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

by
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# 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.

## GENERAL BACKGROUND INFORMATION

### Submersible Traveling Screen Evaluation

As an STS had not been tested previously at Bonneville Dam, evaluation studies were intended to determine: 1) its fish-guiding efficiency (FGE) for each species and principal race of downstream migrant salmon and steelhead passing the project, 2) its optimal configuration within the turbine intake, 3) its vulnerability to debris, and 4) the condition of the fish guided.

STS testing (30 April-7 June) coincided with the principal spring juvenile outmigration through the lower Columbia River.

### Distribution and Passage of Fingerlings Through the Powerhouse and the Ice-trash Sluiceway

It was necessary to make a daily population estimate of the number of fingerlings passing through the powerhouse as a part of the ice-trash sluiceway evaluation program. This involved two phases: (1) determining the horizontal distribution of fingerlings among individual units and adjacent intake slots, and 2) determining the percentage of the fingerlings entering the gatewells.

### Orifice Cycling

Cycling the operation of the orifices in the gatewells would reduce both the amount of water needed to operate the bypass system and construction costs. The experiment tested various on-off cycles that involved the operation of only one-third of the orifices at a time.

## 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.

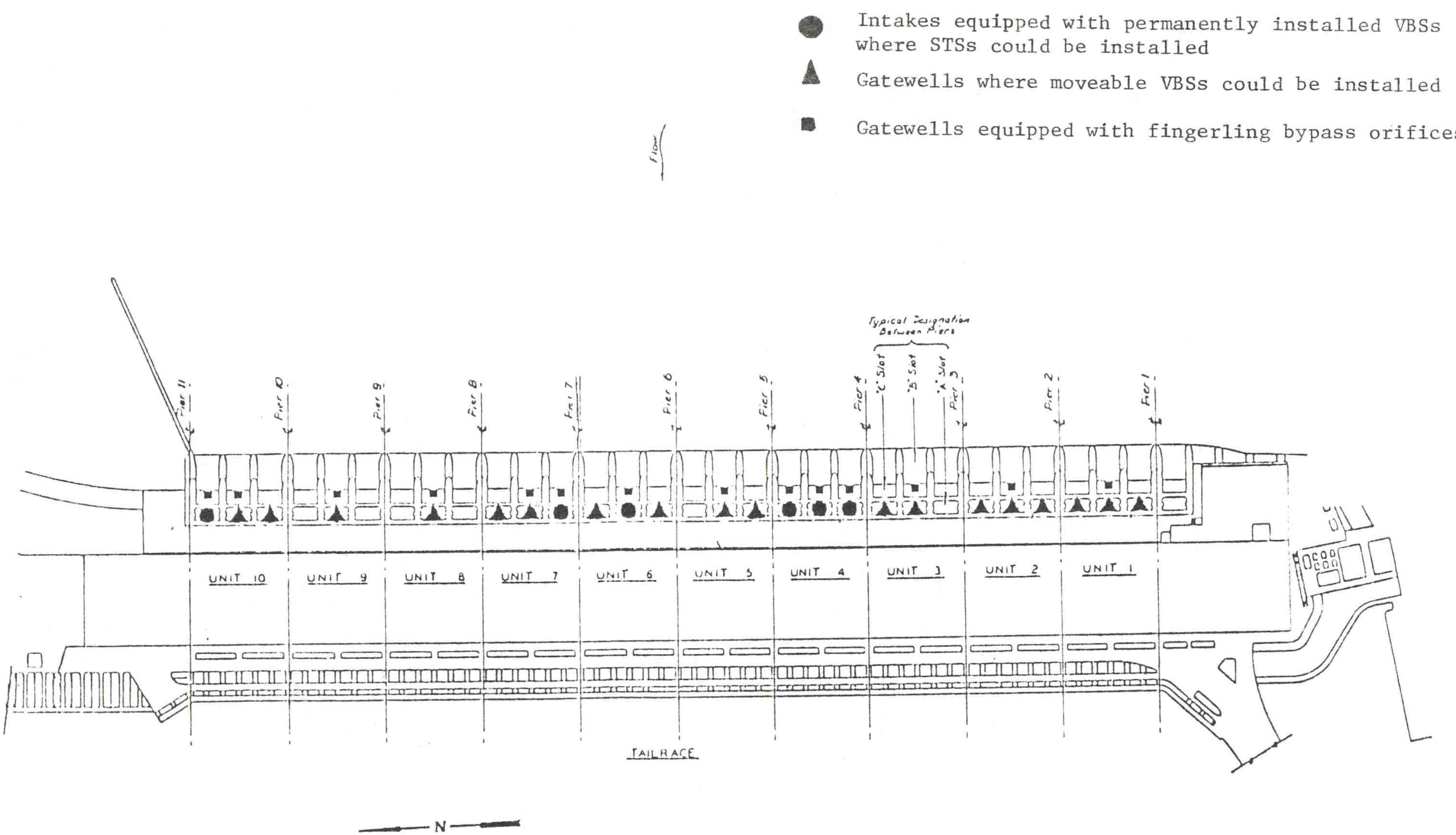



Figure 1. Gatewells in the Bonneville First Powerhouse with provisions for permanent vertical barrier screens and STSs, moveable vertical barrier screens, and gatewells with fingerling bypass orifices (1981).

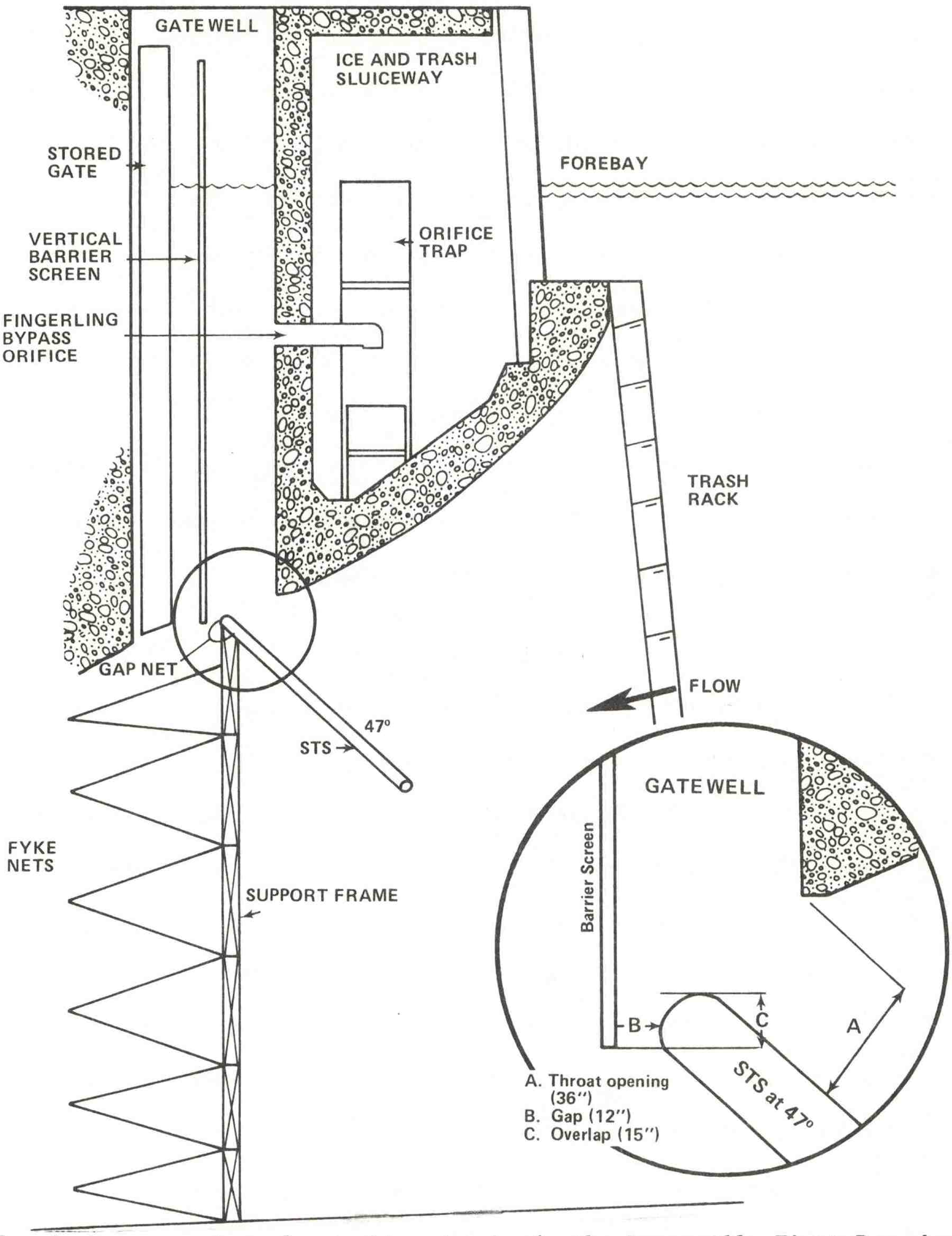



Figure 2. A cross section of a turbine intake in the Bonneville First Powerhouse showing location of vertical barrier screen, fingerling bypass orifice (with orifice trap), submersible traveling screen (STS) (with fyke nets), and position and angle (47°) of STS that provided optimum FGE (Throat opening,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

STSs were placed in the A, B, and C Bulkhead Slots of Unit 4. The fixed screen-guiding device was utilized in the adjacent slots (3C and 5A) to simulate an adjacent STS. Each test condition was replicated a minimum of three times. Tests were initiated in the middle to late afternoon and terminated in late evening to coincide with the principal period of movement of juveniles through the turbine intakes. The duration of each test was adjusted to attempt to maintain catches in excess of 50 fish of each species in each replicate. This was not always possible, especially during periods of movement of large numbers of hatchery reared fall chinook salmon released from nearby hatcheries.

FGE tests began on 30 April 1981 and the principal series were concluded on 13 May 1981. FGE tests of individual screens were carried on periodically through the remainder of the study.

## Experimental Design

Fish Guiding efficiency (FGE) is that percentage of the total number of fish moving through the turbine intake over the test period which are deflected into the intake gatewell by the fish guiding device. For FGE tests the STSs were fitted with net frames which allowed determination of the number of fish passing underneath the STS and through the gap at the top of the STS. Fyke nets below the STS sampled the center one-third of the area of the turbine intake. A gap closure net sampled the entire width of the gap area. The number of fish deflected in the intake gatewell was determined by removing accumulated fish from the intake with a basket-like dip net. Intake gatewells were cleared of fish by dipnetting at the start and conclusion of each test.

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 1.--Fish-guiding efficiency and gap loss by species for the submersible traveling screens in the Bonneville First Powerhouse (1981).[a]

| | FGE (%) | Gap loss[b] (%) |
|---|---|---|
| Spring Chinook | 76.4 | 2.8 |
| Fall Chinook | 71.5 | 8.7 |
| Steelhead | 77.6 | 0.6 |
| Coho | 81.3 | 2.1 |
| Sockeye[c] | 81.7 | 1.0 |

a/ Pooled total collection at 47 and 53° screen angles over duration of study.

b/ Gap opening 12 inches.

c/ Small sample size.

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.

### Quality of Guided Fish

The STS had very little effect on fish quality based on the minor differences noted in the rate of descaling between test and control fish, except for sockeye salmon where the rate of descaling increased from 3 to 7% (Table 2). However, the sample size was relatively small for this test group.

### Effects of Debris on Operation

Debris occasionally collects rapidly in the forebay during peak fingerling migrations. Due to the configuration of the first powerhouse turbine intake (the ceiling starts only about 10 feet below forebay elevation), large amounts of debris were sucked through the trash racks by the turbines and consequently were intercepted by the STS.

Determining the effects of debris on the STS was accomplished by a visual inspection of the STS from Unit 7A immediately after a period of extremely heavy debris load in the river. During one 24-h period of operation, approximately 5 cubic yards of material was intercepted by the STS and diverted into the gatewell (Figure 3). The debris consisted of material both large and small and included things such as portions of old railroad ties, large tree limbs (4-5 feet long and up to 6-inch diameter), pieces of lumber of various sizes, wood chips, bark, leaves, grass, etc. The STS operated normally throughout this period, and a visual inspection showed no sign of damage. It was noted, however, that rub marks on the lower shaft assembly indicated an area of marginal clearances for small pieces of debris that got between the screen.

It should be cautioned that these results do not mean that debris damage to an STS will not occur; however, the probability would appear low since all three screens ran smoothly with existing debris loads during

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 |

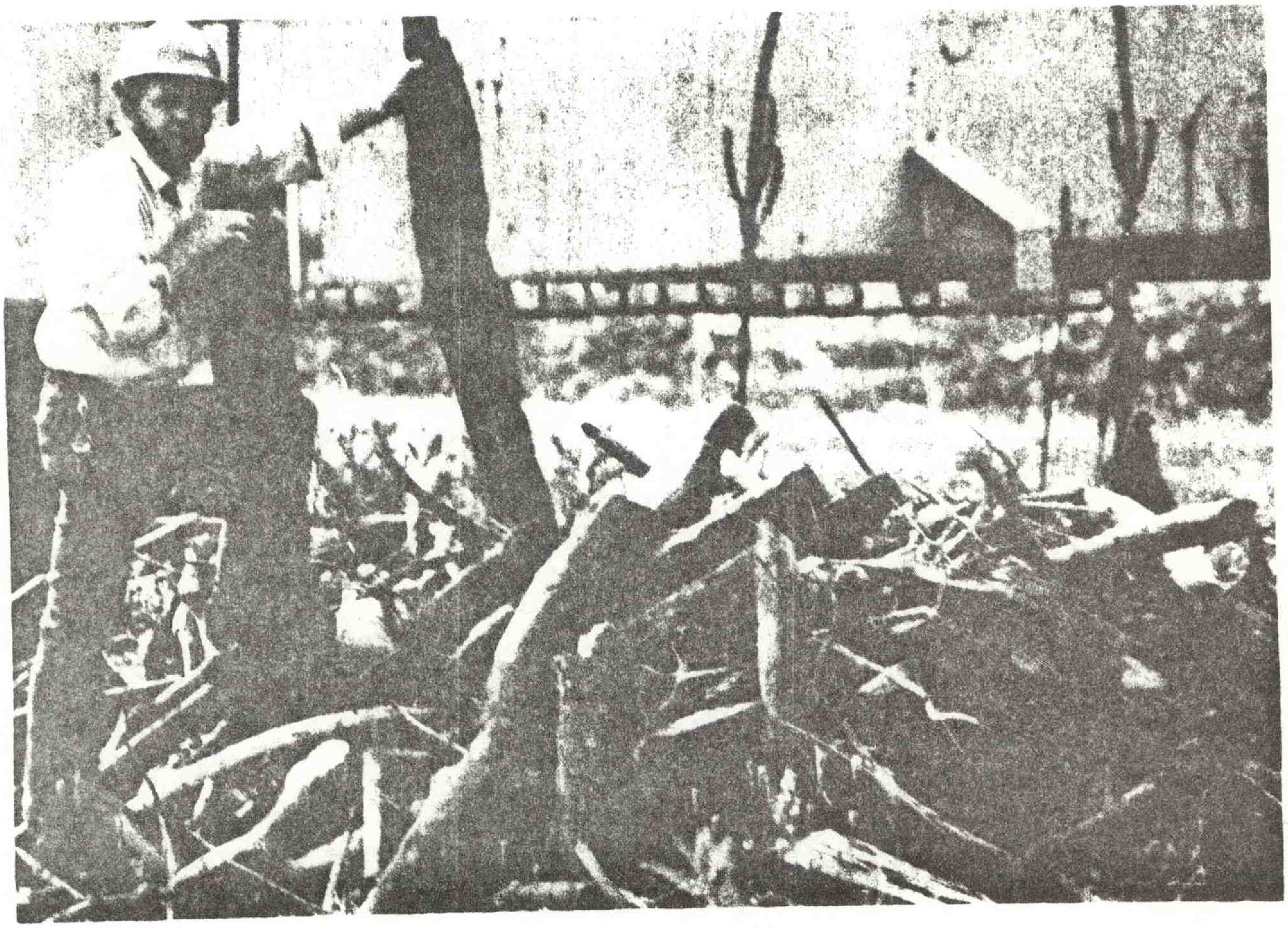


Figure 3.--A 24-h accumulation of debris (approximately 5 cubic yards) removed from gatewell 7A with an STS in operation at Bonneville Dam, 1981.

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.

Vertical distribution and percent gatewell catch by species was determined from sampling Intake Slots 5A and 5B with fyke nets and gatewell dip nets. The fixed screen guiding device was removed from Slot 5A for these tests. The fyke net array sampled the middle one-third of the cross-sectional area of the turbine intake. Each of the six nets sampled approximately 7 feet of depth. The gatewells were equipped with vertical barrier screens so that fish entering the gatewell were retained for daily sampling by dip nets. Prior to lowering the fyke net frame into the intake, the previous day's accumulation of fish in the gatewells was removed with the dip net. The fyke nets were generally fished for 3 to 6 h depending on species abundance. The gatewell was again dipnetted and the fyke net array brought up. Catches in both were then tabulated by species. Vertical distribution was determined from the fyke and dipnet catches. The percent gatewell catch (% GW) was calculated according to the following equation:

$$\% \text{ GW} = \frac{\text{GW}}{\text{GW} + (3)(\text{FN})} \times 100$$

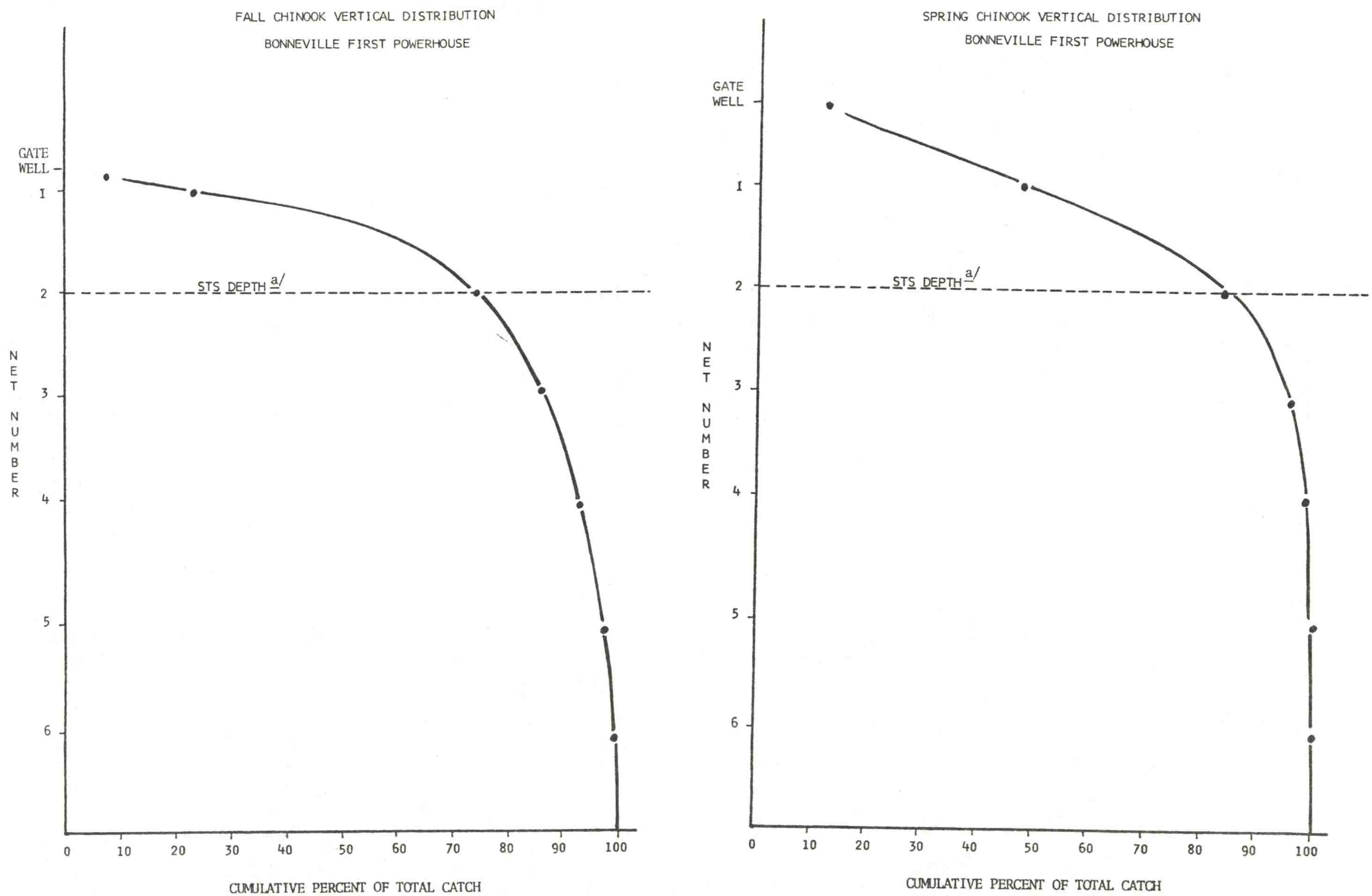
GW = gatewell catch

FN = fyke net catch

Gatewell catch expanded by % GW provided the measure of total passage through B Intakes of the turbines, expressed as:

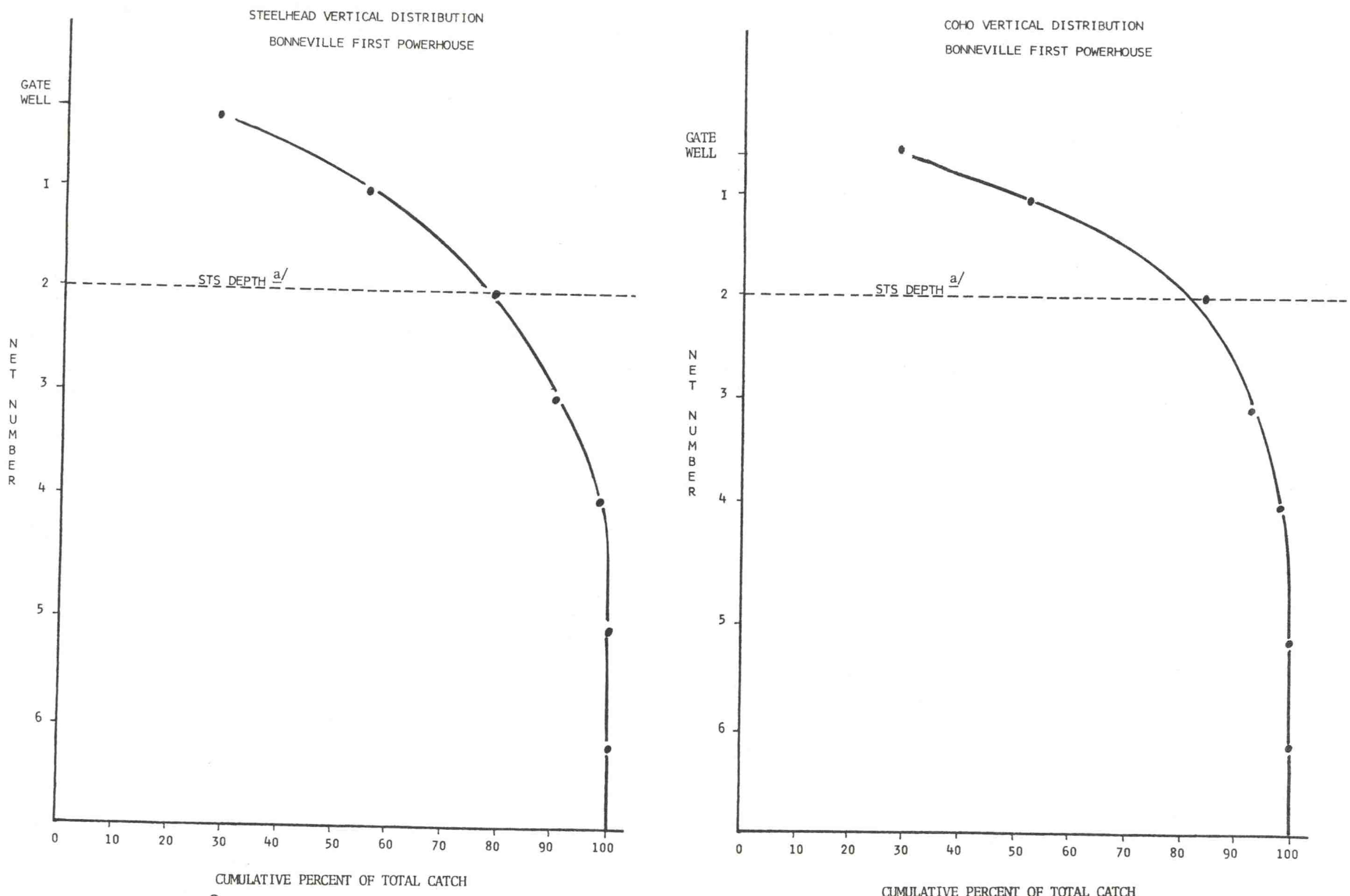
$$\text{B Intake passage} = \frac{\text{GW} \times 100}{\% \text{ GW}}$$

The data obtained on spring and fall chinook salmon, steelhead, and coho and sockeye salmon are presented in Figures 4, 5, and 6.



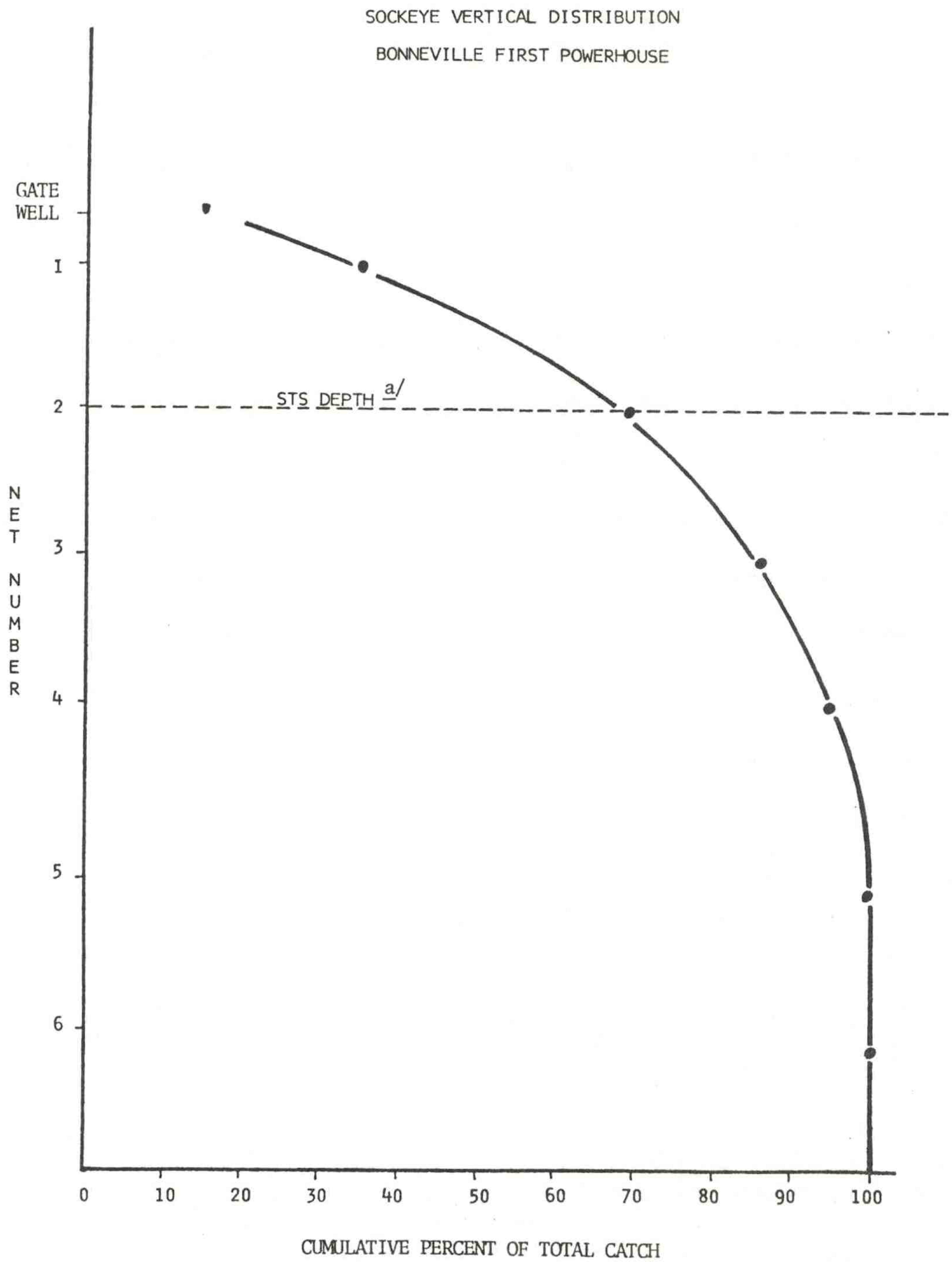

a/ STS at 47° angle.

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




a/ STS at $47^{\circ}$ angle.

Figure 5.--Vertical distribution of coho salmon and steelhead 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.

In general, the vertical distribution data indicated that: (1) a much higher percentage of the larger coho salmon and steelhead entered the gatewell than did the smaller fall chinook salmon; (2) between 75 and 90% of the fingerlings were distributed in the area of the intake intercepted by the STS (approximately the first 14 feet below the ceiling of the intake); and (3) fall chinook and sockeye salmon appeared to be distributed deeper than spring chinook salmon, coho salmon, and steelhead.

Percent gatewell catch in other units appeared to generally correspond to observations in Unit 5 with the exception of the A Slot of Unit 7 (data summarized in Appendix Table A4). Because of a guidewall extending upstream between Units 6 and 7, a large eddy forms in front of Unit 7. Apparently, large numbers of steelhead smolts accumulate in this eddy and pass through Unit 7 with a very shallow distribution. Nearly 40% of the steelhead passing through the intake of 7A entered the gatewell slot of their own volition. Accordingly, separate expansion factors were used for the Unit 7 gatewell catch in estimating daily B Intake passage. Data and expansion factors are contained in Appendix Tables A5 and A6.

## Turbine Intake Distribution

The difference in water flow through each of the three intakes of a turbine unit at Bonneville Dam is small. The flow through the center, or B Intake, is 33.5% of total flow; the A Intake passes 31.0%; and the C Intake, 35.5%. Comparisons of gatewell and fyke net catches between the A, B, and C Intakes of Unit 4 indicated there was a good relation between percent intake flow and gatewell catch, with the B Intake accounting for about 33% of the total catch. This distribution was subsequently verified at Units 1, 5, 6, and 7. Intakes 6C and 7A (the intakes on either side of 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:

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

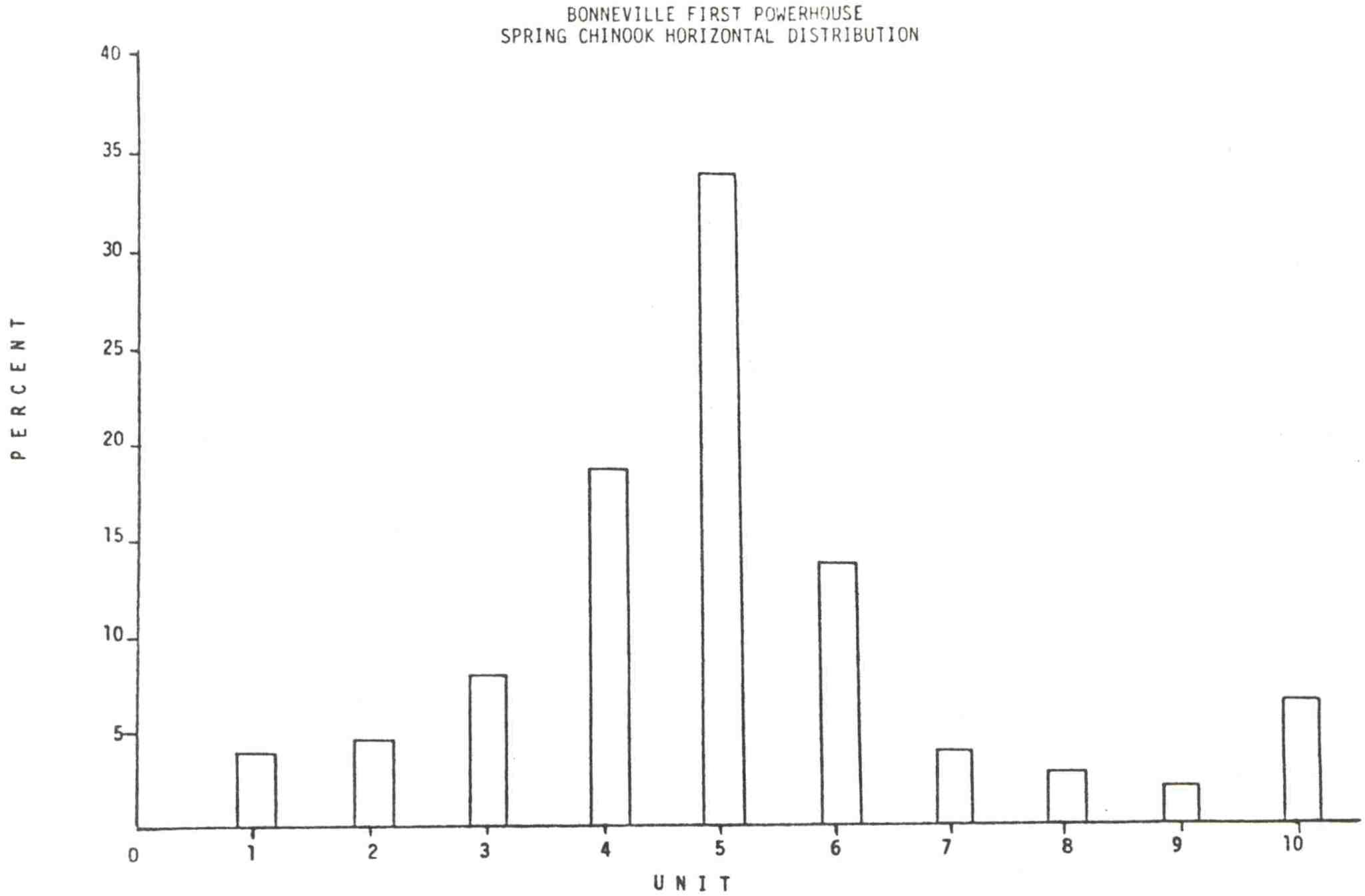
Total daily passage through each turbine by species was estimated as follows:

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

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.



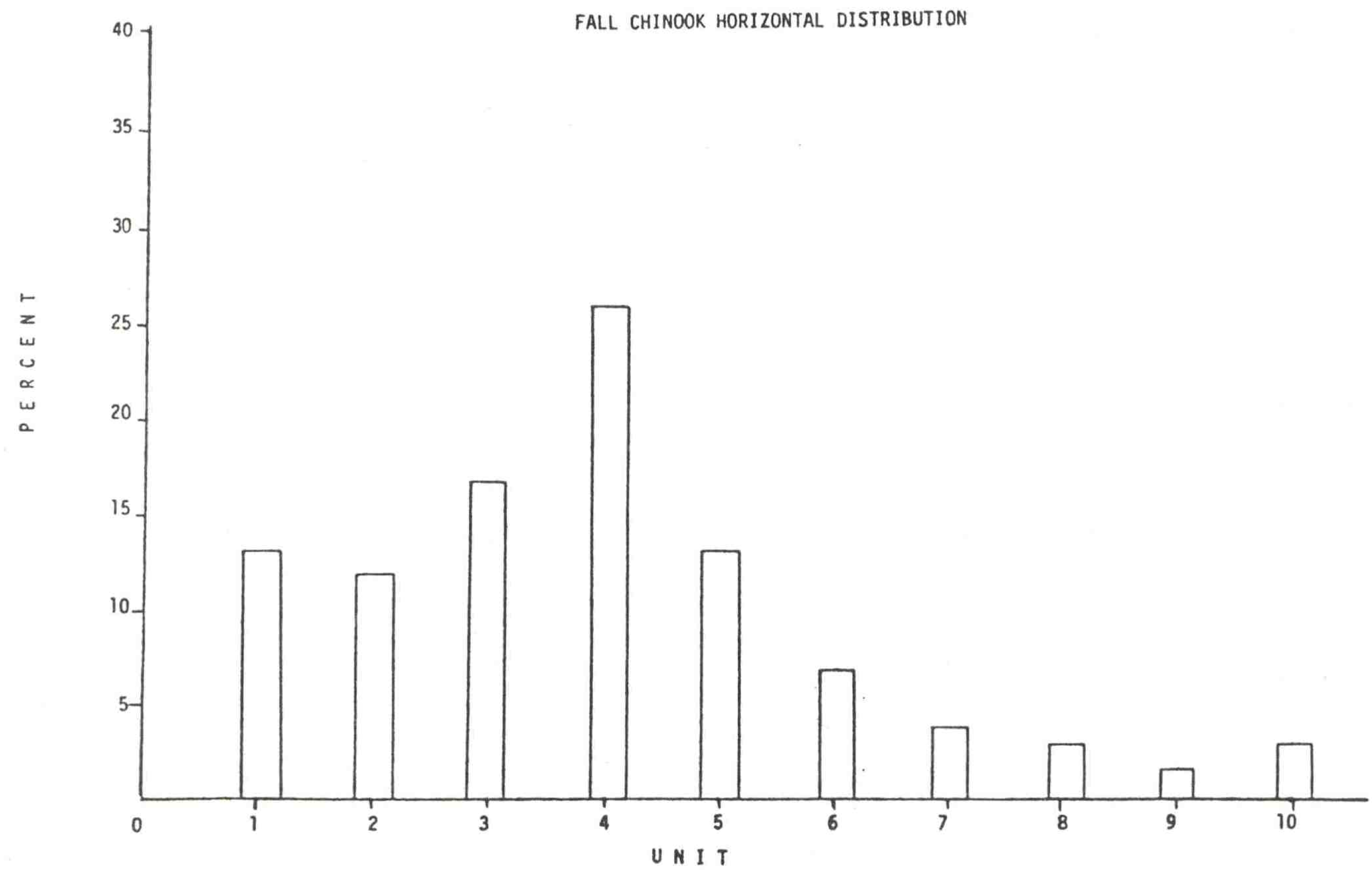
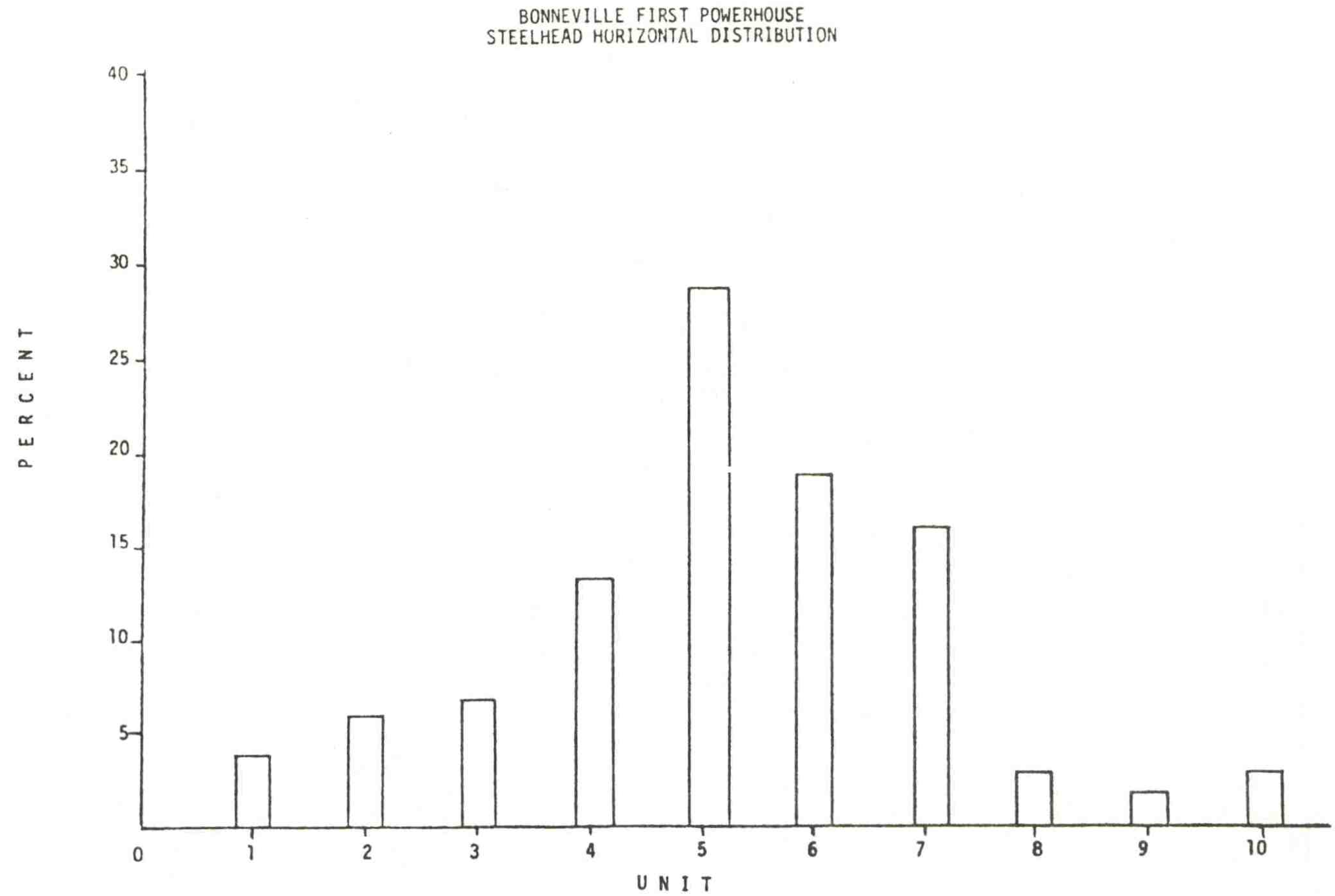




Figure 7.--Horizontal distribution of spring and fall chinook fingerlings at Bonneville Dam computed from gatewell dipnet catches in 1981.



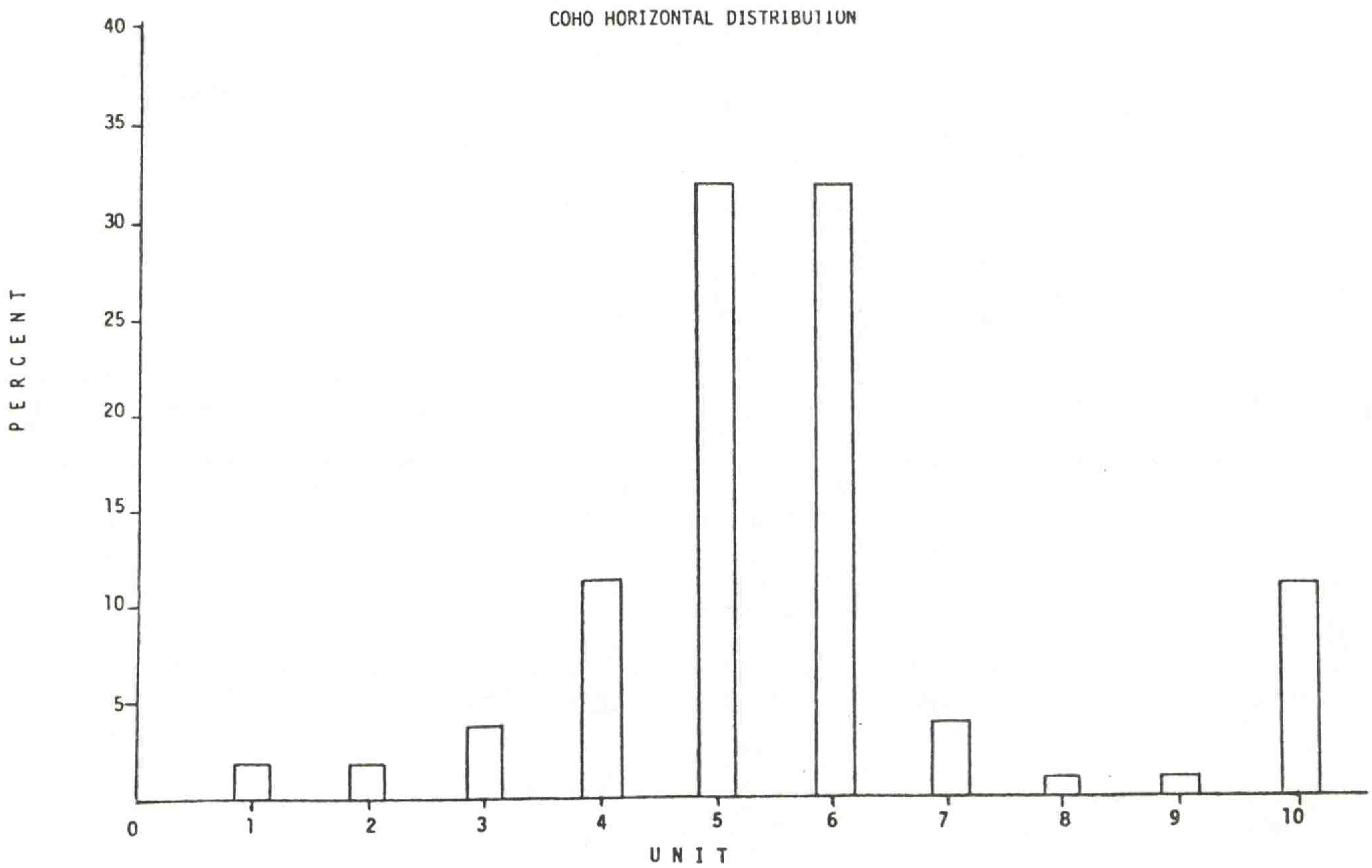




Figure 8.--Horizontal distribution of steelhead and coho salmon fingerlings at Bonneville Dam computed from gatewell dipnet catches in 1981.

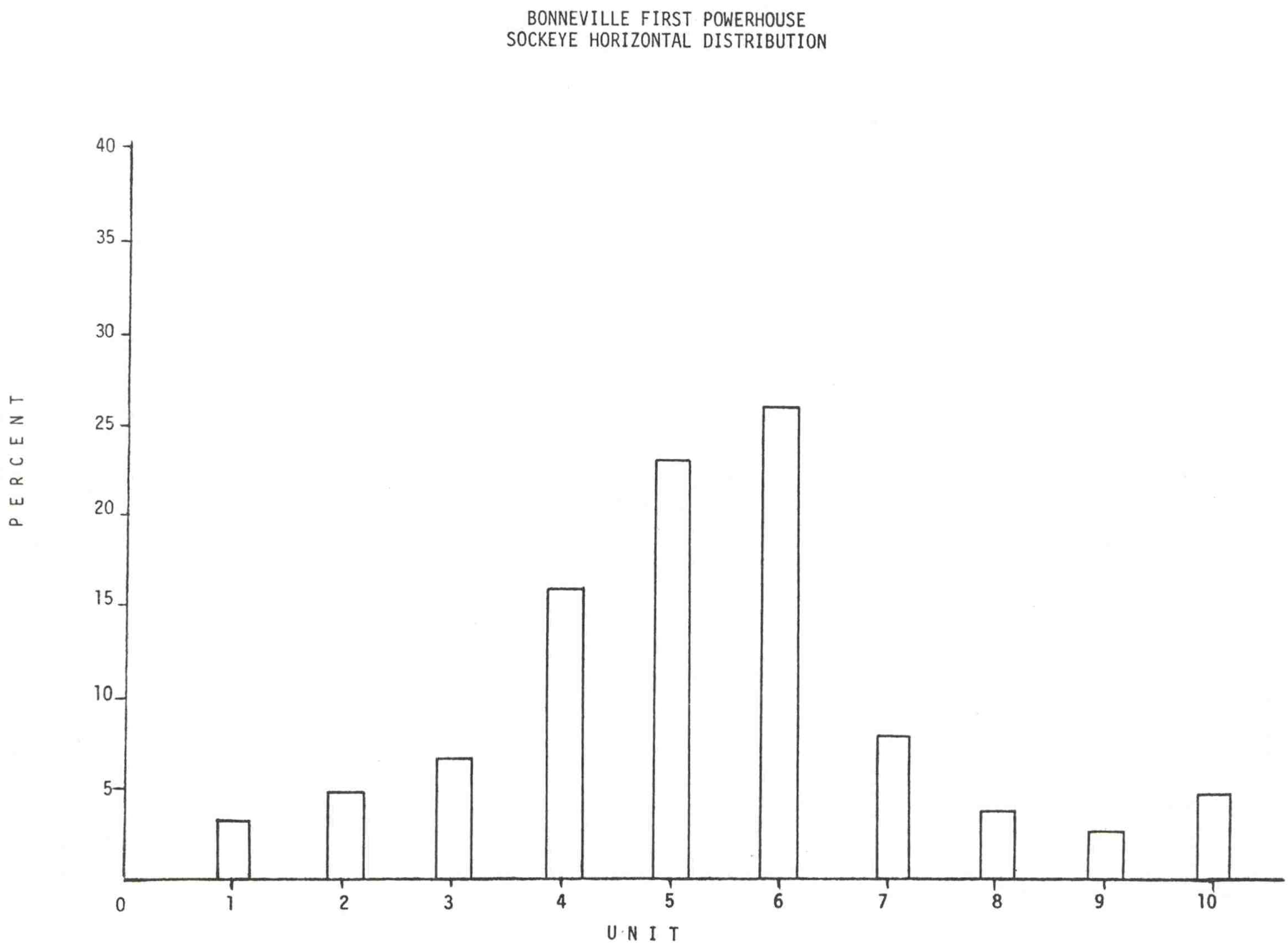



Figure 9.--Horizontal distribution of sockeye salmon fingerlings at Bonneville Dam computed from gatewell dipnet catches in 1981.

## 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):

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

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

Table 3.--Estimated daily powerhouse turbine intake passage, Bonneville Dam, 5 May to 17 June 1981. (Noon to noon gatewell catches expanded using B slot and Unit 5/7 gatewell factors--see Appendix Tables A5 and A6.)

| Date | Sluicway | SpCh | FCh | St | Co | So |
|---|---|---|---|---|---|---|
| 5/26 | closed | 10,777 | 9,052 | 12,309 | 19,493 | 6,089 |
| 27 | open | 5,991 | 8,356 | 6,795 | 12,162 | 4,227 |
| 28 | closed | 3,863 | 9,513 | 7,618 | 8,771 | 2,615 |
| 29 | open | 3,655 | 10,783 | 8,104 | 6,352 | 2,722 |
| 30 | closed | 5,384 | 9,188 | 6,595 | 4,590 | 2,472 |
| 31 | open | 2,779 | 11,819 | 6,791 | 3,827 | 2,006 |
| 6/01 | closed | 4,894 | 18,612 | 6,747 | 4,255 | 3,045 |
| 02 | open | 2,904 | 14,210 | 6,167 | 1,799 | 2,543 |
| 03 | closed | 5,467 | 24,010 | 7,462 | 3,303 | 4,012 |
| 04 | open | 5,086 | 13,618 | 3,160 | 1,745 | 3,385 |
| 05 | closed | 8,691 | 31,167 | 5,612 | 3,148 | 5,570 |
| 06 | open | 3,690 | 441,847 | 2,564 | 1,603 | 3,869 |
| 07 | closed | 4,353 | 1,382,142 | 2,997 | 3,605 | 3,313 |

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.

the sluice-closed day and passed on the succeeding day were accounted for. SPE was therefore calculated in the following manner:

$$SPE = \frac{S}{\frac{PH1 + (PH2 + S)}{2}} \times 100$$

S = sluice passage

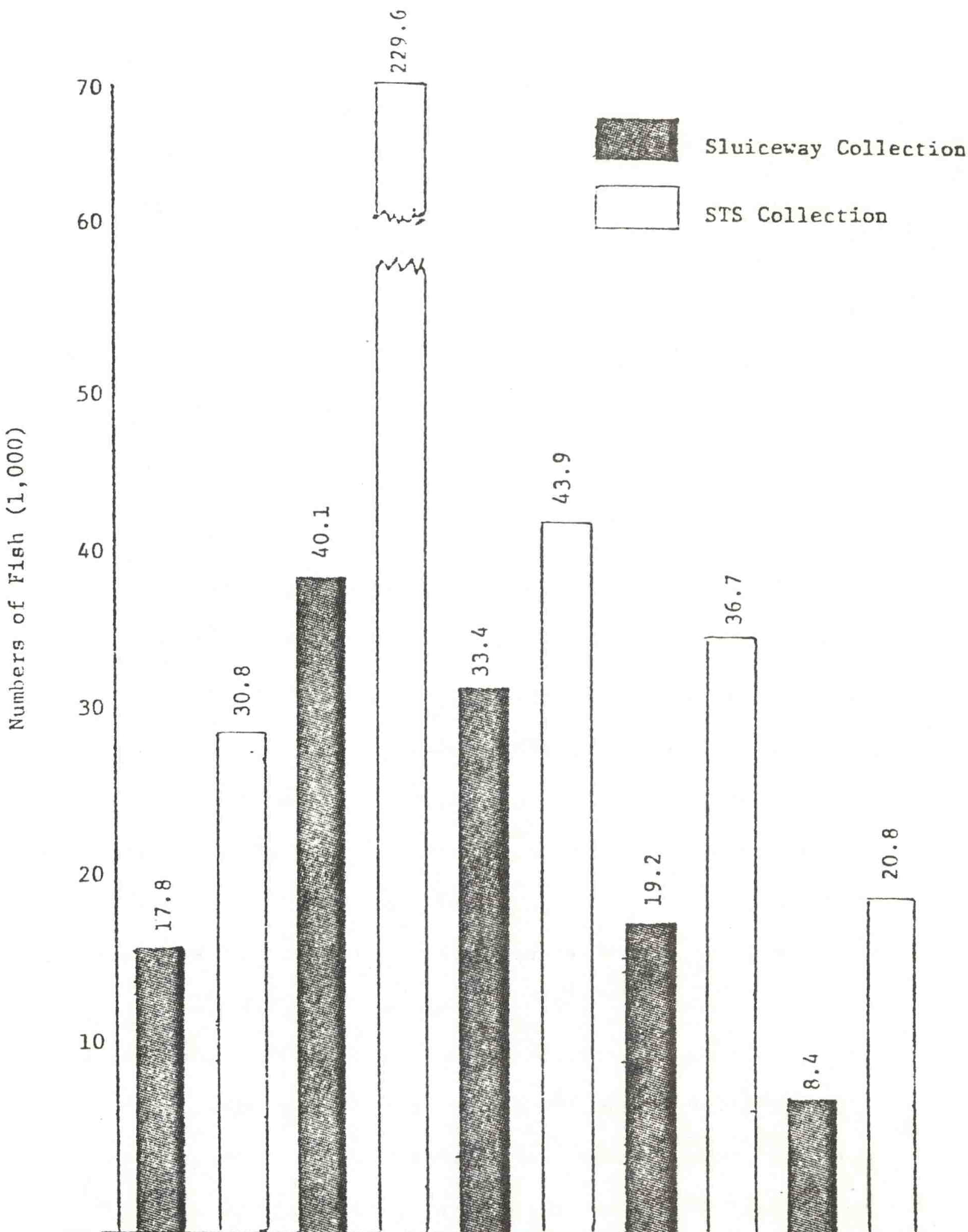
PH1 = turbine passage on preceding day

PH2 = turbine passage on sluice-open day

Sluice Gates 4B, 5B, 6B, 7A, and 10A were open during the first period of sluice testing which ended on 27 May. Gates 4B, 6B, 7A, and 10A were used for the remainder of the test series.

Figure 10 shows that the calculated sluiceway passage efficiency was lower than the estimated powerhouse collection efficiency for all species assuming that all intakes were equipped with STSs. Sluiceway passage efficiency ranged from 12.5% for fall chinook salmon to 58.9% for steelhead. For all species combined, the sluiceway guided an estimated 118,967 fish, or ≈ 24%, of the estimated 488,726 passing through the powerhouse. By contrast, if all intakes had been screened, an estimated 361,892 fish would have been diverted out of the turbine intakes, or ≈ 74% of the total powerhouse passage.

Daily estimates of sluiceway passage efficiency by species are contained in Appendix Table A12. On the first two sluice-open days of the test, passage was less than on succeeding days for all species due to low forebay elevations which reduced the total flow into the sluiceway. Appendix A also includes the results of two alternative methods of calculating daily powerhouse and sluiceway passage efficiencies. The method summarized in Table A14 estimates total daily passage as the average




| 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.)

of passage on the day preceding and the day following the test. This method appears to underestimate total passage. The method summarized in Table A15 utilizes daily estimated intake and sluiceway passage. This method is biased by systematic differences in total passage between sluiceway open and sluiceway closed days as previously discussed. (Similar results are presented in the ODFW report--Appendix B, although some differences in efficiency estimates occur due to the specific daily data included in calculations.)

## ORIFICE CYCLING

The initial orifice cycling studies were in Unit 10C (25 May-12 June), but the studies were completed in Unit 4 (17 June-9 July) because there were more fish in Unit 4 and turbulence problems in Gatewell 10C interfered with the efficiency of the orifice. The orifice in Gatewell 10C was selected orginally because an orifice trap could be installed in the ice-trash sluiceway at this location (the far north end unit of the powerhouse) and not interfere or prevent normal sluiceway operation. While operating in Gatewell 10C, it was noted that full-time orifice operation was not meeting the acceptable standard of 75% fish passage efficiency (FPE). The problem appeared to be related to an upwelling at the north end of the gatewell (the end where the orifice was located) which resulted in a traversing flow towards the south end of the gatewell.

### Methods and Procedures

Each gatewell was equipped with a vertical barrier screen (VBS) and a fish-guiding device (Figure 2). A crane and dip basket were used to remove fish from the gatewells. The orifice trap on Unit 10C collected all fish 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 accumulate fish for a set number of hours (24 or 72); and dip net, identify, and count the fish from each gatewell. These data gave a proportionate number for each gatewell. The probability formula was then developed to estimate the total number of fish entering a given gatewell.

A series of marked fish releases were conducted to check the efficiency of the dip net and to determine if escapement from the gatewells occurred when the orifices remained closed during the Unit 4 indexing tests. Fingerlings were anesthetized in a solution of MS-222 and marked with either an upper or lower partial caudal fin clip. The marked fish were held for a minimum of 2 h before being released.

The results indicated high dip net efficiency and minimal gatewell escapement. Four releases of 200 fish each were made between 22 and 24 April with a recovery percentage of 91-99%. On 26 May, 46 coho salmon were released at 1500 h; 44 (95.6%) were recovered at 1230 h on 27 May. On 2 June, 50 coho salmon were released at 1330 h; 50 (100%) were recovered at 1400 h the same day.

## Fish Passage Efficiency of Cycled Orifices

Orifice FPE in Gatewell 10C was much lower during cycling tests. The index FPE (no-cycling) for fall chinook salmon was 65.9%, whereas cycling the orifice on a 2-h closed and 1-h open schedule gave a FPE of only 34.9%. Neither of these percentages meet the acceptable FPE established for efficient orifice passage. Sample size for all other species was insufficient for evaluation.

The probability formula developed for estimating FPE for the Unit 4 orifice cycling studies required a sample size of at least 150 fish; species not meeting this requirement could not be evaluated. The only 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

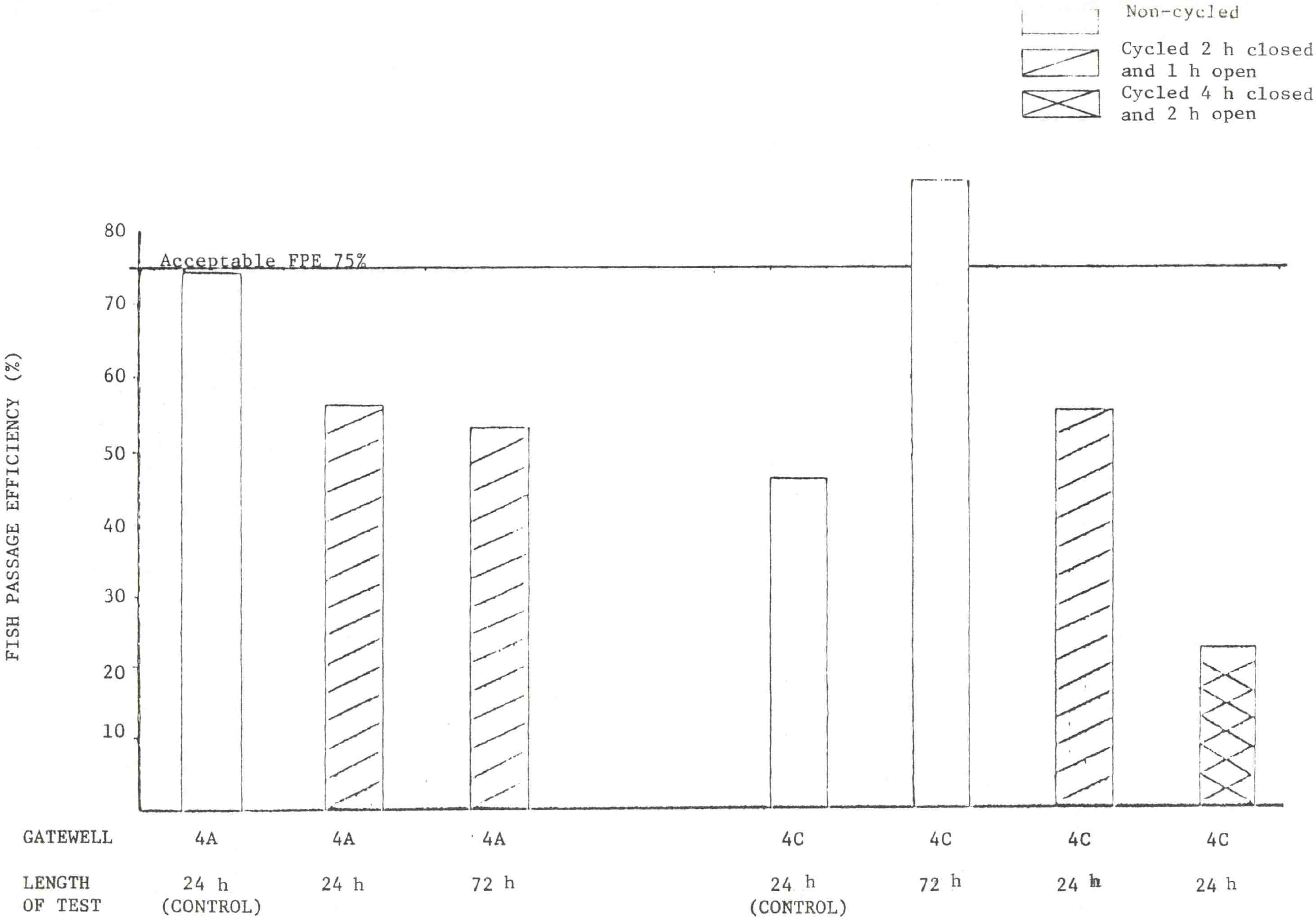



Figure 11.--A comparison of the orifice FPE for fall chinook salmon for a cycled and non-cycled condition and test of 24 h and 72 h duration at Bonneville Dam, 1981.

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.

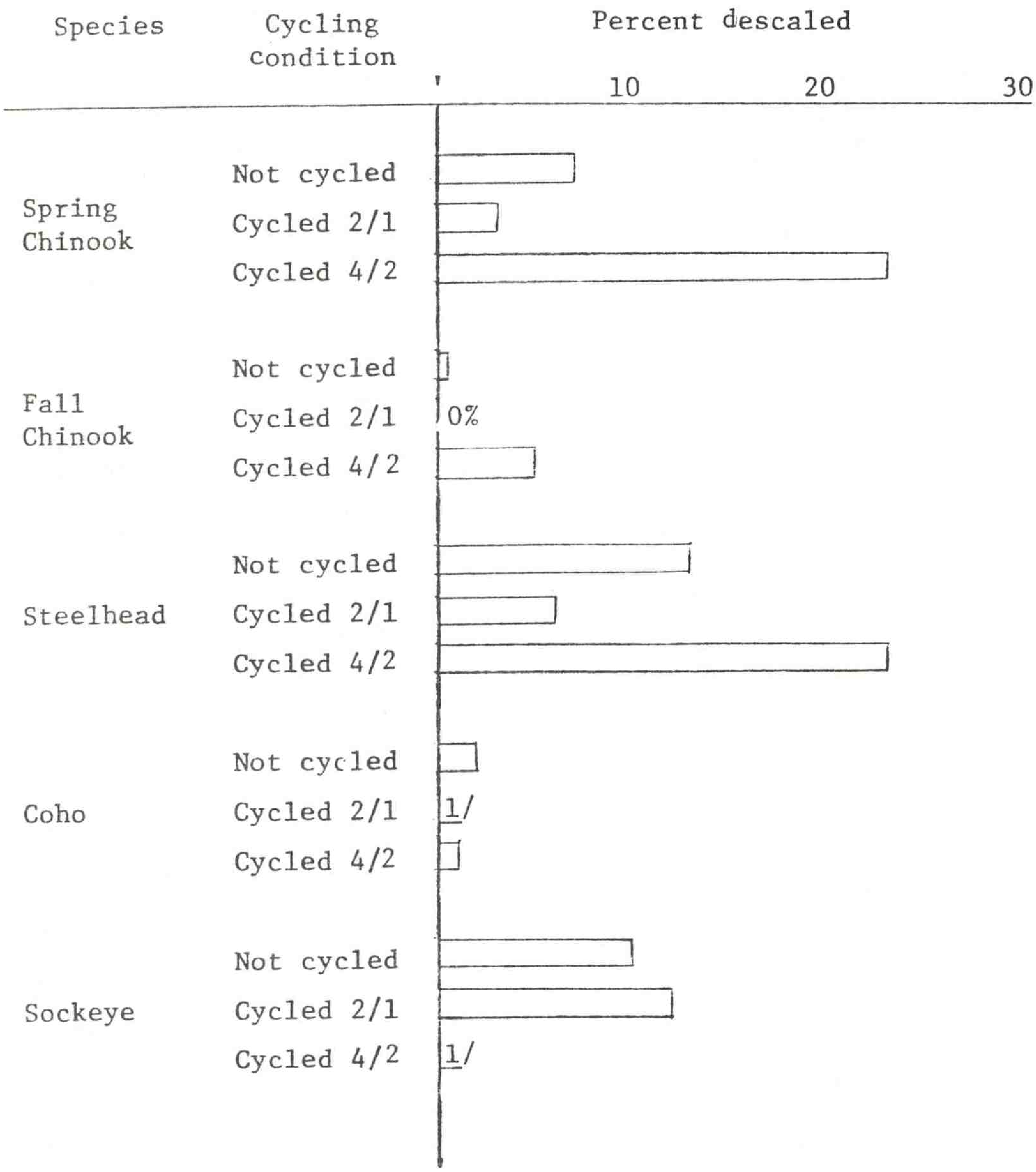



Figure 12.--Percent descaling of fingerling salmonids for orifice cycling and non-cycling tests at Bonneville Dam, 1981.

1/ Insufficient sample.

## 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.

C. Sluiceway passage efficiency tests

Sluiceway passage efficiency averaged 24%, ranging from 12.5% for fall chinook salmon to 58.9% for steelhead. The STS guiding efficiency averaged 74%, ranging from 71.5 to 81.7%.

III Orifice cycling

Orifice cycling does not appear to be an acceptable alternative to full-time orifice operation. It was also noted that even full-time orifice operation in Unit 10C failed to meet acceptable FPE standards (75% FPE). Descaling of spring and fall chinook salmon was significantly higher during orifice cycling than for full-time orifice operation. Turbulence in the gatewell, influenced by the presence of the STS in the intake, appeared to create flow patterns that hindered orifice passage.

IV Balanced flow vertical barrier screens

Results of the BFVBS model studies indicated potential benefits for improving orifice FPE. However, time did not allow for the purchase of materials and modification of an existing VBS for additional orifice FPE tests this year.

# APPENDIX A

## Powerhouse and Sluiceway Passage Data

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 A2.--Mean FGE (%) for STS tests in Unit 4 at 47° angle and 44-foot elevation, Bonneville Dam, 1981.

| | $\bar{X}$ | n | S | SE | 95% CI |
|---|---|---|---|---|---|
| Spring chinook | 78.7 | 25 | 12.1 | 2.4 | $\pm$5.0 |
| Fall chinook | 66.0 | 27 | 14.3 | 2.7 | $\pm$5.6 |
| Steelhead | 79.9 | 26 | 14.0 | 2.7 | $\pm$5.7 |
| Coho | 80.0 | 16 | 28.7 | 7.7 | $\pm$16.6 |
| Sockeye | 70.0 | 1 | -- | -- | -- |

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--Summary of fyke net vertical distribution data for Bonneville First Powerhouse - 1981.

| | Date | Time of day | Sluiceway condition | Length of test (h) | Spring chinook: Fyke net expanded total | Spring chinook: Fyke net and gatewell catch | Spring chinook: % gatewell catch | Fall chinook: Fyke net expanded total | Fall chinook: Fyke net and gatewell catch | Fall chinook: % gatewell catch | Steelhead: Fyke net expanded total | Steelhead: Fyke net and gatewell catch | Steelhead: % gatewell catch | Coho: Fyke net expanded total | Coho: Fyke net and gatewell catch | Coho: % gatewell catch | Sockeye: Fyke net expanded total | Sockeye: Fyke net and gatewell catch | Sockeye: % gatewell catch | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gatewell 5A | 5/9 | 1300-1930 | CL | 6.5 | 987 | 1,106 | 11.0 | 609 | 636 | 4.0 | 96 | 133 | 28.0 | 72 | 87 | 17.0 | | a/ | | d/ |
| | 5/11 | 2000-2300 | CL | 3.0 | 132 | 151 | 13.0 | 93 | 95 | 2.0 | 42 | 63 | 33.0 | 30 | 35* | 14.0 | | a/ | | |
| | 5/13 | 1400-1930 | CL | 5.5 | 399 | 464 | 14.0 | 72 | 88 | 18.0 | 63 | 102 | 38.0 | | a/ | | | a/ | | |
| | 5/13 | 2000-2300 | CL | 3.0 | 138 | 146 | 5.0 | 54 | 56 | 4.0 | 75 | 91 | 18.0 | | a/ | | | a/ | | |
| | 5/15 | 2000-2300 | CL | 3.0 | 300 | 337 | 11.0 | | a/ | | 60 | 89 | 33.0 | 36 | 47 | 23.0 | 39 | 40* | 2.0 | d/ |
| | 5/16 | 0900-1300 | CL | 4.0 | 270 | 293 | 8.0 | | a/ | | | a/ | | 36 | 47 | 23.0 | | a/ | | d/ |
| | 5/16 | 1400-1700 | CL | 3.0 | 465 | 514 | 9.5 | 63 | 73 | 13.7 | 30 | 55 | 45.4 | 45 | 68 | 33.8 | | a/ | | d/ |
| | 5/16 | 2000-2300 | CL | 3.0 | 183 | 207 | 11.6 | | a/ | | 18 | 33* | 45.0 | | a/ | | 51 | 54 | 5.5 | |
| Gatewell 5B | 5/12 | 1400-1900 | CL | 5.0 | 237 | 282 | 16.0 | 63 | 73 | 14.0 | 90 | 129 | 30.0 | 21 | 33* | 36.0 | | a/ | | |
| | 5/14 | 1900-2300 | CL | 4.0 | 195 | 217 | 10.1 | 48 | 52 | 7.7 | 48 | 67 | 28.0 | 60 | 69 | 13.0 | | a/ | | |
| | 5/15 | 1400-1930 | CL | 5.5 | 438 | 511 | 14.3 | 51 | 59 | 13.6 | 108 | 144 | 25.0 | 45 | 61 | 26.0 | 27 | 45* | 40.0 | |
| | 5/26 | 1400-2100 | OP | 7.0 | 84 | 119 | 29.4 | 21 | 40* | 47.5 | 72 | 121 | 40.5 | 123 | 218 | 43.6 | 45 | 57 | 21.0 | d/ |
| | 5/27 | 1500-2200 | CL | 7.0 | 75 | 96 | 22.0 | 36 | 40* | 10.0 | 141 | 192 | 26.5 | 252 | 326 | 23.0 | | a/ | | d/ |
| | 5/30 | 1500-2100 | OP | 6.0 | 66 | 98 | 33.0 | 201 | 231 | 13.0 | 45 | 99 | 55.0 | 60 | 97 | 38.0 | | a/ | | b/c/d/ |
| | 5/31 | 1530-2130 | CL | 6.0 | 75 | 91 | 17.5 | 177 | 244 | 27.4 | 45 | 94 | 52.0 | 168 | 194 | 13.4 | 30 | 32* | 6.0 | b/c/d/ |
| | 6/3 | 2030-2230 | OP | 2.0 | | a/ | | 33 | 38* | 13.0 | | a/ | | | a/ | | | a/ | | b/c/ |
| | 6/4 | 2000-2230 | C1 | 2.5 | | a/ | | 96 | 122 | 21.0 | | a/ | | 36 | 41 | 12.0 | | a/ | | c/ |
| Gatewell 6B | 4/22 | 1800-2200 | CL | 4.0 | 705 | 754 | 6.5 | | a/ | | | a/ | | | a/ | | | a/ | | |
| | 4/23 | 1730-2130 | CL | 4.0 | 513 | 589 | 12.9 | | a/ | | 15 | 32* | 53.0 | | a/ | | | a/ | | |
| | 4/24 | 1700-2200 | OP | 5.0 | 456 | 500 | 11.3 | | a/ | | | a/ | | | a/ | | | a/ | | |
| | 4/25 | 1700-2200 | OP | 5.0 | 495 | 524 | 5.5 | | a/ | | 30 | 38 | 21.0 | | a/ | | | a/ | | |
| | 5/28 | 1400-2300 | OP | 9.0 | | a/ | | 33 | 40* | 17.5 | 30 | 98 | 69.0 | 21 | 34* | 38.2 | 30 | 46* | 34.8 | |
| | 5/29 | 1430-2130 | CL | 7.0 | 39 | 42* | 7.0 | 51 | 53 | 4.0 | 9 | 30 | 70.0 | 72 | 86 | 15.0 | | a/ | | b/c/ |
| | 6/1 | 1845-2215 | OP | 3.5 | | a/ | | | a/ | | | a/ | | | a/ | | | a/ | | b/c/ |
| | 6/2 | 1900-2230 | CL | 3.5 | | a/ | | 78 | 97 | 24.3 | 21 | 59 | 64.4 | 30 | 46* | 34.7 | | a/ | | b/c/ |
| | 6/5 | 1900-2130 | OP | 2.5 | | a/ | | 465 | 480 | 3.1 | | a/ | | | a/ | | | a/ | | |

Appendix Table A4--(continued)

| | Date | Time of day | Sluiceway condition | Length of test (h) | Spring chinook: Fyke net expanded total | Spring chinook: Fyke net and gatewell catch | Spring chinook: % gatewell catch | Fall chinook: Fyke net expanded total | Fall chinook: Fyke net and gatewell catch | Fall chinook: % gatewell catch | Steelhead: Fyke net expanded total | Steelhead: Fyke net and gatewell catch | Steelhead: % gatewell catch | Coho: Fyke net expanded total | Coho: Fyke net and gatewell catch | Coho: % gatewell catch | Sockeye: Fyke net expanded total | Sockeye: Fyke net and gatewell catch | Sockeye: % gatewell 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 A5.--Percent gatewell catch, Unit 5, Bonneville Dam, 9 May to 16 May 1981. a/

| | GW | Total | % GW | Factor |
|---|---|---|---|---|
| Spring chinook | 495 | 4338 | 11.41 | 8.76 |
| Fall chinook | 91 | 1252 | 7.27 | 13.76 |
| Steelhead | 299 | 1011 | 29.26 | 3.42 |
| Coho | 126 | 513 | 24.56 | 4.07 |
| Sockeye | 48 | 288 | 16.67 | 6.00 |

a/ Gatewell slots 5A and 5B

Appendix Table A6.--Percent gatewell catch, Unit 7, Bonneville Dam, 26 April to 8 May 1981. a/

| | GW | Total | % GW | Factor |
|---|---|---|---|---|
| Spring chinook | 362 | 2450 | 14.78 | 6.77 |
| Fall chinook | 70 | 988 | 7.09 | 14.11 |
| Steelhead | 715 | 1872 | 38.17 | 2.62 |
| Coho | 387 | 854 | 45.32 | 2.21 |
| Sockeye | b/ | | | |

a/ Gatewell slot 7A.

b/ Insufficient numbers of sockeye.

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 A8.--B slot, Bonneville Dam gatewell counts for fall chinook.

| | Gatewell | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Total | Sluice |
| 5/25 | 18 | 18 | 61 | 119 | 110 | 48 | 8 | 5 | 3 | 11 | 401 | Closed |
| 26 | 7 | 18 | 18 | 52 | 3 | 101 | 1 | 4 | 3 | 13 | 220 | Closed |
| 27 | 14 | 9 | 17 | 39 | 63 | 22 | 4 | 7 | 6 | 22 | 203 | Open |
| 28 | 7 | 14 | 29 | 55 | 41 | 45 | 9 | 7 | 3 | 21 | 231 | Closed |
| 29 | 16 | 28 | 45 | 39 | 41 | 31 | 4 | 13 | 14 | 31 | 262 | Open |
| 30 | 27 | 9 | 33 | 35 | 67 | 26 | 13 | 2 | 7 | 4 | 223 | Closed |
| 31 | 16 | 17 | 35 | 82 | 54 | 27 | 11 | 13 | 14 | 18 | 287 | Open |
| 6/01 | 16 | 38 | 45 | 80 | 102 | 84 | 15 | 9 | 9 | 54 | 452 | Closed |
| 02 | 14 | 14 | 28 | 73 | 115 | 28 | 15 | 15 | 7 | 36 | 345 | Open |
| 03 | 42 | 19 | 50 | 91 | 211 | 75 | 23 | 24 | 14 | 34 | 583 | Closed |
| 04 | 23 | 27 | 33 | 83 | 82 | 29 | 21 | 8 | 10 | 16 | 332 | Open |
| 05 | 80 | 56 | 78 | 111 | 242 | 84 | 21 | 16 | 4 | 65 | 757 | Closed |
| 06 | 691 | 1240 | 1950 | 4637 | 1415 | 362 | 136 | 116 | 48 | 141 | 10736 | Open |
| 07 | 5272 | 4320 | 5759 | 7223 | 3943 | 2603 | 1734 | 960 | 827 | 909 | 33550 | Closed |
| **Total** | 6243 | 5827 | 8181 | 12719 | 6489 | 3565 | 2015 | 1199 | 969 | 1375 | 48582 | |
| **Percent** | 12.9 | 12.0 | 16.8 | 26.2 | 13.4 | 7.3 | 4.1 | 2.5 | 2.0 | 2.8 | | |

**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 A10.--B slot, Bonneville Dam gatewell counts for coho.

| | Gatewell | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Total | Sluice |
| 5/25 | 10 | 23 | 80 | 328 | 809 | 957 | 68 | 20 | 14 | 219 | 2528 | Closed |
| 26 | 7 | 16 | 24 | 109 | 489 | 682 | 66 | 22 | 28 | 189 | 1632 | Closed |
| 27 | 5 | 15 | 21 | 51 | 253 | 372 | 45 | 15 | 16 | 227 | 1020 | Open |
| 28 | 15 | 17 | 45 | 76 | 224 | 255 | 40 | 10 | 20 | 37 | 739 | Closed |
| 29 | 15 | 22 | 28 | 57 | 115 | 66 | 11 | 7 | 4 | 202 | 527 | Open |
| 30 | 14 | 21 | 16 | 58 | 193 | 52 | 15 | 4 | 5 | 6 | 384 | Closed |
| 31 | 22 | 15 | 39 | 42 | 133 | 29 | 23 | 13 | 3 | 6 | 325 | Open |
| 6/01 | 6 | 11 | 14 | 30 | 166 | 85 | 16 | 6 | 5 | 18 | 357 | Closed |
| 02 | 12 | 13 | 19 | 24 | 56 | 12 | 7 | 6 | 1 | 1 | 151 | Open |
| 03 | 14 | 8 | 23 | 43 | 75 | 77 | 21 | 5 | 9 | 6 | 281 | Closed |
| 04 | 5 | 16 | 7 | 31 | 47 | 19 | 10 | 6 | 2 | 5 | 148 | Open |
| 05 | 7 | 16 | 20 | 34 | 105 | 57 | 16 | 2 | 4 | 5 | 266 | Closed |
| 06 | 12 | 10 | 11 | 20 | 39 | 25 | 5 | 6 | 3 | 3 | 134 | Open |
| 07 | 13 | 12 | 21 | 46 | 73 | 93 | 28 | 4 | 2 | 17 | 309 | Closed |
| **Total** | 157 | 215 | 368 | 949 | 2777 | 2781 | 371 | 126 | 116 | 941 | 8801 | |
| **Percent** | 1.8 | 2.4 | 4.2 | 10.8 | 31.6 | 31.6 | 4.2 | 1.4 | 1.3 | 10.7 | | |

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

Appendix Table A11.--B slot, 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.--Sluiceway passage efficiency, Bonneville Dam, 26 May to 6 June 1981, using total estimated passage for each 24-h period calculated as the average of powerhouse passage on the preceding day and powerhouse plus sluiceway passage on each test day.

| Spring chinook | Sluice | Ave. total | % sluice |
|---|---|---|---|
| 5/26 - 27 | 1,222 | 8,995 | 13.6 |
| 5/28 - 29 | 770 | 4,144 | 18.6 |
| 5/30 - 31 | 3,648 | 5,906 | 61.8 |
| 6/01 - 02 | 3,948 | 5,873 | 67.2 |
| 6/03 - 04 | 3,629 | 7,091 | 51.2 |
| 6/05 - 06 | 4,300 | 8,340 | 51.6 |
| Total | 17,817 | 40,349 | 44.2 |

| Fall chinook | Sluice | Ave. total | % sluice |
|---|---|---|---|
| 5/26 - 27 | 832 | 9,120 | 9.1 |
| 5/28 - 29 | 1,029 | 10,662 | 9.7 |
| 5/30 - 31 | 3,703 | 12,355 | 30.0 |
| 6/01 - 02 | 2,177 | 17,499 | 12.4 |
| 6/03 - 04 | 2,647 | 20,169 | 13.1 |
| 6/05 - 06 | 29,651 | 251,332 | 11.8 |
| Total | 40,039 | 321,139 | 12.5 |

| Steelhead | Sluice | Ave. total | % sluice |
|---|---|---|---|
| 5/26 - 27 | 5,155 | 12,129 | 42.5 |
| 5/28 - 29 | 6,673 | 11,197 | 59.6 |
| 5/30 - 31 | 7,606 | 10,496 | 72.5 |
| 6/01 - 02 | 6,647 | 9,780 | 68.0 |
| 6/03 - 04 | 4,827 | 7,724 | 62.5 |
| 6/05 - 06 | 2,426 | 5,301 | 45.8 |
| Total | 33,334 | 56,627 | 58.9 |

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 A13 --A comparison of the estimated sluiceway passage efficiency with calculated STS guidance for a 6-day period during 26 May to 7 June at Bonneville Dam, 1981.

| | Total[a/] | % sluice | 95% CI | Sluice | STS FGE | 95% CI | STS[b/] |
|---|---|---|---|---|---|---|---|
| Spring chinook | 40,349 | 44.2 | ± 23.6 | 17,834 | 76.4 | ± 5.0 | 30,827 |
| Fall chinook | 321,139 | 12.5 | ± 8.2 | 40,142 | 71.5 | ± 5.6 | 229,614 |
| Steelhead | 56,627 | 58.9 | ± 12.6 | 33,353 | 77.3 | ± 5.7 | 43,773 |
| Coho | 45,126 | 42.6 | ± 15.2 | 19,224 | 79.4 | ±16.6 | 35,830 |
| Sockeye | 25,485 | 33.0 | ± 12.9 | 8,414 | 81.7 | — | 20,821 |
| Total | 488,726 | 24.3 | 17.0 | 118,967 | 73.8 | 7.3 | 360,865 |

a/ Total daily passage for 6 days of test corrected for delay by averaging the passage estimate on each test day with the powerhouse passage estimate on the previous day when the sluiceway was closed.

b/ Calculated STS guidance assuming screening of all turbine intakes.

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 |

Appendix Table A15.--Sluiceway passage efficiency using total daily passage determined by using the sum of estimated powerhouse passage for that day based on gatewell recovery plus estimated sluiceway passage.

| | Total | % sluice | 95% CI | Sluice |
|---|---|---|---|---|
| Spring chinook | 41,850 | 42.6 | ± 19.9 | 17,817 |
| Fall chinook | 538,319 | 7.4 | ± 5.8 | 40,039 |
| Steelhead | 67,932 | 49.1 | ± 6.8 | 33,334 |
| Coho | 47,259 | 40.6 | ± 12.6 | 19,207 |
| Sockeye | 27,166 | 31.0 | ± 10.1 | 8,414 |
| Total | 722,526 | 16.4 | ± 13.0 | 118,811 |

APPENDIX B

# Evaluation of the Ice and Trash Sluiceway at Bonneville Dam as a Bypass System for Juvenile Salmonids

by

Oregon Department of Fish and Wildlife

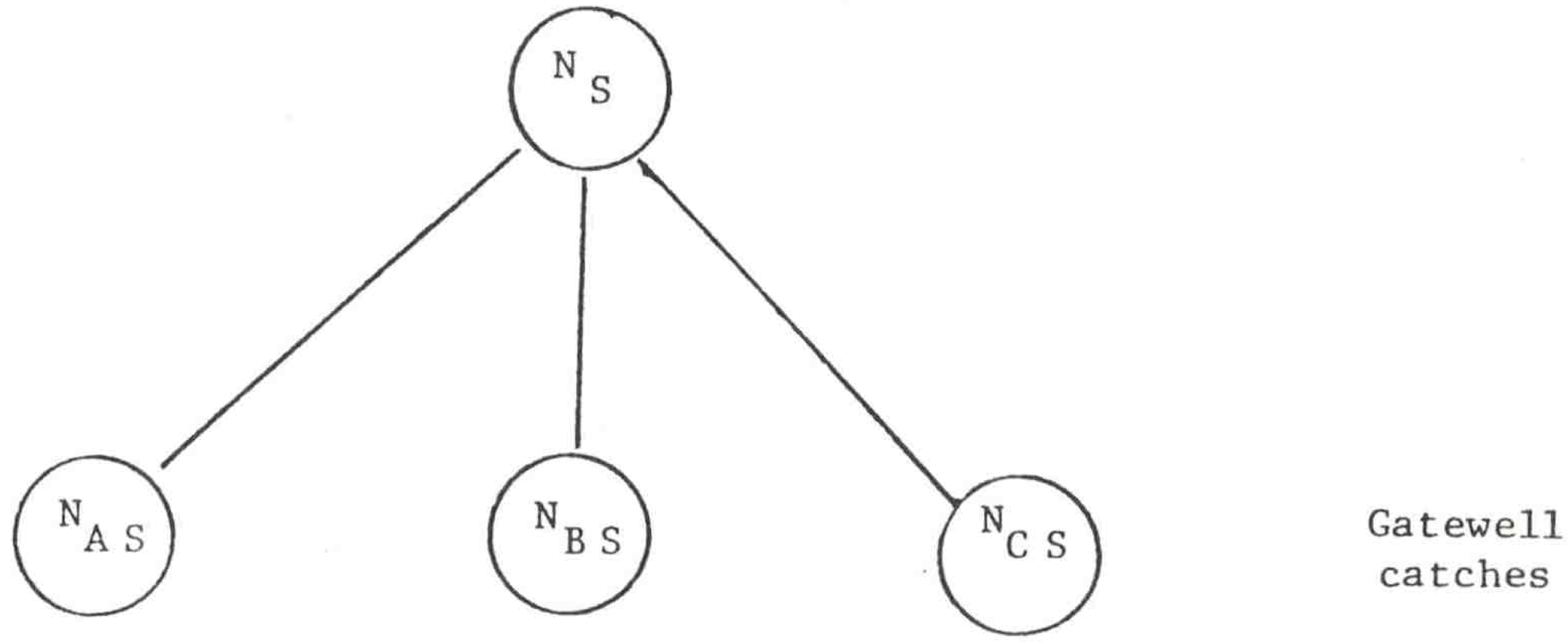
The material for Appendix B was not received from the Oregon Department of Fish and Wildlife in time to be bound into this report. It will be distributed to recipients of this report when it becomes available.

# APPENDIX C

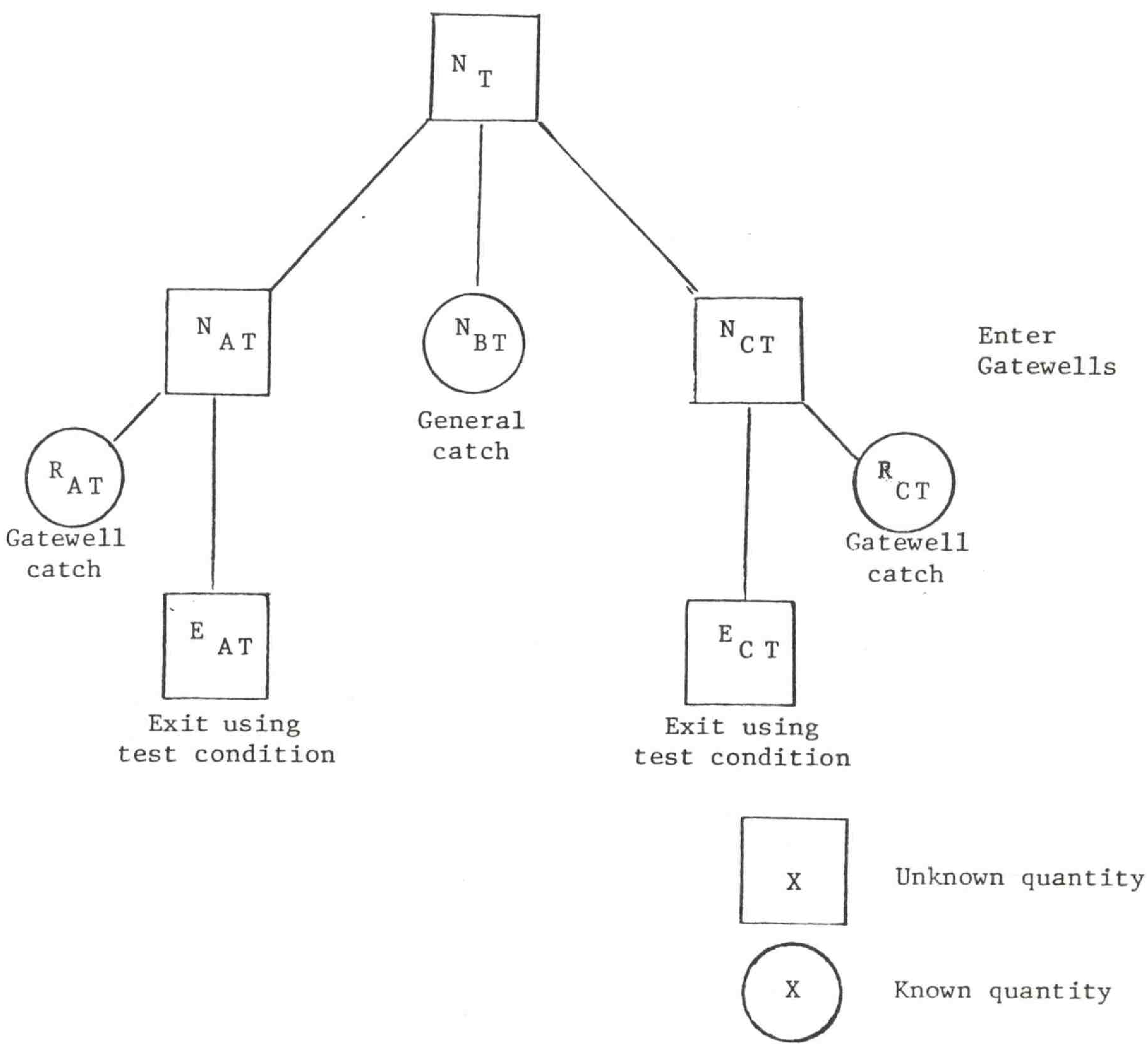
## Orifice Cycling Data

Appendix Table C1.--Probability formula for estimating FPE for test conditions in A and C Slots with a standard condition in the B Slot for gatewells in Unit 4. Test condition was: (1) orifice open or (2) cycled on a set schedule. Standard condition was the orifice closed continually. The procedure utilizes data from a series of standard condition runs in the A, B, and C Slots in Unit 4.

STANDARD RUN: ALL ORIFICES CLOSED




TEST RUN: ORIFICE B CLOSED; ORIFICES A AND C OPEN OR CYCLING



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.

$$P_{AS} = N_{AS}/N_S \; ; \qquad P_{AT} = N_{AT}/N_T$$

$$P_{BS} = N_{BS}/N_S \; ; \qquad P_{BT} = N_{BT}/N_T$$

$$P_{CS} = N_{CS}/N_S \; ; \qquad P_{CT} = N_{CT}/N_T$$

FPE: Fish Passage Efficiency, the proportion of those fish that entered the gatewell that used the test condition.

For a test run the FPE of Gatewell A is,

$$FPE_A = E_{AT}/N_{AT}$$

Both $E_{AT}$ and $N_{AT}$ are unknown but an estimate of them can be obtained using results from standard runs and the current standard condition of Gatewell B.

The estimates are worked out as follows, using the A Slot as an example:

Estimate of $N_T$:

This can be done using results from the standard runs and the fact that the B Slot is operated under standard conditions.

$$P_{BS} = N_{BS}/N_S \quad \text{and}$$

$$P_{BT} = N_{BT}/N_T \quad \text{or}$$

$$NT = N_{BT}/P_{BT}$$

$P_{BS}$ 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 estimate of $FPE_A$ is:

$$\widehat{FPE}_A = \frac{\hat{N}_{AT} - R_{AT}}{\hat{N}_{AT}}$$

$$= 1 - \frac{R_{AT}}{N_{AT}}$$

substitute

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

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

This can be written:

$$\widehat{FPE}_A = 1 - P_{BA} \; N_{BA} \quad \text{where}$$

$$P_{BA} = \frac{P_{BS}}{P_{AS}}$$ : these proportions are obtained from the standard runs

$$N_{BA} = \frac{R_{AT}}{N_{BT}}$$ : these quantities are obtained from the test run.

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:

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

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

Appendex Table C2.--Gatewell index in Unit 4 at Bonneville Dam, 1981 (Tests conducted on June 16, 22, and July 6, 1981...all orifices closed).

| Gatewell slot | Gatewell catch: Spring chinook | Fall chinook | Steel-head | Coho | Sockeye | Total | Spring + fall chinook |
|---|---|---|---|---|---|---|---|
| 4A | 168 | 2686 | 57 | 1729 | 26 | 4666 | 2854 |
| 4B | 458 | 4698 | 118 | 4851 | 47 | 10172 | 5156 |
| 4C | 378 | 4741 | 121 | 4977 | 52 | 10269 | 5119 |
| TOTAL | 1004 | 12125 | 296 | 11557 | 125 | 25107 | 13129 |
| Proportion in each gatewell slot | | | | | | | |
| 4A | 0.167 | 0.222 | 0.192 | 0.149 | 0.187[a/] | 0.187 | 0.217 |
| 4B | 0.456 | 0.387 | 0.399 | 0.420 | 0.405[a/] | 0.405 | 0.393 |
| 4C | 0.377 | 0.391 | 0.409 | 0.431 | 0.408[a/] | 0.408 | 0.390 |
| $P_{BA}$ [b/] | 2.726 | 1.749 | 2.070 | 2.806 | 2.171[a/] | 2.171 | 1.807 |
| $P_{BC}$ [b/] | 1.212 | 0.991 | 0.975 | 0.975 | 0.991[a/] | 0.991 | 1.007 |

a/ Sockeye sample size is inadequate; therefore, proportions were estimated using total numbers.

b/ $P_{BA} = N_{BS}/N_{AS}$

c/ $P_{BC} = N_{BS}/N_{CS}$

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 |