WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

STUDY OF PERMEABILITY OF ROCK JETTY MODELS

TECHNICAL MEMORANDUM NO. 133-1

OF THE

U. S. WATERWAYS EXPERIMENT STATION

VICKSBURG, MISSISSIPPI

APRIL 12, 1938

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Technical Memorandum No. 133-1

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U. S. Waterways Experiment Station

Vicksburg, Mississippi

April 12, 1938

TABLE OF CONTENTS

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TECHNICAL MEMORANDUM NO. 133-1

Subject: Study of Permeability of Rock Jetty Models.

To: The District Engineer, U. S. Engineer Office,
900 Customhouse, 2nd and Chestnut Streets,
Philadelphia, Pa.

SYLLABUS

1. This memorandum describes the results of experiments conducted at the U. S. Waterways Experiment Station to determine the relative permeabilities of small-scale models of all-stone jetties of the "chip-stone-core" type.

2. Three general types of model jetties were tested, the three types differing only in the size-distribution of the material in the jetty cores. For each type of jetty model, two conditions of compaction of the core material were tested, one with the cores closely compacted, and the other with the cores loosely arranged. Thus, six different models were tested.

3. It was found as a result of the tests: (a) that Jetty No. 3, having the largest percentage of fine materials in the core, was the least permeable; (b) that Jetty No. 2, having the smallest percentage of fine materials in the core, was the most permeable; and (c) that a close compaction of the core produced a jetty which was considerably less permeable than the jetty whose core was loosely arranged.

METHOD OF PRESENTING RESULTS

Text and Plates

4. All details concerning the study are described and discussed in the text of this memorandum. Pertinent data are presented graphically in plates as follow:

- a. Plate 1: This plate contains a transverse section view of the 1:6-scale jetties and a table showing the percentages of the various sizes of materials in the cores of the three basic jetty types. The data concerning the sizes of 1:4- and 1:8-scale models are included for comparative purposes. No tests were made of models to those scales.
- b. Plate 2: This plate contains curves illustrating the size distribution of the materials in the cores of each of the three basic jetty types.
- c. Plates 3-6: Each of these drawings contains six curves, each showing--for a given elevation of the tailwater--the relation between the rate of seepage through one of the six jetties and the headwater-tailwater differential.
- d. Plates 7-10: These drawings illustrate in a pictorial manner the same data shown on Plates 3-6. Only the data pertaining to the compacted jetty cores are shown on Plates 7-10, however.

Basic Data

5. All the basic data obtained from the tests are recorded in Appendix 1 of this memorandum.

Photographs

6. Photographs 1-8, which follow the text of this memorandum, contain views of the flume and apparatus used for the tests.

PERSONNEL

7. This study was performed in Experiment Section No. 1 of the Hydraulics Laboratory of the U. S. Waterways Experiment Station. In charge of Experiment Section No. 1 is Mr. J. B. Tiffany, Jr., Assistant Engineer. Mr. H. P. Theus, Assistant Civil Engineering Aide, supervised the construction of the jetties, performed the tests, and prepared the first draft of this memorandum.

PART I

THE PROBLEM AND PURPOSE OF THE MODEL STUDY

History of the Study

8. The study described in this report was made for the U. S. Engineer Office, Philadelphia, Pa. On November 23, 1937, the District Engineer requested authority from the Chief of Engineers to have the tests conducted by the Beach Erosion Board in Washington, D. C. In the 3rd indorsement to the basic letter, dated December 8, 1937, the Beach Erosion Board suggested that the study could be made more conveniently at the U. S. Waterways Experiment Station. In a letter to the Station dated December 20, 1937, the District Engineer presented the problem to be studied and requested estimates of the time and cost of conducting the proposed tests. On January 2, 1938, a letter was forwarded from this Station to the District Engineer containing the requested estimate and outlining the procedure suggested to be followed in conducting the tests. On January 10, 1938, the authority for the model study was granted by the Chief of Engineers in the 7th indorsement to the basic letter dated November 23, 1937.

The Problem

9. In connection with the preparation of specifications for all-stone jetties of the "chip-stone-core" type for use in the Chesapeake and Delaware Canal, Indian River Inlet, Delaware, and Barnegat Inlet, New Jersey, it was desired to determine the relative permeability of three types of jetties. General specifications for the three types were as follows:

Mat Stone

Pieces to weigh not less than 15 lb. and not more than 200 lb. each.

Core Stone

Weight of Material	Quantity in Core (Percentage, by Weight)		
	Jetty No. 1	Jetty No. 2	Jetty No. 3
15 lb. to 200 lb.	25	20	30
200 lb. to 2 tons	35	30	40
2 tons to 4 tons	40	50	30

Cap and Slope Stone

Pieces to weigh not less than 5 tons and not more than 9 tons.

Weight of Stone

All stone to weigh not less than 160 lb. per cu. ft. Thus, the three types of jetty differed only in the percentages of the core stone components.

10. The specifications contemplated jetties built to a uniform crest elevation of +6 ft. (referred to mean low water), 10 ft. wide at the crest, and with side slopes of 1 on 1-1/2. Plate 1 contains a transverse section view of the 1:6-scale jetty models.

The Purpose of the Model Study

11. As previously stated, the purpose of the model study was to determine the relative permeability (under idential conditions of compaction of the core stone) of the three general types of jetties described in Paragraphs 9 and 10. A secondary purpose was to determine the effect -- on permeability -- of the arrangement and compaction of the stones in the cores of each of the jetties.

The Scope of the Study

12. The scope of the study was limited to include the permeability

of the jetty models to the flow of clear water only. It was not believed practicable to study on the models the effect on permeability of the deposition of silt or sand in the interstices of the structures. Furthermore, although in the prototype much of the seepage through the jetties would be the result of wave action, it was believed to be neither necessary nor practicable to simulate in the models the effect of wave action. Rather, the relative permeabilities were determined from comparisons of the rates of seepage through the structures under conditions whereby the elevations of the headwater and of the tailwater were arbitrarily controlled. Hence, the results of the study are considered as being qualitative only.

PART II

DESCRIPTION OF APPARATUS AND MODELS

Apparatus

13. The model jetties were tested in a brick and masonry flume (see Plate 1 and Photograph 1) the dimensions of which are 20 ft. x 4.9 ft. x 3.6 ft. Water was supplied to one side of the jetty through an 8-in. pipe leading from a constant-head tank to the flume (see Photograph 5); this pipe was paralleled by one of 2-in. size used in making close adjustments of the quantity of water supplied. A 6-in. waste pipe (see Photograph 6) from the headbay side of the jetty made possible an even closer control of the net quantity of water supplied to the headbay. Seepage through the jetty was carried away through an 8-in. pipe (see Photograph 7) extending from the flume to a weir box, in which the rate of seepage was measured. Each of the latter two pipes was also paralleled by a smaller pipe which was used in making close adjustments. By manipulation of the flows in these six pipes, any desired combination of headwater and tailwater elevations could be obtained. The measuring equipment for the seepage was composed of a V-notched weir installed in a weir box equipped with a hook gage to measure the head on the weir (see Photograph 8). The headwater and tailwater elevations were measured with point gages installed in the flume. The temperature of the water was measured with a centigrade thermometer.

The Models

14. Each of the jetty models was constructed to a scale of 1 to 6. The overall dimensions of the models (see Plate 1) were as follows:

Height 3.0 ft.; length 4.9 ft.; top width 1 ft. 8 in.; bottom width 10 ft. 8 in.; side slopes 1 on 1-1/2. Thus, the models represented 29.4-ft. sections of full-scale jetties 18 ft. high, 10 ft. wide at the top, and 64 ft. wide at the bottom. The mat and core in each jetty were constructed of stone graded to size, while the cap and slope stones were cut to proper dimensions (see Photographs 2-3). As outlined in Paragraphs 2 and 9, three general types of jetties were tested, differing only in the size of the material in the core; the mat stone and the cap stone were the same for all models. For each type of jetty model, two conditions of compaction of the core material were tested. In one case the core was closely compacted, the small stone being carefully fitted into the openings between the large stones. In the second case, the core was constructed less carefully, the stone being allowed to fall into place from a platform above the model. A more permeable core resulted from this method of construction.

15. Individual stones in the jetty models were so selected or prepared as to be 1/6 the size of the corresponding stones in the full-scale jetties. In determining the sizes of stones in the prototype corresponding to the weight specifications listed in Paragraph 9, it was assumed that the stones would have a unit weight of 160 lbs. per cubic foot. The controlling size, then, was computed under the assumption that the stones would be generally cubic in shape; that is, the controlling size was assumed to be the cube root of the volume as determined from the weight and unit weight of the stones. The resulting general specifications for the jetty models, then, were as follows:

Mat Stone

Not less than 7/8 in. and not more than 2-1/8 in.

Core Stone

Size of Material	Quantity in Core (Percentage, by Weight) Jetty No. 1	Jetty No. 2	Jetty No. 3
7/8 in. to 2-1/8 in.	25	20	30
2-1/8 in. to 5-7/8 in.	35	30	40
5-7/8 in. to 7-3/8 in.	40	50	30

Cap and Slope Stone

6 x 9 x 9-1/2 in. to 6 x 12 x 12-1/2 in.

16. It was believed, however that the above general specifications for the mat and core were not close enough to insure adequate control of the tests. It was believed possible that accidental variation in the sizes of stones within the size ranges outlined above might have a greater effect on the rates of seepage through the models than would the difference in percentages of materials in the ranges themselves. (For example: it might be more significant that within the range 7/8 in. to 2-1/8 in. there was a uniform variation in size, than that the total percentage within the range was 25, rather than 20 or 30). Accordingly, the above general specifications were enlarged, each of the above size ranged being broken down into two or more smaller size ranges. Within each of the general ranges of size, a straight-line variation of size with quantity was established. The model jetties were constructed according to the following specifications (Plate 2 illustrates the size distributions assumed for the core stones):

Mat Stone

50 per cent between 7/8 in. and 1-1/2 in.

50 per cent between 1-1/2 in. and 2-1/8 in.

Core Stone (see Plate 2)

Size of Material	Quantity in Core (Percentage, by Weight)		
	Jetty No. 1	Jetty No. 2	Jetty No. 3
7/8 in. to 1-1/2 in.	12.5	10.0	15.0
1-1/2 in. to 2-1/8 in.	12.5	10.0	15.0
2-1/8 in. to 3 in.	8.2	7.0	9.33
3 in. to 4 in.	9.3	8.0	10.67
4 in. to 5 in.	9.3	8.0	10.67
5 in. to 5-7/8 in.	8.2	7.0	9.33
5-7/8 in. to 6-1/2 in.	16.7	20.8	12.5
6-1/2 in. to 7 in.	13.3	16.7	10.0
7 in. to 7-3/8 in.	10.0	12.5	7.5

Cap and Slope Stone

As indicated in Paragraph 15 above.

PART III

PROCEDURE AND TEST RESULTS

17. In testing each model jetty, various controlled headwater-tailwater combinations were established, the discharge resulting from each combination being measured and recorded. In addition, the temperature of the water and the elevation of the water where it entered and emerged from the core were recorded. The headwater elevations were varied by 0.25-ft. increments from a maximum of 2.5 ft. (elevation referred to that of the bottom of the mat stone) to a minimum of 0.75 ft. (except in the last three tests, in which some of the lower headwater elevations were omitted). For each headwater elevation, tests were made with several tailwater elevations, the maximum tailwater elevation in each case being about 0.10 ft. below that of the headwater. Before beginning the test of Jetty No. 1, several repeat tests were run to determine whether the same rate of seepage would occur each time a given combination of headwater and tailwater was established in the flume. It was found that the model was extremely accurate (within 2 per cent) in reproducing rates of seepage under identical headwater-tailwater conditions.

18. The basic data from the tests are contained in Appendix 1, following the text of this memorandum. The results of the tests and the conclusions to be drawn therefrom are described in the following paragraphs, and are illustrated on Plates 3-10.

19. Important among the observations from the tests is the fact that the flow through the jetties was at all times clearly of the turbulent variety; it was not observed that laminar flow occurred at any time in the testing program. There was a measurable difference in elevation

between the water in the headbay and the water at the point where it entered the core of the jetties, there being an appreciable fall of the water through the cracks between the slope stones. The velocity of the flow through the jetties was surprisingly high, frequently being of magnitude of the order of 0.5 ft. per sec.

20. The results obtained from the tests are summarized below:

a. Jetty No. 3, whose core contained the largest percentage of fine material, was the least permeable.

b. Jetty No. 2, whose core contained the smallest percentage of fine material, was the most permeable.

c. Each of the jetties was less permeable when the stones in the core were closely compacted than when the stones were loosely arranged.

d. In the case of Jetties Nos. 3 and 1, the permeabilities were affected more by the arrangement of the stones in the cores than by the sizes of the stones themselves. That is, considering either the compacted condition or the loose condition of the core stones, Jetty No. 3 was less permeable than Jetty No. 1; on the other hand, Jetty No. 3 with the loose arrangement of the core stones was more permeable than Jetty No. 1 with the compact arrangement of the core stones.

e. The six jetty models are listed below in ascending order of permeability:

(1) Jetty No. 3 - core compact (least permeable).

(2) Jetty No. 1 - core compact.

(3) Jetty No. 3 - core loose.

(4) Jetty No. 1 - core loose.

(5) Jetty No. 2 - core compact.

(6) Jetty No. 2 - core loose (most permeable).

PART IV

DISCUSSION OF RESULTS

21. In comparing permeabilities of the six jetties texted (see Plates 3-6), it should be noted that for each of the four tailwater elevations plotted, the order of the six curves representing the permeabilities of the jetties is the same.

22. Another significant result of the tests, which can be determined best from Plates 3-6, is that the effect of arrangement and compaction of core materials is less with Jetty No. 2 than with either Jetty No. 3 or Jetty No. 1. In the case of Jetties Nos. 3 and 1, the rate of seepage through the loosely arranged cores was from 9 to 14 per cent greater than through the compacted cores. In the case of Jetty No. 2, however, the difference was only 2 to 4 per cent. It appears, therefore, that the larger percentage of large materials in Jetty No. 2 makes it so inherently porous that no amount of careful placing of the stones can make that jetty appreciably less permeable.

23. No effort was made in any of the computations to determine any corrections to be applied to the rates of seepage to compensate for viscosity changes. The meager information in the literature available on this subject points to the conclusion that where the percolation through the interstices of materials is of turbulent nature, the effect of viscosity is negligible. Several pairs of duplicate tests were made during the study, in each of which all conditions were kept constant except the temperature of the water. In these duplicate tests, the water temperature was varied between approximately 10°C and 20°C. No difference in the rates of seepage could be detected; these tests thus tended to confirm the belief

that viscosity is of negligible importance in the case of percolation where turbulent flow exists.

24. Efforts were made to compare the permeabilities of the jetties on the basis of some rational coefficient such as that in the Darcy formula for laminar flow through sands. It was found, however, that the non-uniformity of the jetty sections made such computations impossible; that is, the existence of the mat stone and the cap and slope stone introduced uncertainties which made the computations inconclusive. Had it been possible to isolate the flow through the mat from the flow through the core, such computations might have been successful. The apparatus did not permit such individual measurements of the components of the total seepage through the jetty.

25. It was found, however, that the rate of seepage through the jetty models varied with the hydraulic slope, to a power of the slope factor of approximately 0.57. Tests similar to those conducted in this study, but with the elimination of the mat stone and the cap and slope stone would probably produce data from which reliable calculations could be made both of the value of the slope exponent and of a rational coefficient of permeability.

Submitted:

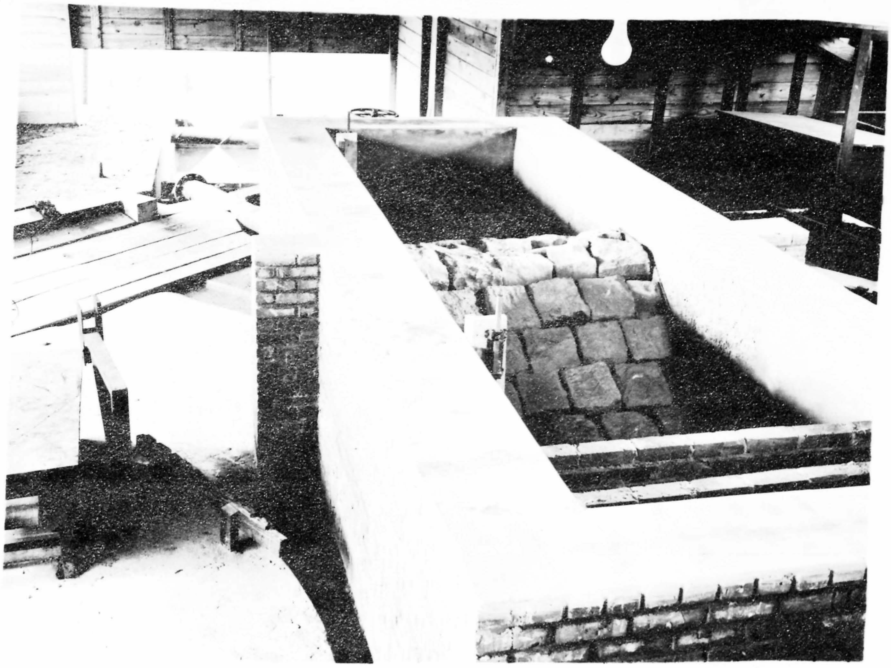
H. P. Theus
H. P. Theus,
Assistant Engineering Aide.

Recommended:

J. B. Tiffany, Jr.
J. B. Tiffany, Jr.,
Assistant Engineer.

Approved:

Paul W. Thompson
Paul W. Thompson,
1st Lieut., Corps of Engineers,
Director.



Photograph 1

General view of testing flume showing model jetty in place.

Photograph 2

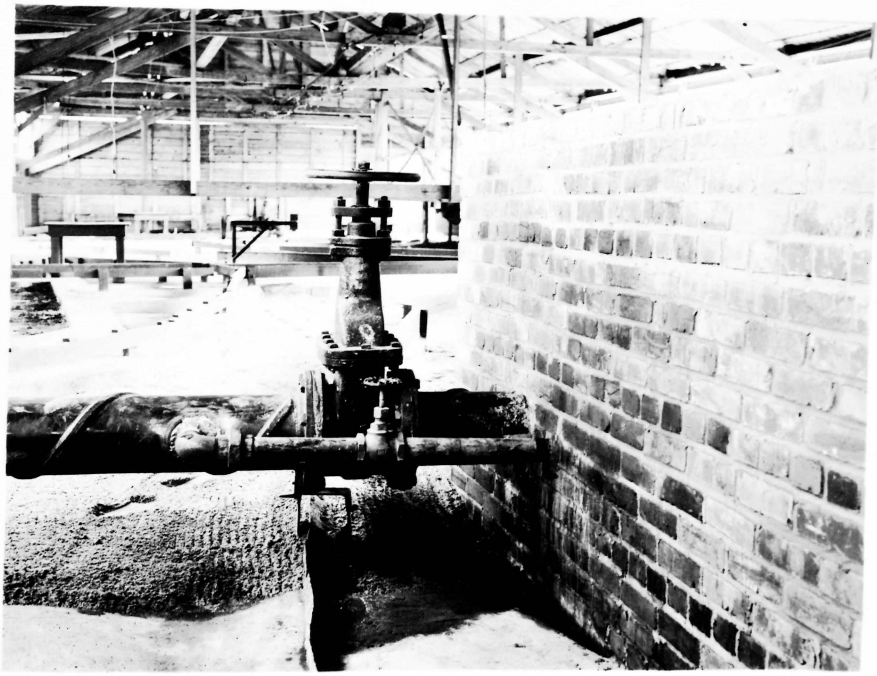
View of rock jetty model completely assembled in flume.

Photograph 3

Mat and core of Jetty No. 3 in place in the flume. The lines on the walls of the flume mark the limits of the cap and slope stone.

Photograph 4

Mat and core of Jetty No. 3 with headwater of 1.95 ft. and tailwater of 1.75 ft.



Photograph 5

Water-supply pipes (8-in. and 2-in.) connecting flume and constant-head tank.

Photograph 6

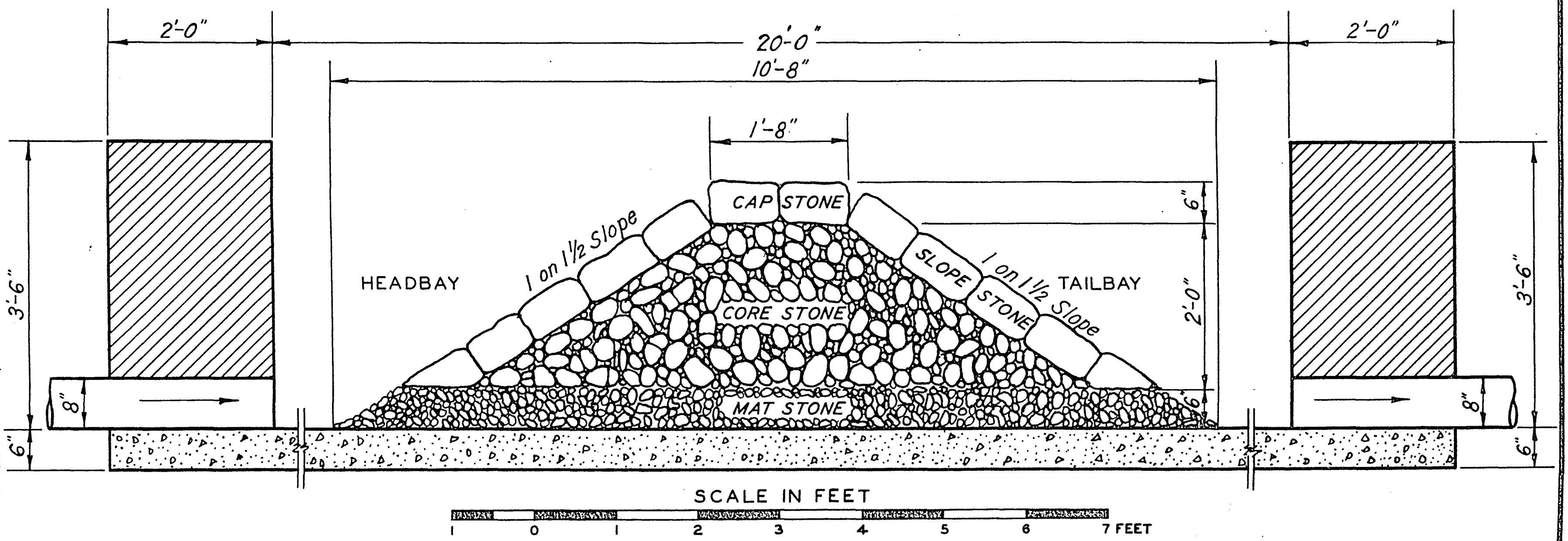
Waste-water pipes (6-in. and 1-in.) extending from headbay of flume to sump.

Photograph 7

Discharge pipes (8-in. and 2-in.) extending from tailbay of flume to weir box.

Photograph 8

View of V-notched weir and weir box. Water discharges directly from the weir into the sump, from which it is pumped to the constant-head tank for recirculation.



SIZE OF MATERIAL IN JETTY CORES

SIZE OF MATERIAL, FULL SCALE JETTY	PERCENTAGE IN JETTY CORE			EQUIVALENT SIZE IN MODELS		
	JETTY NO. 1	JETTY NO. 2	JETTY NO. 3	1:4 SCALE	1:6 SCALE	1:8 SCALE
15 LBS. TO 200 LBS.	25	20	30	1 3/8" TO 3 1/4"	7/8" TO 2 1/8"	5/8" TO 1 5/8"
200 LBS. TO 2 TONS	35	30	40	3 1/4" TO 8 3/4"	2 1/8" TO 5 7/8"	1 5/8" TO 4 3/8"
2 TONS TO 4 TONS	40	50	30	8 3/4" TO 11"	5 7/8" TO 7 3/8"	4 3/8" TO 5 1/2"

PERMEABILITY OF ROCK JETTY MODELS

PROFILE OF 1:6 JETTY MODELS AND TESTING FLUME

U. S. WATERWAYS EXPERIMENT STATION
VICKSBURG, MISSISSIPPI

SUBMITTED: RECOMMENDED: APPROVED:

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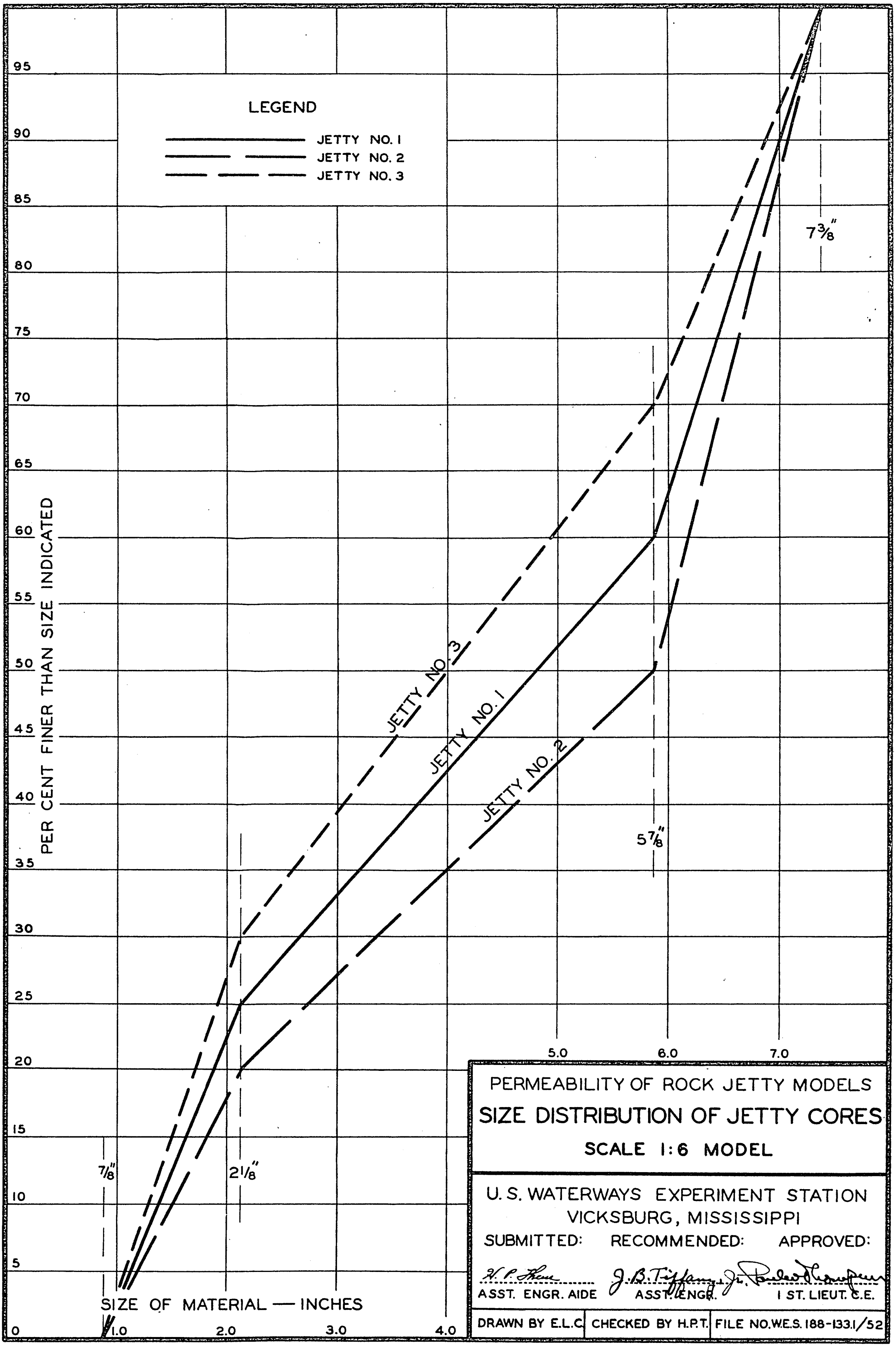
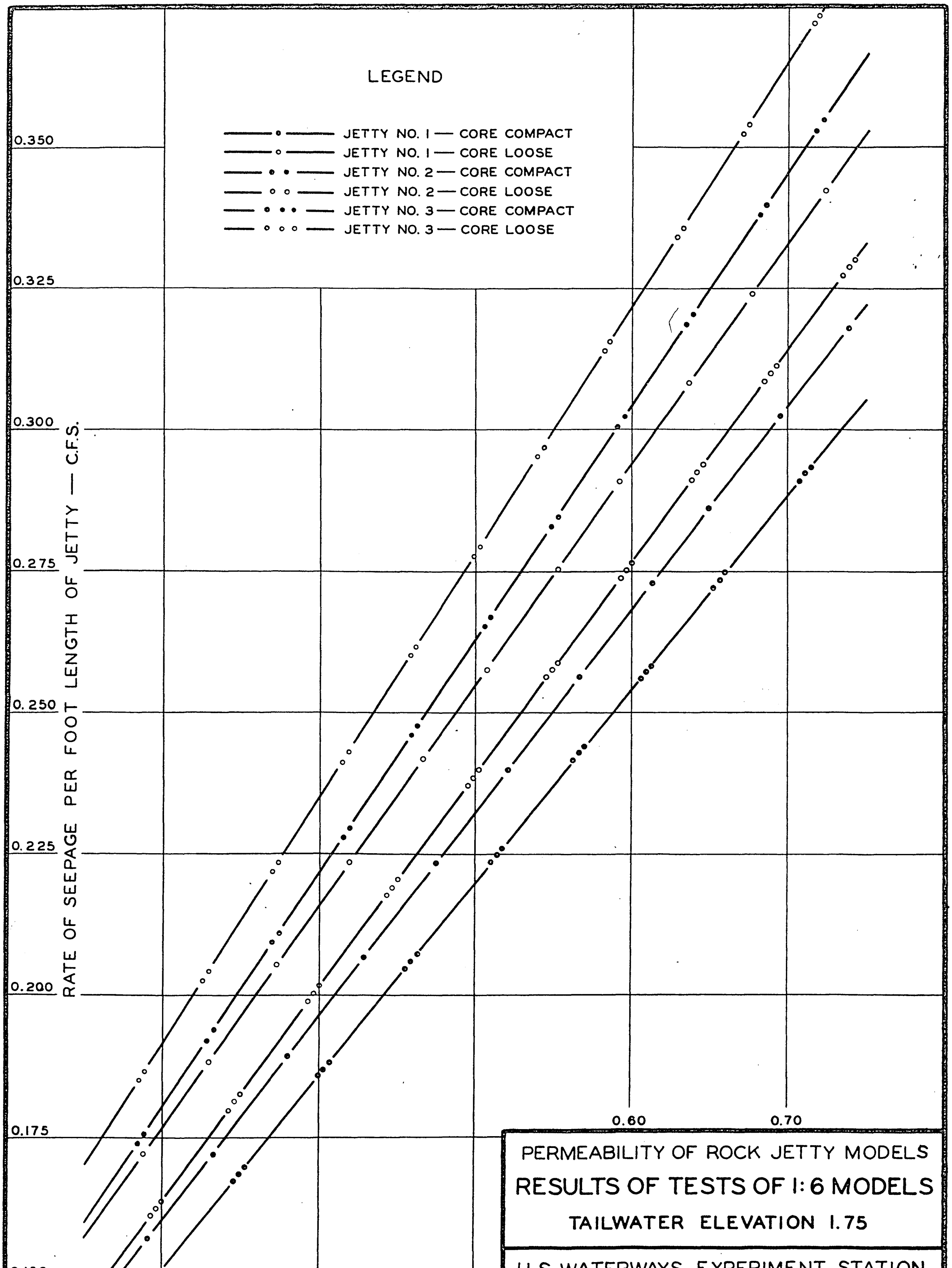
PLATE I

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY





PERMEABILITY OF ROCK JETTY MODELS

RESULTS OF TESTS OF 1:6 MODELS

TAILWATER ELEVATION 1.75

U. S. WATERWAYS EXPERIMENT STATION
VICKSBURG, MISSISSIPPI

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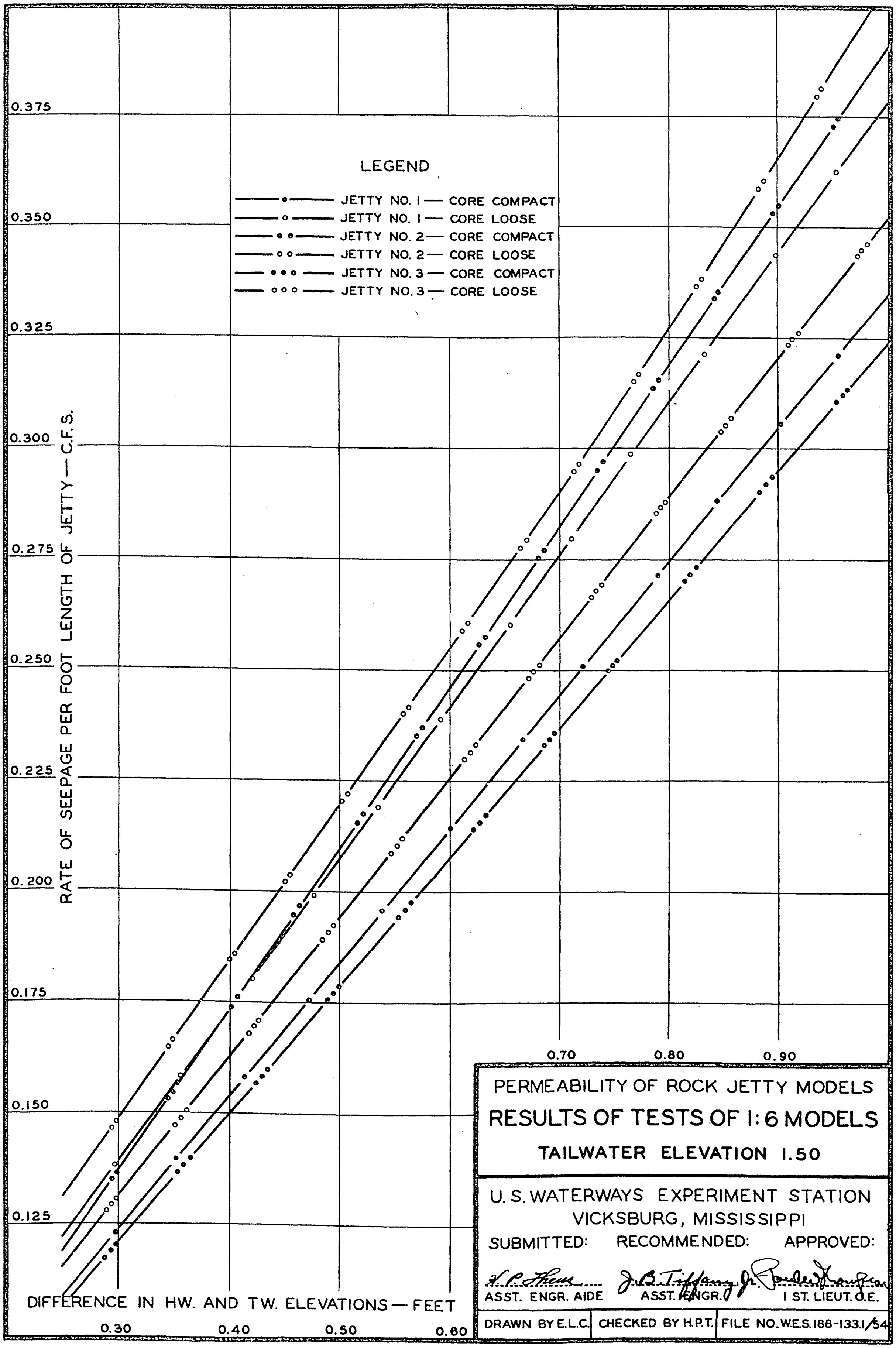

PERMEABILITY OF ROCK JETTY MODELS

RESULTS OF TESTS OF 1:6 MODELS

TAILWATER ELEVATION 1.50

U. S. WATERWAYS EXPERIMENT STATION
VICKSBURG, MISSISSIPPI

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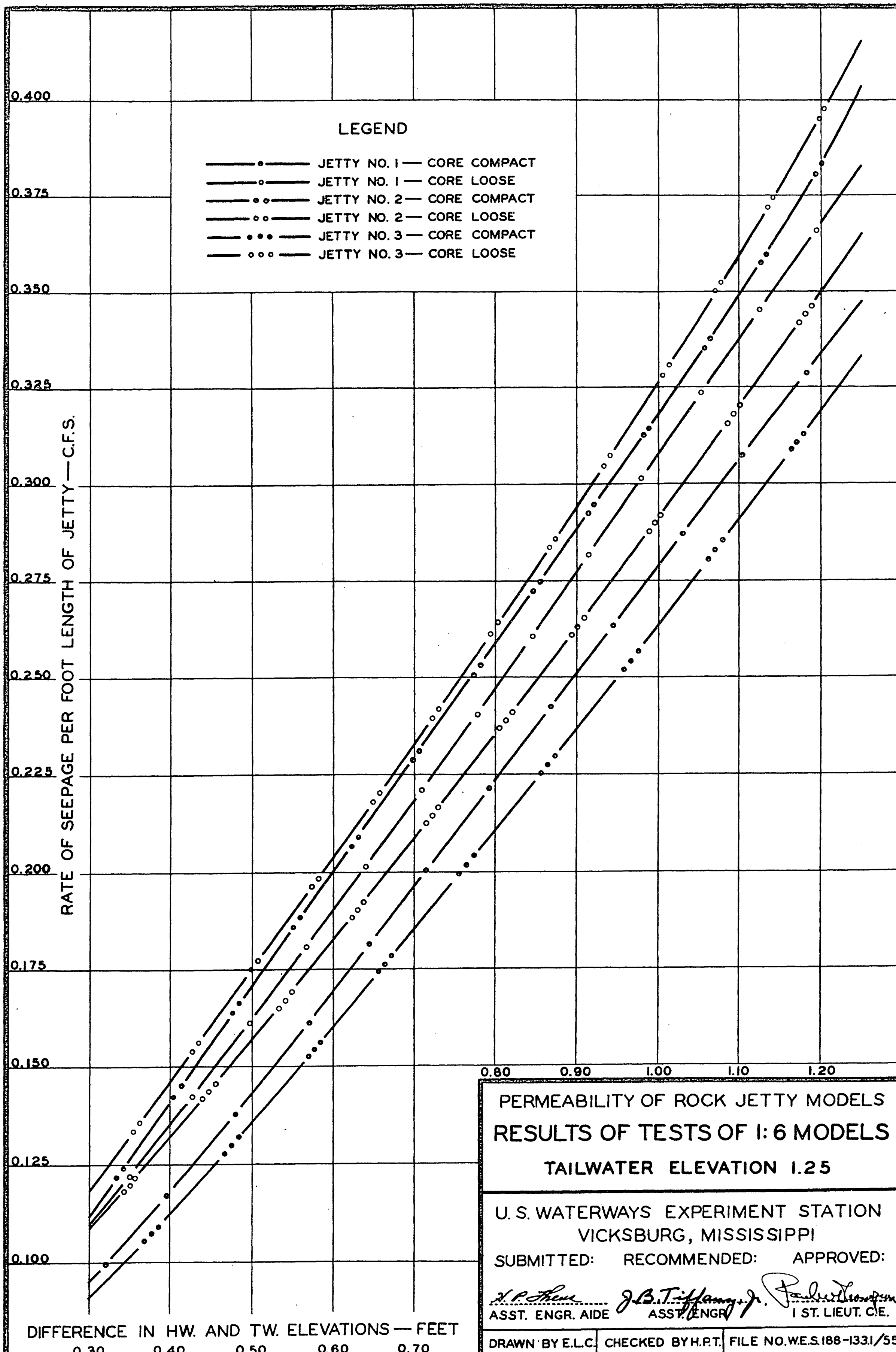

PERMEABILITY OF ROCK JETTY MODELS

RESULTS OF TESTS OF 1: 6 MODELS

TAILWATER ELEVATION 1.25

U. S. WATERWAYS EXPERIMENT STATION
VICKSBURG, MISSISSIPPI

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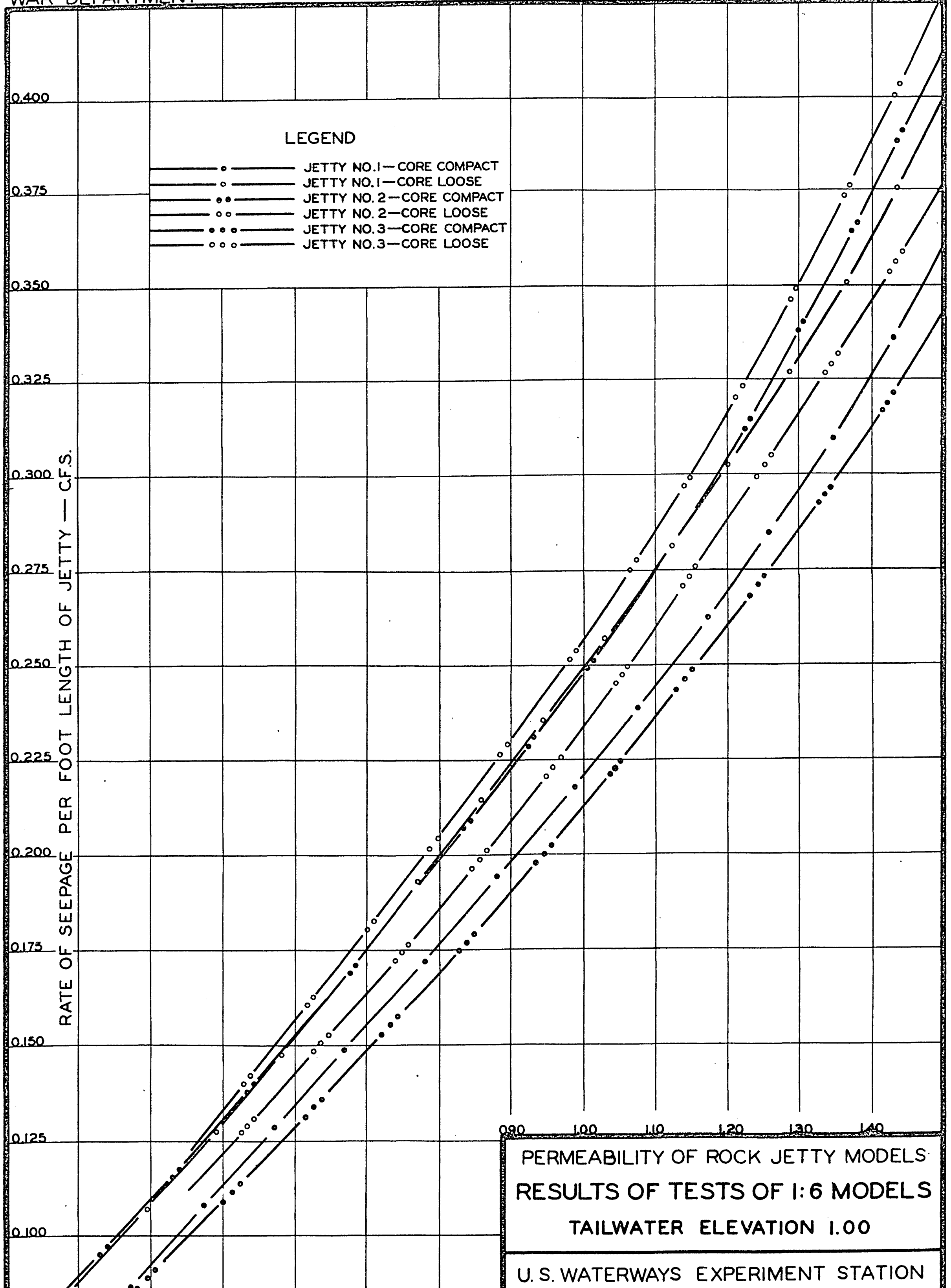

PERMEABILITY OF ROCK JETTY MODELS

RESULTS OF TESTS OF 1:6 MODELS

TAILWATER ELEVATION 1.00

U. S. WATERWAYS EXPERIMENT STATION
VICKSBURG, MISSISSIPPI

SUBMITTED:	RECOMMENDED:	APPROVED:
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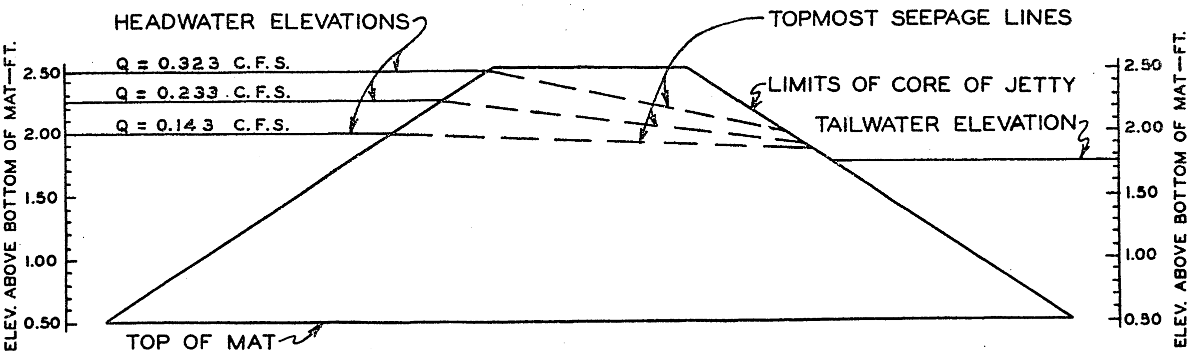
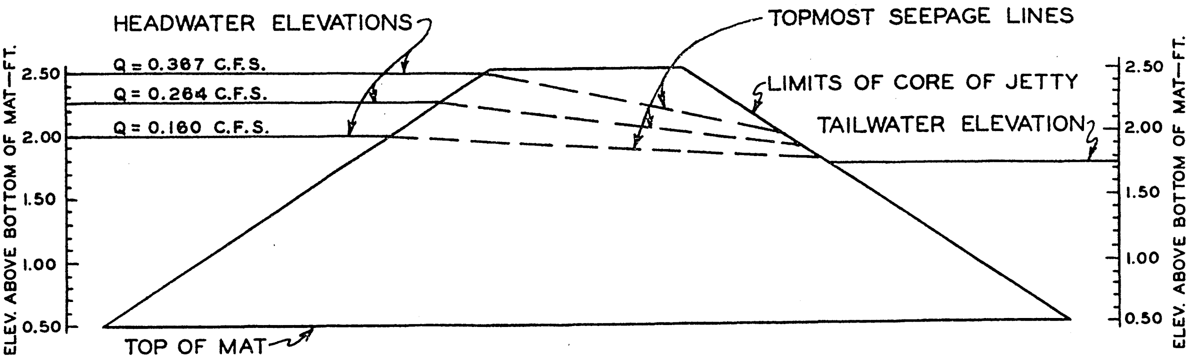


JETTY NO. 1 — CORE COMPACT



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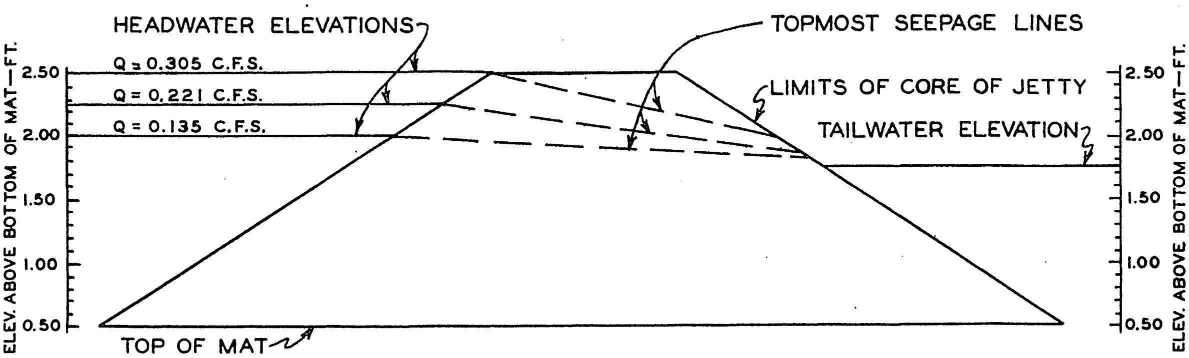

JETTY NO. 3 — CORE COMPACT

NOTE:
DISCHARGES SHOWN ARE PER FOOT LENGTH OF JETTY.

PERMEABILITY OF ROCK JETTY MODELS

RESULTS OF TESTS OF 1: 6 MODELS

TAILWATER ELEVATION 1.75

U. S. WATERWAYS EXPERIMENT STATION
VICKSBURG, MISSISSIPPI

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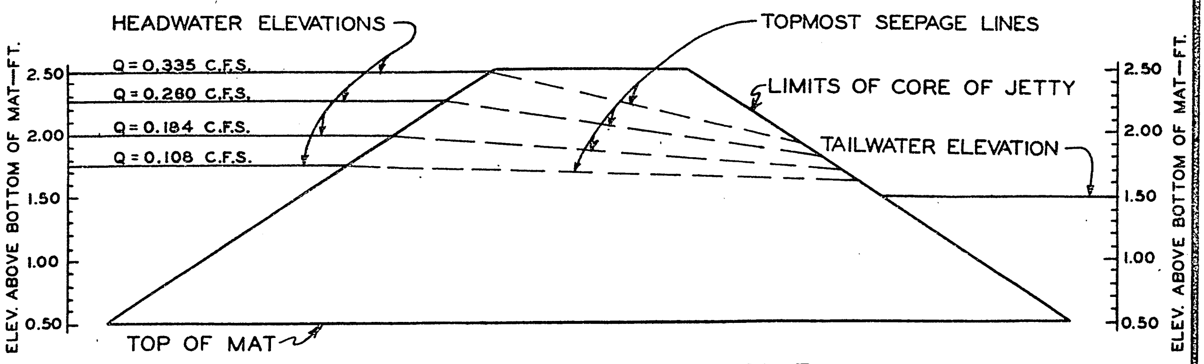

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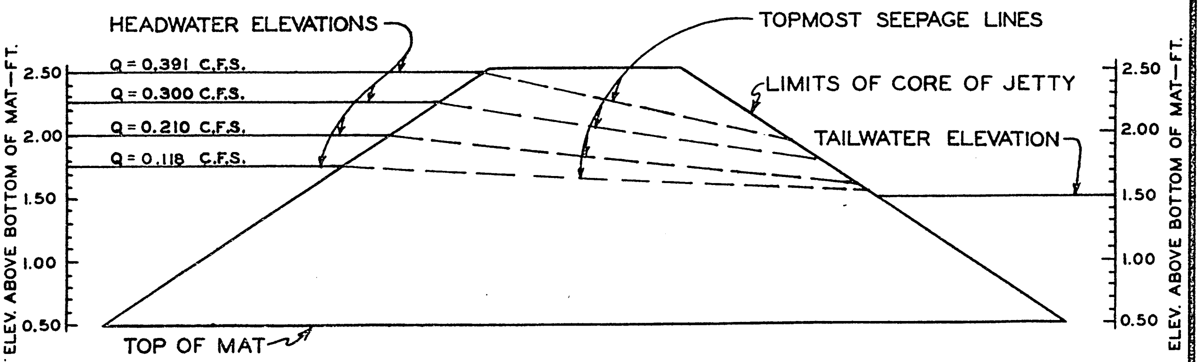

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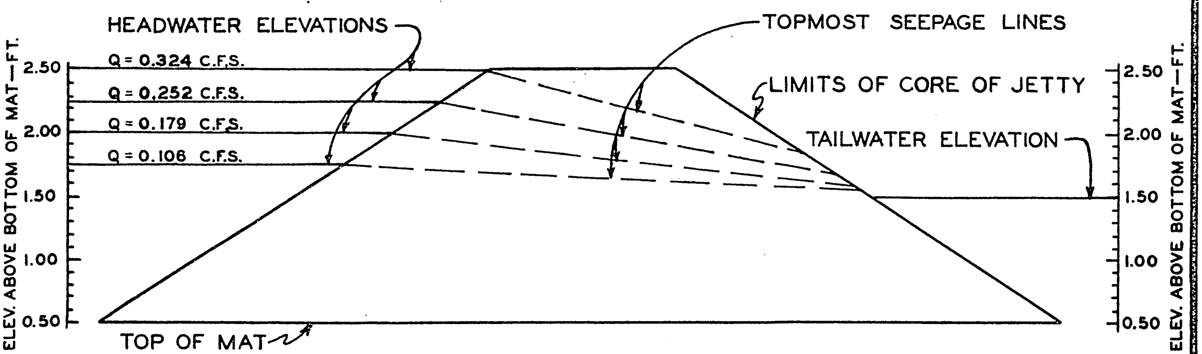

JETTY NO. 3 — CORE COMPACT

NOTE:
DISCHARGES SHOWN ARE PER FOOT LENGTH OF JETTY

PERMEABILITY OF ROCK JETTY MODELS

RESULTS OF TESTS OF 1: 6 MODELS

TAILWATER ELEVATION 1.50

U. S. WATERWAYS EXPERIMENT STATION
VICKSBURG, MISSISSIPPI

SUBMITTED:	RECOMMENDED:	APPROVED:
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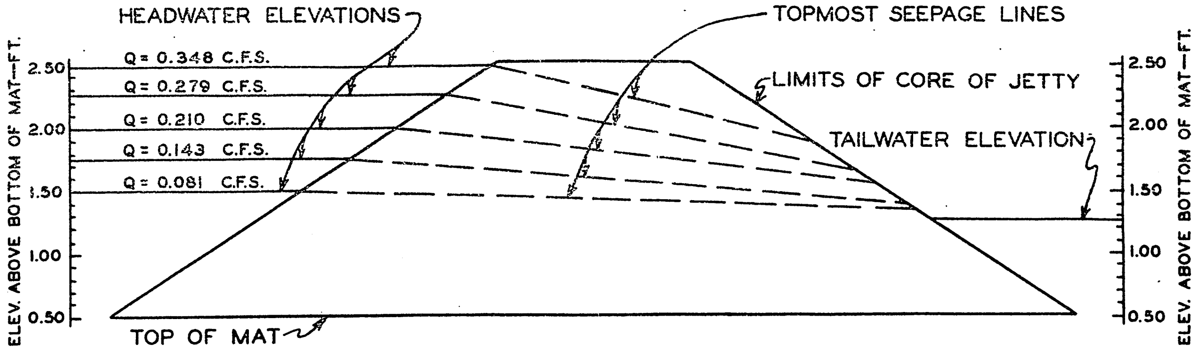

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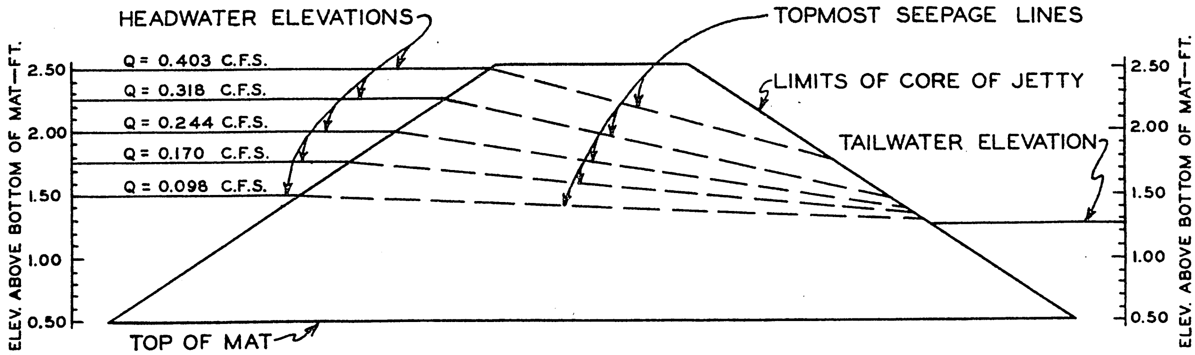
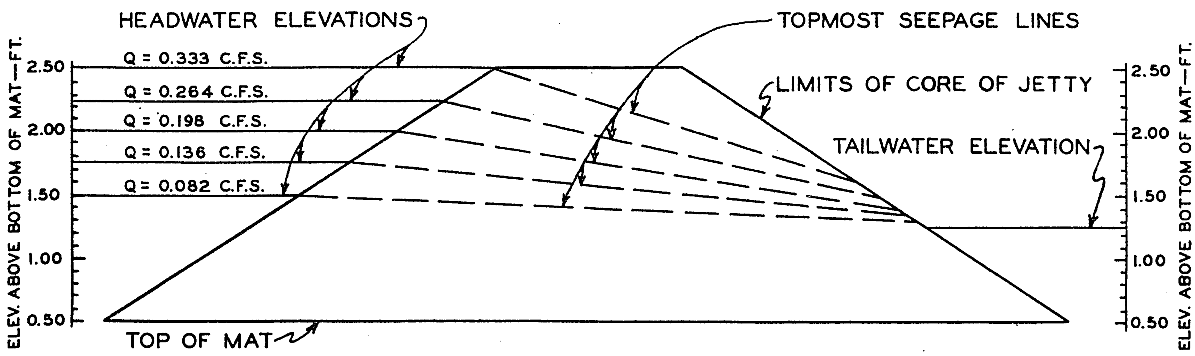


JETTY NO. 2 — CORE COMPACT



JETTY NO. 3 — CORE COMPACT

NOTE:
DISCHARGES SHOWN ARE PER FOOT LENGTH OF JETTY

PERMEABILITY OF ROCK JETTY MODELS

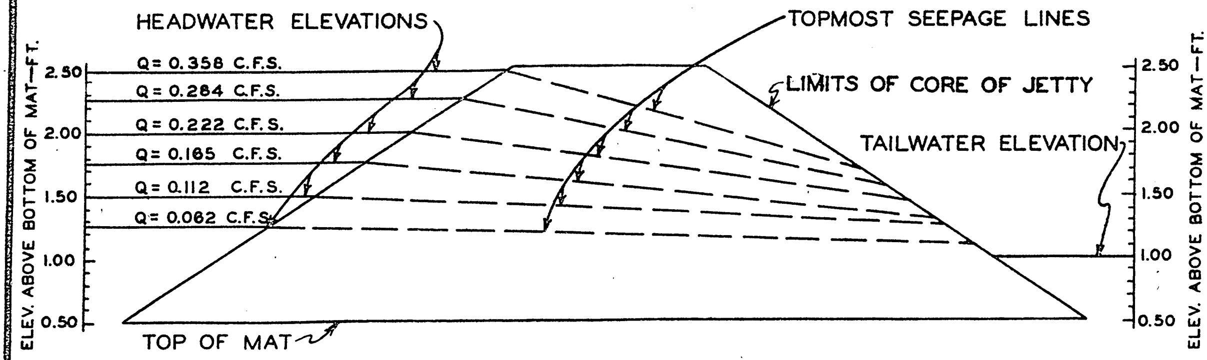
RESULTS OF TESTS OF 1:6 MODELS

TAILWATER ELEVATION 1.25

U. S. WATERWAYS EXPERIMENT STATION
VICKSBURG, MISSISSIPPI

SUBMITTED:	RECOMMENDED:	APPROVED:
H. P. Thurm (signature)	J. B. Tiffany, Jr. (signature)	Paul W. Thompson (signature)
ASST. ENGR. AIDE	ASST. ENGR.	1 ST. LIEUT. C.E.

DRAWN BY E.L.C. | CHECKED BY H.P.T. | FILE NO. W.E.S. 188-1331/59



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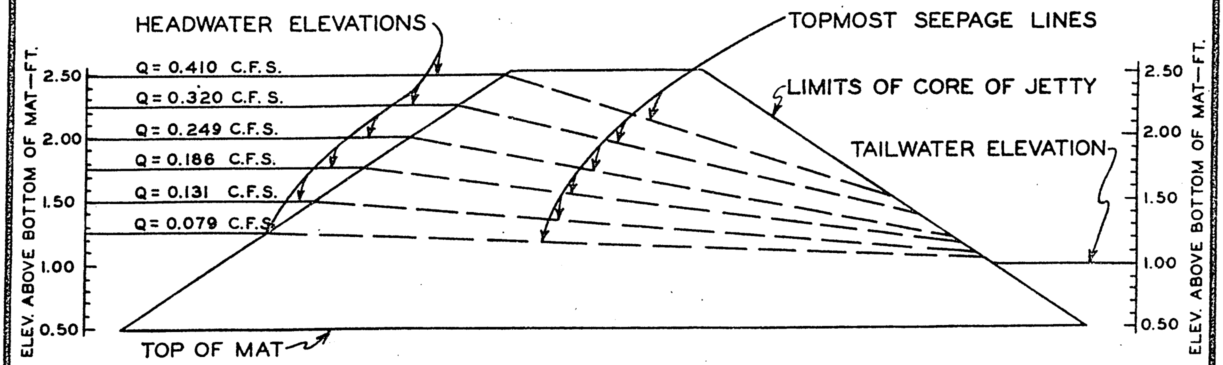

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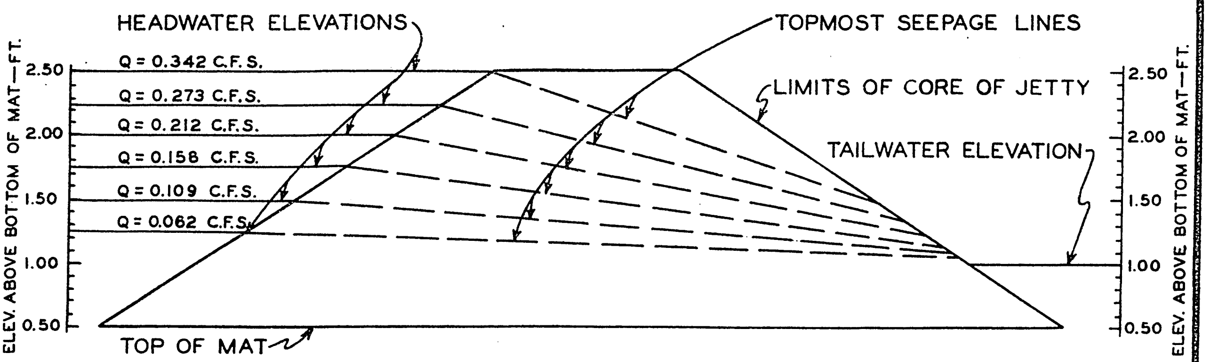

JETTY NO. 3 — CORE COMPACT

NOTE:
DISCHARGES SHOWN ARE PER FOOT LENGTH OF JETTY

PERMEABILITY OF ROCK JETTY MODELS

RESULTS OF TESTS OF 1:6 MODELS

TAILWATER ELEVATION 1.00

U. S. WATERWAYS EXPERIMENT STATION
VICKSBURG, MISSISSIPPI

SUBMITTED:	RECOMMENDED:	APPROVED:
H. P. Thuss	J. B. Tiffany, Jr.	Paul W. Thompson
ASST. ENGR. AIDE	ASST. ENGR.	1 ST. LIEUT. C.E.

DRAWN BY E.L.C.	CHECKED BY H.P.T.	FILE NO. W.E.S. 188-133.1/60

APPENDIX 1

Basic Data from Tests.

STUDY OF PERMEABILITY OF ROCK JETTY MODELS

TEST DATA

JETTY NO. 1 — Core Arranged Compactly.

Elev.* of Headwater	Elev. of Tailwater	Diff. in Elevations	Elev. of Entrance**	Elev. of Emergence***	Seepage per ft. (c.f.s.)	Temperature (Deg. C)
2.50	1.71	0.79	2.50	2.00	0.330	7.6
2.53	1.54	0.99	2.50	1.90	0.351	8.6
2.51	1.27	1.24	2.40	1.85	0.356	8.9
2.51	0.99	1.52	2.40	1.70	0.364	9.0
2.51	0.73	1.78	2.40	1.70	0.366	9.1
2.24	2.12	0.12	2.20	2.15	0.121	9.9
2.22	1.99	0.23	2.20	2.05	0.163	10.1
2.24	1.77	0.47	2.20	1.90	0.226	10.2
2.25	1.50	0.75	2.15	1.80	0.257	8.4
2.24	1.22	1.02	2.15	1.65	0.272	8.6
2.26	0.98	1.28	2.15	1.55	0.286	9.0
2.25	0.66	1.59	2.15	1.50	0.286	9.1
2.00	1.86	0.14	2.00	1.90	0.106	10.2
2.00	1.74	0.26	2.00	1.85	0.143	10.8
2.00	1.52	0.48	2.00	1.70	0.181	11.0
1.99	1.25	0.74	1.95	1.55	0.206	11.5
2.02	0.99	1.03	1.95	1.45	0.229	11.7
2.00	0.62	1.38	1.95	1.35	0.228	11.8
1.76	1.65	0.11	1.75	1.70	0.077	12.1
1.75	1.52	0.23	1.75	1.60	0.107	12.4
1.72	1.27	0.45	1.70	1.40	0.138	13.0
1.76	0.98	0.78	1.70	1.30	0.168	13.4
1.77	0.54	1.23	1.70	1.00	0.180	13.9
1.49	1.37	0.12	1.49	1.40	0.062	12.5
1.50	1.28	0.22	1.50	1.35	0.084	12.7
1.50	1.04	0.46	1.50	1.25	0.112	12.9
1.48	0.40	1.08	1.45	0.75	0.127	13.0
1.24	1.11	0.13	1.24	1.15	0.048	13.5
1.25	1.03	0.22	1.25	1.10	0.062	13.9
1.25	0.75	0.50	1.25	0.85	0.082	14.0
1.24	0.30	0.94	1.24	0.55	0.091	14.5
1.04	0.90	0.14	1.04	0.95	0.0394	15.0
0.98	0.72	0.26	0.98	0.77	0.0457	15.5
1.00	0.21	0.79	1.00	0.48	0.059	15.6
0.76	0.61	0.15	0.76	0.65	0.0236	15.7
0.75	0.12	0.63	0.75	0.20	0.0343	15.5

* All Elevations are in feet above bottom of mat.
** Elevation of flow entering core of jetty.
*** Elevation of flow emerging from core of jetty.

STUDY OF PERMEABILITY OF ROCK JETTY MODELS

TEST DATA

JETTY NO. 1 — Core Arranged Loosely

Elev.* of Headwater	Elev. of Tailwater	Diff. in Elevations	Elev. of Entrance**	Elev. of Emergence***	Seepage per ft. (c.f.s.)	Temperature (Deg. C)
2.51	1.76	0.75	2.43	2.15	0.354	14.8
2.50	1.50	1.00	2.43	1.90	0.378	14.8
2.50	1.25	1.25	2.43	1.80	0.384	14.9
2.50	1.00	1.50	2.40	1.75	0.399	15.0
2.50	0.79	1.71	2.40	1.75	0.403	15.0
2.23	2.13	0.10	2.23	2.16	0.113	15.0
2.23	1.97	0.26	2.22	2.04	0.189	15.3
2.24	1.73	0.51	2.22	1.90	0.258	15.6
2.25	1.51	0.74	2.20	1.75	0.291	15.8
2.24	1.26	0.98	2.20	1.65	0.307	16.2
2.25	1.00	1.25	2.20	1.45	0.315	16.5
2.25	0.73	1.52	2.20	1.38	0.322	16.6
1.97	1.90	0.07	1.97	1.94	0.081	13.5
1.99	1.76	0.23	1.99	1.85	0.152	13.8
1.99	1.51	0.48	1.99	1.64	0.203	14.0
2.00	1.25	0.75	1.99	1.43	0.233	14.3
2.02	1.02	1.00	2.00	1.27	0.252	14.4
2.00	0.65	1.35	1.97	1.25	0.250	14.5
1.73	1.64	0.09	1.73	1.68	0.080	14.8
1.74	1.53	0.21	1.74	1.58	0.118	15.0
1.78	1.25	0.53	1.78	1.40	0.174	15.5
1.74	1.01	0.73	1.73	1.20	0.184	15.7
1.75	0.58	1.17	1.74	1.03	0.196	15.7
1.51	1.41	0.10	1.51	1.47	0.066	15.2
1.51	1.28	0.23	1.51	1.35	0.099	15.3
1.52	0.99	0.53	1.52	1.11	0.135	15.5
1.50	0.45	1.05	1.49	0.82	0.148	15.7
1.26	1.14	0.12	1.26	1.18	0.056	15.9
1.25	0.98	0.27	1.25	1.06	0.078	16.0
1.25	0.78	0.47	1.25	0.92	0.092	16.5
1.26	0.35	0.91	1.25	0.68	0.105	16.7
1.01	0.90	0.11	1.01	0.95	0.039	17.0
1.00	0.80	0.20	1.00	0.87	0.049	17.5
0.98	0.22	0.76	0.96	0.56	0.062	17.8
0.78	0.66	0.12	0.78	0.68	0.024	18.2
0.75	0.12	0.63	0.75	0.19	0.035	18.2

* All Elevations are in feet above bottom of mat.

** Elevation of flow entering core of jetty.

*** Elevation of flow emerging from core of jetty.

STUDY OF PERMEABILITY OF ROCK JETTY MODELS

TEST DATA

JETTY NO. 2 Core Arranged Compactly

Elev.* of Headwater	Elev. of Tailwater	Diff. in Elevations	Elev. of Entrance**	Elev. of Emergence***	Seepage per ft. (c.f.s.)	Temperature (Deg. C)
2.50	1.75	0.75	2.47	2.02	0.366	16.4
2.50	1.50	1.00	2.47	1.93	0.392	16.5
2.51	1.26	1.25	2.48	1.77	0.409	16.7
2.50	1.01	1.49	2.47	1.52	0.410	16.8
2.50	0.77	1.73	2.47	1.50	0.414	16.9
2.24	2.15	0.09	2.24	2.19	0.117	17.8
2.24	2.00	0.24	2.24	2.08	0.192	18.2
2.25	1.74	0.51	2.24	1.91	0.267	18.8
2.25	1.50	0.75	2.24	1.78	0.297	19.0
2.25	1.25	1.00	2.24	1.47	0.318	19.0
2.26	1.01	1.25	2.25	1.38	0.328	19.2
2.25	0.70	1.55	2.24	1.32	0.332	19.2
2.01	1.91	0.10	2.00	1.97	0.104	16.4
2.01	1.74	0.27	1.97	1.79	0.164	16.4
2.00	1.50	0.50	1.94	1.56	0.206	16.7
2.00	1.26	0.74	1.94	1.40	0.234	16.9
2.01	1.01	1.00	1.94	1.17	0.250	17.2
2.01	0.64	1.37	1.93	1.03	0.257	17.5
1.76	1.65	0.11	1.75	1.67	0.087	18.2
1.75	1.51	0.24	1.73	1.54	0.124	18.5
1.76	1.25	0.51	1.73	1.35	0.173	18.5
1.76	1.01	0.75	1.72	1.16	0.190	18.7
1.76	0.59	1.17	1.72	0.92	0.201	18.8
1.51	1.39	0.12	1.50	1.42	0.074	18.0
1.51	1.25	0.26	1.49	1.29	0.102	18.0
1.51	1.00	0.51	1.49	1.09	0.133	18.2
1.51	0.47	1.04	1.48	0.71	0.153	18.3
1.27	1.17	0.10	1.25	1.20	0.053	18.7
1.25	1.00	0.25	1.24	1.03	0.078	19.0
1.25	0.74	0.51	1.23	0.81	0.098	19.5
1.26	0.35	0.91	1.23	0.60	0.107	19.8
1.01	0.90	0.11	1.00	0.92	0.040	19.9
1.00	0.75	0.25	0.99	0.80	0.053	20.2
1.00	0.24	0.76	0.98	0.40	0.067	20.2
0.75	0.65	0.10	0.75	0.67	0.022	20.2
0.76	0.14	0.62	0.74	0.20	0.039	20.2

* All Elevations are in feet above bottom of mat.

** Elevation of flow entering core of jetty.

*** Elevation of flow emerging from core of jetty.

STUDY OF PERMEABILITY OF ROCK JETTY MODELS

TEST DATA

JETTY NO. 2

Core Arranged Loosely

Elev.* of Headwater	Elev. of Tailwater	Diff. in Elevations	Elev. of Entrance**	Elev. of Emergence***	Seepage per ft. (c.f.s.)	Temperature (Deg. C)
2.50	1.76	0.74	2.47	2.16	0.382	12.2
2.49	1.52	0.97	2.46	2.00	0.403	12.5
2.50	1.25	1.25	2.46	1.95	0.419	12.5
2.51	0.99	1.52	2.47	1.90	0.430	12.7
2.25	1.75	0.50	2.23	2.00	0.277	13.0
2.25	1.51	0.74	2.22	1.85	0.311	13.2
2.27	1.26	1.01	2.23	1.78	0.334	13.3
2.26	1.01	1.25	2.20	1.65	0.342	13.0
2.00	1.75	0.25	2.00	1.85	0.171	10.3
2.00	1.50	0.50	1.98	1.66	0.219	10.3
1.99	1.26	0.73	1.97	1.57	0.241	10.3
1.99	0.99	1.00	1.96	1.52	0.251	10.5
1.77	1.51	0.26	1.77	1.61	0.140	10.8
1.77	1.27	0.50	1.76	1.48	0.179	11.0
1.75	1.00	0.75	1.74	1.36	0.195	11.1
1.51	1.23	0.28	1.50	1.34	0.107	11.7
1.50	0.99	0.51	1.46	1.16	0.129	11.9

* All Elevations are in feet above bottom of mat.

** Elevation of flow entering core of jetty.

*** Elevation of flow emerging from core of jetty.

STUDY OF PERMEABILITY OF ROCK JETTY MODELS

TEST DATA

JETTY NO. 3 — Core Arranged Compactly

Elev.* of Headwater	Elev. of Tailwater	Diff. in Elevations	Elev. of Entrance**	Elev. of Emergence***	Seepage per ft. (c.f.s.)	Temperature (Deg. C)
2.50	1.75	0.75	2.44	2.00	0.306	19.0
2.51	1.50	1.01	2.44	1.85	0.328	19.4
2.50	1.26	1.24	2.42	1.58	0.331	20.4
2.50	1.00	1.50	2.42	1.47	0.341	19.6
2.50	0.72	1.78	2.42	1.40	0.342	20.4
2.23	2.15	0.08	2.23	2.20	0.091	18.5
2.26	2.02	0.24	2.26	2.09	0.161	18.6
2.26	1.76	0.50	2.25	1.86	0.222	20.0
2.25	1.50	0.75	2.25	1.65	0.248	18.6
2.25	1.25	1.00	2.24	1.49	0.264	18.6
2.25	1.00	1.25	2.24	1.32	0.280	20.1
2.25	0.65	1.60	2.22	1.22	0.277	18.6
2.00	1.91	0.09	2.00	1.96	0.078	18.8
2.01	1.77	0.24	2.01	1.82	0.135	20.2
1.99	1.49	0.50	1.98	1.57	0.175	19.0
1.99	1.25	0.74	1.96	1.40	0.196	19.1
2.01	1.01	1.00	1.96	1.22	0.211	19.5
2.00	0.60	1.40	1.96	1.08	0.217	19.5
1.76	1.67	0.09	1.76	1.71	0.069	19.5
1.73	1.50	0.23	1.72	1.55	0.101	19.6
1.75	1.27	0.48	1.72	1.37	0.139	19.7
1.75	0.99	0.76	1.72	1.12	0.159	19.7
1.76	0.52	1.24	1.72	0.90	0.171	19.8
1.51	1.26	0.25	1.50	1.30	0.086	11.4
1.50	0.98	0.52	1.50	1.10	0.114	11.0
1.27	1.00	0.27	1.27	1.06	0.067	10.9

* All Elevations are in feet above bottom of mat.
** Elevation of flow entering core of jetty.
*** Elevation of flow emerging from core of jetty.

STUDY OF PERMEABILITY OF ROCK JETTY MODELS

TEST DATA

JETTY NO. 3 Core Arranged Loosely

Elev.* of Headwater	Elev. of Tailwater	Diff. in Elevations	Elev. of Entrance**	Elev. of Emergence***	Seepage per ft. (c.f.s.)	Temperature (Deg. C)
2.50	1.75	0.75	2.45	2.00	0.334	11.1
2.50	1.50	1.00	2.45	1.86	0.352	11.2
2.50	1.25	1.25	2.44	1.78	0.364	11.2
2.50	1.00	1.50	2.44	1.67	0.376	11.2
2.24	1.75	0.49	2.22	1.90	0.235	11.5
2.25	1.53	0.72	2.22	1.76	0.269	12.2
2.25	1.25	1.00	2.22	1.60	0.292	12.6
2.25	1.00	1.25	2.20	1.44	0.302	13.0
1.98	1.73	0.25	1.97	1.80	0.143	13.5
2.00	1.51	0.49	2.00	1.65	0.191	13.7
2.03	1.28	0.75	2.00	1.50	0.226	13.8
2.00	1.01	0.99	1.96	1.25	0.232	13.8
1.77	1.52	0.25	1.77	1.60	0.120	13.8
1.74	1.26	0.48	1.73	1.37	0.155	13.8
1.75	0.99	0.76	1.73	1.20	0.174	13.8
1.51	1.25	0.26	1.51	1.30	0.100	13.8
1.49	1.00	0.49	1.49	1.10	0.120	13.6

* All Elevations are in feet above bottom of mat.
** Elevation of flow entering core of jetty.
*** Elevation of flow emerging from core of jetty.