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Optimization of Hydroacoustic Equipment Deployments at Lookout Point and Cougar Dams, Willamette Valley Project, 2010

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ES Fischer

March 2010

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Prepared for
U.S. Army Corps of Engineers, Portland District
Portland, Oregon 97208

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Richland, Washington 99352

Summary

This report documents the results of an acoustic optimization study conducted by the Pacific Northwest National Laboratory (PNNL) for the U.S. Army Corps of Engineers Portland District (USACE) at Lookout Point and Cougar dams during January and February 2010. The goal of the study was to optimize performance of the fixed-location hydroacoustic systems at Lookout Point Dam (LOP) and the acoustic imaging system at Cougar Dam (CGR) by determining deployment and data acquisition methods that minimized structural, electrical, and acoustic interference. Optimization of the hydroacoustic systems will establish methodology for sampling by active acoustic methods during year-long evaluations of juvenile salmonid passage and behavior at LOP and CGR, respectively. The objectives for this optimization study were to:

1. Lookout Point Dam
    a. Design and test mounts to deploy fixed-location hydroacoustic transducers to sample juvenile salmonid passage into the regulating outlets and turbine penstock intakes, and vertical distribution at the forebay face of the dam.
    b. Test various aiming angles and ping rates to optimize the performance of the hydroacoustic systems at the regulating outlet, penstock, and forebay locations.
2. Cougar Dam
    a. Design and test a platform and apparatus to deploy an acoustic imaging system to sample juvenile salmonid behavior in the immediate forebay of the intake tower.
    b. Test various aiming angles and transmission frequencies to optimize the performance of the acoustic imaging system at the intake tower location.

The general approach was a multi-step process from mount design to final system configuration. First, we developed designs for transducer mounts and had them reviewed and approved by USACE engineers and project personnel. Second, field trials were undertaken to perfect the mount design. Third, aiming angles and ping rates were tested in the field. And, fourth, the optimum configuration for each hydroacoustic system was established. Acoustic system configurations resulting from the optimization process are organized by deployment location in the following table.

Dam	Location	Hydroacoustic Equipment	Beam Width (deg)	Mount Design	Elevation (ft)	Aiming Angle (deg)	Ping Rate (pps)
LOP	Regulating Outlet	Split-beam Transducers (4)	10	Bracket	763	11	33
	Turbine Intake	Split-beam Transducers (3)	10	Trash rack "Modified Tiltzer"	803	42	25
	Forebay	Single-beam Transducers (2)	6	Bracket	822	vertical	20
CGR	Intake Tower	Acoustic Camera (1)	29x11	Barge w/ Pole Mount	1546	7 down	7

The LOP turbine intake optimization was limited by presence of the head gates. We recommend that any future optimization efforts at turbine intakes at dams in the Willamette Valley Project be improved by integrating the type of work performed in February 2010 with test pinging after head gates are removed and turbine units are operating. Because this will necessitate interruptions in diving activities for the turbine intakes, other work for the diver should be planned for these periods.

In conclusion, the optimization effort resulted in successful deployments of hydroacoustic equipment at LOP and CGR during 2010. If hydroacoustic methods are selected for use at other Willamette Valley Project dams in the future, similar optimization processes will benefit from the experience at LOP and CGR during 2010.

Preface

This study was funded to support fish passage and behavior evaluations at Lookout Point and Cougar dams, respectively, during 2010 as part of the U.S. Army Corps of Engineers' (USACE's) Willamette Valley Project Program. The study was conducted by the Pacific Northwest National Laboratory (PNNL) for the USACE Portland District, whose technical lead was Dave Griffith (503 808 4773). The PNNL technical leads were Gary Johnson (503 417 7567), Fenton Khan (509 371 7230), and Gene Ploskey (509 427 9500). This report constitutes one of the deliverables for this project (PNNL Project No. 58030).

Acknowledgments

The authors are thankful to all who contributed to this study, including:

- USACE personnel at Lookout Point and Cougar Dams;
- USACE personnel at the Portland District: David Griffith, David Hamernik, and Mike Langeslay;
- Honald Crane Services: Bob Austin and Mike Honald;
- PNNL: Julie Hughes, Kathy Lavender;
- Precision Acoustic Systems: Alan Wirtz;
- Schlosser Machine Shop: Vinnie Schlosser;
- Cascade Diving Company: Tommy Kidwell and crew;
- Pacific States Marine Fisheries Commission: Aaron Cushing, Jina Kim, Mike Kaufman, and Tyler Mitchell.

Acronyms and Abbreviations

CGR	Cougar Dam
dB	decibel(s)
deg	degrees
DIDSON	dual frequency identification sonar
El	elevation
ft	foot/feet
HA	hydroacoustic(s)
in.	inch(es)
kcfs	1000 cubic feet per second
kHz	kilohertz
LOP	Lookout Point Dam
m	meter(s)
MSL	mean sea level
NA	not applicable
PAS	Precision Acoustic Systems
PNNL	Pacific Northwest National Laboratory
pps	pings per second
RO	regulating outlet
TSW	top spillway weir
μPa	micro-Pascals
USACE	U.S. Army Corps of Engineers

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1.0 Introduction

This report documents the results of an acoustic optimization study conducted by the Pacific Northwest National Laboratory (PNNL) for the U.S. Army Corps of Engineers Portland District (USACE) at Lookout Point and Cougar dams during January and February 2010. The goal of the study was to optimize performance of the fixed-location hydroacoustic systems at Lookout Point Dam (LOP) and the acoustic imaging system at Cougar Dam (CGR) by determining deployment and data acquisition methods that minimized structural, electrical, and acoustic interference. Optimization of the hydroacoustic systems will establish methodology for sampling by active acoustic methods during year-long evaluations of juvenile salmonid passage and behavior at LOP and CGR, respectively.

1.1 Background

The USACE stated in the draft research, monitoring, and evaluation plan for the Willamette Valley Project that key management questions included (USACE 2009): "*What are the continuing affects of the Willamette Valley Project on Willamette ecosystem function and on ESA-listed fish species? What can effectively be done to protect, improve, restore, or mitigate for impacted species, their habitat, and related ecosystem function while also maintaining authorized Willamette Project functions?*" The 2008 Willamette Project Biological Opinion requires improvements to operations and structures to reduce impacts on Upper Willamette River Chinook and Upper Willamette River steelhead, including evaluations of the feasibility of installing new juvenile collection and bypass facilities at three Project Dams (NMFS 2008). As a part of these studies, NMFS and U.S. Fish and Wildlife Service (USFWS) have required that USACE develop interim operations and investigate the feasibility of employing surface flow outlets or other structures to collect and convey fish past the dam in order to provide safe passage for downstream migrating fish. An understanding of when, where, and how many juvenile salmonids pass into the dams, the relative efficiency of existing routes at passing them, and their behavior in the near forebays will be important components to fisheries managers and the USACE to use to develop operations and structures that pass juvenile salmonids safely and efficiently.

Basic information is needed that characterizes juvenile salmonid passage efficiencies, temporal and spatial distributions, behaviors and movement patterns in forebays of USACE dams in the Willamette basin. The priority projects for research on juvenile salmonid passage during 2010 are Cougar and Lookout Point dams (Figure 1). Accordingly, the USACE contracted with the Pacific Northwest National Laboratory to conduct year-long studies of juvenile salmonid passage and behavior at Lookout Point and Cougar dams, respectively during 2010. The hydroacoustic optimization study reported herein directly supports this research. Ploskey et al. (2002; 2008) provide good examples of hydroacoustic optimization work.

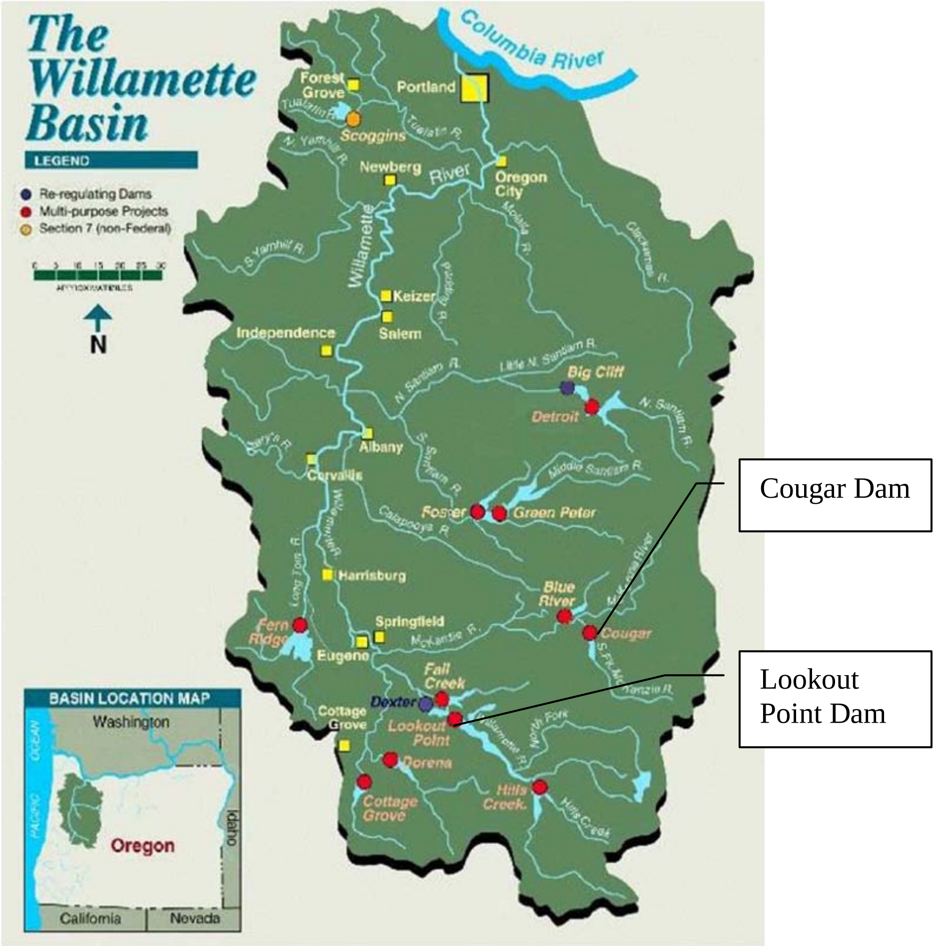

Figure 1. Map of the Willamette Basin (from Figure 2-1, NMFS 2008).

1.2 Objectives

The objectives for this optimization study during January and February 2010 were to:

1. Lookout Point Dam
   a. Design and test mounts to deploy fixed-location hydroacoustic transducers to sample juvenile salmonid passage into the regulating outlets and turbine penstock intakes, and vertical distribution at the forebay face of the dam.
   b. Test various aiming angles and ping rates to optimize the performance of the hydroacoustic systems at the regulating outlet, penstock, and forebay locations.
2. Cougar Dam
   a. Design and test a platform and apparatus to deploy an acoustic imaging system to sample juvenile salmonid behavior in the immediate forebay of the intake tower.
   b. Test various aiming angles and transmission frequencies to optimize the performance of the acoustic imaging system at the intake tower location.

1.3 Study Area

Lookout Point Dam (Figure 2) is located on the Willamette River near Lowell, Oregon. The optimization study was conducted on the forebay side of the dam at the regulating outlets, turbine intakes, and forebay face (Figure 3). The centerlines of the four regulating outlets are at elevation (El.) 730 ft above mean sea level (MSL). (All elevations are referenced to mean sea level.) For the turbine intake structure, the lower deck is at El. 860 ft, the intake ceiling on the downstream side of the gate slot is El. 794 ft, and the bottom of the trash racks is at El. 764 ft. LOP normal pool level is at El. 929 ft and minimum pool is at El. 811 ft.

Figure 2. Lookout Point Dam

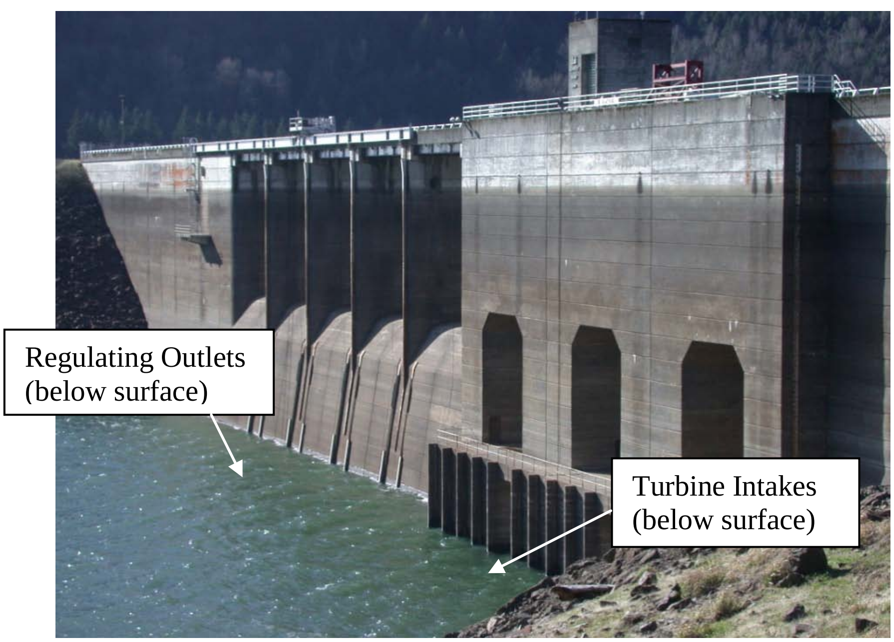

Figure 3. Forebay Face of Lookout Point Dam.

Cougar Dam (Figure 4) is located on the South Fork McKenzie River near Blue River, Oregon. The optimization study occurred on the forebay side of the dam at the intake tower (Figure 5). The top of the intake tower is at approximately El. 1,748 ft. Maximum pool is El. 1,699 ft.

Figure 4. Cougar Dam

Figure 5. Cougar Dam Intake Tower

1.4 Report Contents

The ensuing sections of this report describe the study methods and results for each dam and conclusions. There are no appendices. The raw data are archived at PNNL offices in Richland, Washington.

2.0 Methods

The methods section includes the general approach, study preparations, dive plans, and calibrations.

2.1 General Approach

The general approach was a multi-step process from mount design to final system configuration. First, we developed designs for transducer mounts and had them reviewed and approved by the USACE engineers and project personnel. Second, field trials were undertaken to perfect the mount design. Third, aiming angles and ping rates were tested in the field. And, fourth, the optimum configuration for each hydroacoustic system was established.

2.2 Study Preparations

Preparation for conducting the study started with obtaining the necessary permissions and security access to the dam for all required staff. PNNL conducted a hazards analysis, developed a safety plan, and received a safety briefing from project personnel. Communication avenues were established between PNNL and USACE staff at the project and at USACE Portland District headquarters.

2.3 Dive Plan

To perform underwater mount installations at Lookout Point Dam, PNNL helped the USACE develop a dive plan for USACE contracted divers. The dive plan is on file at the USACE Portland District.

2.4 Performance Tests

The fixed-location hydroacoustic equipment was performance tested before the study by Precision Acoustic Systems, Inc. of Seattle, Washington. Performance test data are archived with the project records at PNNL offices in Richland, Washington.

The acoustic imaging system was performance tested for proper operation by PNNL staff.

3.0 Results

The following description of methods is organized by sampling location. For each location, we describe the transducer mount, deployment, optimization tests, and the final result.

3.1 LOP Regulating Outlets

The purpose of the transducers at the regulating outlets (RO) at LOP is to estimate passage rates of juvenile salmonids into the four regulating outlets.

3.1.1 Mount

The mount for the RO transducers (Figure 6) consists of a triangular base that is attached to the concrete face of the dam with concrete anchors. A stanchion with a right angle bracket was welded to the base. An aluminum cage containing a split-beam transducer was attached to the bracket.

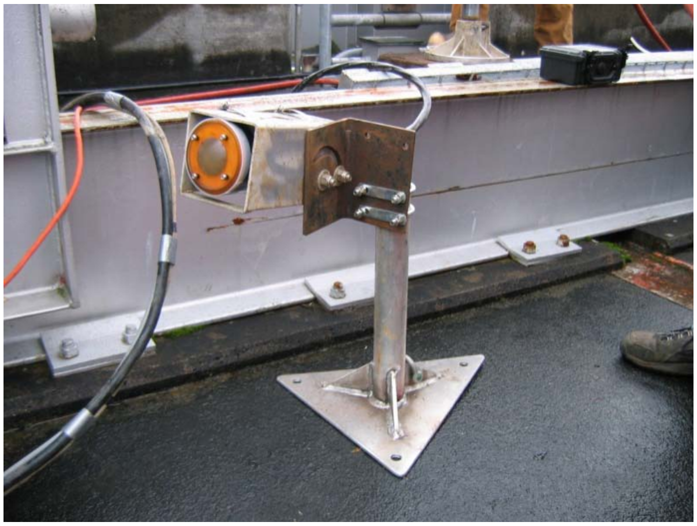

Figure 6. Mount Used for Transducers at LOP Regulating Outlets

3.1.2 Deployment and Testing

For the regulating outlets, we originally proposed deploying four down-looking, 10-degree, split-beam transducers along the longitudinal axis of the RO just below minimum pool elevation on the forebay face of the dam (Figure 7). During February 1-2, 2010, divers installed the mount/transducer assembly. A test target was attached to the face of the RO headgate to verify proper aim of the transducer. Tests were conducted by transmitting sound energy (“pinging”) at 33 pings per second (pps) and examining the data for echoes from the target. Quality echoes from the target would imply that the deployment was optimal.

At the pre work meeting with LOP project staff, the project discovered that the axial deployment would not work because the mount would block the deployment of a headgate to close the RO. Therefore, the transducer was moved to one side and aimed down at an oblique angle across the RO portal. Various aiming angles and ping rates were attempted. The transducer was aimed as close as possible to the dam but without excessive structural interference from the dam.

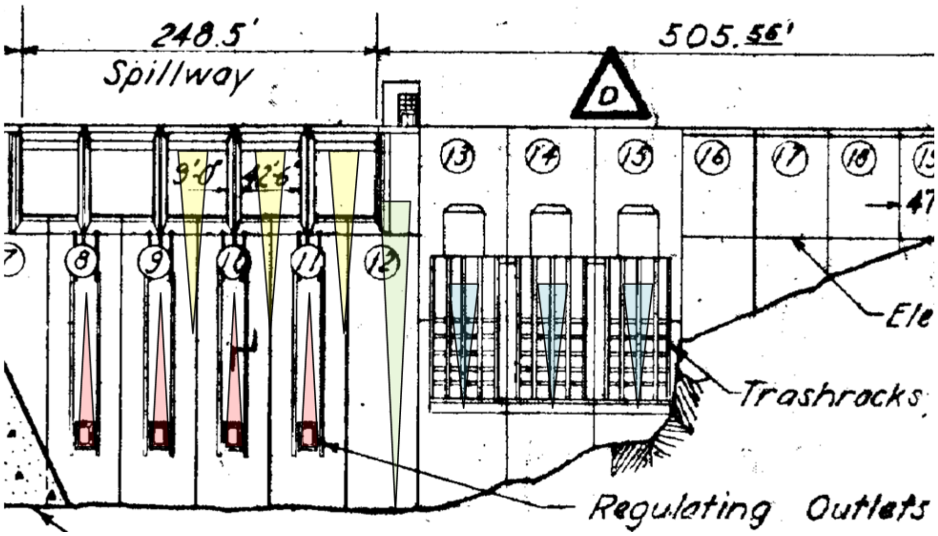

Figure 7. Front view of Lookout Point Dam from the forebay showing *original proposed* deployments of transducers. Four down-looking 6-degree split beam transducers (red triangles) are for sampling fish passage into four regulating outlets. Three ten-degree split beam transducers for sampling fish passing the spillway are shown in yellow in front of each of three spill bays [NOT USED in 2010]. One up-looking 6-degree single beam transducer would be used for sampling vertical distributions of fish in the forebay (green triangle in the middle of the figure). The final deployment used two 6-degree single beam transducers; one down-looking and one up-looking deployed at the same location (green triangle in the figure). Three 10-degree split beam transducers for sampling fish passing into penstock intakes are shown in blue in front of trash racks.

3.1.3 Final Result

The optimal deployment for the RO transducers was a down-looking 10-deg split-beam transducer aimed obliquely 19 deg off vertical and 11 deg off the face of the dam (Figures 8 and 9). The four RO transducers will transmit at 33pps and be sampled for 15 min each per hour. The spatial expansion of detections will depend upon range of detection from a transducer and the ratio of the distance across the opening perpendicular to the main axis of the acoustic beam. Given the aiming angle across the rectangular openings, the distance across the opening perpendicular to the beam axis will have to be entered in a lookup table for every possible range of detection.

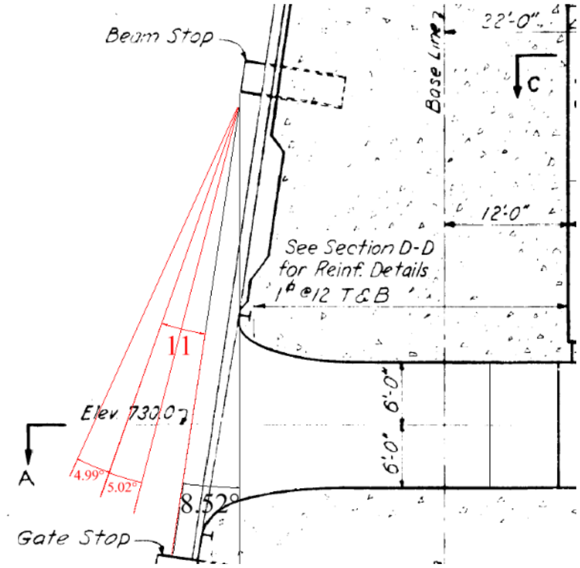

Figure 8. Side View Depicting the Final Orientation of a Transducer at a LOP Regulating Outlet

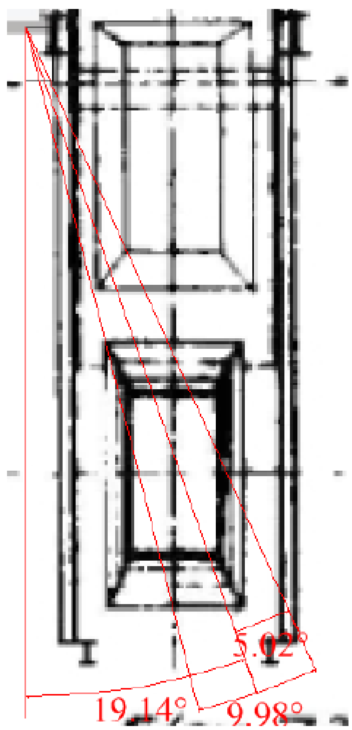

Figure 9. Front View Depicting the Final Orientation of a Transducer at a LOP Regulating Outlet

3.2 LOP Turbine Intakes

The purpose of the transducers inside the turbine intakes at LOP is to estimate passage rates of juvenile salmonids into the three turbine penstocks.

3.2.1 Mount

The mount for the turbine intake transducers consisted of a base with an adjustable arm (Figure 10). A cage for the transducer was attached to the arm. An in-line screw mechanism allowed divers to adjust the aiming angle. Anchor chains were attached to the mount and subsequently to the trash rack to prevent the assembly from moving into the penstock should it come loose from the trash rack.

The transducer mounts for the LOP turbine intakes were designed to fit between the vertical bars of the trash rack. This design allowed divers to secure the mount to the trash rack of each intake from the forebay. The mount was secured to the trash rack with "J" bolts.

Figure 10. Mount Used for Transducers at the LOP Turbine Intakes

3.2.2 Deployment and Testing

We proposed to deploy up-looking transducers inside the penstock mouth (Figures 7 and 11), which is preferred because fish will be committed to passing when sampled. This deployment requires a diver to install the transducer mount through the trash rack and bolt the mount onto the trash rack bars. However, at a pre work meeting with LOP project staff, we were notified of a high possibility of woody debris at the bottom of the trash racks. The project had conducted ROV surveys of the trash racks several months prior to our work and found piles of woody debris at the bottom of each trash rack. Therefore, a new deployment location was chosen during testing February 3-5, 2010.

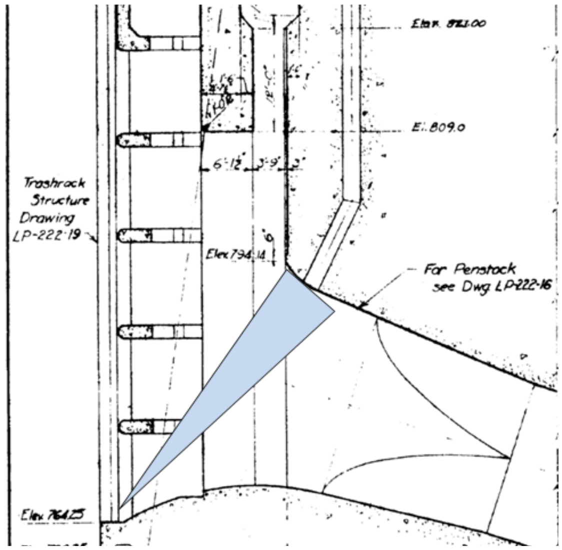

Figure 11. Side View of Lookout Point Dam Showing *Original Proposed* Deployment of Transducers in the Turbine Intakes

The new location for sampling turbine intake passage was at the top of the fourth set of trash racks from the bottom (Figure 12). The transducer initially was aimed down at 42 deg off horizontal. The presence of a head gate prevented the PNNL team from testing more than one aiming angle that was obtained from a scaled CAD drawing (Figure 12). After the divers finished the installation and the head gates were removed, a variety of ping rates were tested to select the best rate.

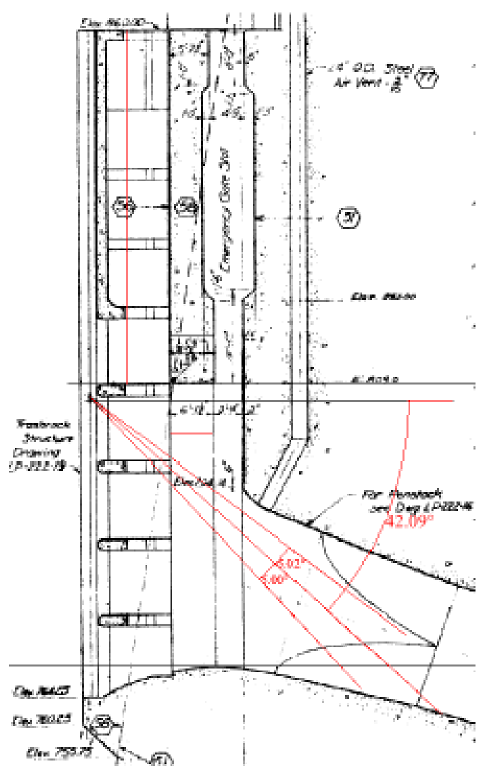

Figure 12. Side View Depicting the Final Orientation of a Transducer at a LOP Turbine Intake

3.2.3 Final Result

The final deployment for the turbine intake transducers was down-looking 10-deg split-beam transducer aimed 42 deg below horizontal (Figures 9). The three turbine intake transducers will transmit at 25 pps and be sampled for 20 min each per hour.

3.3 LOP Forebay Face

The purpose of the transducer at the forebay face at LOP is to estimate the vertical distribution of fish in the immediate forebay of the dam.

3.3.1 Mount

This mount was similar to RO mount but had two transducers, one aiming up and the other aiming down (Figure 13).

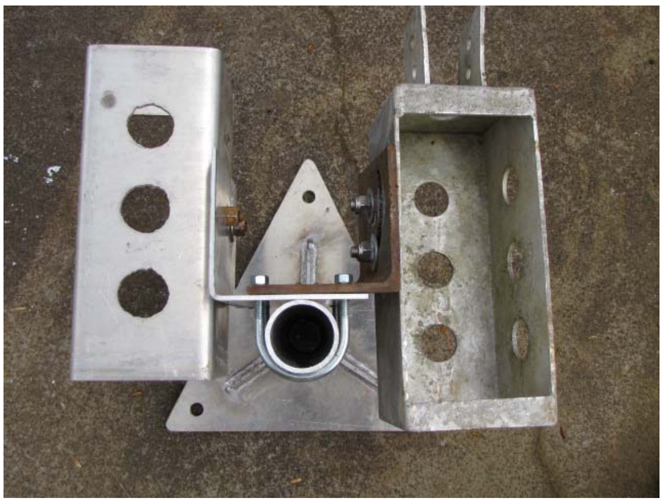

Figure 13. Mount Used for Transducers at the LOP Forebay Face

3.3.2 Deployment and Testing

For this deployment, we originally proposed deploying one up-looking, 6-degree, single-beam transducer on the concrete face of the dam, near the bottom (elevation 725 ft), between the penstock intakes and the spillway. However, the transducer would be very deep in the summer when the forebay is at normal pool and the return of the sound energy ("pings") would be very slow. Therefore, we modified the deployment and use two 6-degree, single-beam transducers attached to one mount. One transducer was aimed directly upwards and the other directly downwards. The mount was installed by divers on February 4, 2010 at a location on the concrete face of the dam at El. 822 ft (Figure 14). Tests were conducted to verify proper aiming and ping rates.

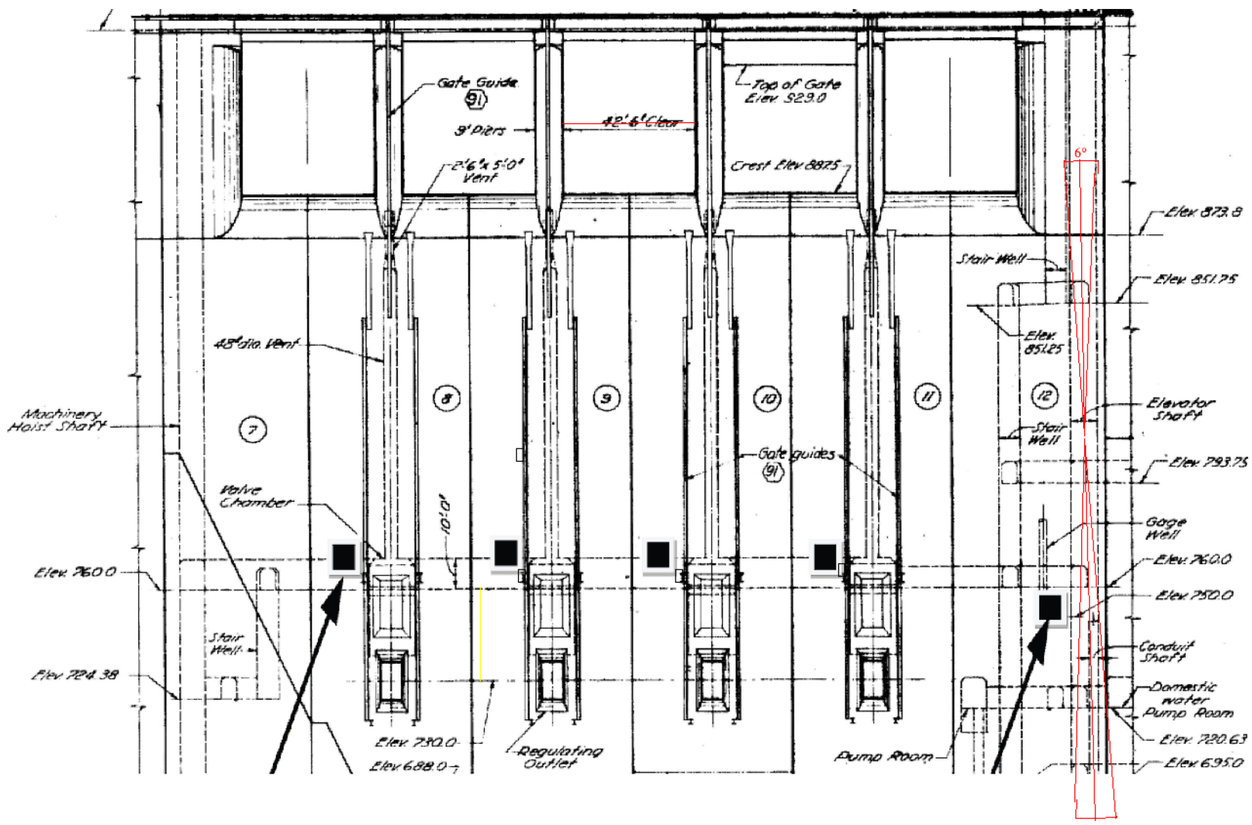

Figure 14. Frontal view of transducer beams (red triangles) deployed to sample vertical distributions of fish in the forebay between the spillway and powerhouse.

3.3.3 Final Result

The optimal deployment for the forebay vertical distribution was a pair of 6-deg transducers, one down-looking and one up-looking, deployed at mid-water column (El. 822 ft). The two forebay transducers will transmit at 20 pps and be sampled for 30 min each per hour (1/2 time sampling).

3.4 CGR Intake Tower

The purpose of the acoustic imaging work at the CGR intake tower is to characterize juvenile salmonid behavior and movement patterns in the forebay (within 20 m) of the intake tower on a diel and seasonal basis.

3.4.1 Mount

A 14-ft floating platform was designed to accommodate drastic yearly water level fluctuations of the CGR forebay (Figure 15). Securing of the platform consisted of three engineered brackets that were concrete-anchored to the parapet wall on the roof of the tower and paired with brackets at the water's surface. Stainless steel cables were tensioned between these pairs of brackets. This apparatus will serve as vertical guides for the platform to move up and down as forebay levels fluctuate. A weak link was engineered into the bracket system to ensure the link would fail before damage occurred to the tower should the platform break away. A cable spooling system was also designed to ensure data cables would remain properly tended on the deck of the platform as the platform ascended or descended.

A pole mount system was constructed for deployment from the platform for the acoustic imaging camera. The mount allowed aiming angles of the acoustic camera to be optimized from the deck of the platform.

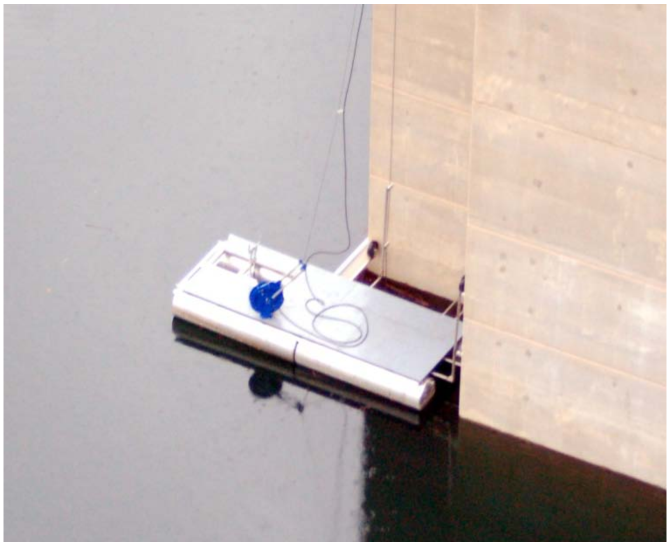

Figure 15. Platform and Apparatus Used for the Acoustic Imaging Camera at the CGR Intake Tower

3.4.2 Deployment and Testing

The platform was deployed on the southeast corner of the intake tower at CGR. Initial deployment design was to secure the platform to the tower in front of the trash racks; however, from a site visit and input from project staff, it was determined that the amount of debris present in and around the track racks would make this deployment infeasible. Thus, the acoustic camera was deployed 4 feet below the water surface (El. 1546 ft). Various horizontal and vertical aiming angles of the acoustic imaging system were tested.

3.4.3 Final Result

At the Cougar Dam intake tower, optimal aiming of the acoustic camera was directly across and in front of the track racks and at a seven degree down angle. Sampling will be conducted during twenty-four 24-h periods over the year-long 2010 study.

4.0 Summary and Recommendations

This report described the acoustic optimization study conducted during January and February 2010 at Lookout Point and Cougar dams. The study provided valuable insight into how to sample successfully with underwater acoustic systems.

Optimization can be achieved by limiting interference to acoustic telemetry systems through several approaches, including: 1) placement and aiming angles of transducers; and 2) ping rates of echo sounders. PNNL pursued all of these approaches in the study reported herein. To summarize, we established the following system configurations for the year-long hydroacoustic studies at LOP and CGR (Table 1).

Table 1. Results of the LOP and CGR Hydroacoustic Optimization Study

Dam	Location	Hydroacoustic Equipment	Beam Width (deg)	Mount Design	Elevation (ft MSL)	Aiming Angle (deg)	Ping Rate (pps)
LOP	Regulating Outlet	Split-beam Transducers (4)	10	Bracket	763	11	33
	Turbine Intake	Split-beam Transducers (3)	10	Trash rack " Moified Tiltzer"	803	42	25
	Forebay	Single-beam Transducers (2)	6	Bracket	822	Vertical	20
CGR	Intake Tower	Acoustic Camera (1)	29x11	Floating Platform w/ Pole Mount	1,546	7 down	7

Because the transducers deployed inside turbines at LOP will be so deep at full pool that divers will not be able to dive and replace a faulty transducer or cable, the PNNL team proposes to deploy a series of three down-looking transducers in the forebay to sample fish moving downstream into the turbines at no additional cost to the project. This deployment is an insurance policy against equipment failure that could not be repaired when the reservoir is full. The transducers will be deployed on pole mounts from the deck at elevation 860 ft above mean sea level and will be aimed out from the dam face about 11 degrees. These transducers also may provide supplemental information about fish behavior upstream of the trash racks as well as provide a backup method to sample fish passage into turbines.

The LOP turbine intake optimization was limited by presence of the head gates. We recommend that any future optimization efforts at turbine intakes at dams in the Willamette Valley Project be improved by integrating the type of work performed in February 2010 with test pinging after head gates are removed and turbine units are operating. Because this will necessitate interruptions in diving activities for the turbine intakes, other work for the diver should be planned for these periods.

In conclusion, the optimization effort resulted in successful deployments of hydroacoustic equipment at LOP and CGR during 2010. If hydroacoustic methods are selected for use at other Willamette Valley Project dams in the future, similar optimization processes will benefit from the experience at LOP and CGR during 2010.

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Ploskey, GR and thirteen co-authors. 2008. *Optimization of Concurrent Deployments of the Juvenile Salmon Acoustic Telemetry System and Other Hydroacoustic Equipment at John Day Dam*. PNNL-17837, prepared by the Pacific Northwest National Laboratory, Richland, Washington for the U. S. Army Corps of Engineers, Portland District, Portland, Oregon.

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