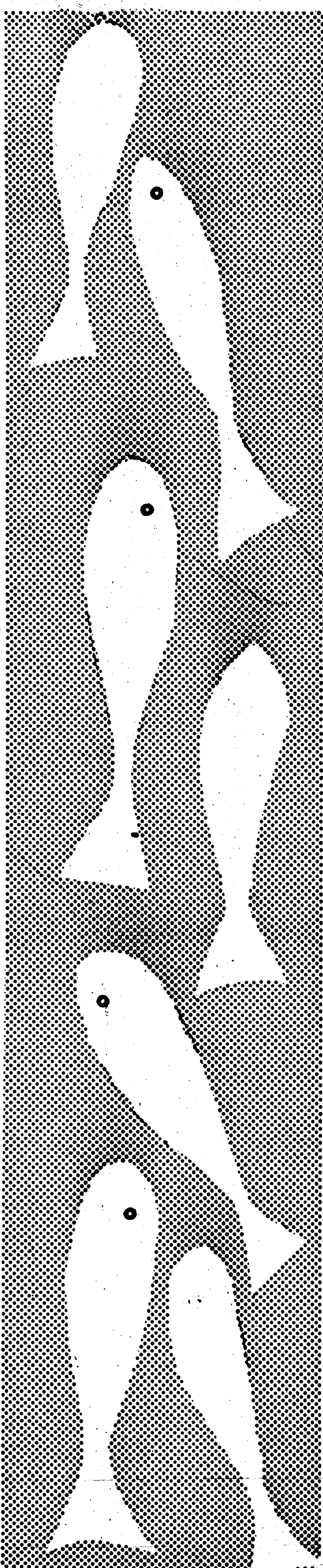

FURTHER RESEARCH ON A FINGERLING BYPASS FOR LOW-HEAD DAMS (1970)

By

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INTRODUCTION

Long and Krcma (1969: attached) have described a fingerling bypass system for low-head dams being developed jointly by the Bureau and Corps of Engineers. Fig. 1 shows the system installed at a typical dam. This report covers research in 1970 on this fish-protective system at Ice Harbor Dam. Experiments measured (1) efficiency of a prototype traveling screen in diverting juvenile chinook and steelhead from turbine intakes into gatewells, (2) escapement of fish from gatewells back into the intake, and (3) rate at which fish entering a gatewell found and passed through the single submerged port leading to the ice sluice.

METHODS AND PROCEDURES

Methods and procedures used were similar to those described by Marquette, et al. (1970: attached).

The traveling screen was installed in intake A of turbine No. 3. Numbers of fish entering the associated gatewell, designated 3-A, were compared with those entering the adjacent gatewell, 3-B, which served as the control.

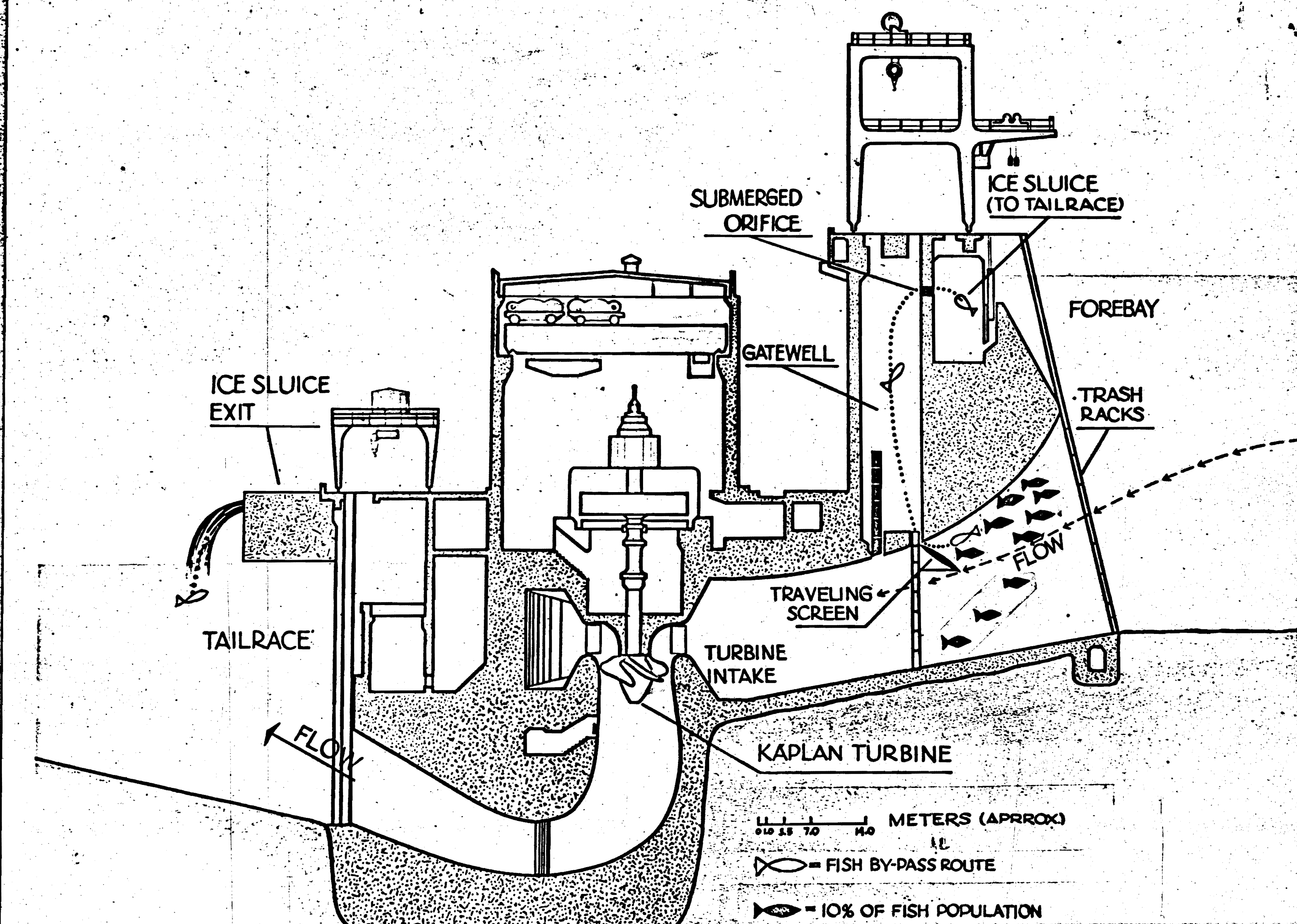

Figure 1.--Fish bypass system for low-head dams employs traveling-screen fish-guiding device in turbine intakes to intercept flows containing about 75-80 percent of the fish. Fish are diverted up into gatewells, then pass through submerged ports and are carried through the dam to the tailrace by flows in the ice sluice.

Raymond[1] had previously determined that about 20 percent of the chinook entered standard, unmodified gatewells of their own volition and remained long enough to be removed by dip netting at intervals ranging from once every 24 hours to once every 72 hours. Furthermore, both chinook and steelhead volitionally entered gatewells 3-A and 3-B in about equal numbers, implying that fish entered both intakes in equal numbers. Therefore, the efficiency of the traveling screen could be approximated by the following steps: (1) Compute the total number of fish entering control intake 3-B; i.e., the number of fish taken from gatewell 3-B = 20 percent of the total. (2) Assume an equal number of fish entered test intake 3-A. (3) Convert the number of fish removed from gatewell 3-A to a percent of the estimated total entering intake 3-A. These steps are simplified by multiplying 20 by the ratio of fish taken from 3-A to fish taken from 3-B; if the ratio was 4, then guiding efficiency would be 80 percent (4 x 20 = 80).

During the season we determined that the drive mechanism of the traveling screen was malfunctioning. Though data may have been obtained part of the time when the screen was not traveling, we feel this probably had a

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[1] Personal communication, Howard L. Raymond, Biological Laboratory, Bureau of Commercial Fisheries, Seattle, Washington.

minimal effect on the number guided. One might expect that more fish would be guided with the screen traveling than when it was stationary.

Fish entering gatewells at Ice Harbor Dam normally faced three choices. They could (1) pass through a submerged port (one per gatewell) leading to the ice sluice, (2) remain in the gatewell, or (3) escape back into the intake.

Fish passing through the submerged ports in gatewells 3-A and 3-B were automatically collected and held in an inclined plane trap.

Fish remaining in a gatewell at the end of a test were removed by dip net, using a minimum of three dips, or until less than 12 fish were taken in a single dip (Marquette, et al., 1970). The combined catches of the trap and from dip netting was taken as the total number of fish that had entered a gatewell during a test.

Comparison of the trap catch and dip net catch at the end of any test period gave a measure of the rate at which fish entering the gatewell found and passed through the submerged port.

Experience had indicated few fish escaped from standard, unmodified gatewells for at least 72 hours, in spite of easy access to the intake. Model studies have shown, however, that the presence of a traveling screen in an intake would divert a greater than normal volume of water into (and through) the associated gatewell (Fig. 2). We anticipated that the resulting stronger water velocities might cause significant escapement. Therefore, special screens (called closure screens) were installed so that escapement could be prevented (Fig. 3). Tests with the screens closed gave data on the total number of fish guided, and tests with the screens open gave the total number guided minus the number that voluntarily escaped back into the intake.

No closure screens were installed in the control gatewell, to conform with conditions that prevailed when original estimates were made by Raymond of the percentage of fish entering gatewells of their own volition.

All tests were conducted with darkened gatewells and lighted orifices after the fashion described by Marquette (1970) because these conditions, tested at McNary Dam in 1969, resulted in the least delay of fish in finding and passing through submerged ports; residualism at the end of only 24 hours at McNary averaged 26 percent for chinook and 7 percent for steelhead.

Tests of 24-, 48-, and 72-hour durations were conducted at Ice Harbor Dam.

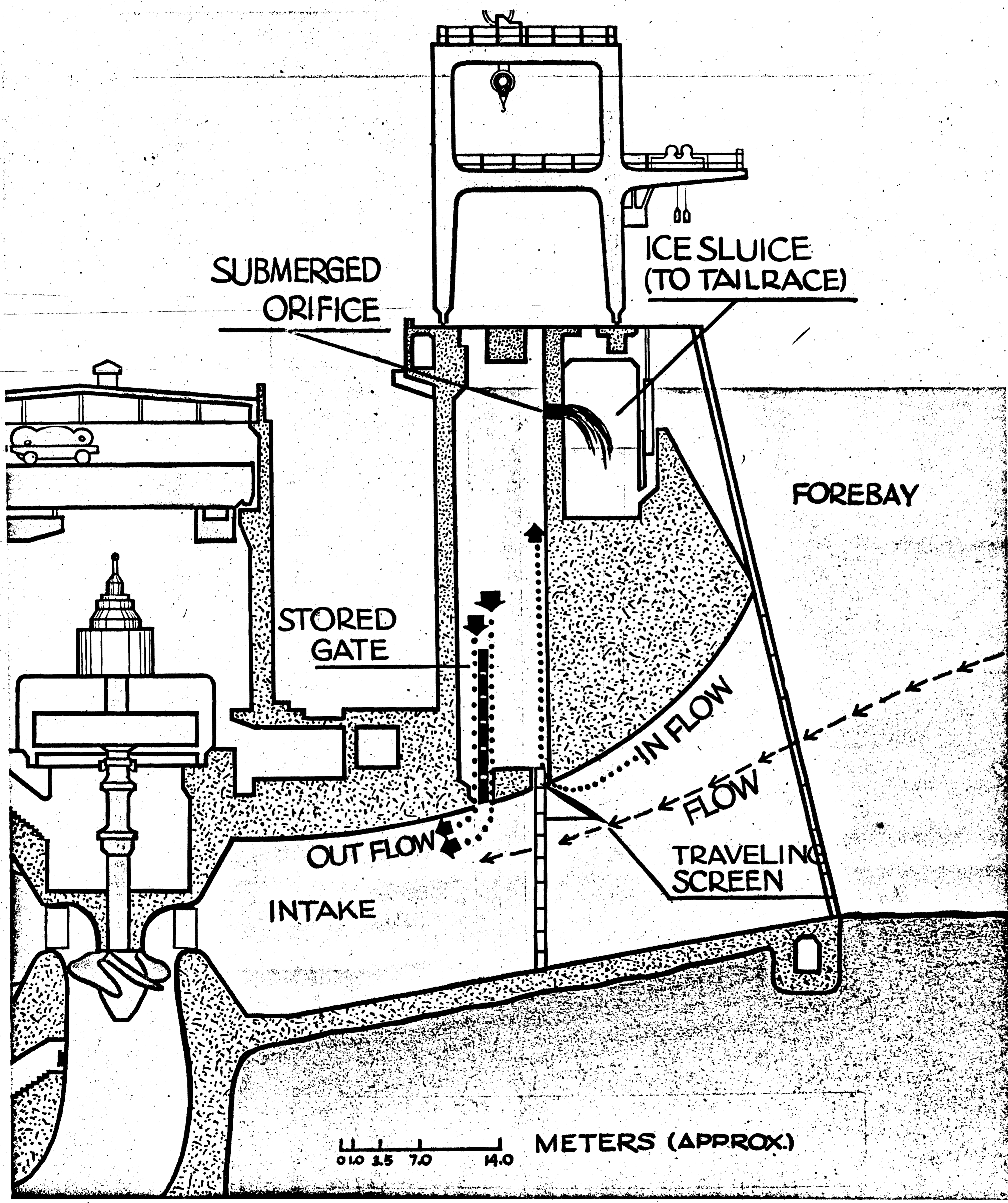

Figure 2.--The traveling-screen fish-guiding device directs additional water up into gatewells. Most of the water returns to the intake through openings on both sides of the stored gate; guided fish can return to the intake with the flow.

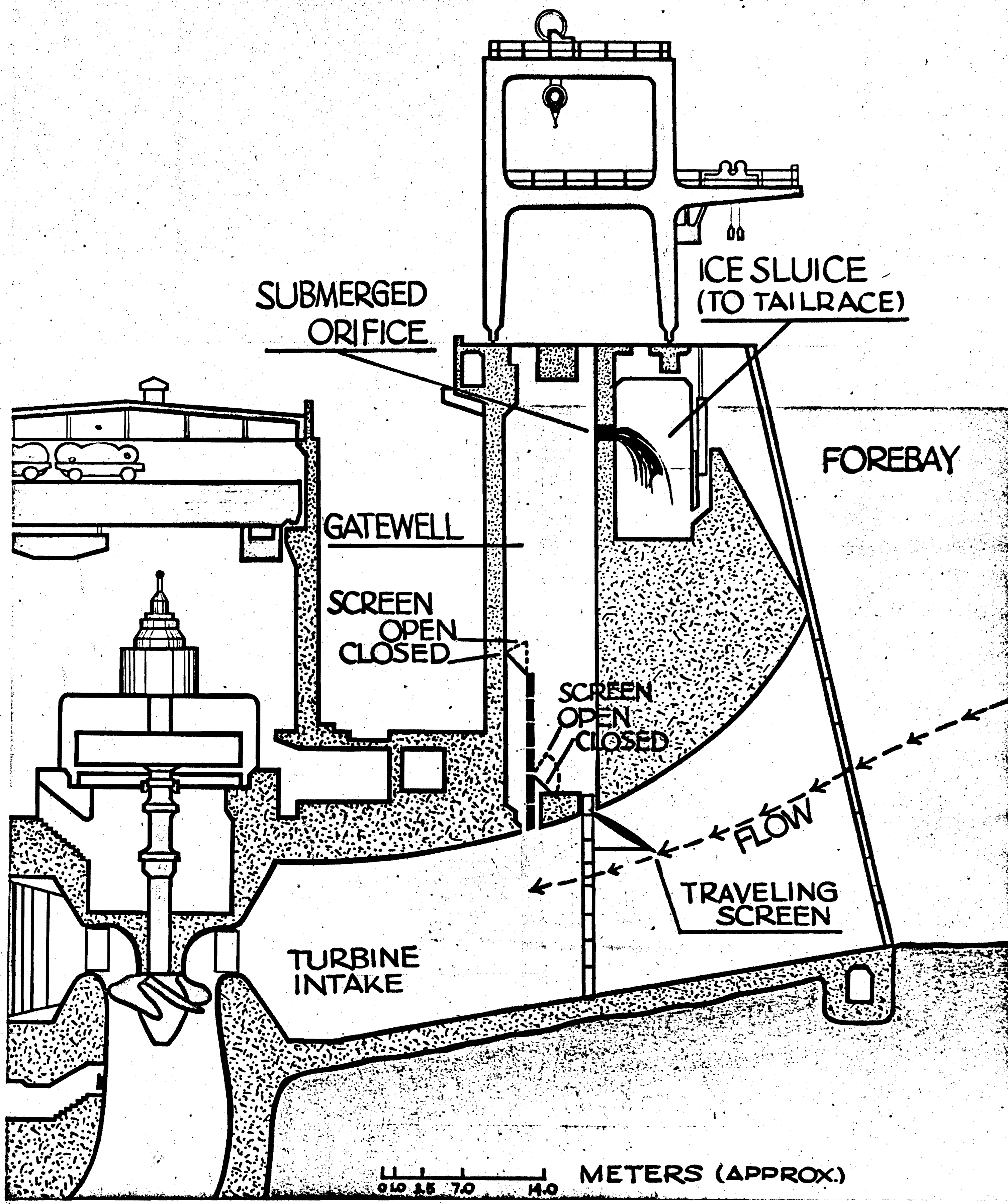

Figure 3.--Screens were attached to the stored gate to prevent (by closing) or allow (by opening) escapement of guided fish back to the intake.

GUIDING EFFICIENCY OF THE TRAVELING SCREEN

Significant numbers of both chinook and steelhead were available during tests conducted from April 22 to May 14. This series of tests was made with the closure screens closed to prevent escapement of fish from the gatewell. Trap and dipnet catch are summed in Table 1. A graphic comparison of the average number of fish taken from the test and control gatewells (Fig. 4) shows that chinook were successfully guided, for the number entering test gatewell 3-A averaged 3.2 times the number entering control gatewell 3-B of their own volition; individual test ratios ranged from 2.2 to as high as 8.7.

Steelhead, however, were apparently avoiding the screen; only 0.7 as many were taken in the test gatewell as in the control gatewell.

The success obtained with chinook implies that similar success is possible with steelhead. Research proposed for 1971 is based on an analysis of how steelhead might be avoiding the guiding device and what methods might be employed to counteract each possible avoidance reaction to achieve successful guiding of steelhead.

Steelhead may be avoiding the traveling screen in one of the following ways: (1) The fish may be selecting adjacent unscreened intakes because water velocities at the

Table 1.--Numbers of chinook salmon and steelhead trout taken from test and control gatewells during 24-, 48-, and 72-hour studies; escapement prevented.

TEST PERIOD	CHINOOK GATEWELL A (with screens closed) TOTAL NO. CAPTURED	CHINOOK GATEWELL B (control) TOTAL NO. CAPTURED	CHINOOK GUIDING FACTOR (A/B)	STEELHEAD GATEWELL A (with screens closed) TOTAL NO. CAPTURED	STEELHEAD GATEWELL B (control) TOTAL NO. CAPTURED	STEELHEAD GUIDING FACTOR (A/B)
24 hr. TESTS						
APR. 22-23	338	39	8.7	15	15	1.0
APR. 28-29	216	42	5.1	7	3	2.3
APR, 29-30	98	38	2.6	14	10	1.4
APR. 30-MAY 1	196	43	4.6	12	14	0.9
MAY 1-2	231	50	4.6	16	12	1.3
MAY 5-6	135	26	5.2	35	30	1.2
48 hr. TESTS						
APR. 23-25	648	91	7.1	13	12	1.1
MAY 6-8	1053	376	2.8	340	362	0.9
MAY 8-10	1930	642	3.0	1272	1462	0.9
MAY 10-12	1405	635	2.2	1446	2452	0.6
MAY 12-14	2738	1087	2.5	2296	3699	0.6
72 hr. TESTS						
APR. 25-28	1300	173	7.5	82	31	2.6
MAY 2-5	577	143	4.0	100	112	0.9
TOTALS	10865	3385		5648	8214	
AVERAGE			3.2			0.7

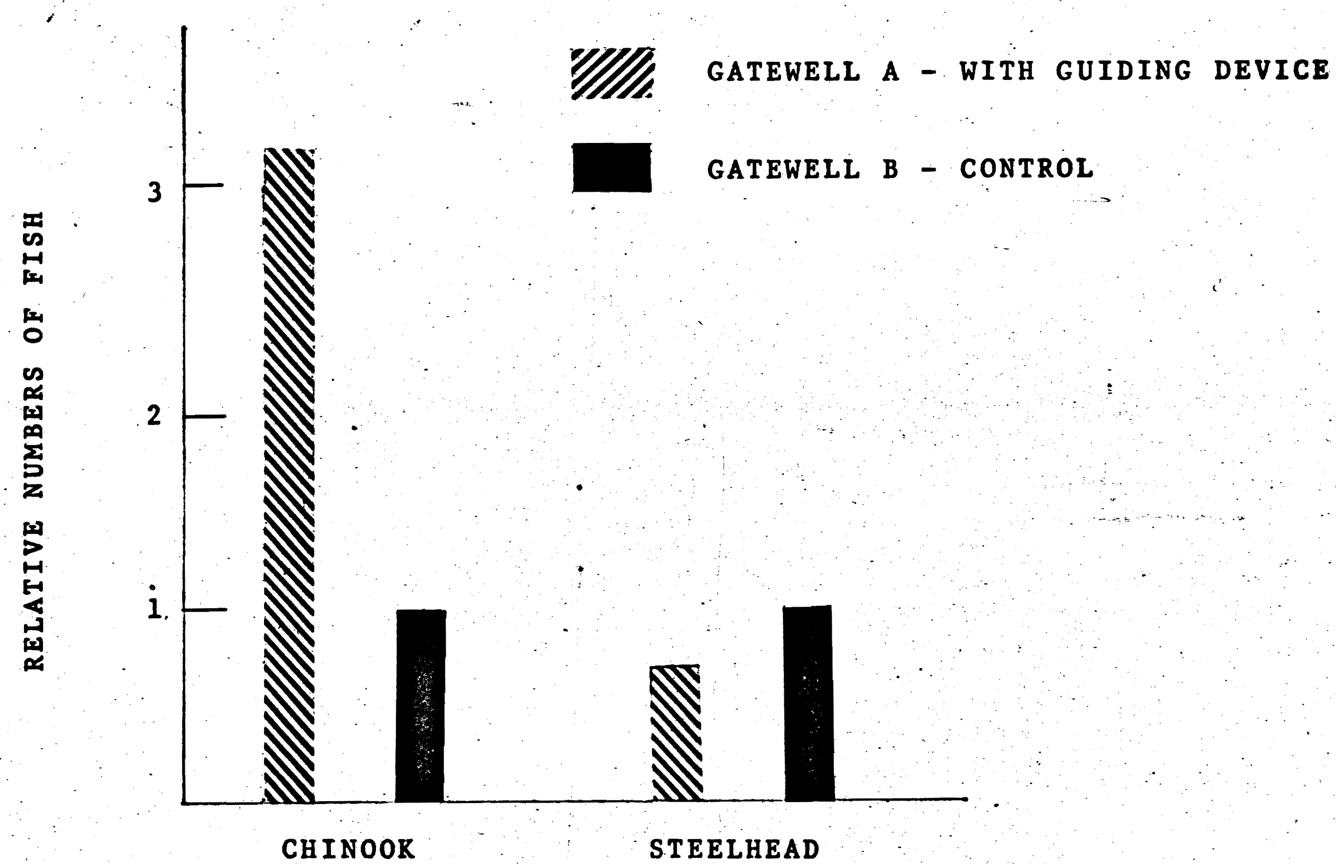

Figure 4.--Relative numbers of fish entering gatewells 3-A and 3-B (based upon the number of fish entering gatewell 3-B).

entrance are higher (the screen reduces the velocity of water it intercepts from about 6 f.p.s. to a range of from 1 to 3 f.p.s., causing a "cone of resistance" that probably extends upstream beyond the entrance of the intake).[2/] (2) The fish may enter the intake, but upon contacting the screen swim back into the forebay to enter some other (unscreened) intake. (3) The fish, upon contacting the screen, may sound and pass under the screen.

The solutions to these problems are as follows. If fish are avoiding the slower entrance velocity to the intake or contacting the screen and swimming back out, the addition of traveling screens to all intakes will cancel this type of behavior; i.e., there will be no velocity differences between intakes, and fish that avoid one screen must ultimately be guided by another. If steelhead are contacting the screen and sounding to pass under the device, this escape route can be blocked with a horizontal flow splitter or false floor in the intakes (Fig. 5). Although this modification may be out of the question at existing dams, there is no problem including it in Lower Granite Dam for which we have at least one more year to make design modifications.

[2/] Similar behavior by juvenile steelhead has been observed in the Snake River in conjunction with large smolt traps.

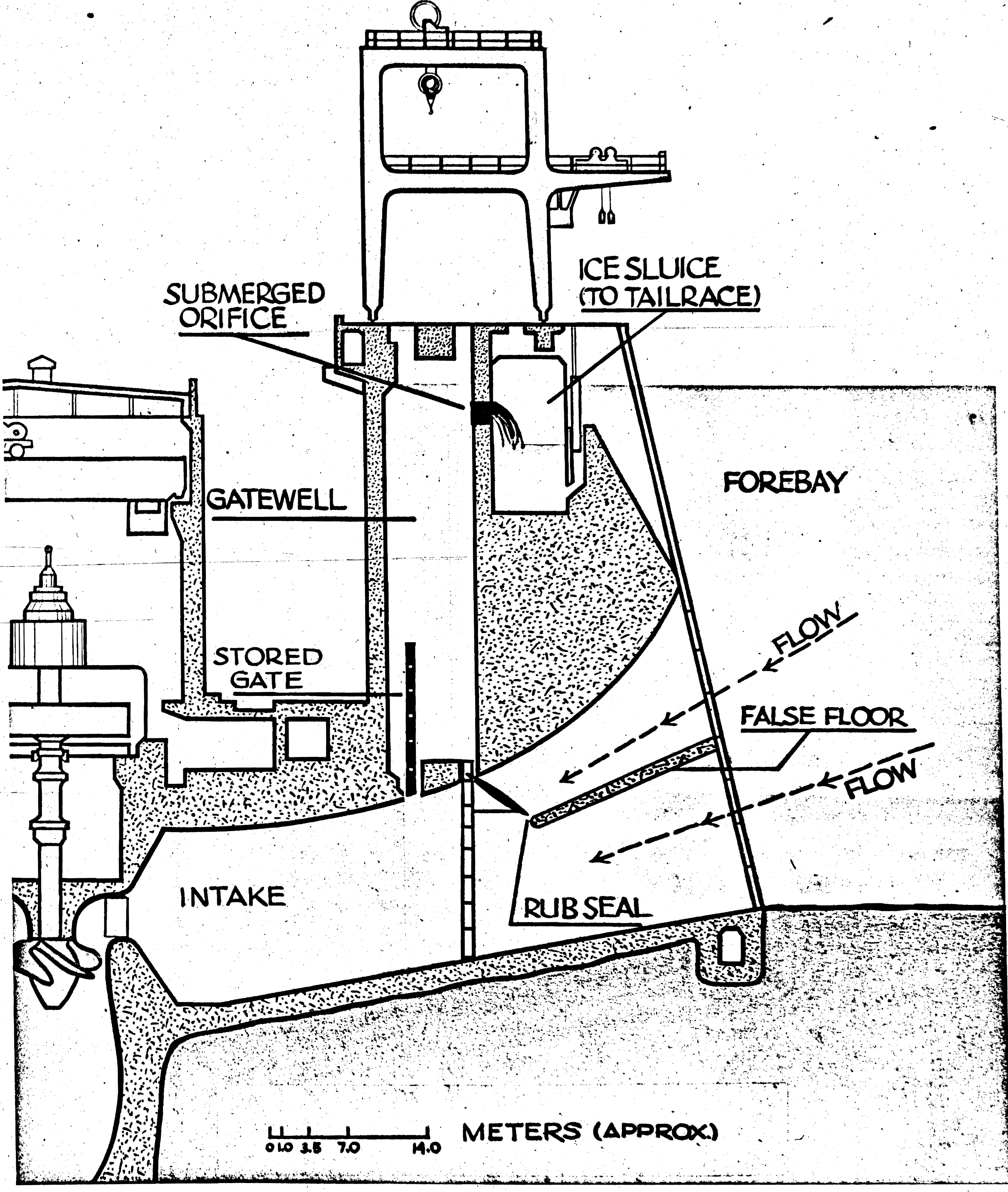

Figure 5.--The addition of a flow splitter, or false floor, in turbine intakes would prevent steelhead in the upper water mass from sounding and passing under the traveling screen.

Research proposed for 1971 would determine whether steelhead are escaping beneath the screen. The support structure of three traveling screens would be modified to hold fyke nets (Fig. 6) to capture all fish in the water mass passing beneath the screens. Thus, all fish entering the three intakes of one turbine will be captured; i.e., guided fish will enter the gatewells, and unguided fish will be captured in the nets. This plan not only would remove all doubts concerning experimental results, but also could be accomplished with a minimum number of tests.

The importance of obtaining a definite answer by next year cannot be overemphasized; any decision to modify the intakes of Lower Granite Dam--such as to install the horizontal flow splitter--must be made within a year.

ESCAPEMENT OF GUIDED FISH

Tests conducted from May 14 to June 4 were made with the closure screens open in the test gatewell (3-A) to allow voluntary escapement of fish back into the intake. The data are listed in Table 2 and presented graphically in Fig. 7 together with data obtained when escapement was prevented.

The data clearly show that chinook escaped in significant numbers unless prevented from doing so; data for steelhead, however, are inconclusive.

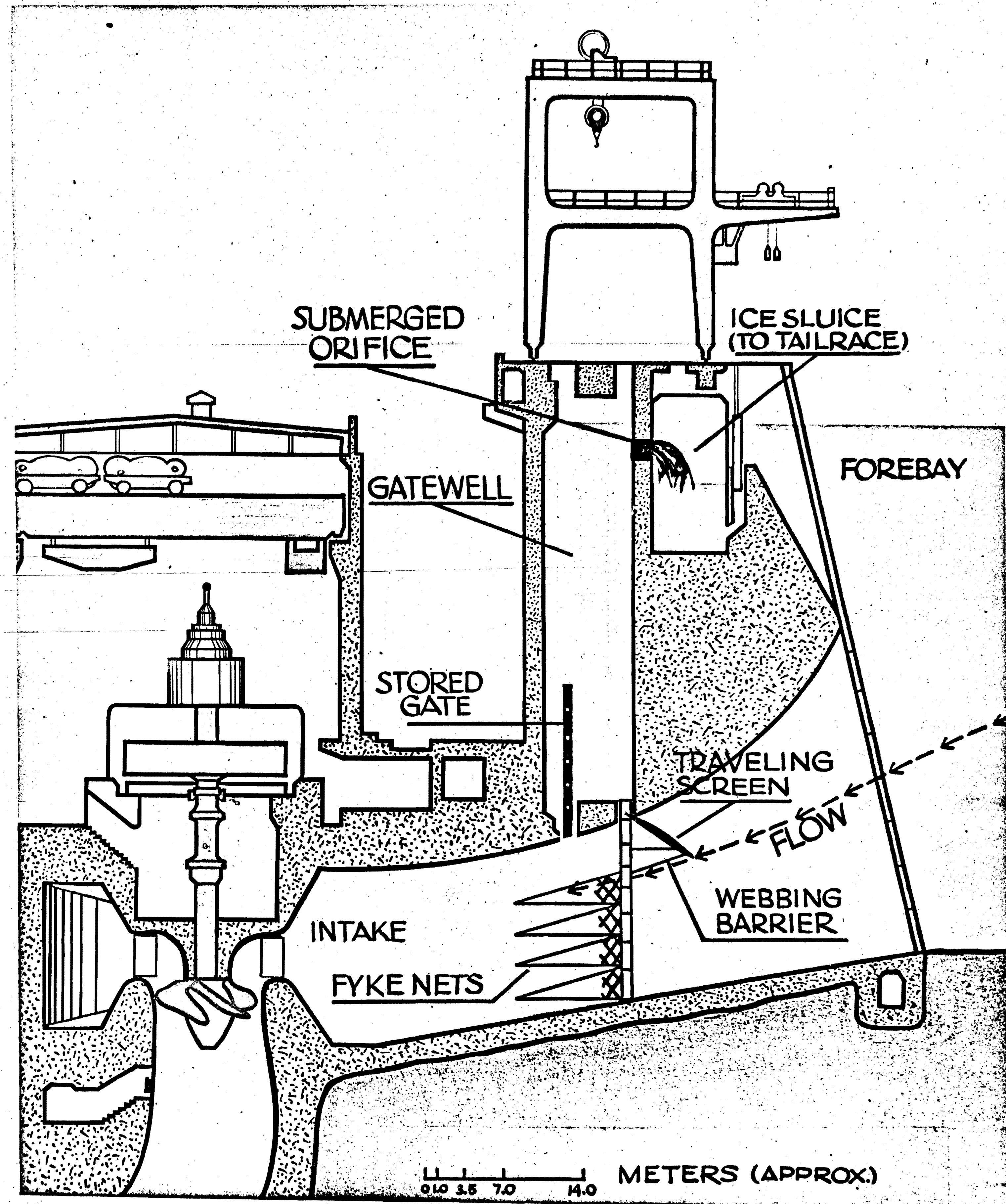

Figure 6.--The capture of guided fish (in gatewells) and unguided fish (with fyke nets as shown) will provide irrefutable data on guiding efficiency of the traveling screen.

Table 2.--Numbers of chinook salmon and steelhead trout taken from test and control gatewells during 24-, 48-, and 72-hour studies; escapement allowed.

TEST PERIOD	CHINOOK GATEWELL A (with screens open) TOTAL NO. CAPTURED	CHINOOK GATEWELL B (control) TOTAL NO. CAPTURED	CHINOOK GUIDING FACTOR (A/B)	STEELHEAD GATEWELL A (with screens open) TOTAL NO. CAPTURED	STEELHEAD GATEWELL B (control) TOTAL NO. CAPTURED	STEELHEAD GUIDING FACTOR (A/B)
24 hr. TESTS						
MAY 14-15	730	452	1.6	780	942	0.8
MAY 15-16	526	217	2.4	546	584	0.9
MAY 19-20	170	99	1.7	264	324	0.8
MAY 25-26	130	54	2.4	203	311	0.7
JUNE 2-3	98	77	1.3	69	139	0.5
JUNE 3-4	39	28	1.4	44	92	0.5
48 hr. TESTS						
MAY 23-25	240	144	1.7	615	1235	0.5
72 hr. TESTS						
MAY 16-19	692	562	1.2	541	1279	0.4
MAY 20-23	701	386	1.8	1385	1712	0.8
TOTALS	3326	2019		4447	6618	
AVERAGE			1.6			0.7

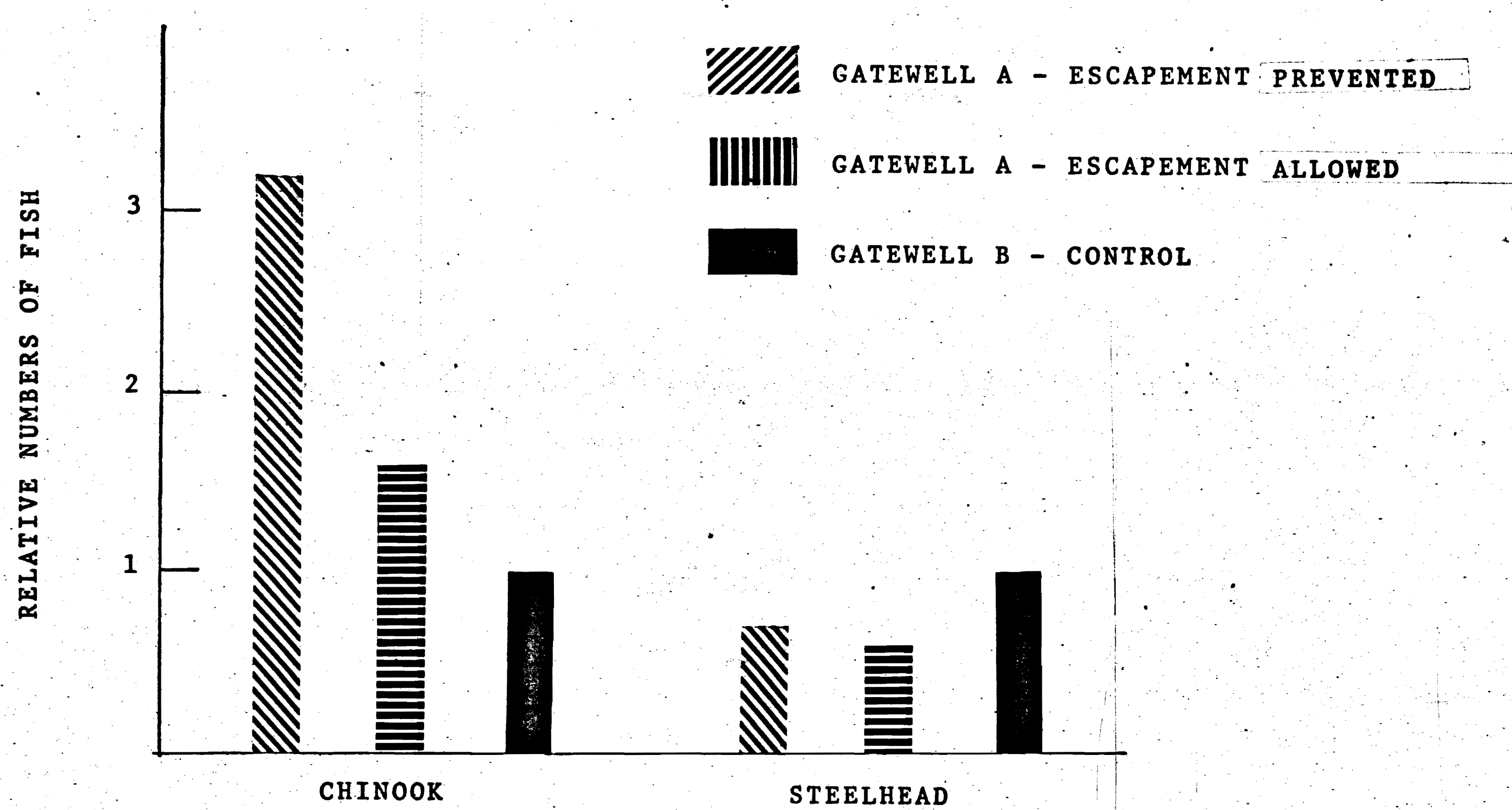

Figure 7.--Relative numbers of fish entering gatewells 3-A (under two test conditions) and 3-B (based upon the numbers of fish entering 3-B).

The solution to the problem of escapement is relatively simple. A selection of one of several alternatives has been made because of the potential application of this method to reduce the delay of fish in finding and passing through submerged ports. The method and its description are included in the next section.

PASSAGE OF FISH THROUGH SUBMERGED PORTS

At the outset of testing it was apparent that residualism in the gatewells would be much higher than we found at McNary Dam. Data for six 24-hour tests, five 48-hour tests, and two 72-hour tests (Table 3) bear out this initial finding. Results obtained at Ice Harbor Dam are compared with those for McNary Dam in the bar graph in Fig. 8.

The percent residualism in unmodified (control) gatewells at McNary Dam was surprisingly small for 24-hour periods. Under the same conditions (control) at Ice Harbor Dam (1970), however, residualism was very high, implying the cause is inherent in the dam (gatewell) itself. By adding the traveling screen and closing off the escape routes to the intake at Ice Harbor Dam, residualism was reduced, but not to an acceptably low level.

Table 3.--Number of chinook salmon and steelhead trout remaining in gatewells (called residuals) at the end of 24-, 48-, and 72-hour test periods.

	CHINOOK								STEELHEAD							
	GATEWELL A (with screens)				GATEWELL B (control)				GATEWELL A (with screens)				GATEWELL B (control)			
TEST PERIOD	ORIFICE TRAP (No.)	DIPNET (No.)	TOTAL CATCH (No.)	RESIDUALS (%)*	ORIFICE TRAP (No.)	DIPNET (No.)	TOTAL CATCH (No.)	RESIDUALS (%)*	ORIFICE TRAP (No.)	DIPNET (No.)	TOTAL CATCH (No.)	RESIDUALS (%)*	ORIFICE TRAP (No.)	DIPNET (No.)	TOTAL CATCH (No.)	RESIDUALS (%)*
24 hr. TESTS																
APR. 22-23	87	251	338	74.3	7	32	39	82.0	8	7	15	46.7	3	12	15	80.0
APR. 28-29	44	172	216	79.7	4	38	42	90.5	7	0	7	0	3	0	3	0
APR. 29-30	34	64	98	65.3	2	36	38	94.7	8	6	14	42.8	3	7	10	70.0
APR. 30-5/1	10	186	196	94.9	1	42	43	97.7	4	8	12	66.7	8	6	14	42.8
MAY 1-2	51	180	231	77.9	4	46	50	92.0	10	6	16	37.5	7	5	12	41.7
MAY 5-6	14	121	135	89.6	2	24	26	92.3	28	7	35	20.0	17	13	30	43.3
48 hr. TESTS																
APR. 23-25	74	574	648	88.6	10	81	91	89.0	8	5	13	38.5	7	5	12	41.7
MAY 6-8	194	859	1053	81.6	22	354	376	94.1	153	187	340	55.0	78	284	362	78.4
MAY 8-10	696	1234	1930	63.9	103	539	642	84.0	552	720	1272	56.6	562	900	1462	61.6
MAY 10-12	621	784	1405	55.8	99	536	635	84.4	1037	409	1446	28.3	1044	1408	2452	57.4
MAY 12-14	1058	1680	2738	61.4	290	797	1087	73.3	1662	634	2296	27.6	1879	1820	3699	49.2
72 hr. TESTS																
APR. 25-28	668	632	1300	48.6	95	78	173	45.3	67	15	82	18.3	26	5	31	16.1
MAY 2-5	174	403	577	69.8	35	108	143	75.5	32	68	100	68.0	38	74	112	66.1
TOTALS	3725	7140	10865		674	2711	3385		3576	2072	5648		3675	4539	8214	
OVERALL RESIDUALS (%)				65.7				80.1				36.7				55.2

$$* \frac{\text{DIPNET CATCH}}{\text{TOTAL CATCH}} \times 100$$

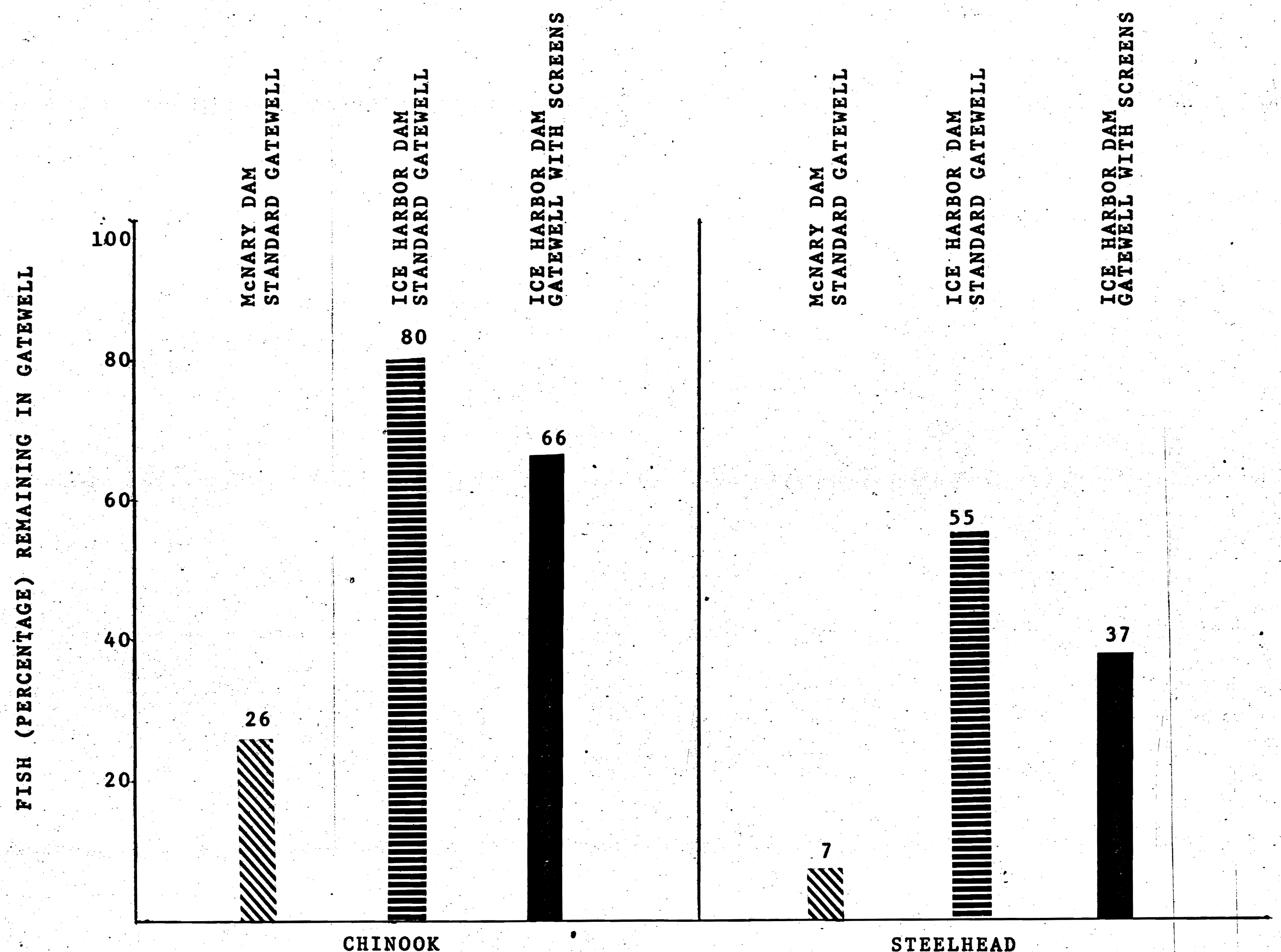

Figure 8.--Percentages of chinook salmon and steelhead trout remaining in gatewells under various conditions.

Closer examination of Table 3 shows that percent residualism of chinook in both test and control gatewells reduced as duration of tests increased; e.g., in gatewell 3-A the average for 24-hour tests was 80 percent; for 48-hour tests, 66 percent; and for 72-hour tests, 55 percent. Even after 72 hours, however, residualism was too high for acceptability.

A possible solution to this problem is shown in Fig. 9. By installing a vertical, stationary screen in each gatewell, as shown in the figure, the fish in the gatewell will be restricted to about one-fourth of the area normally available to them. This should increase the rate at which searching fish are exposed to the submerged orifice and reduce the delay of fish accordingly.

The use of a vertical screen has the effect also of preventing guided fish from escaping back into the intake through the downstream openings of gatewells, thus providing a solution for the problem of escapement described in the preceding section.

CONCLUSIONS AND RECOMMENDATIONS

Evaluation of the prototype traveling screen yielded positive results for juvenile chinook salmon, one of the two important species of upriver stocks of fish requiring

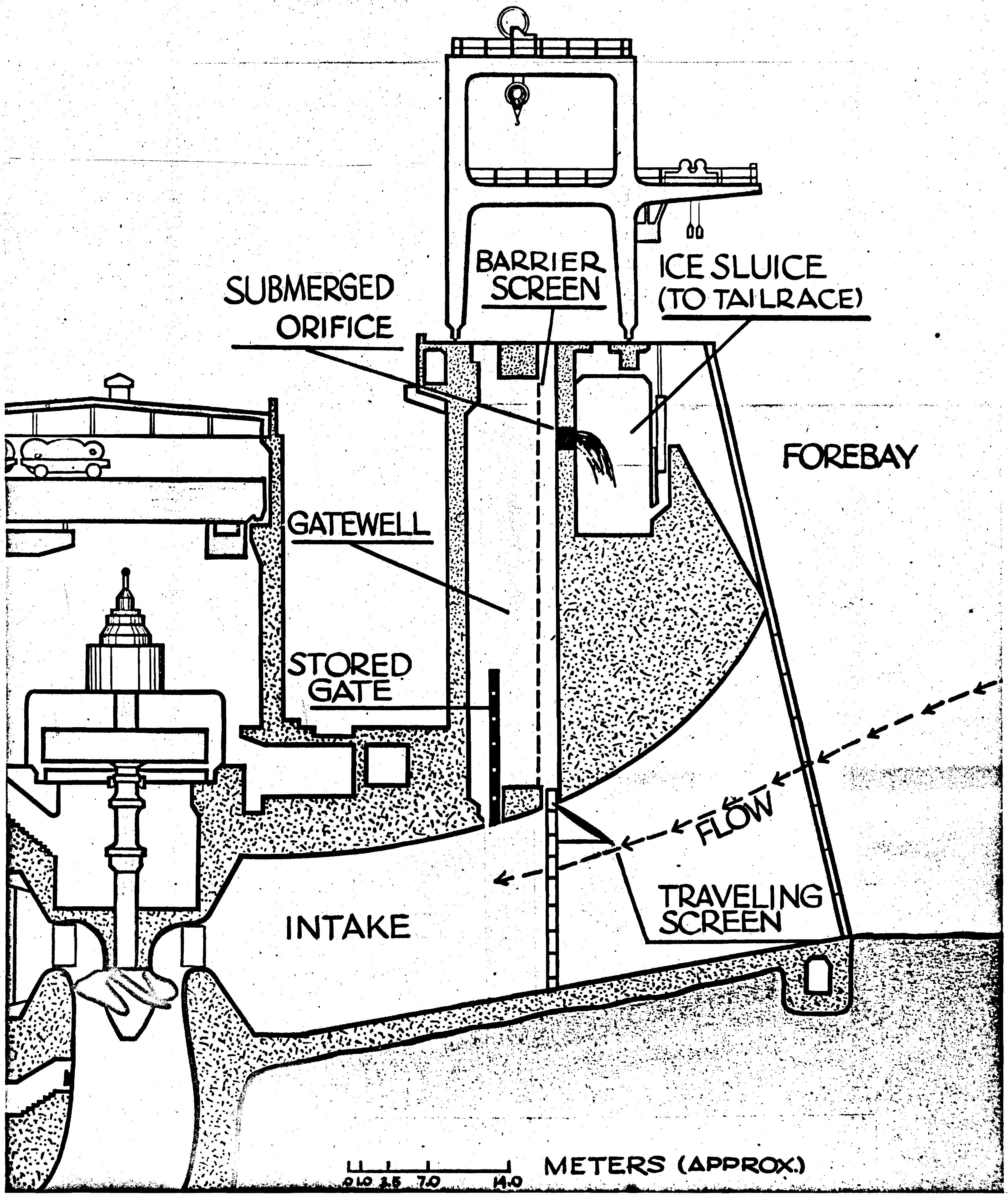

Figure 9.--Installing a barrier screen in all gatewells will (a) prevent guided fish from escaping to the intake through the downstream opening of the gatewell, and (b) restrict fish to a smaller area in the region of the submerged orifice, thus enhancing passage of fish through the orifice.

protection at low-head dams. Consideration of methods for enhancing the diversion of steelhead leads us to the judgment that successful guiding of this species probably will be achieved, no matter what avoidance behavior is employed by the steelhead. Therefore, indicated research should be pursued vigorously.

Although significant numbers of chinook will escape from gatewells when traveling screens are installed in the associated intakes, one solution to this problem has already been demonstrated (Fig. 3), and the proposed barrier screen (Fig. 9) also should be adequate.

Difficulty of fish locating and passing through submerged ports is a problem only if the additional delay causes residualism of fish in the river system (where fish are bypassed rather than collected for transport) or excessive accumulations of fish in gatewells, which could result in excessive predation, a higher disease transmission factor, high susceptibility to gas bubble disease, and possibly deoxygenation of the water in the gatewells.

For these reasons, we strongly recommend that research continue on methods for reducing delay of fish in gatewells.