HYD 59

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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

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HYDRAULIC LABORATORY REPORT NO. 59

- - -

HYDRAULIC MODEL STUDY OF THE STILLING POOL FOR THE CONCHAS CANAL HEADWORKS - TUCUMCARI PROJECT, NEW MEXICO.

By

H. G. DEWEY, JR.

- - -

Denver, Colorado
July 31, 1939

HYD 59

Denver, Colorado, July 31, 1939.

MEMORANDUM TO CHIEF DESIGNING ENGINEER
(H. G. Dewey, Jr.)

Subject: Hydraulic model study of the stilling pool for the Conchas Canal Headworks, Tucumcari project, New Mexico.

1. Introduction. The Conchas Dam in the South Canadian River, New Mexico, (figures 1 and 2), was designed and constructed under the direction of the Corps of Engineers, U. S. Army. The main dam is a gravity type concrete structure having a maximum height of 235 feet and a crest length of 1,250 feet. Incorporated in the center of the main dam is a 300-foot service spillway, without gates, which will pass ordinary high-water flows. A stilling pool 127 feet long, equipped with baffles, lies below this spillway. Penstocks have been provided through the dam to furnish flow for future water supply and power development. Wing dams of earth-rock fill (figure 2) extend from the abutments of the main dam to high ground 1,000 feet north from the left abutment, and 4,000 feet southeast from the right abutment. A 3,000-foot emergency spillway is located one mile north of the main dam, flanked by two earth-fill dikes extending to high ground at either end. Discharge from this spillway will enter the river 1½ miles downstream from the main dam. The Conchas Reservoir will have a storage capacity of 600,000 acre-feet.

The Conchas canal headworks consists of a concrete-lined tunnel through the right abutment of the south dike (figures 2 and 3). The outlet tunnel, approximately 700 feet long, consists of an 11-foot diameter pressure tunnel 328 feet long, extending from the intake structure to the gate chamber. At this point a transition is made to two 90-inch diameter steel outlets, each outlet being provided with a six-foot by seven-foot six-inch hydraulically operated emergency slide gate just below the transition. From the gate chamber to the outlet gate house, 310 feet, the 90-inch diameter outlets are carried in a horseshoe tunnel 22 feet wide by 15 feet high. At the outlet gate house a transition is made in each outlet to a six-foot by seven-foot six-inch rectangular section, each outlet being provided with a six-foot by seven-foot six-inch slide gate, hydraulically operated, for regulating the flow into the Conchas canal (figures 4 and 5).

The Conchas canal for developing irrigation of the Tucumcari project, and the stilling pool of the headworks will be designed and constructed by the Bureau of Reclamation, United States Department of the Interior. When the design of the canal was started by this office, the outlets were in place to station 23+54.58 (figure 3). After the

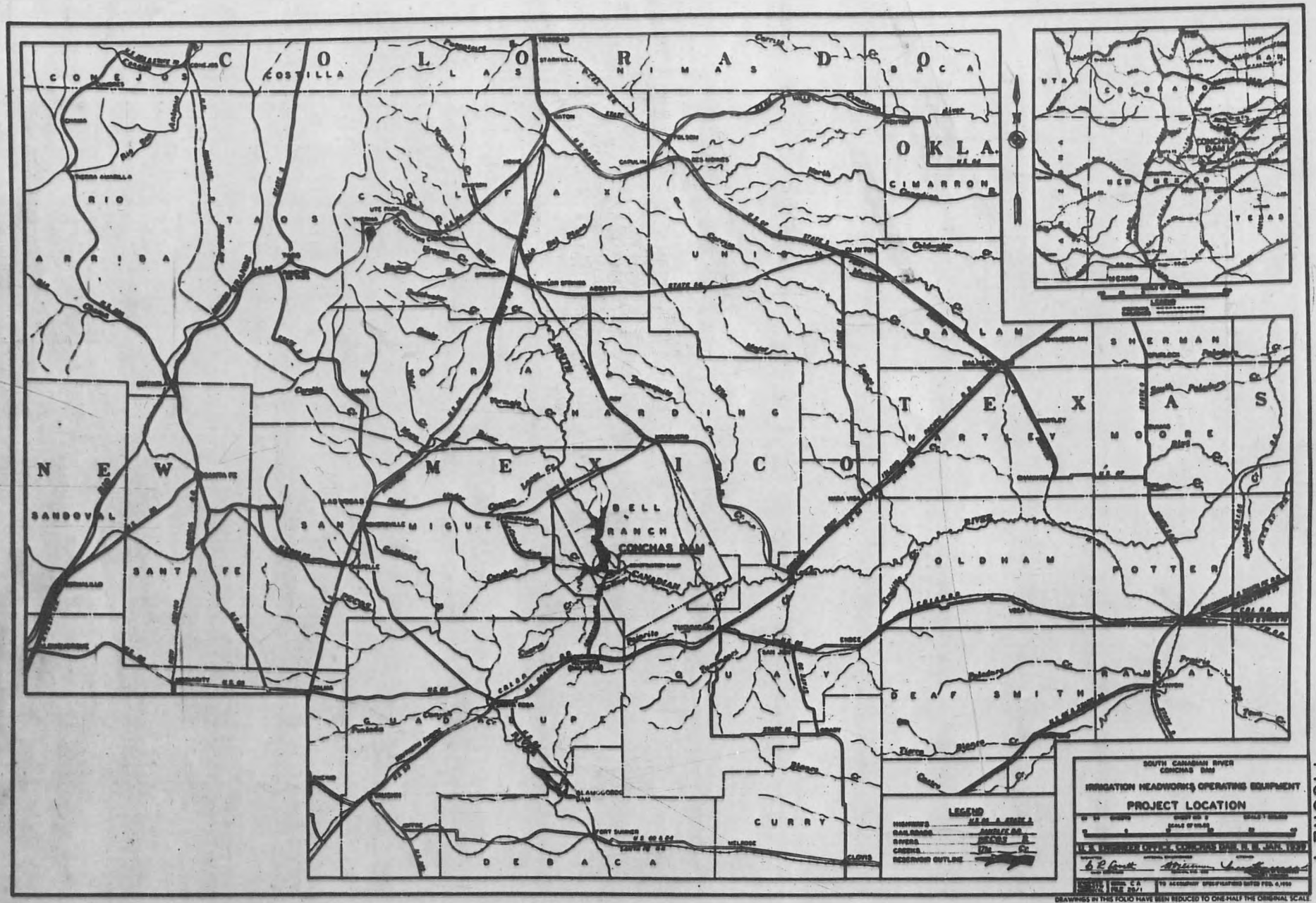

COLORADO
NEW MEXICO
TEXAS
OKLA.
CONEJOS
COSTILLA
LAS NIMAS
BACA
RIO ARRIBA
TAOS
COLFAX
UNION
CIMARRON
MORA
CHARDING
DALLAM
SHERMAN
HARTLEY
MOORE
SANDOVAL
SANTA FE
SAN MIGUEL
BELL RANCH
CONCHAS DAM
OLDHAM
POTTER
GUADALUPE
QUAY
DEAF SMITH
RANDALL
CURRY
DEBACA
LEGEND
HIGHWAYS
RAILROADS
RIVERS
CREEKS
RESERVOIR OUTLINE
SOUTH CANADIAN RIVER
CONCHAS DAM
IRRIGATION HEADWORKS OPERATING EQUIPMENT
PROJECT LOCATION
DRAWINGS IN THIS FOLIO HAVE BEEN REDUCED TO ONE-HALF THE ORIGINAL SCALE.

FIGURE I

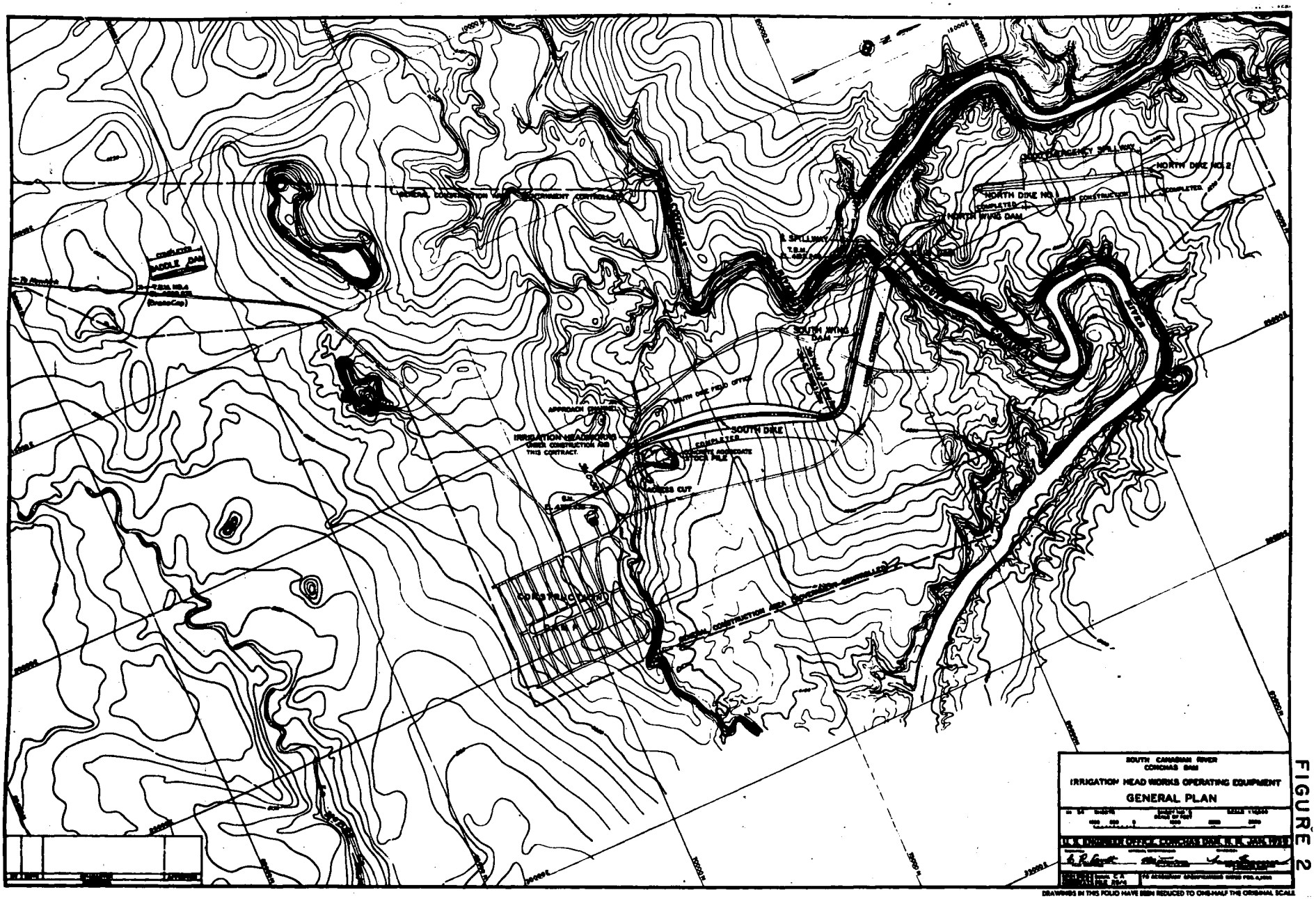
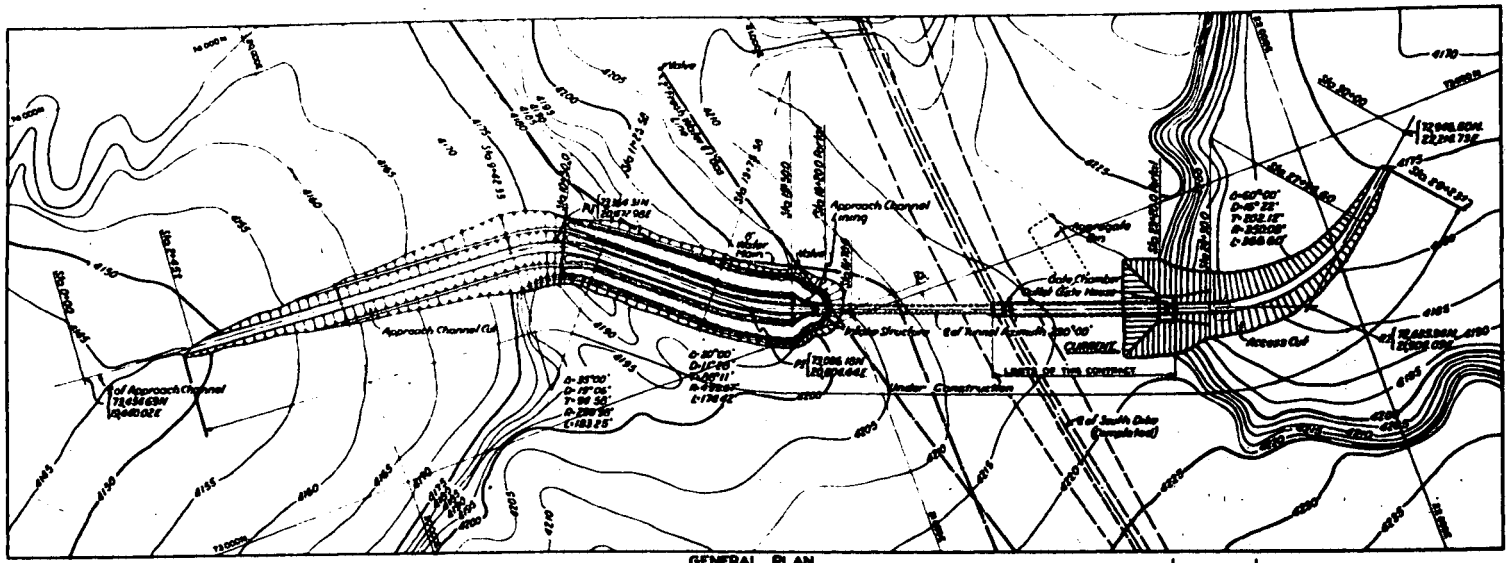

SOUTH CANADIAN RIVER
CONCHAS DAM
IRRIGATION HEAD WORKS OPERATING EQUIPMENT
GENERAL PLAN
SADDLE DAM
NORTH DIKE NO. 1
NORTH DIKE NO. 2
NORTH WING DAM
SOUTH WING DAM
SOUTH DIKE
SPILLWAY
RIVER
DRAWINGS IN THIS FOLIO HAVE BEEN REDUCED TO ONE-HALF THE ORIGINAL SCALE

FIGURE 2



Note: Portions heavily outlined on Plan and Profile to be constructed and installed under this contract.

SOUTH CANADIAN RIVER
CIMARRON BASIN

IRRIGATION HEADWORKS OPERATING EQUIPMENT

PLAN AND PROFILE

U.S. ENGINEER OFFICE CIMARRON BASIN, OKLA. JAN 1938

FIGURE 3

DRAWINGS IN THIS FOLIO HAVE BEEN REDUCED TO ONE-HALF THE ORIGINAL SCALE

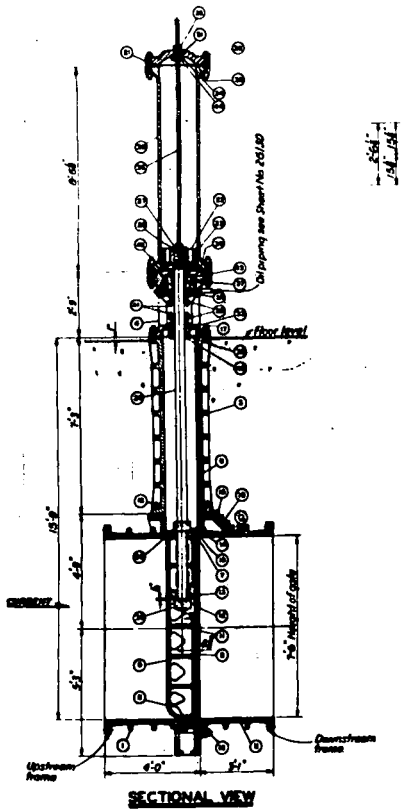
MARK	LIST OF HYDRAULIC SLIDE GATE DRAWINGS
26/13	Rectangular Conduit Linings
26/14	Transition Conduit Linings
26/15	Hydraulic Slide Gates - Assembly
26/16	Hydraulic Slide Gates - Gate Leaf
26/17	Hydraulic Slide Gates - Upstream Frame
26/18	Hydraulic Slide Gates - Downstream Frame
26/19	Hydraulic Slide Gates - Bonnet, Sill and Seals
26/20	Hydraulic Slide Gates - Bonnet Cover
26/21	Hydraulic Slide Gates - Hoist Cylinder
26/22	Hydraulic Slide Gates - Hoist Cylinder Details
26/23	Hydraulic Slide Gates - Leaf Position Indicator
26/24	Hydraulic Gate Hanger - Assembly
26/25	Hydraulic Gate Hanger - Cylinder
26/26	Hydraulic Gate Hanger - Details No. 1
26/27	Hydraulic Gate Hanger - Details No. 2
26/28	Hydraulic Gate Hanger - Details No. 3
26/29	Allowances and Tolerances

LIST OF PARTS FOR ONE GATE

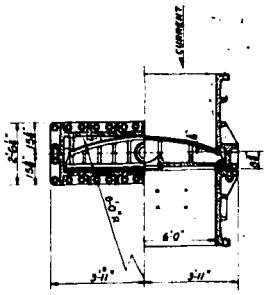
PART NO.	DESCRIPTION	MATERIAL	NO REQD	SHEET NO.
1	Upstream frame	Semi-steel	1	26/17
2	Downstream frame	Semi-steel	1	26/18
3	Bonnet	Semi-steel	1	26/19
4	Bonnet cover	Semi-steel	1	26/20
5	Gate leaf	Semi-steel	1	26/16
6	Gate sill	Semi-steel (Babbitt)	1	26/19
7	Horizontal leaf seat	Class 'C' bronze	1	"
8	Vertical leaf seat	Class 'C' bronze	2	"
9	Bonnet seat	Class 'C' bronze	1	"
10	Horizontal frame seat	Class 'C' bronze	1	"
11	Vertical frame seat	Class 'C' bronze	2	"
12	Leaf recess cover	Steel plate	1	26/16
13	1" dia. Pothead rubber	Rolled bronze	16	"
14	1 3/4" Pothead rubber	Rolled bronze	69	"
15	1" dia. Stud	Bolt steel Class 'B'	16	"
16	1 3/4" dia. Stud	Bolt steel Class 'B'	69	"
17	1" dia. Stud	Bolt steel Class 'B'	32	26/20
18	1 3/4" dia. Stud	Bolt steel Class 'B'	32	26/19
19	Protective Flange	Steel	4	As Req'd

PAYMENT ITEM NO 11

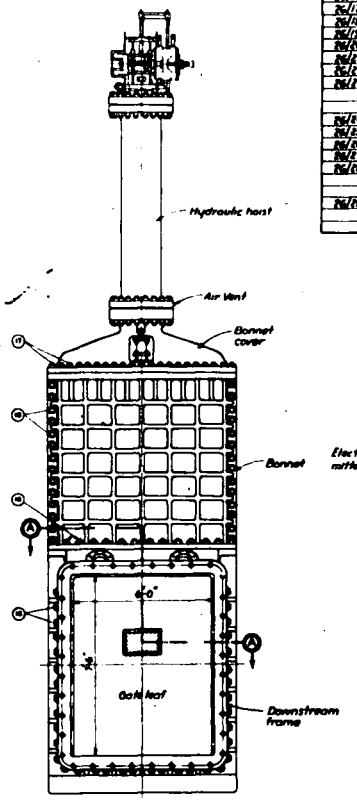
For list of parts - One hydraulic hoist, see Sheet No. 26/22
For list of parts - One hydraulic hanger, see Sheet No. 26/25
For list of parts - One tell position indicator, see Sheet No. 26/23
For list of parts - One cylinder ladder, see Sheet No 26/23



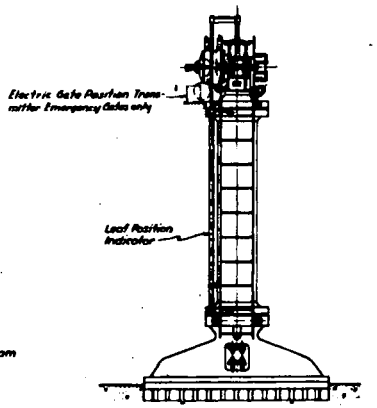
SECTIONAL VIEW



SECTION A-A



ELEVATION



UPSTREAM VIEW

Design Data:
Maximum design head 90 Feet
Maximum operating head 76 Feet
Bonnet cover design head 115 Feet
Coefficient of friction = 0.6 (Steel on Steel)
Concrete surrounding conduit and bonnet castings to carry all the load due to internal hydrostatic pressure.
Hydraulic hoist cylinder - Working oil pressure 600 lbs/in²
Designed oil pressure 1000 lbs/in²

Shop Notes:
When screw fit and bronze seats 2, 8, 9, 10 and 11 are in place, lock screws with 4 center punch scores in head.
After this assembly, make final machining on sliding faces of bronze seats which must be in a true plane.

Field Notes:
When assembling for installation the finished faces of all flanged joints are to be smoothly coated with a mixture of white lead and graphite and bolted together while this coating is plastic.
The shanks and threads of all bolts and studs are to be similarly coated.

SOUTH CANADIAN RIVER
CONCHAS DAM
IRRIGATION HEADWORKS OPERATING EQUIPMENT
HYDRAULIC SLIDE GATES
ASSEMBLY

SCALE 1/8"=1'-0"
SCALE VARIOUS 1/16 1/8 1/4 1/2 1" 2"
SCALE VARIOUS 1:192 1:96 1:48 1:24 1:12 1:6 1:3

U.S. BUREAU OF RECLAMATION DENVER, COLORADO

DESIGNED [illegible] DRAWN [illegible]
TRACED [illegible] CHECKED [illegible]
APPROVED [illegible]

DENVER C.S. FILE 26/13

TO ACCOMPANY SPECIFICATIONS DATED FEB. 4, 1939

DRAWINGS IN THIS FOLIO HAVE BEEN REDUCED TO APPROXIMATELY ONE-HALF THE ORIGINAL SCALE

FIGURE 4

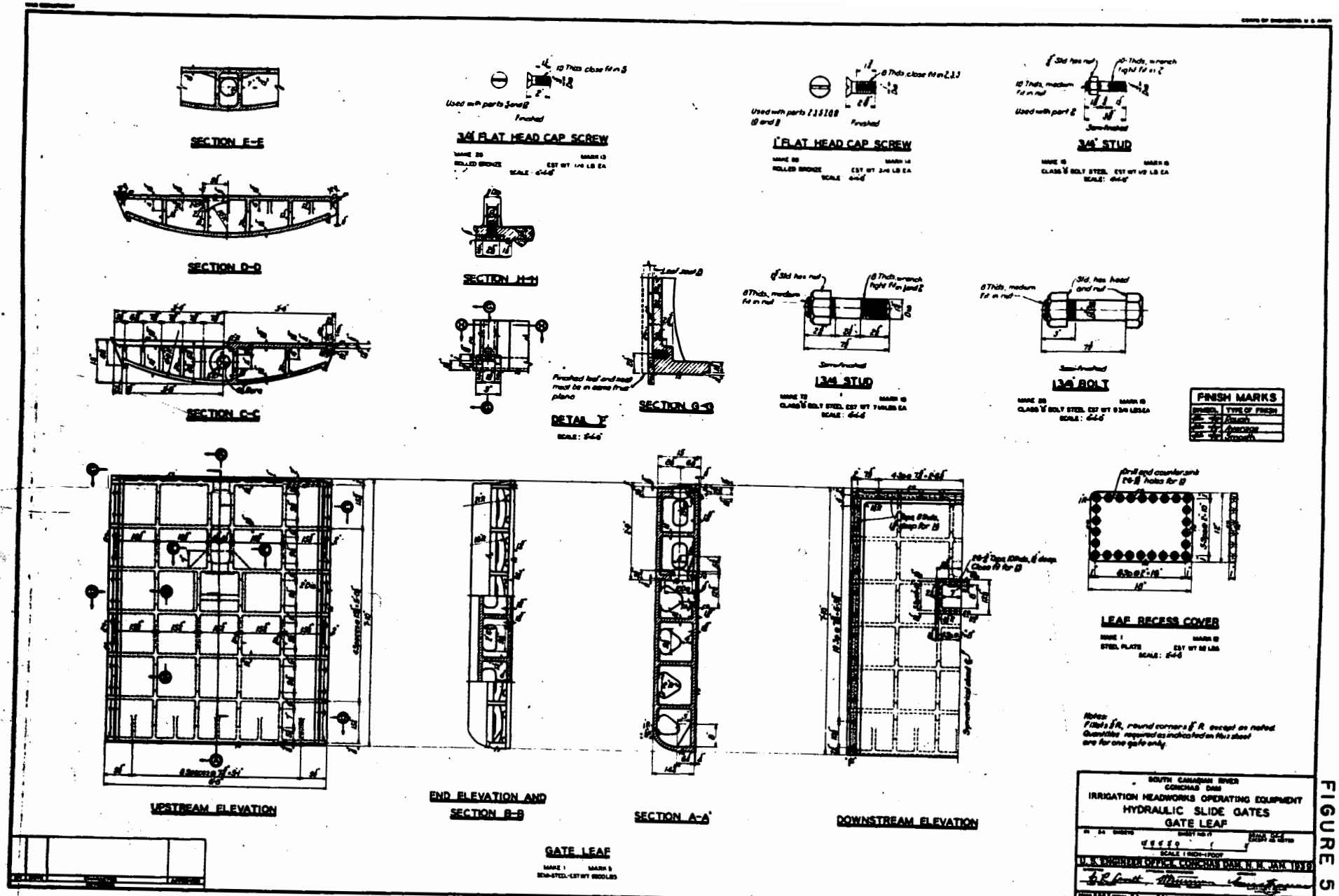

SECTION E-E
SECTION D-D
SECTION C-C
3/4" FLAT HEAD CAP SCREW
SECTION H-H
DETAIL F
SECTION G-G
1" FLAT HEAD CAP SCREW
3/4" STUD
1 3/4" STUD
1 3/4" BOLT
FINISH MARKS
LEAF RECESS COVER
UPSTREAM ELEVATION
END ELEVATION AND SECTION B-B
SECTION A-A
DOWNSTREAM ELEVATION
GATE LEAF
SOUTH CANADIAN RIVER
CONCHAS DAM
IRRIGATION HEADWORKS OPERATING EQUIPMENT
HYDRAULIC SLIDE GATES
GATE LEAF
U.S. ENGINEER OFFICE, CONCHAS DAM, N. M. JAN. 1939
DRAWINGS IN THIS FOLIO HAVE BEEN REDUCED TO ONE-HALF THE ORIGINAL SCALE

FIGURE 5

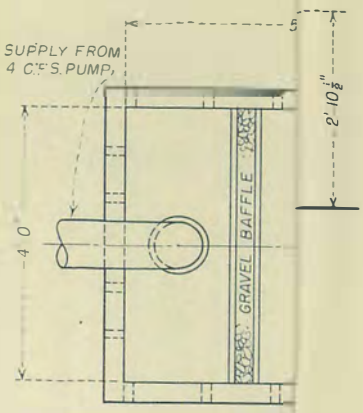
canal section and grade had been established, it was necessary to provide a stilling pool between the outlet gate house and the canal to dissipate the energy of the high-velocity jets issuing from the outlets into the tailwater. The maximum operating conditions will occur at the stilling pool when each outlet is discharging 350 second-feet under a maximum head of 64 feet, or when only one outlet is discharging the maximum flow of 700 second-feet under the maximum head, during emergency operation.

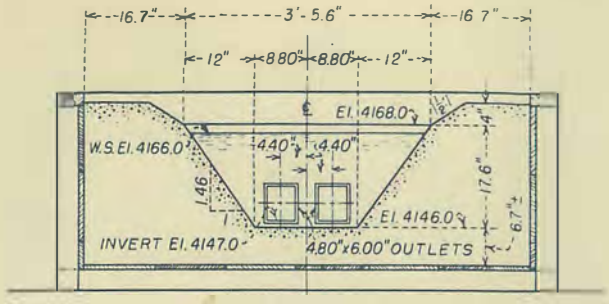
Although the access cut downstream from the outlets (general plan, figure 3) provided somewhat of a stilling pool, it would have been difficult to predict the pool action during the maximum operating conditions. It would have been also difficult to design a stilling pool because of excessive tailwater, which was caused by the large difference in elevation between the maximum canal water surface and the invert of the existing outlets. It was impossible to eliminate this unfavorable condition since the position of the outlets was fixed, and the grade of the canal could not be changed to suit. Accordingly, a model study was considered necessary to investigate the pool action in the access cut and to determine a satisfactory stilling pool design.

2. The model. A 1 to 15 scale model was built and tested in the hydraulic laboratory of the Bureau of Reclamation, Denver, Colorado, (figure 6). A short length of the 90-inch outlets was duplicated in the model. They were built of light-gage galvanneal with a bellmouth entrance provided at station 22+93.03, and for calibration purposes piezometers were installed at station 23+19.28 (figure 6). Each outlet was provided with a rectangular slide gate, the head on the gates being recorded by the piezometers, and the tailwater being controlled by a tailgate. Since the entrance to the outlets in the model (station 22+93.03) was not located in a position similar to the prototype (station 16+20.00), the maximum head for the maximum discharge was determined by computing the prototype pressure-head at station 23+19.28; the corresponding model value was then established by regulating the slide gates. Sufficient length of the access cut was installed downstream from the headwall of the outlet gate house to permit observation of the flow.

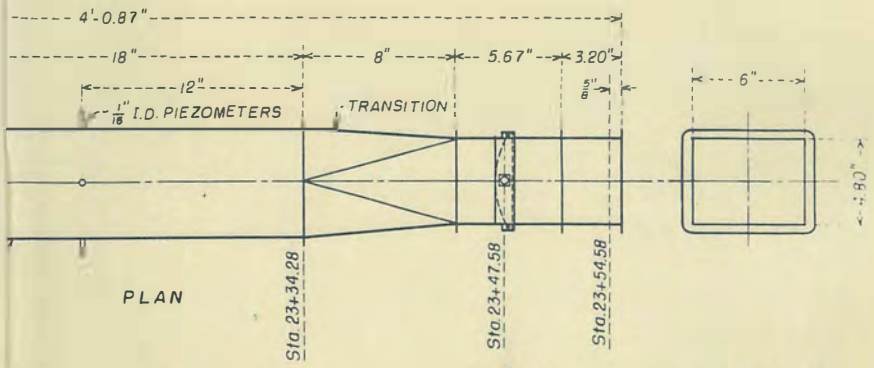
3. Stilling pool study. Preliminary tests were made on the stilling pool formed by the access cut (figures 7A and 8A). As anticipated, the flow conditions were very poor. When both outlets were discharging under the maximum head (figure 8B), the pool was exceedingly rough; the same was true for the left gate (or right gate) discharging 700 second-feet under the maximum head (figure 8C). The latter condition was particularly unfavorable, since the high-velocity jet issuing near the side of the access cut caused large eddies and return flow along the opposite side of the pool. For nearly all dis-

FIGURE 6

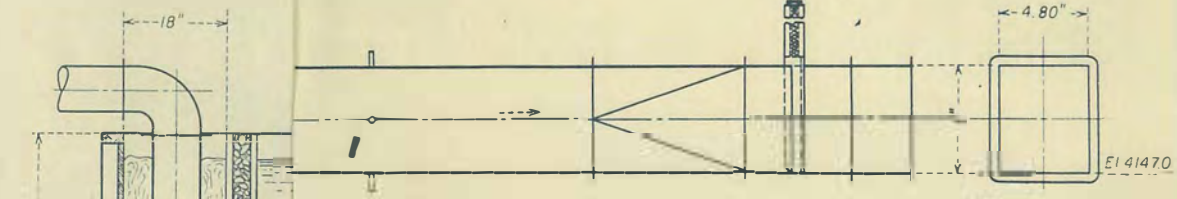




SECTION B-B



PLAN



ELEVATION

OUTLET DETAIL

D SURFACE

SCALE IN FEET-PROTOTYPE
0 5 10 15
0 4 8 12
SCALE IN INCHES-MODEL

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
TUCUMCARI PROJECT - NEW MEXICO

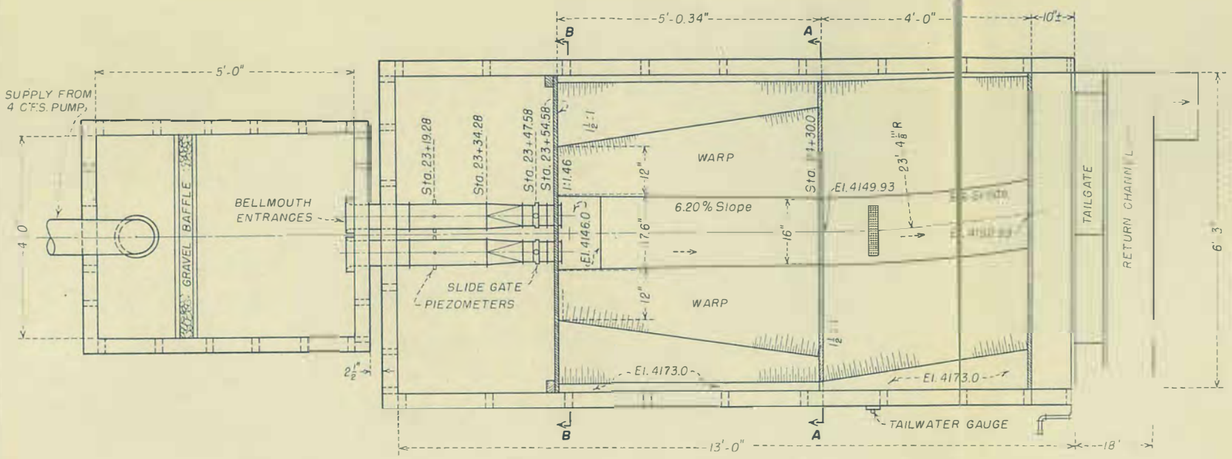
CONCHAS CANAL HEADWORKS

HYDRAULIC MODEL STUDIES - 1:15 SCALE

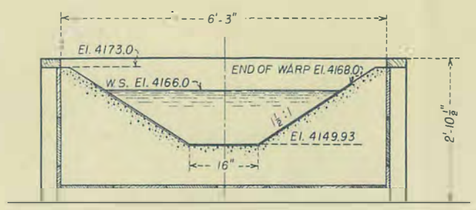
GENERAL PLAN AND SECTIONS OF MODEL

DRAWN H.G.D. JR. SUBMITTED Jacob C. Warnock
TRACED B.B. O.W.S. RECOMMENDED R. F. Blanks
CHECKED H.G.D. JR. APPROVED W. H. Holden

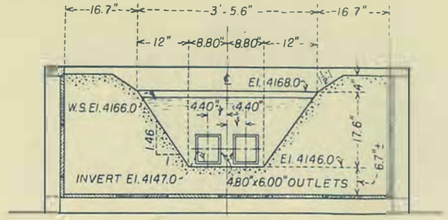
DENVER, COLORADO, MAR. 21, 1939 257-D-35



PLAN

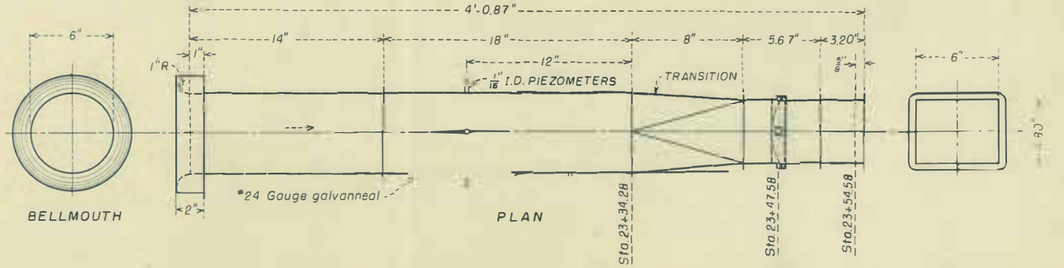


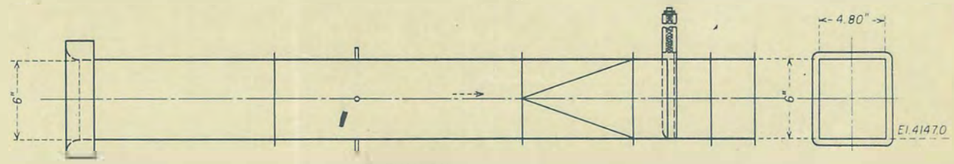
SECTION A-A



SECTION B-B

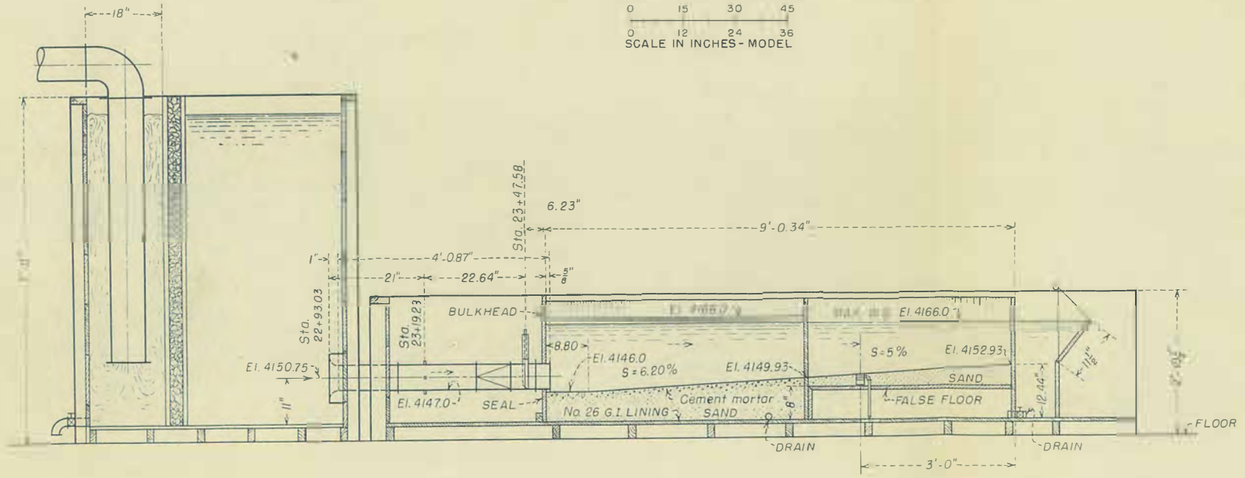
SCALE IN FEET - PROTOTYPE
0 15 30 45
0 12 24 36
SCALE IN INCHES - MODEL



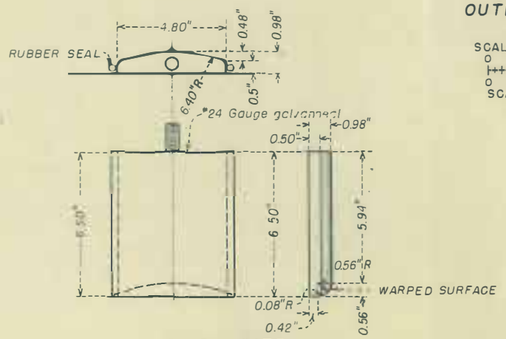


OUTLET DETAIL

SCALE IN FEET - PROTOTYPE
0 5 10 15
0 4 8 12
SCALE IN INCHES - MODEL



SECTION ON CENTER LINE



SLIDE GATE

SCALE IN FEET - PROTOTYPE
0 2.5 5.0 7.5
0 1 2 3 4 5 6
SCALE IN INCHES - MODEL

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
TUCUMCARI PROJECT - NEW MEXICO

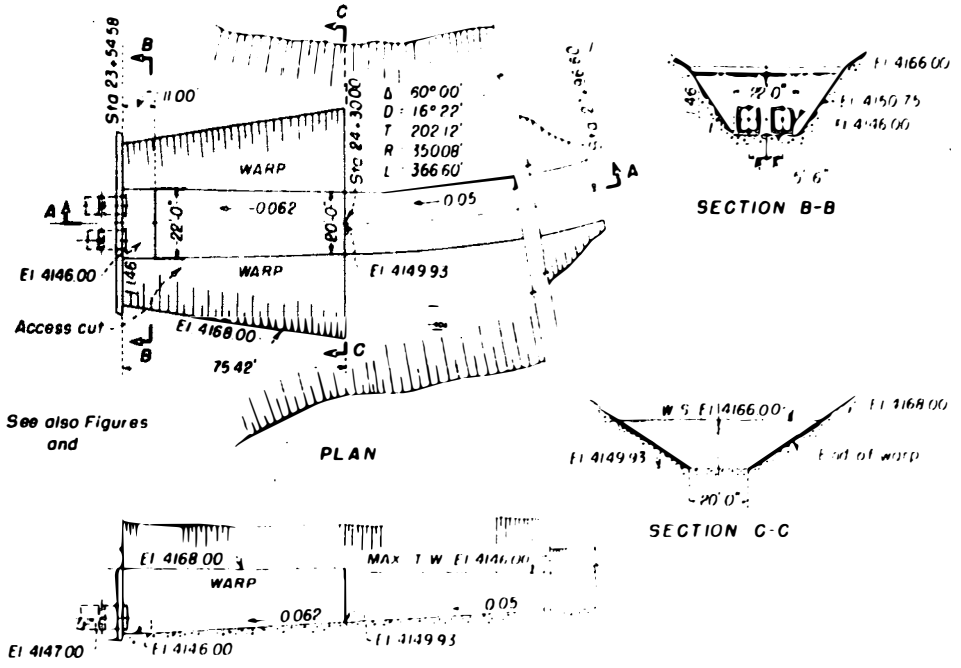
CONCHAS CANAL HEADWORKS

HYDRAULIC MODEL STUDIES - 1:15 SCALE

GENERAL PLAN AND SECTIONS OF MODEL

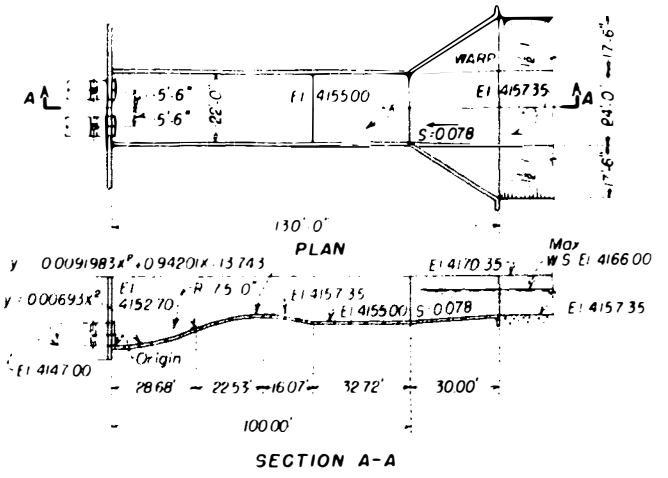
DRAWN H.G.D. JR. SUBMITTED Jack E. Warnock
TRACED B.B. D.W.S. RECOMMENDED R. J. Blanchard
CHECKED H.G.D. JR. APPROVED W. H. Madden

DENVER, COLORADO, MAR. 21, 1939 257-D-35



A

STILLING POOL IN ACCESS CUT



B

HYDRAULIC HUMP IN STILLING POOL

A

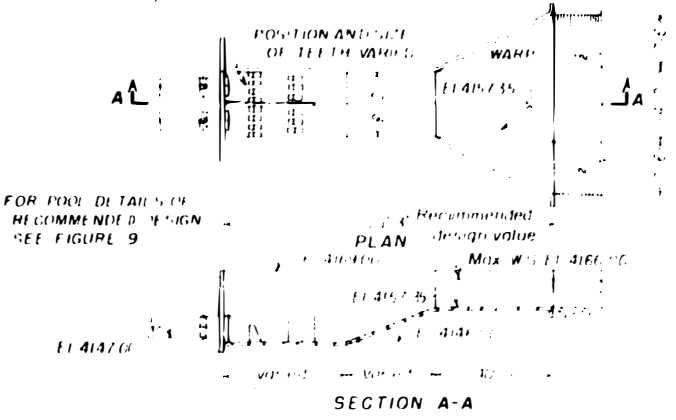
STILLING POOL IN ACCESS CUT

SCALE IN FEET - PROTOTYPE

0 15 30 45 60 75 90

0 12 24 36 48 60 72

SCALE IN INCHES - MODEL



C

IMPACT STILLING POOL LEADING TO RECOMMENDED DESIGN

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
TUCUMCARI PROJECT - NEW MEXICO

CONCHAS CANAL HEADWORKS

HYDRAULIC MODEL STUDIES - 1:15 SCALE

STILLING POOLS INVESTIGATED IN MODEL

DRAWN H.G.D.JR	SUBMITTED	Jacob E. Warnock
TRACED C.F.M. J.W.S.	RECOMMENDED	R. J. Blanke
CHECKED H.G.D. JR	APPROVED	W. H. Holden
	DENVER, COLORADO, JUNE 20, 1939	257-D-37

FIGURE 7

A. LOOKING UPSTREAM INTO ACCESS CUT

B. DISCHARGE 350 SECOND-FEET EACH OUTLET; MAXIMUM HEAD TAILWATER ELEVATION 4166.00

C. DISCHARGE 700 SECOND-FEET LEFT OUTLET; MAXIMUM HEAD TAILWATER ELEVATION 4166.00

STILLING POOL IN ACCESS CUT
ORIGINAL MODEL

charges, particularly under maximum head, excessive velocities extended downstream the length of the model and completely removed the sand topography.

From the initial observations it was evident that some means must be provided to dissipate the energy and velocity of the jets issuing from the outlets, but at the same time the width of stilling pool in the access cut must be greatly reduced to prevent eddies and return flow from occurring during unsymmetrical gate operation. There was a possibility of adopting one of the following types of stilling pool designs applicable when excessive tailwater is present at outlet works: (1) Enclosed stilling chamber; (2) hydraulic hump; and (3) impact stilling pool.

The enclosed stilling chamber, in which a high-velocity jet is directed into a chamber containing horizontal baffle plates, was not studied. Although this type of design works satisfactorily under certain conditions of pressure flow, it was desirable to have an open channel solution.

The hydraulic hump is used in stilling pools to obtain a hydraulic jump when the tailwater depth is excessive. Figure 7B shows this type of design, which was studied in the model. The hump, confined in a rectangular pool, was designed to give a d_1 value conjugate to the given d_2 value as determined by the depth of flow in the canal for maximum discharge. The hydraulic jump would then form just downstream from the top of the hump and in the rectangular section. Unfortunately, this design did not perform as anticipated. The jets from the outlets did not spread uniformly across the width of the pool; but instead, the flow of the jet concentrated in a vertical sheet of water. Due to this uneven flow distribution, the required d_1 was not obtained, thus allowing the tailwater to move upstream and go over the hump until the outlets became submerged.

The impact stilling pool (figure 7C) was studied in the model and was found to operate satisfactorily for all flow conditions. The effectiveness of this design depended on the baffle piers which were placed in the path of the issuing jets, since they dispersed the high-velocity flow and broke up the solid jets. Excessive tailwater was particularly desirable with this type of pool, because it helped to dampen the boiling at the water surface, and it permitted a more rapid development of uniform velocity distribution below the baffle piers. Observations on the model of the impact pool disclosed that the jets, instead of discharging as a thin sheet under the tailwater, expanded upward to form a solid stream of water. This necessitated larger baffle piers and required the downstream row to be higher than those of the upstream row. A training wall was placed along the center

line of the pool, its height extending to the top of the outlets (figure 7C). This wall guided the issuing jets into the baffle piers, and helped to prevent excessive boiling at the water surface, which would have been aggravated if the flow of the two jets had come in contact with each other. Figure 9 shows the recommended design developed from a study in the model of the impact stilling pool (figure 8C).

The pump chambers (figure 9) were added to permit flow into the canal during low reservoir level. When sufficient head is not available on the outlets, the downstream end of the stilling pool will be closed by flashboards, and with the outlets discharging as open channels, the pumps will lift the water from the stilling pool and into the canal through the channels on each side of the pool. Each pump will deliver 250 second-feet. Figures 10, 11, and 12 show the model of the recommended design in operation. The effectiveness of the impact stilling pool may readily be seen by comparing figures 8B and 8C with figures 11 and 12.

In the Appendix, an analysis is made to show whether the flow at outlets is submerged or free; in addition, some rules are stated as an aid in designing the impact stilling pool.

4. Calibration of slide gate. The slide gate in the right outlet was calibrated in the model. For gate openings in increments of 0.1, various discharges were run and the corresponding tailwater set. For each setting, the pressure head at station 23+19.28 was read. Figure 13 shows a plot of the calibration, in which the effective head, h, is plotted against the discharge for various gate openings. Due to the small pressures recorded in the model for 0.9 and full-gate opening, the data were not consistent and are not shown.

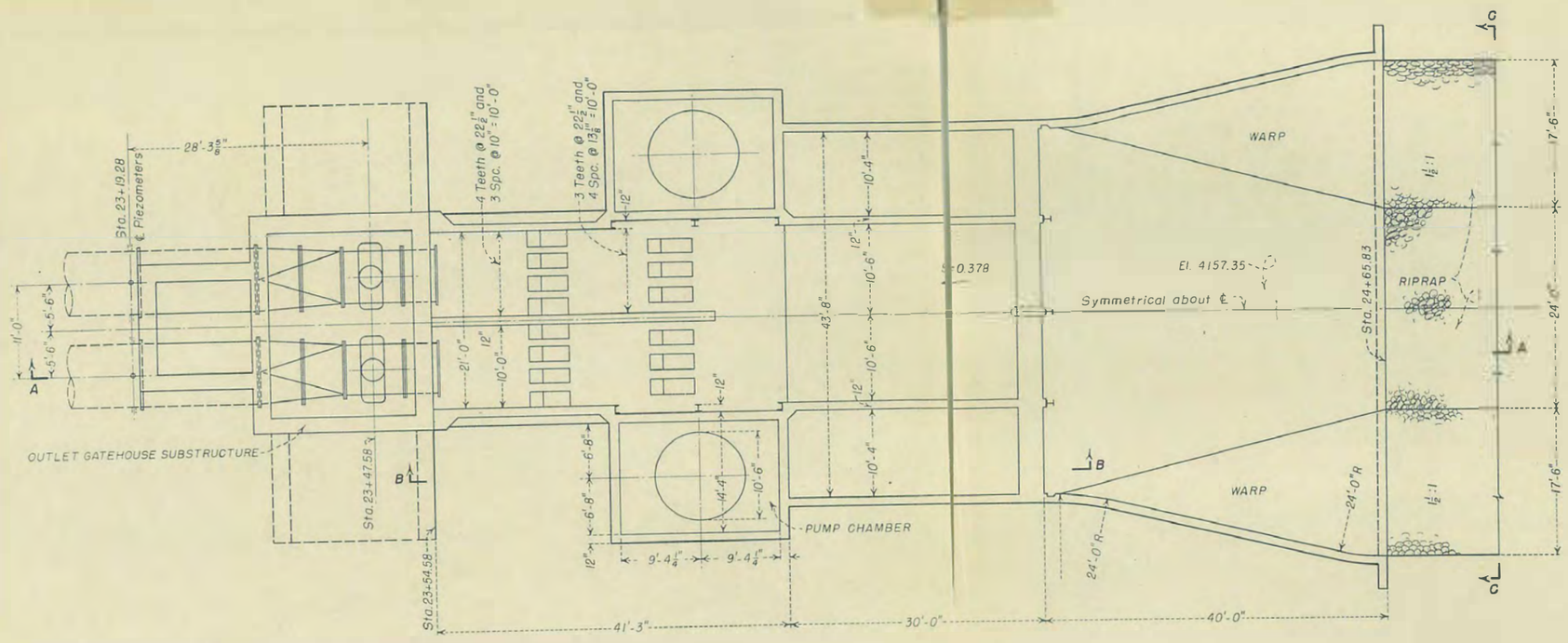
It is recommended that piezometers be installed at station 23+19.28 on each prototype outlet. If this is done, the curves of figure 13 will act as a guide for determing the discharge of the outlets until sufficient prototype data are taken to adjust the model curves to conform with the variation between the model and prototype. The calibration curves may also be used for the left gate, the total discharge being the sum of the values obtained from the curves for each gate.

Figure 14 shows coefficients of discharge versus head for the right slide gate for various gate openings. The coefficients are based on the total head in the model (figure 14A), and on the pressure head plus velocity head at station 23+19.28 (figure 14B). The coefficients increase with the head for a given gate opening, but they increase more rapidly for larger gate openings. The curves of

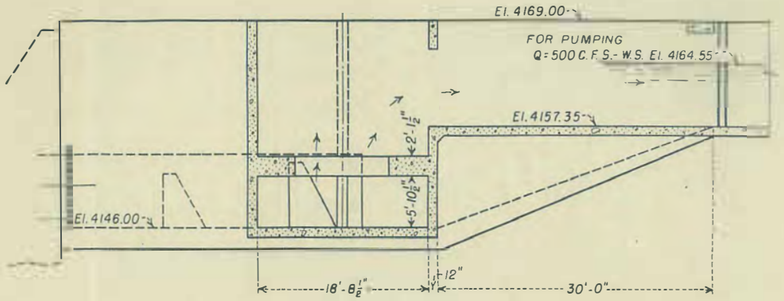
figure 14A, in which the total model head is used, are only of interest experimentally. The actual total prototype head could not be fully determined, since the prototype losses from the actual prototype inlet, station 16+20.00, to station 22+93.03, the inlet position of the model, could not be accurately determined.

5. Conclusions. Although the access cut below the outlet gate house was not intended to act as a stilling pool, its performance, for maximum flow conditions, as observed in the model, illustrated the unfavorable conditions that will exist when energy dissipation is allowed to occur in a trapezoidal or expanding stilling pool. In the access cut, even for symmetrical gate operation, numerous eddies and vortices developed, and heavy return flow along the sides of the cut caused unstable flow conditions. It is possible, moreover, that excessive tailwater may have aggravated the poor conditions; but it has frequently been domonstrated from observations in the laboratory and in the field that even a hydraulic jump, for example, is very unstable in a trapezoidal pool. As a result, the energy dissipation and velocity reduction is less than that for a hydraulic jump confined in a stilling pool of rectangular section. It is believed, therefore, that energy dissipation in open channel flow should always occur in a rectangular section.

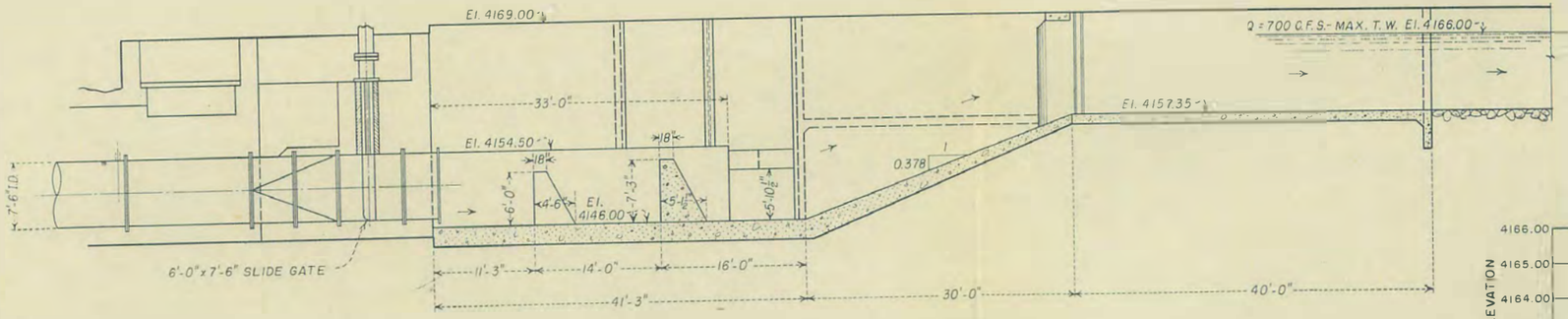
The impact stilling pool which was adopted for the recommended design is a special type and would ordinarily not be used unless excessive tailwater is present. This condition existed in this problem, since the outlets had been placed before the Conchas canal grade had been established, making it impossible to relocate the outlets or to change the canal grade to suit.



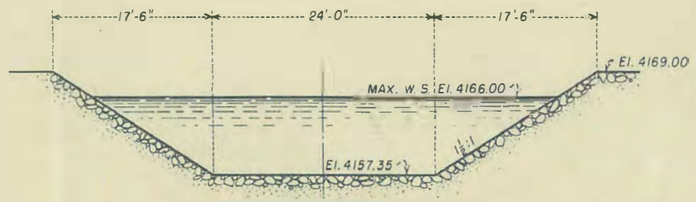
PLAN



SECTION B-B

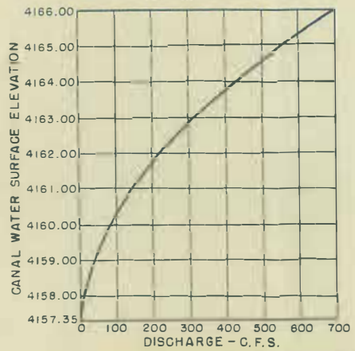


SECTION A-A



SECTION C-C

SCALE IN FEET - PROTOTYPE
0 7.5 15
0 3 6 9 12
SCALE IN INCHES - MODEL



CONCHAS CANAL RATING CURVE

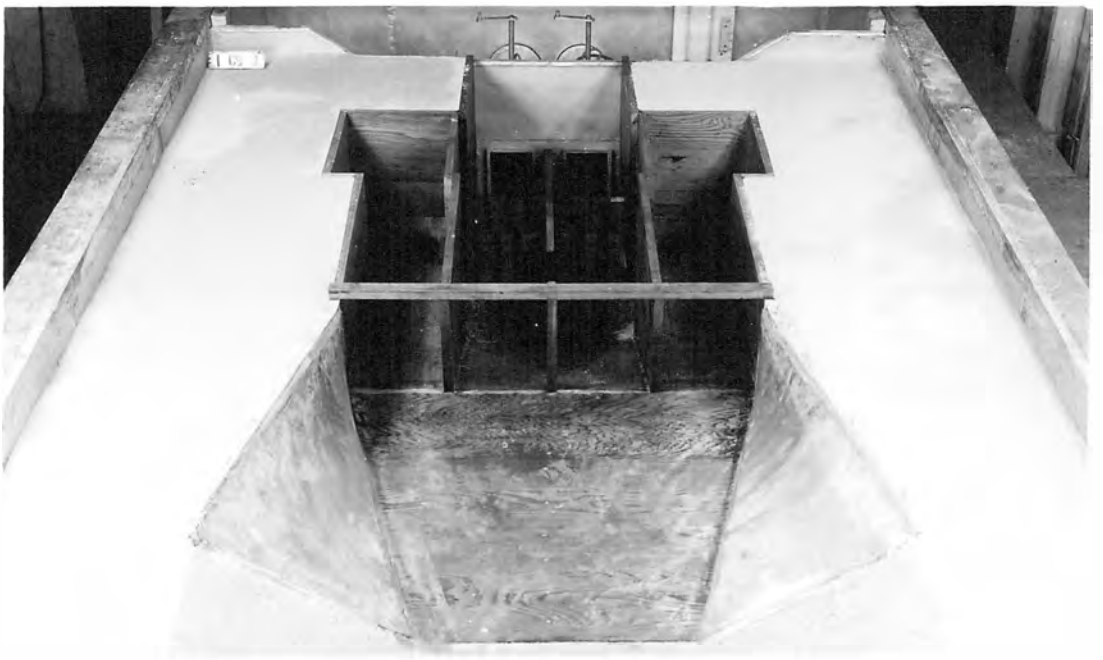
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
TUCUMCARI PROJECT - NEW MEXICO

CONCHAS CANAL HEADWORKS

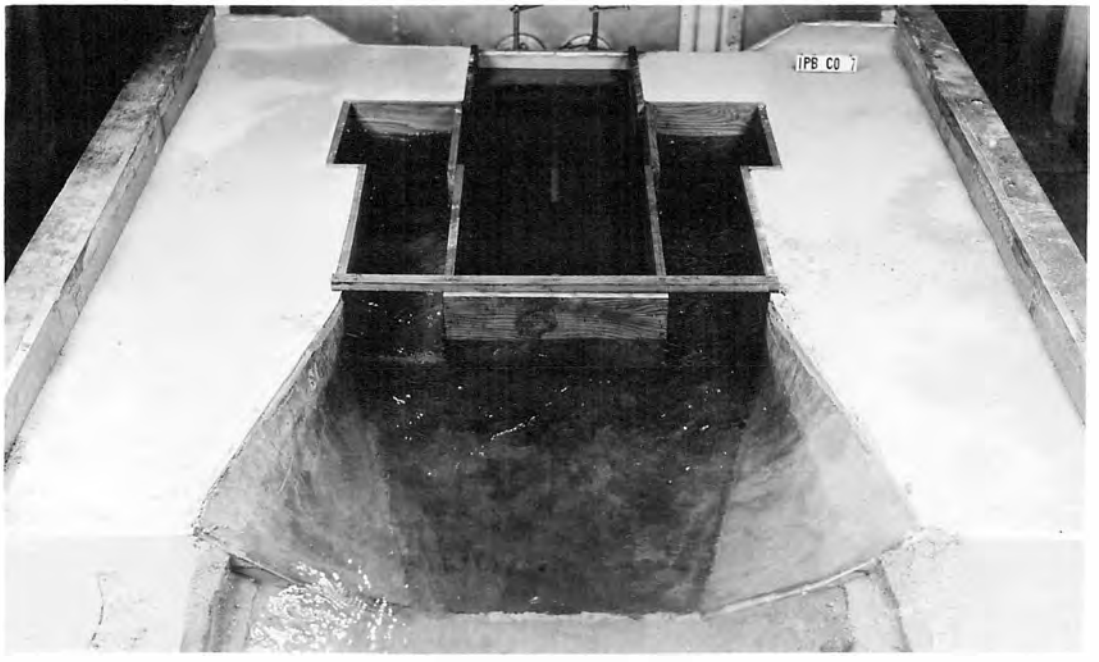
HYDRAULIC MODEL STUDIES - 1:15 SCALE
RECOMMENDED STILLING POOL DESIGN

DRAWN H.G.D., JR. SUBMITTED Jacob C. Stuart
TRACED F.A.J. DWS. RECOMMENDED R. F. Blanks
CHECKED H.G.D. JR. APPROVED W. H. Mueller

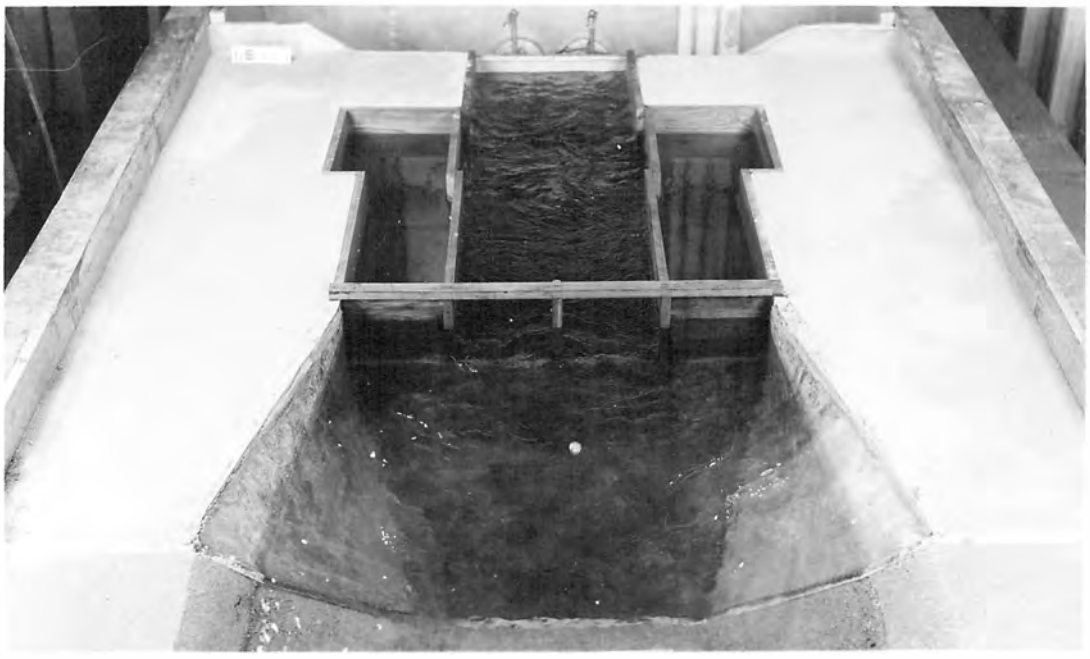
DENVER, COLORADO, JUNE 15, 1939 257-D-36



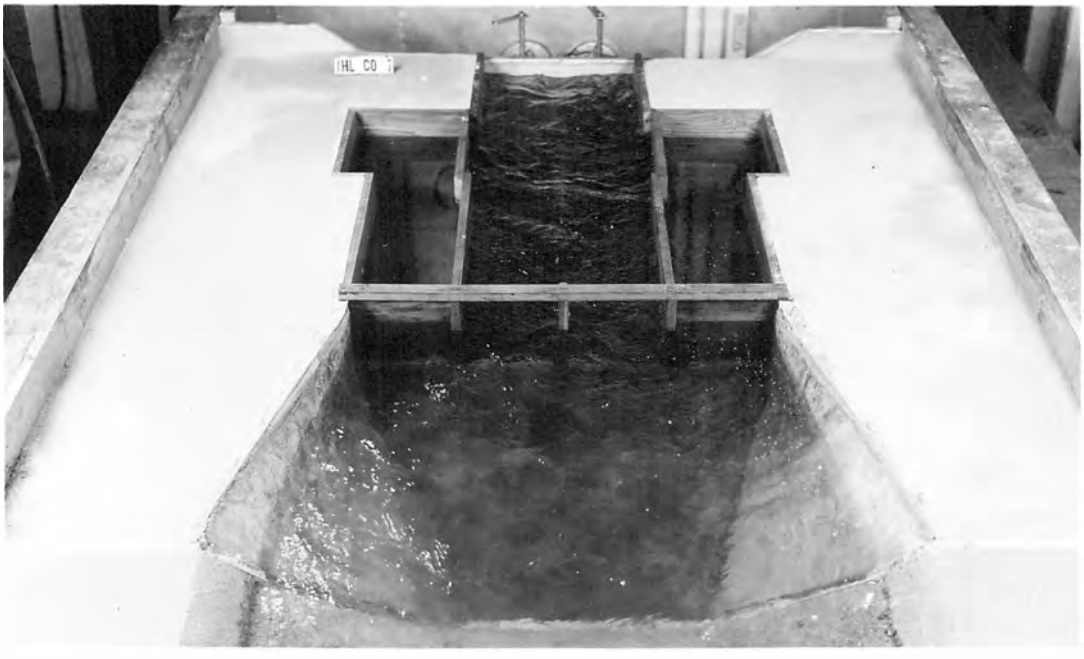
A. STILLING POOL AND PUMP CHAMBERS



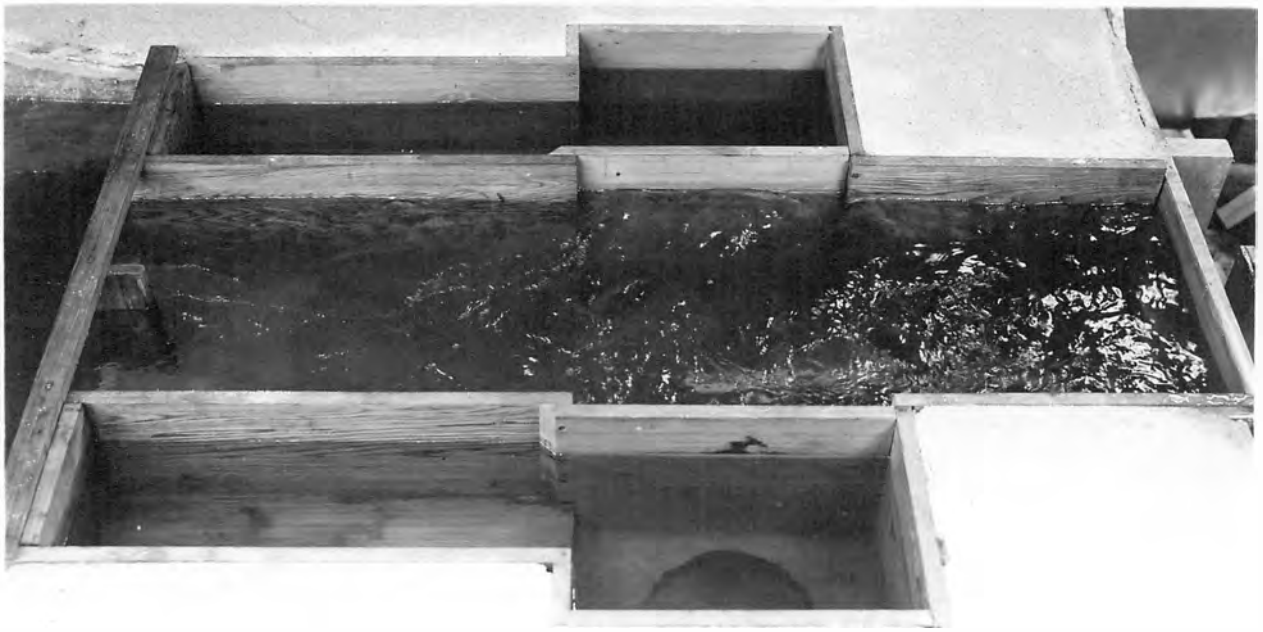
B. FLOW THROUGH PUMP CHAMBERS
DISCHARGE 500 SECOND-FEET
TAILWATER ELEVATION 4164.55



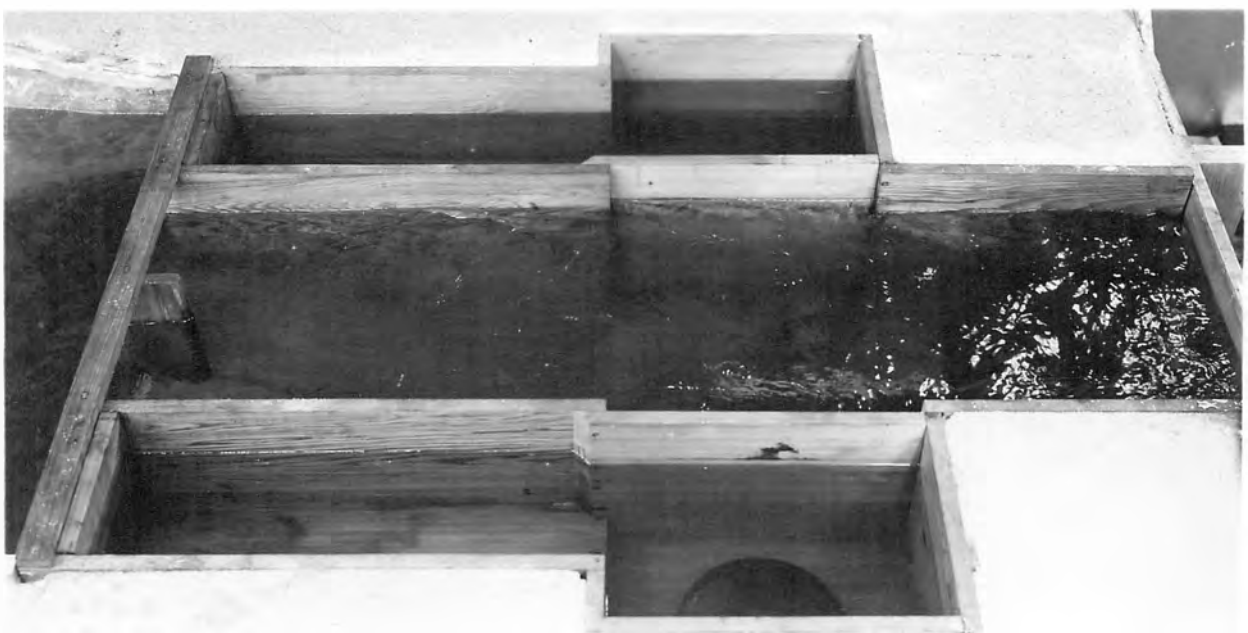
A. DISCHARGE 350 SECOND-FEET EACH CUTLET; MAXIMUM HEAD
TAILWATER ELEVATION 4166.00



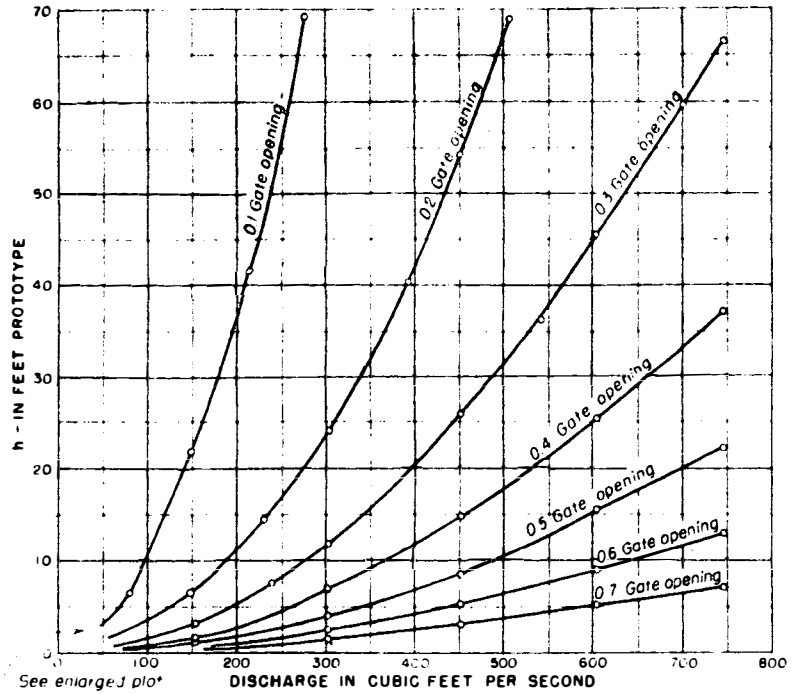
B. DISCHARGE 700 SECOND-FEET LEFT GATE; MAXIMUM HEAD
TAILWATER ELEVATION 4166.00

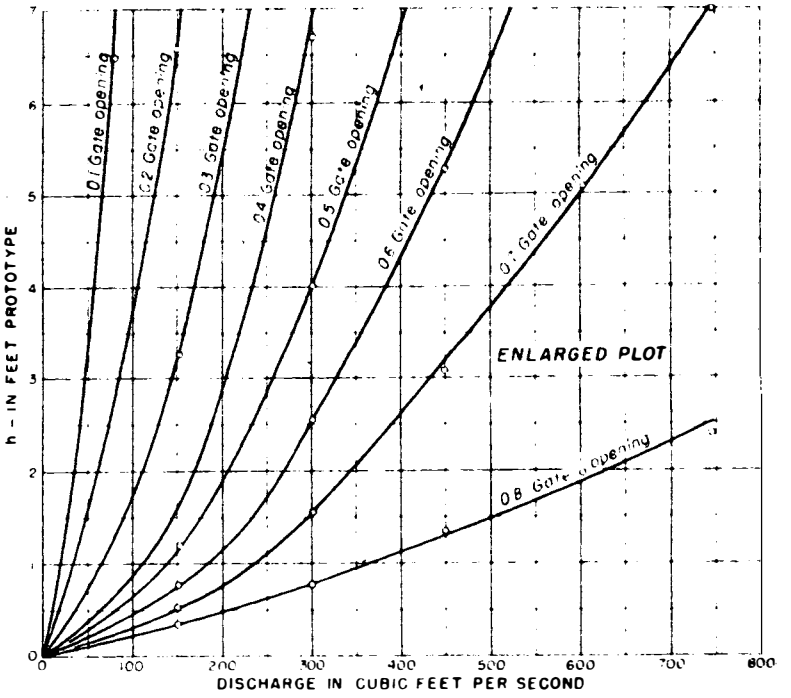


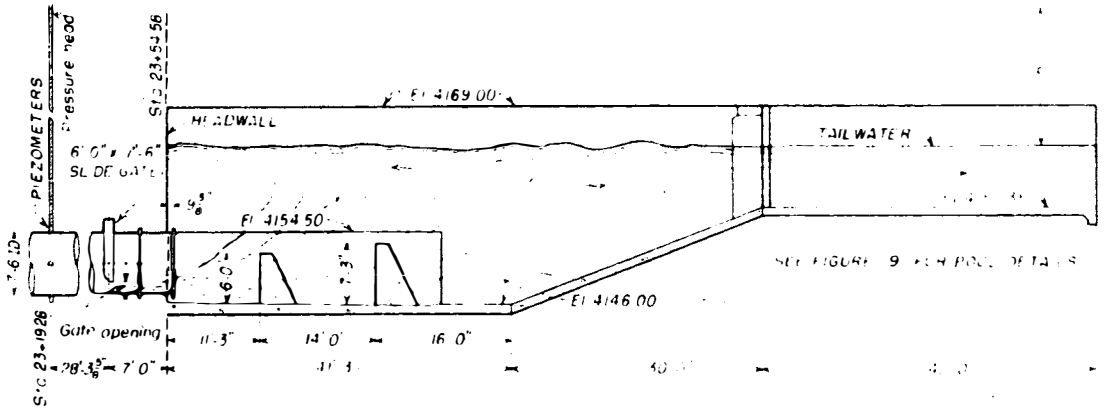
A. DISCHARGE 350 SECOND-FEET EACH OUTLET; LOW HEAD
TAILWATER ELEVATION 4166.00



B. DISCHARGE 350 SECOND-FEET EACH OUTLET; MAXIMUM HEAD
TAILWATER ELEVATION 4166.00







UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
TUCUMCARI PROJECT - NEW MEXICO

CONCHAS CANAL HEADWORKS

HYDRAULIC MODEL STUDIES - 1:15 SCALE

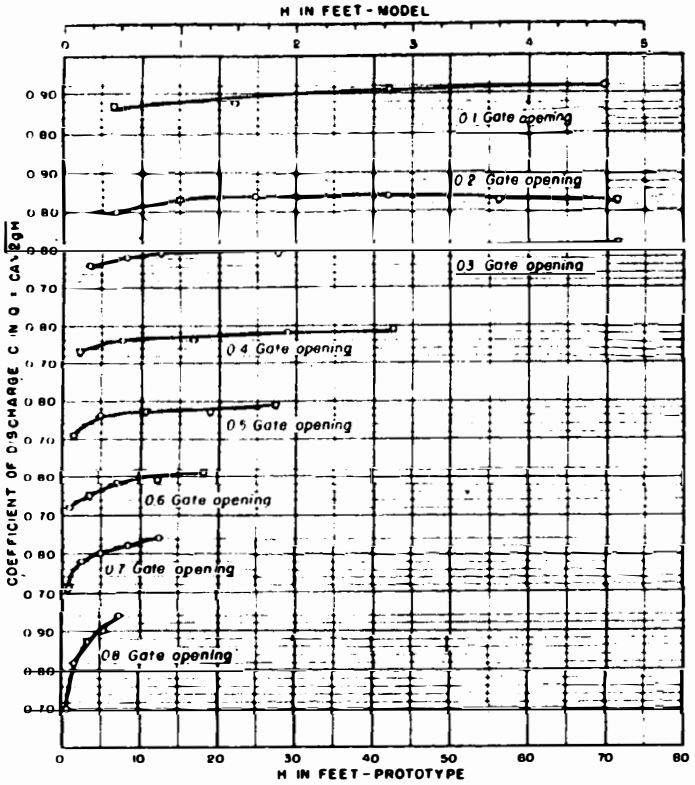
CALIBRATION CURVES FOR RIGHT SLIDE GATE

DRAWN H.R.D., JR. SUBMITTED Jacob E. Warnock
TRACED T.A. DWS RECOMMENDED K. T. Blanks
CHECKED H.R.D., JR. APPROVED W. H. Nalder

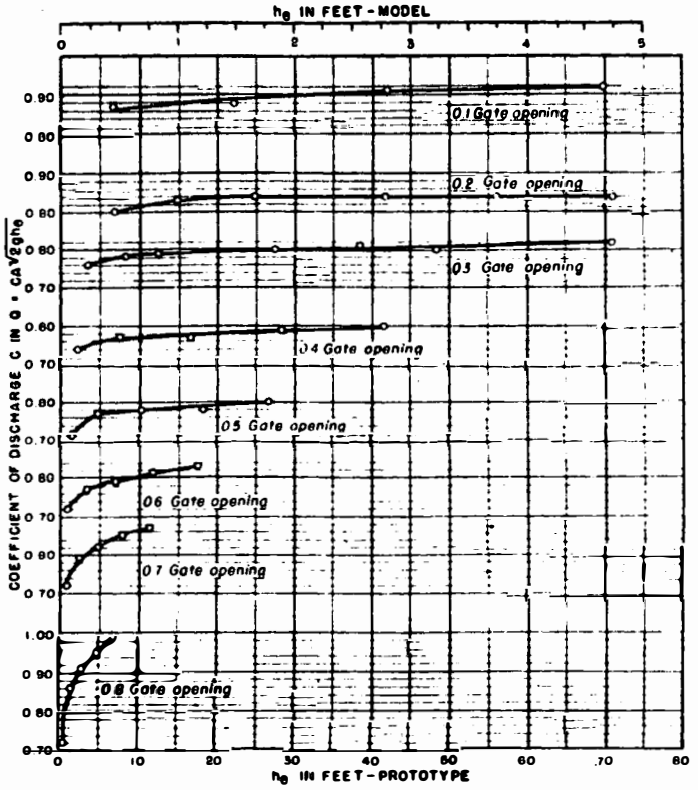
DENVER, COLORADO, JUNE 15, 1939

257-D-38

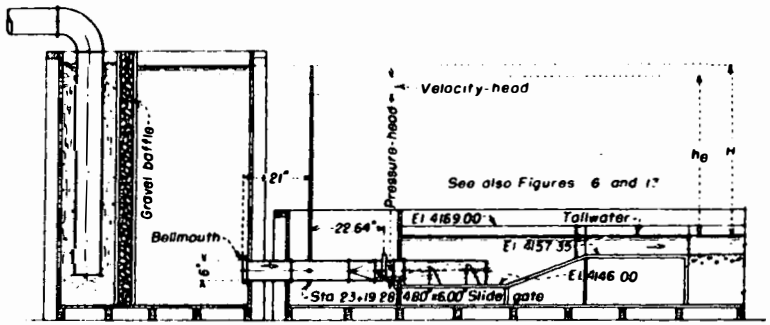
FIGURE 13



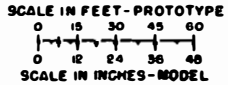
A - COEFFICIENTS BASED ON TOTAL HEAD



B - COEFFICIENTS BASED ON PRESSURE-HEAD PLUS VELOCITY-HEAD AT STA. 23+19.28



MODEL ARRANGEMENT FOR CALIBRATION



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
TUCUMCARI PROJECT - NEW MEXICO

CONCHAS CANAL HEADWORKS

HYDRAULIC MODEL STUDIES - 1:15 SCALE

COEFFICIENTS OF DISCHARGE FOR RIGHT SLIDE GATE

DRAWN H.G.D., JR.	SUBMITTED Jacob E. Warnock
TRACED E.F.J. D.W.S.	RECOMMENDED R. F. Blanks
CHECKED H.G.D., JR.	APPROVED W. H. Holder

DENVER, COLORADO, JUNE 10, 1939 1257-D-39

APPENDIX

ANALYSIS OF FLOW AT OUTLETS

1. Determination of submergence. It is frequencly necessary to determine whether a hydraulic jump will form, or whether the flow will be submerged below regulating sluices or outlets. To determine which condition exists, it is necessary to determine for a given gate opening, discharge, and the corresponding tailwater depth, whether the conjugate depth relation of the hydraulic jump holds. If it is found that the required value of d_2 is greater than that existing, then the flow is free and adjustments may be made to obtain the required d_2; or, if it is found that the required d_2 value is less than that existing, then the flow is submerged and a hydraulic jump will not form unless adjustments are made.

Figure 15A shows the variables for the stilling pool of the Conchas canal headworks, where:

H = Total head on invert of outlets

d_1 = Thickness of jet at vena contracta

V_1 = Velocity in vena contracta

H_1 = Effective head at vena contracta

d_2 = Tailwater depth

h = Head producing flow

s = Distance gate is open

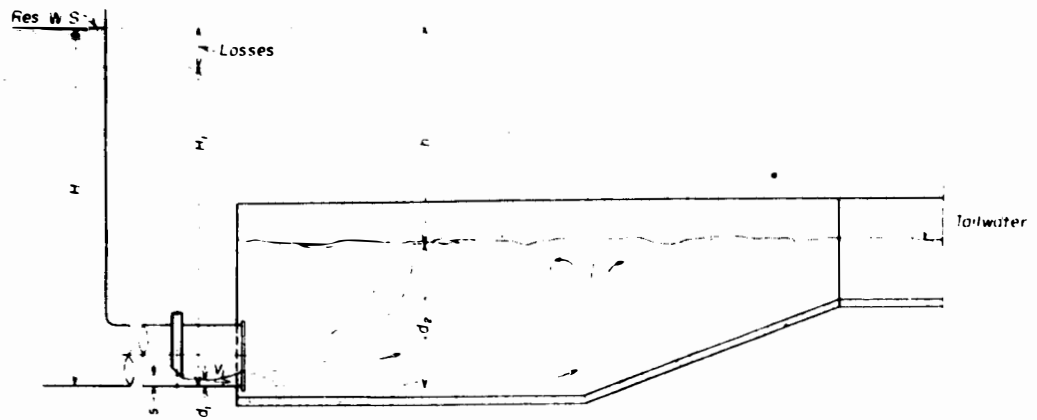
The velocity in the vena contracta may be expressed,

$$V_1 = C_v \sqrt{2\,g\,(H-d_1)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

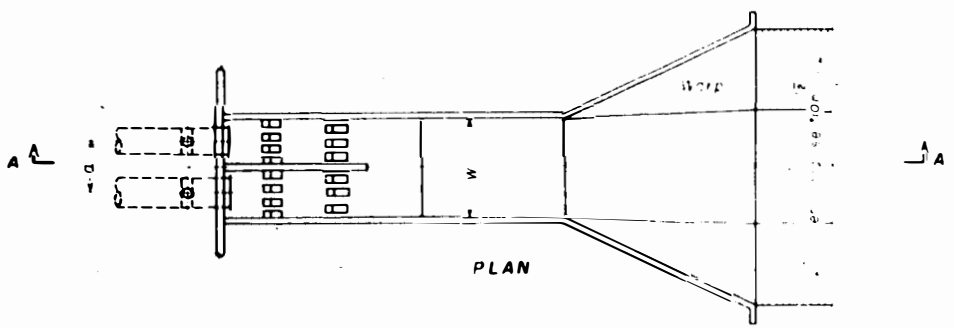
where C_v = velocity coefficient. The effective head may be expressed as

$$H_1 = d_1 + \frac{V_1^2}{2g} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

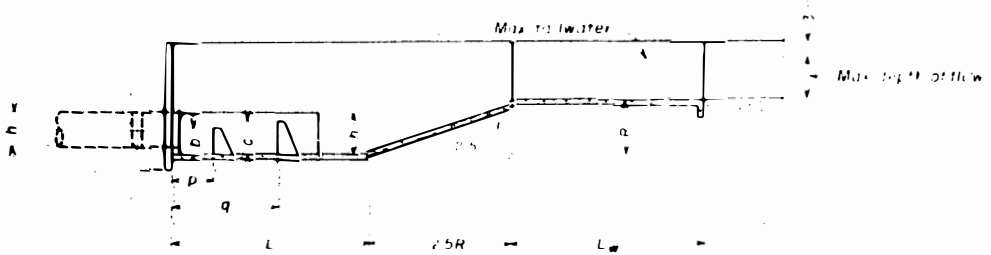
and from equation (1), $\frac{V_1^2}{2g} = C_v^2\,(H-d_1)$, which when substituted in



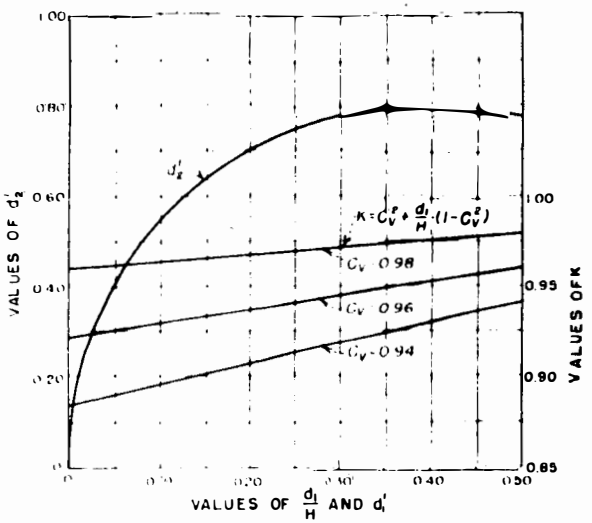
A
POOL AT OUTLET



PLAN



SECTION A-A
C
IMPACT STILLING POOL



B
DIAGRAM FOR FLOW AT OUTLETS

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
TUCUMCARI PROJECT - NEW MEXICO

CONCHAS CANAL HEADWORKS

HYDRAULIC MODEL STUDIES - 1:15 SCALE
ANALYSIS OF FLOW AT OUTLETS

DRAWN	H G D JR	SUBMITTED	Jacob E. Warnock
TRACED	F T D ORS	RECOMMENDED	R. F. Blanks
CHECKED	H G D, JR	APPROVED	W H Nalder
	DENVER, COLORADO	JUNE 20, 1939	257-D-40

FIGURE 15

(2) gives:

$$H_1 = d_1 + C_v^2 (H-d_1), \text{ and simplifying}$$

$$H_1 = H \left[C_v^2 + \frac{d_1}{H} (1-C_v^2) \right] = K \cdot H \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

where $K = C_v^2 + \frac{d_1}{H} (1-C_v^2)$

Figure 15B shows values of K and $\frac{d_1}{H}$ for various values of the velocity coefficient C_v.

Consider now the conjugate depth relation for the hydraulic jump:

$$d_2 = -\frac{d_1}{2} + \sqrt{\frac{2V_1^2 d_1}{g} + \frac{d_1^2}{4}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

This relation may be expressed as a function of d_1 and H_1 where $H_1 = d_1 + V_1^2/2g$, effective head.

Then $V_1^2/2g = H_1-d_1$

or $2V_1^2/g = 4 (H_1-d_1)$, substituting in (4) we obtain,

$$d_2 = -\frac{d_1}{2} + \sqrt{4(H_1-d_1)\, d_1 + \frac{d_1^2}{4}}, \text{ which reduces to}$$

$$d_2 = \frac{d_1}{2} \left[-1 + \sqrt{16 \frac{H_1}{d_1} - 15} \right] \quad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Now let $d_1' = \frac{d_1}{H_1}$ and let $d_2' = \frac{d_2}{H_1}$

equation (5) then reduces to,

$$d_2' = \frac{d_2}{H_1} = \frac{d_1'}{2} \left[-1 + \sqrt{\frac{16}{d_1'} - 15} \right] \quad \ldots\ldots\ldots\ldots (6)$$

Figure 15B shows the relation between the values of $d_2' = \frac{d_2}{H_1}$ and $d_1' = \frac{d_1}{H_1}$.

In effect, this curve represents the conjugate depth relation for $H_1 = 1$, a "unit hydraulic jump." This curve could also be considered for H, the total head.

A sample computation will illustrate the application of the foregoing relations. Consider figure 15A and apply known values of the Conchas Canal Headworks, where:

H = 83 feet (Maximum reservoir elevation 4230.00 - Invert elevation 4147.00).

d_2 = 19 feet (Maximum tailwater elevation 4166.00 - Invert elevation 4147.00).

h = 64 feet (Maximum reservoir elevation 4230.00 - Maximum tailwater elevation 4166.00).

Assume the discharge to be 350 second-feet through each outlet, and let the gate opening be 14.50 percent. Consider either outlet and let the coefficient of contraction, $C_c = 0.85$, for submerged gate with rounded bottom:

Then gate opening, s = 0.145 x 7.5 = 1.09, (outlet at gate is 6 feet by 7 feet 6 inches); and $d_1 = 0.85 \times 1.09 = 0.93$. Then,

$$\frac{d_1}{H} = \frac{0.93}{83} = 0.011$$

From figure 15B for $C_v = 0.98$ and $\frac{d_1}{H} = 0.011$, find K = 0.96. Since the effective head from equation (3) is,

$$H_1 = K \cdot H$$

then

$$H_1 = 0.96 \times 83 = 79.70$$

Now $d_1' = \frac{0.93}{79.70} = 0.012$, referred to H_1, effective head.

From figure 15B with $d_1' = 0.012$, the conjugate unit value is $d_2' = 0.21$; and since $d_2' = d_2 / H_1$, then $d_2 = d_2' \cdot H_1 = 0.21 \times 79.70 = 16.74$. This value, $d_2 = 16.74$, is less than the existing value, for which $d_2 = 19.00$; the flow is therefore submerged. To check the assumed discharge:

$$q = C_c \cdot C_v \cdot \sqrt{2gh}$$

$$\text{or } q = 0.85 \times 0.98 \times 1.09 \sqrt{2g \times 64}$$

$$q = 58.28 \text{ per foot; outlet is 6 feet wide,}$$

hence, $Q = 58.28 \times 6 = 350$ c.f.s., as assumed.

If a similar computation is made considering the discharge of 700 second-feet through one outlet, it will be found that the flow is free for the one outlet; however, due to the poor spread of the jet a jump did not form in the model for this unsymmetrical condition.

2. Conchas Canal Headworks stilling pool compared to other designs. In design, when it is found that the flow is submerged, the position of the outlets and the canal grade may be adjusted until the required d_2 is furnished. The foregoing example illustrates, however, actual conditions at the Conchas Canal Headworks for which the model study indicated that submerged flow existed. Further consideration of the stilling pool discloses that although a hydraulic jump could have been adopted for certain high head flows, assuming correct tailwater conditions could be adjusted, the jump would be drowned for low head flows for the same discharge. Assuming, therefore, that a hydraulic jump stilling pool is the ideal solution, it would have been necessary, if the jet distribution had been more uniform to either use a hydraulic hump pool (figure 7B), or place the outlets above the tailwater and allow the jets to enter the tailwater on a sloping apron. These solutions are quite satisfactory, particularly when the flow of outlets is controlled by needle valves. As a rule, the decision as to when slide gates or needle valves are used will evidently depend on the total head. Generally, needle valves are used under high head conditions, whereas slide gates would probably not be used for heads greater than 75 feet.

3. Impact stilling pool design. It is impossible in this report to formulate any definite rules for designing an impact stilling pool, particularly since only one model was studied which represented only one set of conditions. However, it is believed that a few general statements relating the variables may aid in the design of a similar structure. Accordingly, referring to figure 15C, the following rules are offered:

1. The width of stilling pool should be, $W = 2a$, twice the distance between the center line of the outlets.

2. The height, h, of the training wall on the center line of the pool may be made equal to the height of the outlets. The length should at least extend to the toe of the downstream baffle piers.

3. The height, b, of the baffle piers in the upstream row may be, $b = 0.8h$; and the height, c, of the downstream row may be, $c = 0.9h$

to 1.0h. The distance, p = 2b, and q = 3c to 4c. Let the baffle piers occupy 0.75 W in the upstream row, and in the downstream row 0.5 to 0.6 W.

4. The value of L is not readily determined. The value in the model was determined by observing the point of nondirectional flow at the water surface when both outlets were operating under maximum head and discharge. Accordingly, the value of L may be taken as the length of the top roller - the distance from the head wall to the point of nondirectional flow. Evidently L is a function of the amount of submergence, d_2/d_1, and the velocity of the issuing jets. Experiments conducted by K. Woycicki[1] on the length of top rollers of sub-

[1] Woycicki, K. Wassersprung, Deckwalze und Ausfluss unter einer Schütze. (The Hydraulic Jump, Top Roller and the Discharge under a Sluice Gate), Federal Institute of Technology, Zurich, Jan. 23, 1934. Translation by I. B. Hosig, Bureau of Reclamation, Denver, Colorado; Technical Memorandum No. 435.

merged hydraulic jumps below a sharp-edged sluice indicated the following relation:

$$\frac{L}{h_2 - h_1} = (6.0 - 0.05 \frac{h_2}{h_1})$$

where for any units:

L = length of top roller - the distance from the sluice to the point of nondirectional flow.

h_1 = depth at vena contracta (submerged).

h_2 = depth of tailwater.

If the data obtained from the computations on page 24 are substituted in this relation, the value of L is 81 feet, which is nearly twice the value of L obtained in the model (L = 41.25 feet). The difference may be explained when it is considered that the sluice used by Woycicki was sharp-edged, while the slide gates of the Conchas Canal outlets have a rounded upstream edge. In the first case the issuing jet is relatively thin and uniform in depth, but in the latter case the jet expands vertically in a thick stream of water, thus causing the point of nondirectional flow to occur farther upstream and to form a shorter top roller.

5. The slope from the lower part of the pool to the canal bottom should be 2.5:1.

6. The length of the warped transition, Lw, depends on the depth of flow in the canal; the length being determined by making in plan the angle between the center line of the canal and the line formed by the intersection of the maximum water surface with the warp, between 25 and 30 degrees, the central angle being between 50 and 60 degrees. Some designs, however, use the central angle as 25 to 30 degrees.