Research to Develop an Improved Fingerling Protection System for Lower Granite Dam

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COASTAL ZONE AND ESTUARINE STUDIES

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INTRODUCTION

Juvenile spring chinook salmon and steelhead may travel several hundred miles downstream in the Snake and Columbia Rivers and encounter up to eight hydroelectric dams during their seasonal migration to the ocean (Figure 1). In some years, over 95% of these smolts have died during passage through the dam complex. Most losses occur to fingerlings passing through the turbines at the dams. Fingerling bypass systems are being developed and constructed to reduce these dam related mortalities.

To reduce the losses of juvenile salmonids from passing through the turbines, the fish must be diverted from the turbine intakes. The most effective method of achieving this has been to employ submersible traveling screens (STS) to guide fish out of the turbine intakes into the gate slots (Figure 2). The fish are passed from the gate slots through orifices into a bypass that carries them around the dam into raceways where they can be either released back into the river below the dam or transported by barge or truck to safe release areas downstream.

The theoretical fish guiding efficiency (FGE) of the STS at most dams varies from 70 to 80%. This means that 70% or more of all fingerlings entering turbine intakes are traveling in the water mass intercepted and diverted by the STS into the gate slots. Tests at McNary and Bonneville Dams (first powerhouse) determined that the measured FGE approached this theoretical figure (Krcma et al. 1980 and 1982).

Lower Granite and Little Goose Dams are the upstream collection sites for smolts to be transported from the Snake River. Optimizing FGE at these

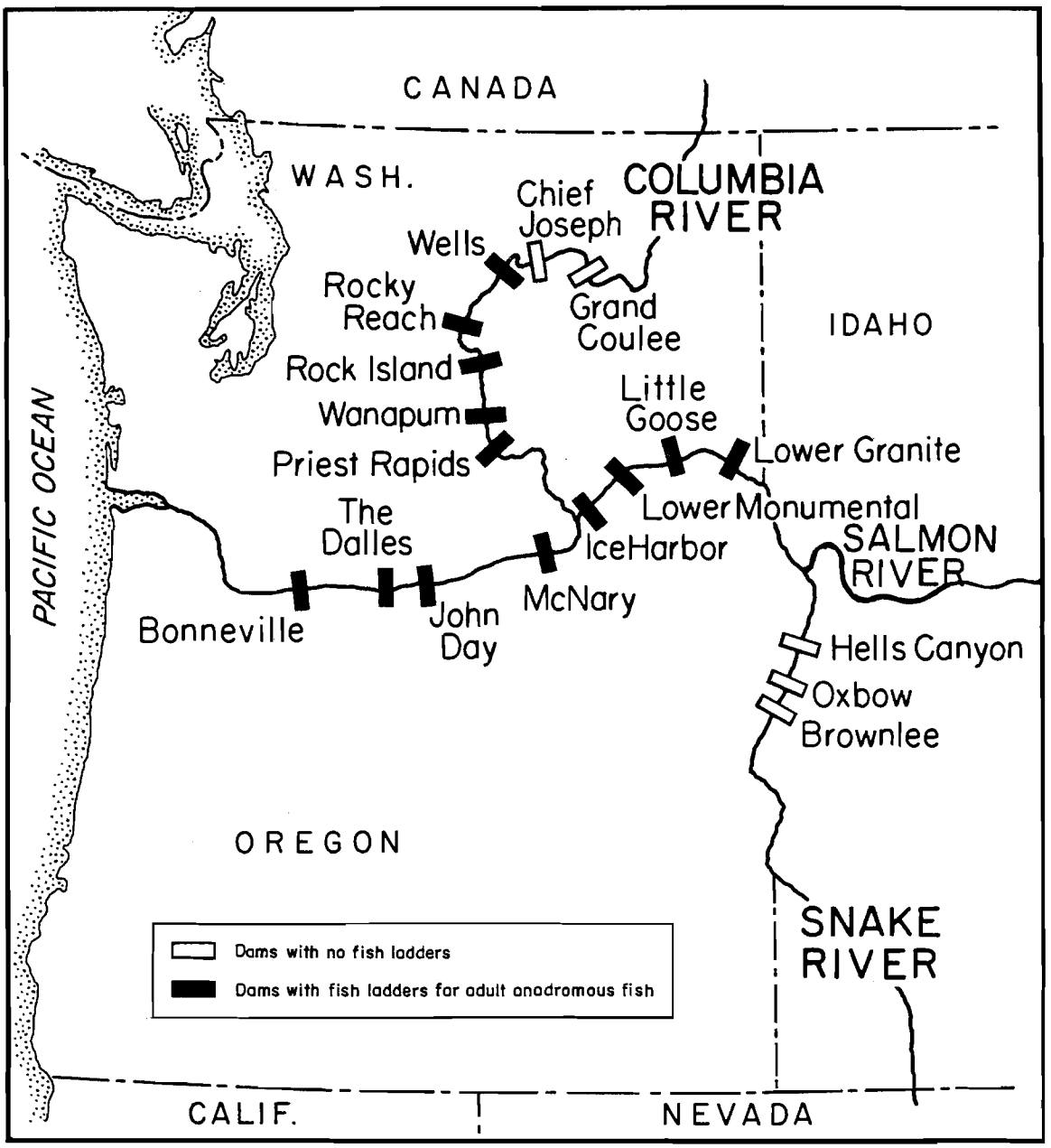

Figure 1.--Main stem dams in the Columbia River Basin.

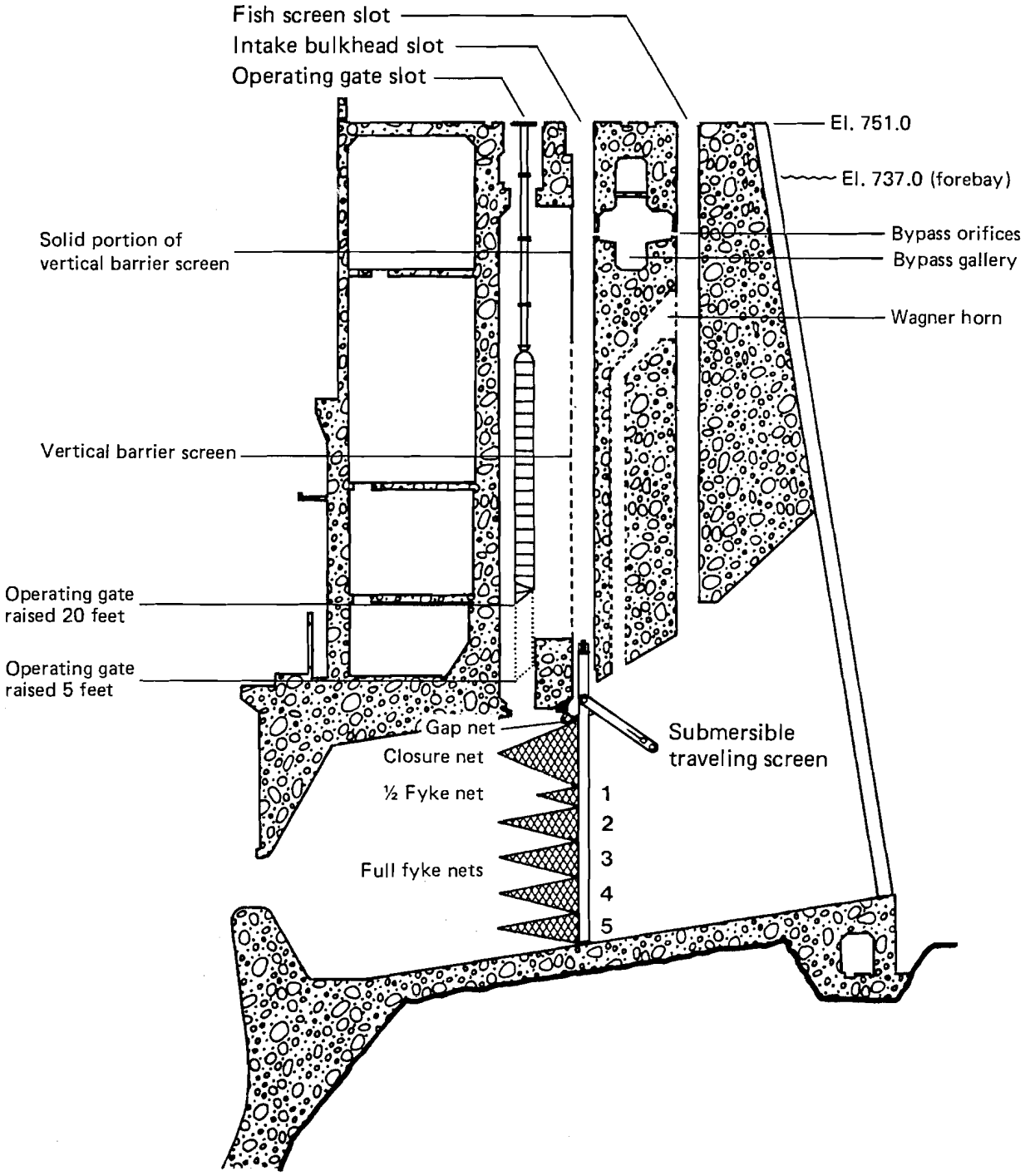

Figure 2.--Cross section of Unit 4-A turbine intake at Lower Granite Dam showing STS, fyke nets, and position of operating gates when raised 5 ft and 20 ft for FGE testing.

dams is vital to the success of the transportation program and/or bypass mode of operation. Tests conducted in 1982 at Lower Granite Dam, however, showed that the average STS FGE for spring chinook salmon was only 50%, significantly below the theoretical 76% FGE determined from vertical distribution tests. It was apparent, therefore, that some modifications were required to raise the efficiency of the STS to an acceptable level. Hydraulic model studies conducted by Engineering Hydraulics Inc., of Longmont, Colorado, in the fall of 1982 showed that the major problem was probably due to deflection of a considerable percentage of flow under the STS. The studies further showed that this deflection could be minimized by increasing water flow into the bulkhead slot (BHS). This was accomplished by raising the operating gate that is normally stored in the downstream slot or operating gate slot (OGS) and by lowering the STS farther into the turbine intake to increase the throat opening at the entrance to the BHS. The first objective of our 1983 research program was to field test these conditions at Lower Granite Dam.

The turbine intakes at Lower Granite Dam are unique in that they are constructed with a conventional BHS and a special fish screen slot (FSS). The FSS, however, were later determined to be unsatisfactory, and the STS were placed in the BHS (Park et al. 1976 and 1977). To allow fish to enter the bypass conduit, there are two 8-inch diameter orifices leading from both the BHS and the FSS (Matthews et al. 1977). Tests in 1982 showed that orifice passage efficiencies (OPE) for chinook salmon and steelhead were unacceptably low through these 8-inch diameter orifices (Swan et al. 1983). To install 12-inch diameter orifices in the BHS, like there are at other dams, without enlarging the bypass conduit requires that the orifices in

the FSS be closed. Consequently, the second objective of the 1983 research at Lower Granite Dam was to evaluate the benefit of using 12-inch diameter bypass orifices for improving OPE and to determine if closure of the FSS would adversely impact FGE.

METHODS AND MATERIALS

Experimental Equipment

The following equipment or services were used to conduct the research:

1. One modified STS, equipped with a full complement of fyke and gap nets. Modifications included:

   a. Internal solid plates of the STS were replaced with perforated plate (46% open area) at the upper and lower ends of the traveling screen (shown from 1982 testing to significantly enhance FGE for chinook salmon).

   b. When the STS was lowered 2 ft in the intake to increase interception, the throat opening increased from about 36 inches to 60 inches. To maintain a continuity in the distance between the upper truss and the traveling mesh similar to that of a standard STS, it was necessary to extend the truss. Also, this truss was enclosed in sheet metal to reduce turbulence and create a smoother flow pattern up into the BHS.

2. One standard STS equipped with a full complement of fyke and gap nets.

3. Two portable orifice traps.

4. Two gatewell dip nets (Swan et al. 1979).

5. On-deck fish examining facilities.

6. Two mobile cranes.

7. Two 12-inch diameter orifices in 4-A BHS.

8. Two FSS closure devices.

9. U.S. Army Corps of Engineers (CofE) services

a. Provided gantry crane service for preparation and performance of STS FGE tests.

b. Drilled out the two 8-inch diameter orifices in 4-A BHS to 12-inch diameter.

c. Installed a turbine ceiling beam extension just downstream from the 4-A BHS to maintain a 13-inch gap opening when the STS was lowered 2 ft into the turbine intake.

d. Modified the operating gate with a special hydraulic system to provide the capability of raising it 5 and 20 ft up in the OGS.

Measurements and Procedures

STS Fish Guiding Efficiency

Tests were conducted in Intakes 4-A and 4-B. The test intake (4-A) was equipped with a balanced flow vertical barrier screen (BFVBS), a modified STS, and a modified operating gate that could be raised 5 or 20 ft (Figure 2). The control intake (4-B) was equipped with a standard vertical barrier screen (SVBS), a standard STS in normal operating position, and the operating gate in the normal position.

The STS in 4-A and 4-B were equipped with a composite of nets for recovering a percentage of the unguided fish. These nets included one closure net attached to the back of the STS. A net frame suspended below the STS supported a vertical column of five fyke nets. On the upper part of this frame, these nets were flanked on each side by a column of three additional fyke nets (Figures 2 and 3). The uppermost net (one-half fyke net) in each column was approximately 3.5 by 6.5 ft, and the lower nets (full size fyke nets) were approximately 6.5 ft square. A gap net,

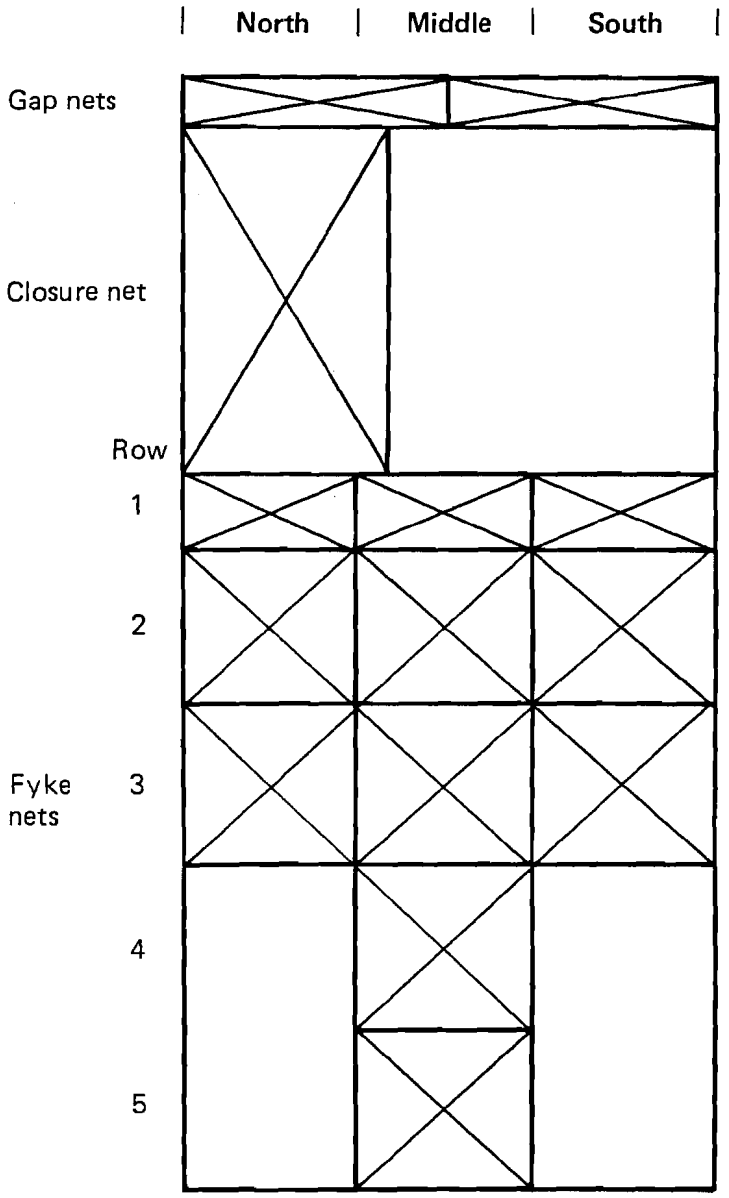

Figure 3.--Layout of fyke nets used to measure FGE at Lower Granite Dam.

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 OGS and BHS.

To minimize mortality of fish in fyke nets, initial 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 fish in a single vertical column of fyke nets that fished the center one-third of the intake not intercepted by the STS. To minimize differential flow conditions that could cause fish to veer off and not be trapped, nets were in place in the remaining area of the intake, but the cod ends of the nets were left open to allow fish to pass on through the intake. To verify the validity of our estimate, we conducted some tests that included fyke net catches from the full complement of nets.

The procedures for determining FGE were similar to those used in previous experiments of this type (Swan et al. 1983). The STS FGE tests consisted of a series of test conditions each of which had a corresponding control condition for direct comparison. Gatewell dipnet catches provided the number of guided fish; catches from the gap and fyke nets attached to the STS provided numbers of unguided fish. Guided fish included fish from both the BHS and FSS. FGE was calculated as guided fish divided by the total number of fish passing through the intake during the test period:

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

GW = gatewell catch (BHS + FSS when applicable)
GN = gapnet catch
FN = fyke net catch (times 3 when fishing only the center one-third of the intake)
CN = closure net catch

Contingency tables utilizing the "G" statistic were used to analyze the data for significance.

Descaling of fish was monitored as a measure of fish quality throughout the testing.

The following conditions were tested in 1983:

1. STS lowered 2 ft, operating gate raised 20 ft.
2. STS at normal level, operating gate raised 20 ft.
3. STS lowered 2 ft, operating gate raised 5 ft.
4. STS at normal level, operating gate raised 5 ft.
5. STS lowered 2 ft, operating gate at normal level.

For these tests, the sample size requirements and number of replicates for desired levels of statistical significance are given in Appendix A.

During all tests, the STS was operated in a screen cycling mode (4 min out of every 24 min) to be consistent with operations of the rest of the project STS, and turbine loading was held constant at 135 MW. To determine if increased impingement occurred due to the replacement of the solid plate inside the STS with a 46% porosity plate, two gap net operating procedures were used. During one test day, the gap net was held in the fishing position during the entire test to collect both impinged fish (when the screen rotated) and fish passing through the gap volitionally. On alternate days, the gap net was raised into the fishing position only during the "on" portion of the screen cycling mode (4 min out of every 24 min) capturing primarily only impinged fish. The percent gap loss was based on the gap net catch and was represented as a percentage of the total estimated population passing through the intake (guided plus unguided).

The following sequence of events was typical for conducting an STS FGE test:

1. Unit 4 was shut down.

2. The STS with attached fyke net frames were lowered into position in BHS 4-A and 4-B with the gantry crane.

3. The bypass orifices in Intakes 4-A and 4-B were closed, and the BHS and FSS were dipped to remove all fish present at that time.

4. The operating gate was raised (as appropriate) with the gantry in Unit 4-A.

5. Unit 4 was returned to service and brought to full load (135 MW).

6. The numbers of fish entering each BHS were monitored by periodic dipnetting.

7. The test was terminated when adequate numbers of fish for statistical needs were collected (Appendixes A and B).

8. The turbine was shut down, and final cleanout dips were made in the BHS and FSS in Units 4-A and 4-B.

9. The operating gate was lowered (when appropriate) to its normal position.

10. The STS with attached fyke nets and frames were brought to the surface, and the fish were removed from the nets for identification and enumeration.

11. The unit was returned to service.

Each test was about 2 to 8 h long depending upon the density of the fish run. The turbine was shut down for about 2 h to install the STS and again for its removal.

Tests were started between 1700 and 1800 h and terminated about 2100 or 2200 h when adequate numbers of fish had been guided into the BHS. The number of guided fish removed from the BHS by dipnetting determined the duration of a test. The experimental design required specific sample sizes

and replicates to satisfy specified statistical significance levels for detecting relevant differences of a stated magnitude. This called for three or more replicates with a goal of 300 fish per sample (BHS catch) for each condition tested. Contingency table procedures using the G-test were used in the statistical analysis (Sokal and Rohlf 1981). The formulas and procedures used are given in Appendix A.

Fish Screen Slot Closure Tests

FSS closure devices, similar to a gatewell dipnet basket with plywood floors, were installed in FSS 4-A and 4-B. The plywood was bolted down so that the FSS in 4-A would remain closed during each test whereas the plywood in 4-B was hinged so that the device in 4-B could be alternately opened or closed on successive test days. The contribution from the FSS to the total number of guided fish could then be measured and closure of the FSS evaluated.

Orifice Fish Passage Efficiency

Tests were conducted to compare OPE through 12-inch and 8-inch diameter orifices and to determine if there was a bias between north and south locations. To test OPE, both the north and south orifices in BHS 4-A were drilled out to a 12-inch diameter, and each was connected to a trap in the bypass gallery. When testing two 8-inch diameter orifices, plates with 8-inch diameter openings were centered over the 12-inch diameter orifices in the BHS. When each orifice was tested, it was open for 24 h, and fish passing into the trap were routinely monitored. After 24 h, the orifice was closed, and a dip basket was used to remove residual fish from the BHS. The OPE was measured by comparing the number of fish caught in the trap to the total number of fish that entered the BHS during the preceeding 24-h

period. A minimum of five replicates of 24-h duration were conducted with uninterrupted, fully loaded (135 MW) unit operation. The OPE tests started at 1200 h after dipping out the residual fish and ended 24 h later by again dipping out residual fish. Contingency tables utilizing the "G" statistic were used to analyze the data for significance.

Fish Quality

Descaling of fish in the BHS was monitored as a measure of fish quality throughout the FGE and OPE testing.

RESULTS

STS Fish Guiding Efficiency

Catches of spring chinook salmon and steelhead during the fish guiding efficiency tests are shown in Appendix B.

The position of the gate in the OGS significantly influenced FGE (Table 1). FGE for spring chinook salmon was improved to an acceptable 74% (90% C.L. = $\pm$ 1%) when the operating gate was raised 20 ft. The increase was highly significant $G = 87.22$, $P < 0.001$. The already acceptable FGE for steelhead was also improved by raising the operating gate 20 ft. Tests conducted with the operating gate raised 5 ft produced a lower than acceptable FGE for spring chinook salmon (63%, 90% C.L. = $\pm$ 12%). Highest FGE for spring chinook salmon occurred early in the testing (22 April - 1 May) when the run was composed primarily of spring chinook salmon. However, when the same test condition was repeated later (9-11 May), the composition of the run had changed to primarily steelhead, and the resulting FGE was about 5% lower and on the borderline for acceptable

Table 1.--Average percent fish guiding efficiency and 90 percent confidence limits of the submersible traveling screen operated at two different positions in conjunction with the operating gate stored at three different elevations at Lower Granite Dam during 1983.

Dates	No. replicates	Test conditions	Chinook salmon		Steelhead	
			Test	Control	Test	Control
4/22-4/27	6	STS lowered 2 ft* Gate raised 20 ft	74 ± 7	53 ± 7	82 ± 4	74 ± 7
4/29-5/1	3	STS standard level Gate raised 20 ft	74 ± 1	55 ± 13	85 ± 8	70 ± 20
5/9-5/11	3	Repeat first test**	69 ± 2	53 ± 3	88 ± 4	81 ± 3
5/2-5/4	3	STS standard level Gate raised 5 ft	63 ± 12	52 ± 7	83 ± 6	79 ± 3
5/6-5/8	3	STS lowered 2 ft Gate raised 5 ft	64 ± 8	52 ± 6	92 ± 3	86 ± 6
5/12	1	STS lowered 2 ft Gate standard level	48	53	82	85

* Fish run composed primarily of chinook salmon.
** Fish run composed primarily of steelhead.

guidance. Similarly, the FGE for steelhead was highest when the run was predominantly of that species. This would appear to indicate that fish behavior and/or distribution may vary throughout the season.

Lowering the STS 2 ft had little or no effect on FGE (Table 1). Time and lack of sufficient spring chinook salmon for testing prohibited more than one test with the modified STS lowered 2 ft and the operating gate at the standard level. This test resulted in the lowest FGE for spring chinook salmon (48%).

Results of the gap net testing indicated, if anything, less impingement or gap loss resulted from the replacement of the solid plate with a 46% porosity plate. Both spring chinook salmon and steelhead had lower gap losses with the modified STS and BFVBS test condition (Table 2). Assuming that the gap net catch during the part-time operation consisted of mostly impinged fish, the test screen also reduced impingement from 1.3 to 0.1% for spring chinook salmon and from 0.5 to 0.3% for steelhead.

Fish Screen Slot Closure Tests

The FSS closure test series was not successful. Problems with the closure devices were suspected when fish continued to enter the FSS. Efforts were made to make the devices more fish tight, but fish still continued to enter the FSS. An underwater inspection by NMFS scuba divers revealed there were gaps between the Wagner Horn screens and the FSS walls that allowed fish to swim freely to and from the Wagner Horn conduits and the FSS. Time and priorities did not permit further work on this problem in 1983.

Table 2.--Percent gap net loss during FGE test at Lower Granite Dam - 1983.

	Gap net fishing procedure			
	Full-time		Part-time	
Species	Test	Control	Test	Control
Chinook	1.4	2.1	0.1	1.3
Steelhead	0.5	1.7	0.3	0.5

The standard errors for the gap net catches were 0.0116 for chinook salmon and 0.0087 for steelhead.

Orifice Fish Passage Efficiency

A single 12-inch diameter orifice is slightly but not significantly more effective in passing juvenile chinook salmon and steelhead out of a BHS than two 8-inch diameter orifices, if the orifice is located properly (74 vs 70% for chinook salmon and 52 vs 44% for steelhead) (Table 3). More fish passed through the south orifice (55% for chinook salmon and 52% for steelhead), but the confidence limits for the percentages overlap 50% and do not show a fish preference for either orifice.

Fish Quality

Quality of the fish sampled throughout the season, as determined by descaling measurements, remained high. Descaling for chinook salmon averaged 4 and 6% in BHS 4-A and 4-B, respectively. Descaling for steelhead averaged 5% in BHS 4-A and 4% in BHS 4-B.

CONCLUSIONS AND RECOMMENDATIONS

1. Improving FGE--Acceptable 74% FGE was measured at Lower Granite Dam for spring chinook salmon when the operating gate was raised 20 ft. When the operating gate was raised 5 ft, lower than acceptable FGE of 63% for spring chinook salmon resulted. Lowering the STS 2 ft had little or no effect on FGE. With the positive improvements in FGE resulting from raising the operating gate 20 ft, we recommend that operating gates be either removed or raised 20 ft. We realize that additional testing would be required if the operating gates were removed to determine the impact of additional flow into the gatewells on FGE and OPE.

2. Improving OPE--A single 12-inch diameter orifice, while about as effective as two 8-inch orifices, will not provide adequate OPE for steelhead. Even with the larger diameter orifices, a bias still appears to

Table 3.--Average percent orifice passage efficiency and 90 percent confidence limits of spring chinook salmon and steelhead through a single 12-inch diameter orifice compared to that of two 8-inch diameter orifices (operated simultaneously) over a 24-h period at Lower Granite Dam - 1983.

Dates	No. replicates	Test conditions	Spring chinook (%)	Steelhead (%)
5/16-5/24	5	North 12" orifice South closed	64 ± 8	37 ± 6
5/24-6/10	6	South 12" orifice North closed	74 ± 7	52 ± 11
6/10-6/15	5	Two 8" orifice Operated simultaneously	70 ± 7	44 ± 6
	Distribution	North 8" orifice	45 ± 10	48 ± 6
		South 8" orifice	55 ± 10	52 ± 6

exist between the north and south orifices. Therefore, we recommend drilling two 12-inch diameter orifices in each BHS to improve OPE and fish condition.

3. Fish Screen Slot Closure--Efforts to complete the FSS closure evaluation in 1983 were unsuccessful; original screens placed in the Wagner Horn to prevent entry of fingerlings were found to be inadequate. While the limited test data was unable to determine effects of FSS closure, overall catches in the FSS were much smaller than in the BHS (Appendix B). Therefore, we feel there would be little impact from closing off the fish screen slots and their orifices, so that the 12-inch diameter orifices can be drilled in each bulkhead slot without having to enlarge the existing bypass conduit. The unneeded slots would provide an excellent weather proof storage area for the STS.

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APPENDIX A

Sample sizes needed to detect differences among test groups

Typically the information needed to determine the number of replicates and the sample sizes required per test group are the treatment variability expected (which may be expressed as a difference between treatment means of interest), the number of means (or experimental categories) being compared, and the α and β (the probability of the type I error, α , and the probability of the type II error, β) levels desired from the statistical test.

In these experiments, we have mainly chosen to compare experimental units by means of a test of significance. We will be attempting to establish that one procedure is superior or different than another by at least some stated amount. Consequently, the experiments must be large enough to reasonably ensure that if the true difference is equal to or greater than the specified amount, we have a high probability of detecting it, or obtaining a statistically significant difference. The exact calculation of the probability is rather complicated. The procedures used provide an approximation that is adequate for design purposes.

Very often in field work, conditions may provide the opportunity for more measurements or force some curtailment. In view of field uncertainties, which may result in more or fewer measurements, alternative statistical analyses were planned. The primary statistical analysis being categorical data analysis using the count data. The alternative analysis being a data transformation to stabilize the variance and approximate normality and then apply analysis of variance type of procedures. The alternative procedure is usually less powerful than a direct categorical analysis of the count data, but may be necessary in some cases where the requirements for categorical analysis cannot be fulfilled.

Occasionally we plan repeated measurements as assurance against the lack of uniformity in field conditions. These may not be stipulated by a formal experimental design. They have several uses in subsequent data analysis. Replicated measurements should steadily decrease the error associated with the comparisons among treatment groups, and they can also be used to make an assessment of measurement accuracy, e.g., the closeness among comparable measurements (Tsao and Wright 1983). This assessment is especially useful to identify problem areas in the data collection system which may require special investigation.

The information for sample size determination is applied for the following cases. The notation for the formulas is given below.

1. Two group comparison case: This case is concerned with determining whether one condition is better than another condition (a one-way comparison), or with determining whether two conditions differ (a two-way comparison). The formula used is:

   $$NT = (ZA + ZB)^2 / 2 (\arcsin\sqrt{P1} - \arcsin\sqrt{P2})^2.$$

   This formula is given by Paulson and Wallis (1947), it is also used by Cochran and Cox (1957), sample size graphs were calculated by Feigl (1978), and Lemeshow et al. (1981) showed that it provided the closest approximation to an exact method when the underlying proportions are small. This formula may be expressed in different forms, depending on the definition of ZA and ZB. We follow the form used by Feigl.

2. More than two groups or multinomial case: The procedures used for obtaining confidence intervals and sample sizes follow methods

given by Angers (1974), Bailey (1980), Goodman (1965), and Miller (1966).

The formula used is:

$$NM = [(B)\ (P_i\ (1-P_i)]\ /\ D^2.$$

3. For determining the number of replicates, the procedures follow those given in Steel and Torrie (1960) and Cochran and Cox (1957).

   The formula used is:

$$R \geq 2(T_1 + T_2)^2\ (S^2)\ /\ D^2.$$

   This formula is an approximation which depends on how well S^2 estimates the experimental error. Successive approximations must be used since the number of degrees of freedom associated with T_1 and T_2 depends upon R.

The following notation is used in the sample size formulas:

NT - sample size in the the two group comparison.

ZA - standardized normal deviate exceeded with probablity A. Where A is $1 - \alpha/2$ for the two-sided case and A is $1 - \alpha$ for the one-sided case.

ZB - standardized normal deviate exceeded with probability B. Where B is $1 - \beta$. This corresponds to the probability of obtaining a significant result. Note that ZB = -ZB' where B' equals β. Hence, (ZA + ZB) could be written as (ZA - ZB') without altering the value of NT.

P1 - proportion in the control group.

P2 - proportion in the test group.

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 $1-\alpha/k$ statistical precision level with one degree of freedom. Where k is the number of proportions being compared.

P_i - expected proportion in each multinomial category, i = 1, 2, ..., k.

D - level of difference it is desirable 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, α .

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, $1-\beta$.

S - estimated experimental error, this is usually obtained from previous experiments.

The degrees of freedom for T_1 and T_2 are the product of (L-1)(R-1), where L 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

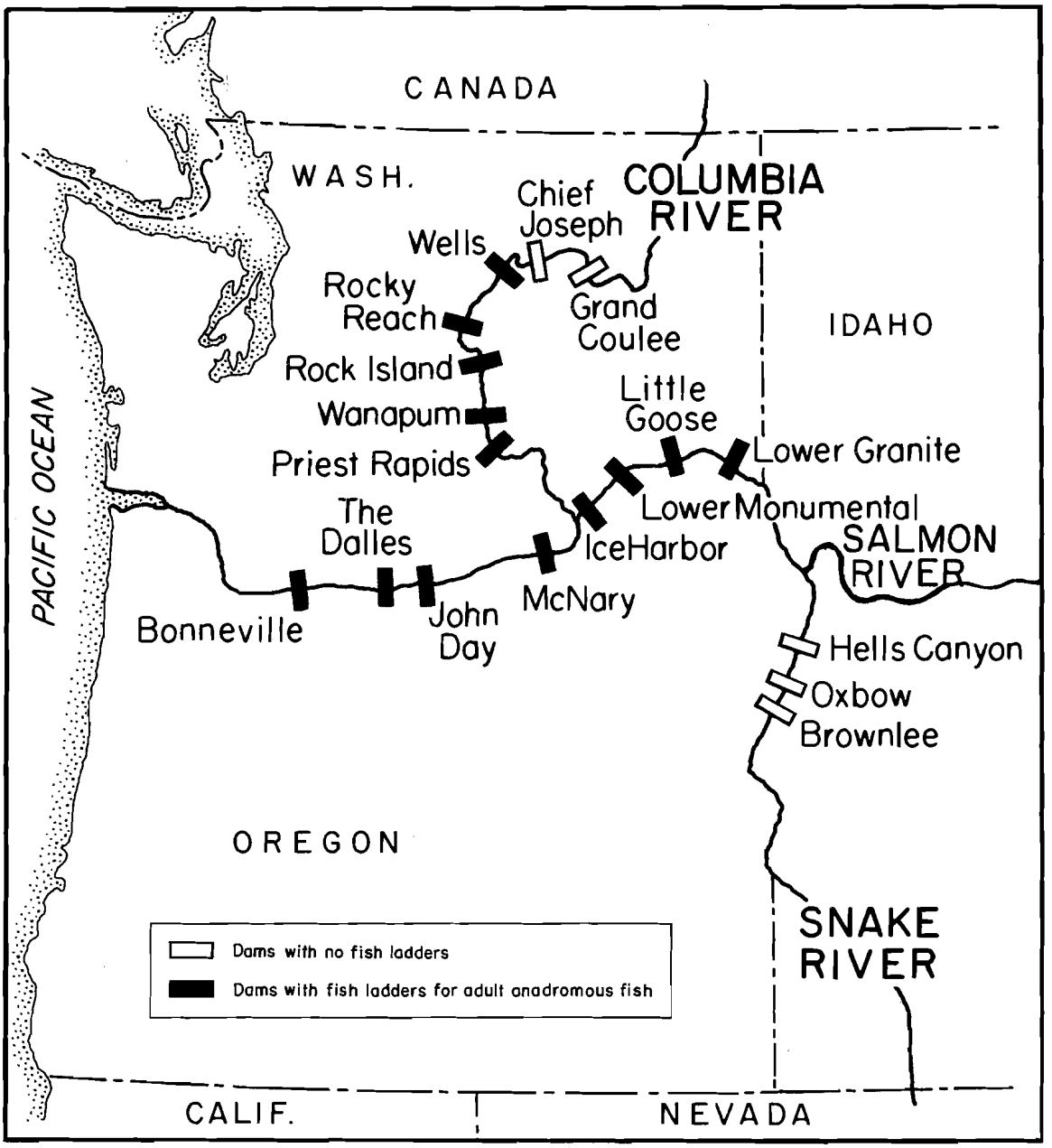
Catches of spring chinook salmon and steelhead during fish guiding efficiency tests at Lower Granite Dam, 1983.

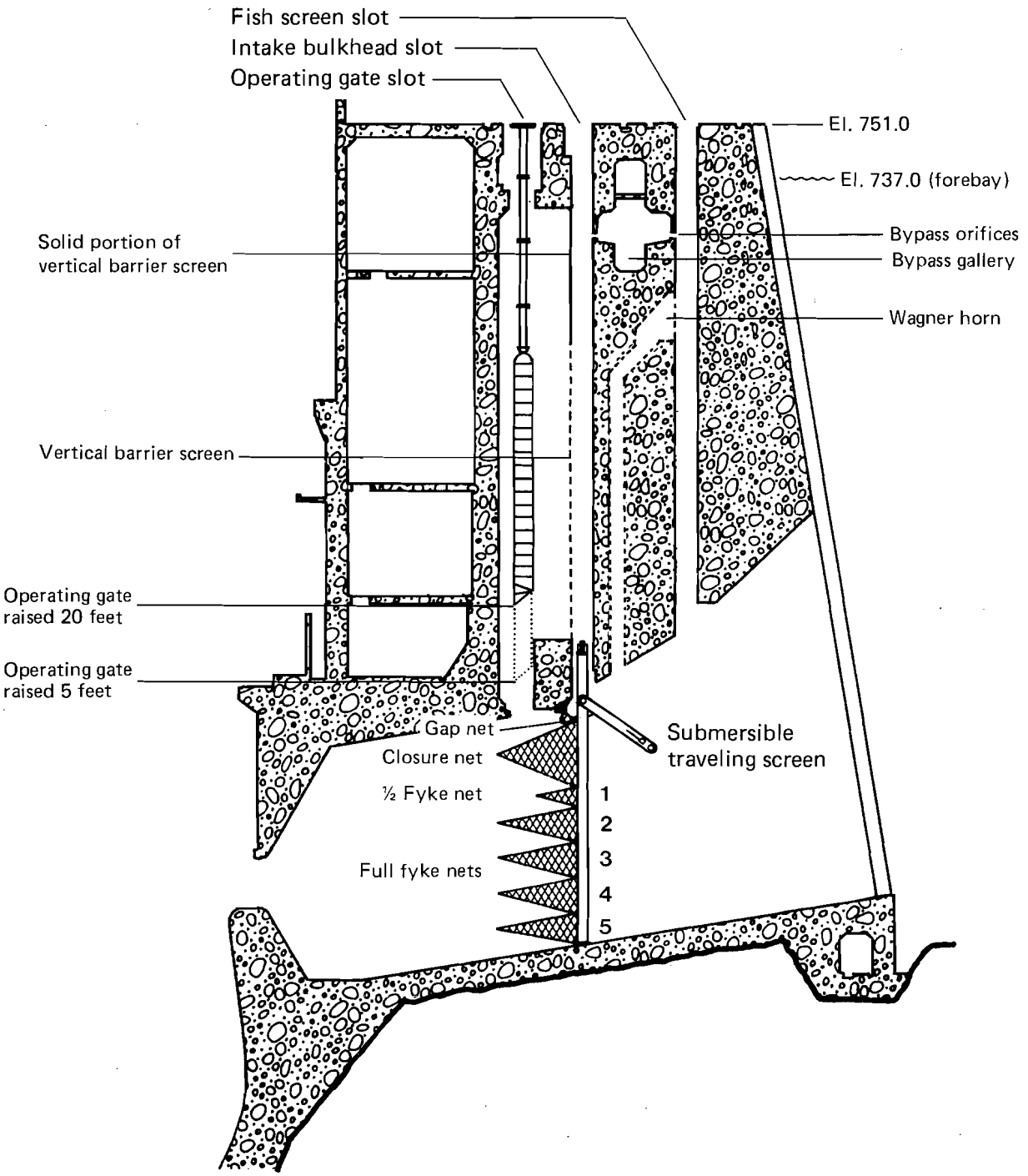
Appendix Table B--Catches of spring chinook salmon and steelhead during fish guiding efficiency tests at Lower Granite Dam comparing test and control conditions at 135 megawatt turbine load in spring of 1983.

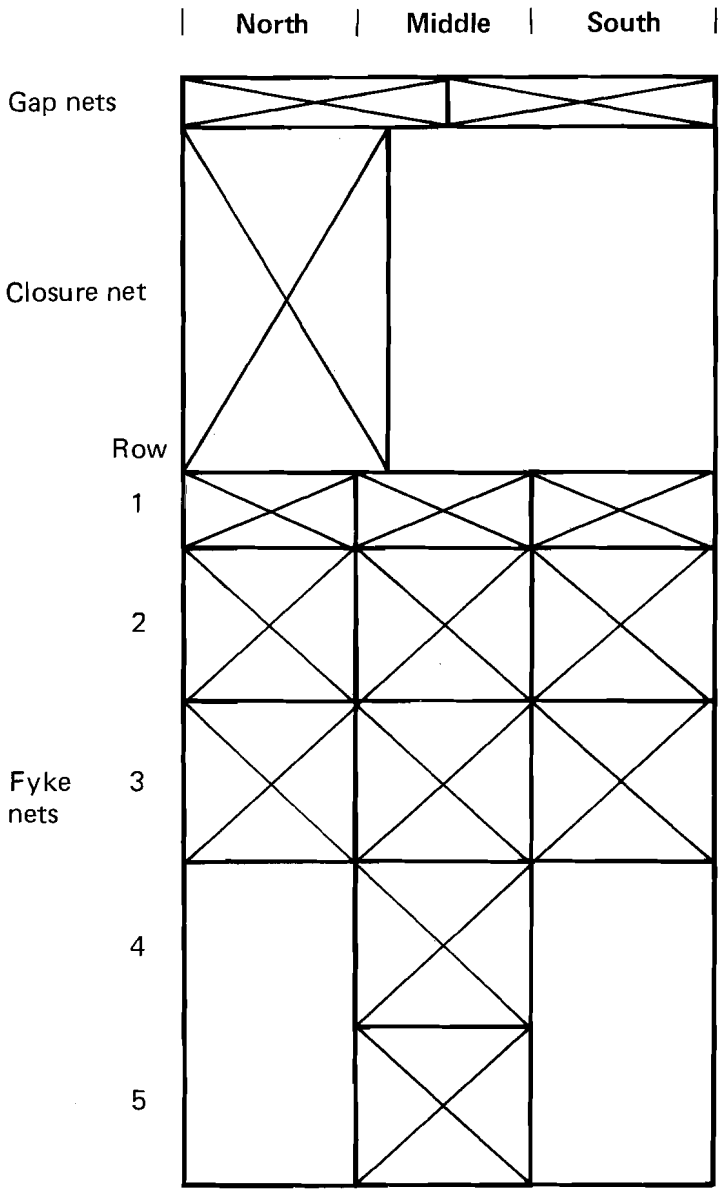
	CHINOOK SALMON														STEELHEAD													
	MODIFIED STS - BFVBS (4-A)							STANDARD STS - SVBS (4-B)							MODIFIED STS - BFVBS (4-A)							STANDARD STS - SVBS (4B)						
Date	BHS catch	FSS catch	Gap net catch	Fyke net catch	Total un-guided (Est.)	Total guided and un-guided	% FGE[a]	BHS catch	FSS catch	Gap net catch	Fyke net catch	Total un-guided (Est.)	Total guided and un-guided	% FGE[a]	BHS catch	FSS catch	Gap net catch	Fyke net catch	Total un-guided (Est.)	Total guided and un-guided	% FGE[a]	BHS catch	FSS catch	Gap net catch	Fyke net catch	Total un-guided (Est.)	Total guided and un-guided	% FGE[a]
TEST CONDITION - STS LOWERED 2 FT, OPERATING GATE RAISED 20 FT																												
4/22	1,309	35	24	299	849	2,193	61	816	13	39	379	1,059	1,888	44	41	3	0	0	0	44	b/	10	0	0	1	3	13	b/
4/23	5,284	183	5	512	1,529	6,996	78	2,317	135	60	629	1,767	4,291	58	194	17	2	14	38	249	85	72	29	1	9	25	126	80
4/24	1,313	46	34	404	482	1,841	74	1,032	19	36	763	840	1,891	56	702	80	2	94	96	895	87	543	18	6	134	123	721	79
4/25	513	24	2	238	278	815	66	377	6	13	288	328	711	54	414	47	0	69	71	538	86	372	16	2	85	89	477	81
4/26	1,580	44	47	690	796	2,420	67	793	63	30	938	1,074	1,930	44	656	69	3	212	224	965	75	495	118	16	293	313	926	66
4/27	1,347	52	3	244	254	1,653	85	654	28	14	334	374	1,056	65	659	72	1	166	174	905	81	370	121	3	175	183	674	73
TOTAL	11,346	384	115	2,387	4,188	15,918		5,989	264	192	3,331	5,442	11,767		2,666	288	8	555	603	3,596		1,862	302	28	697	736	2,937	
Grand average							74							53							82							74
STS STANDARD LEVEL, OPERATING GATE RAISED 20 FT																												
4/29	362	127	2	143	167	656	75	339	6	15	171	193	538	64	146	112	5	52	58	314	82	115	14	7	89	101	230	56
4/30	668	49	2	226	240	957	75	475	33	9	444	514	1,022	50	144	81	2	46	50	305	74	138	38	1	53	65	241	73
5/1	605	52	4	233	235	892	74	634	11	32	449	513	1,158	56	164	68	2	23	23	255	91	216	18	8	57	61	295	79
TOTAL	1,635	228	8	602	642	2,505		1,448	50	56	1,064	1,220	2,718		454	261	9	121	131	874		469	70	16	199	227	766	
Grand average							74							55							82							70
STS STANDARD LEVEL, OPERATING GATE RAISED 5 FT																												
5/2	727	68	1	340	348	1,143	70	640	68	9	569	657	1,365	52	220	138	2	55	57	415	86	213	80	3	70	86	379	77
5/3	675	61	17	503	591	1,327	55	506	108	24	538	634	1,248	49	174	80	1	63	69	323	79	196	29	3	54	56	281	80
5/4	559	50	4	300	320	929	66	497	16	19	345	393	906	57	150	76	2	47	49	275	82	200	15	6	55	57	272	79
TOTAL	1,961	179	22	1,143	1,259	3,399		1,643	192	52	1,452	1,684	3,519		544	294	5	165	175	1,013		609	124	12	179	199	932	
Grand average							63							52							83							79
STS LOWERED 2 FT, OPERATING GATE RAISED 5 FT																												
5/6	507	33	26	284	336	876	62	422	7	25	382	434	863	50	1,662	637	5	134	160	2,459	93	2,330	389	43	317	353	3,072	89
5/7	347	24	10	132	160	531	70	245	13	16	185	211	469	55	1,526	639	16	169	185	2,350	92	1,666	267	44	282	312	2,245	86
5/8	307	74	17	178	218	599	64	300	6	16	226	254	560	55	1,251	474	15	171	189	1,914	90	1,318	153	41	282	314	1,785	82
TOTAL	1,161	131	53	594	714	2,006		967	26	57	793	899	1,892		4,439	1,750	36	474	534	6,723		5,314	809	128	881	979	7,102	
Grand average							64							52							92							86
STS LOWERED 2 FT, OPERATING GATE RAISED 20 FT																												
5/9	441	26	6	174	210	677	69	322	19	24	264	318	659	52	1,071	459	4	173	209	1,739	88	1,097	113	41	294	314	1,524	79
5/10	324	17	6	123	147	488	70	213	11	16	178	210	434	52	1,217	436	7	235	255	1,908	87	1,336	126	39	303	323	1,785	82
5/11	316	21	4	128	164	501	67	233	12	15	179	203	448	55	732	325	3	92	110	1,167	91	711	73	17	152	164	948	83
TOTAL	1,081	64	16	425	521	1,666		768	42	55	621	731	1,541		3,020	1,220	14	500	574	4,814		3,144	312	97	749	801	4,257	
Grand Average							69							53							88							81
STS LOWERED 2 FT, OPERATING GATE STANDARD LEVEL																												
5/12 (One replicate)	131	6	23	125	149	286	48	141	3	13	117	129	273	53	454	168	35	129	139	761	82	637	73	22	112	124	834	85

a/ Percent FGE for all test conditions represents total fish guided into bulkhead slot (BHS) and fishscreen slot (FSS).

b/ Insufficient numbers of steelhead collected in this replicate for statistical validity.


CANADA
WASH.
COLUMBIA RIVER
Chief Joseph
Wells
Rocky Reach
Grand Coulee
IDAHO
Rock Island
Wanapum
Little Goose
Priest Rapids
Lower Granite
PACIFIC OCEAN
The Dalles
Lower Monumental
Ice Harbor
SALMON RIVER
McNary
Bonneville
John Day
Hells Canyon
Oxbow
Brownlee
OREGON
SNAKE RIVER
Dams with no fish ladders
Dams with fish ladders for adult anadromous fish
CALIF.
NEVADA


Fish screen slot
Intake bulkhead slot
Operating gate slot
El. 751.0
El. 737.0 (forebay)
Solid portion of
vertical barrier screen
Bypass orifices
Bypass gallery
Wagner horn
Vertical barrier screen
Operating gate
raised 20 feet
Operating gate
raised 5 feet
Gap net
Closure net
½ Fyke net
Full fyke nets
Submersible
traveling screen
1
2
3
4
5


North
Middle
South
Gap nets
Closure net
Row
1
2
Fyke nets
3
4
5

Appendix Table B--Catches of spring chinook salmon and steelhead during fish guiding efficiency tests at Lower Granite Dam comparing test and control conditions at 135 megawatt turbine load in spring of 1983.

	CHINOOK SALMON														STEELHEAD													
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4/23	5,284	183	5	512	1,529	6,996	78	2,317	135	60	629	1,767	4,291	58	194	17	2	14	38	249	85	72	29	1	9	25	126	80
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4/25	513	24	2	238	278	815	66	377	6	13	288	328	711	54	414	47	0	69	71	538	86	372	16	2	85	89	477	81
4/26	1,580	44	47	690	796	2,420	67	793	63	30	938	1,074	1,930	44	656	69	3	212	224	965	75	495	118	16	293	313	926	66
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5/4	559	50	4	300	320	929	66	497	16	19	345	393	906	57	150	76	2	47	49	275	82	200	15	6	55	57	272	79
TOTAL	1,961	179	22	1,143	1,259	3,399		1,643	192	52	1,452	1,684	3,519		544	294	5	165	175	1,013		609	124	12	179	199	932	
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