	9.836	11.370	14.370	14.068	13.726	11.479	6.233	5.932	7.959	10.603	11.380	-2.122
FOS-Weir_500-01Oct-15May-withpower	2.233	10.384	16.178	14.219	7.014	8.397	11.274	10.740	11.959	11.438	6.178	5.932	7.918	10.384	9.705	-3.797
FOS-Weir_860-01Oct-15May-withpower	1.959	10.274	15.945	13.904	6.712	8.151	11.082	10.521	11.767	11.425	6.164	5.932	7.918	10.288	9.539	-3.963
FOS-300-all-year-wcm	11.055	14.986	17.562	15.712	9.178	11.685	15.795	16.178	17.863	11.630	6.205	5.932	6.384	10.219	12.371	-1.132
FOS-500weir-allyear	6.356	12.712	16.630	14.836	7.507	10.438	14.836	14.795	14.260	5.753	0.192	0.041	0.219	5.096	9.068	-4.435
FOS-860allyear	2.082	10.795	15.795	13.808	6.521	7.616	11.918	11.836	11.384	4.192	0.082	0.027	0.233	0.685	7.087	-6.415
FOS-300Weir-NoPower	10.548	0.027	0.068	0.000	0.027	0.000	0.000	1.205	14.671	11.466	6.205	5.932	6.356	10.260	5.037	-8.466
FOS-Weir500-NoPower	10.534	0.027	0.068	0.000	0.027	0.000	0.000	1.205	14.685	11.466	6.219	5.932	6.397	10.274	5.041	-8.462
FOS-Weir860-NoPower	10.507	0.055	0.068	0.000	0.027	0.000	0.000	1.205	14.658	11.452	6.205	5.932	6.356	10.247	5.032	-8.470
FOS300-allyear-nopower	0.000	0.000	0.000	0.000	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	-13.501
FOS-500-allyear-nopower	0.000	0.000	0.000	0.000	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	-13.501
FOS-new860-allyear-nopower	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-13.502
FOS_Spillbay4	10.425	1.055	1.685	1.014	0.890	0.315	0.137	1.000	14.808	11.562	6.219	5.932	6.466	10.164	5.442	-8.061
FOS-bay4-low-nopower	10.274	0.397	0.137	0.411	1.110	0.849	0.137	1.233	14.425	11.425	6.219	5.932	6.466	10.178	5.221	-8.281
FOS_Spillbay_HighPool_12-21-15	7.370	15.233	19.534	17.685	11.781	13.438	16.397	14.973	0.027	0.014	0.000	0.000	0.000	0.205	8.394	-5.109
FOS-spillbay4-high-nopower	7.370	15.192	19.493	17.685	11.753	13.397	16.384	14.973	0.000	0.014	0.000	0.000	0.000	0.205	8.378	-5.124

BPA staff provided information and data that is the basis for developing long-term monetary value of hydropower. The "levelized" monthly energy prices of hydropower production for Foster hydropower plant over a 50-year planning horizon is described in Chapter 4 of Appendix B – Hydropower Impacts and listed in Table 7-4.

Table 7-4 "Levelized" Monthly Energy Prices (2015 dollars)

Month	"Levelized" Energy Price ($2015)
Jan	$25.03
Feb	$24.85
Mar	$21.36
Apr	$20.08
May	$16.97
Jun	$17.45
Jul	$17.45
Aug	$26.27
Sep	$26.57
Oct	$23.24
Nov	$23.35
Dec	$25.14

The average annual replacement cost of hydropower at Foster for the operational and structure alternatives considered were calculated by applying the "levelized" monthly energy prices to the monthly generation for the alternatives evaluated. The net benefit for each alternative is the difference between the alternative generation and the generation of the Willamette IRRM – Base Case. The net present value of the annual net-benefits has also been computed. The hydropower impacts are summarized as the monetary net present value of the annual net benefits in Table 7-5.

Table 7-5 Summary of Hydropower Impacts

Run Names (alternatives)	Annual Generation	Net Generation	Annual Energy	Annual Energy Net-Benefits	Present Value
	aMW	aMW	$	$	$
Willamette IRRM - Base Case	13.502	---	$2,639,964.78	---	---
FOS-Weir300-N-A	11.903	-1.599	$2,328,169.57	-$311,795	-$7,835,437.58
FOS-Weir500-Nov-Apr	11.331	-2.172	$2,212,522.03	-$427,443	$10,741,668.95
FOS-Weir860-N-A	10.823	-2.679	$2,111,978.55	-$527,986	-$13,268,334.25
FOS-Weir_300-01Oct-15May-withpower	11.380	-2.122	$2,228,763.58	-$411,201	-$10,333,517.66
FOS-Weir_500-01Oct-15May-withpower	9.705	-3.797	$1,899,676.82	-$740,288	-$18,603,492.94
FOS-Weir_860-01Oct-15May-withpower	9.539	-3.963	$1,866,348.15	-$773,617	-$19,441,045.14
FOS-300-all-year-wcm	12.371	-1.132	$2,402,299.21	-$237,666	-$5,972,553.90
FOS-500weir-allyear	9.068	-4.435	$1,771,197.99	-$868,767	-$21,832,175.86
FOS-860allyear	7.087	-6.415	$1,384,793.43	-$1,255,171	-$31,542,552.00
FOS-300Weir-NoPower	5.037	-8.466	$919,528.86	-$1,720,436	-$43,234,686.37
FOS-Weir500-NoPower	5.041	-8.462	$920,319.33	-$1,719,645	-$43,214,821.74
FOS-Weir860-NoPower	5.032	-8.470	$918,671.84	-$1,721,293	-$43,256,223.31
FOS300-allyear-nopower	0.001	-13.501	$228.75	-$2,639,736	-$66,336,768.48
FOS-500-allyear-nopower	0.001	-13.501	$228.75	-$2,639,736	-$66,336,768.48
FOS-new860-allyear-nopower	0.000	-13.502	$0.00	-$2,639,965	-$66,342,516.88
FOS_Spillbay4	5.442	-8.061	$1,005,085.11	-$1,634,880	-$41,084,651.16
FOS-bay4-low-nopower	5.221	-8.281	$958,780.07	-$1,681,185	-$42,248,300.27
FOS_Spillbay_HighPool_12-21-15	8.394	-5.109	$1,719,680.28	-$920,285	-$23,126,819.98

FOS-spillbay4-high-nopower	8.378	-5.124	$1,716,665.51	-$923,299	-$23,202,581.32

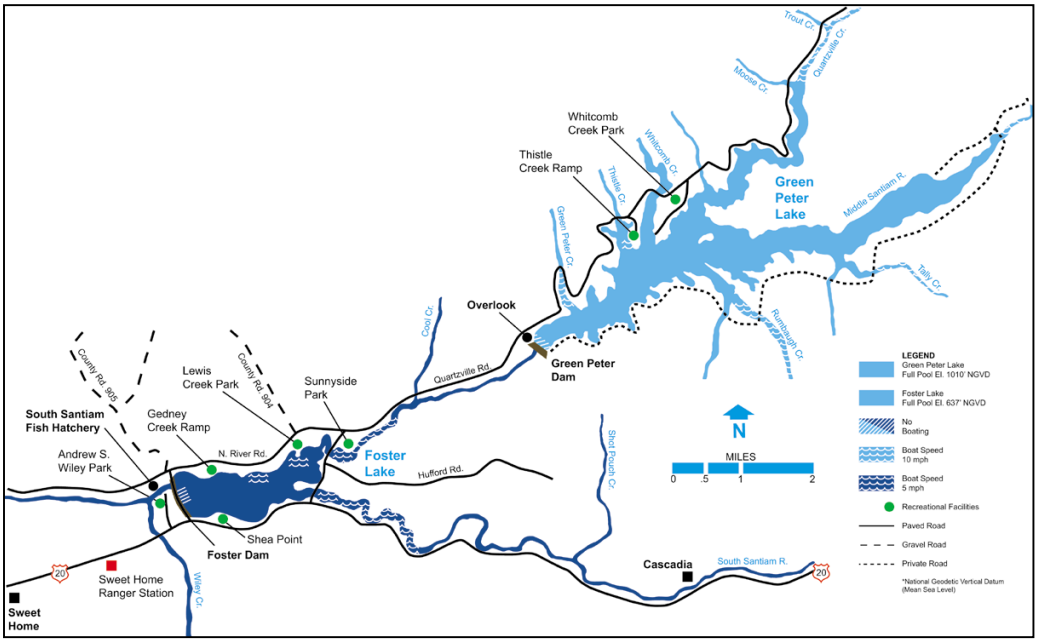
Table 7-5 summarizes the lost hydropower associated with each alternative. Impacts range from $6 million to $66 million.

7.5.3. **Recreation**

Foster Lake is relatively small at 3.5 miles in length with 1220 acres when full. It is located 3 miles east of Sweet Home (population 8925 in 2010) in the foothills of the Cascades and is 21 miles from I-5. It rests at the urban-rural interface. This lake has high level of development with the dam, highways and roads, and developed public and private facilities.

The lake is a popular summer recreation site averaging nearly 500,000 project visits over the last 10 years. The Oregon State Marine Board (OSMB) 2008 survey ranked Foster 17th overall in terms of boat-use days (28,000). Most of the visitation occurs in the summer when camping and day use parks are open but boat ramp access is available year-round. This is one of the Willamette projects where visitors can confidently expect to enjoy a full or nearly full reservoir for the whole summer. Camping, water skiing, fishing and jet skiing are just a few of activities that make it a popular Willamette Valley site. Camping is mostly oriented to recreational vehicles. The ODFW actively stocks the lake with legal trout from March to September. Because of the high level of visitor use (in summer weekends especially), the degree of recreation diversity, ready access to safety, security, comfort and convenience, and the lack of remoteness, this recreation area would probably be categorized as a suburban recreation experience.

Foster and Green Peter Recreation Area



Private facilities include the Edgewater RV Resort and Marina with a 49 space RV park and marina with boat and slip rentals. The development also includes the Edgewater at Foster condominiums. There is also a private day-use area at Shea Point with a view point, toilets, and paved shoreline trail.

In FY 2010, Foster had a total of 575,000 project visits. This estimate is based on eight annual or seasonal vehicle counters at various locations, plus an estimate for "reservoir general." It appears that the counters capture a large share of Foster visitation. The Linn County Sunnyside Park accounted for 145,000 of the tally and Shea Point about 102,000. The total includes the South Santiam Fish Hatchery (57,000) which is divorced from the reservoir. According to the Corps operations report, *Willamette Basin Year in Review, Water Year 2010*, "Foster was operated for downstream fish passage from April 15 to May 15, [and] then was filled to provide lake recreation opportunities from late May through September." Table below represents Corps estimates for Foster for FY 2010.

Table 7-6 Foster Visitation Estimate, FY2010

Area Name/Location	Type	Project Visits
Lewis Creek	CS	64,291
Andrew S. Wiley Park	C	70,371
S. Santiam Fish Hatchery	C	56,875
Shea Point	C	101,801
Gedney Creek	C	25,149
Sunnyside Park	CS	144,556
Lake Shore Park	C	17,168
Calkins Park	C	50,916
Reservoir General	E	43,028
Total		574,155

CS= Counter seasonal, C=Counter, E= Estimate

A recreation impact assessment was conducted for each Willamette project as part of the Configuration Operation Planning (COP) study effort to determine how measures are likely to affect recreation visitation and use. Refer to that report for analysis details. The recreation analysis focused on describing the recreational opportunities at the affected reservoirs, collecting the best available information on current and past recreation demand (visitation) at these lakes, and assessing the impact of operational alternatives on recreation facilities, principally boat ramps. A determination of the level of impacts was based on the following evaluation criteria and conversion standards to define the level of recreation impact.

Table 7-7 Evaluation Criteria and Standards

Factor and Standard	Index Value	Comments
Additional days pool is below ramp toe		
Less than -30	-3	
-30 to -16	-2	
-15 to -5	-1	
Between -5 and 5	0	Applies to cases where additional out-of-service days occur when facility is normally closed by management.
5 to 15	1	
16 to 30	2	
>30	3	
Annual visitation		Based on OMBIL/state data where applicable for fiscal year (FY) 2010
<100,000	1	HCK, LOP, CGR
100,000 to 300,000	2	GPR, FAL
>300,000	3	DET, FOS
Seasons of Impacts		
Winter	1	
Spring	2	
Summer	3	
Fall	1	

Key: HCK = Hills Creek, LOP = Lookout Point, CGR = Cougar, GPR = Green Peter, FAL = Fall Creek, DET = Detroit, FOS = Foster

Table 7-8 Reservoir Recreation Conversion Standards—Level of Recreation Impact

Index of Recreation Impact	COP Matrix Score	Description
-27 to- 18	5	High positive impact
-17 to -6	4	Moderate positive impact
-5 to 5	3	Low impact
6 to 17	2	Moderate negative impact
18 to 27	1	High negative impact

The COP study evaluated an extended operation and modified operation of a fish weir and determined recreation impacts would be minor or be limited to one of the three boat ramps and acceptable level of impacts based on their criteria.

In the current evaluation of Foster downstream fish passage analysis, there are more alternatives under consideration. The following table summarizes how each alternative would likely impact recreational boat ramp access. Based on this data, the potential impacts to recreation are high with the new fish weir with 860 cfs or the operational improvement at high pool alternative. Recreation impacts would need to be addressed if either of these two alternatives were selected. This recreation impacts information is included with the other evaluation criteria summarized in Table 7X.

Table 7-9 Number of Days Boat Ramp is Not Available Annually May through October, Compared to Current Operations (a negative number indicates more days boat ramp available)

	Number of Days Boat Ramp is Not Available Annually May through October, Compared to Current Operations (a negative number indicates more days boat ramp available)

Boat Ramp Locations	**New Fish Weir 300cfs Oct-May**	**New Fish Weir 500cfs Oct-May**	**New Fish Weir 860cfs Oct-May**	**New Fish Weir 500cfs Year Round**	**New Fish Weir 860cfs Year Round**	**Double Bypass Canel**	**Operational Improvements, Spillbay 4, Low Pool**	**Operational Improvements, Spillbay 4, High Pool**	**Single Bypass Canel**	**Turbine Exclusion Screens**
Calkins Boat Ramp, 631 ft	45	45	139	-25	51	51	-3	135	25	25
Gedney Boat Ramp, 619 ft	42	42	167	-17	-17	-17	-11	108	17	17
Sunnyside Boat Ramp, 613 ft	0	0	161	0	0	0	0	11	0	0
Overall Boat Ramp Impacts:	**Moderate Negative Impacts**	**Moderate Negative Impacts**	**High Negative Impacts**	**Positive Impacts**	**Mixed Impacts**	**Mixed Impacts**	**Positive Impacts**	**High Negative Impacts**	**Moderate Negative Impacts**	**Moderate Negative Impacts**

7.5.4. Stakeholder Impact

Previous studies and ongoing regional stakeholder involvement and discussions indicate the proposed actions would not negatively impact stakeholders.

7.6. ALTERNATIVES COMPARISON

Biological benefits, costs and impacts of each alternative are summarized in Table 7.X. The cost-effectiveness was calculated as project lifecycle cost over change in average downstream passage survival. Results are shown, along with the top three alternatives based on cost-effectiveness and minimizing impacts to other uses.

Three different versions of a new fish weir were determined to be the most cost-effective alternatives among those evaluated (Alternatives 1.1, 1.2, and 1.4). Cost effectiveness was lowest (best case) for Alternative 1.1, however biological benefits was at or just above the minimum screening threshold of 70% downstream passage survival, whereas biological benefits were 8 to 16% above the minimum screening threshold for Alternatives 1.2 and 1.4. Therefore, Alternatives 1.2 and 1.4 are preferred above 1.1 to ensure adequate biological benefit. Cost effectiveness of Alternatives 1.2 and 1.4 was determined to be the same, however impacts for these two alternatives were different. Hydropower impacts were estimated higher, and recreational impacts lower, for Alternative 1.4 than 1.2, respectively. Alternative 1.3 was eliminated due to significant impacts to recreation. All other alternatives maintained a boat ramp throughout the season.

It appears feasible to achieve the assumed downstream passage conditions for the new fish weir given that the data indicates most juvenile steelhead passing the dam under current conditions do so via the existing weir, and we expect the fish passage rate should increase for both species with a higher weir flow rate and longer seasonal operational period (covering when most juvenile Chinook and steelhead are expected to pass). Certainty decreases somewhat with estimated benefits among alternatives 1.1, 1.2 and 1.4, respectively.

TABLE 7.10: Comparison of estimated biological benefit and cost of downstream passage alternatives for Foster Dam. The three alternatives ranked as most cost effective are highlighted in gray.

Alternative Name		**Biological Benefits** (downstream passage % survival)		**Quantified (Costs)**				**Cost Effectiveness**	**Other Impacts**		
		Spring Chinook	Winter steelhead	Project First Costs (Total CRFM) ($ MIL)	Additional O&M (PV) ($ MIL)	Lost Hydropower (PV)($ MIL)	Total Life Cycle (Project First Costs + (PV) O&M + (PV) Lost Hydropower) in $ MIL	Alternative Cost (First, O&M, Lost Hydro)/Net Change in %Downstream Passage of Spring Chinook and Winter steelhead*	Flood Risk Management Impact & Dam Safety maintained(Y/N)	Recreation Impacts (High, Moderate, Mixed, Positive)	Projected Negative Stakeholder Impact
	Baseline	60	43								
1.1	New Fish Weir 300cfs 1Oct-15May	73	70	$2 M	$500 k	$10.3 M	$12.8 M	0.64	N	Mod	N
1.2	New Fish Weir 500cfs 1Oct-15May	82	78	$2 M	$500 k	$18.6 M	$21.1 M	0.74	N	Mod	N
1.3	New Fish Weir 860cfs 1Oct-15May	87	78	$2 M	$500 k	$19.4 M	$21.9 M	0.71	N	High	N
1.4	New Fish Weir 500cfs yr-round	85	86	$2 M	$500 k	$21.8 M	$24.3 M	0.71	N	Pos	N
1.5	New Fish Weir 860cfs yr-round	90	86	$2 M	$500 k	$31.5 M	$34 M	0.93	N	Mix	N
2.1	Operational Improvements Spillbay 4 Low Pool	89	76	$0	$500 k	$42.2 M	$42.7 M	1.38	Y	Pos	N
2.2	Operational Improvements Spillbay 4 High Pool	80	77	$0	$500 k	$23.1 M	$23.6 M	0.87	Y	High	N
4.1	Single Bypass Canal	86	84	$20 M	$2 M	$6.0 M	$28 M	0.84	N	Mod	N
3.1	Double Bypass Canal	91	86	$30 M	$2 M	$31.5 M	$63.5 M	1.72	N	Mix	N

6.1	Turbine Exclusion Screens	76	75	$45 M	$1 M	$0.14 M	$46.1 M	0.64	N	Mod	N

*Alternative Cost = (First Cost, O&M, Lost Hydropower) divided by (averaged percent survival increase for chinook and Steelhead). Example Option 1.1 (12.8M/20 = 0.64)

8. CONCLUSIONS AND RECOMMENDATIONS

The PDT recommends Alternative 1.2, a new fish weir operated with flows of 500 cfs between October 1 and May 15 annually, as the alternative for improving downstream fish passage at Foster Dam. Alternative 1.2 is expected to effectively improve attraction, passage, and survival of downstream migrating, surface oriented, juvenile Chinook salmon and steelhead compared to baseline conditions, as well as limiting impacts to other missions of Foster Dam (flood risk reduction, hydropower, and recreation). The higher flow capacity and longer seasonal operation of the new weir will provide passage opportunity during a period when most juvenile Chinook salmon and steelhead are migrating downstream. Additionally, this alternative will benefit downstream migrating steelhead kelts (adult steelhead returning to the ocean) because these fish are surface oriented and out-migrate during spring months.

Given the inherent uncertainty in the benefits that will be achieved, and operational flexibility required to manage real time hydrologic conditions, it is recommended that a final design of the fish weir have the capability to operate across a range of flows from 300 cfs to 860 cfs or more, and be capable of operations at any and all months of the year. Operational alternatives using the spillway could be further considered in the future if performance of a new fish weir alone is determined insufficient after implementation and evaluation.

Post construction fish passage and survival studies will be conducted to assess the efficiency and effectiveness of the new fish weir at improving downstream fish passage. The post construction studies will also inform operations of the fish weir, for example, the weir may only have to be operated during some hours of the day. PNNL (Hughes et al 2016) found most juvenile Chinook salmon and steelhead passed the dam during night time hours. Furthermore, the post construction studies will verify that the flows at the weir are adequate for attracting, entraining, and passing fish. The structural design of the recommended alternative (Alternative 1.2) will not change, however, the operational alternatives could change after post construction studies. The post construction studies will inform a variety of operational alternatives of the new fish weir, which will then be vetted before selecting one or more operational alternatives for the fish weir. If during the testing phase it is determined that more than 500 cfs is needed, a reevaluation will be required because of the potential impacts to recreation and hydropower.

Surface flow outlets, such as top spill weirs (TSWs) is the preferred route at a dam for providing downstream passage of juvenile and adult fish (Johnson and Dauble 2006; Sweeney et al. 2007). The Corps installed TSWs at hydropower dams on the Snake and Columbia rivers in recent years. Fish passage studies indicate the TSWs were successful at improving fish passage at the dams; increasing passage at the surface route and reducing passage at the turbines (Ham et al 2015; Weiland et al 2011; Colotelo et al 2014; and Harnish et al 2014). At John Day Dam, Weiland et al (2011) found the proportion of fish passing the turbines were approximately 50% lower at the turbines after installation and operation of a TSW in one of the spill bays. The TSW at McNary Dam decreased juvenile and adult (steelhead kelts) fish passage though the turbines and improved

total downstream passage (a higher proportion of fish used the surface outlet) (Ham et al 2015). Colotelo et al (2014) and Harnish et al (2014) found the TSWs operated at Little Goose and Lower Monumental dams improved downstream fish passage and less fish passed through the turbines at these dams. Therefore, the Foster Downstream Passage PDT concludes a new fish weir (Alternative 1.2 above) will decrease fish passage at the turbines and improve overall downstream juvenile and adult fish passage at Foster Dam.

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