Yale Hydroelectric Project No. 2071 Entrainment Final Report

And

Bull Trout Entrainment Reduction Plan

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Washington Dept of Fish and Wildlife
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December 14, 2007

Frank Shrier
PacifiCorp
825 NE Multnomah,
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Dear Mr. Shrier,

The Washington Department of Fish and Wildlife (WDFW) appreciates the opportunity to provide comments on PacifiCorp's Yale Hydroelectric Project Entrainment Final Report and Bull Trout Entrainment Reduction Plan *Working Draft*. – dated November 6, 2007.

First, a comment on the PacifiCorp review process. The following excerpt is from the Lewis River Settlement Agreement: § 4.9.3 Yale and Merwin Bull Trout Entrainment Reduction. *"PacifiCorp shall allow at least 45 days for members of the ACC to comment on the draft plan."* On November 7, PacifiCorp released the draft Entrainment Plan and notified ACC members of a 30-day review and comment period. Then on December 13, PacifiCorp agreed to extend the comment period to December 14th. We are trying to accommodate this rushed review schedule, but ask PacifiCorp that this be the exception rather than the rule in future document and plan reviews.

WDFW provided extensive comments to the initial review draft of the "Yale Hydroelectric Project Entrainment Final Report". We do not believe that all our comments and concerns were adequately addressed final report dated November 6, 2007. WDFW's detailed comments and PacifiCorps responses are attached in Appendix 4 of that final report; we request that all subsequent distributions of this report include this appendix so that future readers of the report are made aware of WDFW's concerns.

In regards to the **Bull Trout Entrainment Reduction Plan *Working Draft***, WDFW appreciates that PacifiCorp has recognized the need for development and implementation of an entrainment reduction plan. We agree with PacifiCorps' preferred alternative, i.e., an electrical barrier to reduce entrainment at the Yale project. If the electrical barrier proves impractical, or the technology proves unfeasible, then WDFW recommends deferring to a full barrier net. This barrier net should be capable of being used in conjunction with a Merwin Trap – for the collection of target fish, as indicated in the following excerpt from the Lewis River Settlement Agreement: § 4.9.3:

> *"installation of barrier nets with submersible cork lines and designed to accommodate a Merwin-type floating trap."*

The mean size fish entrained in turbines 1 and 2 (Figure 1) correspond to fish captured in the Eagle Cliffs screw trap in 2001 (PacifiCorp, 2002). Page 3 of the working draft states: "However, given the low abundance of bull trout in Yale Lake and the observed length-frequency distribution of entrained fish, we expect that few adult bull trout were entrained during the entrainment evaluation." WDFW does not anticipate that adult bull trout are entrained. WDFW is not aware of any documented bull trout abundance estimate for Yale Lake, but we are aware of a series of yearly peak counts. WDFW's concern is that yearlings to three-year-old fish in the 80-240 mm size range are most likely to be entrained; and this fits the pattern of entrainment illustrated in Figure 1.

In summary, WDFW concurs with an electrical barrier system, recognizing that it must be field-tested to prove its feasibility. An effective barrier, coupled with a modified spillway and spill practice should prevent transit of bull trout from Yale to Merwin reservoirs.

WDFW appreciates the opportunity to provide comments. If you have any questions or responses to our comments, please contact Jim Byrne at 360-906-6751, John Weinheimer at 360 906-6746 or Steve Vigg at 360-360-6710.

Sincerely,

Pat Frazier,
Region 5 Fish Program Manager

References

PacifiCorp. 2002. Evaluation of anadromous salmon behavior ands habitat selection in the upper Lewis River Watershed AQU 13. Final Technical Report for Aquatic Resources. Lewis River Relicensing Documents. Portland, Oregon.

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1.0 Abstract

The Lewis River Settlement Agreement calls for a study to evaluate bull trout entrainment reduction methods at both Yale and Merwin hydroelectric projects and subsequently the development of an Entrainment Reduction Plan that minimizes negative impacts to bull trout and other species associated with entrainment. We investigated entrainment rates at Yale Hydroelectric Project using hydroacoustic equipment coupled with underwater video cameras. Hydroacoustics detections were filtered to eliminate debris and non-fish hits then analyzed in relation to a calculated fish entrainment zone. Overall fish were entrained at a rate of 0.19 fish per hour with a size range of 4.78 to 44.04 cm. Underwater cameras allowed us to observe only two fish that appeared to be kokanee. In addition, results of the 2006 study were compared with the previous 1997 Yale entrainment study.
Based on the results and analysis of bull trout entrainment at Yale dam, we find that there is a potential to entrain a small number of bull trout annually. In keeping with the Settlement Agreement, a Bull Trout Entrainment Reduction Plan is attached to address bull trout entrainment prior to installation of a downstream surface collector at Yale dam.

2.0 Introduction

The Lewis River Settlement Agreement calls for a study to evaluate bull trout entrainment at both Yale and Merwin hydroelectric projects and subsequently the development of an Entrainment Reduction Plan that minimizes negative impacts to bull trout and other species associated with entrainment. Settlement Agreement Section 4.9.3 specifically describes evaluation of either strobe lights or a barrier net with submersible cork lines that could be designed to accommodate a Merwin-type floating trap (See Appendix 1).

PacifiCorp has previously studied fish entrainment during relicensing of the Lewis River Hydroelectric Project. These past entrainment studies have provided useful information and guidance for designing a proposed entrainment study at Yale and Merwin dams. A brief summary of the pertinent information from these studies follows.

The 1997 entrainment study at the Yale facility (PacifiCorp 1999) used hydroacoustics to evaluate fish entrainment that occurred over a four-month period extending from January through April. Entrainment rates during this time averaged approximately 21 fish per hour with a range of 40 to 180 fish per hour (unfiltered data). Estimated fish size ranged from 7 to 16 cm (2.75 to 6.30 inches). Fish were observed at higher frequencies in the upper, as opposed to lower, portion of the water column and also higher frequencies in the intake Bay 2 (Turbine 1) as compared to Bay 1 (Turbine 2). PacifiCorp also found the highest percent of the fish (60%) were entrained at the Turbine 1 intake.

A 2002 entrainment study at Swift Dam (PacifiCorp 2004) used a rotary screw trap and fish salvage operations to capture fish downstream of Swift No.1 turbine discharge that were presumably entrained at Swift No. 1 and entered the Swift canal. The purpose of this study was to assess species composition and relative abundance of fish entrained in the Swift No. 1 project. This study identified 12 species of potentially entrained fish. The total number of entrained fish decreased from the start of the study in winter to the end of the study in summer. Three Bull trout were collected during spring and one during the summer sampling periods. Since this was not a quantitative study, the actual number of entrained bull trout could not be determined.

The approach to the SA Section 4.9.3 requirement was to evaluate current entrainment at the Yale intakes to obtain more recent information on fish sizes and numbers in order to make more informed recommendations for an entrainment reduction device. In order to do that, the 1997 entrainment study of the Yale facility was repeated with hydroacoustic equipment with underwater video cameras added.

There were two major objectives established for this Study and approved by the Lewis River Aquatics Coordination Committee (ACC): 1) Evaluate fish entrainment into the turbine intakes at Yale and Merwin dams, and 2) Develop a draft Entrainment Reduction Plan for review by the ACC. We developed this report to address these two objectives and include a total of five (5) interrelated tasks that are described below. This report focuses on the Yale project in the near term both in the study phase and the entrainment reduction plan phase. Once an entrainment reduction plan is in place and actions at Yale implemented, the Merwin phase of this project will be addressed. That phase will include an assessment of the need for entrainment reduction at Merwin and, if that moves forward, then we will conduct an evaluation of applying the Yale plan and design to Merwin.

3.0 Study Site

Our research was conducted at Yale dam along the mainstem Lewis River in Southwest Washington (Figure 3.0-1). Yale Dam is located on the North Fork Lewis River approximately 30 miles upstream from the confluence with the Columbia River. The Yale Hydroelectric Project is a 134 MW plant owned and operated by PacifiCorp that lies directly upstream of the Merwin Hydroelectric Project on the Lewis River. Construction of the Yale Project began in 1951 and was complete by 1953. The project consists of a main embankment dam, saddle dam, reservoir, penstocks, powerhouse, and transmission line. The Yale project is operated in coordination with the other three hydroelectric facilities (Merwin, Swift No. 2 and Swift No. 1) on the North Fork Lewis River.

3.1 Yale Dam and Reservoir

The main dam is a rolled earthen fill embankment type dam with a crest length of 1,305 ft and a height of 323 ft above its lowest foundation point. Its crest elevation is 503 ft-msl. The saddle dam is located ¼ mile west of the main dam and is approximately 1,600 ft long and 40 ft high with a crest elevation of 503 ft-msl. The main dam has a chute-type spillway, located in the right abutment, with a capacity of 120,000 cfs through five 30-foot by 39-foot taintor gates at reservoir elevation 490 ft-msl.

Yale Lake is approximately 10.5 miles long with a surface area of approximately 3,800 acres at elevation 490 ft-msl (full pool). At full pool, the reservoir has a gross storage capacity of approximately 401,000 acre-ft. At the minimum pool elevation of 430 ft-msl, the reservoir has a capacity of approximately 190,000 acre-ft.

The Yale Project consists of two tunnels/penstocks leading from Yale Dam to the powerhouse. Water is delivered to the tunnels/penstocks via a common intake. The intake for the Unit number 2 penstock is located on the intake gallery side nearest the spillway while the Unit number 1 penstock is located closest to the shoreline. The Yale intake is a relatively

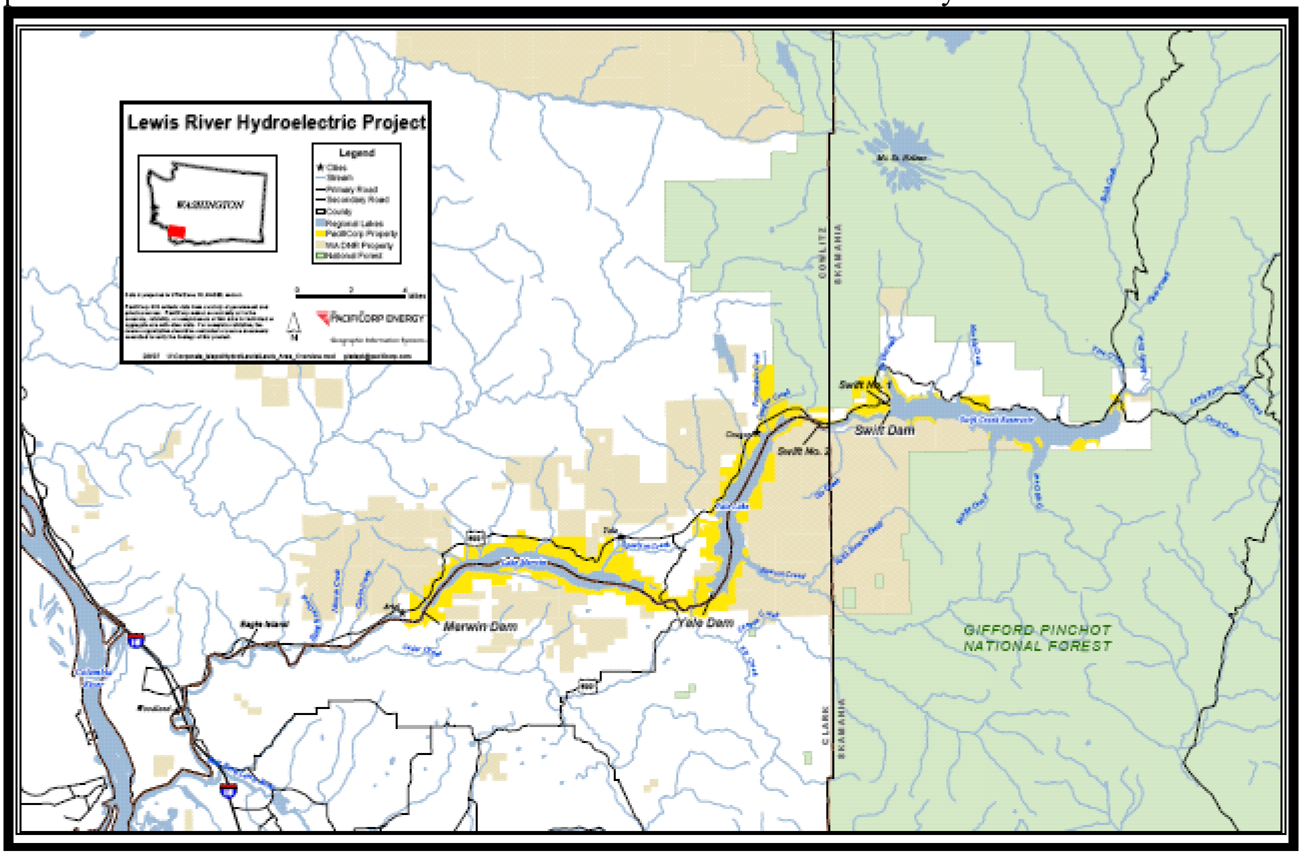


Figure 3.0-1. Map showing location of Yale Lake and the Lewis River Hydroelectric Projects.

deep (approximately 90 ft. below full pool), high-head intake with design velocities ranging from between 10 and 20 feet per second (fps). The intakes are protected from large debris by steel trash racks on approximately 4-inch spacing. The maximum diameter of each of the Yale penstocks is 18.5 ft; the minimum diameter is 16 ft. Penstock velocities range from 18.2 fps in the tunnel to 24.3 fps in the penstocks' smallest sections. The Yale penstocks are each capable of passing a maximum of 4,880 cfs. The Yale powerhouse contains 2 Francis-type generator units with a total installed capacity of 108 MW (nameplate). The powerhouse is located at the base of the earth embankment on the left side (facing downstream) of the old river channel. The generators were originally installed in 1952. The turbines were rehabilitated coincident with generator rewinds in 1987 and 1988, respectively. In 1995, PacifiCorp installed a new fish friendly/more efficient runner in Yale Unit No. 2. A similar runner was installed in Unit No. 1 in 1996. The new runners increased Yale generating capacity to 134 MW. Power generated at the Yale Project is transmitted 11.5 miles over a 115 kilovolt (kV)-transmission line (Lake Line) to a substation adjacent to the Merwin Project.

Yale reservoir is used heavily for recreational fishing and boating and supports natural self-sustaining populations of Kokanee (*Onchorhynchus nerka),* Bull trout (*Salvelinus confluentus*), and Coastal Cutthroat trout (*O. clarki*). Large-scale Sucker (*Catostomus macrocheilus)*, Mountain Whitefish (*Prosopium williamsoni*), Northern Pikeminnow (*Ptychocheilus oregonensis)*, Threespine Stickleback (*Gasterosteus aculeatus*), Long-nose Dace (*Rhinichthys cataractae*) and Sculpins (*Cottus sp*). also reside in Yale Lake. WDFW does not typically stock Yale Lake with artificially produced fish. However, rainbow trout (*O. mykiss*) that are stocked in Swift Reservoir and Swift No. 2 power canal (just upstream of Yale Lake) occasionally enter Yale Lake through the upriver project turbines or through spill.

4.0 Methods

The following are ACC-approved sub tasks for this study:

Task 1a. Investigate the Amount of Entrainment Occurring at Each Project Prior to Placement of a Barrier Net; and

Task 1b. Determine if any of the Entrained Fish are Bull Trout.

We combined these two tasks (Tasks 1a and 1b) to estimate both the number and species composition of fish being entrained into the Yale Dam intakes. For this, we used a combination of hydroacoustic and underwater video technologies. As stated earlier, investigations at Merwin follow Yale implementation. Hydroacoustic technology was used to determine the amount of entrainment that occurred, while sampling with an underwater video camera was used to determine the occurrence and relative proportion of bull trout that were entrained.

Data from past Lewis River entrainment studies indicated that overall entrainment of small fish at Yale Dam can be high (40-180 fish per hour) during the winter and spring but drops off during the summer (PacifiCorp 1999) and also that three bull trout (75mm to 300mm) moved downstream in the Swift Canal during spring and summer (PacifiCorp 2004). Data from other Pacific Northwest rivers indicate that post-spawning adult bull trout migrate downstream in the fall (Wade and Tranquilli 2002; US Bureau of Reclamation 2004). Recent data from tagged bull trout in the Willamette River basin documented adult movement out of the Cougar reservoir during October (personal communication with Mark Wade, Oregon Department of Fish and Wildlife, Leaburg, OR). Based on these studies, a sampling window was selected that began in early October 2005 and continued into July 2006.

4.1 Underwater Video Design

To generate data relevant for species composition and species proportions of the fish entrained by the intakes, two SEA VIEW® underwater video cameras were mounted to the dam upstream of the intakes. The cameras were mounted and focused to cover as much as possible of the entrance to both intakes. The cameras were attached to the dam at the mouth of the intakes by commercial divers.

The cameras were equipped with internal illumination. Since it was possible that the lighted camera at a depth of 70 feet would serve as a source of fish attraction, we minimized this concern by operating the camera for a brief period each day. In addition, the 24-hour hydroacoustic data was intended to be used to test the hypothesis that the use of the camera light does not alter the fish entrainment.

With an 18-degree lens, each camera allowed coverage of an area approximately 20 feet wide by 10 feet deep, about one half of each intake opening. Past entrainment sampling at Yale found that the majority of fish moved through the upper half of the water column (PacifiCorp 2004). We therefore focused the cameras on the upper half of the water column within the intake. The cameras were illuminated with 21 internal sources of white light that provided a clear color image and allowed the best conditions for species identification.

The video camera installed on Unit 1 and was operated for two, 4-hour blocks per day for approximately one week. After that period, the raw hydroacoustic data was reviewed to determine timing changes that would allow us to maximize our chances of filming fish being entrained. The hydroacoustic observations suggested most detections occurred during pre-dawn and evening period. Thus, the cameras were set up with timers to record from 0600h to 1000h and again from 1600h to 2000h.

The videos were reviewed manually to determine species composition of the entrained fish and to determine relative abundance by species in each sample. The total number and proportions of fish species captured on film were summarized by week. Limited video observations of fish prevented any additional testing of cameras. However, it was obvious from the lack of fish seen that the illuminated camera did not serve to attract fish to their immediate vicinity.

4.2 Hydroacoustic Design

The total amount of entrainment was determined using split beam hydroacoustics. Two BioSonics' 200-kHz split beam transducers were mounted near the surface and aimed downward to cover the intake openings (see Figure 4.2-1). In the event that surface mounts would be inadequate for complete coverage during winter drawdown, the transducers were mounted approximately 18 feet below full pool by commercial divers. The amount of data collected by the transducers was extensive and generated large data files approximately 16 MB data in one hour. Nevertheless, to collect the most complete data set possible the transducers were set up to operate continuously for the duration of the study.

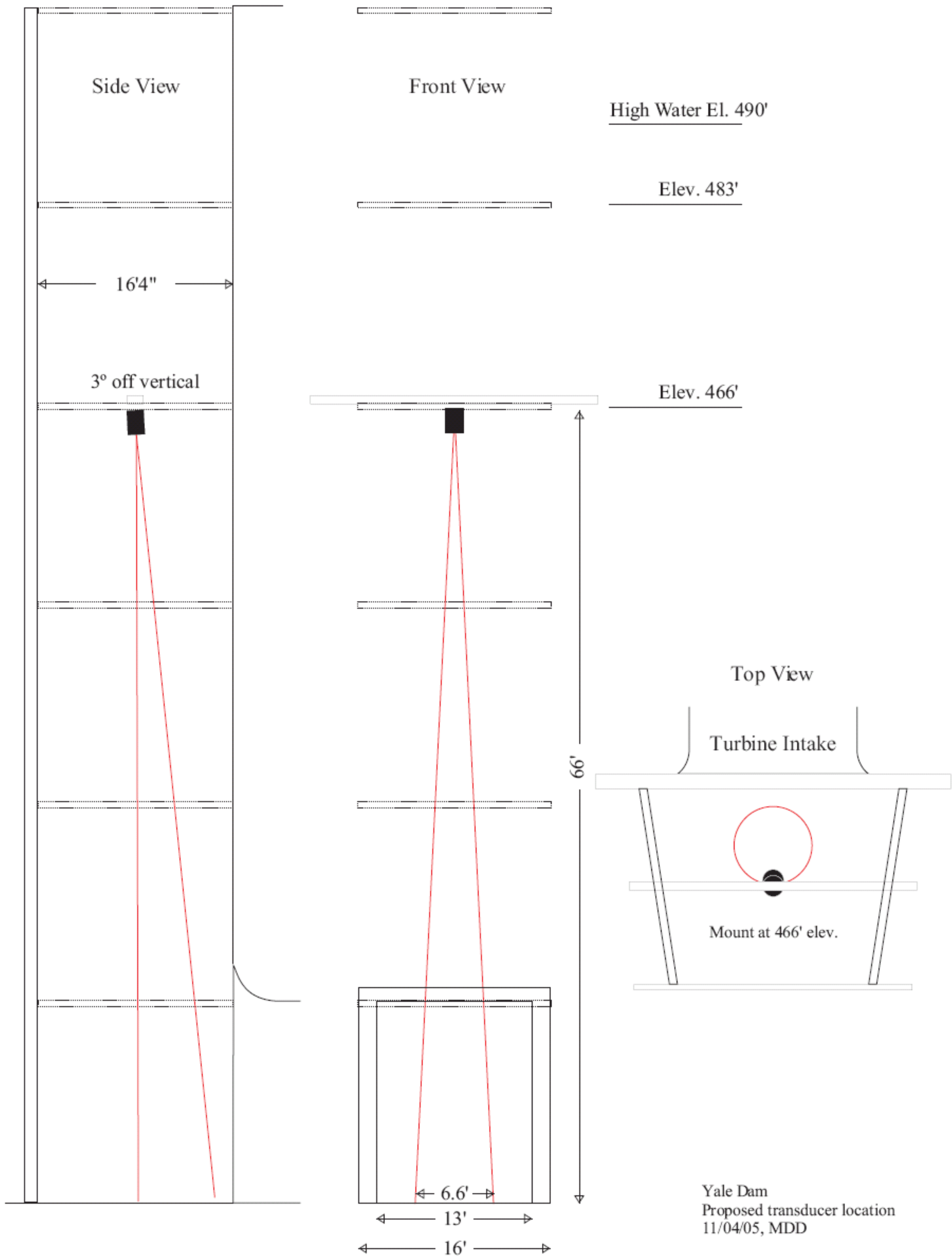


Figure 4.2-1. Schematic of one of the hydroacoustic transducer placement and orientation in the Yale intake structure.

4.3 Data Analysis

4.3.1 Initial Data Processing

Hydroacoustic data was analyzed to determine daily and hourly entrainment rates. The split beam data also provided information on the direction of fish travel, the distribution of fish within each of the intakes, and acoustic size of the entrained fish. Acoustic data files were run through a 2-dimensional (time/range) trace formation program, as well as manually reviewed for erroneous records. Tracking parameters were determined by testing trace formation performance with those from manual analysis. The date/time, mean Target Strength (TS), and mid-range of each accepted fish trace was written to file, along with a host of other descriptive measurements.

There was a large amount of debris entangled in the trash rack and support structures of the dam that created a high volume of false targets in the data files. To address false targets, post processing of the trace formation output was required. False targets generated by debris and other static structures are characterized by horizontal banding in the echograms (Figure 4.3-1). To eliminate these erroneous data, the trace formation output was analyzed for temporal and spatial peaks in target detection. After identifying the spatial and temporal peaks in false targets, the corresponding acoustic files were then reviewed to confirm the presence of debris interference. All targets matching the temporal and spatial location of the observed debris were filtered out of the dataset. Additional erroneous data was noted during periods when the turbine units were off and the wicket gates were closed. Since it is impossible for fish to be entrained during this time, the data was subject to a second layer of filtering that removes all targets collected during times when the corresponding turbine was non-operational, defined in this study as flows of less than 100 cfs.

4.3.2 Determination of Entrainment Area

The split-beam hydroacoustic units only covered a portion of the intake opening (Figure 4.2-1). In addition, due to their near surface mounting location targets were detected far as 41.6 ft above the intake in areas of estimated low flows. Thus, it was deemed inappropriate to equate filtered target data with entrained fish. Instead, we used an approach similar to that used in recent entrainment studies on the Columbia River (Simmons et al. 2006) and we defined a Fish Entrainment Zone (FEZ) (Figure 4.3-2). Hydroacoustic data was then adjusted, expanded or eliminated as described below, to account for entrained fish within the FEZ.

No data were available to describe the water velocity in the vicinity the intakes; thus, a conceptual model of a flow field was generated. The general shape of the flow field was comprised of a half cylinder covering the intake opening topped by a wedge (Figure 4.3-3). This shape was similar to a Computational Fluid Dynamics model constructed for turbine intakes at Grand Coulee Dam (Simmons et al. 2006). A half cylinder extended from the floor to the top of the intake and out a radius of 8 ft into the forebay. We assumed that for the height and width of the intake opening, the flow would enter largely along horizontal vectors and that any fish entrained in this flow would pass through this half cylinder. Flow velocities inside the cylinder were estimated to be greater than 11.75 ft/sec (fps). For the upper portion of the FEZ, we defined a wedge with the following three borders: one below can be described as a horizontal plane that extended out from the top of the intake; the second was the defined by the side of the dam; and, a third was bounded above by the 3 fps isovel (velocity contour) (Figure 4.3-3). The 3 fps velocity contour was used as a conservative approximation of minimum capture velocity for fish in the vicinity of the intake.

To calculate the distance from the intake to the outer limit of the FEZ, we considered the basic equation:

$$AV = Q \qquad (1)$$

where:
A = Area
V = Velocity
Q = Flow

The equations for calculating the surface areas of each shape around the intake opening (Figure 4.3-3) were then used in equation 1:

$$(A_1 + A_2)V = Q \qquad (2)$$

where:
$A_1 = 1/4 \text{ surface area of sphere} = \pi r^2$
$A_2 = 1/2 \text{ surface area of cylinder} = \pi r h$

which can be further stated as the quadratic equation:

$$F(x) = \pi r^2 + \pi h r - \frac{Q}{V} = 0 \qquad (3)$$

The radius, r, in these equations is the unknown distance from the center of the intake openings to the point in which a velocity of 3 fps would occur. In order to solve for r, the quadratic equation is solved:

$$r = \frac{-\pi h + \sqrt{(\pi h)^2 + 4\pi \frac{Q}{V}}}{2\pi} \qquad (4)$$

where:
r = radius, or the distance from the center of the intake opening to the point of velocity, V
h = height of the ½ cylinder, or the center of the intake opening = 8.5 ft
Q = maximum flow through the turbines = 4880 cfs
V = velocity = 3 fps.

The result of this calculation described the outer limits of the wedge portion of the FEZ. This portion extended horizontally a distance of 18.89 ft from the center of the intake opening. Vertically, the upper limit of the entrainment zone would be approximately 6.4 ft above the top of the intake opening or 38.6 ft below the transducer (Figure 4.3-3). Using this information, further data filtering was then conducted, removing all data collected outside the defined entrainment zone.

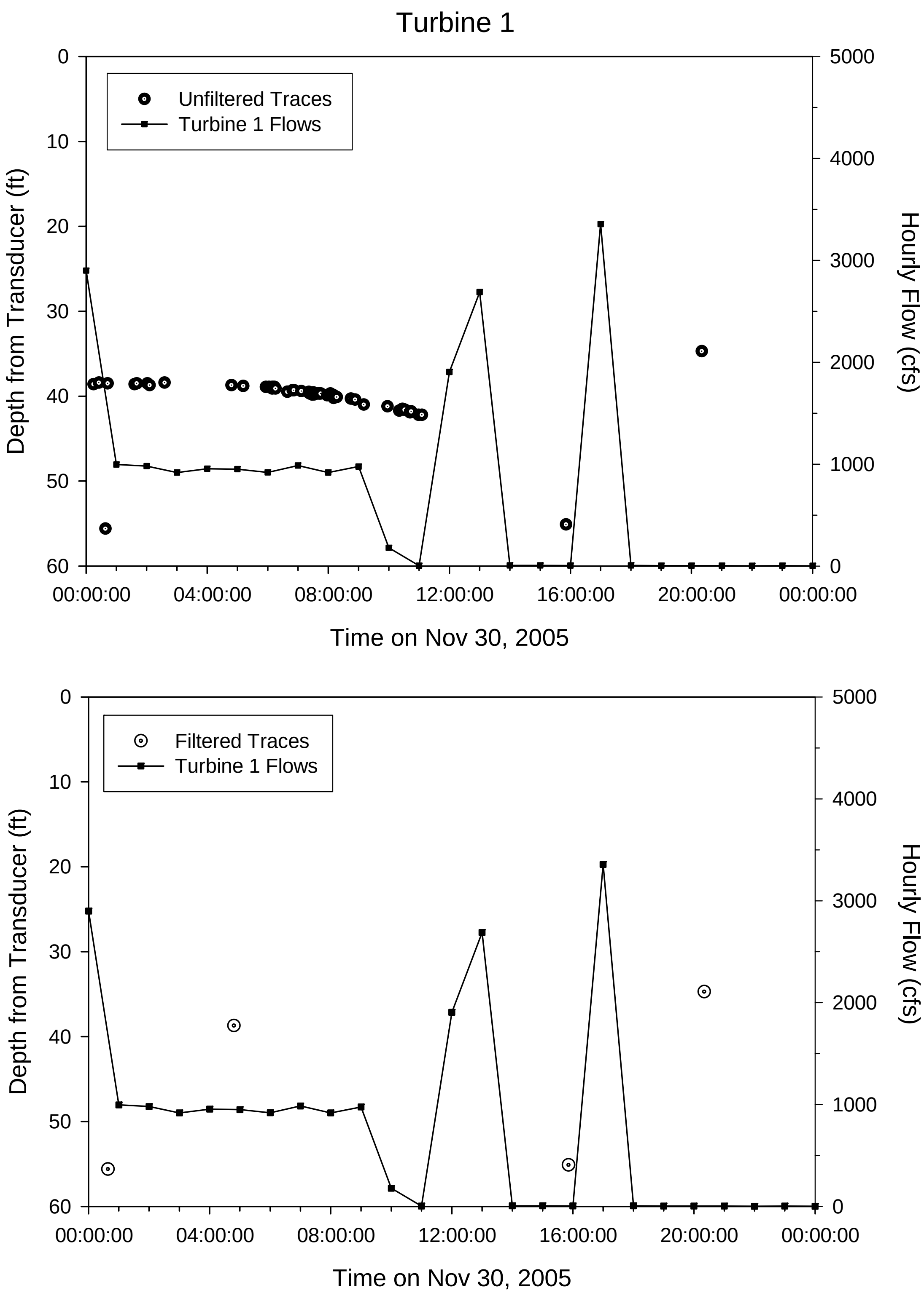


Figure 4.3-1. Example of false targets evidence by horizontal banding in the upper graph and probable fish targets following filtering in the lower graph. Flows are hourly averages.

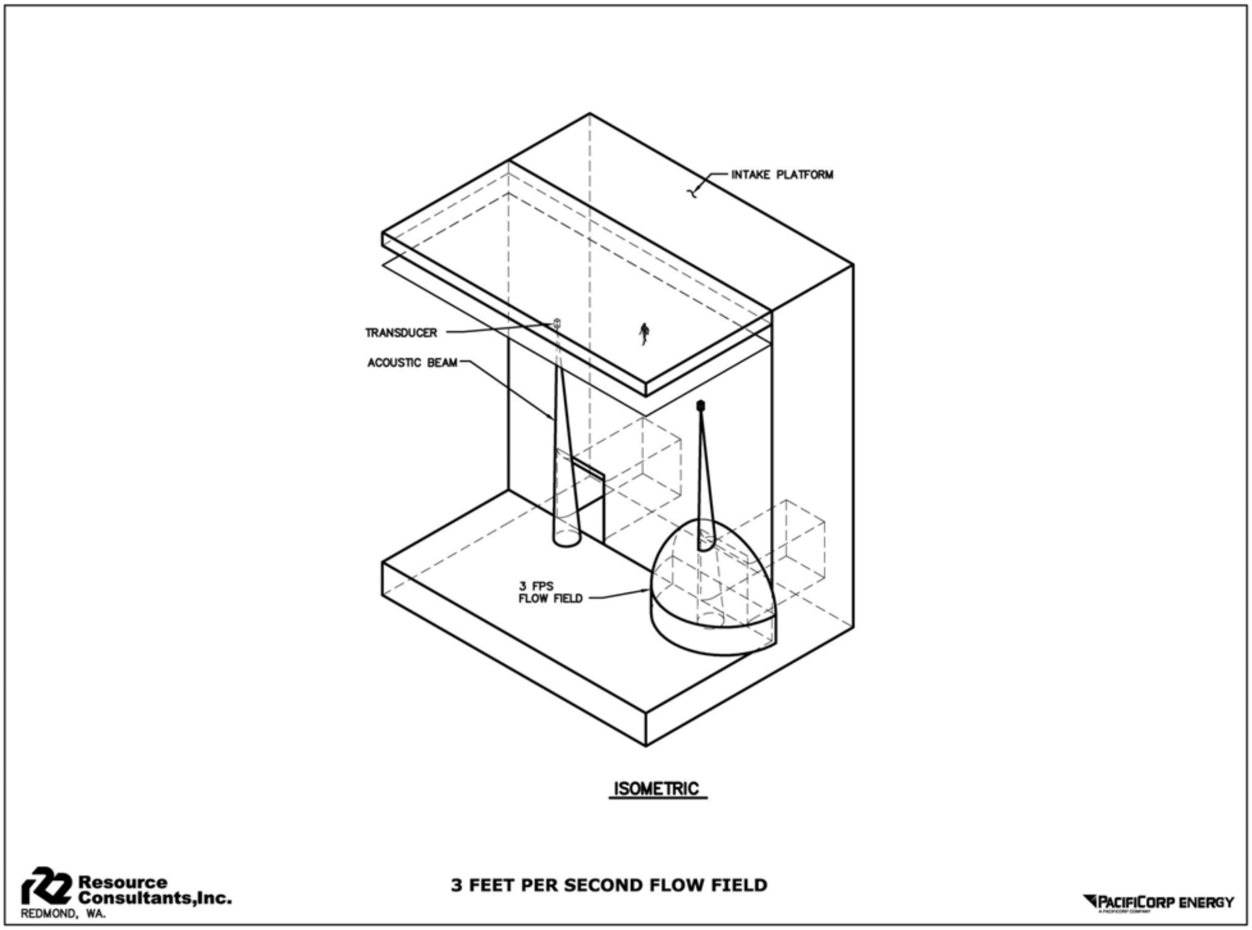


Figure 4.3-2. Graphic depiction of the fish entrainment zone (FEZ) at the Yale hydroelectric facility intakes.

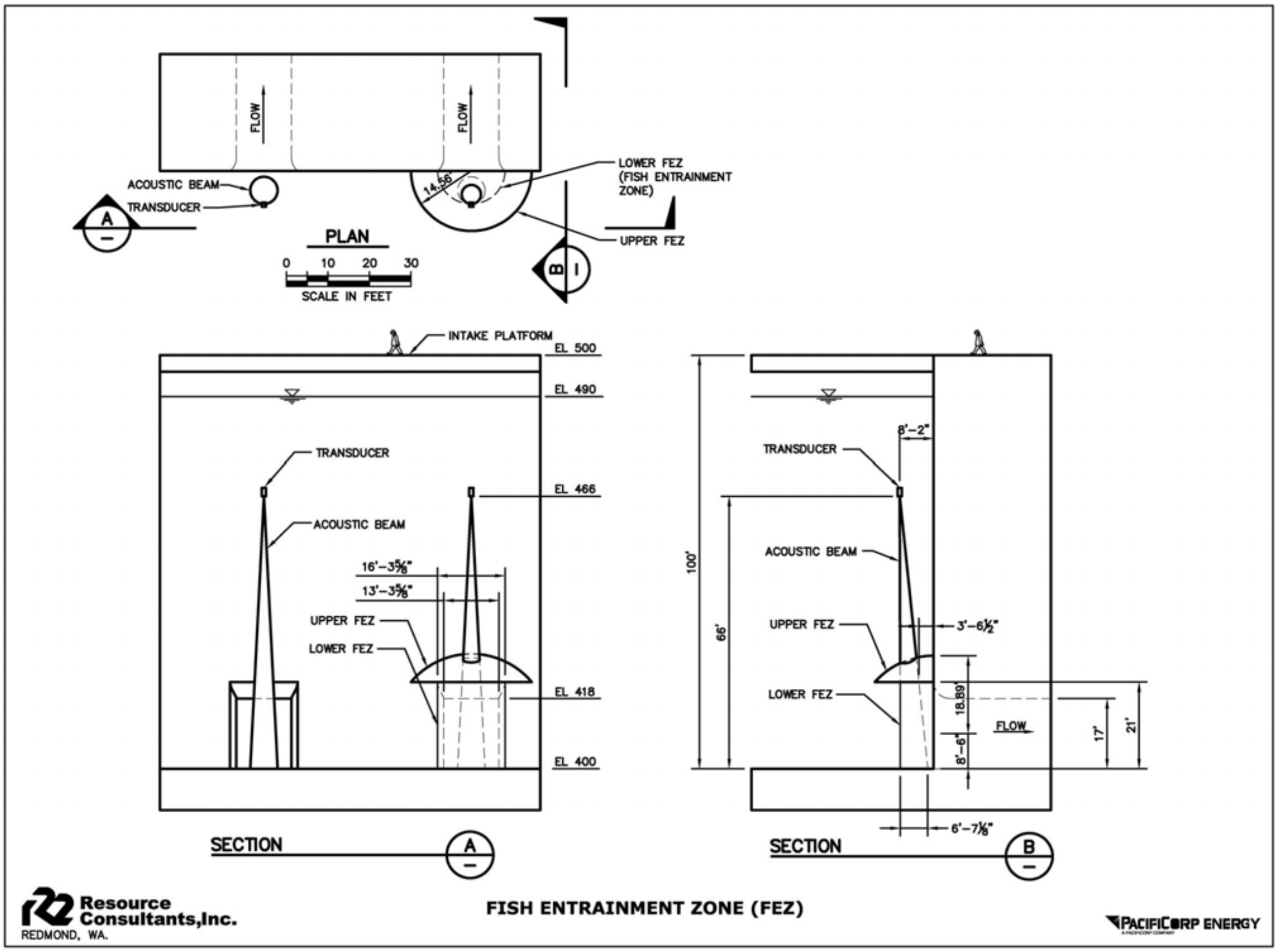


Figure 4.3-3. General shape and dimensions of the flow field in front of the Yale intakes as determined by a computational model of the flow field.

4.3.3 Weighting of Fish in Entrainment Area

The area in front of each intake sampled by the split-beam transducer was only a portion of the area where entrainment was possible. Thus, to estimate total entrainment it was necessary to expand the data collected within the beam to the entire FEZ. Because the FEZ was composed of two areas with distinct shape, cylinder and wedge, fish traces were weighted differently according to these areas, as well as to their depth within each area. Fish detected in front of the intake opening were weighted according to the proportion of the beam's width at a given depth to the total length of the perimeter of the half cylinder, appearing in cross-section as an arc running from the side margins of the intake to the back margin of the acoustic beam (Figure 4.3-3). The arc's length was used to accommodate the general shape of the velocity contours around the intake. Therefore, the weighting factor used for fish traces in front of the intake was calculated:

$$W_{ij} = \frac{\text{Arc length}}{\text{Subsample width}} = \frac{I_j}{2 * D_{ij} * \tan * (\Theta/2)} \quad (5)$$

where:

W*ij* = the weighted observation of fish *i* at location *j*
Subsample width = 2 * sample beam radius
I*j* = the effective width of location *j* = 28.82 ft
D*ij* = distance of fish *i* from transducer at location *j*
Θ = angle of major axis of acoustic beam (degrees)

Fish detected above of the intake opening were weighted according to the proportion of the beam's area to the total area of the cross-section of the wedge at the corresponding depth of each fish detection. Therefore, the weighting factor used for fish traces above of the intake was calculated as:

$$WeightingFactor_{(3ft/s)} = \frac{\text{Total Entrainment Area}}{\text{Beam Area}} = \frac{\frac{1}{2}\left(r^2 - a^2\right)}{\left(\tan(\Theta/2) * D_{ij}\right)^2} \quad (6)$$

where:
r = radius from the center of the intake opening to the point of velocity of 3 fps
a = distance from the center of the intake to fish *i* at location *j*
Θ = the effective acoustic beam width (degrees)
D*ij* = distance of fish *i* from transducer at location *j*

4.3.4 Conversions of Target Strengths to Fish Lengths

Target strengths of each fish trace in the data set were converted to fish lengths using a formula adapted from Love (1971, 1977):

$$TS_{dB} = 19.1 \log L - 64.77 \qquad (7)$$

where:
TSdb = target strength, and
L= fish length

Total Length, TL, was then solved for each fish target using the equation:

$$TL = 10^{\left(\frac{TSdB + 64.77}{19.1}\right)} \qquad (8)$$

These estimated fish lengths were averaged for each week. In addition, 95% confidence intervals were calculated to quantify variation in the estimates.

4.3.5 Entrainment Rates

Entrainment rates were estimated throughout the 34-week period of study. First, hourly entrainment rates were calculated by dividing the total weighted number of fish for a given day by the total number of hours that both the turbines and transducers were operational. These hourly rates were pooled by week and then averaged for a mean hourly entrainment rate per week. The 95% confidence intervals were also estimated to quantify variation in the data.

5.0 Results

5.1 Study Flow Periods

We observed that there were five different operational conditions that occurred during the study period (Figure 5.1-1). These were:

1) November 24th to December 27th - Variable turbine operation;
2) December 28th to February 4th - Steady, high turbine operation;
3) March 13th to April 22nd – Variable turbine operation;
4) April 24th to June 10th – Turbines off to steady, high turbine operation; and,
5) June 11th to July 19th – Variable turbine operation.

There was a period between March 1st and March 15th that the hydroacoustic transducers were not operating due to reservoir drawdown. No data was collected during this period (Table 5-1).

5.2 Video Analysis

The video cameras were actually mounted on the side wall of the intake chamber and were oriented to view across the plane of the intake entrance in the upper third of the intake area (Figure 5.2-1). The videos were reviewed manually to determine species composition of the entrained fish and to determine relative abundance by species in each sample. Unfortunately, because the camera was not able to capture the entire width of the intake, very few fish were actually observed by video camera. While the video image was clear and it was easy to observe sticks and other debris, it was determined that the camera could only pick up an image of half the intake width. Therefore, any fish entering the intakes at greater than or equal to about 10 feet from the camera lens were beyond detection.

Using a randomized block design for video observations, we collected a total of 616 hours of film for each intake that documents entrainment at all hours of the day and each day of the week. This resulted in approximately 50 hours of film for each of the 12 possible time blocks at each intake. With this sampling design, we intended to capture seasonal or diel patterns in entrainment as well as increasing the chance of capturing rare events. However, video observations of fish were too illuminate any patterns and furthermore, suggested that additional targeted filming would be unproductive. At the end of the study we noted periods of peak hydroacoustic counts and reviewed the available video footage to see if the entrainment was documented by the video cameras.

No fish were observed for the recording period 11/22/05-02/15/06. Overall, the quality of the video was poor for this recording period. For lack of larger objects in their field of view, the camera lenses were focusing on particulates in the water and this made viewing difficult. A total of two fish observations were made from the video footage collected for dates covering 02/15/06-03/09/06 (Table 1). We were unable to identify the species of the two fish observed on 02/15/06. However, both fish displayed holding behavior in front of the camera for approximately 8 seconds. The fish observed on 02/28/06 appeared to be a Kokanee salmon. No fish were recorded by the video at the times indicated as peak entrainment periods based on hydroacoustic data.

5.3 Fish Observations using the Hydroacoustics

Operation of the video and hydroacoustic monitoring began on November 22, 2005 and ended on July 27, 2006. Reservoir elevations during the study period ranged from a low of approximately 460 ft-msl to full pool at 490 ft-msl (Figure 5.3-1). During the March period, water level in the reservoir was reduced to below the transducer level in order to complete some Swift No. 2 canal construction. Therefore the transducers were shut down during this period and no entrainment was evaluated.

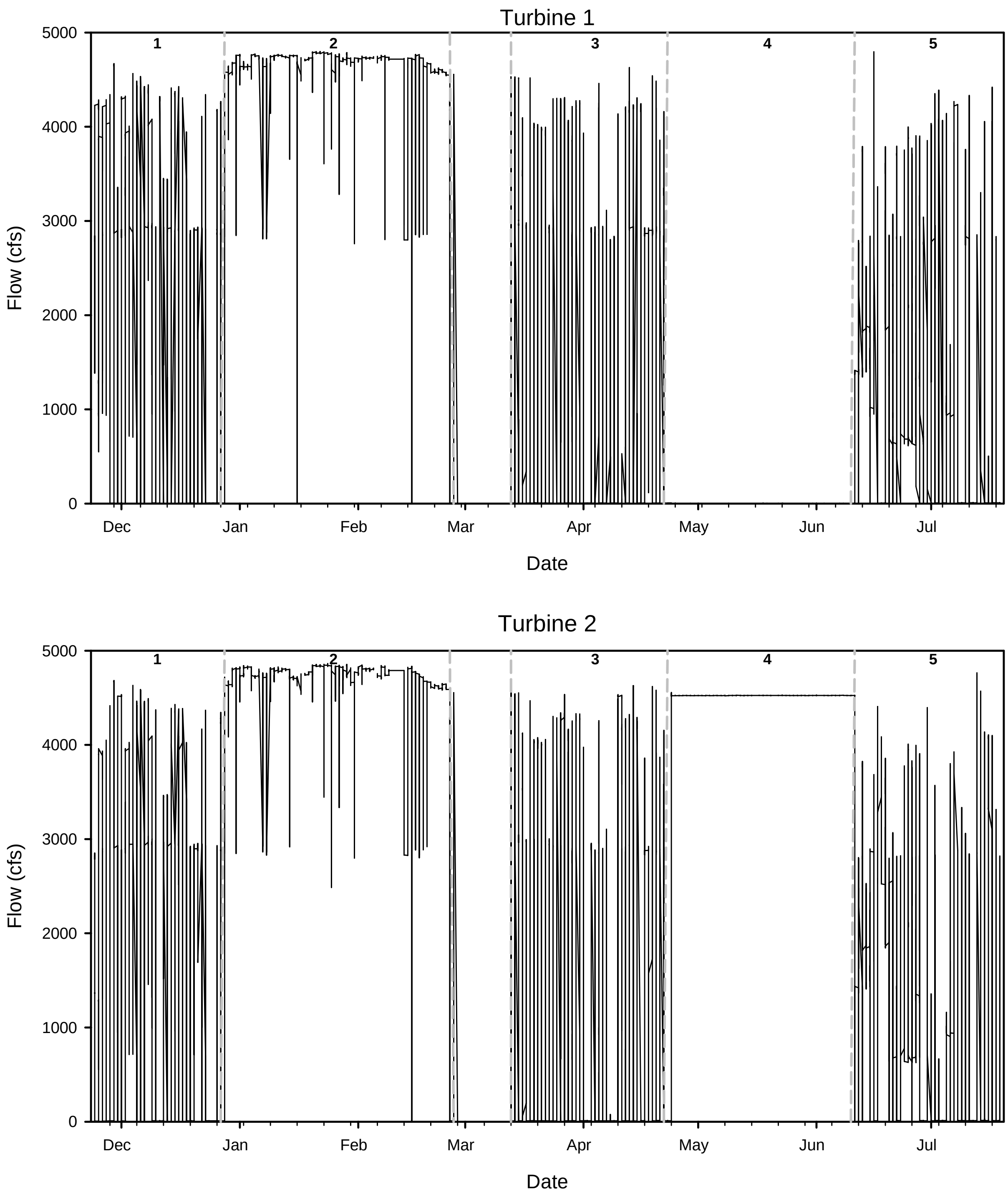


Figure 5.1-1. Average Hourly flow operations (cubic feet per second, cfs) for Yale Dam Turbine 1 (top) and Turbine 2 (bottom) from November 24, 2005 to July 19, 2006. Flow-type periods are defined along the top margins for reference.

	Week	Mean Flow (cfs)		Comment
Dates		Turbine 1	Turbine 2	
11/24/05 - 11/30/05	1	2507.17	1947.32	
12/1/05 - 12/7/05	2	2802.11	2609.34	
12/8/05 - 12/14/05	3	1877.57	1778.99	
12/15/05 - 12/21/05	4	2002.30	2334.37	
12/22/05 - 12/28/05	5	1489.84	1257.60	
12/29/05 - 1/4/06	6	4649.07	4755.73	
1/5/06 - 1/11/06	7	4656.75	4696.40	
1/12/06 - 1/18/06	8	4383.39	4421.22	
1/19/06 - 1/25/06	9	4739.61	4791.53	
1/26/06 - 2/1/06	10	4670.30	4721.36	
2/2/06 - 2/8/06	11	4702.64	4794.39	
2/9/06 - 2/15/06	12	4448.54	4515.36	
2/16/06 - 2/22/06	13	4425.86	4446.51	
2/23/06 - 3/1/06	14	4575.54	4611.55	Only 2 days of data
3/2/06 - 3/8/06	15	-	-	Transducers Exposed
3/9/06 - 3/15/06	16	-	-	Transducers Exposed
3/16/06 - 3/22/06	17	1613.12	1760.94	Only 5 days of data
3/23/06 - 3/29/06	18	1765.44	1566.52	
3/30/06 - 4/5/06	19	2072.20	1245.87	Only 2 days of data
4/6/06 - 4/12/06	20	649.22	2236.95	Only 3 days of data
4/13/06 - 4/19/06	21	2253.10	1456.71	
4/20/06 - 4/26/06	22	757.95	2397.75	
4/27/06 - 5/3/06	23	1.05	4521.91	
5/4/06 - 5/10/06	24	1.04	4522.16	
5/11/06 - 5/17/06	25	1.09	4522.71	Only 4 days of data
5/18/06 - 5/24/06	26	1.24	4523.41	Only 5 days of data
5/25/06 - 5/31/06	27	1.21	4522.82	
6/1/06 - 6/7/06	28	1.29	4523.32	
6/8/06 - 6/14/06	29	882.93	3300.86	
6/15/06 - 6/21/06	30	1289.92	1988.12	Only 5 days of data
6/22/06 - 6/28/06	31	1451.82	1457.26	Only 6 days of data
6/29/06 - 7/5/06	32	1189.76	328.75	
7/6/06 - 7/12/06	33	680.85	661.95	
7/13/06 - 7/19/06	34	686.51	919.54	

	Period	Mean Flow (cfs)		Flow Type
Dates		Turbine 1	Turbine 2	
11/24/05 - 12/27/05	1	2103.46	1944.36	Variable
12/28/05 - 2/24/06	2	4557.60	4616.02	Steady, High
3/13/06 - 4/22/06	3	1762.31	1618.15	Variable
4/24/06 - 6/10/06	4	1.21	4492.14	OFF / Steady, High
6/11/06 - 7/19/06	5	945.05	1259.71	Variable

Table 5-1. Weekly study periods with mean operational flows for Yale Dam Turbines 1 and 2 from November 24, 2005 to July 19, 2006.

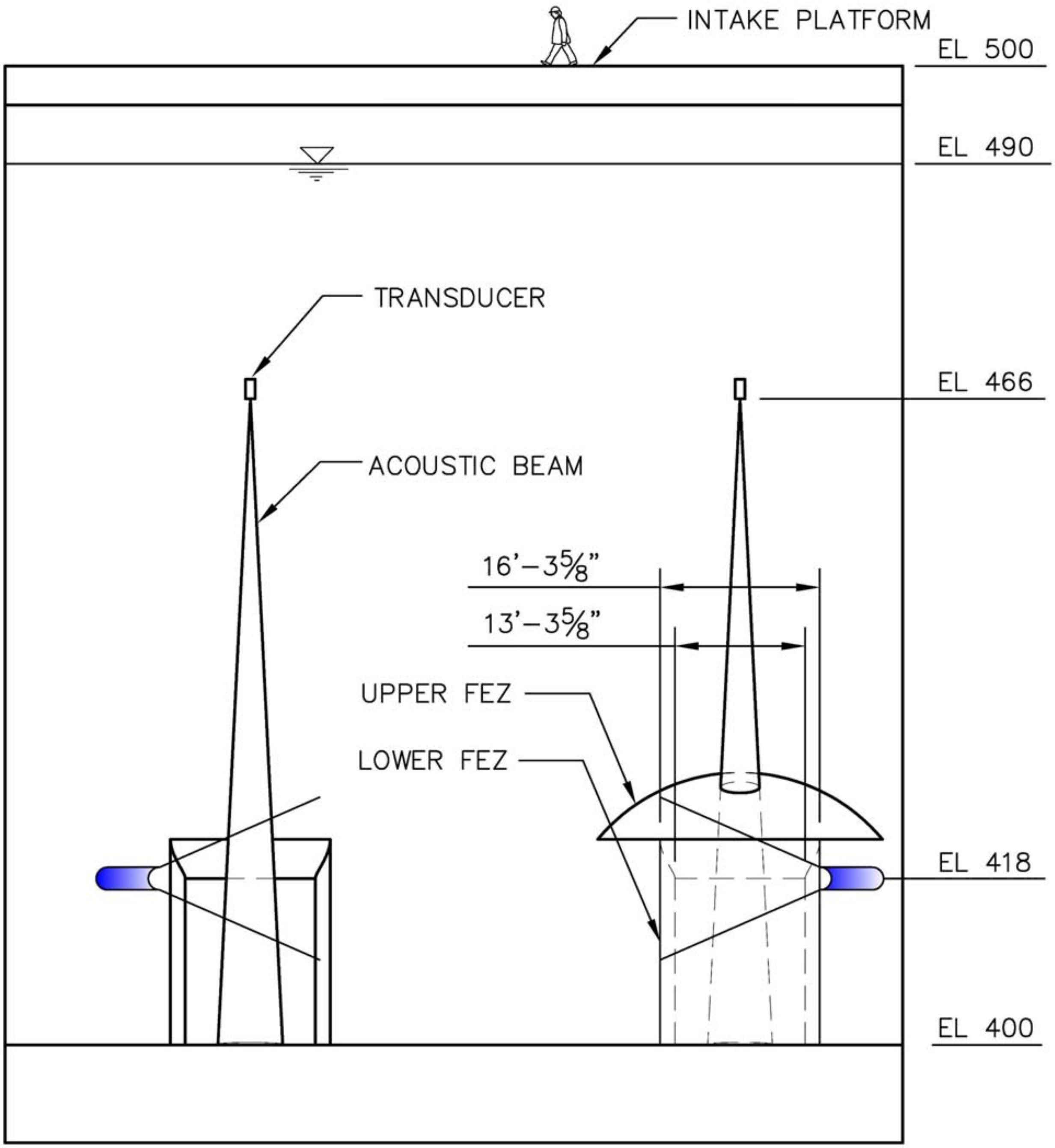
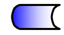


Figure 5.2-1. General location and coverage of the underwater video cameras (). Turbine 1 intake is on the left and Turbine 2 intake is on the right.

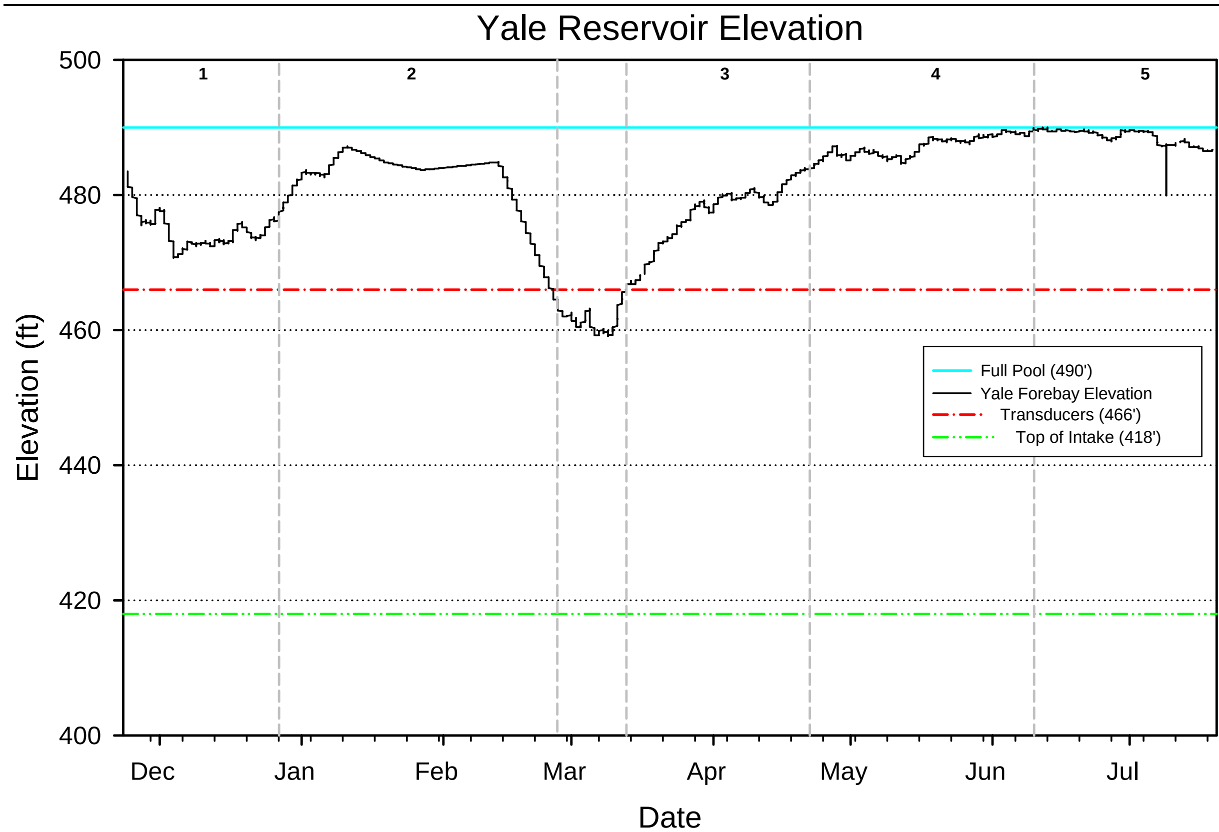


Figure 5.3-1. Hourly forebay elevation (ft) for Yale Reservoir from November 24, 2005 to July 19, 2006, in relation to full pool, transducers, and turbine intake locations. Flow-type periods are defined along the top margins for reference.

Mean hourly entrainment rates and 95% confidence intervals were also calculated in a similar fashion for each of five flow periods defined during the course of the study (Table 5-3).

The transducer over the Turbine 1 intake collected data for a total of 4,885 hrs during the 34-week study period. The amount of this time in which the turbine was ON (flows >100 cfs) totaled 2,741 hours, indicating that Turbine 1 was operational 56.1% of the total monitoring time during the study. The Turbine 2 transducer collected data for a total of 4,789 hrs during the 34-week study period. The amount of this time in which the turbine was ON (flows >100 cfs) totaled 3,671 hours, indicating that Turbine 2 was operational 76.7% of the total monitoring time during the study.

Hydroacoustic data was analyzed to determine daily and hourly entrainment rates. The split beam data also provided information on the distribution of fish within the water column and acoustic size of the entrained fish. A total of 2,741 hours of acoustic observations at the Turbine 1 intake and 3,671 hours at the Turbine 2 intake were logged when the units were on (Table 5-3). During the observation period, 207 fish targets were detected by the hydroacoustic transducers. This number was expanded to approximately 1,132 fish entrained during the study period. The expanded number of detections at Turbine 1 was 795.76 fish, and 336.15 fish at Turbine 2. The majority of the fish (69.6%) were observed entering the intake bay to Turbine 1 (Figure 5.3-2).

5.4 Fish Observations

Estimated fish lengths were then averaged for each week, and for each of five distinct flow periods that occurred during the course of the study (Figure 5.4-1). In addition, 95% confidence intervals were calculated to quantify variation in the estimates (Table 5-3).

The estimated total length for the 144 observed fish at Turbine 1 averaged 18.47 ±1.35 cm (7.3 in), with a range of 4.78 cm to 44.04 cm. Not included in this analysis was one 80 cm fish that briefly moved into and out of the intake area at about 28 feet below the transducer. For Turbine 2 the estimated total length for the 63 entrained fish averaged 17.17 ±1.84 cm (6.8 in), with a range of 4.94 cm to 37.62 cm. One 69 cm fish also briefly entered and left the Turbine 2 area also at about 28 feet below the transducer.

Hourly entrainment rates averaged 0.26 fish/hr at Turbine 1, with the highest rate (0.70 ±0.41 fish/hr) occurring during Week 8 (January 2006) and during Flow-type Period 2 (0.39 ±0.10 fish/hr). At Turbine 2 hourly entrainment rates averaged 0.14 fish/hr, with the highest rate (1.84 ±1.55 fish/hr) occurring during Week 33 and during Flow-type Period 5 (0.58 ±0.37 fish/hr). These higher rates were the result of three days in July when fish were detected during only 1-6 hours of monitoring time. For example, July 8, 2006 recorded only 1 hour of data, during which time one fish was detected. The hourly entrainment rate for that day was then expanded to 5.0 fish/hr. The 95% confidence intervals surrounding the estimated rates are an indication of large amount of variability in the data for Turbine 2 during these weeks and this period (Figure 5.4-2). Overall entrainment averaged for the two intakes was 0.1927 +/- 0.0484 (range 0.1443-0.2411) fish per hour combined over the entire study period. That equates to an annual estimate with a 95% CI that ranges from 1,264 to 2,112 fish/yr, averaging 1,688 fish/yr.

The upper limit of the zone of entrainment was calculated to be a distance of 18.89 ft from the center of the intake opening. Extended vertically, the upper limit of the entrainment zone would be approximately 38.6 ft from the transducer, or 6.4 ft above the top of the intake opening. Figure 5.4-3 shows all fish traces that were recorded while the turbines were operational (> 100 cfs) and the transducers were functioning. For Turbine 1, 681 fish traces were recorded during the study; 537 (78.9%) of the traces were located at depths above the defined entrainment zone, whereas 144 (21.1%) traces were within the entrainment zone. For Turbine 2, 613 fish traces were recorded during the study; 550 (89.7%) of the traces were located at depths above the defined entrainment zone, whereas 63 (10.3%) traces were within the entrainment zone.

Viewing the distribution of the estimated total lengths of the fish traces in Figure 5.4-3, a majority of fish above the entrainment zone are 10 cm or less (61.8% for Turbine 1, 61.5% for Turbine 2). For entrained fish, less than 20% are 10 cm or less (13.9% for Turbine 1, 17.5% for Turbine 2; shown in Figure 5.4-4). A greater number of smaller fish were observed at the surface than at depth within FEZ.

Table 5-3. Flow-type periods with mean operational flows for Yale Dam Turbines 1 and 2 from November 24, 2005 to July 13, 2006. Total fish detected and estimated mean lengths of detected fish are also shown. The lower table summarizes entrainment by the operational periods.

		Turbine 1					Turbine 2				
Week	Starting Date	Total Hrs	Total Fish	Total Weighted Fish	Mean Daily Rate (Fish/Hr)	Mean TL (cm)	Total Hrs	Total Fish	Total Weighted Fish	Mean Daily Rate (Fish/Hr)	Mean TL (cm)
1	11/24/2005	148	15	76.60	0.48	18.87	115	6	31.63	0.25	13.42
2	12/1/2005	132	6	30.79	0.24	16.65	121	1	10.17	0.11	15.85
3	12/8/2005	102	0	0	0	-	93	0	0	0	-
4	12/15/2005	104	0	0	0	-	121	0	0	0	-
5	12/22/2005	76	0	0	0	-	65	0	0	0	-
6	12/29/2005	168	8	41.46	0.25	19.16	168	2	10.43	0.06	25.02
7	1/5/2006	168	10	56.06	0.33	23.76	168	1	10.76	0.06	7.59
8	1/12/2006	156	24	116.29	0.70	21.38	157	1	5.51	0.03	21.68
9	1/19/2006	168	5	44.89	0.27	19.07	168	1	15.79	0.09	14.31
10	1/26/2006	168	12	95.38	0.57	16.16	168	1	5.35	0.03	29.33
11	2/2/2006	168	18	102.48	0.61	19.27	168	2	22.74	0.14	18.07
12	2/9/2006	160	7	33.98	0.22	19.87	160	0	0	0	-
13	2/16/2006	168	8	45.79	0.27	17.70	168	0	0	0	-
14	2/23/2006	48	4	18.16	0.38	19.46	48	0	0	0	-
15	3/2/2006	Transducers exposed					Transducers exposed				
16	3/9/2006	Transducers exposed					Transducers exposed				
17	3/16/2006	53	0	0	0	-	58	0	0	0	-
18	3/23/2006	101	1	3.62	0.03	27.04	93	1	17.17	0.15	37.62
19	3/30/2006	27	0	0	0	-	15	0	0	0	-
20	4/6/2006	14	0	0	0	-	43	0	0	0	-
21	4/13/2006	115	0	0	0	-	83	0	0	0	-
22	4/20/2006	45	0	0	0	-	99	0	0	0	-
23	4/27/2006	Turbine 1 OFF					168	2	8.57	0.05	11.84
24	5/4/2006	Turbine 1 OFF					168	5	10.63	0.06	14.90
25	5/11/2006	Turbine 1 OFF					96	1	1.55	0	12.23
26	5/18/2006	Turbine 1 OFF					120	3	7.11	0.06	13.66
27	5/25/2006	Turbine 1 OFF					168	1	5.35	0.03	17.71
28	6/1/2006	Turbine 1 OFF					168	1	4.92	0.03	18.32
29	6/8/2006	75	1	4.95	0.05	12.00	159	6	26.12	0.16	19.22
30	6/15/2006	80	0	0	0	-	102	1	5.30	0.08	22.37
31	6/22/2006	130	13	64.24	0.49	14.71	132	15	75.98	0.61	17.66
32	6/29/2006	86	6	30.08	0.55	12.82	28	0	0	0	-
33	7/6/2006	40	1	4.90	0.08	11.51	36	8	40.53	1.84	13.70
34	7/13/2006	41	5	26.12	0.45	11.91	47	4	20.53	0.48	22.25
Total		2741	144	795.76	0.26	18.47	3671	63	336.15	0.14	17.17

		Turbine 1					Turbine 2				
Period	Date Range	Total Hrs	Total Fish	Total Weighted Fish	Mean Daily Rate (Fish/Hr)	Mean TL (cm)	Total Hrs	Total Fish	Total Weighted Fish	Mean Daily Rate (Fish/Hr)	Mean TL (cm)
1	11/24/05 - 12/27/05	544	21	107.38	0.16	18.24	496	7	41.80	0.08	13.77
2	12/28/05 - 2/24/06	1390	96	554.48	0.39	19.78	1392	8	70.59	0.05	19.88
3	3/13/06 - 4/22/06	355	1	3.62	0.01	27.04	326	1	17.17	0.04	37.62
4	4/24/06 - 6/10/06	Turbine 1 OFF					1025	16	48.72	0.05	14.87
5	6/11/06 - 7/19/06	452	26	130.28	0.31	13.51	432	31	157.86	0.58	17.76
Total		2741	144	795.76	0.26	18.47	3671	63	336.15	0.14	17.17

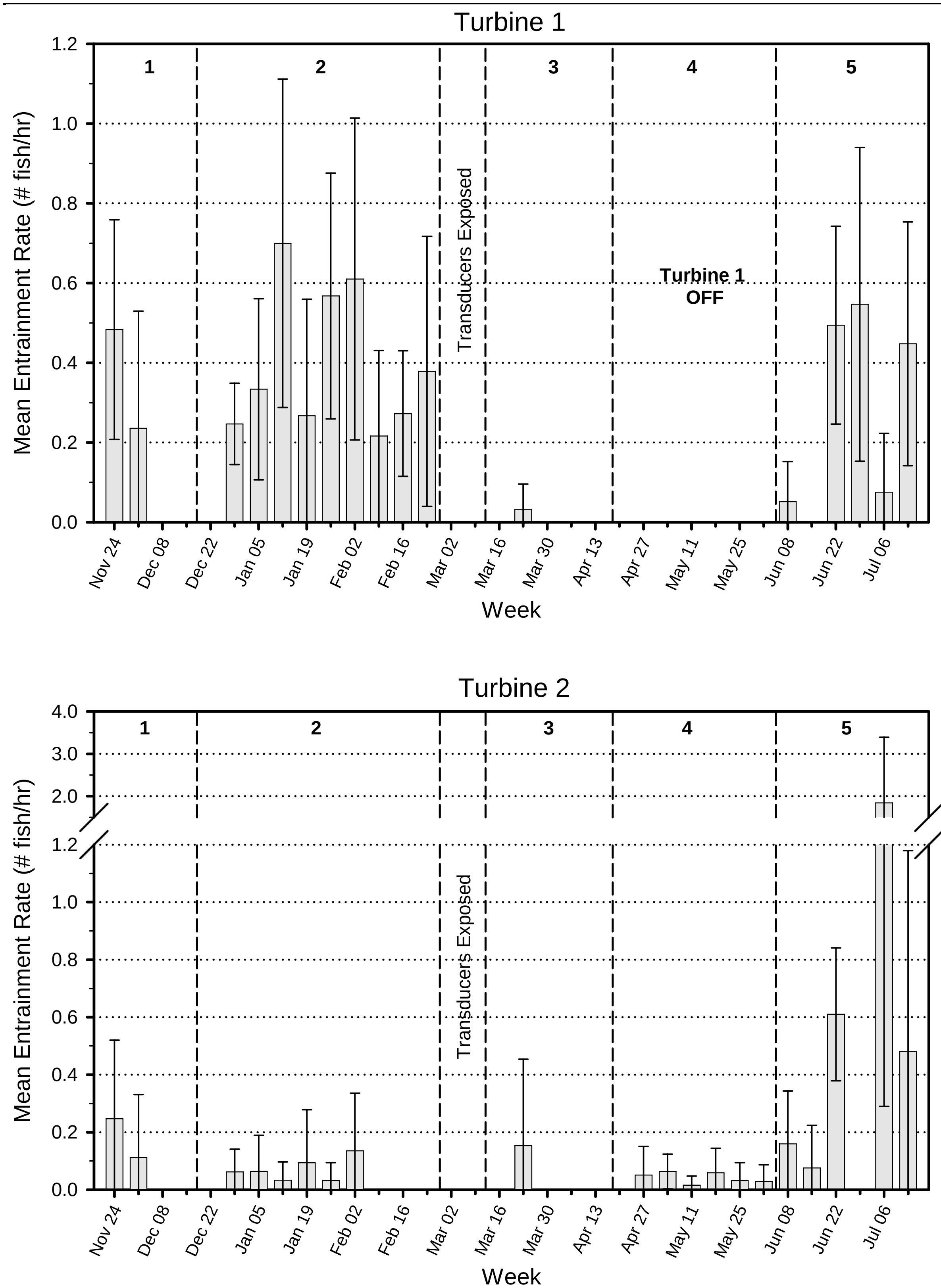


Figure 5.3-2. Weekly estimates of mean entrainment rates (number of fish per hour) with 95% confidence intervals for Yale Dam Turbine 1 (top) and Turbine 2 (bottom) from November 24, 2005 to July 19, 2006. Flow-type periods are defined along the top margins for reference.

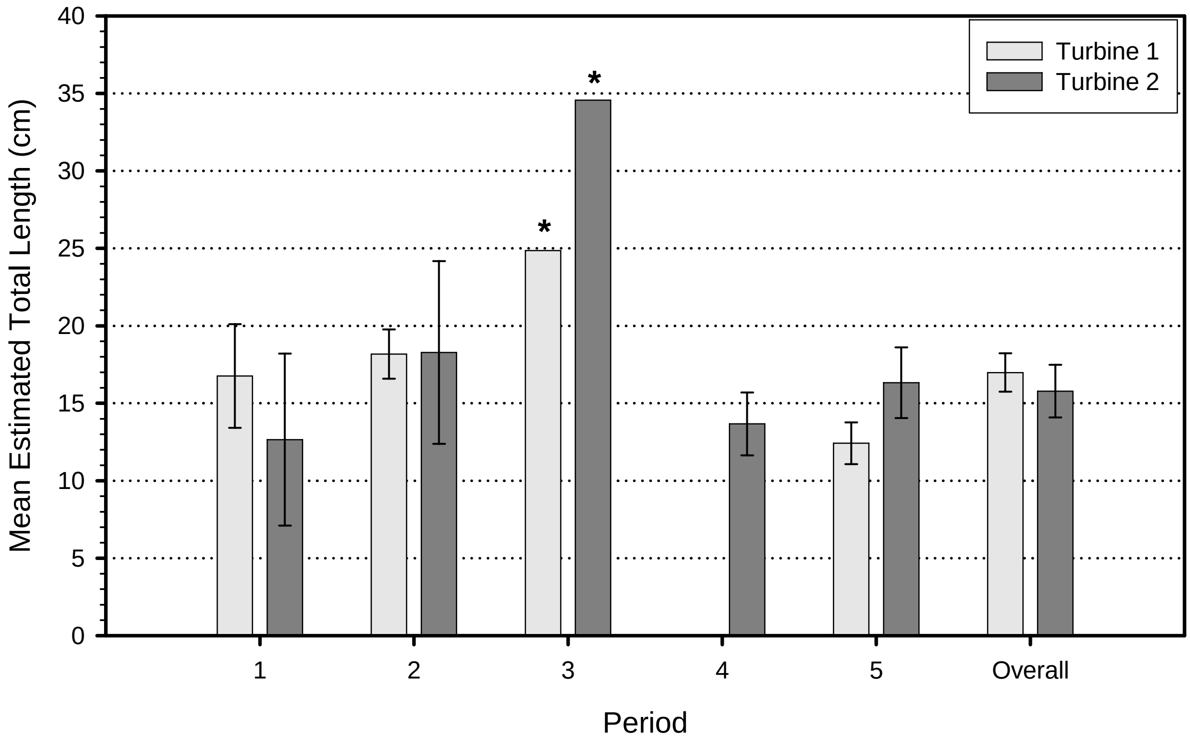


Figure 5.4-1. Mean estimated total lengths (cm), with 95% confidence intervals, for fish defined as entrained through Yale Dam Turbines 1 and 2 during each of the five flow-type periods and the overall study period. Bars with asterisks (*) denote single fish.

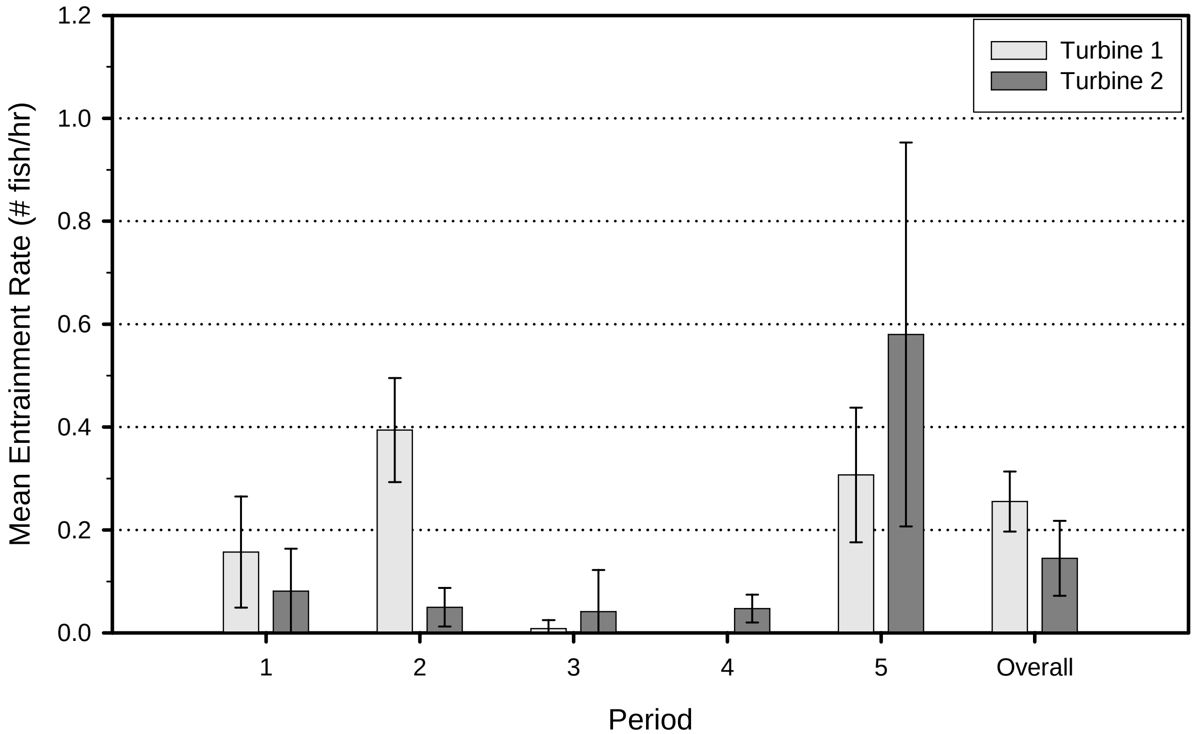
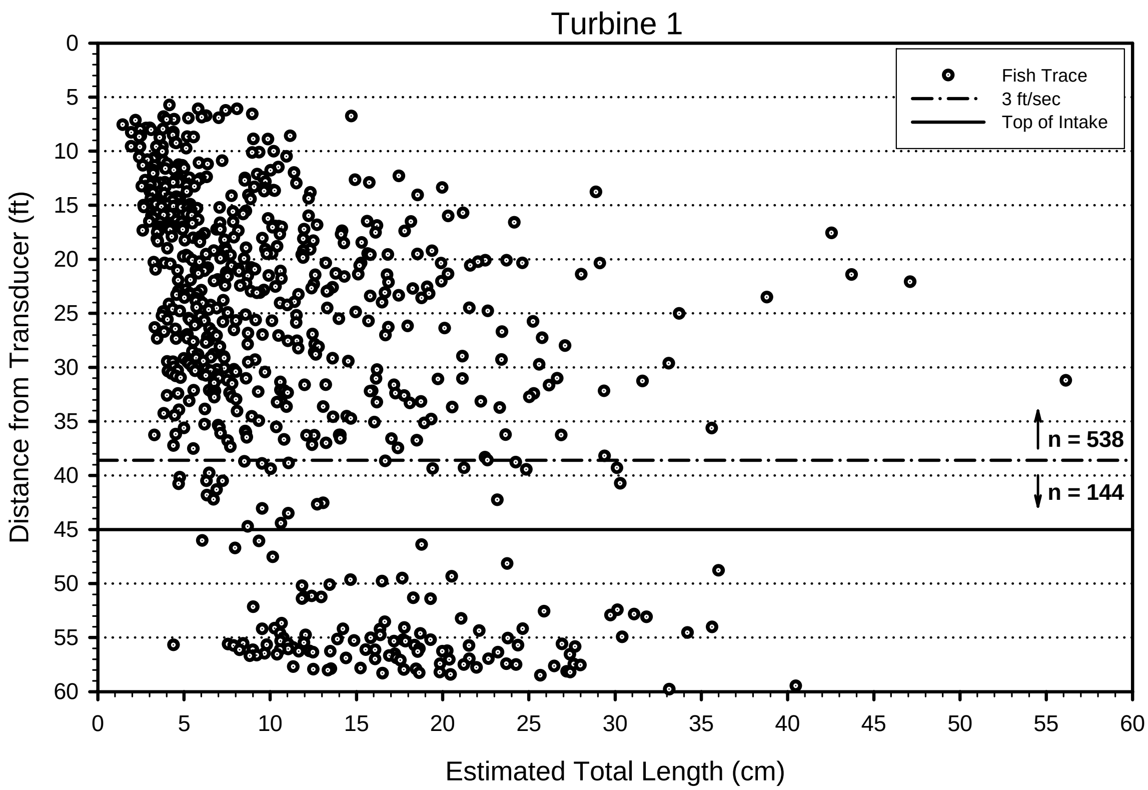


Figure 5.4-2. Estimates of mean entrainment rates (number of fish per hour) with 95% confidence intervals for Yale Dam Turbines 1 and 2 during each of the five flow-type periods and the overall study period.



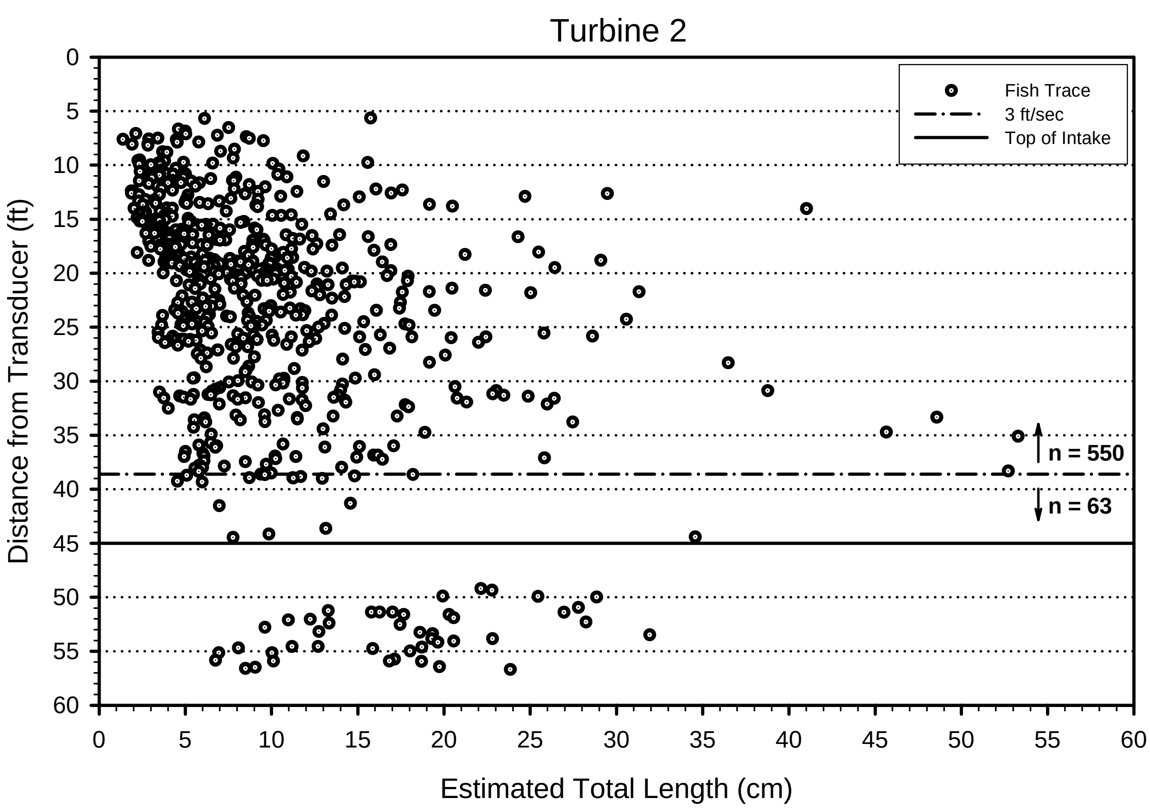


Figure 5.4-3. Vertical distribution of all individual fish traces by their estimated total lengths within the entire acoustic beam for Yale Dam Turbine 1 (top) and Turbine 2 (bottom) from November 24, 2005 to July 19, 2006. The hatched line indicates the upper limit of the Fish Entrainment Zone.

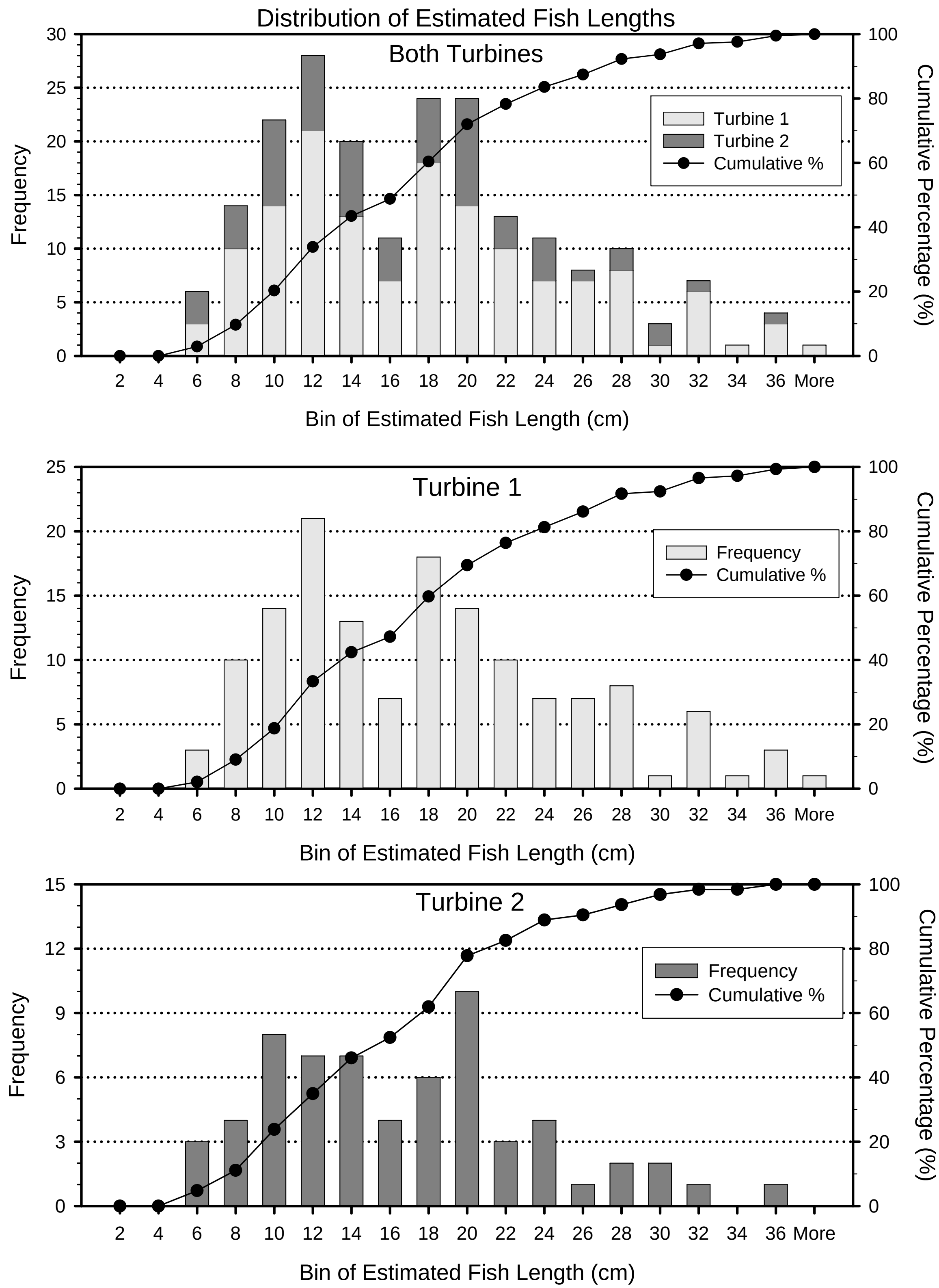


Figure 5.4-4. Distribution and cumulative percentages of estimated total lengths (cm), converted from mean acoustic target strengths, for fish defined as entrained through Yale Turbines 1 and 2 from November 24, 2005 to July 19, 2006.

6.0 Discussion

6.1 Fish Entrainment Zone

The methodology of this study attempted to take into account the water velocity contours around the turbine intakes in order to calculate a biologically appropriate velocity threshold from which fish would be unable to escape and thus, be entrained. The velocity chosen for this threshold was 3 fps, well below the escape velocity criteria established for most salmonid life stages. For reference, PacifiCorp and the ACC Engineering Subgroup are using 7 fps as a capture velocity (25.4 cm steelhead surrogate) for the Swift Floating Surface Collector. We chose a lower threshold to be conservative and to allow for the possibility that smaller fish may be entrained at lower flows, and that some fish may not attempt to avoid flows, but may instead detect them as a cue and actively move towards the increase in velocity. This defined area was designated the Fish Entrainment Zone (FEZ).

Currently the FEZ top wedge is based on 3 fps velocity contour and extends 18.9 ft above the center point of the intake. If we would have used 2 fps the FEZ would extend 23.9 ft and 1.5 fps would extend it to 28.2 ft from intake center point. At 2 fps this would have resulted in increased fish entrainment estimates by 1,305 fish for Turbine 1 and 1,121 fish for Turbine 2. Regardless of the characteristics of the FEZ, when looking at percent of total fish entrained at Turbine 1 versus Turbine 2 are remarkably similar to the 1997 study indicating conditions between the two studies was similar and repeatable.

6.2 Entrainment Rates

During this study fish, overall entrainment at Yale intakes was estimated to be approximately 0.19 fish per hour or about 1,664 fish per year. In comparison, Hiebert (Bureau of Reclamation website www.ykfp.org/par04/Exe.Sum.Rimrock20032002) found approximately 5,500 fish per year entrained at Rimrock Reservoir in eastern Washington. The majority of those entrained fish (97%) were kokanee. In a recent study at Grande Coulee Dam, about 0.17% of the entrained fish were bull trout (9 bull trout per year). Simmons et al. (2006) detected 3,256 entrained fish at Grand Coulee dam during a 3 month study period. The entrained fish observed by Simmons et al. (2006) included kokanee, rainbow trout and walleye (*Sander vitreus).* Simmons et al. (2006) estimated annual entrainment for salmonids was to be 3 fish per year at Grand Coulee dam with the remainder of the entrained fish being primarily walleye and other non-salmonids.

6.3 Video Observations

One element of the Yale entrainment studies continues to elude resolution. That is, the identification of the species entrained. We do, however, have a clear idea of the sizes and numbers of fish but, since there are salmonid species of similar body form and length in Yale Lake, we cannot definitively identify species entrained.

Of the 616 hours of underwater video, only a few fish were actually observed. This is more a function of the viewing area than it is water clarity or fish size. Simmons et al. (2006) experienced similar problems and were only able to film 6 fish in 72 hours of video. Their equipment was much more sophisticated and able to make progressive scans which may account for more fish observations despite the larger intake area (48' high and 29' wide). After making a second attempt to identify species using different methods in 1997 and 2005/6, we remain challenged by this information need and the lack of technology to resolve the question at the Yale facility. This segment of the study failed to provide conclusive evidence of the species entrained.

6.4 Hydroacoustics

Overall, the hydroacoustic transducer performed very well and enabled to us to make very good observations of the Yale turbine intakes. Because of the ability to store data and analyze it from a number of different angles, we were able to filter out debris, identify fish size, distribution in the water column, and proximity to the fish entrainment zone. Figure 6.4-1 is an example of how filtering allows one to focus on fish targets and their location in relation to the intake portals.

6.4.1 Entrainment Rates

In comparison to the previous Yale Dam entrainment study (PacifiCorp 1999), the current estimates of total entrainment are much lower (see Appendix 2). For instance, the hourly entrainment rate from the previous study was estimated to be 28.5 fish per hour while the current level of entrainment is estimated to be 0.19 fish per hour. For the 11-week study period in 1997, the hourly rate equates to 50,000 fish entrained annually, yet in September of the same year the total Yale reservoir fish population was estimated to be between 82,000 and 110,000 using hydroacoustic surveys. It is unlikely that over half the lake population was potentially entrained in the short 11-week study period. Given this finding in combination with the more recent hydroacoustic estimates, members of the ACC requested us to take a second look at the 1997 hydroacoustic data estimates and compare those to the current information.

There are several differences between the 1997 and 2006 studies that are consistent with advances in hydroacoustic technology over that time period. First, during the 1997 study the transducers were operated in a sub-sampling mode during which they sampled the water column for acoustic signals in five minute cycles for a total of 30 minutes every hour. In contrast, during the current study the transducers were continuously sampling for the duration of the study and the extensive data was remotely downloaded each week to free up hardware storage space for additional data. By sampling continuously in 2006 we were able to avoid error associated with expanding data from a sub-sample.

A second difference between the studies involved methods of fish weighting. In 1997, each detected fish was grouped into 1-meter-range bins, based on its distance from the transducer. The number of fish detected in each bin was multiplied by the intake width (16 ft), and then divided by the acoustic beam width to determine the appropriate number of weighted fish for that bin. All weighted fish were then summed on an hourly basis (i.e., further expanded by two) to provide an estimate of total fish passage into the turbine unit or spillway. By this method, all fish detected within the beam, regardless of their distance from the intake opening or to any region with velocities that were high enough to entrain them, were weighted and counted as entrained fish. Furthermore, the proportion of intake width to beam width would have been higher nearest the transducer than the proportion near the intake. The result would be that fish farthest away from the intake opening would have been weighted the most, at a near 16:1 ratio. In 2005, it was deemed inappropriate to equate filtered target data with entrained fish. Instead, we used a newer velocity-based approached and weighted fish differently within the distinct sections of the FEZ, as described above in the methods section.

To calculate the entrainment rate in 1997, the data set was subsampled, randomly selecting two consecutive days from each week to use in the estimate. The pooled two-day total of weighted fish was divided by the pooled two-day total of hours sampled, to supply an estimated hourly rate of entrainment. This estimated rate was then applied to represent the rate of the entire week. This calculation introduces a third source of error in expanding the two-day total out to the week. The 2005 study did not sub-sample the data set. Weekly entrainment estimates during the 2005 study were based on data from each day sampling as it occurred during any one week. Entrainment rates were first calculated for each day, taking the weighted number of fish for a given day and dividing by the total number of hours sampled for that given day. These daily entrainment rates were then averaged for each week, along with 95% confidence intervals to show the amount of error involved with each estimate.

During the 2005 study, it was obvious, especially during shutdown and startup periods, that there was a large amount of debris in the intake area that becomes dislodged or that settles during these periods (Appendix 3). These results were confirmed by divers during installation of the transducers. The resulting hydroacoustic record falsely would have documented this debris as fish targets without a filtering methodology that allowed for differentiation of woody/detrital debris and fish targets. In 2005, the scientists at BioSonics, Inc. applied a project-specific algorithm to filter the debris from actual fish targets. No filtering methodology was applied in the 1997 study. The basic assumption in 1997 was that if a target was observed within the intake bar racks, it was an entrained fish regardless of depth of the signal, capture velocity at the signal location, and movement of the signal (or lack there of).

In an attempt to better understand how the more advanced filtering and expansion methods used in 2005 may help to explain the data difference between the two studies, we obtained five weeks of 1997 hydroacoustic data and applied the same filtering methods used in 2006 to account for a fish capture zone within a 3 fps flow field and to eliminate targets that showed no movement (vertically or horizontally). Application of the filtering techniques to the 1997 data resulted in approximately a 95% reduction in the entrainment estimates (Table 5-4) effectively reducing the overall estimate hourly entrainment in 1997 to 0.80 for Turbine 1 and 0.56 for Turbine 2.

With the current study, we have a very good estimate of how many actual fish targets entered the intake gallery and, of those, how many were actually entrained using the FEZ criteria. Consistent with the 1997 study, we observed a difference between fish entrainment at Turbine 1 and Turbine 2. We can only attribute that to location. In other words, it appears that fish approach the intake gallery from the southern shore line rather than along the face of Yale Dam. This results in more fish entering the Turbine 1 penstock. The importance of that fact is debatable. What is important is total entrainment and what that means to the bull trout population in particular. There is uncertainty around how many of the entrained fish are actually bull trout. An analysis of fish length, migration timing and vertical pelagic position may assist with minimizing the uncertainty.

Table 5-4. Data from 1997 hydroacoustic study in original form and with 2006 filter techniques applied .

			1997 Original Data				1997 Data with 2006 Filters			
Turbine	**Week**	**Total Hours**	**Count**	**Weighted No. of Fish**	**Fish/Hr**	**Expanded No. of Fish**	**Count**	**Weighted No. of Fish**	**Fish/Hr**	**Expanded No. of Fish**
1	1	13	84	1419.25	109.17	18341	6	42.24	3.25	546
1	2	48	29	256.74	5.35	899	5	28.11	0.59	98
1	3	47	25	226.23	4.81	809	6	25.44	0.54	91
1	4	71	44	252.18	3.55	597	3	22.43	0.32	53
1	11	47	86	639.50	13.61	2286	12	61.65	1.31	220
1	**5-week total**	**226**	**268**	**2793.92**	**12.36**	**10384**	**32**	**179.87**	**0.80**	**669**
2	1	13	58	911.36	70.10	11778	1	7.09	0.55	92
2	2	48	38	226.77	4.72	794	5	27.71	0.58	97
2	3	47	91	1822.25	38.77	6514	5	29.02	0.62	104
2	4	71	76	959.74	13.52	2271	2	15.33	0.22	36
2	11	47	53	233.2	4.96	834	7	47.03	1.00	168
2	**5-week total**	**226**	**316**	**4153.33**	**18.38**	**15437**	**20**	**126.17**	**0.56**	**469**

6.4.2 Fish lengths

For entrained fish, less than 20% are 10 cm or less. So that means 80% of the entrained fish ranged from 12 to 40 cm (4.7 to 15.7 in.) in length. From Figure 6.4-2 we can see that only about 14 individual fish in that size range within the FEZ were greater than 30 cm (11.8 in.). Also, Table 5-3 lists the weekly data for the project. Note that the bulk of the larger entrained fish (mean total length of 12 to 40 cm) occurs in the January to March period for Turbine 1. For Turbine 2 the majority of the larger fish were entrained during the same period but about two-thirds of those larger fish were entrained during May and June (33 actual observations). In the 1997 Yale Lake hydroacoustic population estimate (PacifiCorp 1997), 25 percent of the acoustic targets were less than 5 cm (2 in.). Mid-water trawls revealed that the majority of the fish sample consisted of pelagic threespine stickleback with the remaining being a few kokanee and sculpins. The average size of an adult threespine stickleback is about 5 cm (Scott and Crossman 1979). Kokanee, in general, can reach 9 to 20 cm by their second year (Scott and Crossman 1979). Kokanee captured in the trawl were 5 and 6.5 cm but we know that they rear in the lake and can reach an adult size of about 29 cm (Lesko 2006).

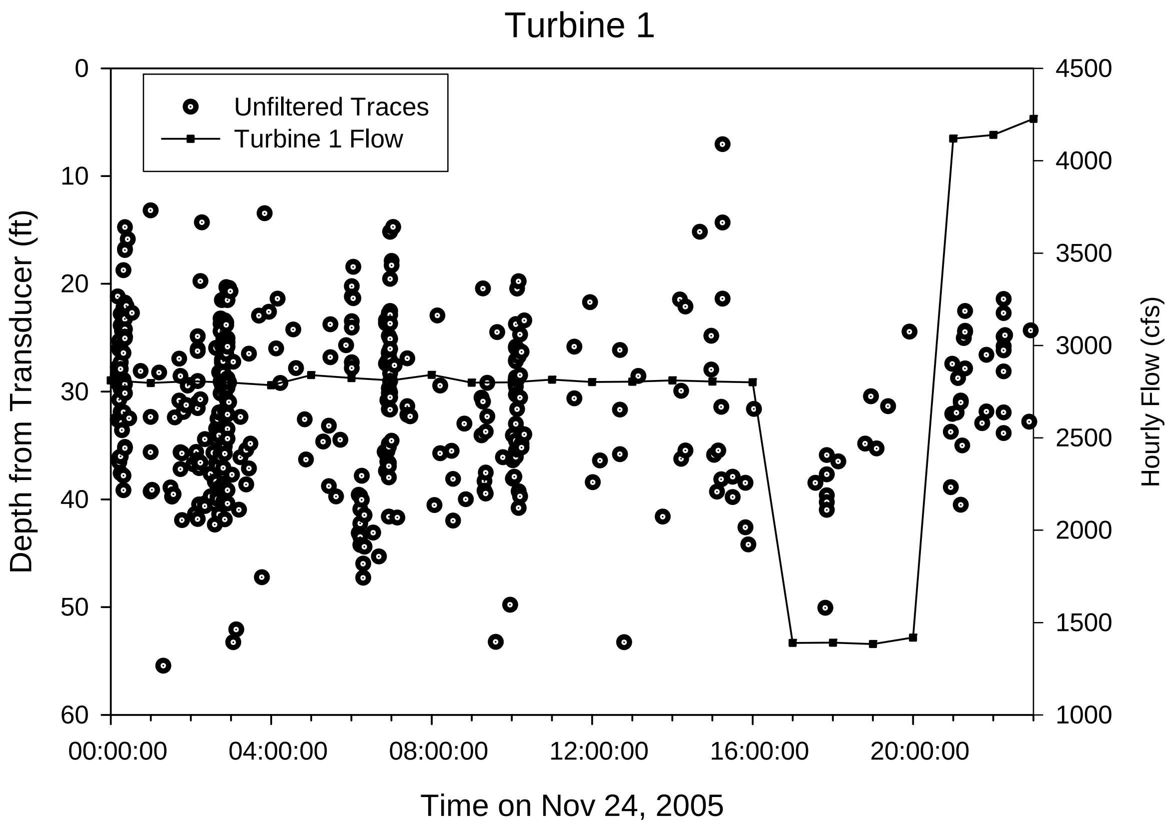
Lesko (2006) estimates the 1995 kokanee spawning escapement to be 89,252 adult while in 1997 and 2006, the estimate was 82,821 and 55,095 adults, respectively. Clearly, even though there were still age-1, 2 and 3 kokanee remaining in Yale Lake in 1997 and if you consider the hydroacoustic population estimate to be fairly accurate, the majority of the fish population consisted of spawning-age kokanee. Also, during a creel survey in 1996, kokanee made up 76 percent of the harvest. For the salmonids harvested, kokanee ranged from 18 to 34 cm, rainbow trout ranged from 18 to 36 cm and cutthroat were 20 to 36 cm. In addition, one 33 cm bull trout was illegally creeled. All of these harvested salmonids fit within the length range for the entrained fish greater than 30 cm observed during this study. However, since kokanee are the dominant species in Yale Lake, there is a high probability that the entrained fish over 10 cm observed during this current study are predominantly kokanee.

Bull trout generally reside in their natal stream for the first 1 to 4 years of life (Fraley and Shepard 1989). During an effort to collect juvenile genetic material in Cougar Creek in 2003, most of the 24 fish collected were age-1 at 55 to 75 mm, about 29 percent were age-2 ranging from 110 to 130 mm, and one age-3 bull trout was 190 mm. It is reasonable to assume, then, that the majority of the bull trout juveniles emigrate from Cougar Creek into Yale Lake in their second year at 11 to 13 cm. This falls within the lower size range of the larger entrained fish observed at the Yale Intake. This seemingly complicates the level of certainty regarding bull trout entrainment but we must also include timing of movement and location in the water column within our analysis.

Bull trout move into freshwater lakes in the spring at about the same time that anadromous salmonids migrate to sea (April and May) (Scott and Crossman 1979). Shepard et al. (1984) found juvenile bull trout to emigrate from early May to mid-July. To take that further, let's assume the Cougar Creek bull trout juveniles enter Yale Lake by the end of June at about 13 cm in length. Very little is known about juvenile adfluvial bull trout once they enter their lake rearing habitat. Generally, bull trout juveniles occupy and forage in the littoral area for some time before entering the pelagic zone. Bull trout juveniles in a lake environment can grow as much as 1.4 to 4.2 cm per month (Ratliff 1992, (Stelfox 1997) depending on the habitat conditions and food supply.

Given the topography, food supply and water conditions, Yale Lake is much closer in comparison to Lake Billy Chinook than it is to Lake Roosevelt so it is likely that for fish available to be entrained, bull trout juveniles would be approximately 13 cm in June and 14.4 cm in July. With their estimated size and littoral orientation, those larger entrained fish observed in the Yale Intake Gallery are not likely to be juvenile bull trout. To carry this analysis further, after one year in the reservoir, these same juveniles would be in the 30 cm size range. By the time they reach that age and size, bull trout are usually found in the profundal zone of a reservoir (22.5m to 40m) (Connor, et al. 1997) where they follow the diel movements of their prey. Based on the previous information, we believe that it is safe to assume that very little sub-adult bull trout entrainment occurs at Yale dam.

From the adult perspective, adult and sub-adult bull trout captured in the Yale tailrace over the past 11 years range in size from 29 cm to 82 cm while Swift Reservoir bull trout range in size from 17 cm to 80 cm for the past 10 years. The Lewis River Settlement Agreement defines an adult bull trout to be greater than 13 inches (33 cm). So it's relatively safe to assume that, if adults were not in the profundal zone and were subjected to entrainment, then those fish would fall within the defined adult size (33 cm) to the observed adult size (82 cm). For larger fish detected using hydroacoustics, only 5 fish in the adult size range (33cm to 41 cm) were observed within the FEZ for Turbine 1 and only one fish in the adult size range (35 cm) was observed in the Turbine 2 FEZ (Figure 5.4-3).



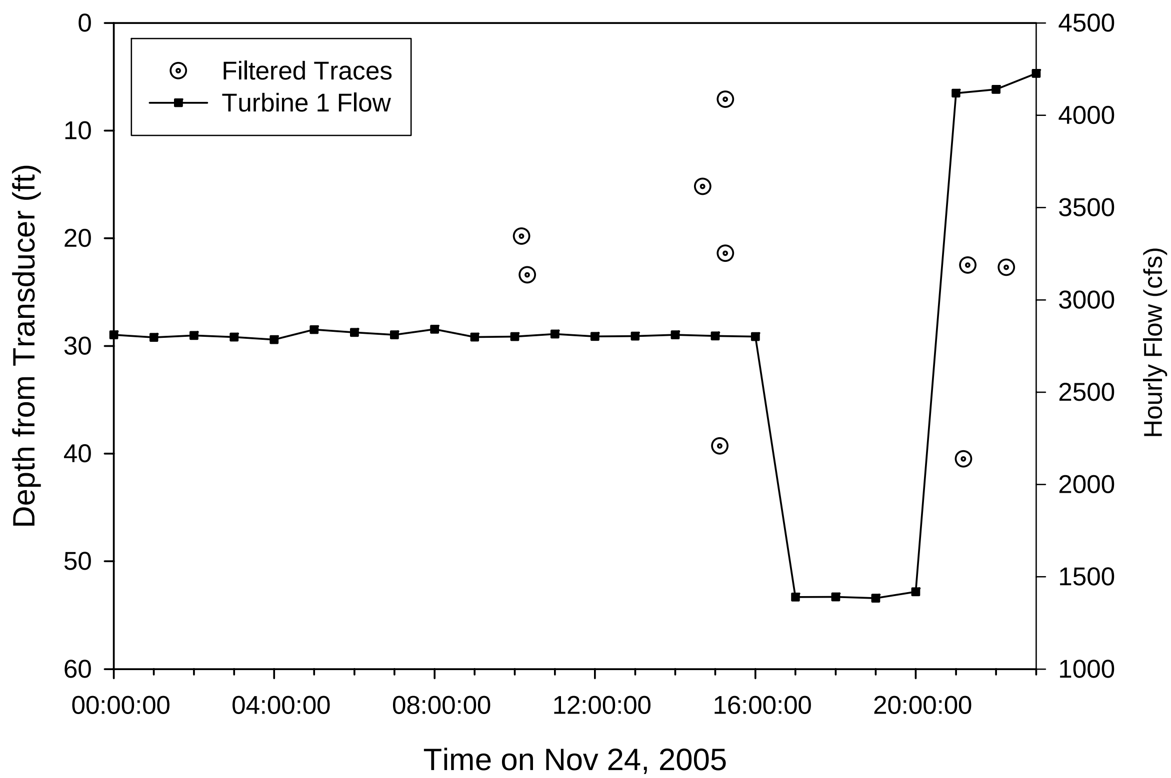
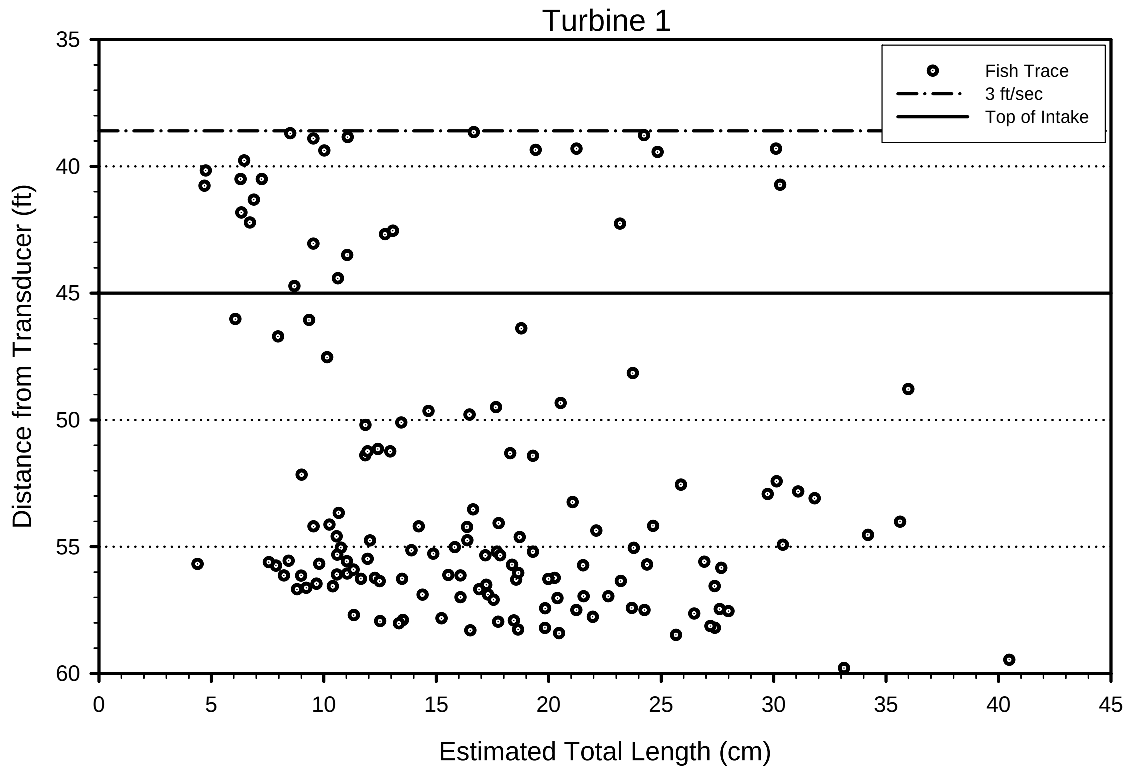


Figure 6.4-1. Vertical distribution of all fish traces by detection time in front of Yale Dam Turbine 1 on November24, 2005, before (top) and after (bottom) filtering was conducted.



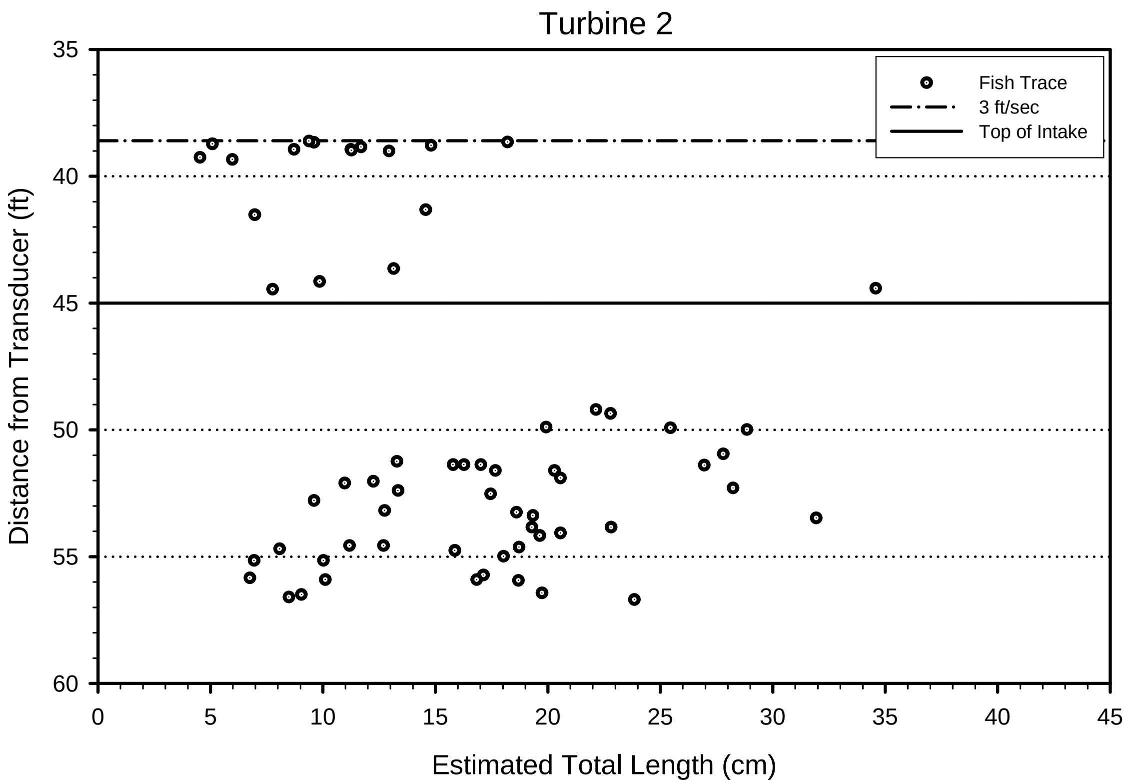


Figure 6.4-2. Vertical distribution of fish by their estimated total lengths within the defined zone of entrainment for Yale Dam Turbine 1 (top) and Turbine 2 (bottom) from November 24, 2005 to July 19, 2006.

The size range of the observed fish within the FEZ also includes the upper size range for kokanee (18 to 34 cm) rainbow trout (18 to 36 cm) and cutthroat (20 to 36 cm**).** Only one fish observed in the FEZ exceeded 36 cm so it is quite possible that the remaining fish targets were salmonids other than bull trout since bull trout numbers are a very small percentage of the total fish population in Yale Lake. The current Biological Opinion (US Fish and Wildlife Service 2006) assumes that 2 or fewer bull trout will be entrained per year at Yale Dam and, given the preceding discussion, we believe that this is a reasonable assumption.

6.5 Recommendations

Based on the results and analysis of entrainment at Yale dam, there is a very small number of bull trout that are potentially entrained (less than 2 bull trout per year). Relative to the spawning population size in Cougar Creek that may seem high (perhaps as much as 10 percent). However, the size of spawners observed in Cougar Creek far exceed the larger fish that were observed in the Yale intake area. During data collection for pre-spawning adult bull trout in Cougar Creek, observed adult sizes averaged 56.2 cm (s.d.=10.2 cm) (Shrier – unpublished data from 1993 and 1994) so it does not appear that any potentially entrained fish are greater than or equal to spawning sized bull trout.

Considering the efforts by PacifiCorp Energy to protect bull trout habitat and their combined effort with Washington Department of Fish and Wildlife to transport bull trout adults from the Yale tailrace and to monitor the spawning population in Cougar Creek, these actions protect and foster bull trout survival in Yale Lake and Cougar Creek and serve to offset any potential loss from entrainment at the dam. Regardless of the numbers though, PacifiCorp agreed to install some type of entrainment reduction device for bull trout. Therefore, an Entrainment Reduction Plan is included in Attachment 2.

7.0 References

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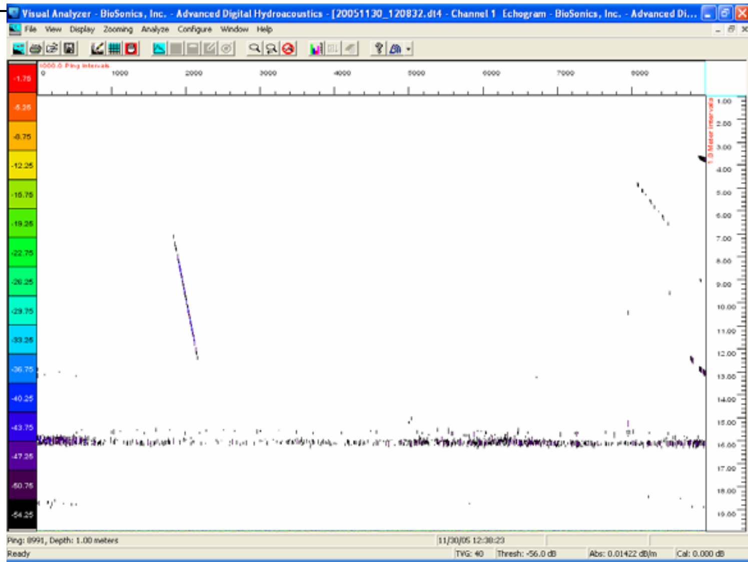
Appendix 1

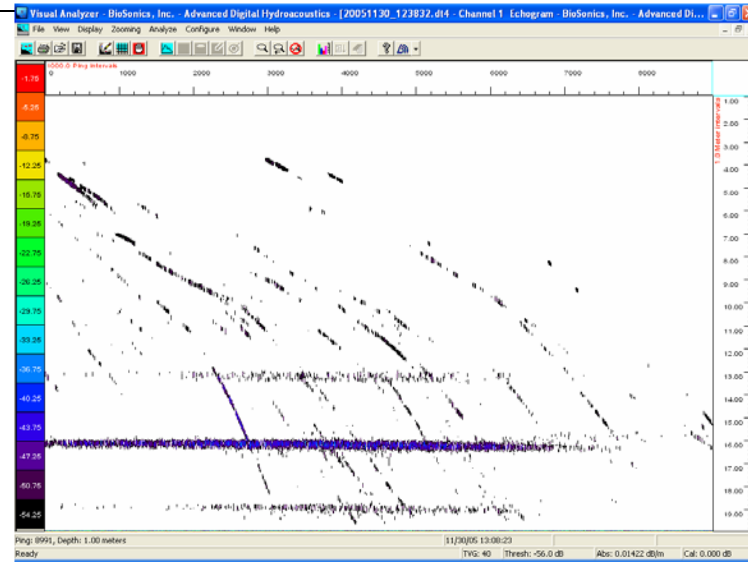
The following is an excerpt from the Lewis River Settlement Agreement:

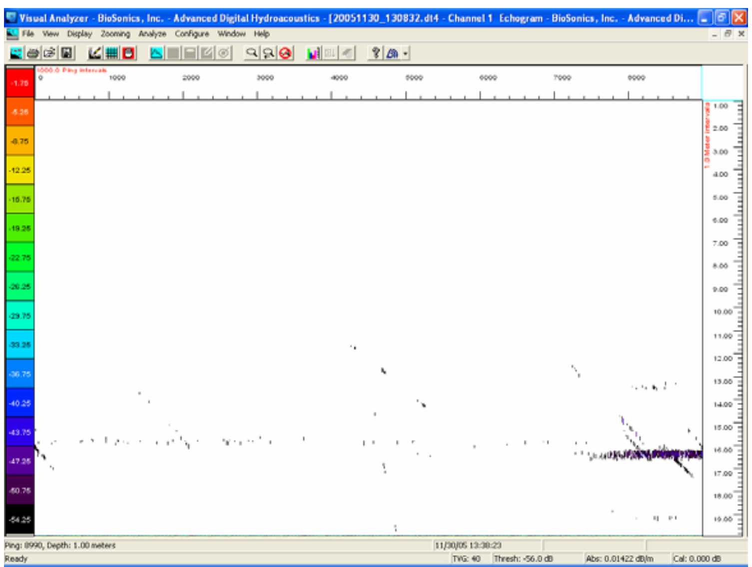
4.9.3 <u>Yale and Merwin Bull Trout Entrainment Reduction</u>. Immediately following the Effective Date, PacifiCorp shall design and implement a study to evaluate bull trout entrainment reduction methods for Yale and Merwin dams in Consultation with the ACC. Potential entrainment reduction methods include installation of exclusion devices, such as strobe lights, and installation of barrier nets with submersible cork lines and designed to accommodate a Merwin-type floating trap. Due to the small numbers of bull trout in Yale and Merwin, any evaluation of strobe lights will be performed in Swift Reservoir. Based upon its study, PacifiCorp shall prepare, in Consultation with the ACC, a draft entrainment reduction plan for the Yale Project. The plan would be developed to minimize unacceptable incidental impacts to bull trout or other species. PacifiCorp shall submit the draft plan to members of the ACC for comment within 16 months after completing the entrainment reduction study. PacifiCorp shall allow at least 45 days for members of the ACC to comment on the draft plan. PacifiCorp shall finalize the plan and obtain the approval of USFWS. PacifiCorp shall submit the final plan to the Commission upon approval by USFWS, subject to Section 15.14, but not later than the third anniversary of the Effective Date. PacifiCorp shall commence the approved entrainment reduction measures at Yale Dam within one year after the Issuance of the New License for the Yale Project, and shall maintain such measures until commencing operation of the Yale Downstream Facility. Upon the request of USFWS, PacifiCorp shall, in Consultation with the ACC and subject to the approval of USFWS, develop criteria to determine when similar entrainment reduction measures should be implemented at Merwin Dam. PacifiCorp shall submit the criteria to the Commission for approval after obtaining USFWS approval, subject to Section 15.14, within 12 months after the USFWS request for criteria. Once approved by the Commission, if and when such criteria are met PacifiCorp shall commence the same entrainment reduction measures approved for Yale at Merwin Dam, and shall maintain such measures until commencing operation of the Merwin Downstream Facility.

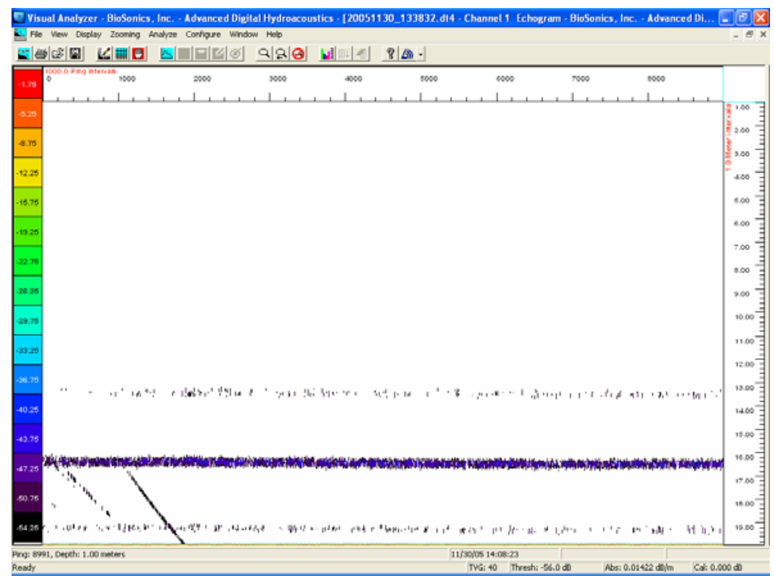
Appendix 2. Comparison of 1997 and 2006 Yale Entrainment Studies

1997 Study	2006 Study
Transducer 59ft above penstock floor. Pg3-53	Transducer 66ft above penstock floor.
Sampled alternately for 5 minute intervals 6 times each hr. pg3-53	Sampled continuously for term of study
11 week sample window. Pg3-52	34 week sample window
Randomly selected 2 consecutive days from each week to represent fish entrainment rates for the week, used to expand fish entrainment rates per hour. Pg3-53	Data was taken from complete data set. Hourly entrainment means taken from entire sample time.
Used Love's equation for target strength and fish lengths. Pg3-54	Used Love's equation for target strength and fish lengths
Weighted and numerically expanded each detected fish to compensate for inability to cover entire penstock opening. Pg3-55	Weighted and numerically expanded each detected fish to compensate for inability to cover entire penstock opening.
Mean hourly entrainment rate was 28.5 fish for both turbines combined. Pg3-56	Mean hourly entrainment rate for both turbines combined was 0.19 fish
Total estimated entrained fish during study, 50,780. pg3-56	Total estimated entrained fish during study, 1131.9
Estimated average length of entrained fish, 138mm. pg3-57	Estimated average length of entrained fish, 178mm
Suggest fish were surface oriented. Pg 3-57	Suggest fish are surface oriented.
More fish entrained in Turbine 1(noted as Bay 2) (60%) than in Turbine 2 (noted as Bay 1) (40%). Pg3-59	Turbine 1 had 70%, Turbine 2 had 39%
No mention of filtering data, do mention removing behavioral and other biases? Pg3-61	Data filtered to not include hits outside of fish entrainment zone (FEZ), also filtered to exclude debris and other static structures characterized by horizontal banding in the echograms
In September of same year as entrainment study did a Yale total fish population study, estimate total population at 82,843 -109,629, yet in 11 week entrainment study they estimate 50,000 fish entrained. Pg3-67	No population estimate made
Did not determine an entrainment zone	Created a fish entrainment zone (FEZ) based on water velocities and swimming ability.
Did not mention whether or not data was filtered to not include hits received from something right below the hydro acoustic arrays, 38ft above the top of the penstock opening.	Use water velocities and escape velocity criteria to create the concentric FEZ arcs that expand out from the intake openings. Filtered out hits that were outside of the concentric FEZ arcs.

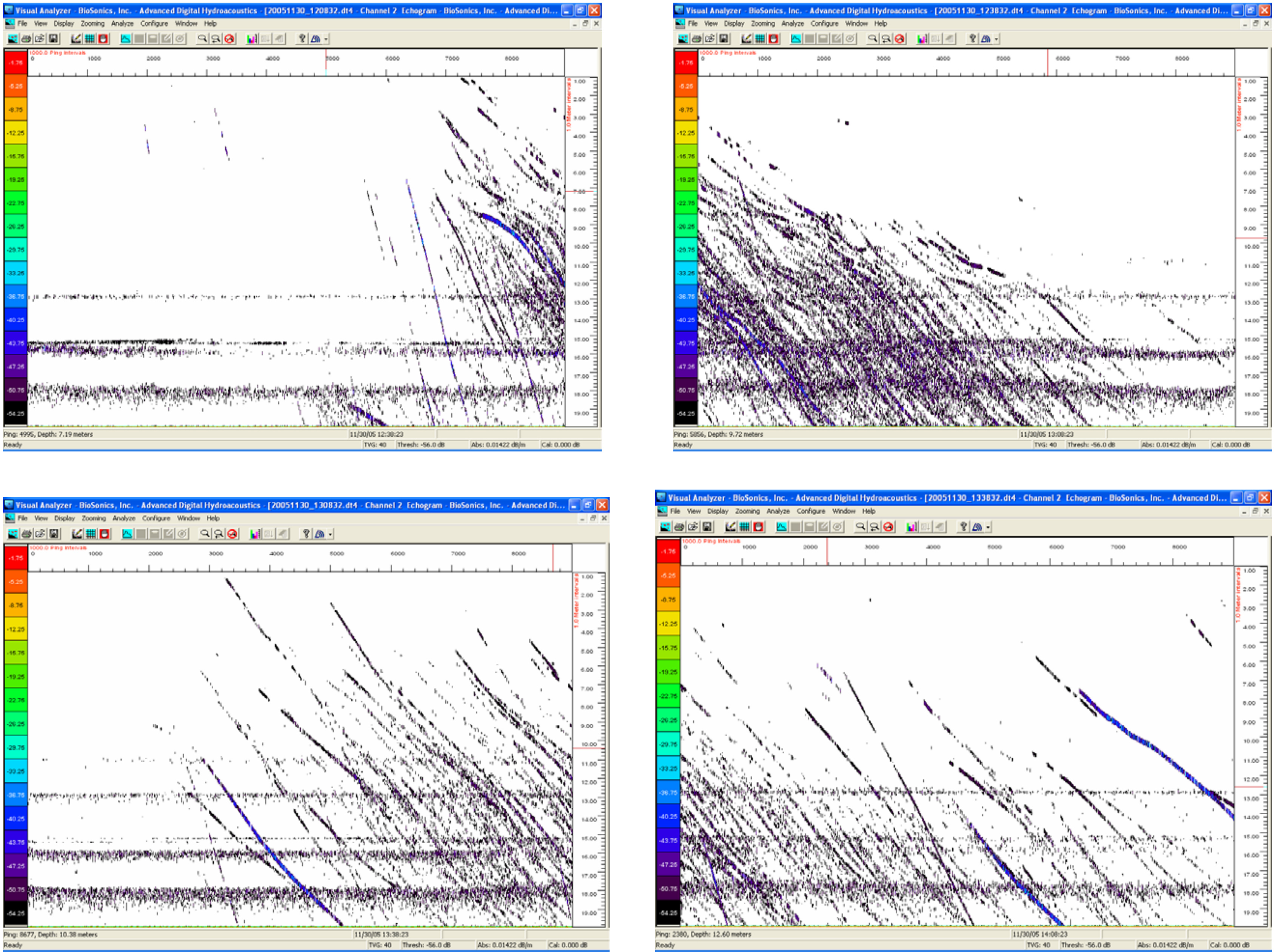








Appendix 3a. Actual hydroacoustic screen images showing debris settling during turbine shutdown.



Appendix 3b. Actual hydroacoustic screen images showing debris movement during turbine startup.

Appendix 4. Comments on the draft report and PacifiCorp's response to those comments(next page).

State of Washington
Department of Fish and Wildlife
2108 Grand Blvd. Vancouver WA 98661 (360) 696-6211

June 13, 2007

Frank Shrier
Lead Senior Fish Biologist
PacifiCorp
825 NE Multnomah Street, Suite 1500
Portland, Oregon 97232

SUBJECT: ACC Review DRAFT Yale Hydroelectric Project Entrainment Final Report

Dear Mr. Shrier;

Washington Department of Fish and Wildlife appreciates the opportunity to provide comments on PacifiCorp's Draft – ACC Review DRAFT Yale Hydroelectric Project Entrainment Final Report, May 1, 2007 (2007 Entrainment Report). First we will provide some general comments, followed by specific comments referencing page and paragraph.

Overall, the research conducted by PacifiCorps (and consultants) to identify the fish species and quantify the numbers of fish passing through the turbines at the Yale Hydroelectric Project is inconclusive. In the 2007 Entrainment Report, PacifiCorp compares its results to a 1997 PacifiCorp study using similar hydroacoustic methodologies (1997 Entrainment Report) – the two PacifiCorp sponsored studies had very disparate results regarding the number and rate of fish entrained and passing through the turbines at Yale Dam. The estimate of the fish entrainment rate in the 1997 Entrainment Report (28.5 fish per hour) is apparently 150 times higher than was estimated in the 2007 Entrainment Report (0.19 fish per hour; Appendix 1). An explanation is needed for the discrepancy in the findings of these two studies with similar methodologies.

PacifiCorp will provide further analysis of the two studies in the report text to provide a comparison of the methodologies and why the large discrepancy occurred.

In the 2007 Entrainment Report, fish species identification in the turbine intake was attempted using video cameras (616 hours of film) but only 3 fish images were recorded – two unidentifiable and one that "appeared to be a Kokanee salmon". In the 1997 study, mid-water trawls were used to sample for fish species composition in the reservoir of Yale Dam (80 minutes of effort) – with a total catch of 2 juvenile kokanee salmon, 40 sculpin, and 17 threespine stickleback[1].

[1] The 1997 trawl results are probably not representative of mid-water fish relative abundance since Lesko (2006) estimates the adult kokanee spawning escapement to be: 89,252 in 1995, 82,821 in 1997, and 55,095 in 2006 – compared to the 1997 hydroacoustic population estimate of 82,843-109,629 total fish in the limnetic zone. Also having a benthic species – sculpin – as the

Therefore, because of inconclusive total fish entrainment rate and inconclusive species identification in the turbine intake – the PacifiCorp research has failed to estimate the annual number of bull trout entrained at Yale Dam. We find no scientific basis to support the following quantitative estimate (page 38 of the 2007 Entrainment Report): "Based on the results and analysis of entrainment at Yale dam, there is a very small number of bull trout that are potentially entrained (less than 2 bull trout per year)."

However, the Lewis River Settlement Agreement language cited in Appendix 1 of the 2007 Entrainment Report raises an even more fundamental and important issue; that is, the study called for in § 4.9.3 Yale and Merwin Bull Trout Entrainment Reduction – is research to evaluate bull trout **entrainment reduction methods** – not to determine if the magnitude of bull trout entrainment is sufficient to warrant an entrainment reduction plan:

> *"Immediately following the Effective Date, PacifiCorp shall design and implement a study to evaluate bull trout entrainment reduction methods for Yale and Merwin dams in Consultation with the ACC. Potential entrainment reduction methods include installation of exclusion devices, such as strobe lights, and installation of barrier nets with submersible cork lines and designed to accommodate a Merwin-type floating trap. Due to the small numbers of bull trout in Yale and Merwin, any evaluation of strobe lights will be performed in Swift Reservoir."*

After the bull trout entrainment reduction method study is completed then the Plan should be developed:

> *Based upon its study, PacifiCorp shall prepare, in Consultation with the ACC, a draft entrainment reduction plan for the Yale Project. The plan would be developed to minimize unacceptable incidental impacts to bull trout or other species. PacifiCorp shall submit the draft plan to members of the ACC for comment within 16 months after completing the entrainment reduction study.*

The 2007 Entrainment Report, currently under review, did not evaluate potential entrainment reduction methods called for in § 4.9.3, e.g., installation of exclusion devices, such as strobe lights, and installation of barrier nets with submersible cork lines – designed to accommodate a Merwin-type floating trap. Therefore, there is no basis for the statement (page 38 of the 2007 Entrainment Report): "Based on the above analysis and continued conservation efforts, we do not find there to be enough compelling evidence to warrant placement of an entrainment reduction device at Yale for the prevention of bull trout entrainment."

There is a definite difference in numbers between the two studies. PacifiCorp will work to further explain the differences between the two studies and will work to resolve the differences. An entrainment reduction plan will accompany the final version of the entrainment report.

WDFW's specific comments:

predominant species in a mid-water trawl sample is unusual. Sculpins do migrate upwards in lakes during the nighttime hours to feed so this is not unusual (see Larson and Brown 1975 – JFRBC 32-21-28; Neverman and Wurtsbaugh 1994 – Oecologia 98:247-256; and Hammar, et al. 1995 – Eniron. Biol. of Fishes 46:185-195)

Page 6 Abstract. The draft states, “Overall fish were entrained at a rate of 0.19 fish per hour with a size range of 4.78 to 44.04 cm.” Please explain the discrepancy in entrainment rate with the 1997 study in terms of numbers of fish within the entire area behind the trash racks versus the entrainment zone.

Page 6 Par. 4 It states, “The 1997 entrainment study at the Yale facility (PacifiCorp 1999a) used hydroacoustics to evaluate fish entrainment . . . Entrainment rates during this time averaged approximately 21 fish per hour with a range of 40 to 180 fish per hour (unfiltered data).” The 1997 mean entrainment rate is **110 times greater** (21 fish per hour versus 0.19 fish per hour) than that reported for 2004-2005. Please explain the discrepancy.

PacifiCorp will provide further analysis of the two studies in the report text to provide a comparison of the methodologies and why the large difference in fish numbers occurs.

Page 6 Par. 5 The draft states, “The total number of entrained fish decreased from the start of the study in winter to the end of the study in summer. Three Bull trout were collected during spring and one during the summer sampling periods.” Four bull trout were captured in the power canal in 2002. However, there was no measure of trap efficiency; there was no attempt to quantify total number of fish entrained. The draft refers to only one 8-foot screw trap placed in a canal whose width could have potentially held ten traps side by side. Without a measure of trap efficiency, we have no idea of the number of fish that were actually entrained. So, if one trap captured four bull trout; then theoretically ten traps could have captured 40 fish.

Actually an efficiency test was conducted with the Swift screw trap using 519 trout and found the overall trap efficiency to be 2.3%. The study, however, was not designed to quantify entrainment. Instead, the Aquatic Resources Group (ARG) approved objectives to assess species composition and relative abundance. If there had been 10 screw traps and 40 bull trout were captured, that would still only represent about 4% of the spawning population in Swift. Given the Yale bull trout spawner population is magnitudes smaller than Swift, the entrainment numbers in Yale would be quite small.

Bull trout are benthic oriented fish. An 8-foot screw trap only samples the top waters ≈ 3’ below the surface. The likelihood of rotary screw traps capturing bull trout in 20+ feet of water (depth of the tailrace) is remote. At best, it would capture only those bull trout injured or disoriented enough to be in the upper surface layers of the tailrace. When bull trout are netted in the Yale tailrace, weighted gill nets are set on the tailrace bottom where bull trout inhabit, they are not fished in the surface waters as this screw trap was.

Yes, bull trout are predominately benthic but this argument does not hold up when discussing fish coming through a turbine discharge at Swift. Those fish would stay suspended in the water column until they regained their equilibrium and exited the discharge plume. Bull trout in the Yale tailrace reside there and are not disoriented. In fact the turbines are shut off during the Yale tailrace collection periods.

The screw trap was installed sometime in February; the power canal failed on April 21; and the trap was reinstalled two weeks later (Lesko 2003). Rush Creek screw trap data (2005) indicate this is a major period of young-of-the-year bull trout migration. Additionally, otter predation was documented in the Swift tailrace trap and additional fish (bull trout) were removed from the live box. To imply a total of four bull trout were captured that season is misleading.

Correct, this was not a quantitative study so it cannot be implied that the total entrainment was 4 bull trout. The text will be modified.

Page 7 Par. 2 The draft states, "There were two major objectives established for this Study and approved by the Lewis River Aquatics Coordination Committee (ACC): 1) Evaluate fish entrainment into the turbine intakes at Yale and Merwin dams, and 2) Develop a draft Entrainment Reduction Plan for review by the ACC. WDFW does not feel the utilities; 1) have provided sufficient evidence for their entrainment estimate and 2) have not provided an Entrainment Reduction Plan. We do not believe these entrainment reduction objectives were adequately addressed by the 2007 Entrainment study.

This was a draft that included uncertainties about the need for an entrainment reduction device. The final report will provide further evidence to support the entrainment estimate and will provide an entrainment reduction plan.

Page 9 Par. 2 Previously, (Par. 5 on Page 6) stated that three bull trout were captured in spring and one additional was captured in summer. These numbers should be interpreted in terms of trap efficiency to extrapolate total numbers of bull trout entrained.

See above response

Page 10 Par. 1 Remote detections of adult bull trout migration from Aug.-Oct. 2006, at the Rush Creek PIT tag detector indicated movement occurred in two peaks from 1500h to 1800h (27% of daily detections) and 2100h to 2400h (24%). The video schedule described in the draft missed the second peak entirely and only captured a portion of our first peak. In the Rush Creek data, from 1800h to 2100h twelve percent of daily passage was detected. From 600h to 900 only 3 % of fish were interrogated. Rush Creek peak migration periods did not match well with video sessions. Possible adaptive management measures include: 1) checking camera operation, 2) repositioning or adding additional cameras for full coverage and 3) revising recording periods.

PacifiCorp staff does not think it prudent to assume adult bull trout behavior in Rush Creek, where fish are actively migrating to spawning areas can be projected on bull trout residing in Yale reservoir. Also it was not feasible to send divers down to the Yale intake on a frequent basis to make fine camera adjustments. As it is stated in the report, the video sample times were closely coordinated with actual hydroacoustic fish observations and were thus calibrated to be recording at the most likely time periods for fish movement.

Page 19 Par. 5 Video was started Nov. 22 and ran through Feb. 15 with no detections. It is understood that the cameras were not modified due to the logistics involved, however, it resulted in inconclusive information on species of fish entrained.

The same is stated as such in the report – the video study was inconclusive.

Page 25 Par. 4
The 80, 69 and 44 cm detections indicate that adult bull trout were entrained. They fit the size range for adult bull trout. We have captured bull trout in Swift Reservoir and in the Yale tailrace within this size range.

Agree that bull trout have been captured in this size range but the point is that, out of the 1,000 plus fish observed, only three were observed that were 44, 69, and 80 cm. The rest of the observations were considerably smaller.

Page 25 Par. 6 The entrainment rates presented indicate that large differences occurred between the 1997 and 2007 studies – please explain the discrepancies.

See above response

Turbine 1, which this draft indicates generates the greatest level of entrainment (0.26 vs. 0.14 fish/hr, nearly double that of Turbine 2), was inoperative during late April through early June, a time of peak bull trout migration (Scott and Crossman, 1979). The lack of operation of the primary entraining turbine could have reduced estimated detections.

The April to Early June period is for juveniles migrating downstream into a lake or reservoir rearing area and does not directly equate to movement through and out-of a reservoir. In looking at Table 5.3, the greatest amount of entrainment for Turbine 1 occurred from Dec. 29 through February 23rd. for the 41-day period leading up to Turbine 1 being off line, only 1 fish was entrained at each of the 2 units. This indicates there was very little migration going on during that period. At Turbine 2, 13 fish were entrained during the Turbine 1 outage period, but that is likely because Turbine 2 was the only outflow at that time. After Turbine 1 was restarted, only 1 fish was entrained in the ensuing 7 days while Turbine 2 entrained 7 fish so it is possible that a shift occurred toward Turbine 2 in that timeframe. Still it does not appear that large numbers of fish were missed during the outage period.

Page 26 Par. 2 A greater percentage of larger fish are at depth (Figure 5.4-3) within the entrainment zone. Migrating fish of this size have appeared in the Rush and Eagle Cliffs screw trap and in the Swift 1 entrainment screw trap. This indicates that a large number of fish the size of that bull trout are vulnerable to entrainment at Yale.

The majority of the fish traces (around 90% of the targets) were, by far, less that 20 cm. The majority of the larger fish >20 cm were not in the Fish Entrainment Zone.

2001 Eagle Cliffs screw trap data indicate migrating bull trout had a tri-modal length distribution (PacifiCorp 2003). Bull trout migrant peak fork lengths ranged from 130-160 mm, 180 and 200 mm. Lesko (PacifiCorp 2004) reported bull trout from 75-300 mm being entrained through Swift 1 during 2002. Migrating and entrained bull trout have certainly been reported in size ranges denoted in Fig. 5.4-4. The largest fish detected was during the 3/13- 4/22 period when bull trout are actively migrating.

There is no argument that some bull trout in this size range can be entrained at Yale dam. The point made in the report was that, logically, the possibility of an entrained fish being a bull trout (of any size) was very small but not impossible.

Page 31 Fig. 5.4-3 The largest fish recorded at both turbines are present in the Fish Entrainment Zone. Sub-adult and adult bull trout are vulnerable to entrainment. The size of fish in Page 25 Par. 4 confirms this. 2001 Eagle Cliffs screw trap data (PacifiCorp 2003) and Swift 1 screw trap data (PacifiCorp 2004) reported bull trout in these size ranges.

Agree. The report considers that single 40 cm fish to be entrained.

Page 35 Par. 3 The text states, "Bull trout generally reside in their natal stream for the first 1 to 4 years of life (Fraley and Shepard 1989)". In Rush Ck. 80% of juvenile bull trout emigrate as sub-yearlings (young of the year YOY, <30mm). We did not find YOY bull trout emigration from Cougar Ck. in two years of trapping. Fish in the entrainment study within the 11-13 cm size range could be bull trout. 2001 Eagle Cliffs screw trap data (PacifiCorp 2003) and Swift 1 screw trap data (PacifiCorp 2004) reported entrained bull trout in these size ranges.

Rush Creek is a unique system and does not offer much in the way of juvenile holding habitat so it is not surprising that the YOY leave that system at a very early age. It is most likely that those Rush Creek juveniles rear in the Mainstem Lewis River and migrate down to Swift Reservoir much later when they are big enough to begin a pisciverous life history.
PacifiCorp staff collected genetic samples from twenty-four Age 0, 1, and 2 bull trout juveniles in a half-day of sampling and covering only a small portion of the lower creek which indicates there are a fair number of juveniles of several age classes residing in Cougar Creek.

Page 35 Par. 4 The draft states, "Bull trout move into freshwater lakes in the spring at about the same time that anadromous salmonids migrate to sea (April and May) (Scott and Crossman 1979)". We found greatest emigration from Rush Ck. to occur in March through May. Unfortunately, Turbine 1, which entrains the greatest numbers of fish, was inoperative from April 27 through June 8; this could reduce the number of reported detections.

See above response

Page 38 Par. 1 We question a direct comparison between Lake Billy Chinook and Yale Reservoir.

Both lakes support similar populations (bull trout, kokanee, sculpins, and pelagic threespine sticklebacks), both lakes have similar depth, shape, and shoreline complexity and Yale is about 3300 acres while Lake Billy Chinook is 4,000 acres. For these reasons, we thought it was most appropriate to compare these two systems as a check on the validity of the data collected at Yale.

Since fish netted are surviving adult or sub-adults; that implies that there were additional juvenile or sub-adult bull trout present that suffered some unknown level of mortality over the years prior to being caught. The text implies that entrained bull trout would be two at 13- 15 cm. The mesh sizes used in the Yale tailrace are 1-3 inch stretch, which can allow juvenile bull trout to swim through and not be caught in the nets. Pratt (1985) suggested that bull trout annual survival ranges xx to xx for sub-adult fish. For example, if we use Pratt's mean annual survival figure (0.20), then netting 9 sub-adults (given that adult spawners are six years of age) would imply that 9 fish survived to five year olds, 12 to four year olds, 15 to three year olds, and 24 to two year olds. Thus we could infer that 48 two-year old fish were entrained through Yale Dam, given a 50% turbine mortality rate.

PacifiCorp staff does not necessarily agree with a bull trout initially becoming a spawner at 6 years old – there simply is not any data to support that contention. Regardless, Pratt's paper says that bull trout annual mortality ranges from 18 to 23% or a mean of about 80% survival so, using the 6 year-old analogy, a life table might look like this:

Adult Age	# fish
6	9
5	11
4	14
3	17
2	21

Page 38 Par.3 WDFW disagrees with the recommendations, "*Based on the results and analysis of entrainment at Yale dam, there is a very small number of bull trout that are potentially entrained (less than 2 bull trout per year).*" If this were so; how do an average of nine bull trout get captured annually from the tailrace? The number transiting the dam has to exceed two; and incorporating Pratt's multiple year survivals the number approaches 48 (see estimate above).

One cannot infer that all twenty-one 2 year old bull trout were entrained through the turbines. In fact, our data shows a strong correlation between numbers of bull trout captured in the Yale tailrace and the amount of spill that occurred at Yale dam in each previous winter. Also, we have recovered two tagged adult bull trout that were captured in the Yale tailrace, taken to Cougar Creek and recaptured in the Yale tailrace the next year so not all the bull trout that occur in the Yale tailrace can be attributed back to turbine-entrained 2 year olds. If your point is that bull trout can be entrained at Yale dam, we agree. There is no way of verifying how many actually go through the turbines, the report just concluded that, based on probability and a logical analysis, out of the total number of fish entrained the numbers of entrained bull trout are likely to be very small.

The draft states, "*However, the size of spawners observed in Cougar Creek far exceed the larger fish that were observed in the Yale intake area.*" Can we review this length data from Cougar Creek.

Here's the data from the unpublished Cougar Creek adult holding habitat study:

Location	Date	Time	Length (cm)	Sex
Cougar	07-Sep-93	09:28	61.0	M
Cougar	23-Sep-93		55.9	M
Cougar	23-Sep-93		71.1	F
Cougar	23-Sep-93		50.8	F
Cougar	23-Sep-93		45.7	M
Cougar	17-Nov-93		71.1	M
Cougar	17-Nov-93		48.3	F
Cougar	17-Nov-93		45.7	F
Cougar	17-Nov-93		40.6	M
Cougar	17-Nov-93		55.9	F
Cougar	17-Nov-93		45.7	M
Cougar	17-Nov-93		45.7	M
Cougar	17-Nov-93		61.0	M
Cougar	07-Oct-94	12:40	38.1	U
Cougar	07-Oct-94	12:40	61.0	M
Cougar	07-Oct-94	12:40	61.0	M
Cougar	07-Oct-94	12:40	53.3	F
Cougar	07-Oct-94	12:40	76.2	F
Cougar	07-Oct-94	13:05	68.6	F
Cougar	07-Oct-94	13:15	45.7	M
Cougar	07-Oct-94	13:15	63.5	M
Cougar	07-Oct-94	13:15	61.0	F
Cougar	07-Oct-94		63.5	F
Cougar	07-Oct-94	13:45	45.7	F
Cougar	07-Oct-94	13:45	76.2	U
Cougar	07-Oct-94	13:45	61.0	M
Cougar	07-Oct-94	13:45	45.7	U
Cougar	07-Oct-94	13:40	71.1	M
Cougar	07-Oct-94	13:40	61.0	M
Cougar	07-Oct-94	13:40	50.8	F
Cougar	07-Oct-94	13:55	61.0	M
Cougar	07-Oct-94	14:00	63.5	U
Cougar	07-Oct-94	14:45	50.8	F
Cougar	07-Oct-94	14:30	45.7	M
Cougar	07-Oct-94	14:30	45.7	U
Cougar	07-Oct-94	14:30	55.9	F

In summary, the specific points detailed above show that the Draft 2007 Entrainment Report is deficient in the at least nine major areas:

1) The discrepancy with the 1997 entrainment study was not adequately explained.

2) The debris filter methodology used to discount “false” detections was not adequately explained nor was the algorithm quantified.
3) The authors cite bull trout catch data below Yale Dam (PacifiCorp 1999), but do not adequately analyze the data in terms of total population size. Four bull trout entrained at Swift 1 Dam, were captured in a rotary screw trap in the upper power canal in 2002, and were referenced as a total fish captured. If one considers the low trap efficiency, the total bull trout numbers present in the power canal would be much greater.
4) The turbine generating the highest entrainment levels (0.26 vs. 0.14 fish/hr.) in the 2007 study was not in operation during the months of reported greatest bull trout migration as cited in references (Scott and Crossman 1979).
5) This draft seems to indicate that fish entrained were not of a size that might indicate bull trout. However, data cited by the 2001 Eagle Cliff migration study and 2002 Swift 1 entrainment trapping indicate migrating bull trout were of the size that could be entrained at Yale.
6) Adaptive management should have been utilized to improve the effectiveness of the video observation methodology; e.g., when it was apparent that only a portion of the intake was covered, why weren’t additional cameras employed to give full coverage? When no video detections were observed, filming hours were not altered to capture observations.
7) Finally, the PacifiCorp estimate that only two bull trout are entrained is inconsistent with the number of bull trout netted from the Yale tailrace, i.e., nine adults per year. We make the inference – from Pratt’s mean survival value, that an additional (24-48) sub-adult bull trout were either entrained or spilled into the Yale tailrace – to observe nine adults.

Thank you for the opportunity to comment on the ACC Review DRAFT Yale Hydroelectric Project Entrainment Final Report. WDFW would appreciate a response from PacifiCorps to our general and specific comments. WDFW believes an independent outside review of the hydroacoustic methodology would be valuable in order to explain the discrepancy between the 1997 and 2007 study results. We look forward to working with you and the ACC in collaboratively developing a study design for an entrainment reduction evaluation, and subsequently a draft entrainment reduction plan for the Yale Project. If you have any questions or responses to comments, please contact Jim Byrne at 360-906-6751 or Steve Vigg at 360-906-6710.

Sincerely,

Pat Frazier
Region 5 Fish Program Manager
Washington Department of Fish and Wildlife

Attachment 1: References

Graves, S. 1983. Final report evaluation of Merwin, Swift and Yale Reservoirs. Unpublished data.

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Attachment 2: Draft Bull Trout Entrainment Reduction Plan

Yale Hydroelectric Project No. 2071

Bull Trout Entrainment Reduction Plan

January 22, 2008

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1. Introduction

1.1. Settlement Agreement Summary

The Lewis River Settlement Agreement (2004) calls for (1) a study to evaluate bull trout entrainment at the Yale Hydroelectric Project and subsequently, (2) the development of an Entrainment Reduction Plan to minimize negative impacts associated with the entrainment of bull trout and other species (see Settlement Agreement Section 4.9.3). Prior to the Settlement Agreement, PacifiCorp studied fish entrainment during relicensing of the Lewis River Hydroelectric Projects (PacifiCorp 1999A; PacifiCorp 2004). In addition, PacifiCorp recently completed a hydroacoustic evaluation of fish entrainment at the Yale facility in 2006 to meet the initial requirement of the Settlement Agreement described above (PacifiCorp 2007). The goal of the 2006 evaluation was to obtain more recent information on entrained fish sizes and numbers in order to make more informed recommendations for an entrainment reduction device and to assess the effectiveness of the selected device. The results were submitted in draft form to the Lewis River Aquatics Coordination Committee (ACC) for review. Comments received from WDFW and USFWS are attached at the end of this document. This document represents a formal proposal to the USFWS. The Lewis River Settlement agreement requires formal approval by the USFWS before the final Plan can be submitted to FERC.

This Plan addresses the second condition of the Settlement Agreement regarding entrainment at the Yale Project by identifying and evaluating the potential of various entrainment reduction technologies. To the extent possible, we reviewed the potential of each technology in the context of at-risk fish characterized during the entrainment study. However, as stipulated in the Settlement Agreement, the primary factor in evaluating each technology was its potential ability to reduce the entrainment of bull trout.

1.2. Summary of Fish Entrainment

The 2006 entrainment study at the Yale Project (PacifiCorp 2007) used hydroacoustics coupled with underwater video to evaluate entrainment over a 34-week period from November 2005 through July 2006. Overall entrainment rates during this time averaged 0.19 (+/- 0.048) fish per hour with a range of 0.14 to 0.24 fish per hour. The length of entrained fish ranged from 4.8 to 44.0 cm (1.9 to17.3 inches), with an average of 18.5 cm (7.3 inches) for Turbine 1 and 17.2 cm (6.8 inches) for Turbine 2. The estimated length-frequency distribution of entrained fish is shown on Figure 1. Only two fish, which appeared to be kokanee, were observed by video. Limitations of the video system precluded an estimate of how many bull trout, if any, were entrained over the course of the study. However, given the low abundance of bull trout in Yale Lake and the observed length-frequency distribution of entrained fish, we expect that few adult bull trout were entrained during the entrainment evaluation.[2]

[2] The Lewis River Settlement Agreement (2004) defines adult bull trout to be greater than 33 cm (13 inches) in length.

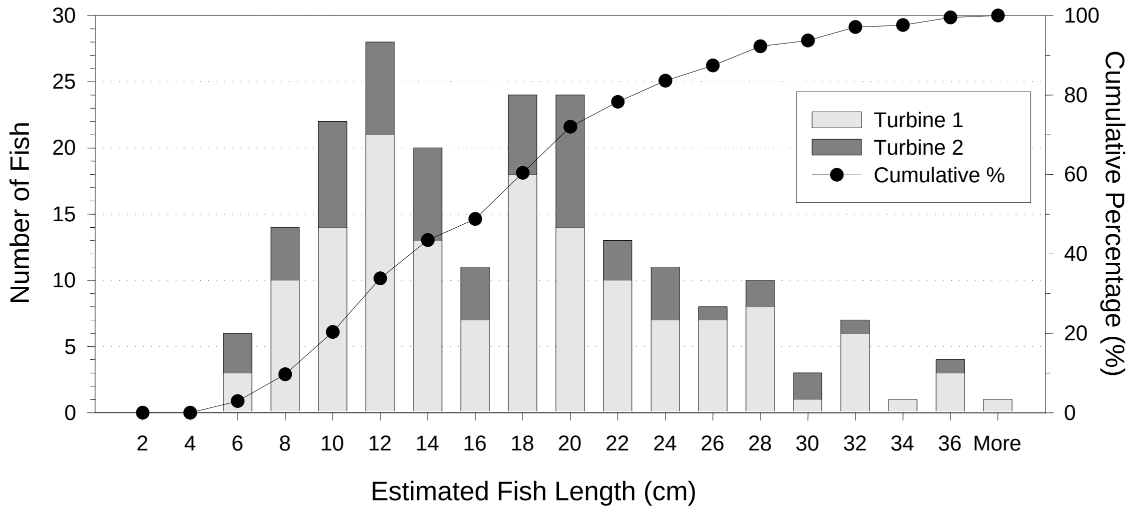

Figure 1. Estimated length-frequency distribution of entrained fish at the Yale Project (from PacifiCorp 2007)

1.3. Rationale and Assessment Criteria

Because we were unable to document species-specific entrainment, we attempted to focus the entrainment results by applying relevant information on the life history of adfluvial bull trout. With an understanding of the age and size at which bull trout typically enter a lacustrine environment, we can target our evaluation of entrainment reduction technologies towards their ability to protect bull trout of the age/size most likely to be at risk. Further, we reviewed the literature to determine whether the spatial distribution of adfluvial bull trout within a lake or reservoir differed among age/size classes. A discussion of these findings can be found below in Section 3.

Settlement Agreement Section 4.9.3 explicitly requires that the Entrainment Reduction Plan include evaluations of strobe lights and barrier nets as potential entrainment reduction technologies. However, to ensure that the most appropriate technology is selected for reducing entrainment, we expanded our review to include a comprehensive range of experimental and established technologies used to guide or exclude fish at water intakes. We conducted a preliminary evaluation of these technologies to identify those with the greatest potential for effective use at the Yale Project. Several of these qualifying technologies were then evaluated in detail, taking site-specific information into consideration to identify the technology (or technologies) most suitable for implementation.

In choosing which technologies to evaluate in detail, we considered the following criteria:

- *A demonstrated and quantifiable ability to successfully reduce entrainment.* The strength of studies demonstrating the effectiveness of a technology were considered in the following order based on the guidelines laid out by the Bioengineering Section of the American Fisheries Society:
    - Evaluations at existing water intakes (hydroelectric projects in particular)
    - Field or prototype evaluations
    - Laboratory evaluations
- *A demonstrated ability to exclude or elicit an avoidance response from bull trout.* Because few technologies have been evaluated specifically for bull trout, studies targeting other species were considered in the following order with regard to relevance at the Yale Project:
    - Other char spp.
    - Other salmonid spp.
    - Species with similar morphologies, behavior, or swimming abilities.
- *General applicability of the technology based on the physical characteristics of the Yale Project.* Some technologies may be deemed inappropriate based on the following considerations:
    - Project layout (*e.g.,* bathymetry, intake size, water depths)
    - Operating conditions of the Yale Project (*e.g.,* reservoir fluctuations, water velocities)
    - Environmental conditions in Yale Lake (*e.g.,* turbidity, ambient noise, debris loading/biofouling)

2. Adfluvial Bull Trout Biology

Juvenile bull trout typically remain in their natal streams for 1 to 4 years of age before moving downstream into mainstem or lake habitat (Fraley and Shepard 1989). In the Flathead River system (Montana), the average total lengths of emigrating age-1, -2, -3, and -4 juveniles were 73, 117, 155, and 228 mm, respectively. In investigations of the bull trout population in Mission Reservoir, part of the Flathead River system, Hansen and DosSantos (1993) use the assumption that stream rearing takes place in the first three years of life and three year olds average 170 mm total length. Reviewing the literature of bull trout biology, Goetz (1989) states that most juveniles emigrate at two to three years of age in most river systems. Stelfox (1997) found that most juvenile bull trout entering a reservoir associated with a hydro project in Alberta did so at three years of age (151-200 mm length). Stelfox further states that either few bull trout enter the reservoir before age 3 or survival for these younger fish is poor upon entering the reservoir. Connor et al. (1997) found that juvenile bull trout in the upper Cedar River (Washington) likely enter Chester Morse Lake after two years in tributary habitat. In the Lewis River basin, an effort to collect juvenile genetic material in Cougar Creek in 2003, found that most of the 24 fish collected were age-1 (55 to 75 mm), about 29 percent were age-2 (110 to 130 mm), and one fish was age-3 (190 mm) (PacifiCorp unpublished data).

Bull trout move into freshwater lakes in the spring at about the same time that anadromous salmonids migrate to the sea (April and May; Scott and Crossman 1979). Shepard et al. (1984) found juvenile bull trout to emigrate from early May to mid-July. In contrast, Stelfox (1997) found that most juvenile downstream movement in an Alberta stream occurred from late August to early September. Data from other Pacific Northwest rivers indicate that post-spawning adult bull trout move downstream in the fall (Wade and Tranquilli 2002, US Bureau of Reclamation 2004). It is possible that Lewis River could follow similar patterns with seasonal movement occurring in both spring and fall.

Bull trout are generally well-distributed throughout lake environments, inhabiting depths as great as 360 feet as well as traveling along shorelines (Goetz 1989). They are found throughout the water column for much of the year, moving to deeper water in the summer. In Chester Morse Lake, Connor et al. (1997) observed a similar trend with relatively high abundance in deeper areas (*i.e.,* the profundal zone) based on hydroacoustic surveys as well as in littoral areas based on gill netting and angling surveys. The pelagic zone contained few trout.

3. Preliminary Assessment of Entrainment Reduction Technologies

Many different technologies have been used to reduce fish entrainment at hydroelectric facilities and water intakes, with varying degrees of success. The effectiveness of a given technology is typically a function of the size and species of fish to be protected and site-specific characteristics of the installation. We included the technologies evaluated below because they have had some demonstrated ability to exclude, divert, or elicit a behavioral response from fish. Some of these technologies are more broadly applicable and have been more thoroughly evaluated than others.

Technologies for protecting fish at water intakes generally fall into the following three categories:

- *Physical barriers*

  Physically exclude fish from entering water intakes by creating a structural barrier through which fish cannot pass (*e.g.,* barrier nets, screens, bar racks).

- *Behavioral technologies*

  Function by eliciting a behavioral response to a generated stimulus (*e.g.,* sound, light, electricity, flow, air bubbles). Depending on the targeted species and the stimulus, exposure can result in avoidance or attraction. Behavioral technologies are often used in tandem with other exclusionary devices.

- *Diversion systems*

  These technologies (*e.g.,* angled bar racks, louver arrays, surface collectors, Eicher Screens), are typically employed to provide safe downstream passage for migratory species by guiding fish to some pathway that bypasses turbines.

The goal of the Entrainment Reduction Plan is to prevent bull trout entrainment, thereby protecting the adfluvial population of bull trout in Yale Lake. This goal possibly could be accomplished with the implementation of a physical barrier, behavioral technology, and/or a diversion system. Downstream collection facilities at Yale dam were conditioned as part of the Settlement Agreement and are scheduled for completion in the 13th year of the new Federal Energy Regulatory Commission (FERC) licenses which, as of the date of this document, have yet to be issued by FERC. Because a time lag of approximately 13 years was anticipated between licensing and construction for Yale downstream facilities the Settlement Agreement called for an evaluation of entrainment and an interim entrainment reduction plan prior to construction of downstream collection facilities. Thus, a temporary entrainment reduction device is sought to operate for this interim period. Because of the SA condition calling for downstream passage facilities at Yale we did not include diversion systems in this evaluation of entrainment reduction technologies.

In the following section, we review the general effectiveness of suitable physical and behavioral barriers and then consider application of selected technologies at Yale Dam for more detailed evaluation. A summary of the advantages and disadvantages of each technology is provided at the end of the section in Table 1.

3.1. Physical Barriers

Physical barriers are designed to physically prevent objects in the water column (*i.e.,* fish, flotsam, etc.) from passing downstream into water intakes. Their effectiveness and structural integrity can be compromised by heavy debris loads and high flow events. The biological effectiveness of a physical barrier is highly dependent on the relationship between the size of the fish to be protected, the size of the barrier element (*i.e.,* mesh size, slat-clear spacing, or slot width), and velocity. Physical barriers are most effective when deployed in areas with low water velocities. Below, we review information from several existing physical barrier installations.

3.1.1. Barrier Nets

Barrier nets have been used successfully at both hydroelectric projects and cooling water intakes throughout North America. To date, the largest barrier net installation is at the Ludington Pumped Storage Plant on Lake Michigan (EPRI 2004). The net is 2.5 miles long, extends up to 0.6 miles offshore, and covers the full depth of the water column (to 45 feet) with a mesh size (bar) from 0.5 to 1 inch. The net was originally installed in 1989 but was modified several times to improve its effectiveness and durability. Based on comparative gillnetting inside and outside of the net, the most recent data (1995 to 1996) show overall exclusion rates of 96% (85% for salmonids). The effectiveness of this installation is attributed to the low water velocity through the net (<0.1 ft/s), which is facilitated by its large size. The net is removed from October to April when fish abundance is reduced and ice and weather prevent deployment.

A barrier net was installed at the Pine Hydroelectric Project on the Pine River, Wisconsin in 1990 (Michaud and Taft 2000). This installation is considerably smaller than that at Ludington, with a length of 260 feet and full depth coverage ranging from 2 to 35 feet. The 1-inch mesh (stretch) net is deployed along an angled log boom upstream of the intake canal. Effectiveness monitoring in 1990 and 1991 showed that entrainment (primarily catfish, bluegill, and sucker spp.) decreased from 7.8 fish per hour to 2.3 fish per hour after installation of the net (EPRI 2004). As at Ludington, low velocities along the net (less than 0.15 ft/s and as low as 0.03 ft/s;

Michaud and Taft 2000) are believed to contribute to the nets integrity and biological effectiveness.

In 1999, a barrier net was installed at the Hayward Hydro Project on the Namekagon River, Wisconsin (EPRI 2004). The dimensions of the net are 75 ft long by 10 ft deep with a 3/8-inch (square) mesh. Again, the installation was designed to have low water velocities approaching the net (considerably less than 0.5 ft/sec). The net was primarily deployed to reduce entrainment of young-of-the-year walleye. To date, results of an ongoing evaluation of the net's effectiveness are unavailable.

A 4,400-foot long barrier net with 3 1/4 –inch mesh (stretch) was installed in Banks Lake, Washington to prevent the entrainment of mature kokanee salmon into an irrigation canal (Stober et al. 1983). Deployment of the net reduced the rate of entrainment from 64% to 10%.

The barrier net installations described above are all exclusionary devices rather than guidance devices. At the Puntledge Hydroelectric Project in British Columbia, a 141-foot long barrier net was installed to guide juvenile salmonids to a downstream bypass (EPRI 2004). A ¾-inch mesh (stretch) was deployed at an angle to the flow upstream of the power canal and guided fish towards a bypass at the face of the dam. The net successfully guided over 99% of coho smolts towards the bypass during a two-year evaluation from 1991 to 1992. However, the project owners did not believe that the net would remain effective during years with greater flow and abandoned the barrier net in lieu of Eicher Screens installed in the penstocks.

A similar approach has been employed at both the Upper and Lower Baker Dams on the Baker River to guide fish to a floating surface collector (Puget Sound Energy 2002). Initial guidance efficiency results were mixed due to net positioning and sagging associated with reservoir level fluctuations. However, recent modifications have been made to address these concerns and the improved installation is currently being evaluated.

Barrier nets have a demonstrated ability to significantly reduce fish entrainment at water intakes. However, their effectiveness is largely tied to the maintenance of structural integrity that, in turn, is a function of minimal debris loads, manageable biofouling, and favorable hydraulic conditions at the installation site. As such, barrier nets were selected as a potentially viable alternative for reducing bull trout entrainment at the Yale Project and are evaluated in more detail in Section 5, taking site-specific conditions into account.

3.1.2. Narrow-Spaced Bar Racks

Bar racks and louvers oriented at an angle to the approaching flow have been extensively used to prevent entrainment by guiding migratory species towards a downstream bypass, especially in the Northeastern U.S. (OTA 1995). Where the objective is to simply prevent entrainment rather than guide fish to a bypass, bar racks oriented perpendicular to the flow may be a viable alternative and require substantially less capital investment than the construction of a louver array or an angled bar rack structure.

Whereas studies evaluating the guidance efficiency of angled bar racks and louver arrays are numerous, we found no studies quantifying the exclusion efficiency of a narrow-spaced bar rack oriented perpendicularly to the flow. One study cited by EPRI (1998) evaluated the operational effects of a narrow-spaced bar rack and quantified fish impingement at the Chippewa Falls Hydroelectric Project. Impingement increased as debris loading on the bar racks increased, but there was no discussion of exclusion efficiency.

3.2. Behavioral Barriers

Behavioral barriers function by eliciting a behavioral response to a generated stimulus. In some cases, physical structures such as angled bar racks or louver arrays are considered behavioral technologies because they create small scale hydraulic environments that guide fish. However, for the purposes of this discussion, we focus on the effectiveness of lights, sound, electricity, and air-bubbles.

3.2.1. Light

Light has a well-established ability to elicit behavioral responses in fish, though the response varies depending on the type of light used. Mercury vapor lights have been used to attract fish to a desired location (*e.g.,* downstream bypass), whereas strobe lights have been more effective as a deterrent causing fish to move away from a desired location (*e.g.,* turbine intakes; OTA 1995). Because the objective of reducing bull trout entrainment would best be met by deterring fish from the intakes rather than attracting them to some other location, we focus our discussion on the effectiveness of strobe lights as an exclusionary device.

The ability of strobe lights to deter fish has been studied extensively in the laboratory, in open-water field tests, and at field installations, with mixed results. Perceived effectiveness can be quite complicated and is thought to be largely related to species-specific responses and site-specific conditions such as ambient lighting and turbidity. In a recent study at Grand Coulee Dam, Johnson et al. (2005) found that ambient light and flow were the primary factors determining the movement of rainbow trout and kokanee in the vicinity of a strobe light installation. They found that strobe lights had little effect during the day. At night, while fish avoided the area in the immediate vicinity of the lights (<33 feet), they congregated in the general area where the lights were deployed.

Mueller et al. (1999) performed cage tests to evaluate the response of juvenile Chinook (40-50 mm) and brook trout and rainbow trout (25-100 mm). Exposure to the light increased movement of Chinook and rainbow trout, but not brook trout.

Stark and Maiolie (2004) tested the ability of strobe lights to repel kokanee from the intakes at Dworshak Dam. With the strobe lights activated, fish densities decreased by 66%. Through testing in two Idaho lakes, Maiolie et al. (2001) estimated that kokanee remained at least 79 feet away from the strobe lights for the duration of a trial lasting nearly six hours and moved away from the lights an average of 98 to 446 feet.

Johnson et al. (2001) successfully used strobe lights to vertically displace juvenile salmon upwards and away from the filling culvert intake at the Hiram M. Chittenden Locks. Densities at the culvert decreased by 96% when the lights were activated and peak densities shifted vertically by 23 feet.

Highlighting species-specific differences in response to strobe light (and mercury vapor light), Nemeth and Anderson (1992) characterized the behavior of juvenile coho and Chinook. Coho "hid" 47% of the time when exposed to light whereas Chinook actively swam 74% of the time.

Unfortunately for the purposes of the Yale Project, we found no studies that specifically evaluated the response of bull trout to strobe lights. Nonetheless, extensive study of the response of other salmonids to strobe lights warrants further consideration of this technology as an effective means for reducing bull trout entrainment.

3.2.2. Sound

The response of many species to several types of sound has been evaluated in the laboratory and at field installations. Infrasound and low- and high-frequency sound has been evaluated with mixed results. Successful manipulation of fish movement using sound is largely dependent on the sensory capability of the targeted species. High frequency sound has been successfully used to repel alosids such as blueback herring (Nestler et al. 1992) and alewife (Ross et al. 1996; Ross et al. 1993; Dunning et al. 1992). However, these species are hearing specialists able to detect higher frequency sounds inaudible to other taxa. Additional testing of infrasound (reviewed by Sand et al. 2001) and low-frequency sound has been evaluated with variable results as a means to repel salmonids at hydroelectric facilities. Mueller et al. (1998) observed a startle response by juvenile salmonids. While research into this technology continues, there has been limited success in field applications. Possible factors limiting this technology include habituation of fish to sound over continued exposure, interference from ambient noise, and differing responses among life stages. The use of sound to repel salmonids from turbine intakes has not developed to the point where it would be applicable at the Yale Project.

3.2.3. Electrical Barriers

Electrical barriers have been used in limited applications to guide fish towards a bypass or to create barriers to upstream migration. The latter application has some utility at hatcheries to divert adult salmon towards the hatchery facility (*e.g.,* Quilcene National Fish Hatchery; Hilgert 1992) and to prevent the spread of non-indigenous fish species to upstream habitats (Clarkson 2004; Savino et al. 2001; Maceina et al. 1999; Verrill and Berry 1995; Swink 1995; and McClain 1957). An electrical fish guidance system was installed at the Puntledge Diversion Dam in British Columbia (EPRI 1994) to divert coho salmon smolts toward a downstream bypass. However, this installation was unsuccessful due to an incomplete electrical field, unsuitable hydraulic conditions, an ineffective bypass system, or some combination of these factors.

To date, electrical barriers have not been used as a long-term measure specifically to exclude fish from passing downstream into water intakes. Concerns about the use of an electrical barrier as an exclusionary device have included the following: (1) differences in sensitivity to an electrical field based on fish size (i.e., larger fish tend to be more susceptible to an electrical field compared to smaller fish experiencing the same field), (2) an electrical field can be harmful to fish, (3) fish experiencing the electrical field can fatigue and be swept through the field, and (4) high velocities and turbulent flows near the electrical field can reduce effectiveness (EPRI 1994).

Smith-Root Inc. recently has developed a conceptual model for a deep water electrical barrier that has yet to be installed and tested. This technology, termed a Graduated Field Fish Barrier, has been used successfully in some installations as described above and addressed many of the earlier concerns of using electricity to deter fish. With this technology a low-level, graduated electrical field is generated such that fish experience an increase in electrical stimulus as they approach the source. As the stimulus increases fish react to avoid further stimulation. Thus, fish would presumably move closer to the source until an adequate stimulus is detected and then would turn away to avoid further stimulation. This barrier can be set to function for fish in multiple size classes. Further, the strength of the field would be well below the levels documented to increase the risk of injury to fish, regardless of the proximity of the fish to the source.

Many studies have used 15 to 60 Hz as the pulse frequency during electrofishing sampling programs. High pulse frequencies (from 30-60 Hz) are more effective at capturing fish, but can result in fish injury (Reynolds and Holliman 2004; Holliman and Reynolds 2002; McMichael et al. 1998). Pulse rates below 30 Hz usually reduce injury, but can be ineffective for fish collection. A pulse rate of 30-60 Hz has been recommended by some researchers to enhance capture rates in studies where fish are handled, tagged and released for subsequent mark-recapture research. The National Marine Fisheries Service prepared guidelines for the safe use of electrofishing in waters containing salmonids listed under the ESA (NMFS 2000). Their parameters (Table 1) were intended to provide a basis for evaluating ESA-related permit requests.

Table 1. Guidelines for electrofishing in waters containing ESA-listed salmonids (NMFS 2000).

Criterion	Initial Settings	Maximum Settings	
Voltage	100 v	Conductivity <100 µS/cm 100-300 µS/cm >300 µS/cm	Max Voltage 1100 v 800 v 400 v
Pulse Width	500 microseconds	5 milliseconds	
Pulse Rate in Hz (pps)	30 Hz	70 Hz	

Protocols established by Washington State's Department of Transportation for fish removals (WSDOT 2006) mimic those established by NMFS, but Washington recommends somewhat lower pulse-frequency settings (from 15-60 Hz). Pulsed DC frequency is the most critical waveform factor relative to fish injury (Reynolds 1996), and should be lowered to 15-30 Hz if injury is to be significantly reduced (Reynolds and Holliman 2004). The frequencies utilized by the Graduated Field Fish Barrier (up to 5 Hz) are considerably lower than those recommended by agencies for use in waters having listed species, are below those typically used by researchers in establishing electrofishing sampling protocols, and are well below levels documented to increase risk of injury to fish.

An electrical barrier theoretically could function similarly to a barrier net without the intensive maintenance required for continually successful operation. The electrical barrier would have an added advantage of being remotely controlled. Given the potential for effective operation we have included a downstream electrical barrier for further analysis in Section 5.

3.2.4. Air bubble curtains

The use of air bubble curtains to create a behavioral barrier to prevent entrainment has largely been limited to cooling water intake structures. For the most part, air bubble curtains have been ineffective at reducing entrainment at these sites (EPRI 2004). Because the intakes at the Yale Project are relatively deep compared to most cooling water intakes, it would be difficult to maintain the integrity of the curtain throughout the water column. The velocities and general hydraulic conditions at the intakes would likely contribute further to the degradation of the curtain as it approached the surface. Thus, air bubble curtains as a means of reducing entrainment at the Yale Project have been eliminated from further consideration.

4. Potential Entrainment Reduction Technologies at Yale Project

Of the technologies evaluated above, the following were considered to have potential for reducing bull trout entrainment at the Yale Project:

- Strobe Lights
- Narrow-Spaced Bar Racks
- Barrier Nets
- Electrical Barrier

The advantages and disadvantages of each of these technologies are summarized below in Table 2. A strobe light array would be a cost effective way to reduce entrainment with minimal implications for project operations. Strobe lights have a proven ability to elicit a response from numerous species and would likely only be hindered by turbidity during certain extreme events at the Yale Project. However, the response of bull trout to strobe light is a significant unknown. In addition, even for species that have demonstrated a response to strobe light, their behavior is often inconsistent and may actually include an attraction to strobe light. Primarily for this reason, strobe lights do not offer the greatest potential for reducing bull trout entrainment at the Yale Project.

4.1 Strobe Lights

The two primary physical factors that influence the effectiveness of strobe lights for repelling fish are turbidity and the contrast with ambient lighting conditions. Many studies found that fish response to strobe light dramatically decreased during the day because of ambient light conditions. At full pool, the effectiveness of a strobe light installation at the Yale Project would not likely be compromised by ambient light conditions because of the depth of the intakes. At minimum pool, though, ambient light penetration during the day could reduce the effectiveness of strobe lights, especially towards the upper portion of the intakes.

With the exception of high flow events and disturbances, the turbidity at the Yale Project would not preclude the use of strobe lights. Turbidity measurements in the reservoir ranged from <5 to 30 NTU, but at the Yale Tailrace was typically less than 5 NTU (PacifiCorp 1999B).

The effectiveness of strobe lights, like other behavioral technologies, is highly dependent on species-specific responses to stimuli. Even within the Oncorhynchus genus, species response can vary considerably and some fish have actually been attracted to strobe lights. A high degree of variability has also been observed within the same species in different water bodies. Thus, it is difficult to predict the reaction of bull trout to strobe lights at the Yale Project. This highlights the need for field evaluation within the Lewis River system. Cage tests are a useful means of evaluating behavioral technologies in the field to maximize the similarities to site-specific conditions. Such tests could be conducted in Yale Lake by transporting bull trout collected elsewhere in the system. Alternatively, as stipulated in the settlement agreement, open water tests could be conducted in Swift Reservoir where bull trout are far more abundant. Prototype testing would be necessary to evaluate bull trout response to strobe light at the Yale Project.

4.2 Narrow-Spaced Bar Racks

The primary considerations in the successful use of a bar rack to reduce entrainment is (1) the slat-clear spacing of the rack relative to the size of fish to be protected, and (2) the water velocity at the face of the bar rack relative to the swimming ability of the fish to be protected. Bar racks with too great a spacing would not be expected to elicit much of an avoidance response and would still allow small fish to become entrained. Further, velocities that were too high could result in the impingement of fish unable to maintain position. Additional concerns related to narrow-spaced bar racks are the potential for increased head loss and reduced generating capacity. These concerns would be exacerbated by high levels of debris loading.

The ability of a narrow-spaced bar rack to physically exclude fish is a function of the slat-clear spacing of the rack, fish behavior, and the size and morphology of the fish to be protected. There is also a tradeoff between exclusion efficiency and effects on project operations, both with regard to debris loading and head loss (*i.e.,* reduced generation). Project engineers estimate that reducing the bar racks to a 1-inch slat-clear spacing would result in minimal head loss (0.07 feet) over the existing rack if it is kept clean. A 1-inch bar rack would certainly exclude all adult bull trout as well as larger sub-adults. Morphometric data was limited for bull trout, but Stelfox (1997) reported that the maximum body width for bull trout in the 161-189 mm length class was between 17 and 18 mm. Further morphometric data is needed to more accurately determine the minimum length at which smaller sub-adult bull trout would be physically excluded. Nonetheless, it appears that fish less than 190 mm in length would be able to pass through a one-inch (25.4-mm) slat clear spacing

A retrofit or replacement of the existing bar racks with narrow-spaced bar racks could be installed at the Yale Project at a relatively low cost and with little infrastructure addition. Assuming that approach velocities were sufficiently low, a narrow spacing would provide safe exclusion for fish large enough to be physically excluded. However, the tradeoff between the size of fish that can be excluded and effects on project operations are likely prohibitive. While a 1-inch slat clear spacing would have little effect with regard to head loss, debris loading would increase and the bar rack would need to be clean more frequently than current operations require. More importantly, a 1-inch slat clear spacing would not be sufficiently narrow to exclude juvenile bull trout. A narrower spacing would be required, which would have incrementally adverse effects on project operation.

Another consideration of bar racks is the potential for fish to become gilled between the bars. Fish of a certain size class would be too large to pass completely through the spaces between bars but small enough to become stuck if they attempt to swim in. However, as long as velocities are sufficiently low, the risk of fish gilling on the bar racks would be minor.

4.3 Barrier Net

Based on the above review of existing barrier net installations, barrier nets can effectively reduce fish entrainment, though several factors may limit their success, including: heavy debris loading, biofouling, and unfavorable hydraulic conditions. A preliminary analysis of typical debris loads at the Yale Project would have to be performed to confirm that debris loading would be sufficiently minimal to not compromise the nets integrity. Considering the proximity of the Swift Project, one would assume the amount of debris entering Yale Lake to be minimal. Additional information in the proposed location of a net would be needed to ensure successful operation. The success of the Ludington and Pine barrier nets is largely tied to low approach velocities (<0.1 ft/sec). This low velocity is important not only to maximize the biological effectiveness of the net but also to maintain the net's integrity. A cursory review of the bathymetry of Yale Lake and the angle of the dam relative to the south bank of the lake suggests that a wide range of net designs could be accommodated to achieve the desired hydraulic conditions.

A barrier net installation would also have to accommodate the large fluctuations in the reservoir water levels as well as the changes in approach velocity caused by operational conditions. The Settlement Agreement includes the possibility for the barrier net with submersible cork lines to meet this need. The Upper Baker barrier net was designed to accommodate the large fluctuations in Baker Lake using an array of floats on the lower portion of the net and weights on the upper portion. Prior to a more detailed design of a prospective net at the Yale Project it is difficult to determine which approach is preferable. However, with regard to biological effectiveness, the best approach will allow for the least sag in the net to maximize fish guidance.

For guiding anadromous juveniles (surface migrators), some nets are deployed only to an intermediate depth. Because bull trout are often found along a lake's bottom (Connor et al. 1997) and because of the considerable depth of the Yale Project intake, a partial-depth net would be ineffective. Thus, a full-depth net would be necessary to protect bull trout at Yale Dam.

A final consideration in designing a barrier net for the Yale Project is the appropriate mesh size for excluding bull trout. Because the targeted life stages for protection are sub-adult and adult bull trout a relatively coarse mesh may be acceptable. A coarser mesh could incrementally reduce debris loading, reduce the overall drag on the net, and reduce the likelihood of structural failure. Also related to mesh size is the potential for fish to become gilled on the net. Fish of a certain size class would be too large to pass completely through the net but small enough for their opercula to catch on the net filament. However, as long as velocities are sufficiently low and fish are able to visibly detect the net, the risk of fish gilling on the barrier net would be minor.

Barrier nets have a proven ability to reduce entrainment as long as the installation remains structurally sound and is positioned such that approach velocities are minimized (<0.1 ft/sec). The effectiveness of a barrier net at the Yale Project would primarily be a function of a mesh size chosen to physically exclude the smallest size bull trout at risk of entrainment as well as sufficiently low velocities to prevent impingement on the net and reduce debris loading. Further, to effectively guide fish to a safe location away from turbine intakes, a considerably large installation would be required. Routine maintenance would be required to remove debris, mend holes and address sagging of float lines. While a barrier net would likely be an effective technology at Yale continual maintenance should be anticipated and could have operational considerations.

4.4 Electrical Barrier

In order for an electrical barrier to be an effective entrainment reduction technology hydrologic conditions must be suitable. Concerns regarding appropriate flow conditions and the potential for fish to fatigue are a function of the swimming capacity of the fish to be protected. Thus, for an electrical barrier to be successfully implemented at the Yale project, water velocities would have to be sufficiently low to allow fish to avoid entrainment upon detecting the electrical field. This is a function of bull trout swimming speed, water velocities near the intake, and the scope of the prospective electrical field. Preliminary investigations of water velocities outside the existing trash rack have shown velocities consistently below 1 fps throughout the water column with about one-fourth generating capacity (PacifiCorp unpublished data). This test was not able to be conducted at full capacity and additional velocity profiling is planned for the near future.

The conceptual design for as electrical intake barrier at Yale would utilize a grid of electrified cable that extend out from and surround the existing trash racks (Figure 2). It would extend vertically from the water surface (or above a low pool) to the bottom of the reservoir. Based on velocity measurements, the electrical field would be positioned approximately 10 feet out from the existing trash racks. The system would be operated directly from the dam and could be set up for remote operation.

Electrical barriers designed for deep water intakes are still considered an experimental technology. However, advancements in this technology to promote fish safety and engineering improvements warrant consideration for application at the Yale Project. An electrical barrier would have minimal impacts on project operations and most importantly, would effectively exclude most sizes of fish as long as certain hydraulic conditions are met.

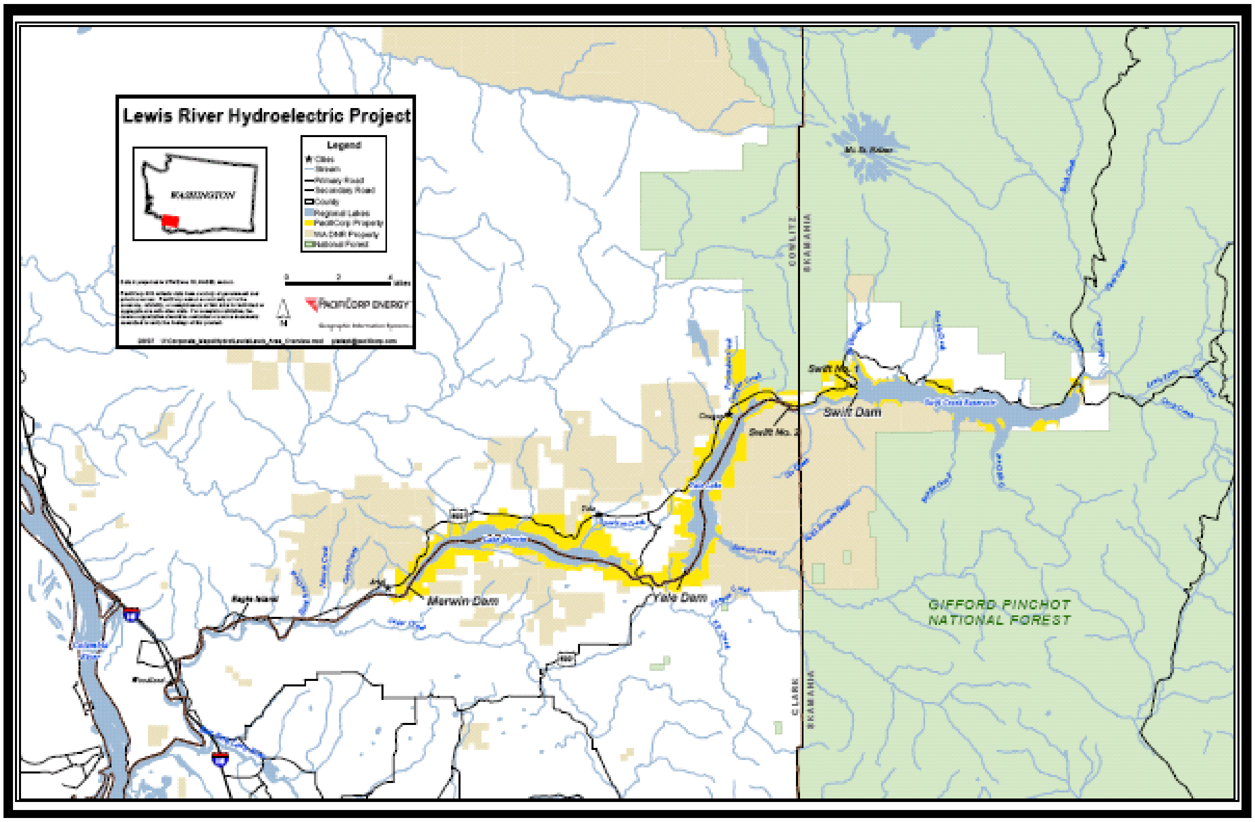

Figure 2. Map showing location of Yale Lake and the Lewis River Hydroelectric Projects.

Table 2. Summary of entrainment reduction technologies with potential for application at Yale Project.

Technology	Description	Advantages	Disadvantages
Strobe Light	A strobe light array would be installed near the intakes. The number of elements would be dependent on the turbidity at the Yale Project and the area targeted for fish exclusion based on hydraulic conditions.	• Proven effectiveness for certain species under certain site-specific conditions • Comparatively low maintenance requirements • Minimal impact on project operations	• Effectiveness varies by species and location • Need for evaluation • Effectiveness hindered by high turbidity events and daylight under certain conditions • Unknown ability to elicit avoidance response in bull trout • Could impact downstream collection if used simultaneously.
Narrow-Spaced Bar Rack	Existing bar rack structure would be replaced or retrofitted with a narrow-spaced bar rack. Appropriate slat-clear spacing would be dependent on size of fish to be protected and ability to minimize head loss.	• Could be installed at existing Yale intakes with minimal infrastructure additions • Some demonstrated effectiveness	• To reduce entrainment of smallest life stages would require spacing that could increase debris loading and have impact on project operations • Requires frequent routine maintenance • Risk of impingement or gilling certain size classes of fish.
Barrier Net	A barrier net would be deployed upstream of the intakes with the lateral portions angled upstream approaching the shore to guide fish towards a trap at the center of the net.	• Demonstrated effectiveness at other installations • Relies primarily on physical exclusion – less species-specific • Relatively inexpensive compared to other physical barriers • Can be modified to enhance downstream collection.	• Routine maintenance required • Requires low approach velocities and thus a large structure • Biological effectiveness tied to maintenance of structural integrity • Risk of failure with large debris loads • Restricts boat access inside net.
Electrical Barrier	A low power (up to 5 Hz) pulsed DC graduated electrical field would be established upstream of the intakes.	• Presumably, little variation in species-specific effectiveness • Will protect even the smallest size bull trout given sufficiently low water velocities • Minimal impact on project operations • Could be modified to enhance downstream collection.	• Experimental technology unproven effectiveness for hydroelectric applications

5. Proposed Action

We recommended that the Bull Trout Entrainment Reduction Plan begin with the deployment of an electrical barrier at the Yale Project as an experimental technology. An electrical deterrence barrier for this proposed application would consist of a pulsed DC current passing through water via metal electrodes embedded in a platform that spans the areas adjacent to the existing trash racks that surround the water intake structures at the Yale Project. This electrical barrier application would be designed to produce a graduated, low level electrical field. Custom-designed pulse generators will be used for this deterrence project, producing up to 1 volt/cm (peak), and DC pulse frequencies up to 5 Hz in the graduated electrical field. The pulsers will operate at pulse widths from 3-5 ms (depending upon water conductivities at the deployment sites). The pulsers will be connected to a series of electrode cables, evenly spaced across the deployment location, in an insulating medium. The resulting electrode array would be deployed in front of the intake structure, far enough out and into the reservoir that fish are deterred before water-intake attraction velocities are encountered. Because this is considered an experimental technology, a rigorous evaluation with an approved, robust experimental design will be performed to determine the effectiveness of the barrier. The experimental design will be developed by PacifiCorp and approved by USFWS within 120 days of USFWS approval of this plan. If the evaluation demonstrates an electrical barrier to be ineffective, a barrier net will be deployed as an alternative entrainment reduction device with design approval from the USFWS.

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7. Literature Search Parameters

During our review of entrainment reduction technologies, we performed an exhaustive literature search using both CSA (formerly Cambridge Scientific Abstracts) and Google Scholar search engines. Hierarchical search terms included the following with "*" indicating wildcard characters.

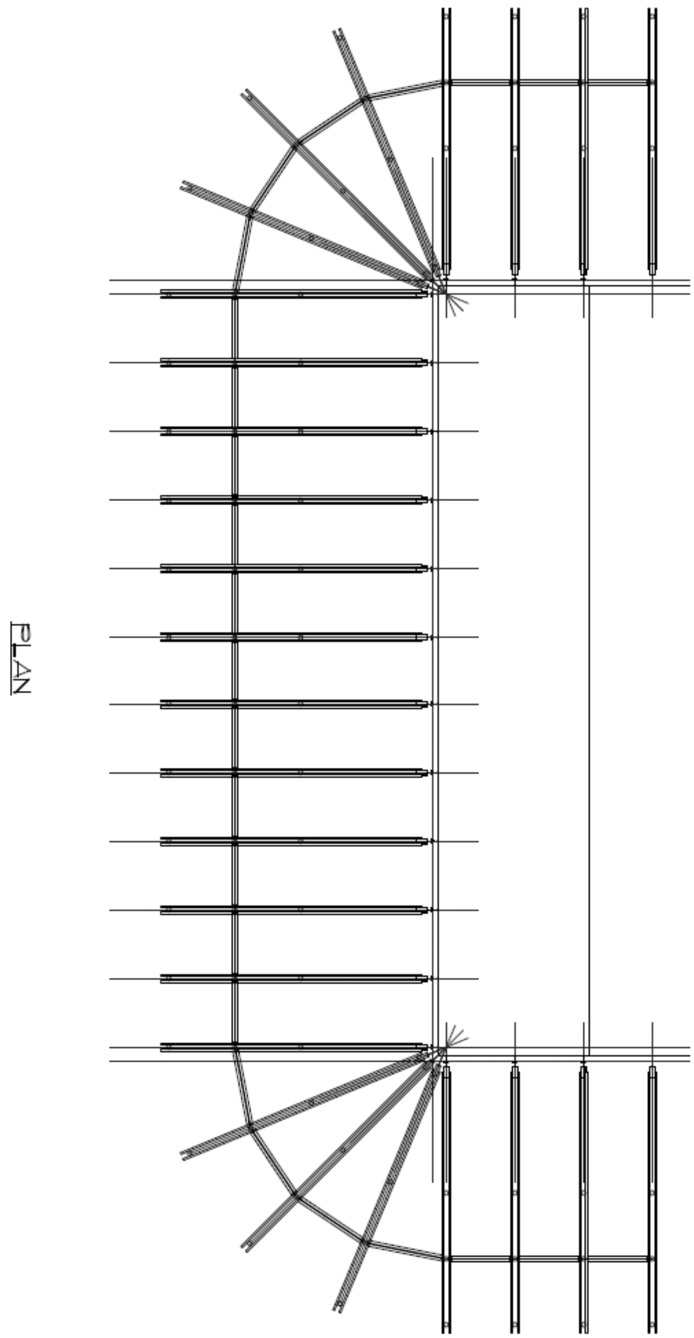
- Fish and
- entrain* or exclu* or diver* or guid* and
- behavioral or barrier net* or strobe or light* or electric* or sound*

8. Lewis River Settlement Agreement

The following is an excerpt from the Lewis River Settlement Agreement:

4.9.3 Yale and Merwin Bull Trout Entrainment Reduction. Immediately following the Effective Date, PacifiCorp shall design and implement a study to evaluate bull trout entrainment reduction methods for Yale and Merwin dams in Consultation with the ACC. Potential entrainment reduction methods include installation of exclusion devices, such as strobe lights, and installation of barrier nets with submersible cork lines and designed to accommodate a Merwin-type floating trap. Due to the small numbers of bull trout in Yale and Merwin, any evaluation of strobe lights will be performed in Swift Reservoir. Based upon its study, PacifiCorp shall prepare, in Consultation with the ACC, a draft entrainment reduction plan for the Yale Project. The plan would be developed to minimize unacceptable incidental impacts to bull trout or other species. PacifiCorp shall submit the draft plan to members of the ACC for comment within 16 months after completing the entrainment reduction study. PacifiCorp shall allow at least 45 days for members of the ACC to comment on the draft plan. PacifiCorp shall finalize the plan and obtain the approval of USFWS. PacifiCorp shall submit the final plan to the Commission upon approval by USFWS, subject to Section 15.14, but not later than the third anniversary of the Effective Date. PacifiCorp shall commence the approved entrainment reduction measures at Yale Dam within one year after the Issuance of the New License for the Yale Project, and shall maintain such measures until commencing operation of the Yale Downstream Facility. Upon the request of USFWS, PacifiCorp shall, in Consultation with the ACC and subject to the approval of USFWS, develop criteria to determine when similar entrainment reduction measures should be implemented at Merwin Dam. PacifiCorp shall submit the criteria to the Commission for approval after obtaining USFWS approval, subject to Section 15.14, within 12 months after the USFWS request for criteria. Once approved by the Commission, if and when such criteria are met PacifiCorp shall commence the same entrainment reduction measures approved for Yale at Merwin Dam, and shall maintain such measures until commencing operation of the Merwin Downstream Facility.

9. Draft figures depicting electrical barrier

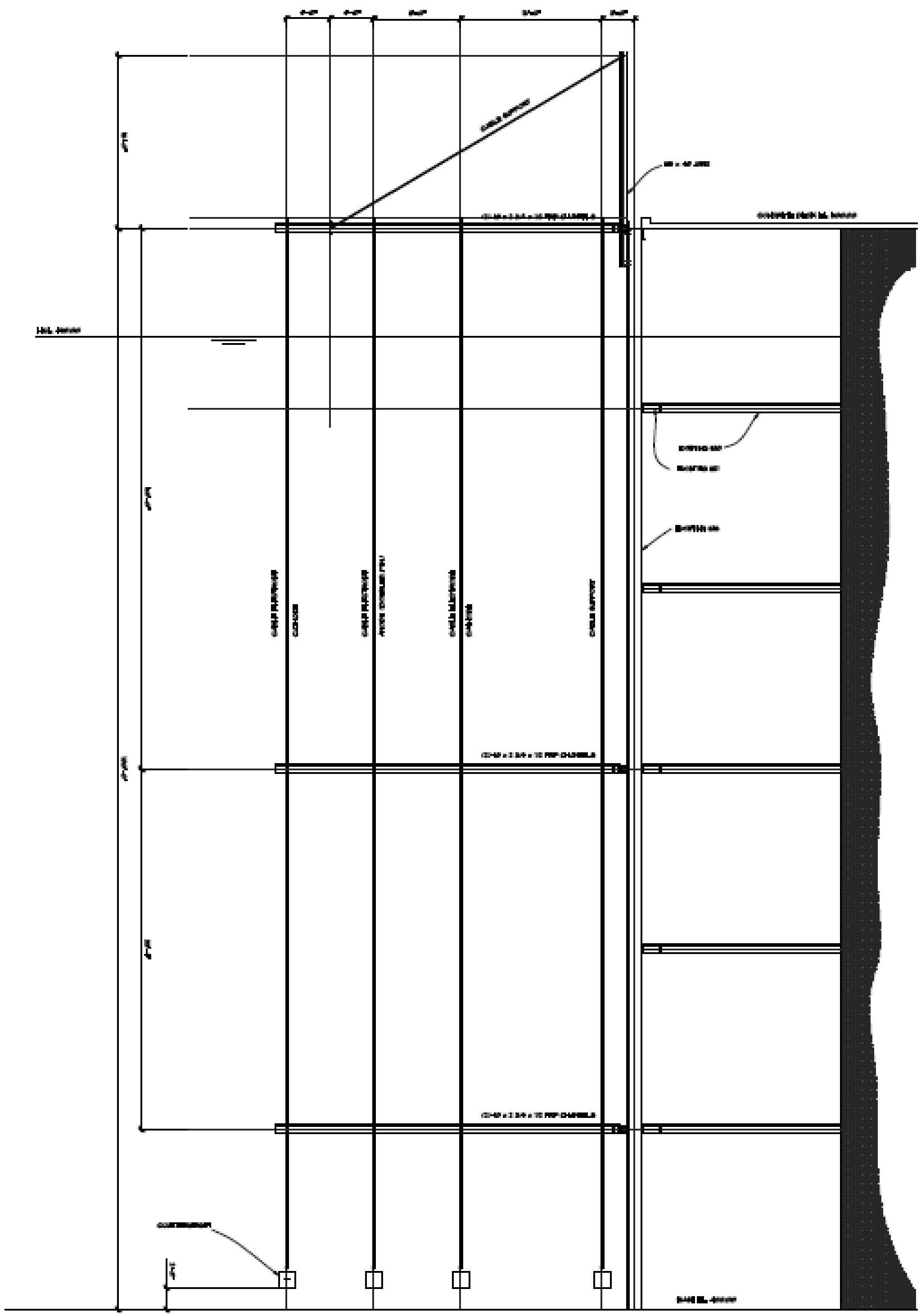


YALE PENSTOCK FISH BARRIER
SMITH-ROOT, INC
CONCEPT DRAWING - PLAN

DRN. JP
CHK. JP
SCA. 1/4

PARKIN ENGINEERING INC.

STRUCTURAL ENGINEERS



TYPICAL FRAME @ 8'-4" O.C.

10. Comment from some ACC members.

Washington Dept of Fish and Wildlife
Region 5
2108 Grand Blvd.
Vancouver, WA 98661

December 14, 2007

Frank Shrier
PacifiCorp
825 NE Multnomah,
Portland, OR 97232

Dear Mr. Shrier,

The Washington Department of Fish and Wildlife (WDFW) appreciates the opportunity to provide comments on PacifiCorp's Yale Hydroelectric Project Entrainment Final Report and Bull Trout Entrainment Reduction Plan *Working Draft*. – dated November 6, 2007.

First, a comment on the PacifiCorp review process. The following excerpt is from the Lewis River Settlement Agreement: § 4.9.3 Yale and Merwin Bull Trout Entrainment Reduction. *"PacifiCorp shall allow at least 45 days for members of the ACC to comment on the draft plan."* On November 7, PacifiCorp released the draft Entrainment Plan and notified ACC members of a 30-day review and comment period. Then on December 13, PacifiCorp agreed to extend the comment period to December 14th. We are trying to accommodate this rushed review schedule, but ask PacifiCorp that this be the exception rather than the rule in future document and plan reviews.

WDFW provided extensive comments to the initial review draft of the "Yale Hydroelectric Project Entrainment Final Report". We do not believe that all our comments and concerns were adequately addressed final report dated November 6, 2007. WDFW's detailed comments and PacifiCorps responses are attached in Appendix 4 of that final report; we request that all subsequent distributions of this report include this appendix so that future readers of the report are made aware of WDFW's concerns.

In regards to the **Bull Trout Entrainment Reduction Plan *Working Draft***, WDFW appreciates that PacifiCorp has recognized the need for development and implementation of an entrainment reduction plan. We agree with PacifiCorps' preferred alternative, i.e., an electrical barrier to reduce entrainment at the Yale project. If the electrical barrier proves impractical, or the technology proves unfeasible, then WDFW recommends deferring to a full barrier net. This barrier net should be capable of being used in conjunction with a Merwin Trap – for the collection of target fish, as indicated in the following excerpt from the Lewis River Settlement Agreement: § 4.9.3:

> *"installation of barrier nets with submersible cork lines and designed to accommodate a Merwin-type floating trap."*

The mean size fish entrained in turbines 1 and 2 (Figure 1) correspond to fish captured in the Eagle Cliffs screw trap in 2001 (PacifiCorp, 2002). Page 3 of the working draft states: "However, given the low abundance of bull trout in Yale Lake and the observed length-frequency distribution of entrained fish, we expect that few adult bull trout were entrained during the entrainment evaluation." WDFW does not anticipate that adult bull trout are entrained. WDFW is not aware of any documented bull trout abundance estimate for Yale Lake, but we are aware of a series of yearly peak counts. WDFW's concern is that yearlings to three-year-old fish in the 80-240 mm size range are most likely to be entrained; and this fits the pattern of entrainment illustrated in Figure 1.

In summary, WDFW concurs with an electrical barrier system, recognizing that it must be field-tested to prove its feasibility. An effective barrier, coupled with a modified spillway and spill practice should prevent transit of bull trout from Yale to Merwin reservoirs.

WDFW appreciates the opportunity to provide comments. If you have any questions or responses to our comments, please contact Jim Byrne at 360-906-6751, John Weinheimer at 360 906-6746 or Steve Vigg at 360-360-6710.

Sincerely,

Patrick A. Frazier

Pat Frazier,
Region 5 Fish Program Manager

References

PacifiCorp. 2002. Evaluation of anadromous salmon behavior ands habitat selection in the upper Lewis River Watershed AQU 13. Final Technical Report for Aquatic Resources. Lewis River Relicensing Documents. Portland, Oregon.

Email from US Fish & Wildlife Service dated 12/19/2007:

USFWS agrees that testing of an electrical barrier is a logical next step in reduction of bull trout entrainment at Yale Dam. Part of the entrainment reduction plan should be an experimental design for the use and testing of this device.

Some of the concerns/questions raised about electrical barriers include their effectiveness at modifying movements of various sizes of bull trout, effectiveness at low water conductivity (which we assume is the case with Yale Reservoir), and effectiveness at higher flows. We want to see how you will determine effectiveness of using an electrical barrier, given these factors/concerns, and what would trigger the decision to replace this device with an exclusionary barrier net.

Thank you for the opportunity to comment.

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