SUMMARY OF THE HYDRAULIC MODEL STUDY FOR THE PROPOSED MODIFICATION TO KLANG GATES DAM, MALAYSIA

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Introduction

The proposed modification to Klang Gates Dam raises the nonoverflow section of the dam 10 feet and adds four 16.5- by 9-foot radial gates on the existing spillway. These studies were initially requested to verify the hydraulic design of the radial gates, spillway, and stilling basin. However, as the studies progressed, it became apparent that the immediate downstream river channel and appurtenant structures were threatened by scour, flood, and wave action during discharges that are well within the design capacities of both the proposed gated spillway and the existing free-flow spillway. Therefore, a request was made to include in these studies an investigation of the channel immediately downstream from the dam.

Klang Gates Dam Model

Constructed to a scale of 1:36 the model included 144 feet of horizontal reservoir approach to the spillway, part of the concrete arch dam, the spillway and stilling basin, and 235 feet of river channel downstream from the stilling basin (figure 1). The spillway and slotted-bucket energy dissipator were milled from high density polyurethane plastic and sanded to the desired profile. Model topography was determined from 5-foot interval contour maps supplied to the Bureau of Reclamation by the Malaysian Government. Scaled contours were cut from wood, placed in the model, and covered with metal lath. The lath was covered with approximately three/fourths inch of cement-sand mortar. Three removable portions of topography were utilized to study possible channelization of the downstream river channel (figure 2). Rock gabions, constructed in the prototype after flooding, and the water supply control house, scaled from the contour maps and recent photographs, were simulated with wood. Riverbed material was scaled from photographs of the riverbed and represented 3/4- to 6-foot boulders. A flap-type tailgate was used to adjust the tailwater elevation and to collect eroded gravel. Water was supplied to the model through the permanent laboratory system and was measured by Venturi meters.

Pressures on the spillway surface were measured using a pressure transducer connected consecutively to 17 piezometers installed along the centerline of the gated right spillway bay. The transducer output voltage was measured by a digital voltmeter calibrated to display pressure in feet of water. Due to limited space in the model, a 6-inch strip was left out of the downstream channel topography. This strip was parallel to the dam, in a straight portion of the channel, and immediately upstream of the turn in the rock gabions (figure 2). Foreshortening the model at this location had negligible effect on water surface elevation compared with form losses caused by the channel topography.

Investigations

A study of the hydraulic performance of the proposed spillway modification was advisable because the existing spillway was not designed originally for the addition of radial gates. Pressure data measured using the piezometers on the spillway were plotted to show the spillway pressure profiles at various reservoir heads and gate openings. Pressures were also recorded using a raised sillplate as well as a flush sillplate requiring a curved bottom gate seal. Discharge measurements at various reservoir heads and gate openings were recorded and plotted to obtain discharge curves to be used during field operations. Tailwater elevations were recorded at locations along the downstream channel for various discharges. This information was used to calculate average velocities in the channel from discharge and cross-sectional area of the flow.

The study of the downstream river channel was concerned with observing stilling basin effectiveness, recording tailwater elevations, and recognizing possible scour problems.

The portion of downstream channel that was modeled had three flow control points, figure 2. The first constriction was the right canyon wall beginning at the end of the stilling basin and extending about 75 feet downstream. This protrusion into the channel constricted the flow leaving the stilling basin. The second constriction was formed by the narrowing of the channel about 100 feet downstream. Bounded on the left by the rock gabions and on the right by the high riverbank, hereafter referred to as the nob, this constriction controlled the spillway tailwater depth for flows up to approximately 6,000 ft^3/s. The third constriction occurred at the end of the rock gabion where an outcrop formed the left bank and a nearly vertical cliff formed the right bank. Three removable topography sections (figures 3, 4, and 5), one at each of the above control points, were removed in various combinations to study the effect on tailwater elevations and flow conditions.

Results

The minimum pressures on the spillway during both gated and free-flow discharge occurred near piezometer No. 4. Figure 6 shows that at design maximum reservoir elevation of 321 feet the minimum pressure decreased to -4 feet of water as the gate opening increased to 9 feet. Figure 7 shows that with gates full open the minimum pressure decreased to -5.5 feet of water as the reservoir elevation increased to 326 feet. Figure 8 shows that the raised sillplate had very little effect on the spillway pressures. The lowest pressure for the design reservoir elevation of 321 feet was also -4 feet of water with gates full open. The pressures measured on the spillway were damped or averaged but are not considered low enough to cause cavitation for the velocities expected on the spillway. No periodic pressure fluctuations that could be attributed to flow tending to separate from the spillway surface were noted. Small pressure variations of ± 4 percent were measured by the transducer system.

To determine the spillway capacity, heads and discharges were measured for gate openings of 1 foot, 2 feet, 3 feet, 5 feet, 7 feet, and full open. A maximum discharge of 13,300 ft^3/s occurred at maximum reservoir elevation with gates full open as shown on capacity curves of figure 9. The stilling basin originally designed for 11,800 ft^3/s operated well at all discharges.

Color slides, black and white photographs, and a 16-mm color movie were taken as methods of recording downstream river channel data while the model was operated at discharges of 1,900 ft^3/s, 3,100 ft^3/s, 4,400 ft^3/s, 5,800 ft^3/s, and 13,300 ft^3/s. A tabulation of tailwater elevations and calculated velocities at several locations during the above discharges is given in table 1. The existing channel was satisfactory for discharges up to 1,900 ft^3/s, figure 10. However, at discharges greater than 1,900 ft^3/s scouring started.

When the discharge reached 4,400 ft^3/s gravel representing riverbed material up to 3 feet in diameter was being moved in the model, figure 11. Scouring was most prominent immediately downstream of both the nob and rock. Average velocities along the gabion between the nob and rock were about 20 ft/s. Also, at 4,400 ft^3/s water was beginning to splash over the stilling basin retaining walls. After removing the nob section, the tailwater elevation in the stilling basin was lowered approximately 1 foot and the overtopping stopped, figure 12. However, this channelization increased the downstream velocities.

There were several bad flow conditions at the discharge of 5,800 ft^3/s. Water was flowing over the retaining walls, over the highest part of the backfill behind the rock gabions, and also over the section of gabions protecting the control house, figure 13. Water was about 2 feet deep around the control house. Removing both the nob and rock sections alleviated all the conditions mentioned above. Water now splashed only over the retaining walls, and no water reached the control house from either behind the gabions or over the gabions, figure 14. However, downstream velocities were considered high, being 20 to 25 ft/s. Removing the canyon section, in addition to the nob and rock, did not lower the tailwater elevation, figure 15.

At a discharge of 13,300 ft^3/s, water flowed approximately 4 feet over the retaining walls, 2 feet over the highest section of gabions, and 6 feet deep along the side of the control house, figure 16. Wave action was very rough throughout the channel, and velocities averaged greater than 20 ft/s. Removal of the nob and rock lowered tailwater elevations approximately 1 foot, figure 17. Removal of the canyon section proved detrimental by creating a very strong back eddy at the right side of the stilling basin, figure 18.

Conclusions

The hydraulic performance of the proposed spillway modification was satisfactory. At the design reservoir elevation of 321 feet, and with the gates fully opened, the release was 13,300 ft^3/s. This is greater than the previous design maximum discharge of 11,800 ft^3/s. The existing stilling basin operated adequately during all equally gated discharges. The immediate downstream river channel handled discharges less than 1,900 ft^3/s without foreseeable problem, but at higher discharges damage to the gabions and control house by scour, flood, or wave action appeared possible. This potential river channel damage is not associated only with the proposed modifications to Klang Gates Dam but could occur with the existing spillway for discharges exceeding 1,900 ft^3/s.

The extent of possible damage cannot be determined from the model. Channelization is advisable if the spillway is to be operated at discharges greater than 1,900 ft^3/s.

Table 1

TAILWATER ELEVATIONS, FT - CALCULATED VELOCITIES, FT/S

Q (ft^3/s)	Topo	Elevations (ft) L.W.	Grd	House	Velocity (ft/s) No. 1	No. 2	No. 3	Comments
1,900	EX	227	227	214	10	14	15	
3,100	EX	228	228	221	12	19	21	
4,400	EX	230	230	224	12	22	20	Splashing over retaining walls
4,400	N	229	229	223		25	22	Splashing nearly stopped
5,800	EX	231	231	226		19	15	Flowing over retaining walls Water on house from behind and over gabion
5,800	R&N	230	230	223		25	20	Water no longer on house
5,800	R,N&B	230	230	223				
13,300	EX	235	235	232				
13,300	R&N	234	234	231				Removal not much help
13,300	R,N&B	234	234	231				Strong back eddy at basin

Q - Discharge
Topo - Model topography
EX - Existing topography
N - Nob topography section removed
R - Rock section at end of gabions removed
B - Canyon section at stilling basin removed
L.W. - Left wall of stilling basin
Grd - Backfill behind gabions
House - Average along riverside of house or gabion at middle of house

Locations of Calculated Average Velocities

No. 1 - Just upstream of nob
No. 2 - Just downstream of turn
No. 3 - Just upstream of rock

Figure 1. - Upstream view of 1:36 model showing gated spillway.

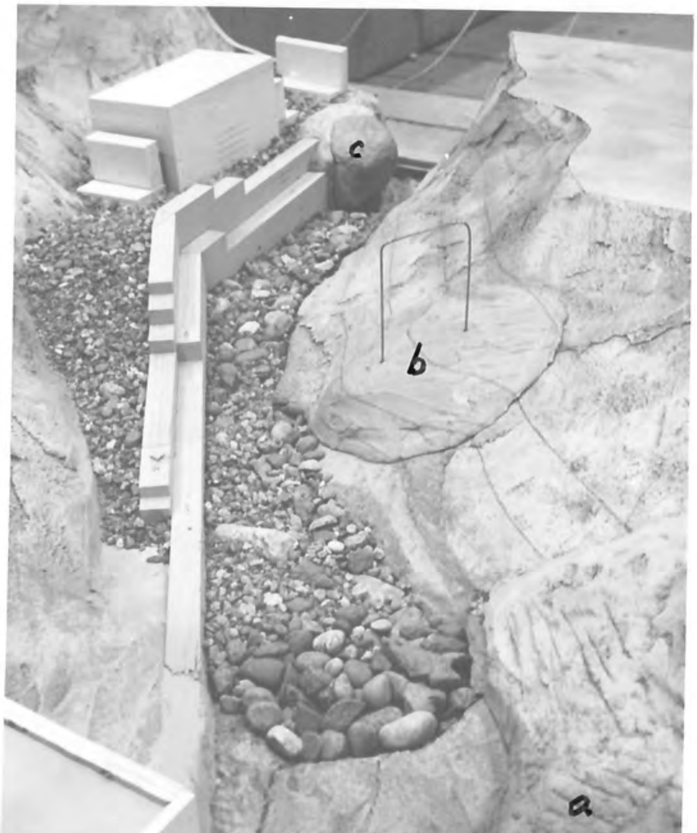


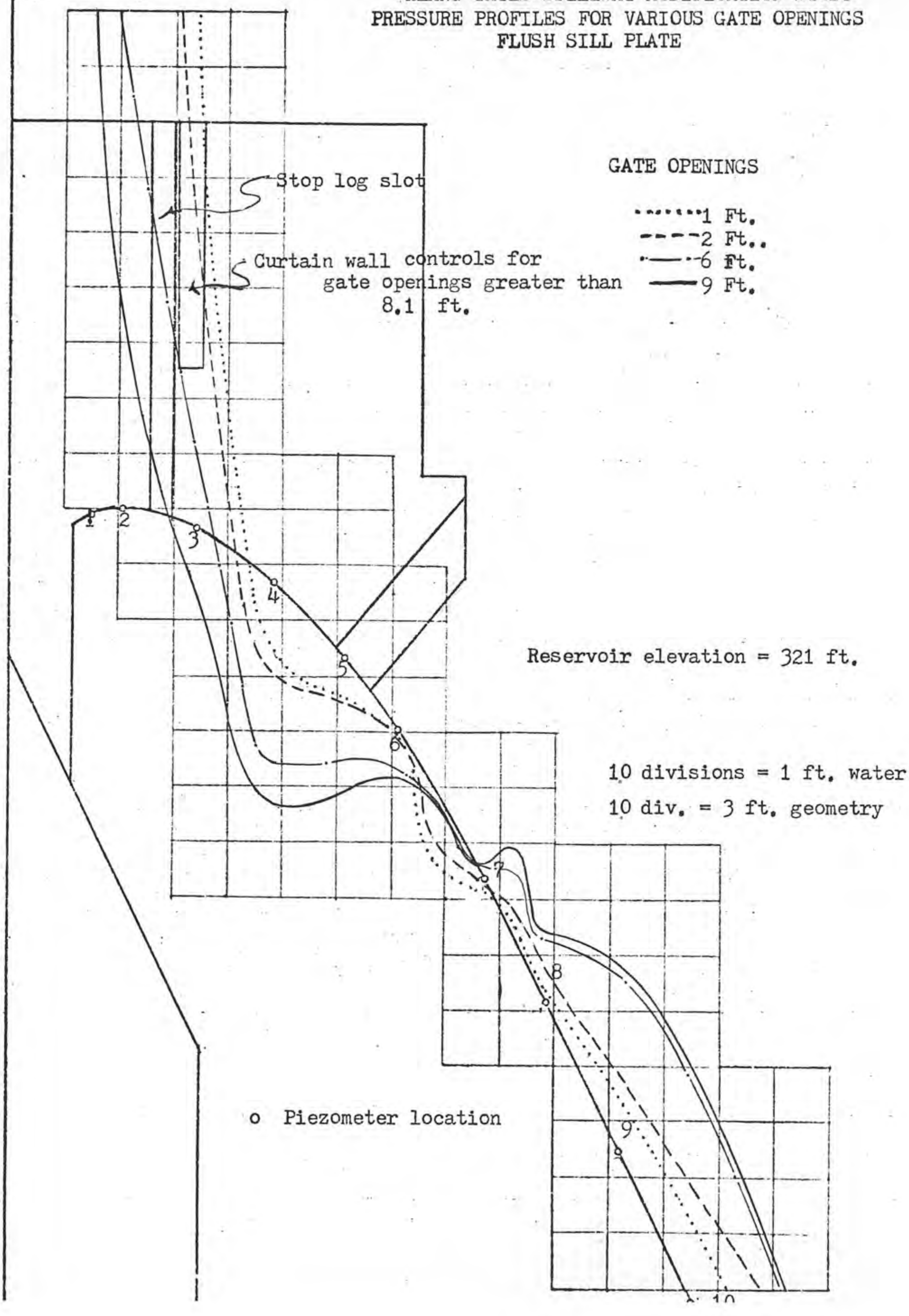
Figure 2. - Downstream channel with gabions and removable topography
(a) canyon
(b) nob
(c) rock

Figure 3. - Downstream view without removable topography in place.

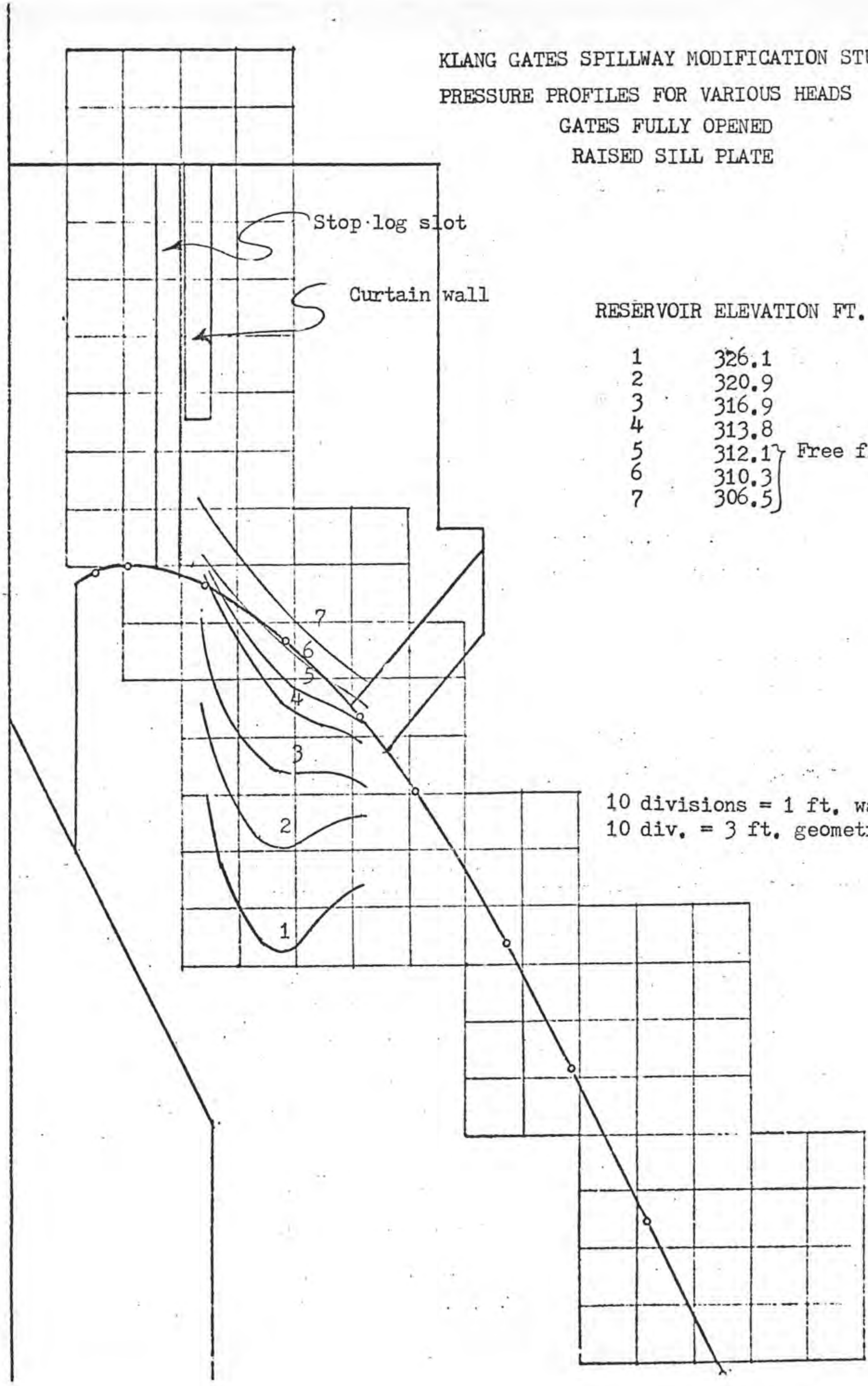
Figure 4. - View from right bank with the removable topography in place.

Figure 5. - Right bank view without removable
topography.

KLANG GATES SPILLWAY MODIFICATION STUDY
PRESSURE PROFILES FOR VARIOUS GATE OPENINGS
FLUSH SILL PLATE



KLANG GATES SPILLWAY MODIFICATION STUDY
PRESSURE PROFILES FOR VARIOUS HEADS
GATES FULLY OPENED
RAISED SILL PLATE



RESERVOIR ELEVATION FT.

1	326.1	
2	320.9	
3	316.9	
4	313.8	
5	312.1	Free flow
6	310.3	
7	306.5	

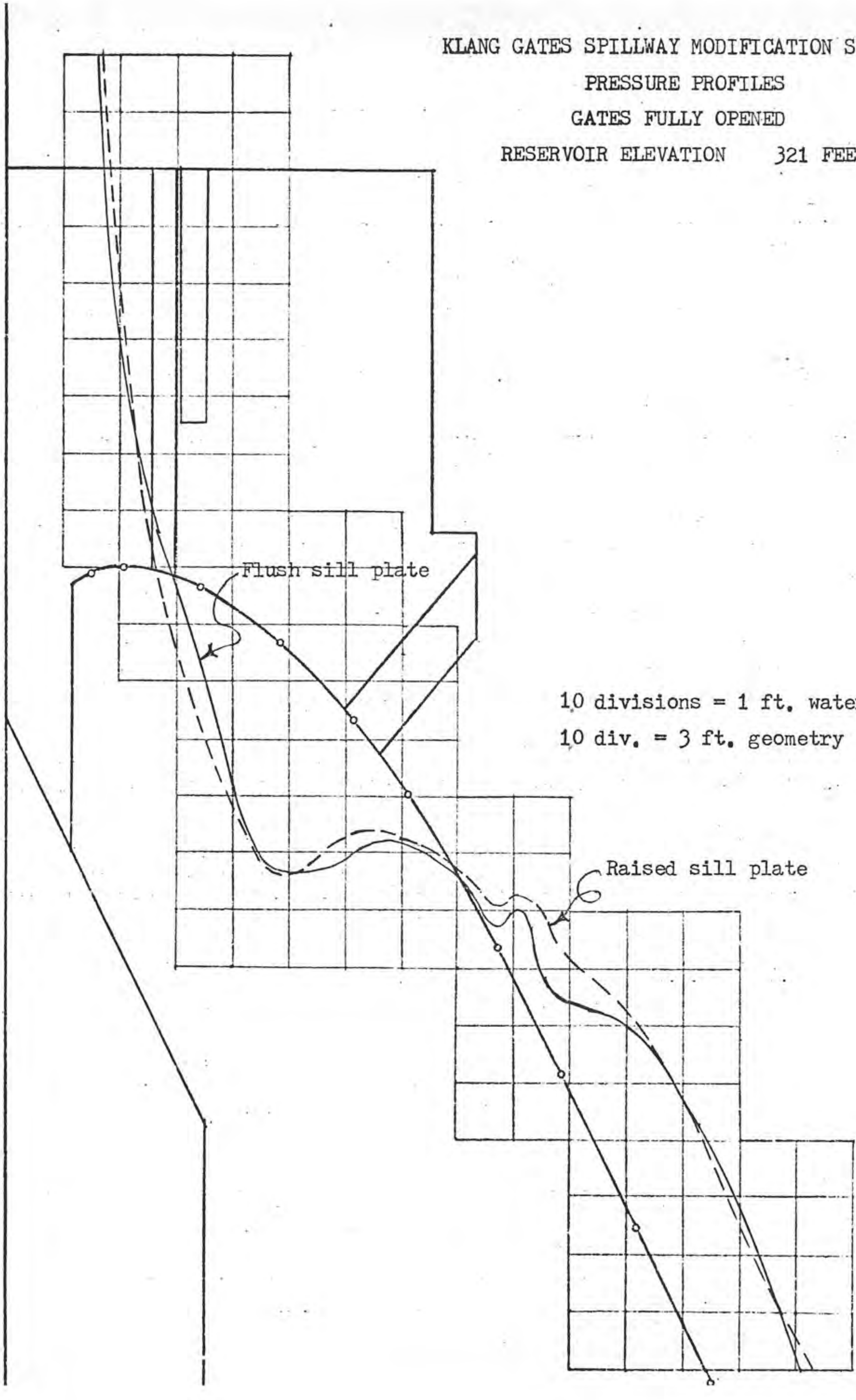
10 divisions = 1 ft. water
10 div. = 3 ft. geometry

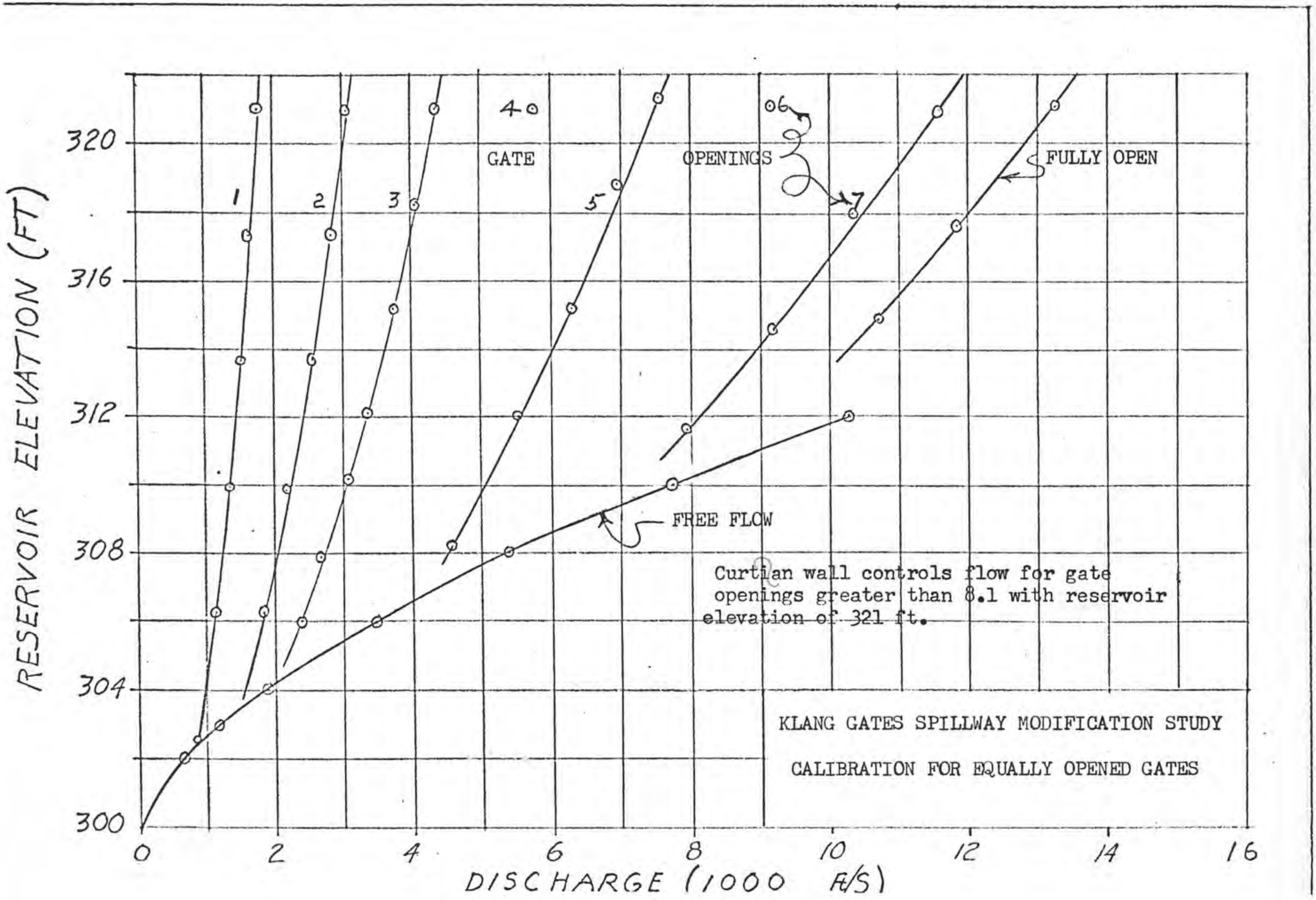
KLANG GATES SPILLWAY MODIFICATION STUDY

PRESSURE PROFILES

GATES FULLY OPENED

RESERVOIR ELEVATION 321 FEET





RESERVOIR ELEVATION (FT)
DISCHARGE (1000 ft/S)
300
304
308
312
316
320
0
2
4
6
8
10
12
14
16
1
2
3
4
5
6
7
GATE
OPENINGS
FULLY OPEN
FREE FLOW
Curtian wall controls flow for gate openings greater than 8.1 with reservoir elevation of 321 ft.
KLANG GATES SPILLWAY MODIFICATION STUDY
CALIBRATION FOR EQUALLY OPENED GATES

Figure 10. - Flow of 1,900 ft^3/s, channel with topography features in place.

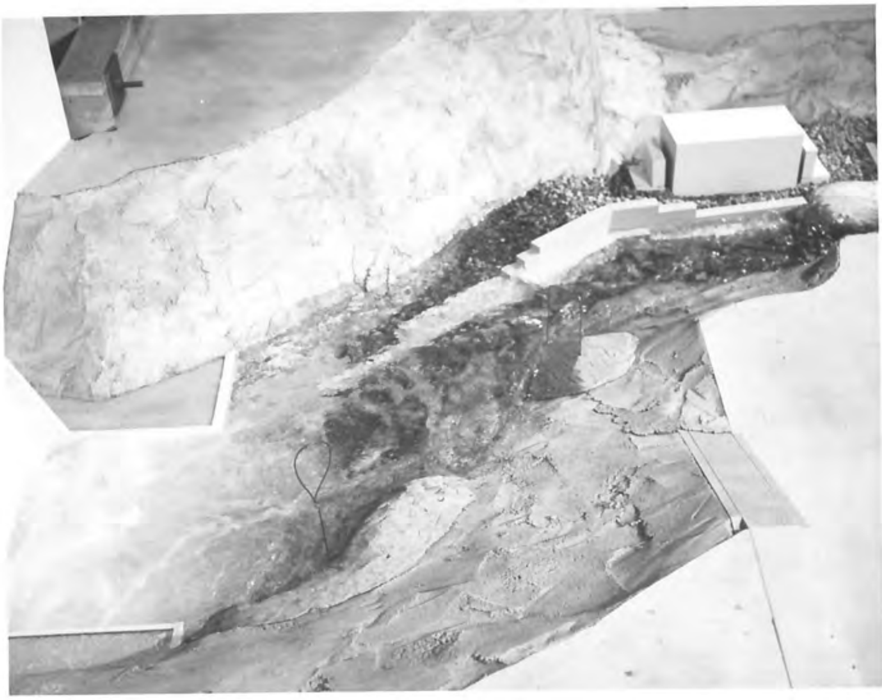


Figure 11. - Flow of 4,400 ft^3/s, nob in place.

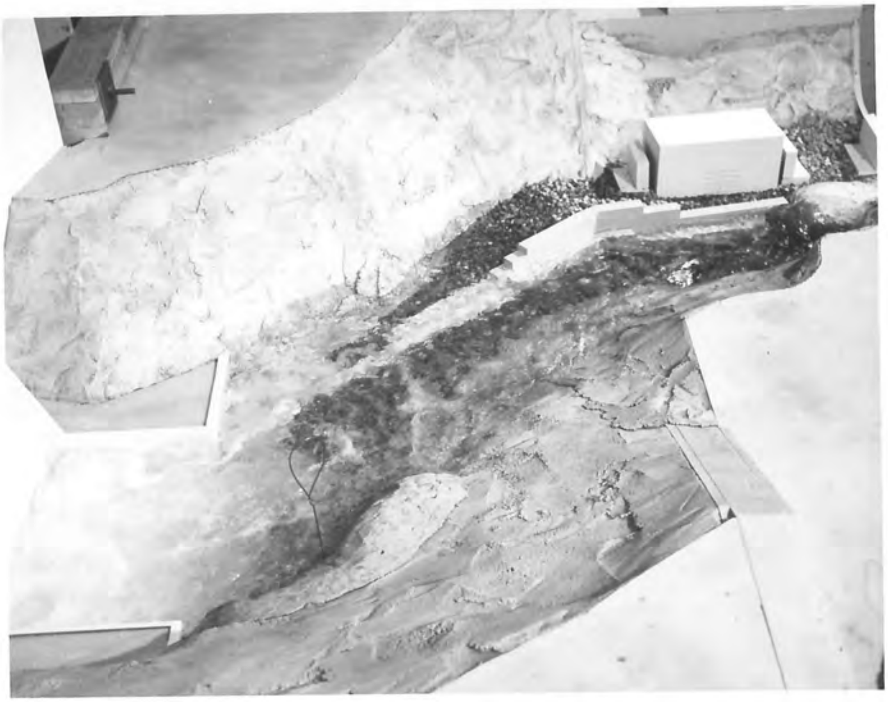


Figure 12. - Flow of 4,400 ft^3/s, nob removed.

Figure 13. - Flow of 5,800 ft^3/s, nob in place.

Figure 14. - Flow of 5,800 ft^3/s, nob and

Figure 15. - Flow of 5,800 ft^3/s, canyon wall, nob and rock removed.

Figure 16. - Flow of 13,300 ft^3/s, channel with topography features in place.

Figure 17. - Flow of 13,300 ft^3/s with nob and rock removed.

Figure 18. - Flow at 13,300 ft^3/s with canyon wall, nob and rock removed.

APPENDIX A

KLANG GATES DAM MODIFICATION
HYDRAULIC MODEL STUDY
MOVIE NARRATIVE

Scene No. 1. Various views of the model are shown with no flow.

Scene No. 2. Flow at 1,900 ft^3/s. No appreciable scouring velocities and channel velocities range from 10 to 15 ft/s.

Scene No. 3. Flow at 3,100 ft^3/s. Scouring has started particularly just downstream from the nob control point. Velocities below the nob 15 to 20 ft/s.

Scene No. 4. Flow at 4,400 ft^3/s. Splashing has begun over the left and right retaining walls of the stilling basin. Velocity through the channel range from 15 to 20 ft/s. By removing the nob the stilling basin water surface elevation is lowered approximately by 1 foot. However, the velocities in the channel are slightly increased.

Scene No. 5. Flow at 5,800 ft^3/s. Water is now flowing over both retaining walls. Water is also flowing behind the rock gabions and then flowing back over the rock gabions into the channel at the control house. By removing both the nob and the rock, the water surface in the stilling basin is lowered approximately 1 foot and the water no longer goes behind the gabions or over the gabions protecting the house. Removal of the canyon immediately in front of the stilling basin proves to be of no benefit.

Scene No. 6. Flow at 13,300 ft^3/s. This is the maximum discharge at maximum reservoir elevation of 321 feet. Water is flowing approximately 3 to 4 feet above the retaining walls, approximately 2 feet above the highest part of the backfill behind the rock gabion and approximately 6 feet along the side of the control house. Removal of the nob and rock has negligible effects upon the stilling basin water surface elevations. Removal of the canyon wall has detrimental effect by creating a strong back eddy.

-11
Reclamation

INFORMATIONAL ROUTING

1532
(Dodge)

Memorandum
Chief, Dams Branch

Denver, Colorado
January 29, 1976

Chief, Division of Design RSS. 2/12
Chief, Division of General Research HJC 2/10/76

Chief, Hydraulics Branch

Hydraulic Model Study of Klang Gates Dam

By copy of this memorandum eight copies of the model study report written by Ken Gibson are transmitted to code 221. His performance of study was under the direction of Hydraulics Branch engineers who also reviewed the report.

The report may be used for informing the Malaysian Team of the extent and results of the study.

D. L. KING

Enclosure

Copy to: 221 (James Legas) (eight enclosures)
1530 (one enclosure)
1531
1532

RADodge:ber-MC2