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Project Title: Model Study of the Upper Reservoir Intake Structure

Project No: E-20-660 (Addendum No. 3 to E-20-637) Green card

Project Director: Dr. P. G. Mayer

Sponsor: Southern Company Services, Inc.

Agreement Period: From 2/7/79 Until ~~11/6/79~~ 3/31/80

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Technical Matters

Contractual Matters
(thru OCA)

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in confidence?
check basic E20-637

Defense Priority Rating: N/A

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Date 1/8/82

Project Title: Model Study of the Upper Reservoir Intake Structure

Project No: E-20-660 (Addendum No. 3 to E-20-637)

Project Director: Dr. P. G. Mayer

Sponsor: Southern Company Services

Effective Termination Date: 7/1/80

Clearance of Accounting Charges: 7/1/80

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FINAL REPORT
Project No. E–20–660

ROCKY MOUNTAIN PROJECT, UPPER RESERVOIR INTAKE STRUCTURE MODEL STUDIES

By
Paul G. Mayer

Prepared for
SOUTHERN COMPANY SERVICES
BIRMINGHAM, ALABAMA

June, 1980

GEORGIA INSTITUTE OF TECHNOLOGY
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ROCKY MOUNTAIN PROJECT, UPPER RESERVOIR INTAKE STRUCTURE MODEL STUDIES

FINAL REPORT

by

Paul G. Mayer

Project No. E-20-660
Southern Company Services
Birmingham, Alabama

June, 1980

TABLE OF CONTENTS

List of Tables

List of Tables
(cont.)

List of Tables
(cont.)

List of Tables
(cont.)

List of Tables
(cont.)

List of Tables
(cont.)

List of Figures

List of Figures (cont'd)

Final Report: Rocky Mountain Project, Upper Reservoir Intake Structure Model Studies

I. Introduction

The Rocky Mountain Project (RMP) is a proposed pumped storage hydroelectric power development located some 10 miles northwest of the city of Rome in Floyd County, Georgia. It will be a part of the Georgia Power Company System. The project location map is shown in Figure 1.

The project is a pure pumped storage development in which three reversible pump turbines deliver water from an operating pool into an upper reservoir during periods of low system load, and in which power will be generated to satisfy peak power demands.

The lower reservoir will be created by means of a man-made impoundment in the Heath Creek Valley, a small stream with a watershed of less than 20 square miles drainage area. The lower reservoir provides for adequate storage to operate the project at dependable capacity. The upper reservoir is to be located on top of Rocky Mountain, an oval shaped and relatively flat-topped mountain some 700 feet above the valley floor. The upper reservoir is to be formed by an encircling dike to accomodate the pumped storage. The project can be operated on daily pumping and generating cycles. The water surface fluctuation in the upper reservoir during a typical daily cycle will be some 50 feet. A schematic plan view of the project is shown in Figure 2.

The upper reservoir intake structure is a key installation whose proper functioning is critically important to the efficiency and reliability of the Rocky Mountain Project. The design, design verification, design modification and location of the intake structure are the object of careful study and review. In this context, Southern Company Services, Incorporated, of Birmingham, Alabama contracted with the Georgia Institute of Technology to build and test hydraulic models of the upper reservoir and of the intake structure. The liaison with Southern Company Services was carried out through SCS's Mr. G.B. Dougherty, Hydro Advisor, and the principal investigator was Dr. P.G. Mayer, Regents' Professor of Civil Engineering, Georgia Institute of Technology.

The active advice, interest and support of Dr. C. Chiou, Southern Company Services, and of Mr. A.W. Elkins, Georgia Power Company, was invaluable. In the laboratory, Messrs. D. Bates, H. Bates, N. Barashick, and numerous student assistants were involved in building the models and in carrying out the experiments. These contributions are acknowledged.

II. Purpose and Scope

In general, the performance of hydraulic structures and of hydraulic machinery may be significantly influenced by approach flow conditions. Adverse approach flow conditions may lead to loss of efficiency, air-entrainment, vibration and structural damage. The presence of swirling motions and of asymmetrical inflows may lead to vortex formation and flow pre-rotation. Free surface vortices are of particular concern to designers of hydraulic structures because of the present lack of mathematical predictability and even physical understanding of vortexing.

Since it is not yet possible to predict analytically either the occurrence or the strength of a free surface vortex at a particular intake structure, hydraulic model studies are required to investigate the phenomenon. For the Rocky Mountain Project Upper Reservoir it was thus deemed necessary to construct and test hydraulic models to investigate the general flow patterns during filling and emptying and to observe specifically local phenomena which could be used to establish reasonably safe limiting conditions.

The models were to be investigated under representative water levels during pumping and generating modes and structural modifications of the intake structure were to be installed and tested in order to eliminate vortex flows at the intake structure. The model of the intake structure was also to be tested for pressure distributions at the top disk during pumping and during generating modes.

Specifically, model tests were to establish:

a. flow patterns and velocity distributions in the upper reservoir.

b. flow patterns and velocity distributions at the intake structure, including vortexing.

c. flow patterns inside the intake structure including prerotation in the vertical shaft.

d. pressure distributions at the top disk of the entrance structure.

e. an optimal location of the intake structure.

All text results together with observations were to be transmitted to Mr. G.B. Dougherty as soon as they became available, and all test results were to be included in a Final Report. Extension of the scope of the hydraulic model tests, modifications of the intake structure or any other work was not to be undertaken except by mutual agreement between the parties and by extension of the original contract.

In summary, the scope and purpose of the modeling program was to provide convicing evidence that the Upper Reservoir Intake Structure was designed to provide for satisfactory flows into and out of the structure and thus contribute to the safe and efficient operation of the pump/turbine units of the project.

III. The Hydraulic Models

Two hydraulic models were built and investigated. One was a 1:40 scale model of the intake structure with a partial model of the upper reservoir. The other was a 1:300 scale comprehensive model of the upper reservoir including a simplified model of the intake structure. In the context of this report the models will be designated as the 1:40 scale model and the 1:300 scale model. The 1:40 scale model allowed a detailed investigation of the flow patterns near the intake structure and in the vertical shaft. The 1:300 scale model allowed for an investigation of upper reservoir flow patterns and of the large scale circulation in the reservoir. The 1:300 scale model was thus used largely as a verification study of flow patterns in the upper reservoir, flow patterns which were then introduced into the 1:40 model for detailed studies of the influence of reservoir circulation on the performance of the intake structure.

In modeling the intake structure of the upper reservoir of the Rocky Mountain Project, both geometrical and dynamical similitude requirements were considered. Since the nature of the hydraulic problem included both pressure-difference-force dominated flows in the entrance structure and possibly viscous-force dominated flows in the vertical and horizontal shafts, complete dynamical similitude could not be attained in the models. However, it was agreed that the flow patterns at the entrance structure could be best reproduced by an Euler criterion model which inherently also satisfies the Froude criterion. The model was then operated at sufficiently high Reynolds numbers in order to overcome the viscous and surface tension (scale) effects on the performance of the models.

The 1:40 Scale Model. The 1:40 model scale was adopted in order to allow a direct coupling of the intake structure model test results with the results of tests on a separate model studying flow in the tunnel bifurcations. The bifurcations tests were also made on 1:40 scale models; and this work was carried out and reported by Dr. C.S. Martin.

The 1:40 scale model of the upper reservoir intake structure included three major components: the partial reservoir and its structural support system, the intake structure, and the hydraulic filling and emptying system. The model components are described below.

In order to operate an upper reservoir model it was necessary to provide elevational differences between the centerline of the horizontal shaft and the upper reservoir.

In the prototype the horizontal tunnel is located at an elevation of about 610 feet (MSL) and the floor of the upper reservoir intake structure is at an elevation of 1315 feet, representing thus an elevational difference of 705 feet. In the model this elevational difference should have been some 17.6 feet. However, because of the limited vertical laboratory clearance of 25 feet and because of the requirements of reservoir drawdown, freeboard, working platform and working space above the model of the upper reservoir the vertical distance between the horizontal tunnel center line and the floor of the upper reservoir was foreshortened to some 16 feet.

The elevational difference was provided in the laboratory by locating the upper reservoir on a wooden deck supported by a steel structure. The laboratory installation is shown schematically on Figure 3. Thus, the partial model of the upper reservoir was simulated by a 27-foot diameter vinyl-lined 'Kiddie' pool. The pool was placed on a 32-foot by 32-foot working platform which consisted of two layers of 3/4-inch plywood and 2 by 6-inch wooden joists at 16-inch centers. The supporting steel structure had been designed with the aid of a computer analysis, modified conservatively to simplify fabrication. The fabrication drawings were developed by structural engineers of the Georgia Power Company. The structure was then fabricated and erected by Tri City Fabricators of Atlanta, Georgia. Figure 4 provides detailed elevation views of the steel structure. The structural asymmetry was necessitated by the floor support constraints of the laboratory. All vertical support columns were thus 8 WF 18 sections with one foot square bottom plates. Four-inch angle braces provided for structural stiffness. Figure 5 shows the structural framing of the support floor. All floor beams were 10 W 12. All connections were bolted and were made by using high strength bolts.

After erection of the steel structure and the placement of the wooden floor the vinyl-lined pool was installed. The pool has a wall height of 36 inches. A wooden railing system around the platform provided for the worker's security. The railing also provided support for a metal rail which in turn accomodated a movable observation bridge across the upper reservoir model. An overall view of the 1:40 scale upper reservoir model is shown in Figure 6. Figure 7 shows details of the movable bridge track system.

The intake structure of the upper reservoir was built according to specifications provided by Southern Company Services. It consisted of a circular structure with a top disk supported by 12 radially oriented piers. The intake structure also featured a circular ogee section and a transition cone which joined the ogee section and the vertical shaft. A schematic plan view of the intake structure is shown in Figure 8.

The model of intake structure was carefully constructed to reproduce the geometrical details. The intake structure itself consisted of a circular top disk and a doughnut-shaped bottom plate separated by twelve stream-lined piers. The intake structure was made of clear acrylic plastic. Attached to the bottom plate was a fiber glass adapter to accomodate the ogee section and to connect to a clear plastic cone section. Figure 9 shows a schematic view of the assembled intake structure. The adapter and cone are shown in Figure 10, the intake structure is seen mounted on the adapter in Figure 11. Figure 12 shows the intake structure installed in the model of the upper reservoir. The plywood section visible behind the intake structure was installed to simulate the reservoir embankment. The embankment was sloped at one on two (1:2) and could be moved relative to the position of the intake structure. The model also shows the tufts mounted on wire poles used to observe local flow directions. Figure 13 shows a typical cross section through the ogee spillway crest ring. The ring was made of laminated ash and was turned on a large lathe at the Georgia Tech Experiment Station.

A schematic view of the laboratory water supply system was shown previously in Figure 3. Since the model tests required simulation of both the pumping modes and the generating modes, the piping had to be built to accomodate a reversible flow system. Thus, the model was to be operated to allow flow into the upper reservoir by discharging out of the intake structure to simulate pumping and to allow flow out of the upper reservoir by discharging into the intake structure to simulate the generating mode. The limited storage capacity of the partial model required simultaneously that additional flow was withdrawn from the upper reservoir during pumping and that additional flow was supplied to the reservoir during generation simulation. For this purpose, the model was built not only with an appropriate vertical shaft and horizontal tunnel but also with an auxiliary pipe and diffuser system to accomodate the supplemental flow requirements. The shaft and tunnel were modeled by using 10-inch diameter piping. The auxiliary piping system was made with 8-inch PVC.

The water was supplied by a centrifugal pump. A cross-over system of pipes and valves accomodated operation of the model either in the pumping mode or in the generating mode. An orifice meter was installed in the 10-inch horizontal line. The meter was calibrated in both directions and a U-tube differential air-water manometer was used to determine the flow rates through the intake structure. A mercury manometer was used to monitor the water level in the upper reservoir.

Figure 14 shows the flow control system in the laboratory. To the right of the cross-over piping are the centrifugal pump and the electrical controls. In the background are the vertical pipes and the steel support structure. Figure 15 shows the horizontal piping along the laboratory floor. The 10-inch horizontal pipe was some 40 feet long and required a foot bridge over it to protect the orifice meter and to accomodate the laboratory traffic. The vertical shaft was connected to the horizontal pipe by a clear plastic elbow as shown in Figure 16. The vertical shaft was partly made of 10-inch PVC and partly of 10-inch clear plastic pipe. Pressure taps were installed in the vertical shaft to monitor the pressure gradients in the system as was a no-pitch vortimeter to observe possible flow rotation. The conical transition beneath the intake structure was fabricated of clear plastic. A close-up view of the vertical long-radius elbow is shown in Figure 17. The elbow had an equivalent radius of 90 feet. The vortimeter is seen in the vertical pipe in Figure 18. Figure 19 shows the terminal section of the vertical shaft at the underside of the model floor. Figure 19 shows the transition cone, some of the pressure taps, and some of the tufts glued to the clear plastic sections to allow visual observations of the flow patterns.

The auxiliary piping terminated in the upper reservoir model in a perforated pipe diffuser system. Figure 20 shows a schematic view of the upper reservoir with its diffuser pipe system. Figure 21 shows a section of the perforated diffuser pipe. Several hundred one-half inch holes were drilled into the 6-inch diffuser pipes to accomodate a distributed inflow and outflow through the auxiliary pipe system. In order to further smooth out the inflow through the diffuser pipes, a series of expanded metal baffles were installed which were supplemented by wooden slats. Figure 22 shows the expanded metal sections as well as the wooden baffles in the upper reservoir of the 1:40 scale model. Thirteen pressure taps were installed in the top disk of the intake structure model to measure pressure distribution under various operating conditions. The pressure taps were connected by means of plastic tubes to air-water manometer boards for direct observations.

The 1:300 Scale Model. The 1:300 scale was adopted for the comprehensive reservoir model in order to accomodate the model in the available laboratory space. The topography of the upper reservoir is shown in Figure 23. The relative extent of the 1:40 scale partial model of the upper reservoir is indicated in the plan view of the 1:300 scale comprehensive reservoir model in Figure 24. The extent of the 1:40 scale model is indicated by the dashed line. The indicated radial lines and distances were used in the observations of flow patterns. A birds-eye view of the comprehensive model is shown in Figure 25. A close-up view of the 1:300 scale intake structure is shown in Figure 26. The model was made of plywood and was supported by a wooden table. The intake structure was made of clear acrylic plastic.

The 1:300 model was supplied from the laboratory floor storage channel by means of centrifugal pumps and PVC piping. The supply pipe was provided with a calibrated orifice meter and with flow control valves. An air-water manometer was connected to the orifice meter and was used to regulate the flow rates. The centrifugal pump was used during the pumping mode simulations, gravity flow was used to simulate the generating modes. A staff gage was used to measure the water surface elevation in the model.

In summary, the hydraulic models were built and operated to study flows through the intake structure. These flows were best reproduced by satisfying the Euler/Froude criterion. For the laboratory program, the table below lists the appropriate scale ratios which were used in the operation of the models:

	1:40 Scale Model	1:300 Scale Model
Length	1:40	1:300
Velocity	1:6.3	1:17.3
Discharge	1:1790	1:1,557,000
Time	1:6.3	1:17.3

In the prototype the design flow rates were some 18,000 cfs in the generating mode and some 16,000 cfs in the pumping mode. The models were operated to simulate design flow conditions as well as to simulate flow rates above and below design flows. Excessive flow rates were used to test the structure under adverse flow conditions, particularly since it accentuated vortexing in the generating mode of operation. Lower flow rates were used to simulate project operation with only one or two pump/turbines in operation.

IV. Test Procedures

Observations of the flow patterns in the 1:40 scale model of the upper reservoir demonstrated a strong dependency of the flow patterns in the intake structure, especially during generation simulation, on the prevailing flow conditions in the upper reservoir. The inflow into the reservoir through the auxiliary piping was extensively modified through the perforated diffuser pipes, through the expanded metal sections, and through the wooden baffles previously described. The flow modification yielded primarily better flow distributions, considerable reduction of large-scale high-intensity turbulence, and a reduction of reservoir circulation which were a direct consequence of the reservoir inflow from the auxiliary piping system. Ultimately, the 1:300 reservoir model flow patterns were used to "tune" the 1:40 scale reservoir model and representative flow conditions were reproduced in the upper reservoir. At any one time, some adverse flows could be introduced in order to test the performance of the intake structure under adverse conditions and to establish the structure's response characteristic under exaggeratedly adverse flow conditions. Systematic test series were conducted to establish:

a. pressure distributions in the vertical shaft and at the top disk of the intake structure.

b. flow patterns and velocity distributions in the proximity of the intake structure.

c. vortexing at the intake structure.

d. flow rotation in the vertical shaft.

All tests sequences were conducted for pumping and for generating modes and at various conditions of reservoir elevation.

Pressure Measurements. The pressure measuring stations in the vertical shaft are indicated in Figure 27. These stations were designated by the numerals 1 through 7, and their corresponding elevations are shown also in Figure 27. The pressure measuring stations in the top disk are shown in Figure 28. These stations were designated by numbers 8 through 20, and their locations are also shown in Figure 28.

Flow Patterns and Velocity Distributions. Flow patterns were observed both by dye injections and by strategically placed tufts. Generally, the dye injections were useful to indicate prevailing flow patterns through the reservoir. The wire poles which supported the tufts were usually placed either immediately at the edge of the intake structure or they were placed one foot away from the edge (40 feet prototype). The flow patterns were recorded by vector diagrams at the center of each opening and at several different elevations. A typical plan view is shown in Figure 29. The flow patterns were observed for various orientation of the intake structure. Figure 29 shows Pier B (long pier) normal to the embankment. Tests were also conducted with the centerline between Piers A and B normal to the embankment as shown in Figure 30. Similar test sequences were undertaken for varying distances between the intake structure location and the embankment. Figures 29 and 30 show that distance to be some 230 feet. Other tests were made with the intake structure at some 150 feet and 110 feet.

Velocity measurements were made with a midget current meter at the edge of the structure and at a distance some 40 feet (prototype) from the edge. The meter was placed in the center of each opening and velocities were measured at elevations some six feet above the reservoir floor, at mid height of the opening, and at six feet below the roof of the structure. Tufts were used to indicate flow directions. The measuring stations are shown in Figure 30.

Vortexing. Careful attention was given to vortex motions in the reservoir. The vortices were observed for their strengths, for their frequency of occurrence, for their persistence, and for possible air-entrainment. Also, as previously noted, flow rates higher than the design flows were used to accentuate the effects of vortexing at the intake structure. Dye injections and surface dimples were used in these observations.

Flow Rotation. The vortimeter in the vertical shaft was used to observe flow rotation. Dye injections, air injections and tufts were used to assist in these observations.

During some of the tests it appeared that the flow patterns at the intake structure could be improved by installing a splitter wall between the intake structure and the reservoir embankment. In the laboratory models, the splitter wall consisted of thin sections of various lengths and heights. A typical splitter wall is shown in Figure 31.

Except where noted, all results are presented in prototype dimensions.

V. Test Results

All test results reported in this chapter represent repeated test measurements. The results are presented in tabular form and in graphs where appropriate. For each presentation the prevailing pumping rates, operating modes, reservoir elevation and intake structure location are indicated. The test results are organized to present pressure measurements, flow patterns, velocity distributions, vortexing and flow rotation in that order even though the actual testing did not take place completely in that chronological order. All results are in prototype dimensions.

Pressure Measurements

The static pressure measuring stations were indicated in Figure 27 for the vertical shaft and in Figure 28 for the top disk. Test results have shown that the pressures in the system were independent of the variables of location of the structure and were only dependent on flow rates, operating mode and reservoir water surface elevation. Pressure measurements were made during model operation during pumping modes and during generating modes. The typical results are for flow rates of some 16,000 cfs and for some 25,000 cfs, each for pumping and generating and each for a relatively low reservoir level and for a relatively high reservoir level. In Tables 1 through 4, results from generating flows are presented; in Tables 5 through 8, results from pumping tests are presented. The results are from static pressure measurements. They are presented in prototype dimensions and are rounded off to the nearest foot of water to indicate the degree of precision that can be extracted from the test results. The data indicate the location of the hydraulic grade line in the prototype structure. Each set of data can be referenced to the reference piezometer which measured the reservoir elevation only.

Flow Patterns

As was indicated earlier, the comprehensive 1:300 scale model was used primarily to establish appropriate flow patterns in the 1:40 scale model. For the performance evaluation of the models, the generating mode was of considerably more critical importance in terms of flow patterns that might adversely affect the system than was the pumping mode. The pumping mode on the other hand created a general circulation in the upper reservoir as observed in the 1:300 scale model. When the reservoir was allowed to remain inactive as would normally be the case between pumping and generating periods, the circulation diminished sufficiently as to not affect subsequent flow patterns in the generating mode. When, however, the 1:300 model was operated in the generating mode immediately after the pumping period, the prevailing reservoir circulation had a noticable effect on the flow patterns at the intake structure. These flow patterns could then be reproduced in the 1:40 scale model and the effect of reservoir circulation on flow patterns at the intake structure were carefully observed.

As would be expected, near-field flow patterns during pumping were completely dominated by the geometry of the intake structure. Generally, the velocity distributions were symmetrically distributed in the radial directions. However, the flow directions varied dramatically in the vertical. Because of the ogee crest ring, a flow separation occurred near the floor of the intake structure and velocities were directed inward. Above that separation zone the velocities were strongly in the outward direction. Another separation zone appeared above the top disk of the intake structure. At some 40 feet from the structure, Figure 32 indicates some typical flow patterns during pumping operation. The two bottom tufts still point in the inward direction. The two tufts located in the pump jet are strongly in the outward direction. The tufts nearest the water surface are in some places oriented toward the structure and in some places away from the structure, and are located in an unsteady region near the expanding pumping jets issuing from the intake structure. During this experiment the pumping rate was some 25,000 cfs and the reservoir water surface was at elevation 1395 feet. 25,000 cfs represent some 150 per cent of the design flow.

Figure 33 shows another study of the flow direction during pumping. These observations were made at the edge of the intake structure. The pumping rate was some 16,000 cfs or about 100 per cent of design flow. At the edge of the structure all the tufts were in a purely radial direction; the tufts at an equivalent height of six feet above the floor were in the separation zone and were indicative of the reversed flow near the bottom, the tufts at mid-height and at six feet below the top of the structure were definitely in the radially outward direction. The flow patterns during pumping modes as shown in Figures 32 and 33 were typical for all pumping test sequences. Typically, during pumping the geometry of the intake structure was seen to dominate the near-field flow patterns. Geometrical modifications in the reservoir were of no consequence to the resulting flow patterns at the intake structure during pumping.

A radically different condition prevailed during model tests in the generating mode. The flow patterns at the intake structure were dramatically influenced by flow conditions in the model reservoir. A considerable amount of effort was expended to study the effects of model inflow conditions. In the 1:40 scale model, the model's performances were highly influenced by the diffuser pipes and by the baffle system. Many test conditions were investigated in order to minimize the influences which were only typical of the model basin and were not necessarily typical of flow patterns in the prototype reservoir. Since it was clearly a model condition, this suggested improvements of the diffuser pipe design and of the baffle system, and modifications were made and led to progressively improved inflow conditions. Nevertheless some large scale secondary flows and some general circulation patterns persisted in the 1:40 scale model during tests in the generating mode. The installation of a splitter wall between the intake structure and the embankment reduced the secondary flow significantly in the 1:40 scale model. What was not known at that time was whether these reservoir circulation flow patterns were a characteristic of the model basin or whether these flow patterns were intrinsic to the reservoir-intake structure system.

It was then agreed that a comprehensive model of the system should be built and tested. The comprehensive reservoir model was built on a scale of 1:300. The operation of the 1:300 scale reservoir model demonstrated conclusively that strong general circulation about the intake structure was not indegenous to the system and that further modifications of the 1:40 scale reservoir were thus necessitated. The tests with the 1:300 scale reservoir model did however demonstrate that during the pumping mode (filling of the upper reservoir) a weak general circulation resulted in the upper reservoir. If the reservoir was allowed to settle for an equivalent period of some five hours before the generating mode was initiated, that circulation was essentially dissipated and withdrawal from the upper reservoir started with a still reservoir. If, however, the generating mode was initiated immediately after the filling of the upper reservoir had been completed, the initial flow patterns toward the intake structure were weakly asymmetric and some eddying motion persisted for a large portion of the reservoir drawdown period. That particular flow asymmetry was then also introduced into the 1:40 scale upper reservoir model and the resulting flow patterns were studied.

Whereas it was originally helpful in the 1:40 scale model to eliminate or at least to influence the circulation about the intake structure by means of a splitter wall, the splitter wall did little to influence the general reservoir circulation in the 1:300 model, and the splitter wall was similarly ineffective in affecting the asymmetrical inflows to the intake structure. Based on the results from the 1:300 scale model the splitter wall was not required, neither was there any harm in having it installed in case a wall may be desirable as an access to the top of the intake structure.

Among the studies in the 1:40 scale model were investigations of the effects of the structure orientation on the resulting flow patterns. Originally, the structure was oriented with Piers A and B straddled about a line normal to the embankment. Thus Figure 34 shows a typical flow pattern at the structure. The general circulation about the structure was evidenced by the orientation of the tufts in the model. The residual effects of the circulation were still evident by the tuft orientations at the entrances to the structure. When the structure was reoriented with Pier B directly opposite the embankment the resulting flow patterns were not discernably changed. Figure 35 shows typical flow patterns around the reoriented structure. The general circulation was still evident. Both flow patterns shown in Figures 34 and 35 were observed with flow rates of some 150 per cent of design flow and with the reservoir water surface at about 1390 feet.

In the attempts to eliminate the reservoir circulation, various splitter walls were installed in the space between the intake structure and the embankment. The initial splitter wall extended horizontally from the structure to the embankment and rose from the floor to the high water surface elevation. Although this 80-foot high wall appeared to be an implausible solution for the prototype reservoir, the splitter had an exceedingly salutary effect on the flow patterns in the 1:40 scale reservoir model. Figure 36 indicates the effectiveness with which the splitter wall eliminated the circulation about the intake structure. The flow rate was some 150 per cent of the design flow and the reservoir water surface was at 1395 feet. For the same splitter wall and for the same flow rate, but for a reservoir water surface at about 1350 feet the resulting flow patterns are shown in Figure 37. During that particular test sequence some stationary vortices appeared at a distance some 40 feet outside Piers F and I, rotating in opposite directions, which accounted for some of the tuft orientations.

From Figures 34 through 37 it is obvious that a clockwise reservoir circulation prevailed in the 1:40 scale model. In order to test the importance of the circulation on the resulting flow patterns at the intake structure and in the vertical shaft, a strongly anticlockwise circulation was introduced. Figures 38 and 39 show the tuft orientations during these tests. Figure 38 represented inflows at some 150 per cent of the design discharge where the reservoir was at an elevation of 1395 feet, and Figure 39 at a reservoir elevation of some 1350 feet. Pronounced flow separations existed in every bay of the intake structure under these extreme inflow conditions. Nevertheless for all of the above described flow patterns, including the artificially introduced circulations, there were no sufficiently strong prerotations in the vertical shaft which would turn the vortimeter installed there. When, however, the top disk of the structure was removed, strong vortexing was observed over the structure, some air-entrainment did occur, and the vortimeter indicated strongly rotational motion.

It appeared thus that the combination of the piers as flow straighteners and the top disk as a vortex suppressor was effective in preventing air-entrainment and flow prerotation for all conditions investigated. Observations of intermittent vortices were made and are presented later on in this chapter. All of the above tests were made before the 1:300 scale model was built and operated. When the 1:40 scale model was subsequently 'tuned' in order to incorporate the results of tests with the comprehensive reservoir model, all resulting flow patterns were less adverse than those previously investigated. Figure 40 shows typical flow patterns in the 'tuned' 1:40 scale model. The test results shown in Figure 40 were obtained without a splitter wall in the 1:40 scale model.

Velocity Distributions

As was established earlier in the discussion of flow patterns during pumping modes, the velocities near the bottom of the intake structure were directed inward indicating a separated flow region downstream from the ogee crest ring. The velocity distributions at the structure during pumping were not influenced by reservoir modifications. The earlier tests were made in order to establish velocity distributions and were carried out with a short-radius elbow in the model. Later test sequences were made with a long-radius elbow installed. Velocities were generally measured in the plane of the outer rim of the intake structure, in the center of a bay, and at three elevations. These elevations were some six feet above the floor (prototype), at mid-height of the twenty-five foot high entrances (i.e. 12.5 feet), and some six feet below the top of the intake structure. Some velocity measurements were also made at a distance of 40 feet (one foot in the model) from the edge of the structure. The results are presented in tabular form. When a splitter wall is indicated in later test sequences, the wall was terminated at elevation 1342, an elevation equivalent to the elevation of the top of the top disk.

Originally, the structure was located with its center some 230 feet from the toe of the embankment. Subsequently the structure was moved to a distance of some 150 feet, and finally to a distance of some 110 feet from the embankment. Also, as previously reported, different orientations of the structure were investigated. Neither the location of the structure nor its orientation had a significant effect on the velocity distributions during pumping operation, and only minor effects during generation. During generation tests, however, the prevailing reservoir approach flow conditions had a significant influence on the flow patterns.

Table 9 lists the velocity distribution at the edge of the intake structure at design flow during a pumping test sequence. At the time the structure was some 230 feet from the embankment and no splitter wall was installed. Table 10 shows the velocity distribution for some 150 per cent of design flow for geometrical conditions similar to those of Table 9.

Tables 11 and 12 show some early results from tests in the generating mode. The structure was still some 230 feet from the embankment and no splitter vane was installed. Table 11 shows the velocity distribution for a flow rate of some 150 per cent of design flow, and Table 12 shows the velocities for design flow conditions.

The data presented in Tables 9 through 12 were taken with Piers A and B equally off-set. Another test sequence was undertaken with Pier B directly opposite the embankment. Thus, Tables 13 and 14 show pump test data with the structure in the new orientation but still at some 230 feet from the embankment. Again, the pumping flow rates were at design flow (Table 13) and 150 per cent of design flow (Table 14). Tests in the generating modes are summarized in Tables 15, 16 and 17. Table 15 shows the velocities at flow rates of some 150 per cent of design flow and at two different water surface elevations in the reservoir. The apparent differences in the data sets for the different water surface elevations are most likely due to the varying approach flow conditions which were at that time not fully understood or controlled.

The previous results gave rise to experiments with artificially induced strong circulation as shown in Figures 38 and 39, as previously described. The structure was still located some 230 feet from the embankment. In order to indicate the strength of circulation, velocities were also measured some 40 feet from the structure. Tuft orientations showed almost purely tangential motion. Table 18 shows the magnitude of the tangential velocities away from the structure. Table 19 shows the velocities in the rim plane of the structure. Both Table 18 and 19 are for design flow rates. The rather high velocities at the entrance to the structure were a consequence of the severe flow separation at the pier noses and of the concomitant reduction in effective flow cross sections. Tables 20 through 23 are test results for flow rates of 150 per cent of design flow at two different reservoir surface elevations.

The results presented in Tables 18 through 23 are of interest only because they emphasized the significance of approach flow conditions and highlighted the need for better information on realistic motion patterns in the upper reservoir. These results also reinforced the need for a comprehensive reservoir model.

While the debate over the need for a comprehensive model took place, other questions were raised and appropriate test sequences were undertaken in the 1:40 scale model in order to clarify the issues. Principally, two areas of interest came about which required inquiries: one pertained to the prevailing flow patterns and magnitudes of the velocities along the embankment during pumping, the other pertained to the feasibility of moving the intake structure closer to the embankment. The velocities along the embankment were important in the evaluation of embankment stability, and a location of the structure closer to the embankment would reduce the length of the horizontal tunnel and thus could represent a potential saving in project cost. Although these inquiries were carried out simultaneously, for the sake of clarity of presentation the results are presented first in terms of velocities at the intake structure and later in terms of velocities at the embankment.

The original distance from the center of the intake structure to the toe of the embankment was 230 feet. Since the structure's diameter is some 140 feet, the clear distance was 160 feet. At G. B. Dougherty's suggestion the structure was moved to half the clear distance to some 80 feet, and then to half of that or some 40 feet. No adverse conditions were observed at the intermediate distance and it was concluded to collect extensive data in subsequent tests, at the shortest distance only. That distance was then 110 feet from the center of the intake structure to the toe of the embankment.

For pumping tests at the 110-foot location, velocities were measured at the edge of the structure and at a distance some 40 feet away from the structure. Thus, Tables 24 and 25 present velocities for a flow rate equal to the design discharge and for a reservoir elevation of 1355 feet. A low splitter wall was in place (see Figure 31). Tables 26 and 27 are for the same flow rates and for a reservoir elevation of 1395 feet. For a flow rate of 150 per cent of the design discharge, Tables 28 and 29 present the appropriate velocity distributions at a reservoir elevation of 1395 feet, and Tables 30 and 31 present velocities at a reservoir elevation of 1355 feet.

For generating tests at the 110-foot location and for design flow rates, Tables 32 and 33 show the velocity distribution. A low splitter wall was in place. For flow rates of 150 per cent of design flow, Tables 34 and 35 show the velocities when the reservoir was at elevation 1395 feet, and Tables 36 and 37 show the velocities when the reservoir was at elevation 1355 feet.

A final test sequence was conducted after the long radius elbow (R = 90 feet) was installed and after the structure was rotated so as to place Pier A directly opposite the embankment. Again a low splitter wall was in place. These tests were conducted at design flow rates only. For typical pumping tests, Tables 38 and 39 present the velocity distributions when the reservoir was at elevation 1395, and Tables 40 and 41 present velocities when the reservoir was at 1355 feet. For a typical generation test, Tables 42 and 43 present the appropriate velocities.

By that time, too, the comprehensive 1:300 scale reservoir model had been built and tested. When the results of the comprehensive model tests had been obtained, the results were then applied to 'tuning' the 1:40 scale model reservoir. The results thus presented in Tables 38 through 43, although not dramatically different from some other test data, are the most representative results.

Reservoir Embankment Studies

Velocity measurements were also made along the embankment where jet impingement during pumping operation might cause scouring action. For this purpose the midget current meter was placed into a vertical plane intersecting the toe of the embankment and at mid-depth along the embankment. Generally, the pumping jet near the embankment demonstrated eddying motions showing the effect of flow stagnation directly opposite the intake structure, and resulted in strongly oriented flows to the right and to the left along the embankment away from the stagnation region. When the splitter wall was installed, velocity measurements were made immediately adjacent and at both sides of the wall.

Tables 44 and 45 show velocity surveys along the reservoir embankment for pumping rates of 150 per cent of design flow and for reservoir elevations of 1395 feet and 1355 feet. For these test sequences the structure was located 230 feet from the toe of the embankment. For similar test sequences, Tables 46 and 47 show velocity surveys when the structure was located 150 feet from the toe of the embankment. For the preliminary tests summarized in Tables 44 through 47, no splitter wall was installed.

Since the above preliminary results indicated the feasibility of moving the structure closer to the embankment, an extensive series of tests was undertaken in order to establish the velocity distributions near the embankment when the structure was located 110 feet from the toe of the embankment. Also, a splitter wall was installed. Thus, Tables 48 and 49 show the velocity distribution for pumping rates of 150 per cent of design flow and for reservoir elevations of 1395 feet and 1355 feet. For pumping rates at the design flow, Tables 50 and 51 show the corresponding velocities along the embankment.

Then, tests were conducted without the splitter wall. For pumping rates of 150 per cent of design flow and for a reservoir elevation of 1395 feet, Table 52 summarizes the test results. Table 53 shows the results with the reservoir at elevation 1355 feet. In order to define better the decay of the velocities with increasing distances from the structure, a test sequence was carried out and the results summarized in Tables 54 and 55. The velocities in Tables 54 and 55 were measured near the embankment surface at the locations indicated.

Also, a cursory investigation of the effect of the back slope of the spillway crest ring on velocity distributions was made. For this purpose, the original slope as shown in Figure 13 was altered by connecting the crest to the outer edge of the floor with a continuously sloping ramp. This ramp change was made in three continuous openings and velocities were measured in the centrally located opening (IJ). Corresponding velocities were measured at the same time at the opposite opening (CD) in which the original spillway crest geometry was preserved. For pumping rates of 150 per cent of the design flow the comparable velocities are shown in Tables 56 and 57. Similar comparison tests at the design flow rate are summarized in Tables 58 and 59. The results shown in Tables 56 through 59 show essentially that a change in the crest ring ramp will not change the velocity distributions. Visual observations of dye streaks and of debris indicated a different separation zone for the two geometries. Whereas there was no debris accumulation in the separation zones of either spillway crest geometry, there seemed to be a somewhat stronger return flow in the separation zone of the modified entrance structure with gentler ramp slope. Some debris was seen to be carried into the structure along bottom ramps during the pumping mode, only to be then entrained by the pump jets and swept out of the intake structure.

Vortexing at the Intake Structure

The ultimate test of the ability of a hydraulic model to predict prototype vortexing will only be provided by comparing model test data to prototype observations. Such a statement is not intended to negate the usefulness of model data but it is warranted in view of a lack of published model-prototype verification studies. Variously, it has been said that prototype vortices are stronger than those observed in the model, it has been said that the vortices are comparable, and it has been said that prototype vortices are less intense than those observed in models. Most observations as reported in the literature indicated that model and prototype vortices are comparable when the modeling was based on the Froude criterion. The upper reservoir models of the Rocky Mountain Project were operated to satisfy the Froude criterion.

It is often concluded in Froude scaled models which show only swirls and surface dimples, but no air-core vortices, that the prototype structure will also experience only swirls and surface dimples. For this reason strong vortices and air-core vortices are usually deemed undesirable and are eliminated by model modifications. In the test sequences of the Rocky Mountain upper reservoir models, no strongly persistent vortices and no air-core vortices were ever observed.

During the present test program, particularly after the construction of the comprehensive reservoir model, it was possible to eliminate a number of extraneous vortex producing flow patterns in the 1:40 scale model. The extraneous flow patterns could be traced to the diffuser pipe and the baffle system. After appropriate changes, the model tests then included systematic observations of residual vortex types, such as dimples and dye cores. The observations concentrated on vortex type, location and persistence.

In the 1:300 scale model, only a very weak vortex existed and was made visible by dye injection. This vortex was usually seen to occur over the top disk near the edge of the intake structure, generally at piers I and H. At no time was a dye-core vortex formed and drawn into intake structure.

In the 1:40 scale model, the vortexing studies were carried out under various modes of reservoir operation. In order to model the reservoir emptying on an appropriate time scale in the partial reservoir model, the reservoir withdrawal through the intake structure had to be replenished in part by inflow through the diffuser pipe. This diffuser pipe inflow inevitably introduced turbulence and eddying which was not completely dampened out before the flow reached the intake structure. To what degree this turbulence and eddying represented extraneous flow patterns can only be conjectured.

The extraneousness of the induced flow patterns was made evident by the considerably reduced number of dimples and dye-core vortices when the model was operated with lower generating flows and thus with reduced inflows through the diffuser and baffle system. Further emphasis to this conclusion was given by an experiment in which the partial reservoir had filled and then allowed to settle. Subsequently, when the generating mode was simulated without any make-up flow through the diffuser pipe, the dimples and dye-core vortices were essentially absent. The strongest vortex motions in the model tests were always associated with the largest flow rates of make-up water.

Some 23 test runs were made with the 1:40 scale model. All of the tests were in the generating mode. The flow rates varied from some 13,000 cfs to as much as 30,000 cfs. Generally, tests commenced with a full reservoir and were continued to a low reservoir water surface of some 1345 feet. When no make-up water was used, the flow patterns in the 1:40 scale model were most like those observed in the 1:300 scale model. Usually, there was some weak residual circulation without dye-core vortices and without dimples, provided the reservoir had some time to settle. When the reservoir was filled and then emptied without any rest time, there usually existed a general flow across structure due to a clockwise circulation in the reservoir. This cross flow was locally not unlike the asymmetrical approach flow seen in the 1:300 scale model when operated without any rest period. Under these conditions, short-lived dimpled flows and dye-core vortices could be observed in the 1:40 scale model.

Dimpled flows and dye-core vortices existed only intermittently. In the 1:40 scale model the durations were usually less than one minute (real model time). Rarely were there more than two vortices around the structure at one time. Usually, too, vortices were not stationary and drifted along the edge of the intake structure. Even under the worst operating conditions of maximum make-up flow, there were no persistently strong vortices at the intake structure. Under none of the test conditions did the dye-core vortices develop into air-core vortices. When a dye-core vortex has its dye streak extended into intake structure, the dye was seen to disperse rapidly and at no time was a dye-core vortex seen to continue into the transparent transition cone and into the vertical shaft.

Dimpled flows and intermittent dye-core vortices, although never an impediment to the acceptability of the design of the intake structure, were perhaps somewhat more frequent at high reservoir elevations than at low elevations. When the reservoir was drawn down below the roof of the structure, no eddying was observed.

A possibly adverse flow condition was observed when the reservoir had been lowered sufficiently to result in crest controlled flows (critical depth flows). Then the rate of withdrawal from the reservoir, as controlled by the turbines, was in excess of the inflow over the crest ring acting as a circular spillway. At conditions equivalent to full powerhouse operation a considerable amount of air-entrainment resulted and was seen to be swept toward the turbines. At flow rates equivalent to one turbine unit in operation, no air-entrainment into the vertical shaft was observed. The obvious conclusion to be drawn from these observations is that full powerhouse operation cannot be maintained when the reservoir inflow is controlled by the crestring acting as a spillway, and that during emptying of the system for repair or inspection the rate of withdrawal through the powerhouse must be carried out at the lowest practicable rate in order to avoid air-entrainment and to avoid possible damage to the turbine units.

Flow Rotation in Vertical Shaft

A no-pitch vortimeter had been installed in the vertical shaft to observe possible flow rotation. In addition, tufts had been glued into the walls of the transition cone and the transparent section of the vertical shaft. The laboratory arrangements are shown in Figures 18 and 19.

Observations were made both during the pumping mode and during the generating mode, and both with the short-radius elbow and with the long-radius installed in the 1:40 scale model.

Neither the tufts nor the vortimeter indicated any general rotation of the flow. In the model, the vortimeter never rotated continuously and then only a rate of less than one revolution per minute. And just as often, the motion was in opposite directions during the same test sequence.

VI. Conclusions

Hydraulic model tests were conducted on a 1:40 scale model and on a 1:300 scale model of the intake structure of the upper reservoir of the Rocky Mountain Pumped Storage Project. The 1:40 scale model consisted of a carefully constructed replica of the intake structure which was placed into a partial model of the upper reservoir. The 1:300 scale model was a comprehensive model of the reservoir and contained a somewhat simplified intake structure. The models complemented each other in that the general reservoir flow patterns could only be observed in the 1:300 scale model, and detailed flow patterns and their effects on the performance of the intake structure could only be studied in the 1:40 scale model.

Test results from the 1:300 scale model were used to obtain appropriate flow patterns in the 1:40 scale model. The flow patterns in both models as well as their effects on the performance of the intake structure can be summarized as follows:

a. During pumping modes the velocity distributions at the edge of the structure were only a function of the geometry of the structure and of the prevailing rate of pumpage.

b. During generating modes some weak circulatory motion persisted around the entire structure as a consequence of motion patterns in the upper reservoir. This generally weak circulation in the reservoirs was more prevalent when the generating mode was initiated immediately after the pumping mode was terminated. When the reservoir was allowed to rest for an equivalent period of five hours (prototype) the circulation about the structure was imperceptible.

c. A combination of circulatory flows about the structure and of radial inflows resulted in intermittent weak vortices at the edge of the intake structure, predominantly in the north-east quadrant of the structure. In the laboratory these vortices persisted for a time without gathering strength. At no time did these vortices entrain air. Rarely were there more than two vortices active at one time. At no time did these motions result in a sufficiently strong secondary motion in the vertical shaft in order to rotate the vortimeter installed there.

d. Ramp modifications in the intake structure were made by installing a uniformly sloping ramp from the edge of the structure to the crest of the throat section. These geometrical changes did not change the observed motion patterns during generating modes. During the pumping modes, the separation zones at the crest were altered but some debris was seen to be swept onto the sloping ramps of either ramp geometry.

e. The intake structure was tested with a long pier normal to the embankment, with a short pier normal the embankment, and with the center line of an opening normal to the embankment. Either the long pier or the short pier normal to the embankment resulted in more symmetrical flow patterns in the proximity of the structure. Tests with a short-radius elbow and tests with a long-radius elbow at the bottom of the vertical shaft did not result in discernably different flow patterns at the intake structure.

f. In order to further minimize the general circulation about the model intake structure, a splitter wall was installed between the edge of the structure and the embankment. The splitter was a section of plywood. Several elevations were investigated extending the splitter as high as the maximum pool (somewhat impractical in the prototype) and as low as the top of the intake structure (1340 ft.). Generally, all splitter walls reduced the circulation about the structure but did not eliminate the weak vortices which still occurred mostly in a quadrant away from the splitter. After utilization of the 1:300 scale model test results in 'tuning' the approach flow patterns in the 1:40 scale model, there was no obvious need for a splitter wall. At the same time the splitter wall was <u>not</u> creating any adverse flow conditions and such a wall could be employed to provide access to the top disk of the intake structure.

g. Model tests were directed toward locating the intake structure closer to the embankment which would result in a shortening of the horizontal tunnel of the project. The center of the structure was located in these tests at distances of some 230 feet, 150 feet, and 110 feet from the toe of the embankment. Extensive test sequences were made involving pumping modes in order to establish velocity distributions at the embankment and involving generating modes to study potentially adverse flow conditions. These studies were made with and without the splitter walls. No adverse results resulted from moving the structure closer to the embankment during generating modes. During pumping modes the velocities at the embankment increased, as expected, but the resulting local velocities never exceeded some four feet per second at the nearest embankment location and the velocities quickly diminished with increasing distances along the embankment.

h. A location of the structure of 110 feet from its center to the toe of the embankment was carefully investigated and was found to be satisfactory.

i. Static pressure measurements were made in the top disk of the 1:40 scale model. The test results indicated that for a pumping mode at design flow the pressure varied from some two feet (above hydrostatic in prototype) at the center of the top disk to hydrostatic pressure at the outer edge of the disk. For a pump flow rate of some 150 per cent of design flow, the pressure difference varied from five feet at the center to zero at the edge.

During generating modes, the pressures at the top disk were uniformly at hydrostatic pressure with some slight tendency toward negative pressures. The negative pressures extrapolated for model test never exceeded one foot of water (prototype).

In summary, the model tests established that the proposed geometry of the Rocky Mountain Project Upper Reservoir Intake Structure is acceptable. The intake structure should be aligned with one of its piers normal to the embankment. The intake structure can be located with its center as close as 110 feet to the toe of the embankment. The pressure distributions prevailing at the top disk during pumping and generating modes should be incorporated in the design of the structure.

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 1. Pressure Measurements

Q = 15,900 cfs.
Generating Mode
Reservoir Water Surface Elevation = 1346 ft.

Piezometer	Location Elev., ft.	Prototype H.G.L.
1	865	1340
2	935	1340
3	1105	1341
4	1155	1341
5	1230	1343
6	1250	1344
7	1270	1345
8	1340	1346
9	1340	1346
10	1340	1346
11	1340	1346
12	1340	1346
13	1340	1346
14	1340	1346
15	1340	1346
16	1340	1346
17	1340	1346
18	1340	1346
19	1340	1346
20	1340	1346
Reference	1386	1346

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 2. Pressure Measurements

Q = 15,900 cfs.
Generating Mode
Reservoir Water Surface Elevation = 1386 ft.

Piezometer	Location Elev., ft.	Prototype H.G.L.
1	865	1381
2	935	1381
3	1105	1382
4	1155	1382
5	1230	1384
6	1250	1385
7	1270	1385
8	1340	1385
9	1340	1385
10	1340	1385
11	1340	1386
12	1340	1385
13	1340	1385
14	1340	1385
15	1340	1385
16	1340	1385
17	1340	1385
18	1340	1385
19	1340	1385
20	1340	1385
Reference	1386	1386

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 3. Pressure Measurements

Q = 24,600 cfs.
Generating Mode
Reservoir Water Surface Elevation = 1348 ft.

Piezometer	Location Elev., ft.	Prototype H.G.L.
1	865	1333
2	935	1334
3	1105	1335
4	1155	1336
5	1230	1341
6	1250	1343
7	1270	1344
8	1340	1348
9	1340	1348
10	1340	1348
11	1340	1348
12	1340	1348
13	1340	1348
14	1340	1348
15	1340	1348
16	1340	1348
17	1340	1348
18	1340	1348
19	1340	1348
20	1340	1348
Reference	1348	1348

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 4. Pressure Measurements

Q = 24,900 cfs.
Generating Mode
Reservoir Water Surface Elevation = 1392 ft.

Piezometer	Location Elev., ft.	Prototype H.G.L.
1	865	1377
2	935	1378
3	1105	1380
4	1155	1380
5	1230	1385
6	1250	1387
7	1270	1389
8	1340	1391
9	1340	1391
10	1340	1392
11	1340	1392
12	1340	1392
13	1340	1391
14	1340	1392
15	1340	1392
16	1340	1392
17	1340	1392
18	1340	1392
19	1340	1392
20	1340	1392
Reference	1392	1392

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 5. Pressure Measurements

Q = 15,900 cfs.
Pumping Mode
Reservoir Water Surface Elevation = 1347 ft.

Piezometer	Location Elev., ft.	Prototype H.G.L.
1	865	1345
2	935	1345
3	1105	1344
4	1155	1344
5	1230	1345
6	1250	1346
7	1270	1347
8	1340	1347
9	1340	1347
10	1340	1348
11	1340	1350
12	1340	1348
13	1340	1347
14	1340	1347
15	1340	1347
16	1340	1347
17	1340	1348
18	1340	1348
19	1340	1347
20	1340	1347
Reference	1347	1347

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 6. Pressure Measurements

Q = 15,900 cfs.
Pumping Mode
Reservoir Water Surface Elevation = 1395 ft.

Piezometer	Location Elev., ft.	Prototype H.G.L.
1	865	1393
2	935	1393
3	1105	1392
4	1155	1392
5	1230	1393
6	1250	1394
7	1270	1395
8	1340	1395
9	1340	1395
10	1340	1396
11	1340	1397
12	1340	1396
13	1340	1395
14	1340	1395
15	1340	1395
16	1340	1395
17	1340	1396
18	1340	1396
19	1340	1395
20	1340	1395
Reference	1395	1395

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 7. Pressure Measurements

Q = 24,900 cfs.
Pumping Mode
Reservoir Water Surface Elevation = 1347 ft.

Piezometer	Location Elev., ft.	Prototype H.G.L.
1	865	1340
2	935	1341
3	1105	1340
4	1155	1340
5	1230	1343
6	1250	1344
7	1270	1346
8	1340	1347
9	1340	1347
10	1340	1350
11	1340	1353
12	1340	1349
13	1340	1347
14	1340	1347
15	1340	1347
16	1340	1347
17	1340	1350
18	1340	1350
19	1340	1347
20	o340	1347
Reference	1347	1347

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 8. Pressure Measurements

Q = 24,900 cfs.
Pumping Mode
Reservoir Water Surface Elevation = 1378 ft.

Piezometer	Location Elev., ft.	Prototype H.G.L.
1	865	1371
2	935	1371
3	1105	1370
4	1155	1370
5	1230	1373
6	1250	1375
7	1270	1376
8	1340	1377
9	1340	1378
10	1340	1381
11	1340	1383
12	1340	1380
13	1340	1377
14	1340	1377
15	1340	1377
16	1340	1377
17	1340	1381
18	1340	1380
19	1340	1377
20	1340	1377
Reference	1378	1378

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 9. Velocity Distributions at Intake Strucutre
Pumping Mode
Q = 15,900 cfs
Reservoir Elevation = 1,355 ft MSL
Structure at 230 feet from Embankment

Station	Top*	Middle*	Bottom*
AB	3.4	0.5	- 0.2
BC	3.4	0.6	- 0.2
CD	4.2	0.7	- 0.1
DE	3.6	0.8	- 0.2
EF	3.5	0.5	- 0.2
FG	3.5	0.5	0
GH	4.5	0.7	0
HI	4.2	0.4	- 0.3
IJ	3.7	0.5	- 0.2
JK	3.0	0.4	- 0.2
KL	3.3	0.4	- 0.2
LA	4.3	0.6	- 0.3

*Top = 70" below top
Middle = Midheight
Bottom = 70" from floor

All measurements in plane of rim

+ = velocity in outward direction
- = velocity in inward direction
± = unsteady flow

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 10. Velocity Distributions at Intake Structure
Pumping Mode
Q = 24,600 cfs
Reservoir Elevation = 1,355 ft MSL
Structure at 230 feet from Embankment

Station	Velocities, feet per second		
	Top*	Middle*	Bottom*
AB	5.9	± 1.2	-1.1
BC	5.6	± 1.5	- .9
CD	6.5	± 1.4	- .9
DE	5.9	± 1.6	-1.1
EF	5.8	± 1.5	- .6
FG	5.7	± 1.5	- .7
GH	6.2	± 1.4	- .6
HI	7.4	± 1.4	- .8
IJ	5.5	± 1.5	- .9
JK	4.8	± 1.6	-1.1
KL	5.8	± 1.6	-0.6
LA	6.4	± 1.3	- .8

*Top = 70" below top
Middle = Midheight
Bottom = 70" from floor

All measurements in plane of rim.

+ = velocity in outward direction
− = velocity in inward direction
± = unsteady flow

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Spillway Model

Table 11. Velocity Distributions at Intake Structure
Generating Mode
Q = 24,500 cfs
Reservoir Elevation = 1,360 ft MSL
Structure at 230 feet from Embankment

Station	Velocities, feet per second		
	Top*	Middle*	Bottom*
AB	1.3	1.5	1.4
BC	1.5	1.4	1.4
CD	1.4	1.6	1.4
DE	1.7	1.5	1.1
EF	1.7	1.5	1.3
FG	1.5	1.4	1.5
GH	1.2	1.5	1.9
HI	1.9	1.4	1.6
IJ	2.0	1.6	1.4
JK	1.9	1.6	1.4
KL	1.7	1.5	1.2
LA	1.7	1.6	1.2

*Top = 70" from top
Middle = Midheight
Bottom = 70" from floor

All measurements are in plane of rim.

All velocities are in inward direction.

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 12. Velocity Distributions at Intake Structure
Generating Mode
Q = 15,900 cfs
Reservoir Elevation = 1,355 ft MSL
Structure at 230 feet from Embankment

Station	Velocities, feet per second		
	Top*	Middle*	Bottom*
AB	1.2	1.1	0.7
BC	1.1	1.1	0.8
CD	1.3	1.1	0.8
DE	1.2	1.1	0.9
EF	1.3	1.1	0.9
FG	1.1	1.0	0.9
GH	1.2	1.1	1.1
HI	1.9	1.0	0.8
IJ	1.4	1.4	0.8
JK	1.3	1.1	0.8
KL	1.3	1.0	0.8
LA	1.3	1.2	0.8

*Top = 70" below top
Middle = Midheight
Bottom = 70" from floor

All measurements in plane of rim.

All velocities are in inward direction

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 13. Velocity Distributions at Intake Structure
Pumping Mode
Q = 15,900 cfs
Reservoir Elevation = 1,390 ft MSL
Structure at 230 feet from Embankment

Station	Velocities, feet per second		
	Top*	Middle*	Bottom*
AB	3.9	± .4	-1.5
BC	4.3	± .4	-1.5
CD	4.1	± .8	-1.3
DE	3.8	± .8	-1.2
EF	4.2	± .7	-1.2
FG	3.5	± .6	-1.5
GH	3.6	± .4	-1.2
HI	3.6	± .4	-1.1
IJ	3.2	± .7	- .9
JK	3.1	± .7	-1.3
KL	3.7	± .6	-1.3
LA	3.8	± .5	-1.0

*Top = 70" below top
Middle = Midheight
Bottom = 70" from floor

All measurements in plane of rim

+ = velocity in outward direction
- = velocity in inward direction
± = unsteady flow

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 14 . Velocity Distributions at Intake Structure
Pumping Mode
Q = 24,900 cfs
Reservoir Elevation = 1,395 ft MSL
Structure at 230 feet from Embankment

Station	Velocities, feet per second		
	Top*	Middle*	Bottom*
AB	6.3	1.6	-1.8
BC	6.7	±1.6	-1.7
CD	6.9	1.9	-2.2
DE	6.3	1.8	-1.8
EF	6.4	1.8	-1.7
FG	6.2	1.9	-1.9
GH	6.7	1.6	2.1
HI	6.0	1.6	-2.0
IJ	5.8	1.2	-2.3
JK	6.1	1.3	-2.2
KL	5.8	1.4	-2.4
LA	6.5	1.4	-2.1

*Top = 70" below top
Middle = Midheight
Bottom = 70" from floor

All measurements in plane of rim

+ = velocity in outward direction
- = velocity in inward direction
± = unsteady flow

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 15 . Velocity Distributions at Intake Structure
Generating Mode
Q = 15,900 cfs
Reservoir Elevation = 1,395 ft. MSL
Structure at 230 feet from Embankment

Station	Velocities, feet per second		
	Top*	Middle*	Bottom*
AB	1.1	1.3	1.3
BC	1.5	1.8	1.7
CD	1.6	1.8	1.6
DE	1.5	1.6	1.4
EF	1.3	1.3	1.2
FG	1.3	1.3	1.2
GH	1.3	1.4	1.3
HI	1.2	1.4	1.2
IJ	1.0	1.3	1.2
JK	1.1	1.2	1.1
KL	1.2	1.2	1.1
LA	1.3	1.1	1.1

*Top = 70" below top
Middle = Midheight
Bottom = 70" from floor

All velocities are in inward direction, in plane of rim.

All measurements are in plane of rim.

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 16. Velocity Distributions at Intake Structure
Generating Mode
Q = 24,900 cfs
Reservoir Elevation = 1,354 ft. MSL
Structure at 230 feet from Embankment

Station	Velocities, feet per second		
	Top*	Middle*	Bottom*
AB	2.0	1.9	1.7
BC	1.8	2.0	1.7
CD	1.9	1.9	1.7
DE	2.0	2.0	1.8
EF	2.3	2.1	1.8
FG	1.9	1.9	1.7
GH	1.8	2.0	1.6
HI	1.8	1.9	1.6
IJ	2.0	2.1	1.5
JK	2.0	2.0	1.7
KL	2.1	1.9	1.7
LA	2.2	2.0	1.8

*Top = 70" below top
Middle = Midheight
Bottom = 70" from floor

All velocities are in inward direction, in plane of rim.

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 17 . Velocity Distributions at Intake Structure
Generating Mode
Q = 24,600 cfs
Reservoir Elevation = 1,395 ft. MSL
Structure at 230 feet from Embankment

Station	Velocities, feet per second		
	Top*	Middle*	Bottom*
AB	2.3	2.7	2.4
BC	2.6	2.6	2.7
CD	2.7	2.5	2.3
DE	2.2	2.1	1.9
EF	2.2	1.7	1.8
FG	2.2	1.8	1.9
GH	2.2	2.0	1.8
HI	2.1	2.1	1.9
IJ	2.1	2.0	1.8
JK	2.0	1.8	1.7
KL	2.1	2.1	1.8
LA	2.1	2.0	1.8

* Top = 70" below top
Middle = Midheight
Bottom = 70" from floor

All measurements are in plane of rim.

All velocities are in inward direction.

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 18. Velocity Distributions at Intake Structure
Generating Mode
Q = 15,900 cfs
Reservoir Elevation = 1,355 ft MSL
Structure at 230 feet from Embankment

Station — Velocities, feet per second
(under conditions of induced circulation)

	Top*	Middle*	Bottom*
AB		4.8	
BC		5.7	
CD		6.1	
DE		4.2	
EF		4.4	
FG		4.2	
GH		4.4	
HI		3.2	
IJ		4.2	
JK		3.6	
KL		3.0	
LA		4.2	

*Top = 70" below top
Middle = Midheight
Bottom = 70" from floor

All measurements in plane forty feet from structure

For vector orientation see Figure 38

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

TABLE 19. Velocity Distributions at Intake Structure
Generating Mode
Q = 15,900 cfs
Reservoir Elevation = 1,355 ft MSL
Structure at 230 feet from Embankment

Station — Velocities, feet per second
(under conditions of induced circulation)

Station	Top*	Middle*	Bottom*
AB	5.3	6.7	6.7
BC	5.3	7.6	7.4
CD	3.2	5.9	7.4
DE	3.4	3.6	2.7
EF	2.2	0.8	1.9
FG	1.7	3.4	3.0
GH	3.9	4.8	4.8
HI	4.6	4.4	5.5
IJ	4.7	5.9	4.8
JK	4.2	5.1	4.8
KL	4.1	4.8	4.4
LA	5.1	6.1	5.5

*Top = 70" below top
Middle = Midheight
Bottom = 70" from floor

All measurements in plane of rim.

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

TABLE 20. Velocity Distributions at Intake Structure
Generating Mode
Q = 24,300 cfs
Reservoir Elevation = 1,395 ft MSL
Structure at 230 feet from Embankment

Station — Velocities, feet per second
(under conditions of induced circulation)

Station	Top*	Middle*	Bottom*
AB		3.1	
BC		3.7	
CD		1.8	
DE		1.2	
EF		4.2	
FG		3.2	
GH		3.4	
HI		3.3	
IJ		3.4	
JK		2.8	
KL		2.7	
LA		2.4	

*Top = 70" below top
Middle = Midheight
Bottom = 70" from floor

All measurements in plane forty feet from structure

For vector orientation see Figure 39.

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

TABLE 21. Velocity Distributions at Intake Structure
Generating Mode
Q = 24,338 cfs
Reservoir Elevation = 1,395 ft MSL
(under conditions of induced circulation)

Station Velocities, feet per second

	Top*	Middle*	Bottom*
AB	5.0	4.4	4.4
BC	5.4	3.8	5.1
CD	6.0	1.6	3.5
DE	2.2	2.4	2.2
EF	3.0	3.0	3.3
FG	3.2	3.3	3.0
GH	3.7	3.9	4.2
HI	4.2	4.3	4.6
IJ	4.0	4.4	4.4
JK	3.9	4.4	4.5
KL	5.1	4.0	4.1
LA	4.7	3.8	4.3

*Top = 70" below top
Middle = Midheight
Bottom = 70" from floor

All measurements in plane of rim.

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

TABLE 22. Velocity Distributions at Intake Structure
Generating Mode
Q = 24,600 cfs
Reservoir Elevation = 1,348 ft MSL
Structure at 230 feet from Embankment

Station — Velocities, feet per second (under conditions of induced circulation)

	Top*	Middle*	Bottom*
AB		8.9	
BC		8.6	
CD		10.4	
DE		10.3	
EF		10.2	
FG		8.4	
GH		8.6	
HI		8.4	
IJ		7.6	
JK		5.9	
KL		6.3	
LA		7.1	

*Top = 70" below top
Middle = Midheight
Bottom = 70" from floor

All measurements in plane forty feet from structure

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 23. Velocity Distributions at Intake Structure
Generating Mode
Q = 24,600 cfs
Reservoir Elevation = 1,348 ft MSL
Structure at 230 feet from Embankment

Station	Velocities, feet per second (under conditions of induced circulation)		
	Top*	Middle*	Bottom*
AB	8.4	12.6	12.2
BC	11.0	12.0	15.2
CD	7.8	13.1	14.1
DE	6.5	7.0	12.0
EF	4.7	8.6	11.8
FG	5.1	5.5	11.6
GH	6.5	9.3	12.2
HI	7.4	9.7	11.0
IJ	8.6	10.5	11.2
JK	6.7	8.6	9.3
KL	8.4	9.1	9.7
LA	8.0	11.2	11.2

*Top = 70" below top
Middle = Midheight
Bottom = 70" from floor

All measurements in plane of rim.

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 24. Velocity Distributions at Intake Structure
Pumping Mode
Q = 16,000 cfs
Reservoir Elevation = 1,355 ft MSL
Structure at 230 feet from Structure
Splitter wall in place

Station	Velocities, feet per second		
	Top*	Middle*	Bottom*
AB	4.3	±1.0	-0.8
BC	4.6	±0.8	-0.6
CD	4.2	±0.8	-0.6
DE	4.0	±0.7	-0.7
EF	4.3	±0.7	-0.5
FG	4.5	±0.7	-0.7
GH	4.7	±0.7	-0 4
HI	4.2	±0.6	-0.4
IJ	3.6	±0.7	-0.4
JK	3.8	±1.0	-0.4
KL	4.1	±1.0	-0.7
LA	4.3	±1.6	-0.6

*Top = 70" below top
Middle = Midheight
Bottom = 70" from floor

All measurements are in plane of rim.

+ = velocity in outward direction
- = velocity in inward direction
± = unsteady flow

See Figure 31 for definition sketch of splitter wall.

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 25. Velocity Distributions at Intake Structure
Pumping Mode
Q = 16,000 cfs
Reservoir Elevation = 1,355 ft MSL
Structure at 230 feet from Embankment
Splitter wall in place

Station	Velocities, feet per second		
	Top*	Middle*	Bottom*
AB		±1.5	
BC		±0.8	
CD		±0.7	
DE		±0.5	
EF		±0.7	
FG		±0.5	
GH		±0.4	
HI		±1.1	
IJ		±0.7	
JK		±0.8	
KL		±1.3	
LA		±1.6	

*Top = 70" below top
Middle = Midheight
Bottom = 70" from floor

All measurements are 40 feet outside plane of rim.

See Figure 31 for definition sketch of splitter wall.

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 26. Velocity Distributions at Intake Structure
Pumping Mode
Q = 16,000 cfs
Reservoir Elevation = 1,395 ft MSL
Structure at 230 feet from Embankment
Splitter wall in place

Station	Velocities, feet per second		
	Top*	Middle*	Bottom*
AB	4.3	1.0	-1.4
BC	4.3	1.2	-1.0
CD	4.0	1.2	-1.8
DE	3.8	1.1	-1.8
EF	4.4	0.8	-1.6
FG	4.6	1.3	-1.7
GH	4.1	0.8	-1.8
HI	4.2	0.7	-1.8
IJ	3.3	0.7	-1.7
JK	4.1	1.0	-1.1
KL	4.4	1.1	-1.2
LA	4.2	1.3	-1.8

*Top = 70" below top
Middle = Midheight
Bottom = 70" from floor

All measurements are in plane of rim.

+ = velocities in outward direction
- = velocities in inward direction
± = unsteady flow

See Figure 31 for definition sketch of splitter wall.

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 27. Velocity Distributions at Intake Structure
Pumping Mode
Q = 16,000 cfs
Reservoir Elevation = 1,395 ft MSL
Structure at 230 feet from Embankment
Splitter wall in place

Station	Velocities, feet per second		
	Top*	Middle*	Bottom*
AB		±3.0	
BC		±3.6	
CD		±3.4	
DE		±1.5	
EF		±1.9	
FG		±2.1	
GH		±3.2	
HI		±1.2	
IJ		±2.2	
JK		±3.1	
KL		±3.2	
LA		±3.7	

*Top = 70" below top
Middle = Midheight
Bottom = 70" from floor

All measurements are 40 feet outside plane of rim.

See Figure 31 for definition sketch of splitter wall.

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 28. Velocity Distributions at Intake Structure
Pumping Mode
Q = 24,900 cfs
Reservoir Elevation = 1,395 ft MSL
Structure at 230 feet from Embankment
Splittre wall in place

Station	Velocities, feet per second		
	Top*	Middle*	Bottom*
AB	4.3	±1.7	-1.3
BC	6.6	±1.8	-1.8
CD	6.7	±1.8	-2.1
DE	5.1	±1.8	-2.2
EF	6.3	±1.6	-2.6
FG	6.8	±1.4	-2.1
GH	7.1	±1.5	-2.8
HI	6.1	±1.5	-3.1
IJ	5.6	±1.5	-2.1
JK	6.2	±1.5	-1.7
LA	7.0	±1.9	-2.4

*Top = 70" from top
Middle = Midheight
Bottom = 70" from floor

All measurements are in plane of rim.

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 29. Velocity Distributions at Intake Structure
Pumping Mode
Q = 24,900 cfs
Reservoir Elevation = 1,395 ft MSL
Structure at 230 feet from Embankment
Splitter wall in place

Station — Velocities, feet per second

Station	Top*	Middle*	Bottom*
AB		±5.4	
BC		±5.6	
CD		±6.0	
DE		±4.3	
EF		±2.5	
FG		±5.3	
GH		±4.8	
HI		±4.2	
IJ		±4.5	
JK		±6.5	
KL		±5.5	
LA		±5.6	

*Top = 70" from top
Middle = Midheight
Bottom = 70" from floor

All measurements are 40 feet outside plane of rim.

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 30. Velocity Distributions at Intake Structure
Pumping Mode
Q = 24,900 cfs
Reservoir Elevation = 1,355 ft MSL
Structure at 230 feet from Embankment
Splitter wall in place

Station	Velocities, feet per second		
	Top*	Middle*	Bottom*
AB	6.9	±1.9	-1.9
BC	6.3	±1.7	-1.7
CD	6.3	±2.0	-1.7
DE	5.5	±1.6	-1.7
EF	6.0	±1.6	-1.4
FG	6.8	±1.4	-1.6
GH	6.1	±1.4	-1.4
HI	6.2	±1.5	-1.4
IJ	5.7	±1.4	-1.4
JK	5.6	±1.7	-1.6
KL	6.2	±1.7	-1.8
LA	6.4	±1.4	-1.5

*Top = 70" from top
Middle = Midheight
Bottom = 70" from floor

All measurements are in plane of rim.

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 31. Velocity Distributions at Intake Structure
Pumping Mode
Q = 24,900 cfs
Reservoir Elevation = 1,355 ft MSL
Structure at 230 feet from Embankment
Splitter wall in place

Station	Velocities, feet per second		
	Top*	Middle*	Bottom*
AB		±2.2	
BC		±1.7	
CD		±1.5	
DE		±1.8	
EF		±1.3	
FG		±1.6	
GH		±1.8	
HI		±1.5	
IJ		±1.7	
JK		±1.3	
KL		±1.8	
LA		±2.6	

*Top = 70" from top
Middle = Midheight
Bottom = 70" from floor

All measurements are 40 feet outside plane of rim.

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 32. Velocity Distributions at Intake Structure
Generating Mode
Q = 16,000 cfs
Reservoir Elevation = 1,395 ft MSL
Structure at 110 feet from Embankment
Splitter wall in place

Station	Velocities, feet per second		
	Top*	Middle*	Bottom*
AB	1.4	1.6	1.0
BC	1.6	1.3	1.1
CD	1.5	1.6	1.4
DE	1.4	1.3	1.2
EF	1.2	1.1	1.0
FG	1.3	1.1	1.1
GH	1.2	1.1	1.2
HI	1.2	1.2	1.1
IJ	1.3	1.4	1.3
JK	1.1	1.2	1.1
KL	1.2	1.2	1.0
LA	1.6	1.3	1.3

*Top = 70" from top
Middle = Midheight
Bottom = 70" from floor

All measurements are in plane of rim.

All velocities are in inward direction

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 33. Velocity Distributions at Intake Structure
Generating Mode
Q = 16,000 cfs
Reservoir Elevation = 1,395 ft MSL
Structure at 110 feet from Embankment
Splitter wall in place

Station	Velocities, feet per second		
	Top*	Middle*	Bottom*
AB		0.2	
BC		0.4	
CD		1.0	
DE		1.0	
EF		0.2	
FG		0	
GH		0.6	
HI		0.5	
IJ		0.9	
JK		0.4	
KL		0.4	
LA		0.6	

*Top = 70" from top
Middle = Midheight
Bottom = 70" from floor

All measurements are 40 feet outside the plane of rim.

All velocities are in inward direction

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 34. Velocity Distributions at Intake Structure
Generating Mode
Q = 24,600 cfs
Reservoir Elevation = 1,395 ft MSL
Structure at 110 feet from Embankment
Splitter wall in place

Station	Velocities, feet per second		
	Top*	Middle*	Bottom*
AB	2.3	2.4	2.3
BC	2.3	2.4	1.9
CD	2.5	2.5	2.3
DE	2.0	2.0	1.9
EF	2.3	1.9	1.9
FG	2.1	2.0	1.8
GH	2.3	1.9	2.0
HI	2.3	2.2	2.1
IJ	2.2	2.2	2.1
JK	2.0	2.0	1.9
KL	2.0	2.4	2.2
LA	2.4	1.9	2.0

*Top = 70" from top
Middle = Midheight
Bottom = 70" from floor

All measurements are in plane of rim.

All velocities are in inward direction

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 35. Velocity Distributions at Intake Structure
Generating Mode
Q = 24,600 cfs
Reservoir Elevation = 1,395 ft MSL
Structure at 110 feet from Embankment
Splitter wall inplace

Station	Velocities, feet per second		
	Top*	Middle*	Bottom*
AB		.8	
BC		1.1	
CD		1.7	
DE		1.6	
EF		1.0	
FG		.5	
GH		.5	
HI		.7	
IJ		1.3	
JK		1.2	
KL		.5	
LA		.7	

*Top = 70" below top
Middle = Midheight
Bottom = 70" from floor

All measurements in plane forty feet from structure

All velocities are in inward direction

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 36. Velocity Distributions at Intake Structure
Generating Mode
Q = 24,900 cfs
Reservoir Elevation = 1,355 ft MSL
Structure at 110 feet from Embankment
Splitter wall in place

Station	Velocities, feet per second		
	Top*	Middle*	Bottom*
AB	2.5	1.9	2.2
BC	2.3	2.2	1.8
CD	2.0	1.9	1.9
DE	2.2	2.2	2.2
EF	2.3	2.2	2.1
FG	2.1	2.1	1.7
GH	2.0	1.7	2.0
HI	2.1	1.9	1.8
IJ	2.3	1.9	1.9
JK	2.2	2.1	2.0
KL	2.4	2.0	1.8
LA	2.5	2.2	2.0

*Top = 70" below top
Middle = Midheight
Bottom = 70" from floor

All measurements are in plane of rim.

All velocities are in inward direction

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 37. Velocity Distributions at Intake Structure
Generating Mode
Q = 24,900 cfs
Reservoir Elevation = 1,355 ft MSL
Structure at 110 feet from Structure
Splitter wall in place

Station	Velocities, feet per second		
	Top*	Middle*	Bottom*
AB		.8	
BC		1.0	
CD		1.1	
DE		1.5	
EF		1.5	
FG		.8	
GH		.4	
HI		.2	
IJ		.6	
JK		1.4	
KL		1.0	
LA		1.0	

*Top = 70" below top
Middle = Midheight
Bottom = 70" from floor

All measurements in plane forty feet from structure

All velocities are in inward direction

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 38. Velocity Distributions at Intake Structure
Pumping Mode
Q = 16,000 cfs
Reservoir Elevation = 1,395 ft MSL

Station	Velocities, feet per second		
	Top*	Middle*	Bottom*
AB	4.0	±1.1	-1.4
BC	4.3	±1.3	-1.6
CD	4.2	±1.2	-1.5
DE	4.0	±1.2	-1.6
EF	5.0	±1.1	-1.6
FG	5.1	±1.3	-1.7
GH	5.1	±1.3	-1.5
HI	5.0	±1.5	-2.1
IJ	3.8	±1.2	-1.8
JK	4.7	±1.4	-1.4
KL	4.1	±1.1	-1.4
LA	4.1	±1.3	-2.0

*Top = 70" below top
Middle = Midheight
Bottom = 70" from floor

All measurements in plane of rim.

Toe distance 110 feet to center; splitter wall in place;
Pier "A" in line with splitter; long radius elbow in model

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 39. Velocity Distributions at Intake Structure
Pumping Mode
Q = 16,000 cfs
Reservoir Elevation = 1,395 ft MSL

Station	Velocities, feet per second		
	Top*	Middle*	Bottom*
AB		±2.6	
BC		±3.4	
CD		±2.4	
DE		±3.2	
EF		±3.5	
FG		±2.7	
GH		±4.5	
HI		±3.8	
IJ		±3.4	
JK		±3.0	
KL		±3.1	
LA		±2.6	

*Top = 70" below top
Middle = Midheight
Bottom = 70" from floor

All measurements in plane 40 feet out from rim.

Toe distance 110 feet to center; splitter wall in place;
Pier "A" in line with splitter; long radius elbow in model

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 40. Velocity Distributions at Intake Structure
Pumping Mode
Q = 16,000 cfs
Reservoir Elevation = 1,355 ft MSL

Station	Velocities, feet per second		
	Top*	Middle*	Bottom*
AB	4.2	±1.2	-1.0
BC	5.3	±1.2	-0.8
CD	4.2	±1.0	-1.0
DE	4.0	±0.7	-0.7
EF	4.8	±0.8	-0.4
FG	4.4	±0.6	-0.6
GH	5.3	±0.7	-0.3
HI	5.0	±1.3	-0.4
IJ	3.9	±1.1	-0.7
JK	4.0	±1.0	-0.4
KL	4.1	±0.8	-0.6
LA	3.7	±0.8	-1.0

Toe distance 110 to center; splitter wall in place;
Pier "A" in line with splitter; long radius elbow in model

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 41. Velocity Distributions at Intake Structure
Pumping Mode
Q = 16,000 cfs
Reservoir Elevation = 1,355 ft MSL

Station	Velocities, feet per second		
	Top*	Middle*	Bottom*
AB		±1.4	
BC		±1.0	
CD		±0.7	
DE		±0.4	
EF		±0.8	
FG		±0.6	
GH		±0.6	
HI		±1.0	
IH		±0.5	
JK		±0.8	
KL		±1.2	
LA		±1.2	

*Middle = Midheight

All measurements in plane 40 feet from rim.

Toe distance 110 to center; splitter wall in place;
Pier "A" in line with splitter; long radius elbow in model

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 42. Velocity Distributions at Intake Strucutre
Generating Mode
Q = 16,000 cfs
Reservoir Elevation = 1,355 ft MSL

Station	Velocities, feet per second		
	Top*	Middle*	Bottom*
AB	1.2	1.2	0.7
BC	1.1	1.0	1.0
CD	1.4	1.4	1.3
DE	1.3	1.2	1.1
EF	1.2	1.2	1.1
FG	1.1	1.1	1.0
GH	1.1	1.1	1.2
HI	1.2	1.2	1.1
IJ	1.3	1.4	1.2
JK	1.3	1.2	1.0
KL	1.5	1.3	1.2
LA	1.2	1.2	1.2

*Top = 70" below top
Middle = Midheight
Bottom = 70" from floor

All measurements in plane of rim.

Toe distance 110 feet to center; splitter wall in place;
Pier "A" in line with splitter; long radius elbow in model

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 43. Velocity Distributions at Intake Structure
Generating Mode
Q = 16,000 cfs
Reservoir Elevation - 1355 ft MSL

Station	Velocities, feet per second		
	Top*	Middle*	Bottom*
AB		0	
BC		0	
CD		0.7	
DE		0.4	
EF		0	
FG		0	
GH		0	
HI		0.1	
IJ		0.5	
JK		0.5	
KL		0.7	
LA		0	

*Top = 70" below top
Middle = Midheight
Bottom = 70" from floor

All measurements in plane 40 feet from rim.

Toe distance 110 feet to center; splitter wall in place;
Pier "A" in line with splitter; long radius elbow in model

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 44. Velocities Near Reservoir Embankment (fps)
Pumping Mode
Q = 24,900 cfs
Reservoir Elevation = 1,395 ft MSL

Location	10' Above Floor	Mid-Depth	30' Above Floor
A) Toe Plane*			
160' to right	2.0 (R)	0.4	-1.2
Centerline	2.5 (R)	0.6	-0.9
160' to left	1.9 (R)	±0.6	1.3 (L)
B) Mid-Bank**			
160' to right		0.6(R)	
Centerline		-0.5	
160' to left		0.6(L)	

*Distance from toe of embankment to center of intake structure 230 feet.

**Embankment slope 1:2; mid-bank distance from center of intake structure 310 feet.

(+) values are velocities towards embankment.
(R) values are velocities to right facing embankment.
(L) values are velocities to left facing embankment.

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 45. Velocities Near Reservoir Embankment (fps)
Pumping Mode
Q = 24,900 cfs
Reservoir Elevation = 1,355 ft MSL

Location	10' Above Floor	Mid-Depth	30' Above Floor
A) Toe Plane*			
160' to right	-0.5	-0.4	0.8(R)
Centerline	-1.1	-0.8	1.1
160' to left	-0.5	-0.7	0.8(L)
B) Mid-Bank**			
160' to right		0.9(R)	
Centerline		-0.5	
160' to left		1.4(L)	

*Distance from toe of embankment to center of intake structure 230 feet.

**Embankment slope 1:2; mid-bank distance from center of intake structure 270 feet.

(+) values are velocities towards embankment.
(R) values are velocities to right facing embankment.
(L) values are velocities to left facing embankment.

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 46. Velocities Near Reservoir Embankment (fps)
Pumping Mode
Q = 24,900 cfs
Reservoir Elevation = 1,395 ft MSL

Location	10' Above Floor	Mid-Depth	30' Above Floor
A) Toe Plane*			
160' to right	2.7(R)	±0.6	-0.9
Centerline	2.7	0.7	-1.5
160' to left	2.3(L)	0.5	-1.3
B) Mid-Bank**			
160' to right		-0.9(R)	
Centerline		-0.9	
160' to left		1.3(L)	

*Distance from toe of embankment to center of intake structure 150 feet.

**Embankment slope 1:2; mid-bank distance from center of intake structure 230 feet.

(+) values are velocities towards embankment.
(R) values are velocities to right facing embankment.
(L) values are velocities to left facing embankment.

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 47. Velocities Near Reservoir Embankment (fps)
Pumping Mode
Q = 24,900 cfs
Reservoir Elevation = 1,355 ft MSL

Location	10' Above Floor	Mid-Depth	30' Above Floor
A) Toe Plane*			
160' to right	-1.2	-1.1	2.5(R)
Centerline	-1.7	1.5	3.7
160' to left	2.1(L)	-2.0	-1.8
B) Mid-Bank**			
160' to right		2.2 (R)	
Centerline		2.2	
160' to left		1.7 (L)	

*Distance from toe of embankment to center of intake structure 150 feet.

**Embankment slope 1:2; mid-bank distance from center of intake structure 190 feet.

(+) values are velocities towards embankment.
(R) values are velocities to right facing embankment.
(L) values are velocities to left facing embankment.

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 48. Velocities Near Reservoir Embankment (fps)
Pumping Mode
Q = 24,900 cfs
Reservoir Elevation = 1,395 ft MSL

Location	10' Above Floor	Mid-Depth	30' Above Floor
A) Toe Plane*			
160' to right	2.3(R)	0.7(L)(R)	-1.2
80' to right	2.4(R)	-1.0(R)	-0.8
Centerline to right	4.1	1.2(R)	2.0(R)
Centerline to left	3.7	1.3	1.2(R)
80' to left	3.5	0.7(R)	-1.4
160' to left	3.1(L)	0.8(R)	-1.1(L)
B) Mid-Bank**			
160' to right	-1.5(R)	1.1(R)	1.2
80' to right	1.0(R)	0.8(R)	1.5(R)
Centerline to right	1.1(R)	±0.7	-0.7(R)
Centerline to left	0.7(L)	0.5(L)	-1.1
80' to left	1.5(L)	±0.7(L)	-0.8
160' to left	1.2(L)	-0.7(L)	-1.0(L)
C) Top-Bank***			
160' to right		1.1(R)	
80' to right		±1.4(R)	
Centerline to right		1.3(R)	
Centerline to left		±0.3	
80' to left		1.2(L)	
160' to left		1.8(L)	

*Distance from toe of embankment to center of intake structure 110 feet.

**Embankment slope 1:2; mid-bank distance from center of intake structure 150 feet.

(+) values are velocities towards embankment.
(R) values are velocities to right facing embankment.
(L) values are velocities to left facing embankment.
*** measurements some ten feet below water surface

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 49. Velocities Near Reservoir Embankment (fps)
Pumping Mode
Q = 24,900 cfs
Reservoir Elevation = 1,355 ft MSL

Location	10' Above Floor	Mid-Depth	30' Above Floor
A) Toe Plane*			
160' to right	2.0(R)	1.7(R)	2.3(R)
80' to right	-1.9(R)	2.1(R)	3.1(R)
Centerline to right	±2.0	5.1	5.3
Centerline to left	-3.3	5.7	4.6
80' to left	-3.1	±2.5	3.2(L)
160' to left	-2.3(L)	-2.0(L)	2.6(L)
B) Mid-Bank**			
160' to right		2.2(R)	
80' to right		1.5(R)	
Centerline to right		±1.1(R)	
Centerline to left		±2.0(L)	
80' to left		1.8(L)	
160' to left		2.6(L)	

*Distance from toe of embankment to center of intake structure 110 feet.

**Embankment slope 1:2; mid-bank distance from center of intake structure 150 feet.

(+) values are velocities towards embankment.
(R) values are velocities to right facing embankment.
(L) values are velocities to left facing embankment.

See Figure 31 for definition sketch of splitter wall.

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 50. Velocities Near Reservoir Embankment (fps)
Pumping Mode
Q = 16,000 cfs
Reservoir Elevation = 1,395 ft MSL

Location	10' Above Floor	Mid-Depth	30' Above Floor
A) Toe Plane*			
160' to right	1.6(R)	0.2(R)	-0.3(R)
80' to right	1.8(R)	-0.3(R)	-0.4
Centerline to right	2.8(R)	1.0(R)	1.0(R)
Centerline to left	2.7	0.7	0.5
80' to left	2.0(L)	-0.5(L)	-0.7
160' to left	1.7(L)	0.2	-0.6
B) Mid-Bank**			
160' to right	0.8(R)	0.4(R)	-0.4(R)
80' to right	0.8(R)	0.5(R)	0.6(R)
Centerline to right	0.5(R)	-0.3(R)	-0.4(R)
Centerline to left	0.3	0.3(L)	0.4(R)
80' to left	1.0(L)	0.3(L)	-0.5(L)
160' to left	0.3(L)	0.5(L)	-0.6(L)
C) Top-Bank***			
160' to right		1.2(L)	
80' to right		0.6(L)	
Centerline to right		0.2	
Centerline to left		-0.2(R)	
80' to left		0.5(R)	
160' to left		0.6(R)	

*Distance from toe of embankment to center of intake structure 110 feet.

**Embankment slope 1:2; mid-bank distance from center of intake structure 150 feet.

***Top-bank measurements some ten feet below water surface

(+) values are velocities toward embankment.
(R) values are velocities to right facing embankment.
(L) values are velocities to left facing embankment.

See Figure 31 for definition sketch of splitter wall.

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 51. Velocities Near Reservoir Embankment (fps)
Pumping Mode
Q = 16,000 cfs
Reservoir Elevation = 1,355 ft MSL

Location	10' Above Floor	Mid-Depth	30' Above Floor
A) Toe-Plane*			
160' to right	0.8(R)	-0.5(R)	1.0(R)
80' to right	1.1(R)	0.8(R)	-0.5(R)
Centerline to right	2.7(R)	2.7(R)	-1.2
Centerline to left	2.2(L)	3.4(L)	-1.7
80' to left	1.8(L)	1.4(L)	±1.4(L)
160' to left	1.0(L)	0.8(L)	-1.5(L)
B) Mid-Bank**			
160' to right		0.8(R)	
80' to right		0.6(R)	
Centerline to right		0.7(R)	
Centerline to left		0.3(L)	
80' to left		1.0(L)	
160' to left		1.2(L)	

*Distance from toe of embankment to center of intake structure 110 feet.

**Embankment slope 1:2; mid-bank distance from center of intake structure 150 feet.

(+) values are velocities towards embankment.
(R) values are velocities to right facing embankment.
(L) values are velocities to left facing embankment.

See Figure 31 for definition sketch of splitter wall.

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 52. Velocities Near Reservoir Embankment (fps)
Pumping Mode
Q = 25,900 cfs
Reservoir Elevation = 1,395 ft MSL

Location	10' Above Floor	Mid-Depth	30' Above Floor
A) Toe Plane*			
160' to right	2.7	0.6	-1.0
80' to right	3.0	+1.4	-1.3
Centerline	+3.6	1.8	1.8
80' to left	3.4	-0.6	-1.5
160' to left	2.6	0.5	-1.4
B) Mid-Bank**			
160' to right	1.5 (R)	1.0	1.1(R)
80' to right	1.4 (R)	0.7	1.5(R)
Centerline	1.5	0.8	-1.0
80' to left	1.4	1.2	-1.0
160' to left	1.9(L)	-1.5(L)	-1.2
C) Top-Bank measurements some ten feet below water surface			
160' to right		1.3(L)	
80' to right		1.1(L)	
Centerline		0.3	
80' to left		1.2(R)	
160' to left		1.3(R)	

*Distance from toe of embankment to center of intake structure 110 feet.

**Embankment slope 1:2 mid-bank distance from center of intake structure 150 feet.

(+) values are velocities towards embankment.
(R) values are velocities to right facing embankment.
(L) values are velocities to left facing embankment.

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 53. Velocities Near Reservoir Embankment (fps)
Pumping Mode
Q = 24,900 cfs
Reservoir Elevation = 1,355 ft MSL

Location	10' Above Floor	Mid-Depth	30' Above Floor
A) Toe Plane*			
160' to right	1.7	1.5(R)	1.6(R)
80' to right	1.7	1.3(R)	-1.6
Centerline	2.2	-2.3	-1.7
80' to left	-2.4	2.5(L)	3.0(L)
160' to left	1.6(L)	2.0(L)	1.9(L)
B) Mid-Bank**			
160' to right		2.1(L)	
80' to right		1.4(L)	
Centerline		-0.8	
80' to left		1.5(R)	
160' to left		1.8(R)	

*Distance from toe of embankment to center of intake structure 110 feet.

**Embankment slope 1:2 midbank distance from center of intake structure 150 feet.

(+) values are velocities towards embankment.
(R) values are velocities to right facing embankment.
(L) values are velocities to left facing embankment.

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 54. Velocities Near Reservoir Embankment
Pumping Mode
Q = 18,000 cfs
Reservoir Elevation = 1,395 ft MSL
Velocities in feet per second

	8' Above Floor	Mid-Depth	8' Below Water Surface
Distances to Right	Velocities in feet per second		
20'	2.5	1.0	-0.7(R)
80'	2.1(R)	1.1(R)	0.6(R)
160'	2.0(R)	1.3(R)	1.1(R)
240'	1.2(R)	1.1(R)	1.0(R)
320'	0	1.2(R)	0.6(R)
Distances to Left			
20'	2.4(L)	1.1(L)	0.5(L)
80'	2.6(L)	1.4(L)	0.5(L)
160'	2.1(L)	0.7(L)	0.6(L)
240'	1.4(L)	0.5(L)	0.6(L)
320	0.7(L)	0.4(L)	0.7(L)

Toe distance 110 feet to center; splitter wall in place

(R) values are velocities to right facing embankment.
(L) values are velocities to left facing embankment.

See Figure 31 for definition sketch of splitter wall.

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 55. Velocities Near Reservoir Embankment
Pumping Mode
Q = 18,000 cfs
Reservoir Elevation = 1,355 ft MSL
Velocities in Feet Per Second

	8' Above Floor	Mid-Depth	8' Below Water Surface
Distances to Right			
20'	2.5		-0.7
80'	2.1(R)		0.8(R)
160'	1.7(R)		0.7(R)
240'	0.3(R)		0.8(R)
320'	0		0.7(R)
Distances to Left			
20'	2.5		0.7(L)
80'	2.2(L)		0.7(L)
160'	2.1(L)		0.7(L)
320'	0		0

Toe distance 110 feet to center; splitter wall in place
Pier "A" in line with splitter; long radius elbow in model

(R) values are velocities to right facing embankment.
(L) values are velocities to left facing embankment.

See Figure 31 for definition sketch of splitter wall.

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 56. Velocity Distributions at Intake Structure
Pumping Mode
Q = 24,900 cfs
Reservior Elevation = 1,395 ft MSL

Station	Velocities, feet per second			
	Top*	Middle*	Bottom*	
AB				
BC				
CD	5.5	1.6	-2.3	Original Entrance
DE				
EF				
FG				
GH				
HI				
IJ	5.1	1.9	-2.5	Modified Entrance
JK				
KL				
LA				

*Top = 70" below top
Middle = Midheight
Bottom = 70" from floor

All measurements in plane of rim.

Toe distance 110 feet to center; splitter wall in place;
Pier "A" in line with splitter; long radius elbow in model

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 57. Velocity Distributions at Intake Structure
Pumping Mode
Q = 24,900 cfs
Reservoir Elevation = 1,355 ft MSL

Station	Velocities, feet per second			
	Top*	Middle*	Bottom*	
AB				
BC				
CD	5.8	1.7	-2.4	Original Entrance
DE				
EF				
FG				
GH				
HI				
IJ	5.4	1.8	-2.4	Modified Entrance
JK				
KL				
LA				

*Top = 70" below top
Middle = Midheight
Bottom = 70" from floor

All measurements in plane of rim.

Toe distance 110 feet to center; splitter wall in place;
Pier "A" in line with splitter; long radius elbow in model

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 58. Velocity Distributions at Intake Structure
Pumping Mode
Q = 16,000 cfs
Reservoir Elevation = 1,355 ft MSL

Station	Velocities, feet per second			
	Top*	Middle*	Bottom*	
AB				
BC				
CD	3.5	1.2	-1.3	Original Entrance
DE				
EF				
FG				
GH				
HI				
IJ	3.6	0.8	-1.6	Modified Entrance
JK				
KL				
LA				

*Top = 70" below top
Middle = Midheight
Bottom = 70" from floor

All measurements in plane of rim.

Toe distance 110 feet to center; splitter wall in place;
Pier "A" in line with splitter; long radius elbow in model

ROCKY MOUNTAIN PROJECT
UPPER INTAKE STRUCTURE
1:40 Scale Hydraulic Model

Table 59. Velocity Distributions at Intake Structure
Pumping Mode
Q = 16,000 cfs
Reservoir Elevation = 1,355 ft MSL

Station	Velocities, feet per second			
	Top*	Middle*	Bottom*	
AB				
BC				
CD	3.2	0.8	-1.2	Original Entrance
DE				
EF				
FG				
GH				
HI				
IJ	3.0	1.2	-1.6	Modified Entrance
JK				
KL				
LA				

*Top = 70" below top
Middle = Midheight
Bottom = 70" from floor

All measurements in plane of rim.

Toe distance 110 feet to center; splitter wall in place;
Pier "A" in line with splitter; long radius elbow in model

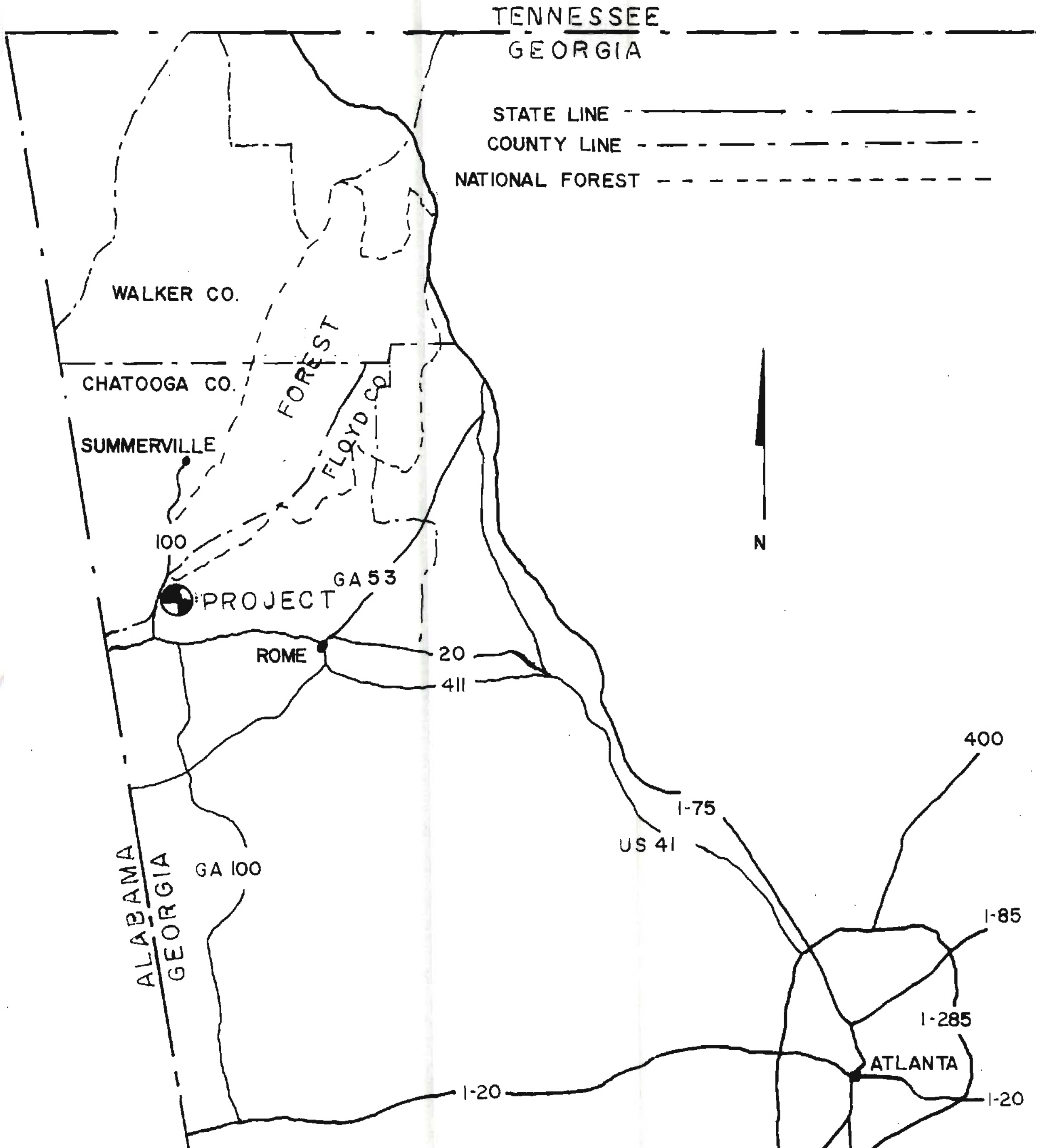
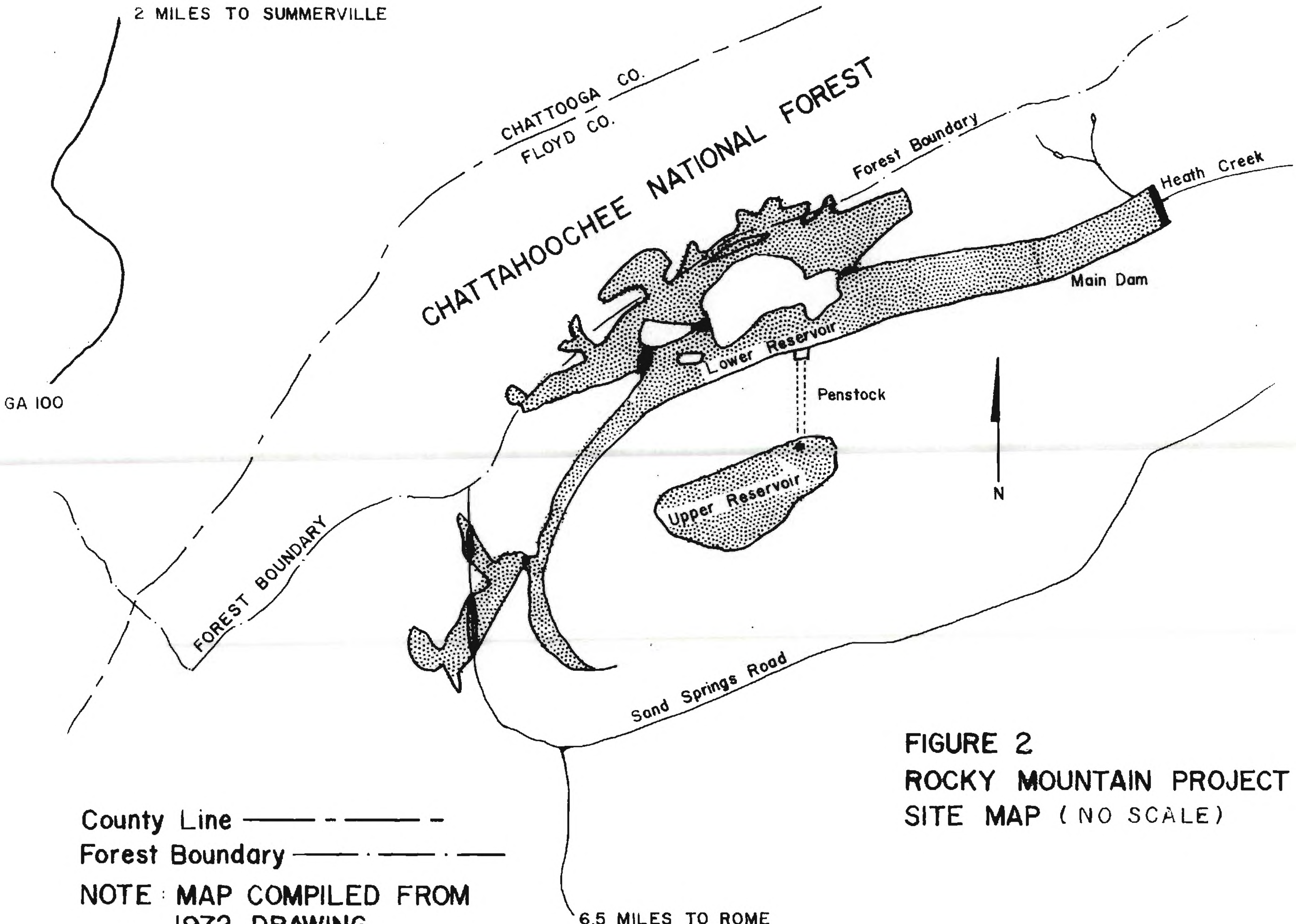


FIGURE 1
ROCKY MOUNTAIN PROJECT
LOCATION MAP (NO SCALE)



County Line
Forest Boundary

NOTE: MAP COMPILED FROM 1972 DRAWING.

FIGURE 2
ROCKY MOUNTAIN PROJECT
SITE MAP (NO SCALE)

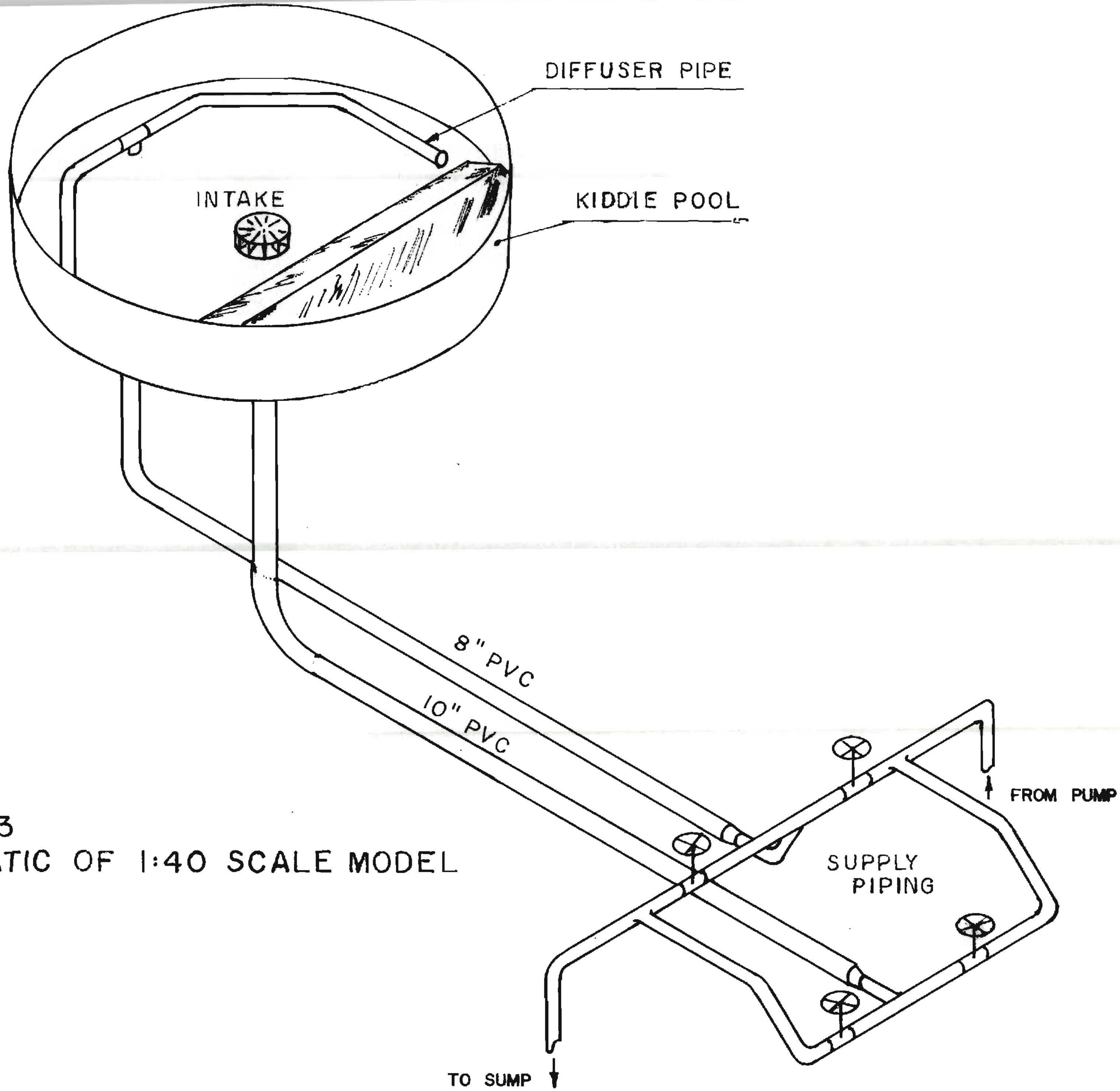


FIGURE 3
SCHEMATIC OF 1:40 SCALE MODEL

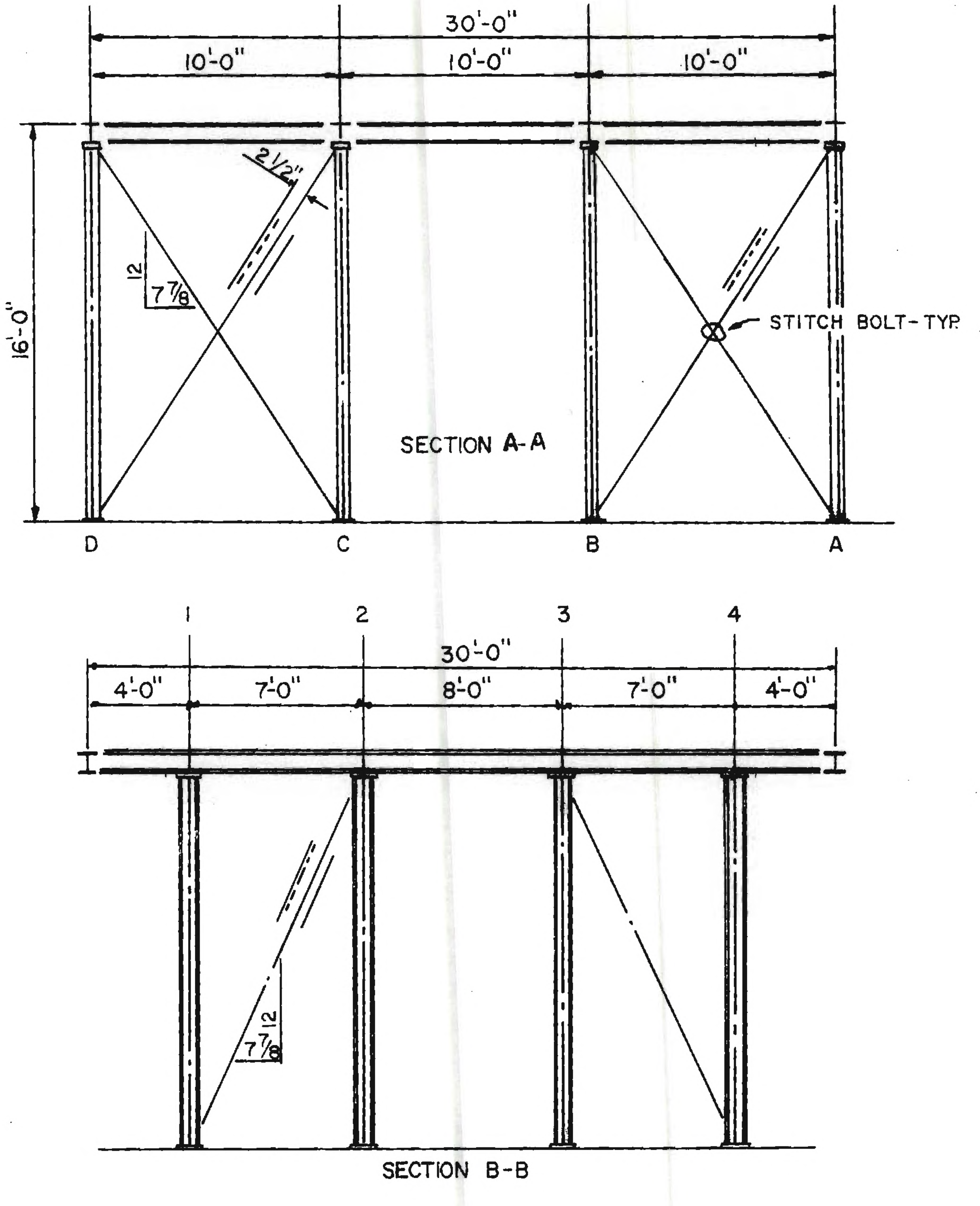
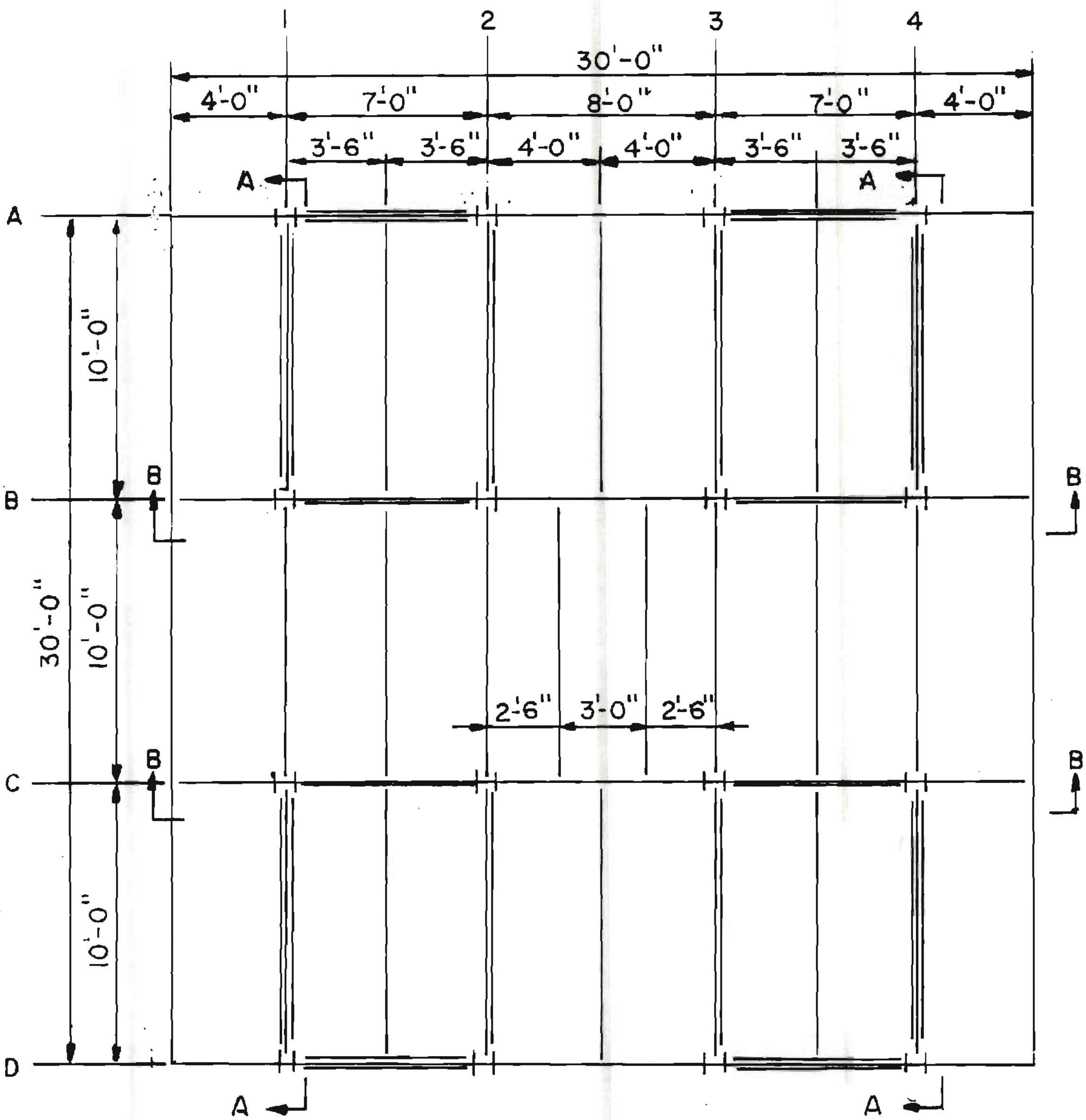


FIGURE 4

ELEVATION VIEWS OF SUPPORT STRUCTURE

ALL COLUMNS 8 WF 18
ALL BEAMS 10 WF 12
ALL BRACES 4 x 4 x 1/4



BEAMS - W10x12
COLUMNS - W8x18
BRACING - L4x4x1/4

FIGURE 5
FLOOR FRAMING OF SUPPORT STRUCTURE

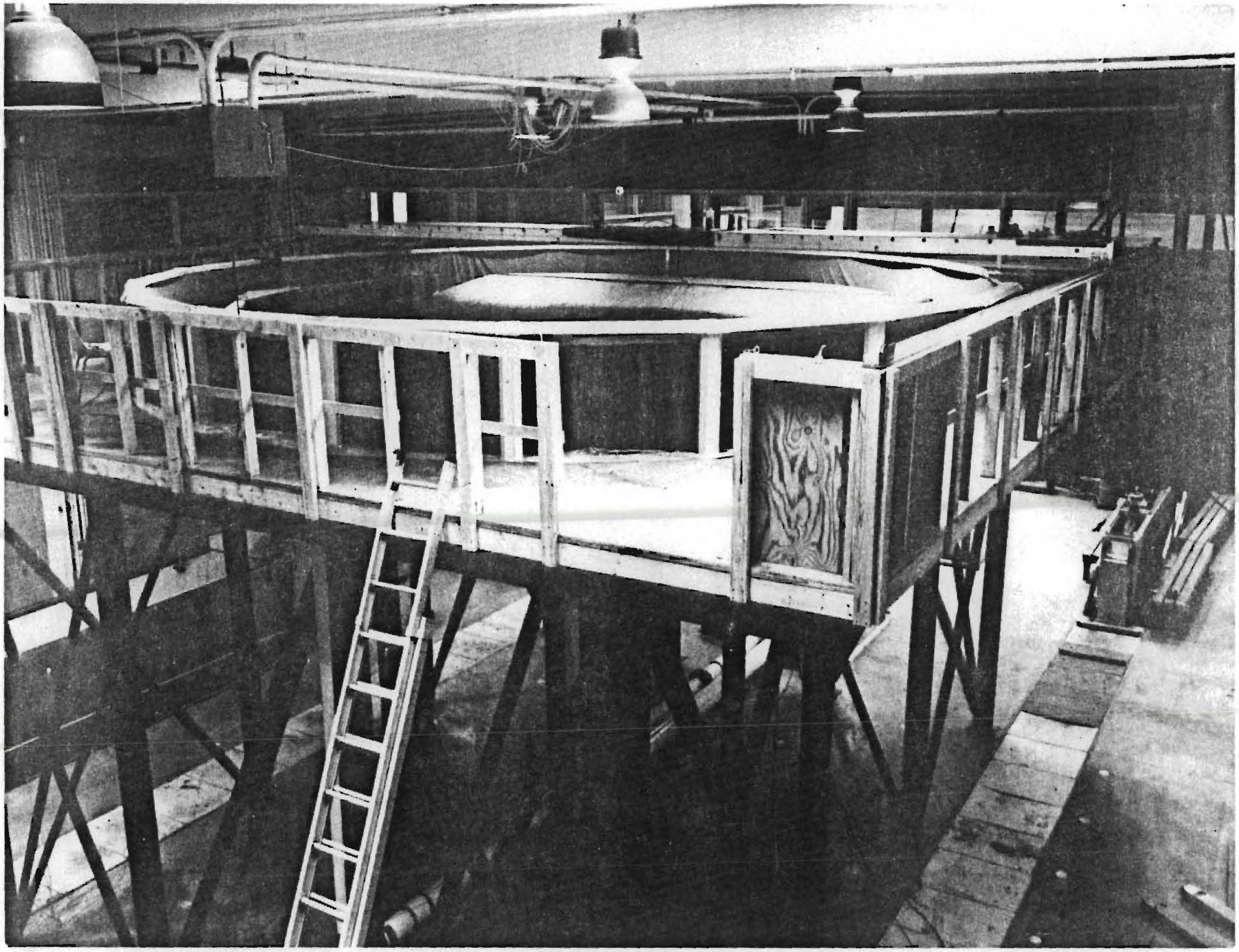


FIGURE 6

1:40 SCALE RESERVOIR MODEL IN LABORATORY

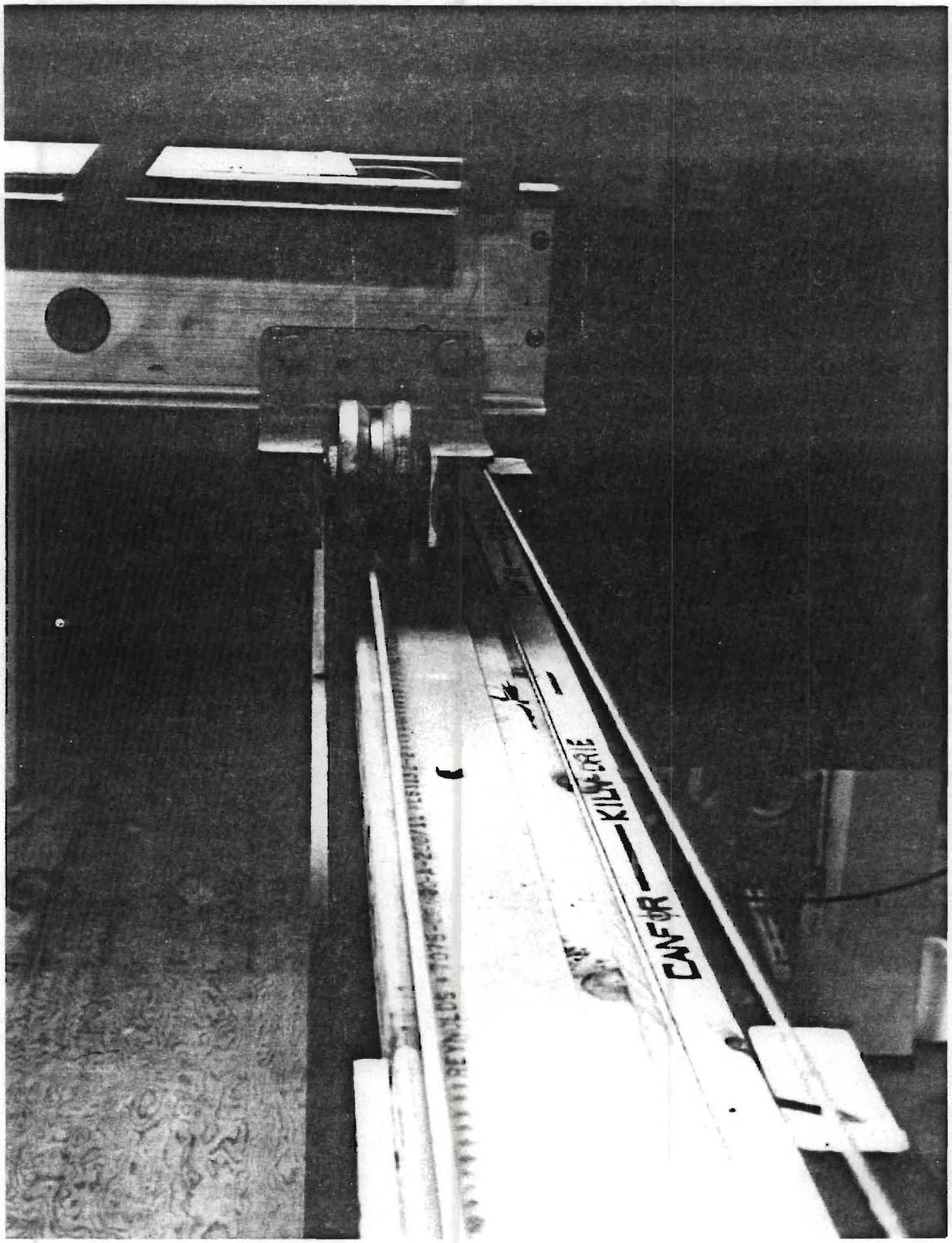


FIGURE 7

DETAILS OF BRIDGE TRACK

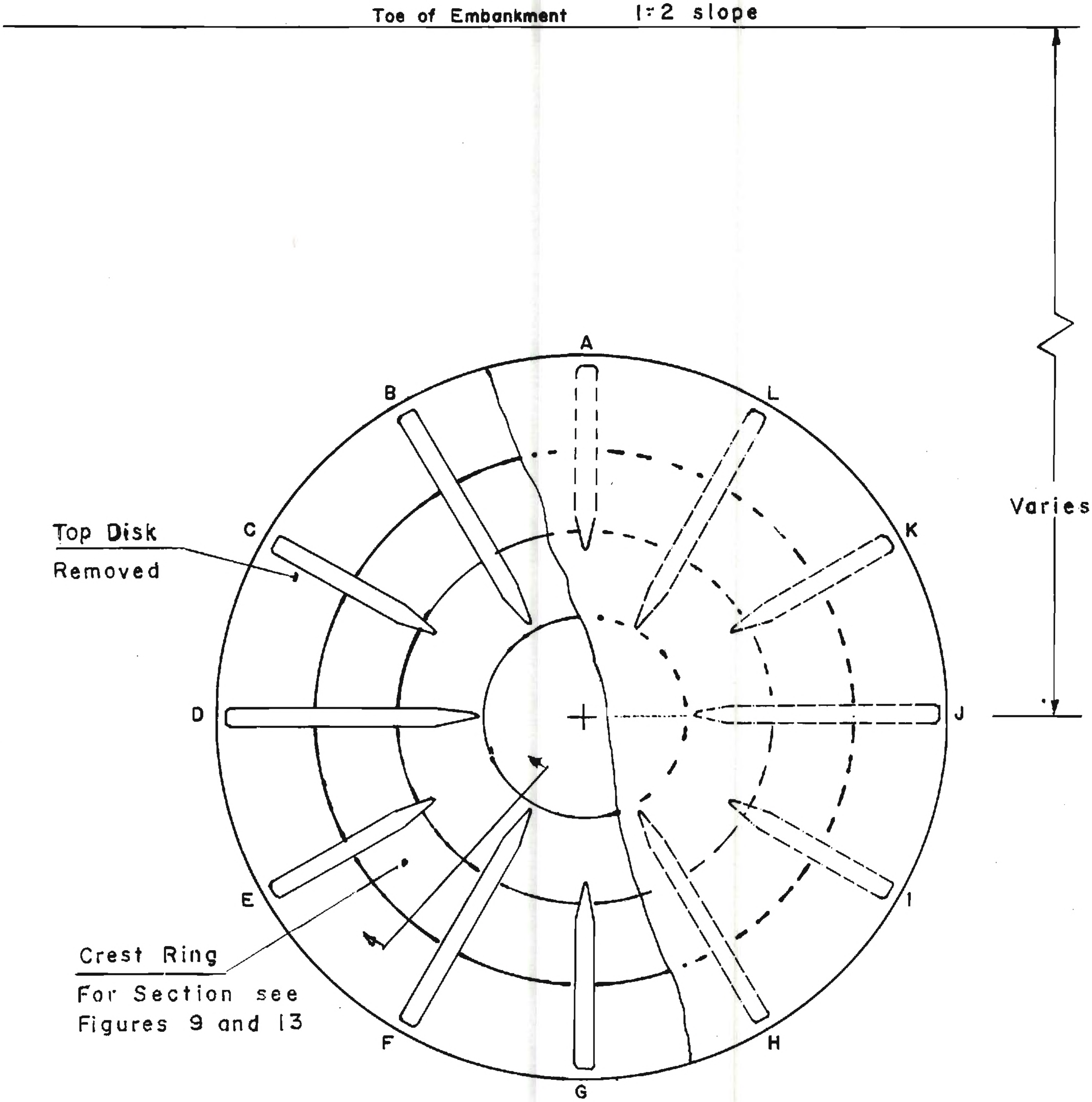


FIGURE 8
SCHEMATIC PLAN VIEW OF INTAKE STRUCTURE

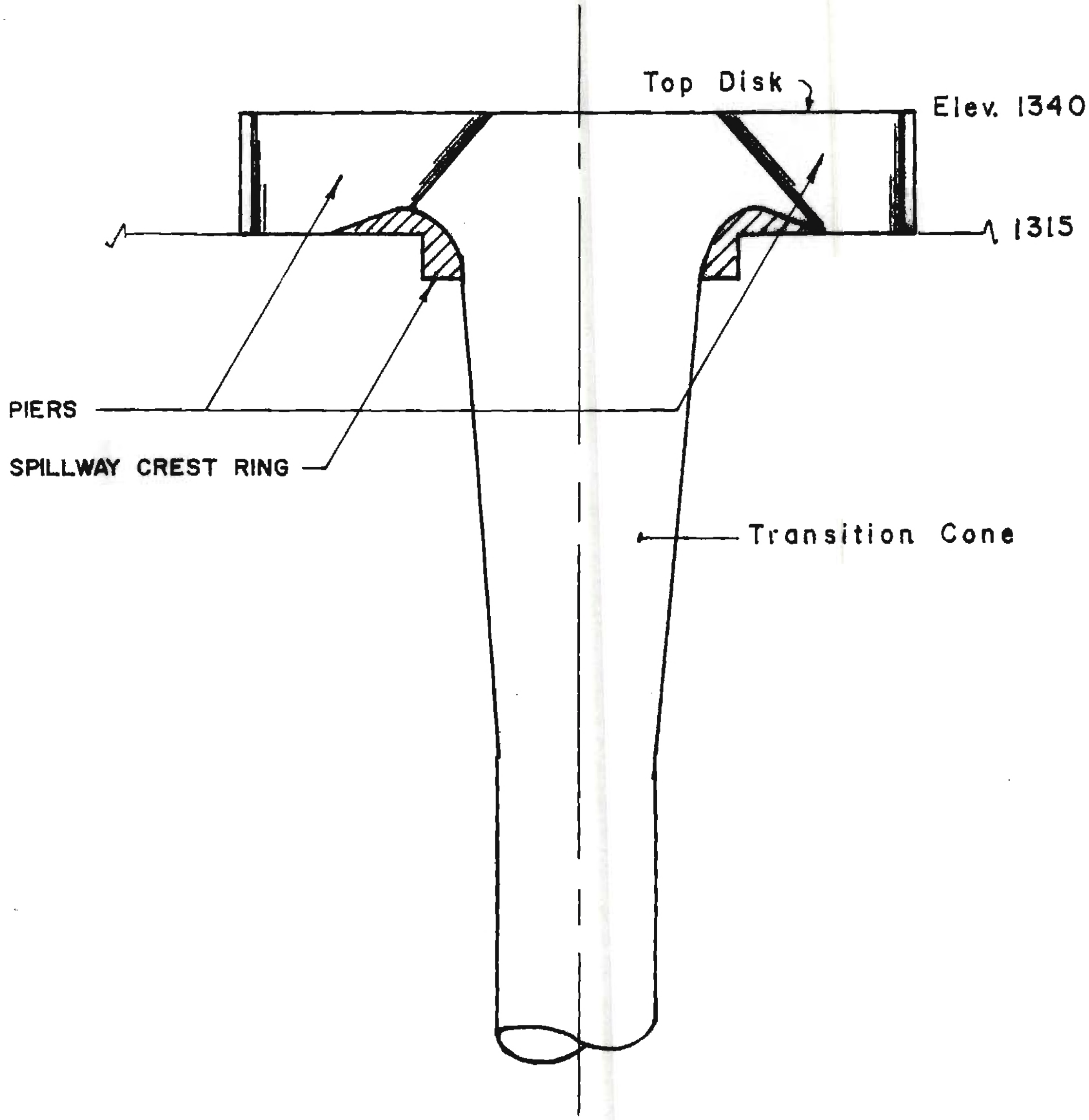


FIGURE 9.
ROCKY MOUNTAIN PROJECT
UPPER RESERVOIR INTAKE
STRUCTURE STUDY
1:40 SCALE MODEL

GENERAL CROSS SECTION

FIGURE 10
VIEW OF ADAPTER
AND TRANSITION CONE

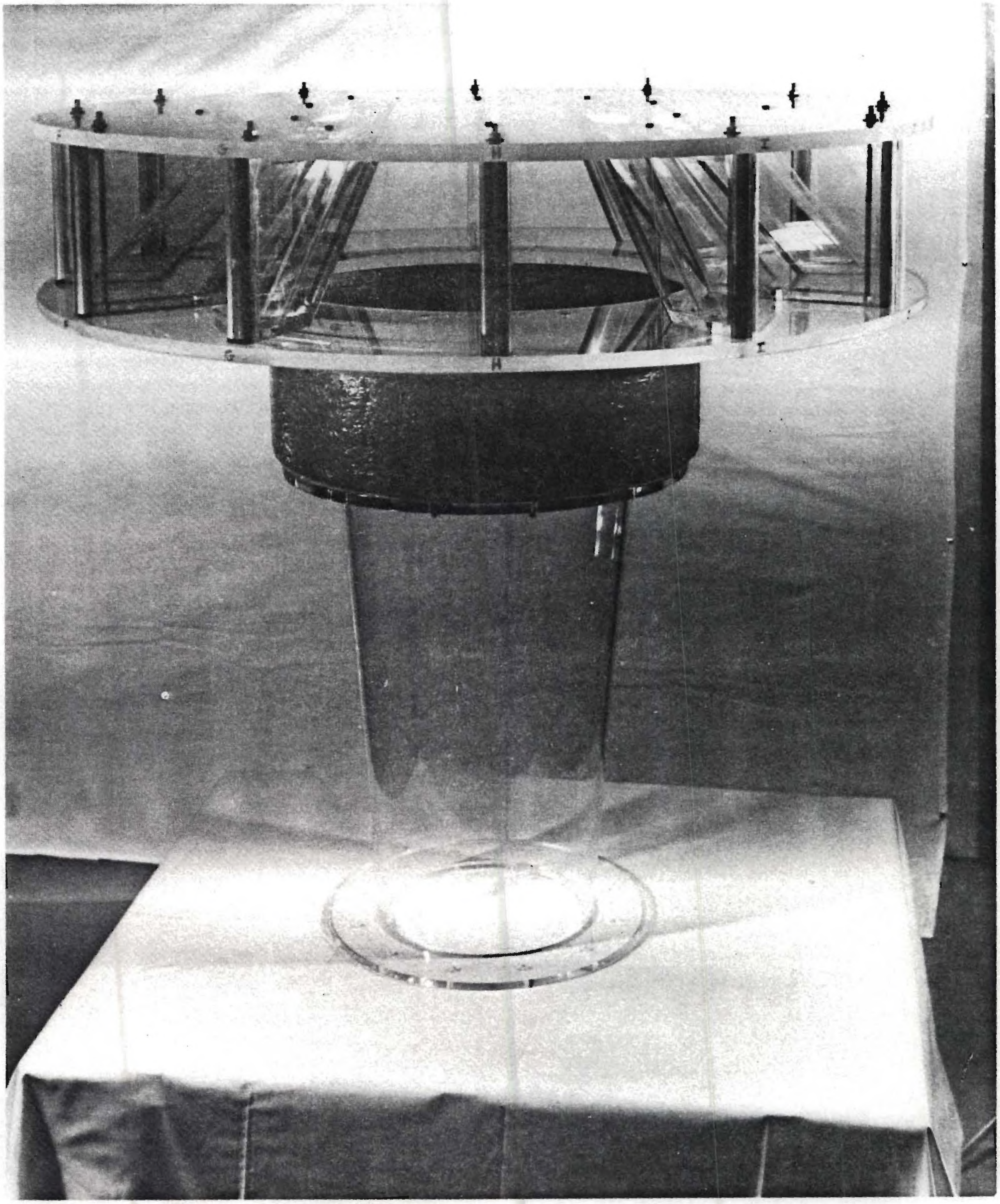


FIGURE 11

ASSEMBLED INTAKE STRUCTURE

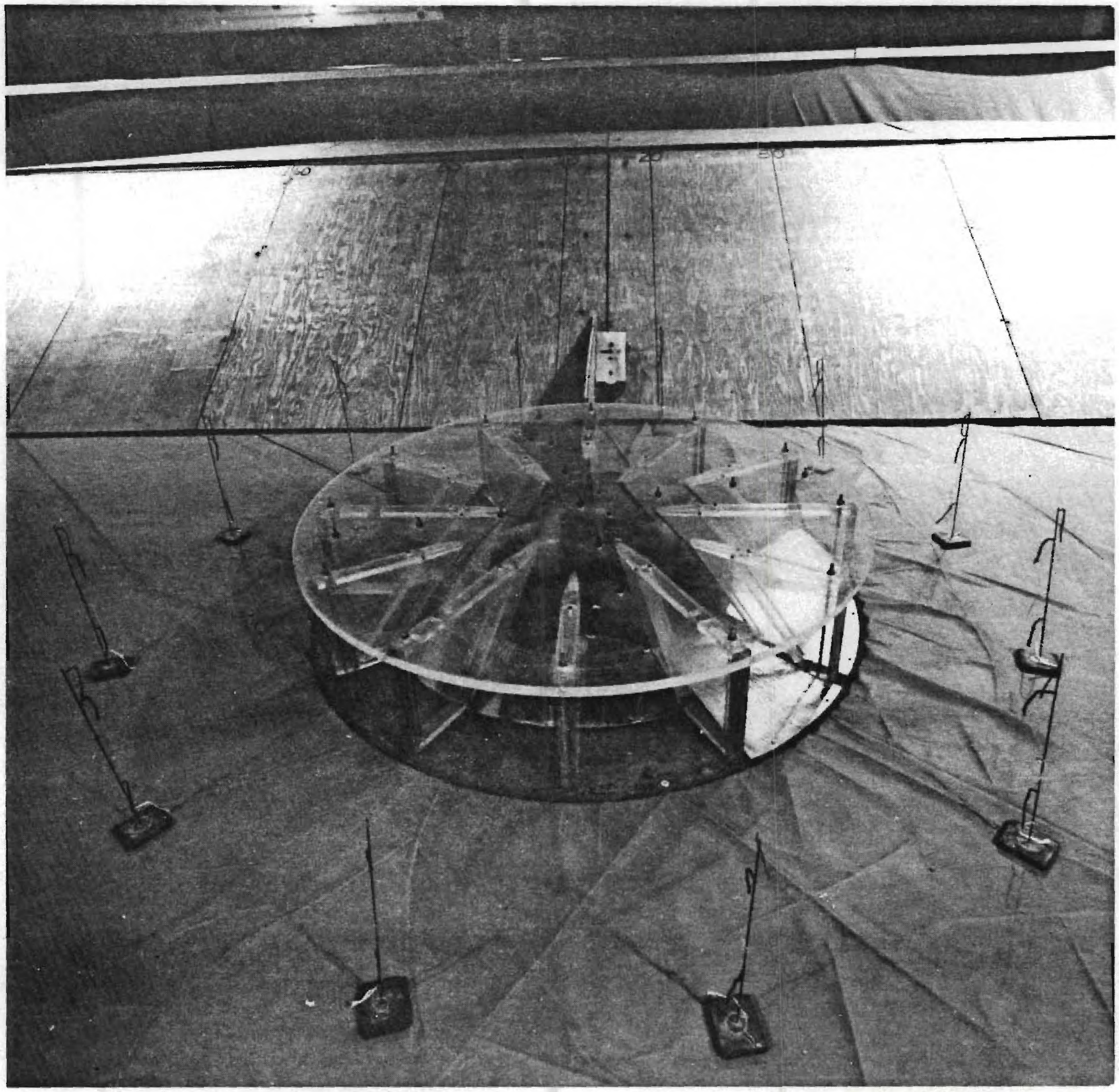


FIGURE 12
INTAKE STRUCTURE IN 1:40 SCALE RESERVOIR

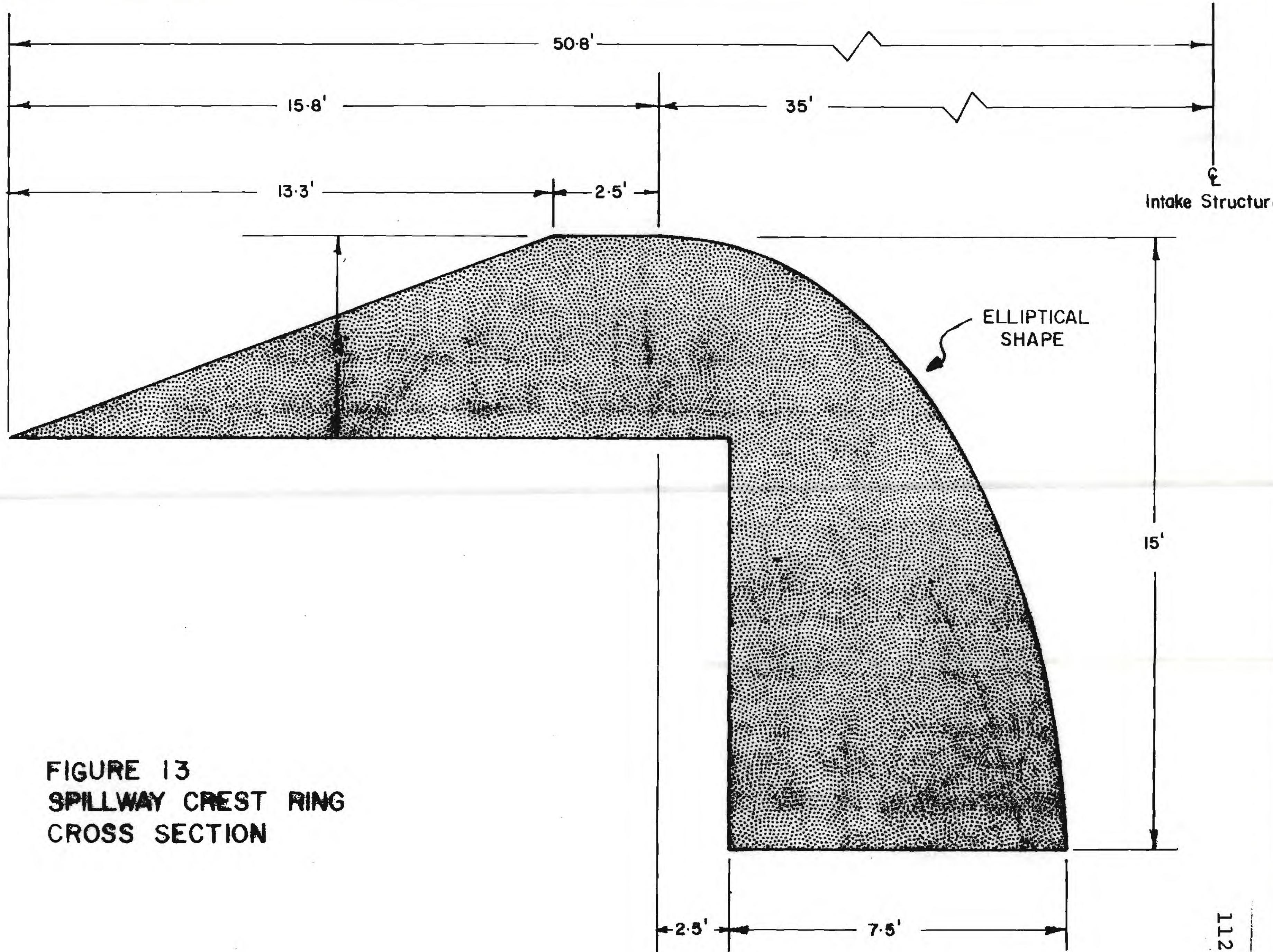


FIGURE 13
SPILLWAY CREST RING
CROSS SECTION

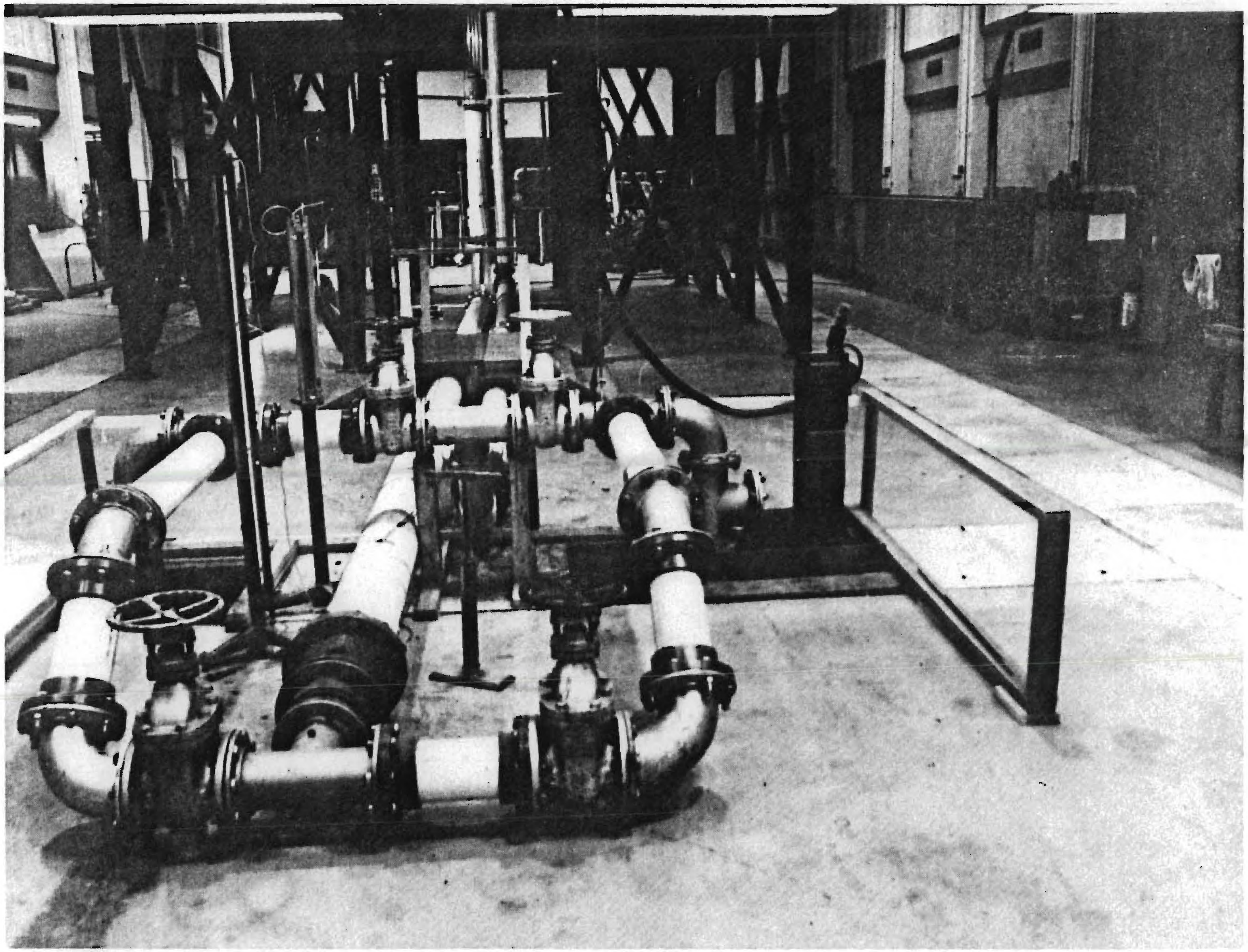


FIGURE 14
LABORATORY FLOW CONTROL PIPING AND VALVES

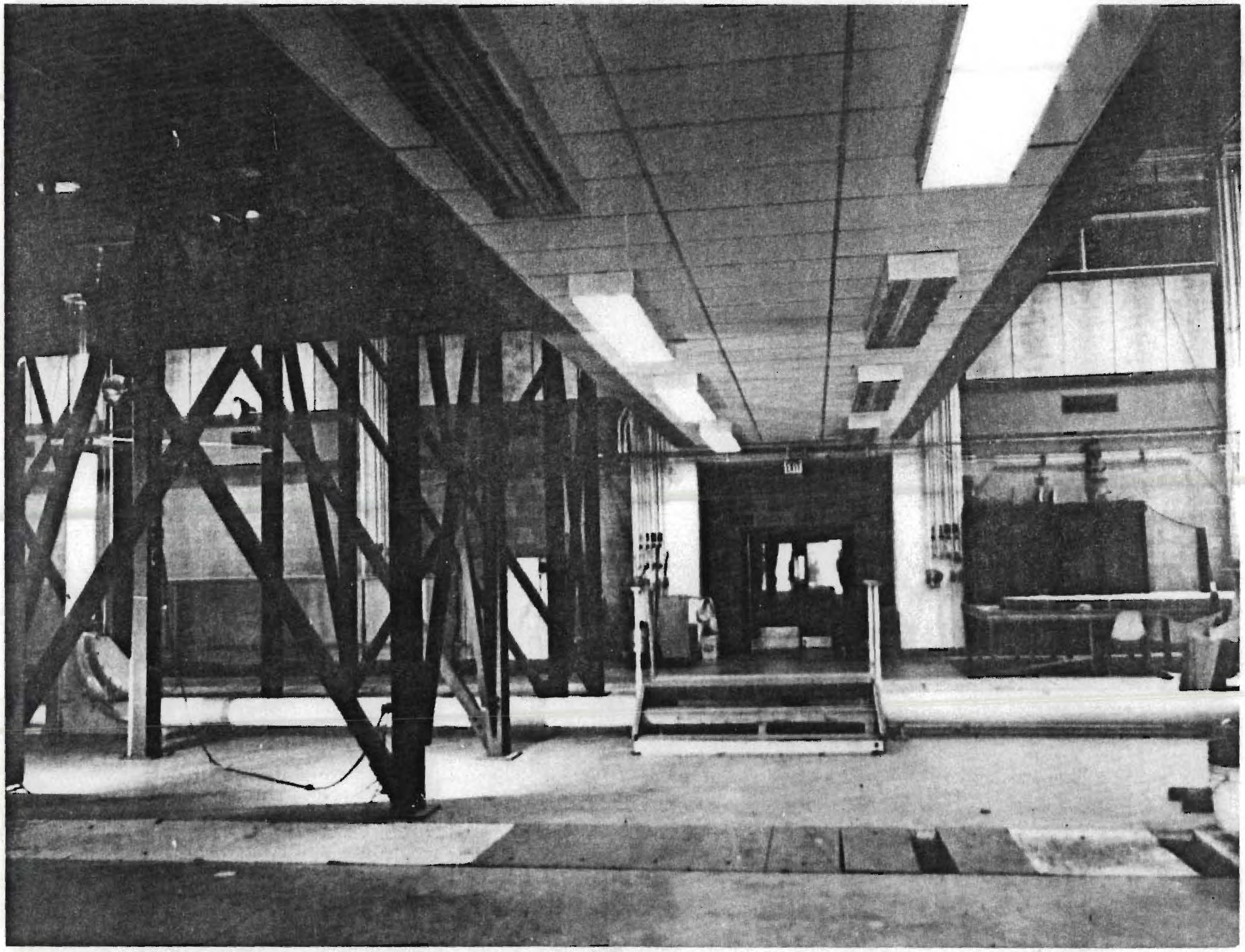


FIGURE 15

HORIZONTAL PIPING IN LABORATORY

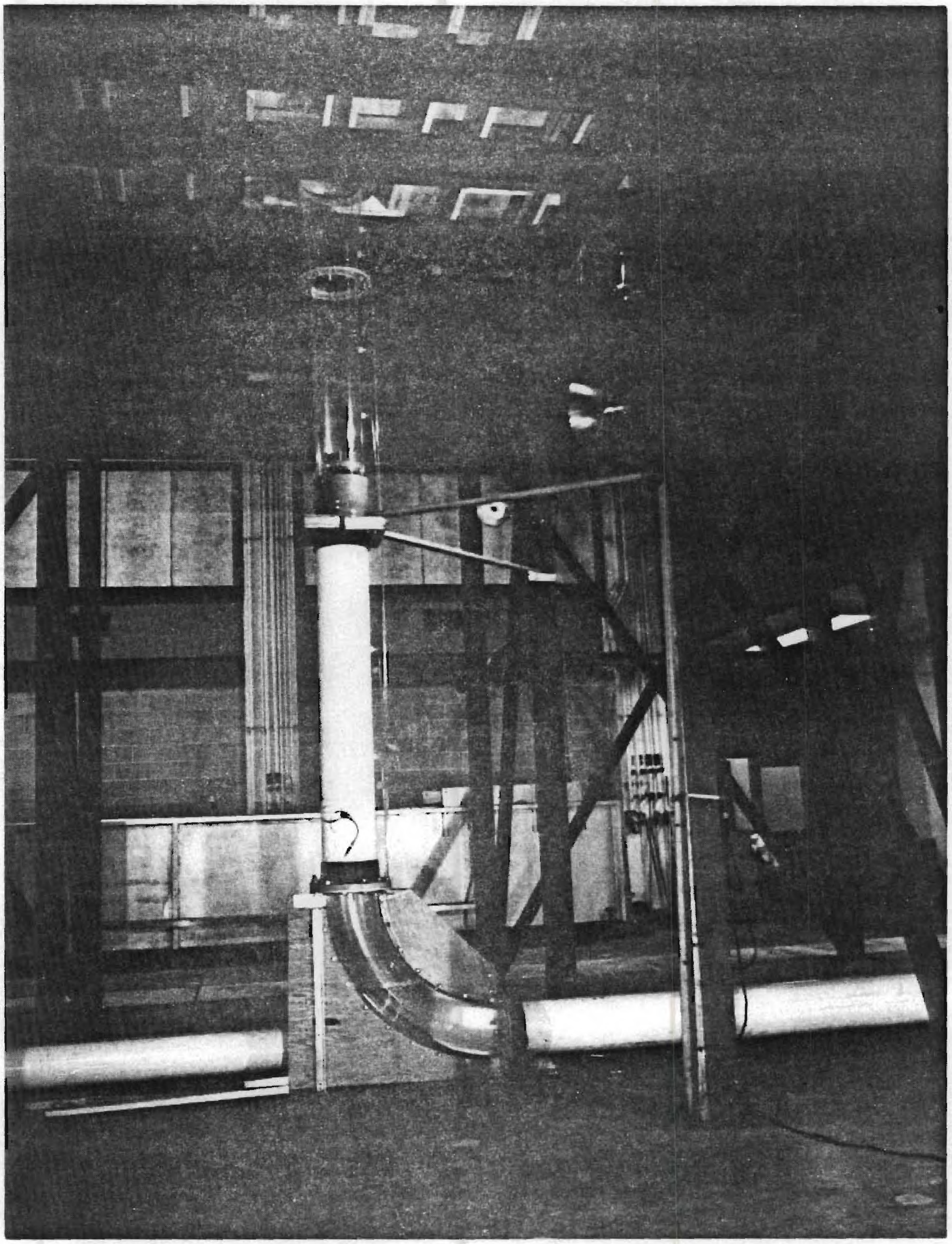


FIGURE 16
VERTICAL PIPING IN LABORATORY

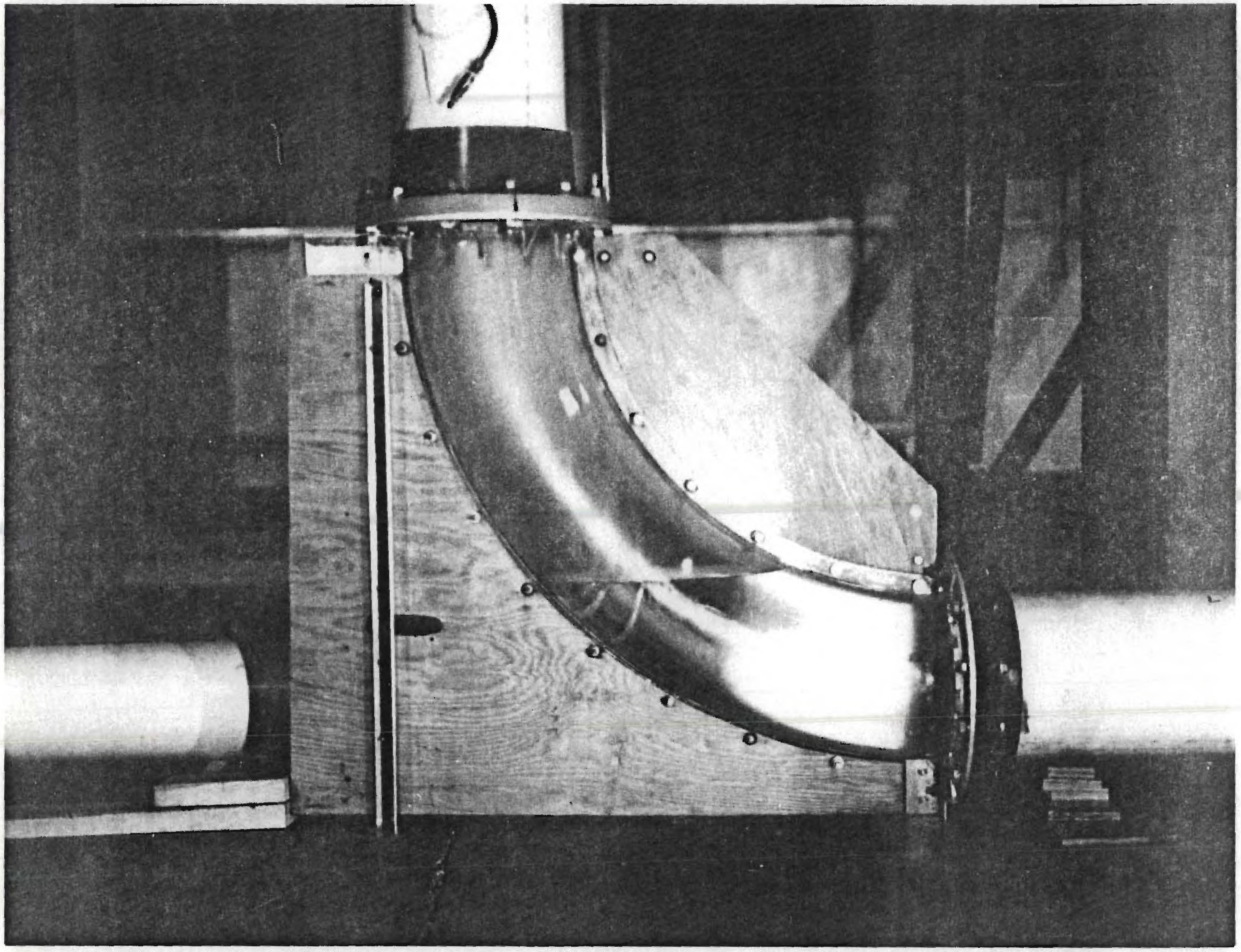


FIGURE 17

VIEW OF LONG-RADIUS ELBOW IN LABORATORY

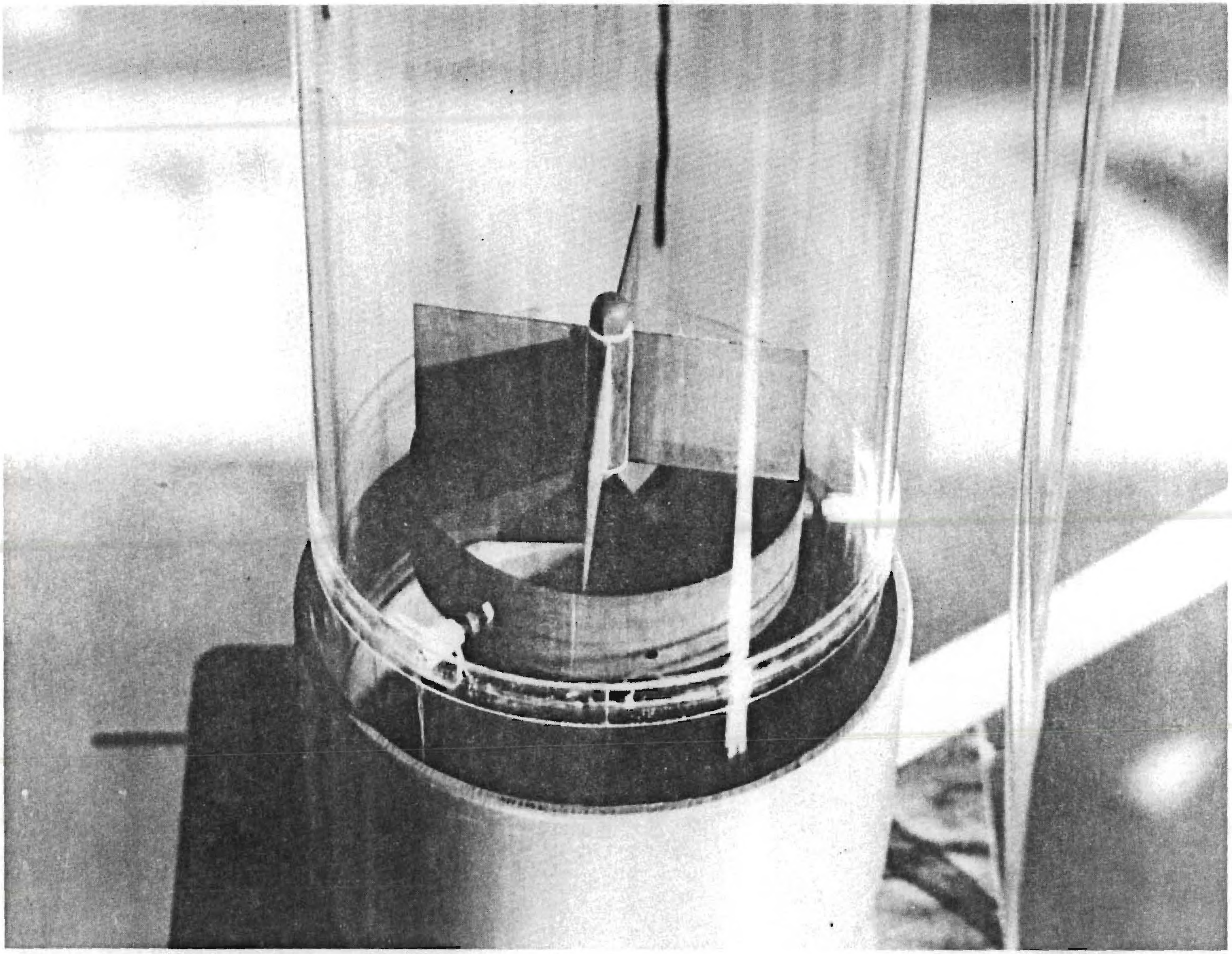


FIGURE 18

VORTIMETER IN VERTICAL PIPE

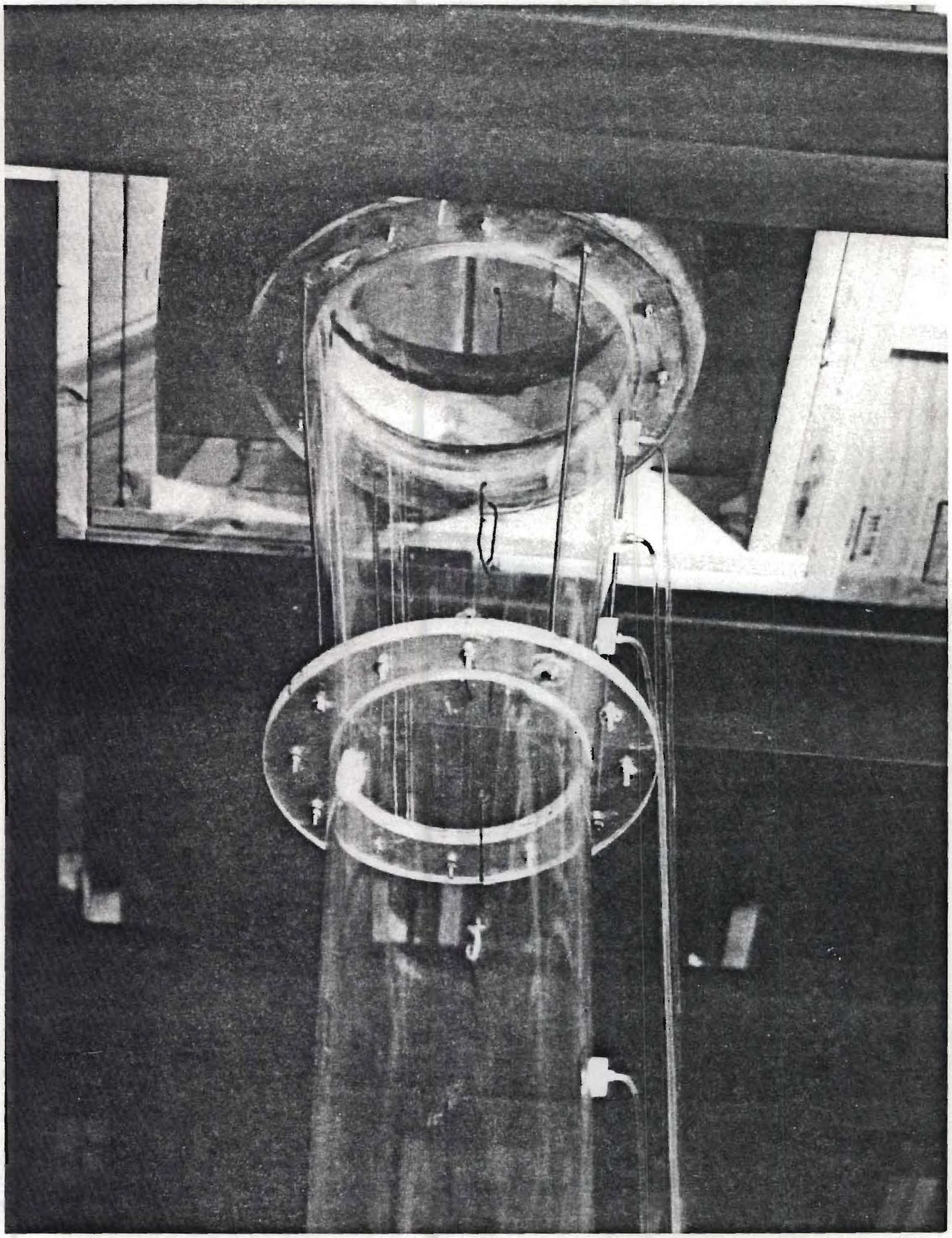


FIGURE 19
INTAKE STRUCTURE TRANSITION CONE

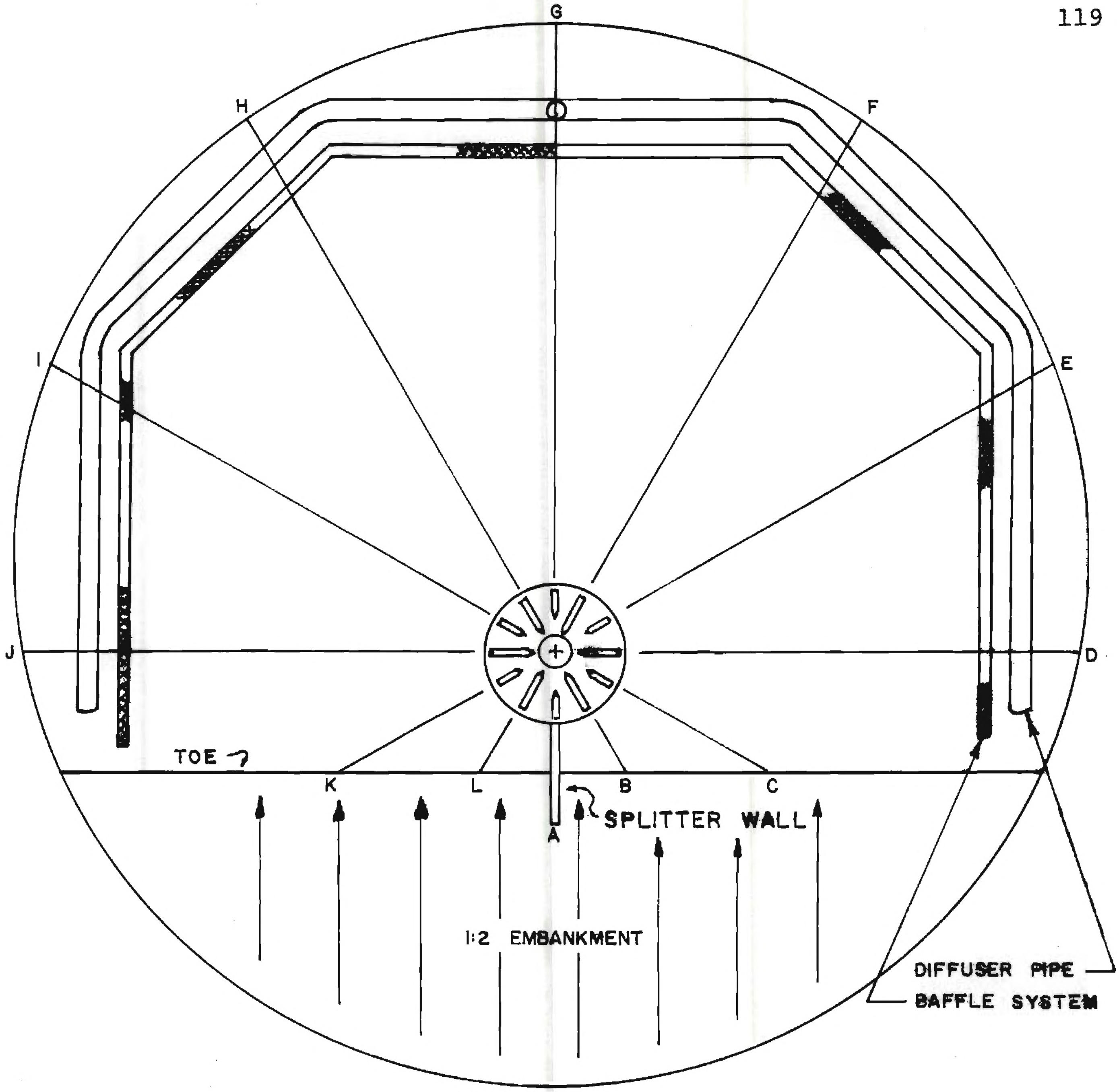


FIGURE 20
ROCKY MOUNTAIN PROJECT
UPPER RESERVOIR INTAKE
STRUCTURE STUDY
SCHEMATIC PLAN VIEW
1:40 SCALE MODEL

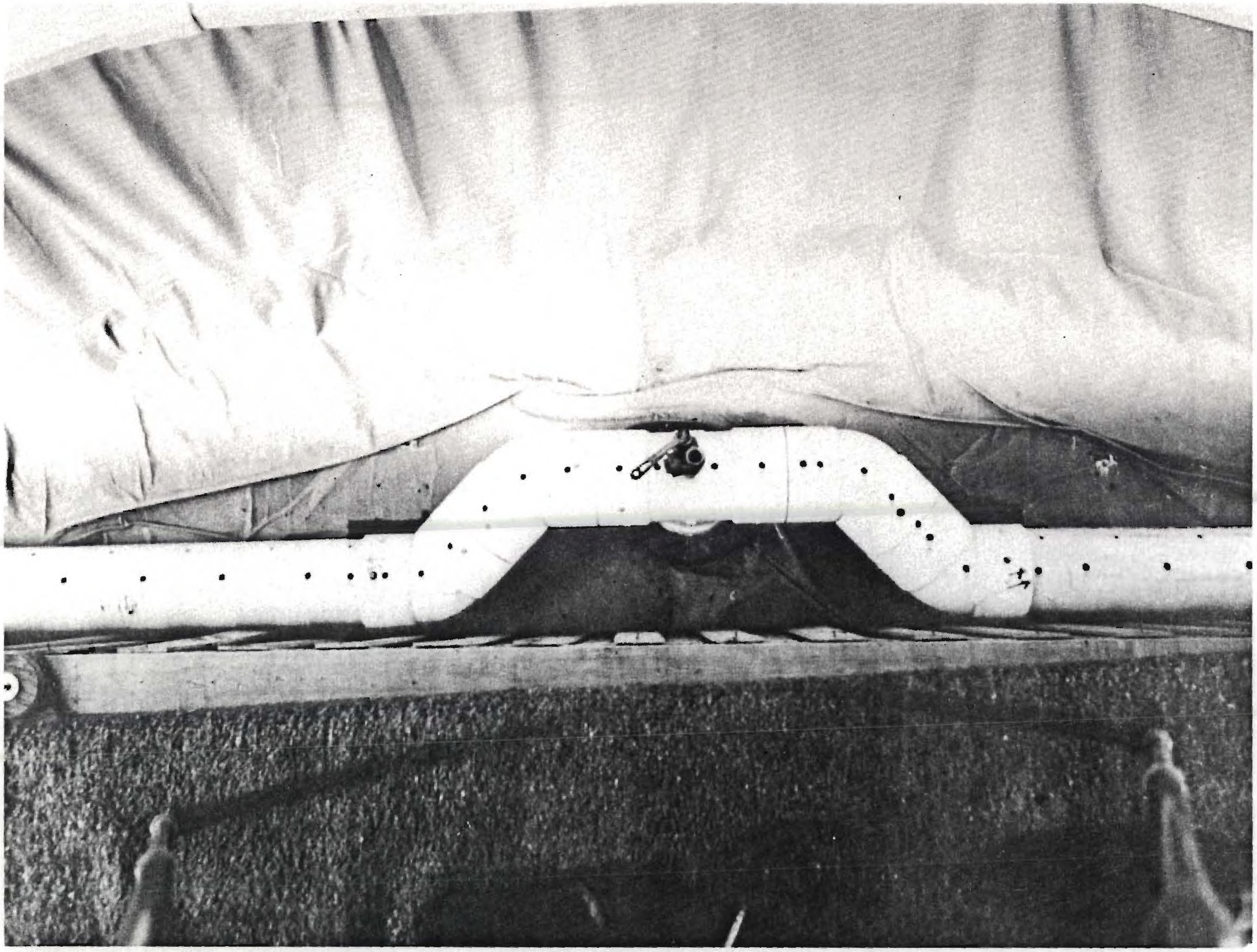


FIGURE 21

SECTION OF DIFFUSER IN 1:40 SCALE MODEL

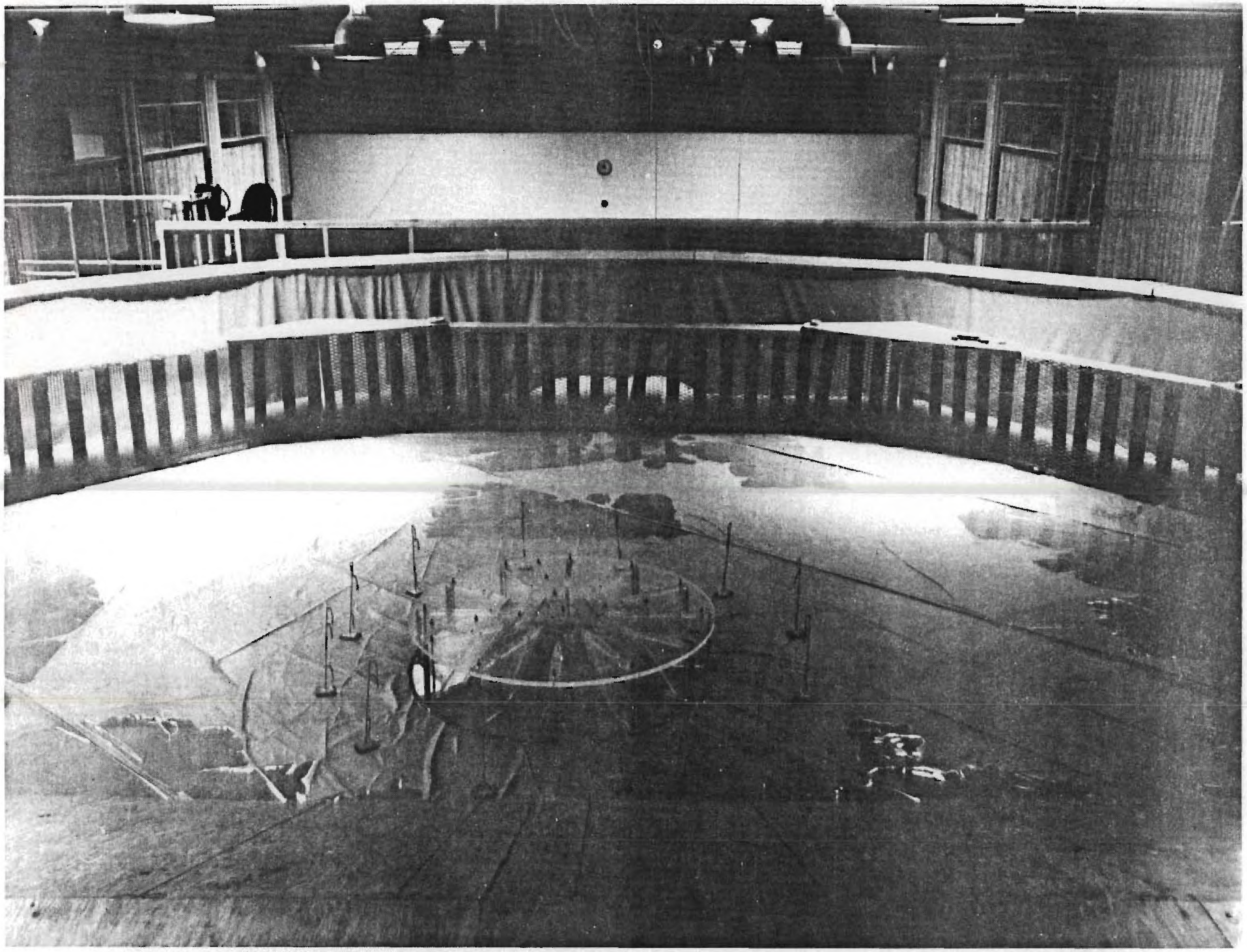


FIGURE 22
BAFFLE SYSTEM IN 1:40 SCALE MODEL

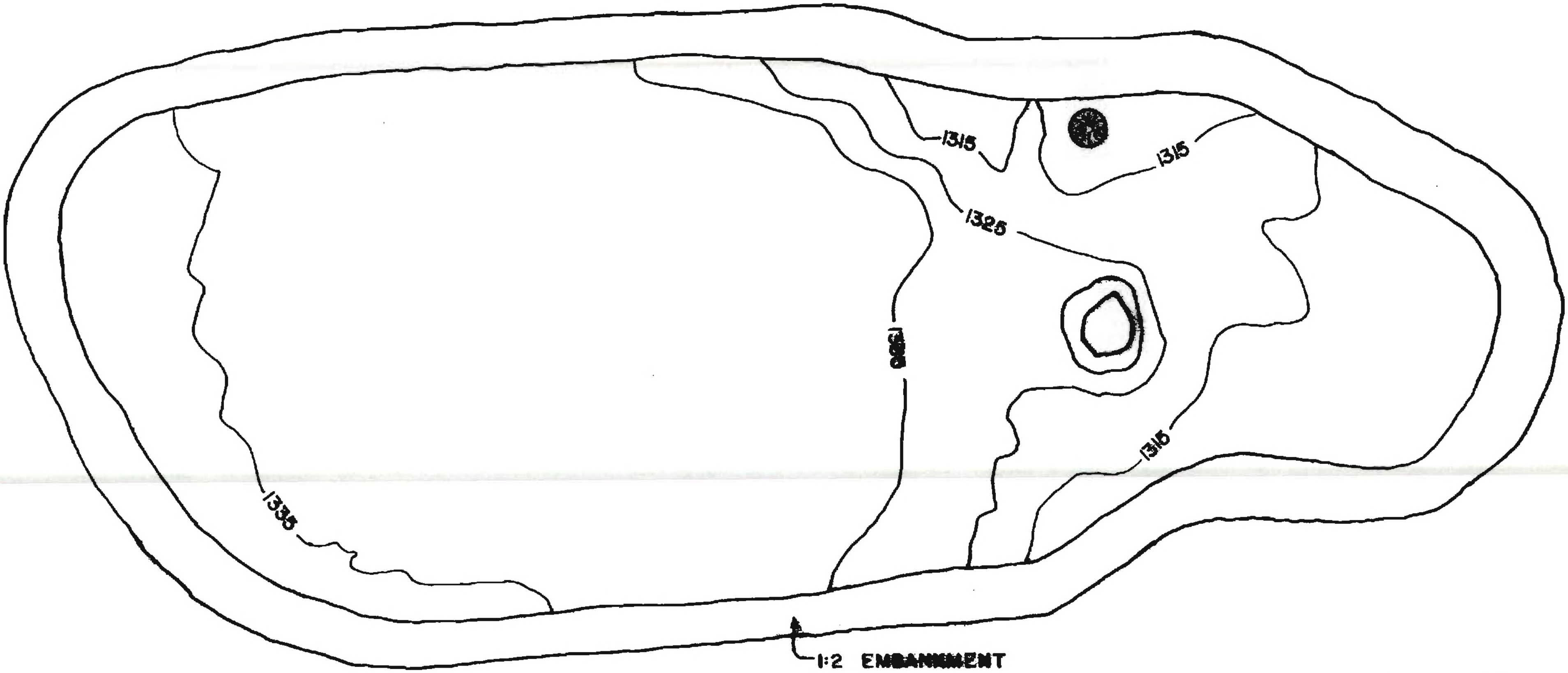


FIGURE 23
TOPOGRAPHIC MAP OF
UPPER RESERVOIR
1:300 SCALE MODEL

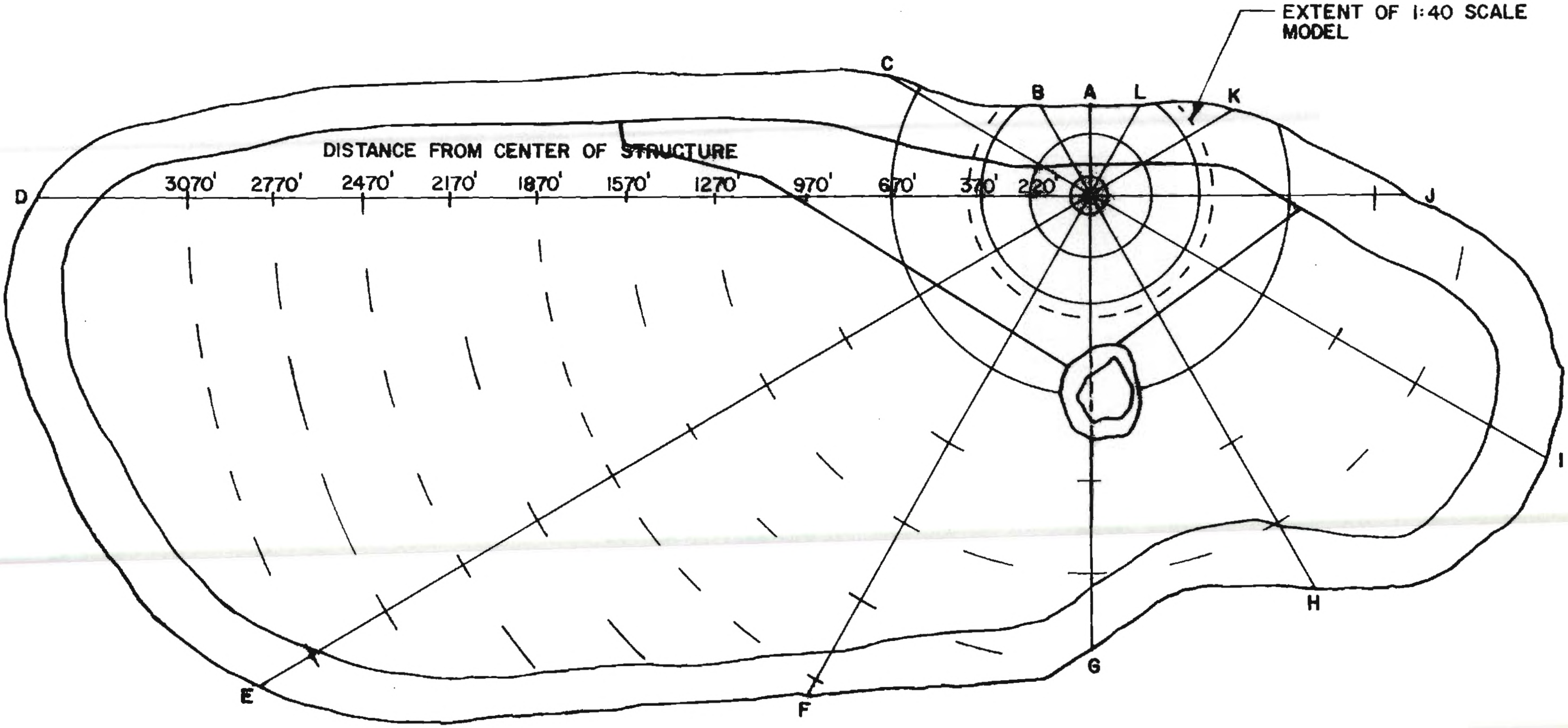


FIGURE 24
UPPER RESERVOIR INTAKE STRUCTURE STUDY
1:300 SCALE MODEL
PLAN VIEW

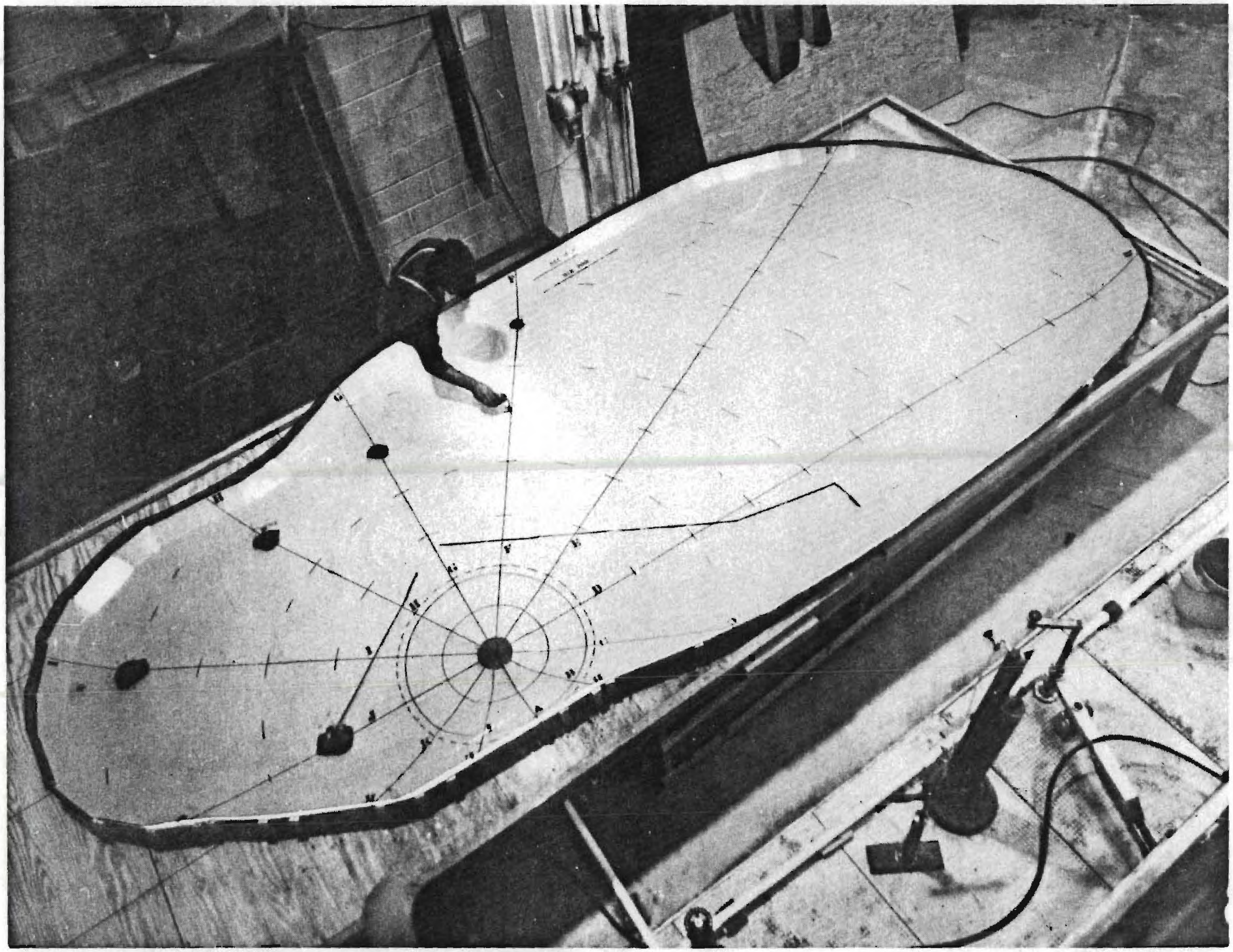


FIGURE 25

BIRDS EYE VIEW OF COMPREHENSIVE 1:300 MODEL

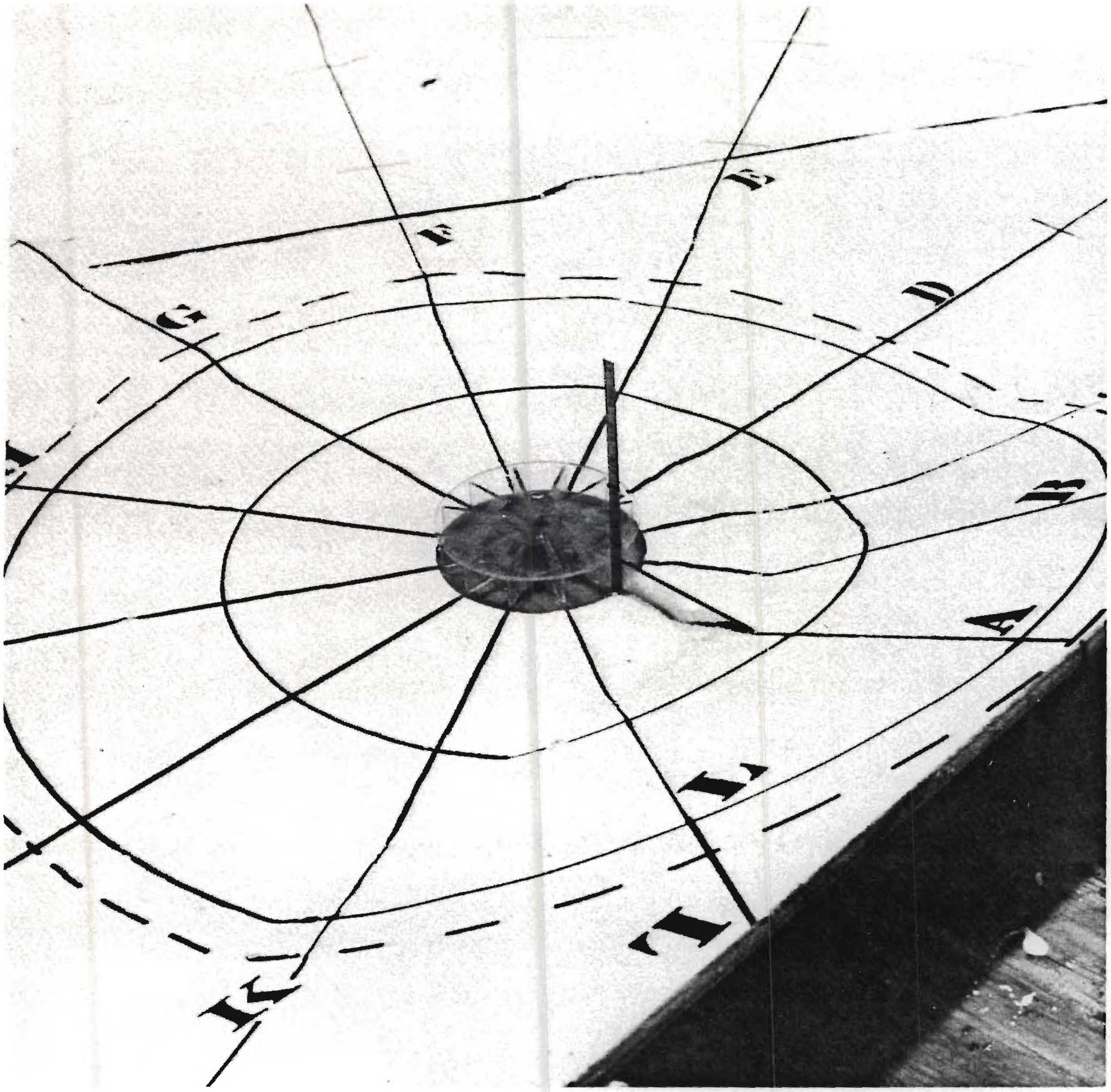


FIGURE 26
CLOSE UP OF 1:300 SCALE INTAKE STRUCTURE

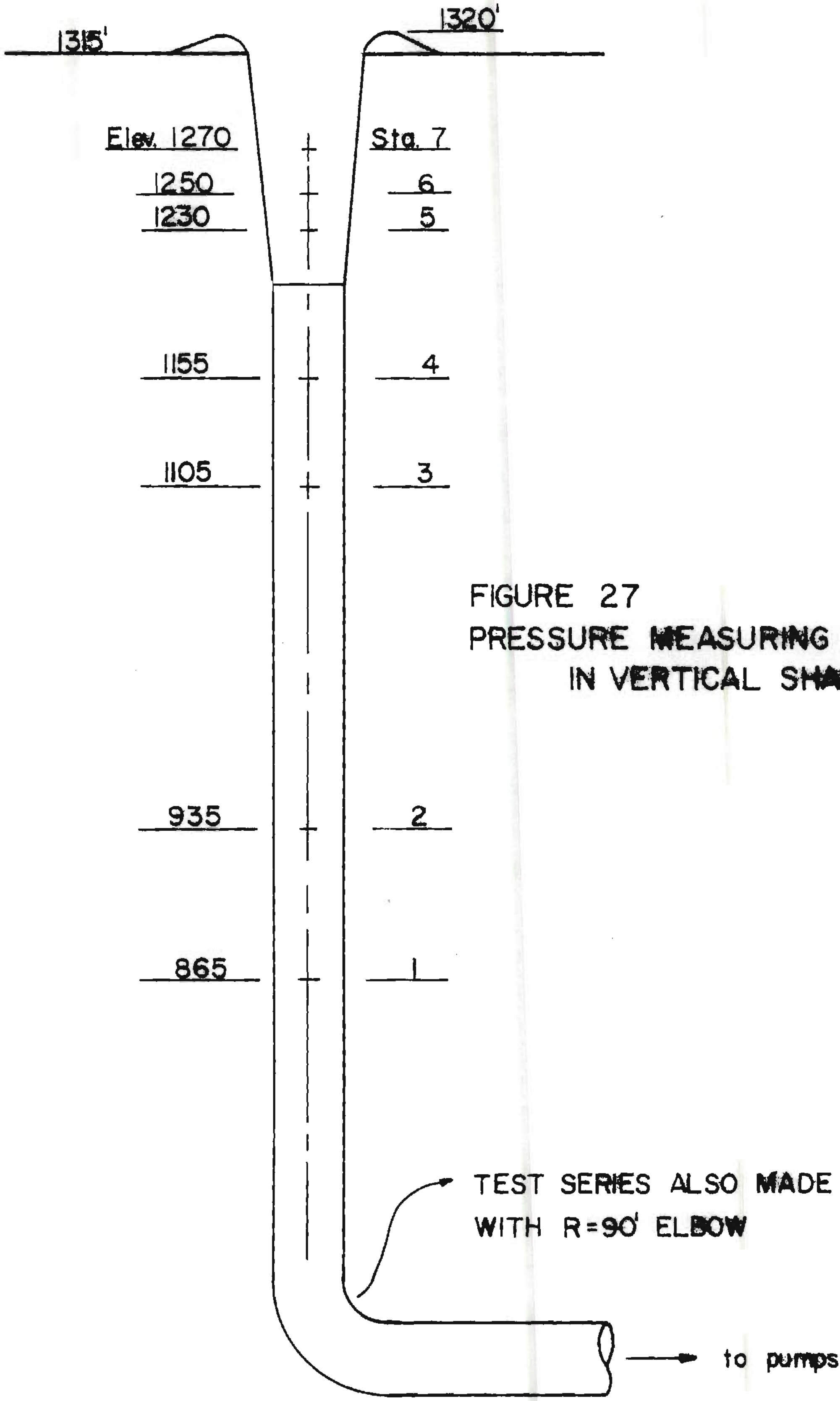


FIGURE 27
PRESSURE MEASURING STATIONS
IN VERTICAL SHAFT

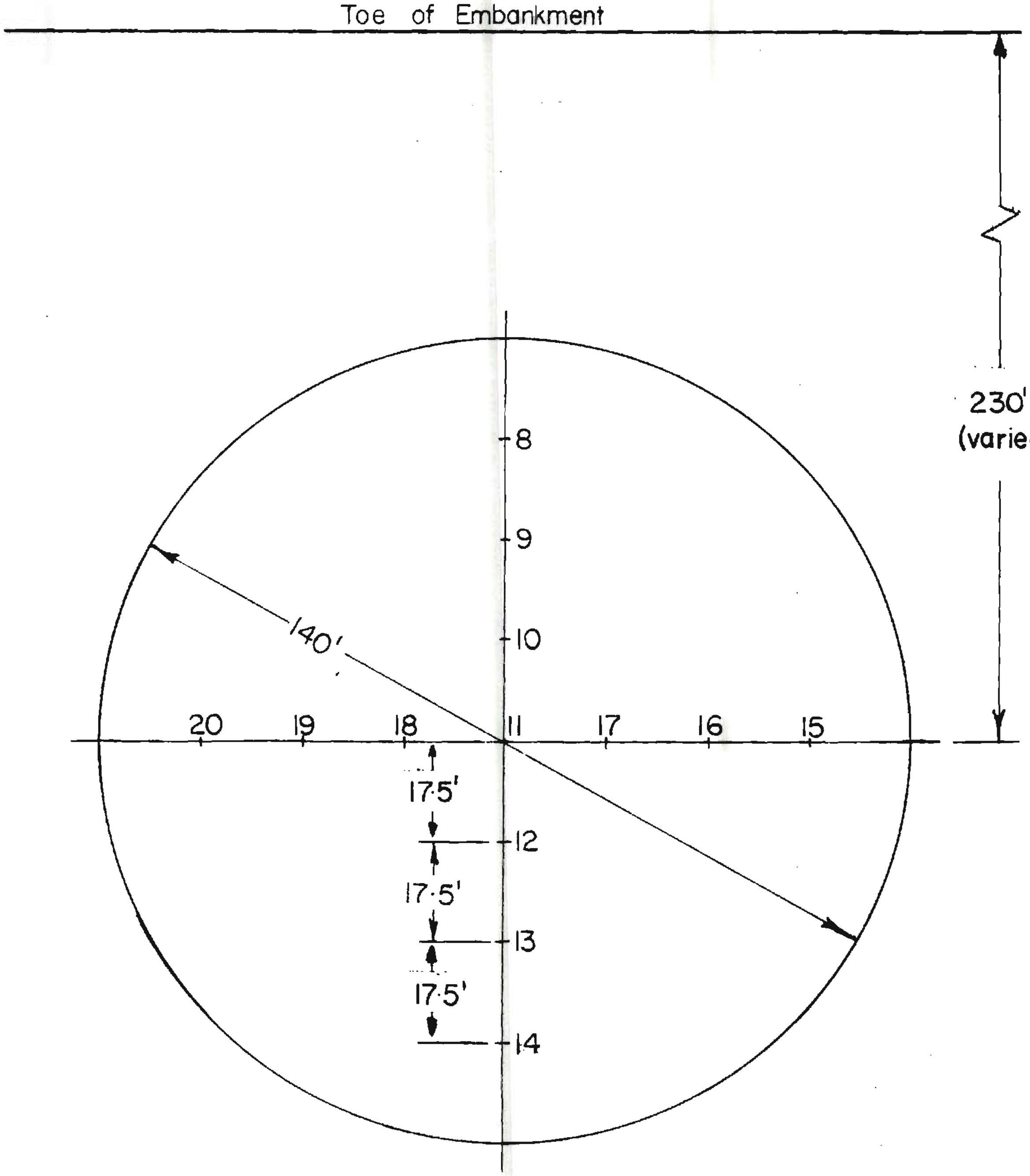


FIGURE 28
PRESSURE MEASURING STATIONS
ON TOP DISK

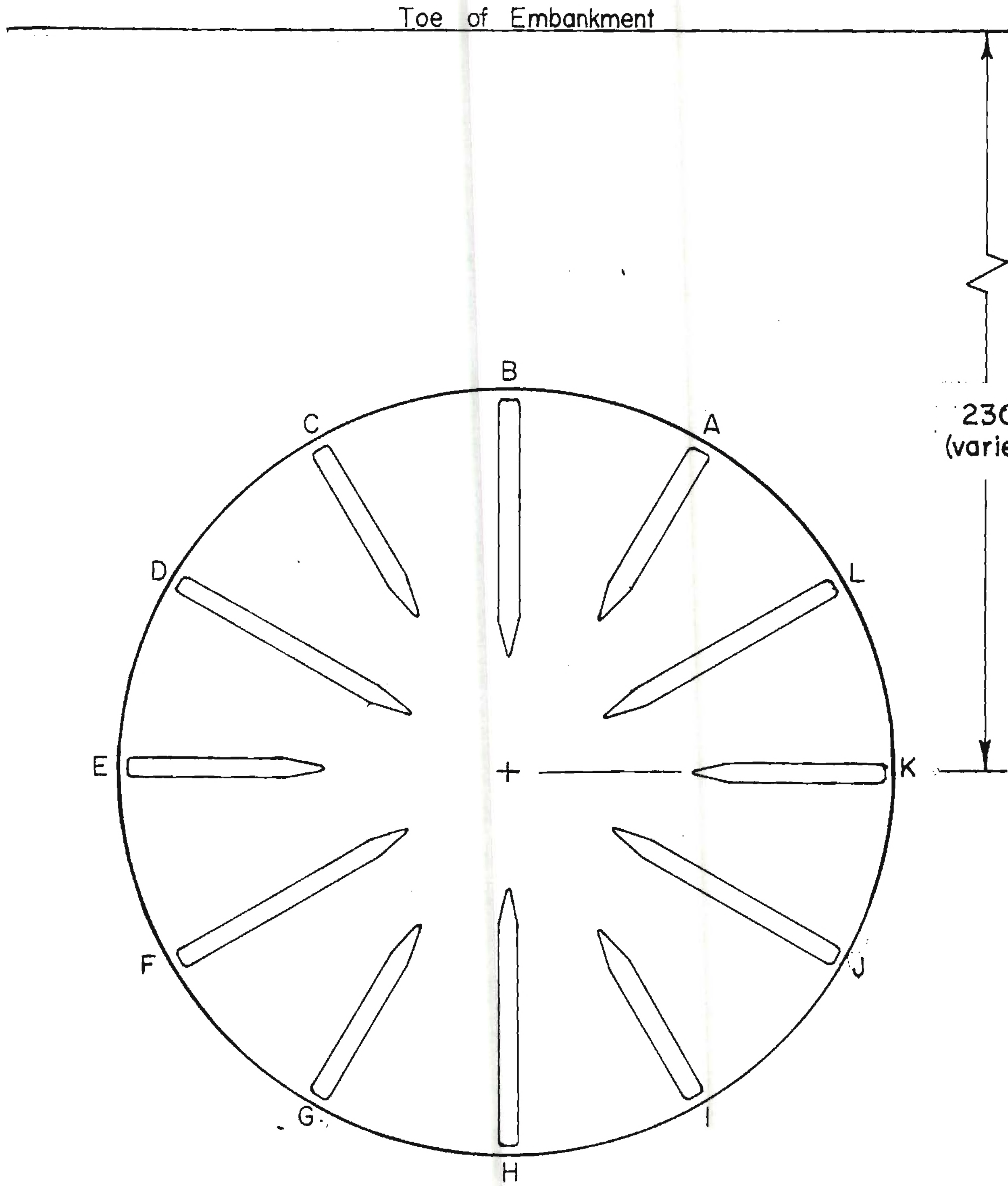


FIGURE 29
TYPICAL PLAN VIEW OF 1:40
SCALE INTAKE STRUCTURE PIERS

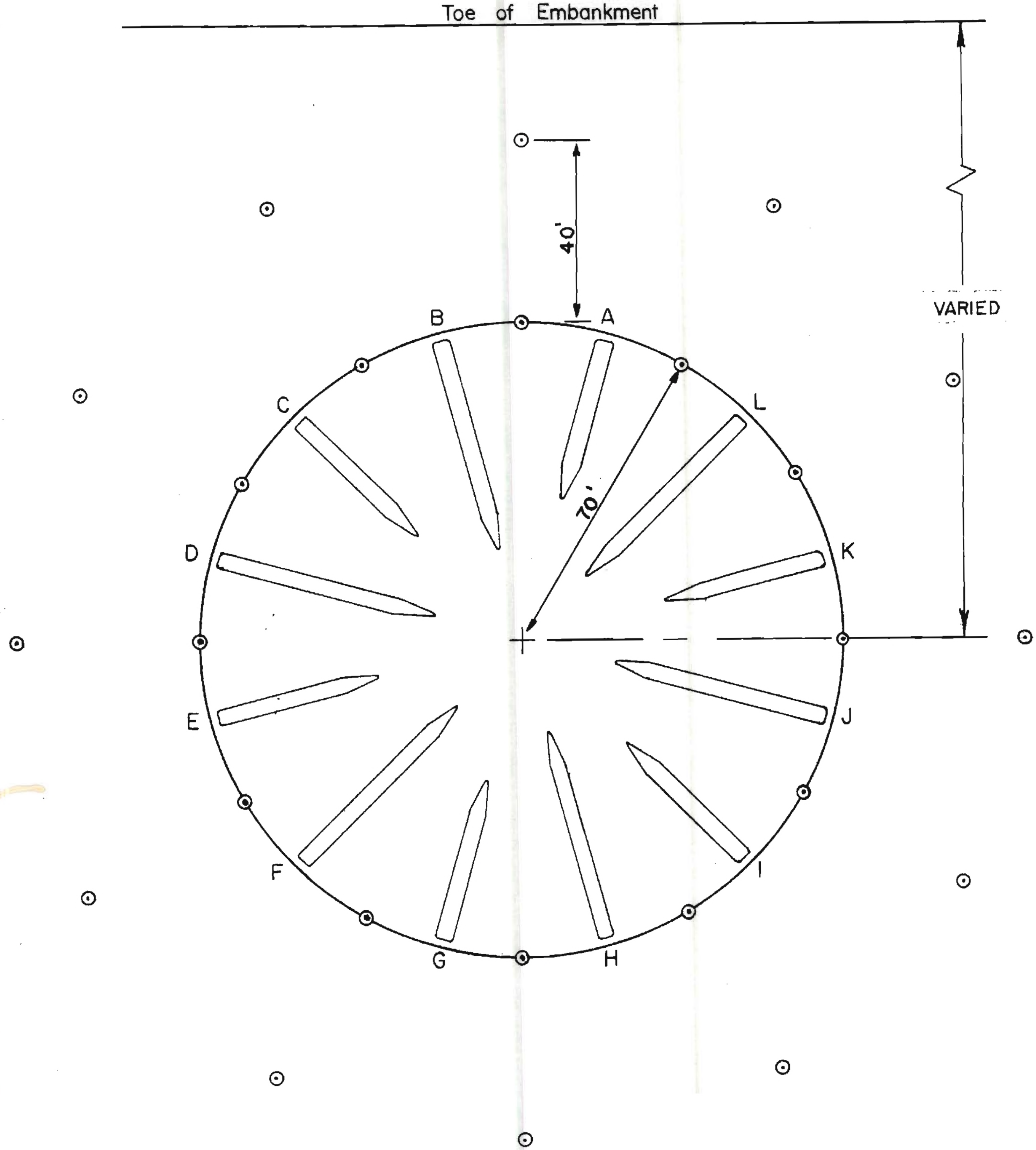


FIGURE 30
VELOCITY MEASURING STATIONS
AT INTAKE STRUCTURE

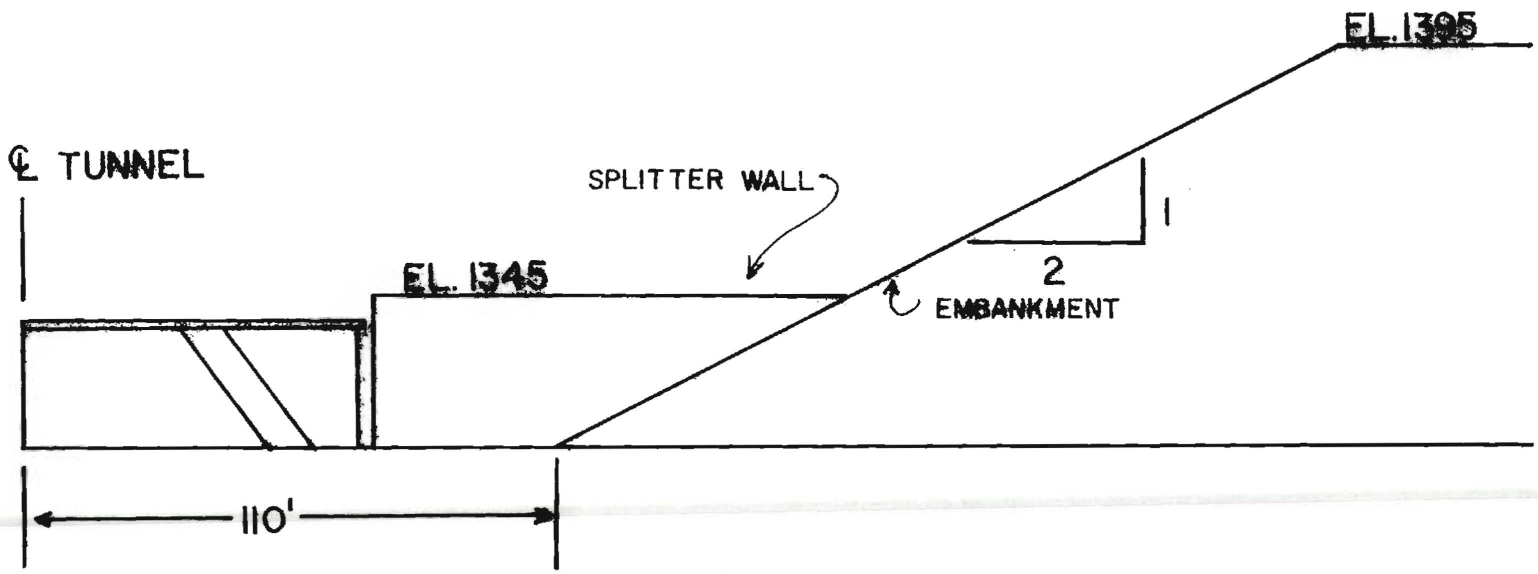


FIGURE 31
TYPICAL SPLITTER WALL

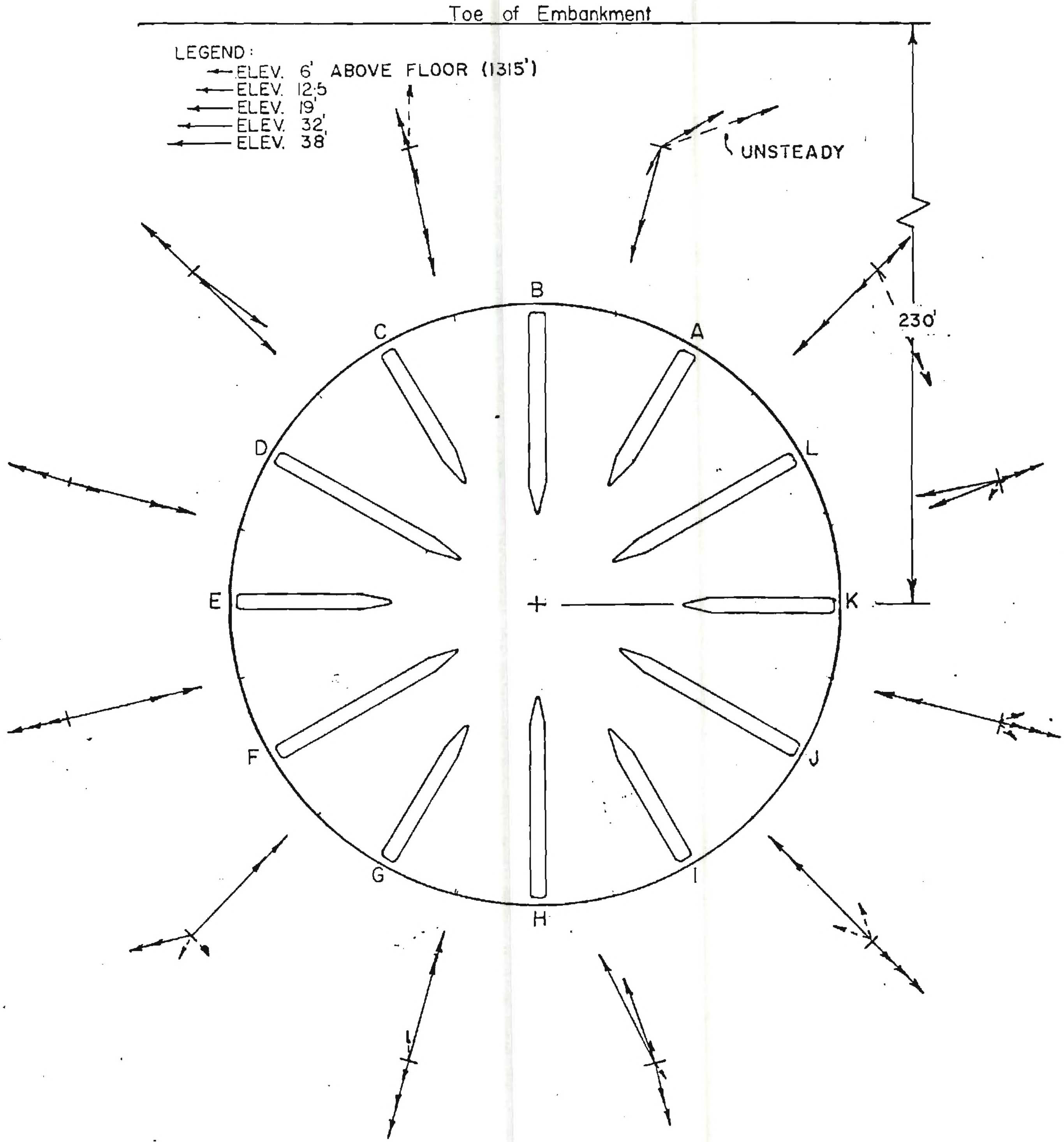


FIGURE 32
FLOW DIRECTIONS AT INTAKE STRUCTURE, PUMPING MODE
150 % DESIGN FLOW, RES. ELEV. 1395' NO SPLITTER WALL

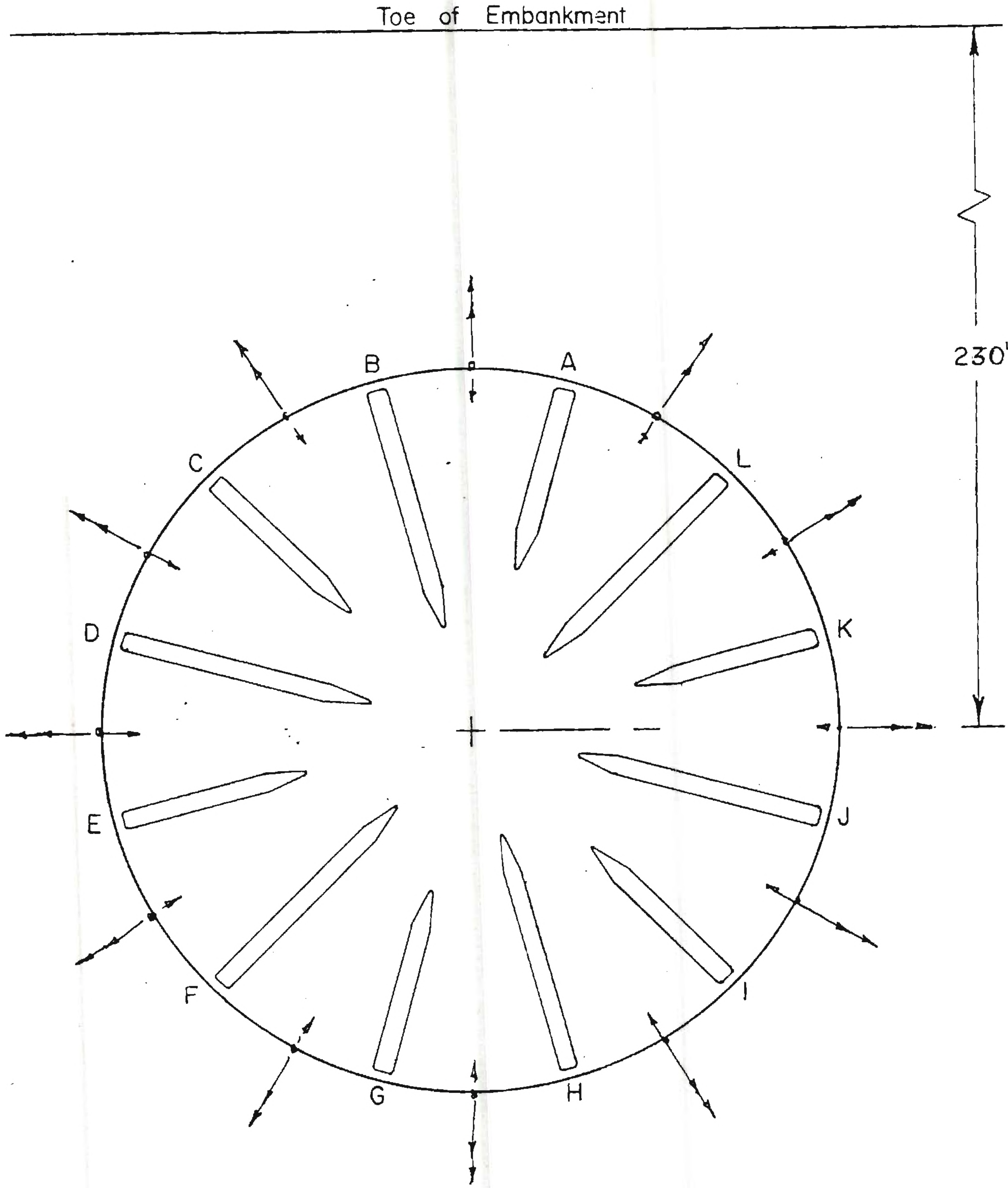


FIGURE 33
FLOW DIRECTIONS AT INTAKE STRUCTURE, PUMPING MODE
100% DESIGN FLOW, RES. ELEV. 1395', NO SPLITTER WALL

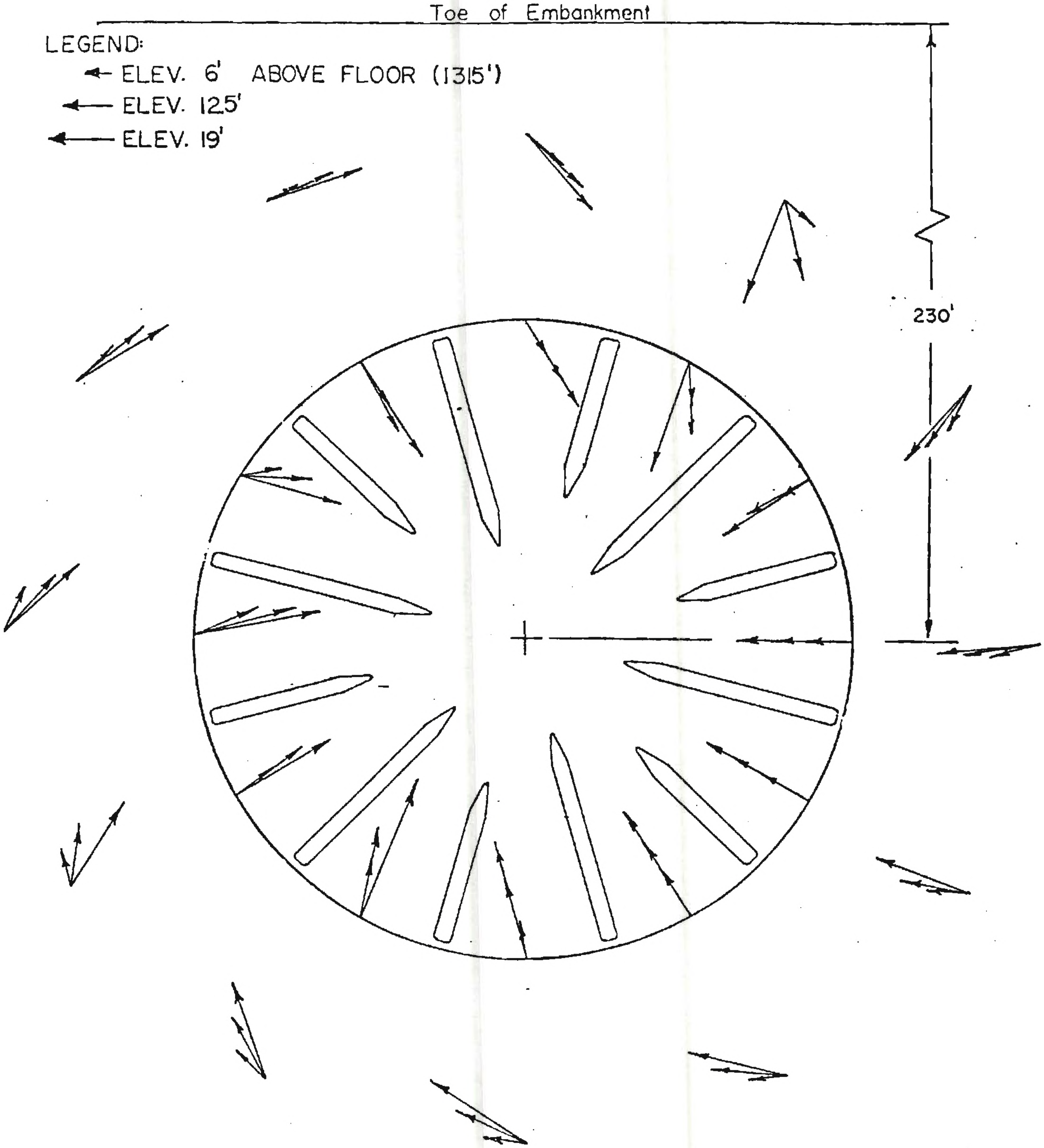


FIGURE 34
FLOW DIRECTIONS AT INTAKE STRUCTURE, GENERATING MODE
150% DESIGN FLOW, RES. ELEV. 1395', NO SPLITTER WALL

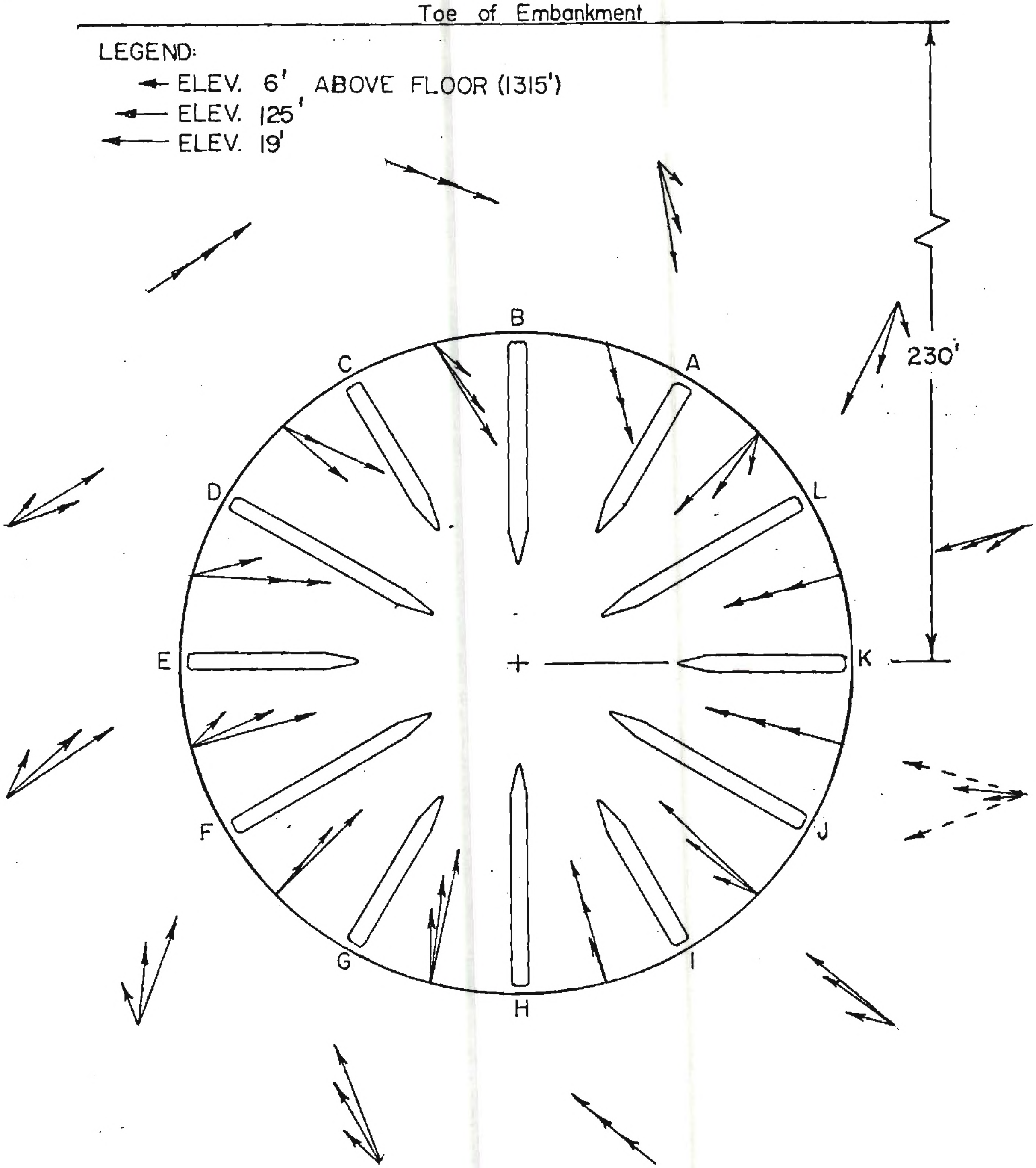


FIGURE 35
FLOW DIRECTIONS AT INTAKE STRUCTURE, GENERATING MODE
150% DESIGN FLOW, RES. ELEV. 1390', NO SPLITTER WALL

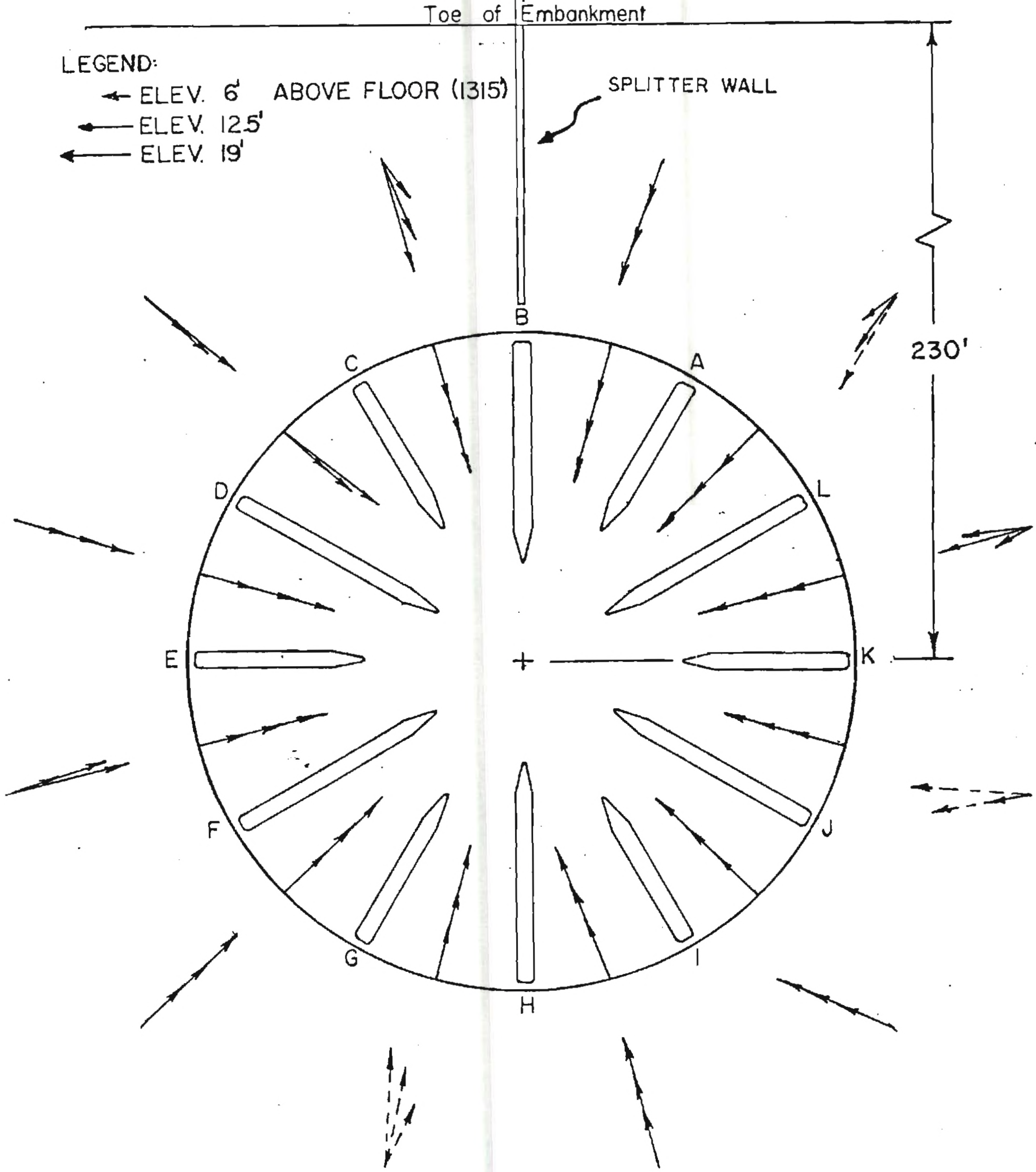


FIGURE 36

FLOW DIRECTIONS AT INTAKE STRUCTURE, GENERATING MODE 150% DESIGN FLOW, RES. ELEV. 1395', HIGH SPLITTER WALL

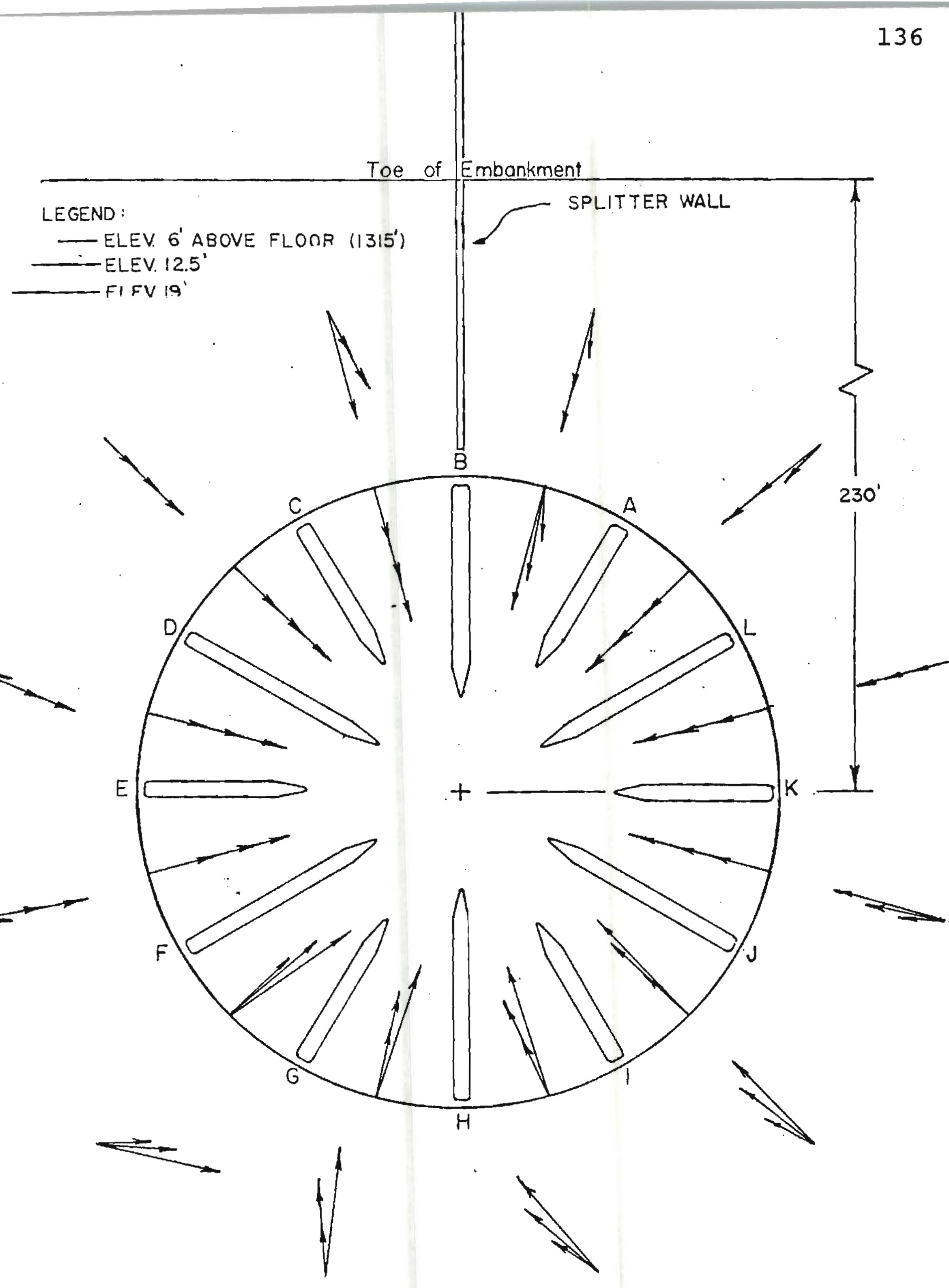


FIGURE 37

FLOW DIRECTIONS AT INTAKE STRUCTURE, GENERATING MODE 150% DESIGN FLOW, RES. ELEV. 1355', HIGH SPLITTER WALL

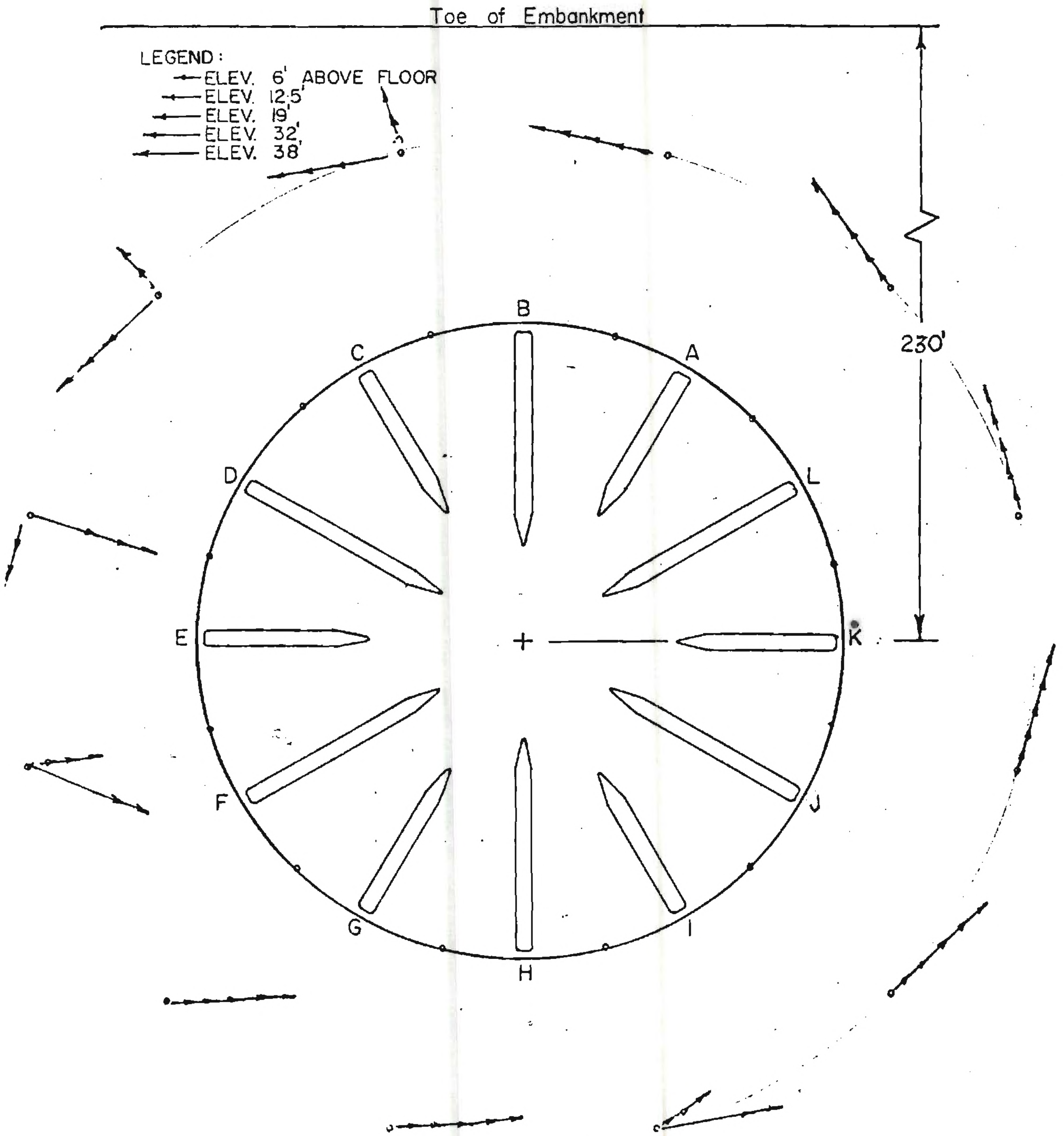


FIGURE 38
FLOW DIRECTIONS AT INTAKE STRUCTURE, GENERATING MODE 150% DESIGN FLOW, RES. ELEV. 1395', NO SPLITTER WALL, INDUCED CIRCULATION

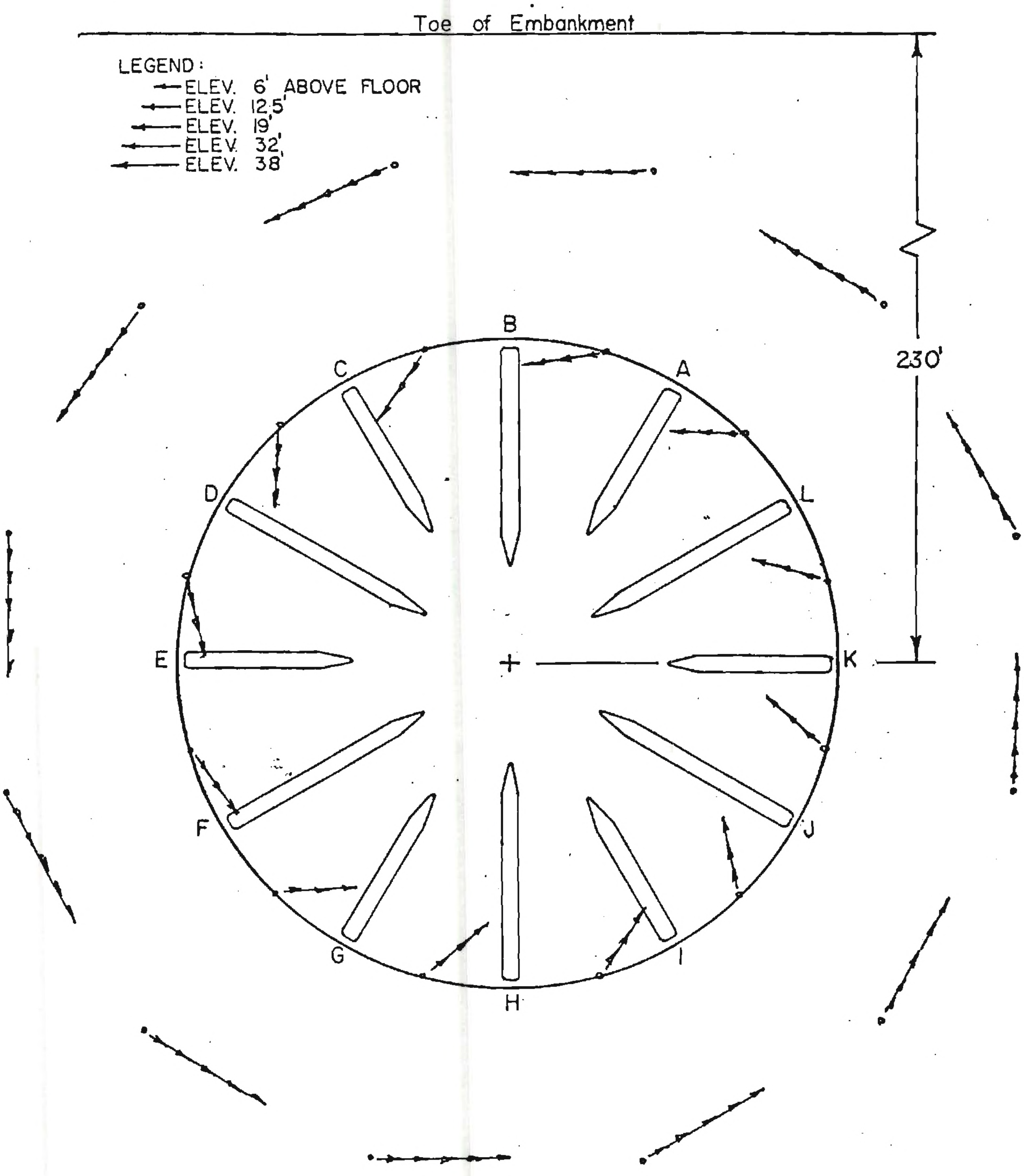


FIGURE 39
FLOW DIRECTIONS AT INTAKE STRUCTURE, GENERATING MODE
150% DESIGN FLOW, RES. ELEV. 1350' NO SPLITTER WALL
INDUCED CIRCULATION

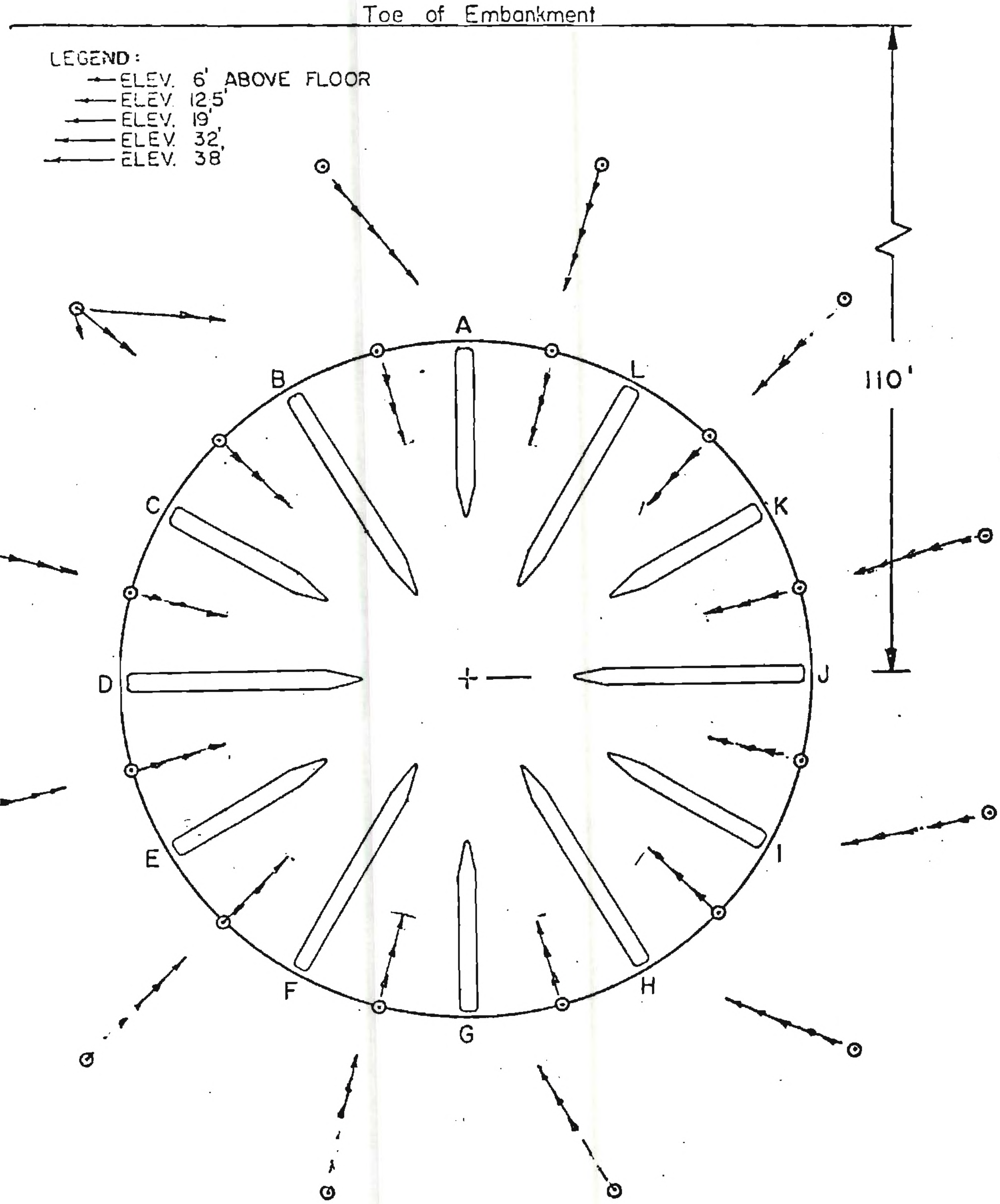


FIGURE 40
FLOW DIRECTIONS AT INTAKE STRUCTURE, GENERATING MODE 100% DESIGN FLOW, RES. ELEV. 1355', NO SPLITTER WALL, FINAL "TUNED" CONDITION