**City of Tacoma,
Department of Public Utilities, Light Division
Cowlitz Hydroelectric Project
FERC No. 2016**

Settlement Agreement License Article 2.

Downstream Fish Passage: Mayfield

Study Results

1. INTRODUCTION

These study results are prepared as a response to the March 13, 2002, Federal Energy Regulatory Commission (the Commission), Order Approving Settlement and Issuing New License, and the July 18, 2003, Commission Order Denying Rehearing and Lifting Stay for FERC Project No. 2016, Settlement Agreement License Article 2. The license article requires the City of Tacoma, Department of Public Utilities, Light Division (Tacoma) to file a study plan or study results evaluating turbine mortality and the effectiveness of the existing louver bypass system at Mayfield Dam within six (6) months of license issuance.

1.1 PROJECT DESCRIPTION

The Cowlitz Project (FERC No. 2016) is located on the Cowlitz River, Lewis County, Washington between river mile (RM) 49.5 and RM 88.0. The project consists of Mossyrock Dam (RM 65.5), Mayfield Dam (RM 52.0), Riffe Lake reservoir, Mayfield Lake reservoir, two hydroelectric powerhouses, the transmission facilities associated with the dams, the Cowlitz Salmon Hatchery (RM 50.0), the Barrier Dam (RM 49.5), the Cowlitz Trout Hatchery (RM 42.0), recreational facilities at the reservoirs and lands within the Project boundary. Construction of the Project began with Mayfield Dam in 1956 and was completed with the construction of Mossyrock Dam ending in 1968. The Project has been operated and maintained continuously since original construction.

Tacoma Power built the Cowlitz Project between 1958 and 1968 and generation capacity was expanded in 1983. The original license for the project was issued November 28, 1951, and expired on December 31, 2001. A new thirty-five year license for the project was made effective on July 18, 2003.

1.2 FERC LICENSE ARTICLE

Settlement Agreement License Article 2 (a): Within six (6) months of license issuance, the Licensee shall develop and file with the Commission, a study plan or study results evaluating turbine mortality and the effectiveness of the existing louver system at Mayfield Dam. The studies shall be designed and results reviewed in consultation with the Fisheries Technical Committee provided for in the August 2000 Settlement Agreement, or if the Settlement Agreement has become void, with the U.S. Fish and Wildlife Service, National Marine Fisheries Service, Washington Department of Fish and Wildlife and Washington Department of Ecology (referred to as "the FTC or agencies"). The Licensee shall include with the study plan and results documentation of consultation and copies of comments and recommendations on the plan and descriptions of how the FTC's or agencies' comments are accommodated by the plan. The Licensee shall submit the final plan to the National Marine Fisheries Service and U.S. Fish and Wildlife Service for approval prior to filing with the Commission. Upon approval by NMFS and USFWS and filing with the Commission, the Licensee shall conduct the studies.

2. OBJECTIVES

1. To provide "a study plan or study results evaluating turbine mortality and the effectiveness of the existing louver system at Mayfield Dam" and to " include with the study plan and results documentation of consultation and copies of comments and recommendations on the plan and descriptions of how the FTC's or agencies' comments are accommodated by the plan".
2. To achieve a "..."Downstream fish passage survival rate" as used in proposed license article 2 and applied to Mayfield Dam, means the percentage of smolts entering the Mayfield louver system that are guided through the juvenile fish guidance and bypass facilities and do not enter the turbines, plus those juveniles that also pass through the project turbines or over the spillway and also survive." greater than 95%.

3. PLAN DEVELOPMENT

3.1 Background

The Cowlitz Fisheries Technical Committee (FTC) was organized and convened in November 2000. At the first meeting the FTC endorsed early implementation actions as encouraged in the Settlement Agreement (SA). At this meeting Tacoma proposed conducting turbine survival and louver evaluations studies at Mayfield Dam in 2001.

The FTC reviewed the proposals and work plans and suggested alternative actions or study protocols during the period the studies were conducted (2000 to 2002). The Tacoma Power representative on the FTC endeavored to keep the FTC informed of all study schedules, actions and findings. The FTC reviewed the draft and final versions of all study results.

3.2 Consultation record

Tacoma Power convened the FTC (Tacoma Power, NMFS, USFWS, WDFW, WDOE and the Yakama Nation; and one Conservation Groups representative) on November 1, 2000 and held the initial meeting in Lacey, Washington to organize the FTC and consider early implementation actions. The study plans for a.) Mayfield turbine survival, and b.) Mayfield Dam louver evaluations were proposed at this initial meeting.

Mayfield louver evaluations

At the December 12, 2000 FTC meeting the FTC endorsed these studies as early implementation actions and approved Tacoma Power to release a request for proposals (RFP) for the Mayfield louver evaluation study. The Mayfield turbine survival study was put on hold at this meeting.

A draft RFP for the Mayfield louver evaluations was prepared and distributed to the FTC representatives on January 2, 2001. Recipients were provided a 15-day review and comment period. The FTC approved Tacoma to issue the Mayfield louver evaluation RFP at the January 23, 2001 FTC meeting (via teleconference). The RFP response was discussed at the March 6, 2001 FTC meeting to provide another opportunity for the FTC to clarify items and answer questions.

The June 5, 2001 FTC meeting was held at the Cowlitz Project, Mayfield Office and began with a tour of the louver facilities and the louver research activities underway. A report on the louver research activities was given at the August 7, 2001 FTC meeting, and an initial discussion was held on continuing louver evaluation studies at Mayfield Dam in 2002.

At the October 2, 2001 FTC meeting Tacoma Power consultants gave a presentation of their initial 2001 study findings and answered questions for the FTC. Several suggestions for additional louver evaluations studies for 2002, building upon findings from the 2001 study season, were discussed and agreed upon. The FTC endorsed proposed 2002 study plans for further Mayfield louver evaluations at the meeting.

The draft 2001 Mayfield Dam louver evaluation study was distributed to the FTC for comments on January 31, 2002. No comments were received on the draft version and the report was finalized. Subsequently, additional figures and corrections to one table in the report were distributed to the FTC in September 2002.

The draft report of 2002 Mayfield Dam louver evaluation studies was distributed by mail to the FTC on February 4, 2003. No timeline was established for review comments to be returned to Tacoma. At the March 4, 2003 FTC meeting the Tacoma representative confirmed that each member of the FTC received a copy of the 2002 Mayfield louver study results.

Mayfield turbine survival

At the August 7, 2001 FTC meeting, the deferred Mayfield turbine survival study plan was discussed. The FTC concurred on proceeding with a turbine survival study at Mayfield Dam in the winter of 2001/2002. Details of the study were discussed and recommendations made by the FTC at this meeting for study protocols. At the December 4, 2001 FTC meeting Tacoma Power presented information regarding project reservoir levels and inflow forecasts confirming there would be sufficient water in March 2002 to conduct the turbine survival study at Mayfield Dam at the recommended flows. The FTC endorsed proceeding with the study in March 2002.

A Mayfield turbine survival study plan and protocol was distributed at the January 9, 2002 FTC meeting. Tacoma requested the FTC review the study and return comments. The FTC discussion at this meeting focused upon required sample sizes for the desired statistical precision and expected survival rates. The FTC was apprised of the study schedule and offered the opportunity to visit during the study to observe the protocols and results firsthand. Preliminary results of the Mayfield turbine survival were shared with the FTC at the May 20, 2002 meeting in Lacey.

The draft report of 2002 Mayfield turbine survival study was distributed by mail to the FTC on February 4, 2003. No timeline was established for review comments to be returned to Tacoma. At the March 4, 2003 FTC meeting Tacoma confirmed that each member of the FTC received a copy of the 2002 Mayfield study.

At the September 4, 2003 FTC meeting Tacoma requested comments upon the 2002 Mayfield Dam juvenile fish guidance and turbine survival studies by October 7, 2003. No comments were received.

4. STUDIES

4.1 2001 Mayfield Dam Fish Guidance Louver Evaluations

In order to evaluate the louver guidance and juvenile fish bypass system at Mayfield Dam, Tacoma Power contracted with Northwest Hydraulic Consultants, Inc. in 2001. The study approach was designed to evaluate the effectiveness of the louver system in diverting downstream migrating juvenile salmonids away from the power tunnel and the turbines, to identify where non-guided fish passed through the louvers and to develop a computational fluid dynamics model to verify flow lines and allow for future testing of different configurations at the louvers.

The fieldwork was completed in 2001 and consultation occurred as documented in Section 3.2. The draft report issued was in January 2002 and finalized in September 2002. The 2001 Mayfield Dam Fish Guidance Louver Evaluations final report is included as Attachment No. 1.

4.2 2002 Mayfield Dam Fish Guidance Louver Evaluations

Upon review of the 2001 study results, the FTC concurred with Tacoma that additional studies were warranted in 2002 to follow up and to evaluate the hydraulic conditions at higher flows. The primary tasks were field velocity measurements and additional CFD simulation runs.

The fieldwork was completed in 2002. Consultation occurred as documented in Section 3.2, and the draft report was distributed to the FTC in February 2003. The 2002 Study Program Results for Mayfield Dam Fish Guidance Louver Evaluations are included as Attachment No. 2.

4.3 2002 Mayfield Dam Turbine survival Evaluations

The FTC endorsed a study of downstream migrant survival through the turbines at Mayfield Dam as part of the 2002 Work Plan for evaluating downstream passage. Consultation on the study plan and activities occurred as documented in Section 3.2, and the field studies were conducted in March 2002. The primary tasks were to estimate the direct effects of passage through two turbine types on the immediate and 48-hour survival of coho salmon and steelhead smolts.

All fieldwork was completed in 2002. The draft results were presented to the FTC at meetings in 2002, and the final draft report was issued in February 2003. No comments were received and the report was finalized in October 2003. The 2002 Passage Survival of Juvenile Salmonids Through Two Francis Turbines at Mayfield Dam, Cowlitz River, Washington is included in Attachment No. 2.

4.4 2002 Mayfield Dam Fish Guidance System Evaluations

Upon review of the preliminary 2001 study results, and in conjunction with the turbine survival study scheduled for 2002, the FTC supported a proposed sequence of studies in 2002 that evaluated the entire fish guidance *system* at Mayfield Dam. Included were evaluations of modifications to the south louver bypass entrance slot, velocity profile measurements (see Section 4.2) and additional fish collection efficiency studies. The 2002 Work Plan was reviewed by the FTC at the March 20, 2002 FTC meeting.

All fieldwork was completed in 2002. Consultation occurred as documented in Section 3.2, and the final report issued in February 2003. The 2002 Study Program Results for Mayfield Dam Fish Guidance Louver Evaluations are included in Attachment No. 2.

4.5 Study results summary to date

At the May 13, 2003 FTC meeting Tacoma Power presented a summary of the Mayfield Dam louver evaluation and downstream fish passage survival studies conducted in 2001 and 2002.

The presentation discussed the fish guidance studies done at Mayfield Dam in the 1960's, the fish guidance studies done in 2002, the continual operation of the Mayfield louver bypass system in either a passive and active mode since 1961, and presented the overall study findings that the downstream fish passage survival rate was, in fact, being met with a 95 percent value for coho and 96 percent value for steelhead and Chinook juveniles. Study results did show that the fish survival was lower through unit 41 and ideas for fish deterrents to the entrance of Unit 41 penstock were discussed at this meeting.

Tacoma Power is planning for areas of possible improvements at the Mayfield downstream collection facility including; investigating improvements to unit 41, reducing noise levels from the attraction pumps, debris handling improvements, improving the hydraulics in the north louver bay bypass pipe and upgrading the counting house operations.

ATTACHMENT No. 1

2001 Mayfield Dam Fish Guidance Louver Evaluations

Cowlitz River Project
Mayfield Dam
Fish Guidance Louver Evaluations

Final Report

January 28, 2002

Evaluation of Juvenile Coho Salmon Behavior and Passage through the Intake Louvers at Mayfield Dam in 2001 using Acoustic Tags. Correlation of Acoustic Tag Tracking Data with Velocity Vector Field Generated with a 3-Dimensional Computational Fluid Dynamic (CFD) Numerical Computer Model. Velocity Field Verification with 3-Dimensional Point Velocities Measured in the Existing Intake with ADV Probe.

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I. PROJECT INFORMATION AND BACKGROUND

Mayfield Dam is located in Southwest Washington State on the Cowlitz River, which is a tributary to the Columbia River. The Cowlitz supports large runs of various anadromous salmonid species, including coho (*Oncorhynchus kisutch*), chinook (*Oncorhynchus tshawytscha*), and steelhead (*Salmo gairdneri*), all of which occur in varying densities in the Cowlitz River watershed. The Cowlitz River has four dams; Cowlitz Falls (~ River Mile 90), Mossyrock Dam (River Mile 65.5), Mayfield Dam (River Mile 52.0), and Barrier Dam (River Mile 48). Cowlitz Falls Dam is a run-of-the-river concrete gravity type hydroelectric dam with relatively low head that is owned by Lewis County PUD and was constructed in the early 1990's. Mossyrock Dam is a high concrete arch-type hydroelectric dam that is owned by Tacoma Public Utilities and was constructed in the 1960's. Mayfield Dam is a moderate head concrete gravity-type hydroelectric dam that is owned by Tacoma Public Utilities and was constructed in the late 1950's and early 1960's (Photo 1, Appendix "A"). Barrier Dam was constructed in 1968, and does not generate electricity. Currently, downstream migrant salmonids are collected at Cowlitz Falls Dam and transported by tanker truck to below Barrier Dam, where they are released back into the Cowlitz River to continue their journey to the Pacific Ocean.

The Mayfield Dam project annually passes an estimated 25,000 to 250,000 salmonid smolts, mainly produced in the Tilton River system. The Tilton River is the only major tributary to the Mayfield reservoir, as the Mossyrock Dam just a few miles upstream and the Cowlitz Falls Dam upstream of that, capture most of the smolt production of the remaining upper basin of the Cowlitz River (LaRiviere, 2001, personal communication). Of that number of smolts, the majority in recent years have been coho salmon, with steelhead and chinook present in lesser numbers.

The existing louvered intake at Mayfield Dam has been estimated to bypass from 60 to 80 percent of the smolts downstream (LaRiviere, 2001, personal communication), but never verified. Since the louvered intake was constructed in the early 1960's, not much additional attention has been paid to improving juvenile fish passage at the project. Instead, Cowlitz Falls Dam received the greater investment in fish passage facilities. Cowlitz Falls Dam has the most modern downstream migrant capture and bypass system of the three hydroelectric dams.

No detailed bypass efficiency measurements have yet been made at Mayfield Dam, nor has there ever been a detailed evaluation of potential problem areas within the existing bypass system. Tacoma Power has no definitive understanding of where in the louvered intake or bypass system improvements are necessary. Observations of flow patterns in the intake suggest that some improvements are needed in the immediate vicinity of the bypass slot entrance. The fish tracking results obtained as part of this study confirm visual observations and suggest that the immediate vicinity of the bypass slot may be one area on which focus should be brought.

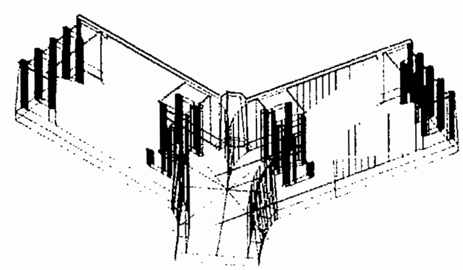
II. Louver Intake Description and Study Purpose

The Mayfield Dam powerhouse draws flow into the multiple Francis turbine units through an open canal and tunnel that extends from the reservoir several hundred feet to the powerhouse forebay pool. Two deep intake channels feed flow from the reservoir into the power tunnel (Photo 2, Appendix "A"), each of which is provided with a vertical louver guidance structure about 65 feet long and 48 feet wide (Photos 3, 4 and 5, Appendix "A"), with an 8 inch wide bypass slot at the terminus of the V-shaped alignment of the louver panels. The intake invert elevation is at about 389 ft (msl), the top elevation is about 428 ft (msl). Floating debris is generally excluded from the intakes by a trash boom deployed at the entrance to each intake bay (Photo 6, Appendix "A"). Downstream migrant fish are diverted into the bypass, where the majority of the total bypass flow is dewatered in a secondary separator structure (Photo 7, Appendix "A") and pumped back into the power tunnel (Photo 8, Appendix "A"). The fish and a small amount of flow are bypassed into a smolt monitoring station at the downstream face of the dam (Photos 9 and 10, Appendix "A"). Smolts are then transported to below the powerhouse through a shallow-sloped closed pipe (Photos 11 and 12, Appendix "A"). The louver screens are not a physically impenetrable barrier to the fish, as the louver vane spacing is about 3 inches, which is large enough for smolts to pass through. They were designed as a guidance structure only, to serve to direct fish into the deep vertical slot bypass conduit at the terminus of the louver bay. Average combined total flow through both intake louver systems from March 1 to July 15 during the downstream migration season is approximately 5 kcfs. The Mayfield Reservoir fluctuates approximately 4 ft (1.2 m) annually, with an occasional daily fluctuation of 1-2 ft (0.3-0.6 m), and an average elevation of about 423 ft (msl). Design capacity of the intake is 10,000 cfs, with inflow equally distributed between louver entrances. The City has operated at inflows of up to 14,000 cfs with no short-term undesirable hydraulic conditions with regard to turbine operation, although there is no information regarding fish guidance efficiency at those high flows.

Tacoma Public Utilities (TPU) wishes to estimate the effectiveness of the louver system in diverting downstream migrating juvenile salmonids away from the turbines, and to identify where non-guided fish pass through the louvers. As part of this evaluation, Hydroacoustic Technology, Inc. (HTI) conducted an acoustic tag study in 2001 to assess patterns of juvenile salmonid movement through the louver intake system. The acoustic tag study was coupled with a Computational Fluid Dynamic (CFD) computer model of the intake to characterize the hydraulic conditions within the louver bay and in the immediate vicinity of the louver vanes, and to evaluate future structural modifications intake for improving bypass efficiency.

The combined goal of these two studies was to assess louver bypass efficiency and performance on a biological basis and to interpret these results based on the hydraulic characteristics of the intake system. By comparing the velocity magnitude and direction data from the CFD model with the observed fish tracks, the study team was able to determine the local velocity field experienced by each fish as it transited the louver bay. Fish tracking was accomplished with active transmitting acoustic tags, which, when monitored with an array of submerged hydrophones in the intake, was able to determine the position of the fish to within approximately 0.1 meter resolution. The CFD modeling was accomplished with a three-dimensional numerical finite element STAR-CD computer model with approximately 700,000 grid elements, varying in size and configuration as necessary to accurately characterize the velocity field within the louver bay and in the immediate vicinity of the intake in the reservoir.

The louver guidance intake structure was constructed at the same time as the dam, following physical hydraulic model studies. At the time, its design was considered technologically advanced. However, fish passage design criteria have changed since construction, and the overall fish guidance efficiency of the louvered system is not well understood. Figure 1 below is a three-dimensional wire-frame representation of the entire intake structure and a photo of the same from the north dam abutment for comparison. The south intake bay is on the right, in which velocity measurements and fish tracking efforts were concentrated.



3-D Wire Frame of Intakes

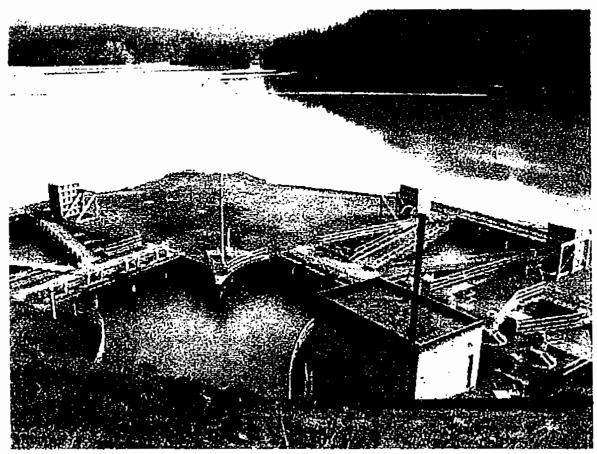


Photo of Intake from Abutment

Figure 1. North and South Louvered Entrance Bays of Intake Structure

The acoustic tag study, in conjunction with the CFD modeling was an effort to assess if these methodologies could be effectively used at Mayfield Dam to establish fish guidance efficiency parameters for the existing intakes. The results will be used in the following phases of assessment to develop structural or operational improvements to the existing system to further enhance fish guidance efficiency at Mayfield Dam. The CFD model will extend the information collected from velocity measurements in the existing intake at two fixed flows through the full range of operation of the intake. The fish tracking study observations were compared to the results of the CFD modeling, and fish position and movement were correlated with the velocity field established in the CFD model to determine causal relationships between fish behavior and velocity.

III. STUDY APPROACH

This report covers the first of two planned phases in the fish guidance efficiency evaluation of the Mayfield louver intake structure, which was completed during 2001. This first phase (Phase 1, hereafter) consists of an evaluation of the fish-guidance efficiency of the existing facility by means of a sequence of investigative steps. In order, these steps include field measurement of hydrodynamic flow conditions, computational fluid dynamic modeling of flow conditions, field tracking of fish movement, correlation of fish movement with flow conditions, bypass performance assessment, and finally identification of potential problem areas within the intake and recommendations for improvement and future studies. Phase 1 is described in detail in this report, while the second phase (Phase 2, hereafter) activities are described in the Recommendations Section of this report.

A. Field Velocity Measurements

1. ADV Current Meter Technical Information

Measurements of velocity vectors within the louvered intake arrangement were made within the louver intake bay with an acoustic Doppler velocity profiler (SonTek model 10 MHz ADV, see Figure 2 below).

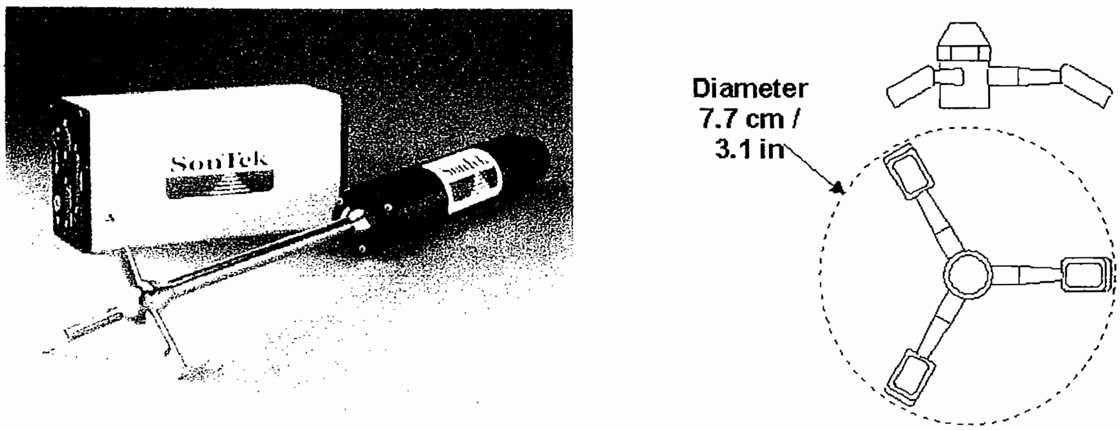


Figure 2: ADV Probe

The ADV measures the velocity of water using a physical principle called the Doppler effect. If a source of sound is moving relative to the receiver, the frequency of the sound at the receiver is shifted from the transmit frequency.

$$F_{doppler} = -2F_{source} (V / C)$$

In this equation, **V** is the relative velocity between source and receiver, **C** is the speed of sound, $F_{doppler}$ is the change in frequency at the receiver, and F_{source} is the transmitted frequency.

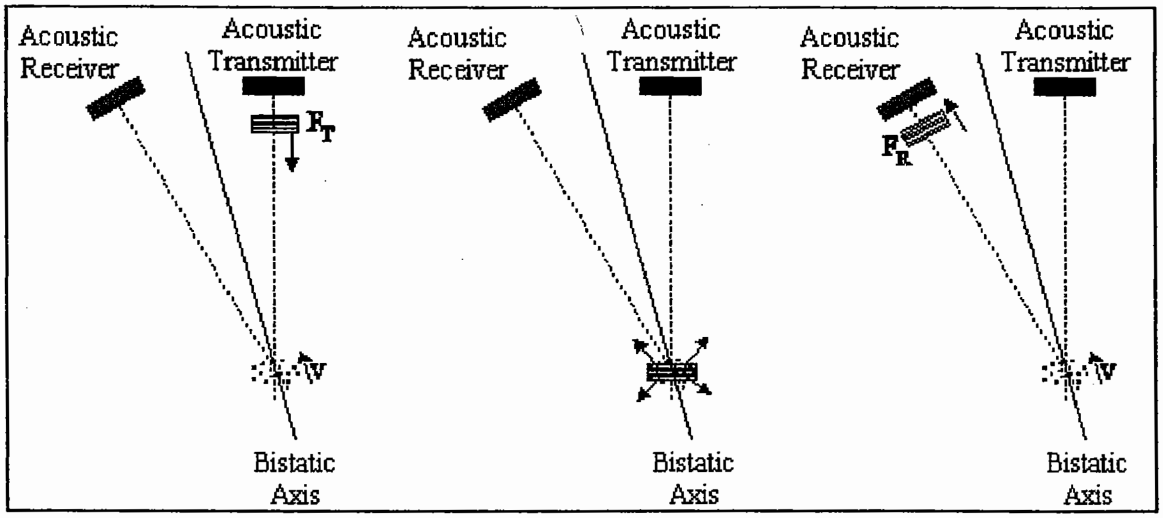


Figure 3: Bistatic Acoustic Doppler Current Meter Operation

Figure 3, above, illustrates the operation of a bistatic Doppler current meter such as the ADV (bistatic systems use separate acoustic transducers for transmitter and receiver). Both transmitter and receiver are constructed to generate very narrow beam patterns. The transmitter generates sound with the majority of the energy concentrated in a narrow cone, and the receiver is sensitive to sound coming from a narrow angular range. The transducers are mounted such that their beams intersect at a volume of water located some distance away. The beam intersection determines the location of the sampling volume (the volume of water in which measurements are made).

The transmitter generates a short pulse of sound at a known frequency, which propagates through the water along the axis of its beam. As the pulse passes through the sampling volume, the acoustic energy is reflected in all directions by particulate matter (e.g., sediment, small organisms, and bubbles). Some portion of the reflected energy travels back along the receiver axis, where it is sampled by the ADV and processed by the electronics to measure the change in frequency. The Doppler shift measured by one receiver is proportional to the velocity of the particles along the bistatic axis of the receiver and transmitter. The bistatic axis is located halfway between the center axes of the transmission and reception beams.

2. Field Velocity Measurement Program

The field measurement program was conducted while the powerhouse intake was withdrawing a nearly uniform flow of 2580 cfs from the reservoir with a forebay elevation of about 423 ft (msl). The first set of measurements were recorded in the south louver bay with both louver entrance bays operating at the same time and with roughly the same inflow to each (1290 cfs each). The ADV meter was lowered into the flow field of the intake at each vertical from a specially fabricated rolling truss spanning the intake bay (Figure 4, below, and Photo 14, Appendix A).

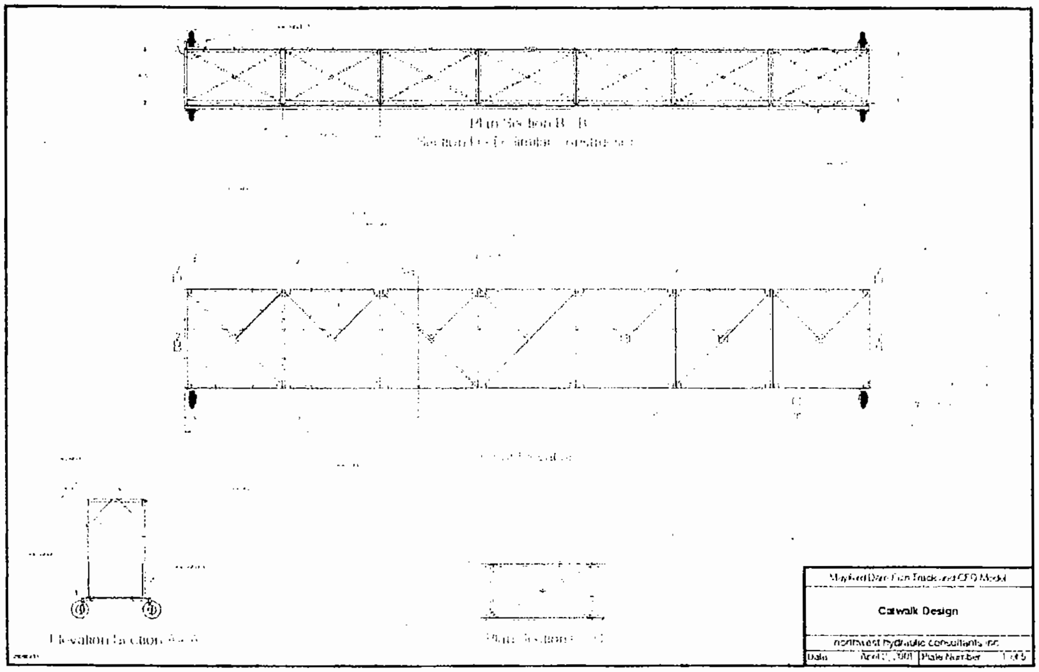


Figure 4: Rolling Truss for Velocity Measurements

A second set of measurements was taken with the north louvered entrance bay closed with the aid of butterfly gates at the downstream end of the intake bay. This, in effect, enabled documentation of three-dimensional velocities in the south, instrumented, louver bay as if the equivalent total project outflow were 5160 cfs. Velocity measurements were taken at cross sections 5 ft, 10 ft, 15 ft, 25 ft, 35 ft, 45 ft, 55 ft, 60 ft, and 70 ft upstream from the bypass entrance slot. At each cross section, measurements were taken within 0.13 ft of the louver vanes, within 1.0 ft from the louver vanes, at the centerline of the bay, and at several other points across the width of the intake at that cross section. Figure 5, below, shows the approximate placement of the verticals at which velocity measurements were made within the louver bay. The numbered symbols represent the magnitude and direction of the flow velocity at each point.

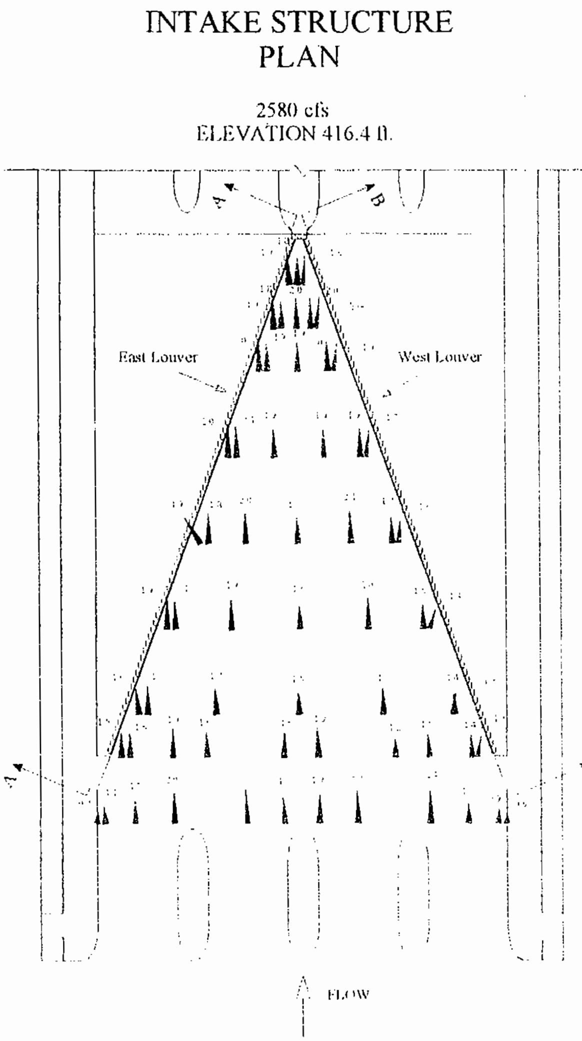


Figure 5: Velocity Measurement Locations Plan View – 2580 cfs

Each vertical included velocity measurements taken at elevations 395.6 ft, 402.3 ft, and 416.4 ft (msl), as shown in Figure 6, below.

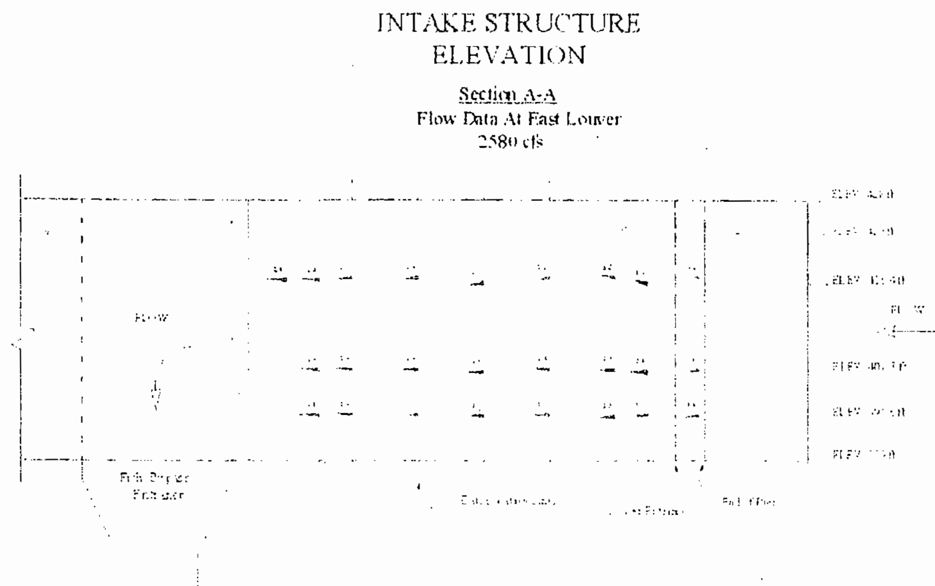


Figure 6: Velocity Measurement Locations Elevation View – 1290 cfs

A total of 183 point velocity measurements were taken at each of the two intake flows. All velocity vectors derived from the field measurement program are provided in Appendix "B" of this report.

The density of velocity measurement points was increased in the vicinity of the louver vanes, such that the turning effect of the louver vanes could be documented. The physical size of the ADV probe, and its attachment to the mounting frame, limited the minimum distance it could measure point velocities from the louver vanes to about half the probe diameter, or about 1.7 inches. The mounting frame members were positioned well downstream of the probe, to avoid any alteration of the true flow field being measured. Future modifications to the mounting frame will enable the probe to measure unobstructed point velocities as much as 1 inch inside the space between louver vanes.

Submerged debris lodged in the louver vane panels necessitated very careful maneuvering of the probe and frame, to avoid damage to the fragile probe. When future measurements are made at higher intake flows, it will be necessary to secure the probe mounting frame more rigidly to the louver vane panel to prevent hydrodynamic drag forces from deflecting the probe alignment. In addition, a more protective enclosure will be constructed to protect the probe from debris. Minor modifications to the probe mounting frame should accomplish this without difficulty.

The density of measurement points within the intake bay and adjacent to the louver vanes and upstream intake bridge piers was selected to provide adequate calibration points for the CFD model. As discussed in the following section, the CFD model calibrated quite satisfactorily with the field velocity measurement points collected at the lower range of intake discharges, indicating good selection of points. Future velocity measurements made at higher intake flows will require a greater number of points in the vicinity of the louver panel surface, in order to adequately characterize the more exaggerated turning of flow by the louver vanes. In addition, it will be necessary to make additional measurements downstream of the intake bridge piers, to capture the additional complexity and greater strength of the wakes generated by the piers themselves. Perhaps most importantly, it will be necessary to increase the density of measurement points in the immediate vicinity of the bypass entrance slot, both vertically and horizontally. As discussed in Section IV below, the behavior of observed smolts appeared to be influenced to some degree by the hydraulic conditions in the immediate vicinity of the bypass entrance slot. Therefore, it is most important that the CFD model accurately characterize the flow field in the vicinity of the bypass slot.

No velocity measurement points were attempted behind the louver panels during this study. The internal supporting framework for the louver panels is not visible from above the water surface, and the design drawings available do not make the configuration of the submerged members precisely clear. Therefore, the significant risk of potential damage to the probe outweighed the value of additional velocity measurements behind the louvers. Instead, simple continuity calculations, using the measured flow field inside the louver bay, were made to approximate the average flow velocity behind the louvers. As it turns out, this was apparently a fine assumption, as the velocity field inside and outside the louver bay is surprisingly uniform at the intake flows measured. Future measurements at higher flows may cast some doubt on the validity of this assumption, however. Therefore, in anticipation, additional point measurements may be required behind the louvers during future work at higher intake flows to define the velocity field exiting the louvers.

B. CFD Model development

1. Background and Objectives

As discussed above, the intake structure at Mayfield Dam consists of two similar entrance bays. Each bay incorporates a louver guidance system to enhance passage of downstream migrating juvenile salmonids. The main objective of this study is to develop the tools and acquire the field data necessary to determine the effectiveness of the louver system. To this end, a 3-D CFD model of the south entrance bay was developed. The main purpose of the CFD model is to quantitatively characterize the flow field in the entrance bay upstream of the louvers. Also, as discussed above, field data velocity measurements were acquired throughout the south entrance bay to calibrate and verify the CFD model. Finally, to quantify fish movement within the entrance bay, a detailed 3-D acoustic tag tracking program was accomplished as discussed in Section C below. As a result of the fish tracking program, approximately 20 usable and distinct fish tracks were acquired, indicating the precise movement of each individual fish within the entrance bay.

The primary purpose of the CFD model is to characterize the flow in the entrance bay upstream of the louvers. To build confidence in the CFD results, the CFD model was verified by comparing computed and field data velocities for both a low flow (Q=1290 cfs) and a higher flow (Q=2580 cfs). Once verified, the computed velocity field (obtained with the CFD model) was compared with the fish track data to discern possible correlations between the velocity field and fish movement as discussed in more detail in Section IV below. Furthermore, the CFD model can be modified to reproduce the flow conditions present during any future fish tracking studies; thus, enabling comparisons between fish movement and the flow field for future fish tracking programs at Mayfield Dam. Additionally, the CFD model can be used as a predictive tool to evaluate the effect of various flow and geometry modifications on the velocity field in the entrance bay. For instance, the CFD model can be modified to represent different louver geometries, and the results from the various scenarios can be compared to ascertain their effectiveness. Similarly, the CFD model can be run over a range of flow rates to determine the effect of flow rate on the velocity field within the entrance bay.

2. CFD Model Description

In general, 3-D CFD modeling consists of two main tasks: (1) generating a grid, and (2) solving the governing equations that describe the fluid flow. The geometry of the south entrance bay was supplied as a solid model CAD drawing (see Figure 7 below).

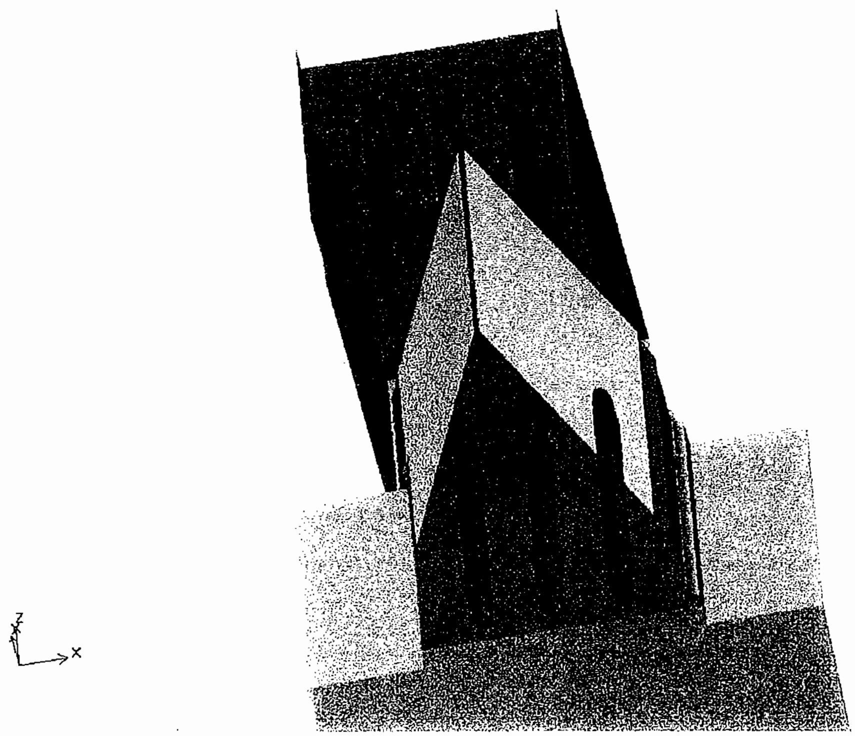


Figure 7: 3-D Solid CAD Model of South Louver Intake Bay

From this CAD drawing, a 3D grid consisting of approximately 700,000 elements was generated using the commercial grid generation software **ICEM-CFD** (see Figure 8 below).

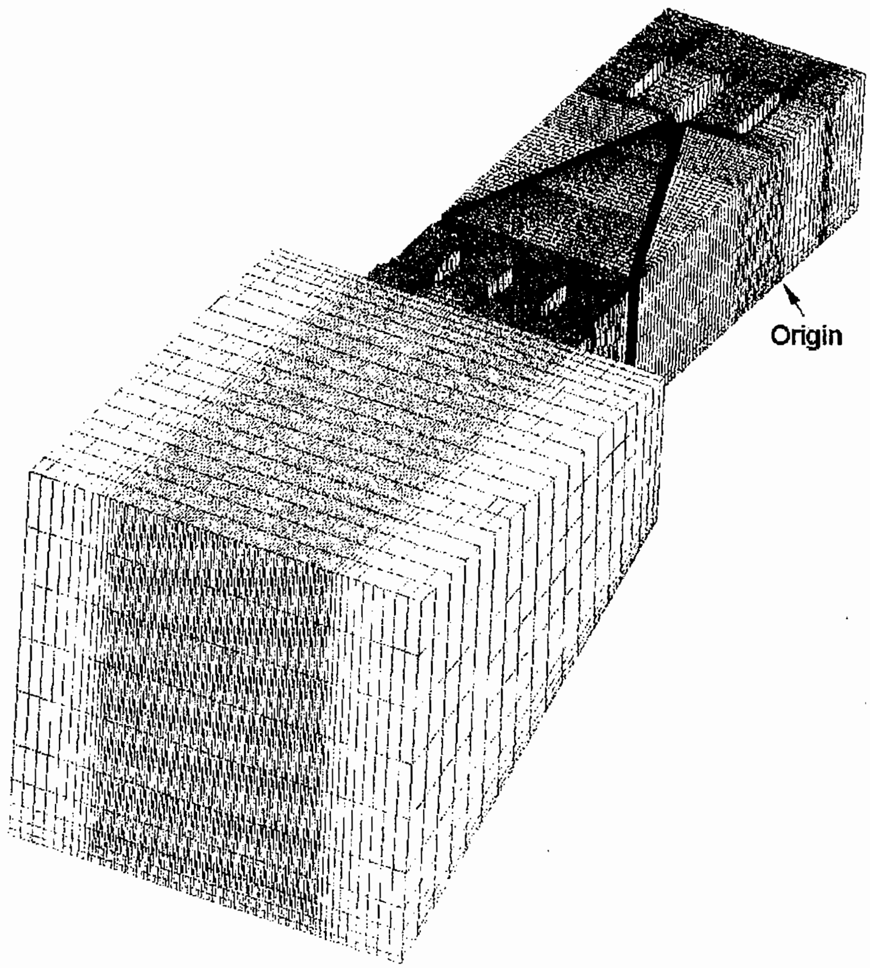


Figure 8: CFD Model Computational Grid

The grid included the piers and louvers as solid boundaries – the support structures downstream of (or behind) the louvers were not incorporated. The fish bypass was included as a specified flow boundary on the downstream center pier. Also, a portion of the reservoir was attached to the entrance bay to help stabilize the entering flow.

Before a CFD model can be run, boundary conditions must be applied to the grid. Several types of boundary conditions were employed in the present model. All solid boundaries were modeled as no-slip no-flow boundaries – except the louvers, which were modeled both as free-slip and no-slip no-flow boundaries. The water surface was modeled as a free-slip rigid-lid boundary. At the inlet, a fixed velocity was specified, producing the desired inflow. Two outlet boundaries were present: the fish bypass slot and the main channel exit. A flow "split" was prescribed between these boundaries.

The governing equations that describe the flow were solved using the commercial CFD solver **STAR-CD**. The model was run in a steady-state mode and turbulence closure was achieved using the industry standard high Reynold's number k-ε turbulence model. The high Reynolds number model is appropriate in this study, since the Reynold's number (flow velocity to fluid viscosity ratio) is well within the turbulent flow range. The model results were graphically depicted using the commercial visualization package **Tecplot**.

Six separate model runs were made as part of this study (Run01 – Run06). Table 1 below lists the various parameters associated with each model run.

Table 1: CFD Model Runs

Run	Flow (cfs)	Louvers	Comments
Run01	1290	free-slip	low flow verification, compare with field data
Run02	2580	free-slip	higher flow verification, compare with field data
Run03	5000	free-slip	show ability to run model at higher flow
Run04	7500	free-slip	show ability to run model at higher flow
Run05	1290	no-slip	examine effect of using no-slip louvers, compare with Run01
Run06	2580	no-slip	examine effect of using no-slip louvers, compare with Run02

The first two runs (Run01 and Run02) are the most important – these are the verification runs. The purpose of Run01 and Run02 is to determine whether the computer model is accurately representing the flow in the entrance bay by comparing the computed results with measured field data. Since normal water years (2001 was a very low water year) typically provide for somewhat higher flows through the entrance bay than those observed during the calibration, it is important to demonstrate the model's ability to run at higher flow rates. Thus, Run03 and Run04 were performed at 5000 cfs and 7500 cfs, respectively. Run05 and Run06 were performed to examine the effect of different boundary conditions on the louver screens (no-slip), as compared to the verification runs 01 and 02 (free-slip).

3. Results

As discussed in Section A above, 3-D velocity measurements of the flow field in the south intake bay were made at elevation 395.6 ft msl (80% of depth), 402.7 ft msl (60% of depth), and 416.4 (20% of depth). The field data were obtained throughout the entrance bay for a low flow (Q=1290 cfs) and a higher flow (Q=2580 cfs). Although the CFD model output includes 3-D velocity vectors throughout the entire intake bay, those vectors computed at the 20%, 60%, and 80% of depth horizontal plumes are shown in most of the plots of modeling results (Appendix C). Figure 9 below shows the 3-D solid model of the intake bay, with the 3-D CFD model grid elements for these three horizontal planes illustrated.

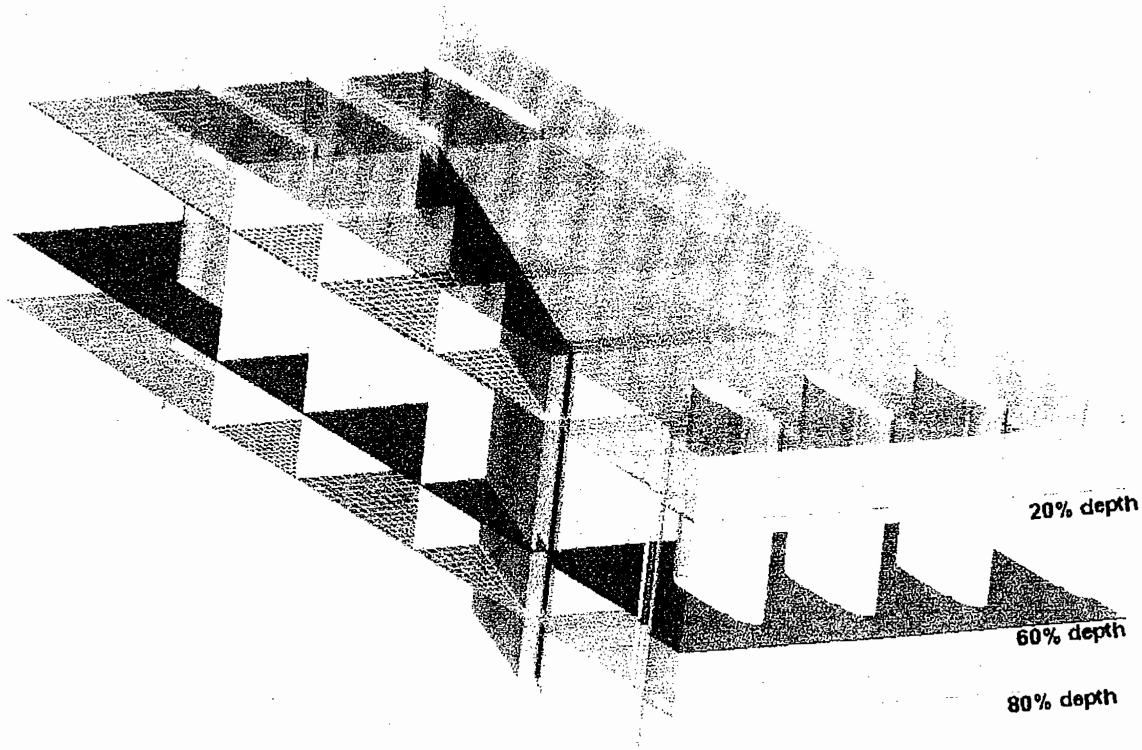


Figure 9: Horizontal Planes in 3-D CFD Grid at which field velocity measurements were made

The computed results are depicted as contour, vector, and streamline plots. First, to verify the model, the computed results were compared with prototype field velocity measurements. Verification Run 01 executed the CFD model for the conditions observed in the field where both intakes where open and passing about 1290 cfs each, with a forebay elevation of about 423 ft msl. Figure C-1 in Appendix C illustrates the predicted velocity field from the CFD model at elevation 395.6 ft msl and 1290 cfs intake flow with a few selected velocity vectors shown. Predicted velocity vector magnitude and direction (shown by the red vectors) at this elevation and discharge compare extremely well with the velocity vectors measured in the field, as shown by the black (CFD-predicted) and red vectors (field-measured) in Figure C-2. The predicted flow field in the local vicinity of the louver vanes for this condition is shown in Figure C-3. Verification runs 01 and 02 were made with a free-slip louver vane surface in the CFD model. Note that flow does not really begin to turn into the louver at more than about 2.5 or 3 inches from the vane edge. This was documented in the field measurement program as well, where point vectors measured within 1.75 inches of the vane edge showed some deflection into the vanes, but point velocities measured 12 inches away from the vane edge showed no such deflection. Figures C-4 through C-6 and C-7 through C-9 show similar information for 1290 cfs at the 60% depth (elevation 402.7 ft msl) and 20% depth (elevation 416.4 ft msl), respectively.

Verification Run 02 executed the CFD model for the conditions observed in the field where only the south intake was open and passing about 2580 cfs, also with a forebay elevation of about 423 ft msl. As discussed above, this condition represents project outflows under normal operation of about 5000 cfs, with uniform flow through each intake bay. Figures C-10 through C-18 show the same information for this higher flow as Figures C-1 through C-9, as discussed above. Note again that the CFD-predicted velocity vectors (black vectors in Figures C-11, C-14, and C-17) compared quite favorably with the field-measured velocity vectors (red vectors). Note also in Figures C-12, C-15, and C-18 that the higher flows cause the flow 'turning' effect of the louvers to extend only a little further into the intake bay. Again, the field measured point velocity vectors confirm this prediction by the CFD model. Overall, the intake flow is quite uniform and the louvers are porous enough to prevent significant influence of the louver vanes on the overall direction of velocity vectors except in the near vicinity of the louver vane edge itself. From the verification runs, the following is evident:

(1) In general, the comparison between the computed and measured velocity magnitude and direction is favorable. This agreement between the computed and measured velocity shows that the model is capable of reproducing actual flow conditions within the entrance bay upstream of the louvers.
(2) Some discrepancies occur between the computed and measured results near the louvers and near the fish bypass entrance; however, it should be noted that obtaining accurate field data at these locations was somewhat difficult.
(3) Throughout the majority of the region upstream of the louvers, the flow pattern is nearly straight and parallel (i.e. the vectors are oriented along the entrance bay's longitudinal axis).
(4) Throughout the majority of the entrance bay, the contour plots indicate only minor variations in the flow field in the vertical direction. The velocity magnitude increases slightly with depth. Also, some variation in velocity magnitude and direction is observed between the piers at different depth slices.

As discussed above, the model was run with the louvers represented as both free-slip surfaces (verification runs), and as no-slip surfaces (Run05 and Run06). Free-slip surfaces model a boundary where the fluid is permitted to 'slide' along the surface without developing a boundary layer resulting from friction with the roughness of the surface itself. No-slip surfaces model a boundary where the fluid is 'stretched' along the boundary as a result of friction with the surface itself. Although the no-slip surface is the more realistic of the two, in this case there is insufficient model grid resolution to produce a realistic boundary layer thickness. The scope of this project did not permit the development of the fully realistic model of the louver vanes themselves as a no-slip surface, as that would require considerably more resolution in the model grid. However, both conditions were run in the model to determine, for this pilot study, the most appropriate method at this reduced scope of representing the louver vanes. Future studies of specific louver variations can and perhaps should represent the louver vanes as no-slip surfaces, with a correspondingly denser grid between the vanes. This will require substantially more computational time, as the grid will consist of perhaps millions of elements, as opposed to the present 700,000.

The results from Run05 and Run06 are shown in Figures C-19 through C-21 (no slip surface and 1290 cfs) and Figures C-22 through C-24 (no slip surface and 2580 cfs). Note that the no-slip surface boundary condition permits better definition of boundary layer effects and hydrodynamic 'shading' of the flow entering and passing through the louver vane structure. The areas of lower velocity shown in Figures C-19 through C-24 demonstrate that the 'turning' effect of the louver vanes and the hydraulic characteristics of flow between the louvers may play a large role in the observed behavior of the smolts in the immediate vicinity of the louver vane edge and panel surface. As discussed in Section 1 above, the CFD model grid was generated in such a way as to rather easily modify the porosity and structure of the louver arrangement if the need arises in future studies to evaluate louver panel structural changes. Overall, the following is evident from modeling the louvers as no-slip surfaces:

(1) The streamlines clearly show that the velocity is deflected in the immediate vicinity of the louvers and that the deflection does not persist appreciably into the main flow stream. Away from the louvers, the streamlines are nearly straight and parallel.
(2) The velocity magnitude is reduced as the flow enters the louvers and increased as the flow exits the louvers.
(3) The flow does not enter the louvers evenly. This is due to the turning vanes that are attached to every fourth louver. More flow enters the louver slot just upstream of the turning vane, while less flow enters the louver slot just downstream of the turning vane.
(4) Comparing Run01 (free-slip) with Run05 (no-slip) and Run02 (free-slip) with Run06 (no-slip), it is evident that the boundary conditions applied on the louvers affects the computed solution both within the louvers and away from the louvers in the main channel. Modeling the louvers as no-slip boundaries reduces the active flow area between the louver slots because the velocity on the louver itself is set to zero (free-slip louvers allow a velocity at the louver face). This reduced velocity is apparent as a blue zone of low velocity in Figures C-19 through C-21 for the lower discharge of 1290 cfs, and Figures C-22 through C-25 for the higher discharge of 2580 cfs. This low velocity zone is not present when the louvers are modeled as free-slip boundaries (Figures C-3, C-6, C-9 for low discharge 1290 cfs, and Figures C-12, C-15, C-18 for high discharge 2580 cfs). In addition, the no-slip louver boundary condition reduces the velocity magnitude away from the louvers in the main channel. In this study, it was found that free-slip louvers produced a slightly better match with the field data than no-slip louvers.

C. Fish Tracking

1. Study Objectives

The primary objective of this study was to demonstrate the Acoustic Tag Tracking Systems (ATTS) ability to monitor tagged juvenile coho salmon within the fish guidance system at Mayfield Dam. Specifically, the goal of the 2001 ATTS monitoring program was to determine if the technology could resolve the fine-scale location over time (swimming paths) and behavior of juvenile coho as they passed via the louver intake system to either the fish bypass or the power canal. Secondary objectives included:

1) To assess the viability of using the HTI acoustic tag tracking system in a confined area that is bordered by steel which can often be a hindrance to acoustic systems.

2) To characterize swimming behavior patterns (residence time, exit locations, residence locations, etc) of acoustically tagged juvenile coho.

3) Validation of precision surrounding the estimates of target location. A precision of at least 0.3 meters surrounding target location in the hydrophone array was required for the purposes of the study.

Successful resolution of these issues would allow consideration of the ATTS technology for longer-term and more detailed studies of the Mayfield Dam louver bypass system in future years, as part of the FERC project relicensing process.

2. Materials and Methods

a) Background

Acoustic tags have been used to monitor fish movement for over 25 years. The majority of tracking studies to date have used manually-aimed directional hydrophones. In general, a single hydrophone is mounted in a boat, and the boat follows a tagged fish while it migrates. The detection location is recorded; however, the depth and range from the hydrophone to the fish is not known. In the 1970's attempts were made to use multiple hydrophones to better fix the location of tagged fish. By measuring the difference in arrival time of pings from acoustic tags implanted in fish, the approximate location of each fish could be determined. This principle serves as the basis for the operation of the HTI *Model 290 Acoustic Tag Tracking System*. Recent advances in signal processing hardware, computers, software and application techniques have allowed successful field applications of fine-scale acoustic tag tracking techniques.

The HTI *Model 290 System* used at Mayfield Dam in 2001 has the capability to automate the target-tracking process and thereby fix fish in three dimensions with a high degree of precision. Eight omnidirectional hydrophones were used to monitor the south louver bypass at Mayfield Dam. The hydrophones were placed in known locations and were mapped within a three-dimensional grid. As a juvenile coho with an active implanted acoustic tag passed through the monitored area (defined as within the detection range of any of the eight hydrophones), the difference in the arrival time of each pulse was used to triangulate the exact location of the tag. Simultaneous echo returns from at least 4 hydrophones were required to fix a position in 3-dimensions. Fewer hydrophones provided 2-D resolution, or general presence/absence of individual fish. Each tagged fish utilized a unique tag coding to identify individual coho over time and location.

b) Frequency Selection

Most commercial acoustic tags use frequencies between 50 and 100 kHz. Historically, 74 kHz has been the most common frequency (Mitson 1978). Two major factors that affect the selection of a transmitting frequency for acoustic tags are the range of detection and size of the tag. In general, as the frequency decreases, both the size of the tag and range of detection increase.

Hydroelectric projects are acoustically noisy over a broad spectrum of frequencies. In general, the ambient noise level decreases with increasing frequencies, since the sounds generated at hydroelectric projects are due primarily to mechanical noise. Results from a 1997 study (HTI 1997) concluded that the best choice for tag frequency at hydroelectric projects was 300-500 kHz (the background noise levels were lower at these frequencies). Based on these studies, a tag frequency of 300 kHz was selected for the Mayfield Dam 2001 acoustic tag study.

c) Acoustic Tags

The tags selected for use at Mayfield Dam were HTI 795 series tags. The tags were small, capsule-shaped tags designed to be orally or surgically implanted (Figure 10). The tags were 17.7 mm long and 7 mm in diameter (0.8 x 0.3 inches). The weight in air for each tag was 1.5 g (0.05 oz) and weight in water was 0.8 g (0.03 oz). Transmit power level was approximately 157 dB uPa @ 1 m. Pulse rate and pulse width were programmable. Nominal pulse rate was 1 pulse/sec with a transmit pulse width of 1-3 msec. The useful life of the tag, once activated, was on average 10 to 12 days.

Signal-to-noise performance has been enhanced in the 795-series tags over the previous series through the use of phase-code modulation (Figure 11). This technology allows for higher time resolution (and thus range resolution) for a given signal-to-noise ratio. The tags are programmable to accommodate five different phase-code modulations; with pulse widths ranging from 1 ms to 5 ms. The tags can also be programmed with standard CW pulse widths ranging from 0.1 ms to 10 ms, although the phase-code modulation maximizes the signal-to-noise resolution and target detection range and is normally utilized.

Figure 10: **HTI Model 795-series acoustic tags, as used during the 2001 Mayfield Dam acoustic tag study**

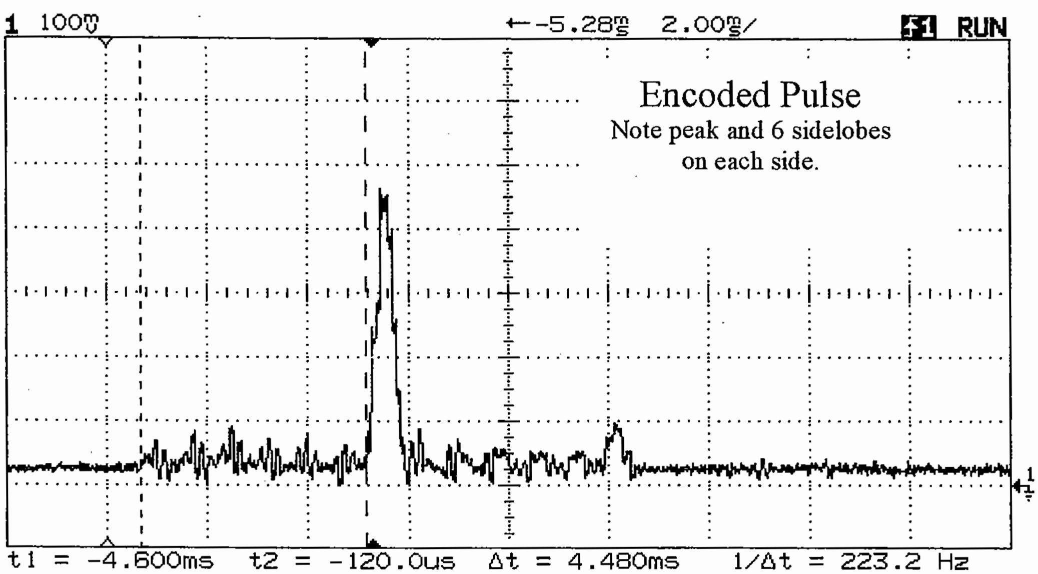


Figure 11: **Acoustic tag encoded pulse used in Mayfield Study. The peak amplitude of the pulse is the effective pulse width used for fish positioning. The surrounding peaks of lower amplitude are used by the 290 system to filter out background noise.**

d) HTI Model 290 Acoustic Tag Tracking System

An HTI *Model 290 Acoustic Tag Tracking System (ATTS)* was used for the 2001 Mayfield Dam louver assessment. The acoustic tag receiver was designed to receive on up to 16 separate hydrophones, though only 8 hydrophones were used in the 2001 deployment at Mayfield Dam. Received signals were synchronized in order to determine time of arrival for each detected pulse. Arrival time of the pulse at each hydrophone was used to determine the location of the tag moving through the forebay. These data were saved in digital format and a tracking program was used to track the received signal from the 8 separate hydrophones. The systems were operated for 24 h/d, 7 d/wk from May 30, 2001 through June 20, 2001.

The fish tracks were plotted in three dimensions using the HTI software program *ACOUSTIC TAG*. The *ACOUSTIC TAG* program is an animated, interactive display that allows the user to view individual pulses, large groups of pulses, or the entire trace for each fish. The display provides a three-dimensional background showing a representation of the coverage area including important structures such as the turbine entrances and spillgates. Figure 12 provides a view from within the *ACOUSTIC TAG* program with labels on the significant structures. While actively viewing fish traces within the program, the user can adjust the field of view to move spatially within the program (forward, backward, up, or down). This allows several different perspectives to be taken for any given fish trace.

Specific operation of the HTI *Model 290 ATTS* and *ACOUSTIC TAG* software is described in the operators manual (Timko et al. 2000).

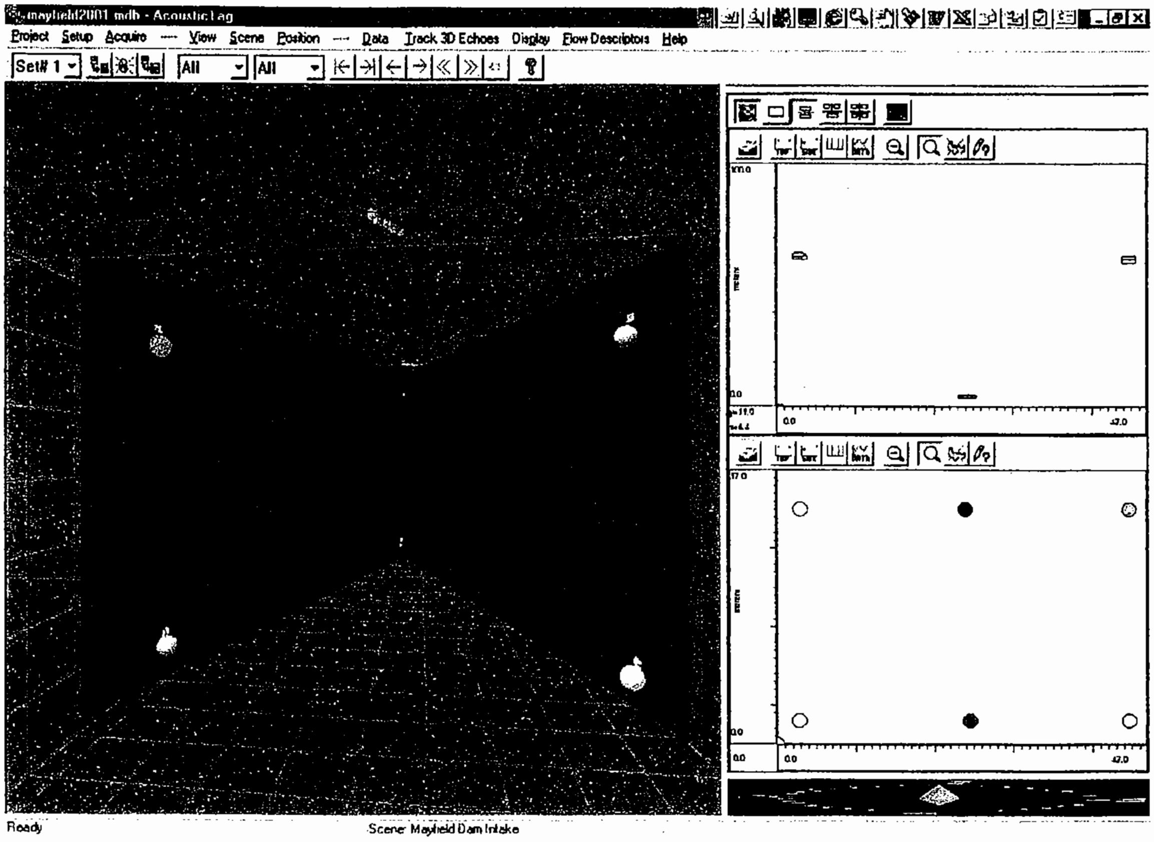


Figure 12: **Typical graphic representation of the Mayfield Dam South Louver Intake as seen in the Acoustic Tag program showing the louver walls, bypass and hydrophone locations.**

e) Hydrophone Deployment

Six omnidirectional hydrophones were installed around the perimeter of the South Intake at Mayfield Dam. A single hydrophone was placed in both the secondary separator (B3) and the power canal powerhouse forebay (B4) (Figure 13). The calculation of the three-dimensional location of the acoustic tags requires that the transmitted signal be detected by four hydrophones that are not located on the same plane. Therefore for this study, three of the hydrophones were mounted on louvers, just below the water surface (A1, A3, B1), while three hydrophones were mounted on the base of the louvers (A2, A4, B2). Table 2 presents the X, Y, and Z coordinates of the 8 hydrophones (in Washington State plane coordinates). For general reference, net movement upstream into the forebay corresponds to increasing northing and easting values. An increasing Z value corresponds to decreasing water depth, i.e. approaching the surface.

Hydrophones were mounted in vertical pairs within the louver array. Each hydrophone within a pair was mounted on an aluminum pole, one high, and one low. Each aluminum pole was then lowered into the water and rigidly mounted directly to the louver panels at each corner of the V-shaped intake structure. The fine-scale positions of the near bottom hydrophones were determined by transmitting a signal from the near-surface sensors (with absolute known X, Y and Z coordinates) to the near-bottom hydrophones and measuring the signal delays, in a manner similar to the method used to calculate the three-dimensional position of the tagged fish. After "surveying in", that is triangulating ranges from all hydrophones to one another based on measured distances and time delays, the overall hydrophone position accuracy within the entire south louver array was estimated to be less than 3 inches (7cm).

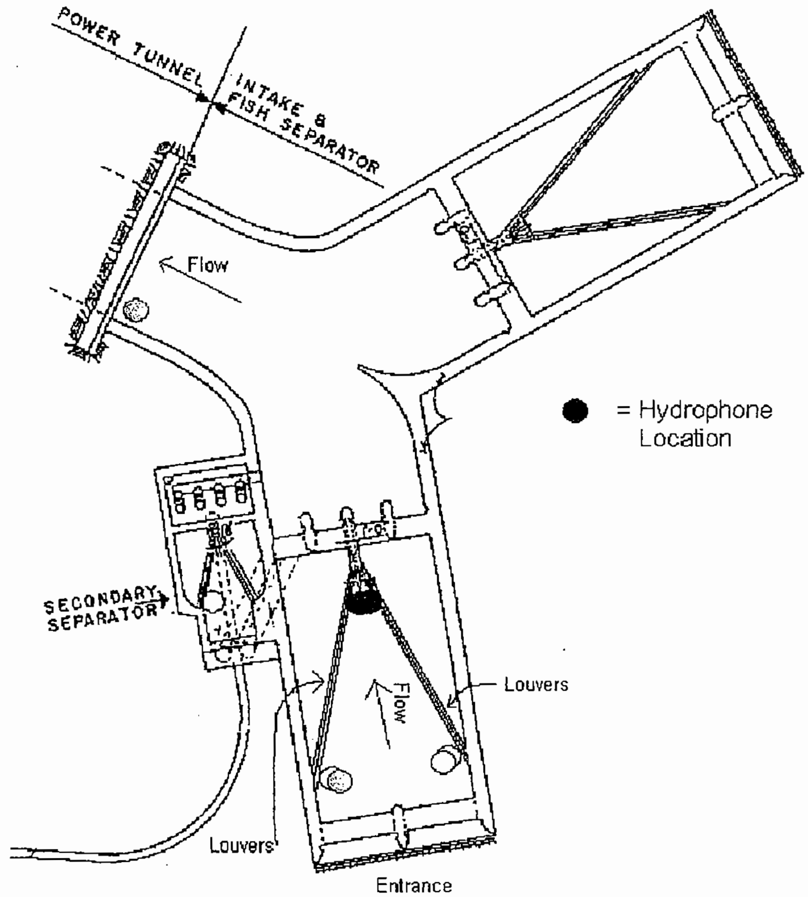


Figure 13: Plan view of the Mayfield louver array and hydrophone locations.

Table 2
Hydrophone mounting locations (X, Y and Z coordinates in meters from the grid origin) in the South Intake Louver during the 2001 acoustic tag study at Mayfield Dam

Hydrophone	Channel	Mount	Location X-plane	Location Y-plane	Depth Z-plane	Label
1	1	BOTTOM	3.00	61.25	31.71	A1
2	2	SURFACE	2.90	62.20	3.21	A2
3	3	BOTTOM	44.75	61.25	31.71	A3
4	4	SURFACE	44.75	59.90	3.21	A4
5	5	BOTTOM	24.00	4.17	31.71	B1
6	6	SURFACE	24.50	4.17	3.21	B2
7	7	SURFACE	N/A - Located in Bypass			#7
8	8	SURFACE	N/A - Located in Power Canal			#8

f) System Calibration and Testing

Each component of acoustic tag system (hydrophones, cables, acoustic tag receiver and computer) were thoroughly tested and calibrated at HTI's facility in Seattle, Washington prior to installation at Mayfield Dam. In addition, the following on-site tests were conducted prior to release of tagged fish.

(1) Stationary Tag Position Test

To verify consistent three-dimensional tag positioning over time (precision), a stationary test was performed by placing a static tag in the center of the array. A tag was fixed to a rigid aluminum pole, which was attached to a walkway that spanned the louver array. The tag was coded to ping at once per second and at the same pulse width as would be used in tags released in smolts. The tag was suspended in the array for 19 minutes. Of the 1,140 individual echoes produced by the stationary tag (60 pings per minute for 19 minutes), solutions were derived for 1,084 of the echoes (95%). The standard deviation of the solved positions along each axis was characterized as very low (X = 1.5 inches, Y = 1.5 inches and Z = 3 inches). A screen display from the *ACOUSTIC TAG* program showing the results of the test is presented in Figure 14.

Physical measurements using a surveyors measuring tape within the south lover array estimated the stationary tag position from grid origin to be 28.35 meters in the X-dimension, 45.65 meters in the Y and 32.4 meters in the Z-dimension (depth), respectively. The measurements were in agreement with hydrophone-derived estimates, indicating that the array was accurately surveyed in place and functioning correctly.

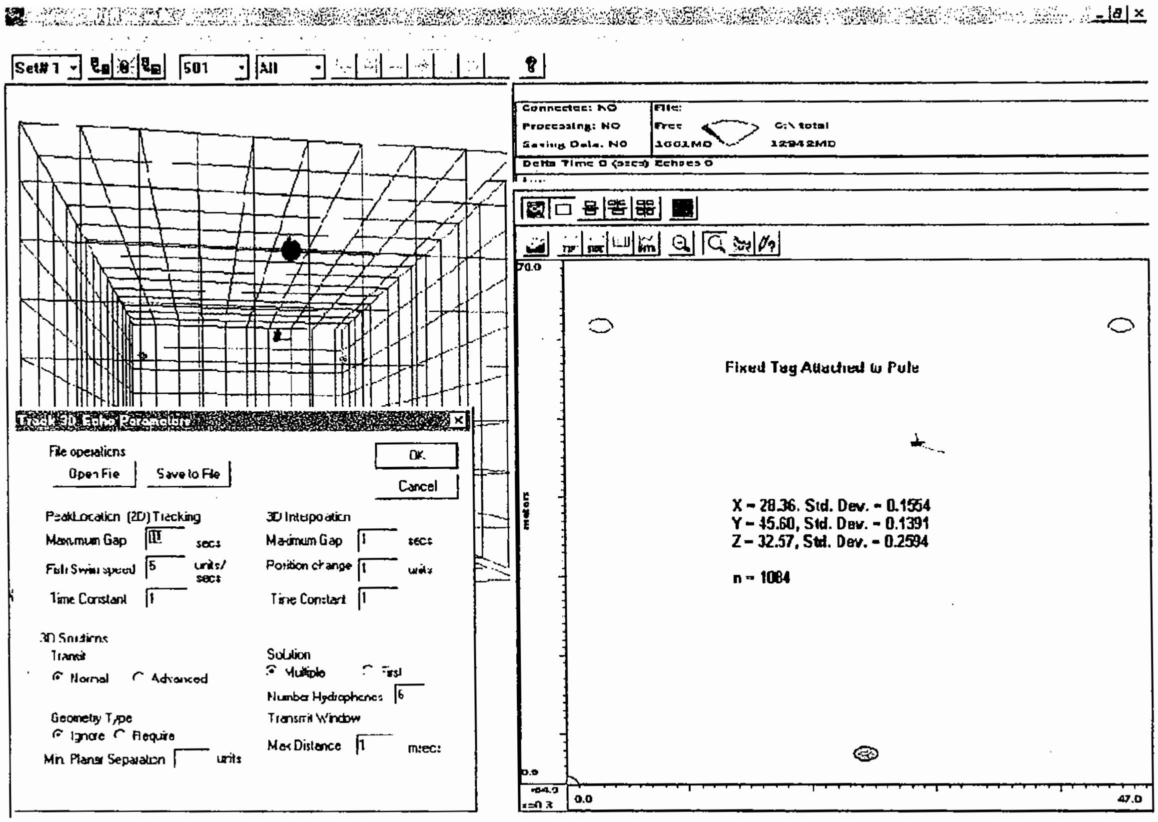


Figure 14: Plan view and 3-D view of stationary test results, including standard deviation of tag position error.

(2) Mobile Tag Position Test

Following verification of accurate tag positioning at a single-point in the approximate center of the array, a mobile tag position or "drag" test was performed by moving a tag affixed to an aluminum pole around the perimeter of the louver array at a fixed depth. Again, the tag was coded to ping at once per second at the same pulse width used during routine monitoring activities. The results of the mobile tag evaluation are shown in Figure 15.

The results of the drag test were generally qualitative in nature and were intended to validate the relative precision and accuracy with which an acoustic tag could be located across the monitored louver bay. In particular, to assess whether areas of diminished resolution existed near the boundaries of the array, i.e. near the louver faces and the surface. These regions were geometrically "outside of the box", that is not bounded by hydrophones on all sides. Typically, the most precise estimates of target location are obtained within the array.

The tag was walked around the perimeter of the south louver racks at a depth of approximately 0.3 meter and 0.1 to 0.4 meters from the louver racks. At the conclusion of the drag test the tag was reinserted behind (downstream) of the louvers in the power canal to determine if it could be detected through the louver structure.

Results of the drag test indicated that high and consistent levels of tag detectability existed across the entire south louver bay, both in close proximity to the louver structure and near the water surface. Both of these areas were expected to be "worst case" locations with respect to target resolution, but the field tests observed positional accuracy on par with the rest of the array and well within the 0.3 meter precision required for the study. The acoustic tag was also found to be detectable through the louvers in the power canal area.

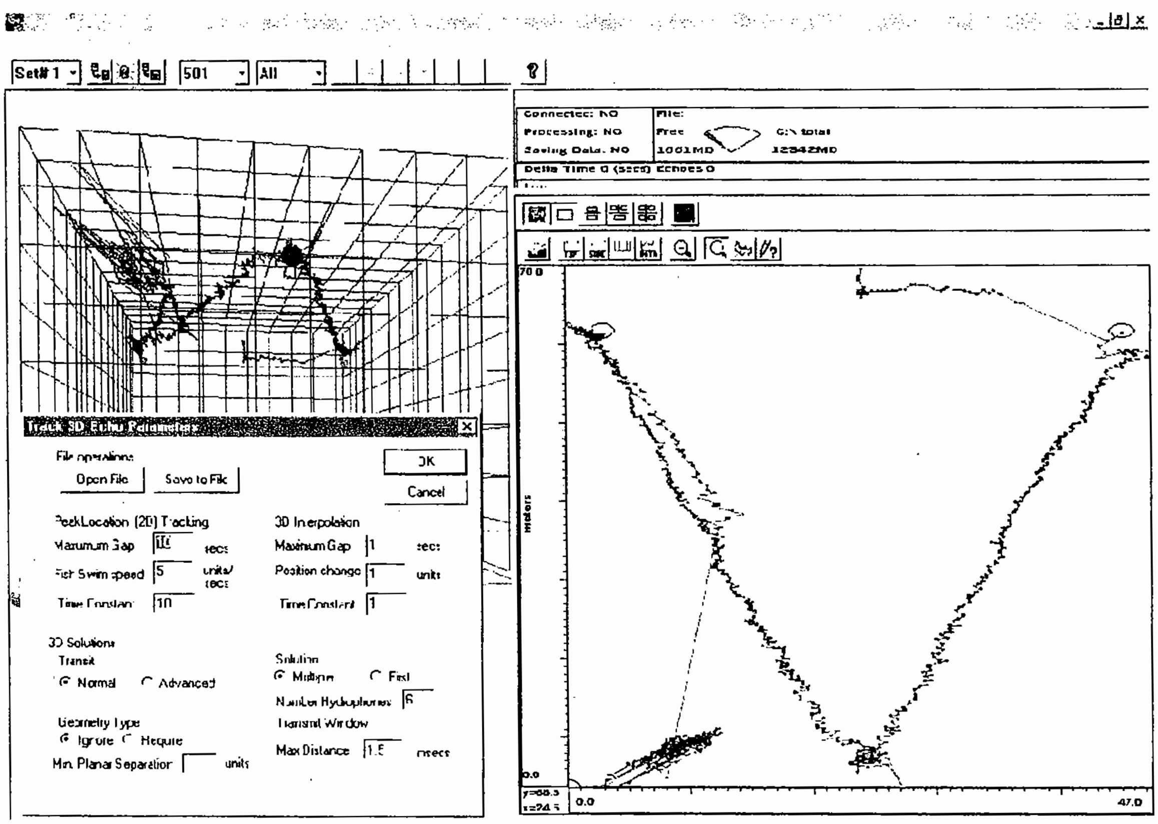


Figure 15: Plan view and 3-D view of mobile acoustic tag positioning test results. Mayfield Dam 2001.

g) Fish Procurement and Tagging

Coho smolts were the juvenile salmonid species of interest used for the 2001 acoustic tag evaluation at Mayfield Dam. All juvenile coho used in this study were of hatchery origin and were obtained from the Cowlitz Salmon Hatchery. All coho tagged in the 2001 Mayfield Dam study were from a single lot of hatchery fish and were marked with fluorescent green dye on the anal fin to aid in identification, if recovered at the fish bypass facility.

Previous to each week's release, sufficient coho were obtained from the hatchery and transported to Mayfield Dam, where they were implanted with tags. Only sufficient fish for that weeks release were transported. Tags were inserted gastrically after the fish were anesthetized with MS-222. Typical meristic characteristics were noted (length, width, scale loss, etc.). Figure 16 shows typical fish measurement and tag implantation procedures.

Fish were held for 24-hours in a shaded, flow through raceway adjacent to the south intake bay prior to release. Mortality or impairment of fish due to tagging was not observed in the release groups during the Mayfield Dam 2001 Acoustic Tag study. A single tag was regurgitated during the first release and was reimplanted in a new fish, held for 24 hours, then released. Following this initial tag regurgitation, which was likely due to technician inexperience with the gastric tag implantation technique, no additional tags were shed during subsequent holding periods.

Changes in behavior of tagged fish are primarily related to the ability of the fish to compensate for the additional mass of the tag in order to achieve neutral buoyancy (Perry, et al., 2001). The recommended maximum tag-to-fish weight ratio is 0.5% (Adams et al. 1998a, 1998b). Given that the weight of the tags in water was 0.8g, all tagged fish in this study were large enough to exceed this ratio.

Figure 16: Following measurement of length, weight and condition, acoustic tags were gastrically-inserted into each coho smolt.

h) Fish Releases

During the 2001 acoustic tag study at Mayfield Dam, tagged coho were released in three different groups, from two different locations (Figure 17).

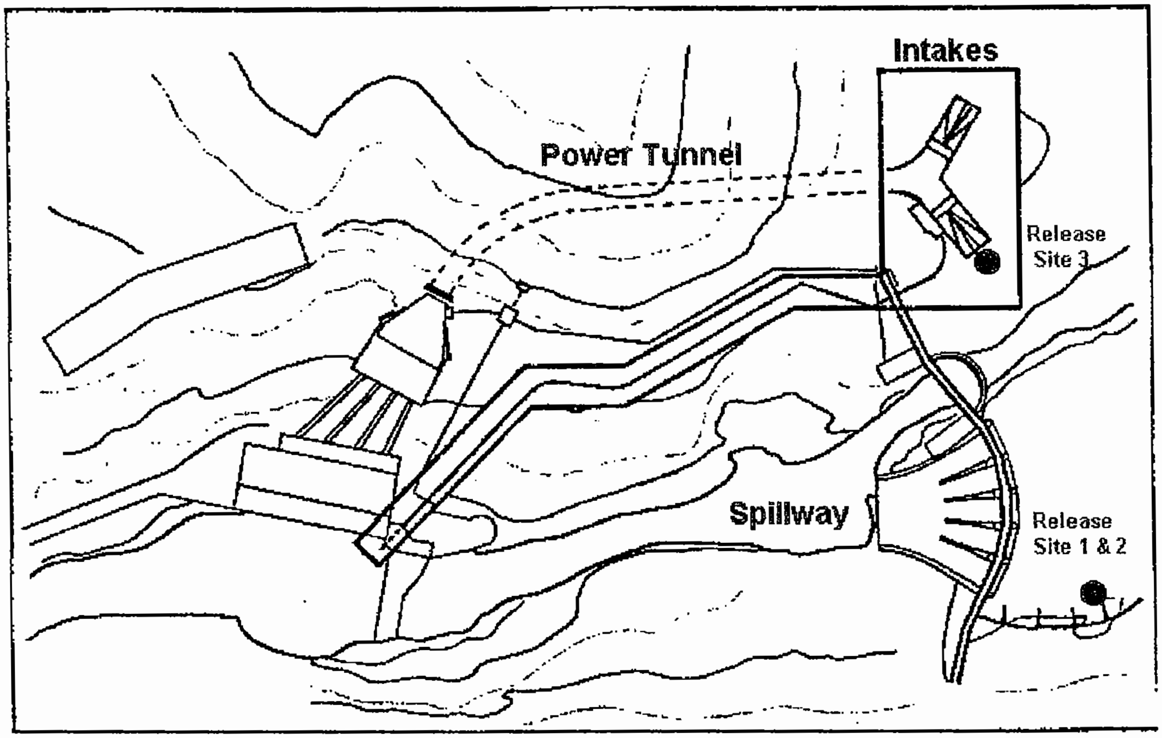


Figure 17: Plan view of Mayfield project area and release locations of acoustically-tagged coho in 2001.

Releases 1 & 2

Releases 1 & 2 occurred across the forebay along the eastern shore of Riffe Lake. Fish were released as a group from the bank, just downstream of the point where the forebay floating trash boom meets the shore. The location is visible in the upper right hand corner of Photo 2, Appendix A.

Release 3

Release 3 occurred on June 12 from atop the trash boom immediately in front of the south louver entrance. Fish were released in pairs at approximately 15 minute intervals just inside of the apex of the floating trash boom structure (Figure 18).

The release location was changed between the second and third releases in an effort to maximize tagged coho passage through the south louver. Although the majority of fish from Releases 1 and 2 were observed by the hydrophone array, a percentage were not observed at all, indicating probable holding or movement upstream in the reservoir. A significant number also passed via the unmonitored north louver intake during the 2001 study period. It was hoped that releasing fish immediately in front of the south louver during Release 3 would influence a higher percentage of coho to pass Release 3 fish to enter the south louver as compared to fish released earlier in the study (Releases 1 and 2).

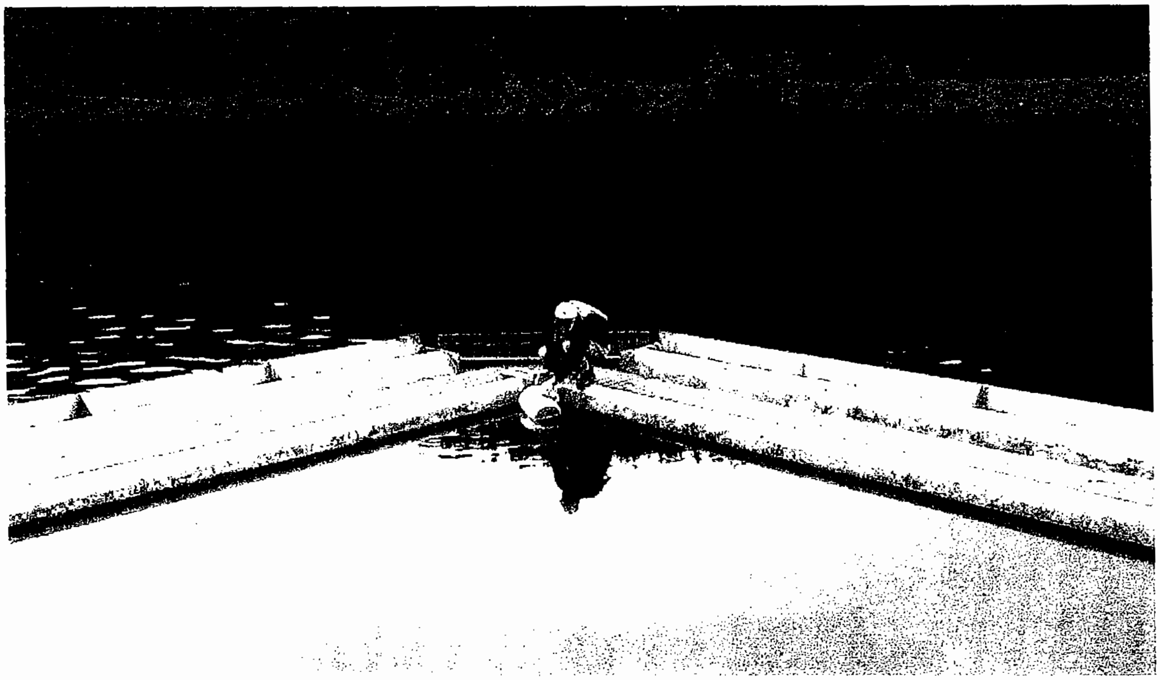


Figure 18: Release site #3 on the Mayfield Dam south intake trash boom. June 12, 2001.

i) Data Analysis

In excess of 250,000 individual target positions (as X, Y, and Z coordinates) were calculated over the entire study from tagged coho within, or immediately in front of, the south intake. Additional data from the bypass separator or power canal hydrophones determined the end destination of the majority of all released tagged coho, whether they passed via the south or north intakes.

These data were analyzed in multiple ways. For initial approach and passage, three-dimensional tracks of each fish were viewed in the *ACOUSTIC TAG* program (and each associated database). For fish passage, the tracks were viewed and exit location was determined based on where the fish was last observed.

For estimation of "residence zones", or patterns of fish distribution over time, data were imported into a modeling software package. The Mayfield Dam study area was subdivided into 97,825 individual "zones", each zone being a 1-foot cube. In order to assess fish residency/density over the duration of the study, fish positions were assigned to a particular "zone" of residence corresponding to their X, Y, and Z positions. Each zone was assigned with a value based on the total number of fish positions detected in that zone over the entire study period.

Data were interpolated based on the kriging method (Davis 1973, 1986) between defined zones to assess general areas of tagged coho residence within the Mayfield Dam south louver intake.

Mayfield Releases 2001

√ – graph of track in final report

No tracks available if not bypassed or present in south louver

Fish Number	This Release	Rep Rate	Date Released	Total Length	Fork Length	Weight (grams)	Scale Loss?	Residence Time (hr:mm:ss)	Final Disposition	Last Seen	Comments	End Code	
1	1	1110	5/30/01 8:20	160	141	23.0	0%	34:33:00	Forays into S. Louver -Exit to Forebay	5/31/01 18:53		F	
2	2	940	5/30/01 8:20	155	142	27.5	0%	192:10:00	Bypassed via N. Louver	6/7/01 8:30		N-B	8 days
3	3	1070	5/30/01 8:20	163	151	35.5	0%	0:00:00	Not Observed	5/30/01 8:20		F	LOST
4	4	1060	5/30/01 8:20	160	145	34.8	0%	7:39:00	Bypassed via S. Louver	5/30/01 15:59		S-B	
5	5	√1080	5/30/01 8:20	153	142	30.2	0%	2:08:00	Power Canal via S. Louver	5/30/01 10:28		S-PC	
6	6	880	5/30/01 8:20	151	135	32.4	0%	5:30:00	Bypassed via N. Louver	5/30/01 13:50		N-B	
7	7	√950	5/30/01 8:20	159	146	34.9	0%	195:37:00	Bypassed via S. Louver	6/7/01 11:57		S-B	8 days
8	8	√1010	5/30/01 8:20	164	153	36.9	0%	1:18:00	Bypassed via S. Louver	5/30/01 9:38		S-B	
9	9	√960	5/30/01 8:20	164	152	32.4	5%	217:57:00	Bypassed via S. Louver	6/8/01 10:17		S-B	9 days
10	1	√990	6/5/01 8:09	172	160	40.3	0%	4:22:00	Bypassed via S. Louver	6/5/01 12:31		S-B	
11	2	√1130	6/5/01 8:09	155	142	31.2	0%	76:49:00	Bypassed via S. Louver	6/8/01 12:58		S-B	3 days
12	3	980	6/5/01 8:09	183	167	47.1	0%	0:00:00	Not Observed	6/5/01 8:09		F	LOST
13	4	900	6/5/01 8:09	174	163	44.2	0%	4:31:00	Bypassed via N. Louver	6/5/01 12:40		N-B	
14	5	√920	6/5/01 8:09	162	150	36.6	0%	29:52:00	Bypassed via S. Louver	6/6/01 14:01		S-B	
15	6	√1140	6/5/01 8:09	158	148	38.4	0%	24:40:00	Bypassed via S. Louver	6/6/01 8:49		S-B	
16	7	870	6/5/01 8:09	154	142	33.6	5%	0:00:00	Not Observed	6/5/01 8:09		F	LOST
17	8	√1090	6/5/01 8:09	164	154	39.3	0%	4:28:00	Bypassed via S. Louver	6/5/01 12:37		S-B	
18	9	√850	6/5/01 8:09	156	144	30.3	0%	50:06:00	Bypassed via S. Louver	6/7/01 10:15		S-B	
19	10	1120	6/5/01 8:09	174	166	45.2	0%	30:56:00	Bypassed via N. Louver	6/6/01 15:05		N-B	
20	11	970	6/5/01 8:09	189	177	56.9	0%	58:06:00	Power Canal via N. Louver	6/7/01 18:15		N-PC	
21	12	√890	6/5/01 8:09	166	154	39.0	0%	2:47:00	Bypassed via S. Louver	6/5/01 10:56	Recycled tag	S-B	Learned behavior
22	1	√810	6/12/01 8:50	159	147	33.0	0%	1:14:00	Bypassed via S. Louver	6/12/01 10:04	Recycled tag	S-B	" "

✓ - graphics of track in final report

Mayfield Releases 2001

Fish Number	This Release	Rep Rate	Date Released	Total Length	Fork Length	Weight (grams)	Scale Loss?	Residence Time (hh:mm:ss)	Final Disposition	Last Seen	Comments	End Code	
23	2	✓840	6/12/01 8:10	149	137	25.4	0%	0:21:00	Power Canal via S. Louver	6/12/01 8:31		S-PC	
24	3	✓1020	6/12/01 8:50	170	159	44.6	0%	27:22:00	Bypassed via S. Louver	6/13/01 12:12		S-B	
25	4	1040	6/12/01 8:10	144	136	22.2	5%	30:11:00	Bypassed via N. Louver	6/13/01 14:21		N-B	
26	5	1050	6/12/01 8:50	154	141	30.7	5%	1:20:00	Seen briefly on release	6/12/01 10:10		F	LOST
27	6	1100	6/12/01 8:10	164	152	35.9	0%	0:40:00	Seen briefly on release	6/12/01 8:50		F	LOST
28	7	✓1000	6/12/01 10:20	165	153	37.3	0%	0:10:00	Bypassed via S. Louver	6/12/01 10:30		S-B	
29	8	✓820	6/12/01 10:20	172	160	43.5	5%	0:42:00	Bypassed via S. Louver	6/12/01 11:02	Recycled tag	S-B	Learned behav
30	9	✓910	6/12/01 10:20	166	153	31.2	0%	79:10:00	Bypassed via S. Louver	6/15/01 17:30		S-B	
31	10	830	6/12/01 11:15	185	170	51.4	0%	17:25:00	Power Canal via N. Louver	6/13/01 4:40	Recycled tag	N-PC	
32	11	✓780	6/12/01 11:15	168	157	37.3	5%	6:41:00	Power Canal via S. Louver	6/12/01 17:56	Recycled tag	S-PC	
33	12	✓1030	6/12/01 11:15	159	147	36.3	0%	10:15:00	Bypassed via S. Louver	6/12/01 21:30		S-B	
34	13	930	6/12/01 14:15	164	151	34.1	0%	26:15:00	Bypassed via N. Louver	6/13/01 16:30		N-B	
35	14	✓860	6/12/01 14:15	170	158	41.2	0%	53:04:00	Bypassed via S. Louver	6/14/01 19:19		S-B	
36	15	✓800	6/12/01 13:15	174	160	42.1	0%	0:21:00	Bypassed via S. Louver	6/12/01 13:36	Recycled tag	S-B	
37	16	✓790	6/12/01 13:15	182	165	44.7	0%	1:06:00	Bypassed via S. Louver	6/12/01 14:21	Recycled tag	S-B	
38	17	1200	6/12/01 15:45	160	150	36.2	5%	14:00:00	Power Canal via N. Louver	6/13/01 5:45	Recycled tag	N-PC	
39	18	1210	6/12/01 15:45	159	148	29.4	5%	0:00:00	Not seen on release weak/dead tag?	6/12/01 15:45	Recycled tag	F	LOST

3. Results and Discussion

The individual tracks of each tagged fish are presented in Appendix D. Note that the tracking data are sequenced by tag code number, not by the date of release. Both the X/Y and Y/Z position data are represented on the simplified graphs, and a full 3-D representation is provided in the graphical output from HTI's software.

a) Fish Composition and Meristics

Thirty-nine tagged juvenile coho were released over the duration of the study. All fish were hatchery coho, collected from the Cowlitz River hatchery facility. Average fork length was 164 mm long (min = 144, max = 189) and average weight was 37 grams (min = 22, max = 57). Table 3 below shows specific information for each of the tagged fish.

Table 3 Replaced M. LeMoire 7/2002
Specific Information for Each Tagged Fish

Fish Number	This Release	Rep Rate	Date Released	Total Length (mm)	Fork Length (mm)	Weight (grams)	Scale Loss?	Comments	Disposition	Last Seen
1	1	1110	5/30/01 8:20	160	141	23.0	0%		Seen in S. Louvers	5/30 1900 h
2	2	940	5/30/01 8:20	155	142	27.5	0%		Entered Bypass via N. Louvers	6/7 1000 h
3	3	1070	5/30/01 8:20	163	151	35.5	0%		Never Observed	N/A
4	4	1060	5/30/01 8:20	160	145	34.8	0%		Bypassed via S. Louver	5/30 1559 h
5	5	1080	5/30/01 8:20	153	142	30.2	0%		Power Canal via S. Louver	5/30 1029 h
6	6	880	5/30/01 8:20	151	135	32.4	0%		Bypassed via N. Louver	5/30 1400 h
7	7	950	5/30/01 8:20	159	146	34.9	0%		Bypassed via S. Louver	6/7 1156 h
8	8	1010	5/30/01 8:20	164	153	36.9	0%		Bypassed via S. Louver	5/30 0938 h
9	9	960	5/30/01 8:20	164	152	32.4	5%		Bypassed via S. Louver	6/8 ??
10	1	990	6/5/01 8:09	172	160	40.3	0%		Bypassed via S. Louver	6/5 1345 h
11	2	1130	6/5/01 8:09	155	142	31.2	0%		Bypassed via S. Louver	
12	3	980	6/5/01 8:09	183	167	47.1	0%		Not Seen	
13	4	900	6/5/01 8:09	174	163	44.2	0%		Bypassed via N. Louver	6/5 2050 h
14	5	920	6/5/01 8:09	162	150	36.6	0%		Bypassed via S. Louver	6/6 1500 h
15	6	1140	6/5/01 8:09	158	148	38.4	0%		Bypassed via S. Louver	6/6 0850 h
16	7	870	6/5/01 8:09	154	142	33.6	5%		Not seen	
17	8	1090	6/5/01 8:09	164	154	39.3	0%		Bypassed via S. Louver	6/5 1310 h
18	9	850	6/5/01 8:09	156	144	30.3	0%		Bypassed via S. Louver	6/7 1000 h
19	10	1120	6/5/01 8:09	174	166	45.2	0%		Bypassed via N. Louver	6/6 1100 h
20	11	970	6/5/01 8:09	189	177	56.9	0%		Power Canal via N. Louver	6/7 1500 h
21	12	890	6/5/01 8:09	166	154	39.0	0%	Recycled tag	Bypassed via S. Louver	6/6 1200h
22	1	1000	6/12/01 10:20	165	153	37.3	0%		Bypassed via S. Louver	6/12 1050 h
23	2	1050	6/12/01 8:50	154	141	30.7	5%		Seen briefly on release	6/12 1000 h
24	3	1030	6/12/01 11:15	159	147	36.3	0%		Bypassed via S. Louver	6/12 1630 h
25	4	1040	6/12/01 8:10	144	136	22.2	5%		Bypassed via N. Louver	6/12 2100 h

26	5	1020	6/12/01 8:50	170	159	44.6	0%		Bypassed via S. Louver	6/13 0845 h
27	6	930	6/12/01 14:15	164	151	34.1	0%		Bypassed via N. Louver	6/13 0500 h
28	7	1100	6/12/01 8:10	164	152	35.9	0%		Seen very briefly on release	6/12 810 h
29	8	910	6/12/01 10:20	166	153	31.2	0%		Bypassed via S. Louver	6/13 0800 h
30	9	860	6/12/01 14:15	170	158	41.2	0%		Bypassed via S. Louver	6/12 1430 h
31	10	840	6/12/01 8:10	149	137	25.4	0%		Power Canal via S. Louver	6/12 1730 h
32	11	830	6/12/01 11:15	185	170	51.4	0%	Recycled tag	Power Canal via N. Louver	6/12 1150 h
33	12	820	6/12/01 10:20	172	160	43.5	5%	Recycled tag	Bypassed via S. Louver	6/12 1005 h
34	13	810	6/12/01 8:50	159	147	33.0	0%	Recycled tag	Bypassed via S. Louver	6/12 1005 h
35	14	800	6/12/01 13:15	174	160	42.1	0%	Recycled tag	Bypassed via S. Louver	6/12 1430 h
36	15	790	6/12/01 13:15	182	165	44.7	0%	Recycled tag	Bypassed via S. Louver	6/12 1430 h
37	16	780	6/12/01 11:15	168	157	37.3	5%	Recycled tag	Power Canal via S. Louvers	6/12 1600 h
38	17	1200	6/12/01 15:45	160	150	36.2	5%	Recycled tag	Power Canal via N. Louver	6/12 1545 h
39	18	1210	6/12/01 15:45	159	148	29.4	5%	Recycled tag	Not seen on release weak/dead tag?	6/12/1545 h

b) Fish Passage

<u>Ultimate Passage Route</u>

The 39 coho salmon tagged during the Mayfield Dam acoustic tag study were released in three groups, approximately one week apart between May 29 and June 12, 2001. Nine coho were released on May 29 (23% of the total study fish), 12 on June 4 (31%) and 18 on June 11-12 (46%). Thirty tags were purchased for the study by TPU. The additional nine tags released were recovered tags from the original lot. These tags were recovered from coho captured and identified at the bypass counting facility, reprogrammed and implanted a second or third time in new fish.

Table 4 presents the ultimate passage route for each tagged fish released during the study period. Total and percent passage are given by intake location and fish release number.

Of the 39 tagged coho released during the study period, 23 passed downstream via the south intake (59% of all fish released). Of these 23 coho, 20 were bypassed (87%) and 3 (13%) passed through the louvers and entered the power canal. General patterns of passage in the south intake were similar across all three fish releases, with 80-100% bypass rates and 0-20% passage via the power canal.

A total of 9 tagged coho passed downstream through the north intake structure (23% of the total study release). Six of these fish entered the north bypass (66.7%) and three passed through the louvers into the power canal (33.3%).

The end destination of approximately 18% of all fish released (7 individuals), were not resolved during the study period. The majority of these tagged coho were observed at least once in the vicinity of the hydrophone array and were presumed to have moved upstream. It is likely that these fish did pass the project at a later date after the tag batteries expired. This presumption is supported by the increased number of unknown destination tags observed in the third release, which included 8 recycled tags. The recycled tags had typically only 1-3 days battery life remaining and would not have been observed by the array if the coho did not move downstream relatively soon following release. Of 39 total fish released, 6 fish remained in the forebay more than 2.5 days (60 hours) prior to being detected as passing through the project, indicating that some fish delayed passing the project after release.

The final coho released during the 2001 survey (Fish 39) was never observed by the system, but the tag had been implanted three times and presumably lost power shortly after release for the final time. With new tags, battery life was estimated at 7-10+ days and virtually all of the coho tagged with new tags were observed by the *ATTS* system at some point (approximately 90% during Release #1). Whenever re-used tags were deployed, they were re-coded to distinguish them from their original release and to keep the results separate from new tags. Data from re-used tags should be considered as ancillary, since battery life may run out if fish delay passing the project. Re-use of tags with expected life of 2 or more days is cost effective and reasonable. Even though the opportunity to collect data from these tags is sometimes limited, it is still useful information.

Table 4
Final tagged juvenile coho downstream passage route by intake and release
Mayfield Dam, May 29 – June 20, 2001

	South Intake Bypass	South Intake Power Tunnel	Unknown	North Intake Bypass	North Intake Power Tunnel	By Release % of Study Total
Release 1	4	1	2	2	0	9
Percent	80.0%	20.0%	5.1%	100.0%	0.0%	23.1%
Release 2	7	0	2	2	1	12
Percent	100.0%	0.0%	5.1%	66.7%	33.3%	30.8%
Release 3	9	2	3	2	2	18
Percent	81.8%	18.2%	7.7%	50.0%	50.0%	46.2%
Totals	20	3	7	6	3	39
Percent	87.0%	13.0%	17.9%	66.7%	33.3%	100.0%

c) Fish Behavior

Tagged coho observed entering and ultimately passing downstream via the south intake generally exhibited one of three basic behavior patterns. These were termed "straight approach", "milling behavior" and "perimeter approach". These three swimming patterns within the south louver intake are shown in Figures 19-21.

(1) Straight Swimming Behavior

This pattern of approach behavior entailed a direct straight vector into the intake near the middle of the louver (away from the walls or structure), proceeding toward and entering the bypass slot opening at the apex of the louvers with little hesitation or meandering behavior. The approach was characterized as direct and relatively rapid. This type of behavior was noted more frequently in the hours following fish release. A typical example of this behavior is presented in Figure 19.

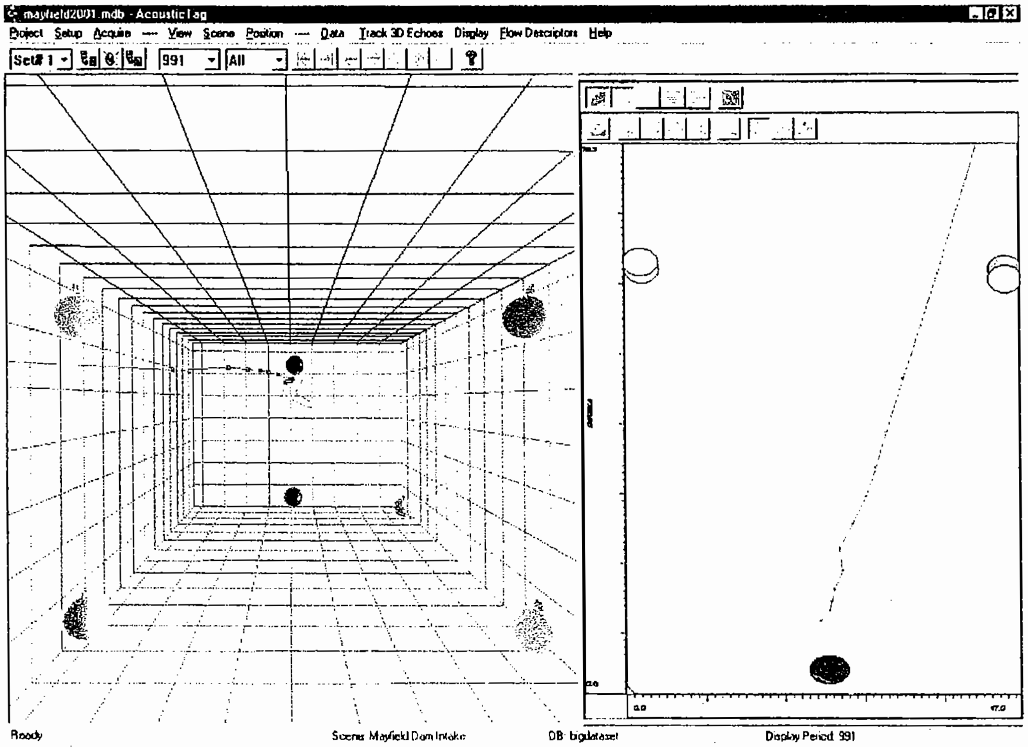


Figure 19: **Acoustic Tag™ program output showing an example of straight approach swimming behavior in the south louver intake, Mayfield Dam 2001.**

(2) Milling Behavior

Milling behavior was characterized as generally random swimming behavior within the south intake louver. Fish often entered the louver, made several forays toward the bypass opening, and then often held in the area downstream of the trash racks for extended periods. During this period of holding activity, these fish would periodically circle within the louver and frequently return to a given region. Fish exhibiting this behavior seemed to be more likely to exit the south louver at some point (relative to other patterns of behavior) in time, either returning at a later time, or entering the north louver. Figure 20 shows a tagged coho in the south intake exhibiting this type of behavior.

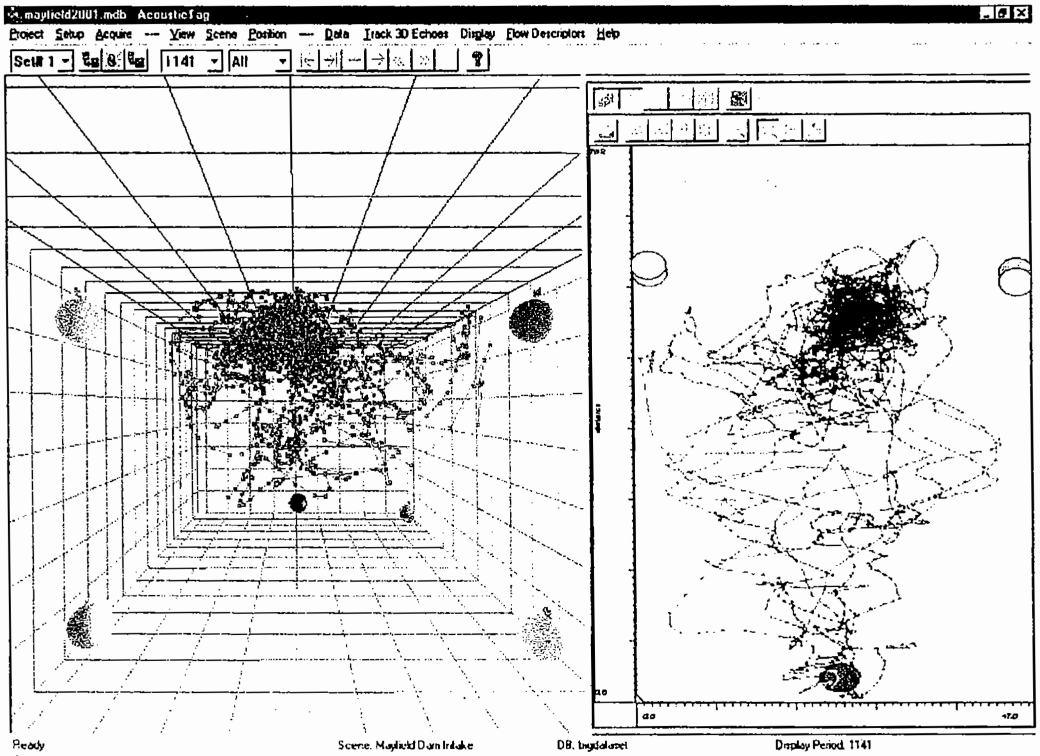


Figure 20: Acoustic Tag™ program output showing an example of milling approach swimming behavior in the south louver intake, Mayfield Dam 2001.

(3) Perimeter Behavior

Fish movement in the south intake that was oriented along the louver faces was designated perimeter approach behavior. This pattern of approach behavior was generally similar to the "straight approach" swimming category, but typically did incorporate several upstream-downstream forays as the tagged coho presumably sought an exit from the intake bay. Fish exhibiting this behavior pattern typically entered the south intake and approached the bypass opening, and then reversed course upstream, following the louver face, then repeated the pattern. This upstream-downstream searching pattern was sometimes repeated many times and coho were observed moving to the opposing louver face at the apex periodically. The majority of fish exhibiting this behavior pattern did enter the bypass after several forays.

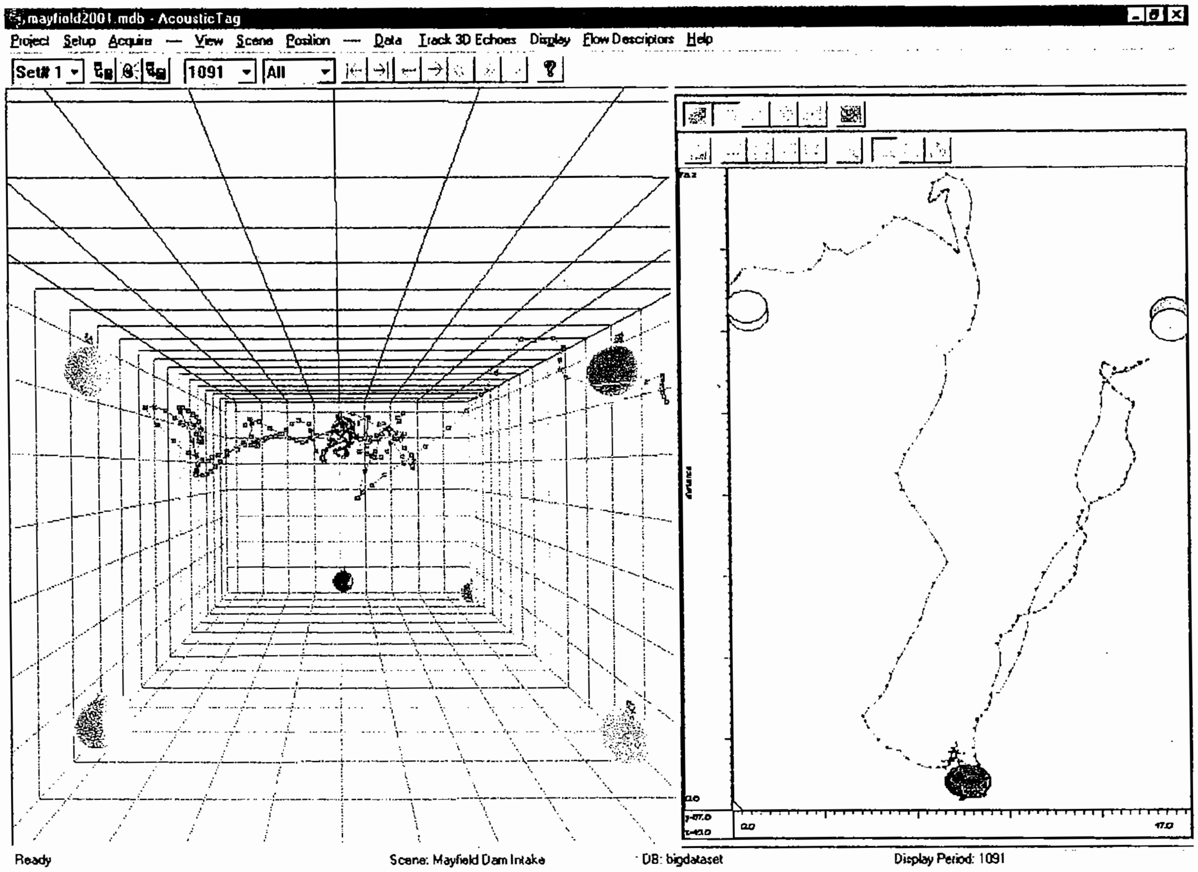


Figure 21: **Acoustic Tag™ program output showing an example of perimeter approach swimming behavior in the south louver intake, Mayfield Dam 2001.**

d) Fish Residence/Holding Areas

There were three primary areas in the south intake where tagged juvenile coho were observed to spend increased amounts of time during the study period. These were termed areas of higher fish residence. A plan view of these residence areas is presented at Figure 22 and a side view in Figure 23. Areas of the highest coho residence within the south louver are represented by light blue and green while lower concentrations are represented by dark blue.

The first residence area was located near the water surface at the upstream louver entrance along the intake centerline. The second and third congregation areas were both at the downstream apex of the array, adjacent to the bypass. One was at the water surface and one at the base of the bypass entrance. In addition to these three primary areas of aggregation, a secondary area of higher fish residence was observed along the northeast edge of the array.

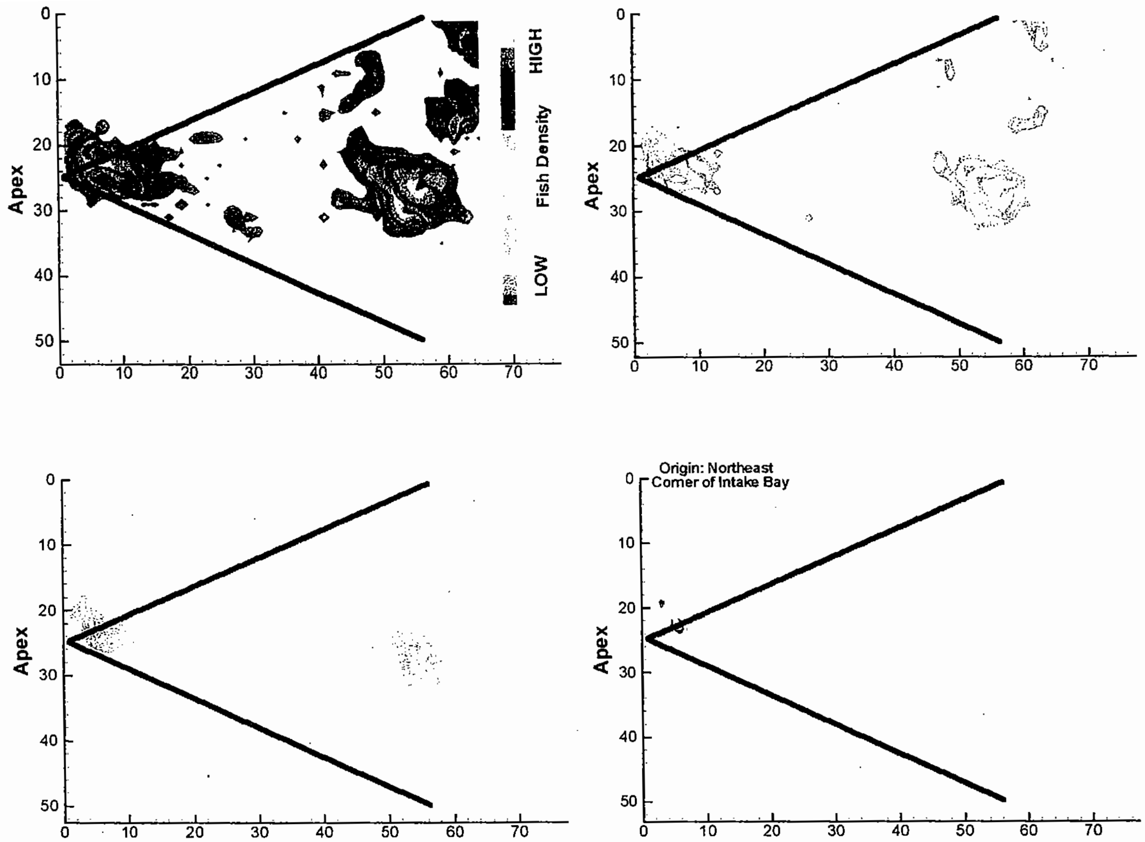


Figure 22: Plan view of observed areas of relatively higher tagged coho residence over the study period in the south louver intake. Mayfield Dam, May 29 – June 20, 2001.

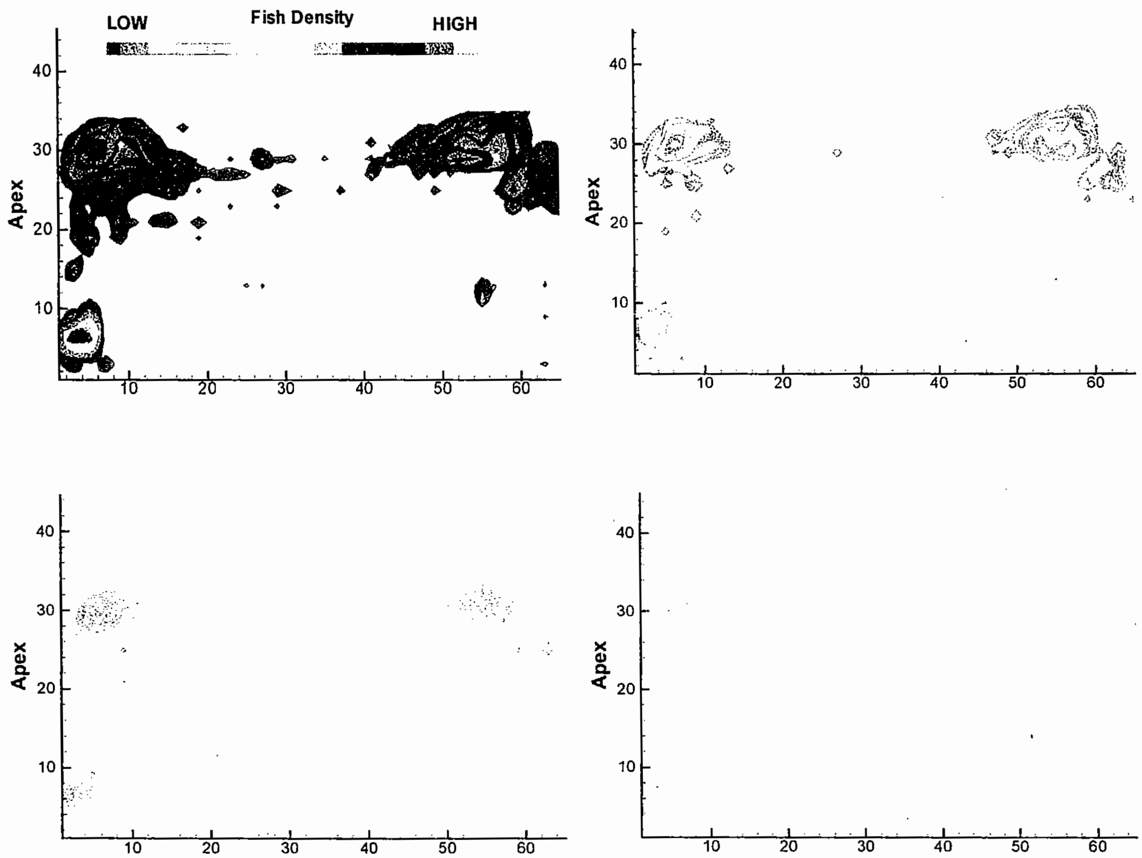


Figure 23: Side view of observed areas of relatively higher tagged coho residence over the study period in the south louver intake. Perspective is from mid-water with the apex of the louver to the left side of the graphic (downstream) and the trashrack opening of the intake to the right. Mayfield Dam, May 29 – June 20, 2001.

e) Fish Residence Time by Location

Only within the south louver bay could three-dimensional tracks be developed for tagged fish. However, there were two hydrophones positioned outside of the south louver that detected tags and provided information about a tagged fish's general location. The hydrophone in the secondary bypass separator detected only fish that entered the bypass separator. This hydrophone thus provided an unequivocal determination of which tagged fish were bypassed.

The hydrophone positioned at the entrance to the power tunnel detected fish that entered the power tunnel as well as those that were present within the north louver bay (but not those that entered the south louver bay). If a tagged fish passed through the north louver bay and into the bypass system, it would be detected first by the power tunnel hydrophone and then by the bypass separator hydrophone. Tagged fish detected only on the power tunnel hydrophone were scrutinized carefully to determine if the fish merely entered and then left the north louver bay, or if they entered the north louver bay and then passed into the power tunnel. The amplitude of the detected tag returns are related to the distance between the tag and the hydrophone. The time between successive tag returns from a given tag depend on the pre-programmed transmission rate of the tag and the distance moved by the fish between tag transmissions. Using these two characteristics of tag returns together allowed a positive determination of the ultimate fate of tags detected only on the power tunnel hydrophone. Figure 24 is an example of a fish that was detected in the north louver bay by the power tunnel hydrophone, but did not pass into the power tunnel. The same tag was later detected in the secondary bypass separator. Figure 25 is an example of a fish that was detected in the north louver bay and passed into the power tunnel. The brightly colored returns indicate very close proximity of the tag to the power tunnel hydrophone, and the region of negative slope of successive returns indicates very rapid movement away from the power tunnel hydrophone, as the fish move downstream within the power tunnel.

Figure 26 presents the location of each tagged fish determined by the detected returns from all hydrophones. Several fish entered and exited both louver bays several times prior to passing downstream. In addition, some fish were found to hold for many hours in the south louver bay and the secondary bypass separator. Overall, fish exhibited widely varying behaviors prior to passing the project.

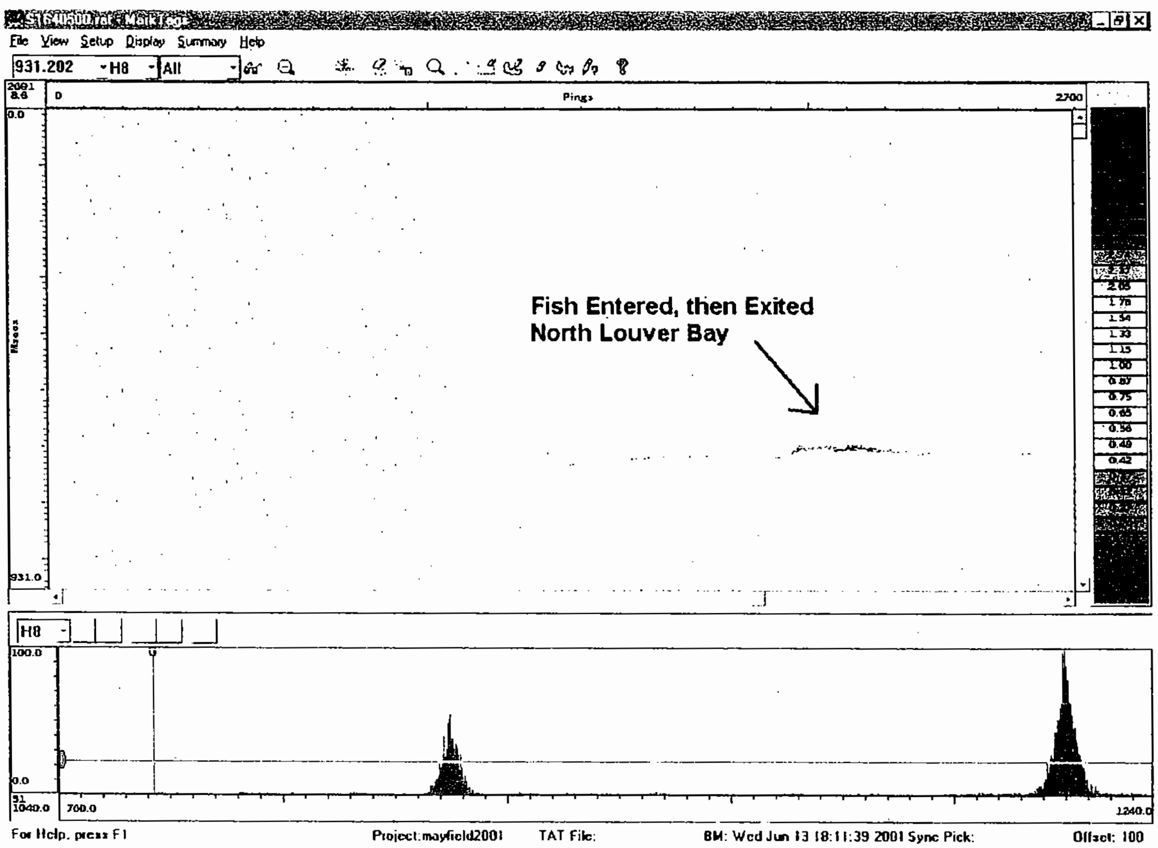


Figure 24: **A series of returns from a tagged fish detected by the power tunnel hydrophone as the fish moved into and then out of the north louver bay. This fish was later detected again in the north louver bay, then immediately afterward in the bypass separator.**

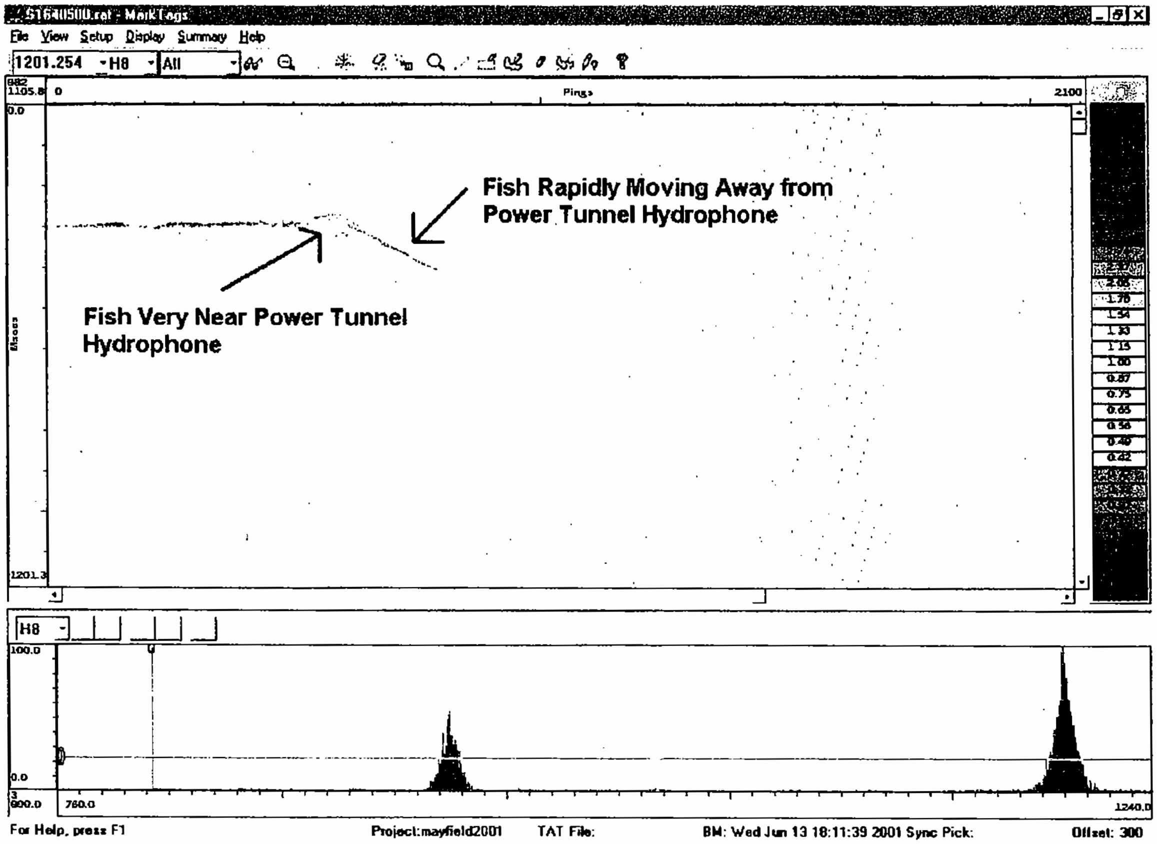


Figure 25: **A series of returns from a tagged fish detected by the power tunnel hydrophone as the fish moved into the north louver bay, and then down the power tunnel. This fish was not detected again after this event.**

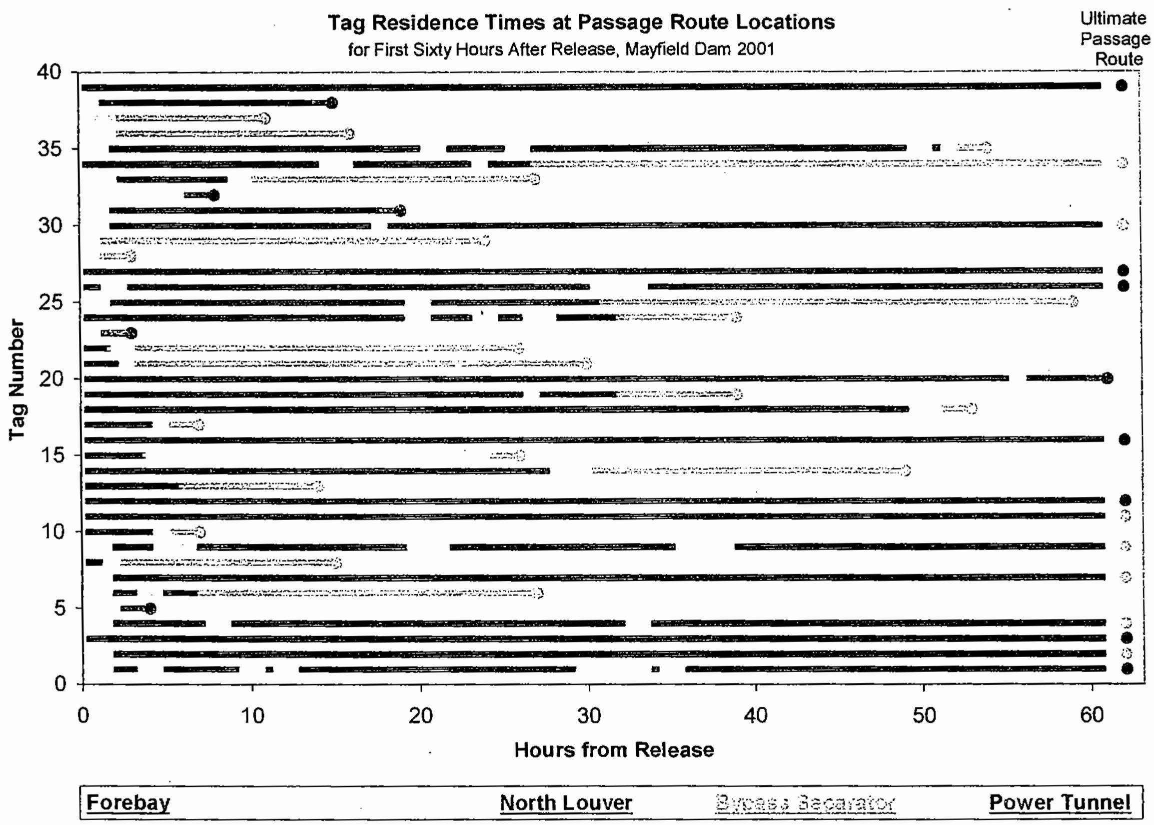


Figure 26: Residence time and location during the first sixty hours after release for each individual tagged fish, Mayfield Dam, 2001.

4. Conclusions

The 2001 tagging study at Mayfield Dam showed that fish could be successfully detected and tracked within the louver bay. By locating one hydrophone in the secondary bypass separator and one in the power tunnel entrance, the ultimate fate of all tagged and detected fish that passed the project during the study period was unambiguously determined.

Overall, for 32 tagged fish with known ultimate passage routes, the number bypassed was 26 (81.3 %). This indicates a preference for the bypass entrance, since fish were not involuntarily entrained into the bypass entrance and were observed to voluntarily move through the louver vanes in both downstream and upstream directions. While a lower proportion of tagged fish that passed the project through the north louver bay were bypassed (6 bypassed out of 9 total or 66.7 %), the sample size was very low in this pilot study.

Tagged fish exhibited widely variable behavior, both in terms of when and where fish moved immediately after release, and how they behaved once inside the south louver bay. Some fish passed the project within a few hours of release, while others remained resident in the forebay for days after release (Figure 26). Some fish passed through the first intake they encountered, while others moved readily between the two louver bays before passing the project. Some fish passed into the bypass within minutes of arrival into the south louver bay, while others remained resident in the south louver bay for hours prior to passage.

Many fish remained in the secondary bypass separator for several hours, while some others exited within one or two hours.

The tagged hatchery coho were clearly not involuntarily entrained inside the south louver bay at the flows encountered during the 2001 study. Tagged fish were observed passing downstream through the louver vanes and then back upstream through the vanes into the louver bay (Figures 20, 21). While most fish were surface oriented, some fish were observed milling near the bottom at the louver apex (Figure 23). There were no clear indications that the fish were influenced by flow characteristics within the south louver bay at the flows present during the study.

The 2001 study period had lower than normal flows through the project due to a generally low water year in general in western Washington. Coupled with these low flows and consequently low water velocities within the south louver bay, the tagged fish were relatively large hatchery coho. This allowed the tagged fish to move freely within the south louver bay, entering, exiting, and holding in the louver bay at will. During higher flow years, or for smaller fish, the louver bay may not provide flow characteristics where fish have the ability or desire to mill or hold as some tagged fish did in 2001.

IV. STUDY RESULTS

A. Fish Behavior and Velocity Data Correlation

1. General Discussion

As discussed above, the primary goal of this first phase study was to determine if there is correlation between observed fish position and hydraulic conditions within the louvered intake structure. To accomplish this, the CFD model velocity vector plots were carefully compared to real-time tracking data provided by the acoustic tags in the juvenile fish. The tracking studies were conducted at the same project outflow discharge as the field velocity measurement program (2580 cfs total through both bays), and for which the CFD model was verified. The fish tracking data showed clearly whether fish entered the bypass or passed through the louver vanes. Additionally, tracking data showed whether any fish that passed through the louvers continued on into the turbine intake or moved back through the louvers. Finally, hydrophones mounted in the fish bypass secondary separator and entrance to the power tunnel determined the ultimate passage route of each tagged fish.

Similar studies of fish tracking with acoustic tags have shown the fish often respond to external stimuli such as non-uniform velocity patterns. Previous work by HTI at Rocky Reach Dam has been successful in establishing relationships between fish movement and velocity patterns (HTI, 1999). Although the Mayfield Dam intake structure is arranged differently than the Rocky Reach intake, one might initially infer similar patterns of movement in response to velocity stimuli. The reverse roller sometimes observed at the surface of the north and south bypass entrance intake slot may be an example of a particular area of concern as indicated by fish avoidance of the bypass slot suggested by the tracking data acquired in this study.

2. Correlation of Fish Movement with Velocity

As discussed above in the Conclusions to the Fish Tracking work, it was evident that the tagged fish did not involuntarily become entrained into the bypass entrance under the flow conditions observed at the project. The relatively large size of the tagged fish (hatchery coho smolts), coupled with the low flows and consequent low velocities entering the louver intake bay (averaging about 1 foot per second), permitted these fish to move about the intake bay freely. The tagged fish were observed with widely varying behaviors. Some entered the bypass directly soon after entering the intake bay, some milled around in the intake for a number of hours, and some appeared to swim right up to the bypass entrance, turn around and swim back out to the entrance to the intake bay. Most of the tagged fish, however, regardless of their specific patterns of movement within the intake bay, eventually entered the bypass entrance.

The only clear correlation with flow velocity noted in the study was that of a few fish generally following the flow into and through the intake bay up to the bypass entrance. Some were guided along the louver vanes, some transited via the centerline or near centerline of the intake, some transited near the surface, and some transited near the floor. Some tagged fish voluntarily moved nearly to the bypass entrance with the flow, and having been guided successfully by the louver vanes, with a few moving directly into the bypass, and others retracing their movement back upstream. Overall, the louver vanes appeared to guide most fish toward the bypass entrance, if only voluntarily.

3. Correlation of Fish Movement with daylight/night conditions

Preliminary examination of the end tracks of the tagged fish that were observed passing via the south louver bay showed that all passed during daylight hours. In addition, nearly all those passed during late morning to mid-day. Just three fish passed during the early morning before 1000 hours, and only two fish passed in late afternoon (after 1500 hours) or early evening. The majority of fish passed between 1000 and 1300 hours.

While no exhaustive investigation was made into this phenomenon as part of this study, it is curious to note that so many fish passed during daylight hours. It is also interesting that most of the fish passed into the bypass during the mid-day hours in late May and early June. Some of these fish actually entered the intake bay some time before they actually passed into the bypass; a few even remained somewhat within the confines of the intake for a number of hours. More insight might be gained into the behavior of the tagged fish in the following sections, as possible explanations for these observations are provided. Additional study is required to confirm the precise environmental conditions that apparently stimulated these fish to pass into the bypass or through the louvers.

4. Correlation of Fish Movement with shade/shadow conditions

As discussed above, all of the tagged fish that were observed passing into the bypass during daylight hours, with the majority passing between the hours of 1000 and 1300. During the latter part of May and early June, at the latitude of the Mayfield project, these hours are typically when the sun is more or less directly overhead. It should be noted here that the louver vanes are aluminum, and as a consequence are fairly light colored when viewed from upstream points at or below the water surface. In contrast, the bypass entrance is dark when viewed from the same vantage point. Since the tracking observations indicated that the tagged fish were fully capable of maneuvering upstream and downstream voluntarily in the ambient velocity field, we know that they likely made a choice to enter the bypass or not.

The water clarity at Mayfield Dam varied from about 72 inches to 180 inches during the field work. Table 5 below provides weekly water clarity observations for the March to July period. These clarity observations indicated that it was clear enough to visual observe objects at least several feet below the surface, and presumably at least that far away from a submerged vantage point. Many of the fish tracks showed that fish would enter the intake, drifting or actively swimming downstream along the louver panel until reaching a point several feet away from the bypass entrance. The CFD model and field velocity measurements indicate that the velocity field is fairly uniform throughout the intake up to within the immediate vicinity of the bypass entrance (See Figures B-7 through B-12 in Appendix B). The velocity field accelerates slightly with increasing depth for the same distance away from the bypass entrance, but in no case at the observed flows does this acceleration extend more than several feet upstream of the apex of the louver panels (the bypass entrance).

Table 5
Water Clarity at Mayfield Dam Forebay – as measured with Secchi Disc

Date	Clarity Reading (inches of visibility)
3/26/01	72
4/2/01	72
4/9/01	78
4/16/01	84
4/23/01	90
4/30/01	96
5/7/01	108
5/14/01	126
5/21/01	126
6/2/01	144
6/4/01	198
6/11/01	168
6/25/01	168
7/2/01	180

The causes for the behavior of some of the tagged fish to turn around and swim back upstream against the current when they reach at least the visually detectable vicinity of the bypass entrance are not clear. It is also not clear whether they reach the zone of accelerated flow at the bypass entrance mouth when they reverse direction and move back upstream in the intake. Additional study of the velocity field in the near vicinity of the bypass slot and the behavior of tagged fish must be completed before theories as to why these fish might reject the bypass entrance can be forwarded. However, it is clear that something in the immediate vicinity of the bypass entrance appears to cause some of the tagged fish to reverse direction and reject the bypass, if only for a time until they choose to pass through the bypass.

In Canada in the early 60s or late 50s, a study of a stream louver clearly showed increasing the width of the bypass eliminated the phenomenon of fish passing through the louver vanes near the bypass slot (Ebel, 2001). In this case, slot width was increased from 6 to 18 inches. Ebel (2001) observed the same performance in a louver system operated on Eagle Creek, Oregon in 1963. He found that an increase in bypass width from 6 to 18 inches and lowering the approach velocity to the louver vanes from about 4 – 6 fps to 2 - 2.5 fps greatly increased efficiency (from 10 to 15% up to 85 to 90%). This solution might be considered at Mayfield but would likely be expensive.

B. Assessment of Existing Fish Passage Efficiency

As discussed in the conclusions to the fish tracking section above, the overall number of fish bypassed was 26 out of 32 tagged fish, or about 81.3 %. Many factors may have influenced the effective guidance efficiency of the bypass system at Mayfield, chief of which may simply be that the tagged fish were hatchery smolts of fairly large size as opposed to wild fish. The observed behavior may or may not be inferred upon the wild population. However, it is clear that, even though the louver system is not a physically impenetrable barrier to fish, the majority of tagged fish entering the intake are indeed bypassed. Little information regarding the performance of the north louver bay with regard to bypass efficiency can be gained from these results, by the nature of the study design and partially as a consequence of the intended limited scope of this study. However, as discussed above, 6 of a total of 9 tagged fish were bypassed in the north intake, or about 67 %.

As discussed above, one should be cautioned against assuming these results will apply uniformly to conditions with higher inflows than those observed during this study. Higher inflows will result in higher average velocity through the intake, and consequently lowered ability of the fish to maneuver within the intake. The apparent selection of the bypass entrance by the majority of the fish may become less voluntary and may be significantly more a function of the hydraulic conditions within the intake. These conditions may lead to quite different bypass efficiency results that those observed in this study.

V. RECOMMENDATIONS

A. Potential Problem Areas Identified in the Intake

As discussed above, some of the tagged fish were observed to approach the bypass entrance, then reject it and swim back upstream in the intake. Some passed freely back and forth through the louver vanes. Some moved up and down within the water column. However, all the fish passed, voluntarily or not, during daylight hours, most between the hours of 1000 and 1300. It seems that the problem of fish rejecting the bypass entrance only when within several feet of it suggest that perhaps they are responding to visual and/or velocity field cues. Although no record of fish movement was made in response to the presence of predators, it is also entirely possible that the fish may initially reject the entrance to avoid predators there. Most commonly accepted understanding of predator behavior suggests, however, that the area immediately upstream of the bypass entrance is not preferred predator habitat. It is interesting to note that some fish were observed to mill around in the intake at a depth of around 20 feet. At this depth, visual cues become less prominent, as a result of the decreased clarity of the water at that location. Other explanations of this rejection behavior may include avoidance of debris or unacceptable acceleration of the velocity field at this depth.

B. Recommended Measures for Addressing problem Areas in Intake

Since the observations indicate that a possible cause for bypass rejection may include visual cues, the distinctly different color difference between the bypass entrance and the adjacent louver panels may be responsible. One strategy may be to provide lighting in the bypass entrance, to lessen the color distinction between the bypass entrance and the louver panels. Additionally, the interior walls of the bypass slot could be painted to match the color of the louver panels. Alternately, the louver panels could be painted dark, or the entire intake bay could be covered and darkened so that there is no visual distinction between the bypass entrance and the louvers.

Although likely more costly, the louver panels immediately adjacent to the bypass entrance could be covered with a physically impenetrable barrier, such as perforated plate or wedge wire screen. Some of the tagged fish observed rejecting the bypass in fact passed through the louver vanes within the immediate vicinity of the bypass entrance. A physical barrier may provide incentive to enter the bypass instead.

A likely far more costly alternative might be to reconfigure the entire bypass system, where the fish are not required to sound to enter the capture point in the bypass entrance. At present, the bypass slot turns the flow 90 degrees to the horizontal prior to passing through the capture point, located at the floor of the intake. This alternative may provide fish with less incentive to reject the bypass as a result of flow field acceleration.

C. Recommended Additional Study Efforts

1. Fish Tracking Studies

Fish tracking studies using acoustic tags in future years at Mayfield Dam should include the following to more completely characterize fish behavior in the louver bays, and to provide information leading to improvements in fish passage efficiency of the bypass system:

1. Instrument the north louver bay to allow tracking tagged fish there, and determine if behavior is similar to that within the south louver bay. This would be especially important if modifications were made to one of the bypass entrances, and comparisons were to be made between modified and un-modified bypass entrances.

2. Conduct the study during periods of higher flows, more typical of normal water years at Mayfield Dam.

3. Tag some smaller fish, perhaps of different species to determine if bypass rates and behavior is similar for the normal range of fish sizes and species migrating downstream at Mayfield Dam. Current technology could allow fish at least as small as 110 mm to be tagged.

4. Tag more fish and vary release times so that some fish are released at night.

Most fish passed into the bypass entrance near the surface, and almost all fish approached the bypass entrance near the surface. Increasing the flow near the surface in the vicinity of the bypass entrance may cause fish to select the bypass entrance more readily. Modifications to the bypass entrance such as widening the near-surface bypass entrance, or occluding the deeper portions of the bypass entrance could be tested and evaluated based on observed fish behavior from tracks of tagged fish.

A secondary study objective could be addressed using tagged fish that pass into the power tunnel. If a hydrophone array were located some distance downstream, then turbine mortality could be assessed. In order to provide an adequate sample size, this may require additional tags or possibly re-use of tags from bypassed fish that were captured soon after release in the bypass collector.

2. CFD Modeling Studies

The CFD model grid should be expanded at least into the bypass slot and down to the capture point at the floor of the intake. The existing flow turning vanes in the slot should be incorporated into the model grid. To evaluate the replacement or covering of some portion of the louver panels with a physical barrier (such as screen or perforated plate), that portion of the grid could be modified to reflect a particular porosity and structure similar to the physical barrier material. Also, if the new water year provides for higher inflows, the CFD model should be verified with velocity measurements made at the higher inflow conditions.

3. Intake Modification Design Studies

As discussed above, one particularly simple modification could be to light the bypass entrance slot. In addition, when dewatering occurs again, the bypass slot could be painted similar colors to that of the louver panels. More complicated and expensive engineered modifications may include replacement or covering of some portions of the louver panels to provide a physical barrier to fish passing through the vanes. Bypass slot configuration modifications may also be evaluated, such as increasing the width of the slot to at least 18 inches. These could also include radical changes to make the bypass entrance and transport system similar to conventional bypasses with free-surface bypass pipes or channels as opposed to the present sounding type of bypass.

VI. SUMMARY AND CONCLUSIONS

The bypass efficiency study reported in this document consisted of precise characterization of the hydraulic conditions within the louvered intake arrangement with the CFD model, field calibration of the CFD model with Acoustic Doppler Velocity (ADV) probes, and documentation of juvenile fish movement into the intake from the reservoir and within the intake area itself on a real-time basis with an acoustic tag tracking system. Ultimate disposition of each tagged fish was also recorded during this study, to determine whether the fish passed into the bypass or entered the powerhouse tunnel. Fish position was determined for each tagged fish within the instrumented louver bell on a continuous basis to an accuracy of within 0.1 meter. The CFD model simulation results corresponding to the prototype conditions during the fish tracking field work were evaluated, and correlation between the fish movement and hydraulic conditions in the intake were made. Using commonly accepted juvenile fish bypass design criteria, CFD model velocity data, and observed fish behavior, areas within the intake that exhibited poor performance were identified, as discussed in the Recommendations Section of this report.

In general, louvered system such as that in use at Mayfield Dam have not been used at hydropower intake structures for many years. Improved screening systems are considered to be the most technologically advanced means of bypassing juvenile fish at present. However, without a thorough understanding of the efficiency of the existing system gained through additional study, it would be far too premature to presume that complete revision to the intake design would be required to accomplish the desired goals for this project. We propose that the minor changes to the bypass entrance such as lighting and/or painting of the bypass slot be completed. Additional tracking studies in one modified intake bay and one unmodified bay would permit evaluation of the importance of these visual cues to voluntary fish movement into the bypass.

Additional CFD modeling effort should focus on first verifying the model for higher inflows by repeating the field measurement program for higher flows. Secondly, by extending the model grid inside the bypass slot and down to the capture point, additional detail may be gained on the velocity field in the immediate vicinity of the bypass entrance area. The field velocity probe should be modified to accommodate measurement of 3 dimensional velocities up to and perhaps inside the bypass slot itself. This additional information can be utilized to evaluate minor structural changes to the entrance slot and louver panels immediately adjacent to the entrance. Field velocity measurements must be acquired at these higher inflows to accomplish these changes to the CFD model.

VII. LITERATURE CITED

Adams, N.S., D.W. Rondorf, S. D. Evans, and J. E. Kelly, 1998a. Effects of surgically and gastrically implanted radio transmitters on growth and feeding behavior of juvenile chinook salmon. Transactions of the American Fisheries Society 127: 128-136.

Adams, N. S., D. W. Rondorf, S. D. Evans, J. E. Kelly, and R. W. Perry. 1998b. Effects of surgically and gastrically implanted radio transmitters on swimming performance and predator avoidance of juvenile chinook salmon (Onchorynchus tshawytshcha). Canadian Journal of Fisheries and Aquatic Sciences 55:781-787.

Davis, J.C. Statistics and Data Analysis in Geology, First Edition. John Wiley, 1973.

Davis, J.C. Statistics and Data Analysis in Geology, Second Edition. John Wiley, 1986.

Ebel, Wesley J. 2001. Personal communication. December, 2001.

HTI. 1997. Phase 1 Report: Acoustic tag feasibility testing at Rocky Reach Dam. Progress Report by Hydroacoustic Technology, Inc. to Chelan County PUD, Wenatchee, WA.

Mitson, R.B. 1978. A review of biotelemetry techniques using acoustic tags. In Rhythmic activities of fishes. J.E. Thorpe, editor. Academic Press, New York.

Perry, R. W., N. S. Adams, and D. W. Rondorf, 2001. Buoyancy compensation of juvenile chinook salmon implanted with two different size dummy transmitters. Transactions of the American Fisheries Society 130: 46-52.

Timko, Mark A. 2000. HTI Model 290 Acoustic Tag System Operators Manual, Version 1.0. Hydroacoustic Technology, Inc., Seattle, WA.

APPENDIX A
PROJECT PHOTOGRAPHS

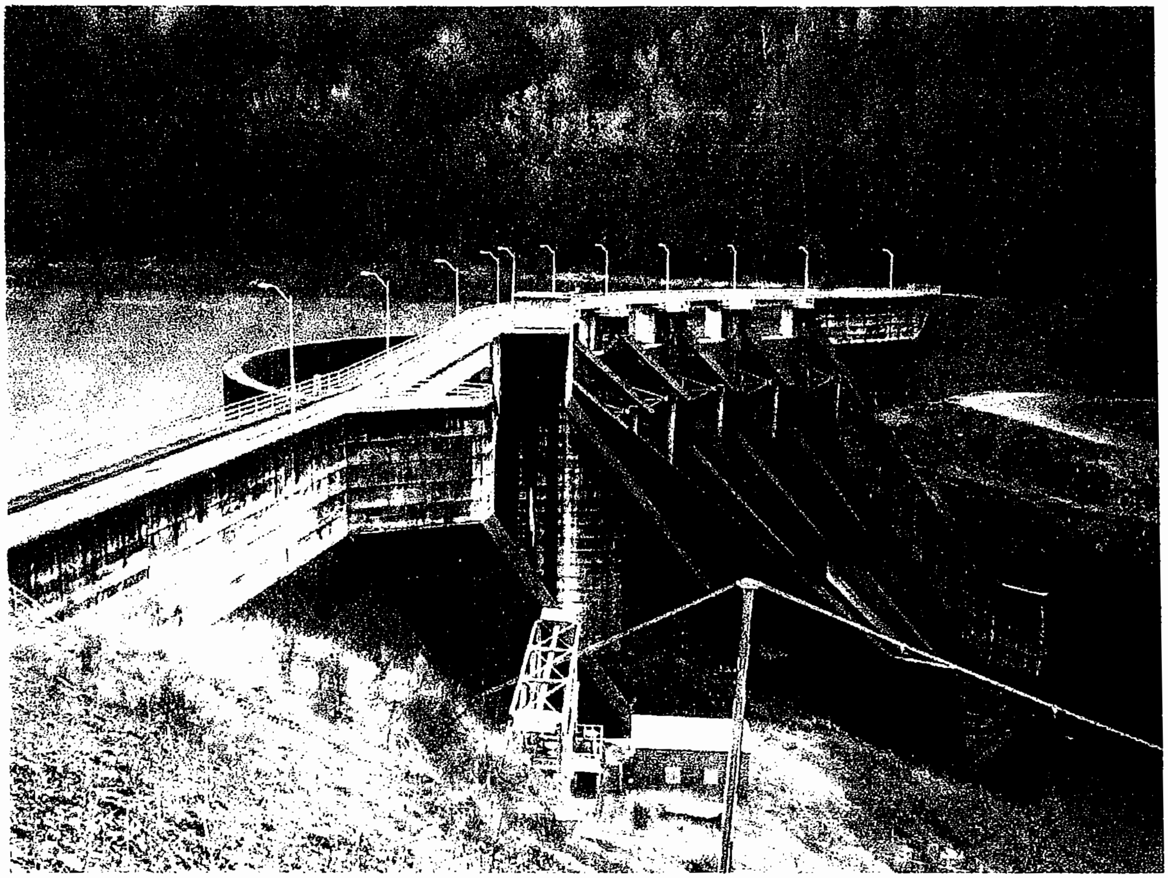


Photo 1 – Mayfield Dam from North Abutment

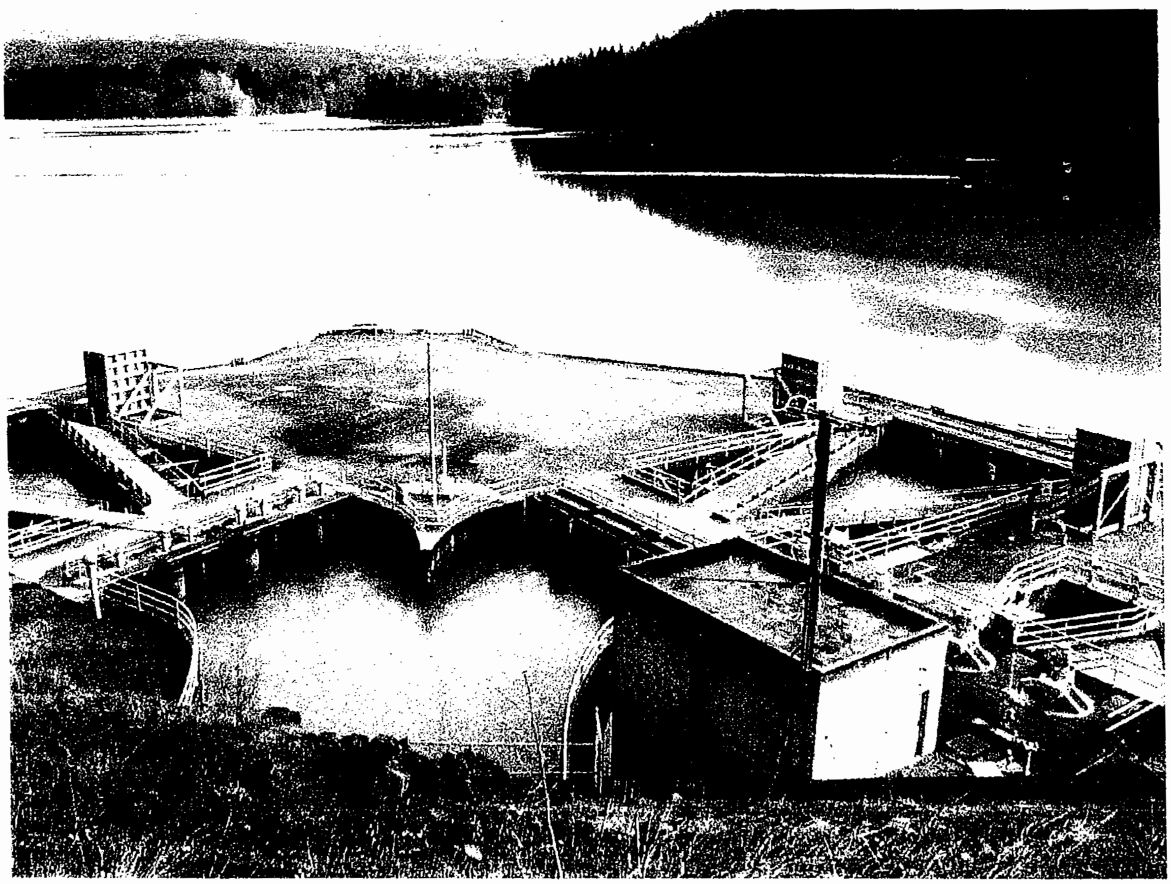


Photo 2 – North (left) and South (right) Louvered Intake Bays

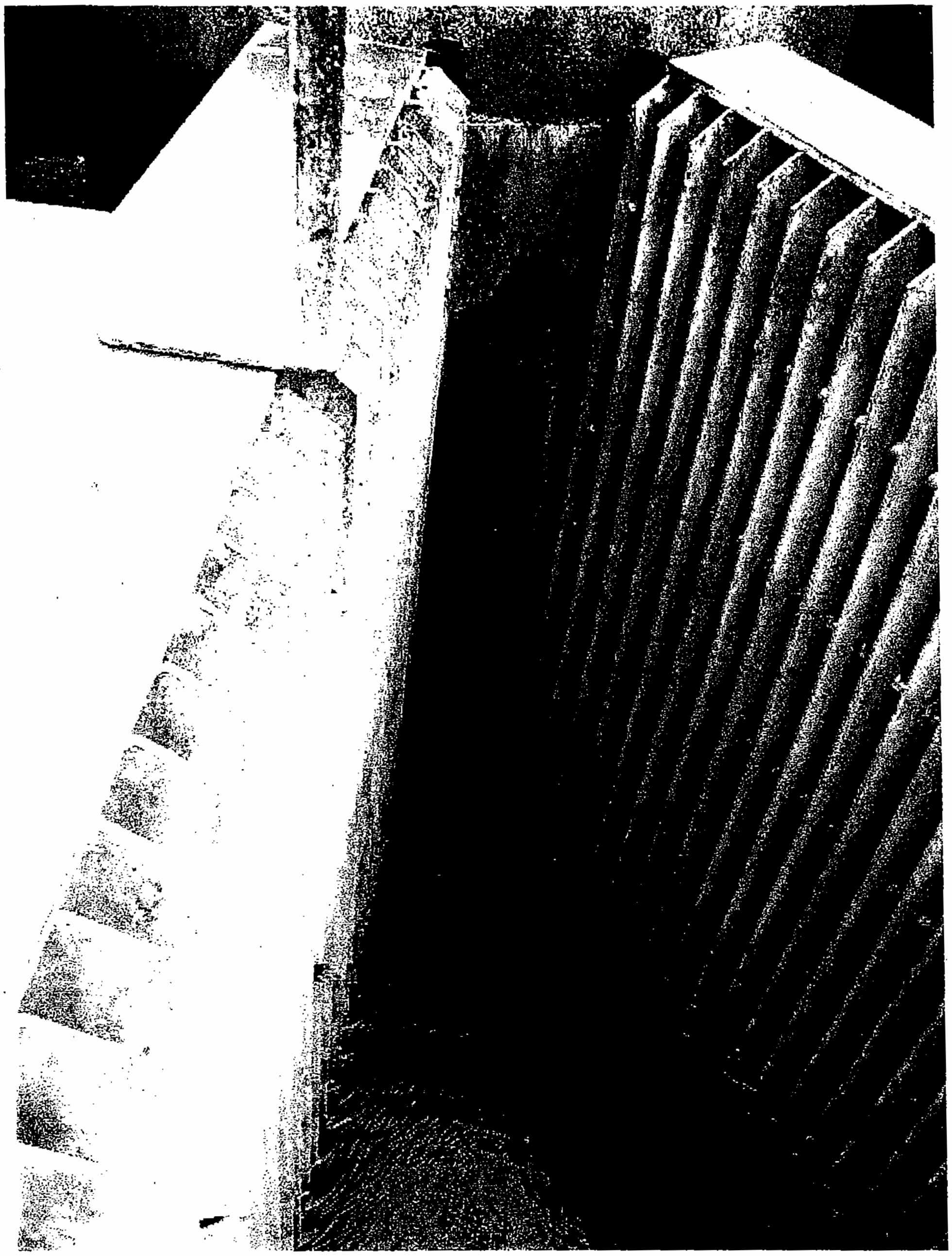


Photo 4 – Bypass Entrance Slot and Louver Detail from U/S

Photo 5 – Louver Detail from Downstream Side of Louver Vanes

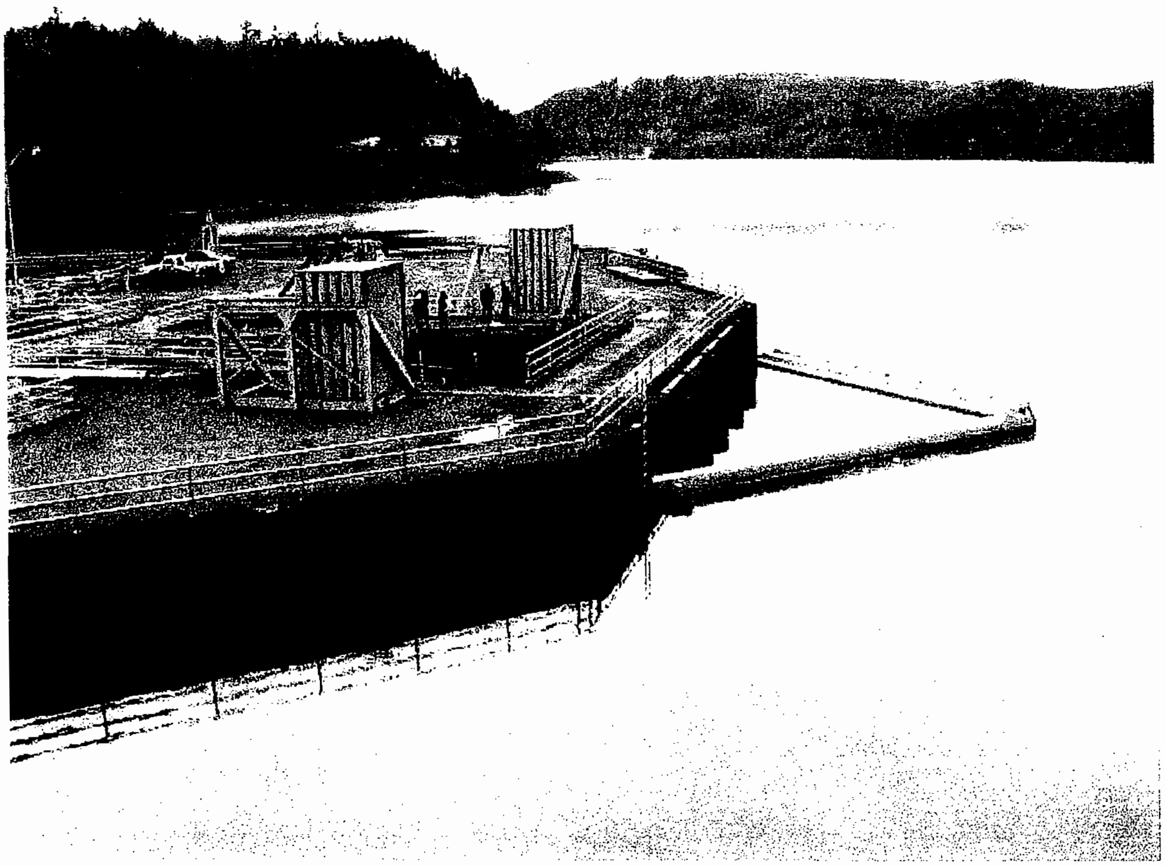


Photo 6 – Intake Trash Boom

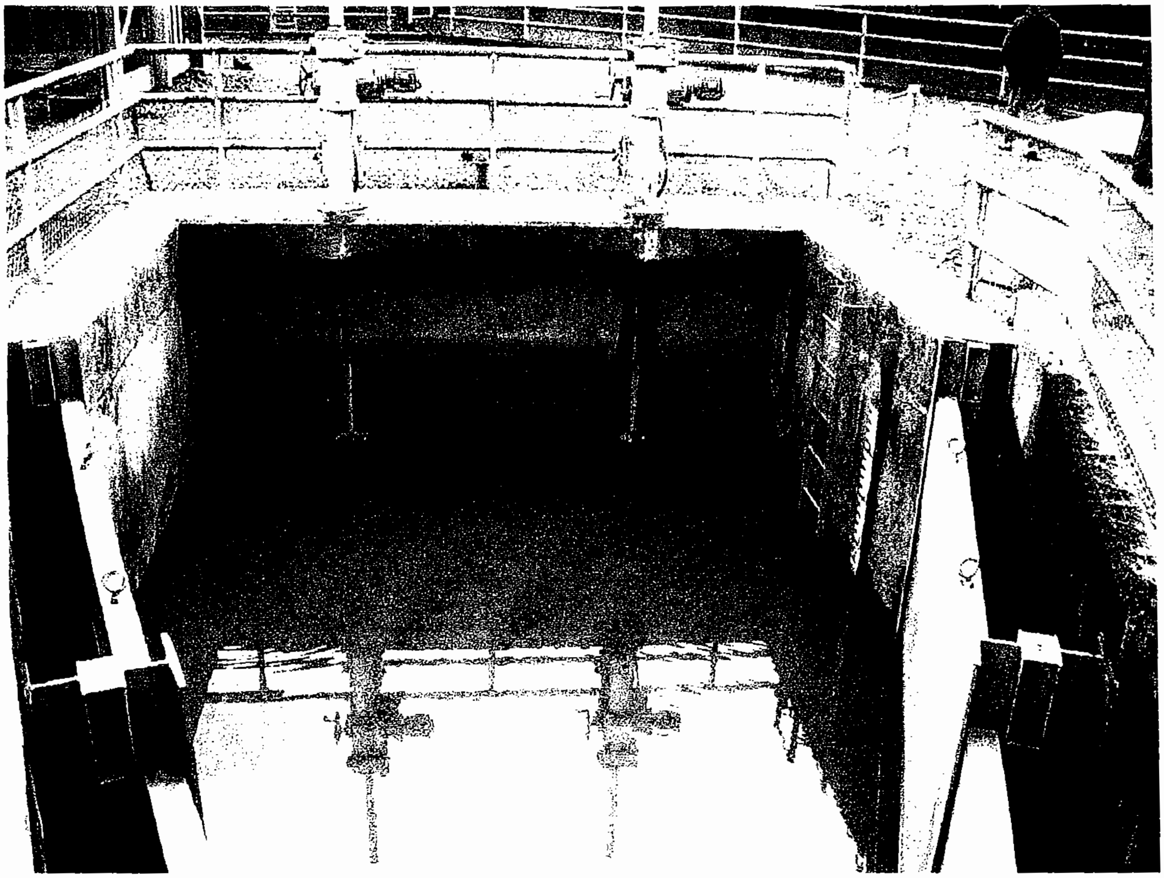


Photo 7 – Secondary Separator Structure, Facing Upstream

Photo 8 – Secondary Dewatering Structure Pump Back Weir (far left) & Power Tunnel Entrance (center top)

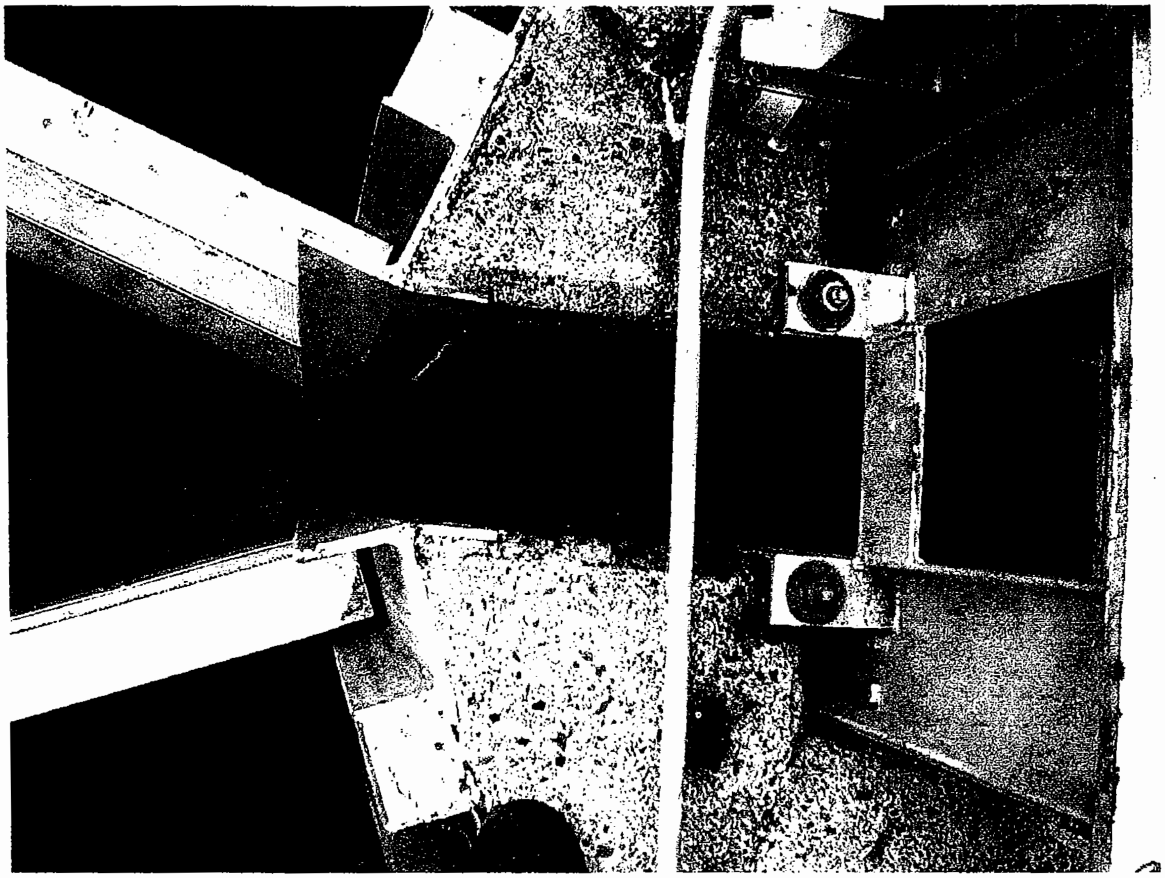


Photo 9 – Secondary Separator Bypass Entrance Weir (flow from left to right)

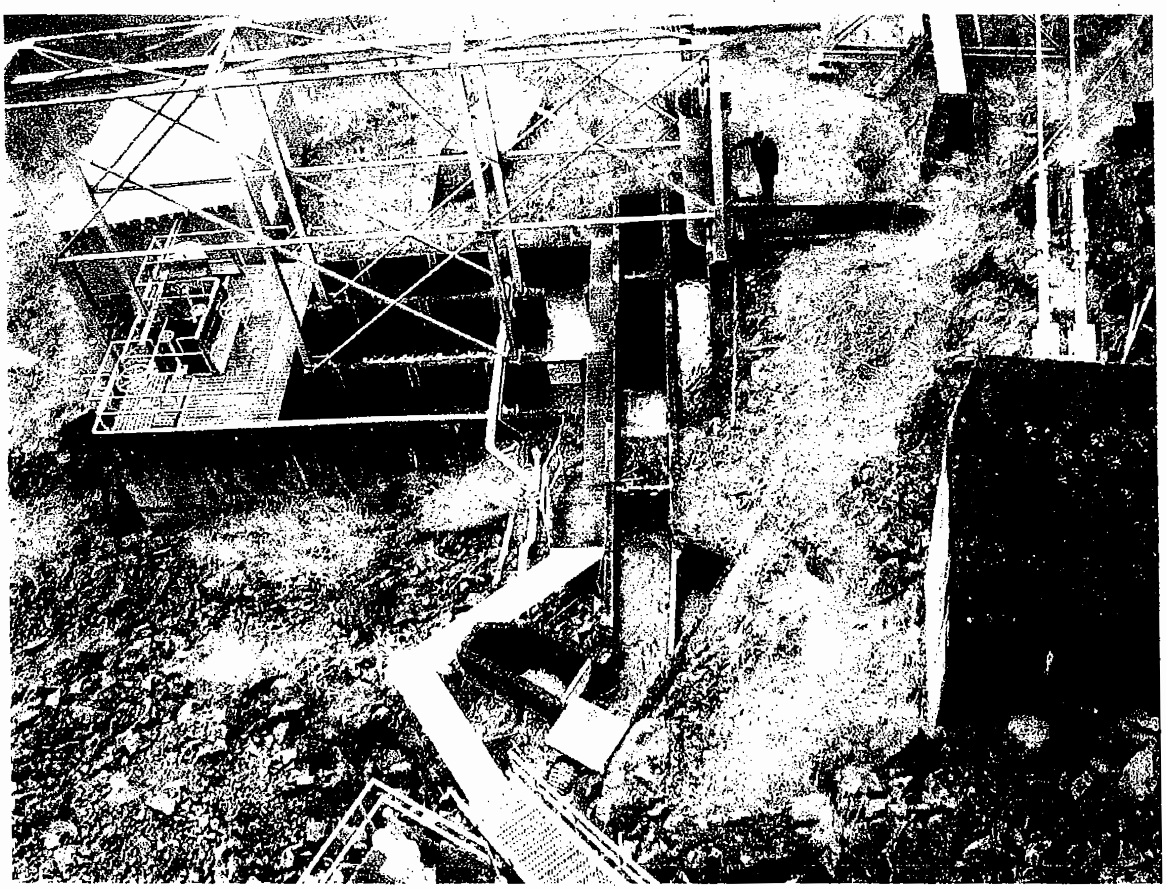


Photo 10 – Smolt Monitoring Station on D/S North Abutment

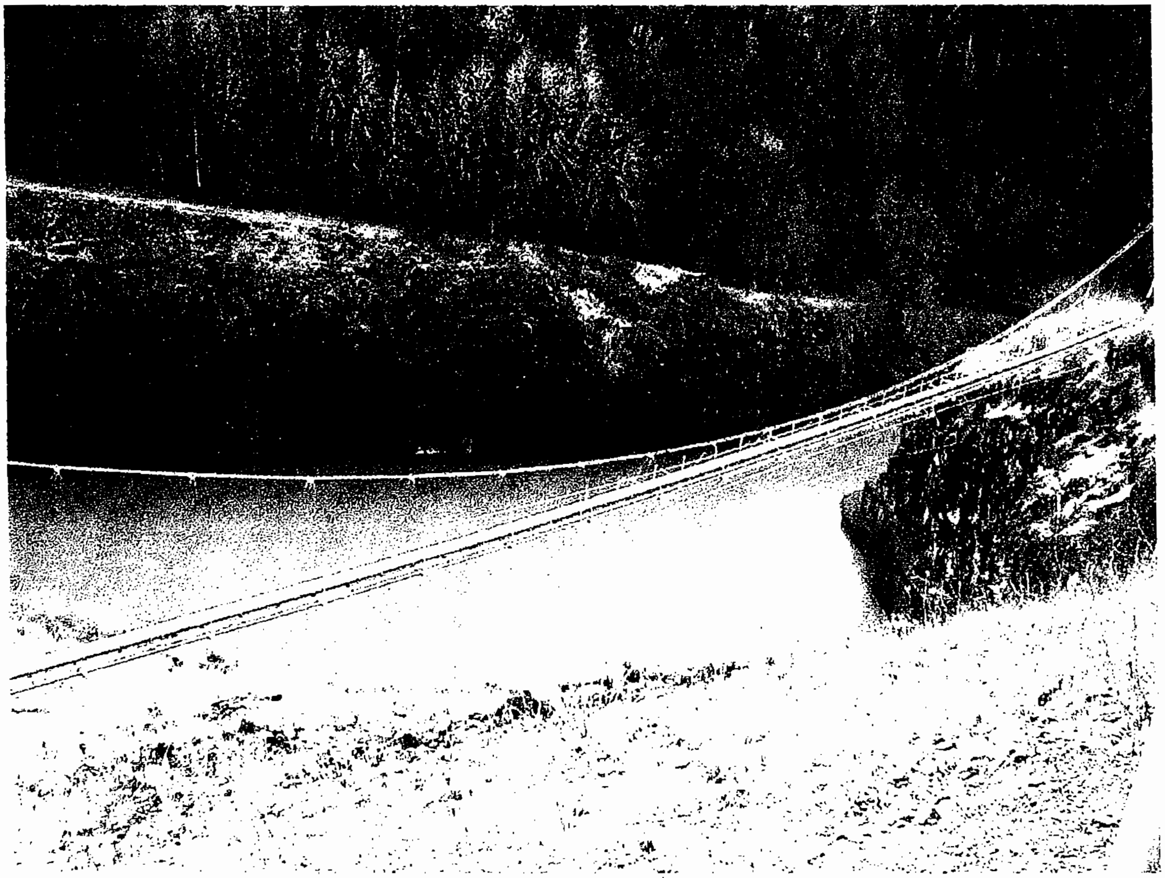


Photo 11 – Smolt Bypass Pipe Leading to Powerhouse (beyond right side of frame)

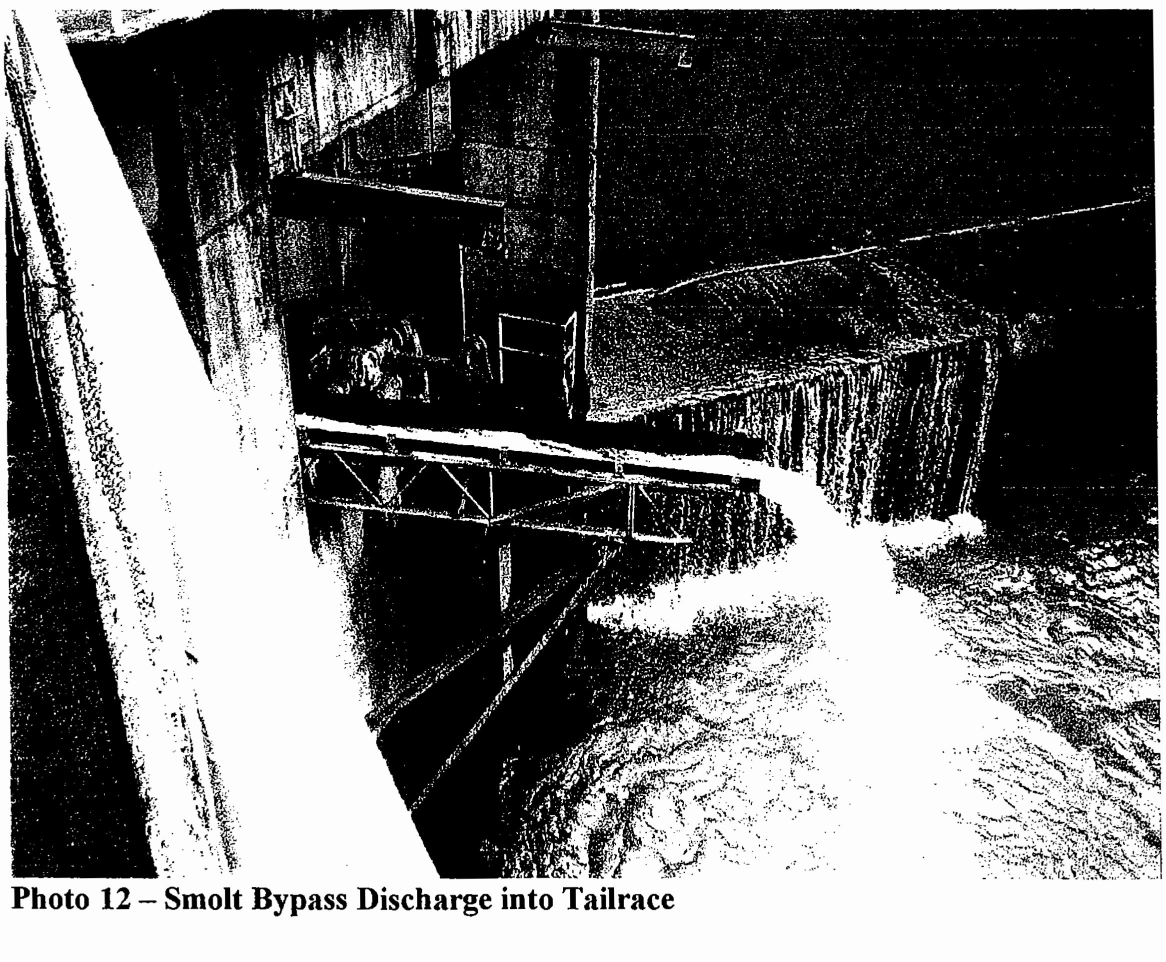


Photo 12 – Smolt Bypass Discharge into Tailrace

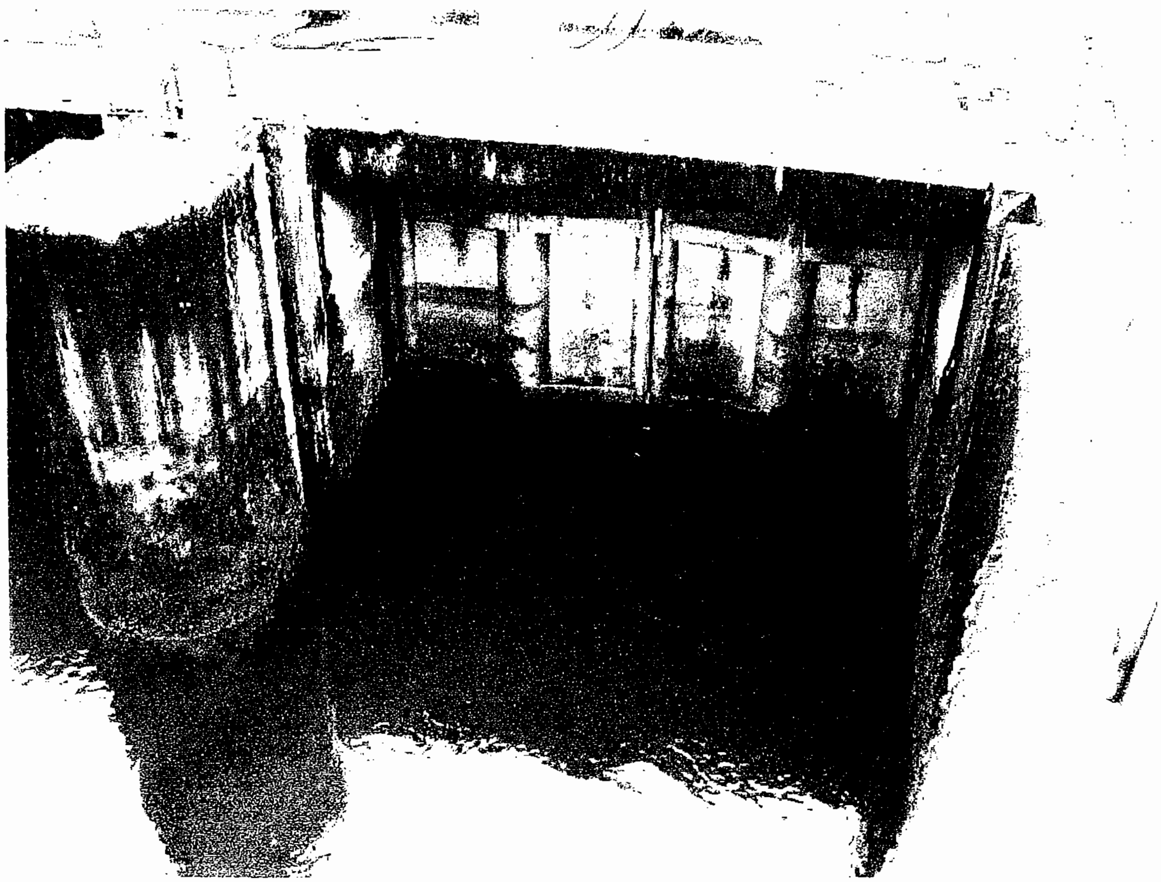


Photo 13 – Wing Gates Closing North Intake Bay

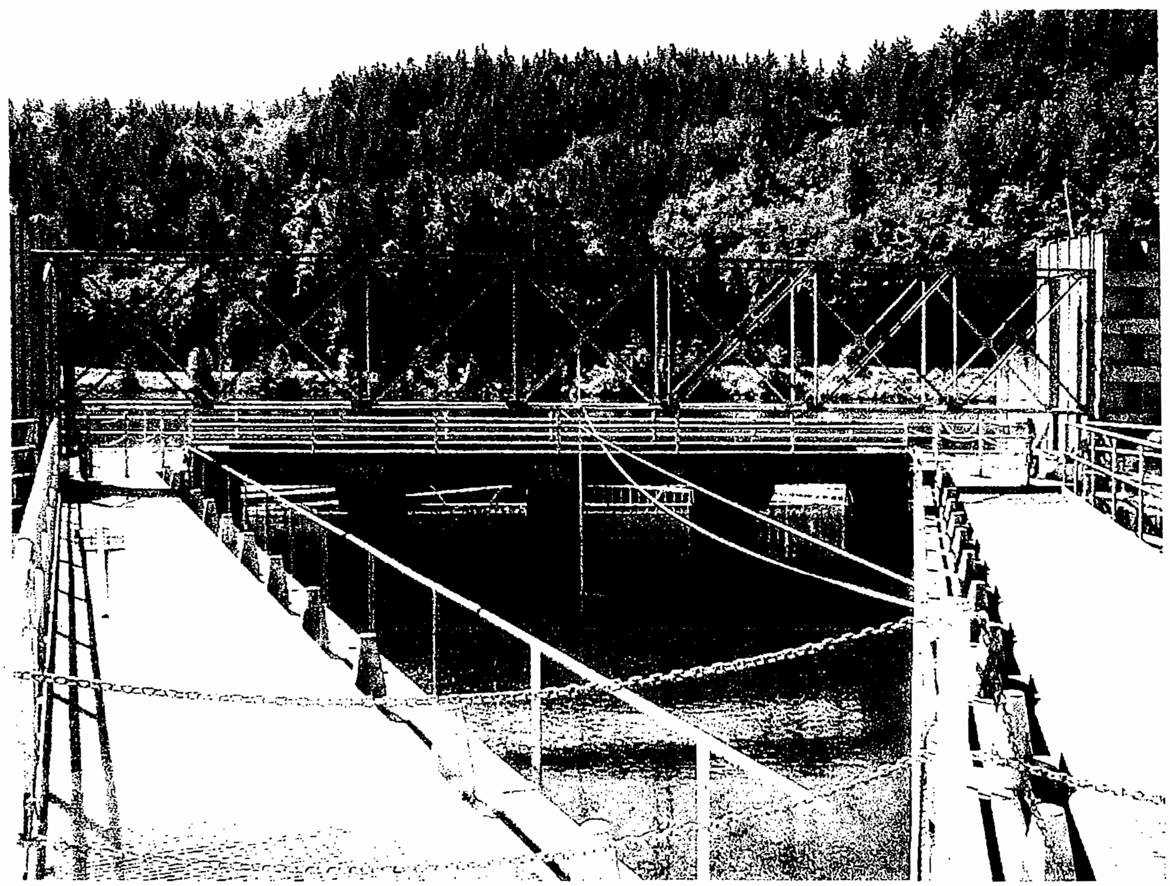


Photo 14 – Truss Spanning Intake Bay & Used To Make Velocity Measurements

APPENDIX B
VELOCITY MEASUREMENT DATA

INTAKE STRUCTURE
PLAN

1290 cfs
ELEVATION 395.6 ft.

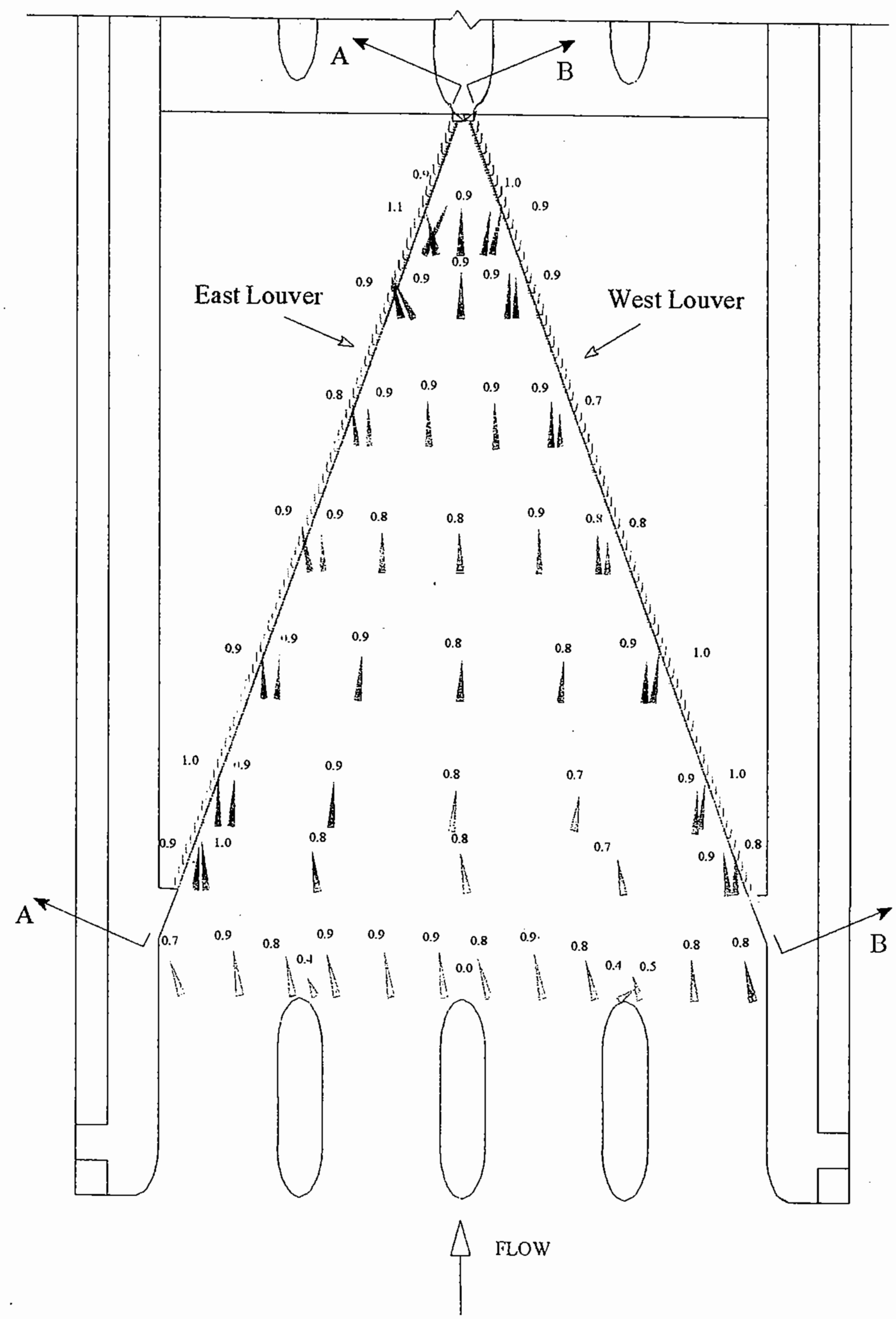


Figure B-1: X-Y Vector Velocity (m/s) at Elev. 395.6 ft (Q = 1290 cfs)

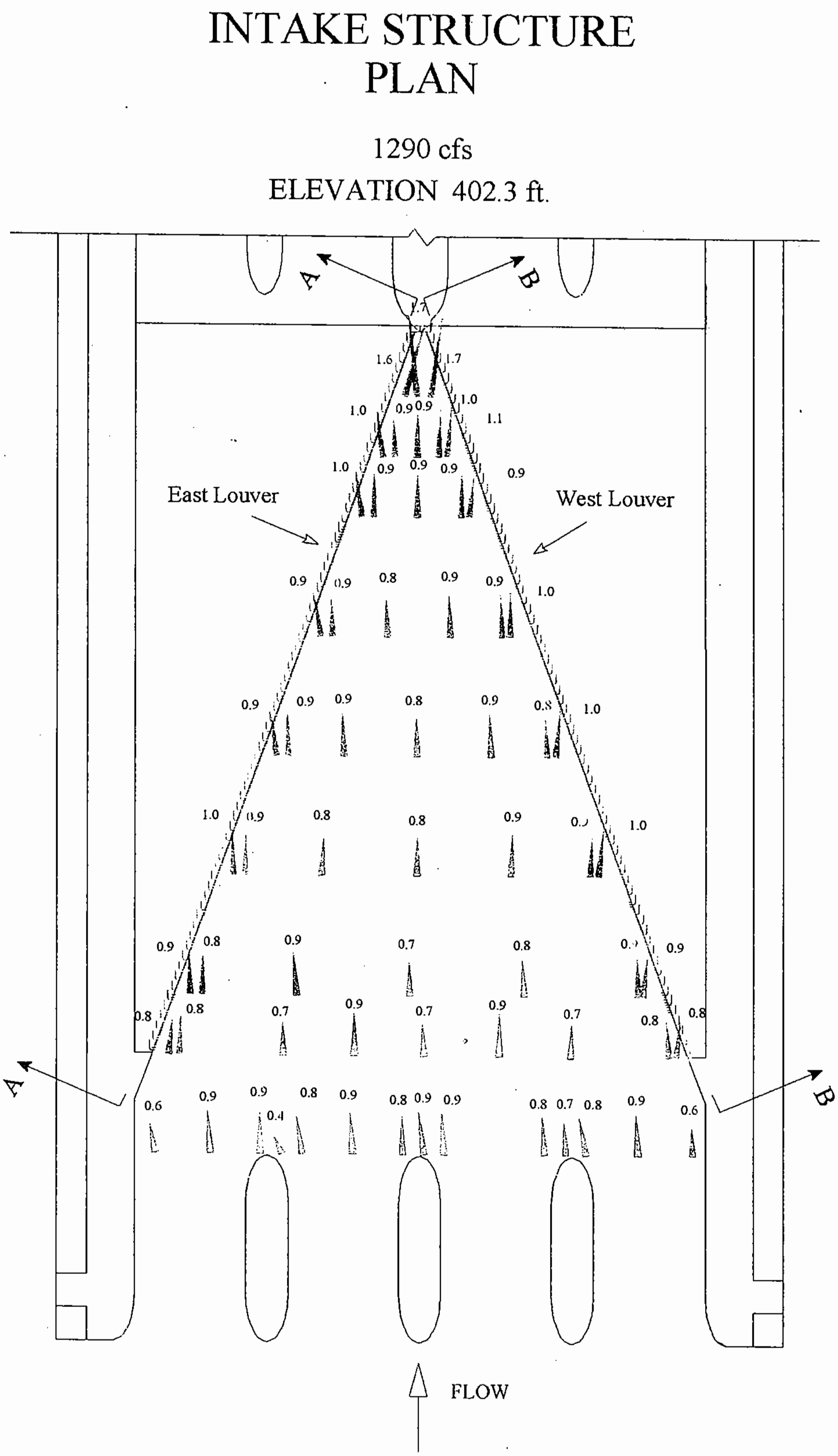


Figure B-2: X-Y Vector Velocity (m/s) at Elev. 402.3 ft (Q = 1290 cfs)

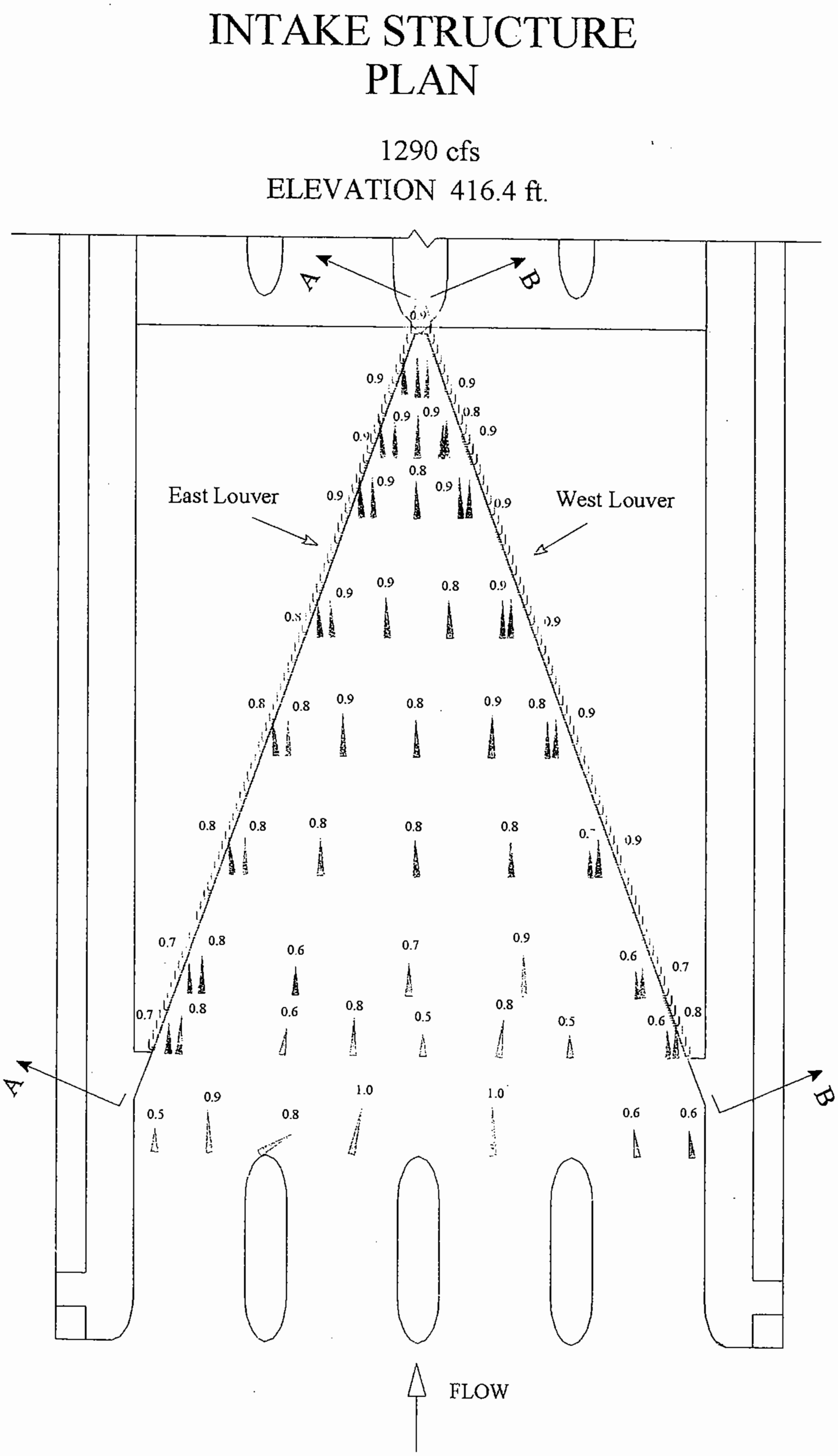


Figure B-3: X-Y Vector Velocity (m/s) at Elev. 416.4 ft (Q = 1290 cfs)

INTAKE STRUCTURE
PLAN

2580 cfs

ELEVATION 395.6 ft.

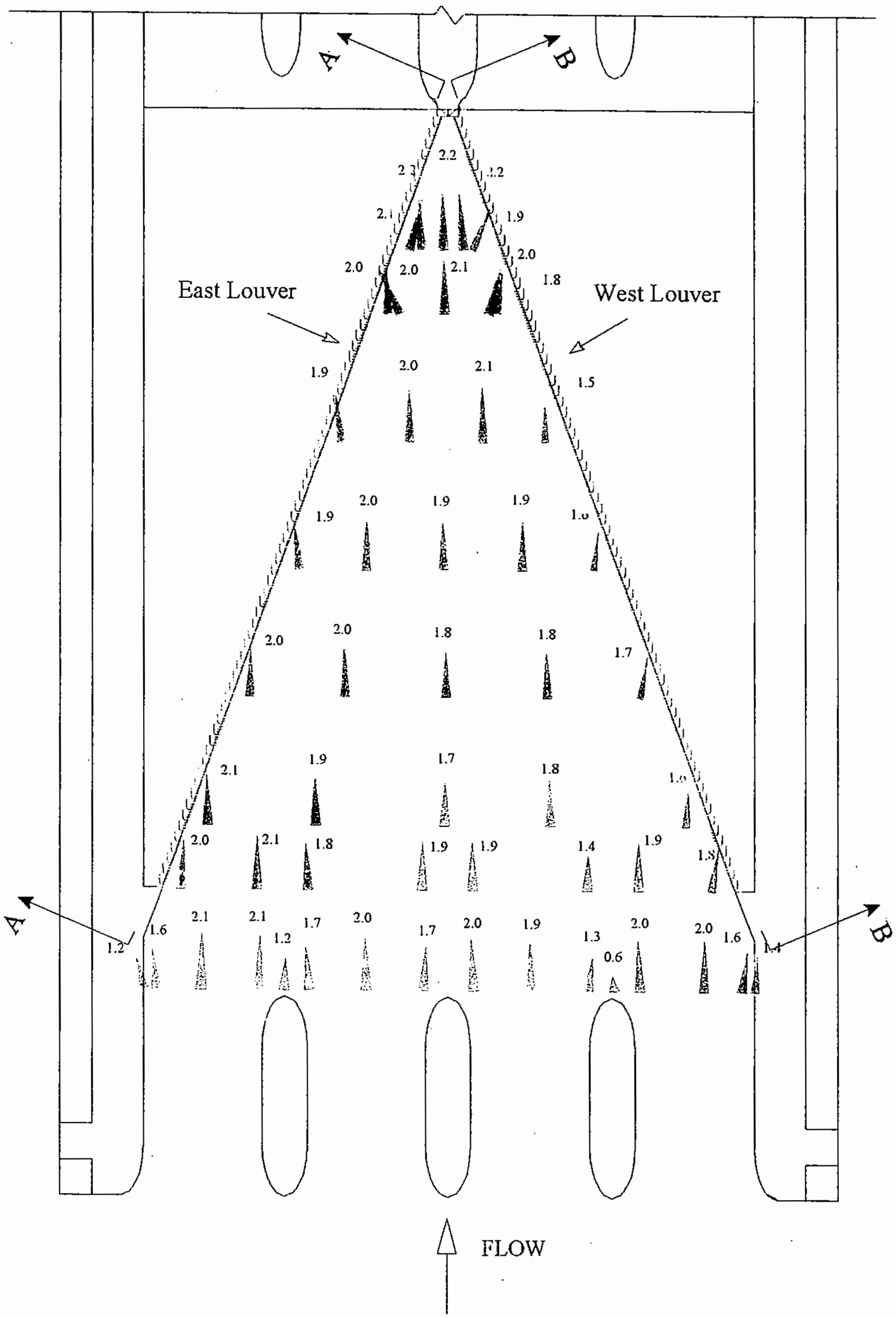


Figure B-4: X-Y Vector Velocity (m/s) at Elev. 395.6 ft (Q = 2580 cfs)

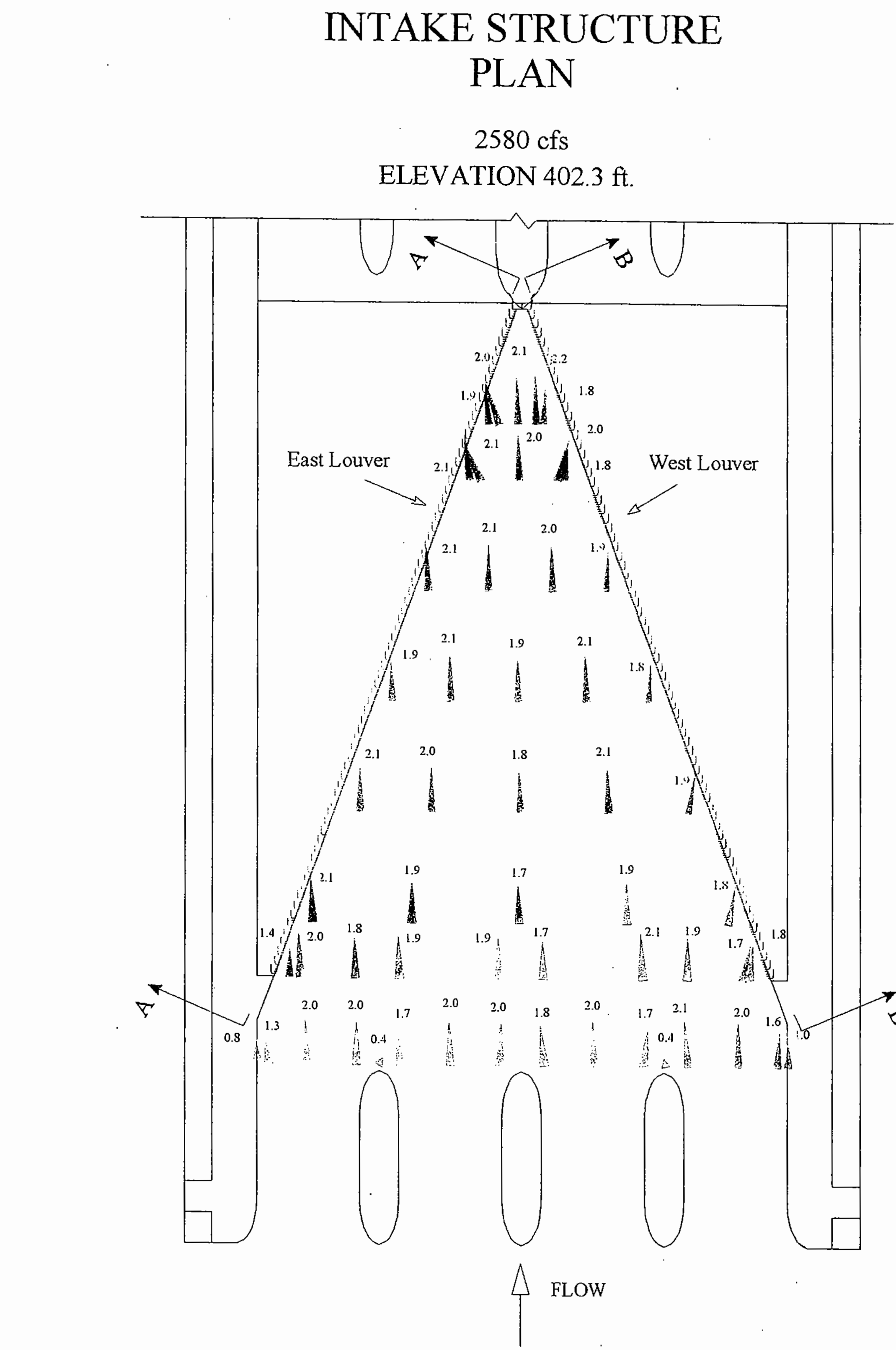


Figure B-5: X-Y Vector Velocity (m/s) at Elev. 402.3 ft (Q = 2580 cfs)

INTAKE STRUCTURE
PLAN

2580 cfs
ELEVATION 416.4 ft.

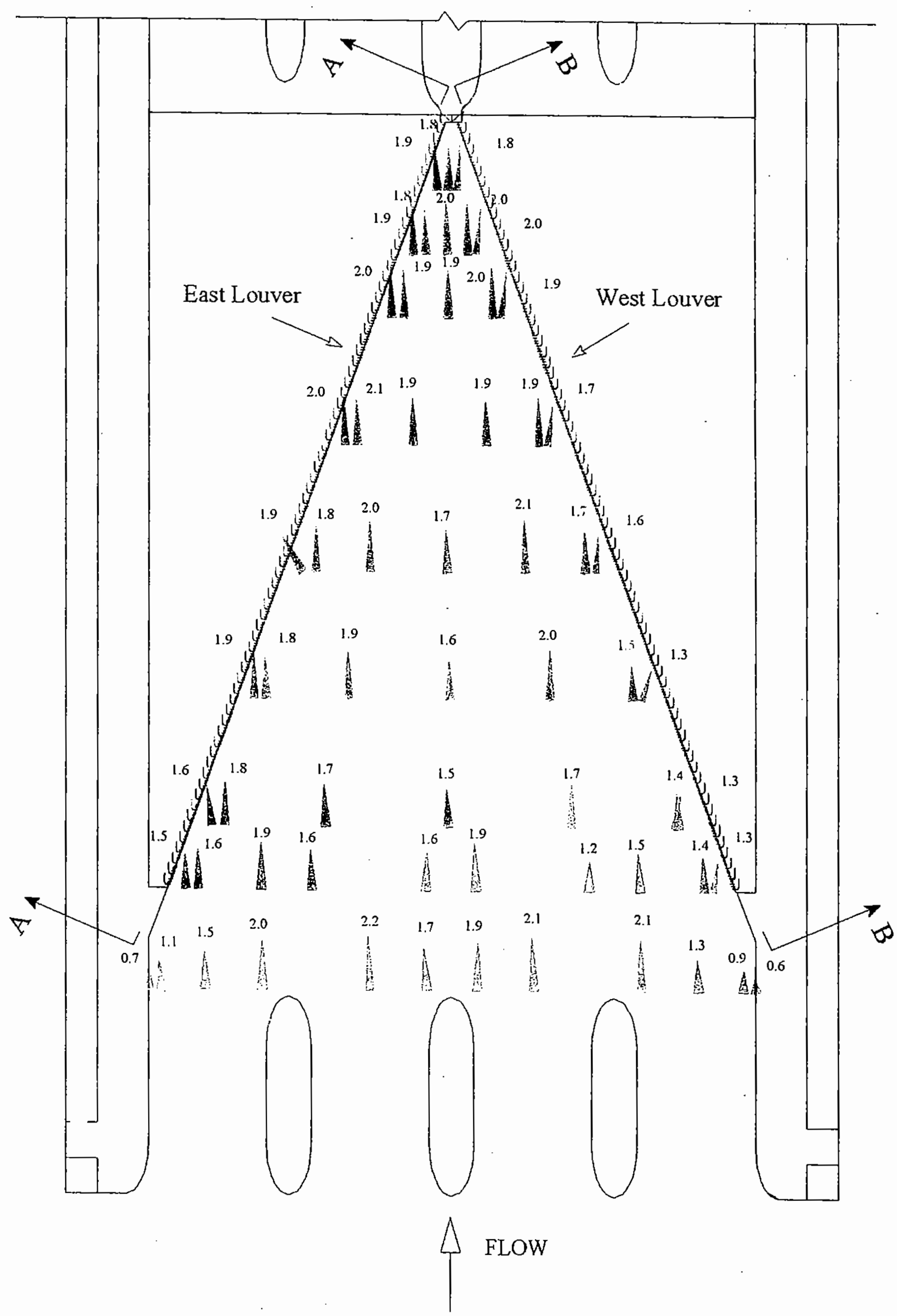


Figure B-6: X-Y Vector Velocity (m/s) at Elev. 416.4 ft (Q = 2580 cfs)

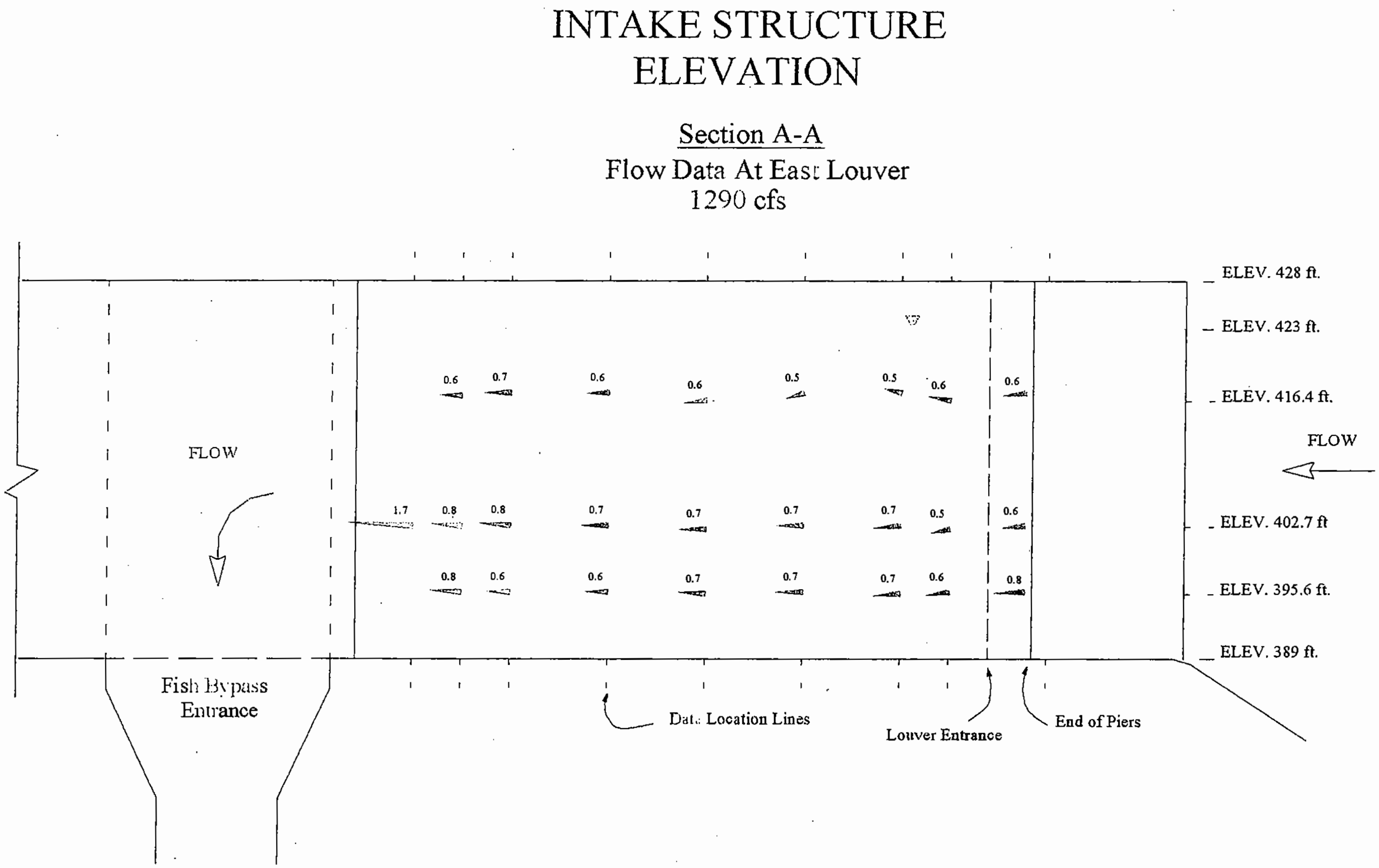


Figure B-7: X-Z Vector Velocity (m/s) at East Louver (Q = 1290 cfs)

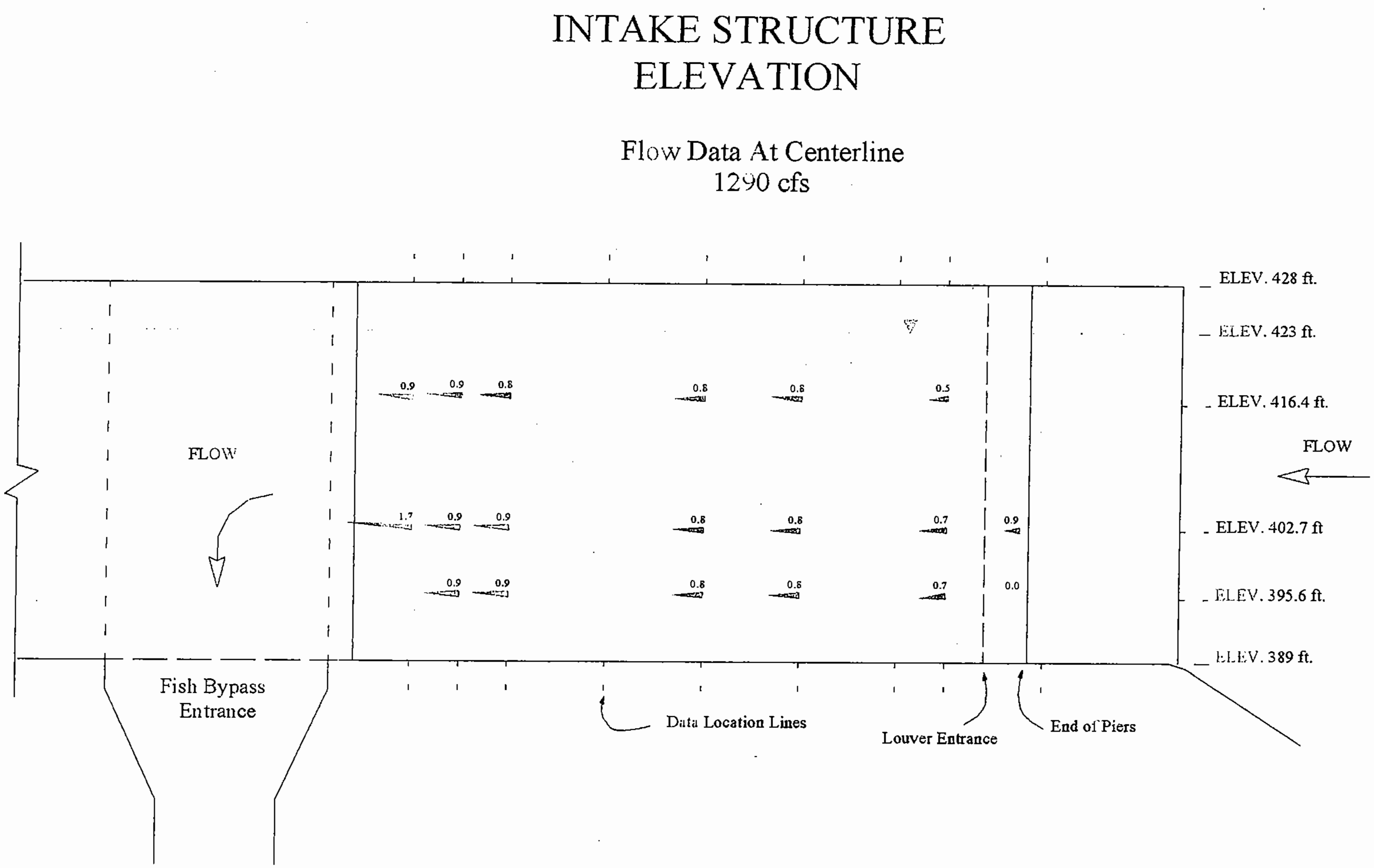


Figure B-8: X-Z Vector Velocity (m/s) at Centerline (Q = 1290 cfs)

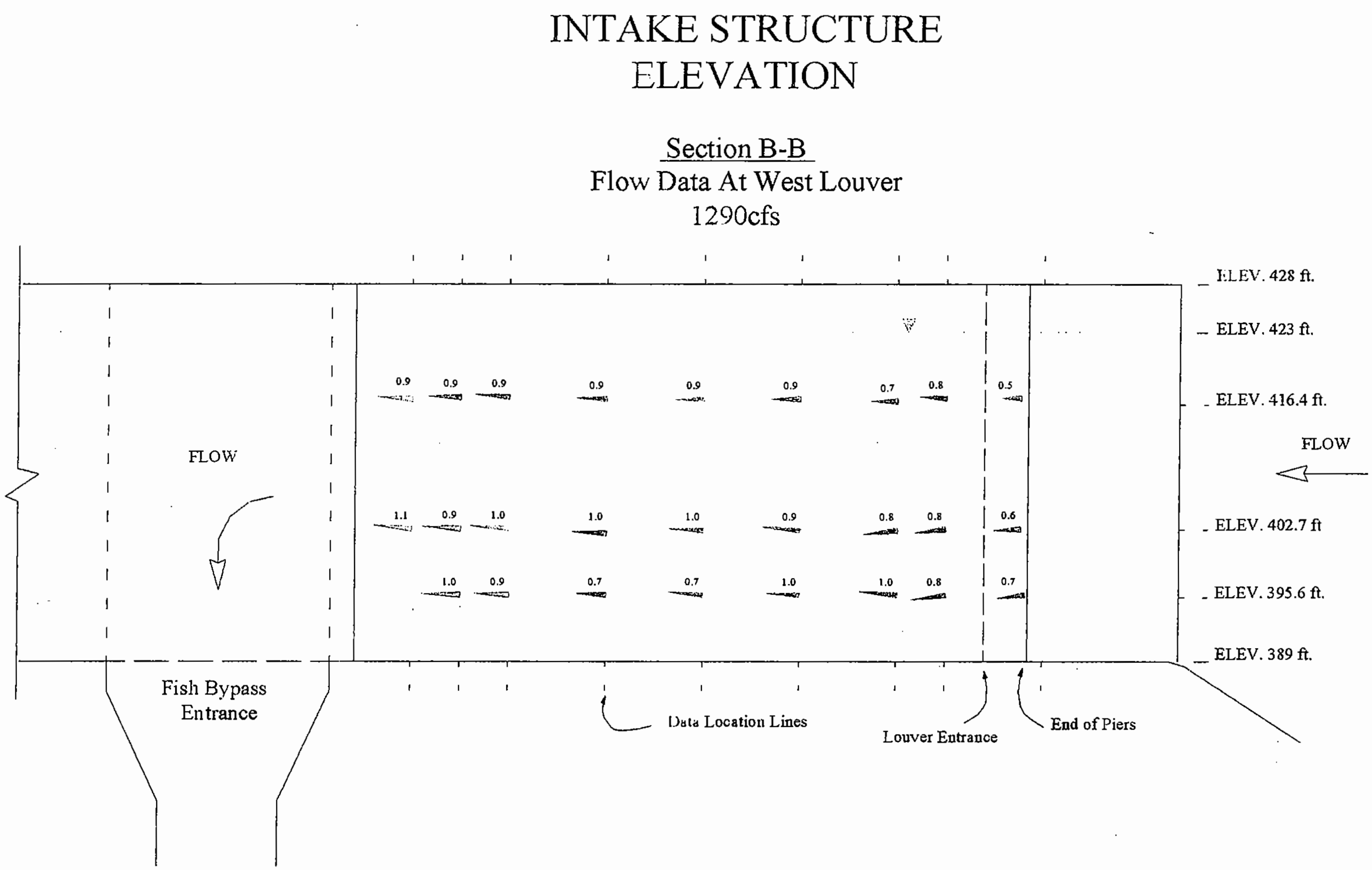


Figure B-9: X-Z Vector Velocity (m/s) at West Louver (Q = 1290 cfs)

INTAKE STRUCTURE ELEVATION

Section A-A

Flow Data At East Louver
2580 cfs

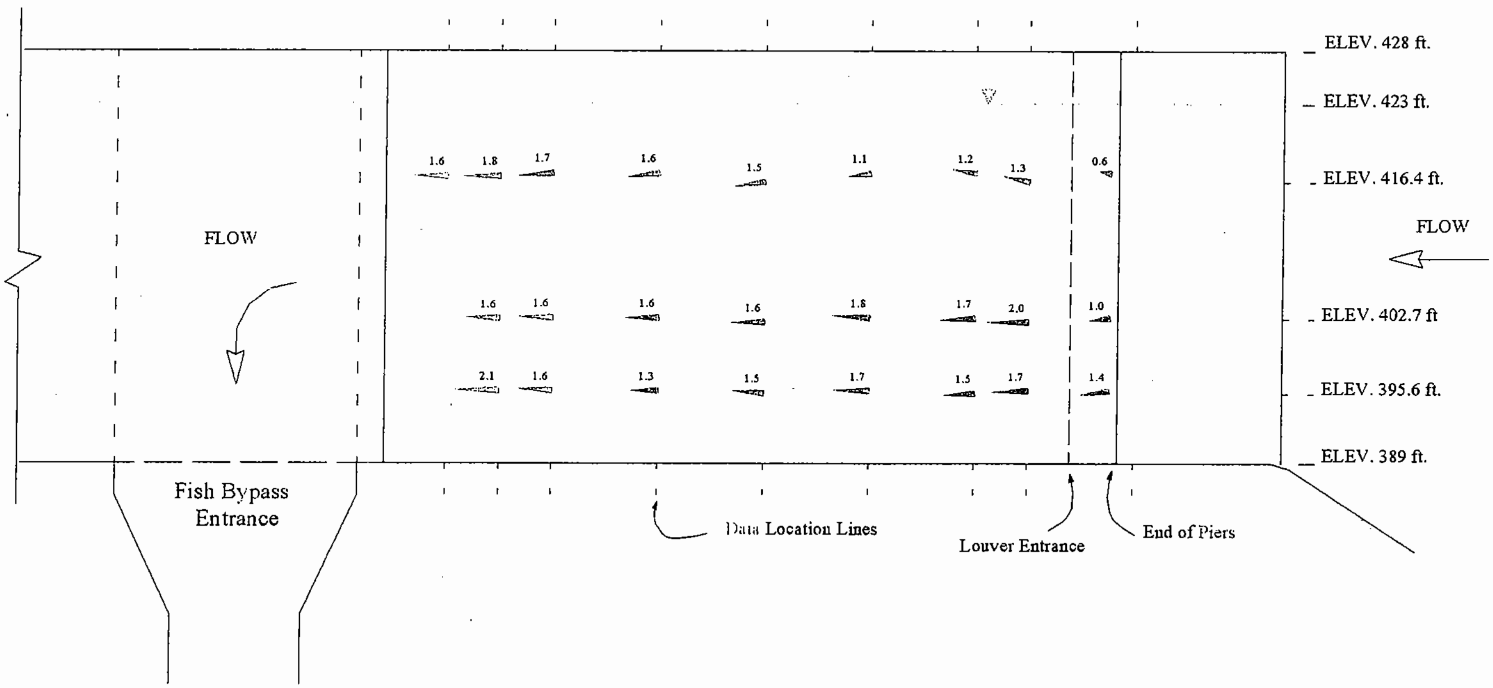


Figure B-10: X-Z Vector Velocity (m/s) at East Louver (Q = 2580 cfs)

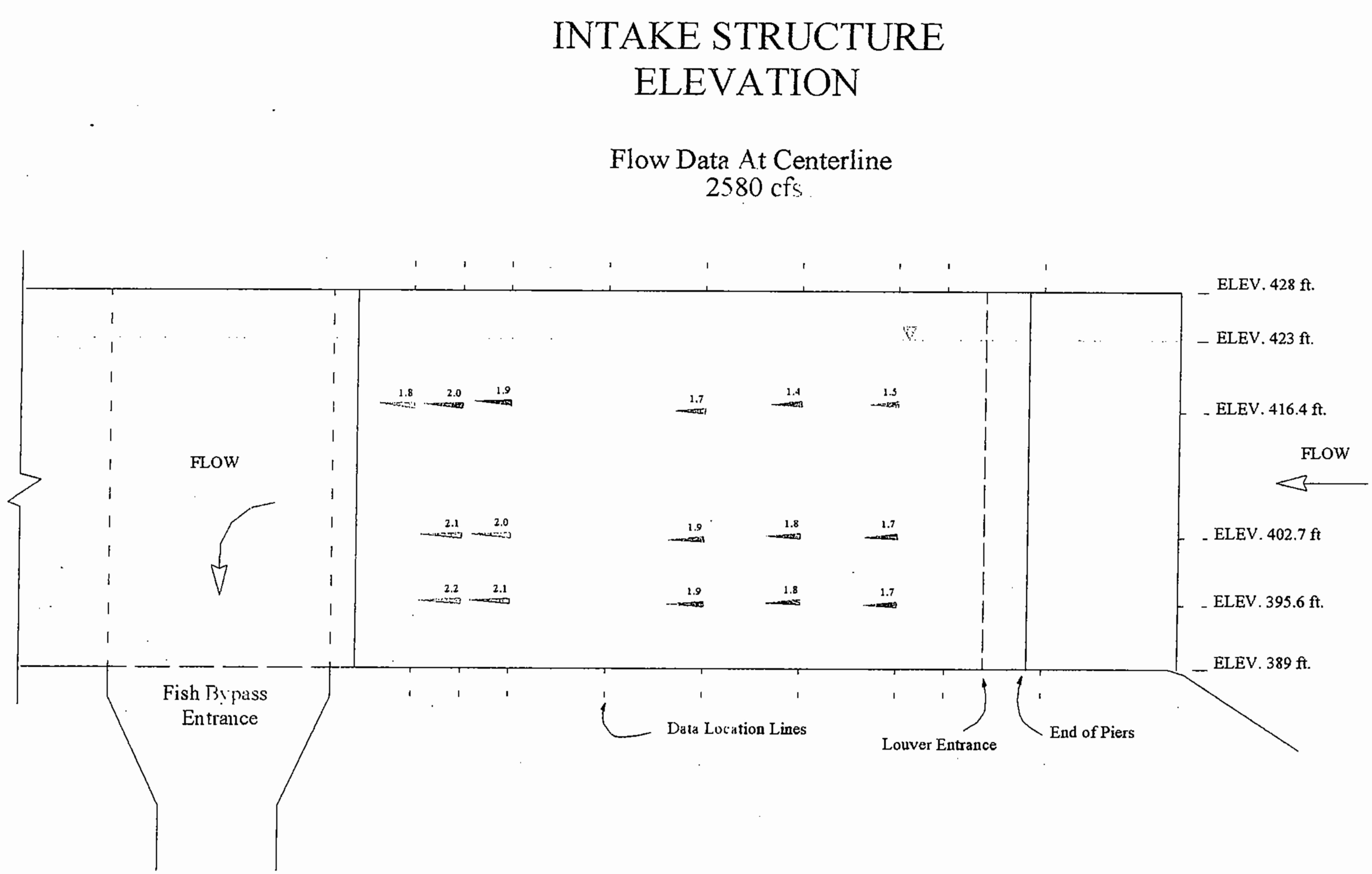


Figure B-11: X-Z Vector Velocity (m/s) at Centerline (Q = 2580 cfs)

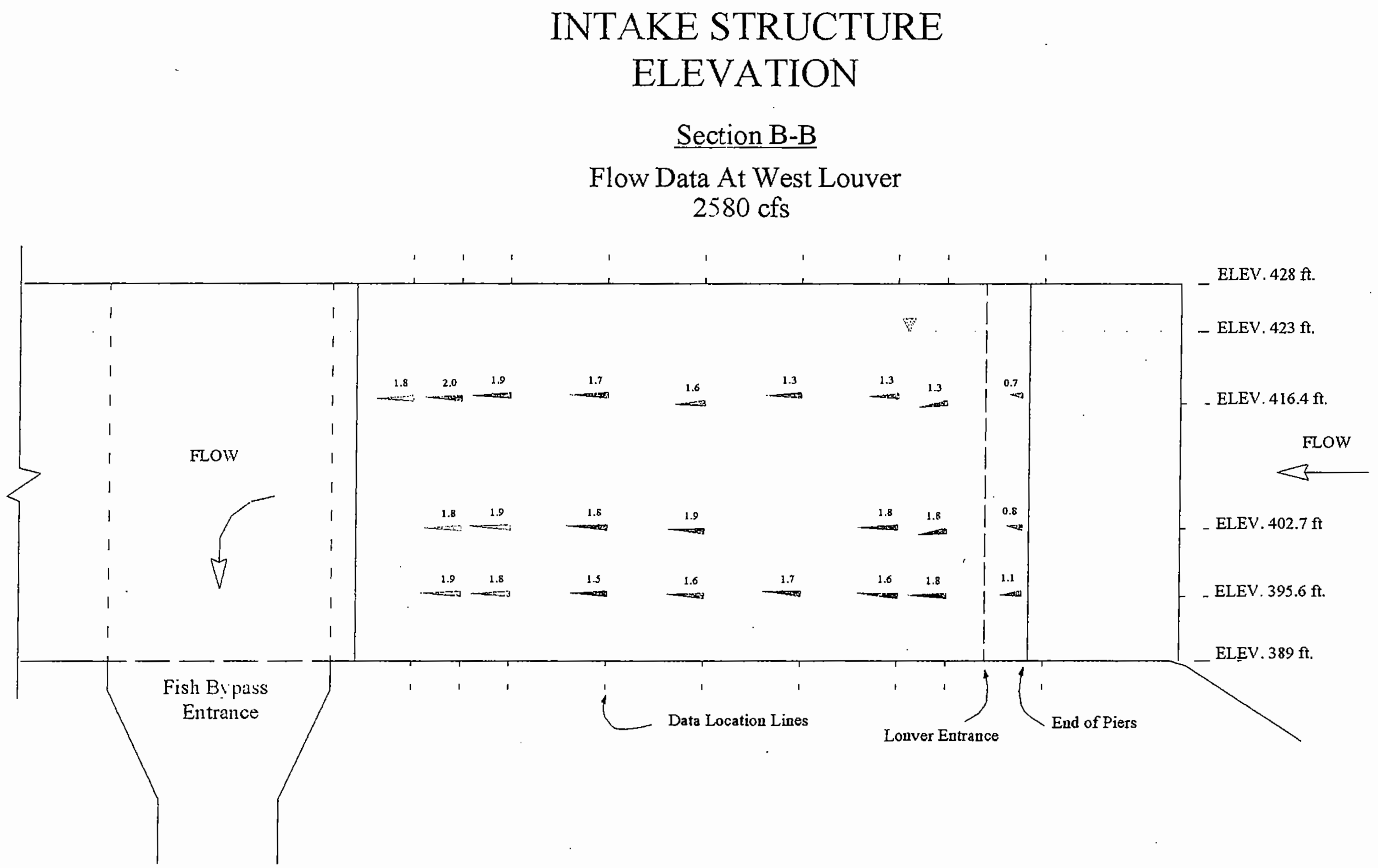


Figure B-12: X-Z Vector Velocity (m/s) at West Louver (Q = 2580 cfs)

APPENDIX C
CFD MODEL RESULTS

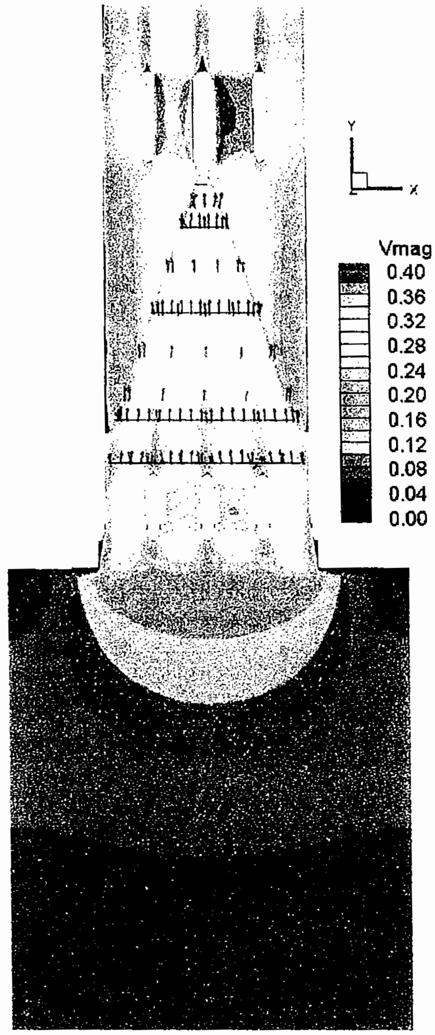


Figure C-1: Verification Run01 (Q=1290 cfs, elev. 395.6 ft, Vmag in m/s)

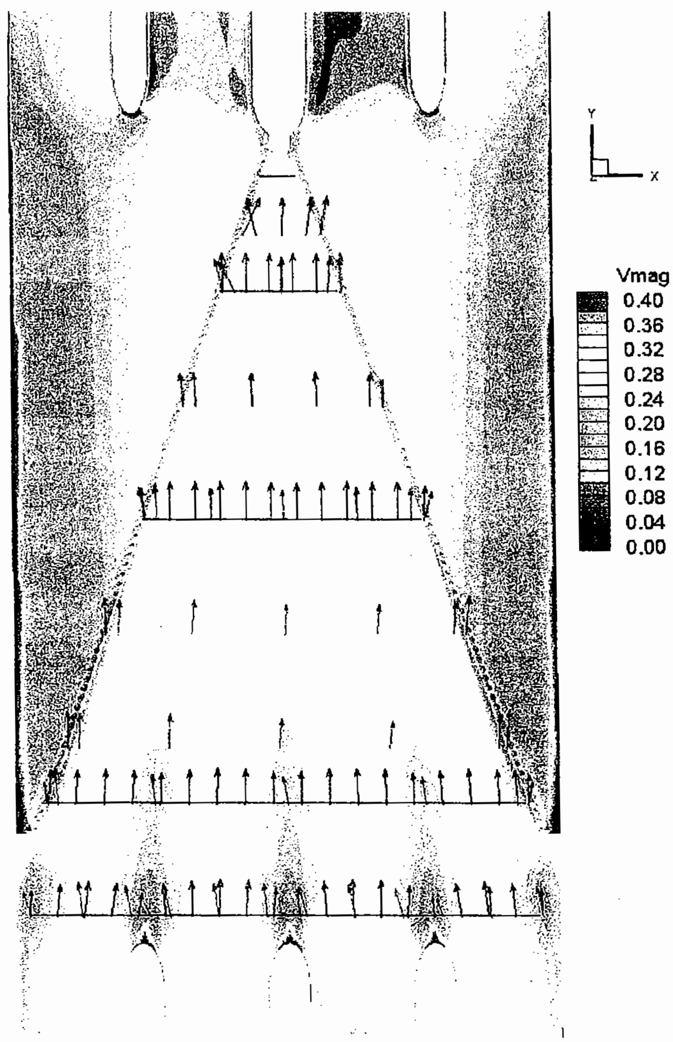


Figure C-2: Verification Run01 zoom view (Q=1290 cfs, elev. 395.6 ft, Vmag in m/s)

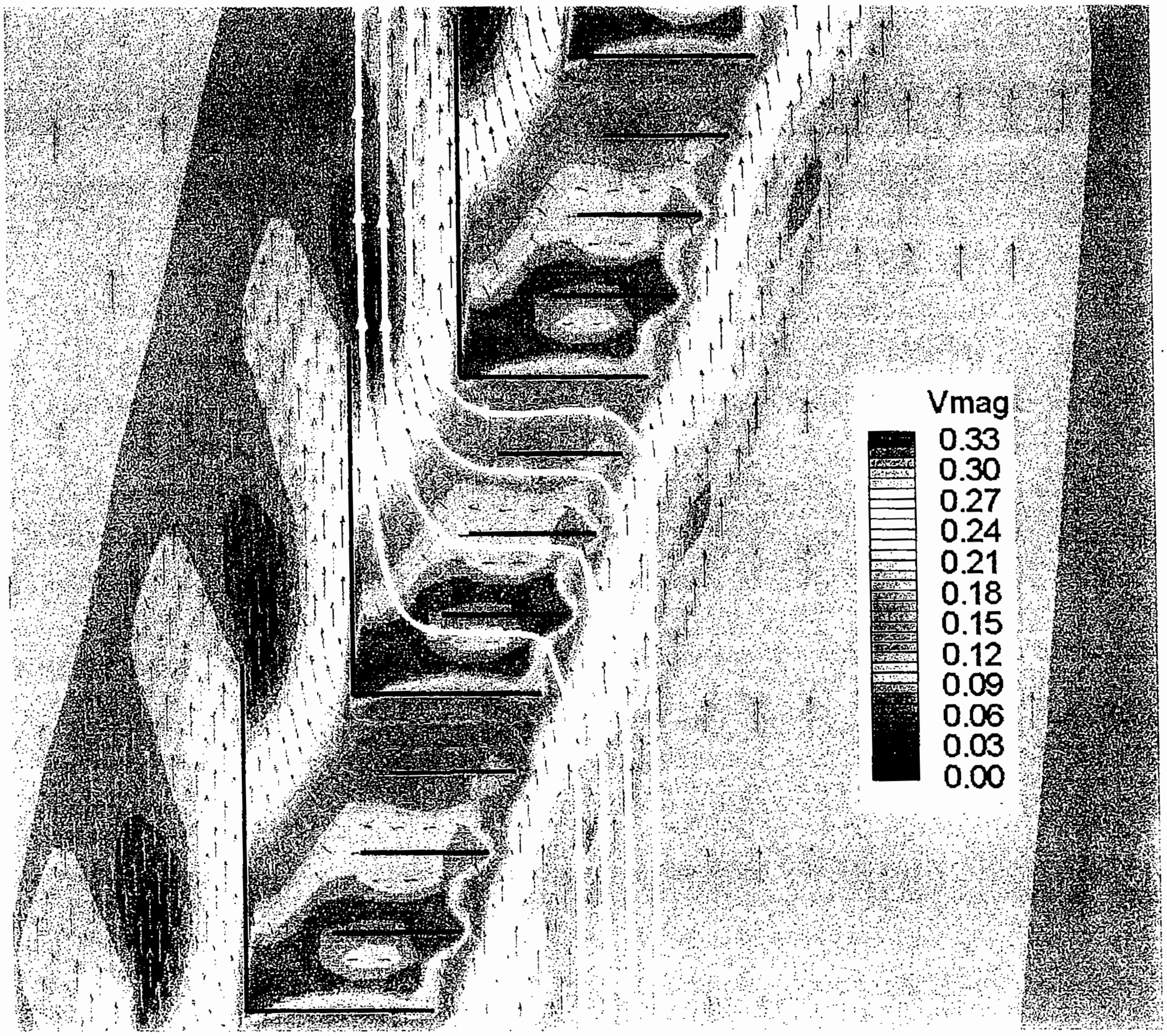


Figure C-3: Verification Run01 louver zoom (Q=1290 cfs, elev. 395.6 ft, free-slip louvers, Vmag in m/s)

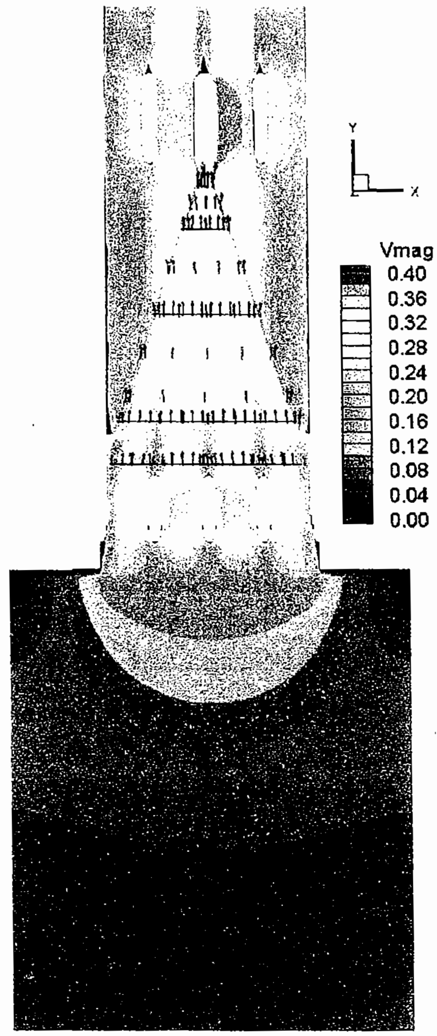


Figure C-4: Verification Run01 (Q=1290 cfs, elev. 402.7 ft, Vmag in m/s)

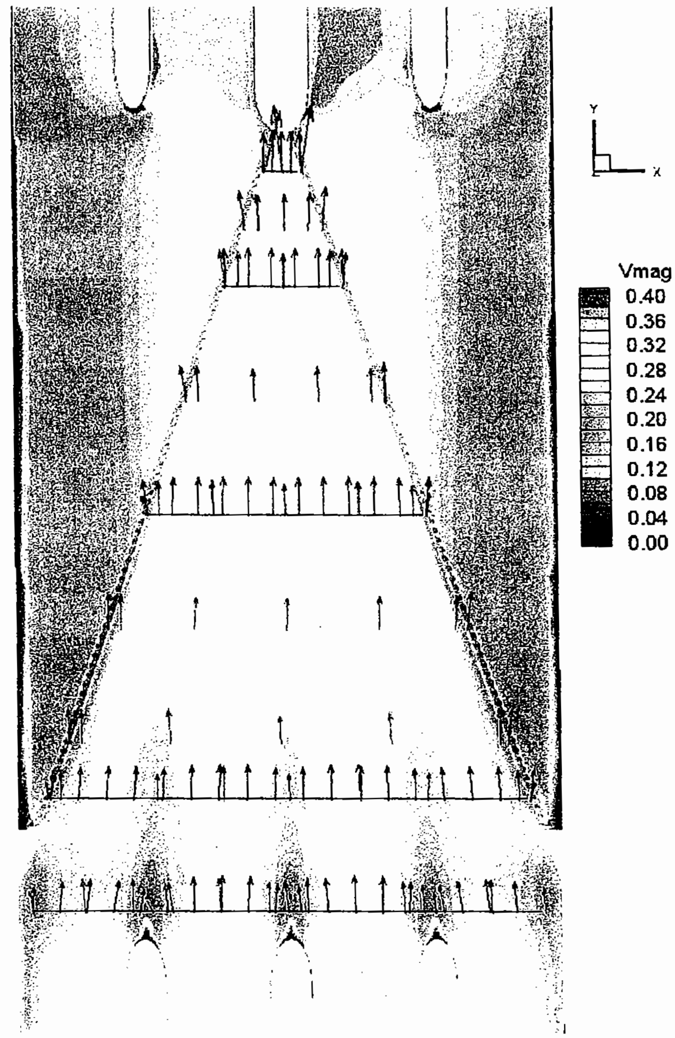


Figure C-5: Verification Run01 zoom view (Q=1290 cfs, elev. 402.7 ft, Vmag in m/s)

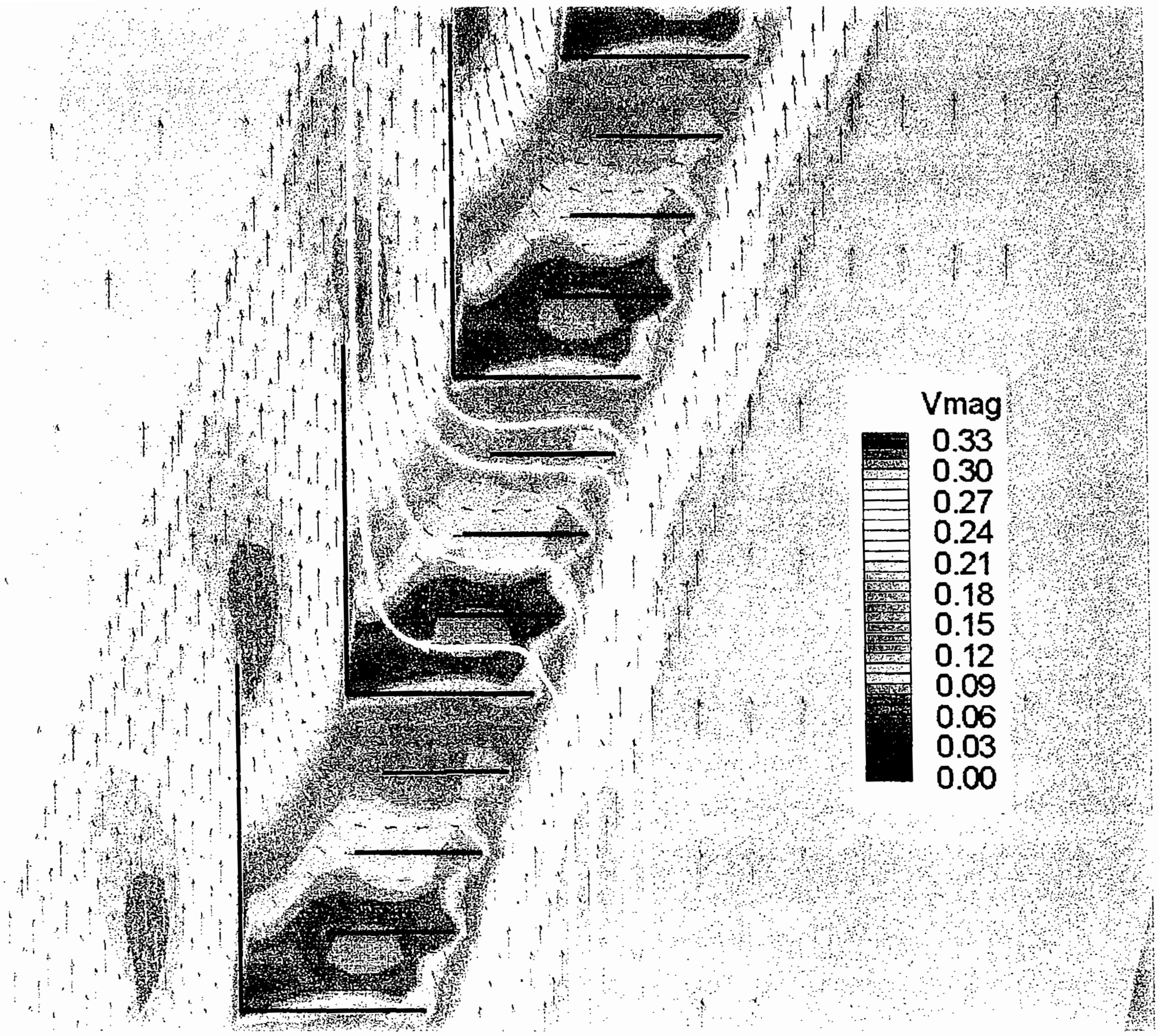


Figure C-6: Verification Run01 louver zoom (Q=1290 cfs, elev. 402.7 ft, free-slip louvers, Vmag in m/s)

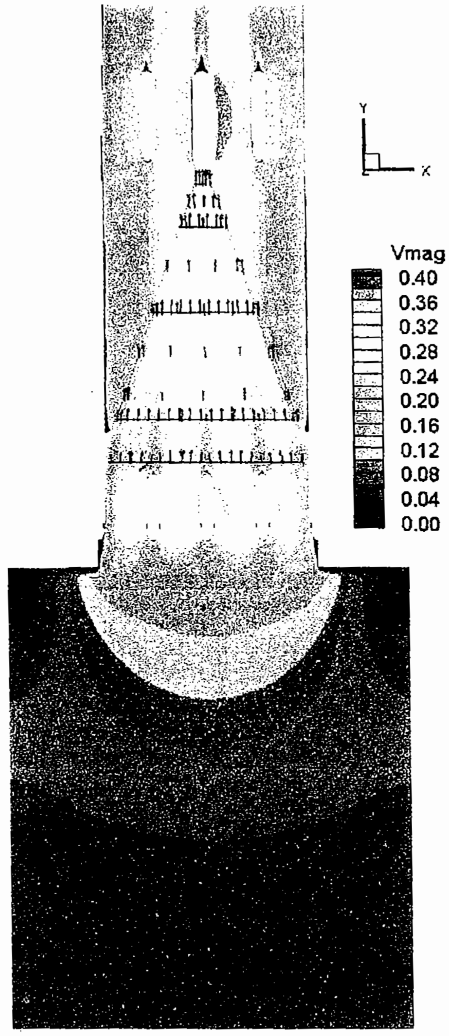


Figure C-7: Verification Run01 (Q=1290 cfs, elev. 416.4 ft, Vmag in m/s)

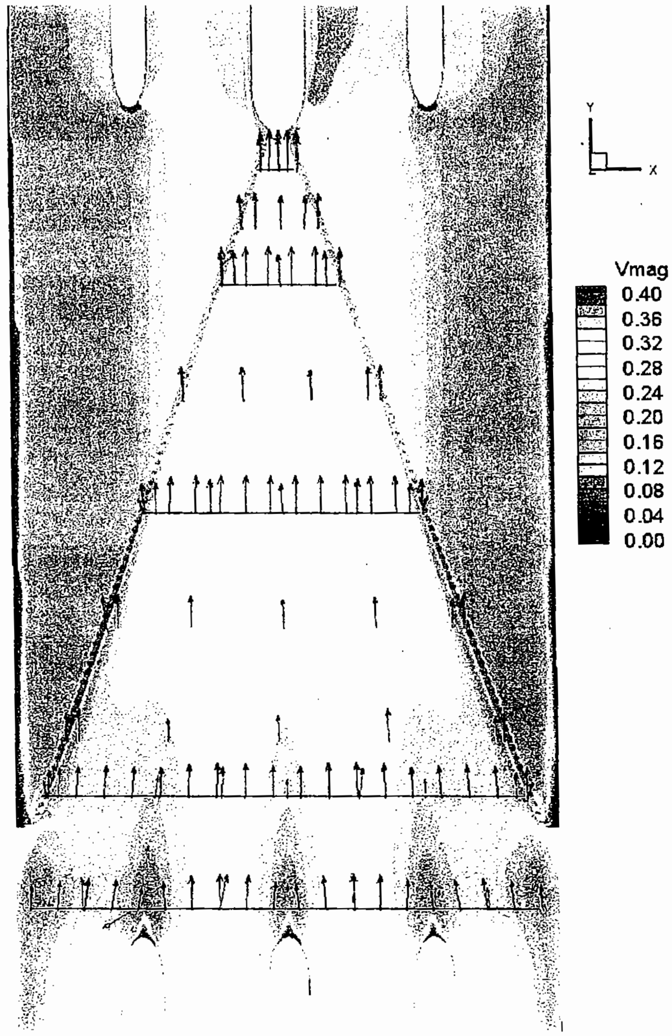


Figure C-8: Verification Run01 zoom view (Q=1290 cfs, elev. 416.4 ft, Vmag in m/s)

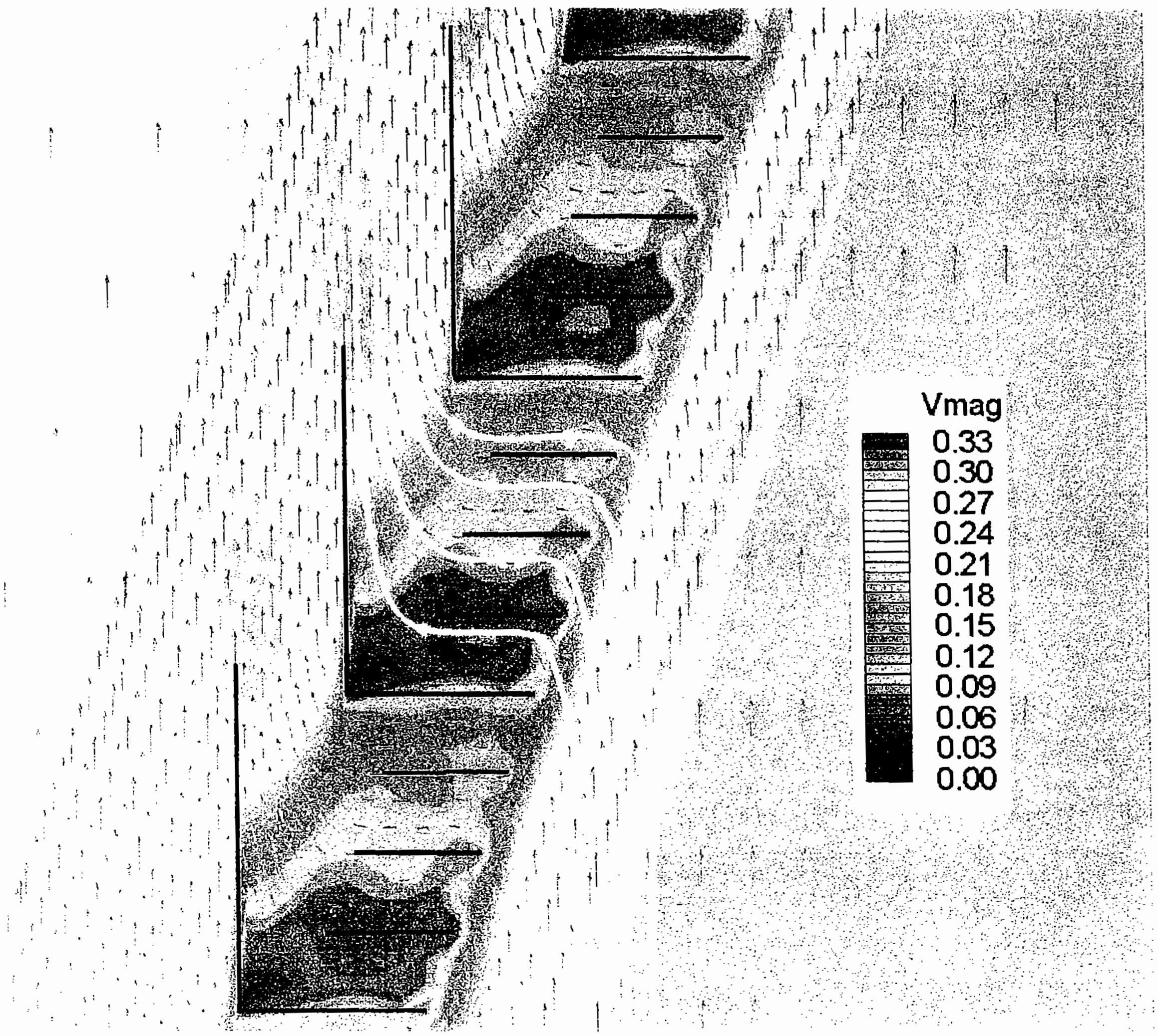


Figure C-9: Verification Run01 louver zoom (Q=1290 cfs, elev.416.4 ft, free-slip louvers, Vmag in m/s)

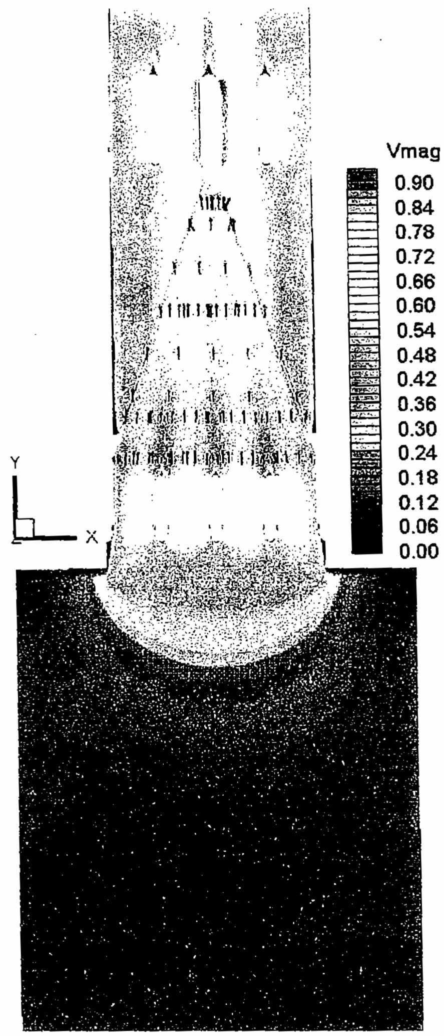


Figure C-10: Verification Run02 (Q=2580 cfs, elev. 395.6 ft, Vmag in m/s)

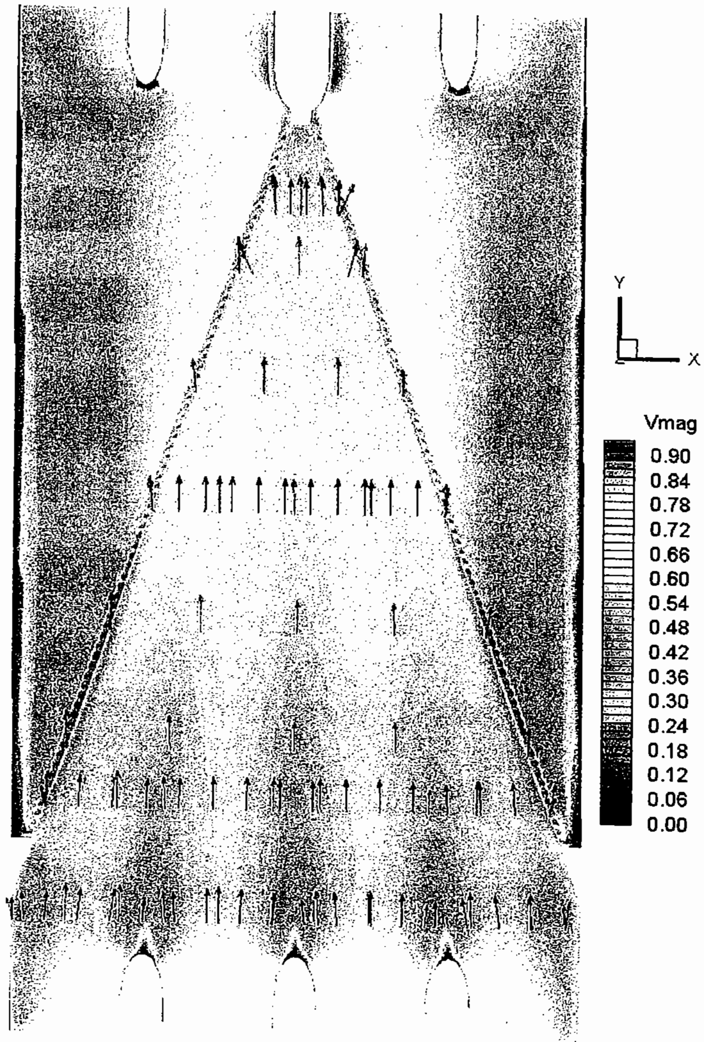


Figure C-11: Verification Run02 zoom view (Q=2580 cfs, elev. 395.6, Vmag in m/s)

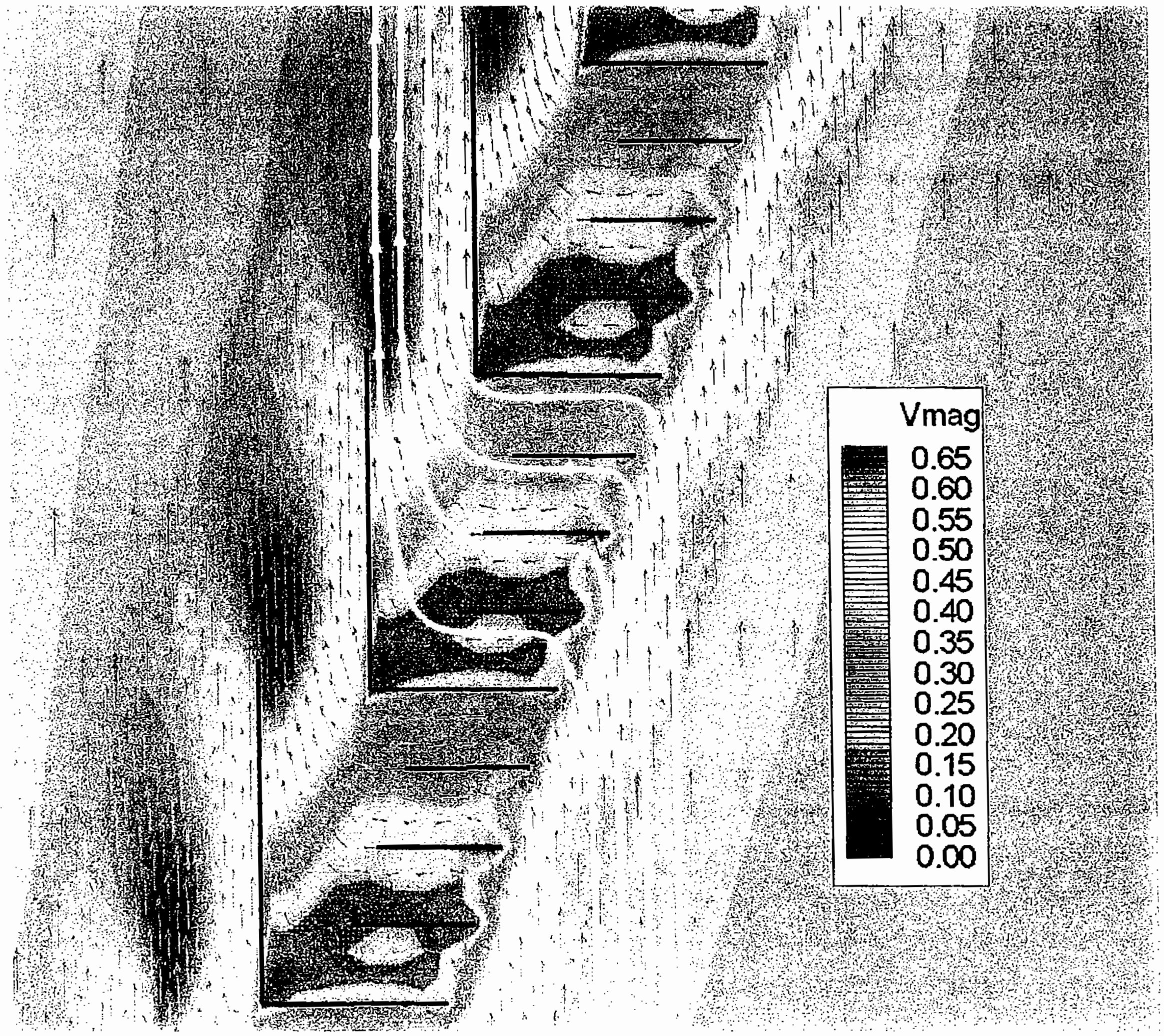


Figure C-12: Verification Run02 louver zoom (Q=2580 cfs, elev. 395.6 ft, free-slip louvers, Vmag in m/s)

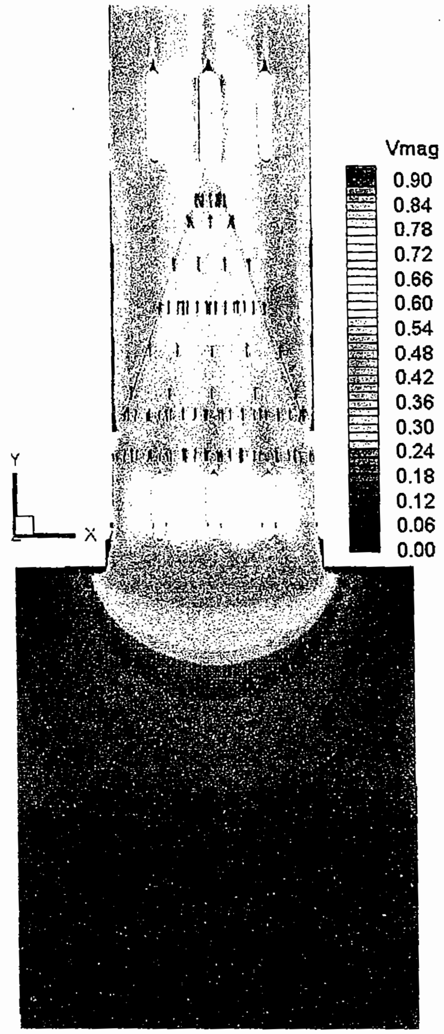


Figure C-13: Verification Run02 (Q=2580 cfs, elev. 402.7 ft, Vmag in m/s)

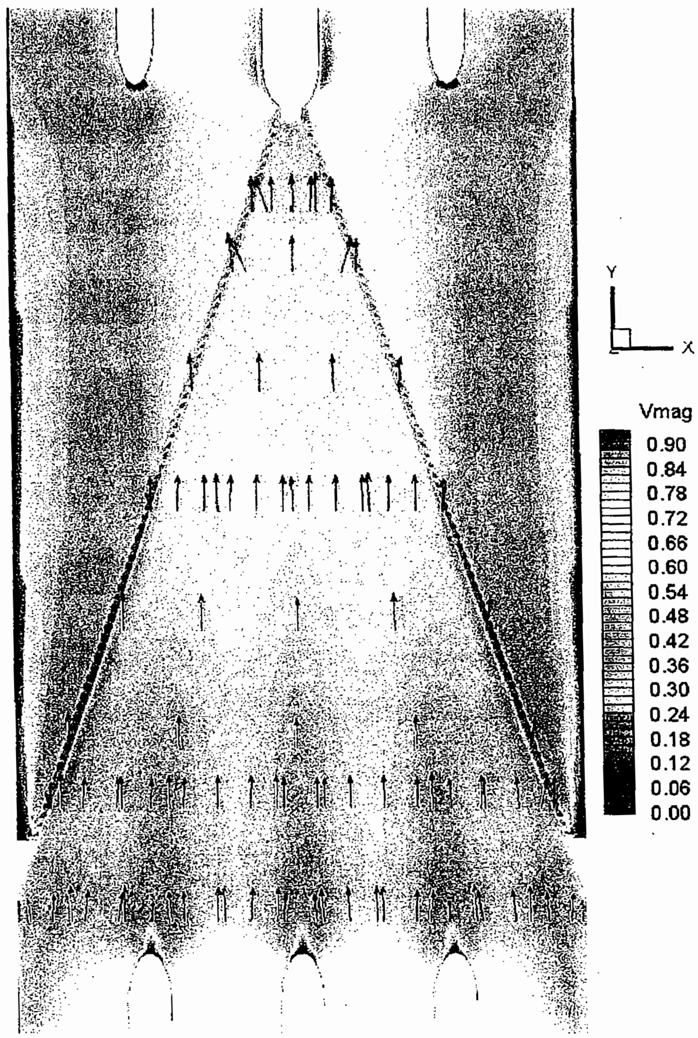


Figure C-14: Verification Run02 zoom view (Q=2580 cfs, elev. 402.7 ft, Vmag in m/s)

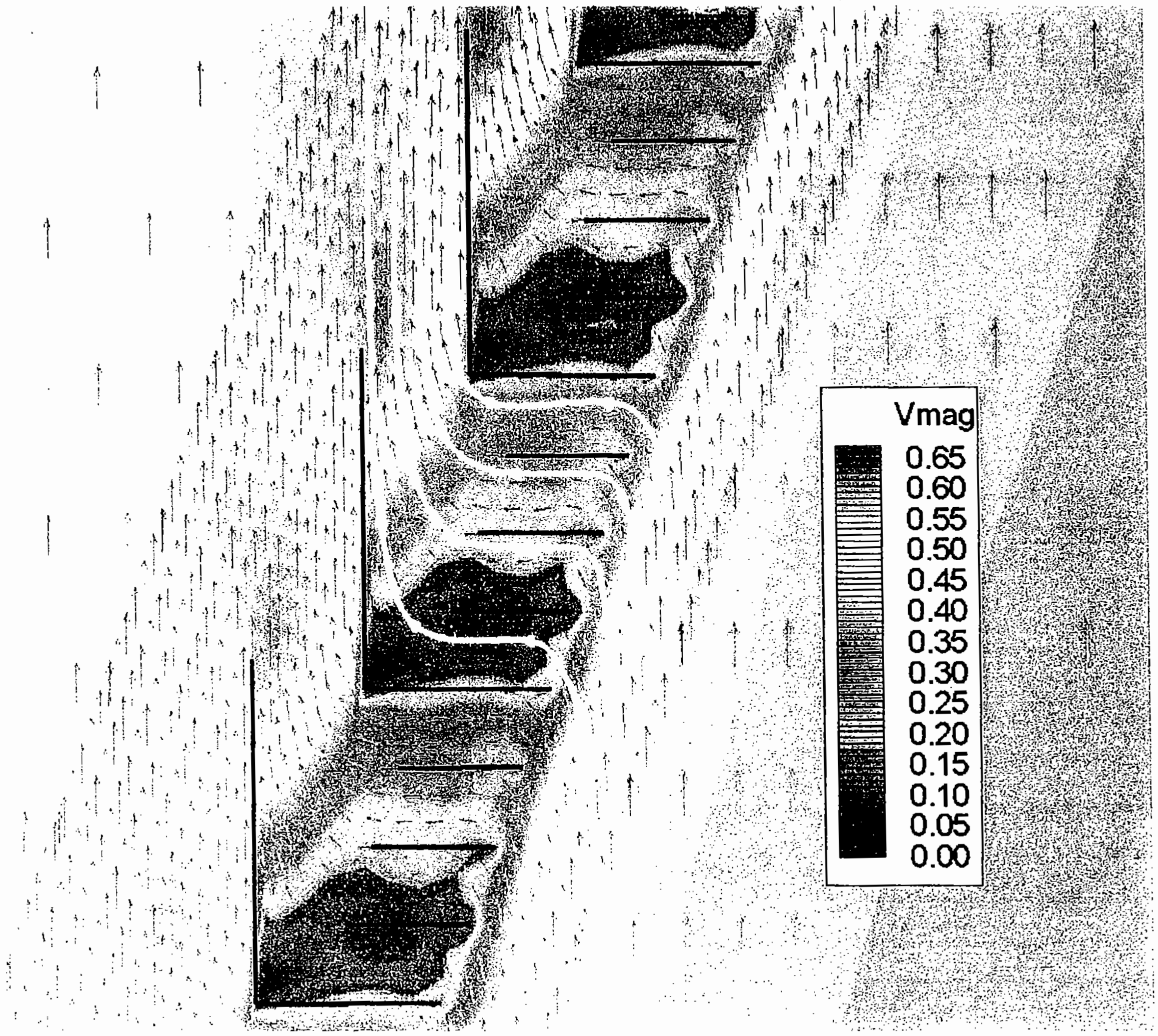


Figure C-15: Verification Run02 louver zoom (Q=2580 cfs, elev. 402.7 ft, free-slip louvers, Vmag in m/s)

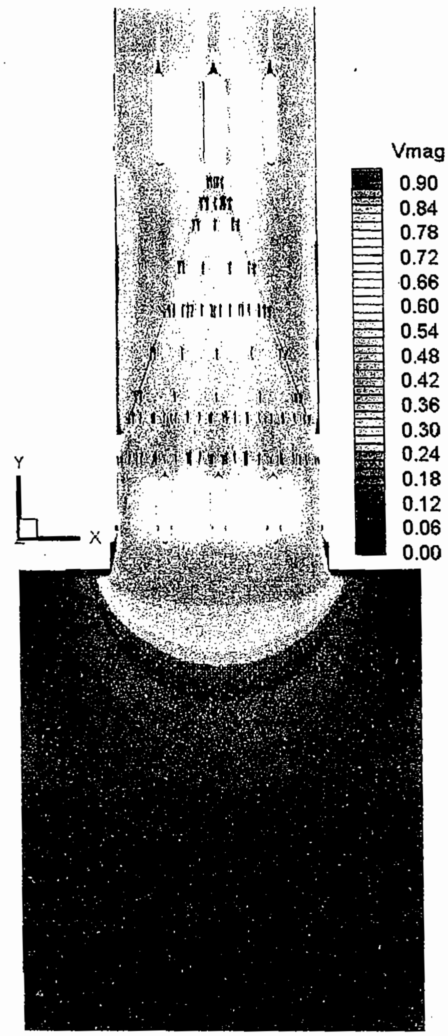


Figure C-16: Verification Run02 (Q=2580 cfs, elev. 416.4 ft, Vmag in m/s)

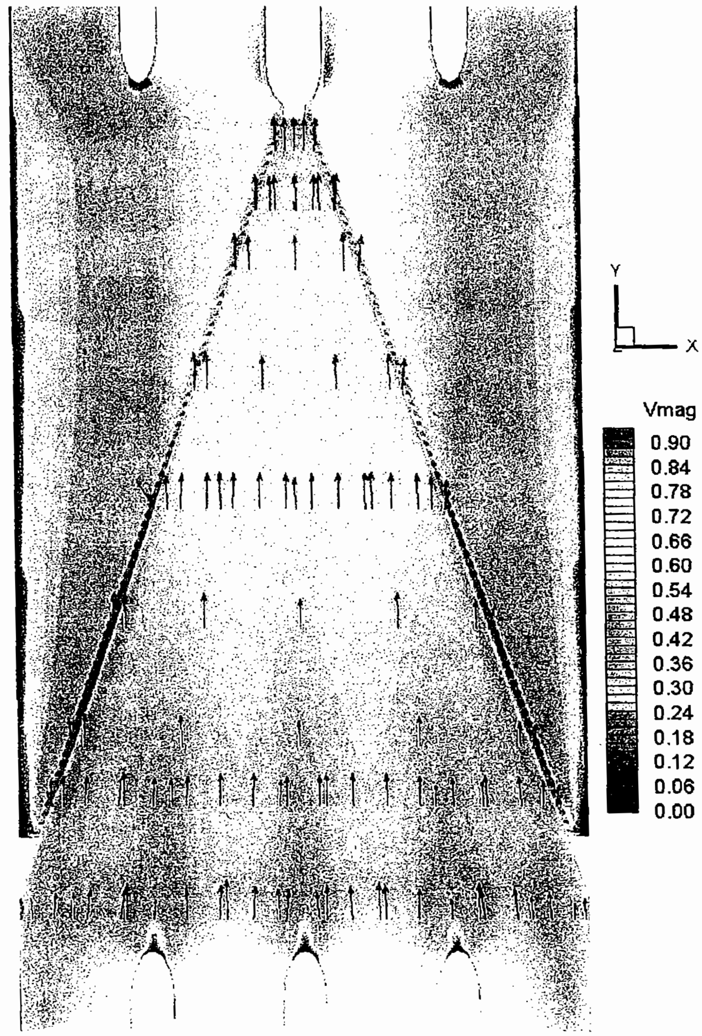


Figure C-17: Verification Run02 zoom view (Q=2580 cfs, elev. 416.4 ft, Vmag in m/s)

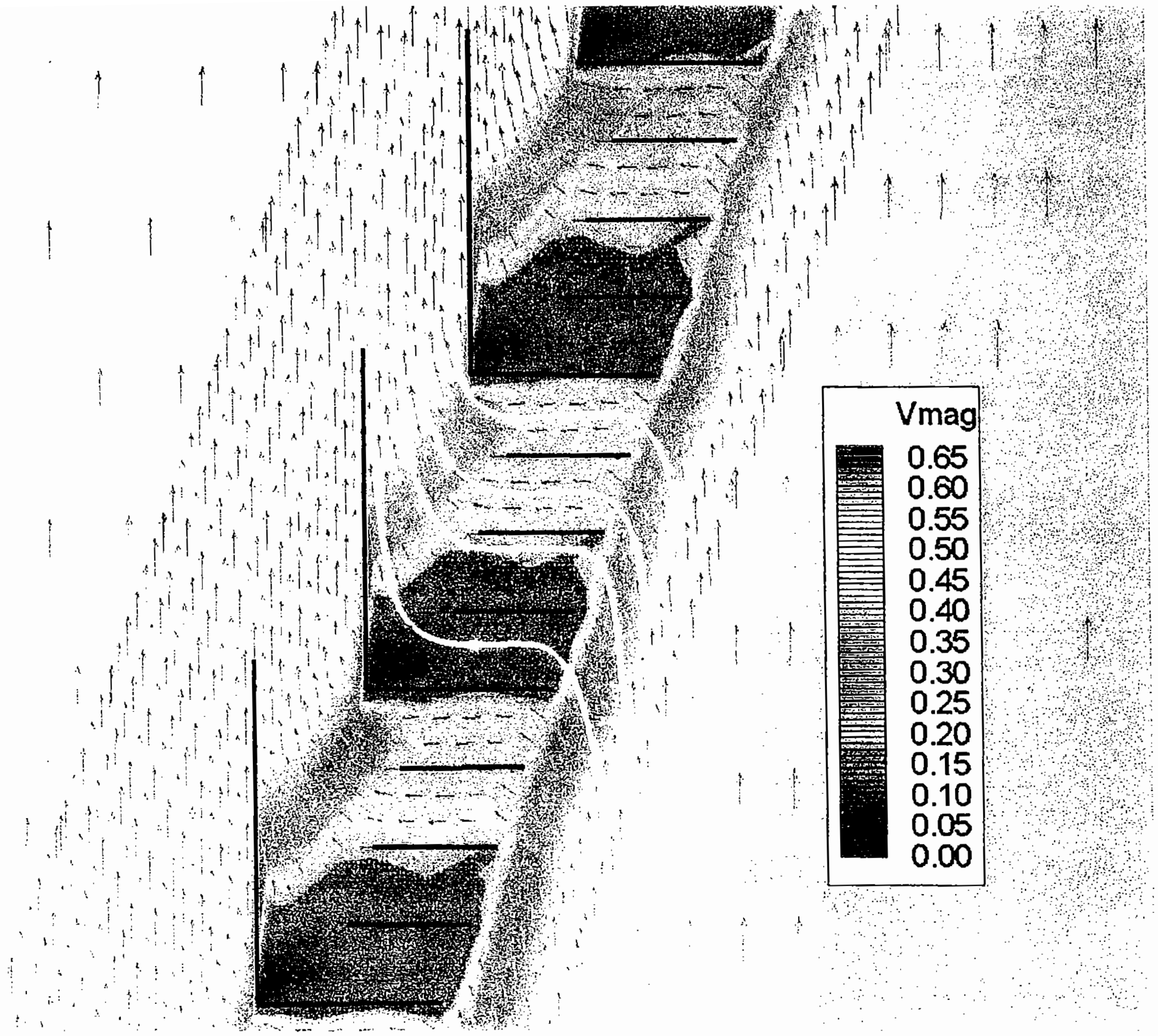


Figure C-18: Verification Run02 louver zoom (Q=2580 cfs, elev. 416.4 ft, free-slip louvers, Vmag in m/s)

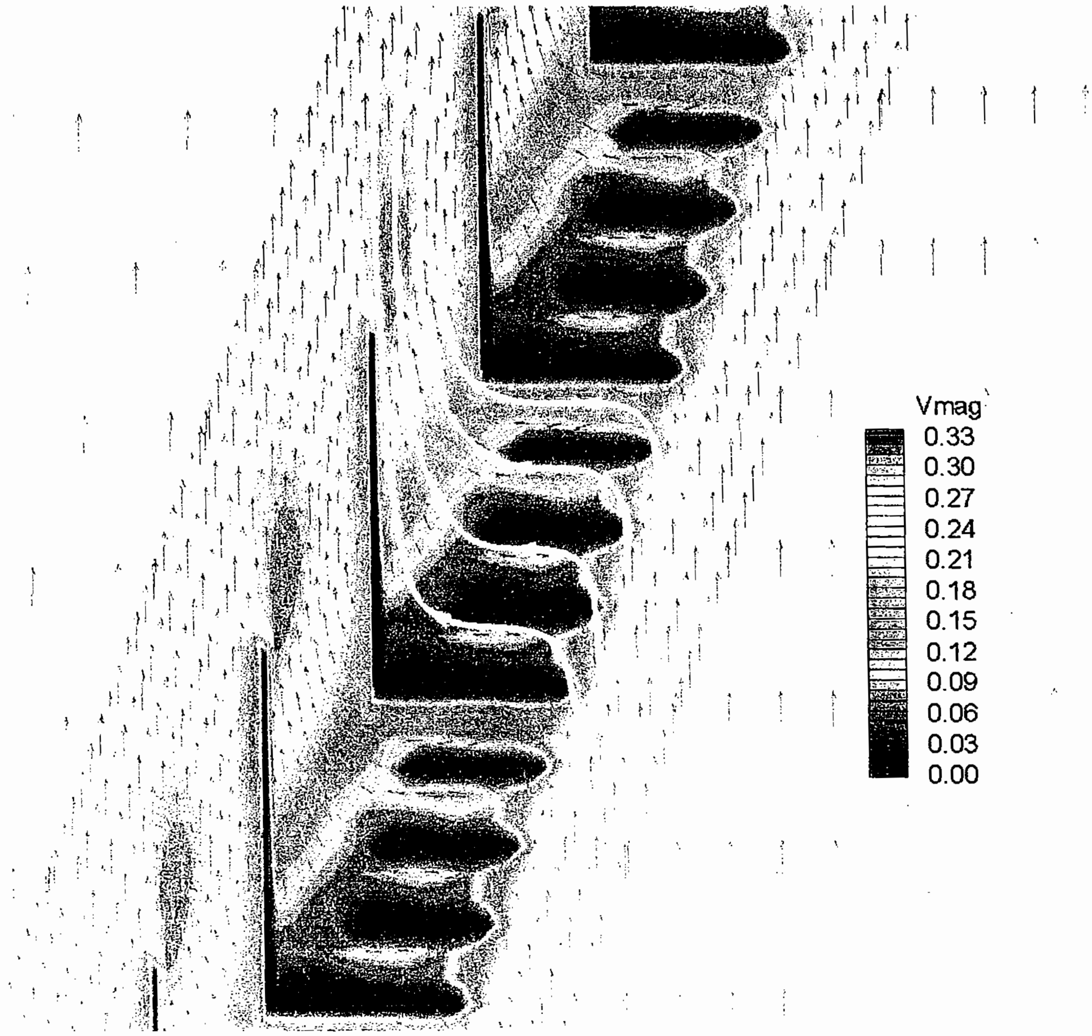


Figure C-19: Run05 louver zoom (Q=1290 cfs, elev. 395.6 ft, no-slip louvers, Vmag in m/s)

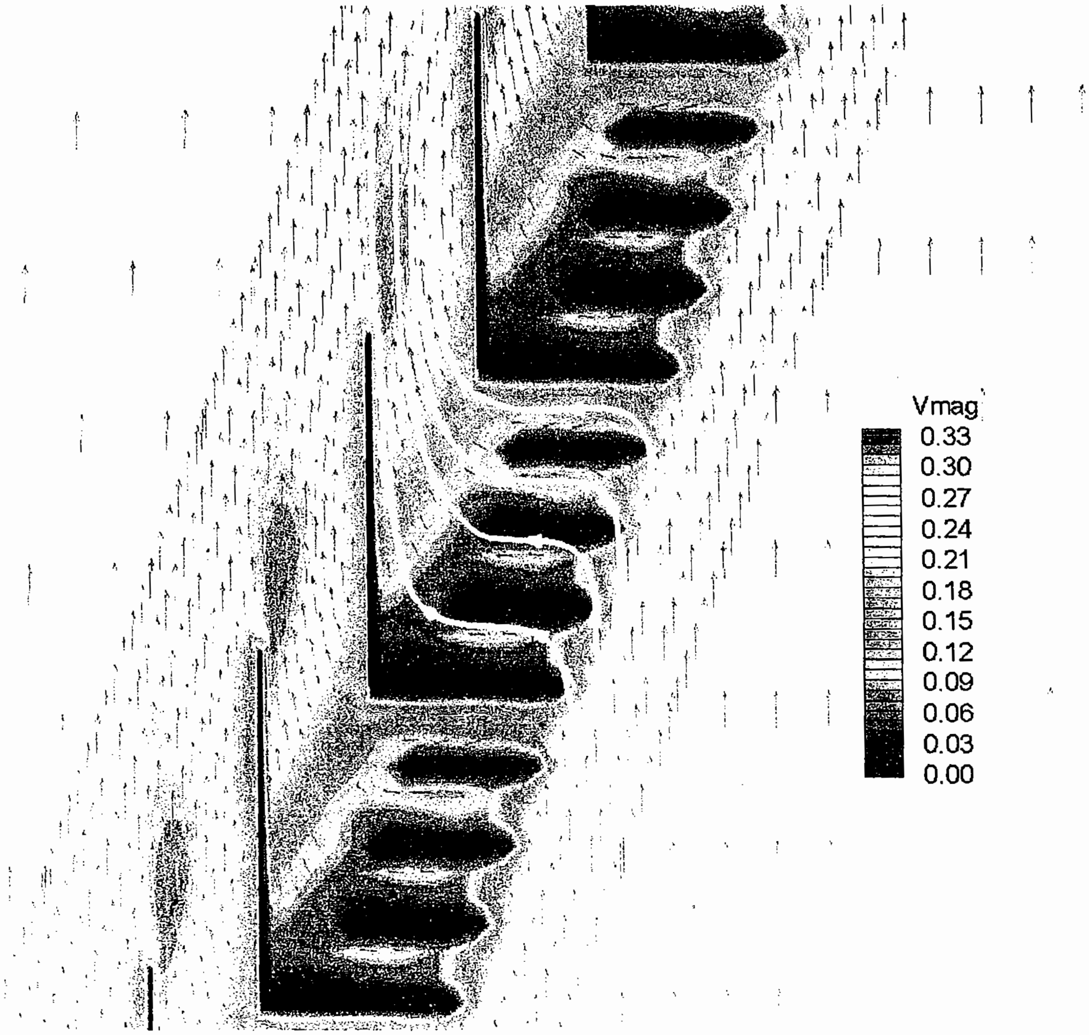


Figure C-20: Run05 louver zoom (Q=1290 cfs, elev. 402.7 ft, no-slip louvers, Vmag in m/s)

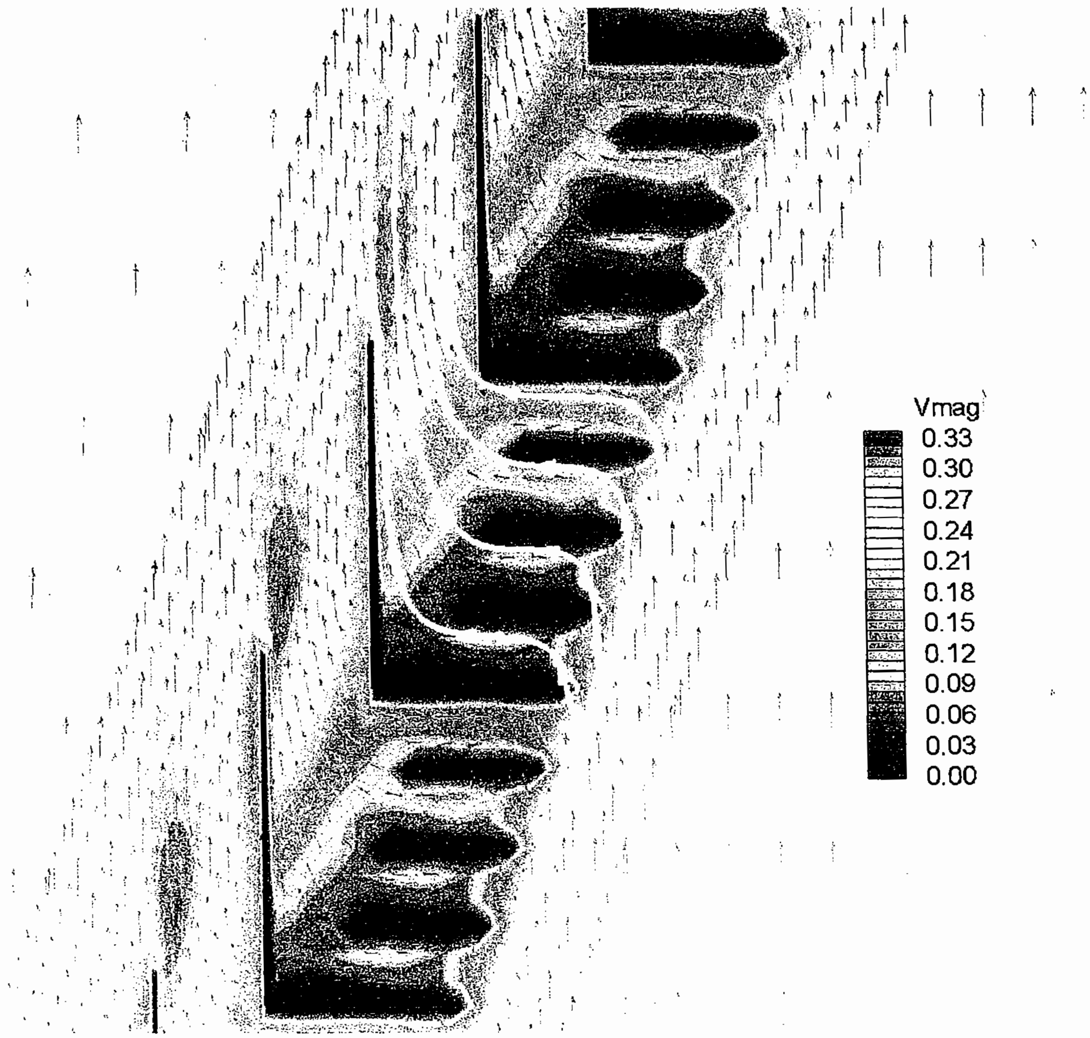


Figure C-21: Run05 louver zoom (Q=1290 cfs, elev. 416.4 ft, no-slip louvers, Vmag in m/s)

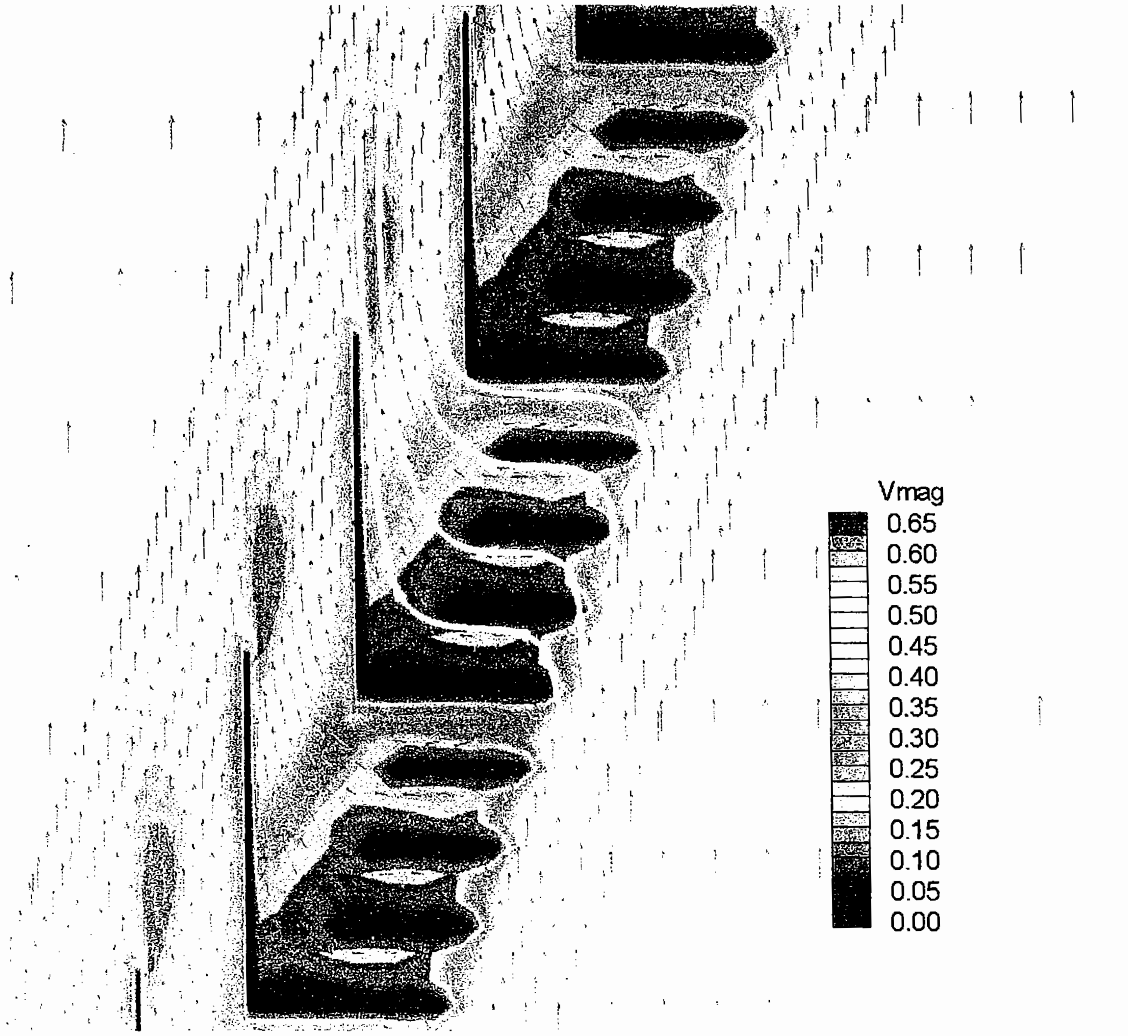


Figure C-22: Run06 louver zoom (Q=2580 cfs, elev. 395.6 ft, no-slip louvers, Vmag in m/s)

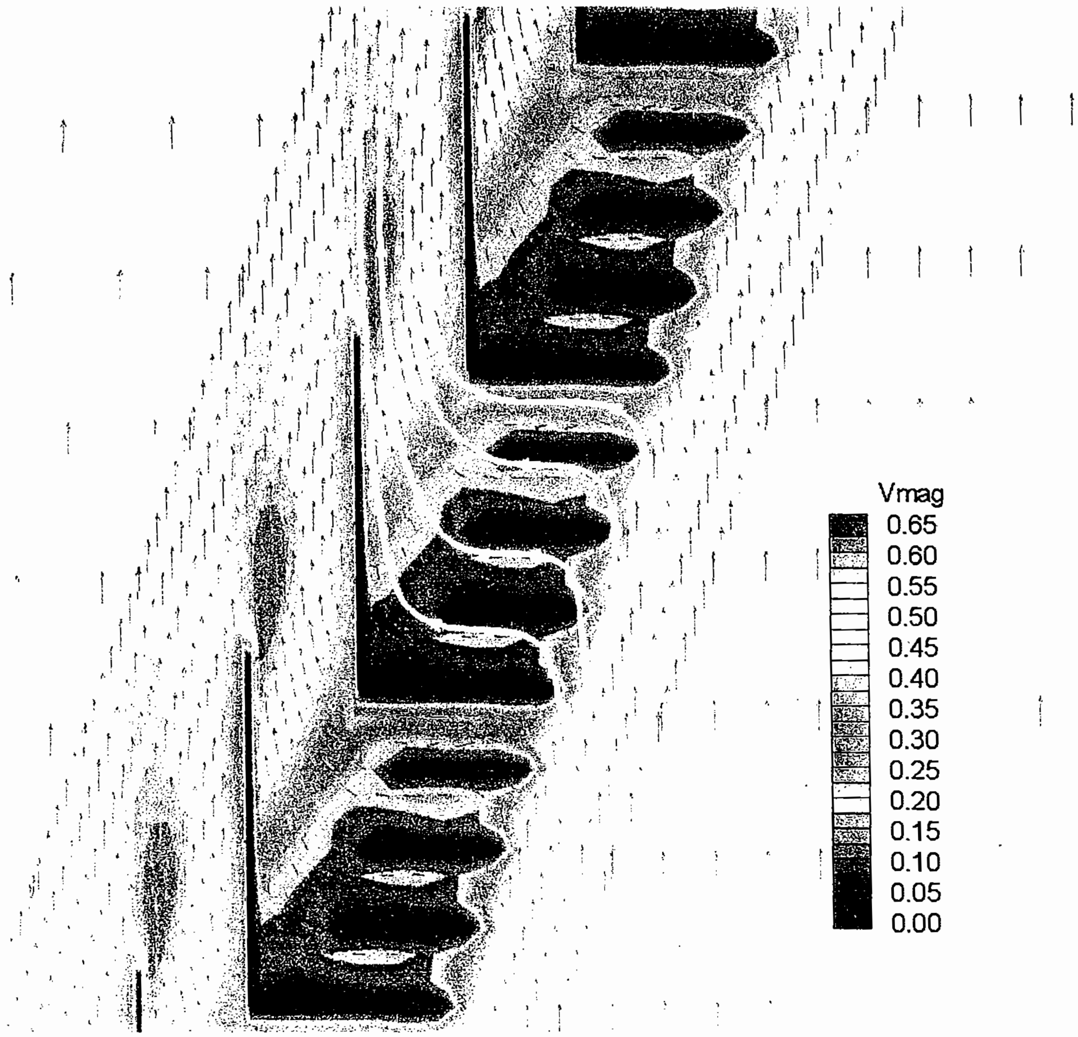


Figure C-23: Run06 louver zoom (Q=2580 cfs, elev. 402.7 ft, no-slip louvers, Vmag in m/s)

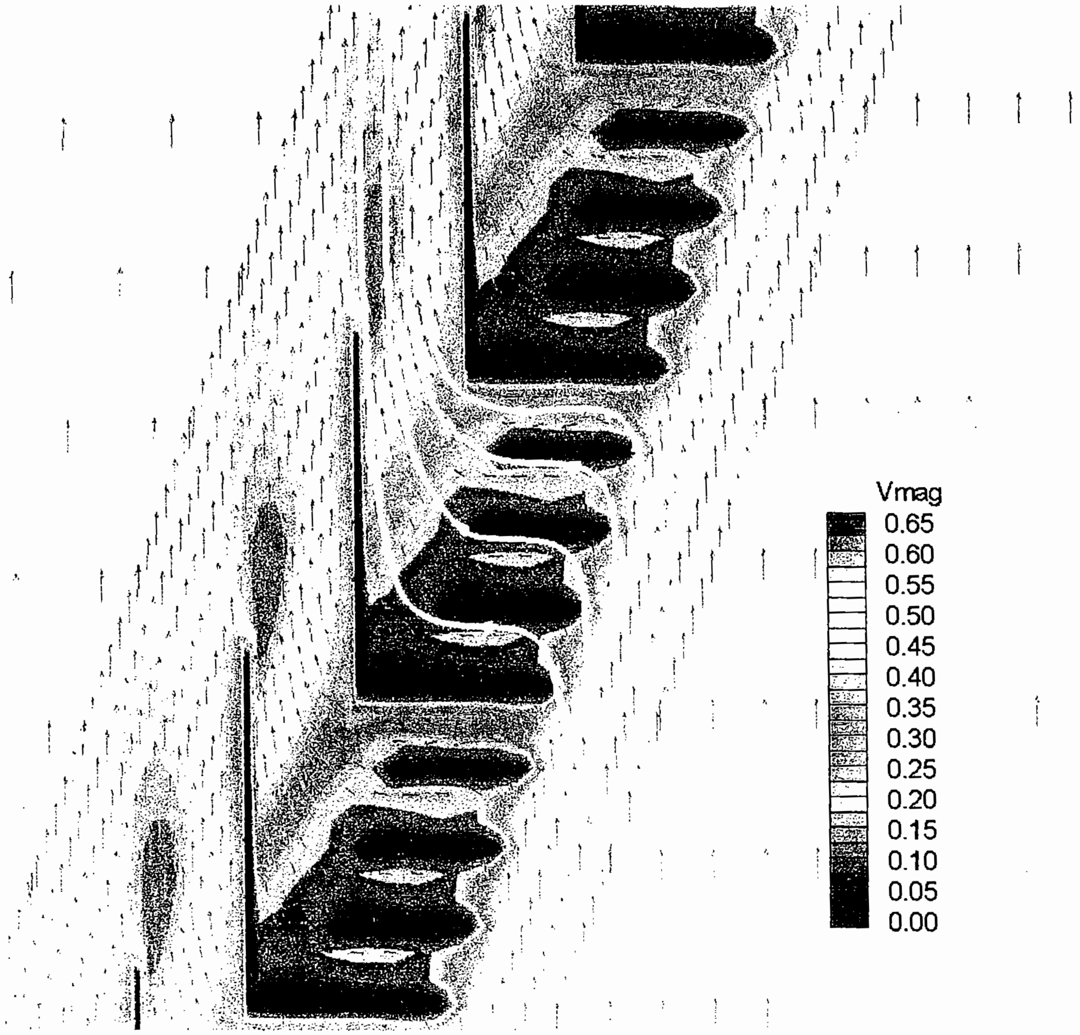


Figure C-24: Run06 louver zoom (Q=2580 cfs, elev. 416.4 ft, no-slip louvers, Vmag in m/s)

APPENDIX D
FISH TRACKING RESULTS

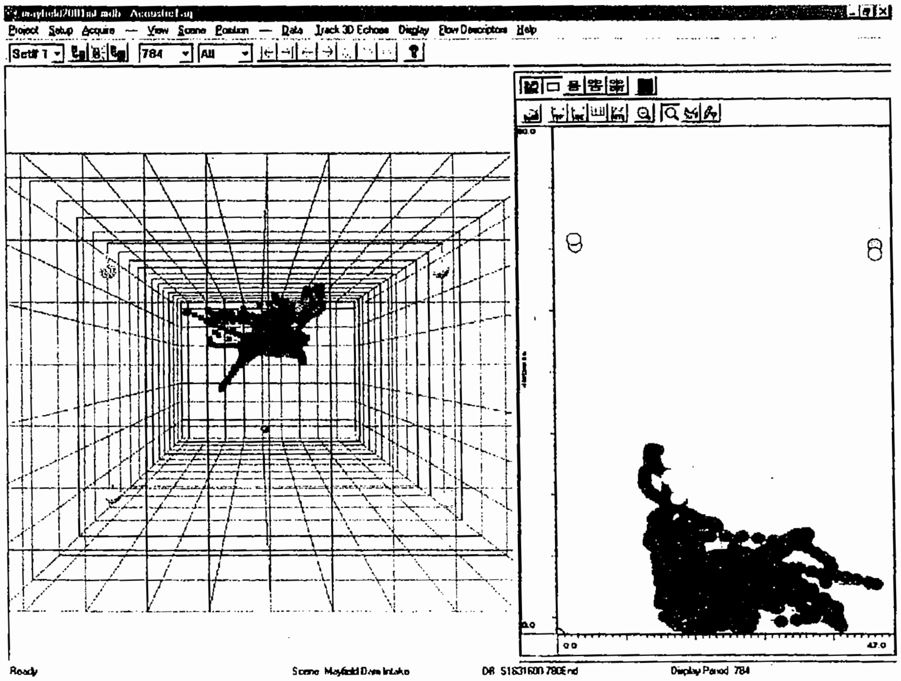


Figure D-1a Fish Number 780 3D Tracking Results

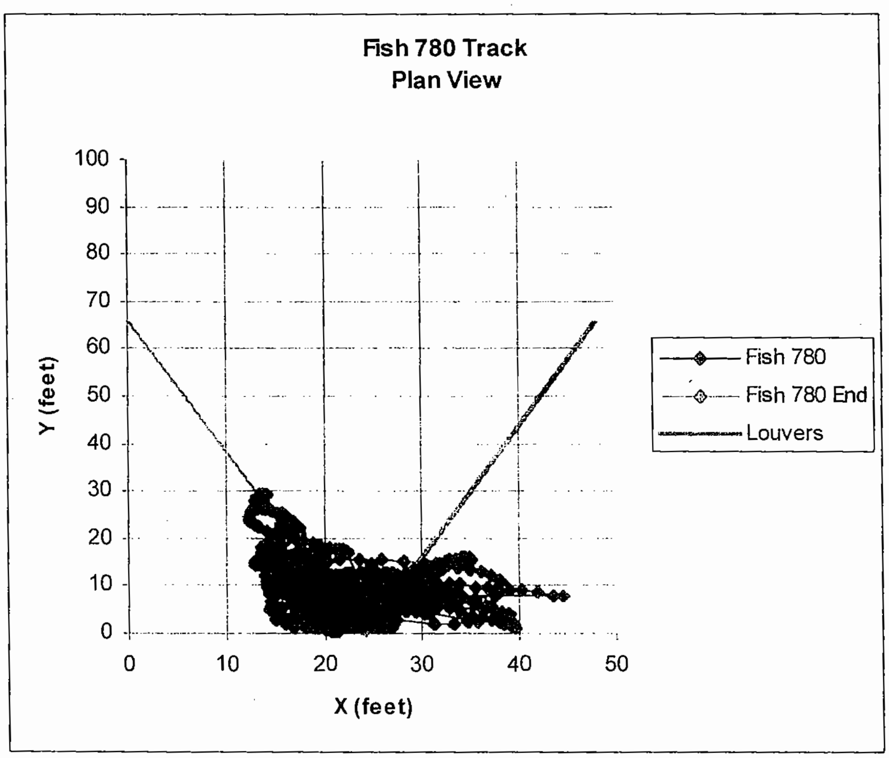


Figure D-1b Fish Number 780 X/Y Tracking Results

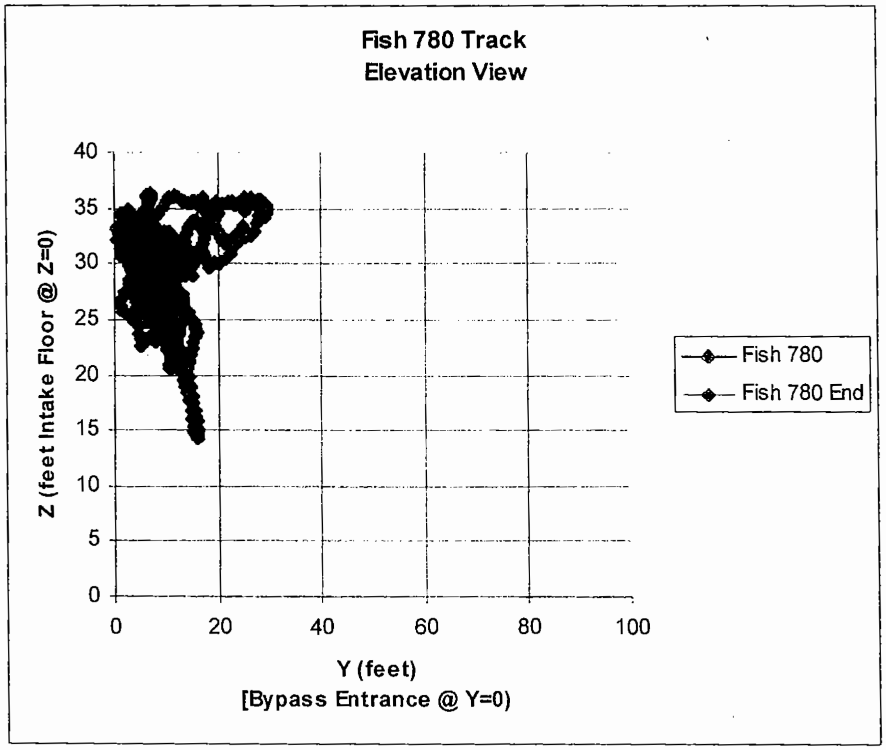


Figure D-1c Fish Number 780 Y/Z Tracking Results

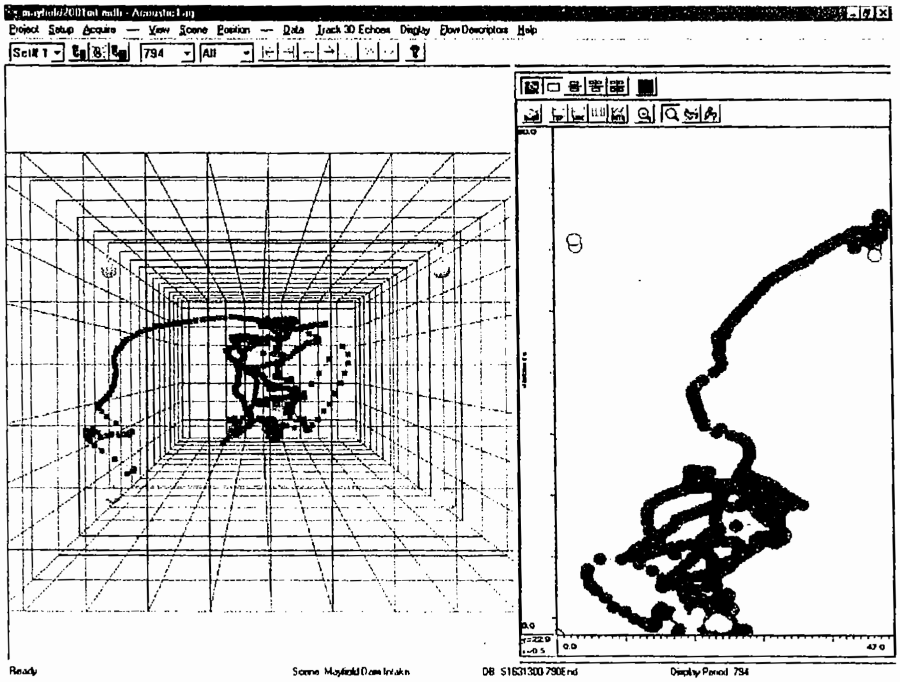


Figure D-2a Fish Number 790 3D Tracking Results

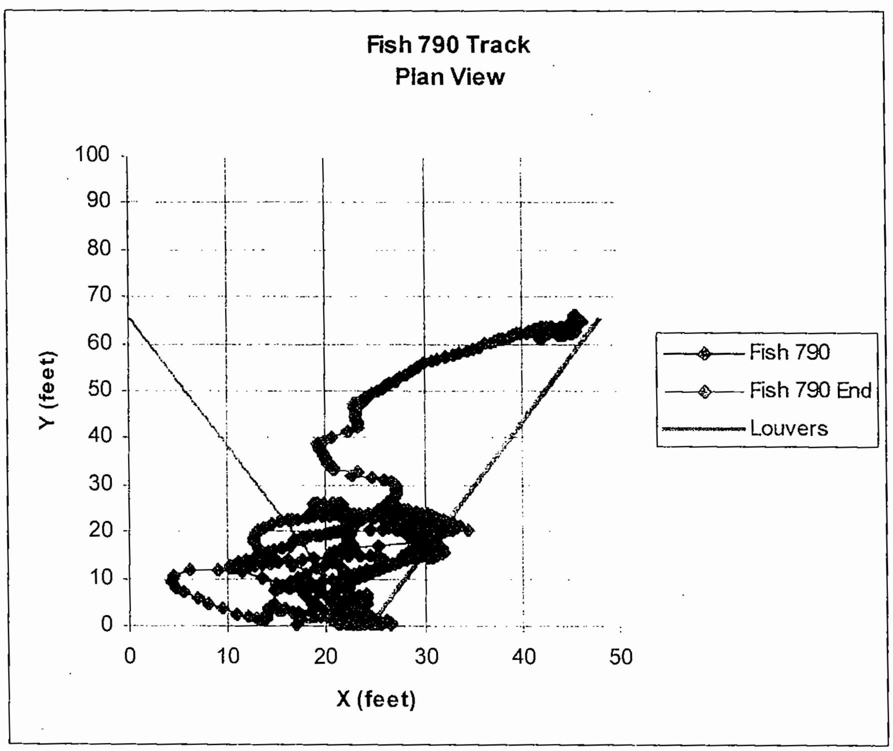


Figure D-2b Fish Number 790 X/Y Tracking Results

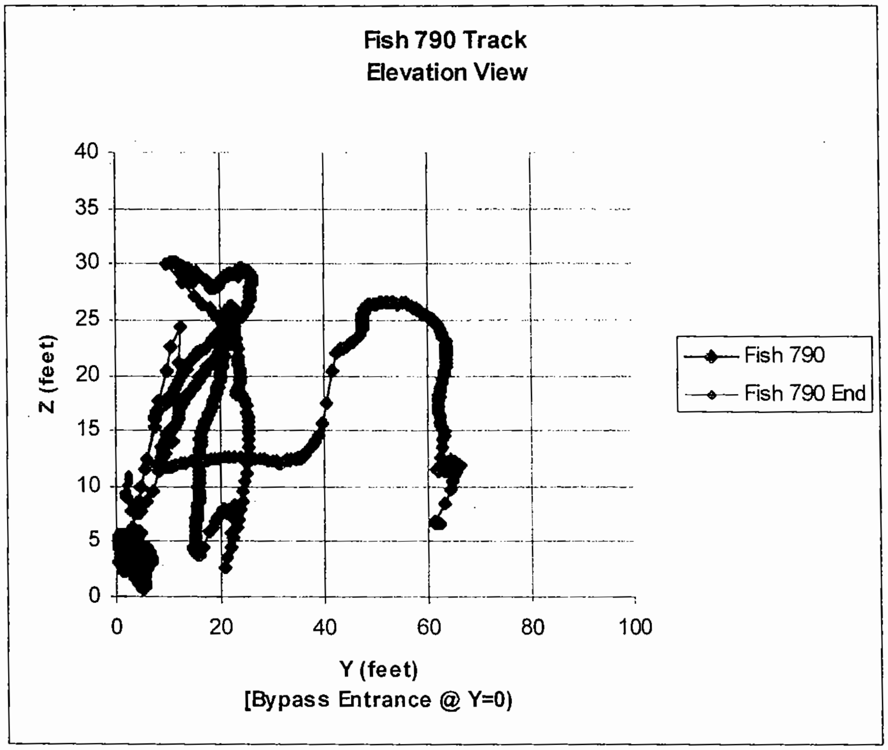


Figure D-2c Fish Number 790 Y/Z Tracking Results

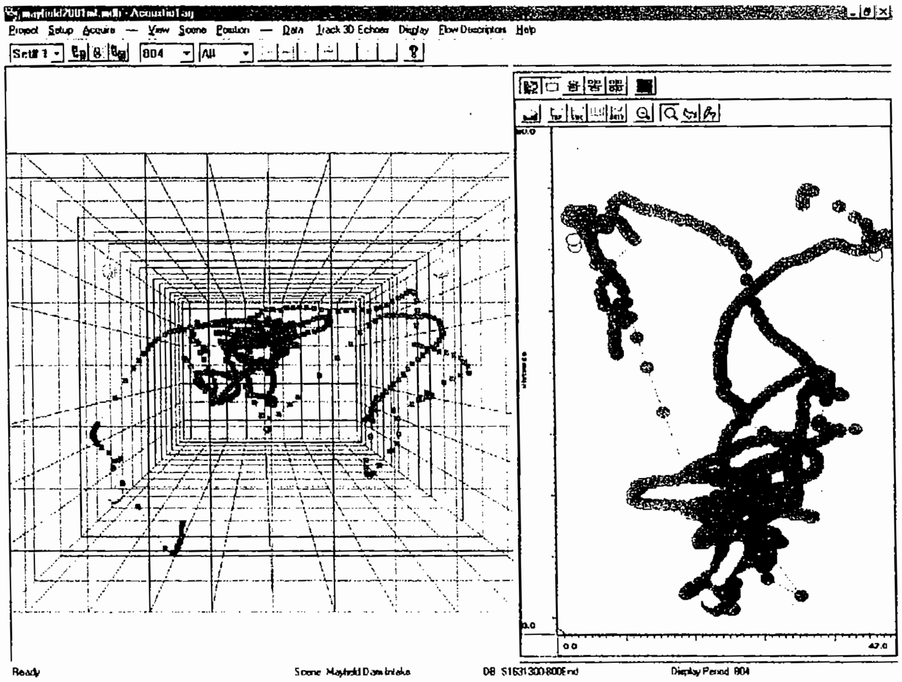


Figure D-3a Fish Number 800 3D Tracking Results

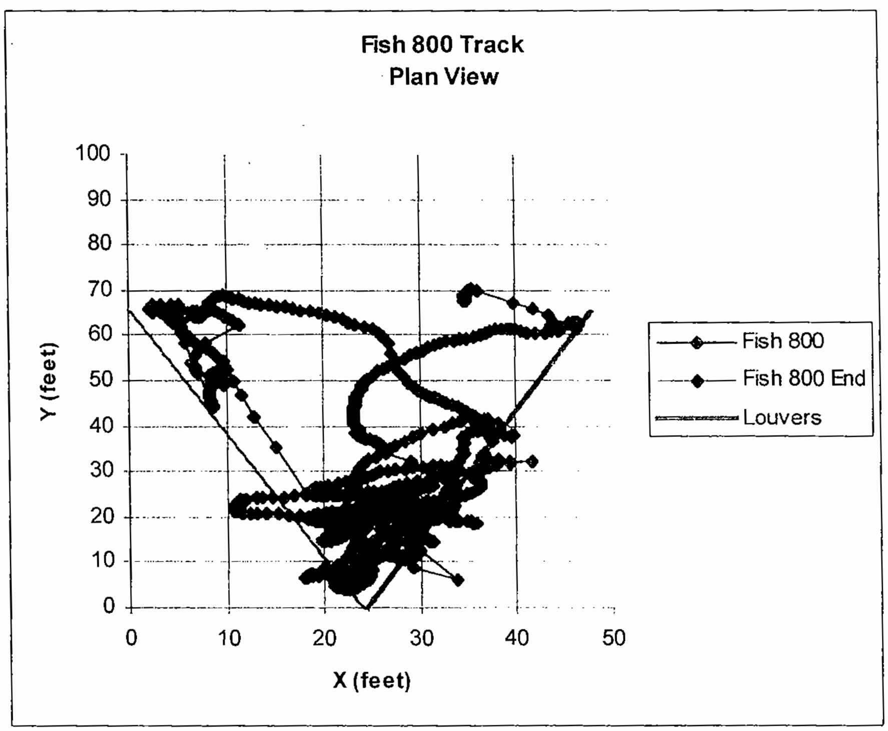


Figure D-3b Fish Number 800 X/Y Tracking Results

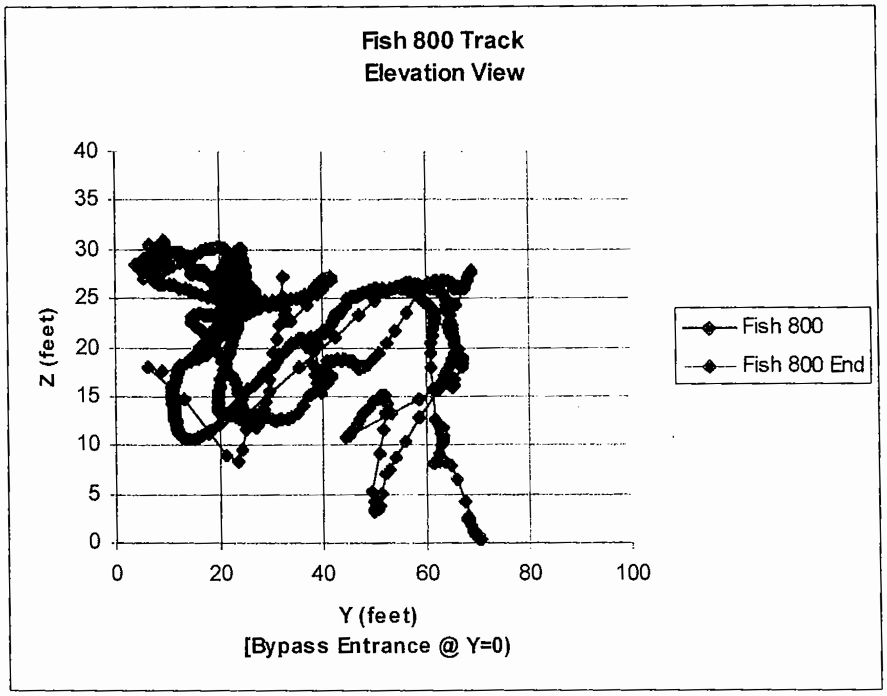


Figure D-3c Fish Number 800 Y/Z Tracking Results

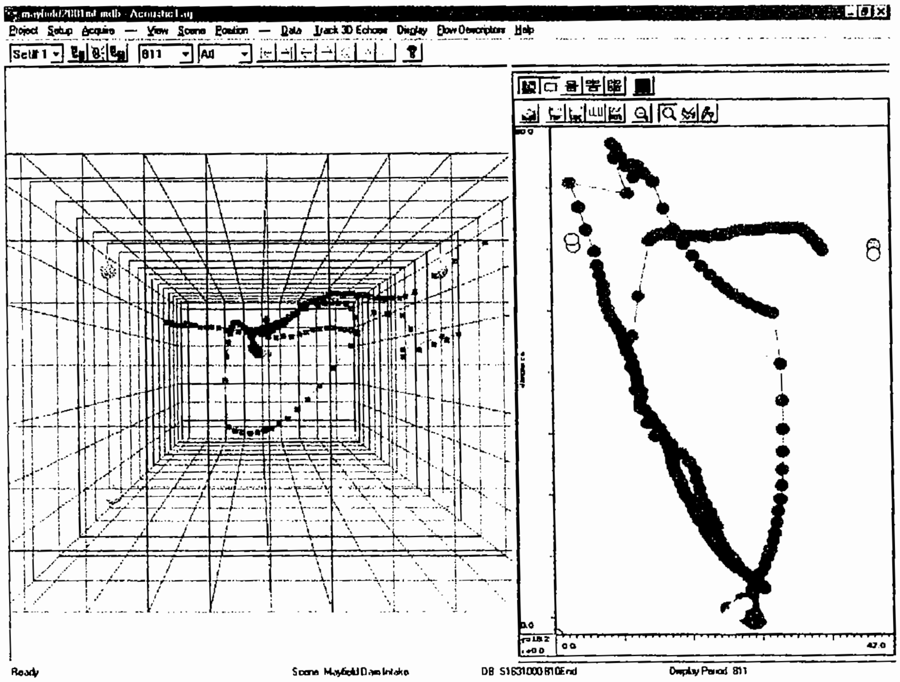


Figure D-4a Fish Number 810 3D Tracking Results

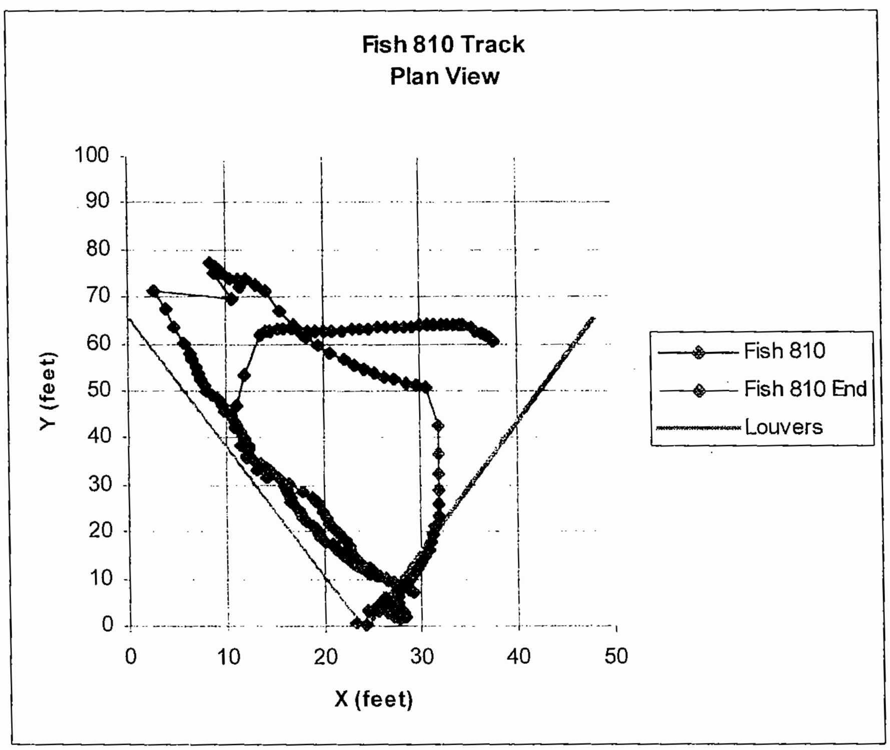


Figure D-4b Fish Number 810 X/Y Tracking Results

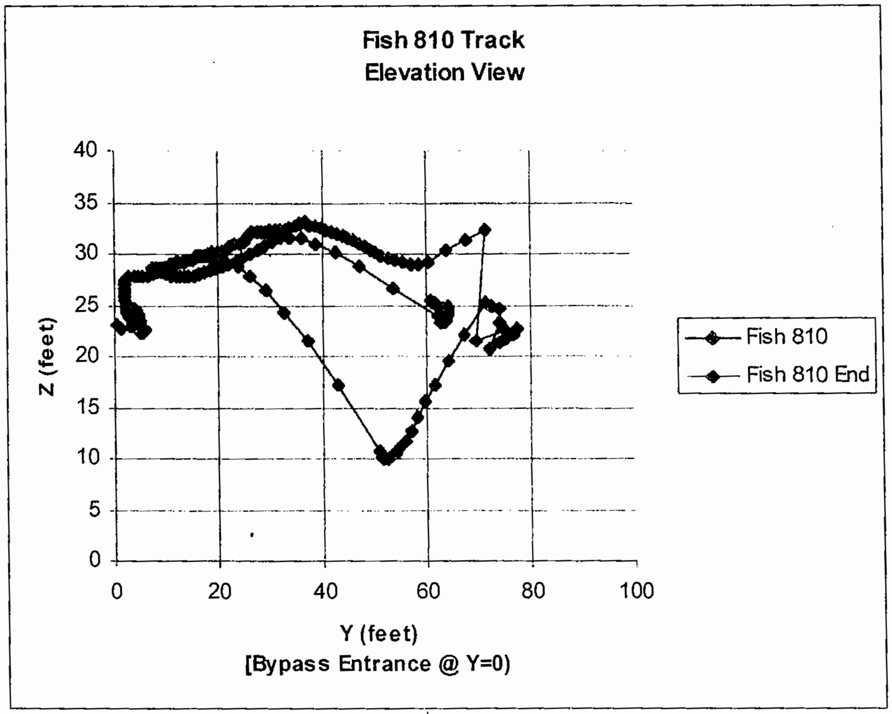


Figure D-4c Fish Number 810 Y/Z Tracking Results

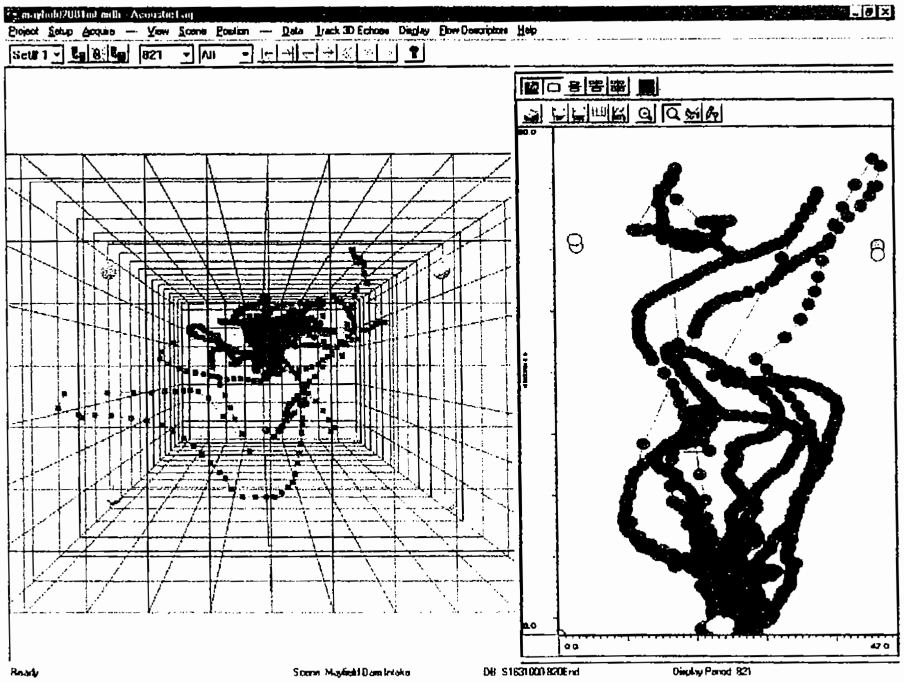


Figure D-5a Fish Number 820 3D Tracking Results

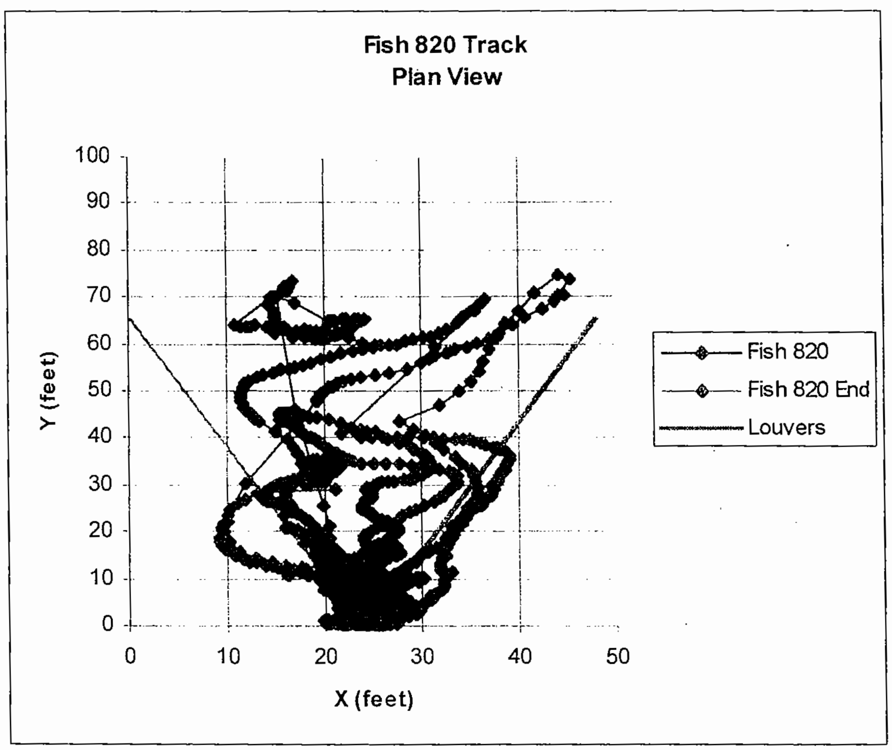


Figure D-5b Fish Number 820 X/Y Tracking Results

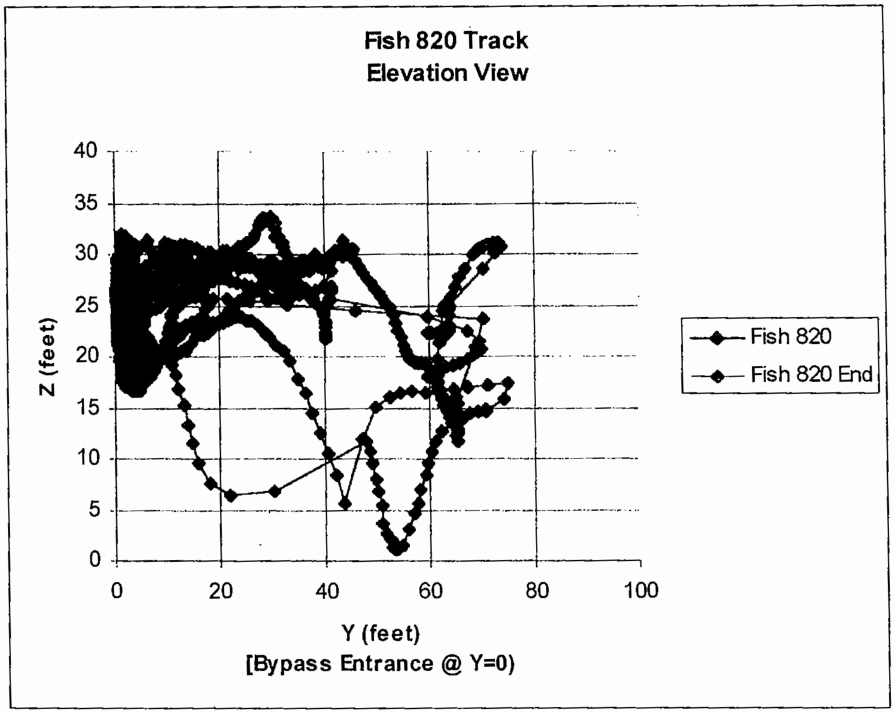


Figure D-5c Fish Number 820 Y/Z Tracking Results

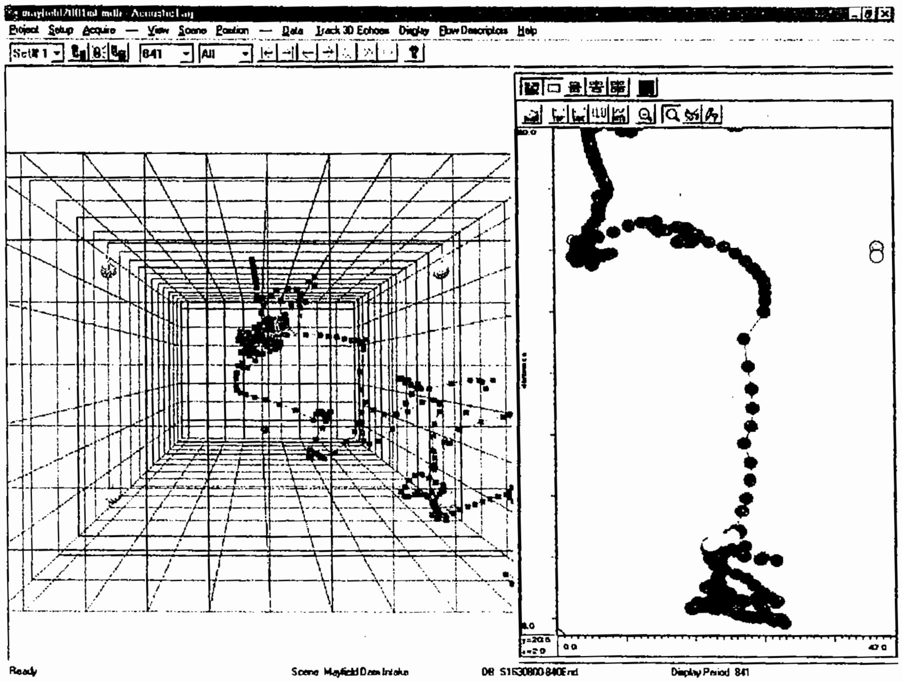


Figure D-6a Fish Number 840 3D Tracking Results

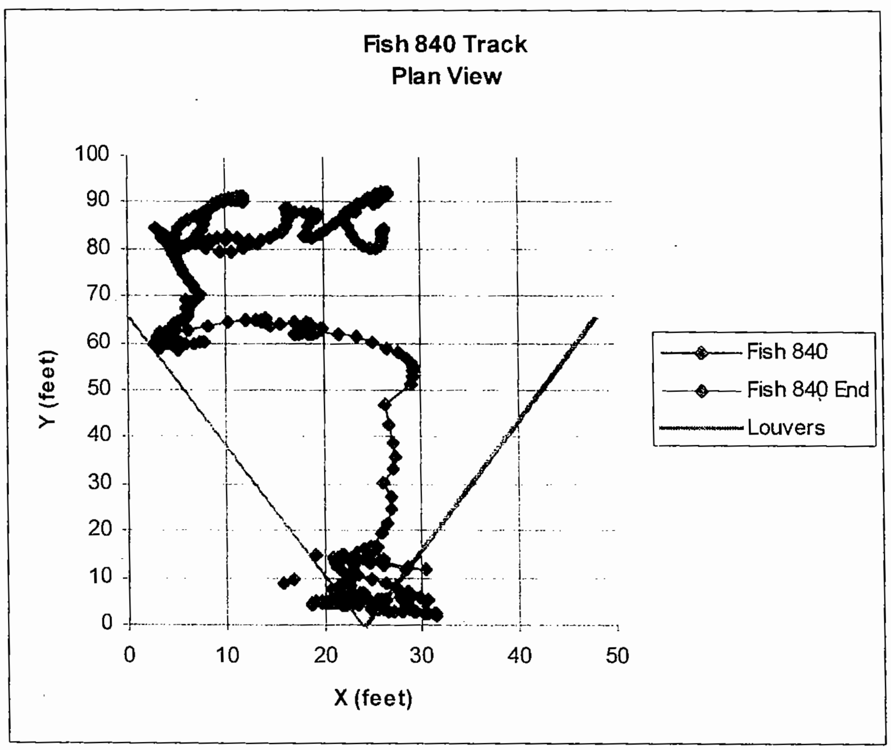


Figure D-6b Fish Number 840 X/Y Tracking Results

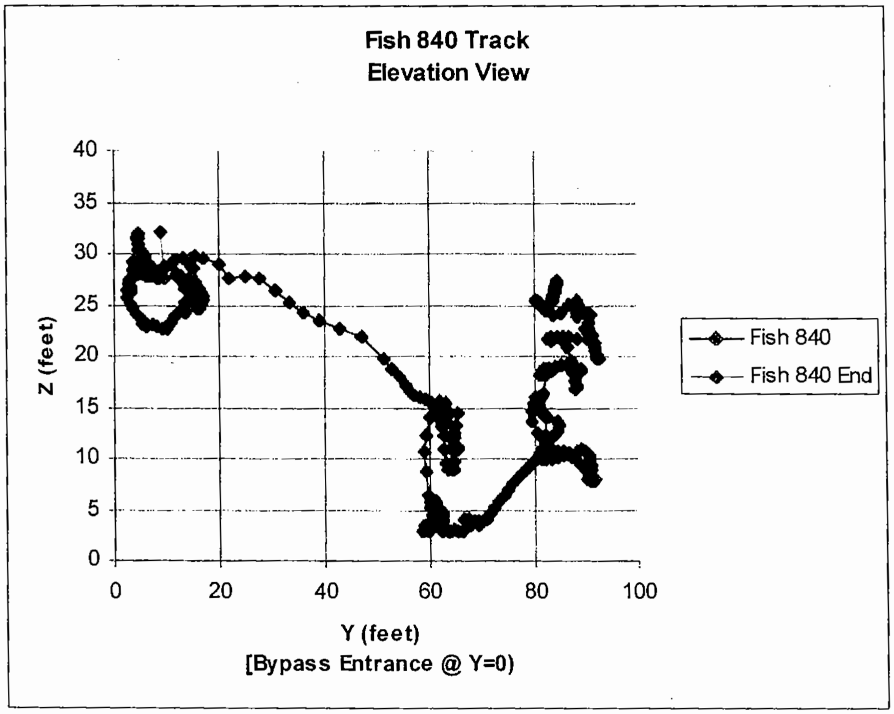


Figure D-6c Fish Number 840 Y/Z Tracking Results

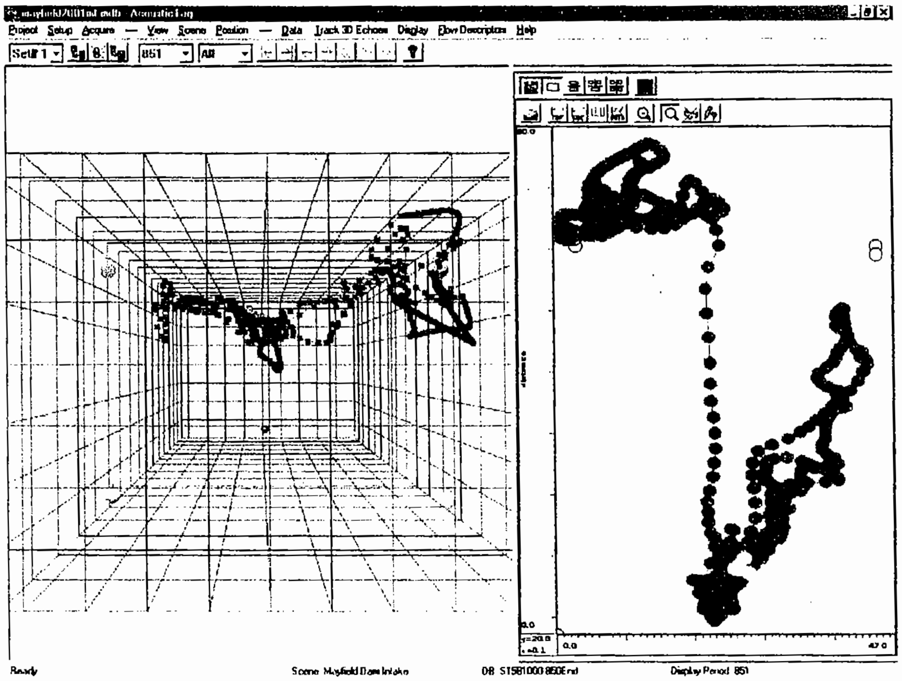


Figure D-7a Fish Number 850 3D Tracking Results

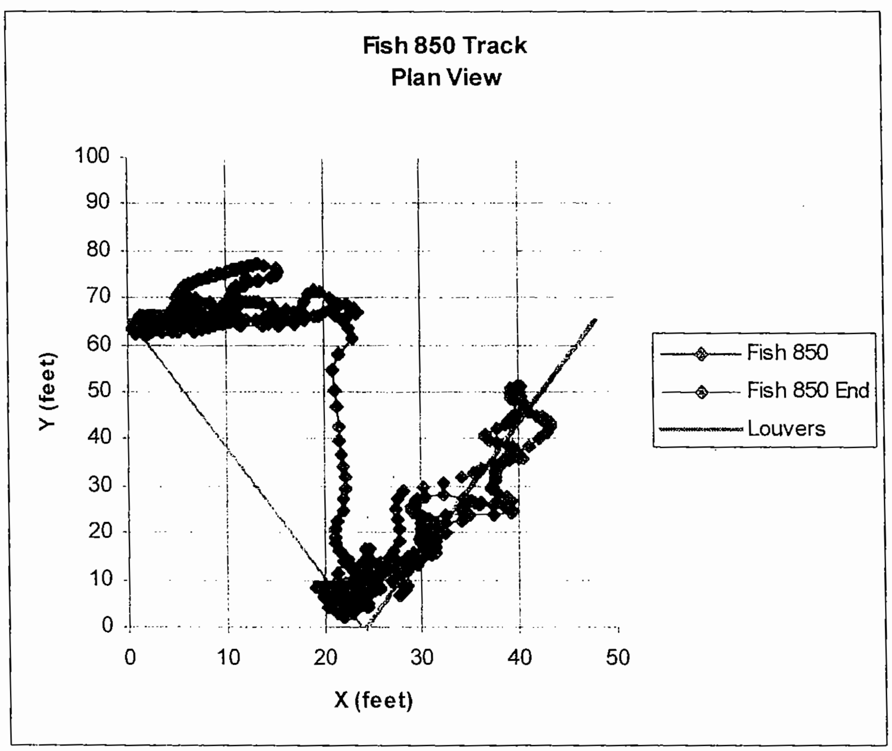


Figure D-7b Fish Number 850 X/Y Tracking Results

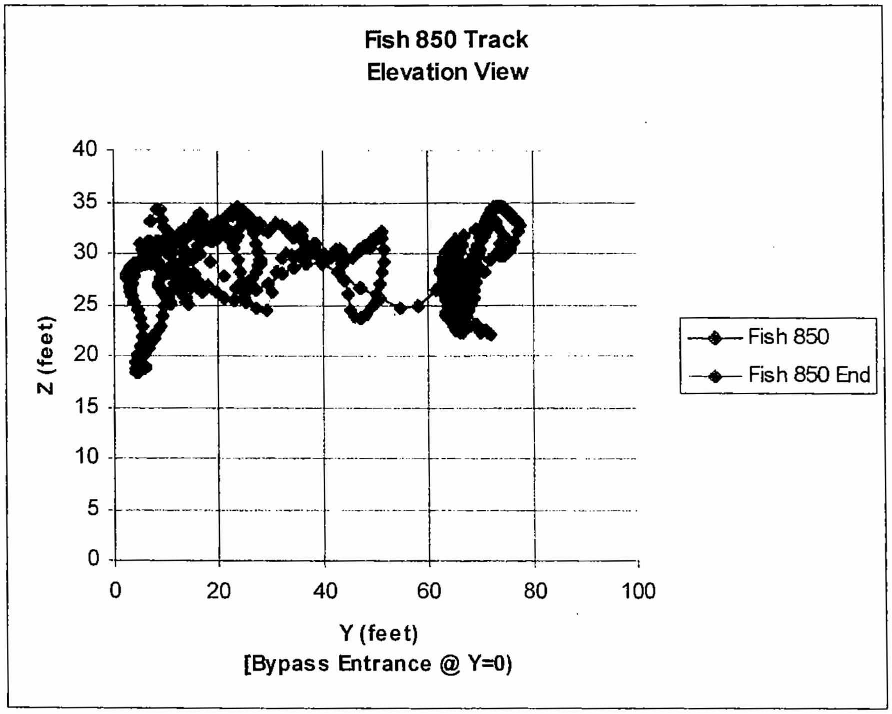


Figure D-7c Fish Number 850 Y/Z Tracking Results

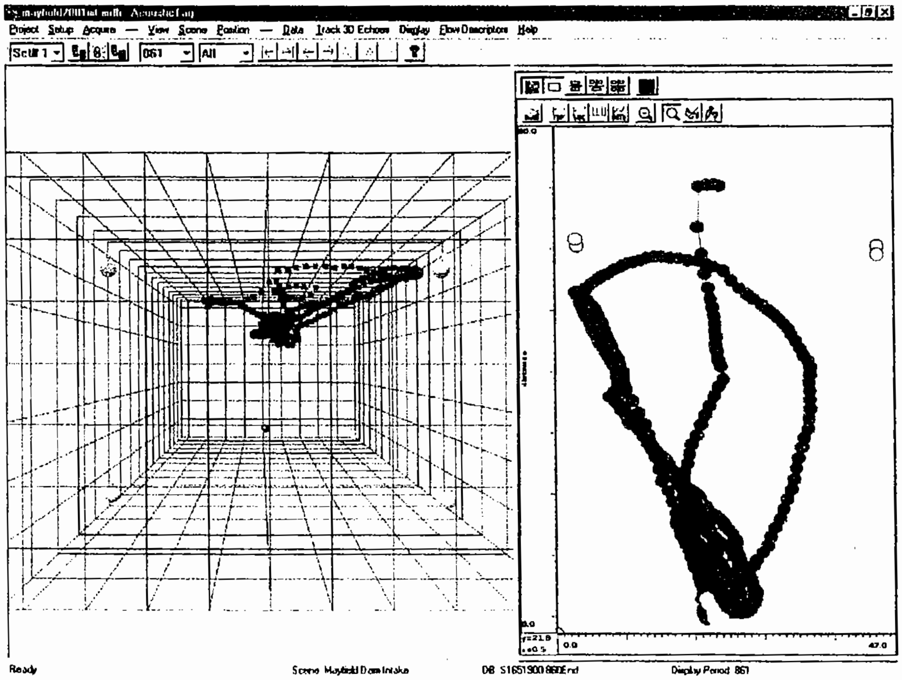


Figure D-8a Fish Number 860 3D Tracking Results

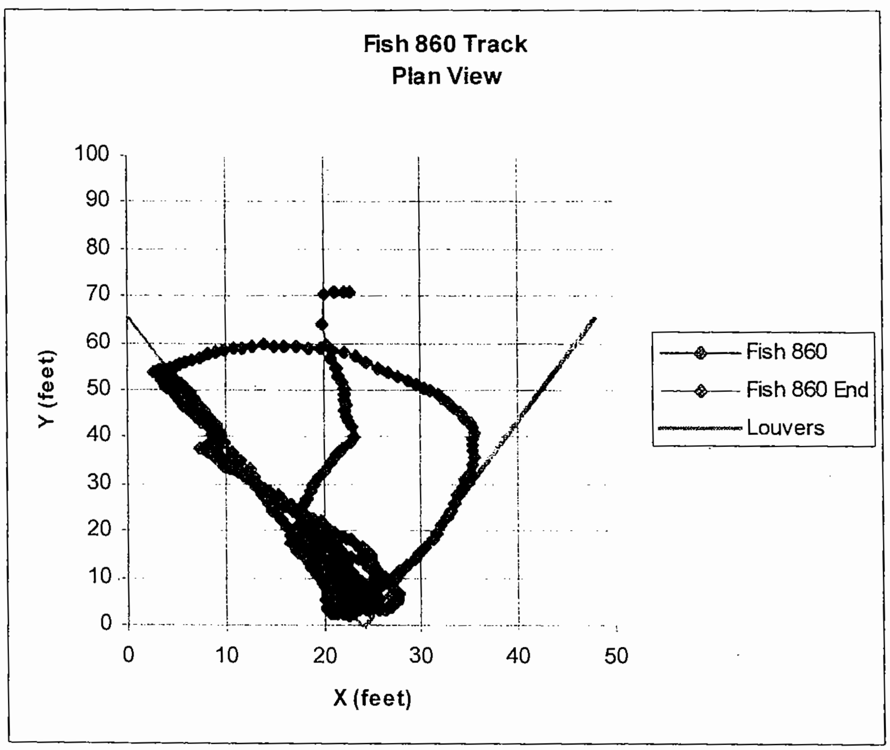


Figure D-8b Fish Number 860 X/Y Tracking Results

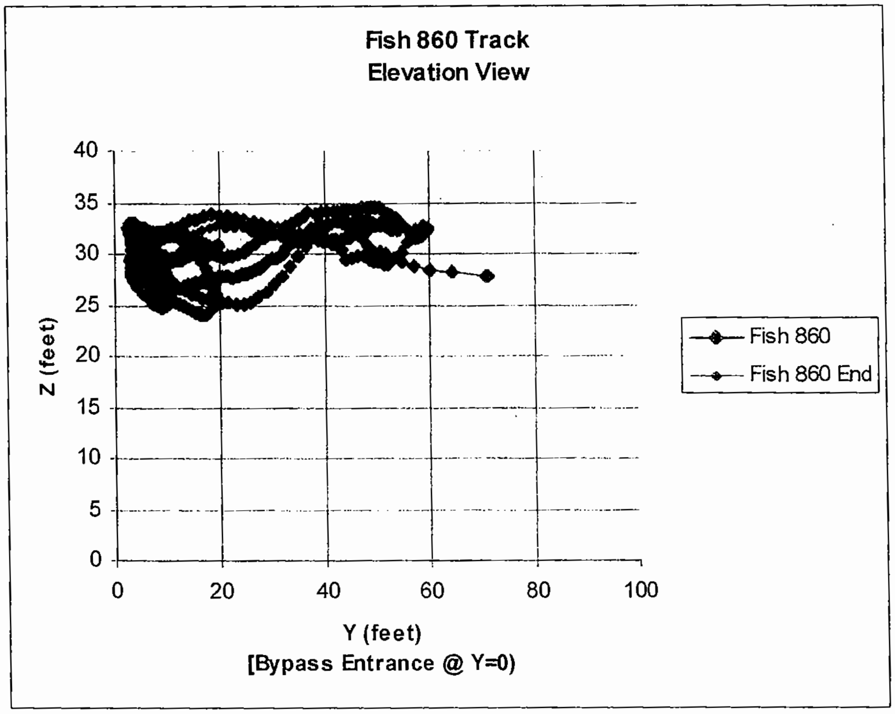


Figure D-8c Fish Number 860 Y/Z Tracking Results

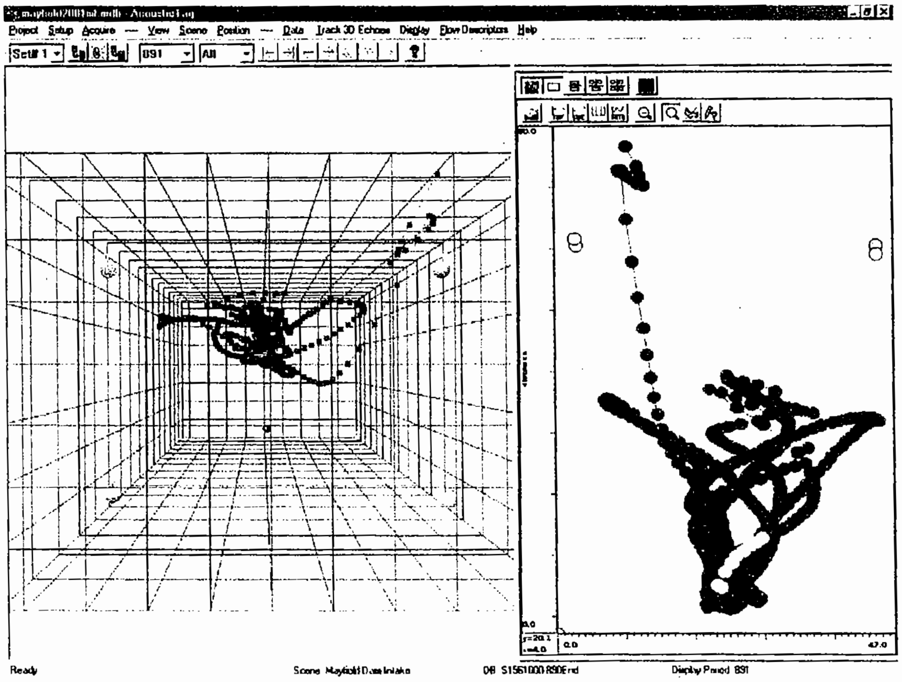


Figure D-9a Fish Number 890 3D Tracking Results

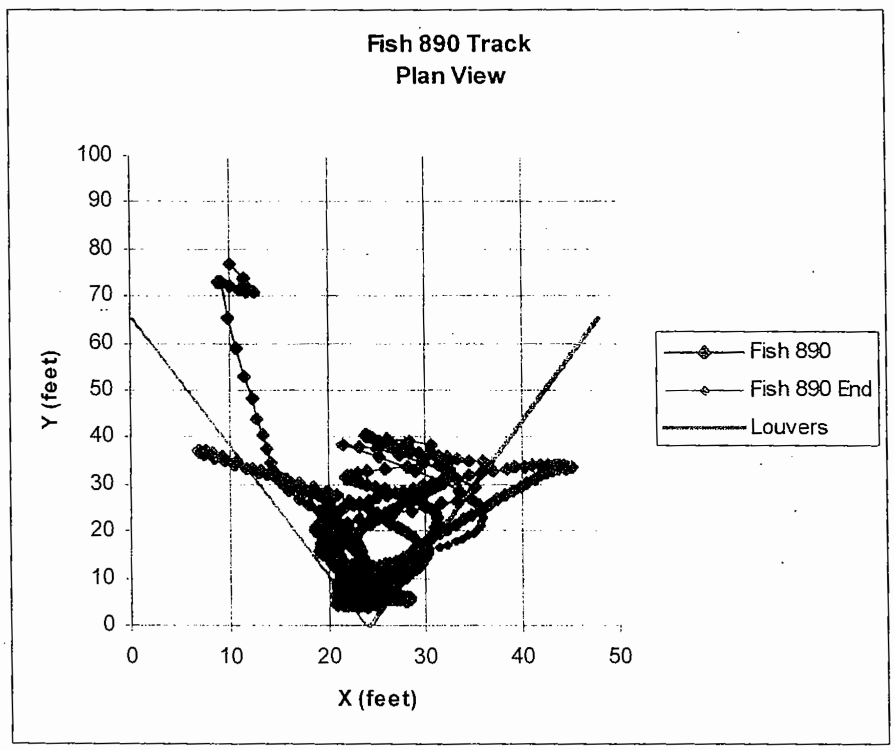


Figure D-9b Fish Number 890 X/Y Tracking Results

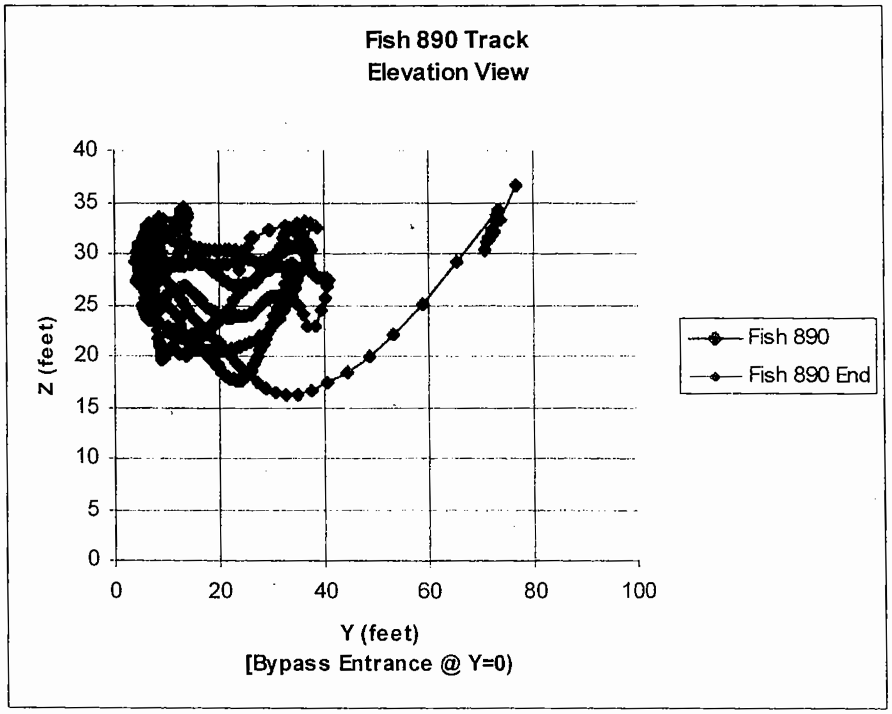


Figure D-9c Fish Number 890 Y/Z Tracking Results

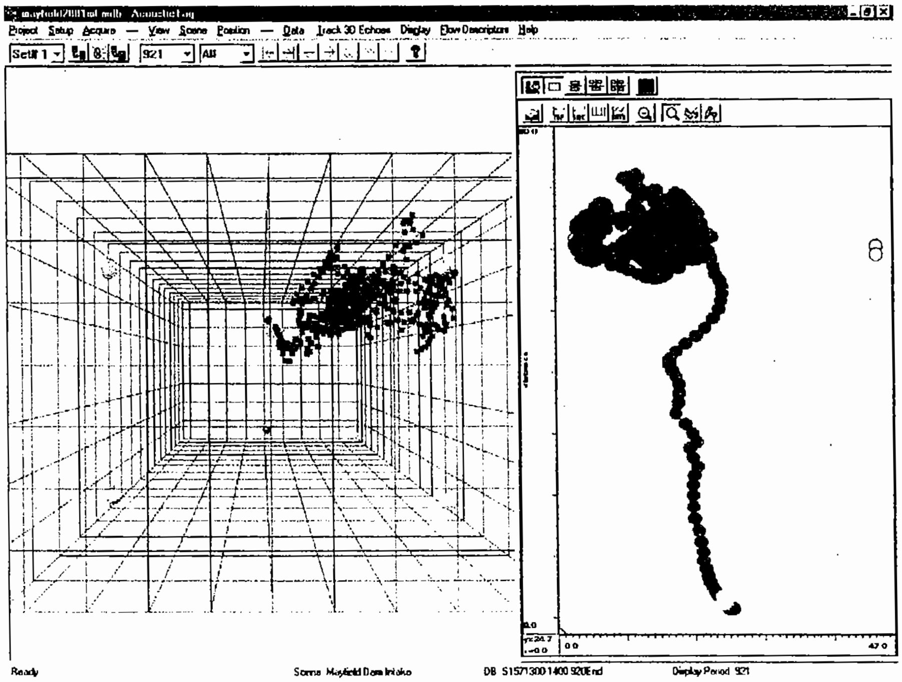


Figure D-10a Fish Number 920 3D Tracking Results

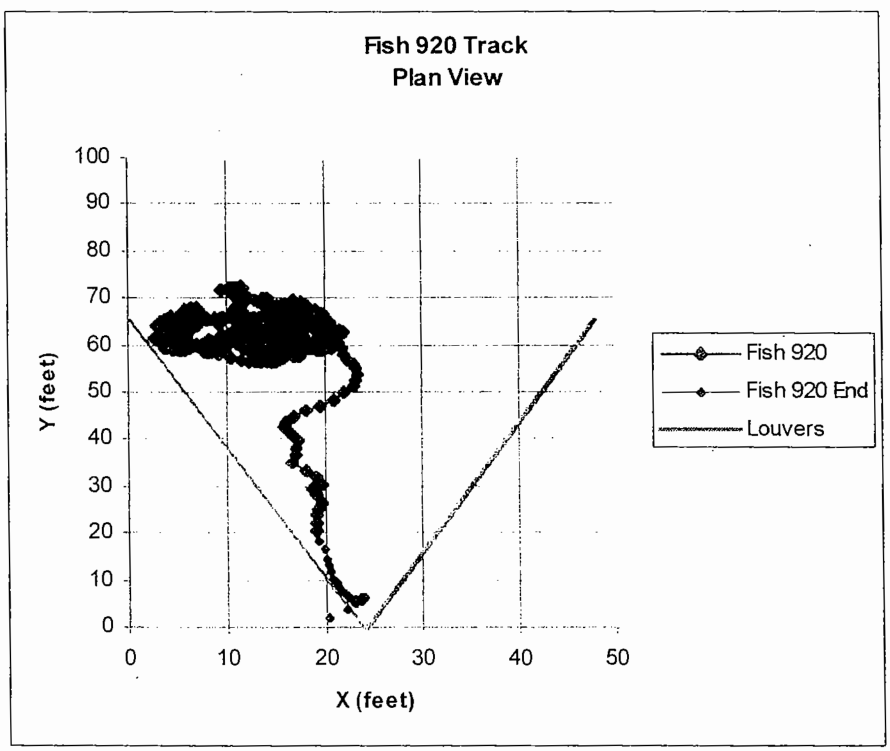


Figure D-10b Fish Number 920 X/Y Tracking Results

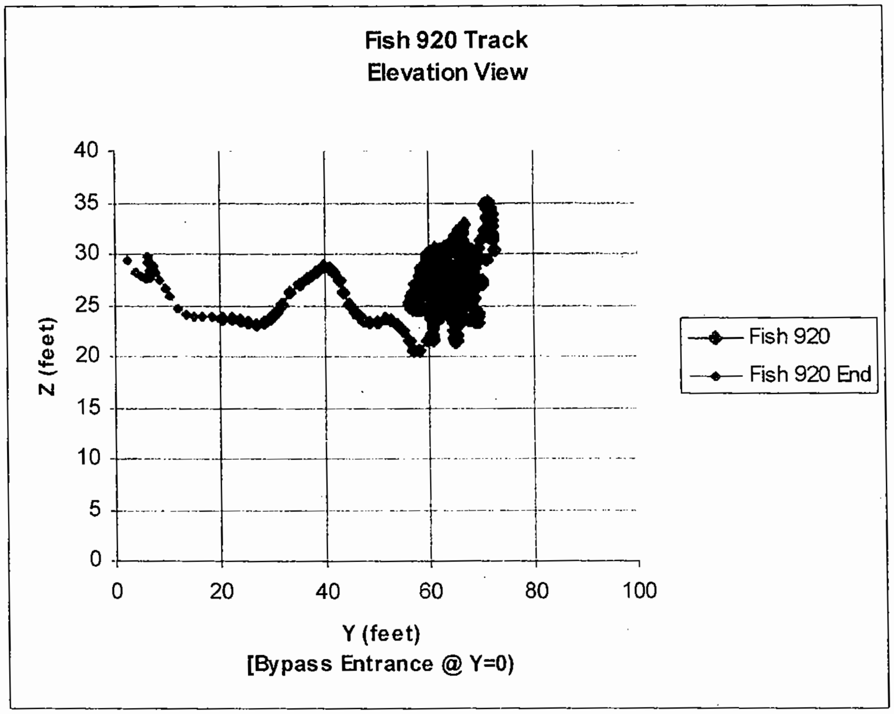


Figure D-10c Fish Number 920 Y/Z Tracking Results

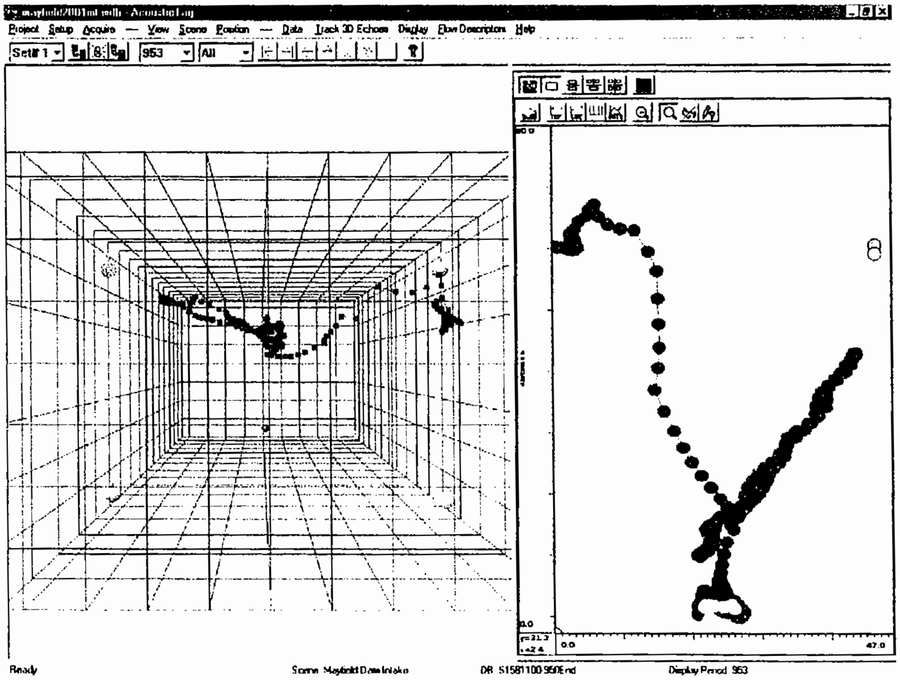


Figure D-11a Fish Number 950 3D Tracking Results

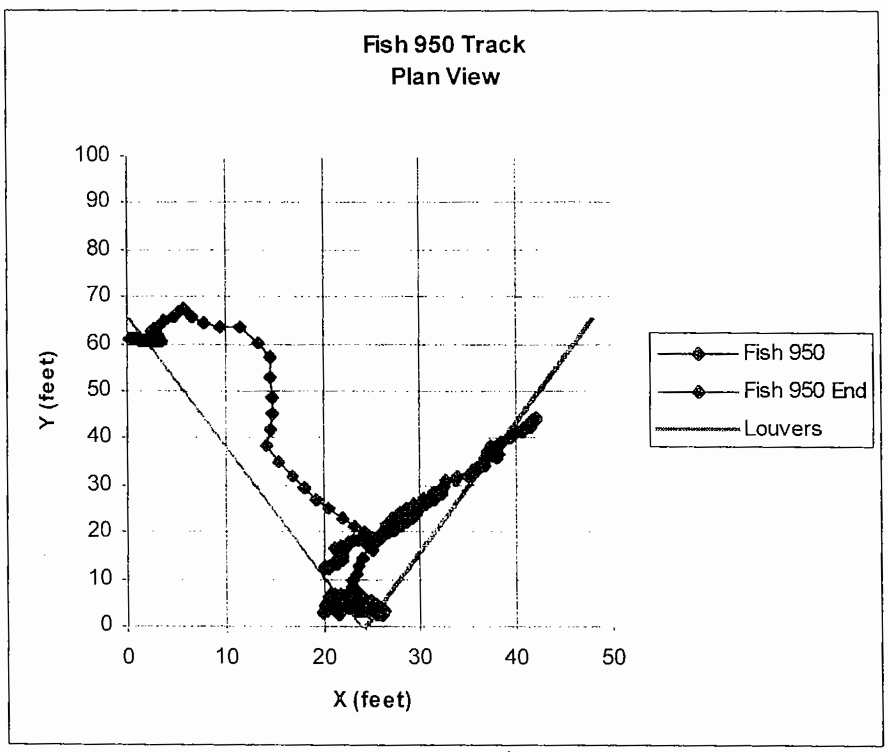


Figure D-11b Fish Number 950 X/Y Tracking Results

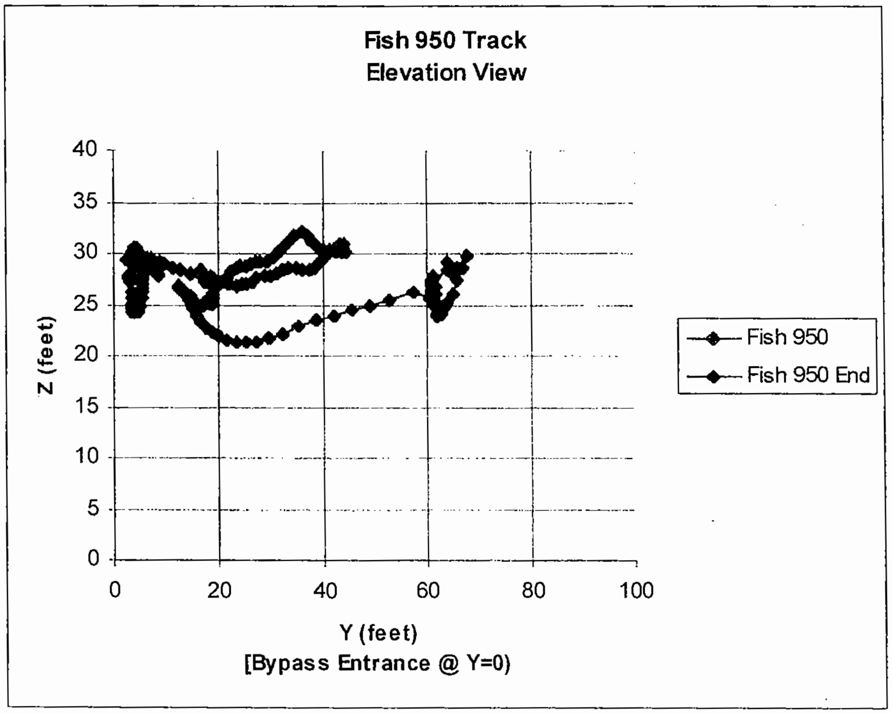


Figure D-11c Fish Number 950 Y/Z Tracking Results

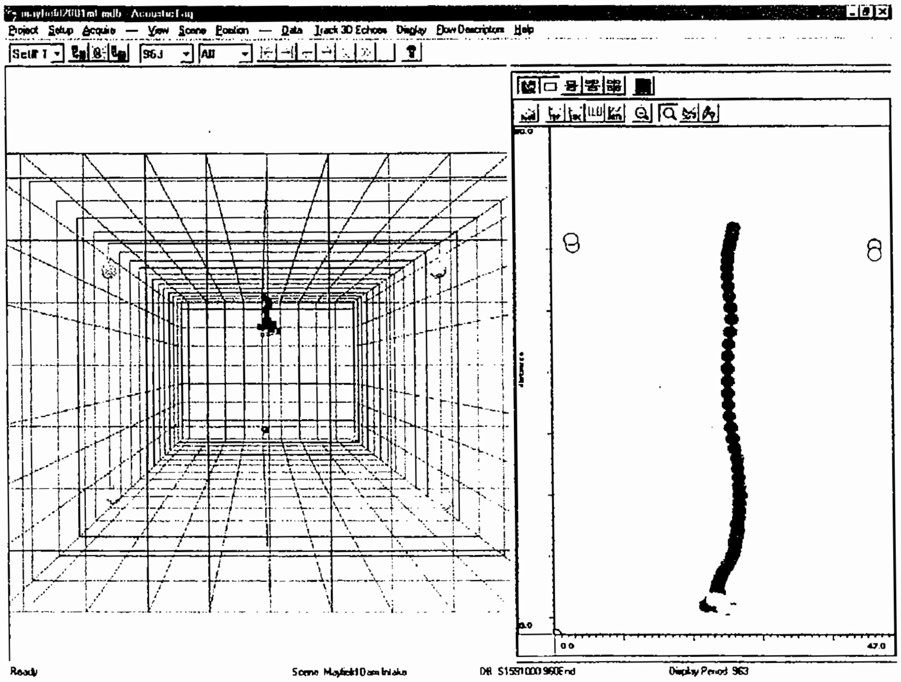


Figure D-12a Fish Number 960 3D Tracking Results

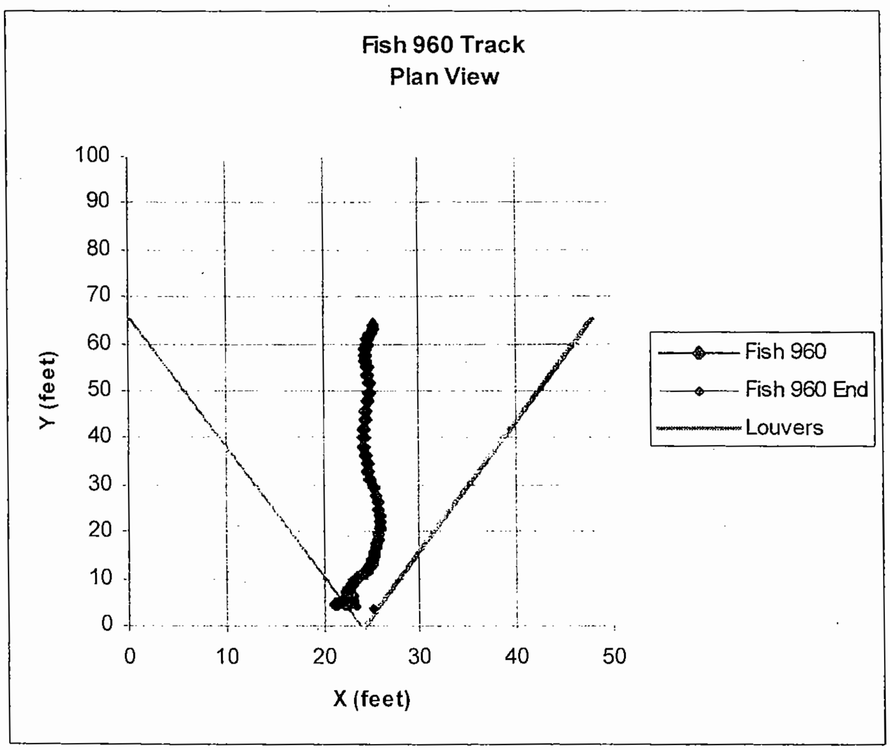


Figure D-12b Fish Number 960 X/Y Tracking Results

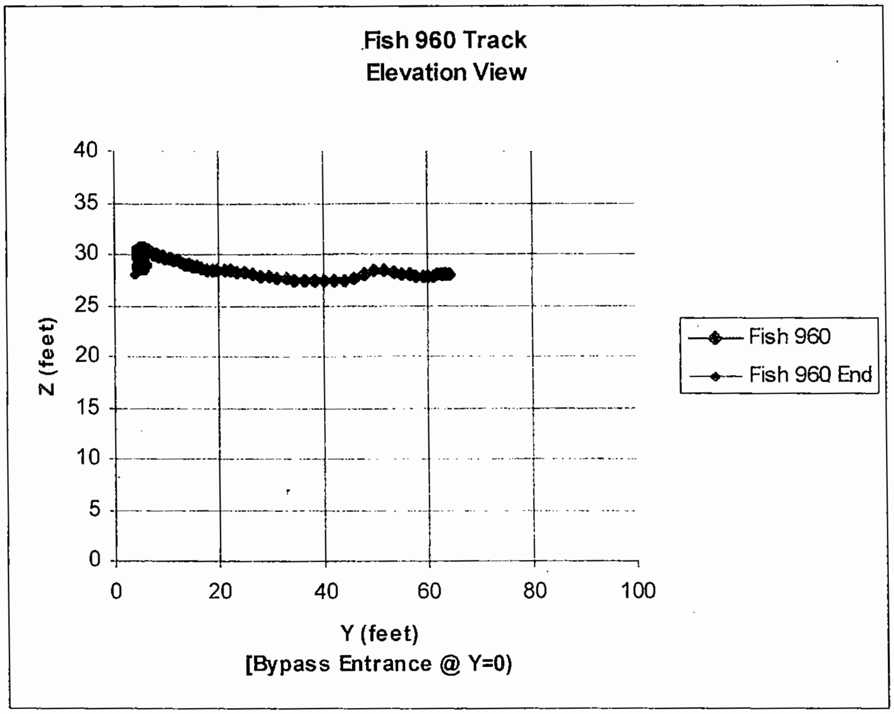


Figure D-12c Fish Number 960 Y/Z Tracking Results

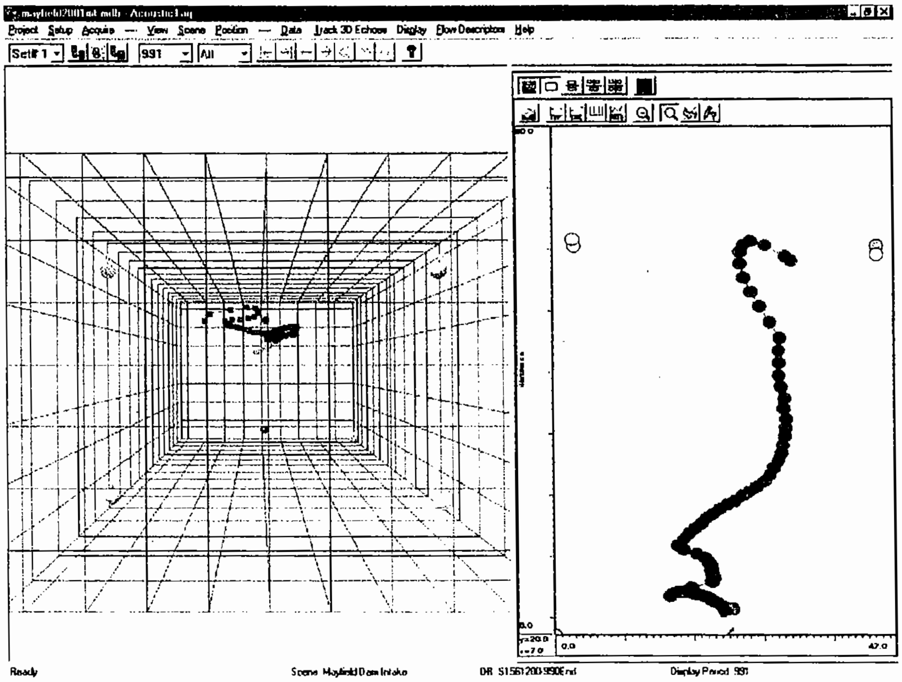


Figure D-13a Fish Number 990 3D Tracking Results

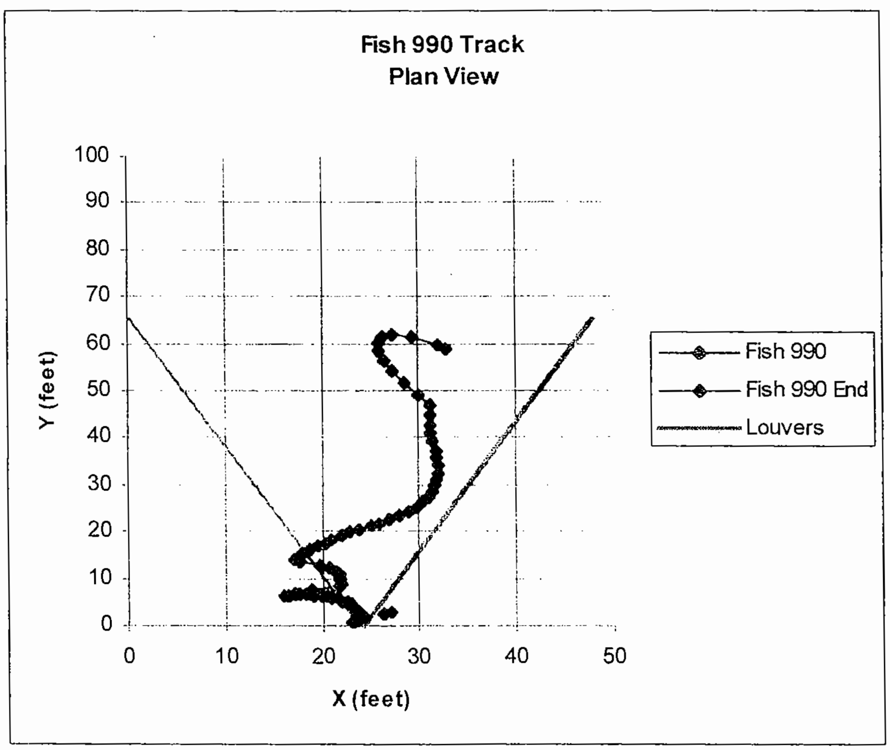


Figure D-13b Fish Number 990 X/Y Tracking Results

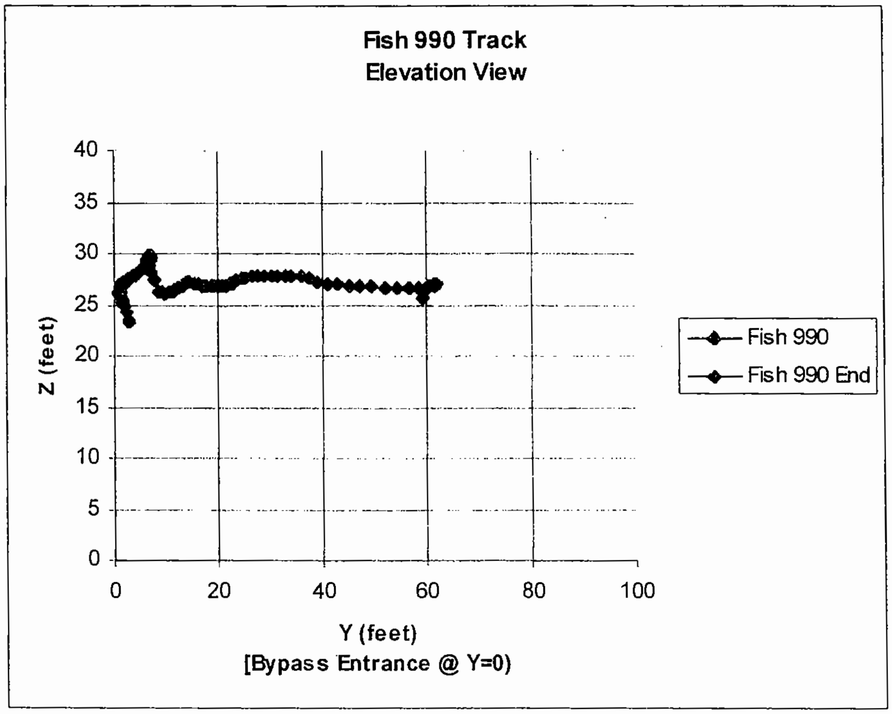


Figure D-13c Fish Number 990 Y/Z Tracking Results

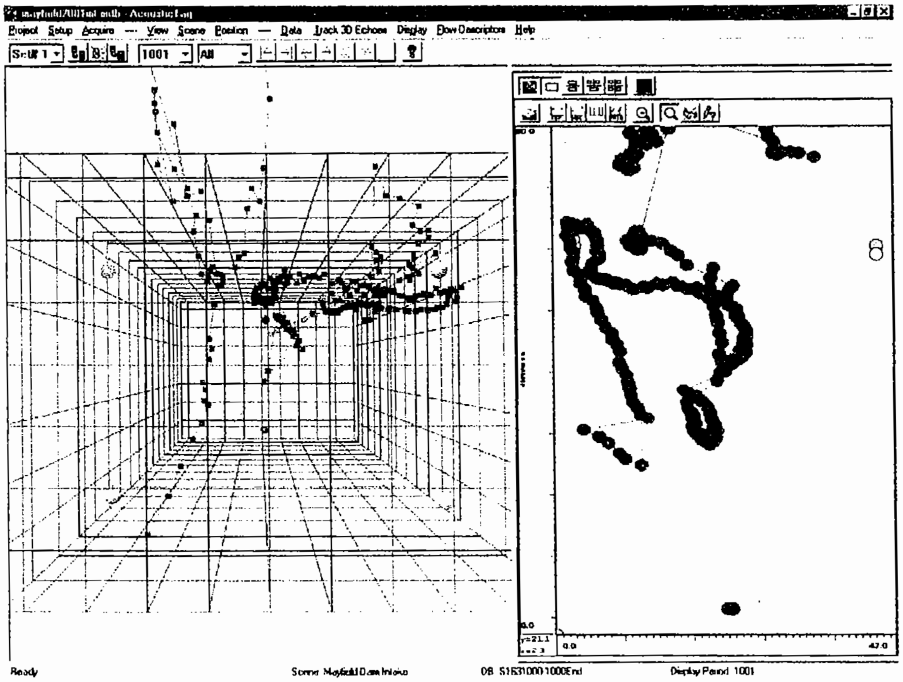


Figure D-14a Fish Number 1000 3D Tracking Results

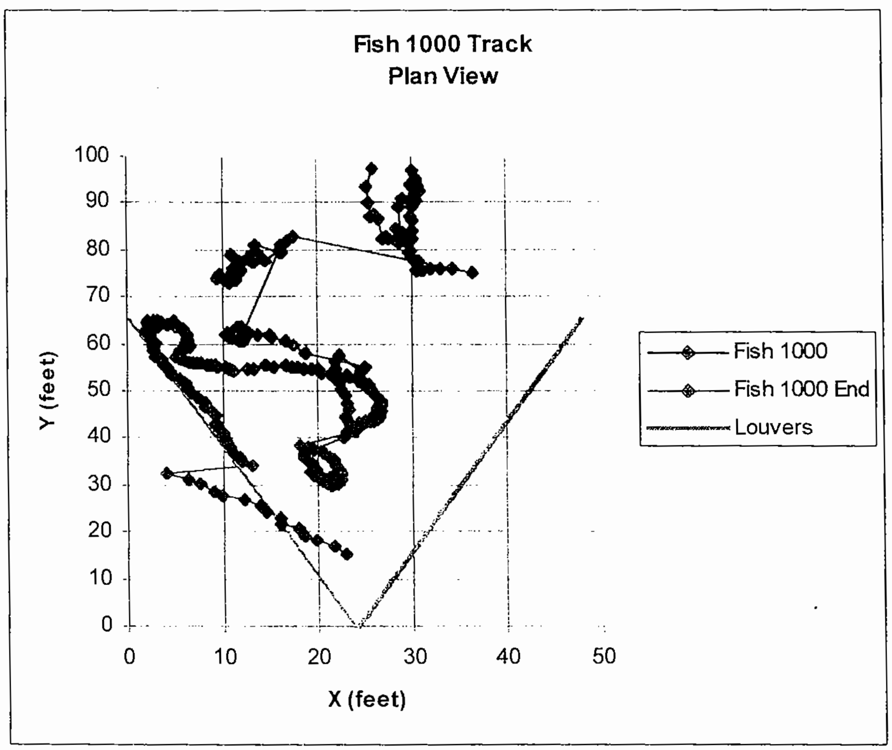


Figure D-14b Fish Number 1000 X/Y Tracking Results

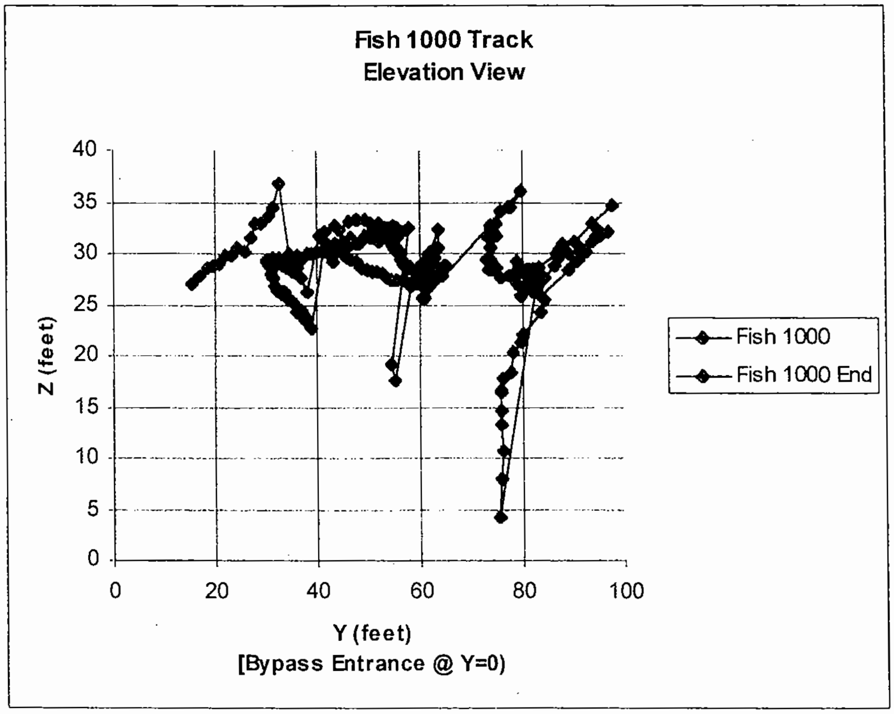


Figure D-14c Fish Number 1000 Y/Z Tracking Results

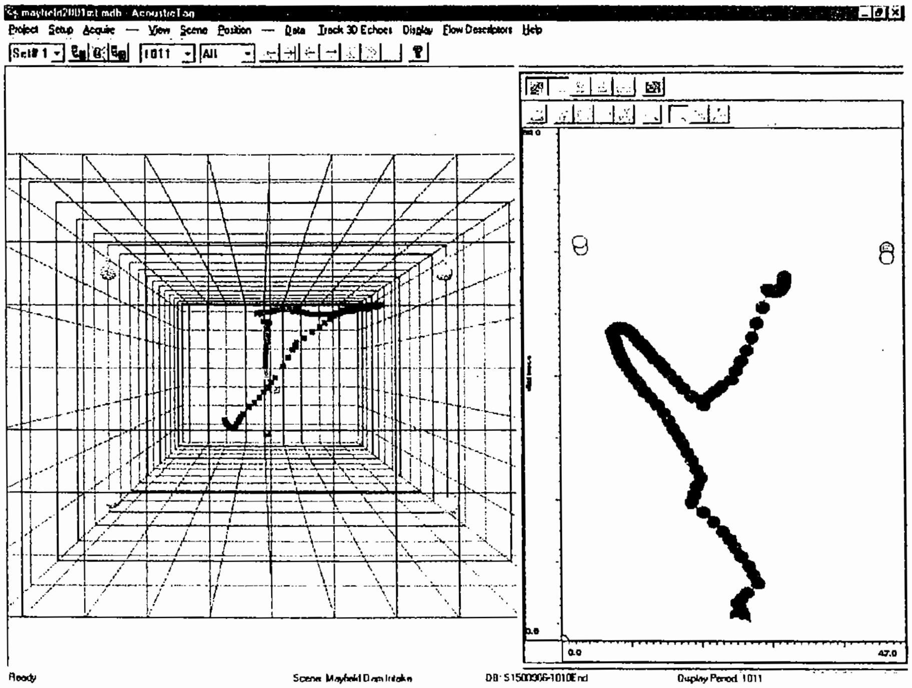


Figure D-15a Fish Number 1010 3D Tracking Results

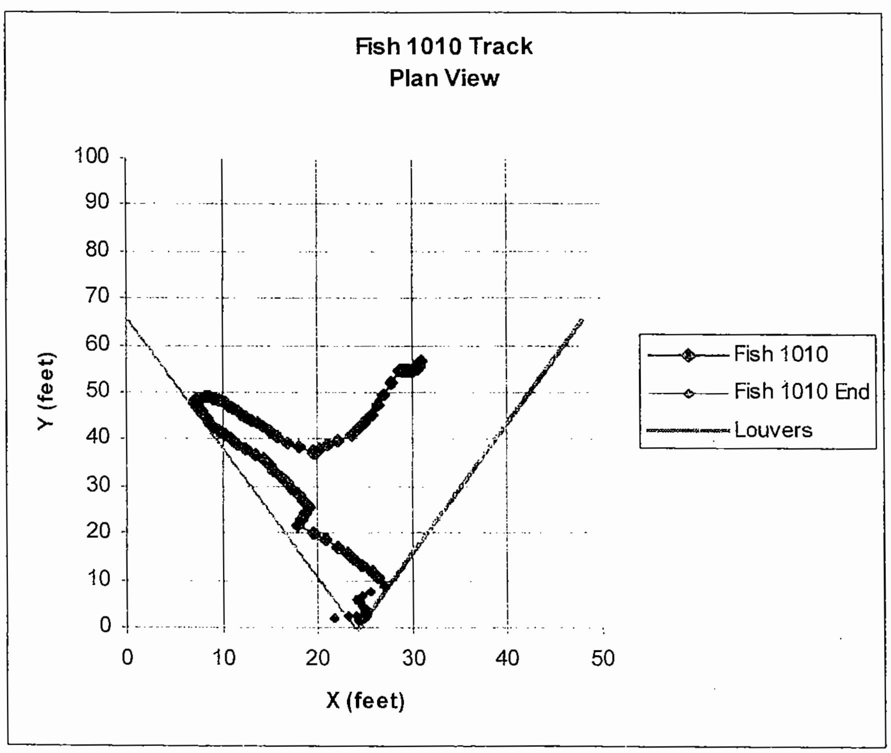
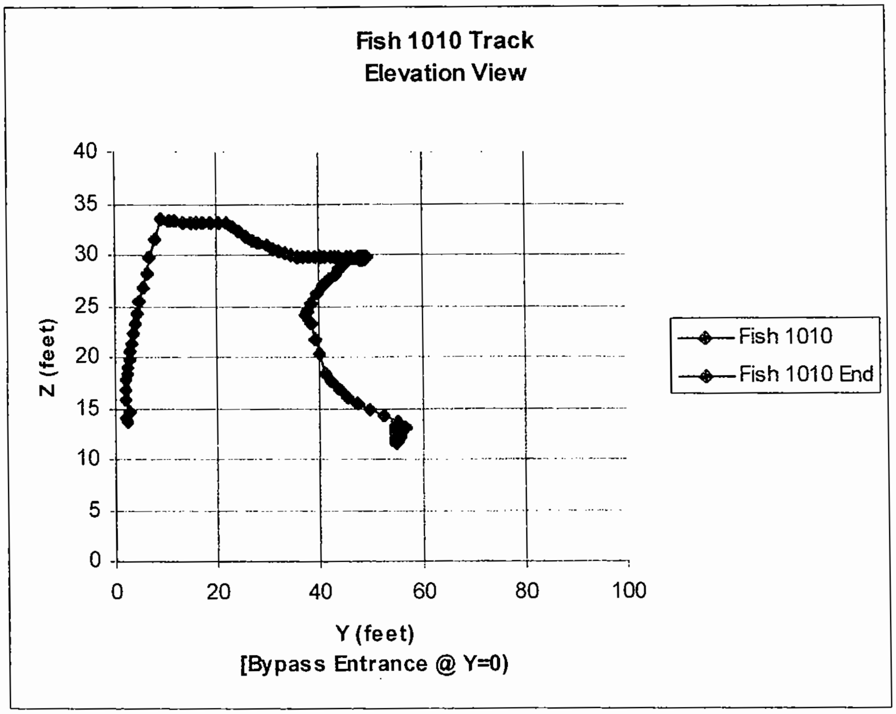


Figure D-15b Fish Number 1010 X/Y Tracking Results



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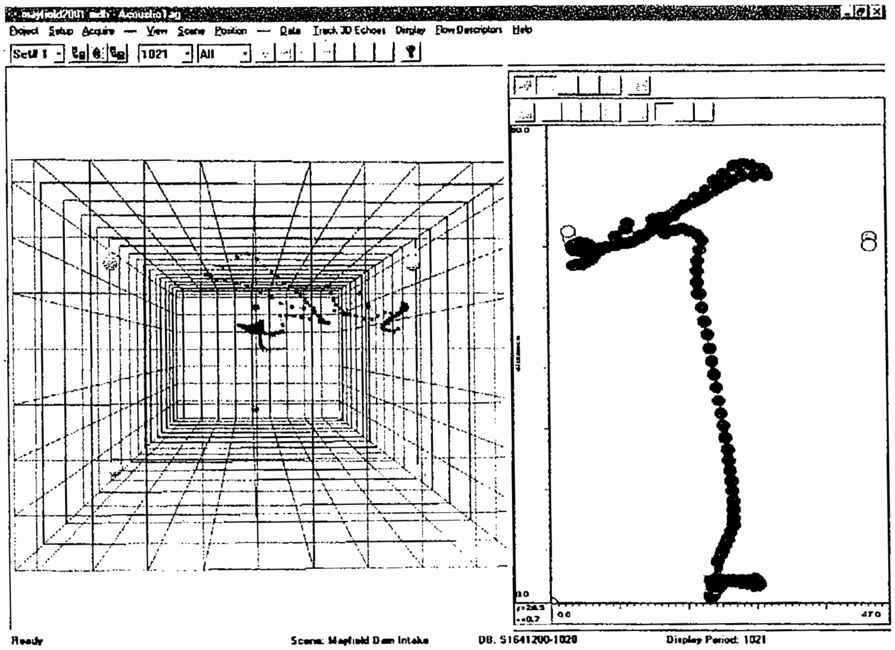

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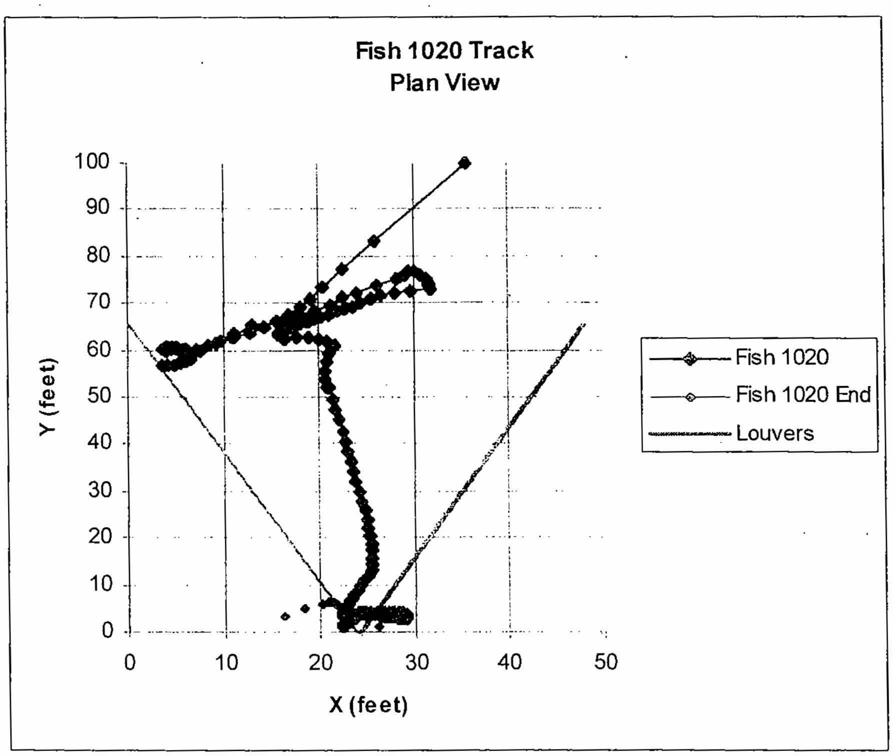

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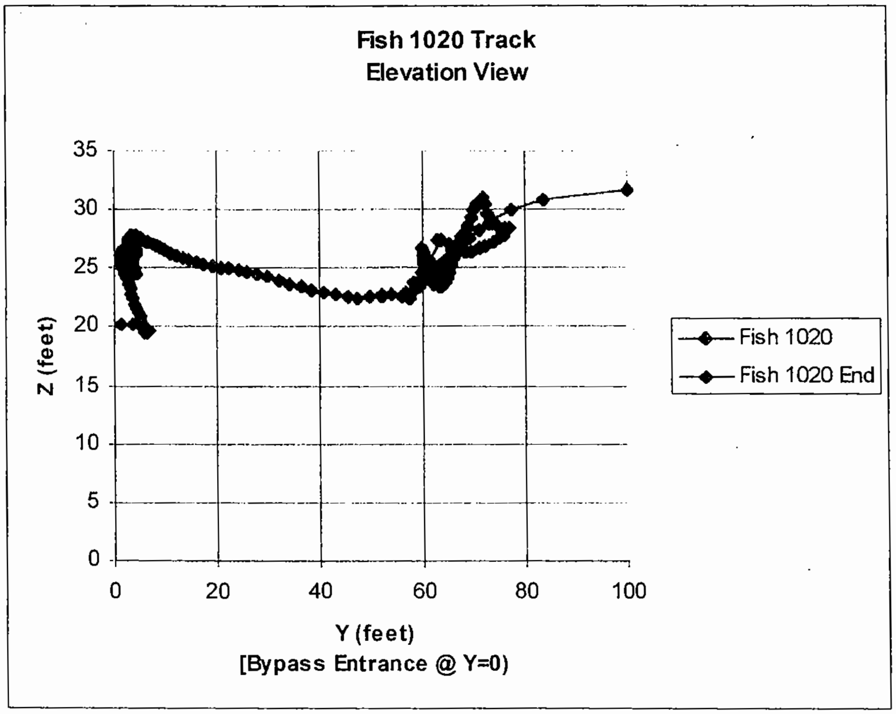

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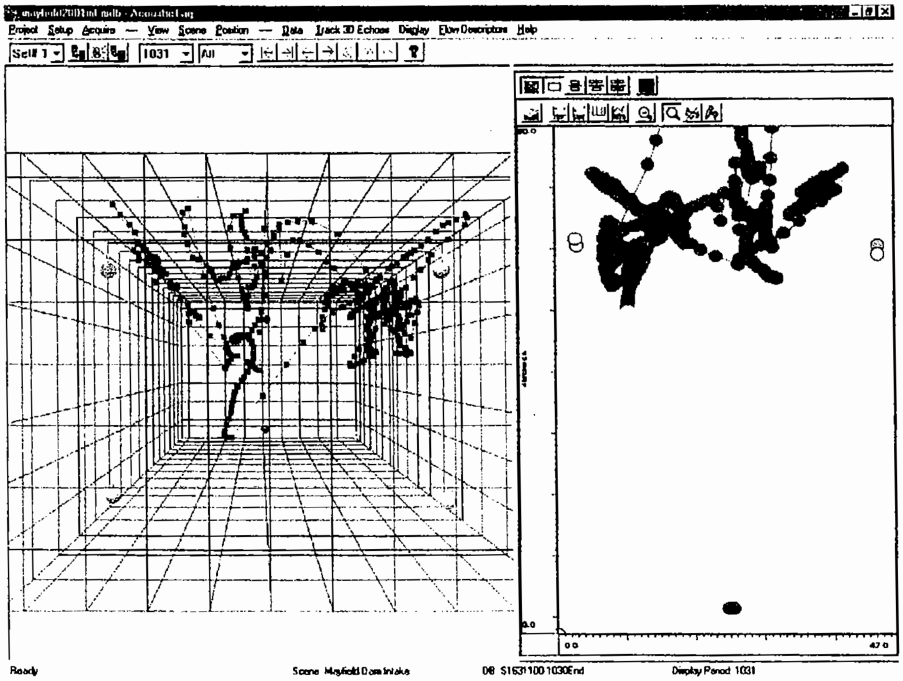

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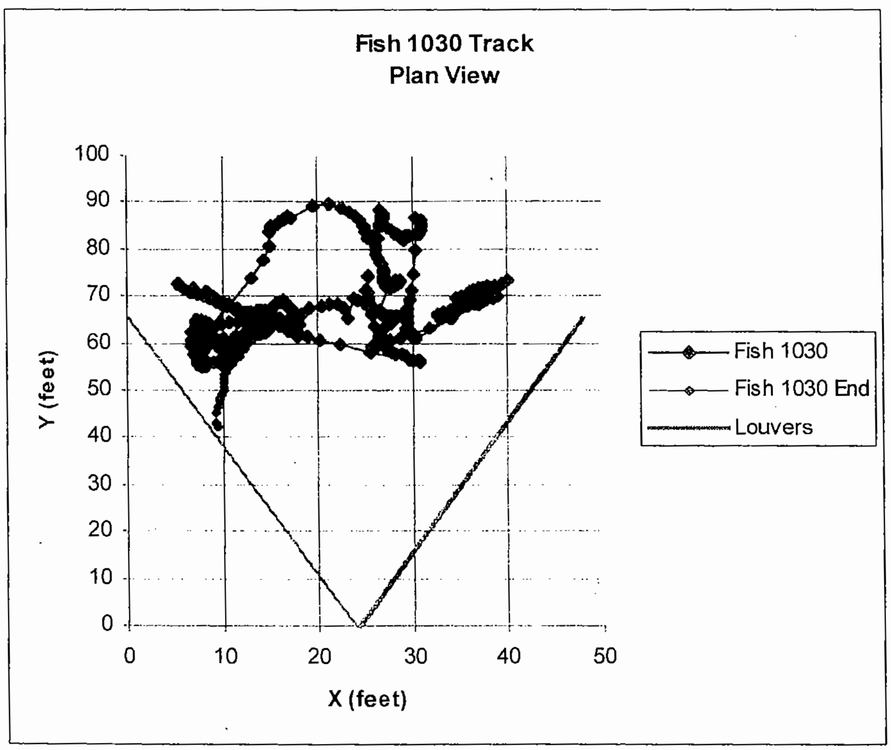

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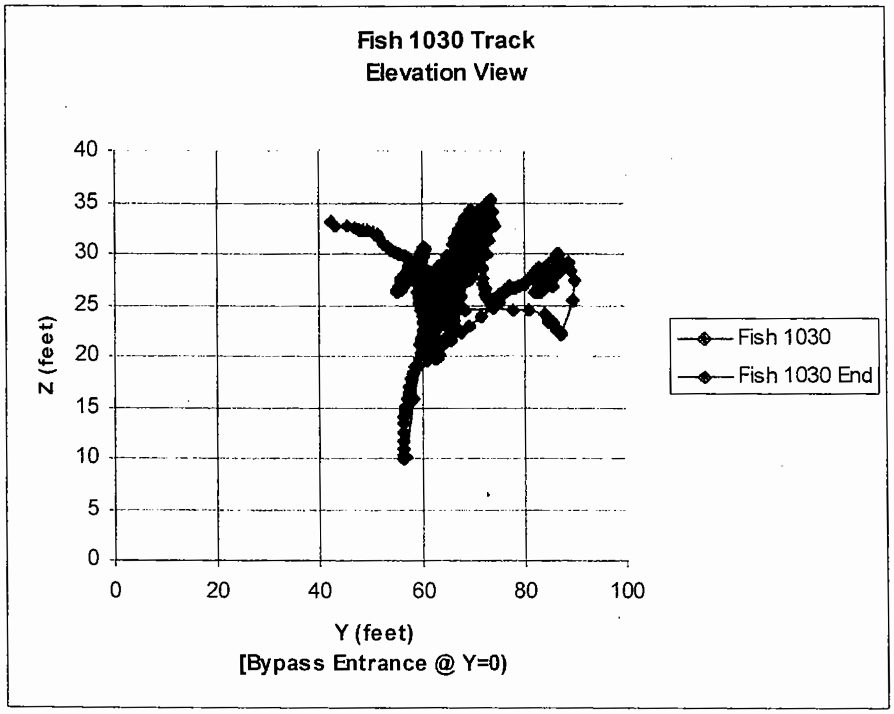

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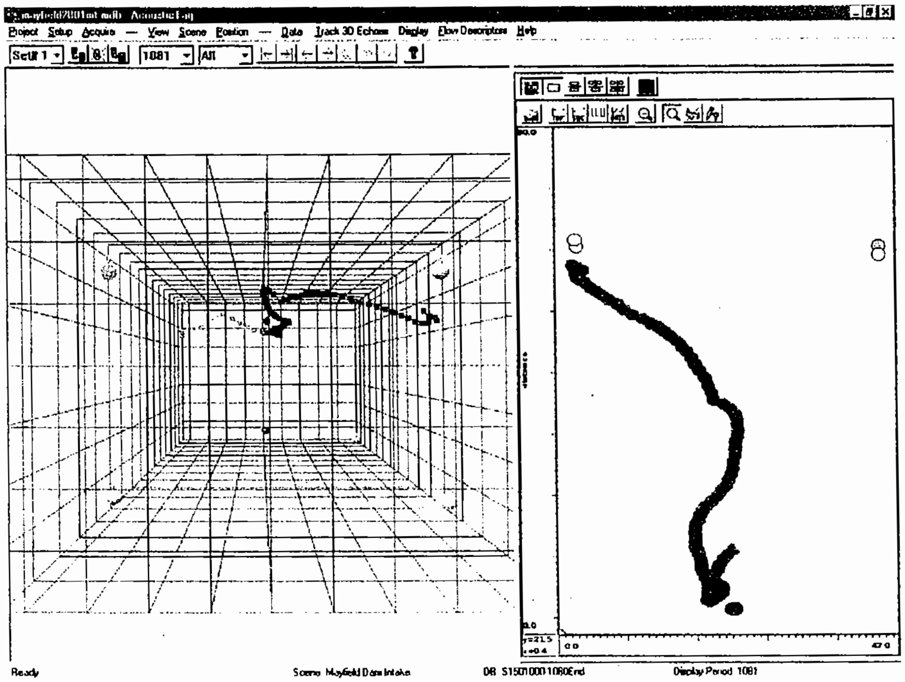

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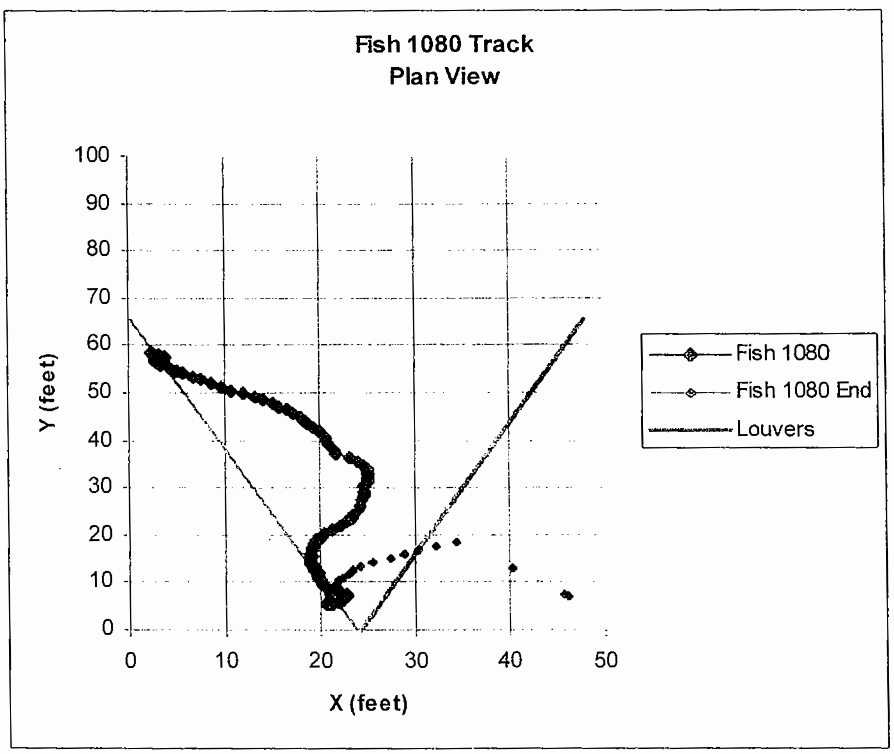

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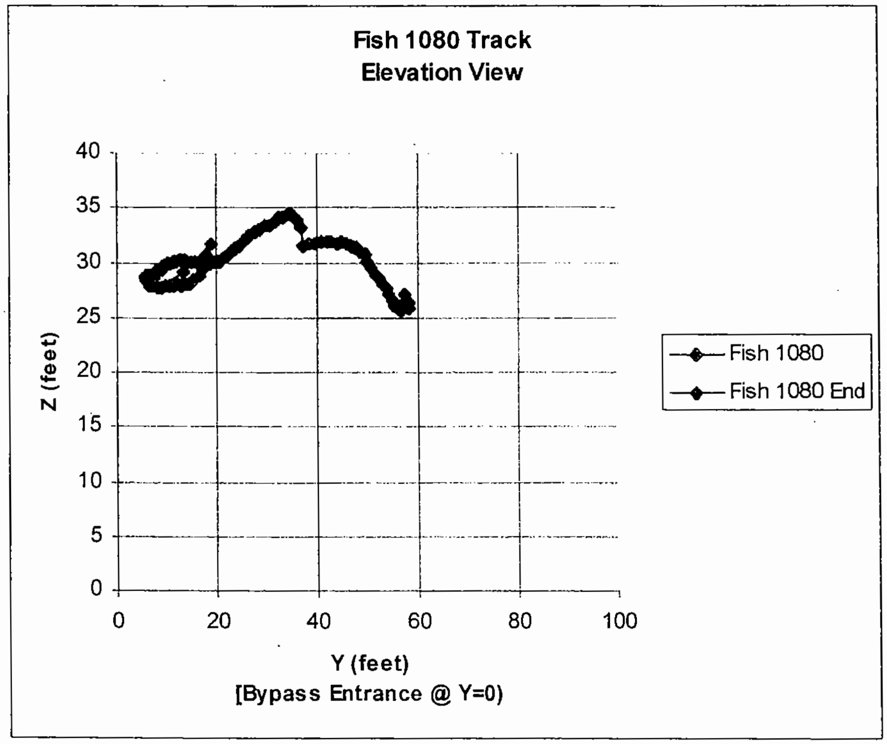

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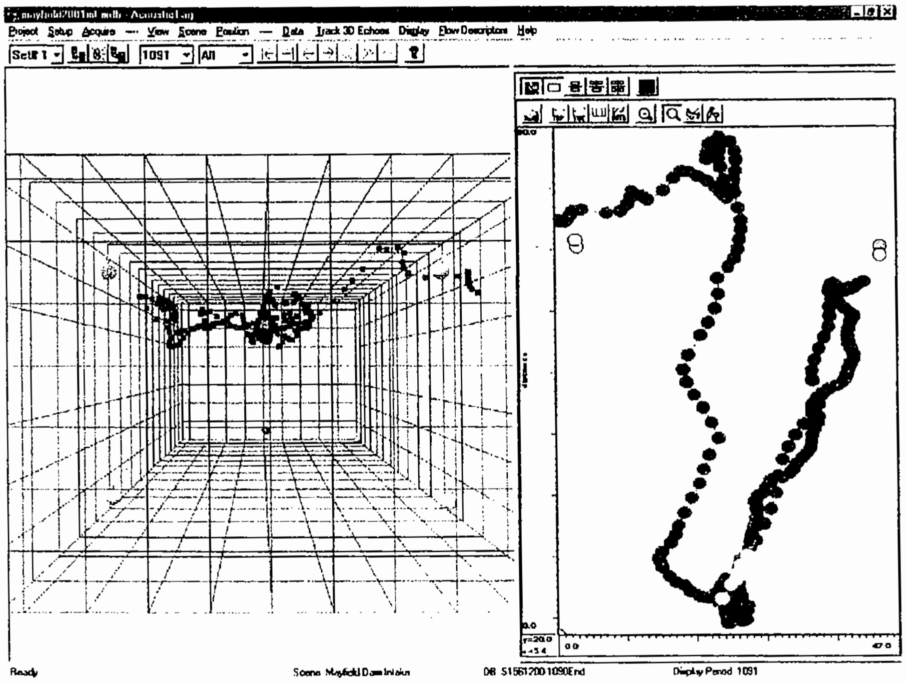

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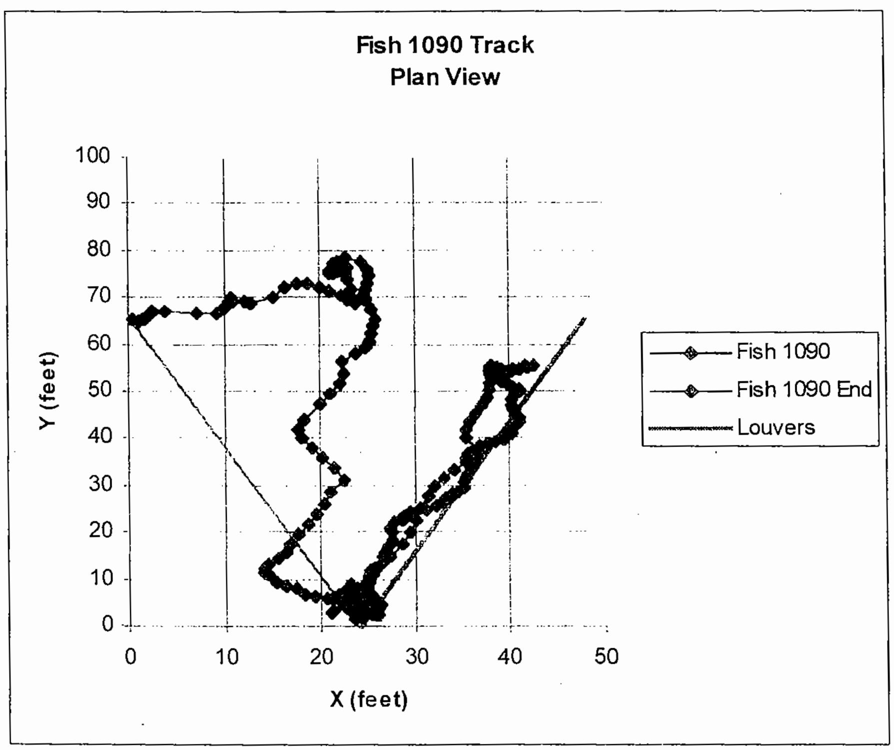

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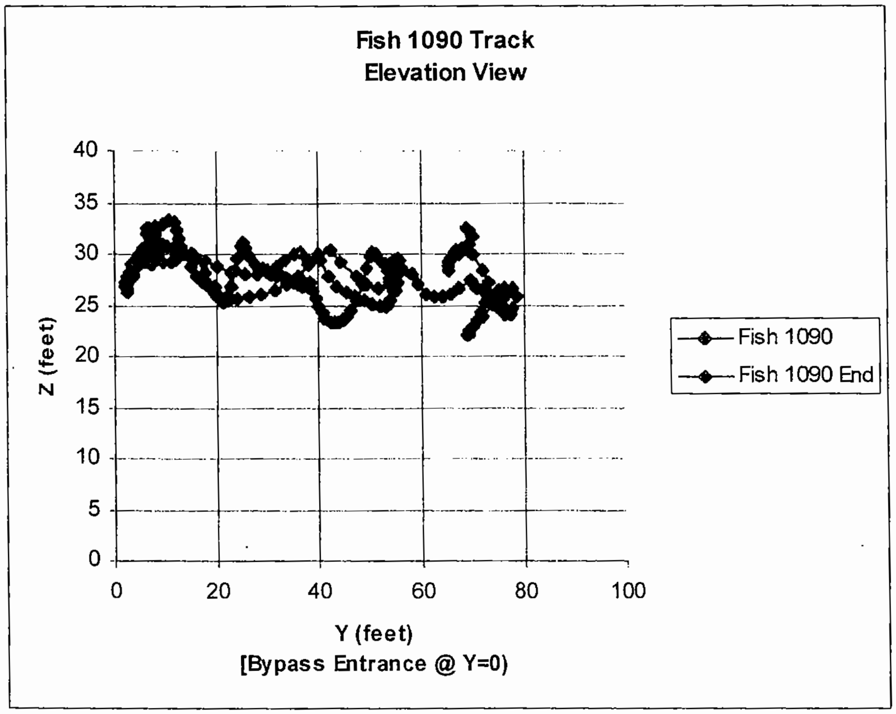

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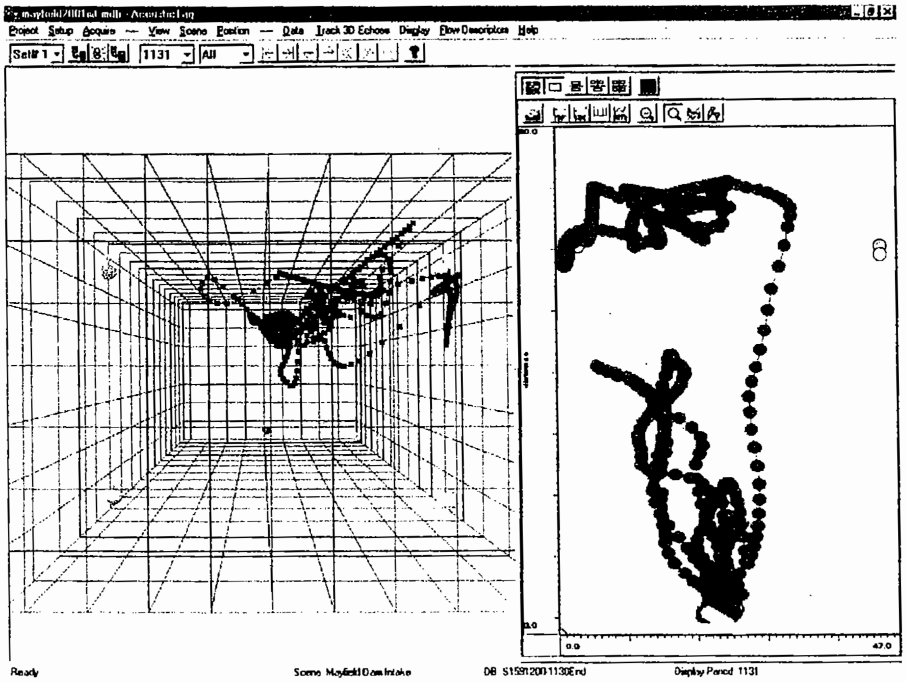

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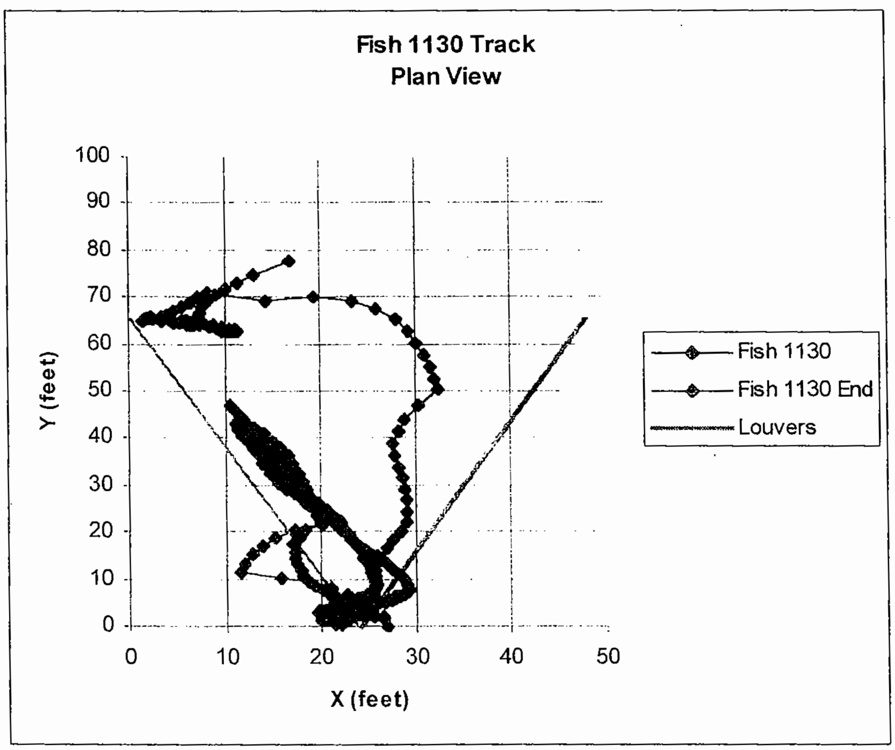

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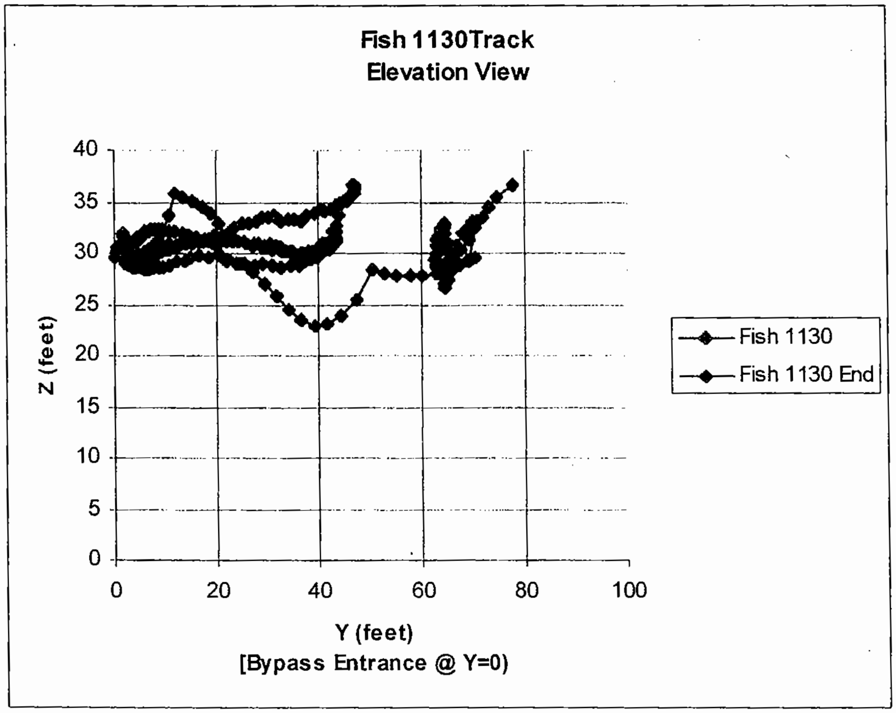

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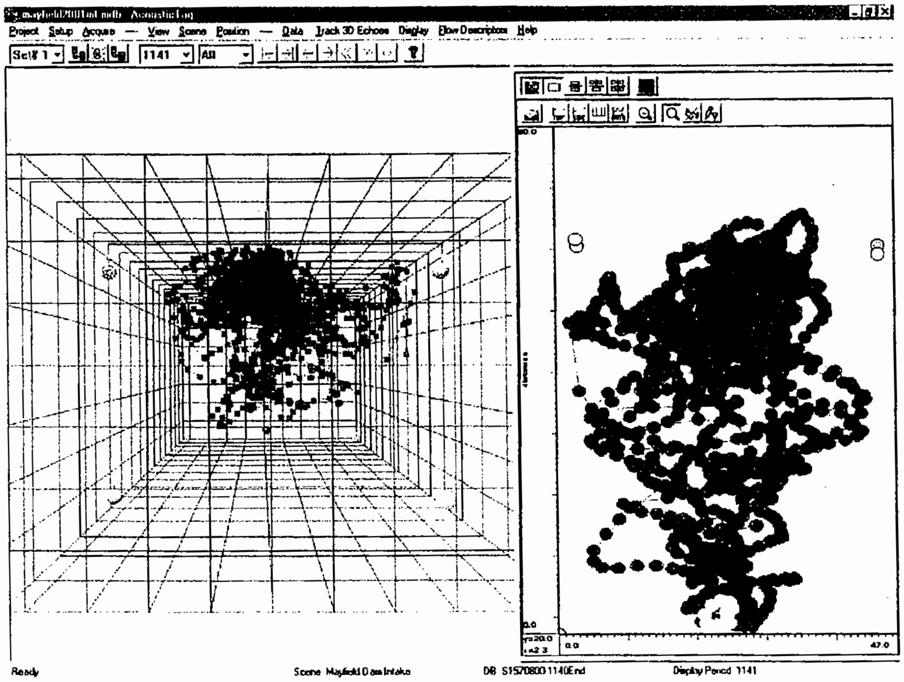

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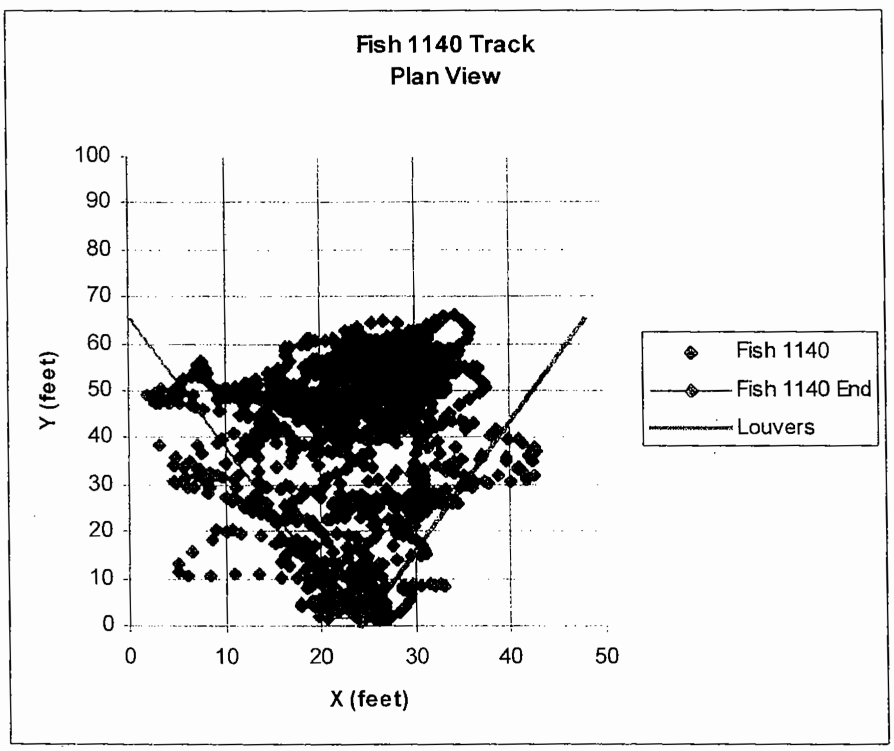

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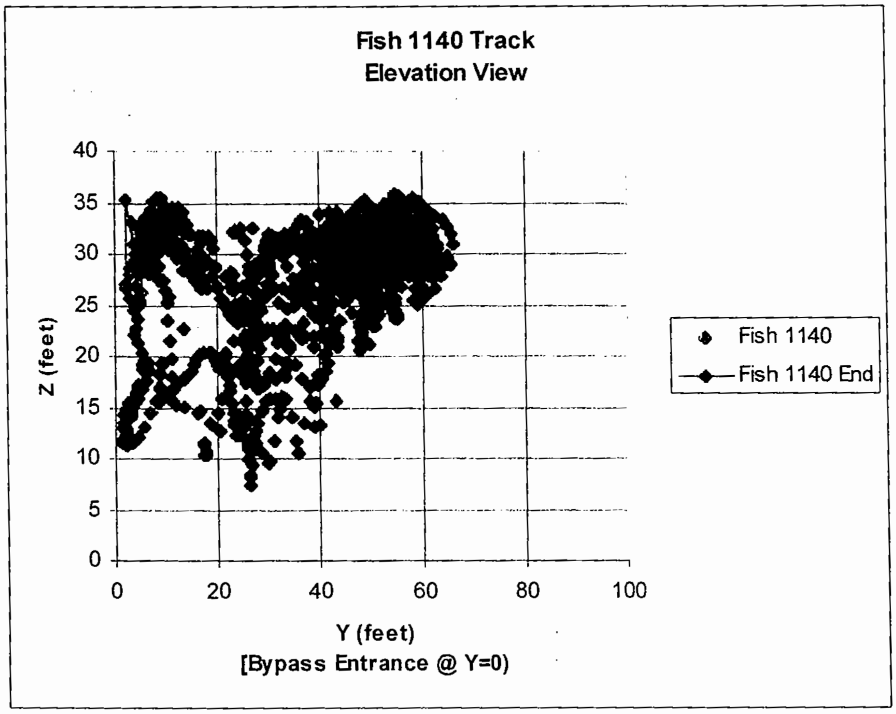

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ATTACHMENT No. 2

2002 Mayfield Dam Fish Guidance System Evaluations

COWLITZ RIVER PROJECT
FERC NO. 2016

MAYFIELD DAM
FISH GUIDANCE EVALUATIONS

2002 Work Plan

Tacoma Public Utilities
Tacoma Power
Generation, Natural Resources

SUMMARY

A second year of fish guidance evaluations of the louver collection system at Mayfield Dam is proposed in 2002 to measure progress towards the goal of achieving a 95% downstream fish passage survival rate. This rate is defined as the percentage of smolts entering the Mayfield louver system that are guided through the juvenile fish guidance and bypass facilities, plus those juveniles that also pass through the turbines or over the spill way and survive.

Spill occurrence is very rare at Mayfield Dam; thus the downstream passage survival rate is generally the combination of successful guidance and those fish surviving passage through the turbines.

Research activities at Mayfield Dam are intended to follow the recommendations of current researchers in the field of fish behavioral guidance (Coutant 2001) to utilize a multi-sensory approach to fish diversion to improve guidance efficiencies.

OBJECTIVES

The 2002 work plan for Mayfield louver efficiency evaluations includes modifications to the existing structure and additional investigation into fish collection efficiency on a species basis. Recommendations from the 2001 study (Zapel, et. al. 2002) focused upon the conditions at the entrance to the bypass slot at a range of flows normally encountered during the spring/summer outmigration period.

Structural Modifications to the intake

1. Provide lighting in the south intake louver bay bypass entrance slot

Velocity profile measurements

1. Measure velocity profiles in the south louver intake at higher springtime discharges
2. Measure velocity profiles at the entrance to the bypass slot at higher discharges

Fish Collection Efficiency

1. Tag and release 600 hatchery coho at the south louver bay entrance.
2. Tag and release 600 hatchery steelhead at the south louver bay entrance.
3. Collect tagged fish at the Mayfield counting house during routine operations.
4. Release tagged fish in groups of 200 (100 of each species) released one week apart, for six weeks.
5. Estimate louver guidance effectiveness during bypass intake slot light on and light off conditions.

METHODS AND MATERIALS

Structural Modifications to the Intake

Tacoma Power personnel will dewater the south louver intake bay during the spring of 2002 to remove all accumulated woody debris and other trash. A cluster of underwater lights will be placed in the bypass intake slot to illuminate the immediate area and to radiate light upstream at the entrance of the bypass slot for fish attraction. This work will require three days of louver bay dewatering after which the louver bay can be refilled, the fish attraction pump re-started and normal operation resumed.

In coordination with peak salmonid outmigration numbers obtained at the Mayfield counting house, an underwater video camera will be used to observe smolt behavior in the immediate vicinity of the bypass entrance slot. The camera will be lowered from the truss structure spanning the louver bay.

Velocity profile measurements

Measurements of velocity vectors within the louver intake bay will be made with a three-dimensional acoustic Doppler velocity measurement probe. The velocity probe mount will be modified to accommodate measurement of point velocities very near to and just inside the bypass entrance slot. These data can be used to verify the accuracy of the CFD model that was developed during the 2001 work.

Fish collection efficiency monitoring

Fisheries personnel will release marked hatchery coho and steelhead smolts from atop the trash boom immediately in from of the south louver entrance. This release location is chosen to maximize the marked fish passage into the louver bay entrance. The fish will be marked with a colored elastomer injected into the adipose eye tissue. Marked fish will be held for 24 hours after marking to assess fish condition prior to release. Only vigorous fish will be released.

Uniquely marked fish releases will occur on Wednesdays starting May 8, 2002. The bypass entrance slot lights will be illuminated in week 1, turned off for week 2 and then turned on the following week. The lights will be left off at the end of week 6 unless study results to that date indicate the value of leaving the lights on.

Recoveries of marked fish will occur in the Mayfield counting house concurrent with the close examination and wire tagging of all unmarked smolts guided to the collector system. The hatchery smolts will be adipose clipped thus yielding an initial mark or clue to the fish technician to examine the fish more closely for the unique mark associated with this study. Data will be recorded on field data sheets and transferred to a personal computer spreadsheet program.

LITERATURE CITED:

Coutant, Charles C. 2001. Integrated, Multi-Sensory Behavioral Guidance Systems for Fish Diversions. Pages 105-114 in C. Coutant, editor. *Behavioral Technologies for Fish Guidance.* American Fisheries Society Symposium 26, Bethesda, Maryland.

Zapel, Ed, Tom Molls, Sam Johnston, Patrick Nealson and Mark Timko. Cowlitz River Project Mayfield Dam Fish Guidance Louver Evaluations, Final Report, 46 pp., January 2002

PASSAGE SURVIVAL OF JUVENILE SALMONIDS THROUGH TWO FRANCIS TURBINES AT MAYFIELD DAM, COWLITZ RIVER, WASHINGTON

October 2003

NORMANDEAU ASSOCIATES
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PASSAGE SURVIVAL OF JUVENILE SALMONIDS THROUGH TWO FRANCIS TURBINES AT MAYFIELD DAM, COWLITZ RIVER, WASHINGTON

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October 2003

EXECUTIVE SUMMARY

The present investigation, sponsored by Tacoma Power, estimated survival rates (direct effects) of juvenile coho salmon, *Oncorhynchus kisutch* (average about 151 mm total length), and steelhead, *O. mykiss* (average about 188 mm total length), in passage through an old Francis turbine (Unit 44) and a new Francis turbine (Unit 41) at the Mayfield Hydroelectric Project on the Cowlitz River, Washington. All experimental fish were obtained from the Cowlitz Salmon Hatchery. Water temperatures ranged from 4.5 to 6.0°C (40.1 to 42.8°F).

Recapture rates (physical retrieval of alive and dead fish) for the treatment groups ranged from 92 to 95.2%; all controls (100%) were recaptured.

Retrieval times differed with species. Retrieval times for coho treatment groups averaged 8 min (Unit 44) to 17 min (Unit 41) and for steelhead they averaged 31 min (Unit 41) to 45 min (Unit 44). Retrieval times for control coho salmon averaged 5 min and for control steelhead it averaged 11 min. The longer retrieval times for steelhead were most likely due to several fish moving to underwater rock ledges in the tailrace prior to balloon inflation or being temporarily trapped in an inaccessible eddy.

Estimated survival probabilities were turbine specific rather than species or size specific. Estimated 1 h survival probabilities (coho salmon 0.876, 90% profile confidence interval 0.837 to 0.916; steelhead 0.884, 90% profile confidence interval 0.842 to 0.926) of both species in passage through the new Francis Unit 41 were significantly lower ($P<0.05$) than for those passing through the old Francis turbine Unit 44 (coho salmon 0.972, 90% profile confidence interval 0.949 to 0.995; steelhead 0.971, 90% profile confidence interval 0.944 to 0.998). Similarly, the 48 h survival probabilities in passage through the new Francis Unit 41 (coho salmon 0.847, 90% profile confidence interval 0.80 to 0.894; steelhead 0.826, 90% profile confidence interval 0.776 to 0.876) were significantly lower ($P<0.05$) than for those passing through the old Francis Unit 44 (coho salmon 0.971, 90% profile confidence interval 0.943 to 1.00; steelhead 0.971, 90% profile confidence interval 0.944 to 0.998).

Surprisingly, the survival probabilities of both species in passage through the old Francis turbine Unit 44 equaled or exceeded those recently reported for juvenile fishes in several investigations at low-head (≤100 ft) hydroelectric dams equipped with Kaplan or propeller type turbines. Although fish survival data from Francis turbines similar in configuration and characteristics to the turbines at Mayfield Dam are scant in the literature for direct comparison, estimated survival probabilities are within the upper range (0.345 to 0.908) of those reported for a handful of sites.

The visible injury rates for the larger-sized steelhead (average 188 mm) were higher than for coho salmon (average 151 mm) in both units. Injury rates for fish passing turbine Unit 41 were 17.9% for steelhead and 9.1% for coho salmon; they were 7.1% for steelhead and 5.1% for coho salmon in passage through Unit 44. These differences may be size related. The probable sources of injuries were mechanical and shear forces.

Most of the observed differences in survival and injury rates between turbines may be due in part to a higher number of buckets (16 in Unit 41 and 15 in Unit 44), wicket gates (24 in Unit 41 and 20 in Unit 44), and narrower wicket gate spacing (22.5 in for Unit 41 and 25.4 in for Unit 44).

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1.0 INTRODUCTION

Fish traveling downstream encounter three major exit routes at hydro dams: turbines, spillways/sluices, or bypasses. A successful passage through any of these routes is of importance, particularly for emigrating migratory fish, for maintenance and enhancement of adult populations. However, for a variety of reasons, fish exclusionary devices are generally less than 100% effective in diverting fish away from turbine entrainment and some proportion of the salmonid run(s) invariably is not excluded. Thus, a concern exists relative to the fate of fish transported through turbines. Several reviews of turbine passage survival (Ruggles 1980; Bell 1981; Monten 1985; Eicher Associates 1987; Ruggles and Palmeter 1989; Cada 1990; EPRI 1992; Franke *et al.* 1997) indicate that with some exceptions most efforts were focused on estimating survival of Pacific salmonids in passage through Kaplan type turbines at low-head (≤100 ft) dams and survival in passage through Francis type turbines was generally thought to be lower. These reviews also indicate that turbine type, fish size relative to runner diameter, trajectory of entrained fish relative to flow stream, clearance between structural components (*i.e.*, spacing between runner blades or buckets, wicket gates, and turbine housing), turbine operating status, depth of fish entrainment, number of runner blades or buckets, flow, and angle of water flow through turbines are important factors affecting fish survival. Although only recently a few fish passage survival studies have been undertaken as side-by-side comparisons of different turbine types (only Kaplan and modified Kaplan types) no such comparative investigation of survival at Francis turbines, particularly at high head dams (>100 ft), has been conducted. Because downstream migrants may be transported through different turbine types at dams with their attendant survival rates, estimates of fish survival in passage through each turbine type may have potential operational implications. At the Mayfield Hydroelectric Station on the Cowlitz River, Washington (Figure 1-1) a fourth (new) unit was added in 1983. Although a fish bypass exists at the dam, it is estimated to exclude up to 60% of the juvenile salmonids from turbine entrainment (Thompson and Paulik 1967). Thus, up to 40% of the down migrating fish may pass through the new and the three older Francis turbines.

The objective of the present investigation at Mayfield Dam was to estimate the direct effects of turbine passage on immediate (1 h) and 48 h survival of juvenile coho salmon, *Oncorhynchus kisutch*, and steelhead, *O. mykiss*, within ±5%, 90% of the time entrained in Units 41 (new) and 44 (old). The two units were selected because 1) both types may transport some proportion of salmonid emigrants, 2) Unit 41 is operated preferentially (Figure 1-2) during the juvenile salmonid emigration period, and 3) among a variety of factors, the configuration of the turbine, number of buckets or blades, and clearances between buckets and other structures may differentially affect fish survival (Franke *et al.* 1997; Normandeau Associates *et al.* 1996, 2001).

1.1 Project Description

The Mayfield Dam is located on the Cowlitz River, near Mossy Rock, Washington (Figure 1-1). The powerhouse contains three old and one new (Unit 41) Francis units, each with a generating capacity of about 40 megawatts (MW) at a normal head of 181 ft. The new Francis Unit 41 has 24 wicket gates compared to 20 in the old units; the wicket gate spacings of the new unit are smaller than that of the old ones (Table 1-1). The height of the wicket gate openings is less in the new unit which reduces the total area at the wicket gates by 5% compared to an old unit. Also, the new unit has 16 buckets, the old units have 15 buckets with a spacing of 27.2 in between the buckets of Unit 41 and 27.1 in for Unit 44. The runners in both the old and new units spin at 138.5 rpm and have an outlet (maximum) runner diameter of 149 and 157.5 in, respectively. The respective inlet runner diameter is 130 and 138 in. Maximum discharge through the new unit is 3,290 cfs at a head of 182 ft. Typical maximum discharge through the old units is 3,370 cfs at 182 ft head. The total hydraulic capacity of the station is approximately 13,400 cfs. Table 1-1 provides other characteristics of the studied turbines.

The new unit is typically placed on-line first and is maintained near 90% operating efficiency with an output of near 35 MW and 2,800 cfs discharge. The older units (Nos. 42, 43, and 44) are typically operated near 87% efficiency, which is also near 35 MW and 2,870 cfs discharge. Figure 1-2 shows the power output of the new and old units in April through June, 1996 through 2000. This pattern of power output coincides with the peak emigration period of juvenile salmonids. Although a fish diversion device (louvers) exists, up to 40% of salmonids have been reported to pass through the operating turbines.

2.0 STUDY DESIGN

The passage survival experiment, using the HI-Z balloon tag-recapture technique, was designed with the recognition that the resulting data would provide overall relative survival of entrained fish in different types of turbines at the Mayfield Dam. Tacoma Power had desired estimation of comparative survival at Francis turbine Units 41 (new) and 44 (old) near a power output of 35 MW, which is typically maintained during the salmon emigration period. Power output ranged from 34.28 to 35.84 MW at Unit 41 and from 34.62 to 35.39 MW at Unit 44 during the fish releases (Table 1-2). Appendix A provides hourly power outputs of Units 41 and 44.

The study was designed to release an adequate number of fish such that the resulting survival estimates would have a precision (ε) of $\pm$5%, 90% of the time. However, to minimize the use of scant resources, two treatment releases (fish released through the two turbines) were paired with a common control release (fish released in the turbine discharge). This scheme has proven well in other passage survival investigations without sacrificing precision (Normandeau Associates *et al.* 1996, 2001).

2.1.1 Sample Size Calculations

Prior to implementation of the investigation, sample size calculations were made to achieve a precision (ε) of $\leq\pm$5%, 90% of the time, on the survival estimates. The sample size is a function of the recapture rate (P_A), expected passage survival ($\hat{\tau}$) or mortality ($1-\hat{\tau}$), survival of control fish (S), and the desired precision (ε) at a given probability of significance (α). In general, sample size requirements decrease with an increase in control survival and recapture rates. Only precision (ε) and α levels can be strictly controlled by an investigator. Expressions to calculate sample sizes for achieving a specified precision (ε) level are given in Mathur *et al.* (1996).

Using the expression given in Mathur *et al.* (1996), we calculated that with the following assumptions of a recapture rate of 0.98, control survival rate (S) of 0.98, and turbine survival ($\hat{\tau}$) of 0.95, a precision (ε) level of $\leq\pm$0.05, 90% of the time, may be achievable by releasing 134 treatment fish and 134 controls (total of 268 fish; Table 2-1). These recapture and survival rates have been observed in recent studies conducted at large Kaplan type turbines at hydroelectric dams on the Columbia River Basin (Table 2-2). These calculated release numbers were used as guidelines prior to initiating the investigation, as the embedded flexibility of the balloon tag-recapture technique permits adjustments of sample sizes as an investigation progresses (Normandeau Associates *et al.* 1996, 2001). The results of daily releases are available for statistical analysis, thus, if the observed results are contrary to initial expectations, sample sizes can be adjusted on-site on a daily basis to achieve the desired statistical precision (ε) level. Additional releases, if needed, could be made to achieve the statistical objectives of the study. Alternatively, if prespecified statistical criterion is met with fewer fish the experiment can be terminated or fish allocated to another test condition.

2.2 Source of Specimens

The juvenile steelhead and coho were obtained from the Cowlitz Salmon Hatchery. Fish were transported via truck to the Mayfield Station and held in separate tanks located on the intake deck (treatment site). Fish were held for about 48 h prior to tagging to acclimate them to ambient river conditions. Both tanks were continuously supplied with ambient river water. Water temperature at the hatchery ranged from 5.6 to 7.2°C (42 to 45°F) and 4.5 to 6.0°C (40.1 to 42.8°F) in the river at Mayfield Dam.

Individual treatment and control specimens were randomly taken from the same group of fish to minimize heterogeneity in size and condition. Figures 2-1 and 2-2 show the length frequency distributions of coho salmon and steelhead. The average total lengths for treatment and control groups were similar for each species. Mean total lengths for coho salmon were 150.6 mm (Unit 41), 151.2 mm (Unit 44), and 150.6 mm (control). Mean total lengths for treatment steelhead were 189.6 mm (Unit 41) and 186.9 mm (Unit 44) and 186.9 for controls.

2.3 Tagging and Release

Fish tagging, release, and recapture techniques followed those used for other similar turbine survival tests (Heisey *et al.* 1992; Normandeau Associates *et al.* 1995, 1996, 1999) and the recent study completed at the Cowlitz Falls Station (Normandeau Associates and Skalski 2001). Briefly, fish were anesthetized with MS 222, equipped with two uninflated balloon tags, and a small radio tag. Balloon tags were attached by a stainless steel pin inserted through the musculature beneath the dorsal and adipose fins. The radio tag was attached in combination with the balloon tag placed beneath the dorsal fin. Prior to release through an induction apparatus, each fish was allowed to recover from anesthesia. Fish were placed individually into the induction holding tub, balloon tags activated, and the fish released. The inflation time of the balloon tags was regulated, to a certain extent, by varying the temperature and amount of catalyst injected into each tag prior to release. All procedures used in handling, tagging, release, and recapture of treatment and control fish were identical.

We utilized a single control release for two simultaneous treatment releases. Results of several recent studies at hydroelectric dams on the Columbia River Basin had indicated that this can be an efficient experimental protocol (Normandeau Associates *et al.* 1995, 1996, 2001; Normandeau Associates and Skalski 1996). Additionally, the release scheme is logistically efficient and reduces the number of fish used and duration required to accomplish the primary objectives of the study. For example, if treatment fish were released in Units 41 and 44 then fish released in the turbine discharge formed the matching control for both treatment groups in that trial. Each day's release constituted an independent trial. The two treatment groups and single control group were randomly released. Controls were released in the turbine discharge in the tailrace primarily to evaluate the effects of handling, tagging, induction, recapture, and to provide additional data on recapture rates. Individual trial data are shown in Appendix A. Appendix B provides the statistical models used and the associated outputs.

2.4 Release Locations

Fish were released via an induction apparatus (Figure 2-3) consisting of a 25 gal holding basin attached to a four inch diameter hose line which was supplied with river water to ensure that fish were transported quickly within a continuous flow of water. The treatment fish for each turbine were released at approximately mid-depth, about 9 ft below the ceiling of the intake pen stock (Figure 2-4). The four in diameter flexible release hoses were positioned and secured in place by threading them through six in diameter steel pipes. These steel pipes were anchored just downstream of the tainter gate that regulated the flow into the pen stock for both Units 41 and 44. A 30 inch radius sweep 90° elbow at the end of the metal pipe ensured that the hose remained in position and that the delivery hose, water, and fish were discharged nearly parallel to the entrained flow.

A similar induction apparatus was used for releasing control fish in the turbine discharge. The discharge hose was deployed approximately 5 ft below the ceiling of the draft tube so that it terminated near the end of the draft tube (Figure 2-4). The four inch flexible hose was deployed in a manner similar to that at the treatment sites. This hose was secured and positioned inside a 6 in steel pipe that was lowered to the desired depth. The end of the release hose was deployed at a depth of about 20 ft below the surface of the tailrace.

The control release point was such that both treatment and control fish entered the tailrace near the same minimum depth. However, the subsequent spatial distribution of each fish in the tailrace could not be controlled.

2.5 Fish Recapture

Buoyed fish were retrieved by one of the two recapture boat crews. Only crew members trained in fish handling were used to retrieve tagged fish. Boat crews were notified of the radio tag frequency of each fish upon its release. Radio signals were received on a 5-element Yagi antenna coupled to an Advanced Telemetry receiver. The radio signal transmission enabled the boat crew(s) to follow the movement of each fish upon entering the tailrace and position the boat for quick retrieval when the balloon tag buoyed the fish to the surface. Recaptured fish were placed into an on-board holding facility, and the tag(s) were removed by a pin puller (modified pliers). Each fish was examined for descaling and injuries and assigned codes relative to descriptions presented in Table 2-3. Tagging and data recording personnel were notified via a two-way radio system of each fish's recovery time and condition.

Recaptured alive fish were transferred in 5 gal pails to an on-shore holding tank located on the tailrace deck to estimate 48 h survival. Both treatment and control fish were held in the same tank. Tanks were continuously supplied with ambient river water and shielded to prevent fish escapement and potential avian predation.

2.6 Classification of Recaptured Fish

The immediate post-passage status of recaptured fish and recovery of dislodged, inflated balloon tag(s) was classified as alive, dead, predation, or unknown as described in Normandeau Associates *et al.* (1995, 1996, 1999). The following criteria have been established to make these designations: (1) alive--recaptured alive and remained so for 1 h; (2) alive--fish does not surface but radio signals indicated movement patterns typical of emigrating juveniles; (3) dead--recaptured dead or dead within 1 h of release or stationary radio signals; (4) dead-- only dislodged inflated tag(s) are recovered without the fish or the manner in which tags surfaced is not indicative of predation; (5) unknown-- neither tags nor fish are recovered or a more detailed status cannot be ascertained within 30 min, however, because of unusual conditions in the tailrace, this criterion was extended to the test day, usually two to six hours; and (6) predation-- fish are either observed being preyed upon, the predator is buoyed to the surface, distinctive bite marks on recaptured fish are present, or dislodged tag recovery indicate predation (*i.e.*, rapid movements of tagged fish in and out of turbulent waters or sudden appearance of fully inflated dislodged tags). For estimation of passage survival, preyed upon fish are treated as dead. No fish were classified as preyed upon in the present investigation.

Mortalities of recaptured fish occurring after 1 h were assigned post-passage effects (48 h) although fish were observed at approximately 12 h intervals. Specimens which died were necropsied to determine the probable cause of death. Injuries and descaling were evaluated immediately following recapture and were categorized by type, extent, and area of body (Table 2-3). Additionally, all specimens alive at 48 h were re-anesthetized and closely examined for injury and descaling. This re-examination of immobilized fish minimized additional handling stress immediately upon recapture (Normandeau Associates *et al.* 1995, 1996). The descaling recorded on each fish during the detailed examination provided a better estimate than that recorded upon immediate recapture. Fish were considered descaled if greater than 20% scale loss was detected on either side of the fish. All injuries were recorded at the initial recapture and later during the detailed examination at 48 h. This procedure allowed assessment of some injuries, such as bleeding, which no longer may be evident at 48 h and detection of other injuries, which may have been overlooked when initially recaptured (Normandeau Associates and Skalski 2001; Normandeau Associates *et al.* 2001). Detailed descriptions and photos of injured fish are presented in Appendix A.

2.6.1 Assignment of Probable Sources of Injury

Limited controlled experiment to replicate and correlate each injury type/characteristic to a specific causative mechanism precludes definitive classification of observed injuries in the field. Literature suggests that given injury symptoms could be manifested by two different sources and accurate delineation of a cause and effect relationship may be difficult in the field (Eicher Associates 1987). Consequently, only probable causal mechanisms of injury can be assigned. However, some injuries (*e.g.*, sliced or pinched bodies) may be assigned to a specific causative source with greater certainty. Injuries likely associated with direct contact with turbine runner blades or structural components are classified as mechanical and include: bruises/hemorrhaging, lacerations, and severed/sliced body (Eicher Associates 1987; Normandeau Associates *et al.* 1995; Normandeau Associates and Skalski 1996). Passage through gaps along the perimeter of the runner may result in pinched bodies (Normandeau Associates *et al.* 1995). Contact with turbine structural components may also result in swaths of scale loss. Injuries likely attributable to shear forces are decapitation with the isthmus still intact, torn or flared opercula, and inverted or broken gill arches (Nietzel *et al.* 2000). The probable pressure-related effects are manifested as bloody eyes, popped/bulging eyes, air bladder rupture, and embolism; however, shear forces may also inflict eye damage (hemorrhage, rupture, missing).

For ease of understanding, injured fish were divided into two basic groups: fish with visible cuts and bruises (missing eyes, decapitation, severed bodies, hemorrhaging, lacerations, etc.) and those with descaling or loss of equilibrium. Probable causes of injury (*e.g.*, mechanical, shear, or pressure-related) were ascribed to each injured fish depending upon the observed injury characteristics described by other investigators (Eicher Associates 1987). In the case of some injuries, probable causes could best be narrowed to only two sources (Nietzel *et al.* 2000). However, in other instances the unique characteristics of the observed wounds were used to delineate specific causes of injury. As an example, in the case of complete or partial decapitation, if the isthmus remained attached to the body the causative mechanism was likely shear-related (Nietzel *et al.* 2000). Cuts and tears suggest mechanically-related decapitation (Normandeau Associates *et al.* 1995). Description of injuries observed on each fish are given in Appendix A.

2.7 Survival Estimation and Data Analysis

Fish passage survival probabilities and associated standard errors for each experiment were estimated using the likelihood models described in Mathur *et al.* (1996) and Normandeau Associates *et al.* (1996). Data from individual trials (see Appendix A) for the treatment and control pairs were used in the analysis. A likelihood ratio test was used to determine whether recapture probabilities were equal for alive (P_A) and dead (P_D) fish for each experiment (Mathur *et al.* 1996). The statistic tested the null hypothesis of the simplified model (H_O:P_A=P_D) versus the alternative of the generalized model (H_A:$P_A \neq P_D$). Depending upon the outcome of this analysis, the parameters and their associated standard errors are reported in the text. However, for the sake of completeness, computer outputs of both models are provided in Appendix B. Because two treatment releases were made concurrently with a single shared control group, the likelihood model accounting for dependencies within the study design was used (Mathur *et al.* 2000). This likelihood has the same assumptions as for the model used in earlier studies (Mathur *et al.* 1996) but has five estimable parameters (S, τ_1, τ_2, P_A, and P_D). The survival rate for treatment T_1 is estimated by τ_1 and for treatment T_2 by τ_2. A likelihood ratio test with 1 degree of freedom was used to test for equality in survival rates between treatments T_1 and T_2 based on the hypothesis $H_O{:}\tau_1=\tau_2$ versus $H_A{:}\tau_1\neq\tau_2$. Appendix B provides the derivation of precision, likelihood model, and sample size calculations.

The 90% confidence intervals on the estimated survival were calculated using the profile likelihood method (Hudson 1971). This profile method constructs confidence intervals without assuming normality for $\hat{\tau}$ and is generally assumed superior to the normal approximations.

Although not a specific objective of the investigation, differences in survival probabilities between two treatment groups were tested for significance using a z-statistic.

Chi-square analyses were performed for homogeneity (P=0.05) within each treatment trial with respect to recapture probabilities of alive, dead, and non-recovered fish. Homogeneity (P>0.05) between individual trial data allowed pooling of data and calculation of survival probabilities for each turbine and species. Because a complete recapture of control fish occurred, a test of homogeneity was considered superfluous.

The statistical outputs are provided in Appendix B and the disposition of individual fish is given in Appendix C. Only summarized information is discussed in the main body of the report.

3.0 RESULTS

3.1 Recapture Rates

Recapture (physical retrieval of alive and dead fish) proportions of treatment groups equaled or exceeded 0.93 (93%) for both turbines while those of controls were perfect, 100% (Table 3-1). However, the proportions of alive and dead fish categories differed between turbine units and species. Some 87.2% of Unit 41 treatment coho and 84.6% of steelhead were recaptured alive while 93.2% of treatment coho and 89.3% of steelhead at Unit 44 were recaptured alive. Tag dislodgment (fish assumed dead in the analysis), primarily confined to fish entrained at Unit 41, ranged from 2.5% (steelhead) to 5.9% (coho salmon). The immediate status (within 1 h) of a relatively high proportion of treatment coho and steelhead (0.08 or 8%) at Unit 44 and steelhead at Unit 41 (0.043 or 4.3%) was unknown. However, some of these fish (7 of 24) were observed alive between 24 and 48 h post-passage downstream of the powerhouse. Since the status was unknown per the criterion established for accurately classifying fish (see Section 2.6) these fish were lumped with unknowns. Many of these fish (primarily the larger steelhead) apparently became lodged among the submerged boulders and rock shelves before the balloons inflated sufficiently to buoy the fish to the surface. The inflation rate of the balloon tags was retarded to some extent by the cold (4.5 to 6.0°C) river water temperature. Since these recaptured fish undoubtedly experienced conditions over the 24 to 48 h period different than those retrieved immediately (within 1 h) after passage they were not included with the other alive fish held in on-shore pools. None of the controls were classified unknown.

Chi-square tests showed that the recapture frequencies of alive and dead fish were homogenous (P>0.05) between trials of each treatment allowing pooling of individual trial data for each treatment group.

Likelihood ratio tests indicated that recapture probabilities of alive (P_A) and dead (P_D) fish were equal (P>0.05) at both turbines. Thus, parameter estimates and their standard errors were based on the simplified model ($H_O{:}P_A=P_D$) for all experiments. However, statistical outputs provided in Appendix B show estimates derived from the alternative model as well.

3.2 Retrieval Times

Retrieval times (the time interval between release through the induction system and recapture) were variable for the coho salmon and steelhead for treatment and control release groups. Mean recapture times for Unit 41 and 44 coho salmon release groups were 16.9 min and 8.1 min, respectively (Figure 3-1). Mean recapture time for coho salmon control group was 5.1 min. Mean steelhead recapture times for Unit 41 and 44 were 31 min and 45.1 min, respectively (Figure 3-2). Mean recapture times for the steelhead control group was 10.8 min.

3.3 Survival Probabilities

The estimated immediate (1 h) survival probabilities differed between turbines but not between species within each turbine (Table 3-2). With respect to turbine differences, survival of both species was significantly ($P \leq 0.05$) lower in passage through Unit 41 (new) than in passage through Unit 44 (old). At turbine Unit 44 coho salmon survival was estimated at 0.972 (97.2%) and for steelhead it was estimated at 0.971 (97.1%). At turbine Unit 41 the survival for coho salmon was estimated at 0.876 (87.6%) and for steelhead it was estimated at 0.884 (88.4%).

Some additional mortality occurred over the 48 h delayed assessment period primarily for fish passing through Unit 41 (Table 3-2). The 48 h survival probabilities for coho salmon and steelhead in passage through Unit 41 were 0.847 (or 84.7%) and 0.826 (or 82.6%), respectively. The respective 48 h estimate for both species in passage through Unit 41 was 0.971 (97.1%). Again, differences in survival between turbines were significant ($P<0.05$) but not between species.

3.4 Injury Rate, Types, and Probable Source

The visible injury rate for both coho salmon and steelhead differed between turbines and species (Table 3-3). The injury rates of both species were higher at turbine Unit 41 (new) than for fish at turbine Unit 44 (old). Injury rates for the larger sized steelhead were higher than for coho at both units. Steelhead and coho salmon passed through turbine Unit 41 sustained injury rates of 17.9 and 9.1%, respectively. At Unit 44, the respective injury rates were 7.1 and 5.1%. The coho control group exhibited 1.4% injuries while the steelhead control group sustained no injuries. The injury rates, adjusted for controls, were 7.7% for coho salmon and 17.9% for steelhead at Unit 41. Control adjusted injury rates for coho salmon and steelhead passed through Unit 44 were 3.7 and 7.8%, respectively.

Injury types differed by species and turbines (Table 3-3). The predominant visible injuries sustained by coho salmon passed through Unit 41 were hemorrhaged eyes or gills (3.4%) and broken backbone or severed body (2.9%). An additional 3.3% (adjusted for controls) exhibited loss of equilibrium following passage through Unit 41. The most common visible injuries sustained by steelhead passed through Unit 41 were hemorrhaged eyes or gills (6.0%), broken backbone or severed body (4.6%), and operculum damage (4.0%). None of the fish passed through Unit 44 sustained broken backbones or severed bodies (Table 3-3). The predominant visible injuries sustained by coho salmon passed through Unit 44 were operculum damage (2.2%) and scrapes or bruises (1.4%). Steelhead sustained mostly hemorrhaged eyes and gills (2.9%) and scrapes or bruises (2.9%).

The likely causes of observed injuries in fish (Table 3-3 and Appendix A) were mechanical and shear related. Mechanical forces were the likely cause of severed bodies, scrapes and bruises, while shear forces were the likely cause of hemorrhaged eyes, and gills, torn opercula, and broken backbones.

The percentage of treatment fish, particularly steelhead, showing loss of equilibrium also differed between turbines although the trend was opposite for that observed for visible injuries (Table 3-3). At Unit 41, 7.3% of steelhead exhibited loss of equilibrium while at Unit 44 it was 3.9%. The rates of loss of equilibrium for coho salmon were similar at both Units (3.3% at Unit 41 and 2.9% at Unit 44).

4.0 DISCUSSION

The primary objectives of the experiment, quantification of direct effects of passage through two turbines (new and old) at Mayfield Dam, were fulfilled. The experiment succeeded in providing reliable survival estimates and in delineating differences between turbine types. The precision (e) on each estimate was ≤±5.0%, 90% of the time. The sample sizes selected for each experiment were sufficient to achieve the desired precision levels and the survival differences were large enough to be declared statistically different. However, it should be noted that statistical detection of differences between two turbines (hypothesis testing), *per se*, was not a stated objective of the experiment.

Passage survival estimates can be considered valid with fulfillment of some underlying assumptions. These assumptions were met to a large extent. The following assumptions, primarily related to the tag-recapture process, were also fulfilled: handling, tagging, and release procedures do not differentially affect the survival rates of control and treatment groups; recapture crews do not differentially retrieve either group of fish; and both the treatment and control groups are exposed to the tailrace conditions for similar times. Although insertion of the tag, induction, and tag removal requires fish handling and may result in injury or mortality, these processes had minimal cumulative effects over the 48 h period. None of the controls died. Both the treatment and control groups showed similar swimming behavior in the holding pools. A perfect homogeneity of control releases suggested that tailrace conditions were similar over the duration of the study where controls exited. Thus, there is a reasonable assurance that comparisons, though *a posteriori*, between turbines were not confounded with time or fluctuations in hydraulic conditions.

A potential source of bias due to non-selective retrieval of treatment and control groups was minimized by not assigning a specific boat recovery crew to recapture either a treatment or control group of fish. Whichever crew was available for fish recapture was assigned the task of individual fish retrieval. Recapture crews were trained in fish handling and retrieved the buoyed fish without inflicting additional external damage.

The assumption of similarity in retrieval times of treatment and control groups was not fully met, particularly for steelhead smolts. Retrieval times of the steelhead treatment group from both turbines averaged 31 (Unit 44) to 45 min (Unit 41), control retrieval time averaged about 11 min. The coho treatment groups' retrieval times averaged 17 min (Unit 41) and 8 min (Unit 44) while that for controls was 8 min. The delay in recapture times of treatment steelhead occurred primarily due to many fish becoming lodged among the boulders and rock shelves in the tailrace prior to being buoyed up or were trapped in an eddy which was not readily or safely accessible. This may have also accounted for a large proportion of steelhead whose status upon passage was classified as unknown (16 of 24 fish classified unknowns were steelhead). Some of these fish buoyed up between 24 and 72 h post-passage and were alive; however, only fish recaptured on the day they were released were included with the alive fish. Fish recaptured subsequent to the test day were classified as unknown. This criterion used to classify fish as unknown appears conservative in survival estimation in the present study. The effect of these unknowns is to slightly increase (depending upon the proportion of unknown) variance estimates thereby widening the confidence intervals.

Differences in recapture times between species may have occurred due to stronger swimming ability of the larger steelhead combined with some delay in balloon inflation time.

Even though retrieval times for steelhead smolts were longer than noted in some recent investigations (Normandeau Associates *et al.* 1995, 1996; Normandeau Associates and Skalski 1997) elsewhere on the Columbia River Basin, survival estimates were unaffected. As stated above, fish that were recaptured several hours after release were alive, no dead fish was recaptured. Additionally, most observed mortality was immediate, mortality in holding pools over the 48 h was confined mostly to injured fish.

Although data on survival rates of fishes (≤200 mm long) entrained in Francis turbines at high head hydroelectric dams with characteristics similar to the Mayfield Station (*e.g.*, runner diameter, discharge, etc.) are scant for direct comparisons estimated probabilities for Unit 41 (new) are within the reported range. Survival rates of sockeye salmon (average 86 mm) at Seton Creek and Ruskin Stations in British Columbia were reported at 90.8 and 89.5%, respectively (cited in Eicher Associates 1987). However, in a series of survival experiments on juvenile chinook salmon, silver salmon, and steelhead at Shasta and Cushman Stations in California the reported survival rates ranged from 34.5 to 89.3% (Cramer and Oligher 1964; Eicher Associates 1987). The above studies utilized netting systems (downstream tailrace fyke nets or full discharge netting system). In contrast the survival rates (97.1 to 97.2%) of salmonids in passage through the old Unit 44 equal or exceed those reported (88.9 to 100%) for either Francis or Kaplan turbines elsewhere (data from recent studies summarized in Normandeau Associates and Skalski 2001).

Factors that are deemed important in affecting turbine passage survival of fish include: turbine type, fish size, turbine operating status, runner diameter size (index of water passage-way), trajectory of entrained fish relative to flow streams, clearance between structural components (*i.e.*, spacing between runner blades or buckets, wicket gates, and turbine housing), number of blades or buckets, runner blade speed, flow, and angle of water flow through the turbines (Franke *et al.* 1997). Although Francis turbines are generally considered less "fish friendly" than Kaplan and propeller type turbines much variation has been observed (Franke *et al.* 1997).

The results of the present study are consistent with the conclusions presented in Franke *et al.* (1997) relative to turbine-specific survival. The survival rates differed between turbines but not between species within each turbine. Estimated survival of both species (≥97%) was significantly higher ($P<0.05$) in passage through the old Unit 44 than through the new Unit 41 (82.6 to 84.7%). The significantly lower survival rates at Unit 41 (new) for both species may have been due in part to the higher number of buckets (16 in Unit 41 versus 15 in Unit 44), higher number of wicket gates in Unit 41 (24) versus Unit 44 (20), and narrower wicket spacing (22.5 in for Unit 41 versus 25.4 in for Unit 44). However, the runner diameters at both inlet and outlet are actually larger for the new unit. The inlet runner diameters are 138 in versus 130 in for the new and old units. The respective outlet runner diameters are 157.5 in versus 149 in. Decreased spacing between structural components of turbines can increase risks of damage due to mechanical forces and may also change the hydraulic environment which could result in shear induced injuries. The observed survival/injury differences between turbines were most likely due to turbine-specific characteristics (*i.e.*, number, thickness of leading edge, and shape of buckets). Mechanically-related fish injuries were common at Unit 44 while hydraulic-related (shear) injuries were more common at Unit 41. The visible injury rates were higher for the larger sized steelhead (average 188 mm) than for coho salmon (average 151 mm) at both units.

There are three principal causal mechanisms for injury/mortality to entrained fishes in turbine passage: direct blade (or bucket) strike or collision with structural components, changes in prèssure, and hydraulic shear forces (Bell 1981; Eicher Associates 1987, EPRI 1992; Franke *et al.* 1997). These causes, however, are not universally applicable to all species and their life stage at all hydro dams. Fish mortality/injury due to any of these factors is generally manifested immediately, though the quantification and separation of these causes have proven difficult in the field (Eicher Associates 1987). However, recent laboratory studies (Nietzel *et al.* 2000) have contributed to the better understanding and delineation of injures related to hydraulic forces, particularly shear. Observed injury types in these studies assisted the investigators at Mayfield Dam in ascribing probable injury source. Thus, the present study, in our view, succeeded to a large extent in quantifying the sources of immediate injury/mortality to fish.

5.0 CONCLUSIONS

The survival rates of juvenile salmonids at Mayfield Dam are turbine type specific rather than species specific, a finding consistent with that supported in recent studies. The older Unit 44 provides higher survival than the new Unit 41; survival of both coho salmon (84.7%) and steelhead (82.6%) juveniles was significantly lower ($P<0.05$) in passage through the new Unit 41 than through Unit 44 (97.1%). The survival difference may be partly related to a higher number of buckets (16 in Unit 41 versus 15 in Unit 44), lower number of wicket gates in Unit 44 (20) than in Unit 41 (24), and narrower wicket gate spacing (22.5 in for Unit 41 versus 25.4 in for Unit 44). The design (blade thickness and shape) of the two turbines may also account for some of the differences in survival/injury. The survival rate of larger sized steelhead (about 186 to 189 mm) was similar to that of smaller sized coho salmon (about 151 mm) within each turbine. Surprisingly, survival rate of both species in passage through the old Unit 44 was comparable to that recently reported for many Kaplan type turbines at low head dams.

6.0 LITERATURE CITED

Bell, M. C. 1981. Updated compendium on the success of passage of small fish through turbines. U. S. Army Corps of Engineers, North Pacific Division, Portland, OR.

Cada, G. F. 1990. A review of studies relating to the effects of propeller-type turbine passage on fish early life stages. N. A. Jour. Fish. Mgt. 10:418-426.

Cramer, F. K., and R. C. Oligher. 1964. Passing fish through hydraulic turbines. Trans. Am. Fish. Soc. 93:243-259.

Eicher Associates, Inc. 1987. Turbine-related fish mortality: review and evaluation of studies. Research Project 2694-4. Prepared for Electric Power Research Institute, Palo Alto, CA.

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

Franke, G. F., *et al.* (nine co-authors). 1997. Development of environmentally advanced hydro turbine design concepts. Report prepared for the U. S. Department of Energy, DOE Idaho Operations Office, Idaho Falls, ID.

Heisey, P. G., D. Mathur, and T. Rineer. 1992. A reliable tag-recapture technique for estimating turbine passage survival: application to young-of-the-year American shad (*Alosa sapidissima*). Can. Jour. Fish. Aquat. Sci. 49:1826-1834.

Hudson, D. J. 1971. Interval estimation from the likelihood function. J. R. Stat. Soc. B. 33:256-262.

Mathur, D., P. G. Heisey, E. T. Euston, J. R. Skalski, and S. Hays. 1996. Turbine passage survival estimation for chinook salmon smolts (*Oncorhynchus tshawytscha*) at a large dam on the Columbia River. Can. Jour. Fish. Aquat. Sci. 53:542-549.

Mathur, D., P. G. Heisey, J. R. Skalski, and D. R. Kenney. 2000. Salmonid smolt survival relative to turbine efficiency and entrainment depth in hydroelectric power generation. Jour. Amer. Water Resour. Assoc. 36:737-747.

Monten, E. 1985. Fish and turbines: fish injuries during passage through power station turbines. Norstedts Tryckeri, Stockholm, Sweden.

Nietzel, D. A. *et al.* (seven co-authors). 2000. Laboratory studies on the effects of shear on fish. Prepared by the Pacific Northwest National Laboratory, Richland, WA for the Advanced Hydropower System Team, U. S. Dept. of Energy, Idaho Falls, ID. DOE/ID-1 of 22.

Normandeau Associates, and J. R. Skalski. 1996. Relative survival of juvenile chinook salmon (*Oncorhynchus tshawytscha*) in passage through a modified Kaplan turbine at Rocky Reach Dam, Columbia River, Washington. Report prepared for Public Utility District No. 1 of Chelan County, Wenatchee, WA.

Normandeau Associates, and J. R. Skalski. 1997. Survival estimation of juvenile salmonids in passage through a new turbine at T. W. Sullivan Station, Willamette River, Oregon. Report prepared for Portland General Electric Company, Portland, OR.

Normandeau Associates, and J. R. Skalski. 2001. Passage survival and condition of coho salmon smolts passed through the Cowlitz Falls Station, Cowlitz River, Washington. Report prepared for Lewis County Public Utility District, Randle, WA.

Normandeau Associates, John R. Skalski, and Mid Columbia Consulting. 1995. Turbine passage survival of juvenile chinook salmon (*Oncorhynchus tshawytscha*) at Lower Granite Dam, Snake River, Washington. Report prepared for U.S. Army Corps Engineers, Walla Walla, WA.

Normandeau Associates, J. R. Skalski, and Mid Columbia Consulting, Inc. 1996. Fish survival investigation relative to turbine rehabilitation at Wanapum Dam, Columbia River, Washington. Report prepared for the Grant County Public Utility District No. 2, Ephrata, WA.

Normandeau Associates, Inc., J. R. Skalski, and Mid Columbia Consulting, Inc. 1999. Relative passage survival and injury mechanisms for chinook salmon smolts within the turbine environment at McNary Lock and Dam, Columbia River. Report prepared for the U. S. Department of the Army, Corps of Engineers, Walla Walla District, Walla Walla, WA.

Normandeau Associates, Inc., J. R. Skalski, and Mid Columbia Consulting, Inc. 2001. Passage survival and condition of chinook salmon smolts through an existing and new minimum gap runner turbines at Bonneville Dam First Powerhouse, Columbia River. Report prepared for the U. S. Department of the Army, Corps of Engineers, Portland District, Portland, OR.

Ruggles, C. P. 1980. A review of the downstream migration of Atlantic salmon. Can. Tech. Rept. Fish. Aquat. Sci. No. 952.

Ruggles, C. P., and T. H. Palmeter. 1989. Fish passage mortality in tube turbine. Can. Tech. Rept. Fish. Aquat. Sci. No. 1664.

Skalski, J. R. 1992. Statistical review of the RMC tagging study. Report prepared for Chelan County PUD, Wenatchee, WA.

Thompson, J. S., and G. J. Paulik. 1967. An evaluation of louvers and bypass facilities for guiding seaward migrant salmonids past Mayfield Dam in Western Washington. Report prepared for City of Tacoma, Department of Public Utilities, Tacoma, WA.

TABLES

Table 1-1

Physical and hydraulic parameters of the Francis turbine Units 41 (new) and 42, 43, 44 (old) at Mayfield Dam.

	Unit 41	Units 42, 43, and 44
Inlet runner diameter (inches)	138	130
Outlet runner diameter (inches)	157.5	149
RPM	138.5	138.5
Number of buckets	16	15
Number of wicket gates	24	20
Space between buckets (inches)	27.2	27.1
Wicket gate spacing (inches)	22.5	25.4
Maximum discharge (cfs)	3,290	3,370
Wicket gate lubrication	Self-lubricating	Grease
Normal headwater elevation (feet)	425.0	425.0
Tailwater elevation (feet) (Q=10,000 cfs)	244.0	244.0
Rated head (feet)	182.0	182.0
Rated output (MW) at rated head	40.5	40.5

Table 1-2

Conditions during the conduct of passage survival investigation at Francis turbine Units 41 (new) and 44 (old) at Mayfield Dam, March 2002.

	Unit 41 (New)	Unit 44 (Old)
Generator output range (MW)	34.28 - 35.84	34.62 - 35.39
Turbine discharge (cfs)	2,800	2,800
Wicket gate opening (%)	77	64
Wicket gate opening (inches)	NA	NA
Operating efficiency (%)	90	85
Reservoir elevation range (feet)	421.72 - 423.78	
Tailwater elevation range (feet)	241.82 - 241.83	

Table 2-1

Required sample sizes (R) if control survival (S) is 0.99, 0.98, or 0.95, recapture rate (P_A) is 0.98 or 0.95, and expected passage survival probability ($\hat{\tau}$) is 0.95, 0.97, and 0.99 to achieve a precision level (ε) of ≤±0.05, 90% of the time.

	Expected Survival ($\hat{\tau}$)		
Control Survival (S)	**0.95**	**0.97**	**0.99**
		Recapture Rate=0.98	
0.99	113	95	76
0.98	134	117	99
0.95	200	185	169
		Recapture Rate=0.95	
0.99	178	162	146
0.98	200	185	169
0.95	268	255	241

Table 2-2

Observed recapture and survival rates of juvenile salmonids passed through Kaplan type turbines at hydro dams on the Columbia and Snake Rivers. All estimates based on balloon tag-recapture technique and portray only direct effects of passage at given operating conditions and entrainment depth.

			Sample Size		Recapture Rate (%)			Estimated	
Station	Species	Average Size (mm)	Treatment	Control	Treatment	Control	Control Survival	Survival Percent	Precision (ε)[3]
Rocky Reach									
1993 Unit 3 (10 ft, 50-100 MW)	Chinook salmon	162	350	350	95	99	98	93.0	[redacted]
Unit 3 (30 ft, 50-100 MW)	Chinook salmon	162	250	250	96	99	98	94.7	[redacted]
Unit 8 (10 ft, 130 MW)	Chinook salmon	113	265	265	86	89	89	96.1	0.043
1996 Unit 5 (10 ft, 60 MW)	Chinook salmon	184	75	95	99	100	100	97.3	[redacted]
Unit 5 (10 ft, 80 MW)	Chinook salmon	184	75	115	99	99	98	98.2	[redacted]
Unit 5 (10 ft, 100 MW)	Chinook salmon	184	85	90	98	98	94	96.4	0.043
Unit 5 (30 ft, 60 MW)	Chinook salmon	184	71	65	96	95	94	91.3	0.066
Unit 5 (30 ft, 80 MW)	Chinook salmon	184	85	80	96	98	96	98.7	0.049
Unit 5 (30 ft, 100 MW)	Chinook salmon	184	85	75	96	100	100	94.1	0.043
Unit 6 (10 ft, 60 MW)[1]	Chinook salmon	184	125	95	96	100	100	88.8	0.046
Unit 6 (10 ft, 80 MW)	Chinook salmon	184	165	115	99	99	98	97.2	[redacted]
Unit 6 (10 ft, 100 MW)	Chinook salmon	184	130	90	97	98	94	96.5	[redacted]
Unit 6 (30 ft, 60 MW)	Chinook salmon	184	75	65	96	95	94	94.8	0.054
Unit 6 (30 ft, 80 MW)	Chinook salmon	184	85	80	99	98	96	96.6	0.053
Unit 6 (30 ft, 100 MW)	Chinook salmon	184	75	75	97	100	100	96.0	0.046
Wanapum Dam									
1996 Unit 9 (10 ft, 9,000 cfs)	Coho salmon	154	160	160	92	99	98	89.7	0.044
Unit 9 (10 ft, 11,000 cfs)	Coho salmon	154	160	160	93	97	96	92.4	[redacted]
Unit 9 (10 ft, 15,000 cfs)	Coho salmon	154	160	160	94	98	98	94.8	[redacted]
Unit 9 (10 ft, 17,000 cfs)	Coho salmon	154	160	160	88	99	99	88.5	0.043
Unit 9 (30 ft, 9,000 cfs)	Coho salmon	154	160	160	96	99	98	94.9	[redacted]
Unit 9 (30 ft, 11,000 cfs)	Coho salmon	154	160	160	96	97	96	96.8	[redacted]
Unit 9 (30 ft, 15,000 cfs)	Coho salmon	154	160	160	98	98	98	100.0	[redacted]
Unit 9 (30 ft, 17,000 cfs)	Coho salmon	154	160	160	96	99	99	96.8	[redacted]

Table 2-2

Continued.

Station	Species	Average Size (mm)	Sample Size Treatment	Sample Size Control	Recapture Rate (%) Treatment	Recapture Rate (%) Control	Control Survival	Estimated Survival Percent	Precision (ε)
Lower Granite[2]									
1994 Intake B (30 ft, 18,000 cfs)	Chinook salmon	134	840	821	94	99	89	93.4	[redacted]
1995 Intake A (10 ft, 18,000 cfs)	Chinook salmon	150	320	320	97	99	92	95.0	[redacted]
Intake A (40 ft, 13,000 cfs)	Chinook salmon	150	250	250	96	100	93	97.2	[redacted]
Intake A (40 ft, 18,000 cfs)	Chinook salmon	150	320	320	97	99	92	93.6	0.043
Intake A (40 ft, 19,500 cfs)	Chinook salmon	150	300	300	97	99	97	94.1	[redacted]
Intake B (40 ft, 18,000 cfs)	Chinook salmon	150	320	320	98	98	90	94.0	[redacted]
Intake C (40 ft, 18,000 cfs)	Chinook salmon	150	320	320	98	98	90	95.4	[redacted]
Rock Island									
1997 Powerhouse I-Nagler (12 ft, 8,000 cfs)	Chinook salmon	179	140	110	99	100	100	93.6	[redacted]
Powerhouse I-Nagler (18 ft, 8,000 cfs)	Chinook salmon	179	139	120	99	100	100	92.8	[redacted]
Powerhouse I-Kaplan (12 ft, 8,000 cfs)	Chinook salmon	179	140	110	99	100	100	97.1	[redacted]
Powerhouse I-Kaplan (18 ft, 8,000 cfs)	Chinook salmon	179	141	120	98	100	100	95.0	[redacted]
Powerhouse II-Bulb (5 ft, 17,000 cfs)	Chinook salmon	179	140	110	100	100	100	96.4	[redacted]
Powerhouse II-Bulb (25 ft, 17,000 cfs)	Chinook salmon	179	140	110	99	100	100	95.0	[redacted]

1 - Unit 6 new turbine design.

2 - Reported 120 h survival for Lower Granite; others 48 h survival. Lower Granite turbine equipped with fish guidance screens.

3 - Shaded values reflect the 90% CI±≤4%.

Table 2-3

Condition codes assigned to fish and dislodged balloon tags for fish passage survival evaluations.

FISH CODES	
A	No visible marks on fish
B	Flesh tear at tag site(s)
C	Minor scale loss, 3 to 20% (%s for entire body in immediate recovery; for detailed injury examination %s are for section only)
D	Major scale loss, >20%
E	Laceration(s); tear(s) on body
F	Severed body parts
G	Hemorrhaging, bruised
H	Stressed (lethargic, swimming poorly or sporadically)
I	Spasmodic movement of body
J	Very weak, barely gilling, died within 60 minutes of recovery
K	Failed to enter system
L	Fish likely preyed on based on telemetry, and/or circumstances relative to Turb'N recapture
M	Substantial bleeding at tag site
N	Bulging or missing eye(s)
P	Observed predator attack or marks indicative of predator
Q	Other information
R	Necropsied, no obvious injuries
S	Necropsied, internal injuries observed
T	Trapped inside tunnel/gate well
V	Fins damaged (ripped, split, torn) or pulled from origin
W	Abrasion/scrape
X	No recovery information at all; fish remains unrecovered
Z	Radio telemetry or other information; fish remains unrecovered
DISSECTION CODES	
B	Swim bladder ruptured or expanded
D	Kidneys damaged (hemorrhaging)
E	Broken bones obvious
F	Hemorrhaging internally
L	Organ displacement
N	Heart damage, ruptured, hemorrhaging, etc.
O	Liver damage, ruptured, hemorrhaging, etc.
FISH SURVIVAL CODES	
1	Alive when recaptured or not recaptured - assigned alive
2	Dead when recaptured or not recaptured - assigned dead
3	Live/Dead status unknown
TURB'N TAG CODES	
A	Fully inflated
B	Partially inflated
C	Pinhole, leaking
D	Burst
E	Not inflated at all
X	Detached from fish

Table 3-1

Summary of tag-recapture data (1 h and 48 h) on juvenile salmonid smolts released through Francis turbine Units 41 (new) and 44 (old) at Mayfield Dam, March 2002. A common control group was released per two treatment releases. Probabilities are shown in parentheses.

	Francis Turbine		
	Unit 41 (New)	**Unit 44 (Old)**	**Control**
	Coho salmon		
Number released	187	148	142
Number recaptured alive	163 (0.872)**	138 (0.932)***	142 (1.00)
Number recaptured dead	12 (0.064)	3 (0.020)	0 (0.00)
Dislodged tag(s)*	11 (0.059)	1 (0.007)	0 (0.00)
Unknown	1 (0.005)	6 (0.041)	0 (0.00)
Number held (1 h)	153	137	142
Number alive at 48 h	148	136	141
	Steelhead		
Number released	162	112	102
Number recaptured alive	137 (0.846)	100 (0.893)	102 (1.00)
Number recaptured dead	14 (0.086)	3 (0.027)	0 (0.00)
Dislodged tag(s)*	4 (0.025)	0 (0.000)	0 (0.00)
Unknown	7 (0.043)	9 (0.080)	0 (0.00)
Number held (1 h)	137	100	102
Number alive at 48 h	128	100	102

* Assigned dead.

** Includes 10 alive fish that escaped during transfer to holding pools.

*** Includes one alive fish that escaped prior to transfer to holding pools.

Table 3-2

Estimated 1 h and 48 h survival probabilities ($\hat{\tau}$) of coho salmon and steelhead in passage through Francis turbine Units 41 (new) and 44 (old) at Mayfield Dam, March 2002. The 90% profile confidence intervals are shown in parentheses.

	Francis Turbine	
	Unit 41 (New)	**Unit 44 (Old)**
Coho salmon		
1 h ($\hat{\tau}$)	0.876 (0.837-0.916)	0.972 (0.949-0.995)
48 h ($\hat{\tau}$)	0.847 (0.800-0.894)	0.971 (0.943-1.00)
Steelhead		
1 h ($\hat{\tau}$)	0.884 (0.842-0.926)	0.971 (0.944-0.998)
48 h ($\hat{\tau}$)	0.826 (0.776-0.876)	0.971 (0.944-0.998)

Table 3-3

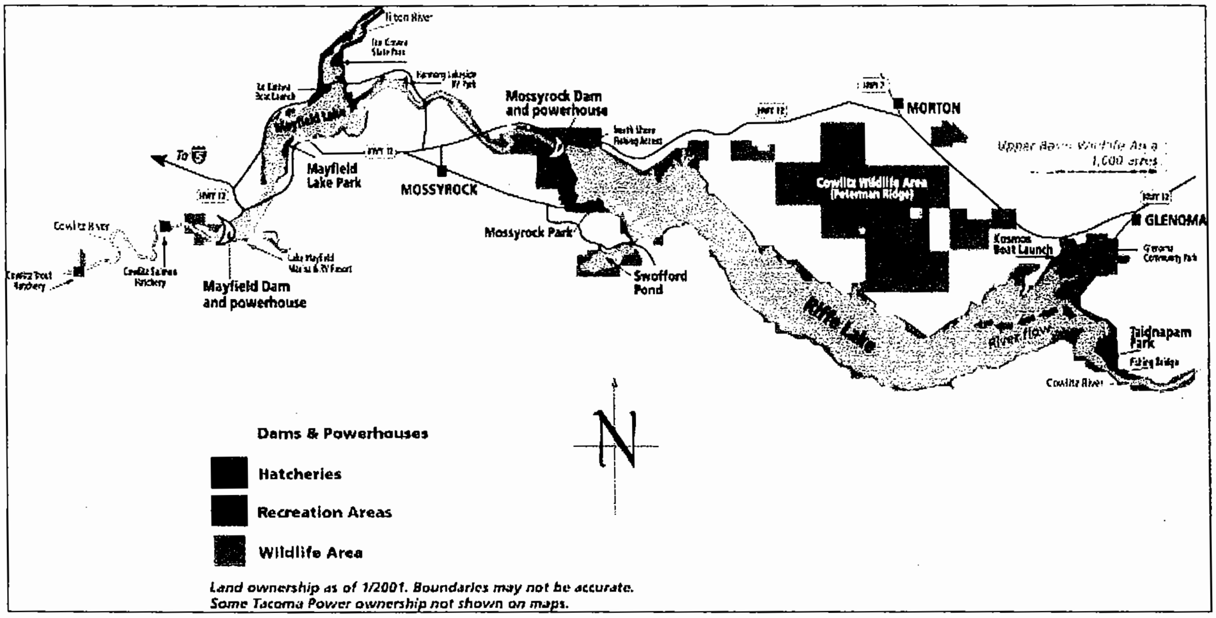
Summary of visible injuries and loss of equilibrium observed on recaptured juvenile coho salmon and steelhead passed through Francis turbine Units 41 (new) and 44 (old) or released into the turbine discharge (controls) at Mayfield Dam, March 2002. Some fish had multiple injuries.

				Injury Type					
	Number Released	**Number Examined**	**Number Injured**	**Hemorrhaged Eye/Gills**	**Operculum Damage**	**Severed Body and/or Backbone**	**Scrape/ Bruise on Head/Body**	**Other**	**Loss of Equilibrium (exclusively)**
Coho salmon									
Unit 41	187	175*	16 (9.1%)	6 (3.4%)	1 (0.6%)	5 (2.9%)	2 (1.1%)	2 (1.1%)	7 (4.0%)
Unit 44	148	138**	7 (5.1%)	1 (0.7%)	3 (2.2%)	0 (0.0%)	2 (1.4%)	1 (0.7%)	5 (3.6%)
Control	142	142	2 (1.4%)	0 (0.0%)	1 (0.7%)	0 (0.0%)	0 (0.0%)	1 (0.7%)	1 (0.7%)
Steelhead									
Unit 41	162	151	27 (17.9%)	9 (6.0%)	6 (4.0%)	7 (4.6%)	3 (2.0%)	2 (1.3%)	11 (7.3%)
Unit 44	112	103	8 (7.8%)	3 (2.9%)	1 (1.0%)	0 (0.0%)	3 (2.9%)	1 (1.0%)	4 (3.9%)
Control	102	102	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

* Includes 10 alive fish that escaped during transfer to holding pool.

** Includes 1 alive fish lost before transfer to holding pool.

FIGURES



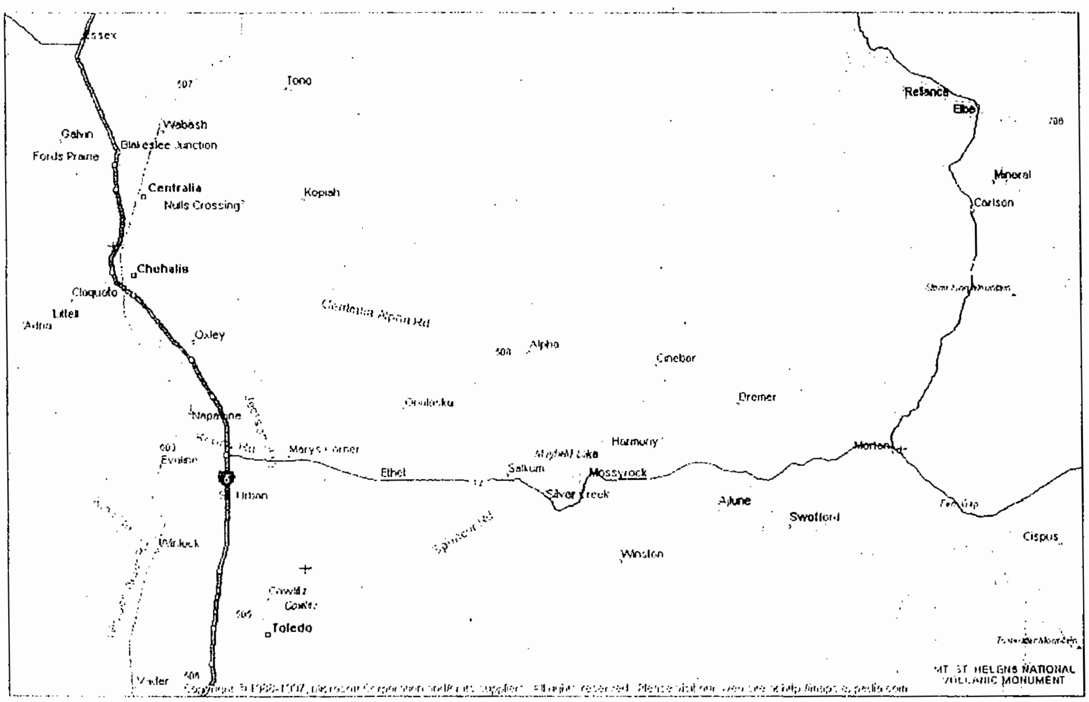


Figure 1-1

General location of Mayfield Hydroelectric Station, Washington.

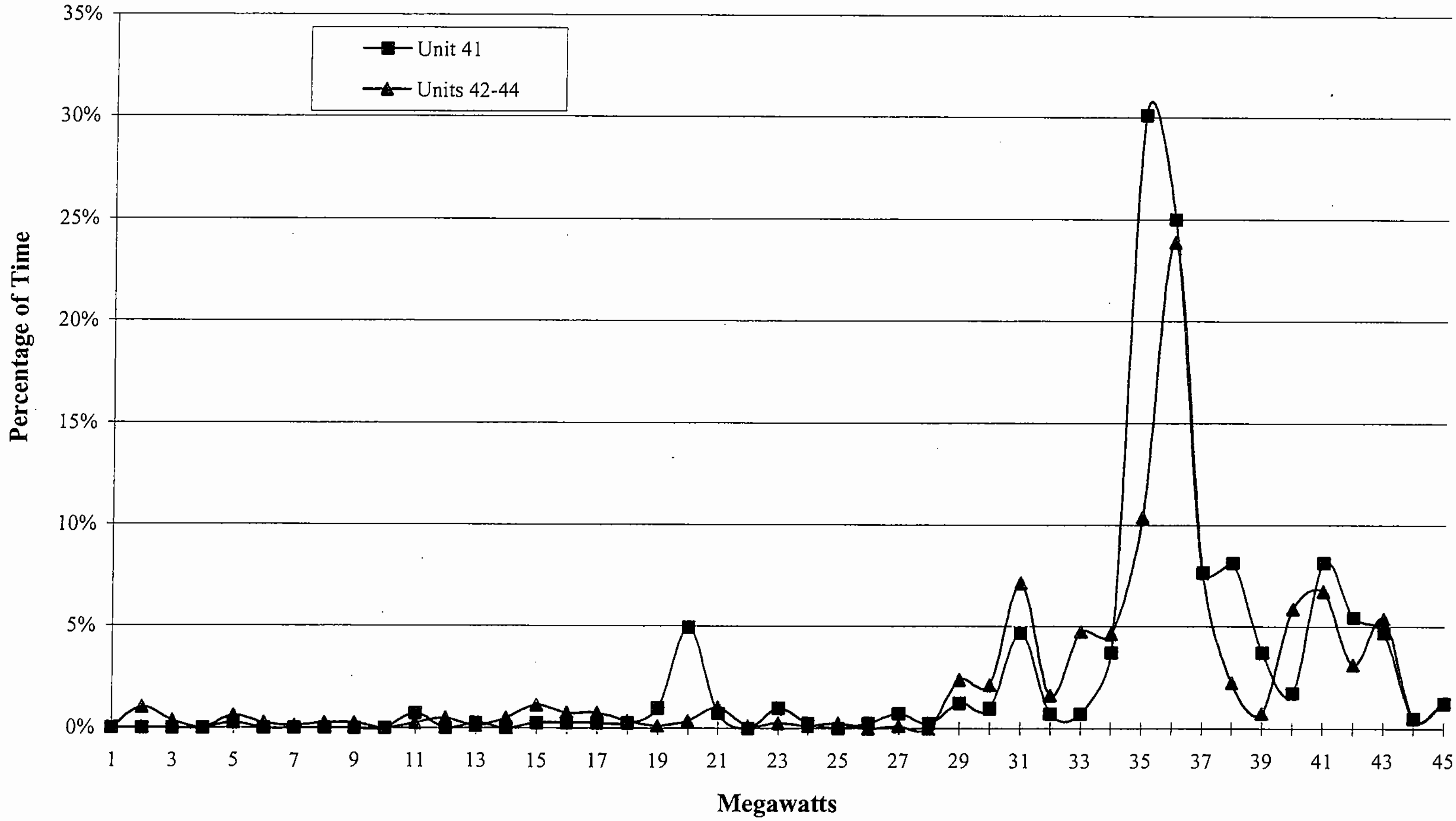


Figure 1-2

Historical pattern (percentage of time) of generational output (MW) of Unit 41 (new) and Units 42 through 44 (old) during the salmonid emigration period, April through June, 1996 to 2000, at Mayfield Station.

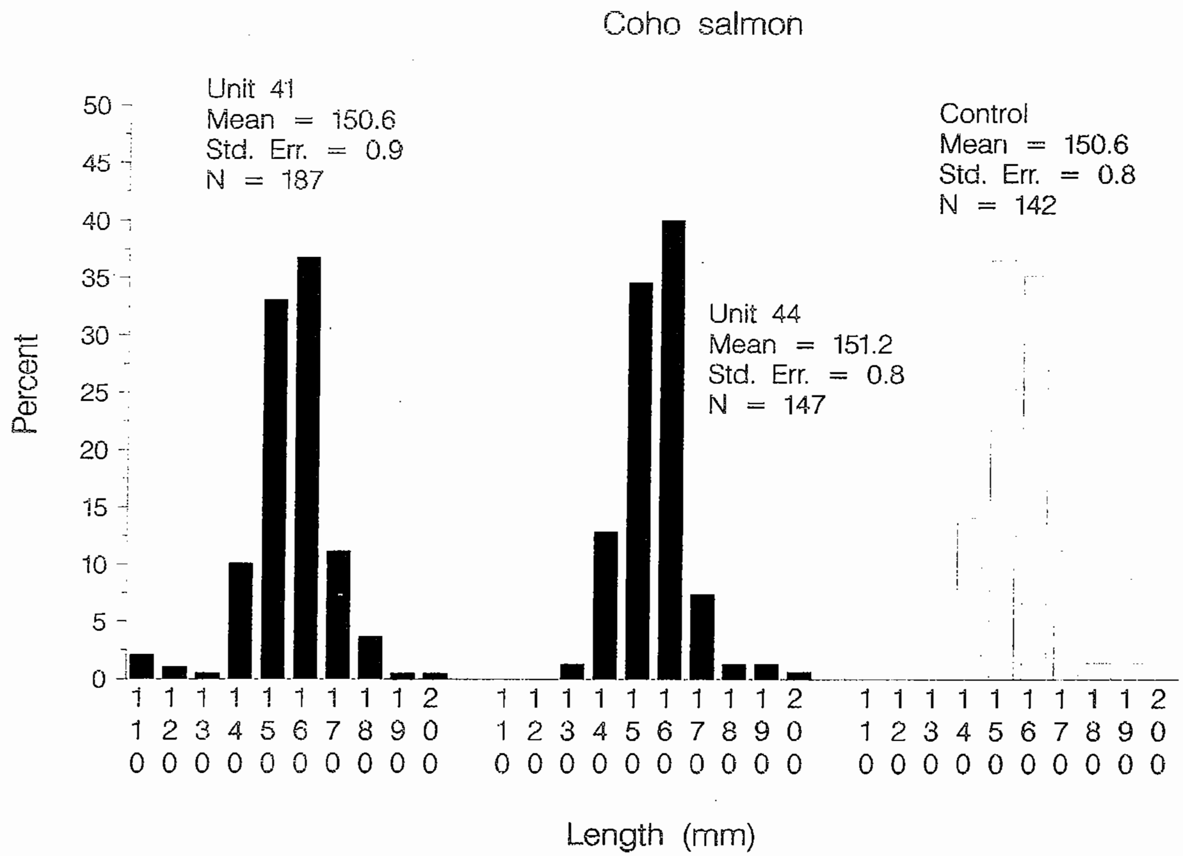


Figure 2–1 Total length (mm) frequency distribution of treatment and control coho salmon smolts released through Units 41 and 44 at Mayfield Dam, March 2002.

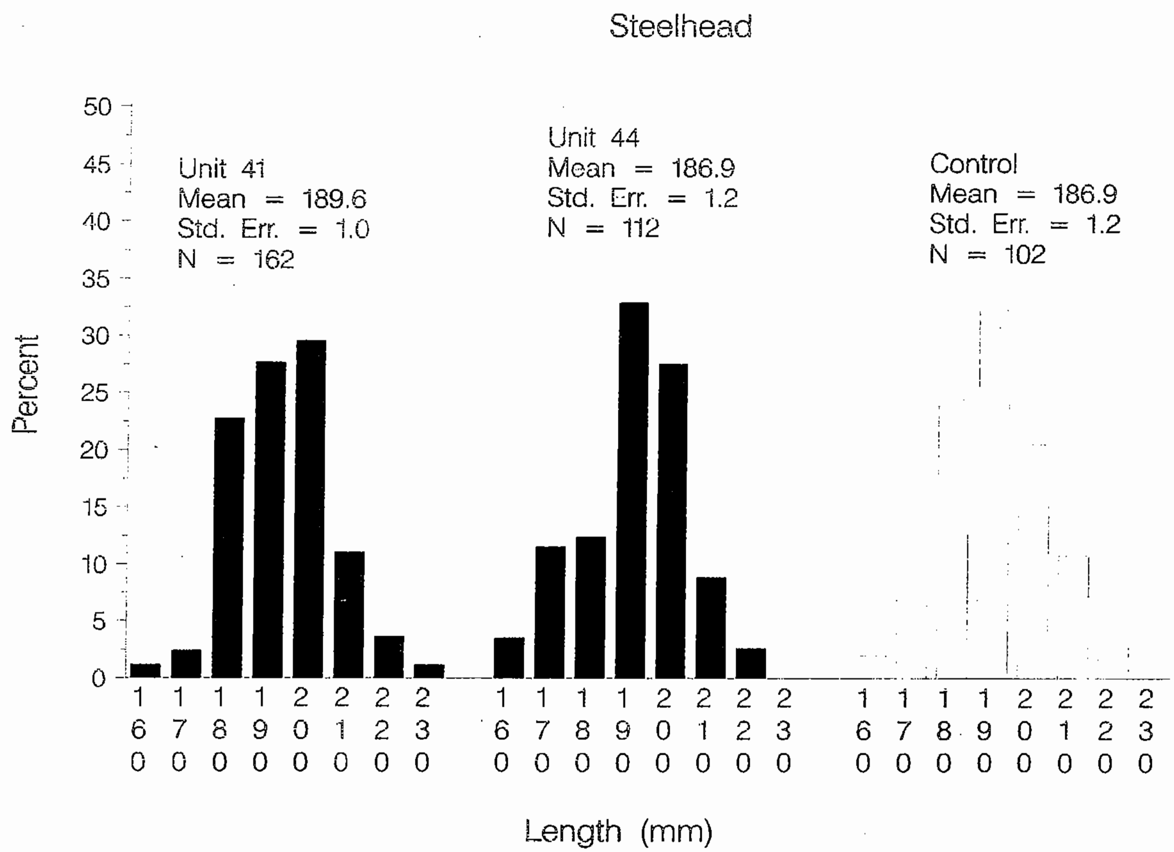


Figure 2-2 Total length (mm) frequency distribution of treatment and control steelhead, released at Units 41 and 44 of Mayfield Dam, March 2002.

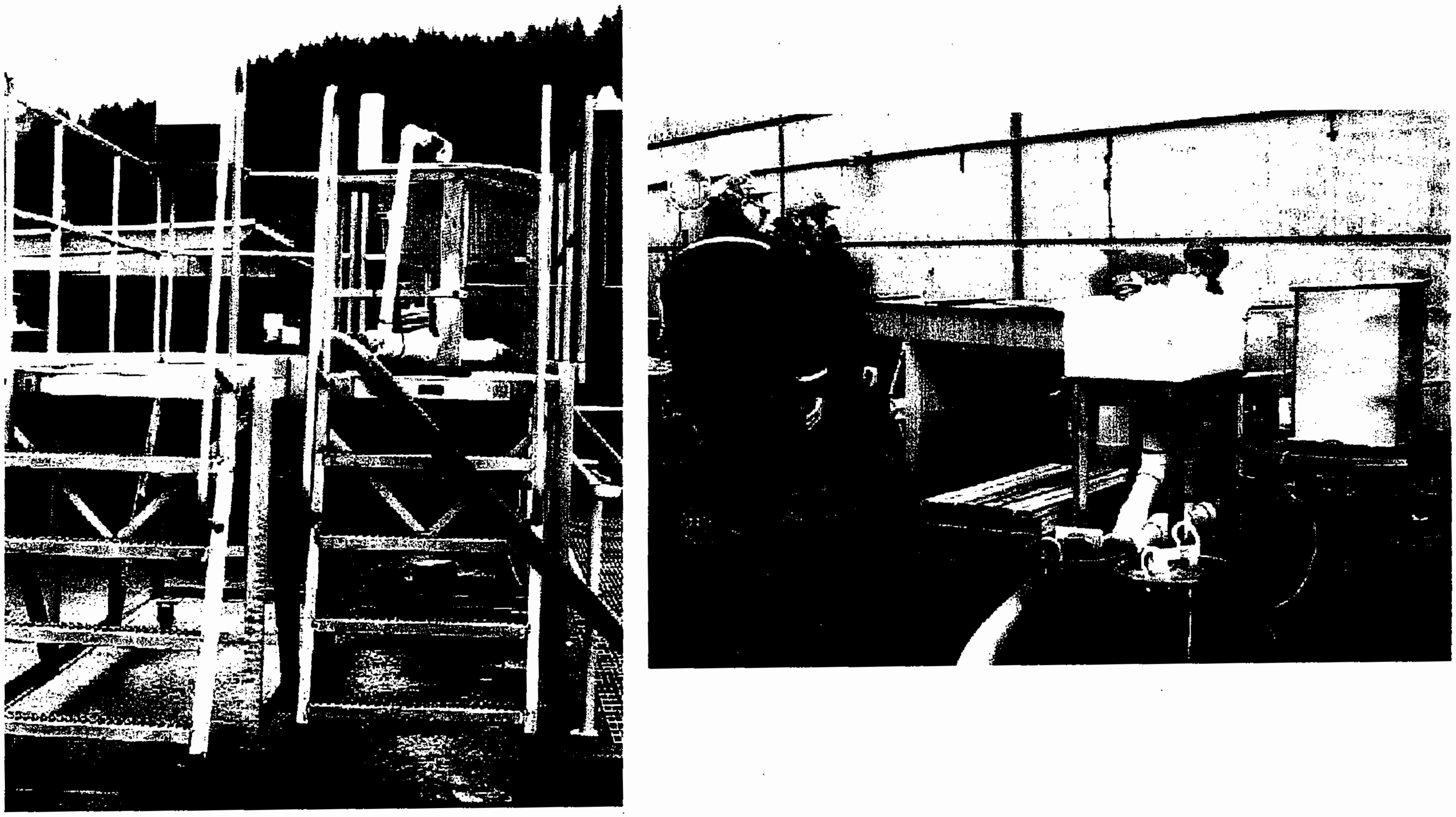


Figure 2-3

Induction systems utilized for treatment (left) and control (right) releases during fish passage survival evaluations at Mayfield Dam, March 2002.

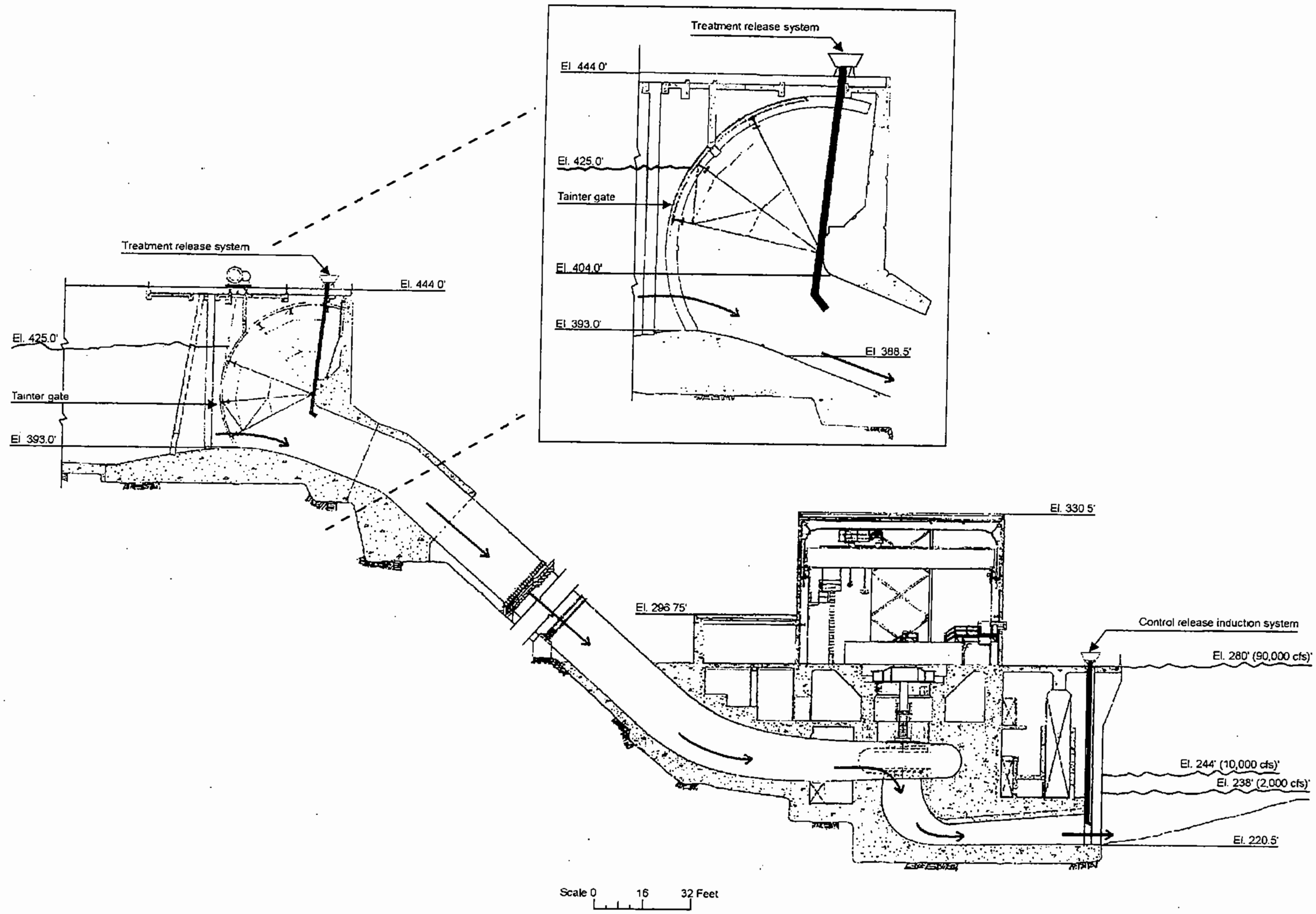


Figure 2-4

Cross section showing treatment and control release sites, Mayfield Dam, 2002.

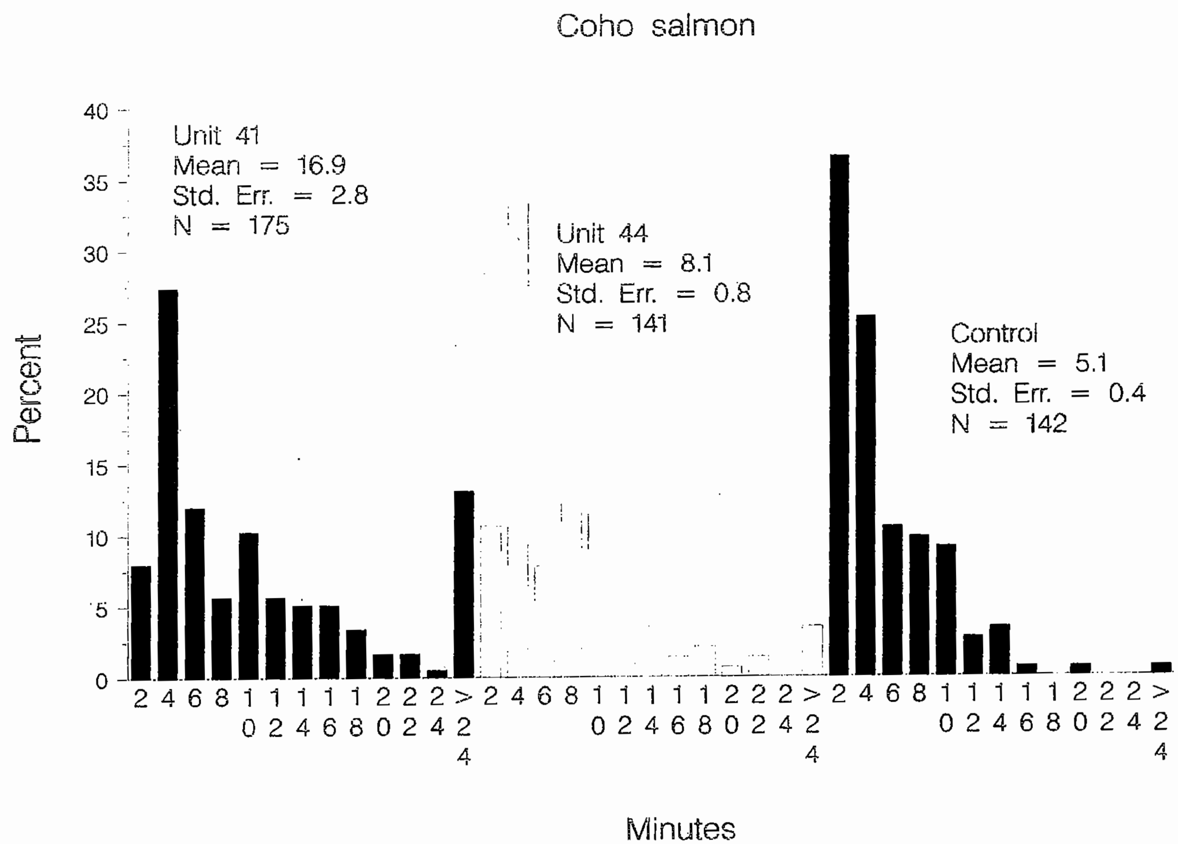


Figure 3–1 Frequency distribution of recapture times (minutes) of treatment and control coho salmon smolts, released at Units 41 and 44 of Mayfield Dam, March 2002.

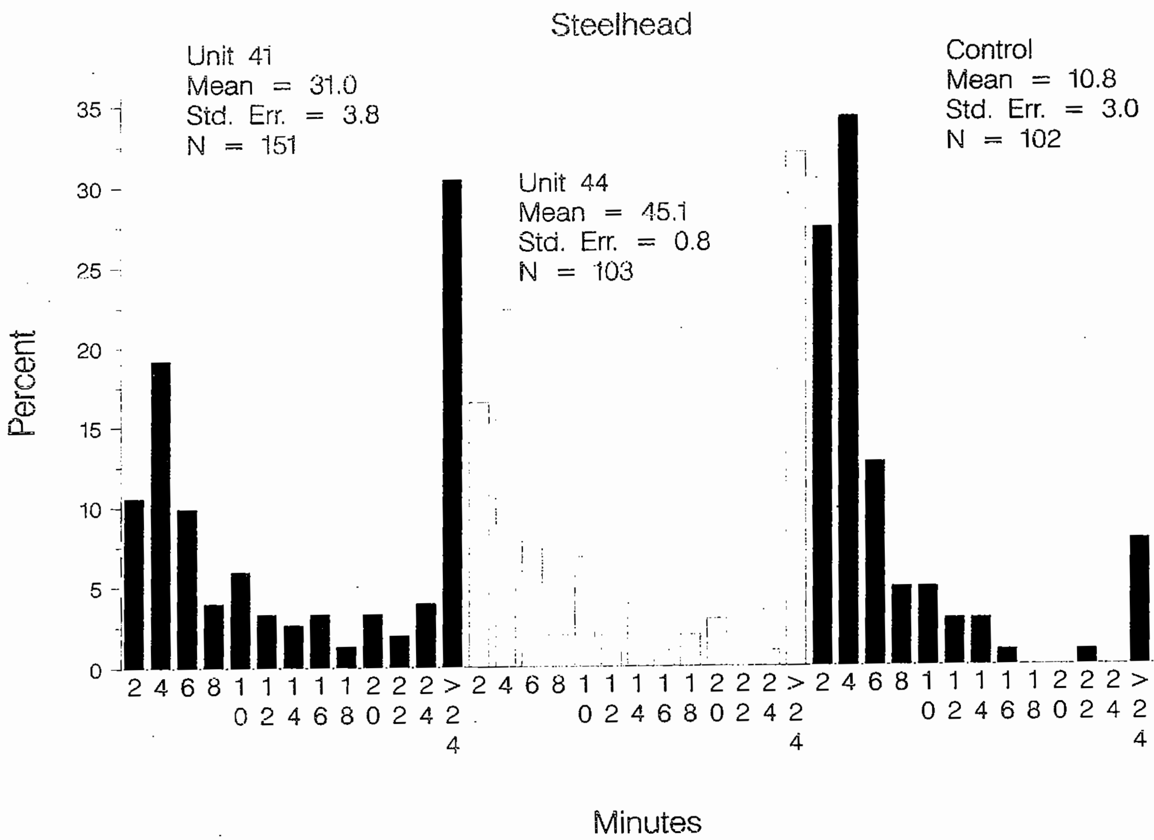


Figure 3-2 Frequency distribution of recapture times (minutes) of treatment and control steelhead, released at Units 41 and 44 of Mayfield Dam, March 2002.

APPENDIX A

HOURLY OPERATIONAL DATA, INDIVIDUAL TRIAL DATA AND FISH INJURY DATA AND RELATED PHOTOS

Appendix Table A-1

Hourly minimum, maximum, and average power outputs (mw) of Francis Units 41 (new), 42, 43, and 44 (old) and lake elevation (ft) during release of juvenile salmonids at Mayfield Dam, March 2002.

		Unit 41 (mw)			Unit 42 (mw)			Unit 43 (mw)			Unit 44 (mw)			Lake Elevation (ft)		
Date	Hour	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
3/4/02	12	34.55	35.30	34.95	0.00	0.00	0.00	0.00	0.00	0.00	34.82	35.11	35.00	423.08	423.25	423.17
3/4/02	13	34.64	35.25	34.87	0.00	0.00	0.00	0.00	0.00	0.00	34.88	35.15	35.00	422.94	423.10	423.02
3/4/02	14	34.59	35.21	34.92	0.00	0.00	0.00	0.00	0.00	0.00	34.87	35.06	34.97	422.79	422.94	422.87
3/4/02	15	34.49	35.23	35.00	0.00	0.00	0.00	0.00	0.00	0.00	34.85	35.16	35.02	422.65	422.79	422.72
3/4/02	16	34.61	35.40	35.03	0.00	0.00	0.00	0.00	0.00	0.00	34.79	35.13	34.99	422.48	422.65	422.57
3/4/02		***34.49***	***35.40***	***34.95***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***34.79***	***35.16***	***35.00***	***422.48***	***423.25***	***422.87***
3/5/02	09	34.80	35.45	35.13	0.00	0.00	0.00	0.00	0.00	0.00	34.93	35.16	35.02	423.30	423.64	423.47
3/5/02	10	34.28	35.84	34.91	0.00	0.00	0.00	0.00	0.00	0.00	34.62	35.39	34.97	423.64	423.95	423.82
3/5/02	11	34.48	35.20	34.93	0.00	0.00	0.00	0.00	0.00	0.00	34.92	35.12	35.01	423.89	424.06	423.99
3/5/02	12	34.58	35.19	34.90	0.00	0.00	0.00	0.00	0.00	0.00	34.82	35.15	34.97	423.75	423.89	423.85
3/5/02	13	34.65	35.33	34.94	0.00	0.00	0.00	0.00	0.00	0.00	34.81	35.13	34.99	423.62	423.75	423.71
3/5/02	14	34.65	35.47	35.01	0.00	0.00	0.00	0.00	0.00	0.00	34.87	35.25	35.02	423.47	423.61	423.56
3/5/02	15	34.72	35.23	34.98	0.00	0.00	0.00	0.00	0.00	0.00	34.86	35.12	35.00	423.33	423.47	423.42
3/5/02	16	34.59	35.24	34.96	0.00	0.00	0.00	0.00	0.00	0.00	34.73	35.15	34.95	423.29	423.36	423.32
3/5/02		***34.28***	***35.84***	***34.97***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***34.62***	***35.39***	***34.99***	***423.29***	***424.06***	***423.64***
3/6/02	09	34.71	35.67	35.18	0.00	0.00	0.00	0.00	0.00	0.00	34.93	35.25	35.06	423.41	423.56	423.49
3/6/02	10	34.82	35.61	35.12	0.00	0.00	0.00	0.00	0.00	0.00	34.91	35.15	35.03	423.56	423.61	423.59
3/6/02	11	34.74	35.47	35.03	0.00	0.00	0.00	0.00	0.00	0.00	34.91	35.32	35.03	423.61	423.61	423.61
3/6/02	12	34.77	35.38	35.03	0.00	0.00	0.00	0.00	0.00	0.00	34.90	35.16	35.00	423.61	423.64	423.62
3/6/02	13	34.50	35.42	34.96	0.00	0.00	0.00	0.00	0.00	0.00	34.91	35.22	35.03	423.61	423.67	423.64
3/6/02	14	34.43	35.09	34.80	0.00	0.00	0.00	0.00	0.00	0.00	34.77	35.02	34.94	423.64	423.67	423.67
3/6/02	15	34.65	35.24	34.86	0.00	0.00	0.00	0.00	0.00	0.00	34.80	35.12	34.94	423.67	423.67	423.67
3/6/02	16	34.73	35.41	35.10	0.00	0.00	0.00	0.00	0.00	0.00	34.88	35.18	35.00	423.67	423.67	423.67
3/6/02		***34.43***	***35.67***	***35.01***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***34.77***	***35.32***	***35.00***	***423.41***	***423.67***	***423.62***
3/7/02	09	34.62	35.46	34.98	0.00	0.00	0.00	0.00	0.00	0.00	34.81	35.20	34.98	423.02	423.05	423.05
3/7/02	10	34.33	35.36	34.89	0.00	0.00	0.00	0.00	0.00	0.00	34.72	35.20	34.98	423.05	423.08	423.05
3/7/02	11	34.50	35.44	35.00	0.00	0.00	0.00	0.00	0.00	0.00	34.82	35.25	35.00	423.05	423.05	423.05
3/7/02	12	34.77	35.24	34.98	0.00	0.00	0.00	0.00	0.00	0.00	34.90	35.15	35.02	423.05	423.08	423.06
3/7/02	13	34.39	35.23	34.82	0.00	0.00	0.00	0.00	0.00	0.00	34.85	35.11	34.98	423.05	423.08	423.07
3/7/02	14	34.63	35.20	34.87	0.00	0.00	0.00	0.00	0.00	0.00	34.89	35.15	35.01	423.05	423.08	423.06
3/7/02	15	34.76	35.27	35.04	0.00	0.00	0.00	0.00	0.00	0.00	34.83	35.11	34.96	423.05	423.08	423.08
3/7/02	16	34.77	35.76	35.18	0.00	0.00	0.00	0.00	0.00	0.00	34.85	35.20	35.03	423.08	423.13	423.10
3/7/02	17	34.57	35.46	35.10	0.00	0.00	0.00	0.00	0.00	0.00	34.82	35.24	35.05	423.13	423.22	423.18
3/7/02		***34.33***	***35.76***	***34.98***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***34.72***	***35.25***	***35.00***	***423.02***	***423.22***	***423.08***

Appendix Table A-1

Continued.

Date	Hour	Unit 41 (mw)			Unit 42 (mw)			Unit 43 (mw)			Unit 44 (mw)			Lake Elevation (ft)		
		Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
3/8/02	10	34.61	35.25	35.02	0.00	0.00	0.00	0.00	0.00	0.00	34.91	35.13	35.05	423.33	423.39	423.37
3/8/02	11	34.72	35.17	34.97	0.00	0.00	0.00	0.00	0.00	0.00	34.86	35.13	34.98	423.39	423.44	423.42
3/8/02	12	34.84	35.29	35.06	0.00	0.00	0.00	0.00	0.00	0.00	34.89	35.07	34.98	423.44	423.50	423.48
3/8/02	13	34.79	35.34	35.05	0.00	0.00	0.00	0.00	0.00	0.00	34.87	35.12	34.99	423.50	423.56	423.54
3/8/02	14	34.65	35.20	34.94	0.00	0.00	0.00	0.00	0.00	0.00	34.84	35.03	34.94	423.56	423.61	423.58
3/8/02	15	34.60	35.24	34.98	0.00	0.00	0.00	0.00	0.00	0.00	34.90	35.07	34.98	423.61	423.70	423.66
3/8/02	16	34.67	35.35	35.08	0.00	0.00	0.00	0.00	0.00	0.00	34.87	35.16	35.04	423.70	423.75	423.72
3/8/02	17	34.65	35.53	35.13	0.00	0.00	0.00	0.00	0.00	0.00	34.77	35.29	34.96	423.75	423.78	423.77
3/8/02		***34.60***	***35.53***	***35.03***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***34.77***	***35.29***	***34.99***	***423.33***	***423.78***	***423.57***
3/9/02	09	34.71	35.16	34.90	0.00	0.00	0.00	0.00	0.00	0.00	34.92	35.08	35.00	422.86	422.88	422.88
3/9/02	10	34.59	35.15	34.85	0.00	0.00	0.00	0.00	0.00	0.00	34.87	35.07	34.98	422.85	422.88	422.85
3/9/02	11	34.43	35.30	34.91	0.00	0.00	0.00	0.00	0.00	0.00	34.88	35.10	34.98	422.82	422.85	422.83
3/9/02	12	34.82	35.36	35.07	0.00	0.00	0.00	0.00	0.00	0.00	34.96	35.24	35.06	422.79	422.82	422.81
3/9/02	13	34.83	35.33	35.06	0.00	0.00	0.00	0.00	0.00	0.00	34.91	35.14	35.05	422.79	422.82	422.82
3/9/02	14	34.79	35.50	35.13	0.00	0.00	0.00	0.00	0.00	0.00	34.93	35.10	35.02	422.79	422.84	422.82
3/9/02	15	34.78	35.32	34.99	0.00	0.00	0.00	0.00	0.00	0.00	34.94	35.13	35.04	422.81	422.85	422.83
3/9/02	16	34.75	35.16	34.97	0.00	0.00	0.00	0.00	0.00	0.00	34.99	35.13	35.05	422.83	422.88	422.86
3/9/02		***34.43***	***35.50***	***34.99***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***34.87***	***35.24***	***35.02***	***422.79***	***422.88***	***422.84***
3/10/02	09	34.66	35.28	34.95	0.00	0.00	0.00	0.00	0.00	0.00	34.88	35.06	34.97	421.79	421.89	421.84
3/10/02	10	34.80	35.32	35.03	0.00	0.00	0.00	0.00	0.00	0.00	34.90	35.09	35.00	421.88	421.95	421.92
3/10/02	11	34.89	35.43	35.09	0.00	0.00	0.00	0.00	0.00	0.00	34.90	35.12	35.00	421.95	422.03	422.00
3/10/02	12	34.77	35.35	35.02	0.00	0.00	0.00	0.00	0.00	0.00	34.85	35.14	35.00	422.03	422.09	422.06
3/10/02	13	34.76	35.35	35.06	0.00	0.00	0.00	0.00	0.00	0.00	34.85	35.19	35.02	422.09	422.12	422.11
3/10/02	14	34.86	35.37	35.13	0.00	0.00	0.00	0.00	0.00	0.00	34.97	35.14	35.08	422.12	422.13	422.12
3/10/02	15	34.75	35.45	35.05	0.00	0.00	0.00	0.00	0.00	0.00	34.88	35.11	34.99	422.12	422.12	422.12
3/10/02		***34.66***	***35.45***	***35.05***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***34.85***	***35.19***	***35.01***	***421.79***	***422.13***	***422.02***
3/11/02	09	34.47	35.44	34.94	0.00	0.00	0.00	0.00	0.00	0.00	34.82	35.16	34.98	421.72	421.78	421.77
3/11/02	10	34.70	35.30	35.05	0.00	0.00	0.00	0.00	0.00	0.00	34.86	35.21	34.97	421.78	421.82	421.80
3/11/02	11	34.89	35.54	35.14	0.00	0.00	0.00	0.00	0.00	0.00	34.89	35.18	35.03	421.81	421.86	421.84
3/11/02	12	34.78	35.40	35.06	0.00	0.00	0.00	0.00	0.00	0.00	34.86	35.20	35.04	421.86	421.95	421.90
3/11/02	13	34.79	35.30	35.02	0.00	0.00	0.00	0.00	0.00	0.00	34.92	35.16	35.04	421.95	422.06	422.00
3/11/02	14	34.75	35.27	35.01	0.00	0.00	0.00	0.00	0.00	0.00	34.91	35.16	35.04	422.06	422.17	422.11
3/11/02	15	34.53	35.20	34.91	0.00	0.00	0.00	0.00	0.00	0.00	34.86	35.12	34.98	422.18	422.26	422.22
3/11/02		***34.47***	***35.54***	***35.02***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***34.82***	***35.21***	***35.01***	***421.72***	***422.26***	***421.95***

Appendix Table A-1

Continued.

Date	Hour	Unit 41 (mw)			Unit 42 (mw)			Unit 43 (mw)			Unit 44 (mw)			Lake Elevation (ft)		
		Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
3/12/02	08	34.62	35.16	34.94	0.00	0.00	0.00	0.00	0.00	0.00	34.82	35.14	35.01	422.88	422.91	422.89
3/12/02	09	34.66	35.13	34.88	0.00	0.00	0.00	0.00	0.00	0.00	34.83	35.11	34.99	422.85	422.88	422.86
3/12/02	10	34.58	35.62	34.99	0.00	0.00	0.00	0.00	0.00	0.00	34.77	35.25	34.95	422.82	422.85	422.83
3/12/02	11	34.56	35.17	34.87	0.00	0.00	0.00	0.00	0.00	0.00	34.82	35.17	35.01	422.79	422.82	422.81
3/12/02	12	34.74	35.18	34.96	0.00	0.00	0.00	0.00	0.00	0.00	34.86	35.17	35.02	422.75	422.79	422.78
3/12/02	13	34.54	35.09	34.90	0.00	0.00	0.00	0.00	0.00	0.00	34.88	35.20	35.03	422.71	422.77	422.73
3/12/02	14	34.84	35.35	35.09	0.00	0.00	0.00	0.00	0.00	0.00	34.89	35.26	35.02	422.65	422.71	422.69
3/12/02	15	34.73	35.32	34.96	0.00	0.00	0.00	0.00	0.00	0.00	34.89	35.13	35.02	422.64	422.77	422.69
3/12/02	16	34.75	35.33	35.01	0.00	0.00	0.00	0.00	0.00	0.00	34.91	35.14	35.01	422.71	422.82	422.77
3/12/02	17	34.73	35.53	35.14	0.00	0.00	0.00	0.00	0.00	0.00	34.79	35.23	35.02	422.79	422.90	422.85
3/12/02		***34.54***	***35.62***	***34.97***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***34.77***	***35.26***	***35.01***	***422.64***	***422.91***	***422.79***
3/13/02	09	34.75	35.22	34.98	0.00	0.00	0.00	0.00	0.00	0.00	34.93	35.10	35.02	422.71	422.79	422.75
3/13/02	10	34.69	35.31	34.98	0.00	0.00	0.00	0.00	0.00	0.00	34.92	35.16	35.01	422.78	422.82	422.81
3/13/02		***34.69***	***35.31***	***34.98***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***34.92***	***35.16***	***35.02***	***422.71***	***422.82***	***422.78***

Appendix Table A-2

Daily tag-recapture data for juvenile salmonids passed through Francis turbines Units 41 (new) and 44 (old) at Mayfield Dam, March 2002.

Coho salmon

	Treatment																	
	Unit 41						*Unit 44*						*Control*					
	04 Mar	**05 Mar**	**06 Mar**	**09 Mar**	**11 Mar**	**Totals**	**04 Mar**	**05 Mar**	**06 Mar**	**09 Mar**	**11 Mar**	**Totals**	**04 Mar**	**05 Mar**	**06 Mar**	**09 Mar**	**11 Mar**	**Totals**
Released	12	40	25	50	60	187	12	40	25	51	20	148	2	40	40	40	20	142
Recovered alive	11	34	23	42	53**	163	12	38	24	44*	20	138	2	40	40	40	20	142
Recovered dead	1	6	2	8	6	23	0	0	0	4	0	4	0	0	0	0	0	0
Unknown	0	0		0	1	1	0	2	1	3	0	6	0	0	0	0	0	0
Held	11	34	23	42	43	153	12	38	24	43	20	137	2	40	40	40	20	142
Alive-24 h	11	31	21	42	43	148	12	38	23	43	20	136	2	40	40	40	20	142
Alive-48 h	11	31	21	42	43	148	12	38	23	43	20	136	2	40	39	40	20	141

Steelhead

	Treatment															
	Unit 41					*Unit 44*					*Control*					
	04 Mar	**07 Mar**	**08 Mar**	**12 Mar**	**Totals**	**04 Mar**	**07 Mar**	**08 Mar**	**12 Mar**	**Totals**	**04 Mar**	**07 Mar**	**08 Mar**	**12 Mar**	**13 Mar**	**Totals**
Released	2	40	40	80	162	2	20	60	30	112	2	40	30	10	20	102
Recovered alive	2	33	35	67	137	2	16	55	27	100	2	40	30	10	20	102
Recovered dead	0	6	3	9	18	0	0	1	2	3	0	0	0	0	0	0
Unknown	0	1	2	4	7	0	4	4	1	9	0	0	0	0	0	0
Held	2	33	35	67	137	2	16	55	27	100	2	40	30	10	20	102
Alive-24 h	2	29	32	65	128	2	16	55	27	100	2	40	30	10	20	102
Alive-48 h	2	29	32	65	128	2	16	55	27	100	2	40	30	10	20	102

* Includes one fish that escaped during transfer to delayed holding pools.

** Includes ten fish that escaped during transfer to delayed holding pools.

Appendix Table A-3

Incidence of injury and temporary loss of equilibrium observed on treatment juvenile salmonids passed through Francis turbine Units 41 (new) and 44 (old) at Mayfield Dam, March 2002.

Date	Fish ID Number	Injury Description	Status	Probable Source of Injury	Photo
		Coho salmon - Unit 41			
04 Mar	UN4	Temporary loss of equilibrium	Alive		No
04 Mar	KL9	Temporary loss of equilibrium	Alive		No
05 Mar	LA5	Hemorrhaged left eye, temporary loss of equilibrium	Alive	Shear	No
05 Mar	LA8	Hemorrhaged right gill	Dead 1 h	Shear	No
05 Mar	LA9	Temporary loss of equilibrium	Alive		No
05 Mar	UY2	Broken back, torn right opercle	Dead 1 h	Shear	No
05 Mar	UY5	Broken back	Dead 24 h	Shear	No
05 Mar	UZ9	Bloody eye, scrape on head	Alive		No
06 Mar	LC0	Bruised left side, loss of equilibrium	Dead 24 h	Mechanical	No
06 Mar	LJ7	No visible injuries	Dead 24 h		No
06 Mar	LK6	Tear at tag site	Dead 1 h		No
09 Mar	VK0	Broken back, torn right opercle	Dead 1 h	Shear	Yes
09 Mar	VK2	Torn right operculum, bleeding gills	Dead 1 h	Shear	Yes
09 Mar	VK9	Temporary loss of equilibrium	Alive		No
09 Mar	VL4	No visible injuries	Dead 1 h		No
09 Mar	VY3	Broken back two locations, torn isthmus, left opercle	Dead 1 h	Shear	Yes
09 Mar	VJ0	Temporary loss of equilibrium	Alive		No
09 Mar	VJ1	Hemorrhaged right gill	Dead 48 h	Shear	No
11 Mar	ZR1	Broken back, hemorrhaged right gill	Dead 1 h	Shear	Yes
11 Mar	ZR2	No visible injuries	Dead 24 h		No
11 Mar	ZR5	Hemorrhaged left gill	Dead 1 h	Shear	No
11 Mar	ZS6	Ruptured right eye	Dead 1 h		Yes
11 Mar	VZ6	Bruise above left eye, temporary loss of equilibrium	Alive	Mechanical	No
11 Mar	VZ7	Temporary loss of equilibrium	Alive		No
11 Mar	VZ8	No visible injuries	Dead 1 h		No
11 Mar	ZN8	Minor internal hemorrhaging	Dead 1 h	Shear	Yes
11 Mar	ZP0	Temporary loss of equilibrium	Alive		No
		Coho salmon - Unit 44			
04 Mar	KJ4	Torn right opercle, temporary loss of equilibrium	Alive	Shear	No
05 Mar	UU3	Torn right operculum, scrape on left side	Alive	Shear	No
05 Mar	UX0	Temporary loss of equilibrium	Alive		No
06 Mar	LL0	Lacerations on body	Alive	Mechanical	No
06 Mar	LL3	Temporary loss of equilibrium	Alive		No
06 Mar	LL9	Tear at tag site	Dead 24 h		No
09 Mar	VR2	Scrape on head	Alive	Mechanical	No

Appendix Table A-3

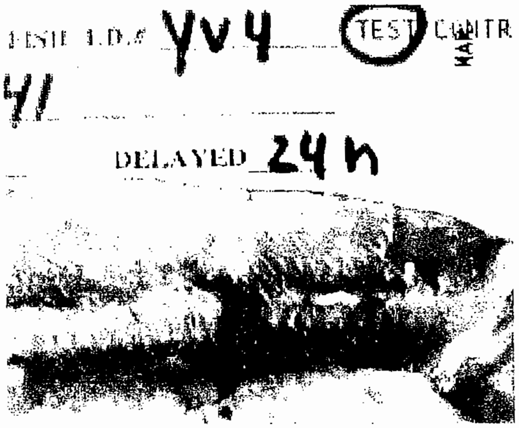
Continued.

Date	Fish ID Number	Injury Description	Status	Probable Source of Injury	Photo
		Coho salmon - Unit 44 (continued)			
09 Mar	VR6	Temporary loss of equilibrium	Alive		No
09 Mar	VR8	Temporary loss of equilibrium	Alive		No
09 Mar	VR9	Hemorrhaged right gill	Dead 1 h	Shear	No
09 Mar	VS8	Torn isthmus, torn operculum	Dead 1 h	Shear	Yes
09 Mar	VX1	Temporary loss of equilibrium	Alive		No
09 Mar	VX8	No visible injuries	Dead 1 h		No
		Coho salmon - Control			
06 Mar	LD4	Right operculum missing	Alive	Shear	No
06 Mar	LE9	Internal hemorrhaging	Dead 48 h		No
11 Mar	ZW7	Temporary loss of equilibrium	Alive		No
		Steelhead - Unit 41			
07 Mar	YT1	Both eyes hemorrhaged, temporary loss of equilibrium	Alive	Shear	No
07 Mar	YT3	Bruise behind left eye	Dead 1 h	Mechanical	No
07 Mar	YT7	Hemorrhaged right eye, torn left and right opercula	Dead 1 h	Shear	Yes
07 Mar	YU4	Body severed at dorsal fin	Dead 1 h	Mechanical	Yes
07 Mar	YU5	Temporary loss of equilibrium	Alive		No
07 Mar	YU8	Torn lft & rght opercula, hemorrhaged lft gill and eye	Dead 1 h	Shear	Yes
07 Mar	YV0	Bruise on nape, tear at tag site	Dead 1 h	Mechanical	No
07 Mar	YV4	Broken back	Dead 24 h	Shear	Yes
07 Mar	YV6	Hemorrhaging from gills	Alive	Shear	No
07 Mar	YV7	No visible injuries	Dead 24 h		No
07 Mar	YW2	Bulging right eye	Dead 24 h	Shear	Yes
07 Mar	YW5	Ruptured right eye, hemorrhaged left eye	Dead 24 h	Shear	Yes
07 Mar	YW9	Temporary loss of equilibrium	Alive		No
08 Mar	VA4	Temporary loss of equilibrium	Alive		No
08 Mar	VA5	No visible injuries	Dead 24 h		No
08 Mar	VA7	Broken back, ruptured left eye	Dead 1 h	Shear	Yes
08 Mar	VA9	Scratches on head	Dead 24 h	Mechanical	No
08 Mar	VB1	Tear at pin site	Dead 24 h		No
08 Mar	VB3	Temporary loss of equilibrium	Alive		No
08 Mar	VB8	Bruised right side, temporary loss of equilibrium	Alive	Mechanical	No
08 Mar	VC1	Torn left & right opercula, hemorrhaged right gill	Dead 1 h	Shear	No
08 Mar	VC5	Hemorrhaging from gills	Alive	Shear	No
08 Mar	VD2	Temporary loss of equilibrium	Alive		No
08 Mar	VD3	Temporary loss of equilibrium	Alive		No

Appendix Table A-3

Continued.

Date	Fish ID Number	Injury Description	Status	Probable Source of Injury	Photo
		Steelhead - Unit 41 (continued)			
08 Mar	VD5	Hemorrhaged left gill and eye	Dead 1 h	Shear	No
12 Mar	ZA5	Torn lft operculum, bruised lft gill, hemrrgd rt gill/liver	Dead 1 h	Shear	Yes
12 Mar	ZA9	Torn right operculum, temporary loss of equilibrium	Alive	Shear	No
12 Mar	ZB2	Temporary loss of equilibrium	Alive		No
12 Mar	ZB5	Broken back, hemorrhaged left and right gills	Dead 1 h	Shear	Yes
12 Mar	ZB9	Temporary loss of equilibrium	Alive		No
12 Mar	ZC6	Hemorrhaged left and right gills	Dead 1 h	Shear	No
12 Mar	ZD0	Temporary loss of equilibrium	Alive		No
12 Mar	ZD1	Temporary loss of equilibrium	Alive		No
12 Mar	ZD3	Broken back, damaged isthmus, hemrrgd lft/rght gills	Dead 1 h	Shear	Yes
12 Mar	ZF1	Broken back, hemorrhaged left gill	Dead 24 h	Shear	Yes
12 Mar	ZF5	Temporary loss of equilibrium	Alive		No
12 Mar	ZH0	Nearly decapitated, internal hemorrhaging	Dead 1 h	Shear	Yes
12 Mar	ZH7	Internal hemorrhaging, bruise on head	Dead 1 h		Yes
12 Mar	ZH8	Hemorrhaged left gill	Dead 24 h	Shear	No
12 Mar	ZJ9	Damaged operculum, scale loss both sides	Alive	Shear	No
		Steelhead - Unit 44			
04 Mar	KJ6	Hemorrhaging left and right gills	Alive	Shear	No
07 Mar	YX7	Temporary loss of equilibrium	Alive		No
08 Mar	BU7	Torn operculum, temporary loss of equilibrium	Alive	Shear	No
08 Mar	BV5	Lacerations on body	Alive	Mechanical	No
08 Mar	BX8	Hemorrhaged left gill	Dead 1 h	Shear	No
08 Mar	BY1	Scratches on head, temporary loss of equilibrium	Alive	Mechanical	No
08 Mar	BY5	Large bruise	Alive	Mechanical	No
08 Mar	BY6	Temporary loss of equilibrium	Alive		No
08 Mar	YZ6	Temporary loss of equilibrium	Alive		No
12 Mar	ZZ0	Hemorrhaged right gill	Dead 1 h	Shear	No
12 Mar	ZZ1	Temporary loss of equilibrium	Alive		No
12 Mar	ZZ9	Internal hemorrhaging	Dead 1 h		Yes



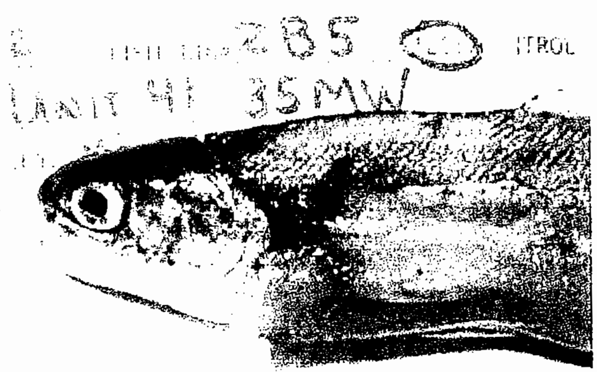
YV4 – Unit 41; steelhead; broken backbone; shear

YW2 – Unit 41; steelhead; bulging right eye; shear

YW5 – Unit 41; steelhead; ruptured right eye; shear

ZA5 – Unit 41; steelhead; hemorrhaged liver

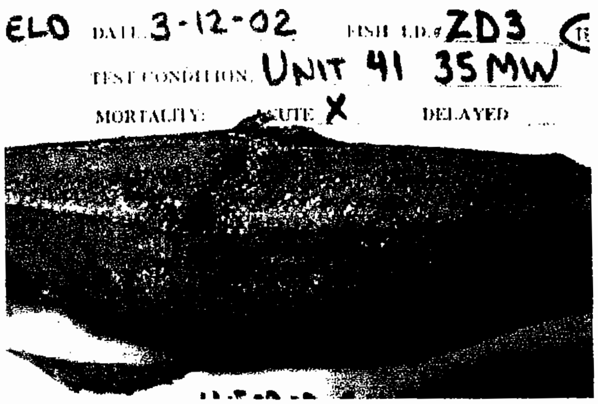
ZA5 – Unit 41; steelhead; torn left operculum; shear



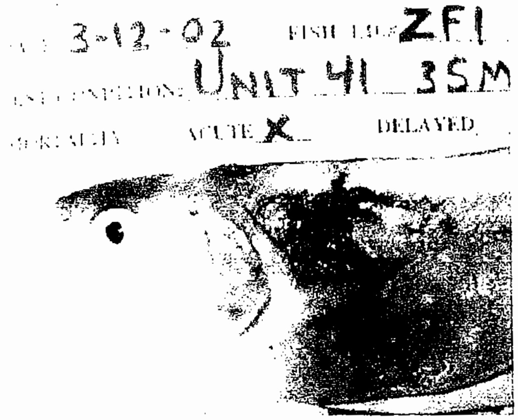
ZB5 – Unit 41; steelhead; broken backbone; shear

Appendix Figure A-1

Photographic record of injuries sustained by juvenile steelhead passed through turbine Unit 41 at Mayfield Dam, March 2002.



ZD3 – Unit 41; steelhead; broken backbone; shear

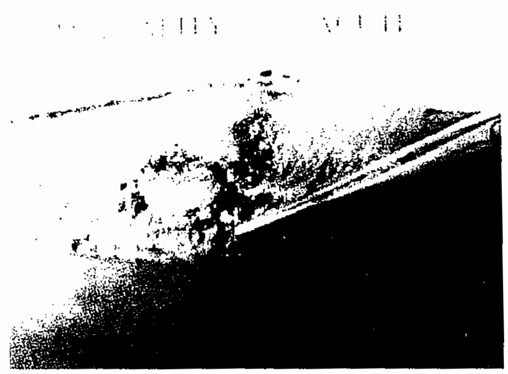


ZF1 – Unit 41; steelhead; hemorrhaged left gill; shear

ZH0 – Unit 41; steelhead; partial decapitation; shear

ZH7 – Unit 41; steelhead; internal hemorrhage

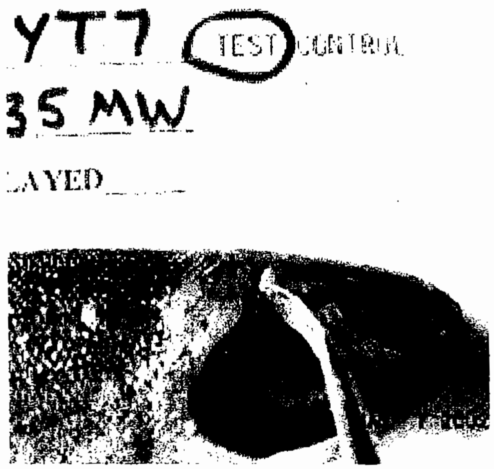
VA7 – Unit 41; steelhead; ruptured left eye; shear



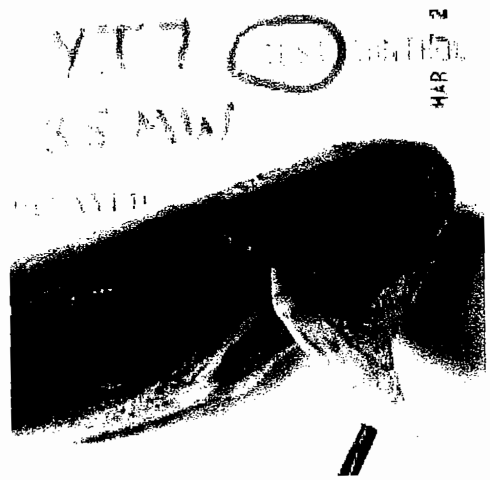
VA7 – Unit 41; steelhead; broken backbone; shear

Appendix Figure A-1

Continued.

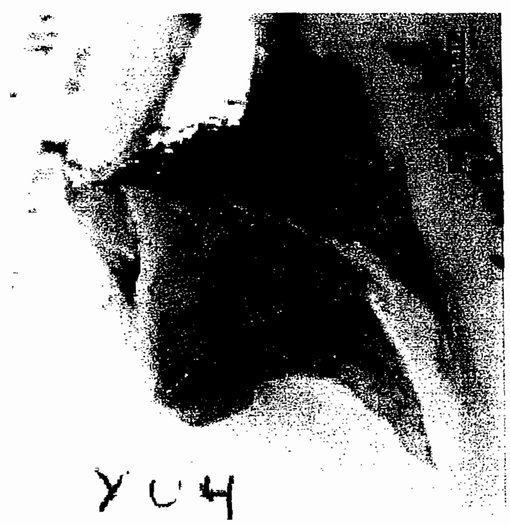


YT7 – Unit 41; steelhead; hemorrhaged right eye, torn opercule; shear



YT7 – Unit 41; steelhead; hemorrhaged right eye, torn opercule; shear

YU8 – Unit 41; steelhead; hemorrhaged left eye; shear

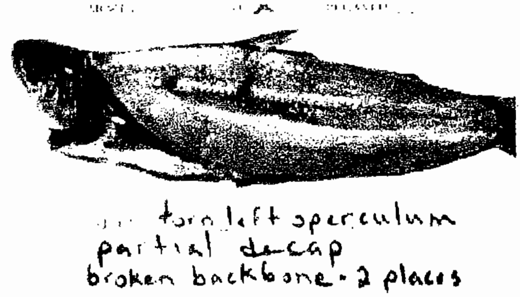


YU4 – Unit 41; steelhead; body severed in half; mechanical

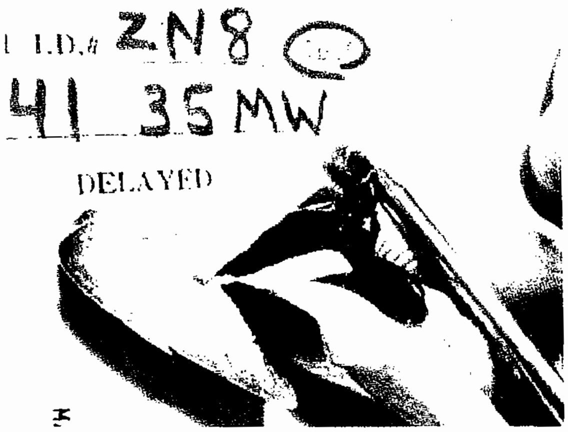
Appendix Figure A-1

Continued.

VK2 – Unit 41; coho; torn right operculum; shear



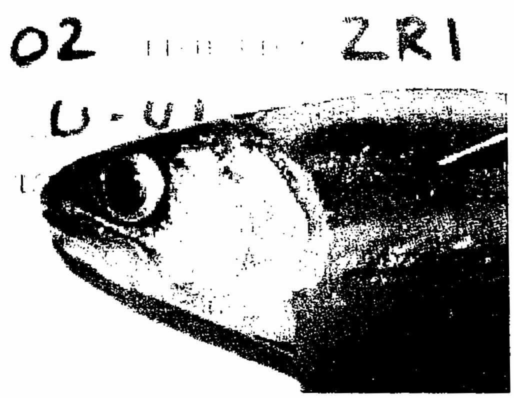
VY3 – Unit 41; coho; broken backbone, torn isthmus; shear



ZN8 – Unit 41; coho; internal hemorrhage; shear

VK0 – Unit 41; coho; broken backbone; shear

ZR1 – Unit 41; coho; hemorrhaged right gill; shear



ZR1 – Unit 41; coho; broken backbone; shear

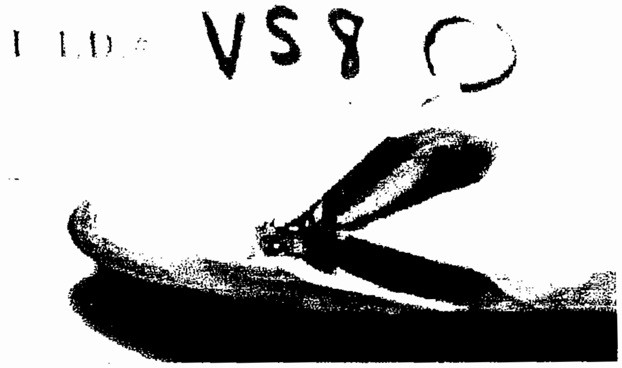
Appendix Figure A-2

Photographic record of injuries sustained by juvenile coho salmon passed through turbine Unit 41 at Mayfield Dam, March 2002.

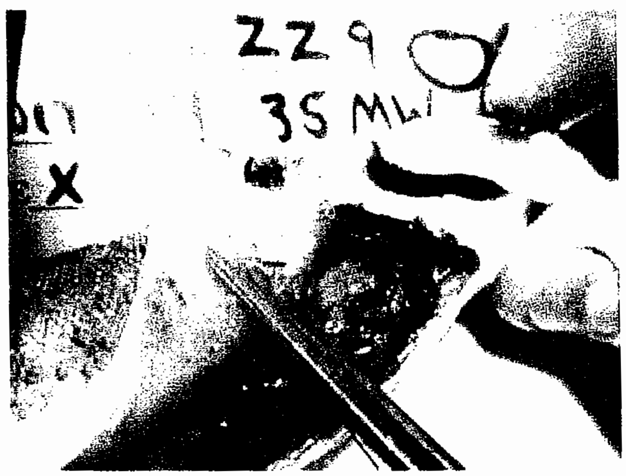
ZS6 – Unit 41; coho; ruptured right eye; shear

Appendix Figure A-2

Continued.



VS8 – Unit 44; coho; torn isthmus; shear



ZZ9 – Unit 44; steelhead; internal hemorrhage; shear

Appendix Figure A-3

Photographic record of injuries sustained by juvenile coho salmon and steelhead passed through turbine Unit 44 at Mayfield Dam, March 2002.

APPENDIX B

DERIVATION OF PRECISION, SAMPLE SIZE, AND MAXIMUM LIKELIHOOD PARAMETERS, AND STATISTICAL OUTPUTS

Derivation of Precision, Sample Size, and Maximum Likelihood Parameters

The estimation for the likelihood model parameters and sample size requirements discussed in the text are given herein. Additionally, the results of statistical analyses for evaluating homogeneity in recapture and survival probabilities, and in testing hypotheses of equality in parameter estimates under the simplified (H_O:P_A=P_D) versus the most generalized model (H_A:$P_A \neq P_D$) are given. The following terms were defined for the equations and likelihood functions which follow:

R_C	=	Number of control fish released
R_T	=	Number of treatment fish released
R	=	R_C=R_T
n	=	Number of replicate estimates of $\hat{\tau}_i$ (i=1,…,n)
a_C	=	Number of control fish recaptured alive
d_C	=	Number of control fish recaptured dead
a_T	=	Number of treatment fish recaptured alive
d_T	=	Number of treatment fish recaptured dead
S	=	Probability fish survive from the release point of the controls to recapture
P_A	=	Probability a live fish is recaptured
P_D	=	Probability a dead fish is recaptured
$\hat{\tau}$	=	Probability a treatment fish survives to the point of the control releases (*i.e.*, passage survival)
$1-\hat{\tau}$	=	Passage-related mortality.

The precision of the estimate is defined (Mathur *et al.* 1996) as:

$$P(-\varepsilon < \hat{\tau} - \tau < \varepsilon) = 1 - \alpha$$

or equivalently

$$P(-\varepsilon <| \hat{\tau} - \tau |< \varepsilon) = 1 - \alpha$$

where the absolute errors in estimation, *i.e.*, $|\hat{\tau} - \tau|$, is <ε (1-α) 100% of the time, $\hat{\tau}$ is the estimated passage survival, and ε is the half-width of a (1-α) 100% confidence interval for $\hat{\tau}$ or 1-$\hat{\tau}$. A precision of ±5%, 90% of the time is expressed as P($|\hat{\tau} - \tau|$<0.05)=0.90.

Using the above precision definition the required total sample size (R) is as follows:

$$P\left(\frac{-\varepsilon}{Var(\hat{\tau})} < Z < \frac{\varepsilon}{Var(\hat{\tau})}\right) = 1 - \alpha$$

$$P\left(Z < \frac{-\varepsilon}{Var(\hat{\tau})}\right) = \alpha / 2$$

$$\Phi\left(\frac{-\varepsilon}{Var(\hat{\tau})}\right) = \alpha / 2$$

$$\frac{-\varepsilon}{Var(\hat{\tau})} = Z_{\alpha/2}$$

$$Var(\hat{\tau}) = \frac{\varepsilon^2}{Z^2_{1-\frac{\alpha}{2}}}$$

$$\frac{\tau}{SP_A}\left[\frac{(1 - S\tau P_A)}{R_T} + \frac{(1 - SP_A)\tau}{R_C}\right] = \frac{\varepsilon^2}{Z^2_{1-\frac{\alpha}{2}}} .$$

where Z is a standard normal deviate satisfying the relationship $P(Z>Z_{1-\alpha/2})=\alpha/2$, and Φ is the cumulative distribution function for a standard normal deviate.

If data can be pooled across trials and letting $R_C=R_T=R$, the sample size for each release is

$$R = \frac{\tau}{SP_A}\left[1 + \tau - 2S\tau P_A\right]\frac{Z^2_{1-\alpha/2}}{\varepsilon^2} .$$

By rearranging, this equation can be solved to predetermine the anticipated precision given the available number of fish for a study.

If data cannot be pooled across trials the precision is based on (Skalski 1992)

$$\sum_{i=1}^{n}(1 - \hat{\tau}_i)/n = 1 - \sum_{i=1}^{n}\hat{\tau}_i / n = 1 - \bar{\hat{\tau}} .$$

Precision is defined as

$$P(|\bar{\hat{\tau}} - \bar{\tau}| < \varepsilon) = 1 - \alpha$$

$$P(-\varepsilon < \bar{\hat{\tau}} - \bar{\tau} | < \varepsilon) = 1 - \alpha$$

$$P\left(\frac{-\varepsilon}{\sqrt{Var(\bar{\hat{\tau}})}} < \tau_{n-1} < \frac{\varepsilon}{\sqrt{Var(\bar{\hat{\tau}})}}\right) = 1 - \alpha$$

$$P\left(\tau_{n-1} < \frac{-\varepsilon}{\sqrt{Var(\bar{\hat{\tau}})}}\right) = \alpha / 2$$

$$\frac{\Phi}{\tau}\left(\frac{-\varepsilon}{Var(\bar{\hat{\tau}})}\right) = \alpha / 2$$

$$\frac{-\varepsilon}{\sqrt{Var(\bar{\hat{\tau}})}} = t_{\alpha/2,n-1}$$

$$Var(\bar{\hat{\tau}}) = \frac{\varepsilon^2}{t^2_{1-\alpha/2,n-1}}$$

$$\frac{\sigma^2_\tau + \frac{\tau}{SP_A}\left[\frac{(1 - S\tau P_A)}{R_T} + \frac{(1 - SP_A)^\tau}{R_C}\right]}{n} = \frac{\varepsilon^2}{t_{1-\alpha/2,n-1}}$$

where σ_τ^2=natural variation in passage-related mortality.

Now letting R_T=R_C

$$\frac{\sigma^2_\tau + \frac{\tau}{SP_A}\left[\frac{(1 - S\tau P_A)}{R} + \frac{(1 - SP_A)^\tau}{R}\right]}{n} = \frac{\varepsilon^2}{t_{1-\alpha/2,n-1}}$$

which must be iteratively solved for n given R. Or R given n where

$$R = \frac{\frac{\tau}{SP_A}\left[(1 - S\tau P_A) + (1 - SP_A)\tau\right]}{\left[\frac{n\varepsilon^2}{t^2_{1-\alpha/2,n-1}} - \sigma^2_\tau\right]}$$

$$R = \frac{\frac{\tau(1+\tau)}{SP_A}}{\left[\frac{n\varepsilon^2}{t^2_{1-\alpha/2,n-1}} - \sigma^2_\tau\right]}$$

$$R = \frac{\tau(1+\tau)}{SP_A}\left[\frac{t^2_{1-\alpha/2,n-1}}{n\varepsilon^2 - \sigma^2_\tau t^2_{1-\alpha/2,n-1}}\right].$$

The joint likelihood for the passage-related mortality is:

$$L\,(S,\ \tau,\ P_A,\ P_D \mid R_C,\ R_T,\ a_C,\ a_T,\ d_C,\ d_T)=$$

$$\binom{R_C}{a_C d_C}(SP_A)^{a_C}((1-S)P_D)^{d_C}(1-SP_A-(1-S)P_D)^{R_C-a_C-d_C}$$

$$\times\binom{R_T}{a_T d_T}(S\tau P_A)^{a_T}((1-S\tau)P_D)^{d_T}(1-S\tau P_A-(1-S\tau)P_D)^{R_T-a_T-d_T}\ .$$

The likelihood model is based on the following assumptions: (1) fate of each fish is independent, (2) the control and treatment fish come from the same population of inference and share that same survival probability, (3) all alive fish have the same probability, P_A, of recapture, (4) all dead fish have the same probability, P_D, of recapture, and (5) passage survival (τ) and survival (S) to the recapture point are conditionally independent. The likelihood model has four parameters (P_A, P_D, S, τ) and four minimum sufficient statistics (a_C, d_C, a_T, d_T).

Because any two treatment releases were made concurrently with a single shared control group we used the likelihood model which took into account dependencies within the study design (Mathur *et al.* 2000). For any two treatment groups (denoted T_1 and T_2), the likelihood model is as follows:

$$L(S,\tau_1,\tau_2,P_A,P_D \mid R_C,R_{T_1},R_{T_2},a_C,d_c,a_{T_1},d_{T_1},a_{T_2},d_{T_2}) =$$

$$\binom{R_C}{a_c d_C}(SP_A)^{a_C}((1-S)P_D)^{d_C}(1-SP_A-(1-S)P_D)^{R_C-a_C-d_C}$$

$$\times\binom{R_{T_1}}{a_{T_1} d_{T_1}}(S\tau_1 P_A)^{a_{T_1}}((1-S\tau_1)P_D)^{d_{T_1}}(1-S\tau_1 P_A-(1-S\tau_1)P_D)^{R_{T_1}-a_{T_1}-d_{T_1}}$$

$$\times\binom{R_{T_2}}{a_{T_2} d_{T_2}}(S\tau_2 P_A)^{a_{T_2}}((1-S\tau_2)P_D)^{d_{T_2}}(1-S\tau_2 P_A-(1-S\tau_2)P_D)^{R_{T_2}-a_{T_2}-d_{T_2}}\ .$$

This likelihood model has the same assumptions as stated in Mathur *et al.* (1996) but has five estimable parameters (S, τ_1, τ_2, P_A, and P_D). The survival rate for treatment T_1 is estimated by τ_1 and for treatment T_2, by τ_2. A likelihood ratio test with 1 degree of freedom was used to test for equality in survival rates between treatments τ_1 and τ_2 based on the hypothesis H_O: $\tau_1 = \tau_2$ versus H_a: $\tau_1 \neq \tau_2$.

Likelihood models are based on the following assumptions: (a) the fate of each fish is independent; (b) the control and treatment fish come from the same population of inference and share the same natural survival probability, S; (c) all alive fish have the same probability, P_A, of recapture; (d) all dead fish have the same probability, P_D, of recapture; and (e) passage survival (τ) and natural survival (S) to the recapture point are conditionally independent.

The estimators associated with the likelihood model are:

$$\hat{\tau} = \frac{a_T R_C}{R_T a_C}$$

$$\hat{S} = \frac{R_T d_C a_C - R_C d_T a_C}{R_C d_C a_T - R_C d_T a_C}$$

$$\hat{P}_A = \frac{d_C a_T - d_T a_C}{R_T d_C - R_C d_T}$$

$$\hat{P}_D = \frac{d_C a_T - d_T a_C}{R_C a_T - R_T a_C} \ .$$

The variance (Var) and standard error (SE) of the estimated passage mortality ($1 - \hat{\tau}$) or survival ($\hat{\tau}$) are:

$$Var(1-\hat{\tau}) = Var(\hat{\tau}) = \frac{\hat{\tau}}{SP_A}\left[\frac{(1-S\hat{\tau}P_{A)}}{R_T} + \frac{(1-SP_A)\hat{\tau}}{R_C}\right]$$

$$SE(1-\hat{\tau}) = SE(\hat{\tau}) = \sqrt{Var(1-\hat{\tau})} \ .$$

DERIVATION OF VARIANCE FOR WEIGHTED AVERAGE SURVIVAL ESTIMATE

$$Var(1-\hat{\tau}_w) = Var\left[\frac{\sum(1-\hat{\tau}_i)\frac{1}{Var_i}}{\sum\frac{1}{Var_i}}\right]$$

$$= Var\frac{\left[\sum(1-\hat{\tau}_i)\frac{1}{Var_i}\right]}{\left(\sum\frac{1}{Var_i}\right)^2}$$

$$= \frac{\sum Var(1-\hat{\tau}_i)\frac{1}{(Var_{i^2})}}{\left(\sum\frac{1}{Var_i}\right)^2}$$

$$= \frac{\sum Var_i\left(\frac{1}{Var_i}\right)^2}{\left(\sum\frac{1}{Var_i}\right)^2}$$

$$= \frac{\sum\frac{1}{Var_i}}{\left(\sum\frac{1}{Var_i}\right)^2}$$

$$Var(1-\hat{\tau}_w) = \frac{1}{\sum_{i=1}^{n}\left(\frac{1}{Var(\hat{\tau}_i)}\right)}.$$

APPENDIX B

One hour survival estimates for coho salmon smolts released into Unit 41 and Unit 44 of Mayfield Dam, March 2002. Control - 142 released, 142 alive, 0 dead. Unit 41 test - 187 released, 163 alive, 23 dead, 1 unknown. Unit 44 test - 148 released, 138 alive, 4 dead, 6 unknown.

RESULTS FOR FULL MODEL (UNEQUAL LIVE/DEAD RECOVERY)

	estim.	std.err.	
S1 =	1.0	N/A	Control group survival*
Pa =	0.9844	(+NAN)	Live recovery probability
Pd =	1.0	N/A	Dead recovery probability*
S2 =	0.8770	(0.0240)	Unit 41 survival
S3 =	0.9730	(0.0133)	Unit 44 survival

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.

log-likelihood : -124.2006

Tau = 0.8770 (0.0240) Unit 41/Control ratio
Tau = 0.9730 (0.0133) Unit 44/Control ratio

Z statistic for the equality of equal turbine survivals: 3.4938

Compare with quantiles of the normal distribution:

	1-tailed	2-tailed
For significance level 0.10:	1.2816	1.6449
For significance level 0.05:	1.6449	1.9600
For significance level 0.01:	2.3263	2.5758

Variance-Covariance matrix for estimated probabilities:

0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	-0.00013084	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00057683	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000	0.00017768

Confidence intervals:

	Unit 41 Tau	Unit 44 Tau
90 percent:	(0.8375, 0.9165)	(0.9510, 0.9949)
95 percent:	(0.8299, 0.9241)	(0.9468, 0.9991)
99 percent:	(0.8152, 0.9388)	(0.9386, 1.0073)

APPENDIX B

One hour survival estimates for coho salmon smolts released into Unit 41 and Unit 44 of Mayfield Dam, March 2002. Control - 142 released, 142 alive, 0 dead. Unit 41 test - 187 released, 163 alive, 23 dead, 1 unknown. Unit 44 test - 148 released, 138 alive, 4 dead, 6 unknown.

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

	estim.	std.err.	
S1 =	1.0	N/A	Control group survival*
Pa = Pd	0.9853	(0.0055)	Recovery probability
S2 =	0.8763	(0.0241)	Unit 41 survival
S3 =	0.9718	(0.0139)	Unit 44 survival

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.

log-likelihood : -124.3121

Tau =	0.8763	(0.0241)	Unit 41/Control ratio
Tau =	0.9718	(0.0139)	Unit 44/Control ratio

Z statistic for the equality of equal turbine survivals: 3.4291

Compare with quantiles of the normal distribution:

	1-tailed	2-tailed
For significance level 0.10:	1.2816	1.6449
For significance level 0.05:	1.6449	1.9600
For significance level 0.01:	2.3263	2.5758

Variance-Covariance matrix for estimated probabilities:

0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00003031	0.00000000	0.00000000
0.00000000	0.00000000	0.00058261	0.00000000
0.00000000	0.00000000	0.00000000	0.00019279

Confidence intervals:

	Unit 41 Tau	Unit 44 Tau
90 percent:	(0.8366, 0.9160)	(0.9490, 0.9947)
95 percent:	(0.8290, 0.9237)	(0.9446, 0.9990)
99 percent:	(0.8142, 0.9385)	(0.9361, 1.0076)

==

Likelihood ratio statistic for equality of recovery probabilities: 0.2230

Compare with quantiles of the chi-squared distribution with 1 d.f.:
For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

APPENDIX B

One hour survival estimates for steelhead released into Unit 41 and Unit 44 of Mayfield Dam, March 2002. Control - 102 released, 102 alive, 0 dead. Unit 41 test - 162 released, 137 alive, 18 dead, 7 unknown. Unit 44 test - 112 released, 100 alive, 3 dead, 9 unknown.

RESULTS FOR FULL MODEL (UNEQUAL LIVE/DEAD RECOVERY)

	estim.	std.err.	
S1 =	1.0	N/A	Control group survival*
Pa =	1.0	N/A	Live recovery probability*
Pd =	0.5676	(0.0814)	Dead recovery probability
S2 =	0.8457	(0.0284)	Unit 41 survival
S3 =	0.8929	(0.0292)	Unit 44 survival

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.

log-likelihood : -133.1249

Tau = 0.8457 (0.0284) Unit 41/Control ratio
Tau = 0.8929 (0.0292) Unit 44/Control ratio

Z statistic for the equality of equal turbine survivals: 1.1580

Compare with quantiles of the normal distribution:

	1-tailed	2-tailed
For significance level 0.10:	1.2816	1.6449
For significance level 0.05:	1.6449	1.9600
For significance level 0.01:	2.3263	2.5758

Variance-Covariance matrix for estimated probabilities:

0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00663338	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00080559	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000	0.00085414

Confidence intervals:

	Unit 41 Tau	Unit 44 Tau
90 percent:	(0.7990, 0.8924)	(0.8448, 0.9409)
95 percent:	(0.7900, 0.9013)	(0.8356, 0.9501)
99 percent:	(0.7726, 0.9188)	(0.8176, 0.9681)

APPENDIX B

One hour survival estimates for steelhead released into Unit 41 and Unit 44 of Mayfield Dam, March 2002. Control - 102 released, 102 alive, 0 dead. Unit 41 test - 162 released, 137 alive, 18 dead, 7 unknown. Unit 44 test - 112 released, 100 alive, 3 dead, 9 unknown.

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

	estim.	std.err.	
S1 =	1.0	N/A	Control group survival*
Pa = Pd	0.9574	(0.0104)	Recovery probability
S2 =	0.8839	(0.0257)	Unit 41 survival
S3 =	0.9709	(0.0166)	Unit 44 survival

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.

log-likelihood : -135.3977

Tau = 0.8839 (0.0257) Unit 41/Control ratio
Tau = 0.9709 (0.0166) Unit 44/Control ratio

Z statistic for the equality of equal turbine survivals: 2.8426

Compare with quantiles of the normal distribution:

	1-tailed	2-tailed
For significance level 0.10:	1.2816	1.6449
For significance level 0.05:	1.6449	1.9600
For significance level 0.01:	2.3263	2.5758

Variance-Covariance matrix for estimated probabilities:

0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00010836	0.00000000	0.00000000
0.00000000	0.00000000	0.00066221	0.00000000
0.00000000	0.00000000	0.00000000	0.00027454

Confidence intervals:

	Unit 41 Tau	Unit 44 Tau
90 percent:	(0.8415, 0.9262)	(0.9436, 0.9981)
95 percent:	(0.8334, 0.9343)	(0.9384, 1.0033)
99 percent:	(0.8176, 0.9501)	(0.9282, 1.0135)

Likelihood ratio statistic for equality of recovery probabilities: 4.5456

Compare with quantiles of the chi-squared distribution with 1 d.f.:
For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

APPENDIX B

Forty-eight hour survival estimates for coho salmon smolts released into Unit 41 and Unit 44 of Mayfield Dam, March 2002. Control - 142 released, 141 alive, 1 dead. Unit 41 test - 177 released, 148 alive, 28 dead, 1 unknown. Unit 44 test - 147 released, 136 alive, 5 dead, 6 unknown.

RESULTS FOR FULL MODEL (UNEQUAL LIVE/DEAD RECOVERY)

	estim.	std.err.	
S1 =	0.9930	(0.0070)	Control group survival
Pa =	0.9838	(0.0061)	Live recovery probability
Pd =	1.0	N/A	Dead recovery probability*
S2 =	0.8418	(0.0274)	Unit 41 survival
S3 =	0.9660	(0.0150)	Unit 44 survival

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.

log-likelihood : -140.8606

Tau = 0.8478 (0.0283) Unit 41/Control ratio
Tau = 0.9728 (0.0166) Unit 44/Control ratio

Z statistic for the equality of equal turbine survivals: 3.8179

Compare with quantiles of the normal distribution:

	1-tailed	2-tailed
For significance level 0.10:	1.2816	1.6449
For significance level 0.05:	1.6449	1.9600
For significance level 0.01:	2.3263	2.5758

Variance-Covariance matrix for estimated probabilities:

0.00004924	0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00003690	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00075236	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000	0.00022351

Confidence intervals:

	Unit 41 Tau	Unit 44 Tau
90 percent:	(0.8013, 0.8943)	(0.9456, 1.0001)
95 percent:	(0.7924, 0.9032)	(0.9404, 1.0053)
99 percent:	(0.7750, 0.9206)	(0.9302, 1.0155)

APPENDIX B

Forty-eight hour survival estimates for coho salmon smolts released into Unit 41 and Unit 44 of Mayfield Dam, March 2002. Control - 142 released, 141 alive, 1 dead. Unit 41 test - 177 released, 148 alive, 28 dead, 1 unknown. Unit 44 test - 147 released, 136 alive, 5 dead, 6 unknown.

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

	estim. std.err.	
S1 =	0.9930 (0.0070)	Control group survival
Pa = Pd	0.9850 (0.0056)	Recovery probability
S2 =	0.8409 (0.0276)	Unit 41 survival
S3 =	0.9645 (0.0156)	Unit 44 survival

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.

log-likelihood : -141.0103

Tau =	0.8469 (0.0284)	Unit 41/Control ratio
Tau =	0.9714 (0.0171)	Unit 44/Control ratio

Z statistic for the equality of equal turbine survivals: 3.7542

Compare with quantiles of the normal distribution:

	1-tailed	2-tailed
For significance level 0.10:	1.2816	1.6449
For significance level 0.05:	1.6449	1.9600
For significance level 0.01:	2.3263	2.5758

Variance-Covariance matrix for estimated probabilities:

0.00004924	0.00000000	0.00000000	0.00000000
0.00000000	0.00003175	0.00000000	0.00000000
0.00000000	0.00000000	0.00076012	0.00000000
0.00000000	0.00000000	0.00000000	0.00024258

Confidence intervals:

	Unit 41 Tau	Unit 44 Tau
90 percent:	(0.8001, 0.8936)	(0.9432, 0.9995)
95 percent:	(0.7912, 0.9025)	(0.9378, 1.0049)
99 percent:	(0.7737, 0.9200)	(0.9273, 1.0155)

==

Likelihood ratio statistic for equality of recovery probabilities: 0.2994

Compare with quantiles of the chi-squared distribution with 1 d.f.:

For significance level 0.10: 2.706
For significance level 0.05: 3.841
For significance level 0.01: 6.635

APPENDIX B

Forty-eight hour survival estimates for steelhead released into Unit 41 and Unit 44 of Mayfield Dam, March 2002. Control - 102 released, 102 alive, 0 dead. Unit 41 test - 162 released, 128 alive, 27 dead, 7 unknown. Unit 44 test - 112 released, 100 alive, 3 dead, 9 unknown.

RESULTS FOR FULL MODEL (UNEQUAL LIVE/DEAD RECOVERY)

	estim.	std.err.	
S1 =	1.0	N/A	Control group survival*
Pa =	0.9655	(0.0186)	Live recovery probability
Pd =	0.8767	(0.1531)	Dead recovery probability
S2 =	0.8139	(0.0373)	Unit 41 survival
S3 =	0.9637	(0.0277)	Unit 44 survival

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.

log-likelihood : -151.2615

Tau =	0.8139	(0.0373)	Unit 41/Control ratio
Tau =	0.9637	(0.0277)	Unit 44/Control ratio

Z statistic for the equality of equal turbine survivals: 3.2273

Compare with quantiles of the normal distribution:

	1-tailed	2-tailed
For significance level 0.10:	1.2816	1.6449
For significance level 0.05:	1.6449	1.9600
For significance level 0.01:	2.3263	2.5758

Variance-Covariance matrix for estimated probabilities:

0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00034413	-0.00223790	-0.00032373	-0.00031164
0.00000000	-0.00223790	0.02345486	0.00293600	0.00282630
0.00000000	-0.00032373	0.00293600	0.00138811	0.00036780
0.00000000	-0.00031164	0.00282630	0.00036780	0.00076559

Confidence intervals:

	Unit 41 Tau	Unit 44 Tau
90 percent:	(0.7526, 0.8752)	(0.9181, 1.0092)
95 percent:	(0.7409, 0.8869)	(0.9094, 1.0179)
99 percent:	(0.7180, 0.9098)	(0.8924, 1.0349)

APPENDIX B

Forty-eight hour survival estimates for steelhead released into Unit 41 and Unit 44 of Mayfield Dam, March 2002. Control - 102 released, 102 alive, 0 dead. Unit 41 test - 162 released, 137 alive, 18 dead, 7 unknown. Unit 44 test - 112 released, 100 alive, 3 dead, 9 unknown.

RESULTS FOR REDUCED MODEL (EQUAL LIVE/DEAD RECOVERY)

	estim.	std.err.	
S1 =	1.0	N/A	Control group survival*
Pa = Pd	0.9574	(0.0104)	Recovery probability
S2 =	0.8258	(0.0305)	Unit 41 survival
S3 =	0.9709	(0.0166)	Unit 44 survival

* -- Because of constraints in the data set, this probability is assumed equal to 1.0; not estimated.

log-likelihood : -151.4143

Tau =	0.8258	(0.0305)	Unit 41/Control ratio
Tau =	0.9709	(0.0166)	Unit 44/Control ratio

Z statistic for the equality of equal turbine survivals: 4.1832

Compare with quantiles of the normal distribution:

	1-tailed	2-tailed
For significance level 0.10:	1.2816	1.6449
For significance level 0.05:	1.6449	1.9600
For significance level 0.01:	2.3263	2.5758

Variance-Covariance matrix for estimated probabilities:

0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00010836	0.00000000	0.00000000
0.00000000	0.00000000	0.00092807	0.00000000
0.00000000	0.00000000	0.00000000	0.00027454

Confidence intervals:

	Unit 41 Tau	Unit 44 Tau
90 percent:	(0.7757, 0.8759)	(0.9436, 0.9981)
95 percent:	(0.7661, 0.8855)	(0.9384, 1.0033)
99 percent:	(0.7474, 0.9043)	(0.9282, 1.0135)

Likelihood ratio statistic for equality of recovery probabilities: 0.3056

Compare with quantiles of the chi-squared distribution with 1 d.f.:

For significance level 0.10:	2.706
For significance level 0.05:	3.841
For significance level 0.01:	6.635

APPENDIX C

INDIVIDUAL FISH DISPOSITION DATA

APPENDIX TABLE C-1

Short-term turbine passage survival data on juvenile salmonids smolts released through Francis turbine Unit 41 (new) and 44(old) Mayfield Dam, March 2002. Fish were tagged with Normandeau's HI-Z Turb-N tags. Description of condition codes and details on injured fish are presented in Table 2-3.

Fish No.	Time			No. of Turb-N Tags recovered	Fish Data		
	Re-leased	Re-covered	At Large (min.)		Alive/ Dead	Condition Codes	Total Length (mm)
4 March 2002 - Testlot 1 : Unit 41, steelhead - Water temp= 6.0 C							
KJ2	12:30	14:00	90	2	ALIVE	A	182
KJ3	12:29	12:31	2	1	ALIVE	B	200
KJ6	13:05	13:09	4	2	ALIVE	HG	162
KJ7	13:05	13:38	33	2	ALIVE	A	202
KK0	14:17	14:21	4	2	ALIVE	A	175
KK1	14:16	14:20	4	2	ALIVE	A	212
4 March 2002 - Testlot 1 : Unit 41, chinook - Water temp= 6.0 C							
KJ1	12:12	12:50	38	2	ALIVE	A	155
KJ4	12:58	12:59	1	2	ALIVE	HE	142
KJ5	12:58	13:00	2	2	ALIVE	A	149
KJ8	14:05	14:10	5	2	ALIVE	A	160
KJ9	14:06	14:13	7	2	ALIVE	A	140
KL9	12:13	12:15	2	2	ALIVE	H	142
UM0	14:57	15:04	7	2	ALIVE	A	146
UM1	14:56	15:06	10	2	ALIVE	A	152
UM2	14:57	14:59	2	2	ALIVE	A	166
UM3	14:56	15:07	11	2	ALIVE	A	158
UM4	14:56	14:58	2	2	ALIVE	A	140
UM5	15:12	15:21	9	2	ALIVE	A	163
UM6	15:13	15:30	17	2	ALIVE	A	149
UM7	15:12	15:15	3	2	ALIVE	A	160
UM8	15:12	15:17	5	2	ALIVE	A	155
UM9	15:13	15:30	17	2	ALIVE	A	141
UN0	15:37	.	.	0	TAG & PIN		156
UN1	15:37	15:41	4	2	ALIVE	A	147
UN2	11:36	15:38	242	2	ALIVE	A	154
UN3	11:56	15:42	226	2	ALIVE	A	149
UN4	15:36	15:42	6	1	ALIVE	HB	142
UN5	15:47	15:55	8	2	ALIVE	A	157
UN6	15:46	15:53	7	2	ALIVE	A	148
UN7	15:48	15:52	4	2	ALIVE	A	152
UN8	15:47	16:13	26	1	ALIVE	B	148
UN9	15:47	16:18	31	1	ALIVE	A	147

APPENDIX TABLE C-1

Continued.

Fish No.	Time Re-leased	Re-covered	At Large (min.)	No. of Turb-N Tags recovered	Fish Data Alive/ Dead	Condition Codes	Total Length (mm)
5 March 2002 - Testlot 2 : Unit 41, chinook - Water temp= 5.0 C							
LA0	15:35	15:46	11	2	ALIVE	A	158
LA1	15:34	15:46	12	1	ALIVE	B	159
LA2	15:35	15:40	5	2	ALIVE	A	141
LA3	15:34	15:38	4	2	ALIVE	A	130
LA4	15:36	15:46	10	2	ALIVE	A	151
LA5	15:54	15:57	3	2	ALIVE	HG	145
LA6	15:55	15:59	4	2	ALIVE	A	149
LA7	15:54	16:01	7	0	TAG & PIN		142
LA8	15:53	16:03	10	2	DEAD	JH	140
LA9	15:55	15:59	4	1	ALIVE	HB	154
LB0	16:09	16:11	2	2	ALIVE	A	151
LB1	16:09	16:12	3	2	ALIVE	A	155
LB2	16:11	16:13	2	2	ALIVE	A	150
LB3	16:10	16:13	3	2	ALIVE	A	161
LB4	16:10	16:13	3	2	ALIVE	A	162
LB5	16:17	16:26	9	2	ALIVE	A	157
LB6	16:18	16:22	4	2	ALIVE	A	140
LB7	16:19	16:32	13	2	ALIVE	A	173
LB8	16:18	16:20	2	2	ALIVE	A	157
LB9	16:19	16:22	3	2	ALIVE	A	152
UP0	8:52	8:59	7	2	ALIVE	A	140
UP1	8:51	8:53	2	2	ALIVE	A	142
UP2	8:45	8:48	3	2	ALIVE	A	152
UP3	8:47	8:49	2	2	ALIVE	A	144
UP4	8:53	9:02	9	2	ALIVE	A	150
UP5	8:57	8:58	1	2	ALIVE	A	163
UP6	9:01	9:04	3	2	ALIVE	A	158
UP7	9:01	9:06	5	2	ALIVE	A	155
UP8	9:03	9:06	3	2	ALIVE	A	169
UP9	8:54	8:56	2	2	ALIVE	A	141
UR0	9:16	9:19	3	2	ALIVE	A	144
UR1	9:17	9:28	11	2	ALIVE	A	150
UR2	9:16	9:22	6	2	ALIVE	A	159
UR3	9:18	9:24	6	2	ALIVE	A	142
UR4	9:15	9:19	4	2	ALIVE	A	144
UR5	9:29	9:31	2	2	ALIVE	A	145
UR6	9:32	9:35	3	2	ALIVE	A	146
UR7	9:30	9:33	3	2	ALIVE	A	153
UR8	9:31	9:33	2	2	ALIVE	A	155
UR9	9:30	9:36	6	2	ALIVE	A	166
US0	10:27	10:28	1	2	ALIVE	A	155
US1	10:29	10:31	2	2	ALIVE	A	152

APPENDIX TABLE C-1

Continued.

Fish No.	Time: Re-leased	Time: Re-covered	Time: At Large (min.)	No. of Turb-N Tags recovered	Fish Data: Alive/ Dead	Fish Data: Condition Codes	Fish Data: Total Length (mm)
US2	10:27	10:29	2	2	ALIVE	A	147
US3	10:30	10:33	3	2	ALIVE	A	175
US4	10:28	10:31	3	2	ALIVE	A	153
US5	10:33	10:37	4	2	ALIVE	A	135
US6	10:31	10:35	4	2	ALIVE	A	154
US7	10:36	10:38	2	2	ALIVE	A	148
US8	10:35	10:38	3	2	ALIVE	A	155
US9	10:33	10:48	15	2	ALIVE	A	162
UT0	12:05	12:14	9	2	ALIVE	A	143
UT1	12:05	12:09	4	2	ALIVE	A	150
UT2	12:04	12:11	7	2	ALIVE	A	157
UT3	12:05	12:18	13	2	ALIVE	A	150
UT4	12:04	12:07	3	2	ALIVE	A	162
UT5	12:21	.	.	0	UNKNOWN	Z	150
UT6	12:21	12:28	7	2	ALIVE	A	147
UT7	12:20	12:23	3	2	ALIVE	A	155
UT8	12:20	12:28	8	2	ALIVE	A	144
UT9	12:21	12:24	3	2	ALIVE	A	152
UU0	12:41	12:50	9	2	ALIVE	A	135
UU1	12:41	12:45	4	2	ALIVE	A	157
UU2	12:39	12:50	11	2	ALIVE	A	160
UU3	12:39	13:00	21	1	ALIVE	WE	159
UU4	12:40	12:44	4	2	ALIVE	A	139
UU5	12:56	13:00	4	2	ALIVE	A	154
UU6	12:57	12:59	2	2	ALIVE	A	145
UU7	12:58	14:07	69	2	ALIVE	A	151
UU8	12:58	13:00	2	2	ALIVE	A	159
UU9	12:57	13:00	3	2	ALIVE	A	153
UV0	10:55	10:58	3	2	ALIVE	A	153
UV1	10:57	10:59	2	2	ALIVE	A	148
UV2	10:56	11:02	6	2	ALIVE	A	135
UV3	10:59	11:09	10	2	ALIVE	A	149
UV4	10:58	11:05	7	2	ALIVE	A	160
UV5	10:53	11:00	7	2	ALIVE	A	140
UV6	10:53	10:54	1	2	ALIVE	A	151
UV7	10:51	10:59	8	2	ALIVE	A	142
UV8	10:50	10:52	2	2	ALIVE	A	149
UV9	10:50	10:52	2	2	ALIVE	A	153
UW0	11:28	11:30	2	2	ALIVE	A	152
UW1	11:29	.	.	0	UNKNOWN	Z	140
UW2	11:29	12:38	69	2	ALIVE	A	166
UW3	11:29	11:32	3	2	ALIVE	A	139
UW4	11:28	11:35	7	2	ALIVE	A	141
UW5	11:47	11:49	2	2	ALIVE	A	139

APPENDIX TABLE C-1

Continued.

Fish No.	Time Re-leased	Time Re-covered	Time At Large (min.)	No. of Turb-N Tags recovered	Fish Data Alive/ Dead	Fish Data Condition Codes	Fish Data Total Length (mm)
UW6	11:46	11:58	12	2	ALIVE	A	150
UW7	11:45	11:53	8	2	ALIVE	A	149
UW8	11:47	11:51	4	2	ALIVE	A	140
UW9	11:46	11:54	8	2	ALIVE	A	157
UX0	13:29	13:33	4	2	ALIVE	H	133
UX1	13:28	13:31	3	2	ALIVE	A	175
UX2	13:27	13:43	16	2	ALIVE	A	159
UX3	13:27	13:41	14	2	ALIVE	A	145
UX4	13:28	13:31	3	2	ALIVE	A	147
UX5	13:45	13:56	11	2	ALIVE	A	155
UX6	13:46	13:55	9	2	ALIVE	A	150
UX7	13:45	13:52	7	2	ALIVE	A	138
UX8	13:46	13:49	3	2	ALIVE	A	149
UX9	13:45	13:51	6	2	ALIVE	A	138
UY0	14:18	14:23	5	2	ALIVE	A	150
UY1	14:18	.	.	0	TAG & PIN		154
UY2	14:19	14:23	4	2	DEAD	JH	149
UY3	14:20	14:24	4	2	ALIVE	A	152
UY4	14:19	14:29	10	2	ALIVE	A	160
UY5	14:36	14:40	4	2	ALIVE	G	175
UY6	14:35	14:47	12	0	TAG & PIN		161
UY7	14:36	14:38	2	2	ALIVE	A	150
UY8	14:36	14:47	11	2	ALIVE	A	155
UY9	14:36	14:41	5	2	ALIVE	A	150
UZ0	14:55	15:13	18	1	ALIVE	A	153
UZ1	14:56	14:59	3	2	ALIVE	A	158
UZ2	14:56	15:44	48	2	ALIVE	A	150
UZ3	14:57	15:06	9	2	ALIVE	A	155
UZ4	14:57	.	.	0	TAG & PIN		141
UZ5	15:18	15:23	5	2	ALIVE	A	147
UZ6	15:18	15:27	9	2	ALIVE	A	155
UZ7	15:19	15:28	9	2	ALIVE	A	170
UZ8	15:20	15:22	2	1	ALIVE	A	198
UZ9	15:19	15:28	9	2	ALIVE	WG	140
6 March 2002 - Testlot 3 : Unit 41, chinook - Water temp= 5.0 C							
LC0	8:59	9:05	6	2	ALIVE	HG	165
LC1	9:00	9:03	3	2	ALIVE	A	161
LC2	8:58	9:38	40	1	ALIVE	B	144
LC3	8:59	9:03	4	2	ALIVE	A	151
LC4	9:00	9:40	40	2	ALIVE	A	158
LC5	11:40	11:48	8	2	ALIVE	A	142

APPENDIX TABLE C-1

Continued.

Fish No.	Time			No. of Turb-N Tags recovered	Fish Data		
	Re-leased	Re-covered	At Large (min.)		Alive/ Dead	Condition Codes	Total Length (mm)
LC6	11:41	11:49	8	2	ALIVE	A	153
LC7	11:43	11:45	2	2	ALIVE	A	162
LC8	11:44	11:47	3	2	ALIVE	A	172
LC9	11:45	11:48	3	2	ALIVE	A	188
LD0	11:31	11:40	9	2	ALIVE	A	143
LD1	11:38	11:49	11	2	ALIVE	A	143
LD2	11:39	11:43	4	2	ALIVE	A	156
LD3	11:39	11:40	1	2	ALIVE	A	137
LD4	11:36	11:39	3	2	ALIVE	E	146
LD5	12:00	12:10	10	2	ALIVE	A	152
LD6	11:59	12:00	1	2	ALIVE	A	140
LD7	12:00	12:03	3	2	ALIVE	A	133
LD8	11:57	11:59	2	2	ALIVE	A	145
LD9	11:58	12:00	2	2	ALIVE	A	148
LE0	12:02	12:05	3	2	ALIVE	A	156
LE1	12:01	12:15	14	2	ALIVE	A	155
LE2	12:05	12:06	1	2	ALIVE	A	132
LE3	12:01	12:04	3	2	ALIVE	A	146
LE4	12:04	12:09	5	2	ALIVE	A	156
LE5	12:53	13:00	7	2	ALIVE	A	157
LE6	12:52	12:54	2	2	ALIVE	A	163
LE7	12:51	13:10	19	2	ALIVE	A	162
LE8	12:54	13:00	6	2	ALIVE	A	141
LE9	12:53	12:59	6	2	ALIVE	A	155
LF0	12:58	13:07	9	2	ALIVE	A	160
LF1	12:56	13:04	8	2	ALIVE	A	147
LF2	12:55	13:05	10	2	ALIVE	A	163
LF3	12:56	13:01	5	2	ALIVE	A	158
LF4	12:58	13:09	11	2	ALIVE	A	150
LF5	13:18	13:27	9	2	ALIVE	A	170
LF6	13:19	13:22	3	2	ALIVE	A	146
LF7	13:17	13:19	2	2	ALIVE	A	132
LF8	13:17	13:23	6	2	ALIVE	A	167
LF9	13:19	13:27	8	2	ALIVE	A	150
LH0	13:21	13:25	4	2	ALIVE	A	165
LH1	13:23	13:37	14	2	ALIVE	A	156
LH2	13:21	13:23	2	2	ALIVE	A	153
LH3	13:22	13:27	5	2	ALIVE	A	157
LH4	13:23	13:27	4	2	ALIVE	A	144
LJ0	13:57	13:59	2	2	ALIVE	A	136
LJ1	13:55	14:11	16	2	ALIVE	A	147
LJ2	13:56	.	.	0	TAG & PIN		153
LJ3	13:56	13:59	3	2	ALIVE	A	141
LJ4	13:57	19:02	305	2	ALIVE	A	147

APPENDIX TABLE C-1

Continued.

Fish No.	Time Re-leased	Time Re-covered	Time At Large (min.)	No. of Turb-N Tags recovered	Fish Data Alive/ Dead	Fish Data Condition Codes	Fish Data Total Length (mm)
LJ5	13:58	14:00	2	2	ALIVE	A	154
LJ6	13:59	14:06	7	2	ALIVE	A	138
LJ7	13:59	14:15	16	2	ALIVE	A	134
LJ8	13:58	14:01	3	2	ALIVE	A	152
LJ9	13:58	14:02	4	2	ALIVE	A	147
LK0	14:26	14:35	9	2	ALIVE	A	131
LK1	14:25	14:41	16	2	ALIVE	A	138
LK2	14:27	14:32	5	2	ALIVE	A	145
LK3	14:25	14:28	3	2	ALIVE	A	143
LK4	14:27	14:47	20	2	ALIVE	A	162
LK5	14:28	14:35	7	2	ALIVE	A	150
LK6	14:29	14:32	3	1	DEAD	B	156
LK7	14:28	14:31	3	2	ALIVE	A	137
LK8	14:29	14:33	4	2	ALIVE	A	137
LK9	14:28	15:04	36	2	ALIVE	A	144
LL0	15:04	15:29	25	2	ALIVE	E	158
LL1	15:03	15:06	3	2	ALIVE	A	151
LL2	15:04	15:35	31	2	ALIVE	A	153
LL3	15:05	15:31	26	2	ALIVE	H	155
LL4	15:04	15:18	14	2	ALIVE	A	146
LL5	15:07	15:11	4	2	ALIVE	A	155
LL6	15:05	15:07	2	2	ALIVE	A	152
LL7	15:06	15:08	2	2	ALIVE	A	145
LL8	15:07	15:25	18	2	ALIVE	A	157
LL9	15:06	15:16	10	1	ALIVE	B	136
YM0	15:42	15:49	7	2	ALIVE	A	167
YM1	15:44	15:50	6	2	ALIVE	A	146
YM2	15:43	15:53	10	1	ALIVE	B	150
YM3	15:43	15:45	2	1	ALIVE	B	165
YM4	15:44	15:47	3	2	ALIVE	A	130
YM5	15:45	15:46	1	2	ALIVE	A	150
YM6	15:45	15:48	3	2	ALIVE	A	145
YM7	15:46	15:49	3	2	ALIVE	A	158
YM8	15:46	15:59	13	2	ALIVE	A	165
YM9	15:45	15:50	5	2	ALIVE	A	142
YN0	16:04	.	.	0	UNKNOWN	Z	155
YN1	16:05	16:11	6	2	ALIVE	A	144
YN2	16:03	16:10	7	2	ALIVE	A	147
YN3	16:04	16:13	9	2	ALIVE	A	154
YN4	16:03	16:11	8	2	ALIVE	A	147

APPENDIX TABLE C-1

Continued.

Fish No.	Time			No. of Turb-N Tags recovered	Fish Data		
	Re-leased	Re-covered	At Large (min.)		Alive/ Dead	Condition Codes	Total Length (mm)
7 March 2002 - Testlot 4 : Control, steelhead - Water temp= 4.5 C							
LL5	9:06	9:11	5	2	ALIVE	A	180
LL6	9:07	9:20	13	2	ALIVE	A	200
LL7	9:08	9:15	7	2	ALIVE	A	190
LL8	9:05	9:12	7	2	ALIVE	A	194
LL9	9:04	9:06	2	2	ALIVE	A	199
YN5	9:10	9:13	3	2	ALIVE	A	199
YN6	9:12	9:16	4	2	ALIVE	A	200
YN7	9:11	9:14	3	2	ALIVE	A	182
YN8	9:14	9:18	4	2	ALIVE	A	204
YN9	9:13	9:16	3	2	ALIVE	A	185
YP0	9:29	9:32	3	2	ALIVE	A	211
YP1	9:30	10:21	51	2	ALIVE	A	176
YP2	9:33	9:41	8	2	ALIVE	A	177
YP3	9:31	10:14	43	2	ALIVE	A	207
YP4	9:32	9:36	4	2	ALIVE	A	170
YP5	9:38	9:42	4	2	ALIVE	A	193
YP6	9:35	9:41	6	2	ALIVE	A	177
YP7	9:36	9:39	3	2	ALIVE	A	202
YP8	9:37	13:33	236	2	ALIVE	A	186
YP9	9:36	10:05	29	2	ALIVE	A	185
YR0	10:36	10:41	5	2	ALIVE	A	180
YR1	10:32	10:37	5	2	ALIVE	A	200
YR2	10:33	10:36	3	2	ALIVE	A	190
YR3	10:34	10:43	9	2	ALIVE	A	197
YR4	10:35	10:36	1	2	ALIVE	A	190
YR5	10:38	10:42	4	2	ALIVE	A	192
YR6	10:40	13:25	165	2	ALIVE	A	216
YR7	10:39	10:41	2	2	ALIVE	A	206
YR8	10:41	10:42	1	2	ALIVE	A	197
YR9	10:37	10:38	1	2	ALIVE	A	165
YS0	10:53	10:57	4	2	ALIVE	A	169
YS1	10:56	11:06	10	2	ALIVE	A	173
YS2	10:55	10:59	4	2	ALIVE	A	176
YS3	10:54	10:56	2	2	ALIVE	A	177
YS4	10:56	11:01	5	2	ALIVE	A	192
YS5	11:02	11:07	5	2	ALIVE	A	180
YS6	11:00	11:03	3	2	ALIVE	A	185
YS7	10:59	11:01	2	2	ALIVE	A	188
YS8	11:03	11:09	6	2	ALIVE	A	203
YS9	11:01	11:07	6	2	ALIVE	A	197
YT0	11:43	12:29	46	2	ALIVE	A	181
YT1	11:44	13:17	93	2	ALIVE	HG	170

APPENDIX TABLE C-1

Continued.

Fish No.	Time Re-leased	Re-covered	At Large (min.)	No. of Turb-N Tags recovered	Fish Data Alive/ Dead	Condition Codes	Total Length (mm)
YT2	11:42	11:45	3	2	ALIVE	A	194
YT3	11:43	11:47	4	2	DEAD	JHG	180
YT4	11:44	11:50	6	2	ALIVE	A	216
YT5	11:45	11:48	3	2	ALIVE	A	175
YT6	11:48	14:20	152	2	ALIVE	A	186
YT7	11:46	11:57	11	2	DEAD	JGH	177
YT8	11:46	12:57	71	2	ALIVE	A	180
YT9	11:45	14:40	175	2	ALIVE	A	176
YU0	13:10	13:16	6	2	ALIVE	A	181
YU1	13:09	17:40	271	2	ALIVE	A	196
YU2	13:11	17:00	229	2	ALIVE		192
YU3	13:09	13:13	4	2	ALIVE	A	210
YU4	13:10	13:36	26	1	DEAD	F	186
YU5	13:12	13:14	2	2	ALIVE	H	195
YU6	13:13	13:26	13	2	ALIVE	A	206
YU7	13:11	17:01	230	2	ALIVE	A	185
YU8	13:13	13:43	30	2	DEAD	EG	180
YU9	13:12	13:28	16	2	ALIVE	A	180
YV0	14:31	15:47	76	1	DEAD	B	184
YV1	14:30	14:33	3	2	ALIVE	A	186
YV2	14:29	14:39	10	2	ALIVE	A	202
YV3	14:31	15:14	43	2	ALIVE	A	192
YV4	14:30	14:36	6	2	ALIVE	H	200
YV5	14:33	.	.	0	TAG & PIN		181
YV6	14:32	14:34	2	2	ALIVE		195
YV7	14:34	14:39	5	2	ALIVE	A	190
YV8	14:33	14:49	16	2	ALIVE	A	191
YV9	14:32	15:34	62	2	ALIVE	A	198
YW0	15:32	15:35	3	2	ALIVE	A	196
YW1	15:33	15:44	11	2	ALIVE	A	195
YW2	15:33	15:35	2	2	ALIVE	A	185
YW3	15:31	15:41	10	2	ALIVE	A	197
YW4	15:32	15:55	23	2	ALIVE	A	177
YW5	15:34	16:39	65	1	ALIVE	HB	190
YW6	15:34	.	.	0	UNKNOWN	Z	205
YW7	15:35	16:44	69	2	ALIVE	TA	195
YW8	15:35	15:59	24	2	ALIVE	A	190
YW9	15:33	15:36	3	2	ALIVE	H	189
YX0	16:27	.	.	0	UNKNOWN	Z	185
YX1	16:28	16:51	23	2	ALIVE	A	200
YX2	16:28	16:37	9	2	ALIVE	A	160
YX3	16:27	.	.	0	UNKNOWN	Z	193
YX4	16:28	16:40	12	2	ALIVE	A	174
YX5	16:31	16:33	2	2	ALIVE	A	166

APPENDIX TABLE C-1

Continued.

Fish No.	Time			No. of Turb-N Tags recovered	Fish Data		
	Re-leased	Re-covered	At Large (min.)		Alive/ Dead	Condition Codes	Total Length (mm)
YX6	16:30	16:32	2	2	ALIVE	A	190
YX7	16:30	16:32	2	2	ALIVE		218
YX8	16:29	17:57	88	2	ALIVE	A	190
YX9	16:29	16:46	17	2	ALIVE	A	198
YY0	17:13	.	.	0	UNKNOWN	Z	186
YY1	17:14	17:17	3	2	ALIVE	A	191
YY2	17:12	17:22	10	2	ALIVE	A	158
YY3	17:14	17:20	6	2	ALIVE	A	175
YY4	17:13	17:46	33	2	ALIVE	A	198
YY5	17:15	17:25	10	2	ALIVE	A	177
YY6	17:15	17:19	4	2	ALIVE	A	198
YY7	17:16	17:18	2	2	ALIVE	A	198
YY8	17:15	17:20	5	2	ALIVE	A	167
YY9	17:16	.	.	0	UNKNOWN	Z	197
8 March 2002 - Testlot 5 : Unit 44, steelhead - Water temp= 4.5 C							
BU0	10:31	10:34	3	2	ALIVE	A	165
BU1	10:30	15:17	287	1	ALIVE	B	192
BU2	10:31	10:33	2	2	ALIVE	A	175
BU3	10:30	10:32	2	2	ALIVE	A	208
BU4	10:31	10:34	3	2	ALIVE	A	195
BU5	10:33	10:42	9	2	ALIVE	A	178
BU6	10:33	10:35	2	2	ALIVE	A	193
BU7	10:33	10:37	4	2	ALIVE	HE	192
BU8	10:32	10:42	10	1	ALIVE	B	187
BU9	10:34	10:40	6	1	ALIVE	B	216
BV0	11:02	11:16	14	2	ALIVE	A	203
BV1	11:02	11:12	10	2	ALIVE	A	178
BV2	11:03	.	.	0	UNKNOWN	Z	193
BV3	11:01	11:04	3	2	ALIVE	A	167
BV4	11:03	11:17	14	2	ALIVE	A	182
BV5	11:04	11:09	5	2	ALIVE	E	182
BV6	11:05	11:22	17	2	ALIVE	A	190
BV7	11:05	11:09	4	2	ALIVE	A	188
BV8	11:04	11:32	28	2	ALIVE	A	182
BV9	11:04	11:06	2	2	ALIVE	A	159
BW0	11:44	11:58	14	2	ALIVE	A	197
BW1	11:44	11:46	2	2	ALIVE	A	210
BW2	11:45	12:45	60	2	ALIVE	A	182
BW3	11:45	12:22	37	2	ALIVE	A	166
BW4	11:46	11:49	3	2	ALIVE	A	177
BW5	11:48	11:51	3	2	ALIVE	A	173

APPENDIX TABLE C-1

Continued.

Fish No.	Time Re-leased	Re-covered	At Large (min.)	No. of Turb-N Tags recovered	Fish Data Alive/ Dead	Condition Codes	Total Length (mm)
BW6	11:46	12:30	44	2	ALIVE	A	182
BW7	11:47	11:50	3	2	ALIVE	A	180
BW8	11:46	11:48	2	2	ALIVE	A	185
BW9	11:48	12:57	69	2	ALIVE	A	190
BX0	12:11	12:15	4	2	ALIVE	A	196
BX1	12:11	12:15	4	2	ALIVE	A	182
BX2	12:10	12:14	4	1	ALIVE	B	188
BX3	12:10	12:47	37	2	ALIVE	A	166
BX4	12:12	12:14	2	1	ALIVE	B	192
BX5	12:13	12:15	2	2	ALIVE	A	186
BX6	12:14	12:15	1	2	ALIVE	A	185
BX7	12:13	12:15	2	1	ALIVE	B	205
BX8	12:13	12:15	2	2	DEAD	JHG	185
BX9	12:12	12:14	2	2	ALIVE	A	200
BY0	12:36	.	.	0	UNKNOWN	Z	187
BY1	12:35	12:38	3	2	ALIVE	WH	178
BY2	12:35	12:50	15	2	ALIVE	A	207
BY3	12:35	12:44	9	2	ALIVE	A	186
BY4	12:36	12:41	5	2	ALIVE	A	196
BY5	12:38	13:25	47	2	ALIVE	G	188
BY6	12:37	12:43	6	2	ALIVE	H	179
BY7	12:38	.	.	0	UNKNOWN	Z	164
BY8	12:37	12:41	4	2	ALIVE	A	184
BZ7	12:37	12:40	3	2	ALIVE	A	197
VA0	13:17	13:26	9	2	ALIVE	B	187
VA1	13:16	13:36	20	2	ALIVE	A	195
VA2	13:17	13:20	3	2	ALIVE	A	205
VA3	13:18	13:21	3	2	ALIVE	A	182
VA4	13:17	13:43	26	2	ALIVE	H	183
VA5	13:19	13:23	4	2	ALIVE	H	222
VA6	13:20	15:55	155	2	ALIVE	A	175
VA7	13:18	13:22	4	2	DEAD	JH	192
VA8	13:19	13:54	35	2	ALIVE	A	210
VA9	13:20	14:09	49	2	ALIVE	HBW	188
VB0	13:58	14:53	55	1	ALIVE	B	190
VB1	13:58	14:16	18	1	ALIVE	B	195
VB2	13:59	14:01	2	2	ALIVE	A	173
VB3	13:59	14:02	3	2	ALIVE	H	188
VB4	13:58	16:24	146	2	ALIVE	A	192
VB5	14:00	15:21	81	2	ALIVE	A	176
VB6	14:01	14:21	20	2	ALIVE	A	186
VB7	14:01	14:28	27	2	ALIVE	A	180
VB8	14:00	14:03	3	2	ALIVE	H	188
VB9	14:00	14:03	3	2	ALIVE	A	185

APPENDIX TABLE C-1

Continued.

Fish No.	Time Re-leased	Time Re-covered	Time At Large (min.)	No. of Turb-N Tags recovered	Fish Data Alive/ Dead	Fish Data Condition Codes	Fish Data Total Length (mm)
VC0	14:32	15:29	57	2	ALIVE	A	187
VC1	14:31	14:35	4	2	DEAD		188
VC2	14:32	14:34	2	2	ALIVE	A	176
VC3	14:31	15:47	76	2	ALIVE	A	183
VC4	14:32	14:35	3	2	ALIVE	A	177
VC5	14:33	16:56	143	2	ALIVE	G	196
VC6	14:34	14:43	9	2	ALIVE	A	197
VC7	14:34	14:40	6	2	ALIVE	A	210
VC8	14:33	14:36	3	2	ALIVE	A	180
VC9	14:34	14:47	13	2	ALIVE	A	190
VD0	15:01	15:03	2	2	ALIVE	A	188
VD1	14:59	.	.	0	UNKNOWN	Z	195
VD2	15:00	15:15	15	2	ALIVE		192
VD3	15:00	15:09	9	2	ALIVE	H	190
VD4	14:59	15:12	13	2	ALIVE	A	208
VD5	15:02	15:05	3	1	DEAD	BG	202
VD6	15:01	16:53	112	2	ALIVE	A	177
VD7	15:03	15:19	16	2	ALIVE	A	184
VD8	15:02	15:24	22	2	ALIVE	A	192
VD9	15:03	.	.	0	UNKNOWN	Z	170
VE0	15:46	16:18	32	2	ALIVE	A	180
VE1	15:45	15:50	5	2	ALIVE	A	188
VE2	15:44	16:09	25	2	ALIVE	A	200
VE3	15:44	15:46	2	2	ALIVE	A	183
VE4	15:43	15:54	11	2	ALIVE	A	188
VE5	15:47	15:50	3	2	ALIVE	A	187
VE6	15:50	15:53	3	2	ALIVE	A	183
VE7	15:49	15:53	4	2	ALIVE	A	177
VE8	15:48	15:52	4	2	ALIVE	A	157
VE9	15:48	15:51	3	2	ALIVE	A	176
VF0	16:09	16:10	1	2	ALIVE	A	207
VF1	16:09	16:11	2	2	ALIVE	A	188
VF2	16:07	16:07	0	2	ALIVE	A	197
VF3	16:09	16:11	2	2	ALIVE	A	192
VF4	16:08	16:09	1	2	ALIVE	A	198
VF5	16:11	16:13	2	2	ALIVE	A	182
VF6	16:11	16:13	2	2	ALIVE	A	207
VF7	16:12	16:15	3	2	ALIVE	A	190
VF8	16:11	16:14	3	2	ALIVE	A	190
VF9	16:13	16:27	14	2	ALIVE	A	175
VH0	16:50	16:53	3	2	ALIVE	A	180
VH1	16:49	16:50	1	2	ALIVE	A	192
VH2	16:48	17:00	12	2	ALIVE	A	178
VH3	16:49	16:57	8	2	ALIVE	A	182

APPENDIX TABLE C-1

Continued.

Fish No.	Time Re-leased	Time Re-covered	Time At Large (min.)	No. of Turb-N Tags recovered	Fish Data Alive/ Dead	Fish Data Condition Codes	Fish Data Total Length (mm)
VH4	16:47	16:49	2	2	ALIVE	A	186
VH5	16:53	16:56	3	2	ALIVE	A	176
VH6	16:51	16:56	5	2	ALIVE	A	186
VH7	16:54	16:57	3	2	ALIVE	A	186
VH8	16:52	16:56	4	2	ALIVE	A	175
VH9	16:51	16:56	5	2	ALIVE	A	157
YZ0	9:46	11:46	120	2	ALIVE	A	186
YZ1	9:44	9:46	2	2	ALIVE	A	200
YZ2	9:45	10:05	20	2	ALIVE	A	193
YZ3	9:45	11:58	133	2	ALIVE	A	187
YZ4	9:45	11:24	99	2	ALIVE	A	210
YZ5	9:47	17:16	449	2	ALIVE	A	202
YZ6	9:47	9:50	3	2	ALIVE	H	188
YZ7	9:46	11:34	108	2	ALIVE	A	161
YZ8	9:48	.	.	0	UNKNOWN	Z	190
YZ9	9:46	10:12	26	2	ALIVE	A	202
9 March 2002 - Testlot 6 : Unit 41, chinook - Water temp= 5.0 C							
VJ0	8:59	9:24	25	1	ALIVE	HB	151
VJ1	8:58	9:13	15	1	ALIVE	BH	147
VJ2	8:58	9:03	5	2	ALIVE	A	160
VJ3	8:59	9:11	12	2	ALIVE	A	170
VJ4	8:58	9:06	8	1	ALIVE	B	145
VJ5	9:01	9:02	1	2	ALIVE	A	150
VJ6	9:01	.	.	0	TAG & PIN		138
VJ7	9:00	9:05	5	2	ALIVE	A	141
VJ8	9:00	9:11	11	2	ALIVE	A	152
VJ9	9:00	9:10	10	2	ALIVE	A	149
VK0	9:24	9:44	20	2	DEAD	EHJ	141
VK1	9:23	9:29	6	2	ALIVE	A	155
VK2	9:24	9:28	4	2	DEAD	EG	150
VK3	9:23	9:27	4	2	ALIVE	A	148
VK4	9:23	9:35	12	2	ALIVE	A	157
VK5	9:26	.	.	0	TAG & PIN		143
VK6	9:25	9:40	15	2	ALIVE	A	145
VK7	9:24	9:28	4	2	ALIVE	A	147
VK8	9:25	9:32	7	2	ALIVE	A	140
VK9	9:26	9:29	3	2	ALIVE	H	168
VL0	9:51	10:04	13	2	ALIVE	A	157
VL1	9:51	.	.	0	TAG & PIN		151
VL2	9:50	9:54	4	2	ALIVE	A	152
VL3	9:50	9:54	4	2	ALIVE	A	173

APPENDIX TABLE C-1

Continued.

Fish No.	Time Re-leased	Re-covered	At Large (min.)	No. of Turb-N Tags recovered	Fish Data Alive/ Dead	Condition Codes	Total Length (mm)
VL4	9:51	10:01	10	2	DEAD	HJ	145
VL5	9:53	9:56	3	2	ALIVE	A	140
VL6	9:52	9:57	5	2	ALIVE	A	175
VL7	9:52	10:03	11	2	ALIVE	A	169
VL8	9:53	10:08	15	2	ALIVE	A	165
VL9	9:53	10:04	11	2	ALIVE	A	140
VM0	10:29	10:34	5	2	ALIVE	A	156
VM1	10:27	10:41	14	2	ALIVE	A	152
VM2	10:28	10:45	17	2	ALIVE	A	152
VM3	10:28	.	.	0	TAG & PIN		149
VM4	10:29	10:35	6	2	ALIVE	A	155
VM5	10:30	10:42	12	2	ALIVE	A	136
VM6	10:29	10:35	6	2	ALIVE	A	160
VM7	10:30	10:49	19	2	ALIVE	A	169
VM8	10:31	10:34	3	2	ALIVE	A	173
VM9	10:31	10:38	7	2	ALIVE	A	160
VN0	11:02	11:06	4	2	ALIVE	A	158
VN1	11:04	11:08	4	2	ALIVE	A	151
VN2	11:03	11:06	3	2	ALIVE	A	157
VN3	11:03	11:06	3	2	ALIVE	A	145
VN4	11:03	11:11	8	1	ALIVE	B	152
VN5	11:05	11:09	4	2	ALIVE	A	133
VN6	11:06	11:08	2	2	ALIVE	A	142
VN7	11:04	11:07	3	2	ALIVE	A	149
VN8	11:05	11:17	12	2	ALIVE	A	152
VN9	11:05	11:07	2	2	ALIVE	A	150
VP0	11:25	11:35	10	2	ALIVE	A	140
VP1	11:26	.	.	0	UNKNOWN	Z	152
VP2	11:25	11:29	4	2	ALIVE	A	138
VP3	11:26	11:30	4	2	ALIVE	A	145
VP4	11:25	11:35	10	2	ALIVE	A	147
VP5	11:28	.	.	0	TAG & PIN	Z	139
VP6	11:28	11:35	7	2	ALIVE	A	140
VP7	11:27	11:39	12	2	ALIVE	A	152
VP8	11:27	11:30	3	2	ALIVE	A	141
VP9	11:27	11:32	5	2	ALIVE	A	171
VR0	12:04	12:08	4	2	ALIVE	A	152
VR1	12:06	12:14	8	2	ALIVE	A	156
VR2	12:06	12:16	10	2	ALIVE	HW	166
VR3	12:05	12:09	4	2	ALIVE	A	143
VR4	12:05	12:14	9	2	ALIVE	A	155
VR5	12:08	12:16	8	2	ALIVE	A	146
VR6	12:07	12:15	8	2	ALIVE	H	151
VR7	12:07	12:17	10	2	ALIVE	A	157

APPENDIX TABLE C-1

Continued.

Fish No.	Time Re-leased	Re-covered	At Large (min.)	No. of Turb-N Tags recovered	Fish Data Alive/ Dead	Condition Codes	Total Length (mm)
VR8	12:07	12:12	5	1	ALIVE	BH	167
VR9	12:06	12:18	12	2	DEAD	JH	152
VS0	12:29	12:33	4	2	ALIVE	A	148
VS1	12:28	12:38	10	2	ALIVE	A	159
VS2	12:17	12:37	20	2	ALIVE	A	168
VS3	12:28	12:38	10	2	L	Q	184
VS4	12:18	12:39	21	2	ALIVE	A	158
VS5	12:31	12:38	7	2	ALIVE	A	142
VS6	12:30	12:33	3	2	ALIVE	A	149
VS7	12:29	12:33	4	2	ALIVE	A	158
VS8	12:30	12:35	5	2	DEAD	HEJ	150
VS9	12:30	12:45	15	2	ALIVE	A	159
VT0	13:20	13:24	4	2	ALIVE	A	141
VT1	13:21	13:31	10	2	ALIVE	A	149
VT2	13:23	13:33	10	2	ALIVE	A	152
VT3	13:24	13:28	4	2	ALIVE	A	150
VT4	13:22	13:25	3	2	ALIVE	A	134
VT5	13:27	13:29	2	2	ALIVE	A	140
VT6	13:26	13:31	5	2	ALIVE	A	150
VT7	13:28	13:30	2	2	ALIVE	A	156
VT8	13:25	13:28	3	2	ALIVE	A	153
VT9	13:29	13:31	2	2	ALIVE	A	145
VU0	13:40	13:42	2	2	ALIVE	A	146
VU1	13:42	13:51	9	2	ALIVE	A	152
VU2	13:44	13:46	2	2	ALIVE	A	151
VU3	13:41	13:43	2	2	ALIVE	A	148
VU4	13:43	13:57	14	2	ALIVE	A	131
VU5	13:48	13:50	2	2	ALIVE	A	152
VU6	13:46	13:48	2	2	ALIVE	A	142
VU7	13:45	13:50	5	2	ALIVE	A	151
VU8,	13:48	13:57	9	2	ALIVE	A	151
VU9	13:47	13:49	2	2	ALIVE	A	153
VV0	14:34	15:22	48	2	ALIVE	A	149
VV1	14:35	14:37	2	2	ALIVE	A	152
VV2	14:35	14:37	2	2	ALIVE	A	155
VV3	14:36	14:38	2	2	ALIVE	A	157
VV4	14:37	14:39	2	2	ALIVE	A	147
VV5	14:41	14:45	4	2	ALIVE	A	146
VV6	14:40	14:42	2	2	ALIVE	A	155
VV7	14:41	14:48	7	2	ALIVE	A	135
VV8	14:38	14:40	2	2	ALIVE	A	151
VV9	14:39	14:41	2	2	ALIVE	A	164
VW0	14:56	14:58	2	2	ALIVE	A	142
VW1	14:55	14:57	2	2	ALIVE	A	150

APPENDIX TABLE C-1

Continued.

Fish No.	Time			No. of Turb-N Tags recovered	Fish Data		
	Re-leased	Re-covered	At Large (min.)		Alive/ Dead	Condition Codes	Total Length (mm)
VW2	14:57	15:07	10	2	ALIVE	A	155
VW3	14:58	15:06	8	2	ALIVE	A	143
VW4	14:55	14:57	2	2	ALIVE	A	190
VW5	15:00	15:04	4	2	ALIVE	A	146
VW6	15:02	15:05	3	2	ALIVE	A	169
VW7	14:59	15:13	14	2	ALIVE	A	140
VW8	15:01	15:03	2	2	ALIVE	A	149
VW9	15:02	15:09	7	2	ALIVE	A	136
VX0	15:32	15:38	6	2	ALIVE	A	155
VX1	15:31	15:34	3	2	ALIVE	H	151
VX2	15:31	15:43	12	2	ALIVE	A	194
VX3	15:32	15:40	8	2	ALIVE	A	160
VX4	15:30	.	.	0	UNKNOWN	Z	149
VX5	15:33	15:40	7	2	ALIVE	A	138
VX6	15:33	15:41	8	2	ALIVE	A	145
VX7	15:33	15:37	4	2	ALIVE	A	156
VX8	15:32	15:35	3	2	DEAD	A	152
VX9	15:34	15:39	5	2	ALIVE	A	154
VY0	15:56	16:11	15	2	ALIVE	A	156
VY1	15:56	15:59	3	2	ALIVE	A	151
VY2	15:57	15:58	1	2	ALIVE	A	154
VY3	15:55	15:58	3	1	DEAD	GE	154
VY4	15:55	16:11	16	2	ALIVE	A	147
VY5	15:58	16:01	3	2	ALIVE	A	150
VY6	15:58	16:11	13	2	ALIVE	A	138
VY7	15:58	16:03	5	2	ALIVE	A	143
VY8	15:57	16:04	7	2	ALIVE	A	158
VY9	15:57	16:03	6	1	ALIVE	B	155
11 March 2002 - Testlot 7 : Unit 41, chinook - Water temp= 5.0 C							
VZ0	8:53	8:56	3	2	ALIVE	A	149
VZ1	8:52	9:14	22	2	ALIVE	A	152
VZ2	8:54	8:58	4	2	ALIVE	A	149
VZ3	8:53	9:10	17	2	ALIVE	A	148
VZ4	8:54	8:57	3	2	ALIVE	A	160
VZ5	8:55	8:57	2	2	ALIVE	A	155
VZ6	8:54	9:03	9	2	ALIVE	HG	152
VZ7	8:56	8:59	3	2	ALIVE	H	154
VZ8	8:55	9:32	37	2	DEAD	A	159
VZ9	8:56	8:58	2	2	ALIVE	A	162
ZM0	9:20	10:58	98	2	ALIVE	TA	102
ZM1	9:21	9:39	18	2	ALIVE	A	156

APPENDIX TABLE C-1

Continued.

Fish No.	Time Re-leased	Time Re-covered	Time At Large (min.)	No. of Turb-N Tags recovered	Fish Data Alive/Dead	Fish Data Condition Codes	Fish Data Total Length (mm)
ZM2	9:21	9:24	3	2	ALIVE	A	151
ZM3	9:22	.	.	0	UNKNOWN	Z	141
ZM4	9:21	9:30	9	2	ALIVE	A	155
ZM5	9:24	9:53	29	2	ALIVE	TA	161
ZM6	9:23	9:45	22	2	ALIVE	A	169
ZM7	9:22	9:31	9	2	ALIVE	A	183
ZM8	9:23	9:25	2	2	ALIVE	A	162
ZM9	9:24	9:52	28	2	ALIVE	A	153
ZN0	10:40	10:44	4	2	ALIVE	A	117
ZN1	10:40	10:42	2	2	ALIVE	A	108
ZN2	10:39	10:47	8	2	ALIVE	A	120
ZN3	10:40	10:55	15	2	ALIVE	A	101
ZN4	10:41	10:46	5	2	ALIVE	A	101
ZN5	10:42	11:00	18	2	ALIVE	A	162
ZN6	10:42	10:54	12	2	ALIVE	A	171
ZN7	10:41	10:55	14	2	ALIVE	A	145
ZN8	10:42	11:04	22	2	DEAD	A	150
ZN9	10:43	10:53	10	2	ALIVE	A	161
ZP0	11:21	11:24	3	2	ALIVE	H	151
ZP1	11:22	11:28	6	2	ALIVE	A	137
ZP2	11:22	11:26	4	2	ALIVE	A	144
ZP3	11:22	11:26	4	1	ALIVE	A	151
ZP4	11:23	11:26	3	2	ALIVE	A	138
ZP5	11:23	11:37	14	2	ALIVE	A	168
ZP6	11:24	11:27	3	2	ALIVE	A	156
ZP7	11:24	11:28	4	2	ALIVE	A	177
ZP8	11:24	11:29	5	2	ALIVE	A	142
ZP9	11:25	11:35	10	2	ALIVE	TA	152
ZR0	11:44	11:54	10	2	ALIVE	A	165
ZR1	11:45	12:21	36	1	DEAD	B	142
ZR2	11:44	11:52	8	1	ALIVE	B	146
ZR3	11:44	11:53	9	2	ALIVE	A	163
ZR4	11:43	12:07	24	2	ALIVE	A	146
ZR5	11:46	11:59	13	1	DEAD	B	157
ZR6	11:45	11:59	14	2	ALIVE	A	140
ZR7	11:46	12:13	27	2	ALIVE	A	152
ZR8	11:46	11:52	6	2	ALIVE	A	143
ZR9	11:47	14:18	151	1	ALIVE	B	151
ZS0	12:14	12:47	33	2	ALIVE	A	158
ZS1	12:44	14:57	133	2	ALIVE	A	155
ZS2	12:43	13:54	71	2	ALIVE	A	141
ZS3	12:43	12:49	6	2	ALIVE	A	144
ZS4	12:45	13:17	32	2	ALIVE	A	141
ZS5	12:46	12:49	3	2	ALIVE	A	146

APPENDIX TABLE C-1

Continued.

Fish No.	Time Re-leased	Time Re-covered	Time At Large (min.)	No. of Turb-N Tags recovered	Fish Data Alive/ Dead	Fish Data Condition Codes	Fish Data Total Length (mm)
ZS6	12:47	13:01	14	2	DEAD	G	156
ZS7	12:45	.	.	0	TAG & PIN		146
ZS8	12:46	13:26	40	1	ALIVE	A	157
ZS9	12:45	13:02	17	1	ALIVE	A	147
ZT0	13:44	13:54	10	2	ALIVE	A	156
ZT1	13:45	13:57	12	2	ALIVE	A	156
ZT2	13:44	13:47	3	2	ALIVE	A	167
ZT3	13:46	13:56	10	2	ALIVE	A	155
ZT4	13:45	13:49	4	2	ALIVE	A	155
ZT5	13:47	13:51	4	2	ALIVE	A	159
ZT6	13:47	13:54	7	2	ALIVE	A	148
ZT7	13:46	13:57	11	2	ALIVE	A	150
ZT8	13:46	13:55	9	2	ALIVE	A	137
ZT9	13:47	14:00	13	2	ALIVE	A	125
ZU0	14:08	14:11	3	2	ALIVE	A	152
ZU1	14:08	14:15	7	2	ALIVE	A	146
ZU2	14:09	14:15	6	2	ALIVE	A	183
ZU3	14:09	14:12	3	2	ALIVE	A	155
ZU4	14:07	14:10	3	2	ALIVE	A	142
ZU5	14:10	14:14	4	2	ALIVE	A	140
ZU6	14:11	14:15	4	2	ALIVE	A	150
ZU7	14:10	14:14	4	2	ALIVE	A	150
ZU8	14:10	14:13	3	2	ALIVE	A	158
ZU9	14:10	14:12	2	2	ALIVE	A	142
ZV0	14:40	14:43	3	2	ALIVE	A	143
ZV1	14:39	14:41	2	2	ALIVE	A	141
ZV2	14:40	14:50	10	2	ALIVE	A	151
ZV3	14:38	14:41	3	2	ALIVE	A	137
ZV4	14:39	14:51	12	2	ALIVE	A	153
ZV5	14:42	14:49	7	2	ALIVE	A	142
ZV6	14:42	14:44	2	2	ALIVE	A	142
ZV7	14:44	14:46	2	2	ALIVE	A	163
ZV8	14:44	14:46	2	2	ALIVE	A	138
ZV9	14:43	14:45	2	2	ALIVE	A	140
ZW0	15:11	15:12	1	2	ALIVE	A	150
ZW1	15:11	15:24	13	2	ALIVE	A	167
ZW2	15:13	15:15	2	2	ALIVE	A	152
ZW3	15:12	15:15	3	2	ALIVE	A	146
ZW4	15:14	15:19	5	2	ALIVE	A	167
ZW5	15:15	15:18	3	2	ALIVE	A	152
ZW6	15:18	15:20	2	2	ALIVE	A	146
ZW7	15:16	15:19	3	2	ALIVE	H	156
ZW8	15:17	15:20	3	2	ALIVE	A	138
ZW9	15:15	15:17	2	2	ALIVE	A	155

APPENDIX TABLE C-1

Continued.

Fish No.	Time Re-leased	Time Re-covered	Time At Large (min.)	No. of Turb-N Tags recovered	Fish Data Alive/ Dead	Fish Data Condition Codes	Fish Data Total Length (mm)
12 March 2002 - Testlot 8 : Unit 44, steelhead - Water temp= 5.5 C							
CP8	9:24	9:27	3	2	ALIVE	A	189
ZA0	11:06	13:13	127	2	ALIVE	A	155
ZA1	11:05	11:31	26	2	ALIVE	A	193
ZA2	11:02	11:09	7	2	ALIVE	A	176
ZA3	11:06	12:04	58	2	ALIVE	A	184
ZA4	11:06	11:09	3	2	ALIVE	A	173
ZA5	11:08	11:32	24	2	DEAD	GHJ	212
ZA6	11:08	12:18	70	2	ALIVE	A	177
ZA7	11:07	11:10	3	2	ALIVE	A	176
ZA8	11:07	11:56	49	2	ALIVE	A	193
ZA9	11:08	11:11	3	2	ALIVE	HE	190
ZB0	12:09	12:36	27	2	ALIVE	A	175
ZB1	12:11	12:17	6	2	ALIVE	A	175
ZB2	12:10	12:17	7	2	ALIVE	H	179
ZB3	12:10	12:45	35	2	ALIVE	A	200
ZB4	11:01	11:03	2	2	ALIVE	A	195
ZB5	12:11	12:16	5	2	DEAD	HJ	172
ZB6	12:12	12:32	20	2	ALIVE	A	158
ZB7	12:12	12:15	3	1	ALIVE	A	192
ZB8	12:13	13:01	48	2	ALIVE	A	177
ZB9	12:12	12:14	2	2	ALIVE	H	205
ZC0	12:47	13:00	13	1	ALIVE	A	172
ZC1	12:46	13:44	58	2	ALIVE	A	191
ZC2	12:46	13:46	60	2	ALIVE	B	181
ZC3	12:47	12:49	2	2	ALIVE	A	202
ZC4	12:46	13:10	24	2	ALIVE	A	206
ZC5	12:48	12:50	2	2	ALIVE	A	190
ZC6	12:48	12:51	3	2	DEAD	GHJ	188
ZC7	12:50	14:18	88	2	ALIVE	A	218
ZC8	12:48	13:12	24	2	ALIVE	A	200
ZC9	12:49	.	.	0	TAG & PIN		177
ZD0	13:21	13:27	6	2	ALIVE	H	188
ZD1	13:22	13:26	4	1	ALIVE	H	191
ZD2	13:20	13:26	6	2	ALIVE	A	196
ZD3	13:21	13:23	2	2	DEAD	EJ	215
ZD4	13:21	15:39	138	2	ALIVE	A	210
ZD5	13:23	13:25	2	2	ALIVE	A	200
ZD6	13:24	.	.	0	TAG & PIN		187
ZD7	13:24	13:34	10	2	ALIVE	A	196
ZD8	13:23	15:02	99	2	ALIVE	A	195
ZD9	13:22	13:25	3	2	ALIVE	A	197
ZE0	14:01	14:28	27	2	ALIVE	A	203

APPENDIX TABLE C-1

Continued.

Fish No.	Time Re-leased	Re-covered	At Large (min.)	No. of Turb-N Tags recovered	Fish Data Alive/ Dead	Condition Codes	Total Length (mm)
ZE1	14:00	14:12	12	1	ALIVE	B	193
ZE2	13:59	14:02	3	2	ALIVE	A	178
ZE3	14:01	14:08	7	2	ALIVE	A	195
ZE4	14:00	14:22	22	2	ALIVE	A	180
ZE5	14:03	14:19	16	2	ALIVE	A	199
ZE6	14:02	14:04	2	2	ALIVE	A	177
ZE7	14:02	14:07	5	2	ALIVE	A	178
ZE8	14:03	14:08	5	2	ALIVE	A	187
ZE9	14:02	.	.	0	UNKNOWN	Z	208
ZF0	14:35	14:47	12	2	ALIVE	A	186
ZF1	14:33	14:38	5	2	ALIVE	H	204
ZF2	14:34	.	.	0	TAG & PIN		191
ZF3	14:33	16:10	97	2	ALIVE	A	193
ZF4	14:34	14:44	10	2	ALIVE	A	173
ZF5	14:37	14:40	3	1	ALIVE	H	180
ZF6	14:35	14:59	24	2	ALIVE	A	188
ZF7	14:35	14:55	20	2	ALIVE	A	192
ZF8	14:36	14:42	6	2	ALIVE	A	200
ZF9	14:36	14:57	21	2	ALIVE	A	193
ZH0	15:28	15:30	2	1	DEAD	F	187
ZH1	15:29	15:41	12	2	ALIVE	A	179
ZH2	15:29	.	.	0	UNKNOWN		187
ZH3	15:28	15:46	18	2	ALIVE	A	185
ZH4	15:29	.	.	0	UNKNOWN		212
ZH5	15:32	15:39	7	2	ALIVE	A	185
ZH6	15:31	16:00	29	2	ALIVE	B	210
ZH7	15:30	15:35	5	2	DEAD	GF	175
ZH8	15:31	15:38	7	1	ALIVE	BGD	198
ZH9	15:30	16:17	47	2	ALIVE	A	211
ZJ0	15:59	16:04	5	2	ALIVE	A	178
ZJ1	15:59	16:06	7	2	ALIVE	A	200
ZJ2	15:59	16:01	2	2	ALIVE	A	170
ZJ3	16:00	16:37	37	2	ALIVE	A	221
ZJ4	16:00	16:04	4	2	ALIVE	A	193
ZJ5	16:01	16:11	10	2	ALIVE	A	166
ZJ6	16:02	16:12	10	2	ALIVE	A	172
ZJ7	16:01	16:05	4	2	ALIVE	A	192
ZJ8	16:02	.	.	0	UNKNOWN		188
ZJ9	16:02	16:22	20	2	ALIVE	ED	208
ZK0	16:47	17:00	13	2	ALIVE	A	175
ZK1	16:45	16:48	3	2	ALIVE	A	190
ZK2	16:46	16:58	12	2	ALIVE	A	169
ZK3	16:44	16:59	15	1	ALIVE	A	195
ZK4	16:52	16:53	1	2	ALIVE	A	163

APPENDIX TABLE C-1

Continued.

Fish No.	Time Re-leased	Time Re-covered	At Large (min.)	No. of Turb-N Tags recovered	Fish Data Alive/ Dead	Condition Codes	Total Length (mm)
ZK5	16:50	16:55	5	2	ALIVE	A	204
ZK6	16:48	16:52	4	2	ALIVE	A	181
ZK7	16:47	16:49	2	2	ALIVE	A	201
ZK8	16:50	16:54	4	2	ALIVE	A	183
ZK9	16:49	16:52	3	2	ALIVE	A	200
ZX0	8:32	9:21	49	2	ALIVE	A	182
ZX1	8:33	9:49	76	2	ALIVE	A	197
ZX2	8:33	9:16	43	2	ALIVE	A	187
ZX3	8:32	17:43	551	2	ALIVE	TA	182
ZX4	8:33	9:10	37	2	ALIVE	A	186
ZX5	8:34	8:41	7	2	ALIVE	A	195
ZX6	8:34	8:38	4	2	ALIVE	A	155
ZX7	8:36	11:21	165	2	ALIVE	A	179
ZX8	8:35	8:42	7	2	ALIVE	A	201
ZX9	8:35	8:55	20	2	ALIVE	A	200
ZY0	9:22	9:49	27	2	ALIVE	A	185
ZY1	9:21	11:14	113	2	ALIVE	A	200
ZY2	9:22	11:03	101	2	ALIVE	A	200
ZY3	9:21	12:43	202	2	ALIVE	A	190
ZY4	9:22	13:19	237	2	ALIVE	TA	168
ZY5	9:24	11:54	150	2	ALIVE	A	198
ZY6	9:23	9:37	14	2	ALIVE	A	200
ZY7	9:24	9:44	20	2	ALIVE	A	197
ZY8	9:23	11:06	103	2	ALIVE	A	184
ZZ0	10:00	10:05	5	2	DEAD	HJ	170
ZZ1	9:59	10:04	5	2	ALIVE	H	188
ZZ2	10:01	10:04	3	2	ALIVE	A	191
ZZ3	10:00	14:06	246	2	ALIVE	A	170
ZZ4	9:59	10:11	12	1	ALIVE	A	211
ZZ5	10:01	.	.	0	UNKNOWN		164
ZZ6	10:01	11:30	89	0	ALIVE		191
ZZ7	10:03	15:15	312	2	ALIVE	A	190
ZZ8	10:02	10:05	3	2	ALIVE	A	180
ZZ9	10:02	10:06	4	2	DEAD	HJ	179
13 March 2002 - Testlot 9 : Control, steelhead - Water temp= 5.0 C							
AX8	9:26	9:29	3	2	ALIVE	A	180
AX9	9:23	9:25	2	2	ALIVE	A	203
PL0	9:20	9:22	2	2	ALIVE	A	176
PL1	9:18	9:21	3	2	ALIVE	A	199
PL2	9:22	9:23	1	2	ALIVE	A	172
PL3	9:17	9:27	10	2	ALIVE	A	188

APPENDIX TABLE C-1

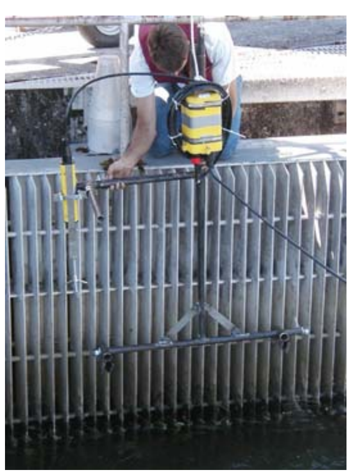
Continued.

Fish No.	Time			No. of Turb-N Tags recovered	Fish Data		
	Re-leased	Re-covered	At Large (min.)		Alive/ Dead	Condition Codes	Total Length (mm)
PL4	9:19	9:20	1	2	ALIVE	A	170
PL5	9:24	9:27	3	2	ALIVE	A	195
PL6	9:23	9:32	9	2	ALIVE	A	190
PL7	9:27	9:33	6	2	ALIVE	A	174
ZL0	8:46	8:47	1	2	ALIVE	A	184
ZL1	8:48	8:50	2	2	ALIVE	A	186
ZL2	8:49	8:51	2	2	ALIVE	A	185
ZL3	8:47	8:49	2	2	ALIVE	A	171
ZL4	8:45	8:48	3	2	ALIVE	A	184
ZL5	8:51	8:52	1	2	ALIVE	A	170
ZL6	8:53	9:14	21	2	ALIVE	A	185
ZL7	8:54	9:03	9	2	ALIVE	A	209
ZL8	8:50	10:25	95	2	ALIVE	A	189
ZL9	8:52	9:00	8	2	ALIVE	A	176

Cowlitz River Project
Mayfield Dam

Fish Guidance Louver Evaluation
2002 Study Program Results

FINAL



Prepared For: Tacoma Power – Mark LaRiviere
Prepared By: Northwest Hydraulic Consultants, Inc.

December, 2002

Introduction

Northwest Hydraulic Consultants (**nhc**) completed an extensive evaluation of the hydrodynamic conditions and fish tracking at Mayfield Dam as part of the relicensing program of the hydroelectric project (**nhc**, 2001). Follow on studies are documented in this letter report summarizing the results of a recently completed field measurement program of the south intake bay at the Mayfield Dam hydroelectric project. This letter report presents comparisons with a much more extensive field measurement, computational modeling, and fish tracking study conducted in 2001. Previously completed studies at Mayfield Dam include a detailed evaluation of the performance and fish bypass efficiency of the louvered intakes at Mayfield Dam on the Cowlitz River. The 2001 study scope included an extensive 3-dimensional flow velocity measurement program, hydroacoustic juvenile fish tracking, and development of a Computational Fluid Dynamics (CFD) numerical model of the south louver intake bay. In the 2001 work, the field velocity measurements were conducted with an Acoustic Doppler Velocimeter (ADV) probe that measures velocity components in the vertical and horizontal directions in three dimensions. Field measurements were used to verify the numerically simulated results from the CFD model. Hydroacoustic fish tracking data was compared to the simulated and measured velocity maps to determine if there was direct correlation between fish movement and velocity vectors.

The 2002 field program at Mayfield Dam was undertaken as a follow-up to the extensive work performed in 2001. This letter report includes a description of the field program, a review of the velocity measurement approach and results of limited CFD simulations performed in 2001 that approximate those measured in 2002, and conclusions regarding the high flow hydrodynamic conditions of the louver screen and fish bypass facilities. Photographs, CAD plots and CFD output plots are enclosed as supporting information.

References

"Cowlitz River Project Mayfield Dam, Fish Guidance Louver Evaluations." Northwest Hydraulic Consultants, December, 2001.

Field Program

nhc personnel arrived at Mayfield Dam on July 9, 2002 to begin the velocity measurement program. The primary task completed on this day was the field modification of a louver vane indexing probe mount constructed specifically for deploying the ADV probe. The concept for the device was based on experience gained during the 2001 field program. The device allows for precise positioning of the velocimeter underwater at any elevation along the vertical length of the louver vanes, and enables collection of velocity measurements at any location within approximately 18 inches of the louver vanes. The probe mount also permits the placement of the velocimeter such that velocities can be measured just inside the louver vane openings. The probe mount required a precise fit to the louver vanes, necessitating final modification of the probe mount on-site.

The louver vane indexing probe mount was first deployed on the east louver vane panel of the south intake bay (Photos 1 and 2) on the afternoon of July 9th following the instrument's field modifications. The indexing guides detached from the louver vanes (Photo 3) as the device was initially lowered underwater, causing the instrument to drift away from the wall. Further modifications to the device, including securing the indexing guides and attaching sheet metal panels and a 100 lb lead weight for stabilization, were necessary to maintain position on the louver vanes.

These modifications were performed prior to deploying the instrument on July 10th (Photos 4 and 5). The device performed well until it was submerged approximately 15 feet, at which point it became stuck. Though not visible from the surface, debris lodged against the louver wall likely prevented the instrument from additional lowering. Tree branches and other debris were visible higher on the louver vanes, and heavier debris was likely present on the louver panel. Attempts to raise and lower the device to push through the debris were unsuccessful and further jarring of the device might have jeopardized the velocimeter.

The vane indexing instrument would not be able to collect data at lower elevations on the louver vanes due to the apparent debris loading on the louver panels. Instead, the device used to deploy the velocimeter in 2001 was readied. This apparatus consisted of an aluminum stay with mounting brackets for the velocimeter, a directional fin, and an attached 100 lb lead weight (Photo 6). The device was void of any indexing guides, but rather could be lowered to any location in the water column. Using this instrument, velocity measurements were recorded on the afternoon of July 10th and completed on July 11th.

Velocity Measurement Approach

Velocity measurements were recorded using an Sontek 10 MHz Acoustic Doppler Velocimeter (ADV). The ADV uses a physical principle called the Doppler effect to simultaneously measure water velocity in three directions. Measurements were made at a sampling rate of 10 Hertz for a period of not less than 60 seconds.

Velocity measurements were recorded at three elevations on four transects within the louvered intake. The transects were located 58.25, 43.25, 28.25, and 3.25 feet upstream of the intake apex at water surface elevations of 395.6, 402.3, and 416.3 feet above msl (NGVD 29). These elevations represent approximately 0.8, 0.6, and 0.2 of total depth in the water column below the surface, respectively.

After the velocity measurements were recorded in the field, they were condensed using the WinADV32 software package. Values for u, v, and w velocity vectors (velocity in x direction, velocity in y direction, velocity in z direction, respectively) at each point were initially filtered of poor quality data and then corrected for the pitch and roll of the ADV underwater (average pitch and roll of the probe were recorded in addition to the velocity components).

Velocity Measurement Results

The results of the field measurements were as expected, showing higher velocity magnitudes for the higher flow conditions present in 2002 in comparison to the lower flow conditions measured in 2001. Flow through the intake was approximately 5,835 cfs (5841 cfs on 10 July, and 5831 cfs on 11 July), which is roughly 4.5 and 2.3 times the flow through the intake during the 2001 measurement program. As in 2001, the wing gates on the north intake bay were used for the second set of measurements to force all project outflow through the south bay, simulating a total project outflow of roughly double the available actual outflow. Velocities in the system range from a minimum of 1.9 fps with both north and south louver bays open, to a maximum of 4.7 fps, with an average of 3.9 fps, with only the south bay open . These velocities are roughly double those recorded at 2,580 cfs, the maximum flow measured in the 2001 field measurement program. During the 2002 measurement program, two fish bypass attraction pumps were operating continuously. The third pump was not started when all flow was confined to the south intake bay.

Figures 1 through 3 depict in plan view the locations where velocities were measured at elevations 395.6, 402.3, and 416.4 feet msl (NGVD 29), respectively. The red arrow at each position indicates the direction of the velocity vector and the vector magnitude is depicted numerically adjacent to the arrow. Figures 4 through 6 show the velocity vectors in elevation view at the east louver wall, intake centerline, and west louver wall, respectively.

Interesting to note is the velocity vector direction in the horizontal plane at the 58.25 and 43.25 feet transects. The average velocity direction at these transects is shifted approximately 9 degrees from the longitudinal axis of the intake. The velocity direction at the remaining transects is closer to being parallel to the intake axis. Three reasons for the skewed velocity vectors are theorized:

1. uneven debris loading on the intake entrance trashrack,
2. uneven debris loading on the louver walls,
3. and/or a water surface elevation differential within the intake.

Photos 7 through 9 show the surface flow patterns entering the intake on the afternoon of July 11th. Debris is clearly unevenly distributed on the entrance trashrack as evidenced by the difference in head loss across the trashrack from one side to the other. Unevenly distributed trash could cause the non-uniform inflow of water to the intake, creating a skewed current that from the longitudinal axis of the intake.

In addition to uneven debris build-up on the entrance trashrack, uneven trapping of debris against the louver walls could also direct the flow away from the longitudinal axis of the intake. Substantial trash was observed lodged on the louver vanes, as shown in the photos and as evidenced by the inability to lower the louver vane indexing probe mount more than about 15 feet below the surface. Finding similar debris lodging against the vanes at greater depths throughout the intake is likely.

A third possible cause for the oblique direction of the velocity vectors is a difference in water surface elevation between the upstream and downstream sides of the east and west louver vane panels. Water reaching the 8-inch bypass slot at the intake apex was pumped back into the system just downstream of the intake (Photos 10 and 11), entering the channel from the left side just downstream of the intake bay. The addition of this water might have caused a difference in water surface elevation across the channel immediately downstream of the louver bay that translated upstream to the exit face of the louvers. The outflow from the right and left louver vanes is separated by the center pier up to very near the pump-back discharge location. A differential water surface elevation across the channel at the pier would cause a corresponding difference in water surface elevation at the exit sides of the two louver walls, further resulting in differential discharge from one side to the other of the intake bay. Even a small difference in water surface elevation within the intake would be enough to skew the flow direction a noticeable amount. Although measurements were not taken to confirm this cross-gradient in the outflow channel, the turbulence patterns and flow direction observed at the water surface suggested that a gradient might be present.

CFD Simulations

There was insufficient budget available to re-acquire lease and licensing rights to the STAR-CD commercial code and perform additional CFD model simulations during the 2002 study program. However, several simulations were made during 2001 that represented conditions nearly similar to that observed in 2002. Therefore, selected output from the previously completed simulations most similar to the 2002 flow conditions was extracted and is presented for comparison purposes in the figures.

The 2001 CFD simulations were completed for 5,000 cfs total inflow into one louver bay, compared to the 5,835 cfs observed during the 2002 tests. However, the CFD model was not used to evaluate the distribution of flow resulting from non-uniform flow through the two sides of the intake bay as observed in 2002. Therefore, the results show uniform velocity distribution through each side of the intake bay and do not approximate the skewed velocity vectors observed in the field in 2002. With additional scope and funding, the CFD model could be used to revisit the simulation to determine the approximate extent of debris accumulation by calibrating the model to the 2002 observed measurements. Figures 7 through 9 show computed velocities throughout the intake on three horizontal planes at elevation 395.6 ft msl, 402.3 ft msl, and 416.4 ft msl, respectively. Figures 10 through 12 show computed velocities in the immediate vicinity of a small area of louver vanes, also on three horizontal planes at elevation 395.6 ft, 402.3 ft, and 416.4 ft msl (NGVD 29), respectively.

Conclusions

Additional field velocity measurements were completed at an approximate intake flow of 5,835 cfs on July 10 and 11, 2002. Measured velocity magnitude and direction are provided in figures 1 through 6 of this letter report. Velocity characteristics indicate roughly parallel, uniform velocities on the order of double the maximum velocities measured during the 2001 program, which was expected given flowrate was approximately twice that which occurred during the 2001 measurement program. The

2001 program was accomplished at a total intake bay flow of about 1240 cfs and 2580 cfs. The higher flow in 2001 was achieved by closing the north louver bay wing gates and forcing all flow through the south bay.

CFD model results from the 2001 study were reviewed for simulation runs made at or near the discharge observed during the 2002 field program. The scope and funding for the 2002 study year was inadequate for relicensing the STAR-CD CFD code used for the Mayfield study, thus the simulations were not completed for the 2002 inflow conditions. However, simulations at 5,000 cfs flow were completed in 2001, and were compared with the 2002 field velocity measurements. Results are provided in figures enclosed in this letter report (Figures 7 through 12).

Comparison of the measured velocities from 2001 and 2002 indicates that the magnitude of the 2002 velocities was, as expected, roughly double that measured in the field in 2001 (230% on average, of those magnitudes measured in 2001). Of note during the 2002 measurements was the presence of significant debris accumulation on the louver vane panels, the upstream intake trashracks, and in the bypass entrance slot. These debris accumulations may have caused an apparent directional skew to one side of the intake bay of the measured velocity vectors at several transects within the intake. Non-uniform or unbalanced debris accumulation on one side of the intake bay results in slightly higher head loss through the most adversely blocked side of the intake, with consequent loss of hydraulic conveyance through the louver vanes. The resulting differential flow capacity is reflected in an average skew of the velocity vectors toward the higher capacity side of the intake. The CFD model simulations from the 2001 study specified uniform approach flow to the intake, in accordance with the measured velocities used for calibration. As a result, the high flow CFD simulations completed in 2001 do not simulate the observed skew in the 2002 field measurements resulting from debris blockage. However, the overall average velocity magnitude of the CFD simulations and field measurements compare quite favorably in the portions of the flow field not influenced by debris blockage. The computed vertical flow distribution of velocity magnitude and direction from the CFD model compares quite favorably with the field measurements. Evidence of significant debris accumulation in the louver vanes and in the bypass entrance was noted by Tacoma during the planned dewatering of the south intake bay during the winter of 2001-2002. The lower 5 to 8 feet of the bypass entrance was completely occluded by debris lodged in the turning vanes. The velocity measurements reflected this occlusion in the vertically non-uniform velocity profiles observed.

Recommendations

Based on the field observations made during these tests in 2001 and 2002, **nhc** recommends regular cleaning of the louver vanes and entrance trashracks. The efficacy of cleaning the turning vanes in the bypass entrance with regard to improving fish guidance efficiency is not fully known at this time. There was some evidence that this occlusion may have benefited fish attraction into the upper bypass entrance during the hydroacoustic tracking work conducted in 2001. We also recommend inspection of the bypass conduit from the secondary separator to the base of the turning vanes by means of underwater video camera. If significant debris is noted, we recommend it be cleaned from the conduit to reduce the chance of fish injury in passing. In addition, to determine the hydraulic characteristics of the louver intake over the full range of project outflows, **nhc** recommends that the CFD model be used to simulate outflows up to 7,000 cfs per bay, which is the maximum design flow for the intake. We also recommend that the CFD model be used to simulate the observed conditions from the 2002 field work, in order to characterize the effects of non-uniform debris accumulation on bypass flow and overall intake flow distribution.

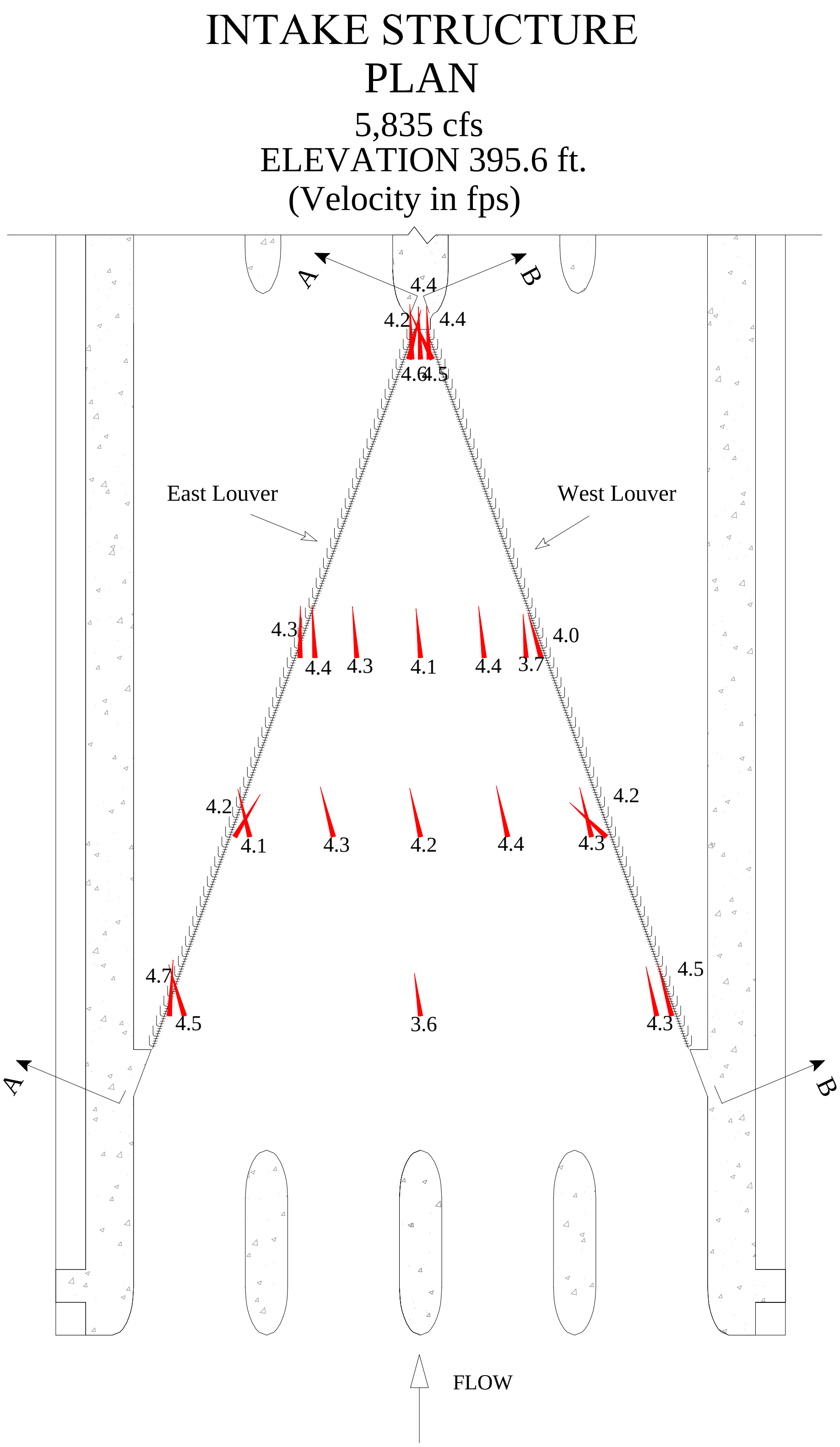


Figure 1 – Field measured velocity at elevation 395.6 ft (msl) and 5,835 cfs. Velocity magnitude shown in feet per second.

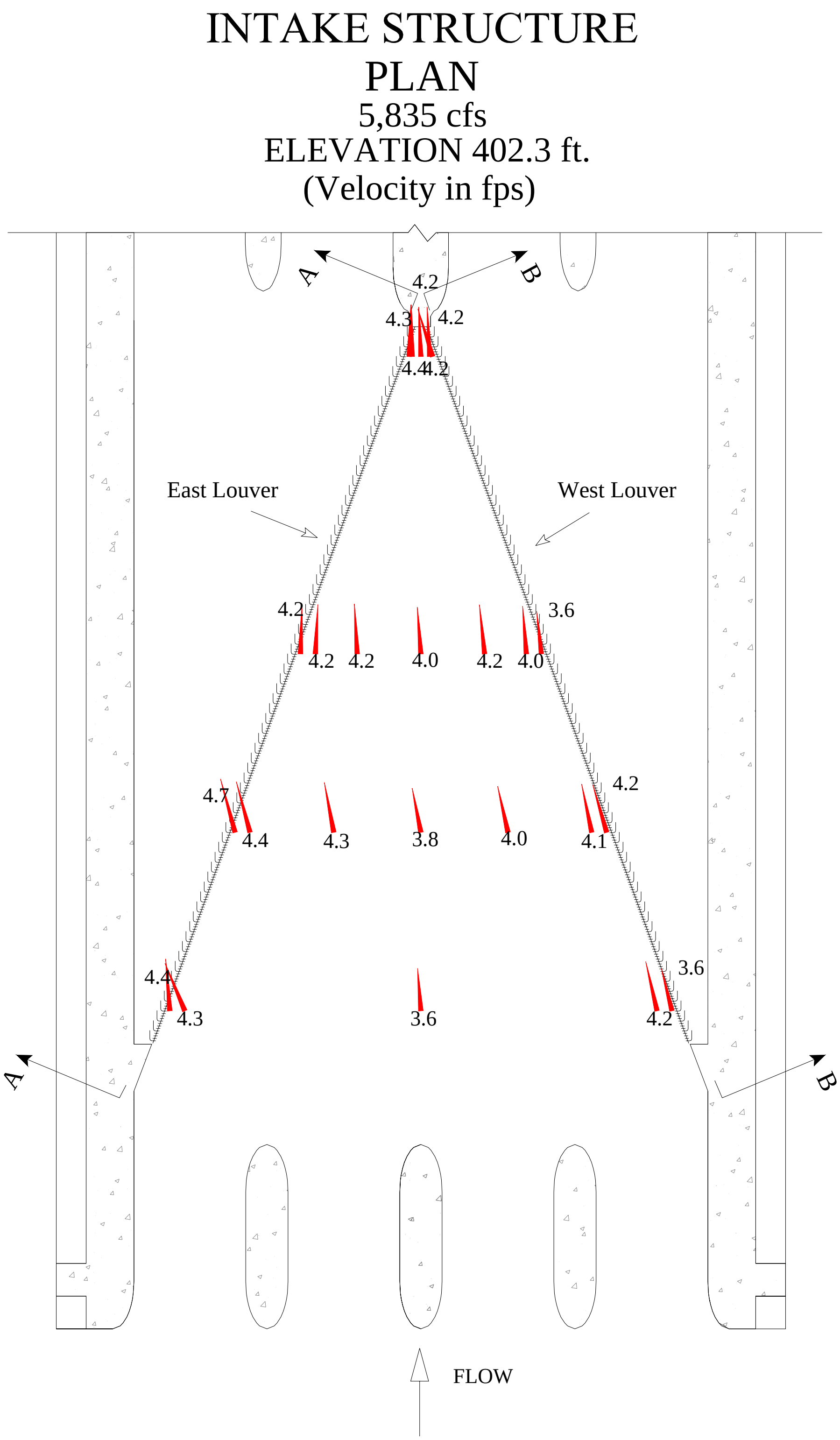


Figure 2 – Field measured velocity at elevation 402.3 ft (msl) and 5,835 cfs. Velocity magnitude shown in feet per second.

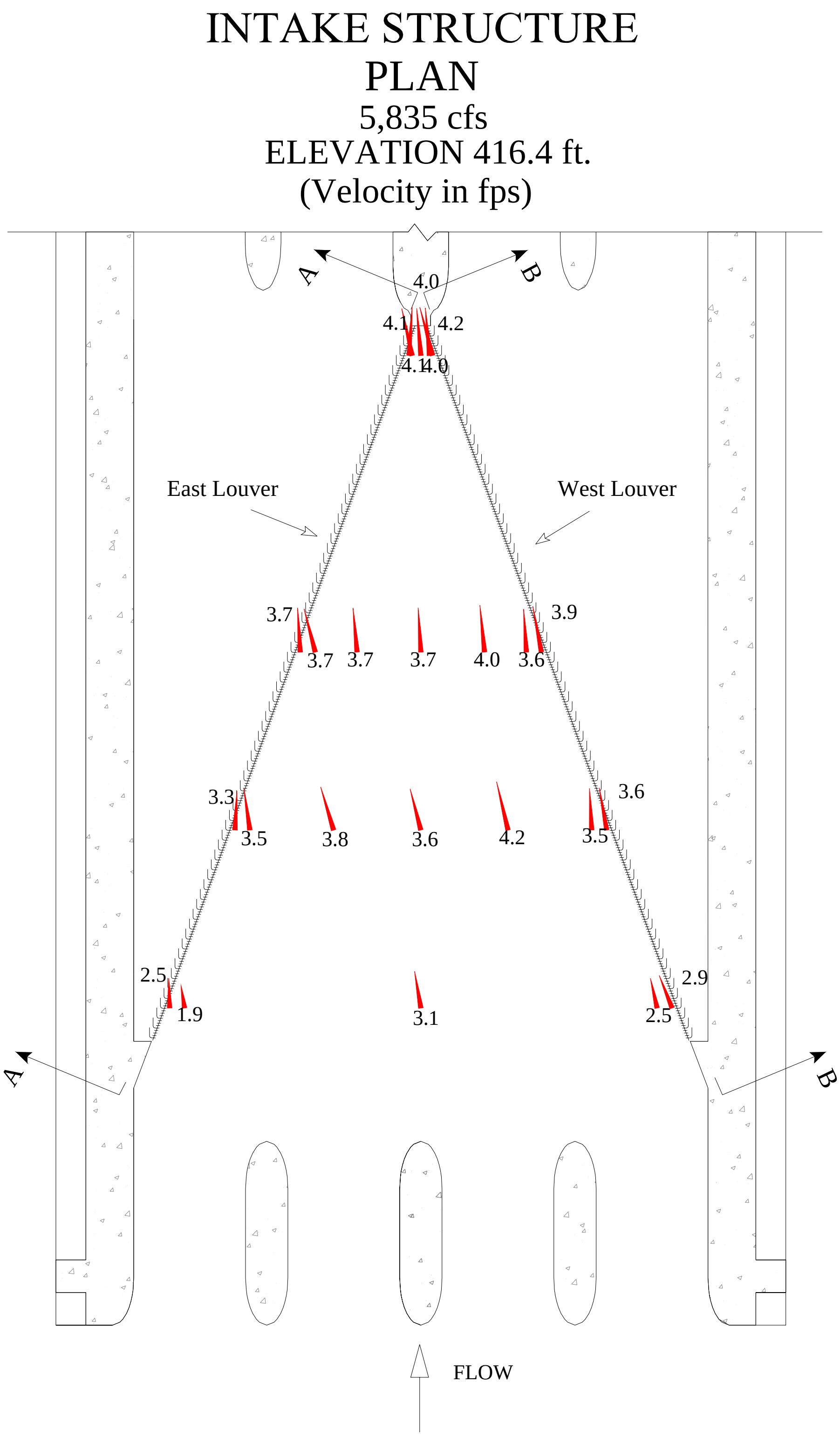


Figure 3 – Field measured velocity at elevation 416.4 ft (msl) and 5,835 cfs. Velocity magnitude shown in feet per second.

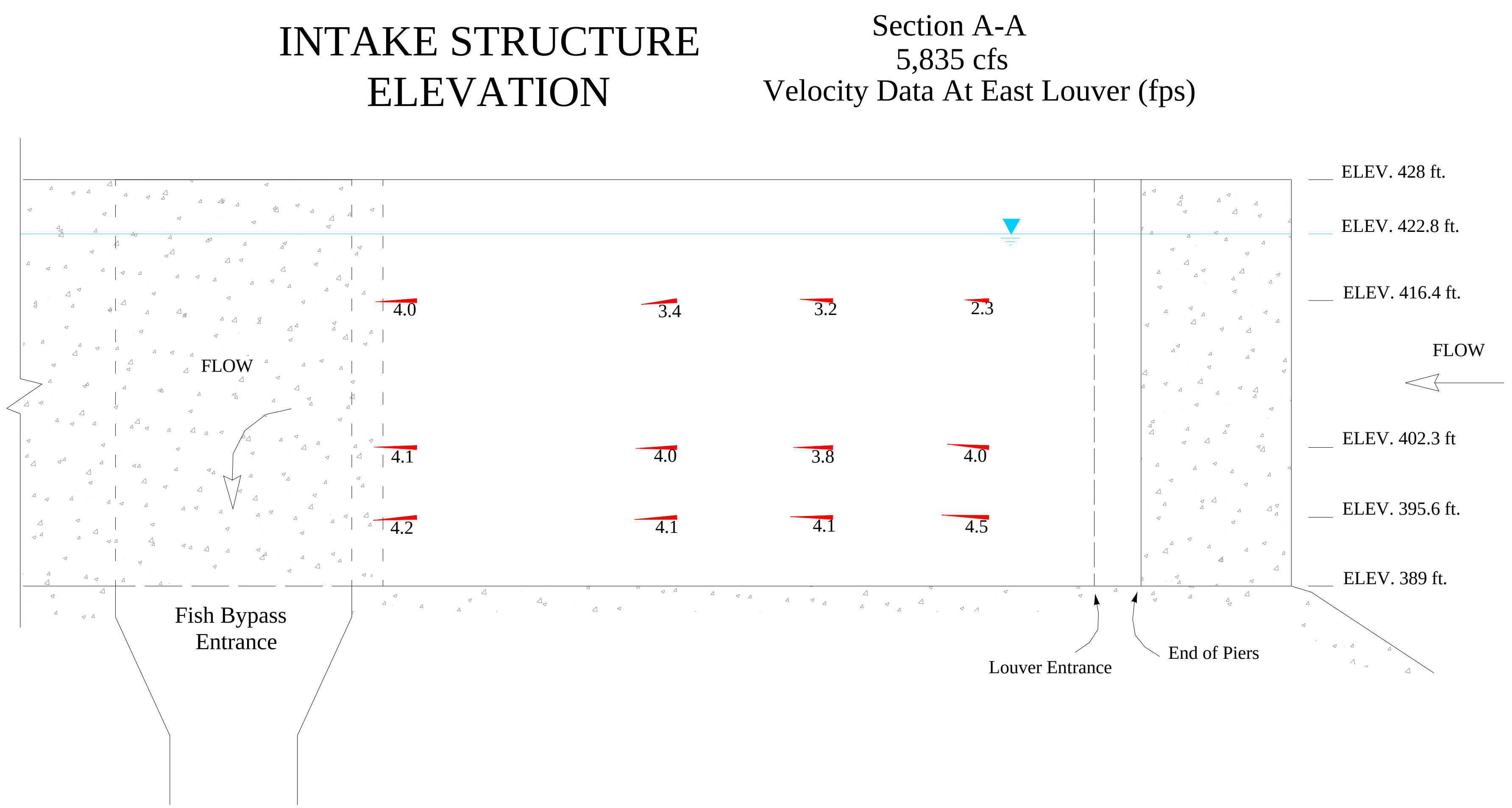


Figure 4 – Field measured velocity along east wall at 5,835 cfs. Velocity magnitude shown in feet per second.

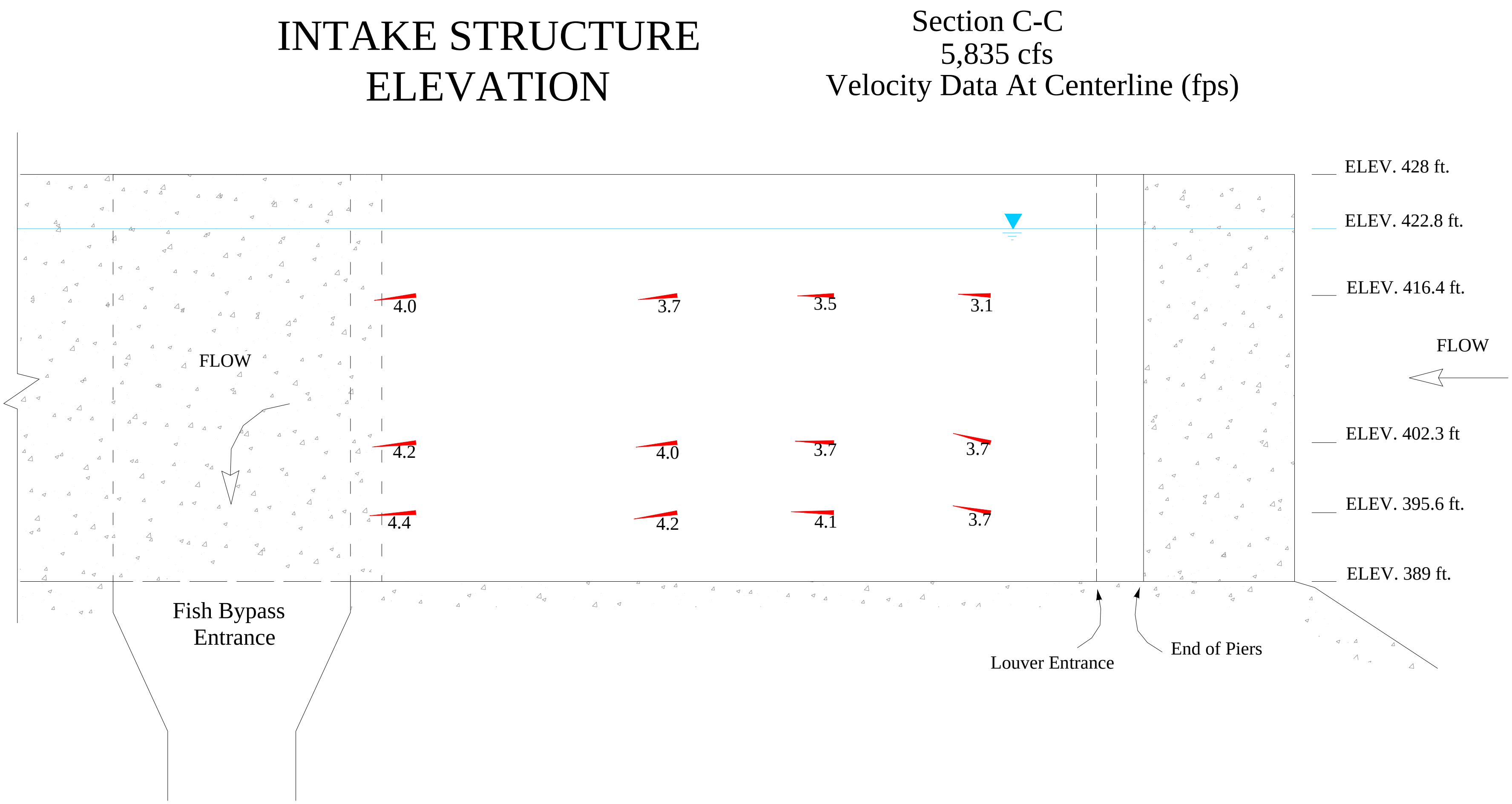


Figure 5 – Field measured velocity along longitudinal centerline of intake bay at 5,835 cfs. Velocity magnitude shown in feet per second.

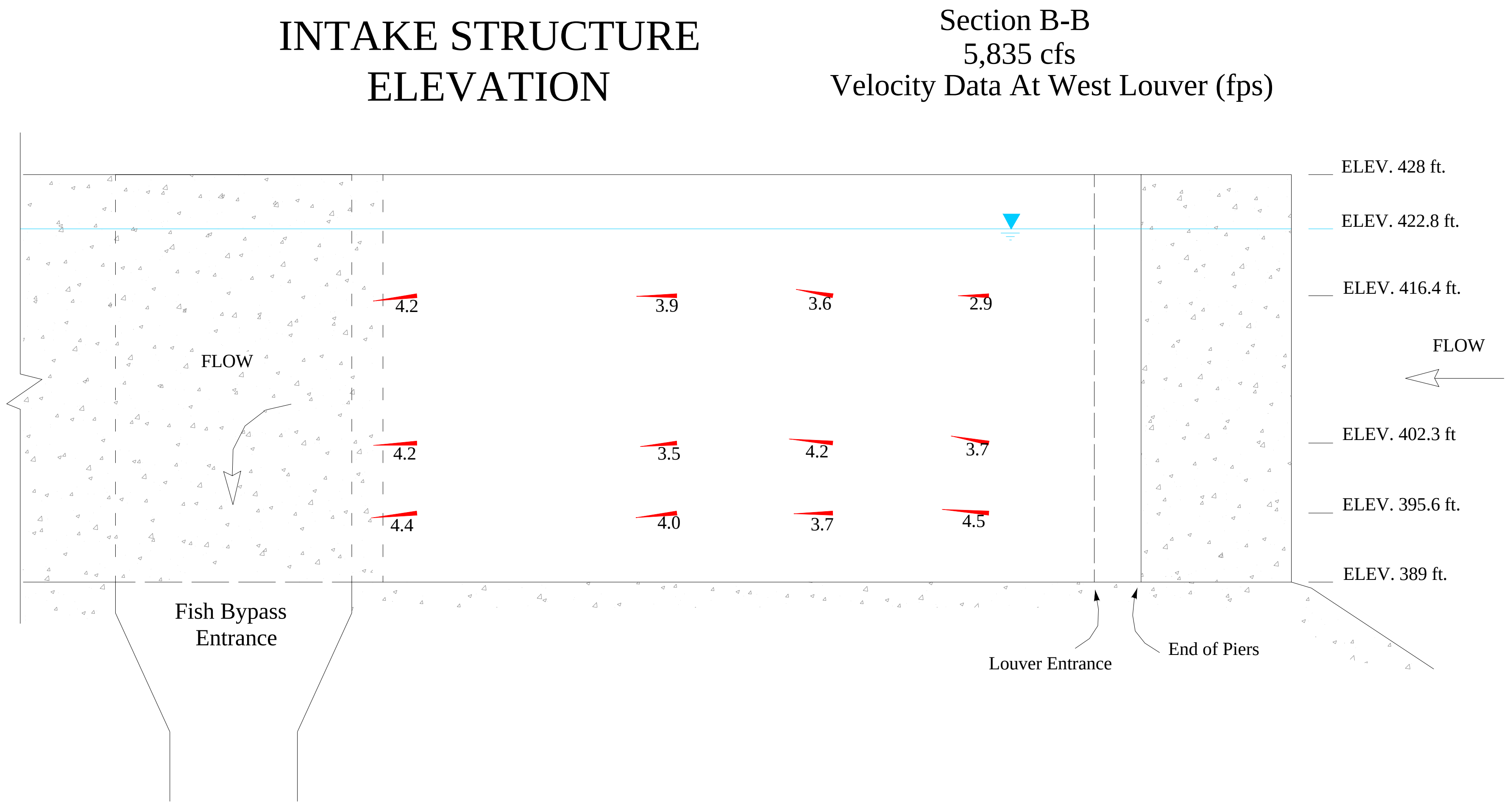


Figure 6 – Field measured velocity along west wall at 5,835 cfs. Velocity magnitude shown in feet per second.

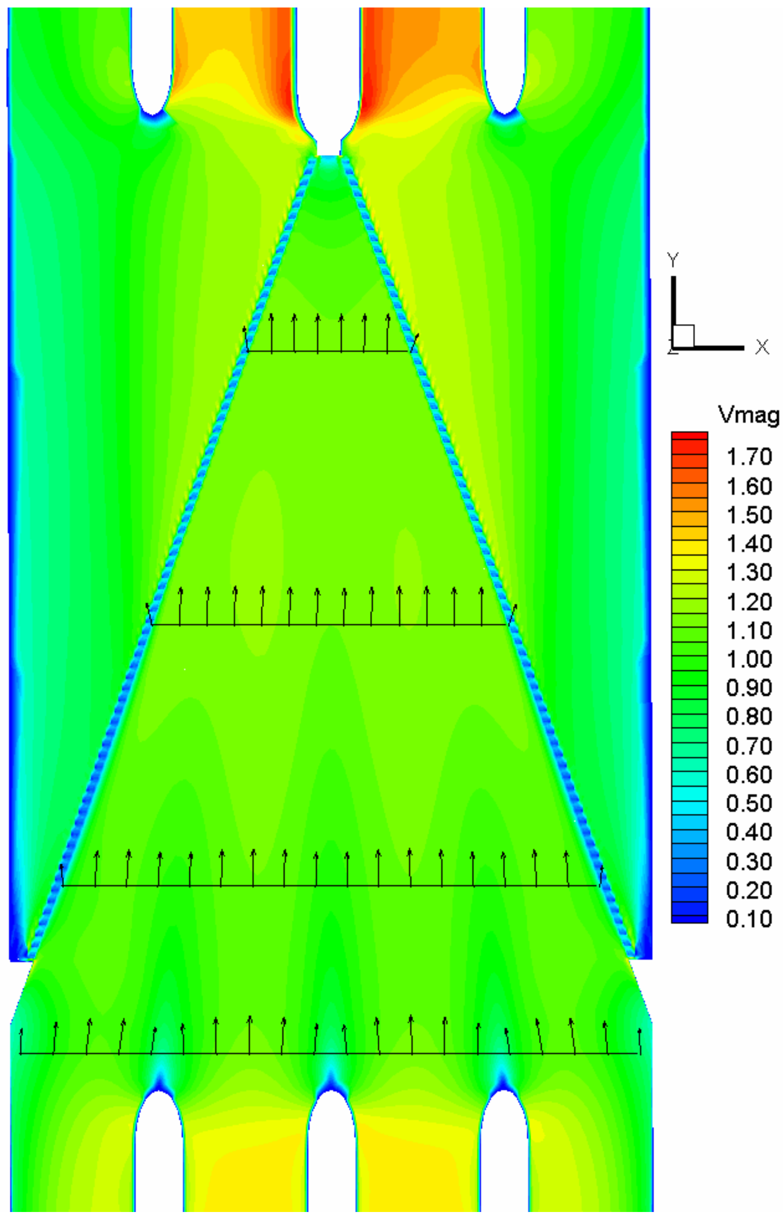


Figure 7 – CFD predicted velocities at elevation 395.6 ft (msl) and 5,000 cfs. Velocity magnitude shown in meters per second.

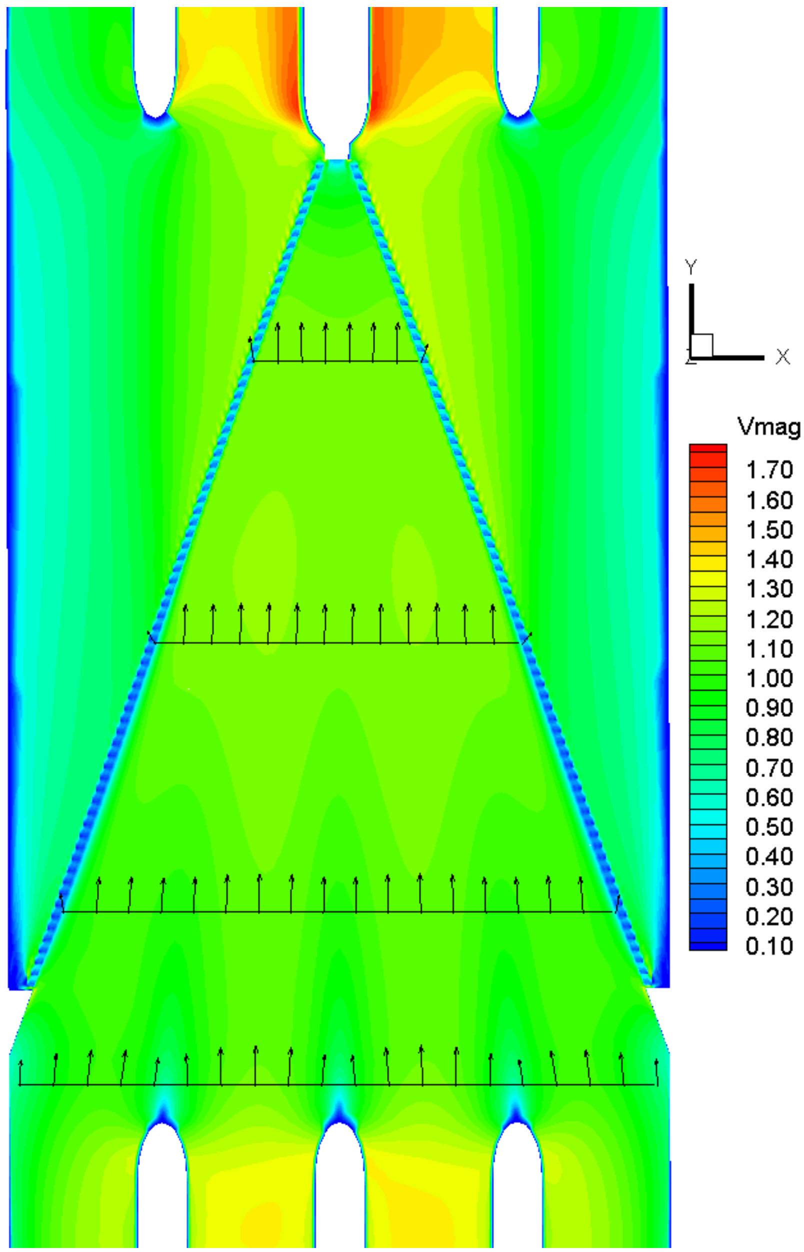


Figure 8 – CFD predicted velocities at elevation 402.3 ft (msl) and 5,000 cfs. Velocity magnitude shown in meters per second.

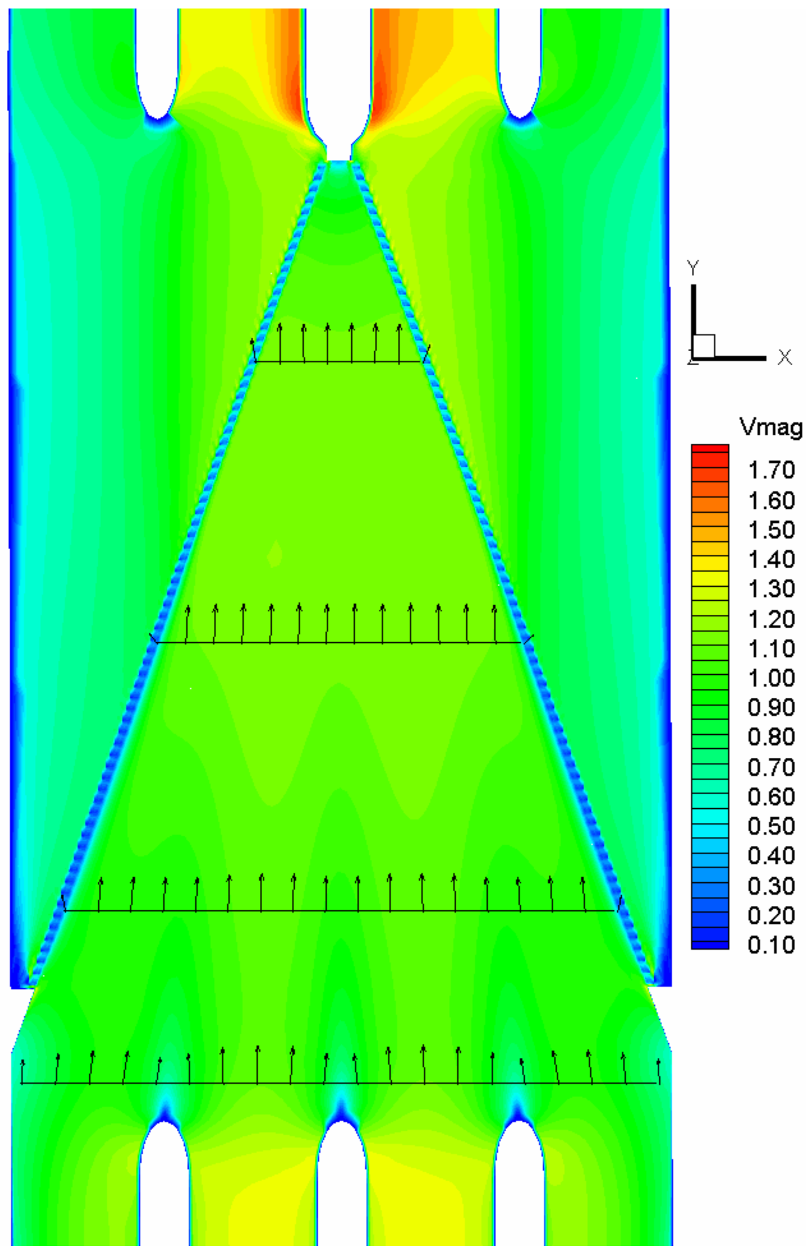


Figure 9 – CFD predicted velocities at elevation 416.4 ft (msl) and 5,000 cfs. Velocity magnitude shown in meters per second.

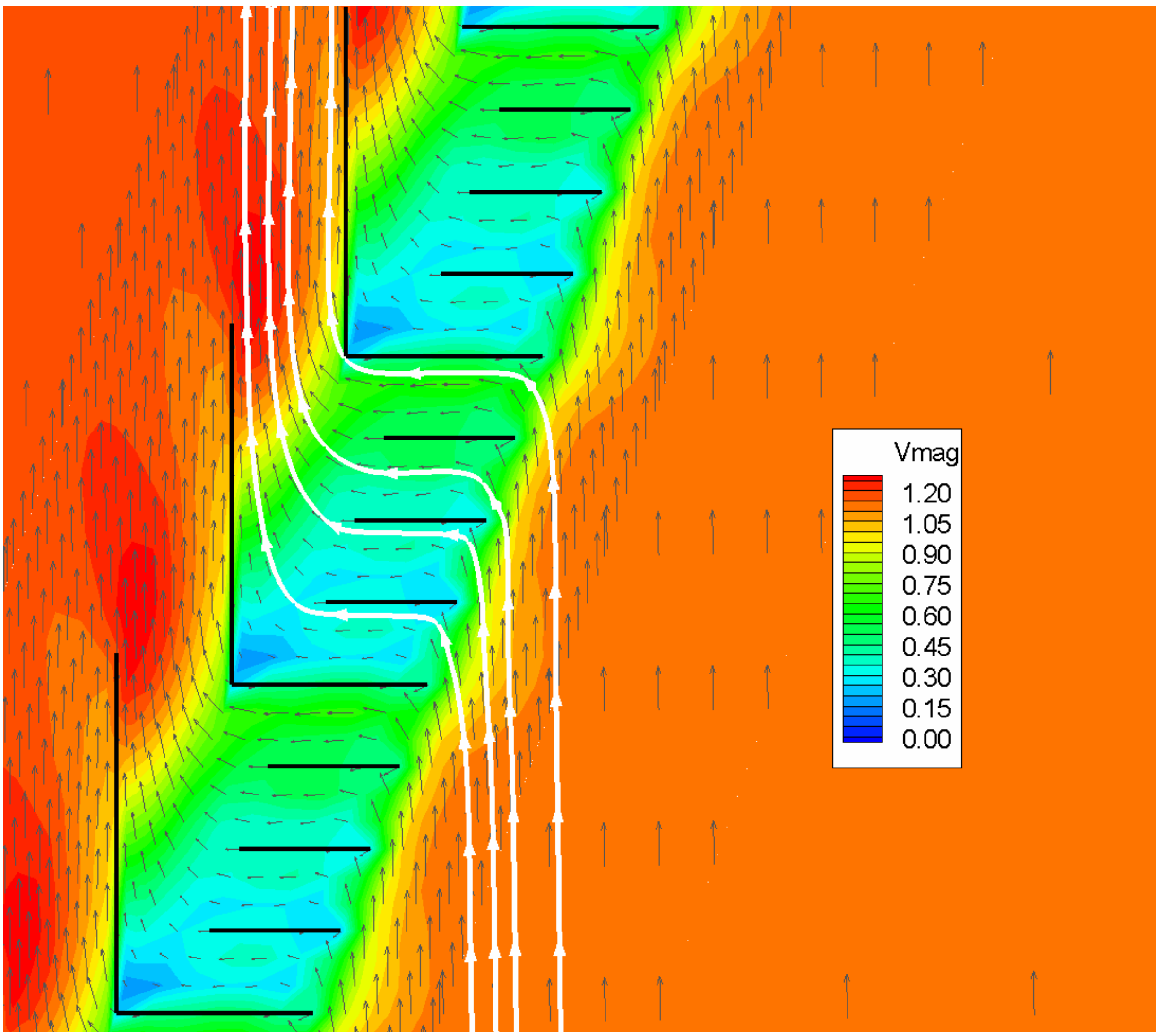


Figure 10 – CFD measured velocities through louver vanes at elevation 395.6 ft (msl) and 5,000 cfs. Velocity magnitude shown in meters per second.

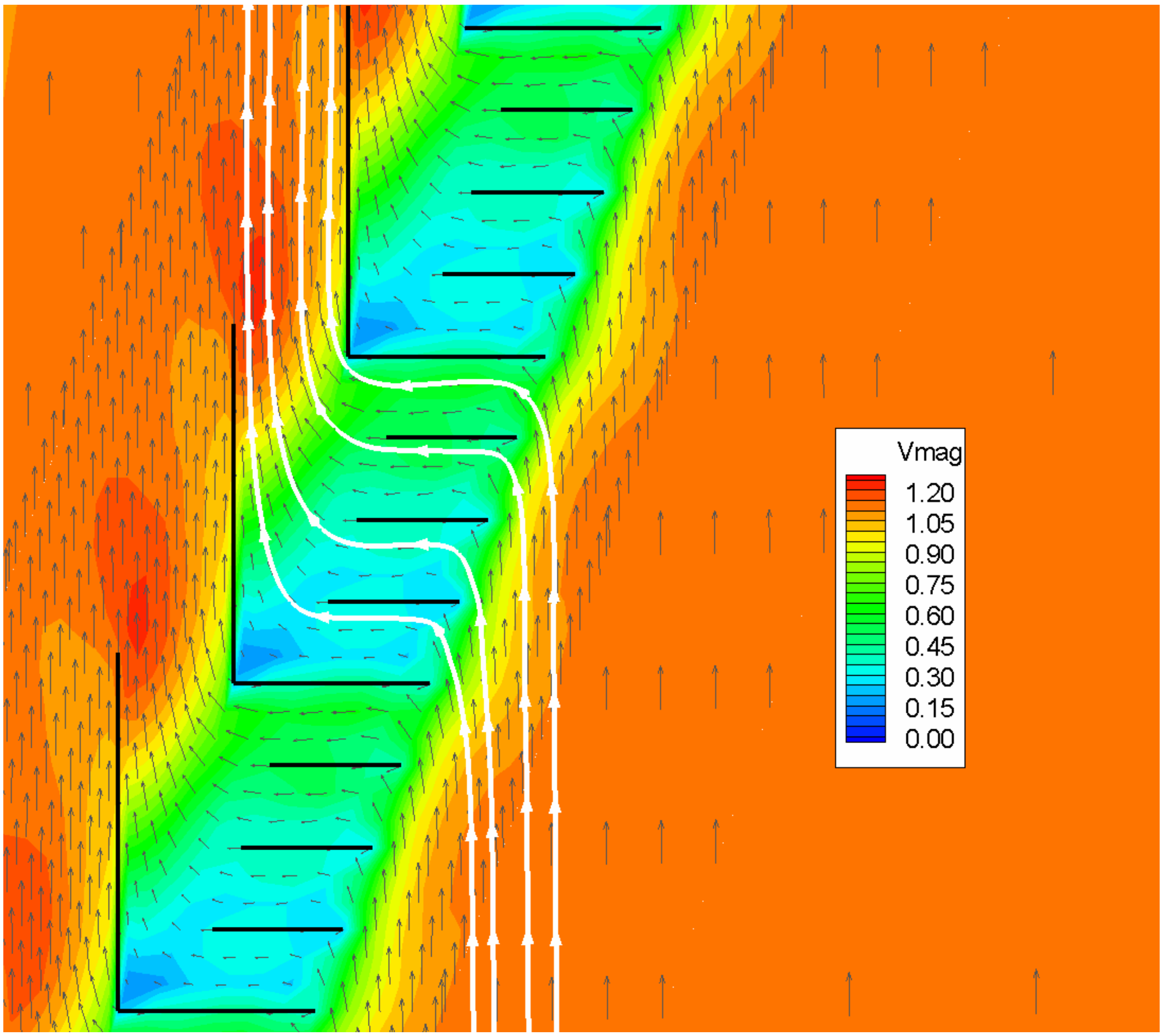


Figure 11 – CFD measured velocities through louver vanes at elevation 402.3 ft (msl) and 5,000 cfs. Velocity magnitude shown in meters per second.

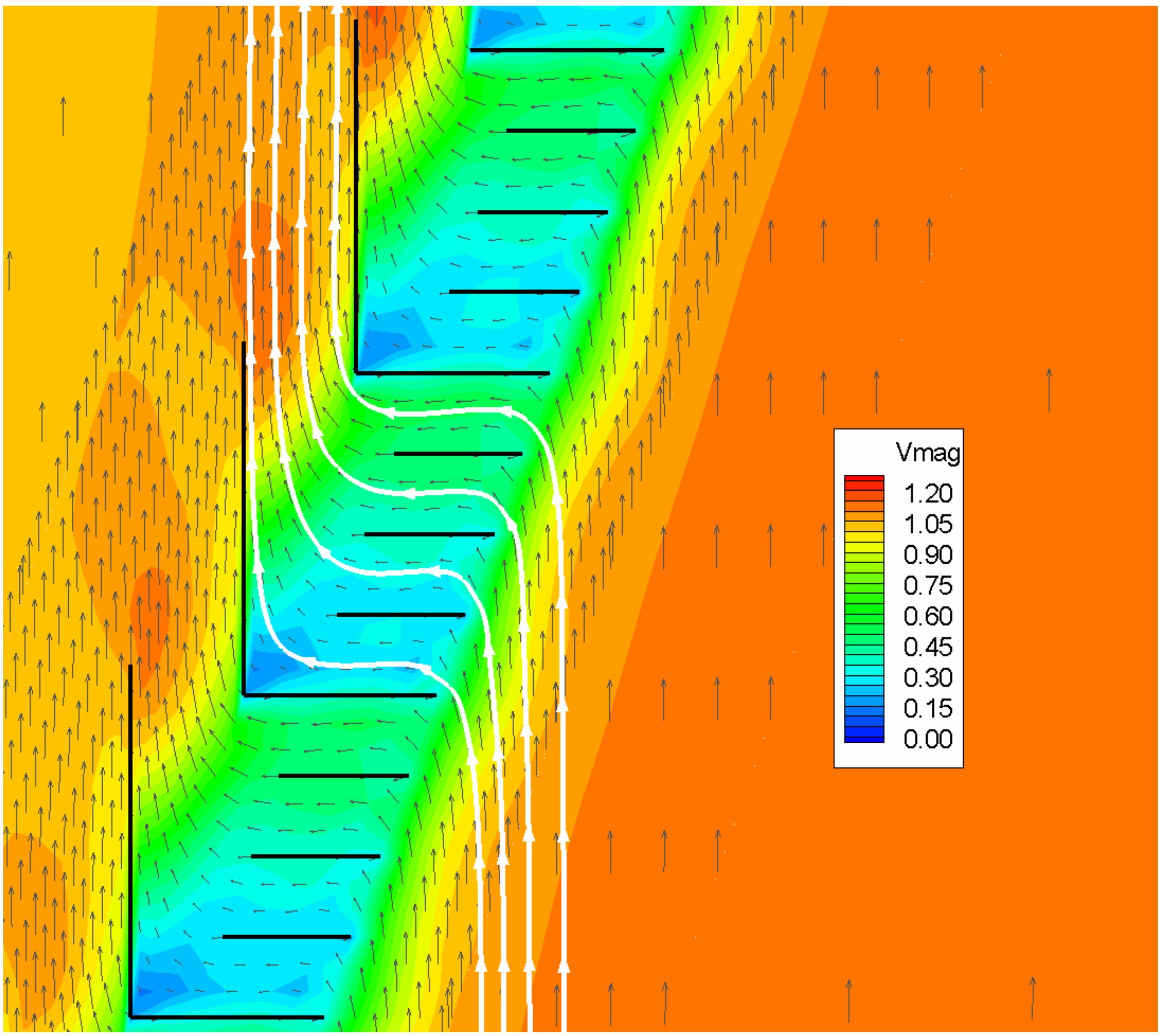


Figure 12 – CFD measured velocities through louver vanes at elevation 416.4 ft (msl) and 5,000 cfs. Velocity magnitude shown in meters per second.

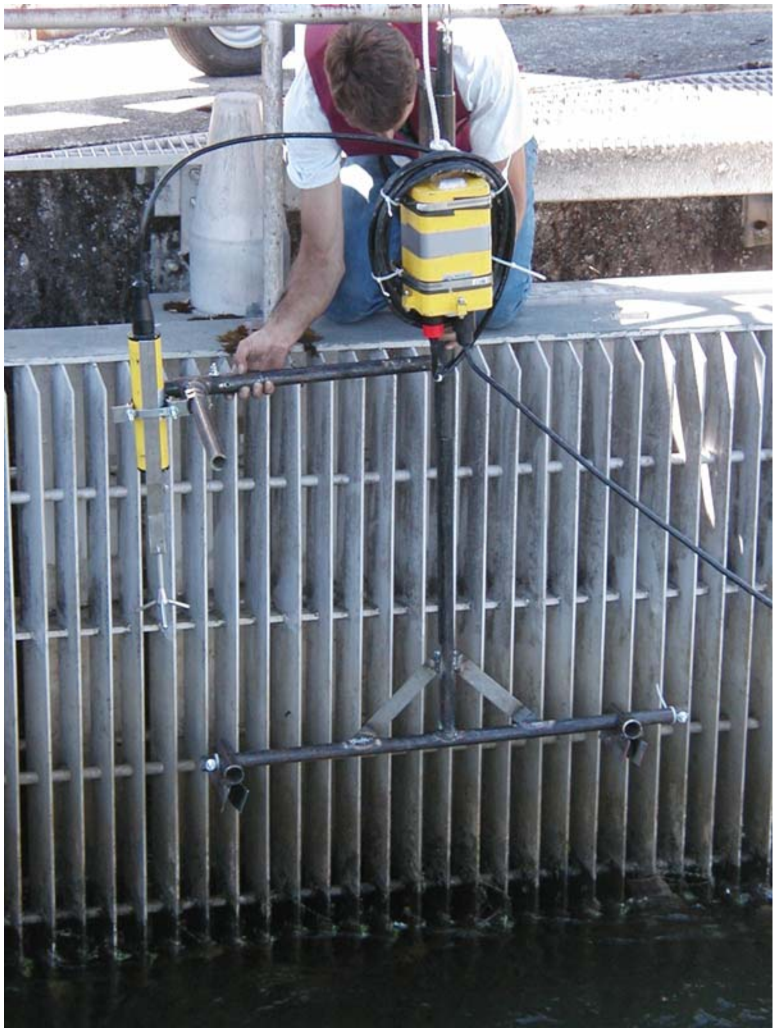


Photo 1 - ADV probe mount designed to deploy ADV by indexing on louver vanes.

Photo 2 - ADV probe mount shown on the left intake louver vanes.

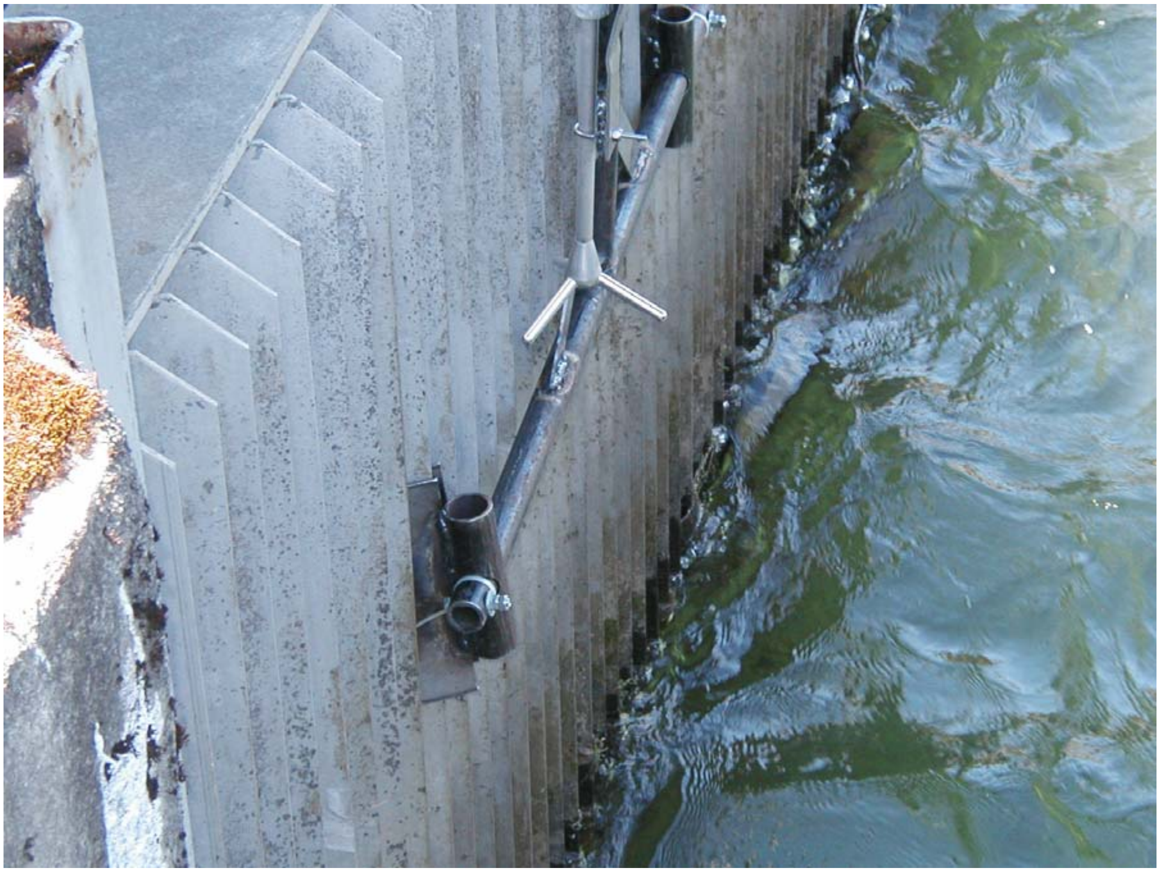


Photo 3 - Zoomed view of ADV probe and louver vane indexing guides.

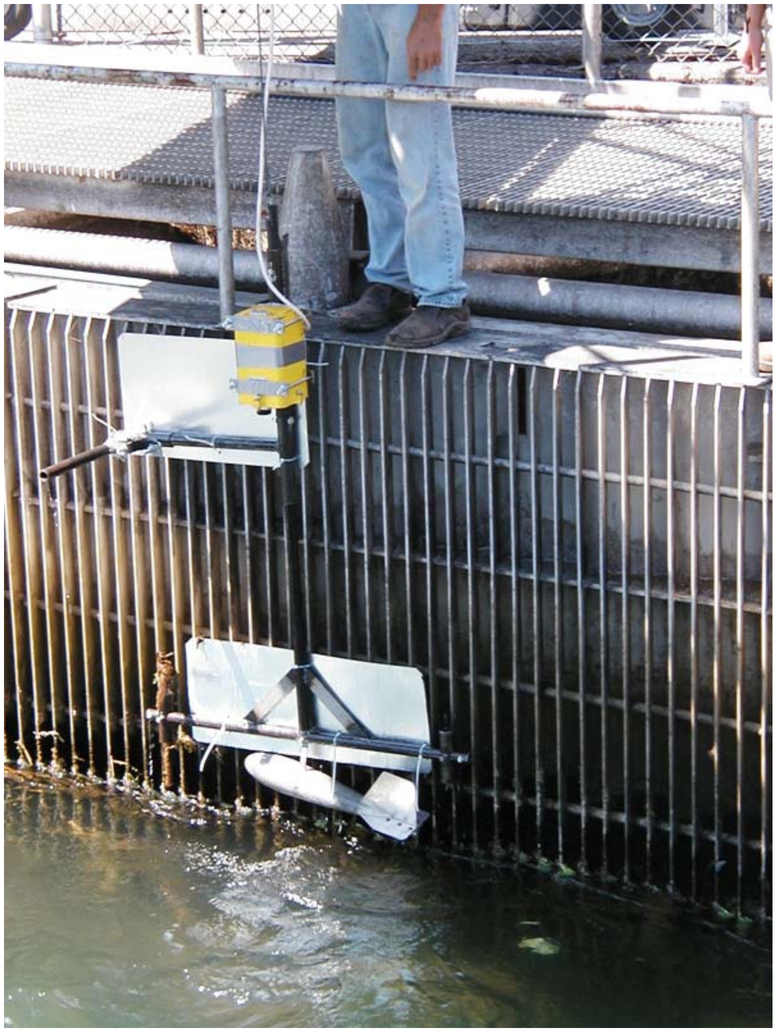


Photo 4 - Instrument retrofitted with sheet metal panels and 100 lb lead weight.

Photo 5 - Lowering ADV along left (east) louver wall.

Photo 6 - Apparatus that replaced initial tool for deploying ADV (also used in 2001).

Photo 7 - South intake bay entrance flow on July 11, 2002.   Note debris on trashrack.

Photo 8 - Close up view of right side of entrance trashrack.

Photo 9 - Close up view of left side of entrance trashrack.

Photo 10 - Bypass flow being pumped back downstream of the louvers.

Photo 11 - Close up view of bypass flow being returned to powerhouse tunnel.

COWLITZ RIVER PROJECT
FERC NO. 2016

MAYFIELD DAM
FISH GUIDANCE EVALUATIONS

Lighted Bypass Slot Study

Tacoma Public Utilities
Tacoma Power
Generation, Natural Resources

January 2003

1.2 Study Objectives

The objective of this study was to identify any increase in downstream migrant fish collection efficiency due to the placement of lights in the bypass slot entrance of the south louver bay at Mayfield Dam. Lighting this area was a recommendation from a 2001 study (Zapel, et. al. 2002) focused upon the conditions at the entrance to the bypass slot at a range of flows normally encountered during the spring/summer outmigration period.

2.2 Study Area

The study area encompassed the forebay, the south louver bay and south louver bay bypass slot at Mayfield Dam, Cowlitz River.

3.2 Methods

Underwater pool lights were suspended on steel frames inside the south louver bypass slot to illuminate the immediate area and to radiate light upstream at the entrance of the bypass slot for fish attraction (see Figure 1.).

Fisheries personnel released marked hatchery coho smolts and steelhead smolts by pouring them directly into the water near the trash boom in front of the south louver entrance according the schedule in Table 1. The release location was chosen to maximize the chance of marked fish passage into the louver bay entrance. Fish were marked with a colored elastomer injected into the adipose eye tissue and held for 24 hours after marking to assess fish condition prior to release. Only vigorous fish were released.

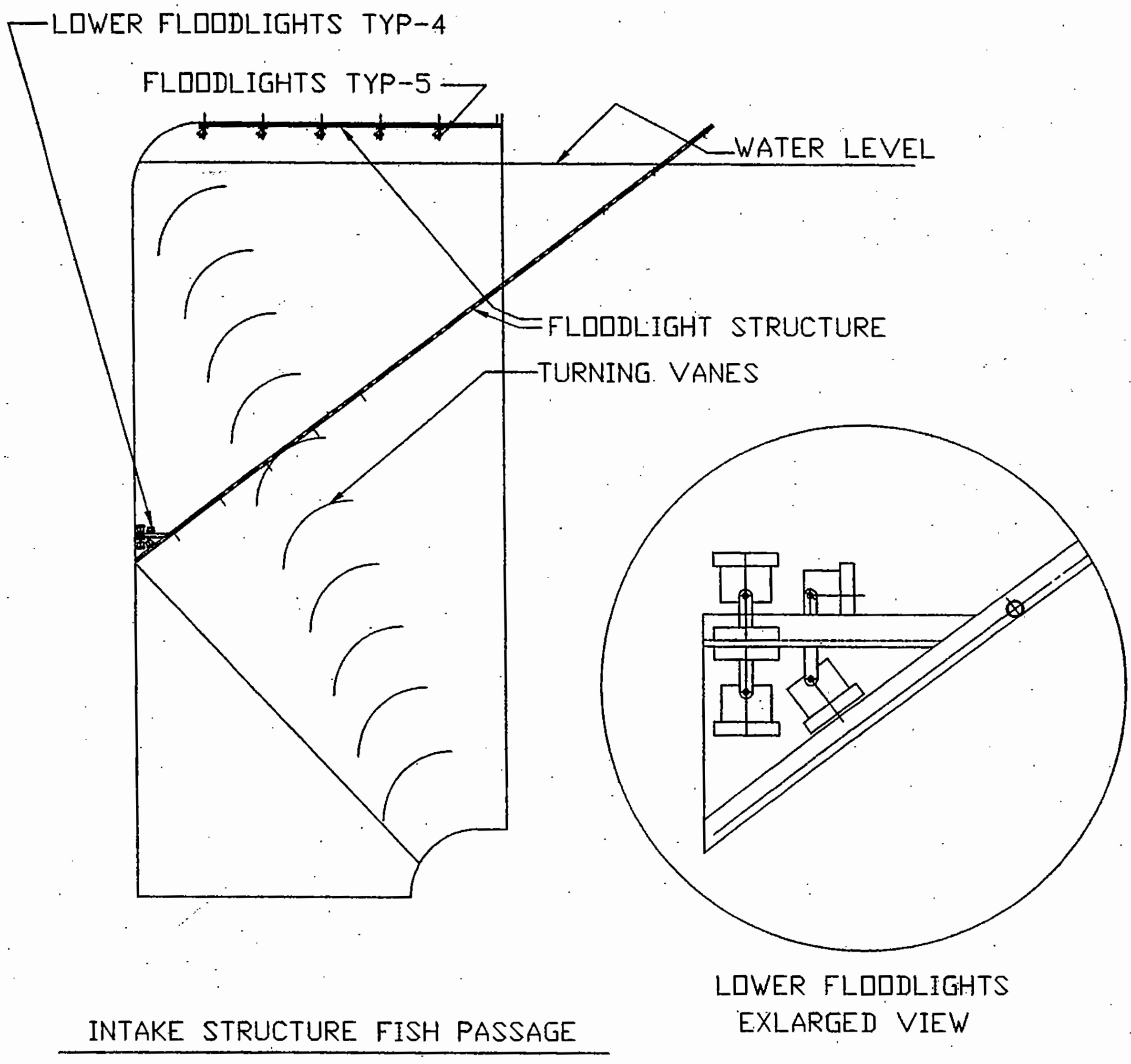
Table 1. Mayfield Dam lighted bypass study fish release schedule.

Week Number & start date	Lights on release		Lights off release		Elastomer mark
1 - May 8	100 coho	100 steelhead			Orange
2 - May 15			100 coho	100 steelhead	Yellow
3 - May 22	100 coho	100 steelhead			Orange
4 - May 29			100 coho	100 steelhead	Yellow
5 - June 5	99 coho	87 steelhead			Orange
6 - June 12			111 coho	80 steelhead	Yellow

A total of 586 orange marked fish and 591 yellow marked fish were released between May 8, 2002 and June 12, 2002. Releases occurred on every Wednesday beginning May 8. The bypass entrance slot lights were illuminated in week 1, turned off for week 2, turned on the following week and so forth until study completion. The lights were left off at the end of week 6. Appendix Table 1. details the U.S. Geological Survey stream gage flows below Mayfield Dam during and after the study period. Except for July 10-11, 2002 when the north louver bay wing gates were closed to divert 100% of the water into the south louver bay for a velocity study, the flows through the south louver bay were equal to 50% of the Mayfield gage flows during the study period.

Recoveries of marked fish occurred at the Mayfield downstream migrant counting house. Several time per week during the study period fisheries personnel closely examined all smolts collected for marks and for adipose fin presence or absence. Adipose intact coho and steelhead were wire tagged. Adipose clipped coho and steelhead smolts were clues for closer examination of the fish for the unique mark associated with this study. Mark recovery data were recorded on field data sheets and transferred to a personal computer spreadsheet program.

Figure 1. Light cluster arrangement installed in the south louver bay, Mayfield Dam downstream collection facility, May 2002.



4.2 Results

There was little difference in collection efficiency between the lights on and lights off conditions (ON – 11.8% versus OFF – 14.4%) for both species combined. However, there was a pronounced difference between steelhead and coho collection efficiencies. Overall steelhead smolt collection efficiency was 19.4% and for coho it was 7.4%. Both species collection efficiencies for this study were much lower than historic estimates of 61.7% to 79.3% (Thompson and Paulik, 1967).

Recoveries of marked fish occurred from May 9 until July 8 at the Mayfield counting house. The collection facility is operated year-round and could collect unrecovered fish throughout the year.

Table 2. Mayfield Dam lighted bypass study results.

Coho		***Releases (N)***				***Recoveries***				
Release	Lights On	Lights Off				Lights On			Lights Off	
date	Orange	Yellow			*By:*	*N*		*By:*	*N*	
8-May	100				22-May	3	3.0%	29-May	16	16.0%
15-May		100			5-Jun	11	5.5%	12-Jun	19	9.5%
22-May	100			TOTALS	17-Dec	14	4.7%	17-Dec	30	9.6%
29-May		100								
5-Jun	99			GRAND TOTAL:		Coho	7.2%			
12-Jun		111								
TOTALS	299	311	610							
Steelhead		***Releases (N)***				***Recoveries***				
Release	Lights On	Lights Off				Lights On			Lights Off	
date	Orange	Yellow			*By:*	*N*		*By:*	*N*	
8-May	100				22-May	19	19.0%	29-May	44	44.0%
15-May		100			5-Jun	36	18.0%	12-Jun	48	24.0%
22-May	100			TOTALS	17-Dec	55	19.2%	17-Dec	55	19.6%
29-May		100								
5-Jun	87			GRAND TOTAL:		Steelhead	19.4%			
12-Jun		80								
TOTALS	287	280	567							

5.2 Discussion

Recoveries of marked fish were low compared to historic collection efficiencies. Differences between lights on and lights off conditions were small and not particularly meaningful for this study.

Hatchery smolts were used in study as surrogates for wild downstream migrants. There may have been behavioral differences in these fish as manifested in a reluctance to enter the louver bay and/or the bypass slot resulting in lower collection efficiencies. Overall, steelhead smolts guided much better than coho smolts with the highest guidance efficiencies occurring immediately after the initial releases. Flows during the study period ranged from 5,100 cfs to 10,600 cfs and may account for variability in fish collection efficiencies. Steelhead smolts were collected at a higher rate than coho smolts under either light condition.

The cluster light bar structure may have disrupted the hydraulics of the bypass entrance and created some negative guidance behavior due to the narrow entrance (8" width) and the surface orientation of the light bar.

6.2 Schedule

This study is complete. Some additional marked fish may be recovered, however, the lights have been removed.

7.2 References

Zapel, Ed, Tom Molls, Sam Johnston, Patrick Nealson and Mark Timko. Cowlitz River Project Mayfield Dam Fish Guidance Louver Evaluations, Final Report, 46 pp., January 2002.

Thompson, J.S. and G.J. Paulik. 1967. An Evaluation of Louvers and Bypass Facilities for Guiding Seaward Migrant Salmonids Past Mayfield Dam in Western Washington. Washington Department of Fisheries, Research Division.

Appendix Table 1.

Reservoir and Flow Data for Mayfield Dam, May to July 2002

Reservoir [illegible]d Stream Flow

Runtime: Friday, June 14, 2002 03:21:53 PM
Closing: 31-MAY-2002

Basin	Cowlitz									Wynoochee					
Project or Location		Mossyrock			Mayfield					Grisdale				Black	Save
	CowEl	Elev 2400 Hour	Calc'd Nat'l Inflow	Daily % Med Inflow	Elev 2400 Hour	Calc'd Nat'l Inflow	Daily % Med Inflow	Calc'd Side Flow	Gage Flow	Elev 2400 Hour	Calc'd Nat'l Inflow	Daily % Med Inflow	Gage Dis-charge	Gage Dis-charge	Gage Dis-charge
01-MAY-02	860.91	763.13	6973	86.5	424.32	8236	89.3	1263	9080	799.25	381	92.3	280	625	487
02-MAY-02	861.35	763.31	8700	107.9	424.12	10018	108.7	1318	9080	799.44	388	93.9	281	612	481
03-MAY-02	861.26	763.85	8042	99.7	422.99	9366	101.6	1324	7623	799.68	419	101.5	284	592	471
04-MAY-02	861.43	764.40	7918	98.2	422.94	9008	97.7	1090	5965	799.74	317	76.8	284	570	465
05-MAY-02	861.43	764.94	6553	81.3	421.86	7620	82.6	1067	5845	799.86	351	85.0	284	592	482
06-MAY-02	860.40	764.58	6089	75.5	422.82	7257	78.7	1168	8532	799.86	284	68.8	284	594	473
07-MAY-02	860.40	764.22	5967	74.0	422.57	6905	74.9	938	9162	799.86	284	68.8	284	572	458
08-MAY-02	861.43	763.67	5200	64.5	422.32	6191	67.1	991	9170	799.74	217	52.5	284	545	446
09-MAY-02	861.59	763.13	5301	65.7	422.23	6125	66.4	824	9193	799.68	275	66.6	308	528	467
10-MAY-02	861.56	762.40	3643	45.2	423.02	4448	48.2	805	7614	799.56	254	61.5	321	542	486
11-MAY-02	861.59	762.40	5107	63.3	422.99	6075	65.9	968	6098	799.37	214	51.8	321	535	483
12-MAY-02	861.61	762.22	3977	49.3	423.53	4748	51.5	771	5135	799.25	254	61.5	321	522	478
13-MAY-02	861.60	762.04	7120	88.3	424.17	8137	88.3	1017	8424	799.37	388	93.9	321	520	482
14-MAY-02	861.59	761.85	6420	79.6	423.81	7599	82.4	1179	9061	799.37	367	88.9	367	546	511
15-MAY-02	861.50	761.85	7648	94.8	423.53	8744	94.8	1096	9085	799.07	306	74.1	475	592	641
16-MAY-02	861.52	761.67	6840	84.8	423.25	7808	84.7	968	9119	798.76	302	73.1	475	636	640
17-MAY-02	861.56	761.85	7665	95.0	423.36	8748	94.9	1083	7606	798.46	302	73.1	469	647	638
18-MAY-02	861.54	762.58	8485	105.2	422.94	9461	102.6	976	5902	798.34	281	68.0	348	595	497
19-MAY-02	861.59	763.49	8504	105.4	422.15	9380	101.7	876	5182	798.28	315	76.3	348	507	477
20-MAY-02	860.67	763.67	8754	108.5	422.26	9695	105.2	941	8884	798.28	348	84.3	348	506	478
21-MAY-02	861.46	764.22	11247	139.5	422.15	12374	134.2	1127	9165	798.34	381	92.3	348	485	472
22-MAY-02	861.41	764.58	9784	121.3	423.84	10779	116.9	995	6947	798.28	315	76.3	348	479	467
23-MAY-02	861.44	765.13	8985	111.4	424.12	10082	109.3	1097	6725	798.28	348	84.3	348	467	461
24-MAY-02	861.44	765.85	8758	108.6	423.92	9587	104.0	829	5777	798.15	276	66.8	348	458	452
25-MAY-02	861.44	766.76	9246	114.6	423.89	10065	109.2	819	5078	798.09	315	76.3	348	453	452
26-MAY-02	861.16	767.67	9359	116.0	424.01	10191	110.5	832	5084	798.09	348	84.3	348	451	451
27-MAY-02	861.15	768.94	11495	142.5	424.34	12458	135.1	963	5080	798.28	454	109.9	348	451	456
28-MAY-02	861.22	770.39	14600	181.0	424.29	15796	171.3	1196	7635	799.13	1063	257.4	587	543	705
29-MAY-02	860.89	772.03	17741	220.0	423.95	19340	209.8	1599	10218	798.89	1177	285.0	1311	1643	1937
30-MAY-02	860.83	773.30	16761	207.8	422.23	18018	195.4	1257	12545	799.07	653	158.1	552	1150	966
31-MAY-02	860.96	773.85	15096	187.2	421.58	16113	174.8	1017	13542	798.95	471	114.0	538	836	875
To-date Total			267978			300372					12048				
To-date Average			8644	107.2		9689	105.1	1044	7856		388	94.1	390	606	572
Hist. Mo. Median*			8065			9220					413				

*7? -ear record (1929-2000)

Reservoir [illegible]d Stream Flow

Runtime: Wednesday, July 24, 2002 01:40:24 PM
Closing: 30-JUN-2002
Page: 1 of 2

Basin		Cowlitz								Wynoochee					
Project or Location		Mossyrock			Mayfield					Grisdale				Black	Save
	CowEl	Elev 2400 Hour	Calc'd Nat'l Inflow	Daily % Med Inflow	Elev 2400 Hour	Calc'd Nat'l Inflow	Daily % Med Inflow	Calc'd Side Flow	Gage Flow	Elev 2400 Hour	Calc'd Nat'l Inflow	Daily % Med Inflow	Gage Dis-charge	Gage Dis-charge	Gage Dis-charge
01-JUN-02	861.33	774.03	12369	186.4	423.81	13184	179.6	815	9530	799.13	449	153.2	348	712	864
02-JUN-02	861.35	774.57	11878	179.0	424.26	12983	176.9	1105	9294	799.25	415	141.6	348	557	849
03-JUN-02	861.34	774.94	11370	171.4	423.78	12133	165.3	763	10484	799.37	415	141.6	348	521	800
04-JUN-02	861.35	775.30	11427	172.2	423.86	12197	166.2	770	10012	799.37	402	137.2	402	507	863
05-JUN-02	861.45	775.84	12219	184.2	423.86	13141	179.0	922	9975	799.37	449	153.2	449	600	800
06-JUN-02	861.28	776.39	11977	180.5	423.58	12825	174.7	848	9964	799.25	383	130.7	450	595	800
07-JUN-02	861.47	776.57	10571	159.3	423.75	11294	153.9	723	9979	799.07	348	118.8	449	575	800
08-JUN-02	861.55	776.39	8273	124.7	423.67	8854	120.6	581	9977	798.89	345	117.7	446	571	800
09-JUN-02	861.47	776.03	7423	111.9	423.84	8013	109.2	590	9977	798.89	300	102.4	300	522	800
10-JUN-02	861.58	775.48	6716	101.2	423.75	7222	98.4	506	10477	798.89	300	102.4	300	423	800
11-JUN-02	861.46	775.30	9331	140.6	423.95	9822	133.8	491	10687	798.95	333	113.7	300	406	800
12-JUN-02	861.44	775.12	9336	140.7	424.15	9841	134.1	505	10671	799.07	367	125.3	300	394	800
13-JUN-02	861.64	775.48	11298	170.3	423.41	12001	163.5	703	10663	799.25	401	136.9	300	384	800
14-JUN-02	861.03	776.03	13961	210.4	424.17	14466	197.1	505	10644	799.37	367	125.3	300	376	800
15-JUN-02	860.89	776.75	13838	208.6	424.20	14270	194.4	432	10038	799.37	300	102.4	300	375	800
16-JUN-02	861.91	777.30	13309	200.6	423.81	13844	188.6	535	10679	799.37	300	102.4	300	370	800
17-JUN-02	861.02	777.30	9687	146.0	423.19	10220	139.2	533	11213	799.56	435	148.5	328	392	800
18-JUN-02	860.92	777.30	11183	168.5	423.78	11813	160.9	630	11196	799.44	387	132.1	454	540	800
19-JUN-02	861.32	776.94	8673	130.7	424.34	9319	127.0	646	10686	799.25	347	118.4	454	560	800
20-JUN-02	861.36	776.75	8494	128.0	424.68	9042	123.2	548	9774	799.07	271	92.5	372	527	800
21-JUN-02	861.42	776.94	8340	125.7	424.68	8816	120.1	476	7675	798.95	260	88.7	327	440	800
22-JUN-02	861.38	777.30	9372	141.3	424.57	9764	133.0	392	7775	798.95	303	103.4	303	401	800
23-JUN-02	861.32	777.66	9919	149.5	424.65	10379	141.4	460	8188	798.95	280	95.6	280	376	800
24-JUN-02	861.32	777.48	8800	132.6	424.43	9119	124.2	319	10424	798.95	272	92.8	272	357	800
25-JUN-02	861.34	777.12	8550	128.9	423.98	8986	122.4	436	11601	798.89	239	81.6	272	343	224
26-JUN-02	861.38	776.75	9271	139.7	424.23	9685	131.9	414	11579	798.89	272	92.8	272	336	337
27-JUN-02	861.34	776.75	10043	151.4	424.37	10441	142.2	398	10301	798.82	231	78.8	270	338	338
28-JUN-02	861.39	776.75	9272	139.7	424.34	9981	136.0	709	9997	799.25	721	246.1	480	388	518
29-JUN-02	861.39	777.48	11906	179.4	423.67	13495	183.9	1589	9930	798.95	882	301.0	1051	1724	1750
30-JUN-02	861.34	777.66	9830	148.2	424.12	10787	147.0	957	9246	798.82	394	134.5	466	1091	759
To-date Total			308636			327937					11168				
To-date Average			10287	155.1		10931	148.9	643	10087		372	127.1	374	523	776
Hist. Mo. Median*			6635			7340					293				

*[illegible]ar record (1929-2000)

Reservoir and Stream Flow

Runtime: Wednesday, August 21, 2002 07:56:14 AM
Closing: 31-JUL-2002

Basin	Cowlitz									Wynoochee					
Project or Location		Mossyrock			Mayfield					Grisdale				Black	Save
	CowEl	Elev 2400 Hour	Calc'd Nat'l Inflow	Daily % Med Inflow	Elev 2400 Hour	Calc'd Nat'l Inflow	Daily % Med Inflow	Calc'd Side Flow	Gage Flow	Elev 2400 Hour	Calc'd Nat'l Inflow	Daily % Med Inflow	Gage Dis-charge	Gage Dis-charge	Gage Dis-charge
01-JUL-02	861.33	777.12	6229	188.8	423.95	7018	198.6	789	10395	798.95	357	185.0	285	731	477
02-JUL-02	861.31	776.39	6264	189.8	424.43	6932	196.2	668	10716	798.95	264	136.8	264	541	408
03-JUL-02	861.32	776.03	6417	194.5	424.15	7053	199.6	636	9483	798.95	264	136.8	264	478	394
04-JUL-02	861.36	775.66	4970	150.6	424.17	5547	157.0	577	7661	798.95	264	136.8	264	454	385
05-JUL-02	861.30	775.66	5289	160.3	424.37	5840	165.3	551	5640	798.95	264	136.8	264	435	370
06-JUL-02	861.38	775.66	4458	135.1	424.15	4880	138.1	422	5096	798.82	192	99.5	264	408	362
07-JUL-02	861.40	775.66	4746	143.8	424.26	5218	147.7	472	5091	798.76	231	119.7	264	393	359
08-JUL-02	861.30	775.66	6329	191.8	424.29	6861	194.1	532	6863	798.64	197	102.1	264	388	136
09-JUL-02	861.34	775.48	4541	137.6	424.15	5031	142.4	490	6216	798.58	231	119.7	264	373	348
10-JUL-02	861.37	775.30	4872	147.6	424.54	5238	148.2	366	5841	798.46	197	102.1	264	362	343
11-JUL-02	861.33	775.30	5235	158.6	424.40	5663	160.2	428	5831	798.28	164	85.0	264	350	337
12-JUL-02	861.33	775.48	5814	176.2	424.43	6241	176.6	427	5165	798.15	192	99.5	264	345	337
13-JUL-02	861.37	775.66	4919	149.1	423.61	5256	148.7	337	5105	797.97	164	85.0	264	336	337
14-JUL-02	861.47	775.66	5515	167.1	424.32	5945	168.2	430	5126	797.79	165	85.5	264	331	332
15-JUL-02	861.34	775.48	3438	104.2	424.23	3922	111.0	484	5110	797.66	192	99.5	264	326	332
16-JUL-02	861.33	775.30	3596	109.0	424.34	3952	111.8	356	4879	797.36	105	54.4	271	321	326
17-JUL-02	861.38	775.48	4443	134.6	424.17	4711	133.3	268	3838	797.18	183	94.8	282	328	343
18-JUL-02	861.35	775.48	3681	111.5	424.32	3912	110.7	231	3758	796.87	125	64.8	296	337	354
19-JUL-02	861.57	775.48	3506	106.2	424.34	3740	105.8	234	3643	796.63	165	85.5	296	341	359
20-JUL-02	861.57	775.48	2348	71.2	424.17	2750	77.8	402	2938	796.32	126	65.3	296	336	354
21-JUL-02	861.52	775.66	3793	114.9	424.29	4131	116.9	338	2973	796.08	175	90.7	306	333	354
22-JUL-02	861.59	775.48	2269	68.8	424.12	2560	72.4	291	3768	795.65	83	43.0	317	341	377
23-JUL-02	861.59	775.48	3547	107.5	424.15	3756	106.3	209	3723	795.34	100	51.8	268	287	377
24-JUL-02	861.53	775.30	2546	77.2	424.32	2845	80.5	299	3722	794.98	85	44.0	280	292	388
25-JUL-02	861.53	775.12	2227	67.5	424.12	2453	69.4	226	3718	794.55	54	28.0	285	304	400
26-JUL-02	861.57	775.12	2825	85.6	424.20	3211	90.9	386	3110	794.12	54	28.0	285	308	400
27-JUL-02	861.53	775.12	2343	71.0	424.15	2725	77.1	382	2794	793.76	93	48.2	285	307	400
28-JUL-02	861.53	775.12	2090	63.3	423.84	2485	70.3	395	2827	793.33	56	29.0	285	304	394
29-JUL-02	861.53	775.12	2470	74.8	423.92	2918	82.6	448	2830	792.90	56	29.0	285	301	394
30-JUL-02	861.56	775.12	2537	76.9	424.03	2931	82.9	394	2800	792.41	26	13.5	285	294	394
31-JUL-02	861.63	774.94	1553	47.1	424.20	1963	55.5	410	2801	792.05	90	46.6	280	291	388
To-date Total			124810			137688					4914				
To-date Average			4026	122.0		4441	125.7	415	4950		158	82.1	276	363	363
Hist. Mo. Median*			3300			3534					193				

*7[illegible] record (1929-2000)

REPORT

Date: June 17, 2002 10:30 a.m.

Subject: Mayfield Dam louver bypass facility. Underwater camera test

Operators: M. Wicke and L. Whitney

Conditions: Water – clear. Secchi disc reading – 9 feet.
Weather – overcast
Flow – Discharge below Mayfield Dam at 10,679 cfs., both louver bays open.

Camera: Black and white underwater camera with red LED lights mounted with electrical tape to a 20' 1.5 inch diameter aluminum pole.

Video sequence 1) South louver bay underwater camera visibility was good to 5 ft. horizontally. There was difficulty getting the camera to more than 5 ft. of depth due to water velocity. Video of fish was taken at 4 ft. upstream from bypass slot. Most of the fish were observed at a depth of 2-3 ft.

Video sequence 2) Secondary separator facility - able to reach camera to a depth of 12 ft. Horizontal visibility was 5 ft. at 12 foot depth.

Video sequence 3) North louver bay – fish present but seemingly more camera shy. Large amounts of debris (wood and trash) was visible in bypass slot.

Video sequence 4) South louver bay – turned lights on / off during filming and observed no fish response.

Video sequence 5) South louver bay entrance (trash rack) no fish on camera but present under trash boom.

Notes: Most of the fish observed appeared to resident rainbow trout from recent net pen releases in Mayfield Lake. No downstream migrant smolts observed.

REPORT

Subject: Mayfield Dam south louver bypass entrance, 2002 underwater speaker test

Operators: M. Wicke and C. Coutant

Conditions: *Water* – clear, Secchi disc reading = 10'+.
Flow – Discharge below Mayfield Dam at 10,000 to 11,000 cfs.
Louver settings - Both louver bays open. North louver bay bypass pipe exit closed.

This test was designed to evaluate the effectiveness of underwater sounds to attract fish to the south louver bay bypass slot. First a hydrophone was used to listen to underwater sounds associated with the collection facility. The results indicated the environment in the louver bay was very noisy with a mechanical whining from the secondary separator attraction pumps dominant. The underwater speaker test premise was to drown out any background noise with broadcast sounds typically associated with a stream channel (water over rocks and rocks knocking together).

An underwater speaker wired to a portable stereo and amplifier was mounted to a 2.5-inch diameter by 10 foot steel pole. The speaker was lowered into the south louver bay to a depth of 4 feet three feet upstream from the bypass entrance slot. The pole was held in place by two U-bolts to a railing riser. The system played continuously during the scheduled hours of operation between June 24 – 28, 2002 (see Table 1).

The sound system was operated on alternate days (on/off) and fisheries personnel operated the counting house for the five consecutive days of testing. The north louver bay bypass flow was closed during the sound tests so that all fish entering the counting house were guided through the south louver bay. Fish numbers decreased dramatically after the north louver bay bypass flow was closed (see Table 2).

Approximately 780 fish/day were entering the counting house prior to the north bay flow shut down. Totals dropped to ~150 after shutdown, suggesting that Tilton River smolts and Mayfield Lake resident rainbow trout are oriented to the north shore of Mayfield Lake and encountering and entering the north bay initially. The north bay louver bypass flow was turned back on Friday, June 28 at 11:00 AM. Fish numbers rebounded slightly after the restart of the north bay flow.

Table 1. Operating schedule for 2002 Mayfield louver sound test

Date	Sound On	Sound Off
6/24	4:15pm	
6/25		3:00pm
6/26	3:00pm	
6/27		3:00pm
6/28		

Table 2. Fish recoveries at the Mayfield counting house, 2002.

Date	CH[1]	CO	CT	SH	RBT	Total	
6/24	25	2,263	7	82	511	2,343	Avg./day 783 (pre test)
6/25	9	166	1	9	47	180	
6/26	2	158	0	2	34	158	
6/27	1	121	0	4	27	123	
6/28	8	31	0	0	29	34	Avg./day 304 (post test)

The results were inconclusive. There were no obvious differences between fish numbers and speaker operation. It appears the shut down of the north louver bay bypass flow had the most affect upon numbers of fish collected at the Mayfield counting house. In addition, there was no way to quantify the delay of fish after entering the bypass slot until reaching the counting house.

Attachment:: Email from Chuck Coutant, Oak Ridge National Laboratory, July 11, 2002

[1] CH = chinook, CO = coho, CT = cutthroat trout, SH = steelhead, RBT = rainbow trout

Wicke, Marc

From: Chuck Coutant [CoutantCC@ornl.gov]
Sent: Thursday, July 11, 2002 12:01 PM
To: Wicke, Marc
Cc: mlarivie@ci.tacoma.wa.us
Subject: Re: Mayfield louver bay

Thanks, Marc. I appreciate the help and the opportunity to learn more about your fish bypass system at Mayfield. It looks like we learned the following:
1. The louver bypass system is very noisy underwater. Fish are entering a
loud environment with both the louver noises and pump noises creating a very loud background for anything else we might include. This high noise level constrasts with the quiet of the reservoir. We don't know what effect this noise has on guidance of fish.
2. The north bypass seems to be passing most of the fish. So the south bypass might not be the best one to modify to improve passage.
3. We might have had a few more fish going through the south bypass with my
sound system on, but this was masked by the lower number of fish going through the south bypass when the north unit was closed, the lumping of times/days of fish counts, and the gap in my CD player operation. Inconclusive, at best.
4. The site looks like a good place to use inexpensive light tags for observing fish trajectories in the louver bays, at least early in the season when water clarity is good like we had it when I was there. The 37-cent cost of each light tag is a lot better than several hundred dollars. For your purposes, you might want a large number of tracks even if
the data are more 2-dimensional than 3-D. With the low cost, you can do hundreds of fish cheaply in a few dark nights. The platform over the louver
bay would make observations easy, either by eye or with video.
5. The congregation of fish at the leaky valve in the fish holding area for
the counting house might suggest another option for increasing fish passage
into the bypass entrance of the louver system. Running a jet of water from
the air into the bypass entrance might have the same attracting power as the leaky valve in the one holding bay. Might be worth a try.
6. The Riffe Lake collector might be a better candidate for some more sound
work, as the background noise will be much less. I'd like to talk with you
folks about it more.

Although my trips down to Mayfield at the end of June were a bit hit-and-run, I know it was worthwhile for me. I hope it was for you. Perhaps we could develop some good experimental designs for another year based on this quick effort. Anyway, it was a pleasure meeting you, and thanks again for the help. ---Chuck

>Hello Chuck,
>I spoke with the project folks yesterday and the North louver bay was turned
>back on at 11 a.m.. Fish numbers increased at the counting house on Monday
>after three days of collection (Friday pm, Sat., Sun.). Averages for those
>days were 234 fish/day (702 total). Let me know if you need anymore
>information.
>Thanks

>
>________________
>Marc Wicke
>Fisheries Biologist
>Tacoma Power
>Ph: 253.502.8196
>Fax: 253.502.8396

****
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http://www.ornl.gov.
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COWLITZ RIVER PROJECT
FERC No. 2016

MAYFIELD DAM

FISH GUIDANCE SYSTEM EVALUATIONS

Louver Operational Change - 2002

Tacoma Public Utilities
Tacoma Power
Generation, Natural Resources

January 2003

1.2 *Objective*

The objective of this action was to increase the collection of downstream migrant fish at the Mayfield Dam fish bypass collection system. Continued operation of the secondary separator collection pumps in 2002 was recommended by the Washington Department of Fish and Wildlife evaluation biologist operating the downstream migrant collection facility.

2.2 *Study Area*

Mayfield Dam louver bypass system; north and south louver bays.

3.2 *Background*

In recent past years the Mayfield Dam louver bypass system secondary separator pumps were shut down when downstream migrant numbers dropped off, usually in the late summer or early fall. It was not necessary to operate the pumps for increased fish collection efficiency due to the few fish present, and there was a desire for energy savings. In 2002, large numbers of spring chinook smolts were present and collected during the late summer, and a recommendation was made to operate the separator pumps continuously.

In 2001, the secondary separator pumps at the Mayfield collection facility were turned off on September 13. Downstream migrant collection numbers dropped immediately thereafter. In 2002, two of four pumps were turned on April 1 and have remained on continuously.

4.2 *Origin of Mayfield spring chinook outmigrants*

Spring chinook salmon outmigrants collected at Mayfield Dam originate in the upper Cowlitz River basin above Cowlitz Falls Dam as no spring chinook are released in the Tilton River basin. A single chinook smolt recovered in 2002 at Mayfield Dam had a red elastomer eye tag (RLE), indicating the fish was part of a mark-recapture test group released above Cowlitz Falls Dam in July 2001. This recovery is evidence of an extended rearing period or a protracted outmigration from the upper and middle sections of the Cowlitz River basin. The marked fish was an age 1+ smolt (244 mm FL), rather than the smaller age 0+ (130 – 190 mm FL) smolts collected at the same time. Scales from the smaller mode of outmigrants collected at Mayfield Dam in 2002 confirmed they were age 0+, or hatchery origin spring chinook released in the upper Cowlitz River basin in 2002.

In recent years upper Cowlitz River basin spring chinook populations have been sustained primarily by releases of fed fry from the Cowlitz Salmon Hatchery. Unmarked juvenile spring chinook are transported upstream and released into tributaries and main stem locations in the Cowlitz River above Cowlitz Falls Dam. Table 1. is the release information for spring chinook in 2000 and 2001.

Table 1. Spring chinook fry plants in the Upper Cowlitz Basin in 2000.[1]

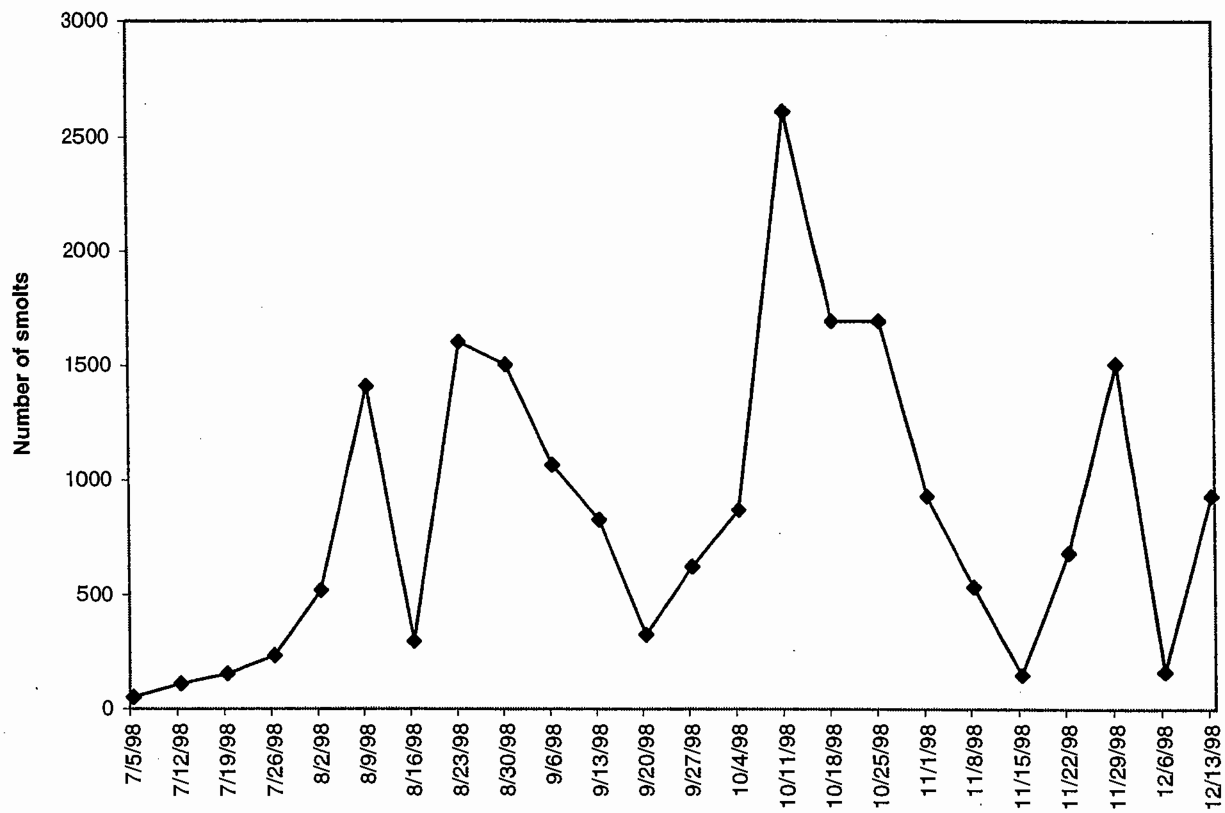
Date	Tributary	Fish Number	Size *fpp*	Date	Tributary	Fish Number	Size *fpp*
3/15/00	Silver Cr.	1,588	79	3/16/00	Yellow	4,680	110
3/15/00	Blue Hole	6,352	79	3/16/00	NF	6,840	110
3/15/00	Muddy Fork	10,163	79	3/16/00	Upper	36,132	85
3/15/00	Johnso	7,728	79	3/16/00	2801	8,180	110
3/15/00	Clear Fork	24,305	79	4/3/00	Yellow	5,240	131
4/4/00	Franklin Br.	7,259	119	4/3/00	NF	7,860	131
4/4/00	Blue Hole	14,000	140	4/3/00	Upper	55,926	131
4/4/00	Muddy Fork	21,728	119	4/3/00	2801	5,751	81
4/4/00	Clear Fork	32,900	140	4/5/00	NF	5,220	87
4/6/00	Skate Cr.	7,812	124	4/5/00	2801	14,744	124
4/6/00	Skate Cr.	12,200	122	4/5/00	Cispus	3,720	124
4/6/00	Lake Cr.	4,880	122	4/5/00	NF Cispus	8,432	124
4/6/00	Muddy Fork	18,192	122	5/4/00	2801	6,293	114
5/10/00	Blue Hole	5,490	55	5/4/00	NF Cispus	39,998	114
5/10/00	Clear Fork	1,098	55	5/8/00	2801	6,794	79
5/10/00	Franklin Br.	11,213	55	5/8/00	Upper	25,890	79
5/10/00	Muddy Fork	48,827	75	5/9/00	Upper	48,162	80
				5/9/00	2801	5,852	76
				5/9/00	NF	3,252	54
				5/9/00	Yellow	3,252	54
				5/9/00	2801	11,693	54
	Cowlitz	235,735			*Cispus*	313,911	
		Total Spring Chinook			**549,646**		

[1] Spring Chinook fry plants in the upper Cowlitz River Basin in 2001 totaled 489,776 between March 26 and May 14, and 497,467 fry planted in 2002.

5.2 *Results*

In 2002, spring chinook not collected at Cowlitz Falls Dam passed through the deep sluiceways or the turbines at the dam and moved into Riffe Lake. These fish spent an undetermined amount of time in the 23-mile long reservoir and eventually passed through the turbines at Mossyrock Dam. To enter the Mossyrock turbine penstock these fish sounded a minimum of 160' to reach the entrance. There was no spill at Mossyrock in 2001 and 2002, thus the only route for these fish to pass Mossyrock Dam was via the turbines. Upon entering Mayfield Lake the fish spent another undetermined amount of time in the 13-mile long reservoir and eventually guided into the collection facility at Mayfield Dam (see Figure 1).

Figure 1. Number of spring chinook collected at Mayfield Dam in 2002.



In 2002, due the large number of spring chinook present at the Mayfield collection facility in September (Table 2), the recommendation was made to keep the separator attraction pumps on. Table 3. shows the drop off in smolt collections at Mayfield immediately following pump shutdown in 2001. This same reduction in catch did not occur in 2002 with the pumps remaining on.

Downstream migrant spring chinook numbers increased throughout the fall at Mayfield Dam to a peak in October. Through January 2003 there are still spring chinook smolts collected at Mayfield and enumerated several times per week. The pumps are on to improve the collection efficiency of the louver bypass system.

Table 2. Spring chinook migrants collected at Mayfield Dam, September 2002.

Date	Number	Notes
August 28, 2002	527	
September 3	1065	
September 9	506	
September 13	319	Pumps remained on
September 19	324	
September 23	400	
September 27	222	

Table 3. Spring chinook migrants collected at Mayfield Dam, September 2001.

Date	Number	Notes
August 29, 2001	50	
September 7	128	
September 11	165	
September 14	0	Pumps shutdown on 9/13
September 23	46	
October 4	0	
October 11	0	

6.2 *Discussion*

Spring chinook collected at Mayfield Dam in 2002 range in size from 130 mm to 190 mm FL, with the occasional fish near 240 mm FL. Fish condition was very good with little scale loss, fin erosion or injuries. The historic estimates of fish collection efficiency (FCE) at Mayfield Dam were in the 60 - 80% range, thus if these estimates are still valid the actual number of spring chinook smolts passing Mayfield Dam in 2002 may near 30,000. These outmigrants are additive to the 26,000 spring chinook collected and transported from Cowlitz Falls Dam during July and August 2002. Together this represents an approximate 11.3% fed fry-to-smolt survival of hatchery fish planted in the upper Cowlitz River basin in 2002. Steelhead fry-to-smolt survivals averaged 12.9% in a study on the Keogh River, British Columbia (Ward and Slaney 1993).

7.2 *Passage past Mayfield Dam*

Passage through the turbines at Mayfield Dam was studied in March 2002 (Normandeau and Skalski 2002). Two sizes of salmonid smolts were used in the tests to establish size-specific survival rates as well as species differences. The sizes of the spring chinook collected at Mayfield Dam in 2002 are intermediate to the coho and steelhead smolts tested at the Mayfield powerhouse. As some of the spring chinook smolts are in the 190 mm range and other 1+ smolts are over 200 mm FL, the survival rates for the larger steelhead tested at Mayfield are likely a good surrogate. Survival rates ranged from 88% to 97% depending upon the unit passed. It is likely spring chinook smolts not guided by the bypass system at Mayfield passed through the turbines and survived at these rates.

8.2 *References*

Normandeau Assoc. and J. Skalski. 2002. Passage survival of juvenile salmonids through two Francis turbines at Mayfield Dam, Cowlitz River, Washington. Normandeau Proj. No. 18661. Prepared for Tacoma Power. Final Draft July 2002.

Ward, B. R. and P.A. Slaney. 1993. Egg-to-smolt and fry-to-smolt density dependence of Keogh River steelhead trout, p. 209-217. *In* R. J. Gibson and R. E. Cutting (ed) Production of juvenile Atlantic salmon *Salmo salar* in natural waters. Ca. Spec. Publ. Fish. Aquat. Sci. 118.

RECORD OF CONSULTATIONS

Cowlitz Fisheries Technical Committee meetings

Cowlitz Hydroelectric Project
FERC NO. 2016
Fish Technical Committee
Finalized Meeting Summary

Date: January 23, 2001 – 10:00 AM to 1:00 PM
Location: via TeleConference Services/ATT

Attendees:
FTC members:
Craig Burley, WDFW
Brad Caldwell, WDOE
Steve Fransen, NMFS
Mark LaRiviere, Tacoma Power
George Lee, Yakama Nation
Bill Robinson, Trout Unlimited

Others:
Mary Church, Adjunct
Steve Parker, Yakama Nation

Agenda Changes
No agenda changes requested.

Approval of Previous Meeting Summaries
During the comment period Mark received only a single word change to the draft December 12 meeting summary. Steve and Craig requested the following additional wording change in the December 12 meeting summary on page 3 regarding the *FTC Decision Making* protocol:

> To be deleted is the sentence: *Four votes or a simple majority will pass the motion.* The next sentence will be modified to read: *In the event of an even split, the motion will be deferred to the following meeting.*

No other edits were requested to the November 1, 2000 meeting summary or to the December 12, 2000 meeting summary. By consensus the FTC approved the summaries. Mark will have the final meeting summaries posted on Tacoma Power's web site within 7 days.

Public dissemination of the final meeting summaries was discussed. Steve and Craig stressed the need for meeting summary approval prior to public dissemination. Bill requested that meeting summaries be emailed separately and clearly be identified as those for informational purposes (i.e., finalized meeting summaries) versus those for action or comment (i.e., draft meeting summaries).

The issue of FTC protocols established in previous meetings was raised. Craig stressed the need for flexibility of the protocol and that there may be a need or desire for the protocol to be "in a state of flux" for effective FTC operations. During the development of the FTC there should be the flexibility to modify previous protocols. By consensus the FTC agreed and established that

- FTC protocols will remain flexible for effective meeting operations and function. The FTC acknowledges that the protocols can be further developed or adjusted in future meetings as the need arises. Protocols will become firm once the entire protocol package is finalized by the FTC.

Old Business/Tabled Issues

FTC Conventions and Protocol: Mark began the discussion with the question of who should attend FTC meetings. Steve offered that the Cowlitz settlement agreement (SA) as written defined the membership of the FTC as a technical representation from the signatory parties. The FTC exists for the sole purpose of implementing the terms of the SA, and non-signatories may not be devoted solely to the agenda of the signatory parties. Steve's view is that there should not be any non-signing representatives present. Besides, he said, the larger the mass (of people) the less work gets done and meetings become a free-for-all environment that is counter productive. Clearly there is a need for a public involvement process Steve said, however, that is a related but separate issue.

Mark agreed with Steve on all points, and said that there is a separate group working on a public involvement protocol – Brett Joseph and Toby Freeman. Components of their discussions include the possibility of; FTC hosted public meetings or forums twice per year, *Cowlitz Currents* mailings with relevant information, and public observation and opportunity to speak at the public meetings.

Bill pointed out that it his desire to get Dave Becker and his knowledge of the Cowlitz basin involved in the workings of the FTC. Although he is not an aquatic scientist per se, allowances were made in the SA for the Conservation Caucus representative to be a person with extensive knowledge of the Cowlitz River basin.

Craig said there are two issues: the need to solicit technical expertise to assist in the deliberations of the FTC, and a public participation process. He would like to have an all-inclusive forum (such as public attendance, observation and discussion) versus a fractured forum (such as individual agencies soliciting from their constituents and bringing the information to the FTC). Craig acknowledged that each agency is free to develop an internal viewpoint on any issue separate from the FTC, and as an example, the WDFW will use their expertise to backfill any gaps in Craig's knowledge of Cowlitz issues. He supports holding public meetings/forums at milestones or document/plan release dates to seek public comment and involvement, however, these forums may not be adequate or timely for FTC needs.

Mark called for consensus on the protocol point of:

> FTC meeting attendance is limited to FTC members, with allowances for technical representative attendance as determined by the individual FTC members.

Consensus was not reached. Prior to a vote, Craig asked for more feedback from the FTC. Bill supported a separate public involvement group from the technical group. Steve Parker offered that it was his opinion the FTC is under no obligation to make their meetings open to the public, he asked the FTC to consider why they would want to turn a technical forum into a political forum and he agreed with FTC members that each agency has their own public outreach and public information gathering process that could be used to bring public opinions to the FTC.

A "straw vote" was taken. The protocol motion was passed as stated. The minorities were given the chance to further discuss their viewpoint. Craig said he was not comfortable making a decision today that would preclude have the public observe FTC meetings. He supported deferring the issue until a later time when it could be addressed in the context of an entire public involvement process. A second vote was taken. The protocol motion passed again, 4 votes to 2 votes.

Using the Sussman Protocol for Decision Making the minority was given three options to conclude the process. They choose to amend the protocol motion regarding public attendance at FTC meetings in such a way that they would not oppose it.

Following discussion the FTC agree by consensus to the following protocol:

- FTC meeting attendance is limited to FTC members and technical representatives as identified by the individual FTC members. A decision regarding public involvement in FTC meetings will be deferred until the completion of a public involvement process for the Cowlitz Project license.

Adult reservoir transit studies: Steve suggested tabling this issue again. Mark disagreed because protocol would require the FTC to revisit the issue at subsequent meetings. Bill asked if there were a window of opportunity that we would miss this year if we did not conduct the study. Mark pointed out that this was not the case, as these studies were to be conducted with only known upper basin origin adults. The major factor in the delay of this proposed study is the lack of steelhead and coho which can be identified as being of Tilton River origin. Steve said the FTC would support and require these studies in the future. Mark explained that due to current marking conventions in the Cowlitz River basin the ability to identify a known origin adult salmonid upon return to the Cowlitz Salmon Hatchery separator is still several years away, thus we would not forgo any opportunity by not conducting the study this year. Bill requested Tacoma report on the results of the 2000 adult spring chinook radio tagged and released in the Cispus River. Mark replied this was a WDFW study conducted by the Cowlitz Falls Fish Collection Facility crew with Tacoma assistance (radio tags and radio tagging equipment). The draft report from WDFW is currently in preparation. The FTC requested Tacoma put together a proposal with timelines for conducting adult salmonid transit research in the future.

FTC Workplan/timeline: Discussion about the need for a more detailed timeline for all FTC tasks and responsibilities occurred. It is especially critical to identify when decisions need to be made in order to complete tasks in a timely manner. Mark pointed out the settlement chronology tasks table in the FTC document handed out at the first meeting. It was acknowledged this was a good start, but that more detail and a second iteration of this table are needed. The FTC requested Tacoma to develop a draft "Gantt chart" or similar tool for the FTC tasks and distribute it to the FTC 15 days prior to the next meeting.

<u>2001 Mayfield Louver Evaluations Study</u>
Mark described the Tacoma request for proposal (RFP) process that was poised to occur upon the concurrence of the FTC for this study. Baring objections from the FTC the RFP will be released later today (1/23/01), with proposals due to Tacoma Power on February 9. It is anticipated this will be the first year of a three year study. The RFP has two components; a description of the hydraulic conditions of the louvers and species specific passage routes through the louvers during the defined study period.

Steve asked for clarification of the hydraulic model portion. Mark explained the this was not a request for a physical model, rather a computational model that could be displayed on a desktop computer and used by the biologists to direct their tagging efforts for determining fine-scale fish movements within the louvers. Mark will bring a demonstration CD of computational fluid dynamics modeling to the next FTC meeting.

The schedule calls for the Notice to Proceed to be issued in early March and work begun in April of this year. Tacoma anticipates partnership proposals where more than one company collaborates on different areas of the RFP. Mark offered that if the proposals were too expensive, or if Tacoma staff was unable to approve a contract through the Tacoma Public Utility Board process, it is possible the study might not occur as planned in 2001. As requested by the FTC, Mark will summarize the salient points of the proposals received and solicit FTC comments via a telephone conference call with the FTC, or individual telephone contacts. This will constitute ad hoc approval from FTC members in lieu of review at the next FTC meeting. By consensus the FTC approved issuing the Mayfield louver evaluation RFP.

Mark offered that Tacoma would host a FTC meeting at Mayfield Dam during the study for committee members to observe the activities and meet the contractor.

George reported that Steve Parker had left the teleconference.

<u>Fish Hatchery and Management Plan</u>
Mark described the use of the documents distributed to the FTC for this meeting. The 2001 Brood Document and the Cowlitz Complex adult handling protocol are

internal WDFW origin documents that are in a constant state of flux (i.e. always DRAFT) and not readily available to Tacoma nor the FTC. These planning documents drive the operation of the hatchery and the disposition of adults that return, they establish broodstock goals and escapement goals, and they drive fishery management decisions. The third document distributed to the FTC, the Cowlitz River Management Framework (WDFW July 1999) is the most recent management plan for the Cowlitz River authored by the WDFW.

Discussion about the need for these plans and documents to be consistent with the terms of the SA followed. Crag said he would meet internally about updating the Brood Document soon, and the WDFW would commit to supplying updated copies of the Brood Document and the status of the adult handling protocol to the FTC at future meetings. Mark offered to answer any questions from FTC members regarding the documents.

Steve questioned why unmarked winter-run steelhead adults were not allowed upstream of Mossyrock Dam prior to March 15. He explained that as recovery of the late winter-run stock occurred in the upper Cowlitz River basin, run timing of these fish would expand and very likely result in returns of upper basin naturally produced winter-run steelhead to the Cowlitz Salmon Hatchery separator prior to March 15. These fish should be taken upstream. Craig offered to look into this particular issue and report back to the FTC with his findings

Discussion turned to the logistics of preparing a Fish Hatchery and Management Plan. Steve suggested WDFW prepare a draft of a fish hatchery and management plan to use as a working document for the FTC. Craig agreed as to the need for this to come from WDFW, but he acknowledged this might not be possible with limited staff resources. It is a time issue. The question arose about Tacoma funding a consultant to work with WDFW to assist, but it is unknown if this would be possible. Craig said he felt there was a possible mechanism in place for Tacoma and the WDFW to work together on developing this plan by having Tacoma expand the funding of the Cowlitz evaluation biologist contract with WDFW. Craig and Mark will report back to the FTC at the next meeting with their findings on a contract or contractor to develop this plan.

<u>Meeting adjournment:</u>
The meeting was adjourned and the conference call ended at 1:00 PM. The next meeting is scheduled for March 6, 2001, 9:00 AM to 1:00 PM, at the USFWS/NMFS office in Lacey, Washington.

Cowlitz Hydroelectric Project
FERC NO. 2016
Fish Technical Committee

Finalized Meeting Summary

Date: March 6, 2001 – 9:00 AM to 1:00 PM

Location: NMFS office, Lacey, WA

Attendees:

FTC members

Craig Burley	WDFW
Brad Caldwell	WDOE
Steve Fransen	NMFS
Mark LaRiviere	Tacoma Power
George Lee	Yakama Nation
Bill Robinson	Trout Unlimited
Gene Stagner	USFWS
Others:	
Mary Church	Adjunct
Wolf Dammers	WDFW

Agenda Changes

The FTC added several agenda items. Craig requested to add 2001 Future Brood Document under Old Business/Tabled Issues. George requested to add Cowlitz River spring chinook status review. Steve requested to add Riffe Lake chinook smolt salvage operation. Mark requested to add Public Meeting.

Approval of Previous Meeting Summary

Steve requested a single edit to the January 23, 2001 meeting summary. All other comments or corrections previously received from the FTC were incorporated in the Draft Meeting Summary mailed out prior to this meeting. By consensus the FTC approved the Meeting Summary.

Old Business/Tabled Issues

FTC Web Site: Mark announced that the Cowlitz Fisheries Technical Team web site, linked from Tacoma Powers' web site, is now up and running at http://www.ci.tacoma.wa.us/Power/parks/cowlitz/default.htm. FTC members were asked to review the site and bring suggestions for improvements, accessibility and format back to Tacoma.

FTC Conventions and Protocol: The January 2001 version of FTC Operating Protocols was reviewed. With respect to the use of the Sussman Consensus Model, Craig suggested adding the following line to the protocol bullet:

> In the event of an even split, the motion will be deferred to the following meeting

By consensus the FTC agreed to the following bullet as a FTC protocol:

- The Sussman Consensus Model, *DECISION MAKING BY CONSENSUS, A STRATEGY* (adapted from Steve Sussman, Organization Training and Consulting) will be the Cowlitz Fisheries Technical Committee decision making process. In the event of an even split, the motion will be deferred to the following meeting.

BY 2001 Future Brood Document: Craig and Wolf handed out two draft tables, Cowlitz Hatchery Complex Mitigation Production 2001 Brood and Cowlitz Complex Production 2001 Brood. Craig described the numbers in these tables as a proposal or draft, and a precursor to the draft brood document. Coho, fall chinook and early winter-run steelhead numbers are decreasing. Total proposed poundage is 771,500 pounds.

The WDFW brood document development process was described by Craig as; developing a *draft* brood document (the proposal), establishing a *future* brood document annually on July 1 (the plan) and operating with an *equilibrium* brood document (as reality). The numbers presented in these two tables are for FTC review and comment, and intended to be consistent with the Settlement Agreement (SA). Craig established that the draft brood document is a first check point and that the WDFW is reluctant to make changes beyond the draft brood document. Craig acknowledges that this proposal keeps intact programs for which no agreements have been made.

This proposal has been reviewed by Rich Turner, National Marine Fisheries Service (NMFS) for Endangered Species Act (ESA) consistency and, with the exception noted below, he has found the proposal to be acceptable. All the issues raised by this proposal will fall under the Hatchery Genetics Management Plan (HGMP) process required by NMFS for the 4 (d) rule.

Team members queried Craig and Wolf on specific sections of the tables.

Summer-run steelhead: Craig pointed out that the F.O.C. cooperative summer steelhead program smolt releases are not included in the Cowlitz Complex program total of 550,000 smolts, that funding for the coop program is undetermined, and that

ESA consistency of the coop program releases (90,000 smolts) has yet to be determined by Rich Turner, NMFS.

Resident rainbow trout: Mark pointed out to Craig the Cowlitz Fisheries Technical Team convened during the relicensing process (prior to the signing of the SA) supported ending the releases of all resident rainbow trout into anadromous fish-bearing waters in the Cowlitz River basin above Mayfield Dam. The focus of the resident program was to shift to stocking of trout into lakes, ponds or reservoirs where there were no conflicts with anadromous fish. Craig responded that; the exact stocking locations were not established in the SA, the WDFW 2002 stocking proposal is a reduction from historical stocking levels; WDFW is still trying to determine if this stocking program is an ESA issue; and that due to the loss of Yellowjacket Ponds on the Cispus River there are few places left to stock these fish.

Discussion followed how resident fish stocking issue is handled in other areas. Craig stated Idaho has been given permission by NMFS to stock resident fish in anadromous waters. Steve pointed out that there is precedent within Washington state to discontinue stocking hatchery catchable trout in anadromous waters – Region 4, possibly Region 6 and the National Park Service have all ended these programs. The WDFW determined that stocking hatchery rainbow trout is an inconsistent fishery management action and stopped the stocking in other regions of the state. Bill pointed out that the Wenatchee River is closed to trout fishing and that hatchery stocking in the river system has been stopped due to the ESA listing of steelhead.

Craig responded that WDFW created a resident fish stocking policy in 1992 that designated streams for stocking with hatchery fish stockings decided on a site-specific basis. The WDFW is looking for solid rationale that stocking hatchery rainbow trout is inconsistent with anadromous production, specifically regarding the issues of predation and competition. The Skate Creek and Tilton River stocking program has been cut back to 15,000 fish planted in June, July and August. The WDFW is looking to establish a balance – harvest opportunity versus natural stock recovery.

Steve asked the WDFW to provide rationale for this stocking program.

Tiger muskie: Mark pointed out that, like the resident rainbow trout program, the Cowlitz FTT favored ending the tiger muskie program in Mayfield Lake. Craig responded that due to a loss in the Columbia Basin hatchery no tiger muskies are available to be stocked in Mayfield Lake in 2001. The 2002 program proposal stands as presented, and that the issue is intended to be resolved through a fish management plan development.

The FTC is charged with bringing comments on the brood 2001 proposed tables to the next FTC meeting.

Cowlitz Complex Adult Handling Protocol: Craig said there have been no changes to the adult handling protocol distributed at the last FTC meeting. The trigger date for returning unmarked winter-run steelhead to be transported upstream is now based upon the arrival of the second RV marked winter-run steelhead, even if it arrives prior to March 15.

2001 Mayfield Louver Evaluations Study

Mark described the RFP and contractor selection process for the louver evaluation study. Six proposals were received and Tacoma's internal committee selected three firms to interview. The proposals varied greatly in their emphasis upon hydraulic evaluations and fish tracking work. Northwest Hydraulic Consultants Inc. was selected based upon their comprehensive approach, cost and use of Hydroacoustic Technology Inc. acoustic tags for fish tracking. Mark showed video animations from demonstration CDs of the kind of results that could be expected from computational fluid dynamics modeling and from fish tracking studies conducted at Mayfield Dam.

The study schedule was discussed. Steve pointed out that receiving 2001 study results in January 2002 will force a short turn-around time for making decisions on how to proceed for a second year of studies. Mark will ask the contractor to get the study results to the FTC by December 2001 at the latest.

Pending Tacoma Public Utilities board approval, the study will begin at Mayfield Dam in April 2001. Mark will schedule a future FTC meeting at the Mayfield office while the study is underway for FTC members to view the work.

Status of Spring Chinook run in the Cowlitz River

George handed out tables that forecasted 2001 spring chinook runs to the Columbia River by tributary. He questioned why the Cowlitz River spring chinook runs were so low compared to other Columbia River runs.

Mark pointed that all the lower Columbia River spring chinook stocks are depressed – Kalama, Lewis and Cowlitz Rivers. The entire Cowlitz River spring chinook run is supported by hatchery releases because, to date, natural production from the upper basin restoration is limited. All Cowlitz hatchery production is released at 4 fish per pound (fpp), more that twice as large as naturally produced chinook smolts in the Cowlitz River and considerably larger than spring chinook smolts released from other hatchery programs on the Columbia River. The severe depression of Cowlitz River spring chinook coincides with the increase in hatchery production (to 1,440,000 smolts) and the increase in size-at-release of spring chinook from the Cowlitz Salmon Hatchery. In recent years the production level has been reduced, but has not returned to the stable levels of 600,000 smolts prior to the early 90's when good returns and survivals were experienced. Historically spring chinook smolts on the Cowlitz River were the same size at outmigration that hatchery-reared smolts are released from the upper Columbia River hatcheries - 10 fpp.

In addition, Mark pointed out that Cowlitz hatchery spring chinook are being released this week, and that March was not a historic outmigration time on the Cowlitz River. Timing of entry into the ocean may be a critical factor in year class survival, and all lower Columbia River hatchery spring chinook from WDFW hatcheries may be entering the ocean too early. Craig agreed that ocean conditions seem apparent for affecting survival, and there are survival differences between upriver and lower river stocks.

A discussion followed on the projected adult coho return to the Columbia River in 2001. The Cowlitz River return may be twice the 2000 return. Mark requested the WDFW allow all coho returns surplus to hatchery needs be allowed to be transported around the dams into the upper river basins. Tacoma Power will be responsible for the transportation. There should be no limits placed on the number of fish taken upstream as they represent a critical source of marine derived nutrients necessary for primary and secondary production in the upper river basin ecosystem.

The removal by sport harvest in the upper basin was roughly estimated at between 6% and 10% of the coho transported upstream. Steve pointed out that the WDFW is allowing a harvest on stocks of salmon in the upper river, whereas management practices on almost all other Washington rivers has been to close the upper basin to harvest and allow harvest only in the lower river. Steve questioned whether it is appropriate to preserve a traditional fishery when the goal of developing a self-sustaining run is not yet met.

Craig responded that the Cowlitz is a unique situation with the hydroelectric dams mid-basin. The situation is not comparable to rivers without hydro dams. At some point in the future harvest may occur upon wild steelhead in the upper Cowlitz River. Bill responded that would only occur following implementation of volitional passage over the dams.

<u>Riffe Lake chinook smolt salvage</u>

Steve Fransen wanted the FTC aware of the possibility of a salvage operation for chinook outmigrants available below Cowlitz Falls Dam in 2001 due to low flows. Mark explained the anticipated reservoir operations, water levels and temperatures and outmigration timing. The use of Merwin traps in Riffe Lake for this operation is unlikely due to reservoir levels and accessibility. It was agreed a limited salvage operation could be done with floating traps, i.e., screw traps. The FTC members agreed to research trap availability for Tacoma. Time is critical and the FTC will revisit this issue at the next meeting.

<u>FTC Workplan/Timeline</u>

Mark introduced the concept of selecting an outside contractor to assist the FTC in developing the Fish Hatchery and Management Plan (FHMP). Steve questioned whether the WDFW had already begun the process and would not a contractor be redundant. Craig responded that the WDFW would prefer to have the resources to conduct the work, and requested funding from Tacoma for WDFW personnel to produce the first draft of key components of the FHMP. WDFW will bring a draft proposal to conduct this work to the next FTC meeting.

Mark pointed out that if the license was written as per the SA, it would be Tacoma's responsibility to see the FHMP is completed and filed with the Federal Energy Regulatory Commission (FERC) within 9 months of license issuance. Thus Tacoma and the FTC need to oversee the contractor and ensure product deadlines are met, however, ultimately it would be Tacoma's responsibility to file a FHMP.

A timeline was drawn on the board assuming a new license for the Cowlitz Project was issued on January 1, 2002 and that the FHMP was due to FERC nine months later. Working backwards in time the FTC agreed they would want to review a first draft of the plan February 1, 2002, thus there are only eleven (11) months available to get the first draft produced.

Mark agreed to provide the names of potential contractors to the FTC prior to the next meeting. Tacoma and WDFW agreed to bring separate proposals to the next meeting for completing a FHMP within the identified timeline.

FTC Public Meeting

Tacoma is in favor of announcing a public meeting regarding the Cowlitz FTC. The FTC agreed it would be good idea, but questioned whether it needs to be a "Cowlitz FTC" meeting. The FTC supports announcing a meeting on public involvement in the Cowlitz Settlement Agreement implementation.

Meeting adjournment

The meeting was adjourned at 1:00 PM. The next meeting is scheduled for April 11, 2001, 10:00 AM to 2:30 PM, Room 2B, Tacoma Public Utilities Building, Tacoma, Washington.

Cowlitz Hydroelectric Project
FERC NO. 2016
Fish Technical Committee

Finalized Meeting Summary

Date: August 7, 2001 – 10:00 AM to 12:30 PM

Location: NMFS and USFWS office, Lacey, WA

Attendees:

FTC members

Craig Burley	WDFW
Gene Stagner	USFWS
Steve Fransen	NMFS
Mark LaRiviere	Tacoma Power
Brad Caldwell	WDOE

Others:

Wolf Dammers	WDFW

Agenda Changes

Mark requested to add two items at the end of the agenda: Cowlitz Evaluations and Cowlitz Falls Dam flow modification request.

Approval of Previous Meeting Summary

All comments or corrections received from the FTC were incorporated in the Draft Meeting Summary mailed out prior to this meeting. By consensus the FTC approved the June 5, 2001 meeting summary.

Old Business/Tabled Issues

Mayfield louver evaluation study: Mark reported on the status of this study. All 2001 fieldwork has been completed – Northwest Hydraulics Inc. has completed the velocity measurements within the louver bay and Hydroacoustic Technology Inc. has gathered tracking information from acoustically tagged coho smolts released at Mayfield Dam. The next steps are to put the results together in the grid format used for computational fluid dynamics modeling, to create video clips of fish and water movements and present the data for further discussion. A demonstration of the preliminary findings is tentatively scheduled for the October FTC meeting. Mark will arrange for the contractor to prepare a product for FTC discussion.

The FTC discussed continuing the study for another year and agreed that if the spring outflows at Mayfield Dam were low once again next year (near minimum flows – 2,600 cfs), it would not be desirable to repeat the study. Steve pointed out that most downstream migrant facilities have their best collection efficiencies at low flows, thus the results from the 2001 Mayfield louver evaluation study may be sufficient to move ahead with designing engineering solutions for improving the fish guidance efficiency rather than studying the issue again at higher flows. The discussion concluded with a suggestion that it may not be desirable to repeat the study under low water conditions.

A supplementary discussion of the deferred Mayfield turbine survival study occurred. The FTC reviewed their reasons for deferring the 2001 turbine survival study and accepted Mark's offer to distribute to FTC the Cowlitz Falls Dam 2000 turbine survival study report. Mark pointed out that given the current elevation of Riffe Lake (~738') and the possibility next spring's outflows remaining at or near minimum flows, the only opportunity for conducting a turbine survival study at higher outflows may be this coming winter – the months of January, February and March. By consensus the FTC agreed it might be necessary to proceed with the study this coming winter. Test species would be hatchery fish the same size as naturally outmigrating coho, steelhead and cutthroat smolts and cutthroat kelts. Mark will provide the data on species, sizes and timing of the 2001 outmigrants captured at the Mayfield counting house for the next FTC meeting. This study will be an agenda item at the next meeting.

Fisheries and Hatchery and Management Plan

Mark handed out the final draft of the Cowlitz River Project FHMP outline, which includes deadlines and proposed lead entities for completing the four tasks. This work product is the result of several meetings held since the last FTC meeting between Tacoma Power, Mobrand Biometrics Inc. (consultant to Tacoma) and the WDFW. The timeline calls for the completion of a review draft plan available for internal Tacoma and WDFW review by December 1. The secondary goal is a February 1 draft plan for FTC review.

Mark asked for FTC comments on the outline by September 1. Those FTC members not present at this meeting will be solicited by mail to comment by the deadline.

Work is currently underway to complete the subtasks under Task 1 and Task 2 of the FHMP outline. Craig explained that the WDFW will propose the August 15 deadlines be pushed back to September 1, and the department will confirm their ability to complete a deliverable by that date.

Steve asked that Rich Turner, NMFS (Sustainable Fisheries Division/Hatcheries & Inland Fisheries Branch, Portland, OR) be added to the FTC mailing list as an additional NMFS technical representative. Craig asked that Wolf Dammers, WDFW be added to the FTC mailing as well. By consensus the FTC agreed.

Cowlitz Evaluations

Task 4, the Monitoring and Evaluation Plan, is the least developed part of the FHMP outline in regards to detailed assignments. Craig confirmed the WDFW will develop a "strawman" of a monitoring and evaluation plan by November 1. The WDFW is interested in developing a monitoring and evaluation plan that will meet ESA section 7 and section 10 permit requirements, will be consistent with the HGMP (Hatcheries and Genetic Management Plan) as required by NMFS, and provide biological and ecological assessment of fisheries actions in the basin. The FTC will review the strawman monitoring and evaluation plan and agreed that the committee should set the priorities and address the need for biological evaluations in the Cowlitz River basin.

Mark handed out a matrix of current biological evaluations in the Cowlitz River basin above the mouth of the Toutle River by geographical region and funding source. Mark explained the details of some of the currently funded evaluations. The matrix was considered, and viewed as a start in developing priorities for basin evaluations, however, other inputs were needed. The FTC was in agreement that all fisheries evaluations in the Cowlitz River basin above the mouth of the Toutle River should be coordinated to avoid duplicity and focus the funding in the highest priority area. Discussion followed on examples of coordinated evaluations in other river basins (Lewis), and systems with a lack of coordination (Skagit).

Cowlitz Falls Dam flow modification request

Lewis County PUD has requested that FERC allow a temporary modification of the instream flow requirements below Cowlitz Falls Dam. Mark discussed that Tacoma Power has concerns with allowing this modification due to biological and ecological impacts, public safety and downstream migrant collection efficiency. Tacoma will file with FERC requesting intervention status for this proceeding.

Craig noted the WDFW comments put together by the Habitat Division, Major Projects have been sent to LCPUD.

Meeting adjournment

The meeting was adjourned at 12:30 PM. The next meeting is scheduled for 10:00 AM, September 4, 2001at the NMFS/USFWS office in Lacey, Washington.

Cowlitz Hydroelectric Project
FERC NO. 2016
Fish Technical Committee

Finalized Meeting Summary

Date/Time:	June 5, 2001 – 9:00 AM to 1:00 PM
Location:	Mayfield Project Office, Silver Creek, WA

Attendees:

FTC members:

Craig Burley	WDFW
Gene Stagner	USFWS
Steve Fransen	NMFS
Mark LaRiviere	Tacoma Power
George Lee	Yakama Nation
Bill Robinson	Trout Unlimited

Others:

Lars Mobrand	Mobrand Biometrics, Inc.
Kevin Malone	Mobrand Biometrics, Inc.
Wolf Dammers	WDFW

Tour Mayfield Louver Collection System

The FTC assembled at Mayfield Dam at 9:00 a.m. to view the tracking array set up by Hydroacoustics Technology, Inc., to study the movement of acoustically tagged coho smolts within the louver bay. Results from the first week of the study were discussed and illustrated with print and video graphics. Twelve additional tagged coho smolts were released earlier in the morning on June 5; however, no "hits" had been recorded at the time of the tour. The FTC then proceeded to the Mayfield counting house below Mayfield Dam to view the smolt handling and fish tagging operations. A crew of temporary employees was inserting blank wire tags into the snouts of unmarked coho and steelhead. Dan Harmon (WDFW), the acting project evaluation biologist, demonstrated the fish handling process and answered questions. Approximately 2,500 coho smolts were bypassed, tagged and released below the Mayfield powerhouse on June 5.

The FTC then assembled at the Mayfield Project office at 10:15 a.m. for the meeting.

Agenda Changes

Bill requested adding an item about information sharing.

Approval of Previous Meeting Summary

All comments or corrections previously received from the FTC were incorporated in the Draft Meeting Summary mailed out prior to this meeting. Bill asked if regulation changes could be considered for stocking decisions. Craig replied that a stocking decision is a management strategy and does not require a regulation change. By consensus, the FTC approved the Meeting Summary.

Old Business/Tabled Issues

Riffe Lake chinook smolt salvage: Mark discussed a letter from Lewis County PUD and Bonneville Power Administration that declined assistance with the chinook salvage operation below Cowlitz Falls Dam this summer unless they were reimbursed. The letter stated, "..this trapping operation is a Tacoma Power obligation." Tacoma disagrees, and envisions a multi-party effort that cannot go forward unless all cooperate. Craig reiterated that the WDFW offered assistance in obtaining the necessary permit(s) at the last FTC meeting, but stated that no manpower was available from WDFW for the collection effort.

Steve expressed that the LCPUD/BPA response was not surprising given the evolving BPA opinion that the results from the Cowlitz Falls turbine survival study relieves them of further obligations. Steve and Gene reviewed the Cowlitz Falls Dam Section 7 permit schedule. There will be a meeting to discuss the latest draft BA from LCPUD/BPA which may lead them to prepare a final draft BA for FERC. The schedule is unknown. Following that, the federal agencies will issue a biological opinion (BO). Steve is not saying what the BO will contain.

By consensus, the FTC agreed the chinook smolt salvage operation would not go forward this year due to a lack of agency cooperation.

Fisheries and Hatchery and Management Plan

Mark described the process that has occurred since the last FTC meeting in developing a Fisheries and Hatchery and Management Plan (FHMP) outline. Jeff Koenings, WDFW Director, requested that Mobrand Biometrics, Inc., be utilized by Tacoma and the FTC to develop the FHMP with assistance from WDFW staff in writing key sections of the plan.

Tacoma and WDFW met on May 30 and developed an outline that was distributed to the FTC via e-mail prior to this meeting. There is a follow-up meeting planned for the afternoon of June 5 at the Mayfield office to review the current outline and assign responsibilities for producing sections.

Kevin Malone described the FHMP outline process development to date and projected the outline on an overhead screen for a line-by-line review of the sections and edits. Discussion regarding the emphasis on harvest occurred and the first task was changed to read:

> *Task 1. Develop fish management goals that prioritize the restoration of wild, indigenous salmonid stocks while allowing for harvest opportunities consistent with the primary objective.*

Steve pointed out that the NMFS legal priorities/objectives are: 1) to recover listed stocks; 2) to provide fish for treaty protected fisheries; and 3) to provide fish for recreational and commercial harvest. These priorities are reflected in the Cowlitz Settlement Agreement (SA), and the FHMP emphasis regarding harvest should be subordinate to wild stock recovery.

Lars offered that Mobrand Biometrics involvement in the FHMP process is due to their involvement in the Hatchery Scientific Review Group. Any hatchery reform plan must be done in a context that includes a harvest component.

The FTC reviewed the entire draft FHMP outline, edited portions for clarification, printed out the new version, and distributed it to all present.

Information Sharing

Bill asked for clarification on how to distribute information (drafts, etc.) and work products from the FTC to members of the groups that he represents. Other groups that did not sign the SA have requested the information as well. The Cowlitz relicensing process is very different from traditional or other relicense proceedings, and there is a demand for the information upon which the FTC is reviewing and working.

There was general consensus that there is no obligation to share this material with non-represented groups. Bill is the technical representative for Trout Unlimited (TU) and American Rivers (AR), thus his sharing would be limited to key members or selected individuals within those organizations. The FTC agreed this is the case with all members – information sharing is to be done on a judgment basis with key individuals from the organization(s) the FTC member represents.

Meeting Adjournment

The meeting was adjourned at 1:15 p.m. The next meeting is scheduled tentatively for August 7, 2001, time and location to be determined later.

Cowlitz Hydroelectric Project
FERC NO. 2016
Fish Technical Committee

Finalized Meeting Summary

Date: January 9, 2002 – 10:00 AM to 1:00 PM

Location: Room 223, NMFS/USFWS office, Lacey, WA

Attendees:

FTC members

Craig Burley	WDFW
Steve Fransen	NMFS
Mark LaRiviere	Tacoma Power
Brad Caldwell	WDOE
Bill Robinson	Trout Unlimited
Gene Stagner	USF&WS

Others:

Wolf Dammers, WDFW

Marc Wicke, Tacoma Power

Rich Turner, NMFS

George Lee was not available to attend

Agenda Changes

Mark requested to add the Riffe Lake downstream migrant collection meeting and a discussion of the Cowlitz Complex adult handling protocol. The FTC agreed to make the additions to the end of the meeting.

Approval of previous meeting summary

Mark moved to adopt the December 4th meeting summary. No comments or corrections were received from FTC and the summary was adopted by consensus.

Old Business

- Mayfield turbine survival study status

Mark announced the Mayfield turbine survival study would begin March 4, 2002 and handed out the study plan the consultant, Normandeau Associates, Inc. has developed. Mark requested the FTC review the plan for consistency. The proposal will go to the utility board on January 23rd for funding approval.

Mark described the general study plan and compared it to the Cowlitz Falls study conducted three years ago. This study will be the first for a high head Francis turbine unit. Up to 100 to 120 smolt size coho and steelhead from the Cowlitz Complex fish will be tagged and put through the turbines each day. The FTC discussed sample and control sizes, expected survival rates and recapture rates. The FTC focused discussion upon the expected survival rates of turbine introduced fish and control fish (95% and 98% respectively) in relation to the sample size.

Gene had concerns that the expected survival rate was too high, comparing it to results from the Cowlitz Falls Dam study given the head difference between the two dams. Gene felt the survival would be closer to 80% and also expressed concerns that if the expected survival rate was in fact too high, there would not be a large enough sample for the desired statistical precision.

Mark felt that the sample size was adequate and the sample number was based on the lowest anticipated rate of turbine survival; control survival rate and recapture rate.

Gene suggested a contingency to the study that in the event survival was lower than anticipated, additional tagged fish could be released. A contingency is in place in the study plan whereby the contractor can do additional releases if on-site survivals indicate the need to increase the sample size. Mark offered to provide the FTC with more information as a follow up.

Bill raised the question about using juvenile chinook for the study, since spring chinook is one of the primary species of concern. Mark said that fall chinook would be too small and we are limited by the available technology. Gene stated that we will have various sizes of fish in the sample and regression could be used to extrapolate spring chinook survival.

10:45 – Rich Turner joined the meeting

Resident fish evaluation discussion

Craig expressed the need for discussion related to the resident trout program. He acknowledged that there was discussion during the relicensing studies and settlement agreement negotiations about ending the program. Craig stated that WDFW needs to evaluate the success and impacts to anadromous fish in detail before its possible

termination in 2004. Craig requested the FTC list possible items to address in an evaluation of the resident trout program.
The FTC recommended the following points of interest:

Impacts to anadromous fish

- Predation
- Competition
- Incidental hooking impacts/mortality
- Increased fishing pressure on non-stocked streams
- Encounter rates of anadromous fish by gear types
- Distribution of stocked fish

Other points to evaluate

- Carry-over rate
- Possible changes to gear specifications
- Benefits of program
- Examination of resident trout stocking programs in anadromous stream state wide

Develop alternatives

- Timing of releases
- Marking of fish to identify hatchery trout
- Alternate release sites (non-anadromous waters)
- Dynamic stocking rates

Steve questioned the rationale behind the resident trout program and asked what hydroelectric project impacts were equal to the need to mitigate with 50,000 pounds of resident trout mitigating. Craig responded that the program was written into the settlement agreement and the WDFW wanted to evaluate the program as a component of that agreement – not its intent.

Mark indicated that the program would continue for three more years and at that time the FTC would review the program. At that time there are three possible scenarios; continue the program, end the program or the FTC will need more data to make a recommendation. Craig said he would rather avoid the third scenario and collect as much data as possible.

Craig stated that WDFW would be looking to Tacoma to fund the evaluation. Mark said that Tacoma's position regarding the resident trout program in anadromous waters has been made very clear. Steve wondered if the FTC should even spend time on the evaluation discussion if it is possible that Tacoma would not be funding it. Craig stated the language in the settlement agreement requires the FTC to make a decision as to whether the resident trout program would continue beyond 2004. Mark pointed out the language says only the FTC will review the program. The WDFW feels the decision should be based on an evaluation of the program in terms of whether the program is meeting its intent (harvest opportunity) and its impacts on anadromous fish.

Gene requested that an evaluation include impacts on both resident and anadromous coastal cutthroat trout.

Craig discussed the need for the FTC to recommend the evaluation take place and for Tacoma to fund it. Mark pointed out that the WDFW could fund the evaluation itself.

Craig made a motion that "The FTC require WDFW to develop a protocol to evaluate the resident trout stocking program and require Tacoma Public Utilities to fund it"

Steve made a second to the motion. Mark excused himself from the vote. The FTC passed the motion by vote with none opposed.

Mark noted that the motion would not be formally adopted until the next meeting upon approval of the meeting summary.

Craig requested a response from Tacoma. Mark requested a more detailed work plan for the resident fish evaluation from WDFW. Craig said they would supply more detail to Tacoma.

Cowlitz Project Information Management Plan

Craig asked how the public would be engaged in the settlement agreement and what was the status of Tacoma's information management plan? Mark stated that the requirement of the information management plan would be spelled out in the FERC license, not the settlement agreement. The draft plan would go through a review process.

Craig questioned the last meeting summary where it stated that the FTC would be responsible for developing the information management plan. Mark said that it will be Tacoma's responsibility to develop the plan, but would look to the FTC to provide assistance in developing the fisheries related portion of the plan.

Mark gave a status report on the issuance of the FERC license. FERC is waiting for the 401 water quality certification from the Department of Ecology as well as the Biological Opinion (BO) from NMFS and the final 4E conditioning authority from the US Forest Service. FERC may choose to issue the license with out the BO, and the license may be issued in as early as two months.

It was brought up that both Friends of the Cowlitz and NMFS may appeal the license issuance if in fact it is issued with out the BO.

License issuance status will be added to next month's agenda as old business.

Fisheries and Hatchery Management Plan status discussion

Mark informed the group that the FTC had developed a time line for the FHMP based on the January 1st issuance of the license. A draft FHMP would be available for FTC review within one month after license issuance. Craig felt there was no need to delay review of the internal draft and requested a copy.

Habitat Advisory Group (HAG) discussion

Mark discussed that within one year of license issuance the Habitat Advisory Group will need to develop a plan for the use of as much as $3 million. Tacoma may be required to set this amount aside to purchase or protect key habitat between the Toutle River and the barrier dam.

Bill mentioned that the Thompson gravel mine in Toledo, Washington inquired about the potential of using the Cowlitz habitat fund to restore sensitive areas within their property. Mark said this is the sort of project that the HAG will be soliciting information about in the future for possible funding.

Riffe Lake downstream migrant collection meeting

The brainstorming meeting to discuss possible methods of improving the collection of outmigrating juvenile salmonids in Riffe Lake is set for January 31, 2002. An invitation to participate has gone out to the USACOE, USGS, NMFS, USFWS, WDFW, private consultants, and others to discuss methods such as seines, lead nets, gulpers, surface traps, and transfer/haul techniques. The FTC will receive the agenda. Lunch will be provided.

Adult Handling Protocol

Mark passed out the Cowlitz Complex adult handling protocol for the FTC to review and described how escapement levels were written into the document. The document was described as somewhat difficult to understand and has some minor inconsistencies as written. Wolf explained how the WDFW develops the document and said it was a dynamic document that describes by species what happens to fish that are above hatchery needs.

Steve expressed concern about introduction of fall chinook to the upper Cowlitz and asked how the WDFW will discern timing differences between sub-yearling fall and spring chinook. Planting fall chinook now could disrupt the current spring chinook evaluation program. Wolf explained the current spring chinook evaluation is based upon fry supplementation plants and adult releases in the Cispus River. A screw trap is located at the mouth of the Cispus to sample yearling spring chinook outmigrants.

Mark pointed out that the WDFW has to do something with surplus hatchery fish and they make the adult handling protocol decisions internally. Steve said the surplus hatchery-origin fall chinook could be recycled downstream or sold. It is envisioned the future Fisheries and Hatchery Management Plan will establish the adult handling protocol.

Wolf said that WDFW could recycle fall chinook but has elected not to. WDFW feels they have enough information to support continuing upper Cowlitz fall chinook plants

Meeting adjournment

This meeting was adjourned at 12:55 PM. The next meeting is scheduled for 10:00 AM, February 6, 2002 at the NMFS/USFWS office in Lacey, Washington. *Other meeting dates were set as follows for the same time and location: March 19th, April 17th, and May 7th.*

Cowlitz Hydroelectric Project
FERC NO. 2016
Fish Technical Committee

Finalized Meeting Summary

Date: October 2, 2001– 10:00 AM to 1:15 PM

Location: Room 261, NMFS office, Lacey, WA

Attendees:

FTC members

Craig Burley	WDFW
Steve Fransen	NMFS
Mark LaRiviere	Tacoma Power
Brad Caldwell	WDOE
Bill Robinson	Trout Unlimited
Gene Stagner	USF&WS

Others:

Wolf Dammers, WDFW

Ed Zapel & Tom Molls, Northwest Hydraulic Consultants, Inc.

Sam Johnston and Mark Timko, Hydroacoustic Technology, Inc.

Agenda Changes

Mark requested to adjust the agenda to accommodate Tacoma's consultants and allow them to give their presentation first. The FTC agreed to move the Mayfield louver evaluation study 2001 results to the start with other agenda items to follow in order.

Mayfield louver evaluation study – 2001 results presentation

Ed Zapel introduced the Northwest Hydraulic Consultants (NHC) representatives as hydraulic engineers on contract to Tacoma Power to investigate the Mayfield louvers. Ed described the three part 2001 study approach designed to understand the hydraulics of the louvers, and to make recommendations for engineering changes to improve the fish guidance efficiency (FGE).

Field velocity measurements. Tacoma Power staff constructed a truss walkway that spanned the south louver bay at Mayfield Dam. NHC then completed a series of fine scale velocity measurements at 0.2, 0.6 and 0.8 depths in the louver bay across seven transects utilizing the walkway. These measurements were made with an acoustic Doppler velocity profiler (ADV) and recorded on a real-time basis onto a field computer. The results were shown to the FTC as a series of slides with velocity direction and magnitude shown in plan and section views. Measurements in the south louver bay were taken at 1,290 cubic feet per second (cfs) and at 2,580 cfs. Flow lines were generally parallel with the louver bay centerline except for minor deflections close to the louver vanes. Some difficulty was encountered obtaining ADV measurements close to the bypass entrance in the louver apex.

Ed then introduced Sam Johnston from Hydroacoustic Technology Inc. (HTI) who presented the fish tracking results.

Fish tracking. Sam explained the HTI acoustic tagging and fish tracking program at Mayfield Dam in 2001. Acoustic tags were inserted into coho smolts from the Cowlitz Salmon Hatchery and a total of 39 fish were released and tracked for varying amounts of time. A PowerPoint presentation was used to demonstrate the study design and show the results. Tag location was tracked in three dimensions and verified to be accurate to within 0.3 feet in all directions. This level of precision is greater than originally envisioned for this study and will assist with evaluating the exact location where entrained fish passed through the louvers. Some difficulty was encountered with determining the ultimate fate of every tagged fish – some may not have entered the louver bays and others may have entered the south bay, exited and re-entered the north bay before being entrained. Minimum estimates of FGE by release group ranged from 56% to 75%, similar to historic values of FGE at Mayfield Dam.

Plotted fish tracks in three dimensions indicated a few trends; the fish were mostly surface oriented, they entered the south louver bay after spending a period of time underneath a debris mat, their approach to the bypass entrance was generally parallel to the centerline, they hesitated and milled in front of the bypass entrance often swimming up along the louver faces before returning to the entrance and entering and some fish entered and subsequently left the south louver intake more than once. HTI is continuing to analyze correlating individual fish tracks with computed (modeled) velocity measurements within the louver bay.

Ed then introduced Tom Molls from NHC who presented the modeled velocity results.

Computational Fluid Dynamics modeling. Tom explained the process used to construct a CFD model, the grid structure built for the Mayfield louver bay and the distribution of entrance and exit flows used in the model. Tom then presented validation results by overlaying the field velocity measurements with the computed velocity measurements at the 0.6 depth. Very good correlation was achieved in all areas except at the bypass entrance where the field velocity measurements were not aligned with computed results. It was generally agreed the difficulty in measuring close to the bypass entrance with the ADV was responsible for the disparity in this area. The computed velocities and vectors are probably closest to the true values.

The model results showed very straight flowlines from entrance to exit with only a little variation at the louver face. At the low flows modeled, the influence of the louvers is very localized. Future changes to the model that could be done with minimal additional effort include changing the inflow, changing the bypass outflow (and therefore the percent split between bypass and outflow), adding vanes or changing the angle of the louvers and adding a porous boundary along the louver face to simulate a screen overlay. If the bypass configuration was changed (i.e., enlarged, flow vane changes, etc.) significant more CFD modeling work would be necessary.

Ed led a discussion about the apparent reluctance of the fish to enter the bypass entrance. The highest velocities the louver bay (at maximum turbine discharge) are still less than the burst swimming speed of outmigrant salmonids, therefore if the fish want to avoid the bypass entrance, physically they can. Craig pointed out a key question will be the fish behavior at higher velocities. Given that some fish swim along the louver face, it was acknowledged that more rejections of the narrow (2.5") louver slots is occurring than rejections of the wider (8") bypass entrance slot – this is a positive point that future experiments should investigate. It was suggested that 2002 studies focus on the bypass entrance and the issue of light versus dark, width (if possible) of the bypass entrance, and any guidance from the correlation of modeled velocity measurements with the track of fish movements.

Conference Call Attendance of FTC meetings

Upon reconvening at 12:15 PM the FTC discussed and agreed it was acceptable, but not necessarily desirable, to attend the FTC meetings via conference call. This option should be made available to all FTC members and their technical representative. By consensus the FTC agreed and established that

- FTC meeting attendance can be via conference call. This option is available to all FTC members and their technical representative. Best faith efforts should be made to attend the meetings in person, however, if unable to do so, the FTC member should contact the Tacoma Power representative prior to the meeting to make the necessary arrangements.

George Lee joined the meeting via conference call from his office in Toppenish.

Approval of Previous Meeting Summary

The previous meeting summary was discussed. No comments or corrections were received from FTC members prior to this meeting. Bill Robinson asked for the following comment to be added under the discussion of the Fisheries and Hatchery Management Plan - *The Conservation Caucus has concerns about short-term spring chinook harvest goals in the upper Cowlitz River basin.* George Lee asked that the following comment be added under the discussion of the Fisheries and Hatchery Management Plan - *The supplementation efforts of the Yakama Tribe's Cle Elum Hatchery have increased the spring chinook runs in the Yakima River by 82%.* These comments were added and by consensus the FTC approved the September 4, 2001 meeting summary. It will be posted on the Tacoma Power web site within seven days.

Old Business

Mayfield turbine survival study triggers: Prior to this meeting, Tacoma Power distributed provisional "triggers" to the FTC that detailed what conditions would be necessary in order to conduct a turbine survival study in the winter of 2002 at Mayfield Dam. The key date is November 30, 2001 with a minimum elevation of Riffe Lake at the 10-year average of 745.5'. Mark explained the current reservoir level and inflow situation at the Cowlitz Project, and said that it is unlikely Tacoma Power will meet the triggers this winter. The contractor (Normandeau Associates, Inc.) has said they could mobilize to conduct the study in January or February 2002 with one (1) month's notice. The FTC asked that this issue is retained as Old Business for future meetings and that Mark provides an update of trigger status to the FTC.

Fisheries and Hatchery and Management Plan

Craig and Mark reported to the FTC the actions that have occurred on the FHMP since the last meeting. No comments were received on the scope or final outline of the plan. Four main tasks are detailed in the outline; the establishment of fish conservation, habitat and harvest goals for the basin; identifying strategies for rearing fish at the Cowlitz Complex; identifying fisheries management strategies for the Cowlitz River basin; and developing a monitoring and evaluation plan.

A modified matrix was established at a meeting among Tacoma Power, the WDFW and Mobrand Biometrics Inc. to better describe the stocks and sub-stocks by basin. The WDFW will be meeting shortly to complete the expanded goal matrix called for in the first task. Craig said no response to a funding request by the WDFW has been received from Tacoma Power, however, they anticipate the discussion will occur shortly. He mentioned it to illustrate the possibility that the schedule called for in the FHMP may not be able to be met by WDFW.

Mark said that Mobrand Biometrics Inc. is conducting the FHMP work within the timelines established by the FTC, WDFW and Tacoma Power. A completed draft FHMP will be made available to Tacoma and the WDFW by early December for internal review and discussion. The revised FHMP will then be prepared for the FTC by February 1, 2002.

A discussion followed regarding the goals in the last matrix available for FTC review. Bill had raised the issue earlier in the discussion of the previous meeting summary. The Conservation Caucus has issues with the short-term goals the WDFW has listed for the upper Cowlitz River basin spring chinook stocks. The Caucus favors precluding harvest opportunity in the upper basin in the short-term to aid in stock recovery. They also support selective fisheries in the lower river, releasing all unmarked fish. Bill said the actual harvest goals and management regime will be a policy call by the WDFW.

Steve is unconvinced that the WDFW intends to recover listed salmon and steelhead in the upper Cowlitz River basin. He uses as his example the performance of the WDFW in 2001; opening a sport fishery in the lower Cowlitz River for spring chinook immediately upon meeting hatchery broodstock needs, rather than protecting for upper basin escapement. The message given is that the WDFW goal is to provide harvest opportunity rather than stock recovery.

Craig responded that there is a need to look at specific stock recovery actions, and that for upper Cowlitz River spring chinook the WDFW is focusing on improving the current collection efficiency at the Cowlitz Falls Dam. The collection efficiency at the Cowlitz Falls Dam needs to be increased to a level that will provide for successful reintroduction into the upper Cowlitz watershed. While the work continues to improve the collection efficiency at the Cowlitz Falls Dam to levels that will provide for healthy runs of spring chinook there is also an ability to provide harvest opportunities. The WDFW describes their Cowlitz River spring chinook recovery plan as a "balance" –one that meets the needs of the stock as well as provides harvest opportunity. (*WDFW comment: WDFW has calculated the harvest rate for spring chinook in the Cowlitz River under a full season, 2 fish daily limit to be about 31%. The fishery in 2001 was a partial season, 1 fish daily limit resulting in a harvest rate that is less than half this rate. During the 2001 spring chinook return 144 adult spring chinook were released into the watershed above the Cowlitz Falls Dam.)*

Steve and Mark responded that there appears to be a pattern of WDFW actions in the Cowlitz River – a priority action to harvest rather than recover listed stocks. It appears harvest opportunity and angler access is more important than adult escapement in the upper Cowlitz River. Steve said this is not a specific or deliberate recovery action. Craig said that when opening a fishery the WDFW knows that not all the fish will be caught and therefore they will be available to be taken to the upper basin.

The WDFW believes is can achieve multiple goals for the Cowlitz River, even in the short-term. Craig looks forward to further development of the goals and strategies in the FHMP.

In 2002 the Cowlitz hatchery spring chinook return will be fully marked (adipose clipped), thus selective fisheries can be held in the lower Cowlitz River. The harvest proposals for 2002 are currently being considered by the WDFW and available for public and agency input. Individual FTC members can provide comments on specific fisheries management actions directly to Craig. The adult handling protocol established for making decisions what to do with adults returning to the Cowlitz Complex will be adjusted accordingly.

By consensus the FTC agreed to continue the FHMP discussion at the next meeting.

Meeting adjournment

This meeting was adjourned at 1:15 PM. The next meeting is scheduled for 10:00 AM, November 13, 2001 at the NMFS/USFWS office in Lacey, Washington.

Cowlitz Hydroelectric Project
FERC NO. 2016
Fish Technical Committee

Finalized Meeting Summary

Date: March 20, 2002 – 10:00 AM to 1:00 PM

Location: Room 102, NMFS/USFWS office, Lacey, WA

Attendees:

FTC members

Craig Burley	WDFW
Steve Fransen	NMFS
Mark LaRiviere	Tacoma Power
George Lee	Yakima Nation
Bill Robinson	Trout Unlimited

Others:

Wolf Dammers, WDFW

Marc Wicke, Tacoma Power

Agenda Changes

Mark requested to reverse the order of the two Old Business items, to discuss the Cowlitz project license first and then the Mayfield turbine survival study. The FTC agreed to make the change.

Approval of previous meeting summary

Mark moved to adopt the January 9th meeting summary. No comments or corrections were received from FTC and the summary was adopted by consensus.

Old Business

- Cowlitz Project FERC License status

Mark announced that the Cowlitz Project was issued on March 13th. Mark offered copies of the license and online sources of the document to the FTC members. George Lee, Bill Robinson and Craig Burley requested hard copies of the license.

Wolf asked to what extent the Settlement Agreement (SA) was included in the project license? Mark stated that the project license was nearly identical to the SA with two additional license requirements: 1) a public information plan, and 2) a hydropower compliance and monitoring plan (HCMP). Mark took a moment to read an excerpt from article 501, page 65, to describe what information the HCMP would include. Mark also announced that Tacoma Power would be hiring a replacement for the Toby Freeman, and this person would be coordinating the implementation of the Cowlitz License.

Mark discussed the water quality certification appeal. The license is not effective until a water quality certification is issued. Currently the certification is stayed by the Pollution Control Hearing Board. The Board will announce a decision on the stay by April 11th. If the Certification stay is lifted, the Project License will be effective on April 12th. If the Certification is stayed, the appeal will be addressed at a hearing in June.

Mark noted that Tacoma Power has 30 days from license issuance to appeal. It was his opinion that Tacoma would not appeal the license as issued.

Some of the measures outlined in the instream flow agreement were already being implemented. A recent flow increase of 7500 cfs is the equivalent of a spring flushing flow. Wolf asked if the increased flows coincided with the spring chinook releases from the Cowlitz Salmon Hatchery? The spring chinook release had occurred more than two weeks prior to the increased flows and that there had not been any coordination between flow increases and hatchery releases.

Mark distributed a table describing timelines for plan submittals as required by article 401. Mark noted that these plans will need FTC review prior submittal to FERC and solicited the FTC for ways in which Tacoma could ease this review process, for example; electronic submissions, mailed copies, formatting suggestions, font preference, color additions, or longer review periods.

Steve suggested that a 45-day review period would assist with internal coordination and Bill requested a 60-day review period.

Mark said that he would discuss longer review periods internally but pointed out that timelines for FERC submittals are often too short to lengthen the 30-day review period.

Craig asked for the status of the Public Involvement Plan and wanted to verify that the public would be included in the review of plans submitted to FERC.

Mark said that the plan is currently in draft form and is due to FERC within 6 months of license issuance. Any plan Tacoma submits to FERC will have public review as stated in Article 405.

Craig stated it would be useful to have public review of all recommendations that the FTC provides to Tacoma. Also, as the public involvement plan was due to FERC within 6 months of license issuance and several other plans were due concurrently, there would not be a public review process in place to allow review of those plans. Craig requested that the public information plan be completed as soon as possible and that it be used to address the plans that are due to FERC within the first 6 months of license issuance.

Bill suggested that an additional page be added to the Tacoma Public Utilities web site to post Cowlitz Project License articles and use this as a venue for public comment. Steve added that a list of interested individuals could be generated from contacts at this web site.

The FTC will discuss this topic and the Public Involvement Plan at next month's FTC meeting.

In conclusion to the license issuance discussion, Mark announced a "License Issuance Celebration" of some sort would be held and FTC members would be invited.

- Mayfield turbine survival study

Mark said the Mayfield turbine survival study was completed according to plans and shared some preliminary data. The study started March 4 and was completed March 13. A total of 852 coho and steelhead were use in the study. The preliminary survival rate results were described as follows:

	Unit 41		Unit 44
Coho	84.1% ± 4.5%	Coho	97.8% ± 2.0%
Steelhead	82.6% ± 5.0%	Steelhead	97.1% ± 2.7%

Recapture rates on sample fish were anticipated to be 97% while 99 % was realized. Most of the mortal injuries were spinal injuries with no visible external wounds. It was theorized that these injuries were a result of shear currents within the unit or draft tube. A substantial differentiation in survival rates was apparent between unit 44 (an older unit identical to 42 and 43) and unit 41 (a newer, more efficient turbine with more wicket gates and buckets). Few fish were observed with external injuries such as scrapes or scale loss.

Steve pointed out that although these fish were of adequate size, scale loss might not have been as apparent of a fish that was actually smolting. He also said these values are good news for salmonid populations in the Cowlitz.

The FTC discussed another agenda item not listed under old business, the Mayfield louver bypass evaluation. Another study scheduled for this May would be an expansion of the last year's louver bypass evaluation. The 2002 study will include adding light to the bypass slot, evaluating steelhead collection efficiency, operating at 5,000 cfs, and expanding the study to both louver bays.

Steve feels it is important to evaluate the collection efficiency for chinook. He understands that the technology is not there to evaluate the smaller sized chinook and that there may be species behavior differences at the bypass.

Mark said some collection efficiency indication might be attainable through fall chinook natural production rates and number of chinook encountered at the counting house in 2002. A long-term study technique may be in the use of hydroacoustics.

Fisheries and Hatchery Management Plan status discussion

Mark read aloud a portion of a letter that Tacoma has sent to Lew Atkins (assistant director of the WDFW fish program). The letter proposes a technical working subgroup of the FTC to work with Mobrand Biometrics, WDFW, and Tacoma Power. WDFW and Tacoma would jointly hire a person as a technical representative to this working group and Tacoma would fund this multi-year position. It is unclear how Tacoma staff representation on the FTC might change as Mark would be the Tacoma representative on the technical subgroup.

Steve asked how the timeline of the FHMP corresponded to the License?

Mark said that the FHMP would be due 9 months after the License becomes effective and to expect a detailed draft plan from Mobrand Biometrics.

Craig reiterated the importance of public review and comment for this document. Steve felt that an abbreviated version of the document should be made available for this review.

Mark stated that Cramer's benchmark report would be updated for the FHMP. The purpose of this is to develop a productivity index and evaluate each brood years performance.

Bill asked Mark to check with Debbie Young why the Yakima Nation was not invited to participate in the technical sub-group.

Hatchery Complex Remodel and Phase-In plan status

Mark announced that some hatchery modifications are moving forward. Work currently underway includes ground water inventories at the CSH and CTH, energy efficiency improvements, and improvements to separator operations.

Wolf asked if there were any modifications planned for the Mayfield counting house. Mark said that the new tank has been purchased and will be in place for the spring outmigration, the louver bays will be cleaned, and lights will be placed in the bypass entrance. This work should be complete by April.

Bill asked Mark about his request for financial information relating to Cowlitz hatchery operations.

Mark asked Bill for clarification of what exactly he wanted.

Bill wanted the projected costs of the hatchery remodel, capital costs, and O&M costs.

Mark said that Tacoma has never prepared that information for distribution but there are some generalized figures in the SA. Mark estimated that costs are $4 million *(correction $4.8 million)* per year for O&M. Mark did not think that budgets would be included in the plans for the hatchery remodel work.

Discussion of study protocols for calculation upper Cowlitz River Basin downstream migrant survival percentages

Tacoma Power hosted a brainstorming meeting on January 31. The results of the meeting included consensus on the need for full exclusionary netting and gulper system to achieve the 95% juvenile survival goal through the projects. A test net will be placed at the upper end of Riffe Lake this spring to mimic a lead net for the gulper system and evaluations would take place to measure water velocities at the site. The net will be evaluated for its ability to withstand current, debris, and wind. The system will be designed to operate at or below 20,000 cfs. Debris is anticipated to be the biggest issue but may be able to be corralled. Steve stated that debris might become a bigger issue at flows above 14,000 cfs, as Cowlitz Falls Dam does not control its debris above 14,000 cfs.

The need for a Riffe Lake collection facility is the poor collection efficiency at Cowlitz Falls Dam and the inability of Tacoma to come to an agreement with Lewis County PUD and BPA for improvements at Cowlitz Falls Dam. Steve felt Tacoma's decision to act independently was a good idea. He stated that a contingency plan would need to be in place in the event that flows exceed 20,000 cfs and the exclusionary netting system was opened.

Debbie Young and Pat McCarty met with the Lewis County Commissioners to discuss the proposed new boat launch at the east end of Riffe Lake, the juvenile trapping facility and its impacts to the sport fishery at the Taidnapam fishing bridge. Wolf asked if the commissioners were upset about the need to close fishing on the fishing bridge to protect migrating smolts. Mark said that he did not have that level of detail from the meeting.

Mark moved to discuss with the FTC the method for calculating the 95% survival of smolts migrating from the upper Cowlitz River Basin. The following equation was discussed.

$$\frac{B}{C_o+C_i} + N = .95$$

Where: C_i = juvenile fish entering Lake Scanewa from the Cispus arm.
C_o= juvenile fish entering Lake Scanewa from the Cowlitz arm.
B = number of transported smolts leaving the stress relief ponds.
N = Natural juvenile mortality through reach in pre-project condition.

The FTC discussed the above equation as a way to calculate juvenile survival through the projects, however in some cases only estimates of the values would be available. Some discussion centered around how best to represent N in the equation. Wolf suggested that we should have a biometrician look at this and review for adequacy.

Discussion continued as to how the values for C_i, C_o, B, and N would be obtained. Steve recollected that the original plan was to estimate the values for C_i, C_o, and N using the best available data. The value for N could be obtained from the EDT analysis performed by Mobrand Biometrics.

Mark asked if Cowlitz Falls had any data to show values for C_o and C_i. Wolf said that there was screw trap data from the Cispus and that the report would be completed soon Also, a second screw trap could be deployed in the Cowlitz arm. Mark pointed out that mark and recapture work may need to be done at both sites as screw trap efficiency is usually only 5-10% and that a quantitative trap operation may differ from a temporal operation.

Mark also said that survival of juvenile fish in Lake Scanewa would need to be determined.

Steve said only a couple of seasons would be needed to evaluate the number of smolts entering Lake Scanewa.

Meeting adjournment

This meeting was adjourned at 12:55 PM. The next meeting is scheduled for 10:00 AM, April 17, 2002 at the NMFS/USFWS office in Lacey, Washington. *Other meeting dates were set as follows for the same time and location: May 15th and June 5th.*

Cowlitz Hydroelectric Project
FERC NO. 2016
Fish Technical Committee

Finalized Meeting Summary

Date: May 15, 2002 – 10:00 AM to 12:15 PM

Location: Bob Turner's office, NMFS/USFWS office, Lacey, WA

Attendees:

FTC members

Craig Burley	WDFW
Steve Fransen	NMFS
Mark LaRiviere	Tacoma Power
Brad Caldwell	DOE
Bill Robinson	Trout Unlimited

Others:

Wolf Dammers, WDFW

Marc Wicke, Tacoma Power

<u>Agenda Changes</u>

Craig Burley wanted to discuss the nature of FTC agenda items and how they are selected sighting that the 11:30 agenda item (Upstream adult hauling discussion) may not be appropriate for FTC discussion.

<u>Approval of previous meeting summary</u>

Mark moved to adopt the March 20th meeting summary. Craig noted that his additions had been adequately included and the summary was adopted by consensus.

<u>Old Business</u>

- Cowlitz Public Involvement Plan

Bill said the plan needs to be used to get the right information to the public. His constituents look to use the Public Involvement Plan (PIP) to maximize their opportunity to provide comments and shape processes and that we need to spend some time on how we develop this.

Steve asked how much feedback was received on the original PIP draft that was sent out for review approximately one year ago?

Mark said the WDFW was the only party who provided any comments.

Craig expressed a concern with the timing of the PIP completion. The PIP should be done as the first step so it will be available to allow comments on implementation of the license. It would benefit the FTC to have the PIP in place to use to make recommendations to FERC. Craig said he does not want to implement the FHMP with out the PIP process in place.

Mark said that the license is complete and we are just waiting for an effective date. It is clear what Tacoma's requirements are and the timeline for the completion of the PIP and implementation plan are laid out. They are both due to FERC at the same and although it may not take the entire six months to complete, it would be up to FERC to approve the plan.

Craig recommends completing the PIP sooner than later so it will be available to benefit other processes.

Steve was surprised that more comments were not received on the original PIP and asked whom it was sent to.

Mark recollected that the PIP had been sent to the attorneys representing the settlement agreement parties.

Craig said that with the new license requiring Tacoma to develop the PIP and since comments on the original PIP are a year old, the PIP should be redistributed for review and comment. Steve and Bill agreed that the PIP should be resent to specific intervening parties.

Mark said that the PIP would essentially be the same as the original. The PIP will be sent to FERC and the agencies for approval but not until the license is resolved.

Craig was concerned with the level of public involvement as we move forward with FTC recommendations.

Bill raised the point that the folks utilizing the PIP process have not been involved in the review of the process.

Mark said that only signers on the settlement agreement have reviewed the PIP but a wider distribution is possible. Craig remembered that 405 in the settlement agreement did not require involvement outside of the settlement parties. Steve felt that review by the settlement parties alone was not a significant enough scope.

Bill said Craig and I are trying to create a win-win situation and try to prevent getting beat up over as the license is implemented. Currently the PIP will not adequately supply a doorway of input from concerned parties.

Craig requested that a copy of the PIP be distributed to the FTC for review in light of the license articles.

Steve said that although the PIP will provide a mechanism for public comment, the framework of the license is complete. The PIP may have a more important role in educating the public as an outreach element. It would not be used to sway the public, but to say we understand your concerns and here is a way you can be involved.

Bill asked Steve how the Cowlitz PIP compares to other related plans at other projects.

Steve said this is a new procedure that is paving the way for others. There are no other public involvement plans as involved as this one.

- Project FERC License status

An update was given on the status of the FERC license. The Pollution Control Hearings Board will be reviewing the water quality certification on June 17, 2002. Findings will be out in 2 or 3 months. It is anticipated that Jonathan File (pro bono representative to the FOC) will pursue all appeal opportunities.

NOAA (representing NMFS) and the FOC are appealing the license. FERC can issue the license without a hearing but will not likely do so until the BO is complete. Steve pointed out that J. File would likely appeal the BO as well.

Mark noted that in light of the lengthy appeal process, the FTC and the implementation process is entering into a period of limbo. Craig said that the SA requires that FTC to move forward on certain items before the license is effective. Mark pointed out that work is being done using the Mayfield studies as an example.

Craig requested that interim items of the SA be identified so the FTC knows what work can be done prior to license resolution.

In light of the stay on the license, Mark requested that future FTC meetings be scheduled on an as needed basis.

Craig added that the FTC agenda items be specific to the FTC role and that there is fewer discussion type topics that don't generally pertain to the FTC's responsibility.

Mark asked how should agenda items be defined, and if Craig wanted to amend the FTC protocol. Mark pointed out that meeting agendas are draft documents sent out in advance to allow additions or omissions.

Craig did not feel a protocol amendment was necessary but asked how discussion of adult upstream hauling had directly to do with the FTC.

Mark added this item to the agenda to share with the FTC challenges the Cowlitz fish crew was facing in regards to fish release sites and land ownership issues.

Steve felt the topic was appropriate for FTC discussion. Bill said such discussion topics were beneficial from the standpoint of public education.

Craig said in general FTC meetings need to be more focussed and contain less items that may be considered filler.

Upper Cowlitz River basin fish passage survival (FPS) model

Mark announced that a biometrician (Lars Mobrand) has reviewed fish passage survival (FPS) model and provided a copy for FTC review. It was pointed out that the P value is the most difficult to obtain. Lars recommended not attempting P on a real-time basis, at least not until collection efficiency is increased at Cowlitz falls. Current collection efficiency would require a prohibitive rate of juvenile fish marking to obtain acceptable statistical values.

Steve recommended that "historical" in the P definition be changed to "without projects."

Craig asked if the Cowlitz EDT was to be used as a surrogate for the P value. Mark said that it would. Values would be 96%, 97%, and 99% for coho, spring chinook, and steelhead respectively.

Upstream adult hauling discussion

Mark described the three fish release sites located upstream of Cowlitz falls; Lake Scanewa at the LCPUD park, Packwood at a private site, and FS road 2810 near Yellow Jacket Creek. Releases have ceased at the Packwood site due to erosion problems, safety, and generalized ill feelings with using private property. Also, the 2810 site is currently unusable due to bank erosion. Tacoma has chosen to release all upper basin fish at Lake Scanewa. There has not been a problem with fall back to Cowlitz falls and this release site allows fish to choose their own tributary.

Craig noted that the 2810 and Packwood sites were chosen to provide harvest opportunity but is aware of some landowner issues associated with Packwood. He stated that the PIP will allow input as to the location of fish release sites and that it should remain status quo but understands the access restraints under current conditions.

Bill pointed out that no matter where the fish are released in the upper basin, they are still present and providing opportunity for anglers. He asked if a hauled fish distribution study had been completed.

Mark said that a radio tag study had been completed for steelhead and coho and the results showed high distribution rates.

Bill suggested that the same be done for spring chinook.

<u>Meeting adjournment</u>

This meeting was adjourned at 12:15 PM. Mark proposed canceling the June 5th meeting but would review the SA for FTC related topics and would distribute any information electronically to the FTC. The PIP will be distributed to the FTC members. Comments sent to Tacoma will be copied to other FTC members.

TACOMA POWER

3628 South 35th Street

Tacoma, Washington 98409-3192

TACOMA PUBLIC UTILITIES

February 4, 2003

Craig Burley
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Gene Stagner
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Steve Fransen
National Marine Fisheries Service
Habitat Conservation Program
510 Desmond Drive SE, Suite 103
Lacey, WA 98503

George Lee
Yakama Nation
Fisheries Resources Management
P.O. Box 151
Toppenish, WA 98948

RE: Mayfield Dam 2002 juvenile fish guidance studies, Cowlitz Project, FERC No. 2016

Gentlemen:

The enclosed document of study results is for review and comment by the Cowlitz Fisheries Technical Committee members. Comments on the draft version of results can be submitted to Tacoma in print or electronic fashion, or brought forward at an FTC meeting. The next scheduled meeting of the FTC is at 10:00 AM on March 4, 2003 at the Tacoma Public Utilities building in the Third Floor Conference Room.

If you have any questions feel free to contact me at (253) 502 - 8767 or at mlarivie@cityoftacoma.org.

Sincerely,

Mark G. LaRiviere

Mark G. LaRiviere
Senior Fisheries Biologist
Natural Resources

Enclosure
cc: D. Young

Cowlitz Hydroelectric Project
FERC NO. 2016
Fisheries Technical Committee

Finalized Meeting Summary

Date: March 4, 2003 – 10:00 AM to 12:15 PM

Location: Tacoma Power, 3rd Floor Conference Room, Tacoma, WA

Attendees:

FTC members

Craig Burley	WDFW
Steve Fransen	NOAA Fisheries
Mark LaRiviere	Tacoma Power
Brad Caldwell	DOE
Bill Robinson	Trout Unlimited
George Lee	Yakama Nation
Gene Stagner	USFWS

Others:

Jim Pacheco, DOE*

Marc Wicke, Tacoma Power

** Jim is a new DOE employee who was a guest of Brad Caldwell.*

Agenda Changes

Bill Robinson announced that he would be leaving his post as T.U. Executive Director. His last day will be March 14, 2003. Currently, T.U. has no replacement to Bill's position. Bill said he hopes to stay involved and provide input to the FTC through the Public Involvement Plan (PIP) process.

An FTC contact list was handed out to the FTC for review and confirmation of correct information. Gene requested that the hypertext underline on his e-mail address be stricken as the underscore is not visible with this line.

Mark proposed adding an update regarding large woody debris management on the Cowlitz River to the agenda following discussion of the Cowlitz Falls agreement status and 2003 activities.

Approval of previous meeting summary

The previous meeting minutes were approved via e-mail correspondence among the FTC members on September 30, 2002.

Old Business

No old business

Cowlitz Water Quality Certification status

Mark welcomed the FTC back from the 10-month hiatus. This Fisheries Technical Committee (FTC) meeting was the outcome of a request from Bill Robinson for an update on the FERC license status.

The license has been stayed based on an appeal to the 401 water quality certification. The appeal was heard by the Pollution Control Hearings Board (PCHB) who made the decision to uphold the 401 certification as written on January 24, 2003. However, the PCHB did condition the certificate with six clarifications:

- References to the Aug 15 – Sept 15 time period in Article 13(d) of the instream flow requirement were amended to read Aug 15 – Nov 20.
- Department of Ecology (DOE) shall require Tacoma to study whether and how instream flow methodologies can be used to supplement existing instream flow settings.
- DOE shall require Tacoma to monitor side channels for native chinook habitat.
- DOE shall require Tacoma monitor the de-watering of redds and the stranding of juvenile or adult fish.
- The 401 Certificate is remanded to DOE for the purpose of review of Article 303 flood control provisions and how it will comply with the State's anti-degradation standard.
- A DOE amendment describing total dissolved gasses (TDG) monitoring was added to the 401 Certification.

Steve asked if there had been any changes to the flood control curve. Brad responded that it had not. Steve also asked what type of chinook habitat was being referenced, spawning or rearing. Mark said that it was not defined but assumed to be spawning habitat.

Mark stated that there have been three documents issued by DOE; the 401 Certification, the final PCHB, and an Amendment document that constitutes the Water Quality Certificate.

There was discussion of sediment transport flows adequate to move sediment in the mainstem Cowlitz below the confluence of the Toutle. With the volume of sediment being transported out of the Toutle, there is no feasible amount of water sufficient to perform this task and there was no intention of pursuing it as a management option.

Steve asked what was the next step to lift the stay on the license. Mark said that it was up to FERC and there were the four plans that needed to be approved by DOE and ultimately the FTC. Brad felt that this would take a few months.

Steve also asked if FERC was waiting for the Biological Opinion (BiOp) before lifting the stay or if there were still other timelines. Mark and Brad responded that there were no other requirements of Tacoma or DOE and that the only other timelines associated with the license were after the stay has been lifted.

Mark asked what the next action should be? Steve suggested contacting David Turner at FERC. Also, Brad suggested staying in contact with Jeff Marti at DOE. Bill suggested that the FTC ask for guidance from FERC and that this issue be included as old business on the next agenda. Bill also requested a status report under this agenda item for the next meeting.

Mark informed the group that Tacoma will be providing information to the FTC in developing the flow monitoring plan and that draft study plans and potential site visits will be forthcoming. As of March 1, 2003 Cowlitz River flows were dropped to 5,000 cfs., and Mark stated that under the new Instream Flow Agreement flushing flows would be required weekly from March through June.

Cowlitz River NOAA Fisheries/USF&WS Biological Opinion status report

Steve announced that NOAA Fisheries has hired Michelle Day to write the BiOp for the Cowlitz and the Cowlitz Falls projects. Her start date is scheduled for March 24, 2003 and will begin the BiOp. sometime after that. This will probably be her highest priority project. He anticipated about 90 days to prepare the draft BiOp and that it would be mostly boilerplate for both projects.

Steve said that FERC has reserved the right to lift the stay before the BiOp is issued but Brian Brown (NOAA Fisheries, Assistant Regional Administrator, Hydro Program) has asked FERC not to lift the stay without the BiOp. Tacoma and Lewis County PUD (LCPUD) have been approached to write letters to support this request but both have chosen to decline without a proposed timeline for BiOp completion.

Mark said that NOAA Fisheries appealed the license because it had been issued prior to completion of the BiOp. If the stay were to be lifted before the BiOp was complete, NOAA Fisheries may require other actions. FERC has issued licenses to other projects without a BiOp but prefers not to.

Mark asked if both BiOp's would be issued concurrently. Steve replied that they would as both projects are on the same system and deal with the same stocks of fish. Steve added that the BiOp could not be appealed, as it is an administrative action. This BiOp may be issued first as a draft followed by a final but typically drafts are only issued if there is a potential jeopardy decision or if requested.

Gene asked if a draft would be circulated to the service list. Steve replied that it would only be circulated between the agencies. A draft should be complete by the end of June with the final out at the end of July 2003.

It was pointed out by Mark that if there were an opportunity for party(s) to appeal the BiOp it would be appealed. Steve felt that barring no procedural problems, the BiOp would be finalized upon transmittal to FERC and, upon their adoption, the hydro projects would be in compliance. However, NOAA Fisheries could be sued by a third party regarding the contents of the BiOp

Steve added that NOAA Fisheries was attempting to coordinate contacts with FERC so that they would be the same persons for both the Cowlitz and the Cowlitz Falls projects.

Gene announced that the USF&WS has completed informal consultation on the Cowlitz Hydroelectric Project.

<u>Cowlitz Project FERC license status</u>

Discussed in previous two agenda items.

<u>Mayfield Dam 2002 downstream migrant survival studies</u>

Mark confirmed that each member of the FTC had received a copy of the downstream migrant studies for their review, passed out additional copies to Craig and Brad and requested any questions or comments with no current timeline. Mark gave a brief overview of each of the studies and observations that had taken place. There are some updates to the 2001 Mayfield Fish Guidance Louver Evaluation Final Report that are available upon request. Craig requested that the meeting summary remind him and others to bring the 2001 Mayfield report to the next FTC meeting for inclusion of these additions.

Mark highlighted the number of spring chinook smolts encountered at the Mayfield counting house in the fall and winter of 2002. The fish did not originate from marked fry plants in the upper basin. Scale analysis had shown that the smolts had put on growth in the reservoir(s). These fish ranged in size from 130mm – 160mm (FL) (probably yearlings) with some reaching 200mm. This timing replicates historic spring chinook emigration timing in the Cowlitz. Mark also noted that all of these fish would have had to pass the turbines at Mossyrock Dam, as there had been no spills prior to smolts reaching the Mayfield counting house. This year there were more chinook smolts collected or passing Mayfield than collected at Cowlitz Falls.

Brad asked why the smolts were not collected at Cowlitz Falls? Mark responded that the collection rate of chinook at Cowlitz Falls was only 25% at best and the system is shut down entirely each September. Brad also asked what the fractional survival of the fry plants were. Mark said he would supply that information at the next FTC meeting.

Steve credited good migration and rearing conditions with the survival rate. Mark added that there had been some operational differences at the project that may have added to these high numbers, such as leaving the attraction flow pumps in the Mayfield secondary separator on for a longer period of time than usual. This may have moved fish more efficiently through the bypass system.

Bill requested that a list of all of the possible reasons for the high chinook smolt numbers be created and provided to the FTC for discussion at the next meeting.

Cowlitz Falls agreement status and 2003 activities

Mark highlighted some of the evaluations that would be taking place at Cowlitz Falls this season including a chinook smolt radio tagging study. Steve expressed concerns with the 100mm-110mm fish that would be used and compared a study using coho of similar size that had poor results. Mark agreed that the fish were at the lower end of the fish size range used in evaluations of this nature. Mark went on to list other activities that would be taking place at Cowlitz Falls including a flume entrance hydraulics study that Tacoma would be performing.

Also, damage to the sluice gates at Cowlitz Falls has a potential of affecting this years collection efficiency. Approximately 600 cfs are being lost through the gates and repairs are not scheduled until fall.

A draft agreement between Tacoma, BPA and LCPUD has been written but not signed pending exact work plans for this year. It is a consolidation of agreements covering juvenile handling, access for adult fish releases, access for Tacoma to perform work at Cowlitz Falls, and shared funding.

Mike Kohn, Fisheries Biologist for LCPUD will be holding the Cowlitz Falls Dam annual review on March 26 from 10:00 - 12:30 at the USFWS office in Lacey.

Cowlitz Large woody debris activities

Mark shared with the FTC that Tacoma has received large quantities of woody debris in Mayfield and Riffe Lakes this winter. Under the previous HPA permit to remove the material from Mayfield Lake, Tacoma was required to place 600 lineal feet of large woody debris in the Cowlitz River below Mayfield Dam. The wood was marked with colored tags and placed on the riverbank near the Cowlitz Trout Hatchery. High flows in January of 2003 carried the wood away. Tacoma will document the distribution of this wood, if it still exists in the river. Mark said that there is a lot of wood in the river now and finding these 20 pieces may be difficult.

Steve asked what size material was placed. Marc responded that the logs with attached root wads ranged in size from 20 to 40 feet in length and 20 to 30 inches DBH.

Much of the large woody debris removed from Mayfield and Riffe Lakes this year will be decked and used by the U.S. Forest Service (USFS) for habitat enhancement projects in the upper Cowlitz. Terry Lawson with the USFS is willing to take up to 1,000 pieces for this purpose.

Wrap up, confirm next meeting date

Mark announced that Tacoma has hired Tom Martin as the Cowlitz License Implementation Coordinator. Tom comes to Tacoma from ASARCO and will begin on March 10, 2003. Mark would like to bring him to the next FTC meeting.

It was decided by the FTC that the next meeting would be held on May 13, 2003 in Lacey. Mark will distribute a draft agenda seven days prior to the meeting.

Meeting adjournment

This meeting was adjourned at 12:15 PM.

Addendum: From Bill Robinson via email, March 12, 2003.
RE: Cowlitz Large woody debris activities

I would add a suggestion, which I failed to address at the last meeting, under the large woody debris discussion. Three to four years back when we were looking at side channel habitat and spawning in those area, I suggested we place LWD in these areas to address two issues:

1. *Spawning, incubation and early rearing protection.*
2. *To protect spawning fish from being harassed or fished upon on the spawning grounds, if LWD were strategically placed anglers might find it difficult to access the fish.*

Cowlitz Hydroelectric Project
FERC NO. 2016
Fisheries Technical Committee

Finalized Meeting Summary

Date: May 13, 2003 – 10:00 AM to 12:15 PM

Location: NMFS/USFWS Office, Lacey, WA

Attendees:

FTC members

Steve Fransen	NOAA Fisheries
Mark LaRiviere	Tacoma Power
Brad Caldwell	DOE
Gene Stagner	USFWS

Others:

Tom Martin, Tacoma Power

Wolf Dammers, WDFW

Agenda Changes

Approval of previous meeting's summary was added

Mark confirmed that which Bill Robinson announced at the previous meeting: that he had stepped down from the Fisheries Technical Committee as a representative of the Conservation Caucus. Mark distributed a copy of Bill's resignation letter. Mark indicated that Tacoma Power had been in touch with American Rivers and Trout Unlimited and that they are working on a replacement for Bill.

Mark introduced Tom Martin, the new License Implementation Coordinator for Tacoma Power and sought FTC's concurrence for Tom to be present and be taking meeting notes. Tom gave a brief summary of his past experience.

Approval of March 4, 2003 meeting summary

Regarding the Biological Opinion, Gene wanted it noted in meeting summary that the USFWS has concluded their informal consultation for ESA listed species under their jurisdiction for the Cowlitz River Hydroelectric Project.

Bill Robinson had requested by e-mail that follow-up information regarding large woody debris be incorporated in the meeting summary. It was agreed that since this email discussion took place after the meeting, the information would be included as an addendum to the meeting summary.

The previous meeting minutes were then approved with the above changes discussed incorporated.

Old Business

Cowlitz Water Quality Certification status

Mark reviewed the status of the 401 Water Quality Certification. The six additional conditions discussed in the last meeting are requirements to be fulfilled after license issuance. He indicated that DOE had asked for comments from Tacoma Power and the plaintiffs by April 15th regarding the limited remand issue. Tacoma Power submitted its comments on the 15th confirming its belief that no further changes are needed.

Brad added that the appellants were given a time extensions to file their comments. He said that Jeff Marti was proceeding expeditiously to get something back to the Pollution Control Hearing Board (PCHB).

There was follow-up discussion that once the water quality certification was issued, as to whether not FERC would remove the stay and issue the license without the biological opinion (BiOp). Steve added that is was their impression that if NOAA Fisheries doesn't meet FERC's schedule to submit the BiOp, that FERC could issue the license without the BiOp.

Cowlitz River NOAA Fisheries/USF&WS Biological Opinion status report

Steve indicated that Michelle Day started work on the biological opinion about one month ago. He reviewed her experience with NOAA Fisheries. He stated that they were proceeding as expeditiously as possible and that the BiOp could be issued by mid-July of this year.

New Business

Fisheries and Hatchery Management Plan

Mark discussed the operation of the technical sub-committee and reported on the meeting held on April 30th at WDFW offices in Olympia. He reviewed the make up of the committee. He discussed WDFW's proposal to revise the FHMP outline that the FTC had previously developed. He indicated that Kevin Malone, Mobrand Biometrics, Inc. is evaluating WDFW's proposal to see if will fit into the FTC outline. Kevin's initial thought is that it will work okay. Mark noted that the next meeting of the technical sub-committee would be June 6th.

Wolf reviewed whom; from the WDFW side is working on this project. He said that Jim Scott was the lead and that Hal Michael and Anne Marshall along with others will be working on this project.

Mark stated that he wants the have the draft FHMP given to the FTC as soon as possible to have the maximum time possible for review as the plan "will be a bit overwhelming."

Wolf noted that the most critical part of this project is the outline and gave Kevin Malone credit for preparing it. He also gave Lars Mobrand credit for keeping the group focused on the "big picture."

Mark reminded the group that this plan will be a product of the FTC and he will keep this item on the agenda.

Mayfield Dam 2002 Fish Passage Survival Studies

Mark started the discussion by circulating updated tables and figures for insertion into the Mayfield Dam Fish Guidance Louver Evaluation Report (January 2002). He then gave a Power Point presentation "Mayfield Dam Downstream Fish Passage Survival Studies" (note that a CD of this presentation will be sent to all members).

The presentation discussed the fish guidance studies done in the 1960's, the different operating modes- passive and active, and presented the 2002 study findings that the fish passage survival rate goal was, in fact, being met, with 95 percent for coho and 96 percent for steelhead and chinook juveniles. It was noted that the fish survival was lower through Unit 41; however, Tacoma Power plans to continue using Unit 41, as it is the most efficient unit. Ideas for fish deterrents to the entrance of Unit 41 penstock were discussed. The use of strobe lights, based on the recent results at Cowlitz Falls Dam, is one possible solution.

Mark noted that Tacoma Power is planning for areas of possible improvements at the Mayfield downstream collection facility including; reducing the noise level from the attraction pumps, debris handling, improving the hydraulics in the north louver bay bypass pipe and improving counting house operations.

Gene confirmed that there were infrequent spills at Mayfield Dam and asked that spill frequency be added to data. He also asked if there were other sizes of fish that were missed in this study. Mark shared that studies of naturally produced juvenile migrants at Cowlitz Falls Dam showed that the lower end was about 130 mm FL, within the range of this study. Gene also asked if the flow rate of 5,400 cfs in the study mimicked actual conditions. Mark indicated this was the typical flow rate for the time of year of the study

Steve stated that some people might questions the results of this test given the relative high head on Mayfield when compared to the Columbia River dams.

Wrap up, confirm next meeting date

It was decided by the FTC that the next meeting date would left open until there was enough agenda items to justify the meeting. Gene requested, and everyone agreed, that the first Tuesday of each month starting in July be set as a placeholder in everyone's schedule.

Meeting adjournment

This meeting was adjourned at 12:15 PM.

Cowlitz Hydroelectric Project
FERC NO. 2016
Fisheries Technical Committee

Finalized Meeting Summary

Date: Sept. 2, 2003 – 10:00 AM to 1:00 PM

Location: WDFW Office, Vancouver, WA

Attendees:

FTC members:

Craig Burley	WDFW
Michelle Day	NOAA Fisheries
Mark LaRiviere	Tacoma Power
Brad Caldwell	DOE
Gene Stagner	USFWS
Ric Abbett	Trout Unlimited

Others:

Tom Martin, Tacoma Power

Wolf Dammers, WDFW

Agenda Changes

Added Introductions.

As there were new members (Ric Abbett of Trout Unlimited (TU) and Michelle Day of NOAA Fisheries) at the meeting, Mark asked everyone to give a brief presentation of current position and professional background. Mark noted the efforts made to contact George Lee, Yakama Tribe, to notify him of this meeting. Ric was unable to contact George prior to this meeting as well.

Mark discussed the background of the Cowlitz Fisheries Technical Committee (FTC) and its protocols. He reviewed the posting of approved meeting summaries on Tacoma Power's website, the standing schedule for the FTC meetings on the first Tuesday of each month, and his role as facilitator/organizer. He noted that there had been a lack of response to his meeting notice emails for this meeting. In the future, he asked that members respond as to whether or not they will attend.

Mark discussed Bob Mottram's articles about the fisheries program of the Cowlitz Hydroelectric Project in the Tacoma News Tribune. He noted that these have been distributed to the FTC members. Mark will send Ric and Michelle copies of these articles. Brad noted that he thought the articles were straightforward and favorable.

Approval of May 13, 2003 meeting summary

The previous meeting summary was approved without changes. It will be posted on Tacoma Power's website within seven days.

Old Business

FERC License and Cowlitz Water Quality Certification Status

Tom and Mark reviewed FERC's action lifting the license stay on July 18th and the Friends of the Cowlitz appeal of Ecology's water quality certification order. Tom talked about FERC's July 9th letter to the Departments of Commerce and Interior indicating their belief that the issuing a license now and not waiting for the delayed biological opinions (BiOp) was of greater benefit to the fish.

Mark distributed copies of the Hydro-Wire Newsletter articles that discussed FERC's letter and the fact that the stay on the Cowlitz Hydroelectric project was lifted before the BiOp was issued. Mark noted the copyright limitations of the newsletter articles.

Ric noted that he was disappointed with this political situation. Michelle said that this puts NMFS in an awkward position. Michelle asked for FTC assistance for understanding the scientific basis for the assumption in Article 1 of the Settlement Agreement (SA) that 75% fish passage was a sustainable level. Mark stated that there was a biological basis and rationale developed for this value during relicensing by the Cowlitz Fisheries Technical Committee (FTT). Mark has provided to Michelle relevant pages from the Cowlitz Ecosystems Diagnosis and Treatment Method (EDT) report. Michelle thought the wording in the SA was awkward. She wants BiOp to be clear and concise and welcomes any support in explaining how the group came to the final agreement. She also stated that she thought Steve Fransen would be reviewing it.

Ric stated that the Sierra Club Legal Defense Fund and EarthJustice has been communicating with TU and will follow TU's lead in this matter. They are supporting the current program. Washington Trout is not cooperative.

It was agreed that the status of the BiOp and the Water Quality Certificate would remain as agenda items under Old Business.

Craig asked that the status of discussions between Tacoma Power and Lewis County Public Utility District (LCPUD) regarding improvements to downstream passage at Cowlitz Falls Dam be included under Old Business at each meeting. Mark pointed out the monthly report on the status is mailed out to the entire Cowlitz service list.

Tom indicated that Tacoma Power is in the process of getting FERC to confirm that July 18, 2003, is the issuance and effective date for the license. Mark said that for the present, Tacoma considers July 18, 2003, the effective date.

Mayfield Downstream Passage Study Results

Mark discussed the distribution of and the review period previously allotted for this report that was distributed to FTC members in March 2003. Ric requested a copy and Michelle indicated that she did not have a copy. Mark pointed out the NOAA Fisheries has received three copies – one for Steve Fransen and two for Ed Meyer in the Portland office. Mark asked for comments on the study report by October 7th.

Review of FTC Tasks

Mark distributed a table listing the fisheries license article plans that the FTC is required to review in 2003 and 2004. Mark briefly discussed each of the eight items listed, including a due date for FTC review of each plan. The following were noted: The report required for SA Article 1 would be a plan for a plan; Tacoma Power would be asking for a delay in filing the SA Article 3 status report due to the unavailability of marked fish; the instream flow fish monitoring plan would be an FTC topic for the next several meetings; there is a considerable demand for large woody debris; and, the Hatchery Remodel and Phase-in Plan will be consistent with the Fisheries and Hatchery Management Plan (FHMP). Craig noted the Public Information Management Plan required by Article 405 should also be listed. It was agreed to add that item.

A discussion of timing and FTC workload for these plan reviews followed.

Fisheries and Hatchery Management Plan

Mark discussed how the plan as directed by the FTC is being put together with the assistance of a technical subcommittee consisting of WDFW, Tacoma Power and Mobrand Biometrics personnel. A Gantt chart for the FHMP review and filing was distributed. Mark reviewed the schedule outlined in this chart. It was noted that as the draft plan will be distributed to the FTC on September 22nd the chart would need to be modified. Gene emphasized the need to track all of the comments and who made them. Tom noted that the license requires Tacoma Power to address all comments, whether or not they are accepted into the final plan. Mark stated that the FTC would have the opportunity to see all of the comments.

Mark asked what form the group thought public review would take. Craig noted that the review should be consistent with the plan outlined in the Public Information Management Plan. Mark noted that plan would likely not be approved by FERC in time for this review. Gene and Craig commented that it should still be used as the model.

Mark noted the WDFW request to change the FHMP outline, as previously approved by the FTC. Mark said that he would have Kevin Malone of Mobrand Biometrics at the November meeting to assist the FTC in stepping through the draft plan and to answer questions. Because of the review schedule, Craig suggested that this review take place at the October meeting. Mark agreed to this.

Ric inquired about a fish hatchery genetic plan for the Cowlitz hatcheries. Craig said that currently there is not a genetic management plan (HGMP) for Cowlitz; however, the WDFW is preparing one. Ric and Gene emphasized the need that the HGMP be consistent with the FHMP for the Cowlitz.

New Business

Discussion of FishPro Inc. for Cowlitz hatchery complex remodel

Mark said that Tacoma Power was currently using FishPro Inc. as a consultant for specific, limited jobs for the hatchery complex remodel plan. Tacoma Power would like to have the FTC endorse FishPro Inc. for hatchery remodel design. He noted that the technical staff at WDFW had recommended them. Ric inquired why Ken Bates was not being used. Mark stated that Ken had been contacted, but since retiring from WDFW he was only working on fish passage issues. Currently, Ken is the consultant for LCPUD on the Cowlitz Falls Dam project. A discussion of some of the technical issues surrounding the hatchery design followed. Craig said that he would have to touch base with his agency's technical folks. Brad made the suggestion that the question from Tacoma Power should be "Does anyone object to the use of FishPro as the consultant for the Cowlitz Salmon and Trout Hatcheries and other rearing facilities?" Brad's suggestion was accepted and it was agreed to add this issue to "Old Business" at the next meeting.

Gene stated that the design does need to be cutting edge to meet the intent of the SA and license articles for innovative rearing. Gene requested a clarification or presentation on the concept of NATURES as it applies to the Cowlitz hatcheries. Mark agreed to facilitate that request at a future meeting. Craig wanted to make sure there was consultation and updates during the process. He did not want any surprises. Ric said that the design of the hatcheries is a critical issue for TU. The group in general voiced the strong desire to have "naturalized" rearing practices. Michelle stated the importance of conveying this guiding principal to any consultant working on designs or plans.

Instream Flow Consultations

Mark reviewed the instream flow requirements in SA Article 13(c). He noted that given the current conditions, it is highly unlikely that a 5,000 cfs or greater flow over a five-day period would occur prior to October 1 this year. The wild card could be the Tilton River, which is prone to flash flows with heavy rain events. Several of these events of up to 8,000 cfs in a row could trigger 5,000 cfs or greater flows at Mayfield Dam. Mark noted an error in this section: where it refers to River Mile 42 in conjunction with redd surveys, he believes it should be River Mile 43 (Otter Creek side channel). As provided for in the article, Mark noted he would give the FTC information at the next meeting for selecting other representative sites -- "Ken Hansen" site and "Jack Welch's Creek" were suggested as possibilities. Mark said he would provide photos and other information for the FTC's consideration. Michelle requested similar information on the sites in the SA and any other sites evaluated be provided as well. Wolf requested that Mark get this information to him before the next meeting so he can have Dan Harmon and John Morrison review it. Ric stated that he would like the same so they could be reviewing this with TU staff before the next meeting as well. Mark agreed to distribute a written proposal before the October meeting.

Mark then discussed issues related to SA Article 13(d). He put the FTC on notice that due to low inflows, Tacoma Power may not be able to provide the 3,500 cfs minimum flows after October 1. He pointed out that relief from this requirement is allowed with FTC approval. Mark then asked what procedure should be used to contact the FTC members to seek approval for relief from the minimum flow and request an alternative flow. It was agreed to use email with telephone follow-ups if there was no response to the email.

Wrap up, confirm next meeting date

The next meeting was scheduled for October 14, 2003 at the Cowlitz Project office at the Mayfield Dam at 10:00 AM.

Meeting adjournment

This meeting was adjourned at 1:00 PM.