TECHNICAL REPORT H-73-14

SELECTIVE WITHDRAWAL FROM BEECH FORK LAKE, BEECH FORK RIVER WEST VIRGINIA

Hydraulic Model Investigation

by

T. L. Gloriod, J. P. Bohan

September 1973

Sponsored by U. S. Army Engineer District, Huntington

Conducted by U. S. Army Engineer Waterways Experiment Station
Hydraulics Laboratory
Vicksburg, Mississippi

ARMY-MRC VICKSBURG, MISS.

FOREWORD

The model investigation reported herein was authorized by the Office, Chief of Engineers (OCE), U. S. Army, on 13 July 1972, at the request of the U. S. Army Engineer District, Huntington. The study was conducted in the Hydraulics Laboratory, U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi, during the period October 1972 through January 1973, under the general supervision of Messrs. H. B. Simmons, Chief of the Hydraulics Laboratory, and T. E. Murphy, Chief of the Structures Division. The tests were conducted by SP4 T. L. Gloriod and Messrs. J. P. Bohan and M. S. Dortch, under the direct supervision of Mr. J. L. Grace, Jr., Chief of the Spillways and Channels Branch. This report was prepared by SP4 Gloriod and Mr. Bohan.

During the course of the investigation, Mr. S. B. Powell of OCE, Messrs. W. H. Browne, Jr., G. R. Drummond, and D. L. Robey of the U. S. Army Engineer Division, Ohio River, and Mr. R. Spurlock of the Huntington District visited WES to discuss the test results and correlate them with the concurrent design work.

Directors of WES during the conduct of the study and the preparation and publication of this report were BG E. D. Peixotto, CE, and COL G. H. Hilt, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

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British units of measurement used in this report can be converted to metric units as follows:

Multiply	By	To Obtain
inches	2.54	centimeters
feet	0.3048	meters
miles (U. S. statute)	1.609344	kilometers
square miles	2.5899881	square kilometers
acres	4.046856	square kilometers
acre-feet	1233.4817	cubic meters
cubic feet per second	0.02831685	cubic meters per second
Fahrenheit degrees	5/9	Celsius or Kelvin degrees*

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use: $K = (5/9)(F - 32) + 273.15$.

SUMMARY

Tests were conducted at the U. S. Army Engineer Waterways Experiment Station (WES) on a 1:36-scale model of a portion of the proposed Beech Fork Lake and multilevel intake structure to determine the effects of the upstream topography and the geometry in the vicinity of the intake structure on the selective withdrawal capability of the structure. A 2500-ft-long by 1800-ft-wide area of the 40-ft-deep lake was modeled, and three alternative locations of the intake structure were investigated. Density stratification caused by differentials in temperature in the prototype was simulated in the model by using saline and fresh waters.

The majority of the tests were conducted with outflow only. The outflow- to storage-volume ratio was very small for the duration of a given test; therefore, no appreciable drop in the pool elevation was observed. Temperature and conductivity profiles were measured in the model, and their effects were combined to determine the density profiles. Dye particles were dropped into the approach channel flow to indicate the upper and lower withdrawal-zone limits.

Density profiles, appropriate discharges, and other required data were used as input to a computer program (based on the selective withdrawal techniques developed in previous WES investigations) to predict the withdrawal-zone limits. A comparison of the observed and predicted limits indicated good agreement for the three alternative locations of the intake structure. Therefore, based on selective withdrawal performance, there appeared to be no distinct difference in the three locations tested.

One test was conducted with a dyed, dense inflow introduced into the model. An equal rate of withdrawal was released through the lowest level intake to determine the path of the inflow through the lake. The flow followed the sinuous river channel from the point of entry to the intake structure. The dyed inflow then remained in the river channel until there was enough buildup for it to enter the approach channel. Thus, the general pattern of density currents in the proposed reservoir and the selective withdrawal characteristics of the proposed outlet works for both single- and multiple-outlet operations were verified to be representative of those anticipated; i.e., they were not affected by either the topography of the reservoir and approach channel or the geometry in the immediate vicinity of the intake structure.

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PART I: INTRODUCTION

Background

1. The ability to effectively predict and control the quality of releases from man-made impoundments is dependent upon numerous physical, chemical, and biological factors. The prediction of reservoir water quality requires a knowledge of the physical processes involved in the development and decay of thermal stratification as well as of the chemical and biological consequences thereof. Selective withdrawal is a method in which intake ports that are placed at various levels in a stratified reservoir are used to withdraw water of a desired quality. Predictive techniques based on WES laboratory investigations[1,2,3] have been developed to determine the vertical extent of the selective withdrawal zone and the velocity distribution therein. These techniques along with the reservoir profiles of various water-quality parameters can be applied to determine the quality of reservoir releases. This procedure is presently being used in designing and analyzing multilevel intake structures. A definition sketch of the variables involved in selective withdrawal is shown in fig. 1.

2. Previous hydraulic model studies at WES[4,5] have shown that the geometry in the vicinity of the intake structure, the alignment of the approach channel, and the upstream reservoir topography can significantly alter the selective withdrawal characteristics of an intake structure. The study reported herein was conducted to investigate the general pattern of density currents within the proposed reservoir and to verify the assumed or determine the actual selective withdrawal characteristics of the proposed outlet works for both single- and multiple-outlet operations.

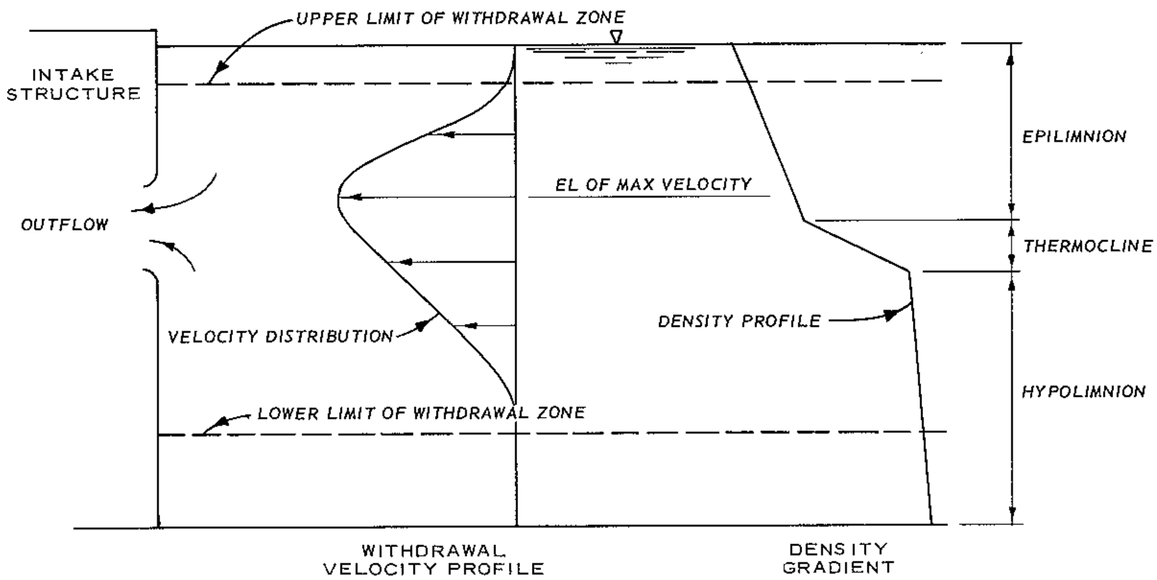


Fig. 1. Selective withdrawal definition sketch

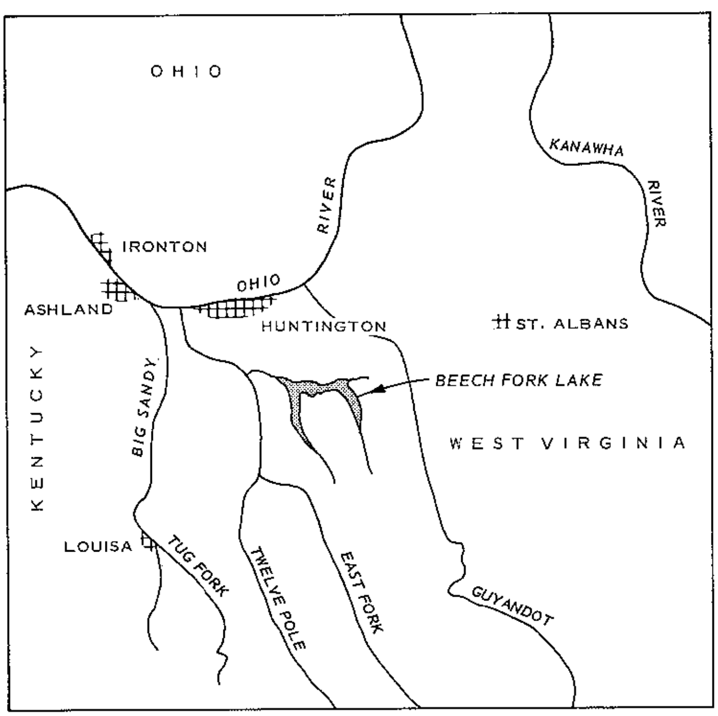


Fig. 2. Vicinity map

The Prototype

3. Beech Fork Lake will be located on Beech Fork River, a tributary of Twelvepole Creek, in Wayne County, West Virginia (fig. 2). The dam will be located 3.6 miles* above the mouth of Beech Fork River and 19.5 miles above the confluence of Twelvepole Creek and the Ohio River. Huntington, West Virginia, lies approximately 7 miles northwest of the reservoir site.

4. The lake will have a surface area of 720 acres and a storage volume of 9180 acre-ft at the seasonal pool. Serving the multiple purposes of flood control, recreation, and fish and wildlife enhancement, Beech Fork Lake will drain an area of 78 square miles.

5. The dam will be an earth-fill gravity type. Low-flow releases of the desired quality will be passed through four intakes in a wet-well-type intake structure. The 4- by 5-ft rectangular intakes will be located with center-line elevations** of 566, 575, and 584, as shown in plate 1. Two intakes will empty into each of two wet wells. A 30-in.-diam conduit with a control valve will drain each of the wet wells into the gate sections of the flood-control conduit just downstream of the service gates. Selective withdrawal releases will vary from 100 to 400 cfs. The design capacity of each intake is for a discharge of 200 cfs.

6. An analysis of hydrologic and meteorologic data for the area indicates that a seasonal temperature variation of approximately 15°F will occur between the 12- to 15-ft-deep epilimnion and the colder regions of the hypolimnion.

Purpose and Scope of Model Study

7. The original design of the Beech Fork outlet works involved a tunneled conduit in the left abutment (location I). This plan was

* A table of factors for converting British units of measurement to metric units is presented on page vii.

** Elevations (el) cited herein are in feet referred to mean sea level.

adequate from a structural, hydraulic, and presumably from a selective withdrawal standpoint. A value engineering study was conducted and resulted in a design calling for a cut-and-cover conduit under the embankment with the intake structure recessed into the embankment. However, with this design, concern developed that the complicated topography in the approach area would affect the selective withdrawal characteristics of the intake structure. For this reason, the conduit was lengthened, and the intake structure was located farther upstream in the reservoir (location II) to avoid the complicated approach topography. Thus, the purpose of the model study was to determine whether there were any differences between the assumed and the actual selective withdrawal characteristics of the intake structures of either of the two alternative locations and, if so, to determine the extent of these differences. In addition, there was an interest in determining the density current patterns created by flow along the sinuous river channel in the reservoir with each of the intake structure locations.

PART II: THE MODEL

Description

8. The model (fig. 3), which was built to an undistorted scale ratio of 1:36, reproduced an 1800-ft-wide section of the reservoir extending for 2500 ft upstream from near the axis of the dam. The intake structures were constructed of transparent plastic, and the reservoir topography (plate 2) was molded in cement mortar to sheet metal templates.

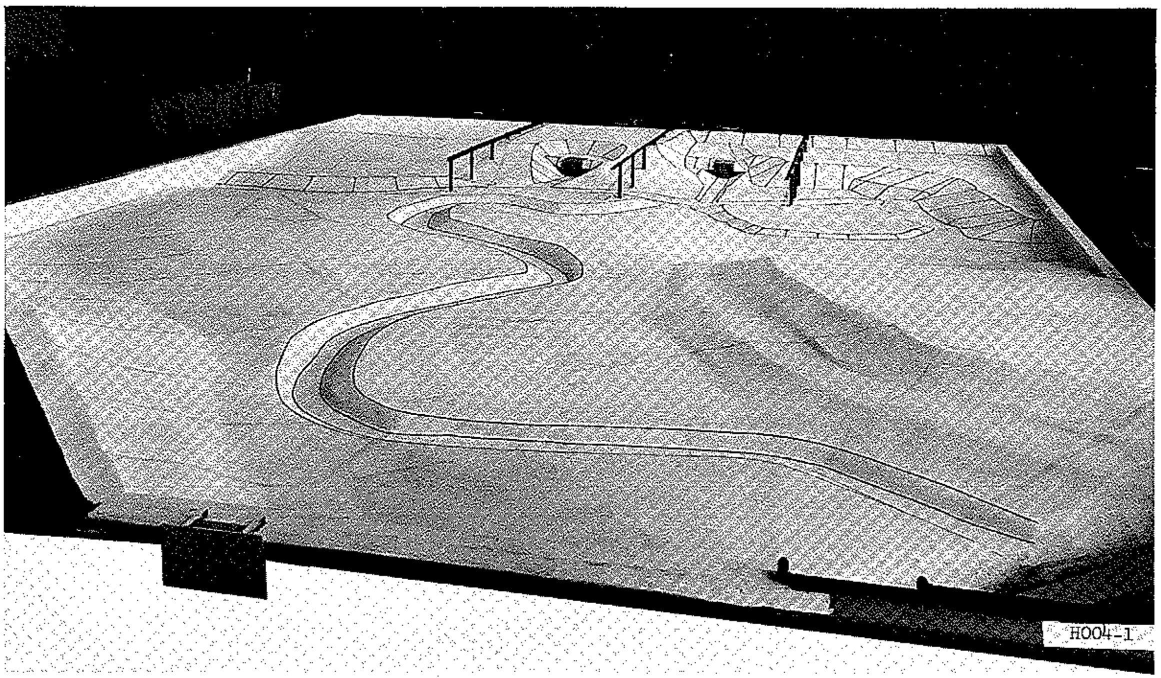


Fig. 3. Beech Fork Lake 1:36-scale model

9. The original model included two intake structures (fig. 4) at different locations: location I had the tunneled conduit outlet works located in the left abutment (plate 3), and location II had the cut-and-cover conduit outlet works located in the dam embankment approximately 825 ft from the axis of the dam (plate 4). Two reproductions of the proposed intake structures were installed in the original model, because it was believed that there was sufficient space between the alternate locations to isolate the selective withdrawal characteristics of each.

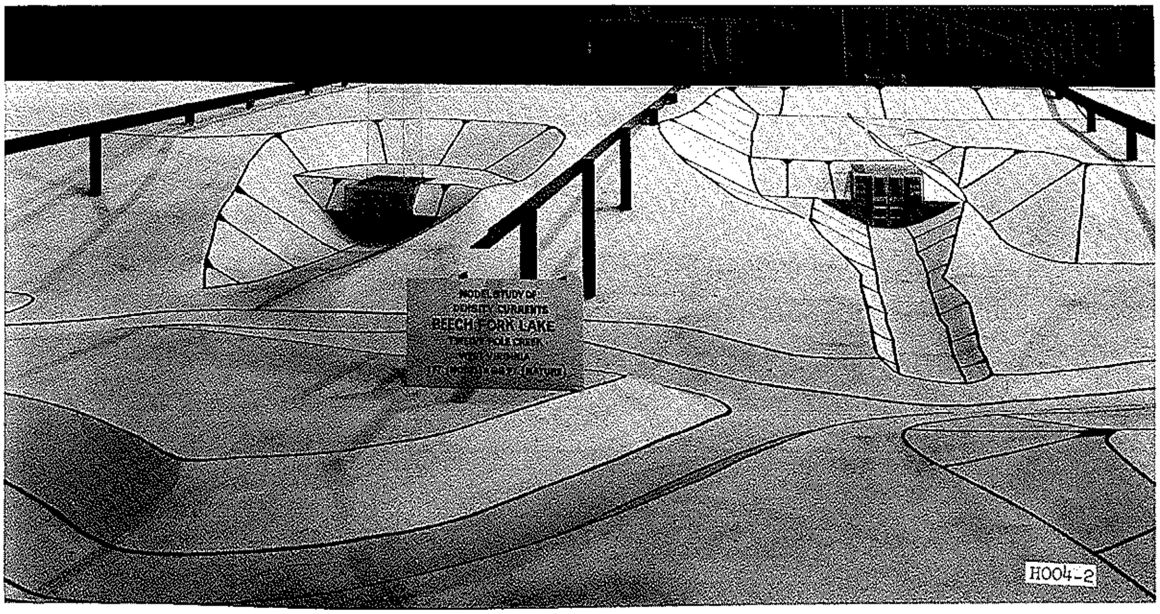


Fig. 4. Intake structure locations I (left) and II (right)

A later revision of the model, location III (fig. 5, plate 5), involved relocating the cut-and-cover conduit outlet works 80 ft closer to the axis of the dam.

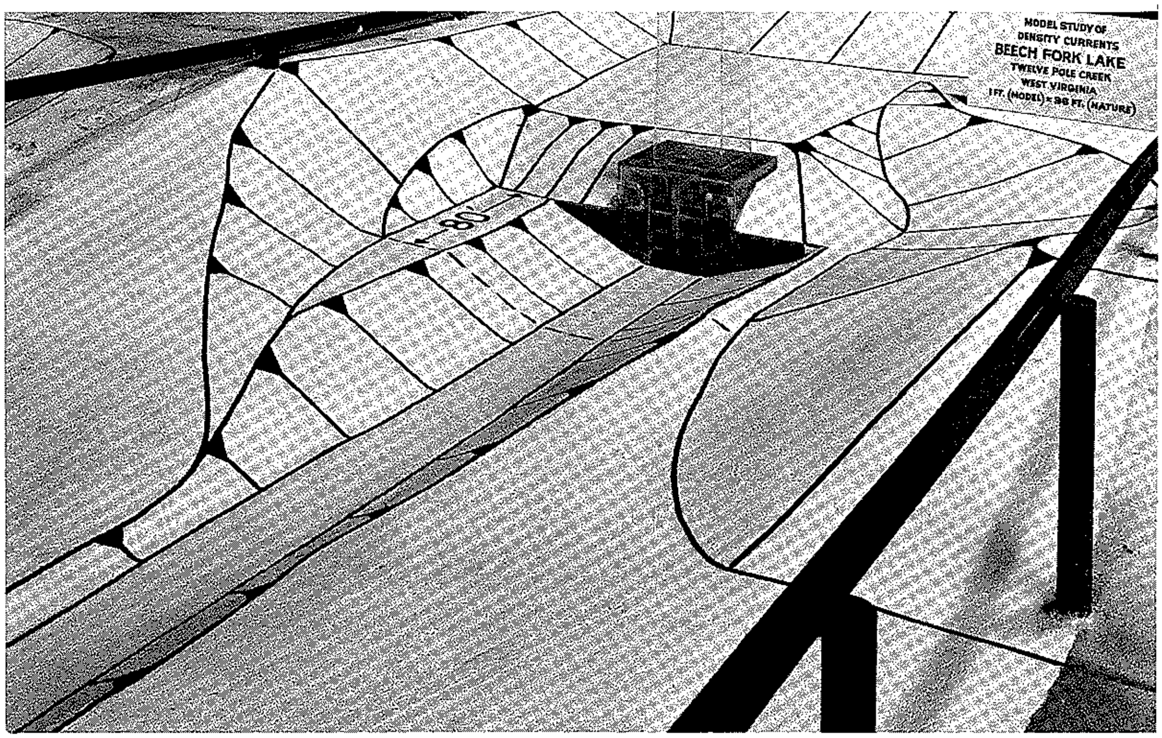


Fig. 5. Intake structure location III

Appurtenances

10. Fresh water used in the operation of the model was supplied from the local water system. A separate sump and pump were used to supply predetermined quantities and concentrations of saline water. Density stratifications corresponding to temperature differences of approximately 15°F within the pool were controlled by means of the salt concentrations of the denser bottom layer.

11. A dual piping and baffle scheme at the upstream end of the model was used to maintain a two-layer stratification. Rotameters were used to measure the rate of both fresh and saline inflow to the reservoir. A 4-in. Van Leer weir calibrated against the rotameters was used to measure the rate of withdrawal released through the outlet works.

Scale Relations

12. The accepted equations of hydraulic similitude based upon the Froudian relations were used to express the mathematical relations between the dimensions and hydraulic quantities of the model and prototype.

Dimension	Ratio	Scale Relation
Length	L_r	1:36
Area	$A_r = L_r^2$	1:1296
Velocity	$V_r = L_r^{1/2}$	1:6
Discharge	$Q_r = L_r^{5/2}$	1:7776
Density	$D_r = L_r/L_r$	1:1

13. Conversion of quantities from model to prototype equivalents can be made by means of the preceding scale relations.

PART III: TESTS AND RESULTS

Test Procedures

14. Density stratification was generated in the model by first adding the necessary amount of dyed saline water required to simulate the desired depth of hypolimnial water. Fresh water from the local supply was added horizontally across an interface baffle to fill the upper or epilimnial portion of the pool. Fig. 6 shows a view of the model with density stratification in the reservoir.

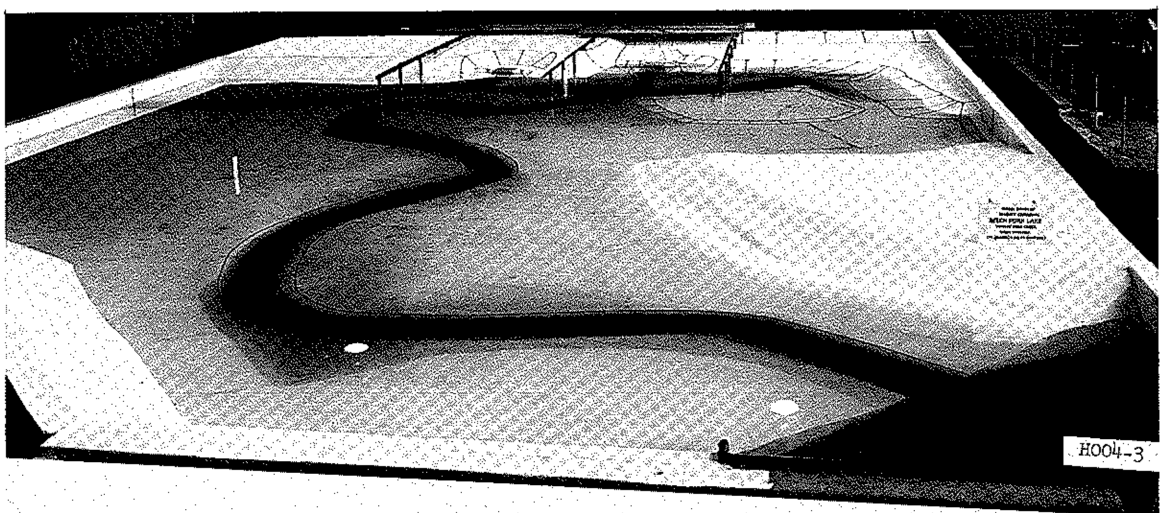


Fig. 6. Beech Fork Lake with density stratification

15. Prior to performing a series of tests, the density in 1-ft increments of elevation (prototype) was measured in the approach channel at a location approximately 35 ft (prototype) upstream from the face of the intake structure. The equipment used to measure densities (fig. 7) included a conductivity probe connected to a conductivity indicator with a millivoltmeter for a digital readout. A thermistor connected to a digital thermometer measured the temperature in degrees Celsius at each elevation. The effects of conductivity and temperature could then be

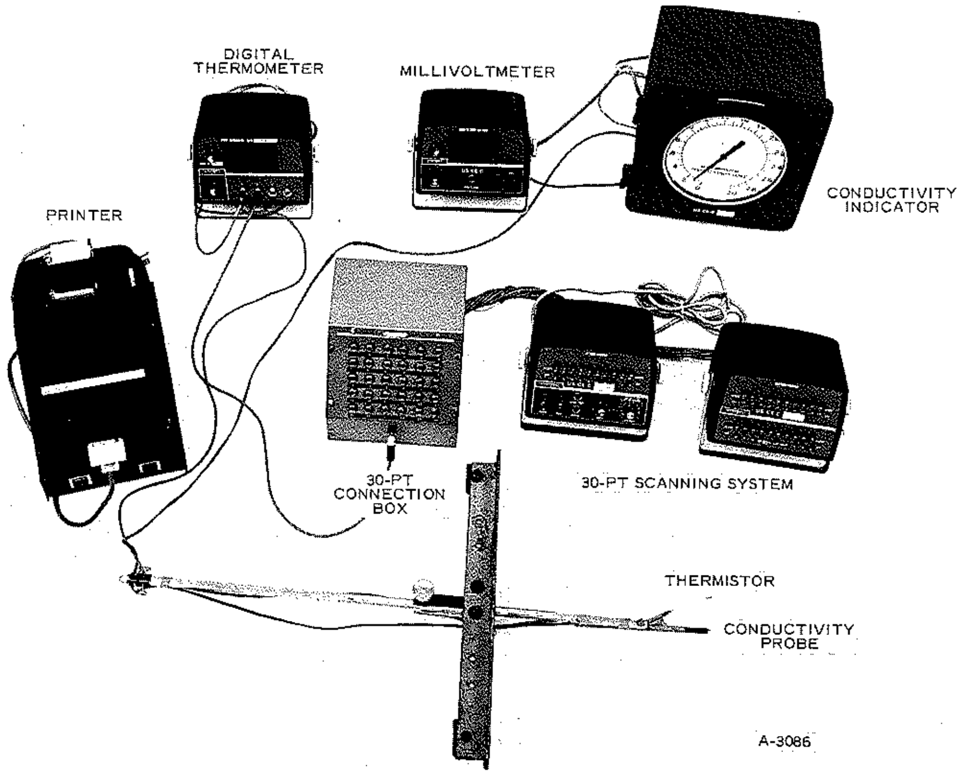


Fig. 7. Instrumentation used to measure temperatures and salinities

combined to determine the density profile. An optional multipoint scanning system was available for multiple-probe operation. The instruments were calibrated against solutions of known density.

16. The desired scheme and rates of release were then set through the appropriate intakes with no inflow to the reservoir. This procedure of model operation maintained a stable density gradient during tests and caused only slight decreases in the elevation of the pool.

17. The upper and lower limits of the withdrawal zone were measured by visually aligning a depth gage with first the upper and then the lower elevation of zero velocity of a vertical dye streak placed in the approach channel (fig. 8). The density of the outflow was also measured.

Test Observations

18. Several tests were conducted varying the interface elevation

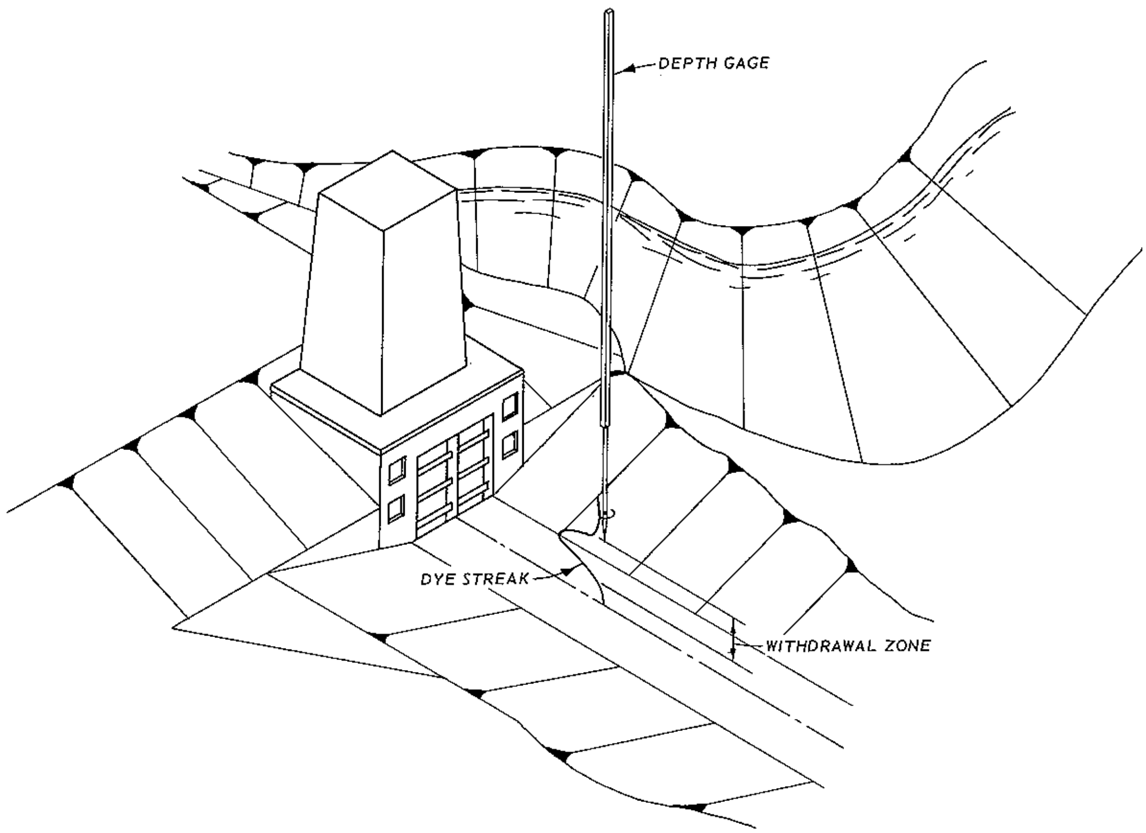


Fig. 8. Measurement of withdrawal-zone limits

and operational scheme for the intake structures at locations I and II. The observed withdrawal limits and outflow densities for various density profiles and operational schemes are shown in plates 6-13. For each of the tests conducted, the withdrawal limits and outflow density were predicted using the WES selective withdrawal techniques which are incorporated in the computer program SELECT (a category C program as defined by Engineer Regulation 1110-1-10[6]). The observed and predicted values are tabulated in table 1 and compared in plates 14, 15, and 16. In general, the comparisons were good. There appeared to be no consistent deviation between the predicted and observed values for the two locations, and the random scatter was attributed to experimental error. It was impossible to control all of the wind currents and rates of heat exchange that occurred at the water surface in the model shelter. In some cases, these external effects induced substantial secondary currents in the upper 3 to 4 ft of the simulated reservoir, even when no inflow or outflow was permitted. Based on these observations and comparisons of the discrepancies between observed and predicted results obtained with and without the existence of externally induced secondary currents, it was concluded that only the upper limit of the withdrawal zone was restricted by such currents. The local geometry effects were negligible, and the outflows of the intake structures at the two alternate locations had comparable selective withdrawal characteristics which agreed with those predicted on the basis of previous generalized results.[7]

19. In the interest of economy, personnel of the U. S. Army Engineer District, Huntington (the sponsoring agency), decided to move the intake structure 80 ft downstream of location II. The model was modified (fig. 5, plate 5), and similar tests were conducted to determine the selective withdrawal characteristics of the intake structure in location III. The results of these tests are shown in plates 17 and 18. Again, the withdrawal limits and outflow densities were predicted and compared with the observed values. These results are also tabulated in table 1, and the comparisons shown in plates 14-16 and 19 indicate that the selective withdrawal performance of the intake structure in location III was comparable to that in locations I and II.

PART IV: DISCUSSION OF RESULTS

20. The results of the model investigation reported herein indicate that the upstream topography and geometry in the vicinity of the proposed intake structure will have no measurable effect on the selective withdrawal characteristics of the intake structure at any of the three locations tested. This is undoubtedly due to the fact that the maximum discharge through the multilevel system is only 400 cfs and the approach geometry is not very irregular. There is a rather severe contraction from the main reservoir pool to the approach channel. On the other hand, the approach channel contains no curvature. Observations of dye particles near the entrance of and in the approach channel indicated very low velocities. It was apparent from such observations that the inertial forces created by the changes in flow direction at the entrance to the approach channel were not large enough to overcome the gravitational or buoyant forces created by the density stratification. Since the buoyant forces predominated, the selective withdrawal characteristics of the intake structures were unaffected.

21. It is very difficult to predict the influence of inertial forces on selective withdrawal. Although the results of this investigation indicate that the inertial forces created by the approach conditions were not great enough to influence the selective withdrawal characteristics of the proposed intake structure, the effect of approach conditions has been observed in other model studies. Therefore, it should not be concluded, based upon the results of this study, that approach conditions are unimportant in determining the selective withdrawal characteristics of orifices and weirs.

22. The selective withdrawal techniques developed at the WES provide an excellent means of designing selective withdrawal structures. However, it must be understood that the techniques are based on gravitational forces only. For this reason, approach conditions should be examined to determine whether they may influence density currents and selective withdrawal characteristics of various outlet works. This type of examination is especially important for relatively high discharges.

If it appears that approach conditions may be a factor in determining selective withdrawal characteristics, a model study should be considered. Since the generalized WES selective withdrawal results were determined and are applicable for random density gradients, it is possible to utilize relatively small, economical physical models in conjunction with a simple two-layer system of stratification to determine the selective withdrawal characteristics of proposed projects. It is not necessary that exact simulations of the density gradients expected in a given impoundment be reproduced in physical models for evaluation of selective withdrawal characteristics of a project. Verification or determination of the actual selective withdrawal characteristics should be accomplished with simple physical models to ensure or refine the accuracy of various mathematical simulation techniques which are available and more appropriate for the analyses required for planning, design, and management purposes.

LITERATURE CITED

1. Bohan, J. P. and Grace, J. L., Jr., "Mechanics of Flow from Stratified Reservoirs in the Interest of Water Quality; Hydraulic Laboratory Investigation," Technical Report H-69-10, Jul 1969, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

2. Grace, J. L., Jr., "Selective Withdrawal Characteristics of Weirs; Hydraulic Laboratory Investigation," Technical Report H-71-4, Jun 1971, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

3. Bohan, J. P. and Gloriod, T. L., "Simultaneous, Multiple-Level Release from Stratified Reservoirs; Hydraulic Laboratory Investigation," Research Report H-72-3, Dec 1972, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

4. Bohan, J. P., "Water Temperature Control Weir for Meramec Park Dam, Meramec River, Missouri; Hydraulic Model Investigation," Technical Report H-70-1, Feb 1970, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

5. Melsheimer, E. S. and Oswalt, N. R., "Outlet Works for New Hope Reservoir, Cape Fear River Basin, North Carolina; Hydraulic Model Investigation," Technical Report H-69-14, Oct 1969, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

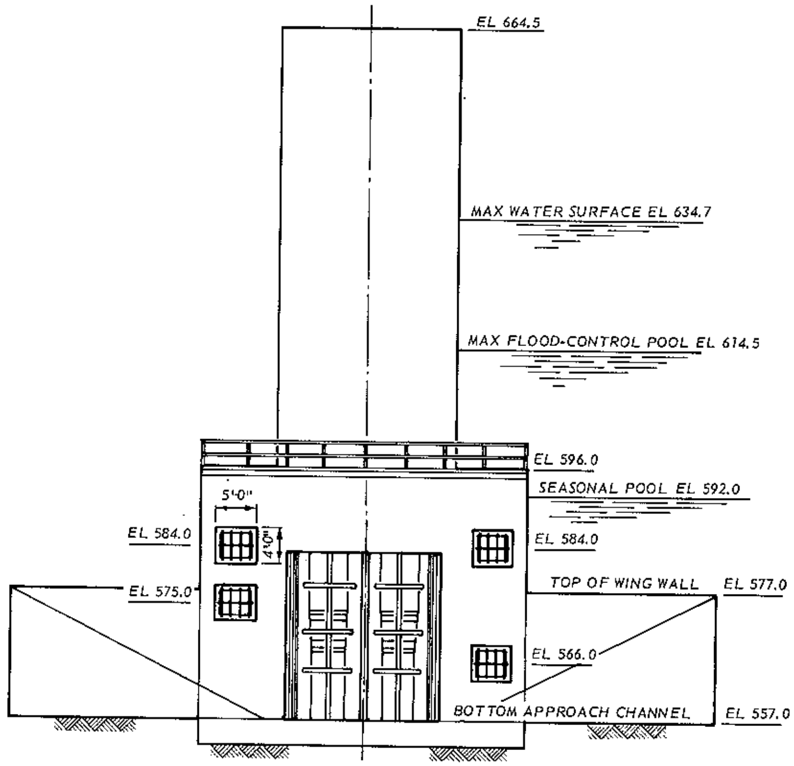
6. Office, Chief of Engineers, U. S. Army, "Development, Review, and Use of Computer Programs," Engineer Regulation 1110-1-10, 30 Jan 1970, U. S. Government Printing Office, Washington, D. C.

7. Bohan, J. P. and Grace, J. L., Jr., "Selective Withdrawal from Man-Made Lakes; Hydraulic Laboratory Investigation," Technical Report H-73-4, Mar 1973, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

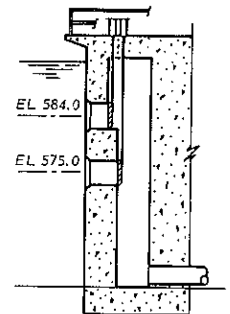
Table 1

Comparison of Observed and Predicted Test Results

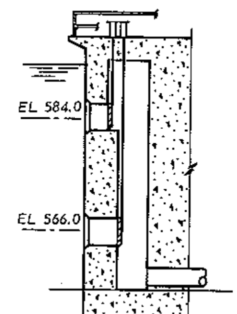
Intake Structure Location	Test No.	Outlet Level	Discharge cfs	Observed Results: Elevation of Withdrawal Limit, ft Upper	Observed Results: Elevation of Withdrawal Limit, ft Lower	Observed Results: Density of Outflow g/cc	Predicted Results: Elevation of Withdrawal Limit, ft Upper	Predicted Results: Elevation of Withdrawal Limit, ft Lower	Predicted Results: Density of Outflow g/cc
I	1	Mid	200	584	565	0.99959	591	562	0.99976
I	2	Low	200	580	557	1.00081	580	557	1.00162
II	3	Low	200	581	557	1.00070	580	557	1.00175
II	4	Mid	200	589	566	0.99967	592	562	0.99975
I	5	Mid	200	589	563	0.99960	591	562	0.99975
I	6	High	200	591	566	0.99950	591	566	0.99960
I	7	Mid/high	400	591	563	0.99960	591	562	0.99972
II	8	High	200	591	577	1.00230	591	566	1.00223
II	9	High	100	591	571	1.00225	591	570	1.00222
II	10	Mid	100	591	557	1.00237	591	560	1.00239
II	11	Mid	200	591	557	1.00236	591	557	1.00252
II	12	Mid/high	200	591	557	1.00235	591	560	1.00233
II	13	Mid/high	400	591	557	1.00238	591	557	1.00232
II	14	Low	100	571	557	1.00266	580	557	1.00281
II	15	Low	200	576	557	1.00250	584	557	1.00280
II	16	Low/high	200	591	557	1.00245	591	557	1.00254
II	17	Low/high	400	591	557	1.00228	591	557	1.00251
II	18	High/high	400	591	570	1.00279	591	560	1.00277
I	19	High	200	591	566	1.00076	591	569	1.00090
I	20	Low	200	577	557	1.00227	581	557	1.00242
I	21	Mid	200	589	557	1.00173	590	557	1.00191
I	22	Mid/high	400	591	557	1.00134	591	557	1.00139
I	23	Mid/high	200	591	557	1.00131	591	560	1.00137
I	24	High/low	400	591	557	1.00160	591	557	1.00157
II	25	Mid	200	592	557	1.00312	592	557	1.00297
II	26	Low	200	586	557	1.00332	584	557	1.00346
II	27	High	200	592	570	1.00297	592	566	1.00290
I	28	Low	200	578	557	1.00219	580	557	1.00233
I	29	Mid	200	591	557	1.00136	591	558	1.00133
I	30	High	200	592	573	1.00022	592	570	1.00032
II	31	Mid	200	589	557	1.00137	589	557	1.00186
II	32	Low	200	578	557	1.00243	579	557	1.00245
II	33	High	200	592	573	0.99991	592	570	1.00001
III	34	Mid	100	589	558	1.00222	590	564	1.00220
III	35	Mid	200	591	558	1.00235	592	561	1.00207
III	36	Mid/high	400	592	557	1.00211	592	561	1.00200
III	37	High	100	592	573	1.00167	592	571	1.00168
III	38	High	200	592	573	1.00165	592	569	1.00171
III	39	Low	100	577	557	1.00353	576	557	1.00368
III	40	Low	200	582	557	1.00329	580	557	1.00359
III	41	Low/high	400	592	557	1.00256	592	557	1.00269



UPSTREAM ELEVATION



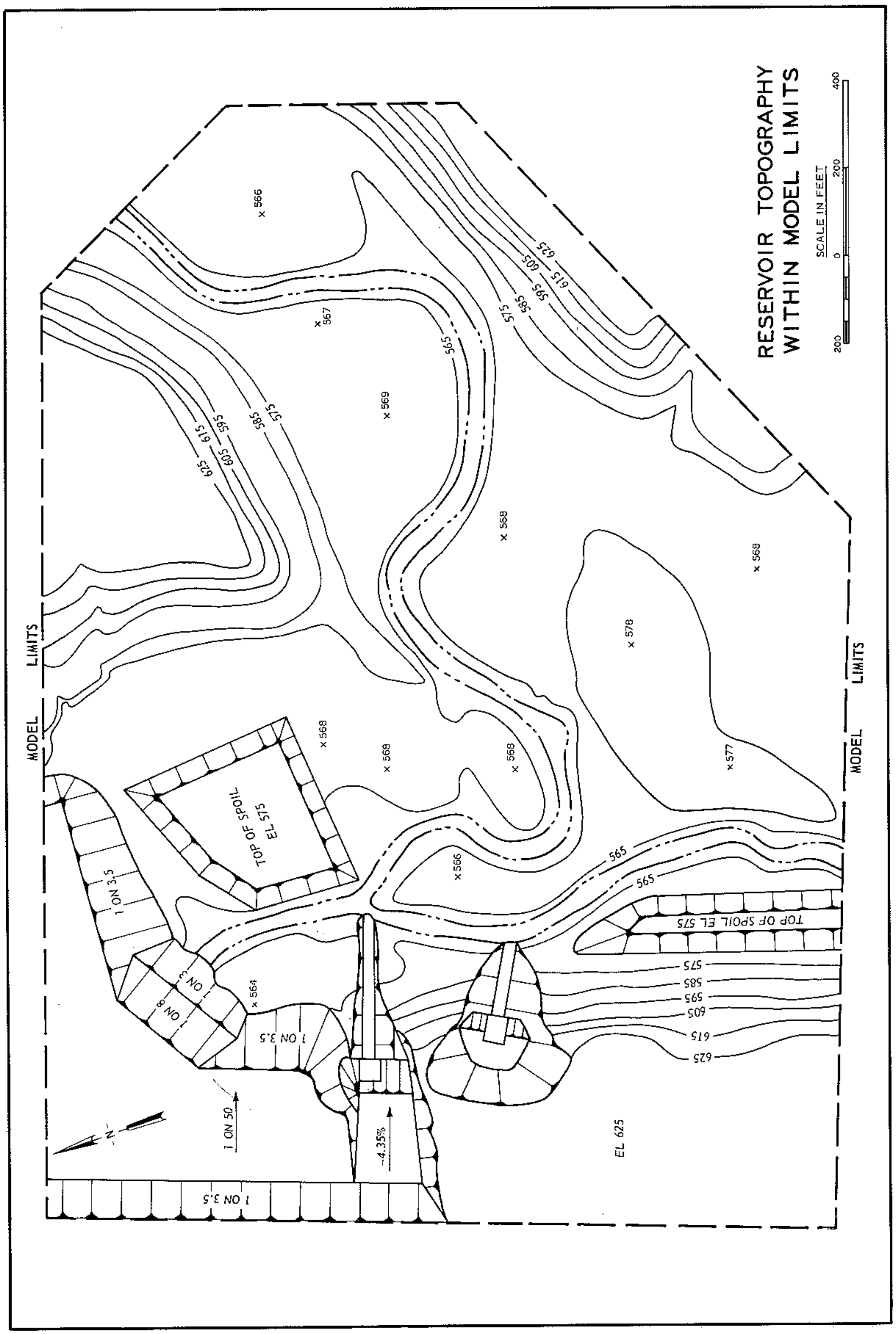
LEFT SELECTIVE WITHDRAWAL WELL



RIGHT SELECTIVE WITHDRAWAL WELL

INTAKE STRUCTURE FOR SELECTIVE WITHDRAWAL SYSTEM

PLATE 1


RESERVOIR TOPOGRAPHY
WITHIN MODEL LIMITS
SCALE IN FEET
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× 566
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× 578
× 577
× 564

PLATE 2

FOREWORD

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Tests were conducted at the U. S. Army Engineer Waterways Experiment Station (WES) on a 1:36-scale model of a portion of the proposed Beech Fork Lake and multilevel intake structure to determine the effects of the upstream topography and the geometry in the vicinity of the intake structure on the selective withdrawal capability of the structure. A 2500-ft-long by 1800-ft-wide area of the 40-ft-deep lake was modeled, and three alternative locations of the intake structure were investigated. Density stratification caused by differentials in temperature in the prototype was simulated in the model by using saline and fresh waters.

The majority of the tests were conducted with outflow only. The outflow- to storage-volume ratio was very small for the duration of a given test; therefore, no appreciable drop in the pool elevation was observed. Temperature and conductivity profiles were measured in the model, and their effects were combined to determine the density profiles. Dye particles were dropped into the approach channel flow to indicate the upper and lower withdrawal-zone limits.

Density profiles, appropriate discharges, and other required data were used as input to a computer program (based on the selective withdrawal techniques developed in previous WES investigations) to predict the withdrawal-zone limits. A comparison of the observed and predicted limits indicated good agreement for the three alternative locations of the intake structure. Therefore, based on selective withdrawal performance, there appeared to be no distinct difference in the three locations tested.

One test was conducted with a dyed, dense inflow introduced into the model. An equal rate of withdrawal was released through the lowest level intake to determine the path of the inflow through the lake. The flow followed the sinuous river channel from the point of entry to the intake structure. The dyed inflow then remained in the river channel until there was enough buildup for it to enter the approach channel. Thus, the general pattern of density currents in the proposed reservoir and the selective withdrawal characteristics of the proposed outlet works for both single- and multiple-outlet operations were verified to be representative of those anticipated; i.e., they were not affected by either the topography of the reservoir and approach channel or the geometry in the immediate vicinity of the intake structure.

SELECTIVE WITHDRAWAL FROM BEECH FORK LAKE
BEECH FORK RIVER, WEST VIRGINIA
Hydraulic Model Investigation

PART I: INTRODUCTION

Background

1. The ability to effectively predict and control the quality of releases from man-made impoundments is dependent upon numerous physical, chemical, and biological factors. The prediction of reservoir water quality requires a knowledge of the physical processes involved in the development and decay of thermal stratification as well as of the chemical and biological consequences thereof. Selective withdrawal is a method in which intake ports that are placed at various levels in a stratified reservoir are used to withdraw water of a desired quality. Predictive techniques based on WES laboratory investigations[1,2,3] have been developed to determine the vertical extent of the selective withdrawal zone and the velocity distribution therein. These techniques along with the reservoir profiles of various water-quality parameters can be applied to determine the quality of reservoir releases. This procedure is presently being used in designing and analyzing multilevel intake structures. A definition sketch of the variables involved in selective withdrawal is shown in fig. 1.

2. Previous hydraulic model studies at WES[4,5] have shown that the geometry in the vicinity of the intake structure, the alignment of the approach channel, and the upstream reservoir topography can significantly alter the selective withdrawal characteristics of an intake structure. The study reported herein was conducted to investigate the general pattern of density currents within the proposed reservoir and to verify the assumed or determine the actual selective withdrawal characteristics of the proposed outlet works for both single- and multiple-outlet operations.

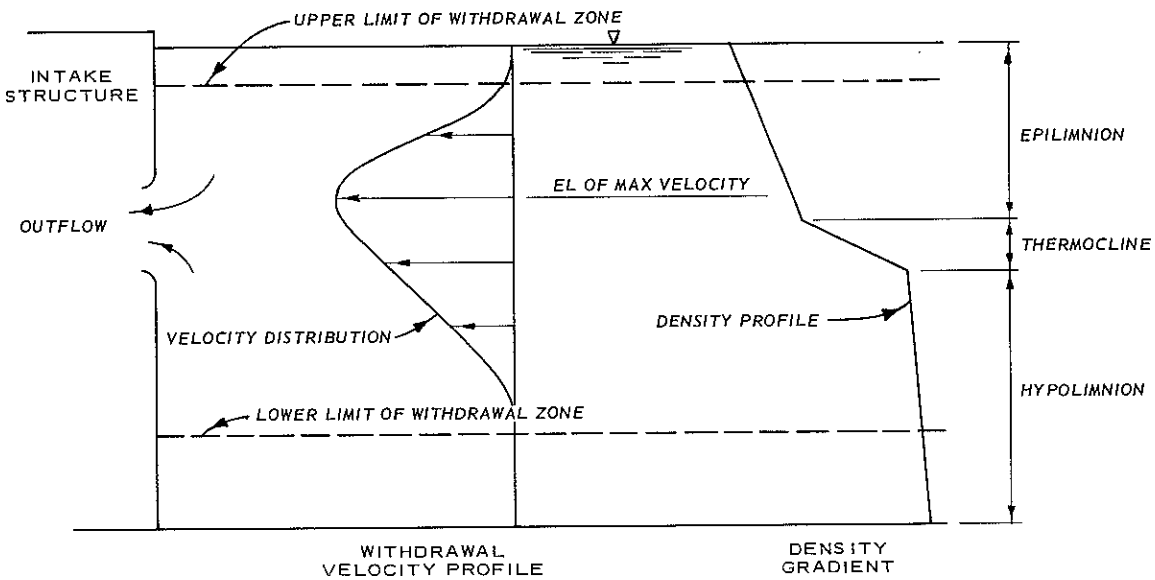


Fig. 1. Selective withdrawal definition sketch

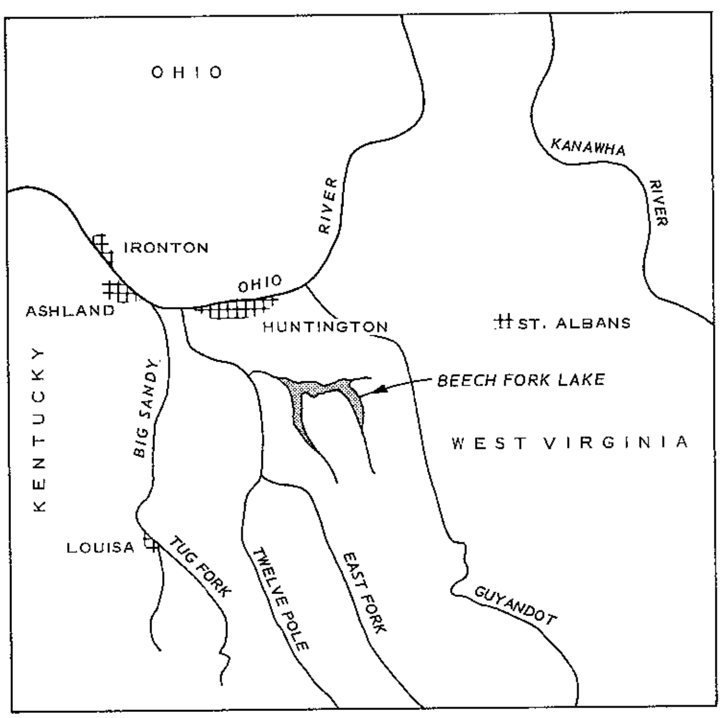


Fig. 2. Vicinity map

The Prototype

3. Beech Fork Lake will be located on Beech Fork River, a tributary of Twelvepole Creek, in Wayne County, West Virginia (fig. 2). The dam will be located 3.6 miles* above the mouth of Beech Fork River and 19.5 miles above the confluence of Twelvepole Creek and the Ohio River. Huntington, West Virginia, lies approximately 7 miles northwest of the reservoir site.

4. The lake will have a surface area of 720 acres and a storage volume of 9180 acre-ft at the seasonal pool. Serving the multiple purposes of flood control, recreation, and fish and wildlife enhancement, Beech Fork Lake will drain an area of 78 square miles.

5. The dam will be an earth-fill gravity type. Low-flow releases of the desired quality will be passed through four intakes in a wet-well-type intake structure. The 4- by 5-ft rectangular intakes will be located with center-line elevations** of 566, 575, and 584, as shown in plate 1. Two intakes will empty into each of two wet wells. A 30-in.-diam conduit with a control valve will drain each of the wet wells into the gate sections of the flood-control conduit just downstream of the service gates. Selective withdrawal releases will vary from 100 to 400 cfs. The design capacity of each intake is for a discharge of 200 cfs.

6. An analysis of hydrologic and meteorologic data for the area indicates that a seasonal temperature variation of approximately 15°F will occur between the 12- to 15-ft-deep epilimnion and the colder regions of the hypolimnion.

Purpose and Scope of Model Study

7. The original design of the Beech Fork outlet works involved a tunneled conduit in the left abutment (location I). This plan was

* A table of factors for converting British units of measurement to metric units is presented on page vii.

** Elevations (el) cited herein are in feet referred to mean sea level.

adequate from a structural, hydraulic, and presumably from a selective withdrawal standpoint. A value engineering study was conducted and resulted in a design calling for a cut-and-cover conduit under the embankment with the intake structure recessed into the embankment. However, with this design, concern developed that the complicated topography in the approach area would affect the selective withdrawal characteristics of the intake structure. For this reason, the conduit was lengthened, and the intake structure was located farther upstream in the reservoir (location II) to avoid the complicated approach topography. Thus, the purpose of the model study was to determine whether there were any differences between the assumed and the actual selective withdrawal characteristics of the intake structures of either of the two alternative locations and, if so, to determine the extent of these differences. In addition, there was an interest in determining the density current patterns created by flow along the sinuous river channel in the reservoir with each of the intake structure locations.

PART II: THE MODEL

Description

8. The model (fig. 3), which was built to an undistorted scale ratio of 1:36, reproduced an 1800-ft-wide section of the reservoir extending for 2500 ft upstream from near the axis of the dam. The intake structures were constructed of transparent plastic, and the reservoir topography (plate 2) was molded in cement mortar to sheet metal templates.

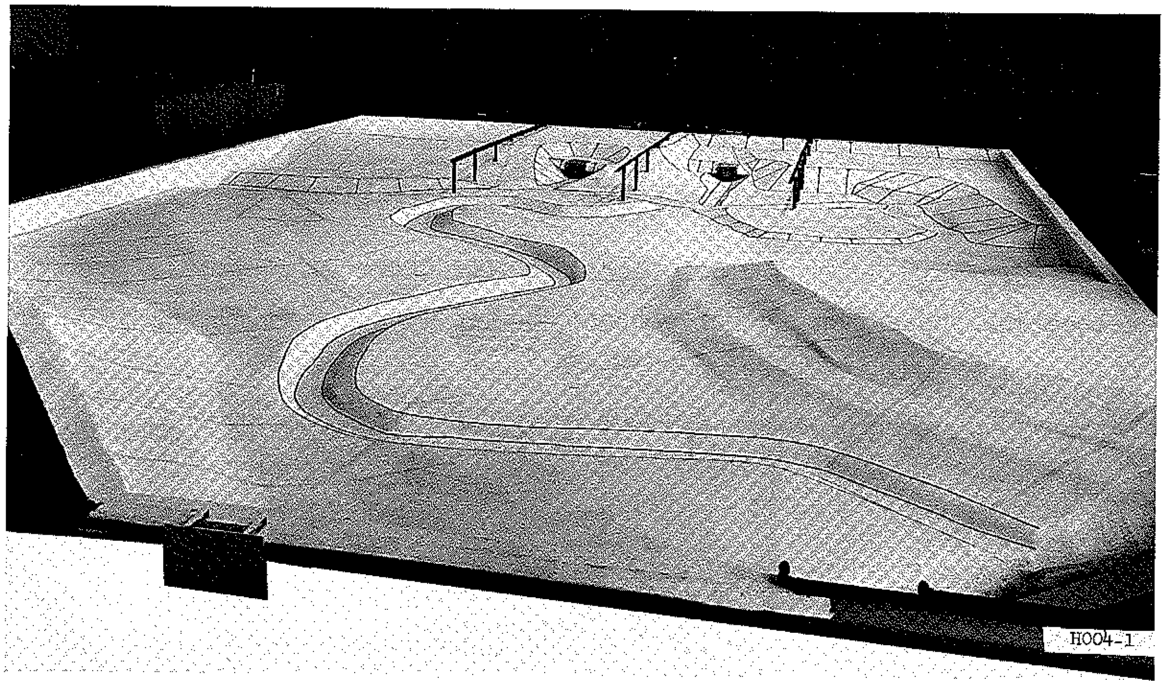


Fig. 3. Beech Fork Lake 1:36-scale model

9. The original model included two intake structures (fig. 4) at different locations: location I had the tunneled conduit outlet works located in the left abutment (plate 3), and location II had the cut-and-cover conduit outlet works located in the dam embankment approximately 825 ft from the axis of the dam (plate 4). Two reproductions of the proposed intake structures were installed in the original model, because it was believed that there was sufficient space between the alternate locations to isolate the selective withdrawal characteristics of each.

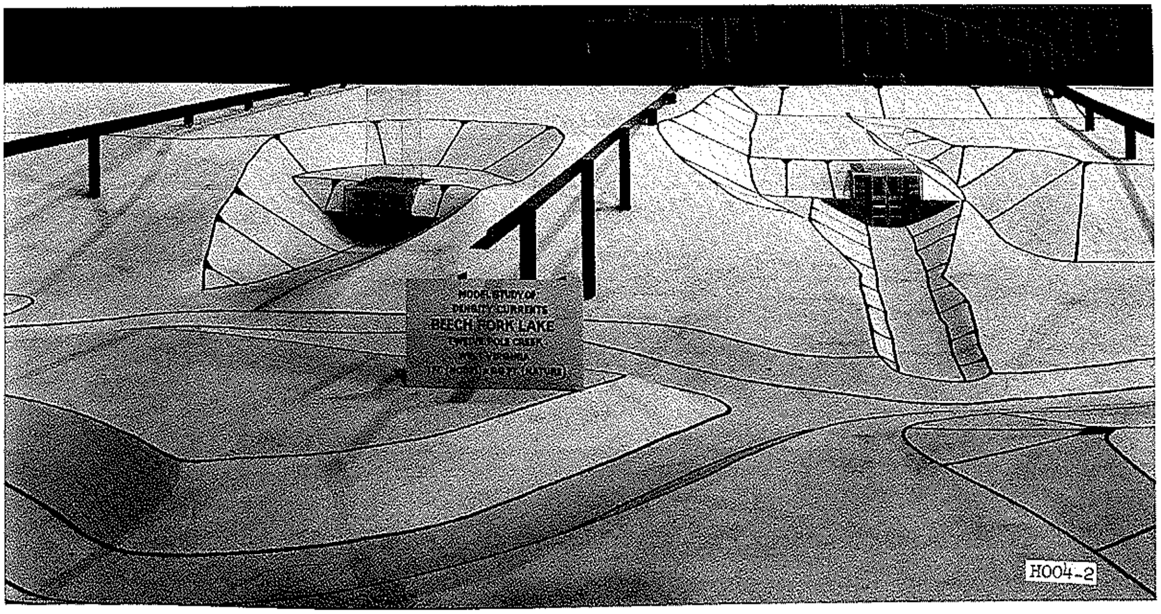


Fig. 4. Intake structure locations I (left) and II (right)

A later revision of the model, location III (fig. 5, plate 5), involved relocating the cut-and-cover conduit outlet works 80 ft closer to the axis of the dam.

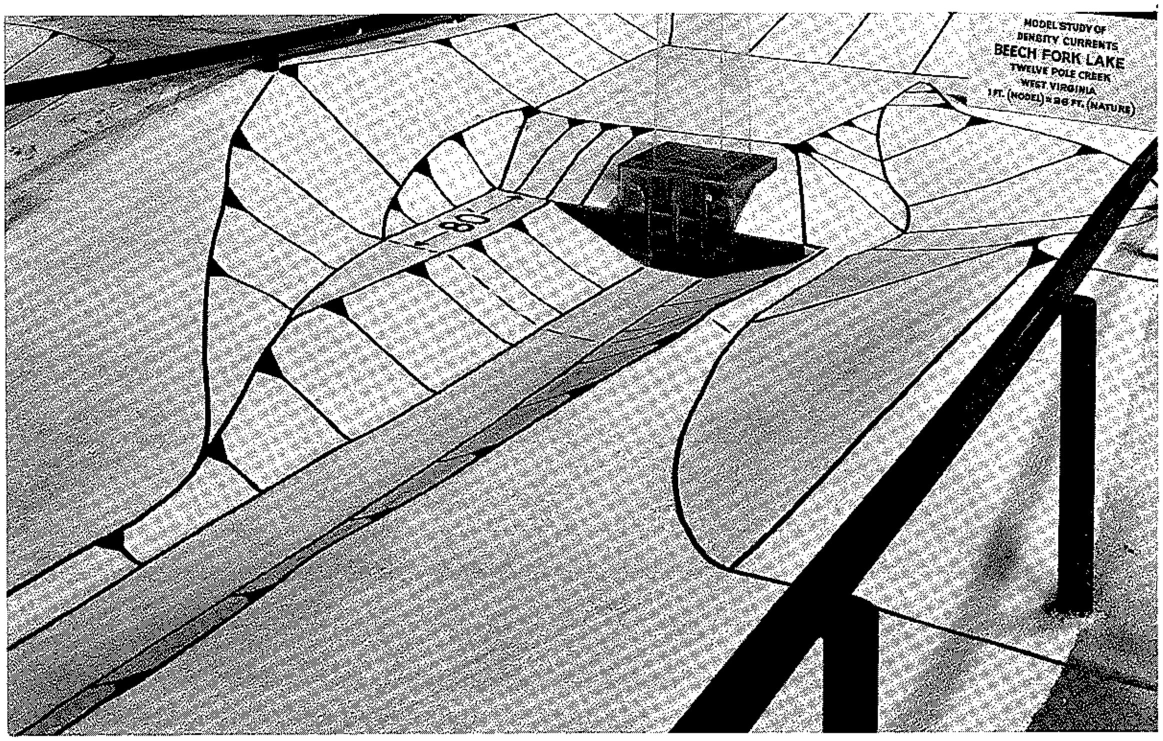


Fig. 5. Intake structure location III

Appurtenances

10. Fresh water used in the operation of the model was supplied from the local water system. A separate sump and pump were used to supply predetermined quantities and concentrations of saline water. Density stratifications corresponding to temperature differences of approximately 15°F within the pool were controlled by means of the salt concentrations of the denser bottom layer.

11. A dual piping and baffle scheme at the upstream end of the model was used to maintain a two-layer stratification. Rotameters were used to measure the rate of both fresh and saline inflow to the reservoir. A 4-in. Van Leer weir calibrated against the rotameters was used to measure the rate of withdrawal released through the outlet works.

Scale Relations

12. The accepted equations of hydraulic similitude based upon the Froudian relations were used to express the mathematical relations between the dimensions and hydraulic quantities of the model and prototype.

Dimension	Ratio	Scale Relation
Length	L_r	1:36
Area	$A_r = L_r^2$	1:1296
Velocity	$V_r = L_r^{1/2}$	1:6
Discharge	$Q_r = L_r^{5/2}$	1:7776
Density	$D_r = L_r/L_r$	1:1

13. Conversion of quantities from model to prototype equivalents can be made by means of the preceding scale relations.

PART III: TESTS AND RESULTS

Test Procedures

14. Density stratification was generated in the model by first adding the necessary amount of dyed saline water required to simulate the desired depth of hypolimnial water. Fresh water from the local supply was added horizontally across an interface baffle to fill the upper or epilimnial portion of the pool. Fig. 6 shows a view of the model with density stratification in the reservoir.

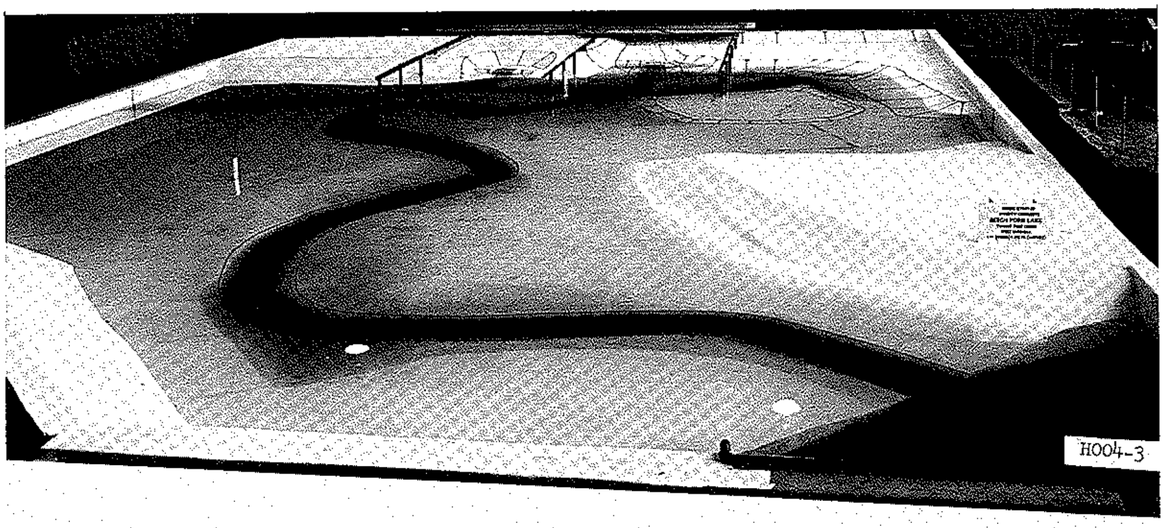


Fig. 6. Beech Fork Lake with density stratification

15. Prior to performing a series of tests, the density in 1-ft increments of elevation (prototype) was measured in the approach channel at a location approximately 35 ft (prototype) upstream from the face of the intake structure. The equipment used to measure densities (fig. 7) included a conductivity probe connected to a conductivity indicator with a millivoltmeter for a digital readout. A thermistor connected to a digital thermometer measured the temperature in degrees Celsius at each elevation. The effects of conductivity and temperature could then be

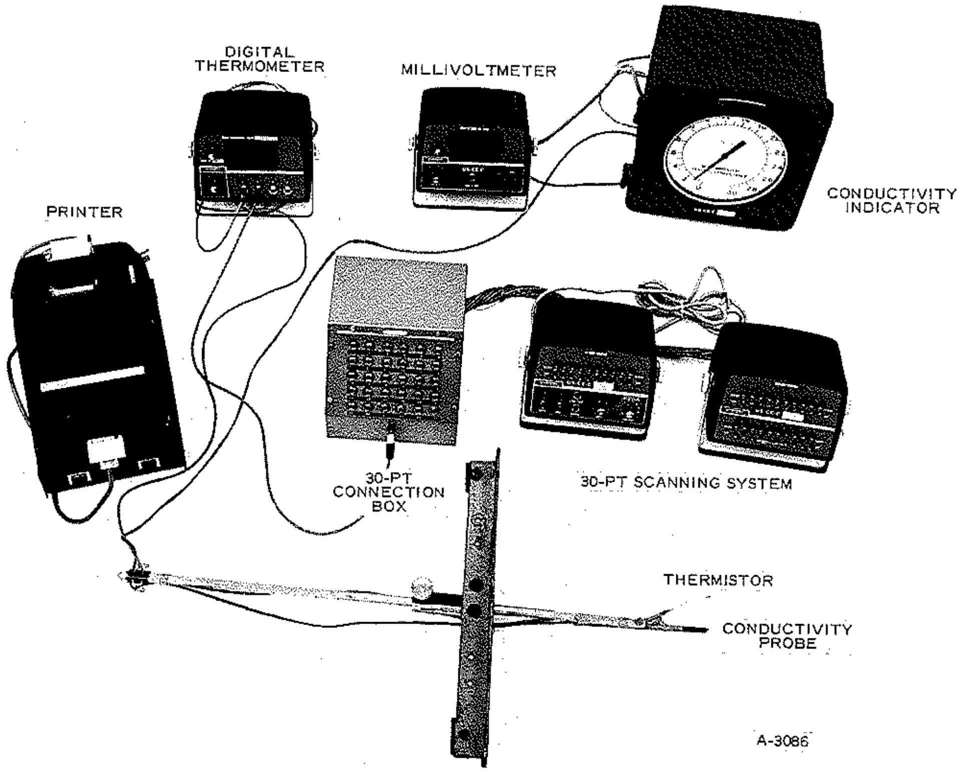


Fig. 7. Instrumentation used to measure temperatures and salinities

combined to determine the density profile. An optional multipoint scanning system was available for multiple-probe operation. The instruments were calibrated against solutions of known density.

16. The desired scheme and rates of release were then set through the appropriate intakes with no inflow to the reservoir. This procedure of model operation maintained a stable density gradient during tests and caused only slight decreases in the elevation of the pool.

17. The upper and lower limits of the withdrawal zone were measured by visually aligning a depth gage with first the upper and then the lower elevation of zero velocity of a vertical dye streak placed in the approach channel (fig. 8). The density of the outflow was also measured.

Test Observations

18. Several tests were conducted varying the interface elevation

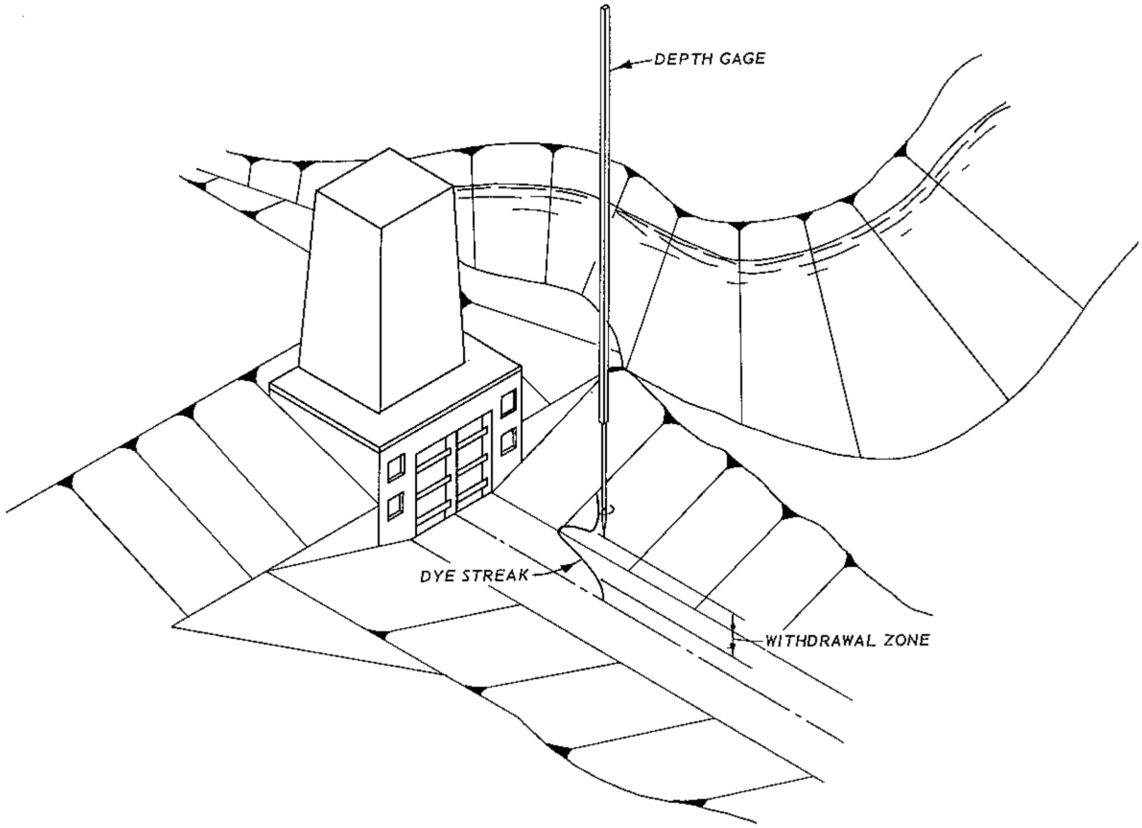


Fig. 8. Measurement of withdrawal-zone limits

and operational scheme for the intake structures at locations I and II. The observed withdrawal limits and outflow densities for various density profiles and operational schemes are shown in plates 6-13. For each of the tests conducted, the withdrawal limits and outflow density were predicted using the WES selective withdrawal techniques which are incorporated in the computer program SELECT (a category C program as defined by Engineer Regulation 1110-1-10[6]). The observed and predicted values are tabulated in table 1 and compared in plates 14, 15, and 16. In general, the comparisons were good. There appeared to be no consistent deviation between the predicted and observed values for the two locations, and the random scatter was attributed to experimental error. It was impossible to control all of the wind currents and rates of heat exchange that occurred at the water surface in the model shelter. In some cases, these external effects induced substantial secondary currents in the upper 3 to 4 ft of the simulated reservoir, even when no inflow or outflow was permitted. Based on these observations and comparisons of the discrepancies between observed and predicted results obtained with and without the existence of externally induced secondary currents, it was concluded that only the upper limit of the withdrawal zone was restricted by such currents. The local geometry effects were negligible, and the outflows of the intake structures at the two alternate locations had comparable selective withdrawal characteristics which agreed with those predicted on the basis of previous generalized results.[7]

19. In the interest of economy, personnel of the U. S. Army Engineer District, Huntington (the sponsoring agency), decided to move the intake structure 80 ft downstream of location II. The model was modified (fig. 5, plate 5), and similar tests were conducted to determine the selective withdrawal characteristics of the intake structure in location III. The results of these tests are shown in plates 17 and 18. Again, the withdrawal limits and outflow densities were predicted and compared with the observed values. These results are also tabulated in table 1, and the comparisons shown in plates 14-16 and 19 indicate that the selective withdrawal performance of the intake structure in location III was comparable to that in locations I and II.

PART IV: DISCUSSION OF RESULTS

20. The results of the model investigation reported herein indicate that the upstream topography and geometry in the vicinity of the proposed intake structure will have no measurable effect on the selective withdrawal characteristics of the intake structure at any of the three locations tested. This is undoubtedly due to the fact that the maximum discharge through the multilevel system is only 400 cfs and the approach geometry is not very irregular. There is a rather severe contraction from the main reservoir pool to the approach channel. On the other hand, the approach channel contains no curvature. Observations of dye particles near the entrance of and in the approach channel indicated very low velocities. It was apparent from such observations that the inertial forces created by the changes in flow direction at the entrance to the approach channel were not large enough to overcome the gravitational or buoyant forces created by the density stratification. Since the buoyant forces predominated, the selective withdrawal characteristics of the intake structures were unaffected.

21. It is very difficult to predict the influence of inertial forces on selective withdrawal. Although the results of this investigation indicate that the inertial forces created by the approach conditions were not great enough to influence the selective withdrawal characteristics of the proposed intake structure, the effect of approach conditions has been observed in other model studies. Therefore, it should not be concluded, based upon the results of this study, that approach conditions are unimportant in determining the selective withdrawal characteristics of orifices and weirs.

22. The selective withdrawal techniques developed at the WES provide an excellent means of designing selective withdrawal structures. However, it must be understood that the techniques are based on gravitational forces only. For this reason, approach conditions should be examined to determine whether they may influence density currents and selective withdrawal characteristics of various outlet works. This type of examination is especially important for relatively high discharges.

If it appears that approach conditions may be a factor in determining selective withdrawal characteristics, a model study should be considered. Since the generalized WES selective withdrawal results were determined and are applicable for random density gradients, it is possible to utilize relatively small, economical physical models in conjunction with a simple two-layer system of stratification to determine the selective withdrawal characteristics of proposed projects. It is not necessary that exact simulations of the density gradients expected in a given impoundment be reproduced in physical models for evaluation of selective withdrawal characteristics of a project. Verification or determination of the actual selective withdrawal characteristics should be accomplished with simple physical models to ensure or refine the accuracy of various mathematical simulation techniques which are available and more appropriate for the analyses required for planning, design, and management purposes.

LITERATURE CITED

1. Bohan, J. P. and Grace, J. L., Jr., "Mechanics of Flow from Stratified Reservoirs in the Interest of Water Quality; Hydraulic Laboratory Investigation," Technical Report H-69-10, Jul 1969, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

2. Grace, J. L., Jr., "Selective Withdrawal Characteristics of Weirs; Hydraulic Laboratory Investigation," Technical Report H-71-4, Jun 1971, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

3. Bohan, J. P. and Gloriod, T. L., "Simultaneous, Multiple-Level Release from Stratified Reservoirs; Hydraulic Laboratory Investigation," Research Report H-72-3, Dec 1972, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

4. Bohan, J. P., "Water Temperature Control Weir for Meramec Park Dam, Meramec River, Missouri; Hydraulic Model Investigation," Technical Report H-70-1, Feb 1970, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

5. Melsheimer, E. S. and Oswalt, N. R., "Outlet Works for New Hope Reservoir, Cape Fear River Basin, North Carolina; Hydraulic Model Investigation," Technical Report H-69-14, Oct 1969, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

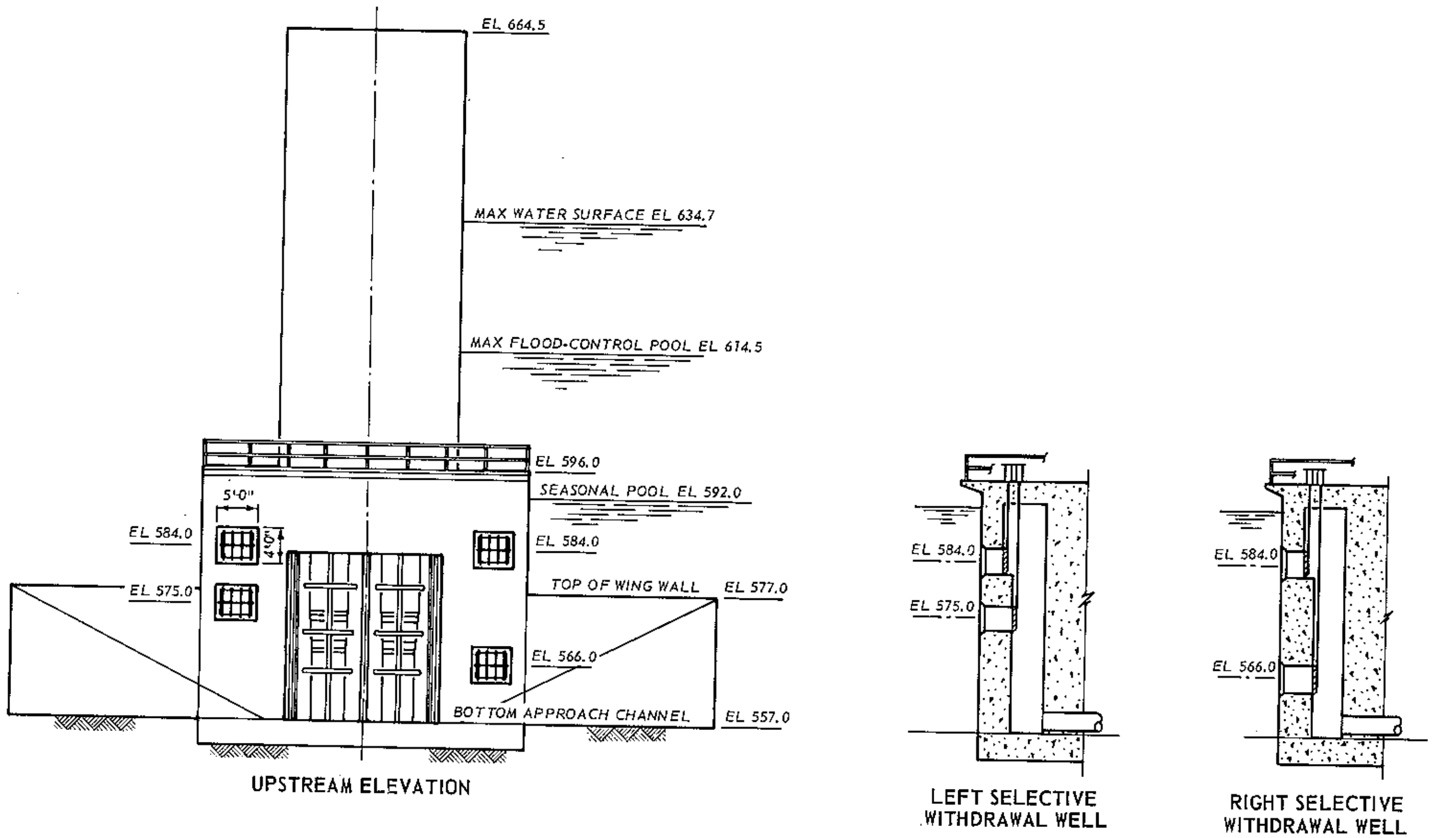
6. Office, Chief of Engineers, U. S. Army, "Development, Review, and Use of Computer Programs," Engineer Regulation 1110-1-10, 30 Jan 1970, U. S. Government Printing Office, Washington, D. C.

7. Bohan, J. P. and Grace, J. L., Jr., "Selective Withdrawal from Man-Made Lakes; Hydraulic Laboratory Investigation," Technical Report H-73-4, Mar 1973, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

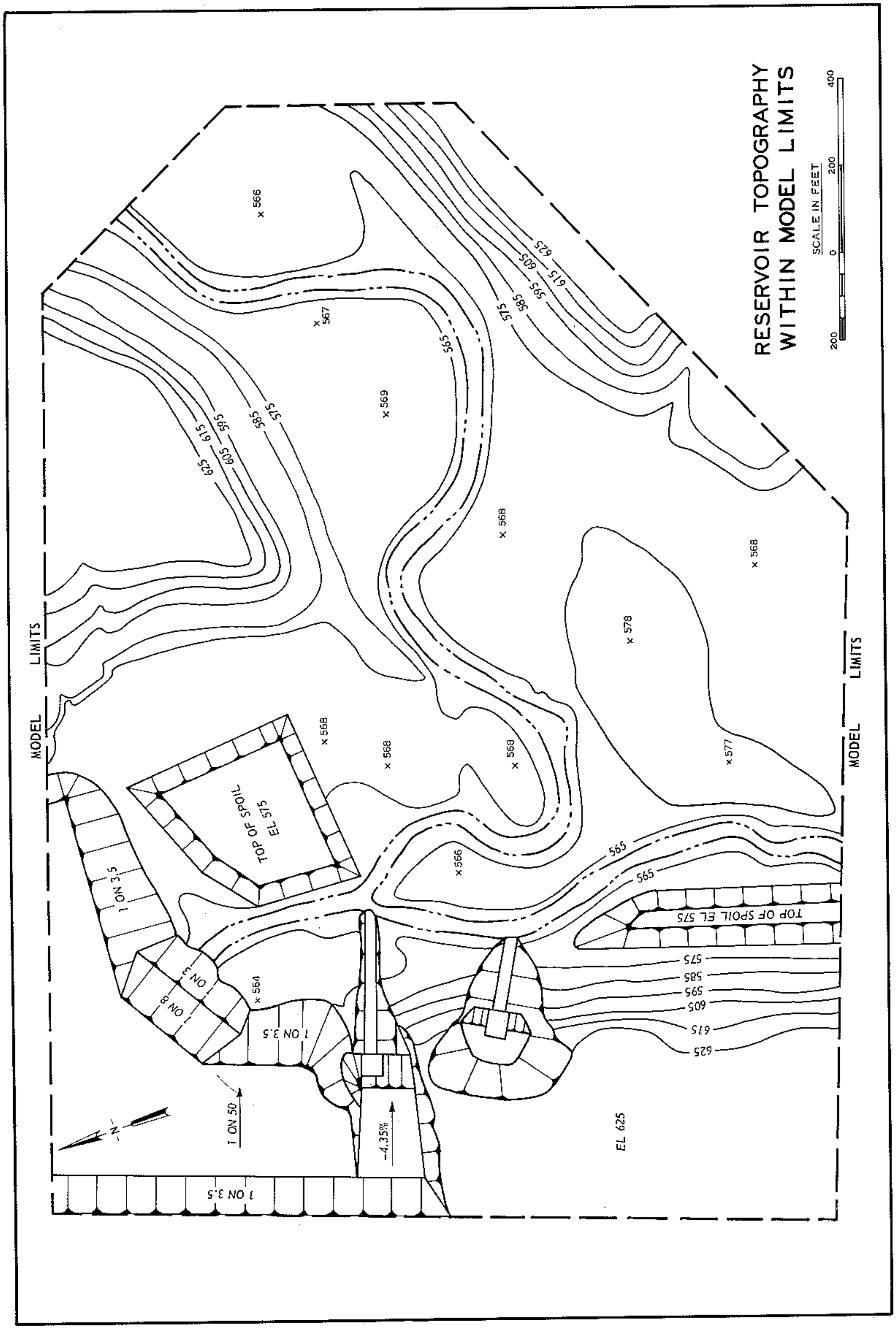
Table 1

Comparison of Observed and Predicted Test Results

Intake Structure Location	Test No.	Outlet Level	Discharge cfs	Observed Results: Elevation of Withdrawal Limit, ft Upper	Observed Results: Elevation of Withdrawal Limit, ft Lower	Observed Results: Density of Outflow g/cc	Predicted Results: Elevation of Withdrawal Limit, ft Upper	Predicted Results: Elevation of Withdrawal Limit, ft Lower	Predicted Results: Density of Outflow g/cc
I	1	Mid	200	584	565	0.99959	591	562	0.99976
I	2	Low	200	580	557	1.00081	580	557	1.00162
II	3	Low	200	581	557	1.00070	580	557	1.00175
II	4	Mid	200	589	566	0.99967	592	562	0.99975
I	5	Mid	200	589	563	0.99960	591	562	0.99975
I	6	High	200	591	566	0.99950	591	566	0.99960
I	7	Mid/high	400	591	563	0.99960	591	562	0.99972
II	8	High	200	591	577	1.00230	591	566	1.00223
II	9	High	100	591	571	1.00225	591	570	1.00222
II	10	Mid	100	591	557	1.00237	591	560	1.00239
II	11	Mid	200	591	557	1.00236	591	557	1.00252
II	12	Mid/high	200	591	557	1.00235	591	560	1.00233
II	13	Mid/high	400	591	557	1.00238	591	557	1.00232
II	14	Low	100	571	557	1.00266	580	557	1.00281
II	15	Low	200	576	557	1.00250	584	557	1.00280
II	16	Low/high	200	591	557	1.00245	591	557	1.00254
II	17	Low/high	400	591	557	1.00228	591	557	1.00251
II	18	High/high	400	591	570	1.00279	591	560	1.00277
I	19	High	200	591	566	1.00076	591	569	1.00090
I	20	Low	200	577	557	1.00227	581	557	1.00242
I	21	Mid	200	589	557	1.00173	590	557	1.00191
I	22	Mid/high	400	591	557	1.00134	591	557	1.00139
I	23	Mid/high	200	591	557	1.00131	591	560	1.00137
I	24	High/low	400	591	557	1.00160	591	557	1.00157
II	25	Mid	200	592	557	1.00312	592	557	1.00297
II	26	Low	200	586	557	1.00332	584	557	1.00346
II	27	High	200	592	570	1.00297	592	566	1.00290
I	28	Low	200	578	557	1.00219	580	557	1.00233
I	29	Mid	200	591	557	1.00136	591	558	1.00133
I	30	High	200	592	573	1.00022	592	570	1.00032
II	31	Mid	200	589	557	1.00137	589	557	1.00186
II	32	Low	200	578	557	1.00243	579	557	1.00245
II	33	High	200	592	573	0.99991	592	570	1.00001
III	34	Mid	100	589	558	1.00222	590	564	1.00220
III	35	Mid	200	591	558	1.00235	592	561	1.00207
III	36	Mid/high	400	592	557	1.00211	592	561	1.00200
III	37	High	100	592	573	1.00167	592	571	1.00168
III	38	High	200	592	573	1.00165	592	569	1.00171
III	39	Low	100	577	557	1.00353	576	557	1.00368
III	40	Low	200	582	557	1.00329	580	557	1.00359
III	41	Low/high	400	592	557	1.00256	592	557	1.00269

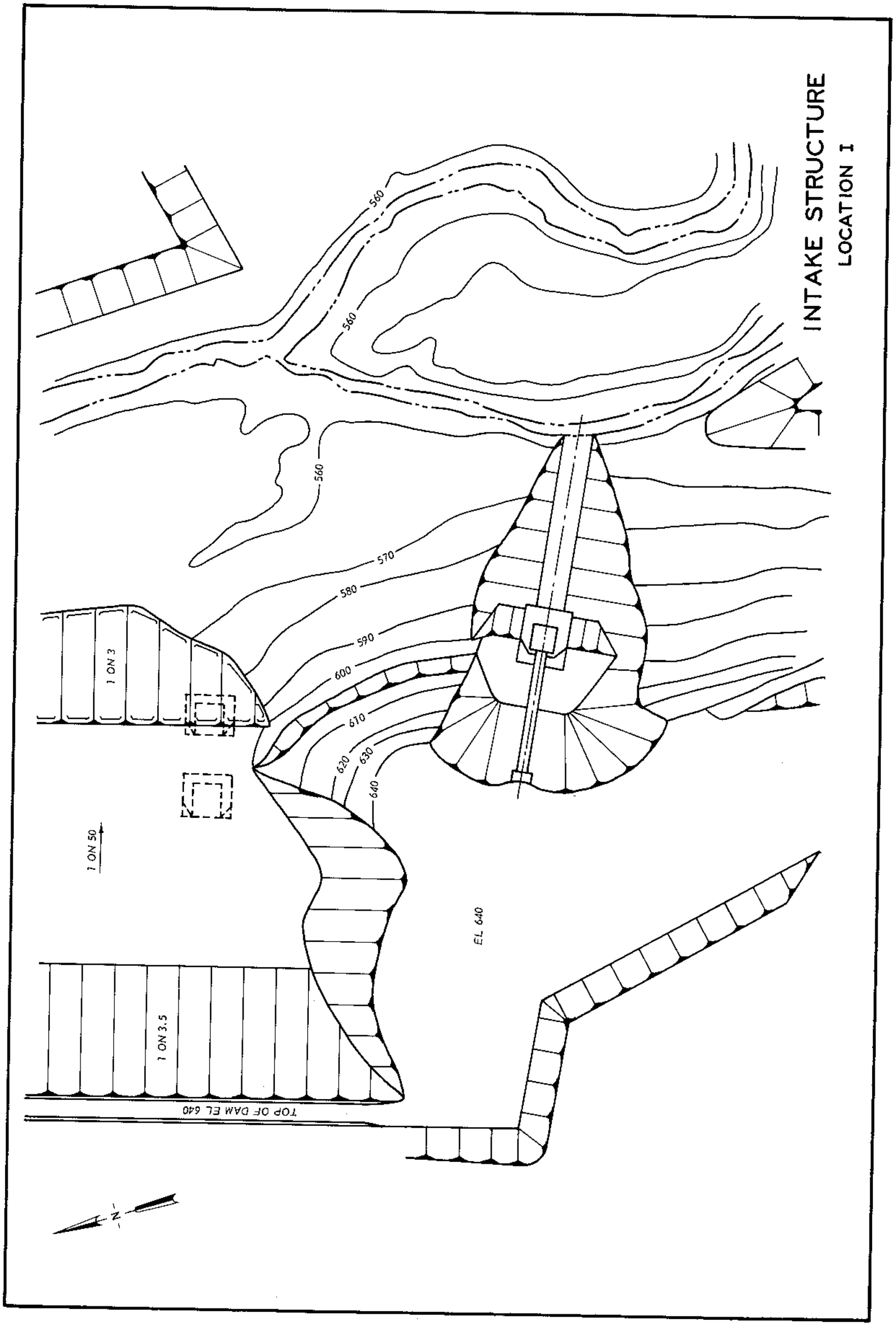


INTAKE STRUCTURE FOR SELECTIVE WITHDRAWAL SYSTEM



RESERVOIR TOPOGRAPHY
WITHIN MODEL LIMITS
SCALE IN FEET
200 0 200 400
MODEL LIMITS
MODEL LIMITS
TOP OF SPOIL
EL 575
TOP OF SPOIL EL 575
1 ON 3.5
1 ON 3
1 ON 8
1 ON 50
-4.35%
EL 625
N
565
575
585
595
605
615
625
x 566
x 567
x 569
x 568
x 578
x 577
x 564

PLATE 2



INTAKE STRUCTURE
LOCATION I
560
560
560
570
580
590
600
610
620
630
640
1 ON 3
1 ON 50
1 ON 3.5
EL 640
TOP OF DAM EL 640
N

PLATE 3

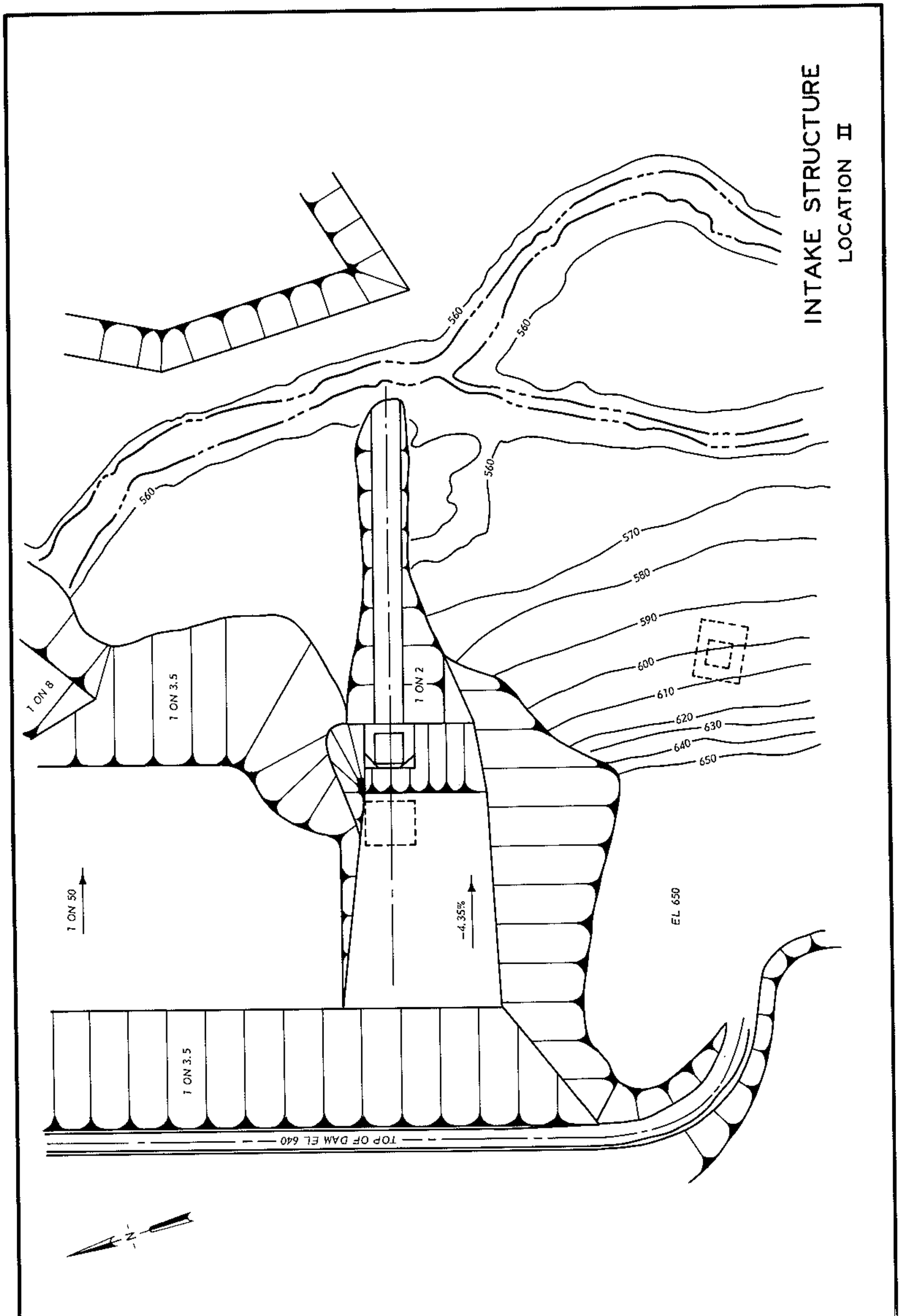
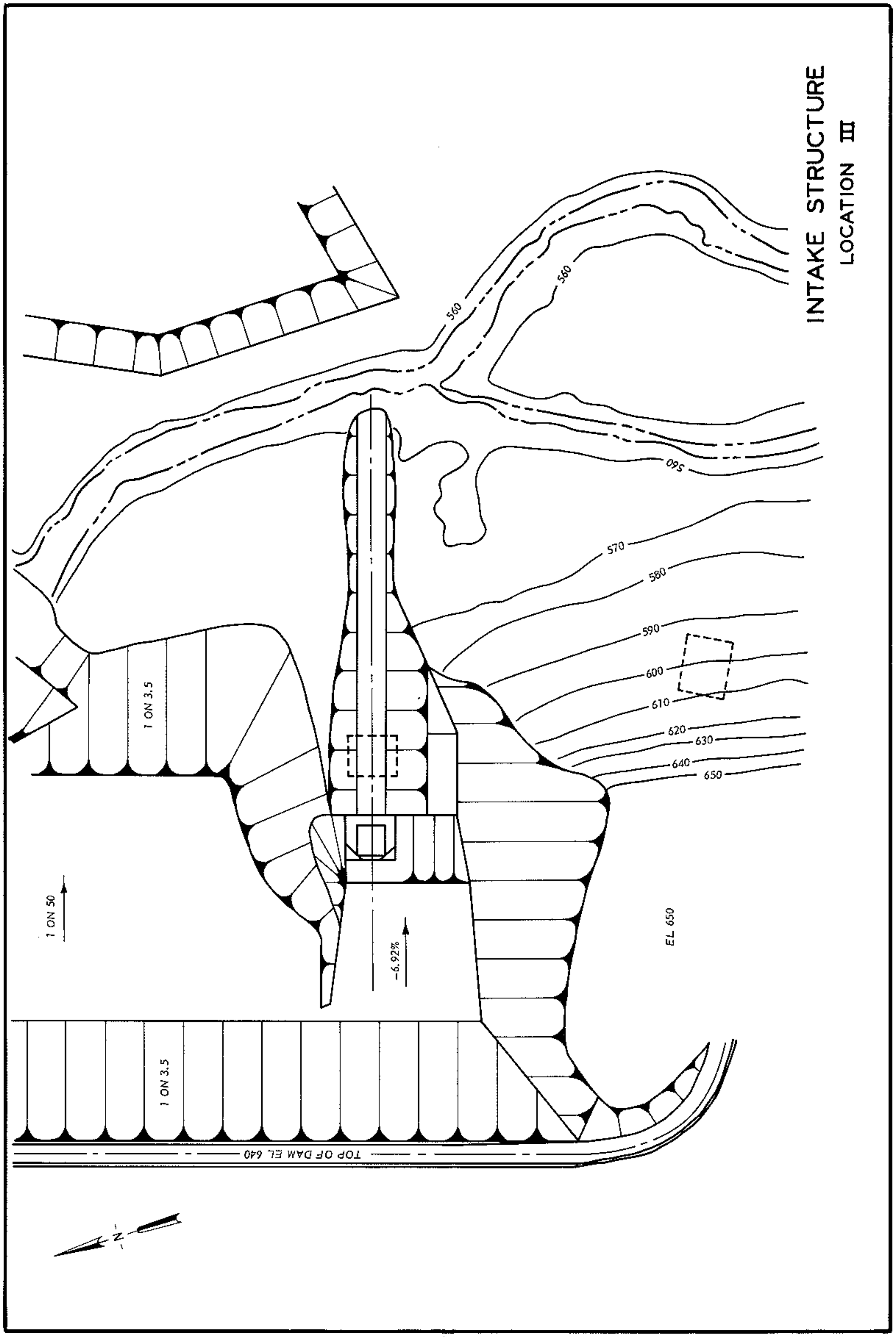
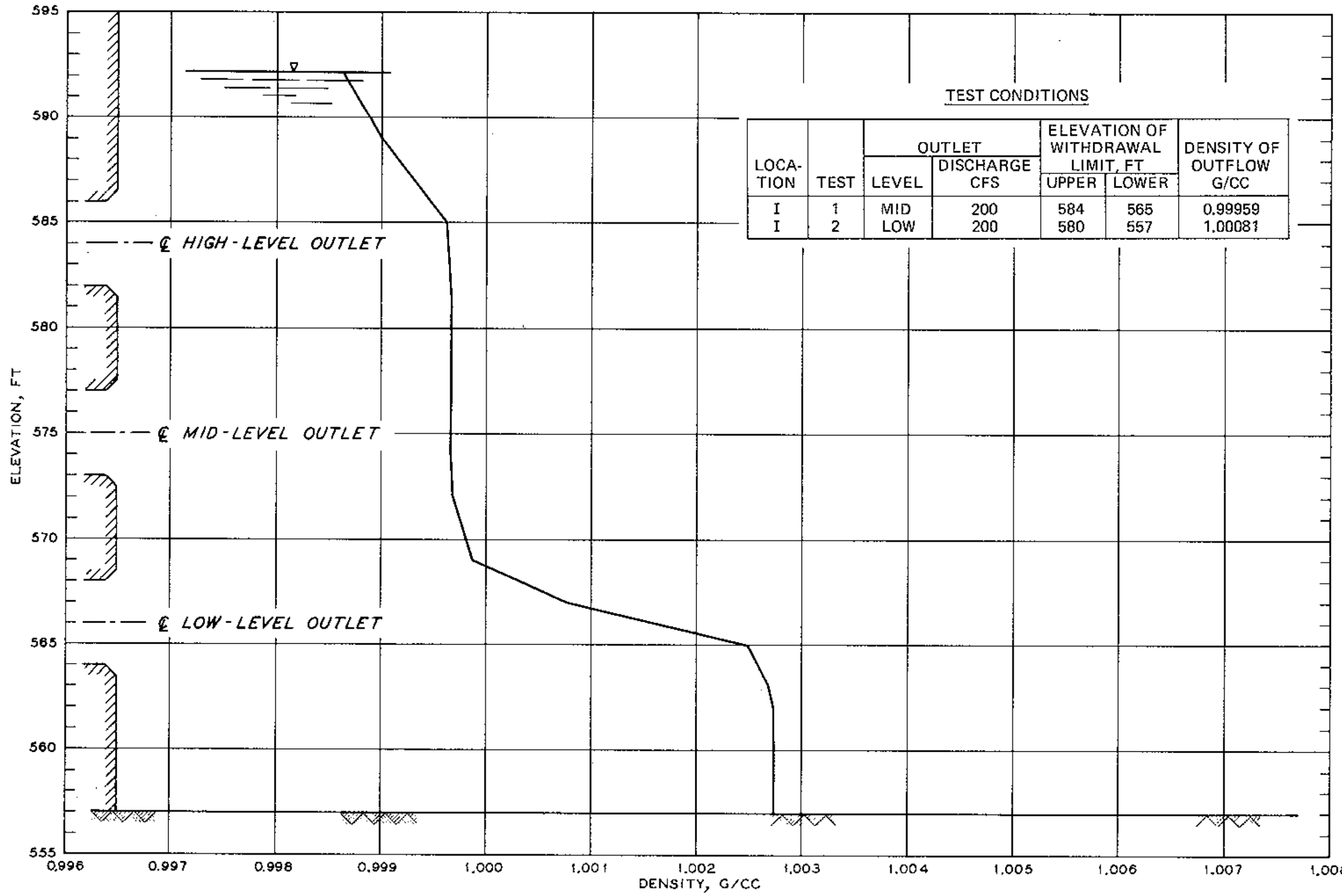

INTAKE STRUCTURE
LOCATION II
560
560
560
560
570
580
590
600
610
620
630
640
650
1 ON 8
1 ON 3.5
1 ON 2
1 ON 50
-4.35%
EL 650
1 ON 3.5
TOP OF DAM EL 640
N

PLATE 4


INTAKE STRUCTURE
LOCATION III
560
560
560
570
580
590
600
610
620
630
640
650
1 ON 3.5
1 ON 3.5
1 ON 50
-6.92%
EL 650
TOP OF DAM EL 640
N

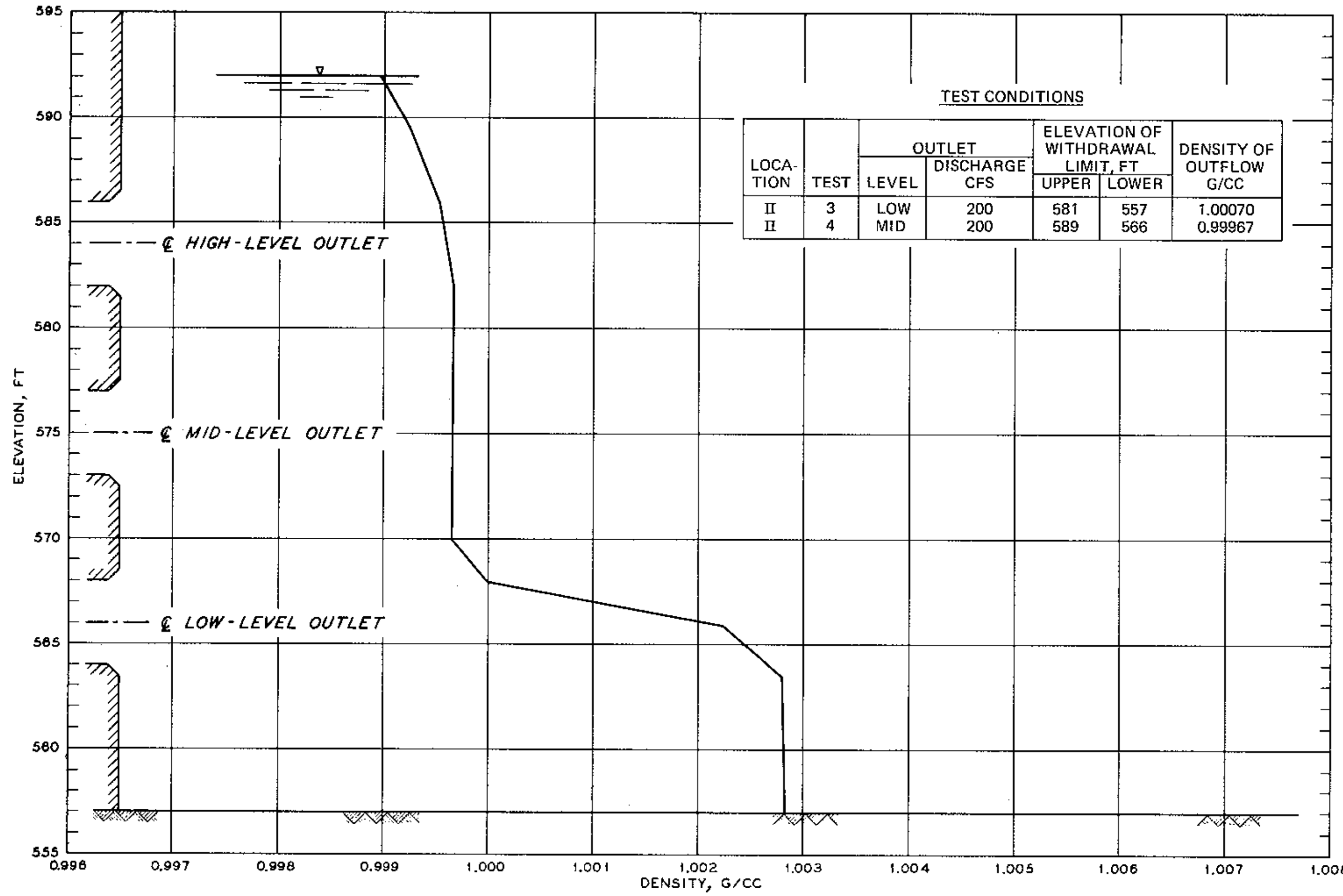


TEST CONDITIONS

LOCATION	TEST	OUTLET		ELEVATION OF WITHDRAWAL LIMIT, FT		DENSITY OF OUTFLOW G/CC
		LEVEL	DISCHARGE CFS	UPPER	LOWER	
I	1	MID	200	584	565	0.99959
I	2	LOW	200	580	557	1.00081

DENSITY PROFILE AND OBSERVED TEST RESULTS

LOCATION I, TESTS 1 AND 2

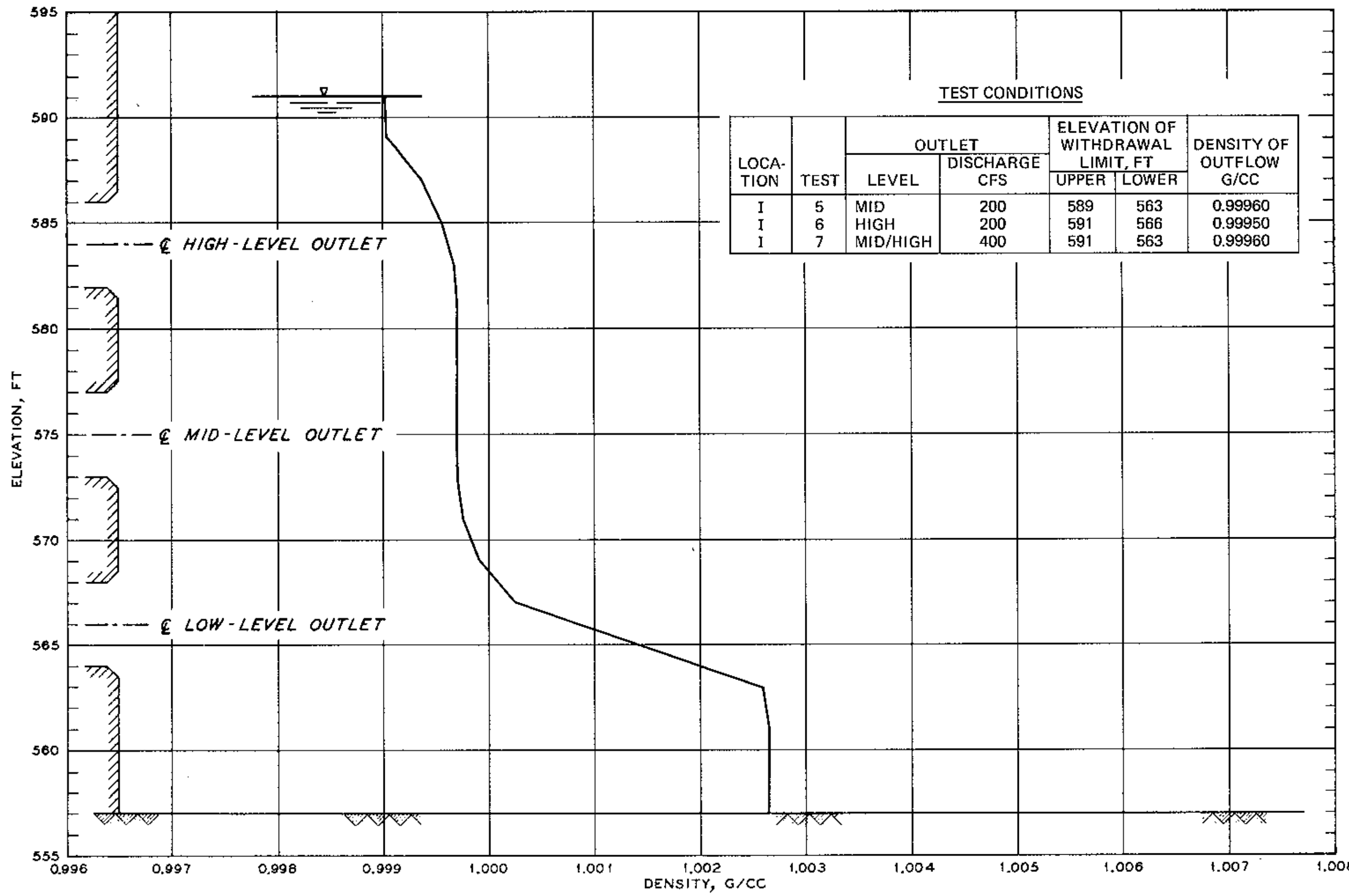


TEST CONDITIONS

LOCATION	TEST	OUTLET LEVEL	OUTLET DISCHARGE CFS	ELEVATION OF WITHDRAWAL LIMIT, FT UPPER	ELEVATION OF WITHDRAWAL LIMIT, FT LOWER	DENSITY OF OUTFLOW G/CC
II	3	LOW	200	581	557	1.00070
II	4	MID	200	589	566	0.99967

DENSITY PROFILE AND OBSERVED TEST RESULTS

LOCATION II, TESTS 3 AND 4

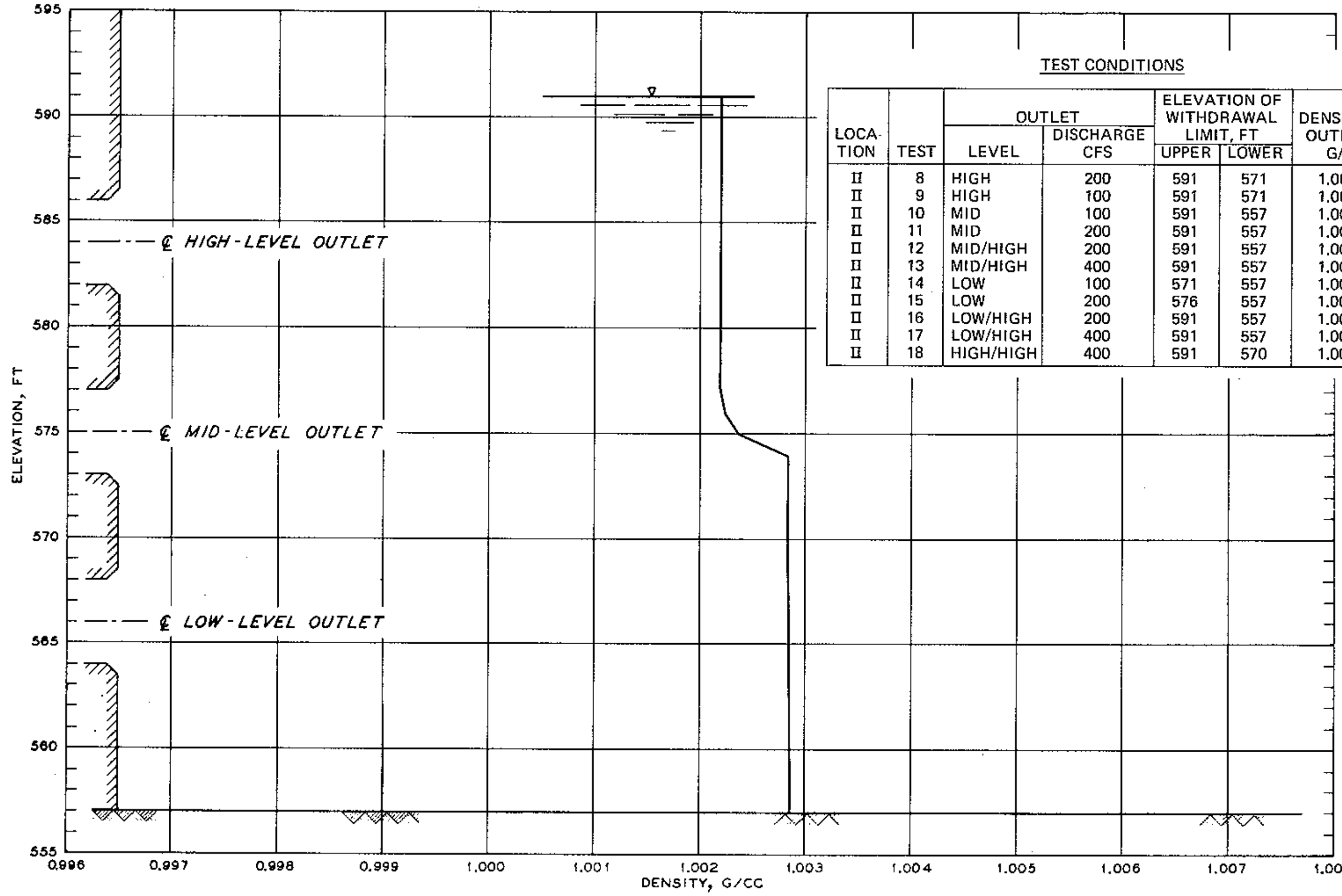


TEST CONDITIONS

LOCATION	TEST	OUTLET		ELEVATION OF WITHDRAWAL LIMIT, FT		DENSITY OF OUTFLOW G/CC
		LEVEL	DISCHARGE CFS	UPPER	LOWER	
I	5	MID	200	589	563	0.99960
I	6	HIGH	200	591	566	0.99950
I	7	MID/HIGH	400	591	563	0.99960

DENSITY PROFILE AND
OBSERVED TEST RESULTS

LOCATION I, TESTS 5-7

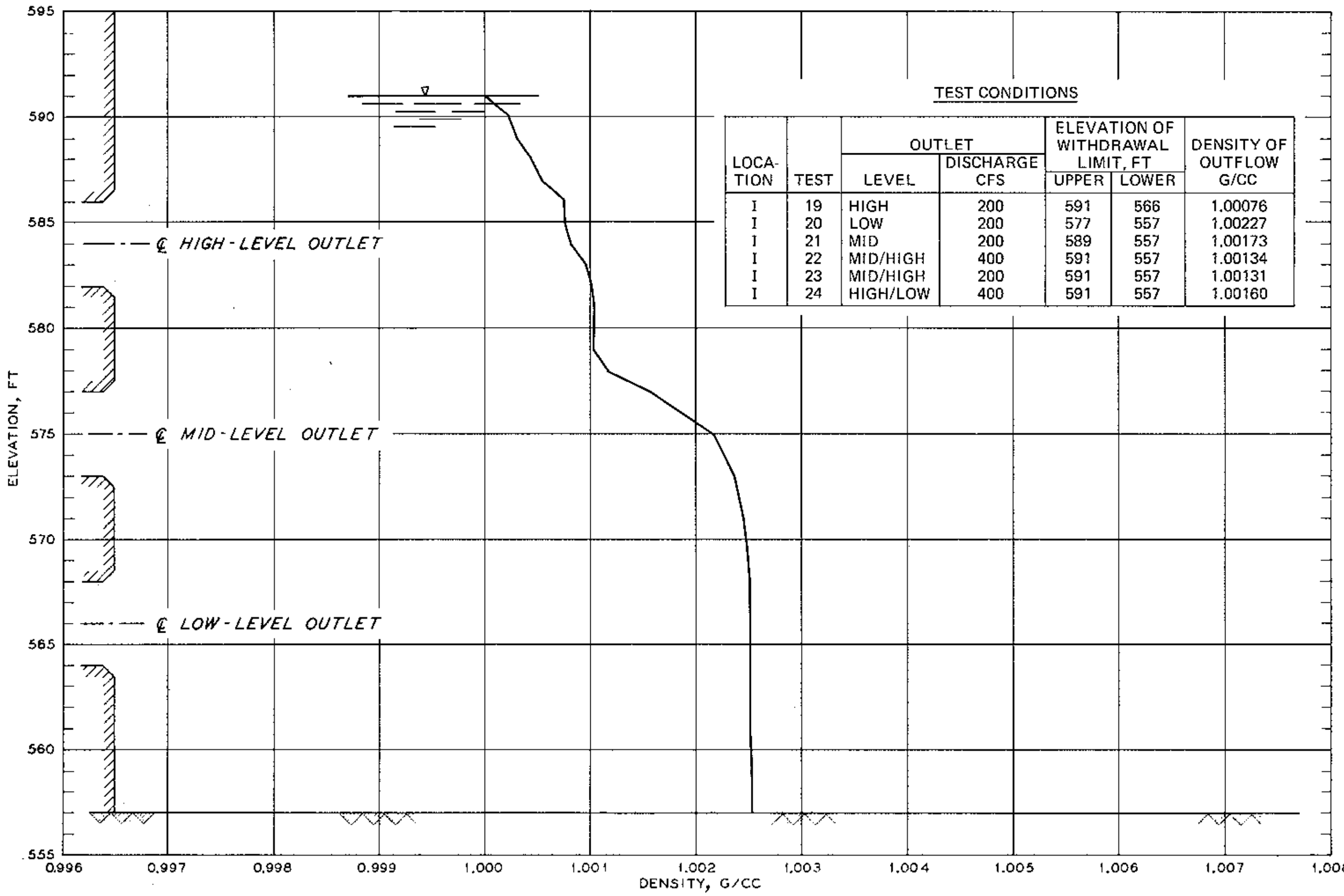


TEST CONDITIONS

LOCATION	TEST	OUTLET LEVEL	OUTLET DISCHARGE CFS	ELEVATION OF WITHDRAWAL LIMIT, FT UPPER	ELEVATION OF WITHDRAWAL LIMIT, FT LOWER	DENSITY OF OUTFLOW G/CC
II	8	HIGH	200	591	571	1.00230
II	9	HIGH	100	591	571	1.00225
II	10	MID	100	591	557	1.00237
II	11	MID	200	591	557	1.00236
II	12	MID/HIGH	200	591	557	1.00235
II	13	MID/HIGH	400	591	557	1.00238
II	14	LOW	100	571	557	1.00266
II	15	LOW	200	576	557	1.00250
II	16	LOW/HIGH	200	591	557	1.00245
II	17	LOW/HIGH	400	591	557	1.00228
II	18	HIGH/HIGH	400	591	570	1.00279

DENSITY PROFILE AND OBSERVED TEST RESULTS

LOCATION II, TESTS 8-18

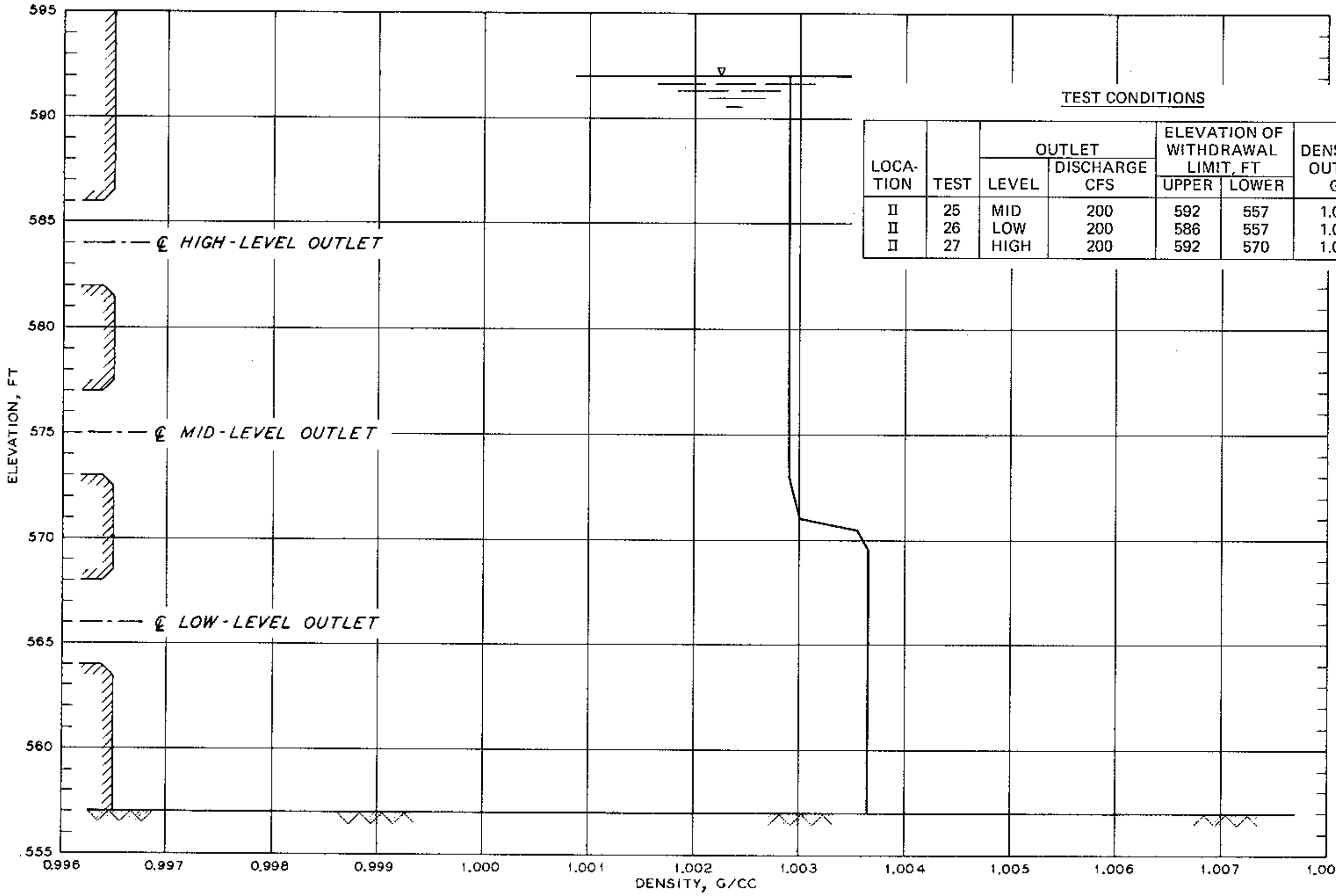


TEST CONDITIONS

LOCATION	TEST	OUTLET LEVEL	OUTLET DISCHARGE CFS	ELEVATION OF WITHDRAWAL LIMIT, FT UPPER	ELEVATION OF WITHDRAWAL LIMIT, FT LOWER	DENSITY OF OUTFLOW G/CC
I	19	HIGH	200	591	566	1.00076
I	20	LOW	200	577	557	1.00227
I	21	MID	200	589	557	1.00173
I	22	MID/HIGH	400	591	557	1.00134
I	23	MID/HIGH	200	591	557	1.00131
I	24	HIGH/LOW	400	591	557	1.00160

DENSITY PROFILE AND OBSERVED TEST RESULTS

LOCATION I, TESTS 19-24

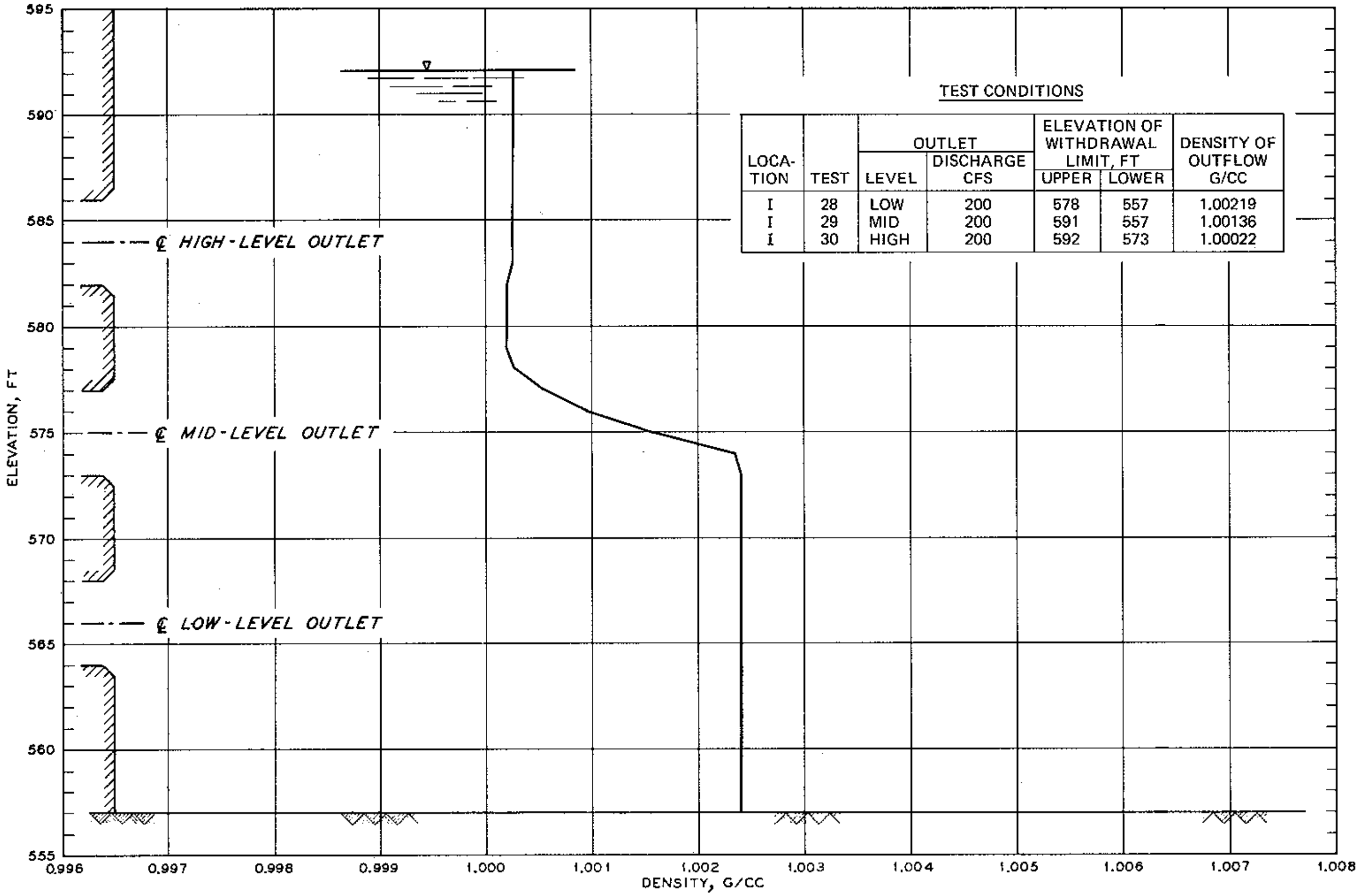


TEST CONDITIONS

LOCATION	TEST	OUTLET LEVEL	OUTLET DISCHARGE CFS	ELEVATION OF WITHDRAWAL LIMIT, FT UPPER	ELEVATION OF WITHDRAWAL LIMIT, FT LOWER	DENSITY OF OUTFLOW G/CC
II	25	MID	200	592	557	1.00312
II	26	LOW	200	586	557	1.00332
II	27	HIGH	200	592	570	1.00297

DENSITY PROFILE AND OBSERVED TEST RESULTS

LOCATION II, TESTS 25-27

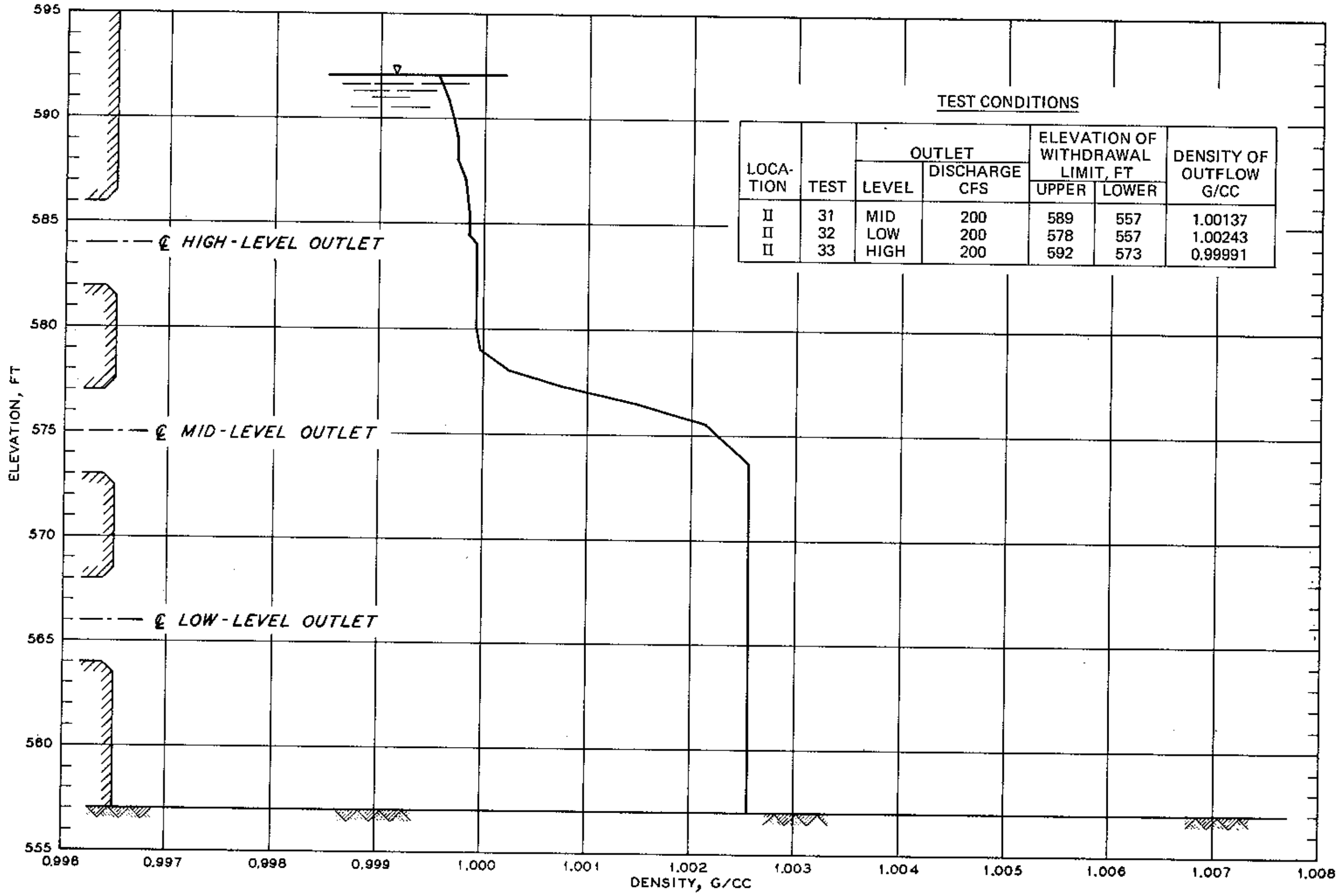


TEST CONDITIONS

LOCATION	TEST	OUTLET LEVEL	OUTLET DISCHARGE CFS	ELEVATION OF WITHDRAWAL LIMIT, FT UPPER	ELEVATION OF WITHDRAWAL LIMIT, FT LOWER	DENSITY OF OUTFLOW G/CC
I	28	LOW	200	578	557	1.00219
I	29	MID	200	591	557	1.00136
I	30	HIGH	200	592	573	1.00022

DENSITY PROFILE AND OBSERVED TEST RESULTS

LOCATION I, TESTS 28-30

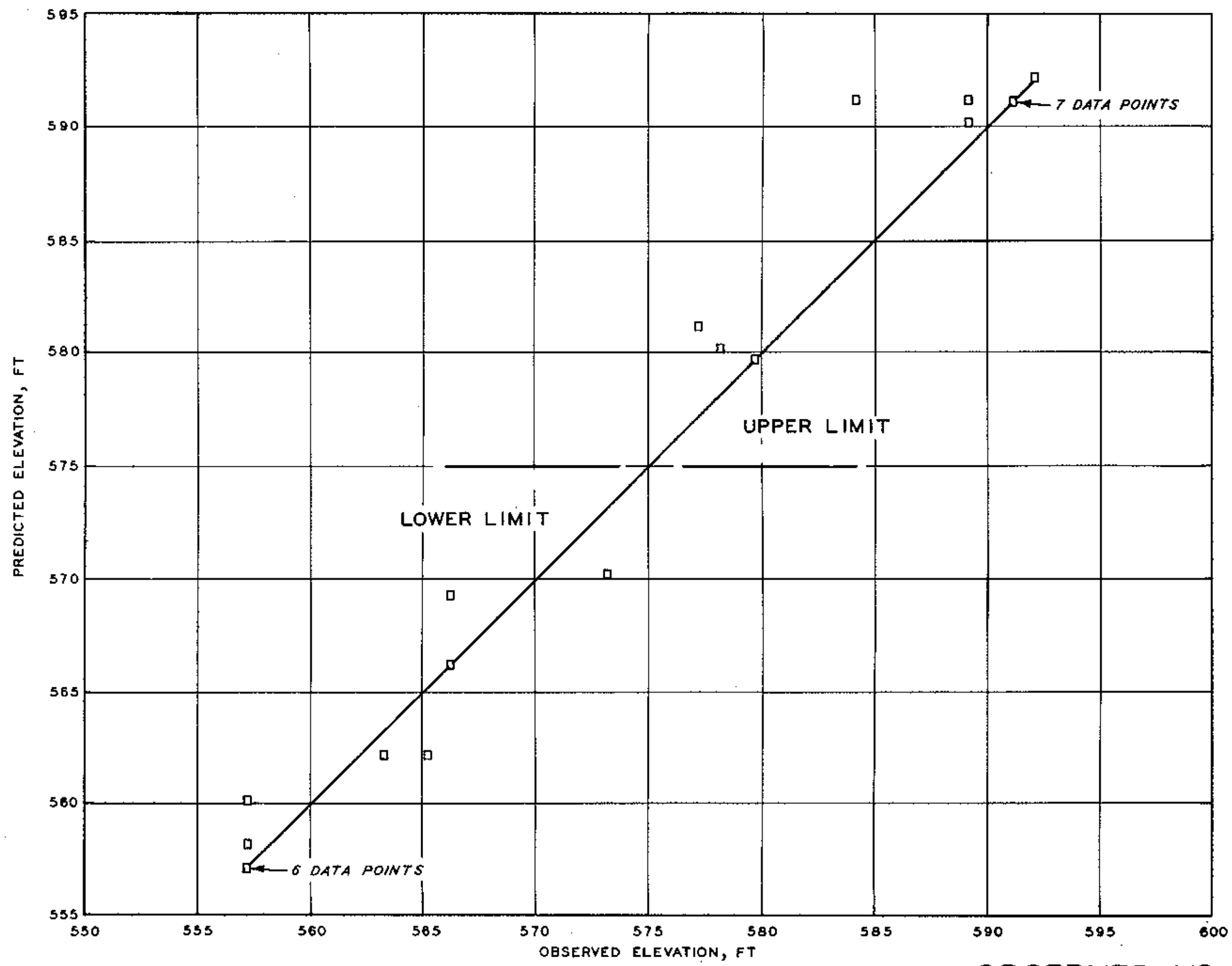


TEST CONDITIONS

LOCATION	TEST	OUTLET LEVEL	OUTLET DISCHARGE CFS	ELEVATION OF WITHDRAWAL LIMIT, FT UPPER	ELEVATION OF WITHDRAWAL LIMIT, FT LOWER	DENSITY OF OUTFLOW G/CC
II	31	MID	200	589	557	1.00137
II	32	LOW	200	578	557	1.00243
II	33	HIGH	200	592	573	0.99991

DENSITY PROFILE AND OBSERVED TEST RESULTS

LOCATION II, TESTS 31-33

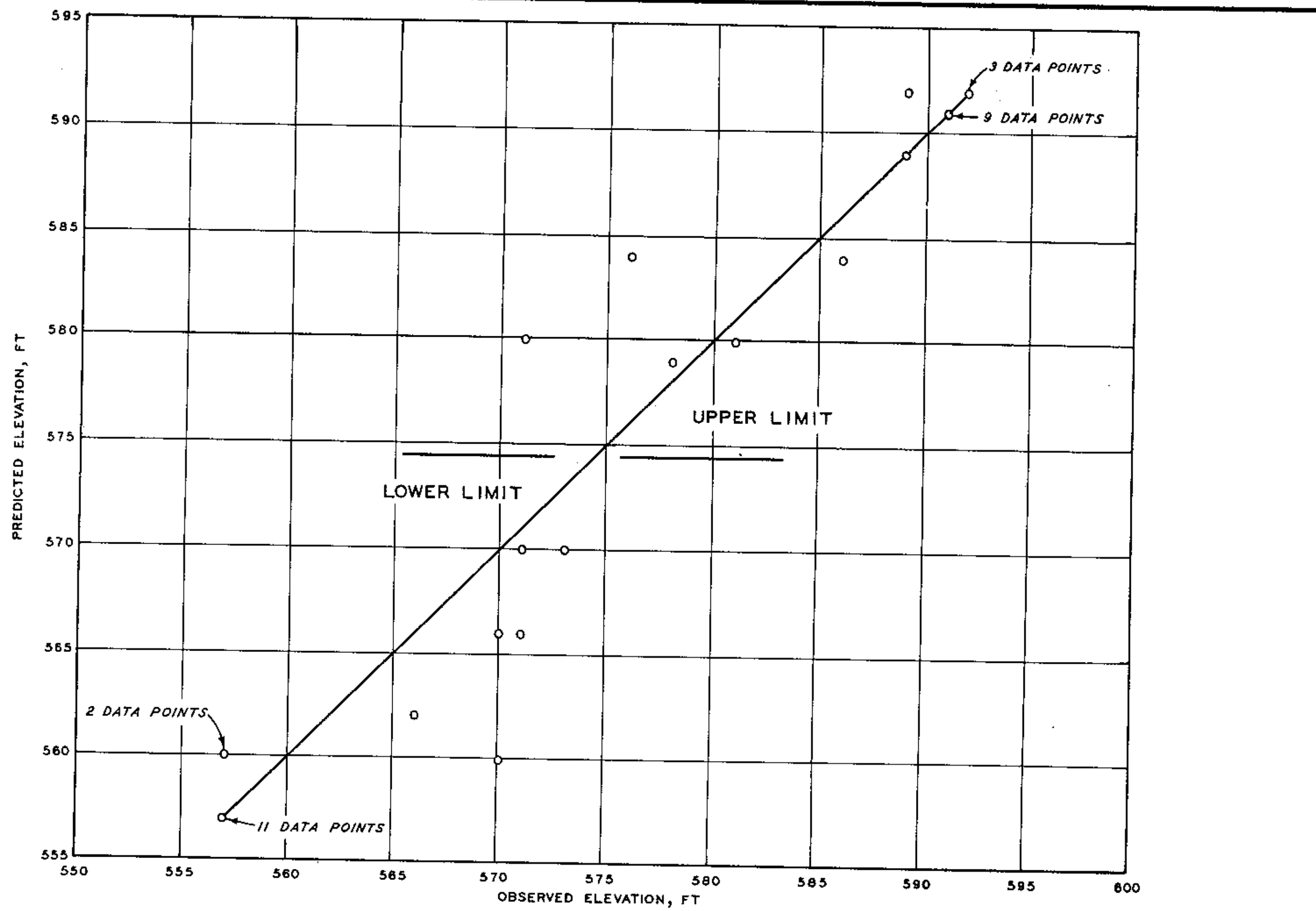


LEGEND

□ LOCATION I – TUNNELED CONDUIT OUTLET WORKS

OBSERVED VS PREDICTED ELEVATIONS OF LIMITS OF ZONE OF WITHDRAWAL

LOCATION I

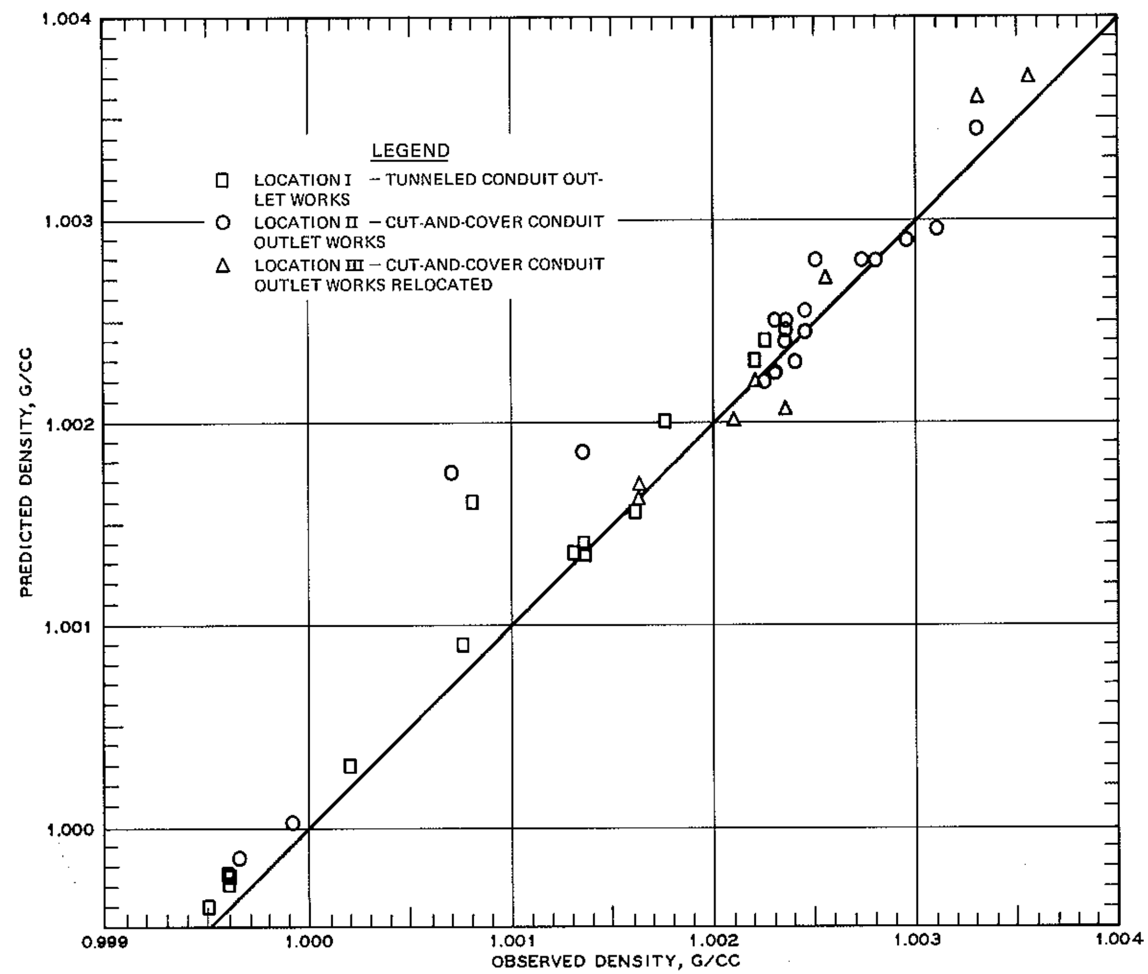


LEGEND

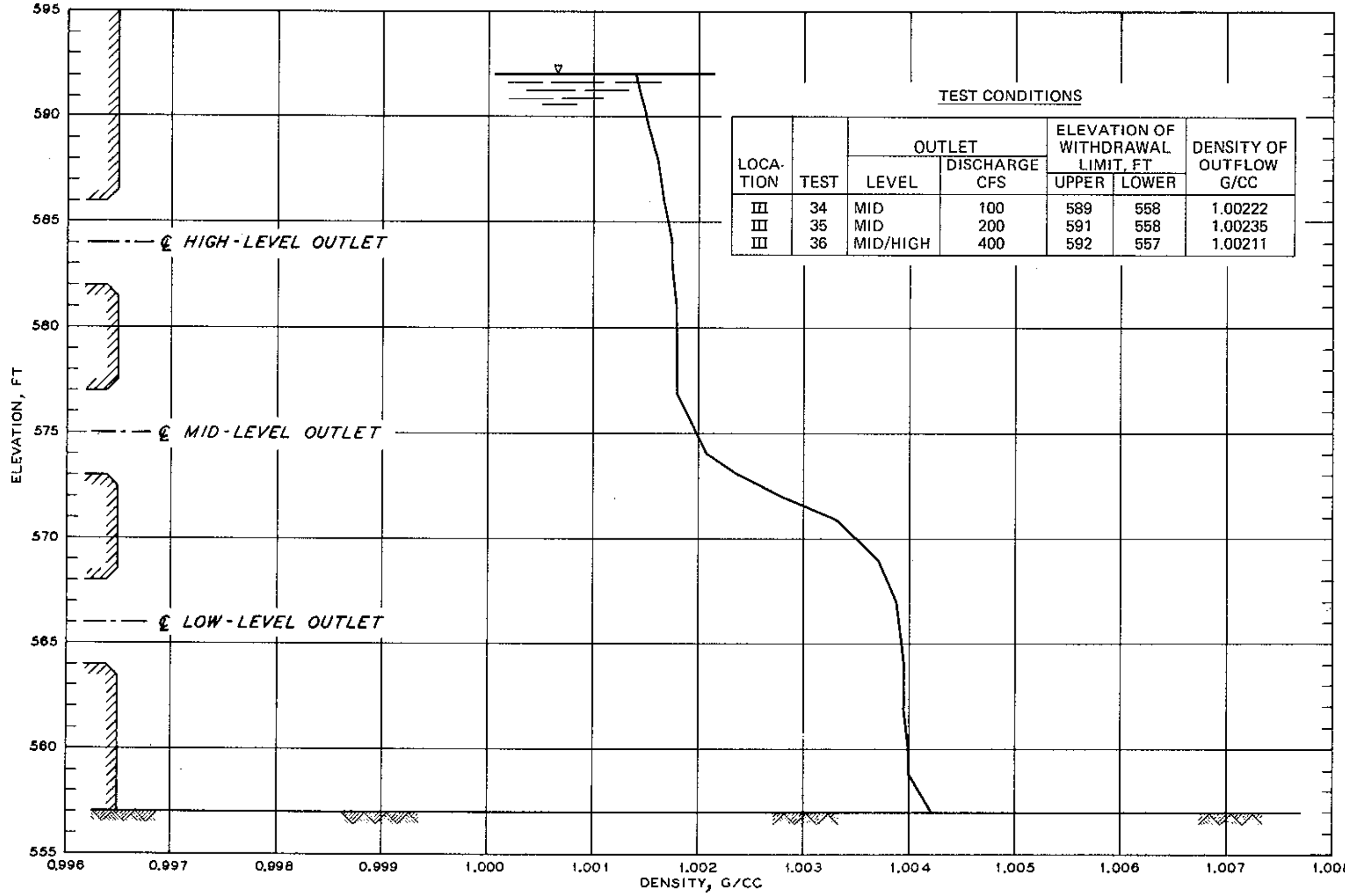
○ LOCATION II – CUT-AND-COVER CONDUIT OUTLET WORKS

OBSERVED VS. PREDICTED ELEVATIONS OF LIMITS OF ZONE OF WITHDRAWAL

LOCATION II



OBSERVED VS PREDICTED
OUTFLOW DENSITY

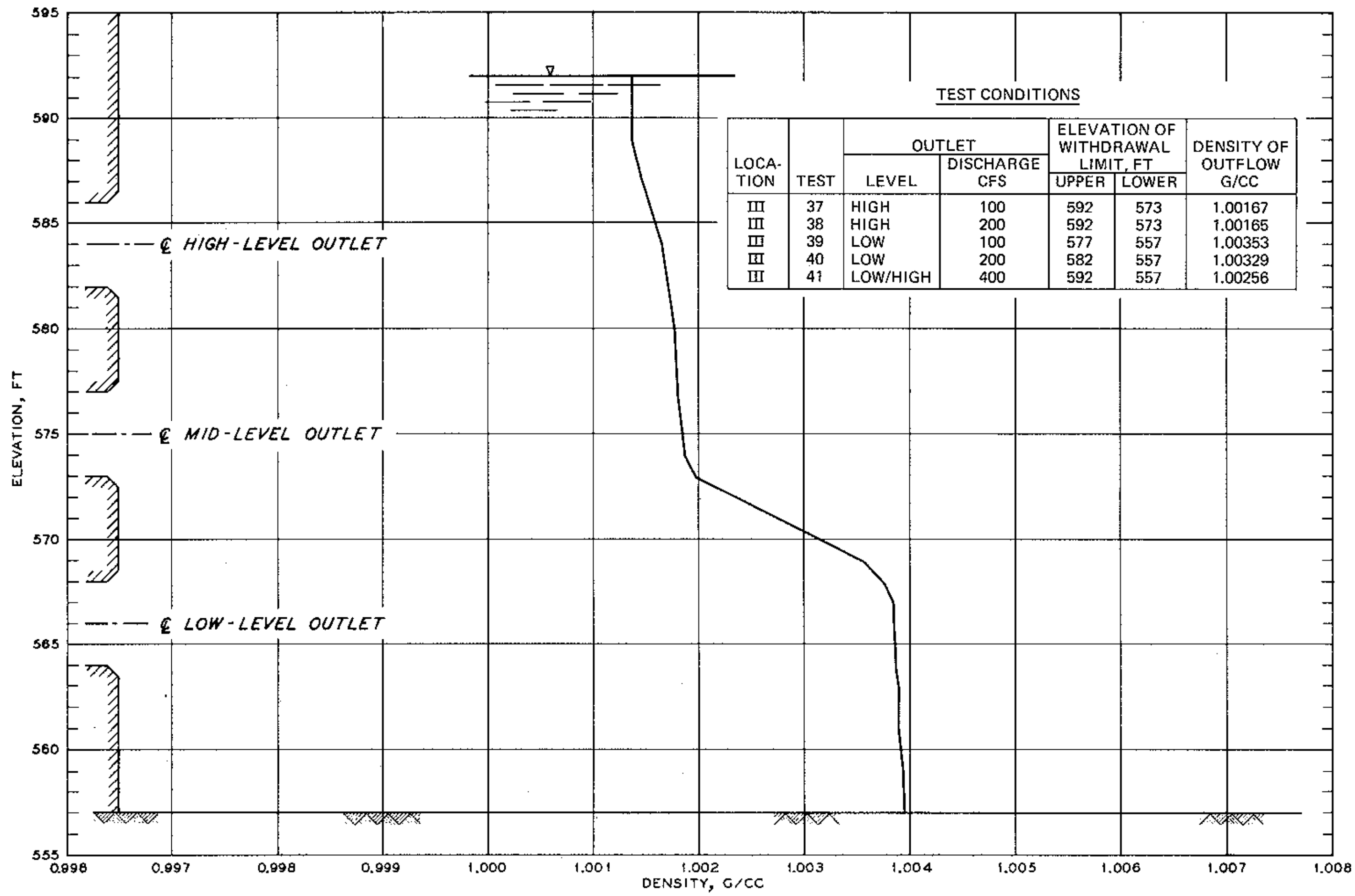


TEST CONDITIONS

LOCATION	TEST	OUTLET LEVEL	OUTLET DISCHARGE CFS	ELEVATION OF WITHDRAWAL LIMIT, FT UPPER	ELEVATION OF WITHDRAWAL LIMIT, FT LOWER	DENSITY OF OUTFLOW G/CC
III	34	MID	100	589	558	1.00222
III	35	MID	200	591	558	1.00235
III	36	MID/HIGH	400	592	557	1.00211

DENSITY PROFILE AND OBSERVED TEST RESULTS

LOCATION III, TESTS 34-36

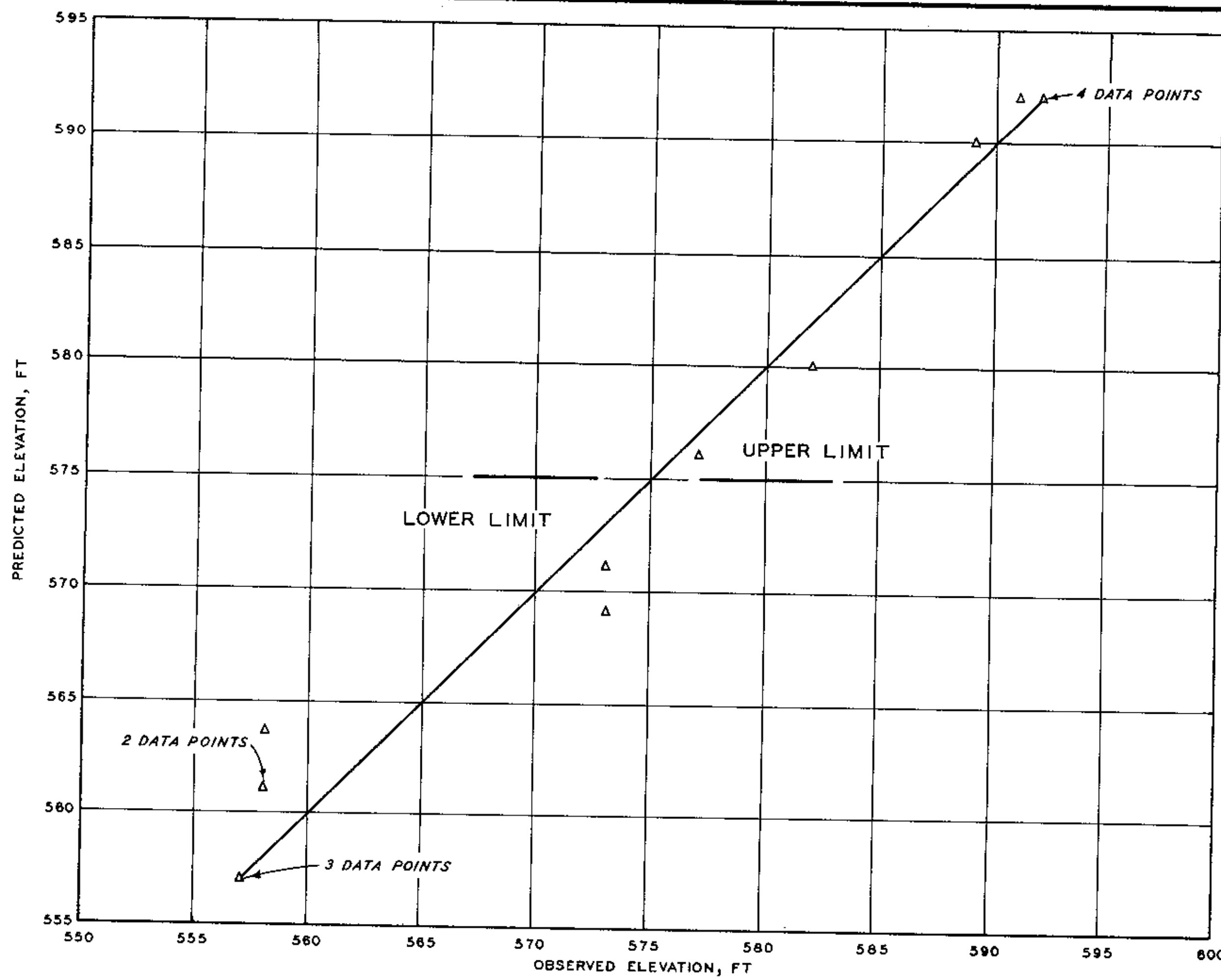


TEST CONDITIONS

LOCATION	TEST	OUTLET LEVEL	OUTLET DISCHARGE CFS	ELEVATION OF WITHDRAWAL LIMIT, FT UPPER	ELEVATION OF WITHDRAWAL LIMIT, FT LOWER	DENSITY OF OUTFLOW G/CC
III	37	HIGH	100	592	573	1.00167
III	38	HIGH	200	592	573	1.00165
III	39	LOW	100	577	557	1.00353
III	40	LOW	200	582	557	1.00329
III	41	LOW/HIGH	400	592	557	1.00256

DENSITY PROFILE AND OBSERVED TEST RESULTS

LOCATION III, TESTS 37-41



LEGEND

△ LOCATION III – CUT-AND-COVER CONDUIT OUTLET WORKS RELOCATED

OBSERVED VS PREDICTED ELEVATIONS OF LIMITS OF ZONE OF WITHDRAWAL

LOCATION III

Unclassified

Security Classification

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4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Final report

5. AUTHOR(S) (First name, middle initial, last name)

Terrence L. Gloriod
Joseph P. Bohan

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	U. S. Army Engineer District, Huntington Huntington, West Virginia

13. ABSTRACT

Tests were conducted at the U. S. Army Engineer Waterways Experiment Station (WES) on a 1:36-scale model of a portion of the proposed Beech Fork Lake and multilevel intake structure to determine the effects of the upstream topography and the geometry in the vicinity of the intake structure on the selective withdrawal capability of the structure. A 2500-ft-long by 1800-ft-wide area of the 40-ft-deep lake was modeled, and three alternative locations of the intake structure were investigated. Density stratification caused by differentials in temperature in the prototype was simulated in the model by using saline and fresh waters. The majority of the tests were conducted with outflow only. The outflow- to storage-volume ratio was very small for the duration of a given test; therefore, no appreciable drop in the pool elevation was observed. Temperature and conductivity profiles were measured in the model, and their effects were combined to determine the density profiles. Dye particles were dropped into the approach channel flow to indicate the upper and lower withdrawal-zone limits. Density profiles, appropriate discharges, and other required data were used as input to a computer program (based on the selective withdrawal techniques developed in previous WES investigations) to predict the withdrawal-zone limits. A comparison of the observed and predicted limits indicated good agreement for the three alternative locations of the intake structure. Therefore, based on selective withdrawal performance, there appeared to be no distinct difference in the three locations tested. One test was conducted with a dyed, dense inflow introduced into the model. An equal rate of withdrawal was released through the lowest level intake to determine the path of the inflow through the lake. The flow followed the sinuous river channel from the point of entry to the intake structure. The dyed inflow then remained in the river channel until there was enough buildup for it to enter the approach channel. Thus, the general pattern of density currents in the proposed reservoir and the selective withdrawal characteristics of the proposed outlet works for both single- and multiple-outlet operations were verified to be representative of those anticipated; i.e., they were not affected by either the topography of the reservoir and approach channel or the geometry in the immediate vicinity of the intake structure.

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Security Classification

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Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Beech Fork Lake						
Beech Fork River, West Virginia						
Hydraulic models						
Selective withdrawal						
Stratified flow						

Unclassified

Security Classification

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Literature cited: p. 14.

1. Beech Fork Lake. 2. Beech Fork River, West Virginia. 3. Hydraulic models. 4. Selective withdrawal. 5. Stratified flow. I. Bohan, Joseph P., joint author. II. U. S. Army Engineer District, Huntington. (Series: U. S. Waterways Experiment Station, Vicksburg, Miss. Technical report H-73-14)

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