FINAL REPORT

RESEARCH ON GATEWELL-SLUICE METHOD OF BYPASSING DOWNSTREAM MIGRANT FISH AROUND LOW-HEAD DAMS

By

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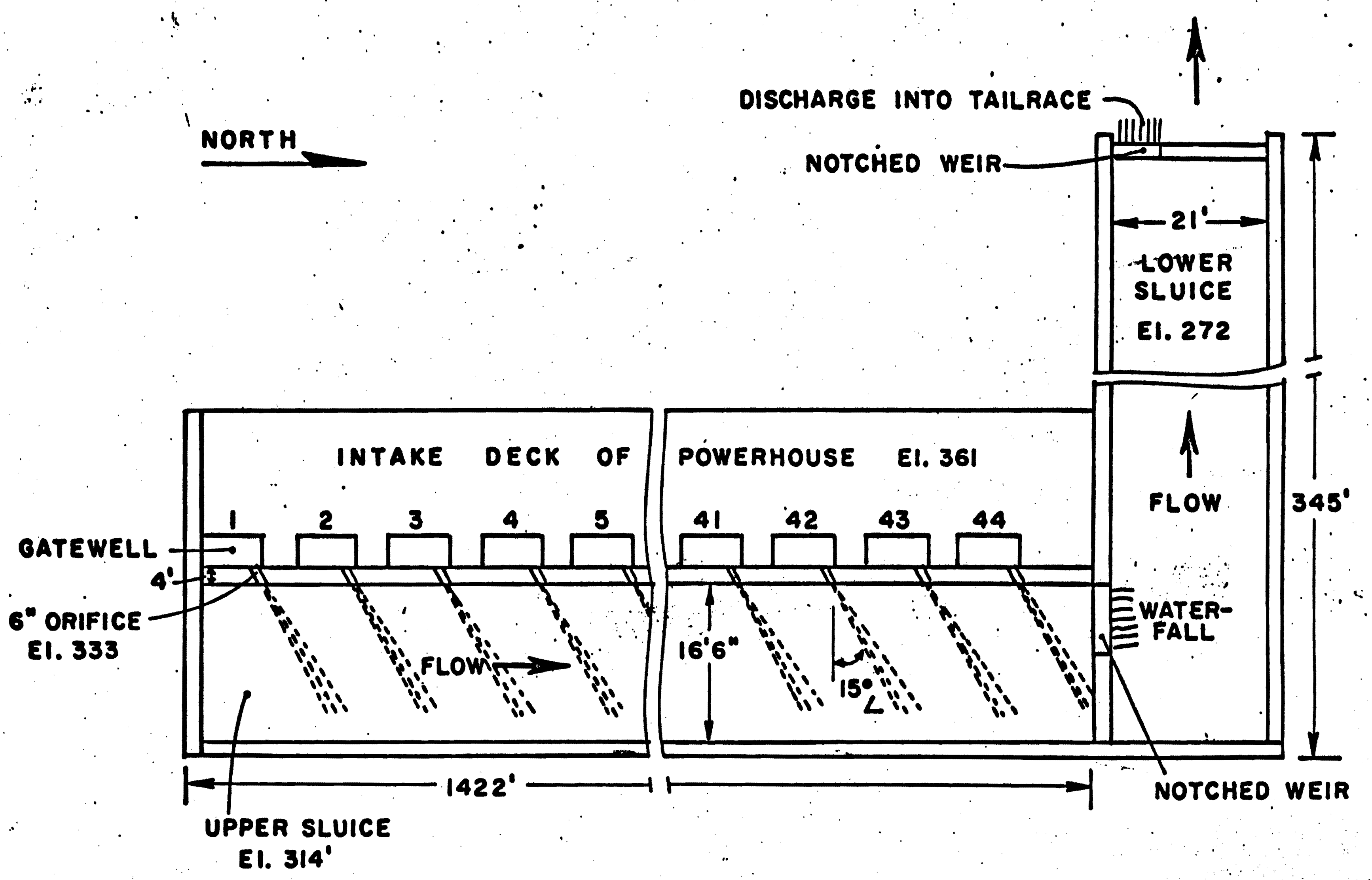

Figure 2.--Plan view of fish bypass system at McNary Dam.

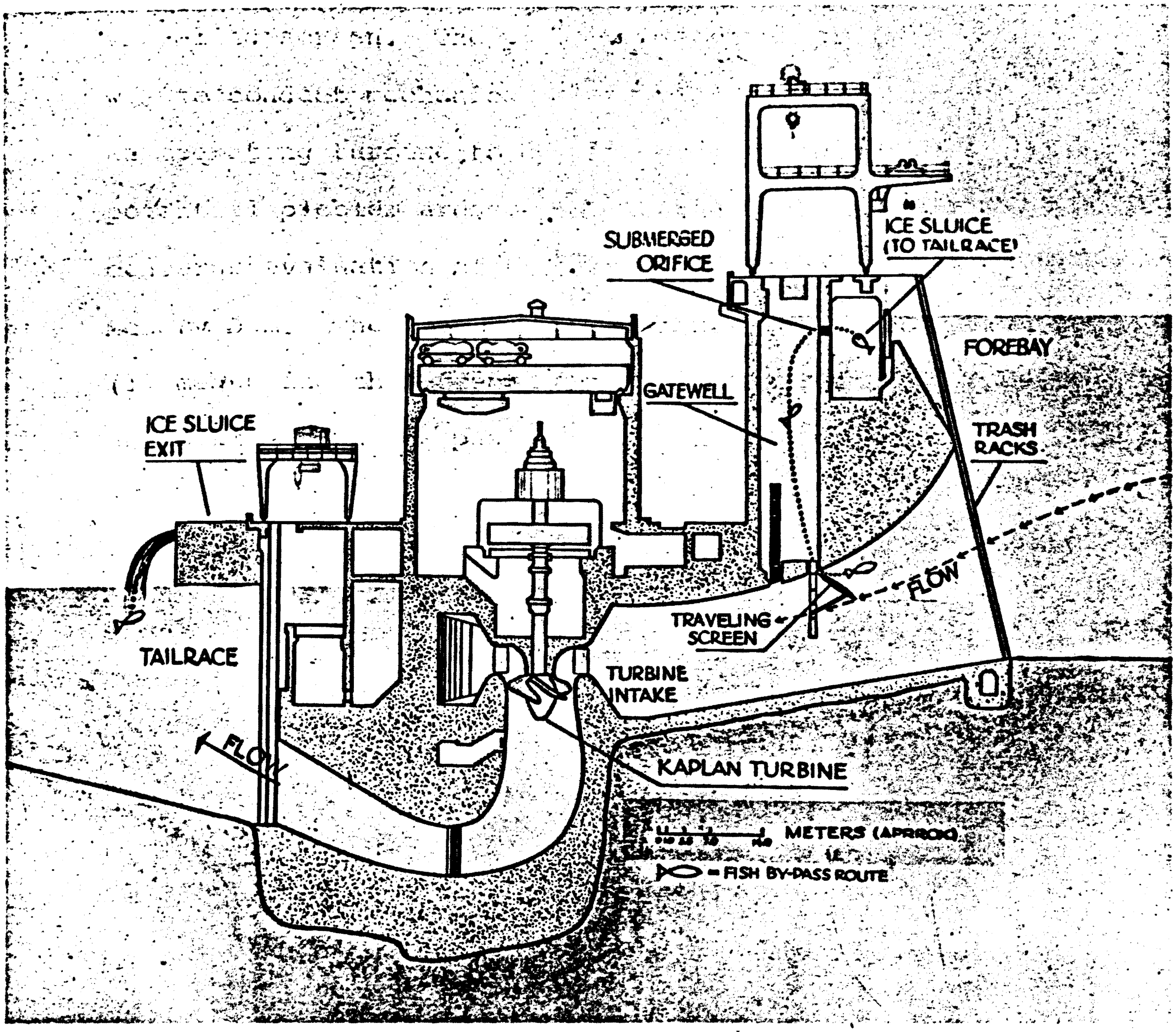

Figure 1.--Section of a typical turbine showing fish bypass route around dam.

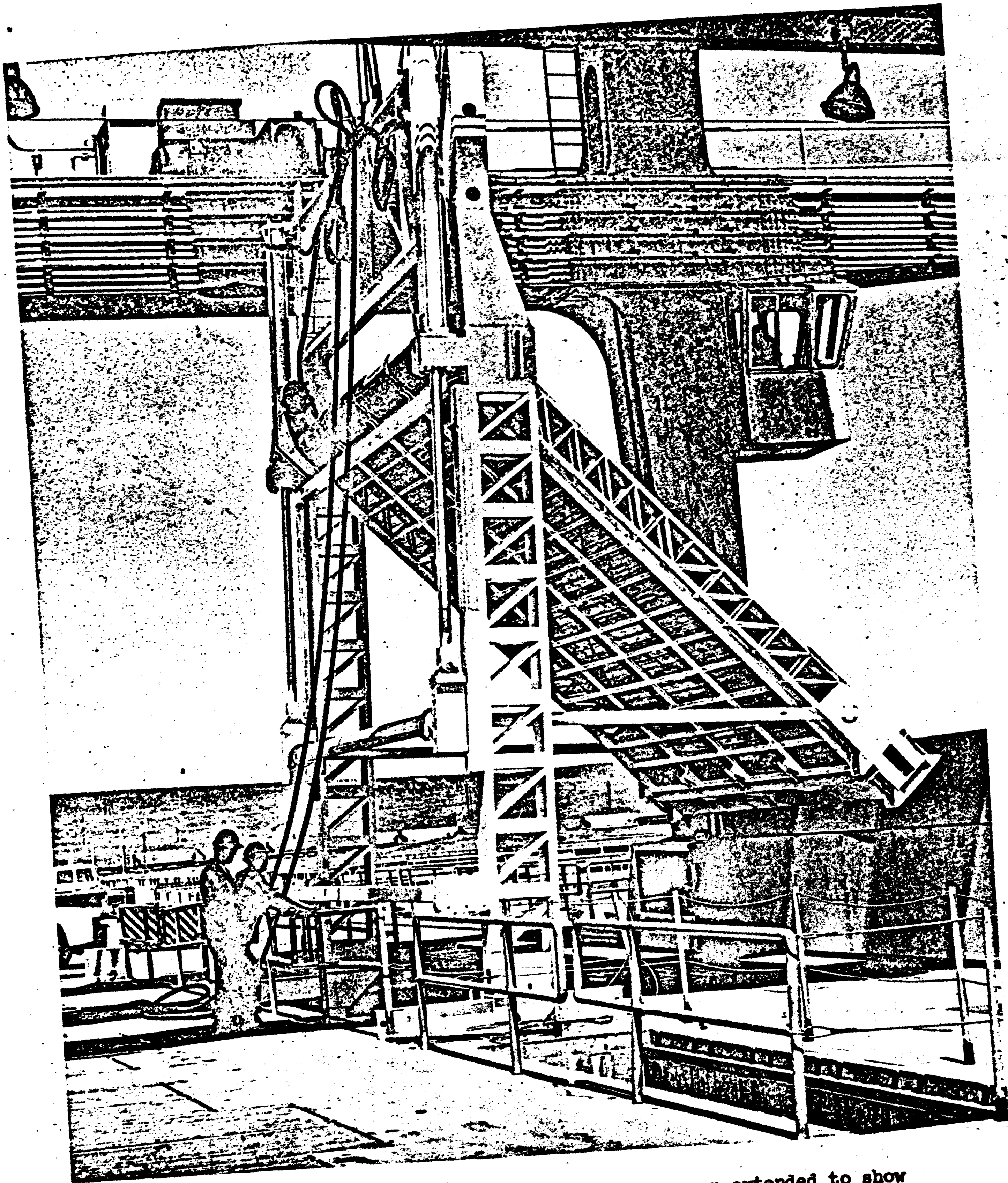

Figure 3.--Traveling screen structure with screen extended to show position during operation.

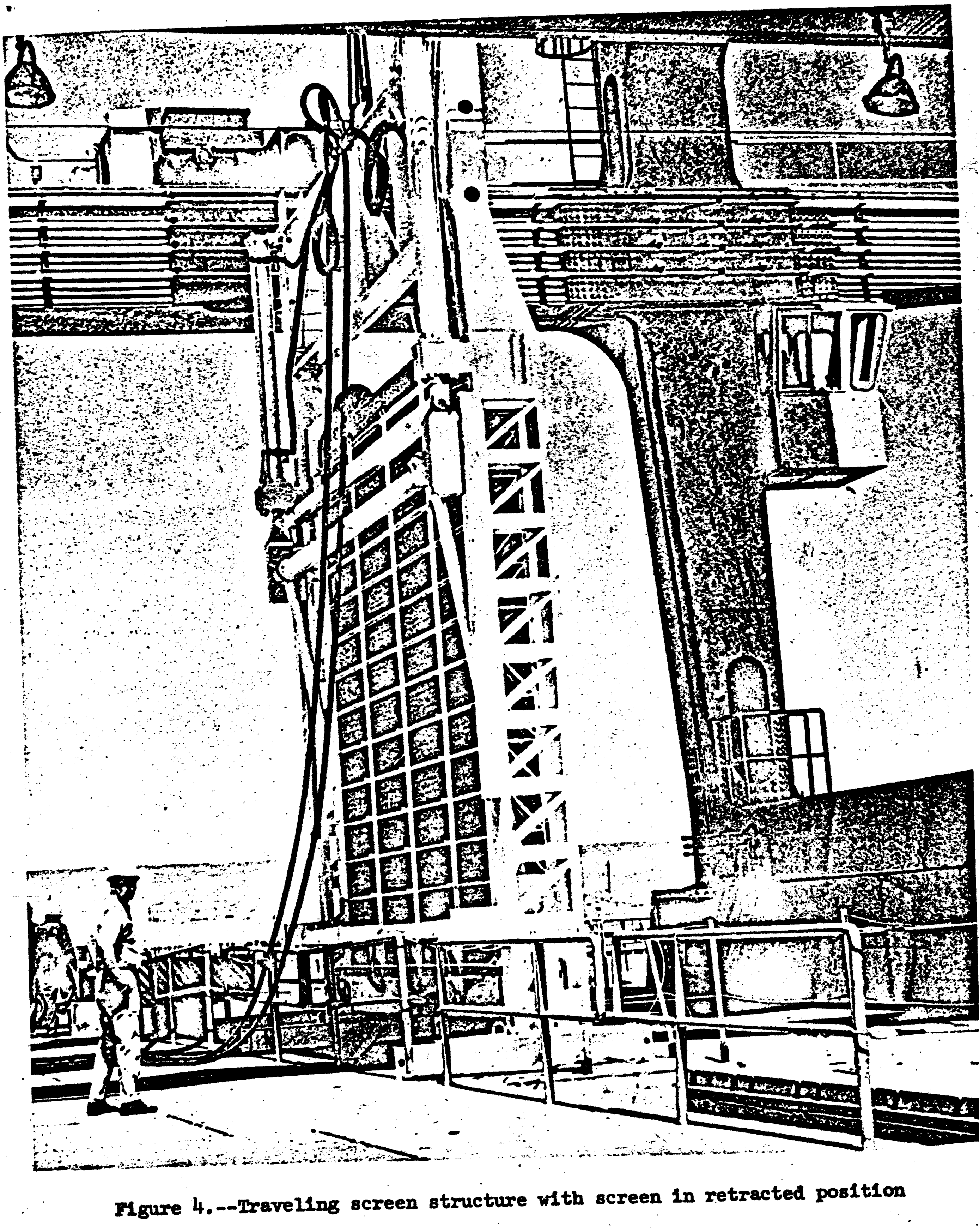

Figure 4.--Traveling screen structure with screen in retracted position for installation or removal from gatewell.

INTRODUCTION

Research was conducted by the Bureau of Commercial Fisheries during 1969 to evaluate a method for safely bypassing fingerling salmon (chinook, Oncorhynchus tshawytscha; coho, O. kisutch; and sockeye, O. nerka) and steelhead trout, Salmo gairdneri, around low-head dams (figs. 1 and 2). The work entailed the (1) construction and preliminary testing at Ice Harbor Dam of a prototype traveling screen for diverting fish from turbine intakes into gatewells (Long and Marquette, 1967) and (2) evaluation of the gatewell-sluice fish bypass at McNary Dam. These investigations were conducted in cooperation with the U.S. Army Corps of Engineers, Walla Walla District, under contract No. DACW68-69-C-0082 to develop a successful bypass system for use at all existing and proposed dams.

The first section of this report deals with the construction of, and results of preliminary tests with, the traveling screen. The primary objective of these studies was to conduct mechanical tests with the device installed in an operating turbine to examine performance and to pinpoint potential problem areas. The second section of the report concerns evaluation of the gatewell-sluice fish bypass at McNary Dam. The objectives of this research consisted of (1) measuring the effect of illumination of the gatewells and orifices on the passage of fish into the sluice,

(2) determining the survival of fish passing from gatewells through orifices to the downstream end of the sluice, and (3) making observations on (a) the species of fish using the bypass and (b) the abundance of predators residing in the bypass system. A final objective (4) was to determine survival of the bypassed fish in relation to where they were released in the tailrace.

PRELIMINARY TEST OF TRAVELING SCREEN

Mechanical tests of the traveling screen (fig. 3) were made in the spring and fall of 1969 at Ice Harbor Dam. Construction of the device was completed in time for only brief testing during the latter part of the spring migration of juvenile fish. At that time, an attempt was also made to measure the number of fish diverted into the gatewell that contained the traveling screen. During the fall, the device was operated continuously in a nonoperating turbine unit to assess wear on mobile units of the screen over an extended period.

In the spring, the traveling screen was installed in turbine intake 3-B (fig. 4). A test was made on May 28, but was limited to 3 hours when the screen failed to travel under full turbine loads. At the completion of this test, a 24-hour test was accomplished by reducing the load on the turbine every 3 to 4 hours to enable travel of the screen and permit intermittent cleaning.

Diversion of fish into the gatewell was measured during two brief tests in the spring. The number of fish that entered the gatewell (3-B) containing the traveling screen was compared to the number of fish entering an adjacent gatewell (3-A) that served as a control. Fish were removed from the gatewells with a standard gatewell dipnet (Bentley and Raymond, 1968). Gatewells 3-B and 3-A were dipnetted (fig. 5) before the start of each test to remove all fish and again at the end of each test to determine the number of fish that had entered each gatewell during the intervening period. The turbine was operated at the normal generating load of 103 megawatts except during intermittent periods of the 24-hour test as previously noted.

Results of the tests are shown in table 1. At the end of the 3-hour test, 62 fish had entered the gatewell containing the traveling screen (3-B) compared to 18 fish in the adjacent control gatewell (3-A). In the longer test (24 hours) on May 28-29, fewer fish (74) were found in 3-B than in 3-A (111). Due to the brevity of these tests and the fact that the screen was not functioning as designed, a determination of the efficiency of the screen must await further testing.

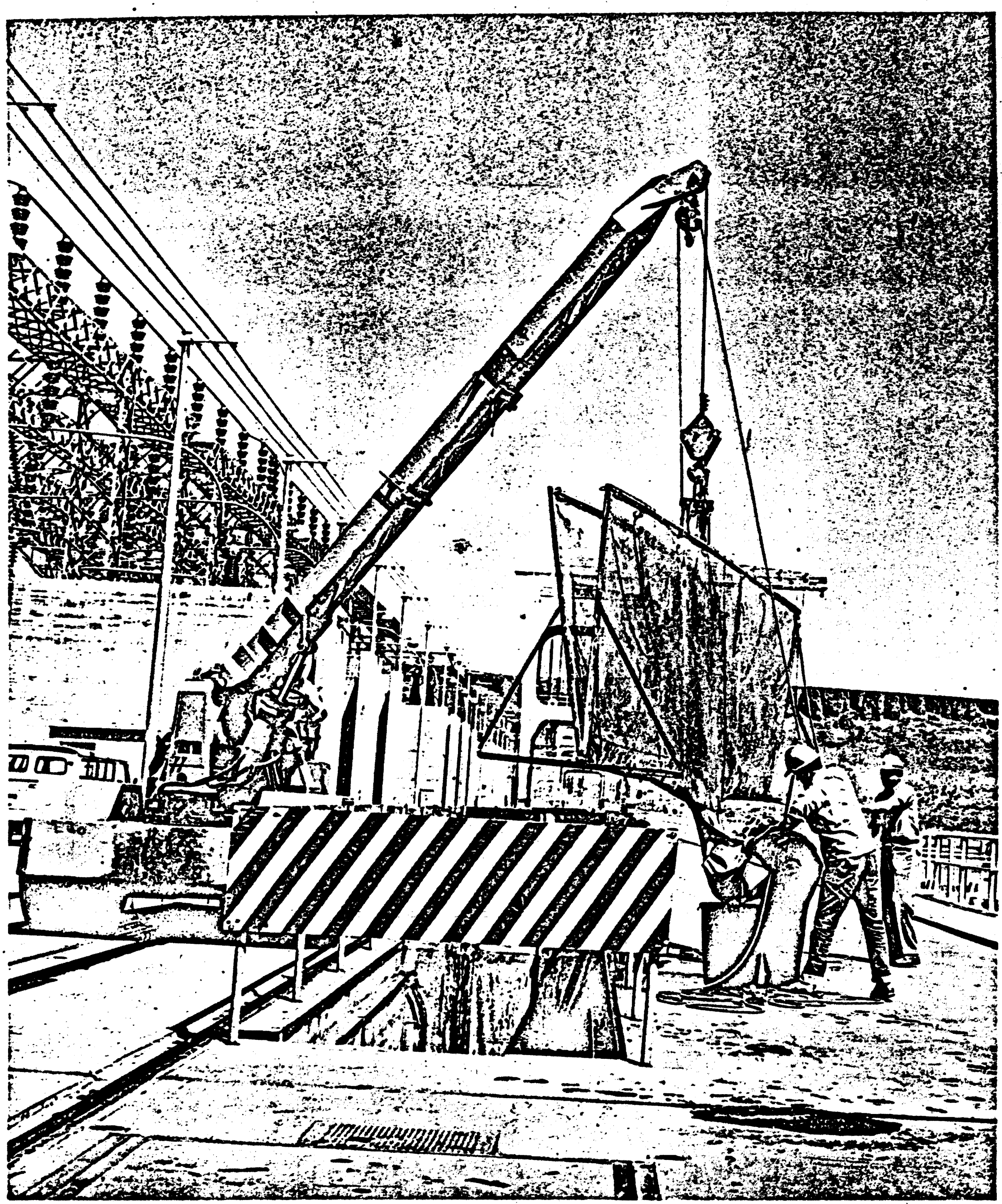

Figure 5.--Dipnet used to remove fish from gatewells.

Table 1.--Number of salmon and trout removed from gatewell containing traveling screen (3-B) and number of salmon and trout removed from gatewell without traveling screen (3-A) at Ice Harbor Dam, spring 1969

Date, length of test (in parentheses), and species of fish	Fish removed	
	Gatewell without screen (3-A)	Gatewell with screen (3-B)
	Number	Number
May 28 (3 hours)		
Species mixed	18	62
May 28-29 (24 hours)		
Chinook	29	31
Steelhead	75	43
Coho	7	0
Sub-total	111	74

During the fall, the traveling screen was again given a mechanical test when it was installed in intake A of skeleton unit 4. Although no load was exerted on the screen because of lack of flow, this test was made to reveal any problems that might occur during continuous operation for an extended time. The screen traveled at 1.5 f.p.s., which is three times the proposed normal operating speed. It operated successfully from October 23 to November 21, a period of 29 days. At that time, the screen suddenly stopped and the test was terminated. Examination showed that a connector link on the drive chain of one of the four screen sections had failed because it had been improperly secured. A complete inspection of the screen sections and drive chains revealed no other detectable wear; no modification of this component is recommended at this time other than the repair of the faulty connector link.

Completed and proposed modifications of other components of the traveling screen are summarized as follows:

1. A faulty relief valve in the hydraulic drive unit was replaced; tests show that the drive unit is now functioning properly and should propel the screen under usual operating loads.

2. All welds made by outside contractors were inspected; questionable welds were removed and remade by a certified welder under direct supervision of the Bureau.

3. The length (height) of the support frame will be increased so that the large-diameter hinge bar will be positioned in the gatewell during operation. Moving the hinge bar upward into the gatewell should reduce the amount of flow deflected from the intake into the gatewell.

4. A submerged gear box, now leaking, will be modified to prevent further loss of fluid.

5. The sides of the frame of the traveling screen will be covered to prevent debris from entering the interior of the operating structure.

EVALUATION OF GATEWELL-SLUICE FISH BYPASS

The gatewell-sluice bypass system consists of gatewells, gatewell orifices, and a sluice (or special bypass) to divert fish around the dam. Success of the system depends on large numbers of fish entering the gatewells and voluntarily passing through the orifices into the sluice or special bypass. An evaluation of a typical system was made at McNary dam in the spring of 1969 when the entire bypass was operational for the first time.

Research Area and Field Conditions

Some low-head dams on the Columbia and Snake Rivers (Bonneville, The Dalles, McNary, and Ice Harbor) contain sluices to divert ice and trash around the dams. A single wall (approximately 4 feet thick) separates the gatewells from the sluice. Small orifices drilled through this wall into each gatewell provide an effective method of discharging downstream migrant fish into the sluice for bypass around the dams (fig. 6).

Most turbine-intake gatewells of low-head dams are covered with concrete slabs, steel grills, or a combination of both, but some may always be uncovered. Illumination within the gatewells varies, therefore, and comes from sources such as daylight, available night light, or electric lights; some gatewells are always dark unless opened for turbine overhaul or other purposes.

Orifices were installed in all 44 gatewells at McNary Dam by the Corps of Engineers before the fingerling migration in the spring of 1969. These openings are 6 inches in diameter and are submerged 2 to 7 feet, depending upon the water level in the forebay. Each orifice is 20 inches from the north corner of the gatewell. Previous research by Liscom (1966) indicated that more fish would enter the orifices if they were located in a corner of the gatewell. The orifices were drilled horizontally into the wall at an angle of 15 degrees to prevent the discharged water from striking the opposite wall of the sluice. Discharge from each orifice averaged about 2.75 c.f.s. The angle of discharge (15°) was in line with the downstream flow of the sluiceway.

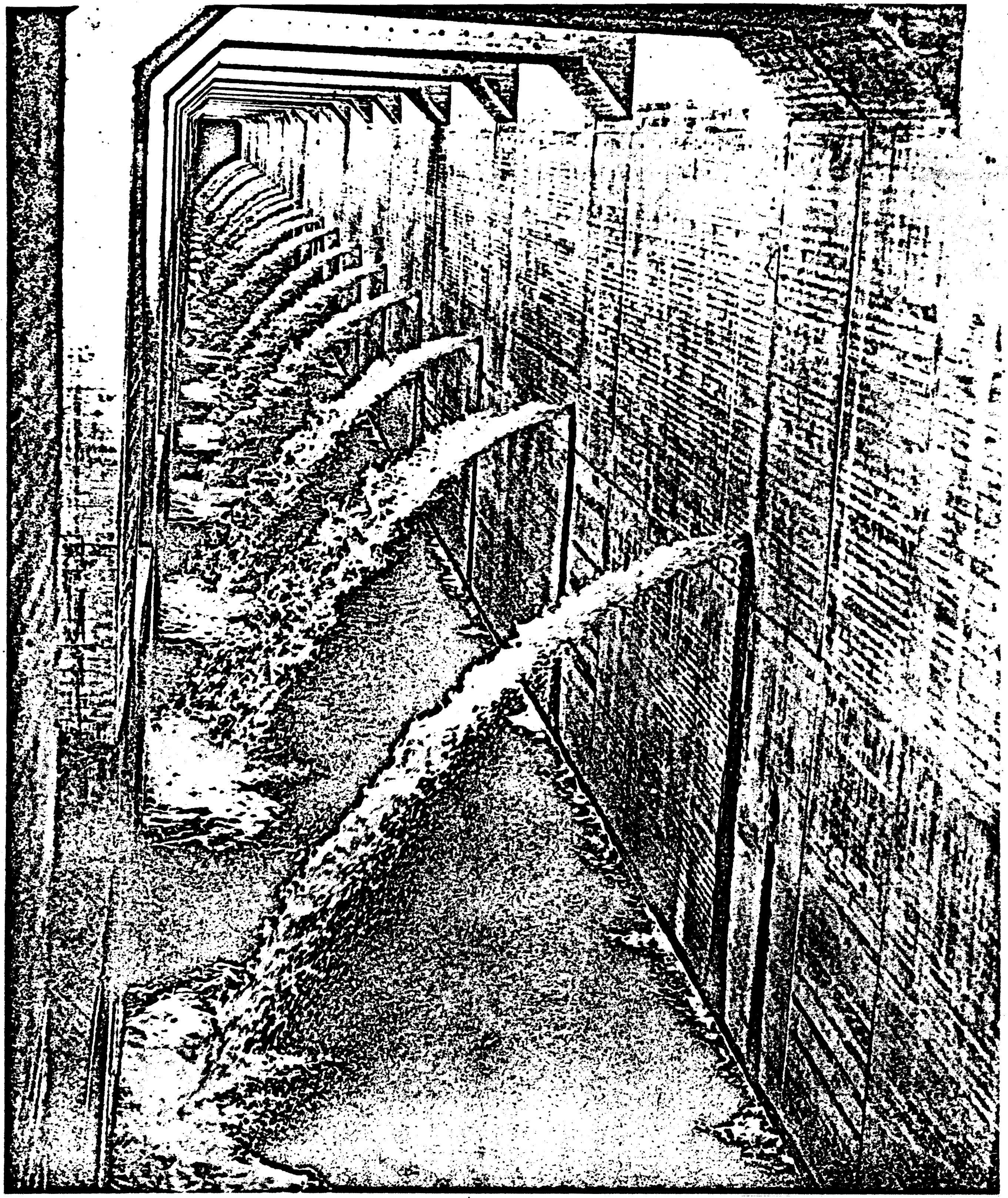

Figure 6.--Orifices at McNary Dam permit fish in gatewells to pass into ice sluice where they are bypassed around dam and discharged into tailrace.

At McNary Dam and similar structures, the upper section of the sluice is exposed to ambient light, to which the gatewell orifices are also exposed. Gatewell bypass systems recently incorporated at John Day, Lower Monumental, and Little Goose Dams operate in complete darkness. As illumination can directly affect the rate of fish passage through the orifices, the optimum light condition conducive to the greatest passage of fish must be determined.

The sluice at McNary Dam contains two modifications to lessen the possibilities of fish loss during bypass. A weir at the downstream end (north end) of the upper sluice maintains a water depth of about 3 feet in this section and provides a plunge pool to receive fish that pass through the orifices and fall about 16 feet into the sluice. This weir contains an overflow area (or notch) which directs the waterfall into deeper portions of the plunge pool in the lower sluice. Another weir at the downstream end of the lower sluice (fig. 7) provides a pool 10 feet deep except for a shallow portion in the extreme northeast corner. A valve at the base of the lower weir permitted dewatering of the lower sluice when required. The waterfall between the upper and lower sluice was 33 feet high. Approximately 120 c.f.s. was discharged from the sluice when all orifices were operating.

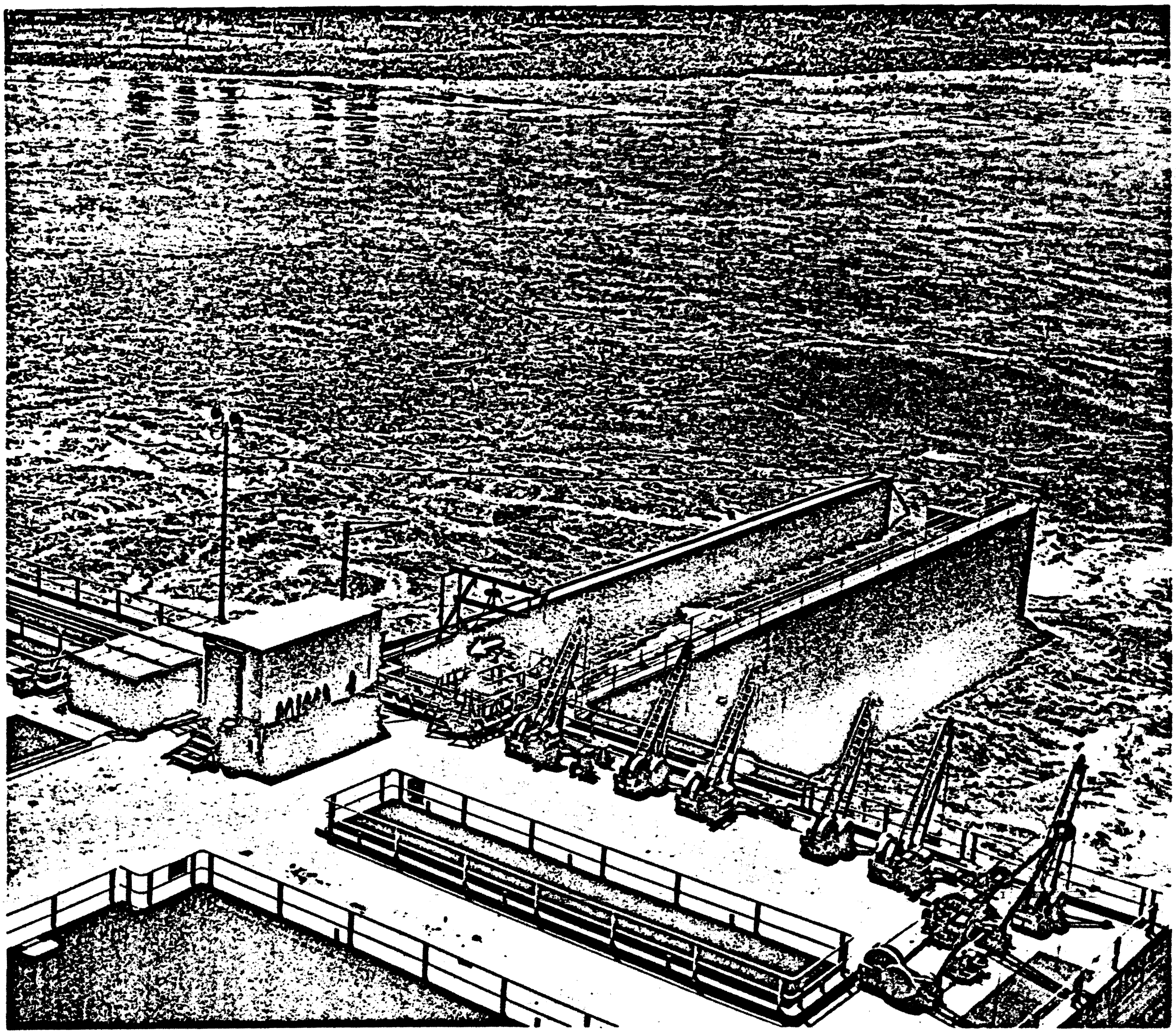

Figure 7.--Dipper trap (arrow) and notched weir in the downstream section of the ice sluice at McNary Dam. Spillway discharge is on right and turbines on left. Hoses extending from wall of sluiceway are for release of migrants in specific tailrace areas.

A high runoff during the spring of 1969 resulted in an extended period of spilling at all dams on the Columbia and Snake Rivers. Spillage prevailed at McNary Dam from March 29 to July 22. As a result, our proposed test procedures and requirements were adversely affected by the unusual spill conditions. For example, many fish that normally would have entered the turbine intakes were carried downstream through the spillways. This greatly reduced the number of naturally migrating fish available for test purposes. In addition, widespread spilling at upriver dams created high levels of nitrogen gas supersaturation which produced gas bubble disease among the captured migrants and made many of them unfit for test animals. Continued heavy spilling also resulted in severe turbulence throughout the tailrace area which, in turn, ruled out the possibility of comparing survival of fish discharged into slackwater areas (nonexistent) with that of those released in the frontroll of the turbine discharge. Despite these difficulties, most tests proceeded as planned with the major exception of those involving release of fish in the tailrace area. Wild or naturally migrating fish were used in all tests except the tailrace releases where hatchery-reared coho salmon were employed to augment the limited sample of wild fish.

Effect of Illumination on Fish Passage

The effect of illumination on the rate of fish passage through the bypass system was determined by subjecting the gatewells and orifices to various light conditions and by comparing the numbers of naturally migrating fish remaining in a gatewell with the number of fish passing through its associated orifice. The experiment was conducted in the A and B gatewells of units 8 through 11. Bentley and Raymond (1969) previously established that fish enter the A and B gatewells in equal numbers at McNary Dam. In addition, units 7 through 12 were operated at equal loads throughout the entire experiment to ensure (as much as possible) an equal distribution of fish between the units.

Fish remaining in the gatewells and those passing through the associated orifices were captured independently to permit comparative enumeration. Naturally migrating fish were removed from the gatewells with a standard gatewell dipnet (fig. 5). The gatewells were fished to a depth of 30 feet; each gatewell was dipnetted three times. Fish passing through the orifices were captured in inclined-plane traps (fig. 8) mounted in the sluice adjacent to the outfall from the gatewell orifices. The top section of each trap was screened to permit a continuous overflow of excess water without loss of fish. Each trap was lined with a net to facilitate the rapid removal of captured fish. All fish

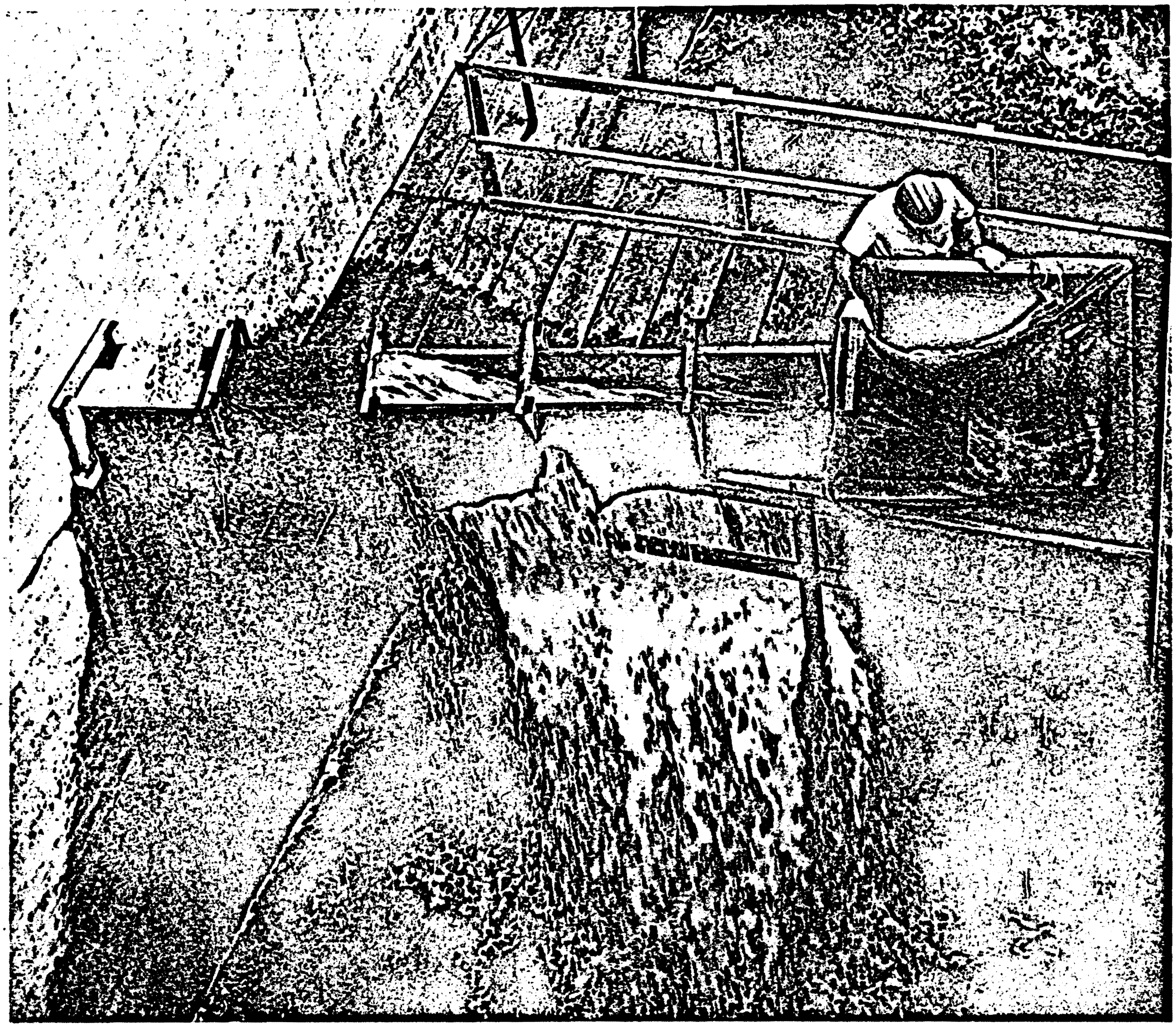

Figure 8.--Inclined-plane traps permitted capture of all fish passing through seven test orifices at McNary Dam. In this view, a 3-foot section of trap was covered with black plastic sheeting to darken exit of orifice.

removed from the gatewells and orifice traps were transported around the dam and released downstream to avoid inclusion of these fish in another study that was also being conducted at this time.

The effect of illumination was determined by testing various lighting conditions for the gatewells and orifices. The gatewells were either (1) uncovered or (2) covered and totally dark. Light conditions (gatewells uncovered) which existed when high efficiencies of passage were obtained in the spring of 1968 (Bentley and Raymond, 1969) were used as the control. The orifices were subjected to (1) normal ambient light, (2) electric light over the orifice exit, and (3) total darkness. Electrical lighting was provided by a 150-watt weatherproof floodlight about 1 foot above the orifice exit (discharge side of orifice) and 1 foot away from the sluiceway wall. The orifices were darkened by covering the inclined-plane portion of the traps with black plastic sheeting. In the first series of tests, a 3-foot section of the trap adjacent to the orifice was covered, but in the following tests, the entire trap (inclined-plane section) was darkened. Although the first condition probably produced a desirable degree of darkness, the entire trap was darkened during the remaining tests to ensure complete darkness.

Unit 8 served as a control throughout the experiment. All gatewells of this unit were uncovered, permitting entry of normal ambient light. The orifice in gatewell 8-A was always closed, and fish entering this gatewell were removed with the dipnet to determine numbers of fish entering this gatewell. The orifice in gatewell 8-B was always open, and all fish passing through it were captured in the orifice trap. Gatewell 8-B was not dipnetted to avoid interference with the normal movement of the fish into the gatewell and through the orifice.

Tests to determine the effect of illumination on the passage of fish through the gatewell orifices were made in units 9, 10, and 11. Each combination of light conditions was alternated between each pair of gatewells (A and B) in a single unit and also between paired gatewells of the other units to reduce the effects of possible variations between these structures. All orifices were simultaneously opened and closed at the beginning and end of each test. This procedure was necessary to obtain test periods of equal length and to facilitate the removal of all fish from the gatewells and orifice traps.

The tests were designed according to the choices available to fish entering the gatewells; that is, they could elect to (1) return into the turbine intake (escapement), (2) delay making a choice and remain in the gatewell (retention), or (3) pass through the submerged orifice (passage). Ideally, all fish entering gatewells would elect to pass through the orifices within a short time after entering the gatewell; escapement to the intake or retention in the gatewell would be minimal at any time.

Fish entering the gatewells must ultimately make one of two choices to leave the gatewell--(1) they may pass out of the gatewell through the submerged orifice (bypassed fish) or (2) they may escape from the gatewell back into the intake (escapement). Prior to making a choice the fish may remain in the gatewell for a variable length of time (retention). At any particular time a fish will be in some stage of this passage process. After an initial time interval, the process would be expected to reach a steady state condition. During the initial phase relatively more fish would remain in the gatewell, but after a passage of time the two exit stages (bypass or escapement) would assume greater importance. One, therefore, can sample the process at different time intervals and obtain data for estimates of the process parameters during various stages. For example, 24-hour sampling periods should provide retention estimates corresponding to the initial stage of the process. Thirty-six and 48-hour sampling periods should provide escapement and bypass estimates during the steady-state stage of the process. Thus, we have a varying process in which some of the intervening and terminal magnitudes are known, but the remaining magnitudes are unknown.

This, of course, limits the type of analysis which can be applied to the data and dictates the form in which the data are collected.

No direct measurement of escapement is possible, although indirectly a minimum estimate of the influence of this factor can be obtained. Fish are presumed to enter adjacent pairs of A and B gatewells in approximately equal numbers. If the combined catch from the orifice trap (bypassed fish) and from dip netting (retention) of an A gatewell exceeds that of the adjacent B gatewell then the difference must be due to escapement from the B gatewell. This estimate is a minimum because escapement may have occurred in the A gatewell. The difference in total catches between the two gatewell systems means that there was more escapement from one gatewell than from the other.

The efficiency of a bypass system depends upon the speedy movement of fish. If fish are diverted into a gatewell and accumulate there, a dense concentration could adversely affect the migrants. The escapement of fish indicates that the bypass is ineffective. The measurement of the retention and escapement parameters provides a means of evaluating the effect of illumination on the efficiency of a bypass system. Information for evaluating the results from short term (24-hour) tests in gatewell units 9, 10, and 11 is given in table 2. Numbers of fish caught in the bypass traps and by dipnetting

Table 2.--Total catches during 24-hour tests

Species	Gatewell	Light condition 1/ Gatewell	Orifice	Catch Trap	Dipnet	Percent retention 2/
Chinook	9	L	Ll	123	203	62
	9	D	Dl	221	115	34
	10	L	Ll	196	295	60
	10	L	Dl	134	253	65
	11	L	Ll	143	266	65
	11	D	Ll	272	95	26
Coho	9	L	Ll	70	65	48
	9	D	Dl	165	54	25
	10	L	Ll	105	113	52
	10	L	Dl	108	91	46
	11	L	Ll	105	78	43
	11	D	Ll	191	31	14
Sockeye	9	L	Ll	20	18	47
	9	D	Dl	71	6	8
	10	L	Ll	28	16	36
	10	L	Dl	22	20	48
	11	L	Ll	23	11	32
	11	D	Ll	67	2	3
Steelhead	9	L	Ll	139	55	28
	9	D	Dl	173	44	20
	10	L	Ll	230	77	25
	10	L	Dl	174	72	29
	11	L	Ll	290	53	15
	11	D	Ll	439	33	7
All species	9	L	Ll	352	341	49
	9	D	Dl	630	219	26
	10	L	Ll	559	501	47
	10	L	Dl	438	436	50
	11	L	Ll	561	408	42
	11	D	Ll	969	161	14

1/ The notation for the light conditions is:
- L : Ambient light for gatewell
- Ll: Ambient light for orifice
- D : Completely darkened gatewell
- Dl: Darkened orifice and trap

2/ Percent retention is computed from:

$$\frac{\text{dipnet catch}}{\text{trap catch + dipnet catch}} \times 100.$$

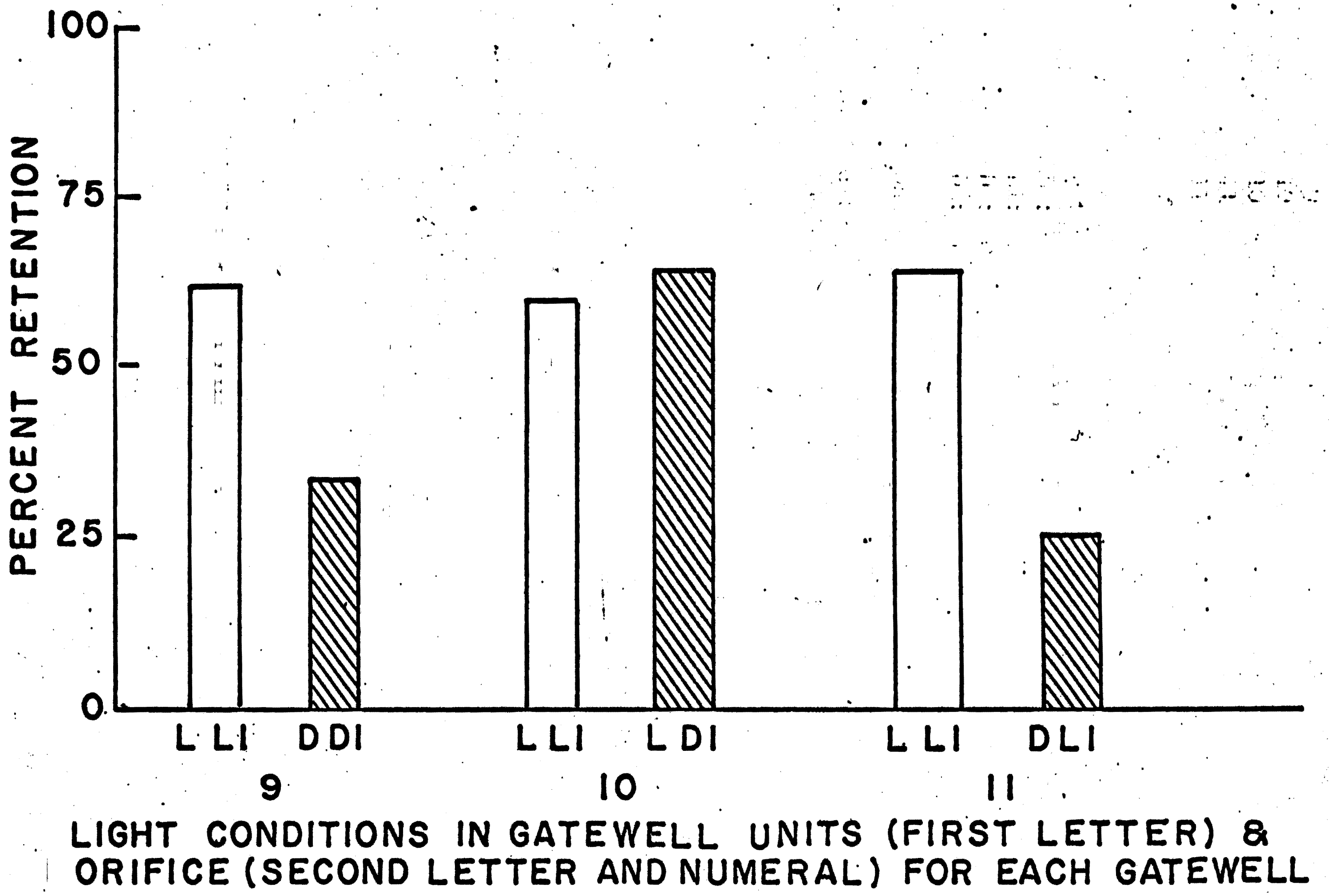

Figure 9.--Percent retention of fingerling chinook salmon during 24-hour tests for various gatewell-orifice light conditions.

are tabulated for each species separately and totaled for all species combined. The important result from these short-term tests is the measurement of retention. The percent retention by species is graphed in figures 9 through 12. Figure 13 is a graph of percent retention for all species combined. These figures show that retention is less for the darkened gatewell regardless of the orifice condition, and indicate that the lighted orifice results in less retention regardless of the gatewell condition. The combination of conditions which gives the minimum retention is obtained with the darkened gatewell and lighted orifice configuration.

Long-term tests were conducted in units 10 and 11 to obtain a measurement of escapement of fish back into the turbine intake. These data are listed in table 3; they compose one 36-hour test and three 48-hour tests. In the evaluation of these data the total catch is used, i.e., orifice trap plus dip net catches. A graph of the data (fig. 14) shows that coho and steelhead accept both the dark and lighted orifices equally, but the chinook prefer the lighted orifice. It is also clear from the graph that a significant number of chinook failed to use the orifice bypass when the orifice was darkened, and these fish must have escaped back into the turbine intake.

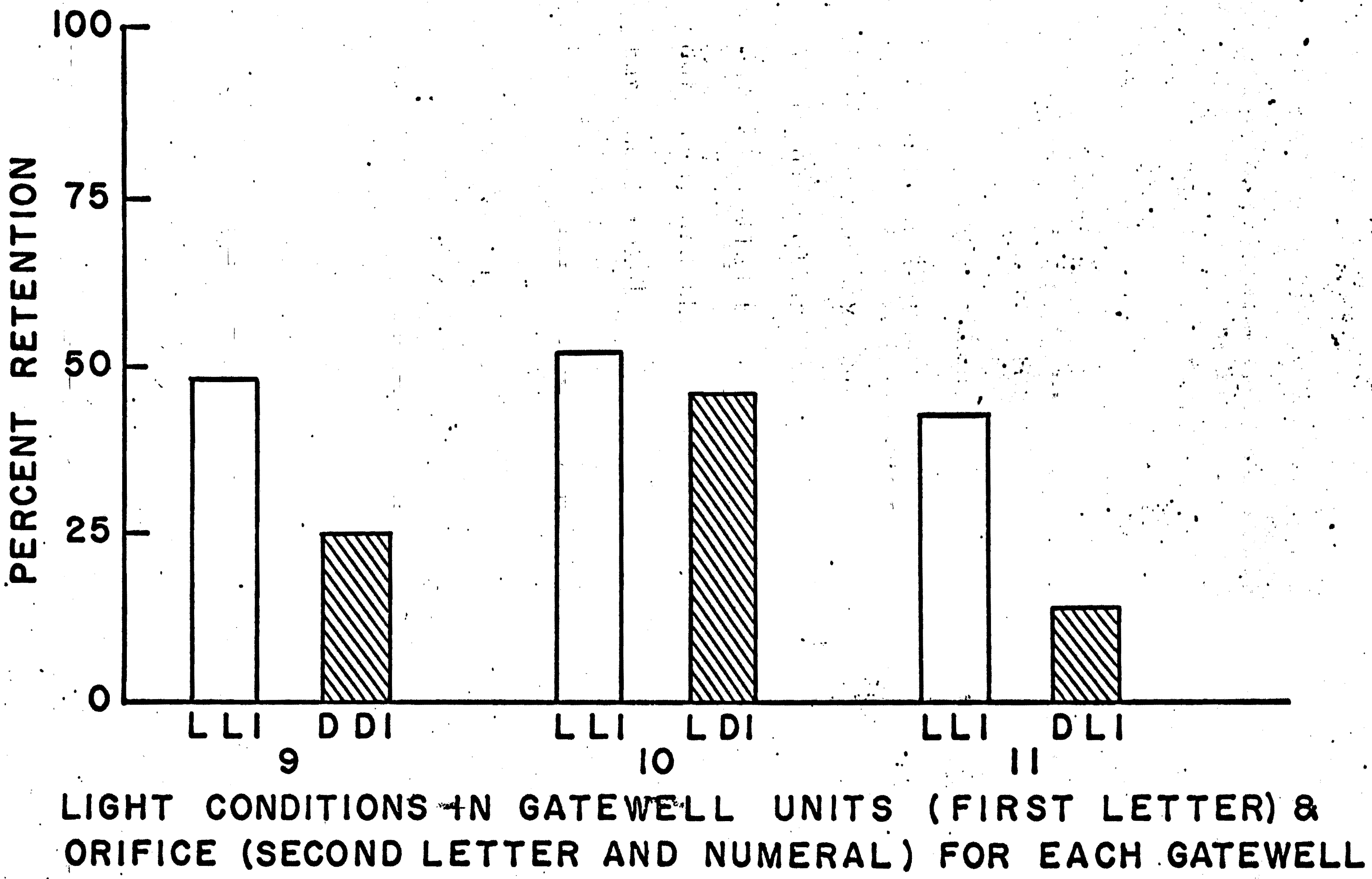

Figure 10.--Percent retention of fingerling coho salmon during 24-hour tests for various gatewell-orifice light conditions.

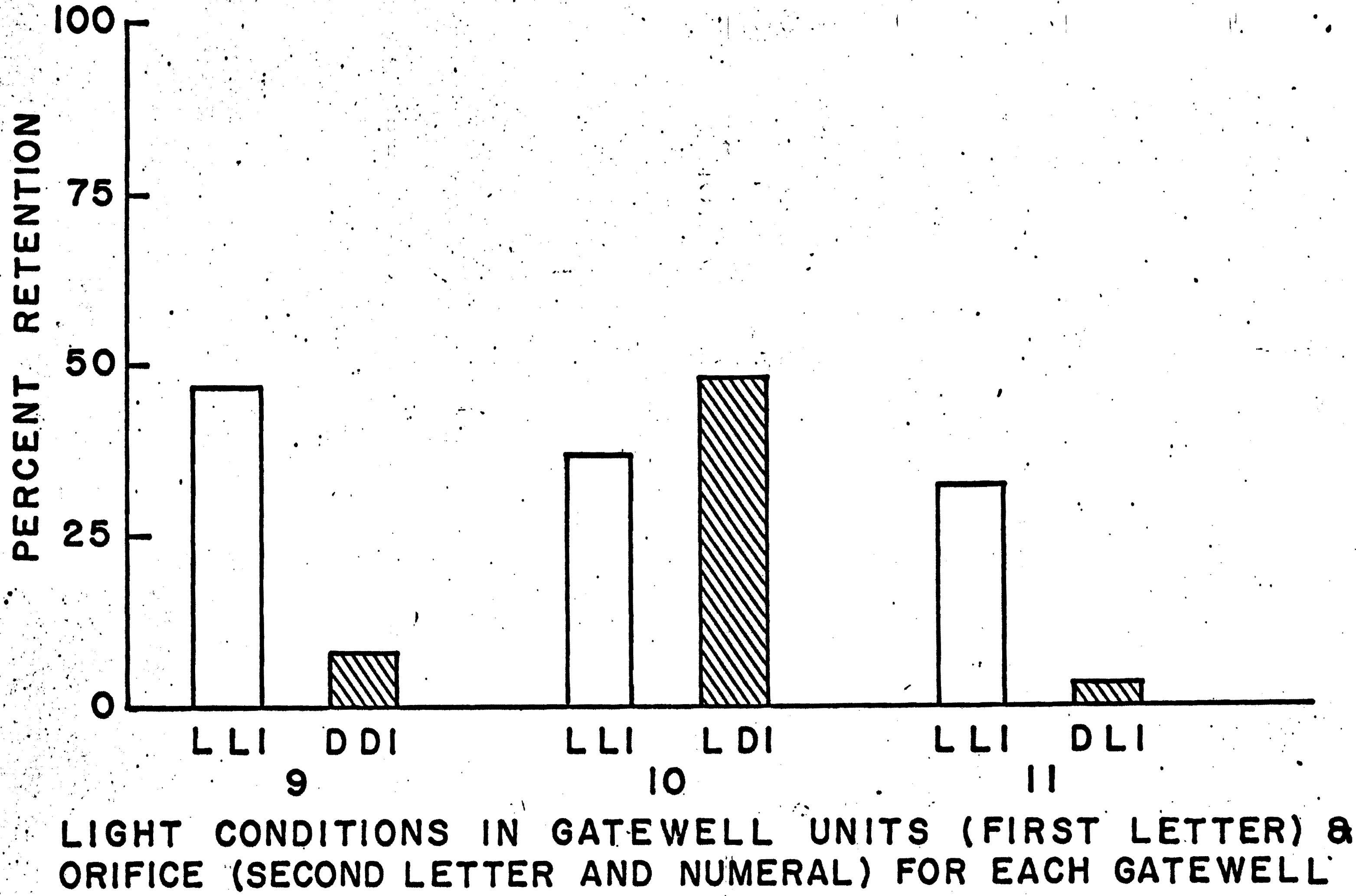

Figure 11.--Percent retention of fingerling sockeye salmon during 24-hour tests for various gatewell-orifice light conditions.

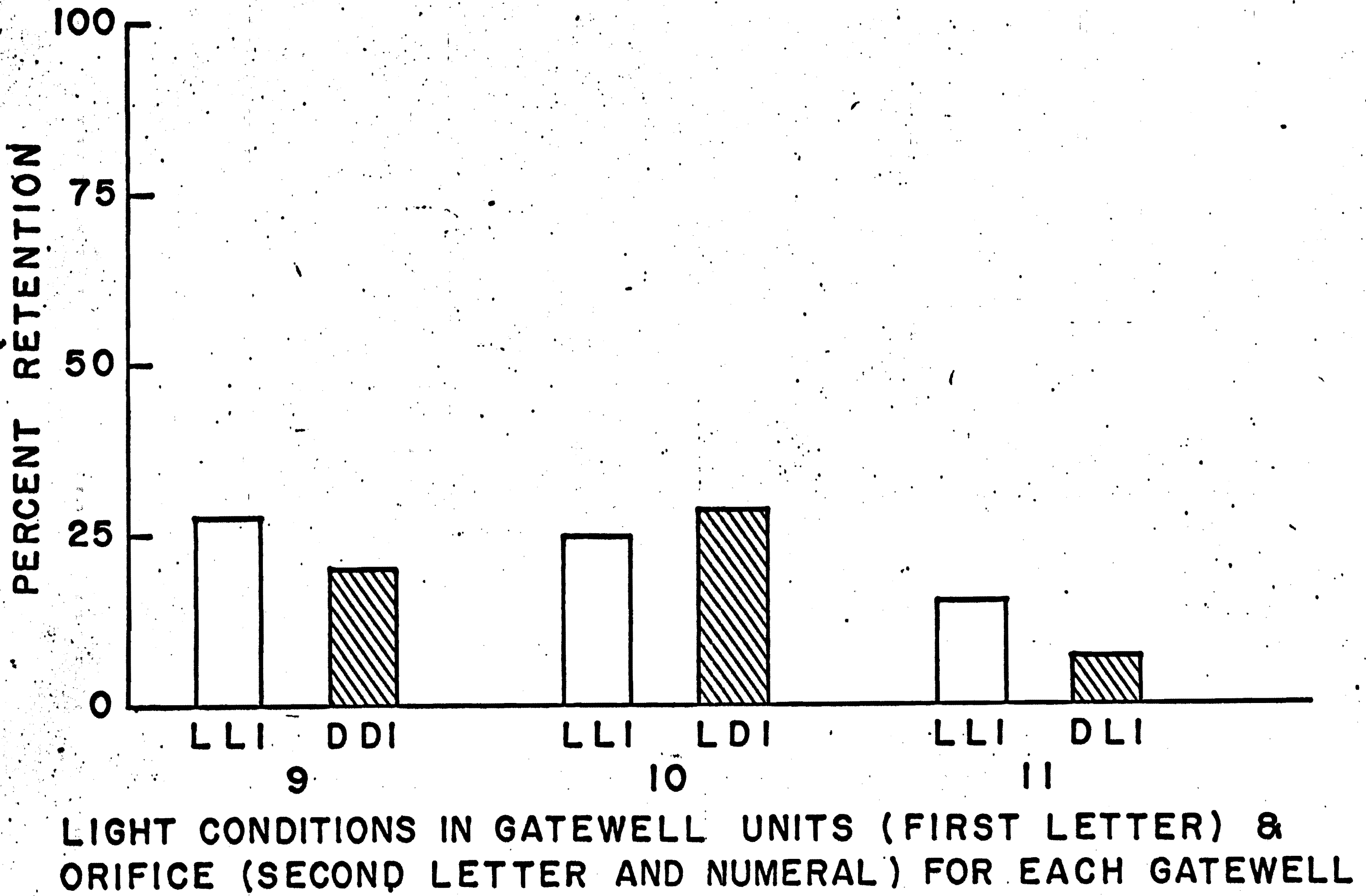

Figure 12.--Percent retention of fingerling steelhead salmonids during 24-hour tests for various gatewell-orifice light conditions.

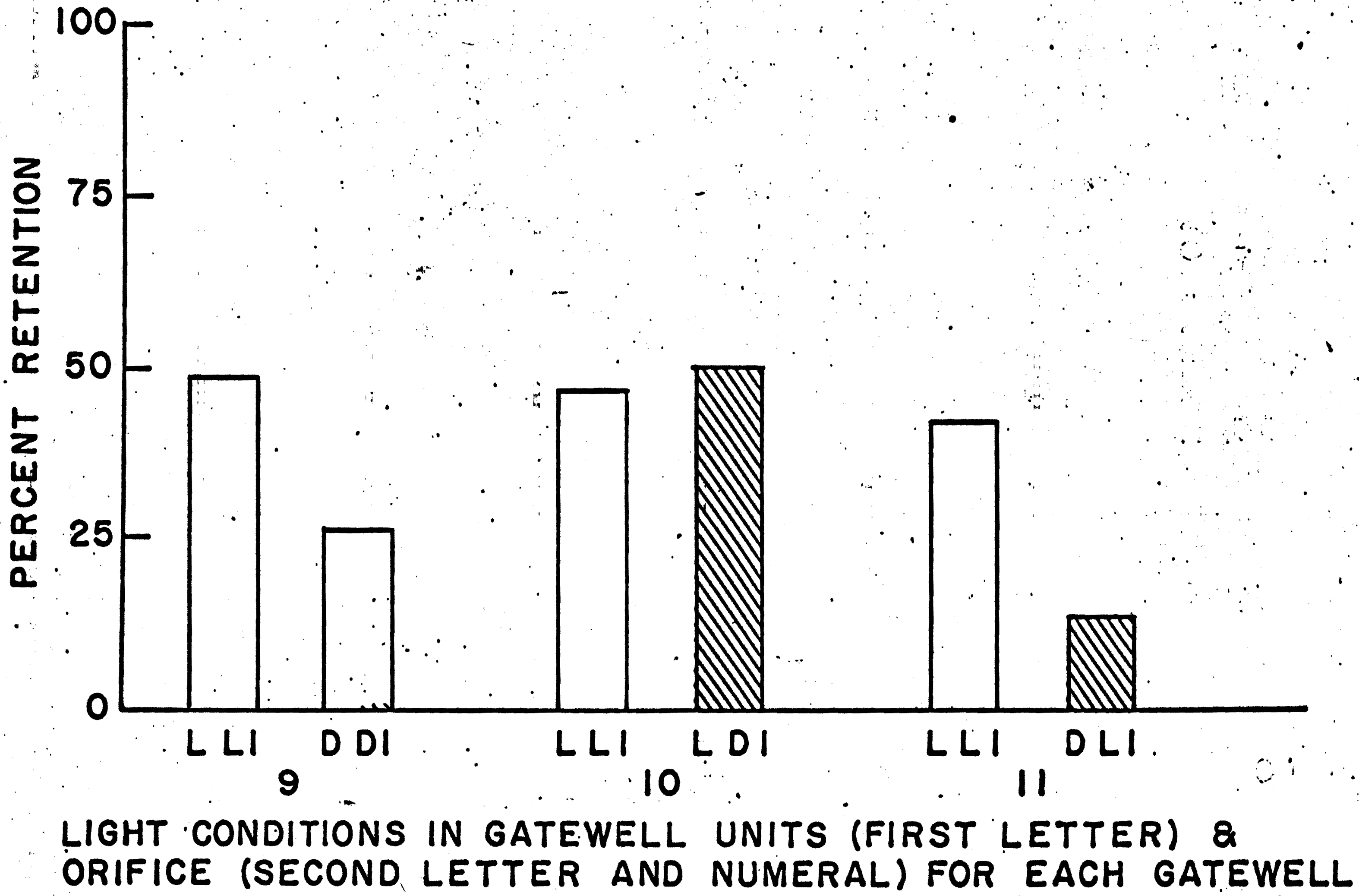

Figure 13.--Percentage retention of fingerling salmonids (all species) during 24-hour tests for various gatewell-orifice light conditions.

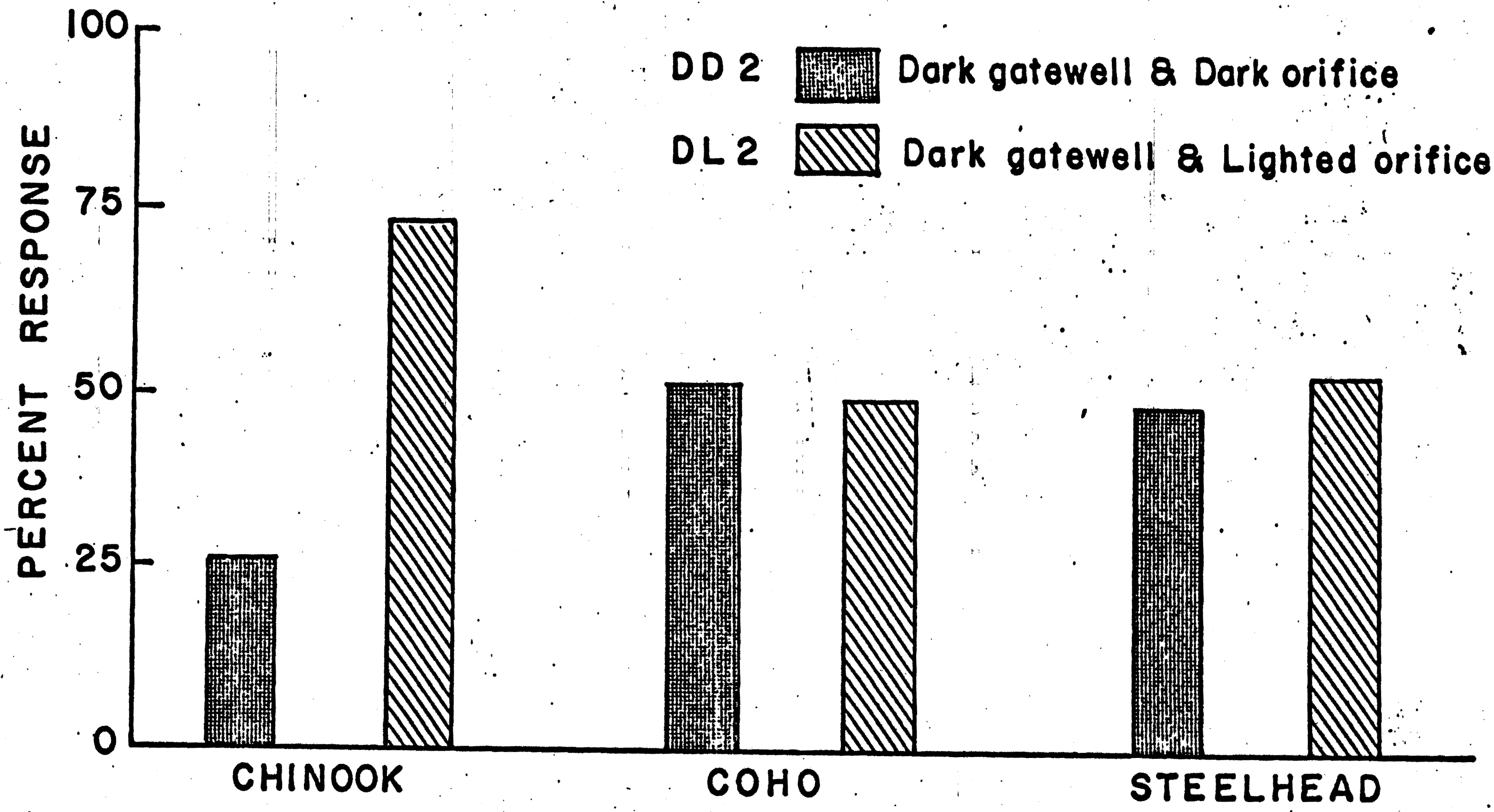

Figure 14:--Percent response of fingerling salmonids to indicated light conditions during 36- and 48-hour tests. The percentage response shows the choice fish make for a particular light condition in comparison to the total passage of fish for both light conditions.

Table 3.--Trap and orifice catches during long term (36 and 48 hour) tests

Species	Gate-well unit	Test period	Light condition[1/] Gate-well	Orifice	Catch Trap	Dipnet	Total
Chinook	10	1	D	D2	17	7	24
	10	1	D	L2	62	2	64
	10	2	D	D2	10	4	14
	10	2	D	L2	21	0	21
	11	3	D	D2	31	8	39
	11	3	D	L2	143	1	144
	11	4	D	D2	15	4	19
	11	4	D	L2	36	2	38
Coho	10	1	D	D2	2	0	2
	10	1	D	L2	6	0	6
	10	2	D	D2	1	0	1
	10	2	D	L2	5	0	5
	11	3	D	D2	14	1	15
	11	3	D	L2	10	0	10
	11	4	D	D2	6	0	6
	11	4	D	L2	2	0	2
Steelhead	10	1	D	D2	43	3	46
	10	1	D	L2	66	0	66
	10	2	D	D2	11	5	16
	10	2	D	L2	27	0	27
	11	3	D	D2	103	5	108
	11	3	D	L2	81	5	86
	11	4	D	D2	20	4	24
	11	4	D	L2	28	1	29
All species	10	1	D	D2	62	10	72
	10	1	D	L2	134	2	136
	10	2	D	D2	22	9	31
	10	2	D	L2	53	0	53
	11	3	D	D2	148	14	162
	11	3	D	L2	234	6	240
	11	4	D	D2	41	8	49
	11	4	D	L2	66	3	69

1/ The notation for the light conditions is:
D : Completely darkened gatewell
D2: Orifice darkened and entire trap covered
L2: Orifice lighted with an electric light

Ideally, the optimum criteria for a gatewell-orifice bypass system is one in which the fish entering the gatewells would pass through the orifices with the least delay and with no escapement back into the turbine intake. These tests indicate that the light condition which best satisfies this optimum is one in which the gatewell is darkened and the orifice is lighted.

<u>Survival of Migrants in Gatewell-Sluice Bypass</u>

The gatewell-sluice fish bypass was evaluated by releasing groups of marked fish at selected locations and comparing the live recoveries of these fish at the downstream end of the system. The test fish were carefully selected from all wild migrants that were available immediately preceding each test. These fish were marked with thread tags or an opercular punch and held for 24 hours to sort out migrants unfit for testing due to handling stress or other causes. Because of the prevalence of gas-bubble disease in the migrants, some of the test groups necessarily contained small numbers of fish.

Four groups of marked fish were passed through a normally operating orifice and recovered after they had passed through the bypass. The marked fish were released into a large cage placed in gatewell 13-B. This cage was constructed to allow the fish to pass naturally through the orifice but to prevent them from escaping into the gatewell. Each group of fish was introduced into the release cage with a pen, lowered from the intake deck to a position directly above the cage. The pen contained a solid, funnel-type bottom with a stopper that permitted the transportation and discharge of fish with water into the release cage. At the end of each 3-hour test period, the cage was removed from the gatewell and the number of fish passing through the orifice to the sluice was obtained by subtracting the count of fish remaining in the cage from the original total.

Four groups of marked fish were also released at specific locations in the sluice (fig. 15) to provide a comparison of the survival of these fish with test fish that had passed through the orifice and the sluice. Group 1 was released in the upper sluice beneath the orifice outfall from gatewell 13-B; group 2 was released at the south end of the upper sluice; group 3 was released into the waterfall at the head of the lower sluice; and group 4 was released 10 feet in front of the recovery trap in the lower sluice. Fish passing through the orifice and those released in the sluice were recovered in a dipper trap (Mason, 1966) near the end of the lower sluice.

Recoveries of fish released at various points in the bypass system appear in table 4. With a single exception, all fish in the four tests involving passage through the

Table 4.--Number and percentage of marked fish (released at various points in the gatewell-sluice bypass) that were recovered alive at McNary Dam, spring 1969

Release site and date (in parentheses)	Species	Fish released	Fish recovered		Fish descaled[1/]
		Number	Number	Percent	Number
Gatewell 13-B (June 3)	Chinook, coho, and steelhead	20	20	100.0	0
Gatewell 13-B (June 3)	Chinook, coho, and steelhead	19	19	100.0	0
Gatewell 13-B (June 5)	Chinook and steelhead	7	7	100.0	1
Gatewell 13-B (June 5)	Steelhead	7	6	85.7	0
Lower sluice in front of dipper trap (May 27)	Chinook, coho, and steelhead	30	26	86.7	1
Lower sluice beneath waterfall (May 28)	Hatchery coho	26	25	96.2	0
Upper sluice below outfall from gatewell 13-B (June 3)	Chinook, coho, and steelhead	40	35	87.5	0
Upper sluice at south end (June 5)	Chinook and steelhead	14	12	85.7	1

1/ Moderate to severe descaling.

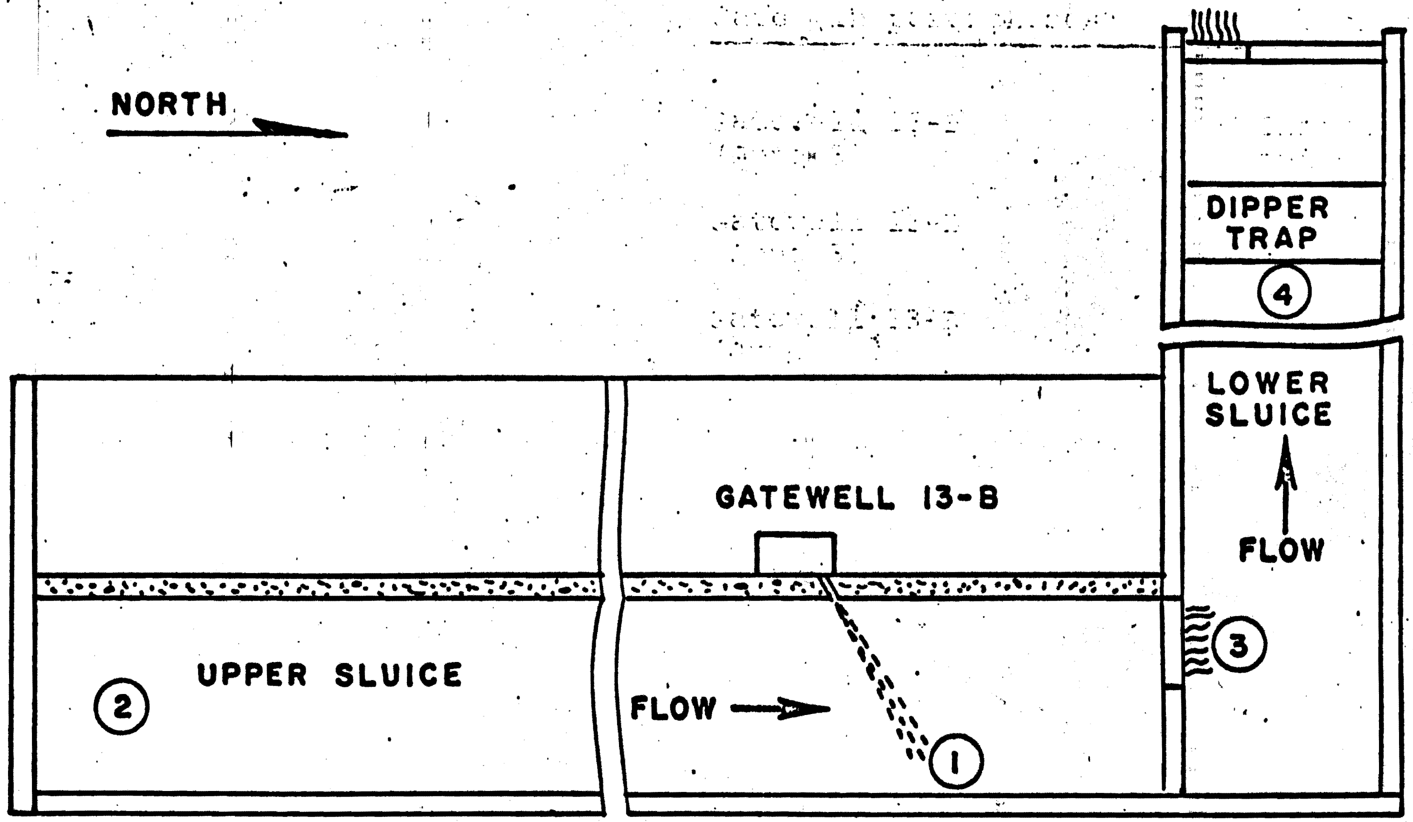

Figure 15.-Locations of marked fish releases to evaluate passage of fish through the gatewell-sluice bypass.

orifice in gatewell 13-B were recovered in the dipper trap. Recoveries of fish released at various points in the upper and lower sluice ranged from 86 to 96%. Approximately equal recoveries were made from releases at the extreme upper end of the sluice (group 2) and at the lower end immediately in front of the dipper trap (group 4). Overall, the recovery of fish released in the sluice areas was somewhat lower than that of fish released in the gatewell. Questions arise, then, concerning the fate of those fish that were not recovered. Did they succumb due to hazards in the bypass system or was their loss due to other causes?

Several factors could have been responsible for the loss of test fish. Most obvious, perhaps, was the generally poor physical condition of the majority of the wild migrants due to nitrogen gas supersaturation. Although only those fish in the best physical condition were selected for testing, it is possible that some may have succumbed shortly after release due to prior stress during handling. Fish that may have died during passage in the bypass system could not be recovered. This was determined by experimental releases of dead fish in the sluice which revealed that these fish did not appear in the recovery trap.

Loss of fish due to escapement at the recovery facility cannot be ruled out completely. Although care was taken to make the trap as "fish tight" as possible, some fish may have escaped capture by passing through undetected cracks or small holes in the recovery installation. Another possible explanation for the unaccounted fish is that they remained in the sluice for an indeterminate period and simply failed to move down to the collection site. Unfortunately this factor could not be assessed because of a breakdown of the trap shortly after the tests were concluded. Had the trap remained intact, evidence of delayed migration may have been detected by continued monitoring. Most fish released in the gatewell or sluice areas appeared in the recovery trap within 1 or 2 days, but in several instances recoveries were made 6 or 7 days after release. One fish released immediately in front of the dipper trap was recovered 7 days after release. It is possible that the dipper trap may have delayed migration out of the sluice and that without this structure, migration through the sluice may have been more rapid.

Loss of thread tags could explain the disappearance of some test fish, but this is only a remote possibility. Finally, predation in the sluiceway cannot be ruled out as a possible explanation for the disappearance of test fish. Predatory fish passing through the sluice were captured in the dipper trap, and examination of their stomach contents revealed some migrant salmon. None contained evidence of the marked test fish, however. If predators remained in the sluiceway during these tests, it is possible that they could have preyed on the test fish. This was never determined, however.

Evidence of descaling among fish descending through the bypass offers another possible means of assessing the efficiency of the system. Only 3 of 150 fish (2%) that were recovered from test releases in the gatewell and sluice showed evidence of moderate to severe descaling. Even in these instances, it is possible that the comparatively minor occurrences of descaled fish could have resulted from capture and handling of fish in the dipper trap and not from passage through the bypass. Effort was made to check the dipper trap and remove fish as frequently as possible (every 2 hours or so during daylight hours), but if fish remained in the trap for longer periods (8 hours or more), descaling very likely could have resulted from the extended confinement.

Wild fish passing naturally through the bypass during a 3-day period (May 27-29) were also examined for evidence of descaling (table 5). Of 1,738 fish recovered in the dipper trap, 101 (6%) were considered descaled. In this instance, a number of these fish may have been descaled before they entered the bypass system at McNary due to previous experience during migration or release from hatcheries. In general, descaling was more prevalent among sockeye and steelhead and least prevalent among chinook and coho.

Summing up, we conclude that descaling of fish due to passage in the McNary gatewell bypass is apparently minimal and that virtually all of the migrants passed safely through the system.

Table 5.--Number of juvenile salmon and steelhead trout that were captured in dipper trap at McNary Dam and number that were descaled[1] May 27-29, 1969

Date	Species	Fish captured	Fish descaled	
		Number	Number	Percent
May 27	Chinook	189	3	--
May 28	Chinook	182	12	--
May 29	Chinook	594	8	--
Total		965	23	2.3
May 27	Coho	46	0	--
May 28	Coho	80	4	--
May 29	Coho	73	7	--
Total		199	11	5.2
May 27	Sockeye	5	0	--
May 28	Sockeye	2	0	--
May 29	Sockeye	7	4	--
Total		14	4	22.2
May 27	Steelhead	76	6	--
May 28	Steelhead	137	16	--
May 29	Steelhead	347	41	--
Total		560	63	10.1

1/ Fish were considered descaled if the injury ranged from moderate to severe. Most descaling was in the moderate category.

Use of Bypass by Other Species

Several species of fish other than juvenile salmon and steelhead trout were captured in the orifice traps and migrant dipper (table 6). In order of abundance, the most numerous were Pacific lamprey (496 ammocoetes), suckers (128), adult steelhead (88), northern squawfish (60), carp (54), whitefishes (42), and chiselmouth (22). Ammocoetes of the Pacific lamprey were recorded in the orifice traps only because the openings in the dipper trap were too large to retain them.

The largest steelhead captured in the orifice traps was 28 inches long and 13 inches in girth. Four larger steelhead were captured in the dipper trap; the largest measured 32 inches and was 15 inches in girth. Table 7 presents the length-frequency distribution for steelhead captured in both types of traps. Fish captured in the dipper trap could possibly have entered the sluice by leaping over the stop logs that separate the forebay from the sluice, especially when the forebay was high because of ponding.

Plans included dewatering of the sluice after the peak of the spring migration to remove predators that may have remained in the bypass system. A sudden storm, however, deposited a large amount of debris in the sluice which damaged the dipper trap and permitted the escape of any fish that may have remained in the sluice. Although data on the abundance

Table 6.--Number of fish other than juvenile salmon and steelhead trout that were captured in dipper trap and orifice traps at McNary Dam, spring 1969

Common and (in parentheses) scientific name of fish	Fish captured		
	In orifice traps	In dipper trap	Total
	Number		
Pacific lamprey (Lampetra tridentata)1/	496	0	496
Suckers (Catostomus spp.)	29	99	128
Steelhead trout (Salmo gairdneri)2/	24	64	88
Northern squawfish (Ptychocheilus oregonensis)	5	55	60
Carp (Cyprinus carpio)	11	43	54
Whitefishes (Prosopium spp.)	6	36	42
Chiselmouth (Acrocheilus alutaceus)	6	16	22
Redside shiner (Richardsonius balteatus)	0	7	7
Peamouth (Mylocheilus caurinus)	4	2	6
White sturgeon (Acipenser transmontanus)	2	2	4
Threespine stickleback (Gasterosteus aculeatus)	4	0	4
Brown trout (Salmo trutta)	1	1	2
Channel catfish (Ictalurus punctatus)	0	1	1
Yellow perch (Perca flavescens)	0	1	1
Bluegill (Lepomis macrochirus)	1	0	1

1/ Ammocoetes
2/ Adults

Table 7.--Length frequency of adult steelhead trout captured in orifice traps and dipper trap at McNary Dam, spring 1969

Length		Steelhead captured	
		In orifice traps	In dipper trap
Inches	Cm.	Number	Number
12	30.0	0	3
13	32.5	0	3
14	35.0	0	0
15	37.5	0	4
16	40.0	1	3
17	42.5	2	3
18	45.0	1	0
19	47.5	1	2
20	50.0	3	5
21	52.5	1	3
22	55.0	5	5
23	57.5	1	3
24	60.0	3	5
25	62.5	1	3
26	65.0	3	2
27	67.5	0	0
28	70.0	1	1
29	72.5	0	2
30	75.0	0	1
31	77.5	0	0
32	80.0	0	1

of predators in the sluice is insufficient, comparatively few predators were captured and these showed no indications of significant predation.

Survival of Bypassed Fish in the Tailrace

An experiment was initiated to determine survival of bypassed fish in the tailrace by comparing the recoveries from releases at three locations. One group was released in the frontroll of the turbine discharge, a second in the backroll, and a third group at the exit of the north sluice. The experiment could not be completed, however, because of unfavorable field conditions.

A total of 46,590 fish were marked and released into the tailrace. These releases consisted of selected wild migrants captured in the dipper trap (table 8) and hatchery-reared coho salmon that had been intended for another experiment. The ratio of hatchery to wild fish in these releases was approximately 3 to 1. Unfortunately the recoveries of these fish downstream from McNary Dam were too low for statistical comparison of the various groups, and no conclusions can be made from this experiment.

Table 8.--Number of juvenile salmon and trout (downstream migrants) collected in the orifice traps and dipper trap at McNary Dam, spring 1969

Species	Fish captured		
	In orifice traps	In dipper trap	Total
	---------- Number ----------		
Steelhead trout	10,331	37,711	48,042
Chinook salmon	5,220	20,048	25,268
Coho salmon	2,916	15,852	18,768
Sockeye salmon	959	1,510	2,469
Total	19,426	75,121	94,547

Conclusions and Recommendations

Conclusions and recommendations are as follows:

1. The passage of downstream migrants through orifices is increased significantly when the gatewells are dark and the orifices are lighted. Fish passage is high at dams where the orifices exit into an ice sluice that is illuminated with normal ambient light. To achieve maximum fish passage for all species, however, we recommend that orifices discharging into ice sluiceways be illuminated continuously with electric lights during the downstream migration. Our tests also show that fish passage is reduced significantly when both the gatewells and orifices are continuously darkened. For this reason, we recommend that where completely darkened fish bypasses have been incorporated in hydroelectric structures (such as John Day, Lower Monumental, and Little Goose), every reasonable effort should be made to illuminate the orifice area with electric lights.

2. Survival in the bypass was determined to be high by the release and recovery of marked test fish and the low incidence of descaling. Much of this descaling, moreover, probably occurred when the fish were captured in the dipper trap and subsequently handled and examined. Predation in the bypass could not be evaluated completely because of storm damage to the dipper trap which prevented capture and examination of potential predators remaining in the bypass.

No test fish were found in stomachs of predators captured in the dipper trap, but these same fish did contain remains of salmon taken at undetermined times and places. In the future, if congregations of predators are observed in the sluiceway, we would recommend periodic flushing of the sluice with large flows from the forebay.

3. Determination of the survival of fish released into various areas of the tailrace depended in part on the existence of a slack-water area adjacent to the north sluice exit. Because of continuous spilling during the study period, this phase of the bypass investigation could not be satisfactorily completed. Previous experience suggests that survival of fish bypassed to the tailrace could be significantly increased by releasing them in predator-free areas such as the frontroll of a turbine discharge or in the spillway discharge.

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