T. J. Rhone

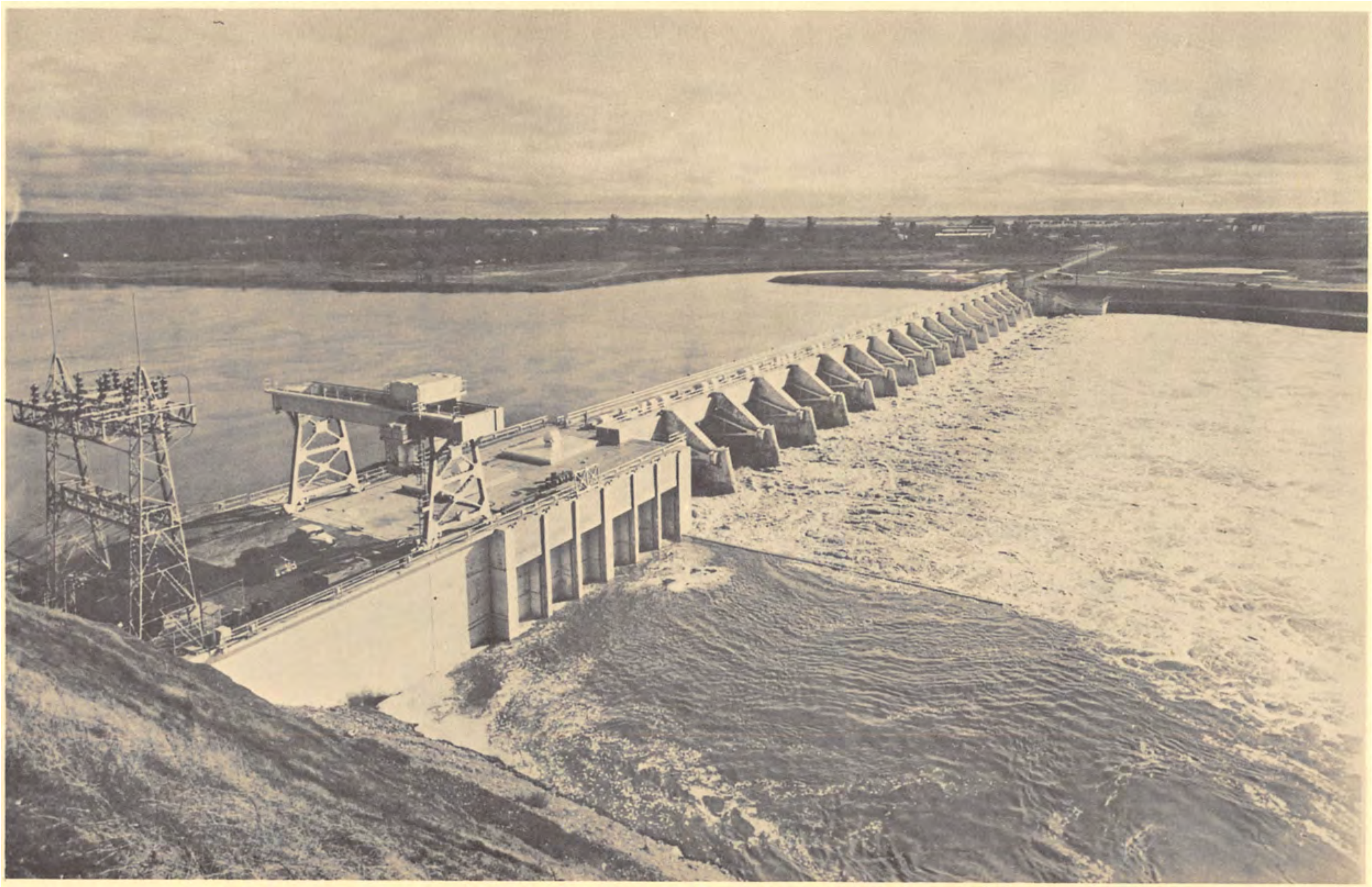
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDIES OF NIMBUS DAM SPILLWAY
FOLSOM UNIT--AMERICAN RIVER DIVISION
CENTRAL VALLEY PROJECT, CALIFORNIA

Hydraulic Laboratory Report No. Hyd-431

DIVISION OF ENGINEERING LABORATORIES

COMMISSIONER'S OFFICE
DENVER, COLORADO



AR-3058-CV NIMBUS Power plant and dam viewed from downstream right abutment. Total flow is approximately 70,000 c.f.s.

DECEMBER 24, 1955

AMERICAN RIVER PROJECT OFFICE

FRONTISPIECE

The frontispiece shows the prototype stilling basin performance for 70,000 cfs. Figure 1c shows that the tail-water elevation for 70,000 cfs is about 99.0 feet. The top of the dividing wall between the powerhouse tailrace and the stilling basin is at elevation 100.0, Figure 2. The water surface elevation in the picture is slightly below the top of the wall indicating that the design tail-water curve is correct.

From the appearance of the flow in the photograph, the stilling basin operation is very satisfactory.

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DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Commissioner's Office, Denver
Division of Engineering Laboratories
Hydraulic Laboratory Branch
Denver, Colorado

Laboratory Report No. Hyd-431
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Subject: Hydraulic model studies of Nimbus Dam spillway--Folsom Unit--American River Division--Central Valley Project, California

SUMMARY

The hydraulic model studies of Nimbus Dam spillway were performed to develop an economical but adequate stilling basin and to determine the capacity and overall performance characteristics of the overflow crest section.

The performance of the preliminary stilling basin was very good, Figures 5 and 6, but model studies indicated that the basin length could be shortened and still be fully effective. The length was reduced from 100 feet to 60 feet and three arrangements of baffle piers and end sills were investigated, Figure 4.

The recommended basin, utilizing a dentated end sill to reduce the height of waves and the extent of bed erosion downstream from the basin, was as efficient as the preliminary basin in dissipating the flow energy, Figures 12 and 13.

The capacity of the spillway was less than the design quantity; the model studies indicated that at the maximum reservoir elevation the discharge per bay was only 15,000 cfs instead of the 16,670 cfs anticipated, Figure 14.

Pressure measurements on the spillway crest section revealed no pressures near the cavitation range. The lowest pressure measured was equivalent to about 4 feet of water below atmospheric, Figure 15.

ACKNOWLEDGMENT

The recommended structures evolved from this study were developed through the cooperation of the staffs of the Canals Branch and the Hydraulic Laboratory.

INTRODUCTION

Nimbus Dam, a part of the Folsom Unit, American River Division, Central Valley Project, California, is located on the American River about 12 miles northeast of Sacramento, California, Figure 1.

The dam is a concrete structure about 1,000 feet long and 22 feet high. The center portion of the dam is divided into eighteen 40-foot-wide spillway bays. The flow through each bay is controlled by a 40- by 24-foot radial gate. The dam is part of a multipurpose project and is used for flood control and to create a reservoir for a hydroelectric powerplant, Figure 2.

Of the 18 bays of the spillway, the 2 bays adjacent to the powerhouse on the right bank are operated in conjunction with the turbines to provide flow in the river at all times. The floor of the stilling basin in these bays is 4 feet lower than the floor in the other 16 bays. The 16 bays are operated in units of 4 adjacent bays. The number of operating units will depend on the size of flood to be routed; for large floods the gates of one unit will not be opened more than 1 foot before the adjacent unit is brought into operation. This gate operation will make it possible to maintain the reservoir level between elevation 118.5 and elevation 125.0. To provide satisfactory spillway performance for the numerous flow conditions resulting from the many gate opening combinations, it was imperative that the stilling basin operation be investigated by hydraulic model studies.

The spillway is located near the center of the river channel, giving symmetrical approach conditions as well as a straight channel downstream from the spillway. Because of this, it was not necessary to test the entire spillway, but only to investigate a part of the spillway with a sectional model.

THE MODEL

The hydraulic model of Nimbus Dam spillway was built to a scale of 1:36. The model was placed in a 40-foot-long, 2-foot-wide by 2-foot-deep, sheet-metal-lined wood flume. One full bay and two partial bays were included in the model, Figure 3.

A 5-foot-long glass panel was located in one wall of the flume. The crest section of the spillway was placed at the upstream edge of the glass panel with the stilling basin apron in the center of the panel, permitting observation of the stilling action in the basin. Two hundred feet of the prototype forebay and 400 feet of the downstream channel were also modeled in the flume.

The overflow section of the crest was formed in smooth finish concrete screeded to sheet metal templates. The floor or apron of the stilling basin was built of galvanized sheet metal as were the radial gates.

The chute blocks, baffle piers, end sills, and crest piers were modeled in wood waterproofed with linseed oil.

The floor of the forebay area was formed with a 6-inch layer of pea gravel. The first 200 feet of the channel bed below the spillway apron were molded in sand and the remaining 200 feet in pea gravel.

Water surface elevations in the forebay and downstream channel were measured by hook gages placed in stilling wells connected to the flume upstream and downstream from the crest; staff gages placed on the inside of the flume were also used to measure the water surface elevations at suitable points, Figure 3. Pressures on the spillway crest were determined from piezometers connected to open-tube glass manometers.

Water was furnished to the model from the main laboratory supply system and measured by either a 4-, 6-, or 8-inch Venturi meter. After entering the flume, the water passed through a 6-inch-thick rock baffle before entering the forebay area thus assuring smooth approach flow. The tail-water elevation was controlled by an adjustable gate placed at the downstream end of the flume. The model layout is shown on Figure 3.

THE INVESTIGATION

Operating Criteria

Because of the numerous gate opening combinations possible with 18 gates, it was impractical to attempt to evaluate all of them with each model modification. Therefore, the most severe flow combination was determined by representing various tail-water conditions and used as a primary criterion in the testing. Fifty thousand cfs discharging through four bays provided the most severe condition since the unit discharge was large and the tail-water elevation was low, resulting in a very rough hydraulic jump in the stilling basin. Two additional flow conditions were also used in evaluating the tests, 150,000 and 300,000 cfs discharging through 18 bays with maximum reservoir elevation and normal tail-water elevation for each discharge.

Stilling Basin Studies

The performance of each basin was evaluated in three ways:

1. The action visible through the glass panel was observed to determine the overall effectiveness of the stilling basin, and to determine the height and frequency of the waves in the downstream channel.

2. The permissible tail-water elevation reduction, before the stilling action on the apron became inadequate, was determined.

3. The extent of riverbed erosion downstream from the apron was determined for the 50,000 and 300,000 cfs discharges after operating the model for 45 minutes. The eroded area was photographed after it had been surveyed and white string placed to make the contours visible. In evaluating the erosion, the eroded areas adjacent to the vertical flume walls were not considered since they were the result of secondary currents caused by the walls and were not representative of actual prototype conditions.

Preliminary stilling basin. The preliminary stilling basin, Figure 4A, used a horizontal concrete apron 100 feet long. One row of chute blocks and two rows of baffle piers were placed on the apron to improve the stilling action. The chute blocks, located at the toe of the overflow section, were 4 feet high, 3.33 feet wide, and about 16 feet long. The spacing between the blocks was 3.33 feet. The first row of baffle piers was 25 feet downstream from the chute blocks and the second row was located at the end of the apron. The piers were 3 feet wide, 3 feet high, and 4 feet long. The upstream faces of the piers were vertical and the downstream faces had a 1:1 slope. The spaces between adjacent piers were 3 feet; in the downstream row the piers were placed opposite the spaces in the upstream row.

The appearance of the stilling action was very good at all three discharges for the preliminary basin. For 150,000 and 300,000 cfs the stilling action took place on the first 50 feet of the apron, Figure 5. At 50,000 cfs the stilling action extended downstream for about 60 feet on the apron, Figure 6. The maximum wave height averaged about 2 feet in magnitude at the 50,000 and 300,000 cfs discharges; for 150,000 cfs, the waves were negligible. The reduced wave action at the intermediate flow was due to the tail-water depth. At 150,000 cfs the flow after entering the basin was well dispersed with respect to both the length and depth of the basin and the stilling action was complete. At 50,000 cfs the tail-water depth was small resulting in a turbulent hydraulic jump and greater wave action. At 300,000 cfs the tail-water depth was excessive and the flow over the spillway did not penetrate to the full depth and most of the stilling action took place near the surface causing some wave action.

The amount that the tail-water elevation could be lowered before the stilling action became unsatisfactory was well below the minimum design tail water. Figure 7 shows the tail-water elevation at which the hydraulic jump sweeps out when the 2 sluiceway bays and 4 overflow bays are operating. The normal design tail-water elevation is also shown.

Erosion resulting from the 50,000 cfs discharge was moderate, the maximum depth of about 5 feet was located approximately 52 feet downstream from the end of the apron, Figure 6. The channel bottom at the end of the stilling basin remained at the same elevation as the apron floor after this test. There was greater erosion from the 300,000 cfs discharge with the deepest area being 7.5 feet located about 48 feet from the end of the basin. The channel bed at the end of the basin had eroded to a depth of 6 inches below the apron floor.

The tests showed that the preliminary stilling basin was very satisfactory. It was apparent, however, that the apron could be shortened and still produce effective stilling action. Since the prototype stilling basin will be over 700 feet wide, any reduction in its length would result in considerable savings in cost. Therefore, it was decided to continue the tests to develop a shorter basin.

Stilling Basin Revision No. 1. For the first revision, the basin length was reduced to 60 feet. The preliminary chute blocks were retained but the baffle piers in the first row were made larger and a dentated end sill was used in place of the second row of baffle piers, Figure 4B.

The performance of the revised basin was not as good as the preliminary basin. At the 150,000 and 300,000 cfs discharges, all of the stilling action took place within the limits of the concrete apron, Figure 8, but for the 50,000 cfs discharge a part of the stilling action extended below the end of the apron. However, the objectionable turbulence was near the surface and did not cause excessive movement of the channel bed, Figure 9.

For discharges of 50,000 and 300,000 cfs the height of the waves at the end of the basin was 4 feet and 3 feet, respectively. The wave action at 150,000 cfs was negligible.

For 50,000 cfs the deepest erosion was 7.0 feet and occurred about 50 feet downstream from the basin. At 300,000 cfs the eroded area was about 100 feet downstream from the basin and was also 7.0 feet deep. At both discharges some of the eroded material moved upstream and was deposited against the end of the apron to a depth of about 2 feet. It was also noticed that the deepest part of the erosion was farther downstream from the end of the apron than it had been for the preliminary design.

The tests showed that the preliminary apron could be shortened 40 feet without greatly increasing the depth of the erosion. The erosion patterns were similar in both designs with the deepest erosion well downstream from the end of the apron. The wave action at the end of the shortened apron was greater than for the preliminary design, however, indicating that there might be more bank erosion with the revised basin.

Stilling Basin Revision No. 2. The second revision to the stilling basin was made to reduce the amount of bed erosion downstream from the apron and to attempt to dampen the waves.

For this revision the 60-foot-long apron, the chute blocks, and the baffle piers used in the first revision were retained but the dentated end sill was replaced. The length of the sill was increased to 12.42 feet and the height reduced to 3.75 feet. The width of the dentils and the space between the dentils were increased to 6.0 feet, Figure 4C.

The flow appearance for 150,000 and 300,000 cfs was very good, Figure 10. At 50,000 cfs the stilling action took place within the limits of the apron, but was accompanied with considerable surface roughness resulting in waves that averaged about 2 to 3 feet in height at the end of the apron, Figure 11.

The eroded area for the 50,000 cfs test was about 7 feet deep with the deepest part about 48 feet downstream from the end of the apron, Figure 11. After the 300,000 cfs test the erosion was 7.0 feet deep with the deepest area about 90 feet from the end of the apron. In both tests, some of the bed material moved upstream and was deposited against the end sill to a depth of about 2 feet.

Based on the flow appearance, wave heights, and extent and location of the erosion, the second revision to the stilling basin did not improve the stilling action. However, either revised basin would be acceptable for use.

Stilling Basin Revision No. 3 Recommended. The recommended basin was 60 feet long and the chute blocks and baffle piers of the previous basin were reused. The end sill, however, was replaced with a dentated triangular sill. The solid portion of the sill was 10 feet long and 2.25 feet high, with 2:1 slopes on the upstream and downstream faces. Dentils, 4.5 feet high and 1.5 feet wide, were placed on the upstream side, Figure 4D.

The flow appearance was very good with this apron. The stilling action was confined within the limits of the apron for all discharges and the wave heights at the end of the apron were about 1 foot high on the average, Figure 12. For the 50,000 cfs test the maximum depth in the eroded area was about 5 feet, located about 50 feet from the end of the apron, Figure 13. After the 300,000 cfs test, the maximum erosion was only 2.0 feet deep and was 60 feet downstream from the end of the apron.

After the 50,000 cfs discharge, the channel bed at the end of the concrete apron had eroded to a depth of about 6 inches prototype. However, at the larger flow the bed material moved upstream and deposited over the edge of the end sill to a depth of about 2 feet. Tail-water sweepout curves showed that the jump would stay in the basin for all discharges at the normal design tail-water elevations, Figure 7B.

Because of the overall good performance of this basin, it was recommended for prototype construction.

Spillway Crest Studies

To determine the hydraulic characteristics of the crest shape, a discharge-capacity curve was obtained for the spillway. In addition, pressure measurements along the center line of one bay were made for several flows.

Calibration. The discharge capacity for uncontrolled flow over the spillway was obtained for two tail-water conditions: (1) the normal tail water for flow through 4 bays, and (2) the normal tail water for flow through all 18 bays. This was done to determine the effect of submergence on discharge capacity since, for flows above 94,000 cfs, the tail-water elevation is higher than the crest elevation.

The results of the calibration are shown on the curves in Figure 14. The free crest curve shows that at the maximum reservoir elevation and with normal tail-water elevation for flow through 18 bays, the discharge through each bay is 14,650 cfs; about 2,000 cfs less than had been predicted during the spillway design. With the tail water at the normal elevation for flow through 4 bays, the discharge per bay increased to 15,000 cfs. The coefficient of discharge for free flow and normal tail-water elevation for flow through 4 bays is also shown on Figure 14.

The spillway capacity for controlled flow was also determined from the model studies. The radial gates of the full bay and two partial bays were equally opened with the lower edges of the gates set at a point equivalent to 1 foot above the crest. The capacity through the three sections was determined for several reservoir elevations up to the maximum. This was repeated, at 2-foot gate opening intervals up to 15 feet. The result of this calibration, in terms of the quantity passing through one spillway bay, is shown on Figure 14.

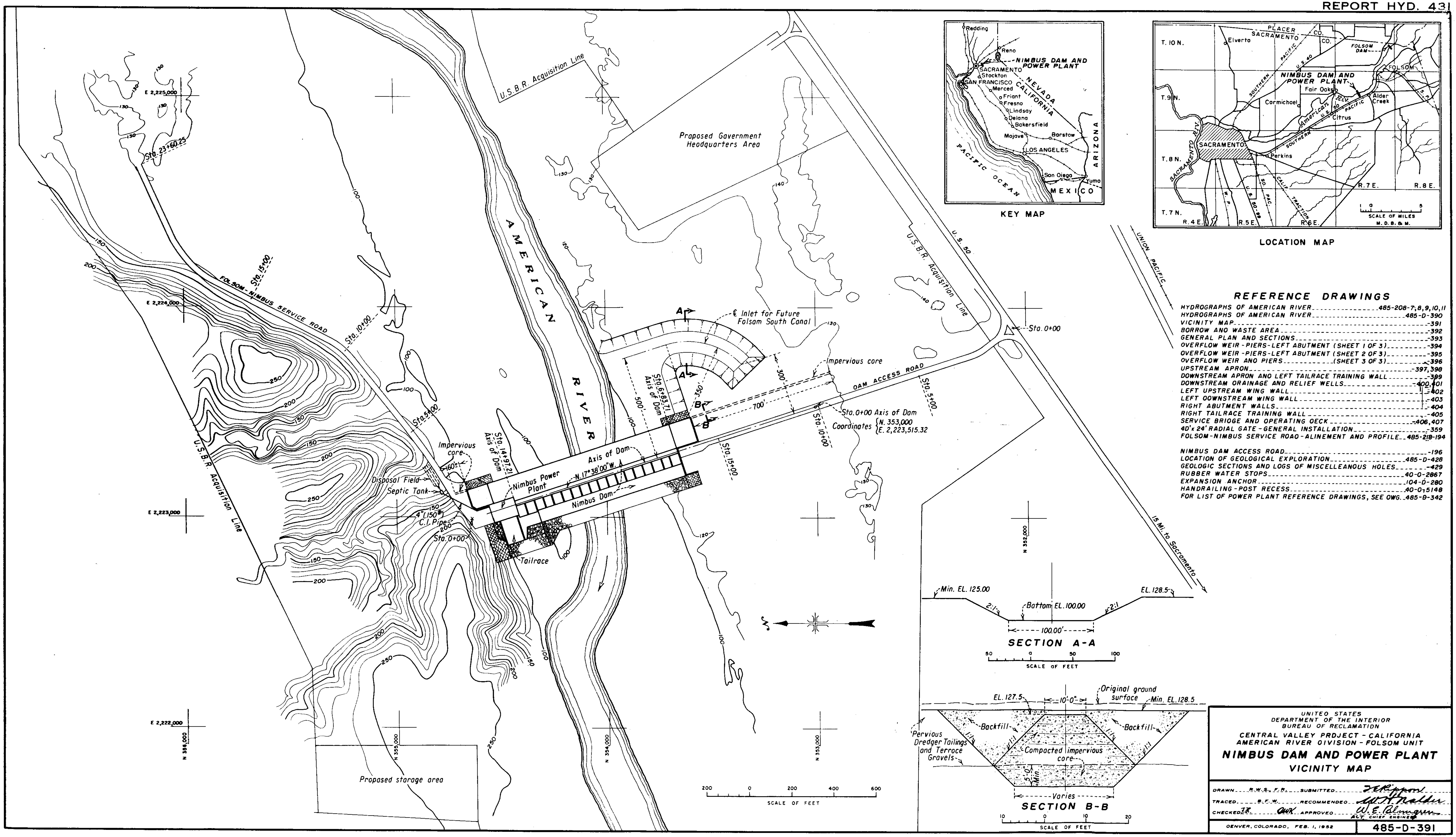
Pressure measurements. Pressure measurements were made using piezometers placed in the center of the full bay of the spillway model. Readings were made for controlled flow at eight different gate openings and for two free flow conditions all at the maximum reservoir elevation. The results of this test are shown on Figure 15. The pressures were near or above atmospheric for all piezometers except No. 8. This piezometer was located at the toe of the crest; when the tail water was lowered and the hydraulic jump moved downstream the pressure at this piezometer was reduced. The minimum pressure recorded at this piezometer was equivalent to 3.5 feet of water below atmospheric. Since this was well above the cavitation range, no change in the crest profile was recommended. The drop in pressure at Piezometer No. 8 with the low tail water was probably caused by the action of the flow around the chute blocks. The chute blocks deflected part of the flow laterally and the change in direction of the flow lines was reflected in the reduced pressure at the piezometer. With the high, or normal, tail water the jet is submerged and the directional effect of the chute blocks greatly reduced.

Gate Opening Procedure

The tail-water depth is an important factor in determining the permissible gate opening increment during spillway operation. If the tail water is not sufficient to retain the hydraulic jump on the apron, there could be considerable riverbed erosion at the end of the stilling basin resulting in damage to the structure. In order to have adequate tail water during the initial gate opening period, the floor of the 2 spillway bays adjacent to the powerhouse was placed 4 feet lower than in the other 16 bays. With this arrangement the flow from the turbines will maintain the tail water at elevation 74.0 or 4 feet deep in these 2 bays. With the tail water at this elevation, the critical tail-water curve for the two bays, Figure 7A, shows that a discharge of 3200 cfs can be released through the two gates without sweeping the hydraulic jump from the apron. The gates can therefore be set at openings to release 1600 cfs each. These openings can be determined from Figure 14.

The normal tail-water elevation for 3200 cfs is about 78.0 and the afterbay water level will gradually build up to this elevation. As this buildup takes place the gates in the two bays can be opened to release larger discharges. This should be done in such a way that the tail-water elevation versus discharge relationship always gives a point on or above the critical tail-water curve of Figure 7A. For example, when the tail water reaches elevation 76.0 the discharge through the gates can be increased to as much as 5000 cfs; for elevation 77.0 the release can be about 6200 cfs. The two radial gates can be opened in increments to give these releases until the tail water reaches elevation 79.5 at which time four or more additional gates can be opened. The critical tail-water curve for four gates (excluding the two adjacent to the powerhouse) Figure 7B, shows that a tail-water elevation of 79.5 will permit release of about 3000 cfs through each group of four gates, or 750 cfs per gate. With the tail water at elevation 79.5 it would be permissible to open all spillway gates, in groups of four, to where each gate is discharging 750 cfs. As the tail water builds up each group of four gates can be opened further, in accordance with the critical tail-water curve of Figure 7B.

This gate opening procedure can be followed until all gates are fully opened. During this operation it is important that the tail-water elevation-discharge relationship for any four adjacent gates, and that for the two gates adjacent to the powerhouse, be kept above the appropriate critical tail-water curves of Figures 7A and 7B. This assures that the hydraulic jump will not sweep from the stilling basin.


KEY MAP
Redding
Reno
NIMBUS DAM AND POWER PLANT
SACRAMENTO
Stockton
SAN FRANCISCO
Merced
Friant
Fresno
Lindsay
Delano
Bakersfield
Mojave
Barstow
LOS ANGELES
San Diego
Yuma
NEVADA
CALIFORNIA
ARIZONA
PACIFIC OCEAN
MEXICO
LOCATION MAP
PLACER CO.
SACRAMENTO CO.
T. 10 N.
T. 9 N.
T. 8 N.
T. 7 N.
R. 4 E.
R. 5 E.
R. 6 E.
R. 7 E.
R. 8 E.
Elverta
FOLSOM DAM
FOLSOM
NIMBUS DAM AND POWER PLANT
Fair Oaks
Carmichael
Alder Creek
Citrus
SACRAMENTO
Perkins
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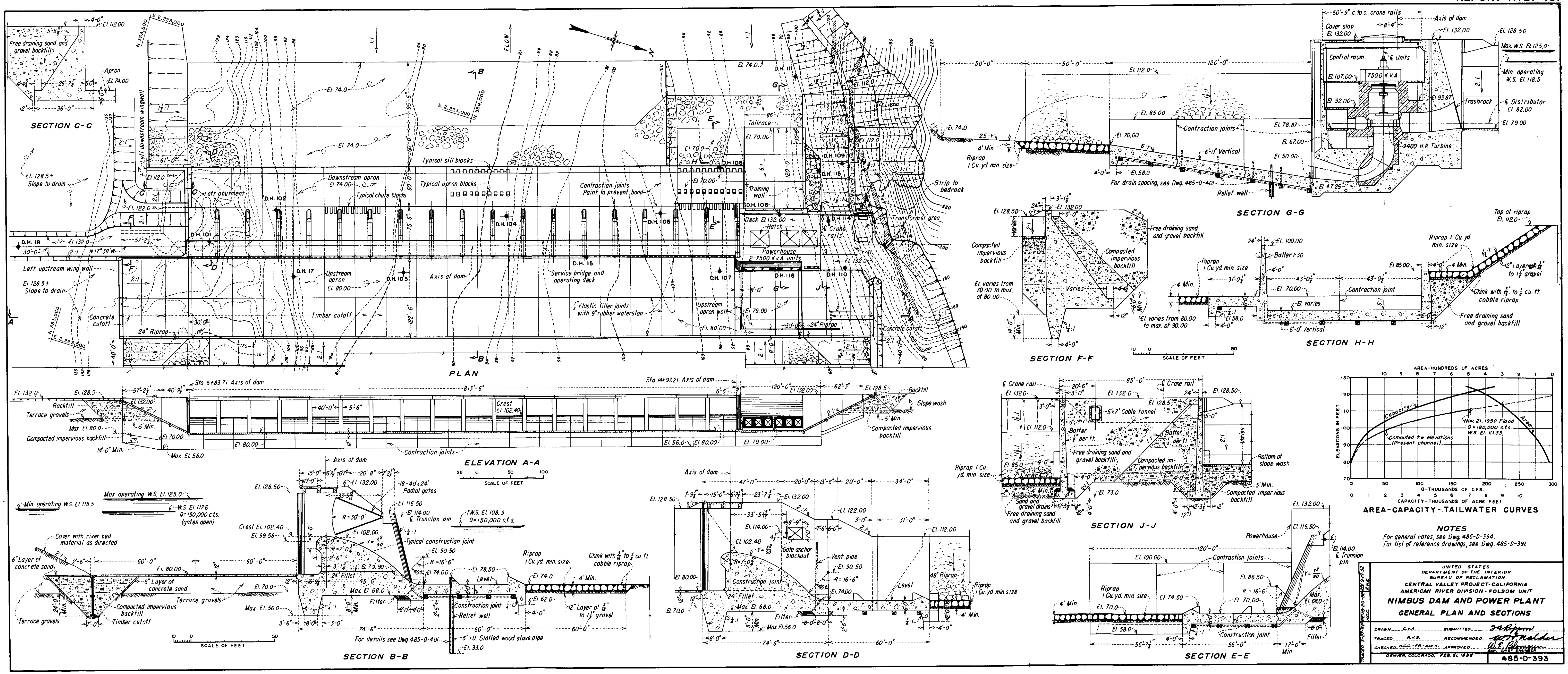
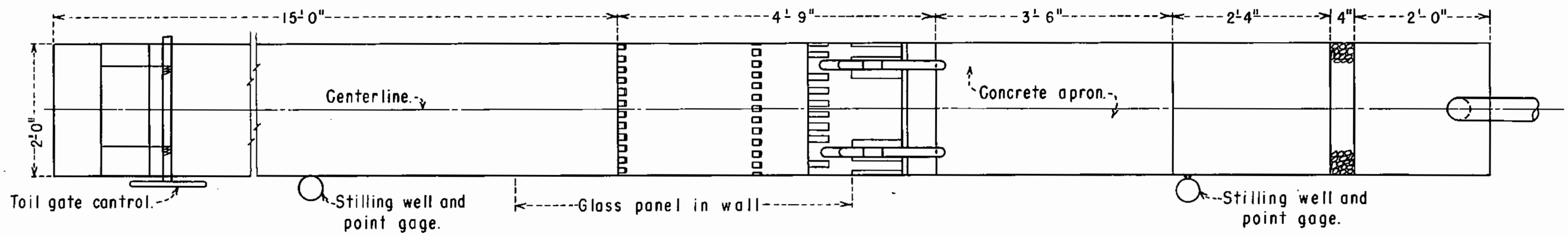
U.S.B.R. Acquisition Line
Proposed Government Headquarters Area
AMERICAN RIVER
Sta. 23+60.25
Sta. 15+00
FOLSOM-NIMBUS SERVICE ROAD
Sta. 10+00
Sta. 5+00
Sta. 0+00
E 2,225,000
E 2,224,000
E 2,223,000
E 2,222,000
N 356,000
N 355,000
N 354,000
N 353,000
N 352,000
℄ Inlet for Future Folsom South Canal
Impervious core
DAM ACCESS ROAD
Sta. 6+83.71 Axis of Dam
Sta. 14+97.21 Axis of Dam
Sta. 0+00 Axis of Dam
Coordinates N. 353,000 E. 2,223,515.32
Axis of Dam
N. 17°38'00" W.
Nimbus Power Plant
Nimbus Dam
Disposal Field
Septic Tank
4" (150#) C.I. Pipe
Tailrace
Proposed storage area
U.S. 50
UNION PACIFIC
15 Mi. to Sacramento
SCALE OF FEET
Min. EL. 125.00
Bottom EL. 100.00
EL. 128.5
2:1
100.00'
SECTION A-A
SCALE OF FEET
EL. 127.5
10'-0"
Original ground surface
Min. EL. 128.5
Backfill
Pervious Dredger Tailings and Terrace Gravels
Compacted impervious core
5'-0" Min.
Varies
1:1
SECTION B-B
SCALE OF FEET
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CENTRAL VALLEY PROJECT - CALIFORNIA
AMERICAN RIVER DIVISION - FOLSOM UNIT
NIMBUS DAM AND POWER PLANT
VICINITY MAP
DRAWN R.W.S., F.R. SUBMITTED
TRACED B.F.W. RECOMMENDED
CHECKED ACT. CHIEF ENGINEER APPROVED W. E. Blomgren
DENVER, COLORADO, FEB. 1, 1952
485-D-391

FIGURE 2
REPORT HYD. 431

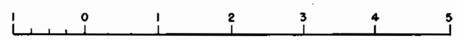


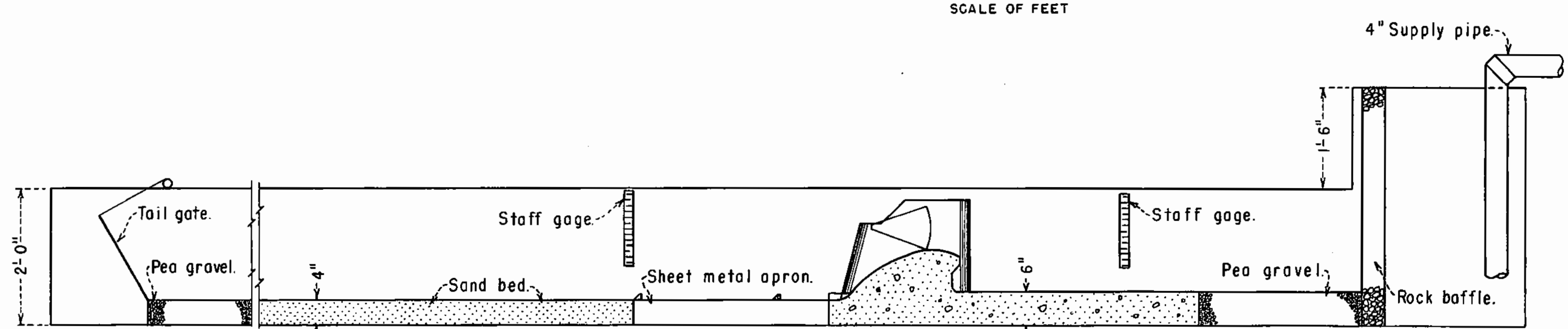


PLAN

NOTES

1. For stilling basin details see figure 4.
2. For crest details see figure 15.
3. Preliminary basin shown on this drawing.





SECTION ALONG CENTERLINE

NIMBUS DAM SPILLWAY
HYDRAULIC MODEL STUDIES
1:36 SCALE SECTIONAL MODEL
MODEL DETAILS

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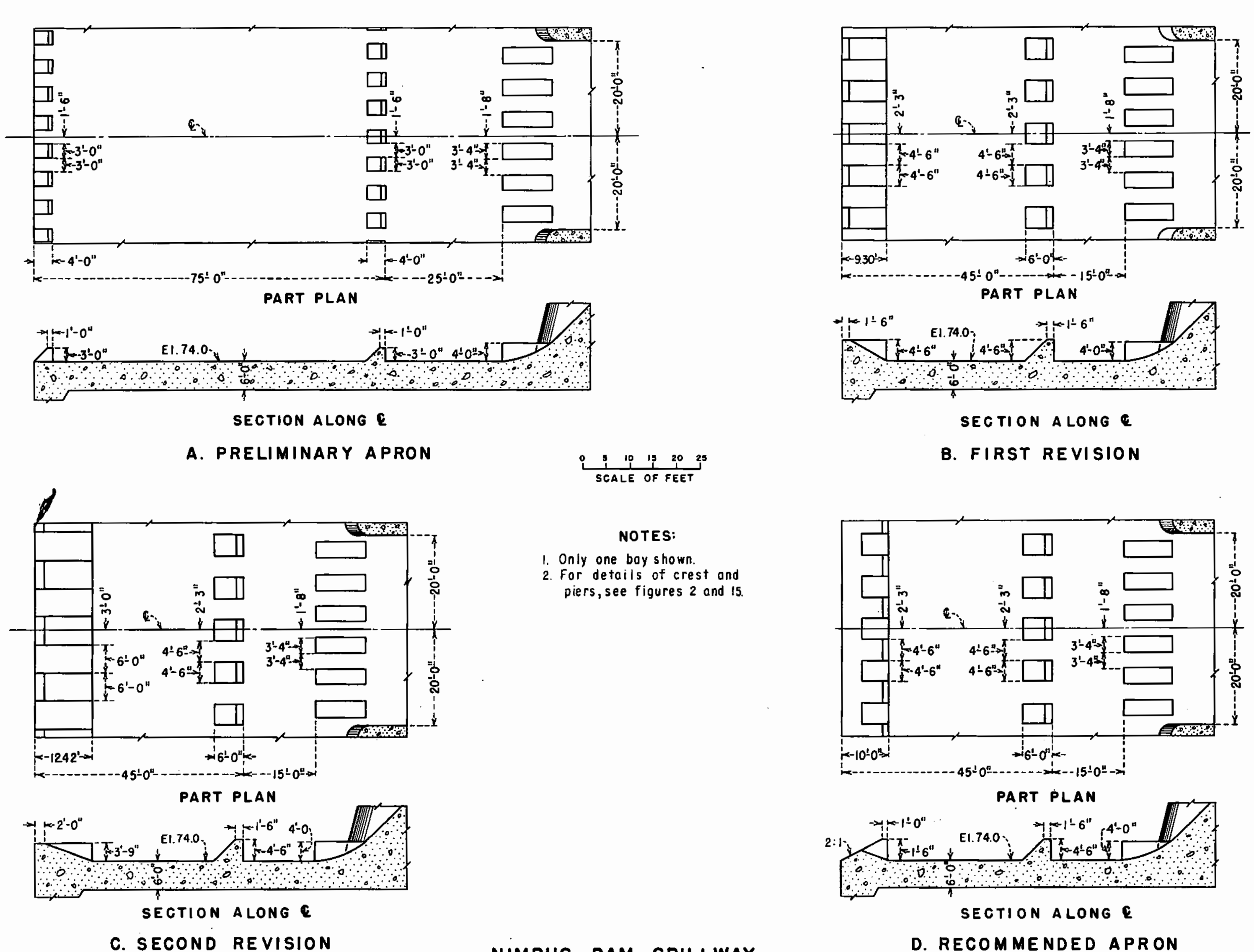
FIGURE 3
REPORT HYD. 431

FIGURE 4
REPORT HYD. 431



NOTES:
1. Only one bay shown.
2. For details of crest and piers, see figures 2 and 15.

NIMBUS DAM SPILLWAY
HYDRAULIC MODEL STUDIES
1:36 SCALE SECTIONAL MODEL
STILLING BASIN APRON DESIGNS

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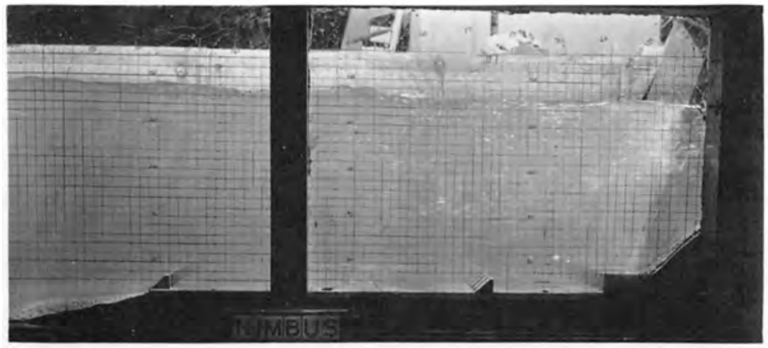
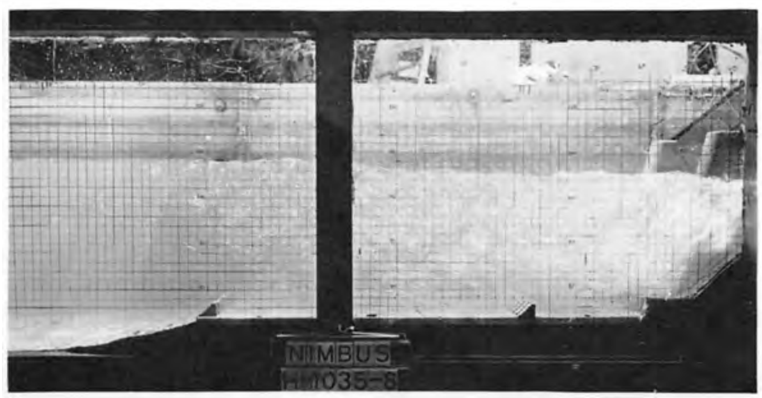
View from downstream



Side view

Discharge 300,000 second feet through 18 feet through 18 gates. Reservoir elevation 126.7. Tailwater elevation 118.5.

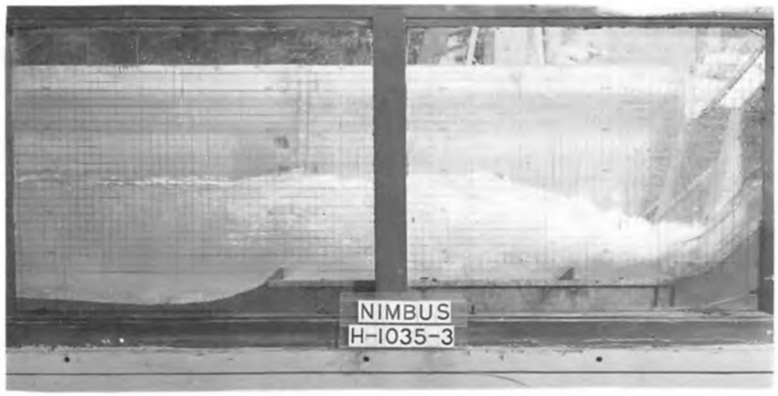
View from downstream



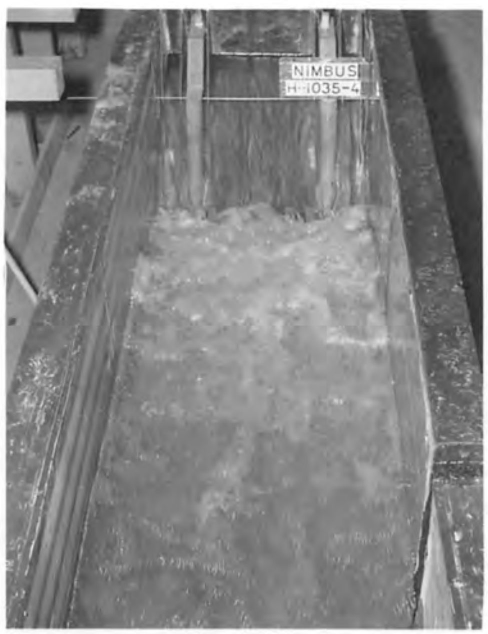
Side view

Discharge 150,000 second-feet through 18 gates. Reservoir elevation 125.0. Tail-water elevation 108.0.

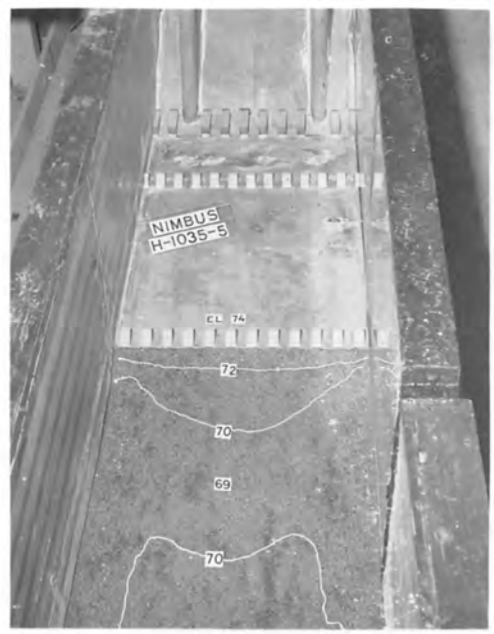
NIMBUS DAM SPILLWAY
Hydraulic Model Studies
1:36 scale sectional model
Preliminary Stilling Basin
Flow Conditions for High Discharges



Side view



Overhead view



Scour after 45 min. operation

Discharge 50,000 second-feet through 4 gates. Reservoir elevation 125.0. Tail-water elevation 97.0.

NIMBUS DAM SPILLWAY
Hydraulic Model Studies
1:36 scale sectional model
Recommended Stilling Basin
Flow Conditions for Low Discharge

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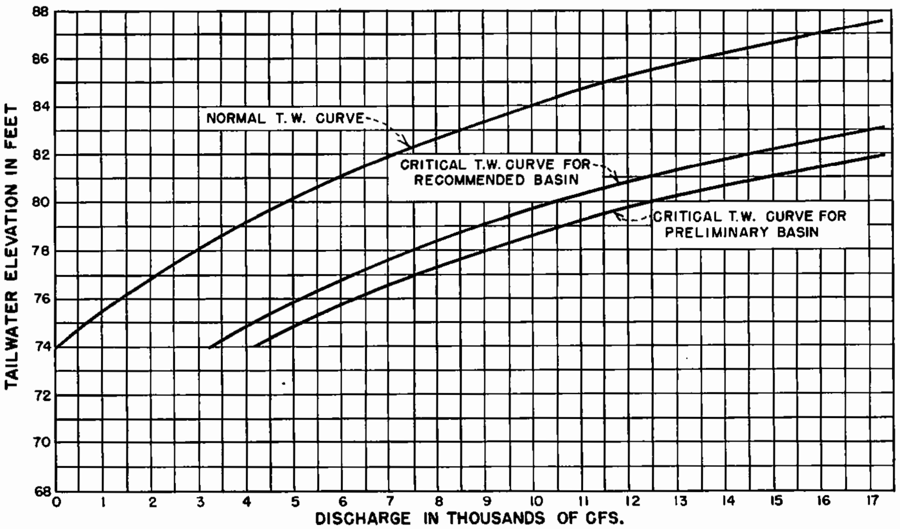
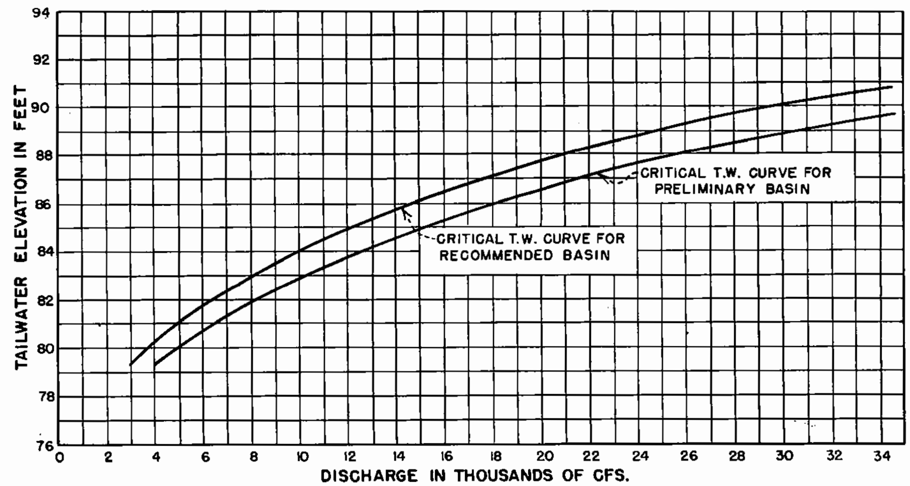
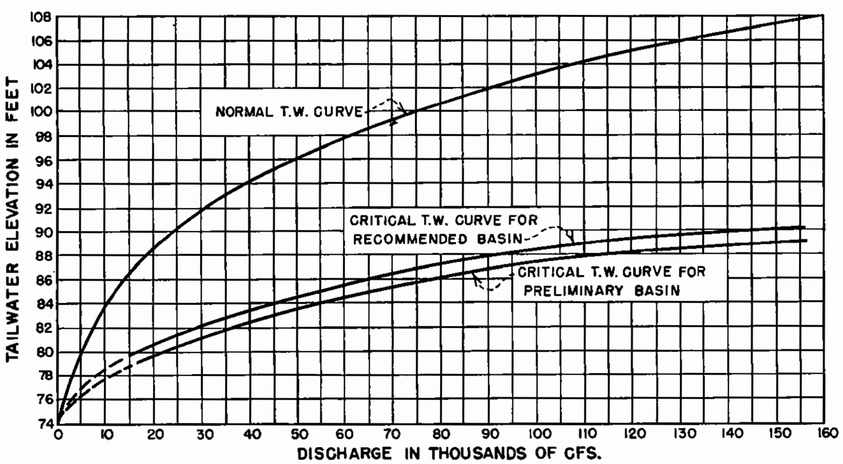


A. TWO POWERHOUSE BAYS OPERATING



B. FOUR SPILLWAY BAYS OPERATING



C. ALL EIGHTEEN BAYS OPERATING

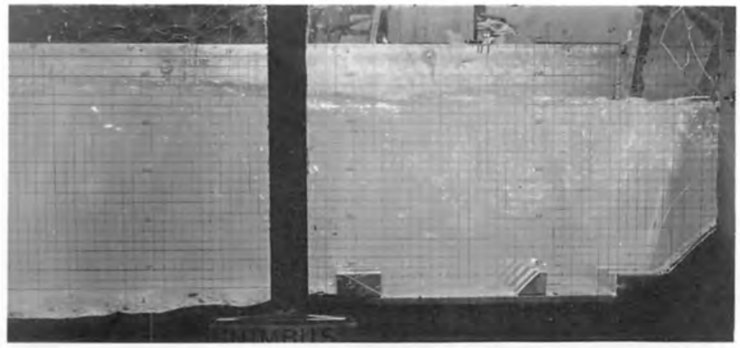
NOTES

1. Reservoir at elevation 118.5; flow controlled by radial gates.
2. All bays are equally opened.
3. Critical tailwater elevation determined as elevation where hydraulic jump in basin becomes unstable and begins to move downstream on apron.

NIMBUS DAM SPILLWAY
HYDRAULIC MODEL STUDIES
1:36 SCALE SECTIONAL MODEL
CRITICAL TAILWATER CURVES FOR STILLING BASINS

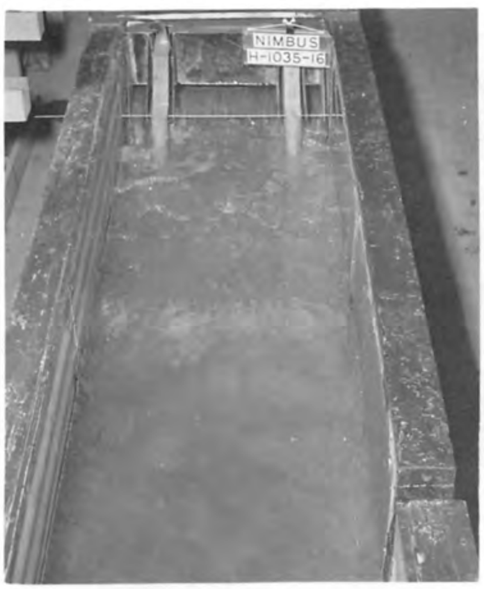
FIGURE 7
REPORT HYD. 431

Overhead view

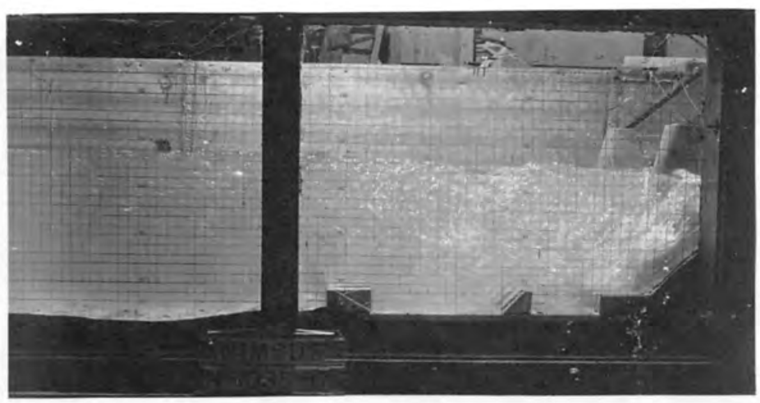


Side view

Discharge 300,000 second-feet through 18 gates. Reservoir elevation 126.7. Tail-water elevation 118.5.



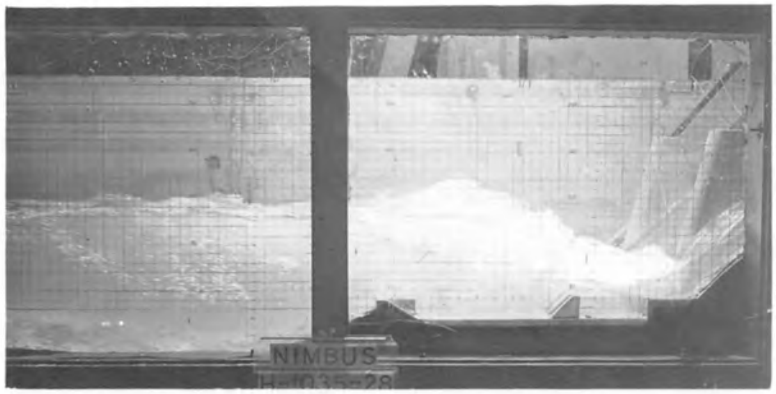
Overhead view



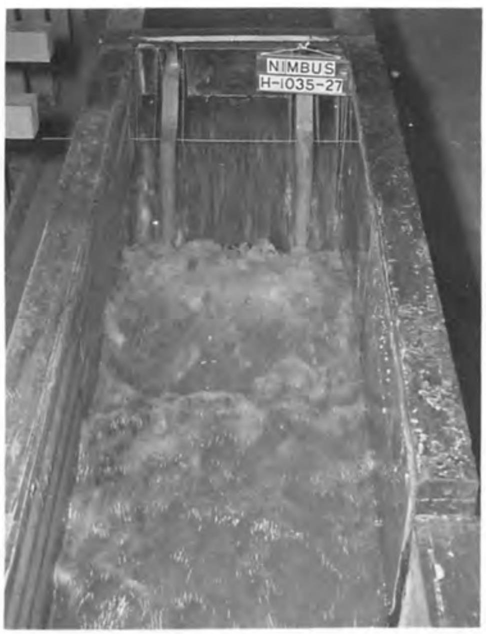
Side view

Discharge 150,000 second-feet through 18 gates. Reservoir elevation 125.0. Tail-water elevation 108.0.

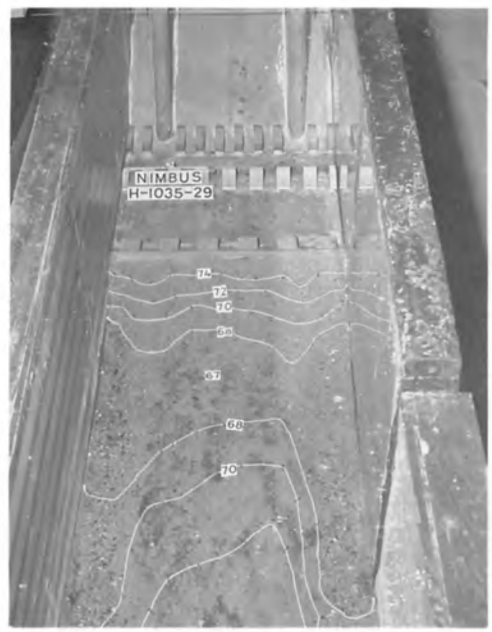
NIMBUS DAM SPILLWAY
Hydraulic Model Studies
1:36 scale sectional model
Stilling Basin Revision No. 1
Flow Condition for Low Discharge



Side view



Over head view

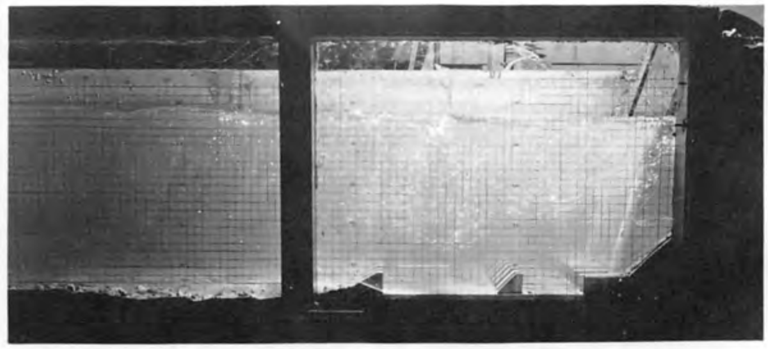


Scour after 45 min. operation

Discharge 50,000 second-feet through 4 gates. Reservoir elevation 125.0. Tail-water elevation 97.0.

NIMBUS DAM SPILLWAY
Hydraulic Model Studies
1:36 scale sectional model
Stilling Basin Revision No. 1
Flow Conditions for High Discharges

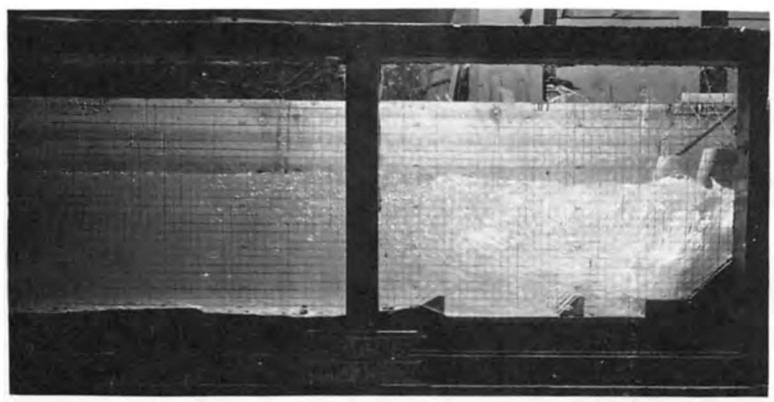
Overhead view



Side view

Discharge 300,000 second-feet through 18 gates. Reservoir elevation 126.7. Tailwater elevation 118.5.

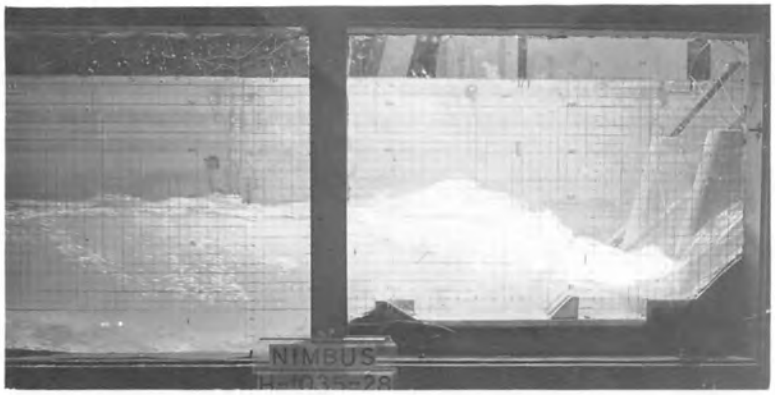
Overhead view



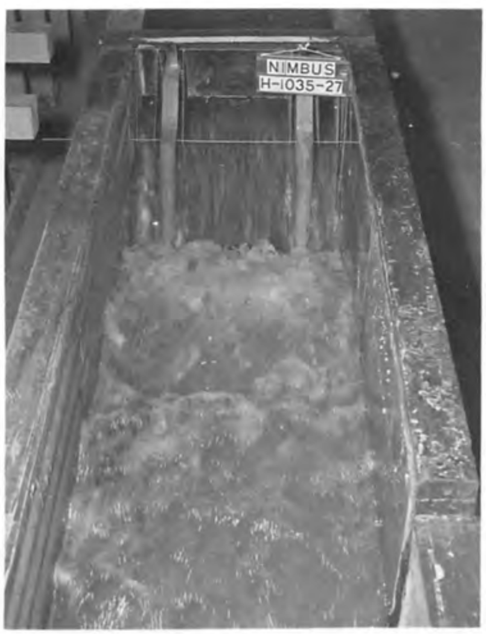
Side view

Discharge 150,000 second-feet through 18 gates. Reservoir elevation 125.0. Tailwater elevation 108.0.

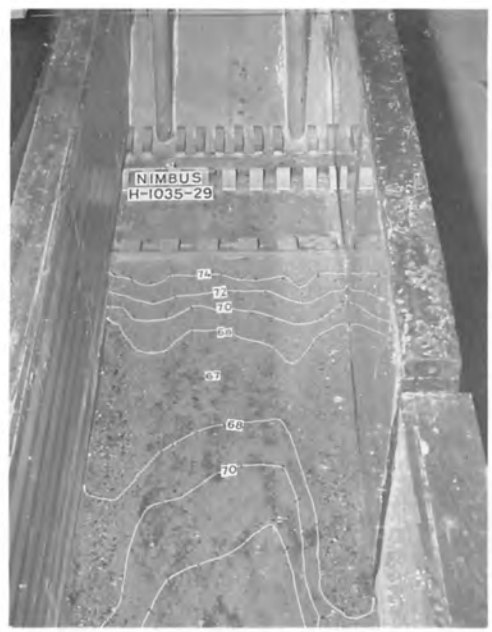
NIMBUS DAM SPILLWAY
Hydraulic Model Studies
1:36 scale sectional model
Stilling Basin Revision No. 2
Flow Conditions for High Discharges



Side view



Overhead view

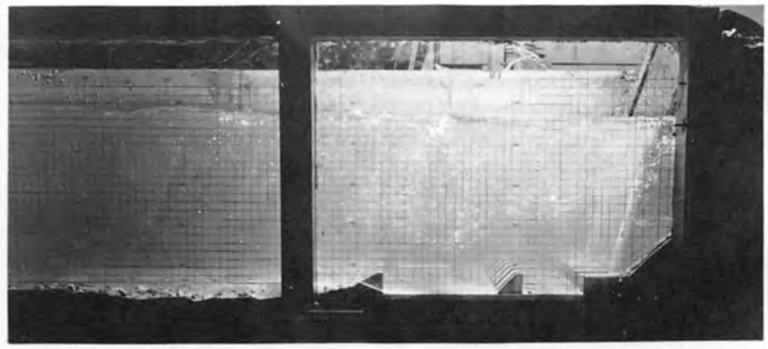


Scour after 45 min. operation

Discharge 50,000 second feet through 4 gates. Reservoir elevation 125.0. Tail-water elevation 97.0.

NIMBUS DAM SPILLWAY
Hydraulic Model Studies
1:36 scale sectional model
Stilling Basin Revision No. 2
Flow Condition for Low Discharge

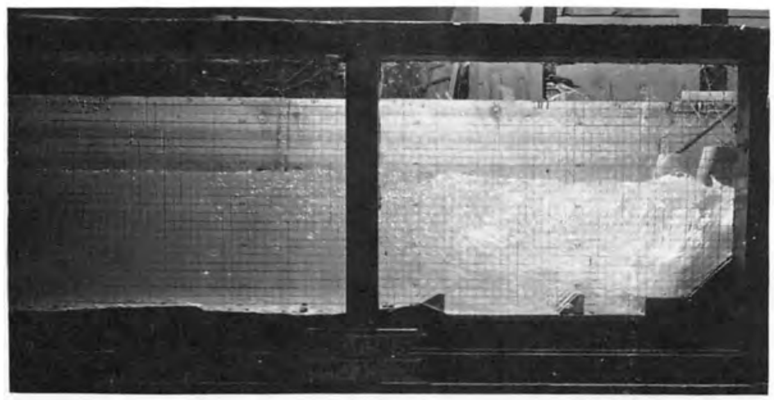
Overhead view



Side view

Discharge 300,000 second-feet through 18 gates. Reservoir elevation 126.7. Tail-water elevation 118.5.

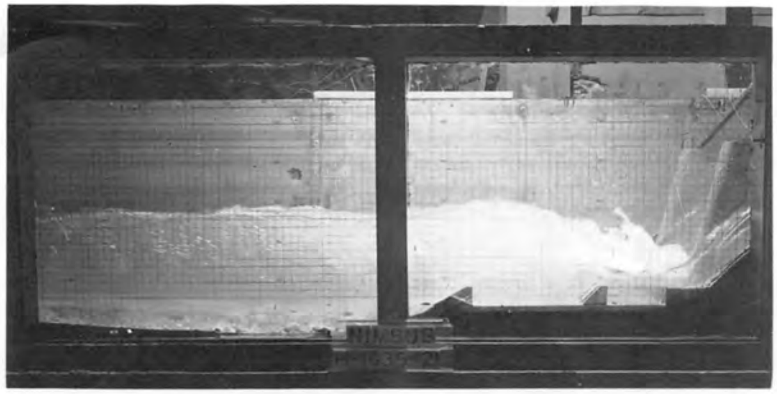
Overhead view



Side view

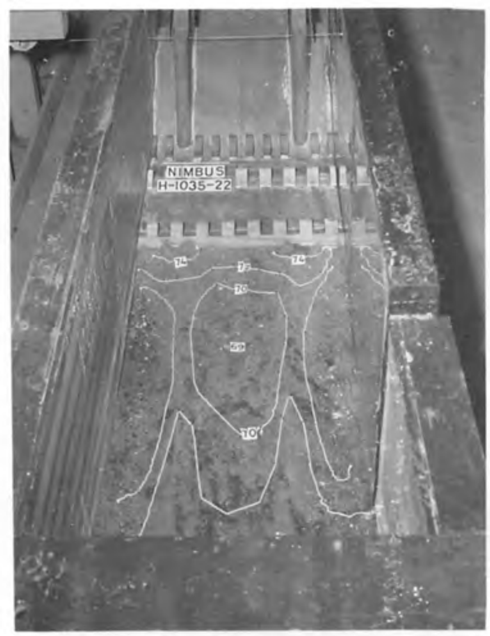
Discharge 150,000 second-feet through 18 gates. Reservoir elevation 125.0.

NIMBUS DAM SPILLWAY
Hydraulic Model Studies
1:36 scale sectional model
Recommended Stilling Basin
Flow Conditions for High Discharges



Side view

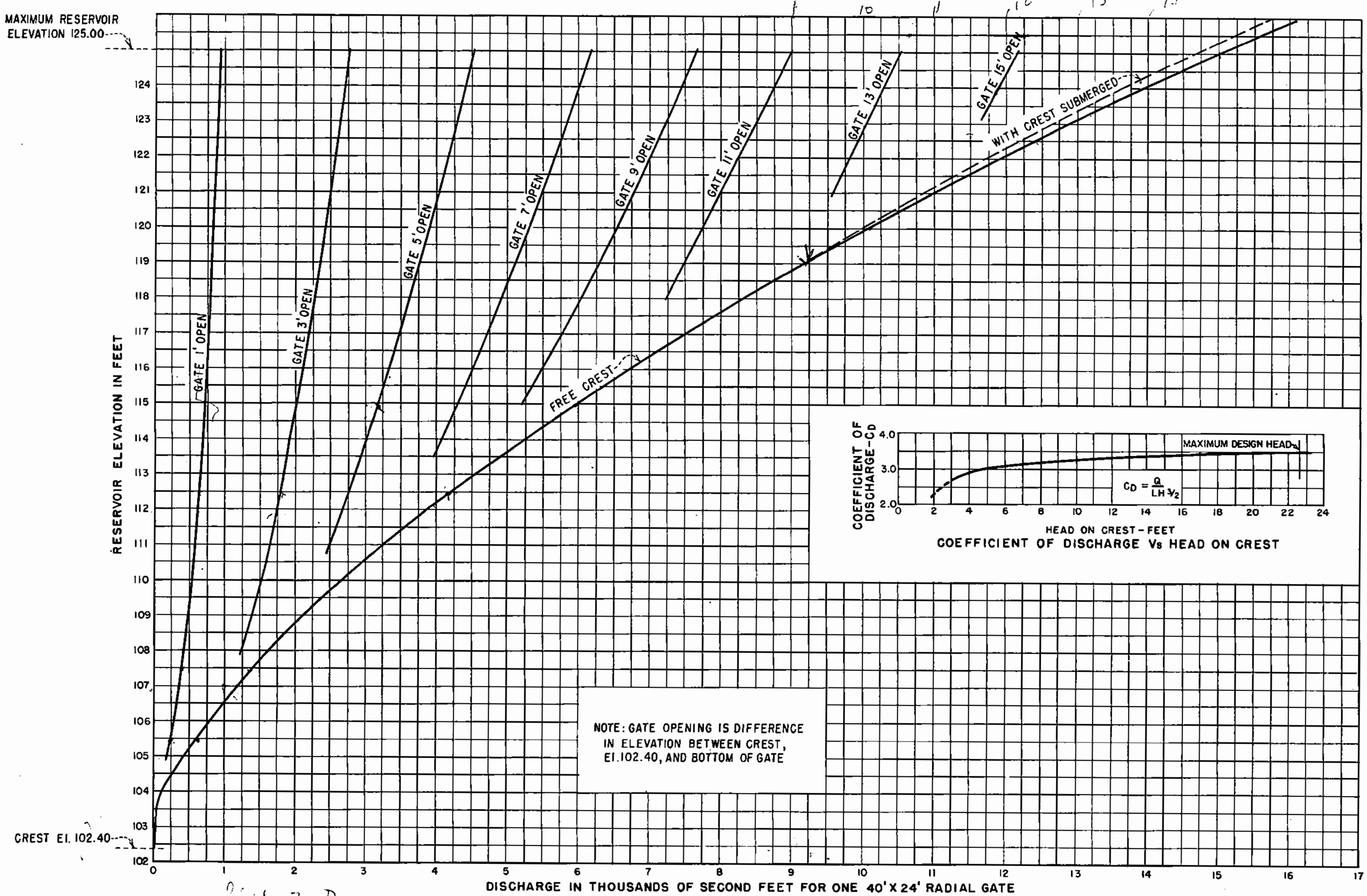
Overhead view



Scour after 45 minutes operation.

Discharge 50,000 second feet through 4 gates. Reservoir elevation 125.0. Tail-water elevation 97.0.

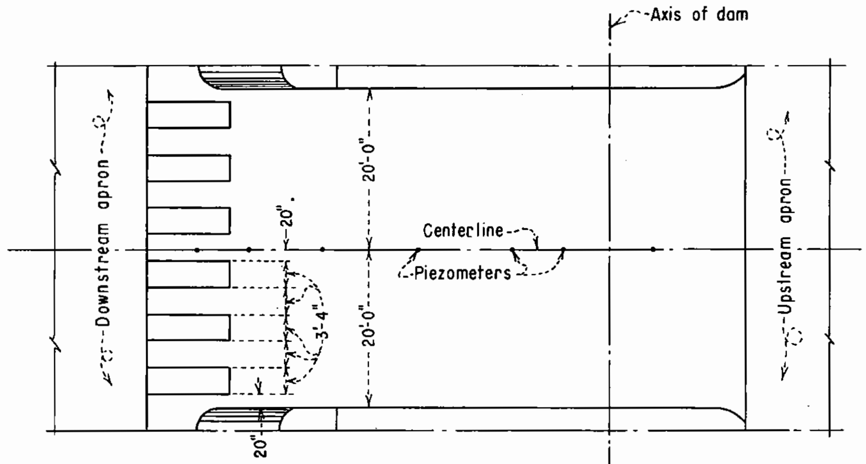
NIMBUS DAM SPILLWAY
Hydraulic Model Studies
1:36 scale sectional model
Preliminary Stilling Basin
Flow Conditions for Low Discharge



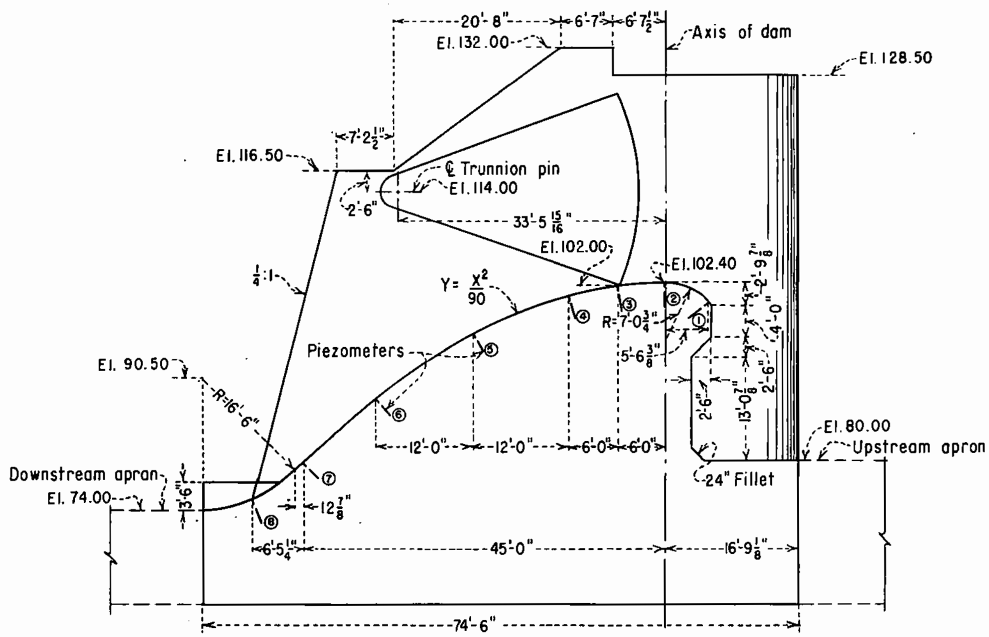
NIMBUS DAM SPILLWAY
HYDRAULIC MODEL STUDIES
1:36 SCALE SECTIONAL MODEL
DISCHARGE CURVES

FIGURE 14
REPORT HYD. 431

FIGURE 15
REPORT HYD. 431



PLAN



SECTION ALONG CENTERLINE

SCALE OF FEET

PIEZO-METER NO.	PRESSURE IN FEET OF WATER (PROTOTYPE) RESERVOIR AT ELEVATION 125.0 FEET GATE OPENING							
	1'	3'	5'	7'	9'	11'	13'	15'
1	26.0	24.6	24.5	24.0	22.8	22.3	22.3	20.5
2	23.4	21.0	19.7	18.2	17.0	16.0	16.0	14.7
3	1.0	1.0	1.7	2.8	3.7	4.7	5.7	6.8
4	0.4	0.6	0.8	1.0	1.5	1.8	2.1	3.0
5	0.3	0.2	0.3	0.4	0.7	0.8	1.0	1.6
6	0.0	-0.1	0.0	0.0	0.3	1.0	1.4	2.2
7	0.8	4.4	6.8	10.2	14.2	17.0	19.3	21.3
8*	9.2	10.3	16.5	22.5	29.3	33.2	39.0	38.0
8**	1.5	0.0	-0.7	-3.5	-3.0	-1.0	2.5	5.2

NOTES

* Tailwater at normal elevation.
** Tailwater lowered so that jump was downstream from chute blocks.

NIMBUS DAM SPILLWAY
HYDRAULIC MODEL STUDIES
1:36 SCALE SECTIONAL MODEL
CREST PROFILE AND PRESSURES

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