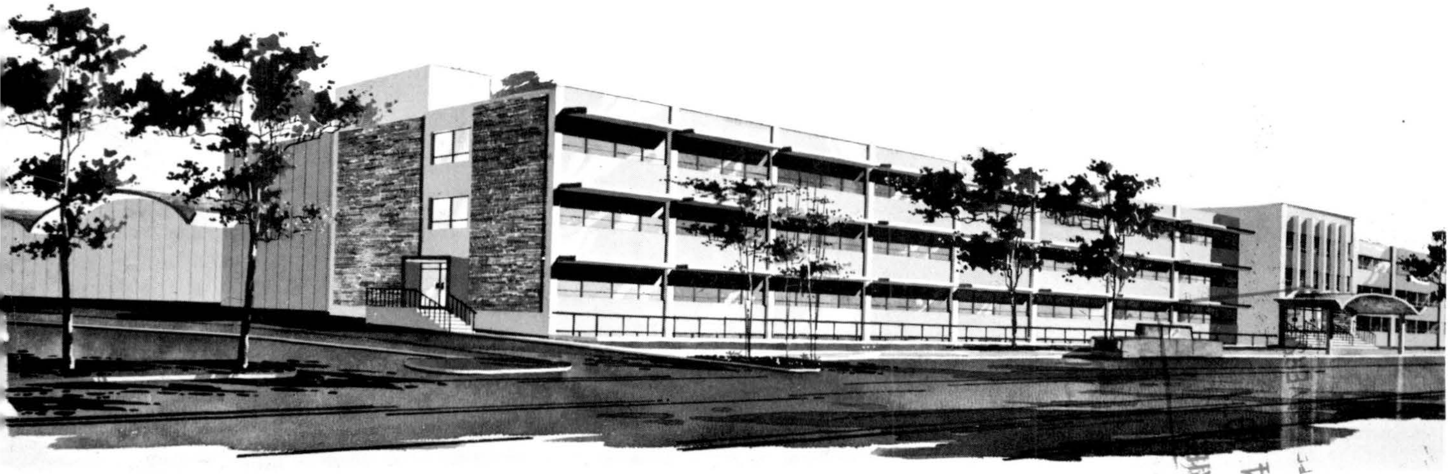
HYDRAULIC MODEL STUDY OF THE WEST MESA INTERCEPTOR ENERGY DISSIPATOR

NEAR ALBUQUERQUE, NEW MEXICO



ENGINEERING RESEARCH CENTER

FOOTHILLS CAMPUS

FORT COLLINS, COLORADO

HYDRAULIC MODEL STUDY OF THE WEST MESA INTERCEPTOR ENERGY DISSIPATOR NEAR ALBUQUERQUE, NEW MEXICO

Prepared for

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Albuquerque, New Mexico

by

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PREFACE

The Engineering Research Center pictured on the cover of this report was dedicated in 1962. It is located just four miles west of the main academic campus which is in the City of Fort Collins, Colorado, in an area now called the Foothills Campus of Colorado State University (CSU). The Foothills Campus has long been devoted to research activity of CSU and the construction of the building complex of the Center was necessitated by the expanding research activity in the College of Engineering. These activities include all phases of research in fluid mechanics, hydraulics, structures, sanitary and environmental engineering, ground water, water resources, hydrology and meteorology. All research is integrally related to the academic functions of engineering education at CSU and is particularly devoted to graduate education and training.

The faculty associated with the Engineering Research Center frequently assist private corporations, individuals and groups, domestic, as well as foreign government agencies in solving a wide variety of complex problems. The resource of knowledge in the collective body of the faculty here is considerable, and it is the purpose of this University, (as it surely is in all universities) to make this resource available to service the community, the nation and the world.

The builidngs which make up the physical complex we call the Engineering Research Center are: a hydraulics laboratory which houses various sizes of small and large recirculating flumes, a fluid dynamics and diffusion laboratory which contain several wind tunnels including a recirculating water-wind tunnel combination and a high vacuum chamber, a hydro-mechanics laboratory with capability for discharges to 100 cfs and pressures to 400 psi (with smaller discharges), a structures laboratory, an outdoor hydrology-hydraulics facility, several smaller soils and sanitary engineering laboratories and a large office building which houses the faculty. A short distance away from this complex is an atmospheric science building and an atmospheric simulation laboratory.

The various activities are too numerous to detail here but are outlined in other brochures published by the University. Those who wish to obtain more descriptive information may write to the Office of the Dean, College of Engineering, Fort Collins, Colorado.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

LIST OF TABLES

WEST MESA INTERCEPTOR ENERGY DISSIPATOR

NEAR ALBUQUERQUE, NEW MEXICO

MODEL STUDY

SUMMARY

There were three energy dissipators modeled in this study to develop a set of acceptable structures for the hydraulic conditions present. The initial design, labelled Design A, is a solution for discharges to 25,000 cfs in an approach channel 70 feet wide. The design includes primary, secondary and tertiary basins to successively dissipate kinetic energy and to spread the flow into the Rio Grande. The total basin is 335 feet long from the toe of the chute to tertiary end sill. Design B borrows much of the fundamental concept from A, but allows for possible staging of construction in consideration of increasing urbanization of the drainage area. The principle difference is allowance for flow overfall from the sides of the primary basin. The total length of the arrangement is 240 feet in comparable dimension to that for Design A. Design C results in a single stilling basin from a chute that is now narrowed to 40 feet, and allows for considerable overfall from the sides after a second stage in construction. The basin is 220 feet long but the walls are 60 feet high during first stage, which are reduced to 43 feet after the second stage. All of the designs are workable. There may be some preference hydraulically to Design A or B but the selection among the three relies heavily upon economic evaluation.

INTRODUCTION

Background

A system of channels is proposed to intercept flood runoff waters from an area located west of the City of Albuquerque, New Mexico. The area is under rapid urban development and an overall scheme for control of flood waters is viewed a necessity for responsible planning. The fully developed channel network will be capable of collecting a total discharge of approximately 25,000 cfs. This network will be constructed in stages, hence maximum flood discharge will increase by stages until ultimate development is complete. The schedule for completion will be dictated entirely by need.

The channel network will terminate at the Rio Grande with a structure (energy dissipator) which will control the velocity of the collected flood flow (therefore the energy content of the flow) before entry into the river to be compatible with the sandy composition of the river bed and banks of the Rio Grande. The structure must be designed to dissipate considerable kinetic energy, as the flow in the channel approaching the river will be supercritical and additionally, a drop in level of approximately 100 feet exists at the bank of the river. The energy dissipator must be located on a portion of the river flood plain. The sandy subsoil and the high water table there make it economically sensible to construct any structure above present ground level. For these reasons and also because of the loose sand which constitutes the banks of the Rio Grande at the location of concern, the choice from various alternative energy dissipators are reduced to consideration only of a hydraulic jump basin. In as much as the river level may rise and hence widen during heavy rainfall, it is desirable to keep the length of the basin as short as possible. Eventually, when the floods of the Rio Grande are under full control by various upstream and tributary flood regulation structures, rise in river level will be minimal and the constriction of the river section imposed by the hydraulic jump basin structure will be of no concern.

At the request of Gordon Herkenhoff and Associates of Albuquerque, New Mexico, a hydraulic model study was implemented to establish an effective energy dissipator for the system. The study was undertaken at the Hydraulics Laboratory of the Engineering Research Center at Colorado State University. A portion of the channel network and requisite location of the energy dissipator are shown on the location map of Figure 1.

The Energy Dissipator

There were many factors to be considered in the design of the stilling basin. The two established criteria were maximum flood discharge of 25,000 cfs and velocity of flow into the river to be acceptable with regard to scour of the river bed. To meet the first of these criteria and to accomplish the second, the energy dissipator was designed with a primary basin, a successive secondary basin followed by a tertiary "spreading-flow" section. The dimensions of each basin and the aggregate arrangement are shown on the drawing of Figure 2. It was assumed for this design that the inflow channel width was 70 ft wide, although the final width is contingent upon hydraulic and economic analysis of the total system.

The primary basin was calculated to be 120 ft long with an end sill (actually a small dam) 25 ft high. The side walls of the basin were expanded at a longitudinal to lateral ratio of 4:1. This spread in the basin width was needed to keep the sequent depth of the hydraulic jump, y_2 , to a minimum. Even so, the velocity of flow over the end sill of the primary basin would be too large to discharge directly into the river. Hence, a secondary stilling basin is established to reduce the energy of the flow still further. This basin is 60 ft long, with an end sill

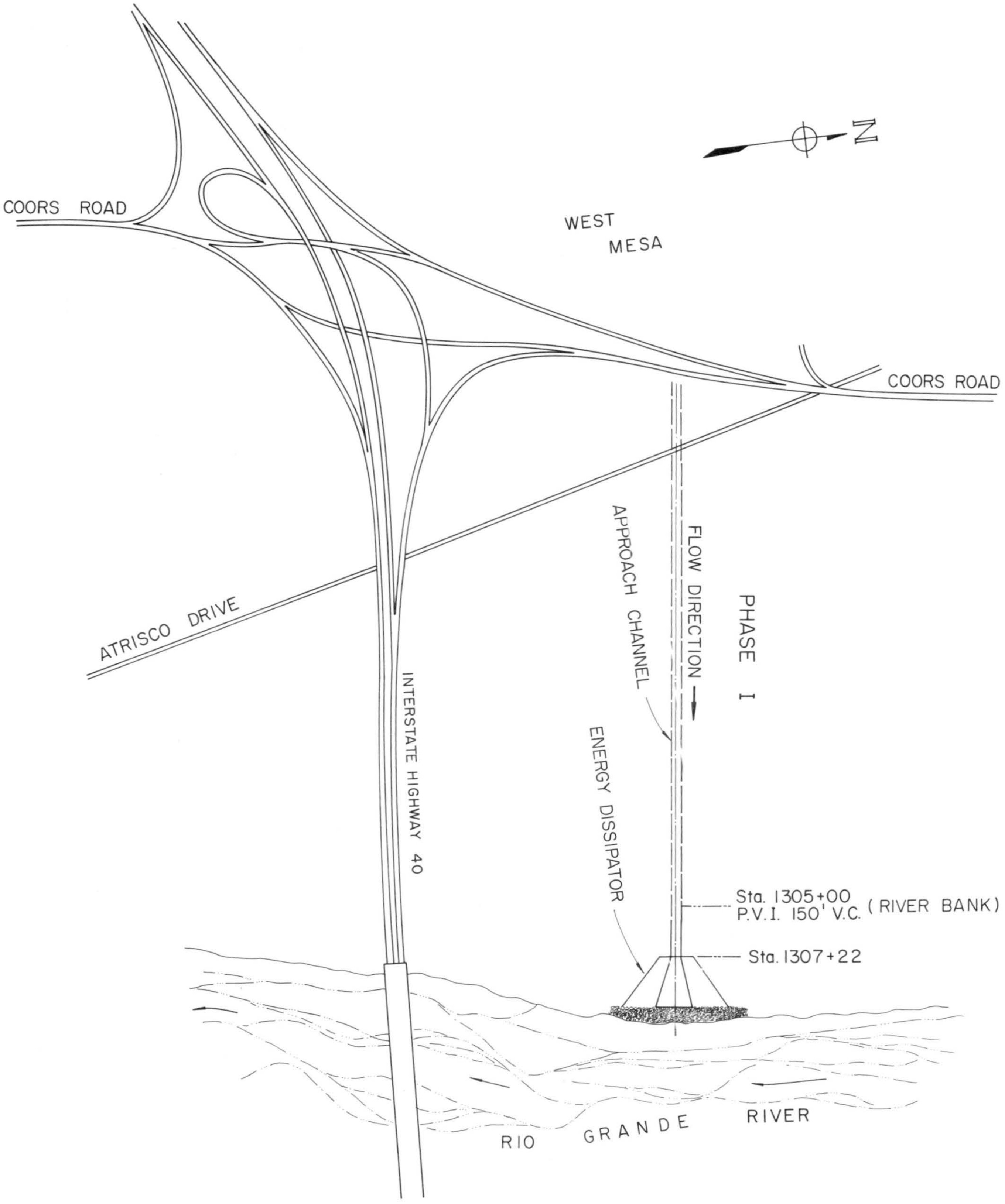


Figure 1. Schematic drawing of proposed location of energy dissipator.

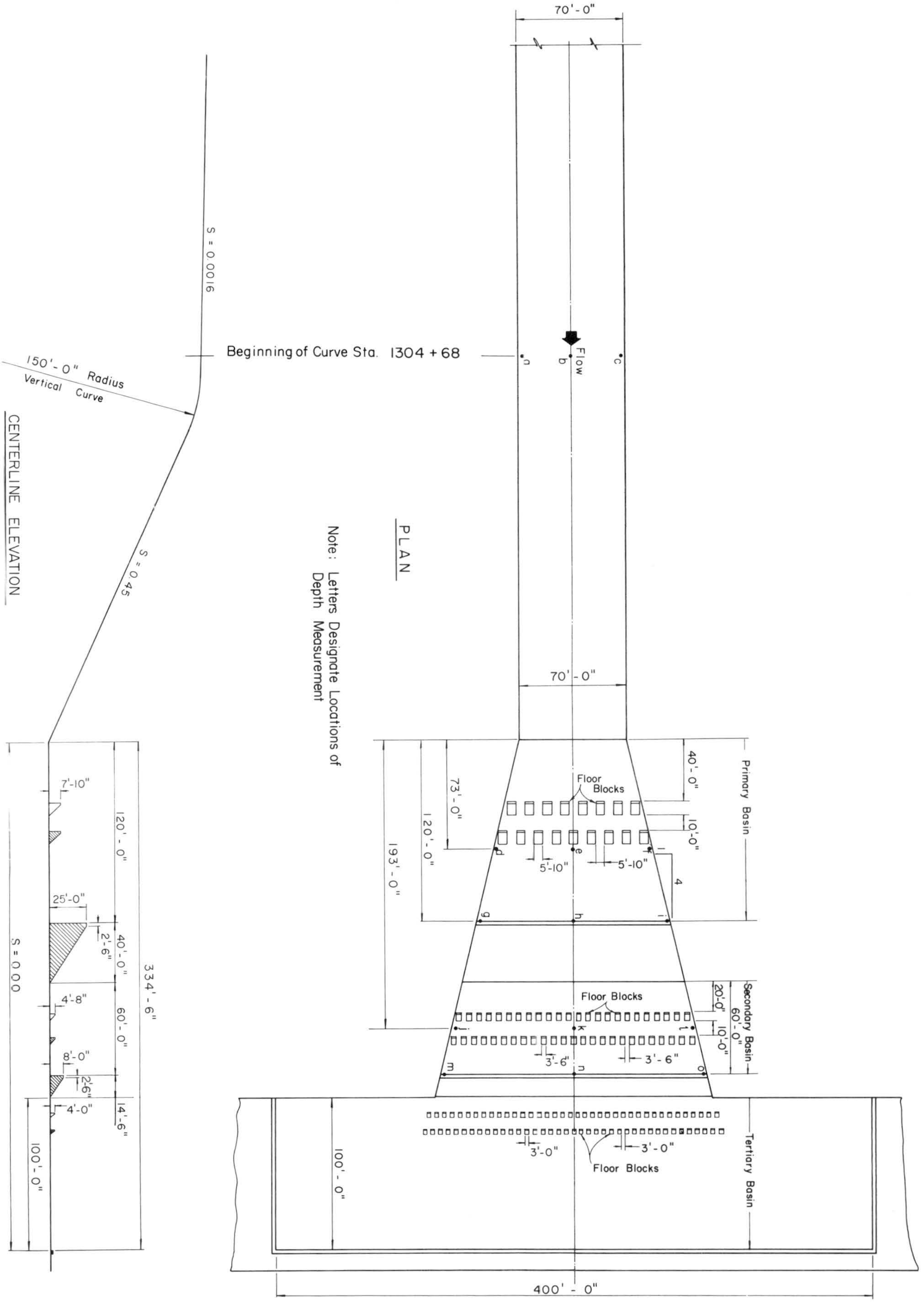


Figure 2. Schematic drawing of Design A.

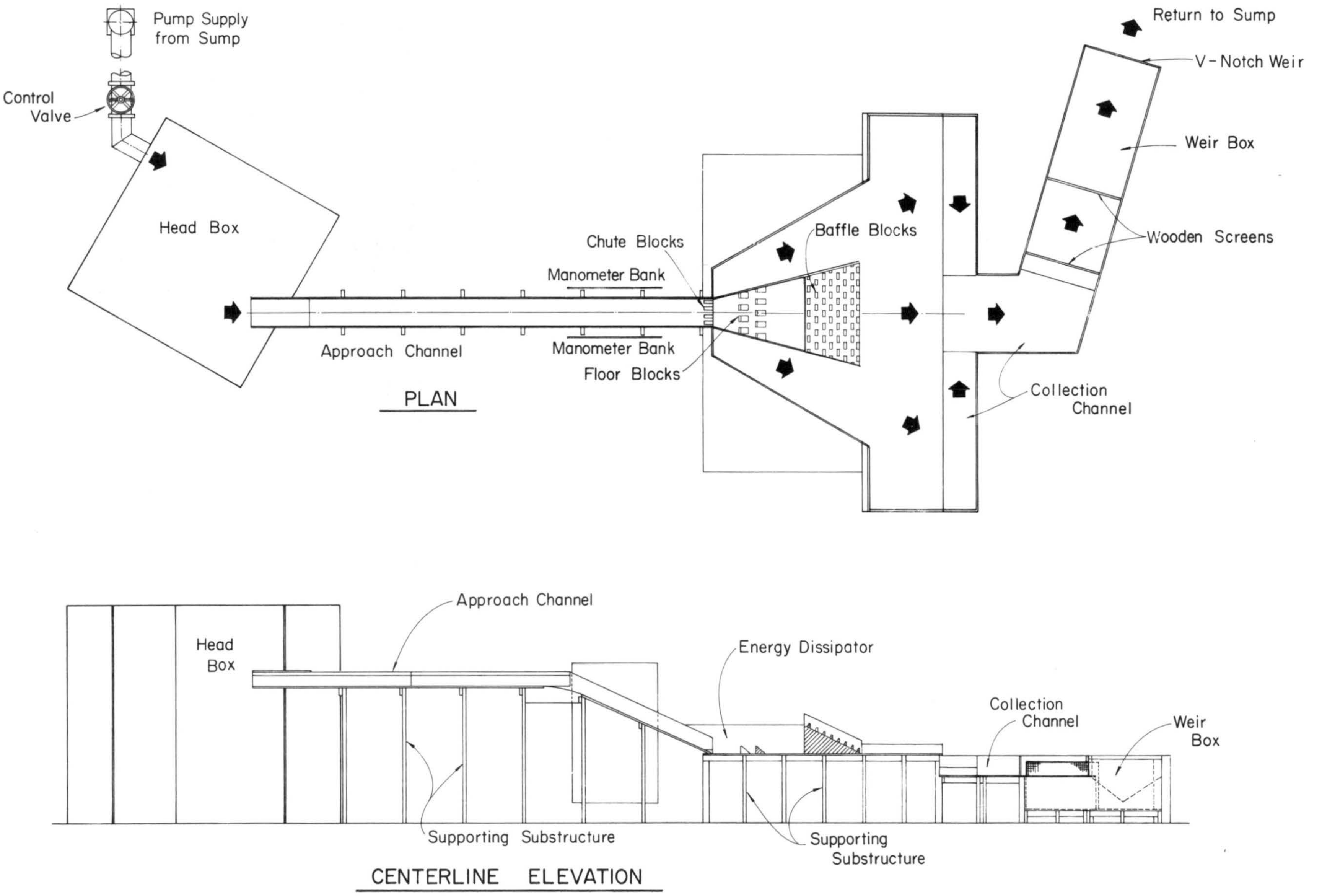


Figure 3. Model layout

8 ft high. Finally, the spreading apron or tertiary section follows in an attempt to spread the flow to further reduce velocities.

Objective and Scope of the Model Study

The principle objective of this study was to design and develop a hydraulic jump stilling basin which would satisfactorily dissipate the kinetic energy of the flow from the collection channel network; further to allow flow into the Rio Grande at such velocities that excessive scouring would not take place. To insure satisfactory operation of the basin, a large range in discharge was utilized, keeping foremost in mind that maximum discharge of 25,000 cfs would be realized only after ultimate development, and therefore that staging in construction and/or operation might be desirable. The following were then of specific interest:

1. Study the bottom shape of the channel at the crest of the river bank (station 1305+00) so that separation or cavitation would not occur.
2. Develop a hydraulic jump stilling basin to dissipate the substantial energy contained by 25,000 cfs.
3. Investigate a two-stage development of the basin initially for flows of about 16,000 cfs, then ultimately for 25,000 cfs.
4. Provide that velocities from the basin into the river be sufficiently low to prevent excessive scouring.

THE MODEL

Model Scales

Scale models of hydraulic structures are utilized to assist designers with problems which cannot yet be solved with mathematical exactness. Such models are constructed with guidance from certain basic physical model laws. Primarily, dynamic and kinematic similarities must be established and maintained between model and prototype (the actual field structure) if the model is to be useful to predict prototype performance. Dynamic similarity means similarity of forces associated with the flow while kinematic similarity relates to motion, i.e., velocity and direction of flow.

Fundamentally for this problem the Froude number, a parameter relating the inertial force to the gravitational forces, must be the same for model and prototype to insure both dynamic and kinematic similarities. There are many model-to-prototype scale ratios which pertain to homologous units. There are ratios which relate geometry, and fluid and flow characteristics. Generally with models of hydraulic structures, the same fluid is used in the model (water in this case) as will be flowing through the prototype. Thus the scales for fluid properties are established. It is necessary then to select only one other scale ratio. It is customary to choose the length scale as the independent ratio, consistent with physical model size and compatibility with laboratory equipment and space. If considered casually, it would seem that the larger the model the better the similarity. However, the cost of construction and operation of a model rises exponentially with size, hence we rapidly reach a size of diminishing effective return.

With due consideration to all of the foregoing, a selection of the length scale (L_r) (all scales refer model to prototype), of 1:30 was made, from which it follows that the time scale (t_r), is 1:5.48, the discharge scale (Q_r) is 1:4932, pressure scale (p_r) is 1:30, and channel roughness scale (n_r) is 1:1.76.

Model Construction

The general arrangement and assembly of the model are shown in Figure 3. The water is supplied to the head box by a 14-in. turbine pump. The discharge was regulated by a by-pass valve near the pump and a control valve near the head box. Within the head box, baffles and screens create uniform distribution of flow and damps all surface disturbances. Discharge from the model was collected into a weir box at the end of which was a calibrated triangular weir. The weir was used to measure the discharge which flowed through the model. The water then passed into a sump underlying the laboratory, thus forming a recirculating system.

The model was constructed of good-grade lumber with the walls and floors coated with polyester resin to form a smooth water-proof finish. The vertical curve in the channel floor, at the river bank, station 1305+00, was rolled from 1/8-in. aluminum sheet to form an accurate smooth shape. A photographic view of the finished model is shown in Figure 4, with more detailed views in Figures 5 and 6.

The baffle and floor blocks of the stilling basin were constructed from sugar pine and coated with polyester resin (see Figure 7). Several of the blocks however, particularly for Design C, were constructed from clear acrylic plastic blocks into which piezometers were located to measure pressures. Pressure measurements were necessary to determine magnitudes of negative pressures as indicators of potential cavitation as well as positive pressures for total forces on the blocks. Readings of pressures were made with standard water manometers; a bank of which is shown in Figure 8.

Several modifications to the original design were developed during the course of this study, fundamentally as a result of change in the approach channel width. It would be informative to follow the chronological development.

1. The original hydraulic jump basin design is referred to as Design A. The dimensions and conditions which led to the design have already been described.
2. The next stilling basin, Design B, was arranged to take hydraulic and perhaps economic advantage of gradual growth of the collection network in the development area, hence gradual increase of maximum discharge into the stilling basin. It was believed possible to establish a two-stage stilling basin, the first stage of which would

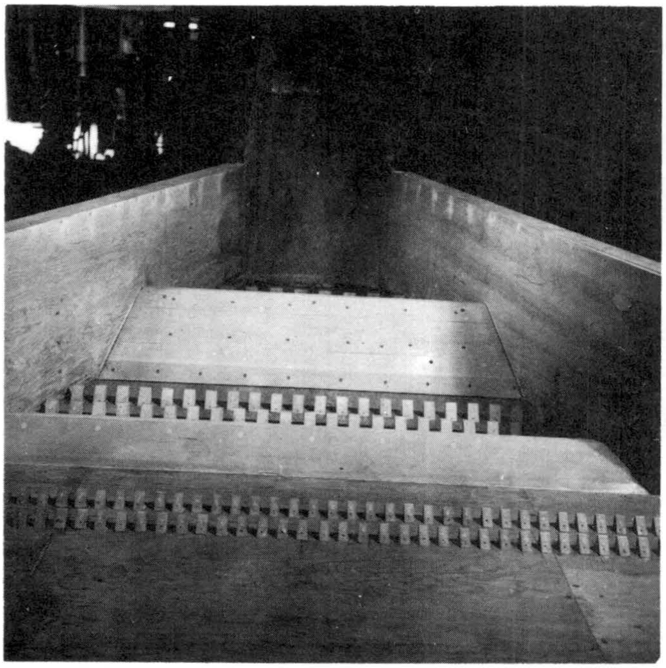


Figure 4. Overall view of the completed model - Design A. Flow is toward the observer.

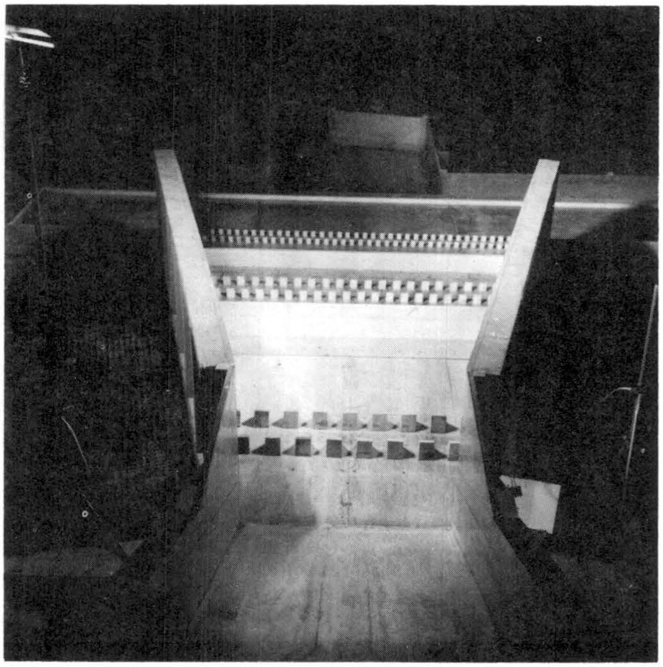


Figure 6. Basin arrangements as viewed from upstream.

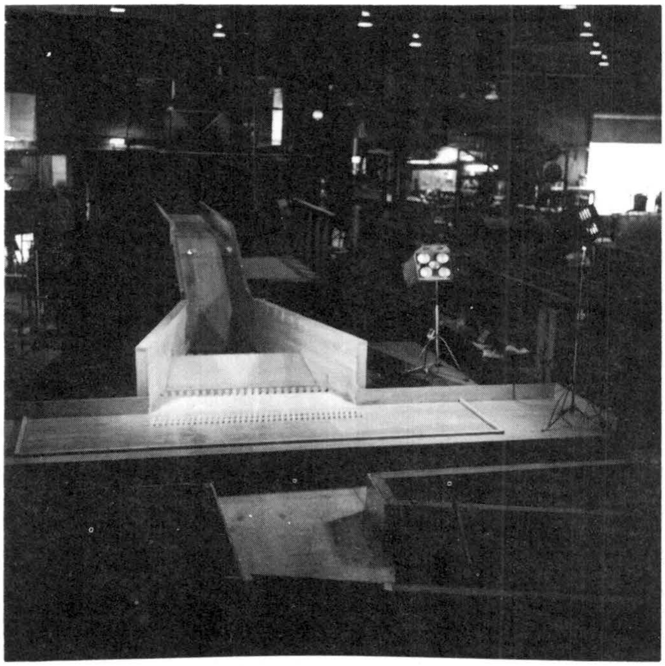


Figure 5. The primary and secondary basins. Note that the model wall heights are not intended to depict requisite prototype walls. Prototype heights are determined from water depths in the basins.

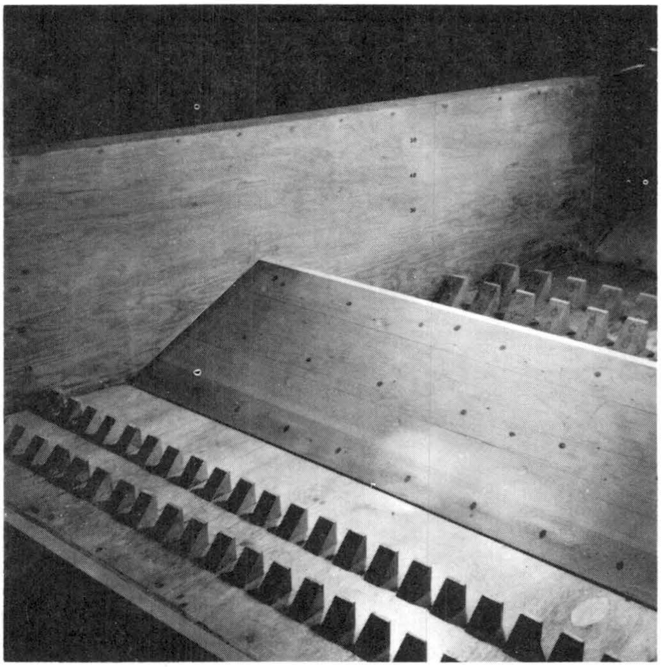


Figure 7. Arrangement of floor blocks in the secondary basin.

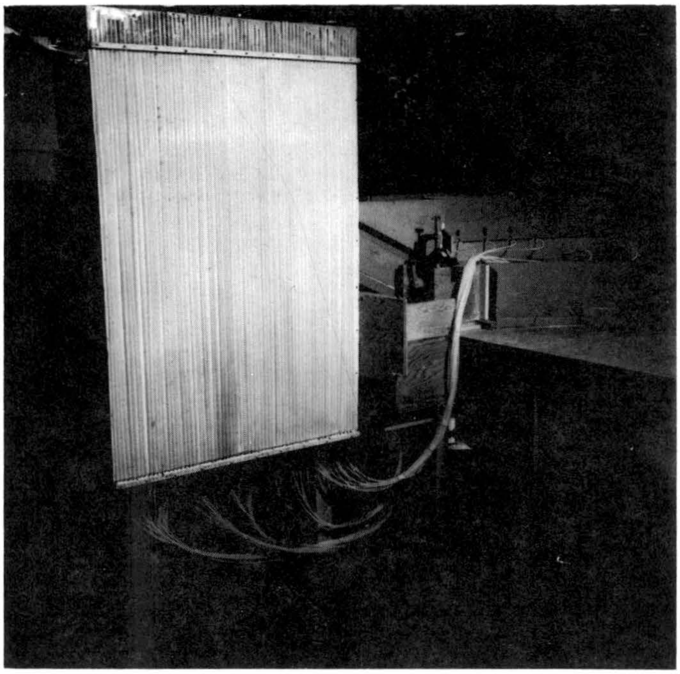


Figure 8. A typical manometer bank to measure pressures in the model.

adequately provide for immediate needs and the second to provide for the ultimate discharge of 25,000 cfs. A question arose concerning the magnitude of this intermediate discharge. After deliberation with the consulting engineering firm (Gordon Herkenhoff and Associates) it was established that this intermediate discharge should be 16,000 cfs. The goal of the second design was then to provide a satisfactory stilling basin for 16,000 cfs, with allowance for some modifications at a second stage to provide for 25,000 cfs. The approach channel width remained at 70 ft. The dimensions of this basin arrangement are more fully described in a later section.

3. A third stilling basin was designed when it became desirable to consider the effect of reducing the approach channel width from 70 to 40 feet. The consequence of this change would of course be immediately registered in a greater sequent depth y_2 , hence in greater height of the end sill and basin walls. However, when considered in the light of two-stage development, with 12,500 cfs at the initial stage flowing over the end sill and an additional 12,500 cfs flowing over the walls of the stilling basin at the second stage, it was not readily apparent that a more complex or more expensive structure was involved. A model was required to establish the results. The details of this basin are also described in a later section. This design is referred to as Design C. A change in the intermediate or first stage maximum discharge from 16,000 for Design B to 12,500 cfs for this basin was made. This is of no real consequence, but resulted from more detailed studies of Gordon Herkenhoff Associates, Inc. regarding the hydrology of the drainage area.

RESULTS

The hydraulic characteristics of the various energy dissipators and components are discussed in the order in which they were studied. This provides a convenient systematic order in presenting the results.

Design A

The channel width for this design was 70 feet, with supercritical flow in the channel approaching the river bank. This gives rise to concern of potential separation or cavitation of the channel flow at the vertical curve located at the top of the river bank where the channel drops down to the energy dissipator. Pressures were therefore measured along the centerline of this 150-ft radius vertical curve. There were no negative pressures along the floor for any discharge in the full range to 25,000 cfs. Although the radius of the curve could therefore be shorter, a different radius was not studied in the model because conditions other than hydraulic bear importance in the determination of this curvature. The important result was then, that hydraulic characteristics were satisfactory.

The conditions of flow within the total energy dissipator are shown in the photographs of Figures 9 through 12 for a flood flow of 6400 cfs. The water surface in the primary basin is relatively smooth as

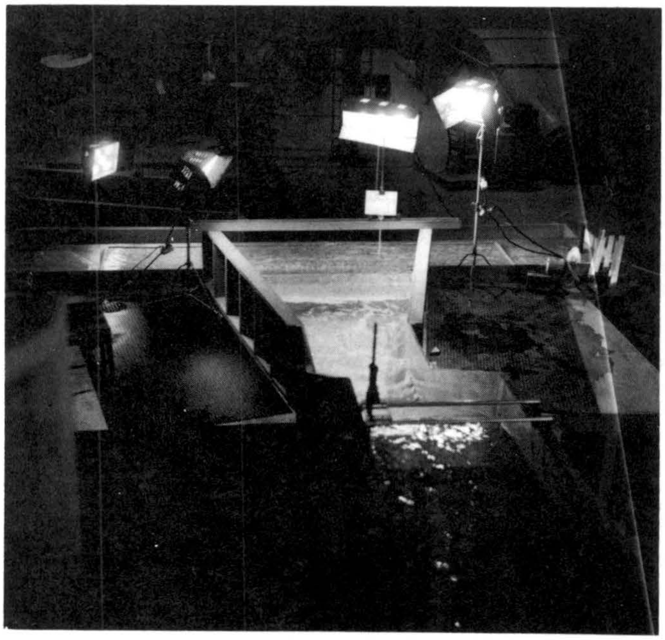


Figure 9. Q = 6400 cfs through the energy dissipator as viewed from above the river bank.

indicated in Figures 9 and 10 and the effectiveness of energy dissipation is obvious. The secondary basin is similarly effective in dissipating energy and is sensed pictorially in Figure 11. The spread of flow in the tertiary or spreading basin is assisted by two rows of floor blocks located downstream from the end sill of the secondary basin and additionally by a long sill surrounding the spread basin. The sill in these photographs is 2.4 ft high. Energy dissipation throughout the model for this discharge is entirely satisfactory.

The depths of flow achieved in various sectors of the basin are indicated on a plan view of the total arrangement in Figure 13 and are also tabulated later in Table 1 for convenient comparison with other discharges.

In the next sequence of photographs, indicated as Figures 14, 15 and 16, the sill surrounding the spread basin was increased in height to 10.5 feet. The purpose in doing so, refers not so much to this discharge of 6400 cfs, but to larger flows as we will see shortly. Nevertheless, it is informative to note the effect increase in height has on flow spread. It should be remembered that the purpose in spreading is to achieve low velocities of the flow which enters the river.

The conditions of flow in the model for a flood flow of 11,800 cfs are depicted in the photographs of Figures 17 through 20. The tertiary basin sill height in these photographs is 2.4 feet. As it would be supposed, the larger discharge creates generally rougher water surface throughout. Nevertheless, this design, Design A, still offers completely satisfactory performance within the primary and secondary basins. Within the tertiary basin however, we see manifestations of difficulty in Figure 20, where the larger kinetic energy of the flow after the secondary basin tends to concentrate the flow over the tertiary sill. This is suggestive then that the sill height should be increased.

The effects of successively increasing the height of the sill is shown progressively in Figures 21-23. While in fact, the 5.4 ft sill in Figure 21 is adequate, the sill was further increased to 8 and 10.5 feet to complete the comparison with the results of other discharges.

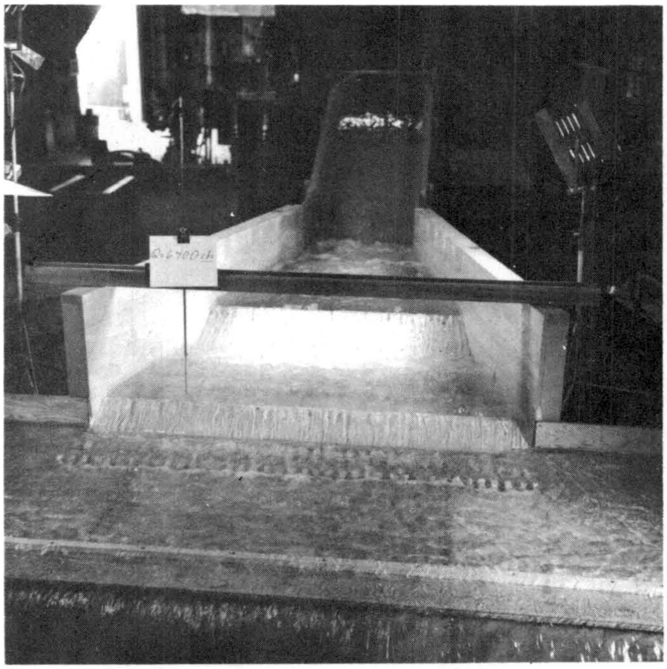


Figure 10. Q = 6400 cfs. A view from the river.

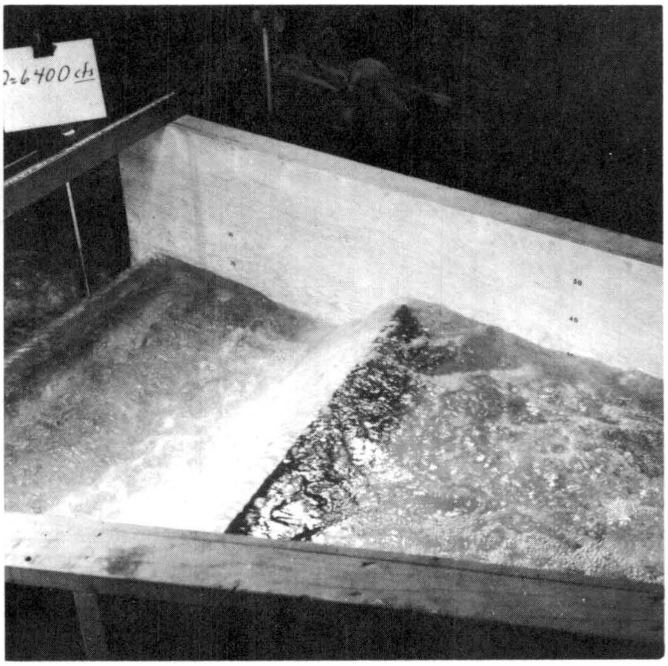


Figure 11. Primary and secondary basins. Note the depths of flow indicated along the wall and the relatively quiescent flow within the basins.

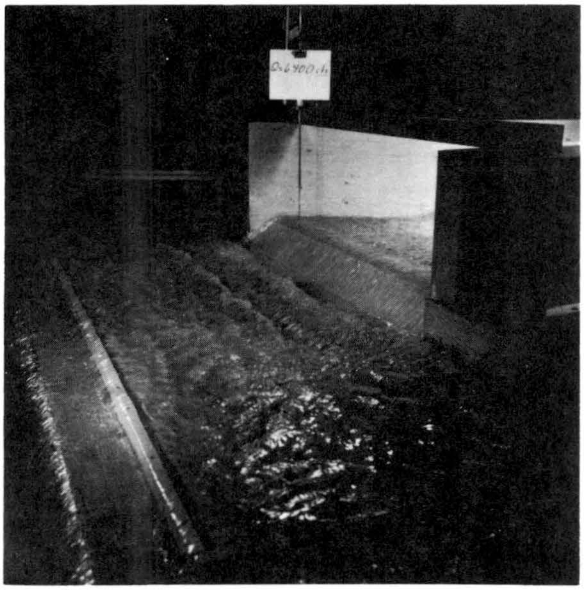


Figure 12. Tertiary basin with Q = 6400 cfs. The flow is spread over a total sill length of 400 feet.

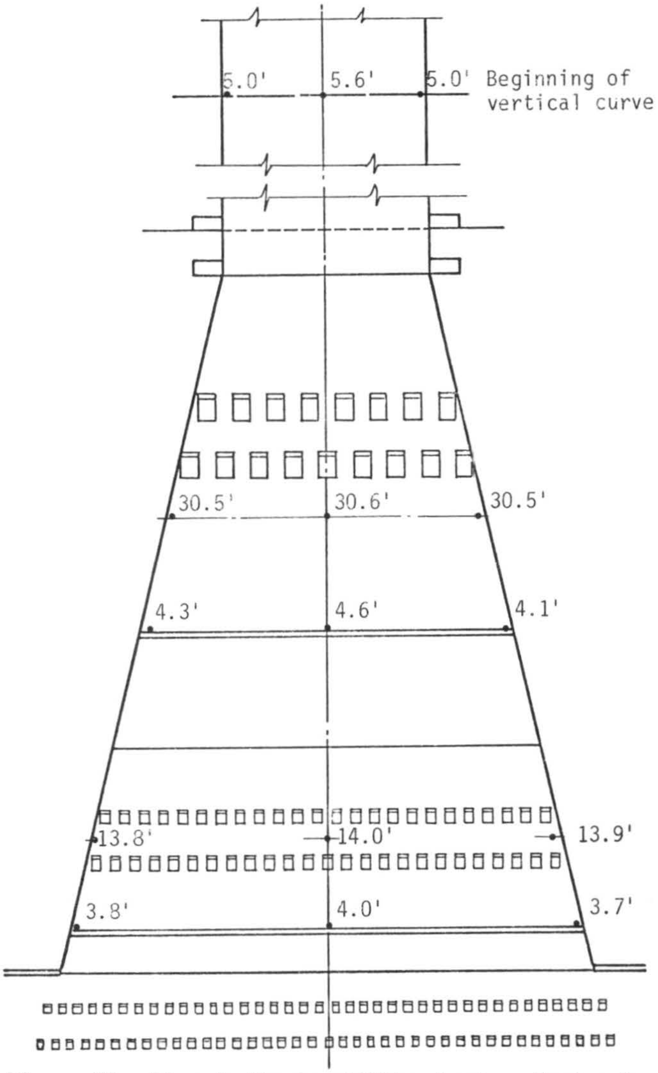


Figure 13. Flow depths in stilling basin - Design A. Q = 6400 cfs.

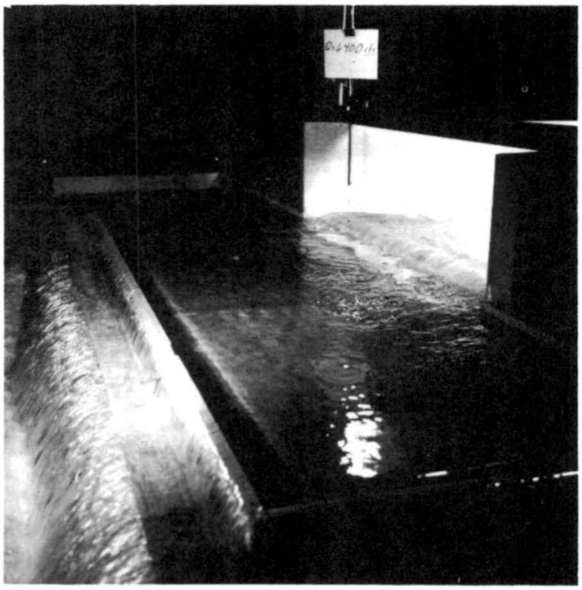


Figure 14. Tertiary basin sill height = 5.4 feet. Q = 6400 cfs.

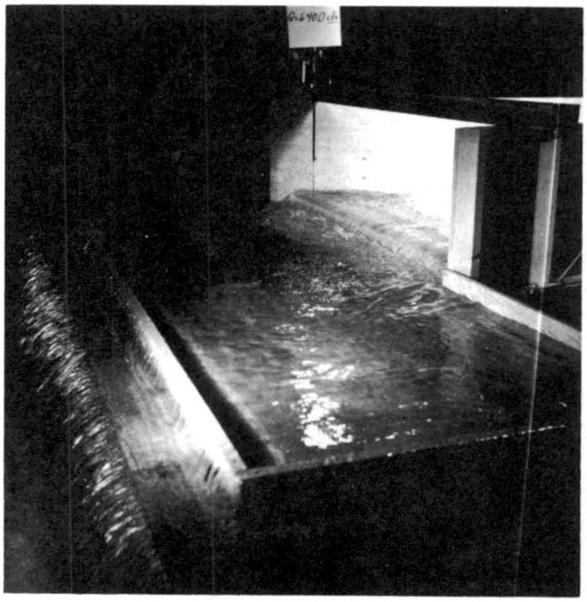


Figure 15. Tertiary basin sill height = 8.0 feet. Q = 6400 cfs.

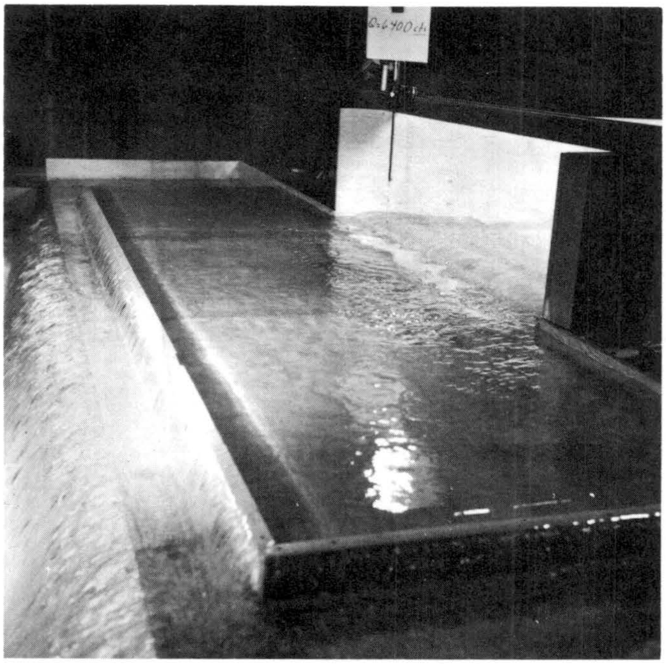


Figure 16. Tertiary basin sill height = 10.5 feet. Q = 6400 cfs.

Figure 18. Q = 11,800 cfs. View is from the river.

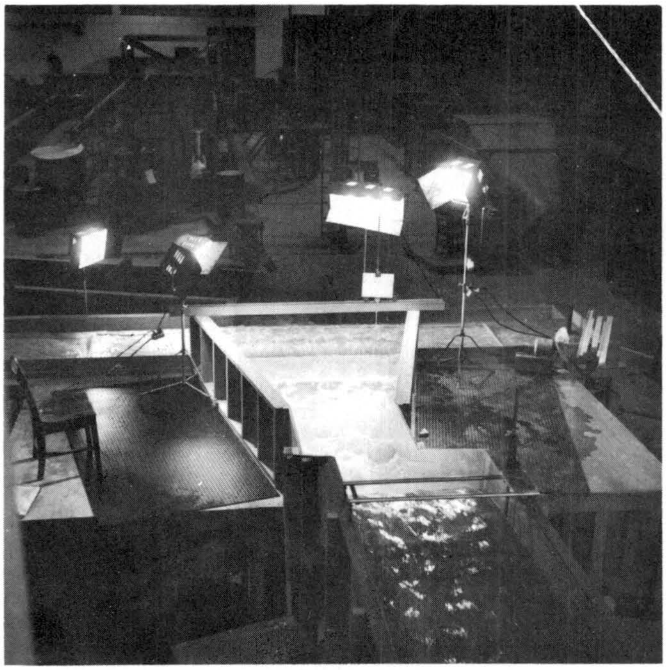


Figure 17. Q = 11,800 cfs. View is from upstream.

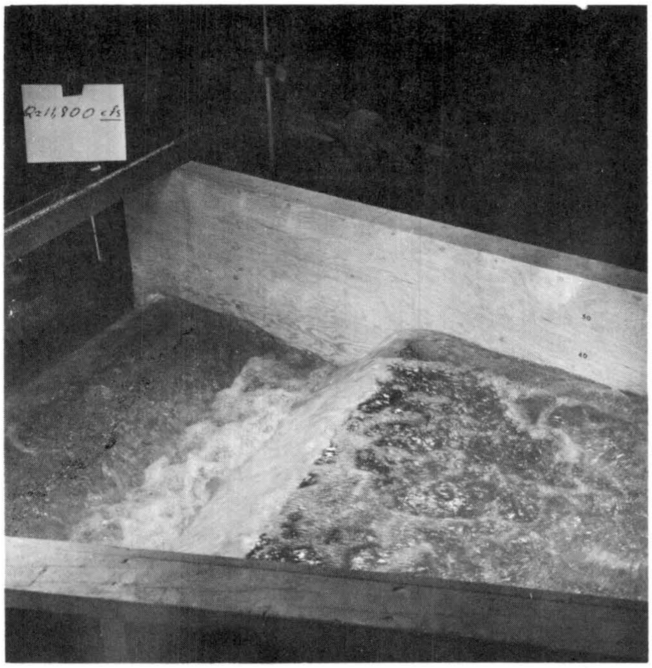


Figure 19. Primary and secondary basins. Note increased turbulence and aeration as compared to Figure 11. Stilling action is completely satisfactory.

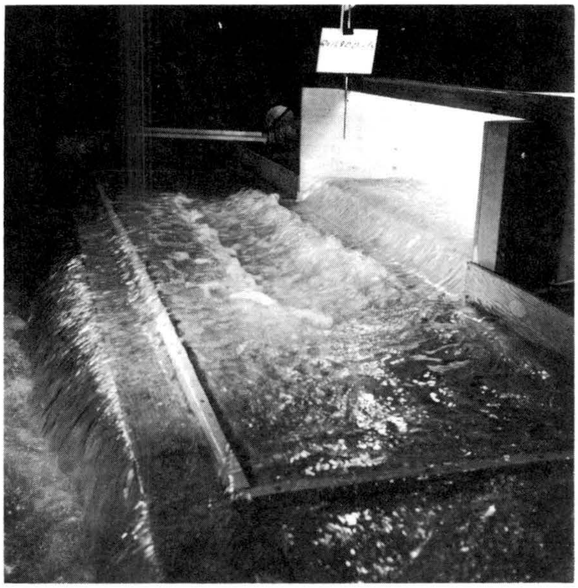


Figure 20. Sill height = 2.4 feet. Tertiary basin is suggestive of inadequate energy dissipation there. A higher sill is necessary.

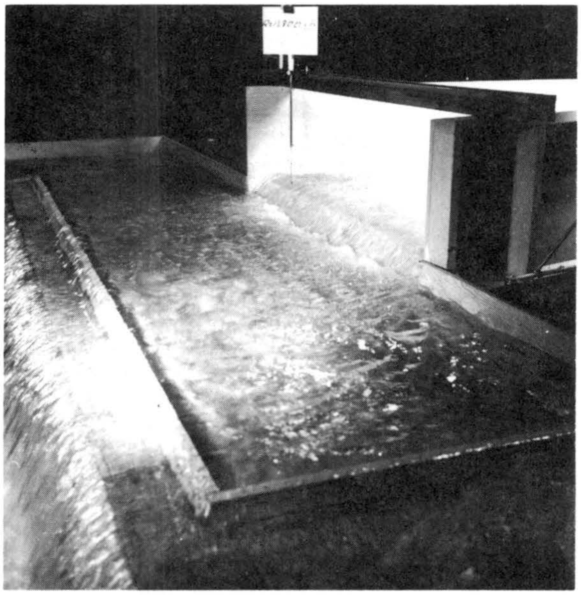


Figure 21. Sill height = 5.4 feet. Q = 11,800 cfs. The stilling action is now adequate.

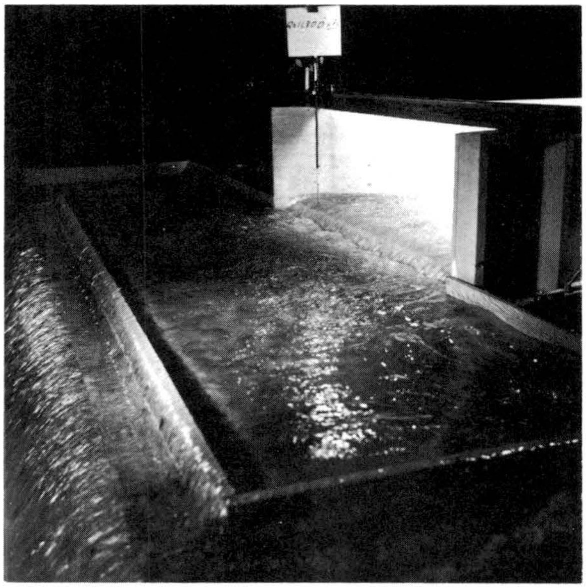


Figure 22. Sill height = 8.0 feet. Q = 11,800 cfs.

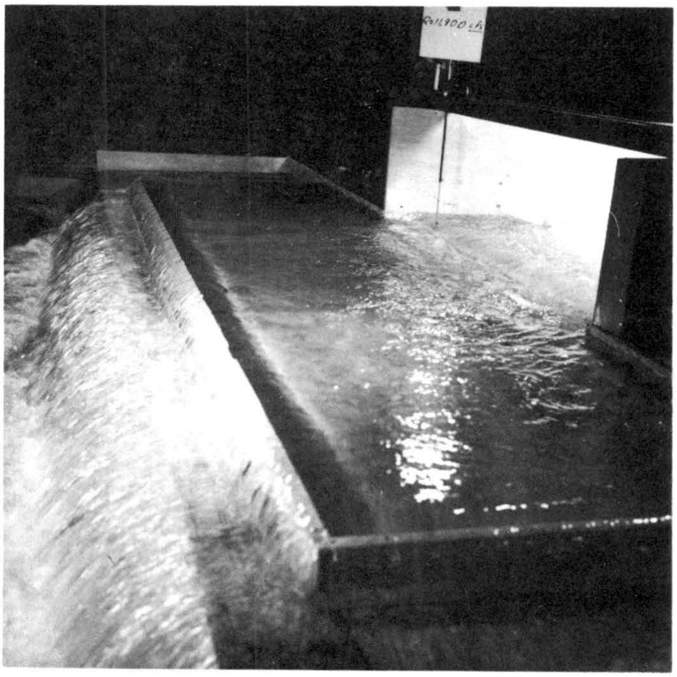


Figure 23. Sill height = 10.5 feet. Q = 11,800 cfs.

The record of selected water depths in the primary and secondary basins, and in the approach channel are indicated on the plan of the basin in Figure 24.

The following conditions of flow are created within the energy dissipator with a discharge of 15,400 cfs:

1. The water surface is rougher when compared to the preceding flow of 11,800 cfs and the dissipation action must of necessity be greater because of the larger energy of the flow.
2. The primary and secondary basins are completely adequate.
3. The tertiary sill height of 2.4 feet is inadequate, 5.4 feet is barely adequate and higher sills are more effective.
4. Maximum flow depth in the primary basin is about 35 feet and in the secondary basin is about 17.5 feet.

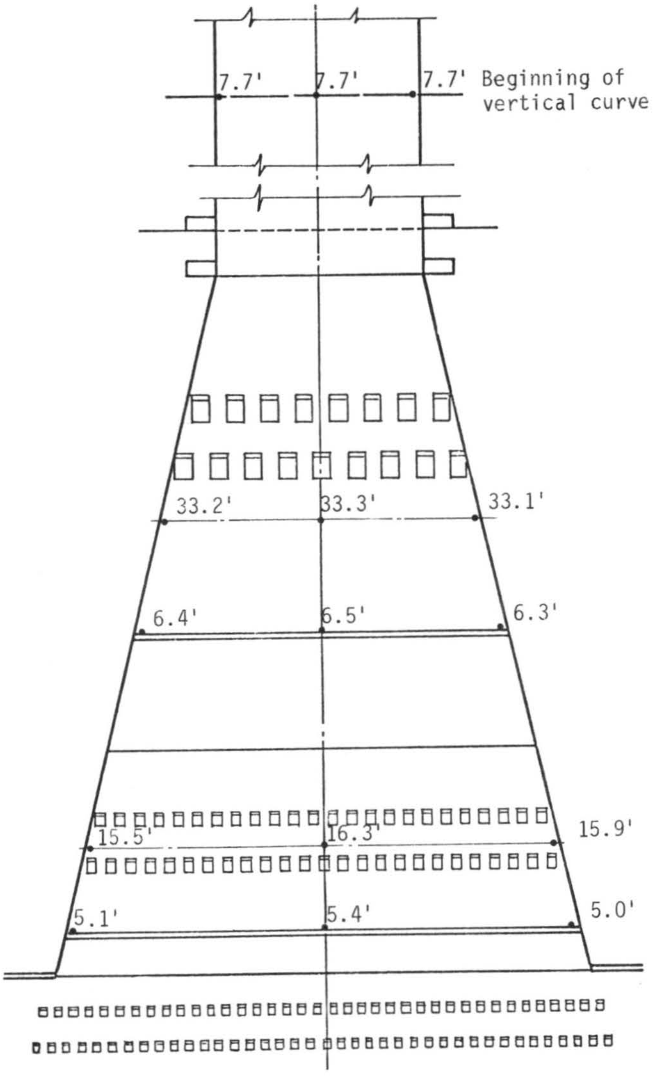


Figure 24. Flow depths at selected locations. Q = 11,800 cfs.

The photographs appropriate to the discharge are arranged as Figures 25-31 in exactly the same order as for previous discharges. It is summarily useful to refer often to the previous photographs in developing a gradual appreciation of the effectiveness of this design.

The maximum discharge of 25,000 cfs creates a highly turbulent condition in the primary basin as it may be noted in Figure 33. The stilling basin is effective, and the flow which enters the secondary basin contains considerably less total energy than that which is contained by the flow at the base of the channel. This turbulent motion within the primary and secondary basins can be appreciated from the photograph of Figure 35. In Figure 36, the sill height is 2.4 feet, and is insufficient to create an effective tailwater depth. As the height of this sill is increased, a more satisfactory result is achieved. It appears that the sill height needs to be about 8 feet in order to provide an adequate tailwater depth. These results are pictorially demonstrated in Figures 37, 38 and 39.

The maximum depth in the primary basin is approximately 40 feet, as noted in the record of flow depths in Figure 40. The wall of the basin then should be about 43 feet which allows for a free board of 3 feet to account for increased bulking of the flow due to air entrainment in the prototype which cannot be truly reproduced in the model. The secondary basin wall height should be about 22 feet when similarly accounted for bulking.

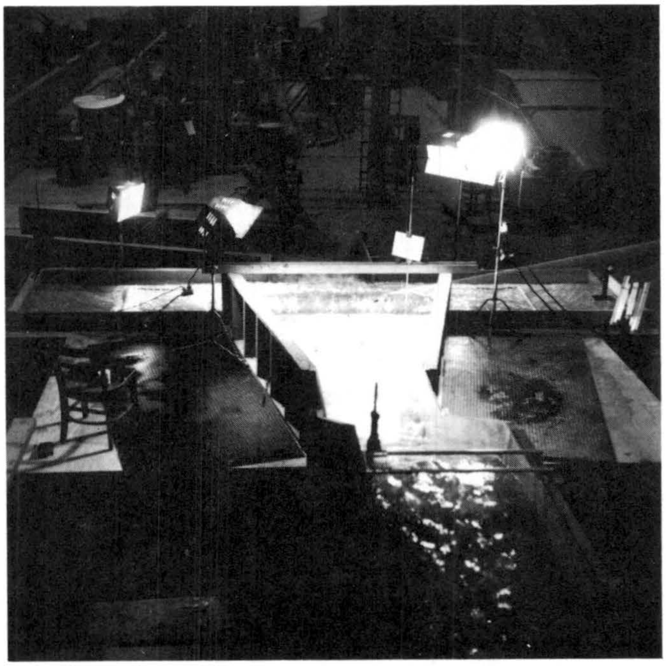


Figure 25. Q = 15,400 cfs. View is from above the river bank.

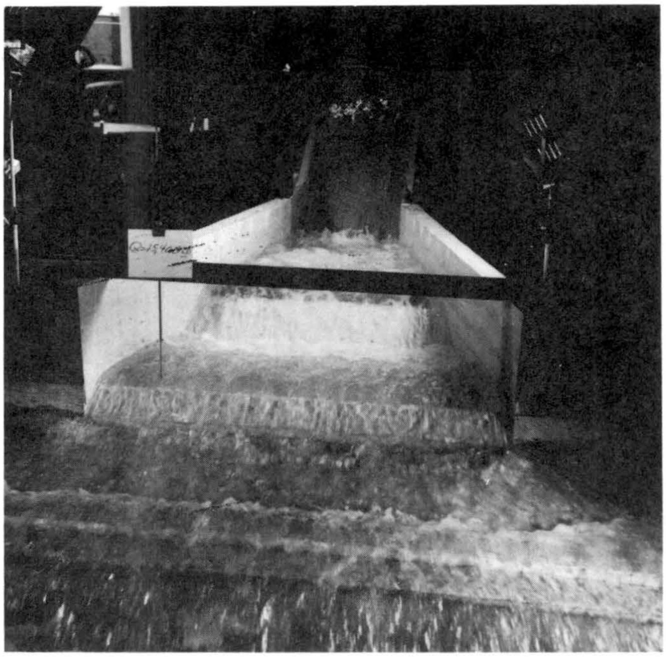


Figure 26. Q = 15,400 cfs. View is from river level.

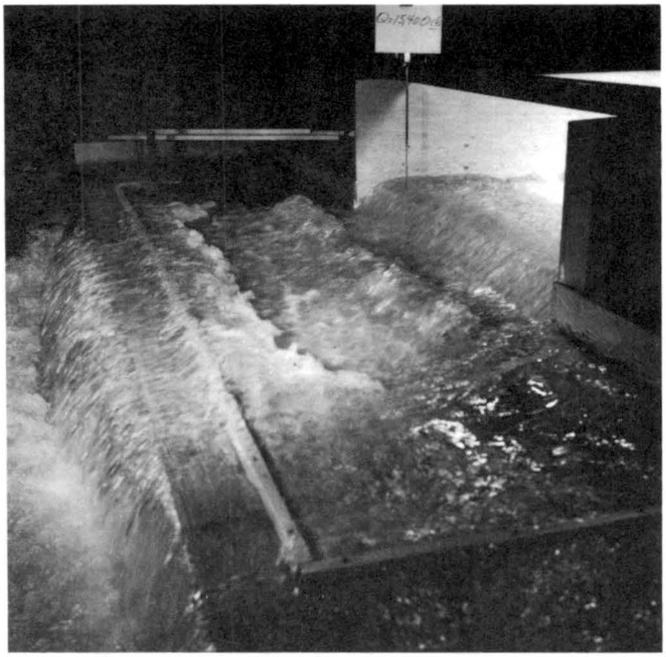


Figure 28. Sill height = 2.4 feet. Q = 15,400 cfs. Tertiary basin is ineffective.

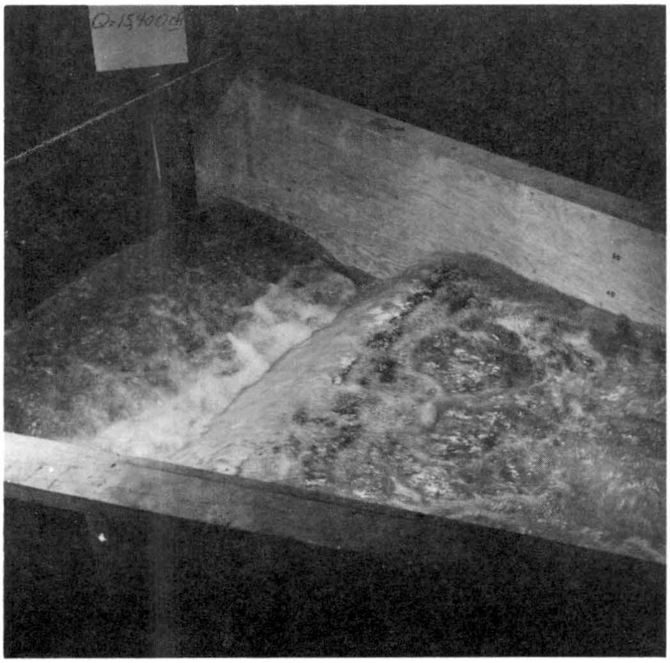


Figure 27. Primary and secondary basins. Water surface is acceptably smooth.

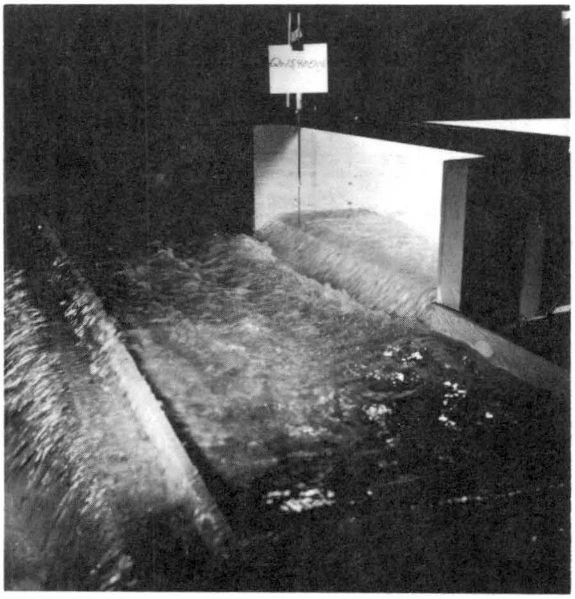


Figure 29. Sill height = 5.0 feet. Q = 15,400 cfs.

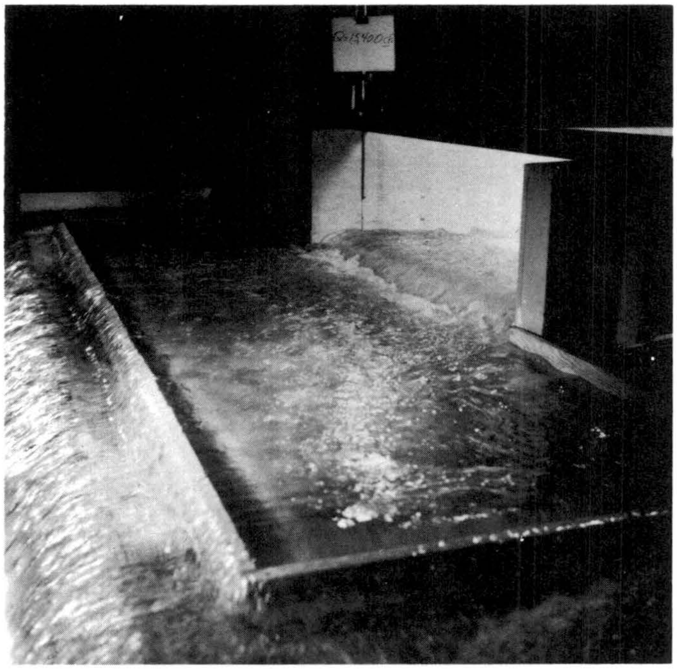


Figure 30. Sill height = 8.0 feet. Q = 15,400 cfs.

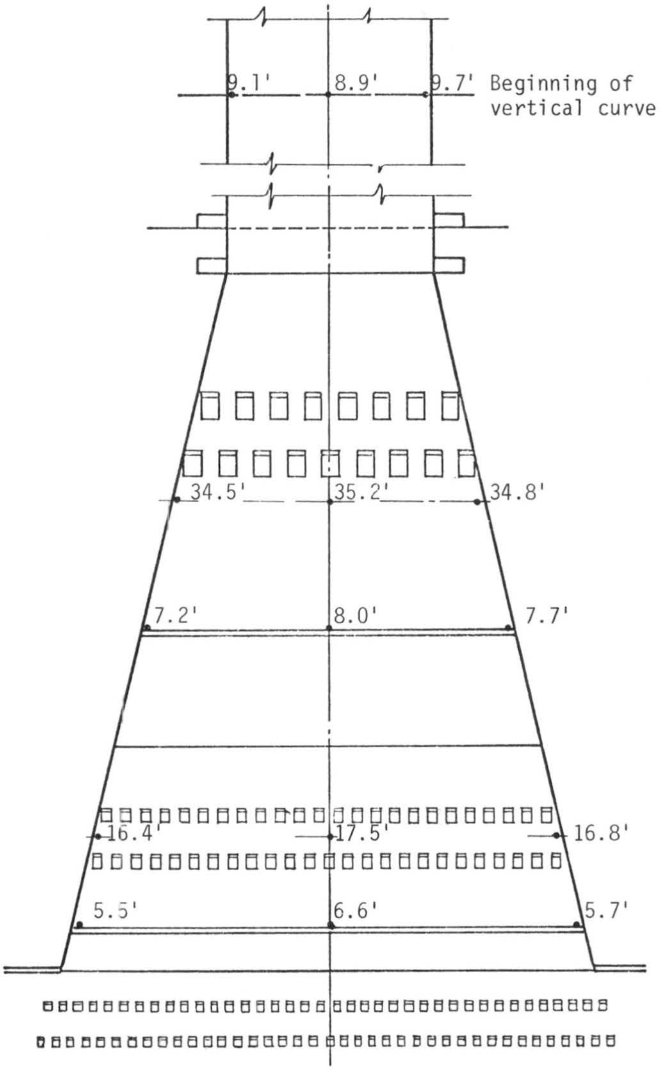


Figure 32. Flow depths in stilling basin - Design A. Q = 15,400 cfs.

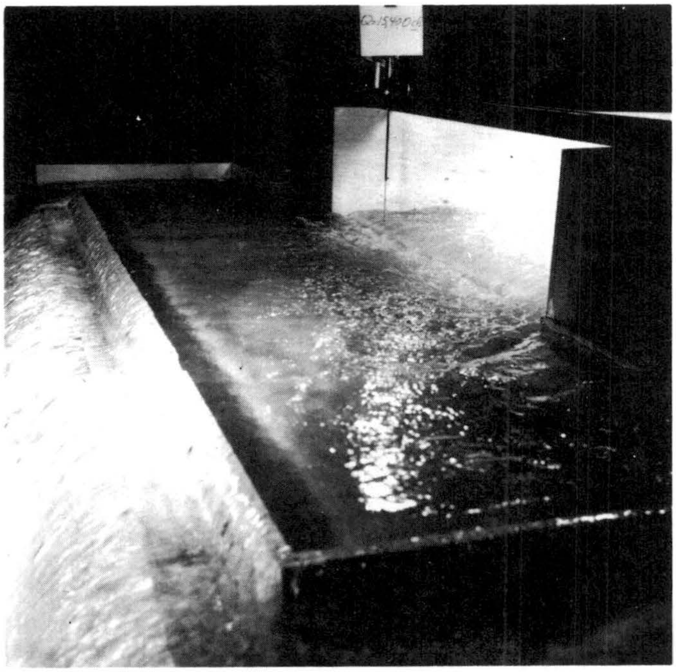


Figure 31. Sill height = 10.5 feet. Q = 15,400 cfs.

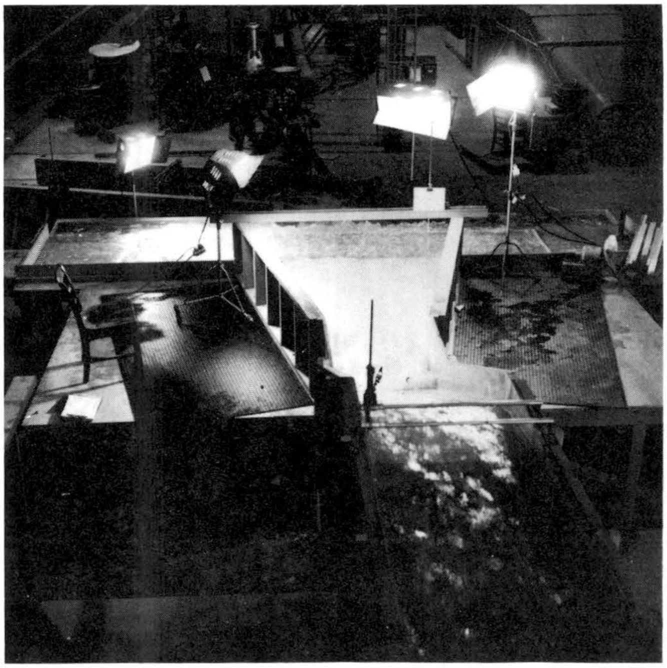


Figure 33. Q = 25,000 cfs. Upstream view. (Turbulent region of the primary basin is somewhat obscured by overexposure, but is nevertheless observable.)

Figure 34. Q = 25,000 cfs. View from river level.

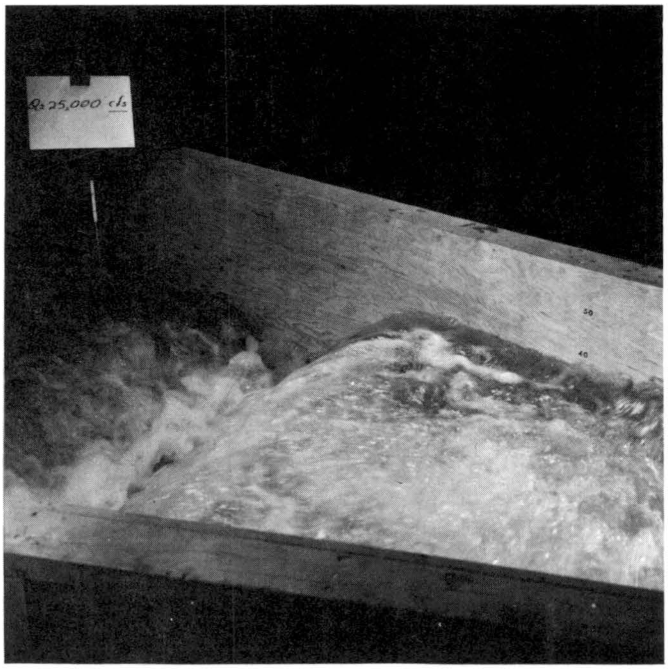


Figure 35. Primary and secondary basins. Compare with Figures 27, 19 and 11 in particular.

Figure 36. Sill height = 2.4 feet. Q = 25,000 cfs.

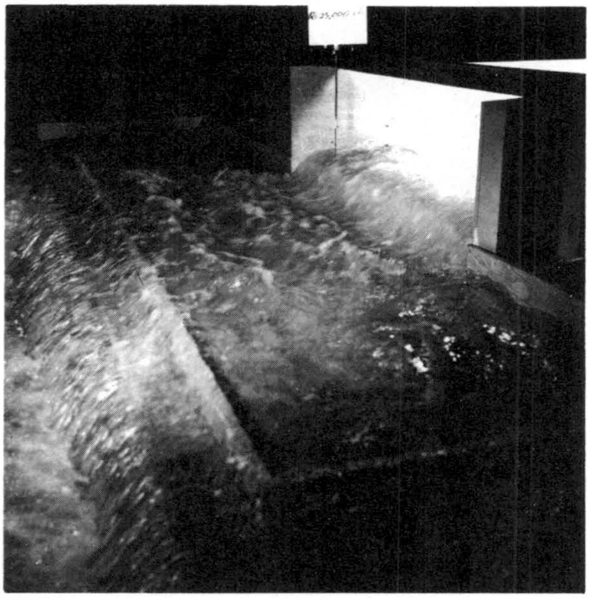


Figure 37. Sill height = 5.4 feet. Q = 25,000 cfs.

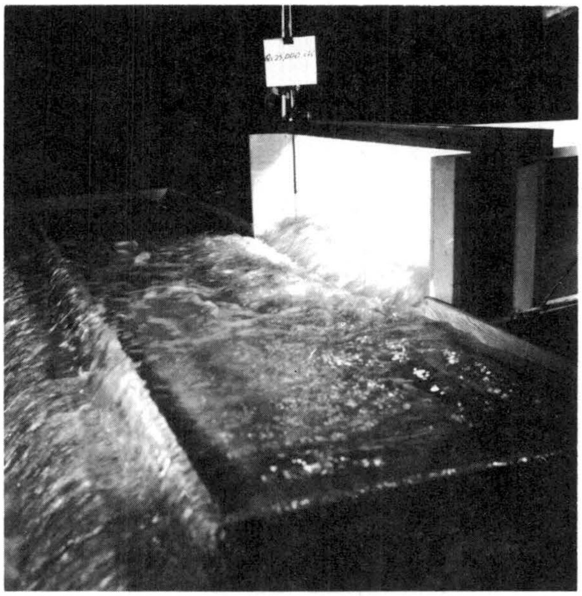


Figure 38. Sill height = 8.0 feet. Q = 25,000 cfs.

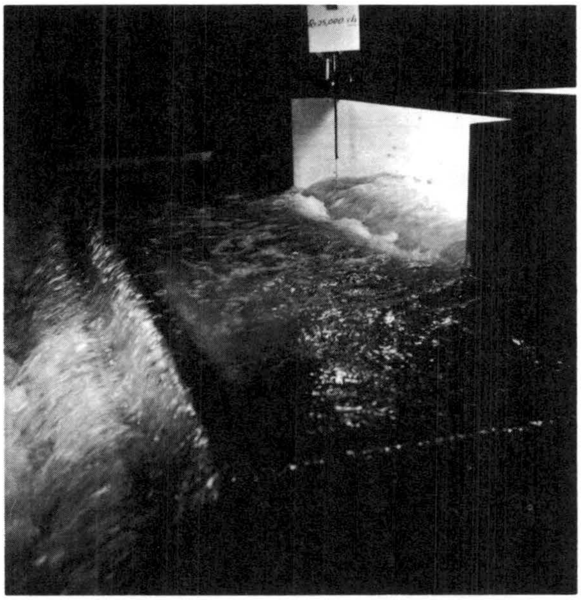


Figure 39. Sill height = 10.5 feet. Q = 25,000 cfs.

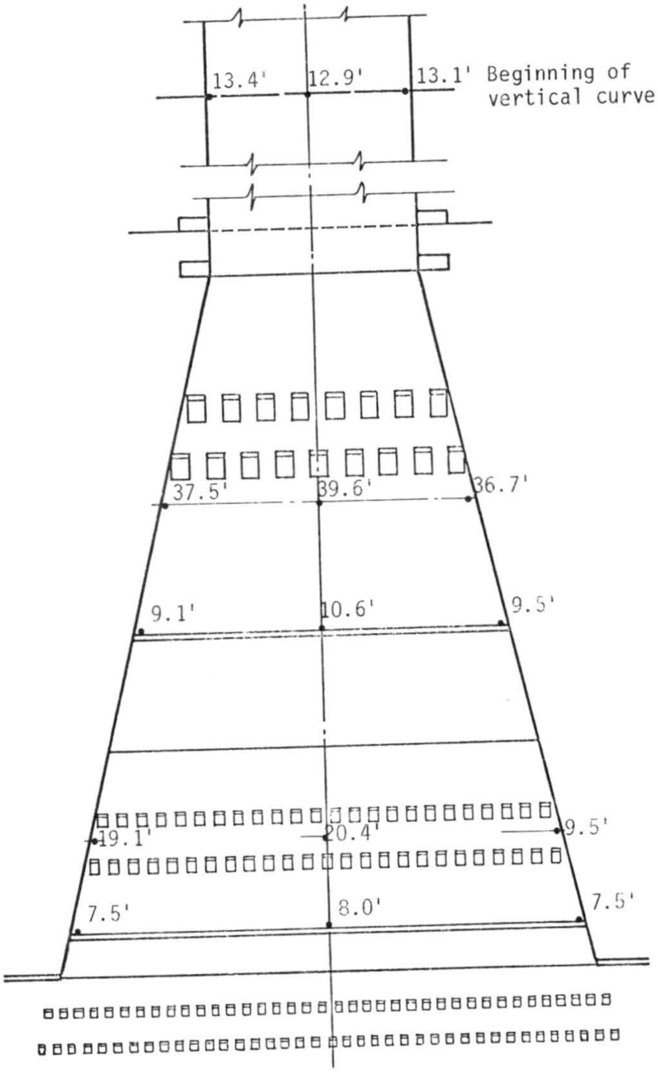


Figure 40. Flow depths in stilling basin - Design A. Q = 25,000 cfs.

Design B

The principle difference from Design A is allowance of limited flows over both sides of the primary basin onto a paved floor. The reason for doing so, relates to the frequency distribution of large flood flows even for the fully developed collection channel network, and more particularly to stage development of the urban area. It was reasoned that the energy dissipator should capably pass some intermediate discharge and allow for future maximum discharge of 25,000 cfs with minimal added cost. If the added cost should result in the form of repair to damage caused by very large discharges, it was considered fair risk in view of the probable frequency of near maximum flows. As explained previously, this intermediate discharge was established to be 16,000 cfs. That is, the energy dissipator should satisfactorily allow 16,000 cfs through the primary, secondary and tertiary basins and permit approximately 9,000 cfs (4,500 cfs on each side) to flow over or through the side walls of the primary basin.

The design of this basin resulted with the dimensions and arrangement shown on Figure 41. The primary basin was 112 ft long with floor blocks as located, and an end sill 28 ft-7 in. high. The side walls of the basin flared wider from the end of the chute at a rate of 4:1 (longitudinal to lateral ratio). The secondary basin was 44 ft long, and the sill height was 7 ft high. The tertiary basin was slightly different from Design A in that it accounted for overflow from the primary basin. The sill height is 6 ft-10 in. The photographic views of Figures 42 and 43 are presented to show the overfall arrangement of the primary basin. The secondary basin is shown in Figure 44 and the tertiary arrangement in Figure 45.

We have chosen to show the results of the model tests for two conditions of flow, the first at 16,000 cfs with no flow over the sides, and the second at 25,000 with 9,000 cfs over the sides. At discharges less than 16,000 cfs the basin operated entirely satisfactorily. A flow of 16,000 cfs is depicted in Figures 46 through 49. The hydraulic jump in the primary basin is well contained toward the upstream section, the secondary basin performs well and the flow spread over the tertiary sill, though non-uniform, is nonetheless effective.

The depths of flow are indicated on Figure 50. The depths are approximately 39 feet and 16 feet in the primary and secondary basins respectively.

The top of the primary basin side wall was initially set in the model at a height of 33.6 feet from the floor. This was calculated to provide a distribution of 16,000 over the end of the basin and 9,000 over the walls. It resulted that the flow over the end sill was somewhat greater than 16,000 cfs as determined by the depth of flow over the sill. (Compare Figures 55 and 50). It is of interest, nevertheless, to observe the total flow at the energy dissipator as depicted in Figures 51 through 54. The wall height was subsequently reduced to 32.4 feet to obtain the prescribed flow distribution through the basin. The results of the flow at 25,000 cfs can be seen in Figures 56 through 59 with flow depths indicated on Figure 60. Selected water depths through the basin are given in Table 2.

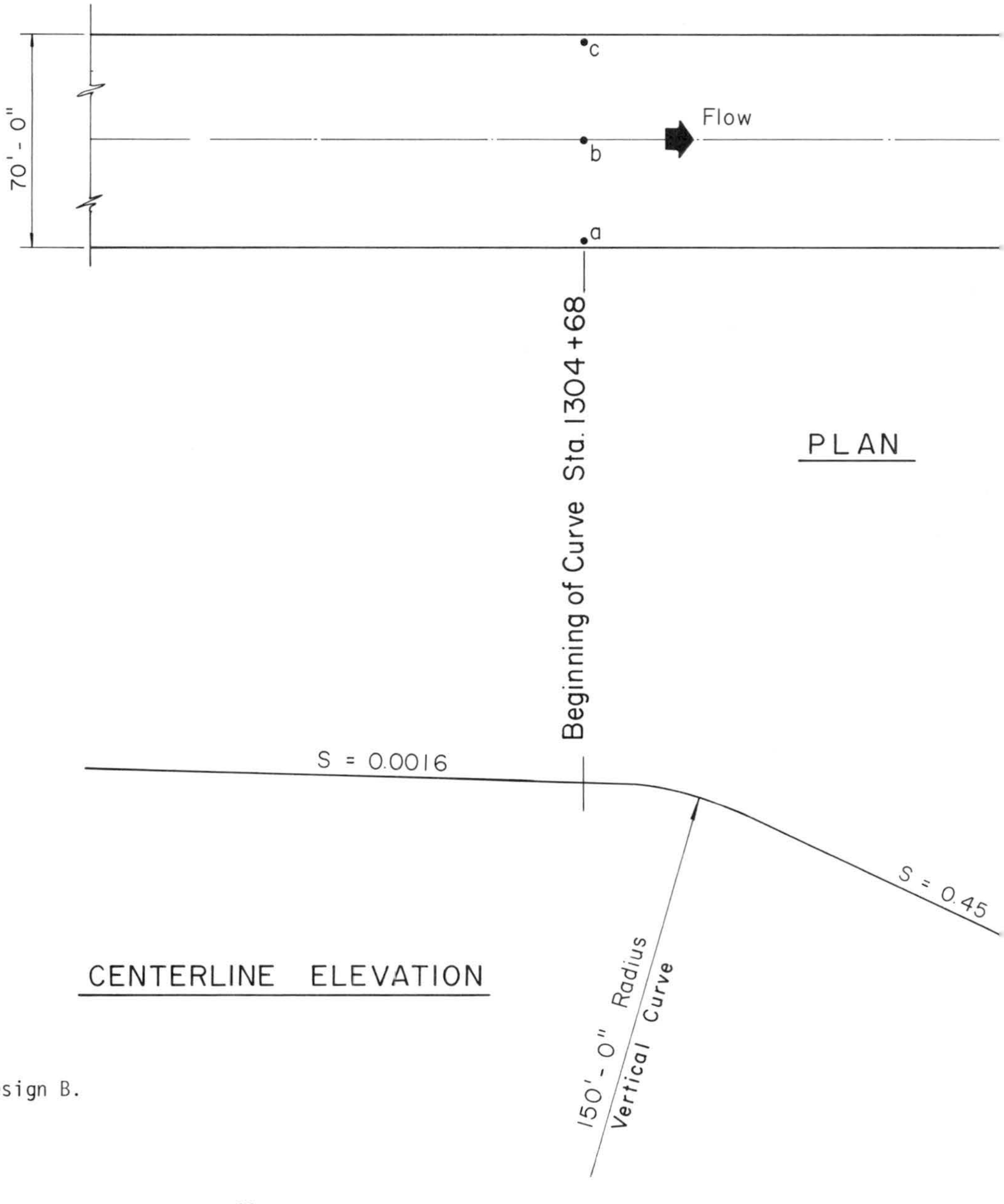
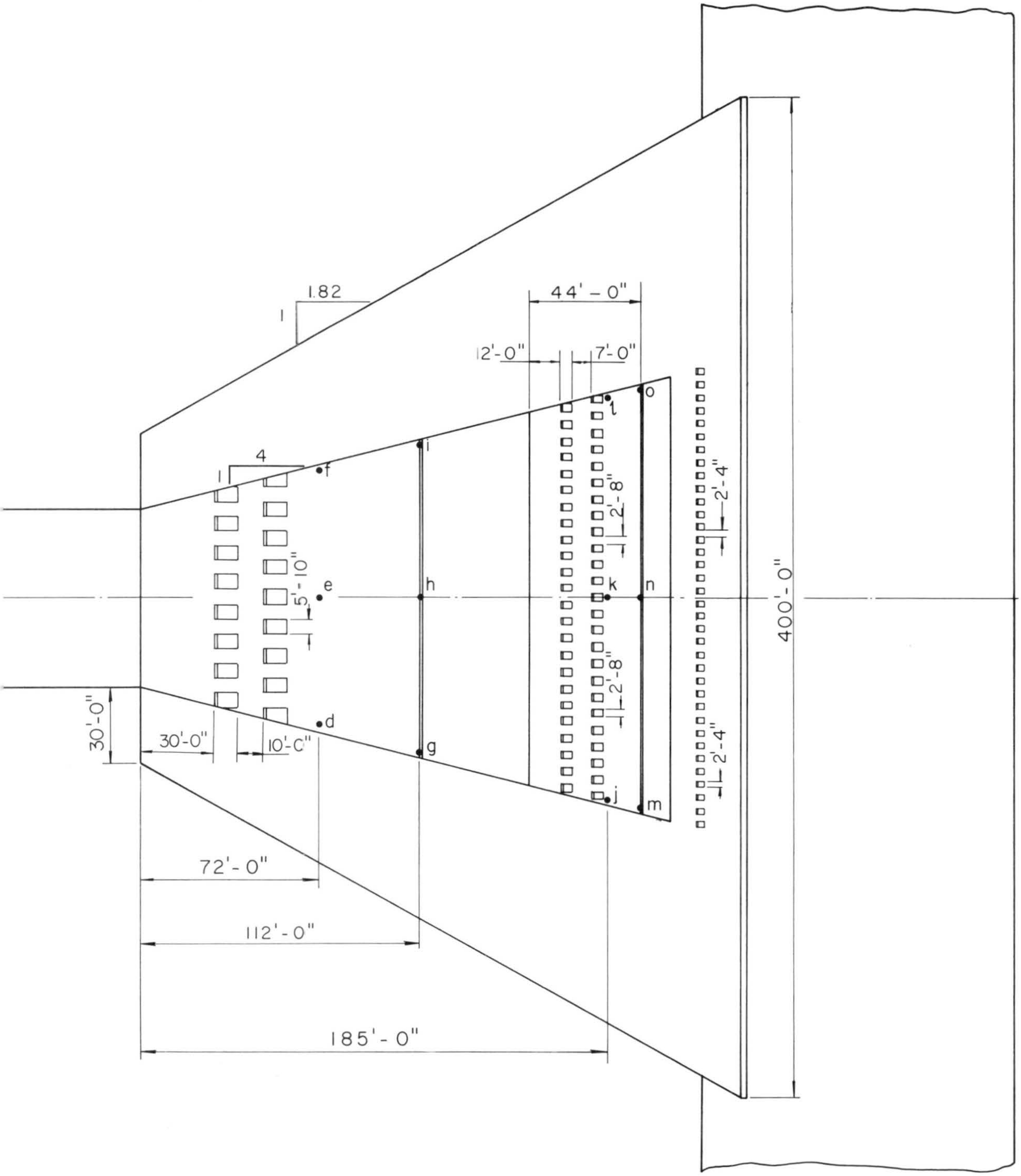
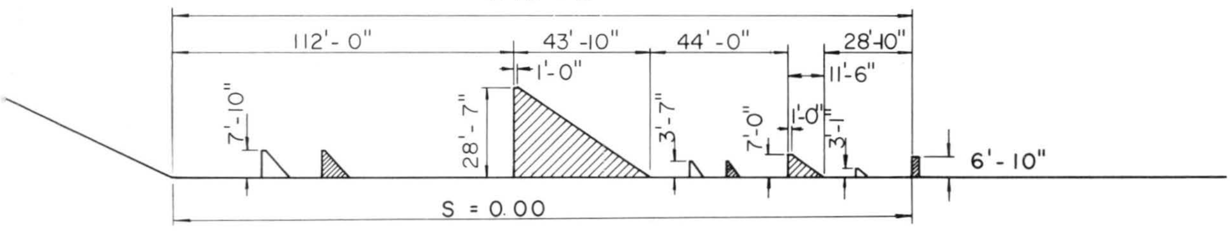


Figure 41. Schematic drawing of Design B.


1.82
1
44' – 0"
12'-0"
7'-0"
o
l
i
4
1
f
2'-8"
2'-4"
e
h
k
n
5'-10"
400'-0"
2'-8"
d
30'-0"
30'-0"
10'-0"
g
j
m
2'-4"
72'-0"
112'-0"
185'-0"


240'-2"
112'-0"
43'-10"
44'-0"
28'-10"
1'-0"
11'-6"
7'-10"
28'-7"
3'-7"
7'-0"
1'-0"
3'-1"
6'-10"
S = 0.00

Although it was intended that this arrangement of overflow from the primary basin would allow for 16,000 cfs to flow over the end sill, the desired division of flows is not achieved until the maximum of 25,000 cfs occurs. With the wall height at 32.4 feet, flow over the wall can be expected at flood discharges greater than 10,000 cfs. One method of containing all flows within the basin until ultimate development of the channel collection network is complete, is to provide "temporary" wall sections that could be removed when final development is complete. Thus, the paved apron around the primary basin and the containment walls could be deferred to a later stage coincident with completion of the collection network.

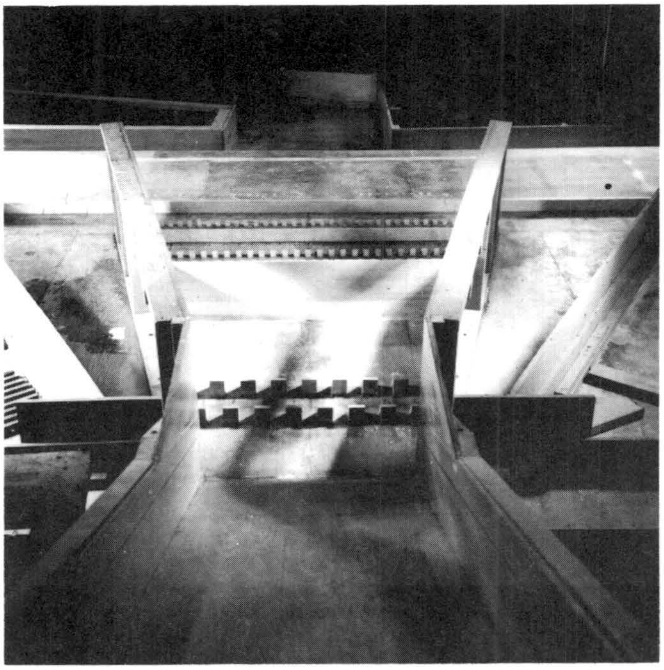


Figure 42. View of the arrangement for Design B from above the model.

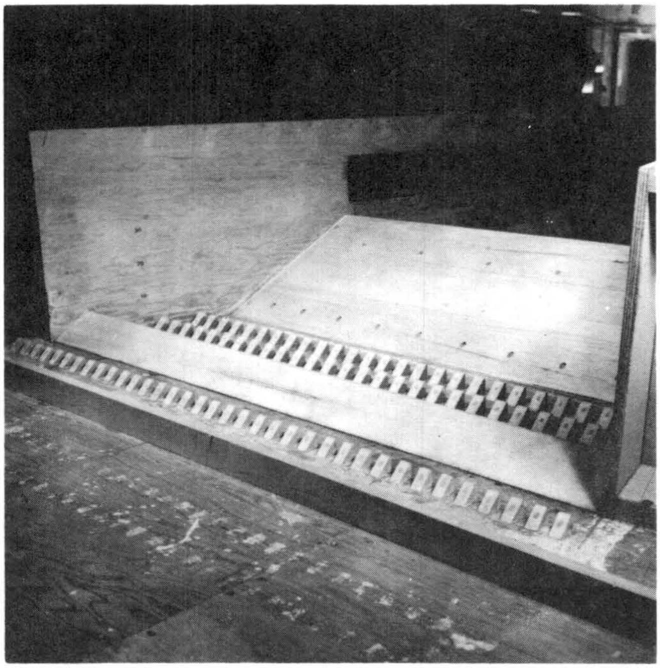


Figure 44. The secondary and tertiary basins of Design B.

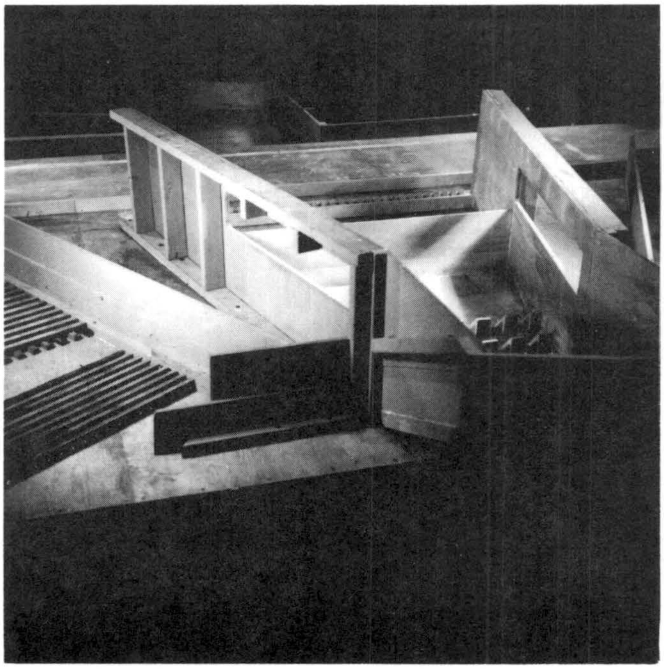


Figure 43. Side view of the model for Design B. Note that slots in the model walls are for the convenience of the model only.

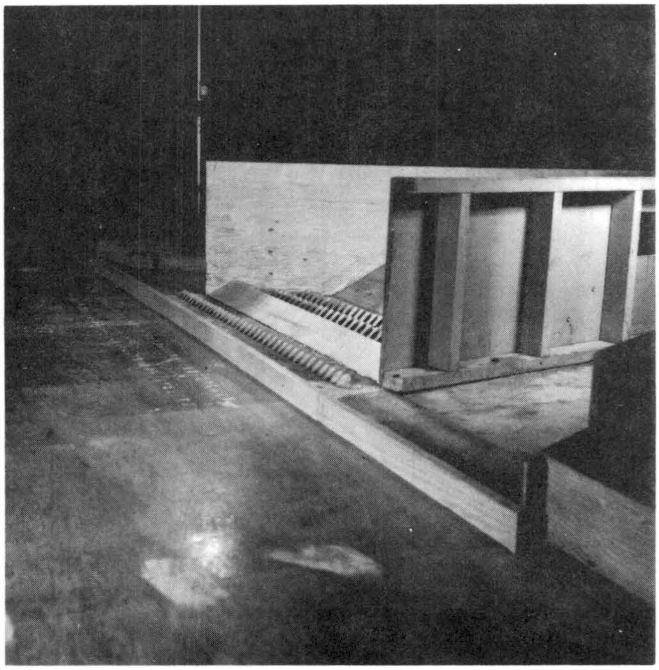


Figure 45. The spread area in the model downstream from the structure.

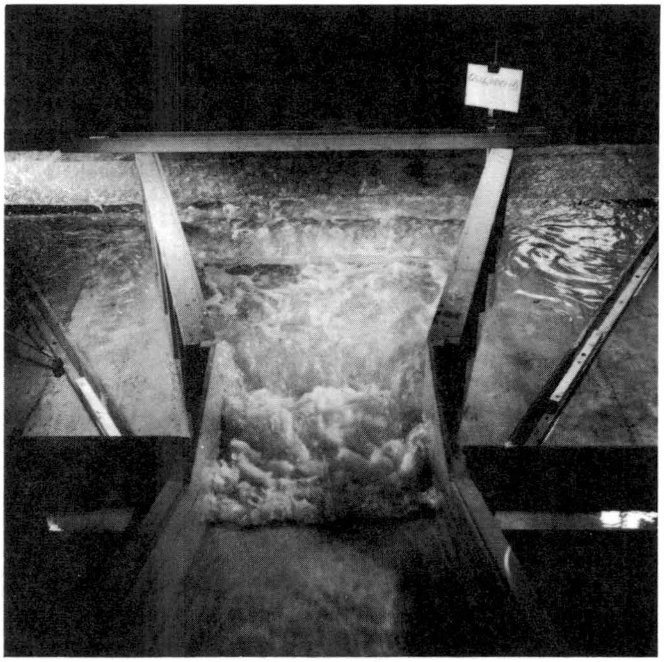


Figure 46. Over view of the energy dissipator, Design B. Q = 16,000 cfs.

Figure 47. A discharge of 16,000 cfs through Design B viewed from the river level.

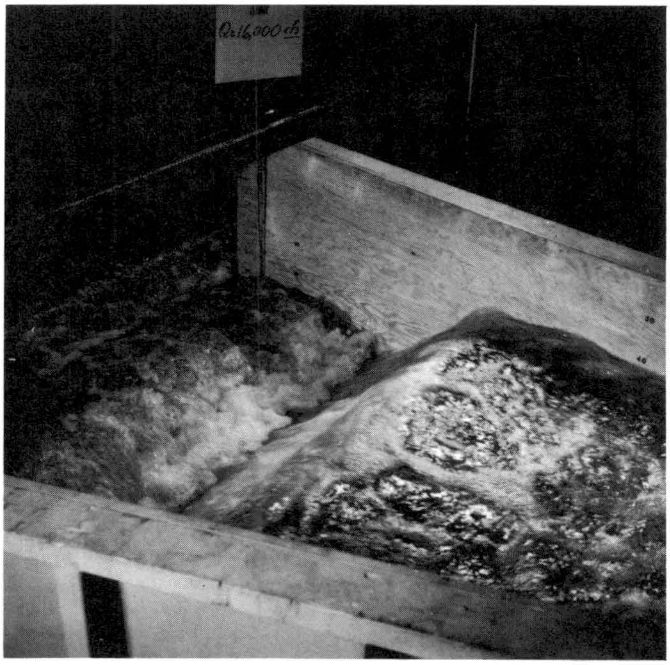


Figure 48. Flow in the primary and secondary basins of Design B. Q = 16,000 cfs.

Figure 49. A view of the flow beyond the tertiary basin. Q = 16,000 cfs.

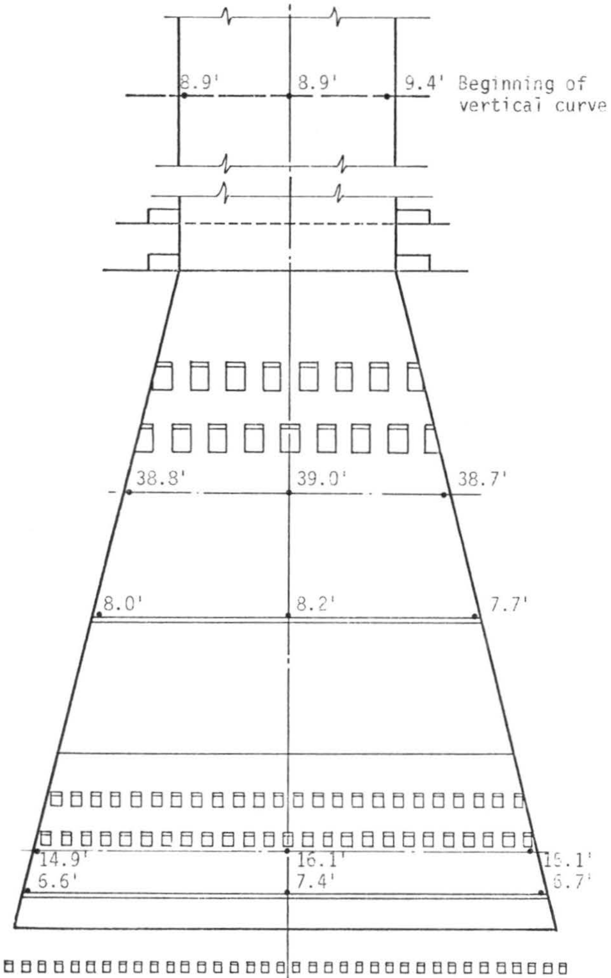


Figure 50. Flow depths in stilling basin, Design B. Q = 16,000 cfs.

Figure 52. Q = 25,000 cfs. A view from downstream.

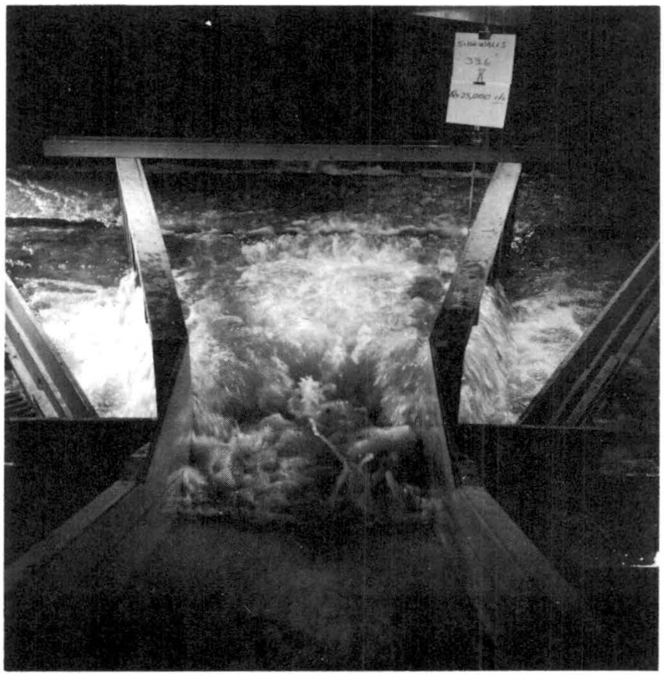


Figure 51. Over view of the energy dissipator, Design B. Q = 25,000 cfs. Side walls are 33.6 feet high.

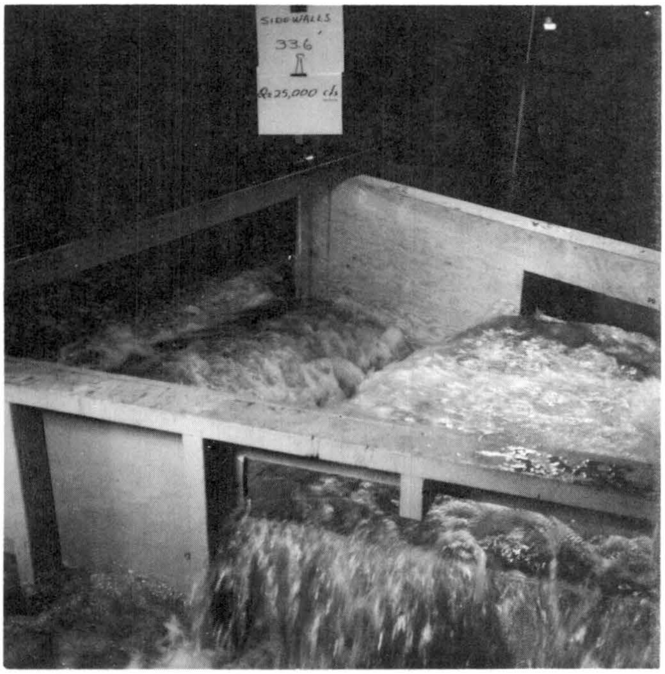


Figure 53. Q = 25,000 cfs. There is flow over the basin walls. The sequent depth is adequate.

Figure 54. Q = 25,000 cfs. The flow spreads across the tertiary sill towards the river.

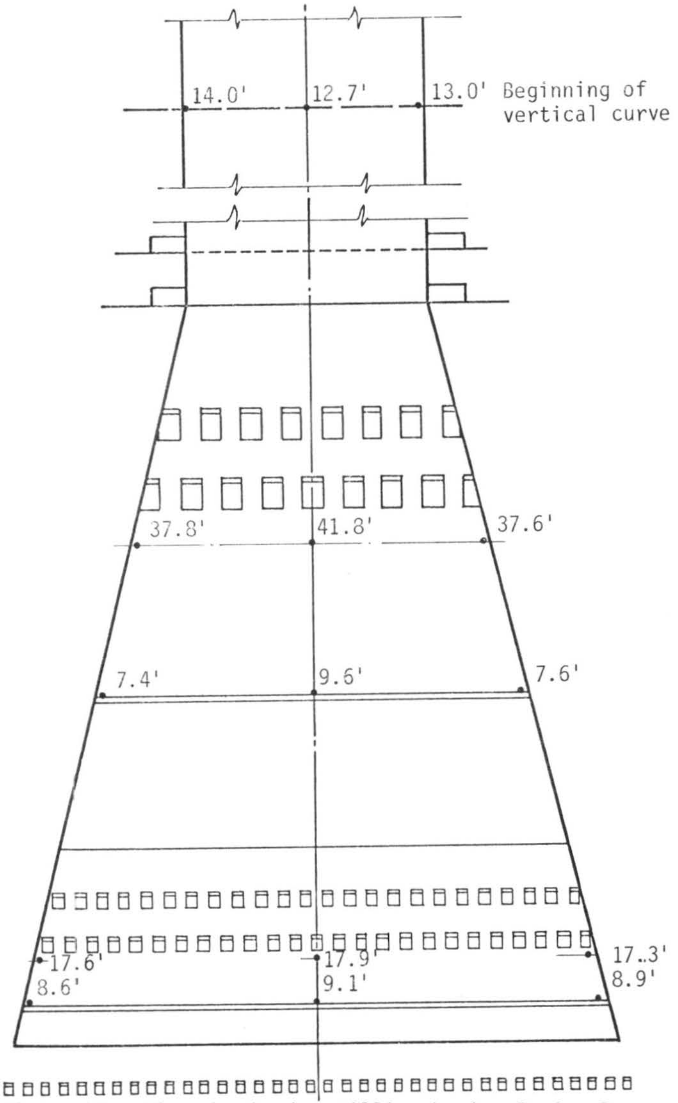


Figure 55. Flow depths in stilling basin, Design B. Q = 25,000 cfs. Walls are 33.6 feet high.

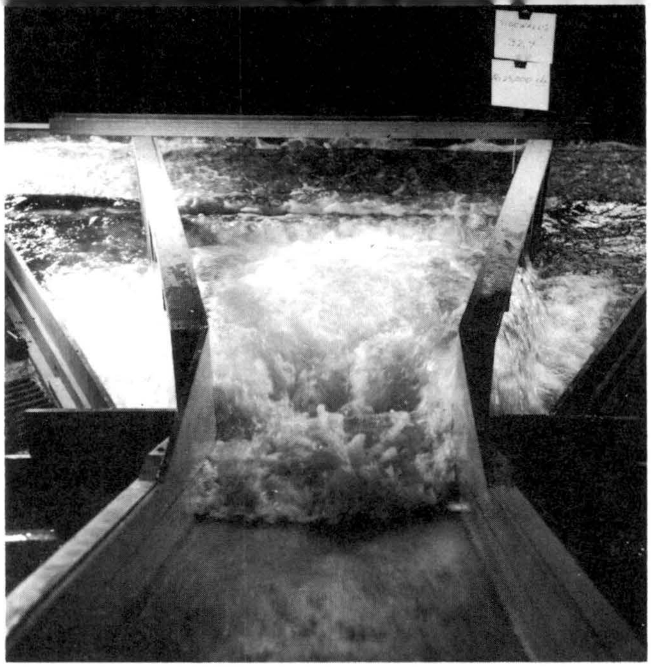


Figure 56. Q = 25,000 cfs. Over view of energy dissipator. Side walls are 32.4 feet high.

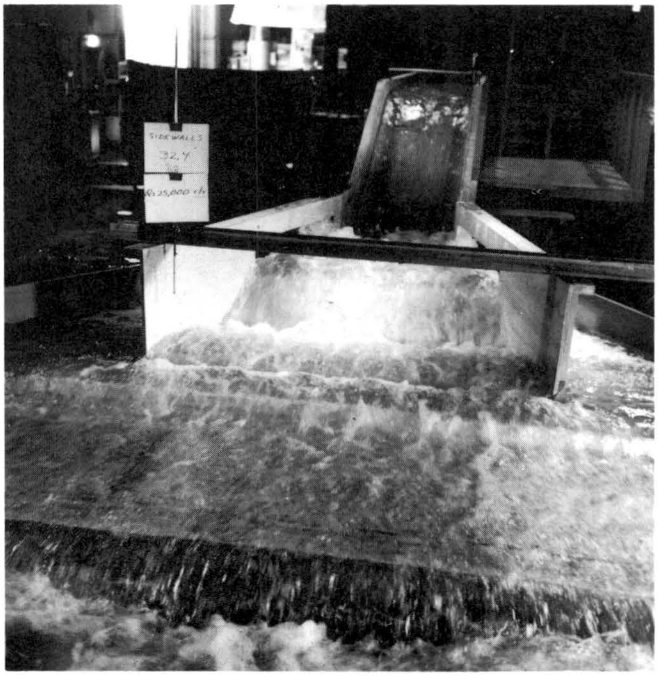


Figure 57. Q = 25,000 cfs. Downstream view.

Figure 58. Q = 25,000 cfs. Primary and secondary basins. Note flow over the walls.

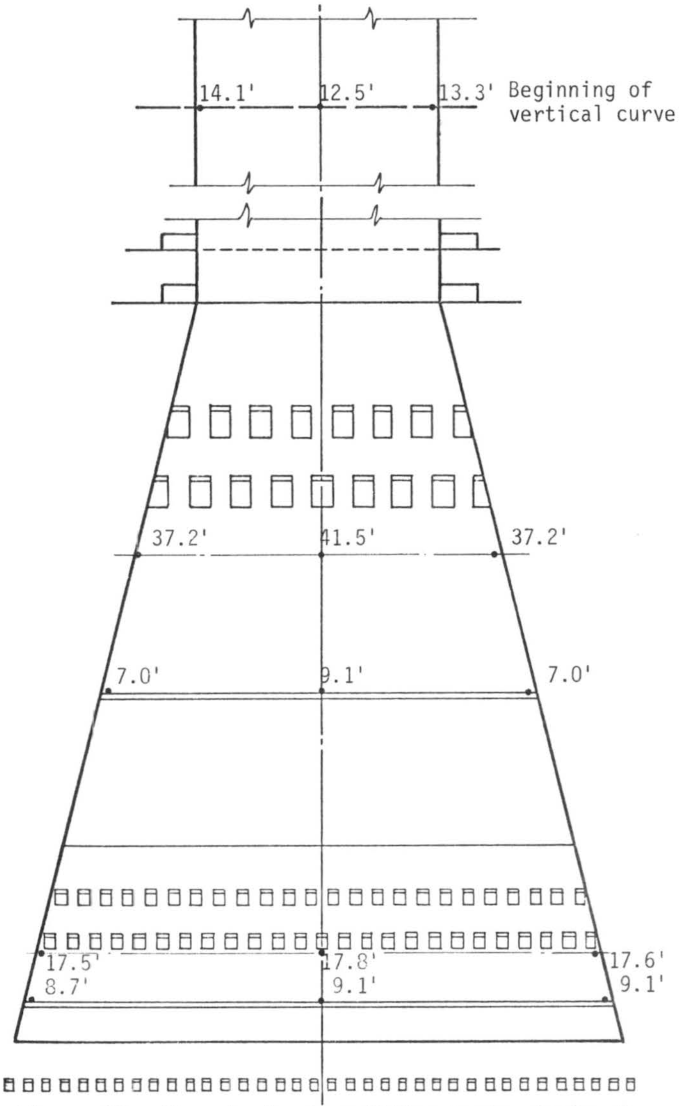


Figure 60. Flow depths in stilling basin, Design B. Q = 25,000 cfs. Walls are 32.4 feet high.

Figure 59. Q = 25,000 cfs. Flow beyond the tertiary sill. Note spread of flow.

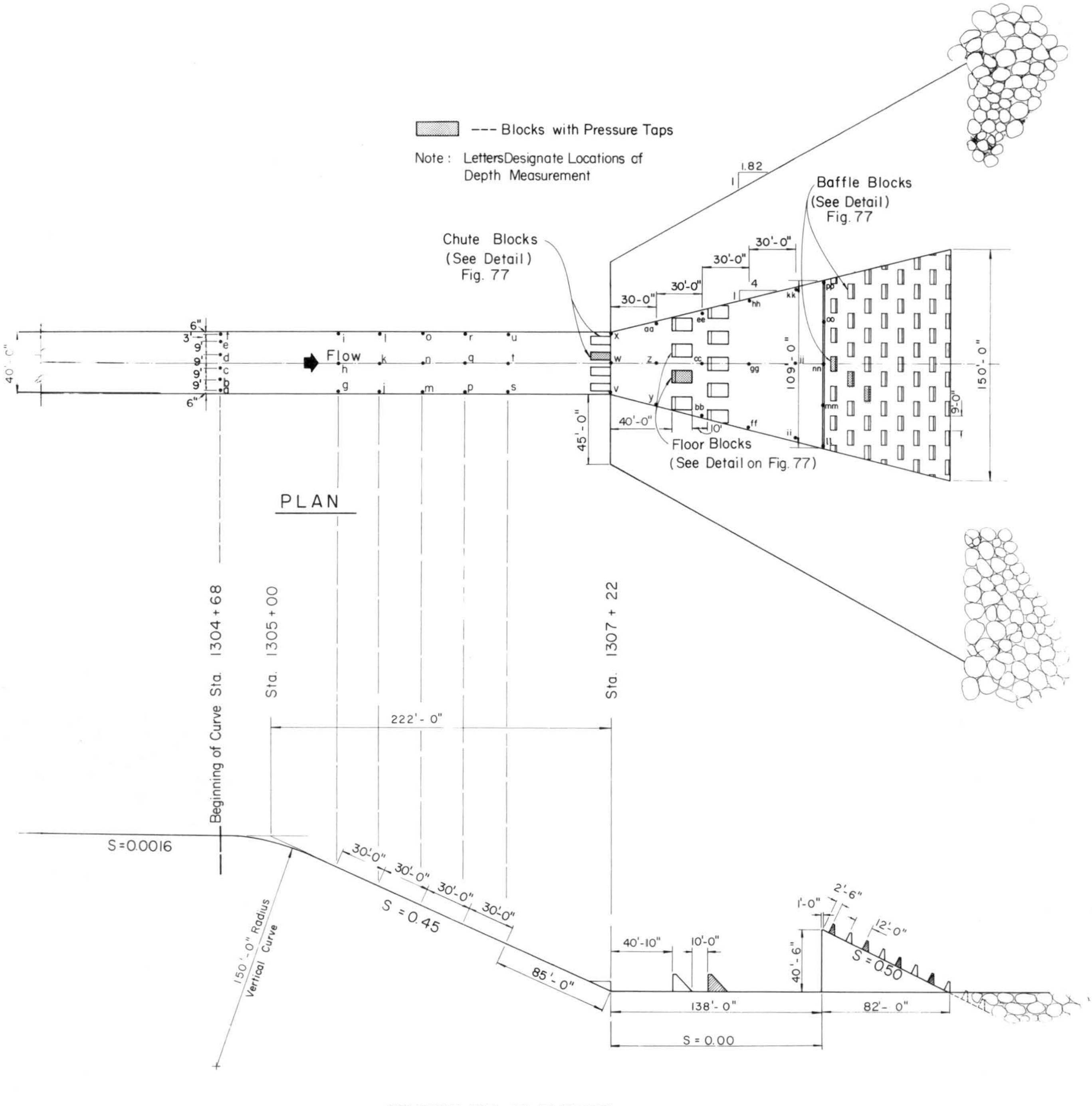


Figure 61. Schematic arrangement of Design C.

Design C

The design of this stilling basin resulted from a change in width of the upstream channel from 70 to 40 feet. The economic advantage of this change, insofar as the channel is concerned, might be readily apparent. The design of the energy dissipator resulted in the arrangement shown on Figure 61. The concept was changed slightly from previous energy dissipators that were modeled. Instead of providing secondary and tertiary basins, baffle blocks were placed on the downstream face of the end sill to dissipate the balance of the energy not dissipated in the stilling basin. This was done primarily to maintain the shortest structure possible. A division of flows was contemplated as in Design B, with 12,500 cfs as design discharge for the initial construction stage to flow over the end sill. After ultimate development, 12,500 cfs would flow additionally over the walls of the basin (approximately 6,250 cfs over each side).

The concentration of flows as a result of change in chute width resulted immediately in increased sequent depth of the hydraulic jump. This in turn required, at least for the initial stage, higher (as compared to Design A or B) basin walls of 60 feet to contain the flow, and a higher end sill of 40.5 feet. Floor blocks within the stilling basin were required, and after a few tests chute blocks were added at the channel terminus to create a more effective hydraulic jump. Photographs of the completed model are shown with 60-ft high walls in Figures 62 through 65 and with 43-ft walls in Figures 66 and 67. In the first instance, the model represents first stage of construction, while the latter model would simulate the stilling basin after modification for discharges to 25,000 cfs.

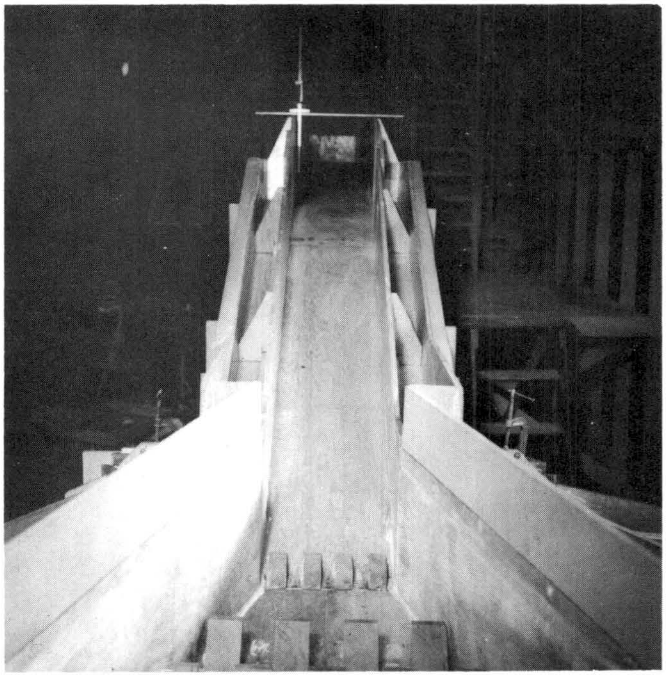


Figure 62. Completed modification of the channel width from 70 to 40 feet.

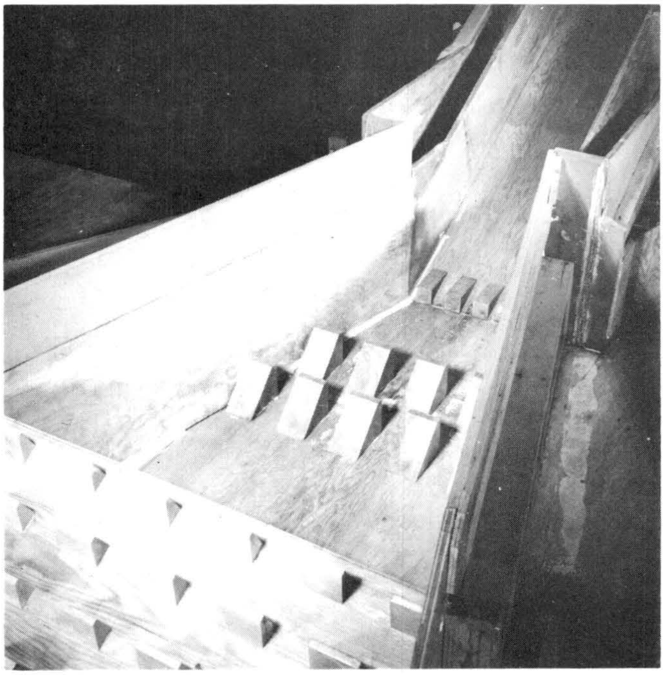


Figure 63. The arrangement of floor and chute blocks within the stilling basin. Walls are 60 feet high.

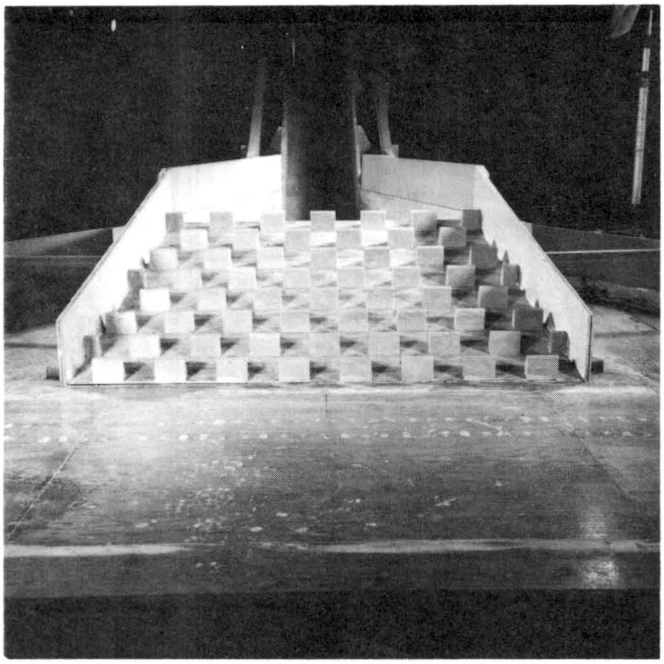


Figure 64. The baffled face of the end sill of the stilling basin.

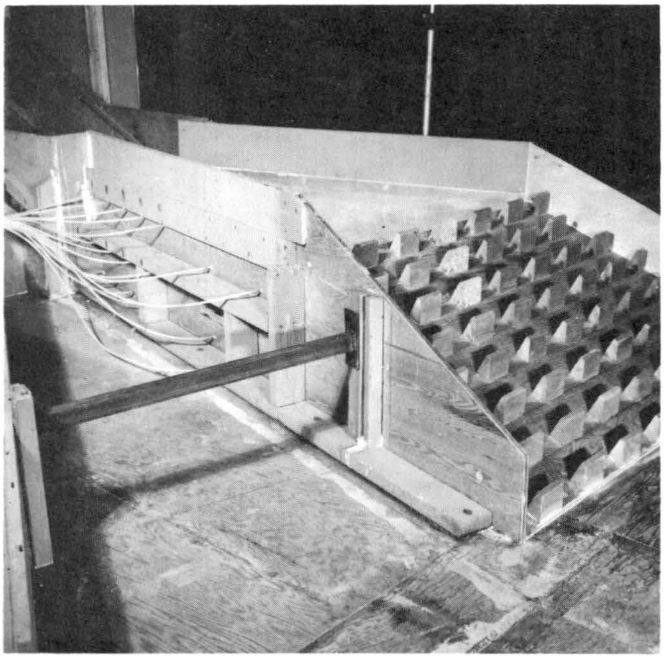


Figure 65. A side view of the baffled end sill.

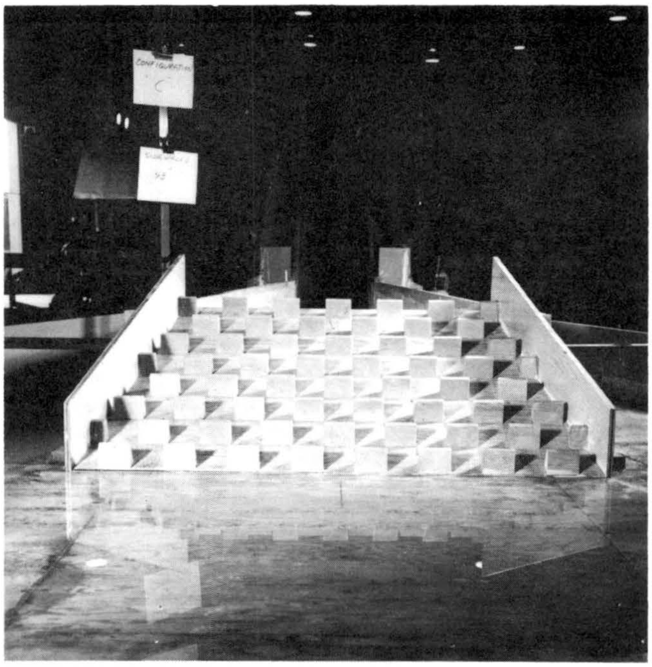


Figure 66. The second stage of construction would include reduction in wall height to 43 feet.

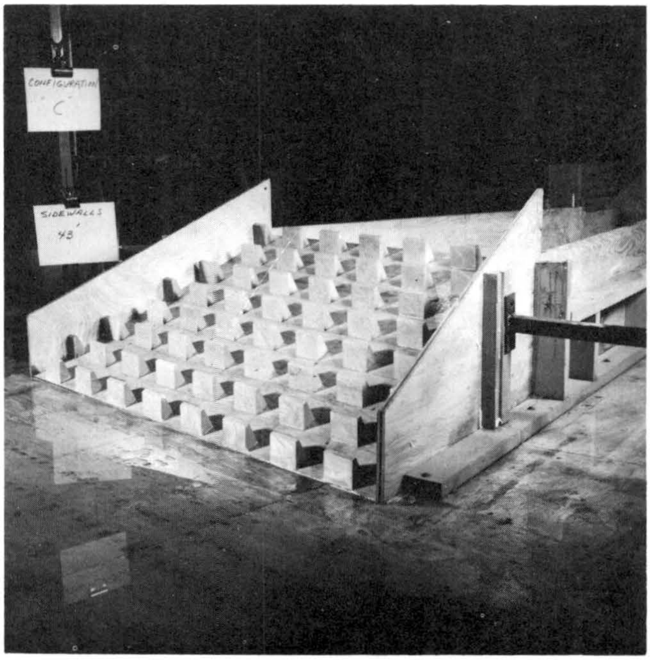


Figure 67. The resulting arrangement after second stage construction. The horizontal bar at right is only a model convenience for flow measurement and is not related to prototype need.

The general flow through the basin for a discharge of 12,500 cfs can be seen in Figures 68 through 70. The stilling basin is over designed for this discharge. Rather the tests were made to observe flow over the baffling blocks on the downstream face of the end sill. The highly turbulent action over the baffles indicates effective dissipation of energy there, but gives rise to some concern of pressures on the blocks. The concern is principally of negative pressures, but some information concerning positive pressures and total forces on the blocks would be needed for structural design purposes. These pressures were measured at selected blocks (chute block, floor block and baffle blocks) and at various locations within the structure. We shall return to discuss pressures later.

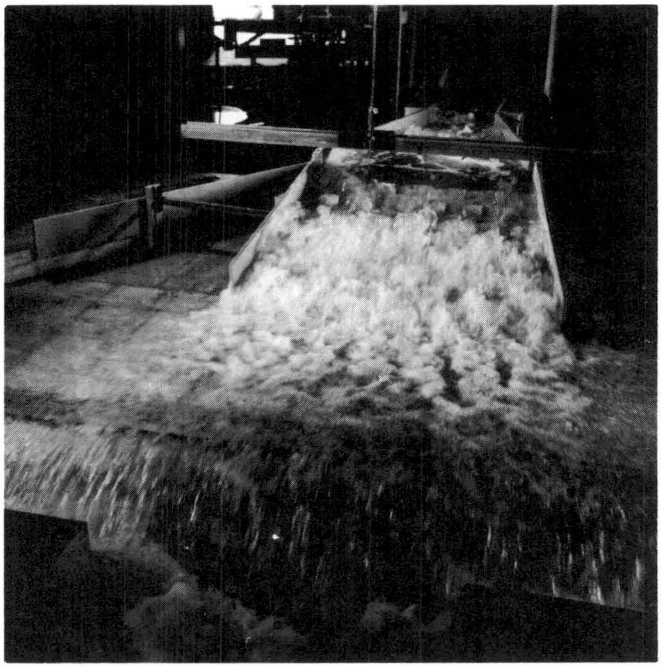


Figure 69. Design C. Q = 12,500 cfs. Flow down the baffled end sill is ruffled, indicative of effective energy dissipation.

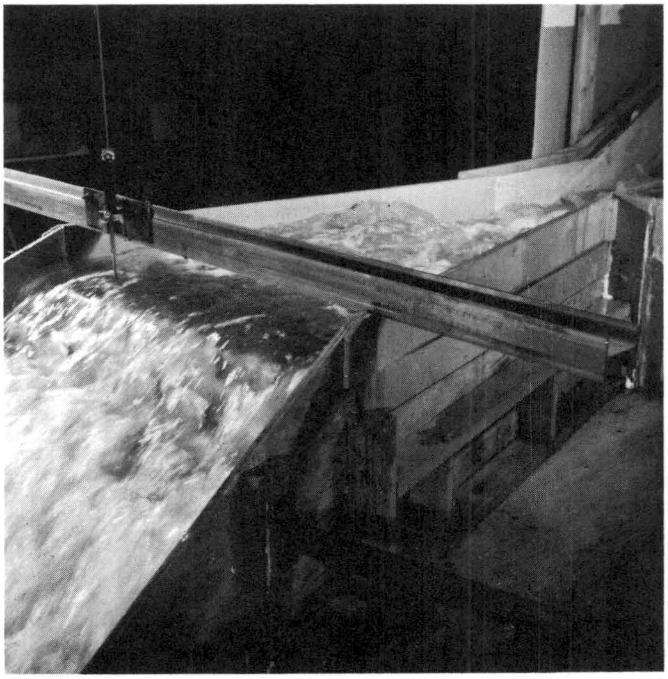


Figure 68. Design C. Q = 12,500 cfs. Stilling basin. There is no allowance for sidewall overflow.

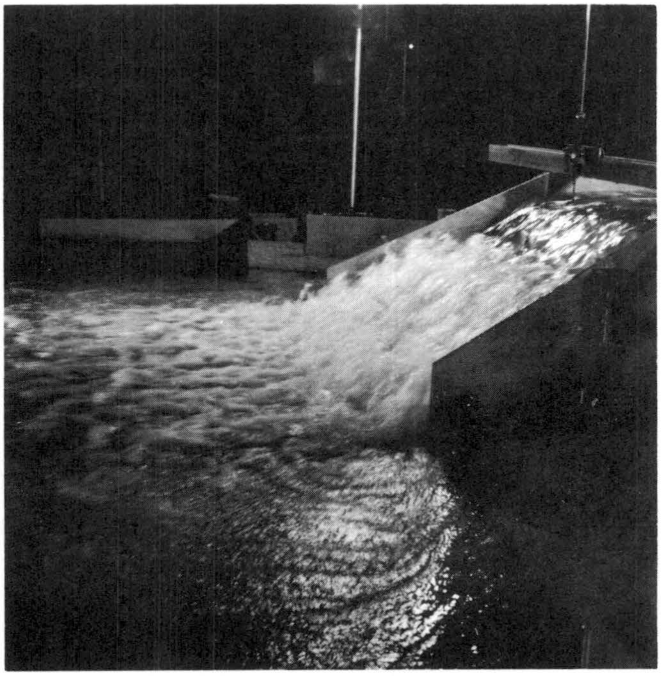


Figure 70. Design C. Q = 12,500 cfs. Flow fans out from the toe of the end sill.

The results of a discharge of 25,000 cfs through the basin are depicted in Figures 71 through 73. The events are summarily spectacular, but the discharge of 25,000 cfs is a respectable flow, and the frequency (or infrequency) of occurrence must be taken into account. The very large "boil" above the floor blocks in the stilling basin is a manifestation of inadequate sequent depth. The high overfall (43 feet) at the sides of the basin, while not commonplace for stilling basins, can impinge on a well founded concrete pavement without excessive damage. The flow can be effectively spread over an area about 400 ft wide, but velocities involved are of the order of 20 to 24 ft per sec. Consequently, this area must be underlain by paving or derrick stone. Representative velocities for 12,500 and 25,000 cfs were measured and are shown in the plan views of Figures 74 and 75. Selected depths of flow for 12,500 and 25,000 cfs are given in Table 3. Locations of these measurements are indicated on the plan of Design C in Figure 61.

Pressure measurements were made extensively in this model because the design solution for the energy dissipator is considered unorthodox with respect to "standard" hydraulic jump basins and it was deemed wise to obtain detailed information at critical points within the structure and its components. The location and labels of the piezometers used to measure pressure are identified in the drawings of Figures 76 and 77. Pressures are tabulated in Table 4 for discharge of 12,500 cfs and in Table 5 for 25,000 cfs. There were several locations with a potential cavitation problem as noted in Table 5. These are at the sides of the floor block and is a direct result of the inadequate sequent depth as already indicated. Again, the frequency of occurrence of this large discharge must be taken into account, and the risk and cost of repairs

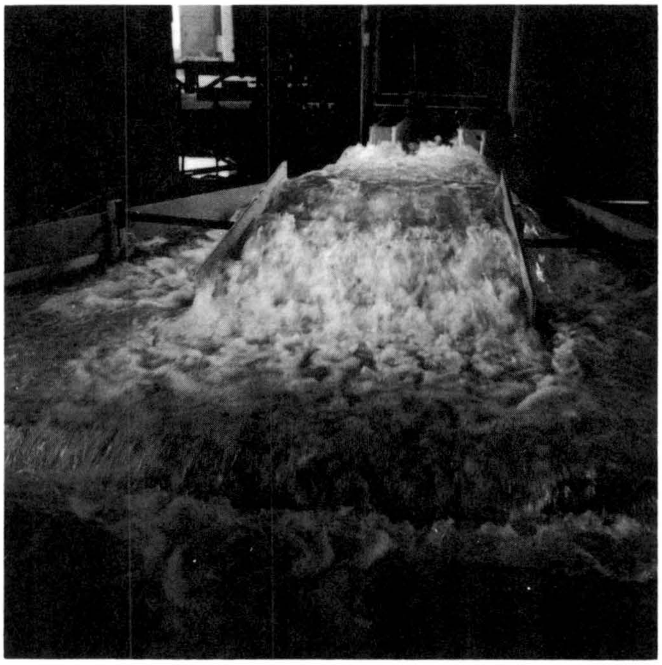


Figure 72. Flow over the baffled end sill. Q = 25,000 cfs.

Figure 71. Design C. Q = 25,000 cfs. Note large boil above the floor blocks. This is indicative of inadequate sequent depth.

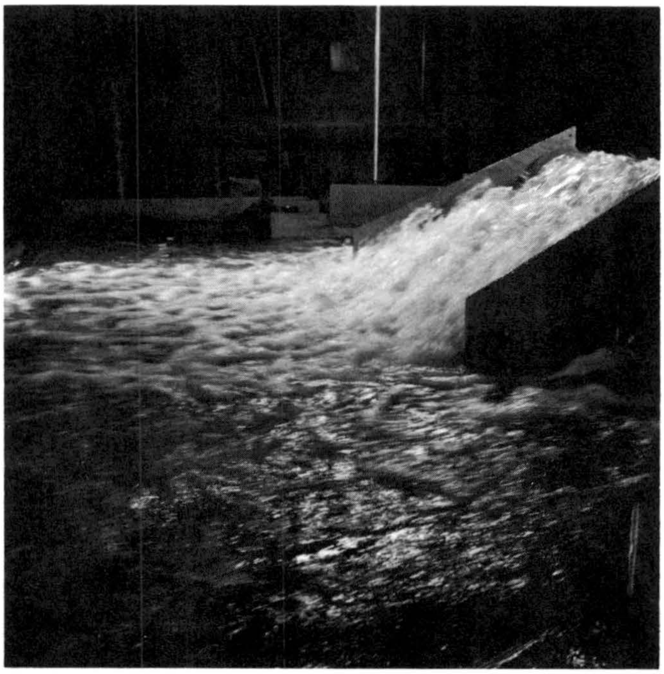


Figure 73. A view of the spreading flow beyond the stilling basin. Q = 25,000 cfs.

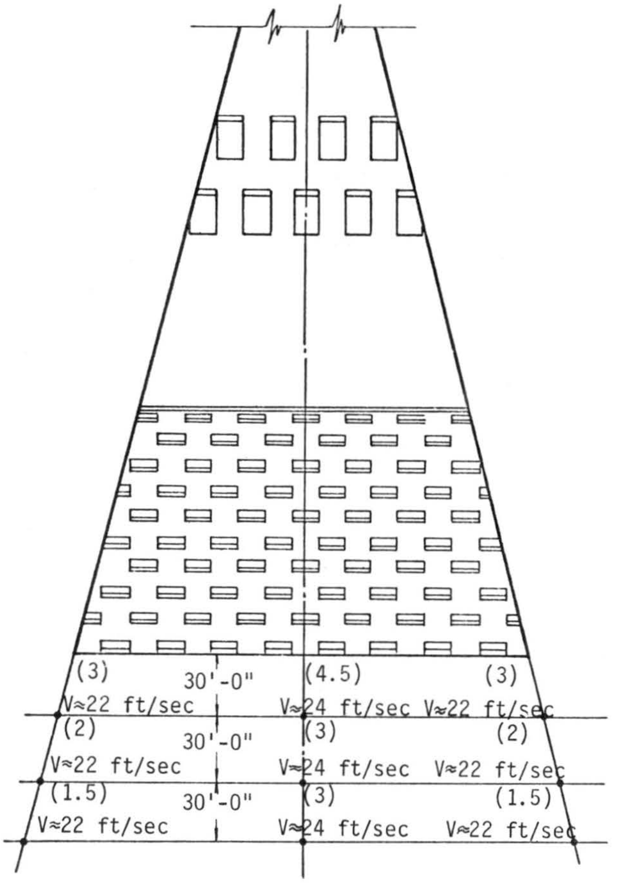


Figure 74. Design C. Q = 12,500 cfs. Flow depths are indicated in parentheses.

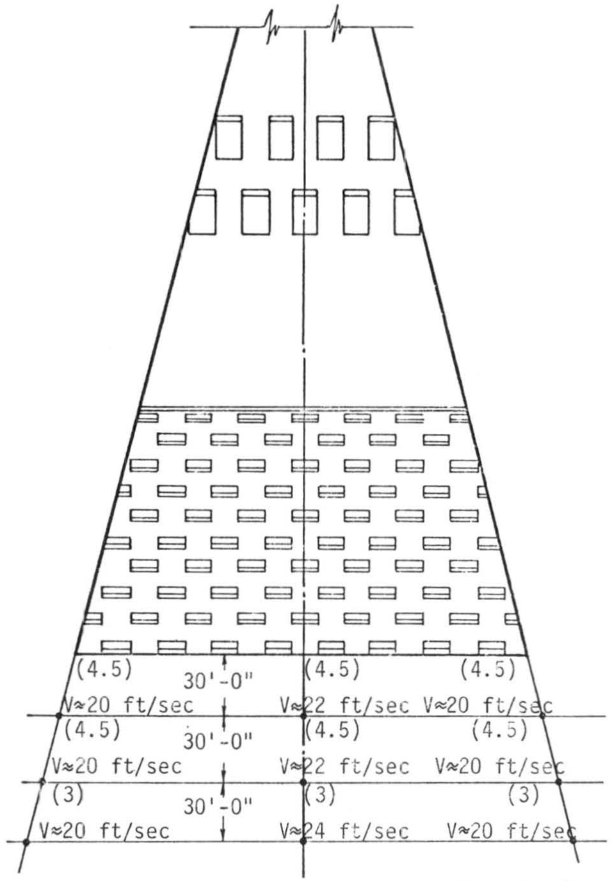


Figure 75. Design C. Q = 25,000 cfs. Flow depths are indicated in parentheses. Lateral velocities and depths at 60 feet on either side of the expanding jet are 22 ft/sec and 3 feet respectively.

must be evaluated accordingly. At all other locations the negative pressures were acceptably small. It would be well to indicate that even though the motion of the flow in the basin is violently turbulent, the pressures on the walls and end sills are not substantially different from hydrostatic pressures.

Discussion of Results

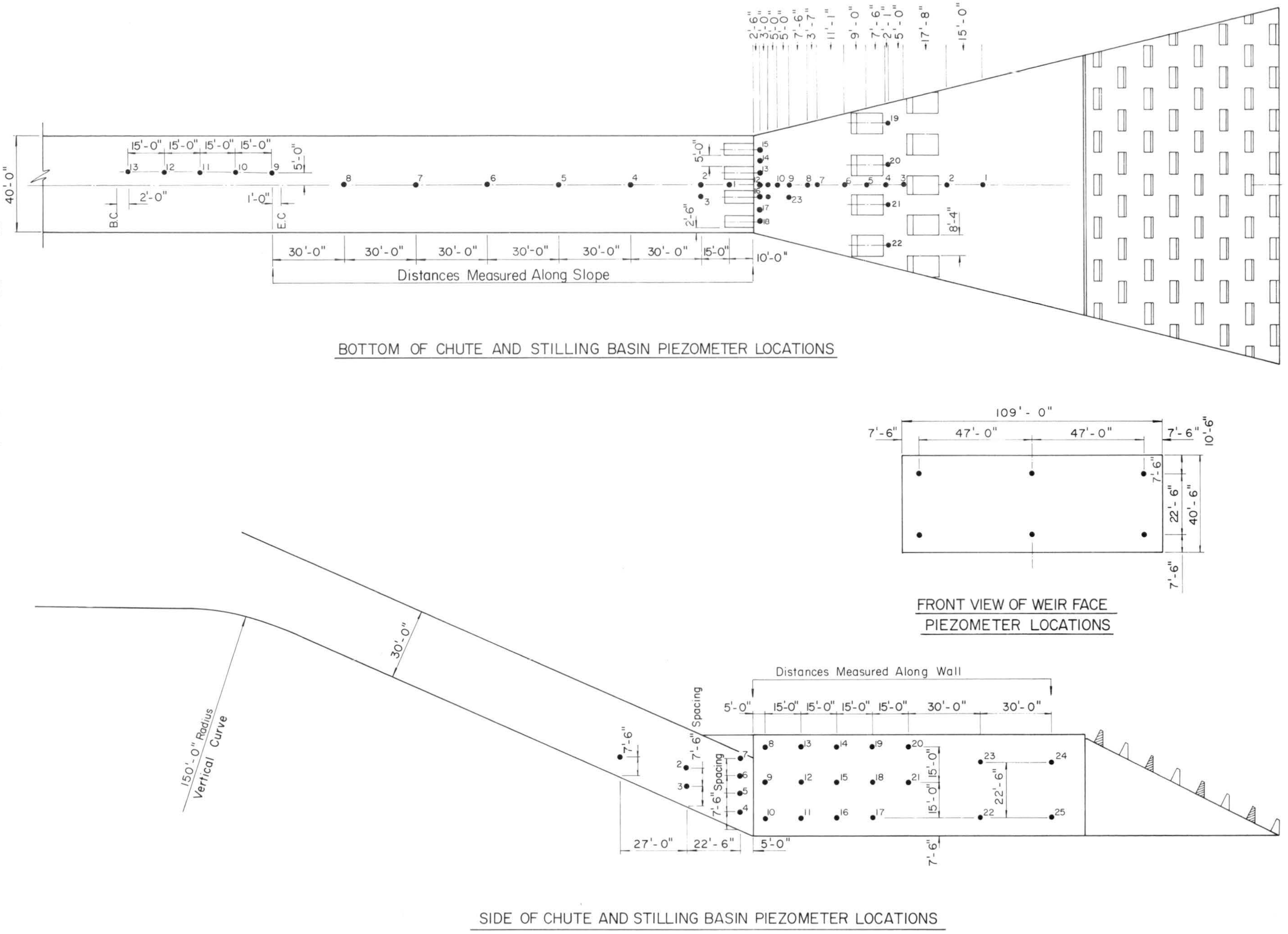
The model studies described here have resulted in three substantially workable designs. Design A, after modifications resulting from the tests, can be effectively utilized, with an approach channel width of 70 feet to contain all flows in the full range to 25,000 cfs. There is effective dissipation of energy in the primary and secondary basins and the tertiary basin can be effectively utilized to spread the flow into the river.

Design B is adaptable to staging should it be desirable to approach the solution in that manner. The design is fundamentally the same as in A, with primary, secondary and tertiary basins, but with provision for overflow after a second stage in construction. Admittedly the staging in this instance does not play a dominant role because it would probably be well to provide for waters backing up into the overfall region even for the small discharges, if solely for the purpose of protecting the foundations of the basin walls. The protection at this stage could be minimal however.

Design C provides for a narrower approach channel, 40 feet in width, and a definite two-stage construction procedure. The possibilities of some damage resulting with very large discharges must be recognized. It is instructive therefore from this view point to observe flow over the side walls of the basin at discharges other than the maximum of 25,000 cfs. Photographs of tests at 11,800 and 16,000 cfs are therefore included as an appendix to this report. Much can be inferred from study of these figures and the definitive data presented in the preceding sections.

The recommended dimensions for each of these basins are detailed in Figure 2 for Design A, Figure 41 for Design B, and Figure 61 for Design C.

Hydraulically, there is some preference for Design A, followed closely by Design B. It is entirely appropriate however to recall that Design C is based on a channel 40 ft wide while the other two are for a channel 70 ft wide. So, while preference in performance leans toward Design A, or B, economic consideration in selection must be respectfully regarded.



BOTTOM OF CHUTE AND STILLING BASIN PIEZOMETER LOCATIONS

FRONT VIEW OF WEIR FACE PIEZOMETER LOCATIONS

SIDE OF CHUTE AND STILLING BASIN PIEZOMETER LOCATIONS

Figure 76. Location of selected blocks for pressure measurement.

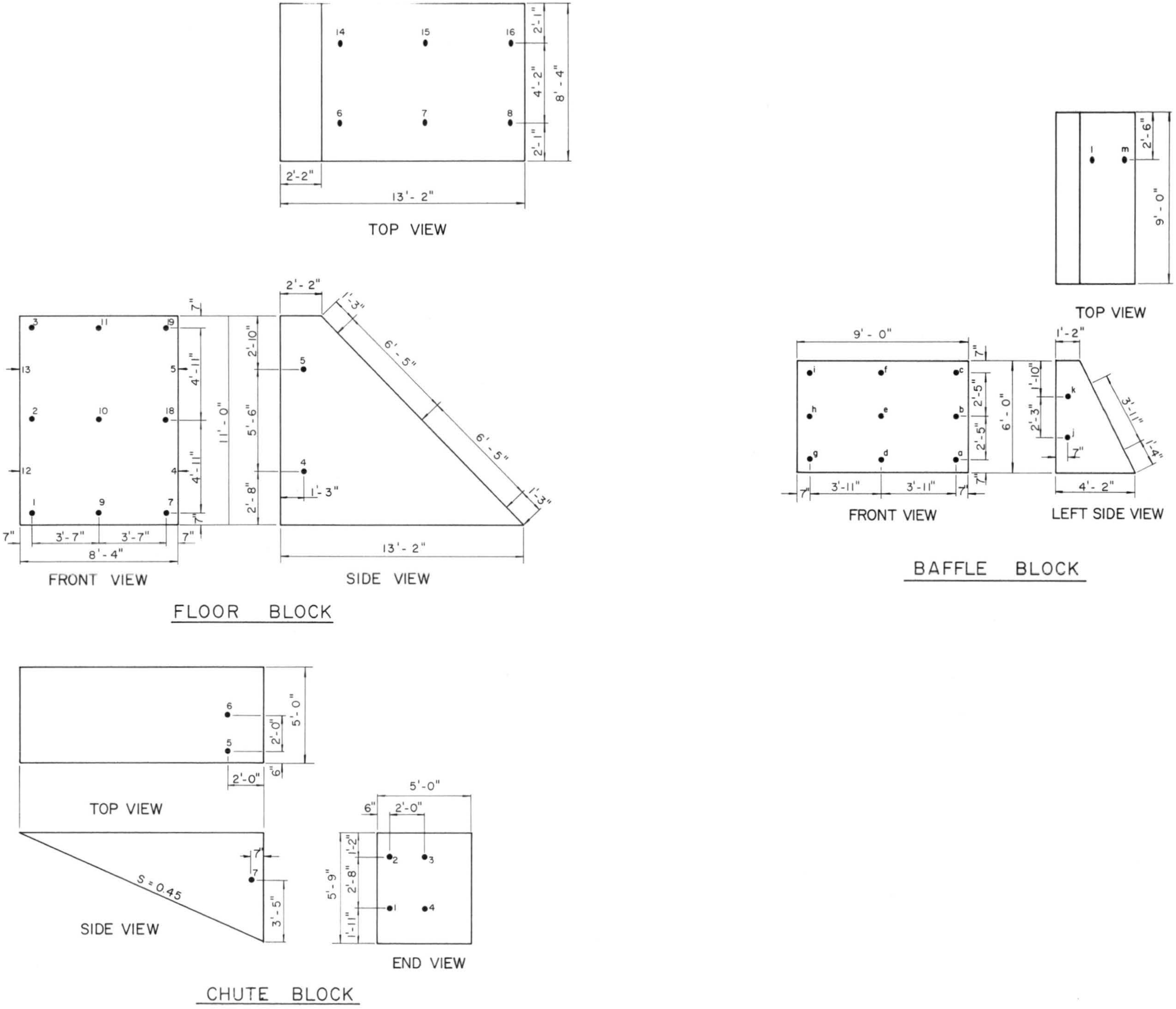


Figure 77. Location of piezometers and labels on the baffle blocks.

TABLE 1. FLOW DEPTHS IN THE STILLING BASIN OF DESIGN A

Location*	Q = 6,400 cfs	Q = 11,800 cfs	Q = 15,400 cfs	Q = 25,000 cfs
a	5.0	7.7	9.1	13.4
b	5.6	7.7	8.9	12.9
c	5.0	7.7	9.7	13.1
d	30.5	33.2	34.5	37.5
e	30.6	33.3	35.2	39.6
f	30.5	33.1	34.8	36.7
g	4.3	6.4	7.2	9.1
h	4.6	6.5	8.0	10.6
i	4.1	6.3	7.7	9.5
j	13.8	15.5	16.4	19.1
k	14.0	16.3	17.5	20.4
l	13.9	15.9	16.8	19.5
m	3.8	5.1	5.5	7.5
n	4.0	5.4	6.6	8.0
o	3.7	5.0	5.7	7.5

* See Figure 2 for location of depth measurements

TABLE 2. FLOW DEPTHS IN THE STILLING BASIN OF DESIGN B

Location*	Q = 16,000 cfs**	Q = 25,000 cfs***	Q = 25,000 cfs****
a	8.9	14.0	14.1
b	8.9	12.7	12.5
c	9.4	13.0	13.3
d	38.8	37.8	37.2
e	39.0	41.8	41.5
f	38.7	37.6	37.2
g	8.0	7.4	7.0
h	8.2	9.6	9.1
i	7.7	7.6	7.0
j	14.9	17.6	17.5
k	16.1	17.9	17.8
l	15.1	17.3	17.6
m	6.6	8.6	8.7
n	7.4	9.1	9.1
o	6.7	8.9	9.1

* See Figure 41 for location of depth measurements
** Full sidewalls (no spill over sides)
*** Wall height 33.6 feet
**** Wall height 32.4 feet

TABLE 3. FLOW DEPTHS IN STILLING BASIN OF DESIGN C

Location*	Q = 12,500 cfs**	Q = 25,000 cfs***
a	11.2	15.0
b	11.5	15.9
c	13.2	16.4
d	12.2	16.3
e	11.4	16.0
f	11.3	15.6
g	8.9	12.9
h	6.9	12.0
i	8.6	13.3
j	7.0	10.8
k	6.5	12.0
l	7.1	11.1
m	5.9	9.7
n	6.2	11.6
o	5.5	10.1
p	4.9	9.5
q	5.9	10.5
r	4.7	9.6
s	---	9.1
t	---	9.4
u	---	8.7
v	47.8	37.6
w	47.9	36.6
x	48.0	36.5
y	49.9	42.2
z	48.5	39.1
aa	50.4	42.0
bb	53.3	50.9
cc	53.9	53.3
dd	53.0	51.8
ee	52.0	48.6
ff	52.5	53.4
gg	52.4	48.3
hh	52.5	49.4
ii	52.2	49.7
jj	51.8	49.0
kk	10.5	8.1
ll	10.1	9.2
mm	10.2	8.9
nn	9.9	9.1
oo	10.6	8.0

* See Figure 61 for location of depth measurements

** No spill over sides

*** 43-ft high sidewalls (12,500 cfs over baffled apron, 6,250 cfs over each side)

TABLE 4. WATER PRESSURES IN STILLING BASIN - DESIGN C

Q = 12,500 cfs

Location*	Pressure Head ft	Location*	Pressure Head ft	Location*	Pressure Head ft	Location*	Pressure Head ft
B-2-a	12.0	B-1-l	0.6	S-23	21.9	CB- 4	40.8
B-2-b	10.2	B-1-m	4.5	S-24	21.9	CB- 3	38.4
B-2-c	11.1	B-1-g	6.3	S-25	44.1	CB- 6	42.3
B-2-j	(-0.9)	B-1-h	6.0	3	53.7	CH- 3	36.9
B-2-k	(-2.7)	B-1-i	7.5	5	45.6	CH- 1	43.2
B-2-d	15.3	W-b	22.8	9	50.1	CH- 2	37.5
B-2-e	13.2	W-d	22.2	23	50.1	CH- 4	24.3
B-2-f	13.5	W-f	23.1	10	51.0	CH- 5	12.6
B-2-l	(-0.6)	W-e	46.5	11	53.1	CH- 6	6.9
B-2-m	3.3	W-c	45.0	24	55.5	CH- 7	7.8
B-2-g	10.8	W-a	45.0	FB-17	57.3	CH- 8	9.3
B-2-h	9.3	C-1	13.5	FB-18	55.2	CH- 9	7.5
B-2-i	10.2	C-2	20.7	FB-19	45.0	CH-10	6.0
B-3-a	13.5	C-3	27.0	FB- 4	32.4	CH-11	5.7
B-2-b	12.6	C-4	36.6	FB- 5	30.3	CH-12	8.1
B-3-c	12.9	C-5	29.4	FB- 6	35.7	CH-13	9.0
B-3-j	(-0.3)	C-6	22.8	FB- 7	41.4	18	45.6
B-3-k	(-1.2)	C-7	15.9	FB- 8	46.8	17	52.2
B-3-d	17.4	S-8	11.4	FB- 9	62.4	16	43.2
B-3-e	15.6	S-9	24.9	FB-10	57.9	12	51.6
B-3-f	14.4	S-10	38.4	FB-11	43.2	13	48.9
B-3-l	(-0.9)	S-11	40.8	FB-13	30.3	14	52.5
B-3-m	2.4	S-12	24.0	FB-12	35.4	15	43.2
B-3-g	12.3	S-13	10.2	FB-14	36.0	8	49.2
B-3-h	11.7	S-14	11.1	FB-15	40.8	7	50.1
B-3-i	13.5	S-15	24.3	FB-16	47.1	6	54.0
B-1-a	7.5	S-16	48.3	FB- 1	55.2	22	47.7
B-1-b	8.4	S-17	42.6	FB- 3	42.9	21	48.9
B-1-c	6.9	S-18	27.9	FB- 2	51.9	4	50.4
B-1-j	1.5	S-19	13.8	CB- 1	39.9	20	48.3
B-1-k	(-5.7)	S-20	14.7	CB- 2	38.4	19	47.4
B-1-d	9.9	S-21	51.6	CB- 5	42.6	2	51.0
B-1-e	8.7	S-22	51.9	CB- 7	41.7	1	51.3
B-1-f	7.8						

* For location of piezometers see Figures 76 and 77

Code

B-2 - Second Baffle Block
B-3 - Third Baffle Block
B-1 - First Baffle Block
W - Front Face of Weir Wall
C - Side of Chute
S - Stilling Basin Side of Wall
Unlettered numbers are in bottom of basin
FB - Floor Block
CB - Chute Block
CH - Bottom of Chute

TABLE 5. WATER PRESSURES IN STILLING BASIN - DESIGN C

Q = 25,000 cfs

Location*	Pressure Head ft	Location*	Pressure Head ft	Location*	Pressure Head ft	Location*	Pressure Head ft
B-2-a	11.4	B-1-l	(-0.9)	S-23	19.2	CB- 4	21.6
B-2-b	9.6	B-1-m	3.3	S-24	19.8	CB- 3	24.0
B-2-c	11.1	B-1-g	6.0	S-25	42.3	CB- 6	39.3
B-2-j	0.0	B-1-h	8.4	3	60.3	CH- 3	31.8
B-2-k	(-1.8)	B-1-i	8.4	5	30.6	CH- 1	36.9
B-2-d	15.0	W-b	20.4	9	53.4	CH- 2	32.4
B-2-e	12.0	W-d	21.0	23	51.9	CH- 4	16.5
B-2-f	13.8	W-f	20.4	10	58.8	CH- 5	12.0
B-2-l	0.3	W-e	42.9	11	62.1	CH- 6	10.5
B-2-m	3.3	W-c	43.2	24	68.7	CH- 7	12.6
B-2-g	9.6	W-a	42.9	FB-17	74.7	CH- 8	14.4
B-2-h	7.5	C- 1	8.1	FB-18	79.8	CH- 9	9.0
B-2-i	8.7	C- 2	9.3	FB-19	58.2	CH-10	6.6
B-3-a	12.9	C- 3	17.1	FB- 4	(-7.5±6.0)	CH-11	4.2
B-2-b	11.4	C- 4	27.9	FB- 5	(-9.0±6.0)	CH-12	7.8
B-3-c	12.6	C- 5	19.5	FB- 6	18.0	CH-13	10.2
B-3-j	0.3	C- 6	12.9	FB- 7	26.1	18	45.0
B-3-k	(-0.6)	C- 7	5.1	FB- 8	35.4	17	54.9
B-3-d	16.8	S- 8	---	FB- 9	101.4	16	32.1
B-3-e	14.1	S- 9	15.0	FB-10	95.4	12	58.8
B-3-f	15.3	S-10	27.9	FB-11	55.5	13	50.4
B-3-l	(-0.3)	S-11	32.7	FB-13	(-12.0±4.5)	14	54.9
B-3-m	2.4	S-12	15.6	FB-12	(-18.0±6.0)	15	35.7
B-3-g	12.3	S-13	2.4	FB-14	17.1	8	50.7
B-3-h	10.8	S-14	4.5	FB-15	24.9	7	51.9
B-3-i	13.2	S-15	16.2	FB-16	32.1	6	64.8
B-1-a	6.3	S-16	49.5	FB- 1	75.6	22	37.5
B-1-b	8.7	S-17	36.9	FB- 3	57.0	21	44.1
B-1-c	8.4	S-18	23.1	FB- 2	77.1	4	48.9
B-1-j	(-0.9)	S-19	9.9	CB- 1	22.2	20	43.2
B-1-k	vapor press.	S-20	12.3	CB- 2	24.3	19	38.1
B-1-d	9.6	S-21	48.3	CB- 5	39.0	2	48.0
B-1-e	10.2	S-22	49.2	CB- 7	34.5	1	48.3
B-1-f	9.3						

* For location of piezometers see Figures 76 and 77

Code

B-2 - Second Baffle Block
B-3 - Third Baffle Block
B-1 - First Baffle Block
W - Front Face of Weir Wall
C - Side of Chute
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Unlettered numbers are in bottom of basin
FB - Floor Block
CB - Chute Block
CH - Bottom of Chute

APPENDIX

Figure A-1. Design C stilling basin. Q = 11,800 cfs.

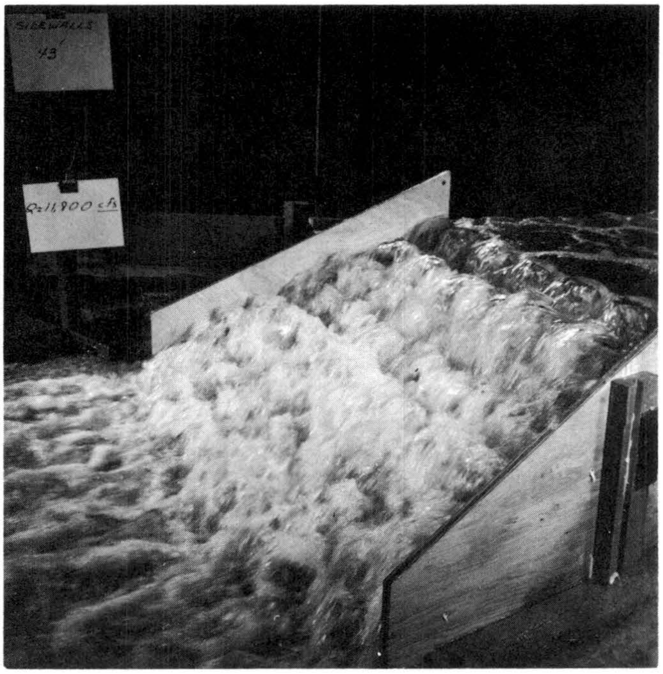

Figure A-3. Design C stilling basin. Q = 11,800 cfs. Flow over the baffled end sill.

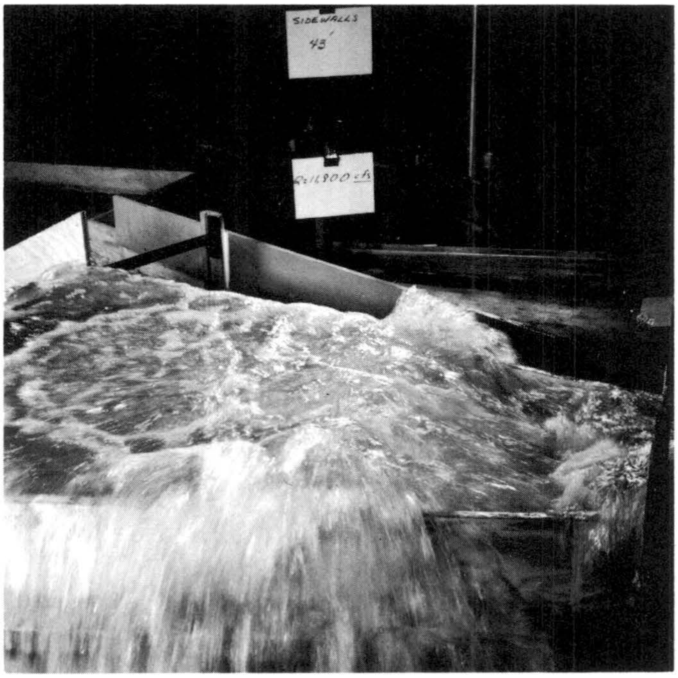

Figure A-2. Design C stilling basin. Q = 11,800 cfs. Flow in the stilling basin.

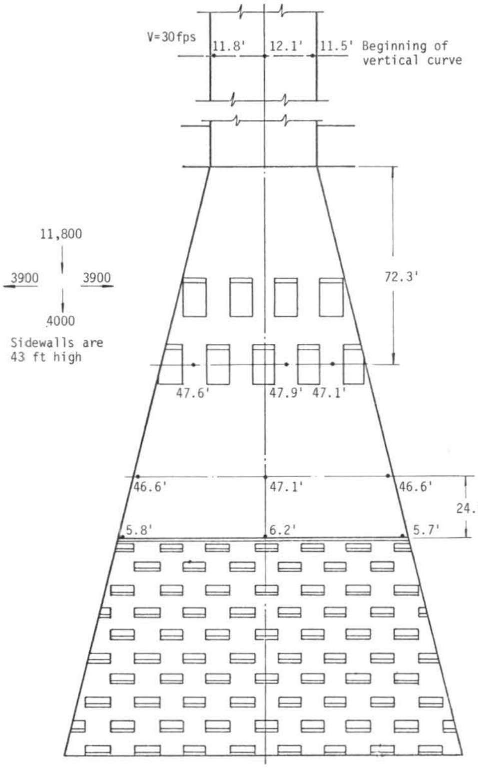

Figure A-4. Flow depth in stilling basin, Design C. Q = 11,800 cfs.

Figure A-5. Q = 16,000 cfs.

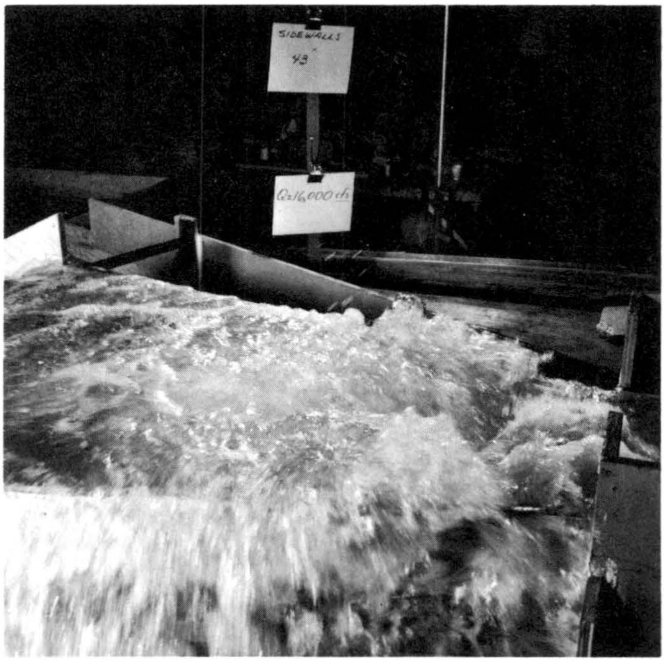

Figure A-6. Q = 16,000 cfs. Boiling above the floor blocks is noticeable.

Figure A-7. Q = 16,000 cfs. Flow spreads over a wide area into the river.

HYDRAULIC MODEL STUDY OF THE WEST MESA INTERCEPTOR ENERGY DISSIPATOR

NEAR ALBUQUERQUE, NEW MEXICO

ADDENDUM TO
CER68-69MMS-SK15
NOVEMBER 1968

ENGINEERING RESEARCH CENTER

FOOTHILLS CAMPUS

FORT COLLINS, COLORADO

HYDRAULIC MODEL STUDY OF
THE WEST MESA INTERCEPTOR ENERGY DISSIPATOR
NEAR ALBUQUERQUE, NEW MEXICO

Prepared for

Gordon Herkenhoff and Associates, Inc.
Albuquerque, New Mexico

by

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and

S. Karaki

Colorado State University
Engineering Research Center
Fort Collins, Colorado
May 1969

Addendum to
CER68-69MMS-SK15

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF PLATES

LIST OF TABLES

HYDRAULIC MODEL STUDY OF
THE WEST MESA INTERCEPTOR ENERGY DISSIPATOR
NEAR ALBUQUERQUE, NEW MEXICO

(Addendum)

SUMMARY

Three hydraulically acceptable energy dissipator designs were described in the parent report, "Hydraulic Model Study of the West Mesa Interceptor Energy Dissipator near Albuquerque, New Mexico," by M. M. Skinner and S. Karaki (CER68-69MMS-SK15). "Design-B" was selected after an economic analysis of the three designs by Gordon Herkenhoff and Associates. The additional model tests reported in this addendum were made to evaluate the hydraulic characteristics peculiar to a two-stage construction of the approach channel. Construction staging was consistent with development of the urban area and available funds.

A 2:1 (horizontal:vertical) sloping right sidewall in the approach channel (looking downstream) was constructed in the "Design-B" model. Pressure measurements on two floor blocks and water depths in the approach channel and in the primary, secondary, and tertiary basins were recorded for a prototype flow of 12,500 cfs.

The hydraulic effect of sediment deposition in the primary basin was investigated for both the initial (Q = 12,500 cfs) and final construction stages (Q = 19,000 cfs and Q = 25,000 cfs).

A sloping sidewall in the approach channel did not adversely affect the hydraulic performance of the stilling basin (dissipator). Sediment deposition may take place in the primary basin, but the energy of the flow will be adequately dissipated for discharges up to 19,000 cfs. For discharges greater than 19,000 cfs, it would be desirable to have a fully effective primary basin. That is, appropriate accommodation for sediment removal should be considered. If, however, the sediment is not "packed" in the basin, the turbulence created by the larger flows will clean the sediment out of the basin and physical removal of the sediment will not be required.

INTRODUCTION

Supplemental model tests were performed to investigate hydraulic conditions in the "Design-B" model. The first stage capacity of the approach channel need not be greater than 12,500 cfs. Accordingly, the 70-ft wide approach channel could be reduced in width to accommodate the discharges. This was done by using a 2:1 sloping right sidewall with a prototype base width of 40 ft.

The performance of the "Design-B" stilling basin for prototype flows of 16,000 and 25,000 cfs was reported in the parent report. This addendum includes results for prototype flow rates of 6,000, 12,500, 19,000, and 25,000 cfs in that basin.

The effect of sediment deposition in the primary basin was studied. It is possible that at small discharges, sediment transported in the collection channels could deposit in the primary basin. If such small flows prevailed over a long period of time without intermittent large discharges, substantial sediment deposits could be accumulated. Studies, therefore, were made to determine the effect of such sediment deposits on the hydraulic performance of the basin, keeping in mind that deposition could occur during initial as well as final development of the total collection and energy dissipation system.

FIG. 1 SCHEMATIC DRAWING OF DESIGN - B

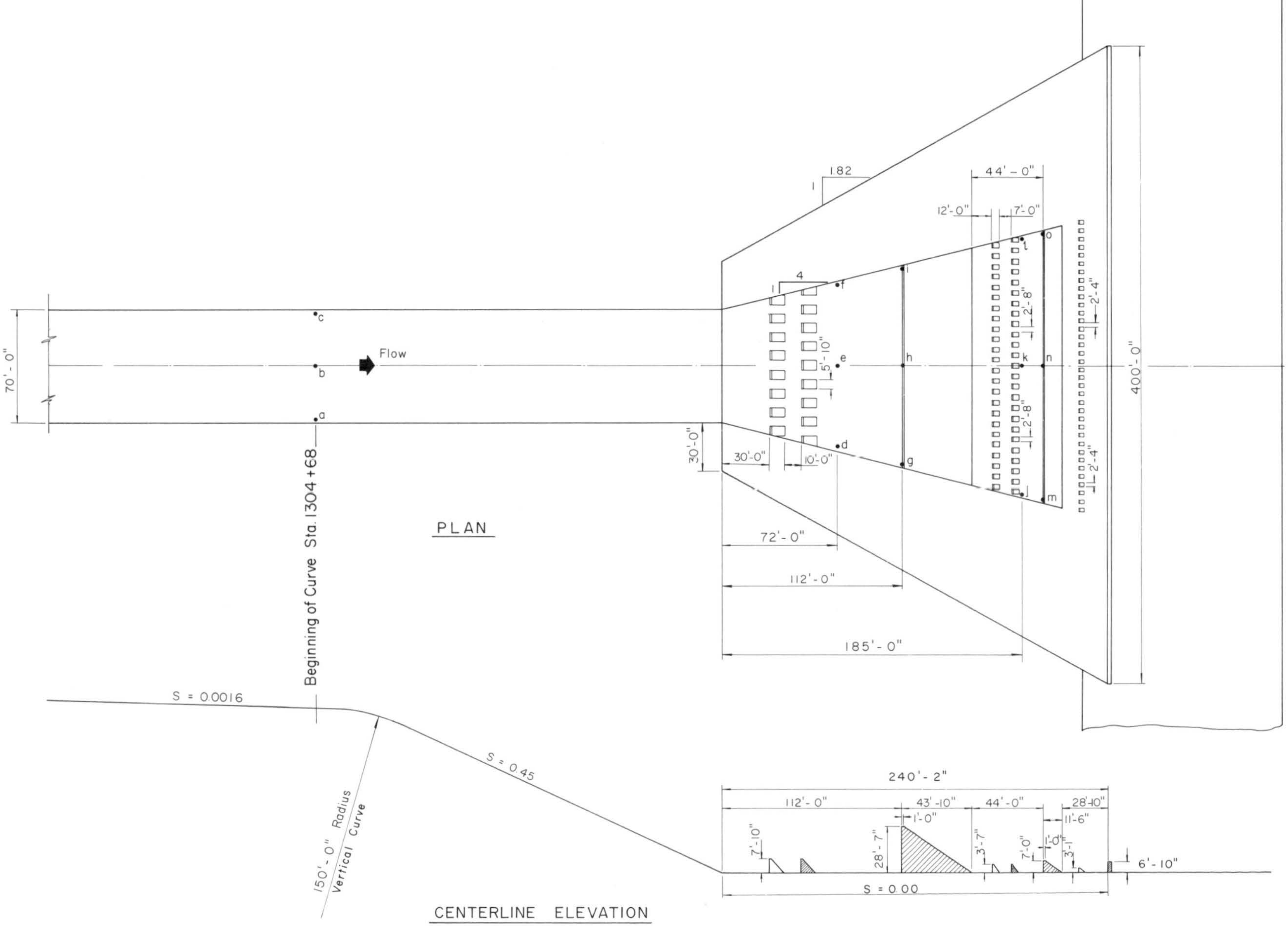
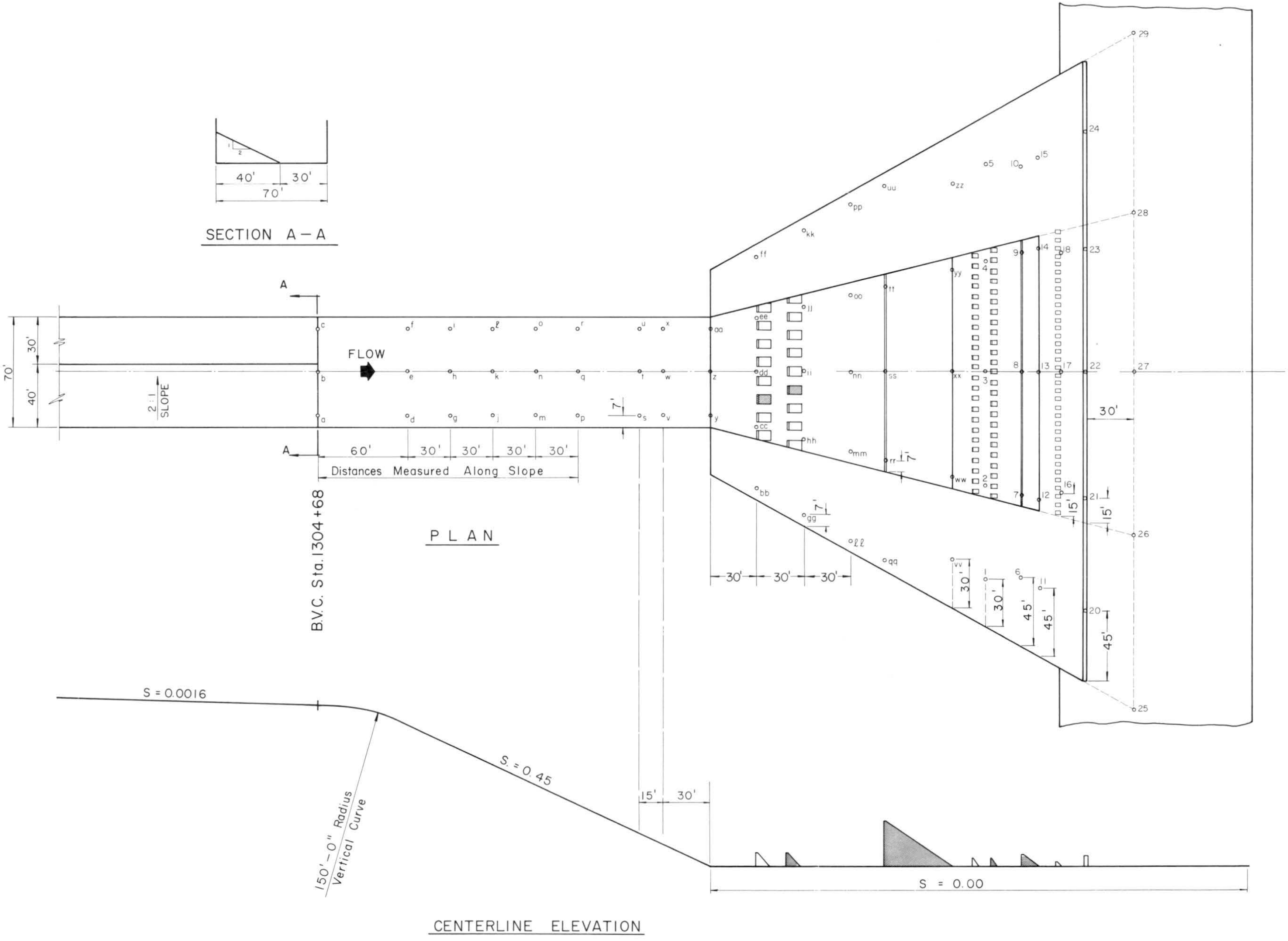


FIG. 2 SCHEMATIC DRAWING OF DESIGN — B / SLOPING SIDEWALL IN APPROACH CHANNEL



MODEL RESULTS

Final Development

The "Design-B" stilling basin was described in the parent report. The plan and centerline elevation views are reproduced here as figure 1. Figure 2 indicates the smaller approach channel which terminates abruptly at the B.V.C. of the vertical curve. Also shown on figure 2 are the indexes for identifying the locations of the water depth measurements. It will be recalled that the top of the primary basin sidewall at final stage was 32.4 ft high. A full sidewall (45 ft) was considered for the first phase construction to prevent side overflow and thus avoid the associated paving and walls around the basin. The added wall height is to be constructed with removable or "knock-out" blocks for final staging.

Prototype flow depths at the designated locations for the selected discharges of 6,000, 12,500, 19,000, and 25,000 cfs are given in Table 1. It should be noted that these results are for a full 70-ft wide approach channel and wall heights of 32.4 ft in the primary basin. Prototype pressures on the two instrumented floor blocks are also given for the corresponding discharges in Table 2. Location indexes for flow depth and floor block pressure measurements are given in figures 2 and 3, respectively. For direct comparison purposes, selected photographs of each of the runs for Q = 6,000, 12,500, 19,000 and 25,000 cfs are given in plate 1.

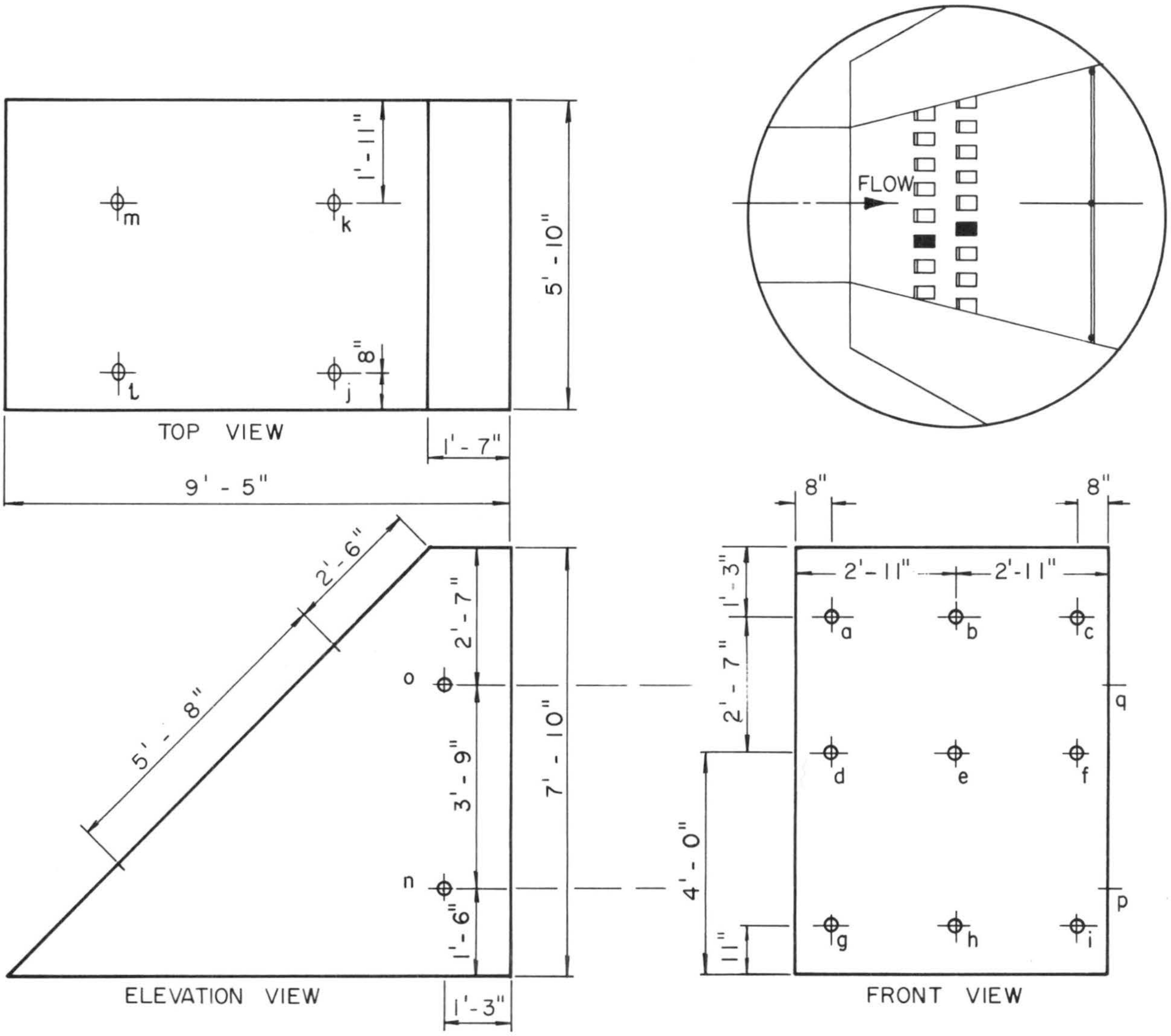


FIG.-3 PRESSURE TAP LOCATIONS - FLOOR BLOCK

Results of Sloping Sidewall in Approach Channel

A 2:1 sloping sidewall was placed in the approach channel of the model and terminated abruptly at the beginning of the vertical curve, as shown in figures 2 and 4.

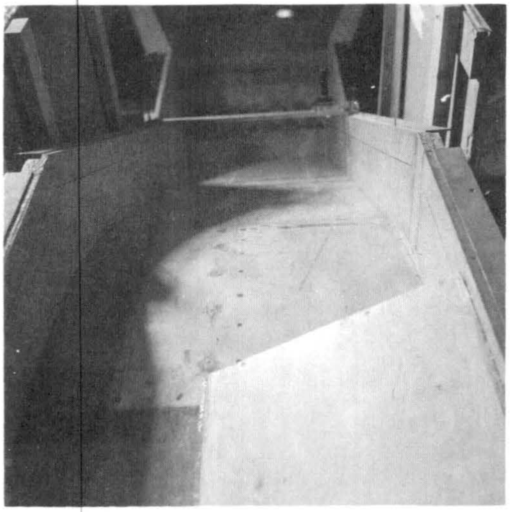


Fig. 4. Downstream view of sloping sidewall in the approach channel.

This arrangement (full sidewalls in the primary basin) was subjected to a prototype discharge of 12,500 cfs. Flow depths and pressure measurements on two floor blocks are recorded in Tables 1 and 2, respectively. Photographs of the flow in the vicinity of the sloping sidewall and stilling basin are shown in plate 2.

Some flow concentrates along the right side of the chute downstream from the sloping sidewall (see figures 5, 6, and 7). However, this concentration of flow does not make the hydraulic jump in the stilling basin unstable. As seen in the photographs, there is some skewness with respect to the front of the jump in the primary basin, but the flow in all basins is completely satisfactory.

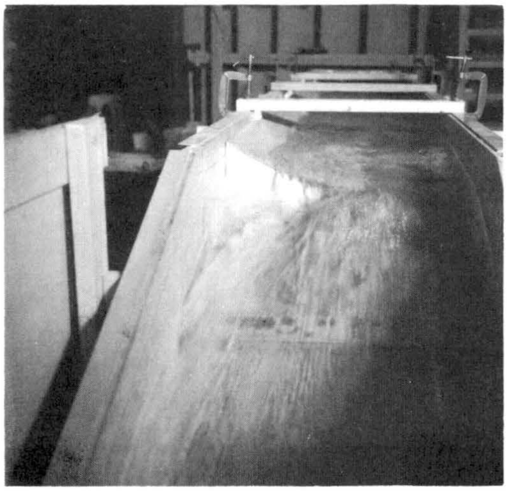


Fig. 5. Upstream view of the flow over the sloping sidewall.

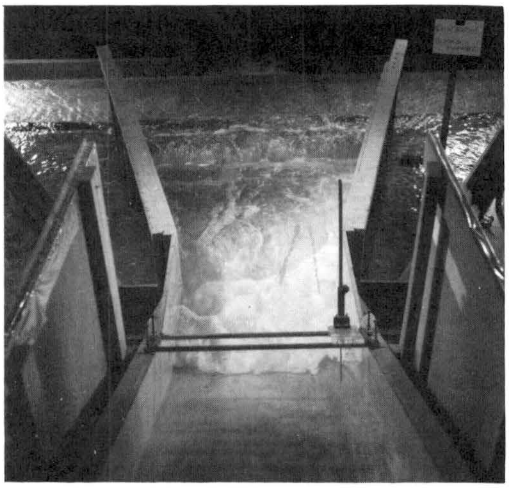


Fig. 6. View looking downstream from end of sloping sidewall. (Note the concentration of flow along right side of chute.)

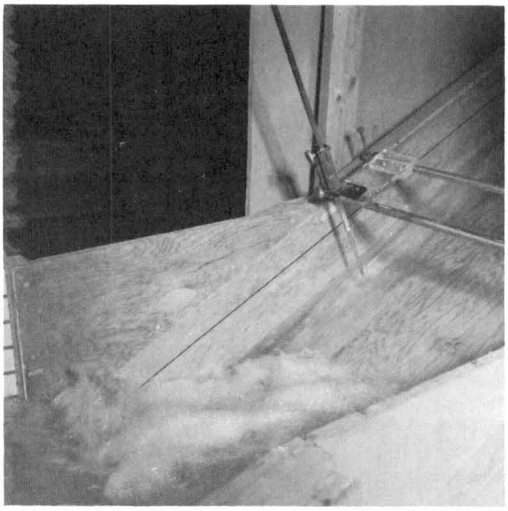


Fig. 7. Close-up view of flow concentration along far side of chute.

Effect of Initial Sediment Deposition in the Primary Basin

Since the intermittent operation of this proposed structure may cause sediment to deposit in the primary basin, a study was made to determine the effect of deposition on hydraulic performance.

An arbitrary amount of medium sized sand was placed in the primary basin in the manner illustrated in figure 8. It is considered unlikely that sediment would deposit over the floor blocks. In any event, it was assumed that this amount of sand would be arranged by the flow according to the hydraulic forces involved. Tests were made for the initial stages of the stilling basin and approach channel construction.

After 20 minutes of flow at 12,500 cfs, the major portion of the sand remained in the primary basin, as shown in figure 9. A scouring pattern was observed along the right side corresponding to the location of the concentration of flow along the right side of the chute. Additional photographs of the scour/deposition pattern and the flow for this case are given in plate 3.

Similar tests were made for the second stage channel and stilling basin. A prototype flow of 19,000 cfs was introduced with the sediment deposition pattern that existed following the test depicted in figure 9. After 30 minutes of operation, the majority of the sediment still remained in the primary basin as illustrated in figure 10. The flow was then increased to a discharge of 25,000 cfs for another 30 minutes. In this case, essentially all of the sediment was transported out of the primary basin (see figure 11). This illustrates two significant points. First, if the sediment from previous flows does not pack in, but remains loose (similar to the bed of the Rio Grande), the sediment deposited in the basin will be removed by the large flows. Second, the volume of the primary basin is being fully utilized to dissipate energy.

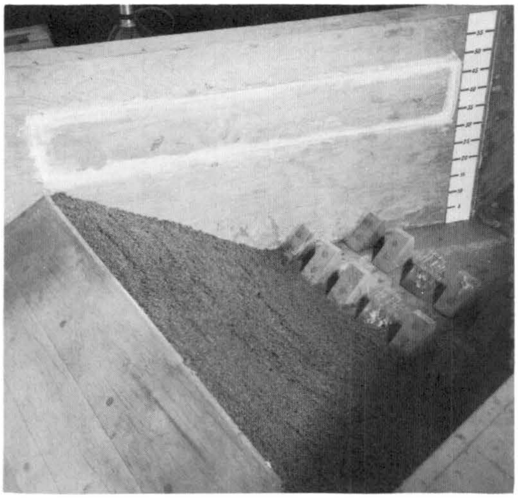


Fig. 8. Medium sand was placed in the primary basin from the end of the last row of floor blocks to the top of the end sill.

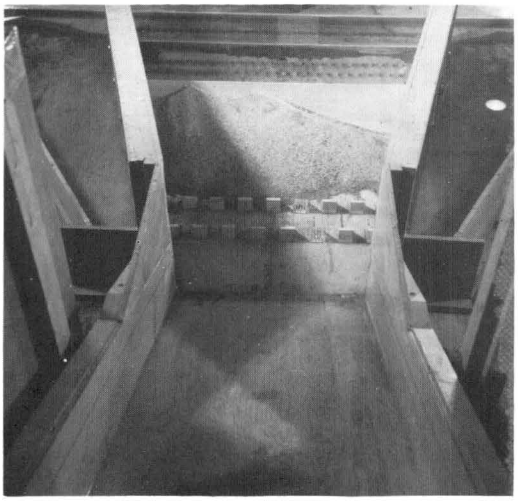


Fig. 9. Downstream view of sediment deposit after 20 minutes of model run time with a prototype discharge of 12,500 cfs. (Note the scour along the right side.)

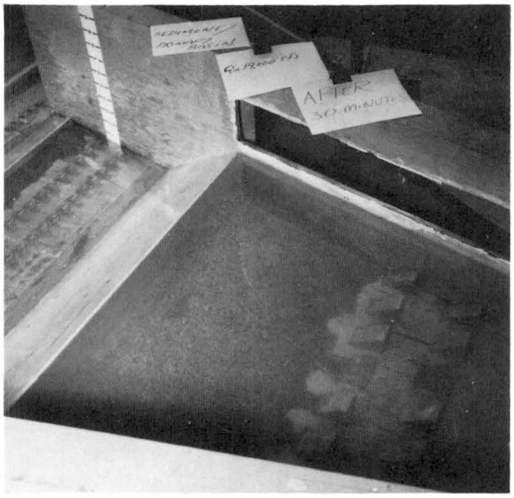


Fig. 10. View of sediment deposit remaining in primary basin after 30-minute model run representing 19,000 cfs.

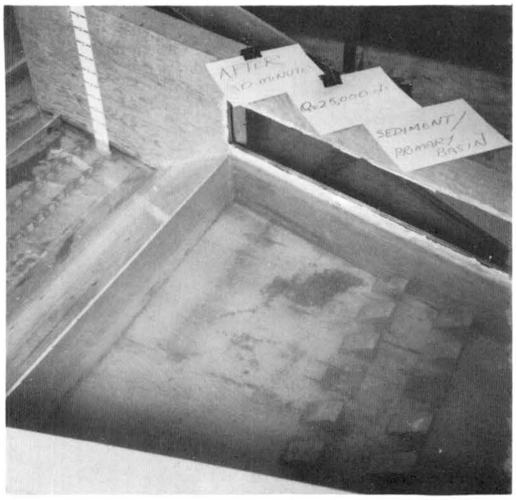


Fig. 11. Essentially all sediment was removed from the primary basin by the flow of 25,000 cfs after a 30-minute model run.

The additional studies of the final development of the basin and approach channel were conducted to document the hydraulic conditions which will occur at various discharges. These tests indicated that the prototype would function satisfactorily for all discharges up to the design capacity. Observations of the model behavior at 25,000 cfs indicated that the primary basin should not be smaller than the recommended size given on figure 1. Quite obviously this means that for discharges below about 15,000 cfs, the primary basin may be somewhat oversized.

The sloping sidewall in the approach channel may be used without adversely affecting the flow in the stilling basin. The end of the sloping sidewall may terminate abruptly at the B.C. of the vertical curve. Noticeable concentrations of flow occurred along the right wall, but this effect was reduced by the circulation in the primary basin and was not noticeable over the last end sill in the model.

A relatively large quantity of an initial sediment deposition in the primary basin produces no significant effect on water depths in the primary basin. Part of the material scoured from the primary basin redeposited in the lower ends of the secondary and the side channel basins (see figures 12, 13, and 14).

At the design discharge of 25,000 cfs, essentially all the material was transported out of the primary basin and redeposited in the lower end of the secondary and side channel basins or swept on downstream (see figure 14).

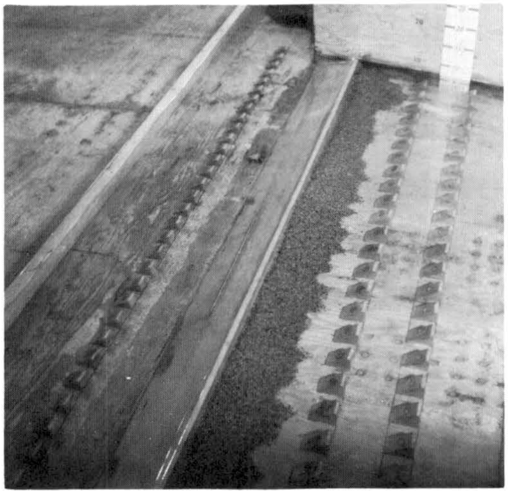


Fig. 13. Deposition pattern in the secondary basin for Q = 19,000 cfs.

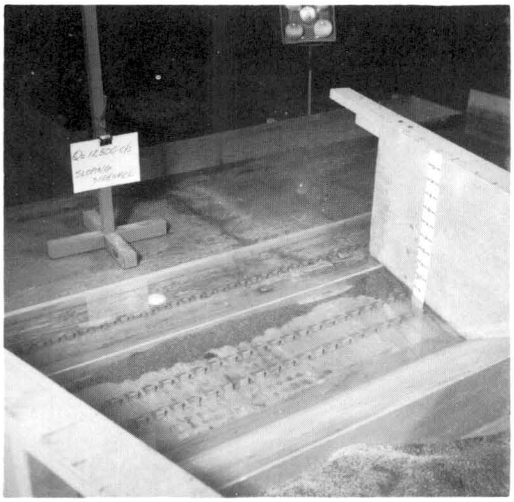
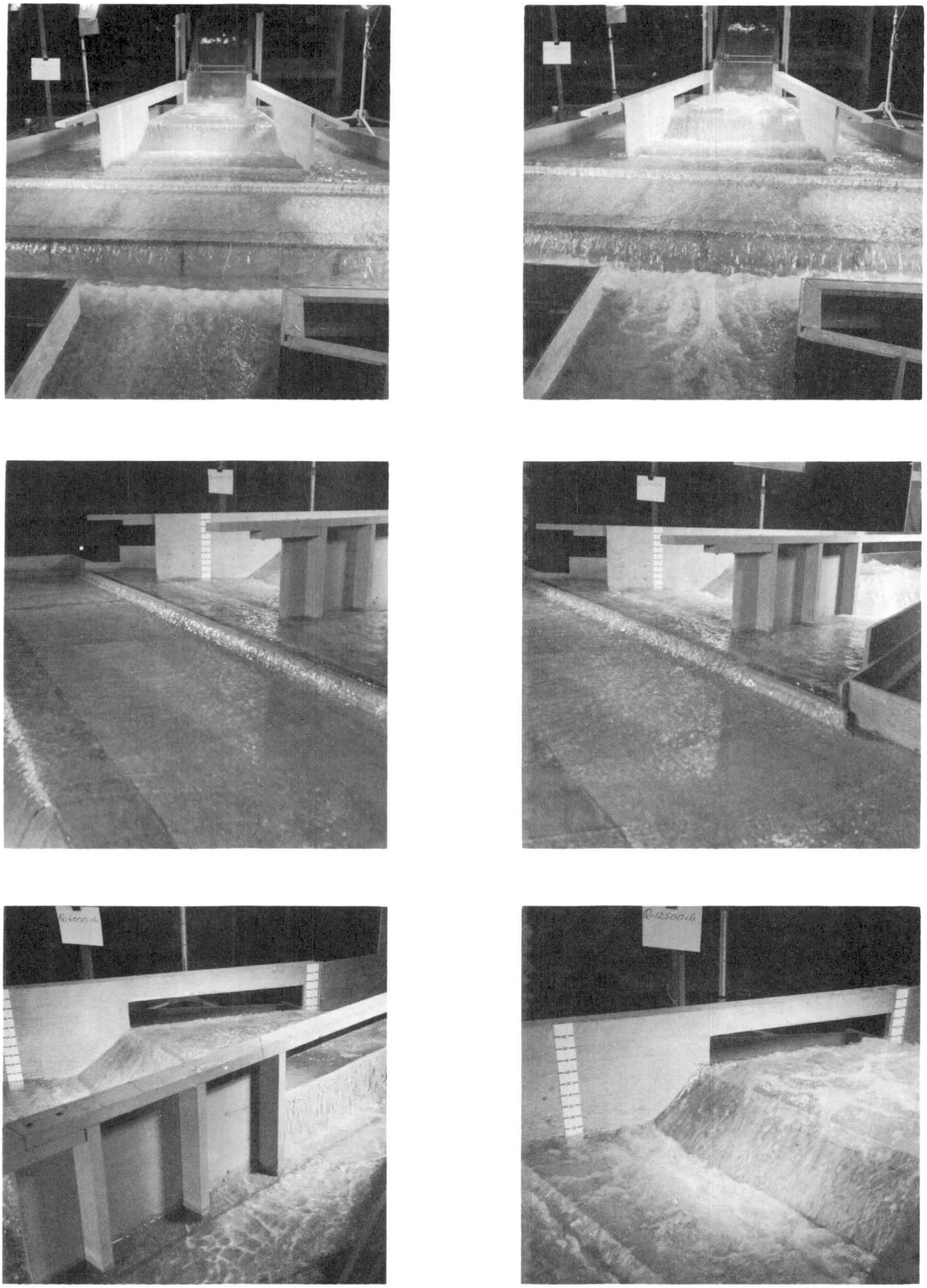


Fig. 12. Some of the scoured material from the primary basin redeposited at the lower end of the secondary basin, Q = 12,500 cfs/sloping sidewall.

Fig. 14. Deposition pattern at lower end of side channel basin for Q = 25,000 cfs.

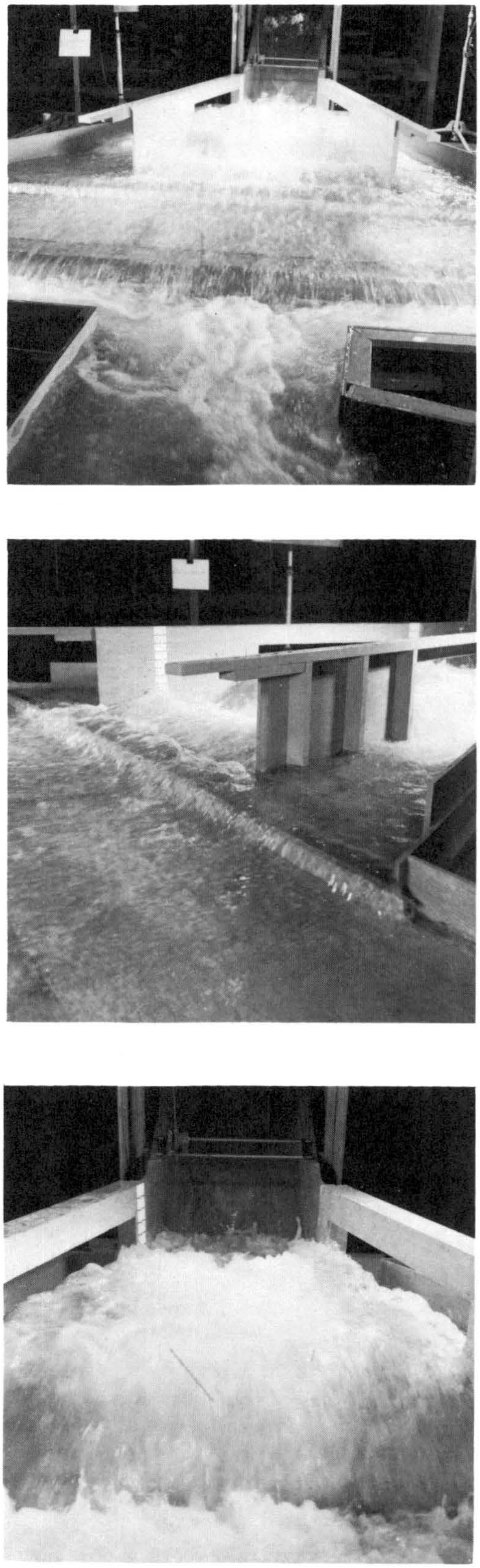


Discharge = 6,000 cfs

Discharge = 12,500 cfs

Plate 1. Comparable views of the operation of the energy dissipator for discharges of 6,000, 12,500, 19,000, and 25,000 cubic feet per second.

Discharge = 19,000 cfs



Discharge = 25,000 cfs

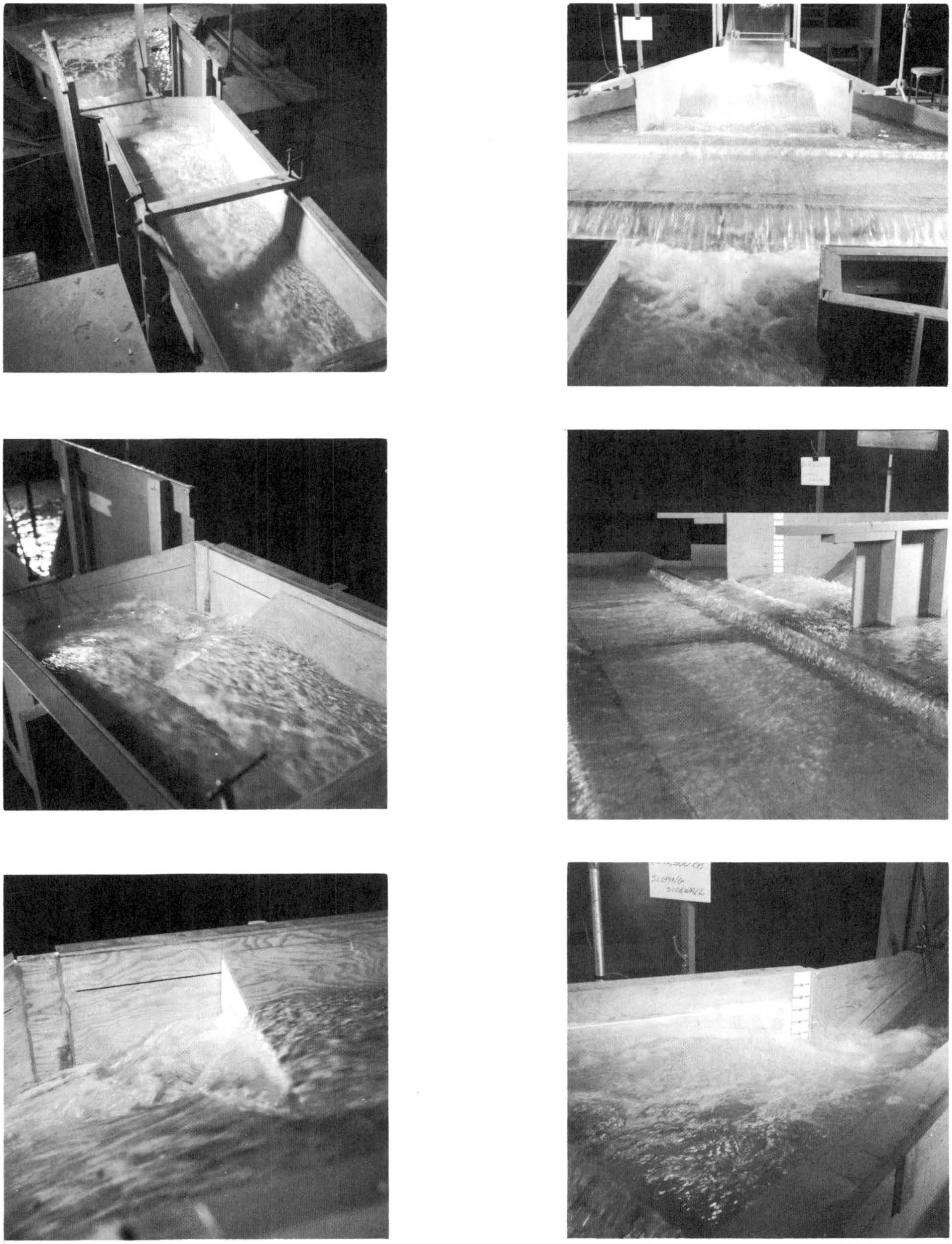


Plate 2. Selected views of flow in the vicinity of the sloping sidewall in the approach channel and of the operation of the energy dissipator.

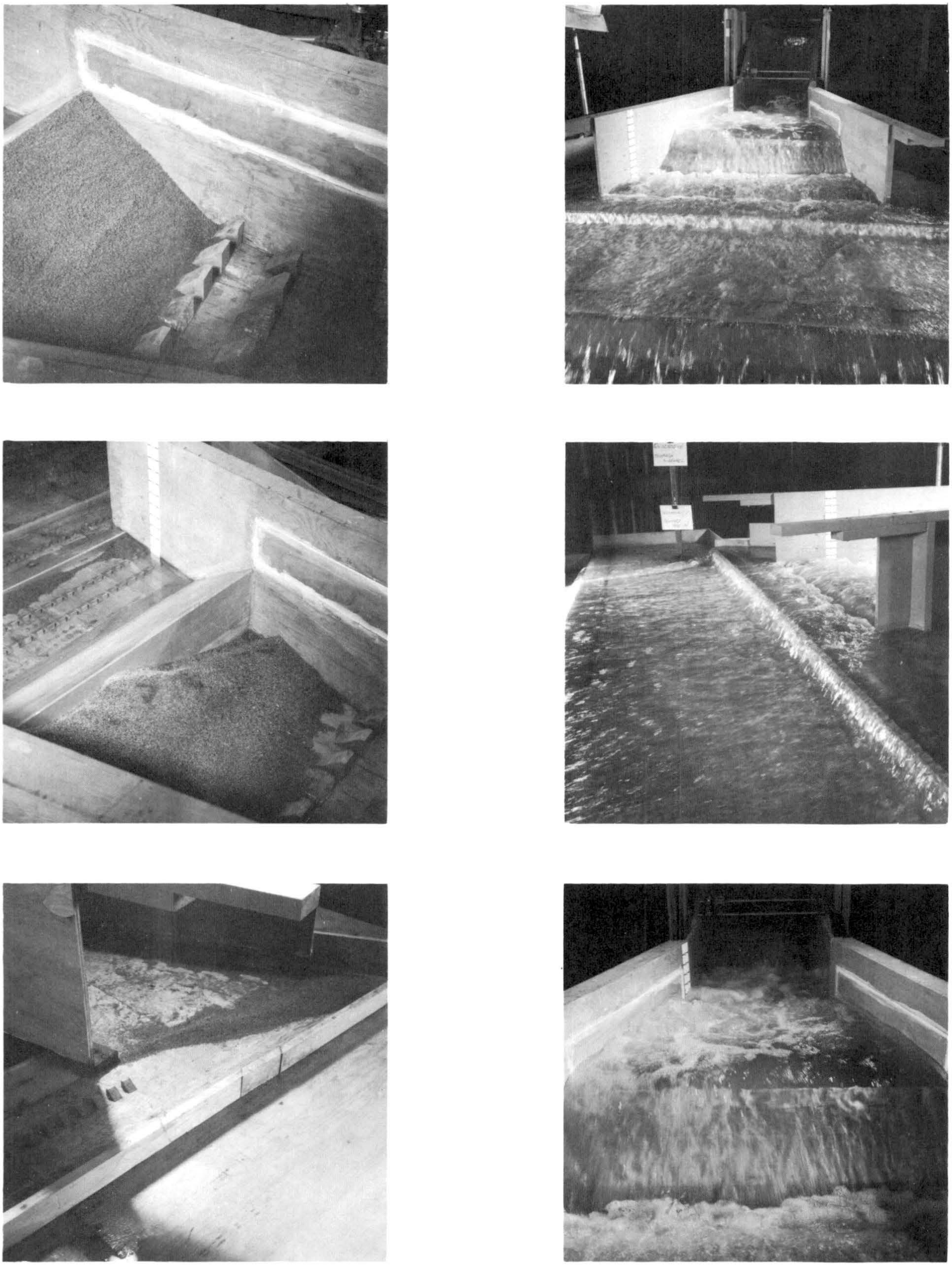


Plate 3. Initial and final sediment deposit pattern in the primary basin and views of the operation of the energy dissipator for Q = 12,500 cfs.

Table 1

PROTOTYPE FLOW DEPTHS (FEET) AT DESIGNATED LOCATIONS IN APPROACH CHANNEL AND ENERGY DISSIPATOR (SEE INDEX DRAWING, FIG. 2) FOR SELECTED DISCHARGES*

	Rectangular approach channel				Sloping sidewall in approach channel
Location	6,000 cfs	12,500 cfs	19,000 cfs	25,000 cfs	12,500 cfs
a	5.0	8.3	11.4	11.8	see sketch at bottom of this table
b	5.6	7.7	10.7	15.2	
c	5.3	8.4	11.8	12.4	
d	2.7	4.8	6.7	8.9	3.2
e	2.5	4.8	8.0	8.0	4.8
f	2.6	4.7	6.5	9.4	6.6
g	2.3	4.0	5.7	8.3	3.1
h	2.1	4.0	6.6	7.2	3.7
i	2.2	3.8	5.7	8.4	5.1
j	1.9	3.3	5.0	7.1	4.2
k	1.7	3.4	5.0	6.2	3.2
l	1.7	3.3	5.1	7.3	4.1
m	1.6	2.9	4.7	6.3	4.8
n	1.6	3.0	4.3	5.7	2.6
o	1.6	3.0	4.5	6.3	3.5
p	1.5	2.8	4.6	5.7	4.9
q	1.4	2.8	3.9	5.3	2.5
r	1.5	2.9	4.4	5.6	3.0
s*	9.5	7.5	4.9	5.5	9.8
t*	10.0	8.1	6.6	5.8	10.9
u*	9.5	7.5	4.6	5.0	9.9
v*	16.2	14.4	12.6	11.4	16.5
w*	17.3	15.3	14.1	13.0	17.8
x*	16.8	14.1	12.5	11.8	16.8
y	31.9	28.5	26.8	24.6	33.1
z	31.7	28.8	28.9	28.6	30.6
aa	32.1	29.1	27.1	25.0	31.9
bb	9.5	10.5	11.5	12.5	---
cc	33.7	35.4	35.3	35.8	35.7
dd	33.7	35.1	33.9	31.4	37.3
ee	33.3	35.4	35.6	36.3	36.8
ff	9.5	11.1	11.8	12.7	---
gg	9.6	11.1	12.2	12.6	---
hh	34.0	35.7	36.9	36.9	38.5
ii	34.0	36.3	38.4	40.1	37.2
jj	33.7	35.7	36.6	36.8	37.5
kk	9.7	11.1	12.3	12.9	---
ll	9.7	11.1	12.2	12.5	---
mm	33.5	35.4	37.1	37.9	38.3
nn	33.7	35.7	37.7	40.1	37.1
oo	33.8	35.7	37.1	37.8	37.1
pp	9.8	11.4	12.0	12.5	---
qq	9.6	10.8	11.8	12.2	---
rr	3.8	5.4	6.5	7.4	7.9
ss	3.8	5.7	7.4	10.0	6.7
tt	3.7	5.1	6.4	7.1	6.3
uu	9.7	11.1	11.8	12.4	---

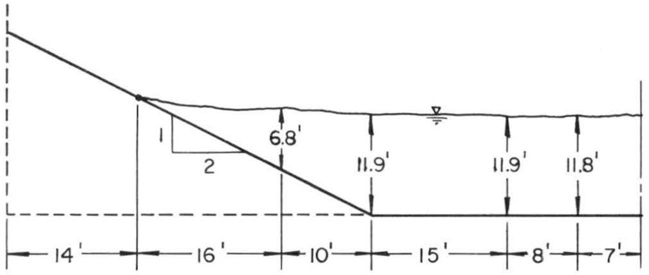
*Depths are measured normal to the bottom, except at locations s, t, u, v, w, and x, where they are measured in a vertical direction.

Table 1 (Continued)

PROTOTYPE FLOW DEPTHS (FEET) AT DESIGNATED LOCATIONS IN APPROACH CHANNEL AND ENERGY DISSIPATOR (SEE INDEX DRAWING, FIG. 2) FOR SELECTED DISCHARGES

	Rectangular approach channel				Sloping sidewall in approach channel
Location	6,000 cfs	12,500 cfs	19,000 cfs	25,000 cfs	12,500 cfs
vv	9.5	10.5	11.5	11.9	---
ww	9.3	10.2	11.3	12.1	10.2
xx	8.7	10.2	10.3	8.0	9.8
yy	9.5	10.8	11.5	12.3	11.1
zz	9.8	10.8	11.6	12.1	---
1	9.5	10.8	11.6	11.8	---
2	10.7	17.6	15.3	17.5	13.5
3	11.6	13.5	16.0	16.4	15.7
4	10.8	12.6	15.5	17.6	13.5
5	9.8	10.8	11.6	12.1	---
6	9.5	10.8	11.7	11.9	---
7	2.8	4.8	6.8	7.8	5.8
8	3.9	6.0	7.4	8.6	7.2
9	3.2	5.1	7.2	8.5	5.6
10	9.6	10.8	11.6	12.0	---
11	9.5	10.8	11.6	12.0	---
12	9.7	9.6	10.1	11.7	8.5
13	9.7	9.6	10.7	12.0	10.2
14	9.7	10.2	9.9	11.3	9.6
15	9.6	11.1	11.7	12.2	---
16	9.8	10.8	12.9	13.6	11.3
17	10.1	11.4	13.5	14.8	12.9
18	9.8	10.8	12.8	13.7	11.3
20	---	3.0	---	---	---
21	2.3	3.6	4.5	5.7	3.4
22	2.5	3.9	5.2	6.1	5.0
23	2.3	3.3	4.7	5.8	3.5
24	---	3.0	---	---	---
25	0.3 (8.)†	0.6 (14.)	0.6 (17.)	0.6 (20.)	---
26	0.9 (18.)	1.8 (20.)	2.4 (22.)	3.6 (24.)	1.5 (21.)
27	1.2 (18.)	2.1 (21.)	3.0 (23.)	3.9 (25.)	3.0 (22.)
28	0.9 (18.)	1.8 (20.)	2.4 (22.)	3.6 (24.)	2.1 (20.)
29	0.3 (8.)	0.6 (15.)	0.6 (18.)	0.6 (19.)	---

†Numbers in parenthesis are estimated prototype velocities (feet per second) at corresponding location.



UPSTREAM VIEW AT BEGINNING OF VERTICAL CURVE X-SECTION

Table 2

PROTOTYPE PRESSURES (FEET OF WATER) AT DESIGNATED LOCATIONS ON TWO FLOOR BLOCKS FOR SELECTED DISCHARGES (SEE INDEX DRAWING OF FLOOR BLOCK, FIG. 3).

	Discharge									
	6,000 cfs		12,500 cfs		19,000 cfs		25,000 cfs		12,500 (sloping sidewall)	
Location	Front Row	Back Row	Front Row	Back Row	Front Row	Back Row	Front Row	Back Row	Front Row	Back Row
a	28.	28.	36.	31.	44.	36.	62.	41.	35.	31.
b	29.	28.	35.	35.	48.	40.	65.	54.	36.	32.
c	28.	28.	34.	32.	42.	38.	55.	47.	35.	31.
d	31.	28.	44.	31.	56.	38.	80.	43.	41.	32.
e	31.	31.	46.	37.	65.	42.	90.	49.	42.	33.
f	31.	26.	41.	31.	58.	37.	70.	43.	41.	29.
g	35.	33.	48.	38.	58.	39.	74.	44.	42.	36.
h	37.	34.	49.	38.	67.	40.	84.	50.	46.	37.
i	34.	33.	42.	37.	57.	41.	62.	46.	44.	38.
j	24.	28.	22.	29.	13.	27.	6.	26.	24.	30.
k	26.	28.	23.	29.	14.	28.	8.	27.	25.	31.
l	30.	32.	29.	33.	23.	34.	17.	33.	29.	35.
m	30.	32.	28.	33.	23.	33.	17.	34.	29.	32.
n	29.	32.	20.	32.	-5.	30.	-23.	25.	26.	36.
o	26.	29.	17.	28.	-6.	26.	-26.	21.	22.	32.
p	29.	32.	17.	33.	-8.	30.	-15.	29.	25.	35.
q	26.	28.	16.	28.	-7.	27.	-17.	20.	20.	31.