Informational Leaflet 12

STEEPPASS FISHWAY DEVELOPMENT

By:

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STATE OF ALASKA
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DEPARTMENT OF
FISH AND GAME
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SUBPORT BUILDING, JUNEAU

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ABSTRACT

A sectional, prefabricated, lightweight, corrosion resistant, functional steeppass fishway of the Denil type has been developed and successfully used for passing upstream migrating salmon over low head barriers.

The average water velocity in relationship to the channel of the Model "A" varies from two and eight-tenths to three and three-tenths feet per second at gradients between twenty and thirty-five percent. Flow patterns in the transit channel are complex and the rate of entrainment is high. The issuing water is attractive to the migrants and they have been observed to consistently enter the stream and fishway without hesitation. The fish in their transit appear to exploit the upstream directional components of motion of the reentrant water jets which are introduced and directed to control the velocity of the water.

Several test installations have been made to evaluate the steeppass under natural conditions and more are contemplated under steadily increasing heads and slopes to equate the uppermost limits of practical application against mathematically computed ceilings.

Attempts to reduce the amount of air entrainment and water turbulence led to development of an alternate model (Model "C") which has been tested hydraulically in full scale but not yet used in field installations. In this model, the average water velocity in relationship to the channel varies from four to one-tenth to four and five-tenths feet per second at gradients between twenty and thirty-five percent.

ADDENDA TO INFORMATIONAL LEAFLET NO. 12

STEEPPASS FISHWAY DEVELOPMENT

March 1965 G.L. Ziemer, P.E.

The Alaska Department of Fish and Game is continuing its research and experimentation with the steeppass fish ladder. Immediate emphasis is being applied to evaluation of transiting migrant behavior and to extension of vertical limits in continuous runs with resting pools.

Developmental work by others with the basic Alaska Steeppass designs includes that of Professor Charles E. Behlke of Oregon State University with an enclosed fishpass and that of Engineer C.H. Clay of the Department of Fisheries, Canada, with deeper sections. The shallow open top Alaska Steeppass is sensitive to small changes in head unless regulatory headworks are included in the construction. The Alaska Model "A" tends to be drowned out in high flow stages as soon as the side panels are overtopped with the result some of the migrants swim out over the sides and are lost from the transit pattern. Installed units have been covered to block the escape of the migrants. An enclosed or a deeper unit may solve this problem at applicable installations. The twenty-seven inch maximum depth of the Alaska design is a control dimension which enables getting the panels into commonly available planes for transport to remote sites.

Progress Report No. 111 (October 1964) from the Fisheries Engineering Research Facility at Bonneville Dam reports experience with an Alaska Model "A" steeppass and cites passage data.

A desire to combine the better features of both the Models "A" and "C" led to development of a Model "D" which duplicates the "A" in every respect except the fins are set obliquely to the lengthwise axis at a $12\frac{1}{2}°$ angle with the tops of the fins displaced upstream (as in the "C"). Then, when installed, the fins will be oriented in a nearly true vertical plane. This modification should help cure the orientation problems expressed by the sockeyes leaping out of the Model "A". The configuration will still hold velocities in the lower ranges and also yield a discharge relatively free of trapped air. Units of this design have been fabricated and will be installed in 1965 at the nine foot block in Ketchikan Creek.

Evaluation by competent biologists of fish behavior in the steeppasses and the connecting resting pools may produce critiques for further improvements in design. A formal program of research along these lines is being initiated in 1965 by the Alaska Department of Fish and Game. The net velocity of the migrating fish becomes very important in relationship to total accomplishment. Very little is known about the fish's reaction to any particular set of specific physical circumstances, but it has been found that fish can and do exert the energy required (within maximum capabilities and for limited periods of time) to make forward progress under proper motivation. Over exertion, however, does require more than a proportional period of time for recovery and may be

lethal if of sufficient magnitude and duration. For maximum net performance we must design fisheries facilities around the fish's performance patterns.

The prefabricated, lightweight component panel concept of a fishway which would be operational at severely steep grades was explored and developed to meet an unique Alaskan situation which involves construction in remote areas where access is difficult and on-site construction is very costly. The resulting Alaskan Steeppass design has its most advantageous application at low head barriers where a single continuous flight can be used and the number of migrants does not exceed 750 per hour. Resting pools add to the cost, increase transit time and may be neither necessary nor desirable in steeppass fishways of low or medium rises. Sockeye salmon have been observed taking up temporary residence in resting pools, moving only when subjected to either intra or interspecific strife. Most pink salmon, which are considered weaker swimmers than sockeyes, move through the Frazer fishway, a thirty-three foot rise in four flights connected by resting pools, without using the pools provided. The current program is designed to help equate the influencing factors by research with in-place runs of native migrating fish.

The Laura Creek project in the Pauls Lake watershed on Afognak Island was completed and operational for the 1964 sockeye and coho salmon runs. This fishway exploits a continuous ninety-foot long steeppass of our Alaska Model "A" design with a 17.35 foot rise on a 19.7 percent grade. This ninety-foot uninterrupted run posed no problems for the transiting fish and they migrated this distance without any discernible adverse effects or strain. The behavior of the exiting fish was the same as that of those passing through only thirty or forty-foot long sections. The results were very impressive and based upon this initial experience with a long continuous run, we now contemplate much more extended horizontal and vertical limits between resting pools on future installations. If future work supports this original showing, resting pools will not be used on elevation differentials of less than twenty feet. The next extension of these tests will be at a twenty-five foot vertical block.

Four tandem flights of paired models "A" and "C" units of forty lineal feet length each were installed at thirty-three foot high Frazer Falls on Kodiak Island in 1963. The rise between successive resting pools of 8.25 feet in a 36.75 foot horizontal run is a slope of 22.4 percent. The design enables a comprison of the two models under working conditions with a contemplated maximum loading of 1,000 migrants (sockeye salmon) per hour. This project is a part of the continuing developmental study of the Alaska Steeppass design to probe the cost factors and to test migrant behavior in multiple flights. The project is located in a virgin area, seven miles from tidewater, with no preproject access roads or trails available. Project costs break down thusly:

32 units of steeppasses	$24,151
Prine construction contract	85,592
Surveys, engineering & construction supervision	9,247
Developmental modifications	17,170
Total project cost	$136,160

An analysis of project costs indicates that a pool and overfall weir design could have been constructed for comparable money. The cost advantage of the steeppass design for simple installations begins to disappear when tandem flights joined by resting pools are used. The developmental modifications included the addition of supplemental attraction water and an entrance lead. Fifteen cubic feet per second of diffused water was added at the entrance portal to produce a discharge velocity of six feet per second in order that the issuing current would be more attractive to the migrating fish in competition with the water coming over the falls itself. A submerged permeable dike of tetrahedrons forming a lead from the approach pool to the entrance portal was placed to break up an eddy producing an adverse flow pattern. The migrants had moved to the falls and away from the fishway entrance. These two items have helped materially in attracting the fish to the adit portal. The normal flow over Frazer Falls during the migrating season varies between two hundred and three hundred cubic feet per second and the problems there underline the importance in design of fishway attraction where the issuing water competes with the discharge over the barrier. Installed steeppass units enjoy excellent success with fishing efficiency in streams where the extraneous flow at the entrance port does not exceed twenty-five cubic feet per second. When the Frazer ladder was first placed in operation, pronounced waves moved down the model "C" units. This condition was completely eliminated by cutting off part of the projecting fins at the upstream ends of the "C" units so the water could accelerate more readily.

In its partially developed stage, the Frazer fishway passed in excess of 2,500 sockeye and 3,000 pink salmon in 1963. 1964 migrants totaled nearly 9,000 sockeye salmon. This is an introduced run just building up through plants of eggs and adult salmon.

Evaluation of the 1963 Frazer data indicated that the early portion of the run of red salmon had a pronounced preference for the "A" model steeppass. During the last half of the 1963 run, preference was still shown for the "A" type, but only to a moderate degree. It was also discovered that the sockeye migrants entered and left the ladder at the same rate after a sufficient number (140-150) of fish had entered and occupied the resting spaces within the pools. Ninety-five percent of the sockeyes entering the ladder passed through and exited into the stream above the falls. Some biologists have expressed the opinion that the tendency of migrating sockeye to take up residence within a ladder may be sufficient reason to consider eliminating the resting pools in low head ladders entirely.

Pink salmon evidenced an entirely different behavioral pattern in the Frazer ladder. They entered in far greater numbers per day and exhibited a hurrying tendency with no disposition to loiter within the ladder once having entered. They did not utilize the resting spaces to the extent that the reds did and continued to exit when further entrants were blocked. Only fifty-seven percent of the pink salmon entering the ladder completed the entire transit in a continuous passage, exiting into the river upstream of the falls. A great number turned in the ladder without passing through. For all to eventually complete passage of the ladder required many to make several attempts. About a dozen sockeyes jumped out of the steeppass, but the pinks did not show any tendency to do so. Also, contrary to the pattern of the sockeyes, the pink salmon evidenced a strong preference for the Model "C" type of steeppass fishway.

This tendency was fairly consistent and uniform throughout the entire migration period.

Coho (silver) salmon moved through the "A" model readily and seemingly without stress. Coho have not been exposed to the "C" units. Dog salmon in limited numbers have passed through both the "A" and "C" models but there has been insufficient exposure to justify comment. The same is true in regard to king salmon. Sea run trout move through all of our installations easily.

Slopes between twenty and thirty percent grades are recommended for the Alaska Steeppass design fishways. In addition to the Frazer Falls and Laura Creek fishways described above, five projects bridging various intermediate heights have been completed. Some of these units have been in use for the last six years. All are functioning successfully on pink, red, and silver salmon runs. Two more are scheduled for construction in 1965.

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INTRODUCTION

The vast areas of lakes and lengths of streams in Alaska presently blocked to upstream migrating adult salmon by waterfalls and rapids, but otherwise suitable for their freshwater environment, indicate that the resource could be expanded were these waters made available to the fish. Most of these upstream migrant blocks are at locations difficult to reach with both construction equipment and materials, which results in very high onsite construction costs, and dictates development and utilization of fishpasses and ladders requiring only the barest minimum of activity at the sites of the blocks. Fish ladders of conventional construction are generally too costly at this time to be employed by the State except at selected locations.

An ideal fishpass for the State's ordinary and most common place needs would be a flexible and versatile unit of limited capacity so designed that it would be fully functional for heads to twenty feet at sites of greatly varying topographical and hydrological characteristics and in addition, be suitable to prefabrication in easily assembled lightweight sections. Supplemental values would accrue if it could also be made strong enough for point instead of continous support, corrosion resistant and relatively maintenance free during the fishing season.

The first approach to the problem in early 1956 involved a review of the literature and an inspection of many fishways maintained for passage of salmon at dams and natural blocks. Association with the Iowa State Conservation Department and through it, with the work conducted by the Iowa Institute of Hydraulic Research (McLeod and Nemenyi, 1939-1940), contributed greatly. Alaska Department of Fisheries (now Alaska Department of Fish and Game) biologists, Walter Kirkness, R.R. Parker, and W.A. Smoker provided critiques throughout the project development.

The entire salmon migration fishway complex is discussed in its entirety in a current publication, Bulletin XI of the International Pacific Salmon Fisheries Commission, by Andrew and Green (1960), for the perusal of those interested and need not be spelled out herein. Nemenyi (1939-1940) and the Committee on Fish Passes (1942), McLeod and Bell (1949) set forth the requirements of a good fishway as "control water velocity below the swimming capacity of the fish; avoid rapid changes in flow pattern; provide physical and visual clearance; provide resting areas as required; operate without manual control; discharge enough water to attract the fish; possess a well located fishing entrance; be economical to construct and maintain; operate without interference by sediment and debris; and, not require more water than is available or allocated."

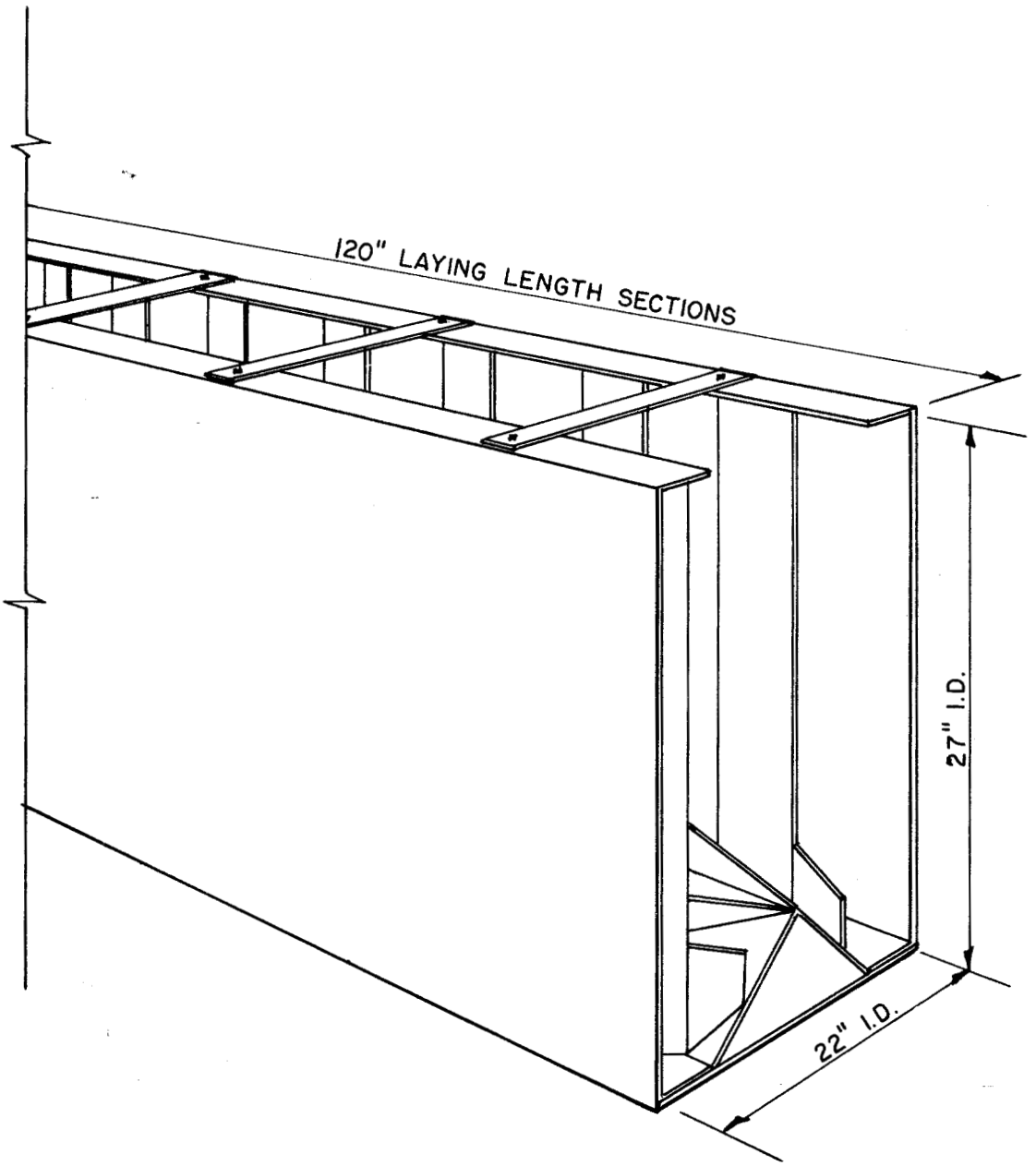
The diverse objectives sought compelled a compromise of existing methods into designs for a fishway meeting the most important ends, with the others satisfied in part only to the extent incidentally possible. A steeppass fishway of a modified Denil type appeared as the one most nearly fulfilling the requirements set up. A great amount of work has been done with this pass in Europe and in other parts of this country but has not been used extensively in Pacific Coast states, chiefly because of the objections to the continous and strenuous effort required of the fish in transit through one, viz, the average water

velocity of 11 f.p.s. cross-section of the Dryden Dam Denil. Other less valid objections are often raised of which some stem from lack of intimate acquaintance with its cardinal operating principles. R.R. Parker, (1956 and repetitively thereafter) counciled that, for low head ladders, (1) the velocity of the water within the fishpass must be held down, if possible, to levels where the momentary rate of work required did not exceed the current rate of energy conversion from the fish's stores; (2) avoidance of resting places within the fishway; and (3) forcing the migrant fish into a continuous non-stop end-to-end transit. However, our major objectives appeared to require a high work output, steep assent, with attendent rapid passage, to avoid long costly fishways and complicated entrances removed some distance from the most upstream area at the very base of the migrant block.

Our initial work involved mock-up models seeking a configuration and spatial arrangement of fins which bore promise of doing the job while remaining amenable to low cost shaping and assembling. One-fifth scale models in sheet metal were then constructed and tested. It was early apparent that our goal of holding the average velocity of the water in the net cross-section to the 3 to 5 f.p.s. range required reducing the friction between the water and channel elements to the lowest possible values in order to increase to the maximum the efficiency of the re-entrant jet action. Use was made in the newer scale models of mirror-smooth highly polished tin plated sheet metal with sharp edged thin fin elements. The net width of the most promising models were then adjusted until the velocity objectives were attained. Data on our model work is not included herein as the facilities and resources available to us for these studies were inadequate for development of the necessary refinements in techniques permitting confident expansion of the model results by application of the established precepts of hydraulic similitude. Two models in testing were so successful, however, that full scale prototypes were contructed for experimental hydraulic tests, and for installation exposing them to natural migrations of salmon.

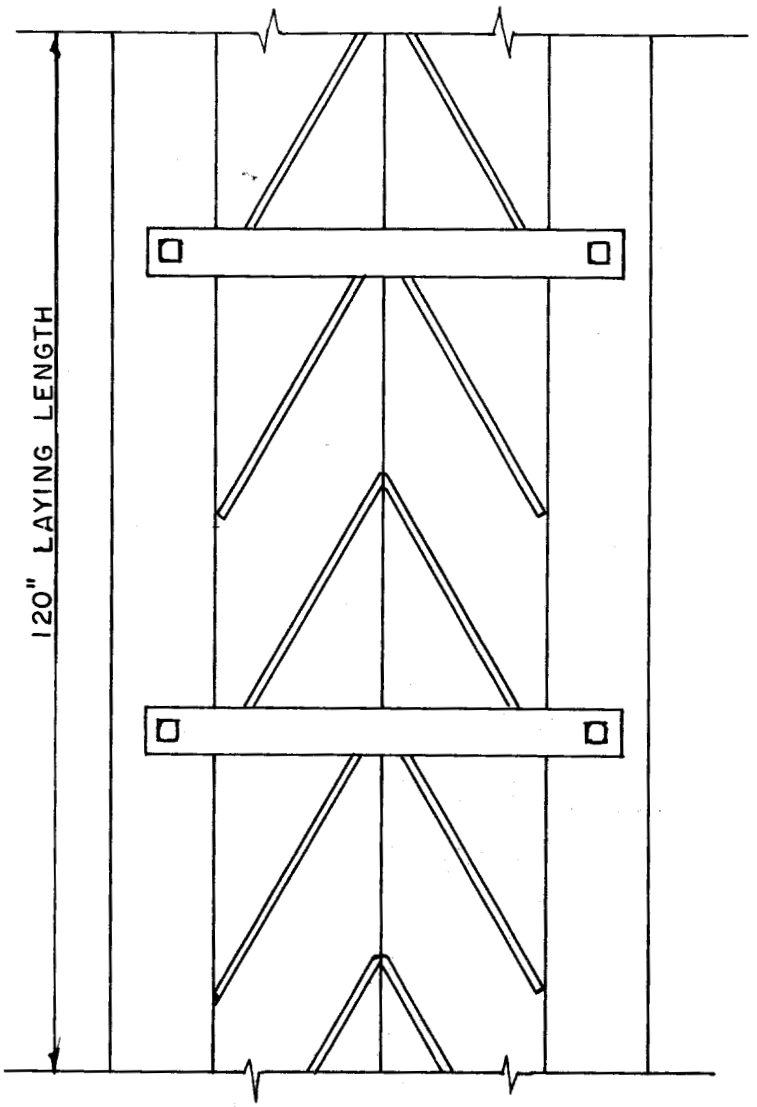
The steeppass fishway designated as Alaska Department of Fish and Game Model "A" is an adaptation of the Modified Denil No. 6 developed by McLeod and Nemenyi (1939-1940). Figures 1 through 4 delineate its essential features. One-quarter inch thick aluminum alloy plate specification 525-0 is used throughout. One-fourth inch thick fins are used to dampen cut all vibration induced by the flowing water. All component parts of each panel are butt welded on one side for their full contact length; joint plates are attached to the panels with 61S-T4 rivets; and, the panels forming a unit and multiple units connected into a steeppass are fastened together with 24S bolts. The side panels weigh approximately 190 pounds each and the bottom panel 150 pounds, giving with connectors, a gross weight of about 55 pounds per lineal foot of steeppass. Panels have been flown into isolated lakes adjacent to migration blocks tied to the floats of light airplanes and then dragged by men to the sites where used. The assembled units form a strong box-type beam and a four unit (40 lineal feet) steeppass end supported and flowing full of water showed no visible deflection, although such long suspensions are definitely not recommended for use.

When fed into operating Model "A" units, transported bed load sands and gravels to sizes passing a one-inch screen cleared through the units at grades of 20

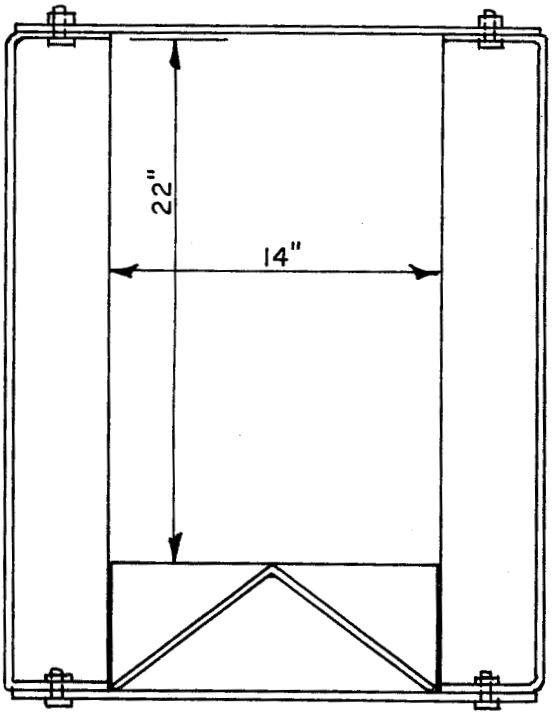


STEEPPASS MODEL A

FIGURE 1



EACH UNIT CONSISTS OF :—
SIX TOP STRAPS
ONE LEFT SIDE PANEL
ONE RIGHT SIDE PANEL
ONE BOTTOM PANEL
THREE JOINT PLATES
RIVETS, BOLTS AND WELDING

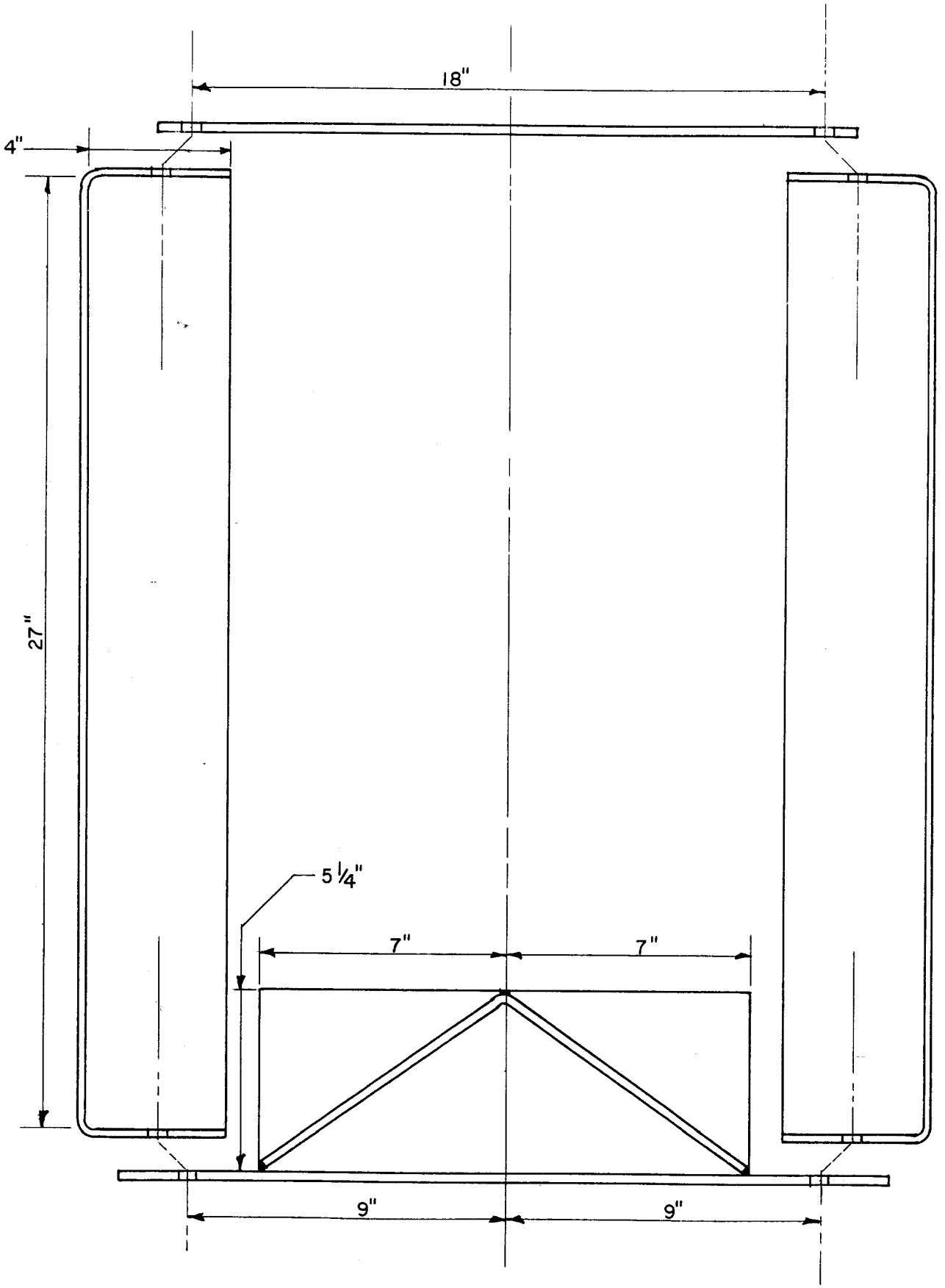


PLAN

ELEVATION

STEEPPASS MODEL A

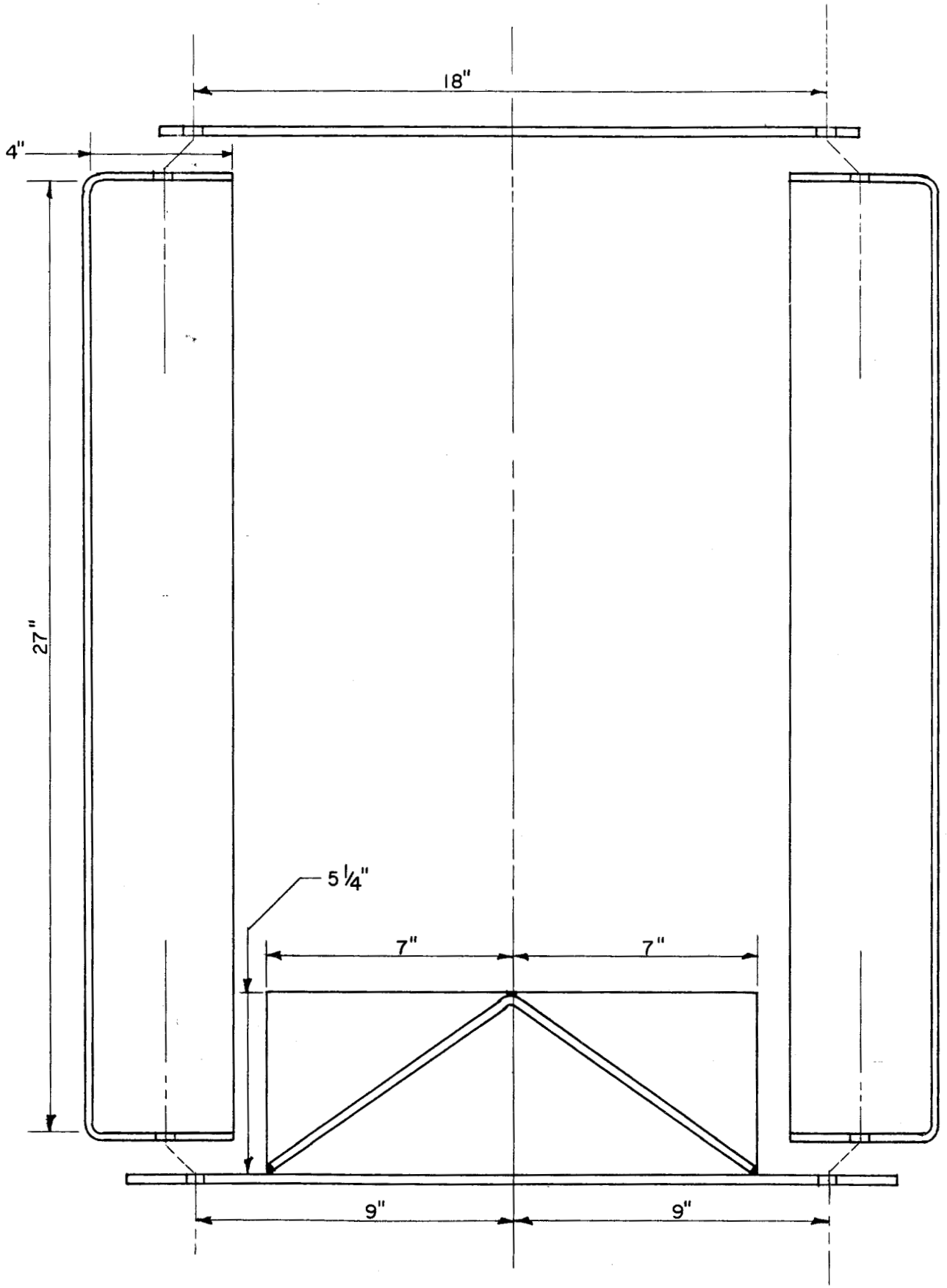
FIGURE 2



COMPONENTS

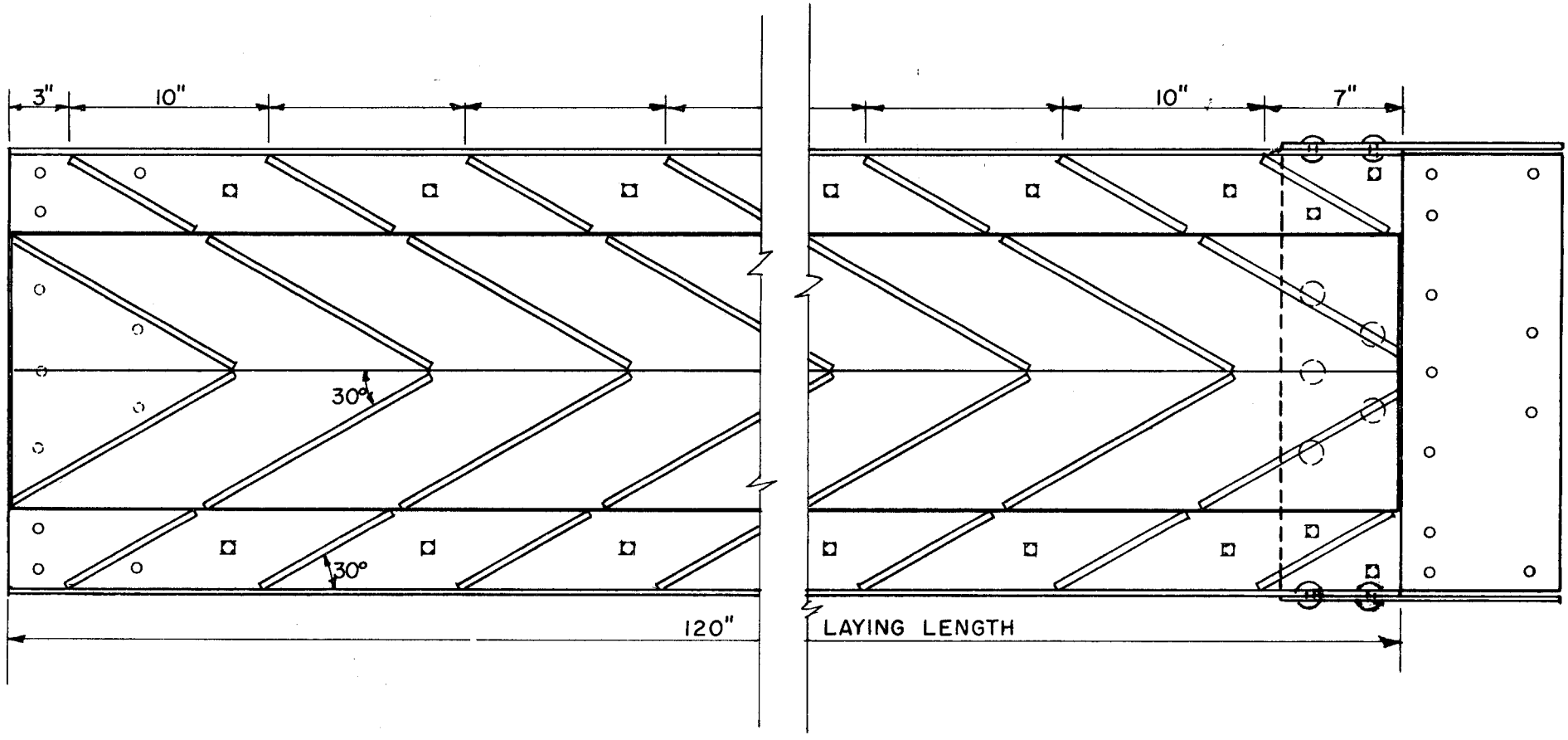
STEEPPASS MODEL A

FIGURE 3



COMPONENTS

STEEPPASS MODEL A FIGURE 3



PLAN SECTION

STEEPPASS MODEL A

FIGURE 4

percent and higher. Larger material of fish-sized wedged between the fins and panel walls. Floating sticks long enough to bridge the clear opening (14") have been observed to hang up when hand fed into the upper end of a working pass. Stream flows in late spring or early summer from snow melt flooding tend to wash Alaska's virgin water courses clean and we have experienced no difficulty from sediment and debris at any of our four test installations. Not a single case of stoppage has occurred in three years but regular inspections are being made to guard against the possibility and for observation. Figure 5 is a photo looking downstream within the Model "A" steeppass. Figure 6 is also of the Model "A" but from the downstream end and shows the character of the flow within the steeppass. This picture is of a unit at 26.2 percent grade and discharging approximately 3.5 c.f.s. In use the lower end is submerged, or nearly so, for efficient fishing.

In the Model "C" steeppass, the fins in the side and bottom panels are set out at a 45° angle and are set obliquely to the lengthwise axis at a 45° angle. In every other detail, the Model "C" is exactly identical to the Model "A" steeppass.

Figure 7 is a downward view into a Model "C", showing the cant of the bottom fins. A downstream view from above an assembled unit, in Figure 8, gives the details of fin placement and especially the co-planar aspect of side and bottom panel fins in each half of the unit.

Hydraulic Analysis

A steeppass testing facility was constructed in 1959 near tidewater on the Ruth Lake outlet stream in Izhut Bay. The setup consists of a water control dam at the outlet of Ruth Lake, a flume carrying water from the creek to a head box, a sharp-crested weir providing close order accuracy of mensuration between one and ten cubic feet per second of water and an elevation providing a range for steeppass slope adjustments of 14.15 feet rise in 40 feet of run. A geared chain hoist suspended from a sky line was used to raise and lower the discharge end of the steeppass under test for slope adjustment and control, the upper end of the steeppass being supported by the weir box. The quantity of water used was manually controlled at the dam by adding or removing dam boards in the flume. The head on the weir was measured by use of a hook gage. The average velocity of the water in the smallest net cross section between fin edges is determined from the Q/A relationship, with the area being established through a procedure of lowering a straightedge in a true horizontal attitude until the flowing water begins to slug before the straightedge. This event regularly occurs at a quite definite stage thereby affording comparative values between tests. See Figures 9 and 10. The steeppass fishway and concrete live box in the foreground of the Figure 10 picture are not a part of our testing installation but a migrant salmon trapping unit operated by the Department of Fish and Game Ktioi Bay Research Station for other research projects. This steeppass fishes in the intertidal zone when in operation. Flow was interrupted at the time to expose all of the installation to better view. The ports shown are closed with damboards when in use.

The results of the hydraulic test are contained in Tables 1 and 2. The head on the 48" long sharp edged end contractions fully suppressed, weir is desig-

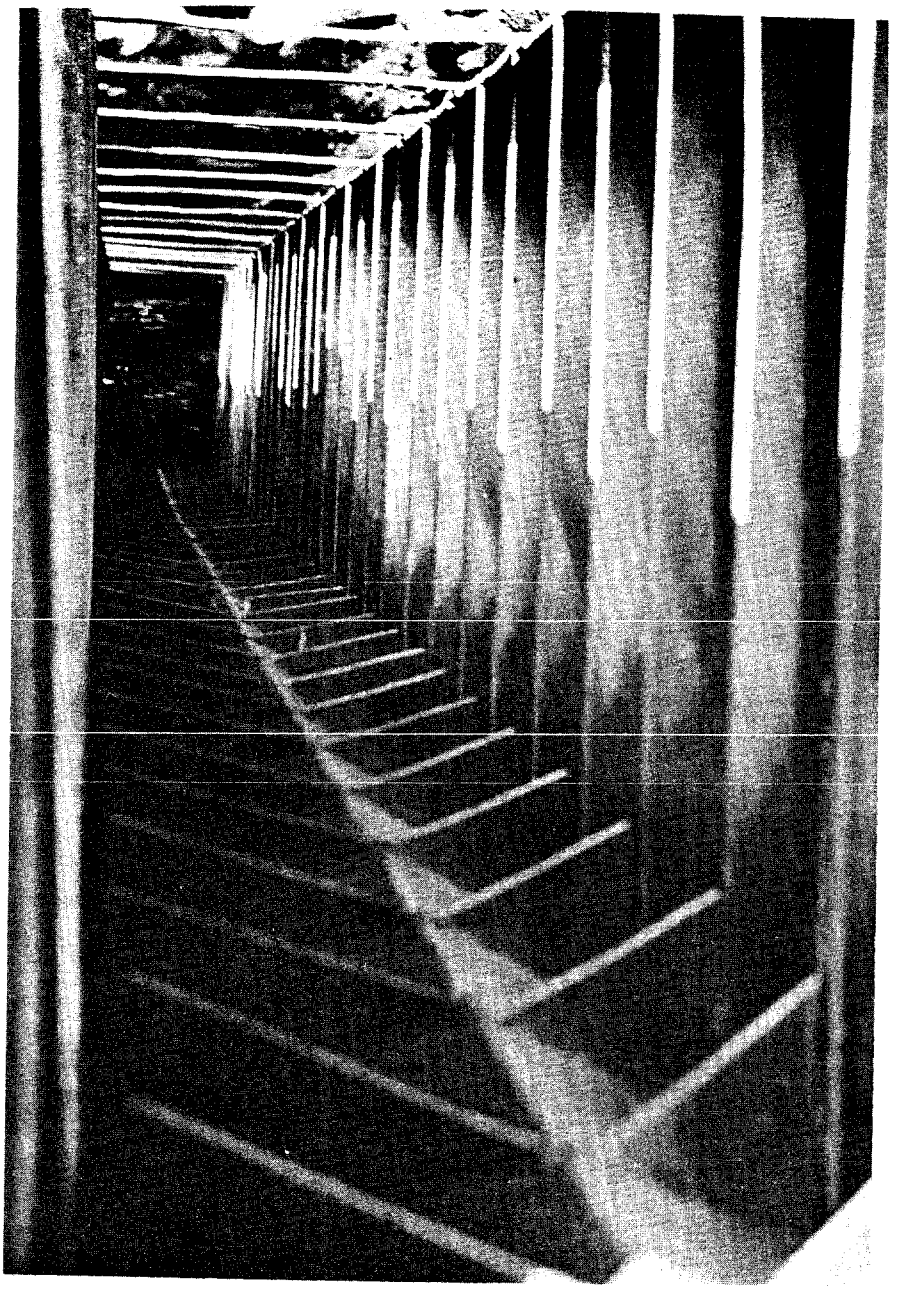


FIGURE 5

MODEL "A" STEEPPASS

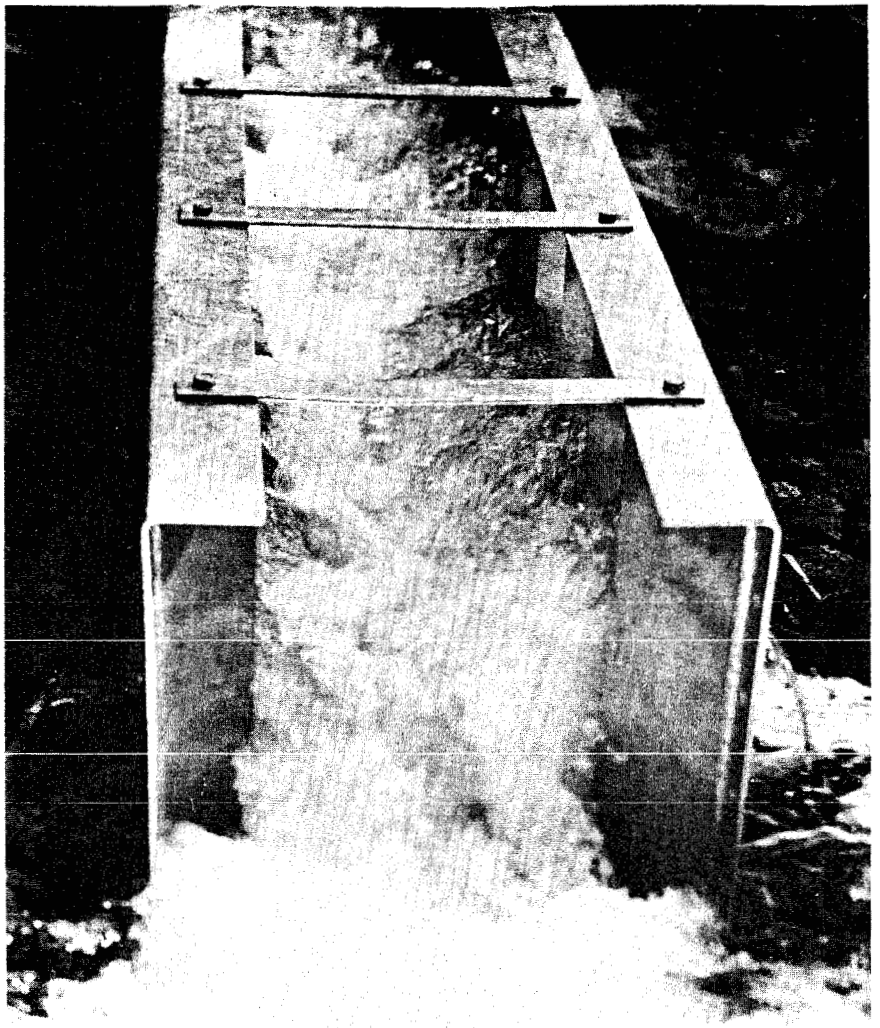


FIGURE 6

MODEL "A" STEEPPASS SHOWING FLOW

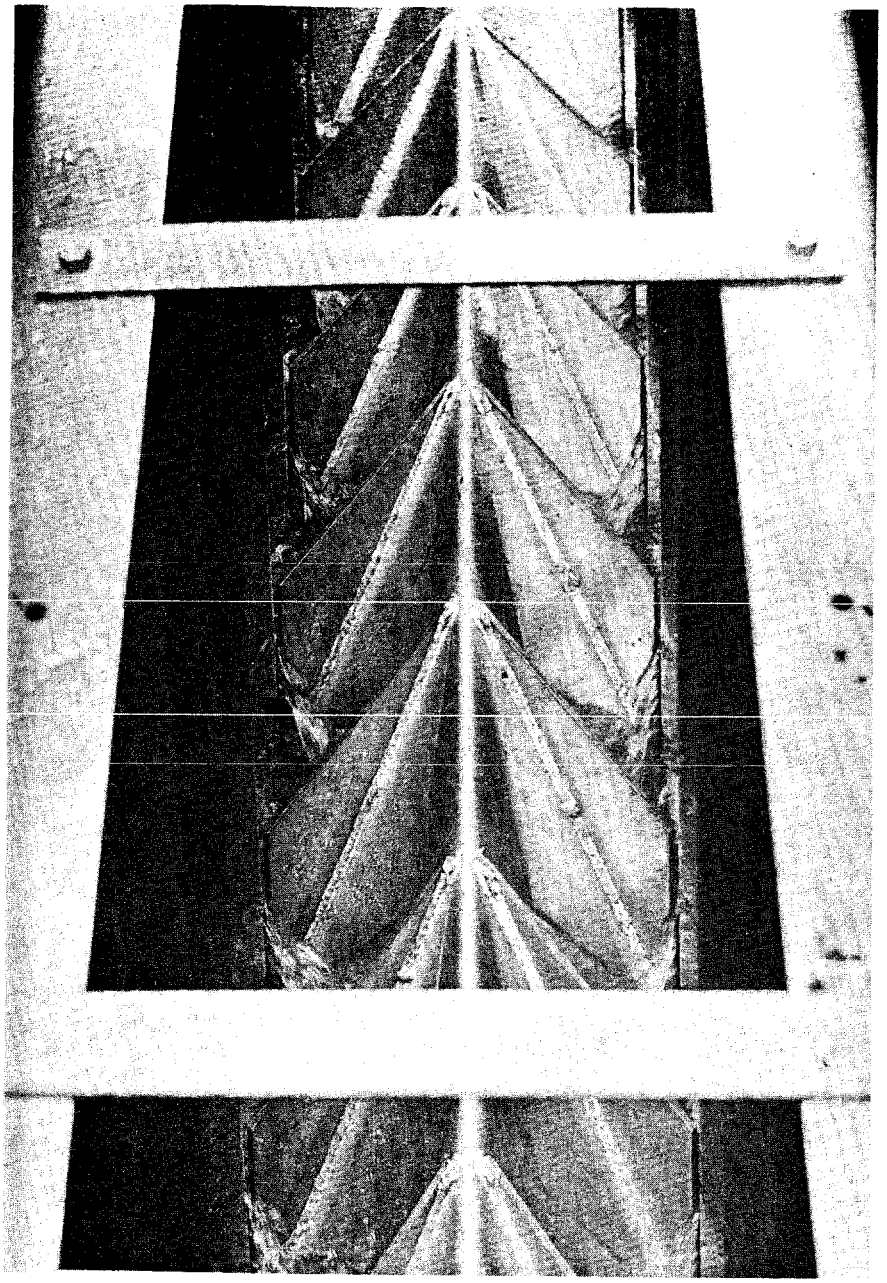


FIGURE 7

MODEL "C" STEEPPASS

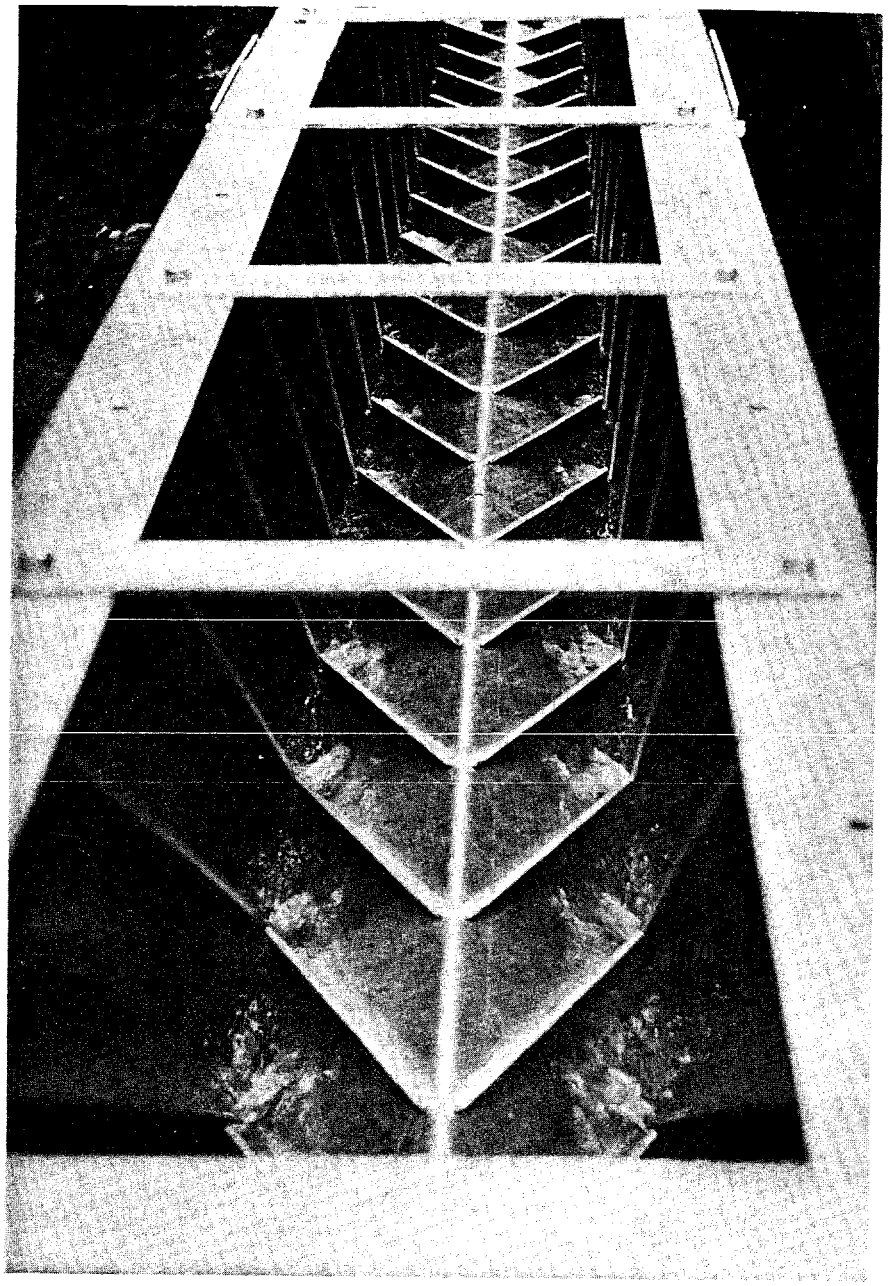


FIGURE 8

MODEL "C" STEEPPASS

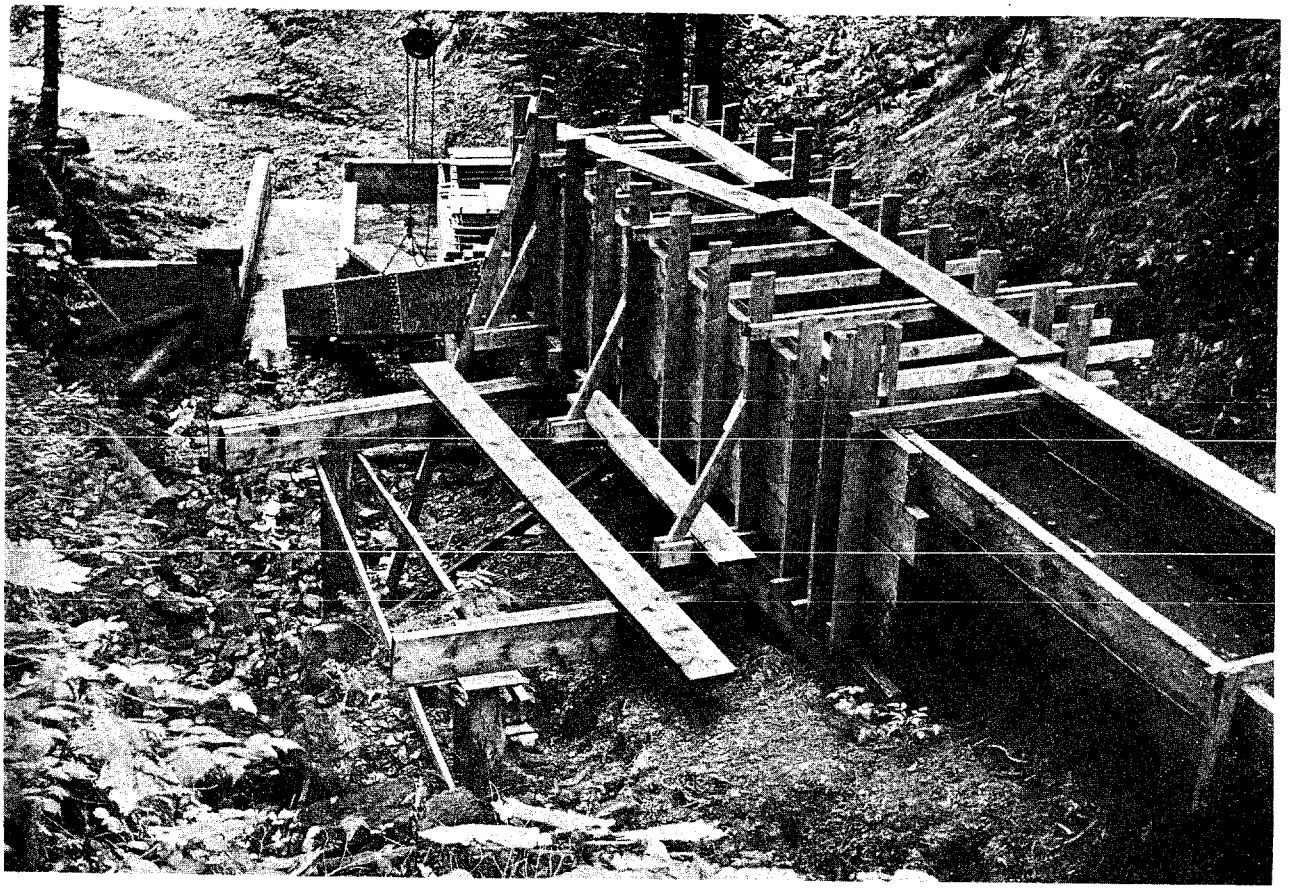


FIGURE 9

STEEPPASS TEST FACILITY

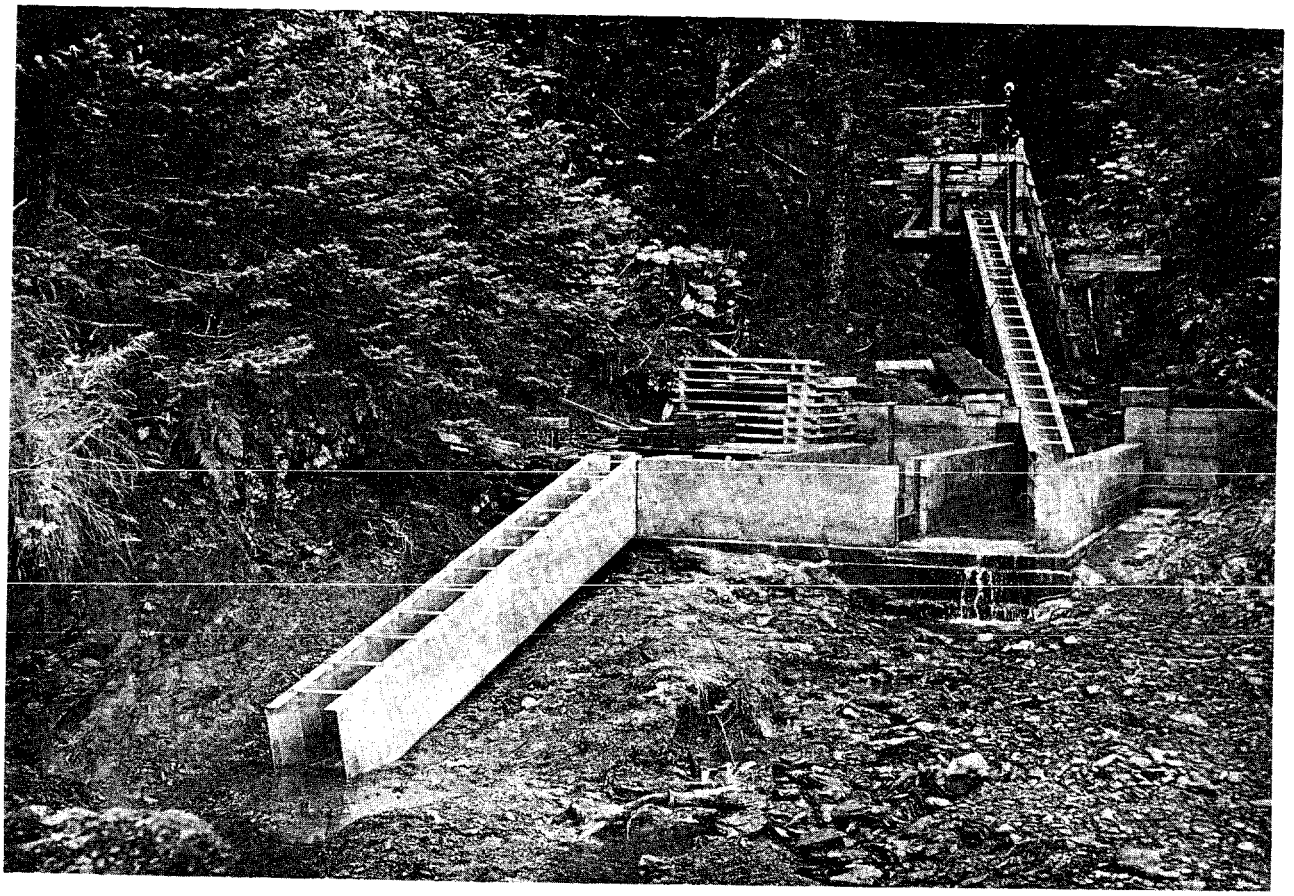


FIGURE 10

STEEPPASS TEST FACILITY

Table 1. Steeppass Model "A" Fishway - Hydraulic Data

Run No. and Slope	h. Feet	d. Feet	Q. c.f.s.	A. sq. ft.	$\overline{V}$ F.S.	C. (chezy)
1960-1	0.13	0.16	0.66	0.19	3.47	5.0
	0.35	0.76	2.88	0.89	3.23	9.1
0.379	0.47	1.07	4.47	1.25	3.57	9.4
1960-2	0.13	0.18	0.66	0.21	3.14	4.5
	0.35	0.81	2.88	0.95	3.03	8.7
0.355	0.41	1.01	3.64	1.18	3.08	8.5
1960-3	0.26	0.54	1.85	0.63	2.94	9.7
	0.35	0.83	2.88	0.97	2.97	8.8
0.329	0.42	1.05	3.78	1.23	3.07	8.7
	0.47	1.17	4.47	1.37	3.26	9.1
1960-4	0.26	0.60	1.85	0.70	2.64	8.8
	0.35	0.87	2.88	1.02	2.82	8.6
0.306	0.42	1.05	3.78	1.23	3.07	9.0
	0.47	1.17	4.47	1.37	3.26	9.4
1960-5	0.26	0.59	1.85	0.69	2.68	9.3
	0.35	0.85	2.88	0.99	2.91	9.3
0.283	0.41	1.03	3.64	1.21	3.01	0.2
	0.47	1.18	4.47	1.38	3.24	9.7
1960-6	0.25	0.57	1.74	0.67	2.60	9.4
	0.35	0.86	2.88	1.01	2.85	9.4
0.261	0.41	1.02	3.64	1.19	3.06	9.8
	0.47	1.19	4.47	1.39	3.21	10.0
1960-7	0.26	0.61	1.85	0.71	2.60	9.5
	0.35	0.89	2.88	1.04	2.77	9.3
0.250	0.41	1.08	3.64	1.26	3.89	9.4
	0.47	1.22	4.47	1.43	3.12	9.9
1960-8	0.26	0.61	1.85	0.71	2.60	9.7
	0.35	0.90	2.88	1.05	2.74	9.4
	0.41	1.07	3.64	1.25	2.91	9.6
0.239	0.47	1.36	4.47	1.59	2.81	9.0
1960-9	0.26	0.63	1.85	0.74	2.50	9.7
	0.34	0.94	2.76	1.10	2.50	8.9
0.217	0.41	1.11	3.64	1.30	2.80	9.7
	0.47	1.26	4.47	1.47	3.04	10.2

-Continued-

Table 1. Steeppass Model "A" Fishway - Hydraulic Data (Continued)

Run No. and Slope	h. Feet	d. Feet	Q. c.f.s.	A. sq. ft.	$\overline{V}$ F.S.	C. (chezy)
1960-10	0.25	0.66	1.74	0.77	2.26	10.0
	0.35	1.03	2.88	1.20	2.40	9.7
0.166	0.40	1.17	3.51	1.37	2.56	10.0
	0.47	1.32	4.47	1.54	2.90	11.2
1960-11	0.47	1.19	4.47	1.39	3.21	
		1.20		1.40	3.19	
0.286		1.23		1.44	3.10	

Table 2. Steeppass Model "C" Fishway - Hydraulic Data

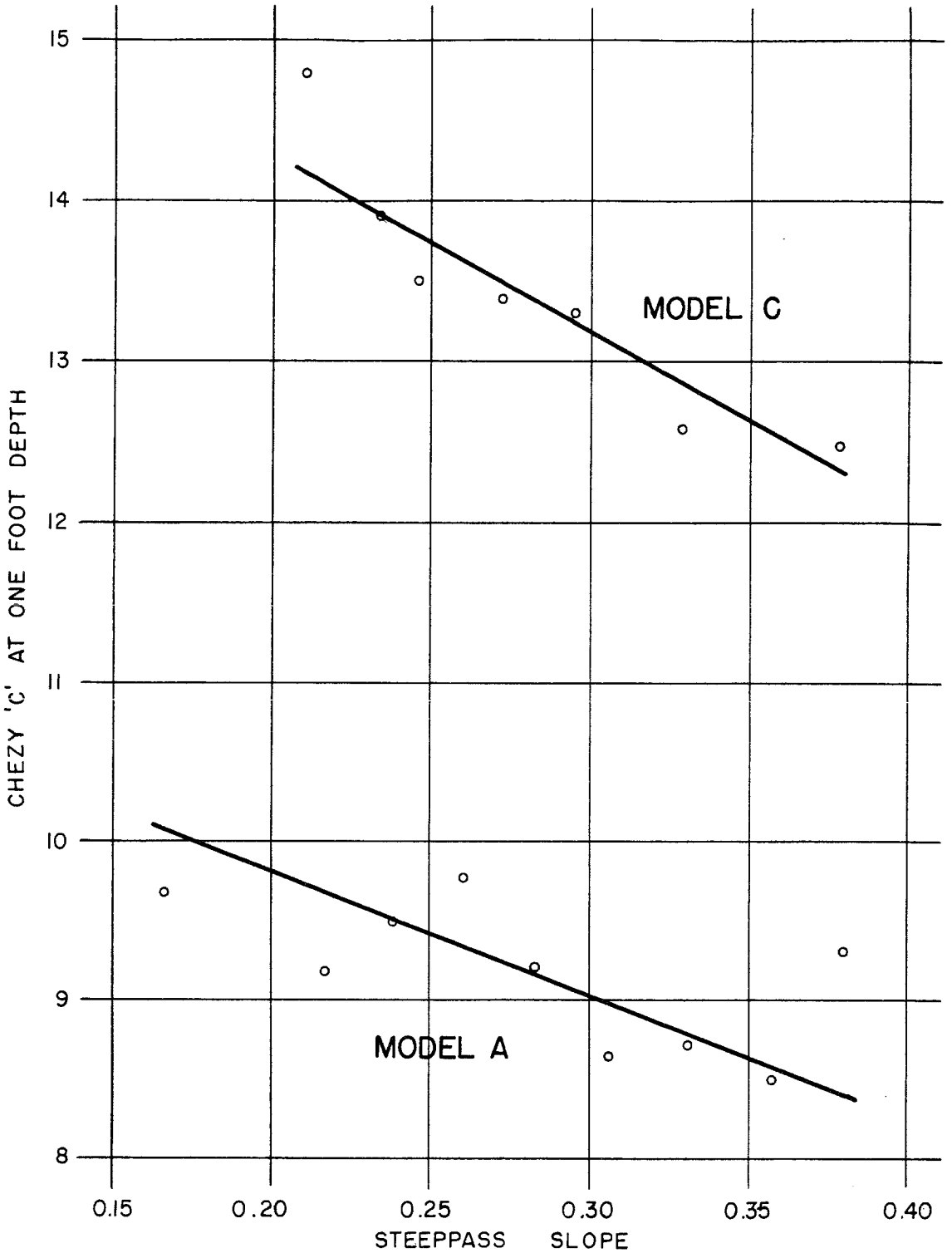
Run No. and Slope	h. Feet	d. Feet	Q. c.f.s.	A. sq. ft.	$\overline{V}$ f.s.	C. (chezy)
1960-12	0.30	0.50	2.29	0.58	3.95	12.4
	0.46	0.82	4.33	0.96	4.51	12.5
0.379	0.55	1.00	5.66	1.17	4.84	12.9
	0.57	1.10	5.97	1.29	4.63	12.1
1960-13	0.30	0.52	2.29	0.61	3.75	12.4
	0.47	0.90	4.47	1.05	4.26	12.5
0.329	0.55	1.06	5.66	1.24	4.56	12.5
	0.565	1.10	5.89	1.29	4.56	12.8
1960-14	0.30	0.58	2.29	0.68	3.37	11.4
	0.47	0.89	4.47	1.04	4.30	13.3
0.295	0.56	1.12	5.82	1.31	4.44	13.2
1960-15	0.30	0.56	2.29	0.65	3.52	12.7
	0.47	0.92	4.47	1.08	4.14	13.3
0.271	0.56	1.14	5.82	1.33	4.27	13.5
1960-16	0.30	0.58	2.29	0.68	3.37	12.5
	0.41	0.77	3.64	0.90	4.04	14.1
0.247	0.47	0.95	4.47	1.11	4.03	13.5
	0.60	1.20	6.45	1.40	4.61	14.8
1960-17	0.30	0.55	2.29	0.64	3.58	14.8
	0.41	0.79	3.64	0.92	3.96	14.1
0.234	0.47	0.95	4.47	1.11	4.03	13.8
	0.57	1.16	5.97	1.36	4.39	14.5
1960-18	0.30	0.61	2.29	0.71	3.22	12.9
	0.41	0.81	3.64	0.95	3.83	14.3
0.210	0.47	0.94	4.47	1.10	4.06	14.7
	0.56	1.19	5.82	1.39	4.19	14.6
1960-19	0.23	0.43	1.55	0.50	3.10	14.7
	0.39	0.81	3.40	0.94	3.62	14.8
0.179	0.47	1.03	4.49	1.20	3.74	14.9
	0.55	1.50	5.69	1.75	3.25	11.9
1960-20	0.25	0.51	1.75	0.60	2.92	14.0
	0.30	0.65	2.29	0.76	3.01	13.6
0.159	0.40	0.82	3.53	0.96	3.68	15.8
	0.47	1.07	4.49	1.25	3.59	14.6
	0.59	1.65	6.33	1.93	3.28	12.5

nated "h", the depth of water flowing in the steeppass under test is "d", "A" is the net area at the least section of the flowing water in the steeppass: "$\overline{V}$" is the average velocity of the water at "A"; and "C" is the coefficient in the Chezy formula $\overline{V} = C\sqrt{rs}$ where "r" is the hydraulic radius and "s" is the hydraulic gradient or slope. The depth of flow was measured at the midpoint of the 40 foot long steeppass under test in every run except the number 1960-11 wherein the first reading was made at the 1/4 point, the second at the midpoint and the third at the 3/4 point to check longitudinal variation.

McLeod and Nemenyi (1939-1940) and the Committee on Fish Passes (1942), discuss methods for evaluating fishways and use the Chezy C as an index of flow impedence. As such, it is a usable tool in comparing a fishway at various stages of flow and at different gradients. The remarkably uniform and narrow 8-1/2 to 10 C-value range of our Model "A" steeppass points up the inherent versatility of this unit and its adaptability to varying conditions of grade and water stage. The Model "C" steeppass also has a close range of C-values but is found to be more sensitive to water stage variations in the grades below 25 percent. Figure 11 gives a graphical comparison of the energy dissipation properties of the two models (given at the one foot water stage) over the slope range most likely to be used in ordinary working installations.

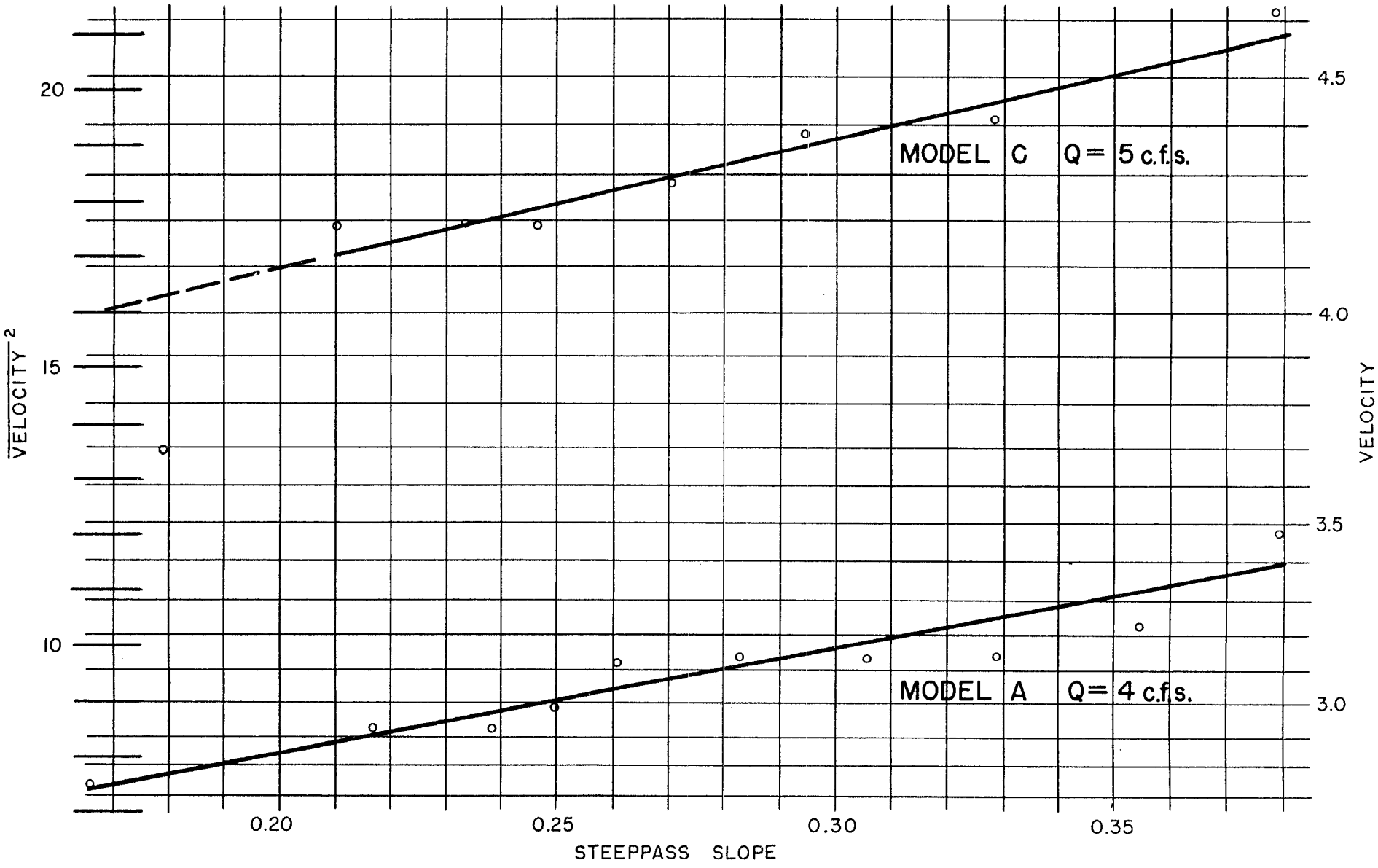
The data, Tables 1 and 2, shows the velocity to decrease as the gradient is flattened, as would be expected from the basic relationship $\overline{V} = \sqrt{2gh}$ and its derivation $\overline{V} = c\sqrt{rs}$. A straight line relationship between the square of the velocity and the slope is observed for a constant stage. The graphic portrayal, Figure 12, sets out at a glance the essential interpretation of the data. The Model "A" at 4 c.f.s. is compared to the Model "C" at 5 c.f.s. to more nearly portray the two at equal stage conditions. Within the ranges of slopes tested, the velocity remains somewhat less than one-tenth of what it would be in an open channel of the same size and gradient. It is apparent that these steeppass models are very effective energy dissipation devices.

The efficiency of a hydraulic device as an energy dissipater is not the sole criterion by which its usefulness as a fishway can be determined. The Chezy "C" analysis yields an overall comparison of individual applications but it does not reveal what is happening in any specified segment of the vertical or longitudinal horizon in and through which the fish may swim. An important and oftentimes controlling factor in the usefulness of a device as a fishpass is the character of the flow within the fish movement channel. In this field of examination, however, standards of comparison are rather more difficult to evolve and apply. Some work was done by us using the Pitot tube to detect patterns and for measuring the magnitude and location of streamlines, but this has not yet been carried far enough along to warrant more than general comments. The steeppass, as we have worked with it, achieves its results by means of a system of uniformly repeated re-entrant jets and not by frictional resistance along the bottom and sides of the channel. The longitudinal flow pattern is in effect a synchronism of discontinuities and merits evaluation as a medium of fish transport. Flow was uniform longitudinally throughout the steeppass at all gradients and depths tested and no flood waves were observed to pass along the channel, but erratic surging was noted at the 35 percent and up slopes. Also, at these steep grades, a very marked sharp surface depression



STEEPPASS FISHWAY

FIGURE 11



STEEPPASS FISHWAY

FIGURE 12

occurred along the centerline in the Model "A" pass.

A procedure for comparative purposes was sought which would yield an index of the air entrainment and entrapment (the bulking or density factor). The method explored entailed comparing the actions taking place in a steeppass by the ratio of the apparent velocity to the net velocity of the water. The apparent velocity for this purpose is defined as the one calculated by means of planemetering the esorropic velocity contours at the least cross-section in the pass using Pitot tube velocity determinations. The net velocity is defined as that determined by the Q/A function mentioned above. Our results to date lack uniformity and the technique requires further exploration and development.

Figures 13 through 22 show the character of flow within the Models "A" and "C" steeppasses at various grades.

Application

Test installations have been and are being made at natural blocks to upstream salmon migration in Alaskan streams. Sites are chosen for steadily more difficult passages in order to determine the limits of application for the design units with particular emphasis on absolute avoidance for all prehandling and guiding facilities. In all installations made to date, the water issuing from the fishway entrances has been sufficiently attractive to the migrants to draw them to and into it without hesitation and, having entered, the fish have passed through without delay or stopping. The work so far has proven that the units are very effective fishing devices under natural conditions.

The first working installation was made in 1958 and has performed satisfactorily since then on the outlet stream of Little Kitoi Lake adjacent to the Department's Kitoi Bay Research Station. Twenty feet of the Model "A" steeppass were installed at a twenty percent grade to elevate all migrants into a live box trap from an intertidal zone. It has been, in season, under continuous observation of the Research Division biologists who have been pleased with its operating characteristics. They have observed at this installation a few instances of red salmon swimming vertically out of the water and steeppass when disturbed in mid-transit due, apparently, either to inability to turn about within this narrow channel to escape or to confusion caused by the complex flow pattern within the channel. This ladder has accommodated red, silver, and pink salmon plus sea-run trout.

Department Management Division biologists in July of 1958 packed the component panels of twenty feet of Model "A" steeppass into the Gretchen Creek block on the Pauls Lake drainage on Afognak Island, assembled the units and anchored the upper end of the lip of this falls to enable migrants to pass over this block at which an earlier fishway (blasted pools) had washed out. They estimated that upward of two-thousand ripe red salmon migrants successfully passed through this improved installation to spawning grounds above. In July of 1959 a permanent steeppass fishway was constructed at this migrant block. Construction was accomplished under force account procedures at a total cost of $6,654. Thirty lineal feet of steeppass was installed on a 26.2 percent grade to span a vertical rise of 7.6 feet for a unit cost of $876 per foot of rise. All the materials used in this project were flown to the shore line of a lake 3,000

FIGURE 13

MODEL "A"

Q = 4½ cfs S = 16.62%

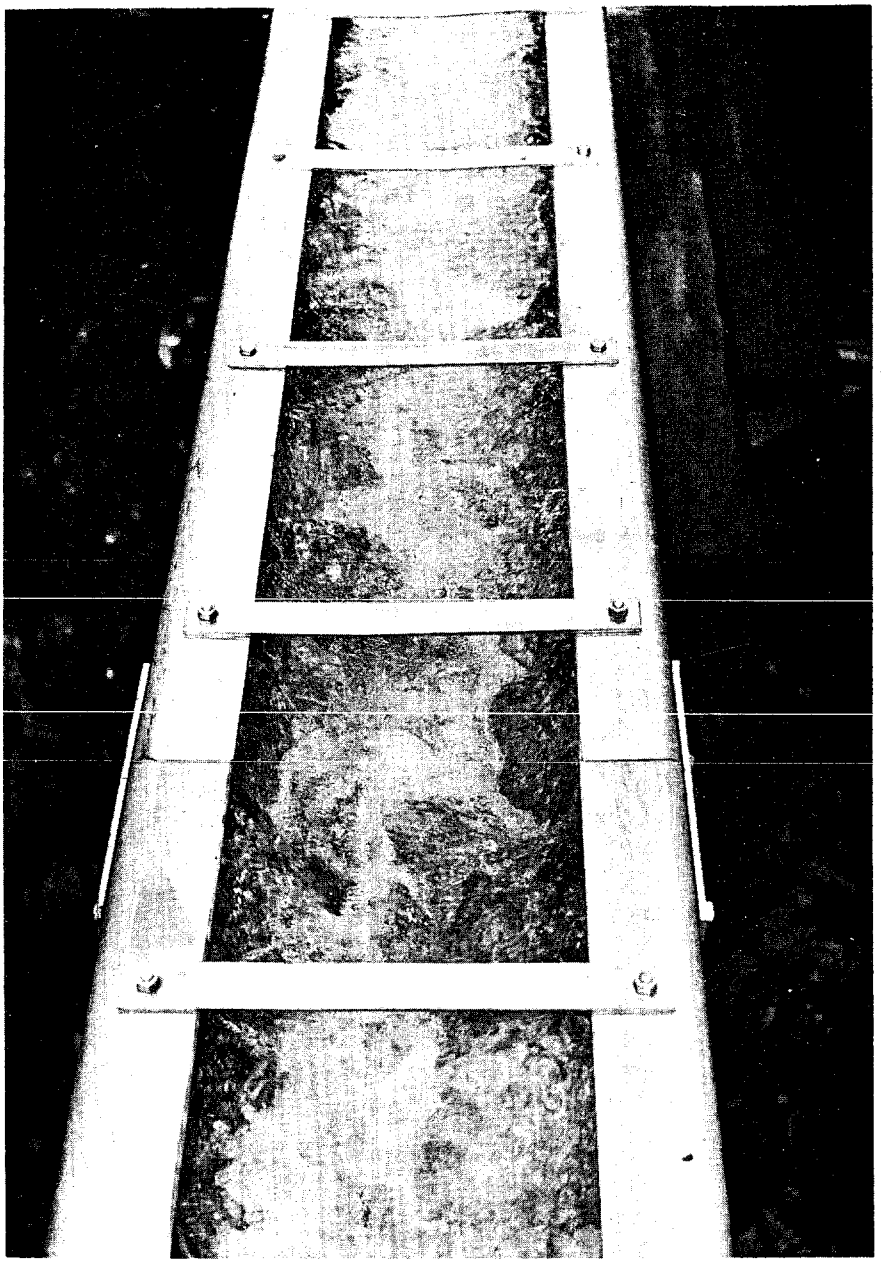


FIGURE 14

MODEL "A"

Q = 4½ cfs S = 16.62%

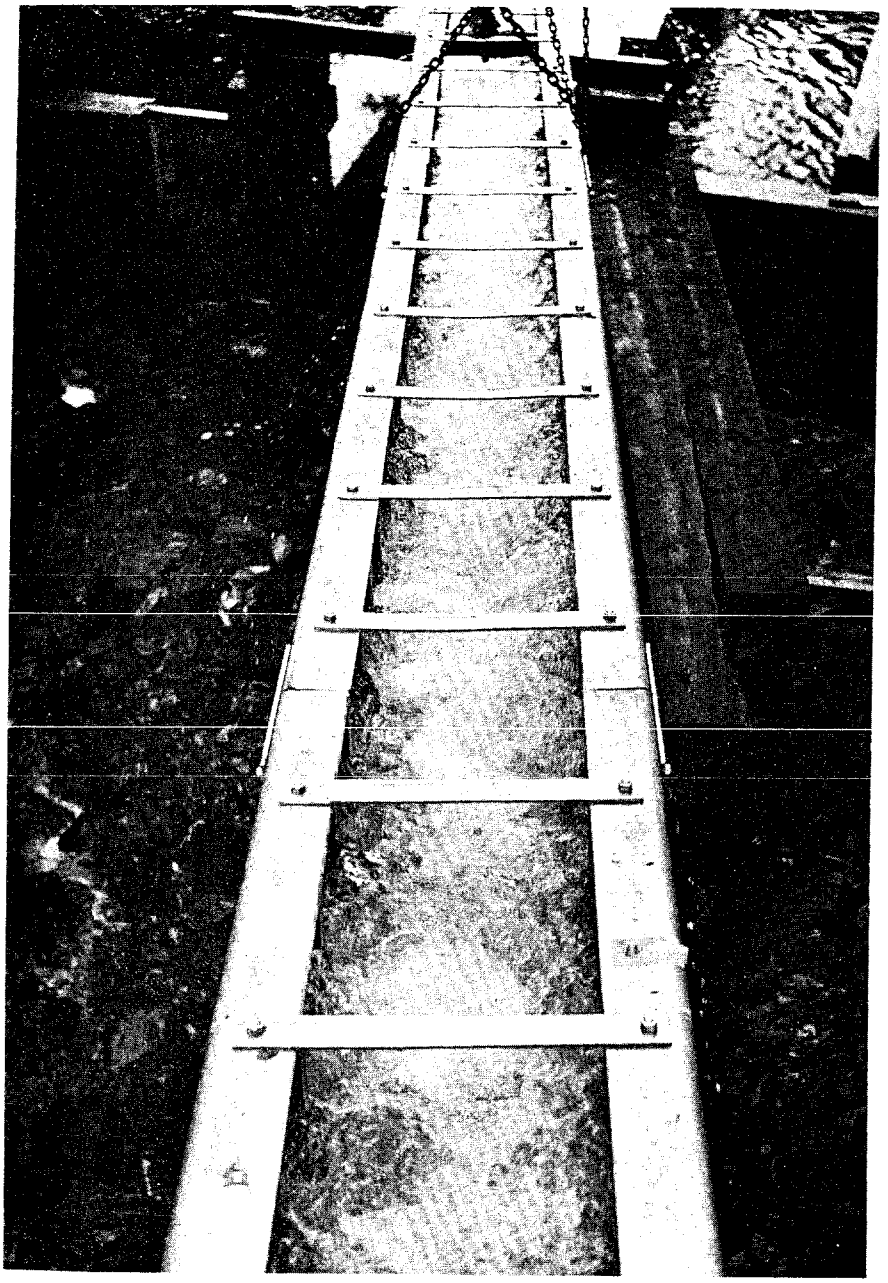


FIGURE 15

MODEL "A"

Q = 4½ cfs S = 21.92%

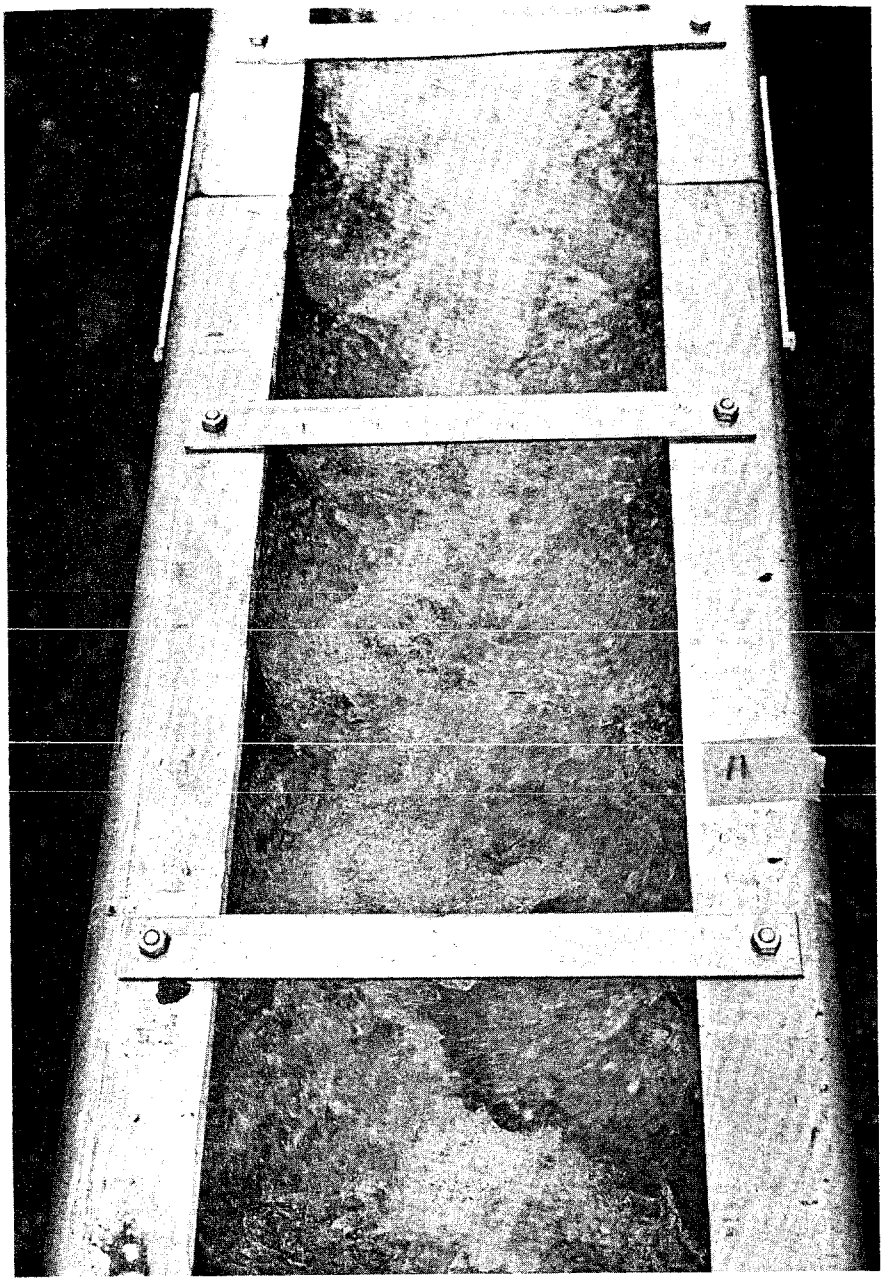


FIGURE 16

MODEL "A"

Q = 4½ cfs S = 21.92%

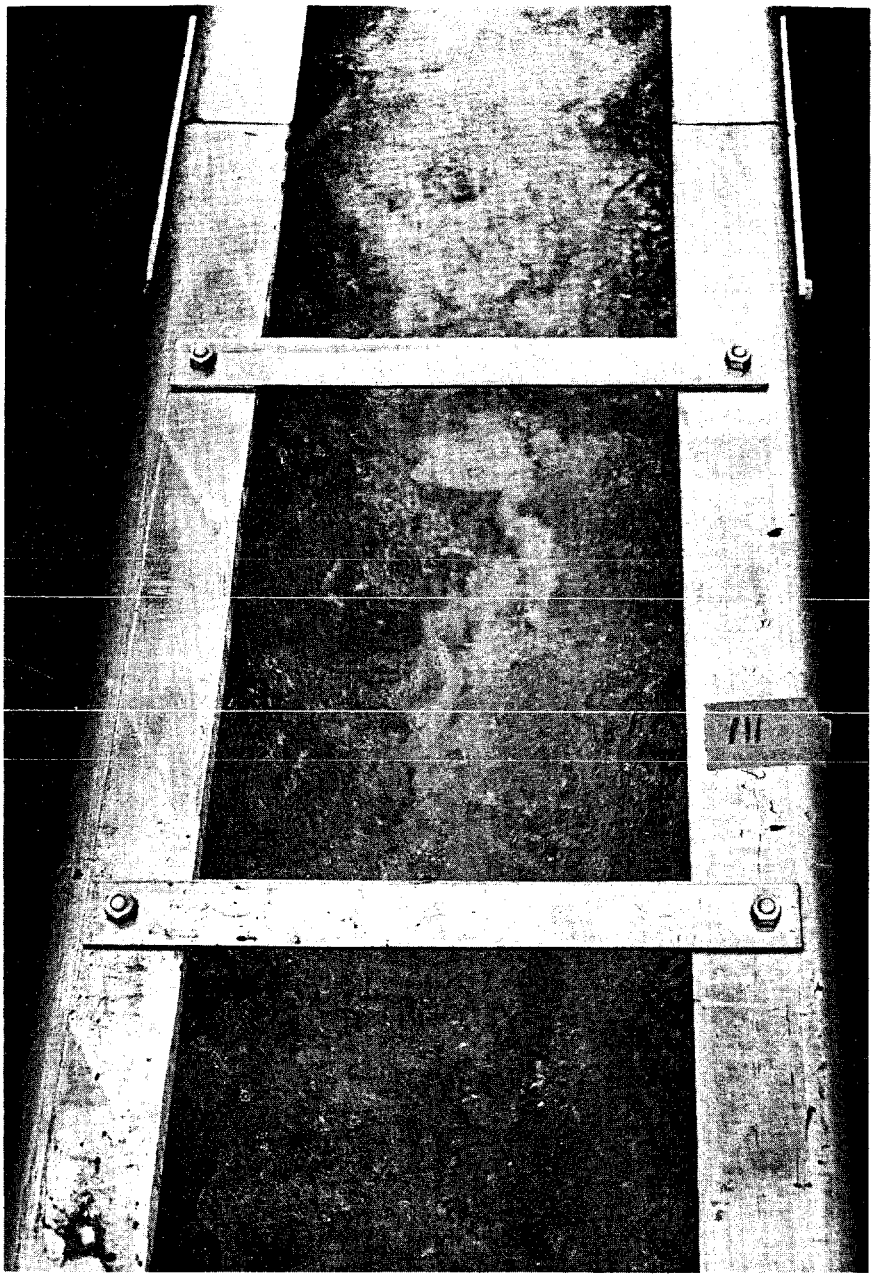


FIGURE 17

MODEL "A"

Q = 4½ cfs S = 25.61%

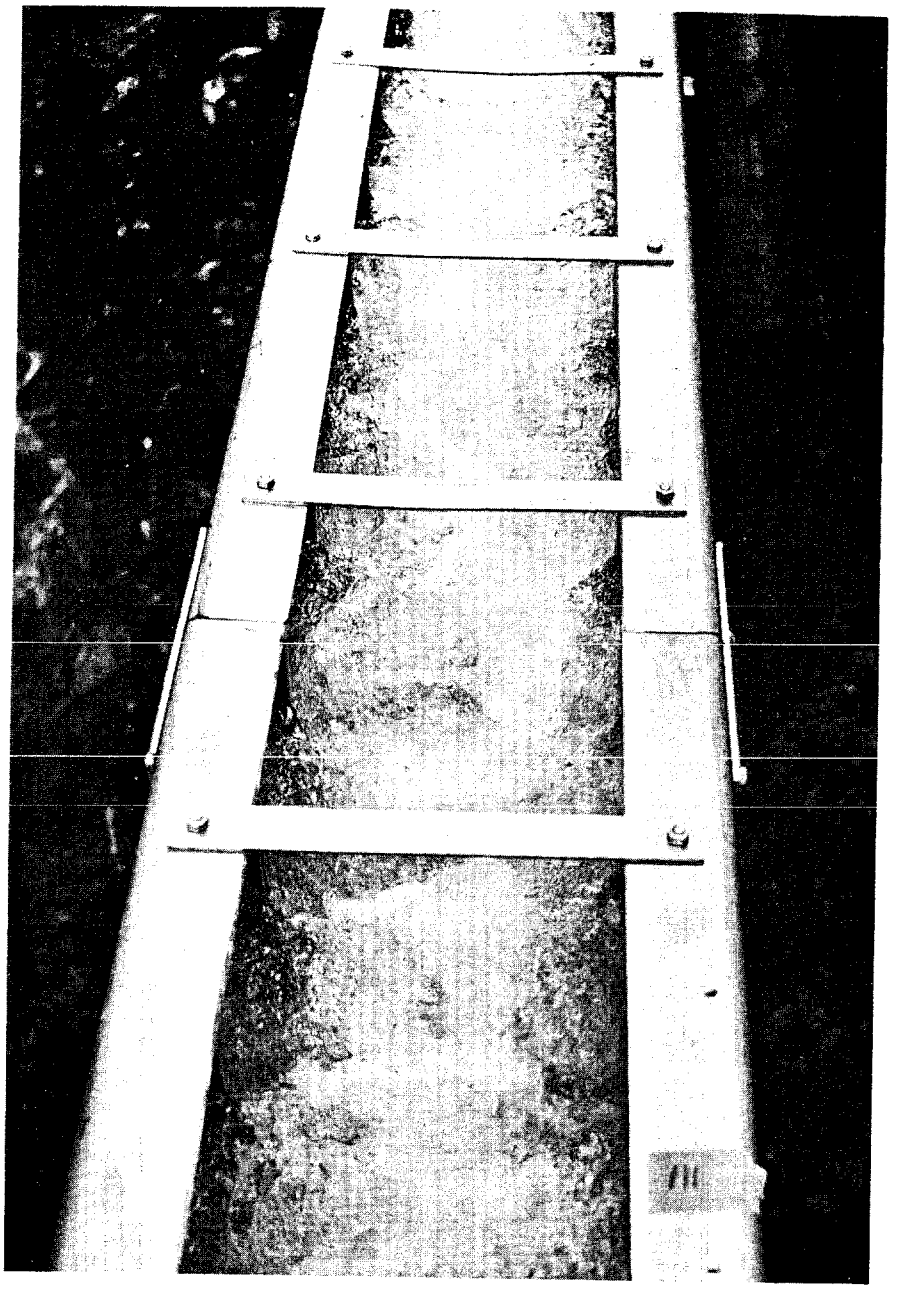


FIGURE 18

MODEL "A"

Q = 4½ cfs S = 25.61%

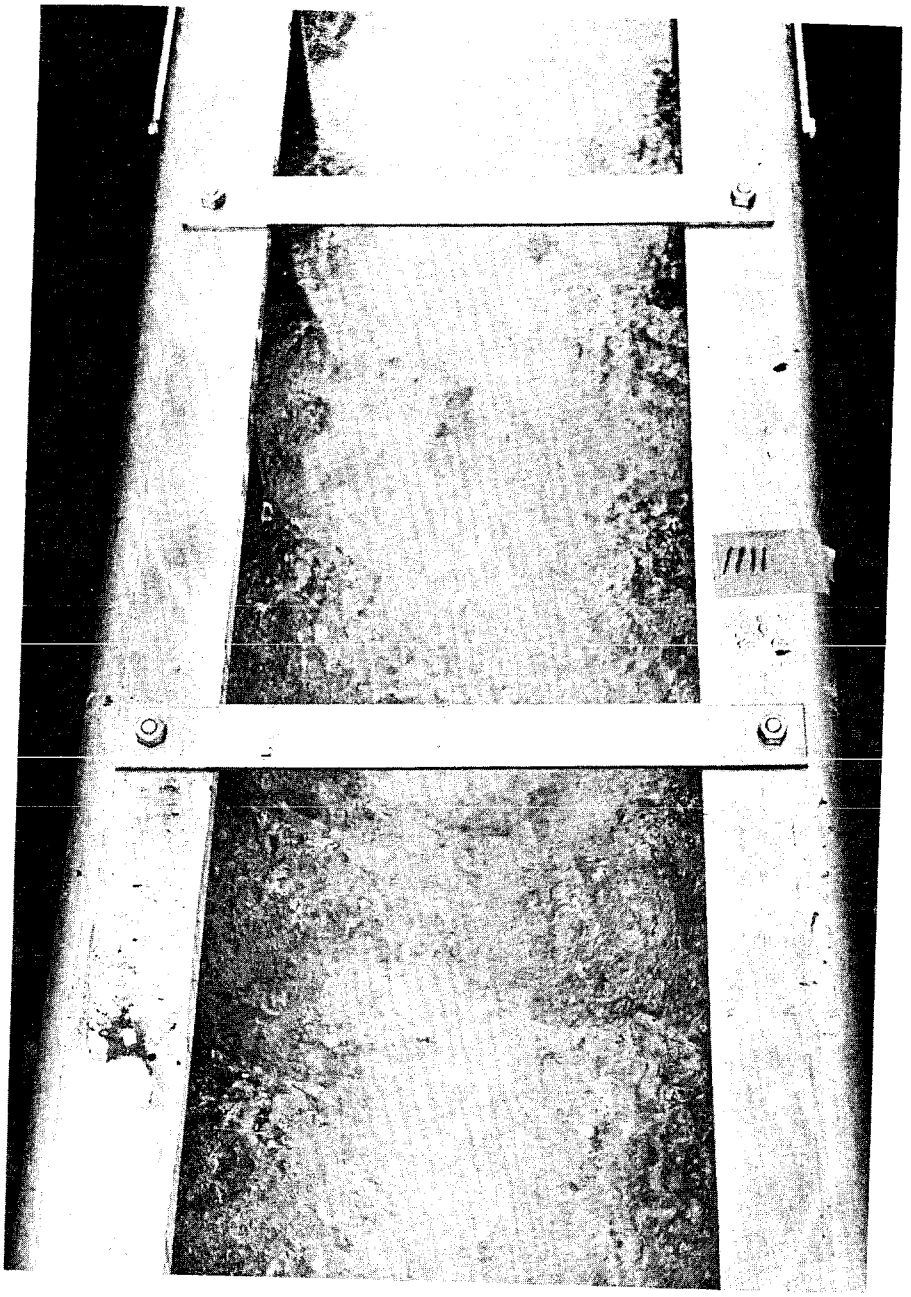


FIGURE 19

MODEL "A"

Q = 4½ cfs S = 28.72%

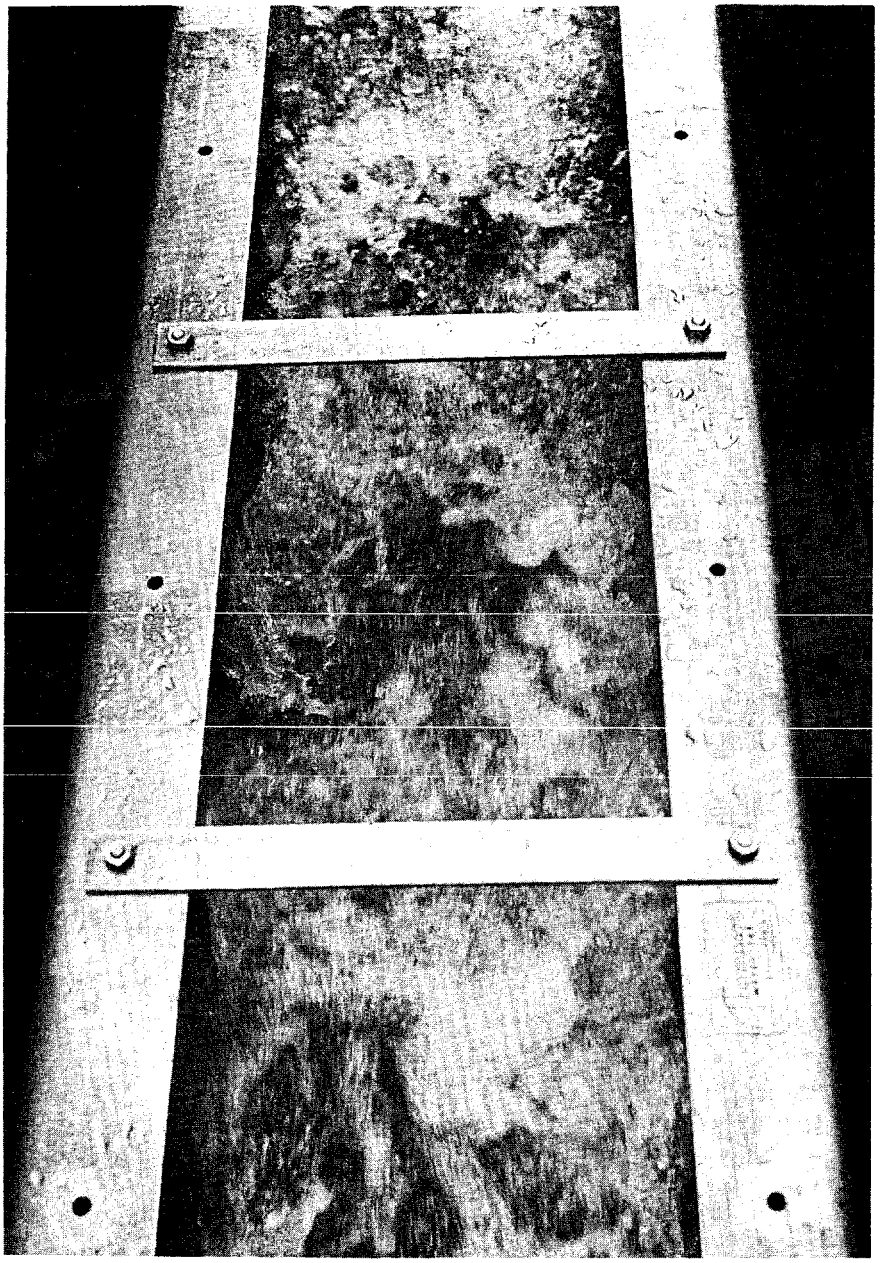


FIGURE 20

MODEL "C"

Q = 5 2/3 cfs S = 17.90%

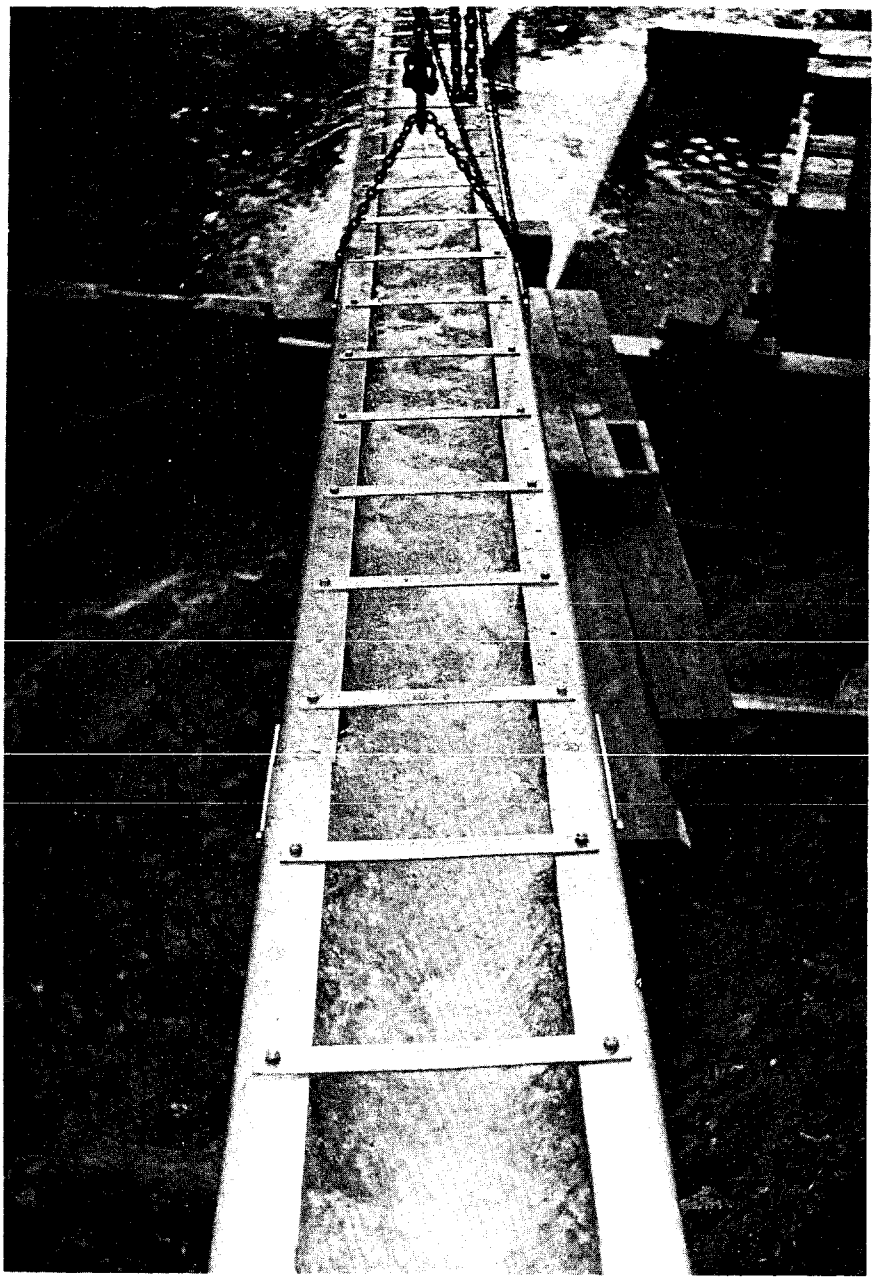


FIGURE 21

MODEL "C"

Q = 5 2/3 cfs S = 17.90%

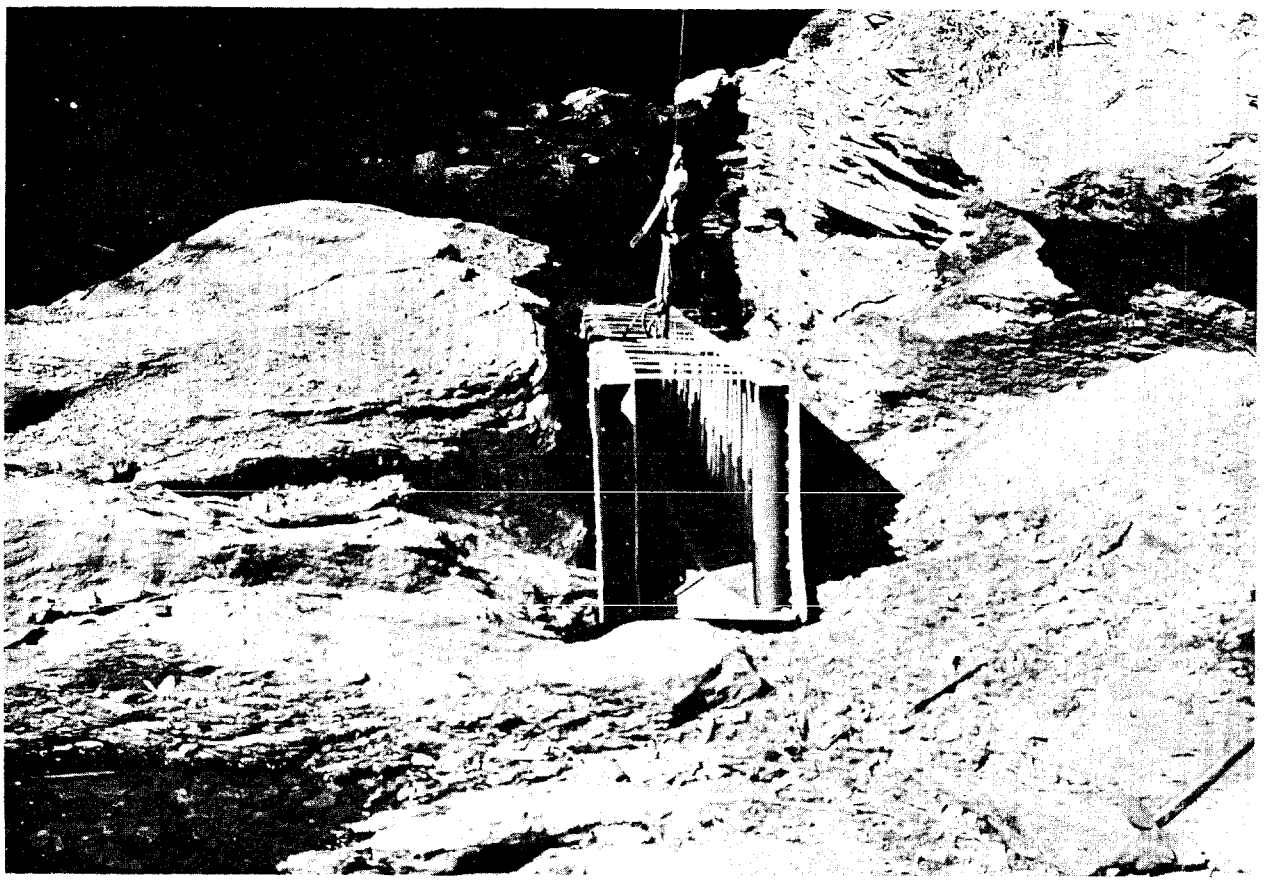


FIGURE 22

GRETCHEN CREEK PROJECT

feet distance using a two place plane on floats and then man-packed to the site. The first red salmon migrant arrived at the fishpass entrance two days after its completion, entered without pause, exited almost immediately and continued up the creek without stopping. During the 1960 season the biologist estimated that 3,500 red salmon passed through this steeppass. Figure 22 is a picture of this project under construction which shows three 10 foot sections being lowered into place using a hand operated 3/16" wire roped power-pull suspended from a stiff-leg boom into a rock cut made with a gasoline powered combination air-drill hammer. The annual space was filled with concrete. Figures 23 and 24 show the completed Gretchen Creek project in operation during the 1960 season.

The upper falls on the outlet creek below Laura Lake on Afognak Island was damaged by floods prior to the 1960 season to the extent of creating almost a total block to upstream migrating fish. When this situation was discovered in late June, several thousand red salmon were at the site attempting unsuccessfully to pass the block. An emergency installation of thirty lineal feet of Model "A" steeppass was made in five days by an engineer and one aide using only hand tools. The 7.4 foot rise is bridged at a 25.4 percent grade. The installation is shown in Figure 25. There were 3,500 silver and 5,000 red salmon passed through this emergency installation during the 1960 season.

Two permanent installations of our design of steeppass fishways are under construction and scheduled for completion in 1962 and 1963. Frazer Falls on Dog Salmon River near the south-end of Kodiak Island will be spanned by parrelleled runs of Model "A" and Model "C" steeppasses over a thirty-three foot rise in four steps with resting pools to check fish preference and performance through the two Models under identical conditions and type situation. The second project is under construction on the Pauls Lake Falls on Afognak Island and consists of a twenty foot run from the base of the falls for an eight foot rise to a turning pool on the bank and thence of a ninety foot run for a sixteen foot rise to an exit above the falls. A weir will divert the necessary water into the upper end of the steeppass. Department biologists will evaluate the effectiveness and efficiency of these installations.

FIGURE 23

GRETCHEN CREEK STEEPPASS

FIGURE 24

GRETCHEN CREEK STEEPPASS ENTRANCE

FIGURE 25

EMERGENCY INSTALLATION PAULS LAKE FALLS 1960

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