CZES Coastal Zone and Estuarine Studies

# Evaluation of Submersible Traveling Screens, Passage of Juvenile Salmonids through the Ice-Trash Sluiceway, and Cycling of Gatewell-Orifice Operations at the Bonneville First Powerhouse, 1981

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APPENDIX A. Powerhouse and Sluiceway Passage Data

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APPENDIX C. Orifice Cycling Data

# INTRODUCTION

The U.S. Army Corps of Engineers (CofE) is proceeding with the design and implementation of the fingerling bypass for the Bonneville First Powerhouse. The final configuration could either be a conventional submersible traveling screen (STS) system (similar to McNary and Lower Granite Dams), a bypass for fish directly from the forebay through the existing ice and trash sluiceway to the tailrace, or some combination of the above. To obtain the necessary data for determining the final configuration, the CofE funded a cooperative study with the National Marine Fisheries Service (NMFS) and the Oregon Department of Fish and Wildlife (ODFW).

The study had the following primary objectives: 1) evaluate the effectiveness of the STS for guiding juvenile salmonids, 2) evaluate the feasibility of cycling the operation of the submerged orifices providing egress for juvenile salmonids from the gatewells, and 3) evaluate the use of the ice and trash sluiceway as a means of bypassing juveniles directly from the forebay to the tailrace. A secondary objective was to evaluate a balanced flow vertical barrier screen (BFVBS) in a model and test a prototype screen if time permitted.

The NMFS was responsible for the STS and orifice cycling studies and also monitored fish entering intake gatewells as part of the evaluation of the effectiveness of the ice and trash sluice. ODFW was responsible for the operation and evaluation of the ice and trash sluice for bypassing fingerling salmonids directly from the forebay to the tailrace. This report covers the NMFS portion of the research. A separate report covering the ODFW segment of the research was prepared by ODFW and is attached as Appendix B.

## SUBMERSIBLE TRAVELING SCREEN EVALUATION

### Methods and Procedures

Three STSs, similar in design to those in use at McNary Dam, were the principal devices used to conduct the evaluation. One fixed screen guiding device (bar screen) similiar to those previously tested at McNary Dam was also available to provide a guiding device in a slot adjacent to an STS for test purposes. Vertical barrier screens (VBS) and 12-inch diameter gatewell orifices were installed in turbine intake gatewell slots intended for STS testing. Six VBSs were permanently installed to allow STS installation for FGE and debris testing. Eighteen additional slots were equipped with support devices for installation of a portable VBS. Ten portable VBSs were provided (Figure 1).

Testing was done to determine the effectiveness of several possible operational configurations of the STS. The STS, as constructed for testing at Bonneville Dam, could be positioned at three elevations within the turbine intake in 6-inch increments. The screen surface could be set at four angles (47, 53, 60, and 65° measured from vertical). These two adjustments allowed considerable flexibility in the critical areas of: (1) throat opening, which is the vertical clearance between the surface of the screen and the roof of the turbine intake; (2) gap opening, which is the horizontal clearance between the back surface of the screen and the bottom of the VBS; (3) overlap, the vertical difference between the top of the STS and an imaginary line across the bottom of the gatewell slot and in line with the ceiling of the intake; and (4) percent of the total turbine intake flow intercepted by the STS in operating position (Figure 2).

The principal FGE tests were conducted in Unit 4 which in past studies passed substantial numbers of all species of fish passing the powerhouse.

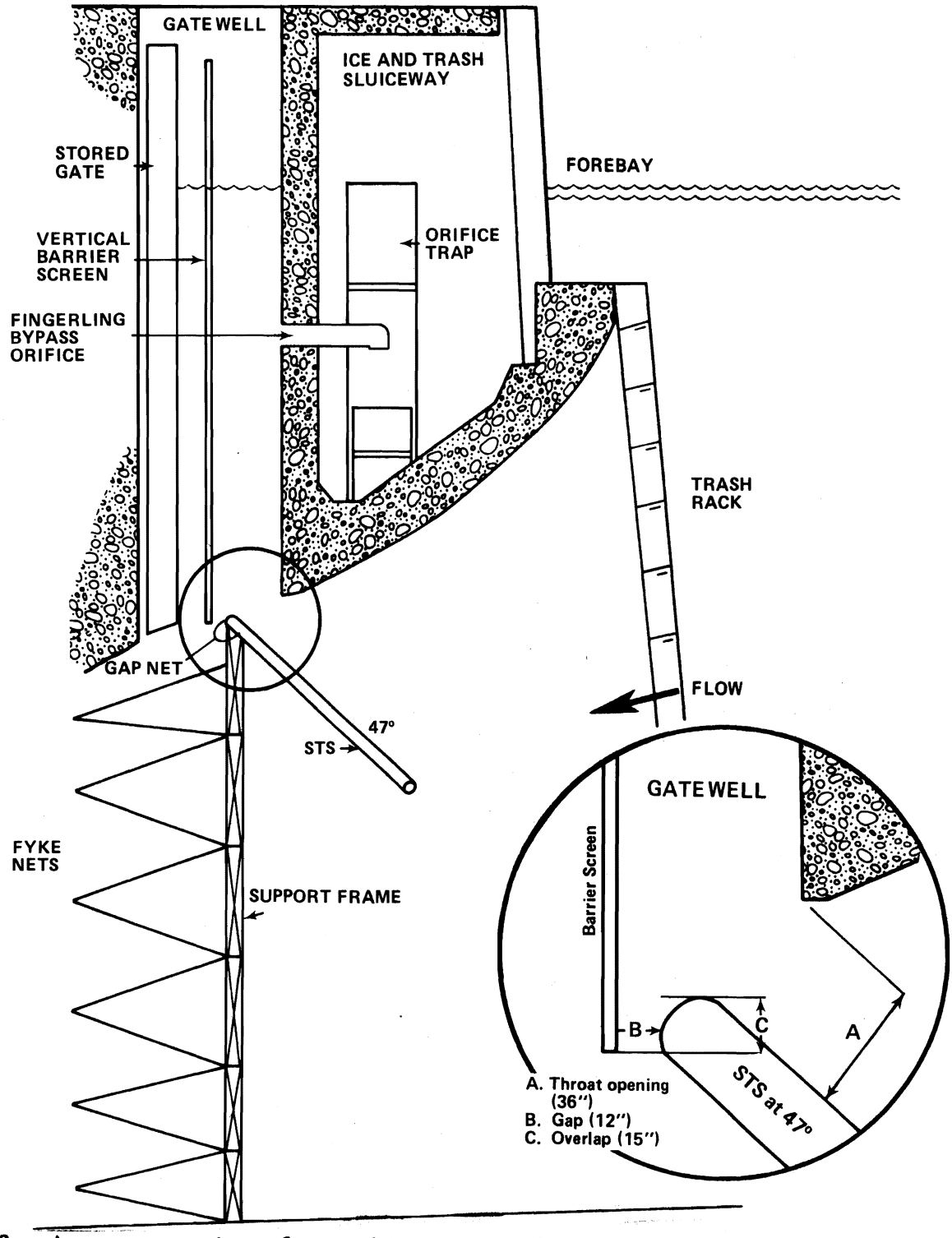



Figure 2. A cross section of a turbine intake in the Bonneville First Powerhouse showing location of vertical barrier screen, fingerling bypass orifice (with orifice trap), submersible traveling screen (STS) (with fyke nets), and position and angle (47°) of STS that provided optimum FGE (Throat opening, gap, and overlap) during 1981 testing.

The total number of fish passing was calculated as gatewell catch plus gapnet catch plus three times the fyke net catch. FGE was calculated as gatewell catch divided by total number of fish passing through the intake during the test period:

$$FGE = \frac{GW}{GW + GN + 3(FN)} \times 100$$

GW = gatewell catch

GN = gapnet catch

FN = fyke net catch

FGE tests were initiated with all three STSs set at the lowest elevation (44.0 feet) and at the smallest angle to vertical (47°) so that the maximum portion of the turbine intake flow was intercepted (approximately the upper one-third). It was reasoned that this would produce high guidance if the steep angle did not cause injury to fish due to impingement on the screen. Extensive testing was done at this setting. Follow-up tests were performed in the raised position (elevation 45.0 feet) and at angles of 53 and 60°.

The effect of the STS on fish quality was determined by comparing the descaling rate for fingerlings collected during STS FGE tests to fingerlings that had entered gatewells with no STS. Fingerlings with more than 10% of their scales missing were considered descaled.

## Results

### Fish-Guiding Efficiency

FGEs in excess of 70% were observed for each of the species and principal races of salmon and steelhead studied at the 47° setting (Table 1). Similar results were observed at the 53° setting (Appendix

Table A3). FGE was consistently several percentage points lower for the smaller fall chinook salmon. This was primarily due to loss through the gap at the top of the screen. Raising the elevation of the screen and changing the angle of the screen to narrow the gap spacing was tried in an effort to reduce this loss. A small reduction in gap loss was observed, but FGE was substantially reduced. Since the general guidance was high and the condition of fish guided by the STS consistently good at the 47° screen angle, extensive testing was not done at the shallower screen angles. In later STS observations, FGE was observed to decline during some high debris periods. This was hypothesized to be due to trash buildup on the turbine intake trash racks deflecting fish deeper into the turbine intakes.

FGE of the fixed screen-guiding device was also determined at the one operating position at which it was used (horizontal). FGEs ranged from approximately 20% for fall chinook salmon to approximately 45% for steelhead and spring chinook salmon. The difference in FGEs between spring and fall chinook salmon was due to gap loss. Gap loss for steelhead was guite low and fall chinook salmon approached 50% compared to 25% for spring chinook salmon.

The fixed screen guiding device was used during the STS FGE testing primarily to simulate another STS. It was operated adjacent to either the A or C Slot STS to provide flow conditions similar to what would normally occur if STSs were operating in all intake slots. Therefore, no attempt was made to adjust the guiding device to reduce the high gap loss observed.

Table 2.--Descaling rates for fingerlings collected with submersible traveling screens (test fish) as compared to fingerlings that entered gatewells volitionally (control fish) at Bonneville Dam First Powerhouse, 1981.

| Species | Percent descaled | N |
|---|---|---|
| Spring chinook | | |
| Test | 7.0 | 257 |
| Control | 7.0 | 7,810 |
| Fall chinook | | |
| Test | 0.1 | 12,899 |
| Control | 0.3 | 16,668 |
| Steelhead | | |
| Test | 14.0 | 479 |
| Control | 13.0 | 18,654 |
| Coho | | |
| Test | 3.0 | 440 |
| Control | 3.0 | 17,611 |
| Sockeye | | |
| Test | 7.0 | 232 |
| Control | 3.0 | 5,661 |

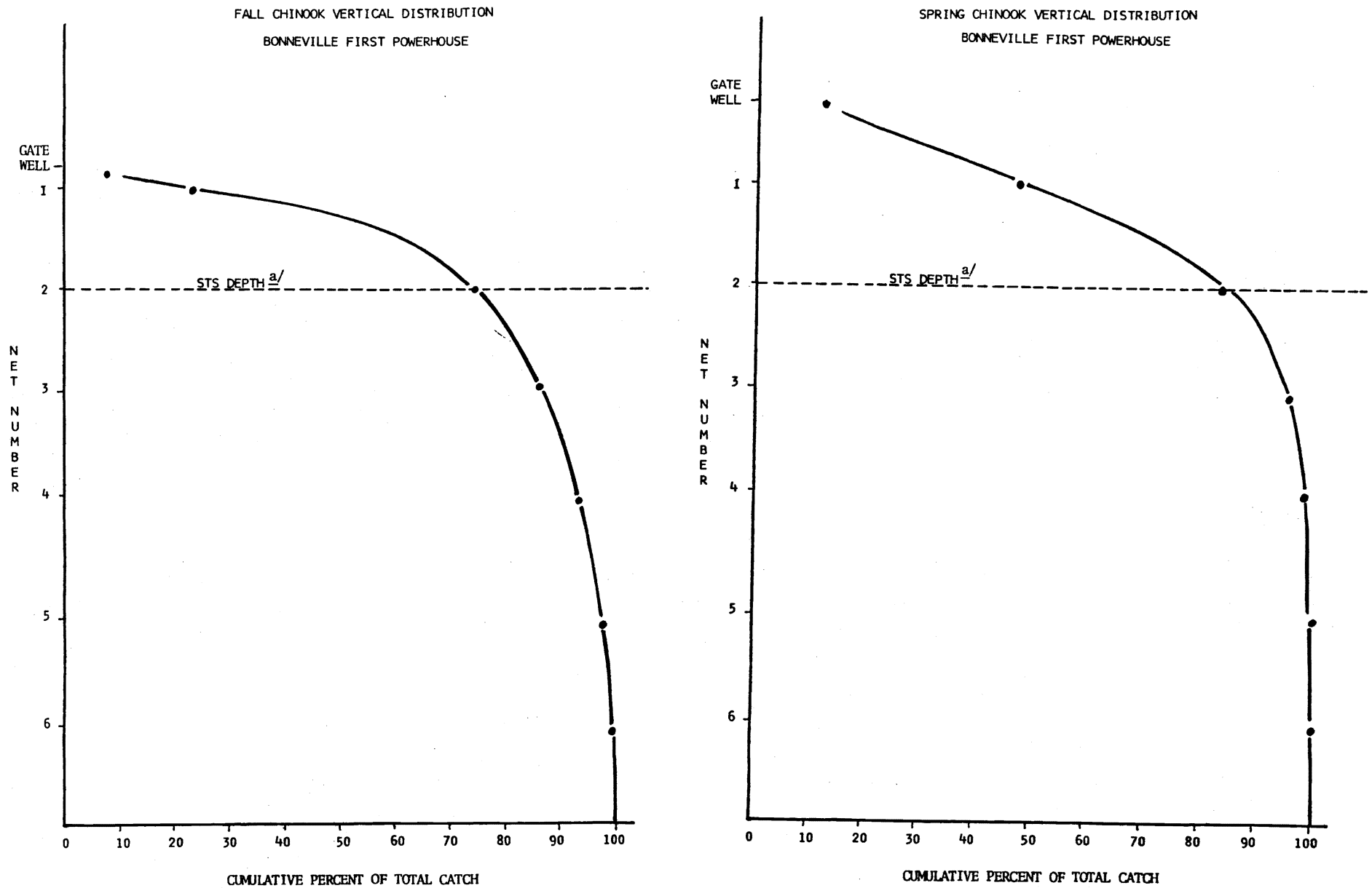
the 1981 operating season. The screen in Unit 7A operated well with an instance of very heavy debris.

## FISH PASSAGE DISTRIBUTION AND SLUICEWAY PASSAGE EFFICIENCY

The principal objectives of this element of the study were to determine the most effective operating mode for the ice and trash sluiceway as a surface-skimmer fish bypass and to estimate sluiceway bypass efficiency determined as a percentage of total powerhouse passage. This required that both total passage through the turbine intakes and through the sluiceway be estimated. Since the approach channels to the powerhouse and spillway are separated by Bradford Island, passage over the spillway was disregarded although substantial spill occurred during the test period. Estimates of total powerhouse passage were expanded from turbine intake gatewell catches in the B intakes of each of the 10 turbine units. To correctly expand gatewell catches to actual powerhouse passage, additional information was needed regarding the vertical and horizontal distribution of downstream migrants through the powerhouse and the proportion of migrants passing through the B Intakes compared to the A and C Intakes.

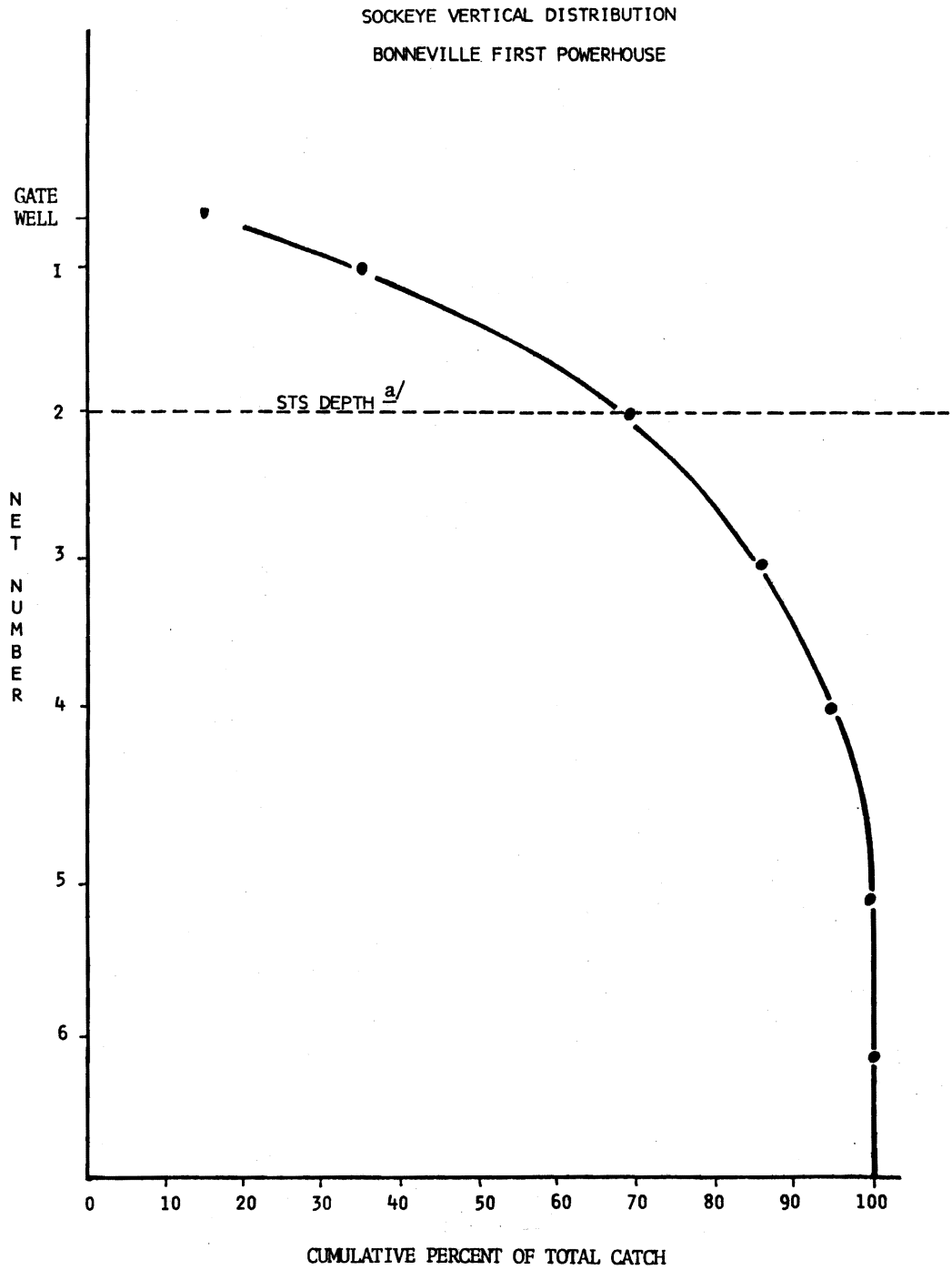
### Vertical Distribution

Measures of vertical distribution by species provided the data to calculate the expansion factors for converting B Intake gatewell catches to the total passage through the B Intake of the turbine. In addition, the data provided the means to determine the proportion of fish that should have been guided by an STS into the gatewell by comparing the fishing depth of the STS with the measured vertical distribution by species.




a/ STS at 47° angle.

Figure 4.--Vertical distribution of all and spring chinook salmon in Units 5A and B at Bonneville Dam in 1981.




a/ STS at 47° angle.

Figure 6.--Vertical distribution of sockeye in Units 5A and B at Bonneville Dam in 1981.

the guidewall) were found to take significantly more than 33% of the fish passing their respective units, but the B Intake was still found to be taking approximately 33% of the total unit passage. Accordingly, the expansion factor used in powerhouse passage estimates for expansion of B Intake passage to total unit passage, based on percent water passage of that intake, was:

$$\frac{100}{33.5} = 2.99$$

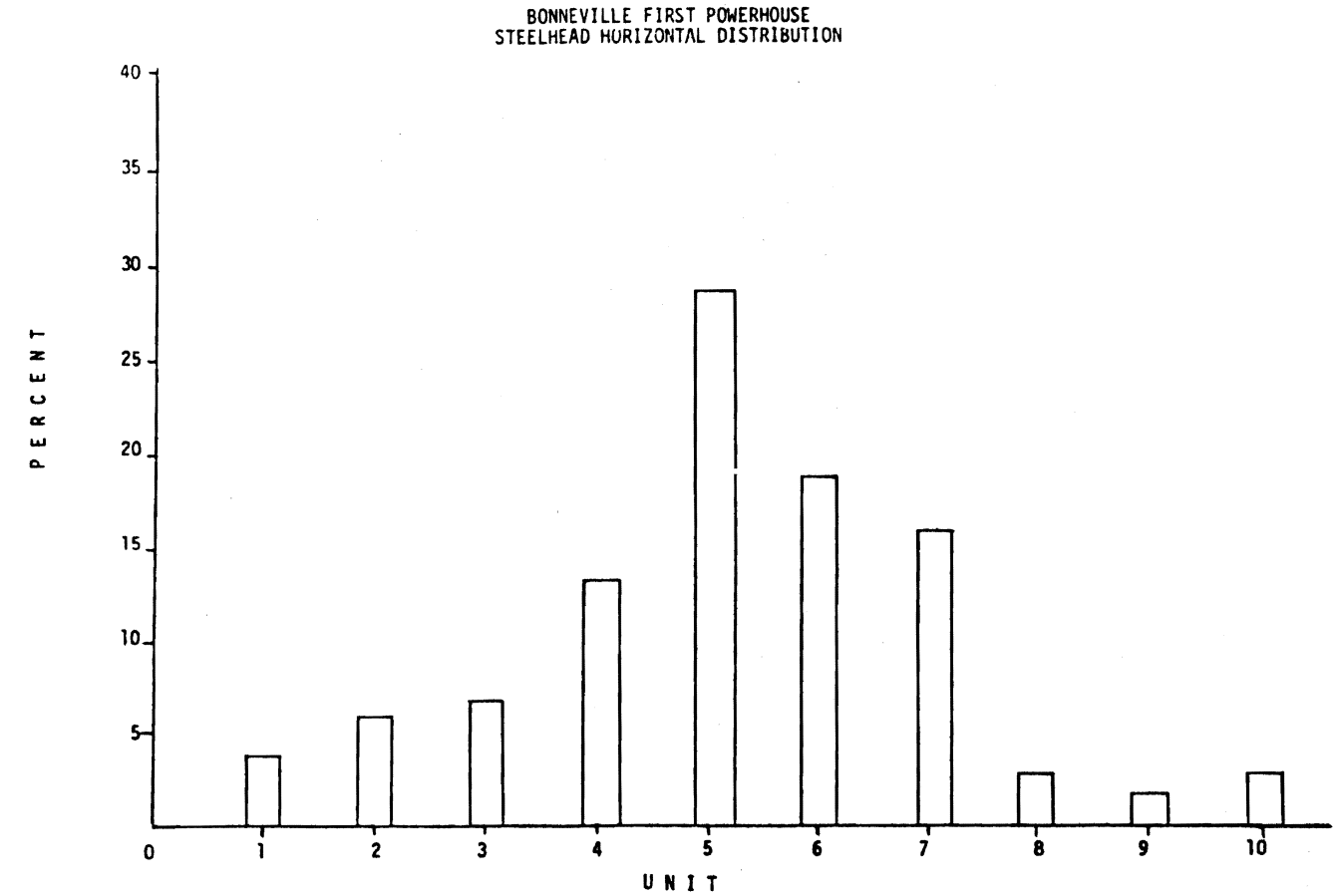
Total daily passage through each turbine by species was estimated as follows:

$$\text{Unit passage} = 2.99 \text{ X GW X } \frac{100}{\% \text{ GW}}$$

Total daily powerhouse passage by species was the sum of the daily passage through each of the turbines.

## Horizontal Distribution

Total daily passage by species through each turbine by species based on gatewell dipnet recovery data from the B Slot was used to calculate the horizontal distribution of fish passing the powerhouse via the turbines. Figures 7, 8, and 9 show this distribution for each species expressed as percent of total powerhouse passage with all generating units operating at full capacity. Generally, the majority of fish were observed to pass Units 4, 5, and 6. The two exceptions were substantial steelhead passage through Unit 7, and the large numbers of fall chinook salmon which passed through Units 1, 2, and 3. The smaller hatchery-reared fall chinook salmon smolts were evidently more strongly oriented to the shore than were the larger downstream migrants. This distributional difference for fall chinook salmon was previously observed at Bonneville and The Dalles Dams.



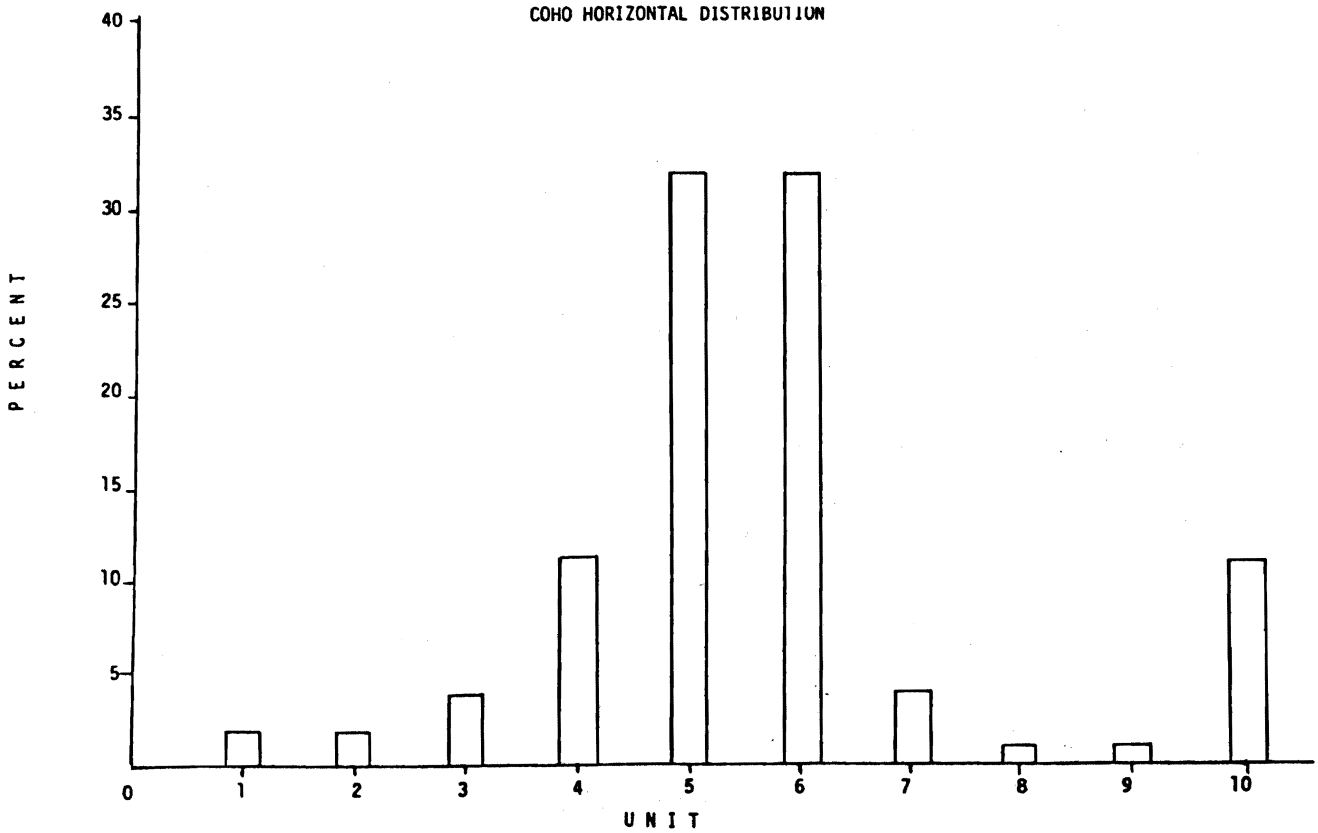




Figure 8.--Horizontal distribution of steelhead and coho salmon fingerlings at Bonneville Dam computed from gatewell dipnet catches in 1981.

## Sluiceway Passage Efficiency

Sluiceway passage efficiency tests were carried out from 26 May to 7 June 1981. Because it was not known if sluiceway operation would affect gatewell catch and, the ability to estimate turbine intake passage, the experiment was designed as a series of 24-h periods alternating operation and closure of the sluiceway. The series began and ended with a sluiceway-closed day to allow treating total passage on each of the six sluice-open days as the average of the preceding and successive sluice-closed days. Each 24-h sequence began at noon. The sluiceway was opened approximately 1 h in advance to avoid an abnormal surge of fish at the beginning of the test period.

Passage through the ice and trash sluiceway was estimated by expanding a partial net sample taken within the sluiceway. The methods for calibrating this net sample and the method of data expansion are treated in the attached report prepared by ODFW ( Appendix B).

As previously discussed, total powerhouse passage by species (through turbines) for each 24-h period was determined by expanding daily B Slot gatewell catches by factors derived from percent gatewell catch and percent B Slot catch. Sluiceway passage efficiency (SPE) could then be calculated for each 24-h period as a proportion of total passage (sluiceway and turbines):

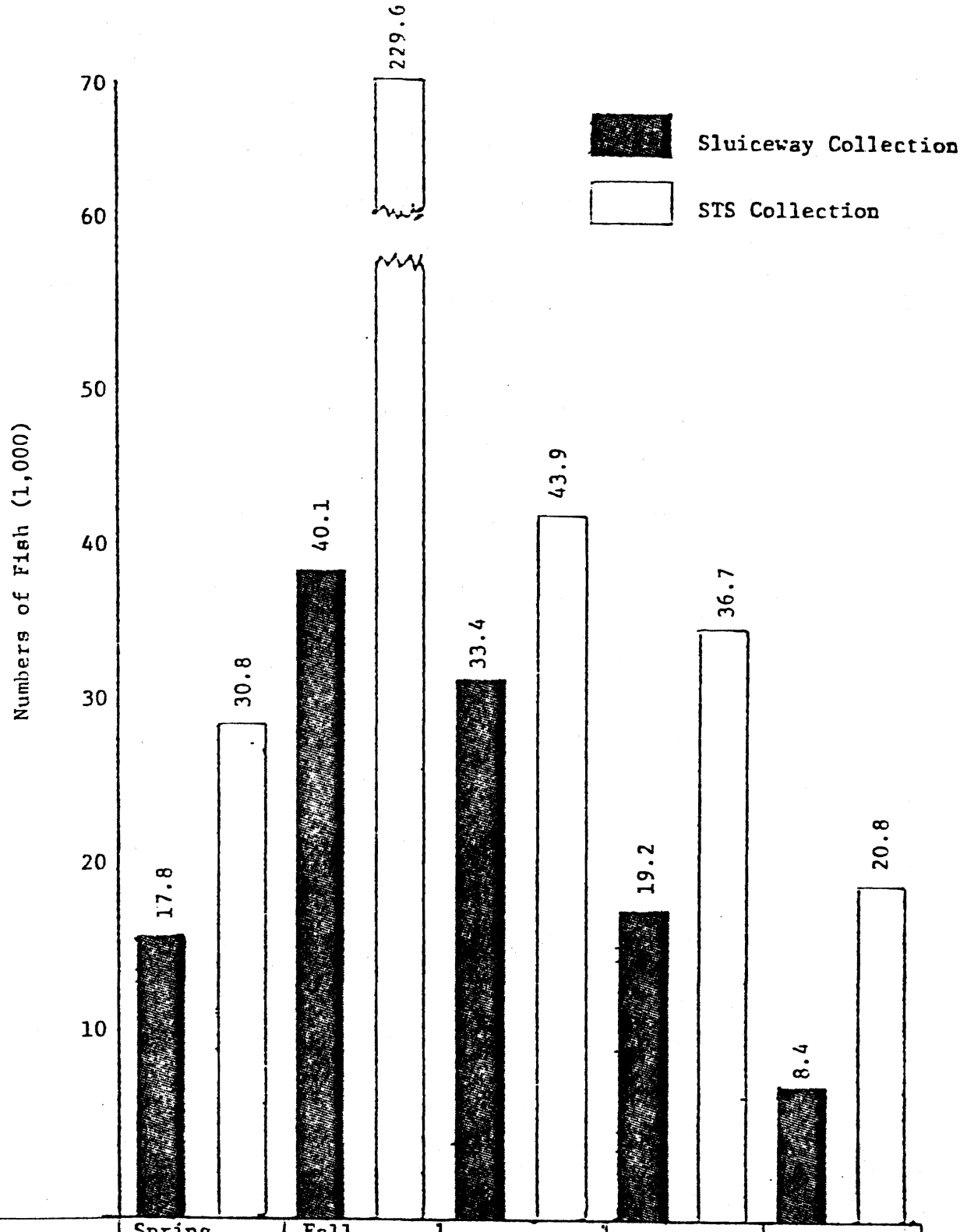
$$SPE = \frac{\text{sluiceway passage}}{\text{sluiceway passage + turbine passage}} \times 100$$

Daily passage through the powerhouse turbine intakes by species is given in Table 3. A large variation in numbers of fall chinook salmon from day to day occurred. This was primarily due to hatchery fish, liberated within Bonneville pool, passing the project within a few days after release. Very high numbers on the last 2 days of the test were the most

extreme example. A second observation of special importance was the comparison of total daily passage (powerhouse intake passage plus sluiceway passage when in operation). Estimated total passage on days when the sluice was in operation typically exceeded total passage on days when the sluiceway gates were closed.

Before conducting the test, it was hypothesized that sluiceway operation might influence vertical distribution and corresponding percent gatewell catches by reducing the number of fish entering near the surface of the intake. This would have resulted in generally lower total passage estimates on days the sluice was in operation. Although vertical distribution data collected during the test period were quite variable, due primarily to debris plugging trashracks and fyke nets, it did not appear that the percent gatewell catch changed appreciably. It appeared more likely that the fish were being delayed, and the difference in total passage on the sluice-open versus sluice-closed days was real and a consequence of the alternating day experimental design. Passage through turbine intakes has repeatedly been observed to occur primarily during the evening and early nighttime hours[1/], whereas observations from trap and net data suggest that fish moved in the river primarily in the daytime hours. Thus, there is other evidence for such a delay. The best method of compensating for such a delay with this experimental design was to calculate the number of fish available for sluiceway passage as the average of the total passage on the day the sluice was in operation and the preceding sluice-closed day. In this way, fish which might be delayed on

1/ Sims, C.W. et al. 1981. Migrational characteristics of juvenile salmon and steelhead in the Columbia River Basin and related passage research at John Day Dam. Processed Report. NMFS, Seattle, WA.




| SPECIES | Spring Chinook | Fall Chinook | Steelhead | Coho | Sockeye |
|---|---|---|---|---|---|
| %Sluiceway Passage | 44.2 | 12.5 | 58.9 | 42.6 | 33.0 |
| %STS Fish Guiding Eff. | 76.4 | 71.5 | 77.6 | 81.3 | 81.7 |

Figure 10.--A comparison of the estimated sluiceway passage efficiency and numbers of fish guided with calculated STS guidance based on measured FGE (assuming all intakes were screened) for a 6-day period between 26 May and 7 June 1981 at Bonneville Dam. (Also see Appendix Table A13.)

passing through the orifice. Fish passage efficiency (FPE) was determined by expressing the number of fish captured in the orifice trap as a percentage of the total number of fish entering the gatewell. Continuous orifice operation for a 24-h interval provided an index of expected FPE. The following steps were taken: (1) the gatewell was dipnetted to remove all fish; (2) the orifice was opened and the trap was checked at set intervals during the 24-h period; and (3) the orifice was closed, the gatewell was dipnetted, and the catch was identified and counted.

Orifice cycling tests in Unit 10C were conducted on a 2-h closed 1-h open cycle. The tests usually began about 1500 h and lasted 21 h. Prior to starting a test, the gatewell was dipped clean, and the fish removed were disregarded--those dipped out at the end of the test were identified and counted. The fish caught during the orifice cycling tests were identified and counted at the end of each 3-h cycle.

The orifice cycling tests conducted in the gatewells of Unit 4, where an orifice trap could not be operated, were done by dipnetting the individual gatewells. The dipnetting procedure was the same as that described for Gatewell 10C. Two orifice cycling schedules were used: (1) 2 h closed with 1 h open and (2) 4 h closed with 2 h open. Individual tests began at 1500 h and normally ran for 24 or 72 h.

During the FPE tests conducted in the gatewell of Unit 4, one orifice was closed, one orifice was cycled, and one remained open. The orifices in 4A and 4C were used alternately for cycling tests. The orifice in 4B remained closed throughout the experiment. The FPE was estimated for the cycled and noncycled orifice by using a probability formula (Appendix C). These formulas required an index of the actual numbers of fish entering these three gatewells. Indexing procedures were as follows: dipnet each gatewell to remove all fish; close the orifices and allow each gatewell to

species of fingerlings that were available in adequate numbers for the entire test period were fall chinook salmon. Therefore, the evaluation emphasizes this species.

None of the cycling tests attained an acceptable level of FPE for fall chinook salmon (Figure 11). Normally it would be expected that the longer a test period runs the higher the FPE would be, assuming that the residual fish do not have sufficient time to find the orifice. This was observed for a 72-h non-cycling test in 4C. The FPE increased from 45% for the 24-h test to 86% for the 72-h test. However, a similar comparison for an orifice cycling test (2 h closed and 1 h open) did not show this type of increased FPE.

Of the two different cycling scenarios, a 2-h closed and 1-h open condition was better than a 4-h closed and 2-h open condition for both fall chinook salmon and coho salmon (Figure 11).

## The Effects of Orifice Cycling on Fish Quality

Descaling evaluation procedures for the orifice cycling tests were similar to those used for STS efficiency tests. However, there is one basic difference between these two groups. Fingerlings examined for descaling in the orifice cycling tests were all residual fish remaining in the gatewell (fish that did not exit through the orifice), whereas the fingerlings for STS decaling information were a sample of the total number that entered the gatewell. If one assumes that unscaled fish, being healthy vigorous swimmers, were capable of finding the orifices more readily than descaled fish, a descaling comparison of these two groups would tend toward a lower degree of descaling for the STS test fish (no opportunity to exit through an orifice). Descaling data obtained for

orifice cycling tests, therefore, cannot be directly compared to descaling data from the STS efficiency tests, but can be used for comparisons of the various orifice cycling scenarios.

Orifice cycling tests could not be conducted continuously through the entire fingerling migration due to conflicts with ice-trash sluiceway evaluation tests and STS efficiency tests. Therefore, descaling samples of all species of downstream migrants were not available in sufficient numbers to be included in an analysis of all the various orifice cycling conditions.

Figure 12 shows the degree of descaling noted for residual fingerlings removed from the gatewells after each cycling experiment. Descaling of spring and fall chinook salmon was significantly higher during orifice cycling than for full-time orifice operation. Fall chinook salmon were the only species with a sufficient sample size for comparing the 4/2 and 2/1 cycling scenarios. Descaling was significantly higher during the 4/2 cycling condition--5% versus 0%.

## BALANCED FLOW VERTICAL BARRIER SCREEN TESTS

Balanced flow vertical barrier screen model studies conducted at the CofE Hydraulic Laboratory showed that water velocities through the vertical barrier screen could range from 0.5 to 2 fps. It was also determined that these velocities could be evened out to 0.5 fps over the gross area of the screen, if the porosity of the screen were reduced to 15%.

Implementing this modification to a vertical barrier screen for testing this season was not feasible due to the unavailability of material on short notice.

## SUMMARY AND CONCLUSIONS

I. STS tests

A. FGE of the STS

FGEs in excess of 70% were obtained for all species with the STS operating at a 47° angle at elevation 44 (lowest position in the intake). FGE was lowest for fall chinook salmon (71.5%) due primarily to loss through the gap (8.7%) at the top of the screen.

B. Quality of STS guided fish

The quality of STS guided fish was acceptable, only minor differences were noted in descaling rates between test and control fish.

C. Effects of debris on STS operation

A large quantity (5 cubic yards) of debris was intercepted by the STS during a 24-h period in Unit 7A, no visible damage was noted. However, rub marks on the lower shaft seemed to indicate an area of marginal clearance for small pieces of debris that got inside the screen.

II Fish passage distribution and sluiceway passage comparison

A. Vertical distribution

Tests indicated that 75 to 90% of the fingerlings were found in the area of the intake intercepted by the STSs (approximately 14 ft below the ceiling of the intake). Fall chinook and sockeye salmon appeared to be more deeply distributed than spring chinook and coho salmon or steelhead.

B. Horizontal Distribution

Generally the majority of the fish passed through Units 4, 5, and 6. Steelhead passage was highest through Unit 7, and fall chinook salmon passage was high through Units 1, 2, and 3 as well as the middle units.

Appendix Table A1.--STS guidance test results [gatewell catch (GW) and total catch], Unit 4, Bonneville Dam, 1981.

| Date | | Spring chinook | | Fall chinook | | Steelhead | | Coho | | Sockeye | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | GW | Total | GW | Total | GW | Total | GW | Total | GW | Total |
| | | | | < 47° El 44' | | | | | | | |
| 30/4 | 4A | 111 | 117 | 10 | 23 | 27 | 30 | 0 | 0 | 0 | 0 |
| 01/5 | 4A | 98 | 165 | 41 | 56 | 13 | 13 | 3 | 3 | 0 | 0 |
| 02/5 | 4A | 136 | 171 | 79 | 133 | 22 | 31 | 6 | 6 | 0 | 0 |
| 06/5 | 4A | 131 | 141 | 1953 | 2595 | 23 | 32 | 14 | 14 | 2 | 2 |
| 07/5 | 4A | 25 | 34 | 417 | 880 | 10 | 16 | 0 | 0 | 0 | 0 |
| 08/5 | 4A | 45 | 75 | 265 | 379 | 16 | 16 | 5 | 8 | 0 | 3 |
| 09/5 | 4A | 112 | 181 | 104 | 232 | 6 | 12 | 6 | 9 | 1 | 1 |
| 30/4 | 4B | 300 | 344 | 17 | 55 | 59 | 62 | 7 | 7 | 0 | 0 |
| 01/5 | 4B | 184 | 312 | 53 | 119 | 21 | 27 | 8 | 8 | 0 | 0 |
| 02/5 | 4B | 242 | 381 | 83 | 140 | 28 | 55 | 16 | 16 | 0 | 0 |
| 04/5 | 4B | 178 | 213 | 87 | 128 | 34 | 46 | 16 | 16 | 0 | 0 |
| 05/5 | 4B | 248 | 306 | 155 | 211 | 37 | 56 | 21 | 27 | 0 | 0 |
| 06/5 | 4B | 192 | 201 | 2201 | 2787 | 40 | 43 | 25 | 25 | 0 | 0 |
| 11/5 | 4B | 135 | 159 | 83 | 106 | 37 | 44 | 6 | 6 | 2 | 2 |
| 12/5 | 4B | 122 | 168 | 30 | 46 | 38 | 50 | 11 | 11 | 2 | 2 |
| 13/5 | 4B | 187 | 284 | 67 | 93 | 55 | 67 | 13 | 26 | 7 | 7 |
| 30/4 | 4C | 159 | 192 | 12 | 18 | 18 | 18 | 6 | 6 | 1 | 1 |
| 01/5 | 4C | 224 | 296 | 44 | 70 | 36 | 43 | 14 | 14 | 0 | 0 |
| 02/5 | 4C | 246 | 330 | 70 | 137 | 45 | 55 | 13 | 13 | 0 | 0 |
| 04/5 | 4C | 227 | 305 | 87 | 117 | 39 | 45 | 16 | 22 | 0 | 0 |
| 05/5 | 4C | 282 | 350 | 118 | 164 | 56 | 74 | 35 | 38 | 0 | 0 |
| 06/5 | 4C | 194 | 221 | 1693 | 2053 | 40 | 52 | 35 | 35 | 2 | 2 |
| 27/5 | 4C | 13 | 16 | 30 | 44 | 32 | 50 | 21 | 44 | 23 | 33 |
| 29/5 | 4C | 30 | 33 | 49 | 67 | 32 | 38 | 31 | 55 | 8 | 8 |
| 02/6 | 4C | 6 | 9 | 94 | 118 | 17 | 17 | 14 | 17 | 4 | 4 |
| 04/6 | 4C | 25 | 25 | 63 | 69 | 11 | 14 | 10 | 11 | 8 | 8 |
| 06/6 | 4C | 1 | 1 | 616 | 800 | 6 | 6 | 0 | 0 | 1 | 4 |
| | | | | < 47° EL 45' | | | | | | | |
| 07/5 | 4B | 43 | 46 | 412 | 772 | 16 | 25 | 3 | 3 | 4 | 4 |
| 08/5 | 4B | 94 | 141 | 240 | 376 | 18 | 37 | 3 | 9 | 1 | 1 |
| 09/5 | 4B | 247 | 393 | 143 | 255 | 18 | 25 | 13 | 19 | 4 | 4 |
| | | | | < 60° EL 44' | | | | | | | |
| 07/5 | 4C | 47 | 50 | 300 | 619 | 25 | 28 | 5 | 5 | 2 | 2 |
| 08/5 | 4C | 102 | 142 | 197 | 323 | 16 | 22 | 7 | 7 | 1 | 1 |
| 09/5 | 4C | 344 | 455 | 97 | 157 | 47 | 62 | 21 | 33 | 7 | 16 |
| | | | | < 53° EL 44' | | | | | | | |
| 11/5 | 4C | 180 | 213 | 62 | 85 | 33 | 46 | 20 | 26 | 5 | 8 |
| 12/5 | 4C | 132 | 158 | 32 | 42 | 37 | 49 | 11 | 11 | 4 | 4 |
| 13/5 | 4C | 248 | 299 | 49 | 58 | 63 | 78 | 21 | 28 | 6 | 6 |

Appendix Table A3.--Pooled STS FGE (%) for tests at individual screen angles and elevations in Unit 4, Bonneville Dam, 1981.

| Condition and species | FGE (%) |
|---|---|
| 47° angle, 44 ft. elevation | |
| Spring chinook | 80.2 |
| Fall chinook | 73.2 |
| Steelhead | 78.9 |
| Coho | 80.5 |
| Sockeye[a/] | 79.2 |
| 47° angle, 45 ft. elevation | |
| Spring chinook | 66.2 |
| Fall chinook | 56.7 |
| Steelhead | 59.8 |
| Coho[a/] | 61.3 |
| Sockeye[a/] | 100.0 |
| 53° angle, 44 ft. elevation | |
| Spring chinook | 83.6 |
| Fall chinook | 77.3 |
| Steelhead | 76.9 |
| Coho[a/] | 80.0 |
| Sockeye[a/] | 83.3 |
| 60° angle, 44 ft. elevation | |
| Spring chinook | 76.2 |
| Fall chinook | 54.0 |
| Steelhead | 78.6 |
| Coho[a/] | 73.3 |
| Sockeye[a/] | 52.6 |

a/ Less than 100 fish in pooled sample.

Appendix Table A4--(continued)

| | Date | Time of day | Sluice-way condi-tion | Length of test (h) | Spring chinook: Fyke net expanded total | Spring chinook: Fyke net and gate-well catch | Spring chinook: % gate-well catch | Fall chinook: Fyke net expanded total | Fall chinook: Fyke net and gate-well catch | Fall chinook: % gate-well catch | Steelhead: Fyke net expanded total | Steelhead: Fyke net and gate-well catch | Steelhead: % gate-well catch | Coho: Fyke net expanded total | Coho: Fyke net and gate-well catch | Coho: % gate-well catch | Sockeye: Fyke net expanded total | Sockeye: Fyke net and gate-well catch | Sockeye: % gate-well catch |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gatewell 6B | 6/6 | 2130-2230 | CL | 1.0 | | a/ | | 618 | 641 | 3.5 | | a/ | | | a/ | | | a/ | c/ |
| | 6/9 | 1830-2000 | OP | 1.5 | | a/ | | 1,926 | 2,181 | 11.7 | | a/ | | 33 | 39* | 15.4 | | a/ | c/ |
| | 6/9 | 2130-2300 | OP | 1.5 | | a/ | | 1,176 | 1,212 | 3.0 | | a/ | | | a/ | | | a/ | c/ |
| | 6/10 | 1830-2000 | CL | 1.5 | | a/ | | 540 | 673 | 19.7 | | a/ | | | a/ | | | a/ | c/ |
| | 6/10 | 2100-2230 | CL | 1.5 | | a/ | | 414 | 437 | 5.2 | | a/ | | | a/ | | | a/ | c/ |
| | 6/11 | 1830-2000 | OP | 1.5 | | a/ | | 45 | 53 | 15.0 | | a/ | | | a/ | | | a/ | c/ |
| | 6/12 | 2130-2330 | CL | 2.0 | | a/ | | 147 | 155 | 5.2 | | a/ | | | a/ | | | a/ | c/ |
| Gatewell 6C | 6/8 | 2100-2200 | OP | 1.0 | 30 | 31* | 3.0 | 4,827 | 4,977 | 3.0 | | a/ | | 105 | 147 | 28.5 | | a/ | c/d/ |
| | 6/8 | 1830-1930 | OP | 1.0 | 33 | 37* | 10.8 | 1,197 | 1,339 | 10.6 | | a/ | | 27 | 38* | 28.9 | | a/ | c/d/ |
| | 6/11 | 2100-2330 | OP | 2.5 | 30 | 35* | 14.0 | 213 | 264 | 19.3 | 18 | 34* | 47.0 | | a/ | | | a/ | c/ |
| | 6/12 | 1900-2000 | CL | 1.0 | | a/ | | 228 | 271 | 16.0 | | a/ | | | a/ | | | a/ | c/ |
| Gatewell 1A | 5/21 | 1330-2330 | CL | 10.0 | 33 | 36* | 8.0 | 60 | 65 | 7.7 | 12 | 40* | 70.0 | 342 | 401 | 15.0 | 42 | 51 | 18.0 d/ |
| | 5/22 | 1400-2300 | CL | 9.0 | | a/ | | 84 | 84 | 0.0 | 18 | 40* | 55.0 | 93 | 108 | 14.0 | 36 | 38 | 5.0 d/ |
| | 5/23 | 1330-2200 | CL | 8.5 | | a/ | | 75 | 79 | 5.1 | | a/ | | 52 | 59 | 11.9 | | a/ | |
| Gatewell 1B | 5/18 | 1900-2300 | OP | 4.0 | 78 | 86 | 9.3 | 33 | 34* | 2.9 | 9 | 41* | 78.5 | | a/ | | 33 | 37* | 10.8 |
| | 5/18 | 1400-1800 | OP | 4.0 | 78 | 84 | 7.1 | | a/ | | | a/ | | | a/ | | | a/ | |
| | 5/19 | 0900-1300 | OP | 4.0 | 30 | 37* | 18.9 | 54 | 58 | 6.8 | | a/ | | | a/ | | | a/ | |
| | 5/19 | 1400-1800 | OP | 4.0 | | a/ | | 63 | 75 | 16.0 | | a/ | | | a/ | | | | |
| | 5/19 | 1900-2300 | OP | 4.0 | 45 | 45* | 0.0 | 71 | 71 | 0.0 | 15 | 32* | 53.0 | 57 | 78 | 27.0 | 39 | 46* | 15.0 d/ |
| | 5/20 | 0900-1300 | OP | 4.0 | 30 | 34* | 12.0 | | a/ | | | a/ | | | a/ | | | a/ | |
| | 5/20 | 1400-2100 | OP | 7.0 | 30 | 32* | 6.0 | 87 | 104 | 16.0 | | a/ | | | a/ | | | a/ | |
| Gatewell 7A | 4/26 | 1700-2200 | CL | 5.0 | 450 | 494 | 8.9 | | a/ | | 84 | 122 | 31.0 | | a/ | | | a/ | |
| | 4/27 | 1800-2200 | CL | 4.0 | 282 | 323 | 12.7 | | a/ | | 174 | 250 | 33.0 | | a/ | | | a/ | |
| | 4/28 | 1730-220 | CL | 4.5 | 357 | 444 | 19.6 | | a/ | | 252 | 466 | 46.0 | | a/ | | | a/ | |
| | 5/5 | 1530-2300 | CL | 7.5 | 381 | 465 | 18.0 | 147 | 159 | 6.0 | 246 | 457 | 46.0 | 165 | 295 | 44.0 | | a/ | d/ |
| | 5/6 | 1230-1630 | CL | 4.0 | 309 | 367 | 16.0 | 693 | 540 | 9.0 | 243 | 327 | 26.0 | 177 | 355 | 50.0 | | a/ | d/ |
| | 5/8 | 1430-1900 | CL | 4.5 | 309 | 357 | 13.0 | 81 | 92 | 12.0 | 159 | 241 | 34.0 | 123 | 204 | 40.0 | | a/ | d/ |

a/ Insufficient numbers

b/ Ripped net

c/ Nets plugged with debris

d/ Fyke net catches of spring chinook and coho salmon hard to identify.

* Sample sizes of 30-50 fish are marginal for statistical significance

Appendix Table A7.--B slot, Bonneville Dam gatewell counts for spring chinook salmon.

| | Gatewell | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Total | Sluice |
| 5/25 | 11 | 8 | 38 | 94 | 142 | 105 | 17 | 11 | 12 | 31 | 469 | Closed |
| 26 | 3 | 11 | 16 | 67 | 197 | 31 | 20 | 12 | 16 | 43 | 416 | Closed |
| 27 | 11 | 2 | 4 | 25 | 66 | 49 | 10 | 6 | 7 | 51 | 231 | Open |
| 28 | 4 | 10 | 5 | 28 | 45 | 22 | 11 | 6 | 6 | 13 | 150 | Closed |
| 29 | 6 | 17 | 27 | 26 | 43 | 4 | 2 | 2 | 9 | 4 | 140 | Open |
| 30 | 10 | 16 | 10 | 31 | 103 | 13 | 2 | 8 | 3 | 10 | 206 | Closed |
| 31 | 3 | 4 | 10 | 13 | 51 | 10 | 4 | 4 | 2 | 6 | 107 | Open |
| 6/01 | 2 | 10 | 19 | 39 | 74 | 32 | 5 | 1 | 3 | 3 | 188 | Closed |
| 02 | 2 | 4 | 6 | 20 | 35 | 18 | 5 | 8 | 3 | 11 | 112 | Open |
| 03 | 6 | 6 | 10 | 51 | 85 | 25 | 10 | 7 | 3 | 8 | 211 | Closed |
| 04 | 16 | 4 | 23 | 60 | 58 | 21 | 8 | 1 | 2 | 3 | 196 | Open |
| 05 | 20 | 37 | 50 | 30 | 89 | 69 | 14 | 9 | 3 | 14 | 335 | Closed |
| 06 | 4 | 8 | 15 | 58 | 24 | 24 | 5 | 2 | 0 | 2 | 142 | Open |
| 07 | 18 | 13 | 14 | 33 | 41 | 18 | 8 | 9 | 4 | 10 | 168 | Closed |
| Total | 116 | 150 | 247 | 575 | 1053 | 441 | 121 | 86 | 73 | 209 | 3071 | |
| Percent | 3.8 | 4.9 | 8.0 | 18.7 | 34.3 | 14.4 | 3.9 | 2.8 | 2.4 | 6.8 | | |

Note: 5/25 is a 2-day accumulation, other days are 24-h accumulation ending approximately at noon.

Appendix Table A9.--B slot, Bonneville Dam gatewell counts for steelhead.

| | Gatewell | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Total | Sluice |
| 5/25 | 35 | 40 | 70 | 202 | 382 | 382 | 146 | 27 | 16 | 30 | 1330 | Closed |
| 26 | 18 | 17 | 67 | 98 | 360 | 309 | 309 | 28 | 24 | 46 | 1276 | Closed |
| 27 | 12 | 15 | 32 | 93 | 148 | 110 | 216 | 27 | 21 | 41 | 715 | Open |
| 28 | 40 | 53 | 74 | 97 | 152 | 149 | 171 | 23 | 16 | 10 | 785 | Closed |
| 29 | 49 | 55 | 69 | 89 | 295 | 115 | 96 | 16 | 14 | 17 | 815 | Open |
| 30 | 26 | 55 | 34 | 72 | 290 | 91 | 60 | 12 | 7 | 12 | 659 | Closed |
| 31 | 49 | 91 | 52 | 99 | 210 | 89 | 55 | 11 | 10 | 11 | 677 | Open |
| 6/01 | 8 | 55 | 32 | 87 | 226 | 140 | 78 | 17 | 17 | 18 | 678 | Closed |
| 02 | 39 | 32 | 86 | 106 | 179 | 69 | 51 | 18 | 16 | 19 | 615 | Open |
| 03 | 35 | 32 | 42 | 106 | 187 | 124 | 168 | 24 | 20 | 31 | 769 | Closed |
| 04 | 10 | 22 | 26 | 83 | 61 | 49 | 30 | 3 | 11 | 21 | 316 | Open |
| 05 | 30 | 38 | 35 | 68 | 137 | 126 | 82 | 17 | 15 | 20 | 568 | Closed |
| 06 | 11 | 30 | 20 | 36 | 66 | 37 | 14 | 11 | 9 | 20 | 254 | Open |
| 07 | 13 | 17 | 18 | 39 | 93 | 58 | 38 | 10 | 7 | 9 | 302 | Closed |
| Total | 375 | 552 | 657 | 1275 | 2786 | 1848 | 1514 | 244 | 203 | 305 | 9759 | |
| Percent | 3.8 | 5.7 | 6.7 | 13.1 | 28.5 | 18.9 | 15.5 | 2.5 | 2.1 | 3.1 | | |

Note: 5/25 is a 2-day accumulation, other days are 24 hr accumulation ending approximately at noon.

Appendix Table A11.--Bslot, Bonneville Dam gatewell counts for sockeye.

| | Gatewell | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Total | Sluice |
| 5/25 | 15 | 28 | 24 | 66 | 108 | 124 | 14 | 12 | 6 | 21 | 418 | Closed |
| 26 | 3 | 6 | 12 | 18 | 64 | 171 | 22 | 18 | 11 | 15 | 340 | Closed |
| 27 | 2 | 8 | 14 | 36 | 42 | 67 | 16 | 14 | 13 | 24 | 236 | Open |
| 28 | 3 | 9 | 9 | 28 | 34 | 31 | 16 | 7 | 4 | 5 | 146 | Closed |
| 29 | 7 | 13 | 9 | 20 | 49 | 40 | 4 | 4 | 5 | 1 | 152 | Open |
| 30 | 5 | 4 | 14 | 26 | 47 | 18 | 11 | 5 | 5 | 3 | 138 | Closed |
| 31 | 3 | 2 | 15 | 18 | 26 | 24 | 13 | 6 | 2 | 3 | 112 | Open |
| 6/01 | 4 | 14 | 20 | 33 | 28 | 37 | 8 | 10 | 11 | 5 | 170 | Closed |
| 02 | 4 | 5 | 14 | 25 | 41 | 25 | 15 | 2 | 6 | 5 | 142 | Open |
| 03 | 4 | 14 | 24 | 26 | 60 | 34 | 28 | 10 | 11 | 13 | 224 | Closed |
| 04 | 6 | 10 | 11 | 42 | 45 | 37 | 22 | 9 | 5 | 2 | 189 | Open |
| 05 | 16 | 18 | 26 | 60 | 53 | 67 | 37 | 9 | 10 | 15 | 311 | Closed |
| 06 | 4 | 8 | 15 | 49 | 38 | 56 | 16 | 12 | 3 | 15 | 216 | Open |
| 07 | 8 | 10 | 14 | 40 | 34 | 31 | 11 | 14 | 8 | 15 | 185 | Closed |
| Total | 84 | 149 | 221 | 487 | 669 | 762 | 233 | 132 | 100 | 142 | 2979 | |
| Percent | 2.8 | 5.0 | 7.4 | 16.3 | 22.5 | 25.6 | 7.8 | 4.4 | 3.4 | 4.8 | | |

Note: 5/25 is a 2-day accumulation, other days are 24-h accumulation ending approximately at noon.

Appendix Table A12.--Continued.

| Coho | Sluice | Ave. total | % sluice |
|---|---|---|---|
| 5/26 - 27 | 7,292 | 19,473 | 37.4 |
| 5/28 - 29 | 1,999 | 8,561 | 23.4 |
| 5/30 - 31 | 4,139 | 6,278 | 65.9 |
| 6/01 - 02 | 1,917 | 3,985 | 48.1 |
| 6/03 - 04 | 2,055 | 3,551 | 57.9 |
| 6/05 - 06 | 1,805 | 3,278 | 55.1 |
| Total | 19,207 | 45,126 | 42.6 |

| Sockeye | Sluice | Ave. total | % sluice |
|---|---|---|---|
| 5/26 - 27 | 916 | 5,616 | 16.3 |
| 5/28 - 29 | 710 | 3,024 | 23.5 |
| 5/30 - 31 | 1,371 | 2,925 | 46.9 |
| 6/01 - 02 | 1,109 | 3,349 | 33.1 |
| 6/03 - 04 | 2,241 | 4,819 | 46.5 |
| 6/05 - 06 | 2,067 | 5,753 | 35.9 |
| Total | 8,414 | 25,485 | 33.0 |

Appendix Table A14.--Sluiceway passage efficiency using total daily passage determined by averaging estimated powerhouse passage on the day before and after each test day when the sluiceway was closed.

| | Total | % sluice | 95% CI | Sluice |
|---|---|---|---|---|
| Spring chinook | 36,235 | 49.2 | ± 27.9 | 17,817 |
| Fall chinook | 782,107 | 5.1 | ± 9.4 | 40,039 |
| Steelhead | 43,331 | 76.9 | ± 25.1 | 33,334 |
| Coho | 36,479 | 52.7 | ± 21.6 | 29,658 |
| Sockeye | 22,416 | 37.5 | ± 12.6 | 18,314 |
| Total | 920,568 | 12.9 | ± 19.8 | 118,811 |

[redacted]

The material for Appendix B was not received from the Oregon Department of Fish and Wildlife in time to be bound into this report. It will be distributed to recipients of this report when it becomes available.

[redacted]

[redacted]

Appendix Table C1--(continued)

$N_S$ : Total number of fish recovered from the unit during a standard run.

$N_{AS}$: Number of fish recovered from A Slot during a standard run.

$N_{BS}$: Number of fish recovered from B Slot during a standard run.

$N_{CS}$: Number of fish recovered from C Slot during a standard run.

NT : Total number of fish that would be recovered from the unit during a test run if the number of fish using the test condition were known. This would be identical to $N_S$ if the number of fish using the test conditions were known.

$N_{BT}$: Number of fish recovered from the B Slot during a test run.

$N_{AT}$: Number of fish entering the A Slot during a test run. This is unknown.

$N_{CT}$: Number of fish entering the C Slot during a test run. This is unknown.

$R_{AT}$: Number of fish recovered from the A Slot during a test run.

$R_{CT}$: Number of fish recovered from the C Slot during a test run.

$E_{AT}$: Number of fish using the test condition in the A Slot. This is unknown.

$E_{CT}$: Number of fish using the test condition in the C Slot. This is unknown.

$P_{XY}$: Probability of a fish using the X slot during a Y run, where

X: is A, B or C Slot

Y: is standard or test run.

Appendix Table C1.--(continued)

$P_{BS}$ can be used as an estimate of $P_{BT}$ and,

$$\hat{N}_T = N_{BT}/\hat{P}_{BT} = N_{BT}/P_{BS}$$

An estimate of $N_{AT}$ can be obtained from,

$$P_{AT} = N_{AT}/N_T$$

$$N_{AT} = N_T \, P_{AT}$$

We can use $P_{AS}$ as an estimate of $P_{AT}$ $\therefore$

$$\hat{N}_{AT} = \hat{N}_T \, \hat{P}_{AT} = \left(\frac{N_{BT}}{P_{BS}}\right) P_{AS}$$

Also,

$$N_{AT} = R_{AT} + E_{AT} \quad \text{and}$$

$$E_{AT} = N_{AT} - R_{AT} \quad \text{and}$$

$$\hat{E}_{AT} = \hat{N}_{AT} - R_{AT}$$

Appendix Table C1--(continued)

The formula for estimating FPE for the C slot is the same and can be written:

$$\widehat{FPE}_C = 1 - P_{BC} \; N_{BC}$$

$$= 1 - \left(\frac{P_{BS}}{P_{CS}}\right) \left(\frac{R_{CT}}{N_{BT}}\right) .$$

These equations apply to each fish species or to combinations of fish species. Also, these equations can be written:

$$\widehat{FPE}_A = 1 - \left(\frac{N_{BS}}{N_{AS}}\right) \left(\frac{R_{AT}}{N_{BT}}\right)$$

$$\widehat{FPE}_C = 1 - \left(\frac{N_{BS}}{N_{CS}}\right) \left(\frac{R_{CT}}{N_{BT}}\right)$$

Appendix Table C3--Percent descaling of fingerlings removed from gatewells upon termination of orifice cycling tests.

| | Species | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Spring chinook | | Fall chinook | | Steelhead | | Coho | | Sockeye | |
| Test condition | % descaled | Sample size | % descaled | Sample size | % descaled | Sample size | % descaled | Sample size | % descaled | Sample size |
| Cycling test 4 h closed and 2 h open | 23.0 | 123 | 5.0 | 1,085 | 23.0 | 34 | 1.0 | 175 | 14.0 | 21 |
| Cycling test 2 h closed and 1 h open | 3.0 | 31 | 0 | 2,057 | 6.0 | 52 | 11.0 | 27 | 12.0 | 60 |
| Not cycled (open 24 h) | 7.0 | 103 | 0.5 | 2,150 | 13.0 | 153 | 2.0 | 571 | 10.0 | 31 |
| Orifice closed 24 h | 18.7 | 726 | 3.4 | 6,442 | 17.2 | 272 | 2.5 | 2,861 | 9.0 | 88 |