REC-ERC-71-4

HYDRAULIC MODEL STUDIES OF THE TEHAMA-COLUSA CANAL FISH CONCENTRATOR, CENTRAL VALLEY PROJECT, CALIFORNIA

G. L. Beichley
Engineering and Research Center
Bureau of Reclamation

January 1971

REC-ERC-71-4

HYDRAULIC MODEL STUDIES OF THE TEHAMA-COLUSA CANAL FISH CONCENTRATOR, CENTRAL VALLEY PROJECT, CALIFORNIA

by
G. L. Beichley

January 1971

Hydraulics Branch
Division of General Research
Engineering and Research Center
Denver, Colorado

UNITED STATES DEPARTMENT OF THE INTERIOR
Rogers C. B. Morton
Secretary

BUREAU OF RECLAMATION
Ellis L. Armstrong
Commissioner

ACKNOWLEDGMENT

These studies were reviewed by T. J. Rhone under the supervision of the Structures and Equipment Section Head, W. E. Wagner, now Hydraulic Branch Chief, and under the direction of the former Hydraulics Branch Chief, H. M. Martin (retired). The final plans evolved from these studies were developed through the cooperation of the staff of the Fish and Wildlife Service and Messrs. R. H. Kouns and V. E. Smith of the Canals and Mechanical Branches, respectively, which at that time were part of the Chief Engineer's Office of the Bureau of Reclamation during the period September 1966 through May 1967. Laboratory photography was by W. M. Batts, General Services Branch.

CONTENTS

LIST OF FIGURES

PURPOSE

The studies were conducted to aid in the development of the hydraulic design of the fish concentrator and to assure that the fish fingerlings be concentrated in a flow of approximately 5 cfs (0.14 cubic meters per second (cu m/sec)).

RESULTS

1. The concept of the preliminary design to discharge the fingerlings over perforated plates with adjustable orifices to control the total flow and provide 5 cfs (0.14 cu m/sec) above the plates to carry the fingerlings to the electronic counting device was, in general, satisfactory.

2. The first three sections of perforated plates sloped upward, but the last was turned downward to provide a crest over which the depth and velocity of flow can be controlled. The fingerlings will not encounter high-velocity shallow flow until they are far enough along on the downward sloping section and unable to turn back to the deeper water upstream.

3. The length of Sections 1, 2, and 3 upstream from the crest was increased from 3 feet 6 inches (1.07 meters (m)) to 3 feet 9 inches (1.14 m). The orifices in each section were relocated as far downstream as possible without changing their relative locations. This eliminated air voids and air entrainment between the perforated plate and the orifice plates, and increased the flow through the orifices.

4. In the fourth section, the orifices were eliminated because the space between the orifice plates and the perforated plate only partially filled with water and created an unstable subatmospheric condition that prevented proper control of the discharge. Instead, the flow through this section is allowed to drop directly into the channel and is controlled by covering a portion of the perforated plate at its downstream end. The length of cover is adjustable.

5. To increase the amount of control, the size of the orifices was increased approximately 12-1/2 percent; and, in addition, a means of adjusting the upward slope of Sections 1, 2, and 3 was provided. These modifications provide additional control of the depth, velocity, and quantity of flow over the perforated plate.

6. The waterfall through Section 4 sealed the space between the underside of Sections 1, 2, and 3 and the water surface; therefore, an air vent was installed in each of the two sidewalls of the compartment below the orifice plates.

INTRODUCTION

The Tehama-Colusa Canal in northern California, Figure 1, is part of the Sacramento Canals Unit of the Central Valley Project. Construction of the canal began in July 1965. The 140-foot (42.67-m) wide by 122-mile (196.33-kilometers (km)) long canal with a design capacity of 2,530 cfs (71.64 cu m/sec) will take its water from the Sacramento River just above Red Bluff Diversion Dam 115 miles (185.07 km) north of Sacramento.

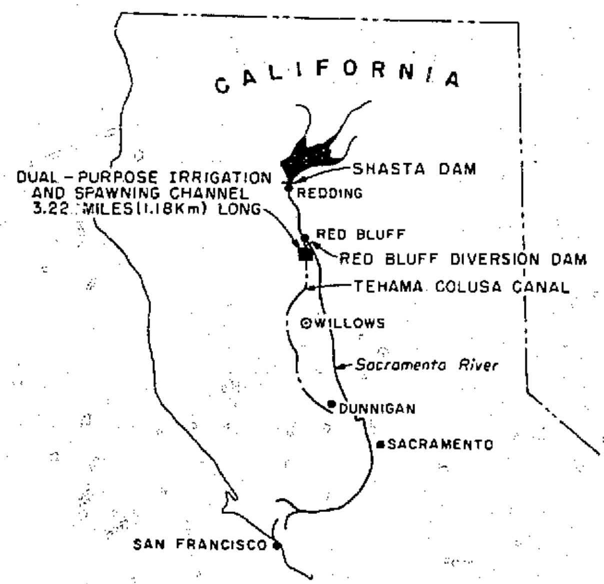


Figure 1. Location map.

A 3.22-mile (5.18-km) long reach of the canal directly below Red Bluff Diversion Dam will be a dual-purpose waterway serving not only to convey water to crops but to provide an artificially created spawning area for chinook salmon.

After construction of this artificial spawning area, some of the adult fish heading up the Sacramento River intent upon laying their eggs north of Red Bluff Dam will be trapped and planted in the new beds. After the eggs hatch, the fingerlings will start down the Tehama-Colusa Canal on their journey to the Pacific Ocean.

A series of drum fish screens will guide the fingerlings from the main canal into a bypass channel carrying 140 cfs (3.96 cu m/sec), Figure 2. In the bypass, a structure will concentrate the fingerlings into a flow of 5 cfs

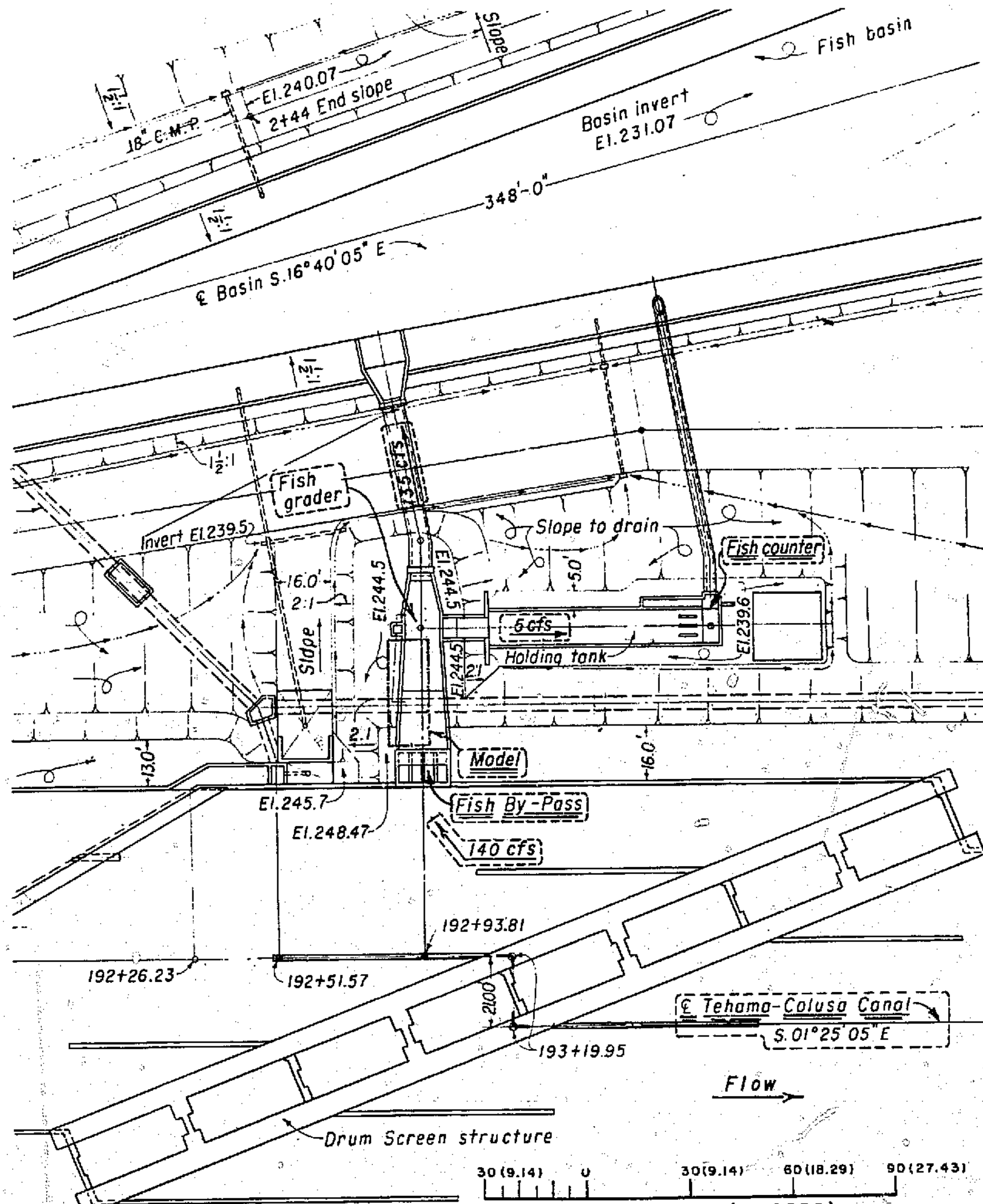


Figure 2. General plan of fish bypass route and model location.

(0.14 cu m/sec) discharging through a fish grader into a holding tank and through an electronic counting device, before being released into a secondary spawning channel that will convey them to a tributary of the Sacremento River.

The fish concentrator, Figure 3, is 16 feet 3 inches (4.95 m) long by 10 feet (3.05 m) wide. The first 11 feet 3 inches (3.43 m) is divided into three 3-foot 9-inch (1.14-m) long sections having perforated plates in an upward sloping floor. The remaining 5 feet (1.52 m) of the perforated plate floor slopes downward at the rate of 1:16. Four inches (10.16 centimeters (cm)) below the first three sections of screen are two superimposed sets of orifice plates that can slide laterally one upon the other to adjust the size of the orifice openings and, thereby, control the quantity of water flowing through the perforated floor to the channel below. Flow through the fourth section is controlled by means of a movable cover plate in contact with the underneath side of the screen which adjusts the length of the open screen area. In addition, the slope of the perforated plate floor can be adjusted to control the elevation of the crest at the end of Section 3.

The functions of the controls are to maintain a flow depth of approximately 4 inches (10.16 cm) at a velocity of less than 10 feet (3.05 m) per second at the crest of the upward sloping sections, and to limit the discharge that carries the fish to the grader to approximately 5 cfs (0.14 cu m/sec). The grader removes the larger fish from the flow leaving only the newborn fingerlings to be carried through the electronic counter. The highly sophisticated screening and counting facilities will handle the tiny fish gently to hold losses to a minimum.

THE MODEL

The model, a 1:2.5 scale reproduction of the left half of the fish concentrator in the fish by-pass route, Figure 2, including a portion of the transition approach section was constructed in a 30-inch (76.2-cm) wide flume, Figure 4. The right transparent plastic sidewall, Figure 5, of the flume was the centerline of the concentrator. The fish were not represented in the model studies.

Two sets of orifice plates in the floor of the concentrator were constructed of 16-gage sheet metal so that the top set could be moved laterally over the lower set to adjust orifice openings from 50 percent open to 100 percent open. The screen was a 22-gage perforated plate having 1/8-inch (3.17-millimeter (mm)) round holes on 3/16-inch (4.76-mm) centers. (This is a 1:2 scale reproduction of the prototype instead of a 1:2.5; however, the percent of open area to total area is identical to the prototype.)

Flow over the downstream end of the concentrator discharged into an auxiliary flume constructed in the upper portion of the main flume, Figure 4. This second flume contained a rock baffle, a staff gage, and a 12-inch (30.48-cm) wide sharp-edged rectangular weir calibrated in place. A piezometer tap was installed in the floor of the main flume to measure the water surface elevation several feet upstream of the concentrator.

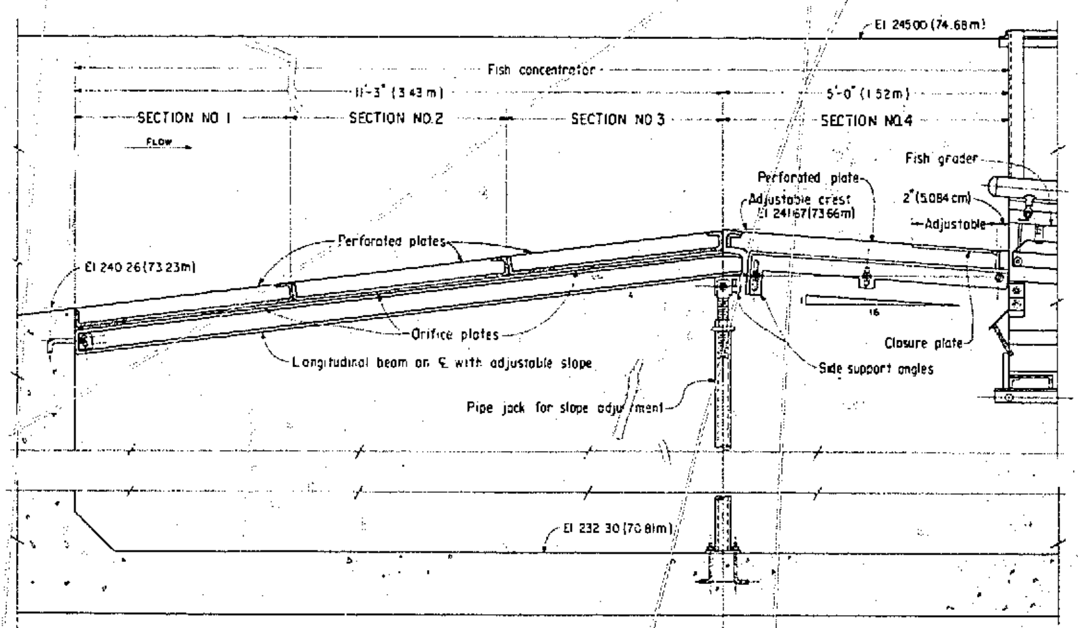
THE INVESTIGATION

The investigation was concerned with the hydraulic flow conditions through the concentrator and with providing the correct rate of discharge for conveying the fingerlings over the downstream end of the structure. Experience has shown that the fish will turn upstream if the flow velocity exceeds approximately 10 feet (3.05 m) per second or the flow depth is less than approximately 4 inches (10.16 cm). Therefore, a method to prevent this from happening was developed.

Preliminary Design

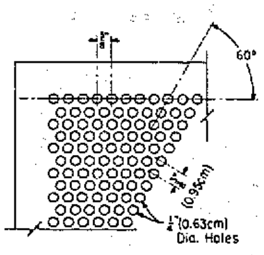
Description.—The preliminary design of the fish concentrator, Figure 4, was patterned after a similar device developed for the Mayfield Fish Facilities for the city of Tacoma, Washington.[1] The preliminary design consisted of a 14-foot (4.27-m) long perforated plate screen on a 10:1 upward slope in a 10-foot (3.05-m) wide channel. The perforated plate screen consisted of 1/4-inch (6.35-mm) round holes punched on 3/8-inch (9.53-mm) centers resulting in an open area that was 40.3 percent of the total area. The screen was designed to divert 135 cfs (3.82 cu m/sec) from an incoming flow of 140 cfs (3.96 cu m/sec), leaving 5 cfs (0.14 cu m/sec) to carry the fish over the downstream end. Four 3-foot 6-inch (1.07 m) long sections of double-layer orifice plates were located 4 inches (10.16 cm) below the screen to control the quantity of flow through the screen. A lateral partition between the orifice plates and the screen separated adjacent sections.

[1] City of Tacoma Department of Public Utilities Light Division—"The Skimmer, A Part of the Downstream Migrant System, Mayfield Fish Facilities—Hydraulic Model Investigations" by Dr. Eugene P. Richey, September 14, 1956.

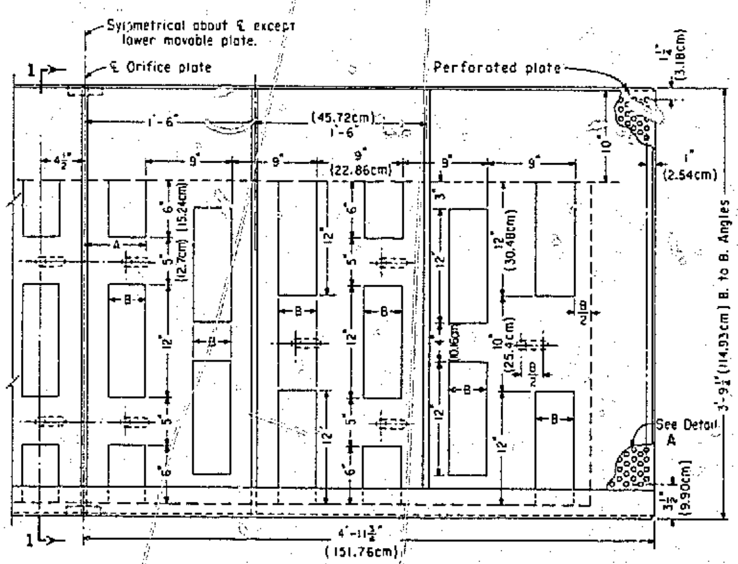


SECTION THROUGH CONCENTRATOR ON ℄

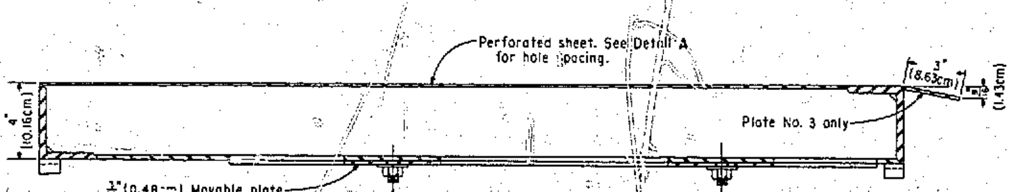
ORIFICE PLATE NO.	A	B
1	6 7/16"(16.35cm)	3 7/8"(9.84cm)
2	6 5/8"(16.83cm)	4 1/4"(10.80cm)
3	7 3/16"(18.26cm)	5 3/8"(13.65cm)



DETAIL A

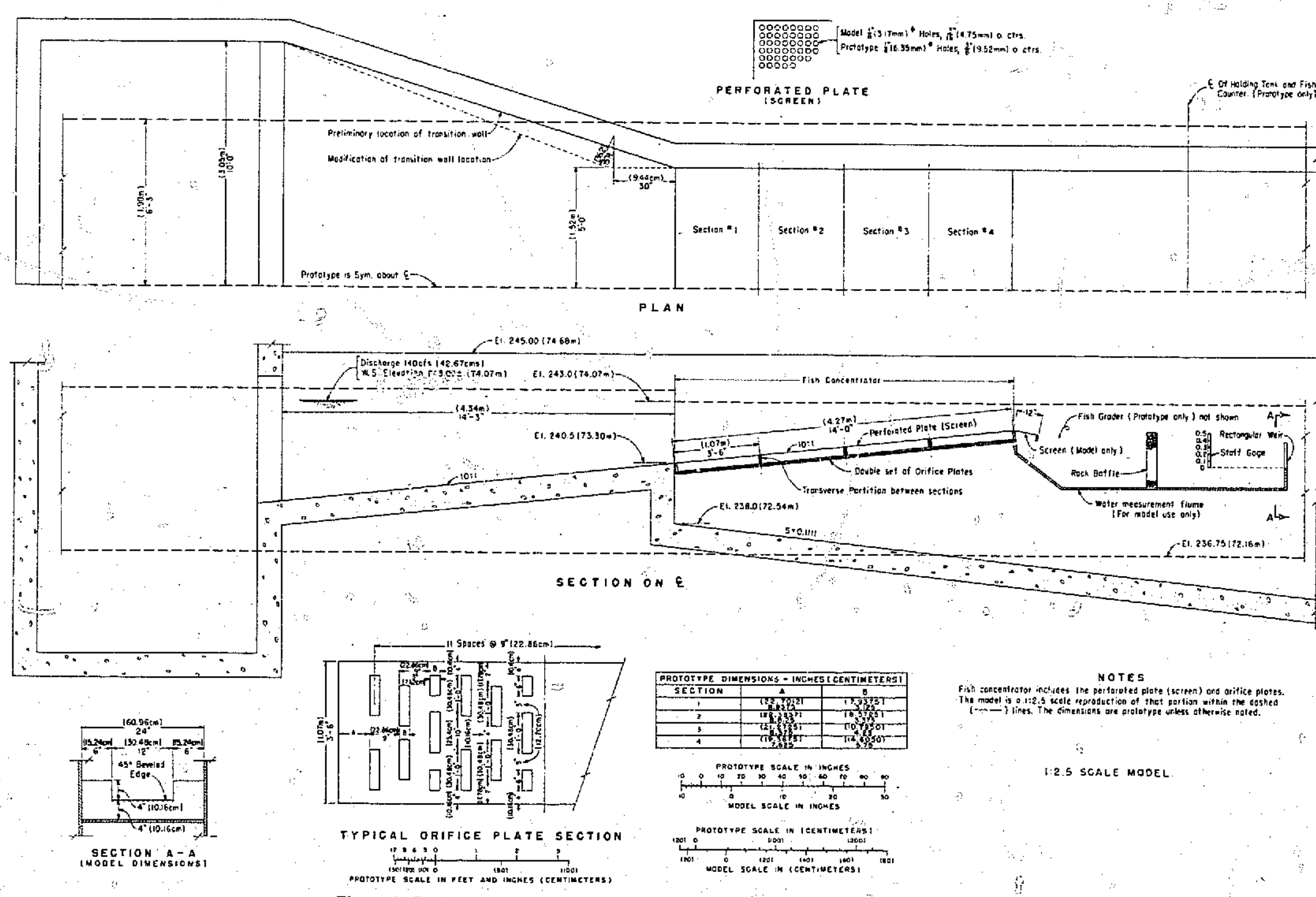


ORIFICE PLATE
(PLATE NO. 1, NO. 2 AND NO. 3)



SECTION 1-1

Figure 3. Recommended fish concentrator.



PROTOTYPE DIMENSIONS - INCHES (CENTIMETERS)		
SECTION	A	B
1	(22.7012) 8.9375	(7.9375) 3.125
2	(22.3837) 8.8125	(8.5725) 3.375
3	(21.2725) 8.375	(10.7950) 4.25
4	(19.3675) 7.625	(14.6050) 5.75

NOTES

Fish concentrator includes the perforated plate (screen) and orifice plates. The model is a 1:2.5 scale reproduction of that portion within the dashed (—— ——) lines. The dimensions are prototype unless otherwise noted.

1:2.5 SCALE MODEL

Figure 4. Preliminary design of fish concentrator prototype and model.

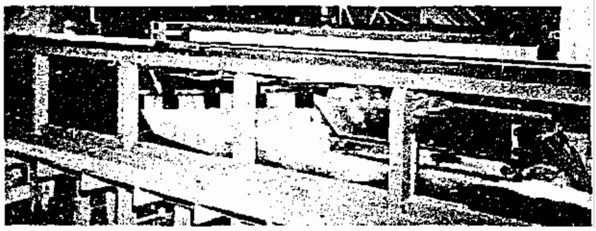


Figure 5. Side view of 1:25 scale model operating. Photo P602-D-68498

The percent of open area provided by the orifices in each of the sections increased in a downstream direction as the average depth of water above each section decreased. Thus, each section of the concentrator was designed to discharge approximately one-fourth of the 135 cfs (3.82 cu m/sec) into the channel below for return to the canal.

The percent of orifice area of the total area in each of the four sections, beginning upstream, was 17.8, 19.2, 24.2, and 32.8. These percentages could be reduced by adjusting the width of the orifices. The widths of the orifices could be adjusted by means of the double layer of orifice plates, one sliding laterally upon the other.

Orifice capacity.—The discharge through the orifices was insufficient in the preliminary design. With the orifices fully open, approximately 129.5 cfs (3.67 cu m/sec) discharged through the orifices leaving approximately 10.5 cfs (0.30 cu m/sec) discharging over the downstream end of the structure. Flow over the end of the structure was also measured for orifice openings of 90, 75, and 50 percent. A capacity curve obtained from these data was extrapolated to indicate the orifice area required to reduce the flow over the end to 5 cfs (0.14 cu m/sec). The curve indicated that the area of the orifice openings should be increased approximately 30 percent to pass approximately 135 cfs (3.82 cu m/sec) through the orifice.

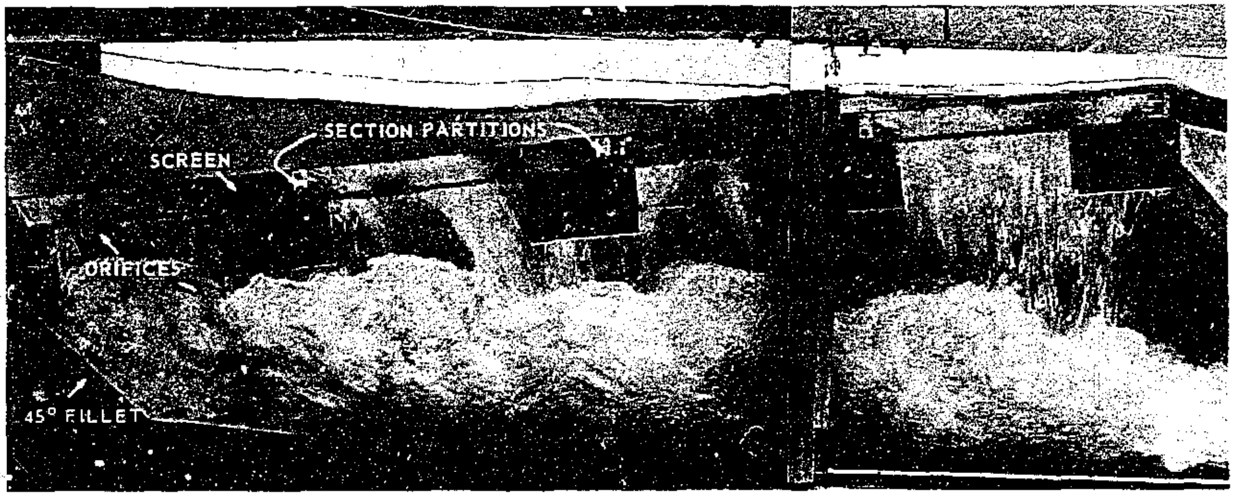
Since there was a double layer of orifice plates in each section of the model, it was possible, for model testing purposes, to use only a single layer of those with the larger orifices made originally for Sections 3 and 4. Therefore, the two layers made for Section 3 could be used in Sections 1 and 2 and those made for Section 4 could be used in Sections 3 and 4. This increased the orifice area in Section 1 to 24.2 percent of the total area of the section, Section 2 to 24.2 percent of the total area of the section, and in Section 3 to 32.8 percent of the section area. The orifice area of Section 4 was not increased in the model, nor would it be practicable to do so, since its orifice area was already 32.8 percent of the total area which is approaching the 40.3-percent open area in the perforated plate screen.

Increasing the size of the first three sections as described above reduced the flow over the end to about 3 cfs (0.08 cu m/sec). It was found by placing the larger size of orifices in Section 1 only, the flow over the end was reduced to 8 cfs (0.23 cu m/sec); but by placing the larger size orifice in Section 3 only, the largest actual area increase of any of the sections, the flow over the end was reduced to 5.5 cfs (0.16 cu m/sec).

It was not practical to block off the orifices in each section to determine the flow through each of the four sections separately as this would change the approach flow conditions. However, when all of the orifice plates were removed to determine the capacity of the screen, none of the flow reached the downstream end, indicating that the screen was capable of discharging the design flow 140 cfs (3.96 cu m/sec). The capacity of the original arrangement of orifice plates was tested with the screen removed and all but 3 cfs (0.08 cu m/sec) of the 140 cfs (3.96 cu m/sec) passed through the orifices. Therefore, it appeared that the total orifice area as designed might be sufficient if more efficient use of the existing orifice area could be made.

Many arrangements of the orifice plates were tested. One of the most promising arrangements was with the orifice plates in reverse order; i.e., the large orifices in the fourth section were placed in the first section, those in the third were placed in the second, etc. This arrangement did not increase the original open area of the orifice, but lowered the water surface over the upstream portion of the concentrator, Figure 6, and increased the total flow through the orifices leaving about 8 cfs (0.23 cu m/sec) to discharge over the downstream end.

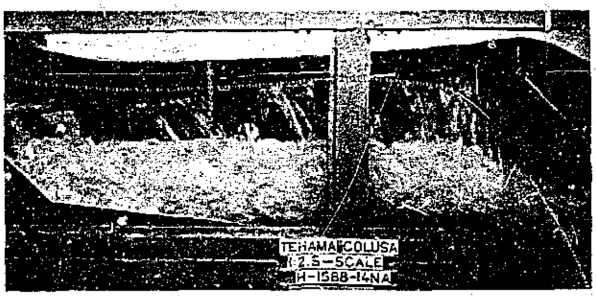
It was noted that a considerable amount of entrained air was present in each of the four sections between the screen and the orifice plates, Figure 6, particularly in the sections having the large orifices. This air appeared to rise through the orifices at the upstream end of each section. Part of the air rose through the downstream portion of the screen in each section and passed over the transverse partitions into the next section. The transverse partitions at the downstream end of each section appeared to obstruct the flow as shown by the rise in the water surface over each partition. Numerous holes drilled through the partitions failed to alter this flow characteristic.



White air entrainment clouds appear between the perforated plate screen and the orifice plates 140 cfs (3.96 cu m/sec). Left photo P602-68499 and right Photo P602-D-68500

Figure 6. Hydraulic operating characteristics with orifice plates in reverse order.

The transverse partitions were replaced with one longitudinal partition at each of the third points. This smoothed the water surface and eliminated the air entrainment, except at the upstream end of the first section, Figure 7. However, the velocity of flow over the orifices was increased due to the lack of obstructions and the flow through the orifices decreased. Flow over the downstream end was about 12.5 cfs (0.35 cu m/sec) as compared to 8 cfs (0.23 cu m/sec) with the transverse partitions. With the orifice plates in the original order, the flow over the downstream end was about 10.5 cfs (0.30 cu m/sec), or about the same as with the transverse partitions.



White air entrainment cloud above orifice plate in Section 1 only, orifice plates are reversed. Photo P602-D-68501

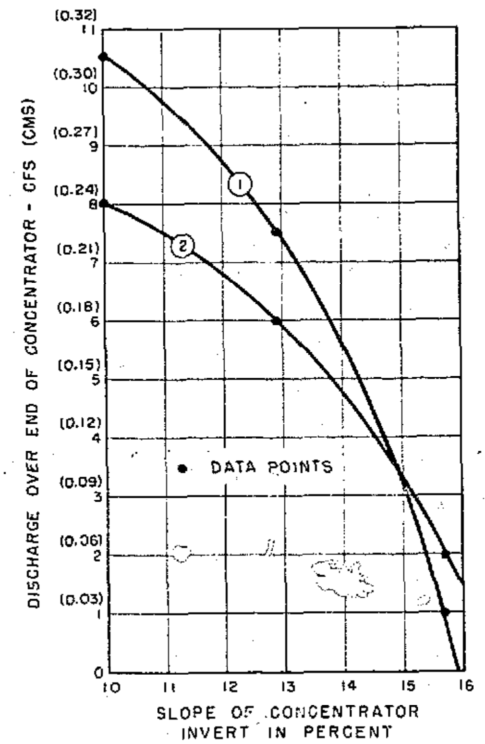
Figure 7. Hydraulic operating characteristics with longitudinal partitions.

The flow over the downstream end of the concentrator was reduced and the flow through the orifices was made greater by increasing the upward slope of the screen and orifice plates. Tests with two steeper slopes in addition to the original 1 on 10 slope were made to establish the curves in Figure 8. The curves indicated that a slope of approximately 14 percent, depending upon the order in which the four orifice plates were placed in the sections, would be required to reduce the flow over the end to 5 cfs (0.14 cu m/sec). The average flow depth over the end of the structure was less than 1 inch (2.54 cm) for 5 cfs (0.14 cu m/sec), and some air entrainment between the screen and orifice plates still persisted.

Water surface characteristics.—At the design flow of 140 cfs (3.96 cu m/sec), the water surface upstream of the concentrator was at approximately elevation 243.1 (74.10 m). The flow passed through critical depth (approximately 1.82 feet (55.47 cm)) immediately downstream from the beginning of the screen, and was approximately 1 inch (2.54 cm) deep for the remaining flow of 10.5 cfs (0.30 cu m/sec) over the downstream end.

The transition section reduced the channel width from 20 to 10 feet (6.1 to 3.05 m) in a distance of 14 feet 3 inches (4.34 m), resulting in considerable drawdown in the water surface at the abrupt change in wall direction. The water surface in the concentrator was wavy and a prominent diagonal standing wave emanated from the break in the sidewall alinement at the upstream end of the concentrator.

Extending the parallel walls of the concentrator 30 inches (76.2 cm) upstream and placing a 15-inch (38.1-cm) radius at the intersection with the converging wall of the approach section, improved the flow appearance. Some drawdown in the water surface



Discharge through orifices = 140 cfs (3.96 cms) minus discharge over end of concentrator.

Curve (1) is with orifice plate sections in the original design order.

Curve (2) is with orifice plate sections in reverse order.

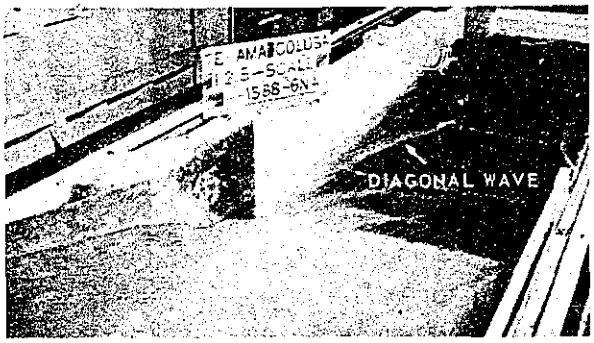
Figure 8. Discharge versus concentrator slope.

at the junction of the walls was still apparent and the diagonal wave still persisted, Figure 9; however, the flow depth over the downstream end was more uniform than before.

Flow characteristics beneath the orifices.—The channel beneath the orifice plates carried the flow away and allowed ample space for ventilation of the jets discharging from the underside of the orifices. However, the getaway of the water was improved by the installation of a 45°, 15-inch (38.10-cm) fillet at the upstream end, Figure 6. The fillet eliminated an upstream eddy and lowered the water surface under the first section of the concentrator.

Second Design

Description.—To smooth the water surface through the concentrator and to increase the depth of flow over the downstream end of the structure, the sidewalls in the transition section at the upstream end of the concentrator and the parallel walls in the concentrator were replaced with converging walls that reduced the width at the downstream end of the concentrator to 8 feet (2.44 m), Figure 10. To compensate for the reduced screen area in the third and fourth sections, the length of the concentrator was increased from 14 to 15 feet (4.27 to 4.57 m) and the width at the upstream end of the screen was increased from 10 feet to 10 feet 11-3/8 inches (3.05 to 3.34 m). To obtain the additional 1 foot (30.48 cm) length in the structure each section was lengthened 3 inches (7.62 cm).



Note: Orifice plates are in reverse order from that of the preliminary design. Photo P602-D-68497

Figure 9. Flow characteristics with approach wall modification.

Because of the narrower width at the downstream end it was necessary to eliminate the two outside rows of orifices in the last section, which amounted to one-sixth of the orifice area in this section. Otherwise, the orifice sizes and the sequence of these sizes in the four sections remained the same as in the preliminary design. The orifices in each section were relocated as far downstream as possible without changing their relative position with each other, Figure 10.

Orifice capacity.—In the preliminary design the flow being in a diagonal direction from above the screen to the orifices below was partially blocked by the partitions, leaving a void in the upstream portion of each section which allowed air to be momentarily drawn upward through the orifices into the voids. This air entrainment was not as prevalent in the second design, Figure 11; primarily because the orifices were 6 inches (15.24 cm) farther downstream from the transverse partitions. Some air entrainment resulting from air voids still persisted intermittently in the fourth section. The orifice locations in this design reduced the flow over the end of the structure to about 5.5 or 6 cfs (0.16 or 0.17 cm m/sec).

In addition to the air entrainment, intermittent air vortices formed between adjacent orifices, Figure 12. These occurred in each section just upstream off the

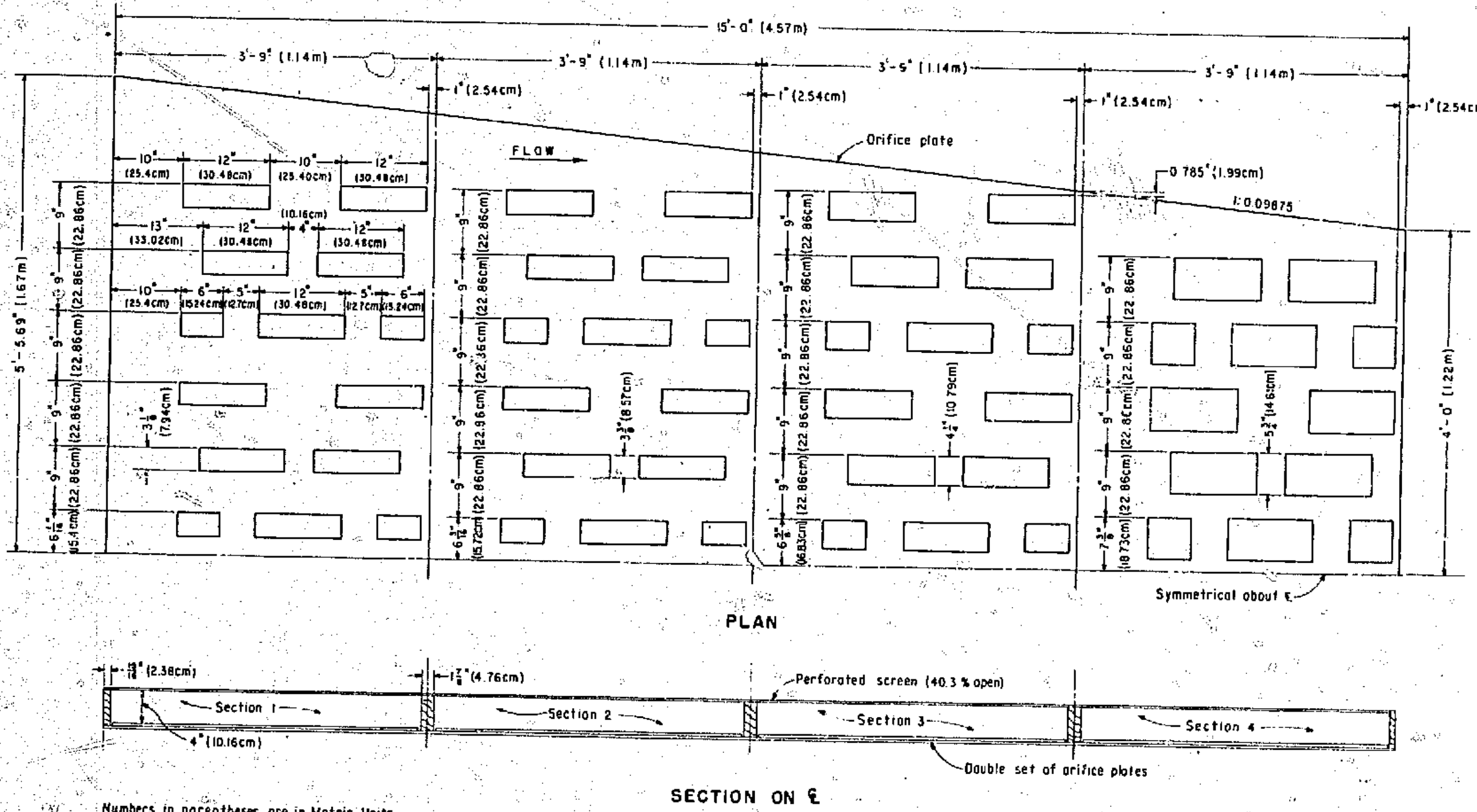
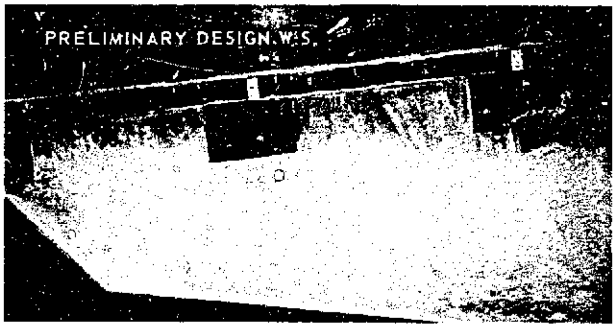


Figure 10. Orifice plate layout in second design.



Note: No white clouds above orifice plates as in Figure 7, 140 cfs (3.96 cu m/sec). Photo P602-D-68503

Figure 11. Second design in operation.

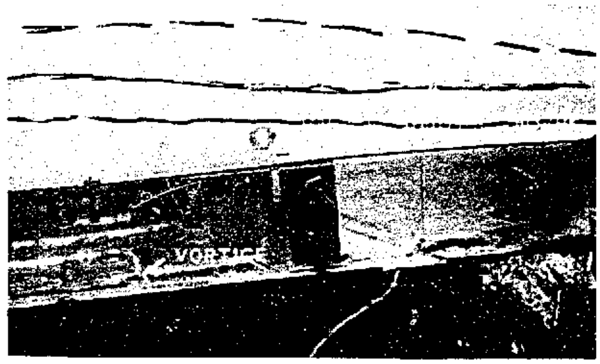


Figure 12. Vortices in Section 3 of second design. Photo P602-D-68502

transverse partitions in the preliminary design as well as in the second design. No attempt was made to eliminate these vortices.

The screen without the orifices discharged the full 140 cfs (3.96 cu m/sec); the orifices without the screen discharged all but about 3.5 cfs (0.10 cu m/sec), which remained to flow over the downstream end.

The model screen had the round perforated holes punched from the top down which provided a slight bellmouth shape to each of the holes. It was suggested that the prototype screen be placed in the same manner to provide a better coefficient of discharge through each of the perforations.

Water surface characteristics.—For a discharge of 140 cfs (3.96 cu m/sec), the water surface was at about elevation 243 (74.07 m) upstream of the transition section, or about 0.1 foot (3.04 cm) lower than in the preliminary design. At the upstream end of the screen the water was approximately 1.85 feet (0.56 m) above floor elevation 240.51 (73.31 m). The flow passed through critical depth for the 140 cfs (3.96 cu m/sec) flow (approximately 1.71 feet (0.52 m)), a few inches downstream from the beginning of the screen. At the downstream end of the screen, elevation 242 (73.76 m), the average flow depth was less than 1 inch (2.54 cm), about the same as in the preliminary design; however, upstream from this point the flow depth throughout the entire length of the concentrator was greater than in the preliminary design, Figure 11. This indicated a slower velocity, at least over the upstream sections, and an increased discharge through the orifices.

The water surface was comparatively smooth. The large diagonal wave in the preliminary design had been eliminated and the flow depth at the downstream end was fairly uniform.

Recommended Design

Design criteria.—Revised design criteria required a discharge of not more than 5 cfs (0.14 cu m/sec) flowing at a minimum depth of 4 inches (10.16 cm) at a maximum velocity of 10 feet (3.05 m) per second to carry the fingerlings from the concentrator. Otherwise, the fingerlings would become frightened of the shallow, fast flow and return upstream.

Description.—To avoid making the structure extremely long and narrow to meet these requirements, it was decided to terminate the upward slope of the perforated plate screen at a point where the flow depth was at least 4 inches (10.16 cm) and the velocity was less than 10 feet (3.05 m) per second, and then to continue the perforated plate on a downward slope until only 5 cfs (0.14 cu m/sec) remained above the plate to carry the fingerlings to the counter. Thus the fingerlings will not sense the shallow depth and high-velocity flow until they have committed themselves to the downward direction of flow. This condition existed at the downstream end of the third orifice plate section; therefore, the fourth section was placed on the downward slope, Figure 3.

The length of sections and orifice placement developed for the second design, Figure 11, were desirable from a hydraulic standpoint and were retained for the recommended design, Figure 3. Other modifications included: returning to the 10-foot (3.05-m) wide structure; elimination of the orifices in Section 4; an increase in the size of orifices in Sections 1, 2, and 3; an adjustable crest elevation between Sections 3 and 4; an adjustable length of screen closure at the downstream end of Section 4; addition of air vents beneath the orifices; and lowering of the floor beneath the orifices.

Development.—In developing this design it was decided to return to the preliminary arrangement of parallel walls 10 feet (3.05 m) apart, to simplify the design and construction of the prototype. At the same time it was desirable to utilize some of the benefits derived in the development of the second design. Therefore, as in the second design, each section was lengthened 3 inches (7.62 cm) to eliminate the air entrainment between the perforated plates and orifice plates. The same arrangement of the orifices was maintained; however, the size of the orifices were increased approximately 12-1/2 percent to provide additional capacity.

Operation of the second design indicated that the flow depth and velocity were within the specified limits at the partition between Sections 3 and 4. Therefore, the upward slope in the recommended design was terminated at this point and the fourth section reinstalled on a downward slope of 8:1 with the crest at elevation 241.92 (73.74 m).

Since the difference between the headwater elevation upstream of the fish concentrator and the tailwater elevation downstream of the fish counter was limited, the question arose as to whether there was enough vertical drop available between these two elevations to accommodate the downward slope of the fourth section and the total drop requirement of all structures through which the flow had to pass. Therefore, to reduce the vertical drop required, the downward slope of the fourth section was reduced to 16:1 and the vertical depth of the fish separator immediately downstream from the concentrator was reduced. Enough reduction in the vertical depth of the structures was gained so that the floor of the concentrator and the transition section upstream could be lowered 3 inches (7.62 cm) to provide extra free board in the approach to the concentrator as a safety factor against unexpected additional head loss through the concentrator.

Operation with this arrangement in the model produced a depth of about 4.5 inches (11.43 cm) over the crest at a velocity of about 7 feet (2.13 m) per second. The velocity was determined by several averaging pitot tube measurements over the length of the crest.

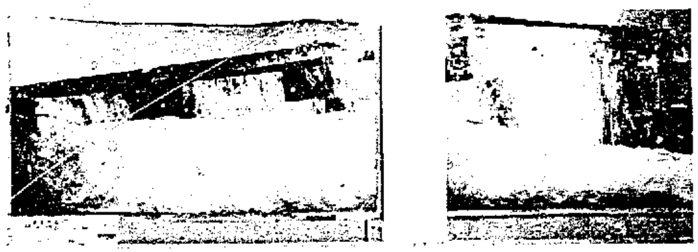
This arrangement of the model provided a flow of only 2.5 cfs (0.07 cu m/sec) above the perforated plate at the downstream end of Section 4 when all orifices were fully open. In addition, a large air void and much entrained air in the flow were present between the perforated plate screen and the orifice plates in the fourth section. By closing the orifices in Section 4 to one-half open, the air voids and air entrainment were eliminated and the discharge through the orifices was increased while the discharge over the end was reduced.

It was found that by removing the orifices in Section 4, the discharge through the screen in Section 4 was reduced and the discharge from the end of the concentrator was increased. This arrangement increased the flow over the end from 2 to about 7.5 cfs (0.06 to about 0.21 cu m/sec). Apparently, removal of the orifice plate beneath the perforated plate screen relieved a subatmospheric pressure condition which drew more water through the perforated screen.

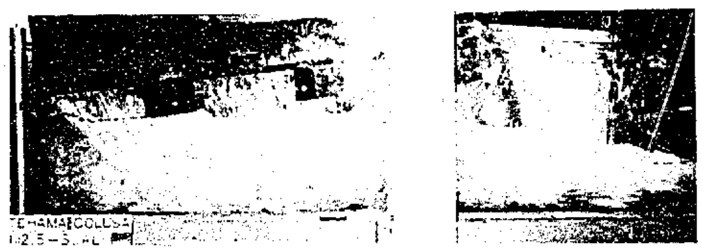
With the orifices removed it was necessary to reduce the flow over the end from 7.5 to 5 cfs (0.21 to 0.14 cu m/sec). Tests showed that the length of the fourth section should be increased from 3 feet 9 inches (1.14 m) to about 4 feet 9 inches (1.45 m). However, to be certain that the capacity of the perforated plate screen would be sufficient at all times to discharge 135 cfs (3.82 cu m/sec), the length of the fourth section was increased to 5 feet (1.52 m); and, an adjustable cover plate was placed under the downstream end so that the open length of the perforated plate in Section 4 could be adjusted, Figure 3.

Additional control of the flow was provided by making the slope of Sections 1, 2, and 3 adjustable. Tests made in the preliminary design studies had shown that flow through the orifices was increased by steepening the upstream slope. However, this flow increase may be offset by reduced flow through Section 4 or reinforced by a reduction in the steepness of the upstream slope. Since the design requirements set forth at the beginning of the recommended design studies were met in the model without adjusting the steepness of the slope, there was no need to test the adjustable feature of the design.

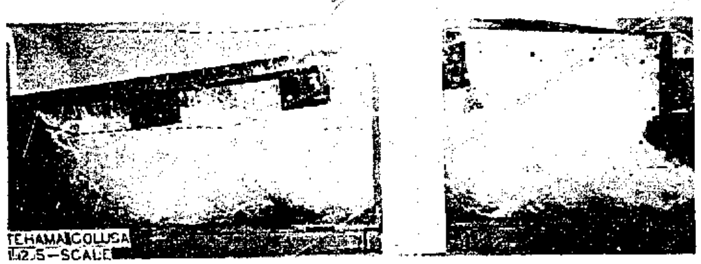
Performance.—The hydraulic performance of the orifices either fully open or partially closed was very satisfactory, Figure 13. Tests were conducted with various combinations of orifices in Sections 1, 2, and 3, either half closed or fully open to determine the length of the closure adjustment in Section 4, Figure 14. The closure plate length is in addition to the width of the supporting angles at the upstream and downstream ends. With all orifices fully open, the closure plate length must be about 19 inches (48.3 cm). With all orifices half closed, the closure plate length should be about 5 inches (12.7 cm). Velocity and depth requirements at the crest were within acceptable limits for any of the combinations of orifice closures tested.



A. All orifices full open. Photo P602-D-68506

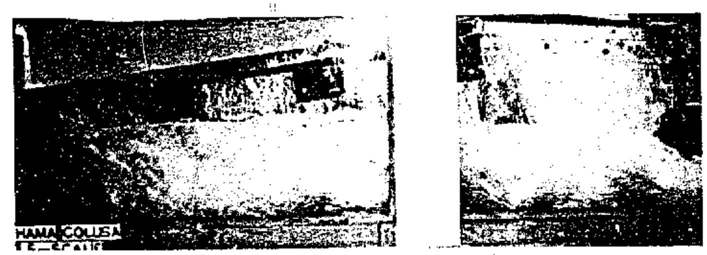


B. Dye streamer in flow. Photo P602-D-68507

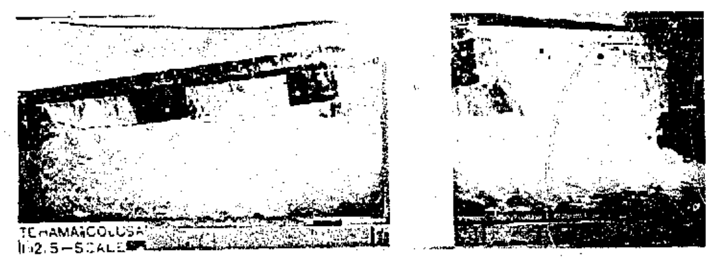


C. All orifices half closed. Photo P602-D-68511

D. Orifices in Section 1 half closed. Photo P602-D-68508



E. Orifices in Section 2 half closed. Photo P602-D-68509



F. Orifices in Section 3 half closed. Photo P602-D-68510

Note: Flow from end of concentrator is adjusted to 5 cfs (0.14 cu m/sec) (see Figure 3). Model floor and, therefore, the water surface under the orifice plates is approximately 4.21 feet too high.

Figure 13. Recommended design discharging 140 cfs (3.96 cu m/sec).

ORIFICE POSITIONS IN EACH SECTION	CLOSURE ADJUSTMENT SECTION NO. 4 INCHES (CM)	DISCHARGE TO THE FISH GRADER CFS (CMS)	TOTAL HEAD ABOVE CREST FEET (M)	AVERAGE DEPTH OF FLOW AT CREST INCHES (CM)	AVERAGE VELOCITY AT CREST FEET/SEC. (M/SEC)
ALL FULLY OPEN	18.62 (47.29)	5 (0.14)	1.190 (36.27)	3.25 (8.26)	7.70 (2.35)
SECTION NO. 1 HALF CLOSED	8.00 (20.32)	5 (0.14)	1.200 (36.58)	4.12 (10.46)	7.43 (2.26)
SECTION NO. 2 HALF CLOSED	8.62 (21.89)	5 (0.14)	1.192 (36.33)	4.37 (11.10)	7.30 (2.23)
SECTION NO. 3 HALF CLOSED	6.75 (17.14)	5 (0.14)	1.190 (36.27)	5.37 (13.64)	6.92 (2.11)
SECTIONS NO. 1 & 2 HALF CLOSED	3.62 (9.19)	5 (0.14)	1.300 (39.62)	5.50 (13.97)	7.36 (2.24)
SECTIONS NO. 1 & 3 HALF CLOSED	5.18 (13.16)	5 (0.14)	1.287 (39.23)	6.45 (16.38)	6.94 (2.12)
SECTIONS NO. 2 & 3 HALF CLOSED	5.50 (13.97)	5 (0.14)	1.192 (36.33)	6.75 (17.15)	6.36 (1.94)
ALL HALF CLOSED	4.87 (12.37)	5 (0.14)	1.305 (39.78)	8.12 (20.62)	6.36 (1.94)

Notes: *Air* pockets momentarily form and disappear between the perforated plate and orifices in the third section when these orifices are fully open. Figures in parenthesis are in metric units. Total flow to the concentrator = 140 cfs (3.96 cu m/sec). Adjustable crest is 241.67 (73.66 m). See Figure 3.

Figure 14. Controlled discharge table.

Water surface characteristics.—The water surface elevation upstream of the fish concentrator depended upon the control of the orifice plates and the elevation of the crest between Sections 3 and 4. With the crest adjusted to midpoint elevation 241.67 (73.66 m) and all orifices fully open the total head above the crest was 1.19 feet (36.27 cm), Figure 14. Even with all of the orifices half closed, the head above the crest did not exceed 1.3 feet (39.62 cm) which places the upstream water surface below elevation 243 (74.07 m). This provided a safety factor of about 0.25 foot (7.62 cm) below the allowable maximum limit in the main canal upstream. The recommended design was purposely set 0.25 foot (7.62 cm) lower than the preliminary or second designs to provide this safety factor.

The recommended transition wall alinement (Figure 15) provided a comparatively smooth water surface drawdown at the junction of the transition wall with the fish concentrator wall, Figure 16. Some of the standing waves observed in the water surface are the result of change in direction of the model wall, which will not exist in the prototype.

At the upstream end of the perforated plate screen the depth and velocity of the flow were approximately 1.92 and 7.28 feet (0.59 and 2.22 m) per second, respectively, with all orifices fully open and approximately 2.13 and 6.57 feet (0.65 and 2.003 m) per second, respectively, with all orifices half closed. Depth of flow and velocity at the downstream end of Section 4 were measured at about 0.62 inch (1.57 cm) and 9.75 feet (2.97 m) per second, respectively.

Flow characteristics beneath the orifices.—The sloping floor beneath the orifices was lowered to a horizontal level at elevation 232.30 (70.81 m) which is the lowest elevation to which the preliminary floor extended. This change was made for reasons other than hydraulic and could not be easily duplicated in the model; however, no adverse hydraulic problems are anticipated. The model floor was horizontal at elevation 236.51 (72.09 m), 4.21 feet (1.28 m) higher than in the prototype. Therefore, the model water surface elevation beneath the orifices was higher by approximately this amount.

The lack of orifices beneath the plate screen in the fourth and final section provided a single

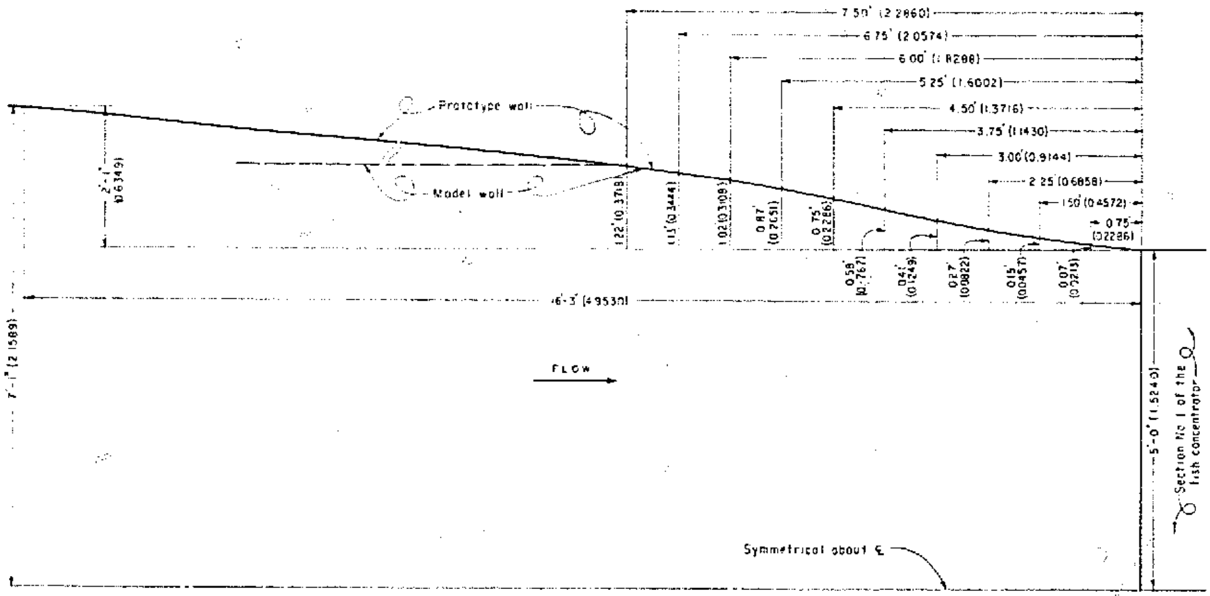
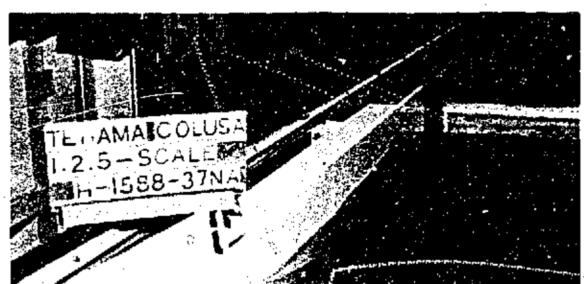


Figure 15. Recommended approach training wall to concentrator.



A. Looking downstream. Photo P602-D-68504

B. Looking upstream. Photo P602-D-68506

Figure 16. Water surface in recommended design.

waterfall from wall to wall, through this section, Figure 13, which sealed off from the atmosphere the space beneath the orifices upstream. A vent hole drilled through the wall of this region indicated that a demand for air existed. Therefore, an 8-inch (20.32-cm) diameter air vent was placed in each wall immediately below the orifices at midpoint of Section 2 where it was believed that the invert of the vent would be above the water surface at all times.

REFERENCES

The following list of drawings and reference drawings, from Volumes 1, 2, and 3 of Specifications No. DC-6734, show details of the recommended design of the fish concentrator and appurtenant structures:

LIST OF DRAWINGS

Fish Grader and Fish Counter Structure:

Fish Concentrator, Fish Grader, Fish Trough, Trash-fish Trap and Miscellaneous Equipment:

- Installation and Assembly 602-D-1635
- Fish Concentrator-Orifice Plates, Perforated Plate snd Baffle Plate Plan, Sections and Details 602-D-1636
- Fish Grader and Fish Grades Baffle Pl—Plan Sections and Details 602-D-1637
- Fish Trough, Fish Trough Divider Screens and Fish Channel Divider Screens—Plan, Sections and Details 602-D-1638
- Trash-Fishtrap, Pipe Jack and Longitudinal Beam Plan, Sections and Details 602-D-1639
- Spray Pump Base Plate Spray Manifold and Supports—Plan Screens and Details 602-D-1640

Reference Drawings

General Plan of Fish Bypass Structures:

- Sheet 1 of 2 .... 602-D-1489
- Sheet 2 of 2 .... 602-D-1490

Fish Grader And Fish Counter Structure:

- Sheet 1 of 2 .... 602-D-1505
- Sheet 2 of 2 .... 602-D-1506

7-1750 (1-70)
Bureau of Reclamation

CONVERSION FACTORS--BRITISH TO METRIC UNITS OF MEASUREMENT

The following conversion factors adopted by the Bureau of Reclamation are those published by the American Society for Testing and Materials (ASTM Metric Practice Guide, E 380-68) except that additional factors (*) commonly used in the Bureau have been added. Further discussion of definitions of quantities and units is given in the ASTM Metric Practice Guide.

The metric units and conversion factors adopted by the ASTM are based on the "International System of Units" (designated SI for Systeme International d'Unites), fixed by the International Committee for Weights and Measures; this system is also known as the Giorgi or MKSA (meter-kilogram (mass)-second-ampere) system. This system has been adopted by the International Organization for Standardization in ISO Recommendation R-31.

The metric technical unit of force is the kilogram-force; this is the force which, when applied to a body having a mass of 1 kg, gives it an acceleration of 9.80665 m/sec/sec, the standard acceleration of free fall toward the earth's center for sea level at 45 deg latitude. The metric unit of force in SI units is the newton (N), which is defined as that force which, when applied to a body having a mass of 1 kg, gives it an acceleration of 1 m/sec/sec. These units must be distinguished from the (inconstant) local weight of a body having a mass of 1 kg; that is, the weight of a body is that force with which a body is attracted to the earth and is equal to the mass of a body multiplied by the acceleration due to gravity. However, because it is general practice to use "pound" rather than the technically correct term "pound-force," the term "kilogram" (or derived mass unit) has been used in this guide instead of "kilogram-force" in expressing the conversion factors for forces. The newton unit of force will find increasing use, and is essential in SI units.

Where approximate or nominal English units are used to express a value or range of values, the converted metric units in parentheses are also approximate or nominal. Where precise English units are used, the converted metric units are expressed as equally significant values.

Table I

QUANTITIES AND UNITS OF SPACE

Multiply	By	To obtain
	LENGTH	
Mil	25.4 (exactly)	Micron
Inches	25.4 (exactly)	Millimeters
	2.54 (exactly)*	Centimeters
Feet	30.48 (exactly)	Centimeters
	0.3048 (exactly)*	Meters
	0.0003048 (exactly)*	Kilometers
Yards	0.9144 (exactly)	Meters
Miles (statute)	1,609.344 (exactly)*	Meters
	1.609344 (exactly)	Kilometers
	AREA	
Square inches	6.4516 (exactly)	Square centimeters
Square feet	929.03*	Square centimeters
	0.092903	Square meters
Square yards	0.836127	Square meters
Acres	0.40469*	Hectares
	4,046.9*	Square meters
	0.0040469*	Square kilometers
Square miles	2.58999	Square kilometers
	VOLUME	
Cubic inches	16.3871	Cubic centimeters
Cubic feet	0.0283168	Cubic meters
Cubic yards	0.764555	Cubic meters
	CAPACITY	
Fluid ounces (U.S.)	29.5737	Cubic centimeters
	29.5729	Milliliters
Liquid pints (U.S.)	0.473179	Cubic decimeters
	0.473166	Liters
Quarts (U.S.)	946.358*	Cubic centimeters
	0.946331*	Liters
Gallons (U.S.)	3,785.43*	Cubic centimeters
	3.78543	Cubic decimeters
	3.78533	Liters
	0.00378543*	Cubic meters
Gallons (U.K.)	4.54609	Cubic decimeters
	4.54596	Liters
Cubic feet	28.3160	Liters
Cubic yards	764.55*	Liters
Acre-feet	1,233.5*	Cubic meters
	1,233,500*	Liters

Table II

QUANTITIES AND UNITS OF MECHANICS

Multiply	By	To obtain
MASS		
Grains (1/7,000 lb)	64.79891 (exactly)	Milligrams
Troy ounces (480 grains)	31.1035	Grams
Ounces (avdp)	28.3495	Grams
Pounds (avdp)	0.45359237 (exactly)	Kilograms
Short tons (2,000 lb)	907.185	Kilograms
	0.907185	Metric tons
Long tons (2,240 lb)	1,016.05	Kilograms
FORCE/AREA		
Pounds per square inch	0.070307	Kilograms per square centimeter
	0.689476	Newtons per square centimeter
Pounds per square foot	4.88243	Kilograms per square meter
	47.8803	Newtons per square meter
MASS/VOLUME (DENSITY)		
Ounces per cubic inch	1.72999	Grams per cubic centimeter
Pounds per cubic foot	16.0185	Kilograms per cubic meter
	0.0160185	Grams per cubic centimeter
Tons (long) per cubic yard	1.32894	Grams per cubic centimeter
MASS/CAPACITY		
Ounces per gallon (U.S.)	7.4893	Grams per liter
Ounces per gallon (U.K.)	6.2362	Grams per liter
Pounds per gallon (U.S.)	119.829	Grams per liter
Pounds per gallon (U.K.)	99.779	Grams per liter
BENDING MOMENT OR TORQUE		
Inch-pounds	0.011521	Meter-kilograms
	1.12985×10^{6}	Centimeter-dynes
Foot-pounds	0.138255	Meter-kilograms
	1.35582×10^{7}	Centimeter-dynes
Foot-pounds per inch	5.4431	Centimeter-kilograms per centimeter
Ounce-inches	72.008	Gram-centimeters
VELOCITY		
Feet per second	30.48 (exactly)	Centimeters per second
	0.3048 (exactly)*	Meters per second
Feet per year	0.965873×10^{-6}*	Centimeters per second
Miles per hour	1.609344 (exactly)	Kilometers per hour
	0.44704 (exactly)	Meters per second
ACCELERATION*		
Feet per second^2	0.3048*	Meters per second^2
FLOW		
Cubic feet per second (second-feet)	0.028317*	Cubic meters per second
Cubic feet per minute	0.4719	Liters per second
Gallons (U.S.) per minute	0.06309	Liters per second
FORCE*		
Pounds	0.453592*	Kilograms
	4.4482*	Newtons
	4.4482×10^{-5}*	Dynes

Multiply	By	To obtain
WORK AND ENERGY*		
British thermal units (Btu)	0.252*	Kilogram calories
	1,055.06	Joules
Btu per pound	2.326 (exactly)	Joules per gram
Foot-pounds	1.35582*	Joules
POWER		
Horsepower	745.700	Watts
Btu per hour	0.293071	Watts
Foot-pounds per second	1.35582	Watts
HEAT TRANSFER		
Btu in./hr ft^2 deg F (k, thermal conductivity)	1.442	Milliwatts/cm deg C
	0.1240	Kg cal/hr m deg C
Btu ft/hr ft^2 deg F	1.4880*	Kg cal m/hr m^2 deg C
Btu/hr ft^2 deg F (C, thermal conductance)	0.568	Milliwatts/cm^2 deg C
	4.882	Kg cal/hr m^2 deg C
Deg F hr ft^2/Btu (R, thermal resistance)	1.761	Deg C cm^2/milliwatt
Btu/lb deg F (c, heat capacity)	4.1868	J/g deg C
Btu/lb deg F	1.000*	Cal/gram deg C
Ft^2/hr (thermal diffusivity)	0.2581	Cm^2/sec
	0.09290*	M^2/hr
WATER VAPOR TRANSMISSION		
Grains/hr ft^2 (water vapor transmission)	16.7	Grams/24 hr m^2
Perms (permeance)	0.659	Metric perms
Perm-inches (permeability)	1.67	Metric perm-centimeters

Table III

OTHER QUANTITIES AND UNITS

Multiply	By	To obtain
Cubic feet per square foot per day (seepage)	304.8*	Liters per square meter per day
Pound-seconds per square foot (viscosity)	4.8824*	Kilogram second per square meter
Square feet per second (viscosity)	0.092903*	Square meters per second
Fahrenheit degrees (change)*	5/9 exactly	Celsius or Kelvin degrees (change)*
Volts per mil	0.03937	Kilovolts per millimeter
Lumens per square foot (foot-candles)	10.764	Lumens per square meter
Ohm-circular mils per foot	0.001662	Ohm-square millimeters per meter
Millicuries per cubic foot	35.3147*	Millicuries per cubic meter
Milliamps per square foot	10.7639*	Milliamps per square meter
Gallons per square yard	4.527219*	Liters per square meter
Pounds per inch	0.17858*	Kilograms per centimeter

GPO 834-550

ABSTRACT

Tests of a 1:2.5 scale model made to develop the design of a fish concentrator to be located on the Tehama-Colusa Canal in California are described. The purpose of the structure is to concentrate chinook salmon fingerlings into a flow of 5 cfs from a flow of 140 cfs for passage through an electronic counting device. The preliminary design consisted of a 14-ft-long, 10-ft-wide upward sloping perforated plate screen with adjustable orifice plates underneath to control flow through the screen. The screen consisted of four 3.5-ft-long sections. The testing resulted in the following: (1) the first 3 sections were each lengthened by 3 in., and the underlying orifices were repositioned to increase capacity at the full open position; (2) the fourth or downstream section was lengthened to 5 ft and was tilted to slope downward; (3) orifice plates under Section 4 were eliminated in favor of a cover plate to regulate flow through that section; (4) the size of the orifices under Sections 1, 2, and 3 was increased by approximately 12.5%; (5) the crest elevation between Sections 3 and 4 was made adjustable for better flow depth and velocity control; and (6) air vents were provided through the side walls of the space below the orifice plates in Sections 1, 2, and 3.

ABSTRACT

Tests of a 1:2.5 scale model made to develop the design of a fish concentrator to be located on the Tehama-Colusa Canal in California are described. The purpose of the structure is to concentrate chinook salmon fingerlings into a flow of 5 cfs from a flow of 140 cfs for passage through an electronic counting device. The preliminary design consisted of a 14-ft-long, 10-ft-wide upward sloping perforated plate screen with adjustable orifice plates underneath to control flow through the screen. The screen consisted of four 3.5-ft-long sections. The testing resulted in the following: (1) the first 3 sections were each lengthened by 3 in., and the underlying orifices were repositioned to increase capacity at the full open position; (2) the fourth or downstream section was lengthened to 5 ft and was tilted to slope downward; (3) orifice plates under Section 4 were eliminated in favor of a cover plate to regulate flow through that section; (4) the size of the orifices under Sections 1, 2, and 3 was increased by approximately 12.5%; (5) the crest elevation between Sections 3 and 4 was made adjustable for better flow depth and velocity control; and (6) air vents were provided through the side walls of the space below the orifice plates in Sections 1, 2, and 3.

ABSTRACT

Tests of a 1:2.5 scale model made to develop the design of a fish concentrator to be located on the Tehama-Colusa Canal in California are described. The purpose of the structure is to concentrate chinook salmon fingerlings into a flow of 5 cfs from a flow of 140 cfs for passage through an electronic counting device. The preliminary design consisted of a 14-ft-long, 10-ft-wide upward sloping perforated plate screen with adjustable orifice plates underneath to control flow through the screen. The screen consisted of four 3.5-ft-long sections. The testing resulted in the following: (1) the first 3 sections were each lengthened by 3 in., and the underlying orifices were repositioned to increase capacity at the full open position; (2) the fourth or downstream section was lengthened to 5 ft and was tilted to slope downward; (3) orifice plates under Section 4 were eliminated in favor of a cover plate to regulate flow through that section; (4) the size of the orifices under Sections 1, 2, and 3 was increased by approximately 12.5%; (5) the crest elevation between Sections 3 and 4 was made adjustable for better flow depth and velocity control; and (6) air vents were provided through the side walls of the space below the orifice plates in Sections 1, 2, and 3.

ABSTRACT

Tests of a 1:2.5 scale model made to develop the design of a fish concentrator to be located on the Tehama-Colusa Canal in California are described. The purpose of the structure is to concentrate chinook salmon fingerlings into a flow of 5 cfs from a flow of 140 cfs for passage through an electronic counting device. The preliminary design consisted of a 14-ft-long, 10-ft-wide upward sloping perforated plate screen with adjustable orifice plates underneath to control flow through the screen. The screen consisted of four 3.5-ft-long sections. The testing resulted in the following: (1) the first 3 sections were each lengthened by 3 in., and the underlying orifices were repositioned to increase capacity at the full open position; (2) the fourth or downstream section was lengthened to 5 ft and was tilted to slope downward; (3) orifice plates under Section 4 were eliminated in favor of a cover plate to regulate flow through that section; (4) the size of the orifices under Sections 1, 2, and 3 was increased by approximately 12.5%; (5) the crest elevation between Sections 3 and 4 was made adjustable for better flow depth and velocity control; and (6) air vents were provided through the side walls of the space below the orifice plates in Sections 1, 2, and 3.