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THE DEVELOPMENT OF AN IMPROVED FINGERLING PROTECTION SYSTEM FOR LOW-HEAD DAMS, 1978

by
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TABLE OF CONTENTS

	Page
INTRODUCTION	1
BONNEVILLE DAM	2
EVALUATION OF BAR-SCREEN GUIDING DEVICE	2
Description of Dam and Experimental Guiding Device	2
Method of Testing Bar Screen	8
Results and Discussion	9
SURVIVAL OF FINGERLINGS RELEASED FROM BRADFORD ISLAND	9
Methods and Procedures	11
Results	13
McNARY DAM	15
EVALUATION OF A TWO-PART BAR-SCREEN GUIDING SYSTEM	15
Experimental Equipment and Procedures	15
Experimental Design and Evaluation	19
Fish-guiding Efficiencies	21
Quality of Guided Fish	32
Backflushing Tests	35
EVALUATION OF SUBMERGED ORIFICES FOR PASSAGE OF JUVENILE SALMONIDS FROM GATEWELLS	35
SUMMARY	39
LITERATURE CITED	40
APPENDIX A	41

INTRODUCTION

In 1975, the National Marine Fisheries Service (NMFS), under contract to the U.S. Army Corps of Engineers (CofE) initiated research to develop an improved fingerling protection system for low-head dams. Research in 1976 at Bonneville Dam concentrated on developing design and operating criteria for submerged orifices to efficiently pass fingerlings from gatewells into a safe bypass. At the NMFS Pasco Field Station, studies were initiated to develop new fish-guiding methods that would be less costly and more effective than the traveling screen system. These initial studies, conducted in an oval flume, were productive and led to the development of a nontraveling bar screen. In 1977, research at Bonneville Dam initiated evaluation of the first prototype bar screen and completed studies on the design and operating criteria for submerged orifices.

In 1978, we conducted studies at Bonneville and McNary Dams. At Bonneville Dam, we completed studies with the prototype bar screen tested in 1977 and conducted fish-release experiments in the tailrace to aid in selecting a terminal location for a future fingerling bypass to serve the Bonneville first powerhouse. At McNary Dam, we tested a more complex bar screen guiding device and measured the fish-passage efficiency of submerged orifices installed according to specifications developed in our studies at Bonneville Dam in 1976 and 1977.

This, the final report on 1978 research, is divided into two parts: (1) research conducted at Bonneville Dam and (2) research conducted at McNary Dam.

BONNEVILLE DAM

Research at Bonneville Dam involved final testing of the bar-screen guiding device and an evaluation of fish-release sites in the tailrace.

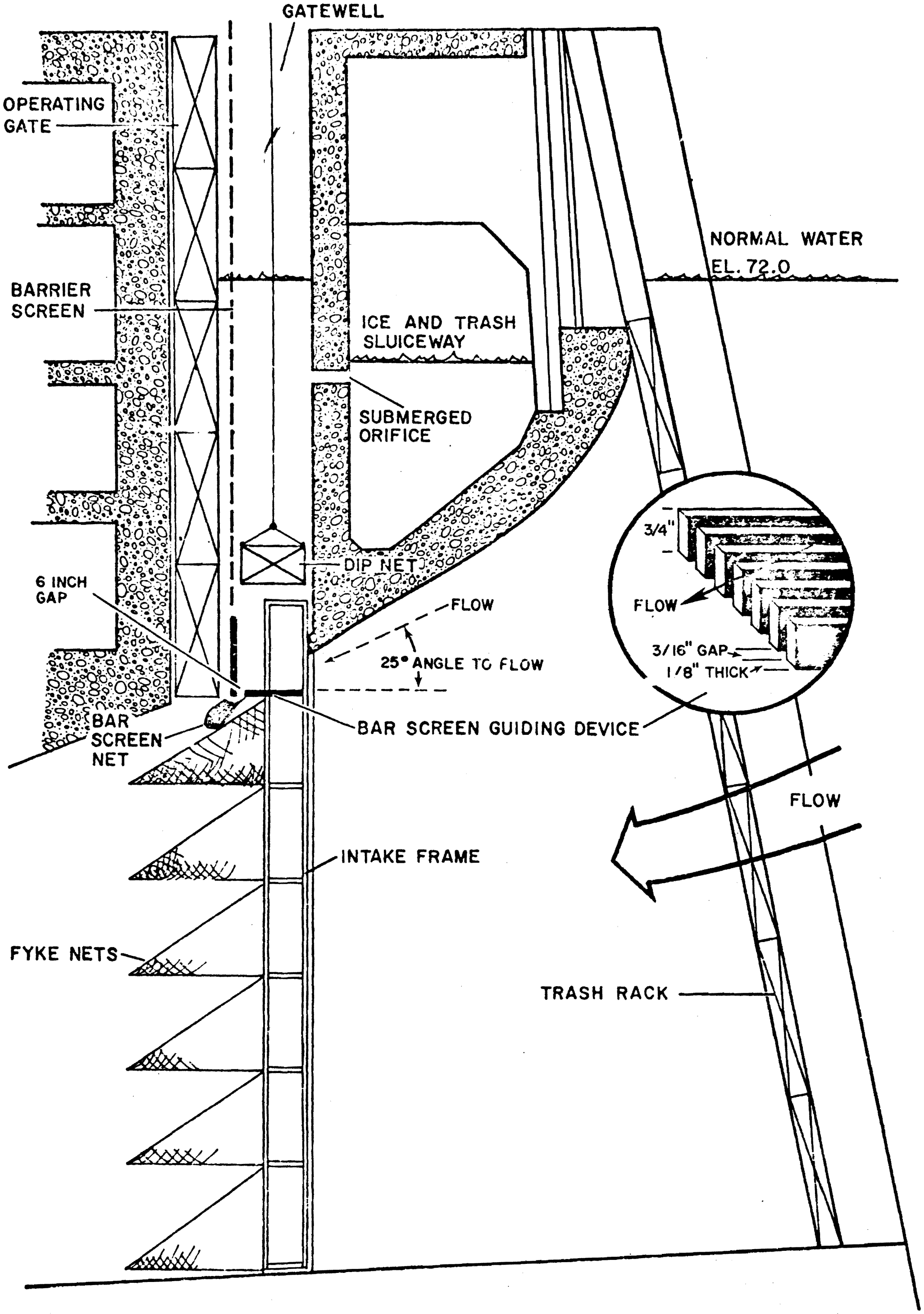
EVALUATION OF BAR-SCREEN GUIDING DEVICE

In 1977, we demonstrated that fish-guiding efficiency (FGE) could be improved significantly by allowing more water to pass into and through the gatewell. This was accomplished by removing the operating gate from the gatewell. Because removal of these gates is not an operationally satisfactory solution for increasing flow through the gatewell, in 1978 we investigated an alternative method. The objective of the studies at Bonneville Dam was to evaluate the effectiveness of increasing the flow through the gatewells by strategically locating a vertical barrier screen (VBS) in relation to the operating gate.

Description of Dam and Experimental Guiding Device

Figure 1 is a cross section of a turbine intake showing the various components of the dam and the equipment used in this research. The bar screen installed in the turbine intake functions as a component of the standard fish bypass system; i.e., fish traveling in flows intercepted by the bar screen (near the intake ceiling) are guided up into the gatewell, volitionally pass out through submerged orifices, and enter a bypass that carries them around the dam. For the purpose of this research, however, the guided fish were retained in the gatewell until they were dipnetted out and counted.

Each turbine intake at Bonneville Dam (three per turbine) is 21 feet wide and 45 feet high (from floor to ceiling at the upstream boundary of the gatewell). Each intake is equipped with a gatewell in which is stored an operating



BONNEVILLE DAM

Figure 1.--Cross-section of turbine intake in Bonneville Dam first powerhouse showing deployment of experimental equipment.

gate. These gates are designed to be lowered into the intakes to stop the flow of water and allow dry access to the turbines for maintenance. The location of the stored gate in the gatewell also influences the amount of flow that enters the gatewell.

One of the factors that can influence the efficiency of a fish-guiding device is the flow that enters the gatewell. Increasing the flow may increase FGE, but unless adequate measures are taken, increasing the flow will also increase the escapement of guided fish back into the intake. To prevent this escapement of fish, we installed a VBS in the gatewell.

A specially designed intake frame (Figures 1 and 2) was used to support the prototype fish-guiding device and six fyke nets (fish traps). The fyke nets were constructed so they intercepted the center one-third of the volume of water passing under the fish-guiding device. Fish trapped in the fyke nets were counted to estimate the number of unguided fish. The intake frame also was designed so the bar screen could be lowered 2 feet below the standard fish-guiding position. The bar-screen guiding device was constructed of flat steel bars, 1/8-inch thick and 3/4-inch wide, placed on the narrow edge in rows 3/16-inch apart, and fastened to supports (Figures 1 and 3). The entire bar screen presented a flat, slotted surface about 21 feet wide and 5 feet long; it was estimated to have a 65% open area (porosity).

The screen was installed in the turbine intake with the bars and slots parallel with the flow of water. The water flowed into the turbine intake at an angle of about 25° from the horizontal, and the bar screen was installed so that its face met the water flow at that angle.

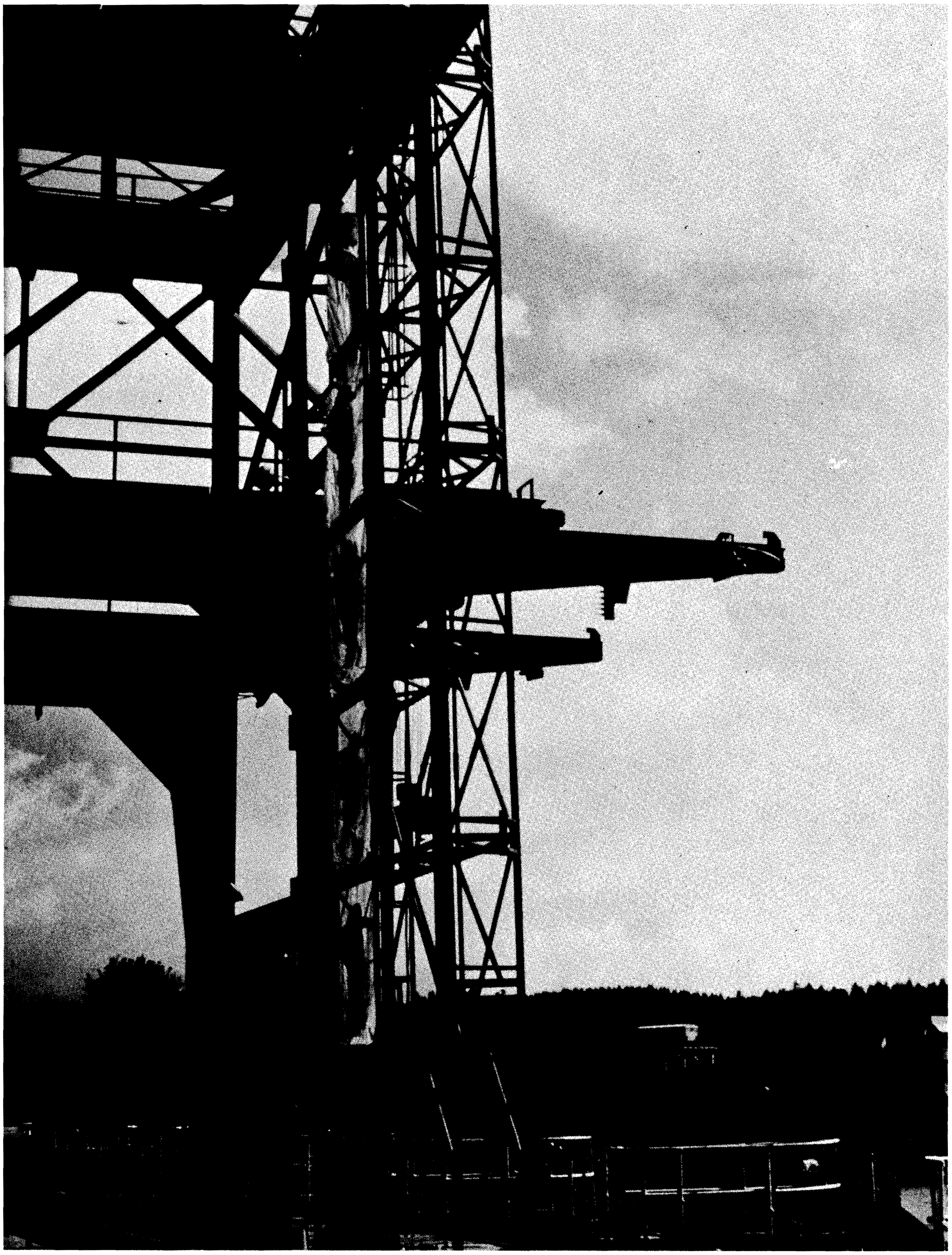


Figure 2.--Intake frame used to support fyke nets and bar-screen scoop at Bonneville Dam.

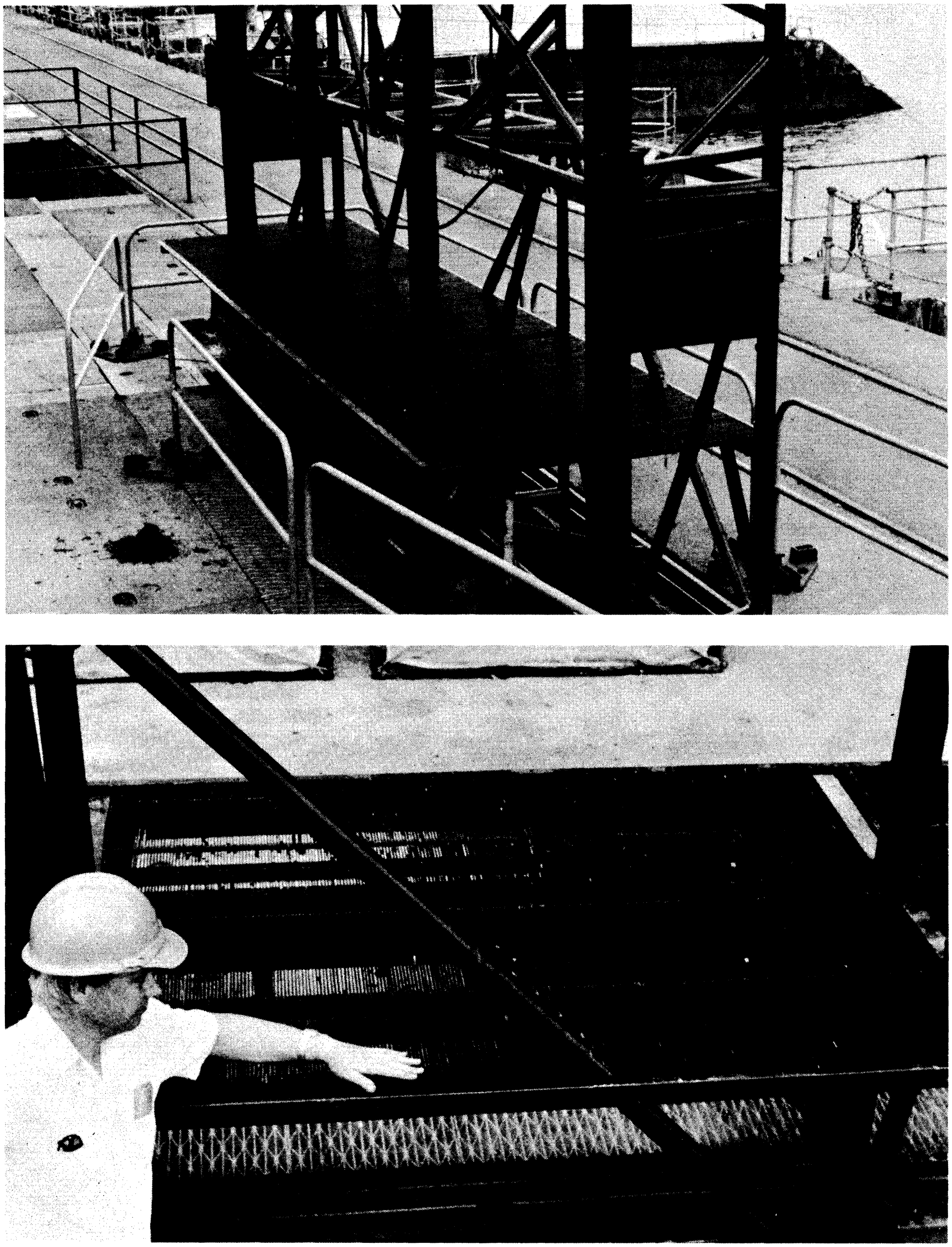


Figure 3.--Two views of bar screen installed in intake frame. (Top portion of frame projects above deck, out of gatewell.)

The bar screen in the standard fish-guiding position intercepted the upper 3.5 feet of water below the intake ceiling and in the lowered position, the upper 5.5 feet of water. (Previous studies by NMFS scientists at Bonneville Dam[1/] indicated that 50 to 60% of the fingerling chinook salmon and steelhead trout were traveling within 3.5 feet of the intake ceiling, and 65 to 70%, within 5.5 feet of the intake ceiling). The downstream end of the bar screen terminated 7 inches upstream from the bottom of the vertical barrier screen (Figure 1) resulting in a 7-inch gap through which debris was flushed. To provide for a minimal gap at the terminal end of the bar screen when the screen was in the lowered fish-guiding position, a vertical solid plate was attached to the intake frame directly above the terminal end of the screen. The resulting opening was 6 inches wide. This solid plate was not in position when the bar screen was tested at the standard elevation.

For evaluation purposes, a hinged net (bar-screen net) was fastened near the terminal end of the bar screen (Figure 1) so it strained water passing through the gap. Thus, debris and fish passing through the gap were caught and presumably retained in this net. To allow more water to pass into and out of the gatewell without removing the stored gate, we prepared three gatewells, each with a VBS in a different location: (1) in gatewell 4-B, we retained the same VBS location used in 1977--1 foot upstream from the stored gate—as a control; (2) installed a VBS in gatewell 4-A at a point 2 feet upstream from the stored gate; and (3) installed a VBS in gatewell 4-C at a point 3 feet upstream from the stored gate. Theoretically, the greater the distance between the VBS and the stored gate, the greater the volume of water passing into and through the gatewell. The objective of the tests was to determine which VBS location was best for FGE.

1/ Final report under CofE Contract No. DACW57-75-F-0569 titled, "Vertical distribution of fingerling salmonids in turbine intakes of the Bonneville first powerhouse," by Clifford W. Long, 1975.

Method of Testing Bar Screen

The experiments were designed to measure the percentage of fish entering the turbine intake that were guided up into the gatewell by the bar screen at each of the three positions of the VBS: 1 foot, 2 feet, or 3 feet upstream from the stored gate. In addition to varying the position of VBS, we lowered the elevation of the bar-screen scoop by 2 feet.

Procedures for conducting a test to determine FGE were as follows:

1. The turbine was shut down to stop the passage of water (and fish) through the intake.

2. The intake frame, used to support the fyke nets and guiding device, was installed in the intake.

3. All fish in the gatewell were removed with the dip net and released.

4. The turbine was brought back into operation to begin a test, which lasted from 3 to 6 hours during regular working hours.

5. The turbine was shut down to terminate a test.

6. The guided fish were removed from the gatewell by dipnetting and counted by species.

7. The intake frame was removed.

8. Fish were removed from all fyke nets and counted by species.

9. The fyke net catches were multiplied by 3 to estimate the total number of unguided fish.

10. FGE (expressed in percent) was determined by dividing the number of guided fish by the sum of the number guided plus the number unguided (including the number of fish that escaped through the gap at the terminal end of the screen, and were captured in the bar-screen net).

Results and Discussion

The objective of the experiment was to determine which of the three VBS positions provided the best FGE and whether the bar-screen scoop was more effective in the standard or lowered elevation. Table 1 summarizes the FGEs obtained for various experimental conditions.

Sufficient numbers of all species of fish were not obtained for all the experimental conditions. However, during tests with spring and fall chinook salmon there were sufficient fish; these tests indicated no significant differences[2/] in FGE between the three VBS positions when the bar screen was at the standard elevation or when it was lowered 2 feet.

These results do not clearly establish that one VBS position is best. Furthermore, the FGEs obtained are generally lower than those obtained in 1977 when the VBS was located 1 foot from the stored gate. At this time we have no explanation for this. Perhaps the vertical distribution of the fish changed so that fewer fish were intercepted.

Need for a device that intercepts a larger percentage of the fish is indicated. By intercepting more fish, we should be able to guide more fish, even though we may not guide 100% of the fish intercepted.

SURVIVAL OF FINGERLINGS RELEASED FROM BRADFORD ISLAND

Selection of a location for the release of fingerlings bypassed around the Bonneville first powerhouse is one of the general objectives of the research program to develop a more effective fish-protection system for low head dams. A specific objective is to find a release site that maximizes survival (minimizes

2/ Scheffé's test was used to make a post hoc comparison.

TABLE 1.--Results of the fish-guiding efficiency tests for the bar-screen scoop at Bonneville Dam, 1978.

Experimental conditions	Spring chinook		Fall chinook		Steelhead		Coho		Sockeye	
	No. of fish	% guided	No. of fish	% guided	No. of fish	% guided	No. of fish	% guided	No. of fish	% guided
Scoop at standard elevation										
VBS-1 foot	1018	22.5	622	22.8	265	52.5	854	48.7	102	25.0
VBS-2 feet	1803	27.5	67	14.9	307	59.0	462	40.9	225	34.7
VBS-3 feet	236	33.9	284	33.5	5	20.0	73	32.9	14	14.3
Scoop at lower elevation										
VBS-1 foot	675	28.9	1539	25.5	157	52.2	772	47.9	52	53.8
VBS-2 feet	1695	26.2	7515	19.8	271	54.6	683	48.8	205	41.0
VBS-3 feet	121	24.0	9864	25.4	18	66.7	52	35.8	16	25.0

VBS=Vertical barrier screen at positions one foot, two feet, and three feet upstream of the hydraulic (stored) gate.

predation) and is economically and operationally feasible. Releasing fish into the center of the river flow, away from the slack water associated with the dam and river shore is theoretically ideal, but expensive; although predator fish do not inhabit the faster flows, extending the fish bypass from shore to such locations is difficult and costly.

Since 1977, fish transported by truck from Little Goose and Lower Granite Dams have been released from the south shore of Bradford Island. To terminate a future fingerling bypass on the island is one of the alternatives under consideration. The least costly point of termination would be just downstream of the dam (the site used for transported fish). The more costly point of termination would be at the downstream end of the island; however, this location would eliminate potential predation occurring along the approximately 1500 feet of island shoreline.

To evaluate the two release sites with reference to survival of fingerlings, we released marked groups of fish in both locations—this report relates the findings to date.

Methods and Procedures

Fingerling coho salmon smolts raised at Oregon State's Cascade Hatchery were used for this study. The fish were marked by cold branding and transported by truck to the control release site and by barge to the test release site.

The control groups were released at the same site used to release fish transported by truck from Little Goose and Lower Granite Dams (Figure 4). The test groups were transported by barge from Cascade Locks (where the fish were taken aboard) to a point 50 feet downstream from the eddy formed at the terminal (downstream) end of Bradford Island for release (Figure 4).

Three test groups and three control groups were marked for paired releases on 2, 3, and 4 May. Each control group was released 15 minutes before its paired test group.

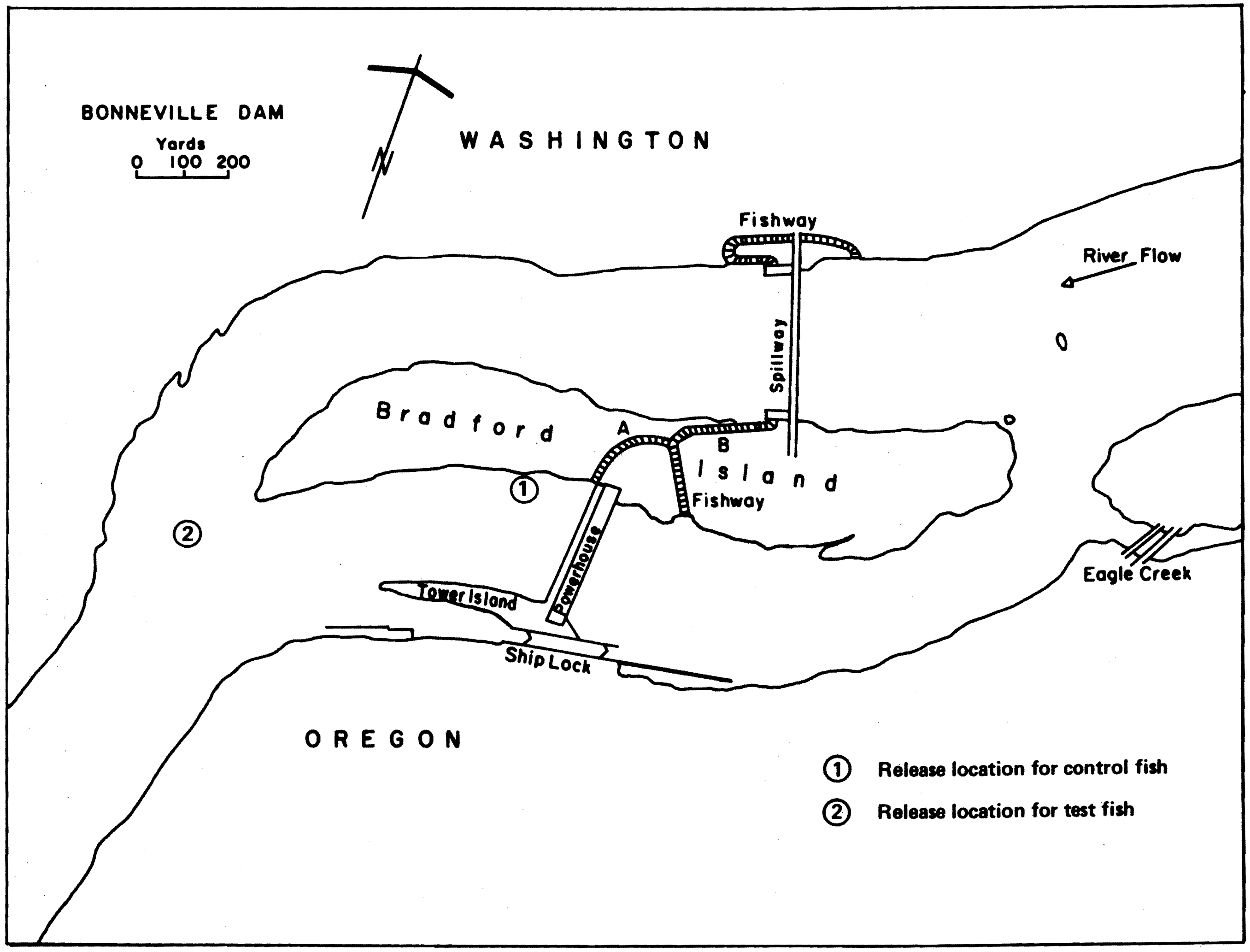


Figure 4.--Location where test and control groups of fingerling coho salmon were released at Bradford Island, Bonneville Dam.

A fish tank used to haul adult salmon held the test fish aboard the barge. The first test group of about 20,000 marked fish was transported all at once in the tank. The 20,000 fish appeared to exceed the capacity of the tank, and an unknown degree of low-oxygen stress was imposed on the fish by the time the fish were released. We fear a significant level of mortality was incurred by this group.

To prevent a recurrence of this problem, we reduced subsequent loads of test (and control) fish by one half. Consequently, two releases of test and control fish were made on both 3 and 4 May.

The relative survival of the test and control fish was to be estimated primarily by sampling the surviving smolts as they passed through the estuary and, secondarily, from adults returning to the hatchery.

Results

Table 2 lists the recovery of smolts in the estuary by group. The percentage of total recoveries was disappointingly low and conclusions cannot be reached at this time. No trend is apparent from the data except that the low returns of the first test group to be released suggest that a substantial loss of these fish may have occurred due to overcrowding in the tank.

Substantial additional recoveries are required before reliable conclusions can be reached. Estimates indicate that the expected return of full term adults will be sufficient. The fish will begin arriving at the Cascade Hatchery about September 1979.

TABLE 2.--Summary of experiment to determine relative survival of coho salmon smolts released in two locations near Bradford Island. Recoveries were made in the Columbia River estuary.

Test number	Number and location of releases					
	Regular site (controls)			Downstream from island (test)		
	Releases	Recoveries		Releases	Recoveries	
	(No.)	(No.)	(%)	(No.)	(No.)	(%)
1	22,221	15	0.0675	21,993	7[a]	0.0318
2	20,295	12	0.0591	21,147	12	0.0567
3	21,532	11	0.0511	20,281	13	0.0641

a/ This group may have suffered an unmeasured mortality due to stress from low oxygen just prior to release.

McNARY DAM

Research at McNary Dam in 1978 was directed toward the following: (1) initial evaluation of a two-part bar-screen system for guiding fish and (2) measurement of fish passage efficiency of submerged orifices installed in the gatewells.

EVALUATION OF A TWO-PART BAR-SCREEN GUIDING SYSTEM

1978 was the first year of a 2-year program of research on the two-part bar-screen system to: (1) define those parameters that would maximize FGE while maintaining acceptably low levels of stress and (2) compare this new fish-guiding system with the submersible traveling screen (STS).

The experiments compared several methods of deploying the bar screens. Evaluation was based on FGE and stress incurred by guided fish. Stress was estimated by assessing the degree of descaling incurred and by measuring swimming performance. In addition, we visually estimated the quantity of debris that accumulated on the face of the screen after various periods of operation and evaluated backflushing as a method of eliminating the debris.

Experimental Equipment and Procedures

Figure 5 depicts a transverse cross-section of the McNary powerhouse showing the two-part bar-screen guiding system. The bar-screen scoop, attached to an intake frame, is lowered into the intake via the intake gatewell. After installation, the hinged portion can be elevated into any of several positions, each of which produces a different angle between the face of the screen and the direction of flow. The uppermost position allows the water to backflush the bar screen.

The intake frame is designed to place the scoop at either of two elevations within the intake. The uppermost elevation is referred to as the standard elevation and the lowered elevation is 2 feet below the standard elevation.

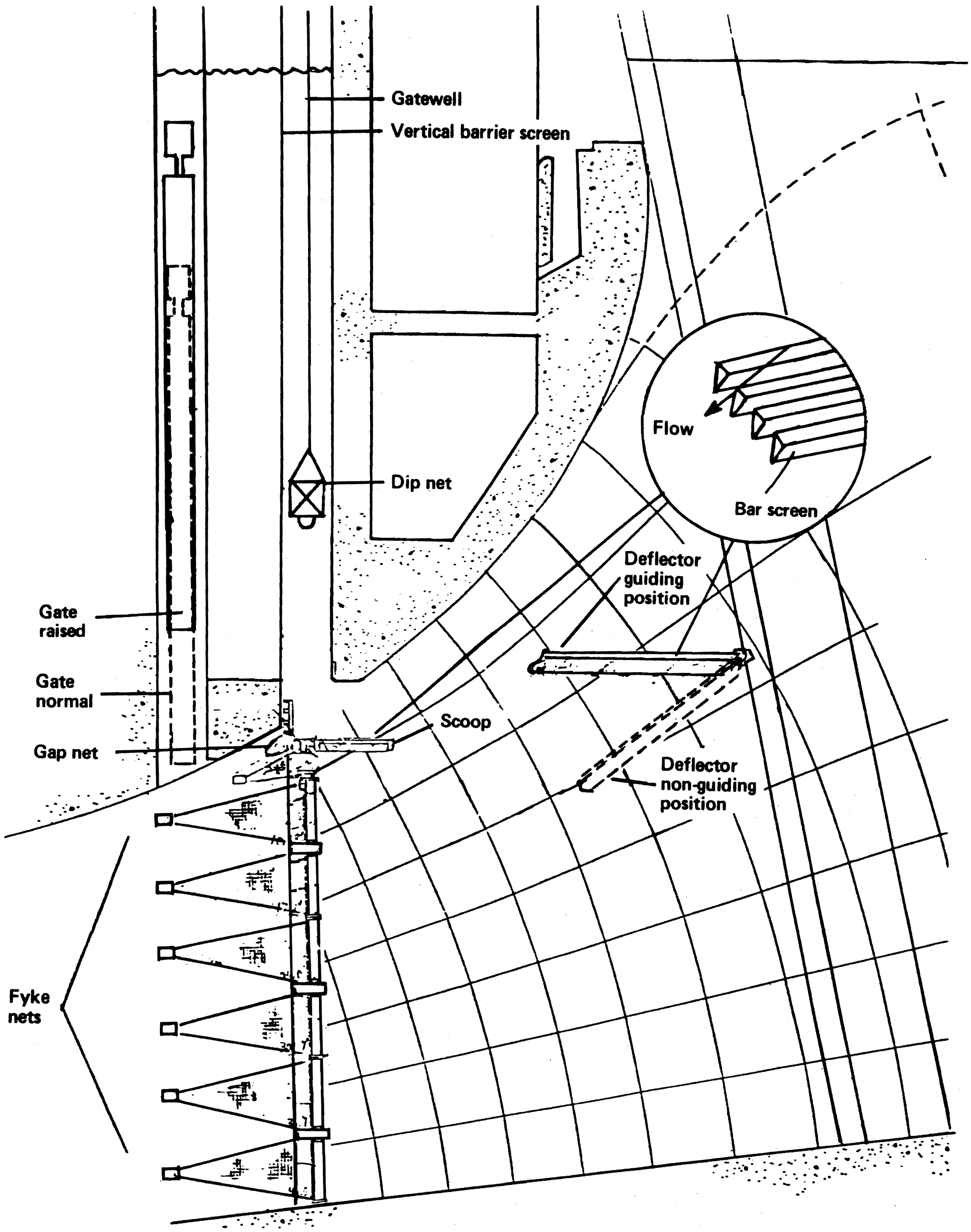


Figure 5.--Cross section of a turbine intake and associated structures in the McNary Dam powerhouse showing location of research equipment (inset shows detail of bar screen).

The downstream end of the scoop terminates to form an unencumbered gap of several inches between the screen and the concrete beam (Figure 5) through which debris can pass rather than accumulate. Fish that pass through this gap escape the guiding system.

The intake frame not only supports the bar-screen scoop but also supports nets that capture the fish that fail to enter the gatewell. A bar-screen net (gap net) captures all guided fish that pass through the gap at the terminal end of the scoop instead of entering the gatewell. Six fyke nets strain the center one-third of the flow passing under the scoop to sample the unguided fish.

The second part of the two-part guiding system is called the bar-screen deflector and is attached to the trash rack by means of hinges. As with the scoop, the position of the deflector in the flow can be varied from the back-flushing position to a very steep angle between the face of the screen and the direction of flow.

The two-part guiding system is designed so that it intercepts the same total flow as the submersible traveling screen--approximately the upper 17 feet of the total flow. The deflector intercepts those fish in the lower portion of these flows and guides them up into flows intercepted by the scoop.

Fish guided into the gatewell are prevented from exiting by a VBS. Fish are removed from the gatewell with a specially designed dip net.

Downstream from the concrete beam (Figure 5), a hydraulic gate restricts the gatewell opening and, therefore, the flow of water that can enter and pass out of the gatewell. For certain tests, we removed this gate to determine if increasing this flow would benefit FGE.

Procedures for conducting a test and estimating FGE were the same as those employed at Bonneville Dam (see preceding section of this report).

One measure of the quality of the guided fish was assessed by determining the number of fish that were descaled. Any fish that had more than 10% of their scales missing was classified descaled. At McNary Dam, we compared the percent of descaled fish guided by the bar screens with fish that entered adjacent gatewells of their own volition (no guiding devices were present).

A second measure of the quality of the guided fish employed a measure of the fish's swimming performance. The swimming performance of fish guided by the bar screens were compared with fish guided by the submersible traveling screens. The equipment and general methods and procedures are described by Thomas et al. (1964).

However, we modified the tunnel at the downstream end by replacing the electrified rings of the Thomas design with a hinged electrified grid of horizontal stainless steel rods of such a dimension that the test fish could not pass through (3/32 inch in diameter on 1/2 inch centers).

Samples of juvenile salmon were taken each test day from appropriate gatewells by means of the standard dip net. These fish samples were then processed as rapidly as possible, through an inclined wet grader to remove most of the steelhead present (0.5-inch slots) and a random sample of 50 to 200 fish was then placed in the stamina tunnel. The water velocity was brought up to 1.0 fps over about 5 minutes, and the few fish which failed to swim were removed from the grid. Following this acclimation period, the remaining test fish were exposed to the 1.0 fps water velocity for 30 minutes. The water velocity was then increased 0.5 fps each 30 minutes until at least 75% of each test population had impinged on the electrified grid. The time of fatigue was noted for each fish along with its fork length (typically 115 ± 20 mm) and species.

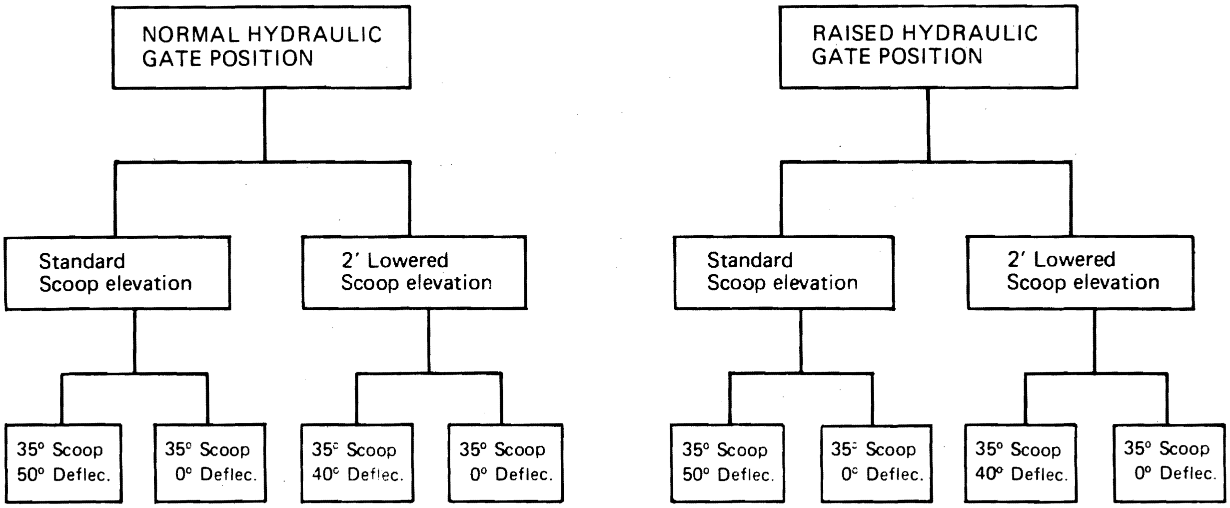
During the course of the fish run and after the fish run was completed, we conducted tests to assess the efficiency of backflushing the bar screens to eliminate debris that had accumulated for periods of time ranging from a few hours to as long as 7 days. To assess the extent of accumulated debris, the turbine would be shut down, the bar screens removed so that a picture could be taken of the accumulated debris, then the bar screens would be lowered, backflushed, and removed again for comparative photographs.

Backflushing the bar-screen deflector was accomplished by lowering the trailing edge of the deflector until the water flow passed through the screen in reverse. Backflushing the bar-screen scoop was accomplished by raising the leading edge of the scoop until the water flow passed through the screen in reverse.

Experimental Design and Evaluation

Figure 6 depicts the various combinations of experimental parameters tested during the 1978 field season. Experiments ranged from 6 to 24 hours in length and included tests conducted exclusively during the day and exclusively during the night.

To provide a measure of the effectiveness of the system for guiding fish, we estimated the potential FGE by the percentage of flow intercepted by the scoop and deflector and knowledge of the approximate percentage of each species found in these flows. Total effectiveness during a test would yield a FGE equal to the percentage of fish found in the intercepted flow. The percentage of fish within various flows was estimated from measurements of the vertical distribution of chinook and sockeye salmon and steelhead fingerlings made at McNary Dam in 1961 (Appendix A).



Block diagram showing the various combinations of test conditions with the bar screen scoop and trash rack deflector at McNary Dam in 1978 (degrees for the scoop and deflector represent angle to flow).

Figure 6.--Experimental conditions employed in tests of the bar-screen scoop and deflector at McNary Dam.

Deployment of the unguided fish can provide valuable information concerning weaknesses in the guiding system and locations where corrective efforts can best be applied. Fish escaping through the gap at the terminal end of the scoop, for example, might easily become guided fish by adjusting the conformation of the gap or flow patterns in the vicinity of the gap. On the other hand, fish that escape under the screens, as evidenced by the deployment of fish within the six fyke nets, might be influenced by the changes in the design and angle-to-flow of the scoop and deflector.

Fish-guiding Efficiencies

Tables 3-5 list the data obtained during the field season by species and experimental condition. In general, there are two basic considerations that limit the number of legitimate comparisons we can make. First, it was not possible to obtain sufficient numbers of all species for large sample statistical methods during all experiments. Second, we found that tests conducted at night yielded significantly lower FGEs than during the day. As a consequence, experiments that did not segregate day and night FGEs cannot be compared with tests conducted exclusively during the night or during the day.

Before the data in Tables 3-5 were analyzed, we considered tests where small numbers of fish were obtained. Where numbers of fish fell below five in any catch category of a single test (except the gap net catch) two or three replicates were combined and reduced to one or two in order to increase numbers of fish in all catch categories to more than five.

The data in Tables 3-5 were subjected to four and five-way analysis of variance tests using various combinations of experimental conditions, which include: (1) night versus day, (2) hydraulic gate in standard position versus removed, (3) bar-screen scoop at standard elevation versus lowered position, (4) bar-screen scoop with the bar-screen deflector in guiding position versus with the deflector not in guiding position, and (5) species.

TABLE 3.—Results of fish-guiding tests with a bar-screen scoop and deflector in a turbine intake at McNary Dam—daytime tests only.

	Gate in																							
	Standard scoop elevation												Lowered scoop elevation											
	With deflector						Without deflector						With deflector						Without deflector					
	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap
Chinook	372	85	1593	2050	78	82	168	19	192	379	51	56	24	26	99	149	66	84	69	41	191	301	63	77
	144	23	251	418	60	66	252	41	309	602	51	58	33	48	237	318	75	90	45	25	74	144	51	69
	60	52	363	475	76	87	453	127	834	1414	59	68	24	9	47	80	59	70	153	70	314	537	58	72
																			42	7	30	79	38	47
	576	160	2207	2943	75	80	873	187	1335	2395	56	64	81	83	383	547	70	85	309	143	609	1061	57	71
Coho	0	0	3	3	100	100	0	0	0	0	0	0	0	0	1	1	100	100	3	2	14	19	74	84
	3	0	4	7	57	57	0	1	5	6	83	100	0	0	1	1	100	100	3	5	17	25	68	88
	9	0	8	17	47	47	3	0	21	24	87	87	3	0	2	5	40	40	0	0	5	5	100	100
																			0	0	2	2	100	100
	12	0	15	27	56	56	3	1	26	30	87	90	3	0	4	7	57	57	6	7	38	51	75	88
Steelhead	18	1	16	35	46	49	6	0	11	17	65	65	3	1	3	7	43	57	0	2	10	12	83	100
	6	0	11	17	65	65	0	0	11	11	100	100	3	0	4	7	57	57	9	1	5	15	33	40
	6	0	9	15	60	60	6	1	20	27	74	78	6	0	8	14	57	57	0	1	2	3	66	100
																			0	0	7	7	100	100
	30	1	36	67	54	55	12	1	42	55	76	78	12	1	15	28	54	57	9	4	24	37	65	76
Sockeye	15	3	35	51	66	72	9	3	9	21	41	57	6	3	8	17	47	65	47	21	68	[illegible]	51	68
	6	0	8	14	57	57	3	1	7	11	64	73	0	3	7	10	70	100	69	27	54	150	36	54
	0	2	9	11	82	100	27	1	23	51	45	47	18	6	25	49	51	63	24	5	8	37	22	35
																			15	0	3	18	17	17
	21	5	52	78	67	73	39	5	39	83	47	53	24	12	40	76	53	68	150	55	133	338	40	56

	Gate raised																							
	Standard scoop elevation[a]												Lowered scoop elevation											
	With deflector						Without deflector						With deflector						Without deflector					
	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap
Chinook													9	1	64	74	86	88	18	7	100	125	80	86
Coho													0	0	7	7	100	100	0	0	14	14	100	100
Steelhead													0	0	11	11	100	100	21	0	22	43	51	51
Sockeye													27	5	73	105	70	74	99	17	147	263	56	62

a/ No data for this condition.

TABLE 4.-- Results of fish-guiding tests with a bar-screen scoop and deflector in a turbine intake at McNary Dam--nighttime tests only.

	Gate in																							
	Standard scoop elevation a/												Lowered scoop elevation											
	With deflector						Without deflector						With deflector a/						Without deflector					
	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap
Chinook																			123	40	128	291	44	58
																			165	50	194	409	47	60
																			228	47	233	508	46	55
																			378	79	202	659	31	43
																			894	216	757	1867	41	52
Coho																			33	2	35	70	50	53
																			21	5	85	111	77	81
																			60	8	116	184	63	67
																			51	13	85	149	57	66
																			165	28	321	514	62	68
Steelhead																			42	3	95	141	67	70
																			87	9	148	244	61	64
																			114	19	205	338	61	66
																			66	10	113	189	60	65
																			309	41	561	912	62	66
Sockeye																			507	82	23	612	4	17
																			759	95	32	886	4	14
																			531	76	24	631	4	16
																			306	35	8	349	2	12
																			2103	288	87	2478	4	15

	Gate raised																							
	Standard scoop elevation a/												Lowered scoop elevation											
	With deflector						Without deflector						With deflector						Without deflector					
	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap
Chinook													72	19	114	205	57	65	168	21	303	492	62	66
																			318	36	439	793	55	60
													72	19	114	205	57	65	486	57	742	1285	58	62
Coho													15	1	12	28	43	46	15	4	43	62	69	76
																			39	5	119	163	73	76
																			54	9	162	225	72	76
Steelhead													15	1	50	66	76	77	78	7	298	383	78	80
																			63	13	321	397	81	84
																			141	20	619	780	80	82
Sockeye													102	9	50	161	31	37	501	33	153	687	22	27
																			498	50	214	752	28	35
																			999	83	367	1449	25	31

a/ No data for this condition.

TABLE 5.—Results of fish-guiding tests with a bar-screen scoop and deflector in a turbine intake at McNary Dam — 22 hour test (day and night combined).

	Gate in																							
	Standard scoop elevation[a]												Lowered scoop elevation											
	With deflector						Without deflector						With deflector[a]						Without deflector					
	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap
Chinook																			192	81	319	592	54	68
																			210	75	268	553	48	62
																			402	156	587	1145	51	65
Coho																			36	4	49	89	55	60
																			24	10	102	136	75	82
																			60	14	151	225	67	73
Steelhead																			42	5	105	152	69	72
																			96	10	153	259	59	63
																			138	15	258	411	63	66
Sockeye																			549	105	91	745	12	26
																			828	122	86	1036	8	20
																			1377	227	177	1781	10	23

	Gate raised																							
	Standard scoop elevation[a]												Lowered scoop elevation											
	With deflector						Without deflector						With deflector[a]						Without deflector					
	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap	Fyke net catch	Gap net catch	Gatewell catch	Total catch	% guided	% guided incl. gap
Chinook	99	11	204	314	65	68	375	26	199	600	33	38	81	20	178	279	64	71	186	28	403	617	65	70
	180	73	671	924	73	81	210	32	322	564	57	63	72	19	181	272	67	74	123	20	239	382	63	68
	363	6	485	854	57	[illegible]7	87	6	112	205	55	58	135	28	212	375	57	64						
	642	90	1360	2092	65	69	672	64	633	1369	46	51	288	67	571	926	62	69	309	48	642	999	64	69
Coho	3	0	15	18	83	83	18	1	16	35	46	49	15	0	18	35	51	51	15	4	57	76	75	80
	6	4	74	84	88	93	33	1	46	80	58	59	6	3	51	60	85	90	18	0	32	50	64	64
	15	0	12	27	44	44	6	2	26	34	76	82	0	1	31	32	97	100						
	24	4	101	129	78	81	57	4	88	149	59	62	21	4	100	127	79	82	33	4	89	126	71	74
Steelhead	18	2	96	116	83	84	39	2	95	136	70	71	15	1	61	77	79	81	99	7	320	426	75	77
	12	1	56	69	81	83	57	1	53	111	48	48	27	4	91	122	75	78	21	2	49	72	68	71
	27	0	23	50	46	46	12	0	22	34	65	65	24	2	103	129	80	81						
	57	3	175	235	74	76	108	3	170	281	60	62	66	7	255	328	78	80	120	9	369	498	74	76
Sockeye	117	10	54	181	30	35	237	11	56	304	18	22	129	14	123	266	46	52	600	50	300	950	32	37
	57	7	56	120	47	53	123	10	32	165	19	25	171	21	84	276	30	38	420	34	202	656	31	36
	51	0	21	72	29	29	9	1	15	25	60	64	273	28	144	445	32	39						
	225	17	131	373	35	39	369	22	103	494	21	25	573	63	351	987	36	42	1020	84	502	1606	31	36

a/ No data for this condition.

A look at FGEs for day versus night will demonstrate one limiting factor. Figure 7 shows data for chinook and sockeye salmon and the test conditions under which these data were obtained. Clearly, the data show a wide variation in FGEs can be expected between day and night periods. The statistical tests of these data show that the differences in FGE between night and day are significant at the 99.9% level. Sufficient day-night data were not obtained for steelhead and coho salmon; however, prudence dictates we assume that a similar difference in FGE between day and night prevails for these species as well.

Because of the difference in FGE between day and night periods, we find that the data are stratified between the "gate in" and "gate raised" conditions (Figure 8 through 12). In Figure 8, for example, day only data for chinook salmon are adequate for the "gate in" experimental condition but are sparse for the "gate raised" experimental condition. For the other species (Figures 9 through 12), we find that the data are adequate for the 24-hour tests but are limited mostly to the "gate raised" experimental condition.

The day-night difference in FGE severely limits the comparison we can make between various experimental conditions. However, the limited data available suggest that the following conclusions may be valid: (1) the deflector contributes about 10% overall to FGE; (2) lowering the scoop does increase FGE but only slightly; (3) lowering the scoop also increases escapement of fish through the gap at the terminal end of the scoop for most experimental conditions; (4) removing the stored gate does appear to be beneficial in terms of increasing FGE, which implies that standard conditions (with the stored gate in normal position) are not optimum; and (5) for those limited cases available for comparison, raising the gate significantly reduced escapement of fish through the gap at the terminal end of the screen.

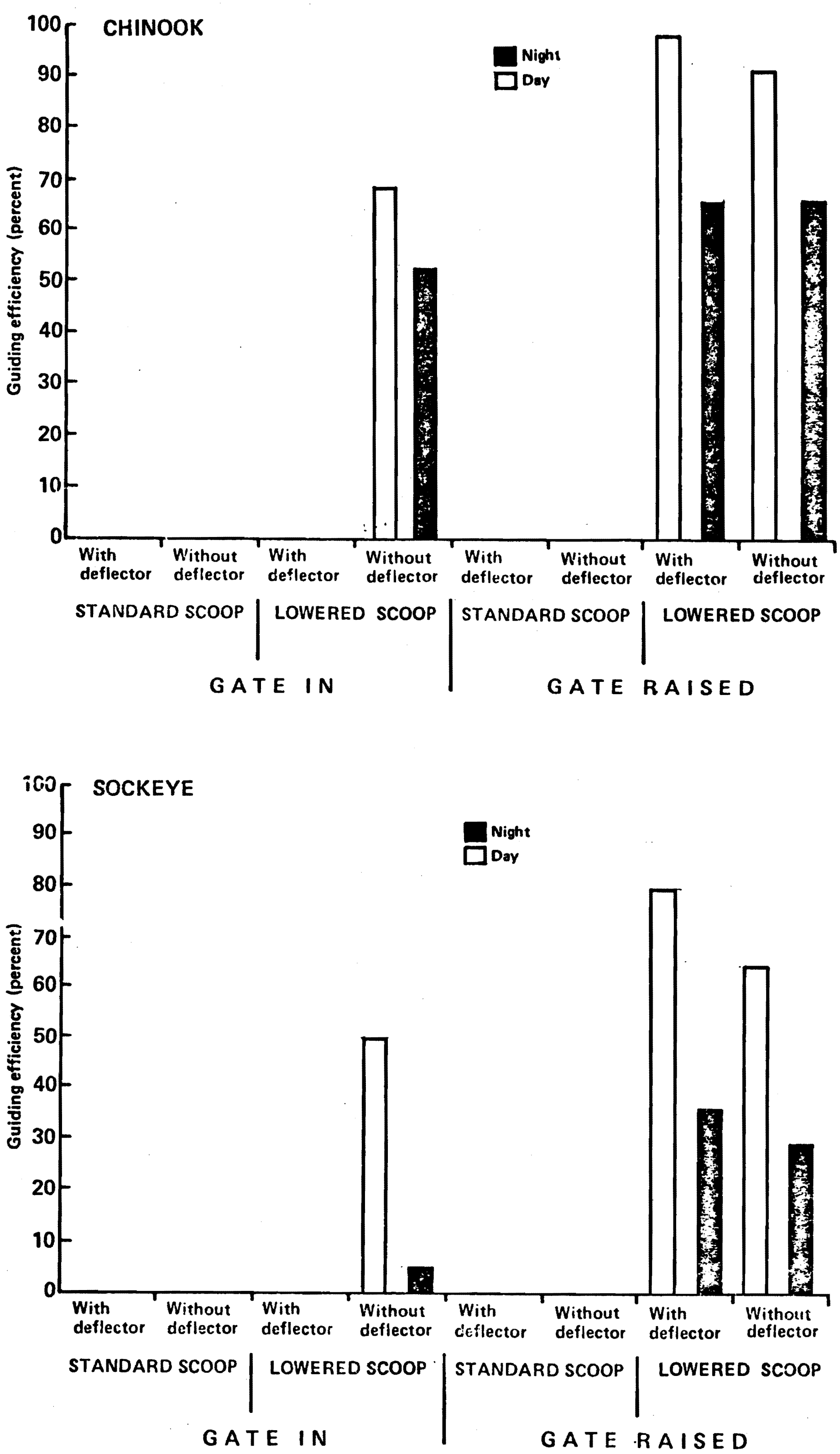


Figure 7.--Comparison of night and day fish-guiding efficiencies of bar-screen scoop and deflector in a turbine intake at McNary Dam.

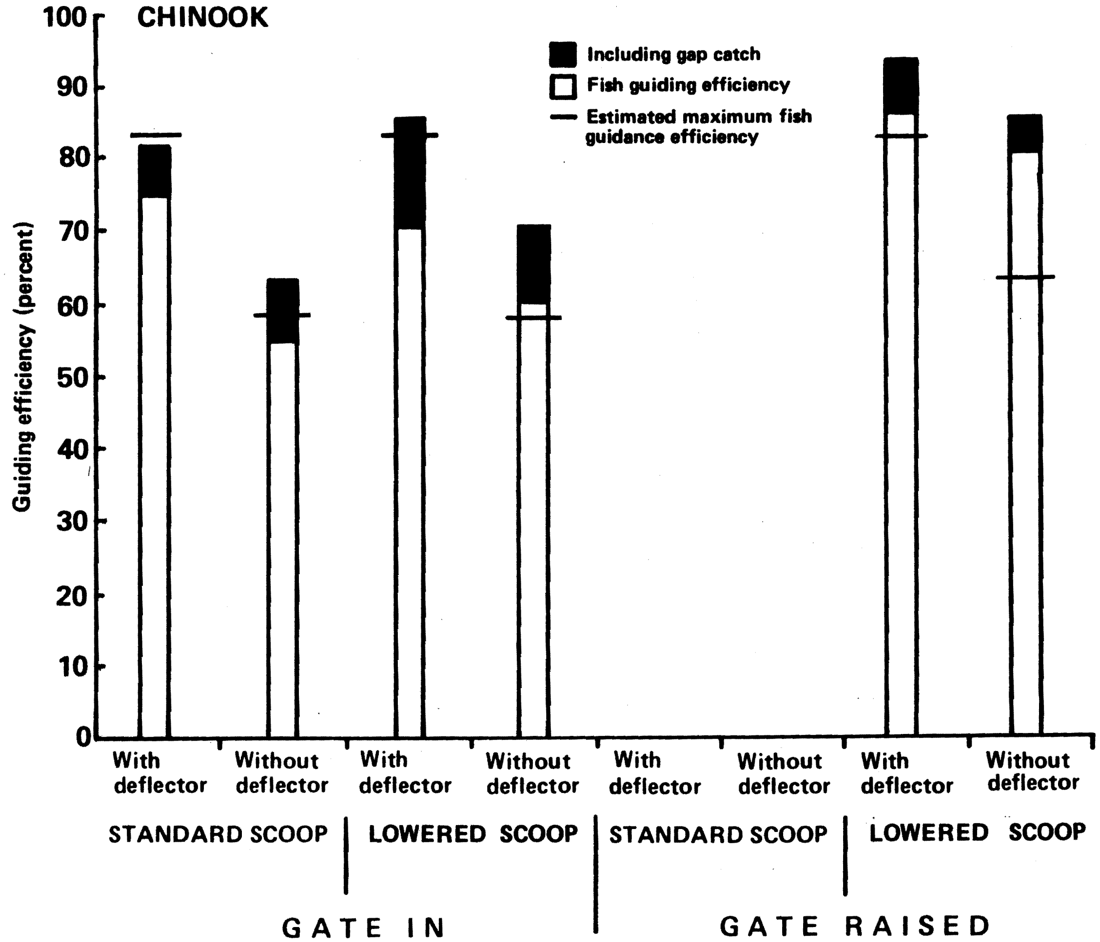


Figure 8.--Fish guiding efficiency for fingerling chinook salmon obtained during daylight hours with the bar-screen scoop and deflector in a turbine intake at McNary Dam. Estimated maximum fish guidance efficiency is based on vertical distribution studies done previously (see Appendix A).

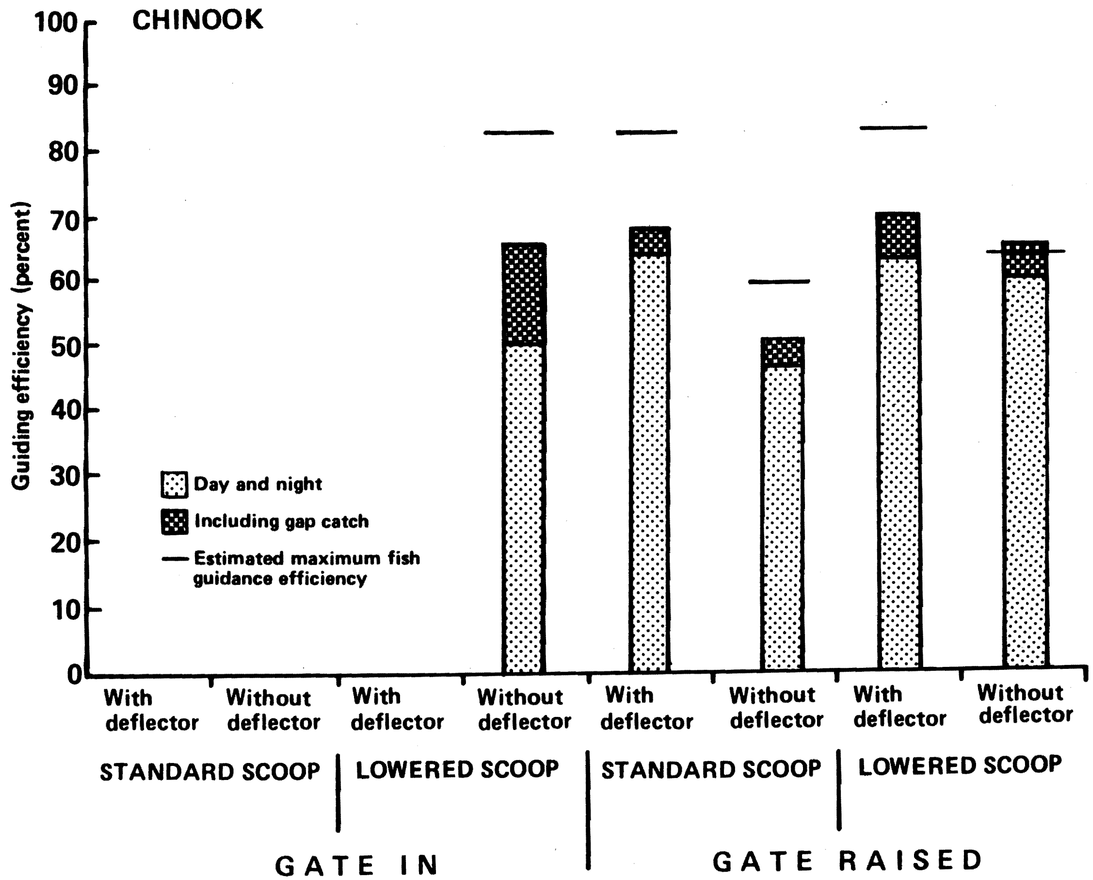


Figure 9.--Fish guiding efficiency for fingerling chinook salmon over a 22-hour period with the bar-screen scoop and deflector in a turbine intake at McNary Dam. Estimated maximum fish guidance efficiency is based on vertical distribution studies done previously (see Appendix A).

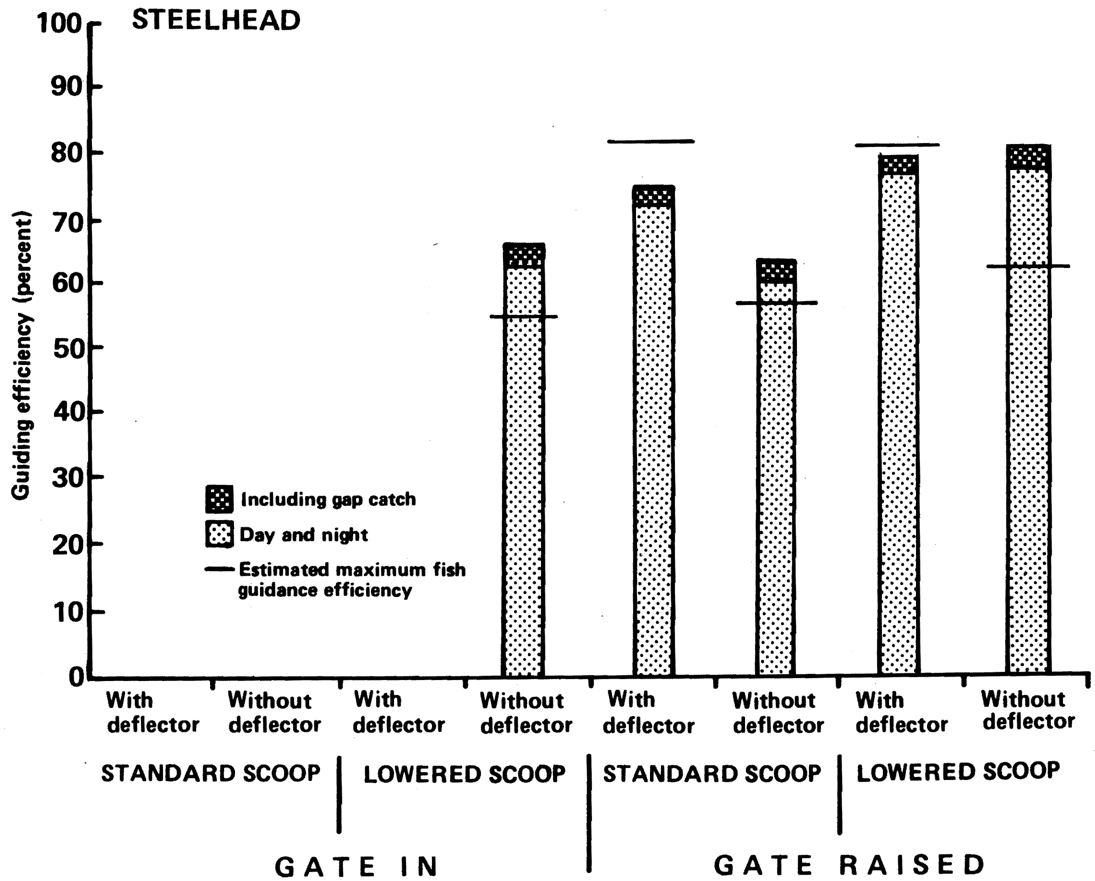


Figure 10.--Fish-guiding efficiency for fingerling steelhead over a 22-hour period with the bar-screen scoop and deflector in a turbine intake at McNary Dam. Estimated maximum fish guidance efficiency is based on vertical distribution studies done previously (see Appendix A).

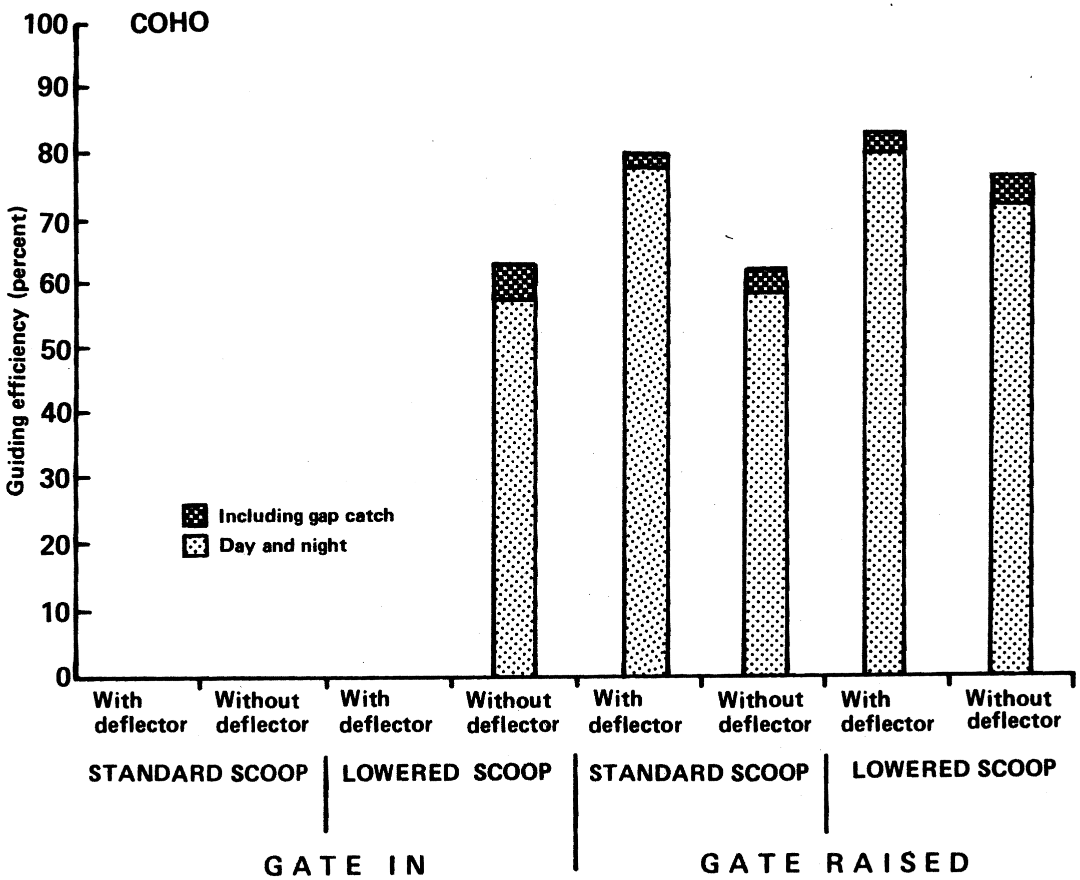


Figure 11.--Fish-guiding efficiency for fingerling coho salmon over a 22-hour period with the bar-screen scoop and deflector in a turbine intake at McNary Dam.

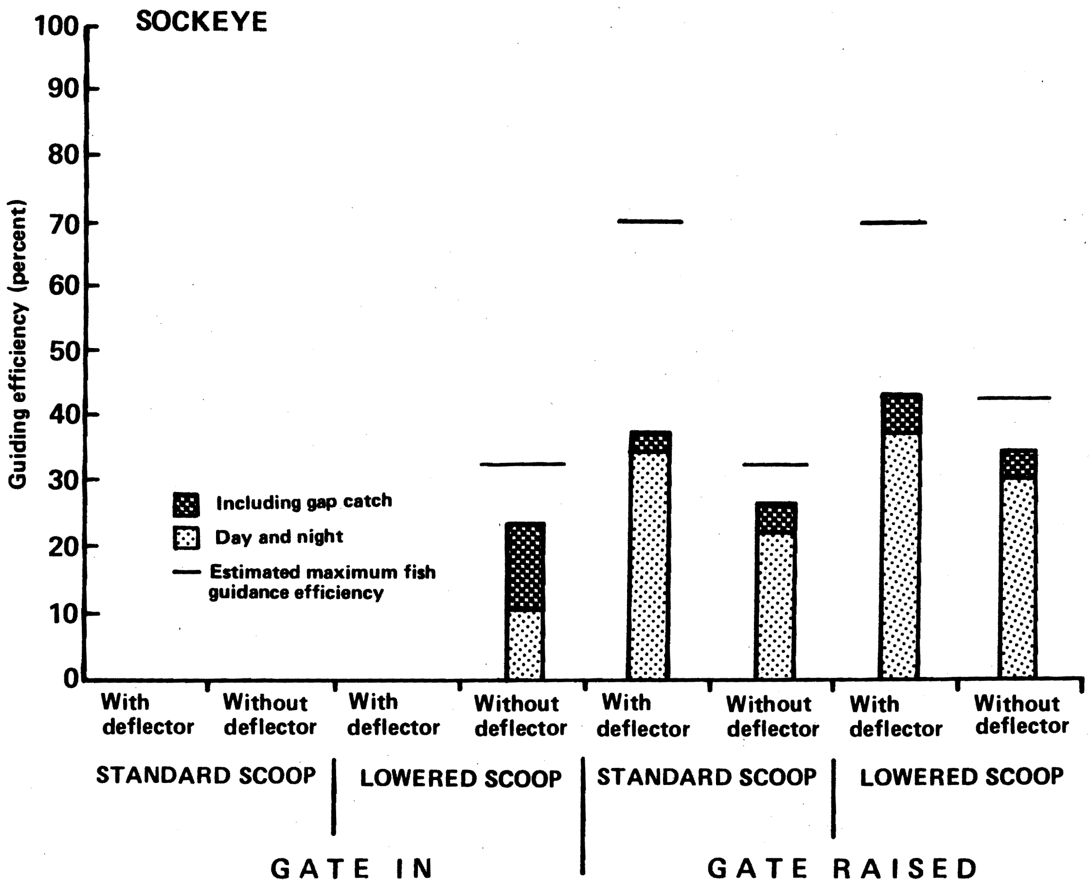


Figure 12.--Fish-guiding efficiency for fingerling sockeye salmon over a 22-hour period with the bar-screen scoop and deflector in a turbine intake at McNary Dam. Estimated maximum fish guidance efficiency is based on vertical distribution studies done previously (see Appendix A).

We caution against drawing firm conclusions based on the results obtained during 1978. Studies to be conducted during 1979 will resolve day-night differentials in FGE by having all tests to be compared conducted over the same hourly periods—only then will we be able to draw definitive conclusions.

Quality of Guided Fish

As a measure of the quality of the guided fish, we examined them for descaling and swimming performance. Descaling of guided fish was compared with descaling of fish entering gatewells of their own volition; i.e. no device was used to guide the control fish into the gatewells. Swimming performance of guided fish was compared with that of fish guided by the STS.

Figure 13 provides information on descaling of guided fish and fish entering gatewells of their own volition during the course of the field season. When the data were combined, descaling for the bar-screen guided fish was not significantly different than for the control fish (according to a chi square test at 90% level).

The swimming performance tests were evaluated using the mean fatigue time as a typical performance index (TPI). This was calculated as an average of the middle 50% of each test group's score. In each test, the TPI value for the fish guided by the bar screen was compared to the TPI value for the fish guided by the submersible traveling screen by means of an ANOVA F test. Fish (primarily spring chinook salmon) guided by the bar screen demonstrated a significantly better swimming performance (TPI) compared to fish guided by the STS (Table 6). However, we do not have any evidence that the reduced swimming performance of the STS guided fish was detrimental to their eventual survival.

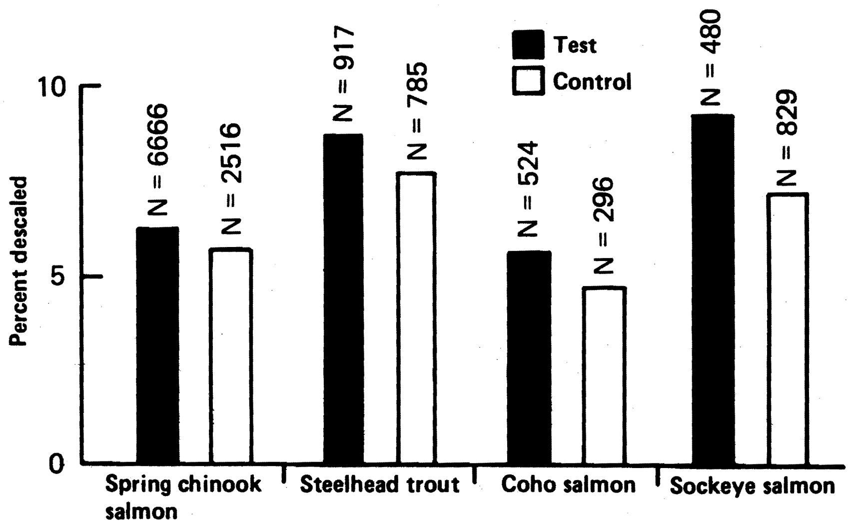


Figure 13.--Comparison of rate-of-descaling of fish guided by the bar-screen scoop and deflector with fish entering a gatewell of their own volition.

TABLE 6.--Results of tests comparing swimming performance of smolting salmonids guided by two types of devices.

Date	Guiding device	Number of swimming fish	TPI (min)
14 June	STS	116	95
	BS	108	106*
15 June	STS	189	95
	BS	125	103*
16 June	STS	129	100
	BS	121	109*
17 June	STS	139	100
	BS	152	103

TPI = mean fatigue time for the middle 50% of each group's scores.

* = $P < 0.05$ by ANOVA F test.

STS = submersible traveling screen.

BS = bar screen.

Backflushing Tests

During fish-guiding tests (up to 24 hours in duration) we found that debris would accumulate on the face of the screen. However, we never found an accumulation that we considered to be serious.

After termination of the fish-guiding tests, we began a series of debris studies designed to: (1) determine the length of time of continuous operation required to cause a serious accumulation of debris on the screens and (2) the effectiveness of backflushing in eliminating the debris.

Figure 14 shows the typical amount of debris accumulation after a 7-day period of operation and the amount of debris retained by the screens following a 10-minute period of backflushing. Several 7-day tests were conducted, all yielding similar results.

Obviously the rate of accumulation of debris on the screen depends upon the debris load in the river at the time. However, we estimate that during the months of July and August 1978, a very conservative backflush rate would be once every 24 hours. Such a rate, we are sure, would have maintained the bar screens in a nearly clean condition most of the time.

EVALUATION OF SUBMERGED ORIFICES FOR PASSAGE OF JUVENILE SALMONIDS FROM GATEWELLS

Newly installed orifices at McNary Dam were evaluated in 1978. The orifices were installed in accordance with specifications developed at Bonneville Dam in 1976-77. Our experiments at McNary Dam were limited to a comparison of: (1) a single 12-inch diameter orifice, (2) two 8-inch diameter orifices, and (3) a single 8-inch diameter orifice. Data were taken so the relative number of fish passing through each orifice could be compared.

Each gatewell was equipped with two 12-inch diameter orifices (designated north and south). Inserts were used to reduce the diameter of the orifices to

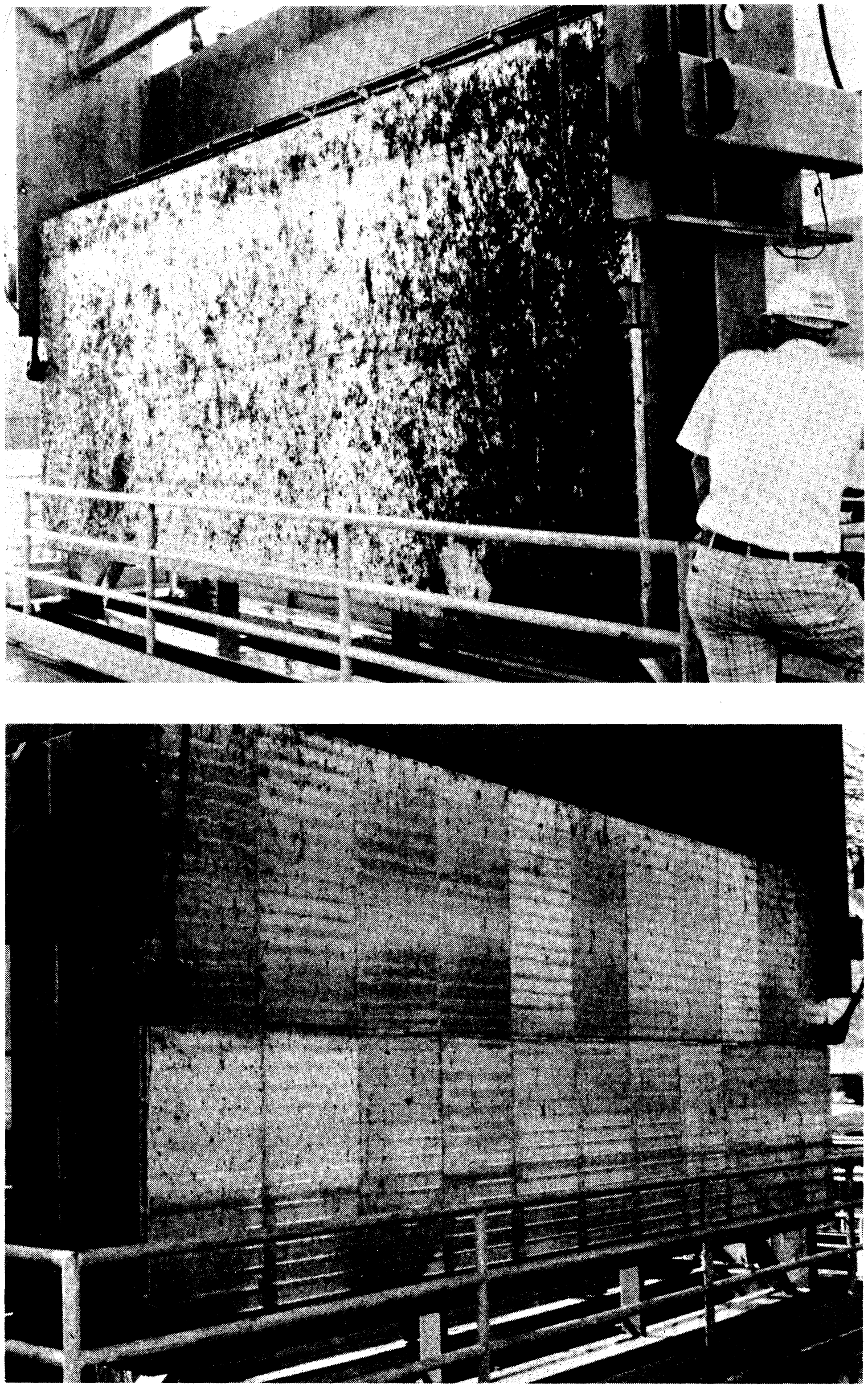


Figure 14.--Photographs of bar-screen scoop showing 7-day accumulation of debris and results after backflushing for 10 minutes.

8 inches. Each gatewell was lighted in the standard fashion, and fish exiting each orifice entered separate traps.

Figure 15 presents the data obtained for chinook, coho, and sockeye salmon and steelhead. For steelhead, two 8-inch diameter orifices were as effective as a single 12-inch diameter orifice. However, for sockeye salmon, two 8-inch diameter orifices were significantly better than a single 12-inch diameter orifice, and for chinook salmon, a single 12-inch diameter orifice was significantly better than two 8-inch diameter orifices. Too few coho salmon were obtained for statistical tests. In all tests with two 8-inch diameter orifices, the north orifice passed significantly more fish than the south orifice.

In the final analysis, we would probably recommend use of a single 12-inch diameter orifice in each gatewell because the 12-inch diameter orifice would be less likely to plug from debris than a 8-inch diameter orifice. The choice of using a north or south orifice may vary from gatewell to gatewell.

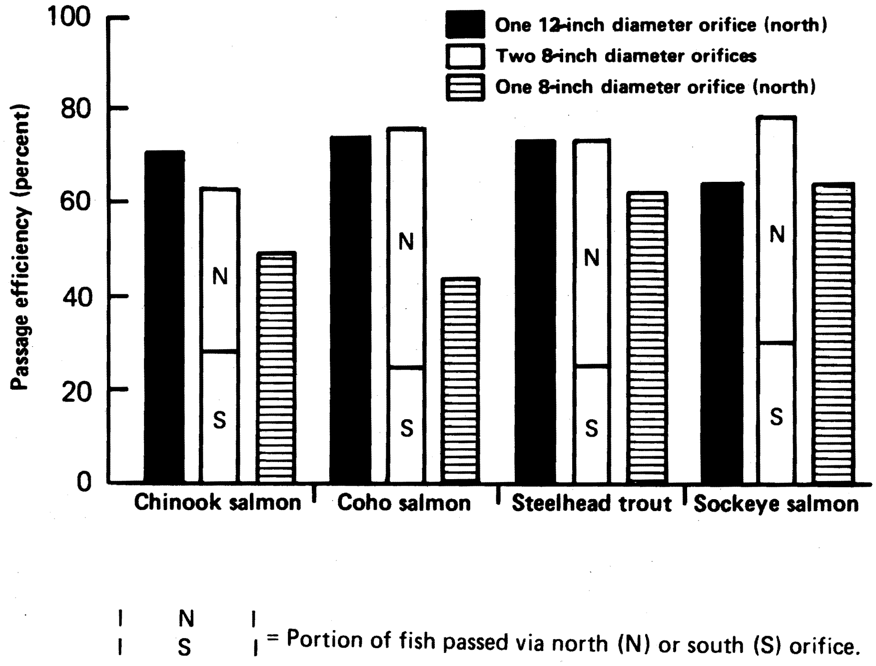


Figure 15.--Results of tests with one 12-inch orifice, two 8-inch orifices, and one 8-inch orifice showing efficiency of passage of various species out of gatewells at McNary Dam.

SUMMARY

In 1978, research on improving the fingerling protection system used at low-head dams was conducted at both Bonneville and McNary Dams.

At Bonneville Dam, research on the prototype bar screen was completed and an experiment to determine the relative survival of fish released along the Bradford Island shore was also conducted. At McNary Dam, a new two-part fish guiding system utilizing the bar screen was initiated. In addition, new submerged orifices for passing fish out of gatewells were installed and evaluated.

At Bonneville Dam, the prototype bar screen proved to be inadequate; i.e., fish-guiding efficiencies under all experimental conditions fell short of the desired level. A larger bar-screen device, one that intercepts a larger percentage of the fish, is recommended.

The fish-release experiment is not completed. Final data will be gathered beginning in September 1979 when the full term adult coho salmon return to the hatcheries of origin.

At McNary Dam it was not possible to examine all of the experimental conditions desired. However, results indicated that fish-guiding efficiency approaches the expected level based on prior data on vertical distribution by species. In terms of descaling and swimming performance, the quality of fish guided by the bar screen is as good as or better than: (1) fish entering gatewells of their volition and (2) fish guided by the submersible traveling screen.

Studies to evaluate newly installed submerged orifices at McNary Dam indicate that a single 12-inch diameter orifice will provide the best fish passage efficiency for most species by comparison with two 8-inch diameter orifices. In addition, a single 12-inch diameter orifice will have less tendency to plug with debris than will two 8-inch diameter orifices.

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APPENDIX A

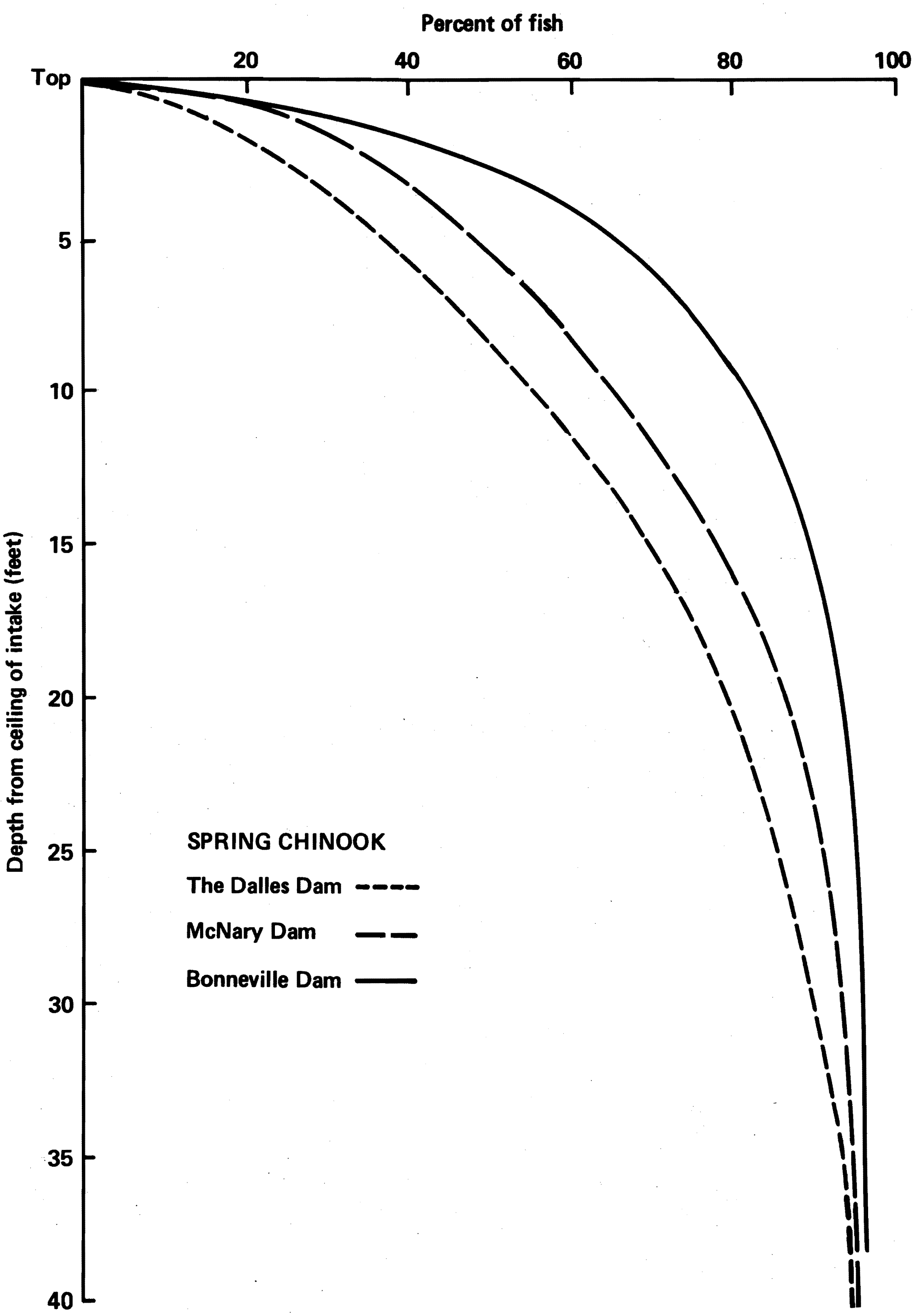
Vertical distribution of fingerling salmonids in turbine intakes of low head dams based on fyke net catches in turbine intake studies completed in 1960, 61, and 75.[1/]

1/ Long, Clifford W.

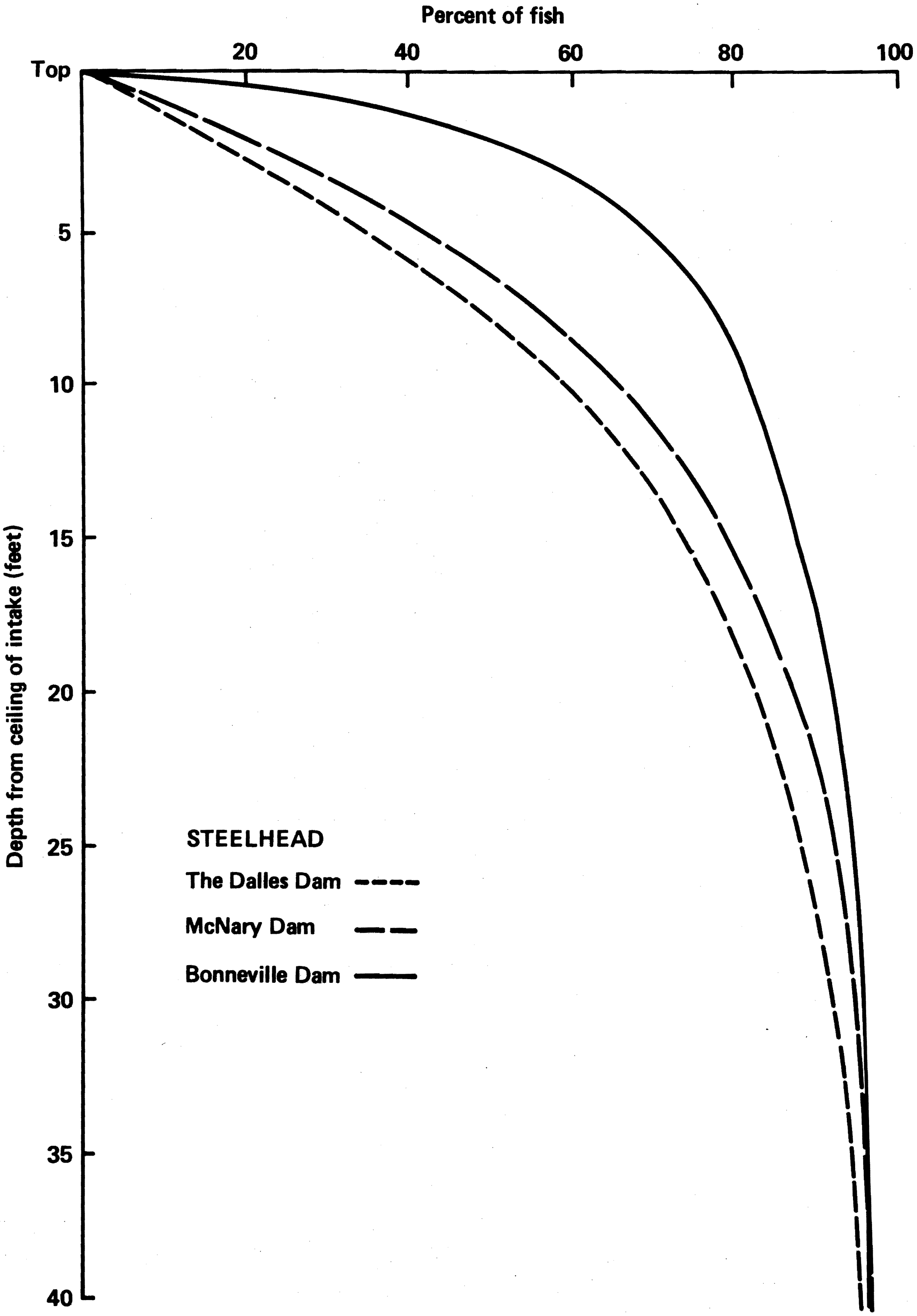
1968. Diel movement and vertical distribution of juvenile anadromous fish in turbine intakes. U.S. Fish and Wildlife Service, Fishery Bulletin, Vol 66, No. 3, p. 559-609.

Long, Clifford W.

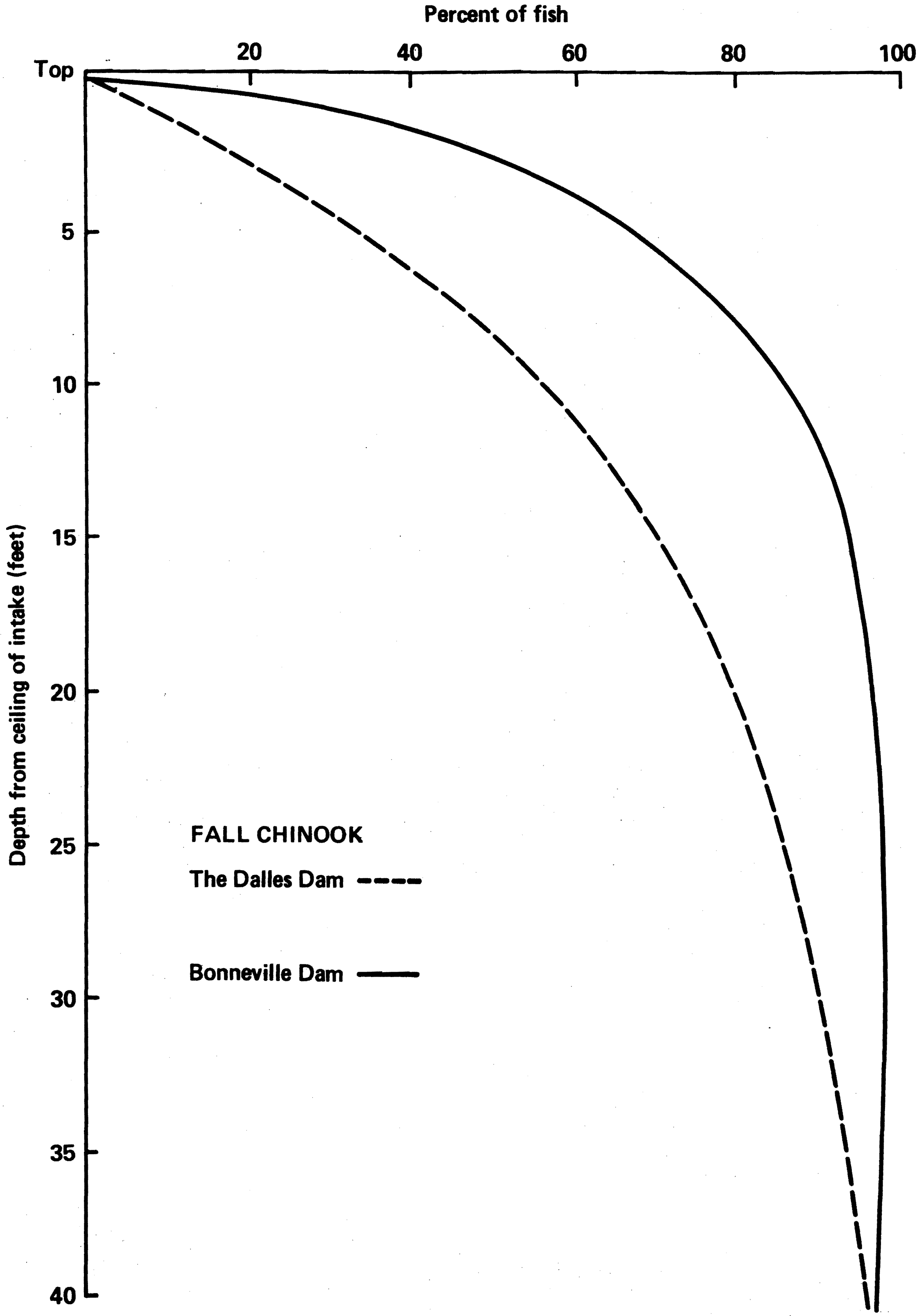
1975. Final report on vertical distribution of fingerling salmonids in turbine intakes of the Bonneville first powerhouse. Report to U.S. Army Corps of Engineers, Contract No. DACW57-75-F-0569, 10 p.



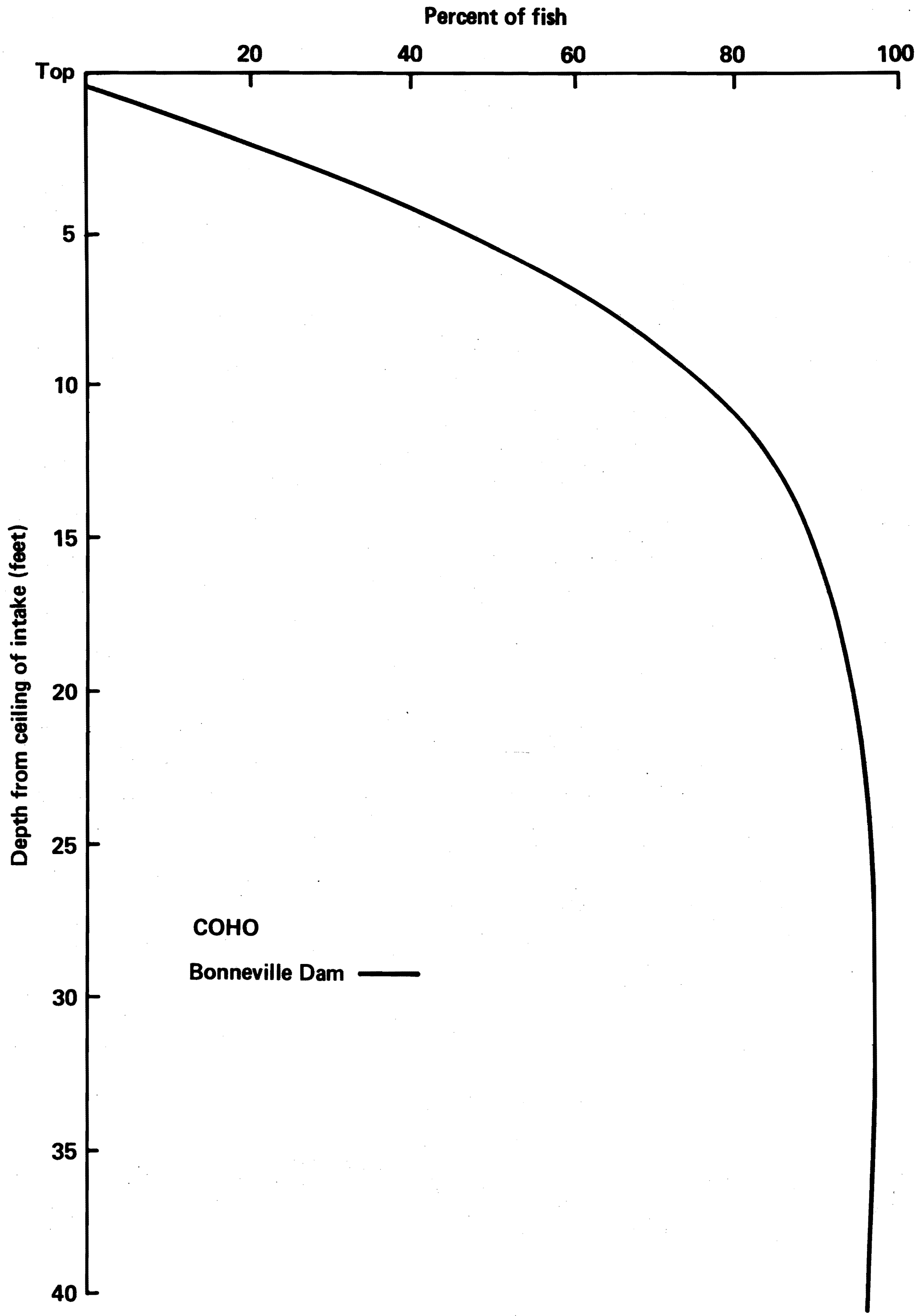
Vertical distribution of spring chinook salmon fingerlings in turbine intakes at Bonneville Dam (1975), The Dalles Dam (1960) and McNary Dam (1961).



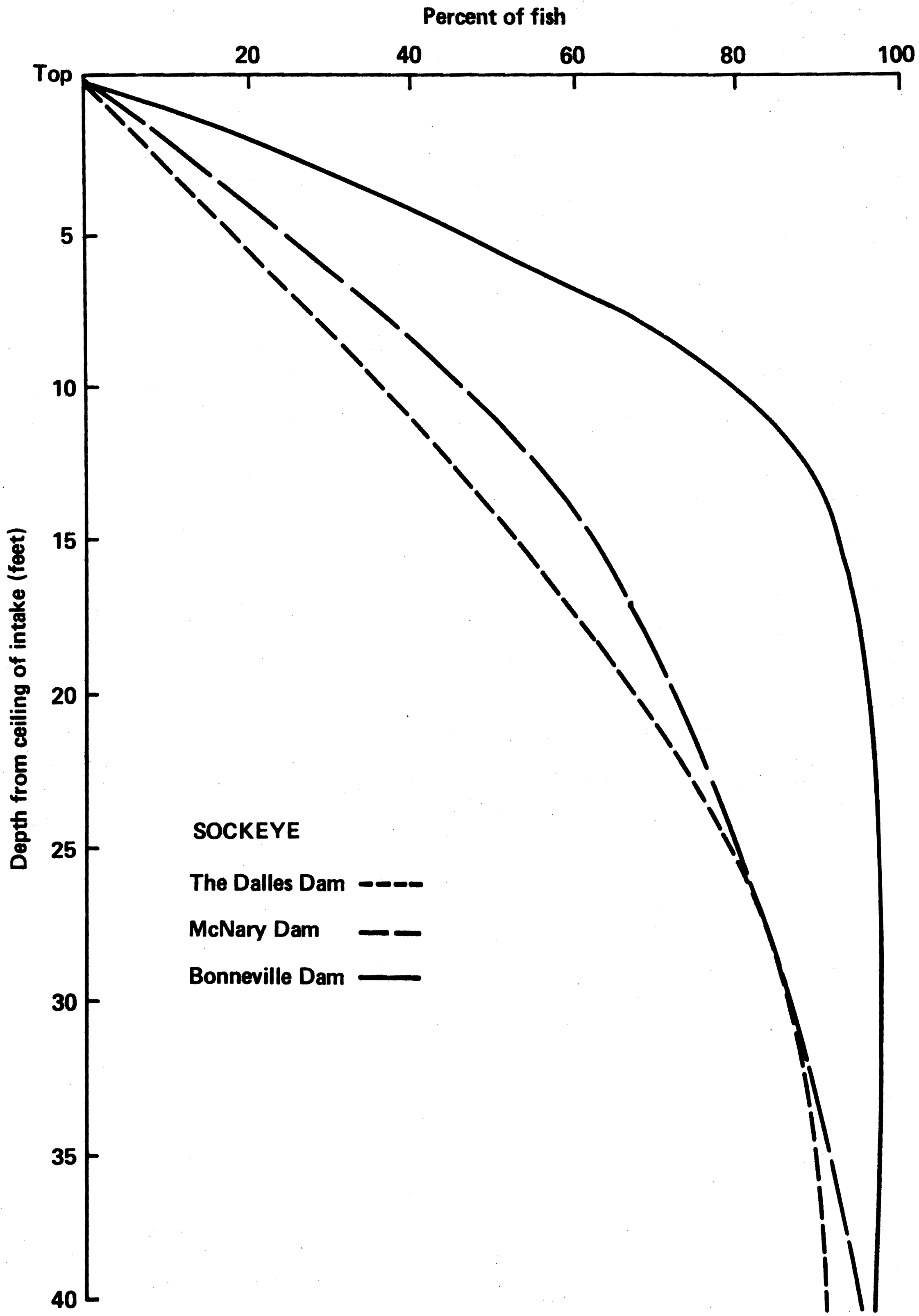
Vertical distribution of steelhead trout fingerlings in turbine intakes of Bonneville Dam (1975), The Dalles Dam (1960) and McNary Dam (1961).



Vertical distribution of fall chinook salmon fingerlings in turbine intakes of Bonneville Dam (1975) and The Dalles Dam (1960).



Vertical distribution of coho salmon fingerlings in turbine intakes of Bonneville Dam (1975).



Vertical distribution of sockeye salmon fingerlings in turbine intakes of Bonneville Dam (1975), The Dalles Dam (1960) and McNary Dam (1961).