UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDIES OF BULLY CREEK DAM
BULLY CREEK OUTLET WORKS
VALE PROJECT, OREGON

Hydraulic Laboratory Report No. Hyd-494

DIVISION OF RESEARCH

OFFICE OF ASSISTANT COMMISSIONER AND CHIEF ENGINEER
DENVER, COLORADO

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Laboratory Report No. Hyd-494
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Subject: Hydraulic model studies of Bully Creek Dam--Bully Creek outlet works--Vale Project, Oregon

PURPOSE

The purpose of this study was to determine the efficiency of the hydraulic jump stilling basin and to observe flow conditions on the chute and in the channel downstream from the stilling basin.

CONCLUSIONS

1. Initial operation of the model indicated undesirable flow conditions in the stilling basin for the maximum discharge of 283 second-feet, Figure 8.

2. Good flow conditions were observed in the stilling basin for the normal discharge of 90 second-feet, Figure 9, and for discharges at maximum reservoir elevation with gate openings of 75, 50, and 25 percent.

3. Sand erosion tests indicated that material would be deposited immediately downstream from the basin, Figure 10. Also, some material was deposited inside the basin.

4. Further studies indicated that the addition of baffle piers 10 feet downstream from the chute blocks would greatly improve the performance of the stilling basin for maximum or near-maximum discharges, Figure 11. No material was deposited in the basin with baffle piers installed.

5. Studies showed that the proposed riprap would give adequate protection against scour in the downstream channel for all operating conditions, with no baffle piers in the basin, Figure 12.

6. In spite of the undesirable operating characteristics of the maximum discharge, the operation of the stilling basin as originally

designed was considered acceptable. A discharge of more than 90 cubic feet per second is not a design requirement and will occur only if the gates are inadvertently opened too far. Also, the dynamic forces on the baffle piers would probably cause destruction of the piers in a short time. The riprap will provide adequate protection against scour in the downstream channel if the maximum discharge accidentally occurs.

7. Flow conditions on the 2:1 sloping chute were found to be satisfactory for all discharges.

8. The angle of inclination of the gate with respect to the 2:1 sloping chute had little effect on the flow distribution downstream from the gate.

9. Piezometers placed at selected points on the chute and in the stilling basin showed that pressures in the structure would be within allowable limits.

10. Waves in the downstream channel had a maximum height of less than 1 foot.

11. Tailwater sweepout tests indicated a safety margin of approximately 4 feet between the expected minimum degraded tailwater and the tailwater elevation at which the hydraulic jump first exposed the chute blocks at the upstream end of the stilling basin. This safety margin was determined for the maximum discharge of 283 second-feet.

INTRODUCTION

Bully Creek Dam is one of the principal features of the Vale Project and is located about 8 miles west of Vale, Oregon, Figure 1. The dam is a rolled earthfill structure about 104 feet high and 3,000 feet long. The principal hydraulic features of the dam are a spillway located in the right abutment, and an outlet works located to the left of the spillway. The outlet works conduit is divided by a wye branch into a creek outlet works and a canal outlet works, Figures 2 and 3. The model studies described herein are for the creek outlet works. Model studies of the canal outlet works are discussed in Hydraulic Laboratory Report No. Hyd-495.

The Bully Creek outlet works, controlled by a single 2-foot 3-inch square high pressure slide gate, Figure 4, has a maximum discharge capacity of 283 second-feet, and a normal operating discharge of 90 second-feet. The gate discharges on to a 2:1 sloping diverging chute, into a hydraulic jump stilling basin, Figure 5, and then into the river channel. Operating criteria specify that for usual operation the gate will be partially opened to pass the normal discharge of 90 second-feet at maximum reservoir elevation. The outlet works will not pass the maximum discharge of 283 second-feet unless the gate is inadvertently opened to 100 percent with the reservoir at maximum elevation.

THE MODEL

The Bully Creek outlet works model, built to a geometrical scale of 1:6.75, consisted of the high pressure slide gate, the 2:1 sloping diverging chute, the hydraulic jump stilling basin, and a portion of the downstream river channel, Figures 6 and 7.

The chute and stilling basin were constructed of plywood treated to resist swelling and the stilling basin included chute blocks and a dentated end sill. The outlet channel was formed with sand having an average size of 0.8 millimeter.

Nineteen piezometers were placed at selected points in the chute and stilling basin to investigate the possible occurrence of adverse subatmospheric pressures or excessively high impact pressures.

Water was distributed to the high pressure gate from a baffled manifold connected directly to the laboratory supply system. Model discharges were measured using volumetrically calibrated Venturi meters which are permanent laboratory installations.

The head on the gate was measured with three pressure taps located immediately upstream from the miter bend, approximately 5 diameters downstream from the baffled manifold, Figure 6. The pressure taps, connected to a mercury pot gage manometer, were located on the sides and bottom of the conduit to measure the average pressure.

Tailwater elevations were controlled with an adjustable tailgate and were measured with a staff gage located near the center of the channel at approximately Station 16+40.

THE INVESTIGATION

The investigation was conducted to determine the efficiency and operating characteristics of the chute and stilling basin for the maximum discharge and the normal discharge, with both normal and degraded tailwater. The tailwater is expected to be lowered 2.8 feet due to degradation of the downstream channel. The discharge tailwater curve for the degraded channel is shown in Figure 3.

The Preliminary Stilling Basin

Initial operation of the model indicated that undesirable flow conditions existed in the stilling basin for the maximum discharge of 283 second-feet. The boil at the end of the hydraulic jump occurred in the channel downstream from the stilling basin, Figure 8, and violent surging occurred at the toe of the jump. Performance of the stilling basin for the normal discharge of 90 second-feet was found to be satisfactory, Figure 9. The stilling basin was also satisfactory for discharges at the maximum reservoir elevation for gate openings of 75, 50, and 25 percent. A sand erosion test was made to determine the erosive tendencies of the maximum discharge. The downstream channel was formed using sand with an average size of 0.8 millimeter, Figure 10A, and was subjected to 4 hours' operation (corresponding to 10 hours' prototype operation) with the maximum discharge of 283 second-feet, tailwater elevation 2422.3, Figure 10B. The turbulence beyond the end of the basin resulted in a deposition of material near the end of the basin, with a small amount of material being deposited inside the basin, Figures 10C and D. This material was apparently pulled down from the side slopes of the channel by wave action then deposited by the action of the turbulence.

Baffle piers. --In an attempt to improve the performance of the stilling basin for the maximum discharge, baffle piers were installed 10 feet downstream from the chute blocks. Several sizes and shapes of piers, as shown in the following table, were tested.

Trial	No. of piers	Height	Width	Spacing between piers	Spacing from walls	Shape*
1	3	10	16	16	8	Square
2	2	10	24	24	12	Square
3	3	10	8	24	12	Square
4	2	10	16	32	16	Square
5	2	10	16	21-1/3	21-1/3	Square
6	2	10	20	18-2/3	18-2/3	6-inch R rounding
7	3	10	16	16	8	4-inch R rounding
8	Trial 7 piers placed 30 feet downstream from chute blocks					

*With reference to upstream corners.
Note: All dimensions are in prototype inches.

The piers used in Trials 1 and 2 eliminated the turbulent boil which previously occurred beyond the end of the basin. However, the piers intercepted too much of the high velocity flow on the floor of the basin, causing a high boil which overtopped the walls. Trials 3 through 6 eliminated this condition but the turbulence beyond the end of the basin again became prevalent. The Trial 7 piers, Figure 11 (Trial 1 piers with rounded upstream corners), eliminated the turbulence in the channel without causing adverse flow conditions within the basin. However, the ability of the Trial 7 piers to withstand the dynamic forces of the high velocity flow on the floor at their proposed location was questioned. Therefore, for Trial 8 the piers were moved to a point 30 feet downstream from the chute blocks or two-thirds the length of the basin. The piers were found to be ineffective in this location because apparently the high velocity flow on the floor turns upward before reaching this point, thus bypassing the piers.

Riprap test. --Geometrical representation of the prototype riprap would require about 3-1/2-inch rock in the model. Rock about one-half the required size was placed in the model with the assurance that adequacy of the smaller riprap would ensure the adequacy of the larger riprap. The riprap remained in place after 4 hours' model operation with no baffle blocks in the basin, with a discharge of 283 second-feet and a tailwater elevation of 2422.3. Some sand was removed from under the riprap by the wave action at the water surface and deposited downstream from the basin as shown in Figure 12. This action may or may not occur in the prototype, depending upon the character of the bedding material.

The Recommended Design

Since the maximum discharge is more than three times the normal discharge and will probably never occur except by accident, and also considering the results of the baffle pier studies and the riprap test, it was decided that the original design of the stilling basin was acceptable. Additional data were then taken concerning the hydraulic characteristics of the recommended design.

Pressure determinations. --Nineteen piezometers were installed in the model, 10 on the chute floor and right wall and 9 on the stilling basin right wall, Figure 13. Water manometer pressures were determined for all piezometers and instantaneous dynamic pressures were measured by means of electronic pressure transducers for 5 piezometers in the very turbulent region at the toe of the jump. These pressures are shown in Tables 1, 2, and 3.

The minimum water manometer pressure of 1.2 feet of water below atmospheric was observed at Piezometer 1 on the chute wall approximately 9 feet downstream from the gate. This pressure was recorded for a discharge of 90 second-feet.

The minimum instantaneous pressure recorded was 8.4 feet of water below atmospheric and occurred at Piezometer 10 on the chute floor about 1 foot from the wall and below the toe of the hydraulic jump, for a discharge of 283 second-feet. Oscillograph traces of the instantaneous pressure fluctuations are shown in Figure 14.

Water surface profiles.--The water surface profiles in the basin were taken in conjunction with pressure readings for use in the structural design of the basin training walls. The water surface profiles, shown on Figure 13, were measured for the maximum discharge of 283 second-feet and the normal discharge of 90 second-feet for the normal and degraded tailwater conditions. Profiles for the maximum discharge could only be estimated because of the violent surging in the basin.

Water surface profiles on the chute were measured for information on the shape of the jet and to aid in determining the effect of changing the angle of the gate with respect to the chute. The profiles were measured for the maximum discharge of 283 second-feet and the normal discharge of 90 second-feet, Figure 13.

Effect of gate angle.--Flow conditions on the chute were observed with the gate mounted at an angle of 2° below the 2:1 slope, as shown in the preliminary design, Figure 4, and then with the gate mounted parallel with the 2:1 slope. No visually detectable difference in the chute flow conditions was noted. The water surface profiles, Figure 13, showed a negligible difference in the depth of flow on the centerline of the chute. With the gate mounted parallel to the 2:1 slope the pressure at Piezometer 2, Figure 13, was found to be 0.5 foot of water lower than the pressure observed at that point with the gate mounted 2° below the 2:1 slope. The 2° angle was retained in the recommended design.

Waves.--The maximum height of waves occurring in the downstream channel was determined for the maximum discharge of 283 second-feet with both normal and degraded tailwater elevations. The maximum wave height, measured on the right bank of the channel, was found to be about 0.7 foot. This height was about the same for both the normal and degraded tailwater elevations. Waves of all sizes encroached on the bank at a frequency of 40 to 45 waves per minute with the larger waves reaching the bank at random intervals. The lapping action of the waves had some effect in removing sand from beneath the riprap, thus allowing the sand to be deposited at the bottom of the slopes, as shown in Figure 12. However, no movement of the riprap was noted.

Tailwater sweepout test.--To determine the safety margin between the expected minimum degraded tailwater and the sweepout tailwater, the tailgate was lowered until the chute blocks at the upstream end of the stilling basin became exposed. The safety margin was determined to be about 4 feet for the maximum discharge of 283 second-feet. Sweepout could not be achieved for discharges less than maximum due to the physical configuration of the downstream channel. However, previous experience has shown that the safety margin increases as the discharge decreases.

Table 1

WATER MANOMETER PRESSURES IN THE CHUTE AND STILLING BASIN--Q = 90 SECOND-FEET--PROTOTYPE FEET OF WATER

Piezometer No.	Tailwater elevation 2424.5			Tailwater elevation 2421.7		
	maximum pressure	minimum pressure	average pressure	maximum pressure	minimum pressure	average pressure
1	-1.0	-1.2	-1.1	-1.0	-1.2	-1.1
2	3.4	3.4	3.4	3.4	3.4	3.4
3	0.3	0.3	0.3	0.3	0.3	0.3
4	3.0	3.0	3.0	3.0	3.0	3.0
5	3.4	2.8	3.2	0.7	0.2	0.5
6	3.9	3.6	3.7	2.0	1.4	1.7
7	1.8	1.6	1.7	Above water surface		
8	8.3	7.4	7.9	5.3	4.9	5.1
9	14.0	13.3	13.6	11.0	10.5	10.8
10	13.2	12.4	12.8	10.2	9.4	9.8
11	2.2	1.8	2.0	Above water surface		
12	8.4	8.2	8.4	5.9	5.0	5.5
13	15.5	15.0	15.3	12.1	12.0	12.0
14	2.0	1.9	2.0	Above water surface		
15	8.7	8.5	8.6	6.1	5.7	5.9
16	15.7	15.4	15.5	13.0	12.5	12.8
17	1.7	1.6	1.7	Above water surface		
18	8.7	8.5	8.6	6.1	5.8	5.9
19	15.7	15.6	15.7	13.1	13.0	13.0

Piezometer locations shown on Figure 13.

Table 2

WATER MANOMETER PRESSURES IN THE CHUTE AND STILLING BASIN--Q = 283 SECOND-FEET--PROTOTYPE FEET OF WATER

Piezometer No.	Tailwater elevation 2425.1 maximum pressure	Tailwater elevation 2425.1 minimum pressure	Tailwater elevation 2425.1 average pressure	Tailwater elevation 2422.3 maximum pressure	Tailwater elevation 2422.3 minimum pressure	Tailwater elevation 2422.3 average pressure
1	0.7	0.7	0.7	0.7	0.7	0.7
2	2.0	2.0	2.0	2.0	2.0	2.0
3	1.6	1.6	1.6	1.6	1.6	1.6
4	2.0	2.0	2.0	2.0	2.0	2.0
5	2.7	1.9	2.3	1.2	1.2	1.2
6	2.5	2.2	2.4	1.0	1.0	1.0
7	Above water surface					
8	6.4	5.1	5.7	3.0	2.1	2.6
9	13.3	12.0	12.6	10.1	9.2	9.7
10	10.9	9.7	10.3	7.1	6.2	6.6
11	Above water surface					
12	7.0	5.3	6.1	3.7	2.3	3.0
13	12.8	11.4	12.1	9.8	8.5	9.1
14	Above water surface					
15	7.8	5.9	6.8	5.2	3.2	4.2
16	13.6	12.0	12.9	10.9	9.5	10.2
17	2.6	1.4	2.0	Above water surface		
18	8.6	7.0	7.8	6.2	4.8	5.5
19	16.3	14.5	15.4	13.8	13.0	13.4

Piezometer locations shown on Figure 13.

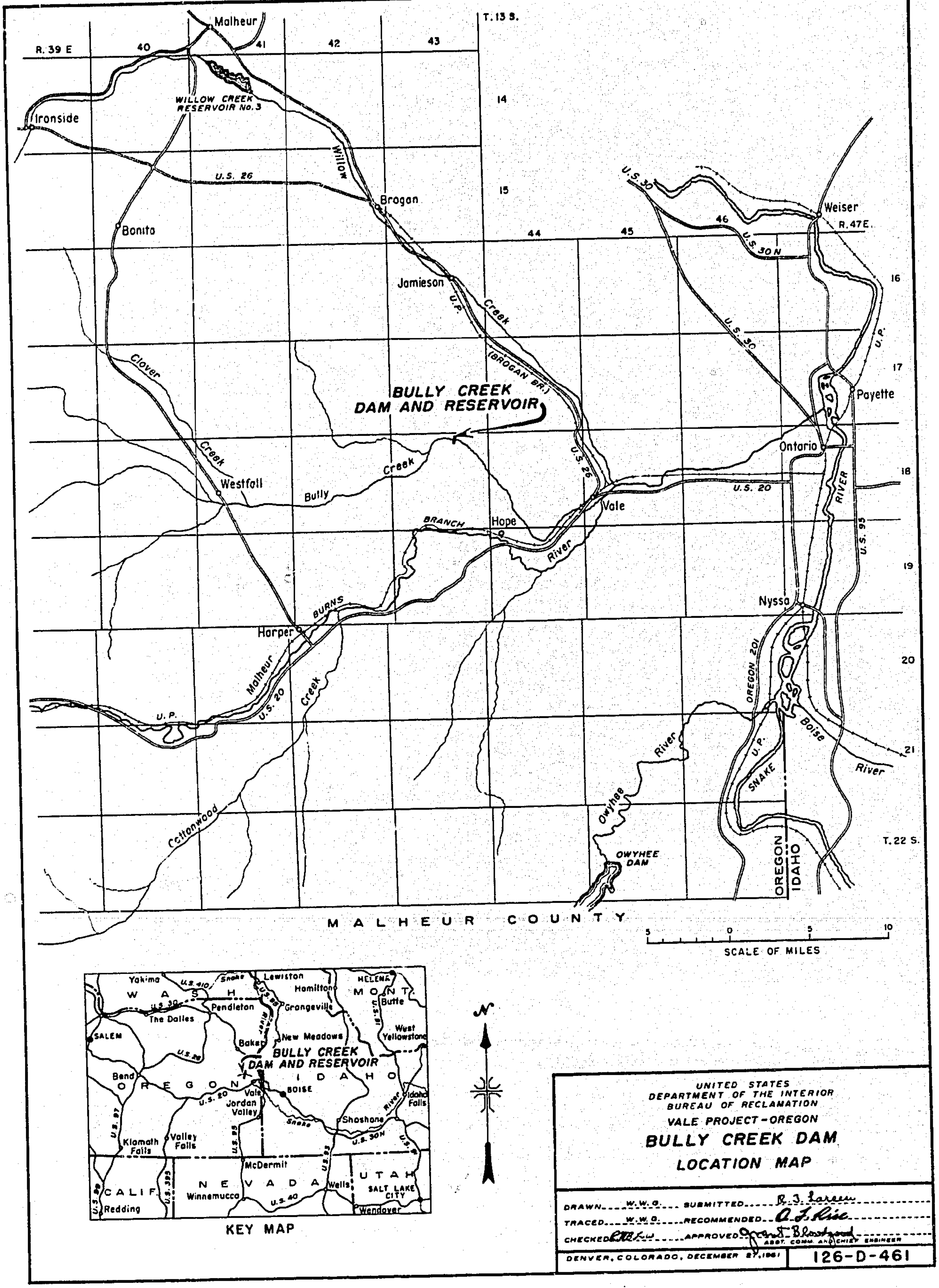
Table 3

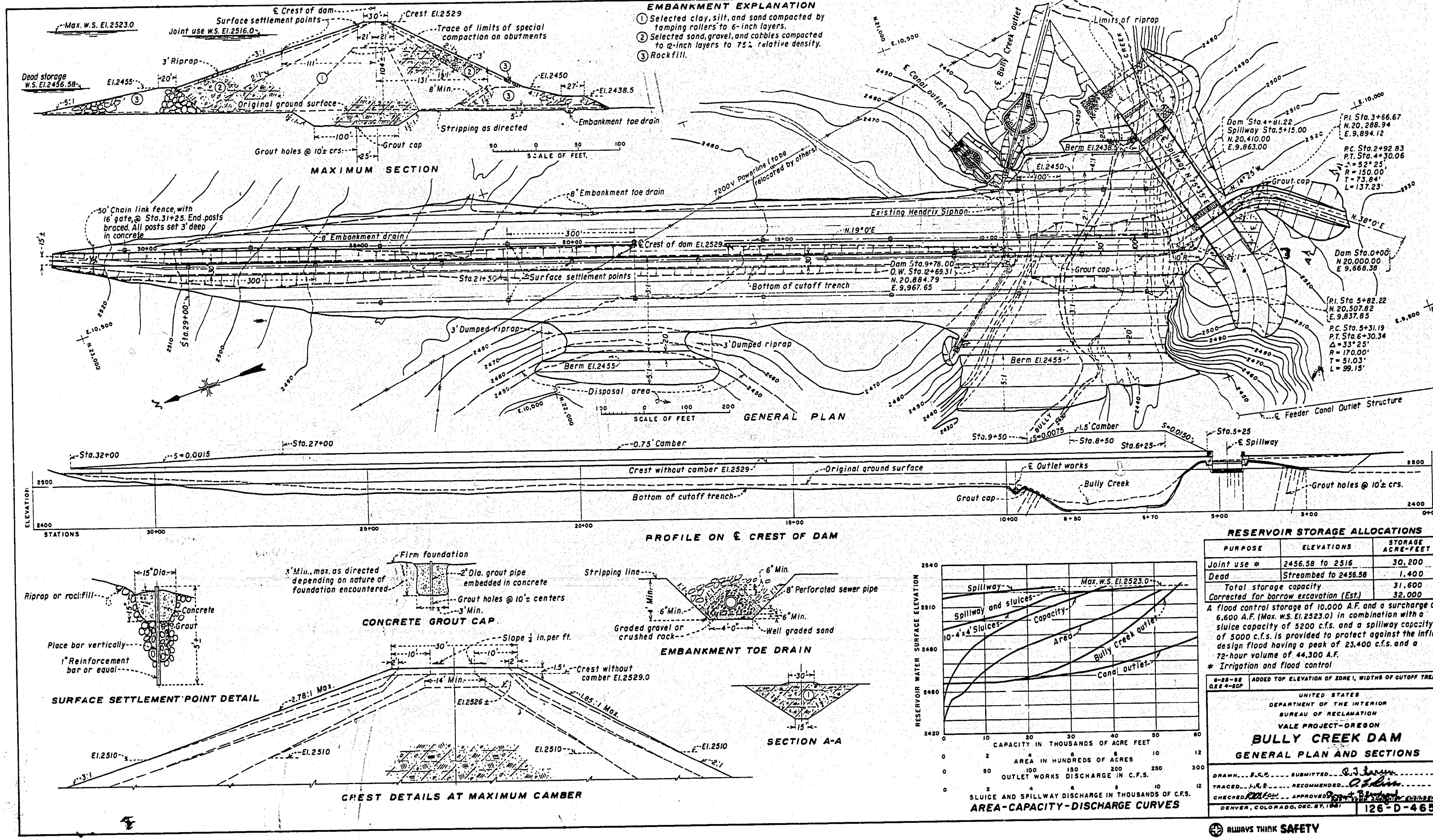
INSTANTANEOUS DYNAMIC PRESSURES IN THE TURBULENT REGION AT THE TOE OF THE HYDRAULIC JUMP--PROTOTYPE FEET OF WATER

Discharge	Tailwater elevation	Piezometer No.	Maximum pressure	Minimum pressure	Average pressure
283	2425.1	5	13.6	-1.2	0.8
		6	17.4	-5.6	1.2
		8	12.4	0.2	6.3
		9	21.9	5.1	11.8
		10	18.6	3.4	10.1
283	2422.3	5	2.8	-1.2	0.8
		6	1.4	0.0	0.7
		8	8.3	-1.2	2.2
		9	23.6	-3.4	8.4
		10	20.3	-8.4	6.8

Piezometer locations shown on Figure 13.

FIGURE 1
REPORT HYD.-494





RESERVOIR STORAGE ALLOCATIONS

PURPOSE	ELEVATIONS	STORAGE ACRE-FEET
Joint use *	2456.58 to 2516	30,200
Dead	Streambed to 2456.58	1,400
Total storage capacity		31,600
Corrected for borrow excavation (Est.)		32,000

A flood control storage of 10,000 A.F. and a surcharge of 6,600 A.F. (Max. W.S. El. 2523.0) in combination with a sluice capacity of 5200 c.f.s. and a spillway capacity of 5000 c.f.s. is provided to protect against the inflow design flood having a peak of 23,400 c.f.s. and a 72-hour volume of 44,300 A.F.

* Irrigation and flood control

ALWAYS THINK SAFETY

FIGURE 3
REPORT HYD.-494

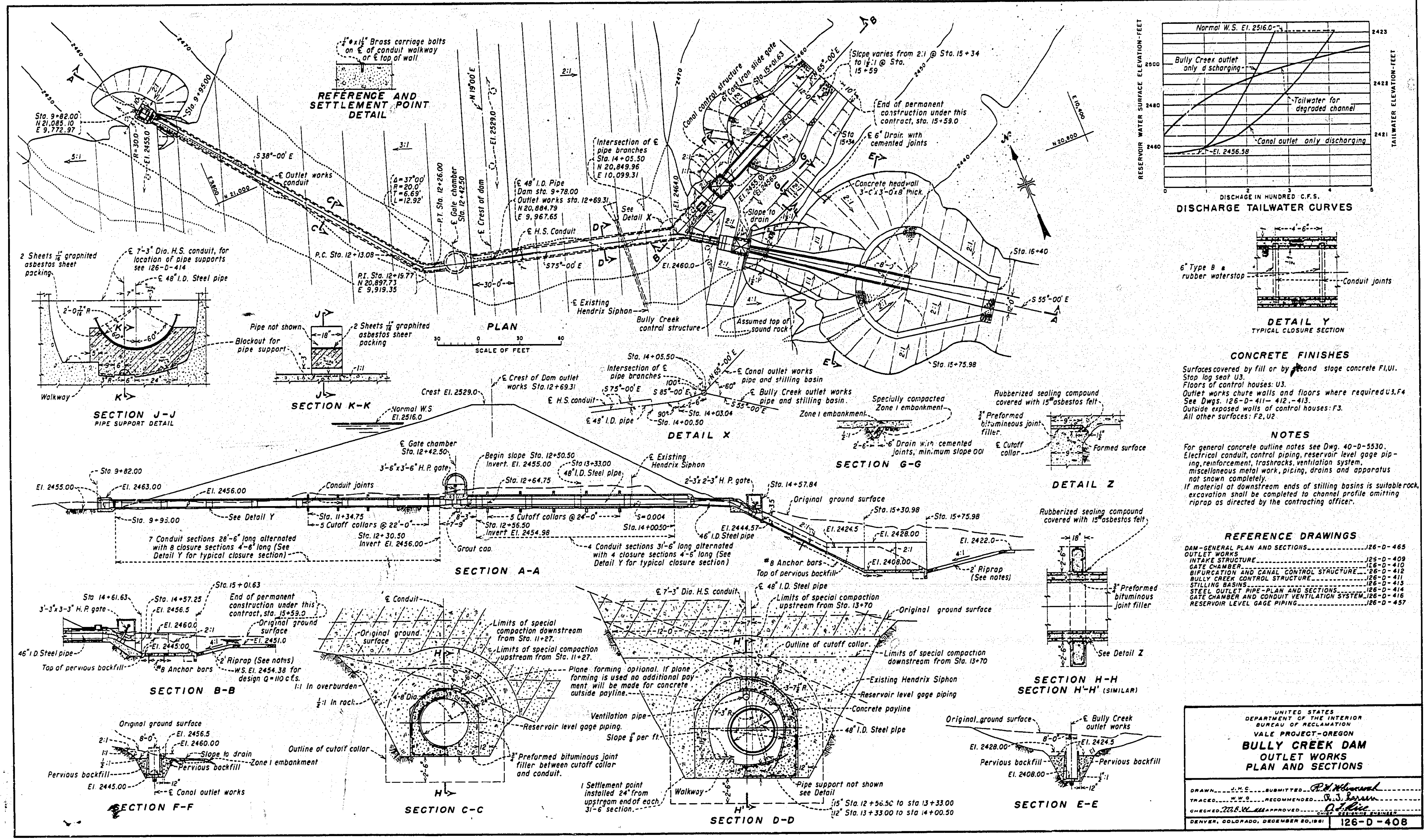


FIGURE 4
REPORT HYD.-494

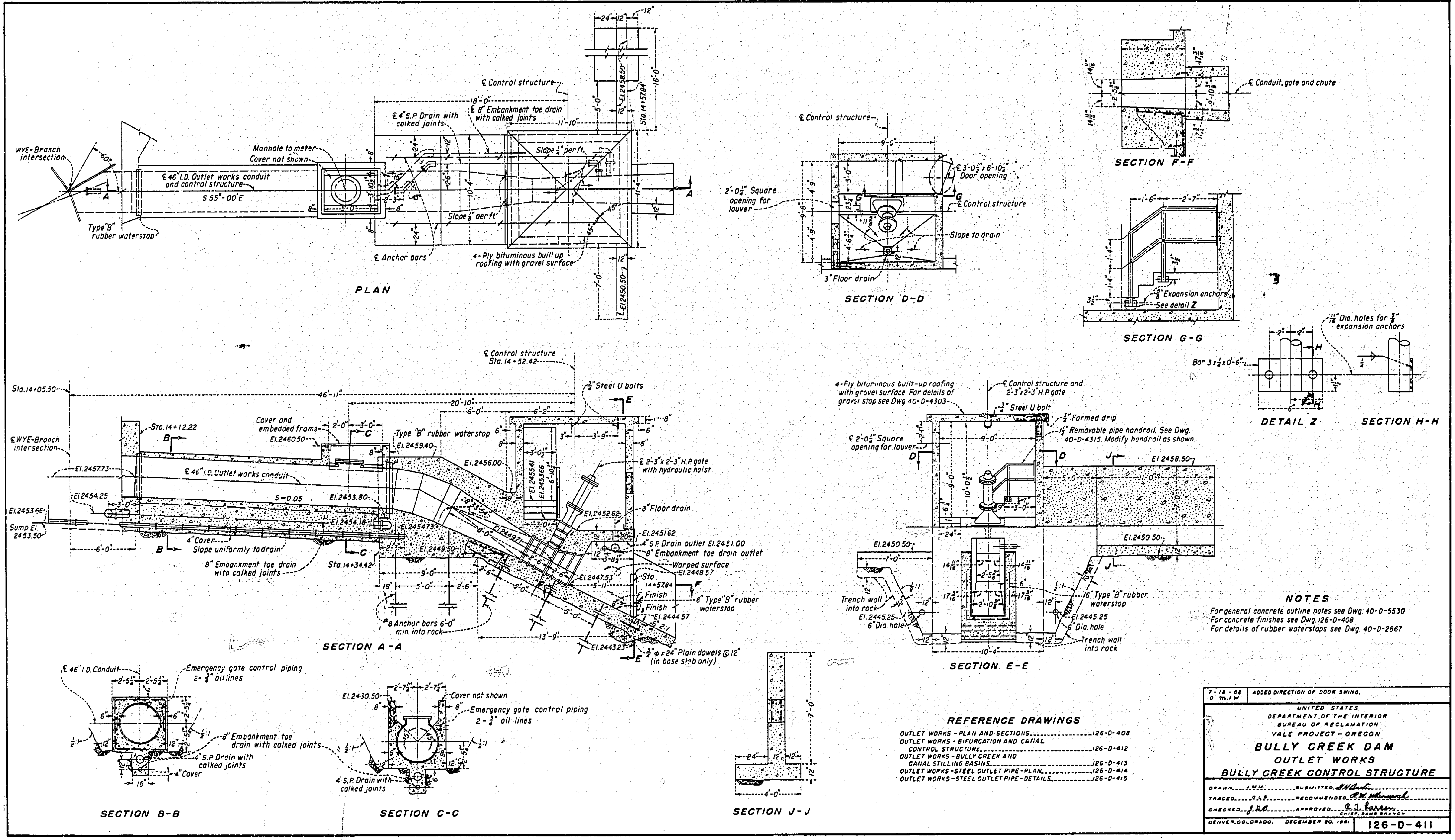
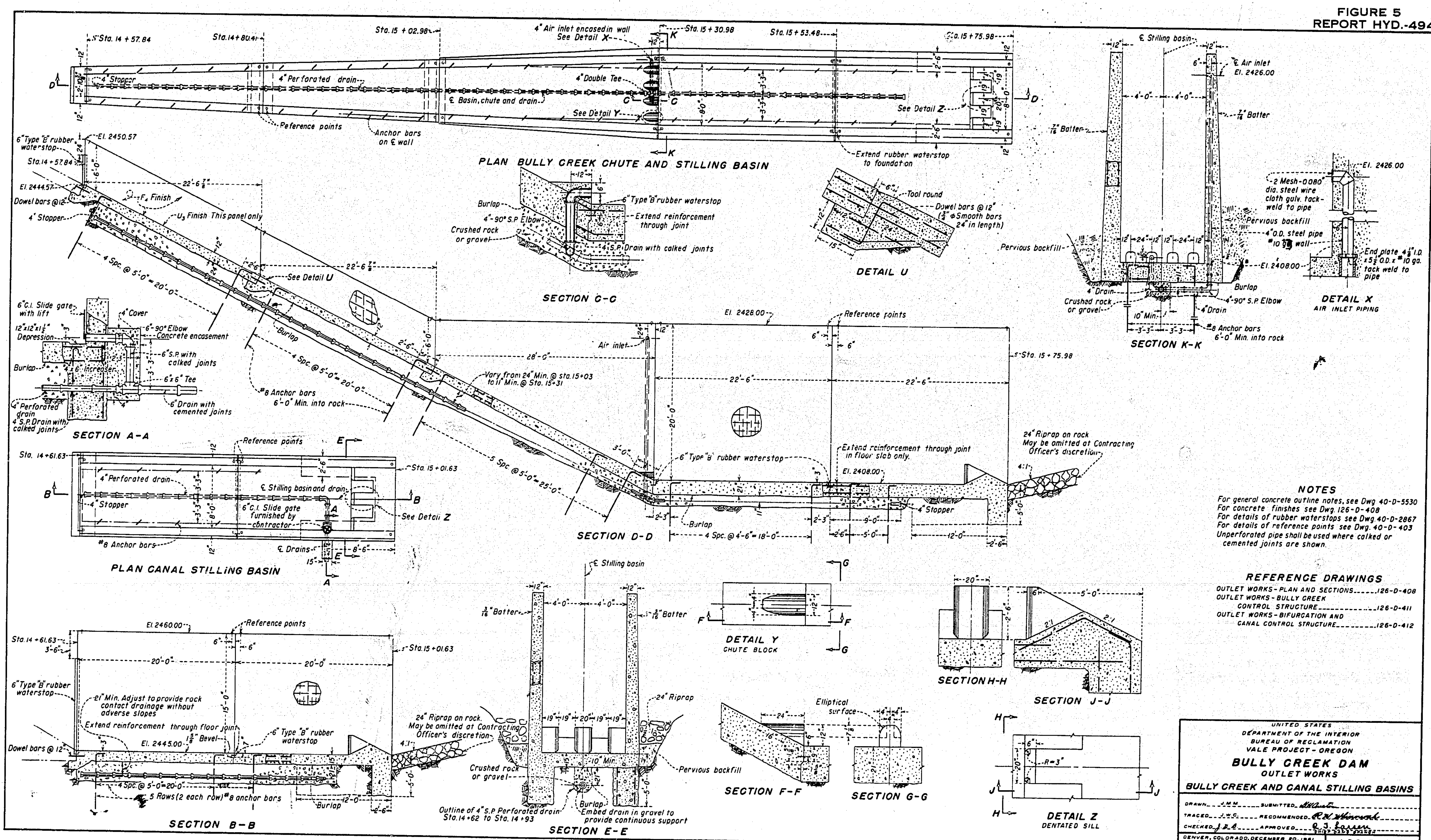
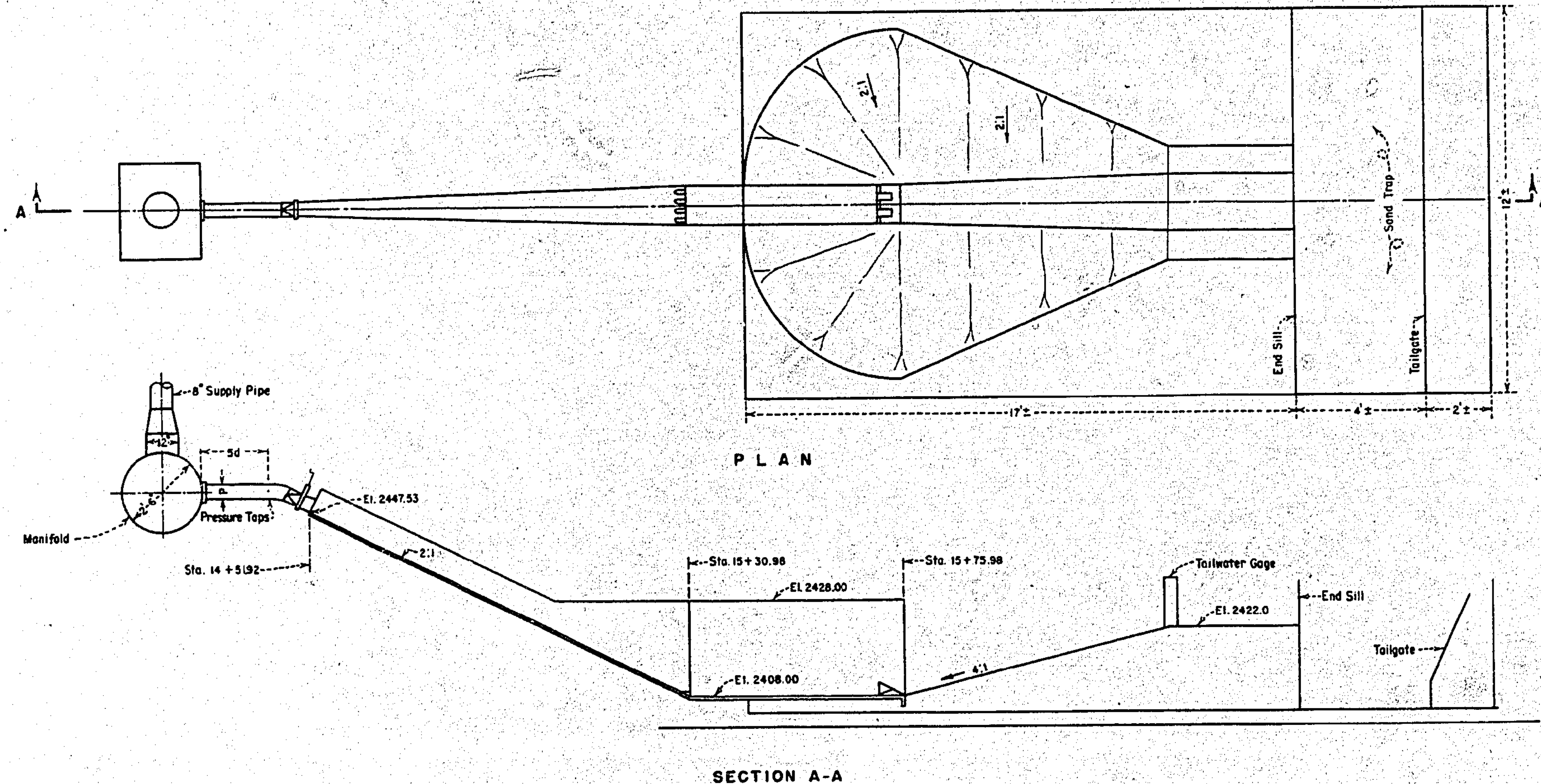


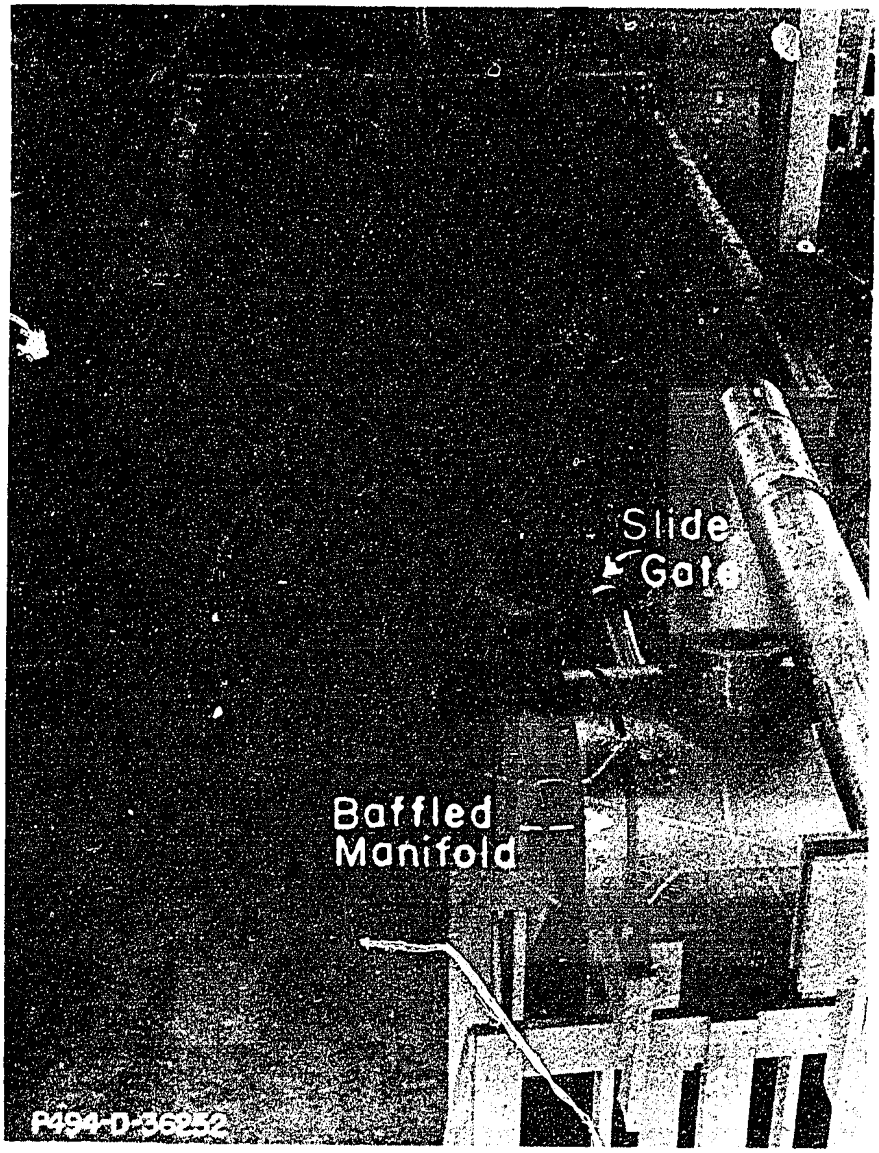
FIGURE 5
REPORT HYD.-494





BULLY CREEK DAM
BULLY CREEK OUTLET WORKS
1:6.75 SCALE MODEL
MODEL ARRANGEMENT

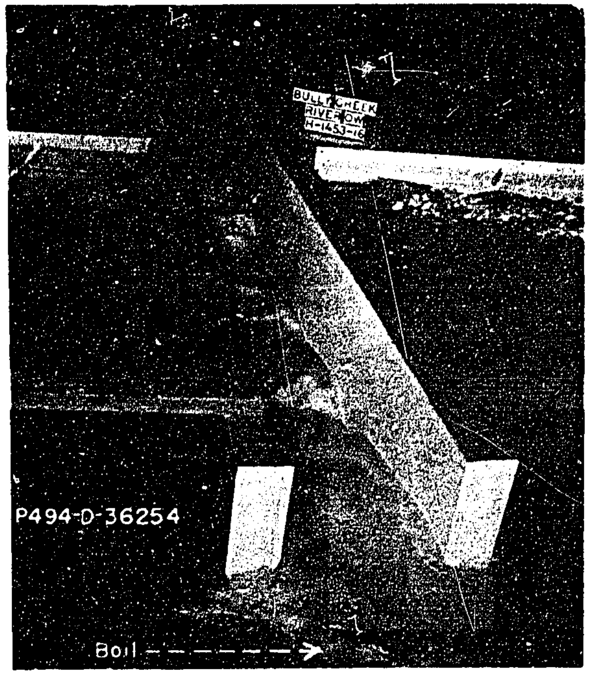
FIGURE 6
REPORT HYD. 494



BULLY CREEK DAM
BULLY CREEK OUTLET WORKS
1:6.75 Scale Model

Completed Model

A. Flow on the 2:1 sloping chute.

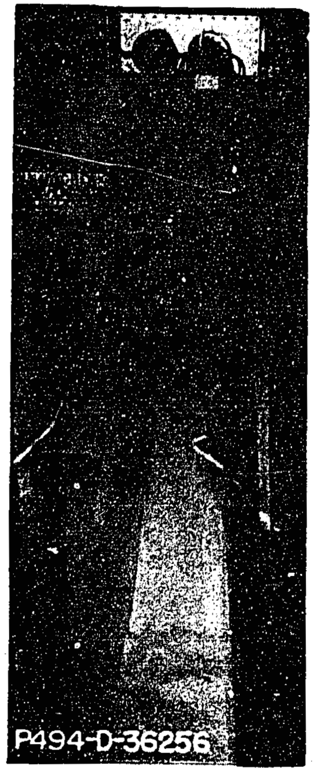


B. Tailwater Elevation 2422.3. Note boil beyond end of basin.

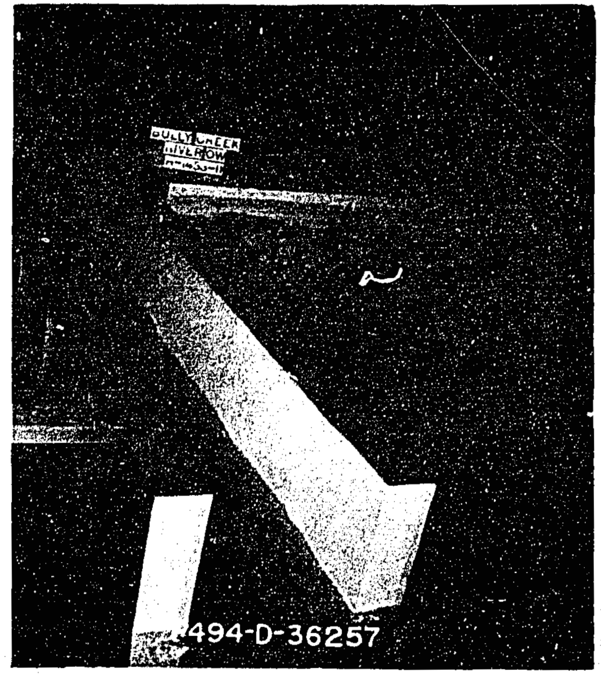
C. Tailwater Elevation 2425.1. Note boil beyond end of basin and traveling surge in basin.

BULLY CREEK DAM
BULLY CREEK OUTLET WORKS
1:6.75 Scale Model

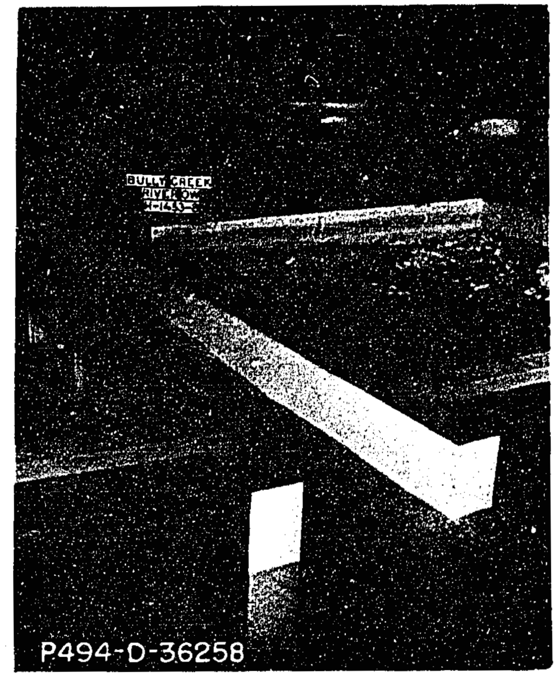
Flow Conditions for the Maximum Discharge of 283 Second-feet; 100 Percent Gate Opening



A. Flow on the 2:1 sloping chute.



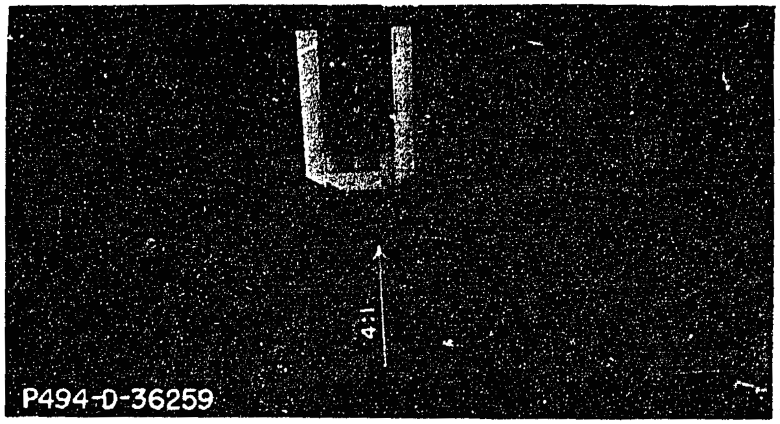
B. Tailwater Elevation 2421.7. Compare with Figure 8-B.



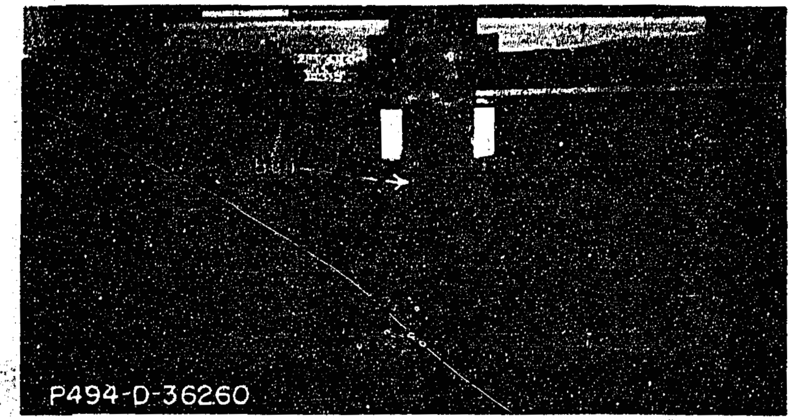
C. Tailwater Elevation 2424.5. Compare with Figure 8-C.

BULLY CREEK DAM
BULLY CREEK OUTLET WORKS
1:6.75 Scale Model

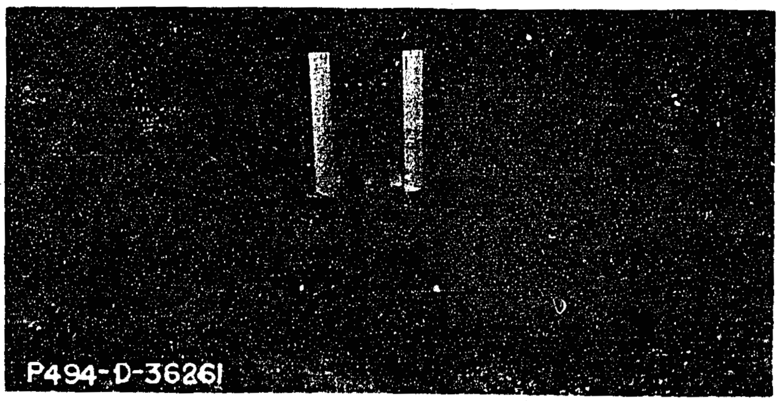
Flow Conditions for the Normal Discharge of 90 Second-feet



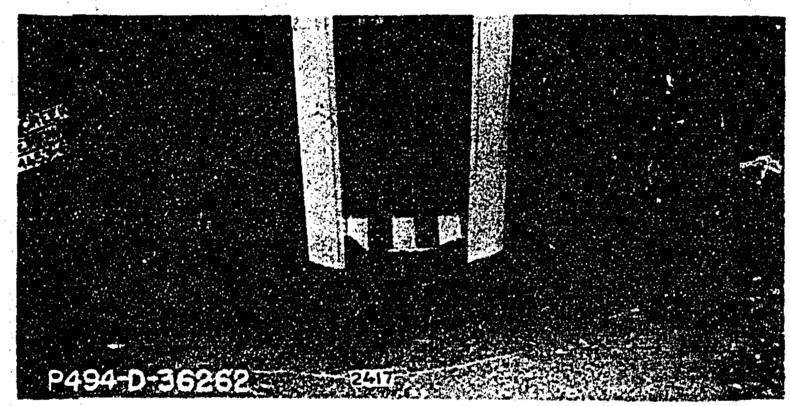
A. Sand bed before erosion.



B. Q = 283 cfs; Tailwater Elevation 2422.3.



C. Sand bed after 4 hours' model operation with flow shown in B. Note beaching action of waves and deposition of material near end of basin.

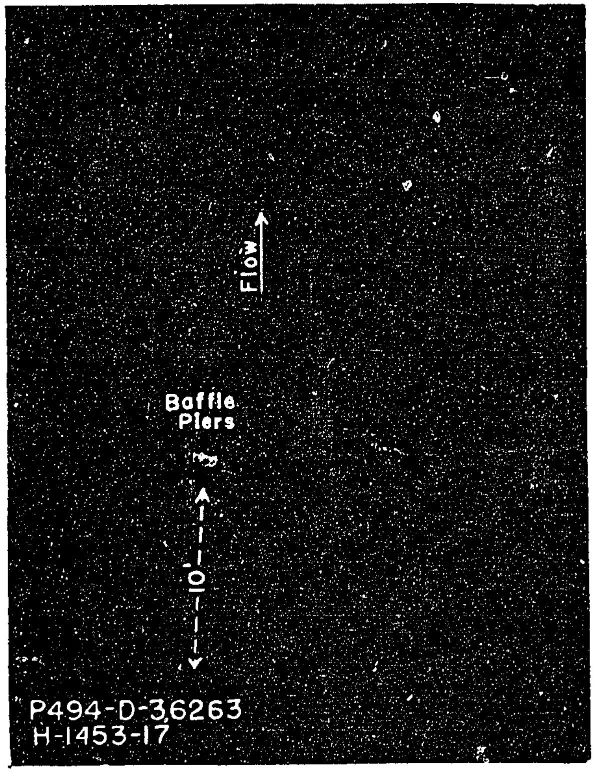


D. Closeup of deposition of material near end of basin. Note that some material is deposited inside the basin.

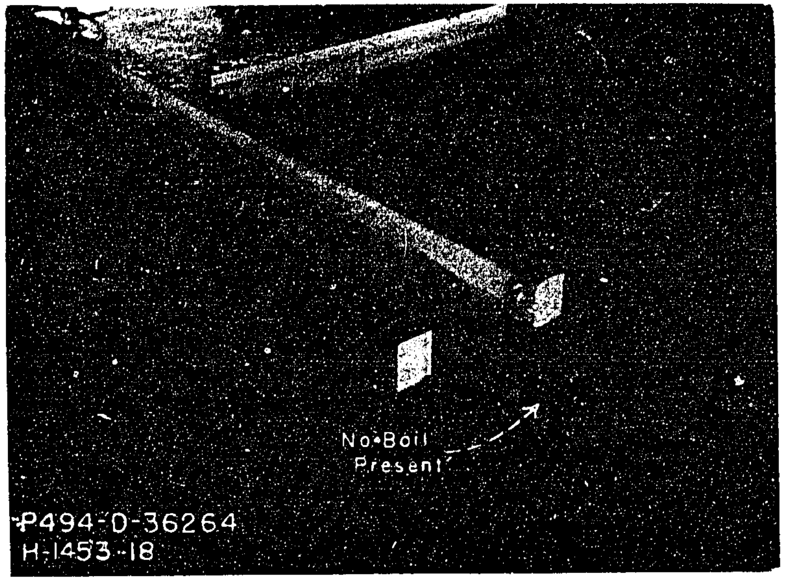
BULLY CREEK DAM
BULLY CREEK OUTLET WORKS
1:6.75 Scale Model

Erosion Tests

Figure 10
Report Hyd-494



View of basin with Trial 7 baffle blocks installed 10 feet downstream from chute blocks. Deposited material at end of basin was due to sloughing of the sand during drainage of the model.



Flow conditions with the Trail 7 baffle blocks in the basin. Q = 283 cfs; Tailwater Elevation 2425.1. Compare with Figure 8-C.

BULLY CREEK DAM
BULLY CREEK OUTLET WORKS
1:6.75 Scale Model

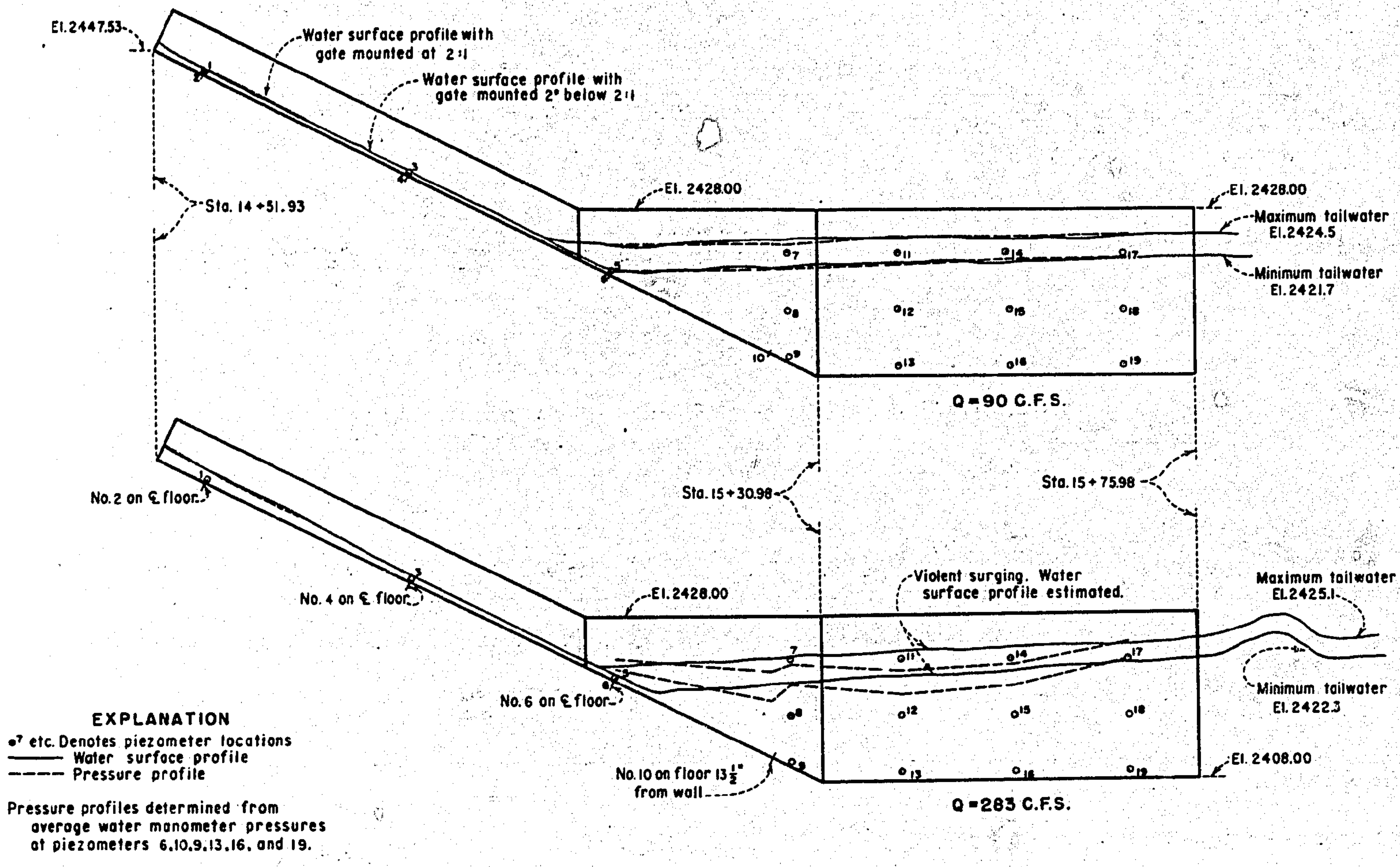
Baffle Pier Studies

Figure 11
Report Hyd-494

Condition of riprap after 4 hours' operation with Q = 283 cfs; Tailwater Elevation 2422.3. Note deposition of sand which was pulled down the slopes due to wave action at the surface.

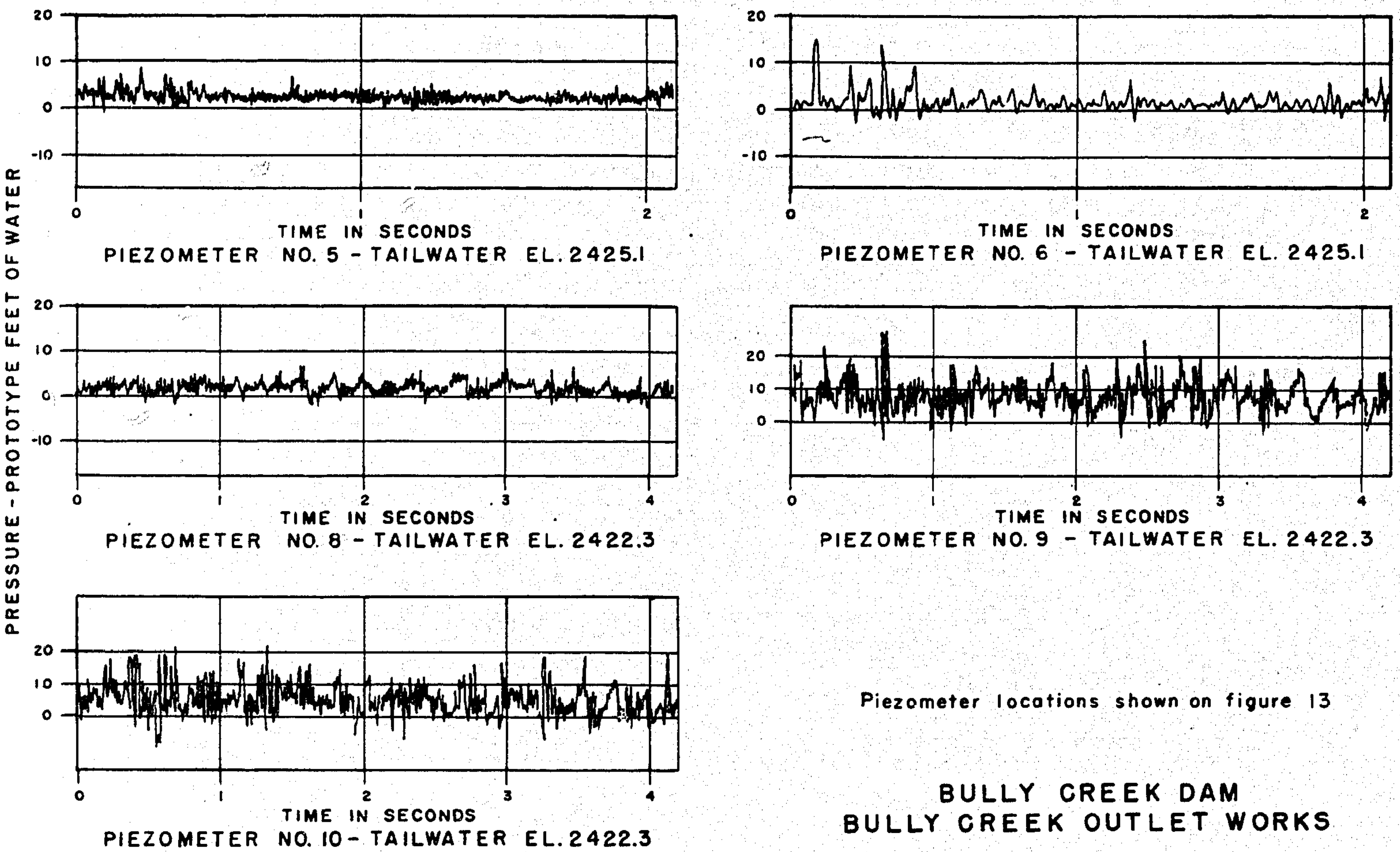
BULLY CREEK DAM
BULLY CREEK OUTLET WORKS
1:6.75 Scale Model

Riprap Test



BULLY CREEK DAM
BULLY CREEK OUTLET WORKS
1:6.75 SCALE MODEL
WATER SURFACE AND PRESSURE PROFILES FOR RECOMMENDED DESIGN

FIGURE 13
REPORT HYD. 494



Piezometer locations shown on figure 13

BULLY CREEK DAM
BULLY CREEK OUTLET WORKS

1:6.75 SCALE MODEL

DYNAMIC PRESSURES AT CRITICAL PIEZOMETERS
DISCHARGE = 283 CFS

GPO 830659