Report to the Federal Energy Regulatory Commission
for activities under the Long Term Settlement Agreement
for the 1991 calendar year
between Fisheries Agencies and Tribes
and Public Utility District No. 1
of Douglas County

Wells Hydroelectric Project

F.E.R.C. Project No. 2149

Public Utility District No. 1
of Douglas County, Washington
1151 Valley Mall Parkway
East Wenatchee, WA 98802-4497

April 1992

DOC # 34316

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Foreword

On January 24, 1991, the Federal Energy Regulatory Commission approved a Settlement Agreement to resolve anadromous fish issues for the Wells Hydroelectric Project on the Columbia River in Washington State. The Agreement was a product of negotiations with state and federal fisheries agencies and tribes on the operations of the Wells Project (No. 2149). The F.E.R.C. directed that the licensee of the Wells Project has certain reporting responsibilities. This document fulfills portion (E)(d) of the Order requiring an annual report to be filed by April 30. This is the second annual report under the Agreement and will cover the period between January 1 to December 31, 1991.

Report to the Federal Energy Regulatory Commission
for activities under the Long Term Settlement Agreement
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of Douglas County

(1) Development of Studies, Plans and Evaluations

The PUD worked closely with fisheries agencies and tribes to carry out various studies and obligations specified in the Agreement. These included the evaluation of the juvenile bypass, various monitoring studies and operation plans.

1.1 Annual Bypass System Operations Plan for 1991

The Long Term Settlement Agreement calls for the District to provide an Annual Bypass System Operational Plan to be submitted by December (Appendix A). The District submitted the Annual Bypass Plan for 1991 to the Wells Coordinating Committee (WCC) for review on December 20, 1990.

The Bypass Team for the Wells Project makes decisions on the start and end of bypass operation during both spring and summer migration periods. The Team is made up of three members from the agencies, tribes and the District (Agreement II.F.3). The members of the Bypass Team were selected at the March 1, 1991 WCC meeting. Representatives for the 1991 Bypass Team were Cindy Wilson (alternate Rod Woodin), Washington Department of Fisheries, Jerry Marco, Colville Confederated Tribes and Rick Klinge, Douglas County PUD.

1.2 Evaluation of the Juvenile Bypass for 1991

The evaluation of the spring bypass operation in 1990 was conducted in accourdance with agreement of the WCC, however, the statistical precision outlined in the Settlement Agreement was not met (Appendix B). The District took necessary steps to modify the 1991 evaluation of the bypass at Wells Dam. The 1991 evaluation called for an additional four transducers for monitoring fish passage in turbine intakes and adjusting the time sequence for sampling of turbine fish passage. The District's contract Statistician, Dr. John Skalski, determined that the adjustments made for the 1991 evaluation would help reduce sampling variance. The WCC requested that a statistical working group be formed to review the proposed changes. BioSonics, Inc. submitted to the District the recommendations of the Statistical Working Group for evaluation of the bypass system on March 15. The WCC approved the plan as endorsed by the statistical working group (WCC minutes March 1, 11 and April 3, 1991). The study plan can be found in the Methods Section of the Draft Report Evaluation of the Smolt Bypass System at Wells Dam in 1991 (Appendix C).

1.3 Miscellaneous Planning for the 1991 Bypass Season

The anticipated starting date of bypass operation for 1991 was April 15. This date coincided with the historical release schedule of hatchery salmon from the Winthrop National Fish Hatchery. In 1991, the Winthrop Hatchery announced they would release fish two weeks earlier than expected (WCC minutes March 11). This meant preparations for installation of bypass barriers and hydroacoustic equipment for the hydroacoustic index would need to be stepped up accordingly (Agreement Sec. II.D.1.). This also meant that a 30 day spring evaluation may not be an adequate period for evaluation of the various salmonid populations that constitute the spring migration. The District requested that the Statistical Working Group make a recommendation to either split the spring evaluation into an early spring and late spring evaluation with a combined time of 30 days or adding additional days to the evaluation and extend the analysis (WCC minutes April 3). The working group suggested extending the analysis beyond the 30 days for the spring evaluation (see Section 2.3 and Methods Appendix C).

1.4 Fyke Netting at Wells Dam in 1991

The Wells Bypass team initiated bypass operation when the hydroacoustic index demonstrated the presence of migrating juvenile fish. This index also was used to suspend bypass operation at the end of the spring and summer migration periods. During the months of April and May, the index was composed primarily of salmonids migrating to the ocean. From mid-May on, the hydroacoustic index also contained detections of resident fish in the forebay that were not migrating. The index was not a good tool to determine the start or completion of migration of salmonids at times when non-migrating fish were in the forebay. Fyke nets at the dam sampled the fish population to provide species discrimination for the hydroacoustic index.

The WCC agreed to not fyke net at Wells between mid-April through mid-May (WCC minutes March 1 and April 3). Historical catch data from this period showed only migrating salmonids occur from in-turbine fyke sampling. Fyke netting was done between May 16 and August 28 (Appendix D).

1.5 Bypass Operation in Association with Top Spill vs. Bottom Spill

The District proposed a study to compare differences in survival of juvenile steelhead that passed through the two different spill gates. The juvenile bypass at Wells used five spill bays during bypass operation. Two of the five spill gates were capable of either top or bottom spill. The other three spill gates were only bottom spill. The study was designed to detect a notable difference in the survival (>10%) between fish released through top spill compared to bottom spill. Two groups of 2,200 steelhead were to be tagged with a passive internal transponder tag (PIT) and released at Wells through top spill or bottom spill. Detection of tagged fish would be at the bypass collection gallery at McNary Dam, 223.6 miles down stream from Wells (Appendix E). Based upon the recommendation of the WCC, the District did not initiate the study for the 1991 season (see WCC notes April 3, 15 and 26). Anticipated high flows would have reduced the collection efficiency of the bypass at McNary and result in low recovery of tagged steelhead.

1.6 Monitoring Juvenile Sockeye Passage at Zosel Dam 1991

The juvenile bypass at the Wells Dam provided protection for migrating salmonids from the Methow and Okanogan/Similkameen River Basins. The last group of spring migrants to reach the Wells Project were Okanogan sockeye. These fish migrate out of Lake Osoyoos to the Okanogan River and into the Columbia River. Wells Dam is the first hydroelectric project these migrants reach in route to the ocean.

A study was proposed to determine the timing of these juvenile sockeye as they leave Lake Osoyoos in 1991. Hydroacoustic equipment was deployed at Zosel Dam, a low head flow control dam at the outlet of Lake Osoyoos. A single transducer was placed in the forebay of Zosel to collect a relative index of fish passage at this dam. This information was useful in determining the timing and magnitude of sockeye migration out of Lake Osoyoos. The study was discussed by the WCC at the April 3 meeting.

1.7 Provisions for trapping facilities at the East Ladder at Wells

Under the hatchery based compensation portion of the Settlement Agreement (IV.D.2.c.v) is a section that describes a trap/sorter to be installed in the Left Bank ladder at Wells. This trap was to be used for collecting broodstock as part of the Rock Island Settlement Agreement. Plans for the trap were circulated to the WCC in 1990. The District made several revisions based upon recommendations of the Joint Fisheries Parties. Interim trapping facilities were used to collect broodstock for the 1991 brood year. Additional improvements to the trap were scheduled for 1992.

1.8 Hydroacoustic Monitoring of adult passage at Zosel Dam

Okanogan sockeye cross Wells Dam in route to spawning grounds in British Columbia, Canada. Counts of adult passage at Wells have been made since 1963. There has been a marked difference between counts of sockeye adults at Wells and escapement to the spawning grounds. Biologists are concerned that high summer water temperatures from the Okanogan River have delayed migration of sockeye to spawning areas or caused substantial mortality after passage at Wells.

The District requested that BioSonics use hydroacoustics to determine passage through fish ladders and spill gates at Zosel Dam. Spill gates are low head (less than five feet) and assessment of upstream passage would require monitoring for upstream passage where gates could be opened. This proposal was discussed in the WCC meeting of June 14. Study methodology is shown in Appendix F.

1.9 Underwater Video monitoring of adult passage at Zosel Dam

Underwater video recording adult sockeye passage has been used successful on the Wenatchee River. The advantage of video monitoring over hydroacoustic sampling is that species identification is possible. A proposal was submitted to the District by Columbia River InterTribal Fisheries Commission (CRITFC) to test the feasibility of underwater video to record adult sockeye

passage at Zosel Dam. The study was explained to the WCC (see June 14 minutes). Study plans can be found in Appendix G.

1.10 Project Mortality Study

The Long-Term Settlement Agreement specified the District, along with consultation from the Joint Fisheries Parties, will develop a study of juvenile mortality associated with Wells Dam by 1990 (Section IV, C, 5). Results from this work would adjust compensation levels of the hatchery programs.

The WCC discussed if it were necessary for the juvenile mortality study to be done before the completion of the bypass evaluation. The bypass evaluation could require changes in how the bypass was operated. The WCC recommended not do this study in 1991 and to wait until the evaluation was completed. The WCC suggested that the mortality study be considered for 1993 (WCC minutes April 15, June 21 and September 20). The WCC also requested that the District's Statistician provide a report showing the number of fish necessary to complete this study. The report Sample Size for a PIT - Tag Study of Project Mortality of Juvenile Salmonids at Wells Dam dated December 9, 1991 was submitted to the WCC for the December 12 meeting (Appendix H). The WCC suggested that the report be modified to include two year classes of summer chinook (yearling and sub-yearlings), a variable number of replicates and a range of statistical precision. The revised report was close to completion at the end of 1991.

1.11 Methow Hatchery Trapping Facilities

The plans for the Methow Spring Chinook Hatchery called for the ability to collect broodstock from the Methow, Chewuch and Twisp Rivers. Through the year, there was discussion in the WCC of all three trapping locations (WCC minutes April 3, November 13 and December 12). The trap on the Twisp River was partially completed at the end of the year. Plans for the trap design for the Chewuck River were approved by the WCC and were scheduled to be completed in 1992 in time to collect broodstock. The trap on the Methow would required further planning in 1992 with an anticipated completion for 1993 trapping season.

1.12 1992 Bypass Operational Plan

The District submitted to the WCC, a Bypass Operational Plan for 1992, at the December 12 meeting as per Section II.F.1 of the Settlement Agreement. The plan outlined scheduled hatchery releases above Wells Dam and anticipated the starting and completion date of bypass operation (Appendix A).

(2) Results of Studies, Evaluations and Monitoring Efforts

2.1 Evaluation of the Juvenile Bypass for 1990

The Long-Term Settlement Agreement for the Wells Project states that the District will conduct a three year evaluation of fish passage efficiency (FPE) of the juvenile bypass system. The 1990 migration season was the first year of this evaluation. The goal for FPE of the Wells bypass is 80% for spring migration and 70% for the summer migration. The Settlement Agreement also required a certain level of statistical precision (Sec. II.H.2). The results of the 1990 evaluation were submitted to the WCC for review (Appendix B).

The 1990 evaluation of the spring FPE was 84.3% ±8.0% at the 95% C.I. and the summer FPE was 76.5% ±4.0% at the 90% C.I. While the 1990 spring bypass evaluations met the FPE goal for bypass operation, it fell short of the statistical precision called for in the evaluation. The evaluation of the summer bypass meet operational and statistical requirements.

2.2 Evaluation of the Juvenile Bypass for 1991

The 1991 evaluation of the juvenile bypass at Wells was the second of a three year study of fish passage efficiency (FPE). A DRAFT copy of the 1991 evaluation was submitted to the WCC for review on December 12 (Appendix C).

The 1991 evaluation of the spring FPE was 95.0% ±0.43% at the 90% C.I. and the summer FPE was 97.0% ±0.29% at the 90% C.I. The 1991 evaluation met and exceeded the FPE goal of both the spring and summer bypass seasons. By modifying the 1990 evaluation plan, the 1991 evaluation met the statistical precision called for in the Settlement Agreement.

2.3 Relative Index of juvenile salmonid migration at Wells Dam for 1991

The operation of the juvenile bypass at Wells requires water to spill through the spill bay. The bypass operation is innitiated by thee WCC Bypass Team when hydroacoustic index rises signifying the start of the spring migration. This index, along with species composition from fyke netting within turbine intake bays provide necessary information to start bypass operation for the spring and summer migrations of juvenile salmonids. During the 1991 migration, the index signifed the beginning of spring migration on April 13. The summer bypass was started when the index plus species composition from fyke netting indicated a high number of juvenile salmonids on July 8 (Appendix C, pages 15, D1 and D2 and Appendix D).

2.4 Evaluation of Juvenile Sockeye Passage at Zosel Dam 1991

An effort to collect a relative index of migrating sockeye from Lake Osoyoos was conducted in 1991. Due to extremely high flows in the Okanogan River, efforts to collect the hydroacoustic index were abandoned.

2.5 Provisions for trapping facilities at the East Ladder at Wells

A series of last minute changes were recommended by the WCC in the East Ladder trap flume and sorting arrangement and associated transportation vehicle to move fish from the ladder to the hatchery. The project was split into two phases. Phase 1 included the concrete flume for the denil ladder, plumbing for the attraction water and fish holding area. Phase 2 included the metal sorting flume for broodstock, a transportation tank and a water - to - water holding tank at the end of the broodstock flume. Also, part of the sorting flume was used for collection of sockeye for various ongoing studies. Phase 1 portion of the work was completed in the spring. The District was unable to award the Phase 2 portion of the work in 1991 (WCC minutes June 14 and 21). The District took the initiative to complete a sorting flume that would be able to collect summer chinook broodstock in 1991. Also a fish transporter trailer was completed to move summer chinook to the Wells Hatchery for holding until spawning. Plans for completion of the Phase 2 portion of the flume were accepted by the WCC and will be constructed in 1992 (WCC minutes November 13 and December 12).

2.6 Spring Chinook Spawning surveys in the Methow River Basin, 1991

This was a continuation of an ongoing effort to determine the wild escapement of spring chinook in the Methow River basin. The number of redds (nests deposited by spawning salmon) in 1991 was 250 for 127 miles of streams surveyed (Appendix I).

2.7 Hydroacoustic Monitoring of Adult Passage at Zosel Dam

BioSonics Inc., placed hydroacoustic sampling equipment at Zosel Dam in August for the monitoring of adult sockeye passage into Lake Osoyoos. The anticipated period of sockeye migration at Zosel was between mid-August and late October. Monitoring of adult passage began on August 20 and continued until October 20.

Hydroacoustic monitoring assessed 1,336 sockeye passing Zosel between August 20 and October 20. The bulk of the sockeye run passed the Wells Project in July. There were 27,492 sockeye that were counted at Wells in 1992. Before this study was completed, over 7,000 adult sockeye were counted on spawning grounds above Zosel Dam. It seems that the sockeye moved immediately up the Okanogan River after passing the Wells Project in July. Efforts to collect passage information of this sockeye run at Zosel Dam in mid-August were too late (Appendix F).

(3) Outline of Action taken toward fulfillment of the Agreement

3.1 Sockeye Salmon Enhancement Potential Above Wells Dam

Chapman and Associates prepared a report for the District that investigated the potential for sockeye enhancement above Wells Dam (Appendix I). The report was submitted to the WCC for review in January 1991. Several members of the WCC commented on the report (WCC minutes April 3 and November 3).

The study reported that the Okanogan drainage with associated Lake Osoyoos was the best candidate for sockeye enhancement. High temperature problems pose a serious obstacle to adult migration to spawning areas. River temperatures during the migration of adult sockeye in the Okanogan River approach lethal levels for salmon and trout. The report suggested several possible avenues for enhancement including holding adults in cooler water, improving spawning substrate and pen rearing fish in Lake Osoyoos.

3.2 Bypass Evaluation

As was mentioned in Section 2.1, the evaluation of the juvenile bypass in 1990 was just shy of meeting the necessary statistical precision as outlined in the Settlement Agreement. The District's contract statistician, Dr. John Skalski recommended that additional hydroacoustic sampling would help to lower the variance around the point estimate. The 1991 Evaluation added hydroacoustic transducers and adjustments in sampling time for each sample location. Also the evaluation for the spring juvenile migration was ten days longer than the 30 day evaluation period seen in 1990.

3.3 Methow River Spring Chinook Hatchery

The plans for the Methow Spring Chinook hatchery, as specified under the Agreement, were reviewed and approved by the WCC. Acquisition of property and necessary permits for construction were obtained. Necessary water rights and permits were acquired. The District solicitted construction bids. A contract for $5,533,222 was awarded to Dyad Construction of Woodinville, Washington. Construction on the facility started on April 23, 1991. By the end of the year most of the work was completed on the hatchery buildings, ponds and wells. Work to be completed in 1992 includes completion of broodstock traps, hatchery piping, finish work and landscaping.

3.4 Contract professional services in implementing the Settlement Agreement.

During 1991, the District contracted with Dr. Richard Whitney to serve as Studies Coordinator for the Wells Coordinating Committee. The District also contracted with Dr. John Skalski to provide statistical evaluation of methods and studies.

3.5 Juvenile and Adult Fish Passage Operations at Wells Dam

During 1991, the juvenile bypass system operated as per conditions outlined in the Settlement Agreement (Section II,C,D,F). The bypass operated between April 14 and June 6 (53 days) for the spring migration and between July 5 and August 19 (45 days) for the summer migration.

The adult fish ladders were operated as outlined in the Agreement (Section III,B,C,D,E,F). Counts at Wells Dam show that 38,898 salmon and steelhead passed the Wells Project in 1991.

3.6 Steelhead Production at Wells Hatchery

The Agreement specified that the District will fund additional steelhead compensation of 30,000 pounds at 6 fish per pound in 1991 (Section IV,3,a). This production was accomplished at the Wells Game Hatchery.

3.7 Other Actions toward fulfillment of the Agreement

The District funded evaluations and studies that are part of the Districts responsibility in the Agreement. These were described in Sections 2 and 3.

(4) Explanation of Alternatives Chosen

4.1 Change in time table of adult studies

The Agreement specified that a study plan to determine the extent of adult delay and mortality at Wells Project would be initiated in 1990 with studies starting in 1991 (Section III, G, 1). The WCC discussed an adult study for Wells in several meetings (September 20 ,November 13 and December 12). The District requested proposals for a study of delay of sockeye salmon at Wells Dam from two entities. At the close of the year, the proposals were being reviewed. The District is planning to fund a study of sockeye passage at Wells in 1992.

4.2 Hatchery Based Compensation

Section IV of the Settlement Agreement dealt with determining a "Production Plan" to be agreed to by the Joint Fisheries Parties and reviewed annually. This plan came in four phases, starting with Phase I in 1991 (Section IV, A, 3 a). The compensation elements for 1991 are as follows,

(1) 49,200 pounds of spring chinook yearlings at about 15/pound
(2) 8,000 pounds of sockeye juveniles at 25/pound
(3) 30,000 pounds of steelhead smolts at 6/pound

The spring chinook program hinged around the Methow Spring Chinook hatchery that was being constructed in 1991. The facility expected to be completed by June 1992. Efforts to collect broodstock are anticipated for the 1992 brood year with the first release of yearling fish in the spring of 1994.

Pursuant to the direction of the WCC sockeye production was delayed pending the results of a study on sockeye enhancement options above the Wells Project. This report was specified as part of the Studies and Evaluations section of the Agreement (Section IV, C, 1). There was discussion at the end of the year to have a Workshop specifically to deal with the issue of enhancement of Okanogan sockeye. The workshop was conducted in March of 1992.

The hatchery based compensation for the additional 30,000 pounds of steelhead was met along with the original steelhead mitigative responsibility for the Wells Project (Section 3.6).

4.3 The Wells Project Juvenile Mortality Study

The Agreement specified that the District will plan for a juvenile mortality study in 1990 to be implemented in 1991 (Section IV, C, 5). The WCC requested that the juvenile mortality study wait until the completion of the evaluation of the juvenile bypass in 1992 (WCC minutes June 21). The District requested a statistical evaluation of the number of summer chinook required to complete a juvenile mortality study. The WCC requested that two year classes and a series of replicate releases be programmed into the analysis (WCC minutes September 20, November 13 and December 12)(Appendix H). The District is currently planning on proceeding with this study for 1993.

(5) Chronology of compliance for 1991

The chronology of compliance for 1991 is contained in items (3) and (4) above. Documentation that the Joint Fisheries Parties were consulted prior to implementation of changes is provided in the minutes of the Wells Coordinating Committee. These records are included as Appendix K.

(6) A schedule of activities for 1992

6.1 Spring Chinook Hatchery

Construction on the Methow Hatchery will continue from 1991 with a projected completion date of June 1992. The projected work schedule is as follows.

```
                    |------------------------- 1992 -------------------------|
                    Jan  Feb  Mar  Apr  May  Jun  Jul  Aug  Sep  Oct  Nov  Dec

Satellite ponds     xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
Hatchery Building   xxxxxxxxxxxxxxxxxxxxxxxx
Hatchery residence  xxxxxxxxxxxxxxxxxx
Hatchery raceways   xxxxxxxxxxxxxxxxxxxxxxxx
Broodstock traps        xxxxxxxxxxxxxxxxxx
Methow R. Trap Plan                                xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
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6.2 Bypass evaluation

During 1992, the proposed schedule for the third year of bypass evaluation is as follows,

Hydroacoustic equipment set up at Wells	April 2
Monitoring forebay of Wells	April 2 - April 17
Spring bypass season	April 17 - May 31
Spring Evaluation (40 days)	April 17 - May 28
Fyke netting of turbine bay	May 15 - Aug 30
Summer bypass season	July 5 - August 20
Summer Evaluation (15 days)	July 5 - July 20
Data analysis and report writing	August - December
Draft report circulated for comments	December - January 93
Final Report out	April 1993

6.3 Sockeye production and Adult Passage Studies.

The WCC did not have the opportunity to fully deal with the issue of sockeye production and adult passage studies. The Committee will continue to deal with both of these issues through 1992. Through this process the WCC will develop a list of recommended studies and actions plus a time table to implement various elements of the Settlement Agreement.

6.4 Operational Activities for 1992

The following schedule of activities is planned for 1992

Dec. (91)	Develop Annual Bypass System Operation Plan between District, Agencies and Tribes
March 1	Annual Bypass System Operation Plan finalized
March 1	Determine Bypass Team members for bypass season
March 1	Develop Annual Passage Monitoring Plan between District, Agencies and Tribes
April 1	Bypass barriers in place Begin monitoring juvenile migration
April 17	Anticipated start of the juvenile migration
October	Production Plan annual review between District, Agencies and Tribes
on going	Planning for Adult Delay Studies
on going	Planning sockeye enhancement strategies
on going	Planning for operations and protocols of the new Methow River Spring Chinook Hatchery
on going	Planning for Methow River broodstock trap

(7) Meeting Minutes of the Wells Coordinating Committee for 1991

The Wells Project was removed from the mid-Columbia proceedings on January 29, 1991 as the Long-Term Settlement Agreement between the Fisheries Agencies and Tribes was approved by F.E.R.C. Minutes from the meetings of the WCC for 1991 are attached as Appendix K.

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ANNUAL BYPASS OPERATION PLAN

FOR

WELLS DAM; 1991 AND 1992

APPENDIX - A

1991 Bypass Plan
for the Wells Dam

December 1990

The Settlement Agreement entered into on October 1, 1990 between Douglas County P.U.D. and the Joint Fisheries Parties members requires that an Annual Bypass Plan be presented to the Wells Coordination Committee by December before each Bypass season (Section II.F.1). This plan outlines the operation of the bypass system for the coming juvenile salmonid migration season.

The 1991 bypass plan for the Wells Project is as follows.

1. The bypass will be in place two weeks prior to the preseason forecasted beginning of the juvenile migration and will be removed two weeks after the end of the juvenile migration period.

2. The PUD will operate 5 bypass baffles at the Wells Project to meet criteria set out in subsections II.C,D, and E. of the Settlement Agreement.

3. No turbine will operate during the migration period unless an adjacent bypass system is operating.

4. The 5 bypass systems bays will be numbers 2, 4, 6, 8, and 10. Operations of the turbines will be in pairs with associated bypass bays, as follows.

Turbines Operated	Bypass Bay Operated
1 and/or 2	#2
3 and/or 4	#4
5 and/or 6	#6
7 and/or 8	#8
9 and/or 10	#10

5. At least one bypass will be operate continuously throughout the juvenile migration period up to August 1.

6. The bypass and spillgates will be operated in configuration K of the 1987 bypass system report (bottom spill, 1 foot spill gate opening, 2.2kcfs, vertical baffle opening.

7. When Chief Joseph Dam Uncoordinated Discharge Estimate is equal to or greater than 140kcfs for the following day, all 5 bypass bays will operate continuously for 24 hours.

8. When Chief Joseph Uncoordinated Discharge Estimate is less than 140kcfs, bypass system operation will be as follows.

Number of Turbines	Minimum Number Bypass Bays Operating
0 - 2	1
3 or 4	2
5 or 6	3
7 or 8	4
9 or 10	5

9. Monitoring the fish run will begin when bypass baffles are in place and will end when baffles are removed.

10. Bypass will be available to operate continuously 24 hours per day during the juvenile migration period.

11. Bypass operation as described are intended to provide fish passage efficiency (FPE) of at least 80% for the juvenile spring migration and FPE of at least 70% for the juvenile summer migration.

12. Members of the Bypass Team (Settlement Agreement Section II.F.2), will be designated by March 1, before the Bypass Season.

Supplement to the
1991 Bypass Plan
for the Wells Dam

In addition to the 1991 Wells Bypass Plan, the following supplemental plan will be in effect as agreed to by the Bypass Team members.

1. The anticipated bypass operation season will be from April 15 to August 15.

2. Operation of the bypass from August 1 to August 15 will be adjusted from a 24 hour schedule to operating between 2200 to 0600.

WELLS HYDROELECTRIC PROJECT

JUVENILE BYPASS SYSTEM OPERATIONS PLAN

for the 1992 Bypass Season

December 12, 1991

Section II. F. 1 of the Wells Long Term Settlement Agreement specifies that an Annual Operations Plan for the Bypass will be submitted by Douglas County P.U.D. to the Wells Coordinating Committee by December prior to the spring migration. This plan will be reviewed and approved by the Coordinating Committee by March 1.

The Bypass System

The P.U.D. will install five bypass baffles in spill gates of the Wells Project. The operation of the bypass will be per criteria outlined in the Settlement Agreement.

Operation Criteria

The bypass will operate as per criteria specified in Section II. C. and E. of the Settlement Agreement. This includes operation of the bypass in partnership with adjacent turbine units, the amount of water required for bypass operation and criteria for full bypass system operation. Should criteria for fish passage efficiency specified in Section II.E. not be reached, then changes in the operation of the bypass will be made to meet criteria.

Bypass Operations Timing Criteria

The bypass will be in place as per criteria specified in Section II. D. of the Settlement Agreement. This includes placement of the bypass two weeks before predicted migration and keeping the bypass in place two weeks after the migration is complete.

Projected Hatchery Releases above Wells Dam

Hatchery releases for 1992 above Wells Dam are as follows,

Facility	Species	No. (thous)	Dates
Winthrop (USFW)	Spr Chinook	1000	4/15
Twisp (WDF)	Sum Chinook	400	5/15
Similikameen (WDF)	Sum Chinook	500	5/15
Wells (WDW)	Sum Steelhead	550	4/15 - 5/15

Starting Dates and Ending Dates

Starting and closure of the bypass system is a decision that is reached by the Bypass Team. A hydroacoustic index of fish in the Wells forebay is used to show the start and completion of the spring and summer migration. Preseason dates used for bypass operation for spring migration are April 15 to May 30. Preseason dates used for summer migration are July 1 to August 30.

EVALUATION OF THE SMOLT BYPASS SYSTEM

AT

WELLS DAM IN 1990

APPENDIX - B

Evaluation of the Smolt Bypass System at Wells Dam in 1990

Final Report

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April 19, 1991

EXECUTIVE SUMMARY

In 1990, we used hydroacoustics to evaluate the smolt bypass system at Wells Dam on the Columbia River. The evaluation, sponsored by Douglas County PUD (DCPUD), took place in spring (April 19 to May 18) and summer (July 9 to 24). The 1990 evaluation was the first of a three-year program to substantiate the efficiency of Wells' bypass system. Fisheries agencies and DCPUD agreed to a three-year evaluation period as part of the Wells Settlement Agreement. The agreement also included criteria for precision which guided development of the sampling design. The primary objective of the 1990 evaluation was to estimate **total project bypass efficiency**.

The bypass concept at Wells Dam is based on Wells' hydrocombine structure. (A hydrocombine is a dam with the spillway located directly above the turbine intakes. Wells is the only dam constructed like this in North America.) Baffles are placed in the spill intakes to create attractant flow for downstream migrant smolts. Once entrained in this attractant flow, smolts enter the bypass and migrate through the dam in bypass flow instead of turbine flow. Data show that a relatively small amount of flow properly baffled is more effective at bypassing smolts than is a large amount of flow that is not baffled.

Annual bypass evaluations using hydroacoustic sampling methods and rigorous experimental designs were critical to the development of an efficient bypass at Wells Dam. A prototype bypass was first installed and tested in 1983 at one spillbay of the dam. The 1983 study showed that smolt passage in bypass flow was greater with baffles in place than without. In 1984, 1985, and 1986, the bypass passage rates for various baffle configurations (underflow, overflow, vertical slot, etc.) were compared. The configuration that passed statistically significantly more fish than the others, all other factors being equal, was deemed the "best." The data showed that the vertical slot and underflow configurations were the best. In 1986, two bypass sections were installed and tests conducted to determine if operating an adjacent bypass section increased passage at the original bypass section; it did not. In 1987, more bypass sections were installed and the study objective was to determine the most effective locations for bypass sections across the dam; the middle and west sections had higher passage than the east section. In 1988 and 1989, detailed data on specific characteristics of the bypass were evaluated to fine-tune the system. The bypass will be officially completed after review and acceptance of total project bypass efficiency data from three years of evaluation beginning in 1990.

In 1990, we used fixed-location hydroacoustic techniques to estimate total project bypass efficiency. Transducers (15°) were deployed at 4 of 10 forebay locations (T2, T4, T6, and T8) and

20 of 30 turbine intake locations (Table 2). Transducers (6°) were deployed at 5 of 5 bypass intake locations (1C, 3C, 5C, 7C, and 9C). The number of transducers and sampling design were based on statistical analysis of previous data from Wells. This analysis was performed in winter 1989/90 and presented in the study plan for the 1990 evaluation.

Total project bypass efficiency (B) was estimated by first estimating total passage in bypass flow (Y) and total passage in turbine flow (X) separately. Total passage in turbine was obtained by extrapolating from sampled intakes into non-sampled intakes. Then the ratio B=Y/(X+Y) and confidence interval were calculated.

The bypass system at Wells Dam in 1990 was operated as in previous years. That is, if the daily flow forecast was greater than 140 kcfs, all 5 bypass units were opened. If the forecast was less than 140 kcfs, only bypass units above operating turbines (one or both of the turbines associated with a bypass unit) were opened. Daily bypass flow averaged 5.8% of total project discharge. Overall, the mid-Columbia River had relatively high water in spring and summer 1990.

DCPUD sampled for species composition with a fyke net in Turbine Intake 4C at least weekly from April 5th to August 30th, 1990. The 1990 fyke net data showed that chinook, sockeye, and steelhead dominated the catch from late April to mid-May. Then, in early and mid-June, there was a decline in the numbers of salmonids and an increase in whitefish and other non-targeted fish. In early July the summer chinook outmigration began. It lasted until mid-August.

The 1990 hydroacoustic run timing data from the forebay transducers show that during the five-month monitoring program the spring and summer outmigrations were reasonably distinct. The outmigration began with spring chinook, as usual, then was influenced by the steelhead releases in late April and early May. In mid- and late May, the natural run of sockeye from Lake Osoyoos moved through the dam. Passage rates were low in mid-June, increased in late June and were relatively high and variable throughout the summer.

Estimated total project bypass efficiency for the 30-day spring study was 84.3% $\pm$ 8.0% at the 95% confidence level. During the 30-day study, however, the coefficient of variation (CV = standard deviation divided by mean) was 30.4% for the bypass, which is abnormally high. The CV for turbine passage during spring was only 4.3%. There was one day (April 25) that had extremely high passage in bypass. The ratio for this day was 99% $\pm$ 2%. With this data point excluded from analysis, the bypass CV is 1.2%. The CV for bypass passage was expected to be less than that for turbine passage because 5 of 5 bypass units were sampled and only 20 of 27 turbine intakes were sampled. (Three intakes were not available because of turbine runner

replacement.) For a 29-day spring study, excluding April 25th, total project efficiency was 77.9% ± 1.5% at the 95% confidence level. Thus, although estimated total efficiency is lower if the date with extremely high passage in bypass is excluded, the confidence interval is much tighter. Estimated total project bypass efficiency for the summer study was 76.5% ± 4.0% at the 90% confidence level.

To summarize, the estimates of **Total Project Bypass Efficiency** at Wells Dam in 1990 were:

Spring	84.3% ± 8.0% at 95% confidence level
Summer	76.5% ± 4.0% at 90% confidence level

ACKNOWLEDGEMENTS

The hydroacoustic studies at Wells Dam are the product of much hard and excellent work by many people. We sincerely thank:

- Douglas County PUD staff at Wells Dam and East Wenatchee for their guidance, cooperation, and assistance. They also provided the dam operations data, the fyke net data, and much logistical support. Without DCPUD staff, this project could not have been done.
- J. Skalski for pre-study sampling design analyses which were incorporated into the study plan.
- Phil Mundy and Ben Sanford for reviewing the sampling design.
- Alex Birmingham, Paul Salomone, Mike Spong, and Jim Thorne for collecting the hydroacoustic data.
- Paul Salomone for post-study data processing.
- J. Skalski and D. Ouellette for developing the statistical tools.
- L. Stone for graphics and word processing.

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1.0 INTRODUCTION

1.1 Objective

In 1990, we used hydroacoustics to evaluate the smolt bypass system at Wells Dam on the Columbia River. The evaluation, sponsored by Douglas County PUD (DCPUD), took place in spring (April 19 to May 18) and summer (July 9 to 24). The 1990 evaluation was the first of a three-year program to substantiate the efficiency of Wells' bypass system. Fisheries agencies and DCPUD agreed to a three-year evaluation period as part of the Wells Settlement Agreement. The agreement also included criteria for precision which guided development of the sampling design. The primary objective of the 1990 evaluation was to estimate **total project bypass efficiency**.

The 1990 study was the first of a three-year program to evaluate the efficiency of Wells' bypass system. Fisheries agencies, tribes, and DCPUD agreed to a three-year evaluation period as part of the Wells Settlement Agreement. The agreement also included criteria for precision which guided development of the sampling design.

1.2 Background

Wells Dam (Figure 1 and Table 1) is the first dam that over two million smolts must pass during annual outmigrations to the Pacific Ocean. DCPUD is responsible for protecting anadromous fish that migrate through Wells Dam because of Federal Energy Regulatory Commission (FERC) license conditions. The type and amount of protection is formally agreed upon by DCPUD, fisheries agencies, and tribes. Between 1980 and 1989, inclusive, provisions in FERC settlement agreements have guided the development of the smolt bypass system at Wells Dam. From 1990 to 1992, the agencies and DCPUD agreed to evaluate total bypass efficiency.

Wells Dam was designed as a hydrocombine (Figure 2) to reduce the area of concrete structures founded on rock (Patrick 1970). The spill bay and turbine intake floors are 73 ft and 133 ft from the surface, respectively. The dam has ten turbines and eleven spill bays (Figure 3). All eleven spillbays are equipped with bottom spill gates, but only Bays 2 and 10 have surface gates which can be opened to accommodate top spill. Each turbine has three intakes and, except for Bays 1 and 11, each spill bay has three intakes. Water enters the bypass intakes above water entering the turbine intakes because of the hydrocombine design.

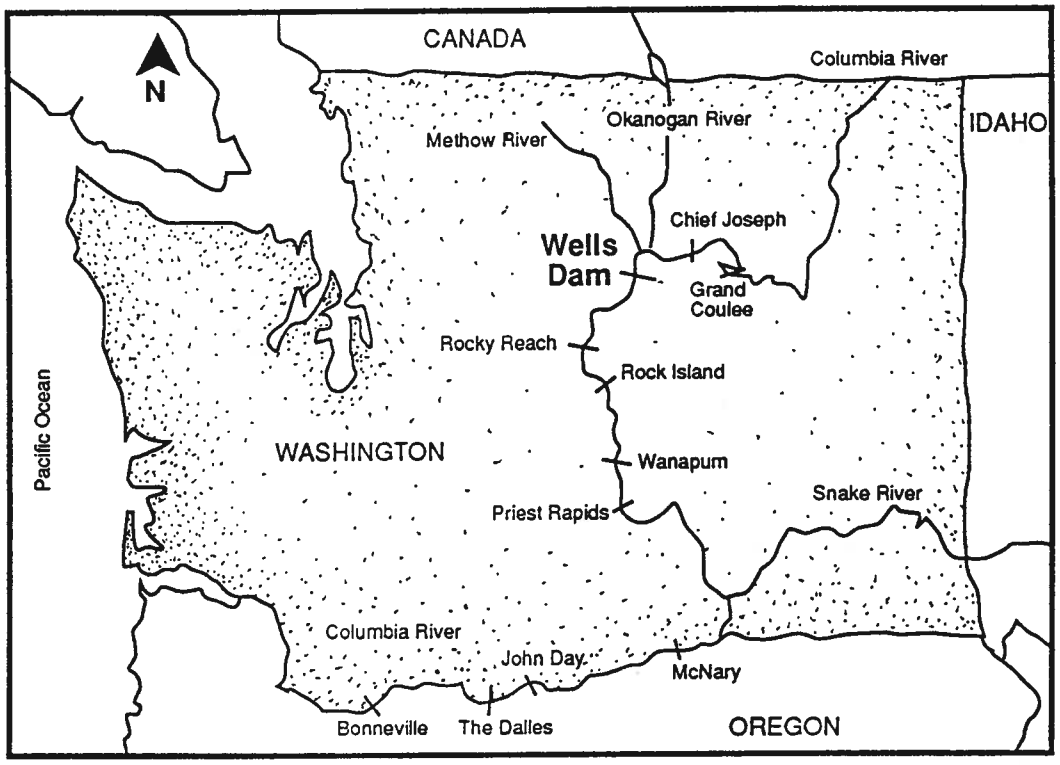

Figure 1. Location of Wells Dam on the Columbia River.

Table 1. Descriptive data for Wells Dam for reservoir elevation 779 ft Mean Sea Level (MSL). (In 1984, the reservoir was raised to 781 ft MSL.)

River Mile at Dam Site	515.8
Drainage Area	85,300 sq mi
Historical Flood (1894)	657 kcfs
Spillway Design Flood	1,180 kcfs
Gross Head (maximum)	74.5 ft
Reservoir Storage Capacity	300,000 acre-ft
Reservoir Length	30 mi
Dam Length (overall)	4,460 ft
Hydrocombine Length	1,130 ft
Hydrocombine Height	185 ft
Generating Units	10
Type of Turbine	Kaplan
Maximum Capability	820,000 kw

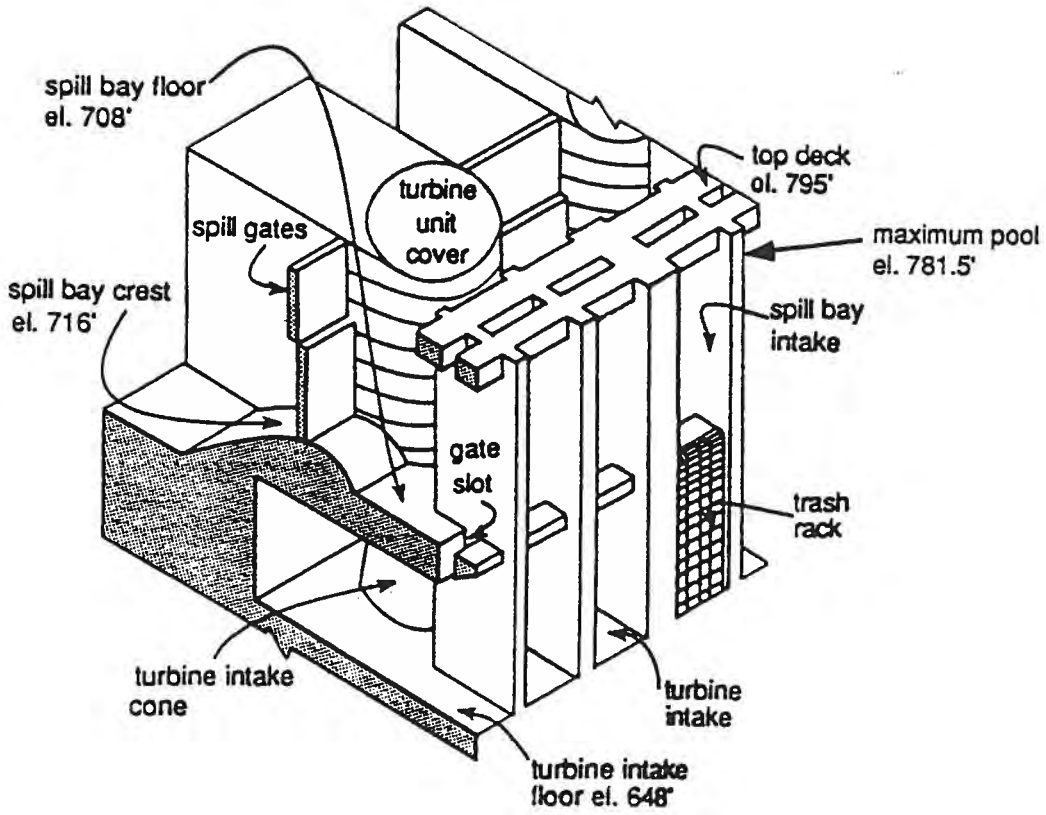

Figure 2. Three-dimensional view of Wells Dam hydrocombine with spill intakes directly above turbine intakes.

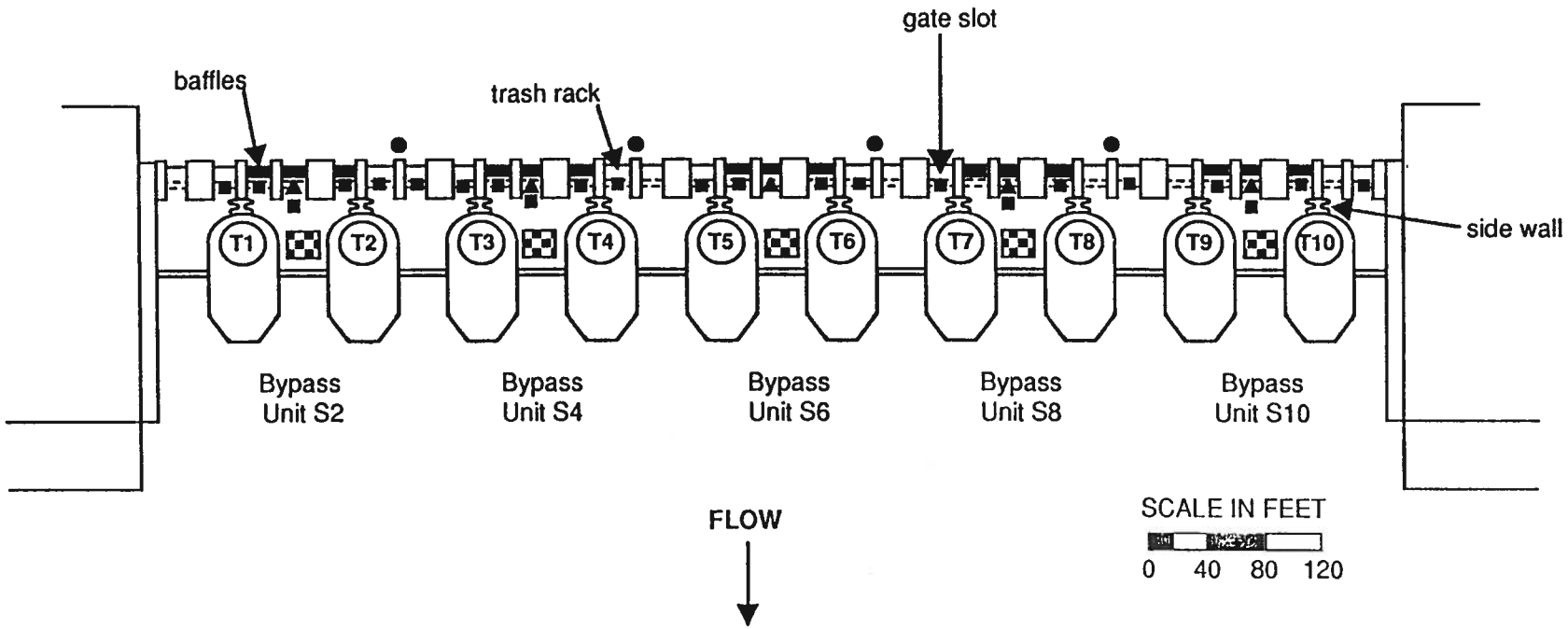

Figure 3. Plan view showing the five bypass units and the locations of forebay transducers (●), turbine intake transducers (■), bypass slot transducers (▲), and [illegible]

The smolt bypass system is based on spill intake baffles which increase flow velocities to attract smolts into the bypass. Once entrained in this attractant flow, smolts enter the bypass and migrate through the dam in bypass flow instead of turbine flow. A relatively small amount of flow, properly baffled, is equally or more effective at bypassing smolts than is a large amount of flow that is not baffled.

The smolt bypass system at Wells Dam has five individual bypass units (Figure 3). A bypass unit is formed by modifying a spill bay with sidewalls, gate slot plugs, and baffles (Figures 3 and 4). Side walls installed between the pier noses and the turbine pit walls on each side of a spill bay prevent water from flowing between adjacent spill bays, thereby increasing the effect of the intake baffles on forebay flows. Gate slot plugs prevent flow between turbine intakes and the bypass unit. Baffles anchored in the trash rack guides in the spill intakes increase flow velocity into the bypass units. The baffle opening can be oriented horizontally (Figure 5a) or vertically (Figure 5b) in 4-ft increments of height or width. The horizontal opening can be placed anywhere in the water column of the bypass unit intakes. The vertical opening is placed in the center intake of the three intakes. The baffles are the most important feature in the design of the smolt bypass system at Wells Dam. After many years of testing, a vertical slot baffle opening was selected.

During the 1980's, annual bypass evaluations using hydroacoustic sampling methods and rigorous experimental designs were critical to the development of an efficient bypass at Wells Dam. A prototype bypass was first installed and tested in 1983 at one spillbay of the dam. The 1983 study showed that smolt passage in bypass flow was greater with baffles in place than without. In 1984, 1985 and 1986, the bypass passage rates for 13 different baffle configurations (underflow, overflow, vertical slots, etc.) were compared. The configuration that passed statistically significantly more fish than the others, all other factors being equal, was deemed the "best." The data showed that the vertical slot and underflow configurations worked best. In 1986, two bypass sections were installed and tests conducted to determine if operating an adjacent bypass section increased passage at the original bypass section; it did not. In 1987, more bypass sections were installed and the study objective was to determine the most effective locations for bypass sections across the dam; the middle and west sections had higher passage than the east section. In 1988 and 1989, detailed data on specific characteristics of the bypass were evaluated to fine-tune the system. The bypass will be officially completed after review and acceptance of total project bypass efficiency data from three years of monitoring beginning in 1990.

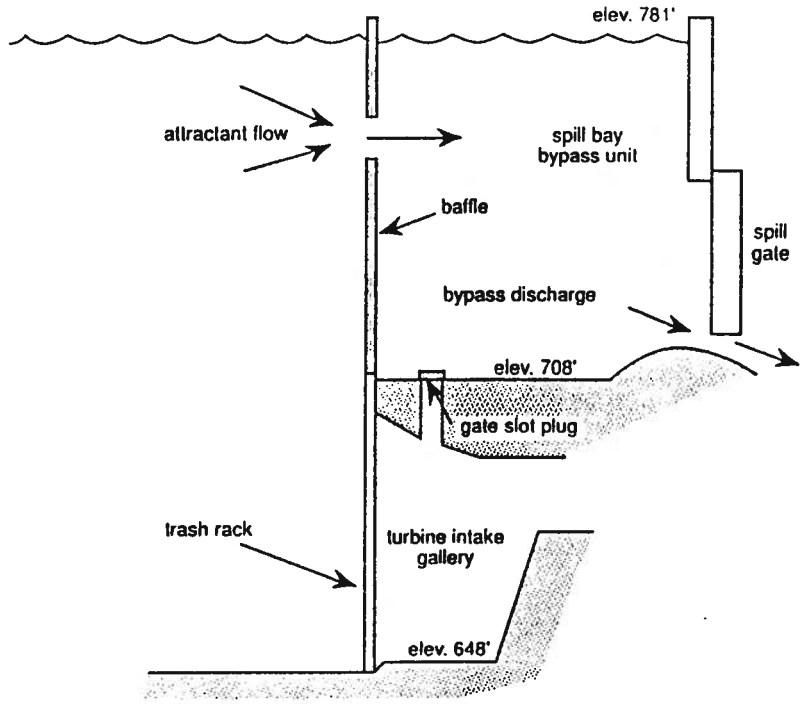

Figure 4. Side view of a bypass unit at Wells Dam showing a horizontal baffle opening and attractant flow.

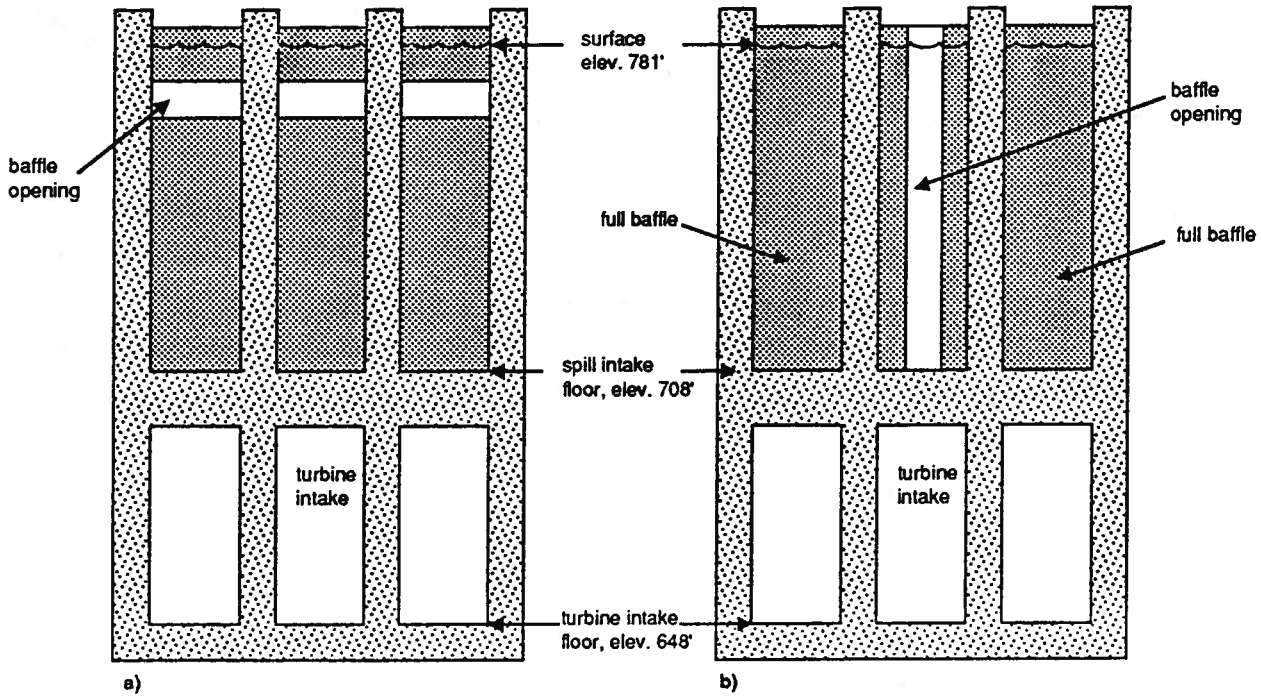

Figure 5. The upstream side (front view) of a bypass unit at Wells Dam with (a) horizontal baffle opening and (b) vertical baffle opening.

2.0 METHODS

2.1 General Hydroacoustics

We used fixed-location hydroacoustic techniques for monitoring smolt passage at Wells Dam in 1990. The techniques were similar to those used in 1989 (Kudera *et al.* 1990) and are explained by Thorne and Johnson (In Press). The following methods are described in detail in Appendix A: (1) operating BioSonics hydroacoustic systems; (2) acquiring data from echograms; and (3) reducing data and calculating the primary statistics. Specific details of transducer locations and orientations, sampling design, and statistical methods are presented below.

2.2 Transducer Locations and Orientations

Transducers were deployed in the forebay, bypass intake slots, and turbine intake galleries. To monitor run timing, transducers (nominal beam width 15°) sampled fish passage in the forebay in front of Turbine Units 2, 4, 6, and 8 (Figure 3). We deployed the forebay transducers at the bottom of the pier nose between the B- and C-slots of the designated units, about 130 ft deep. They were aimed up about 28° off the face of the dam (Figure 6). The forebay had ranges from 118 to 127 feet so a low pulse rate of 4 pulses per second (pps) was used. The forebay data were used to generate a daily index of fish passage before and after the spring and summer bypass studies; the forebay was not sampled during the bypass evaluation.

For the bypass evaluation, five transducers (nominal beam width 6°) were placed in bypass intake slots: 1C, 3C, 5C, 7C, and 9C (Figures 3 and 6). The bypass slot transducers were deployed in the gate slot immediately downstream of the vertical baffle opening in the C-slots of the designated bypass. This location is at the center of a bypass spillbay. These transducers rested at the bottom of the bypass and were aimed straight up toward the surface (Figure 6). The range in the bypass slots was approximately 65 feet so a higher pulse rate of 12 pps was used. The bypass slot transducers sampled fish passage into all five bypass intakes of the smolt bypass system.

Also for the bypass evaluation, 20 transducers (nominal beam width 15°) were deployed in turbine intake galleries (Table 2 and Figure 3). These transducers were mounted on the bottom and aimed upward about 10° downstream (Figure 6). The pulse rate was 12 pps. At least two of three intakes at each turbine unit were sampled. The sampled intakes were selected randomly. At two turbine units (Units 1 and 2), all three intakes were sampled; these two units

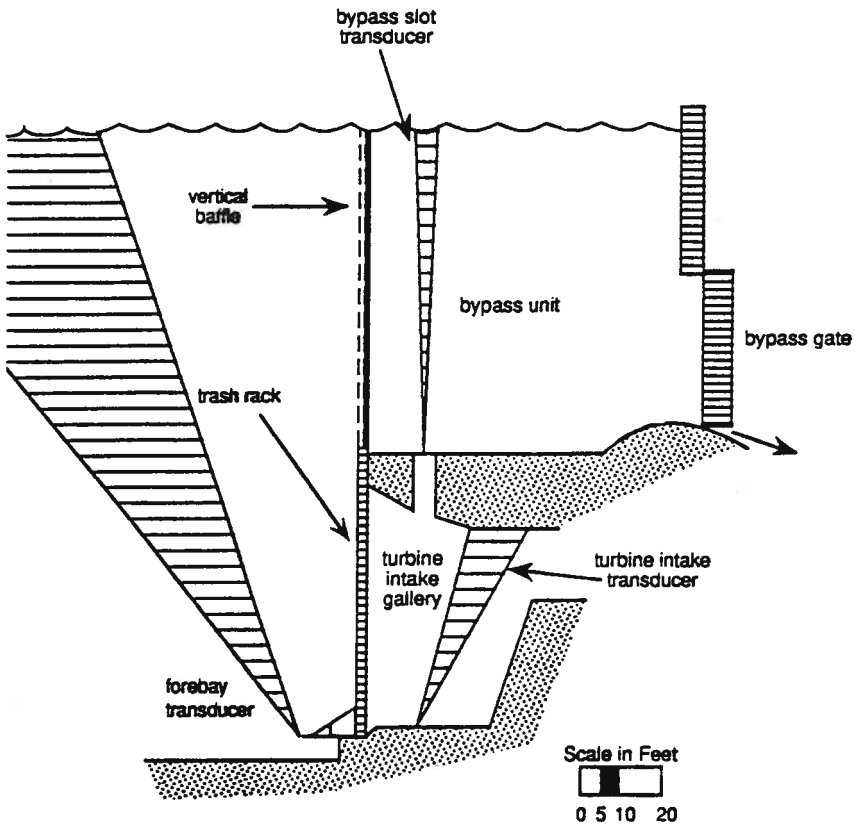

Figure 6. Side view of a bypass unit at Wells Dam showing 1990 transducer sampling areas.

Table 2. Turbine intake sampling locations at Wells Dam in 1990.

LOCATION	DATES SAMPLED Spring	Summer	LOCATION	DATES SAMPLED Spring	Summer
1A	4/19-5/18	7/09-7/24	6A	4/19-5/18	7/09-7/24
1B	4/19-5/18	7/09-7/24	6B	4/19-5/18	7/09-7/24
1C	5/04-5/18	7/09-7/24	6C	NS	NS
2A	4/19-5/18	7/09-7/24	7A	4/19-5/01	NS
2B	4/19-5/18	7/09-7/24	7B	NS	NS
2C	4/19-5/18	7/09-7/24	7C	4/19-5/01	NS
3A	4/19-5/04	NS	8A	4/19-5/18	7/09-7/24
3B	4/19-5/18	7/09-7/24	8B	NS	NS
3C	4/19-5/18	7/09-7/24	8C	4/19-5/18	7/09-7/24
4A	4/19-5/18	7/09-7/24	9A	NS	NS
4B	4/19-5/18	7/09-7/24	9B	4/19-5/18	7/09-7/24
4C	NS	NS	9C	4/19-5/18	7/09-7/24
5A	5/03-5/18	7/09-7/24	10A	4/19-5/18	7/09-7/24
5B	5/03-5/18	7/09-7/24	10B	NS	NS
5C	NS	NS	10C	4/19-5/18	7/09-7/24

were selected because previous data showed relatively high fish passage rates. The turbine intake transducers sampled fish passage into 20 of 27 turbine intakes. (At any given time during the study, three intakes were not available because of turbine runner replacement.) During the spring Unit 5 was out of service until May 3. Unit 7 was out of service for the entire summer study period. The transducers deployed in Unit 7 were moved to Unit 5 when Unit 7 went out of service. The transducer in Turbine Intake 3A was moved to Turbine Intake 1C on May 5 to more intensively sample where preliminary data showed higher fish passage rates. The turbine intake transducers sampled fish that were not diverted into the bypass system.

2.3 Sampling Design

For monitoring run timing, one hydroacoustic system sampled smolt passage in the forebay. The system, which had one chart recorder, sampled in the forebay immediately upstream of the dam. The four forebay locations were each sampled once every hour for a minimum of 15 min at 4 pps. During the spring (April 19 to May 18) and summer (July 9 to July 24) bypass studies, we did not sample the forebay. During the bypass studies, we used data from the bypass intake slot transducers to produce a run timing index. For monitoring run timing, samples were obtained at least eight hrs/day (1300 h - 1700 h and 2200 h - 0200 h) every day from April 7 to August 31.

For both spring and summer, we defined the hours of day and night during a study day as follows:

Day = 0800 h - 2000 h (Date X) and 0600 h - 0800 h (Date X+1)

Night = 2000 h - 0600 h (Date X to Date X+1).

NOTE: This definition was based on previous studies when it was necessary to change experimental conditions each day. These changes were made by work crews starting at 0800 h. In 1991, a study day should be defined as 0600 h to 0600 h.

For evaluating the bypass, one hydroacoustic system sampled the bypass slots and two systems sampled turbine intakes. Each transducer was sampled for a minimum of 12 minutes an hour for 24 hours per day during the spring and summer sampling periods. Typically, three 4-minute samples were collected each hour for each transducer location. The hourly sampling sequence was systematic. The start location of the systematic sequence was randomized at the start of every study day (0800 h).

2.4 Statistical Methods

We determined fish passage (#/hr) at each location each hour by summing the weighted fish detections and dividing by total sample time (usually 12 minutes) at a given location within a given hour and then multiplying by 60 minutes per hour (Appendix A). The hourly passage rate estimates were the basic data for monitoring run timing and evaluating the bypass.

The run timing index from the forebay transducers was calculated by averaging passage rates over the four locations to produce a mean number per eight hrs per location. These numbers were adjusted for the percentage of non-target species present in the fyke net catch for each week. The run timing index from the bypass slot transducers was calculated by averaging passage rates over the five bypass slot locations.

Total project bypass efficiency, for spring and summer separately, was estimated by dividing total fish passage in bypass by total passage in turbine plus bypass.

$$B = y/(y+x)$$

where y = fish passage in bypass, and

x = fish passage in turbine.

$$CI(B) = B * \exp[z * (var(B)(1/B^2 + 3 * var(b)/B^4))^{.5}]$$

where $var(B) = B^2(1-B)^2[var(y)/y^2 + var(x)/x^2]$

z = 1.645 at the 90% confidence level and

z = 1.96 at the 95% confidence level

The methods were developed by Dr. John Skalski of the University of Washington and are presented in Appendix B. The algorithm for estimating the confidence interval was determined by Dr. Skalski (Skalski and Ouellette, 1990).

2.5 Fyke Net Methods

During 1990, DCPUD collected species composition data inside Turbine Intake 4C using fyke nets. Net data were collected at least once per week from April 5 to August 30, 1990. Sampling usually lasted eight hours. For the first three months of the study, sampling was done

only at night. During July and August, day and night samples were collected. The entire cross-sectional area of the turbine could be sampled by the array of three nets across by seven nets down. During 1990 only the center column of seven nets was fished. Each net opening was 7 ft wide and 6.75 ft high. Each net was 13 ft long with 3/8 inch stretch mesh and 1/4 inch mesh cod end. In spring and summer, all captured fish were counted, examined for marks and a subset was measured. The fish were categorized as follows: yearling chinook, zero-age chinook, sockeye, steelhead, whitefish, and other. Fish counts were divided by sample time to produce number passing per unit time.

3.0 RESULTS

3.1 Ancillary Data

3.1.1 Project Discharge and Dam Operations

From April through August 1990, project discharge at Wells Dam was higher than the 15-yr average (Table 3). Overall, the mid-Columbia had relatively high water during spring and summer 1990. Because of the high amount of water, power generation was usually at its maximum during the bypass evaluation. One turbine unit, however, was always off line due to turbine runner replacement.

Table 3. Project discharge (kcfs) for Wells Dam during April through August, 1990. Source: T. Roberts (DCPUD).

	PROJECT DISCHARGE (kcfs)				
	April	May	June	July	August
Min. daily average	72.3	89.4	157.9	92.8	52.3
Max. daily average	186.1	189.5	254.6	186.5	156.4
Avg. hourly discharge	138.7	144.1	208.5	145.3	111.3
15-year average	110.5	132.1	133.9	115.1	100.1
% 15-year average	125	109	156	126	111

Bypass operations for smolt passage at Wells Dam in 1990 were similar to those in previous years. By agreement of the Mid-Columbia Coordinating Committee, bypass flow replaced interim spill. DCPUD operated the bypass daily from April 17 to June 6, and from July 6 to August 15, 1990. The number of bypass units that were operated depended on the daily flow forecast from Chief Joseph Dam. If the flow forecast was greater than or equal to 140 kcfs, all five bypass units were opened for that 24-hr period. There was a total of 22 days during which all bypass units were open due to inflow estimates. If the forecast was less than 140 kcfs, only those bypass units above a pair of turbines, with one or both operating, were opened (Tom Hook, DCPUD, personal communication). Each bypass unit is associated with two turbines (Bypass Unit S2 with Turbines 1 and 2; Bypass Unit S4 with Turbines 3 and 4; etc.). Therefore, if one or both turbines of a pair were on-line, then the bypass unit was opened. If both units were off-line,

then the bypass unit was closed. From August 6 to August 15, bypass operation was limited to dusk through dawn operation (2000 h -0600 h). Minimum bypass flows (kcfs) were: S2 = 1.6 to 2.1; S4 = 2.2; S6 = 2.2; S8 = 2.2; and S10 = 1.6 to 2.1. During 1990, daily bypass flow at Wells Dam averaged 5.8% of total project discharge.

3.1.2 Species Composition

The principle salmonid species migrating past Wells Dam in spring are: chinook salmon (*Oncorhynchus tshawytscha*), steelhead trout (*O. mykiss*), and sockeye salmon (*O. nerka*). Spring chinook are raised and released at the U.S. Fish and Wildlife Service hatchery at Winthrop, 50 miles upstream from Wells. Steelhead are raised at the Wells hatchery and transported to upstream release sites. The quantities, dates, and locations of the spring 1990 releases of hatchery-raised salmonids above Wells Dam are given in Table 4. About 1.8 million fish were released in the drainage above Wells Dam in 1990. Wild stocks of sockeye also migrate downstream through Wells Dam. These salmon migrate out of Lake Osoyoos, about 100 miles upstream from Wells. In spring and summer, wild chinook that reproduce in the Okanogan and Methow drainages (zero-age chinook) migrate downstream through the Mid-Columbia (Figure 1).

Table 4. Species, locations, distances from Wells, dates, and sizes of releases of hatchery-raised juvenile salmonids upstream of Wells Dam in spring 1990. Sources: B. Wallien (USFWS) and S. Miller (WDG).

SPECIES	RELEASE SITE	MILES FROM WELLS DAM	DATE	NUMBER
spring chinook	Winthrop	50	4/17	1,121,395
summer steelhead	Methow RM 27	33	4/27-5/2	163,089
	Methow RM 10	16	4/30-5/9	294,150
	Methow RM 1	7	5/3-5/4	30,000
	Okanogan RM 26	41	5/1-5/3	57,900
	Okanogan RM 5	21	5/4-5/7	40,500
	Similkameen RM 6	90	4/18-4/25	97,494
	Twisp RM 6	46	4/30-5/1	28,500
	Chewuch RM 8	58	4/23	28,800
				Total = 1,861,828

The 1990 fyke net catch data from Wells Dam are tabulated in Table 5 and graphed in Figures 7A, 7B, and 8. Catches from April 5 and April 12 were low and consisted mainly of chinook salmon with only one steelhead present in each catch. On April 19 the catch increased dramatically due to the chinook release from Winthrop on April 17 (Figure 7A and Table 4). The catch from April 19 to May 16 ranged between 96% and 100% chinook, sockeye, and steelhead (Figure 8). There were large numbers of steelhead present in the catches of May 3 and May 10 (Figure 7A). On May 16, a large peak of sockeye occurred. From the end of May through the end of June, whitefish and other non-target species increased in catch proportion (Figure 8). From May 24 to June 28 the catch proportion of whitefish and "other" species ranged from 54% to 90% of the total catch (Table 5). Zero-age chinook began to appear in greater numbers on July 5 (Figure 7A). Between July 5 and August 9 the proportion of chinook in the fyke net catch ranged from 71% to 95% for the night samples (Table 5). Very low numbers of salmon were caught during daytime sampling in July and August (Figure 7B). From mid-August until the end of the study (August 31) the catch consisted mainly of non-target species (Figure 8).

The 1990 fyke net data show the consistent year-to-year trend of a spring period (April 5 to May 16) dominated by chinook, sockeye, and steelhead. Zero-age chinook dominated the catch from July 5 through August 9 (Figure 7A). Whitefish increased in number in late May and were present in noticeable numbers throughout the summer (Figure 8). "Other" fish that were caught in the fyke net included bullhead, carp, chiselmouth, dace, lamprey, peamouth, sculpin, shiner spp., squawfish, sucker, and walleye.

Table 5. Number and proportion of chinook, steelhead and other non-salmonid species caught in the fyke nets at Wells Dam in spring and summer 1990. Data are expressed in number of fish per hour and proportion. Source J. McGee (DCPUD).

		Oncorhynchus Species						Non-Salmonid Species					
	Day/	Chinook		Sockeye		Steelhead		Whitefish		Other		All non-salmonids	
Date	Night	#/hr	Prop.	#/hr	Prop.	#/hr	Prop.	#/hr	Prop.	#/hr	Prop.	#/hr	Prop.
4/05	N	9.6	0.99	0.0	0.00	0.1	0.01	0.0	0.00	0.0	0.00	0.0	0.00
4/12	N	1.4	0.92	0.0	0.00	0.1	0.08	0.0	0.00	0.0	0.00	0.0	0.00
4/19	N	190.8	0.99	0.0	0.00	0.0	0.00	0.0	0.00	1.0	0.01	1.0	0.01
4/26	N	7.9	0.80	0.1	0.01	1.5	0.15	0.0	0.00	0.4	0.04	0.4	0.04
5/03	N	7.1	0.45	0.4	0.02	8.4	0.52	0.0	0.00	0.1	0.01	0.1	0.01
5/10	N	7.9	0.20	6.1	0.16	23.8	0.61	0.3	0.01	1.0	0.03	1.0	0.03
5/16	N	1.0	0.01	116.5	0.99	0.4	0.00	0.1	0.00	0.3	0.00	0.4	0.00
5/24	N	0.4	0.02	9.5	0.42	0.4	0.02	3.3	0.15	8.9	0.39	12.1	0.54
5/31	N	1.4	0.03	3.1	0.07	0.0	0.00	2.4	0.05	39.6	0.85	42.0	0.90
6/04	N	0.3	0.06	0.1	0.03	0.0	0.00	1.1	0.29	2.4	0.61	3.5	0.90
6/07	N	0.3	0.11	0.0	0.00	0.0	0.00	0.5	0.21	1.6	0.68	2.1	0.89
6/14	N	0.9	0.23	0.1	0.03	0.0	0.00	1.0	0.26	1.9	0.48	2.9	0.74
6/21	N	1.4	0.18	0.0	0.00	0.0	0.00	2.1	0.28	4.0	0.52	6.1	0.82
6/28	N	2.1	0.38	0.0	0.00	0.0	0.00	0.9	0.16	2.6	0.47	3.5	0.62
7/05	N	9.9	0.71	0.0	0.00	0.0	0.00	0.9	0.06	3.1	0.23	4.0	0.29
7/06	D	0.3	0.40	0.0	0.00	0.0	0.00	0.3	0.40	0.1	0.20	0.5	0.60
7/12	N	24.4	0.81	0.0	0.00	0.1	0.00	3.0	0.10	2.5	0.08	5.4	0.18
7/13	D	0.1	0.14	0.0	0.00	0.0	0.00	0.6	0.71	0.1	0.14	0.8	0.86
7/19	N	25.7	0.86	0.0	0.00	0.0	0.00	2.4	0.08	2.1	0.01	4.5	0.15
7/20	D	0.5	0.40	0.0	0.00	0.0	0.00	0.6	0.50	0.1	0.10	0.8	0.60
7/26	N	14.0	0.87	0.0	0.00	0.4	0.02	1.0	0.06	0.8	0.05	1.8	0.11
7/27	D	0.1	0.60	0.0	0.00	0.0	0.00	0.4	0.30	0.1	0.10	0.5	0.40
8/02	N	7.6	0.92	0.0	0.00	0.0	0.00	0.1	0.02	0.5	0.06	0.6	0.08
8/03	D	0.1	0.50	0.0	0.00	0.0	0.00	0.0	0.00	0.1	0.50	0.1	0.50
8/09	N	2.3	0.95	0.0	0.00	0.0	0.00	0.0	0.00	0.1	0.05	0.1	0.05
8/10	D	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.1	1.00	0.1	1.00
8/14	N	0.8	0.32	0.0	0.00	0.0	0.00	0.5	0.21	1.1	0.47	1.6	0.68
8/16	N	1.5	0.39	0.0	0.00	0.0	0.00	0.0	0.00	2.4	0.61	2.4	0.61
8/23	N	0.0	0.00	0.0	0.00	0.0	0.00	0.3	0.05	2.4	0.95	4.8	1.00
8/30	N	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	26.3	1.00	26.3	1.00

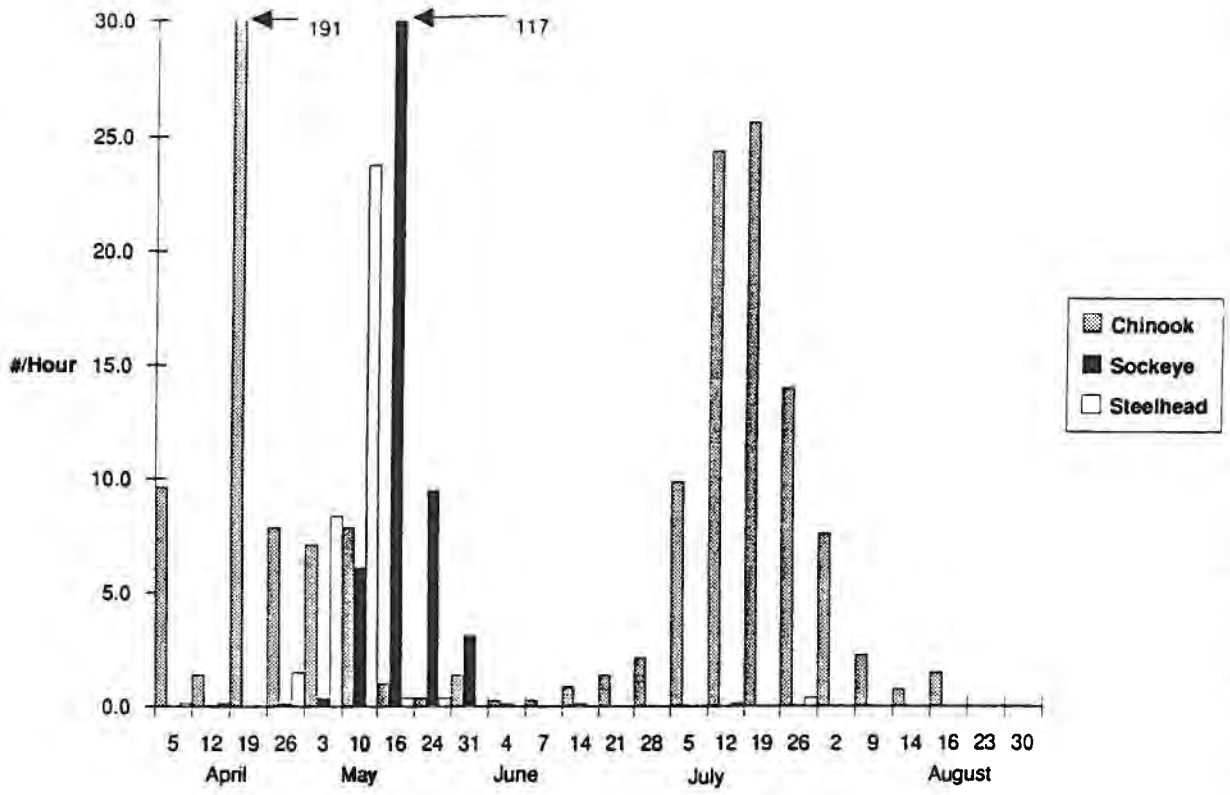

Figure 7A. Catch per hour of chinook (zero-age and yearlings combined), sockeye, and steelhead in the fyke nets at Wells Dam from April 5 to August 30, 1990, for night only.

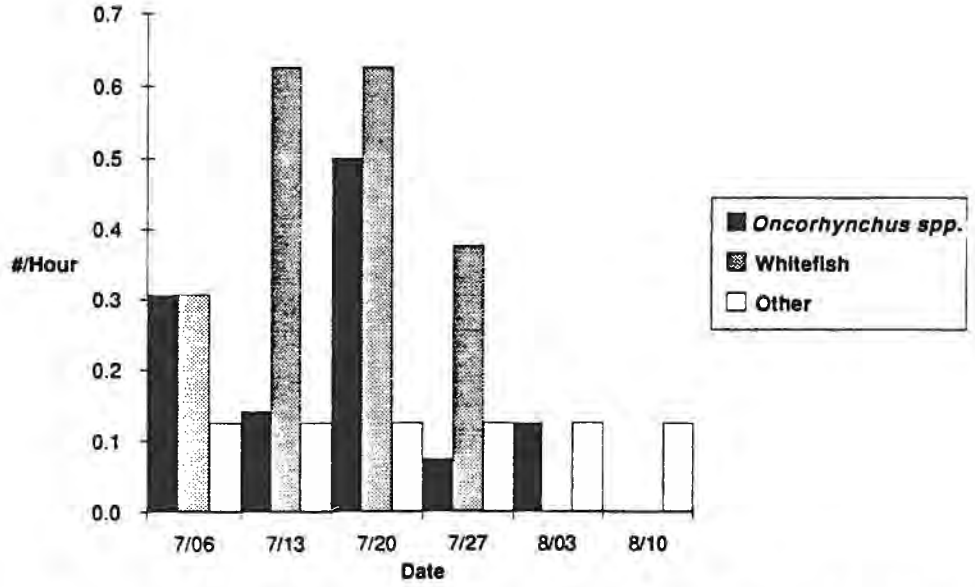

Figure 7B. Catch per hour of *Oncorhynchus spp.*, whitefish, and "other" species in the fyke nets at Wells Dam from July 6 to August 10, 1990, for day only.

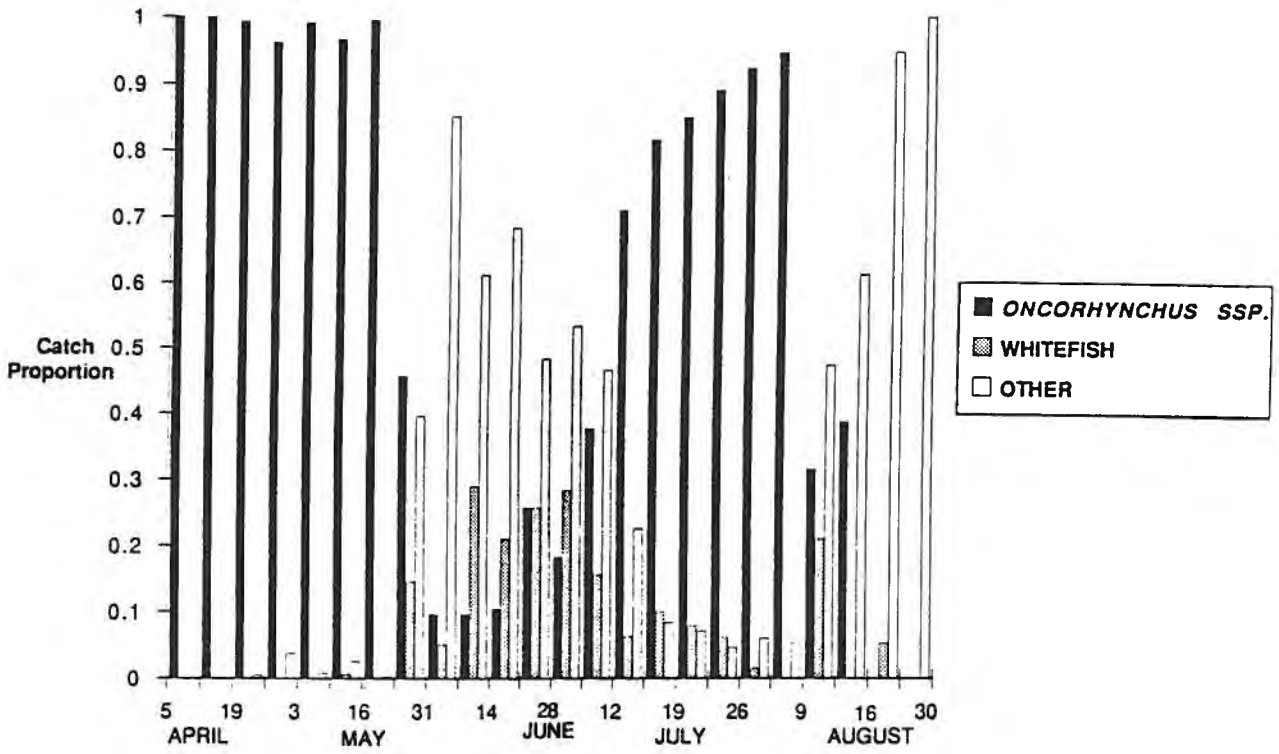

Figure 8. Proportions of the total catch from fyke net samples at Turbine Intake 4C at Wells Dam in 1990, April 5 to August 30, for night only.

3.1.3 Run Timing

The daily "sub-index" of run timing (mean #/8hr/location) from April 7 to August 31, 1990 is presented in Figures 9, 10, and 11. Recall from the methods section that run timing was calculated using forebay data for all days other than those during the spring and summer study periods. Bypass intake slot data were used to generate the run timing index during the bypass evaluation periods.

Passage was generally low in early April (Figure 9). The first peak occurred on April 16. There were significant numbers of chinook present in the fyke net catches of April 5 and April 12 (Table 5). These fish may have been produced in the wild since no 1990 hatchery fish had been released above Wells yet. The next peak occurred on April 19, two days after the chinook release at Winthrop (Figure 10 and Table 4). Passage rates remained high until April 26. Fyke net catches on April 19 and April 26 were 99% and 80% chinook salmon respectively (Table 5). There were two more peaks on May 5 and May 7 (Figure 10). There were significant numbers of steelhead in the fyke net catches of May 3 and May 10 (Figure 7A). This coincides well with the large hatchery releases of steelhead in the Methow River during late April and early May (Table 4). Another peak occurred on May 15 (Figure 10). The fyke net catch of May 16 showed that very high numbers of sockeye were present (Table 5 and Figure 7A). Passage rates then generally declined to the lowest rates of the season which occurred in mid-June. Another peak occurred on June 21 (Figure 9). This was probably a combination of whitefish and other non-target species. The fyke net catches of June 14, 21, and 28 contained between 62% and 82% whitefish and "other" (Table 5). Passage rates began to rise in late June and early July due to the beginning of the summer chinook outmigration. Passage rates remained high from July 12 to July 18 (Figure 11). The fyke net catches from this period were between 81% and 86% zero-age chinook (Table 5 and Figure 8). Very low numbers of salmon were caught during daytime sampling in July and August (Figure 7B). As in previous years (Kudera *et al.* 1990), after the end of the summer study period passage rates began to rise due to the influence of other non-target species. The highest passage rate of the season was on August 3 (Figure 9).

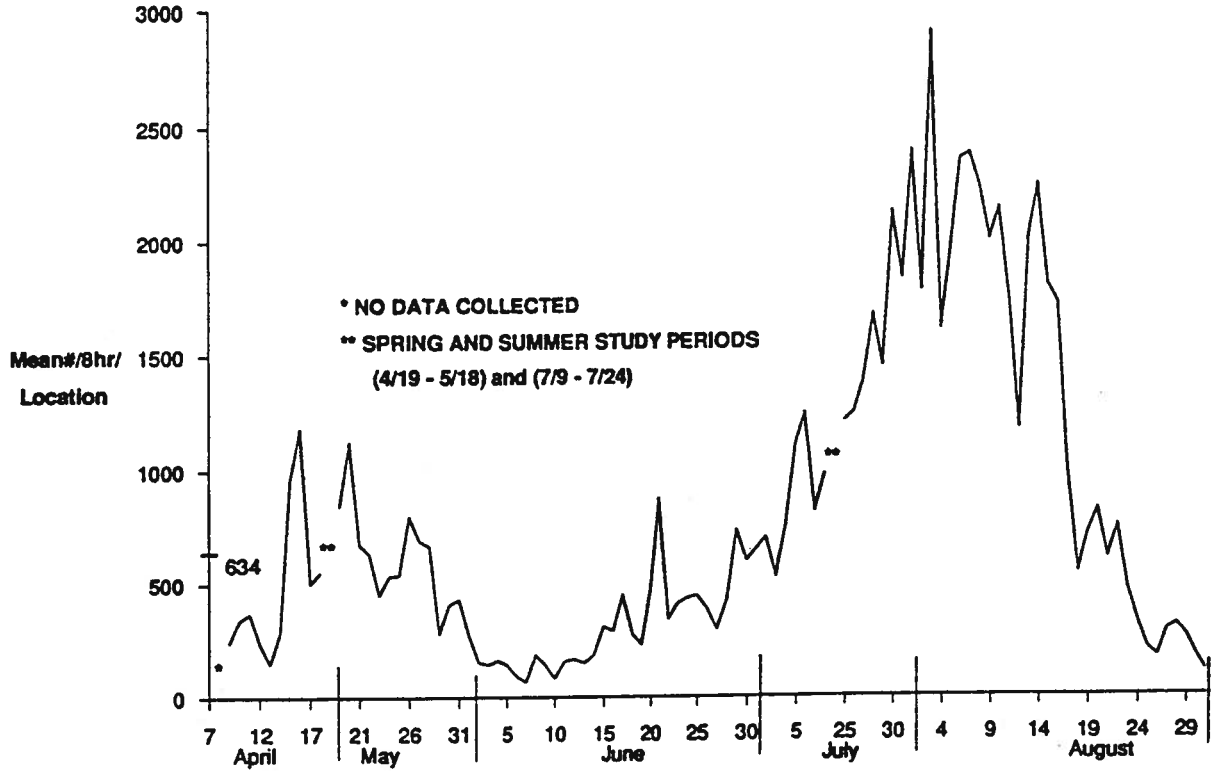

Figure 9. Daily fish passage indices (mean #/8hr/location) for day (1300 h - 1700 h) and night (2200 h - 0200 h) combined at Wells Dam forebay between April 7 and April 18, May 19 through July 8, and July 25 through August 31,1990.

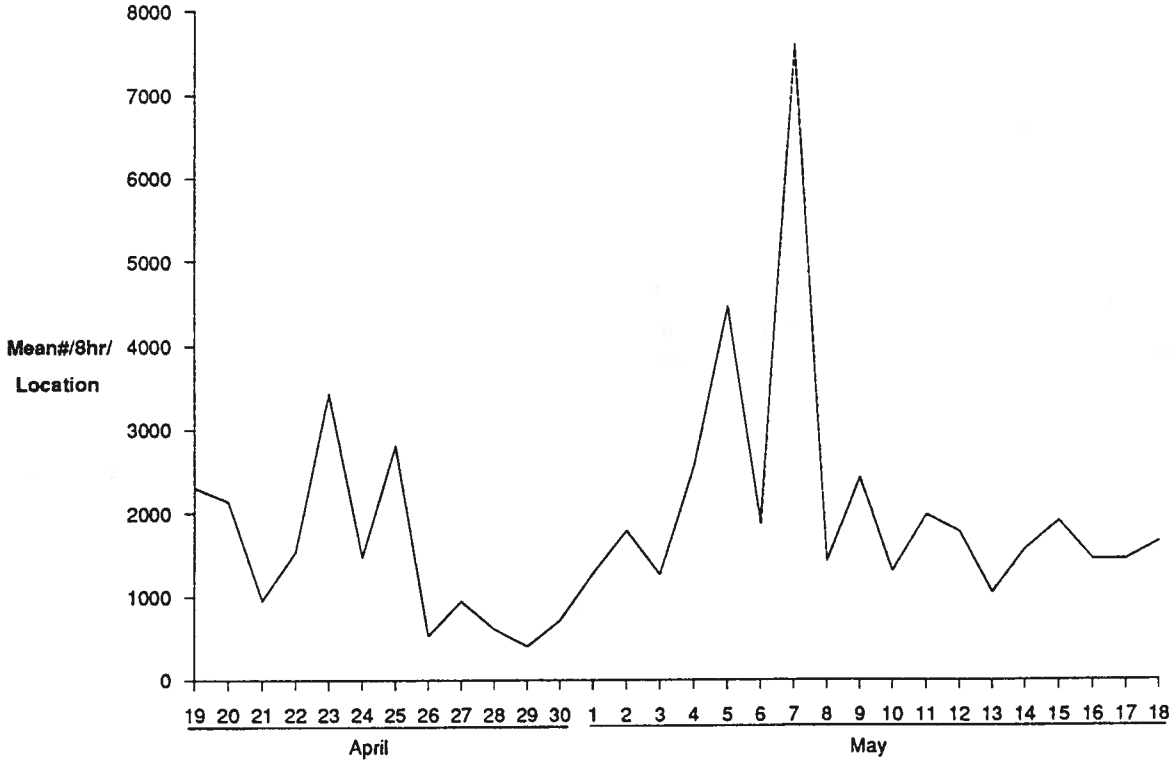

Figure 10. Daily fish passage indices (mean #/8hr/location) for day (1300 h - 1700 h) and night (2200 h - 0200 h) combined using bypass slot data at Wells Dam between April 19 and May 18, 1990.

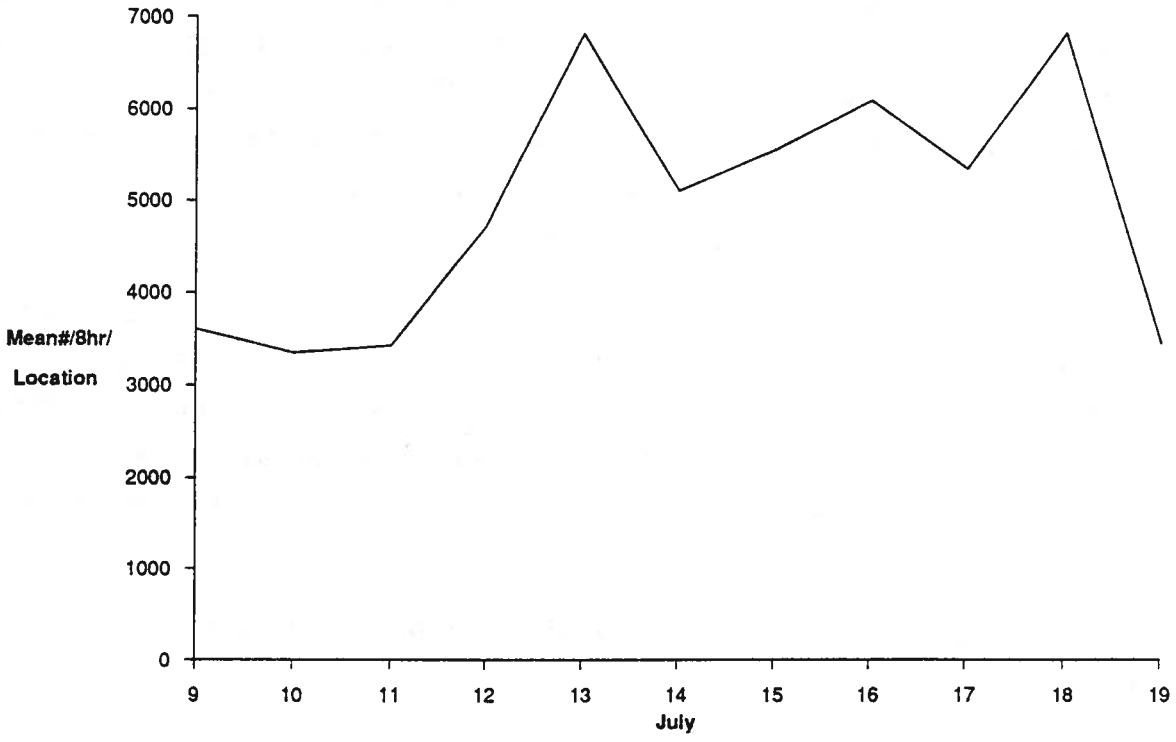

Figure 11. Daily fish passage indices (mean #/8hr/location) for day (1300 h - 1700 h) and night (2200 h - 0200 h) combined using bypass slot data at Wells Dam between July 9 and July 19, 1990.

3.2 Estimated Total Project Bypass Efficiency

Estimated total project bypass efficiency in spring 1990 was 84.3% ± 8.0% at the 95% confidence interval. Daily bypass ratios for spring are given in Figure 12. Bypass efficiency was generally lower at the beginning of the study than at the end. The lowest efficiency during the spring was 53% and occurred on April 19. The highest efficiency was 99% and occurred on April 25.

The coefficient of variation (CV = standard error divided by the mean) for the 30-day spring study was 30.4% for bypass and 4.3% for turbine passage. The bypass CV was unusually high because of the high bypass passage rates sampled on April 25, although the ratio CV and confidence interval met the criteria (Appendix C). Excluding this date, the CV for bypass for a 29-day spring study was 1.2%. Excluding April 25 bypass and turbine data, the 29-day bypass efficiency for spring was 77.8% ± 1.45% at the 95% confidence level.

Estimated total project bypass efficiency in summer 1990 was 76.5% ± 4.0% at the 90% confidence level. Thus, the bypass results for the 1990 summer study do meet the criteria. Daily bypass ratios for summer are given in Figure 13. Bypass efficiency during the summer was generally lower than during the spring. The highest rates were generally at the beginning and the end of the study period. The highest efficiency of 82% occurred on July 18. The lowest efficiency, 69%, occurred on July 14.

To summarize, the estimates of **total project bypass efficiency** at Wells Dam in 1990 were:

Spring	84.3% ± 8.0% at 95% confidence level
Summer	76.5% ± 4.0% at 90% confidence level

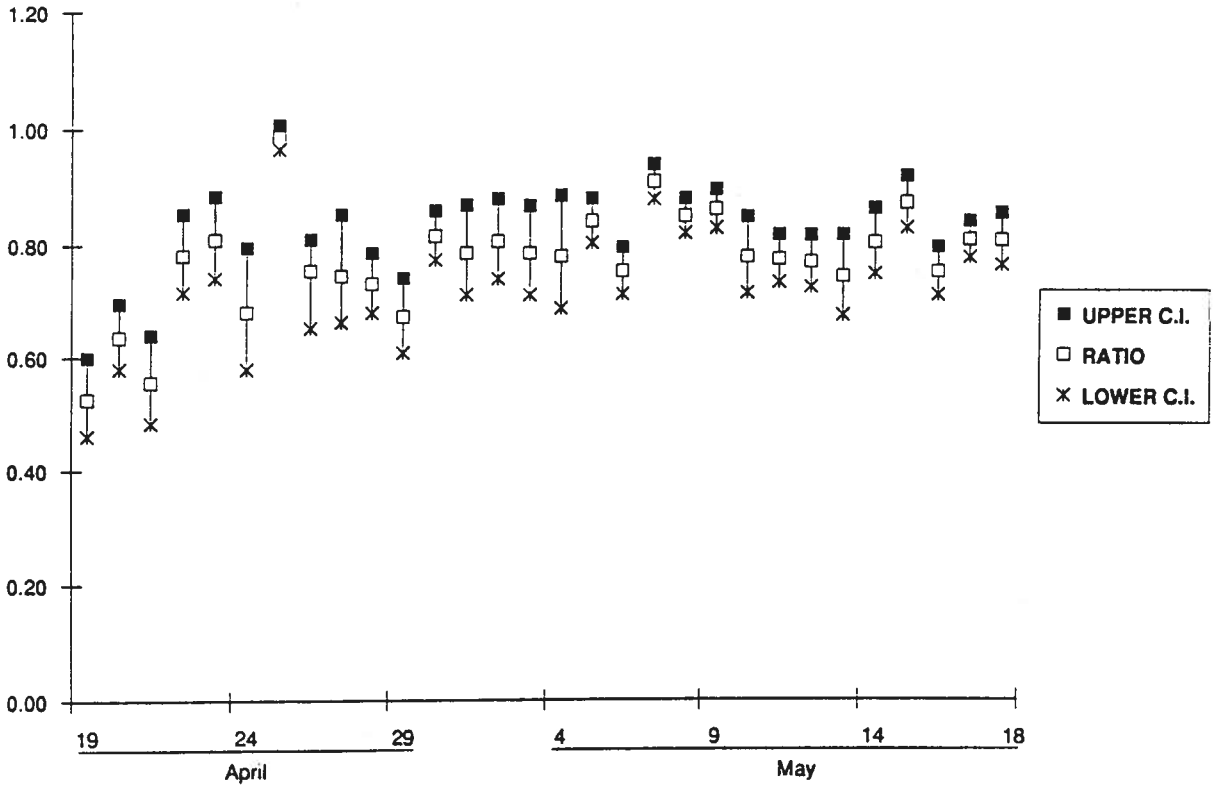

Figure 12. Daily bypass efficiency estimates for spring (April 19 to May 18) at Wells Dam, 1990. Ratios are expressed for 90% confidence levels.

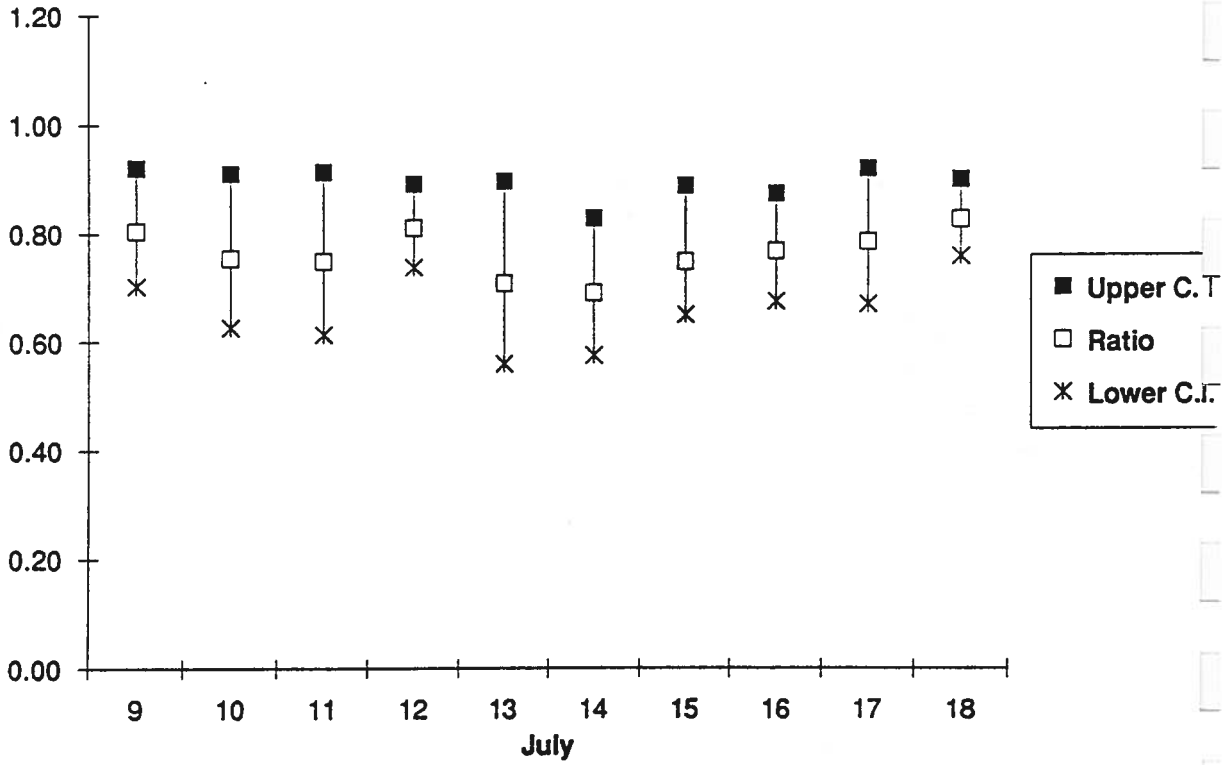

Figure 13. Daily bypass efficiency estimates for summer (July 9 to July 19) at Wells Dam, 1990. Ratios are expressed for 90% confidence levels.

4.0 CONCLUSIONS

(1) Total project bypass efficiency was estimated using hydroacoustic techniques during spring (April 19 to May 18) and summer (July 9 to 24) study periods at Wells Dam in 1990.

(2) Species composition and run timing data were collected using fyke net and hydroacoustic methods from April 5 to August 31, 1990.

(3) Chinook and sockeye salmon and steelhead trout juveniles were predominant in spring from April 15 to May 16. Zero-age chinook were predominant in July. During the periods between the spring and summer studies and after the summer study, other species such as whitefish were prevalent.

(4) Estimated total project bypass efficiency for the 30-day spring study was 84.3% $\pm$ 8.0% at the 95% confidence level. There was one day (April 25), however, that had extremely high passage in bypass. The bypass efficiency for this day was 99%. With this data point excluded from analysis, estimated total project efficiency in spring was 77.9% $\pm$ 1.5% at the 95% confidence level.

(5) Estimated total project bypass efficiency for the summer study was 76.5% $\pm$ 4.0% at the 90% confidence level.

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APPENDIX A

HYDROACOUSTIC SYSTEM, DATA ACQUISITION, AND DATA REDUCTION

APPENDIX A. Hydroacoustic System, Data Acquisition, and Data Reduction

A.1 Hydroacoustic System Equipment, Operation, and Calibration

A.1.1 Equipment Description

The hydroacoustic studies at Wells Dam in 1990 required three BioSonics systems. Each system (Figure A1) consisted of the following components: high-frequency transducers (420 kHz) with cable, an echo sounder/transceiver, a multiplexer/equalizer, one or two chart recorders, and an oscilloscope. Specific manufacturers and model numbers of the electronic equipment used are listed in Table A1. The hardware parameters used in 1990 are presented in Table A2.

Table A1. Model numbers, manufacturers, and serial numbers of electronic equipment used by BioSonics, Inc. at Wells Dam in spring and summer 1990.

MODEL NO. AND EQUIPMENT	MANUFACTURER	SERIAL NO.
Model 101 (420 kHz) Echo Sounder	BioSonics, Inc.	101-81-010 101-83-030 101-81-031
Model 151 MPX/EQ Multiplexer/Equalizer	BioSonics, Inc.	151-83-006 151-87-026 151-89-029
Model X-MPX Multiplexer	BioSonics, Inc.	MPX-81-004
Model X-EQU Equalizer	BioSonics, Inc.	EQ-82-010
Model 111 Chart Recorders	BioSonics, Inc.	111-85-004 111-86-029 111-88-038 111-88-039 111-89-048 111-90-062
Transducers	BioSonics, Inc.	Too numerous to list
Model V-423 Oscilloscope	Hitachi, Inc.	5017445

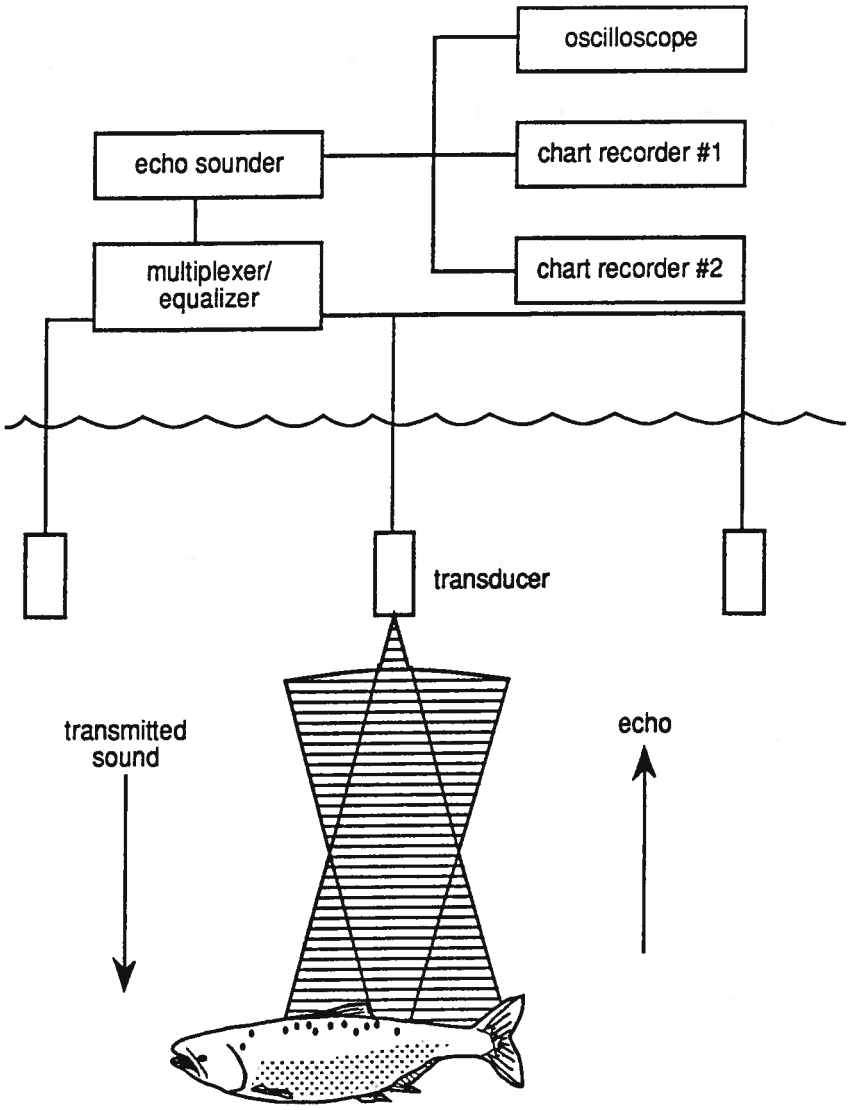

Figure A1. Block diagram of hydroacoustic data collection system used at Wells Dam in 1990.

Table A2. Hydroacoustic system parameters used for studies at Wells Dam in 1990.

ECHO SOUNDER	Transmit frequency: 420 kHz
	Transmit power: 0 dB
	Band width: 5 kHz
	Pulse width: 0.4 msec
	TVG: 40 log(R)
	Trigger source: Thermal chart recorder
	Receiver gain -6 dB
CHART RECORDERS	Threshold: 0.1 volts

A.1.2 Equipment Operation

A BioSonics hydroacoustic system works as follows. When triggered by the Model 101 Echo Sounder, a high-frequency transducer emits short sound pulses in a relatively narrow beam aimed toward an area of interest. As these sound pulses encounter fish or other targets, echoes are reflected back to the transducer which then reconverts the sound energy to electrical signals. The signals are then amplified by the echo sounder at a 40 log(R) time-varied-gain (TVG) to compensate for the loss of signal strength due to absorption and geometric spreading of the acoustic beam with distance from the transducer. Thus, equally sized targets produce the same signal amplitudes at the echo sounder receiver output regardless of their distance (range) from the transducer. The range of each target from the transducer is determined from the time it takes the sound pulse and echo return to travel that distance (velocity of sound in fresh water = 1445 m/sec).

The echo sounder relays the returning TVG-amplified signals to the chart recorder, oscilloscope, and tape recorder. The return signals are visually displayed on the oscilloscope to observe echo strength and echo duration. Returns from individual fish are recorded on the chart recorder's echograms which provide a permanent record of all targets detected throughout the study. The threshold circuit on the chart recorder is adjusted to eliminate signals less than the echo levels of interest.

The Model 151 Multiplexer/ Equalizer (MPX/EQ) permits a single echo sounder to automatically interrogate up to 16 different transducers in an operator-specified sequence. The MPX/EQ channels transmit pulses from the echo sounder to the appropriate transducers and equalizes the return signals to compensate for the different receiving sensitivities resulting from varying cable lengths and transducer characteristics.

A.1.3 System Calibration

Each acoustic system was calibrated before the study began. Calibration assured that an echo from a target of known acoustic size passing through the axis of the acoustic beam produced a specific output voltage at the echo sounder. Based on the calibration information, the adjustable print threshold on the chart recorder was set so that it would print signals from targets larger than -56 dB on the acoustic axis of the transducer. The calibration information was also used to equalize the system sensitivity (using the MPX/EQ) for each receiving channel. A system calibration at the end of the season verified that the sensitivities had remained constant throughout the study. A detailed description of the calibration of hydroacoustic systems can be found in Albers (1965) and Urich (1975).

A.2 Data Acquisition Methods

A.2.1 Migrant Detection Criteria

Echogram traces had to satisfy two criteria to be classified as fish: 1) the strength of target echoes had to exceed a predetermined threshold; and 2) the targets had to be detected by consecutive acoustic pulses (redundancy).

As stated above, the hydroacoustic systems were calibrated so that the chart recorder marked only targets with echo strengths greater than -56 dB on the acoustic axis of each transducer. This echo strength threshold was chosen so that even the smallest outmigrant salmon and steelhead returned an echo strong enough to mark the echogram.

At least four successive echoes were required for a target to be classified as a fish. Most of the observed fish were detected more than four times in succession. This high redundancy occurred because of the relatively wide beamwidths of the transducers and the high pulse repetition rates. This redundancy criterion enhanced fish detectability in the presence of background

interference. Further details of fish detection criteria for fixed-location hydroacoustics can be found in Carlson, *et al.* (1981).

Based on echogram "trace types" (i.e., the pattern of marks produced by successive detections), fish were classified as either "migrants" or "wallowers." Wallowers produced marks consistent with large resident fish milling about in the forebay. Migrant trace types exhibited change-in-range consistent with the smaller smolts. Only fish classified as migrants were included in the analyses.

A.2.2 Background Interference Level

The background interference level on the echograms of each interrogation period was rated on a scale of 1 to 5.

1 = No interference
2 = Little interference, no effect on fish trace recognition
3 = Moderate interference, no effect on fish trace recognition
4 = Excessive interference, adverse effect on fish trace recognition
5 = Black

Interrogation periods with the highest interference levels (4 and 5) were not included in data analysis. For the 1990 studies at Wells Dam, less than 4% of all interrogation periods were excluded because of excessive interference.

A.2.3 Data Entry and Storage

Microcomputers were used for data storage and analysis. Data from individual fish detections recorded on the echograms were written to computer data files using a digitizing pad and appropriate software. For each fish detected passing through the acoustic beam, a technician used the digitizing stylus to record the following:

time of entrance
time of exit
range at entrance
range at exit
trace type

The following information was recorded for each interrogation period:

date
start time of transducer interrogation
duration of transducer interrogation
transducer location
transducer depth
transducer beamwidth
transducer orientation
background interference level

A.3 Data Reduction Methods

A.3.1 Data Selection

Two criteria were used to select the data for the various analyses. First, all fish detections from interrogation periods with excessive background interference were eliminated, as explained in Appendix A.2. Second, based on trace type classification, all non-migrant fish ("wallowers") were excluded. The remaining fish detections were used in the analyses.

A.3.2 Range of Fish

For a given outmigrant, the range from the transducer (R) was the mid-point range of the echo trace as calculated by:

$$R = \frac{R_{in} + R_{out}}{2}$$

where R_{in} and R_{out} are the ranges at which the fish entered and exited the acoustic beam, respectively.

A.3.3 Weighting Factor

Since only a portion of the cross-sectional area at a sampling location was ensonified, individual fish detections were multiplied by a weighting factor to estimate the total relative number of fish passing that location at that particular range and time. To account for the cone-shaped geometry of the acoustic beam, the weighting factor was defined as the ratio of the width at the

sampling location to the width of the acoustic beam at the range of detection. (Sampling location widths were: pier nose = 90 ft; turbine intake = 22.5 ft; bypass slot = 22.5; and bypass spill bay = 46 ft). The weighting factor was:

$$W_{ij} = \frac{I_j}{2R_{ij}\mathrm{Tan}(\theta_j/2)}$$

where:

W_{ij} = weighted observation of fish (i) at location (j);

I_j = width of location (j);

θ_j = nominal beam width (degrees) of transducer at location (j);

R_{ij} = range of fish (i) from transducer at location (j).

Thus, fish detected closer to the transducer were weighted more (to represent more fish) than those detected further away. All subsequent analyses were based on these weighted fish detections.

A.3.4 Fish Passage Indices

An hourly estimate of relative fish passage (#/hr) at location (j) was computed as:

$$F_{jh} = \frac{\sum_{i=1}^{n_{jh}} W_{ijh}}{t_{jh}} \times 60$$

where:

F_{jh} = number of fish per hour at location (j) during hour (h)

W_{ijh} = weighted fish (i) at location (j) during hour (h)

t_{jh} = total number of minutes in hour (h) that location (j) was sampled

n_{jh} = total number of migrant detections at location (j) during hour (h).

APPENDIX B

STATISTICAL DESIGN FOR ESTIMATING TOTAL PROJECT BYPASS EFFICIENCY

STATISTICAL DESIGN FOR ESTIMATING TOTAL PROJECT BYPASS EFFICIENCY AT WELLS DAM IN 1990

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8 June 1989

INTRODUCTION

The objective of the 1990 bypass study at Wells Dam is to estimate total project bypass efficiency (B). Using hydroacoustic techniques, estimates of B will be obtained separately for the spring and summer outmigrations. Total project bypass efficiency is defined as

$$B = \frac{Y}{Y + X}$$

where

Y = total passage of smolt through bypass facilities,

X = total passage of smolt through turbine units.

However, direct enumeration of bypass (Y) and turbine (X) passage is not feasible. Instead, estimates of passage, $\hat{Y}$ and $\hat{X}$, must be used in estimating total project bypass efficiency where

$$\hat{B} = \frac{\hat{Y}}{\hat{Y} + \hat{X}} .$$

The sampling error associated with the estimate, $\hat{B}$, includes two sources of error, the hydroacoustic measurement error and the subsampling error associated with sampling only a fraction of the total spatial and temporal dimensions of the outmigration at Wells Dam. Proper statistical analysis must account for these sources in subsequent confidence interval construction.

The objective of the statistical design and analysis of total project bypass efficiency is to provide a consistent and statistically efficient estimator ($\hat{B}$) and expressions for its variance ($Var(\hat{B} \mid B)$) and estimated variance ($\hat{V}(\hat{B} \mid B)$) which can be subsequently used in designing the survey and confidence interval construction. The form of the estimator and its variance will depend on the sampling schemes used to estimate $\hat{Y}$ and $\hat{X}$ at Wells Dam. Unlike traditional ratio estimators (Cochran 1977), estimates of Y and X will be independent because separate hydroacoustic sampling schemes will be used in monitoring bypass and turbine passage.

Using hydroacoustic data collected at Wells Dam in 1988 and 1989, the magnitude of the anticipated sampling variance associated with $\hat{B}$ can be projected. The projected estimates of $Var(\hat{B} \mid B)$ will be used to evaluate alternative sampling schemes and levels of sampling effort at Wells Dam during the studies of total project bypass efficiency in 1990. Consequently, an important aspect of the statistical design research is the prediction of sampling precision and the selection of a cost-effective, logistically feasible and precise sampling design.

HYDROACOUSTIC MEASUREMENT ERROR AND SUBSAMPLING ERROR

The basis of proposed sampling designs is a stratified random sampling scheme at a turbine slot or bypass unit on an hour-by-hour basis. In other words, the basic stratum is a "unit hour." Within that hour, only a fraction of the time will be sampled by the hydroacoustic apparatus. For example, let the hour be divided into N equal time intervals of length $60/N$ minutes. Then, if the sampling scheme monitors n of these N intervals, an unbiased estimate of total passage during that unit hour (Z) is

$$Z = \frac{N}{n}\sum_{i=1}^{n} \hat{z}_i$$

where

$\hat{z}_i$ = number of fish estimated to have passage through the unit during the ith interval by the hydroacoustic apparatus,

provided $\hat{z}_i$ is an unbiased estimate of z_i, the actual fish passage in the ith interval.

The variance of $\hat{Z}$ will consist of both subsampling error and hydroacoustic measurement error. To see how these error sources contribute to the overall variance, we can use the total variance formula

$$
\begin{aligned}
Var(\hat{Z}) &= Var_{z_i}[E(\hat{Z} \mid z_i)] + E_{z_i}[Var(\hat{Z} \mid z_i)] \\
&= Var_{z_i}\left[E\left(\frac{N}{n}\sum_{i=1}^{n} \hat{z}_i \mid z_i\right)\right] + E_{z_i}\left[Var\left(\frac{N}{n}\sum_{i=1}^{n} \hat{z}_i \mid z_i\right)\right] \\
&= Var_{z_i}\left[\frac{N}{n}\sum_{i=1}^{n} z_i\right] + E_{z_i}\left[\frac{N^2}{n^2}\sum_{i=1}^{n} Var(\hat{z}_i \mid z_i)\right] \\
&= N^2\left(1-\frac{n}{N}\right)\frac{S^2_{z_i}}{n} + \frac{N}{n}\sum_{i=1}^{N} Var(\hat{z}_i \mid z_i) \\
Var(\hat{Z}) &= \frac{N^2}{n}\left(1-\frac{n}{N}\right)S^2_{z_i} + \frac{N^2}{n}\overline{Var(\hat{z}_i \mid z_i)} \qquad (1)
\end{aligned}
$$

where

$$S^2_{z_i} = \frac{\sum_{i=1}^{N}(z_i - \bar{z})^2}{N-1} .$$

In a sample survey of fish passage, the $Var(\hat{Z})$ would be estimated by

$$\hat{Var}(\hat{Z}) = \frac{N^2}{n}\left(1-\frac{n}{N}\right)s^2_{\hat{z}_i}$$

where

$$s^2_{\hat{z}_i} = \frac{\sum_{i=1}^{n}\left(z_i - \hat{\bar{z}}\right)^2}{(n-1)} .$$

This estimate of the variance has the expected value

$$
\begin{aligned}
E\left[\frac{N^2}{n}\left(1-\frac{n}{N}\right)s^2_{\hat{z}_i}\right] &= \frac{N^2}{n}\left(1-\frac{n}{N}\right)E\left(s^2_{\hat{z}_i}\right) \\
&= \frac{N^2}{n}\left(1-\frac{n}{N}\right)S^2_{z_i} + \frac{N^2}{n}\left(1-\frac{n}{N}\right)\overline{Var(\hat{z}_i \mid z_i)} \cdot \qquad (2)
\end{aligned}
$$

Hence, the empirical variance, $s^2_{\hat{z}_i}$, implicitly incorporates both the subsampling error and the hydroacoustic measurement error. Comparison of variance formulas (1) and (2) shows, however, the variance estimate (2) is negatively biased. The second term in formula (2) has the additional

factor of $\left(1-\frac{n}{N}\right)$ which variance formula (1) does not possess. Typically, it is believed that the measurement error ($Var(\hat{z}_i \mid z_i)$) is small relative to $S^2_{z_i}$, so the bias will be small. Furthermore, the bias is proportional to $\left(1-\frac{n}{N}\right)$, which for the Wells Dam study will be .80, close to the required 1.0 in formula (1). A conservative but always valid estimator of the true variance can be obtained by ignoring the finite population correction (i.e., $\left(1-\frac{n}{N}\right)$).

The conclusion of these computations is that we can avoid explicit measurement of hydroacoustic measurement error and still incorporate that error source in the overall variance of $\hat{B}$ and in confidence interval construction of B.

PROPOSED SAMPLING DESIGN

The sampling design has two major components which need to be considered; these are the spatial sampling of the bypass and turbine units at Wells Dam and the temporal sampling of days during the outmigration. Independent estimates of the spring bypass efficiency ($\hat{B}$) and summer bypass efficiency ($\hat{B}$) will be derived during the 1990 sampling program. The sampling designs will be the same for both seasons. Outlined below are general descriptions of the proposed sampling schemes and the statistical designs for the estimates of total project bypass efficiency (B).

Wells Dam Sampling Scheme

A. Temporal Sampling

- Sampling will be conducted every day during the designated spring and summer study periods.
- The spring period will last from 20-30 days. The period will begin shortly after the Winthrop chinook releases and will sample varying proportions of chinook, sockeye and steelhead.

- The summer period will last from 10-20 days. The sampling will begin when subyearling chinook occur in reasonable numbers in weekly fyke net catches.
- Sampling will occur 24 hours each day.
- Each "unit hour" will be sampled for a total of 12 minutes per hour.
- Within a "unit hour," a minimum of two samples will be taken. Prior data will be used to determine the benefits of allocating sampling effort, as

    a. 2 6-minute samples,

    b. 3 4-minute samples,

    c. 4 3-minute samples,

    d. 6 2-minute samples.

- Within a "unit hour," systematic sampling will be conducted. The choice of the systematic sampling sequence at a unit will be randomly assigned to each unit at the beginning of spring and summer seasons.

B. Spatial Sampling

1. Bypass Units

    - Five of the five bypass units at Wells Dam will be sampled.

2. Turbine Units

    - Ten of the ten turbine units will be sampled.
    - At each turbine unit, two of three turbine slots will be sampled randomly. The choice of turbine slots will remain constant during a season.

STATISTICAL SAMPLING DESIGN

The proposed sampling design at Wells Dam can be characterized by the separate designs for bypass units and turbine units. The results of the separate sampling schemes are then combined to provide the estimate of total project bypass efficiency (B). Below are formal descriptions of the estimators and variances for each sampling scheme.

Bypass Sampling Design

Sampling every day of the study period simplifies the statistical design and eliminates a potentially large error source (i.e., day-to-day variation) in estimating bypass passage (Y). Furthermore, by sampling at each bypass unit, the bypass-to-bypass variation is also eliminated. The resulting sampling design at the bypass units is a single stage sample using stratified sampling of "unit hours" across the dam and through time. Within a "unit hour," a systematic sample will be collected during the hour, and repeated each hour of the survey. In constructing the estimator, variance and estimated variance of the estimator, sampling will be assumed to be stratified random sampling. The consequences of assuming random sampling will be assessed using Monte Carlo simulations.

Define the following terms:

y_{ijkg} = number of fish detected in the gth sampling unit ($g = 1, 2, \ldots, l_{ijk}$) in the kth hour ($k = 1, 2, \ldots, 24$) at the jth bypass ($j = 1, 2, \ldots, 5$) on the ith day ($i = 1, 2, \ldots, D$),

L_{ijk} = number of sampling units in the kth hour ($k = 1, 2, \ldots, 24$) at the jth bypass ($j = 1, 2, \ldots, 5$) on the ith day ($i = 1, 2, \ldots, D$),

l_{ijk} = number of sampling units sampled in the kth hour ($k = 1, 2, \ldots, 24$) at the jth bypass ($j = 1, 2, \ldots, 5$) on the ith day ($i = 1, 2, \ldots, D$).

Then the estimate of total bypass passage (Y) is

$$\hat{Y} = \sum_{i=1}^{D}\sum_{j=1}^{5}\sum_{k=1}^{24}\sum_{g=1}^{l_{ijk}}\left[\frac{L_{ijk}}{l_{ijk}}y_{ijkg}\right] . \tag{3}$$

The variance of $\hat{Y}$ follows directly from stratified random sampling (Appendix A), where

$$Var(\hat{Y}\,|\,Y) = \sum_{i=1}^{D}\sum_{j=1}^{5}\sum_{k=1}^{24}\left[L_{ijk}^2\left(1-\frac{l_{ijk}}{L_{ijk}}\right)\frac{S_{y_{ijk}}^2}{l_{ijk}}\right] \tag{4}$$

and where

$$S_{y_{ijk}}^2 = \frac{\sum_{g=1}^{l_{ijk}}(y_{ijkg}-\overline{y_{ijk}})^2}{(L_{ijk}-1)} .$$

Note, the proposed sampling fraction within a "unit hour" is

$$\frac{l_{ijk}}{L_{ijk}} = \frac{12}{60} = .20 .$$

Turbine Sampling Design

The estimate of total turbine passage is based on a two-stage sampling scheme. The first stage of sampling is the selection of two of three turbine slots in each turbine unit. The second stage of the sampling design is the stratified random sampling of each "unit hour." As was the case in estimating bypass passage, in practice, a systematic sample within the "unit hour" will be used in estimating total turbine passage. The anticipated consequence of using a systematic sample in conjunction with a variance formula based on random sampling is to overestimate the true variance.

Define the following terms, where:

x_{ijklg} = number of fish detected in the gth sampling unit ($g = 1, 2, \ldots, h_{ijkl}$) in the lth hour ($l = 1, 2, \ldots, 24$) during the kth day ($k = 1, 2, \ldots, D$) in the jth slot ($j = 1, 2$) of the ith turbine unit ($i = 1, 2, \ldots, 10$),

H_{ijkl} = number of sampling units in the lth hour ($l = 1, 2, \ldots, 24$) of the kth day ($k = 1, 2, \ldots, D$) in the jth slot ($j = 1, 2$) of the ith turbine unit ($i = 1, 2, \ldots, 10$),

h_{ijkl} = number of sampling unit sampled in the lth hour ($l = 1, 2, \ldots, 24$) of the kth day ($k = 1, 2, \ldots, D$) in the jth slot ($j = 1, 2$) of the ith turbine unit ($i = 1, 2, \ldots, 10$).

Then the estimate of total turbine passage is

$$\hat{X} = \sum_{i=1}^{10}\left[\sum_{j=1}^{2}\frac{3}{2}\left[\sum_{k=1}^{D}\sum_{l=1}^{24}\sum_{g=1}^{h_{ijkl}}\left[\frac{H_{ijkl}}{h_{ijkl}}x_{ijklg}\right]\right]\right] . \tag{5}$$

Since $\hat{X}$ is based on two-stage sampling, the variance of $\hat{X}$ will consist of two variance components. The variance of $\hat{X}$ can be expressed as (Appendix B)

$$Var(\hat{X} \mid X) = \frac{3}{2}\sum_{i=1}^{10} S^2_{X_{ij}} + \frac{3}{2}\sum_{i=1}^{10}\sum_{j=1}^{3}\sum_{k=1}^{D}\sum_{l=1}^{24}\left[H^2_{ijkl}\left(1 - \frac{h_{ijkl}}{H_{ijkl}}\right)S^2_{X_{ijkl}}\right] \tag{6}$$

where

$$S^2_{X_{ij}} = \frac{\sum_{j=1}^{3}(X_{ij} - \overline{X}_i)^2}{(3-1)}$$

and where

$$S^2_{X_{ijkl}} = \frac{\sum_{g=1}^{H_{ijkl}}(x_{ijklg} - \overline{x}_{ijkl})^2}{(H_{ijkl} - 1)} .$$

Overall Sampling Design

Using the delta method (Appendix C), the overall variance of the estimate of total project bypass efficiency ($\hat{B}$) can be expressed as a function of the variances (4) and (6). The variance of $\hat{B}$ is

$$Var(\hat{B} \mid B) = B^2(1-B)^2\left[\frac{Var(\hat{Y} \mid Y)}{Y^2} + \frac{Var(\hat{X} \mid X)}{X^2}\right] \tag{7}$$

or

$$Var(\hat{B} \mid B) = B^2(1-B)^2[CV(\hat{Y})^2 + CV(\hat{X})^2] \tag{8}$$

where CV denotes the coefficient of variation. Unlike variances for typical ratio estimators, the covariance between $\hat{X}$ and $\hat{Y}$ is not incorporated in the variance of $\hat{B}$. The reason the covariance of $\hat{X}$ and $\hat{Y}$ does not enter into the variance of $\hat{B}$ is that independent sampling schemes are used to estimate $\hat{X}$ and $\hat{Y}$ and all D of D days within a bypass study are sampled.

PRECISION OF THE BYPASS STUDY

The precision of the estimate of total project bypass efficiency ($\hat{B}$) will be defined as

$$P(|\hat{B} - B| < \epsilon) = 1 - \alpha \quad . \tag{9}$$

In other words, we want the absolute difference between the estimate ($\hat{B}$) and true bypass efficiency (B) to be less than ϵ, with probability $1-\alpha$. For example, letting $\epsilon = .05$ and $\alpha = .10$, specifies a precision of

$$P(|\hat{B} - B| < .05) = .90$$

where we want the absolute error in estimating bypass efficiency to be less than 5%, 90% of the time, with the proposed sampling design. Assuming $\hat{B}$ to be approximately normally distributed, the anticipated sampling error in the Wells bypass study can be predicted by the formula (Appendix D)

$$\epsilon = Z_{1-\frac{\alpha}{2}} B(1-B)\sqrt{CV(\hat{Y})^2 + CV(\hat{X})^2} \quad . \tag{10}$$

Hence, we can investigate the precision of $\hat{B}$ by determining the precision of the proposed bypass and turbine passage estimates. Data from the 1988 and 1989 hydroacoustic studies at Wells Dam will be used to evaluate the precision of the anticipated design for 1990.

FUTURE DESIGN RESEARCH

Two aspects of the research on the study design have yet to be performed. The first aspect is the analysis of the 1988, 1989 data for purposes of predicting the precision of the 1990 total project bypass efficiency estimate. Among the outcomes of this investigation will be the determination of whether 12 min./hr. is adequate sampling within a "unit hour" and how to allocate that sampling time within the hour (e.g., two 6-min. samples versus six 2-min. samples).

The second aspect of the statistical design is the identification of the most appropriate means of confidence interval estimation of B. It is not always sufficient simply to have a point estimate, $\hat{B}$, and its variance estimate, $V\hat{a}r(\hat{B} \mid B)$, for valid and efficient confidence interval estimation. Monte Carlo studies will be performed to assure the confidence interval estimator has nominal coverage with minimum width. Another aspect of the Monte Carlo studies is to assess the effect of using systematic sampling within a "unit hour" and computing the variance based on the formula for random sampling. Wolter (1984) suggests the systematic sampling will overestimate the true variance, making the resulting confidence interval estimation conservative yet valid.

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Appendix A

Variance of Total Bypass Passage

The single stage sampling design used in estimating total bypass passage constitutes stratified random sampling (in practice systematic). The variance of $\hat{Y}$ follows directly, where

$$Var(\hat{Y}\,|\,Y) = Var\left[\sum_{i=1}^{D}\sum_{j=1}^{5}\sum_{k=1}^{24}\sum_{g=1}^{l_{ijk}}\left[\frac{L_{ijk}}{l_{ijk}}y_{ijkg}\right]\right]$$

$$Var(\hat{Y}\,|\,Y) = \sum_{i=1}^{D}\sum_{j=1}^{5}\sum_{k=1}^{24} Var[L_{ijk}\overline{y_{ijk}}]$$

$$Var(\hat{Y}\,|\,Y) = \sum_{i=1}^{D}\sum_{j=1}^{5}\sum_{k=1}^{24}\left[L_{ijk}^{2}\left(1-\frac{l_{ijk}}{L_{ijk}}\right)\frac{S_{y_{ijk}}^{2}}{l_{ijk}}\right]$$

and where

$$S_{y_{ijk}}^{2} = \frac{\sum_{g=1}^{L_{ijk}}(y_{ijkg}-\overline{y_{ijk}})^{2}}{(L_{ijk}-1)} \quad .$$

Appendix B

Variance of Total Turbine Passage

The estimate of total turbine passage is obtained using two-stage sampling, the first stage, the selection of two of three turbine slots per turbine unit, the second stage, the sampling within a "unit hour." Similarly, the variance of $\hat{X}$ can be found in stages

$$Var(\hat{X} \mid X) = Var_{S_1}[E_{S_2}(\hat{X} \mid S_1)] + E_{S_1}[Var_{S_2}(\hat{X} \mid S_1)] \qquad (B1)$$

and where S_1 denotes the stratified random sampling of slots within a turbine unit, and S_2 denotes the stratified random sampling within a "unit hour."

Considering the first term of the variance

$$Var_{S_1}[E_{S_2}(\hat{X} \mid S_1)] = Var_{S_1}\left[E_{S_2}\left[\sum_{i=1}^{10}\sum_{j=1}^{2}\frac{3}{2}\sum_{k=1}^{D}\sum_{l=1}^{24}\left(\sum_{g=1}^{h_{ijk}}\frac{x_{ijklg}}{h_{ijkl}}H_{ijkl}\right)\middle| S_1\right]\right]$$

$$= Var_{S_2}\left[\sum_{i=1}^{10}\sum_{j=1}^{2}\frac{3}{2}X_{ij}\right]$$

$$Var_{S_1}[E_{S_2}(\hat{X} \mid S_1)] = \sum_{i=1}^{10}\frac{9}{2}\left(1-\frac{2}{3}\right)S^2_{X_{ij}} = \frac{3}{2}\sum_{i=1}^{10}S^2_{X_{ij}} \qquad (B2)$$

where

$$S^2_{X_{ij}} = \frac{\sum_{j=1}^{3}(X_{ij}-\overline{X}_i)^2}{(3-1)} .$$

The second term of the variance is evaluated as

$$
\begin{aligned}
E_{S_1}[Var_{S_2}(\hat{X} \mid S_1)] &= E_{S_1}\left[Var_{S_2}\left[\sum_{i=1}^{10}\sum_{j=1}^{2}\frac{3}{2}\sum_{k=1}^{D}\sum_{l=1}^{24}\left(\sum_{g=1}^{h_{ijkl}}\frac{x_{ijklg}}{h_{ijkl}}H_{ijkl}\right)\middle| S_1\right]\right] \\
&= E_{S_1}\left[\frac{9}{4}\sum_{i=1}^{10}\sum_{j=1}^{2}\sum_{k=1}^{D}\sum_{l=1}^{24}\left(\frac{H_{ijkl}^2}{h_{ijkl}}\left(1-\frac{h_{ijkl}}{H_{ijkl}}\right)S_{x_{ijkl}}^2\right)\right] \\
&= \frac{9}{4}\sum_{i=1}^{10}\frac{2}{3}\sum_{j=1}^{3}\sum_{k=1}^{D}\sum_{l=1}^{24}\left(\frac{H_{ijkl}^2}{h_{ijkl}}\left(1-\frac{h_{ijkl}}{H_{ijkl}}\right)S_{x_{ijkl}}^2\right) \\
&= \frac{3}{2}\sum_{i=1}^{10}\sum_{j=1}^{3}\sum_{k=1}^{D}\sum_{l=1}^{24}\left(\frac{H_{ijkl}^2}{h_{ijkl}}\left(1-\frac{h_{ijkl}}{H_{ijkl}}\right)S_{x_{ijkl}}^2\right) \qquad (B3)
\end{aligned}
$$

where

$$
S_{x_{ijkl}}^2 = \frac{\sum_{g=1}^{H_{ijkl}}(x_{ijklg}-\bar{x}_{ijkl})^2}{(H_{ijkl}-1)}
$$

The variance of $\hat{X}$ given by (B1) is therefore the sum of (B2) and (B3), where

$$
Var(\hat{X} \mid X) = \frac{3}{2}\sum_{i=1}^{10} S_{X_{ij}}^2 + \frac{3}{2}\sum_{i=1}^{10}\sum_{j=1}^{3}\sum_{k=1}^{D}\sum_{l=1}^{24}\left[\frac{H_{ijkl}^2}{h_{ijkl}}\left(1-\frac{h_{ijkl}}{H_{ijkl}}\right)S_{x_{ijkl}}^2\right]
$$

Appendix C

Variance of the Estimate of Total Project Bypass Efficiency

Using the delta method, the variance of $\hat{B}$ is computed to be

$$Var\left(\frac{\hat{Y}}{\hat{Y}+\hat{X}}\right) \doteq Var(\hat{Y})\left(\frac{X^2}{(X+Y)^4)}\right)+Var(\hat{X})\left(\frac{Y^2}{(X+Y)^4}\right)-2Cov(\hat{X},\hat{Y})\left(\frac{XY}{(X+Y)^4}\right) \cdot \quad (C1)$$

However, the covariance term is shown to be zero by computing it in stages, where

$$Cov(\hat{X},\hat{Y}) = E_{S_1}[Cov_{S_2}(\hat{X},\hat{Y}\mid S_1)]+Cov_{S_1}[E_{S_2}(\hat{X}\mid S_1),E_{S_2}(\hat{Y}\mid S_1)]$$

and where S_1 denotes sampling of days during the study, and S_2 denotes sampling within a day. Evaluating the covariance

$$Cov(\hat{X},\hat{Y}) = E_{S_1}[0]+Cov_{S_1}\left[\sum_{k=1}^{D} X_k,\sum_{k=1}^{D} Y_k\right]$$

$$Cov(\hat{X},\hat{Y}) = \frac{D^2}{D}\left(1-\frac{D}{D}\right)Cov(X_k,Y_k) = 0$$

from Hansen, Hurwitz and Madow (1953: eq (1.15), page 148, Vol. 2).

The resulting variance (C1) can then be expressed as

$$Var(\hat{B}\mid B) = B^2(1-B)^2\left[\frac{Var(\hat{Y})}{Y^2}+\frac{Var(\hat{X})}{X^2}\right]$$

or

$$Var(\hat{B}\mid B) = B^2(1-B)^2[CV(\hat{Y})^2+CV(\hat{X})] \cdot$$

Appendix D

Precision of Total Project Bypass Efficiency ($\hat{B}$)

Defining precision in terms of the absolute deviation between the estimate ($\hat{B}$) and the true value of total project bypass efficiency (B), we have the probability expression

$$P(|\hat{B}-B|<\epsilon) = 1-\alpha$$

$$P(-\epsilon<\hat{B}-B<\epsilon) = 1-\alpha$$

$$P\left(\frac{-\epsilon}{\sqrt{Var(\hat{B})}}<\frac{\hat{B}-B}{\sqrt{Var(\hat{B})}}<\frac{\epsilon}{\sqrt{Var(\hat{B})}}\right) = 1-\alpha \ .$$

Assuming approximate normality,

$$P\left(\frac{-\epsilon}{\sqrt{Var(\hat{B})}}<Z<\frac{\epsilon}{\sqrt{Var(\hat{B})}}\right) = 1-\alpha$$

$$P\left(Z<\frac{-\epsilon}{\sqrt{Var(\hat{B})}}\right) = \frac{\alpha}{2}$$

$$\Phi\left(\frac{-\epsilon}{\sqrt{Var(\hat{B})}}\right) = \frac{\alpha}{2}$$

where Φ denotes the cumulative normal distribution. The error in estimation (ϵ) for a particular probability ($1-\alpha$) of coverage (e.g., 90% implies $\alpha = .10$) can be solved as a function of the variance of $\hat{B}$ and $1-\alpha$ where

$$\frac{-\epsilon}{\sqrt{Var(\hat{B})}} = Z_{\frac{\alpha}{2}}$$

$$\epsilon = Z_{1-\frac{\alpha}{2}} B(1-B)\sqrt{CV(\hat{Y})^2+CV(\hat{X})^2}$$

and can be used in evaluating the anticipated performance of the sampling program.

APPENDIX C

HORIZONTAL AND DIEL DISTRIBUTION RESULTS

APPENDIX C. Horizontal & Diel Distribution Results

C.1 Horizontal Distributions

The horizontal distribution data from the bypass slots during the spring study (April 19 to May 18) showed greater passage rates towards the west end of the dam (Figure C1). The lowest passage rate occurred at 7C. The highest rate occurred at 1C, followed by 3C, 5C, and 9C. In the middle sections of the dam, daytime passage rates were higher than nightime rates. At the east and west ends of the dam nighttime passage rates were higher.

Turbine horizontal distribution data from the spring also showed that passage rates towards the west end of the dam were generally higher (Figure C2). The highest rates occurred at Units 1 and 10. The lowest rate occurred at Unit 8. The "C"-slots showed a generally lower nighttime passage rate. Overall passage rates were much lower in the turbine intakes than in the bypass slots.

The bypass slot horizontal distribution data for the summer study (July 9 to July 24) also showed highest passage rates occurring towards the west end of the dam (Figure C3). The highest rate occurred at slot 5C, followed by 3C, 1C, and 9C. As in the spring, 7C had the lowest passage rate. The west end locations (1C, 5C, 7C) showed higher daytime passage rates. 7C and 9C had slightly higher nighttime passage rates.

As in the spring, the turbine horizontal distribution data for summer showed highest passage rates at Units 1 and 10 (Figures C2 and C4). As was the case with the bypass slot data, Unit 5 had high daytime in-turbine passage rates. Unit 2 had the next highest passage rate. The "A" and "B" slots showed generally higher daytime passage rates. Turbine passage rates were lower overall than those for the bypass slot locations.

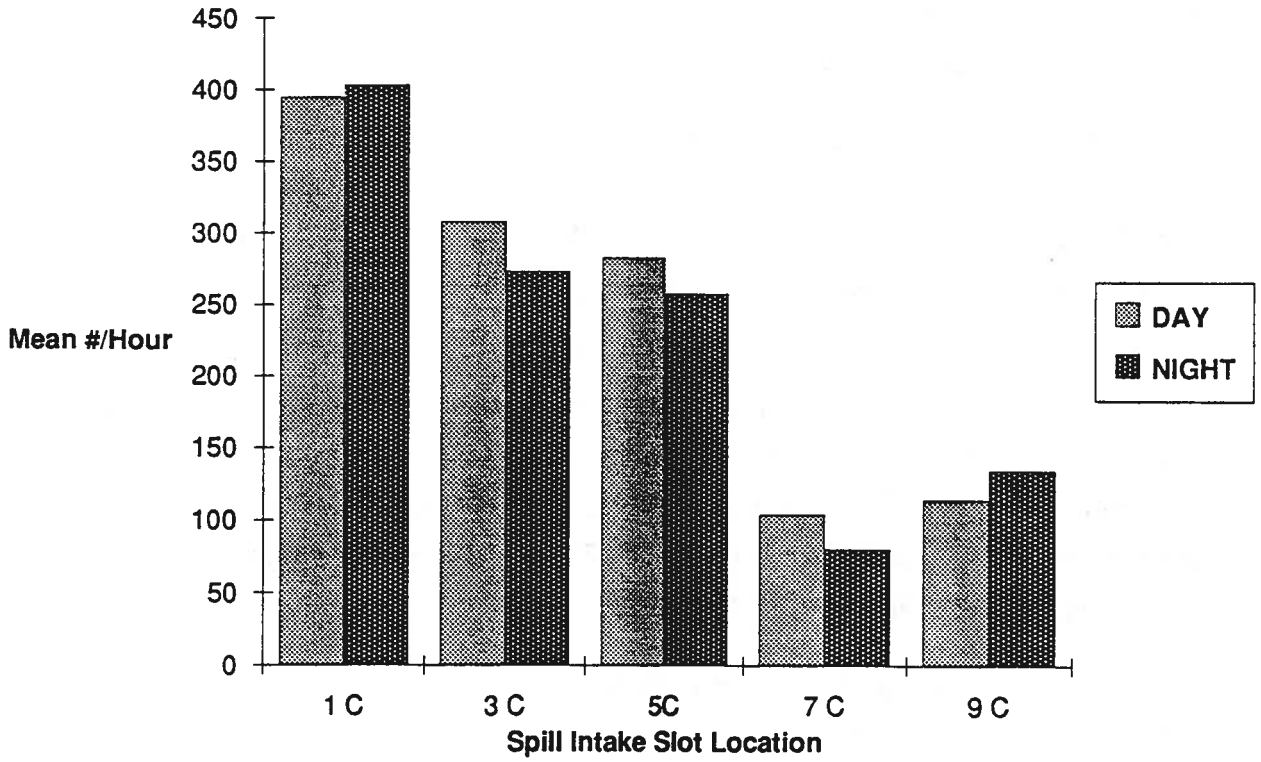

Figure C1. Horizontal distribution of slot passage indices (mean#/1hr/location) for day and night separately at Wells Dam between April 19 and May 18, 1990.

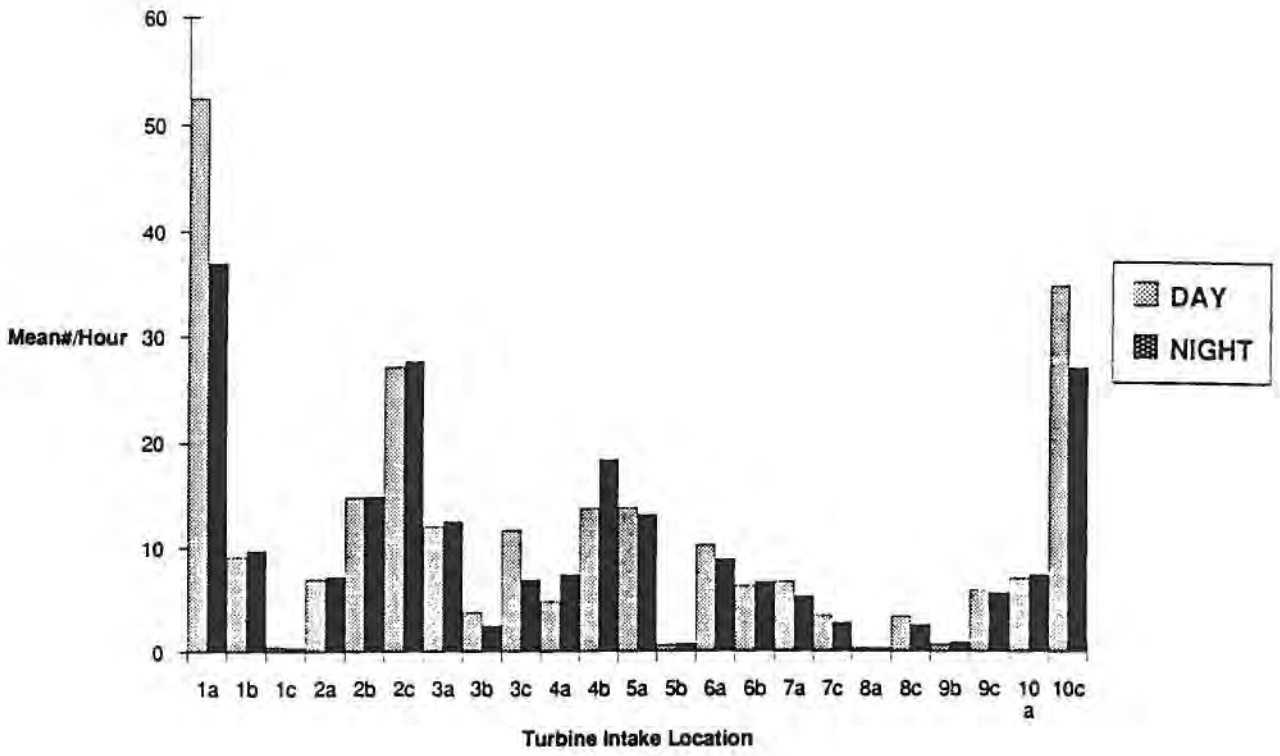

Figure C2. Horizontal distribution of turbine passage indices (mean#/1hr/location) for day and night separately at Wells Dam between April 19 and May 18, 1990.

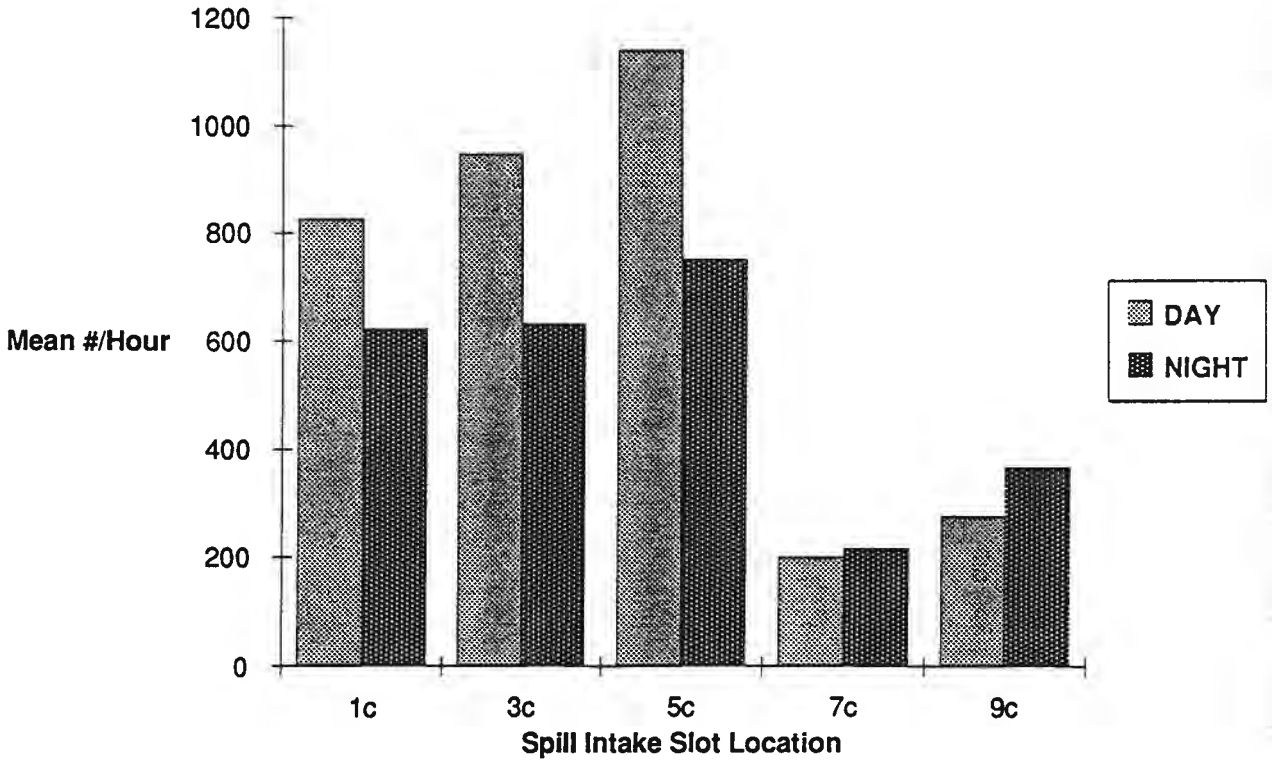

Figure C3. Horizontal distribution of slot passage indices (mean #/1hr/location) for day and night separately at Wells Dam between July 9 and July 19, 1990.

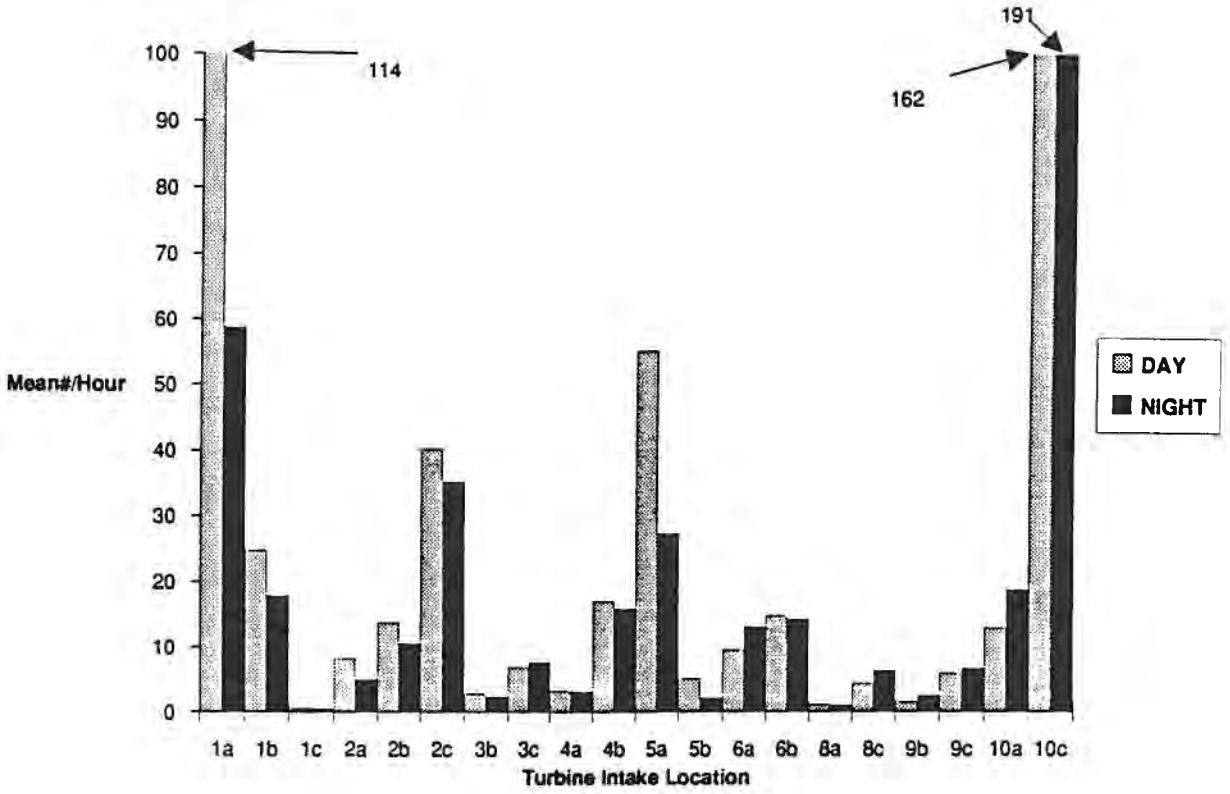

Figure C4. Horizontal distribution of turbine passage indices (mean #/1hr/location) for day and night separately at Wells Dam between July 9 and July 24, 1990.

C.2 Diel Distributions

The diel distribution data for the bypass slots during spring (April 19 to May 18) showed that variable high passage rates occurred during daylight hours (Figure C5). Passage rates declined during the late evening hours (1700 h - 1900 h) and then rose to the highest passage rate, which occurred at 2200 h. Passage rates then declined to the lowest rate at 0100 h. Passage rates were lowest during the early morning hours (0100 h - 0700 h).

The turbine intake diel distribution data also showed generally higher passage rates during the day (Figure C6). The lowest passage rate occurred at 0200 h. There was then a general increase in passage rates until the peak occurred at 1100 h. Passage rates then declined but remained relatively high until 1600 h. As in the bypass slots, passage rates were generally lower between 1700 h and 1900 h.

The summer (July 9 to July 24) bypass slot data again showed highest passage rates during daylight hours (Figure C7). Passage was lowest at 0300 h. There was then a gradual rise until peak passage occurred at 1000 h. Passage rates remained relatively high until 1800 h. The rates then declined until 2200 h.

As in the bypass slots, passage rates for the turbine locations were highest during daylight hours (Figure C8). The highest rate occurred at 1200 h. The lowest rate occurred at 0200 h. The passage rates between 1400 h and 0600 h were relatively constant, with another slight peak at 2200 h. Again, passage rates in turbine were far lower than those in the bypass slots.

For both the diel and horizontal distributions, overall passage rates were higher during the summer study period than during the spring study.

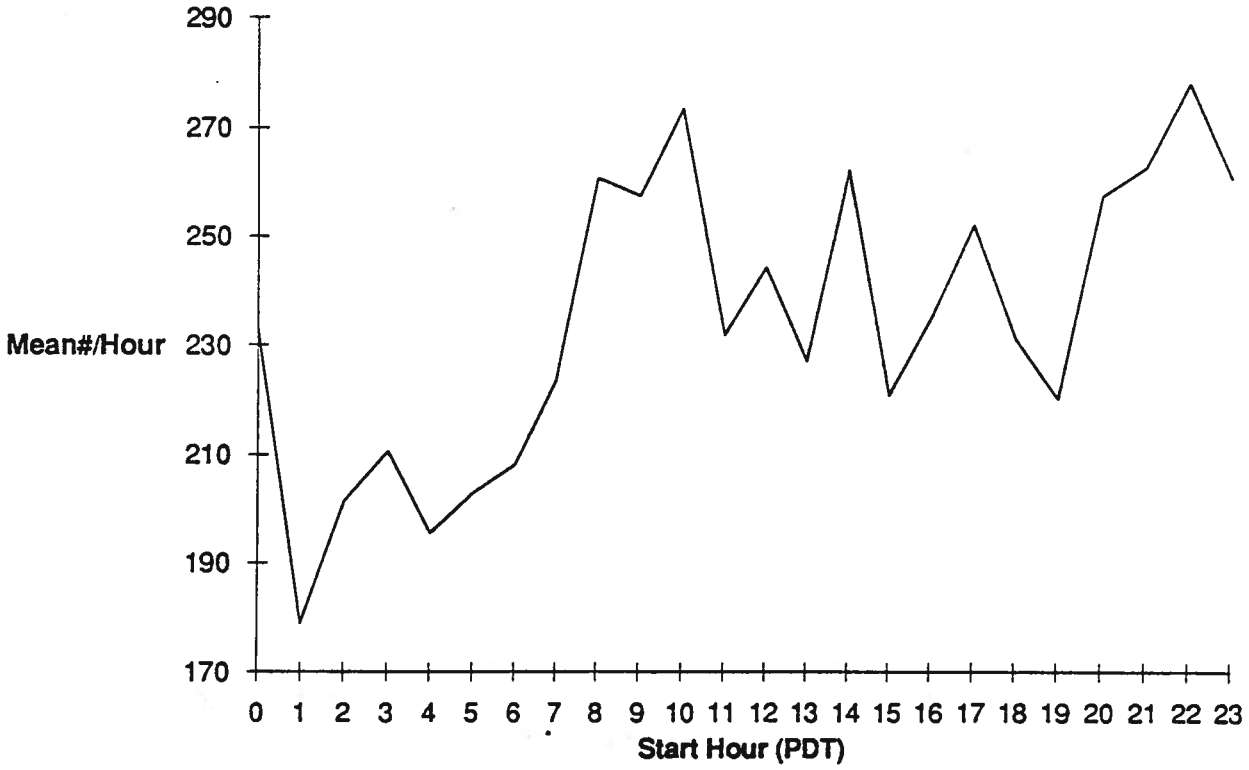

Figure C5. Diel distribution of slot passage indices (mean #/1hr/location) at Wells Dam between April 19 and May 18, 1990.

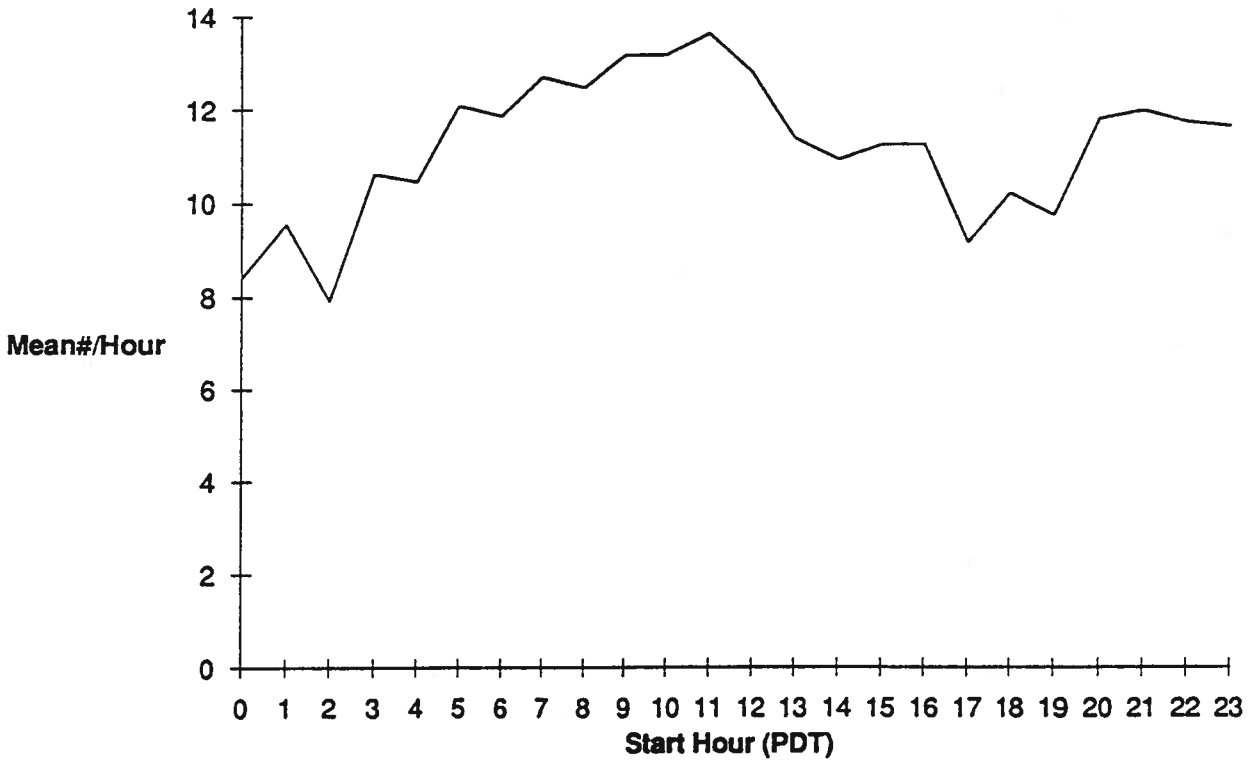

Figure C6. Diel distribution of turbine passage indices (mean #/1hr/location) at Wells Dam between April 19 and May 18, 1990.

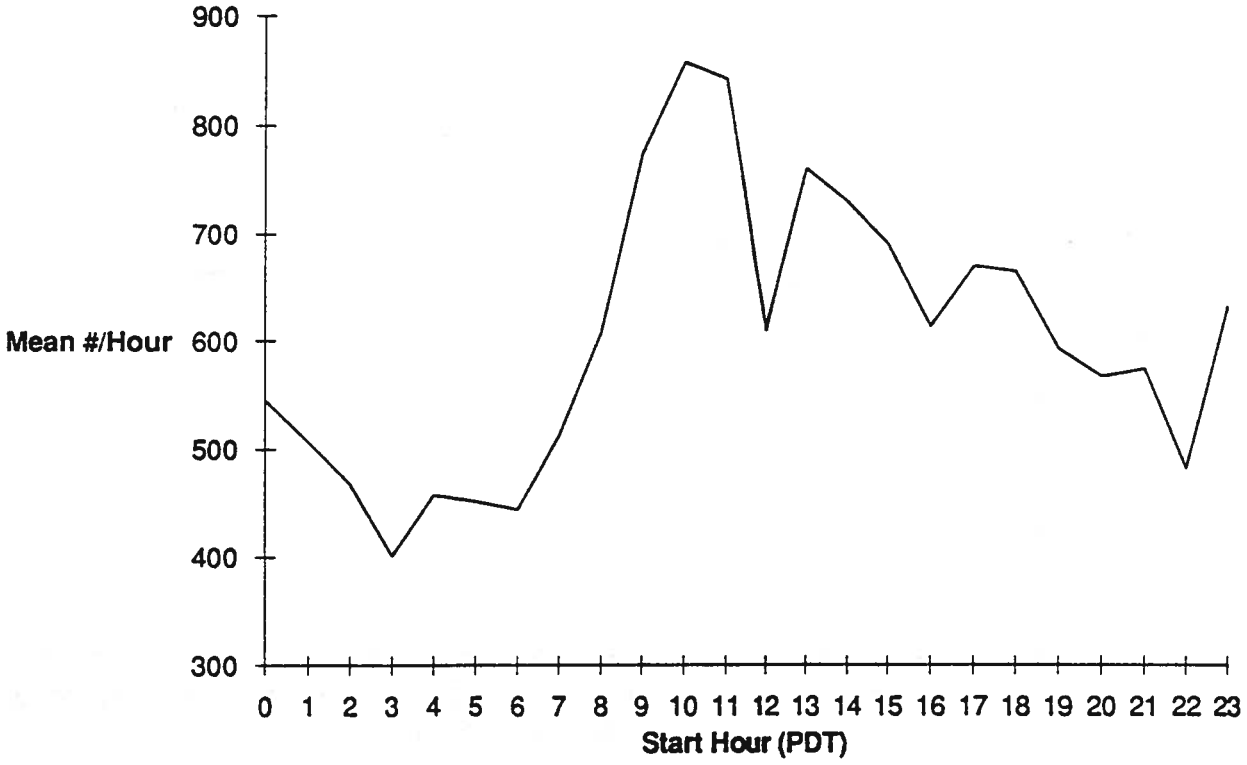

Figure C7. Diel distribution of slot passage indices (mean #/1hr/location) at Wells Dam between July 9 and July 19, 1990.

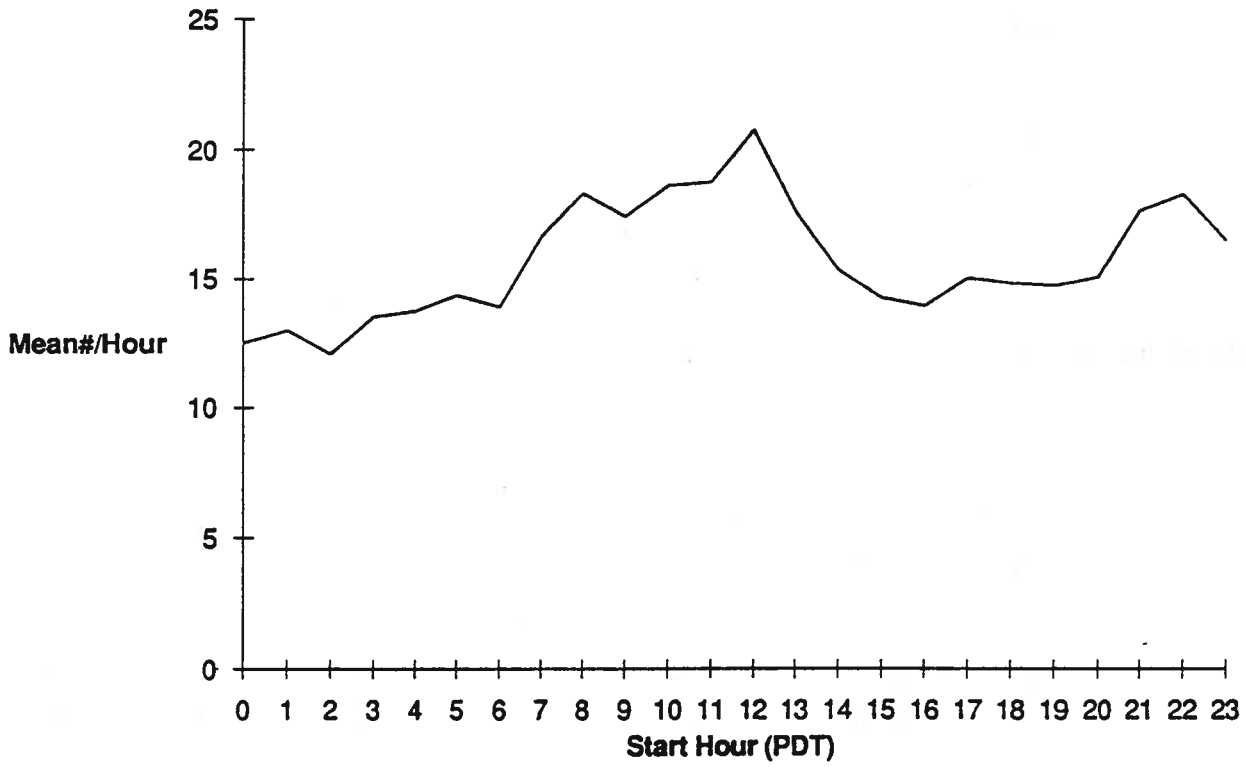

Figure C8. Diel distribution of turbine passage indices (mean #/1hr/location) at Wells Dam between July 9 and July 24, 1990.

APPENDIX D

FISH PASSAGE DATA

APPENDIX D. Fish Passage Data

WELLS DAM FOREBAY HYDROACOUSTIC INDEX
1990

		MEAN #/8 HR/LOCATION			
	DATE	DAY	NIGHT	COMBINED	
April	7	417	217	634	
	8	NO DATA COLLECTED			
	9	122	116	239	
	10	122	217	339	
	11	178	192	370	
	12	109	126	236	
	13	49	97	146	
	14	176	108	283	
	15	448	512	960	
	16	379	807	1186	
	17	324	178	502	
	18	173	378	551	
		BYPASS EVALUATION			
May	19	240	605	846	
	20	138	989	1128	
	21	399	278	676	
	22	99	534	633	
	23	218	230	449	
	24	146	390	536	
	25	151	391	542	
	26	41	758	799	
	27	152	538	690	
	28	200	466	666	
	29	160	117	277	
	30	160	249	410	
	31	141	291	432	
June	1 *	107	163	270	*
	2 *	104	47	151	*NO T2 DATA COLLECTED
	3 *	85	57	140	*
	4	55	105	160	
	5	61	79	140	
	6	51	39	90	
	7	36	29	65	
	8	80	106	185	
	9	71	69	140	
	10	26	53	79	
	11	78	77	155	
	12	68	97	164	
	13	47	104	148	
	14	102	79	181	
	15	109	199	309	
	16	101	186	287	
	17	119	333	452	
	18	127	147	273	
	19	131	135	226	
	20	144	328	472	
	21	172	705	876	
	22	47	293	340	
	23	63	348	412	
	24	263	173	436	
	25	91	357	448	
	26	138	251	389	
	27	118	174	292	
	28	262	163	425	
	29	242	494	736	
	30	254	346	599	

WELLS DAM FOREBAY HYDROACOUSTIC INDEX
1990

		MEAN #/8 HR/LOCATION		
	DATE	DAY	NIGHT	COMBINED
July	1	288	363	651
	2	255	488	703
	3	146	383	529
	4	285	468	752
	5	428	684	1112
	6	423	828	1251
	7	177	638	815
	8	299	684	983
		BYPASS EVALUATION		
	25	735	478	1213
	26	880	372	1252
	27	782	608	1390
	28	1141	536	1677
	29	674	775	1449
	30	1376	756	2132
	31	1153	684	1837
August	1	1731	666	2397
	2	1033	748	1781
	3	1599	1312	2911
	4	854	755	1609
	5	1397	571	1968
	6	1451	910	2361
	7	1358	1026	2384
	8	1072	1168	2240
	9	1092	912	2004
	10	1033	1110	2143
	11	867	874	1741
	12	334	843	1177
	13	862	1148	2010
	14	1432	813	2245
	15	1035	771	1806
	16	994	730	1724
	17	744	239	982
	18	217	326	543
	19	385	330	715
	20	407	418	825
	21	464	142	606
	22	491	259	750
	23	142	330	472
	24	154	175	322
	25	132	72	204
	26	62	104	166
	27	162	123	285
	28	174	136	310
	29	146	113	259
	30	120	56	176
	31	56	48	104

Wells 1990 Study Periods Run Timing

SPRING

	DATE	Mean #/8hr/location
	19	2309.153
	20	2138.762
	21	952.743
April	22	1538.939
	23	3433.595
	24	1472.464
	25	2816.421
	26	533.548
	27	946.636
	28	610.704
	29	404.914
	30	718.377
	1	1273.352
	2	1791.739
	3	1257.21
	4	2569.183
	5	4463.141
	6	1870.937
	7	7597.808
May	8	1420.551
	9	2430.4
	10	1300.336
	11	1981.585
	12	1771.326
	13	1038.334
	14	1563.674
	15	1906.176
	16	1441.71
	17	1443.143
	18	1655.434

SUMMER

	DATE	Mean #/8hr/location
July	9	3605.891
	10	3350.332
	11	3432.103
	12	4725.418
	13	6828.106
	14	5117.422
	15	5565.642
	16	6102.154
	17	5351.98
	18	6833.601
	19	3454.016
	20	1093.029

WELLS 1990 BYPASS EFFICIENCY DATA

	Date	Ratio var.	Upper C.I.	Ratio	Lower C. I.
April	19	0.00172	0.59972	0.52606	0.46145
	20	0.00118	0.69370	0.63425	0.57989
	21	0.00216	0.63835	0.55552	0.48343
	22	0.00180	0.85387	0.78062	0.71366
	23	0.00189	0.88415	0.80894	0.74013
	24	0.00419	0.79547	0.67845	0.57864
	25	0.00016	1.00649	0.98561	0.96515
	26	0.00231	0.80976	0.75272	0.65040
	27	0.00276	0.85340	0.74305	0.66090
	28	0.00108	0.78597	0.72961	0.67729
	29	0.00161	0.74010	0.67034	0.60716
	30	0.00069	0.85946	0.81512	0.77307
May	1	0.00230	0.86852	0.78501	0.70953
	2	0.00181	0.87910	0.80574	0.73849
	3	0.00227	0.86692	0.78395	0.70892
	4	0.00360	0.88450	0.77830	0.68485
	5	0.00054	0.87913	0.84001	0.80263
	6	0.00066	0.79476	0.75105	0.70975
	7	0.00032	0.93759	0.90753	0.87843
	8	0.00033	0.87927	0.84899	0.81975
	9	0.00042	0.89507	0.86075	0.82775
	10	0.00167	0.84775	0.77718	0.71249
	11	0.00069	0.81731	0.77293	0.73096
	12	0.00080	0.81595	0.76792	0.72271
	13	0.00190	0.81724	0.74148	0.67274
	14	0.00123	0.86291	0.80290	0.74706
	15	0.00073	0.91793	0.87218	0.82871
	16	0.00070	0.79543	0.75069	0.70847
	17	0.00038	0.84097	0.80814	0.77659
	18	0.00078	0.85500	0.80769	0.76299

	Date	Ratio var.	Upper C. I.	Ratio	Lower C.I.
	9	0.00424	0.92078	0.80495	0.70370
July	10	0.00720	0.91040	0.75386	0.62624
	11	0.00785	0.91251	0.74784	0.61289
	12	0.00211	0.88960	0.80999	0.73750
	13	0.00986	0.89494	0.70722	0.55887
	14	0.00559	0.82596	0.68865	0.57417
	15	0.00583	0.88583	0.74673	0.64927
	16	0.00355	0.87219	0.76666	0.67389
	17	0.00554	0.91774	0.78323	0.66843
	18	0.00178	0.89758	0.82478	0.75789

WELLS 1990 TURBINE HORIZONTAL DISTRIBUTION
(MEAN #/HR)

SPRING Location	Day	Night
1a	52.51346	37.07815
1b	9.174458	9.798657
1c	0.441124	0.415163
2a	6.960445	7.275392
2b	14.81756	14.90514
2c	27.20461	27.7839
3a	12.07515	12.6003
3b	3.799929	2.522599
3c	11.68811	6.954522
4a	4.85051	7.458688
4b	13.78755	18.4116
5a	13.83962	13.18322
5b	0.619614	0.772644
6a	10.3092	8.972811
6b	6.31249	6.772419
7a	6.734731	5.369828
7c	3.498141	2.806808
8a	0.344301	0.377511
8c	3.393753	2.60435
9b	0.692182	0.904875
9c	5.925926	5.666849
10a	7.102214	7.434932
10c	34.94109	27.20164

SUMMER Location	Day	Night
1a	114.1024	58.77659
1b	24.76373	17.96186
1c	0.519828	0.440415
2a	8.190396	5.001823
2b	13.79182	10.6148
2c	40.38445	35.32332
3b	2.790103	2.329952
3c	6.908094	7.731758
4a	3.252117	3.225583
4b	17.1182	16.00998
5a	55.19104	27.41519
5b	5.098664	2.147429
6a	9.570066	13.21482
6b	14.87812	14.35062
8a	1.106333	0.9904
8c	4.318771	6.303814
9b	1.515016	2.533474
9c	5.889639	6.693461
10a	12.99864	18.8735
10c	161.9515	190.6883

WELLS 1990 SLOT HORIZONTAL DISTRIBUTION
SPRING MEAN #/HR

SLOT	DAY	NIGHT	COMBINED
1 C	394.9282	402.9726	398.3255
3 C	307.7809	273.1739	293.3291
5C	282.8525	257.7123	272.5204
7 C	103.7669	80.45155	94.00011
9 C	114.1171	134.367	122.5899

SLOT HORIZONTAL DISTRIBUTION
SUMMER MEAN #/HR

SLOT LOCATION	DAY	NIGHT	COMBINED
1c	826	623	741
3c	948	632	814
5c	1139	751	980
7c	200	217	207
9c	276	367	314

WELLS 1990 TURBINE DIEL DISTRIBUTIONS

SPRING START HOUR	MEAN #/HR	SUMMER START HOUR	MEAN #/HR
0	8.415485	0	12.50679
1	9.55389	1	12.99204
2	7.911116	2	12.07108
3	10.6107	3	13.5258
4	10.44543	4	13.72867
5	12.07459	5	14.34442
6	11.84891	6	13.89417
7	12.68869	7	16.61282
8	12.46306	8	18.27759
9	13.14488	9	17.38088
10	13.16772	10	18.59447
11	13.62068	11	18.74533
12	12.79502	12	20.77358
13	11.36954	13	17.61139
14	10.91398	14	15.30781
15	11.23778	15	14.22762
16	11.23473	16	13.9213
17	9.139967	17	15.00411
18	10.18212	18	14.78851
19	9.719609	19	14.70263
20	11.79284	20	15.04621
21	11.96046	21	17.61477
22	11.71164	22	18.24567
23	11.62496	23	16.45293

WELLS 1990 SLOT DIEL DISTRIBUTION

SPRING START HR	MEAN #/HR	SUMMER START HOUR	MEAN #/HR
0	232.826	0	545.15
1	178.8807	1	506.43
2	201.4395	2	468.07
3	210.6345	3	401.02
4	195.5815	4	457.83
5	202.9509	5	452.12
6	208.2384	6	444.45
7	223.6593	7	513.10
8	260.6907	8	607.75
9	257.3849	9	773.94
10	273.5074	10	857.57
11	231.7502	11	842.41
12	244.3002	12	609.50
13	227.1204	13	760.79
14	262.3545	14	730.03
15	220.986	15	690.47
16	234.968	16	613.70
17	252.2909	17	670.45
18	231.1722	18	664.88
19	220.2819	19	593.28
20	257.6218	20	568.01
21	262.8626	21	575.06
22	278.2303	22	482.88
23	260.7409	23	632.47

APPENDIX E

AGENCY COMMENTS AND BIOSONICS' RESPONSES

APPENDIX E. Agency Comments and BioSonics' Responses

E.1 Introduction

Written comments on the November 28, 1990 draft report were received from Washington Department of Fisheries and National Marine Fisheries Service. Those letters are reproduced on the following pages. BioSonics' responses to these comments follow the two letters.

E.2 Agency Comments

See pages E2 through E7.

JOSEPH R. BLUM
Director

STATE OF WASHINGTON

DEPARTMENT OF FISHERIES

115 General Administration Building, M.S. AX-11 • Olympia, Washington 98504 • (206) 753-6600 • (SCAN) 234-6600

February 19, 1991

BioSonics
Gary Johnson, Manager, Technical Services
3670 Stone Way North
Seattle, Washington 98103

Dear Gary:

We have reviewed the document titled "Evaluation of the Smolt Bypass System at Wells Dam in 1990" and have the following comments and recommendations. Most of these we have discussed already, but there are a few additional suggestions.

Executive Summary, Para 3; and Page 2, Para 3:
CLARIFICATION: It would be helpful if the "best" configuration, determined from the 1984-86 studies, was mentioned here.

Executive Summary, Page 2, Para 1
TYPO: "These analysis were..." should be "These analyses were..." or "This analysis was...".

Executive Summary, Page 2, Para 2:
CLARIFICATION: The formula should read "B = Y/(X+Y)".

Table of Contents, Appendices, C.:
TYPO: "Destribution" should be "Distribution".

Page 8, Para 1: CLARIFICATION: There are two sentences that refer to how many intakes were unavailable because of turbine runner replacement. One refers to two intakes and the other refers to three. Which is correct?

Page 10, Para 2: CLARIFICATION: Some explanation would be helpful to me as to why a study day is defined as running from 8AM-8AM instead of 6AM-6AM? i.e. Why do day hours run 12 hours one day and 2 hours the next?

Page 14, Para 1: TYPO: "...through the end of June, whitefish and..."

Page 18, Para 2: SUGGESTION: The phrase "Fyke catches" is used a great deal here. While the meaning is clear, my opinion is that "Fyke net catches.." is more appropriate. This would hold for the entire document.

Page 24, Para (3): TYPO: I think "predominate" should be "predominant".

Figure C.2: TYPO: "seperately" should be "separately".

Thank you for the opportunity to comment. If you have questions or need further information please call me at (206) 753-2546.

Sincerely,

Cynthia A. Wilson

Cynthia A. Wilson
Fish Biologist
Habitat Management Division

cw

cc: Rick Klinge, Douglas County PUD
Rod Woodin

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
ENVIRONMENTAL & TECHNICAL SERVICES DIVISION
911 NE 11th Avenue - Room 620
PORTLAND, OREGON 97232
503/230-5400 FAX 503/230-5435

FEB 01 1991
DOUGLAS COUNTY P.U.D.

January 30, 1991 F/NWR5

NOT
FEB 01
RWK

Mr. Rick Klinge
PUD No. 1 of Douglas County
1151 Valley Mall Parkway
East Wenatchee, Wa. 98802-4497

Dear Mr. Klinge:

We recently received a draft report titled "Evaluation of the Smolt Bypass System at Wells Dam in 1990". We have reviewed this document and have received comments from the National Marine Fisheries Service (NMFS) scientific staff familiar with hydroacoustic technology. The comments of Bill Karp, NMFS Alaska Fisheries Science Center, are enclosed. We have no further comment at this time.

Sincerely,

Brian J. Brown

Brian Brown
NMFS Representative
Mid-Columbia Coordinating Committee

Enclosure

cc: Dr. Richard Whitney

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Alaska Fisheries Science Center
Resource Assessment and
Conservation Engineering Division
7600 Sand Point Way Northeast
BIN C15700, Building 4
Seattle, Washington, 98115-0070

January 17, 1991 F/AKC1:WK

MEMORANDUM FOR: F/NWR5 - Bill Hevlin

FROM: F/AKC1 - Bill Karp WK

SUBJECT: Review of Draft Report on 1990 Acoustic Studies at Wells Dam

I have reviewed the report and would like to offer the following comments and suggestions.

General

The report reviews the study methods and results well but treats important technical aspects superficially. The data appear to support the interpretations presented in the report but I recommend that more detailed presentations and analyses be provided in future reports. **Particular attention should be paid to calibration procedures and results and other potential sources of bias.** I also recommend that a 90-day review period be incorporated into the report evaluation process.

Executive summary

(1) The equation at the end of the second paragraph on the second page should read: B=Y/(X+Y). This error should be corrected elsewhere in the text.

(2) Care should be taken to qualify terms correctly. For example, "Total bypass efficiency " should read "Estimated total bypass efficiency".

Other issues will be addressed in my comments regarding other sections; responses may require modification of the executive summary.

1.0 Introduction
1.1 Objective

(3) Second Paragraph. The term "substantiate" is inappropriate; I hope the objective was to evaluate!

DEPARTMENT OF COMMERCE
RECEIVED
JAN 22 1991
F/NWR5

1.2 Background

This section is written with the assumption that the reader has a great deal of knowledge about dam operations and fish passage. (4) It would be helpful if the background section could be expanded, especially with regards to the description of the baffle system and its effects, and the long term study objectives.

2.0 Methods
2.2 Transducer Locations and Orientations

First Paragraph. The definition of transducer beamwidth is inadequate. Further technical information should be provided for (5) each transducer and beam patterns should also be available. Since forebay data were based on a slower pulse rate than data collected elsewhere, how did this effect relative detectibility? Was this evaluated?

Paragraph 1, page 8. The report states that "At least two of three intakes at each turbine were sampled...". Was there any (6) investigation of horizontal effects across the intakes of each turbine? What was the potential bias introduced by this approach?

2.3 Sampling Design

The definition of day length is rather surprising. Since the principal reason for assigning day and night periods would be to (7) allow the effects of daylight and darkness to be evaluated, I would have expected the definition to be based on the actual day length for each calendar date.

2.4 Statistical Methods

This section and the supporting appendices are detailed and (8) thorough. The statistical approaches described address issues relating to precision thoroughly but do not deal with bias. Many aspects of the study incorporate potential sources of bias.

3.0 Results
3.2 Total Project Bypass Efficiency

What was unusual about April 25? Where there any notable environmental or operational conditions? How did conditions on (9) that day compare with the two unusually high efficiency dates in May? Are the anomalies somehow related to sample sizes? Anomalous results can often provide useful insights and should be investigated carefully. Why is it appropriate to exclude specific results from the analysis?

(10) Why are the spring and summer bypass efficiency estimates presented with different confidence intervals?

(11) Confidence intervals should be plotted around the passage index

estimates in figures 10 and 11.

4.0 Conclusions

12 "were predominate" should read "were predominant".

Appendix 1.

The section on equipment performance and calibration is rather
13 brief. I suggest that future reports provide detailed pre- and post-study calibration results and a discussion of the effects of breakdowns or changes in performance on study results.

Appendix 2.
A.2.1 Migrant Detection Criteria

After reading the first two paragraphs of this section the reader is left with the sense that target strength and echo strength are
14 interchangeable terms. In fact, the term "target strength" is used incorrectly. Since the data collection and interpretation methods employed at Wells Dam did not provide target strength measurements, detection thresholds must have been based on echo strength criteria.

The rationale for using a criterion of "four successive echoes" for classifying a target as a fish is not provided. The
15 contractor should discuss this rationale and explain why the criterion remains constant regardless of range, pulse repetition rate, or fish target strength.

A.2.2 Background Interference Level

The scale used for rating background interference level should be described. The times and dates of excluded data collection
16 periods should also be provided. Is data collected at intermediate interference levels of reduced quality, and what is the effect of this on the results?

Appendix D Raw Data

This appendix does not provide raw data. I think it would be useful if raw data tables (in the form of individual hourly
17 counts, perhaps broken down by range intervals) were provided in future reports. Averaging over long time periods may make it easier to tabulate the results but does not permit the reader to examine the them closely.

E.3 BioSonics' Responses

E.3.1 WDF Comments

All changes made as requested.

E.3.2 NMFS Comments

(1) Change made as requested.

(2) IBID

(3) IBID

(4) We are currently working on scientific publications which will have an expanded description of the baffle system and its effects, and long term study objectives. We will incorporate this major addition into future reports.

(5) Beamwidths were changed from "15 deg" to "nominal beamwidth 15 deg". Beam pattern plots for all 35 transducers used in this study are available from BioSonics for those interested; 35 pages of beam pattern plots is excessive for this report.

The forebay data were not used in estimating total project bypass efficiency. Relative detectability of spill bay bypass and turbine intake transducers was documented by BioSonics in 1985 ("Hydroacoustic Studies of Downstream Migrant Salmon and Steelhead at Wells Dam in Spring 1984," report to DCPUD, 44 pp).

(6) The horizontal distribution across an intake has been investigated using fyke nets. The data show that passage rates are <u>not</u> significantly different ($P < .05$) between the east, middle and west thirds of the sampled intake. These data validate the extrapolation procedure used for turbine transducers.

(7) The definition of a 24-hour period was based on previous studies when it was necessary to change experimental conditions each day. These changes were made by work crews starting at 0800 h. In 1991, a study-day should be from 0600 h to 0600 h. The appropriate edits have been made to the report.

(8) There are several sources of bias in fish passage studies at dams. These were documented by Thorne in 1987 (Chapter 4 "Sources of Error" in "Hydroacoustic Evaluation of the Spill Program for Fish Passage at John Day Dam in 1987," report to US Army Corps of Engineers, Portland District). They include target strength/calibration and pattern recognition. Dr. Thorne is currently a technical advisor for the hydroacoustic studies at Wells Dam.

(a) Changes in target strength during hydroacoustic studies at Wells Dam during spring can occur as the predominant species changes from chinook to steelhead to sockeye. Steelhead are the largest outmigrants but they are predominant only for a week or so in early May (e.g., see Table 5 of this report). Bias in the data due to fish size changes, however, is minimized because the system is set up with the effective transducer beam width at the -3 dB level of the beam pattern and able to detect a -50 dB target at this level. A chinook or sockeye target is about -48 dB (BioSonics, unpublished data). As the mean target strength gets larger, for example from steelhead, the beam pattern drops off rapidly, therefore there are not drastic changes in the effective beam width.

(b) Differences in transducer orientation relative to fish passage may also affect the effective transducer beam width. We eliminated this effect by aiming transducers up in both bypass and turbine intake locations.

(c) Differences in target strength due to differences in species composition between the fish passing through the bypass and those passing through turbine intakes would affect the effective beam width. Fyke net data taken concurrently in the bypass and turbine intakes do not show any differences in species composition (DCPUD, unpublished data).

(d) Another source of bias is from calibration. Changes in calibration can occur but we check for these with pre- and post-season measurements. If discrepancies are discovered, data from that transducer are discarded.

(e) Differences in transducer depth may also affect transducer performance and hence the calibration values. We minimized this effect by deploying the transducers for bypass and turbine sampling at depths as similar to each other as possible. Bypass and turbine intake transducers were placed at elevations 708 ft and 648 ft, respectively.

(f) Bias due to pattern recognition was minimized by having one person primarily responsible for "marking" the fish traces on the echograms. During the 1990 evaluation, that person was E. Kudera.

(9) We did not notice any unusual environmental or operational conditions for April 25, 1990. The high passage rate in bypass was not due to species composition because other dates with high efficiency estimates (e.g. May 7 and May 15) had different species prevalent. Flows were generally high throughout the study, but we did not examine flows for those particular dates.

We did not exclude any results from the analysis; we presented the results with and without data from April 25 so that readers could draw their own conclusions.

(10) The spring and summer bypass efficiency estimates are presented with different confidence intervals because that was what the Settlement Agreement called for. The parties may have felt that summer passage is naturally more variable than spring passage and, thus, felt a looser confidence interval (larger confidence level) would be appropriate.

(11) This is a good point. Unfortunately, we do not have this information. We will include confidence intervals around "sub-index" data for future studies.

(12) Change made as requested.

(13) See Response No. 7.

(14) Change made as requested.

(15) This comment concerns the fact that at least four consecutive echoes were required for a target to be classified as a fish, regardless of range, pulse repetition rate, and target strength. These are all important factors that can affect detectability. The important point in this study, however, is that detectability between bypass and turbine transducers be equivalent and consistent, which it was.

(16) Change made as requested. Data affected by noise were not included in the analysis.

(17) The title of the appendix has been changed from "Raw Data" to "Fish Passage Data." A table with passage estimates and variances for each date of the study for each sampling location has been added to the report.

EVALUATION OF THE SMOLT BYPASS SYSTEM

AT

WELLS DAM IN 1991; DRAFT REPORT

APPENDIX - C

Evaluation of the Smolt Bypass System at Wells Dam in 1991

Draft Report

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December 4, 1991

EXECUTIVE SUMMARY

In 1991 we used hydroacoustics to evaluate the smolt bypass system at Wells Dam on the Columbia River. The evaluation, sponsored by Douglas County Public Utility District (DCPUD), took place in spring (April 14 to May 24) and summer (July 8 to 22). The 1991 evaluation was the second of a three-year program to substantiate the efficiency of Wells' bypass system. Fisheries agencies, tribes, and DCPUD agreed to a three-year evaluation period as part of the Wells Settlement Agreement (dated October 1990). The agreement also included criteria for precision which guided development of the sampling design. The primary objective of the 1991 evaluation was to estimate **total project bypass efficiency**.

The bypass concept at Wells Dam is based on Wells' hydrocombine structure. (A hydrocombine is a dam with the spillway located directly above the turbine intakes. Wells is the only dam constructed like this in North America.) To form the bypass, baffles are placed in the spill intakes to create attractant flow for downstream migrant smolts. Once entrained in this attractant flow, smolts enter the bypass and migrate past the dam in bypass flow instead of turbine flow. Data show that a relatively small amount of flow properly baffled is more effective at bypassing smolts than is a large amount of flow that is not baffled.

Annual bypass evaluations using hydroacoustic sampling methods and rigorous experimental designs were critical to the development of an efficient bypass at Wells Dam. A prototype bypass was first installed and tested in 1983 at one spillbay of the dam. The 1983 study showed that smolt passage in bypass flow was greater with baffles in place than without. In 1984, 1985, and 1986, the bypass passage rates for various baffle configurations (underflow, overflow, vertical slot, etc.) were compared. The configuration that passed statistically significantly more fish than the others, all other factors being equal, was deemed the "best." The data showed that the vertical slot and underflow configurations were the best. In 1986, two bypass sections were installed and tests conducted to determine if operating an adjacent bypass section increased passage at the original bypass section; it did not. In 1987, more bypass sections were installed and the study objective was to determine the most effective locations for bypass sections across the dam; the middle and west sections had higher passage than the east section. In 1988 and 1989, detailed data on specific characteristics of the bypass were evaluated to fine-tune the system. The bypass will be officially completed after review and acceptance of total project bypass efficiency data from three years of spring and summer evaluations : 1990, 1991, and 1992.

In 1991, we used fixed-location hydroacoustic techniques to estimate total project bypass efficiency. Transducers (15°) were deployed at 4 of 10 forebay locations (T2, T4, T6, and T8) and 24 of 30 turbine intake locations. Transducers (6°) were deployed at 5 of 5 bypass intake locations (S2, S4, S6, S8, and S10). The number of transducers and sampling design were based on statistical analysis of previous data from Wells. This analysis was performed in winter 1989/90 and presented in the study plan for the 1990 evaluation.

Total project bypass efficiency (B) was estimated by first estimating total passage in bypass flow (Y) and total passage in turbine flow (X) separately. Total passage in turbine was obtained by extrapolating from sampled intakes into non-sampled intakes. Then the ratio $B=Y/(X+Y)$ and confidence interval were calculated.

The bypass system at Wells Dam in 1991 was operated as in previous years. That is, if the daily flow forecast was greater than 140 kcfs, all 5 bypass units were opened. If the forecast was less than 140 kcfs, only bypass units above operating turbines (one or both of the turbines associated with a bypass unit) were opened. In 1991, daily bypass flow averaged 6.1% of total project discharge. Overall, the mid-Columbia River had relatively high flows in spring and summer 1991.

DCPUD sampled for species composition with a fyke net in Turbine Intake 4C during the month of May. Samples were taken inside Turbine Intake 8C for the rest of the season. Net data were collected at least weekly from May 16 to August 28. The fyke net effort in 1991 was curtailed to reduce juvenile salmon mortality during the spring out-migration. The data showed that as compared to previous years primarily chinook, steelhead and sockeye were present through the end of May. During June, other non-target species dominated the catch, although chinook were present as well. Whitefish became evident during July. Zero age chinook dominated the catch during July and the first half of August. The latter half of August showed increasing numbers of non-target species.

The 1991 hydroacoustic run timing data from the forebay transducers showed the usual year to year trends. The outmigration begins with a large peak of spring chinook due to the Winthrop hatchery release. In mid- and late May, the wild sockeye migration from Lake Osoyoos passes through the dam. Passage rates are low throughout June. In July the summer chinook outmigration begins and continues through mid-August. In the latter part of August, passage rates are high and variable primarily due to non-target species.

Horizontal distribution data for 1991 again showed highest passage rates at the west and east ends of the dam. Nighttime passage rates were higher than daytime during the spring. Daytime passage rates were higher than nighttime during the summer.

Estimated total project bypass efficiency for the 40-day spring study was 95.0% +/- 0.43% at the 90% confidence level. Daily efficiencies for spring ranged from 73% to 99%. Estimated total project bypass efficiency for the summer study was 97.0% +/- 0.29% at the 90% confidence level. Daily efficiencies for summer ranged from 96% to 99%.

ACKNOWLEDGEMENTS

The hydroacoustic studies at Wells Dam are the product of much hard and excellent work by many people. We sincerely thank:

- Douglas County PUD staff at Wells Dam and East Wenatchee for their guidance, cooperation, and assistance. They also provided the dam operations data, the fyke net data, and much logistical support. Without DCPUD staff, this project could not have been done.
- J. Skalski for pre-study sampling design analyses which were incorporated into the study plan.
- Valerie Stark, Mike Nealson, and Andy Wilson for collecting the hydroacoustic data.
- J. Skalski and D. Ouellette for developing the statistical tools.

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1.0 INTRODUCTION

1.1 Objective

In 1991, we used hydroacoustics to evaluate the smolt bypass system at Wells Dam on the Columbia River. The evaluation, sponsored by Douglas County Public Utility District (DCPUD), took place in spring (April 14 to May 24) and summer (July 8 to 22). The 1991 evaluation was the second of a three-year program to substantiate the efficiency of Wells' bypass system. Fisheries agencies, tribes, and DCPUD agreed to a three-year evaluation period as part of the Wells Settlement Agreement (dated October 1990). The agreement also included criteria for precision which guided development of the sampling design. This year marked the most intensive sampling effort to date. The primary objective of the 1991 evaluation was to estimate **total project bypass efficiency.**

1.2 Background

Wells Dam (Figure 1 and Table 1) is the first dam that over two million smolts must pass during annual outmigrations to the Pacific Ocean. DCPUD is responsible for protecting anadromous fish that migrate past Wells Dam because of Federal Energy Regulatory Commission (FERC) license conditions. The type and amount of protection is formally agreed upon by DCPUD, fisheries agencies, and tribes. Between 1980 and 1989, inclusive, provisions in FERC settlement agreements have guided the development of the smolt bypass system at Wells Dam. Parties to the settlement agreement and DCPUD agreed to evaluate total bypass efficiency from 1990 to 1992.

Wells Dam was designed as a hydrocombine (Figure 2) to reduce the area of concrete structures founded on rock (Patrick 1970). The spill bay and turbine intake floors are 73 ft and 133 ft from the surface, respectively. The dam has ten turbines and eleven spill bays (Figure 3). All eleven spillbays are equipped with bottom spill gates, but only Bays 2 and 10 have surface gates which can be opened to accommodate top spill. Each turbine has three intakes and, except for Bays 1 and 11, each spill bay has three intakes. Water enters the bypass intakes above water entering the turbine intakes because of the hydrocombine design.

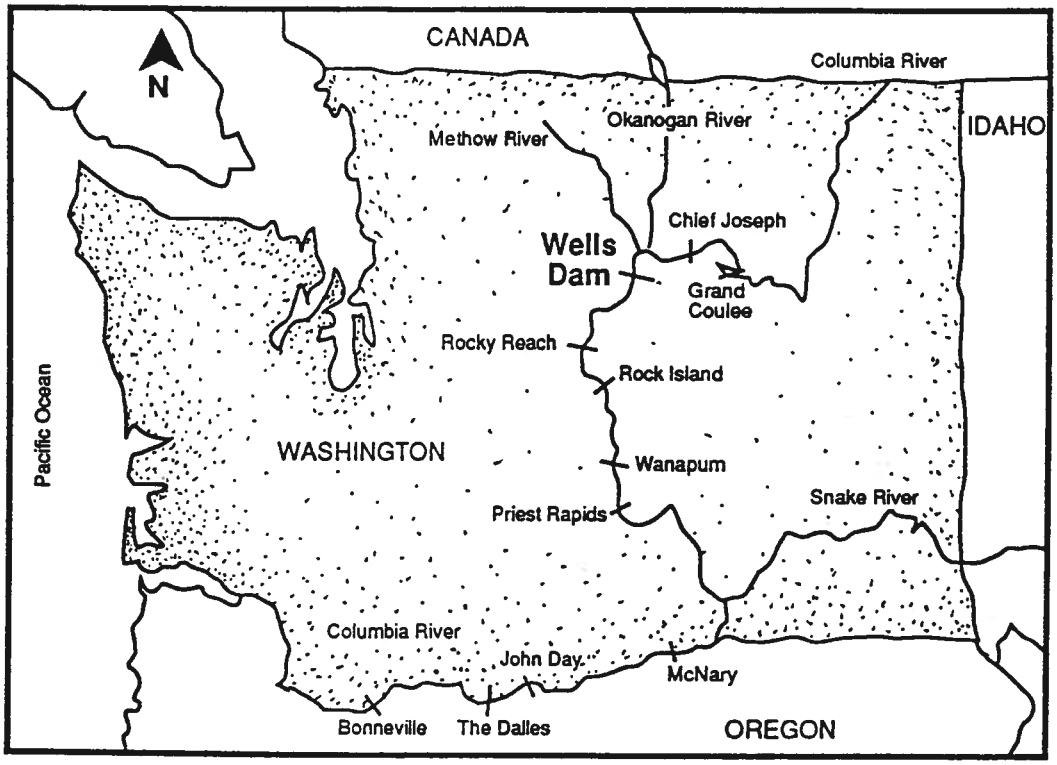

Figure 1. Location of Wells Dam on the Columbia River.

Table 1. Descriptive data for Wells Dam for reservoir elevation 779 ft Mean Sea Level (MSL). (In 1984, the reservoir was raised to 781 ft MSL.)

River Mile at Dam Site	515.8
Drainage Area	85,300 sq mi
Historical Flood (1894)	657 kcfs
Spillway Design Flood	1,180 kcfs
Gross Head (maximum)	74.5 ft
Reservoir Storage Capacity	300,000 acre-ft
Reservoir Length	30 mi
Dam Length (overall)	4,460 ft
Hydrocombine Length	1,130 ft
Hydrocombine Height	185 ft
Generating Units	10
Type of Turbine	Kaplan
Maximum Capability	820,000 kw

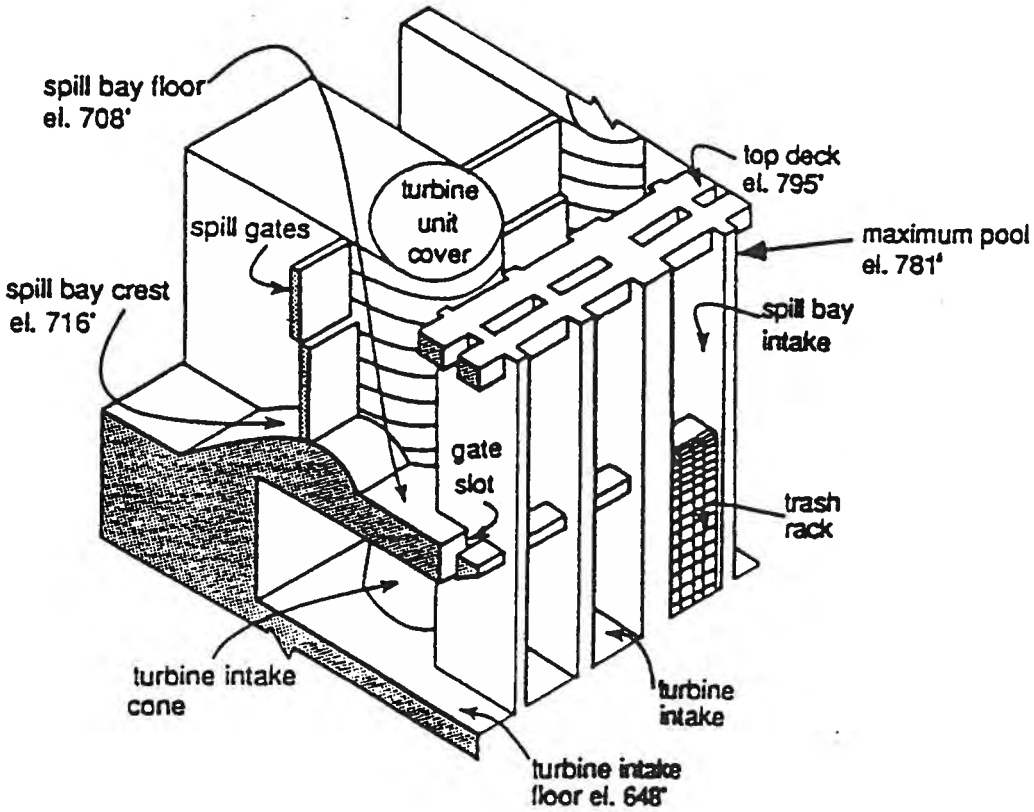

Figure 2. Three-dimensional view of Wells Dam hydrocombine with spill intakes directly above turbine intakes.

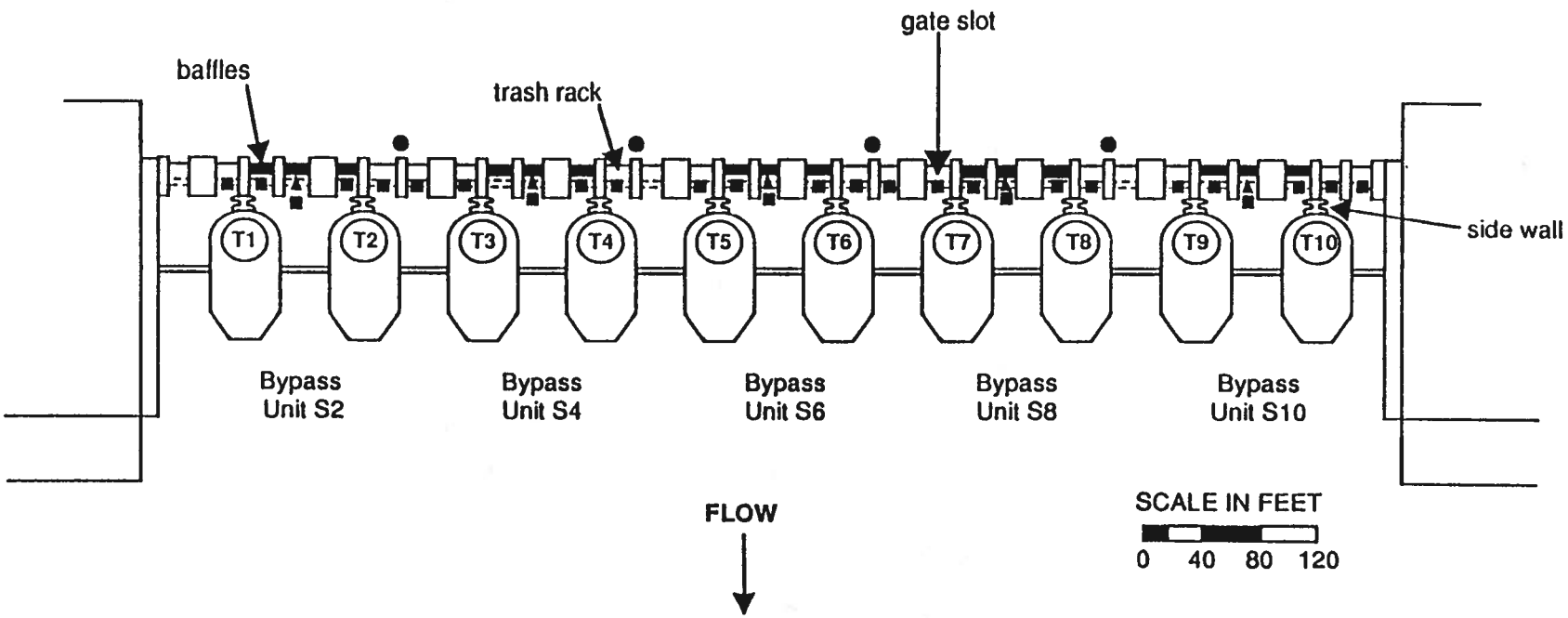

Figure 3. Plan view showing the five bypass units and the locations of forebay transducers (●), turbine intake transducers (■), and bypass slot transducers (▲) at Wells Dam in 1991.

The smolt bypass system is based on spill intake baffles which increase flow velocities to attract smolts into the bypass. Once entrained in this attractant flow, smolts enter the bypass and migrate past the dam in bypass flow instead of turbine flow. A relatively small amount of flow, properly baffled, is equally or more effective at bypassing smolts than is a large amount of flow that is not baffled.

The smolt bypass system at Wells Dam has five individual bypass units (Figure 3). A bypass unit is formed by modifying a spill bay with sidewalls, gate slot plugs, and baffles (Figures 3 and 4). Side walls installed between the pier noses and the turbine pit walls on each side of a spill bay prevent water from flowing between adjacent spill bays, thereby increasing the effect of the intake baffles on forebay flows. Gate slot plugs prevent flow between turbine intakes and the bypass unit. Baffles anchored in the trash rack guides in the spill intakes increase flow velocity into the bypass units. The baffle opening can be oriented horizontally (Figure 5a) or vertically (Figure 5b) in 4-ft increments of height or width. The horizontal opening can be placed anywhere in the water column of the bypass unit intakes. The vertical opening is placed in the center intake of the three intakes. The baffles are the most important feature in the design of the smolt bypass system at Wells Dam. After many years of testing, a vertical slot baffle opening was selected.

During the 1980's, annual bypass evaluations using hydroacoustic sampling methods and rigorous experimental designs were critical to the development of an efficient bypass at Wells Dam. A prototype bypass was first installed and tested in 1983 at one spillbay of the dam. The 1983 study showed that smolt passage in bypass flow was greater with baffles in place than without. In 1984, 1985 and 1986, the bypass passage rates for 13 different baffle configurations (underflow, overflow, vertical slots, etc.) were compared. The configuration that passed statistically significantly more fish than the others, all other factors being equal, was deemed the "best." The data showed that the vertical slot and underflow configurations worked best. In 1986, two bypass sections were installed and tests conducted to determine if operating an adjacent bypass section increased passage at the original bypass section; it did not. In 1987, more bypass sections were installed and the study objective was to determine the most effective locations for bypass sections across the dam; the middle and west sections had higher passage than the east section. In 1988 and 1989, detailed data on specific characteristics of the bypass were evaluated to fine-tune the system. The bypass will be officially completed after review and acceptance of total project bypass efficiency data from three years of monitoring that began in 1990.

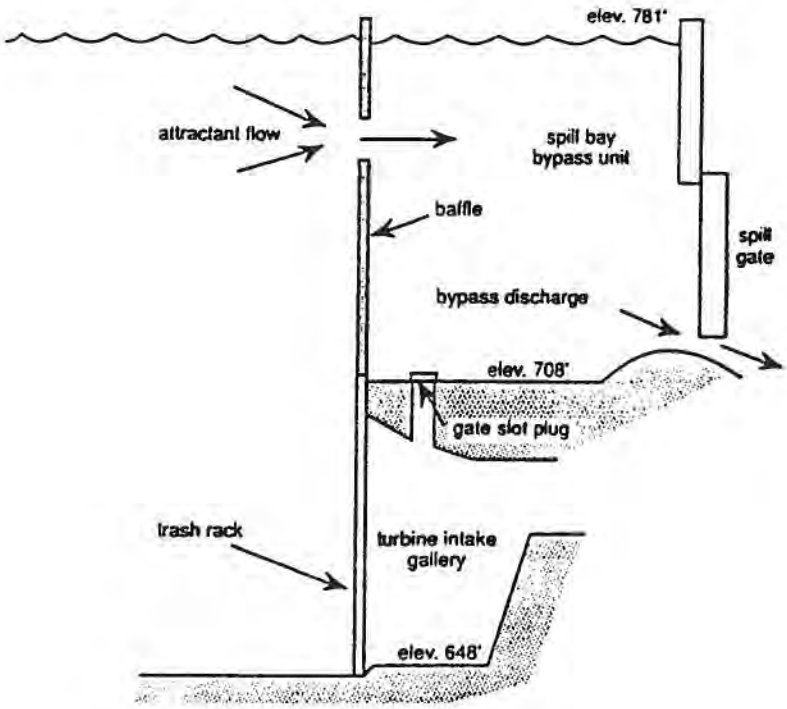

Figure 4. Side view of a bypass unit at Wells Dam showing a horizontal baffle opening and attractant flow.

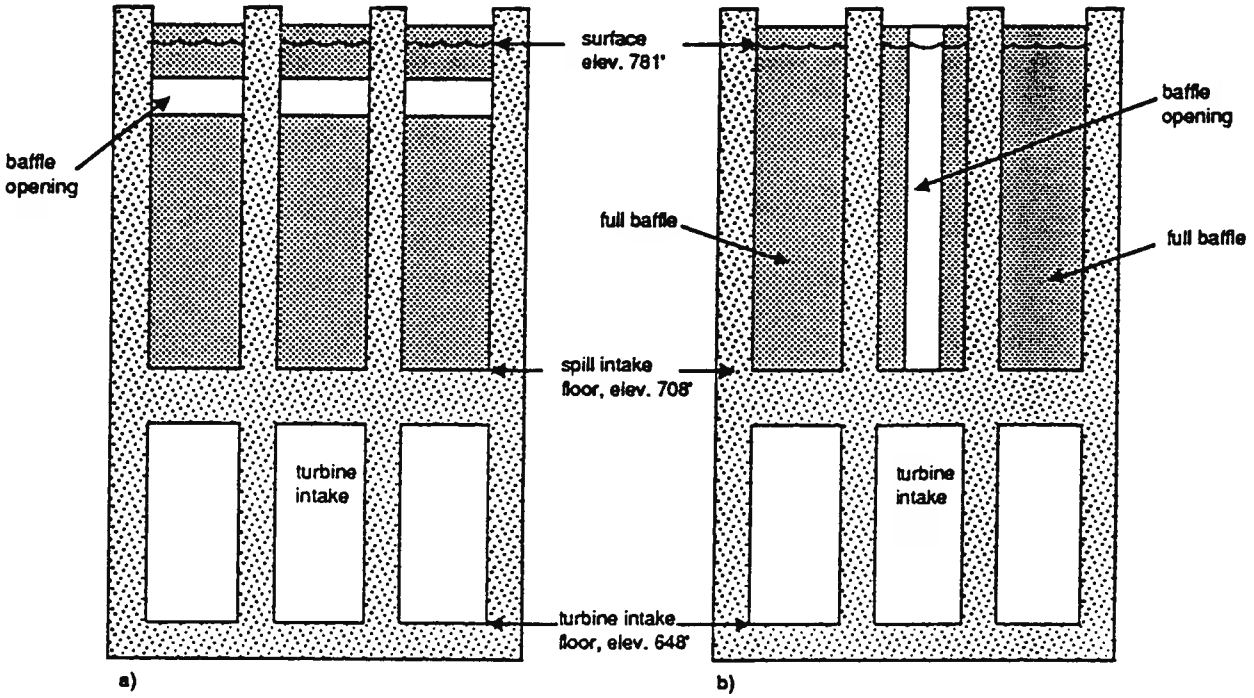

Figure 5. The upstream side (front view) of a bypass unit at Wells Dam with (a) horizontal baffle opening and (b) vertical baffle opening.

2.0 METHODS

2.1 General Hydroacoustics

We used fixed-location hydroacoustic techniques for monitoring smolt passage at Wells Dam in 1991. The techniques were similar to those used in 1989 (Kudera *et al.* 1990) and are explained by Thorne and Johnson (In Press). The following methods are described in detail in Appendix A: (1) operating BioSonics hydroacoustic systems; (2) acquiring data from echograms; and (3) reducing data and calculating the primary statistics. Specific details of transducer locations and orientations, sampling design, and statistical methods are presented below.

2.2 Transducer Locations and Orientations

Transducers were deployed in the forebay, bypass intake slots, and turbine intake galleries. To monitor run timing, transducers (nominal beam width 15°) sampled fish passage in the forebay in front of Turbine Units 2, 4, 6, and 8 (Figure 3). We deployed the forebay transducers at the bottom of the pier nose between the B- and C-slots of the designated units, about 130 ft deep. They were aimed up about 28° off the face of the dam (Figure 6). The forebay transducers had ranges from 118 to 127 feet so a low pulse rate of 4 pulses per second (pps) was used. The forebay data were used to generate a daily index of fish passage before and after the spring and summer bypass studies; the forebay was not sampled during the bypass evaluation.

For the bypass evaluation, five transducers (nominal beam width 6°) were placed in bypass units S2, S4, S6, S8, and S10 (Figures 3 and 6). The bypass slot transducers were deployed in the gate slot immediately downstream of the vertical baffle opening in the C-slots of the designated bypass. This location is at the center of a bypass spillbay. These transducers rested at the bottom of the bypass and were aimed straight up toward the surface (Figure 6). The range in the bypass slots was approximately 65 feet so a higher pulse rate of 10 pps was used. The bypass slot transducers sampled fish passage into all five bypass intakes of the smolt bypass system.

Also for the bypass evaluation, 24 transducers (nominal beam width 15°) were deployed in turbine intake galleries (Table 2 and Figure 3). These transducers were mounted on the bottom and aimed upward about 10° downstream (Figure 6). The pulse rate was 10 pps. At least two of three intakes at each turbine unit were sampled. The sampled intakes were selected randomly. At four turbine units (Units 1, 2, 5, and 10), all three intakes were sampled; Units 1 and

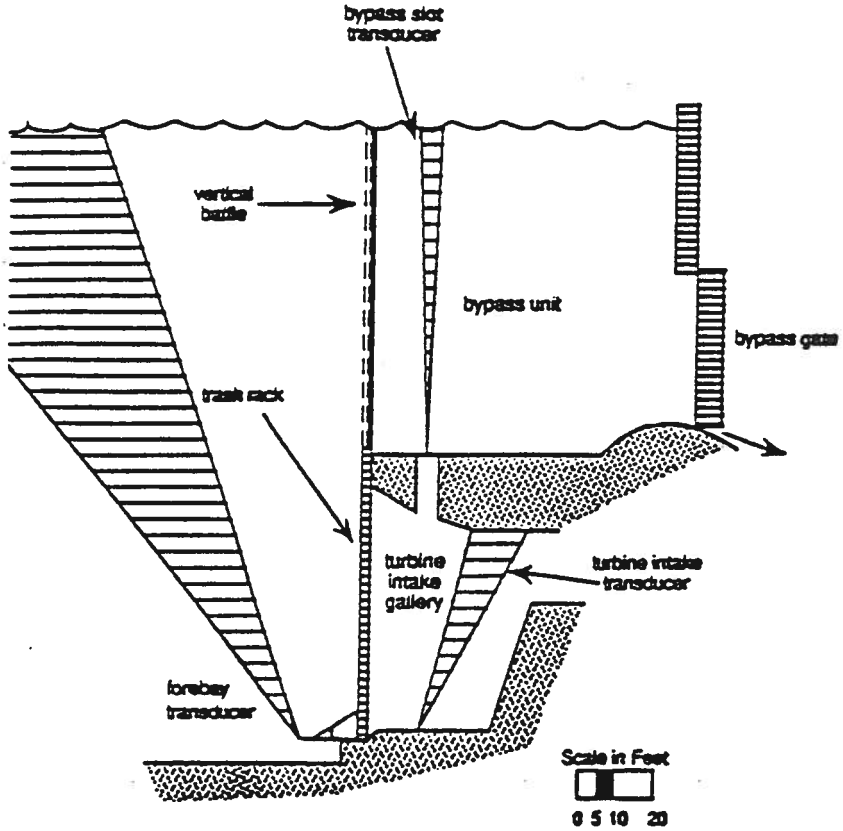

Figure 6. Side view of a bypass unit at Wells Dam showing 1991 transducer sampling areas.

Table 2. Turbine intake sampling locations at Wells Dam in 1991. (NS = Not sampled)

LOCATION	DATES SAMPLED Spring	Summer	LOCATION	DATES SAMPLED Spring	Summer
1A	4/14-5/24	7/08-7/22	6A	4/16-5/02	NS
1B	4/14-5/24	7/08-7/22	6B	4/14-5/24	7/08-7/22
1C	4/14-5/24	7/08-7/22	6C	4/14-5/24	7/08-7/22
2A	4/14-5/24	7/08-7/22	7A	4/14-5/24	7/08-7/22
2B	4/14-5/24	7/08-7/22	7B	4/16-5/02	NS
2C	4/14-5/24	7/08-7/22	7C	4/14-5/24	7/08-7/22
3A	4/14-5/24	7/08-7/22	8A	4/14-5/24	7/08-7/22
3B	NS	NS	8B	4/14-5/24	7/08-7/22
3C	4/14-5/24	7/08-7/22	8C	NS	NS
4A	4/14-5/24	7/08-7/22	9A	4/14-5/24	7/08-7/22
4B	4/14-5/24	7/08-7/22	9B	4/16-5/02	NS
4C	NS	NS	9C	4/14-5/24	7/08-7/22
5A	4/14-5/24	7/08-7/22	10A	5/03-5/24	7/08-7/22
5B	4/14-5/24	7/08-7/22	10B	5/03-5/24	7/08-7/22
5C	4/14-5/24	7/08-7/22	10C	5/03-5/24	7/08-7/22

2 were selected because previous data showed relatively high fish passage rates. Given extra transducers at Units 1 and 2, we chose Units 5 and 10 to gain the most complete east-west coverage. The turbine intake transducers sampled fish passage into 24 of 30 turbine intakes. During the spring Unit 10 was out of service until May 3. The transducers deployed in Unit 10 were moved to Units 6, 7, and 9 when Unit 10 went out of service. Unit 10 was back in service for the entire summer study period. The turbine intake transducers sampled fish that were not diverted into the bypass system.

2.3 Sampling Design

For monitoring run timing, one hydroacoustic system sampled smolt passage in the forebay. The system, which had one chart recorder, sampled in the forebay immediately upstream of the dam. The four forebay locations were each sampled once every hour for a minimum of 15 min at 4 pps. During the spring (April 14 to May 24) and summer (July 8 to July 22) bypass studies, we did not sample the forebay. During the bypass studies, we used data from the bypass intake slot transducers to produce a run timing index. For monitoring run timing, samples were obtained at least eight hrs/day (1300 h - 1700 h and 2200 h - 0200 h) every day from March 29th to August 31st.

For both spring and summer, we defined the hours of day and night during a study day as follows:

Day = 0600 h - 2000 h (Date X)

Night = 2000 h - 0600 h (Date X to Date X+1).

For evaluating the bypass, one hydroacoustic system sampled the bypass slots and two systems sampled turbine intakes. Each transducer was sampled for a minimum of 10 minutes an hour for 24 hours per day during the spring and summer sampling periods. Typically, five 2-minute samples were collected each hour for each transducer location. The hourly sampling sequence was systematic. A new randomized sequence was selected at the start of every study day.

2.4 Statistical Methods

We determined fish passage (#/hr) at each location each hour by summing the weighted fish detections and dividing by total sample time (usually 10 minutes) at a given location within a given hour and then multiplying by 60 minutes per hour (Appendix A). The hourly passage rate estimates were the basic data for monitoring run timing and describing passage distributions in the bypass.

The run timing index from the forebay transducers was calculated by averaging passage rates over the four locations to produce a mean number per eight hrs per location. These numbers were adjusted for the percentage of non-target species present in the fyke net catch for each week. The run timing index from the bypass slot transducers was calculated by averaging passage rates over the five bypass slot locations.

Total project bypass efficiency, for spring and summer separately, was estimated by dividing total fish passage in bypass by total passage in turbine plus bypass.

$$B = y/(y+x)$$

where B = total project bypass efficiency

y = fish passage in bypass, and

x = fish passage in turbine.

$$CI(B) = B +/- z * \sqrt{var(B)}$$

where $var(B) = B^2(1-B)^2[var(y)/y^2 + var(x)/x^2]$

z = 1.645 at the 90% confidence level and

z = 1.96 at the 95% confidence level

The methods were developed by Dr. John Skalski of the University of Washington and are presented in Appendix B. The algorithms for estimating total bypass and turbine passage and the confidence interval were determined by Dr. Skalski (Skalski and Ouellette, 1990).

2.5 Fyke Net Methods

During 1991, DCPUD collected species composition data using fyke nets. Data was collected from inside Turbine Intake 4C during the month of May. Only four nets were fished during the month of May. Data was collected from inside Turbine Intake 8C for the rest of the season, using seven nets. Net data were collected at least once per week from May 16th to August 28th. Fyke netting was started later in 1991 in order to reduce juvenile salmon mortality during the spring out-migration. Sampling usually lasted eight hours. Sample hours were from 2200h to 0600h. The entire cross-sectional area of the turbine could be sampled by the array of three nets across by seven nets down. During 1991 only the center column of seven nets was fished. Each net opening was 7.16 ft wide and 6.75 ft high. Each net was 13 ft long with 3/8 inch stretch mesh and 1/4 inch mesh cod end. In spring and summer, all captured fish were counted, examined for marks and a subset was measured. The fish were categorized as follows: yearling chinook, zero-age chinook, sockeye, steelhead, whitefish, and other. Fish counts were divided by sample time to produce number passing per unit time.

3.0 RESULTS

3.1 Ancillary Data

3.1.1 Project Discharge and Dam Operations

From April through August 1991, project discharge at Wells Dam was higher than the 15-yr average (Table 3). Overall, the mid-Columbia had relatively high flows during spring and summer 1991. Because of the high flows, power generation was usually at its maximum during the bypass evaluation. Unit 10 was not sampled from April 15 to May 3 as it was off line for maintenance.

Table 3. Project discharge (kcfs) for Wells Dam during April through August, 1991. Source: G. Donabauer (DCPUD).

	PROJECT DISCHARGE (kcfs)				
	April	May	June	July	August
Min. daily average	96.8	57.4	69.6	37.0	21.1
Max. daily average	213.3	285.6	234.3	220.2	208.4
Avg. hourly discharge	169.9	177.8	175.6	146.7	132.7
15-year average	113.0	132.1	135.2	113.6	96.8
% 15-year average	150	135	130	129	137

Bypass operations for smolt passage at Wells Dam in 1991 were similar to those in previous years. DCPUD operated the bypass daily from April 11 to June 6, and from July 5 to August 19, 1991. The number of bypass units that were operated depended on the daily flow forecast from Chief Joseph Dam. If the flow forecast was greater than or equal to 140 kcfs, all five bypass units were opened for that 24-hr period. There were a total of 75 days during which all bypass units were open due to inflow estimates. If the forecast was less than 140 kcfs, only those bypass units above a pair of turbines, with one or both operating, were opened (Tom Hook, DCPUD, personal communication). Each bypass unit is associated with two turbines (Bypass Unit S2 with Turbines 1 and 2; Bypass Unit S4 with Turbines 3 and 4; etc.). Therefore, if one or both turbines of a pair were on-line, then the bypass unit was opened. If both units were off-line, then the bypass unit was closed. Minimum bypass flows (kcfs) were: S2 = 1.6 to 2.1; S4 = 2.2; S6 = 2.2; S8 = 2.2; and S10 = 1.6 to 2.1. Top spill was used for bypass flow at

bypass units S2 and S10. Flows at these bypass units varied according to forebay pool elevation. During 1991, daily bypass flow at Wells Dam averaged 6.1% of total project discharge.

3.1.2 Species Composition

The principle salmonid species migrating past Wells Dam in spring are: chinook salmon (*Oncorhynchus tshawytscha*), steelhead trout (*O. mykiss*), and sockeye salmon (*O. nerka*). Spring chinook are raised and released at the U.S. Fish and Wildlife Service hatchery at Winthrop, 50 miles upstream from Wells. Steelhead are raised at the Wells hatchery and transported to upstream release sites. The quantities, dates, and locations of the spring 1991 releases of hatchery-raised salmonids above Wells Dam are given in Table 4. About 2.9 million fish were released in the drainage above Wells Dam in 1991. Wild stocks of sockeye also migrate downstream through Wells Dam. These salmon migrate out of Lake Osoyoos, about 100 miles upstream from Wells. In spring and summer, wild chinook that reproduce in the Okanogan and Methow drainages (zero-age chinook) migrate downstream through the Mid-Columbia River (Figure 1).

Table 4. Species, locations, distances from Wells, dates, and sizes of releases of hatchery-raised juvenile salmonids upstream of Wells Dam in spring 1991. Sources: B. Wallien (USFWS) and S. Miller (WDG).

SPECIES	RELEASE SITE	MILES FROM WELLS DAM	DATE	NUMBER
spring chinook	Winthrop (yearling)	50	4/11	1,055,056
	Winthrop (zero age)	50	5/29	417,864
summer chinook (yearling) (volitional release)	Twisp	38	5/1-5/31	420,000
	Similkameen	86	5/1-5/31	352,600
summer steelhead	Methow RM 10	16	4/22-5/6	343,432
	Methow RM 1	7	4/23-5/8	144,135
	Okanogan RM 28	43	4/24-4/30	72,830
	Similkameen RM 6	90	4/22-5/2	90,320
	Omak Cr. RM 7	43	5/7	6290
				Total = 2,902,527

The 1991 fyke net catch data from Wells Dam are tabulated in Table 5 and graphed in Figures 7A, 7B, and 8. Fyke net effort was greatly reduced this year as compared to previous years to minimize juvenile salmon mortality. Fyke netting began on May 16, after it was believed that the majority of the spring out-migration had passed through Wells Dam. Catch numbers were low and showed less than 50% salmon species (Figure 8 and Table 5). On May 23, there was a large peak of chinook salmon (Figure 7A), but sockeye were also present, constituting about 25% of the catch (Table 5). From May 30 until the end of August, the chinook catch accounted for more than 94% of all salmon caught. During the month of June, the catch consisted primarily of other non-target species (Figure 7B). However, chinook were also present during June. This may be due to an unusually late chinook (zero age) release from the Winthrop hatchery at the end of May (Table 4). No whitefish were caught until the beginning of July (Table 5 and Figure 7B). Large numbers of chinook were caught from mid-July through mid-August (Figure 7A). Zero age chinook were prevalent on July 25 and dominated the catch through August 15. The catch during this period ranged from 83% to 99% chinook-0's. From mid-August through the end of the study, August 31, the catch consisted mainly of non-target species.

The 1991 fyke net data again show a spring and summer period dominated by salmonid species. Whitefish were present throughout July. The catch from July 25 to August 15 was primarily zero-age chinook. Overall, chinook constituted the vast majority of all salmon caught. "Other" fish that were caught in the fyke net included bullhead (*Ictalurus spp.*), carp (*Cyprinus spp.*), chiselmouth (*Acrocheilus spp.*), dace (*Chrosomus spp.*) lamprey (*Entosphenus spp.*), peamouth (*Mylocheilus spp.*), sculpin (*Cottus spp.*), shiner (*Notropis spp.*), squawfish (*Ptychocheilus spp.*), sucker (*Catostomus spp.*), and walleye (*Stizostedion spp.*).

Table 5. Number and proportion of chinook, steelhead, sockeye and other non-salmonid species caught in the fyke nets at Wells Dam in spring and summer 1991. Data are expressed in number of fish per hour and proportion. Source R. Klinge (DCPUD).

	Oncorhynchus Species						Non-Salmonid Species					
	Chinook		Sockeye		Steelhead		Whitefish		Other		All non-salm.	
Date	#/hr	Prop.	#/hr	Prop.	#/hr	Prop.	#/hr	Prop.	#/hr	Prop.	#/hr	Prop.
May - 16	0.9	0.19	1.1	0.25	0.0	0.00	0.0	0.00	2.5	0.56	2.5	0.56
23	10.9	0.62	4.3	0.24	0.4	0.02	0.0	0.00	2.0	0.11	2.0	0.11
30	3.9	0.89	0.1	0.03	0.0	0.00	0.0	0.00	0.4	0.09	0.4	0.09
June - 6	1.8	0.37	0.0	0.00	0.0	0.00	0.0	0.00	3.0	0.63	3.0	0.63
13	2.5	0.29	0.0	0.00	0.0	0.00	0.0	0.00	6.1	0.71	6.1	0.71
20	1.6	0.17	0.0	0.00	0.0	0.00	0.0	0.00	7.8	0.83	7.8	0.83
27	1.0	0.32	0.0	0.00	0.0	0.00	0.0	0.00	2.1	0.68	2.1	0.68
July - 3	1.6	0.48	0.0	0.00	0.0	0.00	0.5	0.15	1.3	0.37	1.8	0.52
11	7.4	0.72	0.0	0.00	0.0	0.00	0.6	0.06	2.3	0.22	2.9	0.28
18	6.6	0.76	0.0	0.00	0.0	0.00	1.3	0.14	0.9	0.10	2.1	0.24
25	17.1	0.94	0.0	0.00	0.0	0.00	0.3	0.01	0.9	0.05	1.1	0.06
August - 1	12.3	0.90	0.0	0.00	0.1	0.01	0.5	0.04	0.8	0.06	1.3	0.09
8	9.5	0.89	0.0	0.00	0.0	0.00	0.3	0.02	0.9	0.08	1.1	0.11
15	2.4	0.83	0.0	0.00	0.0	0.00	0.1	0.04	0.4	0.13	0.5	0.17
19	0.0	0.00	0.0	0.00	0.0	0.00	0.1	1.00	0.0	0.00	0.1	1.00
22	1.3	0.53	0.1	0.05	0.0	0.00	0.0	0.00	1.0	0.42	1.0	0.42
28	0.5	0.03	0.0	0.00	0.0	0.00	0.0	0.00	14.5	0.97	14.5	0.97

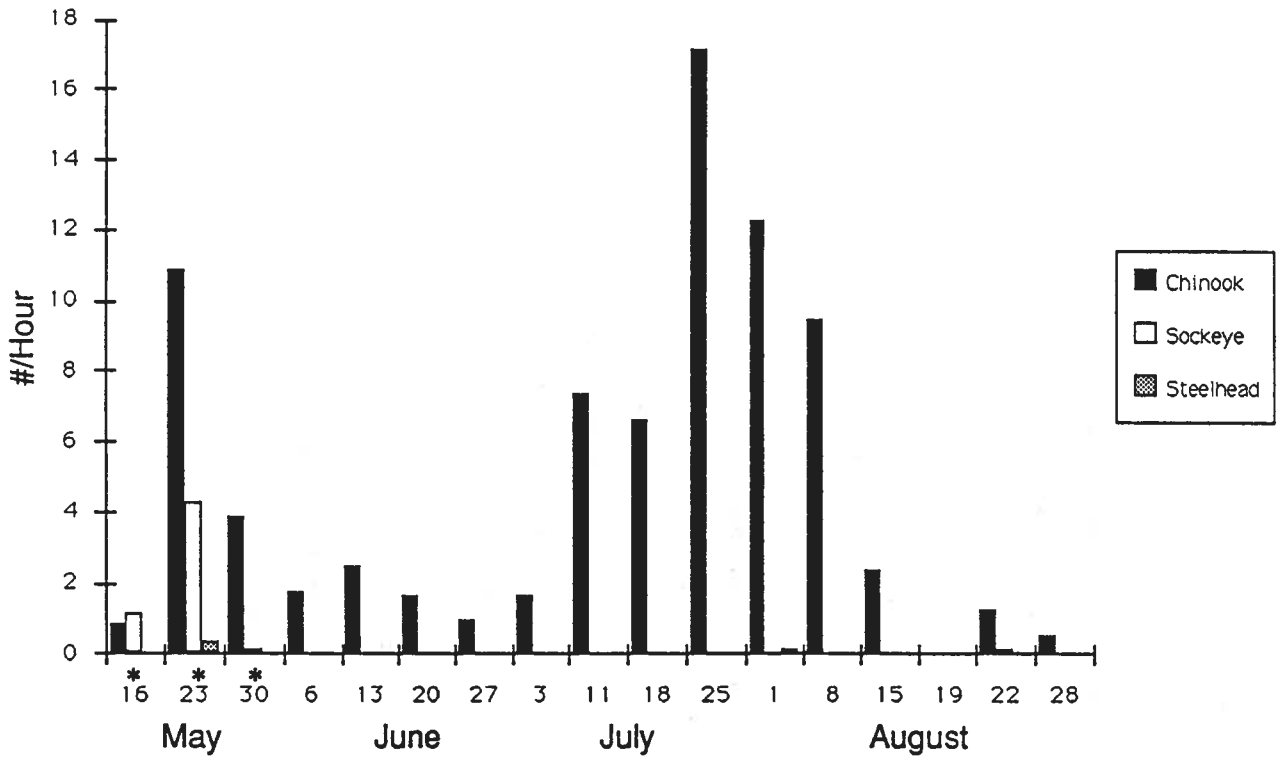

Figure 7A. Catch per hour of chinook (zero-age and yearlings combined), sockeye, and steelhead in the fyke nets at Wells Dam from May 16 to August 28, 1991. (* - Only four nets fished.)

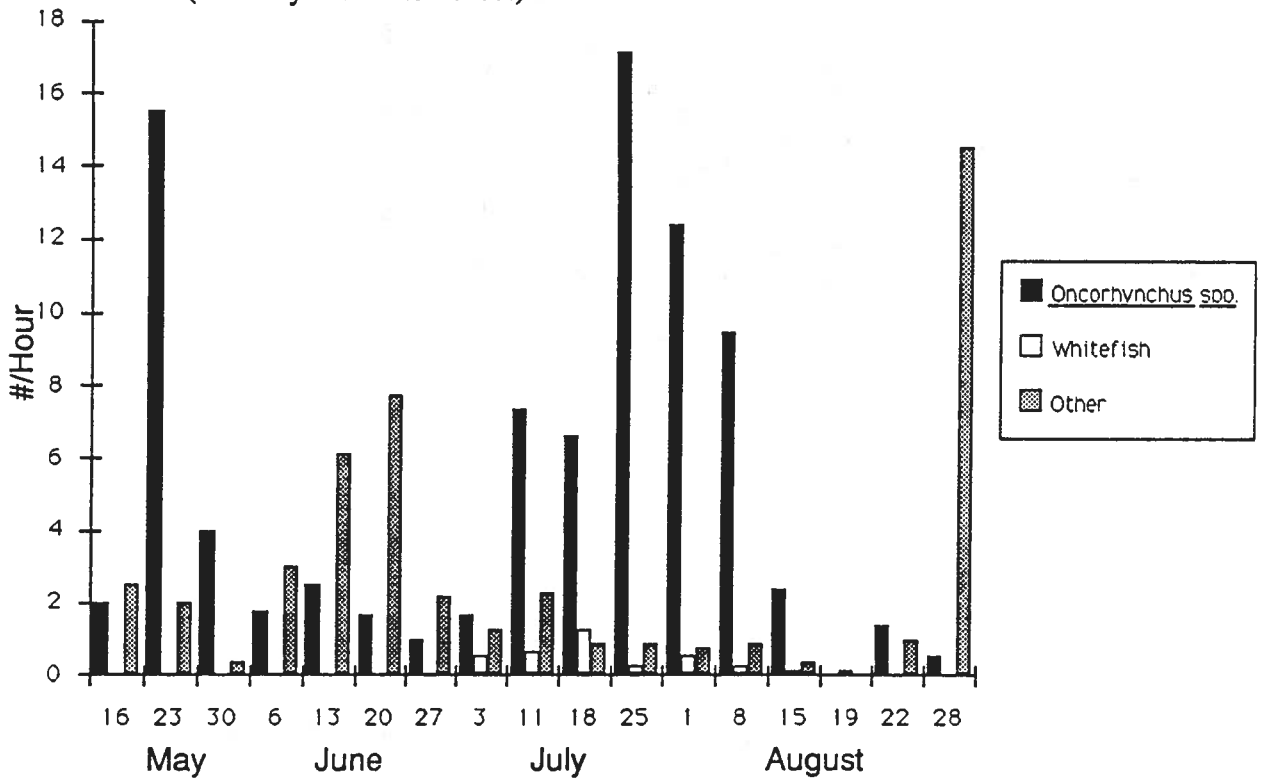

Figure 7B. Catch per hour of *Oncorhynchus spp.*, whitefish, and "other" species in the fyke nets at Wells Dam from May 16 to August 28, 1991.

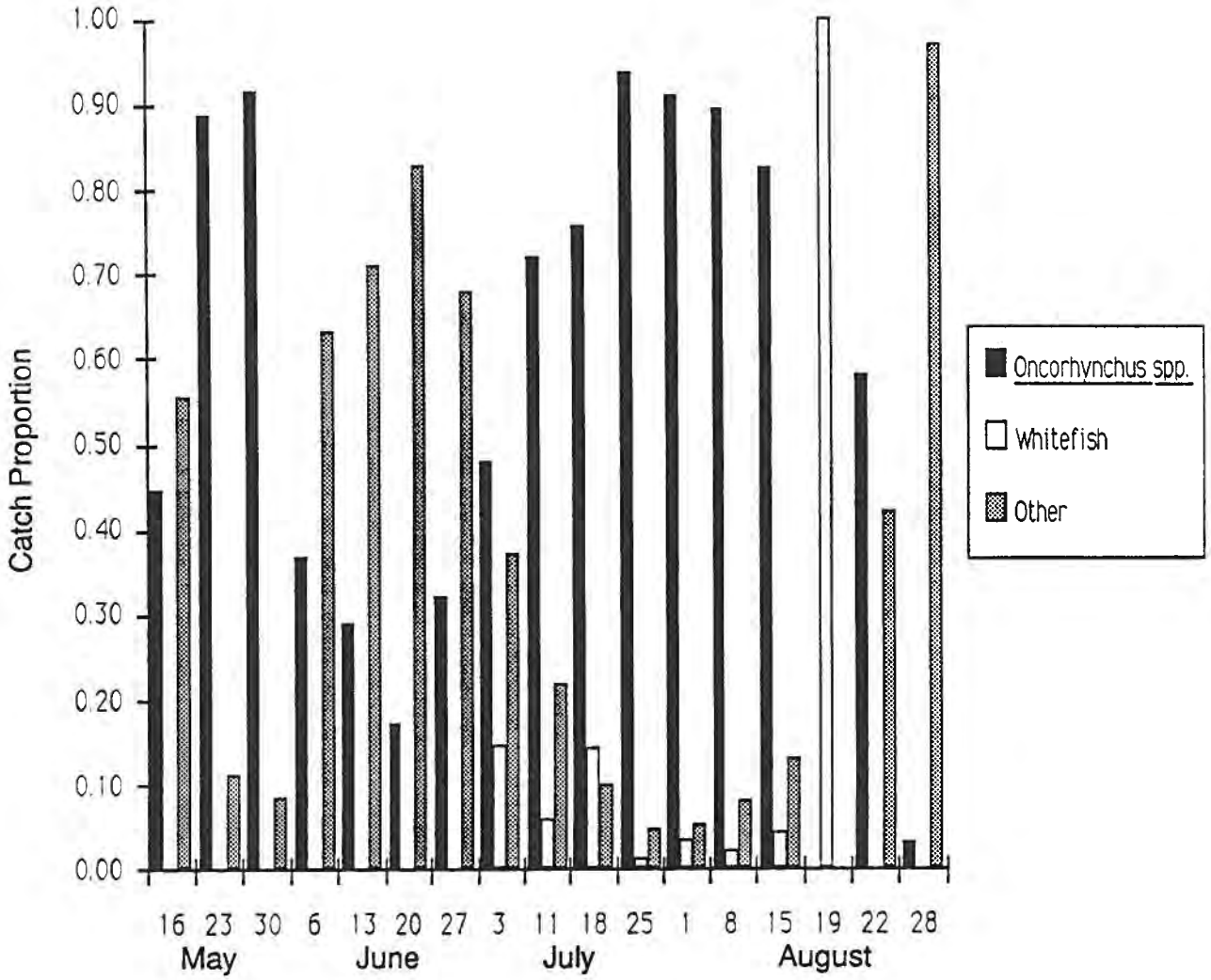

Figure 8. Proportions of the total catch from fyke net samples at Turbine Intake 8C at Wells Dam in 1991, May 16 to August 28.

3.1.3 Run Timing

The daily "sub-index" of run timing (mean #/8hr/location) from March 29 to August 31, 1991 is presented in Figures 9, 10, and 11. The run timing index was calculated using forebay data for all days except during the bypass evaluations when the run timing index was calculated using bypass slot data.

As in past studies, passage was generally low in early April (Figure 9). Passage rates increased dramatically on April 13 with the arrival of chinook from the Winthrop hatchery release. The release occurred on April 11 (Table 4). No fyke netting was done during the first month of the bypass evaluation. Fyke netting began on May 16. Passage rates were generally high during the latter part of April but dropped quickly after April 30 to the lowest passage rate of the spring bypass evaluation on May 2 (Figure 10). After May 2, passage rates gradually increased and there was a large peak on May 14. Passage rates remain high through May 21. The fyke net catch from May 23 was 88% chinook, sockeye, and steelhead (Table 5). As in previous years (Kudera et al. 1990) lowest passage rates occurred during late May and early June (Figure 9).

Passage rates began to steadily increase on June 27 into the summer bypass evaluation period. The fyke net catches from July 3 through August 15 contained between 48% and 94% chinook salmon (Table 5). The summer bypass evaluation showed generally higher passage rates than the spring evaluation. There was a distinct peak on July 12 (Figure 11). The fyke catch of July 11 was 72% chinook (Table 5). Lowest passage of the summer evaluation occurred on July 14. There was another peak on July 16. Passage rates remained relatively constant from July 17 to July 21 and then began to rise dramatically. The fyke data from July 25 and August 1 showed zero-age chinook constituting 86% and 99% of the catch respectively. This was also when the highest fyke net catch rates of the season occurred (Table 5). There was another large peak on August 8 (Figure 9). The fyke catch from August 8 was 89% summer chinook The passage rates remained high and variable through the end of the study period primarily due to increasing numbers of other non-target species. The fyke catch on August 31 was 97% "other" species.

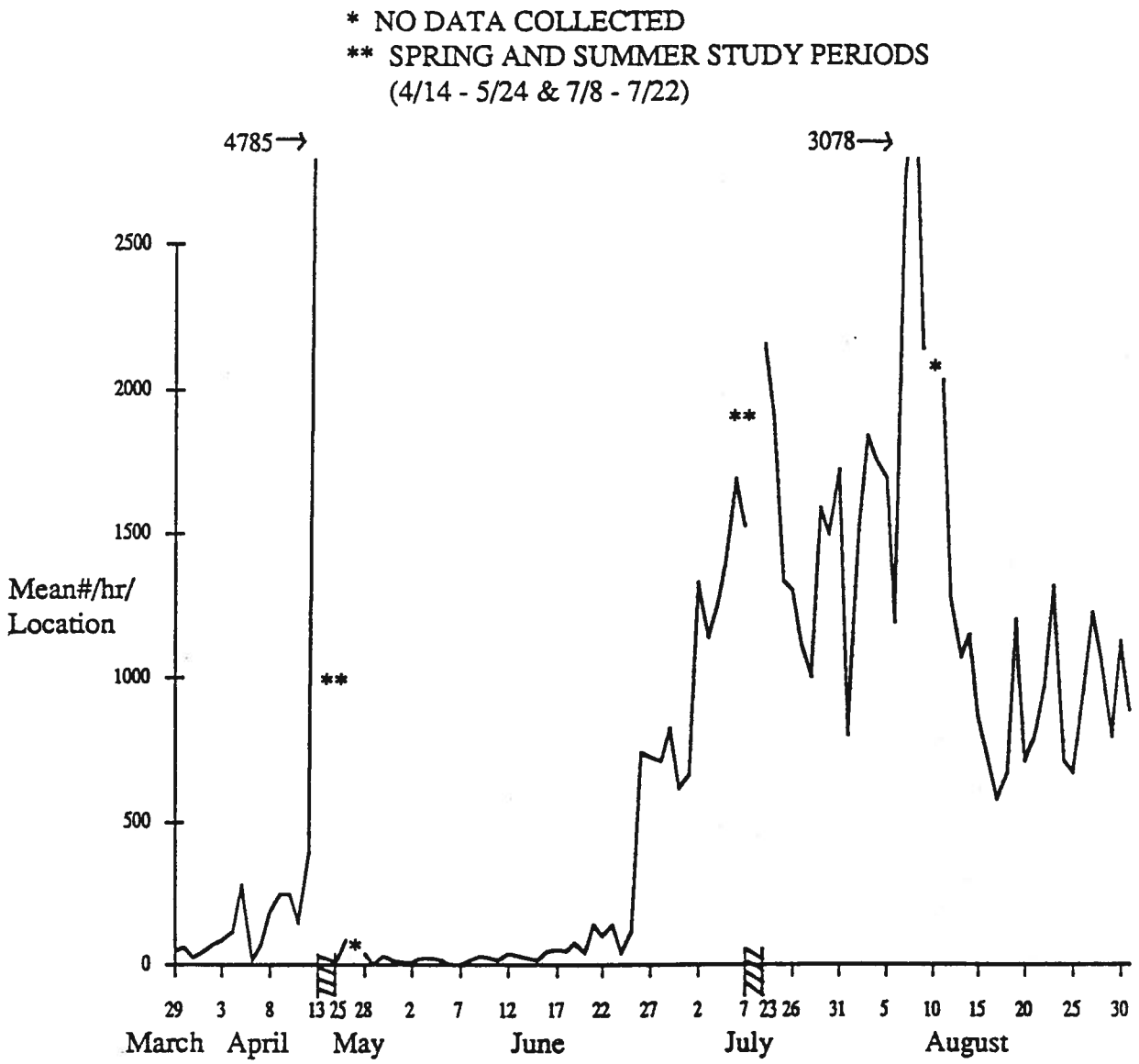

Figure 9. Daily fish passage indices (mean #/8hr/location) for day (1300- 1700h) and night (2200- 0200h) combined at Wells Dam forebay between March 29 and April 13, May 25 through July 7, and July 23 through August 31, 1991.

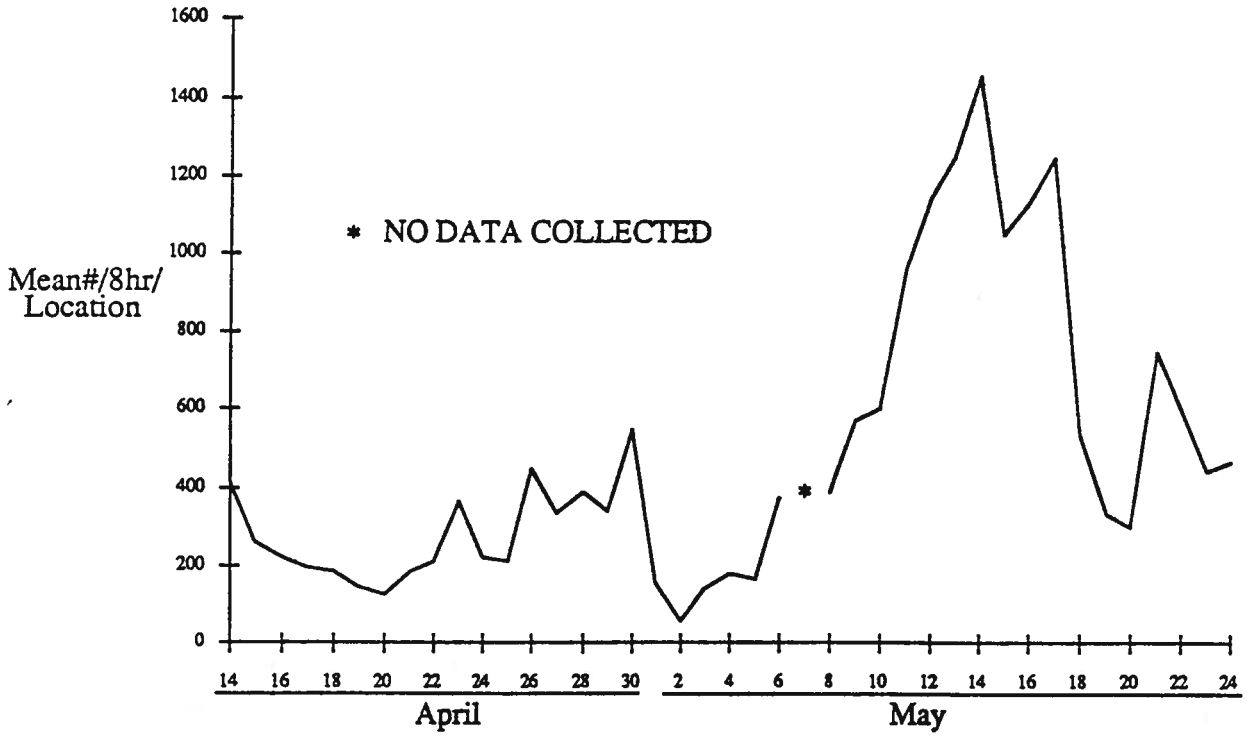

Figure 10. Daily fish passage indices (mean #/8hr/location) for day (1300- 1700h) and night (2200- 0200h) combined using bypass slot data at Wells Dam between April 14 and May 24, 1991.

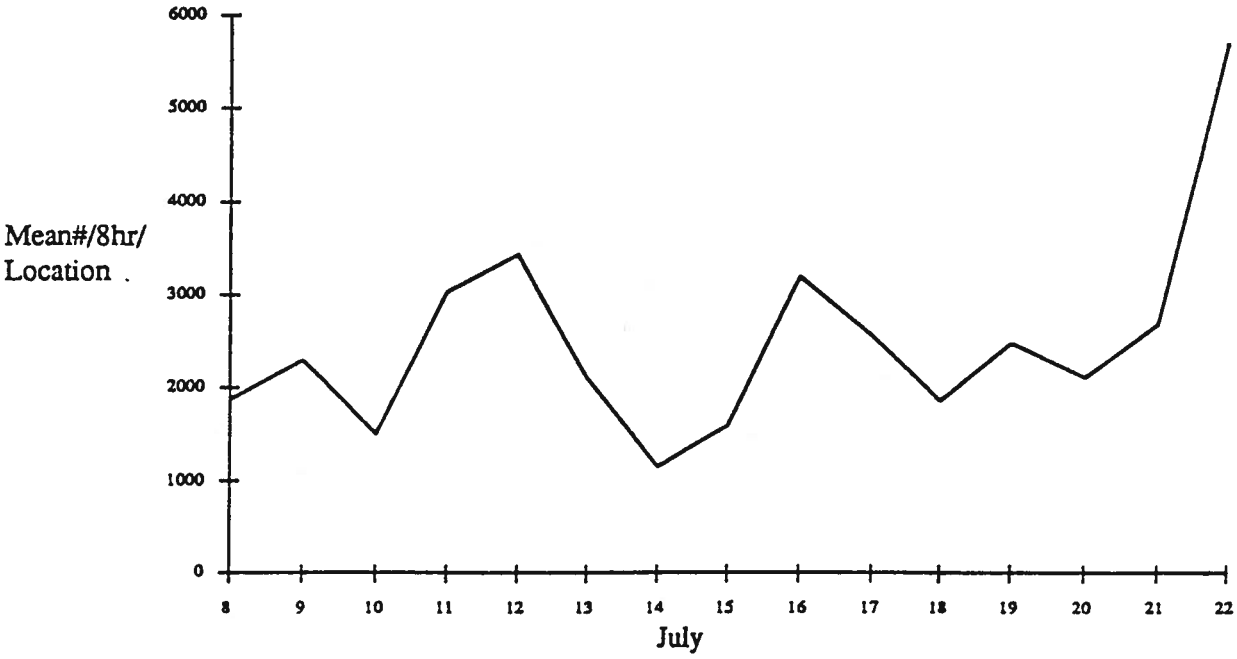

Figure 11. Daily fish passage indices (mean #/8hr/location) for day (1300- 1700h) and night (2200- 0200h) combined using bypass slot data at Wells Dam between July 8 and July 22, 1991.

3.2 Estimated Total Project Bypass Efficiency

Estimated total project bypass efficiency in spring 1991 was 95.0% +/- 0.43%at the 90% confidence level. Daily bypass ratios for spring are given in Figure 12. Daily bypass efficiencies ranged from 73% to 99%. As in 1990, bypass efficiencies were generally higher during the latter part of the spring evaluation. Both April 14 and April 18 had the lowest bypass efficiency of about 73%. The highest efficiency (99%) occurred on May 12.

Estimated total project bypass efficiency in summer 1991 was 97.0% +/- 0.29% at the 90% confidence level. Daily bypass ratios for the summer evaluation are given in Figure 13. Daily bypass efficiencies ranged from 96% to 99%. Bypass efficiencies were higher during the summer than in the spring. Bypass efficiencies were generally higher at the beginning of the summer study. The lowest efficiency (about 96%) occurred on the last day of the evaluation, July 22. The highest efficiency (99%) occurred on July 21.

To summarize, the estimates of **total project bypass efficiency** at Wells Dam in 1991 were:

Spring	95.0% +/- 0.43% at the 90% confidence level
Summer	97.0% +/- 0.29% at the 90% confidence level

The estimate of total project bypass efficiency compares fish passage in bypass flow with passage in bypass plus turbine flow. This estimate assumed that the ability to acoustically detect fish at each location was equivalent . To confirm this assumption, we did an analysis of relative detectability as was done during bypass development (BioSonics 1984). The methods of this analysis are described in Appendix E. The analysis showed that detectabilities between transducers at bypass slot and turbine intake locations under different environmental conditions were equivalent.

Bypass efficiencies were high in 1991. This may have been due to a lesser number of juvenile sockeye migrating past the dam, although data apparently do not exist to support or refute this hypothesis. Fyke net results in past years showed that sockeye were distributed deeper in the water column than other juvenile migrants, hence possibly lowering bypass efficiency. Also, the 1990 bypass efficiencies may have been conservative. The forced spill in 1990 did not allow for complete sampling of all spill bay bypass openings. Some fish undoubtedly passed the dam in this unsampled spill. During 1991, little forced spill occurred during the spring and summer studies.

The confidence intervals were tight because most of the daily bypass efficiencies were very close to one. It is a statistical phenomenon that as the point estimate of a proportion gets close to zero or one, the confidence interval gets smaller (J. Skalski, personal communication). Also, greater sampling effort, i.e. more transducers and smaller sampling intervals than 1990 reduced confidence interval size. The results of the bypass evaluations from 1990 and 1991 show yearly variability.

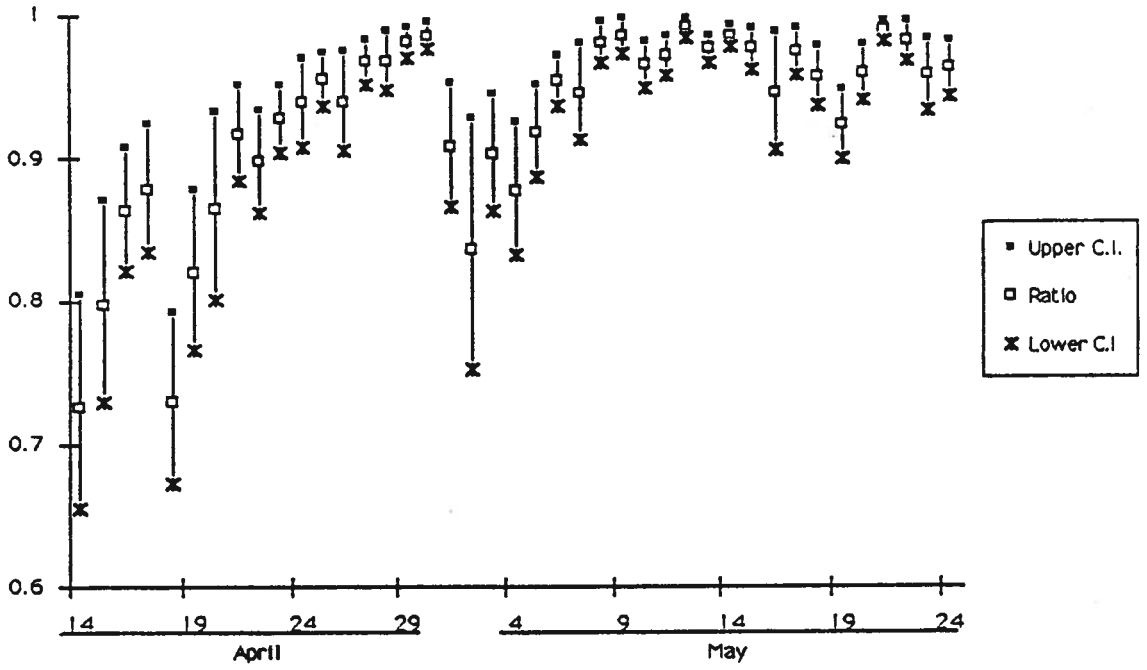

Figure 12. Daily bypass efficiency estimates for spring (April 14 to May 24) at Wells Dam, 1991. Ratios are expressed for 90% confidence levels.

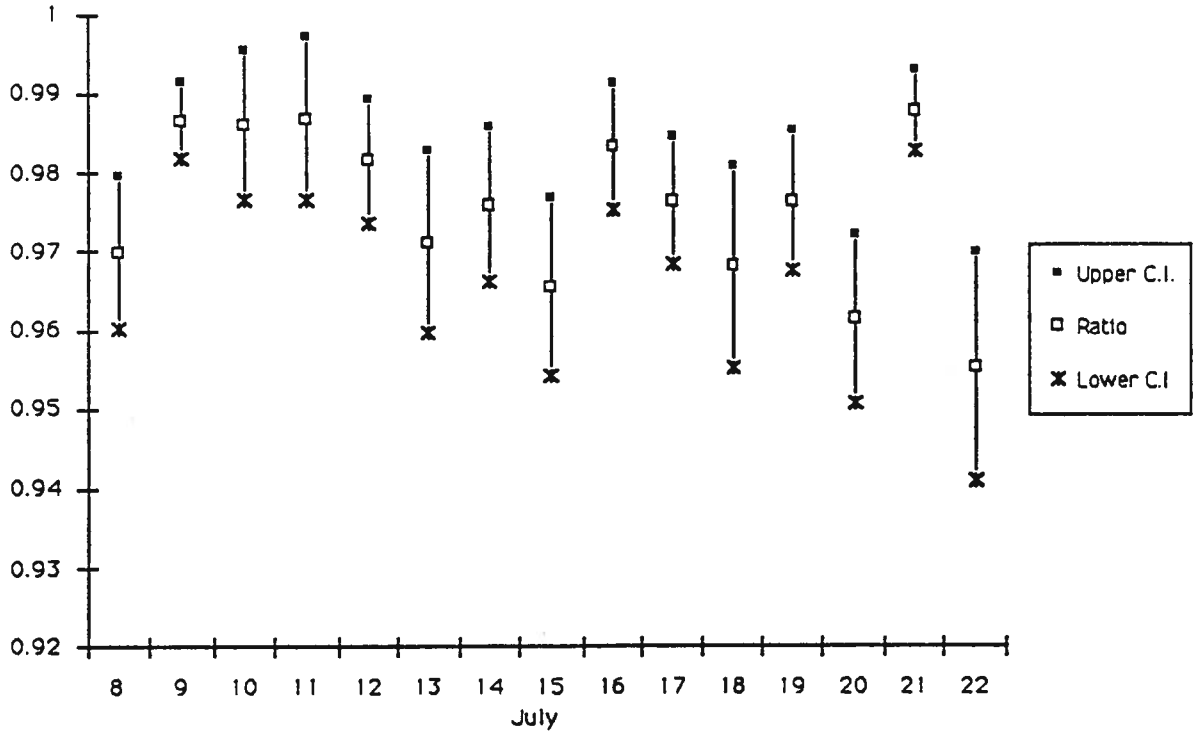

Figure 13. Daily bypass efficiency estimates for summer (July 8 to July 22) at Wells Dam, 1991. Ratios are expressed for 90% confidence levels.

4.0 CONCLUSIONS

(1) Total project bypass efficiency was estimated using hydroacoustic techniques during spring (April 14 to May 24) and summer (July 8 to July 22) study periods at Wells Dam in 1991.

(2) Species composition data were collected using fyke net methods from May 16 to August 28, 1991. Run timing data were collected using hydroacoustic methods from March 29 to August 31, 1991.

(3) Chinook and sockeye salmon and steelhead trout juveniles were predominant during the spring study. Passage rates were lowest during June. Zero-age chinook were predominant from mid-July through mid-August. Whitefish were present in noticeable numbers in July. Other non-target species were predominant through the end of August.

(4) Estimated total project bypass efficiency for the 40-day spring study was 95.0% ± 0.43% at the 90% confidence level.

(5) Estimated total project bypass efficiency for the 15-day summer study was 97.0% ± 0.29% at the 90% confidence level.

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APPENDIX A

HYDROACOUSTIC SYSTEM, DATA ACQUISITION, AND DATA REDUCTION

APPENDIX A. Hydroacoustic System, Data Acquisition, and Data Reduction

A.1 Hydroacoustic System Equipment, Operation, and Calibration

A.1.1 Equipment Description

The hydroacoustic studies at Wells Dam in 1991 required three BioSonics systems. Each system (Figure A1) consisted of the following components: high-frequency transducers (420 kHz) with cable, an echo sounder/multiplexer, two chart recorders, and an oscilloscope. Specific manufacturers and model numbers of the electronic equipment used are listed in Table A1. The hardware parameters used in 1991 are presented in Table A2.

Table A1. Model numbers, manufacturers, and serial numbers of electronic equipment used by BioSonics, Inc. at Wells Dam in spring and summer 1991.

MODEL NO. AND EQUIPMENT	MANUFACTURER	SERIAL NO.
Model 101 (420 kHz) Echo Sounder	BioSonics, Inc.	101-81-010 101-81-031
Model 1005 (420 kHz) Echo Sounder/Multiplexer		1005-91-001 1005-91-002 1005-91-003
Model 151 MPX/EQ Multiplexer/Equalizer	BioSonics, Inc.	151-83-006
Model 111 Chart Recorders	BioSonics, Inc.	111-85-004 111-86-029 111-88-038 111-88-039 111-89-048 111-90-062
Transducers	BioSonics, Inc.	Too numerous to list
Model V-423 Oscilloscope	Hitachi, Inc.	5017445

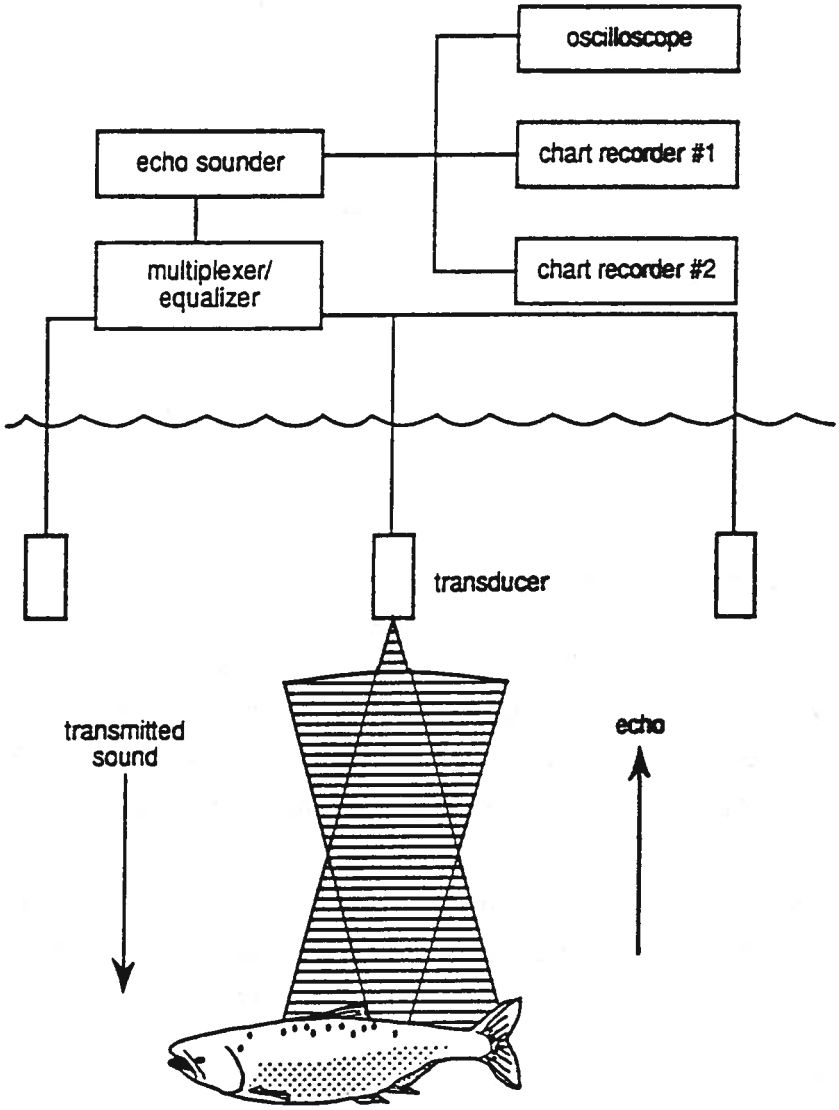

Figure A1. Block diagram of hydroacoustic data collection system used at Wells Dam in 1991.

Table A2. Hydroacoustic system parameters used for studies at Wells Dam in 1991.

ECHO SOUNDER	Transmit frequency: 420 kHz
	Transmit power: 0 dB
	Band width: 5 kHz
	Pulse width: 0.4 msec
	TVG: 40 log(R)
	Trigger source: Thermal chart recorder
	Receiver gain -6 dB
CHART RECORDERS	Threshold: 0.1 volts

A.1.2 Equipment Operation

A BioSonics hydroacoustic system works as follows. When triggered by the Echo Sounder, a high-frequency transducer emits short sound pulses in a relatively narrow beam aimed toward an area of interest. As these sound pulses encounter fish or other targets, echoes are reflected back to the transducer which then reconverts the sound energy to electrical signals. The signals are then amplified by the echo sounder at a 40 log(R) time-varied-gain (TVG) to compensate for the loss of signal strength due to absorption and geometric spreading of the acoustic beam with distance from the transducer. Thus, equally sized targets produce the same signal amplitudes at the echo sounder receiver output regardless of their distance (range) from the transducer. The range of each target from the transducer is determined from the time it takes the sound pulse and echo return to travel that distance (velocity of sound in fresh water = 1445 m/sec).

The echo sounder relays the returning TVG-amplified signals to the chart recorder, oscilloscope, and tape recorder. The return signals are visually displayed on the oscilloscope to observe echo strength and echo duration. Returns from individual fish are recorded on the chart recorder's echograms which provide a permanent record of all targets detected throughout the study. The threshold circuit on the chart recorder is adjusted to eliminate signals less than the echo levels of interest.

The Multiplexer/ Equalizer (MPX/EQ) permits a single echo sounder to automatically interrogate up to 16 different transducers in an operator-specified sequence. The MPX/EQ channels transmit pulses from the echo sounder to the appropriate transducers and equalizes the return signals to compensate for the different receiving sensitivities resulting from varying cable lengths and transducer characteristics.

A.1.3 System Calibration

Each acoustic system was calibrated before the study began. Calibration assured that an echo from a target of known acoustic size passing through the axis of the acoustic beam produced a specific output voltage at the echo sounder. Based on the calibration information, the adjustable print threshold on the chart recorder was set so that it would print signals from targets larger than -56 dB on the acoustic axis of the transducer. The calibration information was also used to equalize the system sensitivity (using the MPX/EQ) for each receiving channel. A system calibration at the end of the season verified that the sensitivities had remained constant throughout the study. A detailed description of the calibration of hydroacoustic systems can be found in Albers (1965) and Urich (1975).

A Biosonics engineer checked the performance of the Model 1005 Sounder/Multiplexer at the end of the spring 1991 study. He discovered an error in the TVG circuit of the receiver boards of all three Model 1005's used. The TVG was slightly under-amplifying the signals. The amount of error was exactly the same on all systems. Thus, although fish detectability was lower than it should have been, it was equivalent for all systems. The ratio of bypass efficiency in spring was not affected by this problem. The TVG was corrected for the summer study.

A.2 Data Acquisition Methods

A.2.1 Migrant Detection Criteria

Echogram traces had to satisfy two criteria to be classified as fish: 1) the strength of target echoes had to exceed a predetermined threshold; and 2) the targets had to be detected by consecutive acoustic pulses (redundancy).

As stated above, the hydroacoustic systems were calibrated so that the chart recorder marked only targets with echo strengths greater than -56 dB on the acoustic axis of each

transducer. This echo strength threshold was chosen so that even the smallest outmigrant salmon and steelhead returned an echo strong enough to mark the echogram.

At least four successive echoes were required for a target to be classified as a fish. Most of the observed fish were detected more than four times in succession. This high redundancy occurred because of the relatively wide beamwidths of the transducers and the high pulse repetition rates. This redundancy criterion enhanced fish detectability in the presence of background interference. Further details of fish detection criteria for fixed-location hydroacoustics can be found in Carlson, *et al.* (1981).

Based on echogram "trace types" (i.e., the pattern of marks produced by successive detections), fish were classified as either "migrants" or "wallowers." Wallowers produced marks consistent with large resident fish milling about in the forebay. Migrant trace types exhibited change-in-range consistent with the smaller smolts. Only fish classified as migrants were included in the analyses.

A.2.2 Background Interference Level

The background interference level on the echograms of each interrogation period was rated on a scale of 1 to 5.

1 = No interference
2 = Little interference, no effect on fish trace recognition
3 = Moderate interference, no effect on fish trace recognition
4 = Excessive interference, adverse effect on fish trace recognition
5 = Black

Interrogation periods with the highest interference levels (4 and 5) were not included in data analysis. During 1991, less than 1% of the data were excluded due to excessive noise.

A.2.3 Data Entry and Storage

Microcomputers were used for data storage and analysis. Data from individual fish detections recorded on the echograms were written to computer data files using a digitizing pad and appropriate software. For each fish detected passing through the acoustic beam, a technician used the digitizing stylus to record the following: time of entrance, time of exit, range at entrance, range at exit, and trace type.

The following information was recorded for each interrogation period:

date
start time of transducer interrogation
duration of transducer interrogation
transducer location
transducer depth
transducer beamwidth
transducer orientation
background interference level

A.3 Data Reduction Methods

A.3.1 Data Selection

Two criteria were used to select the data for the various analyses. First, all fish detections from interrogation periods with excessive background interference were eliminated, as explained in Appendix A.2. Second, based on trace type classification, all non-migrant fish ("wallowers") were excluded. The remaining fish detections were used in the analyses.

A.3.2 Range of Fish

For a given outmigrant, the range from the transducer (R) was the mid-point range of the echo trace as calculated by:

$$R = \frac{R_{in} + R_{out}}{2}$$

where R_{in} and R_{out} are the ranges at which the fish entered and exited the acoustic beam, respectively.

A.3.3 Weighting Factor

Since only a portion of the cross-sectional area at a sampling location was ensonified, individual fish detections were multiplied by a weighting factor to estimate the total relative number of fish passing that location at that particular range and time. To account for the cone-shaped geometry of the acoustic beam, the weighting factor was defined as the ratio of the width at the

sampling location to the width of the acoustic beam at the range of detection. (Sampling location widths were: pier nose = 90 ft; turbine intake = 22.5 ft; bypass slot = 22.5; and bypass spill bay = 46 ft). The weighting factor was:

$$W_{ij} = \frac{I_j}{2R_{ij}\mathrm{Tan}(\theta_j/2)}$$

where:

W_{ij} = weighted observation of fish (i) at location (j);

I_j = width of location (j);

θ_j = nominal beam width (degrees) of transducer at location (j);

R_{ij} = range of fish (i) from transducer at location (j).

Thus, fish detected closer to the transducer were weighted more (to represent more fish) than those detected further away. All subsequent analyses were based on these weighted fish detections.

A.3.4 Fish Passage Indices

An hourly estimate of relative fish passage (#/hr) at location (j) was computed as:

$$F_{jh} = \frac{\sum_{i=1}^{n_{jh}} W_{ijh}}{t_{jh}} \times 60$$

where:

F_{jh} = number of fish per hour at location (j) during hour (h)

W_{ijh} = weighted fish (i) at location (j) during hour (h)

t_{jh} = total number of minutes in hour (h) that location (j) was sampled

n_{jh} = total number of migrant detections at location (j) during hour (h).

APPENDIX B

STATISTICAL DESIGN FOR ESTIMATING TOTAL PROJECT BYPASS EFFICIENCY

STATISTICAL DESIGN FOR ESTIMATING TOTAL PROJECT BYPASS EFFICIENCY AT WELLS DAM IN 1990

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to

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8 June 1989

INTRODUCTION

The objective of the 1990 bypass study at Wells Dam is to estimate total project bypass efficiency (B). Using hydroacoustic techniques, estimates of B will be obtained separately for the spring and summer outmigrations. Total project bypass efficiency is defined as

$$B = \frac{Y}{Y + X}$$

where

Y = total passage of smolt through bypass facilities,

X = total passage of smolt through turbine units.

However, direct enumeration of bypass (Y) and turbine (X) passage is not feasible. Instead, estimates of passage, $\hat{Y}$ and $\hat{X}$, must be used in estimating total project bypass efficiency where

$$\hat{B} = \frac{\hat{Y}}{\hat{Y} + \hat{X}} .$$

The sampling error associated with the estimate, $\hat{B}$, includes two sources of error, the hydroacoustic measurement error and the subsampling error associated with sampling only a fraction of the total spatial and temporal dimensions of the outmigration at Wells Dam. Proper statistical analysis must account for these sources in subsequent confidence interval construction.

The objective of the statistical design and analysis of total project bypass efficiency is to provide a consistent and statistically efficient estimator ($\hat{B}$) and expressions for its variance ($Var(\hat{B} \mid B)$) and estimated variance ($\hat{V}(\hat{B} \mid B)$) which can be subsequently used in designing the survey and confidence interval construction. The form of the estimator and its variance will depend on the sampling schemes used to estimate $\hat{Y}$ and $\hat{X}$ at Wells Dam. Unlike traditional ratio estimators (Cochran 1977), estimates of Y and X will be independent because separate hydroacoustic sampling schemes will be used in monitoring bypass and turbine passage.

Using hydroacoustic data collected at Wells Dam in 1988 and 1989, the magnitude of the anticipated sampling variance associated with $\hat{B}$ can be projected. The projected estimates of $Var(\hat{B} \mid B)$ will be used to evaluate alternative sampling schemes and levels of sampling effort at Wells Dam during the studies of total project bypass efficiency in 1990. Consequently, an important aspect of the statistical design research is the prediction of sampling precision and the selection of a cost-effective, logistically feasible and precise sampling design.

HYDROACOUSTIC MEASUREMENT ERROR AND SUBSAMPLING ERROR

The basis of proposed sampling designs is a stratified random sampling scheme at a turbine slot or bypass unit on an hour-by-hour basis. In other words, the basic stratum is a "unit hour." Within that hour, only a fraction of the time will be sampled by the hydroacoustic apparatus. For example, let the hour be divided into N equal time intervals of length $60/N$ minutes. Then, if the sampling scheme monitors n of these N intervals, an unbiased estimate of total passage during that unit hour (Z) is

$$Z = \frac{N}{n}\sum_{i=1}^{n} \hat{z}_i$$

where

$\hat{z}_i$ = number of fish estimated to have passage through the unit during the ith interval by the hydroacoustic apparatus,

provided $\hat{z}_i$ is an unbiased estimate of z_i, the actual fish passage in the ith interval.

The variance of $\hat{Z}$ will consist of both subsampling error and hydroacoustic measurement error. To see how these error sources contribute to the overall variance, we can use the total variance formula

$$
\begin{aligned}
Var(\hat{Z}) &= Var_{z_i}[E(\hat{Z} \mid z_i)] + E_{z_i}[Var(\hat{Z} \mid z_i)] \\
&= Var_{z_i}\left[E\left(\frac{N}{n}\sum_{i=1}^{n} \hat{z}_i \mid z_i\right)\right] + E_{z_i}\left[Var\left(\frac{N}{n}\sum_{i=1}^{n} \hat{z}_i \mid z_i\right)\right] \\
&= Var_{z_i}\left[\frac{N}{n}\sum_{i=1}^{n} z_i\right] + E_{z_i}\left[\frac{N^2}{n^2}\sum_{i=1}^{n} Var(\hat{z}_i \mid z_i)\right] \\
&= N^2\left(1-\frac{n}{N}\right)\frac{S^2_{z_i}}{n} + \frac{N}{n}\sum_{i=1}^{N} Var(\hat{z}_i \mid z_i) \\
Var(\hat{Z}) &= \frac{N^2}{n}\left(1-\frac{n}{N}\right)S^2_{z_i} + \frac{N^2}{n}\overline{Var(\hat{z}_i \mid z_i)} \qquad (1)
\end{aligned}
$$

where

$$S^2_{z_i} = \frac{\sum_{i=1}^{N}(z_i - \bar{z})^2}{N-1} .$$

In a sample survey of fish passage, the $Var(\hat{Z})$ would be estimated by

$$\hat{Var}(\hat{Z}) = \frac{N^2}{n}\left(1-\frac{n}{N}\right)s^2_{z_i}$$

where

$$s^2_{z_i} = \frac{\sum_{i=1}^{n}\left(z_i - \hat{\bar{z}}\right)^2}{(n-1)} .$$

This estimate of the variance has the expected value

$$
\begin{aligned}
E\left[\frac{N^2}{n}\left(1-\frac{n}{N}\right)s^2_{z_i}\right] &= \frac{N^2}{n}\left(1-\frac{n}{N}\right)E\left(s^2_{z_i}\right) \\
&= \frac{N^2}{n}\left(1-\frac{n}{N}\right)S^2_{z_i} + \frac{N^2}{n}\left(1-\frac{n}{N}\right)\overline{Var(\hat{z}_i \mid z_i)} \cdot \qquad (2)
\end{aligned}
$$

Hence, the empirical variance, $s^2_{z_i}$, implicitly incorporates both the subsampling error and the hydroacoustic measurement error. Comparison of variance formulas (1) and (2) shows, however, the variance estimate (2) is negatively biased. The second term in formula (2) has the additional

factor of $\left(1-\frac{n}{N}\right)$ which variance formula (1) does not possess. Typically, it is believed that the measurement error ($Var(\hat{z}_i \mid z_i)$) is small relative to $S^2_{z_i}$, so the bias will be small. Furthermore, the bias is proportional to $\left(1-\frac{n}{N}\right)$, which for the Wells Dam study will be .80, close to the required 1.0 in formula (1). A conservative but always valid estimator of the true variance can be obtained by ignoring the finite population correction (i.e., $\left(1-\frac{n}{N}\right)$).

The conclusion of these computations is that we can avoid explicit measurement of hydroacoustic measurement error and still incorporate that error source in the overall variance of $\hat{B}$ and in confidence interval construction of B.

PROPOSED SAMPLING DESIGN

The sampling design has two major components which need to be considered; these are the spatial sampling of the bypass and turbine units at Wells Dam and the temporal sampling of days during the outmigration. Independent estimates of the spring bypass efficiency ($\hat{B}$) and summer bypass efficiency ($\hat{B}$) will be derived during the 1990 sampling program. The sampling designs will be the same for both seasons. Outlined below are general descriptions of the proposed sampling schemes and the statistical designs for the estimates of total project bypass efficiency (B).

Wells Dam Sampling Scheme

A. Temporal Sampling

- Sampling will be conducted every day during the designated spring and summer study periods.
- The spring period will last from 20-30 days. The period will begin shortly after the Winthrop chinook releases and will sample varying proportions of chinook, sockeye and steelhead.

- The summer period will last from 10-20 days. The sampling will begin when subyearling chinook occur in reasonable numbers in weekly fyke net catches.
- Sampling will occur 24 hours each day.
- Each "unit hour" will be sampled for a total of 12 minutes per hour.
- Within a "unit hour," a minimum of two samples will be taken. Prior data will be used to determine the benefits of allocating sampling effort, as

    a. 2 6-minute samples,

    b. 3 4-minute samples,

    c. 4 3-minute samples,

    d. 6 2-minute samples.

- Within a "unit hour," systematic sampling will be conducted. The choice of the systematic sampling sequence at a unit will be randomly assigned to each unit at the beginning of spring and summer seasons.

B. Spatial Sampling

1. Bypass Units

    - Five of the five bypass units at Wells Dam will be sampled.

2. Turbine Units

    - Ten of the ten turbine units will be sampled.
    - At each turbine unit, two of three turbine slots will be sampled randomly. The choice of turbine slots will remain constant during a season.

STATISTICAL SAMPLING DESIGN

The proposed sampling design at Wells Dam can be characterized by the separate designs for bypass units and turbine units. The results of the separate sampling schemes are then combined to provide the estimate of total project bypass efficiency (B). Below are formal descriptions of the estimators and variances for each sampling scheme.

Bypass Sampling Design

Sampling every day of the study period simplifies the statistical design and eliminates a potentially large error source (i.e., day-to-day variation) in estimating bypass passage (Y). Furthermore, by sampling at each bypass unit, the bypass-to-bypass variation is also eliminated. The resulting sampling design at the bypass units is a single stage sample using stratified sampling of "unit hours" across the dam and through time. Within a "unit hour," a systematic sample will be collected during the hour, and repeated each hour of the survey. In constructing the estimator, variance and estimated variance of the estimator, sampling will be assumed to be stratified random sampling. The consequences of assuming random sampling will be assessed using Monte Carlo simulations.

Define the following terms:

y_{ijkg} = number of fish detected in the gth sampling unit ($g = 1, 2, \ldots, l_{ijk}$) in the kth hour ($k = 1, 2, \ldots, 24$) at the jth bypass ($j = 1, 2, \ldots, 5$) on the ith day ($i = 1, 2, \ldots, D$),

L_{ijk} = number of sampling units in the kth hour ($k = 1, 2, \ldots, 24$) at the jth bypass ($j = 1, 2, \ldots, 5$) on the ith day ($i = 1, 2, \ldots, D$),

l_{ijk} = number of sampling units sampled in the kth hour ($k = 1, 2, \ldots, 24$) at the jth bypass ($j = 1, 2, \ldots, 5$) on the ith day ($i = 1, 2, \ldots, D$).

Then the estimate of total bypass passage (Y) is

$$\hat{Y} = \sum_{i=1}^{D}\sum_{j=1}^{3}\sum_{k=1}^{24}\sum_{g=1}^{l_{ijk}}\left[\frac{L_{ijk}}{l_{ijk}}y_{ijkg}\right] . \tag{3}$$

The variance of $\hat{Y}$ follows directly from stratified random sampling (Appendix A), where

$$Var(\hat{Y}\,|\,Y) = \sum_{i=1}^{D}\sum_{j=1}^{3}\sum_{k=1}^{24}\left[L_{ijk}^2\left(1-\frac{l_{ijk}}{L_{ijk}}\right)\frac{S_{y_{ijk}}^2}{l_{ijk}}\right] . \tag{4}$$

and where

$$S_{y_{ijk}}^2 = \frac{\sum_{g=1}^{l_{ijk}}(y_{ijkg}-\overline{y_{ijk}})^2}{(L_{ijk}-1)} .$$

Note, the proposed sampling fraction within a "unit hour" is

$$\frac{l_{ijk}}{L_{ijk}} = \frac{12}{60} = .20 .$$

Turbine Sampling Design

The estimate of total turbine passage is based on a two-stage sampling scheme. The first stage of sampling is the selection of two of three turbine slots in each turbine unit. The second stage of the sampling design is the stratified random sampling of each "unit hour." As was the case in estimating bypass passage, in practice, a systematic sample within the "unit hour" will be used in estimating total turbine passage. The anticipated consequence of using a systematic sample in conjunction with a variance formula based on random sampling is to overestimate the true variance.

Define the following terms, where:

x_{ijklg} = number of fish detected in the gth sampling unit ($g = 1, 2, \ldots, h_{ijkl}$) in the lth hour ($l = 1, 2, \ldots, 24$) during the kth day ($k = 1, 2, \ldots, D$) in the jth slot ($j = 1, 2$) of the ith turbine unit ($i = 1, 2, \ldots, 10$),

H_{ijkl} = number of sampling units in the lth hour ($l = 1, 2, \ldots, 24$) of the kth day ($k = 1, 2, \ldots, D$) in the jth slot ($j = 1, 2$) of the ith turbine unit ($i = 1, 2, \ldots, 10$),

h_{ijkl} = number of sampling unit sampled in the lth hour ($l = 1, 2, \ldots, 24$) of the kth day ($k = 1, 2, \ldots, D$) in the jth slot ($j = 1, 2$) of the ith turbine unit ($i = 1, 2, \ldots, 10$).

Then the estimate of total turbine passage is

$$\hat{X} = \sum_{i=1}^{10}\left[\sum_{j=1}^{2}\frac{3}{2}\left[\sum_{k=1}^{D}\sum_{l=1}^{24}\sum_{g=1}^{h_{ijkl}}\left[\frac{H_{ijkl}}{h_{ijkl}}x_{ijklg}\right]\right]\right] . \tag{5}$$

Since $\hat{X}$ is based on two-stage sampling, the variance of $\hat{X}$ will consist of two variance components. The variance of $\hat{X}$ can be expressed as (Appendix B)

$$Var(\hat{X} \mid X) = \frac{3}{2}\sum_{i=1}^{10} S^2_{X_{ij}} + \frac{3}{2}\sum_{i=1}^{10}\sum_{j=1}^{3}\sum_{k=1}^{D}\sum_{l=1}^{24}\left[H^2_{ijkl}\left(1 - \frac{h_{ijkl}}{H_{ijkl}}\right)S^2_{X_{ijkl}}\right] . \tag{6}$$

where

$$S^2_{X_{ij}} = \frac{\sum_{j=1}^{3}(X_{ij} - \bar{X}_i)^2}{(3-1)}$$

and where

$$S^2_{X_{ijkl}} = \frac{\sum_{g=1}^{H_{ijkl}}(x_{ijklg} - \bar{x}_{ijkl})^2}{(H_{ijkl} - 1)} .$$

Overall Sampling Design

Using the delta method (Appendix C), the overall variance of the estimate of total project bypass efficiency ($\hat{B}$) can be expressed as a function of the variances (4) and (6). The variance of $\hat{B}$ is

$$Var(\hat{B}\,|\,B) = B^2(1-B)^2\left[\frac{Var(\hat{Y}\,|\,Y)}{Y^2}+\frac{Var(\hat{X}\,|\,X)}{X^2}\right] \tag{7}$$

or

$$Var(\hat{B}\,|\,B) = B^2(1-B)^2[CV(\hat{Y})^2+CV(\hat{X})^2] \tag{8}$$

where CV denotes the coefficient of variation. Unlike variances for typical ratio estimators, the covariance between $\hat{X}$ and $\hat{Y}$ is not incorporated in the variance of $\hat{B}$. The reason the covariance of $\hat{X}$ and $\hat{Y}$ does not enter into the variance of $\hat{B}$ is that independent sampling schemes are used to estimate $\hat{X}$ and $\hat{Y}$ and all D of D days within a bypass study are sampled.

PRECISION OF THE BYPASS STUDY

The precision of the estimate of total project bypass efficiency ($\hat{B}$) will be defined as

$$P(|\hat{B}-B|<\epsilon) = 1-\alpha \tag{9}$$

In other words, we want the absolute difference between the estimate ($\hat{B}$) and true bypass efficiency (B) to be less than ϵ, with probability $1-\alpha$. For example, letting $\epsilon = .05$ and $\alpha = .10$, specifies a precision of

$$P(|\hat{B}-B|<.05) = .90$$

where we want the absolute error in estimating bypass efficiency to be less than 5%, 90% of the time, with the proposed sampling design. Assuming $\hat{B}$ to be approximately normally distributed, the anticipated sampling error in the Wells bypass study can be predicted by the formula (Appendix D)

$$\epsilon = Z_{1-\frac{\alpha}{2}} B(1-B)\sqrt{CV(\hat{Y})^2 + CV(\hat{X})^2} \quad . \tag{10}$$

Hence, we can investigate the precision of $\hat{B}$ by determining the precision of the proposed bypass and turbine passage estimates. Data from the 1988 and 1989 hydroacoustic studies at Wells Dam will be used to evaluate the precision of the anticipated design for 1990.

FUTURE DESIGN RESEARCH

Two aspects of the research on the study design have yet to be performed. The first aspect is the analysis of the 1988, 1989 data for purposes of predicting the precision of the 1990 total project bypass efficiency estimate. Among the outcomes of this investigation will be the determination of whether 12 min./hr. is adequate sampling within a "unit hour" and how to allocate that sampling time within the hour (e.g., two 6-min. samples versus six 2-min. samples).

The second aspect of the statistical design is the identification of the most appropriate means of confidence interval estimation of B. It is not always sufficient simply to have a point estimate, $\hat{B}$, and its variance estimate, $V\hat{a}r(\hat{B} \mid B)$, for valid and efficient confidence interval estimation. Monte Carlo studies will be performed to assure the confidence interval estimator has nominal coverage with minimum width. Another aspect of the Monte Carlo studies is to assess the effect of using systematic sampling within a "unit hour" and computing the variance based on the formula for random sampling. Wolter (1984) suggests the systematic sampling will overestimate the true variance, making the resulting confidence interval estimation conservative yet valid.

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Appendix A

Variance of Total Bypass Passage

The single stage sampling design used in estimating total bypass passage constitutes stratified random sampling (in practice systematic). The variance of $\hat{Y}$ follows directly, where

$$Var(\hat{Y}\,|\,Y) = Var\left[\sum_{i=1}^{D}\sum_{j=1}^{S}\sum_{k=1}^{24}\sum_{g=1}^{l_{ijk}}\left[\frac{L_{ijk}}{l_{ijk}}y_{ijkg}\right]\right]$$

$$Var(\hat{Y}\,|\,Y) = \sum_{i=1}^{D}\sum_{j=1}^{S}\sum_{k=1}^{24}Var[L_{ijk}\overline{y_{ijk}}]$$

$$Var(\hat{Y}\,|\,Y) = \sum_{i=1}^{D}\sum_{j=1}^{S}\sum_{k=1}^{24}\left[L_{ijk}^{2}\left(1-\frac{l_{ijk}}{L_{ijk}}\right)\frac{S_{y_{ijk}}^{2}}{l_{ijk}}\right]$$

and where

$$S_{y_{ijk}}^{2} = \frac{\sum_{g=1}^{L_{ijk}}(y_{ijkg}-\overline{y_{ijk}})^{2}}{(L_{ijk}-1)} .$$

Appendix B

Variance of Total Turbine Passage

The estimate of total turbine passage is obtained using two-stage sampling, the first stage, the selection of two of three turbine slots per turbine unit, the second stage, the sampling within a "unit hour." Similarly, the variance of $\hat{X}$ can be found in stages

$$Var(\hat{X} \mid X) = Var_{S_1}[E_{S_2}(\hat{X} \mid S_1)] + E_{S_1}[Var_{S_2}(\hat{X} \mid S_1)] \qquad (B1)$$

and where S_1 denotes the stratified random sampling of slots within a turbine unit, and S_2 denotes the stratified random sampling within a "unit hour."

Considering the first term of the variance

$$Var_{S_1}[E_{S_2}(\hat{X} \mid S_1)] = Var_{S_1}\left[E_{S_2}\left[\sum_{i=1}^{10}\sum_{j=1}^{2}\frac{3}{2}\sum_{k=1}^{D}\sum_{l=1}^{24}\left(\sum_{g=1}^{h_{ijk}}\frac{x_{ijklg}}{h_{ijkl}}H_{ijkl}\right)\middle| S_1\right]\right].$$

$$= Var_{S_2}\left[\sum_{i=1}^{10}\sum_{j=1}^{2}\frac{3}{2}X_{ij}\right]$$

$$Var_{S_1}[E_{S_2}(\hat{X} \mid S_1)] = \sum_{i=1}^{10}\frac{9}{2}\left(1-\frac{2}{3}\right)S^2_{X_{ij}} = \frac{3}{2}\sum_{i=1}^{10}S^2_{X_{ij}} \qquad (B2)$$

where

$$S^2_{X_{ij}} = \frac{\sum_{j=1}^{3}(X_{ij}-\overline{X}_i)^2}{(3-1)} .$$

The second term of the variance is evaluated as

$$
\begin{aligned}
E_{S_1}[Var_{S_2}(\hat{X} \mid S_1)] &= E_{S_1}\left[Var_{S_2}\left[\sum_{i=1}^{10}\sum_{j=1}^{2}\frac{3}{2}\sum_{k=1}^{D}\sum_{l=1}^{24}\left(\sum_{g=1}^{h_{ijkl}} \frac{x_{ijklg}}{h_{ijkl}} H_{ijkl}\right) \middle| S_1 \right]\right] \\
&= E_{S_1}\left[\frac{9}{4}\sum_{i=1}^{10}\sum_{j=1}^{2}\sum_{k=1}^{D}\sum_{l=1}^{24}\left(\frac{H_{ijkl}^2}{h_{ijkl}}\left(1-\frac{h_{ijkl}}{H_{ijkl}}\right)S_{x_{ijkl}}^2\right)\right] \\
&= \frac{9}{4}\sum_{i=1}^{10}\frac{2}{3}\sum_{j=1}^{3}\sum_{k=1}^{D}\sum_{l=1}^{24}\left(\frac{H_{ijkl}^2}{h_{ijkl}}\left(1-\frac{h_{ijkl}}{H_{ijkl}}\right)S_{x_{ijkl}}^2\right) \\
&= \frac{3}{2}\sum_{i=1}^{10}\sum_{j=1}^{3}\sum_{k=1}^{D}\sum_{l=1}^{24}\left(\frac{H_{ijkl}^2}{h_{ijkl}}\left(1-\frac{h_{ijkl}}{H_{ijkl}}\right)S_{x_{ijkl}}^2\right) \qquad (B3)
\end{aligned}
$$

where

$$
S_{x_{ijkl}}^2 = \frac{\sum_{g=1}^{H_{ijkl}} (x_{ijklg} - \bar{x}_{ijkl})^2}{(H_{ijkl}-1)}
$$

The variance of $\hat{X}$ given by (B1) is therefore the sum of (B2) and (B3), where

$$
Var(\hat{X} \mid X) = \frac{3}{2}\sum_{i=1}^{10} S_{X_{ij}}^2 + \frac{3}{2}\sum_{i=1}^{10}\sum_{j=1}^{3}\sum_{k=1}^{D}\sum_{l=1}^{24}\left[\frac{H_{ijkl}^2}{h_{ijkl}}\left(1-\frac{h_{ijkl}}{H_{ijkl}}\right)S_{x_{ijkl}}^2\right].
$$

Appendix C

Variance of the Estimate of Total Project Bypass Efficiency

Using the delta method, the variance of $\hat{B}$ is computed to be

$$Var\left(\frac{\hat{Y}}{\hat{Y}+\hat{X}}\right) = Var(\hat{Y})\left(\frac{X^2}{(X+Y)^4)}\right)+Var(\hat{X})\left(\frac{Y^2}{(X+Y)^4}\right)-2Cov(\hat{X},\hat{Y})\left(\frac{XY}{(X+Y)^4}\right) \quad . \quad (C1)$$

However, the covariance term is shown to be zero by computing it in stages, where

$$Cov(\hat{X},\hat{Y}) = E_{S_1}[Cov_{S_2}(\hat{X},\hat{Y}\mid S_1)]+Cov_{S_1}[E_{S_2}(\hat{X}\mid S_1).E_{S_2}(\hat{Y}\mid S_1)]$$

and where S_1 denotes sampling of days during the study, and S_2 denotes sampling within a day. Evaluating the covariance

$$Cov(\hat{X},\hat{Y}) = E_{S_1}[0]+Cov_{S_1}\left[\sum_{k=1}^{D} X_k.\sum_{k=1}^{D} Y_k\right]$$

$$Cov(\hat{X},\hat{Y}) = \frac{D^2}{D}\left(1-\frac{D}{D}\right)Cov(X_k,Y_k) = 0$$

from Hansen, Hurwitz and Madow (1953: eq (1.15), page 148, Vol. 2).

The resulting variance (C1) can then be expressed as

$$Var(\hat{B}\mid B) = B^2(1-B)^2\left[\frac{Var(\hat{Y})}{Y^2}+\frac{Var(\hat{X})}{X^2}\right]$$

or

$$Var(\hat{B}\mid B) = B^2(1-B)^2[CV(\hat{Y})^2+CV(\hat{X})^2] \quad .$$

Appendix D

Precision of Total Project Bypass Efficiency ($\hat{B}$)

Defining precision in terms of the absolute deviation between the estimate ($\hat{B}$) and the true value of total project bypass efficiency (B), we have the probability expression

$$P(|\hat{B}-B|<\epsilon) = 1-\alpha$$

$$P(-\epsilon<\hat{B}-B<\epsilon) = 1-\alpha$$

$$P\left(\frac{-\epsilon}{\sqrt{Var(\hat{B})}}<\frac{\hat{B}-B}{\sqrt{Var(\hat{B})}}<\frac{\epsilon}{\sqrt{Var(\hat{B})}}\right) = 1-\alpha \cdot$$

Assuming approximate normality,

$$P\left(\frac{-\epsilon}{\sqrt{Var(\hat{B})}}<Z<\frac{\epsilon}{\sqrt{Var(\hat{B})}}\right) = 1-\alpha$$

$$P\left(Z<\frac{-\epsilon}{\sqrt{Var(\hat{B})}}\right) = \frac{\alpha}{2}$$

$$\Phi\left(\frac{-\epsilon}{\sqrt{Var(\hat{B})}}\right) = \frac{\alpha}{2}$$

where Φ denotes the cumulative normal distribution. The error in estimation (ϵ) for a particular probability ($1-\alpha$) of coverage (e.g., 90% implies $\alpha = .10$) can be solved as a function of the variance of $\hat{B}$ and $1-\alpha$ where

$$\frac{-\epsilon}{\sqrt{Var(\hat{B})}} = Z_{\frac{\alpha}{2}}$$

$$\epsilon = Z_{1-\frac{\alpha}{2}} B(1-B)\sqrt{CV(\hat{Y})^2+CV(\hat{X})^2}$$

and can be used in evaluating the anticipated performance of the sampling program.

APPENDIX C

HORIZONTAL AND DIEL DISTRIBUTION RESULTS

C.1 Horizontal Distributions

As in previous years, the horizontal distribution data from the bypass slots during the spring study (April 14 to May 24) showed greater passage at the west end of the dam (Figure C1). Nighttime passage rates were higher than daytime passage rates. The highest passage rate occurred at S6. Next highest passage occurred at S2, followed closely by S4. Slot passage was lowest at S10.

Turbine horizontal distribution data from spring showed highest passage rates at 10C (Figure C2). Units 1 and 6 also had high passage rates. The lowest passage rates occurred at Units 4 and 5. Data from turbine intakes also showed generally higher nighttime passage than daytime. Passage rates in turbine were much lower than in bypass slots.

As in spring, summer (July 8 to July 22) bypass slot passage rates are higher towards the west end of the dam (Figure C3). Again, S6 showed the highest rates of all. The lowest passage rate occurs at S10. S2, S4, S6, and S8 had higher daytime passage rates than nighttime. S10 had a slightly higher nightime passage rate. Passage rates overall were higher during the summer than in the spring

As the case with bypass slot, data passage rates in turbine during summer were higher during the daytime hours than during nighttime (Figure C4). The highest rates occured at Units 2 and 9. The highest rate of all occured at 2B. Unit 10 showed the third highest passage rate. The lowest passage rate was at Unit 5 again. Passage rates overall were higher in summer than in spring.

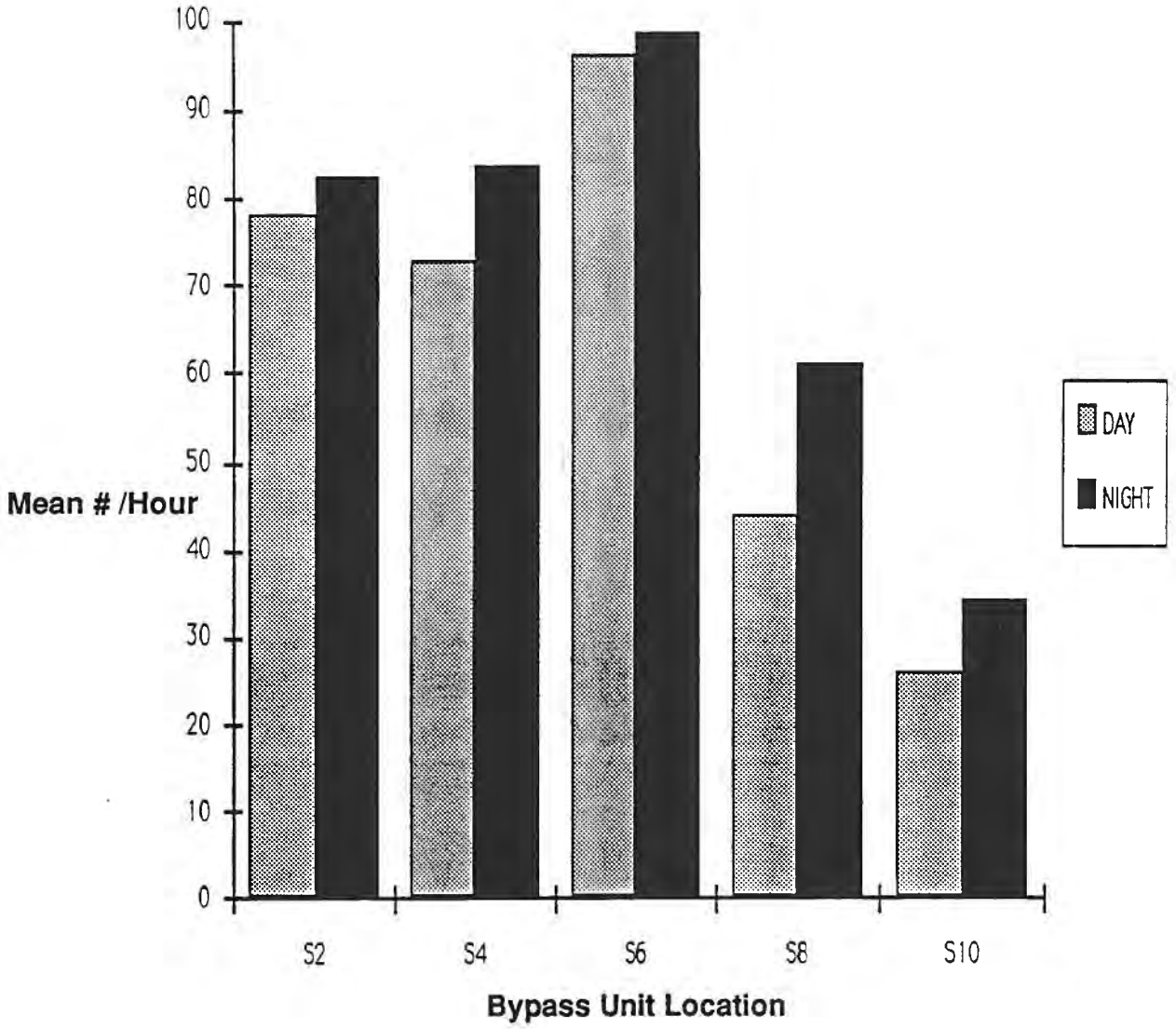


Figure C1. Horizontal distribution of bypass unit indices (mean#/1hr/location) for day and night separately at Wells Dam between April 14 and May 24, 1991.

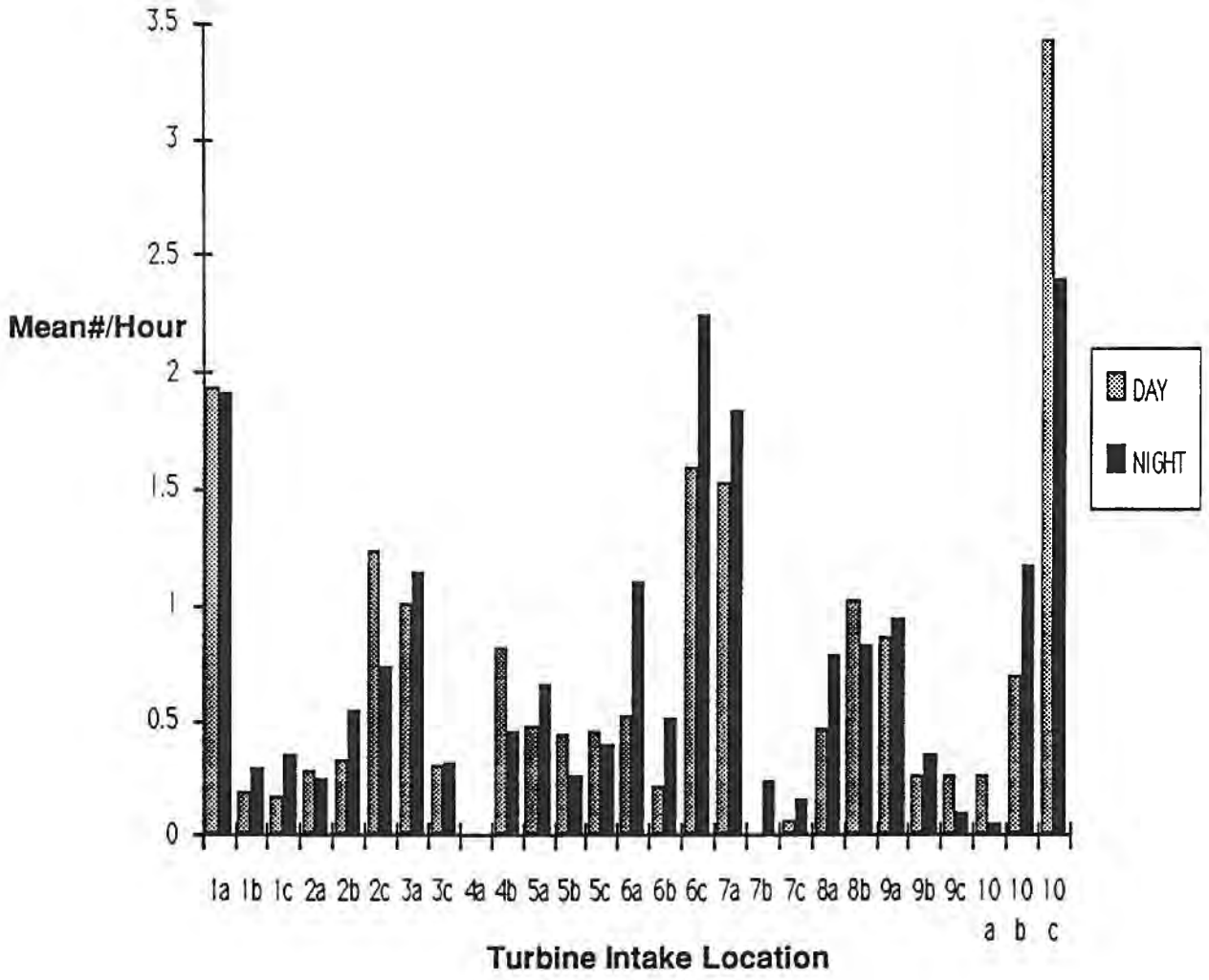


Figure C2. Horizontal distribution of turbine passage indices (mean#/1 hr/location) for day and night separately at Wells Dam between April 14 and May 24, 1991.

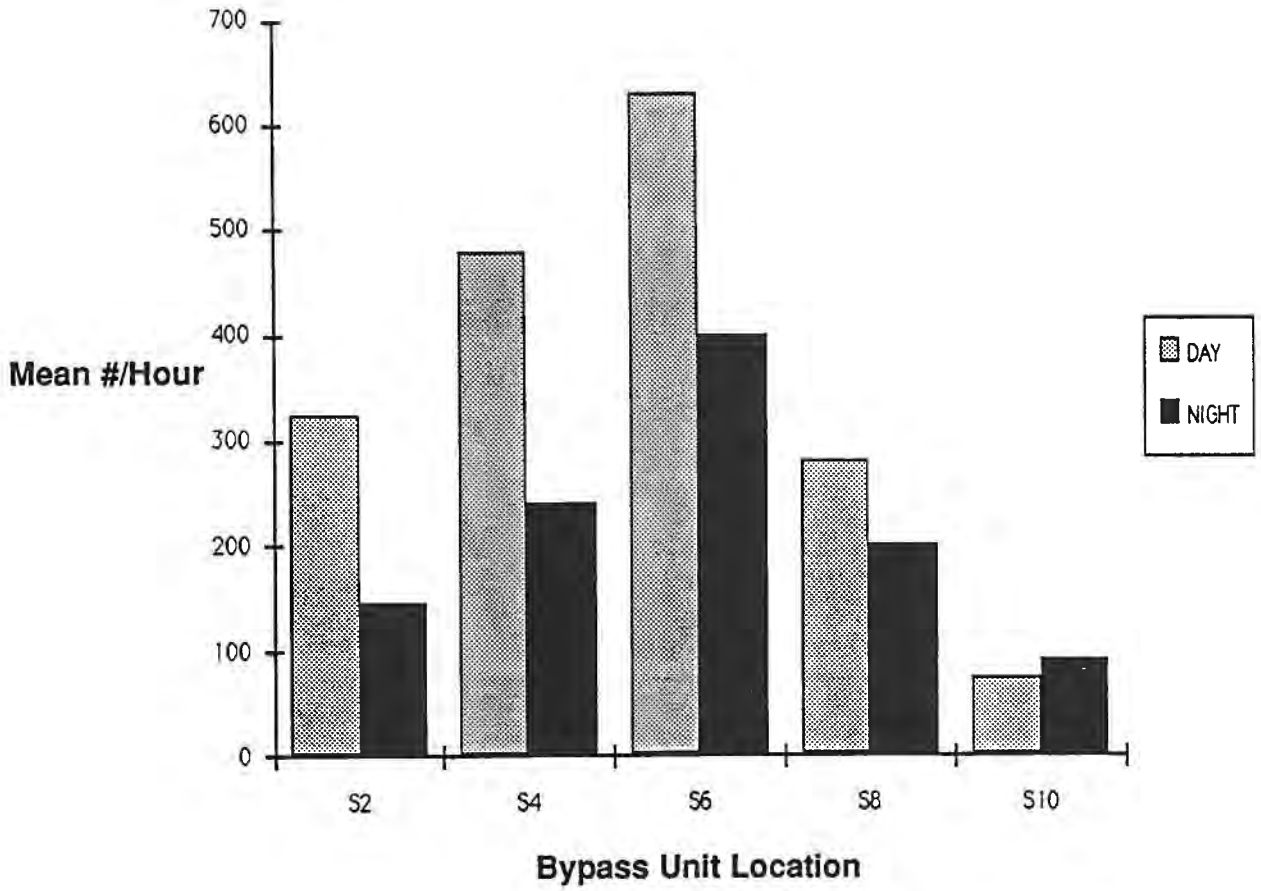


Figure C3. Horizontal distribution of bypass unit indices (mean #/1 hr/location) for day and night separately at Wells Dam between July 8 and July 22, 1991.

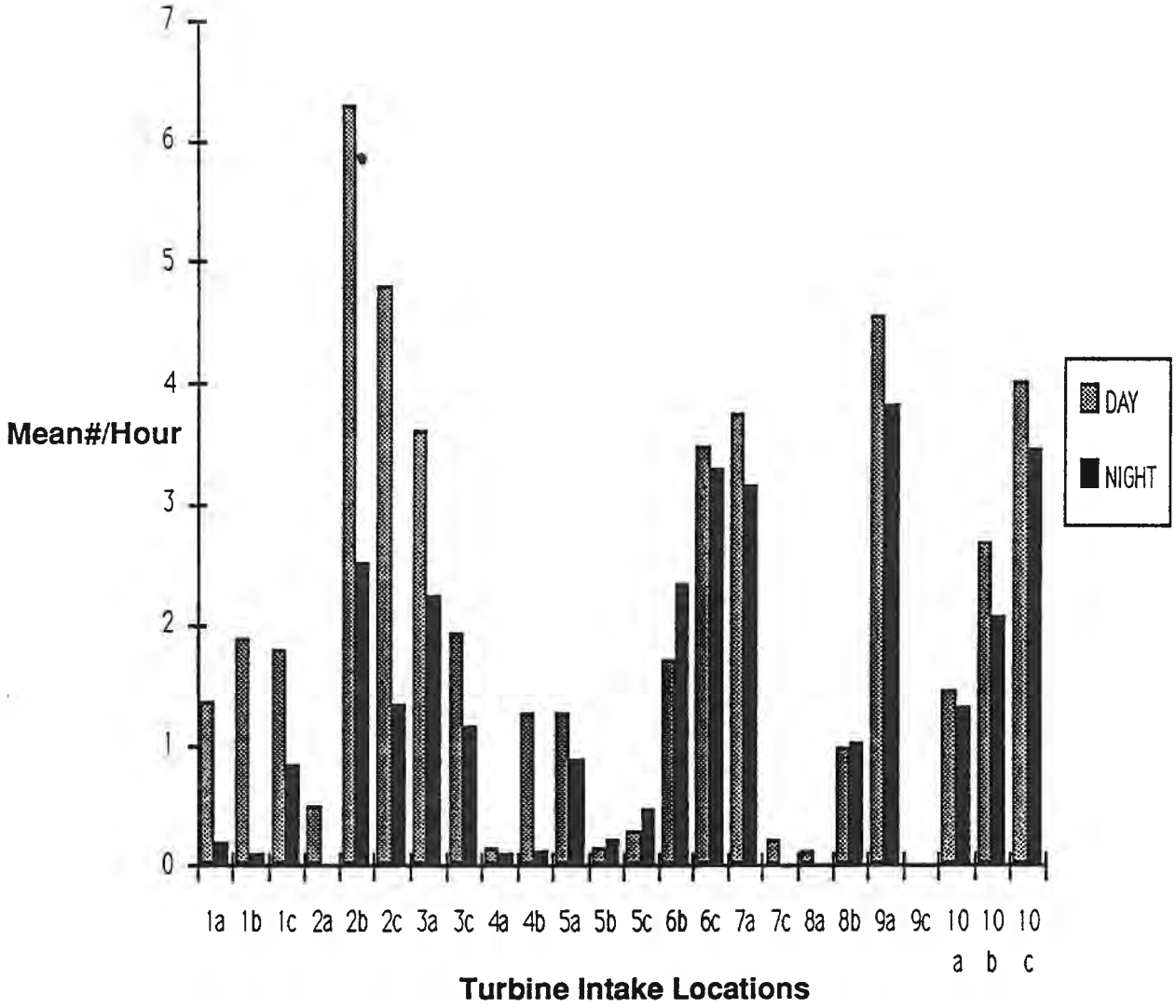


Figure C4. Horizontal distribution of turbine passage indices (mean #/1 hr/location) for day and night separately at Wells Dam between July 8 and July 22, 1991.

C.2 Diel Distributions

The diel distribution data for the bypass slots during spring (April 14 to May 24) show highest passage during the morning hours, 0500h to 1000h (Figure C5). Passage rates were also generally high between 2300h and 0100h hours. Highest passage occurred at 0700h. After 1000h, passage rates dropped to their lowest rate at 1800h.

The turbine diel distribution also show generally higher passage rates between 0000h and 1100h (Figure C6). Highest passage occured at 0800h. Overall, passage rates were much lower in turbine than in the bypass slots. After 1100h passage rates steadily declined to the lowest rate, which occurred at 1500h. Passage rates remained highly variable throughout the evening and nighttime hours.

Bypass slot data for the summer study (July 8 to July 22) are similar to last year's data. There was higher passage during daytime hours with peak passage occurring at 1000h (Figure C7). Passage rates overall were much higher than in the spring. Passage rates were lowest between 2300h and 0500h. The lowest passage occurred at 0500h.

Turbine diel distribution data show similar high daytime passage (Figure C8). Passage rates were relatively high between 0700h and 1500h. The highest passage rate occurred at 1000h. Passage rates were lowest between 0000h and 0400h. The lowest passage occurred at 0100h. As in the spring turbine data, passage rates were highly variable during the evening and nighttime hours (Figures C6 and C8).

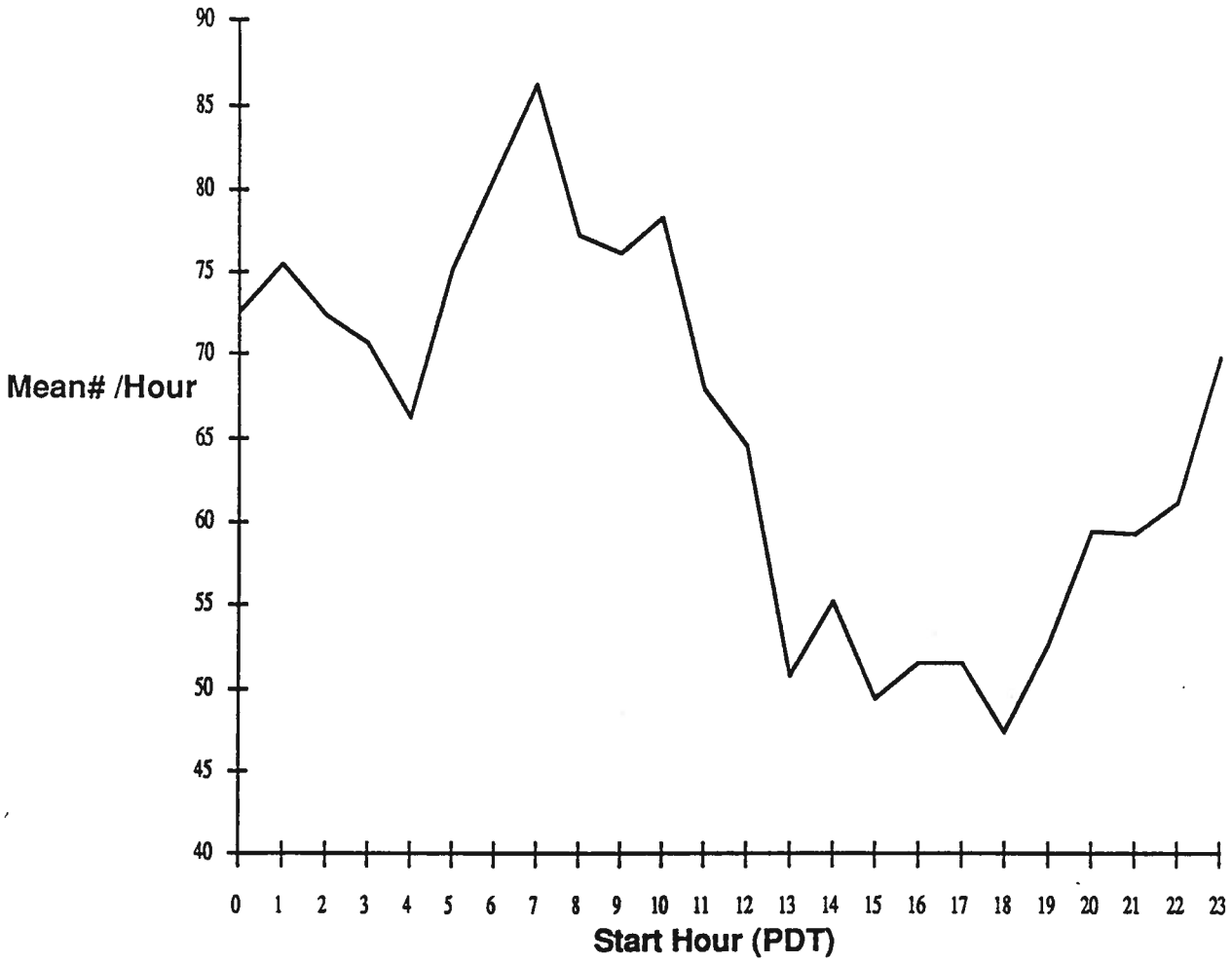


Figure C5. Diel distribution of slot passage indices (mean #/hr/location) at Wells Dam between April 14 and May 24, 1991.

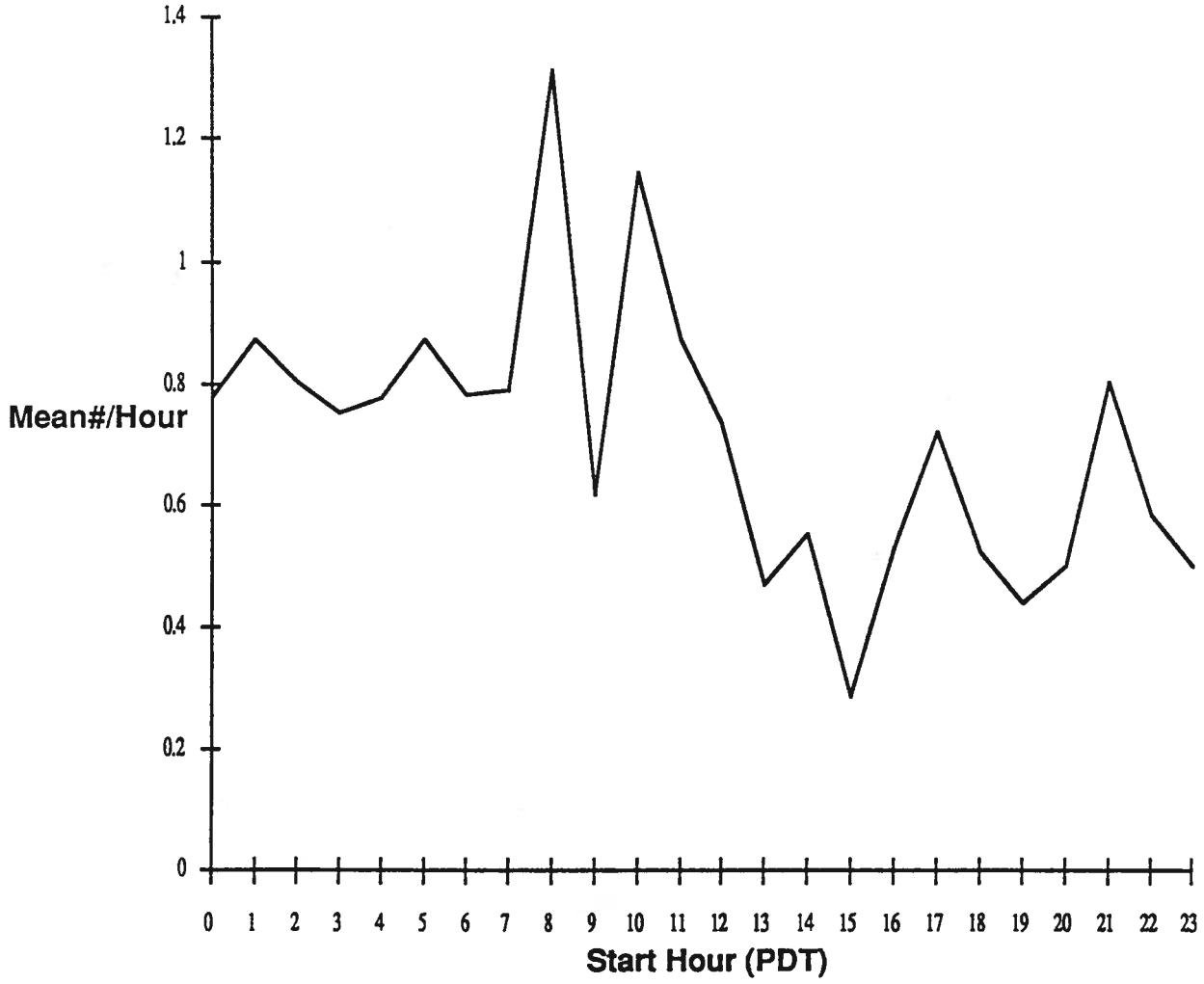


Figure C6. Diel distribution of turbine indices (mean #/1hr/location) at Wells Dam between April 14 and May 24, 1991.

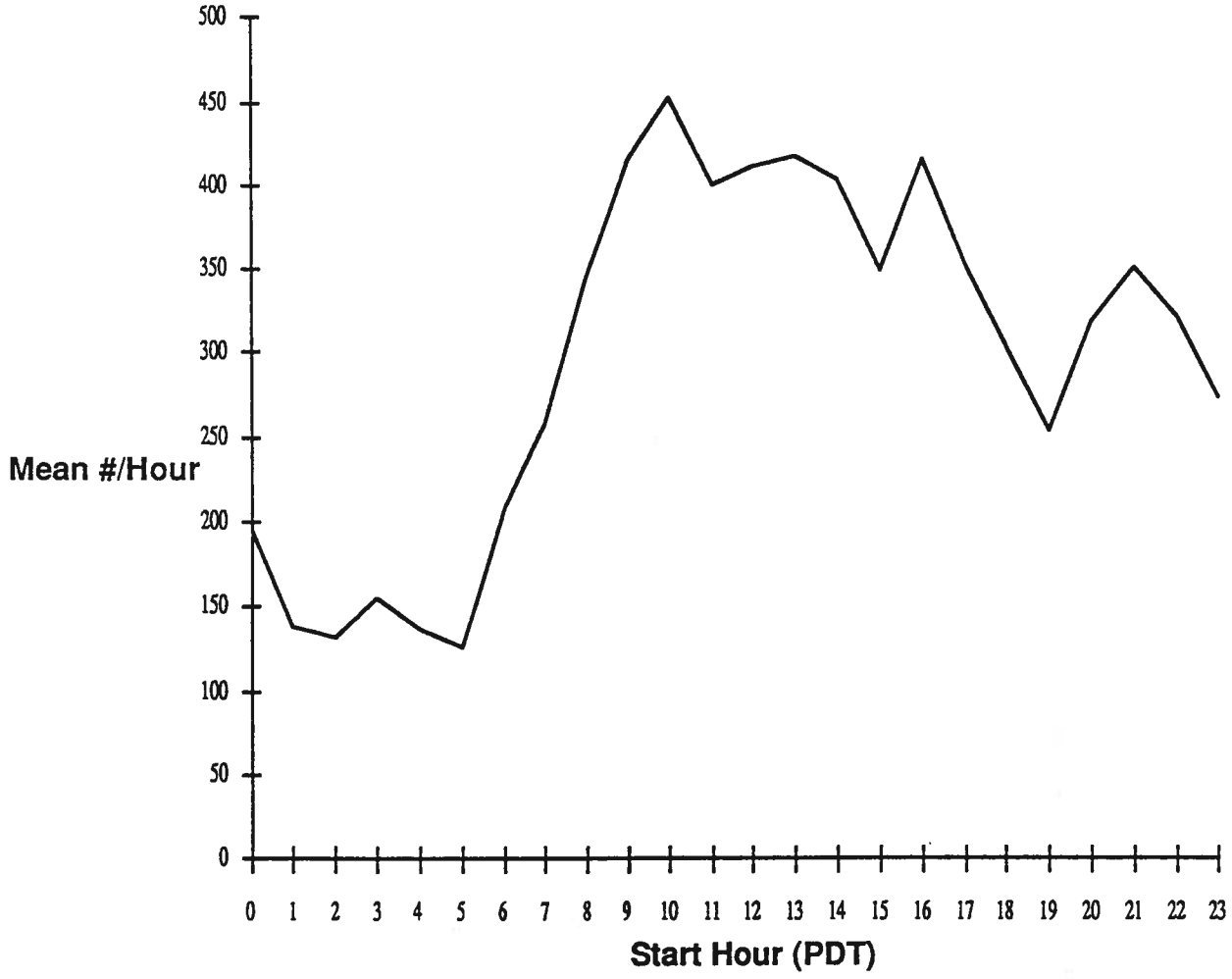


Figure C7. Diel distribution of slot passage indices (mean #/1 hr /location) at Wells Dam between July 8 and July 22, 1991.

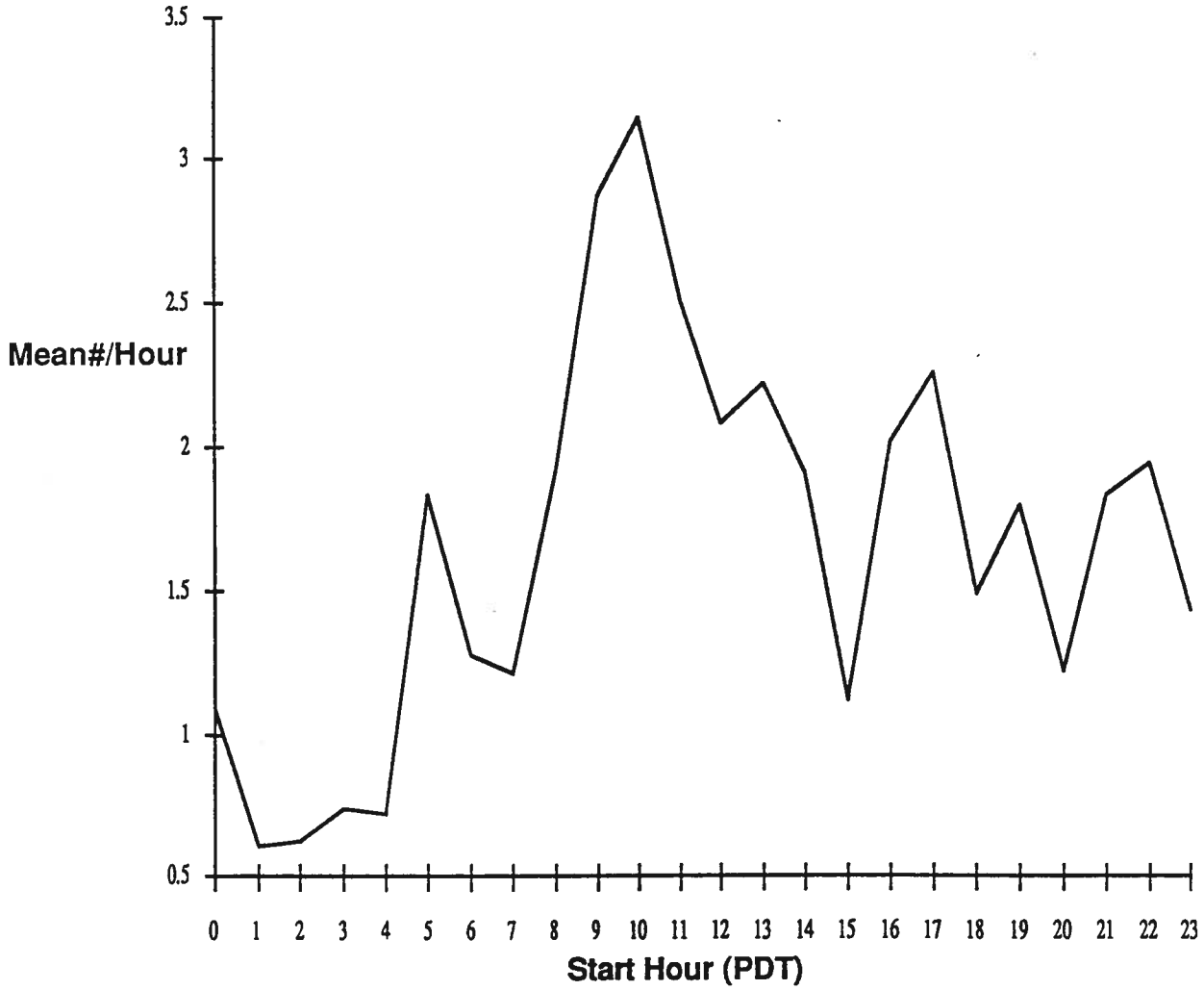


Figure C8. Diel distribution of turbine passage indices (mean #/hr/location) at Wells Dam between July 8 and July 22, 1991.

APPENDIX D

FISH PASSAGE DATA

Wells 1991 Forebay Hydroacoustic Index
Day/Night=Mean #/4hr/location
Combined=Mean #/8hr/location

	Date	Day	Night	Combined
March	29	20.1	25.6	45.8
	30	45.3	18.9	64.3
	31	15.7	7.7	23.4
April	1	35.2	15.3	50.5
	2	49.6	25.3	74.9
	3	62.3	22.6	84.9
	4	91.8	30.9	122.7
	5	86.3	194.0	280.3
	6	13.0	6.6	19.6
	7	29.3	43.7	73.0
	8	44.9	140.9	185.8
	9	122.8	131.4	254.3
	10	180.6	68.8	249.4
	11	73.0	73.7	146.7
	12	37.0	356.1	393.2
	13	198.6	4586.6	4785.2
	Spring Bypass Evaluation			
May	25	14.5	3.8	18.3
	26	0.0	90.3	90.3
	27	N/S	13.4	N/A
	28	26.5	19.0	45.5
	29	0.0	6.5	6.5
	30	21.6	8.8	30.5
	31	3.5	11.5	15.1
June	1	6.0	2.5	8.5
	2	6.2	3.0	9.2
	3	19.5	3.7	23.2
	4	9.4	17.4	26.7
	5	11.3	9.7	21.0
	6	0.0	4.8	4.8
	7	2.8	0.0	2.8
	8	3.9	18.5	22.4
	9	15.8	16.3	32.1
	10	21.1	6.7	27.7
	11	2.9	16.5	19.4
	12	22.9	16.2	39.1
	13	28.8	7.0	35.8
	14	12.6	11.5	24.1
	15	13.8	3.1	16.9
	16	39.6	19.2	48.8
	17	23.0	32.4	55.4
	18	23.4	28.9	52.3
	19	55.4	21.5	76.9

Wells 1991 Forebay Hydroacoustic Index
Day/Night=Mean #/4hr/location
Combined=Mean #/8hr/location

June	20	20.9	18.6	39.5
	21	95.4	48.9	144.4
	22	34.9	70.5	105.4
	23	33.7	110.8	144.5
	24	2.6	40.7	43.3
	25	55.4	63.2	118.6
	26	531.8	202.5	734.4
	27	116.5	603.0	719.5
	28	348.4	361.4	709.8
	29	511.9	311.8	823.8
	30	325.9	286.9	612.8
July	1	425.6	534.0	659.6
	2	441.2	891.6	1332.7
	3	550.2	587.6	1137.8
	4	939.5	309.7	1249.2
	5	1051.8	342.0	1393.8
	6	763.5	922.2	1685.7
	7	777.1	748.9	1526.0
	Summer Bypass Evaluation			
	23	977.6	1177.9	2155.4
	24	1211.0	696.0	1907.0
	25	811.0	520.5	1331.5
	26	735.5	568.7	1304.2
	27	463.2	653.5	1116.7
	28	638.9	360.8	999.7
	29	1210.3	374.7	1585.0
	30	964.3	535.3	1499.6
	31	1236.1	483.8	1719.9
August	1	554.5	245.7	800.1
	2	1029.5	483.2	1512.7
	3	937.9	894.5	1832.5
	4	1344.8	404.9	1749.7
	5	1046.4	640.2	1686.6
	6	1020.6	175.5	1196.1
	7	1636.9	1092.6	2729.5
	8	1871.7	1206.5	3078.2
	9	1528.8	606.2	2135.0
	10	N/S	673.3	N/A
	11	1161.5	865.0	2026.5
	12	410.8	860.1	1270.9
	13	503.0	568.4	1071.5
	14	511.0	653.2	1144.2
	15	341.9	516.9	858.8
	16	310.3	394.5	704.8
	17	303.3	274.4	577.8

Wells 1991 Forebay Hydroacoustic Index
Day/Night=Mean #/4hr/location
Combined=Mean #/8hr/location

August	18	414.7	254.1	668.8
	19	741.9	462.6	1204.4
	20	495.7	214.4	710.1
	21	394.2	409.4	803.5
	22	490.3	477.8	968.1
	23	978.2	341.1	1319.3
	24	465.6	244.2	709.8
	25	353.3	317.8	671.0
	26	381.1	571.6	952.7
	27	755.7	467.6	1223.3
	28	606.8	449.3	1056.1
	29	389.3	399.1	788.4
	30	778.2	349.3	1127.5
	31	505.5	380.8	886.3

Wells 1991 Study Periods Bypass Unit Run Timing

SPRING

	DATE	Mean #/8hr/location
	14	411.881
	15	259.572
	16	221.078
	17	196.740
April	18	183.743
	19	145.994
	20	127.614
	21	183.324
	22	210.881
	23	361.141
	24	219.054
	25	208.981
	26	445.098
	27	335.452
	28	388.487
	29	338.276
	30	546.357
	1	157.038
	2	56.230
	3	138.498
	4	178.435
	5	163.298
	6	372.844
	7	No Data Collected For Day Period
May	8	386.989
	9	573.203
	10	603.065
	11	963.552
	12	1145.567
	13	1247.932
	14	1459.427
	15	1051.563
	16	1135.875
	17	1249.220
	18	537.267
	19	334.367
	20	297.762
	21	749.022
	22	601.226
	23	442.714
	24	466.398

SUMMER

	DATE	Mean #/8hr/location
July	8	1857.244
	9	2295.527
	10	1489.016
	11	3039.483
	12	3445.813
	13	2090.995
	14	1145.023
	15	1576.673
	16	3206.072
	17	2544.649
	18	1851.678
	19	2475.864
	20	2110.247
	21	2685.699
	22	5707.031

WELLS 1991 SPRING BYPASS EFFICIENCY DATA

	Date	Ratio var.	Upper C.I.	Ratio	Lower C.I
April	14	0.00203	0.80438	0.72583	0.65495
	15	0.00180	0.86984	0.79652	0.72938
	16	0.00071	0.90807	0.86301	0.82020
	17	0.00074	0.92339	0.87741	0.83372
	18	0.00130	0.79140	0.72944	0.67233
	19	0.00113	0.87717	0.81984	0.76626
	20	0.00159	0.93276	0.86441	0.80107
	21	0.00042	0.95133	0.91690	0.88372
	22	0.00047	0.93371	0.89716	0.86203
	23	0.00020	0.95098	0.92739	0.90438
	24	0.00036	0.97018	0.93857	0.90798
	25	0.00013	0.97357	0.95440	0.93560
	26	0.00046	0.97488	0.93908	0.90460
	27	0.00009	0.98279	0.96696	0.95139
	28	0.00016	0.98814	0.96728	0.94685
	29	0.00004	0.99074	0.98046	0.97029
	30	0.00003	0.99479	0.98525	0.97581
May	1	0.00070	0.95234	0.90767	0.86509
	2	0.00279	0.92765	0.83553	0.75256
	3	0.00062	0.94436	0.90254	0.86258
	4	0.00081	0.92493	0.87687	0.83131
	5	0.00039	0.95095	0.91801	0.88621
	6	0.00011	0.97120	0.95345	0.93601
	7	0.00042	0.97974	0.94552	0.91249
	8	0.00008	0.99492	0.98018	0.96567
	9	0.00006	0.99671	0.98436	0.97217
	10	0.00010	0.98099	0.96467	0.94862
	11	0.00007	0.98438	0.97102	0.95785
	12	0.00002	0.99698	0.99031	0.98368
	13	0.00003	0.98515	0.97545	0.96585
	14	0.00002	0.99239	0.98494	0.97754
	15	0.00007	0.98984	0.97557	0.96150
	16	0.00061	0.98659	0.94506	0.90527
	17	0.00010	0.98967	0.97317	0.95694
	18	0.00015	0.97700	0.95636	0.93616
	19	0.00022	0.94790	0.92291	0.89857
	20	0.00014	0.97883	0.95915	0.93986
	21	0.00002	0.99464	0.98797	0.98134
	22	0.00007	0.99437	0.98084	0.96750
	23	0.00024	0.98269	0.95711	0.93220
	24	0.00014	0.98139	0.96172	0.94244

WELLS 1991 SUMMER BYPASS EFFICIENCY DATA

	Date	Ratio var.	Upper C.I.	Ratio	Lower C.I
July	8	0.00003	0.97946	0.96978	0.96019
	9	0.00001	0.99139	0.98661	0.98185
	10	0.00003	0.99546	0.98601	0.97664
	11	0.00004	0.99712	0.98672	0.97643
	12	0.00002	0.98924	0.98142	0.97365
	13	0.00005	0.98289	0.97115	0.95955
	14	0.00004	0.98564	0.97583	0.96613
	15	0.00005	0.97692	0.96545	0.95412
	16	0.00002	0.99120	0.98327	0.97541
	17	0.00002	0.98449	0.97640	0.96837
	18	0.00006	0.98088	0.96799	0.95527
	19	0.00003	0.98513	0.97631	0.96757
	20	0.00004	0.97202	0.96126	0.95063
	21	0.00001	0.99304	0.98786	0.98270
	22	0.00008	0.96980	0.95524	0.94090

WELLS 1991 TURBINE HORIZONTAL DISTRIBUTION
(MEAN #/HR)

	SPRING			SUMMER	
Location	DAY	NIGHT	Location	DAY	NIGHT
1a	1.934	1.907	1a	1.345	0.201
1b	0.182	0.291	1b	1.872	0.096
1c	0.169	0.342	1c	1.782	0.838
2a	0.280	0.247	2a	0.499	0.000
2b	0.320	0.536	2b	6.277	2.523
2c	1.238	0.734	2c	4.807	1.326
3a	1.014	1.148	3a	3.609	2.253
3c	0.299	0.318	3c	1.923	1.161
4a	0.000	0.000	4a	0.149	0.103
4b	0.813	0.455	4b	1.269	0.113
5a	0.473	0.655	5a	1.264	0.869
5b	0.440	0.261	5b	0.155	0.216
5c	0.447	0.390	5c	0.274	0.463
6a	0.514	1.105	6b	1.694	2.345
6b	0.209	0.511	6c	3.478	3.296
6c	1.595	2.245	7a	3.741	3.150
7a	1.523	1.829	7c	0.224	0.000
7b	0.000	0.231	8a	0.124	0.000
7c	0.065	0.154	8b	0.971	1.012
8a	0.459	0.777	9a	4.541	3.824
8b	1.017	0.828	9c	0.000	0.000
9a	0.866	0.939	10a	1.440	1.304
9b	0.254	0.349	10b	2.682	2.055
9c	0.256	0.094	10c	4.011	3.444
10a	0.251	0.055			
10b	0.684	1.174			
10c	3.418	2.389			

WELLS 1991 BYPASS UNIT HORIZONTAL DISTRIBUTION
SPRING MEAN #/HR

	DAY	NIGHT
S2	78.060	82.378
S4	72.770	83.633
S6	96.229	98.597
S8	43.923	61.202
S10	25.920	34.310

WELLS 1991 BYPASS UNIT HORIZONTAL DISTRIBUTION
SUMMER MEAN #/HR

	DAY	NIGHT
S2	323.379	147.010
S4	476.401	239.145
S6	629.826	399.484
S8	280.349	200.520
S10	74.190	92.863

WELLS 1991 TURBINE DIEL DISTRIBUTIONS

SPRING		SUMMER	
START HOUR	MEAN #/HR	START HOUR	MEAN #/HR
0	0.778	0	1.088
1	0.872	1	0.608
2	0.803	2	0.621
3	0.751	3	0.731
4	0.778	4	0.721
5	0.872	5	1.836
6	0.783	6	1.273
7	0.791	7	1.213
8	1.312	8	1.916
9	0.615	9	2.867
10	1.144	10	3.148
11	0.874	11	2.511
12	0.735	12	2.078
13	0.468	13	2.223
14	0.551	14	1.907
15	0.289	15	1.118
16	0.531	16	2.016
17	0.720	17	2.255
18	0.523	18	1.485
19	0.439	19	1.793
20	0.499	20	1.221
21	0.802	21	1.831
22	0.583	22	1.938
23	0.501	23	1.431

WELLS 1991 SLOT DIEL DISTRIBUTIONS

SPRING		SUMMER	
START HOUR	MEAN #/HR	START HOUR	MEAN #/HR
0	72.491	0	195.886
1	75.464	1	138.488
2	72.331	2	131.858
3	70.673	3	155.130
4	66.212	4	137.008
5	75.174	5	126.638
6	80.810	6	208.107
7	86.230	7	257.748
8	77.154	8	344.910
9	76.053	9	415.331
10	78.254	10	452.996
11	67.963	11	399.052
12	64.477	12	410.658
13	50.684	13	417.138
14	55.261	14	402.341
15	49.355	15	348.597
16	51.488	16	415.261
17	51.464	17	351.731
18	47.346	18	303.110
19	52.525	19	253.189
20	59.464	20	318.353
21	59.235	21	350.519
22	61.024	22	320.263
23	69.715	23	273.664

Wells 1991 daily bypass unit passage.
(Total Weighted Fish)

Bypass Unit Date	S2	S4	S6	S8	S10
April - 14	2479	1273	924	708	1506
15	729	848	689	1273	299
16	1054	590	683	458	301
17	1210	691	937	441	155
18	848	926	1713	475	225
19	763	759	527	530	194
20	742	483	683	498	111
21	990	838	956	774	215
22	645	827	1124	717	346
23	1345	1281	1204	829	282
24	1206	525	612	525	413
25	1216	1223	1173	520	271
26	1561	1471	1351	874	339
27	1171	1678	1543	816	299
28	1176	1804	1354	603	248
29	822	1501	3192	840	238
30	1133	2334	5522	1630	214
May - 1	111	545	2623	336	172
2	265	186	312	168	53
3	302	389	847	568	103
4	561	608	1107	295	359
5	819	746	842	494	298
6	1339	1393	2645	959	485
7	965	721	1309	450	164
8	1684	1679	2457	1051	521
9	1448	2120	2001	2180	1329
10	3258	3478	2002	1263	648
11	1591	4840	4856	1383	1066
12	1387	6064	6989	1760	1659
13	3143	5544	7037	2948	1758
14	2669	4418	6006	3007	2072
15	3220	3344	5394	2449	2055
16	4846	3441	4344	4120	2699
17	4400	3906	2740	2237	1601
18	4001	2625	1095	509	716
19	1631	811	1159	696	509
20	2983	769	998	871	489
21	5018	1583	3979	2098	529
22	3760	1554	4432	2351	602
23	3097	1436	2149	570	596
24	4558	1332	1539	1091	871

Wells 1991 daily turbine passage.
(Total Weighted Fish)
(-0- Not Sampled)

Turbine loc. Date	1A	1B	1C	2A	2B	2C	3A	3B	3C
April - 14	236	41	34	25	19	26	106	-0-	0
15	131	15	75	17	0	54	124	-0-	12
16	34	13	22	0	0	18	76	-0-	0
17	127	40	19	0	24	73	90	-0-	13
18	108	0	0	0	49	53	81	-0-	33
19	115	0	0	16	48	141	62	-0-	0
20	35	0	0	0	0	51	35	-0-	0
21	79	20	0	0	42	35	0	-0-	39
22	19	0	13	0	0	0	22	-0-	63
23	67	0	0	17	0	49	0	-0-	0
24	41	0	0	0	20	0	0	-0-	0
25	22	0	0	0	0	0	0	-0-	0
26	0	0	0	13	0	17	17	-0-	0
27	15	0	0	0	0	0	0	-0-	0
28	42	17	0	0	0	0	22	-0-	0
29	26	23	19	0	0	0	0	-0-	0
30	41	0	0	0	0	0	32	-0-	0
May - 1	47	0	0	0	0	16	15	-0-	0
2	61	0	0	0	0	0	33	-0-	0
3	79	0	0	0	15	0	0	-0-	0
4	94	0	0	0	13	80	30	-0-	0
5	55	0	0	0	0	0	0	-0-	31
6	60	0	0	0	0	19	18	-0-	0
7	13	0	0	0	0	0	0	-0-	0
8	0	0	0	0	0	20	0	-0-	0
9	0	18	0	0	0	0	0	-0-	0
10	29	0	0	0	0	102	32	-0-	33
11	53	0	18	0	11	0	66	-0-	31
12	0	0	0	0	15	0	49	-0-	0
13	53	0	0	47	0	19	14	-0-	0
14	26	0	0	0	6	8	0	-0-	0
15	12	0	0	0	24	50	0	-0-	21
16	0	0	0	0	0	45	32	-0-	12
17	15	0	0	0	0	0	40	-0-	0
18	24	0	19	18	0	58	0	-0-	0
19	42	0	14	53	65	33	36	-0-	13
20	13	16	0	18	13	17	0	-0-	0
21	36	0	0	16	0	19	16	-0-	0
22	0	0	0	0	30	0	0	-0-	0
23	0	0	0	18	0	0	0	-0-	0
24	14	16	0	0	0	0	0	-0-	0

Wells 1991 daily turbine passage.
(Total Weighted Fish)
(-0- Not Sampled)

Turbine loc. Date	4A	4B	4C	5A	5B	5C	6A	6B	6C
April - 14	0	32	-0-	13	39	65	-0-	18	178
15	0	0	-0-	62	26	137	-0-	0	18
16	0	22	-0-	99	17	0	0	12	62
17	0	49	-0-	0	12	0	20	41	27
18	0	62	-0-	66	99	0	40	0	77
19	0	79	-0-	0	25	15	0	53	62
20	0	0	-0-	26	37	21	0	20	49
21	0	16	-0-	0	0	0	0	0	50
22	0	0	-0-	16	43	15	12	0	48
23	0	0	-0-	45	0	0	47	36	64
24	0	38	-0-	0	0	18	0	12	37
25	0	21	-0-	24	0	0	0	0	61
26	0	24	-0-	24	0	0	0	0	36
27	0	0	-0-	0	0	0	15	25	12
28	0	38	-0-	21	11	0	0	0	0
29	0	0	-0-	0	0	0	0	0	36
30	0	0	-0-	0	0	0	28	0	12
May - 1	0	0	-0-	0	18	0	116	0	12
2	0	16	-0-	0	0	0	13	0	12
3	0	17	-0-	18	0	0	-0-	0	36
4	0	54	-0-	21	0	0	-0-	0	25
5	0	21	-0-	0	0	48	-0-	29	11
6	0	21	-0-	0	18	0	-0-	0	40
7	0	0	-0-	0	0	0	-0-	0	0
8	0	0	-0-	0	0	0	-0-	0	17
9	0	0	-0-	0	0	0	-0-	0	41
10	0	16	-0-	33	0	35	-0-	0	24
11	0	0	-0-	17	0	0	-0-	0	48
12	0	0	-0-	0	0	33	-0-	0	23
13	0	15	-0-	0	0	0	-0-	23	90
14	0	20	-0-	0	0	0	-0-	0	26
15	0	24	-0-	0	0	0	-0-	0	120
16	0	0	-0-	0	0	0	-0-	0	90
17	0	17	-0-	0	0	0	-0-	13	103
18	0	0	-0-	0	0	0	-0-	0	53
19	0	0	-0-	0	13	0	-0-	13	50
20	0	18	-0-	17	0	0	-0-	0	12
21	0	0	-0-	0	0	0	-0-	0	0
22	0	0	-0-	17	0	26	-0-	18	0
23	0	32	-0-	18	0	0	-0-	0	0
24	0	0	-0-	0	0	0	-0-	12	0

Wells 1991 daily turbine passage.
(Total Weighted Fish)
(-0- Not Sampled)

Turbine loc. Date	7A	7B	7C	8A	8B	8C	9A	9B	9C
April - 14	48	-0-	0	54	34	-0-	100	-0-	0
15	68	-0-	0	44	66	-0-	83	-0-	38
16	16	17	29	32	49	-0-	31	17	0
17	31	0	0	0	78	-0-	25	17	0
18	46	0	0	47	61	-0-	0	12	21
19	89	0	0	78	86	-0-	14	23	0
20	15	0	0	35	103	-0-	0	0	26
21	15	0	0	0	42	-0-	14	0	0
22	30	0	0	65	62	-0-	19	29	0
23	14	0	0	30	52	-0-	0	0	0
24	60	0	15	12	20	-0-	0	0	0
25	30	0	0	12	38	-0-	25	0	0
26	46	0	0	0	27	-0-	0	0	59
27	0	0	0	0	22	-0-	52	15	24
28	17	20	0	0	15	-0-	13	0	0
29	0	0	0	0	19	-0-	0	0	0
30	26	0	0	0	0	-0-	23	0	0
May - 1	14	0	0	0	0	-0-	0	0	0
2	0	0	0	18	30	-0-	13	0	0
3	0	-0-	0	0	0	-0-	0	-0-	0
4	13	-0-	0	0	13	-0-	0	-0-	0
5	46	-0-	0	32	0	-0-	0	-0-	0
6	14	-0-	0	0	0	-0-	0	-0-	0
7	0	-0-	0	0	0	-0-	28	-0-	0
8	0	-0-	0	0	0	-0-	22	-0-	0
9	49	-0-	0	0	0	-0-	16	-0-	0
10	30	-0-	0	0	0	-0-	0	-0-	0
11	32	-0-	0	0	0	-0-	0	-0-	0
12	0	-0-	0	0	0	-0-	33	-0-	0
13	63	-0-	0	0	0	-0-	37	-0-	17
14	14	-0-	0	12	0	-0-	12	-0-	0
15	85	-0-	21	0	0	-0-	12	-0-	0
16	419	-0-	16	0	38	-0-	135	-0-	0
17	100	-0-	0	25	12	-0-	25	-0-	0
18	0	-0-	0	0	0	-0-	0	-0-	0
19	31	-0-	0	13	0	-0-	13	-0-	0
20	15	-0-	0	0	13	-0-	13	-0-	0
21	27	-0-	0	27	0	-0-	0	-0-	0
22	0	-0-	0	0	12	-0-	34	-0-	0
23	96	-0-	0	42	0	-0-	44	-0-	0
24	14	-0-	19	0	27	-0-	42	-0-	0

Wells 1991 daily turbine passage
(Total Weighted Fish)
(-0- Not Sampled)

Turbine loc. Date	10A	10B	10C
April - 14	13	86	271
15	0	11	42
16	-0-	-0-	-0-
17	-0-	-0-	-0-
18	-0-	-0-	-0-
19	-0-	-0-	-0-
20	-0-	-0-	-0-
21	-0-	-0-	-0-
22	-0-	-0-	-0-
23	-0-	-0-	-0-
24	-0-	-0-	-0-
25	-0-	-0-	-0-
26	-0-	-0-	-0-
27	-0-	-0-	-0-
28	-0-	-0-	-0-
29	-0-	-0-	-0-
30	-0-	-0-	-0-
May - 1	-0-	-0-	-0-
2	-0-	-0-	-0-
3	0	0	0
4	0	0	39
5	0	63	99
6	0	0	208
7	0	0	209
8	0	0	48
9	0	0	21
10	0	15	21
11	0	34	86
12	0	19	44
13	0	21	80
14	0	38	0
15	0	58	39
16	0	75	0
17	13	0	16
18	0	12	0
19	0	0	107
20	0	0	186
21	0	18	0
22	0	31	33
23	53	0	50
24	12	0	25

Wells 1991 daily bypass unit passage
(Total Weighted Fish)

Bypass Unit Date	S2	S4	S6	S8	S10
July - 8	4350	4984	17558	3527	1274
9	8750	10862	14274	5912	1674
10	3798	3984	4551	4605	1847
11	5512	9039	17749	10534	1774
12	12344	7705	14139	6692	1941
13	5828	9198	9296	5710	2628
14	1069	4512	5776	4212	1726
15	6804	8343	7663	3435	874
16	5273	12737	15632	9607	658
17	7312	10110	11300	4580	1795
18	6861	9431	10472	2995	1079
19	9659	9118	7689	3235	3303
20	3041	7919	9852	4776	3449
21	1160	10186	14145	6971	2164
22	7906	17071	29633	11558	3233

Wells 1991 daily turbine passage
(Total Weighted Fish)
(-0- Not Sampled)

Turbine loc. Date	1A	1B	1C	2A	2B	2C	3A	3B	3C
July - 8	0	54	110	38	173	112	54	-0-	65
9	0	0	41	0	83	132	0	-0-	13
10	0	0	0	0	43	0	0	-0-	17
11	0	0	0	0	40	18	0	-0-	0
12	0	0	0	0	69	75	54	-0-	0
13	0	40	33	0	60	24	48	-0-	35
14	20	24	54	0	20	0	58	-0-	42
15	0	13	58	0	141	137	84	-0-	0
16	44	0	0	0	112	66	17	-0-	37
17	0	13	30	0	102	16	80	-0-	39
18	33	48	15	0	103	44	55	-0-	13
19	0	12	0	38	81	68	19	-0-	35
20	56	56	109	0	0	0	53	-0-	88
21	0	16	0	0	0	0	17	-0-	101
22	156	127	41	28	641	498	537	-0-	81

Turbine loc. Date	4A	4B	4C	5A	5B	5C	6A	6B	6C
July - 8	0	16	-0-	39	0	0	-0-	35	0
9	0	0	-0-	68	0	28	-0-	13	-0-
10	0	0	-0-	17	31	0	-0-	0	63
11	0	0	-0-	19	0	0	-0-	0	78
12	0	0	-0-	0	0	0	-0-	25	119
13	0	0	-0-	0	0	34	-0-	25	65
14	0	0	-0-	23	0	0	-0-	0	42
15	0	32	-0-	49	0	0	-0-	57	94
16	19	0	-0-	17	0	0	-0-	102	97
17	0	0	-0-	0	0	0	-0-	91	177
18	27	0	-0-	52	0	0	-0-	39	89
19	0	17	-0-	0	0	0	-0-	73	26
20	0	79	-0-	70	0	0	-0-	54	37
21	0	34	-0-	0	0	0	-0-	53	54
22	0	103	-0-	35	32	55	-0-	99	84

Wells 1991 daily turbine passage
(Total Weighted Fish)
(-0- Not Sampled)

Turbine loc. Date	7A	7B	7C	8A	8B	8C	9A	9B	9C
July - 8	18	-0-	0	0	0	-0-	58	-0-	0
9	62	-0-	0	0	13	-0-	13	-0-	0
10	62	-0-	0	0	0	-0-	17	-0-	0
11	192	-0-	0	0	20	-0-	33	-0-	0
12	109	-0-	0	0	19	-0-	13	-0-	0
13	117	-0-	27	13	0	-0-	172	-0-	0
14	14	-0-	0	0	27	-0-	27	-0-	0
15	92	-0-	0	0	0	-0-	27	-0-	0
16	135	-0-	0	0	39	-0-	70	-0-	0
17	85	-0-	0	0	13	-0-	40	-0-	0
18	89	-0-	0	0	15	-0-	168	-0-	0
19	76	-0-	0	0	26	-0-	81	-0-	0
20	29	-0-	0	0	63	-0-	121	-0-	0
21	0	-0-	0	0	64	-0-	271	-0-	0
22	86	-0-	16	12	47	-0-	471	-0-	0

Turbine loc. Date	10A	10B	10C
July - 8	0	0	18
9	50	49	20
10	0	0	0
11	25	0	123
12	71	190	142
13	13	119	37
14	36	48	0
15	0	29	52
16	18	0	0
17	0	0	28
18	0	24	156
19	0	71	21
20	103	24	144
21	13	236	339
22	164	73	177

APPENDIX E

RELATIVE DETECTABILITY RESULTS

APPENDIX E. Relative Detectability Results

The primary objective of the 1991 evaluation at Wells was to estimate total project bypass efficiency which compared fish passage in bypass flow with passage in turbine flow. These comparisons assumed that the ability to acoustically detect fish at each location was equivalent. To confirm this assumption, we did an analysis of the relative detectability of fish as a function of range from the transducer. The actual distribution of fish ranges was determined from the data collected at Wells during the 1991 summer study.

The relative detectability model was based on three interrelated analyses: detection angle, vertical distribution, and time in the beam. These analyses are summarized in this appendix.

The analysis showed that detectabilities between transducers at bypass slot and turbine intake locations under different environmental conditions were equivalent.

The parameters and conditions used for these analyses were:

1) Ping rate - maximized at 10 pulses/sec in bypass slots and turbine intakes.

2) Transducer beamwidth - maximized at 15° in turbine intakes and 6° in bypass slots.

3) Transducer aiming angle - aimed toward area where most fish expected.

4) Water velocity - Turbine intake velocities were measured by the Columbia River Turbine Discharge Rating Program (Figure E1). Bypass slot velocities are approximated.

Detection angle

An analysis was done to estimate the angle of the acoustic beam within which fish are detected over all transducer ranges under conditions found at Wells during 1991. Accurate relative estimates will be obtained if the angle over which targets are detected is constant for all depths analyzed.

The following equation was used to calculate actual detection angles assuming a redundancy criteria of four successive echoes for a target to be classified as a fish (Appendix A).

$$\theta_A = \sqrt{\theta_T - \left[\frac{4\ V \cos(|\theta_p + \theta_f|)}{2 r_s R}\right]^2}$$

Where: θA = actual detection angle over which targets exceeded the threshold four times

θT = the half-power beamwidth of the transducer

V = water (fish) velocity

θp = transducer aiming angle relative to horizontal

θf = angle of fish trajectory relative to horizontal

R = range

r_s = pulse rate of the acoustic system

Detection angles for the bypass slot were calculated using water velocities ranging from 3.0 to 5.0 feet/sec. Detection angles for turbine intake locations were calculated for the same range of velocities, and are equivalent to those found where the turbine was block loaded at approximately 65 MW.

This analysis showed that the actual detection angle for both bypass slot and turbine intake locations were very near the half-power beamwidth, except for ranges near the transducer at the highest measured velocity. The point where the angle of detection is constant at the highest velocity occurred at approximately 15 feet from the transducer in the turbine intakes and 35 feet from the transducer in the bypass slots (Figures E2 and E3).

Vertical Distribution

Vertical distributions of fish in spill and turbine were calculated to confirm that the targets of interest were located where the beam angle is constant and the sample volumes are largest (i.e., widest part of the beam).

Separate vertical distiribution functions were calculated for turbine intakes and bypass slots locations during the summer study 1991. Data for the turbine intake distribution included detections from all in-turbine sampling locations. Data for the bypass slot distribution included

detections from all bypass locations for the first seven days of the study. Targets detected within 4 feet from the transducer were not included in this analysis.

Vertical distribution analysis showed over 90% of migrants in turbine intakes and 60% of migrants in bypass slots were found at ranges in the beam where the angle of detection is constant (Figures E4a and b).

Time in the Beam

A third investigation of detectability compared the amount of time targets were observed in the acoustic beam with an expected value calculated using the same model used for the detection angle calculation described above.

The observed time in the beam was estimated using data digitized from the echograms. Data selections were done using the classification described in Appendix A. The time and range of entrance and exit from the acoustic beam were used to determine the average range and the amount of time each target spent in the beam (time exit - time entered). These values were averaged for all singe fish detection over all depths.

The expected time in the beam was calculated using the following equation:

$$T_{exp} = \{(\Pi/4) * 2R \tan(\Phi t/2)\}/V$$

where: R = range of fish

Φt = half-power beamwidth

V = water (fish) velocity

For turbine intake and bypass slot data, the mean observed time in the beam was near the midpoint of the mean expected time in the beam (Table E1). Even at higher velocities where the mean expected time was less than 2 seconds, detection was possible because of the high pulse rates used (10 pulses/sec in bypass and turbine intakes).

The results were consistent and verified that detectabilities were equivalent between bypass and turbine intake sampling locations.

Table E1. Observed and expected times (sec) in the acoustic beam for various velocities (fps) in the bypass slots and turbine intakes.

Location	Estimated Velocities	Mean Time in the Beam Observed	Expected
Bypass slot	1-5 fps	2.3	0.3 - 5.8
Turbine intake	1-5 fps	1.5	0.8 - 8.3

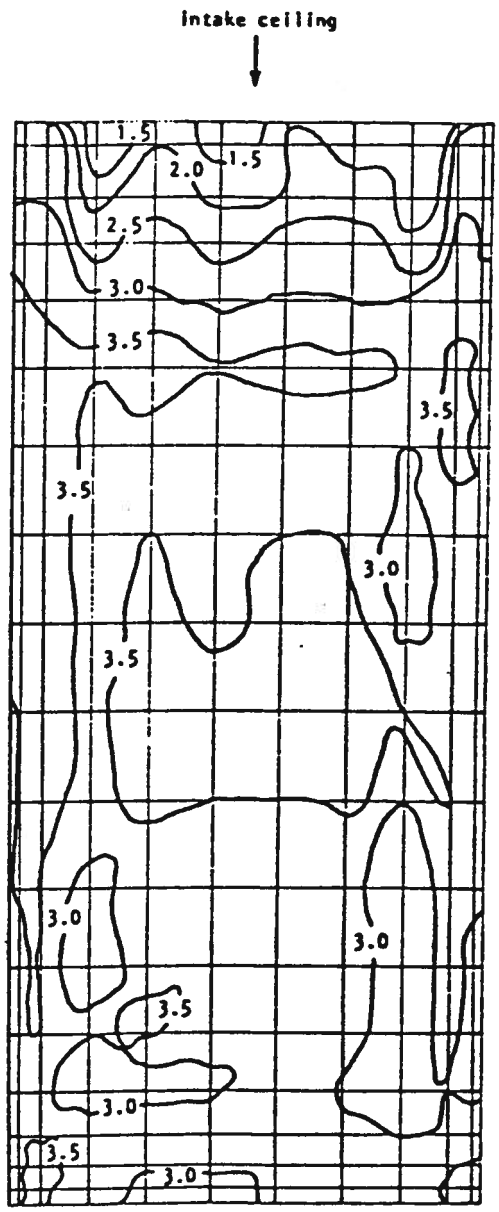


Figure E1. Current velocity profile in fps within Turbine Intake 6A at 67.4 ft gross head and 70% wicket gate opening (DCPUD 1975).

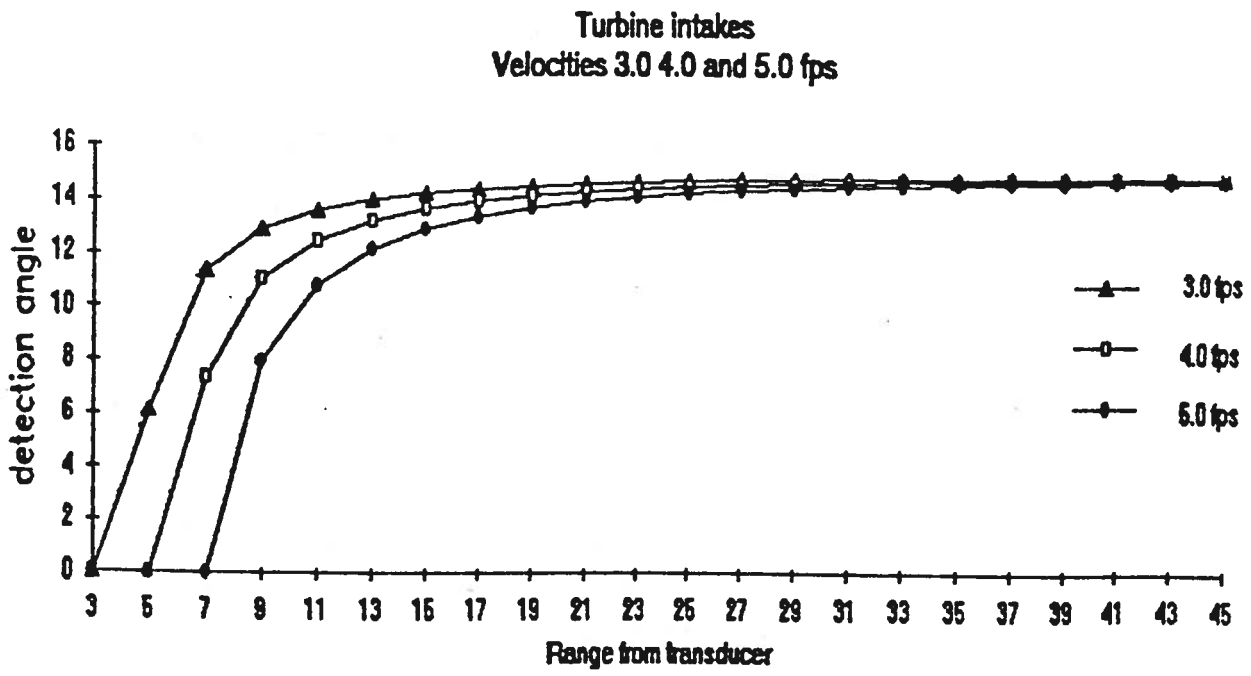


Figure E2. The effective beamwidths over all ranges from the transducer for various velocities for typical turbine intake conditions, Wells Dam 1991.

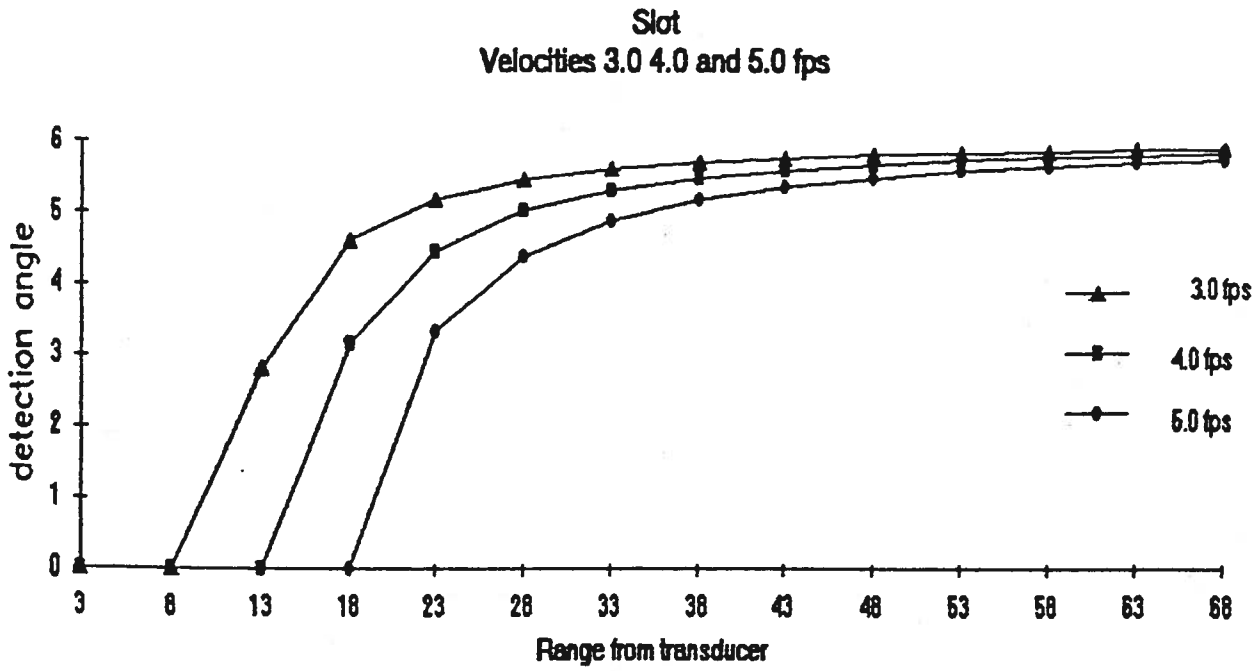
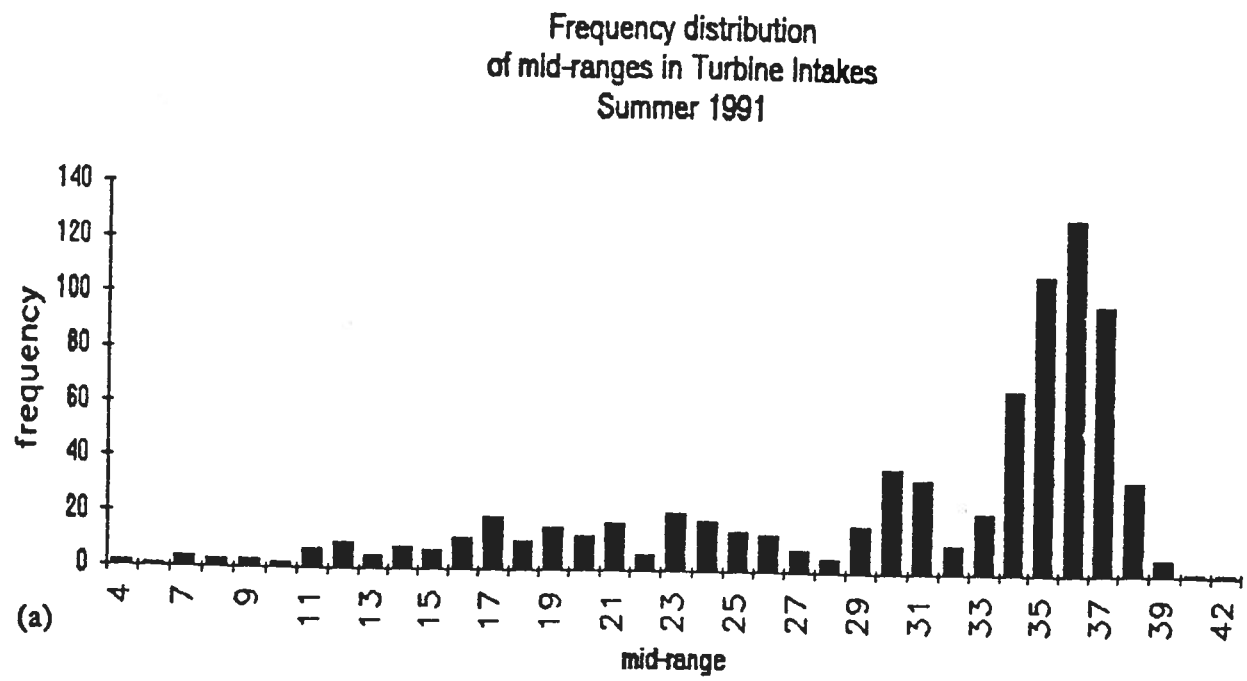


Figure E3. The effective beamwidths over all ranges from the transducer for various velocities for typical bypass slot conditions, Wells Dam 1991.



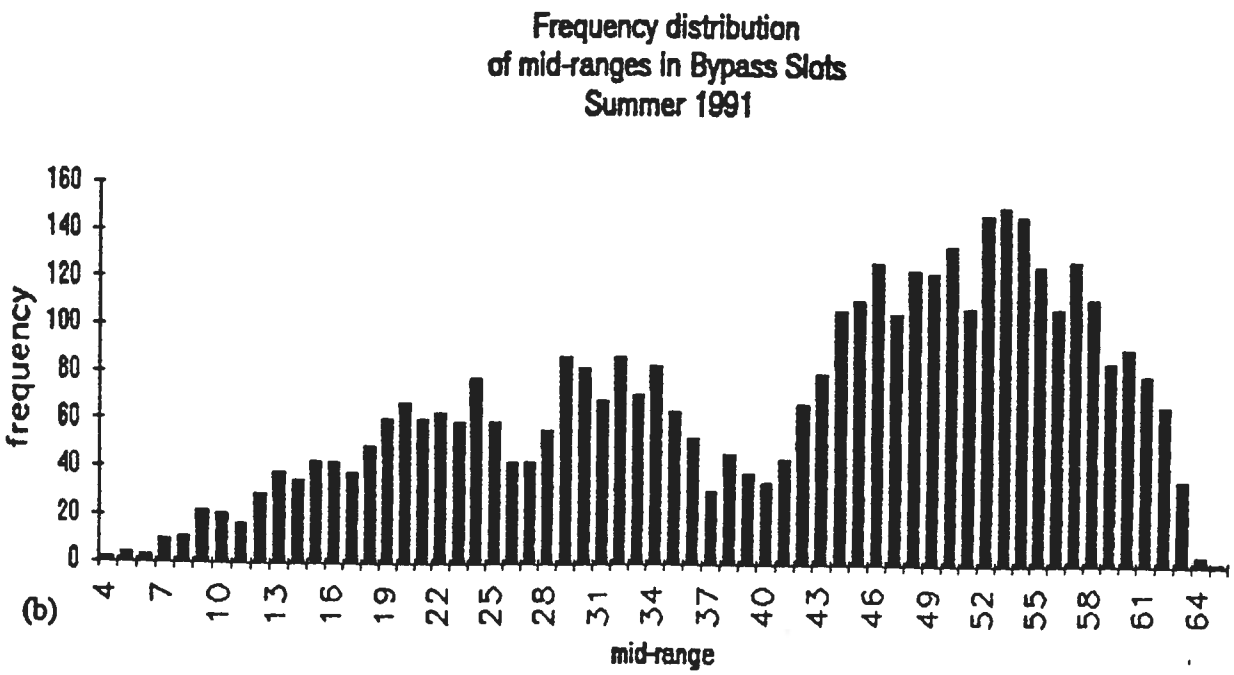


Figure E4. Vertical distribution of migrants for a) turbine intakes and b) bypass slots, Wells 1991.

FYKE NETTING

AT

WELLS DAM IN 1991

APPENDIX - D

Fyke Netting at Wells Dam, 1991

Rick Klinge, Fisheries Biologist
Douglas County P.U.D.
East Wenatchee, Washington

January 1992

During the spring and summer months, the Wells Hydroelectric Project operates a bypass system to protect migrating salmonids (smolts) in route to the Pacific Ocean. The bypass at Wells takes advantage of the unique hydrocombine design of the dam. Conventional dams on the Columbia have separate areas for spill and power generation. The hydrocombine design has intake for the spill gates located directly above the turbine intakes. Five of the eleven spill bay intakes at Wells have been partially constricted, leaving a vertical opening or slot sixteen feet wide and approximately seventy feet deep (Figure 2). Spill gates opened one foot provides the necessary water velocities at the vertical slot sufficient to attract, guide and safely pass smolts. The bypass and it's operations at Wells have been developed under the consultation of Joint Fisheries Parties comprised of various State and Federal fisheries agencies and tribe.

1991 was the second year of a three year evaluation of fish passage efficiency (FPE) of the bypass system. The evaluation was made via hydroacoustic sampling of fish passing Wells. Calculations are made of the numbers of fish migrating through bypass spill and through turbines flow. The percent of the fish that use the bypass is referred to as fish passage efficiency (FPE).

While the hydroacoustic sampling indicated the presence of fish, the fyke netting verifies what species are present. Several years of hydroacoustic and fyke net sampling have shown the migration of three species of salmonids at Wells occurs over several months. The migration is divided into two distinct periods; a spring migration and a summer migration. Earliest migrants are spring chinook, followed by steelhead and sockeye. Summer chinook smolts start their migration around the first week in July. Fish from both the spring and summer periods are composed of hatchery and wild migrants.

Hydroacoustic Index of Fish Passage

Hydroacoustic monitoring of presence of fish began on March 28. Four transducers sampled the Wells forebay for presence of fish. A day index samples between 1:00 PM and 5:00 PM and an evening index sampled between 10:00 PM and 2:00 AM. Index values are used to start bypass operation. Fyke netting a turbine intake provided species composition of the fish detected by hydroacoustic equipment.

The hydroacoustic index of the forebay showed a strong spike on April 13 with the arrival spring chinook from the Winthrop National Hatchery at Wells (Figure 3). The forebay index was not collected during the spring and summer evaluation of the bypass. Once resumed on May 24, the forebay index remained relatively low through the month of June. In years past, the forebay index would build in July as summer chinook migrants reach the dam. Non-salmonids (ie, minnows, squawfish, suckers and lamprey) also are moving more in the reservoir and effect the hydroacoustic forebay index. To adjust the forebay index for non-salmonids, a correction factor of percent salmonids taken in the fyke net samples is applied to the forebay index to produce an adjusted index. The adjusted index is used to determine the start and end of the summer bypass season.

Summer bypass operations were initiated on July 5 when the adjusted index signified the presence of chinook migrants. An evaluation of the bypass for the summer migration was initiate on July 8 and ran for fifteen days. The bypass was operated until August 19 at 2:00 PM when the adjusted index indicated the migration of juvenile summer chinook was finished for the year.

Fyke Netting

Fyke netting collected fish between 10 P.M. and 6 A.M. the following morning. Sampling was done with 3/8 inch mesh fyke nets (7 feet by 6 feet) with 1/4 inch mesh cod end. Seven fyke nets in a column were attached to a metal frame that was lowered into a turbine gate slot. Turbine bay 4C had been selected for fyke netting in the past. In 1991, due to excessive floating debris in front of Unit 4, the fyke netting was moved to Unit 8 after May 16. A reduced number of nets were used to collect information on species composition early in the spring to minimize mortality of fish from sampling. Also, a change from previous years seen in 1991 to minimize sampling mortality, fyke netting was delayed from early April to mid May. Since species composition has been entirely salmonids during April and early May, fyke netting was felt not to be necessary to obtain a catch composition of salmonids.

Fyke netting was started on May 15 and continued weekly through August 28. The catch and amount of effort can be seen on Table 1. Catches were greatest for chinook yearlings on May 23. Records of adipose clipped fish were made from May 30 through the end of August. All clipped chinook were saved by personnel at the Wells Salmon Hatchery for later coded wire tag recovery and tag identification. A total of 36 adipose clipped yearling chinook were captured. Zero aged chinook (0's) contributed the highest catches in late July and early August. Low numbers of sockeye and steelhead

may be partially due the fact that fyke netting started late in the spring migration. Unusually high flows out of the Okanogan and Methow Rivers may have aided an early migrations past Wells before fyke netting started.

Fork length of salmonids caught are provided in Table 2. Chinook lengths have a wide range between high and low size for catches in May and June. The catch during this period was made up of two year classes of fish. Chinook catches in July and August are made up of primarily 0's. There were 36 adipose clips among the chinook felt to be yearlings. No adipose clipped fish were recovered after July 11.

Sockeye migrating out of Lake Osoyoos were a small portion of the fyke net catches in 1991. This may be partly due to the delayed effort to collect species composition of downstream migrants with fyke nets this year. Sockeye collected in May were uniform in size. One zero age sockeye caught on August 22 was 52mm in length.

Fork lengths from only five steelhead were collected in 1991. The size of these fish indicated they were probably smolts. Two steelhead, one caught in late July and the other in early August, were also the size of smolts. The three steelhead measured on May 23 were adipose clipped.

Figure 1. Location of Wells Dam

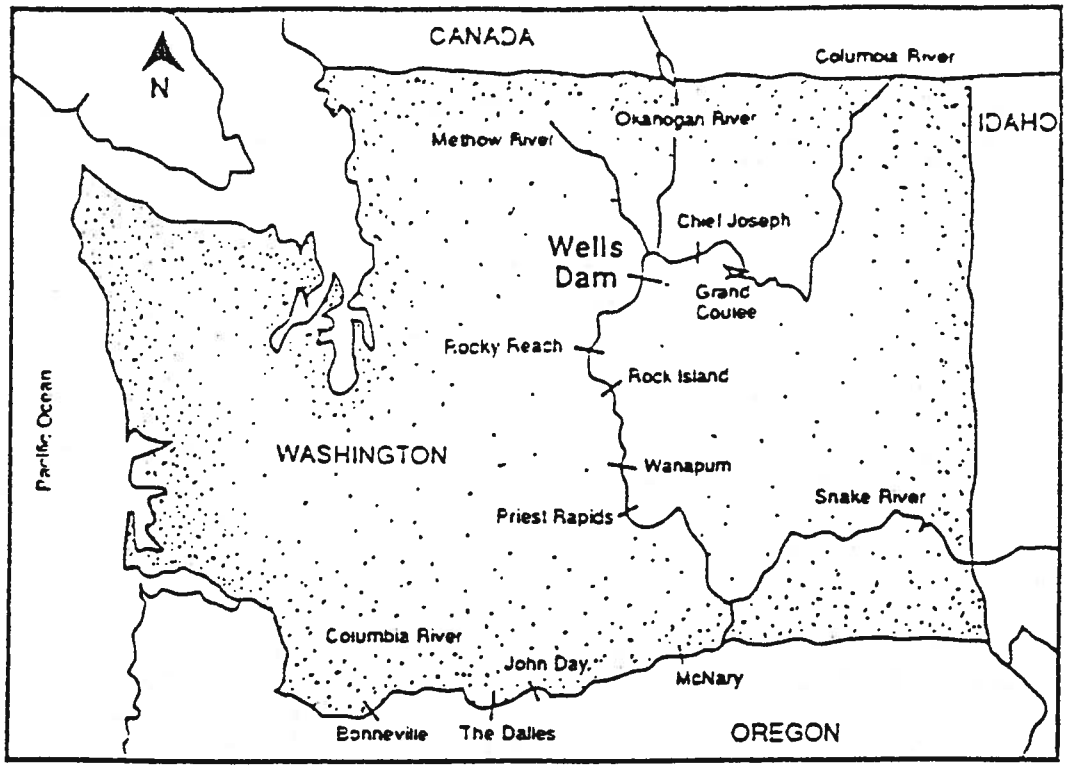


Figure 2. Head on and side view of bypass system and turbine intake at Wells Dam.

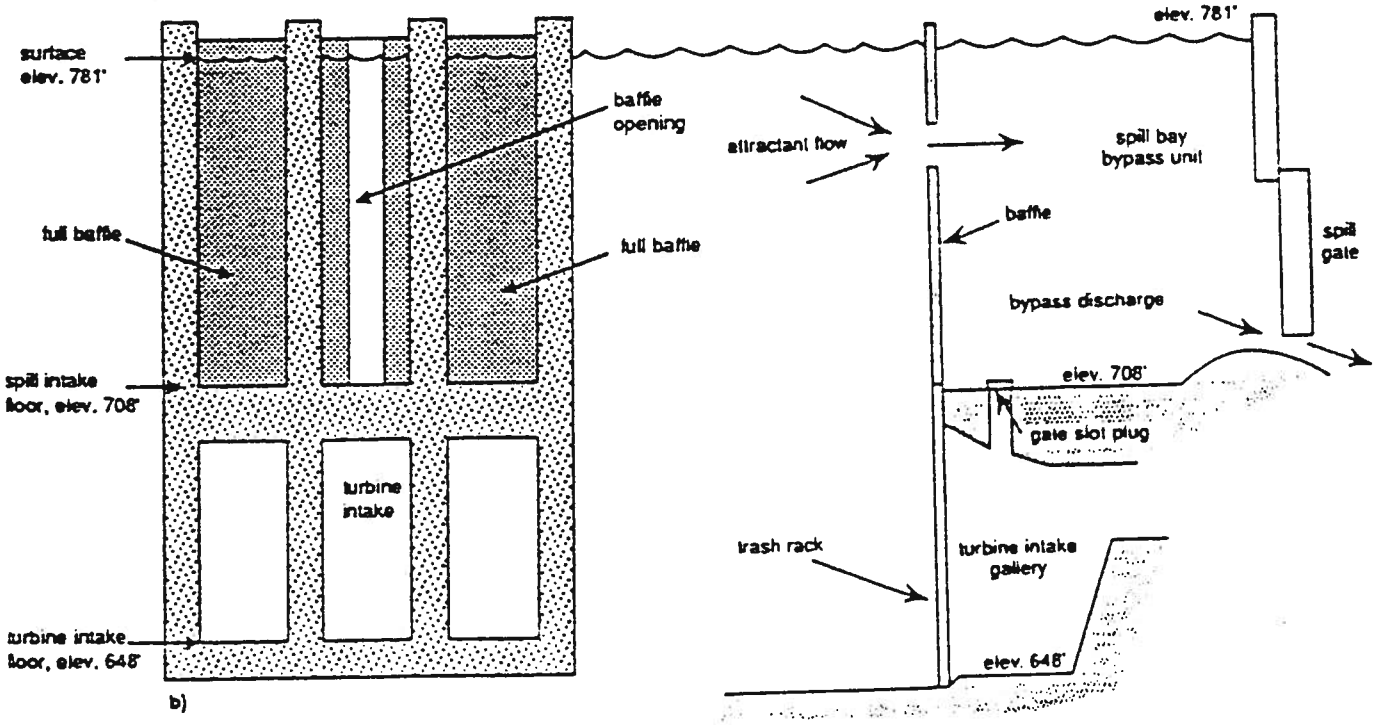


Figure 3. Hydroacoustic Index at Wells Dam

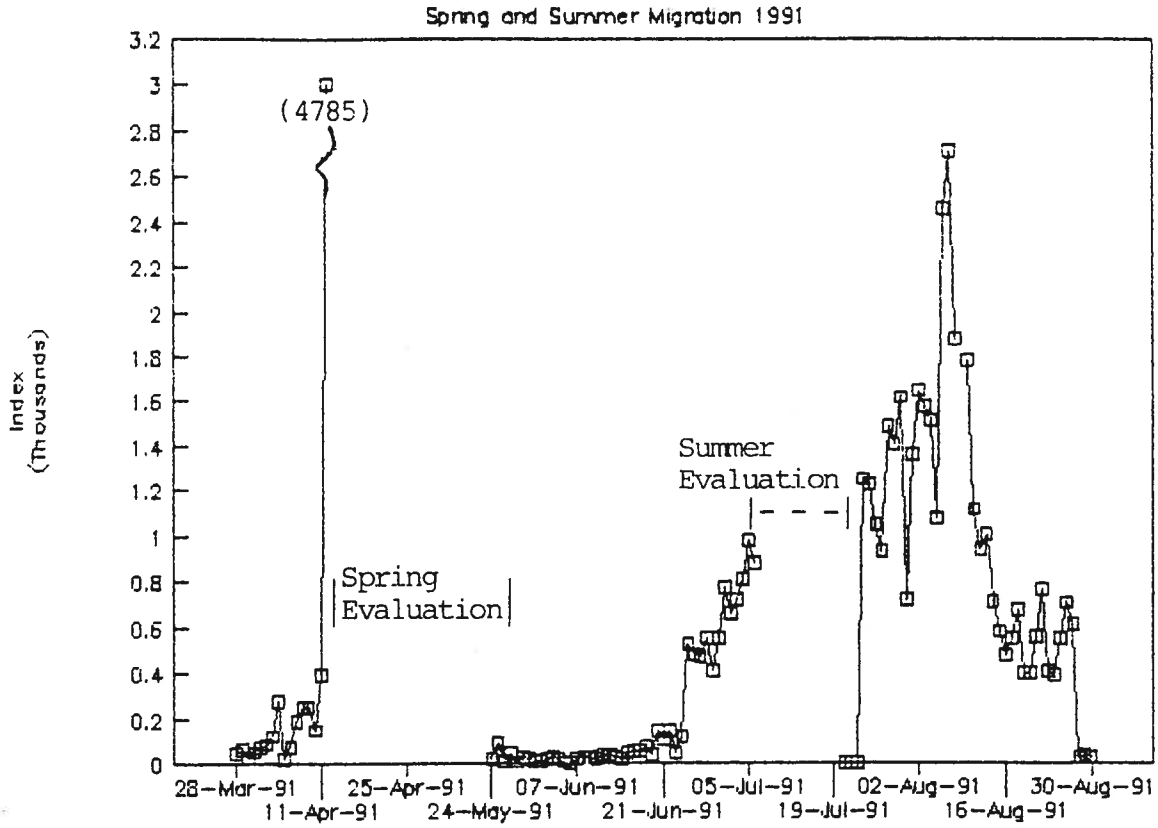


Table 1. Fyke netting turbine intakes at Wells Dam, 1991.

Date	No. Nets	Total Salmon	--Chinook-- 1+	0's	Sock	Sthd	non-salmon	Percen Salmon
16-May	4	16	5	2	9	0	20	44%
23-May	4	302	263	2	34	3	16	95%
30-May	4	32	28	3	1	0	3	91%
06-Jun	7	14	13	1	0	0	24	37%
13-Jun	7	20	13	7	0	0	49	29%
20-Jun	7	13	8	5	0	0	62	17%
27-Jun	7	8	5	3	0	0	17	32%
03-Jul	7	13	10	3	0	0	14	48%
11-Jul	7	59	56	3	0	0	23	72%
18-Jul	7	53	49	4	0	0	17	76%
25-Jul	7	137	11	126	0	0	9	94%
01-Aug	7	99	0	98	0	1	10	91%
08-Aug	7	76	0	76	0	1	9	89%
15-Aug	7	19	0	19	0	0	4	83%
19-Aug	7	15	0	15	0	0	12	56%
22-Aug	7	11	0	10	1	0	8	58%
28-Aug	7	4	0	4	0	0	116	3%
			461	381	45	5	413	

Table 2. Fork lengths from salmonids caught in fyke net at Wells, 1991.

	======= Chinook =======					======= Sockeye ========					======= Steelhead =======				
Date	Avg	High	Low	SD	Count	Avg	High	Low	SD	Count	Avg	High	Low	SD	Count
16-May	130	164	42	48	7	110	122	106	5	9					0
23-May	165	213	98	26	100	114	124	101	5	30	202	228	163	28	3
30-May	146	190	56	25	31	120	120	120	0	1					0
06-Jun	143	172	56	27	14					0					0
13-Jun	117	168	50	38	20					0					0
20-Jun	91	140	51	30	13					0					0
27-Jun	86	113	44	28	8					0					0
03-Jul	101	145	47	27	13					0					0
11-Jul	110	150	69	16	59					0					0
18-Jul	115	194	87	18	53					0					0
25-Jul	107	122	82	11	100					0	228	228	228	0	1
01-Aug	108	130	82	10	98					0	228	228	228	0	1
08-Aug	110	128	75	11	76					0					0
15-Aug	109	135	88	15	19					0					0
19-Aug	110	133	87	13	15					0					0
22-Aug	106	122	73	15	10	52	52	52	0	1					0
29-Aug	121	137	100	14	4					0					0

SAMPLE SIZE CALCULATIONS

FOR

A PIT-TAG STUDY

AT

WELLS DAM IN 1991

APPENDIX - E

Sample Size Calculations
for a PIT-Tag Study at Wells Dam in 1991

To

Douglas County PUD

From

John R. Skalski
Center for Quantitative Science, HR-20
University of Washington
Seattle, WA 98195

March 4, 1991

Introduction

A paired release of PIT-tagged fish is proposed at Wells Dam to evaluate the relative survival rates of steelhead through two alternate routes in the dam. A 10% difference in survival between groups is considered important to detect and is the basis for subsequent sample size calculations. The steelhead will be released simultaneously at Wells Dam with the smolt detected at the decoder facilities at McNary Dam. This paired release-recapture study is the simplest of sampling protocol discussed in Burnham et al. (1987) and is similar to the survival studies conducted at Bonneville Power House #2 in recent years.

An important assumption of the study (a complete list of assumptions can be found in Burnham et al. 1987, pp. 51-52) is complete mixing of the fish of the two release groups below Wells Dam. A test of mixing will be performed by comparing the pattern of daily recoveries of the smolt at McNary Dam. The test of complete mixing will be performed using a test of homogeneity for an K x 2 contingency table. Validity of the survival estimate is predicated upon this assumption of complete mixing being true and the confirmation by the test of homogeneity.

Methods

The survival rate (S_T) associated with the passage of the treatment group through Wells Dam is estimated by the expression (Appendix A):

$$\hat{S}_T = \frac{\left(\frac{y_.}{R_T}\right)}{\left(\frac{x_.}{R_C}\right)}$$

where

R_C = number of control fish released,

R_T = number of treatment fish released,

$y_.$ = total number of treatment fish recovered at McNary Dam,

$x_.$ = total number of control fish recovered at McNary Dam.

The estimate of treatment survival $(\hat{S}_T)$ or the treatment mortality rate $(1-\hat{S}_T)$ has an associated sampling variance of:

$$Var(\hat{S}_T \mid S_T) = \frac{S_T(1-S_T P_.)}{R_T P_.} + \frac{S_T^2(1-P_.)}{R_C P_.}$$

where $P_.$ = probability control fish survive and are detected at McNary Dam.

Sample size calculations are therefore based on "guesstimates" of the anticipated values of S_T and $P_.$ encountered during the PIT-tag study.

The required number of the PIT-tagged fish to be released at Wells Dam also is dependent upon the desired precision of the study. For purposes of this study, precision will be defined by the expression:

$$P(|\hat{S}_T - S_T| < \epsilon) = 1-\alpha \quad .$$

In other words, we want the different between the estimate and the true value $(\hat{S}_T - S_T)$ to be less than or equal to $\pm\epsilon$, $(1-\alpha)$ 100% of the time. For example, if one wanted a precision of ±5%, 90% of the time, precision would be expressed as:

$$P(|\hat{S}_T - S_T| < 0.05) = 0.90 \quad .$$

In subsequent sample size calculations, we assumed sample sizes are equal for both control and treatment groups (i.e., $R_C = R_T = R$).

In a 1987 PIT-tag study, Scott McCutcheon estimated the average recovery rate of PIT-tagged fish at McNary Dam from release at Priest Rapids Dam to be 0.406 (values 0.358, 0.416, and 0.445) for steelhead under no flow spill conditions at the recovery site. Recovery rates will decrease under spill conditions at McNary Dam. Assuming a survival rate of steelhead smolt between Wells and Priest Rapids of ~0.6, the anticipated rate of recovery of PIT-tagged fish from Wells to McNary Dam is about $P. =$ 0.24. Subsequent sample size calculations used a range of $P. =$ 0.2 to 0.3.

Results

Two approaches to sample size calculations were used in evaluating the study design. The first approach was to determine the anticipated precision that might be expected with a total release size of 3000 PIT-tagged fish (i.e., $R_C = R_T =$ 1500) (Table 1). With 1500 fish per group, the differential survival (i.e., S_T projected to be 0.90) can be estimated with a precision of ±0.086, 90% of the time if recovery rates at McNary are 30%. Should recovery rates drop to 20%, the precision drops to ±0.112, 90% of the time. Hence, it appears 3000 fish is about at the minimum release size; for ideally, you would want $\epsilon < 0.10$ $(= 1 - S_T)$ mortality rate considered important to detect.

As an alternative approach, the release size (R) required to have a precision of $\pm\epsilon$, $(1-\alpha)$ 100% of the time was also calculated (Table 2). For instance, to have a precision of ± 0.05, 90% of the time, $R = 7502$ or a total release of 15,000 PIT-tagged fish is necessary. Inspection of Table 2 indicates very large sample sizes are needed for high levels of precision.

From the sample size calculations (Table 2), I would recommend that during this preliminary study, a minimum release of 3712 fish be used (i.e., $R_C = R_T = 1876$). At this release size, under unfavorable conditions (i.e., $P_{\cdot} = 0.2$), the study has a precision of $\epsilon = 0.10$, 90% of the time. In this situation, ϵ equals the mortality rate of 0.10 considered important to detect. In other words, at $(1-S_T) = 0.10$, we can expect a 90% confidence interval to be $CI(0 < 1-S_T < 0.20) = 0.90$. Hence, 90% of the time with $R_C + R_T = 3712$, we will be able to detect the presence of mortality $(1-S_T) \geq 0.10$ if it exists.

Should the 1991 study confirm a potential problem, subsequent studies in 1992 and beyond would use greater sample sizes to more precisely estimate $1-S_T$. As a final warning, if there is appreciable spill at McNary Dam, the above sample sizes would be underestimates.

Table 1. Anticipated precision of the dual release-recapture study at Wells Dam when sample sizes are $R_C = R_T =$ 1500 fish when $S_T = 0.90$ and $P. = 0.2, 0.3$ at $1 - \alpha = 0.90, 0.95$.

$R_T = R_C$	$P.$	$1 - \alpha$	ϵ
1500	0.2	0.90	0.112
1500	0.3	0.90	0.086
1500	0.2	0.95	0.133
1500	0.3	0.95	0.102

Table 2. Predicted sample sizes $(R_C = R_T)$ required to have a precision of ϵ = 0.02, 0.05, 0.10 at $1 - \alpha$ = 0.90, 0.95, when S_T = 0.90 and $P_.$ = 0.2, 0.3.

ϵ	$1 - \alpha$	$P_.$	$R_C = R_T$	$R_C + R_T$
0.02	0.90	0.20	46882	93764
0.05	0.90	0.20	7502	15004
0.10	0.90	0.20	1876	3712
0.02	0.90	0.30	27602	55204
0.05	0.90	0.30	4417	8834
0.10	0.90	0.30	1105	2210
0.02	0.95	0.20	66556	133112
0.05	0.95	0.20	10649	21298
0.10	0.95	0.20	2663	5326
0.02	0.95	0.30	39185	78370
0.05	0.95	0.30	6270	12540
0.10	0.95	0.30	1568	3136

Literature Cited

Burnham, K. P., D. R. Anderson, G. C. White, C. Brownie, and K. H. Pollock. 1987. Design and analysis method for fish survival experiments based on release-recapture. *Amer. Fish. Soc. Monograph* 5. 437 pp.

Appendix A

Statistical basis for the survival estimate $\hat{S}_T$, or analogously $1 - \hat{S}_T$ (differential mortality between release groups) is maximum likelihood estimation. The major assumptions of the estimation scheme are:

1. The probability of mortality through the treatment channel $(1 - S_T)$ is independent of subsequent downstream mortality.
2. Survival of control and treatment groups from below Wells Dam to the recovery site at McNary Dam on day $i(S_i, i = 1, \ldots, K)$ is the same.
3. Daily probabilities of recovery $p_i(i = 1, \ldots, K)$ are the same for control and treatment groups.
4. Fates of the PIT-tagged fish are independent of one another.

Using these assumptions, a likelihood model can be constructed where:

$$L\left(\underset{\sim}{x}_i, \underset{\sim}{y}_i \mid R_C, R_T, S_T, \underset{\sim}{S}_i, \underset{\sim}{p}_i\right) =$$

$$\binom{R_C}{\underset{\sim}{x}_i, R_C - x.}(p_1 S_1)^{x_1}(p_2 S_2)^{x_2}\ldots(p_K S_K)^{x_K}\left(1 - \sum_{i=1}^{K} p_i S_i\right)^{R_C - x.}$$

$$\cdot\binom{R_T}{\underset{\sim}{y}_i, R_T - y.}(S_T p_1 S_1)^{y_1}(S_T p_2 S_2)^{y_2}\ldots(S_T p_K S_K)^{y_K}$$

$$\cdot\left(1 - \sum_{i=1}^{K} p_i S_i S_T\right)^{R_T - y.}$$

and where

R_C = number of control fish released,

R_T = number of treatment fish released,

x_i = number of control fish recovered in day $i (i = 1, \ldots, K)$,

y_i = number of treatment fish recovered on day $i (i = 1, \ldots, K)$,

$x.$ = total number of control fish recovered,

$y.$ = total number of treatment fish recovered.

Note p_i and S_i are not separately estimable; hence, denote $P_i = p_i S_i$. The likelihood function can then be written as:

$$L\left(\underset{\sim}{x_i}, \underset{\sim}{y_i} \mid R_C, R_T, \underset{\sim}{P_i}, S_T\right) = \binom{R_C}{\underset{\sim}{x_i}, R_C - x.} \prod_{i=1}^{K} P_i^{x_i} \left(1 - \sum_{i=1}^{K} P_i\right)^{R_C - x.}$$

$$\cdot \binom{R_T}{\underset{\sim}{y_i}, R_T - y.} S_T^{y.} \prod_{i=1}^{K} P_i^{y_i} \left(1 - S_T \sum_{i=1}^{K} P_i\right)^{R_T - y.} .$$

The maximum likelihood estimates of S_T from the above likelihood is:

$$\hat{S}_T = \left(\frac{y.}{R_T}\right) / \left(\frac{x.}{R_C}\right)$$

with the associated variance

$$Var(\hat{S}_T) = \frac{S_T\left(1 - S_T \sum_{i=1}^{K} P_i\right)}{R_T \sum_{i=1}^{K} P_i} + \frac{S_T^2\left(1 - \sum_{i=1}^{K} P_i\right)}{R_C \sum_{i=1}^{K} P_i}$$

$$= \frac{S_T(1 - S_T P.)}{R_T P.} + \frac{S_T^2(1 - P.)}{R_C P.}$$

and variance estimator

$$\hat{Var}(\hat{S}_T) = \hat{S}_T^2 \left[\frac{1}{y.} - \frac{1}{R_T} + \frac{1}{x.} - \frac{1}{R_C}\right] .$$

The assumption of equal downriver survival and recapture probabilities for control and treatment releases is predicated upon the assumption of complete mixing of the release groups. The condition of complete mixing can be tested using an K x 2 contingency table and a chi-square test of homogeneity. The contingency table is constructed as follows:

Day	Control	Treatment	
1	x_1	y_1	$x_1 + y_1$
2	x_2	y_2	$x_2 + y_2$
3	x_3	y_3	$x_3 + y_3$
.	.	.	.
.	.	.	.
.	.	.	.
K	x_K	y_K	$x_K + y_K$
	$x.$	$y.$	$x. + y.$

The chi-square test of homogeneity has K-1 degrees of freedom.

Supplementary Sample Size Calculations for 1991 PIT-tag Study

To

Douglas County PUD

From

John R. Skalski
Center for Quantitative Science, HR-20
University of Washington
Seattle, WA 98195

March 11, 1991

The proposed PIT-tag study will use a total release of $R_C + R_T = 4400$ fish or each group will have a sample size of $R = R_C = R_T = 2200$. The anticipated precision of the survival study using $R = 2200$ is summarized in Table 1 below.

Table 1. Projected precision (ϵ) for the PIT-tag study when $1 - S_T = 0.10$, $P_. = 0.20, 0.30$, and $1 - \alpha = 0.90, 0.95$.

Release Size (R)	$(1-\alpha)$	$P_.$	ϵ
2200	0.90	0.20	0.0720
	0.90	0.30	0.0552
	0.95	0.20	0.0786
	0.95	0.30	0.0603

Supplementary Sample Size Calculations for 1991 PIT-tag Study

To

Douglas County PUD

From

John R. Skalski
Center for Quantitative Science, HR-20
University of Washington
Seattle, WA 98195

April 2, 1991

The proposed PIT-tag study will use a total release of $R_C + R_T = 4400$ fish or each group will have a sample size of $R = R_C = R_T = 2200$. The anticipated precision of the survival study using $R = 2200$ is summarized in Table 1 below.

Table 1. Projected precision (ϵ) for the PIT-tag study when $1 - S_T = 0.10$, $P. = 0.20, 0.30$, and $1 - \alpha = 0.90, 0.95$.

Release Size (R)	$(1-\alpha)$	$P.$	ϵ
2200	0.90	0.20	0.0720
	0.90	0.30	0.0552
	0.95	0.20	0.0786
	0.95	0.30	0.0603

HYDROACOUSTIC EVALUATION

OF

ADULT SOCKEYE SALMON PASSAGE

AT

ZOSEL DAM IN 1991; DRAFT REPORT

APPENDIX - F

Hydroacoustic Evaluation of Adult Sockeye Salmon Passage at Zosel Dam in 1991

Draft Report

Sponsored by:

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January 17, 1992

ACKNOWLEDGEMENTS

The study at Zosel Dam would not have been possible with the help and guidance of many people. We sincerely thank:

- Tom Scott (OTID) for dam operation information and help during the sampling period. And also the many people of Oroville who opened up their homes and restaurants for the system operators.

- Rick Klinge (DCPUD) and Mike Erho for ancillary information, support, and guidance during this years study.

- Chris Carlson (GCPUD) for information provided on the spawning grounds in Oliver, B.C.

- Eddie Kudera, Brock Stables, and Alex Birmingham for the set-up of the hydroacoustic system, and assistance with the data processing.

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1.0 INTRODUCTION

1.1 Background

A natural run of sockeye salmon (*Oncorhynchus nerka*) migrates up the Columbia River and through the Okanogan River to spawning grounds above Lake Osoyoos. Enumeration of Okanagon sockeye historically has been conducted at Rocky Reach and Wells Dams (Duree 1991). These fish also pass through Zosel Dam at the outlet of Lake Osoyoos. Zosel Dam is a convenient location to count migrant sockeye because of its proximity to the spawning grounds and its structure includes fishways. Gaining a greater understanding of adult Okanogan sockeye migration timing and magnitude is important because these fish reproduce in the wild and are one of the few sockeye runs remaining in the Columbia Basin.

1.2 Objectives

From August 20 to October 20, 1991, a scientific hydroacoustic system was deployed at Zosel Dam. Because hydroacoustic techniques had not been used at Zosel Dam to count adult sockeye, a two-phased study was performed. In Phase 1, the objective was to determine if acoustic techniques would work. If acoustics would work, then in Phase 2 the objective was to estimate the following features of the adult sockeye upmigration past Zosel Dam:

- Run size
- Daily counts (run timing)
- Diel distribution
- Horizontal distribution

1.3 Study Site Description

Zosel Dam is located on the Okanagon River at Oroville, Washington (Figure 1). It is approximately two miles downstream from the outlet of Lake Osoyoos and 20 miles downstream from the spawning grounds. There are no major rivers between the dam and the spawning grounds.

Construction of the dam was completed in 1987. It was built to replace a wood and concrete dam which dated back to 1927. The original dam created a log storage pond for the adjacent lumber yard. The present dam functions solely as a regulatory device for the water level of Lake Osoyoos. Zosel Dam is owned by the Washington State Department of Ecology and operated by the Oroville-Tonasket Irrigation District.

Zosel Dam has four spillgates, two fishways (east and west), and an overflow weir (Figure 2). The spillgates are 29 feet wide. Each fishway has one upstream exit and two downstream entrances. The upstream exits on the face of the dam are oriented toward the river bank . The two downstream entrances differ in size and orientation to the river. The larger entrance is located at the end of the fishway with the exiting water flowing in the same direction as that of the river. This opening is approximately one foot wide and extends from the dam sill to the deck of the fishway. A smaller entrance (1.5 by 2 ft) is located in the inner wall of each fishway. The smaller entrances have gates to regulate flow. During the study, when fishway sidegates were completely open, the upper edge of the entrance was just below the surface of tailrace water. The fishways are located adjacent to each end of the spillway.

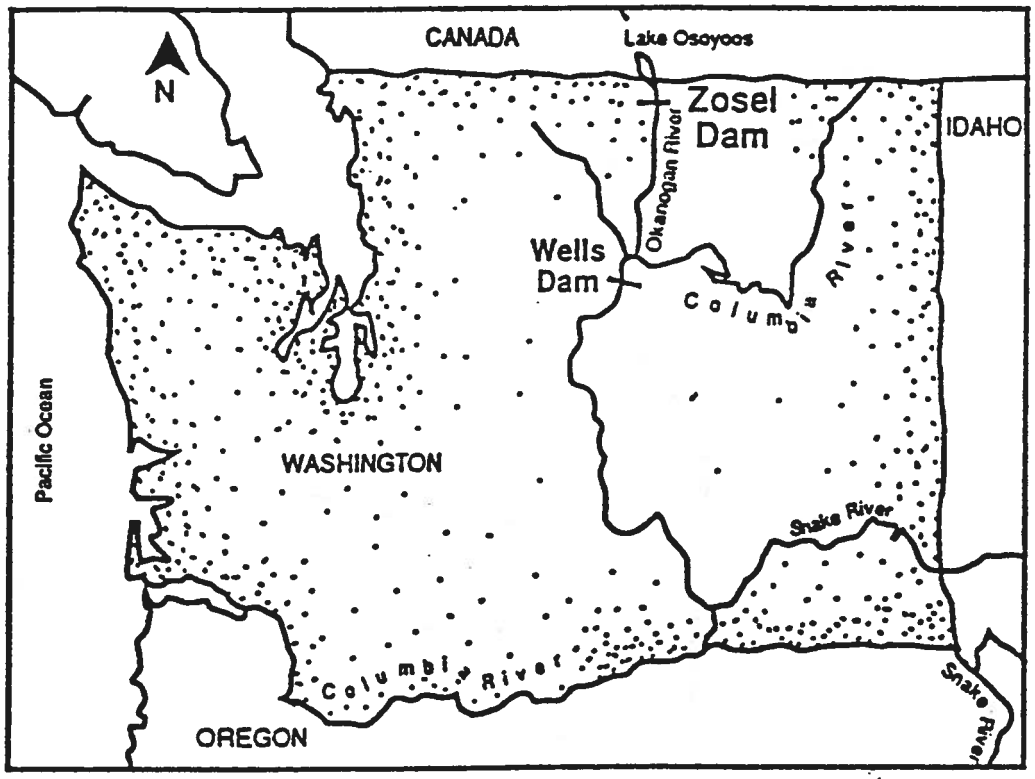

Figure 1. Location of Zosel Dam on the Okanagon River.

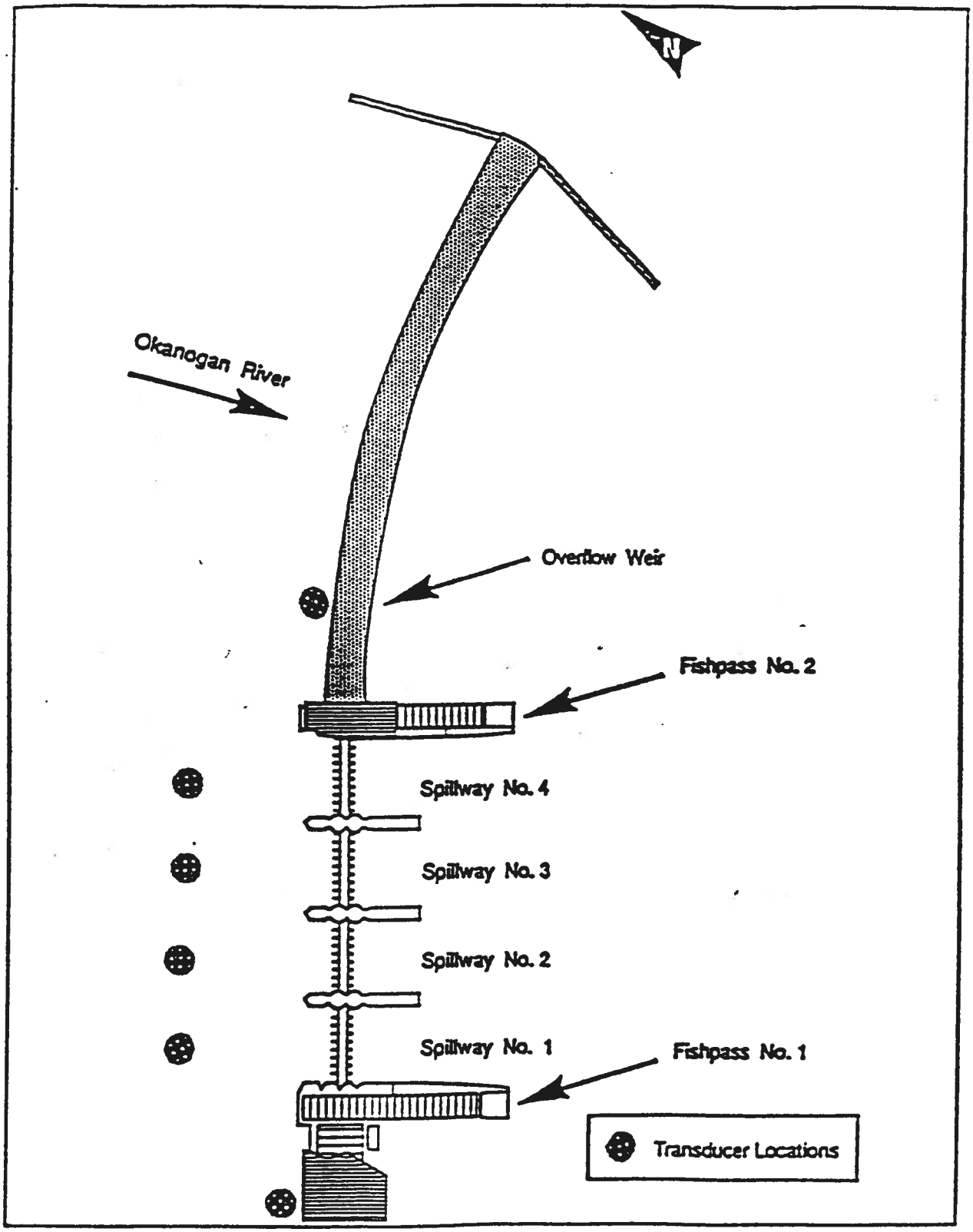

Figure 2. Plan view showing locations of forebay transducers at Zosel Dam in 1991.

2.0 METHODS

2.1 General Approach

We used a phased approach for this study. In Phase 1, we deployed hydroacoustic equipment and assessed the system's ability to detect adult sockeye. In Phase 2, we monitored passage of adult sockeye salmon at Zosel Dam.

During routine monitoring, we used hydroacoustic techniques coupled with extensive visual observations and temperature data. We observed sockeye and resident fish visually from the deck of the dam using a temporary viewing background that was placed immediately outside of the western fishway. The white plastic background was monitored at all times of the day. And, using snorkeling in the forebay and tailrace, we observed fish from underwater. We also made qualitative surveys of sockeye salmon at the spawning grounds to confirm that sockeye had passed Zosel Dam. Douglas County PUD collected temperature data at Wells Dam, Okanogan River Mile 6, and Zosel Dam forebay. The visual observations and temperature data coupled with the hydroacoustic counts provided a comprehensive study approach.

2.2 Hydroacoustic Methods

We used fixed-location hydroacoustic techniques to monitor adult passage at Zosel Dam in 1991. The techniques used were similar to those employed at Wells Dam (Kudera *et al.*. 1991) and are explained by Thorne and Johnson (1992). Operation of BioSonics hydroacoustic systems, reduction of data, and calculation of primary statistics are detailed in Appendix A.

2.2.1 Hydroacoustic System

The BioSonics scientific hydroacoustic system (Figure 3) consisted of: ES2000 Sounder/Multiplexer; transducers; cables; Model 281 Echo Signal Processor (ESP); Model 111 Thermal Chart Recorder; Compaq 386 computer; and Hitachi oscilloscope. We deployed 4X15 deg elliptical and 6 deg circular transducers. The voltages from the ES2000 Sounder were processed in real-time by the Model 281 ESP. The data files created by the ESP were analyzed after the field season.

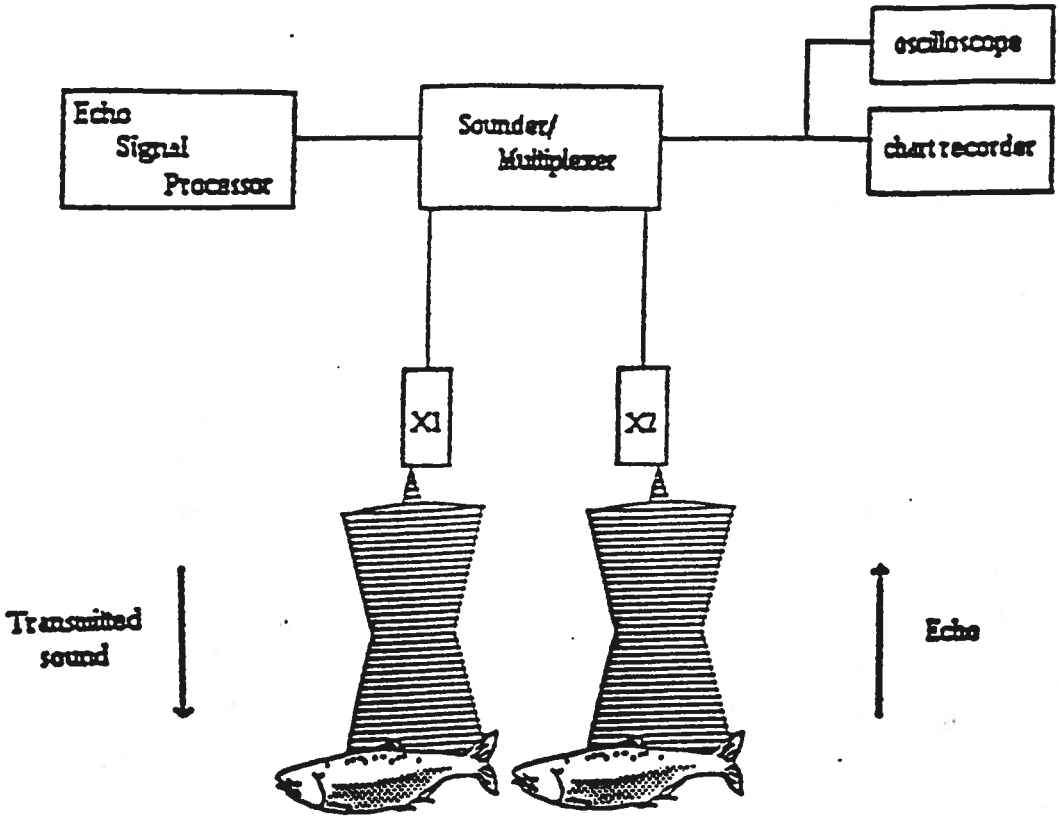

Figure 3. Block diagram of hydroacoustic data collection system used at Zosel Dam between August 31 and October 20, 1991.

2.2.2 Transducer Locations & Orientations

To monitor the passage of salmon through the dam, all dam openings were equipped with hydroacoustic equipment. This was done to ensure that any changes in dam operation, during the study, would not adversely affect the collection of data. Transducers were deployed in the forebay of the dam to monitor passage in the spillway and on the dam face to monitor passage at the fishway exits.

In the forebay, four transducers (4X15 deg) were mounted about 1 ft deep on the bottom of floats which were attached to a nylon line stretching across the forebay approximately 75 ft from the dam. The forebay transducers were aimed downstream toward the spillgate openings 5° down from the surface. To enable the transducers to achieve the correct range, a large amount of milfoil had to be manually removed from the forebay. It was necessary to deploy transducers to sample the spillgates because adult sockeye were seen passing Zosel Dam via the spillway during high flows in 1990 (BioSonics 1991).

Our strategy for sampling the fishways was to position the acoustic beam to detect fish as they exited the fishway (Figures 2, 4, and 5). At the western fishway, a transducer was fastened to a pole-mount and bolted onto the forebay wall 9 meters from the fishway exit (Figure 5a). The transducer was aimed at an angle of 0° angle relative to the surface and downstream toward the exit. At the eastern fishway, a transducer (6 deg) was attached to a pole-mount and bolted onto the overflow weir 9 meters from the fishway exit (Figure 5b). The transducer was aimed at an angle of 0 deg relative to the surface and slightly upstream from the face of the overflow weir. Both fishway transducers were aimed in such a way to give change in range information for discriminating upstream moving fish from downstream moving fish (Figure 6).

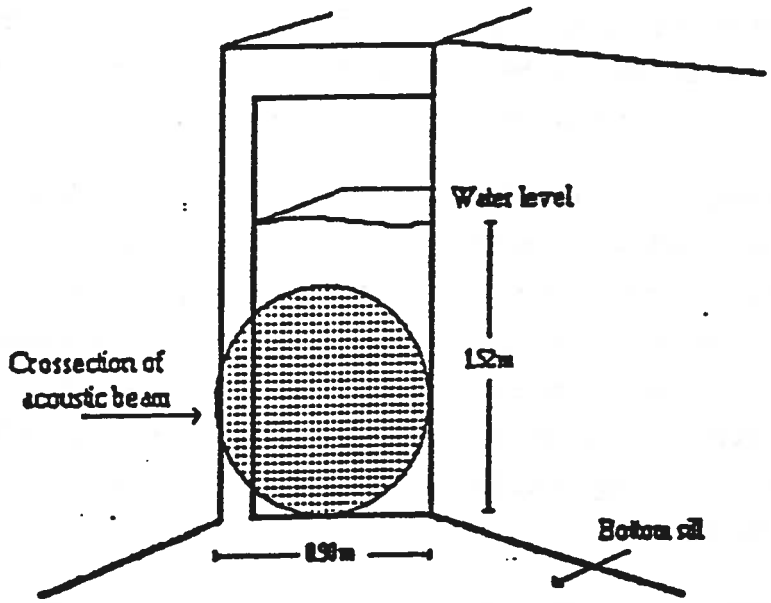

Figure 4. Front view of western fishway opening, showing ensonified cross-section (drawing not to scale).

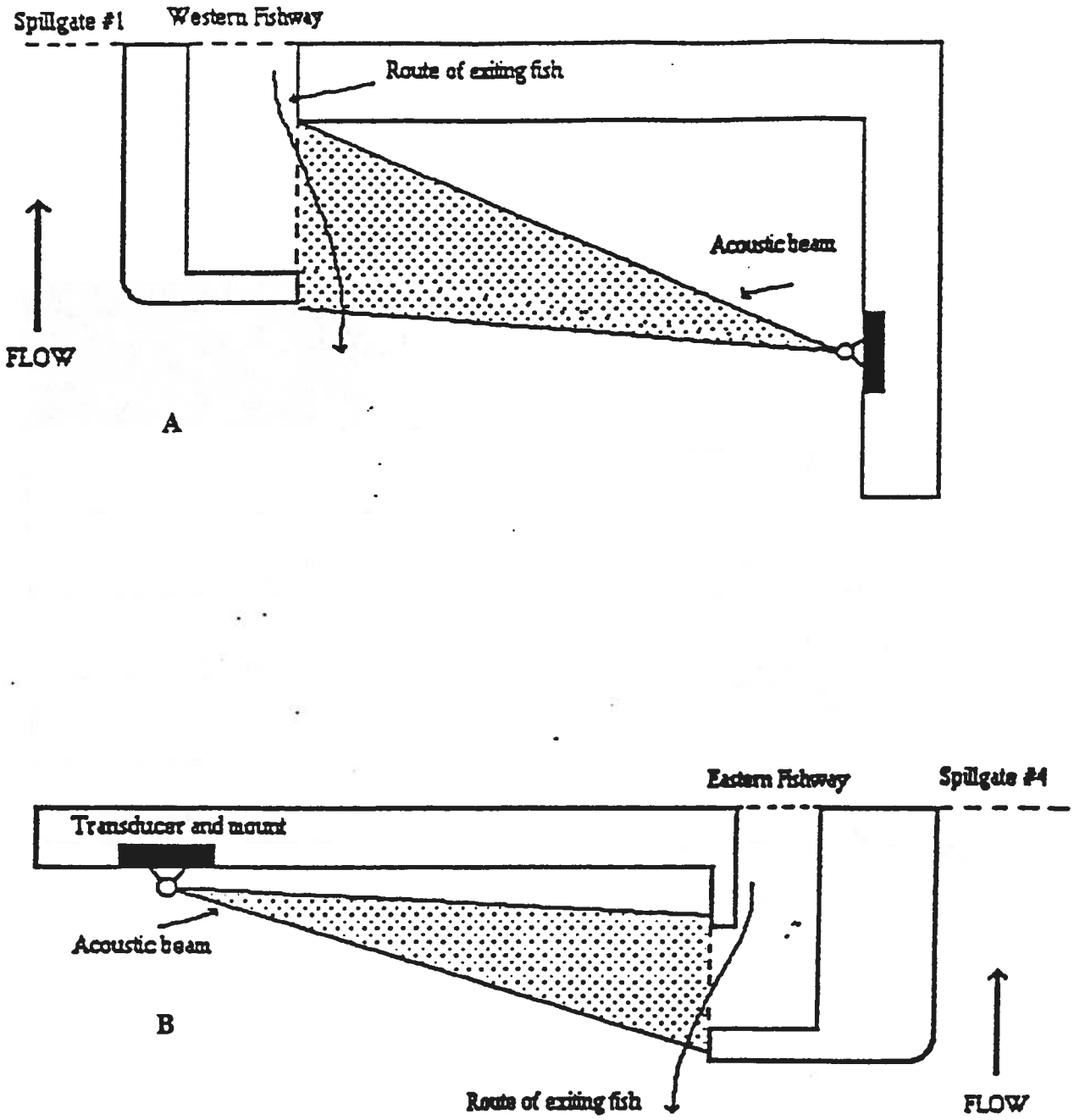

Figure 5. Topview of western and eastern fishways, showing approximate beam angles and travel direction of exiting fish (drawing not to scale).

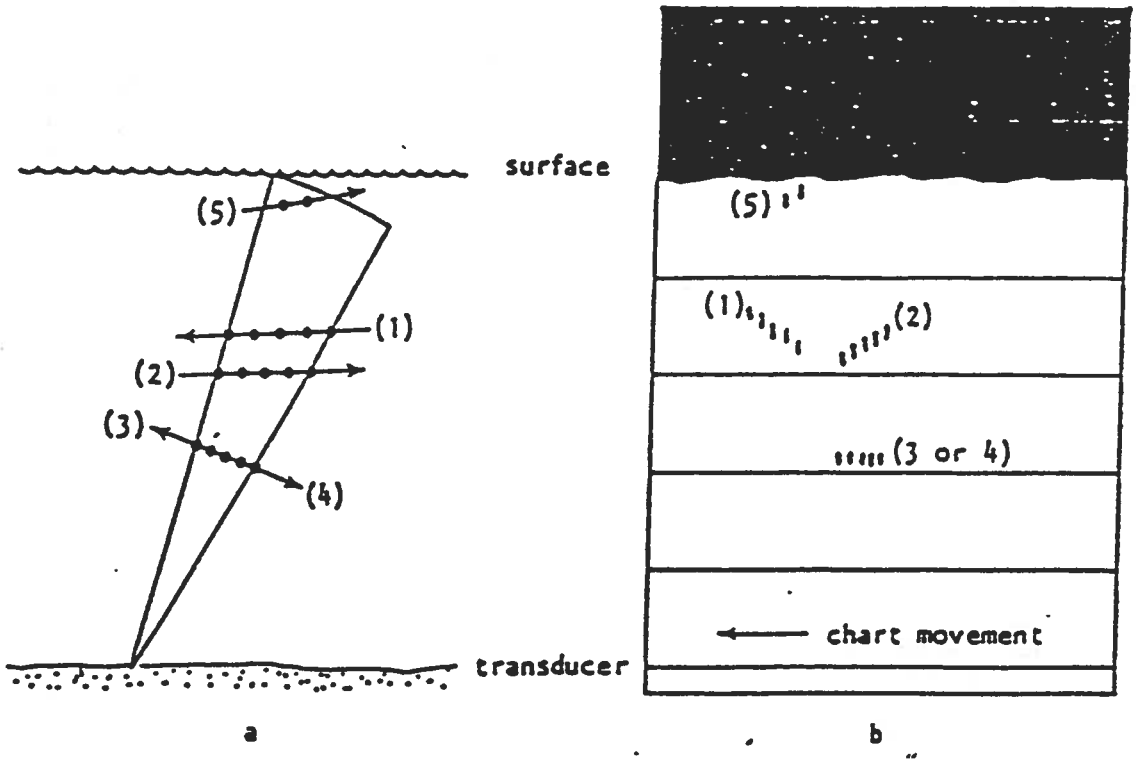

Figure 6. General direction of fish movements determined from trace "trace types" on the chart recordings and computer display.

2.2.3 Sampling Design

Samples were collected 60 min per hour, 24 hours per day from August 31 to October 20, 1991. There were, however, minor stoppages in sampling due to unforeseen complications such as broken cables caused by foraging muskrats.

The hydroacoustic system was programmed to monitor one transducer for a given period of time (5 to 15 min per interrogation), and then switch to the next transducer in the sequence. At the beginning of the study, both fishways and the western-most spillgate (Spillgate No. 1) were included in the sampling sequence (Table 1). All other spillway gates were closed at this time and remained closed throughout the study. Because more fish were seen in the area of the western spillgate and fishway, the western fishway was sampled more intensively than any other location, starting on September 6 (Table 1). After careful analysis of acoustic and visual information, it was determined that there was no passage of salmon through spillgate No. 1, on September 20 we removed this transducer from the sampling sequence. Only information acquired from the fishway transducers was used in the data analysis.

Table 1: Sample minutes per location per hour and dates of changes in sampling design for the hydroacoustic study at Zosel Dam in summer 1991. (X1=western fishway, X2=eastern fishway, X3=westernmost spillway).

Date of Change	Time of Change	X1	X2	X3
8/30/91	0000	20	20	20
9/06/91	0930	30	15	15
9/16/91	1440	30	10	20
9/17/91	0220	30	15	15
9/17/91	1800	30	15	15
9/18/91	0900	30	30	----
9/18/91	1600	30	15	15
9/20/91	1110	40	20	----
10/06/91	1420	35	25	----
10/20/91	2359	35	25	----

2.2.4 Data Analysis

The ESP was programmed with location specific parameters for tracking of adult sockeye salmon moving through the ensonified areas. These parameters were determined after visual and electronic observation of fish movement. The selection criteria used to track salmon and eliminate non-target traces, while data was initially collected, consisted of four parameters:

- Absolute concentration of echoes.
- Concentration of echoes by range.
- Absolute number of echoes from the target.
- Tracked target trajectory through the acoustic beam.

Refer to the Appendix A.2.1 for definition of these and other system parameters. Data for each individual tracked fish were written to computer file automatically. Data files were generated for each day of the study.

To account for unsampled time and cross-sectional area of a fishway exit, each raw tracked fish count was multiplied by a weighting coefficient (Appendix A.3). The basic data set then became hourly weighted fish counts for each day for each fishway during the study. These values were then used to meet the objectives of the study as follows:

- Run size = sum of the daily total passage estimates during the study.
- Daily counts (run timing) = sum of hourly passage estimates for both fishways combined for each day of the study separately.
- Diel distribution = average hourly passage estimates for each of 24 hours separately for both fishways combined during the entire study.
- Horizontal distribution = average hourly passage rate estimates for each fishway separately during the entire study.

3.0 RESULTS

3.1 Dam Operations

There were minor adjustments in gate height, as well as, minor adjustments of the sidegate openings during the 1991 study (Table 2). The western most spillgate was the only gate used during the study period for lake level management. During the study period, the water was maintained at an average elevation of 911.37 ft MSL, resulting in a water depth of 5 feet over the upstream sill of the dam. On October 17 and 18, Spillgate No. 1 was closed to allow construction of a spawning area downstream from the dam. The western fishway sidegate was completely open during the study period, while the eastern sidegate was not opened until September 11, 1991.

Table 2: Changes in gate height at Zosel Dam between August 30 and October 20, 1991. During this period, only the western most spillgate (No. 1) was open; all others were completely closed. Flow information only given for dates indicated. Source. T. Scott (OTID).

Date of Change	Time of Change	Gate Height (in.)	CFS
8/31/91	1902	9.0	274
9/01/91	0745	7.5	345
9/06/91	1051	6.0	301
9/11/91	1300	6.5	284
9/13/91	1500	7.5	309
9/14/91	1705	8.5	339
9/16/91	2000	10.0	484
9/17/91	0800	0.0	349
9/18/91	2005	8.0	195
9/19/91	0745	0.0	218
9/19/91	0759	6.0	***
9/19/91	1650	4.0	***
9/20/91	1300	5.0	247
10/06/91	1230	6.5	271
10/08/91	1030	9.0	336
10/11/91	0900	8.0	350
10/14/91	1400	7.0	325
10/18/91	0954	6.0	285

3.2 Environmental Information

River water temperature data from thermistors located at Wells Dam pool, Okanagon River Mile 6, and the log boom in the forebay of Zosel Dam show that temperatures exceeded 22 deg C in the Okanogan in mid-late August (Figure 7). Data from the Zosel Dam thermistor may be biased, because of the flushing of warm surface waters of Lake Osoyoos. Prolonged temperatures above 22 deg C may be lethal for adult sockeye (Bouck *et al.* 1975). The temperature data will be discussed in context with the run timing data in Section 4.0.

3.3 Visual Observations

3.3.1 Resident Fish

Due to the similarity in size of some resident fish and the migrating adult sockeye, concern was expressed about misinterpreting resident fish as salmon. To assess this potential problem, we visually observed fish and their behavior in the acoustic sampling area. We saw the following resident fish at Zosel Dam in summer 1991: carp (*Cyprinus spp.*), squawfish (*Ptychocheilus spp.*), bass (*Micropterus spp.*), yellow perch (*Perca flavescens*), sunfish (*Lepomis spp.*) and suckers (*Catostomus spp.*). We found that the angle of the sun upon the river influenced greatly the ability to see any fish in the water; optimal lighting conditions occurred between 1300 and 1700 hours.

Some resident fish were observed in the area of the fishways. One small squawfish was observed maintaining position in the eastern fishway opening. Smallmouth bass and yellow perch were seen in schools near the opening of the western fishway. Suckers were frequently seen the area of the western fishway exit scouring the algae-covered walls and bottom sill. But, because the suckers and squawfish were relatively stationary, the ESP excluded them from the acoustic data. The only observed incidence of a resident fish actively exiting a fishway was a carp at the western fishway. Based on our extensive visual observations, upstream movement of resident fish in the fishways was considered negligible when calculating sockeye passage rates.

3.3.2 Sockeye Salmon Observations

The first known observation of adult sockeye salmon in 1991 around Zosel Dam was made by a worker at the lumber yard next to the dam. The employee reportedly saw an adult sockeye salmon below the dam during the first week of August, 1991. Later in August after the acoustic system was installed, the system operator saw a salmon catapulting itself toward the western most spillgate (No. 1). We observed sockeye salmon exhibiting upstream migrant behavior, such as jumping at the spillgate or maintaining a position on the sill behind the spillgate, repeatedly in the first two weeks of the data collection period (August 31 to September 14, 1991). The greatest number of adult sockeye salmon were visually observed between September 12th and 14th, 1991. During this period, schools of 20 to 30 salmon were seen in the tailrace. After this time, however, this activity was not seen. We did continue to see salmon milling near the surface of the water, but they were not exhibiting the pronounced upstream migrant behavior to the degree that we witnessed earlier. During the remainder of the study, we saw variable numbers of sockeye salmon in the tailrace. At no time during the course of the study period did the water above or below the dam appear to be teaming with adult sockeye salmon.

Salmon were seen near entrances to the fishways. Observations of fish movement was aided by the white plastic background in the western fishway, but relatively low numbers of salmon during the study made it extremely difficult to see salmon passing on a regular basis. An adult salmon, however, was seen exiting the western fishway on August 29, 1991. This was the only sighting of an exiting salmon.

At Wells Dam on the Columbia River, sockeye salmon were seen between July 1 and October 10 (Figure 8). The greatest single day passage occurred on July 26 when 2,301 sockeye passed Wells Dam. A total of 27,492 sockeye salmon were seen passing through Wells Dam (R. Klinge, DCPUD, pers. comm.).

At the spawning grounds above Oliver, B.C. we observed sockeye salmon during our informal surveys on October 6 and later dates. A final survey on October 20 revealed that salmon were still present in the spawning grounds. A post-spawn count at the spawning grounds above Zosel Dam found 7,830 sockeye salmon present (C. Carlson,

Grant County PUD, pers. comm.). It was felt that an estimated 2,000 sockeye had not been tallied, due to them being alive.

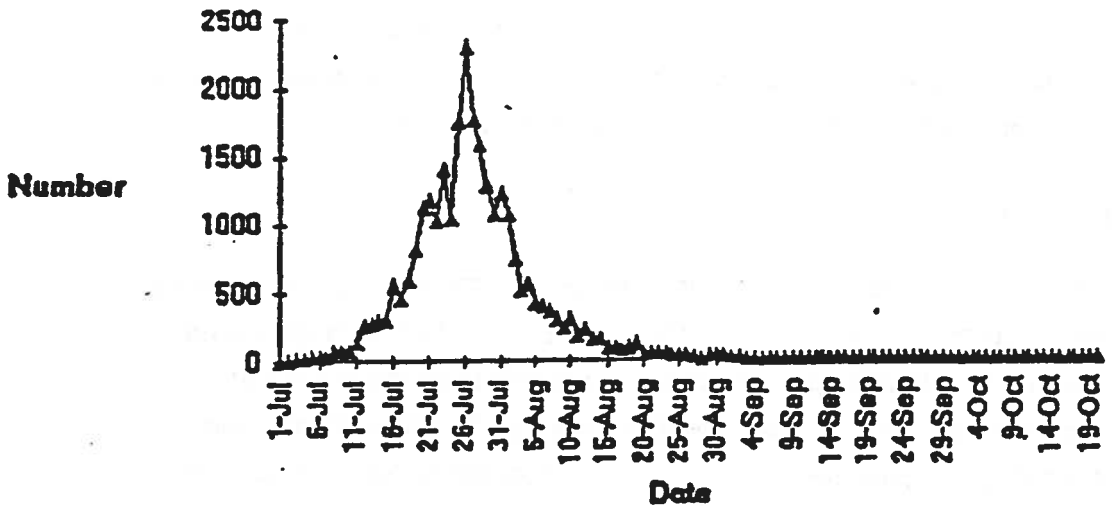

Figure 8. Daily counts of sockeye salmon passage at Wells Dam between July 1 and October 20, 1991. Source R. Klinge (DCPUD).

3.4 Hydroacoustic Data

3.4.1 Phase 1 Feasibility

After the hydroacoustic system was deployed, we found that migrant salmon could be detected exiting the fishways. Our detectability tests were successful; we saw active migrant traces on the echograms and in the computer files. Thus, we decided to proceed with routine monitoring. (Note: echograms were not prepared for this draft report, but are available).

3.4.2 Run Size

Between August 31 and October 20, 1991, we estimate that 1,336 adult sockeye salmon passed through Zosel Dam. The total number of sockeye salmon we counted at Zosel Dam was considerably lower than that observed at either Wells Dam or the spwaning grounds. Thus, we believe that most Okanogan sockeye seen at the spawning grounds passed through Zosel Dam before the hydroacoustic study began.

3.4.3 Daily Counts

The run-timing curve shows the greatest passage occurring during the beginning of the study with a gradual decrease over time (Figure 9). Peak daily passage was on September 6, 1991 when 96 salmon were detected passing through the dam via the fishways. Since the study apparently was conducted after peak salmon passage had occurred, it is not surprising that the data show a steady decrease in daily counts instead of a unimodal peak associated with the beginning and ending of a migration. Both run size and daily count data are consistent with our visual observations (Section 3.2.2).

After consulting with residents of Oroville, we learned that the summer run of sockeye salmon typically pass through the area from the middle to the end of July. A run of chinook salmon usually follows in late August. Sockeye run-timing observed in 1991 at Wells and Zosel dams was consistent with what has historically been seen .

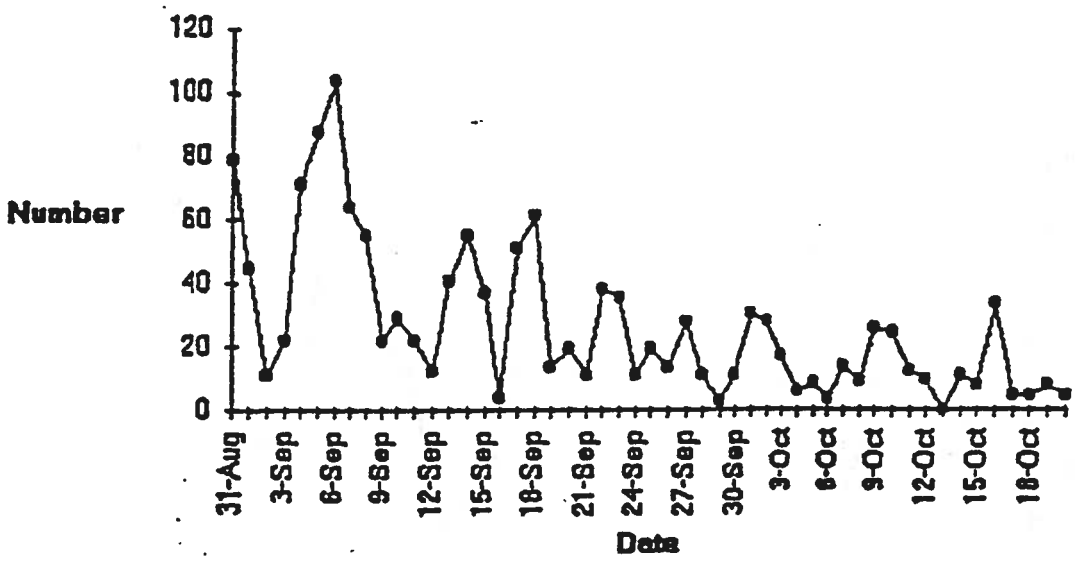

Figure 9. Daily counts of sockeye salmon through Zosel Dam between August 31 and October 20, 1991.

3.4.4 Diel Distribution

The diel distribution data show four peaks in passage (Figure 10). The two largest peaks occurred at sunrise and sunset. These two peaks indicate crepuscular activity within the upstream migrant sockeye. Other peaks were in daytime and nighttime hours. Sockeye passage occurred during all hours of the day.

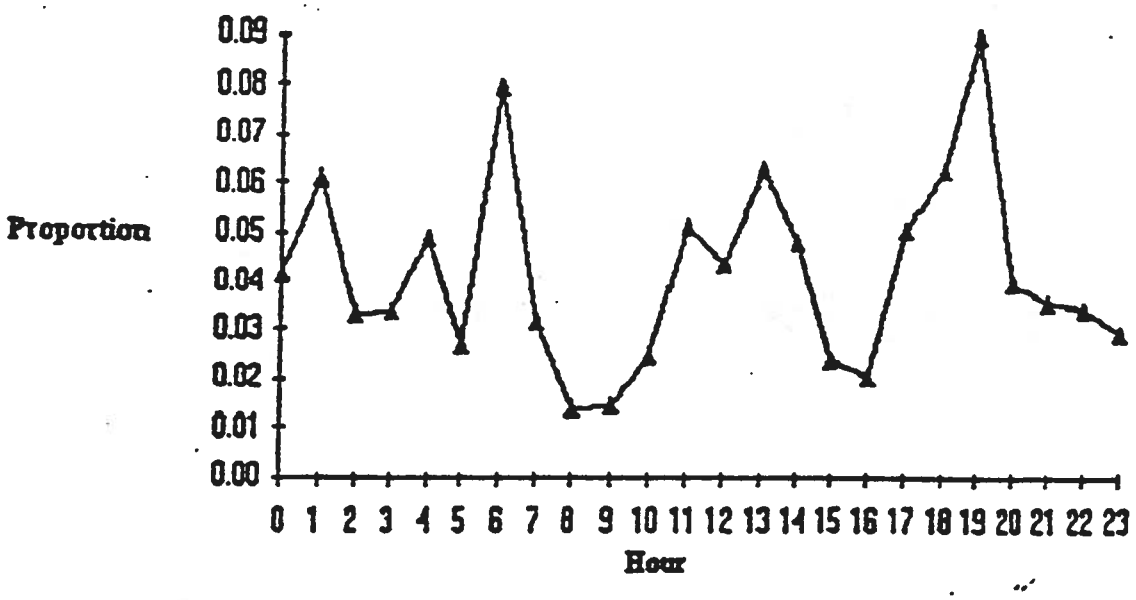

Figure 10. Diel distribution of sockeye salmon through Zosel Dam between August 31 and October 20, 1991.

3.4.5 Horizontal Distribution

The horizontal distribution data show a marked difference in passage between the two fishways (Figure 11). This was probably due to the operation of only the western-most spillgate during the study. By way of snorkeling, salmon were observed throughout the stilling basin, with the majority being seen swimming in and out of the turbulent water exiting from the western spillbay. Recall that only in the area immediately downstream of the western spillway were salmon seen catapulting out of the water, or maintaining a position on the dam sill. The fishway adjacent to western spillway was the only location were an adult sockeye salmon was seen passing through the dam structure.

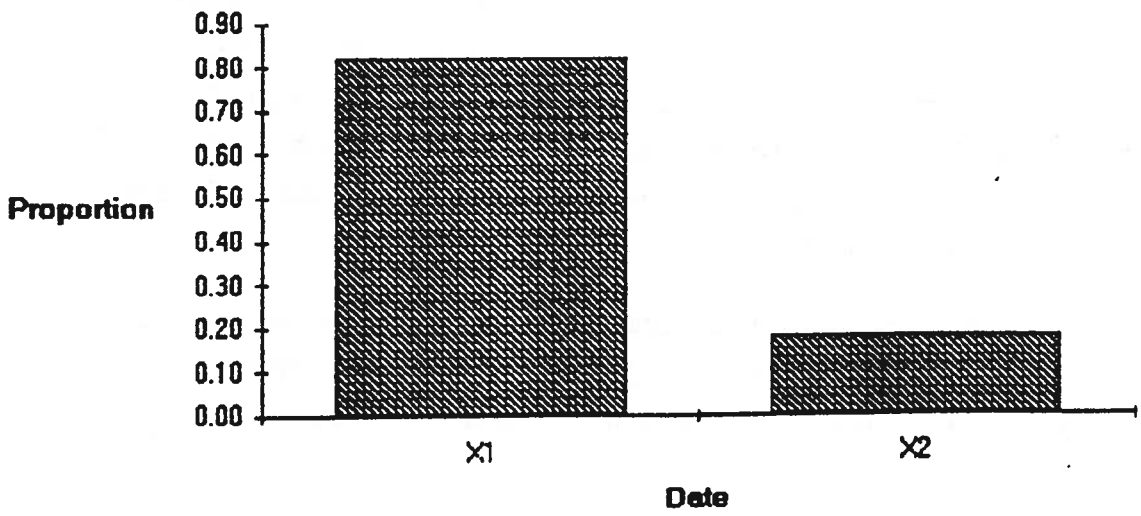

Figure 11. Horizontal distribution of sockeye salmon through Zosel Dam between August 31 and October 20, 1991.

4.0 DISCUSSION OF TEMPERATURE BARRIER HYPOTHESIS

Duree (1991) indicated a thermal barrier at the entrance into the Okanagon River may delay sockeye passage and possibly lead to fish kills within the sockeye population with prolonged exposure to the higher temperatures. Bouck et al. (1975) found that four days of exposure to 22° C water, was lethal to Columbia River sockeye. On July 1, the date of the first sighting of sockeye at Wells Dam, there was not a significant difference in the temperatures recorded in the Wells Dam pool and those at the six mile mark of the Okanagon River (Figures 7 & 8). On July 26, the peak of sockeye through Wells Dam, the temperature of the Okanagon R.M. 6.0 were greater then in the Columbia main stem, but did not exceed 22 °C. The riverine temperature at the six mile mark did not exceed that level which had previously been deemed lethal, until after the peak of the sockeye run had passed through Wells Dam. Counts of sockeye at Wells Dam and on the spawning grounds indicate that there was a considerable amount of mortality within the population.

The amount of mortality that occurs between Wells Dam and the spawning grounds does not comes as a surprise. Allen and Meekin (1980) reported that rarely are half the fish seen as Wells Dam accounted for on the spawning grounds. The main question that seems to arise, is where and when does this mortality occur. Is it within the Wells Dam pool or somewhere along the rising temperatures of the Okanagon. The hydroacoustic study done in 1991 shows that the majority of the salmon had passed previous to August 31. And visual observations of the river before that date indicate that they had passed before August 18.

To answer or look at the question of sockeye mortality in the Okanagon system, in relation to the presence of a thermal barrier, it would be prudent to monitor the temperature of the river at various locations, as well as, monitor fish passage above or below supposed bottlenecks

5.0 SUMMARY and RECOMMENDATIONS

(1) We demonstrated that hydroacoustic techniques could be used to count adult sockeye salmon exiting the fishways at Zosel Dam.

(2) We counted sockeye at Zosel Dam from August 31 to October 20, 1991. Total run size during the study period was 1,336 adult sockeye.

(3) We visually and electronically observed sockeye salmon at Zosel Dam at the beginning of the study. During the study, daily counts were greatest during the first week of September. Counts decreased steadily over the remainder of the study period.

(4) The diel distribution of sockeye passage through the dam showed significant peaks at sunrise and sunset. Passage occurred during daytime and nighttime hours.

(5) Sockeye salmon showed a marked preference for the western fishway which was nearest the only open spillgate (No. 1).

(6) Resident fish were observed visually in the area of the fishway exits and in the tailrace. Because of extensive visual observations and the parameters used to process the acoustic data, we determined that resident fish did not compromise the acoustic data.

(7) The total number of fish determined to have passed through the dam structure (1,336) was considerably less than would be expected, taking into account the number of salmon enumerated at in the spawning grounds (about 7,000). This is due to the majority of the salmon passing through Zosel Dam before our study began.

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APPENDIX A. Hydroacoustic System, Data Acquisition, and Data Reduction

A.1 Hydroacoustic System Equipment, Operation and Calibration

A.1.1 Equipment Description

The remote hydroacoustic system at Zosel Dam in 1991 consisted of the following components: a Model 1005 Portable Sounder/Multiplexer, transducers with cable, a Model 281 Echo Signal Processor (ESP_DBM), a Model 111 Thermal Chart Recorder, an IBM AT compatible computer, and a Hitachi Oscilloscope (Figure A1). Specific manufacturers and model numbers of the electronic components used are listed in Table A1. The hardware parameters used are presented in Table A2.

Table A1. Model numbers, manufacturers, and serial numbers of electronics equipment used by BioSonics, Inc. at Zosel Dam in spring and summer of 1991.

MODEL NO. AND EQUIPMENT	MANUFACTURER	SERIAL NO.
Model ES2000 (420 kHz)	BioSonics, Inc.	1005-91-001
Model 111 Chart Recorder	BioSonics, Inc.	111-90-062
Model 281 ESP	BioSonics, Inc.	281-89-001
Transducers (6 deg)	BioSonics, Inc.	12-420-06-059 12-420-06-060
Model V-423 Oscilloscope	Hitachi, Inc.	5017445

Table A2. Hydroacoustic system parameters used for studies at Zosel Dam in 1991.

ECHO SOUNDER	Transmit frequency: 420 kHz Transmit power: 0 dB Band width: 5 kHz Pulse width: 0.4 msec

Table A2 cont.

ECHO SOUNDER	TVG: 40 log (R) Trigger source:ES2000 Receiver gain: -20 dB
CHART RECORDER	Threshold: 0.17 volts

A.1.2 Equipment Operation

A BioSonics hydroacoustic system worked as follows. When triggered by the Echo Sounder, a high-frequency transducer emits short sound pulses in a relatively narrow beam aimed toward an area of interest. As these sound pulses encounter fish or other targets, echoes are reflected back to the transducer which then reconverts the sound energy to electrical signals. The signals are then amplified by the echo sounder at a 40 log(R) time-varied gain (TVG) to compensate for the loss of signal strength due to absorption and geometric spreading of the acoustic beam with distance from the transducer. Thus, equally sized targets produce the same signal amplitudes at the echo sounder receiver output regardless of their distance (range) from the transducer. The range of each target from the transducer is determined from the time it takes the sound pulse and echo return to travel that distance (velocity of sound in fresh water = 1445 m/s).

The echo sounder relays the returning TVG-amplified signals to the chart recorder, oscilloscope, and system computer. The return signals are visually displayed on the oscilloscope to observe echo strength and echo duration. Returns from individual fish are recorded on the chart recorder's echogram which provide a permanent record of all targets detected throughout the study. The threshold circuit on the chart recorder is adjusted to eliminate signals less that the echo levels of interest.

The Multiplexer/ Equalizer (MPX/EQ) permits a single echo sounder to automatically interrogate up to 16 different transducers in an operator-specified sequence. The MPX/EQ channels transmit pulses from the echo sounder to the

appropriate transducers and equalizes the return signals to compensate for the different receiving sensitivities resulting from varying cable lengths and transducer characteristics.

A.1.3 System Calibration

The acoustic system was calibrated before the study began. Calibration assured that an echo from a target of known acoustic size passing through the axis of the acoustic beam produced a specific output voltage at the echo sounder. The calibration information was also used to equalize the system sensitivity (using MPX/EQ) for each receiving channel. A system calibration at the end of the season verified that the sensitivities had remained constant throughout the study. A detailed description of the calibration of hydroacoustic systems can be found in Albers (1965) and Urich (1975).

A.2 Data Acquisition Methods

A.2.1 Escapement Detection Criteria

Returning voltages had to meet four independent filtering criteria in order for the echo to be stored as a tracked fish:

- Strength of target echoes had to exceed a predetermined threshold.
- Absolute echoes of a particular target were not to be greater than 20 nor less than 4.
- Targets had to be detected by consecutive acoustic pulses (redundancy).
- Slope exhibited by the target had to match that which would be expected by an upstream migrating fish.

Using the calibration information, the threshold of the hydroacoustic system was set to collect targets from targets greater than -54dB on the acoustic axis of each transducer.

Those targets with negatively sloping trace types were accepted as possible adult sockeye salmon. An object moving upstream through the beam would exhibit a negative slope (Figures 5&6) 4). Many resident wallowers were observed visually in the area of concern as well as on the paper echogram. Absolute number of echoes in beam and the

slope criteria were used to reduce the likelihood that one of these fish would be counted as an upstream migrating salmon.

A.2.2 Data Entry and Storage

Microcomputers were used for date storage and analysis. Data from individual tracked fish was written to a database file using BioSonics post processing software. The following information was recorded for each tracked fish: time of detection, date, transducer location, entrance range, exit range, number of absolute echoes in beam, target slope, and average TS value (-dB).

A.3 Data Reduction Methods

A.3.1 Data Selection

Three additional criteria were used to select data for analysis:

- Targets had to have an average TS value greate than -48dB and less than -20dB.
- Absolute number of echoes had to range between four and ten.
- Entrance range of target had to be less than 8.3 meters and greater than 7.8 meters.

Target strength criteria is based on lengths of previous classes of migrating salmon as determined by the sampling efforts of Columbia River Inter-Tribal Fish Commission (Schwartzberg and Fryer 1990). Absolute number of echoes was based on sustained speed of adult sockeye salmon, as determined by Brett (1965). By restricting the range of acceptable targets, fish observed to school in front of the fishway opening would not be included.

A.3.2 Weighting Factor

The weighting factor applied to the generated data, corrected for area of pening not sampled and also the time during the hour that a unit was not active.

The area not sampled was calculated by comparing the area of the cross-section of the formed at the range of the fishway opening, using a nominal beam pattern of 6° as a standard, to the area of the opening that was underwater (Figure 4). The only sightings

of fish, two, showed both fish in the bottom portion of the opening. With the use of a calibration tool, it was determined that this area was infact being sampled, but due to the unpredictable nature of fish, the entire opening was considered as available for passage.

Using the transducer information from above, the amount of time that a location was being monitored was calculated, and fish counts from these times and locations were corrected for time not sampled.

THE FEASIBILITY

OF

ESTIMATING SOCKEYE SALMON ESCAPEMENT

AT

ZOSEL DAM, WASHINGTON, USING UNDERWATER VIDEO TECHNOLOGY

APPENDIX - G

The Feasibility of Estimating Sockeye Salmon Escapement at Zosel Dam, Washington Using Underwater Video Technology

1991 Project Progress Report

Douglas Hatch
Matthew Schwartzberg
Andrew Wand

Prepared for Public Utility District No. 1
of Douglas County

December 11, 1991

Columbia River Inter-Tribal Fish Commission
729 N.E. Oregon St., Portland, OR 97232
(503) 238-0667

COLUMBIA RIVER INTER-TRIBAL FISH COMMISSION
975 S.E. Sandy Boulevard, Suite 202, Portland, Oregon 97214
Telephone (503) 238-0667
Fax (503) 235-4228

December 13, 1991

Rick Klinge, Fisheries Biologist
Public Utility District No. 1 of Douglas County
1151 Valley Mall Parkway
East Wenatchee, WA 98802-4497

Dear Mr. Klinge:

Attached, please find a report titled "The Feasibility of Estimating Sockeye Salmon Escapement at Zosel Dam, Washington Using Underwater Video Technology". This constitutes the Columbia River Inter-Tribal Fish Commission's deliverable for Public Utility District No. 1 of Douglas County purchase order number W913261.

Please contact myself or Matthew Schwartzberg if you have any questions regarding this project.

Sincerely,

Douglas Hatch
Fishery Scientist

enclosure

cc: Ted Strong
Matthew Schwartzberg
Andy Wand
Bob Heinith
Phil Mundy

The Feasibility of Estimating Sockeye Salmon Escapement at Zosel Dam Using Underwater Video Technology

Project Progress Report

by

Douglas Hatch

Matthew Schwartzberg

Andrew Wand

for

Public Utility District No. 1 of Douglas County

East Wenatchee, Washington

December 11, 1991

Columbia River Inter-Tribal Fish Commission

729 N.E. Oregon St.

Portland, Oregon 97232

(503) 238-0667

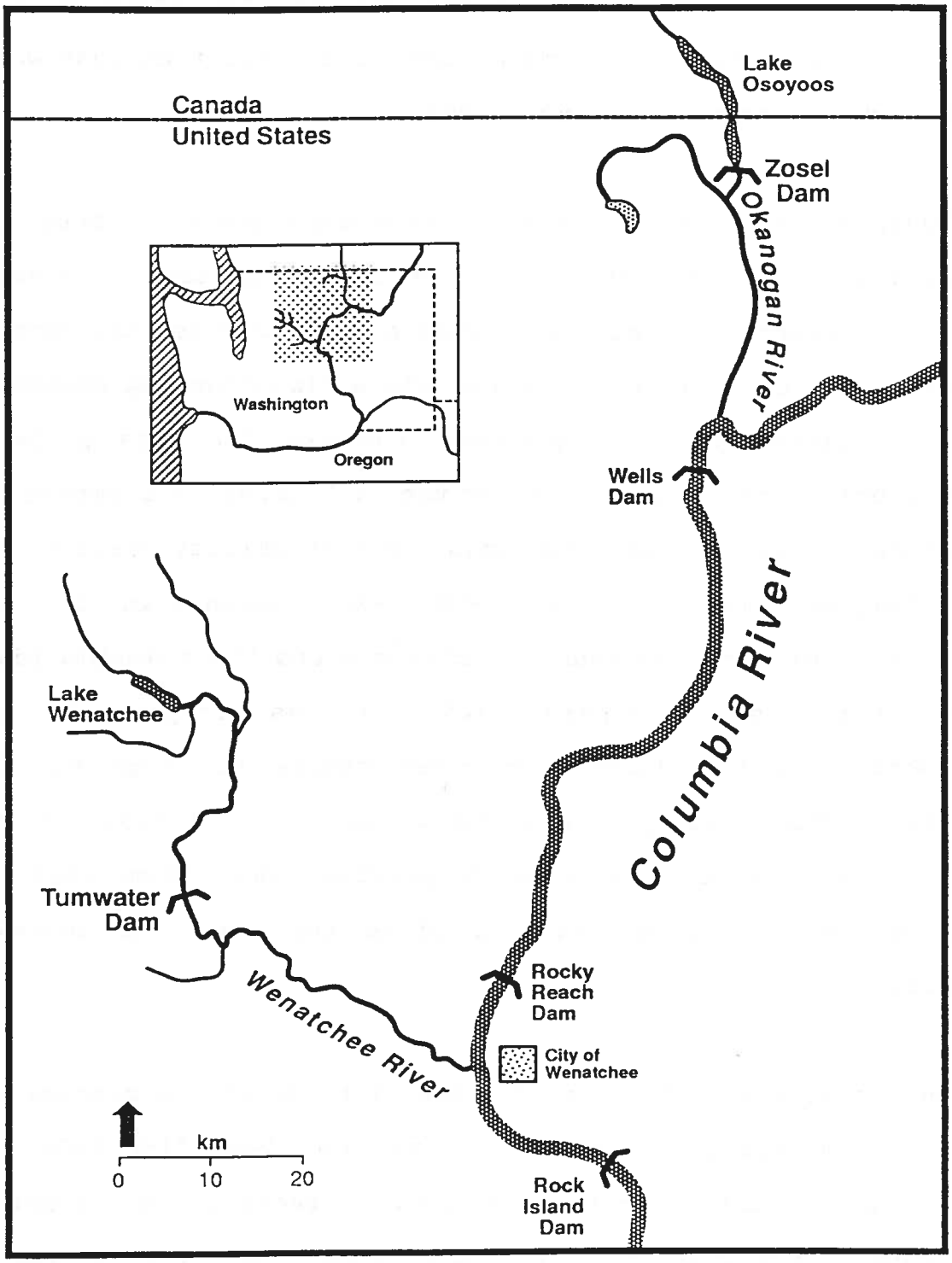
Introduction

Currently, only two major stocks of sockeye salmon exist in the Columbia River Basin (Fryer and Schwartzberg 1991). These include the Lake Wenatchee stock that migrates up the Wenatchee River and the Lake Osoyoos stock that migrates up the Okanogan River (Figure 1). Little is known about adult sockeye salmon migration between Wells Dam (rkm 829) on the Columbia River and Zosel Dam (rkm 85) on the Okanogan River (Pratt et al. 1991). Many scientists have theorized that sockeye salmon migratory timing and survival between Wells and Zosel dams is negatively affected by elevated water temperatures that commonly exist in the Okanogan River (Major and Mighell 1966; Allen and Meekin 1980). If salmon passage is severely affected then fish counts at Wells Dam are not an adequate estimate of sockeye salmon escapement. Therefore, this project was initiated and conducted to devise a method to accurately estimate salmon escapement at Zosel Dam without handling or delaying fish migration. Zosel Dam was rebuilt in 1987 by the Oroville-Tonasket Irrigation District and does not contain fish counting facilities.

Objective

Design, construct, test an underwater video system that in future years will be used to estimate sockeye salmon escapement at Zosel Dam, on the Okanogan River, Washington.

Figure 1. Map of the Okanogan and Wenatchee basins.



Methods

Zosel Dam contains two fish ladders and the intent of this project was to design and construct separate facilities that would permit fish enumeration at each ladder.

Equipment necessary to estimate salmon escapement at Zosel Dam included: video cameras with zoom lenses, video tape recorders, underwater camera housings, waterproof cables, remote lens control apparati, a video monitor, and submersible fish counting chambers. Table (1) lists specific equipment procured for this project. Custom fabrication was required for the fish counting chambers and the underwater video camera housings. Public Utility District No. 1 of Douglas County (Douglas PUD) was responsible for the construction of the fish counting chambers and the Columbia River Inter-Tribal Fish Commission (CRITFC) was responsible for construction of the underwater video camera housings and for selection, procurement, calibration, and installation of all electronic equipment. Sverdrup Corporation was responsible for designing and producing detailed plans for the fish counting chambers.

On December 3, 1991, one complete fish counting apparatus was installed and tested at the exit of the right bank fish ladder in Zosel Dam. Installation included attaching an aluminum guide/support structure to the face of Zosel Dam. This structure

Table 1. List of equipment used for the Zosel Dam sockeye salmon escapement estimation study in 1991.

Number Procured	Number Needed	Item	Make	Model
1	2	Counting Chamber	Custom Built	
2	2	Video Camera	Sony	SSC-S20
2	2	Motorized Len	Rainbow	H6x8MEA-II
2	2	Motorized Lens Control	Pelco	MLZ6DT
2	2	Video Tape Recorder	Panasonic	AG-6720
2	2	Underwater Camera Housing	Marine Metal Products	Custom Built
2	2	Waterproof Cable & Connector	Advanced Cable & Assembly	Custom Built
1	1	Video Monitor	Panasonic	CV-1382-Y

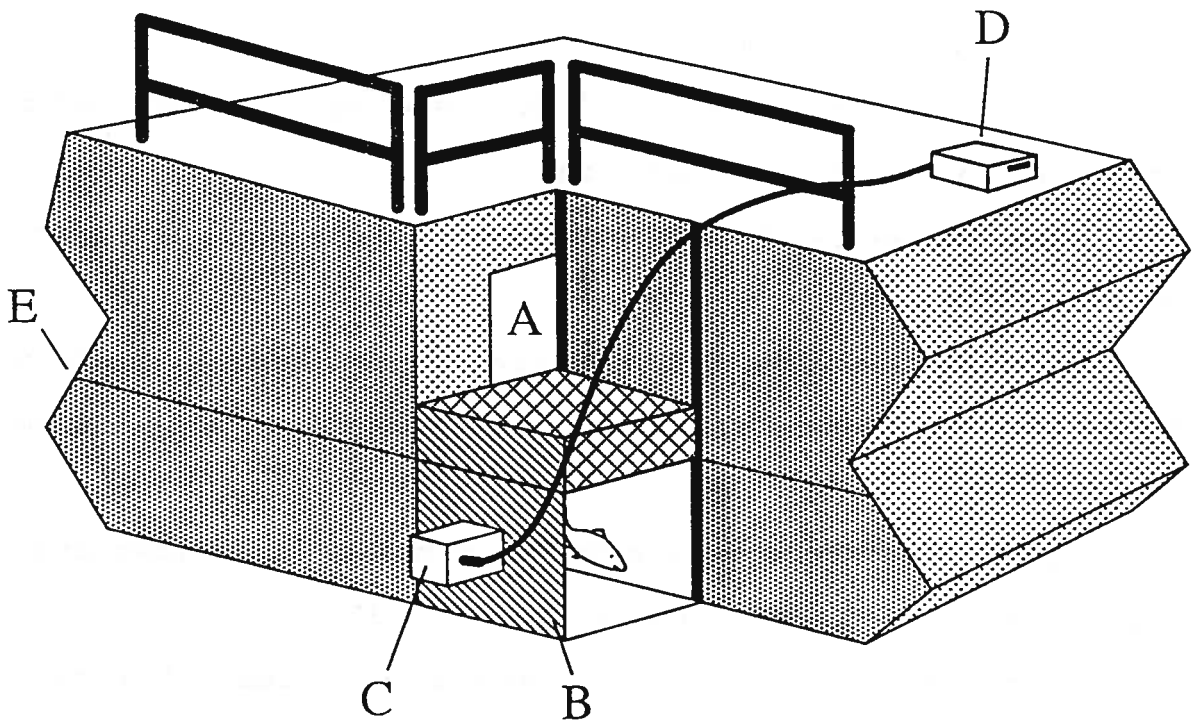
secured the fish counting chamber to the face of the dam adjacent to the fish ladder exit (Figure 2). An underwater video camera housing was attached to the counting chamber to allow imaging of fish passage. Following installation of the counting chamber, video tape recordings were made for approximately 3 hours. During the video taping, several different colored and shaped objects were placed within the counting chamber, video taped, and image quality subsequently analyzed.

Results and Discussion

Appendix (A) lists the chronological order of meetings and events associated with this project. Installation and testing of the right bank fish counting chamber on December 3, 1991 was successful. The fish counting chamber support structure was securely attached to the face of Zosel Dam such that it moored the fish counting chamber firmly. Testing of the video equipment was limited because lights were not attached to the fish counting chamber and a fabrication error in the fish counting chamber's removable background made installation of the background impossible.

Even with the lack of lighting and a constant white colored background, it was possible to distinguish objects from the video recording. Image quality was good enough that actual fish counting may have been possible. Fish counting would certainly have been

Figure 2. Diagram of the fish counting chamber installed at Zosel Dam, Washington. A) Fish ladder exit. B) Fish counting chamber. C) Underwater camera housing. D) Video tape recorder. E) Water level.



possible with just the addition of the removable white background. For future use, two underwater lights need to be installed on the fish counting chamber. Placement of the lights should be adjacent to the underwater camera housing.

Summary

1. A method to enumerate fish passage at Zosel Dam on the Okanogan River was devised by CRITFC.
2. Plans for construction of fish counting chambers were developed by Sverdrup Corporation.
3. One of two necessary fish counting chambers were fabricated by Douglas County PUD.
4. All electronic equipment necessary to record fish passage through the fish counting chambers was procured and calibrated by CRITFC.
5. Two waterproof video camera housings complete with underwater cables were designed and fabricated by CRITFC.
6. The right bank fish counting chamber was installed and tested.
7. Initial tests indicated that recording fish passage with underwater video equipment for escapement estimation at Zosel Dam would be feasible.

Recommendations

1. We recommend continuation of this study in 1992 with the objective of producing salmon escapement estimations.
2. A second fish counting chamber should be fabricated to allow enumeration at the left bank fish ladder.
3. Both fish counting chambers should have removable backgrounds and underwater lights installed.
4. Fish counting chambers should be installed and video taping should begin by July 1, 1992. Taping should continue through October 15, 1992.

References

Allen, R.L., and T.K. Meekin. 1980. Columbia River sockeye salmon study, 1971-1974. Progress Report Number 120, Washington Department of Fisheries, Olympia.

Fryer, J.K., and M. Schwartzberg. 1991. Identification of Columbia basin sockeye salmon stocks based on scale pattern analyses, 1990. Columbia River Inter-Tribal Fish Commission Technical Report 91-2, Portland, Oregon.

Major, R.L., and J.L. Mighell. 1966. Influence of Rocky Reach Dam and the temperature of the Okanogan River on the upstream migration of sockeye salmon. Fishery Bulletin 66(1):131-147.

Pratt, K.L., D.W. Chapman, and M. Hill. 1991. Potential to enhance sockeye salmon upstream from Wells Dam. Report to Douglas County Public Utility District, East Wenatchee, Washington.

Appendix A. Chronological order of events for the Zosel Dam Video Project.

Date	Event
6/27/91	CRITFC received via FAX a purchase order from Douglas County for Zosel Dam Video Project.
6/27/91	CRITFC contacted Glen Ardahl of Sverdrup Corp. regarding designs for underwater fish counting stations. We agreed to meet in Bellevue, WA on 7/30/91.
7/8/91	CRITFC requested bids for cameras, lens, and other electronic equipment from various vendors.
7/12/91	CRITFC received letter from Dennis Berdan, Purchasing Agent, Douglas County PUD regarding purchase order billings.
7/30/91	Meeting at Sverdrup Corp. to discuss project. Attending were Glen Ardahl, Tye Simpson, Sverdrup; Rick Klinge, Douglas County PUD; and Doug Hatch, CRITFC. Logistics of the project and assigned responsibilities were discussed. The responsibilities included: Sverdrup Corp. -- Design fish counting chamber and support mechanism. Drawings were to be sent to CRITFC and Douglas County PUD. Douglas County PUD -- Construct fish counting chambers per Sverdrup's design and be present to install the chambers at Zosel Dam. Other responsibilities included notification of other agencies regarding proposed modifications to Zosel Dam fish ladders, coordination of operations with Washington Department of Ecology and the Oroville-Tonasket Irrigation District. CRITFC -- Procure all necessary electronic equipment. Design and supply underwater housings for the video cameras. Calibrate electronic equipment and install in housings. Coordinate system installation and testing. A time schedule for installing the counting stations in Zosel Dam was discussed. As a result of the late start, CRITFC believed it was probably impossible to install the system in time for a

count of the entire 1991 sockeye run, based on sockeye migratory timing reported by Pratt et al. (1991). Instead, CRITFC suggested that the system be installed and tested after the sockeye migration. At the end of the meeting, it was agreed that another meeting be held in one week via conference call.

8/7/91	Conference call with Glen Ardahl, Rick Klinge, and Doug Hatch. Glen reported that it was possible to install the left bank counting station inside the ladder. We agreed to meet via conference call in two weeks.
8/7/91	CRITFC received drawings of the fish counting chambers from Tye Simpson, Sverdrup.
8/23/91	CRITFC received a letter from Rick Klinge regarding procedures for payment.
9/13/91	Phone conversation from Rick Klinge to Doug Hatch. Douglas PUD was concerned about when the counting stations would be installed.
9/27/91	Phone conversation from Doug Hatch to Rick Klinge. Possible dates for installation of the fish counting stations were set.
12/3/91	Installation and testing of equipment at Zosel Dam. Attending were Rick Klinge and 4 mechanics from Douglas County PUD, and Andy Wand and Doug Hatch from CRITFC.

SAMPLE SIZE CALCULATIONS

FOR

A PIT-TAG STUDY

OF

PROJECT MORTALITY OF JUVENILE SALMONIDS

AT

WELLS DAM

APPENDIX - H

Sample Size Calculations for a PIT-Tag Study of Project Mortality of Juvenile Salmonids at Wells Dam

To

Douglas County Public Utility District

From

John R. Skalski

Center for Quantitative Science, HR-20

University of Washington

Seattle, WA 98195

9 December 1991

Introduction

A paired release of PIT-tagged fish is proposed at Wells Dam to estimate project mortality of juvenile salmon at Wells Dam. The juvenile salmon will be released above and below Wells Dam with smolt detected at the decoder facilities at McNary Dam. The treatment release of tagged fish will occur above Wells Dam with smolt passing through the turbines and bypass facilities. The control release will be in the tailrace of Wells Dam. This paired release-recapture study is the simplest of sampling protocols described in Burnham et al. (1987) and is similar to the survival studies conducted at Bonneville Power House #2 in recent years.

An important assumption of the study (a complete list of assumptions can be found in Burnham et al. 1987, pp. 51-52) is complete mixing of the fish of the two release groups prior to recovery. A test of mixing will be performed by comparing the pattern of daily recoveries of the smolt at McNary Dam. The test of complete mixing will be performed using a test of homogeneity for an K x 2 contingency table. Validity of the survival estimate is predicated upon this assumption of complete mixing being true and the confirmation by the test of homogeneity.

Methods

Sample Size Calculations for a Single Trial

The survival rate (S_T) associated with the extra passage or additional stress of the treatment group is estimated by the expression (Appendix A):

$$\hat{S}_T = \frac{\left(\frac{y.}{R_T}\right)}{\left(\frac{x.}{R_C}\right)}$$

where

R_C = number of control fish released,

R_T = number of treatment fish released,

$y.$ = total number of treatment fish recovered at McNary Dam,

$x.$ = total number of control fish recovered at McNary Dam.

The estimate of treatment survival $(\hat{S}_T)$ or the treatment mortality rate $(1-\hat{S}_T)$ has an associated sampling variance of:

$$Var(\hat{S}_T \mid S_T) = \frac{S_T(1-S_T P.)}{R_T P.} + \frac{S_T^2(1-P.)}{R_C P..} \qquad (1)$$

where $P.$ = probability control fish survive and are detected at McNary Dam.

Sample size calculations are therefore based on "guesstimates" of the anticipated values of S_T and $P.$ encountered during the PIT-tag study.

The required number of the PIT-tagged fish to be released at Wells Dam also is dependent upon the desired precision of the study. For purposes of this study, precision will be defined by the expression:

$$P(|\hat{S}_T - S_T| < \epsilon) = 1-\alpha \quad .$$

In other words, we want the different between the estimate and the true value $(\hat{S}_T - S_T)$ to be less than or equal to $\pm\epsilon$, $(1-\alpha)100\%$ of the time. For example, if one wanted a precision of ±1%, 90% of the time, precision would be expressed as:

$$P(|\hat{S}_T - S_T| < 0.01) = 0.90 \quad .$$

In subsequent sample size calculations, we assumed sample sizes are equal for both control and treatment groups (i.e., $R_C = R_T = R$).

The required sample size for specified ϵ, α, $P_.$, and S_T is found using the equation (Appendix B)

$$R_i = \left(\frac{Z_{1-\alpha/2}}{\epsilon}\right)^2 \left[\frac{S_T(1-S_T P_.)}{P_.} + \frac{S_T^2(1-P_.)}{P_.}\right]$$

where

$Z_{1-\alpha/2}$ = standard normal deviate (i.e., $Z_{0.95}$ = 1.645).

The value of R_i $(i = C, T)$ is the sample size per release group required to produce an expected half-width of a $(1-\alpha)100\%$ confidence interval for S_T of size ϵ.

PIT-tagged fish released at Wells Dam are anticipated to have rates of recovery at McNary Dam that will vary with species and age class. Yearling chinook are expected to be recovered at a rate of $P_.$ = 0.40, and subyearling chinook at a rate of $P_.$ = 0.20. Furthermore, the anticipated survival rate of treatment fish from point of release to the control release site is S_T = 0.86. The precision desired under the conditions of S_T = 0.86 and $P_.$ = 0.20, 0.40 used in subsequent sample size calculations for a single trial is

$$P(|\hat{S}_T - S_T| < 0.05) = 1 - \alpha$$

for α = 0.20, 0.10, and 0.05.

Sample Size Calculations for Replicate Trials

The number of replicate survival studies (n) required is a function of the sampling precision of individual survival estimates ($\hat{S}_{Ti}$; in turn, a function of the number of PIT-tagged fish released) and the variance in survival $(\sigma^2_{S_T})$ over time. At this point in time, the anticipated magnitude of $\sigma^2_{S_T}$ is unknown and will not be known until replicate trials are performed. However, a value of σ_{S_T} = 0.05 would result in S_{Ti} fluctuating over an approximate range of 0.86 ± 0.10. Tentative sample size calculations will be based on this value of σ_{S_T} = 0.05.

The precision of an overall average survival estimate $(\overline{\hat{S}_T})$ across replicate trials can be expressed as

$$P\left(\left|\overline{\hat{S}_T} - \mu_{S_T}\right| < \epsilon\right) \geq 1 - \alpha$$

where μ_{S_T} is the true mean value of survival rates. The required number of replicate trials is that value of n that satisfies the equation

$$n = \frac{t^2_{n-1,1-\alpha/2}\left(\sigma^2_{S_T} + \overline{Var(\hat{S}_{Ti} \mid S_{Ti})}\right)}{\epsilon^2} \qquad (2)$$

where

$t_{n-1,1-\alpha/2}$ = value of a t-statistic with $n-1$ degrees of freedom at $1-\alpha/2$, satisfying the equation $P(|t| > t_{1-\alpha/2}) = \alpha$,

$\overline{Var(\hat{S}_{Ti} | S_{Ti})}$ = average magnitude of the sampling error of a survival estimate $(\hat{S}_i)$.

The anticipated sampling error (1) associated with alternative release sizes of PIT-tag fish can be used in conjunction with Equation (2) to determine the necessary number of replicate trials.

Example. For a precision of

$$P(|\bar{S} - \mu_S| < 0.05) = 0.95$$

with yearling chinook using $R_C + R_T$ = 3310 fish per trial, the number of replicate trials required satisfies the equation

$$n = \frac{t^2_{n-1,0.95}((0.05)^2 + (0.001521)^2)}{(0.05)^2}$$

$$n = 9 .$$

Results

Sample Sizes for a Single Trial

Required release sizes for control (R_C) and treatment (R_T) groups and the total release for a single trial $(R_C + R_T)$ are given in Table 1 as a function of the desired level of precision (i.e., ϵ

= 0.05 ; α = 0.20, 0.10, 0.05) and anticipated level of treatment survival (S_T = 0.86) and interrogation rates (P. = 0.20, 0.40) at McNary Dam. It should be noted that if there is appreciable spill at McNary Dam, the above sample sizes would be underestimates.

Sample Sizes for Replicate Trials

The number of replicate trials was based on several assumptions, these are

1. Number of fish used in each trial is sufficient for a precision of ϵ = 0.05, 1 - α = 0.80 for the point estimate of S_T for an individual trial (i.e., $R_C + T_T$ = 8564 for subyearling chinook, or 3310 for yearling chinook).
2. The variance in S_T between trials is $\sigma^2_{S_T}$ = 0.0025 corresponding to letting S_T vary ±0.10 about 0.86.
3. Each survival trial is independent.

Based on these assumptions, the required number of replicate trials for subyearling and yearling chinook are presented in Table 2.

It is projected that a minimum of four replicate trials will give a precision of

$$P\left(\left|\overline{S_T} - \mu_{S_T}\right| < 0.05\right) = 0.80 \quad .$$

Because σ^2_S used in the calculations (i.e., σ^2_S = 0.0025) is substantially larger than the projected sampling error (i.e., $\overline{Var(\hat{S}_i | S)}$ = 0.001521), increasing the number of PIT-tagged fish per trial is not anticipated to decrease the necessary number of replicate trials greatly.

Table 1. Predicted sample sizes ($R_C = R_T$) required to have a precision of $\epsilon = 0.05$; $1 - \alpha = 0.80, 0.90, 0.95$ when $S_T = 0.86$ and $P. = 0.2$ or 0.4.

Fish	S_T	$P.$	$1 - \alpha$	$R_C = R_T$	$R_C + R_T$	$Var(\hat{S}_T \mid S_T)$
Subyearling Chinook	0.86	0.20	0.80	4282	8564	0.001521
			0.90	7057	14114	0.000924
			0.95	10018	20036	0.000650
Yearling Chinook	0.86	0.40	0.80	1655	3310	0.001521
			0.90	2728	5456	0.000924
			0.95	3873	7746	0.000650

Table 2. Predicted number of replicate survival trials (n) required to have a precision of $\epsilon = 0.05$, $1 - \alpha = 0.80$, 0.90, and 0.95 when number of PIT-tagged fish per trial for subyearling chinook is 8564 and for yearling chinook is 3310.[1]

Fish	S_T	σ_S^2	$P_.$	Release Size/Trial ($R_C + R_T$)	$1 - \alpha$	n	Total Fish
Subyearling Chinook	0.86	0.0025	0.20	8564	0.80	4	34256
					0.90	7	59948
					0.95	9	77076
Yearling Chinook	0.86	0.0025	0.40	3310	0.80	4	13240
					0.90	7	23170
					0.95	9	29790

1 Note that individual survival trials are anticipated to have a precision for $\hat{S}$ of $\epsilon = 0.05$ at $1 - \alpha = 0.80$.

Literature Cited

Burnham, K. P., D. R. Anderson, G. C. White, C. Brownie, and K. H. Pollock. 1987. Design and analysis method for fish survival experiments based on release-recapture. *Amer. Fish. Soc. Monograph* 5. 437 pp.

Appendix A

Statistical basis for the survival estimate $\hat{S}_T$, or analogously $1-\hat{S}_T$ (differential mortality between release groups) is maximum likelihood estimation. The major assumptions of the estimation scheme are:

1. The probability of mortality through the treatment channel $(1-S_T)$ is independent of subsequent downstream mortality.
2. Survival of control and treatment groups from below Wells Dam to the recovery site at McNary Dam on day $i(S_i, i=1,\ldots,K)$ is the same.
3. Daily probabilities of recovery $p_i(i=1,\ldots,K)$ are the same for control and treatment groups.
4. Fates of the PIT-tagged fish are independent of one another.

Using these assumptions, a likelihood model can be constructed where:

$$L\left(\underset{\sim}{x_i}, \underset{\sim}{y_i} \mid R_C, R_T, S_T, \underset{\sim}{S_i}, \underset{\sim}{p_i}\right) =$$

$$\binom{R_C}{\underset{\sim}{x_i}, R_C - x_.}(p_1S_1)^{x_1}(p_2S_2)^{x_2}\ldots(p_KS_K)^{x_K}\left(1-\sum_{i=1}^{K} p_iS_i\right)^{R_C-x_.}$$

$$\cdot\binom{R_T}{\underset{\sim}{y_i}, R_T - y_.}(S_Tp_1S_1)^{y_1}(S_Tp_2S_2)^{y_2}\ldots(S_Tp_KS_K)^{y_K}$$

$$\cdot\left(1-\sum_{i=1}^{K} p_iS_iS_T\right)^{R_T-y_.}$$

and where

R_C = number of control fish released,

R_T = number of treatment fish released,

x_i = number of control fish recovered in day $i (i = 1, \ldots, K)$,

y_i = number of treatment fish recovered on day $i (i = 1, \ldots, K)$,

$x_.$ = total number of control fish recovered,

$y_.$ = total number of treatment fish recovered.

Note p_i and S_i are not separately estimable; hence, denote $P_i = p_i S_i$. The likelihood function can then be written as:

$$L\left(\underset{\sim}{x_i}, \underset{\sim}{y_i} \mid R_C, R_T, \underset{\sim}{P_i}, S_T\right) = \binom{R_C}{\underset{\sim}{x_i}, R_C - x_.} \prod_{i=1}^{K} P_i^{x_i} \left(1 - \sum_{i=1}^{K} P_i\right)^{R_C - x_.}$$

$$\cdot \binom{R_T}{\underset{\sim}{y_i}, R_T - y_.} S_T^{y_.} \prod_{i=1}^{K} P_i^{y_i} \left(1 - S_T \sum_{i=1}^{K} P_i\right)^{R_T - y_.} .$$

The maximum likelihood estimates of S_T from the above likelihood is:

$$\hat{S}_T = \left(\frac{y_.}{R_T}\right) / \left(\frac{x_.}{R_C}\right)$$

with the associated variance

$$Var(\hat{S}_T) = \frac{S_T\left(1 - S_T \sum_{i=1}^{K} P_i\right)}{R_T \sum_{i=1}^{K} P_i} + \frac{S_T^2\left(1 - \sum_{i=1}^{K} P_i\right)}{R_C \sum_{i=1}^{K} P_i}$$

$$= \frac{S_T(1 - S_T P_.)}{R_T P_.} + \frac{S_T^2(1 - P_.)}{R_C P_.}$$

and variance estimator

$$V\hat{a}r(\hat{S}_T) = \hat{S}_T^2\left[\frac{1}{y_.} - \frac{1}{R_T} + \frac{1}{x_.} - \frac{1}{R_C}\right] .$$

The assumption of equal downriver survival and recapture probabilities for control and treatment releases is predicated upon the assumption of complete mixing of the release groups. The condition of complete mixing can be tested using an K x 2 contingency table and a chi-square test of homogeneity. The contingency table is constructed as follows:

Day	Control	Treatment	
1	x_1	y_1	$x_1 + y_1$
2	x_2	y_2	$x_2 + y_2$
3	x_3	y_3	$x_3 + y_3$
.	.	.	.
.	.	.	.
.	.	.	.
K	x_K	y_K	$x_K + y_K$
	$x_.$	$y_.$	$x_. + y_.$

The chi-square test of homogeneity has K-1 degrees of freedom.

Appendix B

Precision of the paired release-recapture study can be expressed as:

$$P(|\hat{S}_T - S_T| < \epsilon) = 1 - \alpha \quad .$$

Using asymptotic normality, the precision expression can be rewritten as

$$P(-\epsilon < \hat{S}_T - S_T < \epsilon) = 1 - \alpha$$

$$P\left(\frac{-\epsilon}{\sqrt{Var(\hat{S}_T)}} < Z < \frac{\epsilon}{\sqrt{Var(\hat{S}_T)}}\right) = 1 - \alpha$$

$$1 - 2P\left(Z < \frac{-\epsilon}{\sqrt{Var(\hat{S}_T)}}\right) = 1 - \alpha$$

$$\frac{-\epsilon}{\sqrt{Var(\hat{S}_T)}} = Z_{\frac{\alpha}{2}}$$

$$\frac{\epsilon}{\sqrt{Var(\hat{S}_T)}} = Z_{1-\frac{\alpha}{2}}$$

or

$$\left(\frac{\epsilon}{Z_{1-\frac{\alpha}{2}}}\right)^2 = Var(\hat{S}_T) \quad . \qquad (B1)$$

Substituting in the expression for the $Var(\hat{S}_T)$ into Eq. (B1), the required sample size for release group is found to be

$$\left(\frac{\epsilon}{Z_{1-\frac{\alpha}{2}}}\right)^2 = \frac{S_T(1-S_T P_.)}{RP_.} + \frac{S_T^2(1-P_.)}{RP_.}$$

$$R = \left(\frac{Z_{1-\frac{\alpha}{2}}}{\epsilon}\right)^2 \left[\frac{S_T(1-S_T P_.)}{P_.} + \frac{S_T^2(1-P_.)}{P_.}\right] .$$

POTENTIAL

TO

ENHANCE SOCKEYE SALMON UPSTREAM

FROM

WELLS DAM

APPENDIX I

POTENTIAL TO ENHANCE SOCKEYE SALMON UPSTREAM FROM WELLS DAM

by

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EXECUTIVE SUMMARY

We examined the potential to enhance the natural production of sockeye salmon in the Okanogan River system. We present a brief review of Okanogan sockeye life history, system capacity compared to smolt production, and a series of enhancement alternatives. We considered any waterways that sockeye could reach from the Columbia River between Wells pool and Chief Joseph Dam.

Many of the waterways above Wells have either spawning or rearing space, but not both. The Methow River has spawning but not rearing space. There is no evidence of spawning in Wells pool. Fry from the lower Okanogan River and Methow River <u>might</u> conceivably rear in Wells pool, but limited zooplankton there makes successful rearing unlikely.

The Okanogan/Lake Osoyoos system provides space for sockeye spawning and rearing. Full use of the rearing potential in Lake Osoyoos could provide more sockeye smolts than any other natural production alternative. The lake now supports sockeye, and we believe could support many additional fry. It is the only lake in the area accessible to natural fry production. It is also the only lake permitting smolt emigration into Wells Pool without transportation.

Lake Osoyoos should support 4.0 million smolts without evidence of density dependent growth. Recent smolt production estimates were about 0.5 million. We suspect the spawning space already available in the Okanogan River is not fully seeded. Egg survival rates are unknown. Potential production estimates based on lake area, on the ratio of spawning area to lake area, and on euphotic zone volume, imply that additional fry could rear in Lake Osoyoos. We recommend alternatives to increase fry recruitment to the lake.

It is not possible to select the most cost effective approach without additional data. We suggest modest investigations directed toward selecting appropriate enhancement programs. We recommend evaluations of spawning substrate quality and methods of increasing egg to fry survival. Enhancement programs that minimize interference with sockeye life history will probably be more cost-effective than hatchery programs.

If available spawning gravels provide effective incubation areas any one, or a combination, of the following could increase production: eliminate all harvest; hold adults in cooler water; transport adults from Wells to Lake Osoyoos after evaluation of water temperatures and dissolved oxygen.

It is possible to hold adult sockeye in net pens successfully at other sites; however, the limnology of Lake

Osoyoos does not favor such a program. We doubt that adult sockeye could be successfully held for long periods in net pens within Wells pool, based on past experiences holding adult salmon in Columbia River waters.

Other potentially successful methods of increasing production from spawning areas include: gravel cleansing, provision of new high-quality spawning space, or use of streamside and lake incubators. Fry recruitment to the lake could increase with hatchery programs. Any approach involving egg incubation, will probably require egg segregation, disease testing, destroying infected eggs, and precautions such as egg treatments.

Drought conditions may reduce the rearing space in Lake Osoyoos. It is not possible to determine the effect of the 1987-88 drought on Okanogan smolt production from the data available. The smolt monitoring program at Rock Island does not detect annual changes in growth rate typical of sockeye populations. The program would not have detected density dependent growth in Lake Osoyoos in 1987-88.

Smolt production should be the evaluation standard for the natural production of Okanogan sockeye upstream from Wells Dam. Future smolt monitoring should include estimates of both smolt numbers and smolt size in the Okanogan system. It will be difficult to detect small changes in the number of Okanogan sockeye smolts, because of limited baseline data. An index such as increased smolt production per spawner, or the presence of smaller smolts (indicating approach of carrying capacity) leaving Lake Osoyoos might provide a measure of success.

It will be very difficult to monitor enhancement programs. Programs emphasizing natural production do not lend themselves to evaluations requiring marked fish. Instead improvements would not be evident without large changes in the population, that result in density dependent growth. Hatchery facilities do not enhance natural production, and often create severe mixed-stock harvest management problems. If natural production is the objective, we recommend avoiding hatcheries. However, if it is important to monitor the success of a fixed number of fish for mitigation, hatcheries offer opportunities to mark fish for monitoring purposes.

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INTRODUCTION

Douglas County Public Utility District (DCPUD) requested an examination of the potential to enhance natural production of sockeye stocks upstream from Wells Dam. Waters available for natural sockeye production are:

1) the main Columbia River between Wells Dam and Chief Joseph Dam
2) the Methow River Basin
3) the Okanogan[1] River Basin.

The Okanogan River Basin arises in British Columbia, flows south through a series of lakes and enters the USA as the southern basin of Lake Osoyoos (Appendix A).

This document reviews the use of these waters by sockeye. In addition, we predict natural production potential and suggest enhancement programs. We note biological and social constraints of each enhancement program.

In general, data available do not provide a basis to evaluate enhancement programs. Therefore we review data needs for enhancement proposals. We outline data deficiencies that influence reliable program selection and refinement. Providing monitoring programs is beyond the scope of this project, but their cost could influence any enhancement program selected.

SOCKEYE USE OF THE STUDY AREA

Sockeye salmon spawned and reared in the Wenatchee, Okanogan, and the upper Columbia River basins of the mid and upper Columbia River Basin[2]. These populations lie near the

---

[1] There are two accepted spellings; Okanogan in the United States, and Okanagan in Canada.

[2] The upper Columbia River Basin is defined as areas upstream from Chief Joseph Dam; while the mid Columbia refers to the main stem of the Columbia, and its tributaries between the confluence of the Snake, up stream to Chief Joseph Dam.

southern limit of inland sockeye distribution[3]. Before the construction of Grand Coulee Dam about 85% of the sockeye production in the mid and upper Columbia River Basin was probably from the Kettle River Basin (Mullan 1986).

Natural production in the Okanogan system cannot sustain the historic production of both the Okanogan River and upper Columbia River sockeye stocks. Federal mitigation relocated the upper Columbia River stocks into other basins with the Grand Coulee Fish Maintenance Project (1939-1960). The program trapped sockeye at Rock Island and released them into the Wenatchee, Okanogan, Entiat and Methow Rivers (Mullan 1986). Today a few sockeye spawn in the Methow River. Since pre-project estimates of sockeye production in the Okanogan are not available, it is difficult to evaluate the success of the Grand Coulee Fish Maintenance Project, or its influence on the gene pool and productivity of the Okanogan stock.

We speculate that the early years of the Grand Coulee Fish Maintenance Project accelerated a rebuilding of the Okanogan stock. Irrigation and storage for irrigation were in place in the Okanogan as early as 1915 (Fisheries Service, Environment Canada 1973). It is likely that only a small population remained after the drought of the late 1920's and early 1930's. The mean monthly flows for the incubation period 1930-31 and 1931-32 were 8-25 cfs and 6-48 cfs[4] respectively in the Okanogan River at Okanogan Falls (Walker 1956). Progeny from these eggs should have returned to the Okanogan in 1933 and 1934 if the stock had a life history similar to fish in the basin today.

It is unlikely that the original stock of sockeye, adapted to the Okanogan basin, dominates the gene pool today. The Okanogan stock was a minor proportion of the Columbia River sockeye collected at Rock Island. The release of mixed stocks, and their progeny, into the Okanogan probably increased genetic diversity while diluting endemic stocks. Enhancement projects

---

[3] The only regions farther south than the Columbia River with records of sockeye populations include coastal streams along the Oregon Coast to the Klamath River of northern California (Scott and Crossman 1973). Today the southern limit of the range is the Columbia River basin (French et al. 1976).

[4] Typical flows for the incubation period from 1916-1953 were between 200 and 600 cfs.

were discontinued in the 1950's[5] (Appendix B). Progeny of naturally-produced fish by 1964-66[6] made up all spawning sockeye in the Okanogan.

During the 25 years of Okanogan stock manipulation (1939-1964), the Columbia River hydropower system continued to develop. During the past 25 years (1965-1990) sockeye research or management included manipulation of harvest, monitoring of adults at Columbia River dams, juvenile transportation evaluations, smolt monitoring at Columbia River dams and flow monitoring during emigration. Allen and Meekin (1980) and Mullan (1986) represent the primary rigorous evaluations of Okanogan stocks.

About 30-120 thousand sockeye from the Okanogan system returned annually to the Columbia River during the past 25 years. Only a small proportion of the fish are seen on the spawning grounds (Appendix B).

Limited habitat is available for natural sockeye production upstream from Wells Dam. Yet 28-91% of the Columbia River sockeye production originates from the Okanogan (Appendix B). The Okanogan River is the only waterway with both spawning and lake rearing habitat accessible to the main stem of the mid-Columbia upstream from Wells Dam.

Habitat in the Okanogan River Basin is atypical of lake/river systems that sustain sockeye populations. Epilimnetic temperatures, lake productivity, hypolimnetic oxygen levels, and potential predation in the Okanogan basin may not favor sockeye production. Yet the population persists. We contend the sockeye population in the Okanogan exists at the fringe of its biological limits. It may lack the population resilience of stocks described in the literature. It is not the purpose of this document to develop this argument, but these ideas influence our evaluation.

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[5] there were two smolt releases in the 1950's, (1953 and 1958); the 1949 smolt release was the last release in the continuous program of the 1940's

[6] dominance of natural production occurred sooner, due to intermittent enhancement programs; smolts planted in 1958 should have returned in 1960-1961 to spawn and their progeny returned in 1964-1966.

GENERAL LIFE HISTORY

Adult sockeye destined for the spawning grounds of the mid-Columbia enter the Columbia River as early as late May. By early July about half of the run has passed Bonneville Dam.

Sockeye of Okanogan origin begin their upstream migration later than fish of the Wenatchee Basin, based on scale analysis (J. Fryer, Columbia River Intertribal Fisheries Commission, CRITFIC, Personal Communications). By July 10, 1989, about half the sockeye moving past Bonneville were Okanogan stock.

The sockeye pass upstream promptly, arriving at Priest Rapids about two weeks after crossing Bonneville Dam (Howell et al. 1985). After passing Rock Island Dam, the fish arrive at Rocky Reach within 4-5 days (Major and Mighell 1966). Within an additional 3-5 days sockeye reach Zosel Dam on the Okanogan River (Major and Mighell 1966). Passage time to Zosel Dam increases when water temperatures in the Okanogan River rise over 70 F (Major and Mighell 1966).

Okanogan sockeye begin to arrive at Wells Dam by mid-June (unpublished data 1982-89 Wells Dam counts). About half of the run has passed Wells Dam by mid-July. A few sockeye continue to cross Wells Dam into September, and in some years October.

Sockeye enter the Okanogan River and reach Lake Osoyoos as early as mid-late July; most fish reach the lake in August (Major and Mighell 1966). In some years adult sockeye delay in the Columbia River instead of entering the Okanogan River. Major and Mighell (1966) report that a thermal barrier (water temperatures of 20-21 C and greater) in the Okanogan River inhibits sockeye passage. Allen and Meekin (1980) document delays of up to a month.

Delayed adult sockeye movement may reduce the reproductive potential of the run (Major and Mighell 1966). High temperatures increase the rate of energy consumption, incidence of disease, and may directly kill fish (Major and Mighell 1966). Bouck et al. (1975) found 22 C was directly lethal within four days to Columbia River sockeye. At 20 C adult sockeye mortality was high

because disease incidence rose. When fish were held at 20 C, 50 percent died within one week, and all fish died within 24 days (Bouck et al. 1975).

Reconstruction of Zosel Dam in both 1948 and 1987 aided adult fish passage. After 1948, adult sockeye could pass upstream without the fish ladder at some flows (Major and Mighell 1966).

After reaching Lake Osoyoos, the adult fish remain in the lake for up to a month (Fisheries Department, Environment Canada 1973). Migration upstream to the spawning grounds in Canada usually begins in mid-September as river temperatures cool (Major and Mighell 1966). At least one observer reports two runs of sockeye into the Canadian regions of the Okanogan River; one in July, and one again in September (B. Kurtz, Personal Communication, Ministry of the Environment, Salmon Arm, British Columbia).

Sockeye spawn in September and October, most actively October 10-20 (Allen and Meekin 1980). Allen and Meekin report pre-spawning mortality as 20 percent in the early 1970's, attributing it to high water temperatures.

Most (70-80%) of the Okanogan run spawns in the 9 miles of unchannelized river between McIntyre Dam[7] (below Vaseux Lake) and the community of Oliver, B.C. (Allen and Meekin 1980). During spawning the regulated river flow is 350-500 cfs (IJC operating procedures 1982).

In some years, other fish spawn in the channelized portion of the river and along the lake shore. Few spawners use the 7 miles[8] channelized in 1957. It is a deep, straight channel with 13 drop structures (Fisheries Department Environment Canada 1973). Sediment, periphyton and macrophytes collect and grow in the substrate located along the upstream side of the structures, reducing the quality of the available spawning substrate (Kohn 1987, Kohn 1988). Allen and Meekin (1980) report limited (4%)

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[7] constructed in 1954

[8] this region of river was a 14 mile meandering section of river

lake shore spawning in 1971. Sockeye may spawn in deeper waters than those visible to aerial observers.

Incubation flows may be as low as approximately 175 cfs. We could not locate the report describing the determination of the suitability of incubation flows. The wetted perimeter changes little as flows drop from 350 to 175 cfs (C. Bull, Ministry of the Environment, Personal Communication).

Egg survival in different regions of the spawning area was variable (Allen and Meekin 1980). Of the eggs and sac fry recovered during March and April of 1972, 2-86% were alive (Allen and Meekin 1980).

Sockeye fry may emerge in March and April in the Okanogan system. Allen and Meekin report finding live eggs as late as March 22, 1972, and live fry on March 22 and April 26, 1972. May trapping in the Canadian section of the Okanogan River did not yield sockeye fry in the early 1970's (Allen and Meekin 1980). Variation of emergence timing should be minor because upstream lakes moderate water temperatures.

Minimum flows vary from year to year during March and April, the period when fry probably emigrate to Lake Osoyoos. Between 1982 and 1988 USGS minimum flow records show between 126-2140 cfs at Okanogan Falls (McGavock et al. 1989, 1988, 1987, 1986, 1985; USGS 1984, 1983). This variation in flow must influence fry arrival time, fry distribution in the lake, and the early spring limnology of the lake.

Canadian resource management requires screening at the numerous irrigation withdrawal sites along the river (Department of Fisheries and Oceans, undated mimeo). Screening practices could influence fry recruitment if we assume: the Canadian irrigation season begins in April (the same month as the irrigation season in the United States) and; fry emerge in April. Even with adequate screens, the impingement of fry in dead macrophyte beds, sloughing downriver as flows increase, could reduce fry survival.

Fry enter the lake at the north end, into the longest and

deepest of the three basins. Early distribution in the lake is not well documented. There is some evidence that in 1983 they remained close to the shore as late as June, instead of moving to pelagic areas (Biosonics 1983b). They rear in the nutrient-rich environment of Lake Osoyoos for one year.

Lake Osoyoos provides a rich rearing environment. Chorlophyll 'a' concentrations, a typical index of lake productivity, were high (23 ug/l) in the early 1970's (Stockner and Shortreed 1979). This represents approximately 10 times the chlorophyll 'a' concentrations reported for other sockeye lakes (Table 1). In recent years (1984-1988) spring concentrations of Chlorophyll 'a' were 8-12 ug/l (unpublished data); these values are still considered high in comparison to other sockeye lakes. The richness of the lake is evident in comparison with other sockeye lakes (Table 1).

Predators, warm temperatures and anoxic waters provide hazards. Eighteen species of fish inhabit the lake, and many are potential sockeye predators. Water temperatures rise early in the year, reaching 18 C at the surface of the lake as early as May (Allen and Meekin 1980). In August surface temperatures reach 25 C and the hypolimnion is anoxic (Allen and Meekin 1980). The entire euphotic zone, as well as the remaining water column within 10 meters of the water surface, was more than 20 C during August of 1972 (Allen and Meekin 1980). Oxygen levels were 5-6 mg/l at about 15 meters. Below 30 meters oxygen concentrations were less than 5 mg/l, and often less than 3 mg/l (Allen and Meekin 1980).

In the spring of 1982 and 1983 approximately 0.4 and 0.6 million fish left Lake Osoyoos. Smolt size has been relatively consistent (110 mm) since the 1960's (Table 2). Smolts of this size survive ocean life better than larger or smaller smolts (Peterman 1981). Smolt weight was approximately 13 grams during the early 1970's (Allen and Meekin 1980). About 95% of the 1985-87 smolts were one year old[9] (Swartzberg and Fryer 1989; Swartzberg and Fryer 1988; Fryer, CRITFIC, personal communication).

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[9] assumes the composition of the freshwater ages of adult sockeye returning to the Okanogan are representative of the composition of ages of emigrating smolts

Table 1. Primary production (chlorophyll 'a') of various sockeye lakes.

Lake	Reference	Chlorophyll 'a' (ug/l)
Okanogan Lakes		
Osoyoos		
1970-71	Stockner and Northcote 1974	23.0
1982-88	Unpublished data	8.0 - 11.0
Skaha	Stockner and Northcote 1974	31.0
Sockeye Lakes Around the World		
Karluk	1 Koenings & Burkett 1987	2.5
Hidden	1 " "	1.6
Tokum	1 " "	0.8
Leisure	1 " "	0.4
Eshamy	1 " "	1.1
Larson	1 " "	1.0
Upper Russian	1 " "	1.9
Falls	1 " "	0.9
Hugh Smith	1 " "	2.0
McDonald	1 " "	1.0
Packers	1 " "	3.3
Cresent	1 " "	1.1
Tustumera	1 " "	1.3
Alistar	2 Stockner & Shortreed 1979	2.7
Bear	2 " "	1.5 - 2.0
Fred Wright	2 " "	1.8
Kiltope	2 " "	0.6
Lowe	2 " "	1.2
Meziadan	2 " "	1.3 - 1.5
Manice	2 " "	0.7 - 0.8
Nimpkish	2 " "	0.7 - 0.9
Owikeno	2 " "	0.9 - 1.9
Simpson	2 " "	1.1
Stephens	2 " "	1.4
Swan	2 " "	0.9
Woss	2 " "	0.8

Table 2. Average ranges in length (mm) of sockeye smolts originating from the Okanogan River Basin based on collections in Lake Osoyoos, the Okanogan River or Wells Pool 1957-1983.

Smolt year	Citation	Location smolts measured	Length avg.	min.	max.	sample size
1957	Allen and Meekin (1980)	Lake Osoyoos[a]	96	75	144	365
1958	Allen and Meekin (1980)	Lake Osoyoos[a]	103	75	139	407
1972	Allen and Meekin (1980)	Lake Osoyoos	106	85	124	122
1973	Allen and Meekin (1980)	Lake Osoyoos	112	90	134	360
1974	Allen and Meekin (1980)	Lake Osoyoos	111	100	124	22
1977	Unpublished	Rocky Reach	115	90	148	174
1977	Unpublished	Rocky Reach	117	100	150	269
1978	Unpublished	Wells Pool	109	86	125	45
1981	Weitkamp & Nuener (1981)	Okanogan R.	128	84	151	1,385
1981	Parametrix 1981	Okanogan R.	128	84	243	1,398
1981	Parametrix 1981	Wells Pool	131	99	275	246
1982	Unpublished		110	76	147	3,418
1982	McGee and Truscott (1982)	Okanogan R.	114	75	232	6,994
1982	McGee and Truscott (1982)	Wells Pool	136	53	187	432
1983	McGee et al. (1983)	Okanogan R.	105	84	123	3,884
1983	McGee et al. (1983)	Wells Pool	106	75	290	1,086
1987	Peven (1987b)	Rocky Reach	116	70	219	170
1988	Peven (1989)	Rock Island	113	54	190	915
1989	Peven (1989)	Rock Island	108	66	220[b]	563

[a] Assumes Lake Osoyoos - Allen and Meekin (1980) cite unpublished NMFS data.

[b] Assumes all from after May 5 are Lake Osoyoos fish

Sockeye smolts move downstream in the Okanogan River from April 9 to May 30 and perhaps longer (McGee and Truscott 1982). Sockeye migrate in two peaks in the United States portion of the Okanogan; a few days during the third week of April, and a few days during the middle of May (Wietkamp and Neuner 1981; McGee and Truscott 1982; McGee et al. 1983).

During smolt emigration the minimum flows out of Lake Osoyoos vary despite flow regulation. Between 1982 and 1988 minimum flows out of Lake Osoyoos ranged from 75 to 2,140 cfs at Oroville (1.7 miles downstream from Lake Osoyoos)[10]. Records of the USGS show mean outflows of 163-2,870 cfs for the same period. Smolts did not seem to find their way over Zosel Dam during the very low flows of May 1987 (B. Zook, WDF, personal communication).

The Similkameen River enters the Okanogan River about 3 km downstream from Zosel Dam. Spring flows from the Similkameen may flow upstream to Zosel Dam, creating a large backwater area. The backwater, with upstream currents, could delay smolts until Similkameen flows subside. We were unable to confirm or disallow a cause-and-effect relationship between smolt movement and the Similkameen flow stage.

The Similkameen River and several other smaller tributaries enter the Okanogan, resulting in April and May minimum flows of 561-4,640 cfs (1982-88) at Mallott, WA (McGavock et al. 1989, 1988, 1987, 1986, 1985; USGS 1984, 1983).

The irrigation season in the State of Washington begins in April[11]. Pumped river water enters closed, pressurized systems. Most of the water is withdrawn from the river by 18 stations operated by the Oroville-Tonasket Irrigation District and are adequately screened (J. Easterbrooks, WDF, personal

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[10] Tonasket Creek enters the river between the lake and Oroville rarely contributing as much as 30 cfs. During most years spring flows at Tonasket Creek were 10-23 cfs.

[11] an April 1987 survey by WDF indicated that 71% of the pump stations were operational in April (J. Easterbrooks WDF personal communications)

communications). WDF estimates that the remaining 229[12] pumping stations do not have adequate screening (J. Easterbrooks, WDF, personal communications).

Juvenile sockeye may arrive in Wells pool one day[13] after passing Zosel Dam on the Okanogan River (McGee et al. 1983). April-June or July sockeye smolts are in Wells pool or passing Wells Dam (Olson 1984; McGee and Truscott 1982; McGee et al. 1983; McGee 1984). Sockeye smolts were more abundant in the middle of May than at other times during April or May (McGee and Truscott 1982; McGee et al. 1983).

The relative abundance (CPUE) of sockeye smolts passing downstream past Wells Dam begins increasing in late April (Table 3 adapted from Olson 1984, and Figure 1). The number of sockeye smolts passing Wells Dam usually declines by June (McGee et al. 1983; McGee 1984; Olson 1984). Estimates of the mortality of Columbia River (Okanogan and Wenatchee stocks combined) sockeye smolts through the hydroelectric system to the estuary range between 15% and 20% per dam (Wahle et al. 1979).

Most sockeye smolts (Okanogan and Wenatchee stocks combined) move through the estuary during May and early June (Dawley et al. 1984). A few sockeye smolts can be found in the estuary until late July (Dawley et al. 1984). We know very little about their ocean distribution, but assume they migrate promptly to the North Pacific. Tagging on the high seas indicates that at least a few Columbia River sockeye use areas west of 150 W and north of 48 N (French et al. 1976).

Data on ocean growth and survival for Columbia River sockeye stocks are sparse. Estimates of smolt to adult survival presented in Mullan (1986) provide an indication of the combined mortality of downstream passage, estuary and ocean life mortality. He estimates 0.6-4.6% survival for Okanogan stocks.

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12 Does not include the Oroville Tonasket Irrigation District

13 the peak downstream migrant count at Zosel dam was one day prior to the peak sockeye purse seine catch in Wells pool

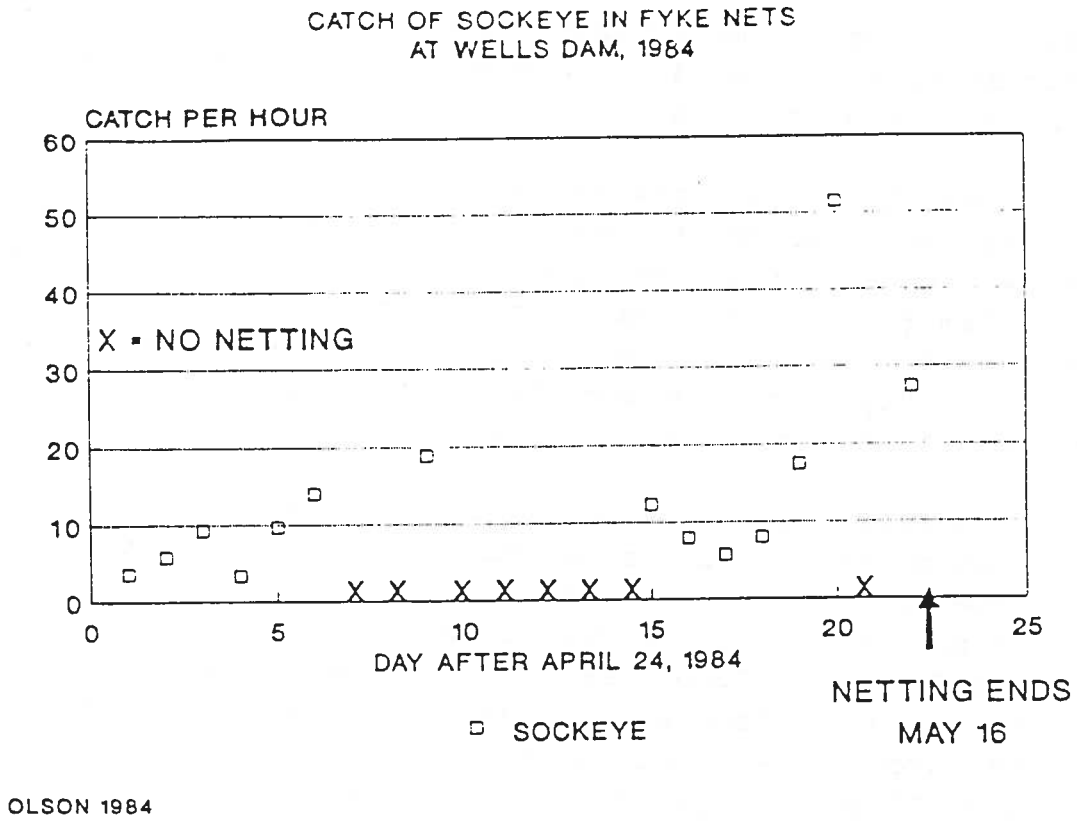


Figure 1. Sockeye smolts caught in Fyke nets per hour in turbine intakes at Wells Dam (Olson 1984).

Table 3. Catch per unit effort (CPUE) of sockeye smolts at Wells Dam as adapted from Olson 1984.

Date	Number Observed	Total Time (hours)[a]	CPUE [b] (fish/hour)
4/25	15	4.2	3.6
4/26	23	4.0	5.8
4/27	67	7.2	9.3
4/28	24	7.0	3.4
4/29	97	10.0	9.7
4/30	140	10.0	14.0
5/03	188	10.0	18.8
5/09	155	12.6	12.3
5/10	110	14.0	7.9
5/11	89	15.5	5.7
5/12	124	15.5	8.0
5/13	271	15.5	17.5
5/14	347	6.8	51.4
5/16	75	2.8	27.3

a. Rounded to nearest tenth of an hour for the table, but more accurate numbers were used for CPUE caculations.

b. Rounded to nearest tenth.

The literature on smolt-to-adult survival shows that the size of sockeye smolts influences ocean survival but not adult size (Ricker 1982). Peterman (1981) reports the highest ocean survival for 110 mm sockeye smolts. Ocean conditions are primarily responsible for adult size (Ricker 1982). Juvenile sockeye density and water temperature may also influence adult size (Ricker 1982). Peterman (1984) reports a 10-22% decrease in adult sockeye body size, due to density-dependent marine growth during the first 16 months of marine life in the Gulf of Alaska. Ricker (1982) reports that cooler ocean temperatures result in larger adult sockeye. He suggests that sockeye seek cool ocean temperatures. If ocean waters warm, the sockeye move north (Ricker 1982). Global warming trends predicted by some scientists could influence the marine distribution of sockeye in the North Pacific as well as utility of freshwater rearing habitats for sockeye.

Eggers (1980) suggests that enhancement may upset the temporal and spatial aspects of migration and ocean rearing; fish size, not species, determines feeding niche of Pacific salmon. Peterman (1984) speculates that juvenile pink and chum salmon use the same ocean areas as juvenile sockeye, but does not discuss their influence on sockeye growth. It seems reasonable that the declining survival of sockeye smolts over 120 mm is in some way linked to ocean feeding competition. Large size should decrease vulnerability to predators.

As Columbia River sockeye begin their return, regulated fisheries within the 200 mile limit do not appear to harvest them. We assume ocean harvest is negligible. We have no data that permit evaluation of effects of high-seas squid fisheries on Columbia River sockeye.

ESTIMATED POTENTIAL

We considered sockeye enhancement opportunities upstream from Wells Dam. Before recommending enhancement projects we attempted to determine the production bottleneck. We looked for:

1) evidence of density-dependent growth or survival; and,

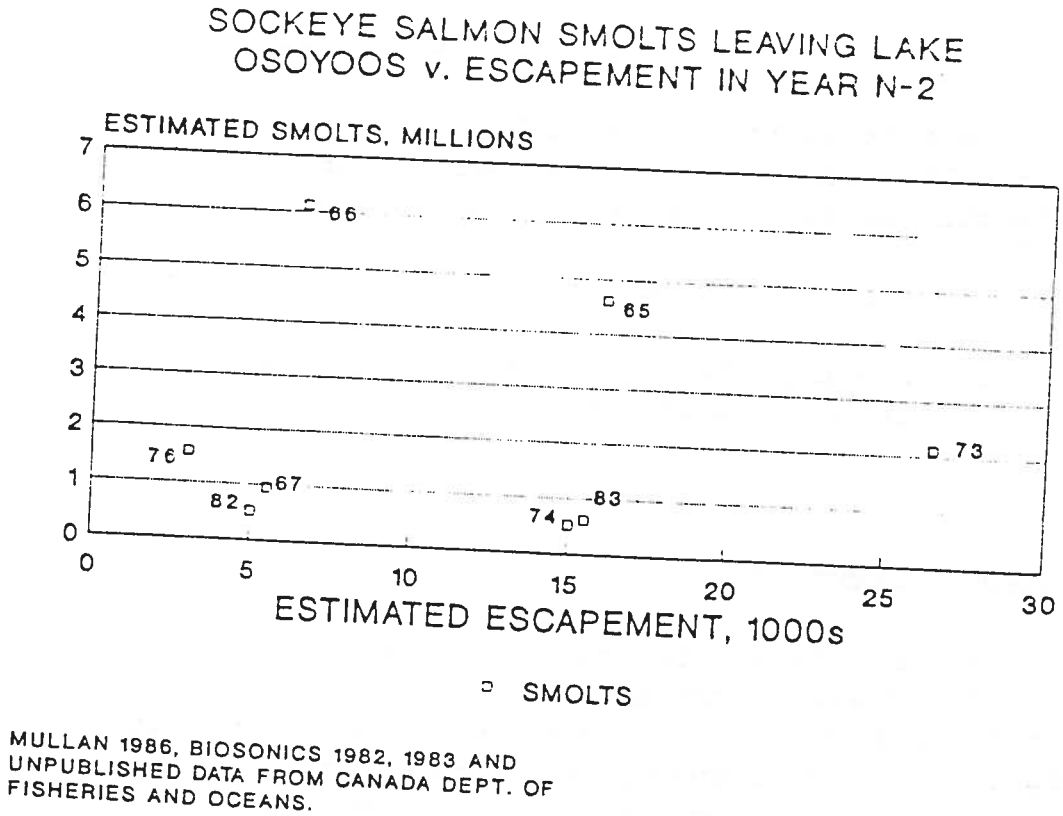
2) comparisons of theoretical production based on space and actual production.

DENSITY DEPENDENCE

Mullan (1986) provides estimates of egg to smolt survival. We plotted escapement and egg to smolt survival for the data available and found a potential, although not statistically significant, density-dependent relationship (Figure 2). This relationship incorporates two major areas of interest: (1) egg to fry survival through the period of fry recruitment to the lake, and, (2) fry to smolt survival, or lake residence. We infer the relative success of these two periods of early sockeye life from limited in-basin data and models in the literature.

A comparison between the estimated number of smolts and the average length of smolts in Lake Osoyoos (Table 4; Figure 3) provides no evidence of density dependent growth. The average size of smolts did not change whether there were 2.1 or 0.4 million.

Koenings and Burkett (1987) provide a theoretical smolt size threshold to infer if a sockeye population is "spawning limited" (which includes escapement, spawning space, spawning habitat quality or egg-to-fry survival) or "rearing limited" by the capacity of the lake rearing environment. They contend that a smolt population composed of more than 85% age 1 fish that are larger than 60-65 mm and 2 grams is "spawning limited". In this case juvenile sockeye growth would not depend on fish density. If the juvenile sockeye saturated the available habitat in a rearing lake then the "rearing limited" lake, they contend, would



MULLAN 1986, BIOSONICS 1982, 1983 AND UNPUBLISHED DATA FROM CANADA DEPT. OF FISHERIES AND OCEANS.

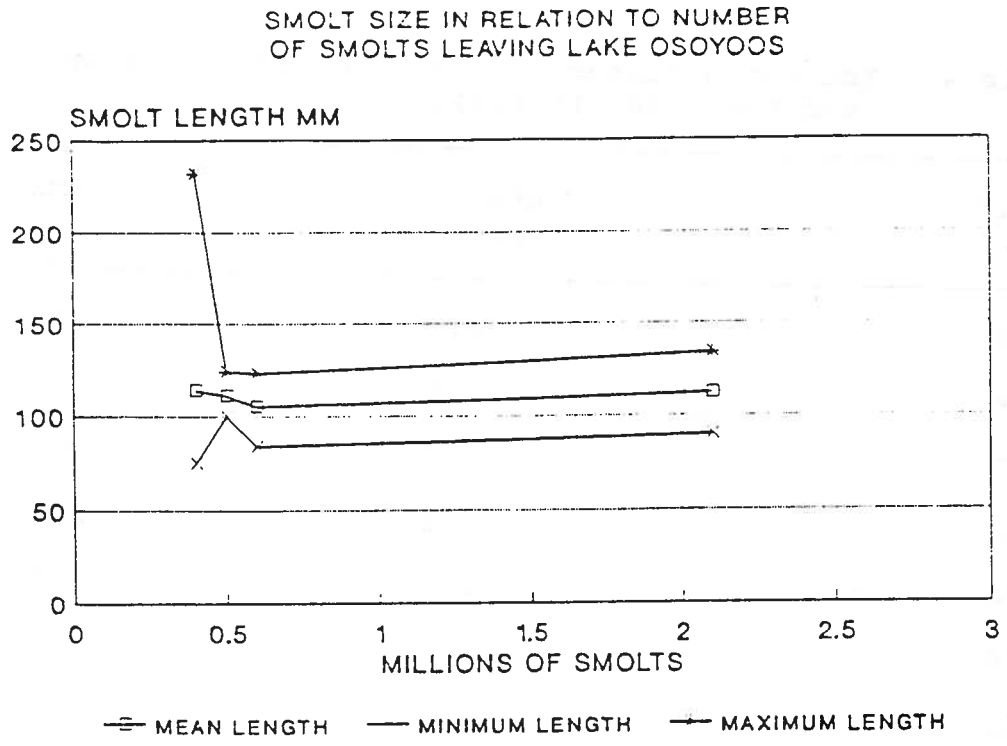
Figure 2. Estimated escapement to the spawning grounds in the Okanogan River upstream from Lake Osoyoos (spawning ground counts) and the resulting estimated smolt production from Lake Osoyoos two years later.

Table 4. Estimated number of smolts emigrating from Lake Osoyoos and their length (mm).

Smolt year	Number of smolts[a] (millions)	Length[b] (mm)
1965	4.6	ND
1966	6.1	ND
1967	0.9	ND
1973	2.1	112 (90-134)
1974	0.5	111 (100-124)
1976	1.6	ND
1982	0.4	114 (75-232)
1983	0.6	105 (84-123)

[a]. Source: Mullan (1986) for 1965-67 and 1973-76; Biosonics (1983a) for 1982; Biosonics (1983b) for 1983.

[b]. Allen and Meekin (1980) for 1973-74; McGee & Truscott (1982) for 1982; McGee et al. (1983) for 1983.



SEE TABLE 4 FOR SOURCES

Figure 3. Sockeye smolt size in relation to estimated numbers of smolts in Lake Osoyoos.

produce a higher proportion of older-age smolts, and less than 85% of the smolt population would be age 1. The age 1 fish in their "rearing limited" systems would likely be less than 60-65 mm and 2 grams.

Based on Koenings and Burkett (1987), we conclude that the smolt size (105-115 mm)[14] and age composition (>95% age 1 smolts) of Lake Osoyoos smolts do <u>not</u> indicate saturation of available rearing space in the lake.

Over 95% of the smolts in 1985-87 were probably age 1 fish[15], based on the freshwater age of adult sockeye returning to the Okanogan (Table 5). Historical data describing the freshwater age of Okanogan sockeye were not found, precluding an evaluation of this variable over time.

One might argue that Koenings and Burkett model Alaskan lakes that may tend to produce smaller smolts because they are cold and have a shorter growing period than Lake Osoyoos. Koenings and Burkett (1987) also examined historic records for Cultus Lake age 1 smolts. Although this lake tends to produce large age 1 smolts, in 1929 and 1941 the age 1 smolts approached the threshold size that Koenings and Burkett (1987) used as evidence of a lake at rearing capacity. Looking at a wide range of sockeye lakes, we find that the Lake Osoyoos smolts[16] are larger than most age 1 sockeye smolts (Tables 4 and 6).

We conclude that survival from egg deposition to fry recruitment is density dependent, but lake rearing is not, based on the limited data available. Our evidence is:

1) the density dependent relationship between escapement and smolts produced,
2) the lack of density-dependent growth in the lake, and,
3) classification of Lake Osoyoos smolt populations into the Koenings and Burkett (1987) `spawning limited' category.

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[14] available data on average length of smolts in the 1980's ; see Table 2.

[15] assuming there is no difference in the marine mortality rates of an age/1 and age/2 smolts.

[16] the effective smolts were over 90% age/1 in the mid 1980's

Table 5. Freshwater age of adult sockeye destined for the Okanogan River Basin.

Run Year	% Age 1	Citation
1987	97%	Swartzberg & Fryer 1988
1988	98%	Swartzberg & Fryer 1989
1989	95%	J. Fryer, CRITFIC, personal communication

Table 6. Comparison of length at age 1 for sockeye smolts from various lakes, adapted from Burgner (1987).

Lake	Length (mm)	
	Average	Range
Lake Washington	125	120-129
Cultus	82	68-94
Chilko	82	75-101
Fraser	90	---
Shuswap	74	---
Babine	79	75-83
Ouikeno	60	59-61
Great Central	69	64-78
Falls	67	---
Summett	92	---
Eshamy	75	73-77
Larson	77	---
Hidden	143	---
Big	132	---
Russian	84	---
Kenai	62	---
Crescent	69	68-69
Kasilof	70	68-73
Packers	83	74-96
Tustumena	70	68-73
Karluk (R1)	111	100-122
Karluk (R2)	107	102-110
Karluk (R3)	102	96-112
Red	85	---
Frazer	135	113-163
Little Ketoi	64	43-75
Ruth	104	88-119
Wood River	83	71-91
Illiamna	88	80-98
Nakpek	100	91-113
Rechapof	103	99-107
Wagasher	91	81-97
Danlee	116	106-133
Tokam	65	63-67

SPACE

Spawning

Fewer spawners reached the spawning grounds during the 1980s[17] than the estimated capacity of the spawning area. Canadian biologists and WDF estimated the region between McIntyre Dam and the community of Oliver could support 35,000 spawners at 325 cfs[18] (Fisheries Service Environment Canada and WDF 1973). Each year the Canadian Department of Fisheries and Oceans estimates the spawning escapement in this same region to derive a spawning escapement index. Only the 1984 escapement approached spawning capacity with an escapement of 37,500 sockeye.

Ellis and McNeil (1979) estimate about 0.15 ha of spawning saturates about 1.0 km^2 of rearing area. The Okanogan/Osoyoos system has 0.48-0.70 ha of spawning space[19]: 1 km^2 of rearing space. Their technique would indicate that there is adequate spawning space in the Okanogan system. If escapement filled all the spawning area available, juvenile sockeye growth should then be density dependent in Lake Osoyoos.

Sediment, periphyton and milfoil degrade spawning habitat, particularly in the channelized portion of the Okanogan River. The net effect of deteriorating spawning habitat would be to reduce egg to fry survival and therefore reduce fry recruitment to the lake.

We conclude that:

1) The spawning space available is not fully seeded most years.

2) Sedimentation, periphyton and macrophyte growth may reduce egg survival.

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17 Estimated by the Canadian Department of Fisheries and Oceans.

18 The minimum flow for the spawning period. Flows may be up to 425 cfs, but generally are not.

19 this refers to the region between McIntyre Dam and the community of Oliver, where approximately 80% of the spawning occurs (Allen and Meekin 1980). Some additional spawning area may be available downstream, or in the lake but its use is minor. Recently WDF has estimated up to 50% of the spawning occurs downstream from Oliver and the VDS 13. The Canadian Department of Fisheries and Oceans indicates in their field notes that they do not agree with, and see no evidence for this estimate (unpublished data)

Rearing

Johnson (1965) reviewed sockeye smolt production in productive and unproductive systems and found that sockeye growth rates vary with productivity. He found a common threshold of 2,000-5,000 smolts produced per ha of lake surface area. His evaluation included the eutrophic Lake Dalnee in the USSR as well as oligotrophic and mesotrophic systems. Lake Osoyoos, (according to Johnson 1965) should be able to produce between 4.6-11.5 million smolts (Table 7).

Some researchers may find these arguments insufficient and prefer to argue for a rearing habitat limitation. Relatively high epilimnion temperatures, anoxic hypolimnion and eutrophication of Lake Osoyoos may not offer optimum rearing habitat. To account for potential changes in the rearing environment, we recalculated smolt capacity based on the euphotic volume of the lake.

Koenings and Burkett (1987) provide a method to estimate euphotic zone volume, relating it to sockeye smolt numbers. We used it to estimate the smolt capacity of Lake Osoyoos as 2.9-7.1 million smolts (Table 8).

In 1964, Mullan (1986) shows[20] 6.1 million smolts in Lake Osoyoos. This estimate is within the range estimates of both the euphotic zone volume method (Koenings and Burkett 1987) and the surface area method (Johnson 1965). The large 1966 Columbia River sockeye run (169,000) tends to support Mullan's smolt estimates.

The worst case might eliminate usable habitat in the central and southern basins of the lake due to high temperatures and anoxic waters. In the early 1970's Allen and Meekin (1980) reported waters at the south end of the lake within 10 meters of the surface with dissolved oxygen concentrations of 2 mg/l and water temperatures of 18.9 C. This was the extreme, but it makes

[20] page 100 of Mullan 1986

? ppm ?

Table 7. Estimated number of smolts that should be produced in Lake Osoyoos, each basin of the lake, Skaha Lake, and Vaseux Lake based on the common threshold of 2,000-5,000 sockeye/ha described by Johnson (1965).

	Surface Area (ha)	Estimated Smolt Capacity (Millions) @ 2,000/ha	@ 5,000/ha
Lake Osoyoos	2,300	4.6	11.5
North Basin	991	2.0	5.0
Central Basin	541	1.1	2.7
South Basin	795	1.6	4.0
Skaha Lake	2,010	4.0	10.1
Vaseux Lake	275	0.6	1.4

Table 8. Smolt production estimates based on euphotic volume

	North Basin	Central Basin	South Basin	Osoyoos Total
Surface Area[a] (km2)	9.91	5.14	7.95	23.0
Secchi Depth[b] (m)	5	5	5	5
Euphotic Depth[c] (m)				
Maximum	13.5	13.5	13.5	13.5
Minimum	5.4	5.4	5.4	5.4
Euphotic Volume ($10^6 m^3$)				
Maximum	133.8	69.4	107.3	310.5
Minimum	53.5	27.8	42.9	124.2
Estimated Number of Smolts[d] (millions)				
Maximum	3.1	1.6	2.5	7.1
Minimum	2.1	0.6	1.0	2.9
Estimated Biomass[e] (kg)				
Maximum	10,837	5,621	8,693	25,151
Minimum	4,335	2,248	3,477	10,060

[a] Stockner and Northcote 1978

[b] Unpublished data (Ministry of the Environment, Penticton)

[c] Euphotic depth = secchi x 2.7 (Cole 1975)

[d] EV units x 23,000 smolts (Koenings and Burkett 1987)

[e] EV units x 81 kg (Koenings and Burkett 1987)

the point that juvenile sockeye may not be able to use the entire lake area. If we eliminate the southern two basins from the rearing area and recalculate the potential capacity of the lake, we find the northern basin alone could support 1.2-3.1 million smolts based on Koenings and Burkett (1987) or 2.0-5.0 million smolts based on Johnson (1965).

The 1982 and 1983 estimates of 0.4 and 0.6 million smolts did not approach even the numeric capacity of the northern basin of Lake Osoyoos. In 1976 the smolt estimate was 2.1 million, a number within the estimated production of the northern basin. We cannot find evidence of approaching or reaching a threshold density of smolts, as smolt size was similar in the 1976, 1982, and 1983 smolt populations.

THE EXCEPTION

We agree that in most years Lake Osoyoos could support more fry. However, there may be notable exceptions. During drought years international water management agreements permit additional storage in, and additional releases from Lake Osoyoos. Such agreements may: (1) reducing the opportunity for smolts to emigrate in the spring of drought years, increasing the density of juvenile sockeye in the lake, and (2) reduce available rearing space by reducing the elevation of the lake a total of 2.5 feet during the summer, or 1.5 feet more than during a normal flow year. Water temperatures in Lake Osoyoos are already higher than reported for most sockeye lakes. During a drought, temperatures could be even higher, especially if water retention time increases. The high temperatures in Lake Osoyoos may reduce the energy available for growth, particularly if an oxygenated cold water refuge is unavailable. It seems logical the size of Lake Osoyoos smolts would decline under drought conditions. We were unable to locate the average length of smolts during 1987, 1988 and 1989 to check this line of reasoning.

ALTERNATIVES INCREASING FRY RECRUITMENT

SITUATION

It is reasonable to expect inconsistent success from any project enhancing natural sockeye production[20] upstream from Wells Dam. The most likely strategies for successful enhancement involve the Okanogan River and Lake Osoyoos. If natural production alternatives are prohibitive for social or biological reasons, we suggest several opportunities incorporating aquaculture technologies.

Our analysis suggests sockeye fry rarely saturate the available rearing space in Lake Osoyoos. The lake currently produces about 0.5 million smolts. A conservative estimate of potential production is 4 million smolts. At smolt populations up to 2.1 million, no evidence appeared for density-dependent growth.

We speculate that smolt production could increase if more fry reach the open waters of the lake. The rearing space in Lake Osoyoos can support additional sockeye (about 4-8x recent estimates), so we consider it unnecessary to look elsewhere in the basin for rearing space. Fry production can increase with: 1) additional spawners, or 2) increased egg survival, or 3) increased survival from emergence to fry recruitment to the open waters of the lake. If we assume the spawner capacity estimates from the 1970s are correct, recent escapements do not fully seed the available spawning space. However, the escapements available may produce more fish if we can increase survival between egg deposition and the beginning of pelagic residence.

We cannot project the number of fry that would result in density-dependent growth (rearing limitation) without additional data. Until we see density-dependent growth, we will not be able to determine the actual rearing capacity of Lake Osoyoos.

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[20] The composite production originating upstream from Wells and downstream from Chief Joseph Dam will be referred to as 'Okanogan' or 'Lake Osoyoos' production.

Inadequate Escapement

Canadian biologists estimated that the available spawning space would support about 35,000 sockeye spawners, in the early 1970s. The egg to smolt survival would have to be about 10% to produce 4 million smolts (assuming a 50:50 sex ratio and an average fecundity of 2,250 egg/female). Ten percent egg to smolt survival would be an excellent survival rate (Table 9). Ten percent is within the range of survival estimates reported by Mullan (1986); but is higher than the median (4-7%) values he presents.

Spawning escapements[21] rarely approach 35,000 fish, the number that may fully seed[22] the available spawning space (Table 10; Figure 4). During the past 20 years spawning escapements estimate were typically 5,000-15,000 fish (Table 11; Figure 4; Appendix B). There were a few exceptional years with spawning escapements of 27-38,000 fish (Table 11). Survival estimates and smolt production estimates are not available for the progeny of the large 1984 spawning run.

Low Incubation Survival

In 1973-74 Allen and Meekin (1980) evaluated incubation survival in the Okanogan River. They concluded that egg survival in the Okanogan was low in comparison to the Wenatchee system (Allen and Meekin 1980). Yet the median egg to smolt survival was similar for the Wenatchee (6%) and Okanogan (4-7%) systems (Mullan 1986). Increasing egg survival in the Okanogan may increase fry and smolt production.

There are no recent reviews of spawning habitat quality, or egg survival in the Okanogan River. We did not find data describing the annual sediment load of the river system. The series of lakes along the river may act as settling ponds, but

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21 Based on spawning ground counts

22 Allen and Meekin (1980)

Table 9. Reported rates of survival during the early life history of sockeye salmon.

Citation	Survival		
	egg to fry	fry to smolt	egg to smolt
Allen and Meekin 1980	0.021-0.84	---	---
Ellis and McNeil 1979	0.66-0.14	0.09	---
Ellis and McNeil 1979	0.85	---	---
Ellis and McNeil 2979	0.70-0.12	---	---
Bowles 1984[a]	0.09	0.07-0.47	0.21
Bowles 1984[b]	0.45	---	---
Bowles 1984[c]	0.67	---	---
Bjorn et al. 1968	---	---	0.01
Burgner et al. 1969	0.50	0.70-0.28	---
Foerster 1968	---	0.53	0.08
McDonald and Hume 1984	0.40	0.07-0.50	---
McDonald and Hume 1984	0.20	---	---
Kyle et al. 1988	0.10	---	---
Personal Communications[d]	0.16-0.45	0.20-0.50	---

[a] Citations from other evaluations

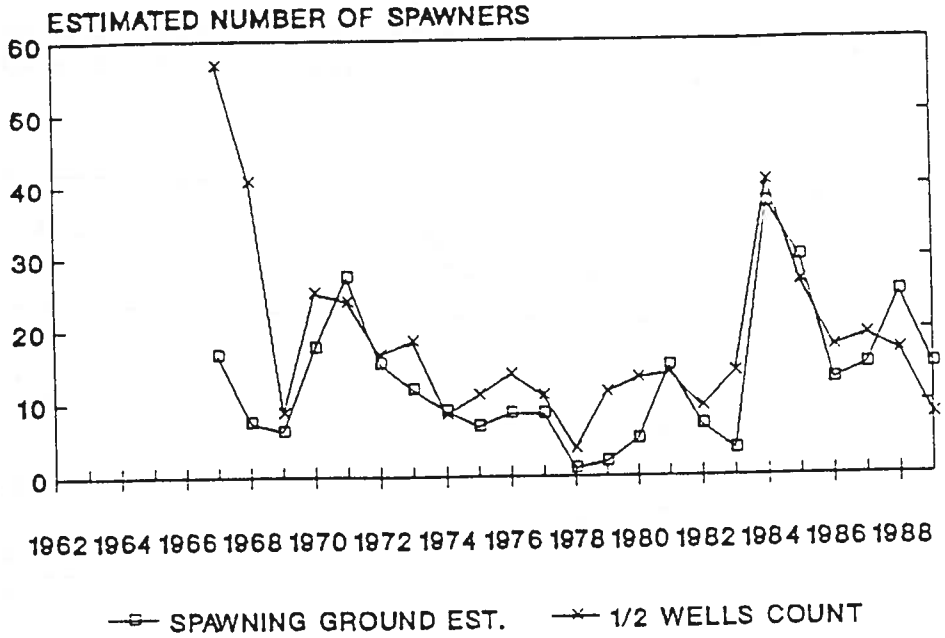
[b] Mean used in the model - for tributary spawning sites

[c] Reported incubation survival of sockeye eggs along lake shoal areas.

[d] Values reported at the Cedar River spawning channel workshop 1990

Table 10. Estimated spawning area, rearing area and ratio of spawning to rearing area for the Okanogan River McIntyre Dam to Oliver) and Lake Osoyoos at two minimum flows during the spawning period, based on Ellis and McNeil (1979).

Flow (cfs)	Spawning Area (ha)	Rearing Area (km2)	Ratio (ha/km2)
325	11	23	.48
425	16	23	.70



SEE APPENDIX B AND MULLAN (1986)

Figure 4. Estimated adult sockeye escapement based on the WDF estimator of half the Wells count (Wells Count) and the Okanogan River spawning surveys.

Table 11. Subsistence harvest by Canadian Indian tribes and the spawning ground count for Okanogan River sockeye salmon 1977-1989.

Year	Canadian Indian Food Fish Harvest	Spawning Ground Count
1977	800	8,475
1978	175	1,050
1979	2,000	2,000
1980	1,000	5,000
1981	500	15,000
1982	400	7,000
1983	500	3,500
1984	2,250[a]	37,500
1985	750	30,000
1986	1,000	13,000
1987	---	15,000b
1988	---	25,000
1989	---	15,000

[a] Raw data sheets show 2,500

[b] File attachment states WDF estimate is 35,000 for total run, but Canadian Department of Fisheries and Oceans does not agree. They state only 2-3 dozen additional fish were found in the channelized area and question if 20,000 spawned in the lake.

the agricultural use of the area could still contribute sediment locally. McIntyre Dam controls flushing flows; impoundments along the Okanogan operate to limit flooding. Annual flushing flows or large spawning populations can disturb and clean the river substrate. Without this annual cleaning, small amounts of sediment probably accumulate in the Okanogan River channel. It is reasonable to speculate that egg survival and spawning habitat quality are declining.

Low Survival from Emergence to Pelagic Residence

Fry migration into Lake Osoyoos may be hazardous. Predatory fish in the river and the lake must take sockeye fry. Fry may become entangled in sloughing weeds in the river and impinged on irrigation pump screens. If adult Okanogan fish carry IHNV, fry with IHNV usually die during migration or the first few weeks in the lake (Data presented at the Cedar Creek Spawning Channel Workshop January 1990).

OBJECTIVES OF ENHANCEMENT

We assume the objectives of enhancement are:

1. enhance natural production without physical manipulation of the fish (or)
2. enhance natural production with minimal manipulation (or)
3. enhance natural production with significant manipulation, ie. a hatchery.

PRELIMINARY EVALUATIONS

Two years of biological investigations will be necessary to select the method of enhancement most likely to succeed with the least manipulation by man. The first year, pilot evaluations should focus on the physical parameters of the enhancement site. Potential incubation sites include 3 parts of the Okanogan River,

the spawning channel at Wells and the waters of Lake Osoyoos. A preliminary evaluation of each incubation site could define its potential utility. The second year a prototype experimental project (biological evaluation) would be useful. A matrix of biological investigations, for each group of enhancement alternatives is available in Appendix D.

We examined sockeye enhancement alternatives using the conservative criteria in Table 12. Some of the literature presents slightly higher survival rates for various development stages than we have used here. However, we feel the selected criteria will provide a reasonable estimate of production potential.

ALTERNATIVES

I. Increase potential escapement

One option is to ban sockeye harvest in the Columbia River Basin until escapement to the Canadian spawning grounds exceeds 35,000-90,000 fish. Perhaps a short, early harvest window could be designed to take Wenatchee sockeye (Preliminary information from CRITFIC implies a difference in the upstream timing of the two mid Columbia sockeye stocks). An escapement of 35,000-90,000 sockeye at Wells Dam is insufficient. Pre-spawning mortality occurs and is probably high (no empirical estimates available). Allen and Meekin (1980) rarely accounted for half the fish crossing Wells dam on the spawning grounds. Canadian expanded spawning ground estimates have been about half of the Wells Dam count (Table 11; Figure 4; Appendix B). We suggest adult escapement monitoring at Zosel Dam (a manned counting station) rather than using Wells Dam counts. Additional studies should seek estimates of survival between Zosel Dam and the spawning grounds.

The social desire to harvest sockeye may make this alternative unrealistic.

Table 12. Assumptions used for sockeye enhancement estimates.

Biological parameter	Estimate
Spawning capacity =	35,000 adults
Spawn ratio =	1:1
Pre-spawn mortality =	20%
Spawning habitat =	0.48 - 0.70 ha
Fecundity =	2,250
Egg take =	October 1
TU/inch of fish growth=	20
Degree days =	900 to eye, 1,200 to hatch, 1,800 to swim-up
Groundwater temperature =	54-63 F
Max. groundwater flow =	1000 gpm
Egg to smolt survival =	4 - 7% natural
Egg to fry survival =	25% natural, 50% baskets, 65-70% tray
Fry to smolt survival =	30% natural, 65% hatchery
Smolt to adult survival =	0.6 - 4.6%
Max. Lake smolt production= (Lake Osoyoos est. capacity)	4,000,000
Average smolt size =	110 mm
Smolt passage period =	late April to mid-June

II. Increase production from available escapement

We recommend an evaluation of spawning habitat to assess if incubation survival is low. If egg to emergence survival is about 25-30%, incubation survival is probably not the problem in the Okanogan. However, if survival rates are considerably less, consider options in section II and III.

II a. Cleaning Okanogan River substrate

This alternative would aim at increasing survival from egg deposition to fry emergence. Gravel cleansing temporarily degrades water quality in the river therefore it will be necessary to develop a cooperative agreement with Canadian authorities. This project could be quite expensive or cheap. To clean several miles of stream a mechanized approach might prove practical. Large hydraulic cleaning units could remove some of the sediment from the river channel. A less expensive approach is the use of volunteer labor (the interested public), and several small hydraulic pumps. The pumps force water into the gravel, agitating it and dislodging sediment and debris. Sediment and debris remain in the river channel with this method. Each approach suspends sediment and dislodges macrophytes, altering water quality downstream. Floating macrophytes could impinge on the screens of pump irrigation withdrawal systems. Canadian regulations require discharge permits. Cleaning gravel could produce an aesthetically disagreeable sediment plume in Lake Osoyoos. Since cleaning would probably be done in the summer[23], the sediment and macrophytes would discharge into the lake during the recreational season.

Despite the potential problems with gravel cleaning in the upper river, the method might provide a durable habitat improvement. There have not been efforts to purge the system in

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[23] river flow is low and the eggs of sockeye or other stream spawning species would not be affected.

the past. The river was channelized in 1957. In 1964, seven years later, about 6.1 million smolts left the Osoyoos system (Mullan 1986). In 1976, almost 20 years later, 2.1 million smolts left Lake Osoyoos. Recent yield has been about 0.5 million smolts.

It seems reasonable that the cleansed gravel would remain relatively clean for several years. Less organic material enters the system today than 15 years ago. The water quality in Skaha and Osoyoos Lakes has improved since 1976, with new sewage treatment and disposal programs. Okanogan, Skaha and Vaseux Lakes all act as stilling basins for suspended materials. The reduction of new inputs, and these stilling basins should prevent rapid sedimentation and macrophyte invasion in the spawning area.

II b. Increase available spawning area

According to our calculations, adult sockeye are not saturating the spawning space available in the Okanogan system today. Additional spawning space will not increase production unless: (1) adult sockeye are available and choose to use the added space, or (2) if the gravel quality of added areas exceeds that of existing spawning areas.

Although we do not recommend seeking additional spawning space, laddering McIntyre Dam and Skaha Dam may increase the available spawning area. There are three small reaches of the Okanogan River: (1) between Vaseux Dam and Vaseux Lake, (2) Vaseux Lake and Skaha Lake, and (3) Skaha Lake and the impoundment at the outlet of Okanogan Lake (Appendix A).

If additional spawning areas prove necessary, it may be possible to develop a cooperative agreement with Canada to ladder McIntyre Dam and possibly the Skaha Lake impoundment. This would allow adult sockeye the opportunity to use additional spawning space in the river upstream from McIntyre Dam, Vaseux Lake, and Skaha Lake. This technique also offers additional rearing space in Skaha Lake. Canadian research planted about 2.7 million kokanee in Skaha lake from 1981-1986 (Appendix C). The kokanee grew well in the lake (Parkinson, in prep), but did not return to

the creel (Bull, 1987).

The drawbacks of this option include potentially low survival as sockeye fry pass through Vaseux Lake. The use of Vaseux Lake for rearing is unlikely to be as successful as rearing in Lake Osoyoos. Vaseux Lake is a shallow basin; summer water quality can be poor. Canadian management plans, presently view Vaseux Lake as a warm-water fishery. Warm-water species are potential predators on juvenile sockeye. Trout and kokanee are not regularly planted in Vaseux Lake because of poor water quality.

III. Increase production with minimal manipulation

III a. Hold adults in cooler water

Trapping and either holding or transporting adults to cooler waters may reduce pre-spawning mortality, and increase effective escapement. It may be possible to increase pre-spawning survival by holding adults in cool water until Okanogan River temperatures drop in the fall. Alternatively managers could trap adults at Wells and perhaps transport them directly to Lake Osoyoos. In the lake the adults could seek preferred water temperatures. The drawback is finding a location for release with adequate water quality at the surface. This technique would likely require international permits to transport adult sockeye to the northern basin of the lake.

Another alternative for holding adult sockeye in Lake Osoyoos would be the use of a floating culture facility similar to those used in Alaska. Facilities fashioned on pontoons could pump cool waters below the thermocline (in the northern basin) to the water's surface and through a heat exchanger to cool the warm surface waters. The temperature control options of this method are very desirable. However this method probably requires an American facility in Canadian waters, as well as the transport of live adult fish over an international border.

A similar concept might work in Wells Pool with a chiller instead of a heat exchanger on a floating culture facility. This alternative would eliminate the international regulation issues associated with holding adults in the northern basin of Lake Osoyoos.

DCPUD developed a ground water source near the mouth of the Okanogan River. Continuous pumping for one year yielded a cool (53-64 F) water supply of about 1,000 gpm. Holding sockeye in a deep pond fed by ground water may reduce pre-spawning mortality. Holding adults is difficult in waters warmer than 17-18 C (60 F). Even with a groundwater source a chiller may be necessary during part of the summer.

Disease such as columnaris may result in excessive pre-spawning mortalities. It is unlikely that (IHNV) is directly responsible for pre-spawning mortality, but holding situations may increase disease transition between adults, and juvenile mortality (Keith Johnson personal communication). A pilot program should evaluate the relative success of holding adult fish in any cool water situation.

III b. Restore the Wells spawning channel

This option would increase available spawning area. The Wells spawning channel was originally constructed for chinook. At first the channel worked well, then juvenile chinook yield declined sharply (Mike Erho, DCPUD, personal communications). Perhaps an annual maintenance program would result in consistent fry yields.

All successful sockeye spawning channels in Canada are cleansed regularly. Annual cleaning is not uncommon. Some channels require cleaning once every 2-3 years.

To estimate the potential success of using the Wells channel preliminary activities include: substrate evaluation in the channel, cleaning the channel, replacement of gravel if necessary, and a biological testing period.

This method would increase quality spawning space for sockeye, but requires human intervention at several stages.

Adult sockeye collected at Wells Dam could be held in the Wells Channel until spawning. The fish would presumably spawn naturally. As fry migrate from the channel, an inclined plane trap could collect them for transport to Lake Osoyoos. Fry releases into the aquatic vegetation along the shore of the lake may increase early survival (Jaenicke et al. 1987).

Holding sockeye to maturity in the Wells channel may prove impractical because of disease. Holding areas may enhance disease, causing pre-spawning mortality. A pilot program should reveal whether holding conditions result in severe losses.

Unfortunately it will be difficult to attribute a relative increase or decrease in disease to any holding facility. We do not feel the extensive investigation required to quantify increases or decreases in pre-spawning mortality due to disease will be cost effective. Instead pilot programs should look at several holding sites, and select the most successful.

III c. Incubate eggs in hanging baskets.

Hanging egg baskets successfully incubate both sockeye and lake trout in lakes (Haddix 1986). Haddix (1986) reports sockeye egg survival[24] in hanging baskets of 73% (52-94%). These baskets offer relatively low-cost artificial incubation. In addition the fry emerge directly into the lake bypassing many of the hazards of fry migration.

The baskets are incubator trays with a screen top. The top screen is large enough to let the fry escape. The baskets are suspended in a lake for the incubation period. Egg survival depends upon basket placement in relation to current, and on sedimentation within the lake. Other potential considerations for basket placement include:

24 fertilized eggs to emergent fry

(1) the fry 'release[25] site,

(2) spring flow patterns in relation to emergence time that do not flush fry from the lake, particularly in the south end of the lake, and

(3) water temperatures in the lake, compared to inter-gravel temperatures and the associated time of hatch.

Lake Osoyoos is a logical location for egg basket incubation. If there are not suitable basket sites in U.S. waters, then a cooperative agreement with Canadian fisheries authorities is necessary. Fish transportation and planting permits across international borders are sometimes difficult to obtain.

Adult sockeye collected at Wells Dam would be held until artificially spawned. The fertilized eggs would be taken to Lake Osoyoos for incubation. Egg baskets, like those described in Appendix E, provide an incubation site. Basket locations should allow for flow over the eggs, but minimize sediment deposition in the basket. Treatment of fertilized eggs with iodiform (100 ppm for 10 minutes) may provide some interruption of vertical disease transmission.

Preliminary research programs should include:

(a) location of suitable sites for basket incubation;

(b) fall temperature and oxygen monitoring will determine the appropriate time to place eggs in the lake;

(c) temperature regimes in the lake during the incubation period to project the timing of emergence;

(d) zooplankton composition in the lake during the projected emergence period.

Adults could be held in the Wells Channel, and conceivably

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25 Fry actually leave the incubation baskets volitionally.

in net pens (eg. Wells Pool). They might be held in floating tanks in Lake Osoyoos. they might better be held in ground water (see III a). To minimize pre-spawning mortality, managers should maintain low densities of adults in any holding facility.

Net pens would be inexpensive and require little maintenance. Additional net pens can easily reduce fish density or increase adult holding capacity. However water temperature control would be difficult or impossible.

Adults can be spawned near net pens. Carcass disposal options may offset program costs. For instance Wisconsin's Sea Grant Program is test marketing an odorless garden mulch product made from fish. One midwest electrical utility facilitated the development of a commercial venture that sells frozen blocks of ground fish carcasses as bait (chum material) to commercial fishermen in Florida. Marketing mechanisms for carcass disposal programs exist. Lake Osoyoos is an unusually productive sockeye lake, and removal of a portion of the carcass "fertilization" may be desirable.

III d. Incubate eggs in streamside hatch boxes

Streamside hatch boxes are inexpensive to install and maintain (Robertson and Holder 1987). Fry emigrate directly from the hatch box, as they would from stream gravel.

Adult sockeye collection at Wells, adult holding space, artificial spawning and egg transport permits will be necessary. If eggs must incubate before disease certification, egg facilities must be available. We recommend iodiform treatment of fertilized eggs to minimize effective vertical transmission of disease.

This method requires the legal right to divert a small amount of water from the Okanogan during the period of lowest flows. Although hatch boxes require a relatively small amount of water, it is unlikely that new water rights will be obtainable. Irrigation, as well as Okanogan Lake kokanee spawning and incubation needs determine the operation of the Okanogan River.

Winter water management is particularly important to kokanee incubating in the shoreline regions of Okanogan Lake. Use of any water in the basin would require a cooperative agreement with several Canadian agencies and approval of the International Joint Commission.

Table 13 shows our calculations for both basket and box incubation. We assumed the loading rate could be similar for both systems. However, basket incubation is the more likely alternative unless additional studies indicate that tributary water quality and quantity is adequate. Use of baskets or box incubation should provide improved egg to fry survival (even though we used conservative parameters). Fifty four units (baskets or boxes) would fully seed[26] the lake without recruits from natural spawning.

III e. Eyeing Station.

Heath trays or streamside incubators are suitable egg incubation facilities. Sockeye eggs held to the eyed stage can continue development in baskets or boxes. At swim-up, fry leave the baskets or boxes by themselves. Table 14 shows our computations for the number of incubators and other facilities required to meet lake rearing capacity. We also show flow and cost estimates.

Pilot programs are necessary to evaluate the horizontal transmission problems commonly associated with IHNV, a common viral disease. Since some vertical transition of IHNV occurs, we recommend iodiform treatment of eggs, realizing it does not eliminate the more common horizontal transition. In addition, we recommend as much egg segregation as possible, with no more than five pairs of parents per egg lot. We recognize that some Alaska programs will incubate eggs of both IHNV negative and eggs with low titers (detectable levels of 10^3-10^5); however we recommend use of only IHNV negative eggs, as they will be transported over an international border.

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[26] Full seeding refers to the estimated number of sockeye fry that could rear in the lake before density influences growth.

Table 13. Estimates of sockeye production and cost of production using basket/box incubation to supplement Lake Osoyoos sockeye salmon production.

Variable	Estimate
Fish production:	
24,000 spawners @ 2250 eggs =	27,000,000 eggs
Incubation survival (egg to fry) = 50% =	13,500,000 fry
Rearing survival (fry to smolt) = 30% =	4,050,000 smolts
Smolt to adult return required = (@ 20% pre-spawn mortality)	0.74%
Basket/box loading density =	500,000 eggs /unit
Units required =	54
Cost:	
Capital investment	> $100,000
O&M	> $225,000/yr

Table 14. Estimates of fish production and cost of an eyeing station to supplement Lake Osoyoos sockeye.

Variable	Estimate
Fish production:	
24,000 Spawners @ 2250 eggs =	27,000,000
Incubation survival (70% to eyed eggs) =	18,900,000 transfer eggs
Basket/box egg to fry survival (72%) =	13,608,000 fry
Rearing survival (30% fry to smolt) =	4,082,400 smolts
Smolt to adult return required = (assuming 20% pre-spawn mortality)	0.73%
Heath tray incubation = (assuming 16-tray stacks @ 7200 eggs/tray)	234
Flow required = (assuming 1 gpm/stack)	0.5 cfs
Basket/Box units = (assuming 500,000 eggs/unit)	38
Cost:	
Capital investment	> $800,000
O&M	$300,000/Yr.

III f. Other spawning channels.

This is not a feasible alternative for the Okanogan because spawning channels require large volumes of water. It is unlikely additional water would be available during this low flow period (see history of water law in the basin Appendix F). Channels are expensive to construct and expensive to maintain. A recent review by Canadian biologists rejected spawning channels in the Okanogan for kokanee enhancement because channels require too much water (Bull 1987).

IV HATCHERY OPTION

We do not recommend the use of a hatchery system, unless there is no other alternative. Hatcheries are expensive, and have a history of declining benefit over time. Hatchery programs may cause loss of genetic variability and reduce viability of wild stocks over time. One advantage of a hatchery program is the ability to mark pre-smolt sockeye for an evaluation program. We provide criteria for a sockeye salmon hatchery, which may prove useful as managers consider other alternatives.

Table 15 shows our calculations for a sockeye hatchery with a production goal of 4,000,000 smolts. Use of a full scale hatchery reduces the escapement requirements for run maintenance. However, hatchery production depends on suitable hatchery water.

We assume barrel incubation will be as successful for sockeye as it has for kokanee. Heath tray incubation requires greater flow and space.

We used groundwater temperatures obtained at a site upstream from Wells Dam to calculate rates of egg development (unpublished data, DCPUD). Eggs will reach the eyed stage on about October 31, and hatch November 11 (Table 16). Alevins should reach swim-up about December 4. Sockeye will reach smolt size for out-migration by May 1. Consequently, full hatchery production would circumvent lake rearing. Hatchery-reared smolts would be

Table 15. Estimated needs and production at various life stages to produce 4 million smolts, or the estimated capacity of Lake Osoyoos.

Variable	Estimate
Fish production	
8,500 spawners @ 2250 egg=	9,562,500 eggs
Incubation survival (65% egg to fry)=	6,215,625 fry
Rearing survival (65% fry to smolt)=	4,040,156 smolts
Adult Holding Requirements	
3.7 lbs /fish=	31,450 lbs
Holding Density =	5.25 lbs/ft^3/pond
Pond Volume =	6,000 ft^3
Number of Ponds = (@10ft x 40 ft x 3 ft deep)	5 @ 1,200 ft^3/pond
Total Flow Required =	1.7 cfs @ 1 turnover/hr
Incubation	
Number Incubators = (@ 270,000 eggs/incubator)	24
Incubator Type =	2 ft diameter, upwelling incubator, 2/rearing pond
Flow Required = (20 gpm/incubator = 480 gpm)	1 cfs
Early Rearing	
Pond Capacity = (6,215,625 fry @ 1100/lb.)	5,650 lbs.
Loading Density =	0.5 lb./ft^3
Pond Volume =	11,300 ft^3
Number of Ponds = (@ 480 ft^3 /pond) (each pond 4 ft x 40 ft x 3 ft deep)	24
Total Flow Required for all ponds= (@ 2 turnover/hr, 1-pass)	6.3 cfs
Final Rearing	
Pond Capacity = 4,040, 156 smolts @ 35/lb =	115,433 lbs
Loading Density =	0.5 lb/ft^3
Pond Volume =	58,000 ft^3
Number of Ponds = (@ 2400 ft^3/pond) (10ft x 80 ft x 3 ft deep)	24
Flow Required = (@ 2 turnovers /hr, 3-pass)	11 cfs
Total Flow Required = (approximately 10 cfs of groundwater with/2-5 wells)	20 cfs
Smolt to adult return required = (@ 20% pre-spawn mortality)	0.26%

Table 15. Continued

Variable	Estimate
Facility Requirements	
Early Rearing Tanks	
Final Rearing Raceways	
Adult Trap	
Feed & Equipment Storage	
Spawning Shed	
Office & Utility	
Effluent Settling Ponds	
Road & Fencing	
Vehicles	
Residences	
Vehicle Storage	
Pumps	
Shop	
Head Tanks	
Barrel Incubators	
3-5 Acres of Land	
Capitol Cost >	$2.5 Million
O&M Cost >	$475,000 /year.

Table 16. Predicted sockeye development and growth rates[a] using groundwater as calculated for water temperatures of groundwater at Cassimer Bar.

Month	Groundwater average Temp (F)	Degree days	Thermal units	Accumulative Growth rate	Fish/ pound	Development stage	Date
Estimates with 1988-89 data							
Oct	65[b]	33	26.4	Incubation	-	Eyed	Oct 27
Nov	59	27	20.4	Incubation	-	Hatch	Nov 11
Dec	56	24	17.4	0.87	3,500	All-Feeding	Nov 28
Jan	55	23	16.4	1.69	581	-	-
Feb	56	24	17.4	2.56	172	-	-
Mar	54	22	15.4	3.33	77	-	-
Apr	54	22	15.4	4.10	41	-	-
May	55	23	16.4	4.92	24	Smolt	May 1
Estimates with 1989-90 data							
Oct	56	24	17.4	Incubation	-	Eyed	Oct 31
Nov	56	24	17.4	Incubation	-	Hatch	Nov 7
Dec	57	25	18.6	0.93	3,500	All-Feeding	Dec 4
Jan	55	23	16.4	1.75	531	-	-
Feb	53	21	14.4	2.47	190	-	-
Mar	53	21	14.4	3.19	88	-	-
Apr	55	23	16.4	4.01	44	-	-
May	55	23	16.4	4.83	25	Smolt	May 1

[a] All calculations assume optimum conditions

[b] October temperatures recorded during first year of pumping (1988) were much higher than those recorded in 1989 (DCPUD unpublished data)

available to migrate in May, one year before their naturally spawned cohorts.

LESS PROMISING ALTERNATIVES

We reviewed other possible sockeye enhancement alternatives suggested by committee members. The following programs provide potentially minor enhancement opportunities compared to reaching the estimated capacity of sockeye production within the habitat already available.

Readers should keep in mind that water allocation in the basin is controversial, and there are other popular sport fishing opportunities and recreational uses in the region. Agriculture, recreation, and international water law compromises that will lead to additional water for sockeye are unlikely.

METHOW RIVER

Although sockeye spawn in the Methow River Basin, they represent less than 0.5% of the spawners above Wells Dam (Appendix B; Mullan 1986; Kohn 1988; Kohn 1987). The Methow "population" of riverine spawners may be progeny from the Methow River or represent strays.

Wells pool would be a logical rearing area for fry from the Methow. There are no data to confirm or refute sockeye rearing in Wells pool. Low zooplankton populations make successful and extensive sockeye rearing unlikely (Mullan 1986). Jaenicke et al. (1987) found juvenile sockeye using chironomids, which Mullan et al. (1986) indicates are abundant in Wells Pool. We conclude sockeye rearing might be possible, but extensive success unlikely.

WELLS POOL

Operation of Grand Coulee influences both water temperatures and the aquatic invertebrate population of Wells Pool. River water is warmer in fall and winter and colder in spring and summer (Mullan et al. 1986). Summer temperatures at Wells Dam do not exceed 18 C (65 F; McGee, Douglas County PUD, Personal

Communication). Water temperature regimes in the mid-Columbia modified both primary and secondary production (Mullan et al. 1986).

Mullan et al. (1986) describes the primary production of the mid-Columbia pools as dominated by detritus, sessile algae, and macrophytes. Diatoms dominate the phytoplankton community. The peak of phytoplankton abundance is April-June with a lesser bloom September to October. Zooplankton are scarce, except in backwaters. The benthic community is within the range of reservoir fluctuation. Where benthos exist, it primarily consists of chironomids and oligochaetes (Mullan et al. 1986).

Mullan et al. (1986) speculate that more nutrients are available today than before impoundment, yet describe the impoundments as similar to unproductive oligotrophic lakes, with low Chlorophyll 'a' concentrations. Reservoirs often act as nutrient sinks; for example the storage reservoirs of the Clark Fork River in the upper Columbia watershed act as phosphorous sinks (Johnson 1989). These upstream projects could actually reduce nutrient load, instead of increasing it.

Today fishes dependent upon periphyton remain or increase while those dependent upon detritus, plankton and zooplankton are generally absent in the mid-Columbia reservoirs (Mullan et al. 1986). It is logical to assume juvenile sockeye that depend on zooplankton foods, would not successfully rear in large numbers.

It has been speculated, but seems unlikely, that Wells pool may be used for sockeye rearing today. An argument for use of the Wells pool stems from the recurring use of the Methow River by spawning sockeye despite the lack of rearing habitat. The zooplankton data available to date for Wells pool do not seem to indicate an abundance of appropriate foods for juvenile sockeye, unless they adapt to use of chironomids as Jaenicke et al. (1987) report for some Alaskan lakes. This seems unlikely, as chironomid use seems to correspond with the presence of aquatic macrophytes (Jaenicke et al. 1987).

Despite low water retention times in Lake Rufus Woods, the kokanee must be finding some zooplankton (or using chironomids).

One explanation could be these fish are sustained on the seston from Lake Roosevelt. It seems unlikely that sufficient seston of Lake Roosevelt origin is still available for juvenile sockeye in the Wells pool.

Unlike the other reservoirs in the mid-Columbia, Wells pool maintains centrarchid populations. For instance, there is a fishery for smallmouth bass. Mullan et al. (1986) suggest this unique centrachid population exists due to the warm waters of the Okanogan River entering an otherwise 'cool' mid-Columbia.

This warmer water, while favoring smallmouth bass, does not necessarily enhance sockeye production and survival. Bouck et al. (1975) examined the survival of adult sockeye held in Columbia River waters between 10 - 22 C. They found 22 C lethal to sockeye by predisposing the fish to disease. The Okanogan River is frequently 22 C, hot enough to discourage sockeye passage into their natal river until temperatures begin to decline in the fall.

PALMER LAKE

Alternative 1

Palmer Lake is located on a high water channel of the Similkameen River upstream from Enloe Dam. The lake receives water year round from a small headwater stream, and seasonally from the Similkameen River. Populations of centrarchids dominate lake sport fish populations, which WDW actively manages.

We did not find O. nerka planting records, but were told of planting programs by several agency employees. Although WDF mentioned a discontinued sockeye planting program, we could not locate the description of the program and its results. There are reports of kokanee in Palmer Lake, but the populations do not provide a substantial fishery.

We found limited limnological data for Palmer Lake. Summer surface temperatures reach 24 C (70 F), and these temperatures extend down to about 8 meters (Langless 1990 DRAFT).

Palmer Lake fills with water from the Similkameen River during high spring flows. The direction of flow changes in the channel between the lake and the river as spring flow subside. By early summer water flows out of (instead of into) Palmer Lake. An impoundment increases the natural water level in Palmer Lake, and controls flow out of the lake. Plans exist for increasing the volume of the lake with a higher impoundment and delaying outflow (Langless 1990 DRAFT).

If juvenile sockeye successfully reared in Palmer Lake, it is unlikely they would successfully pass downstream in the spring as smolts. They would have to voluntarily swim upstream, against the current in the spring to reach the Similkameen. Then their behavior would need to change, allowing them to pass downstream. Later smolts would find less water for passage in the main Columbia River, based on the past use of the water budget.

In the event that sockeye could rear in Palmer Lake, smolt, and successfully return to the Similkameen as adults, they would not be able to pass upstream of Enloe Dam without transportation. If kokanee spawn successfully in the lake, there may be some suitable habitat for sockeye spawning. However we could not confirm the presence of suitable spawning habitat in Palmer Lake or the inlet to the lake.

Alternative 2

The subbasin planning process of the Northwest Power Council proposed using Palmer Lake waters to cool the Similkameen and Okanogan Rivers (Langless 1990 DRAFT). Since surface waters are warm, the plan proposed to siphon cool waters from deep in the lake. Two factors made this alternative unrealistic: 1) the cost of such a siphon is prohibitive, 2) the water law in the state of Washington does not allow water storage specifically for fisheries when there are competing consumptive uses (Langless 1990 DRAFT).

OTHER SMALL LAKES

There are several other small lakes in the region. Most are small irrigation reservoirs, with outlet flows used for irrigation. Lakes that retain water year-round are alkaline and managed for Lahontan cutthroat trout fisheries. None of the lakes maintain outflows throughout the adult sockeye migratory period, preventing natural spawning migrations. We were unable to confirm the presence of suitable sockeye spawning areas associated with any of these lakes. We were unable to confirm suitable sockeye rearing space in any of these lakes.

CANADIAN WATERWAYS

There are two regions in Canada that are presently unavailable to Okanogan sockeye: (1) The upper Okanogan River Basin from the headwaters to the outlet of Okanogan Lake and (2) the region from the impounded outlet of Okanogan Lake to Vaseux Dam, discussed previously in this document.

It is unlikely that the upper Okanogan River/Lake Basin will become available to sockeye. Okanogan Lake supports an economically important kokanee population, generating regional income from recreational opportunities. Water management in the basin considers the kokanee population, acknowledging its economic importance to the region. In contrast, sockeye offer little to Canadian nationals.

Columbia River sockeye carry IHNV, a disease infecting both kokanee and sockeye populations. It is unlikely that Canadian authorities would agree to sockeye passage into Okanogan Lake, on the basis of disease alone.

There is no reason to think that increased production of Okanogan sockeye would benefit Canadians. American harvest allocation in the Columbia River provides for the harvest of additional fish in the U.S. instead of Canada. Management agreements in U.S. v Oregon clearly permit the harvest of sockeye

if more than 75,000 cross Bonneville Dam (assuming 75,000 fish results in 65,000 at Priest Rapids [27]). This harvest allocation procedure potentially limits escapement to the Okanogan and the success of any enhancement program.

Native American tribes in Canada that could have ceremonial and subsistence interests in the Okanogan sockeye, do not have the political influence to generate national interest in U.S. harvest allocation issues affecting sockeye escapement into the Canadian portion of the Okanogan.

LAKE CHELAN

The outlet from Lake Chelan enters the Columbia River downstream from Wells Dam, and therefore lie beyond the scope of this study.

WATER BUDGET AND OTHER COLUMBIA RIVER PASSAGE ISSUES.

All Columbia River passage issues influence Okanogan sockeye at or downstream from Wells Dam, and were therefore beyond the scope of this study. Water budget allocations and management require consultation of regional fisheries scientists operating in both technical and political capacities, and beyond the scope of DCPUD management.

EXPLOITATION

Harvest allocations in marine and freshwater environment are negotiated, beyond the scope of this study, and beyond the sole control of DCPUD. However, the success of any natural production program selected in the basin could improve with additional escapement (as previously discussed in several sections of this report).

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[27] with an interdam mortality rate of 4%, or less than half the inter dam mortality rate currently used by the NWPPC

CONCLUSIONS

The data available suggest it is possible to increase Okanogan sockeye production if more fry reach the productive pelagic regions of Lake Osoyoos. The data provide an incomplete picture of current conditions in the Okanogan River and Lake Osoyoos. We offer several enhancement strategies. We do not select one strategy above all others. Instead we recommend modest and focused biological investigations to refine the selection of an enhancement strategy.

Other sites upstream from Wells Dam are less likely to provide successful enhancement opportunities. The Methow, Similkameen and lower Okanogan rivers provide limited spawning without rearing space. Other small lakes in the region, and the Wells Pool, are less suitable than Lake Osoyoos for rearing juvenile sockeye. Since rearing space does not seem to be the issue, we did not focus on these waters.

We did not develop evaluation programs for each enhancement strategy. We feel that smolt emigration is an appropriate evaluation standard as it addresses sockeye production upstream from Wells Dam. The use of a later stage of life for an evaluation standard for program success inappropriately involves the population at sites downstream from Wells Dam, and outside the scope of this study. An optimum smolt size might be set in the enhancement program goal and used as a standard for success. Peterman (1981) suggests sockeye smolts 100-120 mm survive ocean life better than smaller or larger fish.

We recommend development of a consistent smolt monitoring technique. Baseline data should provide both an estimate and a bound on the error of the estimate. Past estimates are of limited use. Estimates of smolt size did not temporally correspond with hydroacoustic estimates of smolt yield. Trapping data did not include information on trap efficiency and hence could not be used to estimate smolt yield. Some combination of standardized trapping and hydroacoustic estimates might provide appropriate annual estimates of smolt yield.

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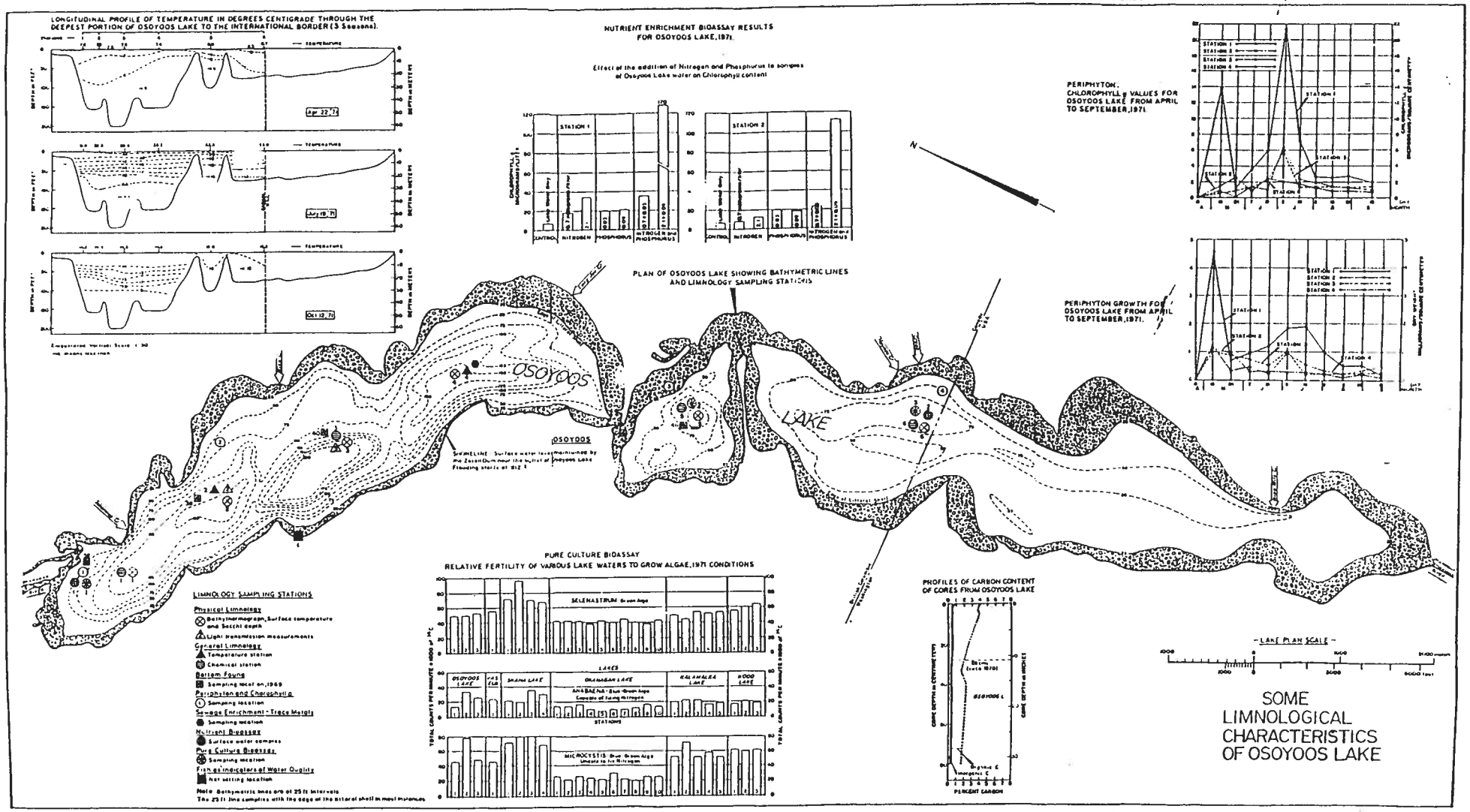
APPENDIX A

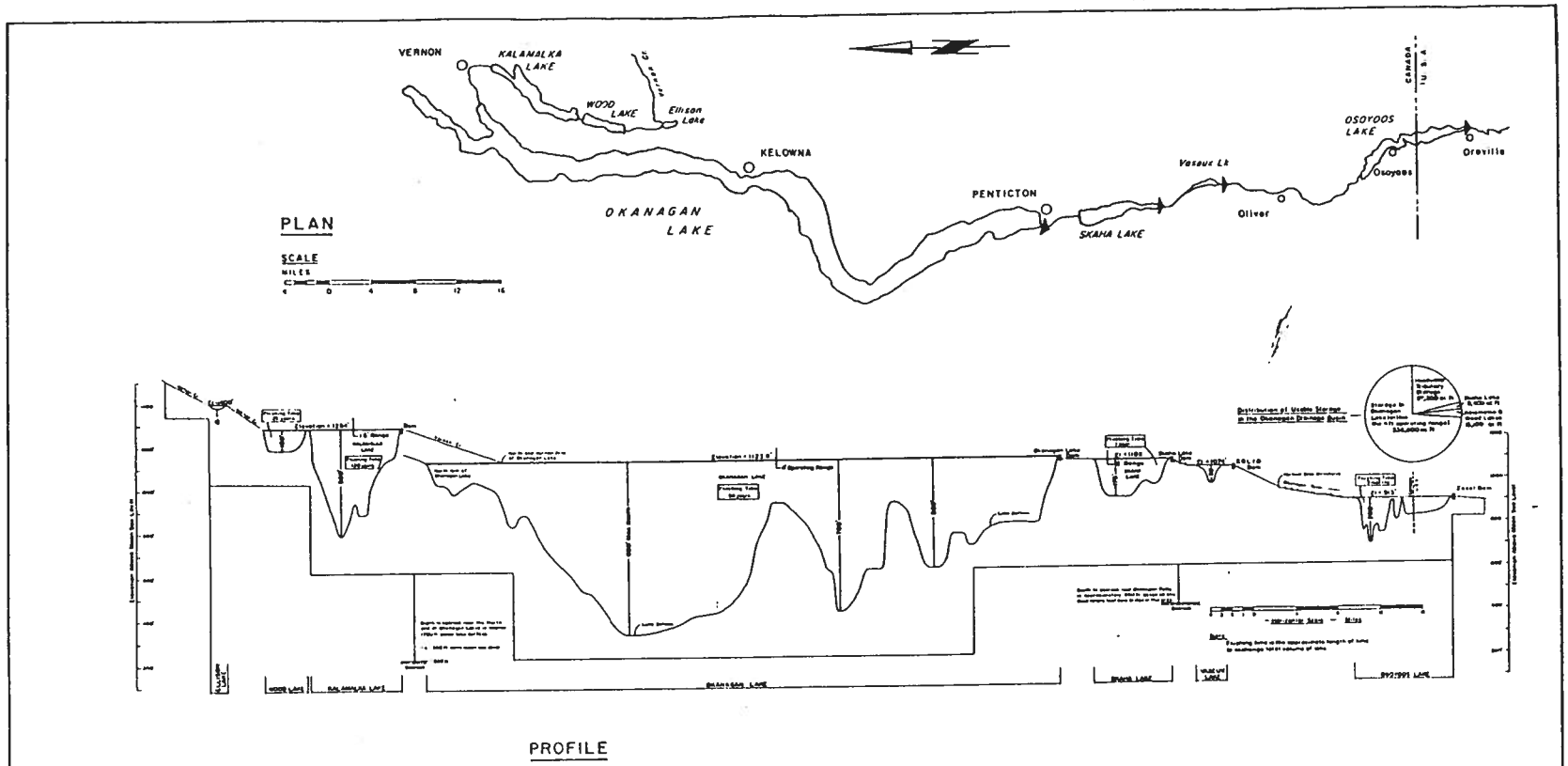
MAPS

APPENDIX A1



RECEIVED FROM CHRIS BULL - MINISTRY OF ENVIRONMENT-BRITISH COLUMBIA

APPENDIX A2



PLAN AND PROFILE of OKANAGAN MAIN VALLEY LAKES

RECEIVED FROM CHRIS BULL - MINISTRY OF ENVIRONMENT
BRITISH COLUMBIA

APPENDIX B

RAW DATA DESCRIBING SOCKEYE POPULATIONS UPSTREAM FROM WELLS DAM

Appendix B1. Estimated sockeye spawning escapement (based on spawning ground counts and the WDF method of 1/2 the Wells Dam count), and number of adults returning to the Columbia destined for the Okanogan River Basin, Washington.

Year of adult return	Estimated production of Okanogan origin [a,b]	Wells Dam count	Estimated spawning escapement [d,e]	
			from 1/2 Wells ct.	from ground observation
1926				nil
1927				nil
1928				------
1929				nil
1930				light
1931				nil
1932				nil
1933				light
1934				300-500
1935				nil
1936				1-50
1939				10,104 [f]
1940				9,691 [f,g]
1942				[g]
1943				[g]
1946				[g]
1947	172,700			6,027
1948	72,600			7,175
1949	35,100			133
1950	------			500
1951	163,600			5,602
1952	247,500			10,360
1953	236,100			15,165
1954	126,900			7,233
1955	158,200			19,320
1956	143,400			16,067
1957	87,600			8,533
1958	196,100			10,628
1959	217,400			20,847
1960	85,000			3,421
1961	36,800			691
1962	12,800			1,969
1963	36,500			---
1964	47,500			6,286
1965	40,300			5,462
1966	132,000	113,232	55,616	44,865
1967	150,000	81,530	40,765	16,786
1968	116,000	17,352	8,676	7,440
1969	39,800	50,667	25,334	6,235
1970	72,000	48,172	24,086	17,810
1971	104,100	33,398	16,699	26,728
1972	75,600	37,178	18,589	14,796
1973	43,400	16,716	8,358	6,328
1974	26,800	22,286	11,143	3,080
1975	29,200			6,684

Appendix B1. (continued).

Year of adult return	Estimated production of Okanogan origin [a,b]	Wells Dam count	Estimated spawning escapement [d,e]	
			from 1/2 Wells ct.	from ground observation
1976	32,900	27,619	13,810	8,535
1977 c.1	28,100	21,973	10,986	4,870
1978	10,100	7,458	3,729	420
1979	29,800	22,655	11,327	839
1980 c.2	29,900	26,573	13,286	5,000
1981 c.3	30,600	28,234	14,117	
1982 c.4	21,100	19,005	9,502	
1983	30,300	27,925	13,962	
1984	108,500	81,054	40,527	
1985	103,900	53,170	26,585	
1986	39,600	34,876	17,438	
1987	84,500	39,948	19,974	
1988	------	33,980	16,990	
1989	------	15,895	7,948	

[a] Estimates from 1926-1936 from Fisheries Service of Environment Canada (1973). Table 1;

[b] Estimates of sockeye run origin Mullan (1986) page 93

[c.1] Estimate from Mullan (1986), and similar within 100 fish to Pratt and Chapman (1989)

[c.2] Estimate from Mullan (1986); Pratt and Chapman (1989) estimate 28,300

[c.3] Estimate from Mullan (1986); Pratt and Chapman (1989) estimate 36,200

[c.4] Production estimated by Pratt and Chapman (1989)

[d] Estimates of escapement 1947-1980 from Mullan (1986) page 83

[e] Canadian Department of Fisheries and Oceans annual spawning ground counts

[f] Estimates for 1939 and 1940 are adults released in Osoyoos Lake; numbers derived from Table 2. Fisheries Service of Environment Canada (1973).

[g] Fingerlings planted in Lake Osoyoos and back calculated to estimate number of additional spawners

Potential to Enhance Sockeye Salmon Upstream From Wells Dam

- p.5 Has anyone checked out the two runs. Spawn mid Sept & Oct.
- p.6 Lake shore spawning limited?
- p.10 Two groups of juvenile migrants.
- p.20 FW age of fish @ 1.- is 95% or more
- p.22 Between McIntyre Dam - Oliver could support 35K spawners.
- p.26 T in Osoyoos is already higher than most sockeye lakes. Lack of cold water refuge areas will decline # smolts.
- p.33 Will we initiate the investigations outlined here?
- p.34 What is status of Zosel dam County CRITFC?
- p.39 Plans for DCPUD ground well @ mouth of Okanogan R.

Appendix B2 Proportion of run destined for Okanogan as estimated by dam counts at Rock Island and Rocky Reach (1962-1989). Adapted from unpublished data from Dell, Grant County PUD, 1-30-90.

Year of adult sockeye return	Adult Sockeye Dam Counts Rock Island[a]	Rocky Reach[b]	% of Run crossing Rocky Reach
1965	42,380	31,735	75
1966	164,547	129,557	79
1967	119,765	109,434	91
1968	104,790	91,376	87
1969	37,965	70,374	54
1970	74,904	57,251	76
1971	71,438	49,838	70
1972	43,467	26,978	62
1973	68,732	48,856	71
1974	33,859	20,976	62
1975	53,405	76,925	50
1976	35,407	27,205	77
1977	90,262	25,648	28
1978	14,748	8,157	55
1979	50,485	28,747	57
1980	52,658	29,906	57
1981	47,139	30,649	65
1982	41,111	17,379	42
1983	86,424	26,079	30
1984	109,074	73,290	67
1985	103,230	54,077	52
1986	49,789	32,912	66
1987	70,673	41,115	58
1988	49,159	34,090	69
1989	37,360	16,176	43

a. Sockeye crossing Rock Island are a mixed stock originating from the Wenatchee River and Okanogan River Basin.

b. Sockeye crossing Rocky Reach are primarily Okanagon fish, though some turn occurs to the Entiat and Methow.

Table B3. Rocky Reach and Wells Dam counts (in thousands) and an estimated percent mortality or turn off. [a]

Year	Rocky Reach (Thousands)	Wells (Thousands)	% Mortality
1967	109.4	110.0	-----[b]
1968	91.4	81.4	11
1969	20.4	17.3	15
1970	57.2	50.3	12
1971	49.8	48.3	3
1972	27.0	33.1	-----
1973	48.9	38.1	22
1974	21.0	16.6	21
1975	26.9	22.2	18
1976	27.2	27.6	-----
1977	25.6	22.0	14
1978	8.2	7.3	11
1979	28.7	26.7	7
1980	29.9	26.5	11
1981	30.6	28.0	8
1982	17.4	18.7	-----
1983	26.1	27.9	-----
1984	73.3	81.1	-----
1985	54.1	53.2	2
1986	32.9	34.9	-----
1987	41.1	40.0	3
1988	34.1	34.0	0
1989	16.2	15.9	2

[a] A few Entiat fish turn off between Rocky Reach and Wells Dam, but their numbers are small enough to have little effect on these estimates of loss or mortality.

[b] Chronic problems exist with the comparison of counts at these two dams: mortalities were not calculated when more fish seen at Wells than Rocky Reach.

Appendix B4. Summary of sockeye planting records for Lake Osoyoos as presented by Mullan (1986).

Brood Year	Egg Source	Number Release	Place Release	Size @ Release	Date Released	% Returning as adults
1939	wild	10,104	Osoyoos	adult	-----	----
1939	Okan R.	15,932	Osoyoos	-----	4&5/41	0.43
1940	wild	9,691	Osoyoos	adult		
1940	Rock Is.	370,420	Osoyoos	87.5/lb	5/42	0.15
1940	Rock Is.	50,040	Osoyoos	95.0/lb	11/41	2.66
1940	Rock Is.	25,000	Osoyoos	80.0/lb*	5/42	0.15
1940	Rock Is.	519,256	Osoyoos	95.0/lb	11/41	2.66
1941	?	84,000	Osoyoos	117.0/lb	/42	--
1942	Rock Is.	31,264	Osoyoos	52.0/lb	3/44	0.20
1942		36,400	Osoyoos	52.0/lb	3/44	0.20
1942	Rock Is.	33,864	Osoyoos	117.0/lb	10/43	1.87
1942		84,456	Osoyoos	117.0/lb	10/43	1.87
1942		534,204	Osoyoos	90.0/lb	10/43	1.87
1943		577,227	Osoyoos	90.0/lb	10/44	1.87
1943		510,911	Osoyoos	106.0/lb	10/44	1.87
1946	Methow	337,590	Osoyoos	95.0/lb	4/47	ND
1948	Methow	524,400	Osoyoos	45.9/lb	9/49	ND
1952	L.Wenatchee	79,040	C.R.@Pateros	159.0/lb	?/53	ND
1957	L.Wenatchee	627,460	Osoyoos	32.0/lb	?/58	ND
1957	L.Wenatchee	466,678	Osoyoos	26.0/lb	?/58	ND

from Mullan (1986); pages 16-17;18-19.

* could be 87.5/lb

APPENDIX C

KOKANEE RELEASED INTO SKAHA AND OKANOGAN LAKES

Table C1. Kokanee (in thousands) released to Skaha Lake from Bull (1987) page 16.

Year	Number released (thousands)	Dates at release	Size (grams)
1981	118	July 17-July 20	0.2-1.0
1982	536	May 1-June 21	1.3-2.5
1983	548	May 6-June 29	1.6-4.5
1984	458	May 2-July 30	2.8-4.6
1985	411	May 30-July 15	0.5-3.7
1986	600	April 21-June 3	1.1-3.0
Total	2,671		

Table C2. Kokanee releases into Okanogan Lake (Bull 1987)

Year	Number (Thousands)	Size @ Release (Partial count in thousands)
1978	210.0	fry (60.0) eggs (150.0)
1979	1145.0	fry (42.0) eggs (1103)
1980	93	fry (@ 0.25 gm)
1981	900	eyed eggs
1982	374	fry
1983	62	fry (@ 1.6 gm)
1984	----	
1985	50	swim up fry
1986	1328	swim up fry (50) eggs (390) fry (888; @ 0.2-2.8 gm)
1987	1238	fry (@ 1.5 gm)

APPENDIX D

SELECTING ENHANCEMENT STRATEGIES AND DESIGNING EVALUATION AND MONITORING PROGRAMS

APPENDIX D

SELECTING ENHANCEMENT STRATEGIES AND DESIGNING EVALUATION AND MONITORING PROGRAMS

Selecting an Enhancement Strategy

We recommend exhausting natural production enhancement possibilities before use of intensive aquaculture facilities. We believe selecting the most cost-effective enhancement of natural production requires an understanding of early survival, since we assume there is additional sockeye rearing space and food in Lake Osoyoos. A series of pilot programs would provide the required information, but require time. Any alternative described might provide an immediate attempt to increase production, without cost-effective criteria.

Any enhancement effort selected would test the fry capacity of Lake Osoyoos to a degree. We recommend monitoring the relationship between smolt production and size for some evidence of approaching density dependent growth with any enhancement effort.

Evaluation and Monitoring

Evaluation and monitoring of the additional yield of naturally produced sockeye smolts is difficult. Additional fish production resulting from enhancement measures cannot be identified for subsequent recovery. Only a discrete period of survival, or component of an enhancement program, can be tested. Attributing small increases in smolt yields to enhanced natural production is not possible. Smolt yield evaluations before-and-after in management-scale enhancement programs might be feasible.

Enhancement with hatchery practices, although less desirable in many respects than promotion of wild/natural production, permits marking fish with half-tag coded wire tags (CWT). Enhancement assessed on a component basis is possible with recoveries of marked smolts and adults.

Although assessment of enhancement success is not within the scope of our evaluation of sockeye potential upstream from Wells Dam, we offer the following suggestions for evaluation and monitoring. No recommended order of priority is attached to numbering. We emphasize that several evaluations in the categories A to C below could proceed at the same time, and are not mutually exclusive.

Evaluation of measures designed to stimulate natural yield

A. Measures with minimal interference:

1. Increased escapement.
   a. Monitor adult escapement at Zosel Dam.
   b. Radio-tag 200 adults for each of two years to assess pre- spawning mortality and assess spawning distributions to find any formerly unidentified areas (eg. deep-water sites).

2. Increased production from escapements.
   a. Assess intragravel temperatures.
   b. Assess gravel composition in spawned and unspawned gravels.
   c. Assess dissolved oxygen in redds.
   d. Hydraulically sample pre-hatch egg survivals.
   e. Measure a-d after gravel cleansing. May be done in parallel on test and control areas.
   f. Expand [e] if successful and repeat as needed, based on monitoring.

3. Best management practices.
   a. Adopt [e] on extended basis if successful, monitor, repeat as needed.

B. Measures with modest interference:

1. Increased pre-spawning survival.
   a. Assess adult survival and egg viability after adult maturation in groundwater.
   b. Assess adult survival and egg viability after holding in tanks chilled by heat exchange with hypolimnetic water or chillers.
   c. Assess adult survival and egg viability after holding in Wells spawning channel.
   d. Expand [a], [b], [c] in accord with success.

2. Increased incubation survival.
   a. Using fertilized eggs from adults from B.1., assess survival and timing to emergent fry in hanging baskets in Lake Osoyoos.
   b. Monitor lake temperatures, benthic plants, fines deposition associated with 2.a.
   c. Using fertilized eggs from adults from B.1., assess survival and timing to emergent fry in streamside hatch boxes.
   d. Using fertilized eggs from adults from B.1., assess survival and timing to eyed stage in Heath incubators. [Eyed eggs may prove more suitable for use in hanging baskets or hatch boxes if emergence timing proves

unsuitable in terms of lake temperature or availability of vegetation for cover.]

e. Expand most successful elements [a-d] sufficiently to provide management level tests. Evaluation must consist primarily of monitoring of component survivals. Hydroacoustic assessment of pre-smolt abundance may be useful, as may scoop trapping at outlet with appropriate efficiency assessment.

3. Best management practices.
   a. Use best combination of measures.
   b. Monitor success with hydroacoustics and scoop trapping with known efficiency.

C. Measures with extensive interference.

1. Partial rearing size.
   a. Using fertilized eggs from adults from B.1., assess egg survival in groundwater incubation to swim-up.
   b. Monitor disease incidence.
   c. Determine survival and growth to partial rearing. [Partial rearing here means to sizes sufficient to permit insertion of half CWTs or PIT tags. Fingerlings should be retained and fed for two weeks minimum after tagging so that disease incidence from tagging can be reduced with antibiotics.]
   d. Test survival to smolt stage of rearing to two sizes; minimum size for CWT insertion, and a larger size.

2. Release of partially reared fish.
   a. Test release locations/times by releasing test CWT groups to (1) pelagic waters; (2) benthic vegetation; (3) net pen for feeding and subsequent release in pelagic waters just before surface of Lake Osoyoos reaches about 58 degrees F.
   b. Scoop trap lake outlet to recover samples of CWTs. Sacrifice to assess codes.

3. Smolt rearing.
   a. Using fertilized eggs from adults from B.1., assess survival from egg to smolt in hatchery rearing.
   b. Assess best time/size for smolt release.

4. Best management practice.
   a. Expand successful elements in C.1-3 sufficiently to provide enough adult returns for evaluation.
   b. Monitor production level efforts with smolt output and/or adult return. Smolt evaluation may demand annual trapping with trap efficiency assessment. Hydroacoustic assessment of pre-smolts may prove useful if partial rearing is used rather than smolt release.

APPENDIX E

DESCRIPTION OF HANGING BASKET INCUBATORS

(QUOTE FROM HADDIX 1986)

The "incubation boxes" used were constructed from Washington pond trays which were previously used in FRED hatchery incubation units.

These trays consist of a 15" x 30 1/2" aluminum frame with 1/4" mesh vexar netting. The trays are used as a top and bottom of a sandwich of plastic saddles. The bottom tray was also lined with #12 nylon Screen. The nylon screen prevented alevins from migrating down and out of the "box" after they hatch.

Eggs were placed evenly over the saddle substrate of each layer approximately 3500 eggs per layer.

The individual trays were stacked in a "jig" frame to hold them in place, with a 3" piece of wood 2" x 2" at each corner to act as spacers between each layer. Four trays were placed in each unit and strapped together with plastic banding tape (Figure 1).

The unit with four egg trays was 15 1/2 x 30 1/2 x 15" and held approximately 14,000 eggs. Any number of trays could be stacked in this manner with 5 1/2" added for each tray and spacer. Anything over 10 trays would be difficult to handle.

APPENDIX F

INTERNATIONAL WATER MANAGEMENT IN THE OKANOGAN

1867-1965 as Described by Quinn (1965)

1867 British North American Act-describes the role of the provincial and federal Canadian entities with respect to water management (Quinn 1965).

Irrigated agriculture dominated the economy of the Okanogan Valley as early as the turn of the century

1909 Boundary Waters Treaty Article III provides for an International Joint Commission to review and make decisions about waters crossing the international border (Quinn 1965).

The drought of 1928-1931 prompted an increased interest in irrigation storage in Canada and the US.

1930's Construction of Grand Coulee Dam.

By 1935 snowpack monitoring and annual run off forecasting procedures were established.

1939 Grand Coulee Dam closed.

1939-1943 Sockeye destined for basins upstream from Grand Coulee, Osoyoos and Wenatchee were trapped at Rock Island Dam and transported to Wenatchee and Lake Osoyoos.

Flooding in 1942 and 1948 destroyed many of the orchards and homes in the Okanogan valley and flood control projects became a priority for the region.

Negotiations for hydroelectric development in the upper Columbia River watershed prompted a review of water uses in the Okanogan.

1943 State of Washington requested the IJC review the restrictive effect of Zosel Dam on Lake Osoyoos; this was prompted by a flood of the area.

1944 the International Joint Commission established the International Columbia River Engineering Board to examine water development in the Columbia River basin

1946 International Joint Commission Order (Sept 12,1946) approving the alteration of Zosel Dam and establishing the International Osoyoos Lake Board of Control.

1946 The International Joint Engineering Board proposes a flood control project that requires the channelization and excavation of the Okanogan River channel upstream from Lake Osoyoos.

1948 the U.S. proposed the Shakers Bend project on the Similkameen River.

1949 Agreement that Canadians would only divert freshett flows in the Similkameen for new irrigation.

By 1949 it was clear that additional water development for irrigation would endanger the sockeye production in the Okanogan. The US objected to the proposed Okanogan Flood Control Project (which included channelization of the river in Canada) on the basis of the sockeye spawning habitat. At the time sockeye populations were low, and fisheries concerns, particularly those of the Indian tribes in Canada eliminated the Okanogan from consideration for hydroelectric development.

1951 Canadian rejection of the American suggestion for fish ladders permitting access to Okanogan Lake.

1952 U.S. Public Law 577 authorizes financial assistance from Chief Joseph power revenues to irrigate lands in the Okanogan valley IF there is an agreement with Canada to store Similkameen waters over Canadian lands.

1953 Canada Water Conservation and Assistance Act

1954 The Okanogan Flood Control Project compromised by leaving one of the 23 miles of river planned for channelization in to 17 miles of river for sockeye spawning and the 3 foot drop structures would only be one foot drop structures.

1955 International River Improvements Act requires federal authorization of anything affecting flows on a river crossing the international order.

_____ Prairie Farm Rehabilitation Administration has subsidized with federal dollars flood relief and control activities in the basin.

1958 British Columbia Provincial Water Act.

1959 The Okanogan Basin studies were complete and the effect of the IJC was to prevent additional storage and use of water in Canada.

APPENDIX F (continued)

WATER MANAGEMENT AGREEMENTS OF THE 1980's

1980 The Province of British Columbia and the State of Washington cooperative plan for Osoyoos Lake levels and trans-border flows (Oct 1980). Agreement concerning criteria for operation of a new control structure at Zosel Dam, the lake outlet.

1982 Okanogan Lake and River operation plan (February 1982) updating the July 1976 operating plan.

1982 International Joint Commission Order of approval for the operation and construction of a new Zosel Dam (Dec. 1982).

1985 Supplementary order (Oct 1985) verifying the reconstruction of Zosel Dam and issued raised by Chief Baptist of the Osoyoos Indian Band.

1987 International Joint Commission Order of Approval for the construction of Zosel Dam (April 1987).

1987 The Province of British Columbia and the State of Washington Memorandum of Understanding concerning the operating plan for Zosel Dam, and Lake Osoyoos water levels (Sept 1987)

1988 Memorandum of Understanding between Washington Departments of Ecology, Fisheries and Wildlife and the Colville Indian tribe related to the operation of Zosel Dam (March 1988)

1989 Addendum to the Memorandum of Understanding between Washington Departments of Ecology, Fisheries and Wildlife and the Colville Indian tribe related to the operation of Zosel Dam. Establishes coordination of flows and sockeye smolt emigration (Sept. 20, 1989)

SPRING CHINOOK SPAWNING GROUND SURVEYS

OF

THE METHOW RIVER BASIN, 1991

APPENDIX J

Spring Chinook Spawning Ground Surveys

of the Methow River Basin

1991

by

Thomas Meekin

Yakima Indian Nation
Fisheries Resource Management

November, 1991

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1.0 ACKNOWLEDGEMENTS

Fisheries Technicians Seymour Billy, Vernon Bogar, Sandy Pinkham, and Jason Rau, performed the surveys. Tom Scribner planned the survey program and reviewed the final report. Michael Kohn and David Lind provided the computer graphics. Louiza Umtuch typed the final report.

All names mentioned above are from the Yakima Indian Nation Fisheries Resource Management. Funding for the surveys was provided through the Wells Dam Agreement by the Douglas County Public Utility District.

2.0 ABSTRACT

The purpose of these surveys was to collect comprehensive data regarding timing, location, and magnitude of spring chinook (Oncorhynchus tshawytscha) spawning throughout the Methow River Basin. The baseline data developed from this study will be useful in planning outplanting from the Methow Valley Spring Chinook Hatchery and associated satellite facilities presently under construction.

The surveys covered approximately 127 river miles and located 250 redds. The Methow River had 74 redds (29.6%) and the Chewuch, Lost and Twisp Rivers has 91, 16 and 69 redds (36.4%, 6.4%, and 27.6%), respectively.

Redds were not found in Early Winters, Gold, Lake or Wolf Creeks. Sockeye salmon were not observed during the surveys.

The Wells Dam spring chinook count of 782 fish was the lowest count on record.

3.0 INTRODUCTION

A mitigation/compensation agreement between State and Federal fisheries agencies, Indian tribes and Douglas County Public Utility District was finalized in July, 1990. One of the stipulations of this agreement is for Douglas County P.U.D. to compensate for losses at their Wells Dam Hydroelectric Project with a central fish hatchery and acclimation facilities. Similar to the Eastbank Production Program (Rock Island Settlement Agreement), this compensation will be based on supplementing natural stocks of spring chinook, steelhead and sockeye in the mid-Columbia River tributaries.

The Douglas County P.U.D. contract provides for the collection of comprehensive spawning ground data on spring chinook in all spawning habitat within the Methow River Basin. Data from these surveys, in conjunction with the Wells Dam counts, will assist fisheries agencies, tribes and Douglas County P.U.D. to assess the status of spring chinook populations within the basin. The information may also be useful in developing an outplanting strategy for the Methow Valley Spring Chinook Hatchery and associated satellite facilities scheduled to be in operation during 1992. The Methow Valley Hatchery's production plan and enhancement program is intended to complement the Northwest Power Planning

Council's system planning process for the Columbia River Basin.

Spawning runs to the Methow River have been impacted by fishing and hydroelectric development (see Bryant and Parkhurst, 1950 and Mullan, 1987). In 1915, Washington Water Power Co. constructed an impassable hydroelectric dam at Pateros near the mouth of the Methow River. Records from 1928 and 1929 indicate that some chinook were netted below the dam and released above it, but by the time the dam was removed in 1930, the Methow River chinook run had been nearly exterminated.

In 1935, the Methow River and its tributaries were estimated to have a run of 200 to 400 spring chinook. The run was placed in jeopardy once again during the Grand Coulee Fish Maintenance Project (1939-43) when all adult salmon were captured downstream from the Methow River at Rock Island Dam.

The first extensive spring chinook spawning ground surveys of the Methow River Basin were conducted from 1954-1960 (French and Wahle, 1965). The Chewuch and upper Methow rivers were found to be the most important spring chinook spawning areas with the peak of spawning occurring in late August.

Beginning in 1961 the Washington Department of Fisheries (WDF) established index areas on the Methow River and tributaries and continued the spring chinook

surveys through 1987 (Meekin, 1963).

The Douglas County Public Utility District assumed responsibility for funding the surveys, beginning in 1988, and since that time the surveys have been conducted by the Yakima Indian Nation.

Hatchery production of chinook salmon for release into the Methow River commenced at the Winthrop National Fish Hatchery in 1943. Spring chinook, coho, and sockeye salmon smolts were released through 1962. From 1963 through 1975 salmon were not reared at the hatchery. Commencing in 1976, spring chinook salmon became the prime focus of the hatchery. Since 1976, spring chinook brood stock from either the Methow River, Icicle Creek, White Salmon, Wind and Carson rivers have been reared and released from the hatchery. Numbers released have ranged from 270,000 in 1976 to 1,200,000 in 1985.[1] Releases averaged approximately one million per year and were usually released in mid-April at an average weight ranging from 12 to 15 fish per pound.

From 1977 through 1979 and again in 1983 summer chinook were reared and released from the hatchery. Releases ranged from 250,000 to 600,000 smolts.

The current Winthrop Hatchery production program is to produce one million spring chinook smolts annually.

---

[1]Hatchery data is personal communication from W. Wallein, Winthrop Hatchery Manager.

4.0 DESCRIPTION OF STUDY AREA

The Methow River Basin is located in north-central Washington on the eastern slope of the Cascade Mountains (Fig.1). The river and its tributaries lie in Okanogan County and drain an area of nearly 1800 square miles. The headwaters of the Methow River are located near the Cascade Crest at an elevation of more than 6000 feet. At the city of Winthrop where the Chewuch River joins the Methow River, the river elevation is 1745 feet. The river elevation drops to 779 feet where the Methow and Columbia Rivers meet at Pateros.

The upper portion of the Methow Basin is heavily forested, predominantly with ponderosa pine. This area is used extensively for recreation and is experiencing significant growth in residential and commercial development. The Washington Department of Ecology has even proposed limitations on development in the upper Methow Basin because of inadequate water supplies (Perrow, 1990).

The lower Methow Valley is a fertile agricultural area. The fruits and crops which are grown here place heavy irrigation demands on the Methow River and its tributaries. Water quality in the lower Methow Basin nonetheless remains high; the Department of Ecology gives the lower Methow River a AA rating.

Private developers have proposed a major

winter/summer recreationl development in the upper valley. Impacts on anadromous fish are potentially high with limited water resources in the basin. Several reaches of the Methow mainstem and areas of its tributaries presently dewater during the low flow seasons.

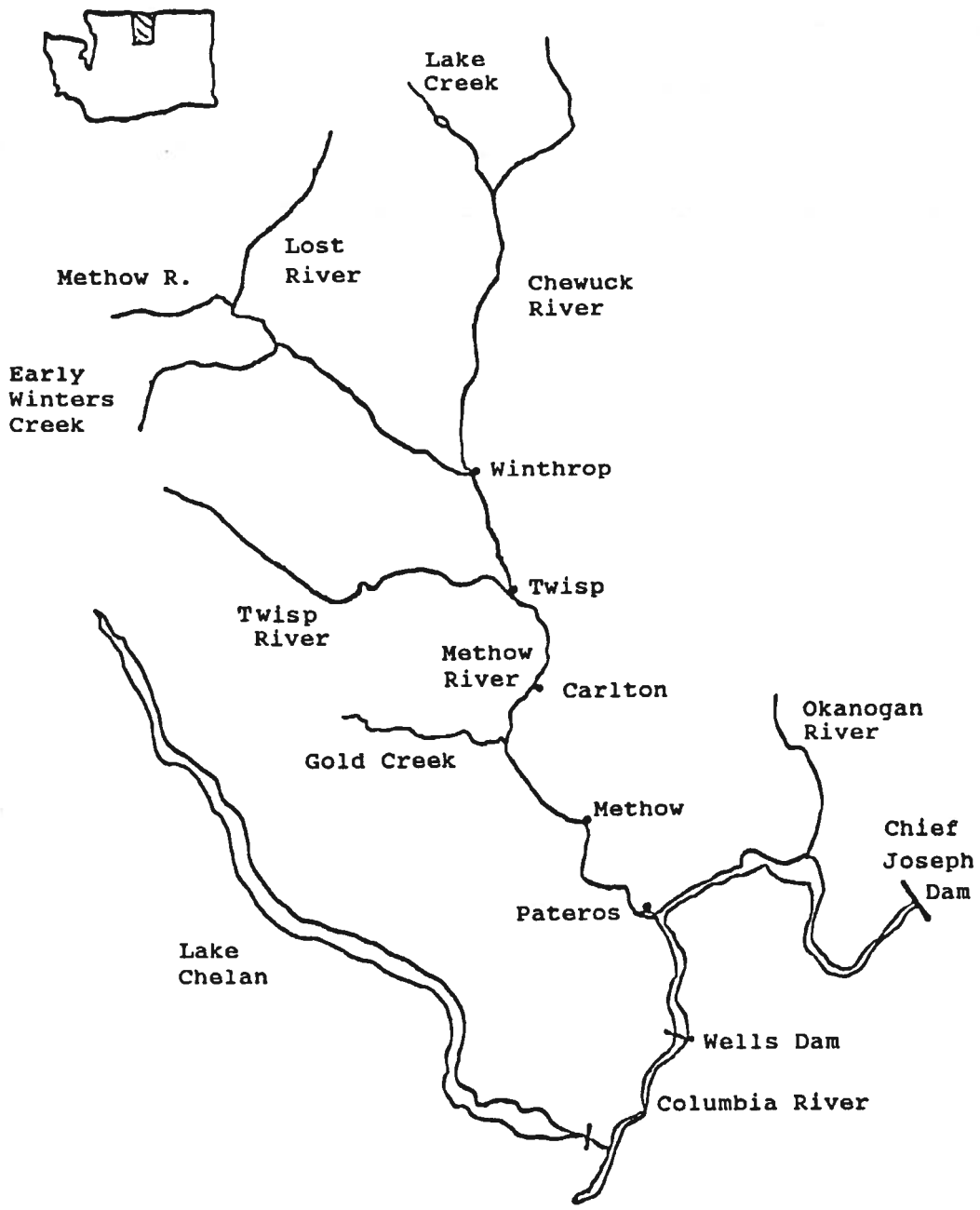

Figure 1. Methow River Basin location map.

5.0 OBJECTIVES OF THE SPRING CHINOOK SURVEYS

The objectives of the spring chinook spawning ground surveys were to determine the timing, location and magnitude of spawning in the Methow River system.

Prior to 1987 spring chinook spawning ground surveys were conducted annually by the WDF, as previously mentioned, and usually consisted of a single count of established index areas (Figure 2). These counts were usually made during or immediately after the peak of spawning in late August or early September.

These surveys, in conjunction with the Wells Dam counts, provided information on spawning trends but did not provide data regarding any changes of timing, location or overall magnitude of spawning. Therefore, it became necessary to initiate the surveys earlier, by late July, in order to obtain time of spawning. In addition, to determine location, as in 1988-1990, the expanded surveys were continued to check all areas of the Methow Basin system where spring chinook spawning might occur.

For purposes of continuity and comparison separate redd counts in the WDF index areas were continued during the 1991 surveys, (Figure 2, Table 1).

Additional objectives were to examine carcasses to determine success of spawning and collect length and scale samples to determine the age of the spawning population.

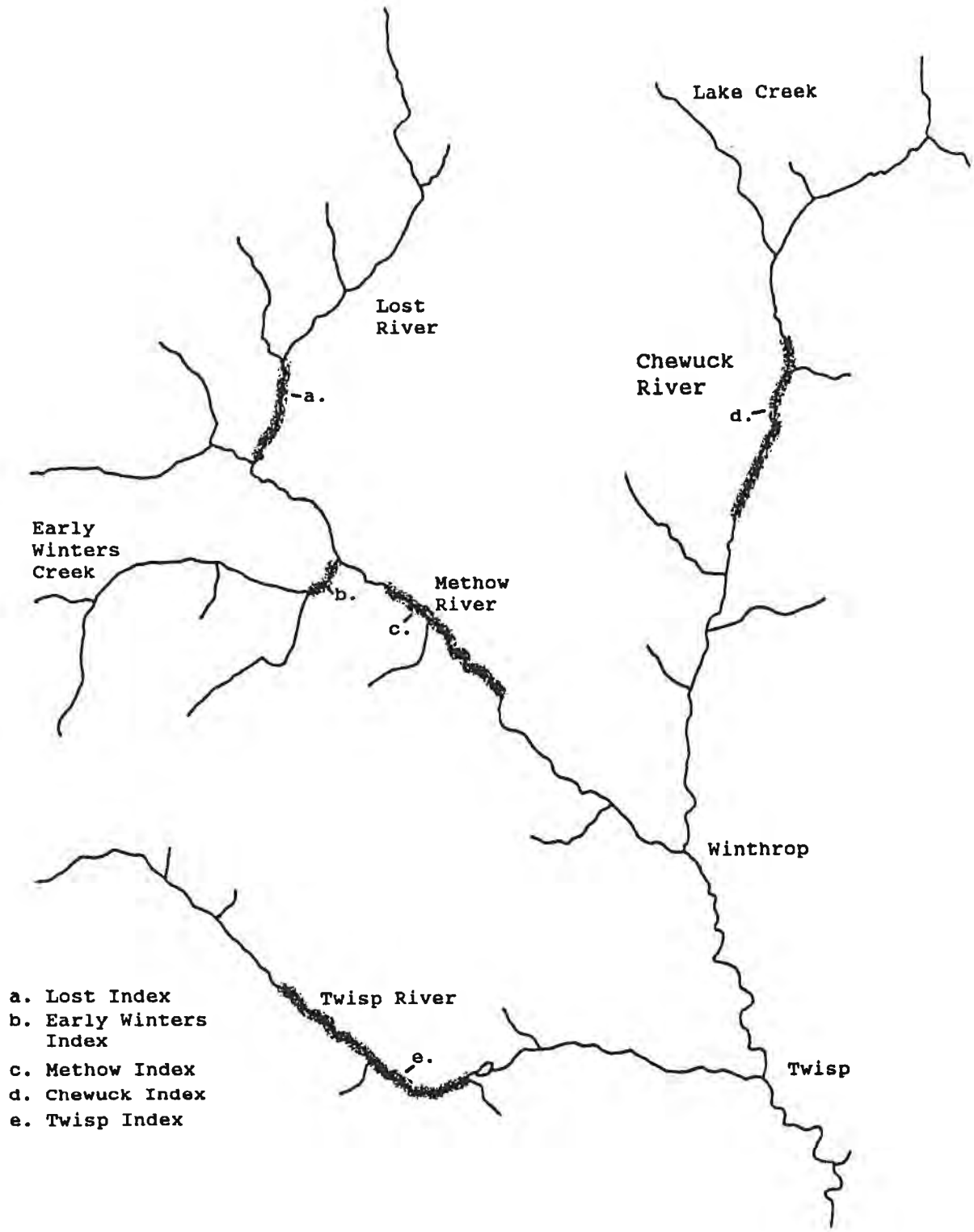

Figure 2. Upper Methow River Basin. Shaded sections indicate spring chinook spawning index reaches.

Table 1. Historical spring chinook index redd counts for the Methow River Basin, 1962-1990.

Spawning Year	Methow River	Chewuch River		Lost River		Twisp River	Early Winters Creek
	Mazama Br. to Weeman Br.	Camp Four to Chewuch C.G.	Chewuch C.G. to Falls Cr. C.G.	Eureka Cr. to Lost R. Br.	Lost R. Cr. to Mouth	Mystery Br. to Buttermilk Br.	Diversion Dam to Mouth
1962	187	9	49	104	N.S.	203	N.S.
1963	110	N.S.	78	35	N.S.	132	N.S.
1964	127	N.S.	176	98	N.S.	311	N.S.
1965	111	N.S.	34	86		138	N.S.
1966	233	N.S.	91	271		257	N.S.
1967	140	N.S.	N.S.	80	22	135	N.S.
1968	92	30	N.S.	35	2	190	1
1969	57	17	32	49	11	123	3
1970	150	14	32	101	N.S.	75	1
1971	113	10	23	61	9	97	6
1972	65	97		58	11	97	N.S.
1973	95	47	42	65	5	247	1
1974	49	22	30	11	N.S.	129	3
1975	39	N.S.	98	59	N.S.	177	2
1976	34	N.S.	22	12	N.S.	53	N.S.
1977	65	N.S.	107	14		174	0
1978	67	87	59	50	N.S.	265	4
1979	12	18	13	23	3	40	0
1980	25	8	14	13	4	27	0
1981	39	1	6	20	5	24	2
1982	56	2	8	29	4	17	0
1983	63	6	29	18	4	58	1
1984	43	24	15	54	6	48	3
1985	23	93	34	5		95	6
1986	63	34		48	N.S.	38	3
1987	75	23	54	52	4	79	1
1988	75	40	15	53	0	111	0
1989	60	12	32	53	4	100	6
1990	80	61		33		77	1

6.0 METHODS

The Methow River and tributaries were divided into sections to define spawning locations. The tributaries and upper Methow River to the Mazama Bridge were surveyed on foot. The Methow River from the Mazama Bridge to Carlton was rafted.

Surveys of known spawning areas in each tributary were usually conducted weekly as time permitted. As in 1988-1990 the surveys were expanded to cover all accessible reaches of the Methow River and its tributaries. The expanded survey areas, usually in the upper reaches, contained minimal spawning habitat and were not surveyed on a weekly basis. However, they were surveyed several times, with the final survey conducted after peak spawning had occurred. As spawning progressed in the upper reaches and fewer redds were observed the surveys concentrated on the lower reaches.

To avoid recounting any spring chinook redds they were flagged on the bank with surveyors tape, dated and numbered. The approximate location of the redd was also noted on the tape. The flag color was changed each week.

The live chinook were also counted. Live fish were only counted once. If fish were observed on a flagged redd during subsequent weekly surveys, they were not recounted.

Carcasses were recovered and checked for tags, fin clips, sex and spawning success. Scales and hypural lengths were collected for age analysis.

Water temperatures were taken at the beginning and end of each survey.

The Wells Dam spring chinook counts and the number of fish returning to the hatchery were utilized to determine the size of the run and the total number of fish available for spawning in the system.

7.0 RESULTS

The spawning ground surveys commenced with spot checks of known spawning areas on July 18 and continued through September 25. A total of 127 river miles was surveyed frequently, many sections were surveyed at least once a week (Tables 2-8). Spawning usually occurred first in the upper reaches of the system.

7.1. Timing, Location and Magnitude of Spawning.

7.1.1. Methow River

The first redds were counted on August 19 (Table 2). Heaviest concentration of spawning, 31 redds (41.9%), was in the index area, Section 5. Most spawning occurred from the Lost River confluence downstream to Wolf Creek. Only 9 redds were found from Wolf Creek downstream to the Carlton Bridge.

Spawning peaked during early September with 43 redds counted during this period (Table 2.). Spawning did not occur in Sections 1, 3, 7 and 11. Section 1 contained minimal spawning habitat and water flow was minimal by mid-August.

The total Methow River redd count was 74.

7.1.2. Chewuch River

Spawning was first observed on August 5 in the upper river in Section 6 near Buck Creek (Table 3.). Spawning next occurred on August 15 in Section 2 in the Dibble Springs area. Spawning peaked in the upper

Table 2. Date and number of spring chinook surveys, timing of spawning, location, number and percentage of redds by river section, total redds, and water temperature range of the Methow River, 1991.

SECTION	ROAD MILES	JULY 20	JULY 29	AUGUST 6	AUGUST 12-13	AUGUST 19-20	AUGUST 26-27	SEPTEMBER 3 & 5	SEPTEMBER 9-10	SEPTEMBER 16-18	SEPTEMBER 23-25	TOTALS Number	TOTALS Percent
1.W.Fork Ballard C.G. to Lost R. Confl.	2.2	*sc 0	0		0							0	—
2.Lost River Confl. to Gate Creek	2.5		0		0	4	2	9	0			15	20.2
3.Gate Creek to Early Winters Cr.	1.3		0	0	0	0	0	0	0			0	—
4.Early Winters Cr. to Mazama Bridge	1.9	*sc 0	0	0	0	0	1	2	0			3	4.1
5.Mazama Bridge to Weeman Bridge	5.2	*sc 0		0	0	1	9	3	16	2	0	31	41.9
6.Weeman Bridge to Hiway 20 along riv.	5.3			0	0	2	7	7	0		0	16	21.6
7.Hiway 20 along riv. to Wolf Creek	1.1			0	0	0	0	0	0			0	
8.Wolf Creek to Diversion Dam	1.5			0	0	0	0		2	0		2	2.7
9.Diversion Dam to Winthrop Bridge	1.3			0	0	0	0		3	0		3	4.1
10.Winthrop Bridge to Diversion Dam	5.0								1	0	2	3	4.1
11.Diversion Dam to Twisp Bridge	4.1								0	0	0	0	
12.Twisp Bridge to Carlton Bridge	10.5									1	0	1	1.3
Totals	41.9	0	0	0	0	7	19	21	22	3	2	74	100
Temperature Range (F)		46-54	48-52	51-57	47-50	51-61	47-52	49-57	48-61	55-60	51-59		

*sc spot check

Table 3. Date and number of spring chinook surveys, timing of spawning, location, number and percentage of redds by river section, total redds, and water temperature range of the Chewuch River, 1991.

SECTION	ROAD MILES	JULY 19	JULY 23	JULY 30	AUGUST 1	AUGUST 5	AUGUST 8	AUGUST 12	AUGUST 13	AUGUST 15	AUGUST 19-20	AUGUST 22	AUGUST 27	AUGUST 29	SEPTEMBER 3-4-5	SEPTEMBER 10-12	SEPTEMBER 17-19	SEPTEMBER 24-25	TOTALS Number	TOTALS Percent
1.Falls to Thirty Mile Bridge	3.4 (est.)			0								0							0	--
2.Thirty Mile Bridge To Roadside Camp	2.5	sc \1 0	0	\1 0	\1 0	\1 0	\1 0	\1 0	\1 0	\1 1	\1 3	\1 1	\1 1	0			\1 0	\1 0	6	6.6
3.Roadside Camp to Andrews Creek	3.4		0											0					0	--
4.Andrews Creek to Lake Cr. C.G.	2.4		0												0				0	--
5.Lake Cr. C.G. to Buck Cr.	2.0	*sc 0	0	0	0	0	0			0	0		0						0	--
6.Buck Creek to Camp 4	1.2	*sc 0	0	0	0	1	1			0	2		7		0		0	0	11	12.1
7.Camp 4 to Roadside Camp	1.2		0	0	0	0	0			0	0		3		0				3	3.3
8.Roadside Camp to Chewuch C.G.	1.6	*sc 0	0	0	0	0	0			0	0		0		7	4	0		11	12.1
9.Chewuch C.G. to Mile 6	1.9	*sc 0	0	0	0	0	0			0	0		6		2	5	0	0	13	14.3
10.Mile 6 to Falls Cr. C.G.	1.4	*sc 0	0	0	0	0	0			0	0		0		2	1	0		3	3.3
11.Falls Creek C.G. to Eight Mile Ranch	2.9			0	0	0	0			0	0		0		5	0			5	5.4
12.Eight Mile Ranch to Memorial Br. Piers	1.5			0	0	0					1		0		8	2	0		11	12.1
13.Memorial Br. Piers to Chewuch River Road Bridge	0.9	*sc 0		0	0	0					0		0		0	0	0		0	--
14.River Road Bridge to 1/2 Way Point	3.3			0	0							5		1	2	7	0	0	15	16.5
15.1/2 Way Point to Mouth	3.4			0	0					0		0		0		13	0		13	14.3
Totals	33.0	0	0	0	0	1	1	0	0	1	6	6	17	1	26	32	0	0	91	100
Temperature Range (F)		50-61	52-59	48-60		53-64		51 - 59			54-64		48-55		51-61	48-58	48-61	48-55		

*sc spot check
\1 Dibble Springs Area only

Table 4. Date and number of spring chinook surveys, timing of spawning, location, number and percentage of redds by river section, total redds, and water temperature range of the Lost River, 1991.

SECTION	MILES (EST)	JULY 20	JULY 29	AUGUST 12	AUGUST 19	AUGUST 26	SEPTEMBER 3	SEPTEMBER 9	TOTALS Number	TOTALS Percent
1.Sunset Cr. to Eureka Cr.	2.0					0			0	0
2.Eureka Cr. to Bridge	4.0		0	0	4	12	0		16	100
3.Bridge to Methow River	0.5	0	0	0	0	0	0	0	0	0
Totals	6.5	0	0	0	4	12	0	0	16	100
Temperature Range (F)		47	48-52	48-52	50-57	47-52	48-53	48		

Table 5. Date and number of spring chinook surveys, timing of spawning, location, number and percentage of redds by river section, total redds, and water temperature range of the Twisp River, 1991.

SECTION	ROAD MILES	JULY 18	JULY 24	JULY 31	AUGUST 7	AUGUST 14	AUGUST 21	AUGUST 28	SEPTEMBER 4	SEPTEMBER 10-11	SEPTEMBER 25	TOTALS Number	TOTALS Percent
1.Road End C.G. up for 2 miles	2.0 (est.)	*sc 0						0				0	---
2.Road End C.G. to South Cr. Bridge	3.1		0					0				0	---
3.South Creek Br. to Poplar Flats C.G.	2.0		0	0	1	2	1	0	0			4	5.8
4.Poplar Flats C.G. to Mystery Br.	2.0	*sc 0		0	0	5	3	0	0			8	11.6
5.Mystery Br. To War Creek	4.4			0	0	10	8	5	0			23	33.3
6.War Cr. Br. to Cabin on Left Bank RD.	2.2			0	0	1	0	1	3	1	0	6	8.7
7.Cabin to Buttermilk Br.	2.5			0	0	0	3	0	8	0	0	11	15.9
8.Buttermilk Br. to Br. with Gate	0.7			0	0	1	2	1	3	0		7	10.2
9.Br. with Gate to Little Br. Cr.	2.0			0	0	0	2	4	4	0		10	14.5
10.Little Br. Cr. to Newby Br.	1.3			0				0		0		0	---
11.Newby Br. to Fish Screens Br.	1.2			0						0		0	---
12.Fish Screens Br. to Wooden Br.	1.0				0					0		0	---
13.Wooden Br. to Poor Man Br.	1.3									0		0	---
14.Poor Man Br. to Twisp River Rd.Br.	2.4									0		0	---
15.Twisp River Rd. Br. to Mouth	1.2									0		0	---
Totals	29.3	0	0	0	1	19	19	11	18	1	0	69	100
Temperature Range (F)		45-46	45-57	47-58	46-57	46-57	49-62	47-54	46-54	46-57	48-51		

*sc spot check

Table 6. Date and number of spring chinook surveys and water temperatures of Early Winters Creek, 1991.

SECTION	ROAD MILES	JULY 20	JULY 29	AUGUST 1	AUGUST 5	AUGUST 12	AUGUST 20	AUGUST 26	SEPTEMBER 3	SEPTEMBER 9	SEPTEMBER 16	TOTALS Number	TOTALS Percent
1.Klipchuck C.G. to Early Winter Br.	0.9		0								0	0	--
2.Early Winter Br. (C.G. Rd.) to Highway 20 Br.	1.3		0								0	0	--
3.Highway Br. to Diversion Dam (EWDD)	1.5		0				0				0	0	--
4.Diversion Dam to Highway 20 Br.	0.2	*sc 0	0	0	0	0	0	0	0	0	0	0	--
5.Highway Bridge to Mouth	0.5	*sc 0	0	0	0	0	0		0	0	0	0	--
Totals	4.4	0	0	0	0	0	0	0	0	0	0	0	--
Temperature Range (F)			48-49	--	53-55	52	55-60	50-52	51	52-54	51-54		

*sc spot check

Table 7. Date and number of spring chinook surveys and water temperature range of Gold Creek, 1991.

SECTION	ROAD MILES	JULY 21	AUGUST 1	SEPT. 11	TOTALS Number	Percent
1.Foggy Dew C.G. to North Fork Bridge	2.4	0	0	0	0	—
2.North Fork Bridge to South Fork Road Br.	1.8	0	0	0	0	—
3.So. Fork Rd. Bridge to Gold Cr. Rd. Br.	1.1	0		0	0	—
4.Gold Cr. Rd. Bridge to Mouth	0.1	0	0	0	0	—
Totals	5.4	0	0	0	0	—
Temperature Range (F)		52-55	53-61	55-57		

Table 8. Date and number of spring chinook surveys and water temperature range of Lake Creek, 1991.

SECTION	ROAD MILES	JULY 19	JULY 30	AUGUST 22	SEPT. 16	TOTALS Number	Percent
1.Lake to Halfway Point	1.5			0		0	—
2.Halfway Point to Parking Lot	1.5			0		0	—
3.Parking Lot to Mouth	2.2	*sc 0	0		0	0	—
Totals	5.2	0	0	0	0	0	—
Temperature Range (F)		55	55-57	55-57	52-55		

*sc spot check

Table 9. Date and number of spring chinook surveys and water temperature range of Wolf Creek, 1991.

SECTION	ROAD MILES	JULY 21	JULY 5	AUGUST 13	SEPT. 4	TOTALS Number	Percent
1.Diversion Dam to First Bridge	0.2			0	0	0	—
2.Bridge to Mouth	1.0	0	0	0	0	0	—
Totals	1.2	0	0	0	0	0	—
Temperature Range (F)		52	58	57	58-63		

river upstream from Falls Creek on August 27. The first spawning in the lower river occurred on August 20 in Section 8, downstream from 8 Mile Ranch. Redd counts in the lower river peaked during the period September 3-12. No redds were observed after September 12.

Section 1, 3, 4, 5 and 13 contain only minimal spawning habitat and redd construction was not observed in these sections. In Section 2 there is only a 0.6 mile area, Dibble Springs, that has suitable spawning area and all 6 redds found in this section were in this area. The redds were scattered throughout the remainder of the river sections with most spawning, 44 redds (48.3%), found below the index area, 30 redds (33.0%) counted in the index area. More redds were also found below the index area from 1988 to 1990 (Kohn, 1988; 1989; and Edson, 1990).

The Chewuch River redd count totaled 91.

7.1.3. Lost River

The initial redds were counted on August 19 (Table 4). Spawning peaked on August 26 with a count of 12 redds. Additional redds were not observed after this date and the final survey was made on September 9.

The total redd count was 16.

7.1.4. Twisp River

Surveys began on July 24 with the

first redd observed on August 7 in the upper river in Section 3 (Table 5). The final redd was counted in Section 6 on September 11. Spawning occurred from Section 3, South Creek Bridge, downstream to Section 9, Little Bridge Creek. Spawning habitat in the remaining sections of the river, 1, 2 and 10 through 15, is limited and no redds were observed. Most redds, 40 (58%) were located in the index area, Mystery Bridge to Buttermilk Bridge.

A total of 69 redds was counted.

7.1.5. Other Tributaries

Redds were not found in Early Winters, Gold, Lake or Wolf Creeks. Tables 6-9 show the survey dates.

7.1.6. Water temperature ranges for all areas surveyed are given in Tables 2-9.

7.2. Live Fish Counts

Live fish counts are depicted in Table 10. A total of 143 or 20.7% of the 690 fish calculated to be spawning in the Methow system was counted.

Sockeye salmon were not found in the Methow Basin system.

7.3. Carcasses Recovered

A total of 57 carcasses, 21 males and 36 females, was recovered (Table 10). Thirty-two of the females (90%) examined were completely spent, two females or (5%)

Table 10. Number of live spring chinook counted and carcasses examined during the surveys, by week, 1991.

Week	Methow River			Chewuch River			Lost River			Twisp River\1			Totals		
	Live	Carcasses		Live	Carcasses		Live	Carcasses		Live	Carcasses		Live	Carcasses	
		M	F		M	F		M	F		M	F		M	F
July 21-27										1\2	0	0	1	0	0
July 28-Aug. 3													—	—	—
Aug. 4-10				3	0	0				1\2	0	0	4	0	0
Aug. 11-17	1	0	0	2	0	0				11	0	0	14	0	0
Aug. 18-24	6	0	0	15	0	1\3	3	0	0	13	0	1	37	0	2
Aug. 25-31	20	1	3\4	8	1	2	10	1	0	6	1	4	44	4	9
Sept. 1-7	6	1	3	17	2	2	0	1	1	5	2	5	28	6	11
Sept. 8-14	3	3	7\5	12	4	2							15	7	9
Sept. 15-21	0	1\6	0	0	2	5							0	3	5
Sept. 22-28	0\7	0	0	0	0	0				0	1	0	0	1	0
Totals	36	6	13	57	9	12	13	2	1	37	4	10	143	21	36

\1 Two unidentified carcass remains not included.
\2 Not spawning, observed in pools.
\3 Unspawned.
\4 One female was unspawned.
\5 Two females retained 10% (est.) of their eggs.
\6 No data collected on carcasses.
\7 20 live fish (summer chinook) observed in pools between Twisp and Carlton.

Note: Live fish and carcasses were not observed in Early Winters, Gold, Lake, and Wolf Creeks.

were 90% spent and 2 (5%) were unspawned. During 1988-1990 the percentages of spent females were 90%, 88% and 95%, respectively (Kohn, 1988; 1989; and Edson 1990). The male to female ratio for the carcass sample was 0.5 to 1. Data from 1988-1990 show male to female ratios of 0.5 to 1, 0.52 to 1, and 0.63 to 1, respectively.

No tags or fin clips were found. Lengths of male and female carcasses are shown in Figures 3 and 4.

7.4 Fish Per Redd

Surveys of the entire spring chinook spawning area in the Methow Basin and the known number of estimated fish available for spawning permits the calculation of a fish per redd factor. Dividing the 250 redds counted into the spawning population of 690 fish (Table 11) indicates a fish per redd factor of 2.8. Data for 1988-1990 of 746, 520 and 502 redds and spawning populations of 1,613, 1,525 and 818 fish (Table 11) show fish-per-redd factors of 2.2, 2.9 and 1.6, respectively. The low 1990 ratio may be attributed to a delayed spring chinook migration at Wells Dam where late-arriving spring chinook were counted as summer chinook.

7.5 Redd Count Summary

Table 12 shows that 117 or 46.8% of the redds were located within the index areas, while 47 or 18.8% were above and 86 or 34.4% were below the index areas.

Data for 1988-1990 shows 40.1%, 50.7% and 50.5%

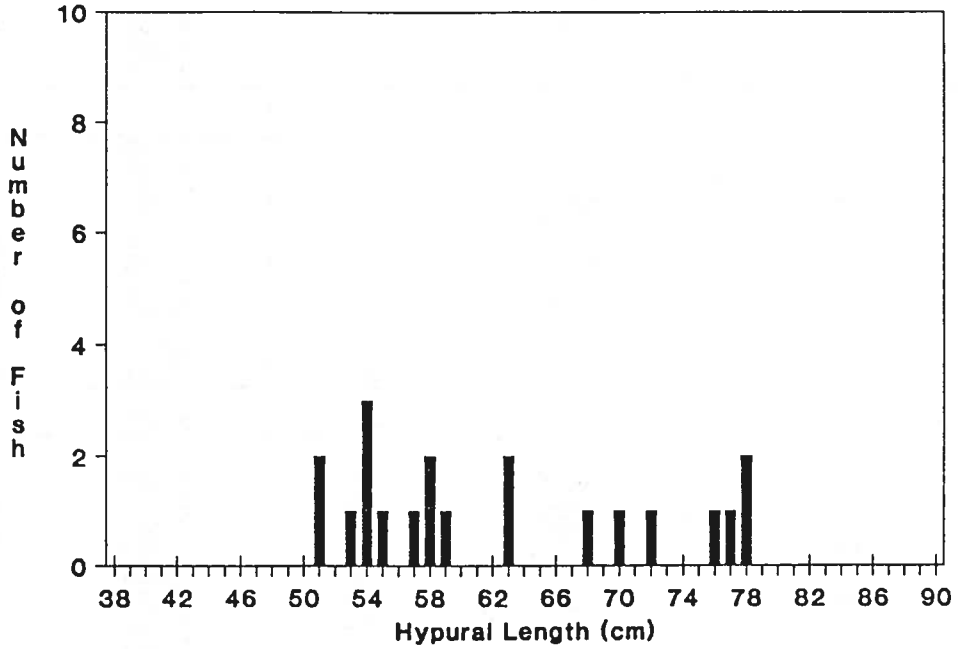

Figure 3. Length frequencies of spring chinook males in the Methow River Basin.

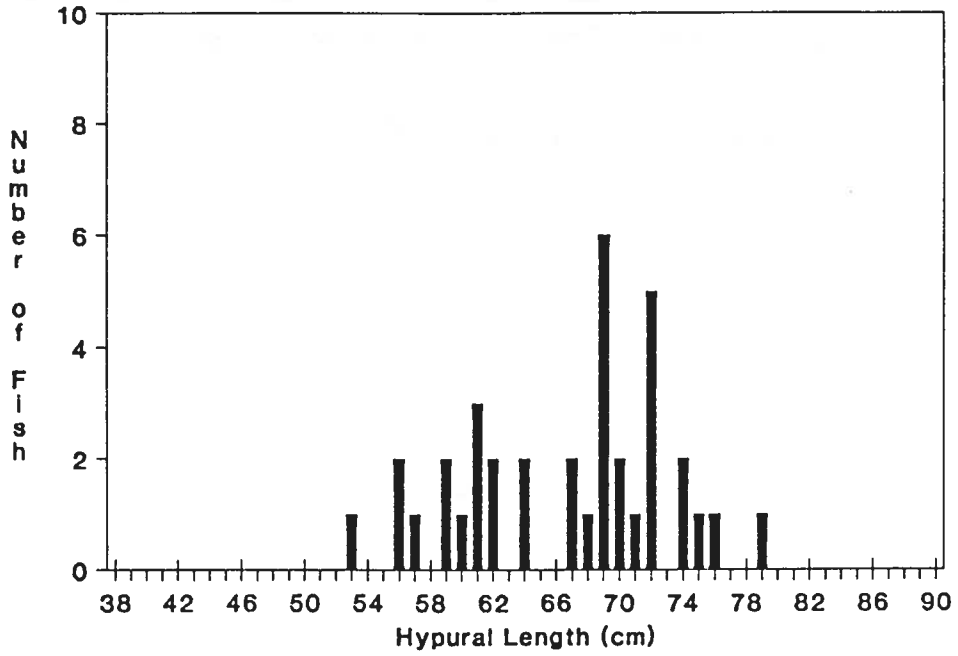

Figure 4. Length frequency of spring chinook females in the Methow River Basin.

Table 11. Spring Chinook counts at Wells Dam, number of fish returning to the Winthrop Hatchery, and number of fish available for spawning in the Methow Basin, 1967-1991.

Year	Adults	Jacks	Total	Winthrop \1 Hatchery	Methow System Spawners
1967	541	616	1,157		1,157
1968	4,086	845	4,931		4,931
1969	3,048	551	3,599		3,599
1970	2,092	578	2,670		2,670
—	—	—	—		
1971	2,535	633	3,168		3,168
1972	3,368	248	3,616		3,616
1973	2,505	507	3,012		3,012
1974	3,199	221	3,420		3,420
1975	2,096	129	2,225		2,225
1976	1,510	1,249	2,759		2,759
1977	3,976	235	4,211		4,211
1978	3,532	83	3,615	38	3,577
1979	971	132	1,103	102	1,001
1980	941	241	1,182	155	1,027
1971-1980 (Avg) \2			2,831	—	2,801
1981	1,367	98	1,465	399	1,066
1982	2,270	131	4,252	601	3,651
1983	2,726	143	2,869	755	2,114
1984	3,066	214	3,280	510	2,770
1985	5,151	116	5,267	1,201	4,066
1986	2,896	65	2,961	836	2,125
1987	2,272	74	2,346	594	1,752
1988	2,844	96	2,940	1,327	1,613
1989	1,633	87	1,720	195	1,525
1990	927	12	939	121	818
1981-1990 (Avg) \2			2,804	654	2,150
1991 \3	682	100	782	92	690

\1 Personal communication from W. Wallein, Winthrop Hatchery Manager.

\2 Not a moving average.

\3 Data from Fish Passage Center, Bi-weekly Report #91-19.

Table 12. Spring Chinook redd count summary, numbers and percentages for the Methow River Basin, 1991. (Redd counts are divided into three sections: above, below, and within the index areas).

River	Index	Above Redds (%)	Index Redds (%)	Below Redds (%)	Total Redds (%)
Methow River	Mazama Br. - Weeman Br.	18 (24.3)	31 (41.9)	25 (33.8)	74 (29.6)
Chewuck River	Camp 4 C.G. - Falls Cr. C.G.	17 (18.7)	30 (33.0)	44 (48.3)	91 (36.4)
Lost River	Eureka Cr. - Mouth	0 (0.0)	16 (100.0)	N/A	16 (6.4)
Twisp River	Mystery Br. - Buttermilk Br.	12 (17.4)	40 (58.0)	17 (24.6)	69 (27.6)
Early Winters Creek	Upper Fish Screen - Mouth	0 (0.0)	0 (0.0)	N/A	0 (0.0)
Basin Total		47 (18.8)	117 (46.8)	86 (34.4)	250 (100)

within the index areas, 22.6%, 13.3% and 14.6% above and 37.3%, 36.0% and 34.9% below, respectively. There has not been a significant overall shift in spawning location.

Table 13 summarizes the total number of redds and percentages found in the Methow River and tributaries since the expanded surveys were initiated in 1988. The percent of the total redds in the tributaries varies from year to year, but sufficient data is not yet available to determine any significant numerical changes in the four primary spawning areas.

7.6 Spring Chinook Run Size

The 1991 Wells Dam spring chinook count of 782 fish was the lowest since counting started in 1967 (Table 11). Assuming the fish are primarily four-year fish, based on the length data, the run was only 33.5% of the 1987 parent-year run of 2,346 and 28% of the 10-year average run size of 2,804 fish. The spring chinook redd counts also indicted a much-reduced escapement to the Methow River Basin.

Table 13. Number and percent of redds found in the Methow River and tributaries, based on expanded surveys, 1988-1991.

Year	Methow River Redds	Methow River Percent	Chewuch River Redds	Chewuch River Percent	Lost River Redds	Lost River Percent	Twisp River Redds	Twisp River Percent	Early Winter Cr. Redds	Early Winter Cr. Percent	Gold Cr. Redds	Gold Cr. Percent	Lake Cr. Redds	Lake Cr. Percent	Wolf Cr. Redds	Wolf Cr. Percent	Totals Redds	Totals Percent
1988	262	35.1	202	27.1	53	7.1	199	26.7	17	2.3	4	0.5	9	1.2	0	—	746	100
1989	110	21.2	160	30.8	57	11.0	179	34.4	11	2.0	3	0.6	0	—	0	—	520	100
1990	194	38.6	158	31.5	33	6.6	113	22.5	1	0.2	3	0.6	0	—	0	—	502	100
1991	74	29.6	91	36.4	16	6.4	69	27.6	0	—	0	—	0	—	0	—	250	100

8.0 SUMMARY

1. Spring chinook surveys in the Methow River Basin were conducted from July 18 through September 25, 1991 and covered approximately 127 miles.

2. The initial redd was observed in the Twisp River on August 7 and the final one in the lower Methow River on September 23.

3. A total of 250 redds was located with 74 (29.6%) in the Methow River and 91 (36.4%), 16 (6.4%) and 69 (27.6%) found in the Chewuch, Lost and Twisp Rivers, respectively. Redds were not observed in Early Winters, Gold, Lake or Wolf Creeks. The redd count indicated a reduced spring chinook escapement to the Methow Basin.

4. There were no significant changes in spawning location.

5. A total of 143 live fish was counted and 57 carcasses were examined. No sockeye salmon were observed.

6. The male to female ratio was 0.5 to 1, and 90% of the female carcasses were spawned out.

7. The fish per redd factor was calculated to be 2.8.

8. The Wells Dam count of 782 spring chinook was the lowest count on record.

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NOTES

FROM THE

WELLS COORDINATING COMMITTEE

FOR 1991

APPENDIX K

WELLS PROJECT COORDINATING COMMITTEE
MEETING MARCH 1, 1991
SUMMARY[1]

Introduction

The committee learned only recently (letter of February 19, 1991 from Dan Diggs) that the scheduled release date for chinook at the Winthrop and Entiat Hatcheries of the U.S. Fish and Wildlife Service will be April 4, 1991, which is two weeks earlier than in previous years. Rick Klinge became concerned about the short time available to organize a plan for operations during the 1991 outmigration period. There were two items of critical importance, appointment of the bypass team as called for in the settlement agreement, and review of the study plan for evaluation of the bypass in 1991. He asked me to arrange a meeting of the Wells Project Coordinating Committee. In the process of consulting with the members of the committee on a schedule for such a meeting, the idea emerged that the two items could be dealt with most efficiently by telephone, thereby avoiding the need for an in-person meeting. Accordingly, a telephone conference call was arranged at 8:15 A.M. March 1, 1991. Those participating were Rick Klinge, amd Jim McGee, Douglas County P.U.D.; Rod Woodin, Washington Department of Fisheries; Bill Hevlin, National Marine Fisheries Service; Bob Heinith, Columbia River Intertribal Fisheries Commission; Gerry Marco, Colville Confederated Tribes, and Richard Whitney.

Agreements Reached

1. Bypass Team. The representatives appointed to the bypass team are as follows:

   Rick Klinge, Douglas County P.U.D.
   Gerry Marco, Tribes
   Cindy Wilson, Agencies (Alternate Rod Woodin)

2. Bypass Evaluation Study Plan. Klinge reported that John Skalski had recommended modification of the study plan for bypass evaluation that was used last year. The committee agreed to appoint a working group to develop an agreed upon study plan to be recommended to the committee as soon as possible. The committee appointed the following members of the working group: Dr. John Skalski, Ben Sandford (NMFS), John Williams (NMFS), and Phil Mundy (Col. River Intertribal Fish Comm.). Klinge will ask Skalski to put his proposal in writing as soon as possible for the others to review, and then arrange a meeting or consultation to develop the agreed upon plan and report back to the committee.

3. Monitoring of Fish Runs. The Settlement Agreement calls for monitoring to begin two weeks prior to the preseason forecasted beginning of juvenile migration. Klinge reported that the early releases from Winthrop Hatchery will create some problems in meeting this schedule. Biosonics will do their best. However, the installation of transducers for monitoring must be coordinated with installation of the

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1. Prepared by R. Whitney, Chairman

bypass. They feel they can have it in place by April 1, 1991, but not two weeks in advance of the probable beginning of the juvenile migration. It was agreed that transducers should be placed in the forebay as was done last year. These could be used to develop an index of migration to assist in the decision as to when to start the bypass, and then to decide when to start the evaluation.

A question was raised whether it would be possible to arrange a break in the 30 day bypass evaluation period if it develops that there is a bimodal distribution in fish migration. Klinge will ask the statistical team to review that possibility and make a recommendation.

It was agreed that fyke net samples to determine species composition of migrants early in the spring could be dispensed with. The committee is now confident that the early fish will be salmonids. Later in the spring, other fish enter into the picture. At that time fyke netting would be useful.

4. Beginning of Bypass Operation. The committee discussed criteria that might be used for deciding when to begin bypass operation. Klinge would like to discuss that further after he has more information.

5. Next Meeting. The committee agreed to meet again by telephone conference call at 9:00 A.M. March, 1991. The agenda will include a progress report from Biosonics on installation of transducers for the bypass evaluation, and criteria to be used for deciding on a starting date for bypass operation.

MEMORANDUM

To: Wells Project Coordinating Committee WELLS 91-2

From: Richard R. Whitney

Date: March 11, 1991

Subject: Your review of enclosed draft summary of meeting of March 11, 1991 by April 3, 1991, the date of the next scheduled meeting.

Enclosed please find the subject draft meeting summary. If I don't hear from you by April 3, 1991, the date of the next scheduled meeting I will assume you have no corrections or comments and will develop a final version that will be included in the annual report to FERC, per the terms of the settlement agreement.

1. The meeting was held at 8:30 A.M. March 11, 1991, by telephone conference call as agreed at the previous meeting. Those participating were Rick Klinge and Mike Erho, Douglas County P.U.D.; Bill Hevlin, NMFS; Rod Woodin, Washington Department of Fisheries; Bob Heinith, Columbia River Intertribal Fisheries Commission; Tom Scribner, Yakima Tribe; Gerry Marco, Colville Confederated Tribes; and Dick Whitney. The purpose of the meeting was to receive progress reports on installation of the bypass and the hydroacoustic monitoring equipment, and on the revised study plan for evaluation of the prototype.

2. Progress in Monitoring. Rick Klinge reported that Biosonics have placed 15 of 20 transducers in their positions for evaluation of the bypass. Douglas County P.U.D. expects to have no problem in meeting the April 4 readiness date, which is the scheduled date for release of fish from the Winthrop Hatchery. However, they might have a problem being ready two weeks ahead of April 4, which would be March 18, 1991. In any case they expect to be ready to monitor for one week before the scheduled release. As soon as monitoring numbers are available they will be sent by Rick Klinge to Gerry Marco and Cindy Wilson. Those three are the representatives who will make the decision as to when to begin operation and evaluation of the bypass. Fyke netting will be delayed until May 15, 1991.

3. Hatchery Release Schedule. There was a discussion of the early hatchery release. Whitney reported that his information from the Fish and Wildlife Service was that there are chronic disease problems that develop in April at Entiat and Winthrop hatcheries, which led this year to recommendations by the hatchery managers for release around the first of April. The committee is not certain that these fish will move down stream right away. They might hold in the river for a while. There are marked groups that will be followed by the Fish Passage Center. Woodin pointed out that fish from the Similkameen facility will be released volitionally, starting around the first of April. These fish might affect the timing of peaks of migration as well.

4. Bypass Evaluation. Klinge reported that he had asked John Skalski to revise the study plam for evaluation of the bypass and to consult with the working group appointed at the previous meeting. Skalski will mail out the

revised plan today. He will attempt to reach the working group members next week and report back to Klinge as soon as he can. Hevlin will notify John Williams so that he will be prepared for a meeting next week. The Wells Project Coordinating Committee agreed that if the working group can agree on a plan, they will accept it. In that case Klinge should notify the Coordinating Committee by memo with a copy of the study plan. If the working group cannot agree, the Coordinating Committee will meet again to decide what to do.

Klinge had been asked to inquire about the possibility of splitting the 30 day evaluation period in the event that a bimodal distribution occurs in the outmigration period. He asked Skalski who advised against that. It would be better to enlarge the 30 day evaluation period, he thought. Douglas County P.U.D. is considering that possibility. Biosonics continue to work on a new random sampler for the hydroacoustic evaluation, but it might not be ready in time. If not, they will go with the same plan as used last year. The Committee agreed that the plan used last year was satisfactory, and could be used if the new one can not be developed in time.

WELLS 91-3

WELLS PROJECT COORDINATING COMMITTEE
MEETING APRIL 3, 1991
SUMMARY[1]

Agreements Reached:

1. Douglas County P.U.D. agreed to provide, if needed, an additional period for evaluation of the bypass in the spring beyond the 30 day period of the evaluation, up to a total of 40 days.

2. Biosonics will report weekly on the hydroacoustic index at Zosel Dam until May 14, 1991, after which they will report daily.

3. The committee agreed that there was no need for special monitoring of the fish released from the Similkameen or Twisp facilities through fyke netting or other methods at Wells.

4. The committee asked Douglas County P.U.D. to develop further information on the proposed study plan for determining whether there might be a difference in survival of fish passing through top spill compared to bottom spill at Wells Dam.

5. Washington Department of Fisheries has comments on the report of Don Chapman and Associates on feasibility of enhancement of sockeye salmon. They will forward to Rick Klinge for distribution to the rest of the committee.

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The committee met at 1:00 P.M. April 3, 1991 in the Small Auditorium at Sea-Tac. The agenda followed was mailed to the committee on March 27, 1991 by Rick Klinge. Those in attendance are listed on the attached roster.

I. Final Report for 1990 Bypass Season. Rick Klinge reported that a draft report by Biosonics on the bypass evaluation was distributed, and comments were received from Washington Department of Fisheries and the National Marine Fisheries Service. The comments will be taken into account in the final version. The final version should be out in about one week. Klinge called upon Gary Johnson of Biosonics, who gave a brief summary of the report, of the comments received, and of Biosonics response.

II. Status of 1991 Bypass Season.

A. Review of 1991 Evaluation Methodology. Klinge called upon Gary Johnson of Biosonics, Inc. and John Skalski of the University of Washington. Increased sampling at the turbine intakes should reduce the variance of the estimate of fish passage efficiency by a factor of 10, according to Skalski's calculations. There will be transducers in 24 of the 30 turbine intake slots, meaning that 4

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[1]Prepared by R. Whitney, Chairman

units will have all three slots sampled. The units chosen were the ones with high numbers of fish last year. Gary Johnson indicated that Biosonics would look at the first 5 days of data and decide whether to move transducers or make other adjustments. Skalski had consulted the other members of the statistical working group, Ben Sandford, John Williams, and Phil Mundy, and they are in agreement on the study plan.

B. Current Status of Bypass Operation. Klinge reported that Douglas P.U.D. began hydroacoustic monitoring of fish abundance at Wells Dam on March 29, 1991. Abundance has been low to date. Douglas P.U.D. have met the requirement in the Settlement Agreement for a two week monitoring period prior to the arrival of major numbers of fish at the project. There is a 30 day period set for the bypass evaluation. Klinge proposed that after that time the bypass team should decide what stage the sockeye migration has reached. Douglas P.U.D. are willing, if necessary, to add a 5 day period of evaluation for late arriving smolts, if the team agrees it should be done. Again, Douglas P.U.D. are willing to add a still further 5 day period, if the team agrees it is necessary, to include late arriving smolts, up to a total evaluation period of 40 days.

C. 1991 Smolt Monitoring at Zosel Dam. Klinge reported that Biosonics intends to monitor with a single transducer at spillbay 1 from April 24 to May 31, 1991. They will consult with the irrigation district to be sure that is the best location. Biosonics will report the monitoring numbers weekly from April 24 to May 14, at which time the numbers will be reported daily until May 31, 1991.

D. Operation of the Fyke Net. Klinge reviewed the decision made during the conference call on March 1, 1991 not to take samples with the fyke net until about May 15, 1991 when it will be desirable to obtain information on sockeye abundance at the project. Klinge is now wondering whether the committee might want to reconsider this decision, considering that it might be useful to collect information on fish being released from the Similkameen and Twisp facilities. The committee decided that fyke netting would not collect information that would be useful, and decided against it.

E. Summer Bypass Operation. Klinge said there is a 15 day period outlined in the Settlement Agreement for summer bypass evaluation. He will check with the designated representatives to decide jointly on the schedule for beginning summer bypass operation.

F. Projected Flows for 1991. Klinge reported that flows are projected to be 120% of normal during the period of the juvenile outmigration. By June or July, flows might reach 250 Kcfs in the mid-Columbia. If it exceeds that, it might be necessary to remove one of the bypass baffles, according to FERC operating criteria for

the project. They would be removed from spillbay 6. If this happens, it might affect the evaluation of the bypass.

III. Top Spill - Bottom Spill Evaluation

A. The Need as Outlined in the Settlement Agreement. Klinge referred to the Settlement Agreeement at Section II C 5, page 10, where there is a statement, "If top spill is shown to be as effective as bottom spill in bypass bays 2 and 10, then top spill will be allowed in these bays." He also referred to Section IV C 5, which calls for a Wells Project juvenile mortality/survival study to begin in 1991. Douglas P.U.D. is proposing to get a start on these by undertaking a study of comparative survival in top vs bottom spill in 1991. He called upon John Skalski to describe the proposed study plan. There would be 4,400 steelhead marked with pit tags. Half would be released into an area in the spillbay where they would have to go through top spill and the other half released into bottom spill. Recoveries would be made at McNary Dam where facilities exist for detecting pit tags. Skalski had asked Klinge to specify a difference he would like to be able to detect between top and bottom spill. On the basis of his response, that he would like to be able to detect a difference of 10%, Skalski had come up with the number of tags that would need to be recovered at McNary Dam, and from that number an estimate of the number that would need to be released, thus the 4,400 number. He assumed a 20-30% recovery rate at McNary Dam, based on experience of others. This assumes no spill at McNary. If there is spill, the recovery rate would be lower.

There was a discussion in the committee about whether the study is necessary. The agency and tribal representatives suggested a paper exercise to try some numbers for relative survival and see what these might lead to in terms of differences in total survival of fish passing the project. A further analysis of data already at hand might provide the information that is desired. Particular concerns were expressed about the assumed recovery rate at McNary and the wide difference in rate of survival in the two routes that would be necessary before it could be detected in the study. Rick Klinge agreed to work further on the proposal and get back to the committee.

IV. Okanogan Sockeye.

A. Don Chapman Report on Enhancement Possibilities Above Wells Dam. There was a discussion of the Chapman report. Agency and tribal representatives would have preferred to see a draft report before it was finalized. Washington Department of Fisheries has some comments on the report which they will send to Rick Klinge. Klinge will circulate these to the committee.

B. Adult Counting Facility at Zosel Dam. The Columbia River Intertribal Fish Commission has assessed the adult passage with a video camera at Tumwater Dam. They have submitted a proposal to Douglas County P.U.D. to do the same sort of monitoring at Zosel

Dam. Douglas P.U.D. will look into it.

V. Progress on the Methow Hatchery.

A. Contract Bid Award. Klinge reported that 6 contractors bid on the Methow hatchery construction job. Low bidder was DYAD Construction Co. of Woodinville, WA, at $5.5 million. Most of the other bids were close, and were near the designers estimate. They will break ground in May. All permits are in hand. The wells are sunk and being developed.

B. Change of Adult Weir Location on the Twisp River. Klinge reported that FishPro had become concerned about the location of the adult weir on the Twisp River. Access was by way of a privately owned bridge with limited weight capacity. They advised moving it to the area where the acclimation ponds are located. Douglas P.U.D. approved this change in the plan. Klinge had talked to Kathy Hopper of WDF. The committee suggested that Klinge consult with the fish committee if further changes of that sort should be required.

C. Comments From Yakima Tribe on Security. The Yakima Tribe had expressed some concerns about security around the acclimation ponds. Douglas P.U.D. will talk to Kathy Hopper of WDF about addressing this problem.

VI. Miscellaneous

A. Progress on the Wells Eastbank Ladder. The ladder is being modified to include a trap. Phase I of construction is completed. The ladder was watered up last Monday, April 1, 1991. Installation of the Denil fish pass and the sorting flumes will be next in Phase II. Douglas P.U.D. has received comments from the agencies on the design. Rod Woodin suggested that Klinge should send a copy of the revised plans to Bob Pearce of NMFS to show how his concerns have been addressed.

WELLS PROJECT COORDINATING COMMITTEE
MEETING APRIL 3, 1991 AT SEA-TAC
ATTENDANCE ROSTER

Name	Representing
Rick Klinge	Douglas County P.U.D.
Bob Clubb	Power Purchasers
Rod Woodin	Washington Department of Fisheries
Gerry Marco	Colville Confederated Tribes
Frank Young	Oregon Department of Fish and Wildlife
Ron Boyce	Oregon Department of Fish and Wildlife
Bill Hevlin	National Marine Fisheries Service
Tony Eldred	Washington Department of Wildlife
Bob Heinith	Columbia River Intertribal Fish Commission
Tom Scribner	Yakima Indian Nation
Richard Whitney	Neutral Third Party
Gary Johnson	Biosonics, Inc.
John Skalski	Consultant
Donn Park	Consultant

WELLS PROJECT COORDINATING COMMITTEE
MEETING APRIL 15, 1991
SUMMARY[1]

Agreements Reached

1. Due to high expected flows and resulting spill at McNary Dam, which would reduce the expected number of marked fish that would be recovered, the committee decided not to pursue the study of relative spill survival in top vs bottom spill at Wells Dam in 1991.

2. The committee agreed that because they had made a decision to conduct an additional bypass evaluation in 1991, the studies of survival of juveniles passing the project should be postponed until 1992.

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At the April 3, 1991 meeting of the Wells Project Coordinating Committee, Douglas County P.U.D. presented a proposal for a study of relative survival of fish passing through top spill and bottom spill at Wells Dam. The committee asked for further clarification of the study plan. Douglas P.U.D. prepared some additional information and asked the committee to meet by telephone conference call to discuss it. The Conference call was arranged for 1:30 P.M. April 15, 1991. Participating were Rick Klinge and Mike Erho for Douglas County P.U.D.; Ron Boyce, Oregon Department of Fish and Wildlife; Tom Scribner, Yakima Indian Nation; Bill Hevlin, National Marine Fisheries Service; Tony Eldred, Washington Department of Wildlife; Gerry Marco, Colville Confederated Tribes; Rod Woodin Washington Department of Fisheries; and Dick Whitney, Neutral Third Party.

Rick Klinge said that Douglas County P.U.D. would like to go ahead with the study. He had faxed out to the committee members a "decision tree" showing the possible outcomes of the study and the related responses by Douglas County P.U.D.. Erho pointed out that information on recovery rate of these fish at McNary Dam would be useful later in the designing of the study of overall project survival which is called for in the Settlement Agreement. Concerns were expressed about the effects of expected high flow and spill on the recovery rate at McNary Dam, about the wide difference that would have to occur in survival in order for the study to detect it, and about the short time interval available between tagging and release of the fish. Discussion of these factors led to a conclusion in the committee that this is not a good year in which to conduct a study to measure recovery rate at McNary Dam because expected high levels of spill will probably reduce the recovery rate to a point where the data will not be useful. Douglas P.U.D. will withdraw the study plan for this year.

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[1]Prepared by R. Whitney, Chairman

Rod Woodin suggested that Washington Department of Fisheries would be willing to sign a joint statement to the effect that because the committee had agreed upon an additional year of measuring fish passage efficiency to include 1991, it would be appropriate to delay the measurement of juvenile survival at the project. The Settlement Agreement calls for a study of survival to begin in 1991. He feels that it should be delayed until 1992. The committee agreed with this suggestion and asked Douglas P.U.D. to draft a statement that could be signed, or to consult with their attorney to get his advice on how to proceed. It was suggested that the members of the committee could document the fact that they are in agreement on the issue, and that this might suffice for the purposes of satisfying FERC that the parties are adhering to the Settlement Agreement.

It was agreed that the next step in dealing with measurement of survival should be a meeting of the Wells Project Coordinating Committee to develop criteria for the study of overall survival at the project.

WELLS PROJECT COORDINATING COMMITTEE
MEETING JUNE 14, 1991
SUMMARY[1]

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The meeting was held by telephone conference call arranged by Rick Klinge. By memo of June 7, 1991 he outlined the agenda and set the schedule for 9:00 A.M. June 14, 1991. Those participating were Rick Klinge, Douglas County P.U.D.; Bob Clubb, Power Purchasers; Bill Hevlin, and Steve Rainey, NMFS; Bob Heinith, Jeff Fryer, and Mathew Schwartzberg, Col. River Intertribal Fish Comm.; Rod Woodin, Wash. Dept. Fisheries; Ron Boyce, Oregon Dept. Fish and Wildlife; and Dick Whitney, Coordinator.

Klinge reported on the situation with modification of the East Bank ladder at Wells Dam to provide for trapping of adult summer chinook. Douglas P.U.D. has an agreement with Chelan P.U.D. to take brood stock for implementation of part of the Rock Island Settlement. Suggestions for the plans were being received right up to the time they went out for bid. There was only one bidder. The bid came in at $161,000. The engineering estimate was $112,000. Because the bid exceeded the engineering estimate by more than 15%, they had to reject the bid. The reason it was so high is that time was so short for finishing the work. Overtime and other factors entered into the picture, accounting for the high bid. Douglas P.U.D. are working out of the problem by entering emergency work orders for metal work, and using a maintenance contract to proceed with some of the work. They will be able to accomplish enough of the work to get just beyond the first sorting station at the ladder. They will be able to select fish either for brood stock or return to the ladder. This means more handling than if the full system were installed. Brood stock will be put into a transportation trailer, or other means will be used. There was a discussion of a procedure in which adults would be placed into tubes for transportation. Careful handling would be required to get the fish into the tubes. Steve Rainey described a tube system that is being used. Klinge asked for a set of drawings that might be used as a basis for preparing something like it at Wells Dam. He pointed out there is not much space available at the ladder.

Klinge said that they had the same problem with bids on the transportation trailer that they had with the ladder modifications. They had to reject the bids. Douglas is looking for something they can borrow temporarily. NMFS will ask Bob Pearce to look at the problem. He was not in at the time. The committee asked Douglas P.U.D. to develop a written description of the trapping plan for this year, distribute it early next week, and discuss it in a conference call next Friday. Klinge mentioned that he has talked to Bob Bugert of Washington Department of Fisheries to develop a plan that will not have an effect on wild fish. He will have something ready early next week. Jeff Fryer expressed an interest in sampling sockeye from the trap. Klinge indicated there should be no problem with that.

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1. Prepared by R. Whitney, Chairman

Study Proposals from Columbia River Intertribal Fish Commission. Klinge asked for comments on the two proposals from CRITFC, one for counting sockeye adults at Zosel Dam, and the other for a limnological study of Lake Osoyoos. Jeff Fryer reviewed the proposal for sockeye counting with video cameras in the fish ladder at Zosel Dam. There has been a concern expressed that there are unaccounted losses between Wells Dam ladders and Zosel Dam. Escapement might be lower than indicated by the Wells counts. Klinge reported that Biosonics had done a study last year with transducers in the ladder and counted no fish, from which they concluded that the adults use the spillway rather than the ladder at Zosel Dam. His proposal would be to have Intertribe do the video monitoring in the ladder and Biosonics monitor the spillway. Mathew Schwartzberg described the proposal for a limnological study of Lake Osoyoos. There is a concern about the Okanagan stock of sockeye. The numbers have been declining, coincidental with the drought years we have experienced recently. Pratt and Chapman's report recommended some study of water quality. There are questions about the water temperature at the mouth of the Okanagan at the time adults normally enter. He feels that there are questions about plankton populations and their suitability for sockeye, as well as interactions of fish species in the lake. Is rearing space a limiting factor? Chapman thinks not, but Schwartzberg thinks it might be. There was a general discussion about the process being used to decide on a set of studies. The thought was expressed that the committee needs to decide on an overall plan for enhancement and then identify from that what studies might be necessary or useful in order to put them in an appropriate context.

The committee had no strong objections to Douglas proceeding on their own with Intertribe. Klinge said that he felt that the Zosel Dam monitoring was very important as an extension of the Wells Dam counts, and that Douglas P.U.D. would probably proceed with that study. With respect to the limnological study and the general question of establishing a process for identifying appropriate studies, he suggested that the committee give the matter some further thought and talk again next week by telephone conference call. The committee agreed to meet again by telephone conference call at 9:00 A.M. Friday June 21, 1991 to discuss these matters and progress with the trapping facility at the ladder.

MEMORANDUM

To: Wells Project Coordinating Committee

From: Richard R. Whitney

Date: July 30, 1991

Subject: Summary of Meeting by Telephone Conference Call on June 21, 1991

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As agreed in the telephone conference call on June 14, 1991. the Wells Project Coordinating Committee met again by telephone conference call at 9:00 A.M. on June 21, 1991 to discuss further the provisions at the East Bank Ladder at Wells Dam for taking summer chinook brood stock, and to discuss proposals from the Intertribal Fish Commission for sockeye monitoring at Zosel Dam and for limnological studies in Lake Osoyoos. Participating in the call were Rick Klinge and Mike Erho, Douglas County P.U.D.; Ron Boyce, Oregon Dept. of Fish and Wildlife; Bob Pearce and Brian Brown, National Marine Fisheries Service; Rod Woodin and Bob Bugert, Washington Department of Fisheries; Gerry Marco, Colville Confederated Tribes; Mathew Schwartzberg and Jeff Fryer, Columbia River Intertribal Fish Commission; and Richard Whitney for the committee.

Construction of the Trapping Facility.
Rick Klinge gave the committee an update on progress on the work on the eastbank ladder. Douglas P.U.D. took the flume drawings to a sheet metal shop to do that part of the work. The flume should be delivered on Tuesday, June 25, 1991. The crew at Wells Dam will install it into the false weir. It will be functional for taking brood stock. Douglas has worked further to solve the problem of getting the fish to the hatchery. They found a shop that has stainless steel tanks in stock. They bought a 500 gallon tank and will install it on a trailer. This will be delivered ready to use on July 8, 1991. Bob Bugert indicated that the hatchery would be ready for taking of fish for brood stock on July 1, 1991. They can start on the west bank ladder. Klinge said that he talked to the hatchery manager about the suggestion put forward at the meeting last week that they use PVC tubes to hold the adults. He did not like the idea. Jeff Fryer asked about the sampling of sockeye that the Intertribal Fish Commission would like to do. The committee agreed that the best procedure would be to sample sockeye on days when chinook are being taken for brood stock. They should operate at the west bank ladder so as to not handle any more chinook than necessary at the east bank ladder. They could then use the same trailer for transporting the sockeye up to the forebay. Bob Pearce pointed out that the east bank set-up is not tested yet and it might be desirable to provide some time to adjust some things as we see how it works. The schedule for chinook will be Monday, Tuesday and Wednesday - subject to change depending on the run size. They could sample sockeye the rest of the week.

Operating Protocol for the Trap at Wells Dam.
Bob Bugert and Rick Klinge have developed a written operating protocol which has been sent to the committee. It is designed to balance the needs for brood stock with protection of the wild spawners. The number of fish to be taken from the trap at Wells will be adjusted depending on the count at the Rocky Reach fish ladders. The number will not include volunteers to the

hatchery. The target number is 677. If the Rocky Reach counts are 75% of the 10 year average, then the take from the trap will be 75% of 677. The decision point is 90%. Anything over 90% at Rocky Reach will lead to a full take of 677 from the Wells trap. The goal is to take no more than 30% of the wild run. Bob Bugert will provide a report weekly beginning June 21, 1991. The committee agreed that the appropriate proceedure should be to take all the fish that come during an operating period. The trap should then be shut down when the desired numbers are obtained. The committee commended the efforts of Bob Bugert and Rick Klinge in developing the protocol, which they then endorsed.

Proposals from Intertribal Fish Commission.

Monitoring Sockeye at Zosel Dam. Discussion on this proposal was continued from the previous meeting. Klinge brought up the subject of the Biosonics proposal to monitor adults at the Dam. Discussion continued on the proposal of the Intertribal Fsih Commission to use video cameras in an attempt to monitor adult passage at Zosel Dam. Woodin expressed a concern about studies getting ahead of the process. He would like the committee to consider what studies are needed first, then develop proposals, rather than accept proposals and consider them without an overall plan of attack to address questions the committee might have on specific subjects. A long-range approach is needed. After further discussion, Klinge noted that he recognized that problem, but that if the committee had no objections Douglas P.U.D. would proceed to contract for these particular studies in the interim. There were no objections. Gerry Marco noted that the Colvilles feel there is a difference between a study at the Dam, a man made project, versus a study in the lake.

Limnological Study of Lake Osoyoos. Gerry Marco indicated that the Colville Tribes have a problem with the Intertribal Fish Commission conducting a study in their ceded territory. The problem is not with the study itself. In fact, the Colvilles have the capability of carrying out such a study and might develop a proposal themselves. However, because of the political considerations, the Colville Tribe would not be able to approve this proposed study at this time. The committee noted that this factor should be addressed before any proposed study takes place.

Future Studies.

The committee feels that an open discussion is needed to develop studies that might be required as part of the Settlement Agreement. The Settlement Agreement, for example, calls for studies of survival after the bypass is evaluated. However, Woodin pointed out that the evaluation is still underway. Modifications to the bypass or its operation might take place as a result of the evaluation. The committee should wait until the evaluation is finished before proceeding with survival measurements. The results this year will show whether the bypass meets the specified criteria. If it does, then it will be time to measure survival. Erho suggested ,however, that it would not be premature to start thinking about the survival study, and what it should consist of. The earliest time for its conduct would probably be 1993.

WELLS PROJECT COORDINATING COMMITTEE
MEETING JULY 22, 1991

SUMMARY[1]

Agreements Reached

1. The Columbia River Intertribal Fish Commission was asked to prepare a study outline for their plan to sample sockeye in the trap at Wells Dam.

2. The committee agreed to develop a comprehensive plan to address development of a comprehensive approach to studies in the Settlement Agreement. A subcommittee was asked to develop a preliminary outline to be discussed by the committee as a whole at a working meeting scheduled for August 27, 1991 at Douglas County P.U.D..

3. Douglas County P.U.D. is moving ahead with plans for study of adult sockeye passage at Zoesel Dam using hydroacoustics in the spillway and video cameras in the ladder at Zosel Dam.

4. Douglas County P.U.D. will respond to a letter from FPAC regarding a recommendation to repel seagulls from the tailrace at Wells Dam.

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The meeting was held in conjunction with the meeting of the mid-Columbia Coordinating Committee and the Rock Island Committee at Sea-Tac on July 22, 1991. In attendance were Tom Scribner, Yakima Indian Nation, Cary Feldman, Power Purchasers, Tony Eldred, Washington Department of Wildlife, Bob Heinith, Columbia River intertribal Fish Commission, Steve Grabowski, National Marine Fisheries Service, Bill Hevlin, National Marine Fisheries Service, Rick Klinge, Douglas County P.U.D., Ron Boyce, Oregon Department of Fish and Wildlife, Richard Fisher, Federal Energy Regulatory Commission, And Richard Whitney, Chairman of the Wells Project Coordinating Committee.

1. East Bank Ladder Trap at Wells Dam. Klinge reported that the trap was ready July 8, 1991. The people using it are happy with it. The slope might be a little too low for sockeye. They are able to turn around in the channel and go back up it. Chinook are too large to turn around. The sorting door operates manually. It will be replaced with one that operates hydraulically.

Brood stock are low in abundance, according to Bob Bugert. His memo of July 8 shows the run as counted at Rocky Reach is 47% of the 10 year average. On July 17, 1991, it was 56% of the average. A protocol has been proposed as a working document.

Klinge asked Heinith for a study outline from the Intertribal

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[1]Prepared by R. Whitney

Fish Commission on their plans for sampling sockeye at the trap. He would like to know how many sockeye will be sampled, on what schedule, and so on.

He noted that the trailer tank used for moving chinook will hold 20 to 25 chinook. A question was raised about whether the temperature increases in the tank. Klinge will get the information. There had been 89 adults and 5 jacks as of yesterday.

A question was raised about what comstruction will be done next year at the trap. Klinge said that it might not be necessary to go through the process of soliciting bids, because the work should be considerably less expensive now that some of it is accomplished. He noted that the flume, up to the point of the first sorting is the same as was in the original plam. Modifications were made from that point to cut the costs and make it possible to proceed this year. Plans for next year have not been fully developed as yet.

II. Methow Hatchery. Klinge reported that this has been a high water year. They had trouble putting in the footings. But the footings are now in for all the buildings. The two residences are framed, roofed and sided. The generator building is built. The generator will be available for backup power.

On the Chewack, the trap is under construction at the irrigation dam, which is a rock dam. The same is true on the Twisp River.

III. Future Studies. The committee discussed the Settlement Agreement and the terms that call for studies of adult passage, juvenile mortality, and sockeye studies. Klinge would like to have something firm in hand next winter. Heinith proposed that a subcommittee meet to begin developing an outline. Klinge would like to have some kind of guidance on paper. He suggested that the agencies and tribes begin as a subcommittee and develop a document to scope out the needs. That document would then be discussed at a working meeting of the full committee scheduled for August 27, 1991 at Douglas County P.U.D..

IV. Adult Sockeye Passage in 1991. Klinge noted that there were two studies that are planned. One is for hyroacoustic study at Zosel Dam by Biosonics. Douglas County P.U.D. is moving ahead. As of July 21 there were 6,103 sockeye counted at Wells Dam. It will probably be a 9-10,000 fish run. They plan to install transducers in each of the 4 spill bays and 1 transducer looking across the dam.

Douglas P.U.D. also has a proposal from the Intertribal Fish Commission for a study using a video camera in the ladder at Zosel Dam.

V. Other. Henith provided a letter from FPAC requesting that steps be taken at Wells Dam to repel seagulls from the tailrace, using

wires. Klinge said that Douglas County P.U.D. will respond.

VI. Next Meeting. The committee agreed to meet again on September 13, 1991 at Sea-Tac. Study outlines will be discussed.

WELLS PROJECT COORDINATING COMMITTEE
MEETING SEPTEMBER 20, 1991
SUMMARY[1]

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The meeting was held at 9:00 A.M. September 20, 1991 in the conference room at Douglas County P.U.D. in East Wenatchee, Washington. Those in attendance are listed on the attached roster. The agenda followed was mailed along with the meeting announcement on August 28, 1991.

I. Settlement Agreement Studies

Tom Scribner reviewed the discussions from the working group meeting that took place near the end of August. The committee had asked Scribner, Jerry Marco and Rick Klinge to meet as a subcommittee, or working group, in order to develop an outline of studies that might be undertaken in 1992 under the Settlement Agreement, and to lay out procedures that might be followed in deciding what studies would be appropriate. The group identified two subject areas that they wanted to address. The first has to do with whether the Pratt and Chapman study is sufficient to complete the part of the Settlement Agreement having to do with exploring possibilities for sockeye enhancement in Lake Osoyoos. To address this subject area, the first step would be for the parties to develop review comments on that report. Washington Department of Fisheries and the Colville Tribe indicated that they will do so. To address the second area involves a subject-by-subject discussion of the studies identified in the Settlement Agreement. Scribner will review the sub-committee discussions as we go through the agenda.

A. Adult Passage Studies.

Scribner reviewed the sub-committee discussions which identified a distinction between adult delay versus adult mortality. The radio tagging study which had been proposed would be designed to measure delay, rather than mortality. Mortality might be inferred from counts at successive dams, but there are difficulties in comparison of those counts. The committee agreed that adult passage, or delay is the first question to be addressed. Estimation of mortality will need to be done later when more information is available. The committee agreed that it would be appropriate to convey this information to FERC, namely, that the committee feels that the adult passage studies being planned for 1991 will satisfy, at least for the time being, the terms of the Settlement Agreement that call for studies of adult mortality.

Bill Hevlin reviewed the proposal for study of adult passage that had been developed by NMFS. This study would involve radio tagging of adults and following them through the reservoirs, through the fish ladders and into the spawning streams. The proposal included following three stocks of fish from Wells Dam to the spawning grounds. These would be spring and summer chinook and sockeye. There was a discussion of the priorities to be assigned to the three stocks. Douglas P.U.D. was not certain that the funds

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1. Prepared by R. Whitney

available would be sufficient to include studies of all three. This will not be clear until a formal proposal is submitted. Douglas would like to ask for proposals to be submitted species by species so that if necessary they could pick a combination that would fit the funds available. The committee agreed that sockeye should have the highest priority, since nothing is known about them in terms of tracking their passage in any system anywhere. The committee, as a first priority, would like to have information on sockeye both at Wells Dam and above, in order to get the most out of marked fish. Studies above Wells Dam only would be a last resort if that is all the money will support. The committee would like to have some information on chinook as groundwork for a larger study that might be carried out in 1993 involving the entire mid-Columbia system. Hevlin suggested that the committee agree on the objectives and leave it to the experts to develop study plans to achieve those objectives. There was a discussion of how many years would be required to complete this study. Rod Woodin thought probably three years in view of the kinds of variability usually encountered. The committee discussed several entities that might be able to carry out the work. Ted Bjornn was mentioned, as well as Lowell Stuehrenberg. Hevlin mentioned that Stuehrenberg was in the process of deciding whether his group should enlarge or reduce its work load in this area. The committee suggested that Douglas P.U.D. representatives meet with one of these people at Wells Dam in order to begin scoping out the project in more specific detail.

B. Juvenile Passage Studies.

Scribner reviewed the discussions of the subcommittee, which suggested that a large number of test fish might be required. They asked Klinge to consult with John Skalski for advice on fish numbers. Klinge did so and got some questions back from Skalski as to what values are to be assumed at certain points. First, what is the total mortality assumed for the project. Rod Woodin said that 14% was the indication of the systems mortality study, and that was used in developing the compensation package in the Settlement Agreement. It is total project mortality, which includes turbine mortality. Whitney pointed out that if the bypass diverts 85% of the smolts, turbine mortality is probably about 3%.

There was a discussion of the species differences that might be expected. The committee felt that the study should include spring chinook, both yearlings and subyearlings. They are willing to assume the results would apply to summer chinook. The committee does not think it necessary to include sockeye. Steelhead are not included in this provision in the Settlement Agreement.

Release sites of test fish should be at the mouths of the tributaries.

There was a discussion of what magnitude of difference would be required in order to conclude that an adjustment was necessary in the compensation package. The committee felt that there should probably be a difference in the range of 5%, in other words 9% to 19% total mortality. The committee would be satisfied with an 80% confidence interval around the new estimate.

There was a discussion of scheduling for the study. Douglas P.U.D. representatives indicated that unless only a small number of fish are required for the study, it will probably be done in 1993.

C. Sockeye Enhancement.

Scribner reviewed the subcommittee's work. Douglas P.U.D. wants to have a clear link between any studies and the Settlement Agreement. Jerry Marco pointed out the the Settlement Agreement has two separate discussions of sockeye. One calls for evaluation of the potential for enhancement of sockeye, and the other calls for 8000 pounds of production of sockeye. He indicated that the Colville Tribe probably needs to comment to Douglas County P.U.D. on the adequacy of the Pratt and Chapman report for evaluating the potential for enhancement. Mike Erho said that Douglas P.U.D. had asked Chapman to look broadly at the opportunities for enhancement. They feel that part of the Settlement Agreement has been satisfied. Some opportunities were identified for developing or increasing sockeye populations. They are ready to move on to part 2 in the Settlement Agreement, calling for producton of sockeye. They are willing to consider comments on the Chapman report. Rod Woodin indicated that Washington Department of Fisheries would comment by November 7, 1991. He likes the idea of using net pens in some sequence that would make them practical for the situation in Osoyoos in combination with adult sockeye taken in 1992. Erho suggested that if there is more rearing area, as Pratt and Chapman indicate, there might be artificial spawning, incubation and release in the lake for rearing. They would have to release earlier in the year than in Lake Wenatchee, due to the high surface temperature at Osoyoos. They would have to choose a time when natural food is available in the lake. Hevlin felt that it is too early for such discussions. We need to develop comments on the Pratt and Chapman report first, so we have the necessary information.

D. Evaluation of the Methow Spring Chinook Hatchery

Scribner pointed out that discussions in the subcommittee brought out the fact that Douglas P.U.D. wants the study to evaluate the production plan, and not be involved in evaluating supplementation per se. The committee agreed that the draft of the Eastbank Hatchery evaluation plan, which is being developed as part of the Rock Island Settlement, would be the best starting point for discussions in the Wells Project Committee. Washington Department of Fisheries is developing one section that has been difficult. Rod Woodin will see that Douglas P.U.D. representatives receive copies of the draft.

II. Discussion of the Methow Adult Trap Issues

A. Current Status of Questions Raised by Steve Rainey. on the Twisp and Chewuck Rivers.

Rick Klinge reviewed the fact that the location of the trap had to be changed due to difficulties in access at the original location. Steve Rainey had raised some questions about the suitability of the design in terms of its effectiveness for trapping fish. The bids for construction of the weir at Twisp exceeded the engineering estimate by too much and they were not able to award. However, Douglas P.U.D. will proceed with pouring the concrete portions of the weir support structure. Mike Erho said Steve Rainey had been there on site and made some suggestions for improvement which will be included. They are aware of some problems with this design at the Chiwawa facility. FishPro has made some suggestions for improvement of

the design.

B. Status of the Proposed Foghorn Ditch Trap on the Methow River.

Mike Erho reported that there will probably be no trap at the Foghorn ditch . Steve Rainey raised some valid questions about its effectiveness. It would probably not be effective in trapping adults, for the same reason the trap is not effective at Dryden Dam. The dam does not amount to a significant barrier to the adult fish and they simply go over it. There is a need to develop an alternative site for the trap.

III. Bird Predation Issue at Wells Dam

Rick Klinge said that Douglas P.U.D. would like to determine the scope of the problem before they identify an appropriate solution. They will develop a plan of action for study to take place in 1992, followed by an action plan in 1993.

IV. Other

Wiith respect to the trap in the east ladder at Wells Dam, Klinge reported that in 1992 it will be possible to sort for sockeye without using a net. Intertribal Fish Commission was asked to outline a procedure to be used there. The original plan was for a hopper to lead into a truck or trailer. Erho indicated that Douglas P.U.D. would build it as designed, but it would not solve the problem identified here of sorting out sockeye. Hevlin suggested that the original plan might be improved upon before the facility is completed. Douglas P.U.D. should talk to the people who use it to develop a better design. Rod Woodin will arrange a meeting of P.U.D. representatives with hatchery people and include Intertribe to discuss what is needed.

ATTENDANCE ROSTER

WELLS PROJECT COORDINATING COMMITTEE

MEETING September 20, 1991

Name	Representing
Cary Feldman	Power Purchasers
Tony Eldred	Washington Department of Wildlife
Jerry Marco	Colville Tribes
Bob Heinith	Columbia River Intertribal Fish Commission
Tom Scribner	Yakima Tribe
Dick Whitney	The Committee
Rod Woodin	Washington Department of Fisheries
Mike Erho	Douglas County P.U.D.
Rick Klinge	Douglas County P.U.D.
Bill Hevlin	National Marine Fisheries Service

WELLS PROJECT COORDINATING COMMITTEE
MEETING NOVEMBER 13, 1991
SUMMARY[1]

The meeting was held at 8:30 A.M. November 13, 1991 in the conference room at Douglas County P.U.D. in East Wenatchee, Washington. Those in attendance are listed on the attached roster. The agenda followed was mailed along with the meeting announcement on November 1, 1991.

Agreements Reached

1. Douglas County P.U.D. will ask John Skalski to evaluate the possible risks that might be involved in reducing the duration of the bypass evaluation from 40 days as in 1990 to 30 days in 1992.

2. Douglas County P.U.D. will arrange with the Intertribal Fish Commission to install video cameras for monitoring of adult passage in the ladder at Zosel Dam. Douglas County P.U.D. will discuss with Biosonics the feasibility of installing hydroacoustic equipment in the spillway to obtain an estimate of total adult passage.

3. The committee accepted the recommendation of the work group for design of the trap in the East Bank Ladder, and for the two traps on the Methow. Douglas P.U.D. will complete the work by spring, 1992.

4. The committee will provide by December 5, 1991, individual comments on the proposal for study of adult passage by means of radio tags. At the December 12, 1991 meeting the committee will agree on what should be in the study.

5. The committee asked Douglas County P.U.D. to request that John Skalski provide a revision of his proposal for a study of project mortality by including information on expected recoveries of pit - tagged chinook at McNary Dam rather than the steelhead now shown in the study plan.

6. The committee will consider at a future meeting whether or not the project mortality study needs to be done in 1992.

7. Douglas County P.U.D. will consider further a project to string wires in the tailrace at Wells Dam to reduce access by birds.

8. Douglas County P.U.D. will develop a preliminary outline of a meeting to discuss options for sockeye enhancement and circulate it at the next meeting. Alaska people will be consulted for information on their programs.

I. Status of 1991 Studies

A. Wells Bypass Evaluation "Data" Report. Rick Klinge reported that Biosonics preliminary analysis of the data from the 1991 evaluation of the bypass at Wells Dam indicates a fish passage efficiency of about 95%. The confidence interval is quite narrow, as a result of having 24 of 30 intake

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1. Prepared by R. Whitney

slots monitored hydroacoustically. In the summer evaluation, fish passage efficiency was estimated at 97%. Other reasons for a narrower confidence interval in 1991 were that in 1990 there were 17 of 30 days with forced spill, whereas in 1991 there were only 2 days out of 40 days in the evaluation period. In the summer tests, there were 6 days of 15 in 1990 and no spill in 15 days in 1991. Douglas County P.U.D. expects to be able to distribute a draft report in the near future.

B. Spring Chinook Spawning Ground Surveys in the Methow. Klinge reported that there were 250 redds observed in the survey. Tom Meekin, formerly with WDF in Wenatchee, worked for the Yakima tribe in conducting the survey. The spring chinook counts at Wells Dam, 681 and 98 jacks were the lowest on record since Wells Dam was built.

C. Monitoring of Adult Passage at Zosel Dam. Biosonics was on station by the middle of August for adult counts at Zosel Dam. They operated from August 19 to October 20, 1991, but saw very few sockeye. There were quite a few on the spawning grounds. Grant County P.U.D. biologists counted 7,000 carcasses in their surveys. Biosonics concluded that the fish must have gone up early, before they were set up.

II. Status of 1992 Studies (Existing Studies to be Continued.)

A. Wells Bypass Evaluation (year 3 of 3). Klinge reported that it is evident that efforts to improve the precision of the estimate were overdone in 1991. In looking forward to 1992, they will explore a study protocol with less precision. Douglas County P.U.D. will probably propose reducing the legnth of the study to 30 days, for one thing. In 1991 there were options for 35 or 40 days duration of the study. The committee recommended caution in order not to go too far in the reduction. Douglas County P.U.D. will consult with Dr. John Skalski to assist in assessing the risks associated with various options for reduction.

B. Methow River Spring Chinook Surveys (year 3 of 5). Klinge said that the surveys will be continued as planned.

C. Monitoring Adult Passage at Zosel. Klinge indicated that they plan to proceed with with placement of video cameras by the Columbia River Intertribal Fish Commisssion in the ladder at Zosel Dam. There was a discussion of whether or not further attempts should be made to monitor hydroacoustically. Some of the committee members expressed an interest in ana ttempt to estimate total sockeye passage at Zosel Dam. Fish might pass through the spill gates and be missed by the video camera. Klinge pointed out that last year Biosonics was unable to obtain an estimate. It was mentioned that if flows are lower in 1992, all of the fish will go through the ladder. If it is high they will probably all go through the spillway. It was suggested that if there is no spill, the hydroacoustic monitoring could be discontinued. Klinge said Douglas County P.U.D. will look into the possibilities with Biosonics.

III. Status of 1992 Studies (new studies)

A. Adult Delay Studies. Lowell Stuehrenberg of National Marine Fisheries Service was called upon to outline the elements of a study that would involve radio tagging of adult sockeye salmon to follow their movements as they approach and pass Wells Dam. The objectives need to be clearly identi-

fied. The method he has used elsewhere establishes stations as check points for recording the time of appearance of tagged fish. This will identify points where delay might occur. While it is not specifically a mortality study, it could assist in clarifying discrepancies in counts, such as those due to fall back of fish, that might otherwise be included in mortality estimates. There was a discussion of sample size. Stuehrenberg commented that this would be the first experience in the mid-Columbia situation, and the first with sockeye, so there is no firm basis for choosing sample sizes The number 100 he suggests is probably the maximum number that could be dealt with effectively, and is probably appropriate for the questions being addressed. Experience in 1992 would help develop a more rigorous design.

The committee discussed the elements of the study plan. There was a discussion of what the source of fish should be. They might be taken from the trap at the Wells ladder, or from a trap at Rocky Reach Dam. The committee felt that Rocky Reach Dam would be preferred. The committee felt that questions beyond the passage at Wells Dam needed to be considered. Some interest was expressed in being able to follow paths of fish as they approach certain check points. Stuehrenberg replied that this is not possible with radio tags. It could be done with sonic tags, and would require putting people out there at triangulation stations. It would be very time consuming and expensive. If automation becomes possible, a concept which the tag manufacturer is exploring, then it would be feasible.

The committee agreed to study the outline prepared by Stuehrenberg and to provide comments by December 5, 1991. Comments should be sent to the Coordinator, R. Whitney. The committee will be prepared for further discussion at the December 12, 1991 meeting. Klinge will find out what procedures will be required for Douglas County P.U.D. to be able to go ahead with a contract or a request for proposals.

B. Project Mortality Study. Klinge has written to and talked to John Skalski about the numbers of pit tagged fish that would be required for the mortality study that is called for in the Wells Agreement. He reviewed the response from Sakalski. Skalski provided a range of numbers depending on the expected recovery rates at McNary Dam and the precision desired. Recovery rates at Mcnary are dependent on river flow. At hgih flows recoveries are low. It was suggested that the February forecast of the Corps of Engineers could be used to decide whether to proceed with the study or not. Rod Woodin suggested that Skalski be asked to look at more current information on expected recovery rates at Mc Nary Dam. Skalski used steelhead recovery rates. There is now information available on chinook. This information is referred to in the Grant P.U.D. proposal for Time and Place of Release Studies under the mid-Columbia Coordinating Committee. It was also suggested that the study should probably include more than one release, and that the control and experimental groups should perhaps be released at different times in order to try to get them to McNary at the same time. Klinge will discuss these questions with Grant P.U.D. and Skalski.

There was a discussion of whether the study should or should not be conducted in 1992. It was pointed out that hatchery programs are still being developed. It might not be of critical importance to have the information from the mortality study quite yet. The committee agreed to consider this question and discuss it further at the next meeting.

C. Bird Predation at Wells. Rick Klinge has talked to George Graves of the U.S. Department of Agriculture, Animal Damage Control, who has worked at Chelan and Grant County P.U.D. projects. Graves made some recom-

mendations. They probably will try to string some wires in the tailrace next spring. Douglas P.U.D. is considering the matter further in consultation with Graves.

IV. Sockeye Issue.

A. Comments on the Chapman Report. Jerry Marco of the Colville Tribes was absent. Rod Woodin has not yet completed the WDF review of the Chapman Report. He will distribute it in the near future. Bob Heinith distributed comments from the Columbia River Intertribal Fish Commission. Intertribe's main concern is that they think rearing in the lake might present a problem for sockeye. Their estimate of smolt production is half that of Pratt and Chapman. Intertribe would appreciate a review of their comments and completion of review of Pratt and Chapman so that we can move forward on sockeye. Rod Woodin said that WDF people are comfortable with the enhancement work being conducted in Lake Wenatchee. They wonder how the committee would feel about going ahead with something like it in Lake Osoyoos. They have some ideas for yearling releases.

B. Other Discussion. Bill Hevlin suggested there be a meeting scheduled just to discuss sockeye. Rick Klinge offered to contact people in Alaska to get information on what they are doing to enhance sockeye production. Douglas P.U.D. will develop a proposed outline for a sockeye meeting and distribute it to the committee for a response at the next meeting.

V. Status of Methow Hatchery.

A. Construction to Date. Rick Klinge called upon Ed Donahue of FISHPRO for a report. Donahue said that at the Foghorn Ditch, with 64% of the time gone in the construction period, they had completed 54% of the work. At the Twisp, 84% of the concrete work has been completed. That will be completed in two weeks if the weather holds. They should be able to test with watering up in March, which would be in plenty of time for spring work. The hatchery manager is on site and will remain there during construction. At the Foghorn Ditch they will be able to withdraw up to 17cfs. Another 10cfs is available from wells on the site.

B. Traps. Construction of the facility on the Twisp River has been divided into three phases. Phase I - involved obtaining access to the site, which has been accomplished. Phase II - is putting the sill in the river and building the skeletal elements. They will pour concrete on friday. Phase III - is the completion stage, involving screens, piping and the remainder of the trap. This will be done in the spring. It will be available for brood stock collection by May 1, 1992. Typical spring chinook timing at Wells Dam extends from May 1 to June 28.

On the Chewack, they have some alternatives. They could modify the existing fish ladder, or build a weir upstream of the dam at the Fulton Diversion. Mike Erho reported that the plan is to try to use the existing ladder. Douglas P.U.D. has asked FISHPRO to look at the upper end of the ladder as a possible collection site. The existing Denil could be used. They will follow the advice of Steve Rainey at the work group meeting and move some boulders below the dam to improve passage conditions so that fish can find the ladder. The Denil will be modified so that it will operate over a wider range of flows. The plan is to collect fish next year if possible.

On the upper Methow, they had originally planned to incorporate a trap into the Foghorn modifications. Steve Rainey is concerned that it

would not work. They have looked for sites for floating weirs and identified a few potential sites. Erho said they will not be able to collect there in 1992. There was a discussion of the floating weir idea. Problems at the Chiwawa facility were pointed out. Donahue is aware of the problems and thinks he has identified the sources and some possible solutions. For one thing, the sill is sloped at the Chiwawa, and it should be flat. The result is that the weir is distorted, leaving gaps through which fish may pass.

VI. Other Topics

A. East Ladder Trap Changes for 1992. Klinge reviewed the work group meeting of October 28, 1991 in Portland. He reviewed the history of construction of the trap, including the fact that the bids came in too high so that it was necessary to simplify the design in order to be able to build it and have it available this year. Basically, the design is the same as planned, except that the flume was built straight rather than have a jog in it. Also, the holding tanks were not built. The plan this year is to proceed with construction of the holding tanks. There will be three of them under cover. A fourth tank for chinook will be built on the open deck. It will be six feet long, three feet wide and four feet deep to hold three feet of water. Flumes will direct fish into the proper tanks. The committee agreed to accept the recommendations of the work group as described in the summary of the work group meeting which is attached to this report.

B. Other Concerns. Ron Boyce referred to an interest in predator indexing. Tom Poe of the U.S. Fish and Wildlife Service and Tony Nigro of the Oregon Department of Fish and Wildlife have been asked to attend the next meeting of the Wells Project Coordinating Committee to discuss this subject. Ron would like to conduct predator indexing studies in the mid-Columbia in 1993.

ATTENDANCE ROSTER
November 13, 1991

Name	Representing
Rick Klinge	Douglas County P.U.D.
Mike Erho	Douglas County P.U.D.
Rod Woodin	Washington Department of Fisheries
Dick Whitney	The Committee
Bill Hevlin	National Marine Fisheries Service
Ron Boyce	Oregon Department of Fish and Wildlife
Lowell Steuhrenberg	National Marine Fisheries Service
Cary Feldman	Power Purchasers
George Swan	National Marine Fisheries Service
Ed Donahue	FISHPRO
Craig Tuss	U.S. Fish and Wildlife Service

SUMMARY OF WORK GROUP MEETING OF OCTOBER 28, 1991
Report to Wells Project Coordinating Committee[1]

The purpose of the meeting was to finalize plans for the facility at the eastbank ladder at Wells Dam. Bob Heinith of the Columbia River Intertribal Fish Commission had asked for the meeting. Those in attendance are listed on the attached roster. The Work Group agreed to recommend to the Wells Project Coordinating Committee that the following actions be undertaken:

1. Recommend to Douglas County P.U.D. that the trap at the eastbank ladder be modified to include three tanks, a holding tank, an anesthetic tank, and a recovery tank, located and sized as shown on drawings presented by Rick Klinge. These would be used for sampling of sockeye.

2. Recommend that an additional tank be provided for chinook out in the open. It should be 6 feet long by 3 feet wide by 4 feet deep, with 1 foot of freeboard.

3. Recommend that the space between the pickets be reduced.

4. Recommend that the flume be lined with material of the sort suggested by Bob Pearce of NMFS.

5. Rick Klinge will try to have the drawings for the ladder facility revised to incorporate these changes in time for distribution at the November 13, 1991 meeting.

6. FISHPRO will provide a one-page summary of proposed improvements in design of the floating weir on the Twisp River. Rick klinge will see that copies of the print as provided to potential bidders will be distributed to the members of the committee.

7. Douglas P.U.D. was asked to study the possibility of collecting chinook at the Fulton Diversion on the Chewack River. This would require improving attraction conditions into the fish ladder and including higher side wall baffles in the Denil fish pass. This subject will be discussed further at the November 13, 1991 meeting.

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The meeting was held in the conference room of the National Marine Fisheries Service in Portland, starting at 9:30 A.M., October 28, 1991.

Trap in the East Bank Ladder.
Bob Heinith had asked for the meeting in order to develop an understanding on the final design for the trap facility in the eastbank fish ladder at Wells Dam. He requested a progress report from Douglas P.U.D.. Rick Klinge reported that developing the blueprints for the design had taken until April 4, 1991, which was quite close to the date when the facility would be

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1. Prepared by R. Whitney

needed. A deadline of July 15, 1991 had been set for completion. In order to assure that it was completed in time, the P.U.D. had included a clause to collect liquidated damages from the contractor for each day that completion was delayed past July 15. That factor and others were probably responsible for the bids coming in well over the engineering estimate for cost of construction. The bids were beyond the limit set by state law for an award. For a number of reasons Douglas P.U.D. was anxious to provide some means of taking chinook out of the ladder in 1991. For one thing, part of the Rock Island Settlement Agreement calls for the chinook hatchery program as an alternative to spill at Rock Island Dam. In order to be able to proceed, the P.U.D. redesigned the facility to simplify it and bring the cost within the limits of a small works project. It was then installed in a simplified but working version. There is a flume in place. An operator can divert fish into a flume which takes them to a wheeled tank for transport to the hatchery. Biologists from the Intertribal Fish Commission also worked there last summer, sampling sockeye by netting them out of the ladder. The P.U.D. sees the need to complete the facility with a holding tank, an anesthetic tank, and a recovery tank. There was a discussion of whether the size of the tanks, their location near the stairs, and the space around them was sufficient for working with sockeye and chinook. Intertribe representatives felt that the plan as presented was good for their purposes. The discussion centered on its adequacy for chinook. Erho and Hopper emphasized that its primary function is as a collection device for chinook. Hopper expressed satisfaction in general with the way the system operated this year. Mortality of adults was low. As low as among volunteer chinook into the hatchery. Fryer reported that chinook entered slowly, perhaps two or three an hour. Erho said that criteria had been set to hold no more than 10 fish in the tank at one time, and to hold no fish for more than 1 hour. Bob Pearce expressed concern about the small size of the tanks (5 X 3 feet) fo chinook, and the limited working space around them. The Work Group decided that there should be a separate tank for chinook out in the open on the deck. It should be 6 feet long by three feet wide by four feet deep with 1 foot of freeboard to reduce the likelihood of fish jumping out. Bob Pearce recommended lining the flume with a soft material to protect the fish. He suggested some material and a way of attaching it.

Rick Klinge will try to arrange to have the drawings revised in time for the next meeting, which will be November 13, 1991 at Wells Dam. The plan will incorporate four recommendations from the Work Group, as follows: 1). Reduce the spacing of the pickets, 2). Include the three tanks as shown in the plan for holding, anesthetizing and recovery of fish, 3). Add a larger tank for chinook outside on the deck, and 4). Line the flume with soft material.

Traps for Taking Brood Stock in Tributaries.
Rick Klinge called upon Mike Erho to summarize the development of plans for the tributary traps. Erho reviewed the sequence of events up to date. The intention is to take fish from the tributaries after the stocks have separated. Otherwise, there are advantages to taking them at Wells Dam. For example, it would be possible at Wells Dam to take fish throughout the duration of the run, whereas in the tributaries it will be necessary to depend upon traps that will only be effective at certain times, depending on river flow. As the Settlement Agreement was being fleshed out, the parties began to look for sites where brood stock could be taken. The upper Methow River and its tributaries, the Twisp River and the Chewack River

were identified as having the desired characteristics. The Foghorn Ditch on the Methow is a source of water for the U.S. Fish and Wildlife Service hatchery at Winthrop. As part of the arrangements that made the Settlement Agreement possible, the P.U.D. contracted with the Fish and Wildlife Service to improve the intake at the Foghorn Ditch, in exchange for which the Fish and Wildlife Service agreed to provide for P.U.D. hatchery use, in an emergency low river flow situation, a volume of water out of their water right. The U.S. Fish and Wildlife Service is proceeding with work on the ditch intake. In addition, as the facility on the Chiwawa was being built by Chelan P.U.D., Douglas P.U.D. asked FISHPRRO to look at the potential for constructing such a floating weir on the Twisp River to collect chinook brood stock for Douglas' hatchery program on the Methow. They identified 12 potential sites. The preferred site was complicated by difficulty in obtaining easements, so they went to the second choice, which was adjacent to the acclimation pond where the P.U.D. already had land. Again the P.U.D. had problems with bids that came in too high to award. They only had two bids. To move ahead, the P.U.D. split the job into phases. Phase I is installation of the concrete sill. That job went out on a small works contract for a $70,000 bid. In fact, the total job, including installation of the floating weir, then came in at less than $100,000, so they will be able to proceed with a full award. He reminded the group that at the August meeting, the Wells Coordinating Committee had agreed to go with the floating weir concept on the Twisp River and that the concrete sill portion should be provided as designed. He called upon Ed Donahue of FISHPRO for a discussion of the design of the floating weir itself. Ed pointed out that the work is actually divided into 4 phases. Phase III calls for anchoring of the weir, and Phase IV for providing the slats and finishing the weir. FISHPRO has some ideas for improvement of the weir itself to strengthen it and prevent some of the problems encountered with the Chiwawa River weir. Steve Rainey had some questions that arose as a result of his being left off the mailing list to receive copies of the plan. Erho apologized for that omission on behalf of Douglas County P.U.D.. Rick Klinge promised to send a copy of the plans to NMFS immediately. In addition, Klinge asked FISHPRO to send NMFS a copy of a one-page summary description of improvements he proposes in the components of the weir. Participants were in agreement that communication in the committee should be improved.

There was a discussion of the effects of river flow on operation of the weir. Steve Rainey indicated that the floating weir is a compromise in design to arrive at an acceptable barrier. Floating weirs are able to function as traps only during medium levels of flow. They are submerged at high flows. Full blocking of the river would require a large structure, and these are no longer acceptable to the agencies or the public. Bob Heinith expressed concern about the potential effects on run timing of omitting part of the the run from the brood stock. He would like to discuss this at a future coordinating committee meeting.

There was a discussion of the Foghorn Ditch situation. Erho said that he hoped whatever was built at Foghorn would not preclude adding a collection system, but it is not included in the design at this time. He and Rick explored upstream for another site, and they, along with Ed Donahue, evaluated potential sites for a floating weir. There probably are 5 or more potential sites above the Foghorn intake. That is as far as plans have developed there. Rick will report any further developments at the meeting on November 13, 1991.

Chewack River Trap

Erho said that early on, the Fulton Dam and fish ladder looked feasible as a site for a trap. The P.U.D. came up with a simple proposal to determine whether it could be made to work. This was discussed at a meeting on August 19, 1991. Some modifications were suggested at that time. FISHPRO completed design work and the job was ready for bids. The bids came in too high. There is now a need to revise the plan. The group discussed some alternatives. FISHPRO presented a plan for a floating weir. Some concerns were expressed. Steve Rainey expressed the concern that fish might be blocked or delayed at the Fulton Dam, so a trap might not be effective unless passage there is improved. It was suggested that passage could be improved by moving some boulders below the dam to improve channel access, which would better lead fish to the ladder. Denil sidewall baffles could perhaps be added to improve fish ladder passage at mid-range flows. The work might be undertaken as an investigation of the feasibility of locating a permanent trap there. If fish are better able to find their way into the ladder as a result of some improvements in configuration of the fishway, dam, or the river below it, then the P.U.D. might proceed with a more extensive full facility later. Erho said if they work on the dam itself, they might as well locate the collection facility there as well. The work group did not arrive at a decision on this subject, but asked the P.U.D. to further explore the possibilities and to develop a proposal for consideration at the meeting of the committee on November 13, 1991. Hopper implored the group to develop some kind of collection system for next year so that her hatchery people can proceed with their responsibilities under the Settlement Agreement.

ATTENDANCE ROSTER
WORKING GROUP MEETING OCTOBER 28, 1991
WELLS PROJECT COORDINATING COMMITTEE

Name	Representing
Bill Hevlin	National Marine Fisheries Service
Bob Pearce	National Marine Fisheries Service
Ed Meyer	National Marine Fisheries Service
Dick Whitney	The Committee
Bob Heinith	Columbia River Intertribal Fish Commission
Jeff Fryer	Columbia River Intertribal Fish Commission
Cary Feldman	Power Purchasers
Ed Donahue	FISHPRO
Rick Klinge	Douglas County P.U.D.
Mike Erho	Douglas County P.U.D.
Kathy Hopper	Washington Department of Fisheries
Steve Rainey	National Marine Fisheries SErvice

WELLS PROJECT COORDINATING COMMITTEE
MEETING DECEMBER 12, 1991
SUMMARY[1]

Agreements Reached

1. Comments on the draft report on hydroacoustic evaluation of the bypass in 1991 will be provided within 60 days of this meeting.

2. There is a question whether a third year of evaluation of the bypass will be necessary. Douglas County P.U.D. was asked to consult a statistician for advice on what the probability would be of coming up with a number in the third year that would be different enough from the other two to conclude that the bypass is not meeting criteria.

3. There were no comments received on the draft study outline for radiotelemetric tracking of adult sockeye by the agreed upon deadline of December 5, 1991. Therefore, the outline is approved by the committee. Douglas County P.U.D. will proceed to negotiate a contract with one of the qualified investigators identified by the committee.

4. The committee will provide comments on the proposed agenda for a sockeye enhancement workshop to take place in February or March, 1992.

5. The next meeting was scheduled for January 29, 1992.

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The meeting was held at the Red Lion Inn near Sea-Tac in the afternoon of December 12, 1991, following the meeting of the mid-Columbia Coordinating Committee. The agenda followed was mailed to the Wells Project Coordinating Committee, along with the meeting announcement on December 2, 1991. Those in attendance are listed on the attached roster.

I. Discussion Common to the mid-Columbia and Wells Project Coordinating Committees.

There were items of common interest to both committees, so there was overlap in the agenda items. These included discussions of turbine efficiencies at the mid-Columbia projects, adult passage studies using radiotelemetry, predator indexing, and the Findings for 1990. The mid-Columbia P.U.D.'s provided diagrams illustrating turbine efficiencies for each project under specific flow conditions. For adult passage studies, the plan is to begin in 1992 with studies of sockeye at the Wells Project as recommended by the Wells Project Coordinating Committee. Then in 1993, the proposal would be to conduct an additional study to include chinook at all five projects in the mid-Columbia. Issuance of the Findings for 1990 will be delayed until the January 29, 1992 meeting.

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1. Prepared by R. Whitney

II. Status of 1991 Studies.

A. Wells Bypass Evaluation Draft Report for 1991. Rick Klinge called upon Gary Johnson of Biosonics for a report. Gary distributed a written report and reviewed it for the committee. Klinge asked for comments within a 60 day period so that the report can be finalized. During the spring outmigration in 1991 the evaluation extended over a 40 day period. This compares with 30 days in 1990. In 1990 there were periods of forced spill during the evaluation, during which time fish could enter the spillbay without being detected by the transducers. In 1991 there were no periods of that kind. Additionally, there were 24 turbine intake slots monitored in 1991 compared to 20 in 1990. The combination of factors led to an estimate with a very narrow confidence interval. They estimated that during the spring, 95% $\pm$ 0.15% of the fish approaching the project were diverted into the spillbays by the bypass baffles. During the summer outmigration, which extended 15 days, they estimated 97% $\pm$ 0.29% of the fish were diverted.

Klinge commented that the 1991 study is a better estimate of effectiveness of the bypass in several respects, due to the lack of forced spill in 1991 and the increased sampling rate both in time and space.

B. Spring Chinook Spawning Ground Surveys in the Methow. Klinge distributed copies of a report by Thomas Meekin for the Yakima Indian Nation under contract to Douglas County P.U.D..

C. Hydroacoustic Studies of Sockeye Passage at Zosel Dam. Klinge reported that Biosonics will have a report available next month. This study extended from August through October, 1991 to monitor adult passage at Zosel Dam.

III. Operation Schedule for the Wells Bypass in 1992.

A. Plans for Bypass Operation. Klinge distributed a copy of an operating schedule for the bypass in 1992. This schedule is called for in the Settlement Agreement.

B. Plans for Bypass Evaluation. Klinge reminded the committee that at the last meeting he had introduced the idea of reducing the sampling intensity in 1992, because there appeared to be overkill in terms of the precision of the estimate of bypass effectiveness that was obtained. However, Douglas County P.U.D. has now decided that if the evaluation is conducted, it might as well be with the same design as in 1991. But, the thought has also occurred to them that due to the precision obtained, perhaps it might not be necessary to repeat the evaluation. There was a discussion of this suggestion. The committee asked Douglas P.U.D. to consult with John Skalski to provide an idea of the probability of obtaining an estimate in a third year that would be far enough away from the previously obtained estimates to lead to a conclusion that the bypass does not meet criteria specified in the Settlement Agreement.

IV. Status of 1992 Studies

A. Adult Delay Studies. Whitney noted that he had received no comments by December 5, 1991 on the study outline developed by the committee for radiotelemetry of sockeye . That deadline was agreed upon by the committee at the last meeting. Klinge said that Douglas County P.U.D. will therefore proceed to negotiate a contract with either the University of Idaho or National Marine Fisheries Service, the entities with whom the

committee had been discussing the proposed study.

B. Project Mortality. The committee had asked Klinge to discuss further with John Skalski the question of how many chinook might need to be marked in order to recover sufficient numbers at McNary Dam for a good estimate of project survival. His previous submission had been based on steelhead. Klinge distributed a report from Skalski based on expected chinook recoveries. The committee received this report without comment. It will require study. The numbers required for the study vary depending on the precision desired for the estimate and depending on the kind of water year expected (because this affects the recovery rate at Mcnary Dam), but are generally rather high.

V. Okanogan Sockeye.

A. Comments on Chapman Report. Klinge reported that he had received comments from Washington Department of Fisheries. He still expects something from the Colville Confederated Tribes.

B. Other Discussion. Rod Woodin reported that staff in Washington Department of Fisheries are preparing a proposal for Okanogan sockeye enhancement. He expects to distribute it at the January meeting.

In response to a request from the committee at a previous meeting, Klinge distributed a draft agenda for a sockeye workshop to be convened in late February or early March. He asked for comments or suggestions on the proposed agenda.

VI. Update on Methow Hatchery and Traps

Klinge called upon Ed Donahue for a progress report. Donahue reported that they expect to complete the hatchery facility by May, 1992. There are 3 trapping facilities. On the Twisp River, Phase I is completed. In Phase II, a final pour is being completed today. Phase III involves clearing of the site. And Phase IV will be installation of the weir panels, which involves future design of the weir. Mitsubishi has built a prototype and is testing it. He expects it to be installed in March. He expects the weir and trap at the Fulton Diversion on the Chewack River to be completed by spring. In the upper Methow, they are still looking for a site.

Mike Erho added that he had met today with Fish and Wildlife Service peoople regarding the design at the Foghorn Ditch. The intake structure itself needs the most attention, as well as some rock work on the dam itself. With Steve Rainey's advice from NMFS, they decided it was not a good site for brood stock collection. Fish and Wildlife Service and NMFS are working out the details of design and construction of the intake revision.

VII. Other Topics

A. East Ladder Trap Changes for 1992. Klinge distributed revised blueprints for the trap as it will be built. It includes the features agreed upon by the committee.

B. Other. The committee agreed to meet again at Sea-Tac on January 29, 1992. The chairman was asked to schedule the Wells Project Committee meeting in the morning, to be followed by the mid-Columbia Coordinating Committee in the afternoon.

ATTENDANCE ROSTER
WELLS PROJECT COORDINATING COMMITTEE
MEETING DECEMBER 12, 1991

Name	Representing
Rod Woodin	Washington Department of Fisheries
Jerry Marco	Colville Confederated Tribes
Tony Eldred	Washington Department of Wildlife
Ron Boyce	Oregon Department of Fish and Wildlife
Bob Heinith	Columbia River Intertribal Fish Commission
Edward Kudera	Biosonics, Inc.
Gary Johnson	Biosonics, Inc.
Cary Feldman	Power Purchasers
Tom Scribner	Yakima Indian Nation
Dick Whitney	The Committee
Bill Hevlin	National Marine Fisheries Service
Ken Pflueger	Douglas County P.U.D.
Rick Klinge	Douglas County P.U.D.
Mike Erho	Douglas County P.U.D.
Craig Tuss	U.S. Fish and Wildlife Service

Others Present During the Discussion of Items of Interest in Common With the Mid-Columbia Coordinating Committee.

Dick Nason	Chelan County P.U.D.
Willard Fields	Chelan County P.U.D.
Lowell Steuhrenberg	National Marine Fisheries Service
Labh Sachdev	Seattle City Light
Steve Hays	Chelan County P.U.D.
Stephen Brown	Grant County P.U.D.
Don Chapman	Consultant
Eldon Rickman	Chelan County P.U.D.
Tracey Steig	HTI
Elvin Quiring	Grant County P.U.D.
Don Zeigler	Grant County P.U.D.
Don Weitkamp	Parametrix, Inc.
Stuart Hammond	Grant County P.U.D.
Bruce Ransom	HTI
Dave Ward	Oregon Department of Fish and Wildlife
Tony Nigro	Oregon Department of Fish and Wildlife
Jim Petersen	U.S. Fish and Wildlife Service

1991 MEMBERSHIP LIST

OF THE

WELLS COORDINATING COMMITTEE

APPENDIX L

APPENDIX

1992 MEMBERSHIP LIST

OF

WELLS COORDINATING COMMITTEE

Mr. Ron Boyce
Oregon Department of Fish and Wildlife

Mr. Tony Eldred
Washington Department of Wildlife

Mr. Carey Feldmann
Puget Power Company

Mr. Bob Heinith
Columbia River Inter-Tribal Fisheries Commission

Mr. Bill Hevlin
National Marine Fisheries Service

Mr. Rick Klinge
Public Utility District No. 1 of Douglas County

Mr. Jerry Marco
Colville Confederated Tribes

Mr. Craig Tuss
U. S. Fish and Wildlife Service

Mr. Tom Scribner
Yakima Indian Nation

Dr. Richard R. Whitney
Wells Coordinating Committee Chairman

Mr. Rod Woodin
Washington Department of Fisheries

THE LONG TERM SETTLEMENT AGREEMENT

FOR

THE WELLS HYDROELECTRIC PROJECT

APPENDIX M

UNITED STATES OF AMERICA
FEDERAL ENERGY REGULATORY COMMISSION

Public Utility District No. 1 of Douglas County, Washington	)	Project No. 2149 Docket No. E-9569

SETTLEMENT AGREEMENT

This Settlement Agreement is entered into this 1st day of October, 1990, by the Public Utility District No. 1 of Douglas County, Washington (the PUD), Puget Sound Power & Light Company, Pacific Power and Light Company, the Washington Water Power Company, Portland General Electric Company (collectively the Power Purchasers), the Washington Department of Fisheries, the Washington Department of Wildlife, the Oregon Department of Fish and Wildlife, the National Marine Fisheries Service, the U.S. Fish and Wildlife Service, the Confederated Tribes and Bands of the Yakima Indian Nation, the Confederated Tribes of the Umatilla Reservation, and the Confederated Tribes of the Colville Reservation (collectively the Joint Fishery Parties).

I. GENERAL

A. PURPOSE AND SCOPE

1. This Agreement establishes the PUD's obligations with respect to the installation and operation of juvenile downstream migrant bypass facilities and measures; hatchery compensation for fish losses; and adult fishway operation at least until March 1, 2004, as described in subsection I.C. For purposes of the Wells Project, these measures, in conjunction with existing hatchery

compensation programs, and when carried out pursuant to this Agreement, shall be conclusively considered to fulfill the PUD's obligation to protect, mitigate, and compensate for the anadromous fish resource at least until March 1, 2004. These measures are expected to contribute to the Northwest Power Planning Council's goals of rebuilding the natural spawning populations of salmon and steelhead in the Columbia Basin and providing harvest opportunities.

2. This Agreement establishes the Joint Fishery Parties' obligations in support of this settlement. This Agreement also requires evaluation programs for fishery measures and establishes procedures for coordination between the PUD and Power Purchasers and the Joint Fishery Parties.

3. It is the intent of the Parties that this Agreement shall be the basis for the dismissal of the Mid-Columbia proceeding, Docket No. E-9569, insofar as it pertains to the Wells Project, and for compliance by the PUD with the Northwest Power Planning Council's 1987 Columbia River Basin Fish and Wildlife Program, as amended.

4. The fish passage, mitigation, and compensation measures set out in this Agreement are intended to implement Article 41 of the License for Project No. 2149 issued by FERC to the PUD. The PUD's obligations under this Agreement shall be enforceable as if they were conditions of its FERC license. Notwithstanding any other provision of its FERC license, once this Agreement is approved by FERC the PUD shall be bound by the terms of this

Agreement.

5. For purposes of this Agreement, except under subsections VI.B, VII.B and E, VIII.B and D, the Power Purchasers collectively will be a single Party. For all purposes under this Agreement, except under subsections VI.B, VII.B and E, VIII.B and D, the Power Purchasers shall participate through a single representative, whom they will designate from time to time.

B. DURATION

The term of this Agreement shall commence on the date of execution by all Parties and shall continue for the term of the current license for the Wells Project, plus the term of any annual licenses which may be issued after the current license has expired.

C. MODIFICATIONS TO THE AGREEMENT

1. Notwithstanding subsection I.B, at any time after March 1, 2004, any Party may request all other Parties to commence negotiations to modify the terms and conditions of this Agreement in whole or in part. Any such modification shall be subject to FERC approval, except that the Parties may agree to implement on an interim basis, pending FERC approval, any measure not requiring prior FERC approval. No Party shall file a petition with FERC pursuant to subsection I.C.2 to modify this Agreement without first presenting the proposed modification to all Parties and allowing a reasonable opportunity to negotiate, not to exceed 90 days without consent of all Parties.

2. Subject to the limitation stated in the above subsection, at any time after March 1, 2004, any Party to this Agreement may:

(a) Request the imposition by the FERC of different, additional, reduced or modified fish protection measures;

(b) Bring any cause of action, raise any defense or claim, or rely on any theory related to this Agreement in any appropriate forum;

(c) Petition any appropriate administrative agency or political body for relief, including the deletion or addition of one or more measures otherwise in effect under this Agreement; or

(d) Take other appropriate action relating to any issue or matter addressed by this Agreement or which could have been addressed by this Agreement or that otherwise relates to the fisheries issues of the Wells Project.

3. In any action under this subsection I.C, the petitioning Party shall have the burden of proof. The Parties will continue to implement this Agreement pending final resolution of any modification sought in the FERC, or until the relief sought becomes effective by operation of law, or unless otherwise agreed.

4. With respect to any petition or suit filed pursuant to this subsection I.C and any subsequent judicial review thereof, nothing in this Agreement shall bar, limit or restrict any Party from raising any relevant issue of fact or law, regardless of whether such issue is or could have been addressed by this Agreement. Notwithstanding any other provision of this Agreement, no claim shall be made for damages arising from the failure to provide or the provision of inadequate downstream fish passage facilities or programs, or upstream adult passage facilities, or

both, that might have arisen during the period March 7, 1979, through March 1, 2004.

5. Notwithstanding any other provision of this subsection I.C, any Party may participate in any legislative or administrative proceeding dealing with fish protection or compensation issues provided, that, consistent with this subsection, no Party shall advocate or support the imposition of fish protection, mitigation, or compensation measures at the Wells Project that are different from or in addition to those required by this Agreement until after March 1, 2004.

6. The Parties intend that this subsection I.C shall apply to each and every provision of this Agreement, and therefore the terms of this subsection are hereby incorporated by reference into and shall apply to every other provision of this Agreement as if set out fully in each such provision.

D. RESOLUTION OF DISPUTES

1. Any dispute between the Parties concerning compliance with this Agreement shall be referred for consideration to the Wells Project Coordinating Committee (the Coordinating Committee) established under Section V. The Coordinating Committee shall convene as soon as practicable following issuance of a written request by any Party. All decisions of the Coordinating Committee must be unanimous. In the event the Coordinating Committee cannot resolve the dispute within fifteen (15) days after its first meeting on a dispute, it will give notice of its failure to resolve the dispute to all Parties. Thereafter, if the dispute qualifies

under subsection I.D.2, any Party may request the FERC to refer the dispute to (1) the presiding judge in the Mid-Columbia proceeding; or (2) in the event the Mid-Columbia proceeding is terminated, to the Chief Administrative Law Judge of the Commission; or (3) to the Division of Project Compliance and Administration within the Office of Hydropower Licensing, or its successor (any one of which is hereinafter referred to as the Decisionmaker), in the order listed herein (unless otherwise agreed by the Parties or directed by FERC), for expedited review in accordance with the procedures set forth in this subsection. Any issue in dispute that is not subject to the expedited review process may be referred to the FERC for resolution pursuant to the FERC's Rules of Practice and Procedure.

2. The expedited review process specified in this subsection shall be utilized, unless otherwise agreed pursuant to subsection I.D.5, to resolve any issue(s) in dispute between the Parties that arises under this Agreement where the amount in controversy is less than $325,000 (1988 dollars). For the purpose of this subsection I.D, the amount in controversy shall be determined by calculating the difference between the calculated annual cost of the Joint Fishery Parties' proposal for resolution of the dispute and the calculated annual cost of the PUD's proposal for resolution of the dispute.

3. Under the expedited review process, each Party that desires to present an initial position statement to the Decisionmaker shall file the statement with the Decisionmaker and all other Parties within twenty (20) days of mailing of notice by a

Party that expedited review is requested. Responsive statements shall be filed and served within forty (40) days of the mailing of the notice. The Decisionmaker shall set a date for submission of any briefing, affidavits or other written evidence and a further date for hearing of oral evidence and argument. Except by agreement of all Parties involved in the dispute, the hearing shall be held not later than seventy (70) days after the date of mailing of the requesting Party's notice or as soon thereafter as the Decisionmaker shall be available. The hearing shall be held in Seattle, Portland or any other location agreed upon by the Parties, or mandated, upon a finding of special circumstances, by the Decisionmaker. The Decisionmaker shall decide all matters presented within fifteen (15) days of the hearing or as soon thereafter as possible.

4. All decisions under the expedited review process shall be effective upon issuance and pending appeal, if any. Nothing in this subsection I.D shall limit or restrict the right of any Party to petition the FERC for de novo review of any decision under the expedited review process. All such appeals shall be in accordance with the FERC's Rules of Practice and Procedure.

5. The Parties may agree to refer any issue subject to expedited review to a third party Decisionmaker other than someone within FERC for processing pursuant to this subsection or as otherwise agreed by the Parties.

E. EFFECTIVE DATES

1. Except as otherwise specified in this subsection I.E, this Agreement shall become effective upon the issuance of a final order by the FERC approving this Agreement.

2. Notwithstanding subsection I.E.1 above, the Parties will immediately upon execution of this Agreement, implement the provisions of the Agreement that do not require formal FERC approval.

3. The Parties agree to immediately seek interim approval by the FERC of Section IV of this Agreement in order to implement construction of hatchery facilities.

II. JUVENILE FISH PASSAGE

A. GENERAL SCOPE OF JUVENILE PASSAGE MEASURES

1. Subject to the schedules, criteria, and conditions in this Agreement, the PUD will fund the installation, operation, maintenance, and evaluation of juvenile fish bypass systems and measures at the Wells Project. Bypass systems and measures are those intended to attract and route juvenile salmonids past operating powerhouse generating units.

2. All facilities under this Agreement shall be designed and constructed using quality materials and then current engineering standards for the purpose of obtaining a high quality product designed to require low maintenance and have a long useful life.

B. BYPASS SYSTEM

The PUD will continue to implement a program of controlled spill using five (5) bypass baffles at the Wells Project to meet the criteria set out in subsections II.C, D, and E.

C. NORMAL BYPASS OPERATIONS CRITERIA

1. No turbine will be operated during the juvenile migration period unless the adjacent bypass system is operating according to the following criteria.

2. The five (5) bypass system bays will be Nos. 2, 4, 6, 8, and 10. Operation of the turbines will be in pairs with the associated bypass system bays, as follows:

Turbines Operated	Bypass Bays Operated
1 and/or 2	2
3 and/or 4	4
5 and/or 6	6
7 and/or 8	8
9 and/or 10	10

(For example, if turbines 1, 5, and 6 are operating, bypass systems 2 and 6 will be operating.)

3. At least one bypass will be operating continuously throughout the juvenile migration period, even if no turbines are operating.

4. The bypass systems and spillgates will be operated in configuration K of the 1987 bypass system report (bottom spill, 1 foot spill gate opening, 2,200 cfs, vertical baffle opening) for all bypass system bays.

5. If top spill is shown to be as effective as bottom spill in bypass bays 2 and 10, then top spill will be allowed in these bays.

6. If the Chief Joseph Dam Uncoordinated Discharge Estimate is 140,000 cubic feet per second (140 Kcfs) or greater for the following day, all five bypass systems will be operated continuously for 24 hours regardless of turbine unit operation.

7. If the Chief Jcseph Dam Uncoordinated Discharge Estimate is less than 140 Kcfs, bypass system operation will be as follows:

Number Turbines Operating	Minimum Number Bypass Systems Operating
10	5
9	5
8	4
7	4
6	3
5	3
4	2
3	2
2	1
1	1
0	1

D. BYPASS OPERATIONS TIMING CRITERIA

1. Bypass systems will be in place at least two (2) weeks prior to preseason forecasted beginning of juvenile migration.

2. Bypass systems will remain in place for at least two (2) weeks after the juvenile migration period ends.

3. Monitoring of fish runs will begin when bypass baffles are in place and will end when the baffles are removed.

4. Bypass systems will be available to operate continuously, 24 hours per day, during the juvenile migration period.

E. BYPASS PERFORMANCE CRITERIA

1. At a minimum, bypass system operations will be provided as described in subsections II.B, C, and D for the entire juvenile migration period as defined in the annual operations plan under subsection II.F, and subject to the provisions of subsection II.F.3.

2. Bypass operations as described in subsections II.B, C, and D are intended to provide fish passage efficiency (FPE) of at least eighty percent (80%) for the juvenile spring migration, and FPE of at least seventy percent (70%) for the juvenile summer migration. For purposes of this Agreement, FPE is expressed by the following formula:

Where A = Sum of daily migrants successfully passed by the device during the spring or summer migration

and B = Sum of daily migrants passing through the turbine unit intakes during the same migration

$$FPE = \frac{A}{A + B} \times 100$$

3. If bypass operations under subsections II.B, C, and D do not meet the minimum FPE levels specified in subsection II.E.2, the PUD will modify those operations by implementing one or more of the following measures:

(a) Change in configuration or addition of lights or other physical changes.

(b) Change in "normal operation" under subsection II.C to operation of five bypass system bays at forecast flow of 120 Kcfs.

4. Unless and until these modifications are in place to meet the minimum FPE levels specified in subsection II.E.2, or if these modifications are not sufficient to meet the FPE levels specified therein, then the PUD will increase spillbay bypass flow up to two times normal operation (up to a total of 4.4 Kcfs) per bypass at night (1 hour before sunset to sunrise) for the period:

(a) During which 80% of the spring migration pass the Wells Project;

(b) During which 80% of the summer migration pass the Wells Project, or for 40 days, whichever is less.

5. If portions of the runs do not receive protection at the minimum FPE levels specified under subsection II.E.2, then compensation will be provided based on the difference between the minimum FPE levels specified in subsections II.E.2 and 3 and the actual FPE achieved during the evaluation provided under subsections II.H.1 and 2. The appropriate level of compensation will be calculated based on actual loss. The form of this additional compensation (i.e., fish production) will be determined by the Joint Fishery Parties in consultation with the PUD.

F. <u>ANNUAL OPERATIONS PLANS</u>

1. The PUD will develop an annual bypass systems operations plan consistent with the criteria in subsections II.B, C, D, and E in consultation with the Joint Fishery Parties by the December prior to each migration period. The plan will be reviewed and approved by the Coordinating Committee by March 1 of each year. The plan will be developed from inseason projected hatchery release

dates from facilities above Wells and previous passage monitoring data. The plan will contain predicted dates for the beginning and end of the juvenile migration period; criteria for identifying the beginning and end of the spring and summer runs; and procedures for bypass operations within the constraints of subsections II.B, C, D, and E, including dates for installation and removal of spill baffles, dates for run time monitoring, and criteria for initiation and cessation of bypass operations. If unanimous agreement cannot be reached within the Coordinating Committee regarding all items in the plan, disagreements will be resolved by expedited dispute resolution under subsection I.D.

2. A Bypass Team will be established composed of one representative each for the Party fishery agencies, the Party tribes, and the PUD.

3. Notwithstanding the provisions of subsections II.F.1 and 2 above, the Bypass Team may agree to relax the operations and performance criteria of subsections II.C and E for a period between the end of the juvenile spring migration and the beginning of the juvenile summer migration. Such a modification can only be made with the agreement of all of the members of the Bypass Team, and will be limited to one or more of the following measures:

(a) Less than continuous 24-hour operation of bypass systems.

(b) Fewer than one bypass system operated for two adjacent turbines operated.

(c) Less than 1 foot spill gate slot opening.

4. Once the annual bypass plan is adopted, decisions regarding adjustments to the plan will be made by unanimous agreement of the Bypass Team. If unanimous agreement cannot be reached, the decision on such adjustments will be by majority vote of the Bypass Team.

G. ANNUAL PASSAGE MONITORING PLAN

1. The PUD shall develop an Annual Passage Monitoring Plan, in consultation with the Joint Fishery Parties for review and approval by the Coordinating Committee by March 1 of each year. The Plan will include development of inseason indices of relative fish abundance on a daily basis and annual estimates of juvenile migrant production. Estimates of relative abundance will be used to guide bypass operations decisions under subsections II.E.4, II.F.1, II.F.3, and II.F.4. Estimates of juvenile migrant production will be used as the basis for compensation adjustments (Hatchery-Based Compensation - Phase IV) as provided in subsection IV.A.3.

H. FPE EVALUATION PLAN

1. The PUD shall develop an FPE evaluation plan, in consultation with the Joint Fishery Parties, for review and approval by the Coordinating Committee by March 1, 1990. The purpose of the plan shall be to evaluate whether minimum FPE levels set out in subsection II.E are being met. The plan will provide for evaluation beginning in 1990 and continuing for at least three consecutive years after baffles are installed and operating in accordance with this Agreement in all five (5) bypass bays. If physical or

operational changes are made to the bypass systems, additional FPE evaluation under a new or amended plan will be required to provide at least three consecutive years of evaluation after completion of the changes.

2. It is the goal of evaluations under the plan to be able to determine FPE within plus or minus five percent (5%) at the ninety-five percent (95%) confidence level. If the FPE point estimates are equal to or greater than eighty-five percent (85%) for the spring run and seventy five percent (75%) for the summer run, then the accuracy of plus or minus ten percent (10%) at the ninety percent (90%) confidence level is acceptable. If the FPE point estimate for the spring run is between eighty (80) and eighty-five (85) percent, or the FPE point estimate for the summer run is between seventy (70) and seventy-five (75) percent, the PUD will implement one of the following actions:

(a) Take the necessary steps to achieve a FPE accuracy of plus or minus five percent (5%) at the ninety-five percent (95%) confidence level, or

(b) Take steps outlined in subsection II.E.3 to increase the FPE point estimates to eighty-five percent (85%) and seventy-five percent (75%) for the spring and summer runs, respectively.

3. The PUD will fund a biometrician or statistician selected by unanimous agreement of the Coordinating Committee to review the draft plan to ensure that the plan meets the objectives of subsections II.H.1 and 2, and to review results developed under the plan.

III. ADULT FISH PASSAGE

A. GENERAL SCOPE OF ADULT PASSAGE MEASURES

The current operating and maintenance criteria for facilities for the passage of adult anadromous fish over the Wells Project Dam are specified in this Section III. Changes in these criteria must be by unanimous agreement of the Coordinating Committee.

B. WATER DEPTH CRITERIA

The water depth over the weirs of the adult fish ladder will be 1.0 to 1.2 feet.

C. ENTRANCE CRITERIA

1. Head: 1.5 feet

2. Gate Settings:

a) March 1 - November 30

	Side Wing Gate	End Wing Gate
(i) Spill less than 80 Kcfs	4 ft	6 ft
(ii) Spill greater than 80 Kcfs	Closed	8 ft

(iii) Low level fixed orifice entrance to be open whenever side gate is closed.

b) December 1 - February 28

(i) Side and end gates open 2 feet six days per week for 24-hour periods.

(ii) Side and end gates open 4 feet and 6 feet, respectively, one day per week for a 24-hour period.

D. ATTRACTION JET CRITERIA

1. Jets are located in a vertical line immediately upstream of the side wing gates.

2. Lower jet (30-inch diameter) will operate only when the low level fixed orifice entrance is open.

3. Three 24-inch diameter jets (at elevations 700, 708, and 717 msl) will each be discharging when tailwater reaches that level.

E. STAFF GAUGE AND WATER LEVEL INDICATOR CRITERIA

Staff gauge and water level indicators will:

1. Be located upstream and downstream of all entrances, and at convenient locations for viewing along ladder.

2. Be located upstream and downstream of adult fishway exit trashrack.

3. Be readable at all water levels and be kept clean.

4. Be checked against panel board water surface readings to insure proper adjustment of water level sensing equipment.

F. TRASHRACK CRITERIA

1. Visible buildups of debris will be cleaned immediately from picketed leads near counting stations, and from trashracks at adult fishway exits.

2. The staff gauges upstream and downstream of the adult fishway exit trashrack will be monitored for water surface differential, which will reflect buildup on submerged trashrack. The trashrack will be cleaned immediately if the differential reading is greater than 0.3 feet.

G. MONITORING AND EVALUATION OF ADULT PASSAGE

1. In 1990, the PUD, in consultation with the Joint Fishery Parties, will develop a study plan to determine the extent of adult

delay and mortality at the Wells Project. The study plan will be reviewed and approved in advance by the Coordinating Committee. Studies will begin in 1991 and continue for a period of time determined by the Coordinating Committee based on preliminary results.

2. If the study identifies delays and/or mortality, the operating criteria specified in this Section III will be changed to alleviate these problems. If changes in the operating criteria do not alleviate the problems, adult passage facility modifications will be made. Provided, however, that any disagreements over the appropriateness of facility modifications of $325,000 or less (1988 dollars) may be taken through the expedited dispute resolution procedure in subsection I.D. And, provided further, that any disagreements over the appropriateness of facility modifications of more than $325,000 (1988 dollars) may be resolved under the FERC Rules of Practice and Procedure at any time.

IV. HATCHERY-BASED COMPENSATION

The PUD will fund a hatchery-based compensation program (the "Program") as provided in this Section IV. The Program will include the design, construction, operation, maintenance and evaluation of facilities required to implement the elements of a production plan (the "Production Plan") as set forth in this Section. The purpose of the Program is to mitigate for fish passage losses at Wells Dam. The Program is composed of adult collection sites; a central hatchery facility for incubation, early

rearing, and adult holding; and acclimation facilities in the tributaries above Wells Dam for final rearing and release.

A. PRODUCTION PLAN

1. The Joint Fishery Parties have developed the Production Plan to define the requirements of hatchery-based compensation under this Agreement. The Production Plan describes juvenile rearing and release requirements, including species mix and target release sizes; and related broodstock requirements under subsection IV.D.

2. The Production Plan will be reviewed annually by the Joint Fishery Parties, and may be modified by the Joint Fishery Parties in consultation with the PUD. Modifications to the Production Plan may include changes to the species mix and rearing and release strategies as required to accommodate the Joint Fishery Parties' management needs. Modifications to the Production Plan will not require an increase in the rearing capability of the Program beyond that required to satisfy Phases One and Two of the Production Plan as shown in subsections IV.A.3(a) and (b) or Phases Three and Four of the Production Plan to be determined as shown in sections IV.A.3(c) and (d). The Production Plan and any modifications thereto will be consistent with guidelines and procedures developed under the Northwest Power Planning Council's Columbia River Basin Fish and Wildlife Program.

3. The Production Plan is comprised of four phases of hatchery-based compensation as described below. It also includes related broodstock requirements under subsection IV.D.

(a) Phase One

Phase One will begin in 1991 and will consist of the following compensation elements:

(1) 49,200 pounds of spring chinook yearlings at about 15/pound;

(2) 8,000 pounds of sockeye juveniles at about 25/pound; and

(3) 30,000 pounds of steelhead smolts at about 6/pound

(4) After 1991, space to rear additional steelhead will be provided by the PUD at Wells Hatchery, if such space is available and not needed to meet other PUD fish production responsibilities. The PUD will not be obligated to fund or supply well water to rear the fish.

(b) Phase Two

Phase Two will begin after evaluation of the Phase One Production Plan and will be restricted to the Program required by either the Phase Two A or Two B Production Plan as shown below. At the time of implementation, the Phase Two A or Phase Two B Production Plan may be modified based on other Phase One evaluations described in subsection IV.C, Studies and Evaluations, subject to the provisions of subsection IV.A.2.

(1) Phase Two A

Increase sockeye production from 8,000 pounds to 15,000 pounds of juveniles at about 25/pound.

(2) Phase Two B

(i) Eliminate sockeye production;

(ii) Add 15,000 pounds of summer chinook yearlings at

about 10/pound; and 6,500 pounds of zero-age summer chinook juveniles at about 40/pound.

(c) Phase Three

Phase Three will begin as soon as practicable following Coordinating Committee approval of the results of the Wells Project juvenile mortality/survival study or no later than the third brood year after Coordinating Committee determination of the adjustments required and will consist of the following compensation elements:

(1) Except for steelhead, which shall remain at 30,000 pounds, adjust compensation requirement to reflect the difference between the juvenile mortality rate determined by the mortality/survival study under subsection IV.C.5 and the assumed mortality rate shown in Appendix A; and

(2) Adjust compensation requirement to reflect unavoidable and unmitigated adult losses, as determined by Coordinating Committee approved estimates from studies conducted under subsection III.G, and converted to juvenile production based on adult to smolt ratio estimates as described in Appendix B.

(d) Phase Four

Phase Four will begin at such time as the Coordinating Committee approved five-year rolling average estimate of juvenile run size, estimated as described in subsection IV.C.6 and Appendix A, increases to at least 110% of the 9,034,700 estimated juvenile migrant salmon production used to establish the Phase One and Phase Two compensation levels shown in subsections IV.A.3(a) and

IV.A.3(b). Phase Four will consist of compensation adjustment, if requested by the Joint Fishery Parties, to reflect the percentage increase in juvenile run size, except for steelhead, which shall remain at 30,000 pounds. The Joint Fishery Parties, in consultation with the PUD, will determine the appropriate form of compensation (i.e., fish production) for any adjustments required in Phase Four.

B. COMPENSATION PROGRAM

1. The facilities provided in the Program will be designed, constructed, operated, maintained, and evaluated to produce the hatchery-based compensation set forth in the Production Plan.

2. If the evaluations described in subsection IV.C indicate that the Program is not meeting the production levels called for in the Production Plan, then reasonable modifications to the Program will be made.

3. The PUD will only be obligated to assure the capability of facilities provided under this Agreement to produce high quality juvenile fish at the compensation levels shown in subsection IV.A.3.

4. The Program facilities described in this Agreement are in addition to the existing mitigation program at Wells. The existing mitigation program at Wells consists of annual production of 50,000 pounds of steelhead and 56,500 pounds of summer chinook salmon. Under the 1984 Mid-Columbia Stipulation, which expired in 1989, 400,000 summer chinook at 90/pound have been reared at Wells for release into the Methow River. This production will continue until

Phase One production is initiated. Nothing in this Agreement will affect the annual production of 25,000 pounds of steelhead under the Oroville-Tonasket agreement between the PUD and the U.S. Bureau of Reclamation.

5. Facilities provided in the Program will consist of:

(a) Phase One

Phase One compensation facilities, including satellite facilities, shall be capable of rearing and releasing 57,200 pounds of salmon and 30,000 pounds of steelhead annually.

(b) Phase Two

Phase Two compensation facilities shall be capable of increased production to accommodate the Production Plan as described in subsection IV.A.3(b).

(c) Phase Three

Phase Three compensation facilities shall be capable of production levels to reflect the compensation adjustments which may be required as described in subsection IV.A.3(c).

(d) Phase Four

Phase Four compensation facilities shall be capable of production levels to reflect the compensation adjustments which may be required as described in subsection IV.A.3(d). Facilities for the required adjustments will be constructed by the PUD as soon as practicable and be operational no later than the third brood year following the Joint Fishery Parties request under subsection IV.A.3(d).

6. Production and acclimation facilities used in the Program shall be consistent with planning efforts underway by the Northwest Power Planning Council to the fullest extent practicable. The biological criteria and guidelines described in subsection IV.D shall apply to production and acclimation facilities used in the Program.

C. STUDIES AND EVALUATIONS

1. The PUD will develop and fund studies in 1990, approved by unanimous agreement of the Coordinating Committee, to determine:

(a) Potential for spawning and rearing sockeye in unutilized habitat in the Okanogan and Similkameen systems;

(b) Potential for establishing sockeye populations in the new habitat.

2. The PUD will fund the Joint Fishery Parties' effort to determine the success of Phase One sockeye compensation based on review of smolt production. The Joint Fishery Parties may make this determination after the evaluation of the third brood year's production.

3. The PUD will fund the Joint Fishery Parties to develop and conduct studies to evaluate the adequacy of the Program and the effectiveness and success of the Production Plan subject to the provisions of Section V, Coordinating Committee. The studies will meet standards developed for similar efforts under the Northwest Power Planning Council's Columbia River Basin Fish and Wildlife Program. The studies will pass the test of reasonableness with respect to cost and duration.

(a) The studies will involve marking a portion of the juvenile fish produced under subsection IV.B and will involve recoveries of juvenile and adult fish to estimate various parameters such as fish health, fishery contribution, survival, spawning time and spawning locations.

(b) The PUD will fund recovery efforts at Wells Dam and hatchery and tributary spawning areas above Wells Dam. Existing recovery operations, currently funded through different sources, will be utilized to the extent possible. Approved studies may require the PUD's participation in funding a portion of other recovery efforts.

(c) The evaluations provide data necessary to determine the success of the Program to produce the intended compensation levels and the effectiveness of the Production Plan to meet management objectives.

(d) Evaluation of the Production Plan and Program effectiveness will be initiated in Phase One for all species in the Production Plan.

(e) To the extent that the Joint Fishery Parties elect to modify the Production Plan, the PUD will fund studies to evaluate the modifications. The studies will be mutually agreeable and are intended to evaluate only the changes called for in the modification. The studies will be consistent with the provisions of Section V, Coordinating Committee.

(f) The PUD will fund an analysis of annual fish production and adult contribution to harvest and escapement to be conducted

by the Joint Fishery Parties. The analysis will be consistent with the provisions of Section V, Coordinating Committee. Draft and final reports will be provided to the Parties.

5. No later than 1990, a Wells Project juvenile mortality/survival study will be developed by the PUD in consultation with the Joint Fishery Parties and approved by unanimous agreement of the Coordinating Committee. The studies will begin in 1991, after the installation of new turbine runners at the Wells Project, for the purpose of determining juvenile losses.

6. The PUD will provide data from its ongoing, annual adult passage monitoring program that will allow the Joint Fishery Parties to compute the five-year rolling average estimate of juvenile run size which will be the basis for Phase Four compensation, as indicated in subsection IV.A.3(d). Calculation of increases in juvenile run size will be based on fish from existing mitigation programs, natural production and future compensation programs. The method of calculation will be as described in Appendices A and B.

D. PRODUCTION/ACCLIMATION FACILITIES

Production and acclimation facilities under this Section shall be consistent with planning efforts underway by the Northwest Power Planning Council to the fullest extent practicable. The following biological criteria and guidelines shall apply to production and acclimation facilities under this subsection IV.D. Criteria are not to be exceeded. Guidelines are not to be exceeded if practicable.

1. Salmon Criteria

(a) Adult Holding

(i) Density not to exceed one (1) fish per ten (10) cubic feet of space.

(ii) Flow must be at least one (1) gallon per minute per 20 pounds of fish.

(b) Juvenile Rearing

(i) Density not to exceed 0.75 pounds of fish per cubic foot of rearing space for yearling chinook to a size of 10 fish per pound. Maximum density is achieved at release date. The density through out the rearing period is proportionately lower and directly related to fish size.

(ii) Pond or raceway loading rate not to exceed 6.0 pounds of fish per gallon of water per minute inflow for yearling chinook at a size of 10 fish per pound. Maximum loading rate is achieved at release date. The loading rate throughout the rearing period is proportionately lower and directly related to fish size.

(iii) Density for sockeye juveniles in net pens not to exceed 0.33 pounds of fish per cubic foot of rearing space.

(c) Water Supply

(i) Water will be of highest quality practicably available at appropriate sites. Ground water may be required at sites. All water supplies will be pathogen free if practicable. The water source must not preclude transfer of the stocks being reared to their point of origin due to presence of fish disease organisms in the rearing water supply.

(ii) Reuse of water is not acceptable for either egg incubation or juvenile rearing.

(iii) Reuse water is acceptable for adult holding.

(iv) Effluent water from egg incubation may require treatment for fish diseases (e.g., chlorination/dechlorination).

(v) Construction of facilities must accommodate the potential to treat the juvenile rearing and adult holding water for disease pathogens.

(d) General

(i) Facilities must have the capability to maintain stock segregation from adult holding through incubation and rearing.

(ii) Facilities must have reasonable capability to provide for isolation and treatment of diseased fish.

(iii) Protection from mammalian and avian predators must be provided.

2. Salmon Guidelines

(a) Water Temperatures

(i) Egg incubation - no greater than 55°F nor less than 38°F.

(ii) Fry starting - 48-52°F.

(iii) Juvenile rearing - not to exceed 52°F.

(iv) Adult holding - not to exceed 55°F.

(b) Release Size, Time, and Location

(i) Yearling spring chinook - 15 fish/pound in late April.

(ii) Yearling summer chinook - 10 fish/pound in late April.

(iii) Subyearling summer chinook - 40 fish/pound in June.

(iv) Subyearling sockeye - 25 fish/pound in June.

(v) Juvenile fish will be acclimated and released in tributaries above Wells Dam.

(c) Adult Brood Stock

(i) Sufficient adults of the appropriate species and stocks will be trapped and held to meet the egg requirements for each phase of salmon production.

(ii) Fifty percent (50%) of the adults trapped will be females and it is assumed there will be

approximately eighty percent (80%) survival of eggs from trapping of females to ponding of fry.

(iii) Adult brood stock will be collected at the following sites:

a) Spring chinook - Chewack River, Methow River above Winthrop, and Twisp River above river mile 2.0.

b) Summer chinook and sockeye - at Wells Dam

(iv) Tributary brood stock collection facilities will require an annually installed rack and a semi-permanent box trap.

(v) Wells Dam brood stock collection may require a separator/sorter in the left bank fishway. The final design of the left bank trap and any modification of the right bank trap will be approved by unanimous agreement of the Coordinating Committee.

(vi) The adults will be transferred in a water-to-water system from traps to tank trucks to holding ponds.

(vii) The PUD shall provide funds for personnel to separate and sort adult fish in the right bank fishway at Wells Dam and at other required adult collection sites. All brood stock collection shall be conducted in a manner to

minimize delay of non-target species and individual fish.

3. Steelhead Criteria

The goal for this program is to use the existing facilities including well and river water, raceways, rearing ponds, house, shop, freezer, office, etc., in the manner they are being used now. Most of the following criteria and guidelines fit the existing program.

(a) Adult Holding

(i) Density not to exceed 2.5 pounds of fish per cubic foot of water.

(ii) Flow must be at least one gallon per minute for 3.3 pounds of fish.

(b) Juvenile Rearing

(i) Density: Calculated density limit not to exceed Pipers density formula: $W = D \times V \times L$ where

W = Permissible weight in pounds.

D = Density index (.25 for raceways and .03 for rearing ponds).

V = Useable volume in container in cubic feet.

L = Fish length in inches.

ii) Water flow: Calculated flow should not allow weight to exceed Pipers flow formula:

$W = F \times L \times I$ where

W = Permissible weight in pounds.

F = The loading factor from Table 1.

L = Fish length in inches.

I = Water flow in gallons per minute.

Table 1. Load factor as related to water temperature and elevation.

Water Temperature(°F)	Load Factor(lbs/in/gpm) Raceways(1)	Rearing Ponds(2)
40	2.70	3.62
41	2.61	3.53
42	2.52	3.44
43	2.43	3.35
44	2.34	3.26
45	2.25	3.17
46	2.16	3.08
47	2.07	2.99
48	1.98	2.90
49	1.89	2.81
50	1.80	2.72
51	1.73	2.65
52	1.67	2.59
53	1.61	2.53
54	1.55	2.47
55	1.50	2.42
56	1.45	2.37
57	1.41	2.33
58	1.36	2.28
59	1.32	2.24
60	1.29	2.21
61	1.25	2.17
62	1.22	2.14
63	1.18	2.10
64	1.15	2.07

1) From Piper et al. 1978
2) From Wells hatchery

(c) Water Supply

(i) Water supply to be of highest quality practicably available using ground and river water. Any disease contracted because of water source

must not stop release of fish in local watersheds.

(ii) Reuse water not acceptable for egg incubation.

(iii) Reuse water normally acceptable (unless disease problem) for adult holding.

(iv) Effluent water from egg incubation will require treatment for fish diseases.

(v) Adult holding and juvenile rearing water may have to be treated for disease pathogens.

(d) General

(i) Facilities must have reasonable capability to provide for isolation and treatment of diseased fish.

(ii) Protection from mammalian and avian predators must be provided.

4. Steelhead Guidelines

(a) Water Temperatures

(i) Egg incubation: 38°F to 55°F

(ii) Fry starting: 48°F to 54°F

(iii) Juvenile Rearing not to exceed 57°F

(iv) Pre-smolt not to exceed 54°F

(v) Adult holding not to exceed 54°F

(b) Release age, time, size and location

(i) Released as yearlings

(ii) April 10 to May 10 at six to the pound.

(iii) Juvenile steelhead will be released in tributaries or into the mainstem above Wells Dam.

(c) Adult Broodstock

(i) Fifty percent (50%) will be females and assume eighty percent survival of eggs to ponding of fry.

(ii) Adults will normally be trapped at the existing facilities on the right bank, however new trap at left bank may be used sometimes.

(iii) Adults will be transferred in water from traps to holding ponds.

V. WELLS PROJECT COORDINATING COMMITTEE

A. COORDINATING COMMITTEE

There shall be a Wells Project Coordinating Committee composed of one (1) technical representative of each Party to this Agreement. The Coordinating Committee shall meet whenever requested by any two (2) Parties following a minimum of ten (10) days written notice (unless waived), or pursuant to subsection I.D, and shall act only by unanimous agreement of all Parties. Any Joint Fishery Party may, at any time, elect by written notice not to participate in the Coordinating Committee. The PUD shall fund a neutral third party to record and distribute minutes of Coordinating Committee meetings.

B. USE OF COMMITTEE

The Coordinating Committee will be used as the primary means of consultation and coordination between the PUD and the Joint Fishery Parties in connection with the conduct of studies and implementation of the measures set forth in this Agreement and for dispute resolution pursuant to subsection I.D. All study designs and modifications to study designs will be subject to agreement by all Parties.

C. STUDIES AND REPORTS

1. All studies and reports prepared under this Agreement will be available to all Parties as soon as reasonably possible. Draft reports will be circulated through Coordinating Committee representatives for comment, and comments will either be addressed in order or made an appendix to the final report.

2. All studies will be conducted following accepted techniques and methodologies in use for similar studies in the Columbia Basin. All studies will be based on sound statistical design and analysis.

3. Fish passage efficiency tests will be conducted using hydroacoustic means and direct capture methods for species identification.

VI. JOINT FISHERY PARTIES' RESPONSIBILITIES

A. LIMITATION OF MID-COLUMBIA PROCEEDING

The Joint Fishery Parties agree to join with the PUD to request that the FERC terminate the Mid-Columbia proceeding insofar

as it pertains to the Wells Project. The Parties specifically agree to reserve the right to enforce the terms and conditions of this Agreement before the FERC.

B. SUPPORT FOR RELICENSE

The PUD's FERC license for the Wells Hydroelectric Project expires in 2012. The Joint Fishery Parties agree to be supportive of the PUD's new or renewal license application to the FERC, provided that the PUD has adhered to the terms and conditions of this Settlement Agreement, as well as any future terms, conditions, and obligations agreed upon by the Parties hereto or imposed upon the PUD by the FERC. To the extent that the PUD has met such terms and conditions, the Joint Fishery Parties agree that the PUD is a competent license holder with respect to its obligations to anadromous fish resources. Nothing in this paragraph shall limit or preclude any Party hereto from requesting at the time of any license renewal the provision of or supporting different, modified or additional fish protection measures and compensation; or from requiring that the fishery protection measures contained in a competing license application be included as a condition of the PUD's new license, or in the absence of such additional or modified measures in a new license, or in the absence of measures contained in a competing license application requested by the Joint Fishery Parties, from requesting that the PUD's new or renewal license application be denied.

C. STIPULATION OF ADEQUACY

The Joint Fishery Parties stipulate that the performance of the PUD's responsibilities under this Agreement constitutes adequate fish protection and full compensation for all fishery losses caused by the Wells Project at least until March 1, 2004. It is further stipulated that this Agreement satisfies any obligations of any Party relating to the adequacy of fish protection and compensation for fish losses caused by the Wells Project, and arising under applicable laws and regulations, including but not limited to the Federal Power Act, the Pacific Northwest Electric Power Planning and Conservation Act, and the Electric Consumers Protection Act of 1986, at least until March 1, 2004. This Agreement shall not otherwise affect the rights of any Party except as expressly covered by this Agreement.

D. FISH AND WILDLIFE PROGRAM

The Joint Fishery Parties stipulate that the performance of the PUD's responsibilities under this Agreement shall constitute full compliance with the applicable provisions of the Northwest Power Planning Council's 1987 Fish and Wildlife Program, at least until March 1, 2004. The Joint Fishery Parties stipulate that the PUD shall receive full credit for its hatchery production in meeting any requirements that may be established as a result of implementation of Section 203 of the Council's Program.

E. LIMITATION ON REOPENING

The Joint Fishery Parties shall not invoke or rely upon any reopener clause set forth in any license applicable to the Wells

Project for the purpose of obtaining additional fish measures or changes in project structures or operations pertaining to fishery issues until after March 1, 2004.

F. ADDITIONAL MEASURES

The Joint Fishery Parties shall refrain from contending on their own behalf or supporting any contention by other persons in any proceeding or forum that additional fish measures or changes in project structures or operations pertaining to fishery issues should be imposed at the Wells Project until after March 1, 2004.

VII. MISCELLANEOUS

A. COOPERATION

The Parties shall cooperate in conducting studies and shall provide assistance in obtaining any approvals or permits which may be required for implementation of this Agreement.

B. NOTICES

All written notices to be given pursuant to this Agreement shall be mailed by first-class mail, postage prepaid, to each Party at the address listed below or such subsequent address as a Party shall identify by written notice to all other Parties. Notices shall be deemed to be given three (3) days after the date of mailing.

C. WAIVER OF DEFAULT

Any waiver at any time by any Party hereto of any right with respect to any other Party with respect to any matter arising in

connection with this Agreement shall not be considered a waiver with respect to any subsequent default or matter.

D. ENTIRE AGREEMENT -- MODIFICATIONS

All previous communications between the Parties hereto, either verbal or written, with reference to the subject matter of this Agreement are hereby abrogated, and this Agreement duly accepted and approved, constitutes the entire agreement between the Parties hereto, and no modifications of this Agreement shall be binding upon any Party unless executed or approved in accordance with the procedures set forth in subsection I.C.

E. BENEFIT AND ASSIGNMENT

This Agreement shall be binding upon and inure to the benefit of the Parties hereto and their successors and assigns provided, no interest, right or obligation under this Agreement shall be transferred or assigned by any Party hereto to any other Party or to any third party without the written consent of all other Parties, except by a Party:

(a) To any person or entity into which or with which the Party making the assignment or transfer is merged or consolidated or to which such Party transfers substantially all of its assets; or

(b) To any person or entity that wholly owns, is wholly owned by or is wholly owned in common with the Party making the assignment or transfer.

F. FORCE MAJEURE

The PUD shall not be liable for failure to perform or for delay in performance due to any cause beyond its reasonable control. This may include, but is not limited to, fire, flood, strike or other labor disruption, act of God, act of any governmental authority or of the Joint Fishery Parties, embargo, fuel or energy unavailability, wrecks or unavoidable delays in transportation, and inability to obtain necessary labor, materials or manufacturing facilities from generally recognized sources in the applicable industry. The PUD will make all reasonable efforts to resume performance promptly once the force majeure is eliminated.

G. INFLATION CALCULATIONS

All dollars specified in this Agreement are 1988 dollars. Dollar figures shall be adjusted annually for each year after 1988 based on the "Consumer Price Index for All Urban Consumers" published by the Bureau of Labor Statistics of the U.S. Department of Labor. If this index is discontinued or becomes unavailable, a comparable index agreeable to all Parties will be substituted.

H. METHOW RIVER HATCHERY WATER SUPPLY

1. The PUD agrees to cooperate with the Washington Department of Fisheries (WDF) to secure the necessary water rights and permits for facilities to be provided under this Agreement.

2. With respect to the proposed Methow River hatchery, the Parties agree that WDF and the PUD may utilize for the proposed Methow River hatchery facility up to 7 cfs of the water right now

held by the U.S. Fish and Wildlife Service (FWS), and subject to full or partial recall by FWS for any reason. The PUD shall not obtain legal title or ownership of the FWS water right.

3. To the extent that the utilization of water does not occur or is recalled or returned to FWS, the PUD and WDF shall use their best efforts to acquire an alternative source of water that meets applicable State requirements for water rights in order to satisfy obligations under this Agreement.

4. The PUD agrees to cooperate with WDF to secure the necessary permits in order to construct and provide for the operation of the proposed Methow River hatchery. The hatchery will be designed and constructed with the capability of installing pump-back facilities for returning the flow to the point of diversion.

5. If hatchery and/or river water supply requirements dictate the need for installation of a pump-back scheme, the PUD shall install and WDF shall operate the pump-back facilities.

VIII. REGULATORY APPROVAL

A. FERC ORDERS

All Parties agree to join in the filing of an offer of settlement with the FERC based on this Agreement and to request that the FERC issue appropriate orders approving the settlement. All Parties shall refrain from seeking judicial review of the FERC orders approving this Agreement.

B. PERFORMANCE CONTINGENT ON APPROVAL

Performance of all Parties' obligations under this Agreement

is expressly made contingent on obtaining all necessary regulatory approvals, specifically including all FERC orders referred to in subsection VIII.A above, and all applicable federal, state and local permits. It is expressly agreed by all Parties that this Agreement shall be submitted to the FERC as a unit and any material modification of its terms, approval of less than the entire Agreement, or addition of material terms by the FERC shall make this Agreement voidable at the option of any Party.

C. NO PREJUDICE

All Parties stipulate that neither FERC approval nor any Party's execution of this Agreement shall constitute approval or admission of, or precedent regarding, any principle, fact or issue in the Mid-Columbia proceedings, or any other FERC proceeding, including subsequent modification proceedings under Section I.

D. EXECUTION

This Agreement may be executed in counterparts. A copy with all original executed signature pages affixed shall constitute the original Agreement. The date of execution shall be the date of the final Party's signature. Approval of this Agreement must be acknowledged by the Commissioner of Indian Affairs and the Secretary of the Interior, or their delegates, to the extent required by 25 U.S.C. § 81.

E. AUTHORITY

Each Party to this Agreement hereby represents and acknowledges that it has full legal authority to execute this Agreement and shall be fully bound by the terms hereof.

F. ACTION FOR NONCOMPLIANCE

Notwithstanding any other provision of this Agreement, any Party may seek relief arising solely from noncompliance with this Agreement by any Party; provided, all requests for specific performance of any provision of this Agreement shall be filed with the FERC pursuant to subsection I.D.

IN WITNESS WHEREOF, the Parties have executed this Agreement the day and year first written above.

APPENDIX A

JUVENILE MIGRANT LOSS ESTIMATES USED FOR COMPENSATION PLANS IN THE WELLS DAM SETTLEMENT AGREEMENT

1. Steelhead

The number of juvenile steelhead migrants killed by passage through the Wells Project reservoir and dam were not estimated for the purposes of this Settlement Agreement. As an alternative the parties have agreed to continue steelhead production programs and plans initiated under previous Mid-Columbia settlements.

2. Salmon Loss Estimates

The number of juvenile salmon migrants killed by passage through the Wells Project reservoir and dam were estimated as follows:

a. The number of juvenile migrant salmon, by species and race, entering the Wells Reservoir was estimated for natural production by applying sex ratios, egg per female data and theoretical egg to migrant survival rates to the numbers of adults passing above Wells Dam to spawn. These juvenile migrant numbers were computed annually and averaged over the passage years 1975-1984 for spring and summer chinook and averaged over the passage years 1975-1986 for sockeye. The recent average level of hatchery releases at Winthrop National Fish Hatchery were added to the spring chinook migrant estimates. The resulting estimates of average annual numbers

of juvenile migrant salmon entering Wells reservoir are:

Spring Chinook	=	1,504,400
Summer Chinook	=	2,913,300
Sockeye	=	4,617,000
Total	=	9,034,700

b. The total project mortality at Wells, including reservoir mortality, was estimated to be 14%. Applying this mortality rate to the population estimates in Item 1 above results in the following estimates of juvenile migrants killed by species:

Spring Chinook	=	210,600
Summer Chinook	=	407,900
Sockeye	=	646,400
Total loss	=	1,264,900

3. Derivation of Production Plan

a. The Phase I compensation Production Plan and Program is an initial step in production which is not intended to provide full compensation for juvenile migrant losses. The lack of full compensation is due to the experimental nature and developmental aspects of the sockeye Production Plan and Program.

b. To accommodate logistic and per-unit cost factors in Phase I development, about 225,000 (15,000 pounds) spring chinook were substituted for 231,000 sockeye.

c. Items (1) through (3) below describe the derivation of the hatchery-based compensation levels included in the body of the Agreement.

(1) Steelhead production is set at 30,000 lbs./year to continue the successful program initiated under prior Mid-Columbia Settlement Agreements.

(2) Phase I compensation includes a pilot program for hatchery production of sockeye. The sockeye production level is set to allow assessment of Program success rather than provide full compensation for the estimated juvenile losses at Wells.

(3) The Phase II Chinook/Sockeye Production Plan is sized to mitigate for estimated juvenile losses:

	Estimated Annual Losses at Wells	Annual Production Phase IIA or Phase IIB	
Spring Chinook	210,600	450,000	450,000
Summer Chinook	407,900	400,000	810,000
Sockeye	646,400	375,000	-
TOTALS	1,264,900	1,225,000	1,260,000

4. Chelan PUD/Douglas PUD Compensation Exchange

In recognition of the specific requirements for spring and summer chinook rearing facilities and the characteristics of the water supply at the PUD's proposed spring chinook rearing facility on the Methow River, the Joint Fisheries Parties, Douglas PUD and Chelan County PUD have reviewed the respective compensation

15,000 lbs. of Summer Chinook @ 10/lb.

6,500 lbs. of Summer Chinook at 40/lb.

obligations of Douglas PUD as set forth in this Agreement, and Chelan County PUD under terms of the Rock Island Settlement. In consideration of biological efficiency and logistical effectiveness, the parties have agreed to adjusted compensation obligations under this agreement and the Rock Island Settlement in the following manner:

a. Douglas PUD will assume responsibility for 19,200 pounds of Methow River sub-basin spring chinook production.

b. Chelan PUD will assume responsibility for 40,000 pounds of Methow River summer chinook production.

The resulting changes in production with the Douglas-Chelan compensation exchange agreement are (number of juveniles/year):

	Douglas Production	Chelan Production
Spring Chinook	Increases 288,000	Decreases 288,000
Summer Chinook	Decreases 400,000	Increases 400,000
Sockeye	No Effect	No Effect

c. The resultant Douglas PUD annual compensation program under this agreement (Phase II Production) is:

Phase IIA

30,000 lbs. of Steelhead @ 6/lb.

49,200 lbs. of Spring Chinook @ 15/lb.

15,000 lbs. of Sockeye @ 25/lb.

OR

Phase IIB

30,000 lbs. of Steelhead @ 6/lb.

49,200 lbs. of Spring Chinook @ 15/lb.

APPENDIX B

DETERMINATION OF RESPONSIBILITY FOR HATCHERY COMPENSATION

For each year of determination, calculate an average smolt output as follows:

1. Calculate a 5-year running average adult run (by species) for naturally spawned fish (Ays) as follows:

$$\bar{A}ys = \frac{Ay + Ay\text{-}1 + Ay\text{-}2 + Ay\text{-}3 + Ay\text{-}4}{5}$$

Where Ay is the total adult count for each species at Wells minus the hatchery escapement for the species in year y;

Ay-1 = the same in the previous year (y-1) and so on.

2. Multiply Ays by the average expected adult to smolt production factor Kys for each species, where Kys is calculated as follows:

a. Spring Chinook:

Ksp = 0.94 (Wells Dam to spawner survival)
x 0.50 (sex ratio) x 5000 (eggs/female)
x 0.10 (av. survival to smolt) = 235

b. Summer Chinook:

Ksu = 0.94 x 0.50 x 5000 x 0.30 = 705

c. Sockeye:

$$Kso = 0.94 \times 0.50 \times 2700 \times 0.12 = 152$$

3. Add the number of hatchery smolts HSys by species, which is a running average of the same 5 years as in Ays.

$$\overline{HSys} = \frac{HSy + HSy\text{-}1 + HSy\text{-}2 + HSy\text{-}3 + HSy\text{-}4}{5}$$

4. Total smolts (by species):

$$\overline{S}ys = Kys \times \overline{A}ys + \overline{HS}ys$$

5. Grand Total = Sum of all species:

$$Sgt = \overline{S}sp + \overline{S}su + \overline{S}so + \ldots$$

6. If other salmon species or races, for which the above smolt production factors (Kys) do not apply, become established in the production areas above Wells Dam, appropriate K factors for these fish will be established by consensus of the Coordinating Committee. Juvenile migrant production will be computed for these species or races. These numbers will be included in the grand total for juvenile migrant production and the 5-year running averages.

WELLS PHASE IV THEORETICAL CALCULATION EXAMPLE

NATURAL PRODUCTION

DATA USED IN EXAMPLE CALCULATION OF NATURAL PRODUCTION

Adult Count	Ay	Ay-1	Ay-2	Ay-3	Ay-4	5 Year Average
Spring Chinook	3,000	2,200	3,100	5,000	2,900	3,240
Summer Chinook	2,400	2,800	3,700	4,000	4,700	3,520
Sockeye	40,000	20,000	35,000	15,000	30,000	28,000

Ay = Wells Count Minus Hatchery Escapement for Year Y

Ksp = Calculated Spring Chinook Smolts

Ksu = Calculated Summer Chinook Smolts

Ksoe = Calculated Sockeye Smolts

Spring Chinook $\overline{Ay}$

$$= \frac{Ay + Ay\text{-}1 + Ay\text{-}2 + Ay\text{-}3 + Ay\text{-}4}{5}$$

$$= \frac{3000 + 2200 + 3100 + 5000 + 2900}{5}$$

$$= 3240$$

Summer Chinook $\overline{Ay}$

$$= \frac{Ay + Ay\text{-}1 + Ay\text{-}2 + Ay\text{-}3 + Ay\text{-}4}{5}$$

$$= \frac{2400 + 2800 + 3700 + 4000 + 4700}{5}$$

$$= 3520$$

Sockeye $\overline{Ay}$

$$= \frac{Ay + Ay\text{-}1 + Ay\text{-}2 + Ay\text{-}3 + Ay\text{-}5}{5}$$

$$= \frac{40{,}000 + 20{,}000 + 35{,}000 + 15{,}000 + 30{,}000}{5}$$

$$= 28{,}000$$

Ksp, su, soc = Adult/redd factor x sex ratio x eggs/female x eggs to smolt survival x dam count minus hatchery return

Calculated Average Total Smolts (Natural)

Spring Chinook

$$Ksp = .94 \times .50 \times 5000 \times .10 \times 3240$$
$$= 235 \times 3240$$
$$= 761,400$$

Summer Chinook

$$Ksu = .94 \times .50 \times 5000 \times .30 \times Ay$$
$$= 705 \times 3520$$
$$= 2,481,600$$

Sockeye

$$Ksoc = .94 \times .50 \times 2700 \times .12 \times Ay$$
$$= 152 \times 28,000$$
$$= 4,263,800$$

Average Total Natural Smolts

$$= Ksp + Ksu + Ksoc$$
$$= 761,400 + 2,481,600 + 4,263,800$$
$$= 7,506,800$$

HATCHERY PRODUCTION

DATA USED IN EXAMPLE DETERMINATION OF HATCHERY PRODUCTION

SMOLT PRODUCTION IN MILLIONS BY YEAR

Hatchery	Y	Y-1	Y-2	Y-3	Y-4	5 Year Average
Winthrop	1.5	1.1	1.0	.95	.95	1.1
Methow	.8	.8	.675	.40	.25	.585
Twisp Acclimation	.40	.40	.40	.25	.2	.33
Sockeye Net Pens	.2	.2	.2	.15	.1	.17

Hatchery Smolt Production

Winthrop Hatchery 950,000

$$= \frac{1,500,000 + 1,100,000 + 1,000,000 + 950,000 +}{5}$$

$$= 1,100,000$$

Methow Hatchery

$$= \frac{800,000 + 800,000 + 675,000 + 400,000 + 250,000}{5}$$

= 585,000

Twisp Accl. Pond= $\frac{400,000 + 400,000 + 400,000 + 250,000 + 200,000}{5}$

= 330,000

Sockeye Net Pens* = $\frac{200,000 + 200,000 + 200,000 + 150,000 + 100,000}{5}$

= 170,000

*Need Adjustment Factor For Survival To Migration

Average Total Hatchery Smolts

Winthrop	=	1,100,000
Methow	=	585,000
Twisp	=	330,000
Net Pens	=	170,000
		2,185,000

Average Total Hatchery/Natural Smolts
(5 Year Average for Years Y-4, Y-3, Y-2, Y-1 and Y)

Natural	=	7,779,000
Hatchery	=	2,185,000
Total	=	9,964,000

PHASE IV DETERMINATION

Base Number Smolts Used for Initial Compensation	=	9,034,700
Calculated Average Natural + Hatchery Smolts in Years Y-4, Y-3, Y-2, Y-1 and Y	=	9,964,000
Calculated Average Natural + Hatchery Smolts Minus Base Number Smolts	=	929,300
Difference Between Base Number Smolts and Calculated Natural + Hatchery Smolts X Wells Project Mortality Rate	=	929,300 X .14
= Additional Smolts Possible Under Phase IV		130,102

FOR PUBLIC UTILITY DISTRICT NO. 1
OF DOUGLAS COUNTY, WASHINGTON:

Howard Frey
Commissioner

Michael Gilmore
Commissioner

T. James Davis
Commissioner

FOR PUGET SOUND POWER & LIGHT COMPANY:

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FOR PACIFIC POWER & LIGHT COMPANY:

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FOR THE WASHINGTON WATER POWER COMPANY:

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FOR PORTLAND GENERAL ELECTRIC COMPANY:

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FOR THE WASHINGTON DEPARTMENT
OF FISHERIES:

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FOR THE WASHINGTON DEPARTMENT
OF WILDLIFE:

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OF DOUGLAS COUNTY, WASHINGTON:

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OF WILDLIFE:

Ray Ryan 6/11/90
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FOR THE OREGON DEPARTMENT OF
FISH AND WILDLIFE:

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FOR THE NATIONAL MARINE
FISHERIES SERVICE:

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FOR THE U.S. FISH & WILDLIFE SERVICE:

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FOR THE CONFEDERATED TRIBES AND BANDS
OF THE YAKIMA INDIAN NATION:

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OF THE UMATILLA INDIAN RESERVATION:

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Marvin L. Plenert, Regional Director
FOR THE U.S. FISH & WILDLIFE SERVICE

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FOR THE CONFEDERATED TRIBES
OF THE UMATILLA INDIAN RESERVATION:

Edward H. Patawa

FOR THE CONFEDERATED TRIBES
OF THE COLVILLE RESERVATION:

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