

Baker County  
Mason Dam Hydroelectric Project

---

Fish Screening Exemption Proposal

October 2013

## Introduction:

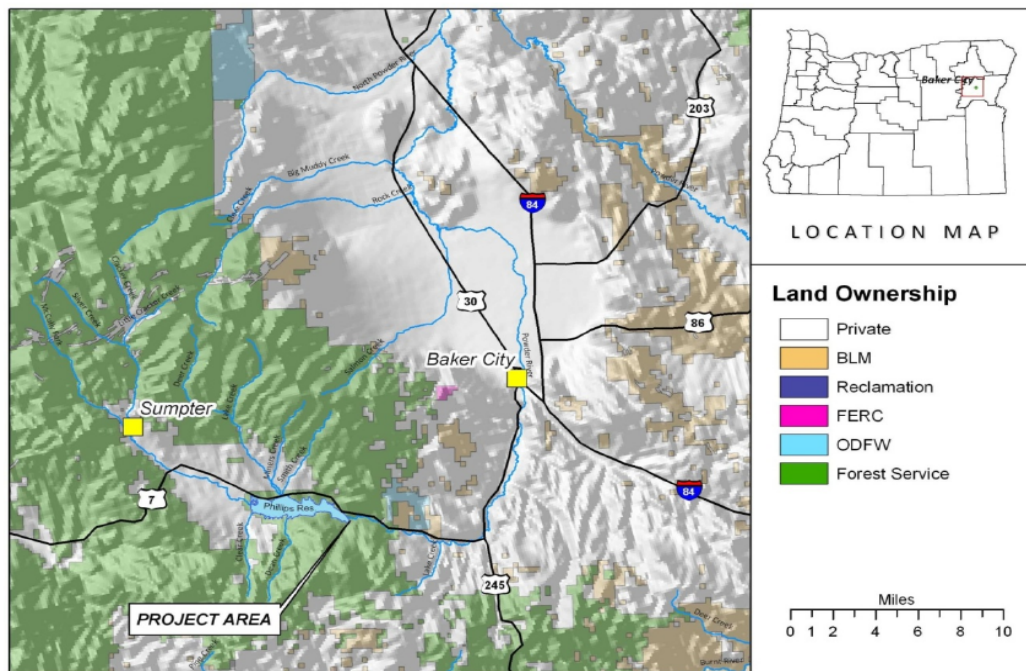
Baker County is seeking an exemption from screening for the existing Mason Dam in the following proposal. On April 30, 2013 Baker County filed an application with the Federal Energy Regulatory Commission (FERC) for a new hydroelectric license at the existing Bureau of Reclamation (BOR) Mason Dam. Because of the addition of the hydroelectric project this triggers Oregon Revised Statute (ORS) 498.301 through 351 screening criteria. The following proposal provides background describing the project, a summary of the project impacts from the Entrainment and Mortality report, Baker County’s proposed mitigation and an explanation of how those measures will provide resource protection.

## Background:

### *Existing Project*

Mason Dam is located in Baker County, Oregon approximately 11 miles southwest of Baker City on State Highway 7(Figure1). Mason Dam was built by the BOR on the Powder River for irrigation, water delivery and flood control. Mason Dam was constructed from 1965 – 1968 and has a total height of 173 feet and a maximum hydraulic height of 157 feet. Phillips Reservoir is a 2,234 acre-reservoir that was formed by the construction of Mason Dam. The reservoir has a total storage capacity of 95,500 acre-feet and an active storage capacity of 90,500 acre-feet.

FIGURE 1: PROJECT VICINITY MAP



### *Existing Operation*

Water is generally stored between October through March with some releases above the minimum flow starting to occur in late March through April. Irrigation season starts in May and runs through September. Releases average approximately 10 cubic feet per second (cfs) between October and January, increase to an average of 20 to 50 cfs during February and March, gradually increasing to 100 cfs during April to early-May. During the irrigation season, releases generally remain between 100 and 300 cfs.

Mason Dam is operated by the Baker Valley Irrigation District (BVID). The proposed hydroelectric project would be “run-of-release” and not change the current dam operation. The Mason Dam Hydroelectric Project would only operate whenever releases by BVID exceed 100 cfs, and not operate at releases lower than 100 cfs. Releases greater than 100 cfs have not occurred between October and January.

### ***Intake Facilities***

The Mason Dam intake is approximately 13 feet high, ranging in elevation between 3,975 and 3,988.25 feet above MSL. The bottom of the intake is 87 feet below full pool depth (4,062 feet above MSL). The intake bottom is located within the dead storage area and the intake top is within the conservation pool area. Water enters the intake on five sides and then enters a 6.5 foot diameter concrete pipe (see Figure 2). This pipe extends 325 feet from the intake to the centerline of the dam, where it narrows into an approximately 4.7foot (56 inch) diameter pipe, with a 1 foot diameter (12 inch) bypass flow pipe (Figure 3). The 56 inch pipe is subsequently bifurcated into two 33 inch (2.75 feet) pipes near the outlet. The regulating high pressure slide gates are contained within the 33 inch pipes.

Figure 2. Photo of the intake with trash racks built in.

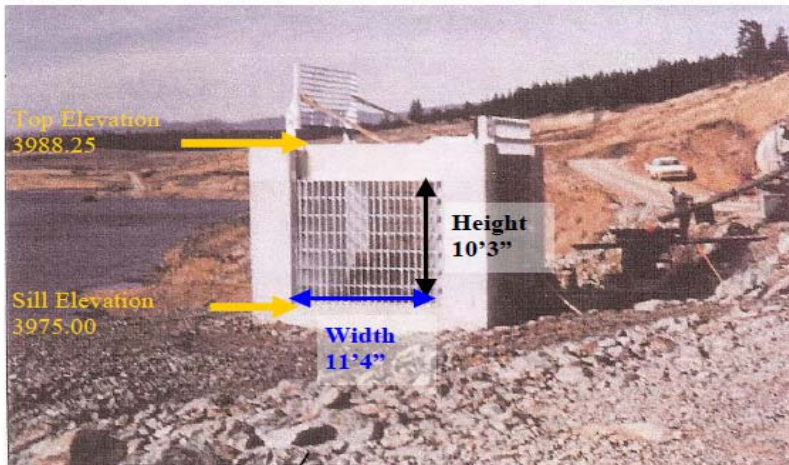
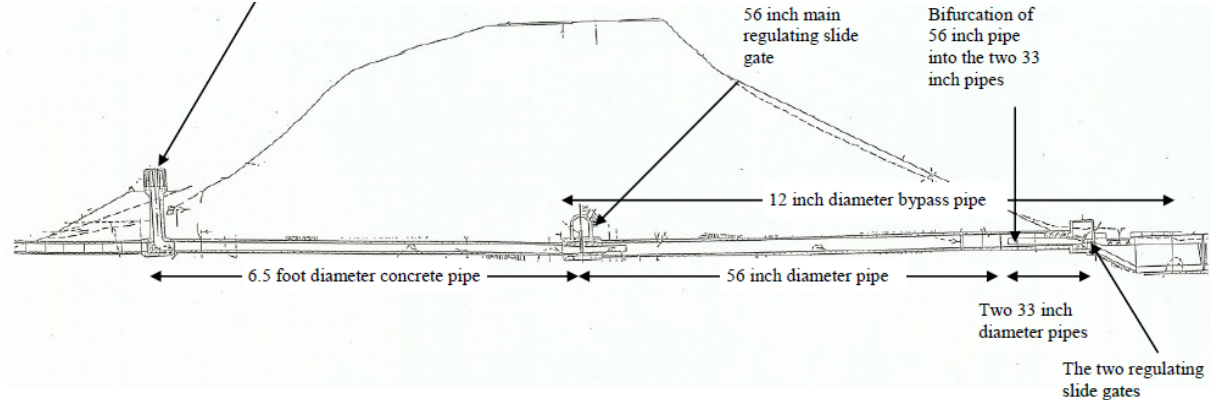


Figure 3. Diagram of the Mason Dam Intake and Outlet Structures



Flows of up to 875 cfs can be conveyed through the dam intake and pipe systems. There is a spillway for emergency flood releases greater than 875 cfs that has not been used since the dam was constructed. Since dam operation began in 1968, all flows have been through the deep intake.

### Impact/Injury Assessment:

To understand the impact with the addition of the hydroelectric project to Mason Dam, Baker County conducted a literature review of entrainment studies done at other projects. The literature review was chosen by Baker County because it was cost effective, the “potential” of entrainment over the life of the project would always exist, and that FERC had determined that there was no nexus of the hydroelectric project to change the current entrainment rate.

Baker County’s understanding was that the full entrainment/mortality study would be estimated to cost \$200,000. By reviewing similar projects (those with similar water depths, deep intake systems, operation, and release gate systems) would provide a good comparison based on similar hydraulics to Mason Dam. Through discussions with stakeholders it was also discussed that if the entrainment/mortality study results found that there was no entrainment or if entrainment was only one type of species (i.e. yellow perch) the “potential” would always exist, somewhat voiding the results of the costly study. FERC’s determination was based on the fact that Baker County was not changing the intake from where the water is drawn, the current operating rules, or timing and amount of water through Mason Dam. What could change is the mortality rate of the fish entrained.

In February of 2011 Baker County provided an Entrainment and Mortality report to the stakeholders that focused on the mortality since the entrainment rate was not going to change. In this report it was found that the mortality rate would decrease through the turbine versus current conditions. The stakeholders requested that instead of a rate or percentage of reduction they would like to have “numbers” of fish entrained to then use the mortality rate to determine mitigation needs. In April of 2013 Baker County updated the 2011 report which is summarized throughout this proposal and is attached as Attachment B.

The Entrainment and Mortality report discovered some main factors that would affect the impact of the hydroelectric project. These factors include: fish species characteristics and habitat preferences, the length of project operation, Phillips Reservoir pool volume, intake velocity, and water quality.

Fish species known to occur in Phillips Reservoir are provided in Table 1 below. ODFW has indicated that Baker County would be responsible for mitigating the impact of the lack of screening for redband trout and hatchery rainbow trout. Because there is no available information on sucker and pikeminnow populations, redband trout will be a surrogate for other native migratory fish species. Understanding the fish species present and their characteristics will help understand the entrainment potential of each species.

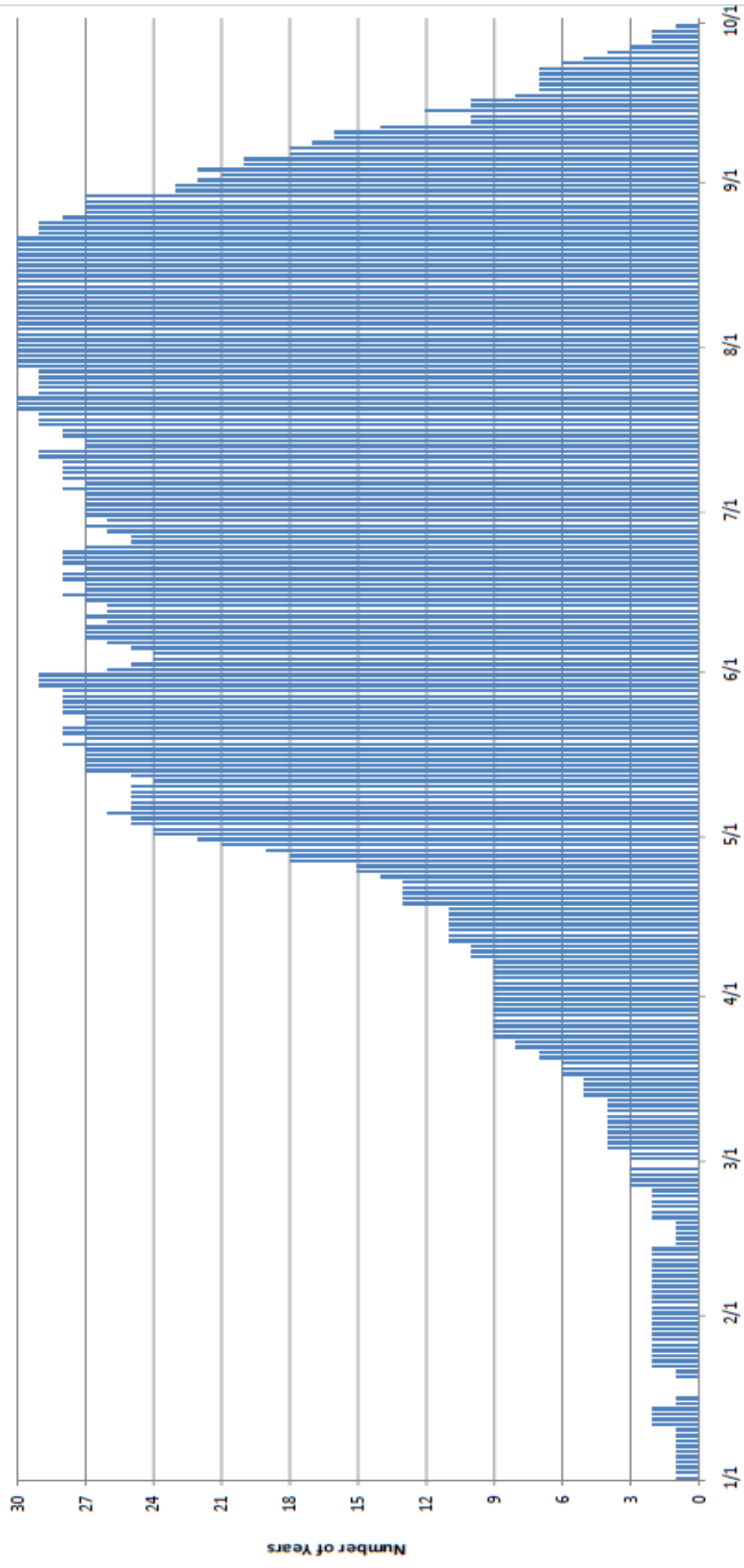
Table 1. Fish Species known to occur in Phillips Reservoir

Species (Common Name)	Native	DO Requirements in parts per million (ppm)	Swimming Speeds in feet per second (fps)
Rainbow Trout (redband and hatchery)	Y	7ppm – optimal 5ppm – strong avoidance 3ppm – lethal	5.0fps Adult
Bull Trout	Y	8ppm – optimal 6-8ppm – short term <6ppm – cannot tolerate	15.08fps Adult 1.79fps Juvenile
Yellow Perch	N	≥5ppm – optimal 2 – 4ppm – can tolerate	1.77fps max Adult 0.88fps average Adult
Walleye	N	≥5ppm – optimal 3ppm – can tolerate for short term	8.57fps Adult 6.02fps Juvenile
Smallmouth bass	N	>6ppm – optimal 4ppm – can tolerate 2ppm – lethal	3.9fps average – 7.8fps max Adult 1.8fps average – 3.6fps max Juvenile
Largemouth bass	N	>8ppm – optimal 4ppm – can tolerate 2ppm – lethal	1.0 – 1.64fps average Juvenile 3.2 – 4.2fps max Juvenile
Black Crappie	N	>5ppm – preferred	0.5 – 0.75fps average with 1.5 max
Suckers (bridgelip, largescale)	Y	>3ppm – preferred <2.4ppm – lethal	1.4 – 4.9fps average with 4 – 7.9fps max Adult
Northern pikeminnow	Y	No specific tolerances were located in the literature could be similar to smallmouth bass	.74fps average with 1.6 – 2.7fps max Adults
Tiger trout	N	Likely to be similar to trout	Likely to be similar to trout

***Hydroelectric Operating Season***

The Mason Dam Hydroelectric Project will only operate when flows are above 100cfs. On average, these flows occur 146 days per year, or between 4 to 6 months per year. Figure 4 depicts the frequency in which releases exceeding 100 cfs have occurred during the January 1 to September 30 period, based on historical flow release data provided by the Bureau of Reclamation from 1983 to 2012. Between October 1 and December 31 flows have never exceeded 100cfs.

Figure 4. Frequency of Flows Exceeding 100cfs between January 1 and September 30. Based on Data from 1983 - 2012



Based on the historical release data, the Mason Dam Hydroelectric Project would be expected to operate most of the time in all years between May 1 and August 30, but not at all between October 1 and January, and very infrequently between February 1<sup>st</sup> and April 15<sup>th</sup>. Operation between mid-April and May and September would vary annually. The entrainment numbers that will be discussed below are based on a full year of entrainment from January to December without the hydroelectric project installed. With this in mind understanding the native migratory fish seasonal movements and their characteristics would most likely keep the species of concern away from the intake during the operational season. This would reduce the impact of entrainment based on the hydroelectric project from the full year estimates.

### ***Phillips Reservoir Volume***

Another factor that is important to fish entrainment is the change in pool volume, particularly in the “dry” years. As pool volumes decrease fish entrainment may increase due to fish being in closer proximity to the intake. Pool volumes have been drawn down in Phillips Reservoir less than 15% of full pool volume in 26.7% of the years or roughly 1 in every 4 years. However in 56.7% of the years the reservoir was maintained at a level more than 60 feet over the intake. In its Entrainment and Mortality report, Baker County used the most liberal numbers available in the literature based on similar or even more extreme hydrologic reservoirs. Instead of using the most extreme case of entrainment plus a conservation factor, Baker County believes a weighted average due to the history of Phillips Reservoir water volume would be more reasonable. ODFW recommended since an actual entrainment study was not done that the “dry” year entrainment numbers plus a conservation factor of 10% should be used as the entrainment rate for every year.

### ***Intake/Outlet Operations and Velocities***

From year to year, day to day, and each irrigation season the water released at Mason Dam varies based on the amount of spring runoff, water stored, and irrigation demand. Long term average irrigation season releases through Mason Dam range between 100 and 350 cfs. At the beginning of the irrigation season when flows are less than 50 cfs, only one outlet is used with the high pressure slide gate typically only open 10% (or a width of 0.27 feet). Once flows exceed 50 cfs, both outlets are used. The high pressure slide gates are gradually opened to a maximum of 30 to 40%. Although the two outlet pipes are 2.75 feet in width, the actual opening through which water flows would generally be between 0.82 and 1.10 feet during the time the Mason Dam hydroelectric project would be operational.

The Mason Dam intake was constructed to have a maximum approach velocity of 1.7 feet per second (fps) for the maximum designed release of 875 cfs through the outlet works. As releases decrease so does the approach velocity of the intake. During typical maximum irrigation releases (350cfs), intake approach velocities are approximately 1.0fps. Native migratory species of interest at Phillips Reservoir would be able to out swim this approach velocity. If a fish is entrained the velocities would increase as it travels through the dam and the operation of the high pressure slide gates can affect these velocities. Table 2 provides a summary of velocities for the range of the high pressure slide gate openings used during the irrigation season.

Table 2. Calculated Velocities (fps) through Mason Dam Outlets and High Pressure Slide Gate Opening Used During the Irrigation Season

Flow (cfs)	Percent of Slide Gate Opening and Opening Width		
	10% (0.27 ft)	30% (0.82 ft)	40% (1.10 ft)
100	84.2	28.1	21.0
150	126.3	42.1	31.6
200	NA-would not occur	56.1	42.1
250		70.2	52.6
300		84.2	63.1
350		98.2	73.6
400		112.2	84.2

Based on the information above Baker County would suggest that the species of concern would likely not be entrained during project operation thus again reducing the impact of the hydroelectric project. If in an event a fish from the species of concern is entrained the velocity through which the fish would be pushed through the outlet works, possibly colliding with the outlet gate and then the pressure experienced going through the high pressure slide gate could affect the fish's chances of survival. By going through the turbine the collision and the pressures experience by the high pressure slide gates would be reduced and could increase the survival rate of entrained fish.

***Water Quality***

Phillips Lake is well aerated throughout the water column during the winter and spring (late November to mid April/early May) with dissolved oxygen (DO) values greater than 8 parts per million (ppm) throughout the profile in May. Beginning in May, the lake starts to stratify with increasing temperatures near the surface and relatively constant temperatures near the bottom of the reservoir.

Dissolved oxygen concentrations change as both the temperature changes and the reservoir starts to stratify according to temperature and water density. The surface layer (epilimnion) remains well oxygenated, but in the mid and lower layer (mesolimnion and hypolimnion) DO levels drop below 7 ppm beginning in June. In mid-June, DO concentrations drop below 6.0 ppm throughout the intake area and remain low until the beginning of September.

Table 3 depicts the range of water quality conditions at the intake between mid-May and October. The water quality data were collected during 2007, which was considered a “dry” year. A thermocline started to develop in June between 16.5 and 49.5 feet (or 5-15 meters) below the surface, with the thermocline between 33 and 49.5 feet (10 to 15 meters) below the water surface at its greatest development. Below the thermocline, water was anoxic.

During a “wet” year the thermocline develops with increasing surface temperatures and the thermocline would develop above the intake elevations. Conditions would likely remain anoxic for a longer period of time (e.g., through September) near the intake.

Table 3. Water Quality Conditions within the Range of the Mason Dam Intake Elevations During 2007

Date	Intake Elevation (Ft below surface)		DO (ppm)		Temperature (° C)	
	Top	Bottom	Top	Bottom	Top	Bottom
11-May	72.3	59.4	8.6	8.6	11.1	11.1
17-May	70.6	57.8	8.1	7.6	9.1	8.9
25-May	69.3	56.4	7.6	7.3	10.8	10.2
1-Jun	68.0	55.1	6.7	5.9	10.1	10.0
9-Jun	66.3	53.5	7.4	6	12.9	10.8
15-Jun	64.4	51.5	6.6	6.6	13.0	13.5
22-Jun	64.4	51.5	5.8	4.2	12.9	11.3
28-Jun	62.4	49.5	5.2	4.8	14.5	14.2
6-Jul	59.7	46.9	3.5	3.5	12.7	12.7
17-Jul	55.4	42.6	2.6	0.9	14.9	12.0
24-Jul	51.8	38.9	1.8	1	15.0	13.5
7-Aug	43.6	30.7	6.0	0.1	20.7	14.8
14-Aug	38.9	26.1	5.2	0.1	20.1	17.0
21-Aug	33.7	20.8	6.2	2.3	19.5	18.9
13-Sep	25.4	12.5	9.6	7.4	17.7	16.9
21-Sep	24.1	11.2	5.8	7.7	15.4	17.0
28-Sep	23.1	10.2	6.0	5.7	13.4	15.4
5-Oct	22.4	9.6	6.2	6.2	No data	No data
12-Oct	21.8	8.9	6.5	6.5	10.8	10.8

Different fish species can handle different dissolved oxygen (DO) levels. Most species of concern prefer DO levels above 6ppm and would avoid DO levels near 5ppm. In a majority of the years a thermocline develops in Phillips Reservoir that acts as a barrier to the intake due to the low DO. With the hydroelectric project operating most of the time after the thermocline is in place would prevent the species of concern from entering the intake area.

### Entrainment Summary

Using some of the data above Baker County estimated the maximum numbers expected for Phillips Reservoir and entrainment through Mason Dam, with or without the hydroelectric project, based on population estimates of Phillips Reservoir and entrainment rates from other studies. Table 4 below provides estimated numbers of fish potentially entrained per year based on the type of water year.

Type of Water Year	Wet	Average	Dry
% of time the water year conditions occur in Phillips Reservoir	56.7%	16.6%	26.7%

Yellow Perch <sup>A</sup>	16,366	32,732	49,097
Native Rainbow & Redband Trout <sup>B</sup>	0-34 <sup>C</sup>	0-452 <sup>C</sup>	0-870 <sup>C</sup>
Stocked Rainbow Trout <sup>B</sup>	0-508	0-610	828
Other <sup>C</sup>	100-200	100-200	100-200
Bull Trout	0 <sup>E</sup>	0 <sup>E</sup>	0 <sup>E</sup>
Small/Largemouth Bass	0 <sup>F</sup>	0 <sup>F</sup>	0 <sup>F</sup>
Yearly Totals	17,108	34,064	49,097
<sup>A</sup> - Based on a estimated yellow perch population of 1,636,575 <sup>B</sup> - Estimated population of 60,000 – 100,000 (annual stocking rate of 58,200 plus unknown number of residents) <sup>C</sup> - Mostly juveniles <sup>D</sup> - Suckers, northern Pike minnow, Black Crappie <sup>E</sup> - Bull trout entrainment during the proposed project operating period is highly unlikely due to their inability to tolerate the water quality conditions near the intake and its very strong swimming ability. <sup>F</sup> - Not likely to be entrained due to their strong avoidance to water quality conditions near the intake.			

The fish species most susceptible to entrainment during both the proposed Mason Dam hydroelectric project 4 to 6 month operating period and the 6 to 8 month non-operating period include yellow perch, black crappie and stocked rainbow trout.

To determine the impact from the hydroelectric project the main factors of: fish species characteristics and habitat preferences, the length of project operation, Phillips Reservoir pool volume, intake velocity, and water quality would reduce the yearly estimated entrainment and only address the potential impacts of the hydroelectric project.

For example: When considering the impact to redband trout, most of the fish entrainment potential occurs in the spring (when DO is acceptable near the intake) and the fall (when the pool volume is low). The hydroelectric project only operates for a maximum of 6 months per year. Most of the anticipated entrainment would occur outside the operational periods. This could probably reduce the maximum entrainment numbers by at least half.

Or

In the spring and the fall when the hydroelectric project could be operating the flows that would be released would be closer to 100cfs. The intake velocity would be near 1fps and most of the redband trout, even juveniles would be able to out swim this. But to be conservative we could use the numbers that half are adults and half are juveniles that are not able to out swim the velocity so we could probably reduce the maximum number entrained by half.

Or

During the peak irrigation season when the hydroelectric project is running and the velocities are higher near the intake, the thermocline will most likely be developed. All redband trout will not want to be near the intake due to the low DO thus reducing the full entrainment rate presented for a “dry” year.

Baker County could also look at a weighted average based on the water years which would be:  $((56.7\% * 34) + (16.6\% * 452) + (26.7\% * 870)) = 326$  entrained fish per year or 360 with the conservation factor added. This would mitigate for a full years worth of entrainment for a project that would only have a maximum operational period of 6 months.

All the above would still present a conservative entrainment potential based on the barriers presented from the main factors and the water year history.

ODFW expressed concerns about Baker County's Entrainment and Mortality report, concerning the accuracy of the entrainment estimates. ODFW was willing to support using the Entrainment report to develop conservative estimates of entrainment to determine the level of mitigation in lieu of screening. Because there is no empirical data ODFW recommended using the most conservative estimate provided in the report as an annual entrainment estimate, plus a conservation factor of 10% to determine the number of fish to be mitigated for. Based on this information the following annual entrainment estimates in "dry" years will be used for every year as follows: 828 hatchery rainbow trout and 870 native redband trout with a 10% conservation factor added would bring the number of mitigated rainbow trout to 910 and native redband trout to 957.

## Screening of current intake:

In the Proposed Study Plans, Baker County originally proposed to screen the intake at Mason Dam. However, subsequent engineering studies and information from BOR has led to the removal of screening from the License Application. The screen engineering study concluded that a separate tower would have to be constructed with footing and foundation work done underwater. The system would have to be fail safe and at all times allow the maximum of 875cfs through the outlet works. The range of costs for this was \$1.59 to \$1.89 million in 2010 dollars which would increase the cost of the project by 48% making the project economically infeasible.

In further discussions with Baker County, BOR made it clear that a screen on the intake would not be acceptable due to the safety of the dam. Even with redundant systems Baker County could not guarantee that flows would be met 100% of the time. If a malfunction occurred it could risk the structural integrity of Mason Dam and endanger downstream residents. Baker County understands this issue and would not support an option that could endanger lives.

As part of ORS 498.306 (13) a project proponent could be excused from screening requirements if the following can be demonstrated:

- (a) The installation and operation of screening or by-pass devices would not prevent appreciable damage to the fish populations in the body of water from which water is being diverted.*
- (b) Installation and operation of screening or by-pass devices would not be technically feasible.*
- (c) Installation of screening or by-pass devices would result in undue financial hardships.*

Baker County may potentially qualify to be excused from screening by addressing a, b, and c above, however, it has chosen to work with State and Federal stakeholders (US Fish and Wildlife, US Forest Service, ODFW, Oregon DEQ, Oregon Water Resources Department) to provide mitigation that will protect and improve fish resources.

## Proposal:

In lieu of screening the Mason Dam intake, Baker County proposes to provide screening at an irrigation diversion, develop a fund for screening in the Powder basin, and supplement the ODFW's stocking program for Phillips Reservoir to meet the mitigation requirements.

To mitigate for native redband trout Baker County has agreed to screen diversions to protect the same number of potentially entrained redband trout. To estimate this number for Baker County, ODFW used trap box data from the John Day basin from two sites with similar flow characteristics as streams in the Powder basin. It was found that the average screen would protect 31.4 fish/cfs. To mitigate for 957 redband trout a total of 30.47cfs would need to be screened.

To select diversions in need of screening, Baker County contacted landowners since, the County does not own any land that contains an irrigation diversion. The Shaw-Stewart diversion was identified as being set up for a fish screen, but no screen has been installed. It is located approximately 9 miles downstream of Mason Dam and diverts a maximum of 12 cfs in the spring. Baker County will work with the landowners, BVID, and ODFW screen shop to complete the screening of this diversion. The proposed screen would be a rotary self cleaning style. Baker County intends to enter into an agreement with BVID to conduct regular daily and yearly maintenance with assistance from ODFW if questions/issues arise.

In addition, Baker County proposes to create a fund to screen the remaining 18.47cfs needing to be screened as mitigation. Based on estimated screening costs provided by ODFW, Baker County will provide \$90,000 to screen diversions in the Powder River watershed. The fund will be administered by the Baker Soil and Water Conservation District (SWCD) or Powder Basin Watershed Council. Projects funded will be selected in cooperation with Baker County, ODFW, and the entity administering the fund.

Baker County also proposes to supplement the current stocking program to ensure that there is no net loss of hatchery rainbow trout for anglers. Based on the entrainment study Baker County's "dry" year estimate had the potential of 828 stocked rainbow trout entrained. ODFW added a conservation factor of 10% bringing the number of potentially entrained rainbow trout to 910. Phillips Reservoir was once known for its rainbow trout fishery by anglers and Baker County would like this to happen again by forming an agreement with ODFW to supplement the current stocking program with an additional 1000 stocked rainbow trout per year for the life of the FERC license.

## Resource Protection:

Based on the above entrainment estimates and ODFW's additional conservation factor of 10%, Baker County is confident that the proposed mitigation will ensure fishery resource protection. This is determined by using already high entrainment numbers for a "dry" year that only happens in a quarter of the years at Phillips Reservoir. In reviewing the weighted average plus the conservation factor, fish entrainment for redband trout would average 360 fish per year compared to the "dry" year plus the conservation factor of 957 for one year. The 957 number of fish entrained would be only 26.7% of the time for Phillips Reservoir but has been changed to a

per year figure. Thus screening for 30.47cfs would protect the same number of fish potentially entrained every year for a one in every four year occurrence. As for stocked rainbow trout the entrainment report plus the conservation factor came out to an estimated entrainment rate of 910 fish per year. Baker County would provide an additional 90 above and beyond the conservation number. Over four years if based on the historical data this would be a gain in the stocked rainbow trout in excess of 1,300 fish over those that may be entrained. Through the above proposal Baker County is mitigating for the Mason Dam project which is above and beyond the impacts from the addition of the hydroelectric project alone.

If the screening exemption is not granted then no benefit to the fish resource will be gained. The hydroelectric project would not be completed and the economic stability it would provide for the County would be lost. We understand this difficult decision and would appreciate your support in providing a benefit to the resources in the Powder River basin.

## Fish Screening Mitigation Requirements



# Oregon

John A. Kitzhaber, M.D., Governor

## Department of Fish and Wildlife

Fish Division  
4034 Fairview Industrial Dr SE  
Salem, OR 97302-1142  
503-947-6200  
Fax: 503-947-6202  
[www.dfw.state.or.us](http://www.dfw.state.or.us)



September 5, 2013

Mr. Fred Warner, Jr.  
Commission Chair  
Baker County Board of Commissioners  
1995 Third Street  
Baker City, OR 97814

Subject: Mason Dam Hydroelectric Project (FERC-12868)  
Fish Screening Mitigation Requirements

Dear Commissioner Warner,

The purpose of this letter is to inform you of the screening mitigation requirements at Mason Dam for the Mason Dam Hydroelectric Project (FERC 12868). On April 30, 2013, Baker County filed a license application with the Federal Energy Regulatory Commission (FERC) proposing to retrofit Mason Dam with a hydroelectric facility. The proposal does not include fish screening at the existing intake at Mason Dam. Under Oregon Revised Statute (ORS) 498.306, the Oregon Department of Fish and Wildlife (ODFW) may require the installation, operation and maintenance of screening at water diversions to protect fish populations. Fish screens designed and operated to ODFW criteria will minimize injury and mortality to fish by preventing entry at water diversions while allowing water to be delivered to its intended use. Having the water user install and operate criteria fish screening is ODFW's primary method of minimizing these harmful impacts to fish populations.

When fish screening is required, ORS 498.316<sup>1</sup> allows a pathway for a water user to seek an exemption from installing fish screening by implementing other provisions that are approved by the Oregon Fish and Wildlife Commission (Commission). The water user is required to prove to the Commission the proposed provisions will provide adequate protection of fish in the body of water that is being diverted. The nature and method of the proposed alternative to screening (i.e. mitigation) is the prerogative of the water user, but it is highly recommended that the project proponent work with local ODFW staff as ODFW will provide a recommendation to the Commission. Applicants for a screening exemption should provide a proposed mitigation package that includes (1) an impact or injury assessment; (2) a justification of why screening at the intake is not being pursued; (3) a detailed explanation of the mitigation proposal; and (4) a description of how the proposed mitigation will provide for adequate protection of identified fish in the body of water that is being diverted.

<sup>1</sup> **ORS 498.316 Exemption from screening or by-pass device.** ORS 498.306 does not require the installation of screening or by-pass devices in those water diversions for which the State Fish and Wildlife Commission, by contract or other form of agreement with the person diverting the water, has made such other provision as the commission determines is adequate for the protection of the game fish in the body of water from which water is being diverted. [Formerly 498.262; 2007 c.625 §6]

The mitigation package will be reviewed by the Fish Screening Task Force (Task Force) prior to submission for Commission approval. The Task Force is comprised of seven members of the public with three members representing agriculture and water users, three representing fishing and fish conservation and one member representing the public at large. The Task Force typically meets three or four times a year throughout the state. These meetings are open to the public, and public input is encouraged. The Task Force will review the proposed mitigation package and provide recommendations to the Commission based on their assessment of the ability of the mitigation package to meet the requirements of ORS 498.316.

The proposed mitigation package will then be presented to the Commission. Project proponents and members of the public will have the opportunity to testify before the Commission on the merits of the proposal. The Commission will determine if the mitigation package will satisfy the requirements of ORS 498.316. If the Commission determines that the proposed mitigation satisfies ORS 498.316, then an exemption may be granted. An agreement between the Commission and the project proponents will be prepared outlining the responsibilities of both parties.

ODFW recommends that you work closely with our staff to ensure important process timelines are met. For hydroelectric projects the process for obtaining a fish screening exemption agreement must be timed to fit within the FERC process for obtaining a license or exemption. This means that the Commission will need to take action on the fish screening exemption request and mitigation proposal prior to ODFW staff development of mitigation measures under FERC's Notice of Ready for Environmental Analysis. ODFW generally needs at least two months after a draft agreement is developed to plan and prepare agenda items for a Commission meeting. If a screening exemption agreement is not in place at the appropriate time in the FERC process, ODFW will need to recommend to FERC that screening be installed.

Given our understanding of FERC's timeline and expected FERC Notice of Ready for Environmental Analysis, we recommend that your proposed screening exemption mitigation package be heard by the Commission at the December 6, 2013, meeting. Since the proposal must be reviewed by the Fish Screening Task Force, we recommend that it be presented at the next Task Force meeting on October 3 and 4, 2013, in Medford, Oregon. Therefore, we request that the complete screening mitigation proposal be submitted to ODFW for staff review by September 20, 2013.

If you have questions regarding this issue, you may contact the Statewide Fish Screening Coordinator, Pete Baki, at (503)947-6217 or [pete.a.baki@state.or.us](mailto:pete.a.baki@state.or.us) or myself at (541) 962-1832 or [elizabeth.a.osiermoats@state.or.us](mailto:elizabeth.a.osiermoats@state.or.us).

Sincerely,



Elizabeth A.O. Moats  
Hydropower Coordinator  
Northeast Region

## Fish Entrainment and Mortality Study

**FISH ENTRAINMENT AND MORTALITY STUDY  
-AMENDMENT-**

**MASON DAM PROJECT  
BAKER COUNTY, OREGON  
Project Number P-12686-001**

**Prepared for**

**Baker County  
1995 Third Street  
Baker City, Oregon 97814**

**Prepared by**

**EcoWest Consulting, Inc.  
Baker, OR 97814**

**April 2013**

**MASON DAM PROJECT FISH ENTRAINMENT AND MORTALITY STUDY  
-AMENDMENT-  
TABLE OF CONTENTS**

<b>1.0</b>	<b>Introduction</b>	<b>1</b>
<b>2.0</b>	<b>Mason Dam Project Description</b>	<b>1</b>
<b>3.0</b>	<b>Methods</b>	<b>20</b>
<b>4.0</b>	<b>Results</b>	<b>22</b>
	<b>4.1 Entrainment</b>	<b>22</b>
	<b>4.1.1 Estimated Annual Entrainment</b>	<b>22</b>
	<b>4.1.2 Species-Specific Entrainment Potential Overview</b>	<b>24</b>
	<b>4.1.3 Salmonids</b>	<b>25</b>
	<b>4.1.4 Percids</b>	<b>34</b>
	<b>4.1.5 Centrarcids</b>	<b>37</b>
	<b>4.1.6 Cyprinids</b>	<b>40</b>
	<b>4.1.7 Catastomids</b>	<b>41</b>
	<b>4.2 Entrainment Summary</b>	<b>42</b>
<b>5.0</b>	<b>Mortality</b>	<b>51</b>
	<b>5.1 Overview</b>	<b>51</b>
	<b>5.2 Overall Mortality Estimate Approach</b>	<b>53</b>
	<b>5.3 Baseline Mortality Estimates</b>	<b>54</b>
	<b>5.4 Project Operation</b>	<b>56</b>
	<b>5.4.1 Salmonids</b>	<b>57</b>
	<b>5.2.4 Percids</b>	<b>58</b>
	<b>5.2.5 Other Fish (Centrarcids, Cyprinids, Catastomids)</b>	<b>58</b>
	<b>5.2.6 Summary</b>	<b>58</b>
<b>6.0</b>	<b>REFERENCES</b>	<b>59</b>
<b>APPENDIX A-1.</b>	Entrainment and Mortality Background Summary	
<b>APPENDIX A-2.</b>	Comparison Reservoir Mortality Studies	
<b>APPENDIX B.</b>	Location of Yellow Perch Spawning Sites in Which Netting Has Occurred Between 2009-2012.	

## **1.0 Introduction**

Baker County conducted a study to address potential effects of the proposed Mason Dam Hydroelectric Project on mortality of fish passing through Mason Dam (GeoSense 2011) according to directives provided by FERC during the May 20, 2010 agency coordination meeting. The directives were to focus primarily on changes in mortality, as entrainment would not be affected by the project.

Agency comments both pre and post study focused on addressing how the study results would translate to changes in mortality of individual species, as well as clarification of the range of baseline entrainment numbers, used to evaluate changes in mortality. In addition, new information has been developed regarding how water quality during the seasonal hydroelectric operating period could affect the previous entrainment estimates.

This report provides an amendment to the 2011 entrainment and mortality study. Specific objectives of the amendment are to:

- Revise the baseline entrainment and related mortality rates based on new information regarding deep reservoir intakes, particularly deep, gated intakes.
- Provide updated information on project operation as pertinent to fish species.
- Add a discussion of the potential for individual fish species impacts.
- Update the study with new information from other regional reservoirs, particularly those containing similar fish species as those found in the Mason Dam project area.
- Identify the range of impacts to be expected from the incremental effects of the hydroelectric project on the overall reservoir operation.

As an amendment, this report incorporates by reference the following reports:

- Initial Fish Entrainment and Mortality Study Report (GeoSense 2011) and the project description therein
- Mason Dam Water Quality Study Report (EcoWest 2009a)
- Combined Vegetation and Threatened, Endangered and Sensitive Species Study Report (EcoWest 2009b).

## **2.0 Mason Dam Project Description**

The proposed Mason Dam project is described in detail in GeoSense (2011) and not repeated herein other than to clarify project details specific to fish entrainment and mortality. The full project description can be found in the previous report.

Based on numerous studies throughout the US, a number of factors have been identified as important in distinguishing the differences between entrainment and mortality under various circumstances (see for example, summaries in FERC 1995, EPRI 1997, Ch2MHill 2003, NAI 2009, Symbiotics 2009; detailed summary in Appendix A).

These factors include:

- Reservoir Characteristics: Operation type, depth, and changes in hydraulic head/surface water levels and pool volumes
- Intake Characteristics: Type, depth, velocity and water quality at intake
- Fish species, size and seasonal/daily movements

Each of these factors is discussed individually below.

### ***Reservoir Characteristics***

Philips Reservoir is an 2,234 acre-reservoir located behind Mason Dam. Mason Dam has a total height of 173 feet and a maximum hydraulic height of 157 feet. The reservoir has a total storage capacity of 95,500 acre-feet and an active storage capacity of 90,500 acre-feet. Average reservoir depths are 41 feet with a maximum depth of 125 feet (Shrader 2000). Approximately 13% of the full pool reservoir area is considered littoral habitat (areas less than 10 feet in depth, Shrader 2000).

Mason Dam is currently regulated for flood control and irrigation. Water is generally stored between October and March and released by the Baker Valley Irrigation District (BVID) for irrigation between May and September 30. As a result, releases average approximately 10 cfs between October and January and increase to an average of 20 to 50 cfs during February and March. During the irrigation season, releases generally remain above 100 to 200 cfs and can go up to 350 cfs.

The proposed project would be “run-of-release” and not change the dam operation. The Mason Dam hydroelectric project would only operate whenever releases by BVID exceed 100 cfs, and not operate at releases lower than 100 cfs. Releases greater than 100 cfs do not occur between October and January. Figure 1 depicts the frequency in which releases exceeding 100 cfs have occurred during the January 1 to September 30 period, based on historical flow release data provided by the Bureau of Reclamation. Between 1983 and 2012, flows exceeding 100 cfs on any one day of the month have occurred within three years in January and within four years in February (or 10 to 13% of years). Beginning in June and extending through August, releases exceeded 100 cfs in all years. Daily flows exceeding 100 cfs occurred in 26 of the 30 years examined in September. Between mid-March and mid-April, releases exceeded 100 cfs in 30% of the years. During the last two weeks of April, flows generally increase, exceeding 100 cfs on any one day of the month in 43 to 60% of the years.

The frequencies described above identify the number of years in which flows of 100 cfs or greater occur during a month, even if for only one day. Figure 1 also depicts the number of days within a month that flows would have been sufficient for the hydroelectric project to operate. Over the last

30 years, flows exceeding 100 cfs in January and February have occurred on 4.4 to 6.3% of the total number of days, with most of the days occurring in 1984, an extremely wet year. In all other years, flows have exceeded 100 cfs during January and February on 1.6 to 3.2% of the days. Except for 1984, the late winter flows were mostly isolated and not occurring on a sufficient number of days for the hydroelectric project to operate.

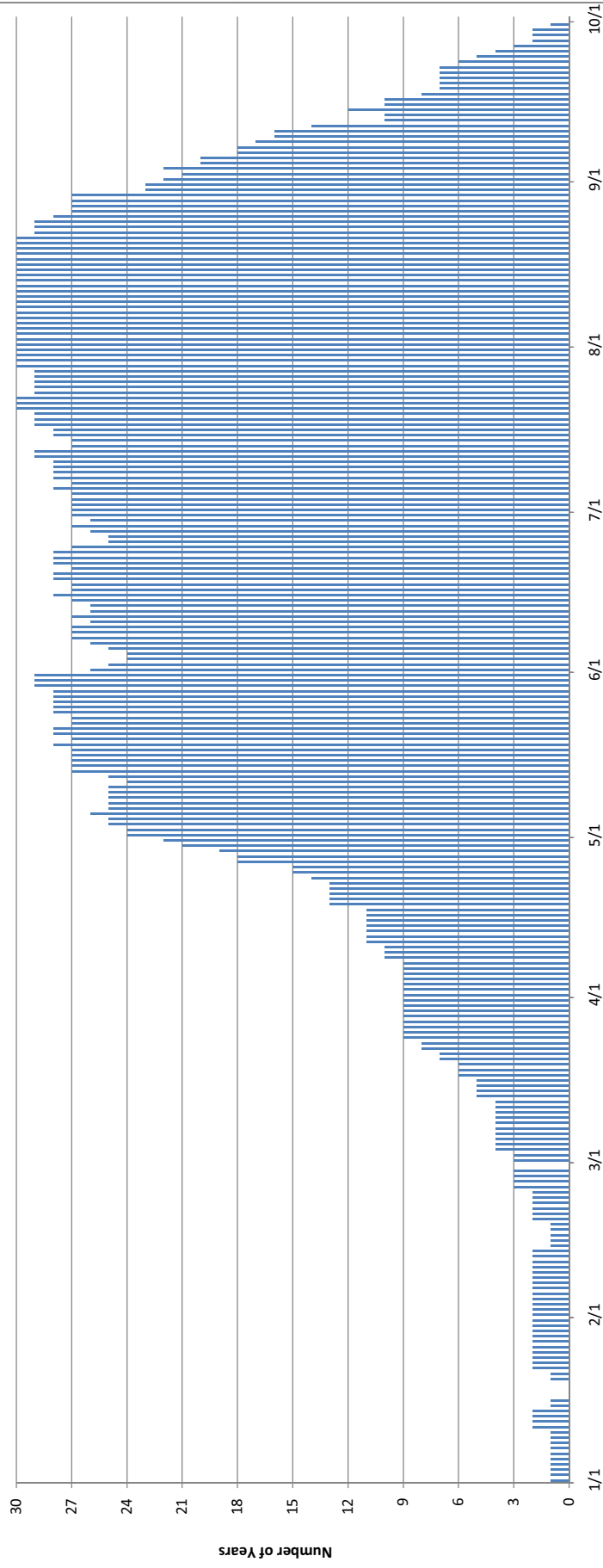
In March, the total percent of days in which flows have exceeded 100 cfs is 19.4%, most of which have occurred during the latter part of the month. April flows have also exceeded 100 cfs on 40.5% of the days, with most of the exceedances during the last two weeks of the month. On a daily basis, flows exceed 100 cfs most of the time between May and August. Although flows may reach 100 cfs on any one day in September in most years, daily flows only exceed 100 cfs on 35% of the days in September. In 70% of the years, flows exceeding 100 cfs cease by mid-September.

Table 1 presents the date on which the hydroelectric project would have been terminated based on the selected representative years

<b>Table 1. Fall Dates on Which Flows Less than 100 cfs Occurred, Ending the Potential For Hydroelectric Generation In Representative Years.</b>			
<b>Year</b>	<b>Year Type</b>	<b>End 100 cfs/End Hydro Operation</b>	<b>Notes</b>
1984	Extremely Wet	August 31	-
1998	Wet	Sept 12	-
1990	Average	Sept 24	Intermittent between 8/30 and 9/24
2000	Average	Sept 19	Intermittent between 9/6 and 9/19
2007	Dry	Sept 4	-
1988	Extremely Dry	August 12	-

Based on the historical release data, the Mason Dam hydroelectric project would be expected to operate all or most of the time in all years between May 1 and August 30, but not at all between October 1 and January. In extremely wet years, the project could operate during January and February, but in the majority of years, the project would initiate operation sometime between mid-March to mid-April. During the third week of April, the project would be operational during an estimated 30% of the years, increasing to being operational 40 to 63% of the years during the last week of April. The hydroelectric project would cease operation during September, generally within the first one or two weeks of the month, with the project being able to continue until the end of September in only 30% of the years.

Figure 1. Frequency of Flows Exceeding 100 cfs Between January 1 and September 30. Based on Data from 1983-2012.



The Mason Dam full pool elevation is at 4062 feet above MSL or 87 feet over the intake top. Water surface elevations during the proposed Mason Dam hydroelectric operating period have varied both annually and during the year. The reservoir is generally at its highest elevation during spring (March-April) and is drawn down to its lowest level in October. Between 1983 and 2012, full pool elevations have ranged from above full pool level (4068 feet in 1984) to 4017 in 1988. Low water surface elevations have ranged from 4053 ft above MSL in 1988 to 3986 ft above MSL in 1984. Figure 2 depicts the water surface level changes between March and October in two extreme years (1984, extremely wet and 1988, extremely dry) as well as surface water level changes in representative wet, dry and average years. The representative years were chosen as follows:

- Average Year: Precipitation is approximately the same as the average annual precipitation of 10.31 inches as recorded at the NOAA Baker City airport weather station (#350412). The years selected were 1990 and 2000.
- Representative Wet Year: Precipitation approximately 1 standard deviation more than the average annual precipitation. The year selected was 1998.
- Representative Dry Year: Precipitation approximately 1 standard deviation less than the average annual precipitation. The year selected was 2007, which was also the year in which the project water quality sampling occurred.

Based on the previous 30-year record of operation (1983-2012), the reservoir surface water level was drawn down to a point between 78 feet over the intake in the wettest year (1984) to 11 feet over the intake in the driest year (1988, see Figure 2). Drawdown levels in the other years fell between these two extremes. Over the 30-year period, the reservoir was drawn down to a level less than 30 feet over the intake in 23% of the years (represented in Figure 2 by 2007), and to a level between 30 to 60 feet over the intake in 20% of the years (represented in Figure 2 by 1990). In the majority of the years (57% of the years), the reservoir was maintained at a level more than 60 feet over the intake during the entire irrigation season (represented in Figure 2 by 1998 and 2000; see also Figure 3).

In general, the end of irrigation season reservoir surface water level is very low in dry years, moderately low in some “average” precipitation years, and kept relatively high in other “average” precipitation and wet years. As noted above, the very low (less than 30 feet over the intake) drawdowns have occurred in 23% of the years, or slightly less than 1 in 4 years.

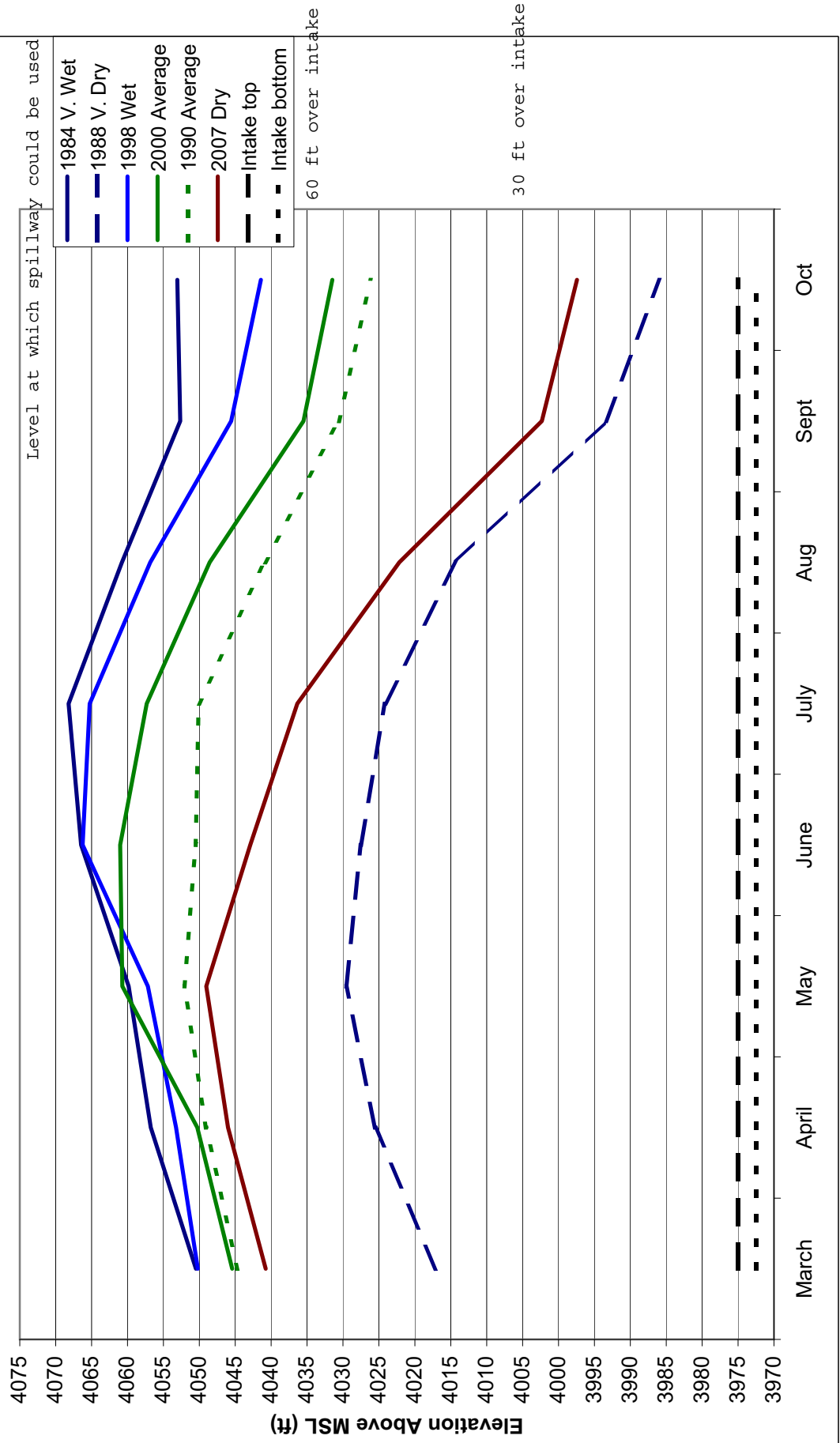
The timing of the low water level is also important, particularly if it occurs during a critical fish life history stage, such as spawning or migration. Except for extremely dry years, such as 1988, the reservoir level is not drawn down to a level less than 30 feet over the intake, in the years that this level of drawn down occurs, until mid-August. In the years when the reservoir level is lowered to a point between 30 to 60 feet over the intake, this level is also reached in mid-August. In all years, except the excessively dry 1988, the reservoir water level was at least 70 feet above the intake during the spring spawning periods for the fish species occurring within Philips Reservoir. In 1988, the reservoir levels were between 45-55 feet above the intake during the spawning period.

Another factor that is important to fish entrainment is the change in pool volume, particularly in the dry years. The Philips Reservoir pool volume has been drawn down to less than 10% of full pool volume six times in the last 30 years, and to between 10 to 15% of full pool volume in an additional 2 of the 30 years. Overall, pool volume has been drawn down very low, less than 15% of full pool volume, in 26.7% of the years, roughly similar to the frequency at which very shallow water is recorded over the intake (Figure 4).

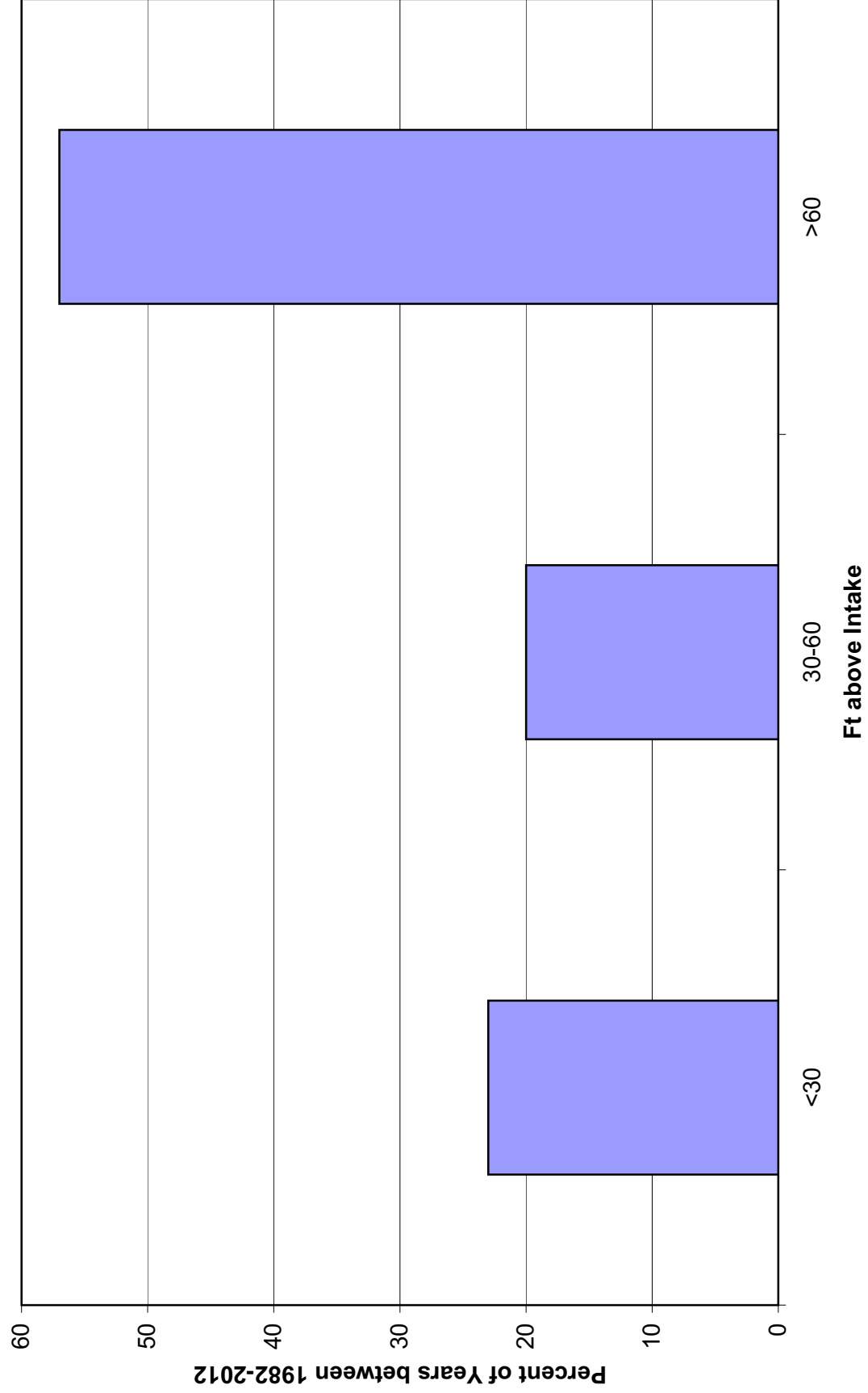
There were three years in which pool volume was drawn down to levels between 15-25% of full pool. In the remaining years pool volumes were maintained at at least 30% of full pool level.

Although long term average irrigation season releases through Mason Dam range between 100 and 350 cfs, discharges do vary from year to year. Figure 5 depicts the mean monthly discharges for each of the representative years depicted in Figure 2.

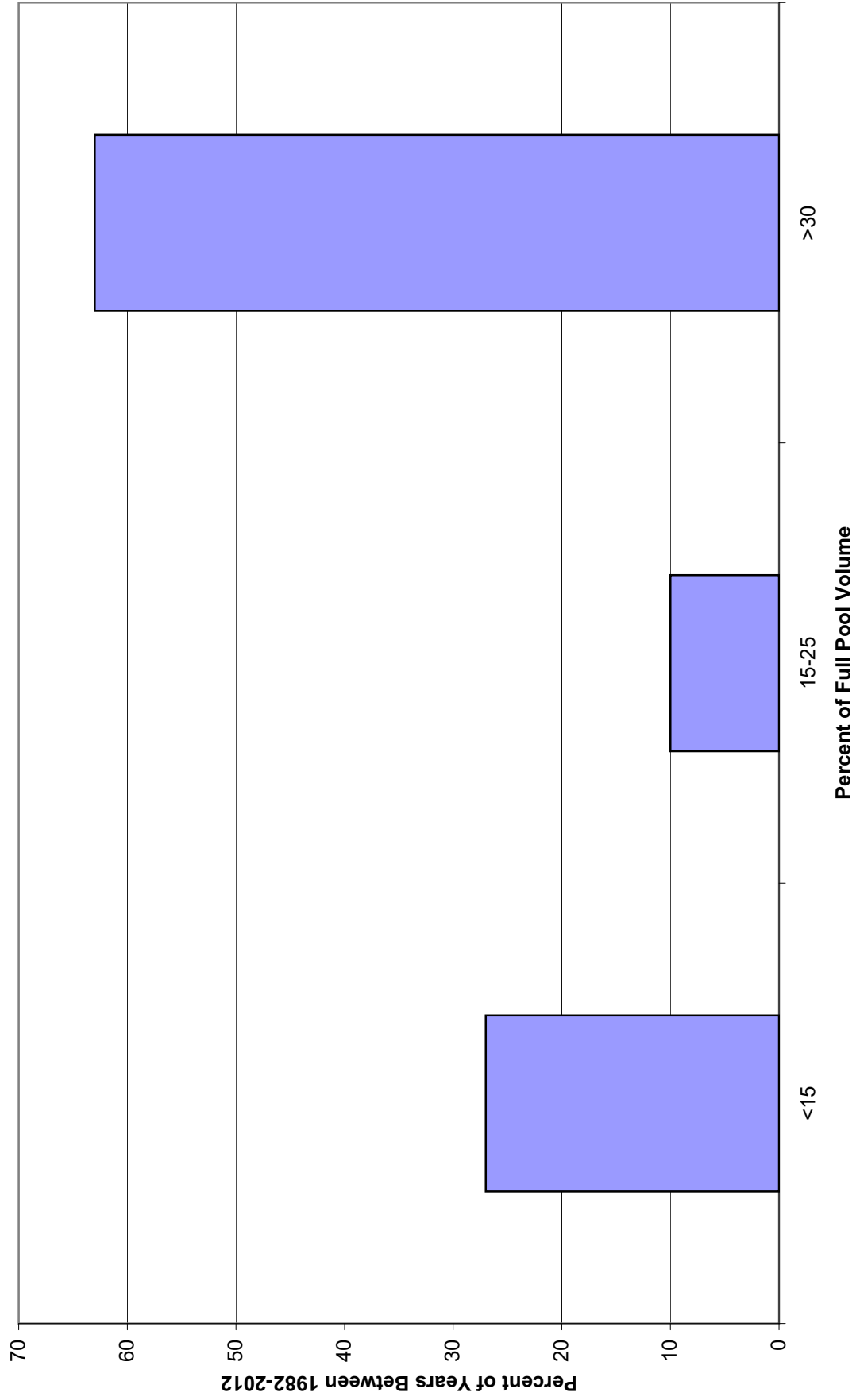
**Figure 2. Changes in Phillips Reservoir Surface Water Levels between March and October in Representative Wet, Dry and Average Years.**



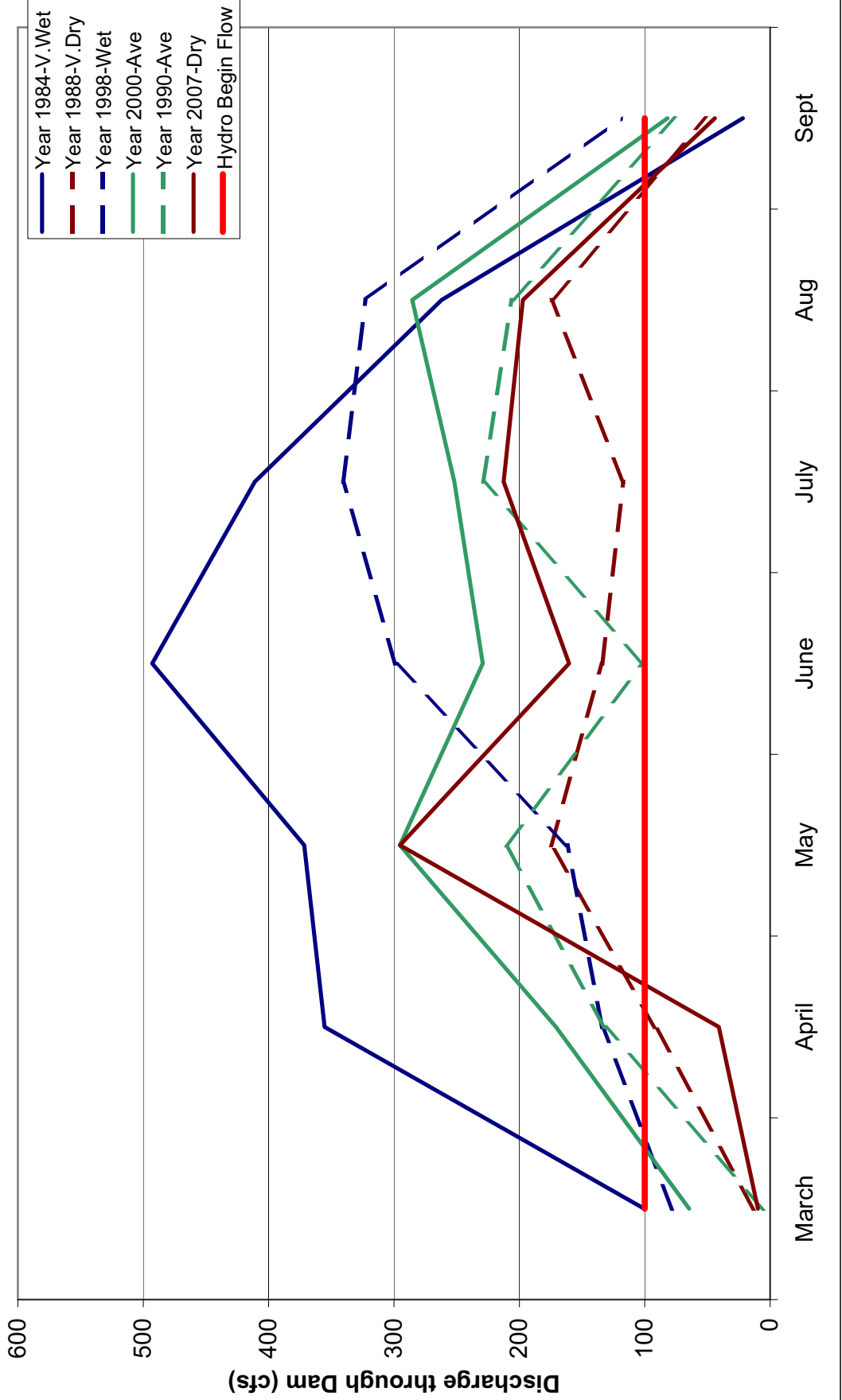
**Figure 3. Frequency of Annual Low Drawdown Levels (Ft above Intake)**



**Figure 4. Frequency of Annual Low Pool Volume Drawdown**



**Figure 5. Mean Monthly Flows Through Mason Dam In Representative Wet, Dry and Average Years. Flows in Extremely Wet (1984) and Extremely Dry (1988) Years are also Depicted.**



### ***Intake Characteristics***

The Mason Dam intake is approximately 13 feet high, ranging in elevation between 3,975 and 3,988.25 feet above MSL. The bottom of the intake is located at an elevation of 3,975 feet above MSL, or 87 feet below full pool depth (4,062 feet above MSL). The intake bottom is located within the dead storage area and the intake top is within the conservation pool area. The intake is located approximately 290 feet west of Black Mountain Road. It is a gated intake, with a regulated outlet that produces high velocity flows.

The intake itself consists of a cement structure 17.25 feet wide by 13.25 feet high, with a trash rack covering a 10.25 by 11.33 foot opening (see Figure 6). A 6.5 foot diameter concrete pipe extends 325 feet from the intake to the centerline of the dam, where it narrows into an approximately 4.7 foot (56 inch) diameter pipe, with a 1 foot diameter (12 inch) bypass flow pipe. The 56 inch pipe is subsequently bifurcated into two 33 inch (2.75 feet) pipes near the outlet. The regulating slide gates are contained within the 33 inch pipes.

Flows of up to 875 cfs can be conveyed through the dam intake and pipe systems. There is a spillway for emergency flood releases greater than 875 cfs that has not been used since the dam was constructed. Since dam operation began in 1968, all flows have been through the deep intake. Mean irrigation season releases range between 100 and 350 cfs, with maximum releases between 490 and 570 cfs over the last 30 years. The spillway could be used in the future if the reservoir exceeded an elevation of 4,070.50 feet above MSL, or 8.5 feet above full pool level.

At the beginning of the irrigation season when flows are less than 50 cfs, only one outlet is used with the slide gate typically only open 10% (or a width of 0.27 feet). Once flows exceed 50 cfs, both outlets are used. The slide gates are gradually opened to a maximum of 30 to 40%. Although the two outlet pipes are 2.75 feet in width, the actual opening through which water flows would generally be between 0.82 and 1.10 feet during the time the Mason Dam hydroelectric project would be operational. At some low flows, particularly at the beginning of the season, the slide gate openings could be as small as 0.27 feet.

During maximum irrigation releases, intake approach velocities are approximately 1.0 feet per second (fps). As releases decrease, velocities decrease and are less than 1 fps at discharges less than 350 cfs. Velocities up to 1.7 fps could occur with releases close to 875 cfs (BOR 2012). Once water enters the 4.7 foot pipe (midway through the dam), velocities increase to 5.8 fps at discharges of 100 cfs and 20.5 fps at discharges of 350 cfs. At the bifurcation point (near the outlet), the velocities accelerate again, with the velocities dependent on the degree of slide gate opening within the outlets. At 100 cfs, velocities would range between 21.0 fps (40% slide gate opening) to 84.2 fps (10% slide gate opening). At 350 cfs, the slide gate would be open between 20 to 40% resulting in velocities of 73.6 to 98.2 fps. Table 2 provides a summary of velocities for the range of slide gate openings used during the time period that the Mason Dam project would be operating.

Figure 6. Diagram of the Mason Dam Intake and Outlet Structures.

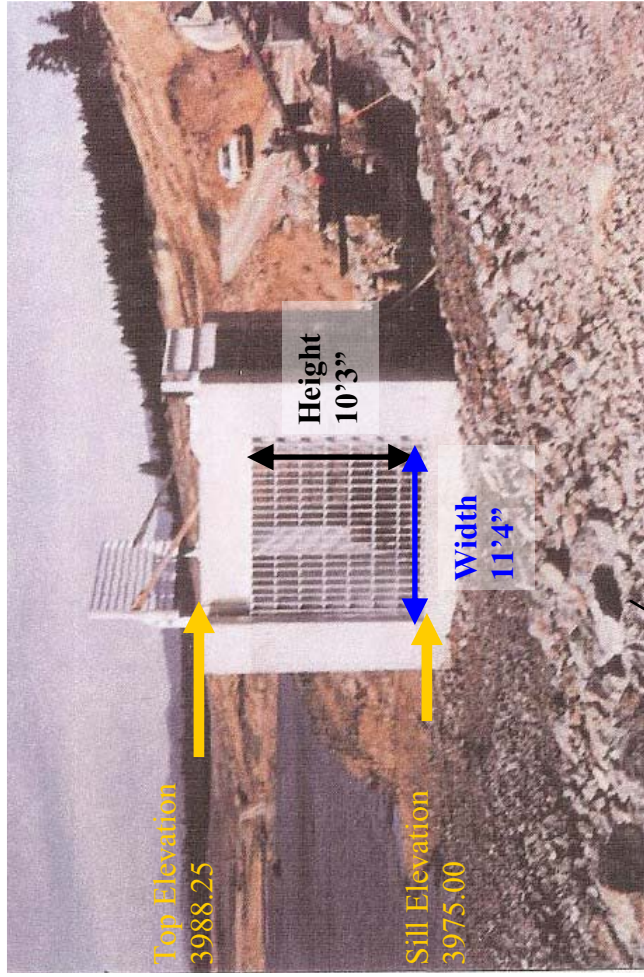
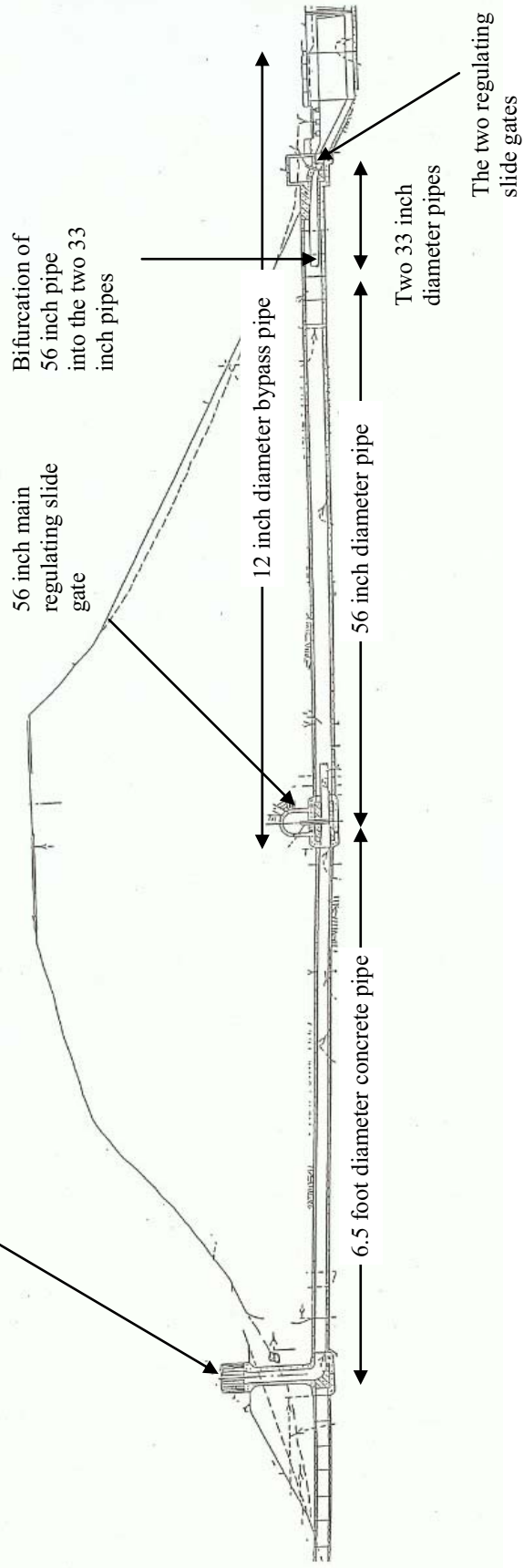


Photo of Intake with trash racks built in. Water enters the intake on all five sides, then enters the 6.5 foot diameter concrete pipe.



**Table 2. Calculated Velocities (fps) through Mason Dam Outlets at Slide Gate Opening Sizes Used During the Irrigation Season.**

Flow (cfs)	Percent of Slide Gate Opening and Opening Width		
	10% (0.27 ft)	30% (0.82 ft)	40% (1.10 ft)
100	84.2	28.1	21.0
150	126.3	42.1	31.6
200	NA-would not occur	56.1	42.1
250		70.2	52.6
300		84.2	63.1
350		98.2	73.6
400		112.2	84.2

Philips Lake is apparently well aerated throughout the water column during the winter and spring (late November to mid April/early May) with dissolved oxygen (DO) values greater than 8 ppm throughout the profile in May (see EcoWest [2009] for full water quality data description). Winter temperatures are unknown but are less than 0 °C in the upper layers as portions of the lake freeze. Beginning in May, the lake starts to stratify with increasing temperatures near the surface and relatively constant temperatures near the bottom of the reservoir. These differences increase to 10 °C by July, as the surface layer warms to more than 20 °C, while the temperatures near the bottom of the reservoir near Mason Dam remain relatively constant between 10.4 to 11.2 °C.

Dissolved oxygen concentrations change as both the temperature changes and the reservoir starts to stratify according to temperature and water density. The surface layers (epilimnion) remain well oxygenated, but in the mid and lower layers (mesolimnion and hypolimnion) DO levels drop below 7 ppm beginning in June.

Table 3 depicts the range of water quality conditions at the intake between mid-May and October. Beginning in mid-June, DO concentrations drop below 6.0 ppm throughout the intake area and remain low until the beginning of September. Temperatures remain cool at the intake level until the beginning of August when they begin to exceed 15 °C and increase to 20.7 °C.

The water quality data were collected during 2007, which was considered a “dry year” and in which the reservoir surface level was 74 feet above the top of the intake at the beginning of May and was drawn down to a level 22 feet over the top of the intake at the end of September. A thermocline started to develop in June between 16.5 and 49.5 feet (or 5-15 meters) below the surface, with the thermocline between 33 and 49.5 feet (10 to 15 meters) below the water surface at its greatest development. Below the thermocline, water was anoxic.

During 1998, a “wet” year, the reservoir water surface ranged between 66 to 75 feet over the intake top between May and October. Because the thermocline develops with increasing surface temperatures, it is likely that in wet years, temperatures at the intake elevations would remain cool longer during the summer. Conversely, with the thermocline developing above the intake elevations, conditions would likely remain anoxic for a longer period of time (e.g., through September).

Date	Intake Elevation (Ft below surface)		DO (ppm)		Temperature (° C)	
	Top	Bottom	Top	Bottom	Top	Bottom
11-May	72.3	59.4	8.6	8.6	11.1	11.1
17-May	70.6	57.8	8.1	7.6	9.1	8.9
25-May	69.3	56.4	7.6	7.3	10.8	10.2
1-Jun	68.0	55.1	6.7	5.9	10.1	10.0
9-Jun	66.3	53.5	7.4	6	12.9	10.8
15-Jun	64.4	51.5	6.6	6.6	13.0	13.5
22-Jun	64.4	51.5	5.8	4.2	12.9	11.3
28-Jun	62.4	49.5	5.2	4.8	14.5	14.2
6-Jul	59.7	46.9	3.5	3.5	12.7	12.7
17-Jul	55.4	42.6	2.6	0.9	14.9	12.0
24-Jul	51.8	38.9	1.8	1	15.0	13.5
7-Aug	43.6	30.7	6.0	0.1	20.7	14.8
14-Aug	38.9	26.1	5.2	0.1	20.1	17.0
21-Aug	33.7	20.8	6.2	2.3	19.5	18.9
13-Sep	25.4	12.5	9.6	7.4	17.7	16.9
21-Sep	24.1	11.2	5.8	7.7	15.4	17.0
28-Sep	23.1	10.2	6.0	5.7	13.4	15.4
5-Oct	22.4	9.6	6.2	6.2	No data	No data
12-Oct	21.8	8.9	6.5	6.5	10.8	10.8

Figure 7-1. Dissolved Oxygen Levels at the Range of Mason Dam Intake Elevations. Based on 2007 Data.

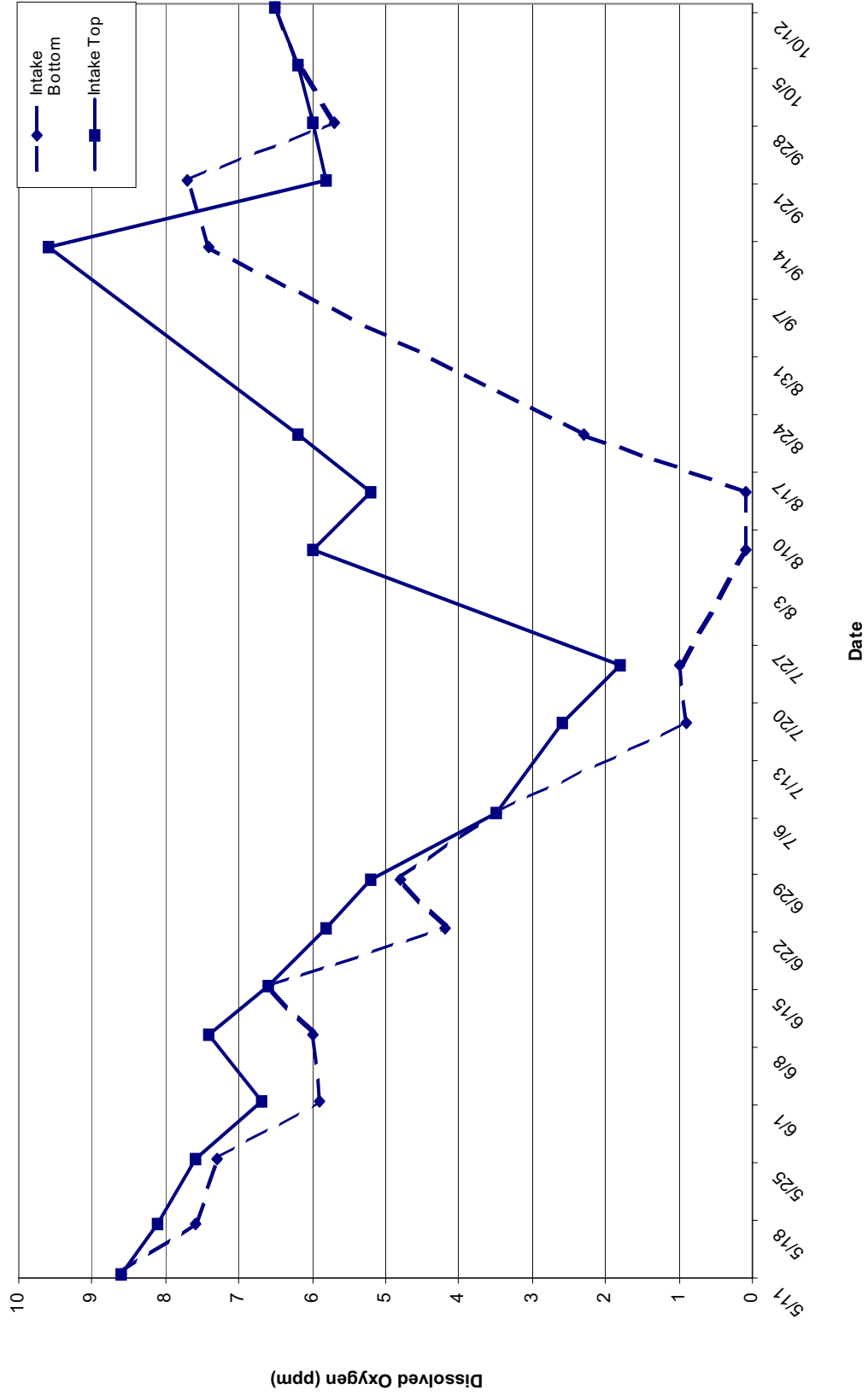
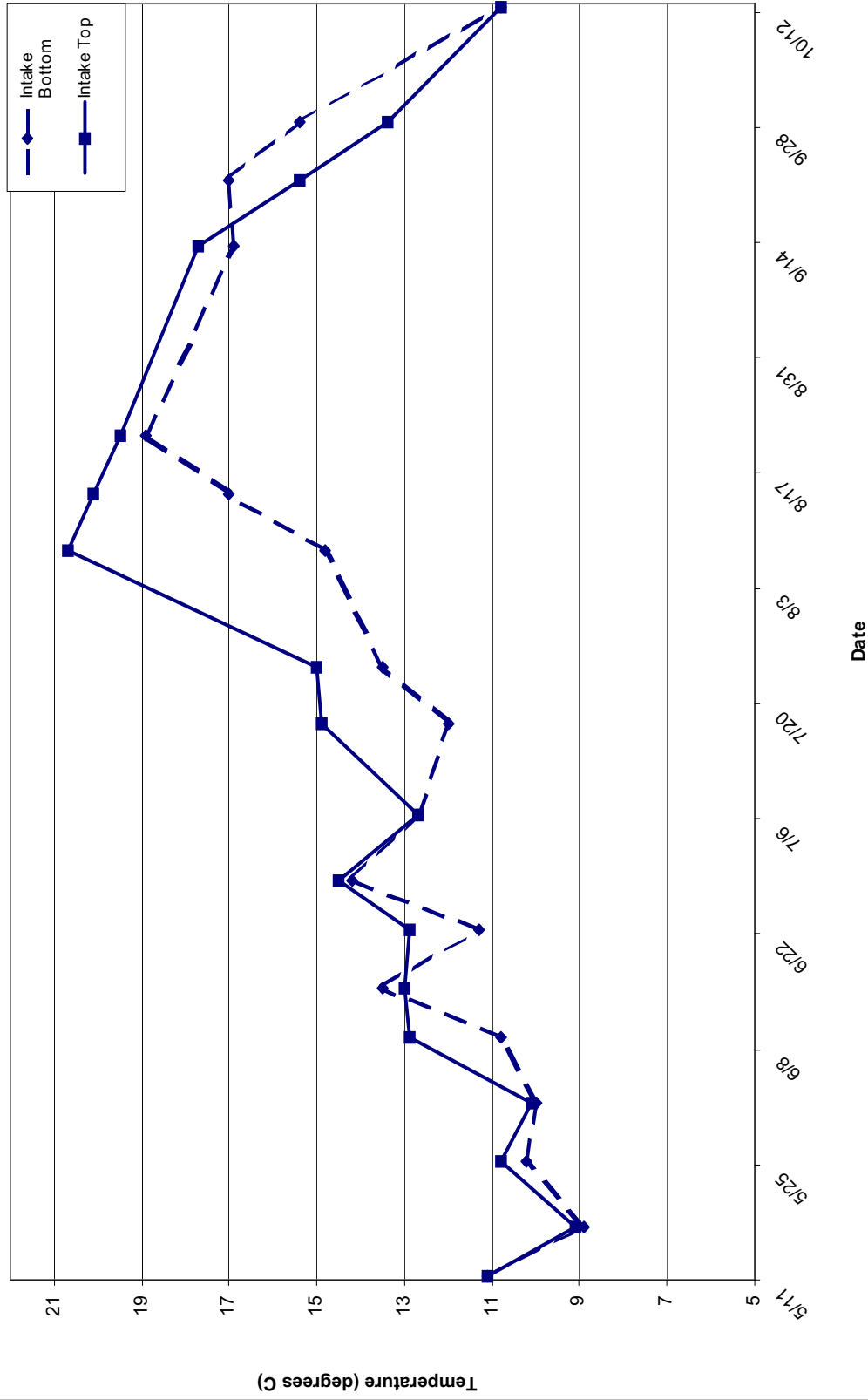


Figure 7-2. Temperatures at the Range of Mason Dam Intake Elevations. Based on 2007 Data.



### ***Fish species***

Philips Reservoir was treated with rotenone on October 7, 1977 and restocked in April, 1978 with 150,000 hatchery rainbow trout and an undetermined number of largemouth bass, crappie and coho salmon (PBWC 2001). Yellow perch and walleye were subsequently illegally introduced in the 1980's, with yellow perch first documented by ODFW within the reservoir in 1991. In 1993, ODFW stocked smallmouth bass and black crappie, although both species were present in the reservoir since at least 1985. PBWC (2001) identified that ODFW annually stocked up to 100,000 hatchery rainbow trout as both fingerlings and adults. However, currently, 33,600 legal (8 inches) adult rainbow trout are stocked throughout the summer, and 24,600 sublegal adult trout (6 inches) in September for an average annual stocking rate of 58,200 (T. Bailey, ODFW, Pers. Comm.). No fingerlings are currently stocked. All stocking occurs at the Union Creek boat launch, which is close to Mason Dam. The northern pikeminnow occurred in the Powder River prior to the construction of Mason Dam and still occurs in both the river and the reservoir, where it is fairly abundant (ODFW 2013).

Between 1985 and 1999, the densities of smallmouth bass and crappie declined by 82 and 96%, respectively, primarily due to competition with yellow perch (ODFW 2008). Conversely, the yellow perch population increased by 245% (Shrader 2000). Efforts to manage the number of perch within the reservoir have been conducted annually between 2009 and 2012 (Bailey 2012). These efforts have focused on netting the perch when they are concentrated in their spring littoral spawning areas. Since spawning occurs right after “ice-off”, the netting typically occurs during a 7 to 10 day period in mid-April. The most productive perch spawning netting areas have varied within the reservoir based on reservoir level, but have included the north side of the reservoir near the Union Creek campground, the south side of the reservoir, and the northwestern edge of the reservoir near where the Powder River enters. When the reservoir is at full pool level, the last site appears to be the most productive spawning area. This site is also the furthest from the Mason Dam intake. Appendix B provides the location of perch spawning areas in which netting has occurred. Although yellow perch can spawn in any shallow embayment, these sites represent the areas in which netting has captured the most perch over the past four years.

The April perch netting resulted in a low of 51,574 perch in 2009 and a high of 354,468 perch in 2011. Yearly total differences reflect the timing of the netting, the netting level of effort and the reservoir level and not population differences. Based on spring netting mark-recapture estimates and other studies, Bailey (2012) estimated a total population of 1,636,575 yellow perch in the reservoir.

Between 2009 and 2011, a total of 769,489 fishes comprising 8 fish species were caught during the April littoral netting (Table 4). Of these fishes, 99.6% of the individuals were yellow perch. Approximately 0.1% each of the individuals netted were northern pikeminnow, suckers and rainbow trout. Other species netted together comprised 0.1% of the catch and included bull trout (2), smallmouth and largemouth bass, and black crappie.<sup>1</sup>

---

<sup>1</sup> The April littoral netting was focused on capturing yellow perch within a subset of habitats, and although yellow perch are the dominant fish in the reservoir, the overall spring netting results do not provide an accurate representation of species composition within the whole reservoir.

Fish species currently known in Philips Reservoir include hatchery and wild rainbow trout (redband), black crappie, smallmouth and largemouth bass, yellow perch, walleye, northern pikeminnow and various species of sucker (Baker County 2009). One thousand six hundred (1600) sterile tiger trout were introduced to the reservoir by ODFW in 2011 to help provide a sport fishery for trophy-sized trout (ODFW 2008). The dominant fish species in the reservoir is the yellow perch. Other species thought to be fairly abundant are the suckers and northern pikeminnow. Populations of crappie, bass and walleye are thought to be very low (Bailey 2013). Two subadult bull trout were found in the reservoir in 2011.

Future short term (i.e., 2-5 years) reservoir fishery management plans are to continue stocking six to eight inch rainbow trout at generally similar levels, continue to annually stock sterile tiger trout, and to continue to reduce the yellow perch population through mechanical means and biocontrol via introduction of the tiger muskie (ODFW 2013). Although more than one million perch have been removed from the reservoir between 2009-2012, yellow perch continue to dominate the fishery. If the yellow perch population can be substantially reduced, the ODFW would return to stocking a variety of rainbow trout age classes, including fingerlings. The ability to achieve this long term goal and the time period in which achievement could occur is unknown and completely dependent upon the success of future efforts to reduce the perch population.

**Table 4. Fish Species Known to Occur in Philips Reservoir.**

Species		Native?	Percent of April Littoral Netting <sup>1</sup>
Common Name	Scientific Name		
Yellow perch	<i>Perca flavescens</i>	No	99.6
Walleye	<i>Sander vitreus</i>	No	0
Smallmouth bass	<i>Micropterus dolomieu</i>	No	<0.01
Largemouth bass	<i>Micropterus salmoides</i>	No	<0.01
Black crappie	<i>Pomoxis nigromaculatus</i>	No	<0.01
Northern pikeminnow	<i>Ptychocheilus oregonensis</i>	Yes	0.1
Suckers (bridgelip, largescale)	<i>Catostomus columbianus</i> <i>Catostomus macrocheilus</i>	Yes	0.1
Rainbow trout (redband and hatchery)	<i>Oncorhynchus mykiss</i> spp.	Mix of native and non-native	0.1
Bull trout	<i>Salvelinus confluentus</i>	Yes	<0.0001
Tiger trout	<i>Salmo trutta</i> X <i>Salvelinus fontinalis</i>	No	0

<sup>1</sup> The April littoral netting was focused on capturing yellow perch within a subset of habitats, and although yellow perch are the dominant fish in the reservoir, the overall spring netting results do not provide an accurate representation of species composition within the whole reservoir.

### 3.0 Methods

A literature review was undertaken to identify key factors important to fish entrainment and mortality with a focus on studies since 1995. The literature review summary can be found in Appendix A. Based on the key factors identified in the literature review, a subset of studies were analyzed to provide an updated estimate of overall potential entrainment, entrainment by species and baseline mortality rates. The reservoirs selected met the following characteristics:

- Located within the Pacific Northwest region and containing a cold/coolwater fishery with a trout component.
- Dam height greater than 25 meters (82.5 feet) and with a deep intake. Intakes needed to be located either more than 75 feet below the water surface at full pool, or if less than 75 feet, containing species-specific trout data and/or end of season intake depths similar to those of Mason Dam.
- Reservoirs operated primarily for flood control/irrigation, as much as possible, or if operated for a different purpose then containing data on non-anadromous salmonid entrainment.

These criteria were used as general selection criteria. Other operational specifics such as seasonal drawdown levels and pool volumes changes, water quality characteristics and approach velocities were discussed in evaluating entrainment potential by species and age class.

Based on the three general screening criteria, 11 reservoirs were selected for analysis and comparison to Mason Dam. These reservoirs and their characteristics are listed in Table 5. Not all reservoirs had data for both mortality and entrainment rates (see Table 5). Of the 11 reservoirs, five were used to estimate baseline mortality rates and 10 contained species-specific data on entrainment. Only three of the reservoirs had data on full annual fish entrainment estimates. Only one reservoir, Fall Creek Reservoir, had data on all three items of interest for deep water intake-Pacific Northwest reservoirs: annual entrainment, entrainment by species and mortality rates. Data summaries developed for the Henry Jackson (Spada Lake) and Wickiup relicensing projects were also used in portions of the analysis (CH2MHill 2007, Symbiotics 2009).

The older entrainment data set from GeoSense (2011) was not used further as it contained only shallow reservoirs that do not stratify and Ch2MHill (2003) showed that shallow, non-stratified reservoirs had substantially greater entrainment rates than deeper reservoirs.

In addition, scientific studies on fish species life history, behavior, and swimming speeds were reviewed for the species known to occur in Philips Reservoir.

The mortality data for Mason Dam under the proposed project operation as described in GeoSense (2011) was used to identify how mortality rates might change under project operation for the species most likely to be entrained.

**Table 5. General Characteristics of Regional Reservoirs with Deep Intakes, with Mason Dam Characteristics for Comparison.**

Reservoir Name	State	Size	Intake Characteristics		Flow Range (cfs)	Operation	Data Type Available		
			Acres/ Acre-Feet	Depth (ft)			Type	Entrainment	
		Total						Species-Specific	
Cougar	W OR	1,280 (207,759)	92	Slide Gate	440-1000	Irrig, FC	X		X
Fall Creek	W OR	1,820 (115,100)	161	Slide Gate	450-1000	FC, Recr	X	X	X
Trail Bridge	W OR	73 (2,088)	59	Slide Gate	to 2,000	FC	X	X	
Blue River	W OR	1,420 (>80,000)	224	Slide Gate	300-2,400	FC, Recr			X
Wickiup	C OR	Unkn (200,000)	82	Tube Valve	100-2,000	Irrig		X	X
Tieton	E OR	2,530 (198,000)	198	Tube Valve	300-2,190	Irrig		X	X
Beulah	E OR	Unkn (59,212)	76	Jet Valve, Spillway	0-950, gen 300-400	Irrig		X	
Arrowrock	W ID	3,150 (286,600)	205	Clam Shell	54-3,000	Irrig, FC		X	
Timothy Lake	W OR	1,280 (Unkn)	79	Valve	0-300	Recr, FC		X	
Lake Lemolo	SW OR	415 (Unkn)	73	Unknown	436	Hydro		X	
Cooper Lake	AL	2,800 (Unkn)	32	Unknown	380	Hydro		X	
Philips Reservoir/ Mason Dam	E OR	2,234 (95,500)	87	Slide Gate	10-400	Irrig, FC			

## 4.0 Results

### 4.1 Entrainment

#### 4.1.1 Estimated Annual Entrainment

Total annual entrainment has been measured at only a few regional reservoirs, with most studies primarily evaluating percent population entrainment or evaluating entrainment potential by species. Annual entrainment numbers were available for three reservoirs -- Cougar, Fall Creek and Trail Bridge, all located within Oregon and all containing gated outlets. These three reservoirs were selected as they represented the only regional reservoirs with cold/coolwater fisheries and deep intakes that also had total entrainment estimates (Table 6).

The comparison reservoirs contained many similarities to Philips Reservoir/Mason Dam, but also some differences in key factors affecting entrainment. These include:

- **Reservoir Characteristics**

***Operation Type:*** Cougar Reservoir is operated for flood control and irrigation, as is Philips Reservoir. The other two reservoirs are operated for flood control (Trail Bridge) or flood control and recreation (Fall Creek). All reservoirs undergo seasonal drawdowns and are operated so that a low pool occurs during the fall and winter.

***Flow Range:*** Flows are much higher at the comparison reservoirs than through Mason Dam, with minimum discharges exceeding the Mason Dam maximum discharges. Because no other regional studies were available with total entrainment numbers, and because higher rates of entrainment would be expected with higher discharges, the comparison reservoirs were still used as they would result in a more conservative (i.e., likely higher than actual) entrainment estimate.

- **Intake Characteristics**

***Depth:*** The Cougar Reservoir intake depth is similar to that of Mason Dam at full pool depth; Trail Bridge and Fall Creek Reservoir slide gate intake depths are similar to those of Mason Dam during seasonal low water levels. Fall Creek Reservoir differs from Philips Reservoir in that it also contains a set of “fish horns” as part of a downstream migrant passage system located 40 to 80 feet above the gated intake. As a result, when these horns are usable, fish can exit the reservoir at multiple locations within the water column.

***Water Quality Near Intake:*** Cougar and Fall Reservoirs thermally stratify, but do not chemically stratify. In contrast to Mason Dam, DO conditions at all three comparison reservoirs remain suitable for most species during the full year.

***Approach Velocities:*** Approach velocities at the Cougar and Fall Creek intakes are unknown, but are greater than 3.3 fps at Trail Bridge, which is higher than the 1.0 fps at Mason Dam.

- **Fish Species**

Full fish species composition and population numbers are not available at any of the reservoirs. However, the comparison reservoirs contained the following species in common with Mason Dam: rainbow trout (native and hatchery), bull trout, largemouth bass, smallmouth bass, walleye, crappie, and a variety of sucker species.

Differences in composition are that yellow perch are not a major component in the comparison reservoirs, and that the comparison reservoirs contain a large anadromous salmonid component, which Mason Dam does not have. The majority of fish entrained at the comparison reservoirs consisted of anadromous salmonid fish (from 78 to 96% of the fish entrained). Because anadromous fish are obligate downstream migrants, they are subject to much higher entrainment levels than other species (see Appendix A). The salmonid species in Mason Dam migrate upstream for spawning (or away from the intake) and are not subject to the episodic entrainment of downstream migrants.

Reservoir	Size		Intake Characteristics		Flow Range (cfs)	Entrainment (# fish)	
	Acres	Acre-Feet	Depth (ft)	Approach Velocity (fps)		All fish	All non-anadromous fish
Cougar	1,280	207,759	92	Unknown	440-1000	78,737	Unknown, almost all fish entrained were Chinook salmon; even if up to 49%, estimated as a maximum of 38,581
Fall Creek	1,820	115,100	161	Unknown	450-1000	254,200-354,800*	55,924-78,056*
Trail Bridge	73	2,088	59	> 3.3	Up to 2,000	up to 22,040	694
Philips Reservoir/ Mason Dam	2,234	95,500	87	1.0	10-400	Unknown	Unknown

\* Estimates derived while multiple outlets throughout the water column were in use and up to 1 million fish were stocked annually.

There is no exact match between Mason Dam and the comparison reservoirs. The reservoir with the closest fit to the Mason Dam project is Cougar Reservoir as it is operated for both irrigation and flood control, has a similar intake depth, and is known to stratify. The non-anadromous fish

composition is unknown but studies indicated that the majority of entrained fish were Chinook salmon. Even if non-anadromous fish comprised up to 49% of entrained fish, that would represent a maximum of 38,581 fish per year.

Fall Creek Reservoir has the most complete entrainment data set for any of the regional reservoirs examined. However, the Fall Creek Reservoir entrainment studies were all conducted when (1) fish were able to exit the reservoir at various locations throughout the water column and not just through the bottom slide gate, (2) during a period in which 1 million chinook salmon were annually stocked and (3) during operations that included very rapid fall drawdowns. Annual entrainment at Mason Dam is likely to be much lower than that measured at Fall Creek as a result of the seasonal water quality limitations near the intake, the low approach velocities, the single bottom gate outlet system and the vast difference in stocking quantities (i.e., 58,000 trout vs 1,000,000 salmon). This point is underscored by a more recent study at Fall Creek following the cessation of the heavy hatchery fish stocking program (Keefer et al. 2010). In this study, total annual entrainment was not estimated, but the total number of entrained fish over 889 days of sampling in a 4-year period was similar to the total number of fish previously enumerated in 54 days of sampling, indicating a substantial decrease in the number of entrained fish with a decrease in the number of stocked fish.

As a result, the total annual non-anadromous fish entrainment at Mason Dam was preliminarily estimated as similar to that of the maximum Cougar Reservoir estimate (38,581), with Fall Creek entrainment data used to identify conditions under which entrainment rates would be highest.

Much of the recent data collected on regional reservoirs has focused on species-specific entrainment and this general estimate was subsequently refined in light of the more detailed fish species information presented below in section 4.1.2.

#### **4.1.2 Species-Specific Entrainment Potential Overview**

##### ***Introduction***

The entrainment potential for individual fish species or group of related fish species was based on the likelihood that a fish would occur near the intake during the Mason Dam hydroelectric project operating period of mid-March to September 30. The following factors were used to evaluate the entrainment potential:

- Species spawning habitat type and location, and spawning timing.
- Seasonal movement patterns.
- General location within the water column.
- Water quality requirements-particularly Dissolved Oxygen (DO), with temperature a secondary factor.

Potential entrainment was evaluated according to the following categories:

**None:** There is no habitat requirement/tolerance or fish behavior that would place the species near the intake during the Mason Dam operating period.

**Minimal:** The species may inadvertently occur near the intake, but the intake is generally located outside of species habitat tolerances.

**Low:** The species may occasionally occur near the intake, but the intake is generally located outside of species habitat preferences, or the project would only occasionally be in operation during the time period that species could occur near the intake.

**Moderate:** Species may routinely or seasonally occur near the intake during portions of the project operating period.

**High:** Species is very likely to occur near the intake during most of the project operating period.

In addition, entrainment potential was also evaluated according to the following question: “If a fish’s behavior placed it in proximity to the intake, would it be able to swim out of the flow field which has a maximum allowable velocity of 1.7 feet/second (fps), but a more normal approach velocity of 1.0 fps?”

Entrainment potential was evaluated for spawning, adult and juvenile life history stages.

#### **4.1.3 Salmonids**

##### ***Rainbow Trout Life History***

According to the ODFW, there are two rainbow trout subspecies in Philips Lake, the native redband trout (a sensitive species) and the stocked rainbow trout.

Optimal lacustrine habitat for both subspecies is characterized by clear, cold, deep lakes. Both rainbow trout subspecies are primarily stream spawners and generally require tributary streams with gravel substrate in riffle areas for reproduction to occur (Raleigh et al. 1984). Locally, redband trout spawn in the spring between April and May in tributaries to Philips Reservoir (PBWC 2011). Migration timing is affected by water temperature and stream flow. After spawning, resident redband trout maintain restricted home ranges until migrating to overwintering areas in the fall (Thurow 1990). Juveniles of migratory forms typically move downstream to lakes or rivers after one to three years in natal streams. At any one time, there could be both fluvial and adfluvial populations in Philips Reservoir as well as non-reproducing juveniles (ODFW 2009).

Optimal oxygen levels for rainbow trout in general are at least 7 ppm, with oxygen needs increasing as the temperatures increases (Raleigh et al. 1984). The lethal DO level is 3 ppm, but the species exhibits strong avoidance behavior of water with DO levels less than 5 ppm. The optimal temperatures for rainbow trout are between 12 to 18 °C , with adults residing in lakes selecting waters with temperatures between 7 to 18 ° C and avoiding areas with temperatures greater than 18 ° C .

The depth distribution of adult lake rainbow trout is generally a function of dissolved oxygen, temperature, and location of food sources. Some reservoir studies have noted a strong tendency for rainbow trout to follow the 18 ° C isotherm, as long as DO remains at satisfactory levels. CH2MHill (2007) noted a tendency for rainbow trout within the Pacific Northwest to be surface oriented. Studies at the Carmen-Smith hydroelectric project in western Oregon (which includes Trail Bridge Reservoir) also noted that rainbow trout were rarely found below the thermocline, even when conditions in the hypolimnion were favorable (Stillwater Sciences 2006). The same study showed that young trout remained in shallow water with abundant vegetative cover and observed no trout more than 10 meters (33 feet) below the surface during spring and summer.

Rainbow trout swimming speeds have been identified as being similar to those of bull trout (Mesa et al. 2004), but studies in the eastern US have identified lower average swimming speeds of 4.3 fps (NY Power Authority 2005) and CH2MHill (2007) estimated maximum rainbow trout swimming speeds at 5 fps.

### ***Rainbow Trout Entrainment Potential***

CH2MHill (2007) reviewed 12 studies in the Pacific Northwest and northern California in which rainbow, cutthroat, brook and/or brown trout entrainment was measured. All of the study reservoirs contained cold and coolwater fisheries and had deep water intakes. No trout were entrained at 8 of the 12 reservoirs. Trout entrainment rates at the other four reservoirs were estimated as ranging from less than 0.001% to 3.2% of the trout population. Trout entrainment details for these reservoirs and their similarities/differences to Philips Reservoir are described below:

- One cutthroat trout out of an estimated 100,000 total cutthroat and rainbow trout population at Timothy Lake was entrained during spring and fall sampling conducted over a three year period. No rainbow trout were entrained in spite of annual stocking of 12,000 to 34,000 adult rainbow trout. Timothy Lake is a 1,280 acre reservoir on the upper Clackamas River, Oregon with an outlet structure 80 feet deep at full pool. Although a smaller reservoir than Philips Reservoir, the total estimated trout population and maximum intake depth below the water surface are similar between the two reservoirs.
- At the Tieton project in eastern Washington, the total trout population is not known, but 60,000 rainbow trout are stocked annually. Entrainment studies identified 37 total rainbow trout, of which 28 were suspected to have been resident in the tailwater below the dam and not entrained fish. Regardless, less than 0.1% of the known rainbow trout population was entrained at this facility. The reservoir covers an area of 2,526 acres with a an intake depth of 200 feet at full pool. The Tieton reservoir covers a similar surface area as Philips Reservoir, but contains a larger volume and is twice as deep.
- During sampling occurring over a three-year period, 16 total trout out of an estimated 100,000 combined cutthroat and rainbow trout population were caught in entrainment studies, most or all of which were thought to be tailrace residents, at Lake Koocanous (Libby Dam) in Montana. This reservoir is much larger than Philips Reservoir (29,000 acres), with

intake depths ranging from 50 to 90-140 feet below the water surface. The intake depths below the water surface are greater than those of Philips Reservoir during dry years, but similar to the levels during wet years and some average years.

- An average of 2.6% of the estimated 51,000 trout population is estimated as being entrained at Lake Lemolo on the North Umpqua River, Oregon. Almost all of the trout were juvenile brown trout (less than 100 mm or 3.94 inches) entrained in the fall as the reservoir was drawn down to its lowest level. In a high drawdown year, where the remaining pool was 12% of its full pool volume, and surface water levels were 36 to 44 feet above the intake, an estimated 1,632 fish were entrained, or 3.2% of the total population. In a low drawdown year in which water levels were 58 to 69 feet over the intake, an estimated 1,005 trout were entrained, or 1.9% of the population. The Lake Lemolo intake depth is similar to that of the Mason Dam intake at full pool. Additionally, although Lake Lemolo is rather deep (80 to 100 feet) directly behind the dam, most of the lake is shallower than 40 feet and the mean depth is only 30 feet at full pool with a large littoral area (Portland State University 2013).

Of the remaining eight studies reviewed by CH2MHill (2007) identifying a lack of rainbow trout entrainment, studies at Cooper Lake, Alaska were quite pertinent to the Mason Dam project. Cooper Lake has a similar surface area to Philips Lake, and although containing a smaller volume and shallower water depths, approach velocities of 1.57 fps are similar to those of the Mason Dam intake. In spite of a minimum pool depth of 8 feet at Cooper Lake, no rainbow trout were entrained (out of an 6,000 total trout population) during the studies.

Other regional studies examined in this report regarding trout entrainment included Fall Creek, Cougar and Trail Bridge Reservoirs in western Oregon, and Wickiup Reservoir in central Oregon. Only Trail Bridge provided detailed information on rainbow trout entrainment in relation to the total population.

- Entrainment studies at Trail Bridge Reservoir identified that 0.01% of the estimated reservoir rainbow trout population was entrained annually (Stillwater Sciences 2006). Trail Bridge is a small reservoir, much shallower than Philips Lake and with approach velocities above 3.3 fps.
- Entrainment studies at Fall Creek identified the number of rainbow trout in relation to the total number of entrained fish, but did not identify the relationship between entrainment and within reservoir populations. Homolka and Smith (1991) identified that most entrainment of rainbow trout and other non-anadromous species occurred when the reservoir was drawn down to levels of 30 feet above the intake and that rainbow trout comprised less than 0.6% of the total entrainment, with steelhead comprising another 1.7% of the entrained fish. More recent studies from 2006- 2009 identified that a mix of rainbow trout and steelhead comprised 0.12% of entrained fish (Symbiotics 2011). Both studies identified low rates of rainbow trout entrainment but no information was provided on the relationship to total population estimates.

- Wickiup Reservoir trout entrainment was thought to mostly occur when pool volume was 20% or less of full pool (Symbiotics 2008). Wickiup is a larger reservoir than Philips, but the intakes are located at similar depths.

Of the studies reviewed, key factors affecting rainbow trout (and related, non-anadromous trout species), the following factors appeared to be the most important in affecting entrainment<sup>2</sup>:

- Changes in Intake Depths. Studies evaluating entrainment in relation to water levels above the intake have indicated greater entrainment rates when surface water levels are less than 30 feet above the intake, with little to no entrainment when surface water levels exceed 50-60 feet above the intake. This relationship first identified in Homolka and Smith (1991), has been confirmed in many other studies, most recently by Keefer et al. (2010). Keefer et al (2010) identified that at Fall Creek Reservoir, approximately 100 fish per day passed through the dam when water levels were less than 30 feet over the bottom intake, with very minimal entrainment (i.e., 1 fish/day) when water levels were more than 60 feet over the slide gate intake and the multi-level DSM system was not in operation.
- Reservoir Drawdown Volumes. Trout entrainment is higher when pool volumes are 10-15% of full pool volume (20% at the larger Wickiup Reservoir).
- Approach velocities. During their review of regional studies, CH2MHill (2007) identified minimal risk to rainbow trout being entrained through deep intakes in cold and coolwater fisheries if approach velocities are 3.5 fps or less as long as the trout are greater than 6 inches. This point was underscored by the lack of entrainment at Cooper Lake in which surface water levels are drawn very low over the intake, but approach velocities are 1.57 fps.
- Population Age Class Structure. Most regional studies report a lack of subadult to adult (> 6 inches) trout entrainment.

In addition, many studies have identified that as although fish may move throughout a reservoir, as long as suitable habitat remains, trout will avoid areas with poor water quality conditions (see Appendix A).

These factors in relation to Philips Reservoir characteristics, local life history data and reservoir trout populations were used to evaluate the rainbow trout entrainment potential under current conditions and potential future conditions during later stages of the license period. The current condition is estimated as a rainbow trout population of between 60,000 to 100,000 fish, of which 58,200 6 to 8 inch fish are stocked annually. The future condition, is for a larger trout population with up to 200,000 rainbow trout fingerlings (3 inch) to be stocked annually along with annual stocking of tiger trout. There is no entrainment information on the tiger trout introduced by ODFW, but ODFW has indicated that tiger trout entrainment is expected to be similar to that of adult

---

<sup>2</sup> In addition to having a deep intake, location with the Northwest or adjacent states, and possessing a cold/cool water fishery with a trout component, which were study selection criteria.

rainbow trout (T. Bailey, ODFW, pers comm).

**Spawning:** Rainbow trout spawn in the Philips Reservoir tributaries which are located well away from and upstream of the intake. There is **no** potential for entrainment of spawning rainbow trout under either current or potential future conditions. Tiger trout are sterile hybrids and do not spawn.

**Adults:** Although redband and other rainbow trout are adapted to a wider range of environmental conditions than other salmonids, they still exhibit seasonal movements and are restricted by very low oxygen conditions. DO levels range from less than 5 ppm to anoxic conditions near the intake between mid June and mid August. During this time period, water levels are maintained at least 30 feet above the intake in all years, and 60 feet or more above the intake in average and wet years. With unsuitable DO conditions near the intake and availability of other habitat, rainbow trout would not be expected to occur near the intake during this time period.

Both temperature and DO conditions at the Mason Dam intake fall within adult rainbow trout tolerances in May to early June and within the preferred range in September. During the spring, water levels in all years except the extremely dry 1988 have been between 60 to 90 feet above the intake. Rainbow trout could occur near the intake during the spring, but if adult rainbow trout encountered the intake, they would be easily able to outswim the 1.0 fps approach velocities.

During September, DO and temperature conditions are quite suitable for rainbow trout near the intake. At this time the reservoir is drawn down to its lowest level with both depths over the intake and pool volume reduced. During September (and the rest of the fall period when the Mason Dam hydroelectric project would not be operating), rainbow trout would most likely be within the intake vicinity. The risk of entrainment would still be low due to the strong swimming speeds of adult trout in relation to the 1.0 fps intake approach velocities.

The overall risk of adult rainbow trout entrainment during the Mason Dam operational period is **none to minimal**. The same risk is expected for adult tiger trout.

**Juveniles:** As described for adults, juvenile rainbow trout would likely exhibit avoidance of deep water habitats near the intake during the spring when surface water levels are well above the intake and there is abundant available littoral habitat. Likewise, juveniles would also avoid the intake area between mid June and mid August when DO levels become anoxic near the intake.

Juvenile trout would likely occur in the intake vicinity as the reservoir is drawn down and DO levels increase in September. At this time, juveniles may or may not be able to outswim the intake velocities resulting in a risk of entrainment. The risk of entrainment would be higher in years in which pool volumes were drawn down to less than 15% or less than 30 feet over the intake. These conditions occur in approximately 25% of the years.

Healthy juveniles have burst speeds greater than the Mason Dam approach velocities. During most years in which pool volumes remain greater than 30% full volume, the risk of juvenile trout entrainment would be **minimal to low**. During dry years when fish are concentrated in a smaller

volume (or approximately 1 in 4 years), entrainment risk would increase to **moderate**.

Only adult tiger trout are stocked in Philips Reservoir so no entrainment risk was evaluated.

**Stocked Fish:** Only subadult and adult rainbow trout are currently stocked in Philips Reservoir. Adults (6-8 inches) are stocked in June and subadults (6 inches) in September. The potential for stocked fish to be entrained would depend on their condition during the stocking period and the location of the stocking. Stocked fish tend to stay in the general vicinity of their release point for at least 7 to 10 days (Gonzalez 2012). Hatchery fish also experience a high level of stress, disorientation and other adverse effects from sudden changes in aquatic environments (from hatchery to truck to reservoir). The likelihood of stocked fish to be entrained if released in June, when water levels are quite high over the intake would be less than the likelihood of entrainment in September when water levels are low.

Because of the release point near the dam, and the initial period of disorientation, the entrainment potential is rated as low to moderate for spring releases and moderate to high for fall releases for an overall rating of **moderate**. The entrainment risk could be substantially reduced with fish stocking at other accessible locations around the lake.

In the future, and if yellow perch can be reduced, up to 200,000 fingerlings could be stocked near the Mason Dam intake in the fall. The combination of initial disorientation, low swimming speeds and a seasonal low pool volume, would place fingerlings at a **high** potential for entrainment. As noted above, the entrainment risk could be substantially reduced with fish stocking at other accessible locations around the lake.

### ***Bull Trout Life History***

Bull trout spawn in the late summer or fall, generally between mid September to October. The eggs hatch during the winter, with fry emerging from the gravel in April or May. Juveniles exhibit a strong benthic orientation, hiding within cobbles, boulders, woody debris and other cover during the day and are more active at night. Juveniles feed mostly on macroinvertebrates, shifting to a piscivorous diet when they reach sizes of 100 to 200 mm (or 2 to 3 years old, and 3.9 to 7.9 inches). Although juveniles can migrate to lakes at any age, it is unusual to find young less than 200 (7.9 inches) in lakes and reservoirs. The majority of adfluvial juveniles migrate to lakes when they are 2 or more years old (Pratt 1992, Goetz 1997, Flatter 2000).

Sexual maturity is not reached until at least four years of age, with an estimated longevity of 5 to 7 years, and up to 12 years (FWS 1998). Adults may spawn either every year or in alternate years. The bull trout can exhibit either migratory or resident life history strategies. Resident fish complete their life history cycle in the same stream in which they spawn. Migratory bull trout hatch and rear in tributary streams and then migrate to larger streams (fluvial form) or lakes (adfluvial form) to mature, returning to the smaller streams only to spawn. Both forms can co-occur and resident fish can produce migratory forms (FWS 1998).

Bull trout require among the coldest water temperatures of any native Pacific Northwest salmonid

(FWS 2002, FWS 2010), requiring temperatures between 2 to 15 °C with thermal refugia where temperatures exceed the upper limit, and with different temperature ranges necessary in different life history stages (e.g., optimal temperatures of 5 to 9°C for spawning, 2 to 4 °C for incubation, and 7 to 8 °C for growth). Bull trout also require well oxygenated water. DO levels > 8 ppm are preferred, with short term tolerances of DO levels between 6 to 8 ppm. The species can not tolerate DO levels less than 6 ppm.

Because of the requirement for cold, well oxygenated water, habitats used by migratory bull trout include bottoms of deep pools in streams and also large coldwater lakes and reservoirs. Within lakes and reservoirs, bull trout inhabit the cold, deeper sections and primarily occur within the upper hypolimnion (Goetz 1989, Fraley and Shepard 1989, McPhail and Baxter 1996, Flatter 2000, Petersen et al. 2002). Bull trout also forage in cool, shallow, littoral zones which tend to occur in the upper reservoir arms where tributaries enter the reservoir. However, bull trout location within a given lake or reservoir varies by season and type of lake.

There are a number of lakes/reservoirs in which bull trout have (1) been documented and (2) for which data on habitat preferences and seasonal movements exist. These include Beulah Reservoir (Gonzalez 1998, Schwabe et al. 1999, Schwabe et al. 2002, Petersen et al. 2002) and Lake Billy Chinook (Ratliff et al. 1996, Beauchamp and Van Tassel 2001) in Oregon, and Flathead Reservoir in Montana (Flatter 2000, Fraley and Shepard 1989). The two Oregon reservoirs differ in thermal regime. Beulah Reservoir temperatures rarely exceed 15 °C and DO levels generally remain above 6.5 ppm, without developing anoxic conditions. Lake Billy Chinook does thermally stratify with temperatures in the epilimnion reaching 15 to 21 °C during the summer. In both of these reservoirs, studies have shown that bull trout migrate out of the main body of the reservoirs during the spring into either upstream tributaries or the unstratified reservoir tributary arms (March to mid-May in Beulah and June to mid-July in Lake Billy Chinook). Migration back to the reservoirs, where the bull trout overwinter, occurs between late October and November.

At Flathead Lake in Montana, bull trout use all parts of the reservoir depending on the season, tending to use littoral zones in the spring and fall, deeper water in the winter and migrating out of the reservoir during the summer (Flatter 2000). The bull trout congregate at the upper end of the reservoir in the spring, moving into the tributaries by mid-June. They return between mid-September to mid-October to the upper portion of the reservoir, where they stay for several weeks before dispersing throughout the reservoir. Fraley and Shephard (1989) suggested that the seasonal movements out of the reservoir reflected a response to changes in temperature, photoperiod and discharge as the lake is oligotrophic, lacking strong stratification.

Philips Reservoir is characterized as a meso to eutrophic lake (Portland State University 2013). In meso and eutrophic lakes, such as Philips Lake, oxygen levels tend to be depleted during the summer. In these types of lakes, bull trout migrate out of the lake in the spring due to a complex set of factors which include changes in temperature and photoperiod (as in oligotrophic lakes), as well as moving within or out of the reservoir when conditions in the hypolimnion become unsuitable. In these lakes, bull trout return in the fall and use the water body primarily as overwintering habitat (see for example, Flatter 2000, Stoval 2001, Petersen et al. 2002 and 2003, McPhail and Baxter

1996).

The bull trout within Philips Reservoir are genetically similar to the Malheur River fish which begin to stage and outmigrate beginning in April (Gonzalez 2012). As for all other regional reservoirs in which bull trout have been studied, it is highly likely that beginning in June (or as early as April), any bull trout near the eastern end of Philips Lake would migrate to other areas according to photoperiod and temperature cues, and also exhibit strong avoidance of areas with unfavorable temperature and DO regimes.

Seasonal outmigration in other reservoirs has been linked to a point in which spring temperatures reach approximately 15 °C, which also tends to occur with increasing photoperiod. In Mason Dam, 15 °C temperatures coincide with the development of low (less than 6 ppm) DO conditions near the intake.

Adult bull trout (300 mm [11.8 inches] or greater) are able to swim at 15.08 fps, with burst velocities of 22.5 fps (Taylor and Lewis 2010). Juvenile bull trout (less than 200 mm or approximately 8 inches) have a maximum swimming speed of 1.79 fps.

### ***Bull Trout Entrainment Potential***

Bull trout entrainment data have been collected at Beulah and Trail Bridge Reservoirs in Oregon. Entrainment at Beulah was measured according to two different water release scenerios: through spillway releases and through a deep water intake located 75 feet below the full pool surface and approximately 3 feet above the bottom. With spillway releases, the entrainment risk was greatest in winter and spring. When the water releases occurred solely through the deep intake, bull trout entrainment was reduced by 80% in 2001, and subsequently reduced to 0 in 2002. Regardless of the release type, Schwabe et al. (2002) identified that entrainment was minimal between mid-June and October. At Trail Bridge Reservoir, 0 bull trout out of an estimated total 2,000 bull trout population were entrained during the monitoring period (Stillwater Sciences 2006).

As of spring 2012, there were no known adult bull trout in Philips Lake. Two subadults were found in 2011, but their status is unclear (i.e., entered reservoir during extremely high spring flows or resident). The analysis presented herein is for the population that currently occurs (2 subadults, 213-234 mm or between 8.4 and 9.2 inches ) or any population that establishes in the future.

**Spawning:** Bull trout spawn in cold tributaries which are located well away from and upstream of the intake. There is **no** potential for entrainment of spawning bull trout.

**Adults:** Three general factors would affect adult bull trout entrainment at Mason Dam during the time period that the hydroelectric project would be operational.

(1) The tendency for seasonal outmigration in response to temperature and photoperiod cues. As for other reservoirs, it is highly likely that beginning in May to June (or as early as April), any bull trout near the eastern end of Philips Lake (where the intake is located) would migrate towards and up the

tributaries which enter the reservoir at the far western end. Migrating adult bull trout would return to the reservoir in the fall for overwintering.

(2) Development of low oxygen conditions near the intake. Bull trout are more sensitive than other salmonids to low dissolved oxygen conditions, not tolerating DO levels than 6 ppm. DO levels less than 6 ppm, and ranging to anoxic conditions, occur between mid-June and mid-August. As DO levels rise between mid-August and mid-September, temperatures remain quite high (see figures 7 and 8). It is highly likely that adult bull trout remaining in the reservoir between June and September, if any, would not occur near the intake during this time period due to highly unfavorable water quality conditions.

(3) The strong adult bull trout swimming speeds of 15 to 22 fps.

The only time period in which the project would be both (1) in full operation in most years, and (2) in which adult bull trout would likely be within the reservoir or occupy habitats near the intake would be between mid-April to May.

Any overwintering adult bull trout would occur at deep levels, such as near the intake. However, the Mason Dam hydroelectric project would not be operational during this time period and releases would be below 10 to 25 cfs with very low approach velocities.

Movements between deep wintering habitat and more shallow lake levels during the spring could put adults in the vicinity of the intake between mid-March and mid-April when the project would operate within one in 10 years (in late March) to three of 10 years (in early April).

Approach velocities between mid-March and May would be less than 1.0 fps, well under both maximum and sustained bull trout swimming speeds. Any fish entering the intake vicinity would easily be able to outswim the intake velocities. The potential for adult bull trout entrainment during project operation is **none to minimal**.

**Juveniles:** Temperature and DO conditions are more restrictive for juvenile bull trout. There would be no months during which the project would be in full operation each year and in which the water quality would be suitable near the Mason Dam intake for juvenile bull trout. The only time period during which both juvenile bull trout entrainment could occur and the Mason Dam project would be operational would be between mid-March and April, during which time, the project is anticipated to run approximately during 10 to 30% of the years.

If juvenile bull trout 200 mm (7.9 inches) or less entered the intake area, they may or may not be able to outswim the intake velocities. However, there is almost no likelihood of juveniles less than 200 mm even occurring within the reservoir, or if within the reservoir, outside of upstream littoral zones.

Two juvenile/subadult bull trout occur within the reservoir. They were netted in the littoral zone near the western end of the lake where the tributaries enter. These fish are greater than 8.4 inches

and would likely forage in both the lake shallows and in the open reservoir area. Fish this size could swim at faster speeds than the 1 fps intake velocities.

The overall risk of juvenile to subadult bull trout entrainment is **none to minimal**.

#### **4.1.4 Percids**

##### ***Yellow Perch-Life History***

Yellow perch often occur in meso and eutrophic lakes with adults preferring summer temperatures of 17.6 to 25 ° C. Spawning typically occurs at temperatures from 6.7 to 12.2 ° C. Yellow perch can successfully overwinter at temperatures from 4 to 6 ° C , although growth tends to stop below 8 to 10 ° C . They are active in the winter beneath ice or in deep water (Scott and Crossman 197, FWS 1983). Upper lethal temperatures are from 26 to 30 ° C.

Optimal DO levels for yellow perch are 5 ppm or greater, but the species is adaptable to a wider range of conditions (DO levels of 2 to 4 ppm, even as low as 1 ppm in some cases), and cooler temperatures. The ability to tolerate very low DO levels allows the species to inhabit deeper water of stratified reservoirs which are often very low in oxygen.

Yellow perch are slow swimmers with maximum speeds of 1.77 fps and average speeds closer to 0.88 fps. They do not accelerate quickly. As a result, yellow perch tend to travel in large schools of 50 to 200 fish which provides protection for younger fish and easier prey capture for older fish (Herman et al. 1959, Craig 1987). Young of the year perch tend to school more than older fish, which occasionally travel alone (Helfman 1979).

Perch exhibit strong diurnal behavior. They are active and feed during the day in open water or shoreline habitat. At night they appear to rest on the bottom and refrain from feeding. The exception occurs during spawning, as the perch become active both day and night.

Generally, yellow perch follow a seasonal migratory pattern that brings them in to littoral zones in the spring, to mid reservoir levels as temperatures rise in the summer, and into very deep water during the winter. They are typically found in water around 30 to 40 feet deep (9 to 12 m), but may seek deeper water in the winter.

Spawning in Philips Reservoir occurs immediately after ice-out, which generally occurs in mid-April. Littoral habitats found in shallow embayments are used for spawning. According to Bailey (2012), although perch generally spawn in water less than 10 feet deep, they have been reported spawning in water as deep as 25 feet.

Although tolerant of the temperatures and DO levels near the Mason Dam intake during most of the year, yellow perch seasonal behavior and depth preferences would place them near the intake most often between mid-July and September. In October when the pool is drawn down to 30 to 40 feet, they would be seeking the deepest water possible, which may or may not be near the intake.

Yellow perch typically inhabit lakes, ponds and reservoirs, but they can occur in river systems. In rivers, they occur in habitats similar to their typical lacustrine habitat, such as low velocity deep pools, backwaters and side channels. Rapidly flowing water does not provide suitable habitat for the species and young perch can not tolerate flows greater than 0.08 fps.

### ***Yellow Perch-Entrainment Potential***

**Spawning:** Spawning occurs in most if not all shallow embayments in Philips Reservoir in water generally around 10 feet deep, although spawning can occur in water up to 25 feet deep (Bailey 2012). Shallow, vegetated or other littoral habitat is located more than 850 feet from the Mason Dam intake which is almost always covered by at least 70 feet of water during the spring spawning period. There is **no** potential for entrainment of yellow perch in their spawning habitat, but there is some potential for entrainment as perch move from deep water to spawning habitats (see discussion below).

**Adults and Juveniles:** The temperature and dissolved oxygen conditions would be suitable for yellow perch at the intake most of the time the Mason Dam project would be in operation. Both the daily and seasonal perch migration patterns could place the perch in the intake proximity. The species' seasonal behavior and depth preferences would place them near the intake most often between mid-July and the end of September. In October when the pool is drawn down to its lowest level, they would be seeking the deepest water possible, which may or may not be near the intake. Because the Mason Dam hydroelectric project would not be operational in the fall or early winter, yellow perch behavior during these seasons was not considered in the entrainment potential analysis

Yellow perch are slow swimmers with average or sustained speeds less than or similar to the approach velocities (with velocities depending on discharge flows). Any yellow perch, adult or juvenile, that approached the intake too closely would likely be entrained. The tendency for yellow perch to travel in large schools could result in episodic entrainment events. Large numbers of dead yellow perch immediately below Mason Dam have been observed from mid-August to mid-October, underscoring the high potential for yellow perch entrainment from late summer into fall (Jeff Colton, BVID, Pers Comm; Leslie Gecy, observations made during other Mason Dam project biological studies).

The potential for both adult and juvenile yellow perch entrainment during project operation is **high**.

### ***Walleye -Life History***

Walleye are a highly piscivorous, cool, deepwater species whose native range is centered in the Great Lakes region (Scott and Crossman 1973). The species eyes' are highly sensitive to light which tends to result in a diurnal pattern of spending daylight hours in deep water and shallower waters in the evening or at other times when light is low, such as under thick ice or in other areas with underwater cover. Although described as an opportunistic feeder, the walleye's diurnal behavior of moving to different water depths at dawn and dusk tends to place them in frequent contact with yellow perch. As a result, where yellow perch and walleye coexist, yellow perch tend to be the walleye's primary prey. On a seasonal basis, walleye tend to follow a similar pattern as

yellow perch as they move to shallow waters in the spring and to deeper reservoir areas in August and September. Lacustrine spawning habitat consists of shallow (1 to 6 ft deep) rocky shores or other areas with rip-rap or rubble, inlet streams or flooded marshes.

Preferred adult temperatures are from 20 to 24 ° C , with the greatest activity between 15 to 18 ° C , and adult growth stopping below 12° C . Spawning tends to occur between temperatures of 6 to 11 ° C and temperatures of less than 10 ° C are required for gonad maturation. Upper lethal temperatures are from 29 to 32 ° C (Kerr et al. 1997). Walleye prefer temperatures at or near the thermocline in stratified lakes, even if less than optimal dissolved oxygen levels (Fitz and Holbrook 1978).

Adult walleye can tolerate DO levels as low as 3 ppm for a short period of time, but prefer DO levels greater than 5ppm. DO levels below 2 ppm tend to be lethal (Kerr et al. 1997).

Juvenile fish require slightly warmer water than adults and tend to seek shallow water habitat in the spring and early summer. As summer progresses, juveniles tend to move to deeper habitats similar to those of adults.

Walleye are vigorous swimmers, with burst speeds measured from 6.02 fps for juveniles and up to 8.57 to 11.2 fps for adults (NAI 2009).

#### ***Walleye-Entrainment Potential***

Although walleye were illegally introduced at a similar time as yellow perch, their abundance has remained very low (ODFW 2013).

**Spawning:** Spawning occurs in shallow water near rubble or rocky shores, flooded marshes or tributary inlets. The nearest tributary inlet or flooded marsh is located more than 2,000 feet from the dam intake. The nearest shallow, rocky shore habitat during the spring spawning period is located 65 to 100 feet from the Mason Dam intake. There is no potential for entrainment of walleye spawning in flooded marshes or lake tributary inlets. There is very limited potential for entrainment of walleye spawning on rocky shores, but with some potential for walleye to travel near the intake while moving between deepwater and shallower spawning habitats. Overall there is a **minimal** risk of spawning walleye entrainment.

**Adults:** The adult walleye diurnal and seasonal patterns of moving between deeper and shallow water mimic (in reverse) those of the yellow perch, its primary prey species. However, yellow perch can tolerate lower DO conditions than walleye. The walleye's general behavior could place it near the Mason Dam intake during most, but not all, of the time the project would be in operation. However, water quality conditions would limit the likelihood of the walleye being near the intake during the project operation to late summer and September.

If an adult walleye approached the intake during this time period, it would not likely be entrained as it is a vigorous swimmer well able to outswim the intake velocities. Even at less than optimal conditions, walleye's could easily escape the intake approach velocities. The exception could occur

if walleye follow their yellow perch into very low oxygen areas, where their swimming ability would be severely comprised.

The potential for adult walleye entrainment during project operation is **minimal**.

**Juveniles:** Because juvenile fish require warmer water than adults, their behavior would limit their likelihood of being near the intake during project operation to late August and September when the intake is oxygenated. As for adults, juveniles are vigorous swimmers with both maximum and sustained speeds greater than intake velocities.

The potential for juvenile walleye entrainment during project operation is **minimal**.

#### **4.1.5 Centrarcids**

##### ***Bass and Crappie-Life History***

Bass and crappie tend to occupy littoral habitats. Optimal conditions for largemouth bass are lakes with extensive areas of shallow water (i.e., less than 15-20 ft) to support submerged aquatic vegetation, but deep enough to allow overwintering (Scott and Crossman 1973).

Largemouth bass spawn during the spring in shallow, littoral habitats and remain to guard the young once hatched. Fry remain in shallow, protected habitats such as coves and flooded tributary mouths as the adults return to other shallow lacustrine habitats with abundant vegetation.

Smallmouth bass were originally limited in range to eastern central North America, but have been widely stocked elsewhere (Scott and Crossman 1973). Unlike the warm, weedy lakes and slow moving rivers preferred by the largemouth bass, cooler lakes, streams, and rivers are preferred by smallmouth bass. Lakes that hold populations of smallmouth bass are generally over 100 acres in size, over 30 feet deep and thermally stratified, and have clear water and large areas with rock or gravel substrate (Scott and Crossman 1973).

Smallmouth bass also move toward shore in early spring, but select sites with a clean stone, rock, or gravel substrate for spawning. As for largemouth bass, the smallmouth guard their young after hatching and the young remain in shallow protected areas after the adults leave. During winter, the adults tend to move to deeper water (Langhurst and Schoenike 1990). Smallmouth bass are found almost exclusively in the epilimnion during summer stratification in northeastern Wisconsin and Ontario, but frequent depths up to 40 ft in northern New York (NAI 2009).

Lacustrine black crappie habitat can be characterized as the littoral zone of large warmwater reservoirs and lakes, usually with some type of in-water cover such as sunken logs (Scott and Crossman 1973). Spawning occurs primarily in April, typically in coves and shallow embayments, near but just beyond the edge of submerged vegetation (approximately 6 to 16.5 ft deep, ODFW 2012). Although this species does not do well in the main body of large lakes, it can become abundant in shallow areas and bays (Scott and Crossman 1973). Crappie feed on the surface during dawn and dusk. During the winter, crappies often move to deeper water along vertical

structure such as pilings or dams (NAI 2009).

In general, optimal temperatures for growth of adult bass range from 24 to 30° C, with very little growth below 15° C. However temperature tolerances differ among species. Lakes and rivers that are clear enough and rocky enough to be suitable for trout, but in which the water temperature is too high for trout, are generally suitable for smallmouth bass. Preferred smallmouth bass temperatures are between 16 ° C and 26 ° C , although nest building and spawning can occur at lower temperatures. Largemouth bass are considered warmwater species, preferring temperatures between 27 to 30 ° C . However, the largemouth bass is intolerant of low dissolved oxygen concentrations and is therefore susceptible to winterkill in its vegetated, high oxygen demand habitat

Optimal temperatures for black crappie are between 22 to 25° C; with no growth below 11° C or above 30° C .

Smallmouth bass require more than 6 ppm DO for optimal growth and largemouth bass more than 8 ppm. Both species can tolerate DO levels as low as 4 ppm, but show distress at these levels. Levels below 2 ppm cause mortality. DO requirements for black crappie are assumed to be above 5 ppm, the general level for warmwater fish. In lacustrine environments, these three species tend to select temperature strata with suitable oxygen levels, although, as noted above, the largemouth bass preference for shallow, high temperature vegetated areas tends to result in late season or winterkill mortality.

Sustained swim speeds for small juvenile largemouth bass range from 1.01 to 1.64 fps within a temperature range of 15 to 30°C (NAI 2009). Swim speeds were higher for larger juveniles and small adults (1.80-2.17 fps). Maximum juvenile or “burst” speeds are estimated at 3.2 to 4.2 fps and higher for adults.

Smallmouth bass sustained swim speeds have been estimated as 1.8 fps for juveniles and 3.9 fps for adults. Maximum speeds of 3.6 to 7.8 fps for juvenile and adults, respectively have been estimated (NAI 2009).

Black crappie swim speeds have not been studied. However, studies of the related white crappie indicate that crappies are quite slow swimmers, with speeds from 0.5 to 0.75 fps at optimal temperatures, and reduced to 0.18 fps in cold water. Maximum speeds have been estimated at 1.0 to 1.5 fps. However, poor orientation to current has also been exhibited (NY Power Authority 2005, NAI 2009).

Swimming speeds of all of the above species is reduced in cold water.

### ***Bass and Crappie-Entrainment Potential***

Most regional entrainment studies are focused on salmonids. Entrainment studies over a 2-year period at Fall Creek Reservoir (Downey and Smith 1992) identified that although anadromous salmonids comprised 77.5% of the total fish moving through the reservoir outlet, that black crappie

comprised another 21.9% of the entrained fish. Crappie entrainment occurred almost entirely during November and December when the reservoir was drawn down to its lowest level, a point 30 feet above the intake. Some entrainment also occurred at reservoir levels between 30 to 60 feet over the intake (Ken Holmolka, ODFW, pers comm).

**Spawning:** All species spawn in shallow water. Largemouth bass tend to spawn in shallow, vegetated or other littoral habitat, which is located more than 850 feet from the intake. Black crappie spawn in shallow water (6-16.5 ft deep), which occurs well away from the Mason Dam intake, which is almost always covered by 70 feet of water during the spring spawning period. There is **no** potential for entrainment of spawning largemouth bass or black crappie.

Smallmouth bass spawn along shallow or rocky shorelines. The nearest potential habitat is located 65 to 100 feet north and east, respectively from the Mason Dam intake. Although the intake is relatively close to potential spawning habitat, smallmouth bass would not be spawning at the depth of the Mason Dam intake. There is **no** potential for entrainment of spawning smallmouth bass.

**Adult:** Both adult largemouth bass and black crappie prefer shallow, warm water habitats and not deep, cool open water areas. Largemouth bass, in particular are strongly oriented towards shallow, vegetated habitats limiting any exposure to a deep intake. There is **no** potential for entrainment of adult largemouth bass.

Although generally preferring shallow water, crappie approach the intake as the reservoir is drawn down or in moving towards deeper water during the winter. In approximately one-quarter of the years, the reservoir is drawn down to a level less than 30 feet above the intake. In these years, crappie would likely be concentrated in water near the intake. The time period in which this would occur would be from mid-August until the end of September. (Also continuing through the fall but the Mason Dam hydroelectric project would not be operational during that time period.) If crappie did occur near the intake, they would likely be entrained, as they are poor swimmers.

The potential for black crappie to be entrained during project operation would be restricted to a period from mid-August to late September, in some years. As a result, the overall potential for black crappie during project operation would be **moderate to high in dry years**, but **minimal to low in other years**. Because the population is extremely low, the actual number of fish entrained would be very low regardless of the year.

Smallmouth bass are cool water species with strong preferences for well-oxygenated water. Although smallmouth bass may overwinter in deep water, the Mason Dam hydroelectric project would not be operational during this time period. DO levels are suitable for smallmouth bass near the intake during the spring, but temperatures are too cold. As described for the salmonids, as temperatures warm near the intake, DO levels drop. This combination results in unsuitable smallmouth bass conditions during most of the project operational period. Smallmouth bass could occur near the intake during September. Because adult smallmouth bass are vigorous swimmers, they would not likely be entrained. The overall risk of adult smallmouth bass entrainment is **minimal**.

**Juveniles:** Juvenile bass and black crappie reside in shallow water but do forage outside of that area. Juvenile smallmouth bass would be vulnerable to entrainment if they occurred within the intake vicinity, but their preference for shallow littoral areas and protected coves limits their exposure to a deep intake. Larger juveniles could move from littoral habitats during the late season and occur within the intake vicinity during September. However, by this time, the larger juveniles bass would be able to escape the intake approach velocities. The crappie would not. The overall risk of juvenile bass entrainment is **none** for small juveniles and **minimal** for larger juveniles. The risk of juvenile crappie entrainment is rated as **moderate to high**.

#### 4.1.6 Cyprinids

##### *Northern Pikeminnow-Life History*

The northern pikeminnow is a native fish that prefers lakes and slow-moving water. The species feeds on aquatic invertebrates as juveniles (up to 300 mm), with crayfish and small fish increasing in importance as the fish grows larger (Gadomski et al. 2001). Adults continue to feed on crawfish, molluscs, and other macroinvertebrates as well as fish. Preferred species include salmonids, sculpins and suckers. Although the pikeminnow has been identified as an important salmonid predator, a number of studies have identified crayfish as a key prey item (Zorich 2004).

Northern pikeminnow spawn in the spring when temperatures reach 12 to 18 ° C . Once spawning occurs, the adults leave the spawning area without parental care. Spawning habitat includes gravelly areas at tributary inlets, and clean rocky substrate along lakeshores in both shallow and deep littoral areas. Spawning typically occurs in slow-moving water.

Seasonally, the pikeminnow tends to move towards the shoreline areas in the spring and into deeper water later in the season (Martinelli and Shively 1997). Within rivers, they are frequently associated with riprap, rocky outcrops or structures (Zorich 2004).

Northern pikeminnow can tolerate a wide range of temperatures. No specific tolerances were located in the literature, but as a coolwater species, the temperature tolerances were assumed to be similar to that of the smallmouth bass.

The pikeminnow is not a strong swimmer with sustained speeds of 0.74 fps and maximum speeds of 1.6 to 2.7 fps (Mesa and Olsen 1993, Zorich 2004).

##### *Northern Pikeminnow-Entrainment Potential*

**Spawning:** Spawning habitats can include both shallow, gravelly areas in embayments and near tributaries, as well as rocky lakeshores. The nearest embayment/tributary habitat is located 850 feet from the intake. There is no potential for northern pikeminnow entrainment during spawning in these habitats. Based on an analysis of spring reservoir water levels in relation to a detailed BOR topographic map of the dam face and adjacent areas (maps on file with Baker County), the intake is located 65 to 100 feet from a rocky shore that could possibly be used for spawning. There is some potential for the pikeminnow to travel near the intake while moving between deepwater and

shallower spawning habitats. Overall there is a **minimal** risk of spawning northern pikeminnow entrainment.

**Adult:** The combination of seasonal movements from shallow to deep water and the northern pikeminnow temperature preferences could place fish within portions of the intake vicinity between mid-August and September. The pikeminnow are relatively slow swimmers, and if they occur within the intake vicinity, would likely be entrained. Entrainment might also be high following the September rainbow trout stocking, which occurs near the dam. There is a **moderate potential** of adult northern pikeminnow entrainment during the late summer and early fall.

**Juveniles:** Juvenile pikeminnow tend to remain in shallow water areas where aquatic invertebrates and small fish are readily available. As the reservoir draws down in September and suitable temperature and DO conditions occur near the intake, juveniles could occur in the intake vicinity. If juveniles occur near the intake they would likely be entrained. Because the overall likelihood of juveniles being near the intake during project operation is low and restricted to the fall, the overall risk of juvenile northern pikeminnow entrainment during project operation is **minimal to low**.

#### 4.1.7 Catostomids

##### *Suckers-Life History*

Suckers are very abundant throughout the Columbia River drainage (Scott and Crossman 1973). Because of their abundance, they have not been as extensively studied as rarer species, introduced species or predaceous fish (Schmetterling and McFee 2006). Their habitat generally occurs within slow-moving portions of rivers and in lakes. Largescale sucker fry feed on zooplankton, but juveniles and adults feed on benthic invertebrates, diatoms, filamentous algae and other plant material. Little is known about seasonal or daily sucker movements in lakes and reservoirs, but adults seem to be relatively sedentary benthic feeders outside of the spawning period. During the summer, adults have been caught both above and below the thermocline in stratified reservoirs.

Largescale suckers use a wide range of substrates and water depths for spawning and are not generally considered spawning-habitat limited. However, some studies have indicated a preference for sandy or gravelly lake shoals in the Columbia River system (Dauble 1986, Baxter 2002).

The bridgelip sucker occurs in lakes and river backwaters with sandy or muddy substrates. Spawning occurs in the spring shortly after ice-out. Their diet consists of aquatic insects, crustaceans and algae that is scraped off of bottom rocks.

Suckers in general prefer DO levels greater than 3 ppm and can not tolerate DO levels less than 2.4 ppm. There is little documentation on temperature preferences.

Sustained swimming speeds for various species of sucker have been measured at 1.4 to 4.9 fps, with maximum speeds from 4.0 to 7.9 fps (Baxter 2002).

### ***Suckers-Entrainment Potential***

Most regional entrainment studies have focused on salmonids. Entrainment studies over a 2-year period at Fall Creek Reservoir (Downey and Smith 1992) identified that anadromous salmonids and black crappie comprised 99.4% of the total fish moving through the reservoir outlet, with other fishes (including suckers) cumulatively totaling less than 1% of the annual entrainment. At the Blue River Reservoir, juvenile suckers comprised 4% and adult suckers 0.5% of the measured entrainment (Downey and Smith 1989). Most of the sucker entrainment occurred between October and December, a time period during which the Mason Dam hydroelectric project would not be operating.

**Spawning:** Reservoir sucker habitat can be varied but given the depth of the Mason Dam intake during the spring (more than 70 feet below the surface), it is not likely that spawning would occur within the vicinity. The nearest likely spawning habitat is located more than 1,000 feet from the intake. The potential for entrainment of spawning suckers is **none to minimal**.

**Adult:** As benthic feeders, adult suckers could occur within the intake vicinity during much of the time the project is in operation. The exception would be between July and August when the bottom near the intake is anoxic. The sucker feeding behavior could place them in close proximity to the intake in other months. Suckers are relatively strong swimmers and can outswim the approach velocities if aware of the intake. However, because sucker behavior would place them within the intake vicinity most of the time, the overall entrainment potential is rated as **Low to Moderate**.

**Juveniles:** Juveniles are also benthic feeders that could occur within the Mason Dam intake vicinity during much of the project operation. Details regarding juvenile bridgelip and largescale suckers movements within reservoirs are sparse. Because of the uncertainty of reservoir movements, the known benthic orientation, and the lower swimming abilities than adults, the overall entrainment potential for juvenile sucker entrainment is rated as **Moderate**.

## **4.2 Entrainment Summary**

The fish species most susceptible to entrainment during both the proposed Mason Dam hydroelectric project 4 to 6 month operating period and the 6 to 8 month non-operating period include yellow perch, black crappie and stocked rainbow trout. Yellow perch behavior and low oxygen tolerance place them frequently within the intake vicinity and their low swimming speeds would likely result in entrainment if they were near the intake. There are an estimated 1,636,575 yellow perch in Philips Reservoir, with a high potential for entrainment, particularly during late summer and fall. Studies in reservoirs with high perch populations have indicated that from 1 to 3 % of the total perch population is entrained annually (see for example, summaries in Kleinschmidt [2011]). This would equate to an existing annual average entrainment rate of 16,366 to 49,097 yellow perch through Mason Dam. The perch entrainment numbers would decrease under the ODFW (2013) proposed new fish management plan.

Black crappie are poor swimmers and any movement within the intake vicinity would likely result

in entrainment. Entrainment rates would be highest during the late summer and fall and during dry years. The crappie population number is unknown but Shrader (2000) identified that the population was in serious decline. With the known very reduced densities, the total number of entrained black crappie would likely be quite low.

Based on a study by CH2MHill (2007), trout entrainment at 11 of 12 other regional reservoirs that both support trout and contain a deep intake ranges from 0 to 0.1% of the population on an average annual basis, with no entrainment of adult trout and most rates less than 0.01%. At one reservoir operated strictly for hydropower production, Lake Lemolo, average annual trout entrainment was estimated at 2.6%, ranging from 1.9% in years in which the water surface remained close to 60 feet over the intake to 3.2% when water surface levels were drawn down much lower and pool volume reduced to 12%. The majority of the entrained fish were hatchery juveniles. Other studies have noted a correspondence between low pool volume and/or reduced intake depths with increased entrainment (see discussion in section 4.1.7). Critical levels appear to be when pool volumes were drawn down to less than 15% or less than 30 feet over the intake. These conditions would occur in approximately one of every four years within Philips Reservoir (or in dry years), beginning in mid-August.

Using the results from the regional studies and the entrainment potential evaluation from the previous section, the following trout population entrainment rates were used to estimate rainbow trout entrainment through Mason Dam.

- Native adult rainbow trout: 0 to 0.01% in all years, as per results of all regional studies.
- Native juvenile rainbow trout: 0.1 (wet years), 1.35% (average pool years) to 2.6% in dry years to reflect the general lack of juvenile trout entrainment in regional studies except in low water years.
- Spring-stocked adult hatchery fish: 0.12%. Although water levels are uniformly high during the stocking period and only a slightly greater entrainment rate than native adults would be expected, a very conservative entrainment estimate recommended by ODFW was used.
- Fall-stocked subadult hatchery fish: 1.9 (wet or high end of year pool conditions), 2.6% (average pool conditions) and 3.2% (dry or low end of year pool conditions). The full range of Lake Lemolo entrainment rates were used as the fall stocked fish would be the most susceptible to being entrained since they are stocked near the intake in the seasonal low pool condition.

With an estimated population of 60,000 to 100,000 rainbow trout (the annual stocking rate of 58,200 fish plus an unknown number of additional residents), this would equate to an average of between 541 to 1,698 rainbow trout being entrained<sup>3</sup> depending on the degree of pool drawdown, with the vast majority being stocked fish.

---

<sup>3</sup> The estimate assumed a population age class structure heavily dominated by juveniles and stunted adults. With a reduction in perch, larger sized rainbow trout would be expected with a corresponding reduction in entrainment.

Bull trout entrainment during the proposed project operating period is highly unlikely due to the bull trout's inability to tolerate the water quality conditions near the intake during most of the project operational period and its very strong swimming ability that would allow it to escape the relatively low intake approach velocities at other times.

Other species susceptible to entrainment during both the project operational and non-operational periods include the native northern pikeminnow and suckers. Although vigorous swimmers, walleye could occasionally be entrained while following their prey into less than optimal dissolved oxygen conditions. Adult suckers are also relatively strong swimmers, but their behavior would place them within the intake vicinity most of the time, potentially resulting in some inadvertent entrainment. Juvenile suckers would have a higher likelihood of being entrained.

The entrainment potential for other species during the proposed project operating period (smallmouth bass, largemouth bass) is nonexistent or very low. These species tend to be entrained in high numbers within reservoirs with shallow intakes located within littoral zones. Entrainment through a deep intake within a stratified reservoir, such as occurs at Mason Dam, is very unlikely.

The preliminary estimate of fish entrainment through Mason Dam was identified as a maximum of 38,581 fish per year. Using species-specific entrainment data, data on seasonal drawdown levels and known Philips Reservoir population data (where available), the following fish species would be anticipated to be entrained on an annual basis. An annual basis was identified for those species that would be susceptible to entrainment both during project operation and outside the project operating period, as the existing data does not allow for accurate monthly entrainment estimates. Entrainment estimates are listed for wet/high average years, average years and dry years based on the degree of water surface drawdown and low pool volumes.

## ESTIMATED ANNUAL ENTRAINMENT

**Wet/High Average Years: Characterized by an end of year low pool volume of at least 30% AND a surface water elevation more than 60 feet over the intake.** These conditions have occurred in 56.7% % of the last 30 years.

- 16,366 yellow perch
- 0 to 34 native rainbow trout, mostly juveniles
- 0 to 508 stocked hatchery rainbow trout
- 100 to 200 other fish. Based on other studies identifying the remaining species as typically comprising 1% or less of total entrainment, from 100 to 200 additional suckers, northern pikeminnow and occasional individuals of other species would likely pass through the outlets.
- Unknown number of black crappie. The population number is unknown but Shrader (2000) identified that the population was in serious decline. With the known very reduced densities, the total number of entrained black crappie would likely be quite low.

The following species would not likely be entrained during the proposed project operating period: bull trout, smallmouth bass and largemouth bass. Neither late fall/winter nor annual entrainment estimates were derived for these species.

- ▶ **Total revised wet/average year estimate: 17,108**

**Average Years. Characterized by an end of year low pool volume of between 15 to 25% and a surface water elevation between 30 to 60 feet over the intake.** These conditions have occurred in 16.6% of the last 30 years.

- 32,732 yellow perch
- 0 to 452 native rainbow trout, mostly juveniles
- 0 to 680 stocked hatchery rainbow trout
- 100 to 200 fish. Based on other studies identifying the remaining species as typically comprising 1% or less of total entrainment, from 100 to 200 additional suckers, northern pikeminnow and occasional individuals of other species would likely pass through the outlets.
- Unknown number of black crappie. The population number is unknown but Shrader (2000) identified that the population was in serious decline. With the known very reduced densities, the total number of entrained black crappie would likely be quite low.

The following species would not likely be entrained during the proposed project operating period: bull trout, smallmouth bass and largemouth bass. Neither late fall/winter nor annual entrainment estimates were derived for these species.

- ▶ **Total revised wet/average year estimate: 34,064**

**Dry Years: Characterized by an end of year low pool volume of less than 15% OR a surface water elevation less than 30 feet over the intake.** These conditions have occurred in 26.7% of the last 30 years.

- 49,097 yellow perch
- 0 to 870 native rainbow trout, mostly juveniles
- 828 stocked hatchery rainbow trout
- 100 to 200 fish. Based on other studies identifying the remaining species as typically comprising 1% or less of total entrainment, from 100 to 200 additional suckers, northern pikeminnow and occasional individuals of other species would likely pass through the outlets.
- Unknown number of black crappie. The population number is unknown but Shrader (2000) identified that the population was in serious decline. With the known very reduced densities, the total number of entrained black crappie would likely be quite low.

The following species would not likely be entrained during the proposed project operating period: bull trout, smallmouth bass and largemouth bass. Neither late fall/winter nor annual entrainment estimates were derived for these species.

► **Total revised dry year estimate: 49,097**

Using a weighted average according to the frequency in which various levels of low pool volumes and water surface drawdowns have occurred, an average long term entrainment of fish through Mason Dam would be 28,970. The majority of the fish entrained under any conditions would be yellow perch (96% of the entrainment), with the next largest group being stocked hatchery fish.

The range of estimates according to variability in Philips Reservoir pool conditions encompasses the preliminary estimate derived from the maximum Cougar Reservoir entrainment number. The long term Mason Dam weighted entrainment average is less than the Cougar Reservoir maximum entrainment. This is to be expected, as the Cougar Reservoir number represented an absolute maximum and not an average value.

As total annual entrainment estimates, these number represent fish entrained both during the time the project is operational (from 33 up to 50% of the year, see Figure 1 in Section 2.0) and when the project is not running (from 50 to 67% of the year). The highest levels of entrainment are expected to occur during the late summer and fall and the project would only be operating within a portion of that time.

The Mason Dam entrainment estimates were derived using very conservative numbers, higher than the averages from other regional reservoirs, and represent maximum levels to be expected under current conditions. Under potential future conditions, the Philips Reservoir fish population could change with lower numbers of yellow perch and higher numbers of other species. In particular, if yellow perch can be reduced, the adult rainbow trout stunting currently observed would be reduced

and 200,000 rainbow trout fingerlings would be released in the fall. The entrainment rate of the fingerlings would be high, with an estimated 3.2% of the release being entrained. This would equate to an annual entrainment of 6,400 rainbow trout fingerlings. Correspondingly, the number of entrained yellow perch would decline. The improved growth of native rainbow trout would also reduce their susceptibility to entrainment, thereby reducing total native rainbow trout entrainment numbers.

<b>Table 7. Summary of General Habitat Requirements for Fish Species Known to Occur in Philips Reservoir.</b>							
<b>Species</b>	<b>Water Quality Requirements</b>				<b>Swimming Speeds (ft/sec)</b>		<b>Reservoir Habitat Preferences</b>
	<b>Preferred</b>		<b>Tolerable</b>		<b>Max</b>	<b>Sustained</b>	
	<b>DO (ppm)</b>	<b>Temp (° C)</b>	<b>DO (ppm)</b>	<b>Temp (° C)</b>			
<b>Salmonids</b>							
Rainbow trout subspecies	≥ 7	12-18	≥ 5	0-25	1.79 juv 4.3+ adult	4.3+ adult	Cool, oxygenated habitat, move within reservoirs based on temp, DO + food sources
Bull trout	> 8	2-15	6-8	0-22	1.79 juv 22.5 adult	15.1 adult	Cold, deep oxygenated water in winter, migrate to tributaries when lakes warm or stratify
<b>Percids</b>							
Yellow perch	≥ 5	17.6-25	<2	4-30	1.77	0.88	Move daily and seasonally between littoral or shoreline areas and deep water
Walleye	> 5	15-18	≥ 3	6-32	6.02-11.2	3.3-4.8	
<b>Centrarchids</b>							
Smallmouth bass	> 6	16-26	≥ 4	0-30	3.6-7.8	1.8 juv 3.9 adult	Rocky shorelines, move to deeper water in winter
Largemouth bass	> 6	27-30	≥ 4.5	? - 30	3.2-4.2	1-1.6 juv 1.8-2.2 adult	Shallow, vegetated habitats
Black crappie	> 5	22-25	≥ 4	? - 30	1-1.5	0.5-0.75	Shallow habitats, move to deeper water in winter
<b>Cyprinids</b>							
Northern pikeminnow	>5	16-26*	>3	0-30*	1.6-2.7	0.74	Seasonal movements between shoreline areas and deep water
<b>Catastomids</b>							
Suckers	>3		>2.4		4.0-7.9	1.3-4.9	Relatively sedentary benthic feeders
* estimated as similar to smallmouth bass, another “coolwater” species.							

**Table 8. Species Entrainment Potential during the Mason Dam Mid-March to Sept 30 Operating Period.**

Species	Life Stage	Entrainment Potential
<b>Salmonids</b>		
Bull trout	Spawning	None
	Adult	None to Minimal
	Juvenile	None to Minimal
Rainbow trout subspecies (and tiger trout)	Spawning	None
	Adult	None to Minimal
	Juvenile	Minimal to Low most years, Moderate in dry years
	Recently stocked fish	Moderate to High*
<b>Percids</b>		
Yellow perch	Spawning	None
	Adult	High
	Juvenile	High
Walleye	Spawning	Minimal
	Adult	Minimal
	Juvenile	Minimal
<b>Centrarcids</b>		
Smallmouth bass	Spawning	None
	Adult	Minimal
	Juvenile	None to Minimal
Largemouth bass	Spawning	None
	Adult	None
	Juvenile	None to Minimal
Black crappie	Spawning	None
	Adult	Minimal to Low in most years, Moderate to High in dry years
	Juvenile	Moderate to High

**Table 8. Continued.**

**Cyprinids**

Northern pikeminnow	Spawning	Minimal
	Adult	Moderate
	Juvenile	Minimal to Low

**Catastomids**

Suckers	Spawning	None to Minimal
	Adult	Low to Moderate
	Juvenile	Moderate

\* Entrainment risk could be reduced by movement of the hatchery fish release point to a location away from its current location near the intake.

## 5.0 Mortality

### 5.1 Overview

Fish mortality from entrainment is generally related to two factors: (1) sudden differences in pressure from being entrained underwater to being suddenly ejected into atmospheric conditions, and (2) physical damage as a result of being thrown about at high velocities (Battelle Research Laboratory 1997). Both factors contribute to the overall mortality rate. For example, at the Tieton Project, pressure changes explained 56% of the observed mortality, with the remaining 44% of mortality resulting from physical damage (Cramer and Associates 2002).

Pressure differences change throughout the season and from year to year, depending upon the water surface elevation at the beginning of the irrigation season and the degree to which the reservoir is drawn down. This relationship has been noted at a number of the comparison reservoirs, particularly Fall Creek, Blue River, Wickiup and Tieton Reservoirs. A general summary of the relationships identified for each of these reservoirs is listed below and in Table 9, with more information provided in Appendix A-2.

- Fall Creek: Mortality studies identified an overall mean mortality of 41.0% through bottom slide gates (Homolka and Smith 1991), but with changes in mean mortality rates under different hydraulic head conditions. Mean mortality with a hydraulic head between 50 to more than 80 feet over the gated intake top ranged from 50.0 to 57.5%. Mortality with less than 15-18 feet of head over the intake was 6.8%. There were no data on conditions ranging between 18 to 50 feet of head.
- Blue River: Although mean mortalities were identified as ranging between 63 to 74%, mortality rates were between 30 and 60% at lower heads.
- Wickiup Reservoir: Symbiotics (2009) identified that mortality was highest between April and June when the hydraulic head was the highest. During these months direct mortality was always greater than 77%. In the fall, as the head was at its lowest, direct mortality was less than 50%.
- Tieton Reservoir: Cramer and Associates (2002) identified a direct relationship between mortality and pressure differential due to changes in water surface elevations. They developed the following regression equation:  $Mortality = -0.412 + 0.0197 * (\text{change in pressure in PSI})$ , with the pressure changing with changes in water surface elevation.

In addition to mortality from changes in pressure, mortality occurs from physical damage. Experiments in open, non-pressurized spillways identified that physical injuries resulting in mortality were rare at velocities less than 50 fps (approximately 34 mph), with major injuries beginning at velocities of 60 fps (approximately 41 mph)(Bell 1991). Mortality rates rapidly increased as velocities increased from 60 fps (20% mortality) to 80 fps or 54 mph (100% mortality).

**Table 9. Summary of Comparison Reservoir Mortality Results and Key Conditions During the Mortality Study Period(s).**

Reservoir Name	Outlet Type	Conditions During Mortality Study Period			
		Hydraulic Head (ft)	Flow Range (cfs)	Velocities (mph)	Mortality Rates (%)
<b>Cougar</b>	Slide gate	65-84	Unknown	Unknown	32.3-40.0 direct mortality only
<b>Fall Creek</b>	Slide gate	18->80	>700	18-43	41.0 chinook salmon
	Slide gate	>80	>700	38-43	57.5 salmon smolts
		50-80	>700	35-37	50.0 salmon smolts
		<18	>700	18-20	6.8 salmon smolts
	Slide gate	Unknown	Unknown	Unknown	29.6 steelhead fingerlings all studies direct and delayed mortality
<b>Blue River</b>	Slide gate	Unknown	Unknown	Unknown	63.0 salmon 74.0 other species direct and delayed mortality
	Slide gate	50-60	150-350	Unknown	30.0-60.0 direct and delayed mortality
<b>Wickiup</b>	Jet Valve	50-80	600-1800	Unknown	86.3 direct and delayed mortality
<b>Tieton</b>	Jet Valve	>60	300-2200	40-68	81.0 direct mortality only

Mean mortality rates associated with gated intakes are variable, ranging from 29.6- 74% (see Table 9), depending on the timing, reservoir conditions and operational parameters. Eliminating all studies through gated intakes either under a rapid drawdown scenario or that include downstream migrant systems data, results in a range of mean mortalities of 29.6 (fingerlings) to 41.0% (smolts) at Fall Creek, 32.3 to 40.0% at Cougar Reservoir (direct mortality only), and 63 to 74% at Blue River (30 to 60% at lower hydraulic heads).

Jet valves are typically identified as having higher mean mortality rates than slide gates (Symbiotics 2009), with jet valve mortalities of comparison reservoirs ranging from 60 to 86%, and mean mortalities approximately 81%. In general, velocities tend to be much higher through jet valves than through slide gates.

The Mason Dam outlets have characteristics in between those of other slide gates and jet valves. The Mason Dam slide gate openings are much smaller than those of the other gated reservoirs examined and are more similar in outlet size and velocities to jet valves at some discharges. Because velocities are related to both discharge and gate or valve opening size, not all comparison reservoirs have either the outlet velocity data or the data needed to calculate velocities. Data is available for the Fall Creek, Mason Dam and Tieton projects and is listed below.

- Mason Dam outlet velocities: Calculated at 14 to more than 76 mph during the time period that the Mason Dam hydroelectric project would be operating. (Slide gate opening range of 0.27 to 1.1 feet)
- Fall Creek outlet velocities: Calculated at 18 to 43 mph during the mortality study period, with slide gate openings ranging in size between 1 and 6 feet.
- Tieton outlet velocities: Measured at 40 to 68 mph during the mortality study period, with jet valve openings of 2.5 feet.

## 5.2 Overall Mortality Estimate Approach

The approach used to identify a literature-based mortality estimate through Mason Dam was to summarize the mortality data from comparison reservoirs, as well as the conditions under which the studies occurred. A particular emphasis was placed on identifying the hydraulic head and discharges/outlet velocities during the study periods. Using this review, the reservoir(s) with the mortality data collected under conditions most similar to Mason Dam in terms of operation, annual changes in head, and outlet velocities were identified in section 5.3.

Mortality rates were also modelled at Mason Dam using the regression equation developed for the nearby Tieton Project in Washington<sup>4</sup> (Cramer and Associates 2002) to identify the effects of pressure changes on mortality, and the equation developed by Bell (1991) to identify the effects of

---

<sup>4</sup> Mortality= -0.412 + 0.0197\*(change in pressure in PSI); PSI=approximately 14.7\* atmospheres

velocity on physical damage resulting in mortality. Recorded discharge and hydraulic head conditions during representative wet, dry and average years were used in the modelling. The same years used to portray water surface changes, and identified in Section 2.0 of this report, were used for the mortality analysis. The modelled results were then compared to the results from the comparison reservoirs. The modelling was not conducted to identify a precise mortality estimate. Instead, the primary purpose was to identify if the modelling of the Mason Dam recorded conditions could be used to clarify which reference reservoir(s) provided the best comparison(s) for the Mason Dam project.

### **5.3 Baseline Mortality Estimates**

#### ***Comparison Reservoirs***

The slide gate outlet reservoir with the most detailed mortality data is Fall Creek. The range of head conditions under which the studies were conducted mostly match the range of water surface changes Philips Reservoir is subject to. There are some key differences between Fall Creek and Philips Reservoirs.

- The Fall Creek outlets are much larger and at low head conditions, they are generally more than half open (6-foot opening) instead of the maximum outlet opening of 2.75 feet at Mason Dam. This means that for a given flow and with gates fully open, velocities would be much higher through the Mason Dam outlets. However, the Mason Dam gates are not operated at a full open level, and generally have openings between 0.82 to 1.10 feet during the period the hydroelectric project would be operating.
- Although flows through Fall Creek exceed those of Mason Dam, the calculated velocities do not. The Fall Creek velocities under the range of high discharge conditions and slide gate openings investigated were similar to those of Mason Dam at moderate discharges (i.e., between 200 to 250 cfs).
- No mortality studies were conducted at conditions of 20 to 50 feet of head meaning that mortality data is not available for the late season 30 to 60 foot hydraulic head conditions that are common in dry and low average years at Philips Reservoir.
- The Mason Dam hydroelectric project would not be operational at the extremely low head conditions observed during the Fall Creek mortality studies. For example, in 2007, a representative dry year, flows sufficient for the project to run would have ceased in September with 27 feet of head remaining over the Mason Dam intake. In 1988, an extremely dry year, the low water pool was only 10 feet above the intake. However, in this year flows sufficient to operate the hydroelectric turbine would have ceased on August 12, with 30 feet of head remaining over the intake.

The overall slide gate mortality rate at Fall Creek ranged from 6.8 (very low head and conditions under which the Mason Dam hydroelectric project would not be operational) to 57.5% (hydraulic head greater than 80 feet) with a mean of 41.0%.

Mortality rates in other comparison slide gate reservoirs (Cougar and Blue River) ranged between 30 to 60%, although indirect mortality was not always included. In all slide gate reservoirs, a minimum average of 30% mortality was observed.

Studies at both Wickiup and Tieton Reservoirs, which contain jet valves, have identified similar mortality rates (mean of 81%). The primary difference between these reservoirs and Philips Reservoir is that the hydraulic head conditions under which Wickiup and Tieton Reservoirs operate are mostly greater than those of Philips Reservoir. Although measured velocities at Tieton Reservoir overlap those through Mason Dam, they can be greater under some conditions. Velocities through Mason Dam would be similar to those at Tieton under the following conditions (Table 10):

- A 10% gate opening (or 0.27 feet) at 100 cfs or greater discharges.
- A 30% gate opening at discharges of more than 250 cfs.
- All flows greater than 300 cfs.

<b>Table 10. Comparison of Flows at which Velocities through the Mason Dam Slide Gates would be Similar to those through the Fall Creek Slide Gates and the Tieton Jet Valves.</b>	
Mason Dam Velocities Similar to Fall Creek Slide Gate Velocities	<ul style="list-style-type: none"> <li>• Flows up to 200 cfs at 30% slide gate openings</li> <li>• Flows up to 300 cfs at 40% slide gate openings</li> </ul>
Mason Dam Velocities Similar to Tieton Jet Valve Velocities	<ul style="list-style-type: none"> <li>• Any flow of 100 cfs or greater with a 10% slide gate opening</li> <li>• All flows greater than 250 cfs with a 30% slide gate opening</li> <li>• Flows greater than 300 cfs with a 40% slide gate opening</li> </ul>

***Modelled Mortality***

Both velocities and pressure changes affect fish mortality. The modelled mortality at Mason Dam included the effects of both changes in hydraulic head and velocities. As previously noted, the modelling was not meant to identify precise mortality numbers but to identify, given the representative range of hydraulic head, discharge and velocity conditions associated with the Mason Dam outlets, the most appropriate comparison reservoir mortality rates to use.

Based on general relationships between pressure, velocity and mortality for representative years, the mean Mason Dam modelled mortality ranged from 24.7 to 53.1% (weighted mean of 44.1%), with mortality only modelled during the time period flows exceeded 100 cfs in the selected years (Table 11).

**Table 11. Modelled Mason Dam Baseline Mortality Results Based on General Pressure Equations and Velocity-Mortality Relationships.**

<b>Representative Year</b>	<b>Year Type</b>	<b>Mean Mortality (%)<sup>1</sup></b>
1998	Wet	49.3
2000	Average	53.1
2007	Dry	24.7
Weighted average from representative years		44.1
<sup>1</sup> Mortality was not modelled at 10% slide gate openings as the overall time of use is limited. However, almost 100% mortality would be expected under such low opening sizes.		

The modelled results indicate that although the slide gate velocities sometimes reach those of jet valves, the combination of velocity and hydraulic head changes that occur at Mason Dam are more similar to those of the comparison slide gate reservoirs than the comparison jet valve reservoirs. The primary reasons are that (1) the typical annual changes in hydraulic head are lower, and (2) velocities are lower through the Mason Dam slide gates than jet valves under some flow conditions.

In general, the modelled Mason Dam mortality rates were similar to those of Tieton Reservoir under conditions in which the hydraulic head was greater than 75 feet over the intake top with discharges greater than 160 cfs (regardless of slide gate opening size). These conditions typically occur in early to mid summer (later in some years).

Under conditions of moderate flows and lower heads, the modelled mortality rates were more similar to those measured at Fall Creek Reservoir. These typically occur in Mason Dam between mid summer and fall.

Although Mason Dam slide gate velocities often exceed those of comparison reservoir slide gates and the project would not operate under the very low head conditions observed at Fall Creek, the combination of hydraulic head and velocity changes indicates that the data collected from Fall Creek Reservoir provides the most appropriate comparison, with the mean mortality of 41.0% providing the best estimate of baseline mortality. Because of the differences noted above, 41.0% is a conservative (low end or minimum) average estimate of baseline mortality for Mason Dam.

#### **5.4 Project Operation**

GeoSense (2011) identified that mortality rates associated with installing Francis turbines would result in relatively constant mortality rates regardless of fish species, and that turbine type, turbine rotational speed and turbine size each affected fish survival in a predictable manner. GeoSense (2011) also identified that hydraulic head was not correlated with fish mortality through hydroelectric turbines, resulting in a relatively constant estimated mortality rate of 24.8% at the

Mason Dam hydroelectric facility.

Under baseline conditions, the mean estimated mortality rate would be 41.0%. According to the GeoSense (2011) post-project estimates, survival would be greater under post project conditions, resulting in an average increase in fish survival of 16.2%.

The overall entrainment potential at Mason Dam is low for most species, with only a few species likely to be entrained. Mortality is discussed below only for those species likely to be entrained during the project operational period. Table 12 provides a summary of the weighted entrainment summary and compares the estimated mortality between pre and post project conditions.

<b>Table 12. Estimated Changes in Mortality Between Baseline and Post Project Conditions Based On Mean Entrainment Values. A “+” symbol indicates a decrease in mortality (increase in survival) and a “-” indicates an increase in mortality (and decrease in survival).</b>				
<b>Fish Species Group</b>	<b>Estimated Mean Number of Fish (#)</b>			
	<b>Annual Entrainment</b>	<b>Baseline Mortality</b>	<b>Project Mortality</b>	<b>Difference in Survival</b>
Native rainbow trout	327	134	81	+ 53
Stocked hatchery trout	622	255	154	+101
Yellow perch	27,822	11,407	6,900	+ 4,507
Other Fish	200	82	50	+32
<b>Total Fish</b>	<b>28,970</b>	<b>11,878</b>	<b>7,185</b>	<b>+4,693</b>

#### 5.4.1 Salmonids

The potential for native adult rainbow trout entrainment is low, with most native trout entrainment consisting of juveniles. The potential for stocked hatchery rainbow trout is higher. Overall, from 0 to 870 native rainbow trout are estimated to be entrained annually, with a weighted annual average of 327 trout. From 508 to 828 hatchery stocked fish would be entrained (weighted annual average of 622 fish). Only a portion of the fish would be entrained during the Mason Dam operating period. Even if all entrainment occurred during project operation, there would be a net mean annual increase in survival of 53 native rainbow trout and 101 hatchery-stocked fish.

Bull trout entrainment is highly unlikely. If entrainment occurred, survival would be increased in the same manner described for rainbow trout. Additional detailed analysis specific to bull trout can

be found in the project biological assessment (Baker County 2013).

#### **4.2.4 Percids**

There are an estimated 1,636,575 yellow perch in Philips Reservoir, with a high potential for entrainment, particularly during late summer and fall. From 16,366 to 49,097 perch would be entrained annually (weighted annual average of 27,822 fish).

Only a portion of the fish would be entrained during the Mason Dam operating period. Even if all entrainment occurred during project operation, there would be a net mean annual increase in survival of 4,507 yellow perch.

#### **4.2.5 Other Fish (Centrarcids, Cyprinids, Catastomids)**

The potential for entrainment of most other fish species is none to minimal, with an estimated annual entrainment of 200 other fish bass, primarily suckers, northern pikeminnow and crappie.

Only a portion of the fish would be entrained during the Mason Dam operating period. Even if all entrainment occurred during project operation, there would be a net mean annual increase in survival of 32 other fish.

#### **4.2.6 Summary**

Under the Mason Dam hydroelectric project operation, there would be an estimated average increase in survival of 16.2%. This would result in increased survival of 4,693 fish on average, most of which would be yellow perch. Other species with increased survival would include native and stocked rainbow trout, suckers, northern pikeminnow and crappie. Because the total number of entrained fish from these species would be fairly low, there would not be much difference between pre and post project conditions (i.e., annual increase in survival of 154 trout and 32 other fish).

## 6.0 REFERENCES

- Bailey, T. 2012. Philips Reservoir Perch Removal Project. 2011 Project Report: Summary of Actions 2009-2011. Oregon Department of Fish and Wildlife, La Grande, OR.
- Baker County. 2009. Preliminary Licensing Proposal for Mason Dam Hydroelectric Project FERC No. P12686. Baker County, Baker City, OR.
- Baxter, C. V. 2002. Fish movement and assemblage dynamics in a Pacific Northwest riverscape. Ph. D. Dissertation, Oregon State University, Corvallis, Oregon.
- Bell, M.C. 1991. Revised Compendium of the Success of Passage of Small Fish Through Turbines. Report to the U.S. Army Corps of Engineers, North Pacific Division, Portland, Oregon.
- Beauchamp, D. J. and J. J. Van Tassel. 2001. Modeling seasonal trophic interactions of adfluvial Bull Trout in Lake Billy Chinook, Oregon. Transactions of the American Fisheries Society, 130(2):204-216.
- BOR. 2012. November 27, 2012 electronic communication from Richard Rieber, Bureau of Reclamation to Jason Yencopal, Baker County.
- CH2MHill. 2003. Literature Based Characterization of Resident Fish Entrainment and Turbine-Induced Mortality, Klamath Hydroelectric Project (FERC No. 2082). Prepared for PacifiCorp during FERC relicensing for the Klamath Project.
- \_\_\_\_\_. 2007. Potential for trout entrainment in Spada Lake, Washington. Public Utility District No. 1 Snohomish County: Henry M. Jackson Hydroelectric Development. FERC No. 2157.
- City of New York. 2011. West of Hudson Hydroelectric Project. Project No. 13287. Fish Entrainment Report: Literature Based Characterization of Resident Fish Entrainment and Mortality.
- Craig, J. 1987. The Biology of Perch and Related Fishes. Portland, OR: Timber Press.
- Cramer and Associates. 2002. Biological Assessment: Potential Impacts from the Tieton Hydroelectric Project on ESA Listed Bull Trout and Steelhead in the Yakima Basin. Prepared for Nick Josten, Twin Falls, Idaho.
- Dauble, D. D. 1986. Life history and ecology of the largescale sucker (*Catostomus macrocheilus*) in the Columbia River. American Midland Naturalist 116(2):356-367.
- Downey, T.W. and E.M. Smith. 1989. Evaluation of Spring Chinook Rearing Program in Blue River Reservoir, 1989. Prepared by Oregon Department of Fish and Wildlife, Portland, OR.
- Downey, T.W. and E.M, Smith. 1992. Evaluation of Spring Chinook Passage at Fall Creek Dam,

1991. Oregon Department of Fish and Wildlife, Portland, Oregon.

EcoWest Consulting. (2009b). Combined Vegetation and Threatened, Endangered and Sensitive Species Assessment. Baker City, OR: Final Report submitted to Baker County.

EcoWest Consulting. (2009a). Mason Dam Water Quality Final Report. Baker City, OR.

EPRI (Electric Power Research Institute). 1992. Fish entrainment and turbine mortality review and guidelines. Final Report. Research Project 2694-01; EPRI TR-101231. Palo Alto, California.

Electric Power Research Institute (EPRI). 1997. Turbine entrainment and survival database – field tests. Prepared by Alden Research Laboratory, Inc. EPRI Report No. TR-108630.

Federal Energy Regulatory Commission. 1995. Preliminary assessment of fish entrainment at hydropower projects, a report on studies and protective measures, volumes 1 and 2. Paper No. DPR-10, FERC Office of Hydropower Licensing, Washington, D.C.

Fitz, R. B., and J. A. Holbrook. 1978. Sauger and walleye in Norris Reservoir, Tennessee, p. 82-88. *In* R. L. Kendall [ed.] Selected Coolwater Fishes of North America, American Fisheries Society Special Publication 11, Washington., D. C.

Flatter, B. 2000. Life history and population status of migratory bull trout in Arrowrock Reservoir, Idaho. Masters Thesis. Boise State University. Boise, Idaho.

Fraley, J.J. and B.B. Shepard. 1989. Life history, ecology, and population status of migratory bull trout (*Salvelinus confluentus*) in the Flathead Lake and river system, Montana. Northwest Science 63:133-143.

FWS. 1983. Habitat Suitability Index Models: Smallmouth bass. U.S. Dept. Interior Technical Report. FWS/OBS-82/10.36.

FWS. 1983. Habitat Suitability Index Models: Largemouth bass. U.S. Dept. Interior Technical Report. FWS/OBS-82/10.16.

\_\_\_\_\_. 1998. Endangered and threatened wildlife and plants; determination of threatened status for bull trout in the Columbia and Klamath River basins; final rule. Federal Register: 63: 31647.

\_\_\_\_\_. 2002. Chapter 13, Hells Canyon Complex Recovery Unit, Oregon and Idaho. US Fish and Wildlife Service. 2002. Bull Trout (*Salvelinus confluentus*) Draft Recovery Plan. Portland, Oregon

\_\_\_\_\_. 2008. Bull Trout (*Salvelinus confluentus*) 5-Year Review: Summary and Evaluation.

\_\_\_\_\_. 2010. Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for the Bull Trout; Final Rule. 70 FR 56212-56311.

Gadomski, D. M., C. A. Barfoot, J. M. Bayer, and T. P. Poe. 2001. Early life history of the northern pikeminnow in the lower Columbia River basin. *Transactions of the American Fisheries Society* 130(2):250-262.

Geosense. 2011. Report on Fish and Entrainment and Mortality at Mason Dam, Oregon. Prepared for Baker County, Baker City, Oregon.

Goetz, F. 1997. Diel behavior of juvenile bull trout and its influence on selection of appropriate sampling techniques. Pages 387-402 In: Mackay, W.C., M.K. Brewin, and M. Monita (eds.). *Friends of the bull trout conference proceedings*. Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary.

Goetz, F. 1989. Biology of the bull trout, a literature review. U.S.D.A., Willamette National Forest, Eugene, Oregon.

Gonzalez, D. 1998. Evaluate the Life History of Salmonids in the Malheur River Basin. 1998 Annual Report. Prepared by the Burns Paiute Tribe, Burns, OR

Gonzalez, D. 2012. November 13, 2012 electronic communication from Dan Gonzalez, USFS to Jason Yencopal, Baker County, Oregon.

Hardin, T. 2001. Comparison of fish mortality at Tieton Dam: jet valves vs. turbines. Prepared for Sorenson Engineering by Hardin-Davis, Inc., Corvallis, Oregon.

Helfman, G. 1979. Twilight activities of yellow perch (*Perca flavescens*). *J. Fish. Res. Board Can.*, 36: 173-179.

Hergenrader, G., A. Hasler. 1968. Influence of changing seasons on schooling behavior of yellow perch. *J. Fish. Res. Board Can.*, 25: 711-716.

Herman, E., W. Wiley, L. Wiegert, M. Burdick. 1959. *The yellow perch: Its life history, ecology and management*. Madison, WI: Wisconsin Conservation Department

Homolka K, Smith EM. 1991. Evaluation of spring Chinook salmon and winter steelhead passage at Fall Creek Dam, 1990. Draft Report. Oregon Department of Fish and Wildlife. Research and Development Section. Salem, Oregon.

Ingram, P and L. Korn. 1969. Evaluation of Fish passage Facilities at Cougar Dam on the South Fork McKenzie River in Oregon. Prepared by Fish Commission of Oregon for the US Army Corps of Engineers, Portland, OR.

Keefer, M.L., G.A. Tayler, D. F Garletts, C.K. Helms, G.A. Gauthier, T. M. Pierce, C. C. Caudill. 2010. Downstream fish passage above and below dams in the Middle Fork Willamette River: A multi-year summary. Prepared For U.S. Army Corps of Engineers, Portland District. Joint Technical Report 2011-2 (Draft).

Kerr, S.J., B.W. Corbett, N.J. Hutchinson, D. Kinsman, J.H. Leach, D. Puddister, L. Stanfield and N. Ward. 1997. Walleye habitat: A synthesis of current knowledge with guidelines for conservation. Percid Community Synthesis, Walleye Habitat Working Group, Ontario Ministry of Natural Resources, Peterborough, Ontario.

Kleinschmidt. 2011. Martin Dam Hydroelectric Project Ferc No. 349 Fish Entrainment and Turbine Mortality Analysis Final Report. Prepared for Alabama Power Company Birmingham, Alabama.

Langhurst, R. W., and D. L. Schoenike. 1990. Seasonal migration of smallmouth bass in the Embarrass and Wolf rivers, Wisconsin. North American Journal of Fisheries Management 10:224-227.

McPhail, J.D., and J.S. Baxter. 1996. A review of bull trout (*Salvelinus confluentus*) life-history and habitat use in relation to compensation and improvement opportunities. British Columbia Ministry of Environment, Lands and Parks. Fisheries Management Report No.104. 35 p.

Mesa, G. and T. Olson. 1993. Prolonged swimming performance of northern squawfish. Transactions of the American Fisheries Society 122:1104-1110.

Mesa, G., L.K. Weiland and G.B. Zydlewski. 2004. Critical swimming speeds of wild bull trout. Northwest Science: 78:(1):59-64

NAI. 2009. Claytor Hydroelectric Project: Fish Entrainment and Impingement Assessment. Prepared for Appalachian Power Company, Roanoke, VA.

New York Power Authority. 2005. Fish entrainment and mortality study: Volume 1 Public. Niagara Power Project. FERC No. 2216..

ODFW. 2012. Website. <http://www.dfw.state.or.us/resources>

ODFW. 2008. Phillips Reservoir tiger trout introduction proposal. Oregon Department of Fish and Wildlife unpublished report. La Grande, Oregon.

ODFW. 2012. Phillips Reservoir tiger muskie introduction proposal. Oregon Department of Fish and Wildlife unpublished report. La Grande, Oregon.

ODFW. 2013. Phillips Reservoir Preliminary Draft Fish Management Plan. Oregon Department of Fish and Wildlife unpublished report. La Grande, Oregon.

Petersen, J. H., E. E. Kofoot, and B. Rose. 2003. Conditions for growth and survival of bull trout in Beulah Reservoir. Annual Report for 2002. Report for the U.S. Bureau of Reclamation, Pacific Northwest Region, Boise, Idaho. 45 pages

Petersen, J. H., and E. E. Kofoot. 2002. Conditions for growth and survival of bull trout in Beulah

Reservoir. Annual Report for 2001. Report for the U.S. Bureau of Reclamation, Pacific Northwest Region, Boise, Idaho. 43 pages.

Pratt, K. L. 1992. A review of bull trout life history. Pp. 5-9 *In* P. J. Howell, and D. V. Buchanan (eds.). Proceedings of the Gearhart Mountain bull trout workshop. Oregon Chapter of the American Fisheries Society, Corvallis, Oregon.

Portland State University. 2013. Atlas of Oregon Lakes. <http://aol.research.pdx.edu/>

PBWC (Powder Basin Watershed Council). 2001. Powder River-Powder Valley Watershed Assessment. Prepared for the Oregon Watershed Enhancement Board.

Raleigh, R. F., T. Hickman, R. S. Solomon, and P. C. Nelson. 1984. Habitat suitability information: rainbow trout. U.S. Department of the Interior, Washington, D.C. FWS/PBS-82/10.60.

Ratliff, D., E. Schulz, and S. Padula. 2001. Pelton Round Butte Project fish passage plan, second edition. Portland General Electric. Portland, Oregon.

Ratliff, D.E., S.L. Thiesfeld, W.G. Weber, A.M. Stuart, M.D. Riehle, and D.V. Buchanan. 1996. Distribution, life history, abundance, harvest, habitat, and limiting factors of bull trout in the Metolius River and Lake Billy Chinook, Oregon; 1983-94. Oregon Dept. of Fish and Wildlife, Portland. Inland Fisheries Report 96-7. 44 p.

Rieman, B.E., and J.D. McIntyre. 1993. Demographic and habitat requirements for conservation of bull trout. U.S. Dept. of Agriculture, Forest Service. Intermountain Research Station, Ogden, Utah. Gen. Tech. Rep. INT-302. 38 p.

Rieman, B.E., D.C. Lee, and R.F. Thurow. 1997. Distribution, status, and likely future trends of bull trout within the Columbia River and Klamath River basins. *North American Journal of Fisheries Management* 17(4):1111-1125.

Rose, B.P., and Mesa, M.G., 2009. Bull trout forage investigations in Beulah Reservoir, Oregon—Annual report for 2006: U.S. Geological Survey Open-File Report 2009-1036.

Schmetterling, D.A. and James A. McFee. 2006. Migrations by Fluvial Largescale Suckers (*Catostomus macrocheilus*) after Transport Upstream of Milltown Dam, Montana.

Schwabe, L., M. Tiley and R. Perkins. 1999. Evaluate the Life History of Salmonids in the Malheur River Basin. 1999 Annual Report. Prepared by the Burns Paiute Tribe, Burns, OR and the Oregon Department of Fish and Wildlife, Ontario, OR.

Schwabe, L., J. Fenton and R. Perkins. 2002. Evaluate the Life History of Salmonids in the Malheur River Basin. 2002 Annual Report. Prepared by the Burns Paiute Tribe, Burns, OR and the Oregon Department of Fish and Wildlife, Ontario, OR.

Scott, W. B. and E. J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada Bulletin 184. Ottawa, Canada.

Shrader, T. 2000. Effects of Invasive Yellow Perch on Gamefish and Zooplankton Populations of Phillips Reservoir. Oregon Dept of Fish and Wildlife, Portland, OR.

Stillwater Sciences. 2006. Fish Entrainment at the Carmen-Smith Hydroelectric Project, Upper McKenzie River Basin, Oregon. Final Report prepared for Eugene Water and Electric Board, Eugene, Oregon.

Stoval, S.H. (Editor). 2001. Boise-Payette-Weiser Subbasin Summary. Prepared for the Northwest Power Planning Council.

Symbiotics, LLC. 2009. Wickiup Dam Hydroelectric Project FERC No. 12965 Draft Study Report. Portland, OR.

Symbiotics LLC. 2011. Fall Creek Dam Hydroelectric Project FERC No. 12778 License Application. On behalf of Fall Creek Hydro LLC. Logan, UT.

Taylor GA. 2000. Monitoring of Downstream Fish Passage at Cougar Dam in the South Fork McKenzie River, Oregon 1998-00. Oregon Department of Fish and Wildlife. Springfield, OR.

Taylor, M. and B. Lewis. 2010. Columbia River Project Water Use Plan: Revelstoke Flow Management Plan. Middle Columbia River Adult Fish Habitat Use, Implementation Year 2. Technical Report Reference: CLBMON-18. Prepared for BC Hydro.

Thurrow, R.F. 1997. Habitat utilization and diel behavior of juvenile bull trout (*Salvelinus confluentus*) at the onset of winter. Ecology of Freshwater Fish 6:1-7.

Zorich, N.A. 2004. Foraging behavior and swimming speed of the northern pikeminnow (*Ptychocheilus oregonensis*) in the Columbia River. Thesis, University of Washington, Seattle, WA

## **APPENDIX A-1: Entrainment and Mortality Background Summary**

Numerous studies have been conducted at reservoirs and hydroelectric facilities throughout the US and Canada. The results have shown variation in entrainment rates according to fish species composition, reservoir operation type and depth, and intake characteristics. However, some general trends have been observed and summarized in a number of reports (FERC 1995, EPRI 1997, Ch2MHill 2003, NY Power Authority 2005, CH2MHill 2007, NAI 2009, Symbiotics 2009, City of New York 2011):

### ***Reservoir Characteristics***

- Entrainment rates are much higher for shallow reservoirs than deeper reservoirs, with up to twice as many fish entrained in reservoirs with dams less than 50 feet high (15 meters) than those greater than 50 feet.
- Reservoirs that are operated to be drawn down over the winter and allow for spring storage can increase winter entrainment rates as more fish are placed in closer proximity to the intake.

### ***Intake Characteristics***

- Intakes adjacent to shorelines tend to entrain more fish than those located away from the shoreline as many fish species tend to follow shorelines or orient to the physical structure associated with shorelines.
- The littoral zone is the most productive area within a reservoir and many species spawn and rear there. Intakes in littoral zones entrain more species than deeper intakes.
- Poor water quality near the intake can form a barrier and reduce fish susceptibility to entrainment. This is particularly true if there is low dissolved oxygen in the hypolimnion.

### ***Fish Species***

- Entrainment is relatively low (less than 20 fish/hour) for most resident warmwater/coolwater fish communities. Entrainment from the coldwater fishery in Trail Bridge Reservoir was estimated at less than 1 fish/hour. Residents tend to be entrained inadvertently in relation to their use of habitats near the intake. Episodic entrainment events have been noted for anadromous salmon and other obligate downstream migrants, as well as fish species that travel in large schools.
- Entrainment rates vary by species and are not necessarily related to the relative composition of a water body. Yellow perch, northern pike and smallmouth bass are species that are particularly susceptible to entrainment. Species less susceptible to entrainment include rainbow trout and some sucker species.
- Species entrainment rates vary both diurnally and seasonally according to species behavior.

- Young-of-year (YOY) and juvenile fish are more susceptible to entrainment than adult fish.

Fish swim speeds in relation to velocities at the intake can also affect entrainment potential. The ability to avoid entrainment depends on both the fish's swimming speed, and its ability to detect and respond quickly to a change in velocity. Detection can be comprised by darkness, turbidity or cold temperatures. If a fish does not respond to a velocity acceleration until it can only maintain position in the flow, it would find itself quite close to the intake and may not have enough time or strength to scape. Detection for strong swimming fish is generally only an issue for river intakes or where approach velocities are greater than or equal to 5 ft/sec. Swimming performance can be decreased by as much as 50% when temperatures fall outside a species' preferred range (Bell 1997). This latter item most often occurs as winter approaches and temperatures cool.

Of all the factors examined by studies of reservoirs with deep intakes, the intake depth and the water quality near the intake tend to be the most important factors affecting fish entrainment. This is because the DO, temperature and depth in relation to other habitat features affect the fishes' potential to occur in the intake vicinity. The reservoir size is not as important.

Once entrained, a separate set of factors affects whether or not the fish survives. Fish mortality from entrainment is generally related to two factors: (1) sudden differences in pressure from being entrained underwater to being suddenly ejected into atmospheric conditions, and (2) physical damage as a result of being thrown about at high velocities (Battelle Research Laboratory 1997). Also important is the type of intake. Valve outlets appear to cause more mortality to fish than gate-controlled flow regulators, perhaps because of increased shear stress around the valve cone. Mortality rates associated with spillways are variable, influenced by velocity and head height, but tend to be lower than those of regulating structures. Multi-intake tower mortality rates are also variable as they draw water from different depths of the reservoir.

Other factors influencing fish mortality during entrainment includes fish species and size, and reservoir operation (e.g., type of operation, hydraulic head, discharge, water velocity). General mortality trends include:

- Young fish are more likely to be entrained and survive than mature fish; conversely mature fish are less likely to be entrained but if they are, their survival rate is lower. According to EPRI (1997), more than 90% of the fish entrained at hydroelectric projects are less than 4-8 inches (approximately 100 to 200 mm), and their high survival rate tends to reduce the overall entrainment impact on fish populations.
- Mortality tends to be positively correlated with both discharge and reservoir head. The higher the discharge and the higher the hydraulic head, the greater mortality will be.
- Mortality rates via pressure change vary by species, with perch, crappie and bass more susceptible to mortality than salmonids and minnows. Survival of percids tends to be very low, 0 to 10%, with large differences in pressure.

- Mortality due to pressure changes is reduced as the reservoir lowers.
- Mortality is relatively low in spillways with water velocities less than 50 fps, but increases sharply at velocities greater than that, with 100% mortality observed at velocities more than 80 fps.

## APPENDIX A-2. Comparison Reservoir Mortality Studies

**Fall Creek Reservoir** is operated for flood control and recreation, with the reservoir generally having an annual change in hydraulic head of approximately 100 feet. Discharges range from a low of 150 cfs, up to 1,000 cfs. Flow is released through two 5.5 by 10 foot rectangular slide gates that can be regulated to decrease the openings to as little as 1 foot tall by 5.5 feet wide.

Mortality studies at the reservoir focused only on salmonids, specifically steelhead and chinook salmon. Both direct and delayed mortality were included in the total mortality rates. The studies identified a chinook salmon mortality rate of 70% with rapid drawdowns and very high discharges (more than 1,000 cfs). Studies conducted at more gradual releases identified mean mortality rates of 41.0 for salmon smolts and 29.6% for steelhead fingerlings. Homolka and Smith (1991) identified that mortality was related to both reservoir head and discharge. In re-examining their data for this study, mortality was separated out according to the following conditions:

- High Head, High Discharge: Discharges greater than 700 cfs (although at times total flow split between two gates), hydraulic head greater than 80 feet over the intake top. Calculated velocities of 38 to 43 mph through the gates based on the reported discharges, number of gates open and degree of gate openings. Mean mortality of 57.5%.
- Moderate Head, High Discharge: Discharges greater than 700 cfs (although at times total flow split between two gates), hydraulic head between 50 to 80 feet over the intake top. Calculated velocities of 35 to 37 mph through the gates. Mean mortality of 50.0%.
- Very Low Head, Moderate Discharges: Discharges between approximately 700 to 1,000 cfs (although at times total flow split between two gates), hydraulic head between 15-18 feet over the intake top. Calculated velocities of 18 to 20 mph through the gates. Mean mortality of 6.8%.

There were no data on conditions ranging between 18 to 50 feet of head.

The steelhead data identified a mean mortality rate of 29.6% under unknown flow, gate opening and velocity conditions.

**Blue River Reservoir** is operated for flood control and recreation. It has a hydraulic head of 92 feet with an annual change of approximately 33 feet. Discharges range between 440 and 1,000 cfs, released through two slide gates. Mortality studies conducted between mid July and mid December 1989 identified mortality rates of 63% (salmon) to 74% (other species) (Downey and Smith 1990). Both direct and delayed mortality were included in the total mortality rates.

There were little data on the full range of flows or gate conditions during the study. However, the study identified a strong relatively linear relationship between discharge and mortality under low head conditions, with mortality ranging from 30% at 150 cfs to 60% at 350 cfs. In this study, “low head” conditions were defined as 50 to 60 feet over the intake.

**Cougar Reservoir** is operated for flood control, irrigation and hydroelectric power. Discharges can range from 440 to more than 1,000 cfs. Flow is released through one of two intakes- one leading to the turbines and one leading to a pair of regulated slide gate outlets. The 3-foot diameter regulating outlet pipes subsequently discharge into an open spillway-type chute.

Between November 1998 and March 1999, Taylor (2000) examined the mortality rates associated with both the hydroelectric turbines and the regulating outlets. Only direct mortality was reported. The study was conducted during winter low pool conditions, with the water surface ranging between 65 to 85 feet over the regulating gate outlets and 10 feet higher over the turbine. The flows and associated velocities during the study are unknown. Mean mortality was 32.3% for chinook salmon and 40% for rainbow trout through the regulating gates. For comparison, the mean mortality rates through the turbines were of 7.1% chinook salmon and 20% rainbow trout.

**Wickiup Reservoir** is operated for irrigation, with a full hydraulic head of 82 feet. Flows are released through two 8-foot pipes that narrow to two 7.5-foot jet valves at the outlet. Discharges can range from 100 to 2,000 cfs, or 50 to 1,000 cfs through each outlet.

Mortality studies at the reservoir examined all fish species captured in traps below the outlet on five days a month, between April and October, 2005 (Symbiotics 2009). Both direct and delayed mortality were included in the total mortality rates. The range of flows during the study was from 600 to 1,800 cfs (or 300 to 900 cfs through each outlet). The hydraulic head changed by 20 feet during the study and the water surface at the end of the study was 50-60 feet over the outlet elevation.

The mean mortality, including both direct and delayed mortality, was 86.3%. As for the Fall Creek study, Symbiotics (2009) identified a relationship between hydraulic head and mortality. Mortality was highest between April and June when the hydraulic head was the highest. During these months direct mortality was always greater than 77%. In the fall, as the head was at its lowest, direct mortality was less than 50%.

There is no information on within pipe or valve velocities.

**Tieton Reservoir** is primarily operated for irrigation with a full hydraulic head of 192 feet and an annual hydraulic head change of up to 130 feet. Flows are released through two 5-foot jet valves that are generally operated with the openings at less than 2.5 feet (Cramer and Associates 2002). Velocities have been identified as 13 to 27 mph within the intake pipes and 40 to 68 mph through the jet valves themselves (Hardin 2001).

Mortality sampling downstream of the outlets occurred from August 27 through October 17, 2001 to coincide with the maximum seasonal water withdrawal for downstream irrigation. This was also to coincide with the season when entrainment was expected to be the highest. Discharges during the study ranged between 300 to 2,200 cfs (or 150 to 1,100 through each outlet). The results indicated an average mortality rate of 81%, with mortality identified for all entrained species (James 2002). Only direct mortality was identified.

**APPENDIX B**

**LOCATION OF YELLOW PERCH SPAWNING SITES IN WHICH NETTING HAS  
OCCURRED BETWEEN 2009-2012.**

From Bailey (2012)

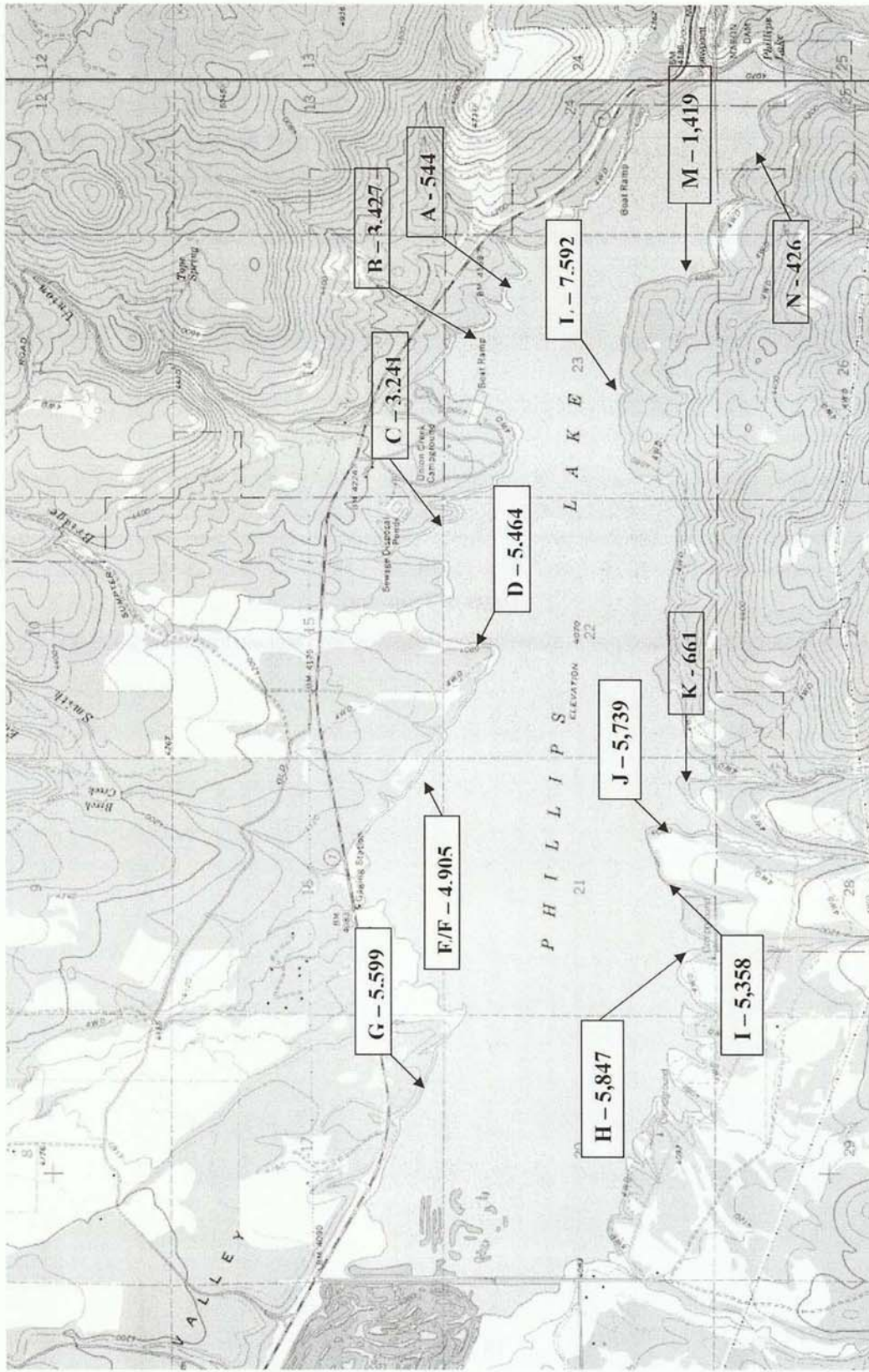


Figure 13. Aggregate of all Merwin trap deployment sites 2009-11, with average catch/day for all three years combined. Those highlighted in yellow were the most productive.