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HYDRAULIC MODEL STUDIES OF BARTLETT DAM

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16. ABSTRACT

Hydraulic model studies were conducted to investigate recommended plunge pool design changes for protection of the Bartlett Dam spillway chute. The laboratory study also included spillway gate sequencing for low discharges, overtopping of the buttress dam, and calibration of free flow and gate-controlled spillway discharges. Impact pressures were evaluated for three plunge pool configurations.

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HYDRAULIC MODEL STUDIES OF BARTLETT DAM

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May 1981

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The data reported in this report were measured in inch-pound units and converted to SI metric units.

CONTENTS

TABLES

FIGURES

CONTENTS – Continued

CONTENTS - Continued

APPENDIXES

TABLES

FIGURES

CONTENTS – Continued

PURPOSE

The primary purpose of this study was to determine the plunge pool modifications necessary to prevent damage to the spillway chute structure resulting from erosion of the underlying rock during spillway releases. Spillway gate sequencing for low discharges, overtopping of the dam, and downstream channel modifications were also investigated during the study.

INTRODUCTION

Bartlett Dam, a part of the Salt River Project, is located about 77 kilometers (48 miles) northeast of Phoenix, Ariz., on the Verde River. The concrete multiple arch buttress dam with a structural height of 86.3 m (283 ft) and crest length of 243.8 m (800 ft) was completed in 1939. The spillway is constructed on the right abutment and is controlled by three 15 240- by 15 240-mm (50- by 50-ft) crawler-type (Stoney) gates. The concrete-lined chute was originally designed for a capacity of 4955 m^3/s (175 000 ft^3/s), and is superelevated to the left with a flip bucket at the end. Downstream of the spillway chute, the granite bedrock has been treated with concrete, gunite, and rockbolts. This repair work was done between 1966 and 1969 due to rock erosion from a spill of 906.1 m^3/s (32 000 ft^3/s) in December 1965. As a result of a 1975 hydrological review, the design flood was revised from 4955 m^3/s (175 000 ft^3/s) to 6371 m^3/s (225 000 ft^3/s). The latest and largest spillway discharge occurred in March of 1978 when approximately 2775 m^3/s (98 000 ft^3/s) was discharged through the spillway for a few hours followed by approximately 1982 m^3/s (70 000 ft^3/s) for 3 to 4 days (fig. 1). This discharge led to severe rock erosion immediately downstream of the spillway chute and prompted concern for the safety of the chute structure (fig. 2).

SUMMARY

A 1:60 model of Bartlett Dam and spillway was constructed to investigate recommended design changes to the plunge pool immediately downstream of the spillway chute. The model was also used to investigate spillway gate sequencing for low discharges, overtopping of the five center bays of the buttress dam during flood discharges, and calibration of the free flow and gate-controlled spillway discharges.

The initial topography, test series "A," which resulted from the March 1978 spillway discharges, and two proposed plunge pool design modifications test series "B" and "C" were tested in the model. Based on visual observations and impact pressure data, the Concrete Dams Section staff designed a concrete mat to prevent further upstream erosion of the rock at the base of the spillway chute. An operational procedure was developed for spillway gate sequencing to prevent overtopping of the left training wall during low discharges. Gate sequencing was also studied to deflect the flow away from the right side of the plunge pool during repairs in 1979.

Two river channel modifications immediately downstream from the plunge pool were studied in the model. One modification dealt with removal of a large boulder field in the plunge pool exit channel. The other modification dealt with removal of material along the right river channel downstream from the plunge pool. To pass flood discharges greater than 6031 m^3/s (213 000 ft^3/s), the five center bays of the buttress dam will be overtopped.

RECOMMENDATIONS

1. The new spillway discharge rating curves for free flow and gate-controlled discharges shown on figure 4 should be used for future spillway discharges.

2. The design modification for test series "C" shown on figure 7 should be constructed downstream of the Bartlett spillway chute to prevent further upstream erosion of the rock foundation.

3. For low spillway releases, the following gate sequencing is recommended:

- For reservoir elevations from 540.4 to 548.0 m (1773 to 1798 ft), spillway discharges of 283.2 m^3/s (10 000 ft^3/s) or less should only be made through the left spillway gate No. 3.*

- For spillway discharges from 283.2 to 368.1 m^3/s (10 000 to 13 000 ft^3/s) for elevation 548.0 m (1798 ft), and 283.2 to 538.0 m^3/s (10 000 to 19 000 ft^3/s) for elevation 540.4 m (1773 ft), discharge the first 283.2 m^3/s (10 000 ft^3/s) through gate No. 3 and the remainder through the center gate No. 2.

- For spillway discharges greater than those encountered in the aforementioned ranges, use the three spillway gates equally open.

4. An exception to the gate operating sequence was the use of No. 3 for emergency spillway discharges during repair to the plunge pool area in 1979. With reservoir elevation 548.0 m (1798 ft), gate No. 3 should be used for the majority of the flow. For discharges up to 566.3 m^3/s (20 000 ft^3/s), use gate No. 3. Above 566.3 m^3/s (20 000 ft^3/s), use gate No. 2 to supplement the discharges through gate No. 3. For instance, for discharges of 991 to 1274 m^3/s (35 000 to 45 000 ft^3/s), pass 850 m^3/s (30 000 ft^3/s) through gate No. 3 and the remainder through gate No. 2. For other ranges of discharges, see table B1 in appendix B.

5. The boulder field located in the exit channel of the plunge pool improves tailwater conditions at the base of the dam and, therefore, should not be removed.

6. Removal of large quantities of material on the downstream right riverbank would be too costly for the benefits realized.

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* Gates are numbered from right to left looking downstream.

7. A reservoir water surface elevation of 549.9 m (1804.2 ft) will produce a free-flow spillway discharge of 6167 m^3/s (217 800 ft^3/s) and will overtop the five center bays of the buttress dam by 0.37 m (1.2 ft). The flow overtopping the dam will be 99.1 m^3/s (3500 ft^3/s) and will impact on a tailwater approximately 13.7 m (45 ft) deep. These two discharges along with 85.0 m^3/s (3000 ft^3/s) from the river outlets will permit passage of a 6351 m^3/s (224 300 ft^3/s) flood at Bartlett Dam.

APPLICATION

In general, results of this investigation apply to the structure studied. However, the design modifications to the plunge pool may be applicable to similar plunge pools which have eroded.

THE MODEL

The model, constructed to a scale of 1:60, included 110 m (360 ft) of the upstream reservoir, the buttress dam and spillway, 293 m (960 ft) of the downstream river channel, and the outlet works (fig. 3). The spillway was handcrafted of urethane using templates as formers. The topography, where no modifications were expected, was constructed of cement-sand mortar on wire lath screen. The plunge pool area and some of the downstream topography were modeled in styrofoam based on 1.52-m (5-ft) field contour intervals to allow for easy modification. Water was supplied to the model through the permanent laboratory system with the discharge determined according to the Froude law of model similitude.

The length ratio, $L_r = 1{:}60$ resulted in a discharge ratio,

$$Q_r = (L_r)^{5/2} = 1{:}27885$$

Seventeen piezometers were located in the plunge pool along the fault lines and impact areas to determine average and instantaneous pressure fluctuations.

INVESTIGATION AND RESULTS

Discharge Measurements

Model calibration tests were conducted to determine free flow and controlled discharges through the spillway, discharges through the river outlet works, and overtopping of the five center bays of the buttress dam for a flood exceeding 6116 m^3/s (216 000 ft^3/s). The permanent laboratory supply and Venturi meter measuring system was used for these calibration tests. The spillway rating curve is shown on figure 4. The head discharge curves for gate control releases were based on the equation,

$$Q = 150\ KG\sqrt{2g(H - G/2)}$$

where:

K = gate coefficient
G = gate opening, ft
H = difference between reservoir elevation and spillway crest elevation, ft
g = acceleration of gravity, ft/s^2

Based on nine gate calibration tests, the value of the gate coefficient, K, was set at 0.653.

The two 1675-mm (66-in) needle valves of the outlet works were not modeled. To determine the overall effect of the outlet discharge on the flow pattern immediately downstream of the buttress dam, two pipes representing 1525-mm (60-in) diameter outlet pipes were installed in the model. These pipes were connected to the model reservoir and had simple plugs placed on the outlet ends. Thus, there was no provision for controlled discharges from the outlets. The valves were either open or closed. The model outlet works discharged approximately 72.5 m^3/s (2560 ft^3/s), somewhat less than the combined release of 85.0 m^3/s (3000 ft^3/s) on the prototype outlet. Calibration tests for overtopping of the five center bays of the buttress dam for a reservoir elevation of 549.9 m (1804.2 ft) indicated an overtopping discharge of approximately 99.1 m^3/s (3500 ft^3/s).

Plunge Pool Modifications

Four representative spillway discharges were chosen for the impact pressure tests in the plunge pool area. Three test series were conducted using various plunge pool configurations. The test series were identified as:

"A" – The original topography after the March 1978 flood discharges.
"B" – The initial design modifications.
"C" – The final design.

Each test series included spillway discharges of 850 m^3/s (30 000 ft^3/s), 1982 m^3/s (70 000 ft^3/s), 3540 m^3/s (125 000 ft^3/s), and 4955 m^3/s (175 000 ft^3/s). Discharges were controlled with the calibrated spillway gates and a reservoir elevation of 548.0 m (1798 ft) for all tests.

The locations of the piezometers in the plunge pool are shown on figures 5, 6, and 7 (letters A to S). The piezometers were constructed of 1.6-mm (1/16-in) copper tubing and installed flush and normal to the styrofoam surfaces. Relatively short lengths of plastic tubing were used to connect the piezometers to the wallplate and water manometer board outside the model. The following test procedure was followed:

a. Recorded water manometer readings for all piezometers noting greatest fluctuations.

b. Attached piezometers with the greatest fluctuations to pressure cells to determine instantaneous pressure fluctuations.

c. Documented the flow conditions on a topographic map showing impact areas, splashes, surface boils, and pool elevations.

d. Recorded tailwater at the base of the dam.

e. Documented flow conditions with photographs and video tape.

Initial testing was performed on the existing topography, series "A," shown on figure 5. The four discharges were tested as shown on figures 8, 9, 10, and 11. At 850 m^3/s (30 000 ft^3/s), the spillway jet impacted on the rock approximately 20 m (66 ft) downstream from the spillway lip with a great deal of splashing over into the pool. The trajectory of the jet moved downstream clearing the rock at discharges of 1982 m^3/s (70 000 ft^3/s) and above, causing high pressures in the plunge pool area. In the area near piezometer A, water pooled creating turbulence. Data for test series "A" are compiled in tables A1 through A4 (appendix A), and a graphical representation of the differential pressure heads is shown on figure 12.

A modified design, series "B," was constructed in the styrofoam which involved removing the overhang near the spillway and placing a concrete slab over the damaged rock immediately downstream from the spillway chute as shown on figure 6. The modification improved the low flow condition and opened up the area to the right of the impact zone significantly. Performance of the plunge pool under the four representative discharge conditions is shown on figures 13, 14, 15, and 16. Data and a graphical representation are given in tables A5 through A8 (appendix A) and on figure 17, respectively.

The final design, series "C," involved further opening of the area downstream and to the right of the spillway with the slopes remaining constant; however, at different orientations, see figure 7. Performance of the plunge pool under the four representative discharge conditions is shown on figures 18, 19, 20, and 21. Data and a graphical representation are shown in tables A9 through A12 (appendix A) and on figure 22, respectively.

Impact pressures were consistently high in the plunge pool area, both with the original topography and with the final design. For a spillway discharge of 4955 m^3/s (175 000 ft^3/s), *instantaneous pressure cell data* ranged from a maximum of 62.0 m (203.4 ft) [representing an elevation of 553.2 m (1814.9 ft)] at piezometer N in test C-4 (table A12), to a minimum of -1.2 m (-3.9 ft) [representing elevation 490.1 m (1607.9 ft)] at N, test B-4 (table A8). The *average pressure cell data* for piezometer N in tests C-4 and B-4 were 27.2 m (89.4 ft) and 18.0 m (59.1 ft), respectively. The corresponding average water manometer pressure data was 26.0 m (85.2 ft) and 20.4 m (66.9 ft). The maximum pressure head differential (water manometer) occurred at a discharge of 4955 m^3/s (175 000 ft^3/s) on piezometer N in test A-4 and was recorded as 6.7 m (21.9 ft) (fig. 12).

The highest instantaneous pressure data occasionally exceeded reservoir elevation 548.0 m (1798 ft). To verify these high instantaneous pressure measurements, the size and, therefore, frequency characteristics of the pressure cells were varied. An oscilloscope was also used as a separate verification to bypass the galvanometer on the recorder and thus rule out the possibility of overrun by the galvanometer. These verification tests supported the early data which indicated instantaneous pressure elevations as high as 553.2 m (1814.9 ft). It is speculated that these high instantaneous pressures result from extremely intense local turbulence near the piezometers; nevertheless, the possibility of inadequate instrumentation for these high instantaneous pressures could also be a factor.

The design of the repair work in the plunge pool was based on a head differential of 6.1 m (20 ft). This design head differential exceeded that of pressure head differentials actually measured in the areas identified for repair. The final plunge pool modification included removal of rock overhangs and rocks surrounding the area of the fault on the right side of the impact area improving the overall flow conditions. The final design called for removal of all overhangs and loose rock in the upstream wall of the plunge pool and the installation of reinforced concrete slabs to protect this area. The final design also included large benches located at elevations 512.1 m (1680.0 ft) and 493.3 m (1618.5 ft) with most sloping faces placed on a 0.6:1 horizontal to vertical slope (fig. 7). The sloping slabs will have a minimum thickness of 450 mm (18 in) and the large horizontal benches will have a minimum thickness of 1.5 m (5 ft). The concrete slabs will be secured to the rock faces by grouted rock bolts 25 mm (1 in) in diameter.

A limited number of tests were conducted to determine the movement of large boulders in the plunge pool. Twelve small stones representing 0.75- to 3.0-m (2.5- to 10-ft) diameter boulders were modeled. The tests were conducted for a period of 1 hour representing a time period of approximately 8 hours in the field. For a spillway discharge of 850 m^3/s (30 000 ft^3/s), 3 of the 12 boulders were washed from the pool. The remaining boulders were found in the center of the plunge pool. For a spillway discharge of 1982 m^3/s (70 000 ft^3/s), 4 of the 12 boulders were washed from the pool. With the exception of a 3.0-m (10-ft) diameter boulder in the center of the pool, the remaining seven boulders were located high in the left downstream corner of the pool. For a spillway discharge of 3540 m^3/s (125 000 ft^3/s), five of the boulders were removed from the pool and the other seven were located high in the left downstream corner of the pool. For a spillway discharge of 4955 m^3/s (175 000 ft^3/s), all of the boulders were removed from the plunge pool in 1 hour of model operation. Throughout these tests, there was no evidence of ball-mill type action in the plunge pool.

Spillway Gate Sequencing

Under certain low spillway flow conditions, the superelevation of the spillway chute can produce overtopping of the left training wall. This overtopping condition was observed both with gate control and free discharge. With gate control, tests were conducted at reservoir elevations of 548.0 m (1798 ft) and 540.4 m (1773 ft). For equal gate openings, the flow initially forms a small hydraulic jump in the chute. However, as the gates continue to open equally, the discharge passes through a range where the size of the hydraulic jump grows and the flow overtops the left training wall. Once a certain flow velocity is achieved, the spillway flow flips out of the chute. Table 1 summarizes the results of the study as they relate to overtopping of the left training wall with equal gate openings.

Table 1.–*Conditions for overtopping the spillway chute training wall*

Control	Reservoir elevation		Discharge, Q					
			No overtopping		Overtopping		No overtopping	
	m	ft	m^3/s	ft^3/s	m^3/s	ft^3/s	m^3/s	ft^3/s
Gate control	548.0	1798	<204	<7200	204-360	7200-12 000	>360	>12 700
Gate control	540.4	1773	<170	<6000	170-518	6000-18 300	>518	<18 300
Free flow			<170	<6000	170-646	6000-22 800	>646	<22 800

During these tests, the three spillway gates were opened the same amount. In general, as the reservoir elevation decreases the discharge required to flip the spillway flow out of the chute increases.

Proper gate sequencing during periods of low spillway discharges can eliminate overtopping of the left training wall. For the two reservoir elevations studied, the following sequencing is recommended:

- For reservoir elevation 548.0 m (1798 ft) and spillway discharges up to 283.2 m^3/s (10 000 ft^3/s), use gate No. 3 only. For spillway discharges between 283.2 and 368.1 m^3/s (10 000 and 13 000 ft^3/s), discharge 283.2 m^3/s (10 000 ft^3/s) through gate No. 3* and the remainder through gate No. 2. For spillway discharges greater than 368.1 m^3/s (13 000 ft^3/s), equal discharges can be made through the the three spillway gates without overtopping the left training wall.

* Ibid.

- For reservoir elevation 540.4 m (1773 ft) and spillway discharges up to 283.2 m^3/s (10 000 ft^3/s), use gate No. 3 only. For spillway discharges between 283.2 and 538.0 m^3/s (10 000 and 19 000 ft^3/s), discharge the first 283.2 m^3/s (10 000 ft^3/s) through gate No. 3 and the remainder through gate No. 2. For spillway discharges greater than 538.0 m^3/s (19 000 ft^3/s), equal releases can be made through the three spillway gates without overtopping the training wall.

Figure 23 shows three gates, equally open, discharging 320.0 m^3/s (11 300 ft^3/s) with the reservoir elevation at 548.0 m (1798 ft). The formation of a hydraulic jump in the chute will produce overtopping of the left training wall, particularly at the higher discharges [above 283.2 m^3/s (10 000 ft^3/s)]. Figure 24 shows three gates, equally open, discharging 356.8 m^3/s (12 600 ft^3/s) with a reservoir elevation of 548.0 m (1798 ft). Figure 25 shows the prototype spillway discharging 266.2 m^3/s (9400 ft^3/s) in 1942. The right gate (No. 1) was discharging approximately 158.6 m^3/s (5600 ft^3/s) and the center and left gates were discharging 53.8 m^3/s (1900 ft^3/s) each (note the hydraulic jump in the chute).

Downstream Channel Modifications

It was evident that the channel topography immediately downstream of the plunge pool affected the water level in the plunge pool and at the base of the dam. A large boulder field located in the plunge pool exit channel immediately downstream and to the left of the spillway chute deflects part of the plunge pool flow across the river channel downstream of the dam, see figure 1. This deflected flow causes a high tailwater condition at the base of the dam. Table 2 shows the tailwater elevation at the dam with and without the boulder field for the three representative discharges.

Table 2.–*Tailwater elevations downstream of dam*

Discharge		Tailwater elevations at base of dam			
		With boulder field		Without boulder field	
m^3/s	ft^3/s	m	ft	m	ft
4955	175 000	500.2	1641	497.9	1633.5
3540	125 000	498.3	1635	496.2	1628
1982	70 000	495.6	1626	494.7	1623

Figures 26 and 27 show the model spillway discharging 4955 m^3/s (175 000 ft^3/s) without and with the boulder field. (Note how part of the flow is deflected around the upstream side of the boulder field on figure 27). As noted by comparing the figures, the presence of the boulder field does not materially affect the depth of water in the plunge pool; however, higher tailwater at the base of the dam, resulting from the presence of the boulder field, provides additional protection for the dam foundation if it should ever overtop.

As a further modification to the downstream channel, approximately 20 000 m^3 (26 000 yd^3) of material were removed along the right side of the channel immediately downstream from the plunge pool. This modification decreased the heavy turbulence along the right side of the downstream channel. Table 3 gives the tailwater elevations at the base of the dam with and without the boulder field for the modified channel.

Table 3.–*Tailwater elevations downstream of dam with modified channel*

Discharge		Tailwater elevations at base of dam			
		With boulder field		Without boulder field	
m^3/s	ft^3/s	m	ft	m	ft
4955	175 000	499.7	1639.5	496.7	1629.5
3540	125 000	497.0	1630.5	495.3	1625
1982	70 000	495.0	1624	494.7	1623

Figures 28 and 29 show the model spillway discharging 4955 m^3/s (175 000 ft^3/s) without and with the boulder field and the modified downstream channel.

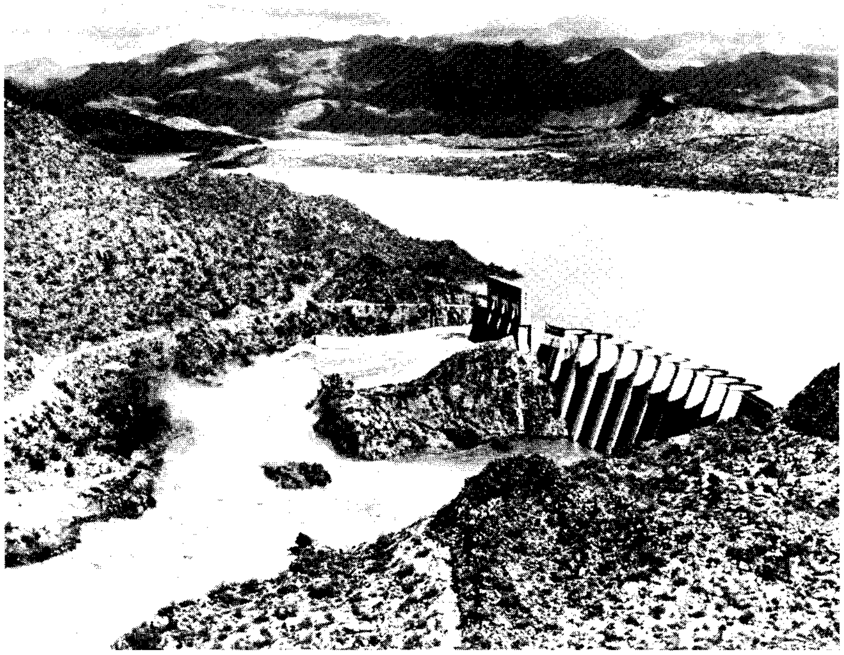
Although flow along the right riverbank is much smoother, the removal of such a large quantity of material would be very costly. Given the poor quality of the rock, it is possible that future spillway releases will accomplish the same objective. Localized excavation of boulder fields on the right side could be considered at a future date if unacceptable turbulence results from the boulder outcrop.

During the course of the investigation, it was noted that with larger spillway discharges, the tailwater will submerge the lower needle valve in the river outlet house. The centerline of the valve is at elevation 497.7 m (1633 ft). Tables 2 and 3 give the tailwater conditions which will prevail under various spillway discharges and downstream channel conditions. The needle valve is designed for free discharge. It should not be operated for long periods under submerged conditions. However, under emergency conditions, the valve damage resulting from submerged operations is not serious enough to warrant closing the valve.

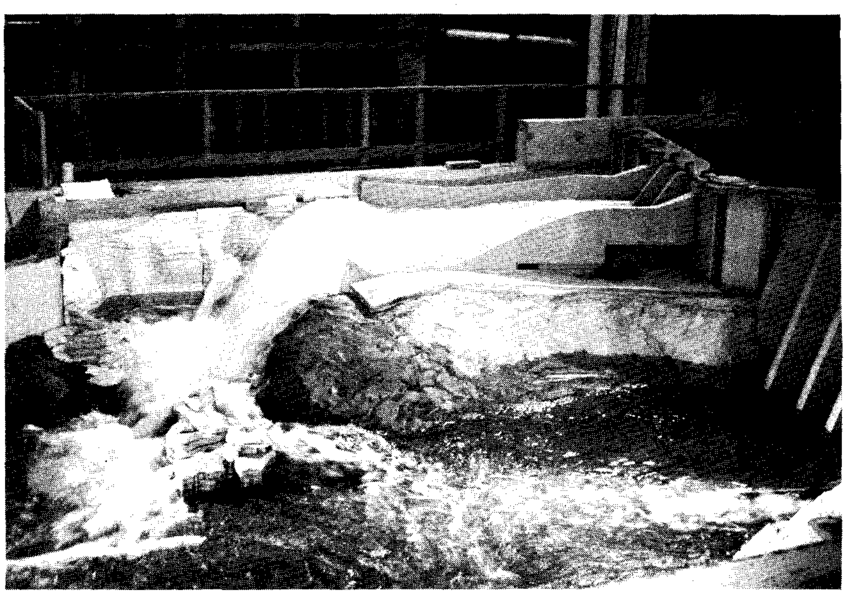
Overtopping of Dam

The new inflow design flood for Bartlett Dam was recently increased to 6371 m^3/s (225 000 ft^3/s). The maximum reservoir water surface elevation is 549.6 m (1803 ft) (top of parapet wall). Once the reservoir water surface exceeds elevation 549.6 m (1803 ft), the five center bays of the buttress dam will overtop. Flashboards have been placed on the left three bays and the right two bays to protect the dam abutments. With a reservoir water surface elevation of 549.9 m (1804.2 ft), approximately 99.1 m^3/s (3500 ft^3/s) overtops the five center bays. The total discharge for a reservoir elevation of 549.9 m (1804.2 ft) is 6351 m^3/s (224 300 ft^3/s) which includes 85.0 m^3/s (3000 ft^3/s) through the river outlets, 99.1 m^3/s (3500 ft^3/s) over the top of the dam, and 6167 m^3/s (217 800 ft^3/s) through the spillway.

When overtopping the dam, the flow is uniform over all five bays. The flow takes the shape of the bays but the nappe forms into a concentrated jet approximately halfway down the height of the dam. The jets impact into the tailwater with the boulder field in place is shown on figures 3 and 30.



a. March 1978 flooding. Photo P801-D-79492



b. The 1:60 scale model. Photo P801-D-79493

Figure 1.–Bartlett Dam discharging 1982 m^3/s (70 000 ft^3/s).

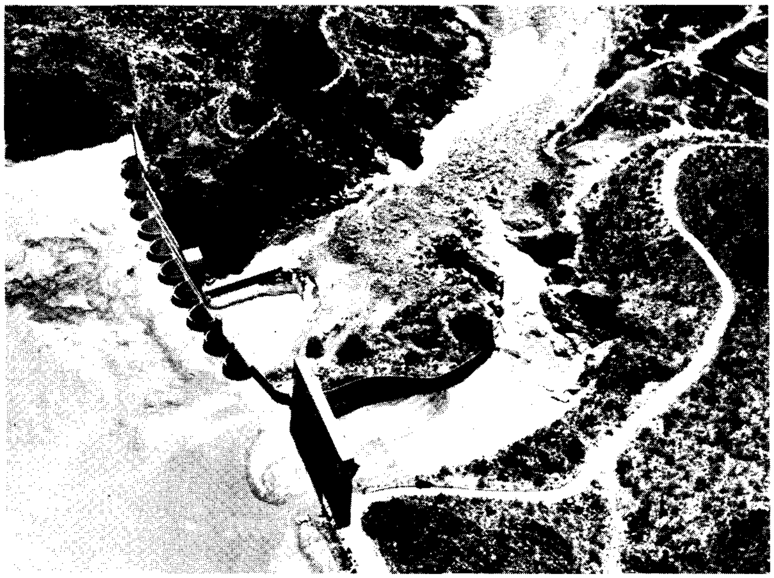


Figure 2.–Aerial view of Bartlett Dam after March 1978 flood (note large eroded hole downstream from spillway chute). Photo P801-D-79494

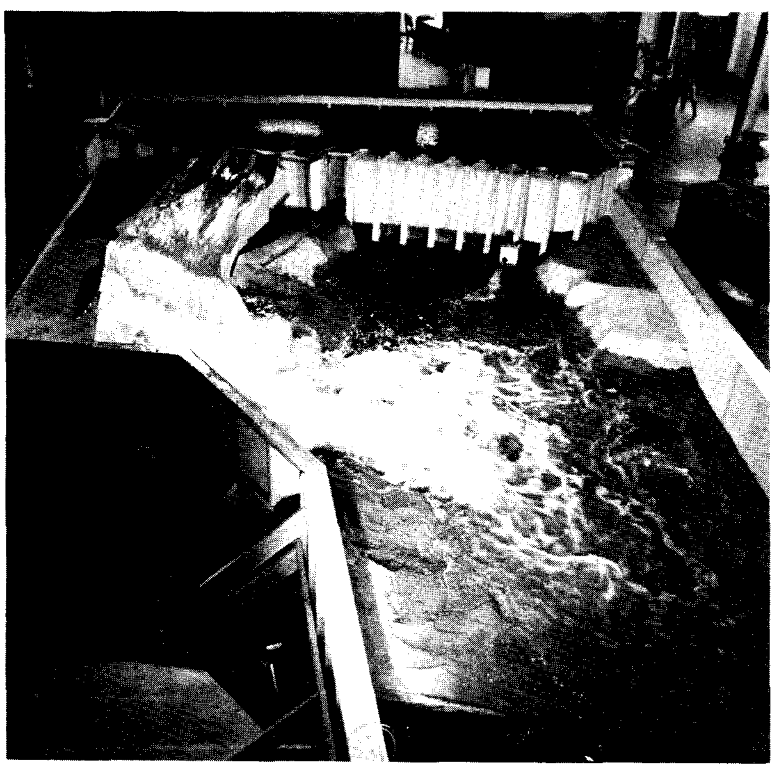


Figure 3.–The 1:60 scale model of Bartlett Dam. Photo P801-D-79495

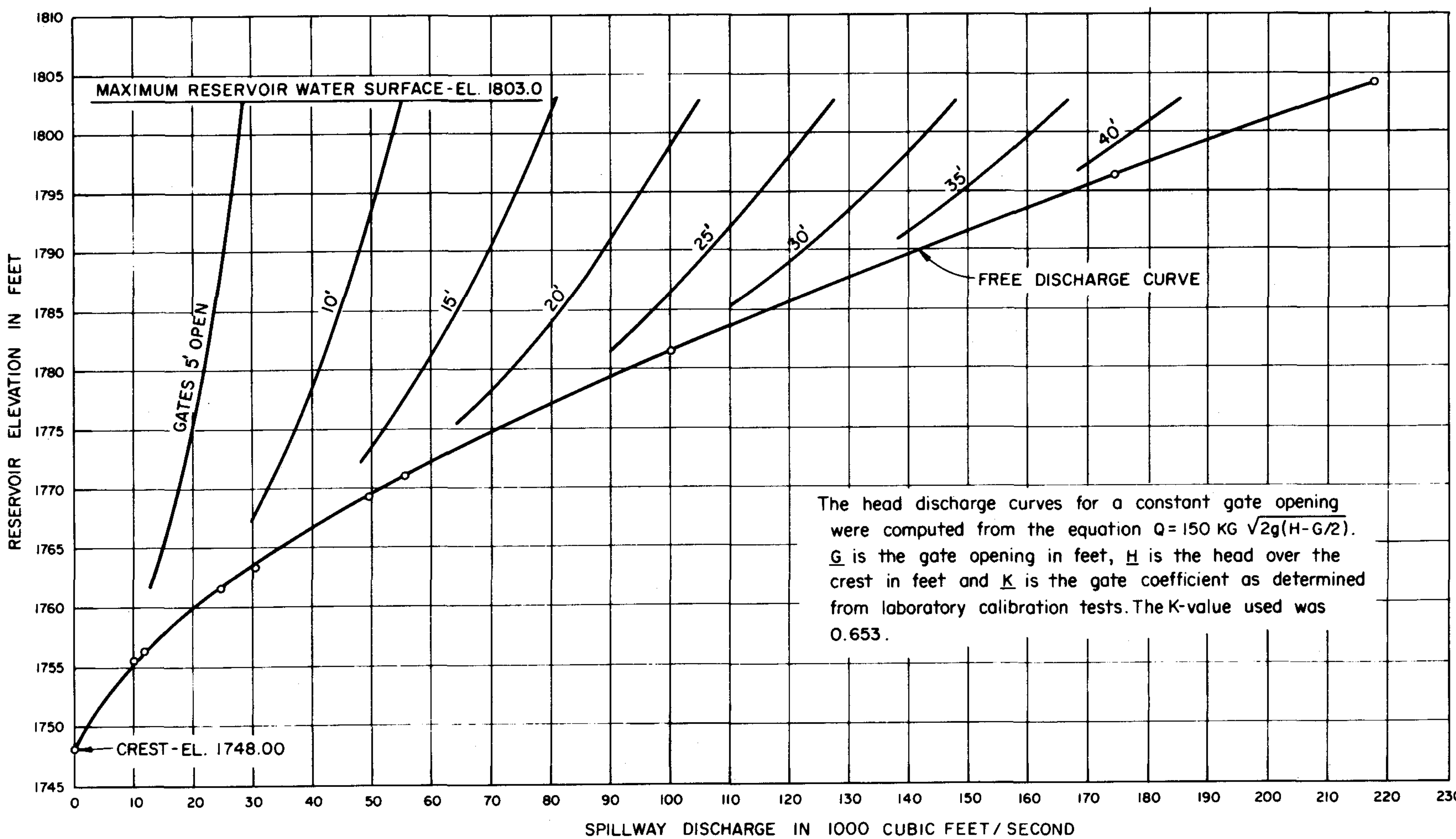


Figure 4.–Spillway discharge rating curve.

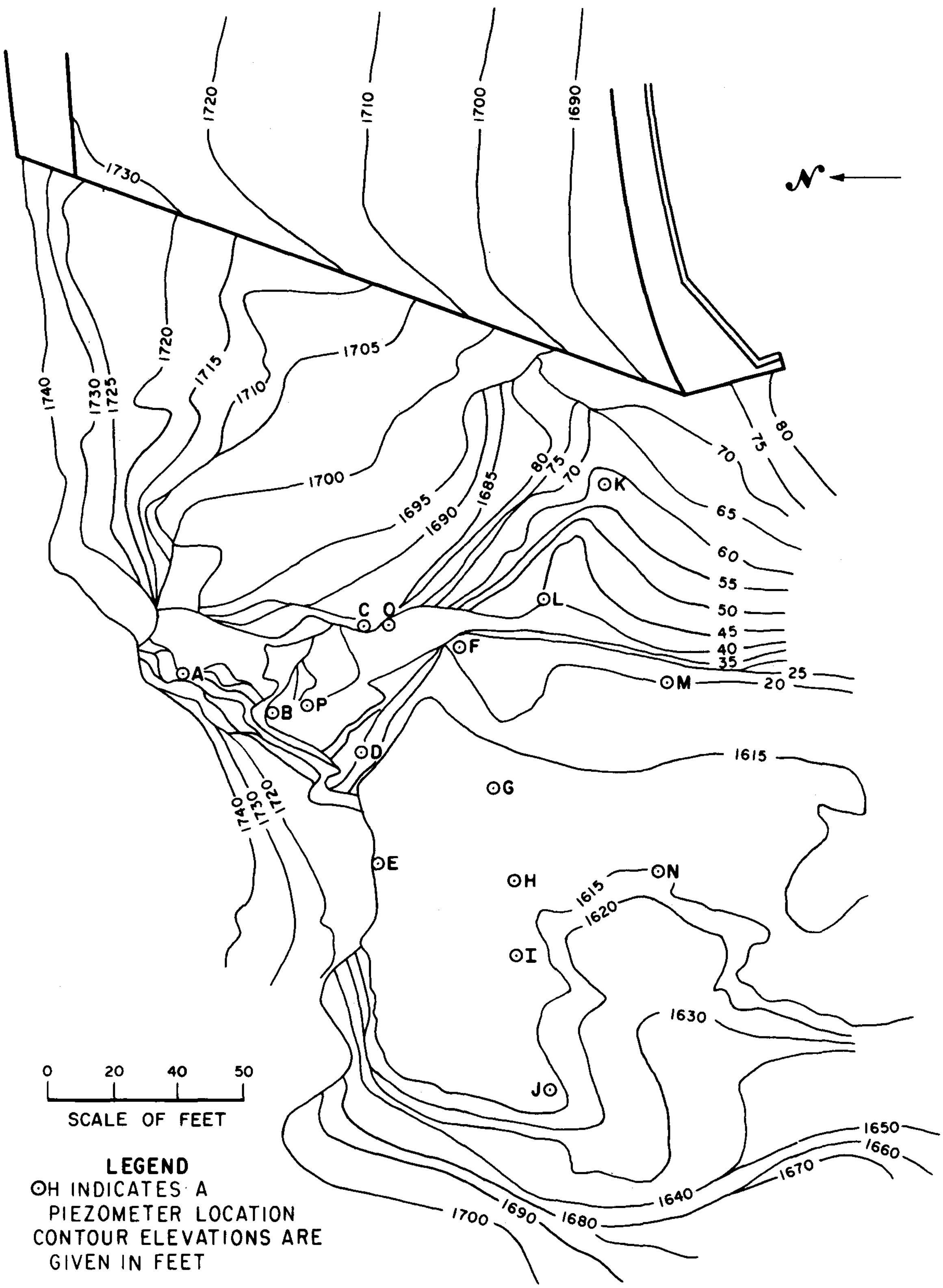


Figure 5.–Topography immediately below spillway chute (test series "A"), (initial condition after flood).

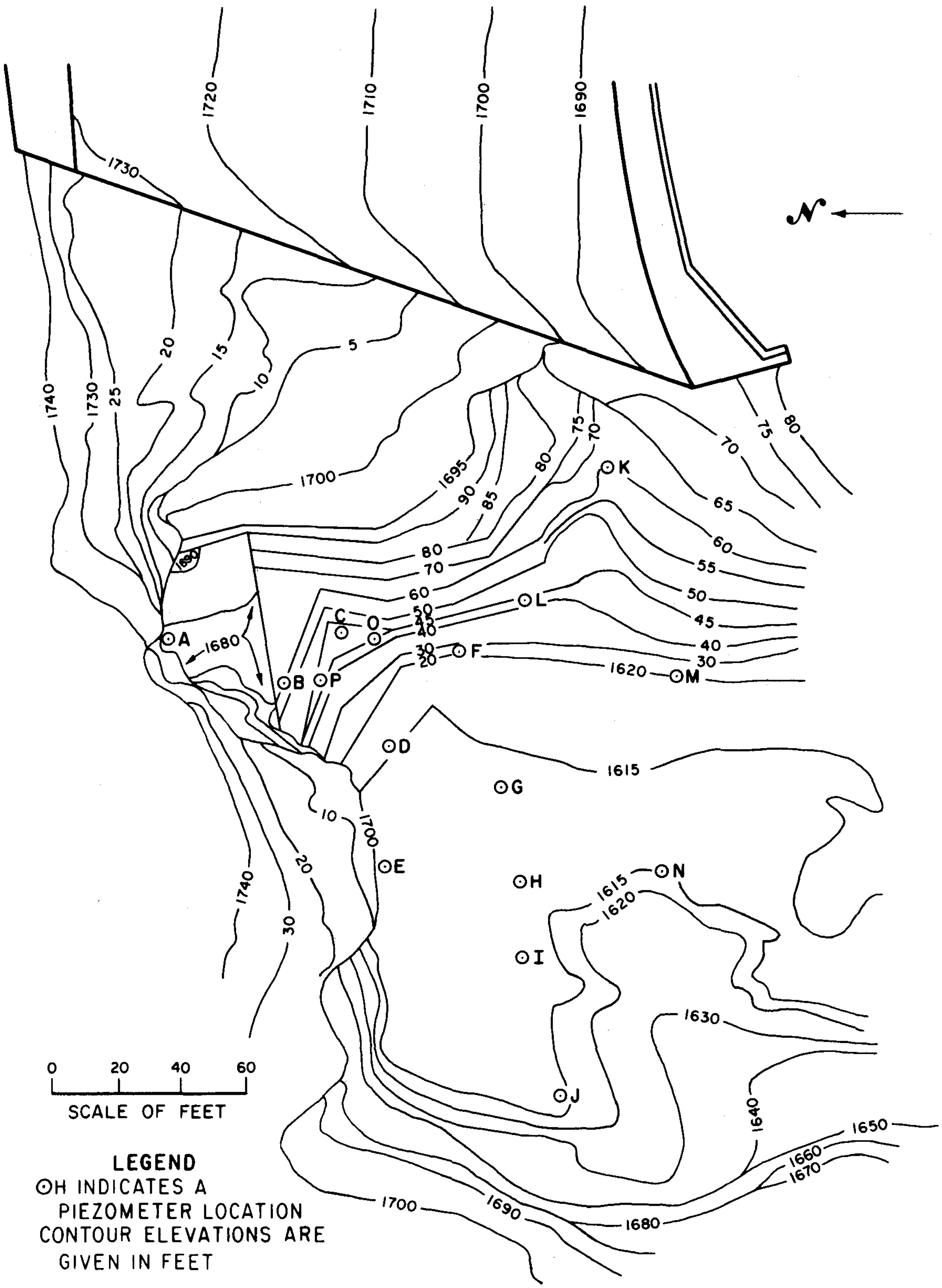


Figure 6.–Topography immediately below spillway chute (test series "B"), (initial design modification).

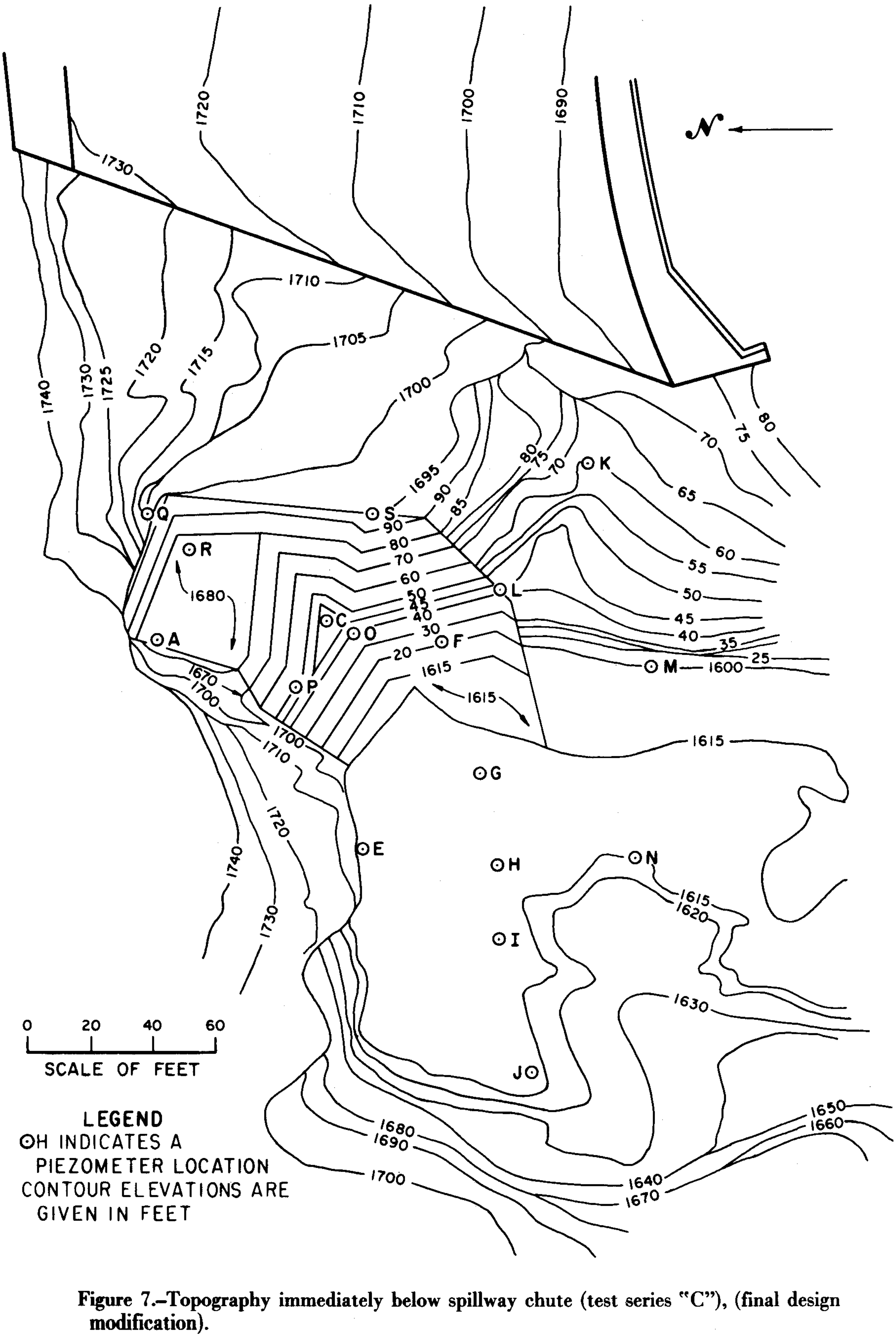


Figure 7.–Topography immediately below spillway chute (test series "C"), (final design modification).

Figure 8.–View of spillway chute and plunge pool (test series "A"), 850 m^3/s (30 000 ft^3/s). Photo P801-D-79496

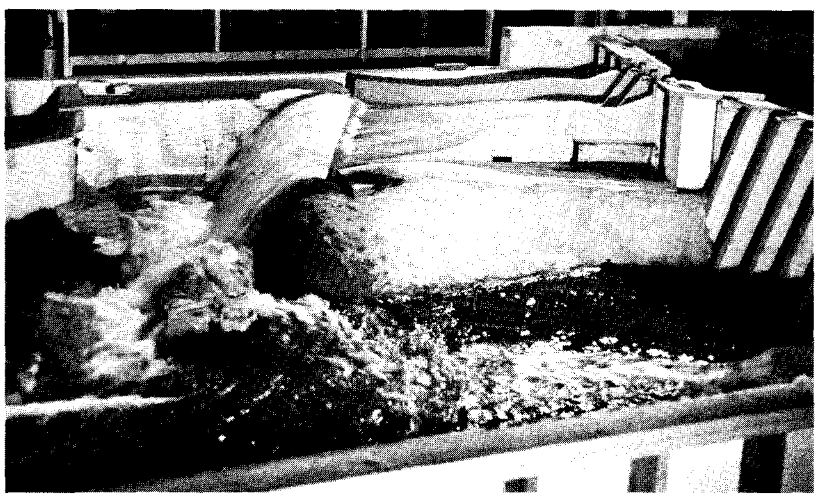


Figure 9.–View of spillway chute and plunge pool (test series "A"), 1982 m^3/s (70 000 ft^3/s). Photo P801-D-79497

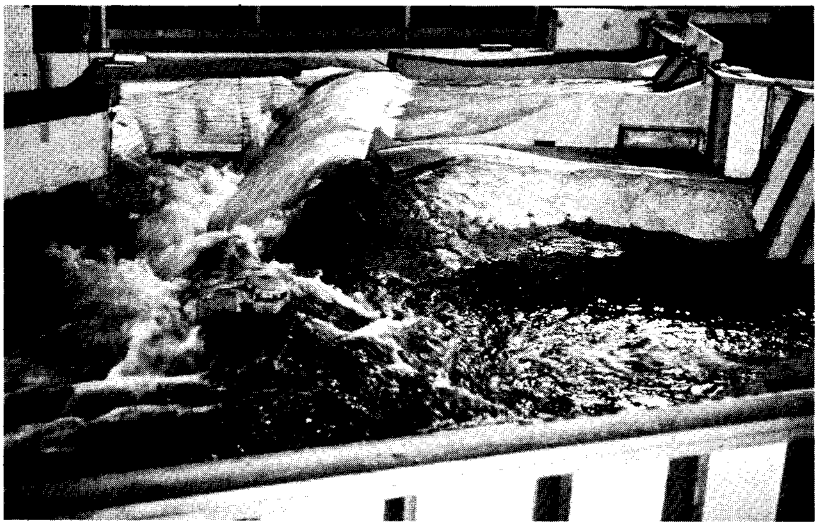


Figure 10.–View of spillway chute and plunge pool (test series "A"), 3540 m³/s (125 000 ft³/s). Photo P801-D-79498

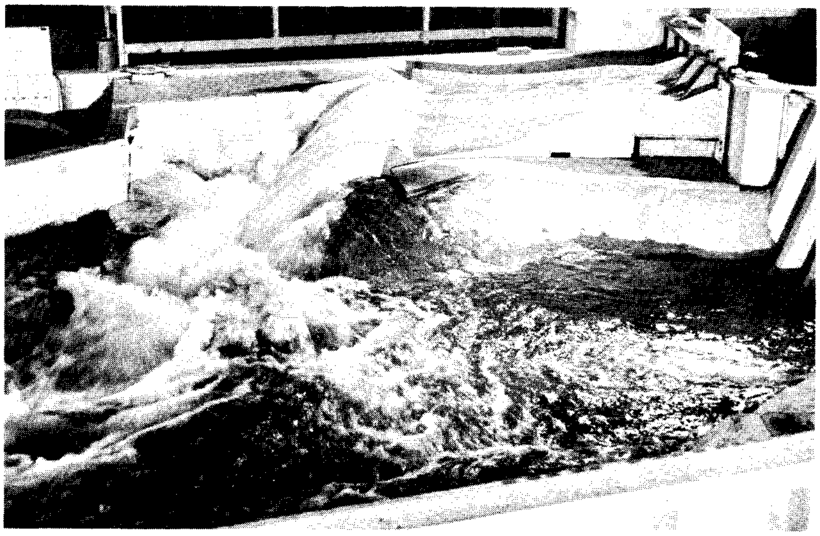


Figure 11.–View of spillway chute and plunge pool (test series "A"), 4955 m³/s (175 000 ft³/s). Photo P801-D-79499

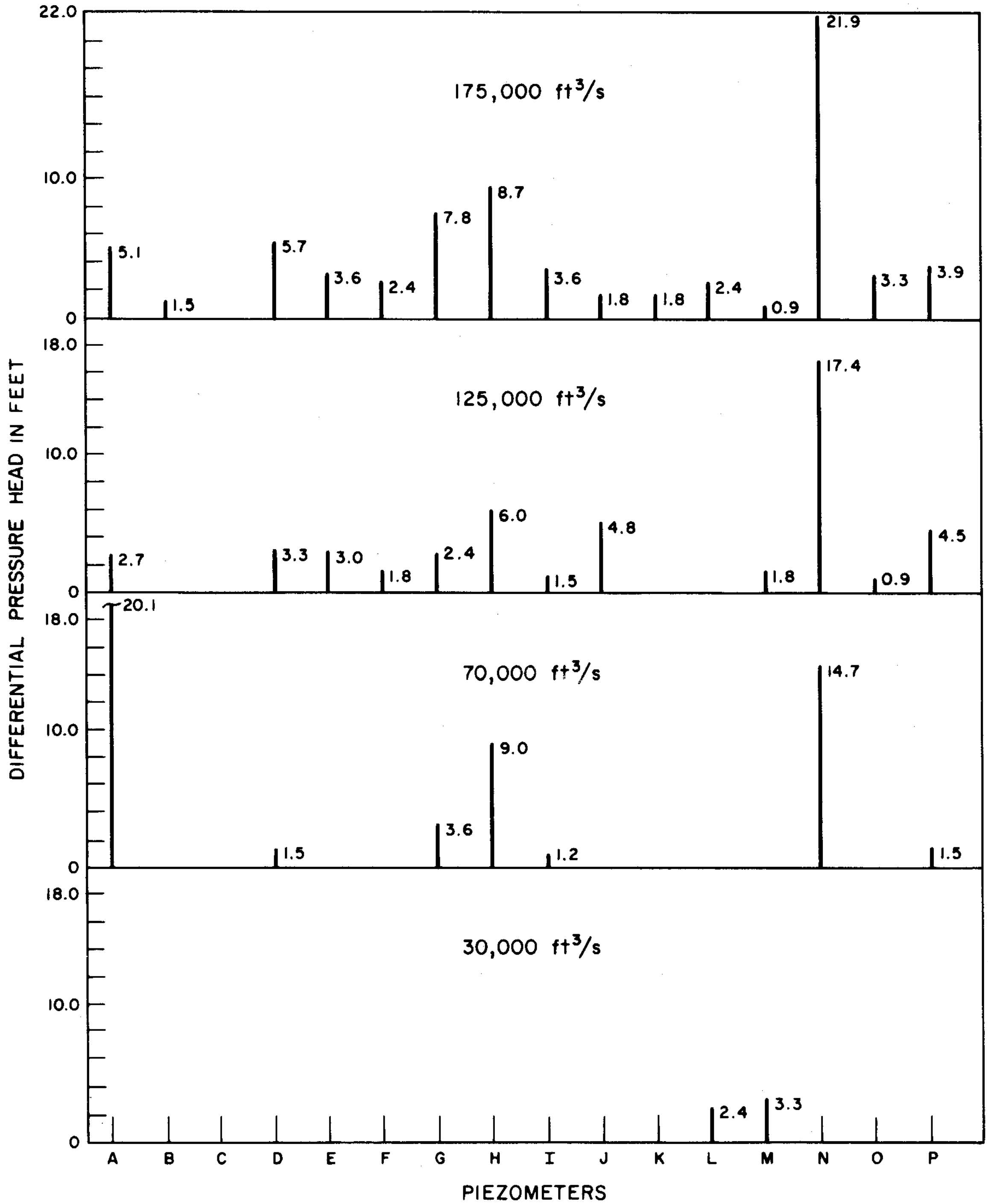


Figure 12.–Differential pressure heads for test series "A."

Figure 13.–View of spillway chute and plunge pool (test series "B"), 850 m³/s (30 000 ft³/s). Photo P801-D-794500

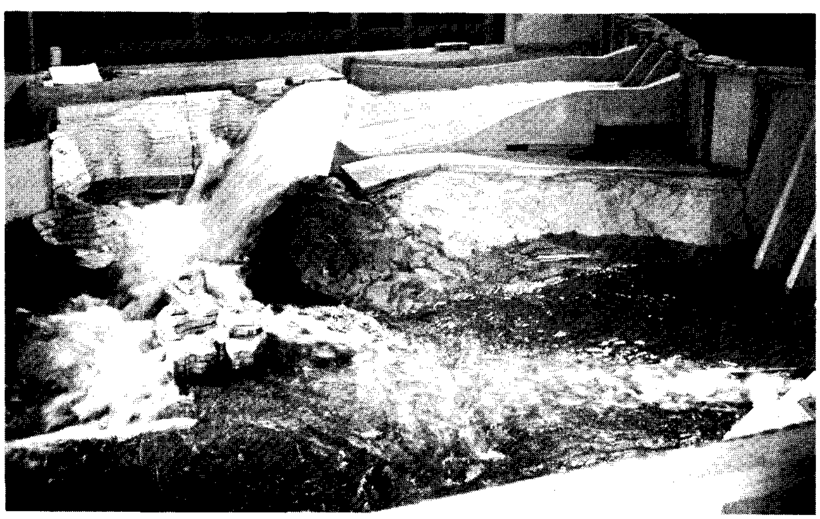


Figure 14.–View of spillway chute and plunge pool (test series "B"), 1982 m³/s (70 000 ft³/s). Photo P801-D-794501

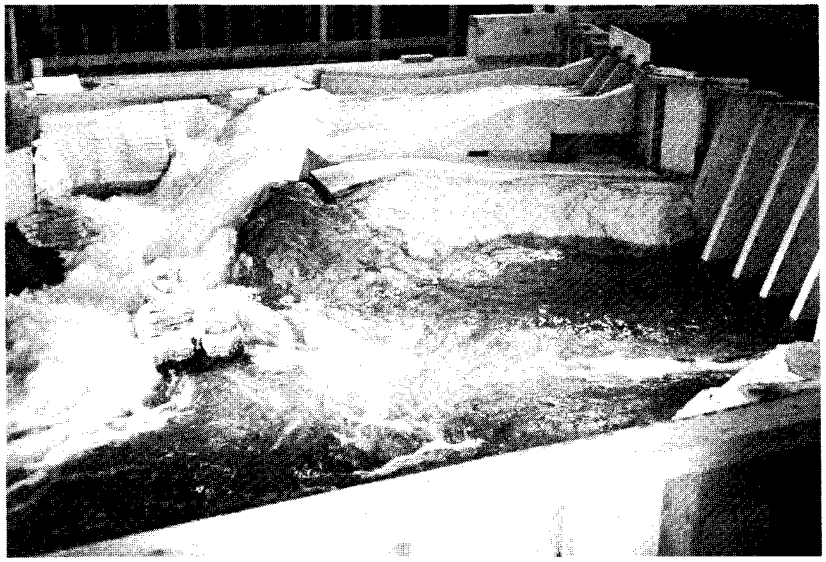


Figure 15.–View of spillway chute and plunge pool (test series "B"), 3540 m³/s (125 000 ft³/s). Photo P801-D-79502

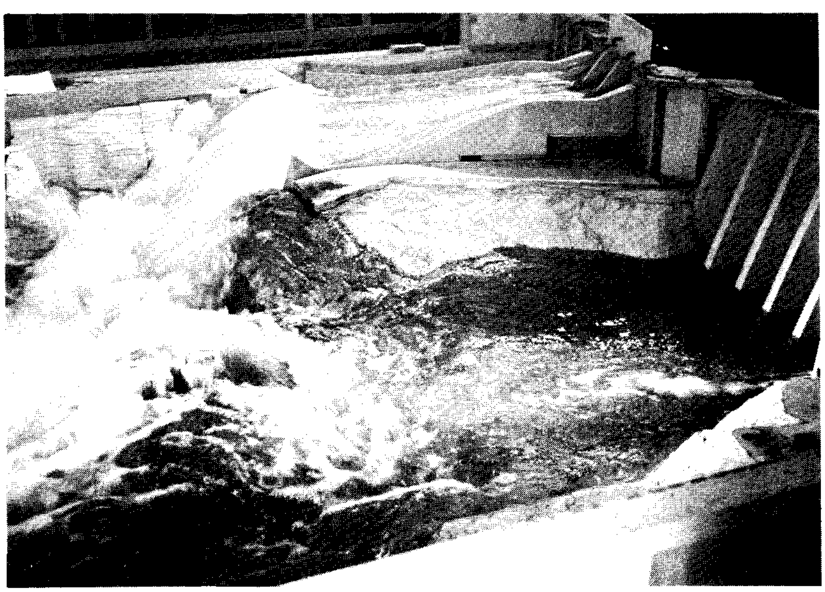


Figure 16.–View of spillway chute and plunge pool (test series "B"), 4955 m³/s (175 000 ft³/s). Photo P801-D-79503

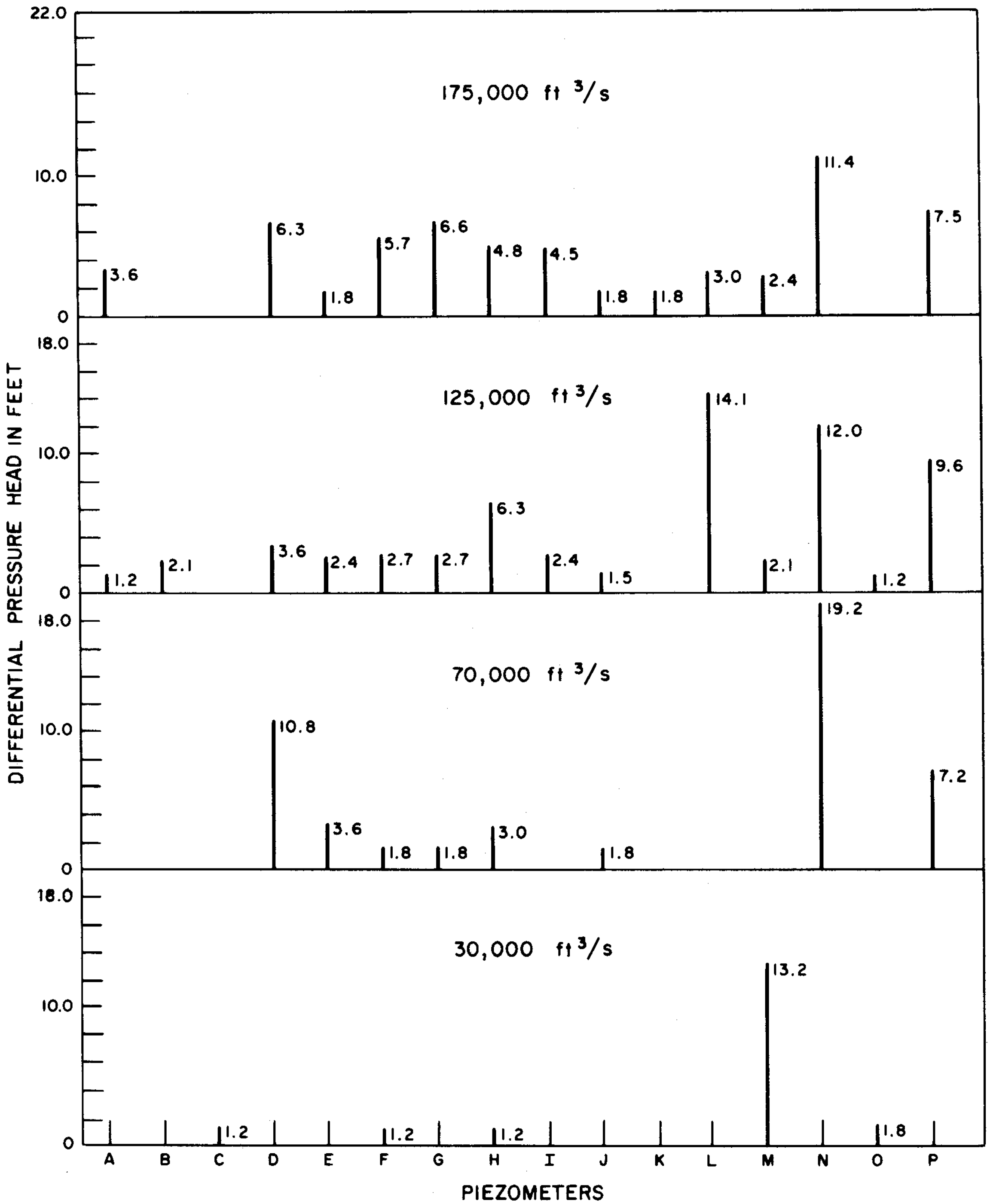


Figure 17.–Differential pressure heads for test series "B."

Figure 18.–View of spillway chute and plunge pool (test series "C"), 850 m³/s (30 000 ft³/s). Photo P801-D-79504

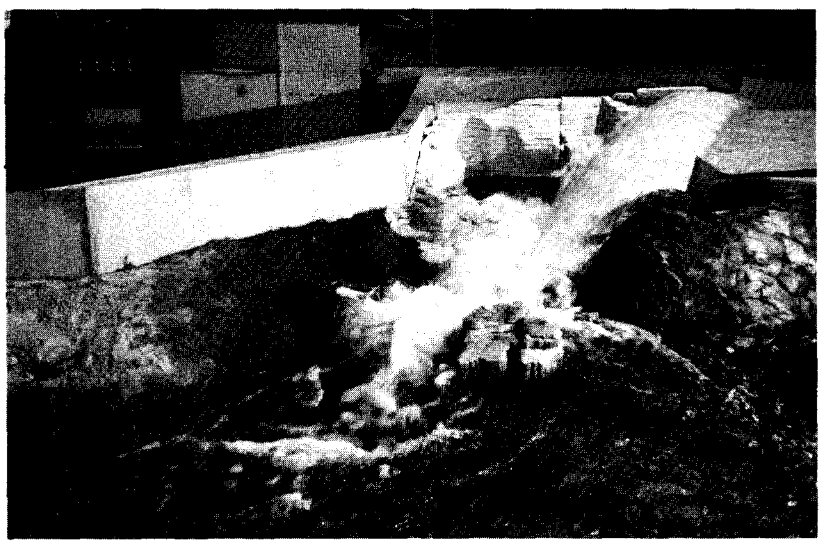


Figure 19.–View of spillway chute and plunge pool (test series "C"), 1982 m³/s (70 000 ft³/s). Photo P801-D-79505

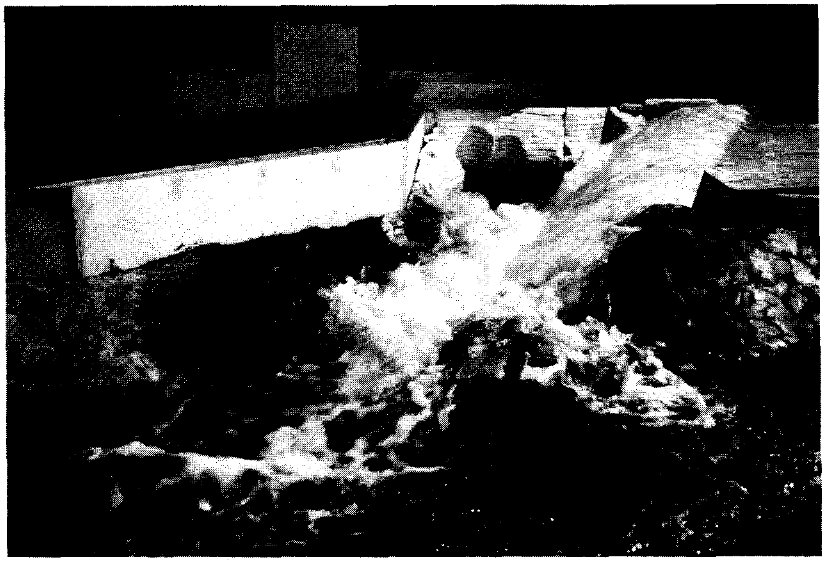


Figure 20.–View of spillway chute and plunge pool (test series "C"), 3540 m^3/s (125 000 ft^3/s). Photo P801-D-79506

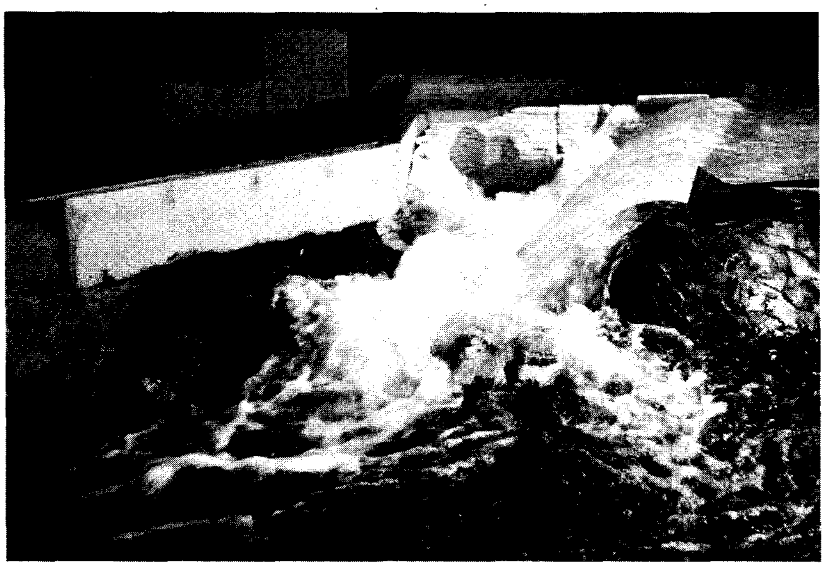


Figure 21.–View of spillway chute and plunge pool (test series "C"), 4955 m^3/s (175 000 ft^3/s). Photo P801-D-79507

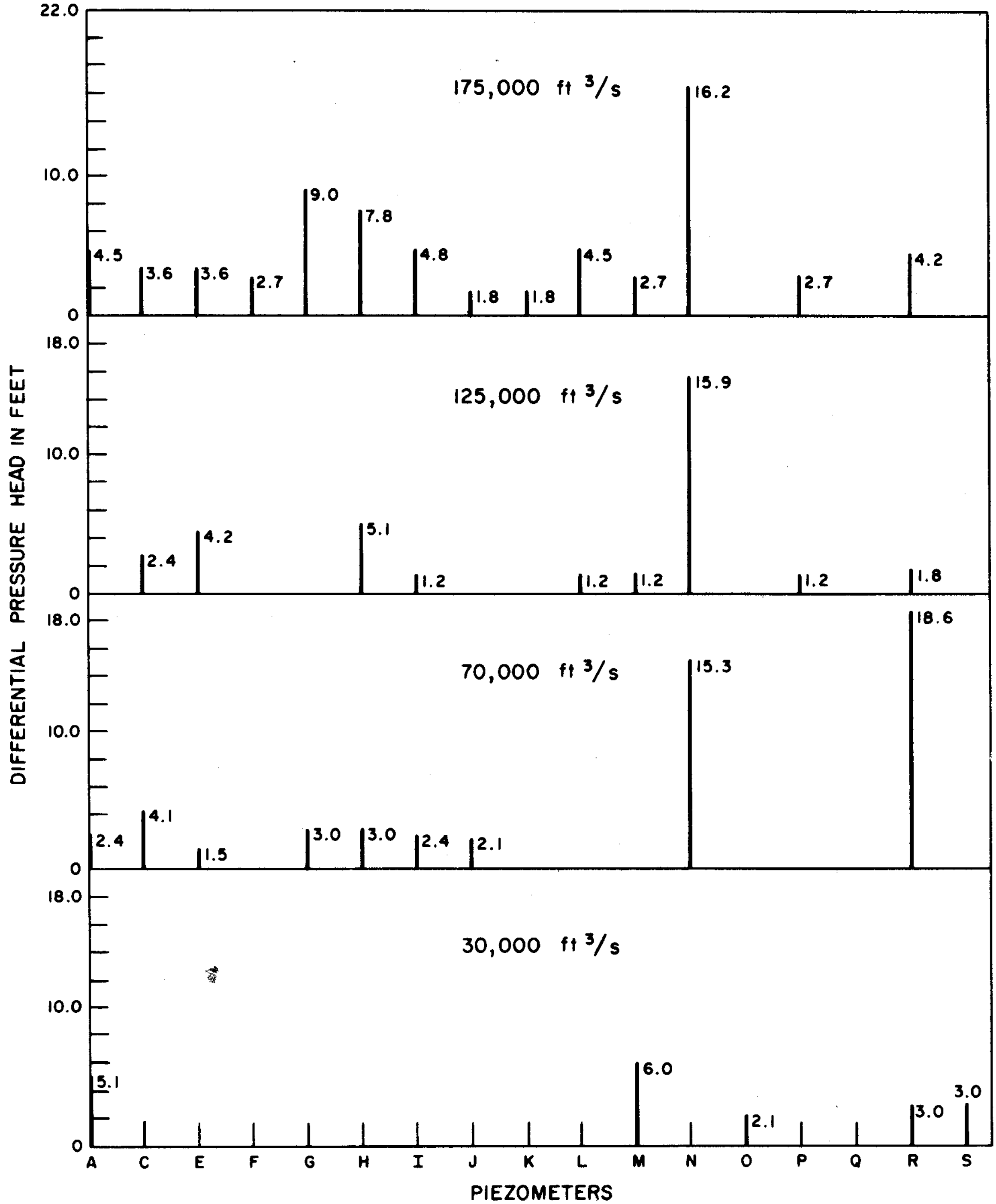


Figure 22.–Differential pressure heads for test series "C."

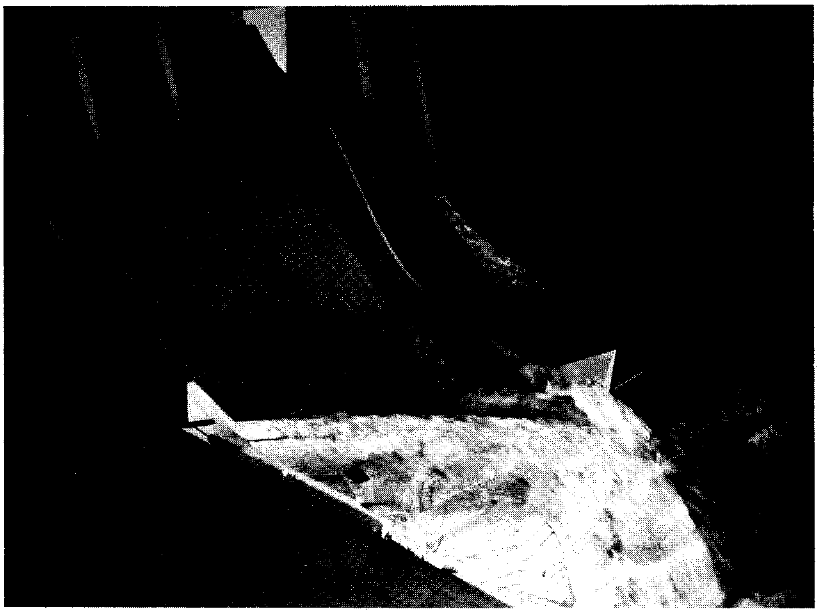


Figure 23.–Hydraulic jump in spillway chute – overtopping of left training wall, reservoir elevation 548.0 m (1798 ft), Q = 320 m³/s (11 300 ft³/s). Photo P801-D-79508

Figure 24.–Minimum spillway discharge flipping over lip, reservoir elevation 548.0 m (1798 ft), Q = 356.8 m³/s (12 600 ft³/s). Photo P801-D-79509

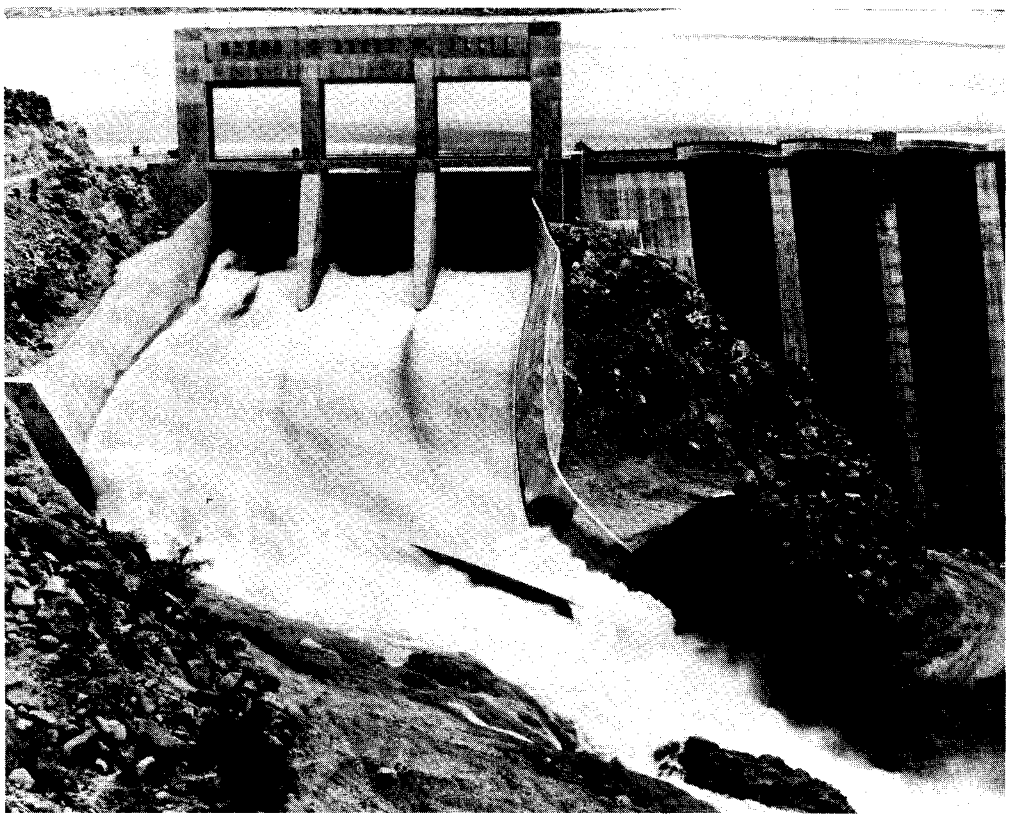


Figure 25.–Prototype spillway discharge; Gate No. 1, 159 m³/s (5600 ft³/s); Gate Nos. 2 and 3, 54 m³/s (1900 ft³/s). Photo P801-D-79510

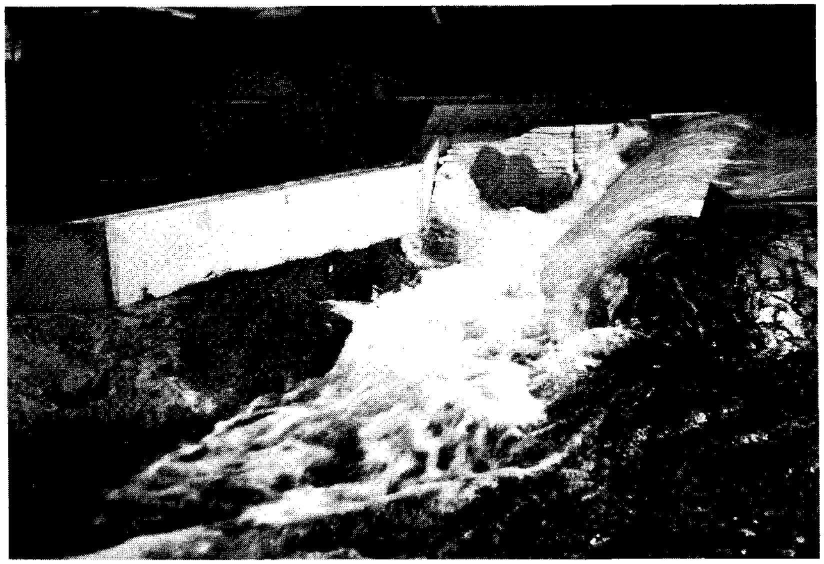


Figure 26.–View of plunge pool and downstream channel without boulder field, Q = 4955 m^3/s (175 000 ft^3/s). Photo P801-D-79511

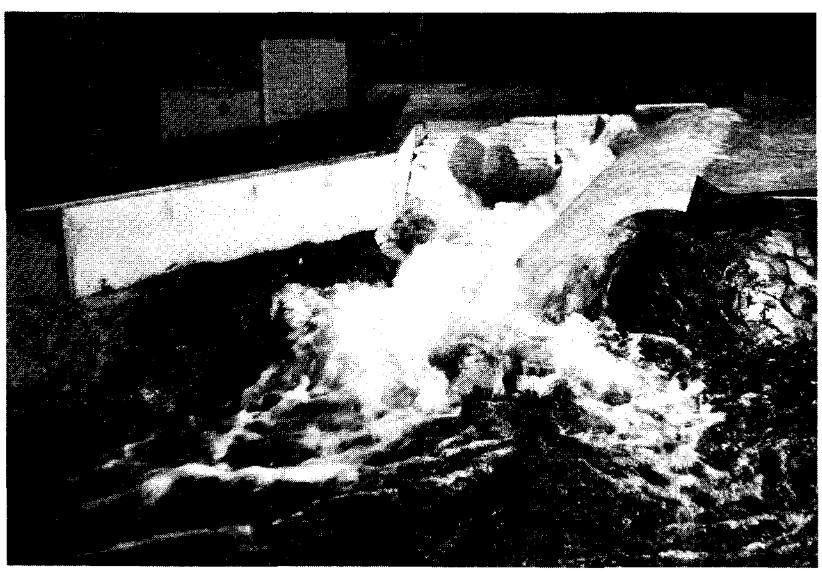


Figure 27.–View of plunge pool and downstream channel with boulder field, Q = 4955 m^3/s (175 000 ft^3/s). Photo P801-D-79512

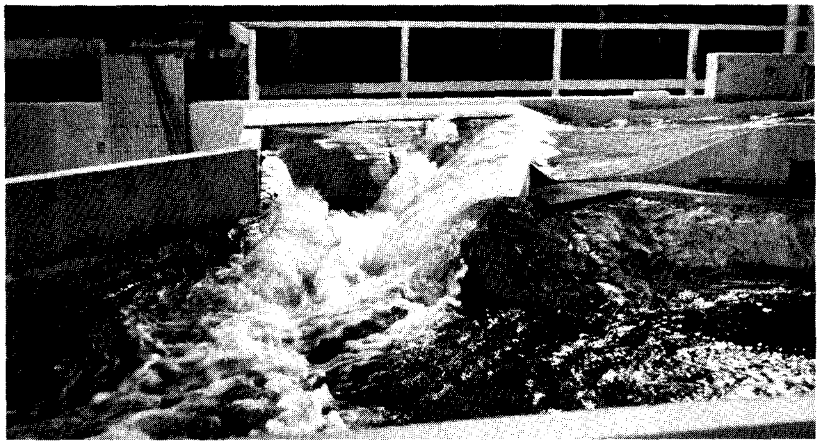


Figure 28.–View of plunge pool and downstream channel without boulder field (channel modified), Q = 4955 m^3/s (175 000 ft^3/s). Photo P801-D-79513

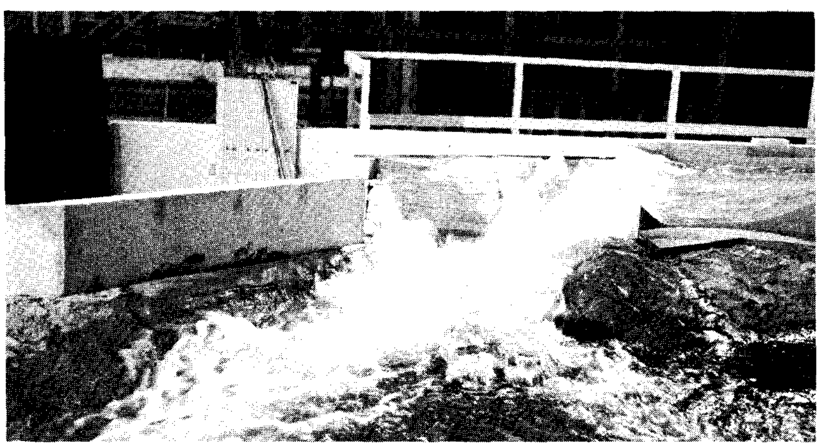


Figure 29.–View of plunge pool and downstream channel with boulder field (channel modified), Q = 4955 m^3/s (175 000 ft^3/s). Photo P801-D-79514

Figure 30.–Spillway discharging 6167 m^3/s (217 800 ft^3/s), dam overtopping 99.1 m^3/s (3500 ft^3/s), and river outlets discharging 85.0 m^3/s (3000 ft^3/s). Photo P801-D-79515

APPENDIX A

PLUNGE POOL PRESSURE DATA

Table A1.—*Test A-1 plunge pool pressures*

Piezometer	Elevation of piezometer (ft)	Manometer El. (ft)			Cell El. (ft)			Head (ft)			
								Manometer		Pressure cell	
		Max.	Avg.	Min.	Max.	Avg.	Min.	Avg.	ΔH	Avg.	ΔH
A	1675.4		1682.6					7.2			
B	1660.1		1663.1					3.0			
C	1660.1		1661.0					0.9			
D	1625.3		1628.1					2.8			
E	1614.2		1630.1					15.9			
F	1622.6		1630.7					8.1			
G	1609.7		1628.9		1661.9	1632.0	1615.4	19.2		22.3	46.5
H	1605.0		1629.2					24.2		31.4	48.0
I	1613.0		1629.5					16.5			
J	1616.3		1631.6					15.3			
K	1660.7		1663.4					2.7			
L	1644.8	1651.1	1649.9	1648.7				5.1	2.4		
M	1618.6	1645.4	1643.8	1642.1	1739.9	1643.9	1583.9	25.2	3.3	25.3	156.0
N	1613.0		1631.0					18.0			
O	1638.5		1641.5					3.0			
P	1643.9		1643.6					0.3			

Q = 30,000 ft^3/s
Tailwater El. 1622.5
Reservoir El. 1797.32

Table A2.—*Test A-2 plunge pool pressures*

Piezometer	Elevation of piezometer (ft)	Manometer El. (ft)			Cell El. (ft)			Head (ft)			
								Manometer		Pressure cell	
		Max.	Avg.	Min.	Max.	Avg.	Min.	Avg.	ΔH	Avg.	ΔH
A	1675.4	1715.6	1705.5	1695.5	1709.9	1697.9	1688.9	30.2	20.1	22.5	21.0
B	1660.1		1662.5					2.4			
C	1660.1		1664.9					4.8			
D	1625.3	1631.0	1630.3	1629.5	1660.7	1622.9	1610.9	5.0	1.5	-2.4	49.8
E	1614.2		1644.8					30.6			
F	1622.6		1637.6					15.0			
G	1609.7	1648.4	1646.6	1644.8	1742.9	1649.9	1616.9	36.9	3.6	40.2	126.0
H	1605.0	1659.8	1655.3	1650.8	1700.9	1652.9	1625.9	50.3	9.0	47.9	75.0
I	1613.0	1642.4	1641.8	1641.2				28.8	1.2		
J	1616.3		1647.2					30.9			
K	1660.7		1660.0					-0.7			
L	1644.8		1644.3					-0.5			
M	1618.6		1638.5					19.9			
N	1613.0	1661.0	1653.7	1646.3	1736.9	1640.9	1595.9	40.7	14.7	27.9	141.0
O	1638.5		1646.9					8.4			
P	1643.9	1646.6	1645.9	1645.1				2.0	1.5		

Q = 70,000 ft^3/s
Tailwater El. 1624
Reservoir El. 1797.44

Table A3.—*Test A-3 plunge pool pressures*

Piezometer	Elevation of piezometer (ft)	Manometer El. (ft)			Cell El. (ft)			Head (ft)			
								Manometer		Pressure cell	
		Max.	Avg.	Min.	Max.	Avg.	Min.	Avg.	ΔH	Avg.	ΔH
A	1675.4	1710.5	1709.2	1707.8	1730.9	1718.9	1709.9	33.8	2.7	43.5	21.0
B	1660.1		1661.3					1.2			
C	1660.1		1661.6					1.5			
D	1625.3	1636.4	1634.8	1633.1	1646.9	1616.9	1583.9	9.5	3.3	-8.4	63.0
E	1614.2	1653.2	1651.7	1650.2				37.5	3.0		
F	1622.6	1645.4	1644.5	1643.6				21.9	1.8		
G	1609.7	1658.6	1657.4	1656.2	1706.9	1655.9	1628.9	47.7	2.4	46.2	78.0
H	1605.0	1685.6	1682.6	1679.6	1766.9	1661.9	1589.9	77.6	6.0	56.9	177.0
I	1613.0	1653.2	1652.5	1651.7	1691.9	1658.9	1625.9	39.5	1.5	45.9	66.0
J	1616.3	1658.0	1655.6	1653.2	1673.9	1658.9	1646.9	39.3	4.8	42.6	27.0
K	1660.7		1660.1					-0.6			
L	1644.8		1640.6					-3.8			
M	1618.6	1649.0	1648.1	1647.2				29.5	1.8		
N	1613.0	1697.6	1688.9	1680.2	1834.7	1673.9	1571.9	75.9	17.4	60.9	262.8
O	1638.5	1649.6	1649.2	1648.7				10.7	0.9		
P	1643.9	1659.8	1657.6	1655.3	1691.9	1658.9	1631.9	13.7	4.5	15.0	60.0

Q = 125,000 ft³/s
Tailwater El. 1635
Reservoir El. 1798.58

Table A4.—*Test A-4 plunge pool pressures*

Piezometer	Elevation of piezometer (ft)	Manometer El. (ft)			Cell El. (ft)			Head (ft)			
								Manometer		Pressure cell	
		Max.	Avg.	Min.	Max.	Avg.	Min.	Avg.	ΔH	Avg.	ΔH
A	1675.4	1720.7	1718.2	1715.6	1745.9	1718.9	1700.9	42.8	5.1	43.5	45.0
B	1660.1	1659.8	1659.1	1658.3				-1.1	1.5		
C	1660.1		1663.4					3.3			
D	1625.3	1646.0	1643.2	1640.3	1700.9	1643.9	1595.9	17.9	5.7	18.6	105.0
E	1614.2	1668.8	1667.0	1665.2	1727.9	1673.9	1619.9	52.8	3.6	59.7	108.0
F	1622.6	1652.0	1650.8	1649.6				28.2	2.4		
G	1609.7	1688.0	1684.1	1680.2	1793.9	1688.9	1625.9	74.4	7.8	79.2	168.0
H	1605.0	1713.8	1709.5	1705.1	1817.9	1709.9	1616.9	104.5	8.7	104.9	201.0
I	1613.0	1662.2	1660.4	1658.6	1715.9	1661.9	1619.9	47.4	3.6	48.9	96.0
J	1616.3	1665.2	1664.3	1663.4	1691.9	1673.9	1655.9	48.0	1.8	57.6	36.0
K	1660.7	1664.6	1663.7	1662.8				3.0	1.8		
L	1644.8	1661.0	1659.8	1658.6				15.0	2.4		
M	1618.6	1654.4	1654.0	1653.5				35.4	0.9		
N	1613.0	1703.6	1692.7	1681.7	1811.9	1697.9	1625.9	79.7	21.9	84.9	186.0
O	1638.5	1658.9	1657.3	1655.6				18.8	3.3		
P	1643.9	1661.9	1660.0	1658.0	1688.9	1661.9	1637.9	16.1	3.9	18.0	51.0

Q = 175,000 ft^3/s
Tailwater El. 1641
Reservoir El. 1798.16

Table A5.—*Test B-1 plunge pool pressures*

Piezometer	Elevation of piezometer (ft)	Manometer El. (ft)			Cell El. (ft)			Head (ft)			
								Manometer		Pressure cell	
		Max.	Avg.	Min.	Max.	Avg.	Min.	Avg.	ΔH	Avg.	ΔH
A	1681.4		1681.7					0.3			
B	1656.8		1657.1					0.3			
C	1640.9	1650.5	1649.9	1649.3	1664.9	1649.9	1634.9	9.0	1.2	9.0	30.0
D	1618.4		1627.7					9.3			
E	1615.4		1632.2					16.8			
F	1621.4	1626.8	1626.2	1625.6				4.8	1.2		
G	1610.9		1629.5					18.6			
H	1605.0	1629.8	1629.2	1628.6				24.2	1.2		
I	1613.0		1631.6					18.6			
J	1618.7		1632.2					13.5			
K	1660.4		1662.8					2.4			
L	1641.1				1697.9	1649.9	1631.9			8.8	66.0
M	1617.2	1657.4	1650.8	1644.2	1778.9	1640.9	1571.9	33.6	13.2	23.7	207.0
N	1611.8		1632.2					20.4			
O	1643.3	1651.4	1650.5	1649.6	1700.9	1655.9	1631.9	7.2	1.8		
P	1643.6		1643.6					0.0			

Q = 30,000 ft^3/s
Tailwater El. 1618
Reservoir El. 1798.10

Table A6.—*Test B-2 plunge pool pressures*

Piezometer	Elevation of piezometer (ft)	Manometer El. (ft)			Cell El. (ft)			Head (ft)			
								Manometer		Pressure cell	
		Max.	Avg.	Min.	Max.	Avg.	Min.	Avg.	ΔH	Avg.	ΔH
A	1681.4		1689.8					8.4			
B	1656.8		1655.6					1.2			
C	1640.9		1647.5					6.6			
D	1618.4	1649.6	1644.2	1638.8	1736.9	1643.9	1583.9	25.8	10.8	25.5	153.0
E	1615.4	1644.2	1642.4	1640.6	1646.9	1637.9	1616.9	27.0	3.6	22.5	30.0
F	1621.4	1638.8	1637.9	1637.0				16.5	1.8		
G	1610.9	1644.8	1643.9	1643.0	1708.4	1646.9	1601.9	33.0	1.8	36.0	106.5
H	1605.0	1649.6	1648.1	1646.6	1661.9	1643.9	1628.9	43.1	3.0	38.9	33.0
I	1613.0		1632.5		1694.9	1634.9	1607.9	19.5		21.9	87.0
J	1618.7	1645.4	1644.5	1643.6	1661.9	1649.9	1636.9	25.8	1.8	31.2	25.0
K	1660.4		1656.8					-3.6			
L	1641.1		1643.0					1.9			
M	1617.2		1638.2					21.0			
N	1611.8	1661.6	1652.0	1642.4	1841.9	1655.9	1571.9	40.2	19.2	44.1	270.0
O	1643.3		1646.0					2.7			
P	1643.6	1649.6	1646.0	1642.4	1748.9	1649.9	1565.9	2.4	7.2	6.3	183.0

Q = 70,000 ft^3/s
Tailwater El. 1627
Reservoir El. 1798.34

Table A7.—*Test B-3 plunge pool pressures*

Piezometer	Elevation of piezometer (ft)	Manometer El. (ft)			Cell El. (ft)			Head (ft)			
								Manometer		Pressure cell	
		Max.	Avg.	Min.	Max.	Avg.	Min.	Avg.	ΔH	Avg.	ΔH
A	1681.4	1692.2	1691.6	1691.0				10.2	1.2		
B	1656.8	1661.3	1660.3	1659.2				3.5	2.1		
C	1640.9		1652.9					12.0			
D	1618.4	1641.2	1639.4	1637.6	1727.9	1637.9	1601.9	21.0	3.6	19.5	126.0
E	1615.4	1647.2	1646.0	1644.8				30.6	2.4		
F	1621.4	1647.5	1646.2	1644.8				24.8	2.7		
G	1610.9	1656.5	1655.2	1653.8	1715.9	1655.9	1619.9	44.3	2.7	45.0	96.0
H	1605.0	1676.6	1673.5	1670.3	1781.9	1670.9	1621.7	68.5	6.3	65.9	160.2
I	1613.0	1640.0	1638.8	1637.6	1685.9	1646.9	1607.9	25.8	2.4	33.9	78.0
J	1618.7	1651.7	1651.0	1650.2	1670.9	1655.9	1640.9	32.3	1.5	37.2	30.0
K	1660.4		1660.1					-0.3			
L	1641.1	1661.6	1654.6	1647.5	1676.9	1646.9	1627.9	13.5	14.1	5.8	49.0
M	1617.2	1646.6	1645.6	1644.5				28.4	2.1		
N	1611.8	1676.6	1670.6	1664.6	1793.9	1670.9	1586.9	58.8	12.0	59.1	207.0
O	1643.3	1646.6	1646.0	1645.4				2.7	1.2		
P	1643.6	1662.2	1657.4	1652.6	1715.9	1649.9	1613.9	13.8	9.6	6.3	102.0

Q = 125,000 ft^3/s
Tailwater El. 1635
Reservoir El 1798.04

Table A8.—*Test B-4 plunge pool pressures*

Piezometer	Elevation of piezometer (ft)	Manometer El. (ft)			Cell El. (ft)			Head (ft)			
								Manometer		Pressure cell	
		Max.	Avg.	Min.	Max.	Avg.	Min.	Avg.	ΔH	Avg.	ΔH
A	1681.4	1714.4	1712.6	1710.8				31.2	3.6		
B	1656.8		1659.2					2.4			
C	1640.9		1655.0					14.1			
D	1618.4	1650.5	1647.4	1644.2	1733.9	1646.9	1589.9	29.0	6.3	28.5	144.0
E	1615.4	1660.1	1659.2	1658.3				43.8	1.8		
F	1621.4	1650.5	1647.7	1644.8				26.3	5.7		
G	1610.9	1677.8	1674.5	1671.2	1748.9	1673.9	1622.9	63.6	6.6	63.0	126.0
H	1605.0	1701.8	1699.4	1697.0	1805.9	1697.9	1625.9	94.4	4.8	92.9	180.0
I	1613.0	1654.4	1652.2	1649.9	1694.9	1658.9	1601.4	39.2	4.5	45.9	93.0
J	1618.7	1666.1	1665.2	1664.3	1682.9	1670.9	1657.4	46.5	1.8	52.2	25.5
K	1660.4	1663.7	1662.8	1661.9				2.4	1.8		
L	1641.1	1653.2	1651.7	1650.2				10.6	3.0		
M	1617.2	1656.8	1655.6	1654.4				38.4	2.4		
N	1611.8	1684.4	1678.7	1673.0	1796.9	1670.9	1607.9	66.9	11.4	59.1	189.0
O	1643.3		1646.0					2.7			
P	1643.6	1655.9	1652.2	1648.4	1802.9	1655.9	1586.9	8.6	7.5	12.3	216.0

$Q = 175{,}000\ ft^3/s$
Tailwater El. 1641
Reservoir El. 1798.04

Table A9.–*Test C-1 plunge pool pressures*

Piezometer	Elevation of piezometer (ft)	Manometer El. (ft)			Cell El. (ft)			Head (ft)			
								Manometer		Pressure cell	
		Max.	Avg.	Min.	Max.	Avg.	Min.	Avg.	ΔH	Avg.	ΔH
A	1680.8		1683.5					2.7			
C	1644.8	1680.5	1678.0	1675.4	1763.9	1676.9	1613.9	33.2	5.1		
E	1614.5		1631.9					17.4			
F	1620.7		1627.1					6.4			
G	1613.6		1629.5					15.9			
H	1605.0		1630.7					25.7			
I	1613.6		1631.6					18.0			
J	1616.5		1631.9					15.4			
K	1659.5		1662.8					3.3			
L	1641.5		1645.7					4.2			
M	1617.2	1642.4	1639.4	1636.4	1811.9	1646.9	1565.9	22.2	6.0	29.7	246.0
N	1611.5		1631.6					20.1			
O	1638.8	1645.7	1644.7	1643.6				5.9	2.1		
P	1647.2		1648.7					1.5			
Q	1706.9		1709.6					2.7			
R	1679.9	1686.8	1685.3	1683.8	1730.9	1685.9	1658.9	5.4	3.0	6.0	72.0
S	1697.0	1700.6	1699.1	1697.6	1805.9	1706.9	1655.9	2.1	3.0	9.9	150.0

$Q = 30{,}000\ ft^3/s$
Tailwater El. 1619
Reservoir El. 1798.40

Table A10.—*Test C-2 plunge pool pressures*

Piezometer	Elevation of piezometer (ft)	Manometer El. (ft)			Cell El. (ft)			Head (ft)			
								Manometer		Pressure cell	
		Max.	Avg.	Min.	Max.	Avg.	Min.	Avg.	ΔH	Avg.	ΔH
A	1680.8	1693.7	1692.5	1691.3				11.7	2.4		
C	1644.8	1652.6	1649.6	1647.5	1718.9	1649.9	1616.9	4.8	4.1	5.1	102.0
E	1614.5	1645.1	1644.4	1643.6				29.9	1.5		
F	1620.7		1635.5					14.8			
G	1613.6	1643.6	1641.5	1640.6				28.5	3.0		
H	1605.0	1649.6	1648.1	1646.6				43.1	3.0		
I	1613.6	1628.6	1627.4	1626.2				13.8	2.4		
J	1616.5	1645.7	1644.7	1643.6				28.2	2.1		
K	1659.5		1659.8					0.3			
L	1641.5		1644.8					3.3			
M	1617.2		1637.6					20.4			
N	1611.5	1660.4	1652.8	1645.1	1826.9	1655.9	1559.9	41.3	15.3	44.4	267.0
O	1638.8		1642.7					3.9			
P	1647.2		1648.0					1.8			
Q	1706.9		1711.7					4.8			
R	1679.9	1724.6	1715.3	1706.0	1817.9	1718.9	1631.9	35.4	18.6	39.0	186.0
S	1697.0		1696.7					-0.3			

Q = 70,000 ft^3/s
Tailwater El. 1626
Reservoir El. 1798.16

Table A11.—*Test C-3 plunge pool pressures*

Piezometer	Elevation of piezometer (ft)	Manometer El. (ft)			Cell El. (ft)			Head (ft)			
								Manometer		Pressure cell	
		Max.	Avg.	Min.	Max.	Avg.	Min.	Avg.	ΔH	Avg.	ΔH
A	1680.8	1709.9		1705.4	1745.9	1706.9	1658.9	24.6			
C	1644.8	1660.7	1659.5	1658.3				14.7	2.4		
E	1614.5	1568.6	1656.5	1654.4				42.0	4.2		
F	1620.7		1644.8					24.1			
G	1613.6		1651.1		1694.9	1652.9	1619.9	37.5		39.3	75.0
H	1605.0	1674.2	1671.7	1669.1	1772.9	1673.9	1607.9	66.7	5.1	68.9	165.0
I	1613.6	1634.0	1633.4	1632.8	1685.9	1637.9	1589.9	19.8	1.2	24.3	96.0
J	1616.5		1649.3		1673.9	1655.9	1637.9	32.8		39.4	36.0
K	1659.5		1660.1					0.6			
L	1641.5	1647.8	1647.2	1646.6				5.7	1.2		
M	1617.2	1644.8	1644.2	1643.6				27.0	1.2		
N	1611.5	1693.7	1685.8	1677.8	1820.9	1697.9	1592.9	74.3	15.9	86.4	228.0
O	1638.8		1643.6					4.8			
P	1647.2	1653.8	1653.2	1652.6				6.0	1.2		
Q	1706.9		1722.2					15.3			
R	1679.9	1692.2	1691.3	1690.4	1778.9	1691.9	1661.9	11.4	1.8	12.0	117.0
S	1697.0		1697.6					0.6			

Q = 125,000 ft^3/s
Tailwater El. 1635
Reservoir El. 1798.04

Table A12.—*Test C-4 plunge pool pressures*

Piezometer	Elevation of piezometer (ft)	Manometer El. (ft)			Cell El. (ft)			Head (ft)			
								Manometer		Pressure cell	
		Max.	Avg.	Min.	Max.	Avg.	Min.	Avg.	ΔH	Avg.	ΔH
A	1680.8	1737.2	1735.0	1732.7	1811.9	1733.9	1667.9	54.2	4.5	53.1	144.0
C	1644.8	1661.6	1659.8	1658.0				15.0	3.6		
E	1614.5	1671.2	1669.4	1667.6	1742.9	1673.9	1619.9	54.9	3.6	59.4	123.0
F	1620.7	1651.7	1650.4	1649.0				26.7	2.7		
G	1613.6	1681.1	1676.6	1672.1	1775.9	1673.9	1613.9	63.0	9.0	60.3	162.0
H	1605.0	1700.9	1697.0	1693.1	1796.9	1691.9	1619.9	92.0	7.8	86.9	177.0
I	1613.6	1644.2	1641.8	1639.4	1691.9	1652.9	1583.9	28.2	4.8	39.3	108.0
J	1616.5	1664.3	1663.4	1662.5	1688.9	1666.9	1649.9	46.9	1.8	50.4	39.0
K	1659.5	1664.3	1663.4	1662.5				3.9	1.8		
L	1641.5	1654.1	1651.9	1649.6				10.4	4.5		
M	1617.2	1659.5	1658.2	1656.8				41.0	2.7		
N	1611.5	1704.8	1696.7	1688.6	1814.9	1700.9	1619.9	85.2	16.2	89.4	195.0
O	1638.8		1644.8					6.0			
P	1647.2	1657.1	1655.8	1654.4				8.6	2.7		
Q	1706.9		1726.1					19.2			
R	1679.9	1698.8	1696.7	1697.6	1808.9	1694.9	1637.9	16.8	4.2	15.0	171.0
S	1697.0		1696.4					-0.6			

Q = 175,000 ft^3/s
Tailwater El. 1641
Reservoir El. 1798.16

APPENDIX B

EMERGENCY SPILLWAY GATE OPERATION

After completion of the Bartlett spillway model study in November 1978, repairs began on the erosion downstream of the prototype spillway chute. Prior to completing the repair work, heavy rains forced spillway discharges on December 18-20, 1978. The discharge reached a maximum of 65,000 ft^3/s, and subsequently decreased to 30,000 ft^3/s lasting for several hours. As a result of these discharges, more damage occurred to highly erodible rock on the right side of the plunge pool. To avoid further damage to the area on the right side of the plunge pool, the Salt River Project office requested that an emergency spillway gate operation be developed on the model which would divert future spillway discharges to the left side of the plunge pool.

The shape of the superelevated spillway chute provided an excellent opportunity to utilize gate sequencing. Gate sequencing was tested at reservoir El. 1784, 1790, and 1798. To save time in completing the tests, the topography used for test series "C" was used with a line drawn on the topography to denote the new upstream erosion boundary.

The use of the left gate for as much of the flow as possible diverted the flow to the left side of the plunge pool. To avoid the exposed rock surface, the maximum discharge from the left gate was 20,000 ft^3/s for reservoir El. 1798 and 1790 and 15,000 ft^3/s for reservior El. 1784. Figure B1 shows a discharge of 25,000 ft^3/s, 20,000 ft^3/s through gate No. 3, and 5,000 ft^3/s through gate No. 2, at reservoir El. 1798 which was representative of the sequencing. For higher discharges at reservoir El. 1978, the following sequencing should be used when diverting the flow away from the right side of the plunge pool.

Table B1.–*Emergency spillway discharge tests – reservoir El. 1798*

Discharge (ft^3/s)	Gates used
0-20,000	No. 3
20,000-25,000	No. 3–20,000 No. 2–remainder
25,000-35,000	No. 3–remainder No. 2–5,000
35,000-45,000	No. 3–30,000 No. 2–remainder
45,000-65,000	No. 3–remainder No. 2–15,000
65,000-75,000	No. 3–remainder No. 2–20,000

For the lower reservoir elevations of 1784 and 1790 and discharges up to 25,000 ft^3/s, releases should be made through gate 3. (See tables B2 and B3 for gate operations.)

Table B2.–*Emergency spillway discharge tests – reservoir El. 1790*

Spillway discharge, ft^3/s	Gates used	Tailwater EL. in plunge pool, ft	Comments
5,000	3	1615	Jet impinges in range from 50 to 130 ft south of piezometer L*
10,000	3	1620	Jet impinges in range from 25 to 145 ft south of piezometer L
15,000	3	1623	Jet impinges in range from 0 to 135 ft south of piezometer L
20,000	3	1625	Jet impinges 25 ft north to 125 ft south of piezometer L
25,000	3	1630	Jet impinges well into plunge pool

* See figure 7.

Table B3.–*Emergency spillway discharge tests – reservoir El. 1784*

Spillway discharge, ft^3/s	Gates used	Tailwater El. in plunge pool, ft	Comments
5,000	3	1614	Jet impinges in range from 50 to 130 ft south of piezometer L*
10,000	3	1619	Jet impinges in range from 10 to 140 ft south of piezometer L
15,000	3	1622	Jet impinges in range from 0 to 130 ft south of piezometer L

* See figure 7.

This emergency spillway operation sequencing was utilized on January 17-21, 1979, when heavy rains again forced spillway releases. This discharge reached a maximum of 30,000 ft^3/s which was deflected to the left side of the plunge pool, causing very minor damage to the repair area. A prototype spillway discharge of 2,500 ft^3/s through gate No. 3, representative of the emergency gate openings, is shown on figure B2.

The repair work below the spillway was completed in July 1979. The final configuration of the repairs was altered slightly from the initial design due to the damage received during the large flood in December 1978. The prototype final topography is shown in figure B3 with the model topography on figure B4. The operation of the model under the test discharges is shown on figures B5, B6, B7, and B8. The prototype spillway with the repairs downstream completed discharged a maximum of 108 000 ft^3/s in February 1980. An inspection after this discharge revealed only minor damage which could easily be repaired.

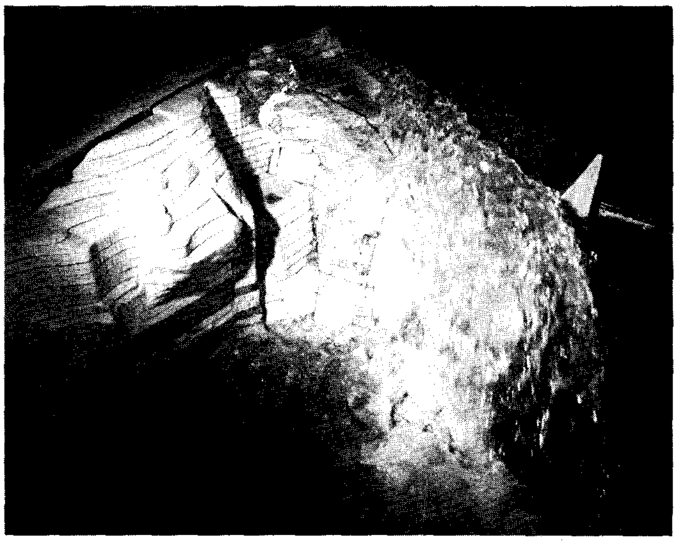


Figure B1.–Emergency spillway gate operation, Q = 25,000 ft^3/s (Gate No. 3 – 20,000 ft^3/s, Gate No. 2 – 5,000 ft^3/s). Photo P801-D-79516

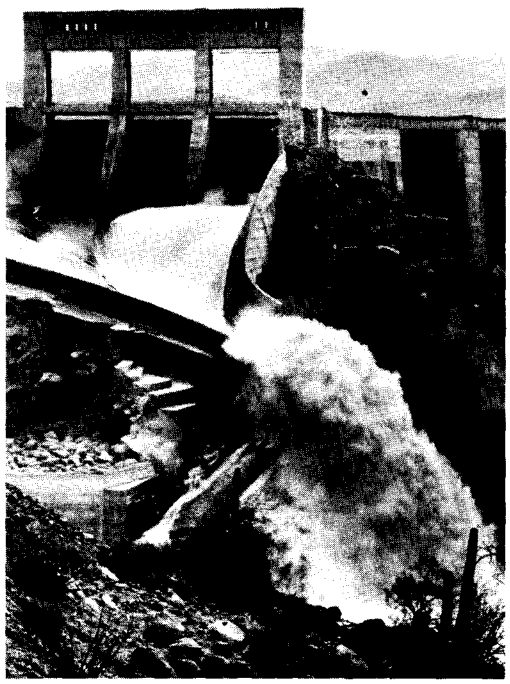


Figure B2.–Prototype emergency spillway gate operation, Q = 2,500 ft^3/s, January 1979. Photo P801-D-79517

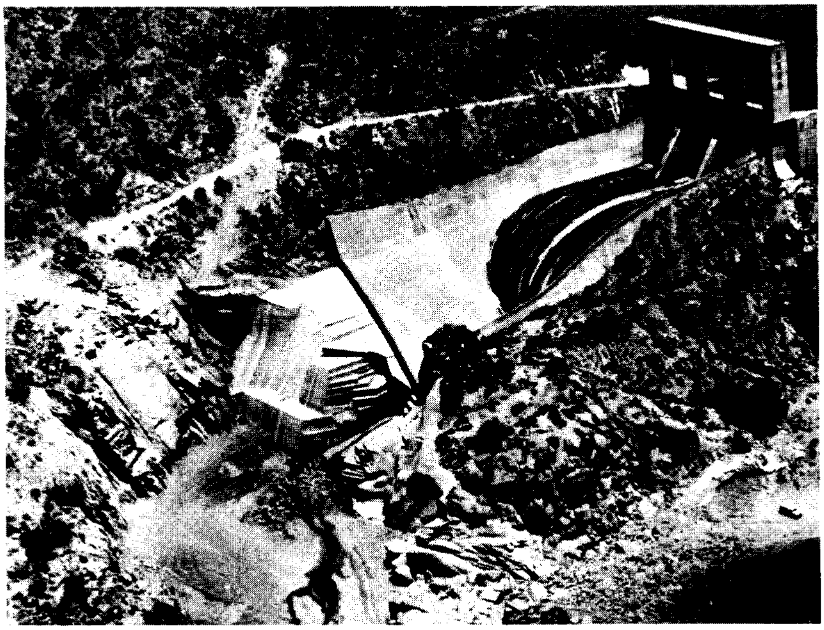


Figure B3.–Prototype structure final topography, July 1979. Photo P801-D-79518

Figure B4.–Final topography in the model. Photo P801-D-79519

Figure B5.–Final topography (Q = 30,000 ft^3/s). Photo P801-D-79520

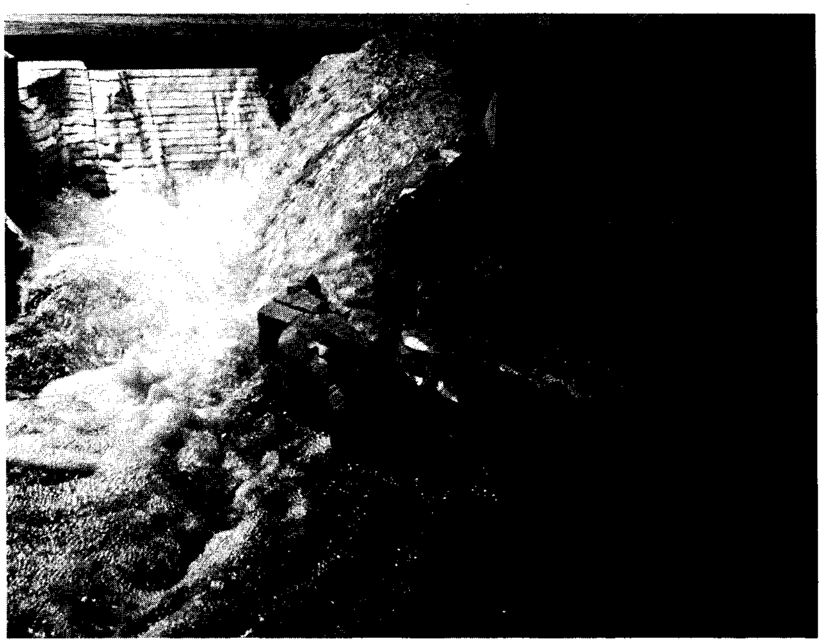


Figure B6.–Final topography (Q = 70,000 ft^3/s). Photo P801-D-79521

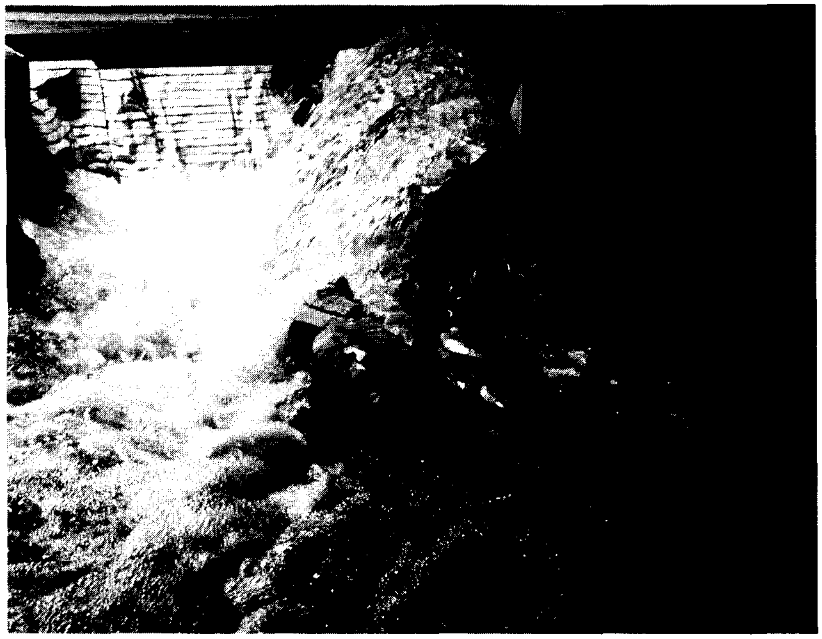


Figure B7.–Final topography ($Q = 125{,}000\ ft^3/s$). Photo P801-D-79522

Figure B8.–Final topography ($Q = 175{,}000\ ft^3/s$). Photo P801-D-79523

GPO 832-867

A free pamphlet is available from the Bureau of Reclamation entitled, "Publications for Sale". It describes some of the technical publications currently available, their cost, and how to order them. The pamphlet can be obtained upon request to the Bureau of Reclamation, E&R Center, PO Box 25007, Denver Federal Center, Bldg. 67, Denver, CO 80225, Attn: 922.