Research Proposal
For 2005 Project Year

I. BASIC INFORMATION

A. TITLE

Hydroacoustic Evaluation of Juvenile Salmonid Fish Passage Efficiency at Bonneville Dam in 2005

B. PROJECT LEADERS

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C. STUDY CODES

SBE-P-00-7

D. DURATION

1 Oct 2004 – 31 Jan 2005

E. SUBMISSION DATE

3 August 2005

II. PROJECT SUMMARY

A. GOALS

Primary goals of this study are to review, summarize, and synthesize juvenile-salmonid studies conducted at Bonneville Dam (Task 1), evaluate (1) route-specific passage of run-of-river juvenile salmonids through Bonneville Dam, (2) the contribution of the B2 Corner Collector to Project and B2 FPE, and (3) effects of changes in generation priorities and percent spill (Task 2), and describe swim paths and entrance efficiencies of smolts approaching the corner collector (B2CC) at Powerhouse 2 (Task 3).

B. OBJECTIVES

Task 1: Synthesis of Research at Bonneville Dam

1. Review, summarize, and integrate 2004 research reports about juvenile fish-passage and survival at Bonneville Dam with information in the synthesis report produced in 2004 that covered research through 2003. Information of interest includes direct and indirect survival studies, fish-passage studies based upon hydroacoustics, telemetry (radio and acoustic), and netting, as well as outfall, fish-guidance efficiency, and predation studies.

Task 2: Hydroacoustic Evaluation of Bonneville Fish Passage Efficiency

1. Estimate numbers of smolt-sized fish that pass downstream through the Bonneville Dam Project by all major routes including above and below in-turbine screens at each powerhouse, through the spillway, B1 sluiceway, and B2 Corner Collector.
2. Estimate route-specific passage proportions, including Project FPE, B1 FPE, B2 FPE, fish guidance efficiency (FGE) by turbine unit, and both the efficiency and effectiveness of the spillway, B1 sluiceway, and B2 Corner Collector (B2CC).
3. Analyze temporal and spatial variations in fish passage, FGE, and major passage metrics. Examples of temporal trends include average diel (hourly) trends in fish-passage rates within days and daily trends within seasons. Spatial trends include lateral distributions at B1, the spillway, and B2 and lateral and vertical distributions at the entrance to the B2 Corner Collector.
4. Compare results with those of previous hydroacoustic studies to identify effects of structural and operational changes through time, and compare results of concurrent studies with other methods such as radio telemetry or fyke netting.

Task 3: Describe swim paths and entrance efficiencies of smolts approaching the B2CC

1. Sample with an acoustic camera mounted on a dual-axis rotator to acquire data on the swim paths of smolts approaching the B2CC entrance three times each season. The data set will be collected with sufficient precision to allow integration of fish and flow data.
2. Develop software for extracting estimates of water velocity and for quantifying flow features from DIDSON images.
3. Process and analyze the fish movement and flow data collected in 2004 and 2005 to quantitatively describe fish behavior by size class and determine effects of hydraulic conditions by fully integrating and analyzing fish and flow data.

C. METHODOLOGY

The review of available literature for juvenile salmonids in Task 1 will involve acquiring a copy of every pertinent report or journal article produced in 2004 and updating and integrating those results with the annotated bibliography and synthesis report that included data through 2003. Studies of interest include project-wide FPE studies by radio telemetry and fixed-aspect hydroacoustics, fish survival studies (direct and indirect), FGE studies powerhouse and unit (by netting, hydroacoustics, and radio telemetry), predation studies in the forebay and tailrace, behavioral studies on forebay approach and egress, and surface-bypass studies.

In Task 2: we will sample with fixed-aspect hydroacoustic equipment 24 h / day for about 45 days each season (spring and summer) to estimate the number of juvenile salmonids passing downstream through all major passage routes at Bonneville Dam in 2005. Methods will be the same as those used in 2004. We will calculate fish-passage metrics, including passage proportions relative to passage at other routes (efficiency) and passage proportions relative to flow proportions (effectiveness), and analyze seasonal, diel, and distribution trends.

In Task 3, we will use a DIDSON acoustic camera to record smolt swim paths immediately upstream of the B2 Corner Collector during three day-and-night periods in early, mid, and late spring and summer (9 day and night samples / season). Rotator coordinates and fish positions in the sample beams will be used to describe fish positions through time in 3-D space. Of particular interest are approach paths relative to turbulent flow, effects of downward flow into Unit 11, and the boundary between eddy flow and flow into the B2CC entrance, and vertical and lateral distributions of smolts. In 2004, this effort focused upon smolt swim paths and did not attempt to integrate fish and flow data because of budget limitations. In 2005, we propose developing a method of processing DIDSON images to provide real-time flow data near fish targets to supplement general information from computational fluid dynamic simulations. The method will be developed by two researchers at the University of Idaho. Results from 2004 indicate that hundreds of long quality fish tracks can be quantified during each 24 h sampling period, and these track data warrant integration with flow data. We will analyze the data on fish movement and fate relative to flow data and compare entrance efficiency between day and night, time of season, and seasons. We also will examine tracked fish and turbulence data to see if we can associate efficiency with turbulent flow. We will use descriptive statistics and figures to describe trends in fish tracks and entrance efficiency, and these data should be valuable for understanding B2CC efficiency and effectiveness in 2005. We will use a Markov Chain model to estimate entrance probabilities for smolts located at varying ranges from the entrance.

D. RELEVANCE TO THE BIOLOGICAL OPINION:

There are several Reasonable and Prudent Alternatives (RPA) in the 2000 Biological Opinion that request FPE and survival evaluations for spillway passage. RPA 54 asks the Corps and BPA to implement an annual spill program to achieve performance standards laid out in the Biological Opinion. RPA 60 says the Corps and BPA shall evaluate adult fallback and juvenile fish passage under daytime spill to the gas cap at Bonneville Dam in 2002 and 2003. RPA 82 asks the Corps to assess the effects of spill passage on smolt survival at all Corps projects, and RPA 83 requests the Corps evaluate the effect of spill volume and duration on spill passage efficiency, spill effectiveness, forebay residence time, total project survival, and system survival.

III. PROJECT DESCRIPTION

A. BACKGROUND

The Portland District is striving to meet the Biological-Opinion goal of maximizing FPE and obtaining 95% survival for juvenile salmonids passing the Bonneville Project. Project FPE is the percent of all juvenile salmonids passing the project by non-turbine routes. To estimate Project FPE and survival, the proportions of juvenile salmonids that pass through all major routes must be estimated. Estimation of FPE is difficult because the Bonneville Project is among the most complex on the Columbia River. From the Oregon shore north toward Washington, the project is composed of a navigation lock, a 10-unit Powerhouse 1, Bradford Island, an 18-gate spillway, Cascades Island, and an 8-unit Powerhouse 2. Principal passage routes include the spillway and two powerhouses, but within each powerhouse, passage can be through ice-trash sluiceways, turbines, or the juvenile bypass system (JBS). Smolts enter the JBS after encountering screens in the upper part of turbine intakes. Screens divert fish to gatewell slots and orifices opening to a bypass channel.

The goal of maximizing FPE largely determines operation of the project. Large volumes of spill are presumed to be necessary to compensate for the low FGE of screens at both powerhouses, particularly in summer. Spill rates are limited to between 50,000 and 75,000 ft^3/s during the day to limit smolt predation in the tailrace during low discharge and the number of adult salmonids falling back through the spillway during high discharge. Spill under 50,000 ft^3/s creates eddies and slack water areas in the tailrace where excessive predation is assumed to occur. At night, spill is increased up to the total dissolved gas cap (120% of saturation) because downstream passage of smolts through turbines is high, and few adult salmonids are migrating and susceptible to fallback.

Primary goals of this study are to evaluate (1) route-specific passage of run-of-river juvenile salmonids downstream through Bonneville Dam, (2) the contribution of the B2 Corner Collector to Project and B2 FPE, and (3) effects of changes in generation priorities and percent spill. Before Corner-collector construction in 2003, Project-wide FPE studies were conducted from 2000 through 2002 and are available for comparison with 2004 and 2005 results, as are less comprehensive data from other years.

This study proposes to use hydroacoustic methods to estimate Project FPE and other fish-passage metrics. Estimates of FPE can be made by radio telemetry as well as by hydroacoustic methods, but usually only for a few species that are tagged and presumed to respond like untagged fish in the run at large. In many years, salmonids like sub-yearling chinook or juvenile sockeye were too small for existing tags, although smaller tags are available every year. Hydroacoustic methods cannot provide species specific data like radio telemetry yields for one or two species, but it does provide robust horizontal and vertical distribution information that is critical for assessing changes in fish passage or for suggesting improvements in interception facilities. In most cases, telemetry sample sizes are simply too small when divided among 18 turbine units and 16 spill bays or among 1-m vertical depth strata. Hydroacoustic sampling not only provides Project-wide measures of performance for the run at large, but also can provide location-specific data based upon thousands of fish detections. For example, vertical distributions of fish passing through turbines can provide estimates of FGE for existing screens or for proposed screens, assuming that the interception point was lower in the water column. The ability to ask such “what if” questions for run-of-river fish is important. In addition, continuous hydroacoustic sampling allows for regression of performance measures (such as spill efficiency) on continuous data such as percent spill or spill discharge. These types of regressions can suggest Project operations to optimize juvenile fish passage at a project. Continuous sampling of a large percentage of the out-migrating fish is unique to hydroacoustic methods.

Evaluation of improvements to juvenile passage facilities at B2 will require a comparison of Project performance in passing juvenile salmonids in 2004 and 2005 with performance in earlier years (2000-2002; Ploskey et al. 2002a, 2002b, 2002c, 2003). The three years of full Project FPE studies conducted in 2000-2002 yielded a baseline of metrics with a great deal of variability because operational strategies and river flow varied greatly. We found significant differences in many metrics in two or three of the years studied. For example, Project FPE and spill efficiency were lower in 2001 than in 2000 or 2002, because of drought that limited the duration and amount of spill. Spill effectiveness also was lower in spring 2001, but it was higher in summer 2001 than it was in summer of 2000 or 2002. The FPE of B1 was higher in 2000 than it was in 2001 or 2002 because the B1 Prototype Surface Collector (PSC) was tested, and it was highly efficient in both seasons. Powerhouse generation priority also varied among the years. Managers assigned generation priority to B1 in 2000, when the PSC was tested, but switched the priority to B2 in 2001 and 2002.

One metric that did not vary a lot among the three years was B2 FPE, and the relative closeness of estimates among baseline years should help us evaluate benefits provided by the B2 Corner Collector. The 3 years of estimates were within 4 % of each other in spring and within 11% of each other in summer. The B2 FPE probably would have been lower in 2000 if that had been a low-water year, because generation priority was given to B1 to facilitate PSC testing, and unit outages at B2 would have been the center units, which have higher FGE than do end units. However, 2000 was a normal water year and unit outages at B2 were not excessive.

The post-construction evaluation of the B2 Corner Collector also can make use of data collected in other years, even though they were not Project-wide FPE studies. The beginning of the Surface Collector Program at Bonneville Dam provided the impetus for collecting more detailed data at the Project. For example, Giorgi and Stevenson (1995) indicated that available biological information was inadequate to design and locate successful surface collector prototypes at Bonneville Dam. They found that information on the vertical and lateral distributions of juvenile salmon in forebay areas of both powerhouses and spillway was very limited. No mobile hydroacoustic sampling had been collected before 1996, and the proportion of juvenile salmon approaching B1, the spillway, and B2 had not been estimated.

Since the assessment by Giorgi and Stevenson in 1995, the Portland District had two years of mobile hydroacoustic data collected (Ploskey et al. 1998; BioSonics 1998) and also acquired fixed-aspect hydroacoustic data from parts of the project each year from 1996-1998. In 1996, researchers sampled turbines at both powerhouses but not the spillway. In 1997, the spillway, sluice chute, and B2 were sampled but not B1. In 1998, sampling was limited to units 1, 2, 3, and 5 at B1 and to the sluice chute and units 11-13 at B2. In 1999, only one unit of the PSC was sampled.

Earlier data specific to B2 should prove useful for evaluating Corner Collector performance in 2005. Ploskey et al. (1998) and BioSonics (1998) found high densities of fish upstream of units 11-13, and Unit 11 had the highest passage of any intake sampled in 1996. BioSonics also found, as had the Fisheries Field Unit (FFU) in previous years, that large numbers of fish passed through the sluice chute when that route was available. However, is it not known what contribution the sluice chute or a corner collector could make to B2 or project-wide FPE. Data from Ploskey et al. (2001) indicated that the combined FGE of Units 11, 12, and 13 was only 35 %. However, operation of the chute increased the combined FGE to 87 % after sluice passage was added to the guided fish terms. An important factor contributing to successful fish passage at B2 in 1998 may have been the removal of one half of the turbine intake extensions (TIEs) so that strong lateral flows carried many juvenile migrants south toward the sluice chute. However, fixed-aspect hydroacoustic sampling has detected a strong skew in the distribution of fish passage toward the south end of B2 even when TIEs were installed (see Ploskey et al 1998 and 2003).

Available data with a variety of methods indicate that the horizontal distribution of smolt passage among intakes is not uniform at individual structures like B1, B2, or the spillway. Lateral distributions of juvenile salmon sampled in gatewells of B1 apparently are influenced by the number and locations of operating units and sluice gates as well as the species of smolts (Willis and Uremovich 1981). Interactions among factors may account for a lack of consistency in measures of horizontal patterns by Uremovich et al. (1980), who found fish concentrated at units 6, 7, and 10, Willis and Uremovich (1981), who found variable patterns depending on operations, and Krcma et al. (1982), who observed most passage at units 4-6. Much of the FGE data collected at B2 with in-turbine hydroacoustics (e.g., Magne et al. 1986; Magne 1987; Magne et al. 1989; Stansell et al. 1990) and netting (Gessel et al. 1988; Muir et al. 1989) are of limited value for evaluating the horizontal distribution of passage because they typically focus on only one or two units at a time. Preliminary data from the full FPE study in 2000 also indicated that the horizontal distribution of passage was seldom uniform and varied with season and time of day.

Hydroacoustic FGE and horizontal distribution data for B2 have not yet been considered for improving juvenile fish passage at B2. For example, late spring and summer operations at B2 now prioritize the use of turbines 11 and 18 for adult salmon attraction. However, many studies showed that these units have the lowest FGE for juveniles passing downstream and that juvenile passage through Unit 11 is exceptionally high relative to other units at B2 (Ploskey et al. 1998, 2001, 2002b, 2002c, 2003). The FGE of traveling screens often is highest at units near the center of the second powerhouse. If units 11 and 18 did not have turbines or were friendly to juvenile fish, the current operations would benefit both adults and juveniles. Ploskey et al. (2003) recommended that generation priority should be given to center units at B2 at night when adult passage is minimal and juvenile passage is high. Hydroacoustic data suggest that B2 FPE could be increased by as much as 20% by shutting down the end units first at night, although conditions at B2 may be very different after the operation of the new corner collector adjacent to units 11 and 12.

We expect fish passage at the B2 Corner Collector to exhibit a similar diel pattern to other surface passage routes, where passage usually is higher during the day than at night (Uremovich et al 1980; Willis and Uremovich 1981; Ploskey et al. 2001, 2002b, 2003). Diel (24 hour) patterns of smolt passage have been estimated for sluiceways (Uremovich et al. 1980; Willis and Uremovich 1981), the JBS (Hawkes et al. 1991; Wood et al. 1994), and turbines (e.g., Ploskey et al. 1998, 2002b, 2003). Diel passage through the JBS often has a bimodal distribution with a major peak occurring just after dark and a minor peak after sunrise.

B. OBJECTIVES

Task 1: Synthesis of Research at Bonneville Dam

1. Review, summarize, and integrate 2004 research reports about juvenile fish-passage and survival at Bonneville Dam with information in the synthesis report produced in 2004 that covered research through 2003. Information of interest includes direct and indirect survival studies, fish-passage studies based upon hydroacoustics, telemetry (radio and acoustic), and netting, as well as outfall, fish-guidance efficiency, and predation studies.

Task 2: Hydroacoustic Evaluation of Bonneville Fish Passage Efficiency

1. Estimate numbers of smolt-sized fish that pass downstream through the Bonneville Dam Project by all major routes including above and below in-turbine screens at each powerhouse, through the spillway, B1 sluiceway, and B2 Corner Collector.
2. Estimate route-specific passage proportions, including Project FPE, B1 FPE, B2 FPE, fish guidance efficiency (FGE) by turbine unit, and both the efficiency and effectiveness of the spillway, B1 sluiceway, and B2 Corner Collector (B2CC).
3. Analyze temporal and spatial variations in fish passage, FGE, and major passage metrics. Examples of temporal trends include average diel (hourly) trends in fish-passage rates within days and daily trends within seasons. Spatial trends include lateral distributions at B1, the spillway, and B2 and lateral and vertical distributions at the entrance to the B2 Corner Collector.
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Task 3: Describe swim paths and entrance efficiencies of smolts approaching the B2CC

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2. Develop software for extracting estimates of water velocity and for quantifying flow features from DIDSON images.
3. Process and analyze the fish movement and flow data collected in 2004 and 2005 to quantitatively describe fish behavior by size class and determine effects of hydraulic conditions by fully integrating and analyzing fish and flow data.

C. METHODOLOGY

Task 1. Literature Review and Synthesis

The review of available literature for juvenile salmonids in Task 1 will involve acquiring a copy of every pertinent report or journal article on the 2004 out-migration, making additions to the a\annotated bibliography prepared from pre-2004 reports, and then writing updating the report that summarized and synthesized available information collected before 2004. Studies of interest include project-wide FPE studies by radio telemetry and fixed-aspect hydroacoustics, fish survival studies (direct and indirect), FGE studies powerhouse and unit (by netting, hydroacoustics, and radio telemetry), predation studies in the forebay and tailrace, behavioral studies on forebay approach and egress, and surface-bypass studies. The FPE effort will include a review of fish-passage available distribution data (horizontal, diel, and vertical).

Task 2. Hydroacoustic Evaluation of Fish Passage Efficiency

<u>Calibration of Hydroacoustic Equipment</u>

Before deployment, all hydroacoustic equipment will be transported to Seattle, Washington, where Precision Acoustic Systems (PAS) will electronically check the echosounders and transducers and calibrate the transducers using a standard transducer. After calibration, we will calculate receiver gains to equalize the output voltages among transducers for on-axis targets ranging in hydroacoustic size from –56 to –36 dB || 1µPa at 1 m. Lengths of fish corresponding to that acoustic size range would be about 1.3 and 11 inches, respectively, for fish insonified within 21° of dorsal aspect (Love 1977). Inputs for receiver-gain calculations include calibration data [i.e., echosounder source levels and 40 log (range) receiver sensitivities for specific transducers and cable lengths] and acquisition equipment data and settings (installed cable lengths, maximum output voltage, and on-axis target strengths of the smallest and largest fish of interest).

General Hydroacoustic Methods

We will sample 24 h / day for about 45 days each season (spring and summer) to estimate the number of juvenile salmonids passing downstream through all major passage routes at Bonneville Dam in 2005. Methods will be the same as those used in 2004. We will use an acoustic camera to record smolt swim paths immediately upstream of the B2 Corner Collector during three consecutive 24 h periods during early, mid, and late spring and summer (9 24-h sessions per season).

A hydroacoustic system consists of an echosounder, cables, transducers, an oscilloscope, and a computer system. Echosounder and computer pairs will be plugged into uninterruptible power supplies. An echosounder generates electric signals of specific frequency and amplitude and at the required pulse durations and repetition rates, and cables conduct those transmit signals from the echosounder to transducers and return data signals from the transducers to the echosounder. Transducers convert voltages into sound on transmission and sound into voltages after echoes return to the transducer. The oscilloscopes will be used to display echo voltages and calibration tones as a function of time, and the computer system will control echosounder activity and record data to a hard disk. The 420 kHz, circular, single- or split-beam PAS transducers will be controlled by PAS 103 echosounders and Hydroacoustic Assessments' HARP software running on Pentium-class computers.

We will sample with two single-beam systems and one split-beam system at B1 turbines, two split-beam systems to sample three B1 Sluice Entrances, three single- and two split-beam system at the spillway, three single- and one split-beam system at B2 turbines, and three split-beam systems at the Corner-Collector entrance. All 18 spill bays will be sampled, as will at least one randomly selected intake of every operational turbine. There will be 53 single- and 17 split-beam transducers deployed in 2005, but 8 of the single-beam transducers and one echosounder will be provided by the B2 FGE study. The sluice entrance at Intake 10C will not be sampled in 2005 because little water and few smolts pass by that route (Ploskey et al. 2003). The next five sections of this proposal describe transducer deployments, aiming angles, and data acquisition settings for sampling fish passage at the spillway, B2 turbines, B2 Corner Collector, B1 turbines, and B1 Sluice Entrance 7A. The sixth section describes the study of smolt approach behavior immediately upstream of the Corner Collector.

Spillway Passage

All spill gates will be sampled. One 10-degree single-beam transducer will be deployed in each of 15 bays and three 10-degree split-beam transducers will be deployed in the remaining three bays. Transducers will be mounted 26.5 ft below the top of spill gates and aimed 5 degrees upstream (Figure 1). Transducers will be at elevation (EL) 56.5 ft when the gate is closed and at EL 69 ft when the gate is opened 12.5 ft. Maximum ranges from the transducer to the ogee will be about 10 m (nominal beam diameter = 1.8 m) when a gate is closed and 13.9 m (nominal beam diameter = 2.45 m) if a gate is up 12.5 ft above the ogee. Echo traces from fish detected at ranges > 5 m from the transducer will be counted as passing if they meet discharge-dependent slope criteria. Given flows upstream of spill gates, fish passing down through the hydroacoustic beam at ranges > 5 m will be traveling at > 6 ft/s when discharge is > 3300 cfs and most will be committed to passing by the time they are detected. Tucking the hydroacoustic beam as close to the gate as possible will assure that most fish are not counted more than once, and we will adjust passage numbers at all bays by multiplying estimates by the proportion of fish detected moving downstream by split-beam transducers in three of the bays. Transducers will transmit at 25 pings per second for 12 1-minute periods (single-beam systems) or 20 1-min periods (split-beam systems) per hour. The high ping rate will assure adequate detectability, and the 20 or 33 % (12/60 or 20/60) sampling rate will provide tight confidence limits on seasonal fish-passage estimates.

Counts of detected fish will be expanded to the width of the spill-gate opening using Equation 1 (see Data Processing below). The sum of spatially expanded numbers of fish sampled during 12 or 20 minutes of sampling each hour will be expanded to a full hour as will the variance among 1-minute samples. Hourly counts and variances will be summed to estimate spillway passage by season. Spill efficiency will be calculated as the number of fish passing the spillway divided by total project passage each hour, day, and season. Spill effectiveness will be calculated as the proportion of all fish spilled divided by the proportion of all water spilled.

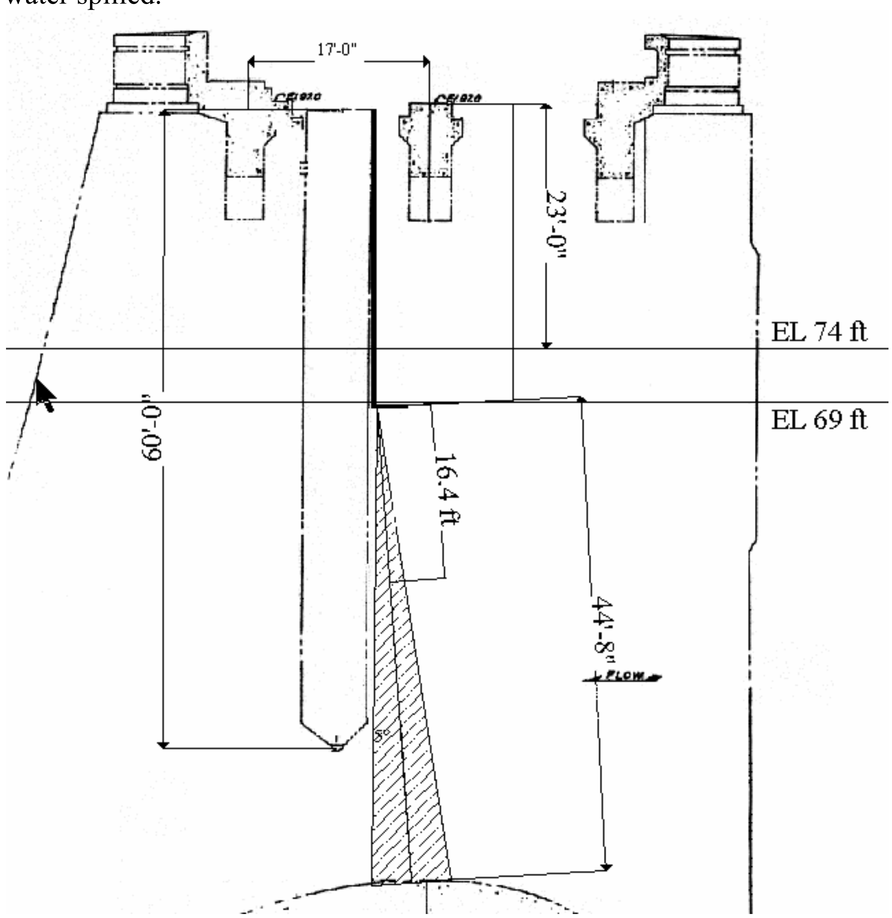

Figure 1. Cross-section of a spill bay showing the deployment of a 10-degree transducer. The transducer will be mounted 26.5 ft below the top of the gate so that it will be at EL 56.5 ft when the gate is closed and at EL 69 ft when the gate is open. Mounting elevation is specific to each gate so that the elevation of the transducer never exceeds EL 70 ft.

B2 Turbine Passage

At Powerhouse 2, one out of three intakes at every turbine unit will be randomly selected for sampling under this study, but this sampling will be supplemented by the B2 FGE study, which proposes sampling one additional randomly selected intake at units 11, 12, and 15, and two additional intakes at Unit 17. A split-beam system will be used to sample one of the intakes. Sampling two of three intakes at each of units 11 and 12 will greatly improve precision for the two units with the highest fish passage rates at B2 and for B2 as a whole. Sampling two out of three intakes at Unit 15 and all intakes of Unit 17 will provide very precise estimates of FGE for these modified units. The additional sampling will allow the exploration of among-intake variation in FGE at B2. At every sampled intake, a pair of transducers will be mounted on the downstream side of trash racks 1 and 4 (Figure 2). One transducer of each pair will be mounted at the bottom of the uppermost trash rack and aimed downward to sample unguided fish passing below the tip of the traveling screen. The second transducer of each pair will be mounted at the middle of the fourth trash rack from the top and aimed upward to sample fish passing above the tip of the screen. The location of transducers within intakes also will be randomized among the north, center, and south. Transducers on each system will be sampled sequentially for 1 minute each to allow a high transmit rate of 23 pings / second. Three transceivers and computers will be used to control the 22 single-beam transducers deployed in 11 B2 intakes. A pair of split-beam transducers will be deployed in a randomly selected intake to obtain fish velocity, trajectory, and target strength data for modeling detectability. Acoustic counts for each intake sampled will be expanded spatially using Equation 1 (see Data Processing below).

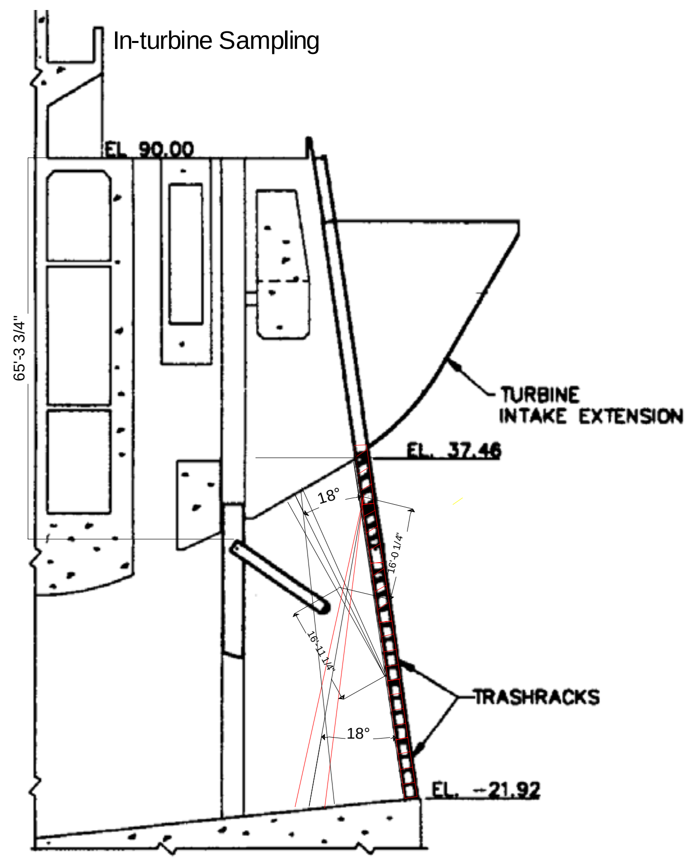

Figure 2. Cross-section view through a Powerhouse-2 turbine intake showing hydroacoustic beams for sampling fish passing above and below the submerged traveling screen (STS). Flow into the intake is from right to left. Fish counts are used to estimate fish passage and guidance efficiency. The turbine intake extensions will be present at every other intake from Intake 15A to Intake 18B but will be removed from units 11 through 14 to facilitate flow to the new corner collector adjacent to Unit 11.

Spatially expanded numbers of guided and unguided fish and within-hour variances for each of 7, 10, or 20 1-minute periods per transducer hour will be expanded to a full hour. Expansion of hourly variances at intakes to represent unit variances is described below under Data Processing. Hourly passage estimates and variances for guided and unguided fish will be summed to obtain daily and seasonal estimates for every turbine and then combined to calculate Powerhouse FPE and its variance. Single-beam systems will be sampled 7-10 minutes per hour and the split-beam system will be sampled 20 minutes per hour. The number of samples per hour will vary among systems depending upon the number of transducers that will be slow multiplexed. Before 2004, we fast-multiplexed transducers at B1 and B2 to maximize the number of samples per hour and to simultaneously sample guided and unguided fish and take advantage of the sampling covariance to increase precision. This strategy changed in 2004 because STSs were not deployed at B1 and sampling was reduced from two to one transducer per intake, and there was no great advantage in fast multiplexing transducers. With B1 turbine systems and all spillway systems sampling sequentially to maximize pulse repetition rates, we decided that it was important to use the same slow multiplexing strategy at B2. The same strategy will be used in 2005, if STSs are not deployed at B1.

B2 Corner Collector Passage

The sluice chute has been extensively modified to serve as the B2 Corner Collector after 2003 and will be operated continuously in spring and summer 2005. Based upon results of CFD modeling, flow passing 3 to 6 ft upstream from the bulk-head slot of the corner collector will be moving at about 20 fps, and this velocity will preclude adequate hydroacoustic detectability for deployments on a bulk-head-slot frame. In 1998, sampling with transducers in the bulkhead slot was possible because the B2 sluice-chute gate was only opened to elevation 63 ft mean sea level (see Ploskey et al. 2001) as opposed to elevation 52 ft MSL proposed for 2004 and 2005. Entrance velocities of 20 fps in 2004 and 2005 would limit fish durations in 6-degree up-looking hydroacoustic beams to less than 0.079 s, and short exposures would keep the number of echoes per fish below the minimum required for detection (4). The use of wider up-looking beams is not an option because volume reverberation is a problem for longer ranges, particularly near the surface. According to CFD modeling efforts by Sean Askelson, flows < 12 fps will only be present > 9-10 ft upstream of the bulkhead slot, an area that is too far upstream to sample with transducers deployed in the bulkhead slot.

The best approach for sampling with traditional hydroacoustic equipment and the one used in 2004 and proposed for 2005 is to locate six split-beam transducers on a vertical pipe about 20 ft to the southeast of the entrance so that acoustic beams can be aimed across the entrance. Fish will be detected mostly in side aspect, thereby maximizing signal to noise ratios and fish detection (Figure 3). The pipe supporting the vertical array of six transducers will be rotated to aim acoustic beams about 12-15 ft upstream of the entrance where flows will be sufficient to capture smolts (8-10 ft / s) but low enough to allow adequate detectability. With a ping rate of 37 pings / s, a fish moving 10 ft / s through the center of an acoustic beam would provide 7 echoes if it passed into the entrance on the south side and 13 echoes if it passed on the north side. Four echoes are the minimum required to classify an echo trace as a fish. The upper two split-beams will have nominal 3-degree acoustic beams to minimize volume reverberation, which typically is worst near the surface. The lower four transducers will have nominal 6-degree acoustic beams. The count of every detected fish will be spatially expanded by the ratio of the height of the rectangle it samples to the diameter of the acoustic beam at the range a fish is detected. Whenever forebay elevations range from EL 74.1-76.0 ft, the deployment will provide passage distribution data within 11 1.85 ft vertical strata in the upper 20.35 ft of the water column and within one variable 1.85-3.75 ft strata below that depth. When forebay elevations are between EL 70.5 and 74.1 ft, the deployment will provide passage distribution data within 10 1.85 ft vertical strata in the upper 18.5 ft of the water column and within a 4.5 ft stratum below 18.5 ft. The vertical resolution is possible because tracked fish can be classified as being in the upper or lower one half of the beam. Laterally, the deployment will provide estimates of passage distribution to the nearest 0.5 ft across the 15-ft wide entrance.

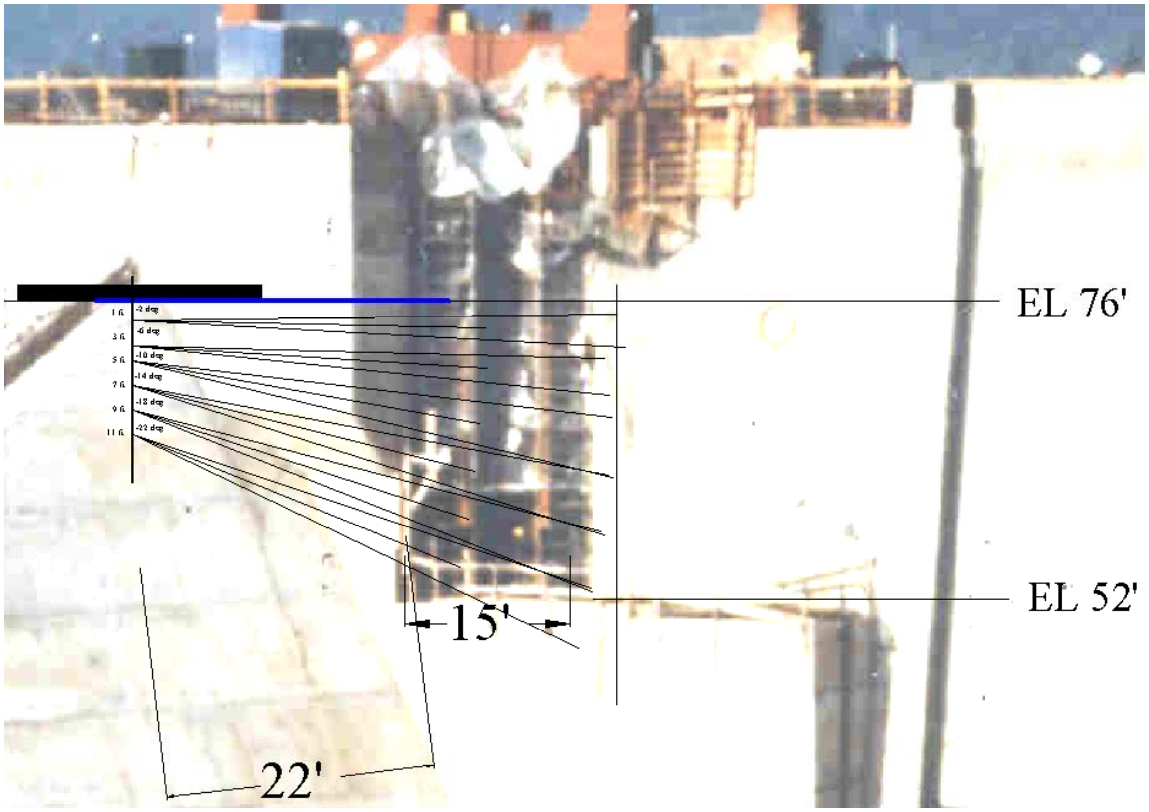

Figure 3. Diagramatic representation of a barge deployed near the Corner Collector entrance to deploy all hydroacoustic transducers with beams aimed across the entrance.

Each of the six transducers will be sampled for 1 minute, 30 times per hour, and spatially expanded counts will be temporally expanded to the whole hour (x 2). Each transceiver will interrogate only one of its two transducers at a time to maximize the pulse repetition rate at 33.3 pings / s. Transmissions from one transducer and transceiver from each of three transceivers will be synchronized. Numbered from the top down, transducers 1, 3, and 5 will sample during odd numbered minutes, and transducers 2, 4, and 6 will sample during even numbered minutes. Counts of detected fish will be expanded by the ratio of the vertical dimension of a trapezoidal area sampled by each acoustic beam to the diameter of the beam at the range of detection. We will sum passage estimates from each of areas to obtain a total for the entrance, and hourly estimates will be summed to estimate passage by day and season.

A problem with sampling sluiceway entrances is that fish densities can sometimes be so high that typical hydroacoustic gear with short pulse widths of 200 μs cannot resolve all individual fish unless they are ≥ 6 inches apart. We encountered this problem at a B1 sluiceway entrance in summer 2002. Therefore, the echosounders and all split-beam transducers proposed for sampling in 2004 and 2005 will have increased bandwidth from 20 to 100 kHz) and shorter pulse widths (80 instead of 200 μs) to reduce the target resolution distance from about 6 inches to about 2.36 inches. Resolution distance is the minimum range between resolvable targets.

B1 Sluiceway Passage

We will sample the sluiceway entrance at all open gates with opposing transducers mounted on the top of the sluiceway weirs and aimed horizontally across the opening (Figure 4). The gates at Intake 2C, 4C, and 6C were opened and sampled in spring and summer 2004. The diameter of a 6º beam at maximum range (21 ft) will be about 2.2 ft, and this will provide spatial coverage of 56% the cross sectional area over the weir. Transducers will be fast multiplexed at 50 pings / second, so each transducer will have a pulse repetition rate of 25 pings / s, and will sample for 20 1-min periods per hour. Only the distal one half of each opposing beam will be used for counting fish. Acoustic counts will be expanded spatially using Equation 1 below, but opening height (water depth over the weir) will be substituted for opening width. Spatially expanded numbers in each of 20 1-minute periods per transducer hour will be expanded to a full hour as will the within-hour variance. Hourly passage estimates and variances will be summed to obtain daily and seasonal estimates. All fish passing into the sluice entrances will be classified as guided fish for estimating B1 and Project FPE.

Echosounders and all split-beam transducers proposed for sampling in 2005 will optimize detectability of closely spaced fish by having bandwidth increased from 20 to 100 kHz and shorter pulse widths (80 instead of 200 μs) to reduce the target resolution distance from 6 inches to about 2.36 inches.

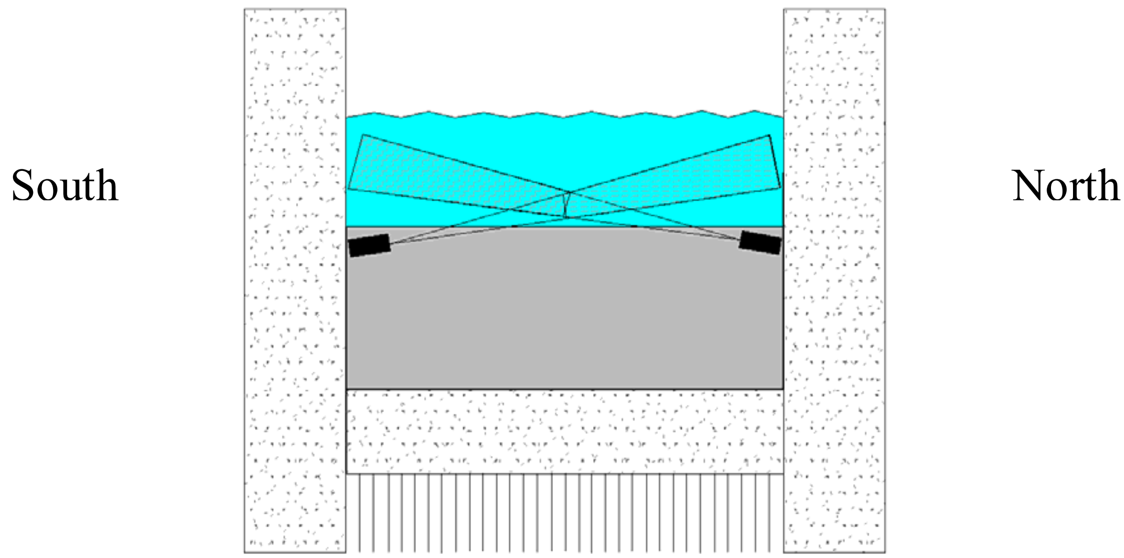

Figure 4. Forebay View of a Sluiceway Entrance at intakes 2C, 4A, and 6C Showing the Deployment of Opposing Split-beam Transducers for Sampling Fish Passage. The transducers were mounted 1-ft below the top of the chain gate. Flow into the entrance is from the reader's location toward the page.

<u>B1 Turbine Passage</u>

At B1, one out of three intakes at each of the 10 turbines will be randomly selected for sampling and then a randomly selected second intake at six of the units also will be sampled. Additional sampling is needed to increase precision of daily fish-passage estimates for B1 turbines that will run infrequently given a B2 generation priority. The additional sampling is possible because the number of transducers needed to sample each intake was cut by one half from what used in 2002 and earlier years when STSs were deployed. In 2004, single-beam transducers were deployed in intakes 1B, 2A, 2C, 3B, 3C, 4A, 4B, 5A, 5B, 7A, 7C, 8C, 9B, and 10B. Split-beam transducers were deployed in intakes 6A and 6B. The lateral location of each single down-looking transducer within an intake will be randomized among the north, center, and south sides. Transducers will be mounted near the top and downstream side of Trash Rack 1 (Figure 5) and aimed downward to sample unguided juvenile salmon passing down into the intake. Every transducer at B1 will transmit at 20 pings / s to maximize detectability. One single-beam transceiver and computer will be used to control seven transducers so that two transceivers will be required to sample 14 intakes at the powerhouse. One other intake will be sampled with a similarly deployed split-beam transducer to obtain fish velocity, trajectory, and target strength data for modeling detectability. In a preliminary study in fall of 2003, we determined that passage estimates for the near-ceiling volume of a single down-looking transducer and for another up-looking transducer (Figure 6) were highly correlated (Figure 7). This correlation indicated that a single down-looking transducer is adequate to estimate fish passage when an STS is not deployed.

Acoustic counts for each intake sampled will be expanded spatially using Equation 1 (see Data Processing below), and spatially expanded numbers of guided and unguided fish and within-hour variances for each of 8 1-minute periods per single-beam transducer hour or 20 1-min periods per split-beam transducer hour will be expanded to a full hour. Hourly passage per intake also will be expanded to estimate passage for entire turbine units, as described below (see Data Processing). Hourly passage estimates and variances for guided and unguided fish will be summed to obtain daily and seasonal estimates for every turbine and then combined to calculate Powerhouse FPE and its variance.

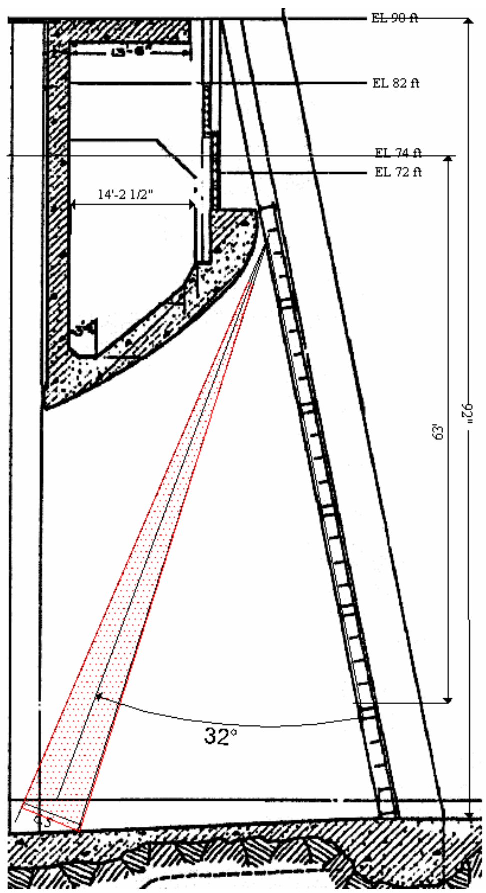

Figure 5. Cross-section view through a Powerhouse-1 turbine intake showing a single down-looking transducer beam for sampling fish passage through the turbine when no STS is deployed. Flow into the intake is from right to left.

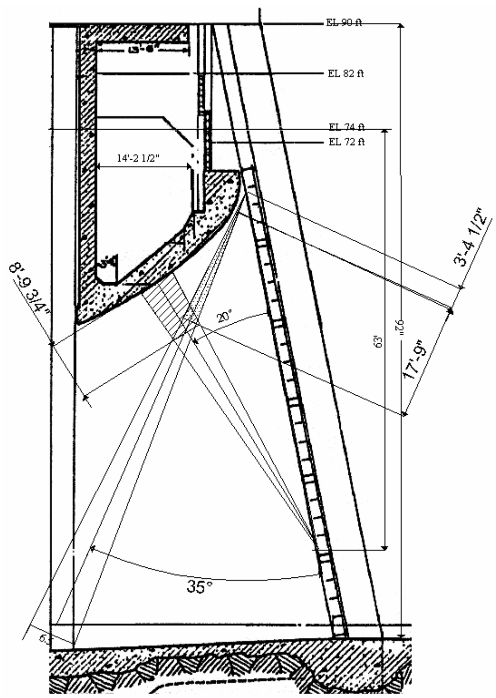

Figure 6. Cross-section view through a Powerhouse-1 turbine intake showing the near-ceiling volumes of a single down-looking transducer beam compared with that of an up-looking transducer for sampling fish passage through the turbine when no STS is deployed. Flow into the intake is from right to left.

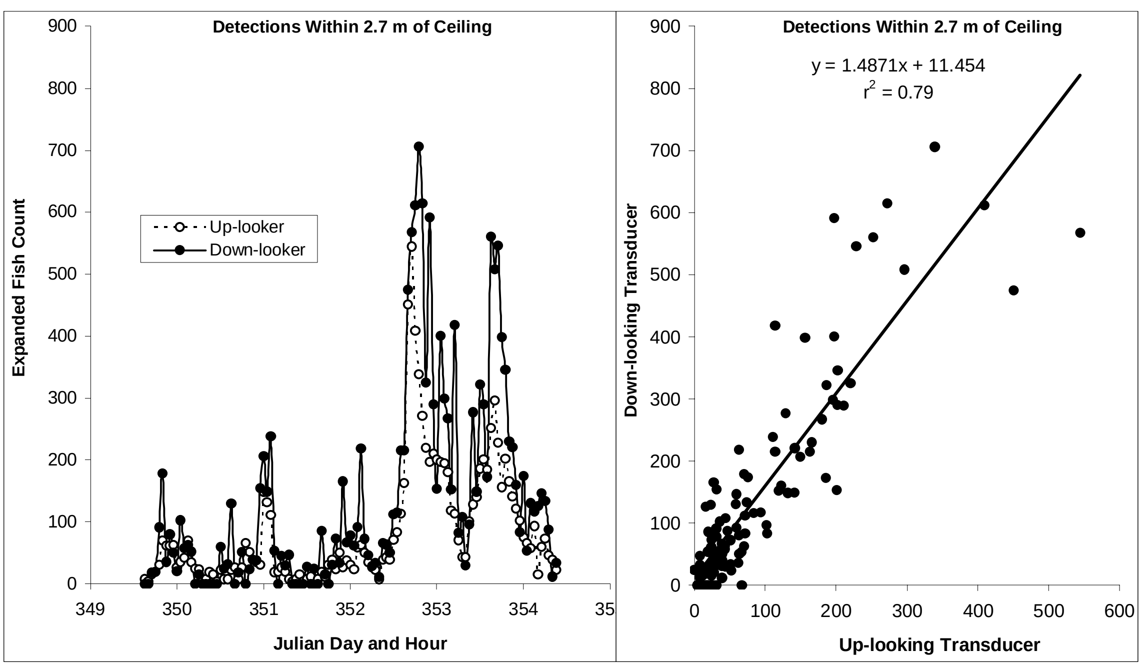

Figure 7. Plots of expanded fish counts by Julian day and hour for the near-ceiling volumes sampled by up-looking and down-looking transducers (left) and a scatter plot of the fit between estimates of expanded fish counts on the up-looking and down-looking transducers.

Hydroacoustic Data Processing

All data files acquired during the study will be processed with automated tracking software after the software has been carefully calibrated for each transducer. The autotracker tracks almost all linear traces of echoes meeting liberal tracking criteria and then tracked traces are filtered to exclude non-fish using filters derived during calibration. We will verify the performance of the autotracker using a pool of technicians to manually track a subset of approximately 2% of all of the data from each deployment. Early in spring technicians will be asked to track some identical data sets from every deployment to evaluate interpersonal differences and to provide for quality control. For each deployment, mean manual tracker counts will be regressed on autotracker counts and the resulting regression equations will be used to correct the autotracker results (as in Ploskey et al. 2003).

Acoustic counts of juvenile salmon acquired at spill bays, and turbine intakes will be expanded based upon the ratio of intake width to beam diameter at the range of detection:

$$\text{Expanded Numbers} = OW / (MID\_R \times TAN(EBA/2) \times 2), \qquad (1)$$

where OW is opening width in m, MID_R is the mid-point range of a trace in m, TAN is the tangent, and EBA is effective beam angle in degrees. For sluiceways, opening height (OH) will be substituted for OW in Equation 1, and it will be calculated as forebay elevation minus weir crest elevation. Effective beam angle depends upon the detectability of fish of different sizes in the acoustic beam and is a function of nominal beam width and ping rate (pings / sec) as well as fish size, aspect, trajectory, velocity, and range.

We will model detectability to determine effective beam angle using fish velocity data by 1-m strata and target strength data from the split-beam transducers, as well as flow velocity data by 1- m strata from the computational fluid dynamics (CFD) model. These data and other hydroacoustic-acquisition data (e.g., beam tilt, ping rate, target-strength threshold, number of echoes, and maximum ping gaps) will be entered into a stochastic detectability model. Effective beam angles for every 1-m range strata (EBA in Equation 1) will be used to expand every tracked fish at its range of detection to the width of the turbine intake.

We know of no other detectability model that incorporates all of these factors in a stochastic framework. One of the most important factors affecting estimates of effective beam width is the minimum echo-pattern criterion (e.g. a core of 4 echoes in 5 pings), which can only be modeled stochastically. An effective beam angle for a nominal 7-degree beam may become asymptotic with increasing range at 7 or 8 degrees if an echo-pattern criterion is not modeled. However, modeling detectability for four collinear echoes in five pings (allowing a 1-ping gap) may top out at 6 or 7 degrees. Requiring four collinear echoes in four pings (allowing no gap in the core of a trace) may top out at only 3 degrees. The target strength of fish also has a major effect on detectability and effective beam width. It is deployment dependent because target strength depends in part on the orientation of fish as they pass through a hydroacoustic beam.

Counts and variances also will be expanded to estimate passage for turbine intakes that were not sampled. To account for the slot-to-slot variance within turbine units as well as temporal variances, the sampling scheme at each powerhouse will be viewed as a stratified random sampling scheme. Using pairs of consecutive turbine units, we will assume that n of 6 intake slots were randomly selected for monitoring within each stratum, where n is the number of intakes actually sampled, which will vary from 2 to 4 out of six. The second stage of sampling was the sampling of time intervals within the slot-hour. For example, a conservative variance estimator for unguided fish at Powerhouse 2 would be as follows:

$$V\hat{a}r\left(\hat{H}U\right)=\sum_{g=1}^{5}\frac{L_g^2\left(1-\frac{l_g}{L_g}\right)s_{\hat{U}_g}^2}{l_g}+\sum_{g=1}^{5}\left[\frac{L_g\sum_{k=1}^{l_g}V\hat{a}r\left(\hat{U}_{gk}\right)}{l_g}\right] \tag{1}$$

where

L_g = number of turbine intake slots in the gth stratum $\left(g=1,\ldots,5\right)$ (here, $l_g=6$);

l_g = number of turbine intake slots sampled in the gth stratum $\left(g=1,\ldots,5\right)$ (here, $l_g=2-4$);

$$s_{\hat{U}_g}^2=\frac{\sum_{k=1}^{l_g}\left(\hat{U}_{gk}-\hat{\bar{U}}_g\right)^2}{\left(l_g-1\right)};$$

$$\hat{\bar{U}}_g=\frac{\sum_{k=1}^{l_g}\hat{U}_{gk}}{l_g};$$

$$\hat{U}_{gk}=\sum_{i=1}^{d}\sum_{j=1}^{23}\frac{R_{ijgk}}{r_{ijgk}}\sum_{l=1}^{r_{ijgk}}b_{ijkl};$$

$$V\hat{a}r\left(\hat{U}_{gk}\right)=\sum_{i=1}^{d}\sum_{j=1}^{23}\left[\frac{R_{ijgk}^2\left(1-\frac{r_{ijgk}}{R_{ijgk}}\right)s_{b_{ijgk}}^2}{r_{ijgk}}\right];$$

and where

r_{ijgk} = actual number of time intervals sampled in the jth hour $\left(j=1,\ldots,23\right)$ of the ith day $\left(i=1,\ldots,d\right)$ at the kth intake slot $\left(k=1,\ldots,l_g\right)$ in the gth stratum $\left(g=1,\ldots,5\right)$ (i.e., 7, 10, or 20 1-minute samples);

R_{ijgk} = number of possible time intervals that could be sampled in the jth hour $\left(j=1,\ldots,23\right)$ of the ith day $\left(i=1,\ldots,d\right)$ at the kth intake slot $\left(k=1,\ldots,l_g\right)$ in the gth stratum $\left(g=1,\ldots,5\right)$ (i.e., nominally 60 1-minute samples);

b_{ijgkl} = estimated unguided fish passage in the *l*th sample $\left(l = 1, \ldots, r_{ijgk}\right)$ in *j*th hour $\left(j = 1, \ldots, 23\right)$ of the *i*th day $\left(i = 1, \ldots, d\right)$ at the *k*th intake slot $\left(k = 1, \ldots, l_g\right)$ in the *g*th stratum $\left(g = 1, \ldots, 5\right)$;

$$s^2_{b_{ijgk}} = \frac{\sum_{l=1}^{r_{ijgk}} \left(b_{ijgkl} - \overline{b_{ijgk}}\right)^2}{\left(r_{ijgk} - 1\right)};$$

$$\overline{b_{ijgk}} = \frac{\sum_{l=1}^{r_{jgk}} b_{ijgkl}}{r_{ijgk}}.$$

<u>Hydroacoustic Data Analysis</u>

Fish passage sums and variances will be combined to estimate the spring and summer FPE for the Project, B1, and B2 separately using the methods of Skalski et al. (1996). Estimates will include 95 % confidence limits. We will calculate fish-passage metrics, including passage proportions relative to passage at other routes (efficiency) and passage proportions relative to flow proportions (effectiveness), and analyze seasonal, diel, and distribution trends. Seasonal, diel, and distribution trends in fish passage and major metrics will be plotted graphically, examined, and discussed. Regression analyses will be used to describe relations between major metrics and percent spill and spill volume. We will make statistical comparisons of fish passage and FGE among units and intakes using Proc Mixed (SAS) and will include repeating Julian day in an AR(1) design to account for autocorrelation within location conditions. We will test for differences among all pairs of least-square means using the LSMEAN statement with Tukey-Kramer adjustment for the unbalance design each season. Unbalanced conditions result from varying turbine operations.

Task 3: Describe swim paths and entrance efficiencies of smolts approaching the B2CC

The goal of this task is to describe swim paths of juvenile salmonids approaching the Corner Collector entrance, estimate entrance efficiency as a function of range from the entrance, and relate fish movements upstream of the entrance to hydraulic conditions. The relationship between entrance conditions and fish responses within 20 m of the entrance is a critical uncertainty in the performance of the corner collector.

We will evaluate smolt approach behavior upstream of the Corner Collector and estimate entrance efficiency for as many samples of 100 fish that can be collected during three consecutive days of sampling in early, mid, and late spring and summer (i.e., 18 24-h sample periods).

An acoustic camera will be used to sample smolts approaching the B2CC to obtain data on smolt entrance efficiencies. We will initiate fish tracking in randomly selected areas where fish have a choice about entering the surface bypass or swimming away. Therefore, we must identify the zone where fish can no longer avoid being entrained (i.e., the entrainment zone) by observing hundreds of approaching fish with the acoustic camera. Sampling upstream of the entrainment zone is important because fish have no choice after they are entrained. Track initiation zones will be randomly selected as a combination of three aiming angles and several range intervals from the acoustic camera. Numbers and the behavior of any predators that happen to be detected also will be recorded because predation is a factor determining the acceptability of a passage route.

We will estimate metrics designed to assess the acceptability of entrances to smolts and enter them into a data base. We define entrance efficiency as the number of fish that passed into the entrance divided by the number that were initially detected in a specific zone upstream of the entrainment zone and that were successfully tracked moving into or away from the entrance. Calculation of entrance efficiency will be done in two ways. First, estimates will be based only upon complete tracks into the entrance or away from the entrance and out of the entire tracking area. In this approach, partial tracks with unknown fates will be discarded. Second, we will base the probability of entry upon all tracks using a Markov-chain analysis. Results for the two methods will be compared. Fish positions through time will be converted to 3-dimensional coordinates from frame-by-frame integration of dual-axis rotator coordinates, time, and fish position in the acoustic camera field of view. We will analyze the data on fish movement and fate relative to physical and hydraulic characteristics of the B2CC entrance to compare entrance efficiency between day and night, time of season, and seasons. Time of sampling likely will affect the species composition and potentially the behavior of detected fish, which is why we plan to sample 24-h per day on every sample day. We will use descriptive statistics and figures to describe trends in fish tracks and entrance efficiency, and these data should be valuable for understanding B2CC efficiency and effectiveness in 2004 and 2005.

We also will characterize flow by CFD modeling of predominant operation conditions at the second powerhouse during DIDSON sampling, by tracking drogues, and by analyzing DIDSON images associated with fish tracks to describe real-time flow, including turbulent events in the vicinity of fish that are tracked. Physical dimensions and characteristics, dam operations, and species composition data from the B2 JBS will be included in the data base. The operations data will be used to set up CFD model runs.

Processing DIDSON images to describe real-time flow characteristics will require a special subtask by Drs. Smith and Liou at the University of Idaho to make use of the advanced microelectronics already packaged into the DIDSON and develop imaging processing techniques to extract real-time velocity vector fields in close proximity to fish being tracked from DIDSON images. Once the velocity fields are known, other hydraulic quantities such as vorticity and shear rate can be estimated. Of special interest is the use of spatial correlations to identify flow structures (Nezu and Nakagama 1993). We anticipate that flow structures with scales ranging from a fraction to multiple fish body lengths can be quantified using the DIDSON data. There has been considerable research in the development of image processing techniques associated with Particle Image Velocimetry (PIV) (Adrian 1991, Westerweel 1993, Raffel et. al., 1998, Hart 1999, 2000). This body of knowledge to a great extent is applicable and will be used to process the DIDSON images. This subtask will consist of a combination of laboratory and field segments designed to develop methods to use the DIDSON camera to characterize flow field conditions. Laboratory work will be conducted at the University of Idaho and field data will be acquired from the forebay within 20 m of the B2CC entrance or The Dalles sluiceway entrance. A 1.8 m wide, 17 m long, and 1.5 m deep (adjustable) concrete sump at the Hydraulics Laboratory of University of Idaho will be used to calibrate DIDSON images against known flow features. Preliminary investigations showed that reflections can be minimized in this sump. Trials will be run in which the water will be seeded so that the “target strength” of particles entrained are within the range measured on the Columbia River. The image processing has five steps:

1) Divide two adjacent (in time) images with known elapse time into sub-regions.
2) Perform cross-correlation or minimum quadratic difference operations between two corresponding sub-regions to establish the sub-region average velocity vector. Repeat the same for all sub-region pairs.
3) Apply super-resolution algorithm to obtain sub-pixel resolution
4) Perform local and global filtering

5) Smooth the resulting velocity vector fields.

Several public-domain software packages for PIV are available to convert images from PIV hardware to velocity vector fields. We will first develop the software by following the processes in MPIV (CRIEPI, Japan and Texas A&M University), MATPIV (University of Oslo), and PIVPROC (NASA Glenn Research Center) to process the images from DIDSON. Information about MPIV, MATPIV, and PIVPROC can be readily found on the Internet. Issues particular to DIDSON, such as non-homogeneous seeding and non-uniform thickness of the view field will be investigated. The achievable spatial and temporal resolutions of the velocity vector fields from DIDSON images will be quantified as a function of frame rate, and the view field's position and size. Software that converts the velocity information into vorticity and strain rates will be developed.

D. SCHEDULE

Timely reporting of results will be a major emphasis of this project. A preliminary summary of spring data will be provided to the Portland District by 31 August and spring and summer data summaries will be provided by 31 October. A formal presentation will be made at the AFEP review in November, and a draft final report will be completed by 31 January 2005. The final report will be completed within 60 days after all reviewer comments have been received.

E. FACILITIES AND EQUIPMENT

All required hydroacoustic sounders and transducers are available for this study. Some of the armored cables and deck cables that failed during sampling during previous years may need to be replaced. Six trailers will be rented to house the electronic equipment at the Project. Automated processing requires one computer for every data acquisition computer in the field and an efficient and consistent way of downloading data from acquisition computers and distributing it to processing computers. Some additional computer equipment may be required to replace outdated or faulty components. A heavy duty dual axis rotator will need to be purchased.

F. IMPACTS

Project assistance in the form of riggers and crane support will be required to deploy transducer mounts at the spillway and both Powerhouses. Once equipment has been installed, crane support will not be needed unless transducers or cables fail. Deep transducers installed in eight intakes at Powerhouse 2 will require the project to rake trash on those intakes and pull the four upper trash racks. Deep transducers in ten intakes at B1 will require the project to pull the uppermost trash racks to provide diver access or pull the top five trash racks. In terms of time, it takes about as long to pull the trash racks at as it does to pull the uppermost rack and use divers to install deep transducers. Since a rigging crew must be present even when divers are used, it is very cost effective to have riggers pull the additional racks. Very close coordination and advanced planning will be required for this study to assure that all transducers are installed before the sampling season begins.

Equipment installation must begin by mid-January to assure that all equipment is installed and operational before the Spring Creek Hatchery release in early March. Work trailers will need to be located on the north and south ends of Powerhouse 2 and the spillway, and in alcoves near Unit 4 and Unit 8 at B1. All trailers will need to be supplied with electricity. Project support also will be required to pull trash racks or spill-gate mounts if any hydroacoustic equipment fails.

G. COLLABORATIVE ARRANGEMENTS AND PROJECT DUTIES

This study will be conducted by PNNL, with subcontracts to the University of Washington School of Fisheries, the University of Idaho, BAE Systems, Inc., and BioAnalysts, Inc.

IV. LIST OF KEY PERSONNEL AND PROJECT DUTIES

Gene Ploskey, PNNL	Principal Investigator
Mark Weiland, PNNL	Co-principal investigator and on-site manager
Gary Johnson	Literature review and synthesis
Al Giorgi (BioAnalysts Inc.)	Literature review and synthesis
BAE, Inc.	Provide technicians for deployment, monitoring, and data processing and scientists to assist in all aspects including analysis and reporting
John Skalski	Statistical design and synopsis
David L. Smith	Development of flow estimates from DIDSON images
Chry Pyng Liou	Development of flow estimates from DIDSON images

V. TECHNOLOGY TRANSFER

All results will be formally documented and disseminated to interested parties in the public and private sectors. The principal means of technology transfer will be presentations and reporting. A presentation will be made at the Corps' annual Anadromous Fish Evaluation Program Review. A final report will be published in 2005. Technology transfer activities may also include presentation of research results at regional or national fisheries symposia, or publication of results in a scientific journal.

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VII. BUDGET

A task specific budget will be submitted under separate cover.