U.S. ENGINEER OFFICE
DEC 28 1940
VICKSBURG, MISS.

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

3429235

MODEL STUDY

OF THE

INTAKE

FOR

BAYOU BODCAU DAM

OUTLET STRUCTURES

TM 174-1

U. S. WATERWAYS EXPERIMENT STATION

VICKSBURG, MISSISSIPPI

DECEMBER 21, 1940

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REPLY TO
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WAR DEPARTMENT
MISSISSIPPI RIVER COMMISSION
U. S. WATERWAYS EXPERIMENT STATION
P. O. BOX 631
VICKSBURG, MISSISSIPPI

IN REPLY REFER TO FILE NO. 376

December 21, 1940

Subject: Final report on the model study of the intake, Bayou Bodcau dam outlet structures.

To: The District Engineer, U. S. Engineer Office, Vicksburg, Mississippi. (Through the Division Engineer, Lower Mississippi Valley Division, Vicksburg, Mississippi.)

This Letter

1. This letter constitutes a final report on the study performed at the Experiment Station on a model of the intake for the Bayou Bodcau dam outlet structures. All details concerning the study are described and discussed in this letter. Accompanying this report are one table, six plates, and thirteen photographs. The table contains the pressures measured throughout the transition section and conduit for various conditions of discharge. The plates show the characteristics of the structural features investigated, rating curves, velocities in the conduit, locations of the piezometers, and a sketch of the original and revised designs of the intake portal. The photographs show a general view of the model, and flow conditions in the model during various phases of operation.

References

2. Reference is made to a letter from the District Engineer, dated October 24, 1940, subject: "Model study of intake - Durden Ferry dam outlet structures," and to the 2nd indorsement thereto from the Experiment Station. (The name of the dam was subsequently changed from Durden Ferry dam to Bayou Bodcau dam.) Reference is also made to such communications and conversations pertaining to the same subject as followed that letter.

Description of the Prototype

3. Reference is made to plates 1 and 6, on which are shown the general characteristics of those elements of the outlet structures for the Bayou Bodcau dam which were reproduced in the model. These elements are (1) an intake structure having an effective rectangular opening with a width of 12.25 ft. and a height of 6.5 ft., (2) a transition section with a length of 25 ft., and (3) an egg-shaped conduit with a height and width of 14 ft. and 12.25 ft., respectively, and a length of 471.5 ft. Elements of the structures not reproduced in the model are a trash rack and a stilling basin. The design contemplates an outflow rate of 4,000 c.f.s. and a head of water on the intake invert of approximately 60 ft. Although the present plans do not include a

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control gate, the intake structure has been designed so that future gate installation can be accomplished.

The Purpose of the Model Study

4. The purpose of the model study was to investigate the hydraulic performance of the intake structure, with especial reference to flow conditions at the maximum head. If unsatisfactory performance was noted, the necessary modifications to the intake structure were to be determined. To accomplish the purpose of the model study, the original design and a revised design for the intake structure were investigated.

Description of the Apparatus

5. The experiments were conducted on a model located in the experiment hall at the Station. (See photograph showing a general view of the model.) The water used in the operation of the model was pumped from a sump and measured over a V-notch weir. The flow over the weir spilled into the headbay of the model, where it was stilled by baffles prior to its passage into the model. After passing through the model, the water was returned to the sump through a return channel. Standard types of hook gages were used for measurements of water-surface elevations, while velocity measurements were made with a pitot tube. Pressures were measured by piezometers located throughout the transition section and conduit.

Description of the Model

6. The model was built undistorted to the linear scale ratio, model-to-prototype, of 1 to 19.2. As has been stated, there were reproduced in the model the intake structure, the transition section, and the conduit. The intake structure was modeled of wood and treated to prevent expansion. The transition section and the greater portion of the conduit were molded of transparent pyralin which permitted direct observation of flow. The remaining portion of the conduit, on the downstream end of the model, was fabricated of sheet metal.

Method of Operation

Headwater-discharge relations

7. The relations of headwater to discharge were determined at small increments of flow from 0 c.f.s. to 4,000 c.f.s. The headwater elevations and the corresponding rates of discharge were used in plotting the rating curves.

Flow conditions

8. The characteristics of flow through the intake structure, transition section, and conduit were obtained from observations of the model. These observations were supported by photographs.

Velocities

9. Velocities were measured with a pitot tube on a vertical range located in the conduit immediately downstream from the transition section. The pitot tube was inserted through a water-tight connection in the crown of the conduit.

Pressures

10. Pressures were measured through piezometer openings connected to a manometer bank. During testing operations, the elevations of the water columns in the manometers were recorded. Actual pressures were indicated by the differences in the elevations of the piezometer openings and the water columns.

Testing Procedure

11. The initial tests were conducted on the outlet structures as originally designed. Subsequent tests had to do with a revised design. This design is the same as the original design, except for fillets located at the intersections of the curved roof and walls of the intake structure. (See plate 6.) The majority of tests were conducted at discharges of approximately 2,000 c.f.s. and 4,000 c.f.s. All tests were conducted with an air vent in the transition section alternately opened and closed. The conduit flowed free at the exit portal.

Results of Tests - Original Design

Explanatory remarks

12. The model investigation of the original design of the intake for the Bayou Bodcau dam outlet structures consisted of (a) determinations of headwater-discharge relations, (b) observations of flow conditions, (c) determinations of the magnitude of velocities, and (d) determinations of pressures.

Headwater-discharge relations

13. Reference is made to plate 2. The headwater elevation for the maximum discharge of 4,000 c.f.s., with the conduit not vented, was 193.5 ft. At the same discharge, with the conduit vented, the headwater elevation was 214.0 ft. The rating curves for the vented and unvented conditions of the conduit coincide at a discharge of about 2,000 c.f.s.; this is attributed to the fact that air was drawn through the intake portal at headwater elevations below 176.0 ft.

Flow conditions

14. Reference is made to photographs 1 to 8. Observation of flow through

the intake structure, the transition section, and the conduit under various conditions revealed that the performance of these elements was generally satisfactory. However, at high discharges it was observed that a large wave formed in the transition section and upstream portion of the conduit. An inspection of the photographs referred to above reveals facts as follow:

a. Photographs 1 and 2 (conduit vented, discharge = 3,993 c.f.s.). A high wave formed downstream from the intake structure and extended well below the transition section. This action was attended by turbulence of considerable intensity in the conduit. The conduit flowed approximately half full.

b. Photographs 3 and 4 (conduit vented, discharge = 1,996 c.f.s.). A hydraulic jump formed in the transition section immediately downstream from the intake structure. The conduit flowed nearly full.

c. Photographs 5 and 6 (conduit not vented, discharge = 3,993 c.f.s.). The transition section and conduit flowed full.

d. Photographs 7 and 8 (conduit not vented, discharge = 1,996 c.f.s.). The transition section and conduit flowed full.

Velocities

15. Reference is made to plate 3. An inspection of the data shown thereon reveals that the maximum velocities measured in the conduit near the transition section were 51 ft. per sec. with the conduit vented and 49 ft. per sec. with the conduit not vented.

Pressures

16. The locations of piezometers and their zeroes, and pressure data are shown, respectively, on plate 5 and in table 1. Analysis of the pressure data contained in table 1 reveals the existence of negative pressures in the transition section and conduit, for the unvented condition of the structures, at all discharges except that of 1,156 c.f.s. The venting of the structures removed all negative pressures.

Results of Tests - Revised Design

Explanatory remarks

17. The tests of the original design demonstrated that the hydraulic performance of the outlet structures was generally satisfactory. The large

standing wave which formed in the transition section and upstream portion of the conduit was not considered to be objectionable, nor did it appear that it could conceivably cause damage to the outlet structures. However, it was believed that the hydraulic performance of the outlet structures could be improved by maintaining uniform contact of the jet with the downstream edges of the intake portal. Accordingly, the intake structure was revised by placing fillets at the intersections of the curved roof and walls. The revised design is shown on plate 6. With the intake structure thus modified, investigations were made which comprised (a) determinations of headwater-discharge relations, (b) observations of flow conditions, and (c) determinations of the magnitudes of velocities.

Headwater-discharge relations

18. Reference is made to plate 2. An inspection of the rating curves shown thereon reveals that the fillets functioned to increase the efficiency of the outlet structures, when these structures were vented. For the maximum discharge of 4,000 c.f.s., with the conduit vented, the headwater elevation was lowered 2.5 ft. to elevation 211.5 ft. For the same discharge with the conduit unvented, however, the headwater elevation was raised 1.0 ft. to elevation 199.5 ft.

Flow conditions

19. Reference is made to photographs 9 to 12. Observation of flow through the intake structure, the transition section, and the conduit revealed considerable improvement to have followed from the addition of fillets to the intake structure, particularly at the maximum discharge. An inspection of the photographs referred to above reveals facts as follow:

a. Photograohs 9 and 10 (conduit vented, discharge = 3,993 c.f.s.). Flow was more evenly distributed than in the case of the original design, which caused a considerable reduction in the height of the wave downstream from the intake portal. This may be seen from a comparison of photographs 9 and 1. The turbulence in the transition section and upstream portion of the conduit was reduced. This may be seen from a comparison of photographs 10 and 2.

b. Photograph 11 (conduit vented, discharge = 2,000 c.f.s.). Flow conditions in the transition section were substantially the same as those in the original design. Compare photographs 11 and 3.

c. Photograph 12 (conduit not vented, discharge = 2,000 c.f.s.). Flow conditions in the transition section were substantially the same as those in the original design. (The air pocket in the top of the

transition section was caused by an imperfect seal of the vent.) Compare photographs 12 and 7.

Upon the completion of the foregoing tests, observations were made of hydraulic-jump action and other flow characteristics in the transition section and conduit for rising and falling reservoir stages. These observations are summarized below:

a. Conduit vented, rising and falling stages. Hydraulic-jump action obtained in various sections of the transition section and conduit for headwater elevations of 170 ft. to 180 ft. For rising stages the jump was swept out of the conduit, and for falling stages the jump formed in the conduit, at a headwater elevation of 180 ft. At no time did the conduit flow full.

b. Conduit not vented, rising stages. Hydraulic-jump action obtained only in the transition section for headwater elevations of 170 ft. to 180 ft. Above elevation 180 ft. the transition section and conduit flowed full.

c. Conduit not vented, falling stages. The transition section and conduit flowed full for headwater elevations above 176 ft. Hydraulic-jump action first occurred in the transition section at a headwater elevation of 174 ft., at which point the transition section and entire conduit started to flow partially full.

Velocities

20. Reference is made to plate 4. Analysis of the data shown thereon reveals that the magnitudes of velocities at the end of the transition section were about the same as those measured in tests of the original design.

Summary and Conclusions

21. There follows a summary of the results of tests conducted on the model of the intake for the Bayou Bodcau dam outlet structures, together with conclusions to be drawn therefrom:

a. The hydraulic performance of the outlet structures as originally designed was generally satisfactory.

b. The hydraulic performance of the outlet structures was improved, and the efficiency of the structures was increased by the addition of fillets to the intake structure. The fillets effected a smooth transformation of flow from the intake portal to the conduit. They

caused a considerable reduction in the height of a wave which formed downstream from the intake structure, and caused a reduction of turbulence in the transition section and upstream portion of the conduit.

c. With the conduit vented, hydraulic-jump action obtained in various sections of the transition section and conduit for headwater elevations of 170 ft. to 180 ft., for both rising and falling stages of the reservoir. With the conduit unvented, hydraulic-jump action obtained only in the transition section for headwater elevations of 170 ft. to 180 ft., for rising stages of the reservoir. For falling stages of the reservoir with the conduit unvented, hydraulic-jump action first occurred in the transition section at a headwater elevation of 174 ft.; this jump action obtained until a headwater elevation of 170 ft. was reached.

d. Negative pressures which existed in the transition section and conduit were relieved by an air vent in the crown of the transition section.

For and in the absence of the Director:

Joseph B. Tiffany, Jr.,
Engineer.

TABLE 1

Model Study of Intake
Bayou Bodcau Dam Outlet Structures

Original Design

PRESSURES IN FEET OF WATER

Piez. No.	Piez. Elev.	Conduit Not Vented					
		Disc. = 3,993 c.f.s. Pool Elev. = 198.0 ft.		Disc. = 3,235 c.f.s. Pool Elev. = 188.3 ft.		Disc. = 2,703 c.f.s. Pool Elev. = 182.3 ft.	
		Piez. Read.	Pressure	Piez. Read.	Pressure	Piez. Read.	Pressure
1	169.0	157.0	-12.0	163.0	-6.0	167.0	-2.0
2	169.0	153.0	-16.0	158.0	-11.0	162.0	-7.0
3	157.0	160.0	3.0	164.0	7.0	166.0	9.0
4	169.1	157.0	-12.1	162.0	-7.1	165.0	-4.1
5	169.2	157.0	-12.2	163.0	-6.2	165.0	-4.2
6	157.0	158.0	1.0	162.0	5.0	165.0	8.0
7	170.9	173.0	2.1	172.0	1.1	171.0	0.1
8	164.1	172.0	7.9	171.0	6.9	171.0	6.9
9	156.9	172.0	15.1	171.0	14.1	171.0	14.1
10	170.7	170.0	-0.7	170.0	-0.7	170.0	-0.7
11	164.4	170.0	5.6	170.0	5.6	170.0	5.6
12	156.6	170.0	13.4	170.0	13.4	170.0	13.4
13	170.5	168.0	-2.5	168.0	-2.5	169.0	-1.5
14	163.5	168.0	4.5	168.0	4.5	169.0	5.5
15	156.4	167.0	10.6	168.0	11.6	169.0	12.6

TABLE 1 (Cont.)

Model Study of Intake
Bayou Bodcau Dam Outlet Structures

Original Design

PRESSURES IN FEET OF WATER

Piez. No.	Piez. Elev.	Conduit Not Vented			
		Disc. = 1,996 c.f.s. Pool Elev. = 176.2 ft.		Disc. = 1,156 c.f.s. Pool Elev. = 168.7 ft.	
		Piez. Read.	Pressure	Piez. Read.	Pressure
1	169.0	166.0	-3.0	*	
2	169.0	166.0	-3.0	*	
3	157.0	168.0	11.0	166.5	9.5
4	169.1	167.0	-2.1	*	
5	169.2	167.0	-2.2	*	
6	157.0	167.0	10.0	167.0	10.0
7	170.9	171.0	0.1	*	
8	164.1	170.0	5.9	167.0	2.9
9	156.9	170.0	13.1	167.0	10.1
10	170.7	170.0	-0.7	*	
11	164.4	170.0	5.6	166.0	1.6
12	156.6	170.0	13.4	166.0	9.4
13	170.5	170.0	-0.5	*	
14	163.5	169.0	5.5	165.0	1.5
15	156.4	169.0	12.6	165.0	8.6

* Piezometer opening not in contact with water.

TABLE 1 (Cont.)

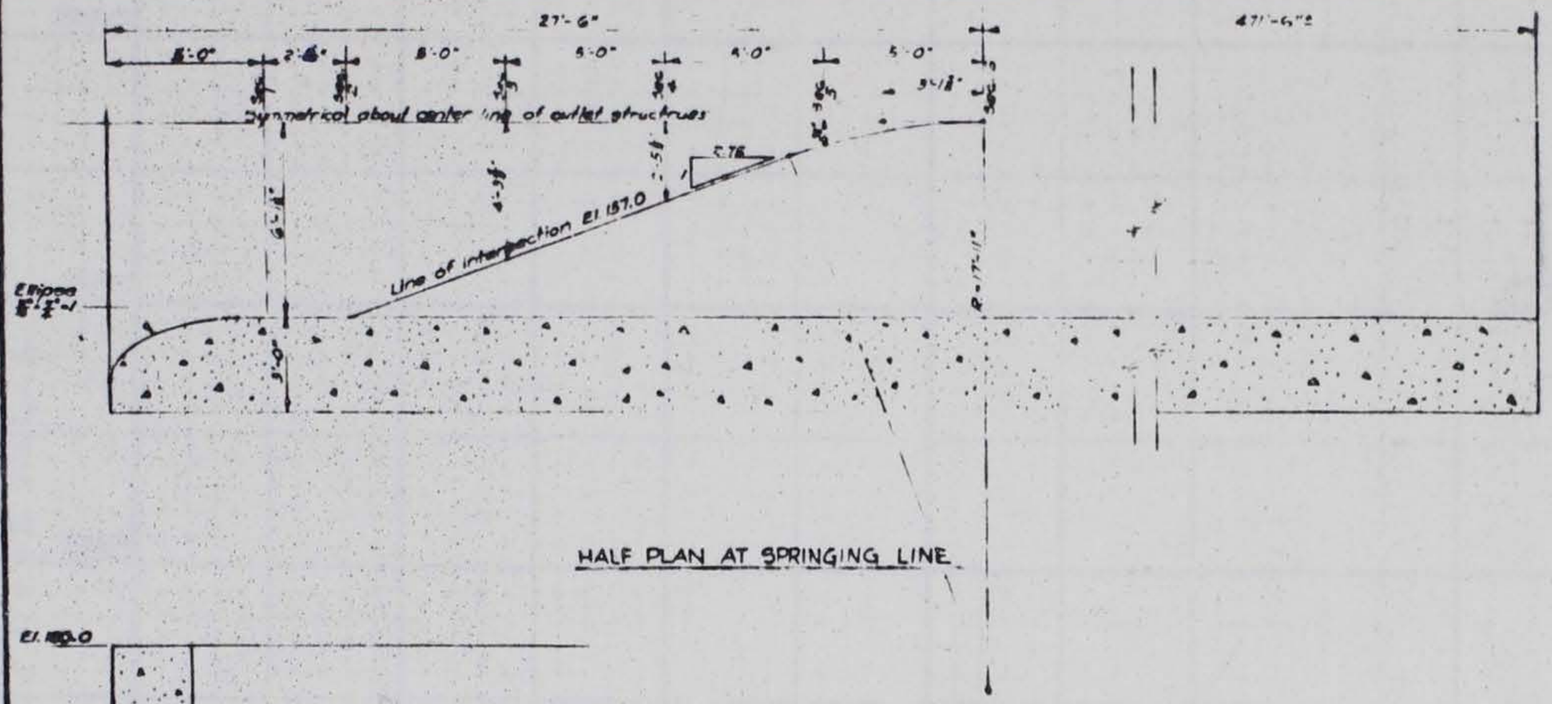
Model Study of Intake
Bayou Bodcau Dam Outlet Structures

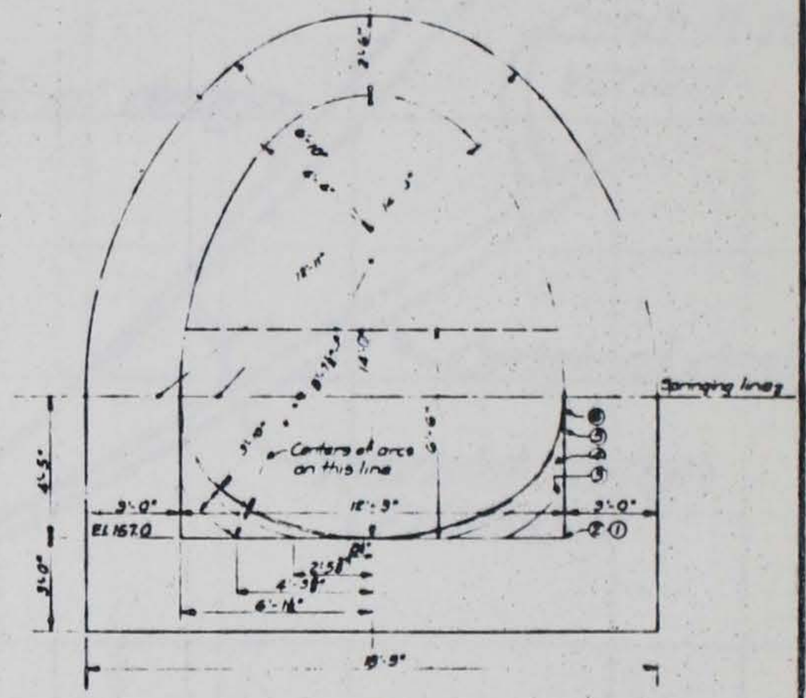
Original Design

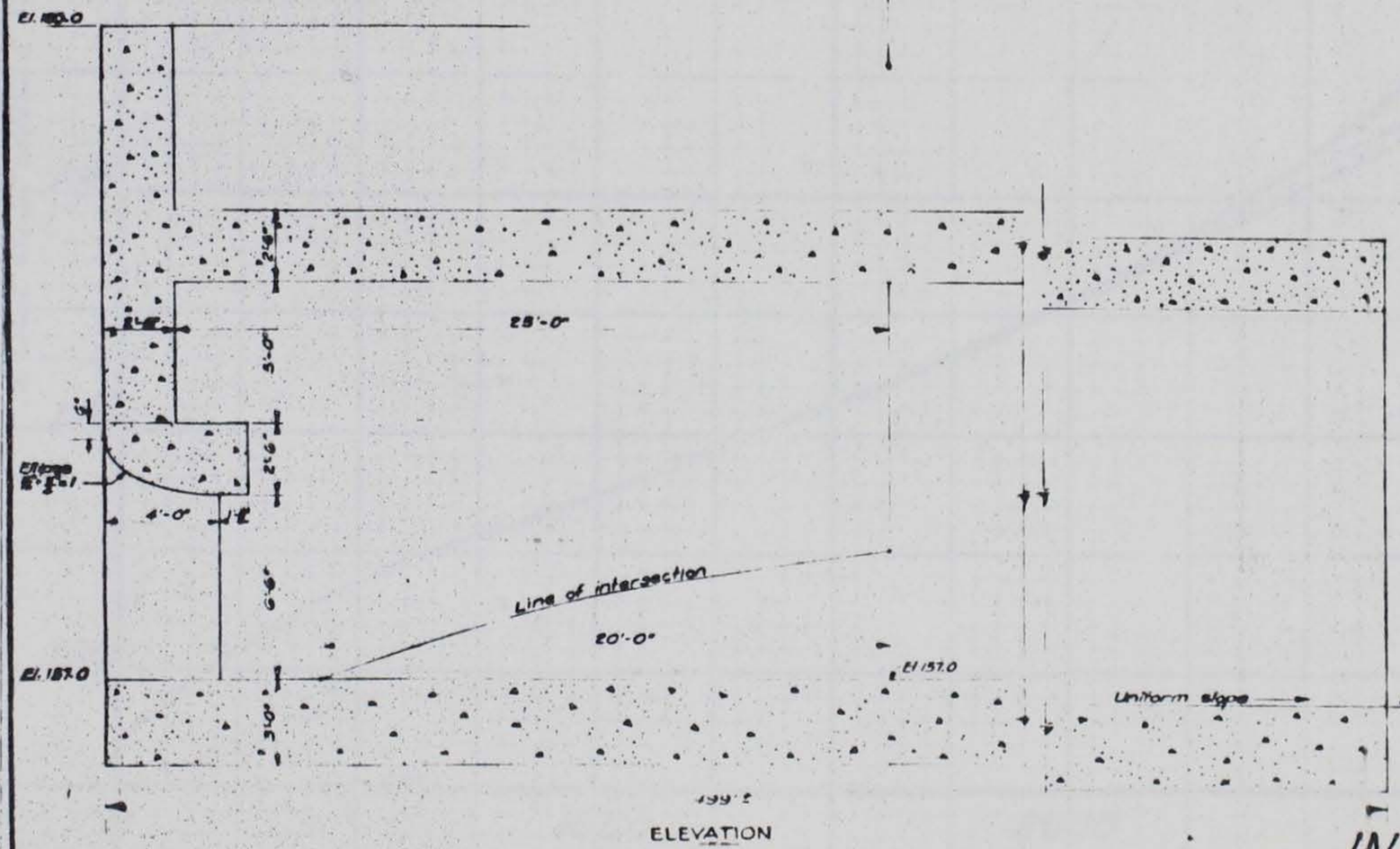
PRESSURES IN FEET OF WATER

Piez. No.	Piez. Elev.	Conduit Vented			
		Disc. = 3,993 c.f.s. Pool Elev. = 213.3 ft.		Disc. = 1,996 c.f.s. Pool Elev. = 175.9 ft.	
		Piez. Read.	Pressure	Piez. Read.	Pressure
1	169.0	*		*	
2	169.0	*		*	
3	157.0	173.0	16.0	167.0	10.0
4	169.1	*		*	
5	169.2	*		*	
6	157.0	162.5	5.5	169.0	12.0
7	170.9	*		*	
8	164.1	164.0	-0.1	170.5	6.4
9	156.9	163.5	6.6	170.5	13.6
10	170.7	*		*	
11	164.4	164.5	0.1	169.5	5.1
12	156.6	164.0	7.4	169.5	12.9
13	170.5	*		*	
14	163.5	164.5	1.0	168.5	5.0
15	156.4	164.0	7.6	168.5	12.1

* Piezometer opening not in contact with the water.







U.S. Waterways Experiment Station

Model Study of Intake

Bayou Bodcau Dam Outlet Structure

INTAKE & CONDUIT-ORIGINAL DESIGN

To accompany letter dated 12-21-40

Plate 1

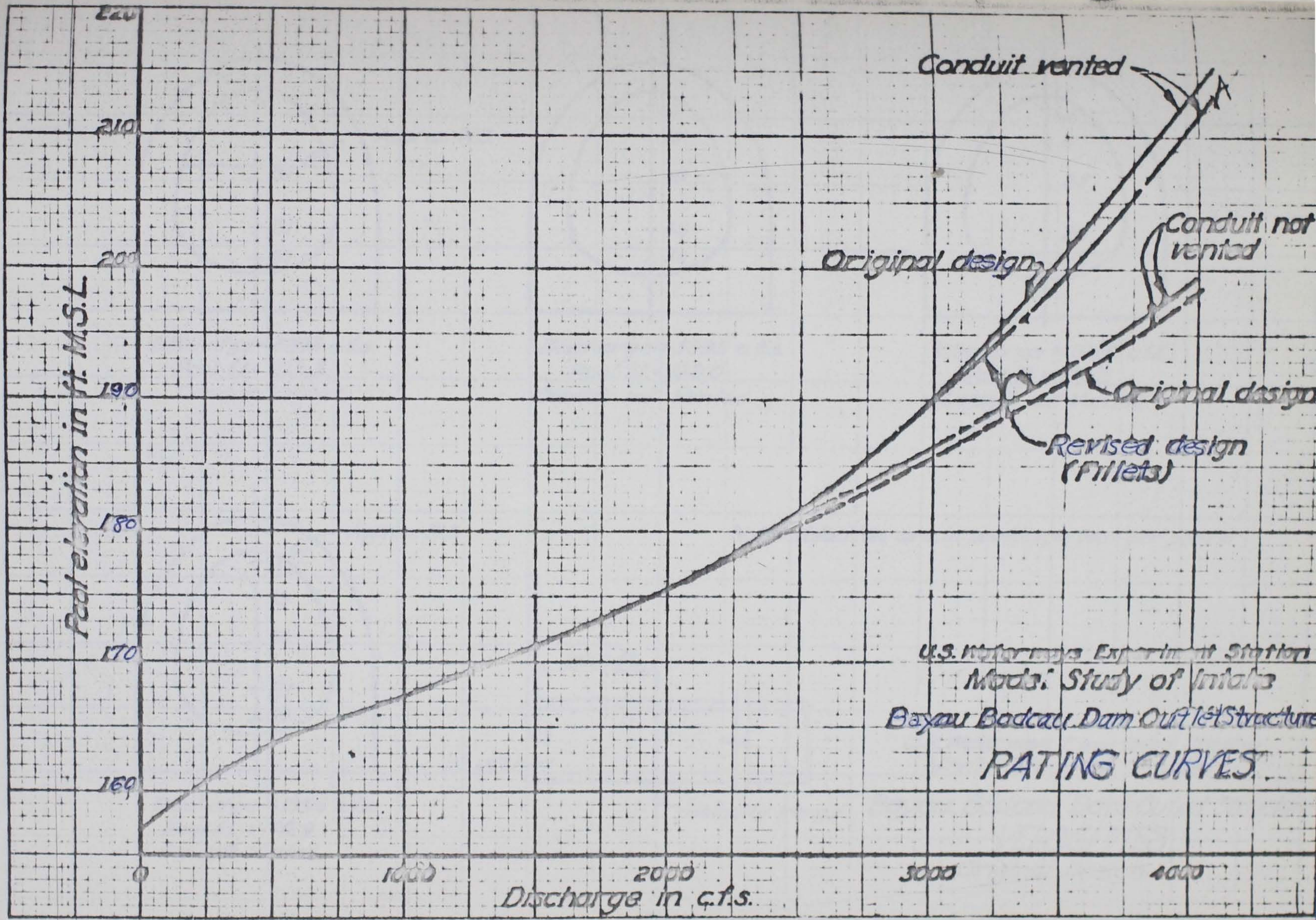
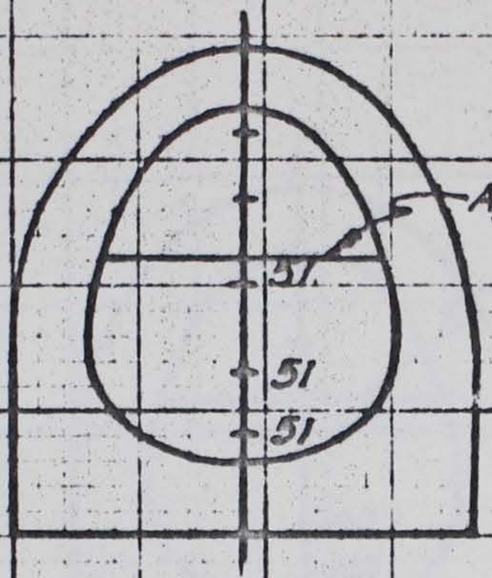
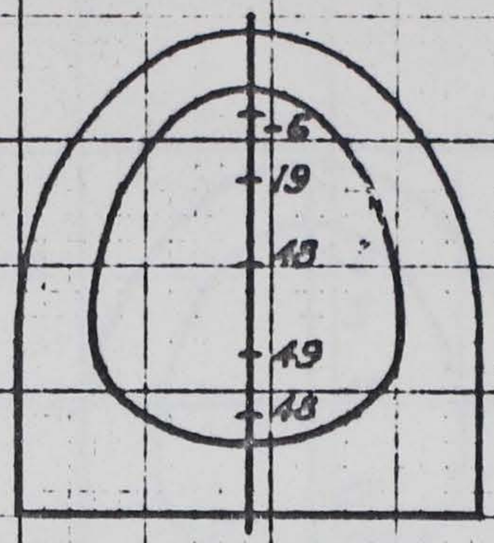


Plate 2

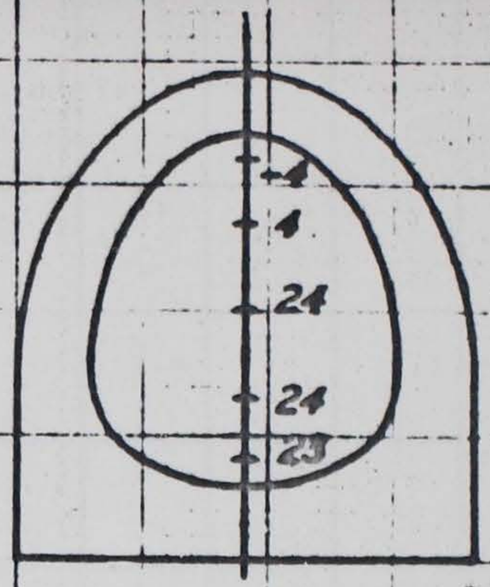
To accompany letter dated 12-21-40



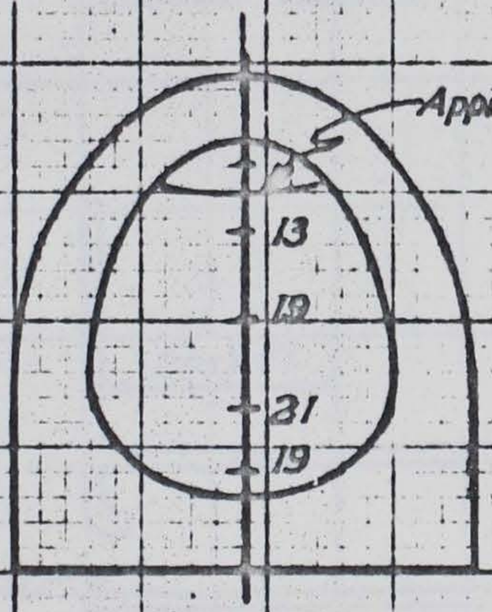
Discharge = 3993 c.f.s.
Pool El.= 213.3
Conduit Vented



Discharge = 3993 c.f.s.
Pool El.= 198.0
Conduit not Vented

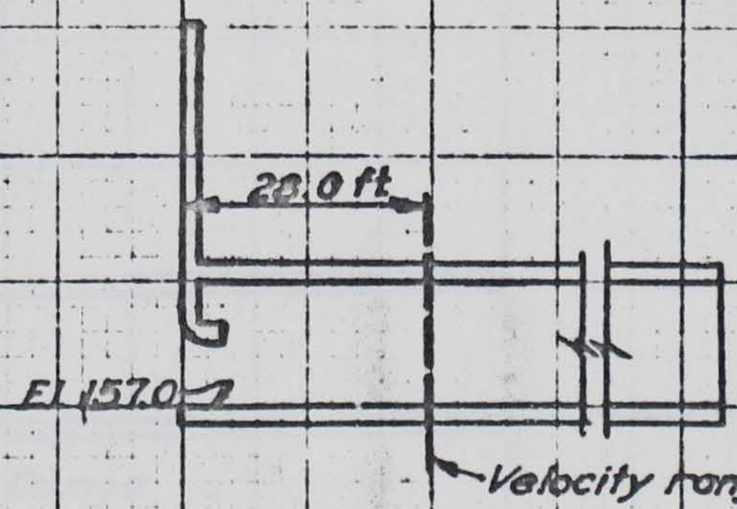


Discharge = 1996 c.f.s.
Pool El. = 176.2
Conduit not Vented



Discharge = 1996 c.f.s.
Pool EL = 175.9
Conduit Vented

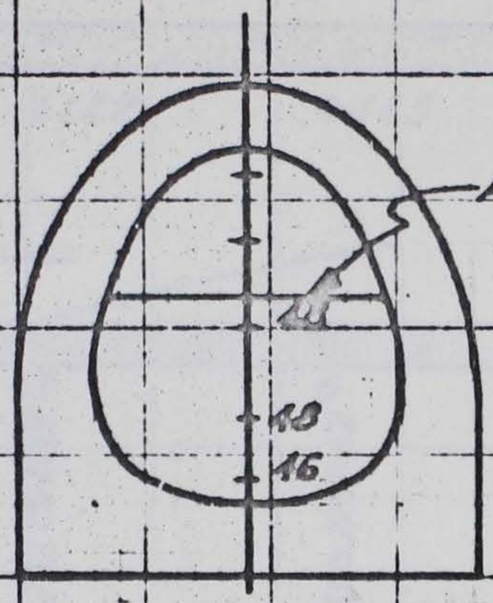
Note: Velocities are in prototype feet per second



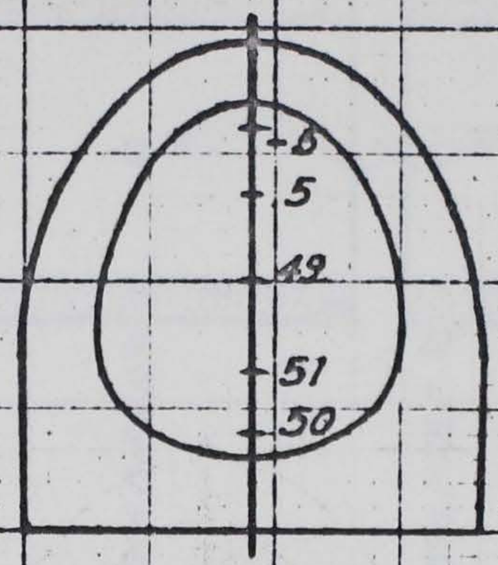
U.S. Waterways Experiment Station
Model Study of Intake
Bayou Bodcau Dam Outlet Structure
VELOCITIES
Original Design

Plate 3

To accompany letter dated 12-21-40

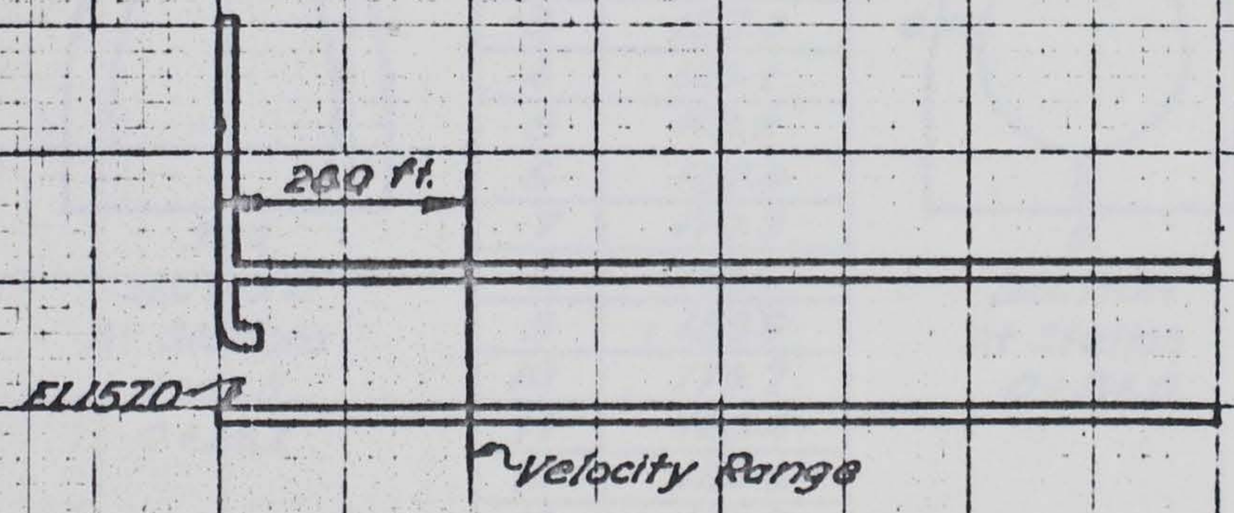


Discharge = 3397 c.f.s.
Pool El. = 198.0
Conduit Vented



Discharge = 3993 c.f.s.
Pool El. = 199.2
Conduit not Vented

Note: Velocities are in prototype feet per second



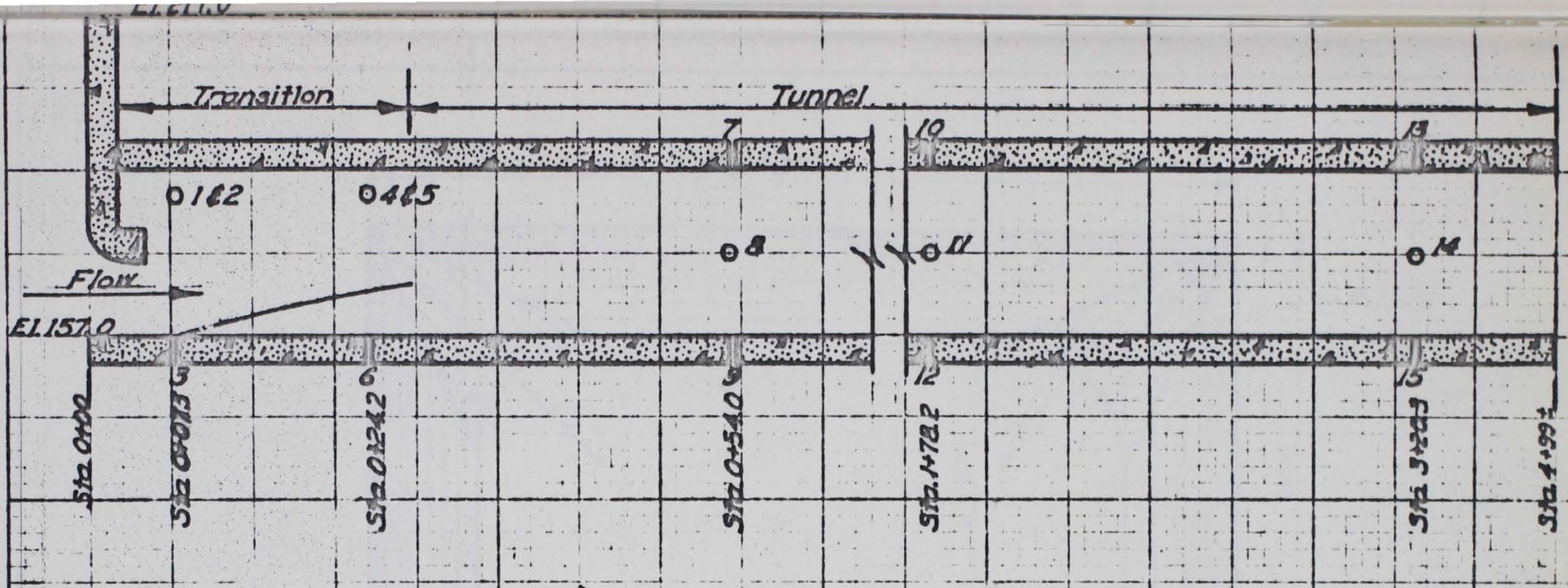
U.S. Waterways Experiment Station
Model Study of Intake
Bayou Bodcau Dam Outlet Structur

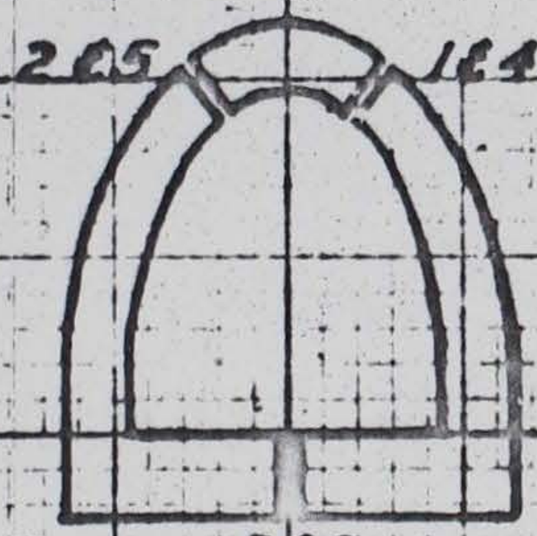
VELOCITIES

Revised Design
(With Fillets)

Plate 4

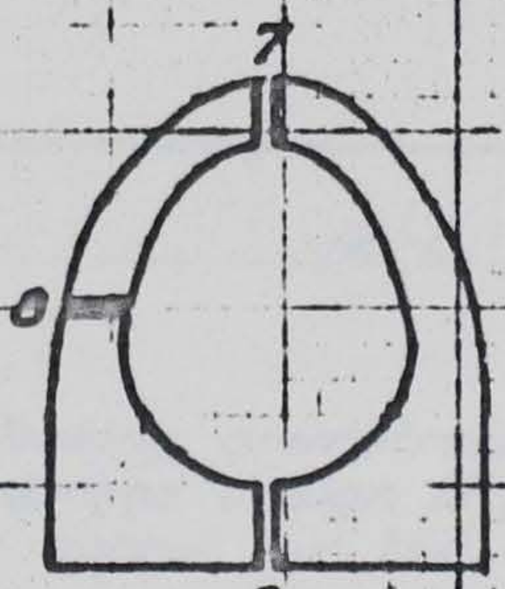
To accompany letter dated 12-21-40



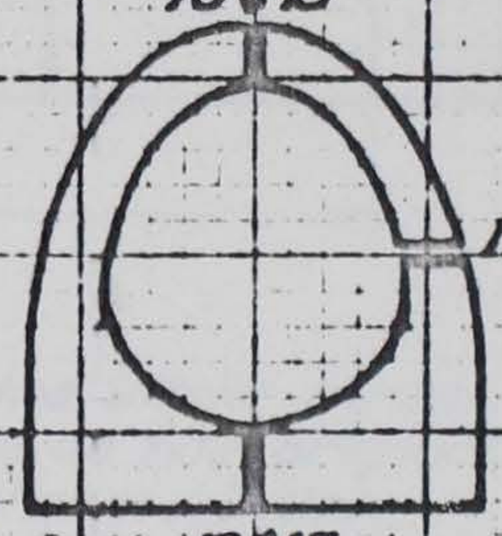


SECTIONS
At Stations
0+07.3
0+24.2

PIEZ No	ZERO
1	169.0
2	169.0
3	157.0
4	169.1
5	169.2
6	157.0
7	170.9
8	164.1
9	156.9
10	170.7
11	164.1
12	156.6
13	170.5
14	163.5
15	156.5



SECTION
At Station
0+54.0



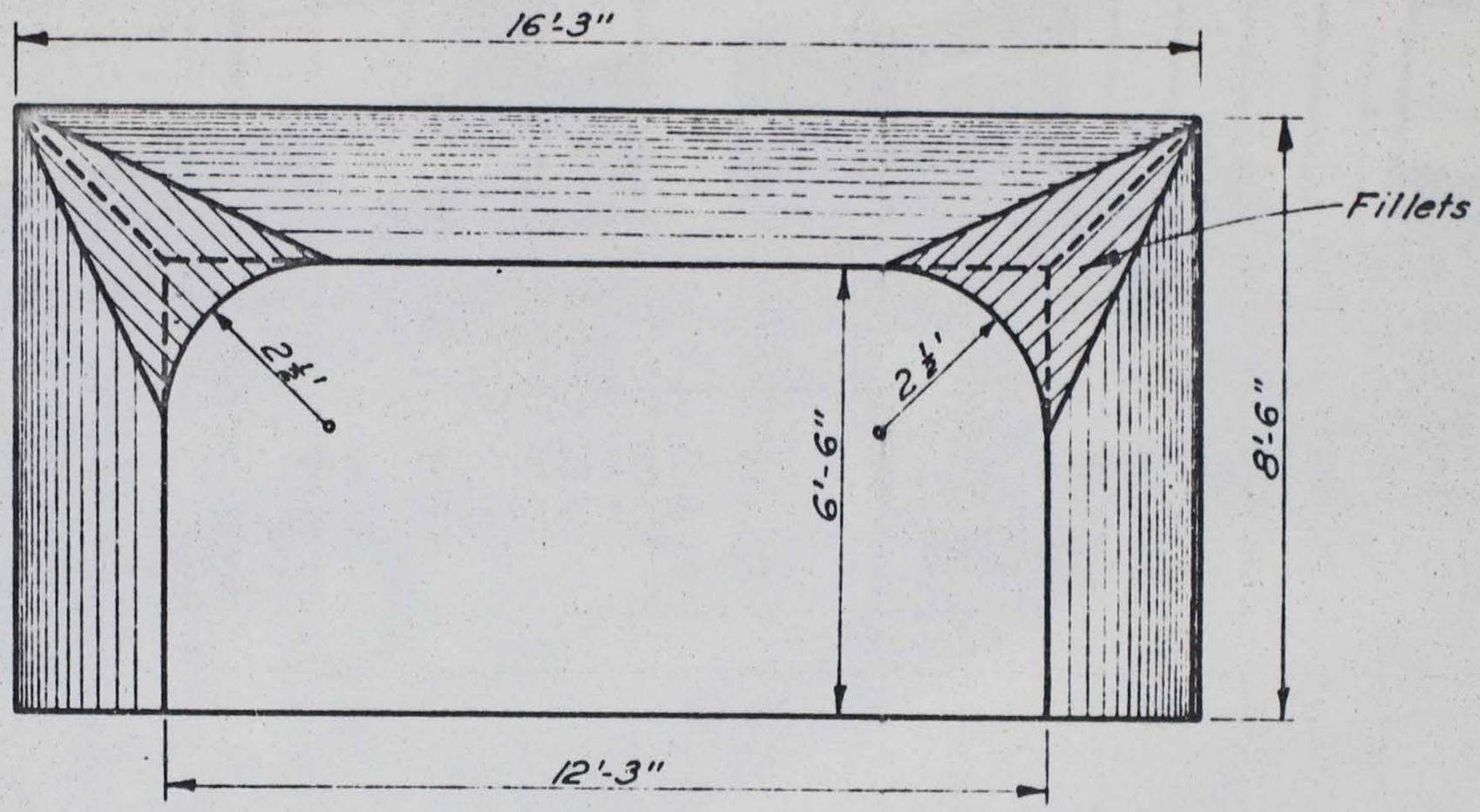
SECTIONS
At Stations
1+78.2
3+20.3

Note: All Sections are shown looking up stream

U.S. Waterways Experiment Station
Model Study of Intake
Bayou Bodcau Dam Outlet Structure
PIEZOMETER LOCATIONS

Plate 5

To accompany letter dated 12-21-40

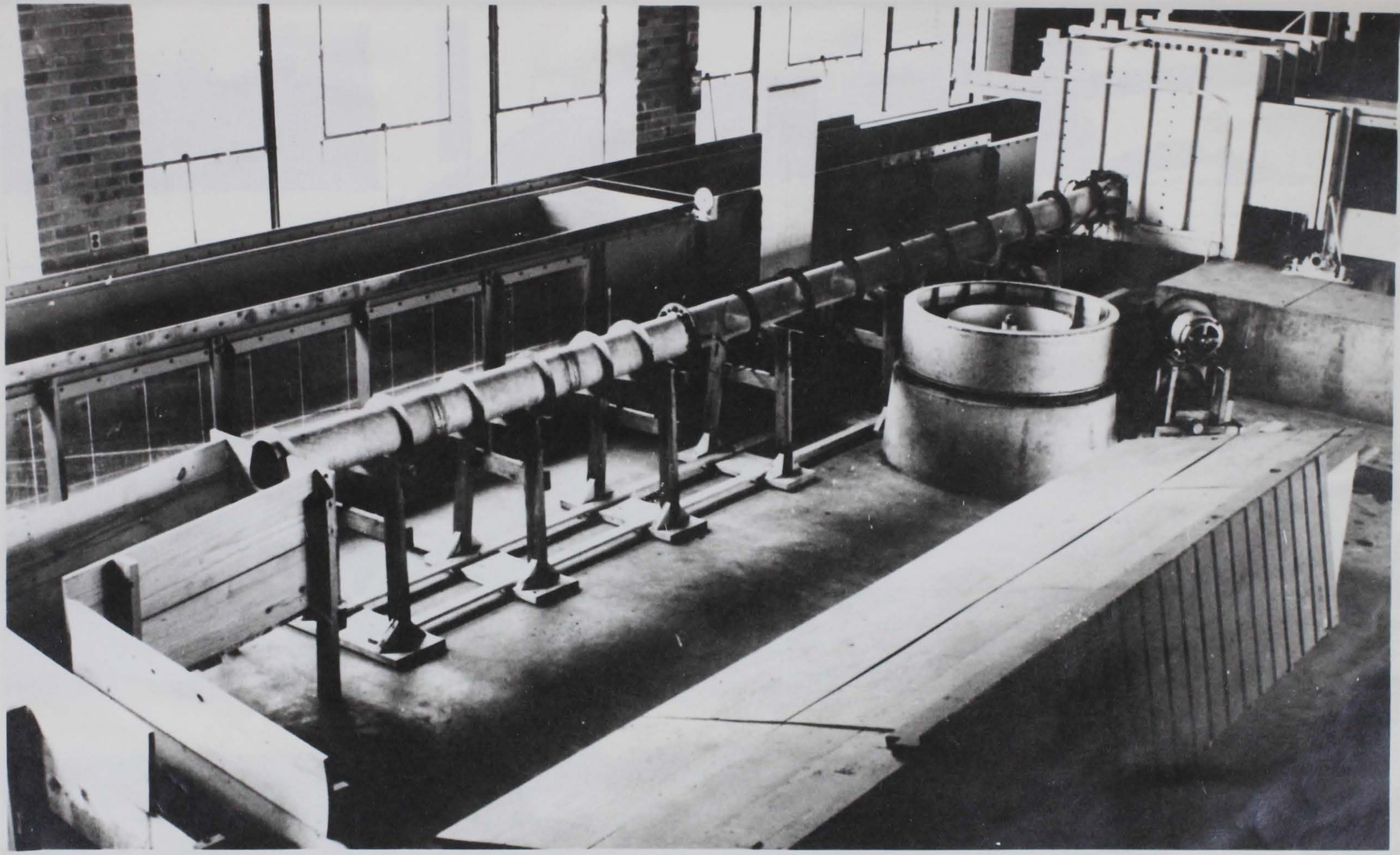


Note: View looking downstream into the intake portal. The revised design is the same as the original design except for the fillets shown above.

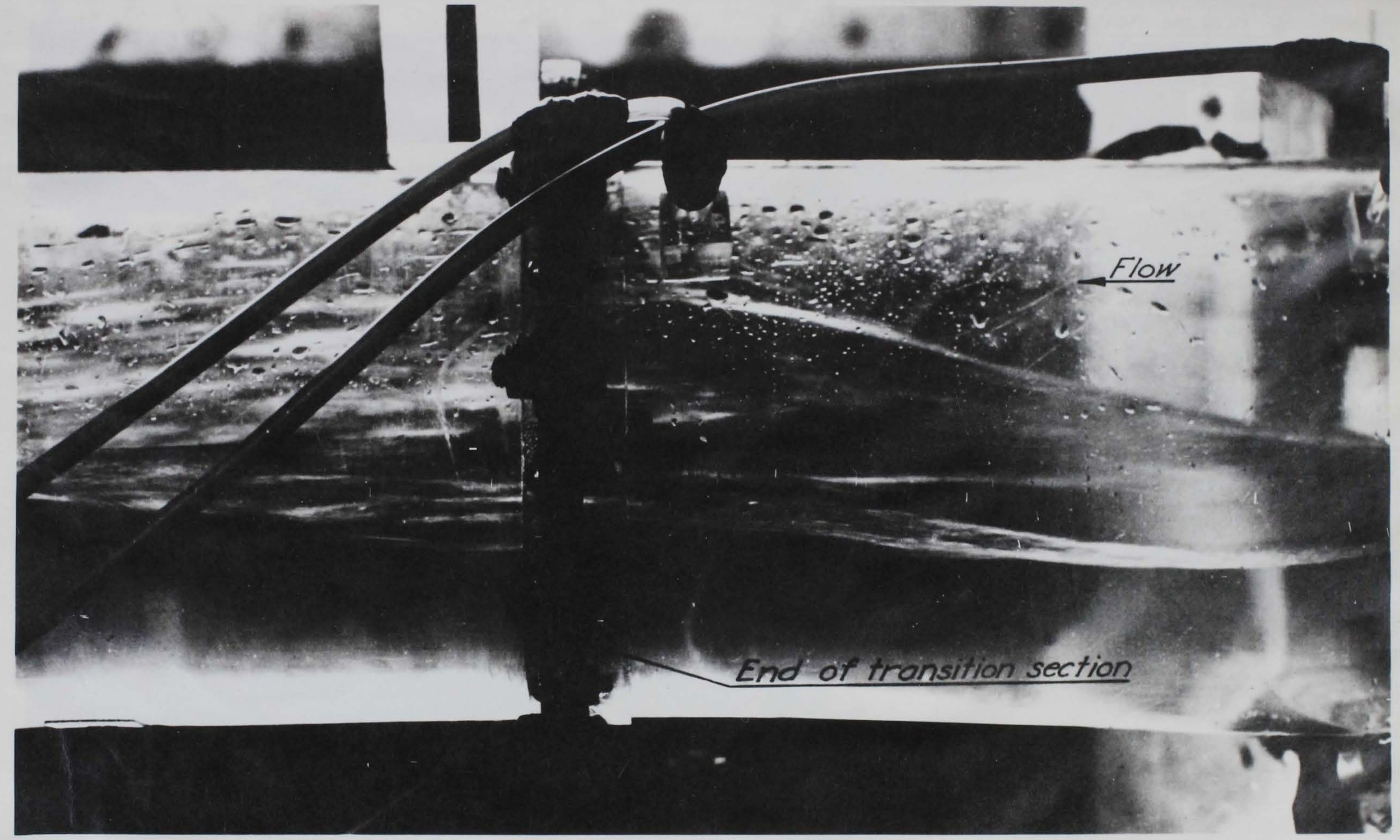
U.S. Waterways Experiment Station
Model Study of Intake
Bayou Bodcau Dam Outlet Structure
INTAKE - ORIGINAL & REVISED DESIGN

Plate 6

To accompany letter dated 12-21-40

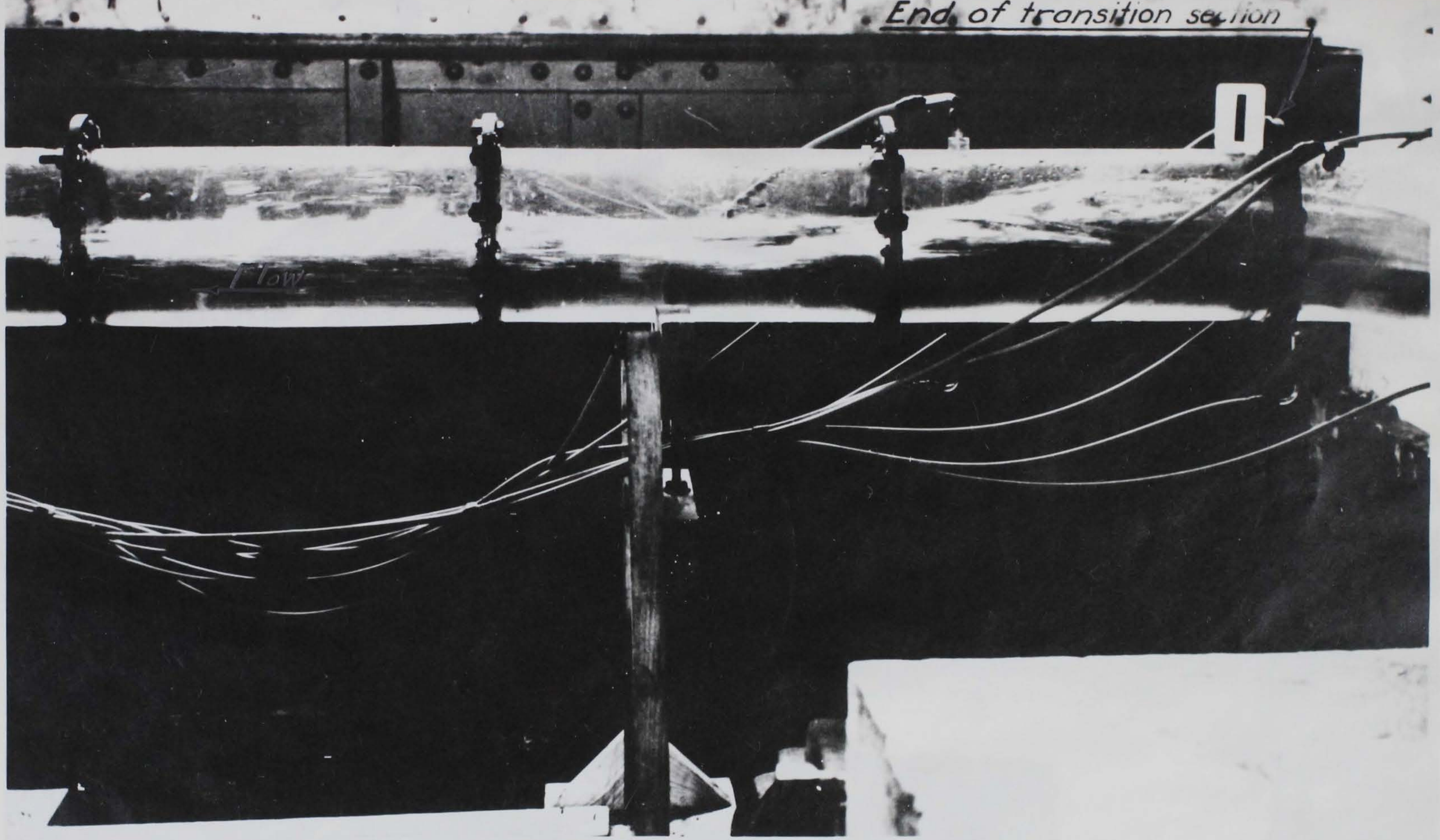


General view looking upstream showing the model of the intake for the Bayou Bodcau dam outlet structures.



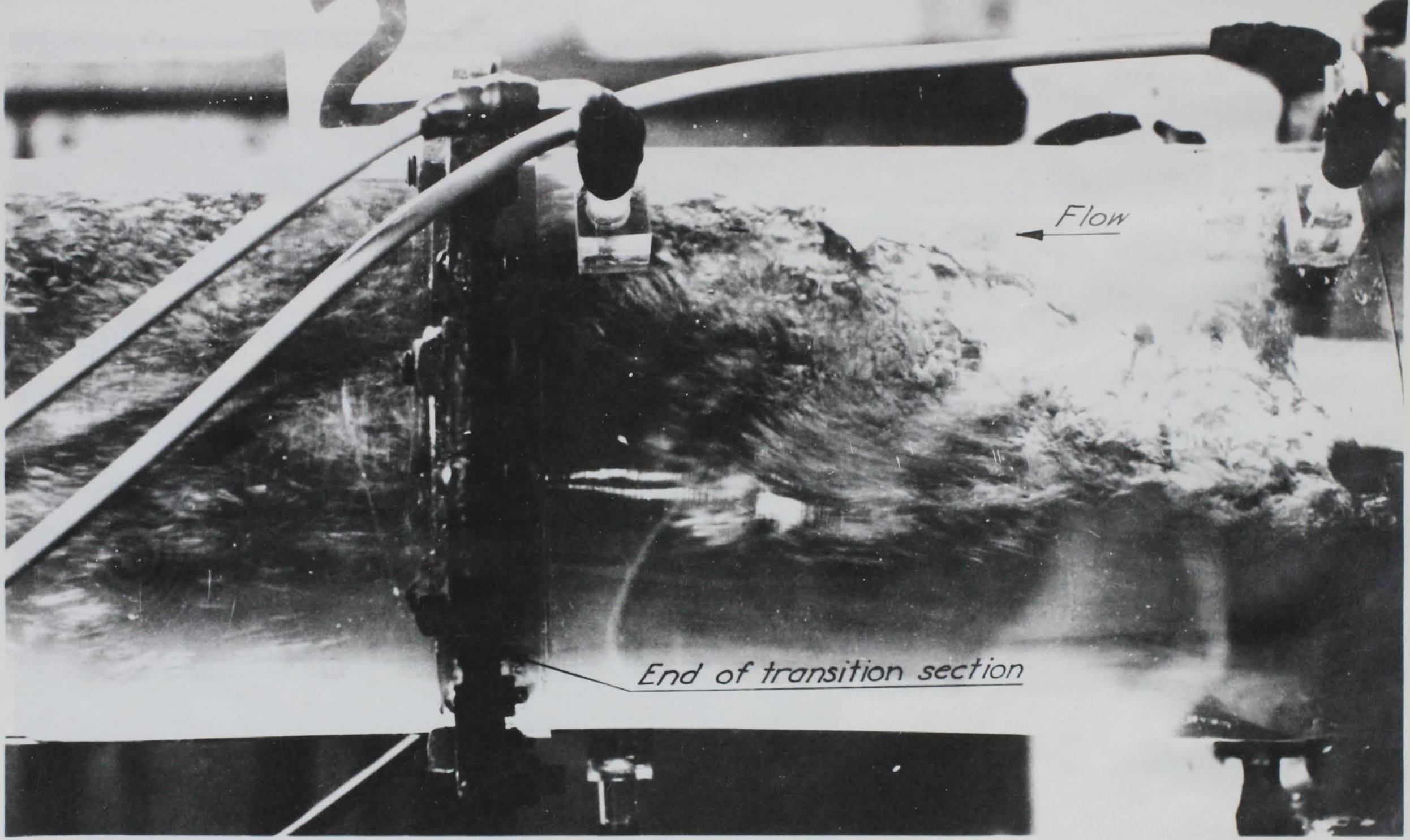
Photograph 1. Original design, conduit vented. Note high wave downstream from the intake structure.

Discharge = 3,993 c.f.s. Pool Elevation = 213.3 ft.



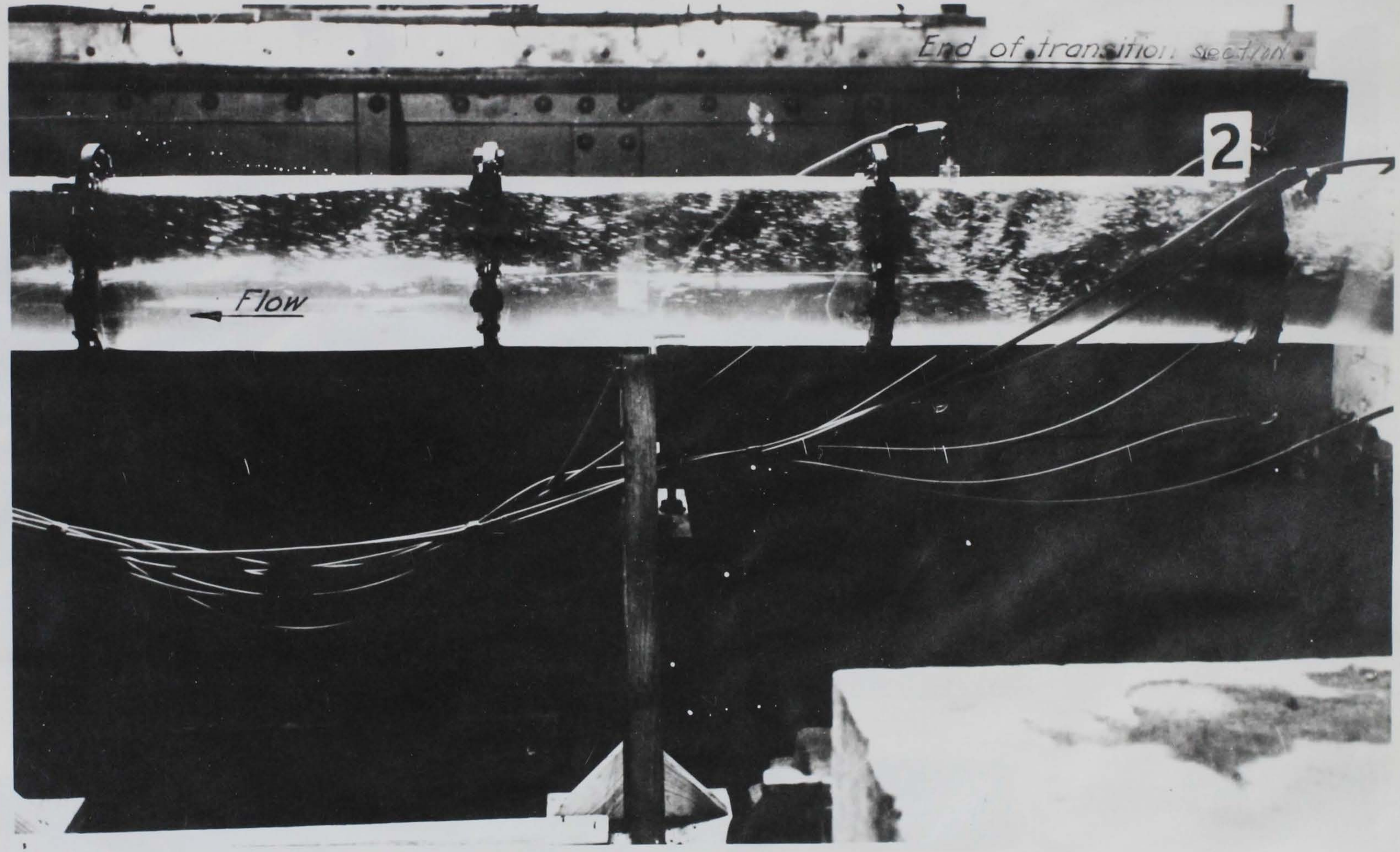
Photograph 2. Original design, conduit vented. Note that the high wave extended well below the transition section, and that the conduit flowed approximately half full.

Discharge = 3,993 c.f.s. Pool Elevation = 213.3 ft.

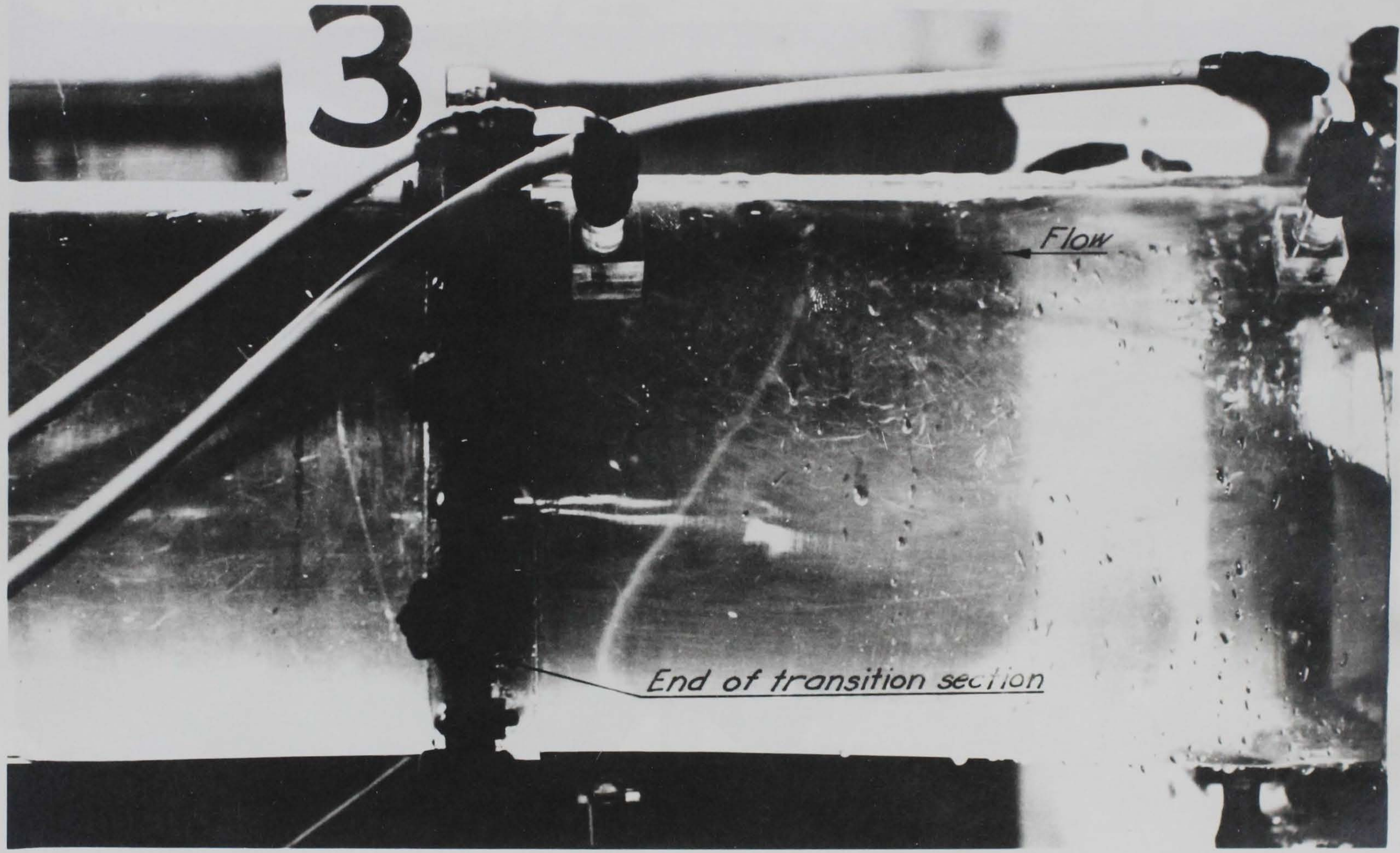


Photograph 3. Original design, conduit vented. A hydraulic jump formed in the transition section immediately downstream from the intake structure.

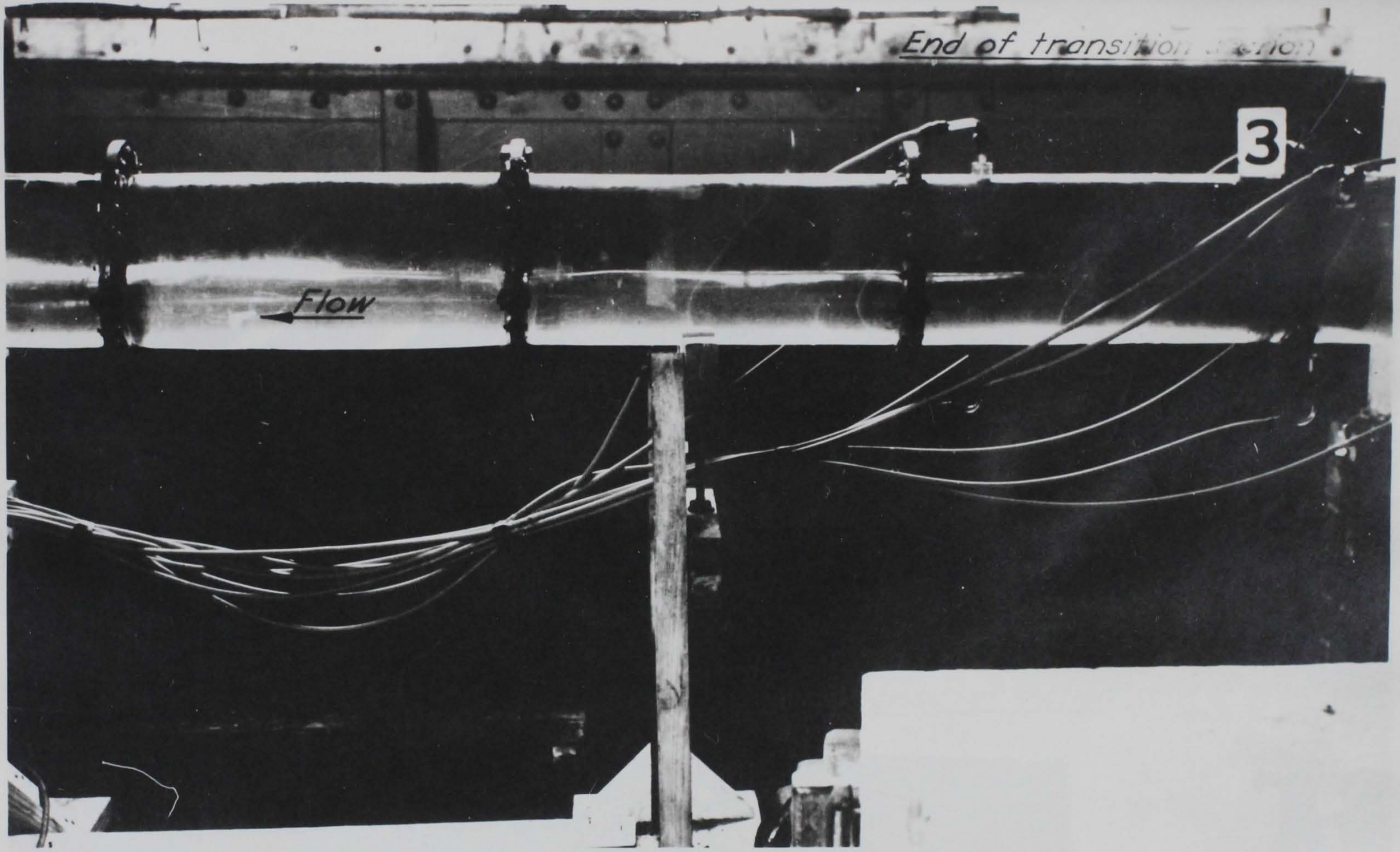
Discharge = 1,996 c.f.s. Pool Elevation = 175.9 ft.



Photograph 4. Original design, conduit vented. The conduit flowed nearly full for a discharge of 1,996 c.f.s. with the pool at elevation 175.9 ft.

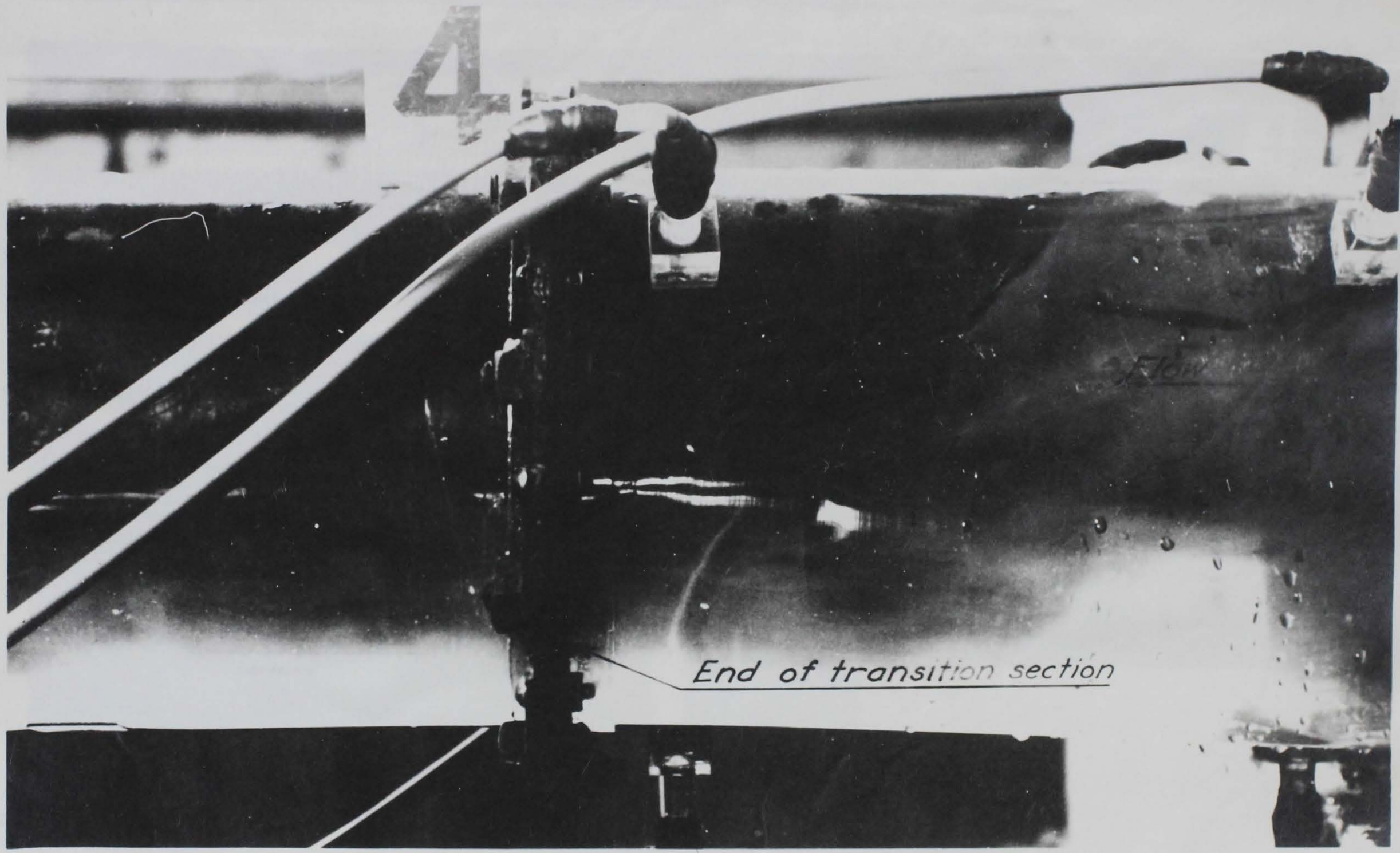


Photograph 5. Original design, conduit not vented. The transition section and conduit flowed full for a discharge of 3,993 c.f.s. with the pool at elevation 198.0 ft.

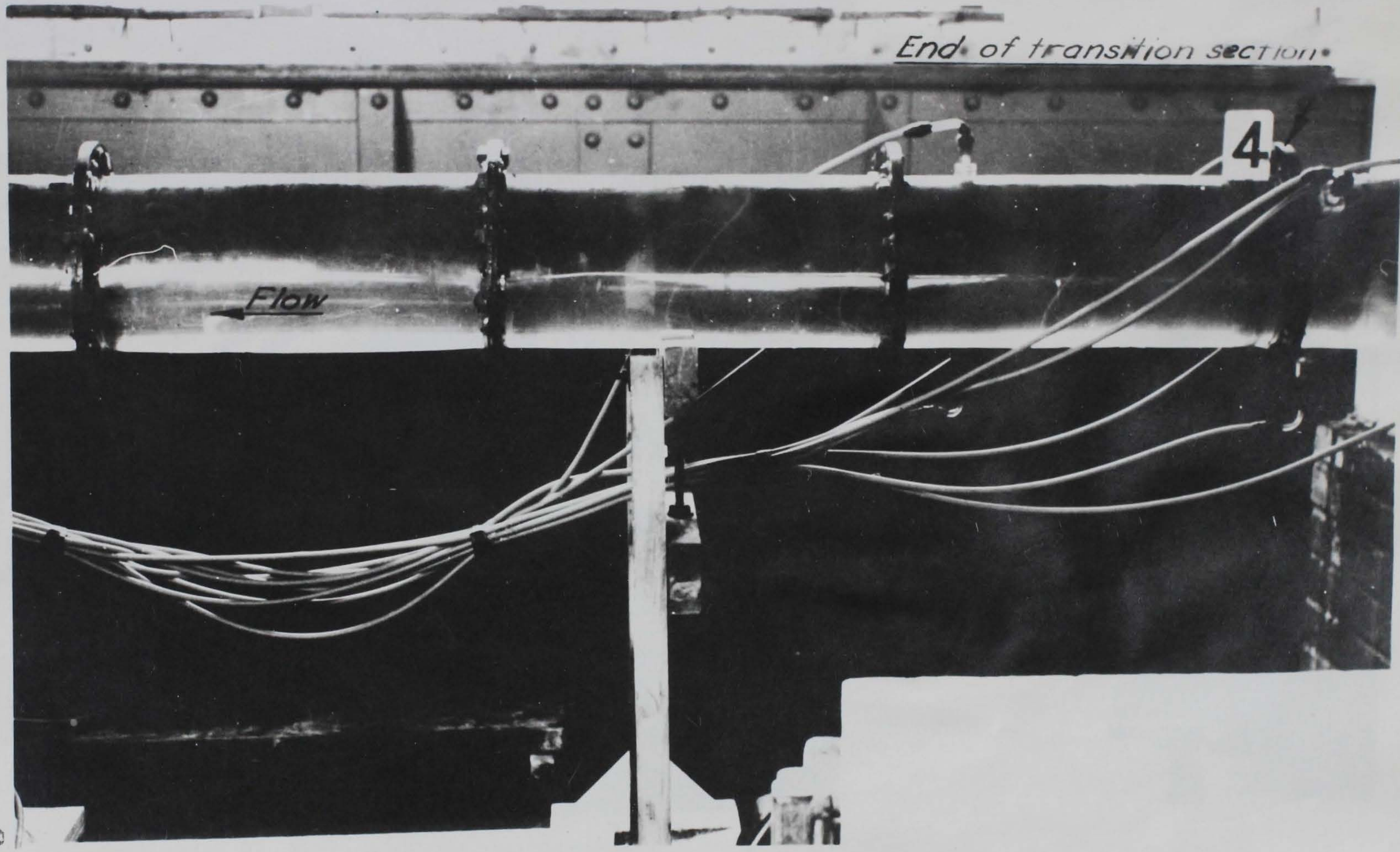


Photograph 6. Original design, conduit not vented.

Discharge = 3,993 c.f.s. Pool Elevation = 198.0 ft.



Photograph 7. Original design, conduit not vented. The transition section and conduit flowed full for a discharge of 1,996 c.f.s. with the pool at elevation 176.2 ft.



Photograph 8. Original design, conduit not vented.

Discharge = 1,996 c.f.s. Pool Elevation = 176.2 ft.

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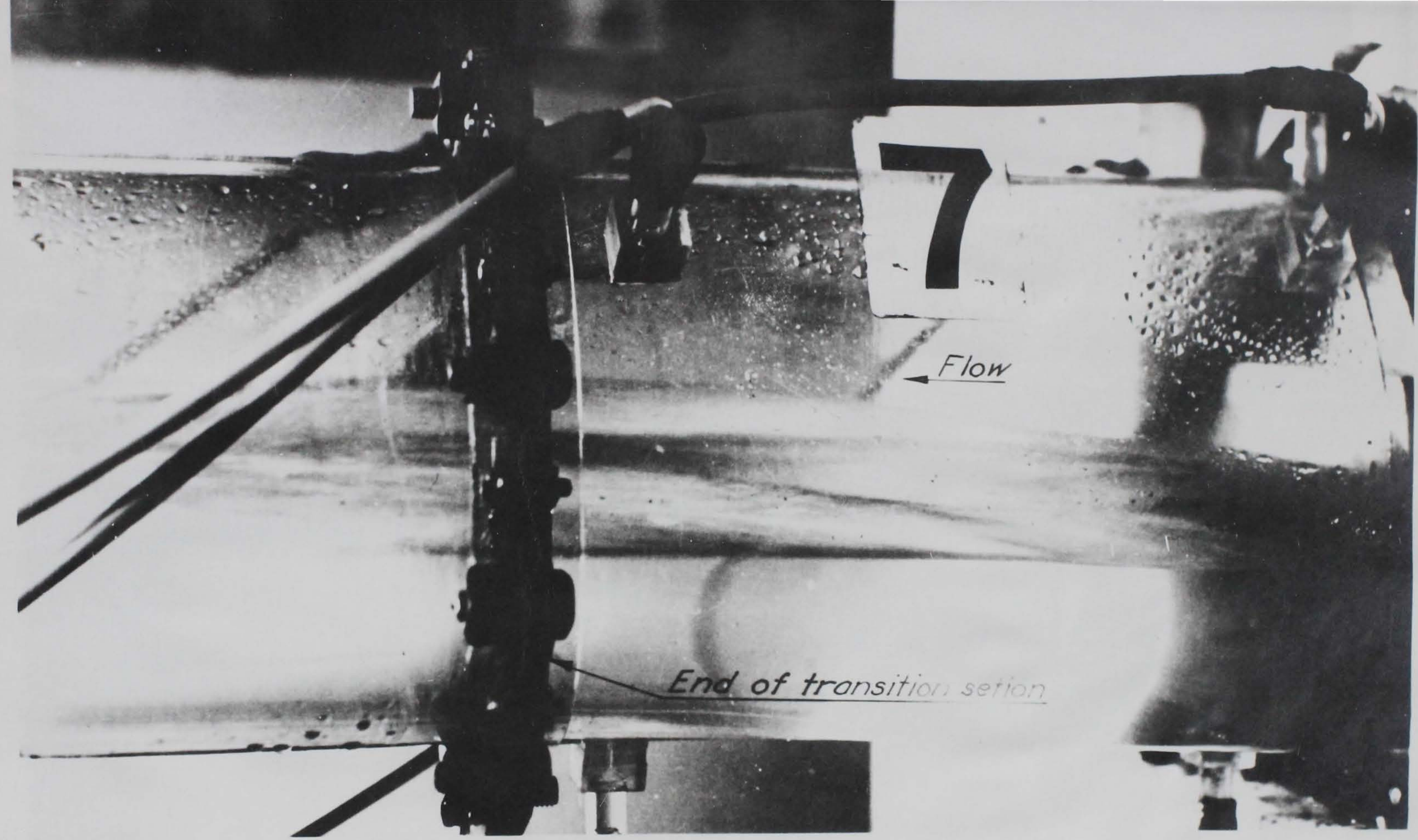
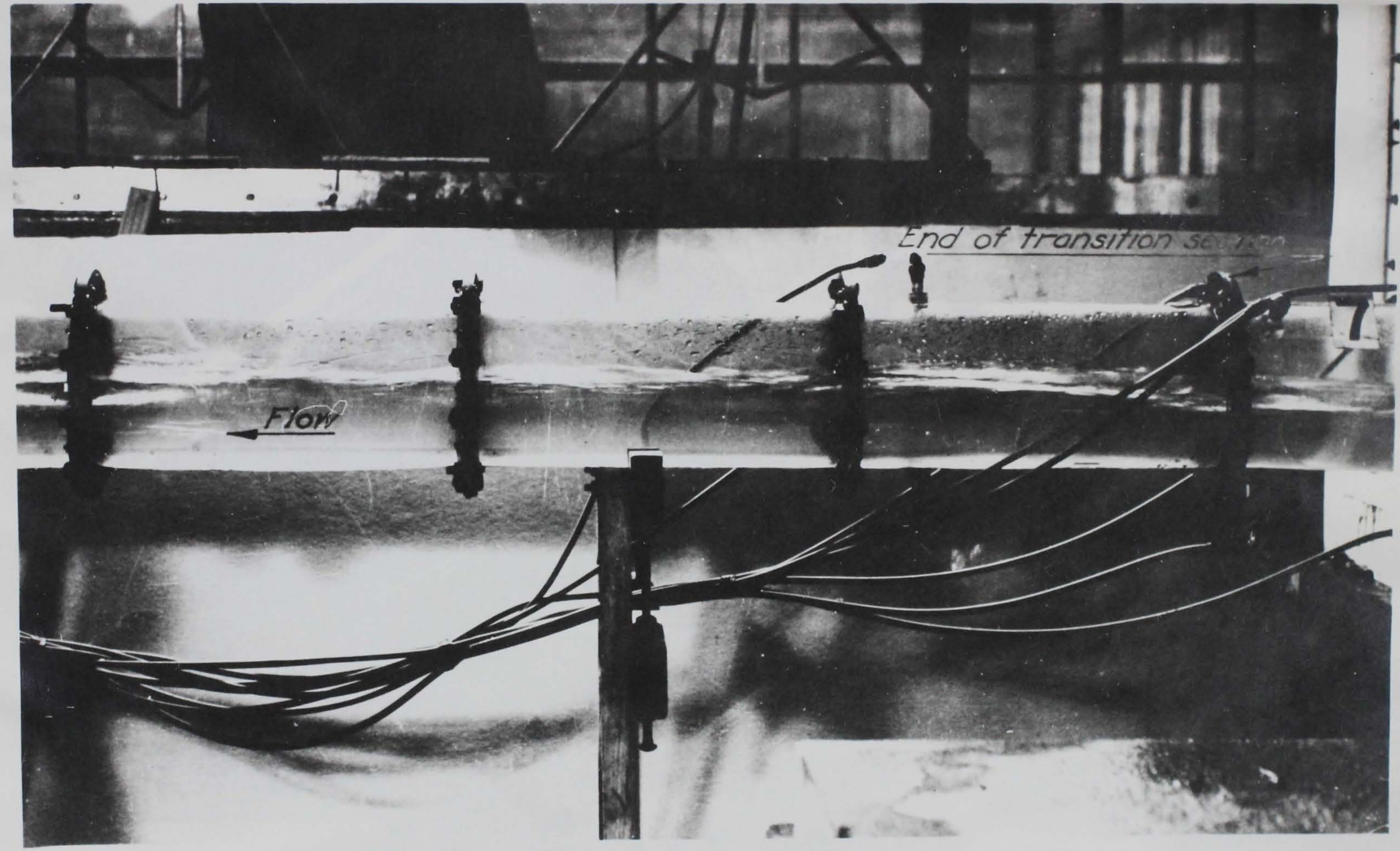


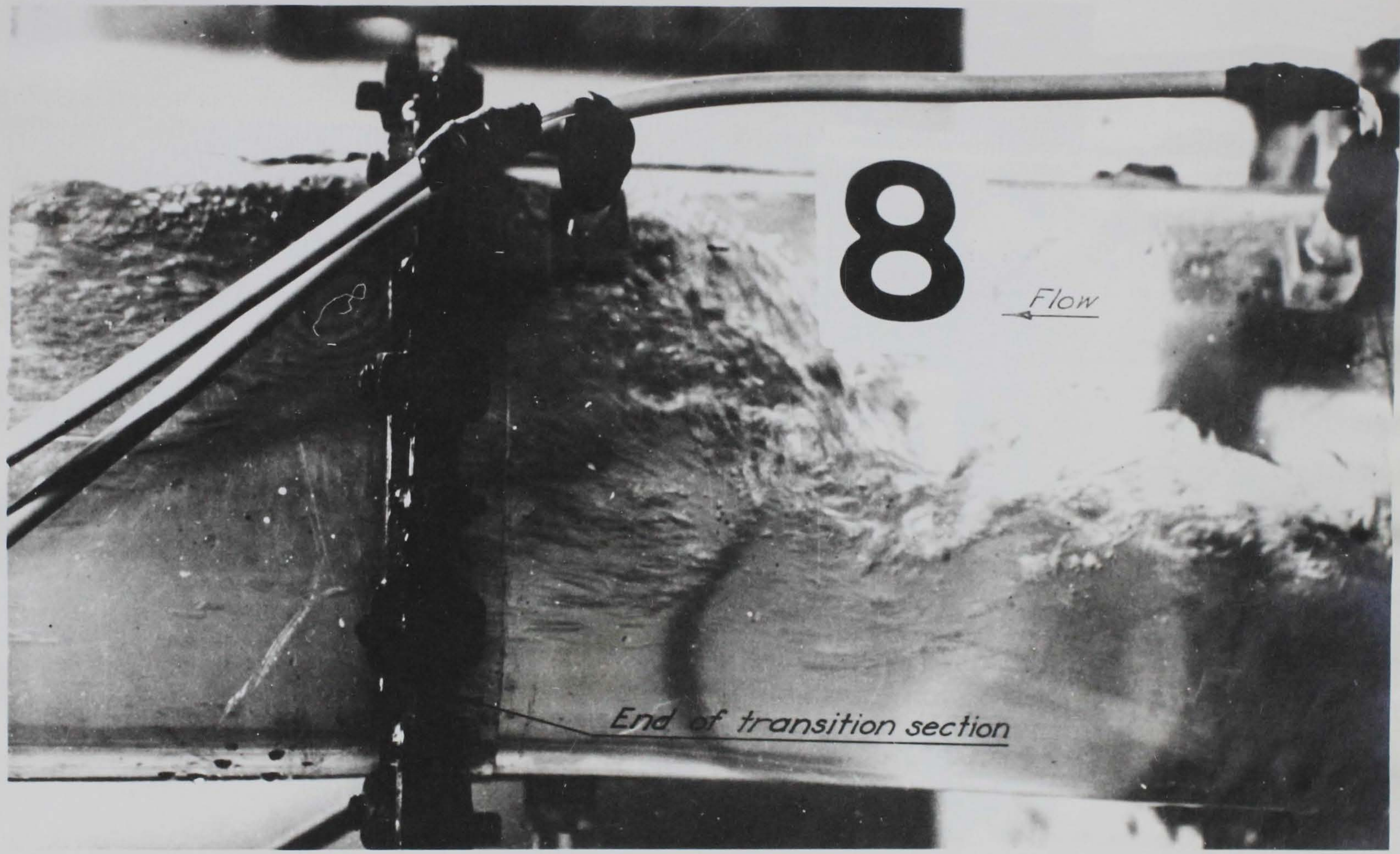
Photograph 9. Revised design, conduit vented. Flow conditions through the intake structure and transition section were improved by the addition of fillets to the intake structure. A reduction in the height of the wave downstream from the intake structure may be seen from a comparison with photograph 1.

Discharge = 3,993 c.f.s. Pool Elevation = 211.4 ft.

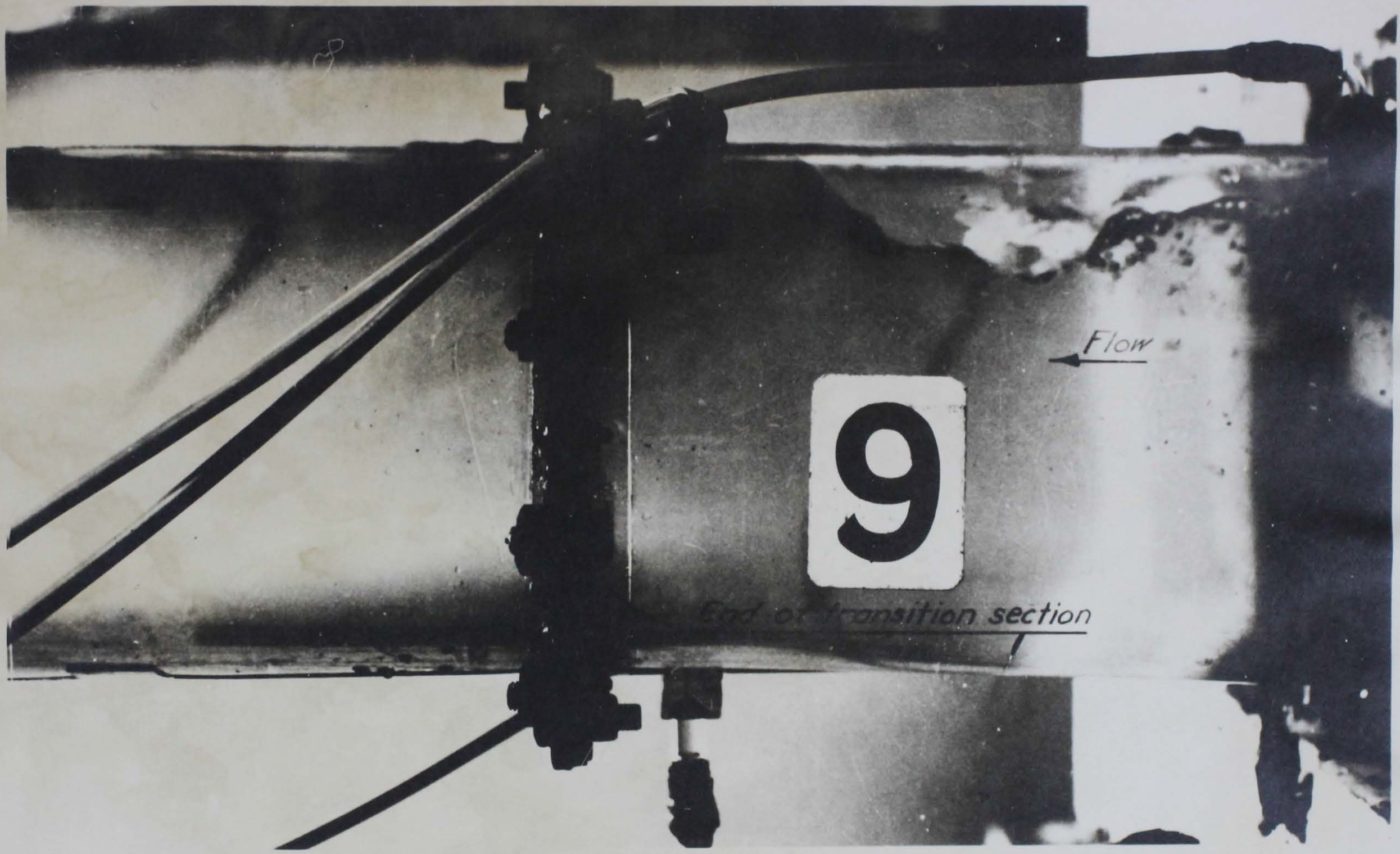


Photograph 10. Revised design, conduit vented. The efficiency of the intake structure was increased, and turbulence in the transition section and upstream portion of the conduit was reduced by the addition of fillets to the intake structure. Compare with photograph 2.

Discharge = 3,993 c.f.s. Pool Elevation = 211.4 ft.



Photograph 11. Revised design, conduit vented. Flow conditions in the transition section were substantially the same as those in the original design for a discharge of 2,000 c.f.s. with the pool at elevation 175.8 ft. Compare with photograph 3.



Photograph 12. Revised design, conduit not vented.

Discharge = 2,000 c.f.s. Pool Elevation = 177.3 ft.