Research at McNary Dam to Develop and Implement a Fingerling Protection System for John Day Dam

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May 1983

COASTAL ZONE AND ESTUARINE STUDIES

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Final Report
Financed by
U.S. Army Corps of Engineers
(Contract DACW57-82-F-0373)

and

Coastal Zone and Estuarine Studies Division
Northwest and Alaska Fisheries Center
National Marine Fisheries Service
2725 Montlake Boulevard East
Seattle, Washington 98112

May 1983

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INTRODUCTION

In 1982, the National Marine Fisheries Service (NMFS), under contract to the U.S. Army Corps of Engineers (CofE), continued research studies initiated at McNary Dam in 1981 to develop and test components for an improved juvenile salmonid bypass system for John Day Dam (Swan et al. 1982).

In 1981, research concentrated in three phases. One phase examined the feasibility of saving much of the existing bypass gallery for use in the new system. This would entail use of an airlift system for removing fish from part of the gatewells and cycling orifices to remove fish from the remaining gatewells. The second phase measured fish guiding efficiency (FGE) of the submersible traveling screen (STS). The third phase measured orifice passage efficiency (OPE) at various submergences with a standard vertical barrier screen (SVBS). Results showed acceptable (>70%) FGE but unacceptable (<70%) OPE especially in a cycling mode. Based on the data obtained in 1981, the CofE rejected any attempts to salvage part of the existing bypass gallery and proceeded with the initial design of the new fingerling bypass system; reserving final design on orifice and barrier screen configuration until additional OPE data could be obtained.

The range in fluctuation of forebay levels indicated that submerged orifices will be required to operate in a range of 6 to 20 ft; therefore, if OPE varies with depth, it may be necessary to install more than one orifice in each gatewell. The roles of turbulence and flow also need further definition. Turbulence and uneven flows from additional water diverted into these gatewells by the STSs may have been responsible for the poor OPE measured in 1981; i.e., the higher OPE was measured in the less turbulent gatewells that had stored gates (McNary condition). A balanced flow barrier screen (BFVBS) could minimize turbulence and enhance OPE. Hydraulic studies have shown that more uniform flow patterns result when the porosity of the barrier screen is reduced to a 15% open area (Krcma et al. 1982). Since FGE may be adversely affected by a BFVBS, it would also be necessary to measure FGE in gatewells equipped with a BFVBS.

Research in 1982 was, therefore, directed toward studying OPE and FGE in conjunction with a BFVBS. The primary objectives of the study were to determine: (1) whether a single or dual orifice system was needed, (2) the effect of the BFVBS on OPE and FGE, and (3) the effect of a set of flow vanes placed at the bottom of the gatewell to create defined and directional flow patterns. The flow vanes would only be tested if acceptable OPEs were not attained throughout the required range of orifice submergences using the BFVBS.[1/]

METHODS AND PROCEDURES

Dam and Experimental Equipment

The research was conducted at McNary Dam instead of John Day Dam for economic and practical reasons. Much of the needed test equipment was already on site at McNary Dam, and the operating gates in Units 5A and 6B could be raised and dogged off at the intake deck level to simulate gatewell flow conditions found at John Day Dam (previously demonstrated in a model study). With the exception of no stored gates at John Day Dam, the general configurations of the two dams are similar. Therefore, the results of the research obtained at McNary Dam should be applicable to John Day Dam.

Experimental equipment for the OPE and FGE tests is shown in Figure 1. The frames below the STS support the fyke nets for estimating the number of

1/ Because OPEs were acceptable, flow vanes were not tested.

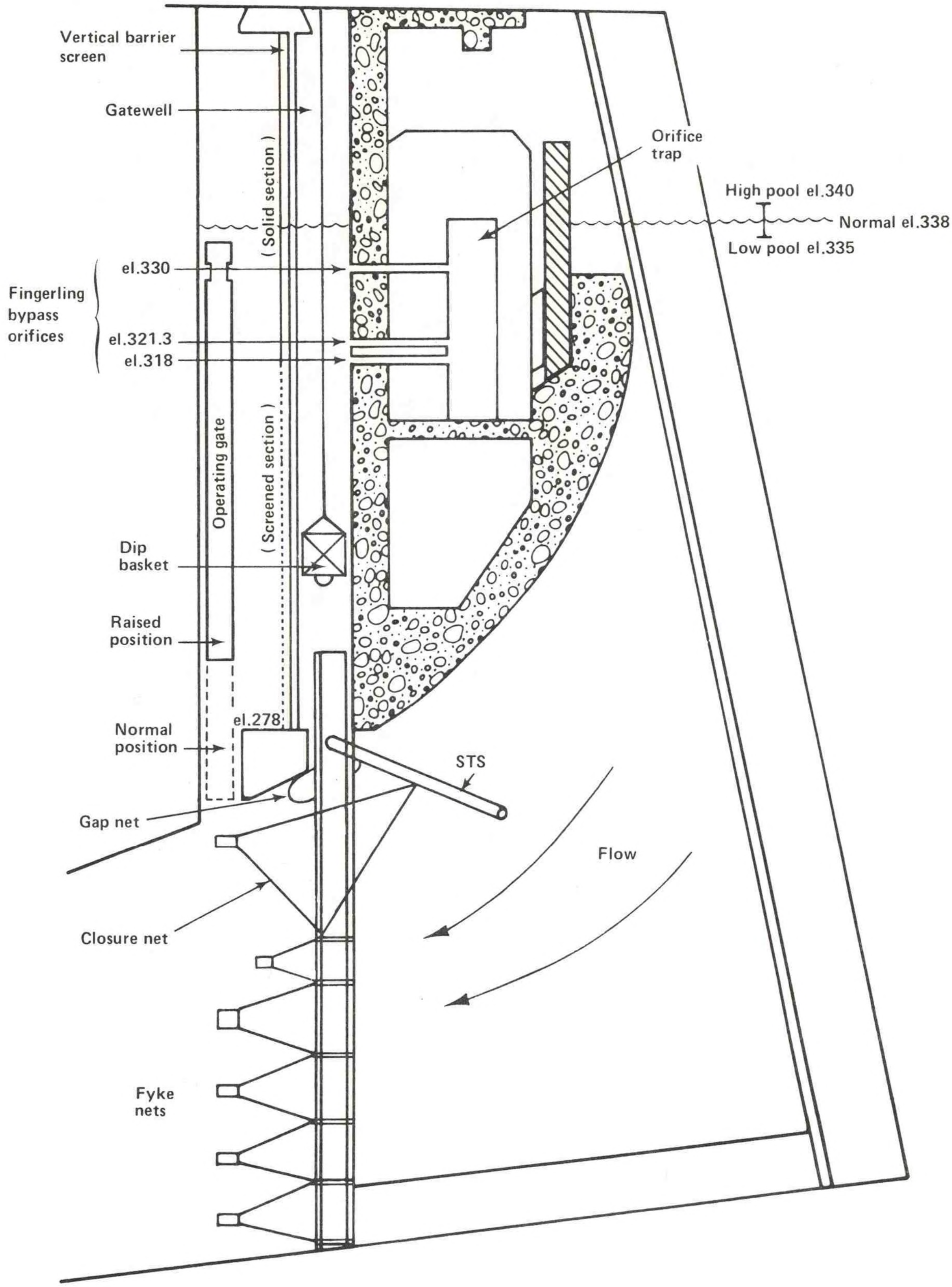


Figure 1.--Transverse section through a typical turbine unit at McNary Dam showing the normal test equipment used in 1982.

unguided fish. The dip basket used to sample the gatewells was similar to the device used by NMFS at other hydroelectric dams on the Snake and Columbia Rivers (Swan et al. 1979). Orifices were drilled at three depths to provide a 6- to 20-ft range of submergences for OPE testing. These orifices were all connected to a trap facility in the sluiceway. Valves were installed to open and close orifices as desired.

BFVBS Design

The barrier screens in Gatewells 5A and 6B were both retrofitted with perforated plates to reduce the overall porosity to 15%. This porosity according to previous model studies provided a relatively uniform flow of about 0.5 fps through the overall screen area.

The barrier screens at McNary Dam are about 60 ft high with 20 ft of solid panel at the top. For one test condition (Test 9), the top solid panels of the BFVBS in Gatewell 6B were replaced with standard mesh screen panels borrowed from Unit 14. This resulted in a modified barrier screen with controlled porosity on the lower 40 ft and standard screening on the remaining 20 ft.

OPE Tests

Tests were designed to measure OPE for a range of submergences of 6 to 20 ft with a 4- and 7- ft head. Comparisons of OPE were made for lighted vs unlighted orifices at all submergences. For the lights on test, light from a standard 12 v automobile headlight was provided through a clear plastic "window" in the pipe leading from the orifice to the bypass trap. Also, north vs south orifice tests were made at the 6- to 8-ft submergence. OPE was usually measured for a 24-h period, however passage was also measured for 48 and 72-h intervals for key test conditions. Acceptable OPE was defined as a 70% or greater exit from the gatewell within a 48-h period, provided no increase in stress was noted in the fish.

Two orifice traps located in the ice-trash sluiceway were used for evaluating OPE. The two traps were able to collect fish for seven different orifice conditions. One trap monitored Gatewell 5A containing two shallow orifices (north or south) with a submergence of 6 to 8 ft and two deep orifices (north or south) with a submergence of 18 to 20 ft. The second trap monitored Gatewell 6B containing two shallow orifices (north and south) with a submergence of 6 to 8 ft and a single orifice (north) at an intermediate submergence of 15 to 17 ft.

Most of the conditions were replicated at least three times except in some cases when OPEs for the target species were exceptionally good or bad. In the interest of saving valuable time for testing additional variables, these conditions were not always replicated--to replicate a 72-h test condition three times takes a total of 9 days.

The orifice traps were attended continuously throughout the test period. The OPE tests were started about 1300 h by dipping a gatewell clean of any residual fish. The desired orifice valve was opened, and the trap adjusted to obtain the proper head in relation to existing forebay levels. To terminate a test, the orifice valve was closed and the gatewell dipped clean of any residual fish. If the test was 24 h, it would terminate the following day when the gatewell was dipped. For tests of 48 or 72 h, the traps were emptied at regular intervals, but the gatewell was only dipped at the end of the test period.

Fish removed from the trap and gatewell were enumerated by species and examined for descaling. OPE was determined by the number of fish caught in the trap vs the number remaining in the gatewell. Analysis of the various test conditions was based on contingency tables utilizing chi-square and/or the "G" statistic. Significance was desired at $P<0.005$, df=1.

STS FGE Tests

FGE is the percentage of the fish (by species) entering the turbine intake that are guided by the STS out of the turbine intake into the gatewell for a particular time interval and test condition. To provide these measures, the STS in Unit 5A was equipped with an array of fyke nets below the STS for estimating the number of unguided fish. These nets included two closure fyke nets attached to the backside of the STS and a vertical row of five fyke nets attached to a fyke net frame suspended from the bottom of the STS. Four of these nets were approximately 6.5 ft square, and one net was approximately 2.5 x 6.5 ft. Another net (referred to as a gap net) attached near the top of the STS captured fingerlings that passed through the space between the top of the STS and the concrete beam that divides the operating gate slot and bulkhead slot. Figure 1 shows the location of the gap net, closure net, fyke nets, and other related test equipment.

The procedures for determining FGE were similar to those used in previous experiments of this type. Gatewell dipnet catches provided the number of guided fish, and catches from the gap and fyke nets attached to the STS provided the number of unguided fish. FGE was calculated as guided fish divided by the total number of fish passing through the intake during the test period.

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

GW = gatewell catch
GN = gap net catch
FN = fyke net catch
CN = closure net catch

To minimize mortality of fish in fyke nets, most STS FGE calculations used estimates of unguided fish derived from a one-third sample of the fingerlings passing below the STS. This was accomplished by trapping only those fish in a column of fyke nets that fished the center one-third of the flow not intercepted by the STS. Nets were in place in the other columns, but the cod ends were left open to allow these fish to pass on through the intake. The full complement of nets rather than a single column of nets was used to assure an accurate measure of unguided fish. With only a single column there was the potential for underestimating the number of unguided fish--differential flow conditions due to the absence of nets on either side of the center net could cause fish to veer off and not be caught.

To verify the validity of this estimate, we conducted some tests that included fyke net catches from a full complement of nets across the upper 60% of the area below the STS (top three rows). This area generally accounts for about 90% of the fish passing underneath the STS.

The sequence of events for conducting a typical STS FGE test was as follows:

1) Unit was shut down.

2) The STS with attached fyke-net frame was lowered into position.

3) The bypass orifice was closed, and the gatewell was dipped to remove all fish present.

4) Unit was returned to service and brought to full load.

5) The number of fish entering the gatewell was monitored by periodic dipnetting.

6) The test was terminated when an adequate number of fish for statistical needs had been collected.

7) The turbine was shut down, and a final cleanout dip was made.

8) The STS with attached nets was brought to the surface and the fish removed from the nets for identification and enumeration.

9) The unit was returned to service.

Each test was about 2 to 4 h depending upon the density of the fish run. The turbine was shut down for about 1 h to install or remove the STS.

Tests were started about 1800 h and terminated when adequate numbers of fish had been guided into the gatewell. The number of guided fish dipnetted from the gatewell determined the duration of a test. The experimental design called for a minimum of three replicates and 200 fish per sample (gatewell catch) to satisfy specified statistical significance levels for detecting relevant differences of a stated magnitude. Contingency table procedures using the log-likelihood G-test were used in the statistical analysis (Sokal and Rohlf 1981). The formulas and procedures used are given in Appendix A.

The number of fish caught and sacrificed in the fyke nets varied depending upon STS FGE; i.e., when 200 fish were in the gatewell and the FGE was 40%, 300 additional fish would have passed on through the intake and 100 of these fish (assuming a one-third sample) would be caught in the fyke nets under each STS per replicate; if FGE was 80%, only 17 fish would be sacrificed. Therefore, for each STS condition tested the total number of net caught fish would not exceed 300 (100 x 3 replicates = 300) at a 40% FGE and not exceed 51 fish at 80% FGE.

FGE tests with a BFVBS were conducted for both the John Day Dam (no stored gate) and McNary Dam (with stored gate) condition.

Fish Quality Measurements

Descaling rates amd seawater challenge stress tests were the primary methods used to determine the impact that various test conditions had on fish. A very limited number of blood chemistry tests were also conducted by Oregon Cooperative Fishery Unit personnel to measure stress on subyearling chinook salmon.

Comparisons of descaling were made for all species and test conditions. Fish with more than 10% of their scales missing were considered descaled (the standard criteria for classifying a fish as descaled).

Samples of yearling chinook salmon (about 300 fish each) were transferred to a test facility prepared for handling seawater challenge stress tests. The test chambers at all facilities were standard 10-gallon glass aquaria set in a water bath of flow-through river water to maintain ambient river temperatures within the aquaria. The aquaria were covered to eliminate possible external interferences, and water quality was sustained by O_2 injection. A stock solution of artificial seawater (Marine Environment)[2/] was mixed at 54 ppt in Living Stream Model 700 recirculating holding systems. These systems cycled the stock solution approximately once every 5 to 7 minutes to provide continuous mixing and were equipped with refrigeration units for temperature control (see Park et al. 1983 for additional details).

The tests were primarily to determine if a BFVBS significantly impaired fish quality, and if delays in excess of 24-h in passing through orifices significantly increased descaling and/or stress. For the BFVBS comparisons, fish from Gatewell 5A with a BFVBS were compared with fish from Gatewell 4A with a SVBS. For the delay tests, we compared fish from Gatewell 5A during 24- and 48-h OPE tests from 10 to 20 May.

2/ Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA

Miscellaneous

A number of groups of about 100 yearling chinook salmon identified by either a partial upper or lower caudal fin clip were released in the gatewell to determine dip basket efficiency and/or if escapement from the gatewells was occurring.

An underwater video camera was used to observe fish behavior and to determine amounts of debris and fish impingement on the BFVBS.

RESULTS

Testing began 21 April and terminated 20 July. A total of 59 individual replicates for OPE tests and 17 individual replicates for STS FGE tests were conducted . The target species were yearling and subyearling chinook salmon and steelhead. Other species present but not included in the general discussion were coho and sockeye salmon. Early in the season, a number of what appeared to be pre-smolt subyearling chinook salmon (<50 mm fork length) were present, but these were not included in any of the test discussions because many of them escaped the collection gear due to their small size.

OPE Tests

At the beginning of the season, a series of tests to evaluate the difference that a 4- or 7-ft head had on OPE was conducted in Gatewell 6B. The results indicated a slightly lower OPE for a 4-ft head (Figure 2). All the remaining tests were therefore conducted at the 4-ft head--assuming that OPE would be even better with a 7-ft head.

A summary of the orifice passage tests conducted with orifices backlighted and a head of 4 ft is given in Figure 3. Specifics on individual tests are given in Appendix Table B1. Levels of OPE with the BFVBS approached or exceeded the 70% criteria throughout the range of

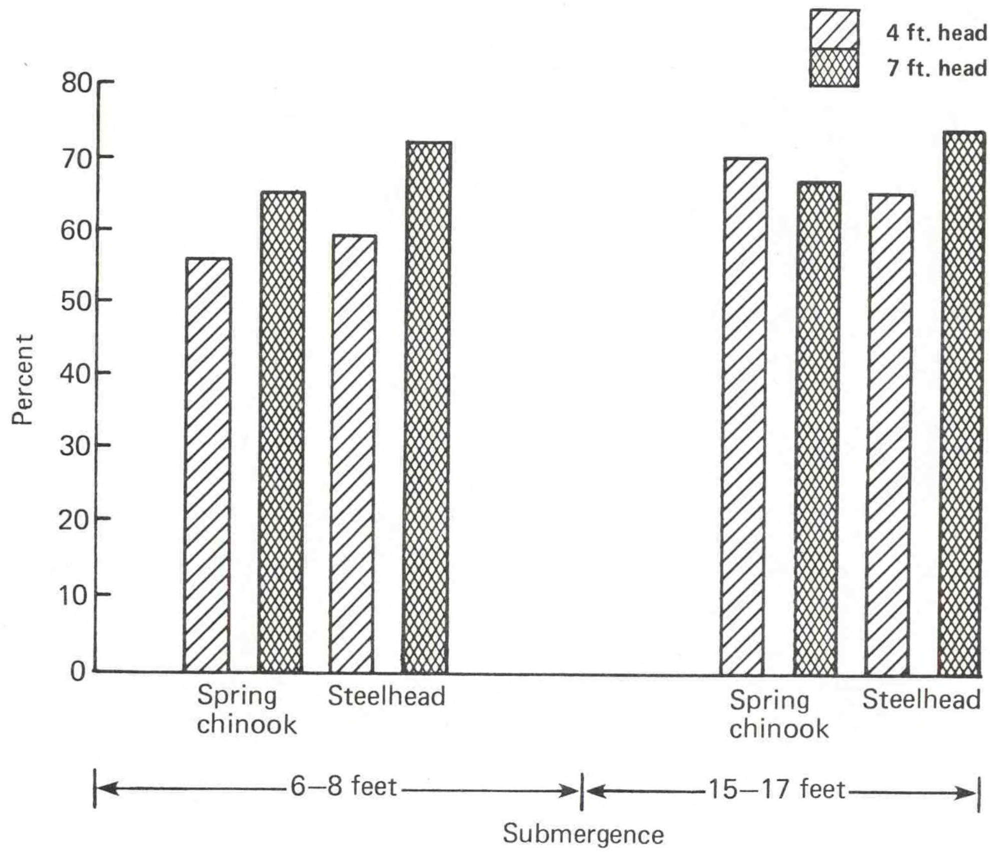
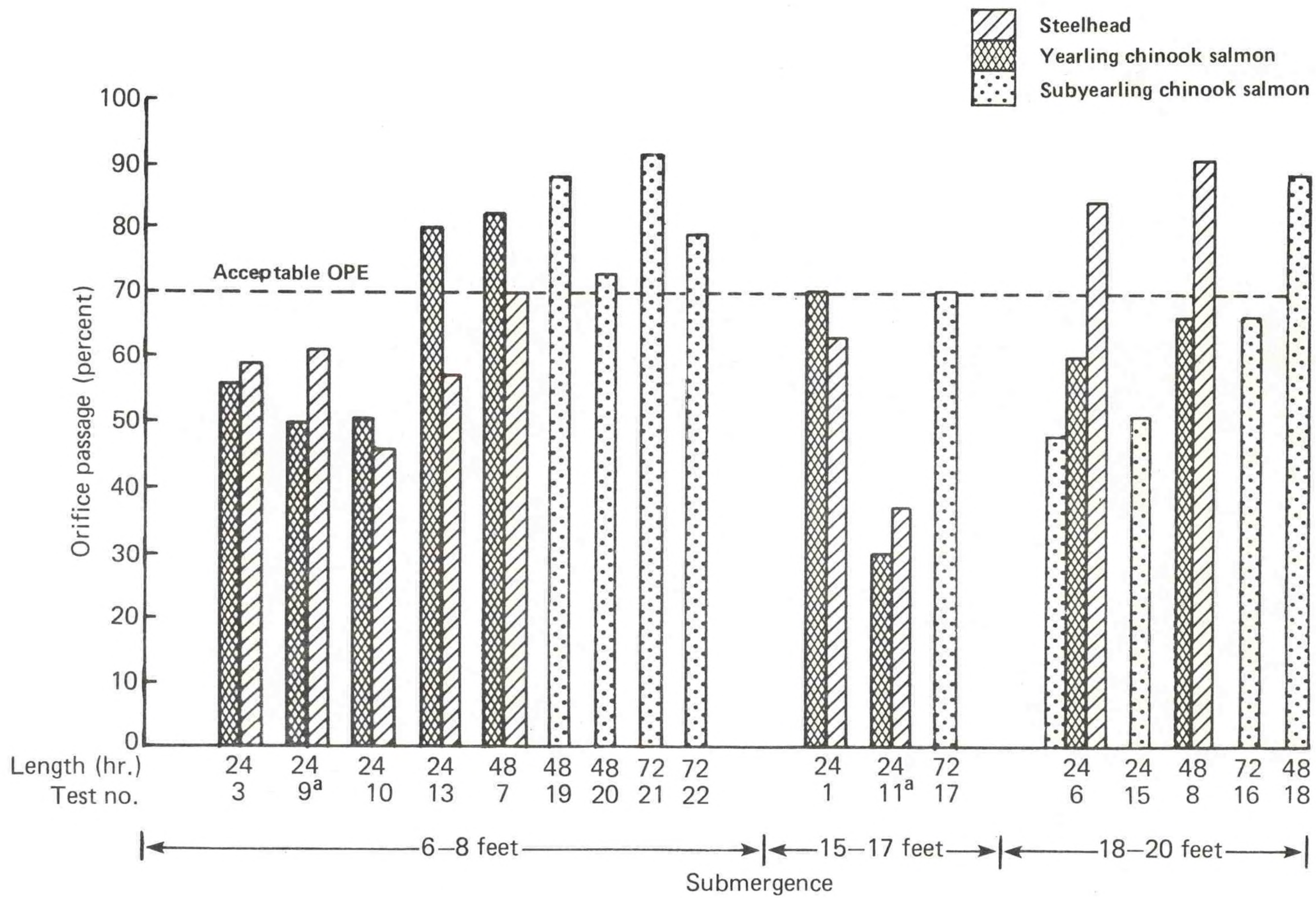


Figure 2.--Paired OPE tests comparing 4- and 7-ft head at a shallow and deep submergence for the north orifice in gatewell 6B at McNary Dam--1982.



a) Top three panel sections of vertical barrier screens are standard screen

Figure 3.--A summary of orifice passage tests conducted at McNary Dam in 1982 (orifices backlighted, head, 4-ft).

orifice submergences, provided the duration was greater than 24 h (Tests 7, 19, 20, 21, and 22; 17; and 8, 16, and 18). It is also encouraging that several of the 24-h tests approached acceptable levels for yearling fish at each of the submergences (Tests 1, 6, and 13). The two 24-h tests with subyearlings at the 18 to 20 ft submergence, averaged only about 50% (Tests 6 and 15). However, when the test duration was extended, nearly acceptable OPEs were measured (Tests 16 and 18).

In 1982, the OPEs measured with the BFVBS were generally much higher than those measured in 1981 with a SVBS (Swan et al. 1982). Best results were at the deeper submergences (15 to 17 ft and 18 to 20 ft). The average 24-h OPE for yearling chinook salmon was 62%--significantly higher than the 47% measured in 1981 ($G=45.00$, $P<0.005$). There was some improvement at the shallow (6 to 8 ft) submergences (63% with BFVBS vs 59% with SVBS), but the differences were not significant. However, the 1981 tests were conducted at about a 12-ft head compared to a 4- to 7-ft head for the 1982 tests. Had the tests been run at the same head in both years, a significant difference might have been measured (OPE is usually higher at greater heads).

Chinook salmon generally appeared to prefer the shallower orifice submergence as indicated by comparing paired tests 21 vs 16 and 7 vs 8. By contrast, steelhead appeared to prefer the deeper submerged orifices (Tests 6 vs 13 and 7 vs 8).

A comparison between OPE obtained with normal BFVBSs and an OPE obtained with a modified BFVBS (top three solid panels of the screen replaced with standard screen material) showed no difference at the shallow submergence (Tests 9 and 10) but a significant decline ($G=83.9$, $P=<0.005$) for both yearling chinook salmon and steelhead occured at the 15 to 17 ft submergence (Test 11).

The OPE tests for lighted and unlighted orifices are compared in Figure 4; except for steelhead at the 15- to 17-ft submergence, backlighted orifices provided significantly higher OPE (G=>12, P<0.005).

The OPE tests for north vs south orifices are compared in Figure 5; with one exception, OPEs through the south orifices were significantly higher than through the north orifices (G=>18, P<0.005). Further studies are recommended before proceeding with final orifice placement. It still may be necessary, for example, to locate some orifices on the south side and others on the north side, unless further studies would show that modified barrier screens or flow control vanes at the bottom of the gatewell would develop uniform attraction flow to a selected orifice.

STS FGE Tests

A summary of FGE tests conducted is given in Figure 6. Individual test data may be found in Appendix Table B2. Average FGE was significantly higher for the John Day flow (no stored gates) than for the McNary condition. For yearling chinook salmon it was 88 vs 83%, respectively, (G=8.53, P<0.005) and for steelhead, 87 vs 76%, respectively, (G=16.7, P<0.005). The increased flow into the gatewell without a stored gate apparently accounted for the increase in FGE for the John Day condition.

The average FGE measured in 1982 with a BFVBS for the John Day condition (no stored gate) was significantly higher than the average FGE measured in 1981 with a SVBS. For yearling chinook salmon the FGE was 88% with a BFVBS--significantly higher than the 75% measured in 1981 with a SVBS (G=46.43, P<0.001). Similar results were obtained with steelhead, 87 vs 79%, respectively, (G=7.19, P<0.005).

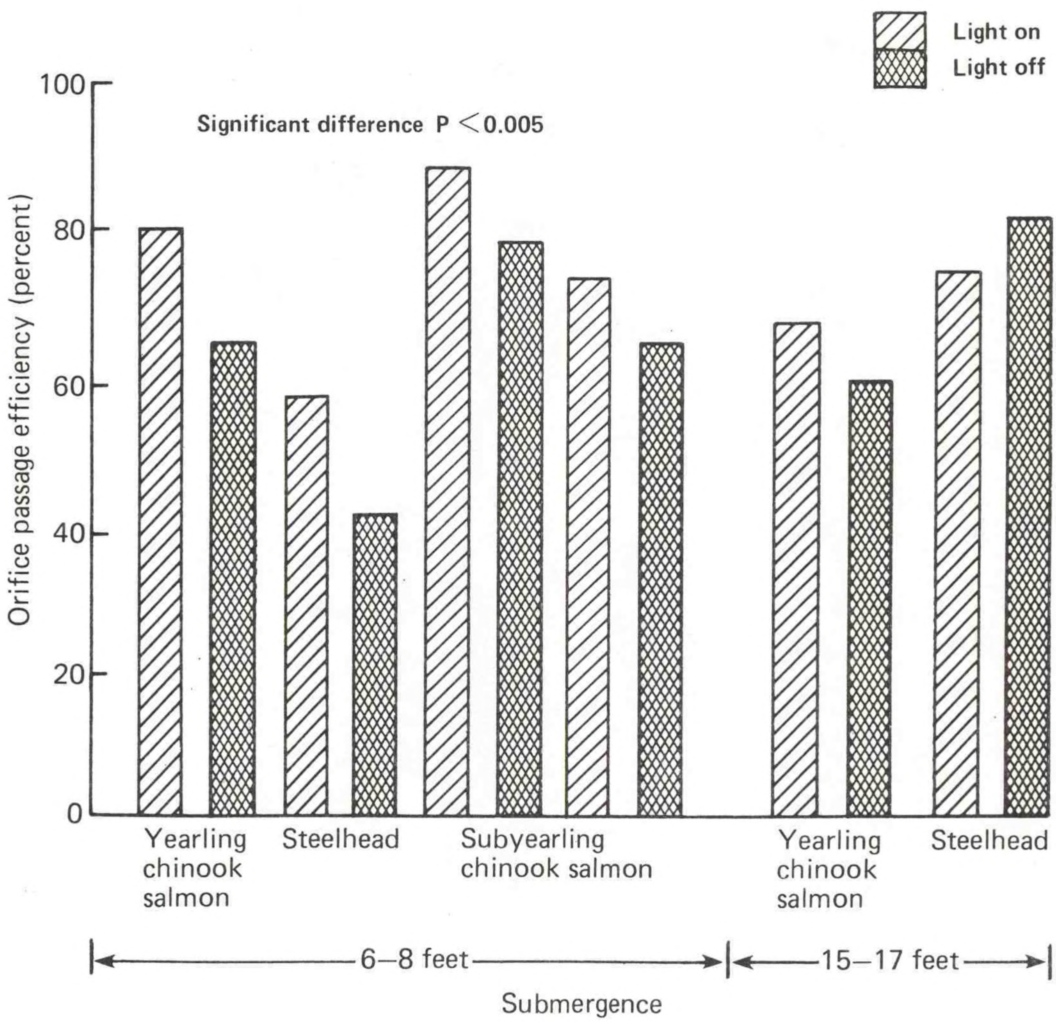


Figure 4.--Comparison of OPE for lighted and unlighted orifices at shallow and deep submergences.

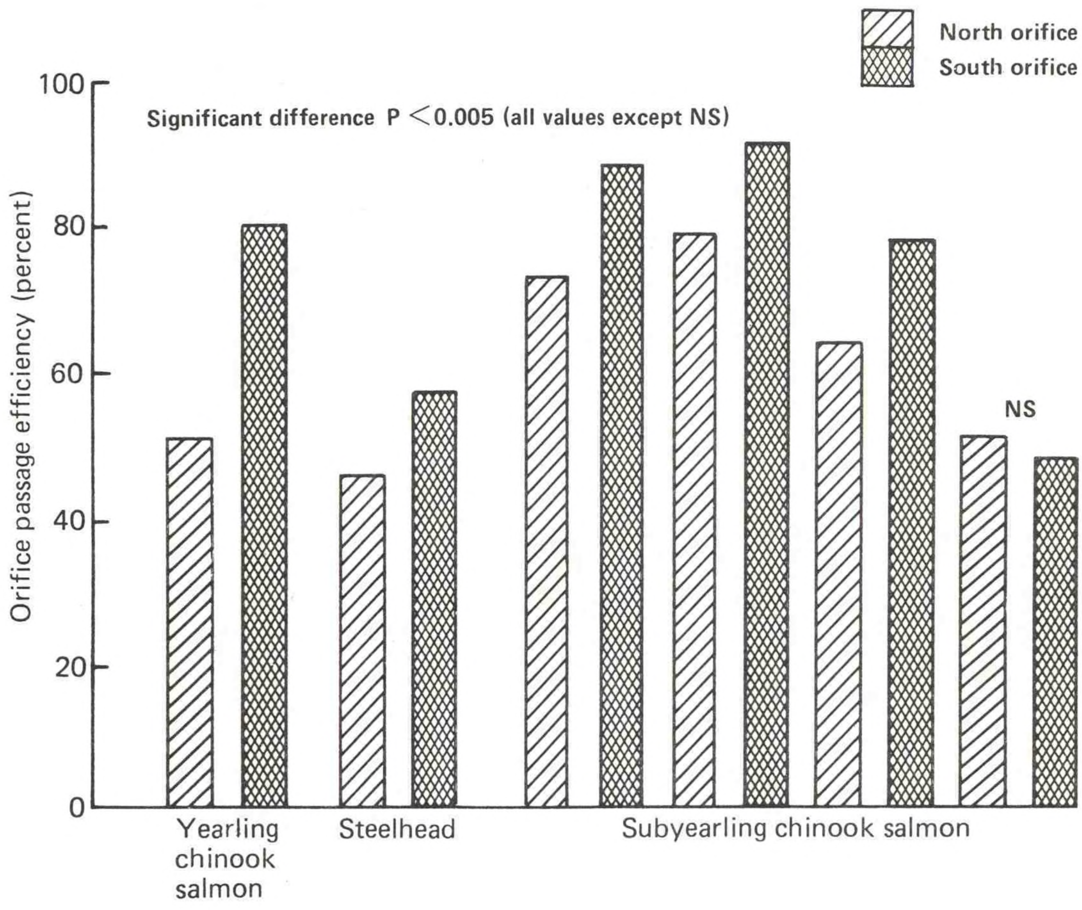


Figure 5.--A comparison of OPE through north and south orifices at McNary Dam, 1982.

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NATIONAL MARINE FISHERIES SERVICE
Northwest & Alaska Fisheries Center
Coastal Zone & Estuarine Studies Division
2725 Montlake Boulevard East
Seattle, Washington 98112

June 24, 1983 F/NWC5:RFK

TO: Recipients of Report Entitled "Research at McNary Dam to Develop and Implement a Fingerling Protection System for John Day Dam" dated May 1983

FROM: F/NWC5, Richard F. Krcma, Station Chief, Pasco Field Station, CZES

SUBJECT: Error on Page 17

There is an error in Figure 6; the part of the figure labeled "McNary gatewell condition" should be labeled "John Day gatewell condition" and vice versa.

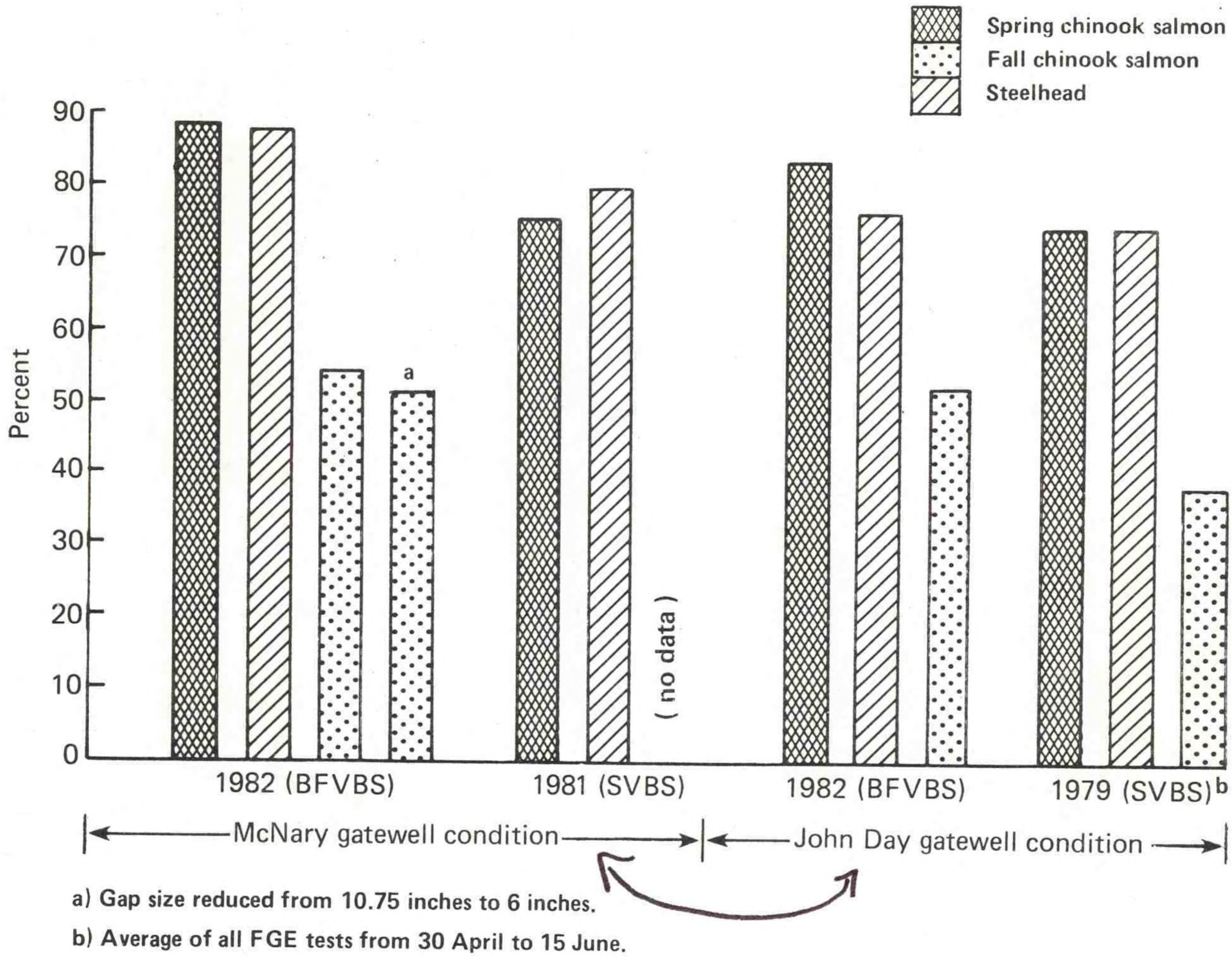

Figure 6.--Comparison of STS FGE tests with and without a BFVBS.

Tests conducted in 1981 did not measure FGE for the McNary condition. However in 1979, FGEs for the McNary condition were measured with an SVBS (Krcma et al. 1980), A comparison of these results with the 1982 results showed that the BFVBS significantly improved the FGE for yearling chinook salmon [74 vs 83% (G=58.87, P<0.001)] but not for steelhead (76 vs 74%).

It also appears that a BFVBS improved FGEs for subyearling chinook salmon. There are no background data for comparing John Day gatewell conditions on subyearling chinook salmon, but for the McNary gatewell conditions, the average FGE was significantly increased from 38% for tests in 1979 with a SVBS to 52% in 1982 with a BFVBS (G=83.58, P<0.001).

It should be noted, however, that the STS FGE data collected in 1979 (Krcma et al. 1980) related to a research study comparing a passive type wedge wire turbine intake screening device to an STS. The chinook salmon data for these tests were divided into two size groups instead of year classes--fish >70 mm and fish <70 mm. Generally though, the >70 mm group was predominantly yearling chinook salmon and the <70 mm group was mostly subyearling chinook salmon.

Regarding the overall FGE for the three target species, it is disturbing to note the significantly lower 51% FGE for subyearling chinook salmon as compared to 88% FGE for yearling fish (G=509.06, P<0.005). The replicated tests were also more variable for subyearling than yearling chinook salmon; e.g., during the FGE tests for the John Day condition, the three replicate tests for yearlings ranged from only 85 to 89%, but the five replicate tests for subyearlings ranged from 40 to 71%. A similar wide range was noted for FGE tests conducted for the screen cycling experiments during this same time period (McCabe et al. 1983).

Underwater video observations of the BFVBS indicated varying amounts of debris were accumulating on the screens. Observations indicated that as much as 80% of the screened panels of the BFVBS were occluded with debris. This degree of plugging could probably cause considerably more flow and fish deflection beneath the STS by reducing the amount of flow that would normally enter the gatewell and pass through the BFVBS. Earlier in the year when the yearling chinook salmon FGE tests were conducted, the BFVBS was clean. It is speculated that the debris problem could be the reason for the low FGE for subyearling chinook salmon and the high variance between replicates.

Model studies (Krcma et al. 1982) showed that the flow discharge through a John Day gatewell with a 15% open area barrier screen (the percent open area of the BFVBS used for our experiments) was 342 cfs. Reducing this porosity to 3% lowered the discharge to 256 cfs and total blockage resulted in 0 cfs discharge. Therefore, the inconsistency in the FGE may have been the result of changes in flow discharge through the gatewell caused by large areas of debris breaking loose from the BFVBS when accumulations reached a maximum carrying capacity. This could have been accentuated if the turbine was shut down rapidly causing a back-surge of water up the penstocks and into the gatewells. Under a John Day condition, considerably more water would probably enter the operating gate slot (on the backside of the BFVBS) than the bulkhead gate slot (upstream side of the BFVBS) because of the presence of the STS. A reverse flow through the BFVBS would result in a backflushing action on the barrier screens.

An additional test condition was incorporated into the John Day condition with subyearling chinook salmon. It involved the attachment of a modification to the STS that reduced the gap at the terminal end of the STS from about 12 inches to 6 inches. This condition simulated the approximate gap the STSs would have at John Day Dam if the present engineering design were used. No significant reduction in FGE occurred. The average FGE for these tests was 51% as compared to 54% for the 12-inch spacing. This does not mean, however, that a potential problem does not exist because time limitations did not allow exact duplication of the type of restriction that would occur in the real John Day Dam prototype.

Fish Quality Measurements

The results of paired tests on yearling chinook salmon showed no significant impact by the use of a BFVBS. The descaling rate was 7.0% for the test and 7.5% for the control condition. The average mortality rate in the seawater challenge tests was 5.0% for the test and 5.4% for the control condition.

The average descaling rate for yearling chinook salmon for the 24- and 48-h OPE tests were 7 and 11%, respectively. For steelhead it was 13% for both the 24- and 48-h test period. A "G" statistic test showed no significant difference for the yearling chinook salmon at a 95% confidence level, and there was no increase in stress as measured by the seawater challenge tests.

Descaling rates for OPE tests on subyearling chinook salmon were generally low for all test conditions, only about 3 to 9%. No significant increase in descaling was measured for OPE tests of greater than 24 h duration. Table 1 compares the average descaling rates for 24-, 48-, and 72-h tests.

Data from blood chemistry stress studies conducted by Oregon Cooperative Fishery personnel showed no increase in stress levels for subyearling chinook salmon from the 24- to 48-h OPE test groups.[3/]

3/ Personal communications from Alec Maule, Oregon Cooperative Fishery Unit, Department of Fish and Wildlife, Oregon State University

Table 1.--Descaling of fall chinook during 24-, 48-, and 72-h OPE tests.

BFVBS (John Day Dam gatewell condition)	
Number of hours	% Descaling
24	5.7
48	6.3
72	5.9

Dip Basket Efficiency and Escapement from Gatewells

The average recovery rate for marked fish released into the gatewell was 94% for yearling chinook salmon and 92% for subyearling chinook salmon, indicating only minimal sounding and exiting from the gatewells with BFVBSs. An additional release of subyearling chinook salmon was made in Unit 8A (SVBS) in which recovery was 88%.

CONCLUSIONS AND RECOMMENDATIONS

1. The levels of OPEs for gatewells equipped with BFVBSs were generally acceptable throughout the range of orifice submergences and heads tested, provided the test duration was greater than 24 h and the orifices were backlighted. This is in contrast to the less than acceptable OPE measured with an SVBS in 1981.

2. OPE tests of 48 h duration did not cause a significant increase in stress or descaling based on seawater challenge and descaling data.

3. The use of the modified BFVBS with standard screens in the top three panels appeared to adversely impact OPE.

4. Even though OPEs were significantly higher through the south orifices of the test gatewells, further studies are recommended before proceeding with final orifice placement because flow conditions vary between gatewells and between turbines. It still may be necessary, for example to locate some orifices on the south side and others on the north side, modify barrier screens, or place flow control vanes at the bottom of the gatewell to have uniform attraction flows to the orifices.

5. The BFVBS significantly improved FGEs over those measured with SVBSs in previous years.

6. Because acceptable OPEs were measured over the range of submergences tested, no increase in stress on fish was measured over a 72-h

period, and FGEs were not adversely impacted by the BFVBS, it is recommended that a single orifice system with a BFVBS and backlighting be employed at John Day Dam. The recommended depth is about elevation 251 ft. This would provide a 7-ft submergence during the yearling migration in the spring when there is usually a low pool (elevation 259) and 16-ft submergence for subyearling fish in the summer when there is usually a full pool (elevation 268).

7. The FGEs for subyearling chinook salmon were significantly lower than that measured on yearling chinook salmon and steelhead. Because there was high variability in results and debris buildup on barrier screens during subyearling chinook salmon migrations, additional testing is recommended to ascertain real FGEs for subyearling chinook salmon and how they are affected by debris, fish size, etc. In addition, it is recommended that a provision be made in the final design of the barrier screens to provide routine cleaning.

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APPENDIX A

Sample Sizes Needed to Detect Differences Among Test Groups

The information needed to determine the number of replicates and the sample sizes required per test group are the treatment variability expected, the number of means (or experimental categories) being compared, and the specified precision (i.e., the probability of the type I error, α, and the probability of type II error, β) desired from the statistical test. This information is applied using the following sample size precision formulas:

(1) For obtaining sample sizes in the two group comparison case (Lemeshow et al. 1981):

$$NT=((ZA-ZB)*2)/(2(SP1-SP2)*2).$$

(2) For obtaining confidence intervals and sample sizes for the multinomial, more than two group case (Angers 1974), (Goodman 1965), (Miller 1966):

$$NM=(B)(P_i(1-P_i))/D*2.$$

(3) For obtaining the number of replicates (Steel and Torrie 1960):

$$R>(2(T_1+ T_2)*2)(ST*2)/D*2).$$

Where the following notation is used:

NT sample size in the two group comparison.

ZA $(1-\alpha)$-th percentile of the standard normal distribution.

ZB β-th percentile of the standard normal distribution.

SP1 is the arcsin transform of the square root of the proportion in the control group

SP2 is the arcsin transform of the square root of the proportion in the test group.

* indicates exponentiation.

NM smallest sample size such that the statistical precision levels for the multinomial parameters, P_i are simultaneously satisfied.

B tabular value for the upper percentile of the chi-squared distribution at the specified statistical precision level with the one degree of freedom.

P_i expected proportion in each multinomial category.

D level of difference it is desireable to be able to detect, this can be different for each treatment (or multinomial) category.

R the number of replicates per treatment.

T_1 t-distribution value associated with type I error.

T_2 t-distribution value associated with type II error; T_2 is the tabulated t for probability 2(1-Q) where Q is the power of the test $(1-\beta)$.

ST estimated experiment-wise error mean square, usually obtained from previous experiments

The degrees of freedom for T_1 and T_2 are the product of (K-1) (R-1) where K is the number of treatment groups, and R the number of replicates. Successive approximations are involved in the calculations for parts (2) and (3) since the number of degrees of freedom associated with tabulated probability distribution values depends on sample size.

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APPENDIX B

Tables Showing Test Results

Appendix Table B1. ORIFICE PASSAGE EFFICIENCY TESTS - McNARY DAM 1982

Date	Test No.	Unit, slot & location	Sub-mergence (ft)	Length (h)	Head (ft)	Light	Pre-smolt Fall Chinook[a/] Orifice trap	Pre-smolt Fall Chinook Gate-well	Pre-smolt Fall Chinook % OPE	Subyearling Chinook Orifice trap	Subyearling Chinook Gate-well	Subyearling Chinook % OPE	Yearling Chinook Orifice trap	Yearling Chinook Gate-well	Yearling Chinook % OPE	Steelhead Orifice trap	Steelhead Gate-well	Steelhead % OPE	Coho Orifice trap	Coho Gate-well	Coho % OPE	Sockeye Orifice trap	Sockeye Gate-well	Sockeye % OPE
22 April		6BN	15-17	24	4	ON	544	16	97	---	---	---	39	16	71	68	39	64	---	---	---	---	---	---
23		"	"	"	"	"	262	2	99	---	---	---	138	57	71	227	124	65	---	---	---	---	---	---
24		"	"	"	"	"	123	5	96	---	---	---	243	104	70	371	221	63	---	---	---	---	---	---
	(#1)						929	23	98				420	177	70	666	384	63						
25 April		6BN	15-17	24	7	ON	152	6	96	---	---	---	247	81	75	309	120	72	---	---	---	---	---	---
26		"	"	"	"	"	159	10	94	---	---	---	417	228	65	477	166	74	---	---	---	---	---	---
27		"	"	"	"	"	93	0	100	---	---	---	416	235	64	353	115	75	---	---	---	---	---	---
	(#2)						404	16	96	---	---	---	1080	544	67	1139	401	74						
28 April		6BN	6-8	24	4	ON	---	--	---	---	---	---	297	451	40	344	175	66	---	---	---	---	---	---
4 May		"	"	"	"	"	95	7	93	---	---	---	1385	794	64	412	316	57	---	---	---	160	107	60
5		"	"	"	"	"	257	4	98	---	---	---	426	455	48	140	145	49	---	---	---	55	95	37
13		"	"	"	"	"	---	--	---	---	---	---	554	365	60	405	257	61	---	---	---	70	34	67
	(#3)						352	11	97	---	---	---	2662	2056	56	1301	893	59				285	236	55
6 May	(#4)	6BN	15-17	24	7	OFF	336	7	98	---	---	---	838	587	59	560	134	81	---	---	---	441	50	80
10 May		6BN	6-8	24	7	ON	122	2	98	---	---	---	424	931	31	292	103	74	---	---	---	64	54	54
11		"	"	"	"	"	78	1	99	---	---	---	1504	395	79	418	171	71	---	---	---	98	35	74
12		"	"	"	"	"	94	1	99	---	---	---	1262	513	71	717	276	72	---	---	---	229	40	85
	(#5)						294	4	99	---	---	---	3190	1839	63	1427	550	72	---	---	---	391	129	75
10 May		5AS	18-20	24	4	ON	130	15	90	---	---	---	515	952	35	484	104	82	---	---	---	93	22	81
11		"	"	"	"	"	73	1	98	---	---	---	1467	751	66	850	111	88	---	---	---	218	34	87
12		"	"	"	"	"	113	3	97	---	---	---	983	276	78	890	186	83	---	---	---	222	27	89
13		"	"	"	"	"	92	4	96	---	---	---	552	384	59	710	141	84	---	---	---	96	18	84
	(#6)[b/]						408	23	95				3517	2363	60	2934	542	84				629	101	86

a/ Majority of these fish are less than 50 mm, fork length.

b/ Test condition #6 was repeated for subyearling chinook 13 June to 19 June.

Appendix Table B1--Continued

ORIFICE PASSAGE EFFICIENCY TESTS - McNARY DAM 1982

Date	Test No.	Unit, slot & location	Sub- mergence (ft)	Length (h)	Head (ft)	Light	Pre-smolt Fall Chinook a/ Orifice trap	Pre-smolt Fall Chinook Gate- well	Pre-smolt Fall Chinook % OPE	Subyearling Chinook Orifice trap	Subyearling Chinook Gate- well	Subyearling Chinook % OPE	Yearling Chinook Orifice trap	Yearling Chinook Gate- well	Yearling Chinook % OPE	Steelhead Orifice trap	Steelhead Gate- well	Steelhead % OPE	Coho Orifice trap	Coho Gate- well	Coho % OPE	Sockeye Orifice trap	Sockeye Gate- well	Sockeye % OPE
14		6BN	6-8	48	4	ON	---	--	---	---	---	---	1925	218	90	974	285	77	---	---	---	239	29	89
16		"	"	"	"	"	---	--	---	---	---	---	956	321	75	471	269	64	76	51	60	159	93	63
18		"	"	"	"	"	---	--	---	---	---	---	1175	371	76	582	323	64	134	30	82	155	94	62
	(#7)												4056	910	82	2027	877	70	210	81	73	553	216	72
14 May		5AS	18-20	48	4	ON	123	6	95	---	---	---	1072	507	68	1244	101	92	---	---	---	204	30	87
16		"	"	"	"	"	140	3	98	---	---	---	1201	684	64	1079	160	87	136	44	76	283	96	75
18		"	"	"	"	"	102	2	98	---	---	---	1158	541	68	1206	118	91	275	78	78	381	133	74
	(#8)						365	11	97				3431	1732	66	3529	379	90	411	122	77	868	259	77
21 May	6B	N	6-8	24	4	ON	---	--	---	---	--	---	363	461	44	164	90	65	90	72	56	89	173	34
22	"	"	"	"	"	"	---	--	---	---	--	---	392	363	52	321	217	60	106	106	50	49	159	24
23	"	"	"	"	"	"	---	--	---	---	--	---	247	109	69	100	70	59	70	13	84	77	92	46
	(#9) b/												1002	993	50	585	337	61	266	191	58	215	424	34
21 May		5AN	6-8	24	4	ON	---	--	---	---	--	---	285	328	47	99	120	45	90	75	55	64	115	36
22		"	"	"	"	"	---	--	---	---	--	---	422	286	60	295	299	50	126	116	52	55	61	47
23		"	"	"	"	"	---	--	---	52	88	37	161	234	41	57	110	34	48	34	59	43	124	26
	(#10)									52	88	37	868	848	51	451	529	46	264	225	54	162	300	35
24 May		6BN	15-17	24	4	ON	---	--	---	1	207	1	19	145	12	43	118	27	3	100	3	99	380	21
25		"	"	"	"	"	---	--	---	34	143	19	143	228	39	173	227	43	24	165	13	501	984	34
26		"	"	"	"	"	---	--	---	3	111	3	37	91	29	82	159	34	10	139	7	70	150	32
	(#11) b/									38	461	8	199	464	30	298	504	37	37	404	8	670	1514	31
24 May	(#12)	5AS	6-8	24	4	OFF	---	--	---	121	214	36	211	121	64	74	106	41	93	90	51	313	329	49

a/ Majority of these fish are less than 50 mm, fork length.

b/ Top three panel sections of vertical barrier screen are standard screen.

Appendix Table B1.--Continued

ORIFICE PASSAGE EFFICIENCY TESTS - McNARY DAM 1982

Date	Test No.	Unit, slot & location	Sub-mergence (ft)	Length (h)	Head (ft)	Light	Pre-smolt Fall Chinook[a/] Orifice trap	Pre-smolt Fall Chinook Gate-well	Pre-smolt Fall Chinook % OPE	Subyearling Chinook Orifice trap	Subyearling Chinook Gate-well	Subyearling Chinook % OPE	Yearling Chinook Orifice trap	Yearling Chinook Gate-well	Yearling Chinook % OPE	Steelhead Orifice trap	Steelhead Gate-well	Steelhead % OPE	Coho Orifice trap	Coho Gate-well	Coho % OPE	Sockeye Orifice trap	Sockeye Gate-well	Sockeye % OPE
25 May		5AS	6-8	24	4	ON	---	--	---	99	89	53	267	60	82	200	170	54	66	44	60	444	541	45
26		"	"	"	"	"	---	--	---	40	116	3	107	34	76	126	72	64	22	41	35	50	38	57
	(#13)									139	205	40	374	94	80	326	242	57	88	85	51	494	579	46
8 June	(#14)	5AN	18-20	24	7	OFF	---	--	---	440	526	46	---	--	---	---	---	--	---	--	---	---	---	---
9 June		5AN	18-20	24	4	ON	---	--	---	354	330	52	---	--	---	---	---	--	---	--	---	---	---	---
10		"	"	"	"	"	---	--	---	215	216	50	---	--	---	---	---	--	---	--	---	---	---	---
	(#15)									569	546	51												
11 June		5AS	18-20	24	4	ON	---	--	---	131	323	29	---	--	---	---	---	--	---	--	---	---	---	---
12		"	"	"	"	"	---	--	---	147	295	33	---	--	---	---	---	---	---	--	---	---	---	---
24		"	"	"	"	"	---	--	---	715	447	62	---	--	---	---	---	---	---	--	---	---	---	---
	(#6)b/									993	1065	48												
13 June		5AS	18-20	72	4	ON	---	--	---	647	466	58	---	--	---	171	12	93	---	--	---	---	---	---
16		"	"	"	"	"	---	--	---	683	225	75	---	--	---	---	---	---	---	--	---	---	---	---
19		"	"	"	"	"	---	--	---	2982	1453	67	---	--	---	---	---	---	---	--	---	---	---	---
	(#16)									4314	2144	67				171	12	93						
16 June		6BN	15-17	72	4	ON	---	--	---	94	232	29	---	--	---	---	---	---	---	--	---	---	---	---
19		"	"	"	"	"	---	--	---	1832	1187	61	---	--	---	---	---	---	---	--	---	---	---	---
22		"	"	"	"	"	---	--	---	1963	500	80	---	--	---	---	---	---	---	--	---	---	---	---
25		"	"	"	"	"	---	--	---	560	280	67	---	--	---	---	---	---	---	--	---	---	---	---
28		"	"	"	"	"	---	--	---	524	45	92	---	--	---	---	---	---	---	--	---	---	---	---
	(#17)									4973	2244	70												
22 June	(#18)	5AN	18-20	48	7	ON	---	--	---	4313	564	88	---	--	---	---	---	---	---	--	---	---	---	---

a/ Majority of these fish are less than 50 mm, fork length.
b/ Test conditions identical to Test No. 6 for yearling fish.

Appendix Table B1.--Continued

ORIFICE PASSAGE EFFICIENCY TESTS - McNARY DAM 1982

Date	Test No.	Unit, slot & location	Sub-mergence (ft)	Length (h)	Head (ft)	Light	Pre-smolt Fall Chinook[a/]			Subyearling Chinook			Yearling Chinook			Steelhead			Coho			Sockeye		
							Orifice trap	Gate-well	% OPE	Orifice trap	Gate-well	% OPE	Orifice trap	Gate-well	% OPE	Orifice trap	Gate-well	% OPE	Orifice trap	Gate-well	% OPE	Orifice trap	Gate-well	% OPE
7 July		6BS	6-8	48	4	ON	---	--	---	394	52	90	---	--	---	---	---	---	---	--	---	---	---	---
12		"	"	"	"	"	---	--	---	522	82	86	---	--	---	---	---	---	---	--	---	---	---	---
	(#19)									916	124	88												
7 July		5AN	6-8	48	4	ON	---	--	---	852	281	75	---	--	---	---	---	---	---	--	---	---	---	---
12		"	"	"	"	"	---	--	---	426	174	71	---	--	---	---	---	---	---	--	---	---	---	---
	(#20)									1278	455	73												
9 July	(#21)	6BS	6-8	72	4	ON	---	--	---	609	57	91	---	--	---	---	---	---	---	--	---	---	---	---
9 July	(#22)	5AN	6-8	72	4	ON	---	--	---	857	221	79	---	--	---	---	---	---	---	--	---	---	---	---
14 July	(#23)	6BS	6-8	48	4	OFF	---	--	---	436	120	78	---	--	---	---	---	---	---	--	---	---	---	---
14 July	(#24)	5AN	6-8	48	4	OFF	---	--	---	412	229	64	---	--	---	---	---	---	---	--	---	---	---	---

a/ Majority of these fish are less than 50 mm, fork length.

Appendix Table B2.--STS guidance test results, Unit 5A, McNary Dam, 1982. (%FGE=gatewell catch (GW) divided by total catch)

	Replicate No.	Yearling chinook GW	Yearling chinook Total	Yearling chinook %FGE	Steelhead GW	Steelhead Total	Steelhead %FGE
John Day gatewell condition							
4/28	1	161	185	87	188	214	88
4/29	2	384	431	89	104	117	89
5/2	3	21	259	85	138	161	86
Combined		766	875	88	430	492	87
McNary gatewell condition							
5/3	1	612	712	85	150	194	74
5/4	2	426	521	81	55	74	71
5/5	3	99	136	73	43	54	80
Combined		1137	1369	83	248	325	76

	Replicate No.	Subyearling Chinook GW	Subyearling Chinook Total	Subyearling Chinook %FGE
John Day gatewell condition				
6/27	1	284	422	67
6/29	2	57	138	41
7/19	3	355	885	40
7/21	4	273	657	42
7/23	5	726	1024	71
Combined		1695	3126	54
John Day gatewell condition with reduced gap size				
7/25	1	171	421	41
7/26	2	116	218	53
7/27	3	392	694	57
Combined		679	1333	51
McNary gatewell condition				
7/28	1	690	1149	60
7/29	2	310	666	47
7/30	3	121	325	37
Combined		1121	2140	52