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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

# HYDRAULIC MODEL STUDIES OF SAN LUIS DAM SPILLWAY CENTRAL VALLEY PROJECT, CALIFORNIA

Report No. Hyd-516

Hydraulics Branch
DIVISION OF RESEARCH

OFFICE OF CHIEF ENGINEER
DENVER, COLORADO

October 21, 1964

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## ABSTRACT

Model studies were conducted to develop the hydraulic design of the spillway approach, morning-glory inlet, vertical shaft, vertical bend, and the nearly horizontal portion of the tunnel. A vertical deflector with an air vent and two horizontal deflectors were devised to provide smooth flow through the vertical bend and to prevent the flow from spiraling through the horizontal portion of the tunnel. These devices were needed particularly when wind waves were generated on the reservoir water surface as this affected the flow in the tunnel. Discharges higher than the design requirements were briefly investigated to obtain general hydraulic research data concerning the flow characteristics of morning-glory spillways.



DESCRIPTORS--*Spillways/ spillway crests/ piers/ discharge coefficients/ hydraulic similitude/ piezometers/ *Hydraulic models/ guide vanes/ vents/ tunnel hydraulics

IDENTIFIERS--*Subatmospheric pressures/ *morning-glory inlets/ tunnel bends/ * tunnel deflectors

UNITED STATES
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Office of Chief Engineer
Division of Research
Hydraulics Branch
Denver, Colorado
October 21, 1964

Report No. Hyd-516
Author: G. L. Beichley
Checked by: T. J. Rhone
Reviewed by: W. E. Wagner
Submitted by: H. M. Martin

# HYDRAULIC MODEL STUDIES OF SAN LUIS DAM SPILLWAY CENTRAL VALLEY PROJECT, CALIFORNIA

## PURPOSE

This study was conducted to develop the hydraulic design of the spillway approach, morning-glory inlet, vertical shaft, vertical bend, and the nearly horizontal portion of the tunnel. The long spillway chute and stilling basin were not studied.

## CONCLUSIONS

1. The flow in the approach to the inlet was satisfactory.

2. The flow in preliminary morning-glory inlet structure and vertical tunnel shaft was satisfactory.

3. The discharge capacity of the structure was 875 cubic feet per second at reservoir elevation 545.80, Figure 13.

4. A vertical deflector with air vent in the vertical bend was needed to provide a uniform flow depth and to insure steady flow throughout the horizontal portion of the tunnel.

5. Two horizontal deflectors placed high on the two sidewalls of the vertical bend and horizontal tunnel were needed to aid in straightening the flow through the horizontal portion of the tunnel.

6. Discharges beyond the design requirements were briefly investigated to obtain general hydraulic research data concerning flow characteristics of morning-glory spillways.

## ACKNOWLEDGMENT

The final plans evolved from this study were developed through the cooperation of the staffs of the spillway and outlets section of the

Dams Branch and the Hydraulics Branch during the period September 1962 through November 1962. Photography was by Mr. W. M. Batts, Office Services Branch.

## INTRODUCTION

San Luis Dam, a part of the San Luis Unit of the Central Valley Project, is located on San Luis Creek about 60 miles northwest of Fresno, California (Figure 1). The purpose of the unit is to store, for use during the irrigation season, wintertime runoff water which otherwise would waste into the Pacific Ocean.

The dam (Figure 2) is an earthfill structure approximately 17,000 feet long at the crest and about 320 feet high above the streambed. It will have a maximum reservoir area of approximately 13,000 acres with a reservoir capacity of about 2,100,000 acre-feet. Its principal feature will be a pumping-generating plant at the downstream end of the outlet works (Figure 3). The outlet works consists of four tunnels through the left abutment adjacent to the spillway.

The spillway (Figure 3) is designed to discharge approximately 900 cubic feet per second at reservoir elevation 545.8 feet. It has a 31-foot-diameter morning-glory-type inlet that discharges into a vertical shaft 9 feet, 6 inches in diameter (Figure 4). The shaft is connected to a vertical bend that joins a nearly horizontal tunnel whose invert is 99 feet below the crest. The tunnel slopes downward at 0.01 for a distance of 309 feet to an open channel which carries the flow to the stilling basin at the toe of the dam.

Dimensions of the hydraulic features are listed in Table 1 for both English and metric units.

## THE MODEL

### Scope

The model (Figure 5) was a 1:14.83 scale reproduction of a portion of the reservoir surrounding the inlet, the spillway inlet, the vertical shaft, the vertical bend, and a portion of the horizontal tunnel. The spillway chute and stilling basin were not modeled, since it was believed that this portion of the structure could be developed for the prototype by standard design practices.

### Reservoir

The reservoir was contained in a 12- by 18-foot head box which allowed reproduction of the reservoir for approximately 110 feet upstream and 130 feet to the right and left of the inlet. The upstream face of the dam and the berm surrounding the inlet were molded of concrete mortar placed on metal lath which had been nailed over wooden templates shaped to the surface contours (Figure 5A). A 6-inch rock baffle was installed along three sides of the box to smooth the water surface and properly distribute the inflow.

The reservoir water surface elevation was measured by means of a hook gage mounted in a stilling well attached to the side of the box and connected to a piezometer tap located in the floor upstream and to the right of the inlet where the velocity of approach was negligible.

### Inlet

The morning-glory inlet was made of concrete screeded to sheet metal templates (Figure 5A). Piezometers were installed in the spillway crest and consisted of 1/16-inch-inside-diameter brass tubes filed flush and soldered at right angles to the profile shape.

### Tunnel

The vertical shaft, vertical bend, and horizontal portion of the tunnel were constructed of transparent plastic to permit visual observation of the flow (Figure 5B). The vertical shaft and horizontal tunnel were made from 7-11/16-inch-inside-diameter extruded plastic pipe, which governed the scale of the model. Plastic piezometers having a 1/16-inch inside diameter were installed throughout the vertical shaft, bend, and tunnel.

## THE INVESTIGATION

The investigation was concerned with flow conditions in the spillway inlet, vertical shaft, vertical bend, and horizontal tunnel. The design flow was 860 cubic feet per second at reservoir elevation 545.8, with a pier located on the crest of the morning-glory inlet. When the pier was removed, the design capacity was increased slightly; however, the model was tested for flows up to 2,060 cubic feet per second, since a flow of this magnitude would be possible under extreme emergency operating conditions. Flow characteristics for still higher discharges were investigated to a limited degree to obtain research data on the hydraulic performance of morning-glory spillways.

## Preliminary Design

Description. The preliminary spillway design was as shown in Figure 4, but without the deflector and air vent in the vertical bend and without the horizontal deflectors through the vertical bend and horizontal tunnel. Although use of deflectors and an air vent were contemplated in the preliminary design, it was believed better to first test the structure without such appurtenances and to develop the best arrangement of these appurtenances by means of the model study.

Flow Characteristics in the Approach and Inlet. The flow approached the spillway inlet in a satisfactory manner, as shown by the confetti streaks on the water surface in Figure 6. However, the flow currents approaching from the right and left of the inlet opposed each other at a plane passing through the center of the inlet and approximately normal to the face of the dam. This caused wrinkling of the water surface in the inlet along this plane (Figures 6 and 7). The wrinkling was about the same on one side of the inlet as on the other side. In Figure 7 it is more apparent on the reservoir side because of the lighting arrangement.

When waves were generated in the reservoir to simulate wind waves in the prototype, the wrinkling became more pronounced around the entire morning-glory surface (Figures 6B and 7C). This wrinkled water surface is to be expected in a morning-glory inlet and is not objectionable.

Flow Characteristics in the Tunnel. The flow in the vertical shaft turned slightly in a clockwise direction as it fell through the shaft, as indicated by the flow lines in Figure 8. This slight spiraling of the flow continued in the vertical bend and horizontal tunnel. The spiraling flow was more pronounced when waves were generated in the reservoir.

## Modifications

Piers. A single, 2.5-foot-wide pier (Figure 9) was tested at various locations on the crest to determine its effect on the spiral flow. This pier could be used to house an air vent intake for the tunnel, should one be required. The pier was not effective in straightening the flow, particularly when 3-foot-high waves were generated in the reservoir. A set of six 12-inch-wide piers (Figure 9) was only slightly more effective. Since piers tend to trap debris in the prototype, plans for the use of piers to straighten the flow were abandoned and tests to develop a deflector in the vertical tunnel shaft were continued.

Deflectors. Deflectors were tested in several locations in attempts to direct the flow to the invert of the vertical bend and to straighten the spiral flow (Figure 10). A 1.75- by 11.25-foot deflector, placed near the top of the vertical shaft above the inside of the vertical bend. (Figure 10A) was ineffective in directing the flow to the outside of the vertical bend or in straightening the spiral flow. The deflector at the midpoint of the vertical shaft (Figure 10B) was effective for flows of 1,030 cubic feet per second and above.

The deflector with its lower end placed at the P.C. on the inside of the bend (Figure 10C) was effective in directing the flow to the outside of the bend and resulted in symmetrical flow in the horizontal tunnel. However, the deflector in this location caused a dishing in the water surface which resulted in water climbing the walls of the horizontal tunnel. This deflector also caused excessive vibration in the vertical shaft and bend. Tests with a smaller deflector at this location indicated only a minor degree of improvement in the flow conditions and vibration tendencies.

## Recommended Design

Description. In the recommended design (Figure 4) a vertical deflector with air vent and two horizontal deflectors were installed in the vertical bend. The vertical deflector began at the point of curvature of the inside of the vertical bend and extended downward until it projected outward a distance of 2 feet from the tunnel crown. The air vent was placed directly below the deflector lip and two horizontal deflectors extended from the downstream corners of the vertical deflector through the bend and for a distance of 42 feet into the horizontal tunnel. The 2-foot-wide undersurfaces of the vanes were tilted downward 4 inches toward the center of the tunnel.

Flow Characteristics in the Approach and Inlet. There were no changes in the preliminary design of the spillway approach or inlet. Therefore, flow characteristics were the same as described in the preliminary design section (Figures 6 and 7).

Flow Characteristics in the Tunnel. Since there was no change in the design of the inlet or tunnel shaft, the flow through the vertical shaft twisted slightly (Figure 10) similar to that observed in the preliminary design.

The deflector provided smooth flow through the bend and horizontal tunnel (Figures 11A and B). It was considered important that the deflector constrict the passageway through the bend a minimum amount; therefore, the 2-foot projection of the deflector was chosen in preference to a larger one.

A model of a 20-foot-long, 2- by 12-inch timber placed in the reservoir floated easily over the crest and through the structure. However, a similar-sized tree with branches might have more difficulty. Only a remote possibility of such an occurrence is expected in the prototype.

The horizontal deflectors were particularly useful in straightening the flow currents when wind waves were generated in the reservoir (Figures 11C and D). The vanes turned the flow inward and downward toward the center of the tunnel, thus maintaining a free passageway along the crown of the horizontal tunnel for the movement of air (Figures 11 and 12).

The air vent was provided as a precautionary measure to supply any additional air that might be required to insure steady flow through the tunnel. Normally, the major portion of the air requirement was drawn in through the morning-glory inlet. At times, air was momentarily expelled through the air vent.

Calibration. Calibration of the spillway showed the anticipated design capacity to occur at or very near the design reservoir elevation (Figure 13). The spillway discharged 875 cubic feet per second at design reservoir elevation, 545.80 feet, and the discharge coefficient was approximately 3.81, based upon the inlet circumference at crest elevation, 544.00 feet.

Pressures. Pressure measurements (Figures 14 and 15) showed slightly subatmospheric pressures to exist on the crest of the morning-glory profile, along the lower portion of the profile, and in the lower portion of the vertical shaft. None of these pressures was more than 2 feet of water below atmospheric for flows up to 1,030 cubic feet per second. For 2,060 cubic feet per second, the subatmospheric pressure was about 1.5 feet of water on the crest and about 2.5 feet in the throat. Pressures were above atmospheric through the vertical shaft for this flow.

Pressures observed on the invert of the vertical bend were above atmospheric (Figure 15). Piezometer 43 on the bottom face of one of the guide vanes at a point immediately below the downstream edge of the deflector indicated pressures that fluctuated slightly above and below atmospheric.

## Additional Test Data

Since the capacity of the morning-glory inlet had not been exceeded by the design requirements, it seemed desirable to briefly investigate discharge characteristics beyond the design requirements to obtain general hydraulic research data concerning flow characteristics of morning-glory spillways discharging into a vertical shaft.

Therefore, discharge measurements, pressure measurements, and photographs were recorded for flows up to and slightly beyond the point at which the inlet became submerged.

Calibration. Calibration of the spillway for flows exceeding the design flow showed the inlet to submerge at approximately 3,150 cubic feet per second as indicated by the change in direction of the discharge and coefficient curves (Figure 13). The data points did not indicate an exact point at which this occurred, but rather a short transition zone through which the flow changed from weir-controlled flow to orifice-controlled flow. At submergence the discharge coefficient is approximately 3.92. The maximum coefficient was about 3.99 at about 2,700 cubic feet per second.

Flow Characteristics. Flow in the inlet and in the approach area before and after submergence (Figures 16 and 17) showed a boil even after submergence. Submergence occurred when the top of boil was near the elevation of the crest. After the inlet submerged, a vortex intermittently appeared in the boil above the inlet. At higher heads, the boil disappeared, but the vortex alternately formed and disappeared.

Air was entrained in the flow in the vertical shaft of the spillway for free-flow discharges up to 3,100 cubic feet per second (Figure 18). For discharges that submerged the inlet, such as 3,240 cubic feet per second, the entrained air bubbles disappeared, and a vortex tail appeared in the vertical shaft. Increasing the flow still further caused the vortex tail to intermittently disappear. The vortex intermittently formed in the upper portion of the shaft and partially filled with foam (Figure 18C).

Pressures. Theoretical design profiles using Creager, Justin and Hinds1/ and Wagner2/ for discharges of 900 and 2,000 cubic feet per second are compared in Figure 19 with the actual design profile. The curvature of the design profile is much steeper than the theoretical profile in the vicinity of the crest and in the region above the throat at elevation 522. Subatmospheric pressures were observed in these areas (Figure 14). The observed pressures were above atmospheric in the regions where the curvature of the actual design profile is flatter than that of the theoretical profiles.

For free-flow discharges through the inlet that are not affected by the presence of a boil, the subatmospheric pressures in the throat were more severe to the right and left of the centerline than on the

1/Creager, Justin, and Hinds "Engineering of Dams," Volume I, General Design.
2/Paper No. 2802, ASCE Transactions, Volume 121, 1956, page 311, Morning-glory Shaft Spillways Symposium, "Determination of Pressure-controlled Profiles," by William E. Wagner M/ASCE.

centerline (Figure 14). The higher pressures on the centerline were due to the flow from the right and left of the morning-glory inlet coming together in this vicinity. This flow condition caused a fin to form over this portion of the inlet and thus produced the higher pressures (Figures 6A, 6C, 7A, and 7B).

The most severe subatmospheric pressure was about 12 feet of water below atmospheric (Figure 20) and occurred in the morning-glory throat when the inlet submerged. These subatmospheric pressures on the walls of the throat became atmospheric in the vertical shaft at about the elevation at which the vortex terminated (Figure 18C). Pressures below this point became increasingly greater than atmospheric because the vertical shaft was filled and operating under pressure.

Just before submergence at 3,025 cubic feet per second, the pressures in the vertical shaft fluctuated as much as 5 feet below atmospheric to 5 feet above atmospheric. Simultaneously the boil, shown in Figure 17A, fluctuated within the moring glory.

For flows not filling the shaft, such as 2,060 cubic feet per second, the pressures on the walls of the vertical shaft were approximately atmospheric (Figures 14 and 20). Near the lower end of the vertical shaft, immediately above the vertical bend, the pressures began to increase to above atmospheric (Figure 14) indicating that the vertical bend was beginning to turn the flow.

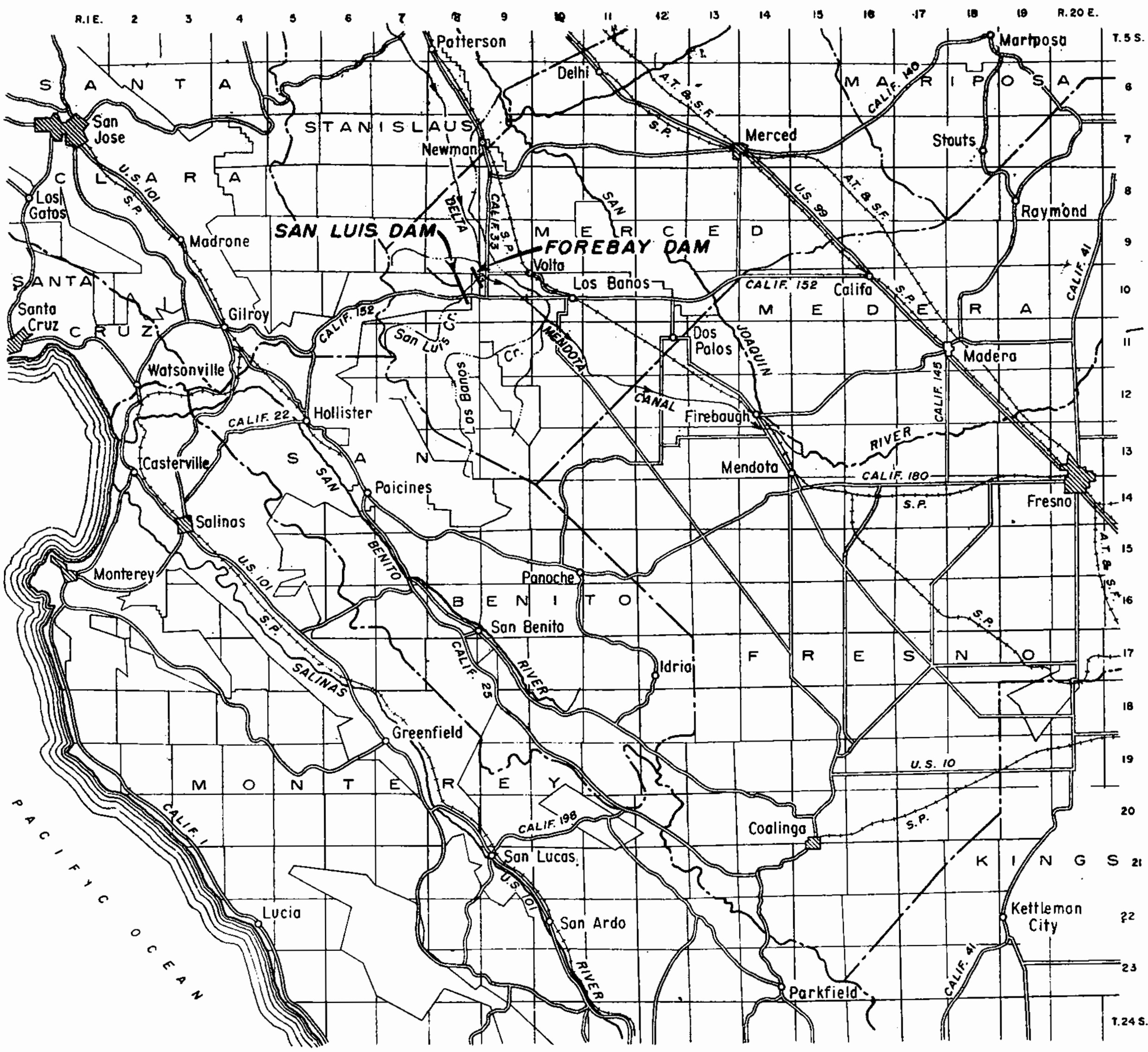
Pressures for submerged flow through the vertical bend (Figure 15) reached approximately 57 feet of water above atmospheric on the invert just upstream from the midpoint of the vertical bend. Pressures for unsubmerged flows reached a maximum at the midpoint.

Downstream from the bend the invert pressures were approximately equal to the depth of flow. This was also true for the submerged flow of 3,300 cubic feet per second since the horizontal tunnel was vented and flowed only partially full.

Table 1

DIMENSIONS OF THE HYDRAULIC FEATURES

| Feature | English units | Metric units |
|---|---|---|
| Height of dam | 320 feet | 97.54 meters |
| Length of dam at crest | 17,000 feet | 5,181.60 meters |
| Reservoir area | 13,000 acres | 52.6 square kilometers |
| Storage capacity | $2.1 \times 10^6$ acre-feet | $2.59 \times 10^9$ cubic meters |
| Spillway design capacity | 900 cubic feet per second | 25.5 cubic meters per second |
| Head on spillway crest at design discharge | 1.85 feet | 56.39 centimeters |
| Morning-glory inlet diameter | 31 feet | 9.45 meters |
| Drop from spillway crest to tunnel invert | 99 feet | 30.18 meters |
| Diameter of tunnel spillway | 9.5 feet | 2.90 meters |





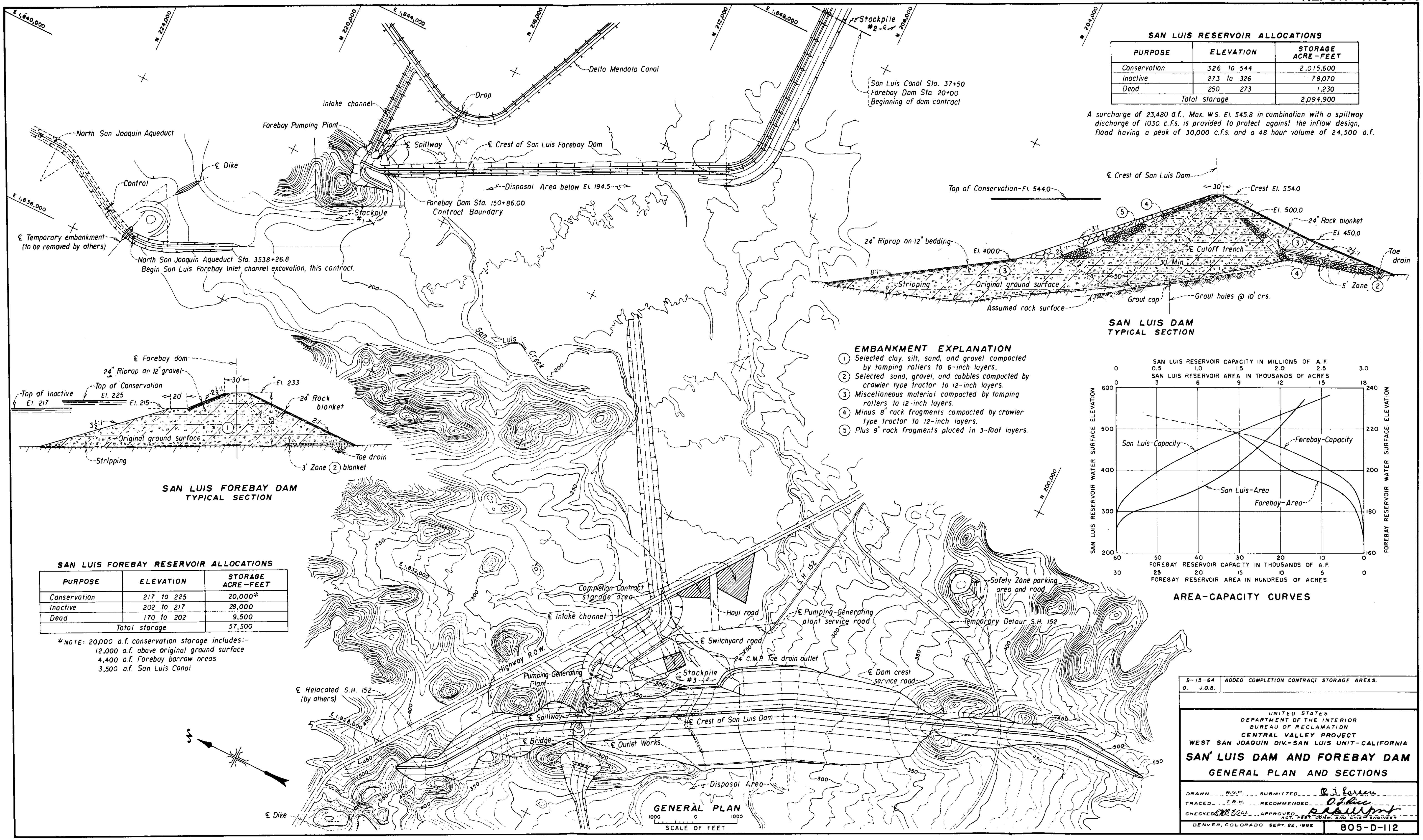
KEY MAP

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CENTRAL VALLEY PROJECT
WEST SAN JOAQUIN DIV. - SAN LUIS UNIT - CALIFORNIA

**SAN LUIS DAM AND FOREBAY DAM**
**LOCATION MAP**

| | |
|---|---|
| DRAWN W.W.G. | SUBMITTED R. J. Larsen |
| TRACED W.W.G. | RECOMMENDED A. L. Rice |
| CHECKED R.M.K.W. | APPROVED B. P. Bellport — ACT. ASST. COMM. AND CHIEF ENGINEER |
| DENVER, COLORADO SEPT. 22, 1962 | 805 - D - 111 |




**SAN LUIS RESERVOIR ALLOCATIONS**

| PURPOSE | ELEVATION | STORAGE ACRE-FEET |
|---|---|---|
| Conservation | 326 to 544 | 2,015,600 |
| Inactive | 273 to 326 | 78,070 |
| Dead | 250 273 | 1,230 |
| Total storage | | 2,094,900 |

A surcharge of 23,480 a.f., Max. W.S. El. 545.8 in combination with a spillway discharge of 1030 c.f.s. is provided to protect against the inflow design, flood having a peak of 30,000 c.f.s. and a 48 hour volume of 24,500 a.f.

**EMBANKMENT EXPLANATION**

1. Selected clay, silt, sand, and gravel compacted by tamping rollers to 6-inch layers.
2. Selected sand, gravel, and cobbles compacted by crawler type tractor to 12-inch layers.
3. Miscellaneous material compacted by tamping rollers to 12-inch layers.
4. Minus 8" rock fragments compacted by crawler type tractor to 12-inch layers.
5. Plus 8" rock fragments placed in 3-foot layers.

**SAN LUIS FOREBAY RESERVOIR ALLOCATIONS**

| PURPOSE | ELEVATION | STORAGE ACRE-FEET |
|---|---|---|
| Conservation | 217 to 225 | 20,000* |
| Inactive | 202 to 217 | 28,000 |
| Dead | 170 to 202 | 9,500 |
| Total storage | | 57,500 |

*NOTE: 20,000 a.f. conservation storage includes:-
12,000 a.f. above original ground surface
4,400 a.f. Forebay borrow areas
3,500 a.f. San Luis Canal

| | |
|---|---|
| 9-15-64 O. J.O.B. | ADDED COMPLETION CONTRACT STORAGE AREAS. |

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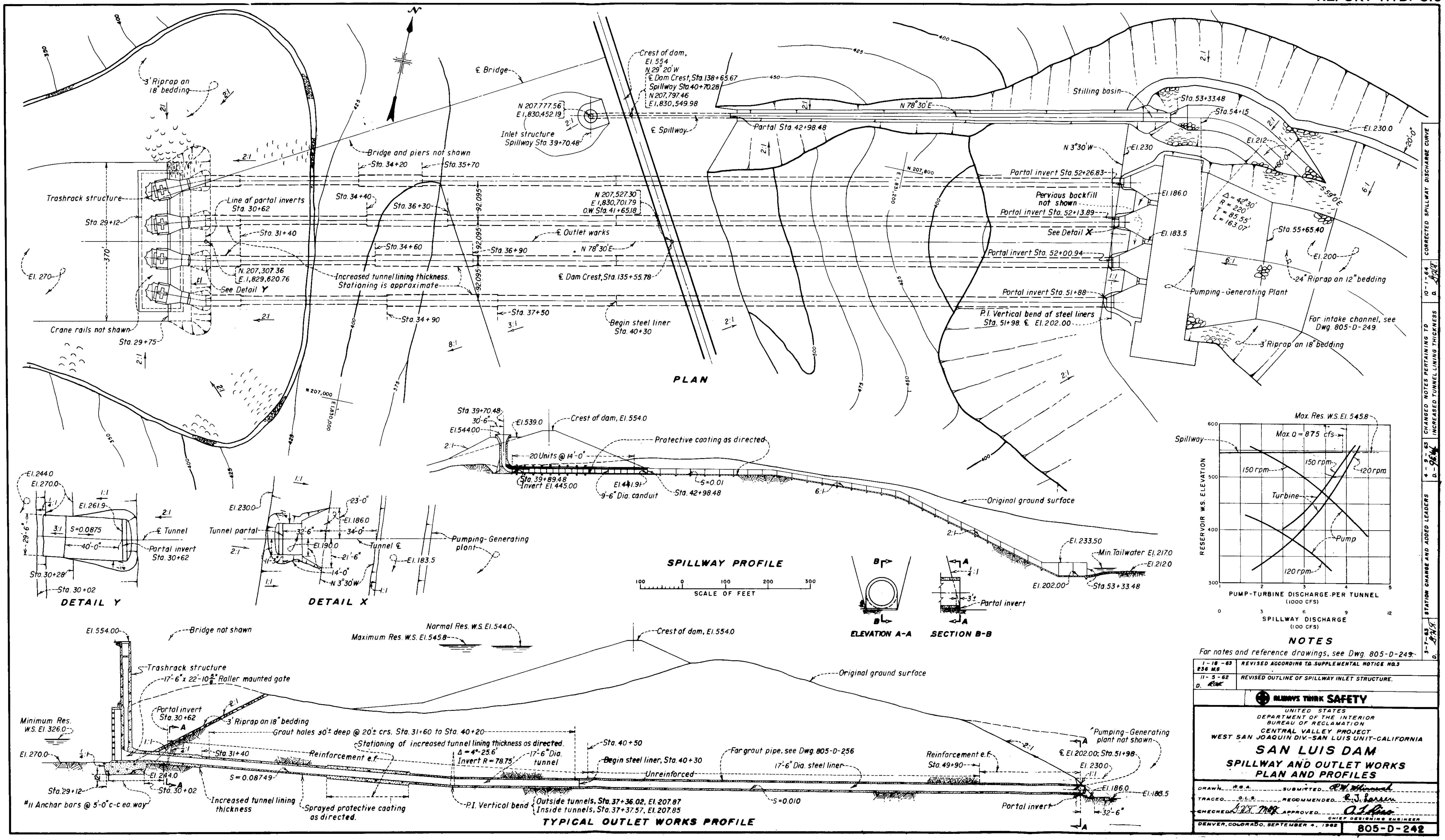
BUREAU OF RECLAMATION
CENTRAL VALLEY PROJECT
WEST SAN JOAQUIN DIV.-SAN LUIS UNIT-CALIFORNIA

**SAN LUIS DAM AND FOREBAY DAM**

GENERAL PLAN AND SECTIONS

DRAWN W.G.H. SUBMITTED
TRACED T.R.H. RECOMMENDED
CHECKED APPROVED
ACT. ASST. COMM. AND CHIEF ENGINEER
DENVER, COLORADO SEPT. 22, 1962 805-D-112


PLAN
SPILLWAY PROFILE
SCALE OF FEET
DETAIL Y
DETAIL X
ELEVATION A-A
SECTION B-B
TYPICAL OUTLET WORKS PROFILE
Crest of dam, El. 554, N 29° 20' W, ℄ Dam Crest, Sta. 138+65.67, Spillway Sta. 40+70.28, N 207,797.46, E 1,830,549.98
℄ Bridge
Inlet structure Spillway Sta. 39+70.48
N 207,777.56 E 1,830,452.19
℄ Spillway
Portal Sta. 42+98.48
N 78° 30' E
Stilling basin
Sta. 53+33.48
Sta. 54+15
El. 230.0
El. 212
S 59° E
Δ = 42° 30' R = 220' T = 85.55' L = 163.07'
Sta. 55+65.40
El. 200
24" Riprap on 12" bedding
Pumping-Generating Plant
For intake channel, see Dwg. 805-D-249
3' Riprap on 18" bedding
Trashrack structure
Sta. 29+12
Line of portal inverts Sta. 30+62
Sta. 31+40
N 207,307.36 E 1,829,620.76
See Detail Y
Crane rails not shown
Sta. 29+75
El. 270
Bridge and piers not shown
Sta. 34+20
Sta. 35+70
Sta. 34+40
Sta. 36+30
Sta. 34+60
Sta. 36+90
Sta. 34+90
Sta. 37+50
Increased tunnel lining thickness. Stationing is approximate
N 207,527.30 E 1,830,701.79 O.W. Sta. 41+65.18
℄ Outlet works
N 78° 30' E
℄ Dam Crest, Sta. 135+55.78
Begin steel liner Sta. 40+30
Portal invert Sta. 52+26.83
Pervious backfill not shown
Portal invert Sta. 52+13.89
See Detail X
Portal invert Sta. 52+00.94
Portal invert Sta. 51+88
P.I. Vertical bend of steel liners Sta. 51+98 ℄ El. 202.00
N 3° 30' W
El. 230
El. 186.0
El. 183.5
Sta. 39+70.48
30'-6"
El. 539.0
El. 544.00
Crest of dam, El. 554.0
Protective coating as directed
20 Units @ 14'-0"
Sta. 39+89.48 Invert El. 445.00
El. 441.91
9'-6" Dia. conduit
Sta. 42+98.48
S = 0.01
Original ground surface
El. 233.50
Min. Tailwater El. 217.0
El. 212.0
El. 202.00
Sta. 53+33.48
El. 244.0
El. 270.0
El. 261.9
S = 0.0875
℄ Tunnel
Portal invert Sta. 30+62
Sta. 30+28
Sta. 30+02
El. 230.0
Tunnel portal
El. 186.0
El. 190.0
Tunnel ℄
N 3° 30' W
Pumping-Generating plant
El. 183.5
Partial invert
Max. Res. W.S. El. 545.8
Max. Q = 875 cfs
Spillway
150 rpm
120 rpm
Turbine
Pump
RESERVOIR W.S. ELEVATION
PUMP-TURBINE DISCHARGE PER TUNNEL (1000 CFS)
SPILLWAY DISCHARGE (100 CFS)
NOTES
For notes and reference drawings, see Dwg. 805-D-249
El. 554.00
Bridge not shown
Normal Res. W.S. El. 544.0
Maximum Res. W.S. El. 545.8
Crest of dam, El. 554.0
Original ground surface
Trashrack structure
17'-6" x 22'-10 5/8" Roller mounted gate
Portal invert Sta. 30+62
3' Riprap on 18" bedding
Minimum Res. W.S. El. 326.0
Grout holes 30'± deep @ 20'± crs. Sta. 31+60 to Sta. 40+20
Stationing of increased tunnel lining thickness as directed.
Δ = 4°-25.6' Invert R = 78.75'
17'-6" Dia. tunnel
Sta. 40+50
Begin steel liner, Sta. 40+30
For grout pipe, see Dwg. 805-D-256
17'-6" Dia. steel liner
Reinforcement e.f.
Sta. 49+90
Pumping-Generating plant not shown
℄ El. 202.00; Sta. 51+98
El. 230.0
El. 186.0
El. 183.5
El. 270.0
El. 244.0
Sta. 31+40
S = 0.08749
Unreinforced
S = 0.010
Sta. 29+12
Sta. 30+02
#11 Anchor bars @ 5'-0" c-c ea. way
Increased tunnel lining thickness
Sprayed protective coating as directed.
P.I. Vertical bend
Outside tunnels, Sta. 37+36.02, El. 207.87
Inside tunnels, Sta. 37+37.57, El. 207.85
Portal invert
32'-6"
CORRECTED SPILLWAY DISCHARGE CURVE
CHANGED NOTES PERTAINING TO INCREASED TUNNEL LINING THICKNESS
STATION CHANGE AND ADDED LEADERS
1-18-63 REVISED ACCORDING TO SUPPLEMENTAL NOTICE NO. 3
11-5-62 REVISED OUTLINE OF SPILLWAY INLET STRUCTURE.
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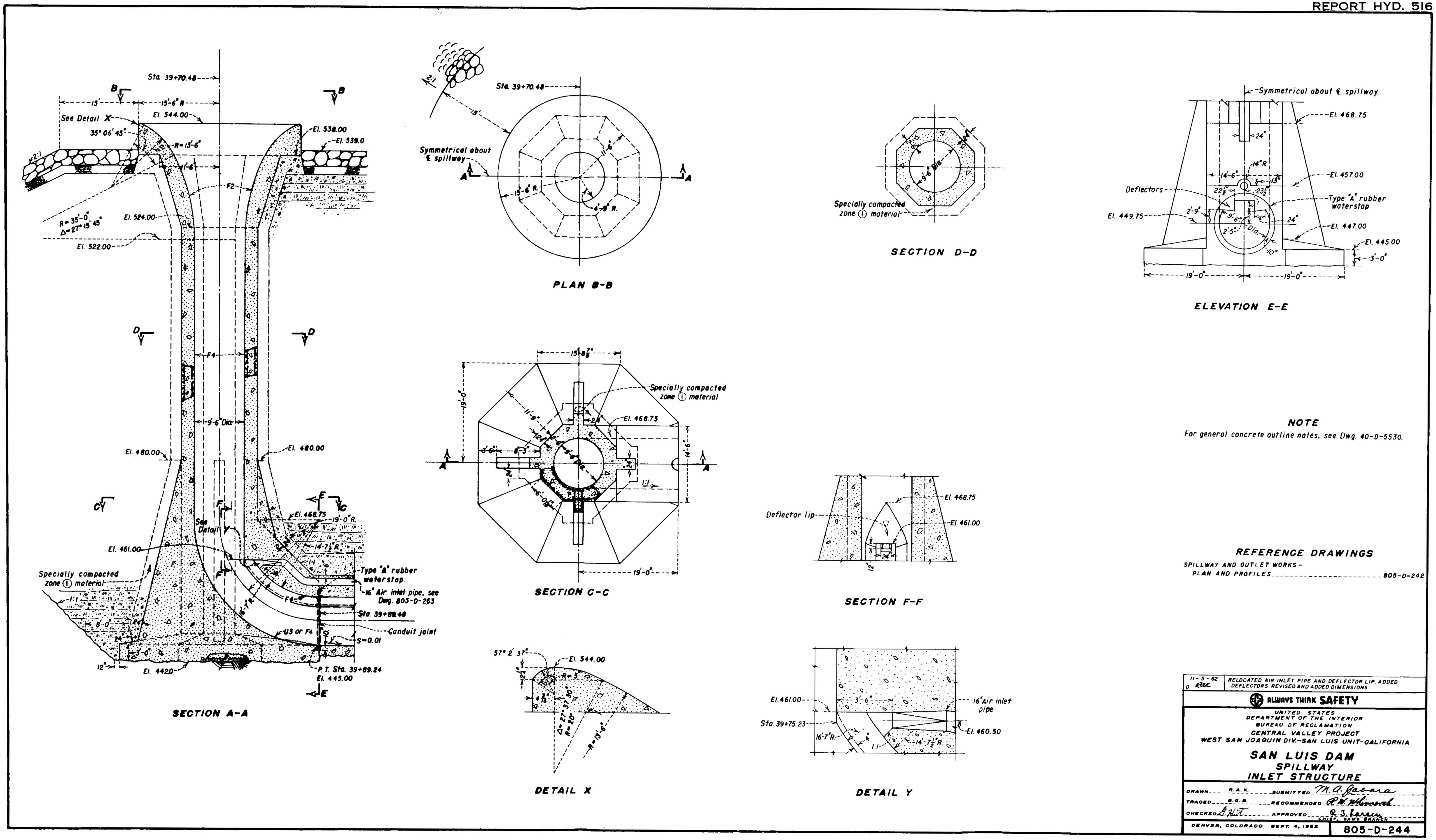
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CENTRAL VALLEY PROJECT
WEST SAN JOAQUIN DIV.-SAN LUIS UNIT-CALIFORNIA
SAN LUIS DAM
SPILLWAY AND OUTLET WORKS
PLAN AND PROFILES
DRAWN
TRACED
CHECKED
SUBMITTED
RECOMMENDED
APPROVED
CHIEF DESIGNING ENGINEER
DENVER, COLORADO, SEPTEMBER 4, 1962
805-D-242


SECTION A-A
PLAN B-B
SECTION C-C
SECTION D-D
ELEVATION E-E
SECTION F-F
DETAIL X
DETAIL Y
Sta. 39+70.48
See Detail X
El. 544.00
El. 538.00
El. 539.0
R=13'-6"
35° 06' 45"
R=35'-0"
Δ=27°15'45"
El. 524.00
El. 522.00
9'-6" Dia.
El. 480.00
El. 468.75
19'-0" R.
El. 461.00
Specially compacted zone (1) material
Type "A" rubber waterstop
16" Air inlet pipe, see Dwg. 805-D-263
Sta. 39+89.48
Conduit joint
S=0.01
P.T. Sta. 39+89.24
El. 445.00
El. 442.0
Symmetrical about ℄ spillway
Deflectors
El. 457.00
El. 449.75
El. 447.00
Deflector lip
16" Air inlet pipe
El. 460.50
Sta. 39+75.23
NOTE
For general concrete outline notes, see Dwg. 40-D-5530.
REFERENCE DRAWINGS
SPILLWAY AND OUTLET WORKS - PLAN AND PROFILES 805-D-242
11-5-62 RELOCATED AIR INLET PIPE AND DEFLECTOR LIP. ADDED DEFLECTORS. REVISED AND ADDED DIMENSIONS.
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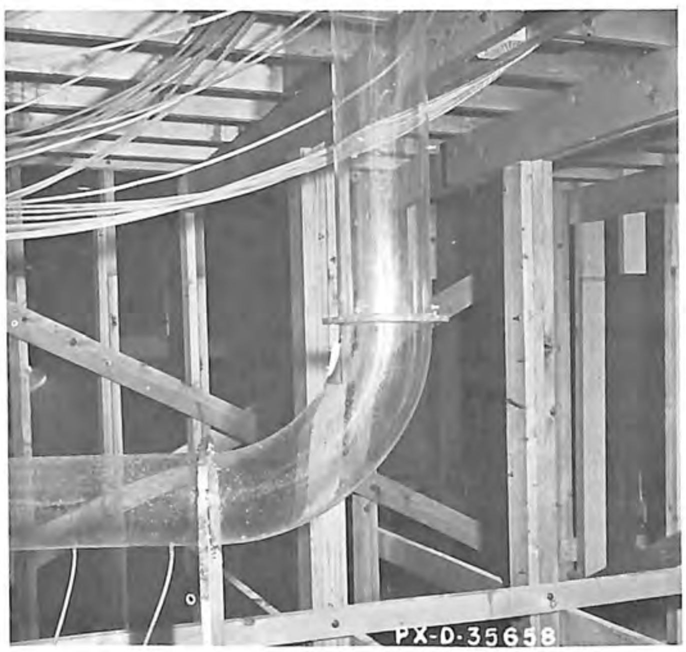
UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION
CENTRAL VALLEY PROJECT
WEST SAN JOAQUIN DIV.-SAN LUIS UNIT-CALIFORNIA
SAN LUIS DAM
SPILLWAY
INLET STRUCTURE
DENVER, COLORADO SEPT. 4, 1962
805-D-244


A. Upstream face of dam and inlet.

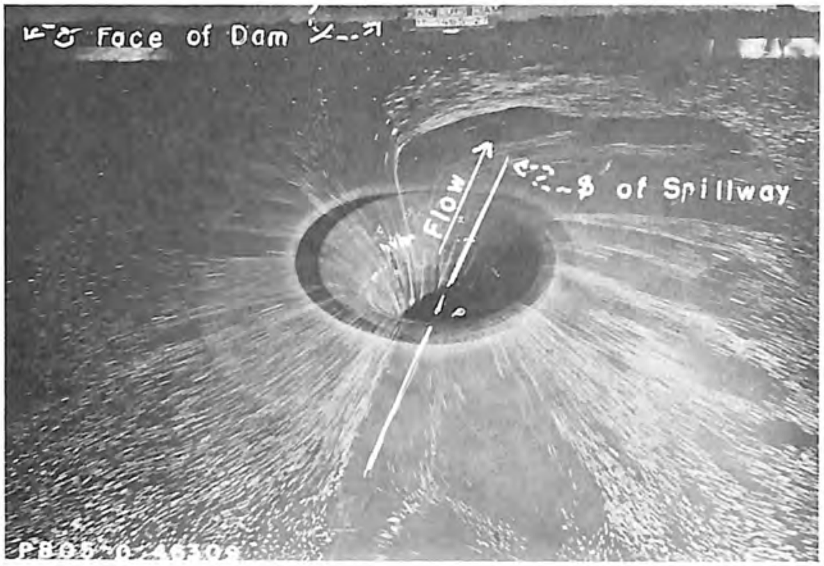



B. Vertical shaft, vertical bend, and horizontal tunnel.

SAN LUIS DAM SPILLWAY

The 1:14.83 Scale Model

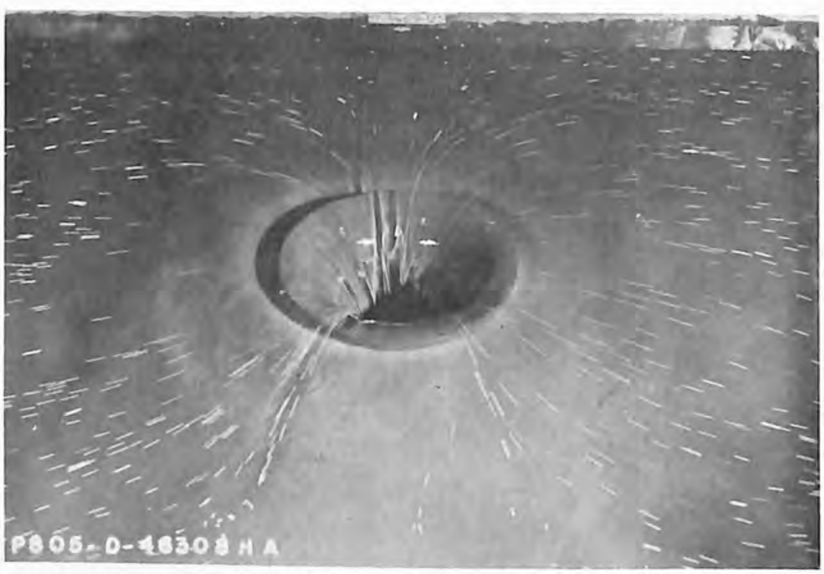
Figure 6
Report Hyd-516




A. 1,030 cubic feet per second.

Note: Flow arrow indicates direction of flow in horizontal tunnel.

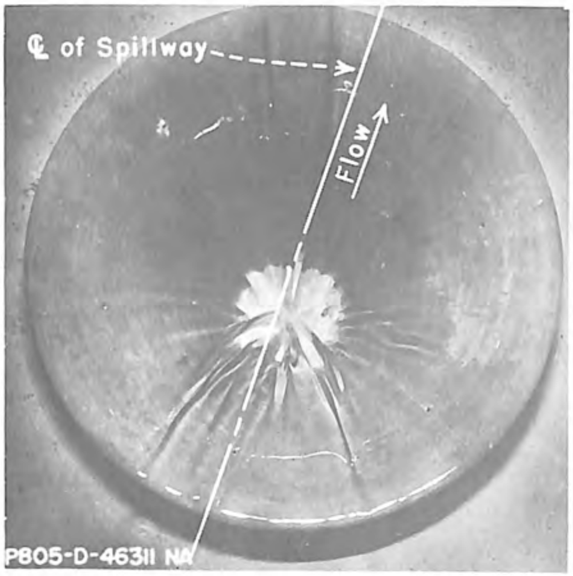

B. 1,030 cubic feet per second with simulated wind waves in reservoir.



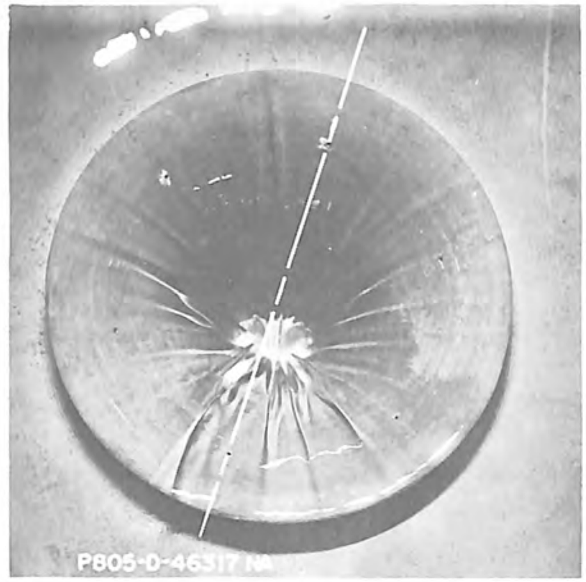

C. 2,060 cubic feet per second.

SAN LUIS DAM SPILLWAY

Flow in Approach Area
1:14.83 Scale Model




A. 1,030 cubic feet per second.




B. 2,060 cubic feet per second.

Note: Arrow shows direction of flow in tunnel.


C. 1,030 cubic feet per second
with simulated wind waves
in the reservoir.

SAN LUIS DAM SPILLWAY

Flow in Inlet
1:14.83 Scale Model

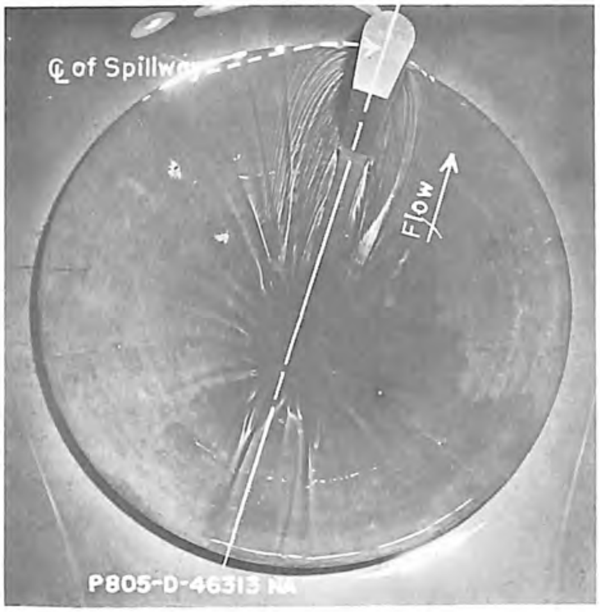
Figure 8
Report Hyd-516


A. 1,030 cubic feet per second.

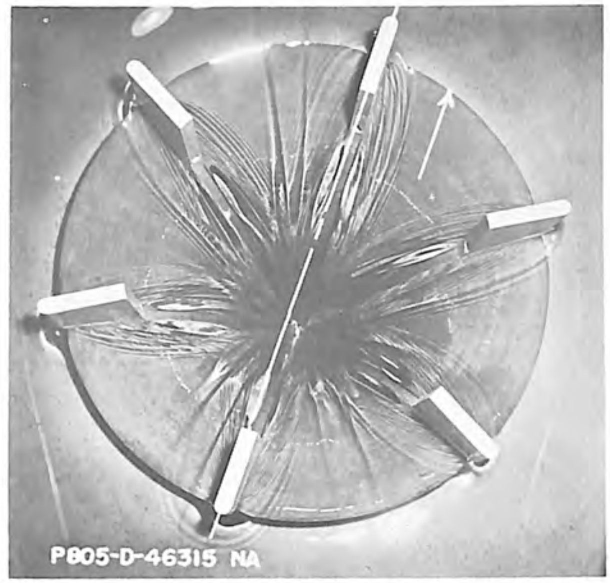

B. 2,060 cubic feet per second.

SAN LUIS DAM SPILLWAY

Flow in Preliminary Tunnel
1:14.83 Scale Model

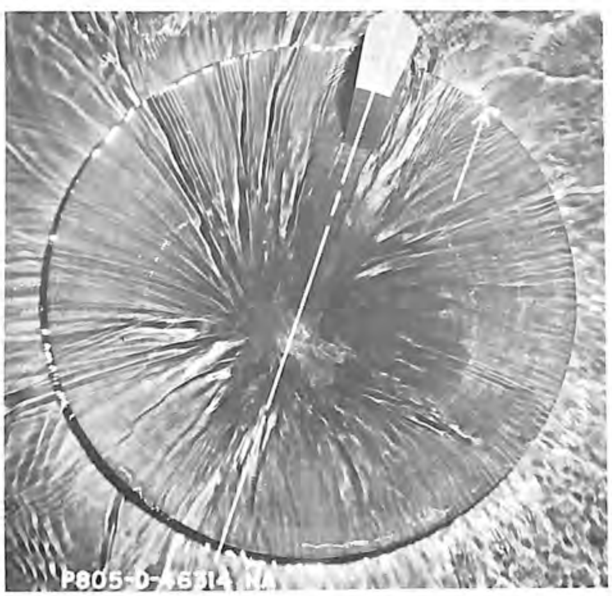


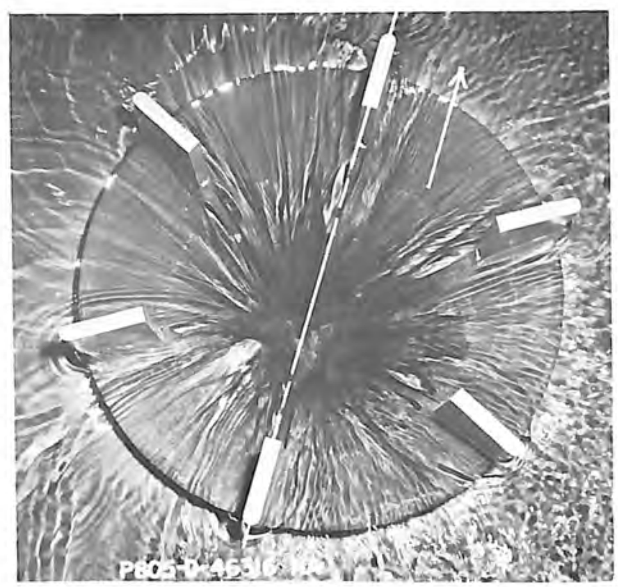

A. Single pier.




B. Six guide piers.

Note: Arrows show direction of flow in tunnel.





C. and D. Piers on crest with simulated wind waves in the reservoir.

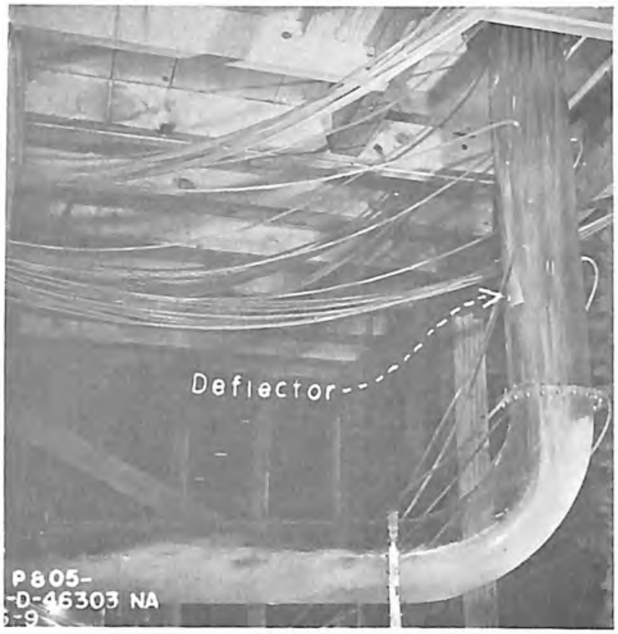
Discharge = 1,030 cubic feet per second.

SAN LUIS DAM SPILLWAY

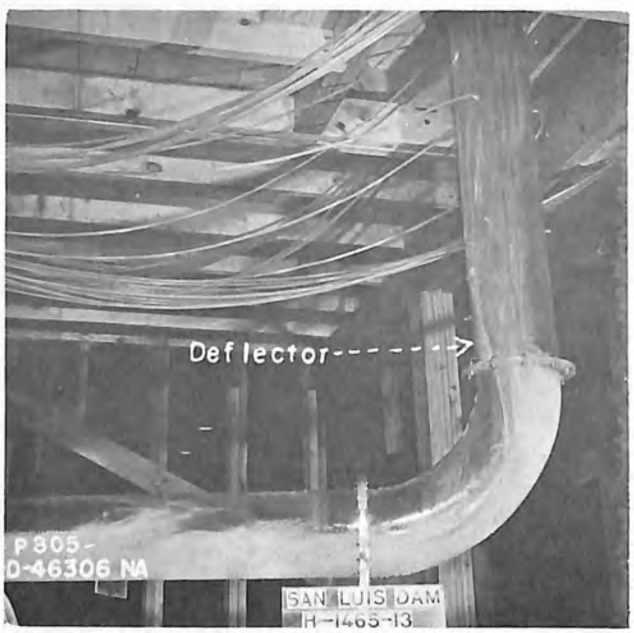
Flow in Modified Inlet
1:14.83 Scale Model

Figure 10
Report Hyd-516

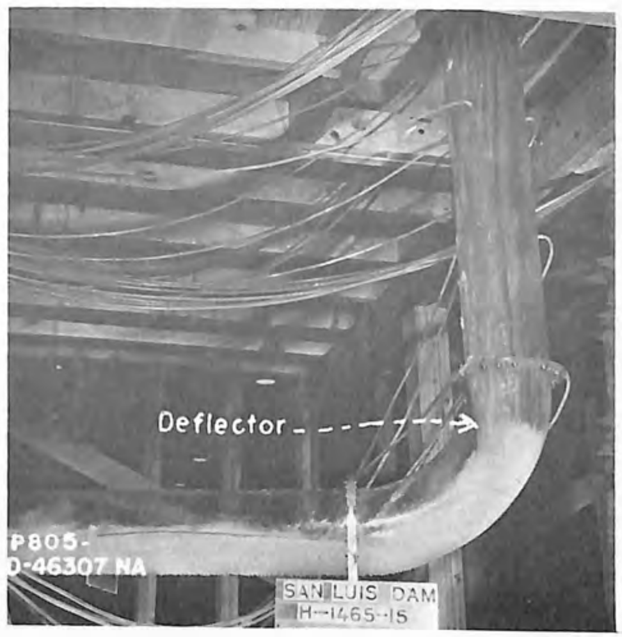

A. Deflector begins at top of vertical shaft.




B. Deflector ends at elevation 485 in vertical shaft.




C. Deflector at base of vertical shaft.



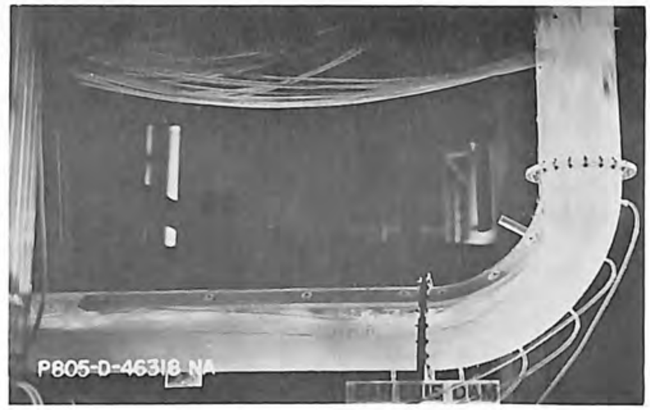

D. Deflector extending into vertical bend.

Discharge = 1,030 cubic feet per second.

SAN LUIS DAM SPILLWAY

Effect of Deflectors in Vertical Shaft
1:14.83 Scale Model


A. 1, 030 cubic feet per second.



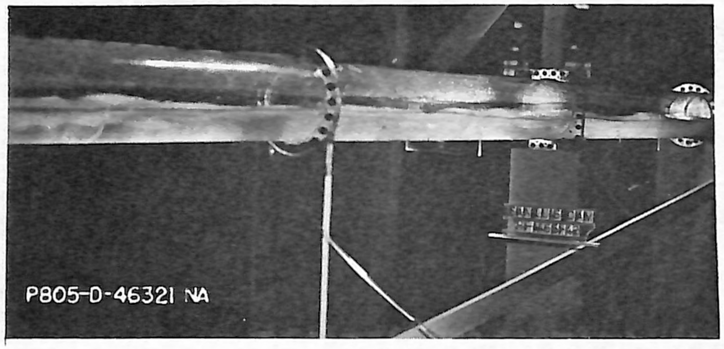

B. 2, 060 cubic feet per second.


C. 1, 030 cubic feet per second with simulated wind waves in the reservoir.

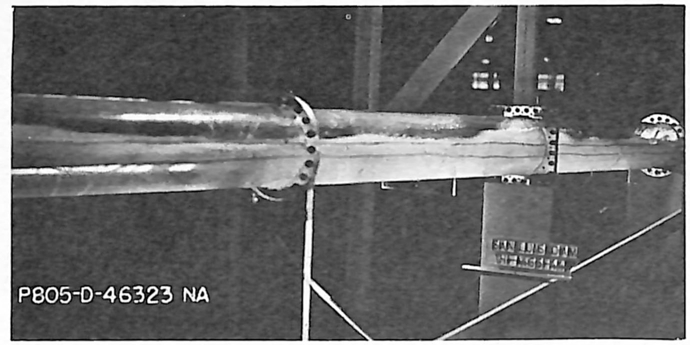

D. 2, 060 cubic feet per second with simulated wind waves in the reservoir.

SAN LUIS DAM SPILLWAY

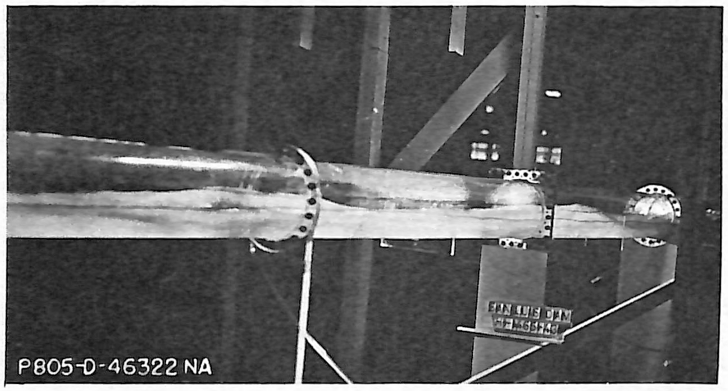
Flow in Recommended Tunnel Bend
1:14.83 Scale Model



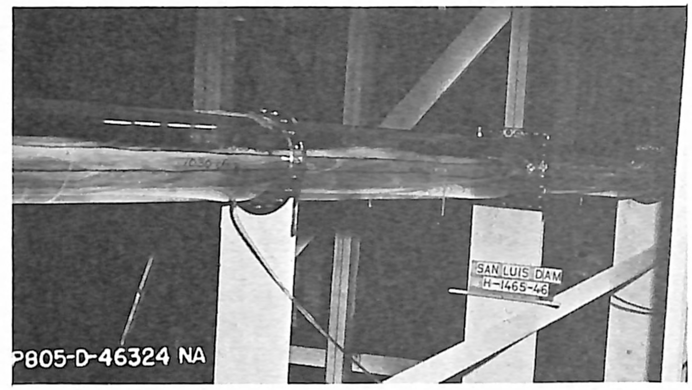

A. 1, 030 cubic feet per second.




B. 2, 060 cubic feet per second.



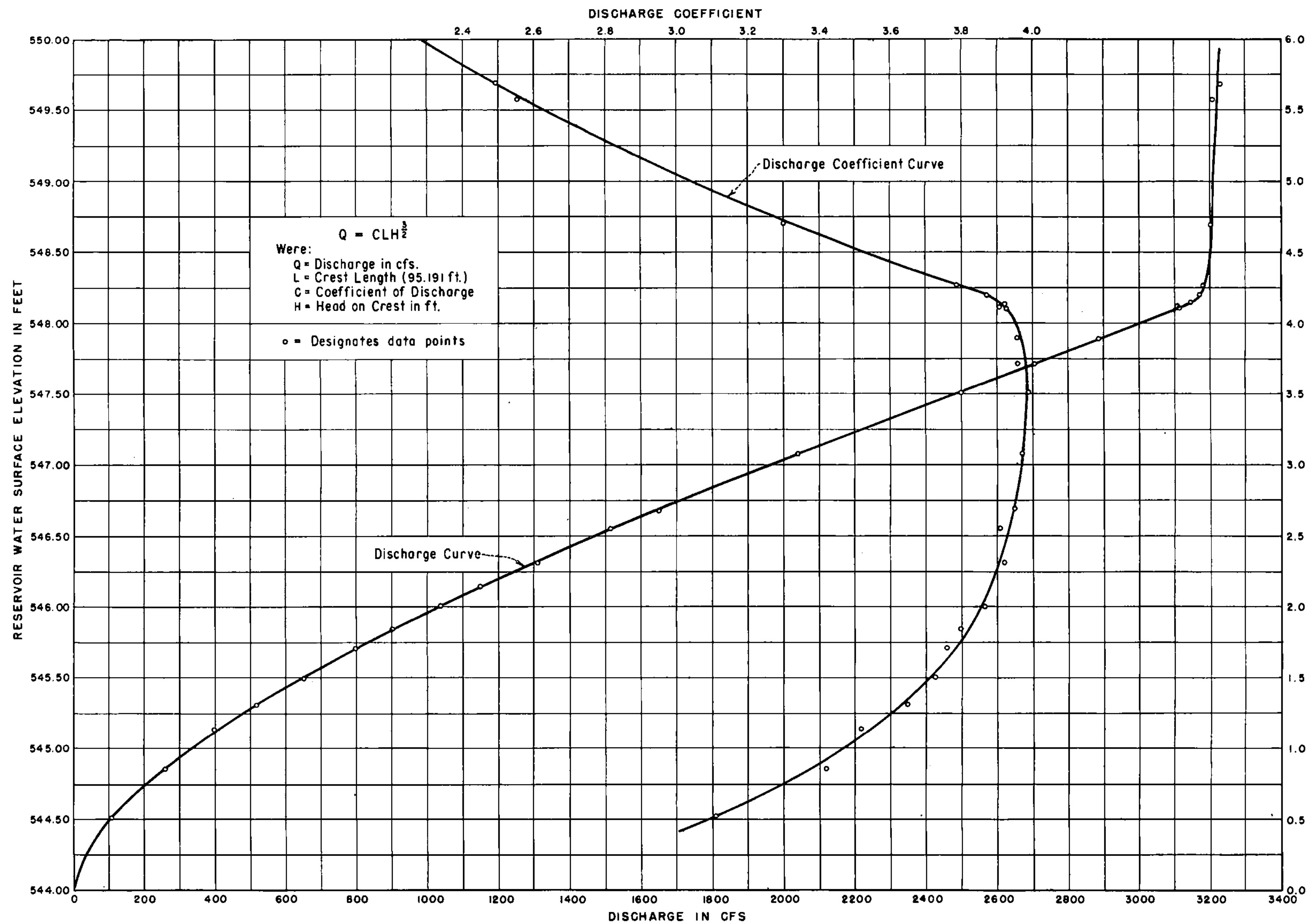

C. 1, 030 cubic feet per second with simulated wind waves in the reservoir.



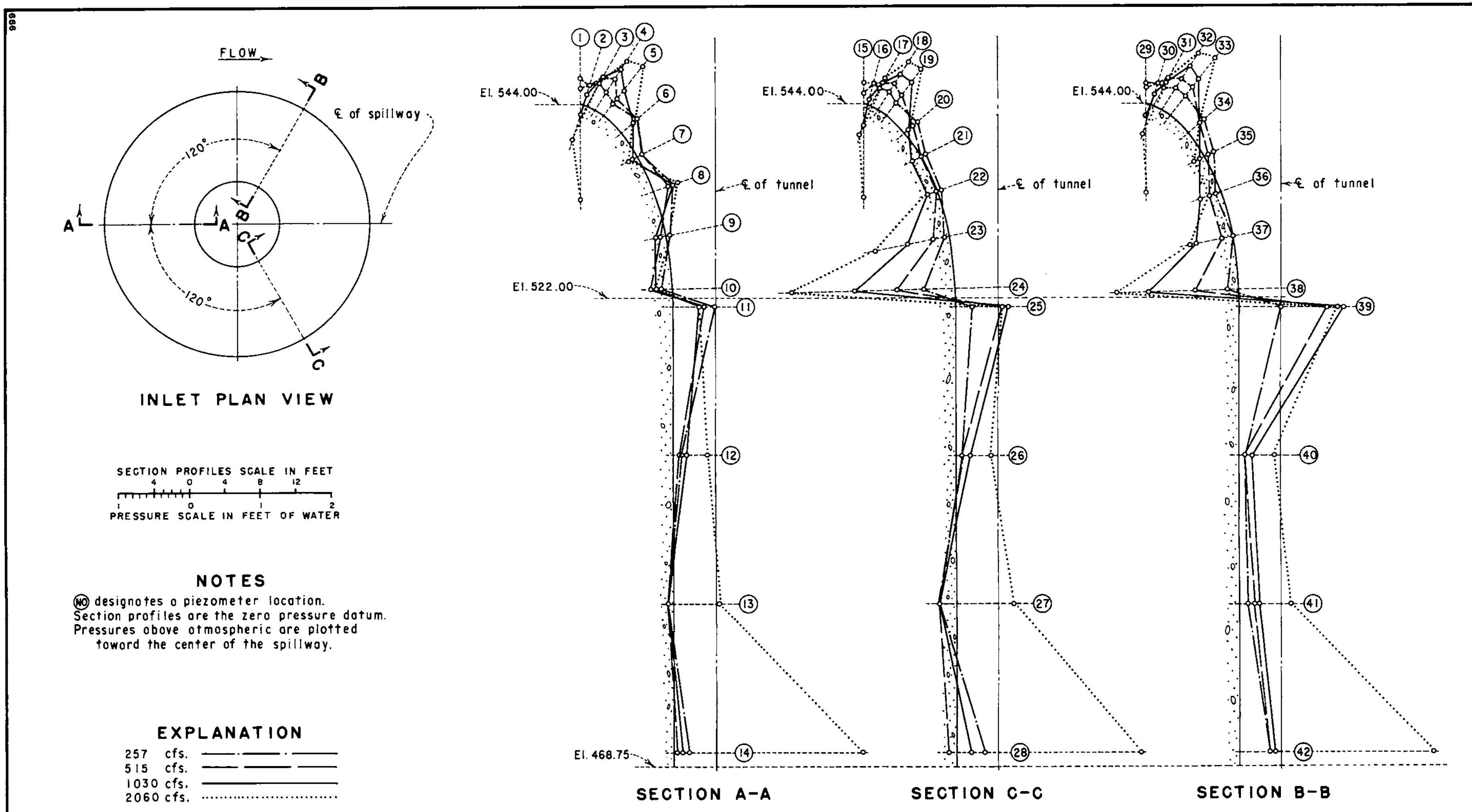

D. 2, 060 cubic feet per second with simulated wind waves in the reservoir.

SAN LUIS DAM SPILLWAY

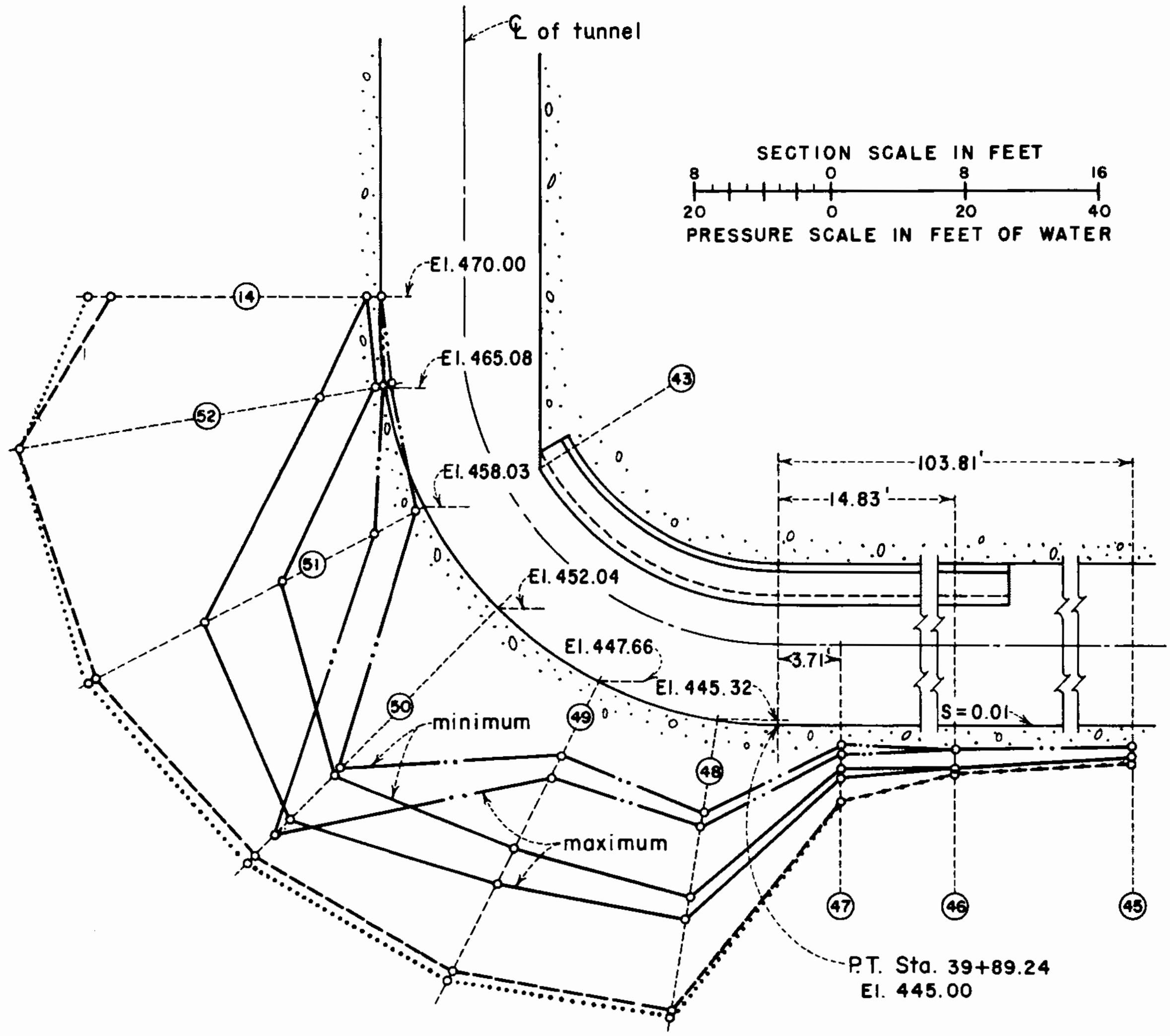
Flow in Horizontal Tunnel
with recommended air vent and deflectors
1:14.83 Scale Model




**SAN LUIS DAM SPILLWAY**
**DISCHARGE CAPACITY AND COEFFICIENT CURVES**
1:14.83 SCALE MODEL




SAN LUIS DAM SPILLWAY
PRESSURES IN INLET AND VERTICAL SHAFT
1:14.83 SCALE MODEL




## NOTES

(NO) designates a piezometer location.

The bend invert is the zero pressure datum. Pressures above atmospheric are plotted outward from the datum. Piezometer NO. 43 is normally not in contact with the flow. The pressure here varies from 1.5 feet below atmospheric to 1.5 feet above atmospheric for 2060 cfs flow and ±0.5 feet at 1030 cfs.

## EXPLANATION

2060 cfs. ————————
3200 cfs. — — — — — —
3300 cfs. ···················
1030 cfs. ———— · · ————

# SAN LUIS DAM SPILLWAY
## PRESSURES IN VERTICAL BEND
1 : 14.83 SCALE MODEL


A. 3,100 cubic feet per second, reservoir elevation 548.1.

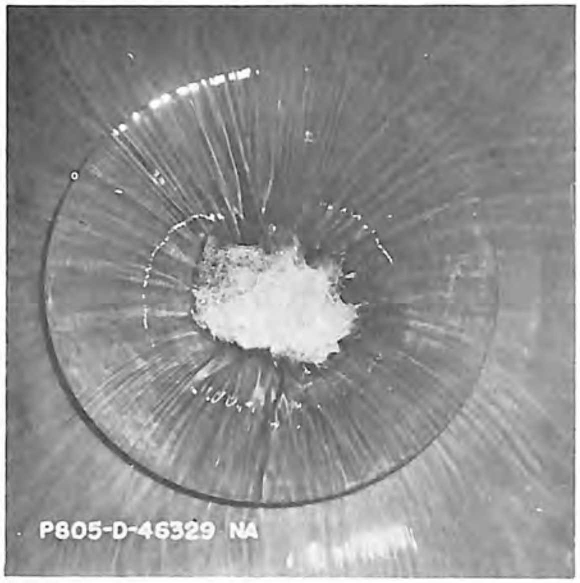

B. 3,240 cubic feet per second, reservoir elevation 550.


C. 3,500 cubic feet per second, reservoir elevation 555 plus or minus.

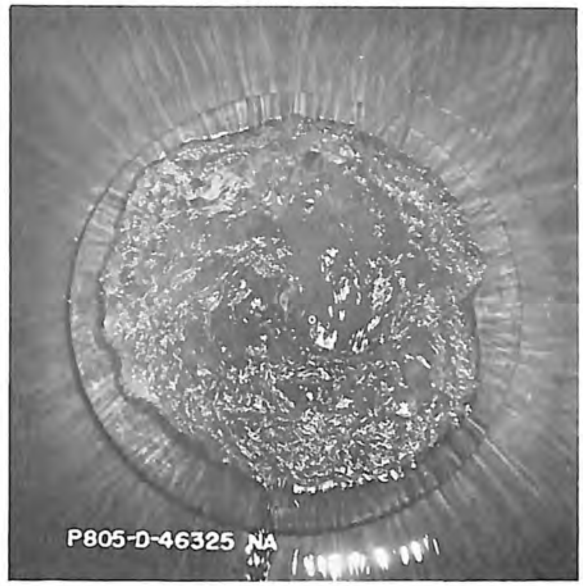
SAN LUIS DAM SPILLWAY

Large Flows in Approach Area
1:14.83 Scale Model

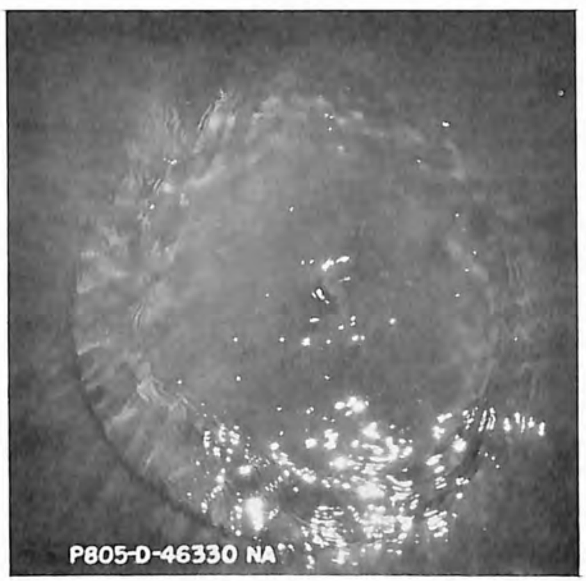
Figure 17
Report Hyd-516




A. 3,100 cubic feet per second, reservoir elevation 548.1.




B. 3,240 cubic feet per second, reservoir elevation 550.




C. 3,500 cubic feet per second, reservoir elevation 555 plus or minus.

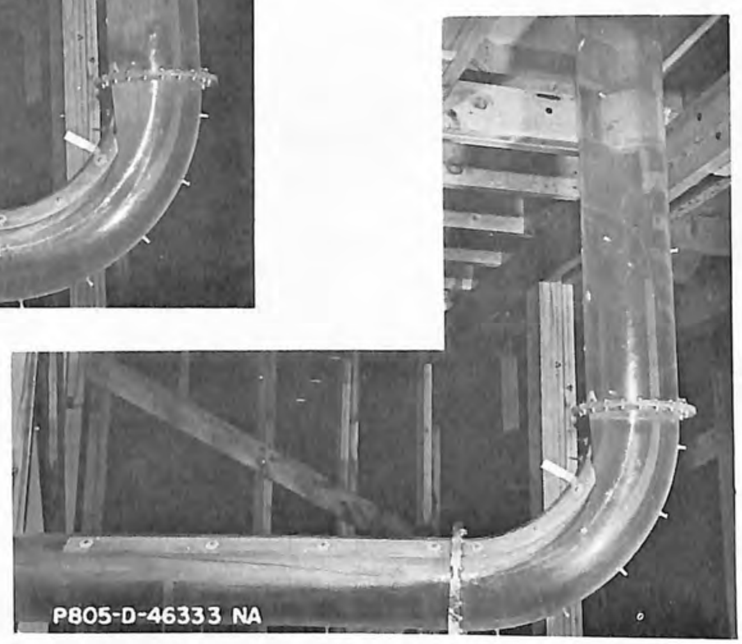
SAN LUIS DAM SPILLWAY

Large Flows in Inlet
1:14.83 Scale Model


A. 3,100 cubic feet per second (air-entrained flow).


B. 3,240 cubic feet per second (vortex present in vertical shaft and bend).

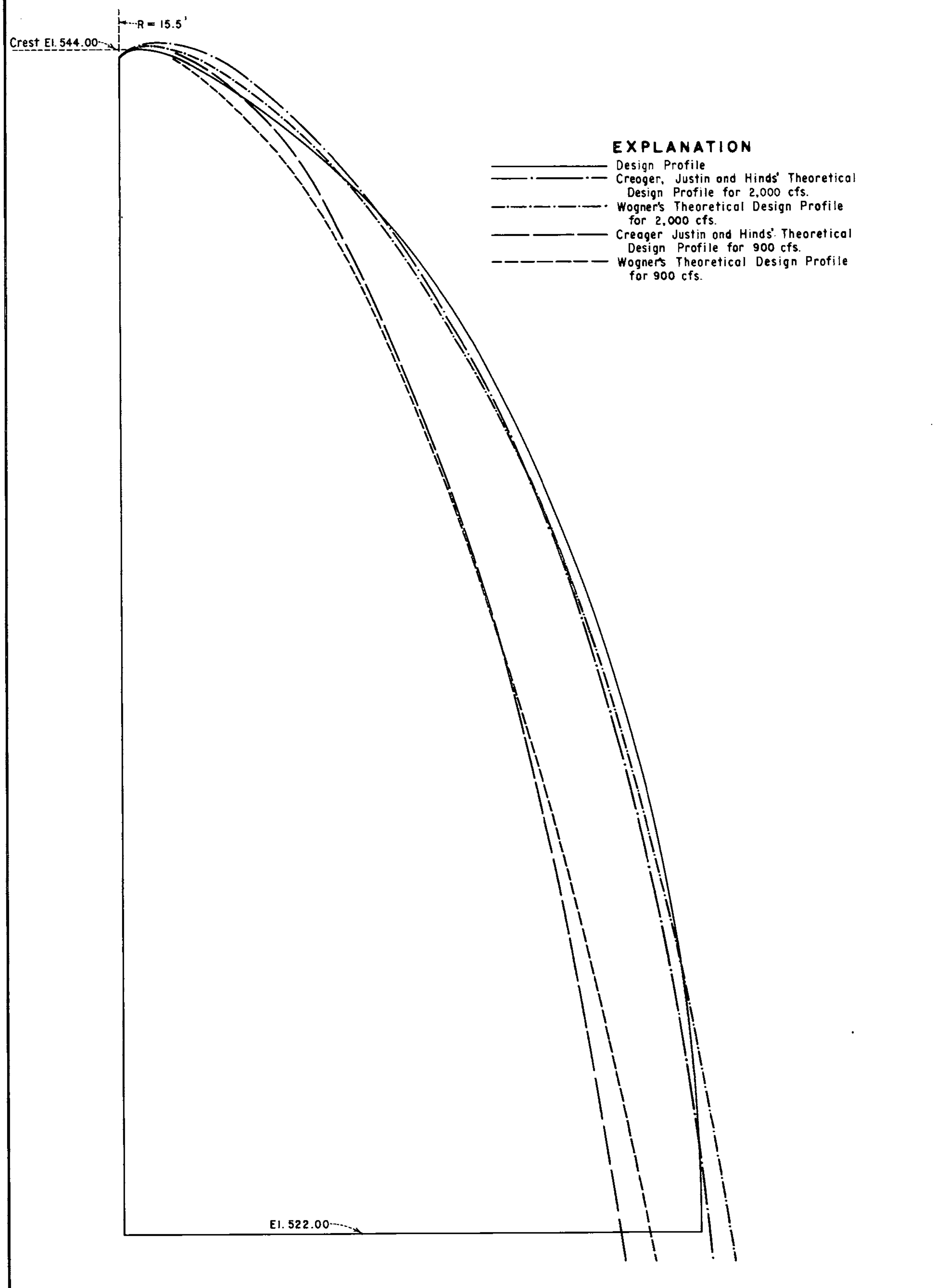

C. 3,500 cubic feet per second (vortex terminates in the upper region of the vertical shaft and partially fills with foam).



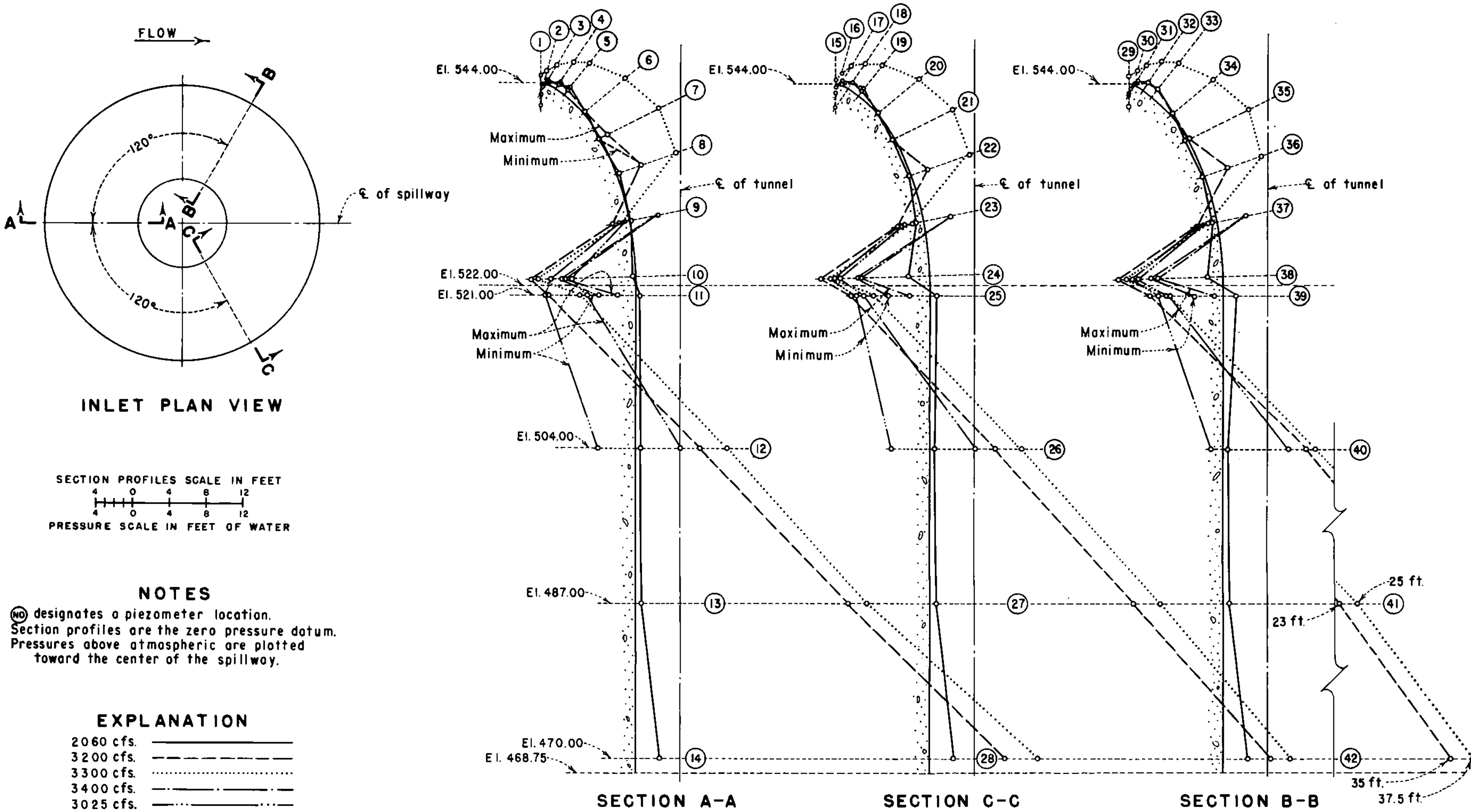

D. 3,500 cubic feet per second (no vortex or air entrained in flow).

SAN LUIS DAM SPILLWAY

Large Flows in Tunnel
1:14.83 Scale Model




SAN LUIS DAM SPILLWAY
CREST PROFILES




## NOTES

(NO) designates a piezometer location.
Section profiles are the zero pressure datum.
Pressures above atmospheric are plotted toward the center of the spillway.

## EXPLANATION

2060 cfs. ——————
3200 cfs. — — — — —
3300 cfs. ··············
3400 cfs. —·—·—
3025 cfs. —···—

# SAN LUIS DAM SPILLWAY

## PRESSURES IN INLET AND VERTICAL SHAFT FOR LARGE FLOWS

1:14.83 SCALE MODEL

7-1750
(10-64)

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, January 1964) except that additional factors (*) commonly used in the Bureau have been added. Further discussion of definitions of quantities and units is given on pages 10-11 of 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.

Table 1

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 (exactly)* | Square centimeters |
| | 0.092903 (exactly) | 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.) | 9,463.58 | Cubic centimeters |
| | 0.946358 | 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 |
| | $1.12985 \times 10^{6}$ | Centimeter-dynes |
| Foot-pounds | 0.138255 | Meter-kilograms |
| | $1.35582 \times 10^{7}$ | 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 | $0.965873 \times 10^{-6}$* | 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 |
| | $4.4482 \times 10^{-5}$* | Dynes |
| **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) | 0.02903* (exactly) | 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 845-237

ABSTRACT

Model studies were conducted to develop the hydraulic design of the spillway approach, morning-glory inlet, vertical shaft, vertical bend, and the nearly horizontal portion of the tunnel. A vertical deflector with an air vent and two horizontal deflectors were devised to provide smooth flow through the vertical bend and to prevent the flow from spiraling through the horizontal portion of the tunnel. These devices were needed particularly when wind waves were generated on the reservoir water surface as this affected the flow in the tunnel. Discharges higher than the design requirements were briefly investigated to obtain general hydraulic research data concerning the flow characteristics of morning-glory spillways.

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Hyd-516
Beichley, G. L.
HYDRAULIC MODEL STUDIES OF SAN LUIS DAM SPILLWAY, CENTRAL VALLEY PROJECT, CALIFORNIA
Laboratory Report, Bureau of Reclamation, Denver, 9 pp., 20 Figures, 1 Table, 2 References, 1964

DESCRIPTORS--*Spillways/ spillway crests/ piers/ discharge coefficients/ hydraulic similitude/ piezometers/ *Hydraulic models/ guide vanes/ vents/ tunnel hydraulics

IDENTIFIERS--*Subatmospheric pressures/ *morning-glory inlets/ tunnel bends/ * tunnel deflectors

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IDENTIFIERS--*Subatmospheric pressures/ *morning-glory inlets/ tunnel bends/ * tunnel deflectors

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