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# RESEARCH ON THE DEVELOPMENT OF A FINGERLING PROTECTION SYSTEM FOR LOW HEAD DAMS — 1977

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# INTRODUCTION

In 1975, the NMFS, under contract to the U. S. Army Corps of Engineers, 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 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.

Research conducted at Bonneville Dam in 1977 was directed toward the following goals: (1) evaluation of a prototype bar screen and (2) completion of studies on the design and operating criteria for submerged orifices. This, the final report on 1977 research, is divided into two parts in accordance with the goals stated above.

# EVALUATION OF BAR SCREENS FOR GUIDING JUVENILE SALMON AND TROUT OUT OF TURBINE INTAKES

The fish-guiding device now in use at Little Goose and Lower Granite Dams, called a submersible traveling screen, is expensive to construct and maintain. As a consequence, an important objective of the research program was to develop a less elaborate and less expensive guiding device.

Because the submersible traveling screen is a complex device with many moving parts, a nontraveling screen (bar screen) was considered in our initial studies. These studies, conducted in an experimental flume, culminated in the construction of a prototype fish guiding device that was installed in a turbine intake at Bonneville Dam for evaluation under field conditions in 1977.

The following parameters were considered in the evaluation of the device: fish guiding efficiency, descaling and mortality of fish, and accumulation of debris on the device.

## 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 prototype guiding device (bar screen), installed in the turbine intake, functions as a component of the standard fish bypass and collection 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 dip netted 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

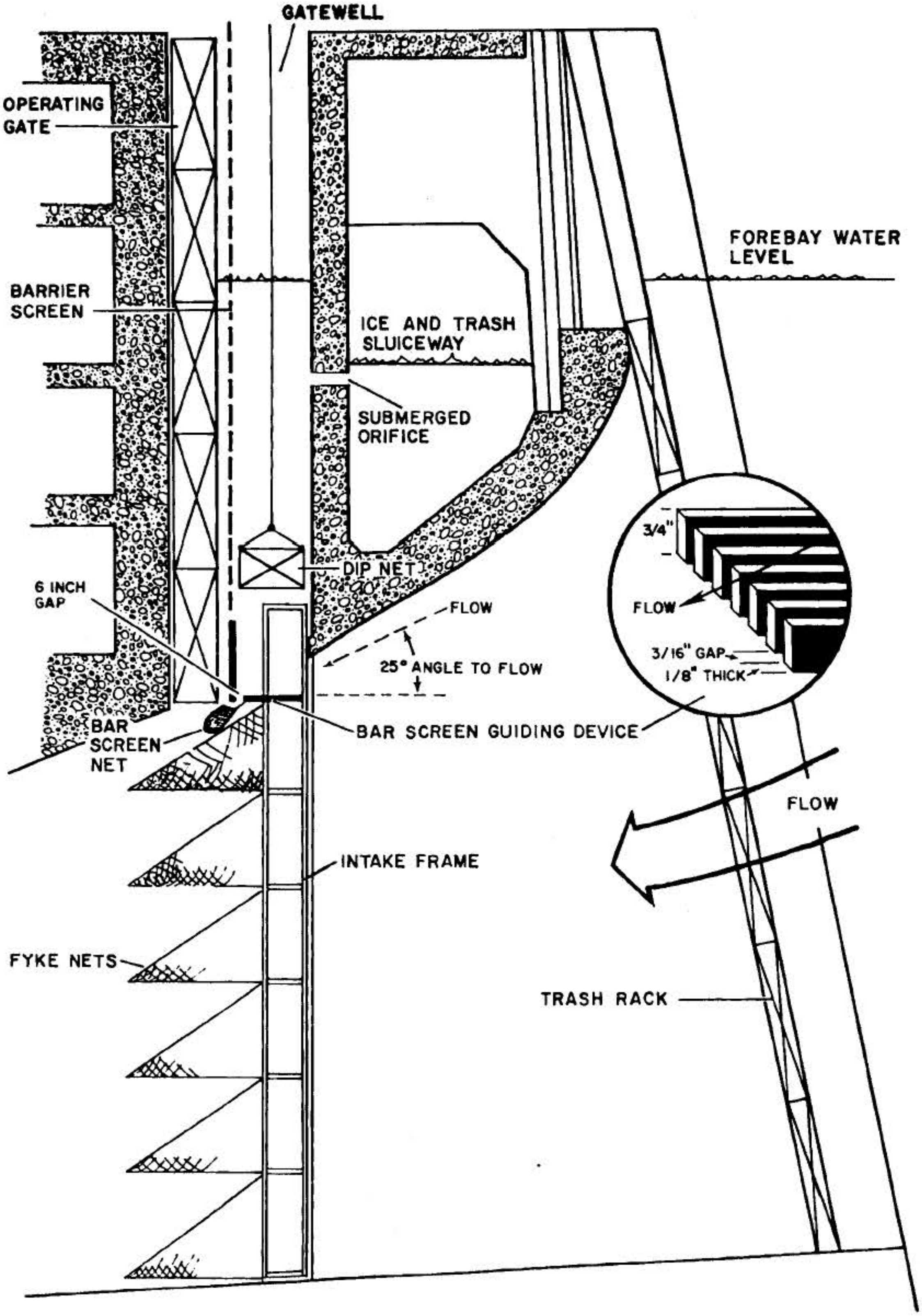


Figure 1.--Cross section of a turbine intake and associated structures in the Bonneville Dam existing powerhouse showing location of research equipment (inset shows detail of bar screen).

stored an operating gate. These gates, when lowered into the intakes, stop the flow of water and allow dry access to the turbines for maintenance.

One of the factors that can influence the efficiency of a fish-guiding device is the flow that enters the gatewell. (The location of the stored gate in the gatewell can also influence the amount of this flow.) Increasing the flow may increase fish-guiding efficiency 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 vertical barrier screen in the gatewell 12 inches upstream from the operating gate. This configuration resulted in a flow through the gatewell of about 50 cubic feet per second (cfs). To test a condition where more flow was allowed to pass through the gatewell, we removed the operating gate leaving the vertical barrier screen in place. This configuration resulted in a flow of 250 cfs through the gatewell.

A specially designed intake frame (Figure 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 water passing under the fish-guiding device, and the trapped fish were counted to estimate the number of unguided fish.

The experimental fish-guiding device was in the form of a screen 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).

Figure 2.--Intake frame, used to support fyke nets and bar screen. Frame is suspended above deck of Bonneville Dam by gantry crane.

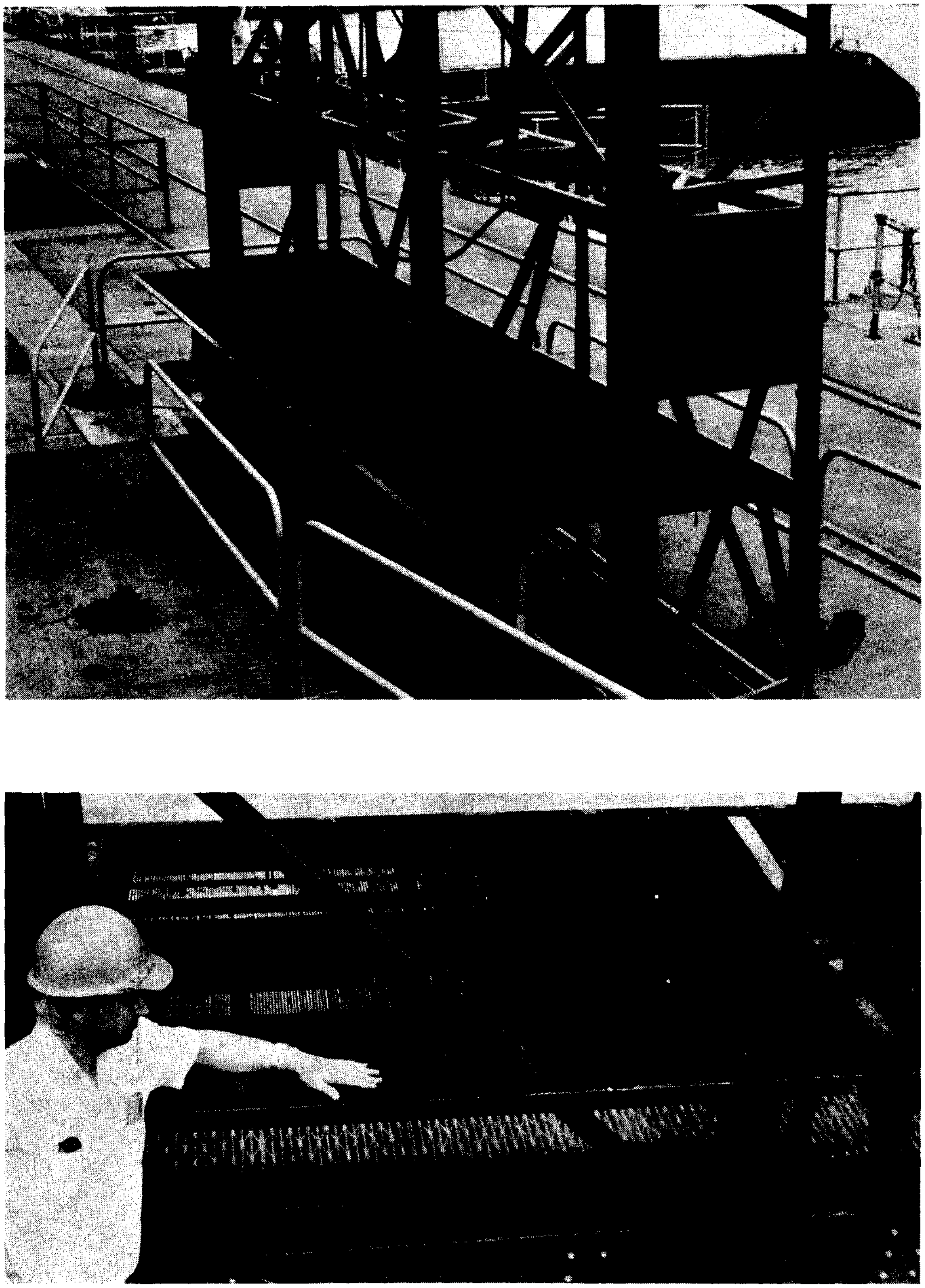

Figure 3.--Two views of bar screen installed in intake frame. (Top portion of frame projects above deck, out of gatewell.)

The screen was installed in the turbine intake, the bars and slots being 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.

The bar screen in the turbine intake intercepted the upper 3.5 feet of water. Previous studies by NMFS scientists at Bonneville Dam in 1975[1/] indicated that 50 to 60% of the fingerling salmon were traveling within 3.5 feet of the intake ceiling. The downstream end of the bar screen terminated 6 inches upstream from the bottom of the vertical barrier screen (Figure 1), resulting in a 6-inch gap through which debris was flushed rather than allowed to accumulate on the bar screen.

For evaluation purposes, a hinged net (bar-screen net) was fastened near the terminal end of the bar screen (Figure 1) so that it strained water passing through the gap. Thus, debris and fish passing through the gap were caught and presumably retained in this net.

## METHOD OF TESTING BAR SCREEN

The experiments conducted at Bonneville Dam were designed to measure the percentage of fish entering the turbine intake that were guided up into the gatewell by the bar screen and to determine whether it caused descaling or death of the fish in the process. Experiments were conducted:

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1/ Final report under Corps contract No. DACW-57-75-F-0569 titled, "Vertical distribution of fingerling salmonids in turbine intakes of the Bonneville First Powerhouse", by Clifford W. Long, 1975.

1) with the operating gate in the normal position (Figure 1), which allowed only 50 cfs of water to enter and pass through the gatewell and 2) with the operating gate removed, which allowed 250 cfs of water to enter and pass through the gatewell.

To determine the effects of porosity of the bar screen on guiding efficiency and descaling, we compared the bar screen as constructed, which had a 65% open area, with modified bar screens having 35 and 0% open areas. To test a configuration having an open area of 35%, plywood strips were used to partially block the bar screen. To reduce the open area to 0%, we blocked the entire bar screen with plywood.

Procedures for conducting a test to determine fish-guiding efficiency 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.

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. Fish-guiding efficiency (expressed in percent) was defined as the number of guided fish divided by the sum of the number guided plus the number unguided.

To determine if the bar screen descaled fish, we compared guided fish with fish that entered the gatewell of their own volition (when the bar screen was removed). A fish having more than 10% of its scales missing was noted as descaled.

We monitored fish taken by the dip-net and the bar-screen net and examined the bar screen itself (upon removal following each test) for dead fish. Marked dead fish were placed in the bar-screen net before certain tests and were released into the gatewell after dipnetting at the end of certain tests to estimate the likelihood of recovering fish killed by the bar screen.

Tests to determine fish-guiding efficiency ranged from 3 to 6 hours during regular working hours. Tests to determine descaling or death of fish and extent of debris accumulation on the bar screen were 24 hours in duration.

## FISH-GUIDING EFFICIENCY OF BAR SCREEN

Fish-guiding efficiency of the bar screen averaged 42 to 75% for all species at flows of 250 cfs through the gatewell (Figure 4). Actual guidance approximated that expected based on previous studies of vertical distribution of fingerlings in turbine intakes.

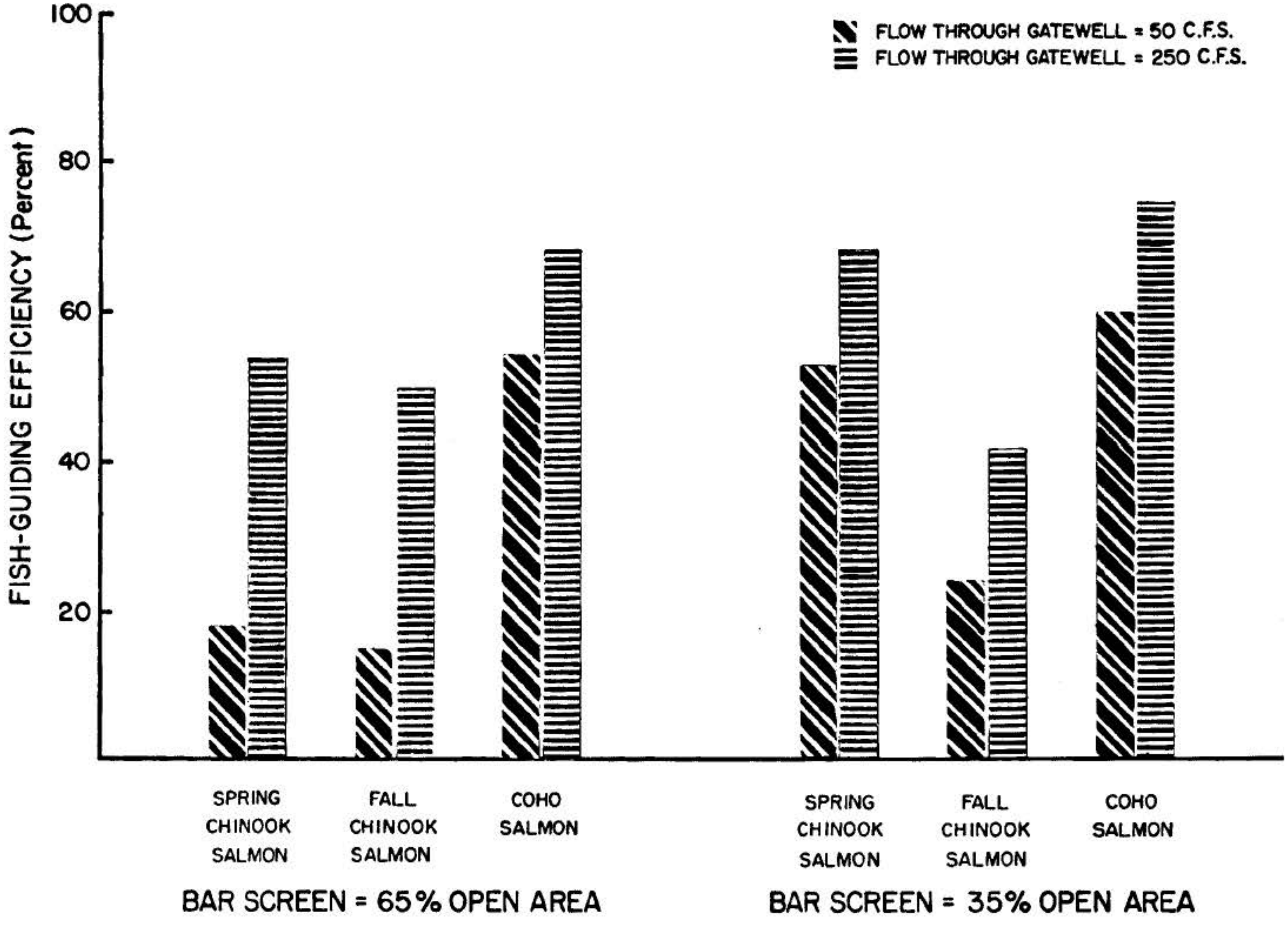


Figure 4.--Fish-guiding efficiency of bar-screen guiding device as affected by flow through intake gatewell.

Tests with spring chinook, fall chinook, and coho salmon indicated that increasing the volume of water passing through the gatewell from 50 to 250 cfs significantly[2/] increased the fish-guiding efficiency of bar screens having either 65 or 35% open area (Figure 4). Insufficient numbers of steelhead trout were caught during these tests to establish a reliable value for fish-guiding efficiency.

Figure 5 compares guiding efficiency of spring chinook, fall chinook, and coho salmon for bar screens having 65, 35, or 0% open area. In all of these tests, the stored gate was removed from the gatewell so a flow of 250 cfs was passing through the gatewell. Results show that the bar screen having a 0% open area guided significantly fewer fish of all species tested than the bar screens having either a 65 or 35% open area.[3/]

Guiding efficiency of spring chinook salmon was significantly[3/] greater for the bar screen having a 35% open area, but guiding efficiency of fall chinook salmon was significantly[3/] greater for the bar screen having a 65% open area. Guiding efficiency of coho salmon was about the same for both porosities.[4/] Apparently, neither the 35 nor 65% open area screen provides a clear cut advantage.

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2/ Significance ($P = < 0.05$) was tested by using a $G^2$ likelihood-ratio statistic.

3/ Significance ($P = < 0.01$) was tested by using a $G^2$ likelihood-ratio statistic.

4/ Nonsignificance ($P = > 0.59$) was tested by using the $G^2$ likelihood-ratio statistic.

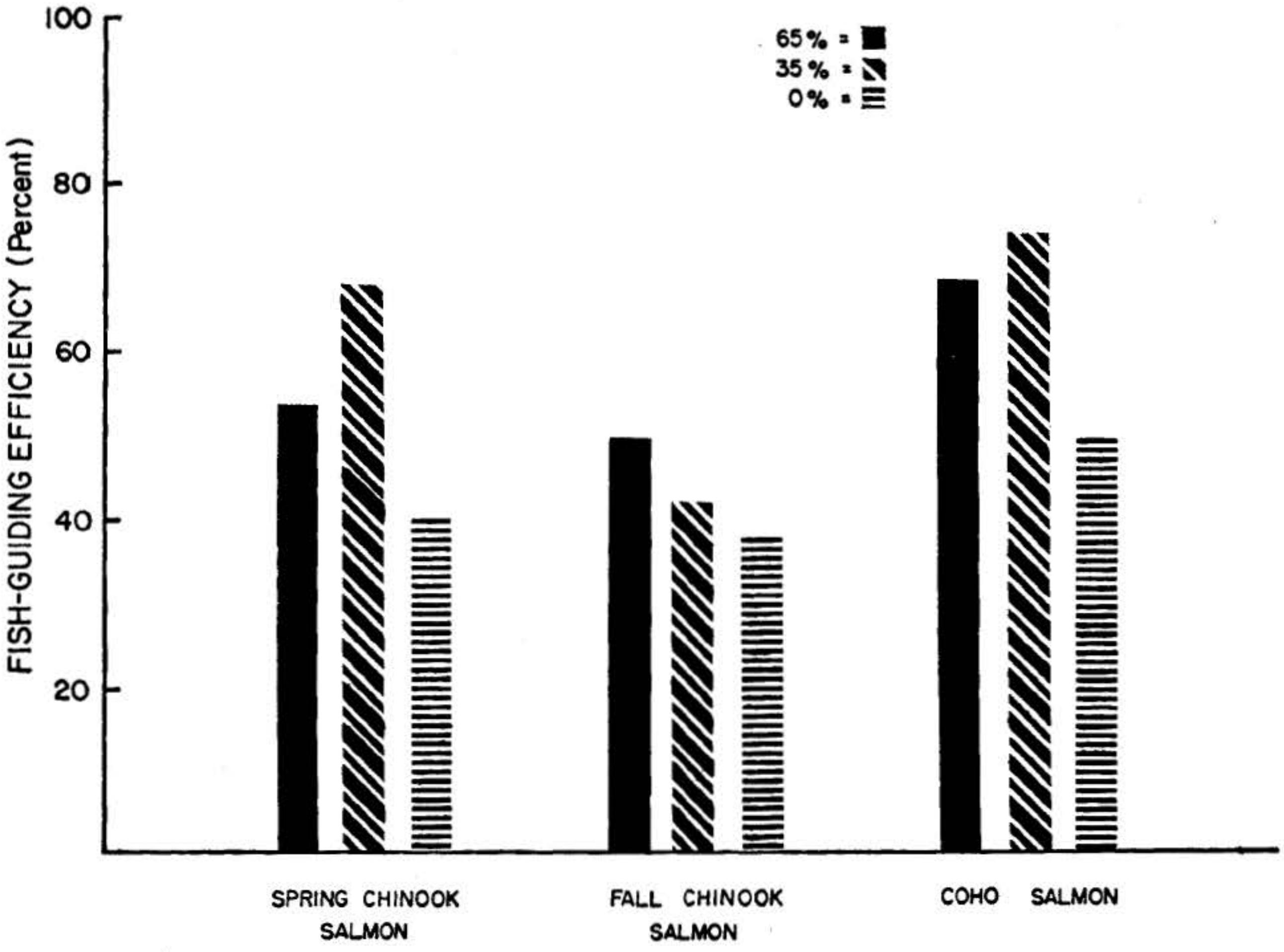


Figure 5.--Fish-guiding efficiency of bar-screen guiding device of varying porosities.

## DESCALING OF FISH DEFLECTED BY BAR SCREEN

Figure 6 shows a comparison of the incidence of descaling in fish taken from gatewells during operation with and without a bar screen; data from tests with screens having 65 or 35% open areas were combined. Clearly, the results show that descaling was not increased appreciably during tests with a bar screen in operation.

## IMPINGEMENT OF FISH AND DEBRIS ON BAR SCREEN

Tests of 24-hour duration showed very little accumulation of debris on the device. At the end of these tests the bar-screen net always contained more debris than was found on the bar screen. On the other hand, not more than 1 to 2% of the fish entering the turbine intake were ever found in the bar-screen net.

Marked dead fish placed in the bar-screen net at the beginning of a test were always found in the net at the end of the test. Of the marked dead fish placed in the gatewell at the end of a test, 80% were recovered upon removal of the bar screen from the gatewell.

## BAR SCREEN WILL BE TESTED AGAIN IN 1978.

From the fish-guiding efficiency, descaling, mortality, and debris accumulation measurements obtained, we feel the bar screen shows sufficient promise to justify additional research and development. Due to varying distributions of juvenile salmon and trout, larger devices of similar design may be required at other dams to obtain similar guiding efficiencies.

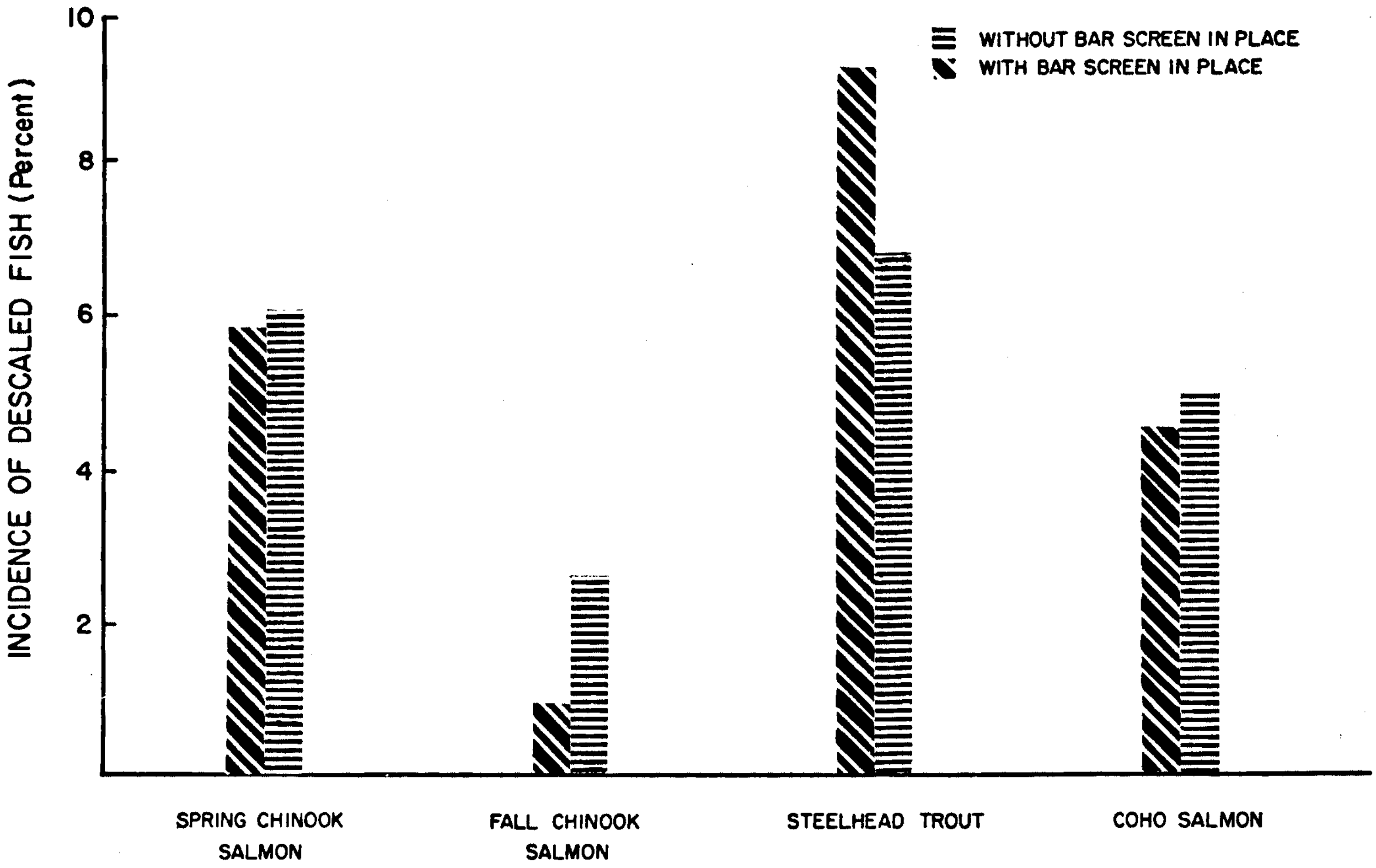


Figure 6.--Incidence of descaled fish recovered from gatewells. Fish guided into the gatewell by a bar screen are compared with fish that entered the gatewell of their own volition.

Because our testing has been restricted to a small bar screen and we do not know what descaling or mortality problems may occur with a larger device, caution is advised in considering this device for use under other circumstances. Testing of a larger device will be carried out at McNary Dam on the Columbia River in 1978.

## DESIGN AND OPERATING CRITERIA FOR SUBMERGED ORIFICES TO PASS FISH OUT OF INTAKE GATEWELLS

Experiments to define design and operating criteria for the orifice bypass system in the Second Bonneville Powerhouse were initiated in 1976 and completed during the spring of 1977. Research results in 1976 indicated that two 10-inch diameter orifices were satisfactory for submergences ranging from 4 to 8.5 feet. However, submergences of 3 to 10 feet are possible at Bonneville Dam where the forebay may fluctuate as much as 7 feet (maximum pool el. 77 to minimum pool el. 70). From the results of only a few tests with a single 12-inch diameter orifice in 1976, it appeared that 12-inch diameter orifices might provide better passage than 10-inch diameter orifices over the entire range of submergences. Therefore, more extensive testing was conducted with the 12-inch diameter orifices in 1977.

These tests included the following factors that may affect fish passage efficiencies: 1) illuminating the orifice, 2) darkening the gatewell, 3) two orifices versus one orifice, 4) north versus south orifice, and 5) the operating depth of the orifice (head and submergence were equal).

The research at Bonneville Dam in 1977 also addressed the significance of fish passage efficiencies of something less than 90% (the level that was arbitrarily set as acceptable during the 1976 study).

## METHODS AND PROCEDURES

In 1977, as in 1976, studies of submerged orifices were conducted in gatewell 9-B at the Bonneville First Powerhouse. Figure 7 illustrates the equipment employed. A caisson installed in the gatewell was equipped with two separate compartments to serve as water passages from the gatewell to the ice sluice. Slide gates on each compartment contained a 12-inch diameter orifice. Vertical adjustment of the slide gates allowed positioning of each orifice at any submergence below the water surface within the gatewell to a maximum depth of 8.5 feet when the elevation of the forebay surface was held at 76.5 feet above m.s.l. The two water passages in the caisson connected to separate 18-inch diameter ports drilled through the concrete wall separating the gatewell and ice sluice. The 18-inch diameter ports in the concrete wall were 2.5 feet lower than the lowest settings of the slide gates. Therefore, by removing the caisson and installing 12-inch diameter adapter plates over the 18-inch diameter port it was possible to test orifice submergences beyond 8.5 feet. Each port was equipped with air operated valves, and water passing through each port entered an individual riser affixed to an inclined plane screen and trap. Thus, fish passing through each port remained separated.

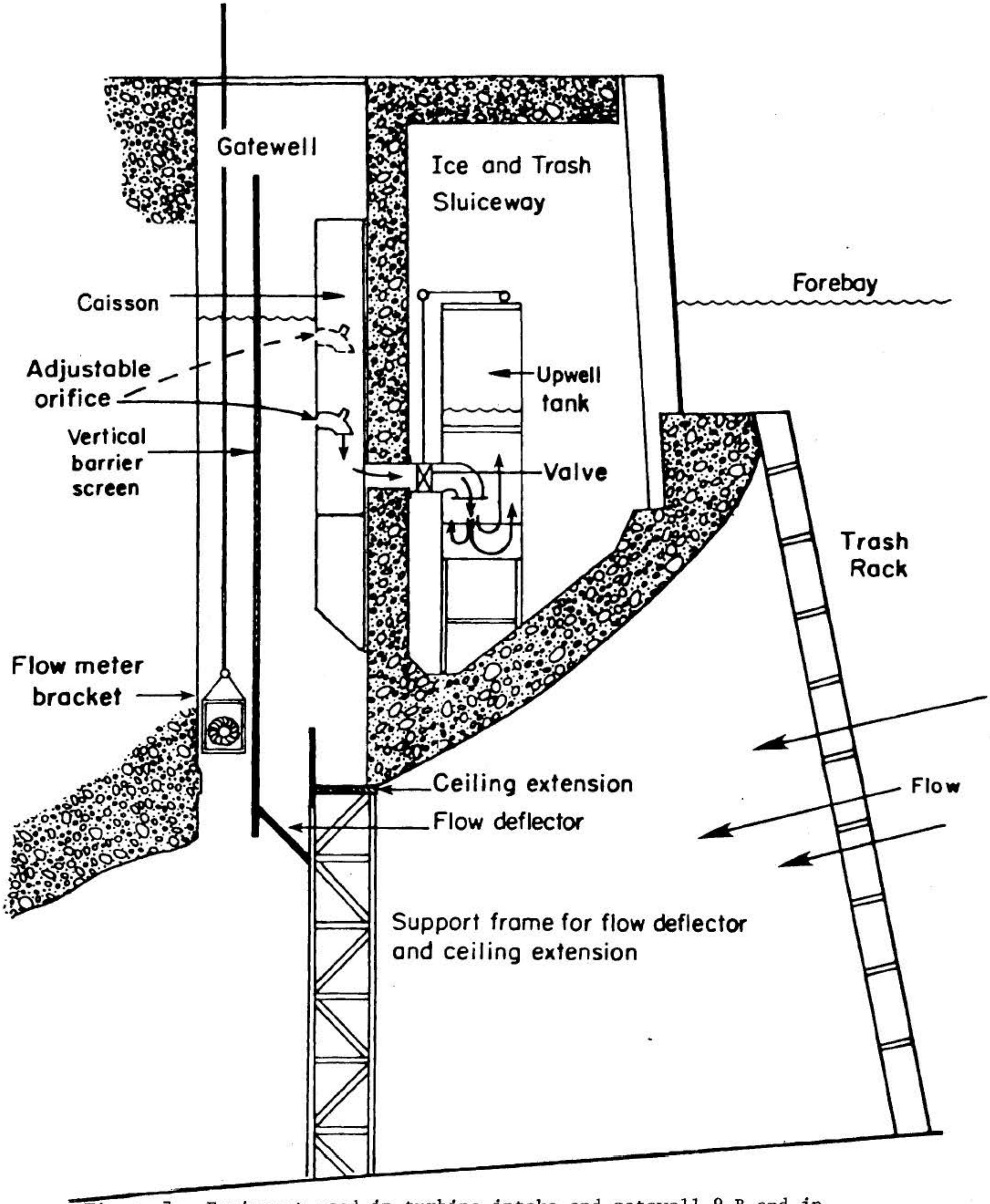


Figure 7.--Equipment used in turbine intake and gatewell 9-B and in the ice sluice at Bonneville Dam to measure fish passage efficiency (FPE) of submerged orifices of various designs.

The gatewell was equipped with a vertical barrier screen. The screen was located about 4 feet from the caisson, a distance approximating the intended position of the screen in the gatewells of the Bonneville Second Powerhouse. The upper and lower portions of the screen were closed with baffles. The resulting screen was 16 feet high and 21 feet wide--the maximum possible screen area available in the gatewells of the Bonneville Second Powerhouse, as presently designed.

A flow deflector was installed in the turbine intake to simulate the presence of a fish-guiding device immediately below the gatewell. Velocity measurements indicated the deflector caused about 250 cfs of flow to pass through the gatewell, creating an average velocity over the gross area of the vertical barrier screen of about 0.74 feet per second.

For certain tests, we compared the percentage of descaled fish in gatewell 9-B with those in gatewell 5-B. In 5-B, the vertical barrier screen was designed for use in the existing powerhouse. The screened area measured 21 feet wide by 26 feet high. The bar screen caused as much as 250 cfs of flow to pass through the gatewell which produced an average velocity over the gross area of the vertical barrier screen of 0.46 feet per second--considerably lower than that in gatewell 9-B.

Individual tests in 9-B lasted 22 to 24 hours beginning about 3:00 p.m. Traps were emptied and the fish identified and counted periodically throughout the test period. At the beginning and end of each test, fish were removed from the gatewell by dipnetting. Fish removed at the start of a test were disregarded; those removed at the end of a test were counted and identified. In addition, fish from the traps and those taken by dipnetting the gatewell were examined to determine the percent of fish having missing scales. Fish with 10% or more of their scales missing were classified descaled.

The relative merit of the various test conditions was determined by comparing their fish passage efficiencies (FPE). FPE is defined as the percentage of fish entering the gatewell during the test that passed out through the submerged orifices before completion of the test. Those fish that remained in the gatewell at the end of a test plus the fish removed from the traps were taken as the total number of fish that entered the gatewell during the test. The number of fish removed from the orifice traps, expressed as a percentage of the total number that entered the gatewell, is the FPE.

Orifice tests conducted at Bonneville Dam in 1976 were conducted entirely with darkened gatewells and back lighted orifices. The gatewells were darkened by means of a plywood cover, and backlighting of the orifices was provided by 75 watt incandescent underwater lights. During the 1977 testing program some of the tests were conducted without the plywood cover, thus allowing natural lighting to illuminate the surface of the gatewell. Also, some of the tests were done without the orifice lights.

Upon completion of the biological studies, we conducted tests to determine the following; 1) the percentage of debris entering gatewells that would pass out through the orifices and 2) whether the orifices would plug with debris. For these tests we used two 12-inch diameter orifices under 6 feet of submergence and head. To ensure using the proper debris, we dipnetted debris from adjacent gatewells. For each test, about 4 cubic feet of debris was placed in a special pen, lowered to a depth of 20 feet in the gatewell, and released. Tests were conducted by releasing debris directly below each orifice (located near opposite corners of the gatewell) and in the center of the gatewell (midway between the orifices). At the conclusion of each test, the debris that passed through the two orifices was removed from each of the orifice traps and weighed, and the debris remaining in the gatewell was collected and weighed. The data were then expressed as the percent of total debris, by weight, that passed through each of the two orifices.

## FISH PASSAGE EFFICIENCY VERSUS DESCALING

Fingerling salmonids that are delayed excessively within gatewells can be descaled by contacting the vertical barrier screen. Water turbulence within gatewells can contribute to this delay by reducing the FPE of the orifices. The presence of a fish-guiding device in the intake not only increases turbulence but also can influence the volume of water passing through the vertical barrier screen. The higher the water volume in relation to the area of the screen, the more likely it is that delayed fish will be descaled.

A comparison was made between the degree of descaling by species and the FPE's of various test conditions (FPE's are shown in Table 1). No statistical relationship between percent descaling and FPE could be established for the range of FPE's experienced during 1977. Only a few of the test conditions had an average FPE, however, that fell below 70%; apparently, the delays of fish associated with FPE's as low as 70% were not detrimental. Eliminating the replicates having fewer than 30 fish of any one species (a minimum number for statistical significance), we find that all of the test conditions except one were above 75% FPE.

That efficiently operating orifices can prevent excessive descaling is shown in Figure 8, which compares, by species, the percentage of fish that were descaled under four separate gatewell conditions. Tests in gatewell 5-B without a bar screen guiding device (and therefore minimum water volume and turbulence) are taken as the primary control condition. The level of descaling under this condition is assumed to be the minimum obtainable. The addition of the bar screen in intake 5-B obviously did not increase the rate of descaling, in spite of the increased turbulence and the fact that fish entering the gatewell over a 24-hour period were prevented from exiting via the orifices.

In gatewell 9-B, which has the smaller vertical barrier screen, delaying fish within the gatewell for a 24-hour period tripled the rate of descaling for spring and fall chinook and coho salmon. On the other hand, operation of the orifices during 24-hour tests reduced the rate of descaling to the level of the control test in 5-B, which has the larger vertical barrier screen.

The results of these tests demonstrate the importance of having vertical barrier screens of sufficient size within gatewells to minimize

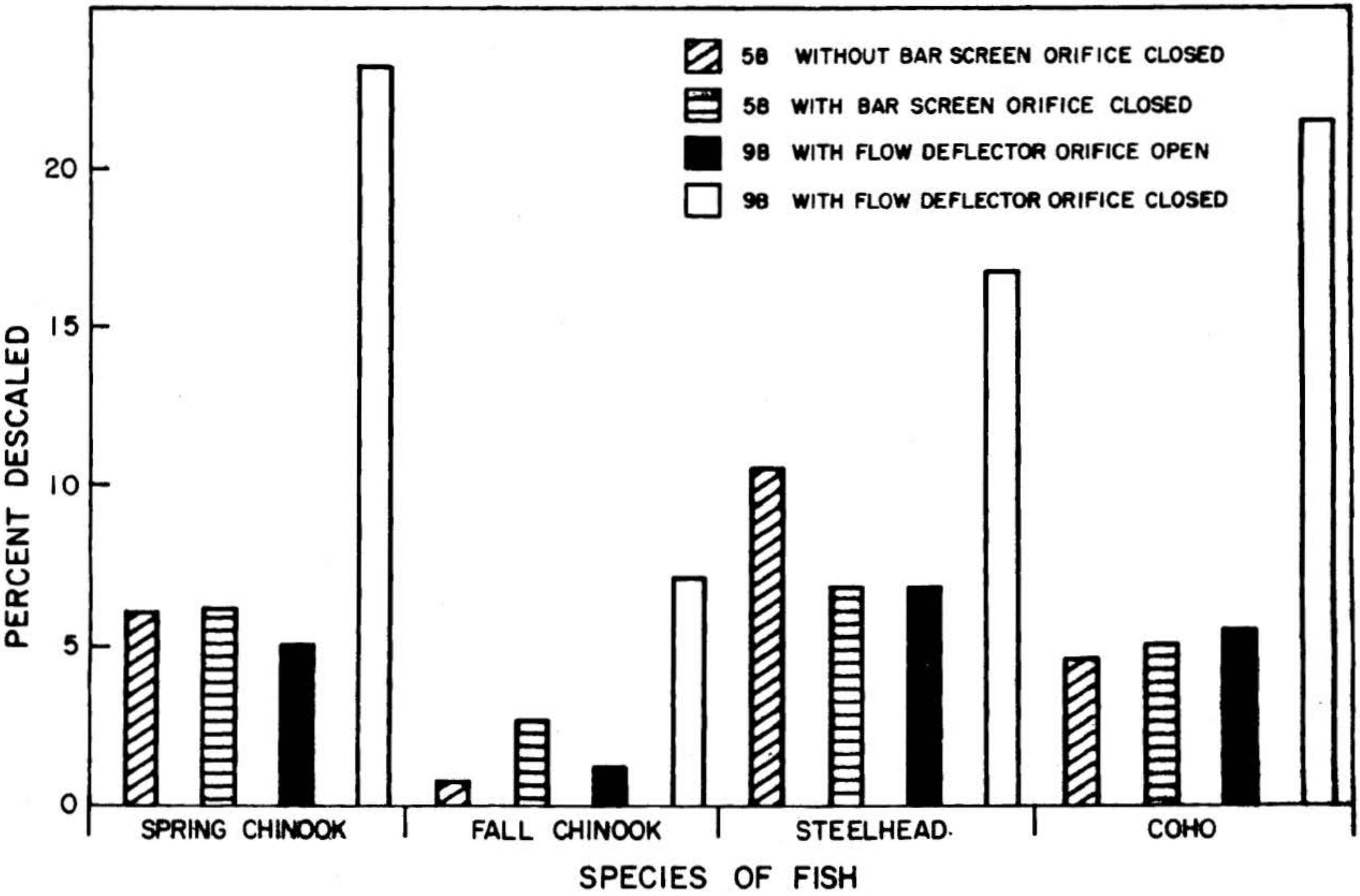


Figure 8.--Percent descaling of fingerling salmonids captured at Bonneville Dam with and without the bar screen (5-B gatewell) as compared to fingerlings from a second-powerhouse simulated gatewell (9-B) with orifices open or closed.

the velocity over the gross area of the screen. At this time, we see no justification for exceeding the present guidelines which call for a maximum of 0.5 fps. These tests also demonstrate the role of efficient orifices in preventing excessive descaling within gatewells.

FISH PASSAGE EFFICIENCIES OF 12-INCH DIAMETER ORIFICES

The 12-inch diameter orifices were tested over a range of submergences of from 3 to 10 feet and included five different test conditions. Each test consisted of at least three replicates. Testing began 21 April and ended 16 June with a total of 46 days of actual testing.

Table 1 provides the FPE for each test completed during the 1977 field season. The weighted averages of the FPE's of the test replicates for each species or race were used either to determine if the specific test condition was acceptable (FPE = 75% or greater) or for comparative analysis.

Figure 9 summarizes the data in Table 1 by combining the average FPE figures for all species in replicates where 30 fish or more were captured. Fish passage efficiencies for replicates with less than 30 fish were not included. It is apparent that one 12-inch lighted orifice in a darkened gatewell provided acceptable FPE through the entire range of submergences (3 to 10 feet). Use of a second orifice increased average FPE from 80% to 89% at 3-foot and 4-foot submergences. Two other single-orifice tests but with a deeper submergence (6 and 10-foot) had average FPE's of 88 and 86%.

Table 1.--Orifice passage efficiency for varying test parameters--Bonneville Dam, 1977. Variables include depth of submergence, orifice lighting, and gatewell illumination. Test duration was 24 hours.

| | Orifice Information | | | | | Gatewell Illumination | | Spring Chinook | | Fall Chinook | | Steelhead | | Coho | | Sockeye | | All species combined | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | No. | Size | Head & Sub. | Light | No Light | Dark | Light | Total No. | FPE % | Total No. | FPE % | Total No. | FPE % | Total No. | FPE % | Total No. | FPE % | Total No. | FPE % |
| 4-21 | 2 | 12" | 3' | | X | | X | 325 | 88 | 4078 | 36 | 6 | 83 | 1 | 100 | 0 | | 4410 | 40 |
| 4-22 | 2 | 12" | 3' | | X | | X | 144 | 70 | 2229 | 44 | 2 | 100 | 0 | | 0 | | 2375 | 46 |
| 4-29 | 2 | 12" | 3' | | X | | X | 65 | 77 | 38 | 76 | 16 | 100 | 12 | 50 | 0 | | 131 | 77 |
| 4-30 | 2 | 12" | 3' | | X | | X | 92 | 65 | 36 | 64 | 32 | 69 | 4 | 25 | 0 | | 164 | 65 |
| | | Weighted average | | | | | | | 79 | | 39 | | 80 | | 47 | | | | 43 |
| 4-26 | 2 | 12" | 6' | | X | | X | 261 | 88 | 176 | 88 | 19 | 84 | 5 | 100 | 0 | | 461 | 88 |
| 4-27 | 2 | 12" | 6' | | X | | X | 185 | 82 | 78 | 81 | 24 | 88 | 0 | | 0 | | 287 | 82 |
| 4-28 | 2 | 12" | 6' | | X | | X | 101 | 80 | 78 | 67 | 15 | 93 | 8 | 100 | 0 | | 202 | 80 |
| | | Weighted average | | | | | | | 85 | | 81 | | 88 | | 100 | | | | 84 |
| 5-1 | 1 | 12" | 3' | X | | | X | 159 | 58 | 19 | 42 | 21 | 57 | 3 | 100 | 0 | | 202 | 57 |
| 5-2 | 1 | 12" | 3' | X | | | X | 521 | 74 | 9 | 89 | 27 | 89 | 24 | 75 | 0 | | 581 | 75 |
| 5-3 | 1 | 12" | 3' | X | | | X | 660 | 79 | 15 | 87 | 32 | 65 | 25 | 76 | 0 | | 732 | 79 |
| 5-4 | 1 | 12" | 3' | X | | | X | 884 | 77 | 5 | 80 | 28 | 89 | 43 | 84 | 0 | | 960 | 78 |
| | | Weighted average | | | | | | | 76 | | 69 | | 76 | | 80 | | | | 75 |
| 5-5 | 2 | 12" | 3' | X | | X | | 700 | 89 | 21 | 100 | 37 | 97 | 138 | 87 | 0 | | 896 | 89 |
| 5-6 | 2 | 12" | 3' | X | | X | | 538 | 82 | 6 | 83 | 29 | 93 | 140 | 94 | 0 | | 713 | 85 |
| 5-7 | 2 | 12" | 3' | X | | X | | 470 | 78 | 7 | 100 | 24 | 92 | 144 | 85 | 0 | | 645 | 81 |
| 5-8 | 2 | 12" | 3' | X | | X | | 488 | 88 | 42 | 98 | 61 | 97 | 120 | 93 | 0 | | 711 | 91 |
| | | Weighted average | | | | | | | 85 | | 97 | | 95 | | 89 | | | | 87 |
| 5-9 | 1 | 12" | 6' | X | | X | | 215 | 82 | 11 | 82 | 22 | 86 | 45 | 87 | 0 | | 293 | 83 |
| 5-10 | 1 | 12" | 6' | X | | X | | 242 | 94 | 5 | 100 | 41 | 88 | 158 | 97 | 3 | 50 | 449 | 94 |
| 5-11 | 1 | 12" | 6' | X | | X | | 182 | 85 | 7 | 86 | 36 | 86 | 134 | 84 | 1 | 100 | 360 | 85 |
| | | Weighted average | | | | | | | 87 | | 87 | | 87 | | 90 | | 75 | | 89 |

Table 1.—Continued.

| | | | | | | Gatewell Illumination | | Spring Chinook | | Fall Chinook | | Steel-head | | Coho | | Sockeye | | All species combined | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Orifice Information | | | | | | | | | | | | | | | | | | |
| Date | No. | Size | Head & Sub. | Light | No Light | Dark | Light | Total No. | FPE % | Total No. | FPE % | Total No. | FPE % | Total No. | FPE % | Total No. | FPE % | Total No. | FPE % |
| 5-13 | 1 | 12" | 10-11.5' | X | | X | | 168 | 90 | 12 | 92 | 30 | 80 | 466 | 85 | 5 | 80 | 681 | 86 |
| 5-14 | 1 | 12" | 10.5-11.5 | X | | X | | 124 | 85 | 4 | 100 | 32 | 100 | 358 | 89 | 7 | 71 | 525 | 89 |
| 5-15 | 1 | 12" | 8'-11' | X | | X | | 134 | 90 | 11 | 91 | 42 | 98 | 372 | 81 | 8 | 75 | 567 | 85 |
| | | Weighted average | | | | | | | 88 | | 93 | | 93 | | 85 | | 75 | | 87 |
| 5-17 | 2 | 12" | 4' | X | | X | | 84 | 92 | 8 | 100 | 30 | 93 | 401 | 92 | 4 | 50 | 527 | 92 |
| 5-18 | 2 | 12" | 4' | X | | X | | 92 | 80 | 11 | 50 | 35 | 94 | 506 | 82 | 12 | 100 | 656 | 82 |
| 5-19 | 2 | 12" | 4' | X | | X | | 81 | 88 | 15 | 73 | 24 | 96 | 384 | 92 | 7 | 86 | 511 | 91 |
| | | Weighted average | | | | | | | 86 | | 71 | | 94 | | 88 | | 87 | | 88 |
| 5-20 | 1 | 12" | 4' | X | | X | | 73 | 85 | 14 | 64 | 41 | 83 | 271 | 82 | 7 | 100 | 406 | 83 |
| 5-21 | 1 | 12" | 4' | X | | X | | 128 | 83 | 32 | 84 | 58 | 89 | 633 | 77 | 8 | 63 | 859 | 79 |
| 5-22 | 1 | 12" | 4' | X | | X | | 126 | 80 | 29 | 66 | 33 | 91 | 692 | 70 | 16 | 88 | 896 | 72 |
| | | Weighted average | | | | | | | 82 | | 73 | | 87 | | 75 | | 84 | | 77 |
| 5-23 | 1 | 12" | 3' | X | | X | | 172 | 93 | 87 | 80 | 27 | 85 | 1516 | 83 | 17 | 71 | 1819 | 83 |
| 5-24 | 1 | 12" | 3' | X | | X | | 69 | 80 | 92 | 80 | 52 | 89 | 1024 | 65 | 22 | 69 | 1259 | 68 |
| 5-25 | 1 | 12" | 3' | X | | X | | 67 | 78 | 134 | 65 | 20 | 95 | 909 | 77 | 12 | 25 | 1142 | 81 |
| | | Weighted average | | | | | | | 87 | | 73 | | 89 | | 76 | | 69 | | 78 |
| 6-2 | 1 | 12" | 7.5-11 | X | | X | | 38 | 74 | 457 | 69 | 18 | 89 | 558 | 69 | 29 | 100 | 1100 | 70 |
| 6-3 | 1 | 12" | 8.5-11.5 | X | | X | | 77 | 87 | 858 | 72 | 33 | 97 | 434 | 72 | 11 | 91 | 1413 | 74 |
| 6-4 | 1 | 12" | 9.5-11.5 | X | | X | | 135 | 93 | 2837 | 78 | 53 | 92 | 217 | 87 | 17 | 100 | 3259 | 79 |
| | | Weighted average | | | | | | | 88 | | 76 | | 93 | | 73 | | 98 | | 76 |
| 6-7 | 2 | 12" | 3' | X | | X | | 76 | 91 | 3198 | 75 | 26 | 100 | 528 | 88 | 5 | 100 | 3833 | 78 |
| 6-8 | 2 | 12" | 3' | X | | X | | 42 | 81 | 2358 | 81 | 22 | 95 | 342 | 97 | 13 | 77 | 2777 | 80 |
| 6-9 | 2 | 12" | 3' | X | | X | | 73 | 85 | 1627 | 76 | 28 | 100 | 136 | 98 | 3 | 66 | 1867 | 85 |
| | | Weighted average | | | | | | | 86 | | 77 | | 99 | | 92 | | 81 | | 79 |

Table 1.—Continued.

| | | Orifice Information | | | | Gatewell Illumination | | Spring Chinook | | Fall Chinook | | Steel-head | | Coho | | Sockeye | | All species combined | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | No. | Size | Head & Sub. | Light | No Light | Dark | Light | Total No. | FPE % | Total No. | FPE % | Total No. | FPE % | Total No. | FPE % | Total No. | FPE % | Total No. | FPE % |
| 6-14 | 1 | 12" | 4' | | X | X | | 159 | 92 | 567 | 91 | 16 | 100 | 84 | 99 | 5 | 80 | 831 | 92 |
| 6-15 | 1 | 12" | 4' | | X | X | | 80 | 81 | 299 | 87 | 7 | 100 | 35 | 97 | 2 | 100 | 423 | 87 |
| 6-16 | 1 | 12" | 4' | | X | X | | 61 | 87 | 309 | 91 | 11 | 100 | 91 | 100 | 0 | | 472 | 92 |
| | | | Weighted average | | | | | | 88 | | 90 | | 100 | | 99 | | 86 | | 91 |

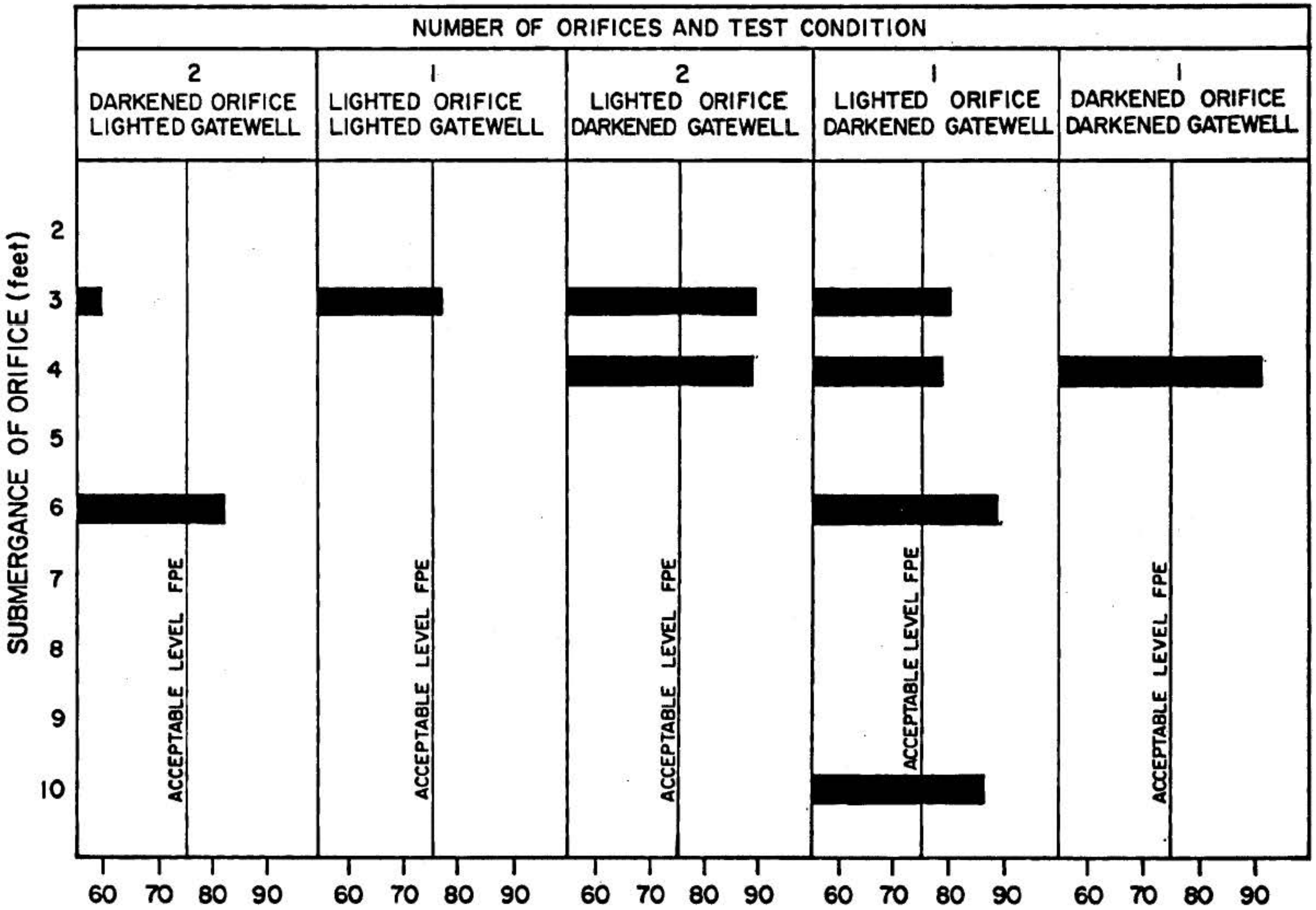


Figure 9.--The average FPE's for 12-inch diameter orifices for various submergences and orifice-gatewell conditions tested at Bonneville Dam in 1977.

Lighting the orifice in a darkened gatewell is desirable, especially with fall chinook salmon. The only test where FPE dropped below the 75% acceptable level occurred when these conditions were reversed (unlighted orifice--lighted gatewell). During this test, conducted between 21 and 30 April, average FPE was only 39% for fall chinook salmon (Table 1).

Comparisons of the total catches for all of the double orifice tests indicated no significant preference for either the north or south orifice (left and right if facing upstream). The north trap caught 7,210 fingerlings and the south trap caught 6,588 (52 versus 48%). Figure 10 shows the comparative results of the north and south trap catches for five tests. In three of the five tests, fish showed a slight preference for the north orifice. However, in the one situation where two tests were conducted with the same orifice-gatewell condition, the reverse was true.

PASSAGE OF DEBRIS THROUGH SUBMERGED ORIFICES

The passage of significant quantities of debris through submerged orifices can influence the design of the bypass. Mixing fingerlings and debris in turbulent water is obviously detrimental. We conducted a series of tests to determine the following: 1) the percentage of debris entering gatewells that passes out through the orifices and 2) whether the orifices plug with debris. Debris was released in three locations: 1) below the north orifice, 2) below the south orifice, and 3) in the center of the gatewell midway between the orifices.

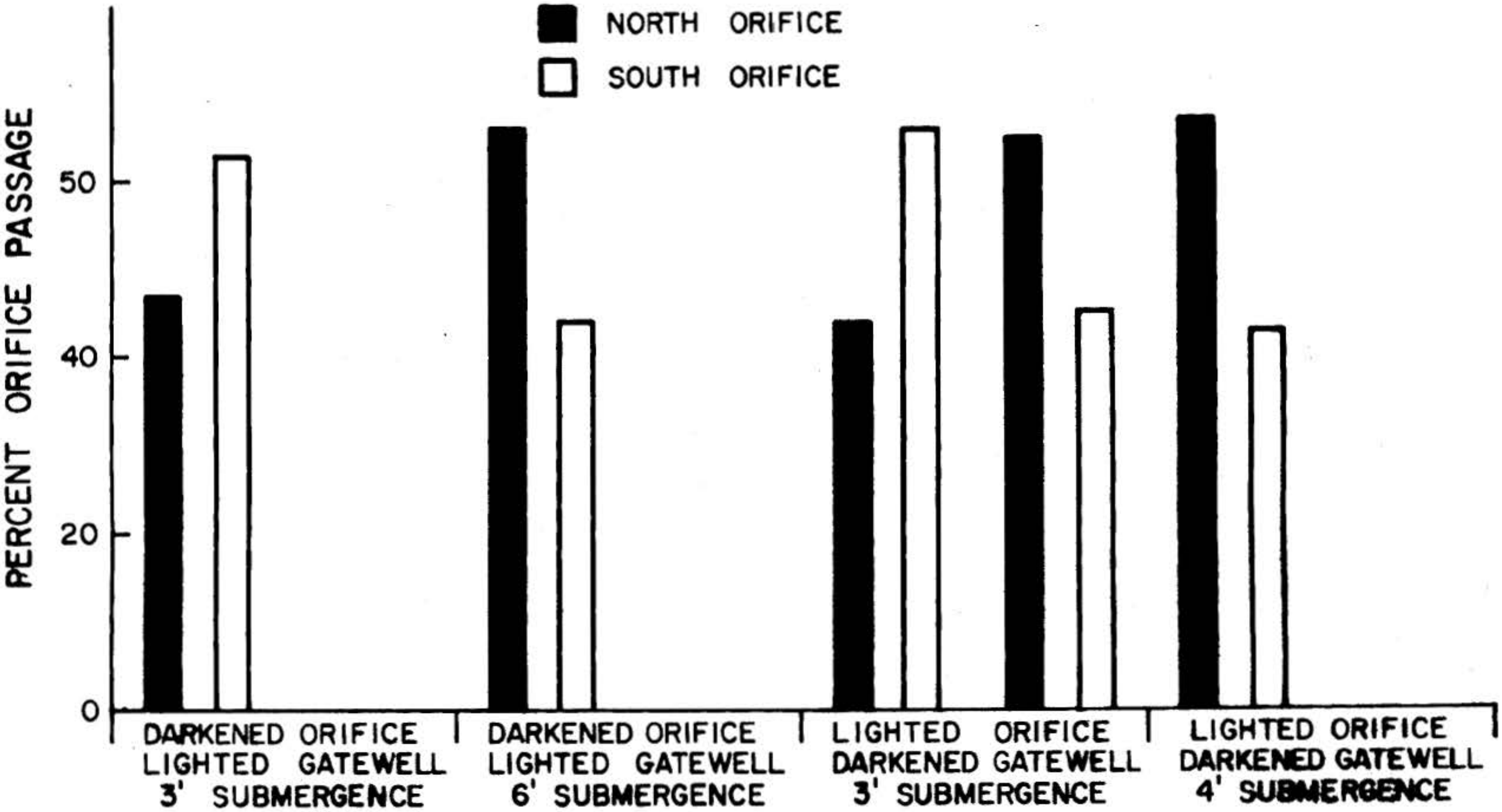


Figure 10.--A comparison of the percentage of fingerlings that utilized a north or south orifice in exiting a gatewell at Bonneville Dam in 1977.

Figure 11 shows the percent of debris that passed out through each orifice according to the release location of the debris. In all tests, not less than 25% of the debris released into the gatewell passed out through the orifices. However, none of the debris became lodged in the orifice.

## CONCLUSIONS

1. Significant descaling of fingerlings occurs when fish are detained in gatewells equipped with vertical barrier screens, especially of the design for the Bonneville Second Powerhouse. To provide fish timely egress from the gatewells, an orifice system with at least a 75% FPE is needed.
2. One 12-inch diameter lighted orifice in a darkened gatewell provides acceptable (>75%) FPE through the entire range of submergence (3 to 10 feet).
3. During the tests conducted in 1977, the fish showed no preference for either the north or the south orifice.
4. A significant percentage of the total debris entering gatewells can be expected to pass out through 12-inch diameter orifices. Although 12-inch diameter orifices will not likely become plugged, the presence of this debris in the fish bypass could be detrimental and may require special handling.

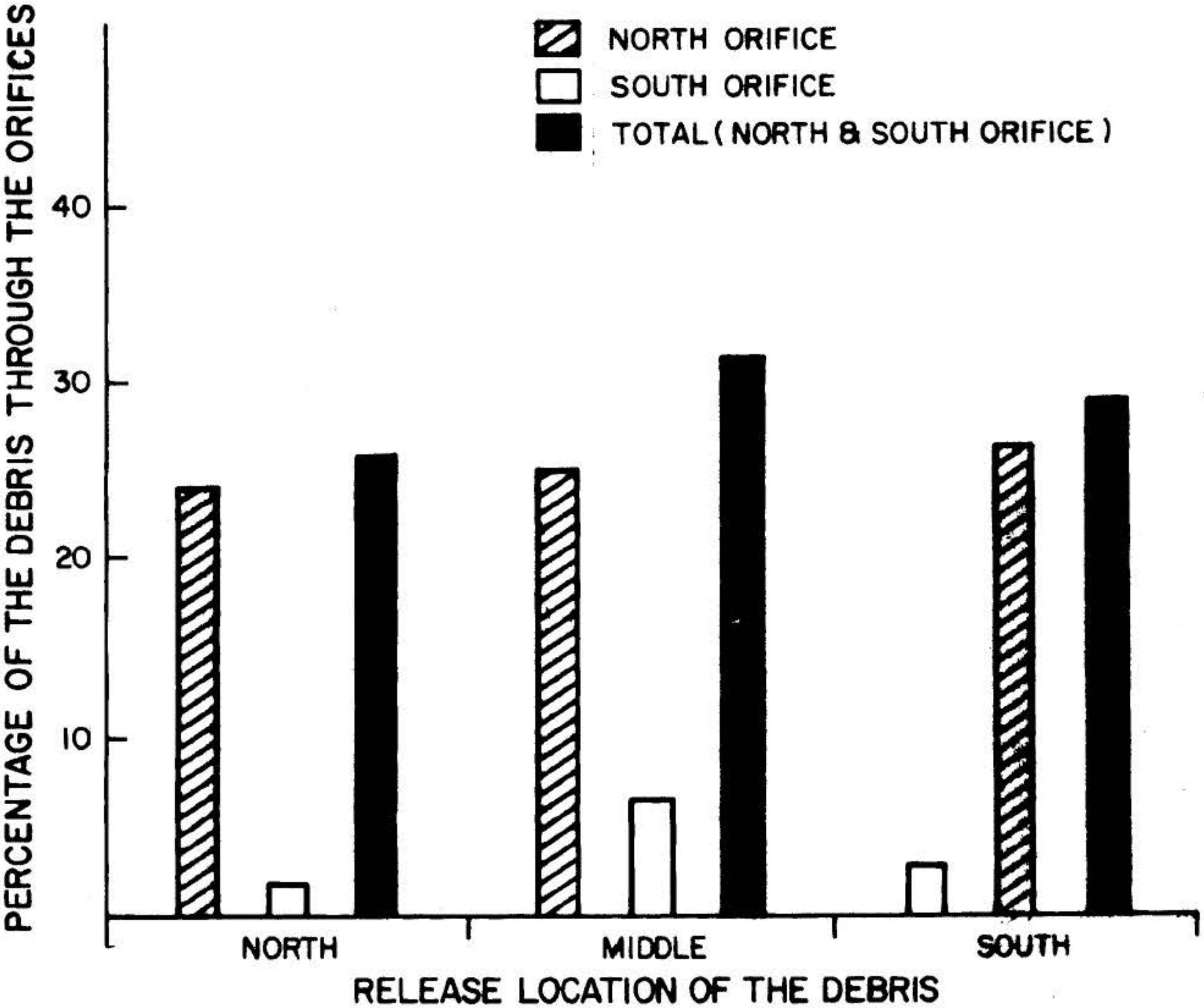


Figure 11.--Percentage of debris that passed through a 12-inch diameter orifice with 6-foot head when debris was released in the north, middle, and south end of a gatewell at Bonneville Dam in 1977.

## SUMMARY

Research to improve fingerling protection systems for low head dams is directed toward the development of 1) an improved method for guiding fish out of intakes and into gatewells, 2) design and operating criteria for submerged orifices that will pass fish efficiently out of gatewells and into a bypass, and 3) methods for releasing bypassed fish into predator-free zones of the tailrace downstream from dams.

This research program was initiated in 1975. During the 1977 field season we not only completed research on efficient submerged orifices, but initiated tests of a prototype fish-guiding device that intercepted only the upper 3.5 feet of water in the turbine intake and successfully guided about half of all the fish entering intakes safely into the corresponding gatewell.

In 1978, research on the first prototype guiding device will be completed at Bonneville Dam, and simultaneously research on a larger version will be initiated at McNary Dam.

Also, in 1978, we propose a study for Bonneville Dam to determine the relative survival of fish released into two areas of the tailrace believed to be relatively devoid of predators. The results of this study will not only apply to methods of bypassing fingerlings around the Bonneville First Powerhouse, but also may result in identifying a safer release location for fish transported from Little Goose, Lower Granite, and McNary Dams.