RJ Cox

CORPS OF ENGINEERS, U. S. ARMY

POTAMOLOGY INVESTIGATIONS

REPORT NO. 7-1

SOILS INVESTIGATION

BAUXIPPI-WYANOKE REVETMENT

WATERWAYS EXPERIMENT STATION

VICKSBURG, MISSISSIPPI

JUNE 1951

POTAMOLOGY INVESTIGATIONS REPORTS

Issued Prior To and Including This Report

Report No.	Title	Date
1-1	Instructions and Outline for Potamology Investigations	November 1947
1-2	Outline of Plans for the Potamology Investigations	December 1947
2-1	Preliminary Flume Tests of Mississippi River Revetment (1st Interim Report)	October 1947
2-2	Preliminary Tests of Mississippi River Dikes, Bank Stabilization Model	June 1950
3-1	Preliminary Laboratory Tests of Sand-Asphalt Revetment	July 1948
* 4-1	Investigation of 110-Volt Echo Sounder	July 1948 (Revised May 1950)
5-1	Geological Investigation of Reid Bedford Bend Caving Banks, Mississippi River	July 1947
5-2	Field Investigation of Reid Bedford Bend Revetment, Mississippi River (3 volumes)	June 1948
5-3	Reid Bedford Bend, Mississippi River, Triaxial Tests on Sands	May 1950
5-4	Piezometer Observations at Reid Bedford Bend and Indicated Seepage Forces	May 1950
5-5	Standard Penetration Tests, Reid Bedford Bend, Mississippi River	May 1950
* 5-6	Undisturbed Sand Sampling and Cone Sounding Tests, Reid Bedford Bend Revetment, Mississippi River	May 1951
7-1	Soils Investigation, Bauxippi-Wyanoke Revetment	June 1951
8-1	Hardscrabble Bend, Mississippi River, Revetted Bank Failure, Soils Investigation	June 1950
* 10-1	Preliminary Development of Instruments for the Measurement of Hydraulic Forces Acting in a Turbulent Stream	June 1948
10-2	Turbulence in the Mississippi River	May 1950
* 10-3	Evaluation of Instruments for Turbulence Measurements, 1948-1949	Mar 1951
* 10-4	Evaluation of Instruments for Turbulence Measurements, 1949-1950	April 1951
11-0	Resume of Conference Initiating Potamology Investigations, 11 February 1947	Feb 1947
11-1	Report of Conference on Potamology Investigations 15 March 1948	March 1948
11-2	Report of First Potamology Conference With Hydraulics Consultants, 9-10 December 1948	December 1948
11-3	Minutes of Conference on Soil Studies, Potamology Investigation, 18 April 1949	April 1949
11-4	Report of Second Potamology Conference With Hydraulics Consultants, 23-24 May 1949	May 1949
11-5	Minutes of Conference With Soils Consultants, Stability of Mississippi River Banks, 5-8 October 1949	October 1949
11-6	Report of Conference on Potamology Investigations, 6-7 October 1949 (Volume 1, Volume 2*)	April 1951
11-7	Minutes of Conference On Soil Aspects of Potamology Program, 17-18 June 1950	October 1950
11-8	Minutes of Potamology Conference, 5 April 1951	April 1951

* Not of general informational value and hence not distributed

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Introduction

1. Soil conditions at a number of sites along the banks of the Mississippi River have been studied as part of the potamology investigations being conducted by the Waterways Experiment Station for the Mississippi River Commission. Heretofore, the major soils investigations have been confined to sites at which large bank failures have occurred. Considerable data have been accumulated which indicate the existence of certain related soil and geological conditions common to all the sites investigated. A study of soil conditions existent on relatively stable river banks is now being conducted in an effort to establish the unfavorable soil conditions peculiar to river banks subject to large failures. Two large-scale stable revetment sites have been selected for study because the history of revetted banks is more completely known and bank recession has been prevented by virtue of the revetment at these sites.

2. This report presents the results of the soils investigations made at one of the sites selected for study, Bauxippi-Wyanoke revetment on the right bank of the Mississippi River at miles 724 to 728 AHP. This revetment has, for practical purposes, a failure-free history dating back to 1917 when revetment work was initiated at the site.

3. The study was intended to furnish information on the following:

   a. The general nature of the soils existing adjacent to the revetment as determined from borings.

b. The penetration resistance of soils encountered as determined by cone sounding tests.

c. The relative and absolute densities of the sands encountered as determined from tube samples recovered from undisturbed borings.

d. The geological conditions in the vicinity of the revetment.

Revetment History

Early revetment

4. The Bauxippi-Wyanoke revetment, located on the Arkansas shore of the Mississippi River opposite Memphis, Tenn., originally consisted of two separate projects. Actively caving banks were threatening the controlling levee and railroad embankment at Bauxippi, Arkansas, and the controlling levee at Wyanoke, Arkansas. Work on the Bauxippi revetment was initiated in 1917 with funds contributed by the Aluminum Ore Company. The original projects for revetments to protect the banks at both Bauxippi and Wyanoke were adopted in 1919. Subsequent work consisted of replacement, minor paving repairs and extensions. The two projects were joined by approximately 6000 linear feet of revetment in 1932. Only three small upper bank failures were recorded up to 1950.

Current revetment operations

5. The revetment was strengthened at several points by placement of 8000 linear feet of 4-in. articulated concrete mat as overlay on the existing revetment during fiscal year 1950. Additional work of this nature is planned for the future with 8200 linear feet of overlay scheduled

during the fiscal year 1951 construction season. Increased severity of attack is anticipated on the Bauxippi-Wyanoke revetment with the closure of Tennessee Chute (on the left bank opposite the revetment) which formerly passed approximately 30 per cent of the river flow at high stages.

Field and Laboratory Investigations

Preliminary investigations

6. All available data, consisting of numerous shallow borings made by the Memphis District, CE, along the levee parallel to the revetment site, and aerial photographs, were examined. A program of six undisturbed borings, six cone soundings, and nine auger borings was adopted for the present investigations. These borings were spaced over the areal extent (23,300 linear feet) of the revetment at locations indicated by the best available information as the most advantageous for developing the soil conditions. The locations of the borings and soundings made by the Waterways Experiment Station are shown on plate 1. The locations of those borings made by the Memphis District which were considered pertinent to this investigation are also shown on plate 1.

Auger borings

7. The purpose of the auger borings made by the Waterways Experiment Station was to determine the thickness of the top stratum and channel fillings and to furnish samples for laboratory classification. The depths of the borings were specified to penetrate through the fine-grained deposits and into the underlying sand strata.

Undisturbed borings

8. The purpose of the undisturbed borings was to furnish samples for laboratory classification and determination of maximum, minimum, and natural densities on sands. The borings were made by use of a 3-in.-diameter piston-type sampler using drilling mud in the bore hole*. The borings were made to an elevation equal to or below the elevation of the thalweg of the river opposite the borings. Borings 5U and 6U were made by continuous undisturbed sampling prior to the cone sounding tests. Cone sounding tests were made prior to borings 1U through 4U and a schedule of sampling at specified depths was prepared on the basis of results obtained from the cone sounding tests.

Cone sounding tests

9. Cone soundings were made adjacent (5 to 20 ft) to each undisturbed boring in order to correlate penetration resistance and soil conditions as determined from the borings. The cone sounding device utilizes a cone having a projected area of 1.55 sq in. connected to a rod and a load-weighing arrangement such that only the point resistance of the cone is measured. The assembly is pushed into the ground at a constant rate and the resistance to penetration is measured at 6-in. intervals.

Discussion of Results

General soil conditions

10. The soils in the area are typical point-bar deposits consisting

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* Waterways Experiment Station, "Undisturbed Sand Sampling Below the Water Table," Bulletin No. 35, June 1950.

of silty top stratum soils averaging 15 ft in thickness, with numerous swale fillings consisting of sands, silts, and lean clays ranging in depth up to 45 or 50 ft. The swales, with one exception, intersect the present river bank at approximately right angles, as shown on plate 1. The location and depth of some of the swales were verified by borings; however, their general configuration was determined largely from examination of aerial photographs.

11. The top stratum and swale filling soils are underlain by clean sands which have been divided into two series, based on their depth and gradation. The upper series consists of fine uniform sands ranging from a few feet up to 50 ft in thickness, with an average thickness of 30 ft. Traces of lignite were detected in the sand at a number of locations. A typical gradation curve of the fine sand is shown on plate 2.

12. The lower series consists of coarse sands, showing traces of gravel in the upper portion of the layer and becoming more graveliferous with depth. The deposit is 60 to 100 ft thick and is underlain by Tertiary clays at about elev 90 msl. A gradation curve of the coarse sand is also shown on plate 2. Two soil profiles, one taken along the river bank (section A-A) and the other taken along the levee center line (section B-B) are shown on plates 3 and 4, respectively.

Penetration resistance

13. Results of the cone sounding tests are shown graphically together with the boring log for each undisturbed boring on plates 5 through 10. Average natural and relative densities as determined by laboratory tests are also shown on the plates for each boring. Reference to the

penetration resistance diagrams and soil profiles will show that the changes in type of soil encountered are clearly indicated by definite sharp changes in penetration resistance values. This relationship is apparent in all six undisturbed borings and cone sounding tests made at the site, but may be most easily recognized in the case of boring 2, plate 6. It will be noted in this case that fine-grained soils were encountered from the ground surface to a depth of approximately 50 ft and that cone penetration resistances were very low, approaching 1000 lb only at two points where silty sand strata were encountered. A fine sand stratum was encountered below the fine-grained soils, with a corresponding sharp increase in cone penetration resistance to approximately 5000 lb. A 2-ft stratum of clay was encountered below the fine sand stratum, and cone penetration resistance rapidly reduced to approximately 200 lb, only to increase rapidly again when coarse sand containing gravel was encountered below the clay stratum. Cone penetration resistances in excess of 6000 lb were recorded in the coarse sand stratum, and these resistances were further increased with increasing gravel content until the capacity of the cone penetration device (9000 lb) was reached. It was necessary to advance the test hole through the stratum containing the gravel by other means where sands containing large quantities of gravel which overtaxed the capacity of the cone penetration device were encountered before the desired full depth of the profile had been explored. Fishtail boring methods were usually employed for this purpose, as in the case of boring 4, plate 8. The presence of lignite in a soil stratum is accompanied by sharp decreases in cone penetration resistance, as will be noted in the case of boring 3, plate 7, at elev 140, 152, and 164 ft msl.

14. All of these cone penetration diagrams show a general trend of increase in penetration resistance with depth for granular soil types, and no increase in penetration resistance for cohesive soils with depth. This trend is to be expected, as increased overburden pressures increase the frictional resistance to shear for granular soils and have no appreciable effect on the shearing resistance for purely cohesive soils.

15. The effect of density variations on the cone penetration resistance may be determined by comparing cone penetration resistance values with average natural density at corresponding depths on the various borings. Reference to the cone penetration diagrams will show that fluctuations in the cone penetration resistance correspond with fluctuations in average natural density. Means of predicting average natural densities from the cone penetration diagram are not apparent from inspection of the diagram. However, considerable progress has been made on this phase of the work by statistical correlation of cone penetration resistance values with the results of laboratory tests. This phase of the cone sounding tests will be reported separately.

16. The use of the cone penetration device at this site also furnished data from which a schedule of sampling could be prepared for adjacent undisturbed borings, thus eliminating the necessity for continuous undisturbed sampling in those holes.

Density conditions

17. The upper series of clean fine sand shows relative densities ranging from 75 to 85 per cent with a few low values around 50 per cent and a general slight increase of relative density with depth. These

densities are generally slightly higher than those obtained at such sites as Morville and Free Nigger Point where bank failures are known to have occurred. However, the slightly higher densities obtained are apparently caused by the somewhat coarser sands encountered here as compared to those encountered at the Morville and Free Nigger Point sites. Correlation work with grain size, cone thrust and natural density has indicated that higher densities are obtained on coarser material. The upper portion of the lower coarse sand series shows relative densities ranging from 55 to 95 per cent which is about the same range of densities as found at Morville and Free Nigger Point for the coarse sand series. Reliable density determinations could not be obtained on samples with high percentages of gravel. Samples with gravel showed some disturbance, which would account for the lower relative density values. Samples with low relative densities in all cases in both sand series contained either traces of lignite or clay.

Water table

18. The elevation of the free ground-water surface was, because of the proximity of the borings to the river, largely dependent upon the river stage at the time of measurement. The borings with thin top strata soils, such as 1U and 4U, were found to have water tables nearly equal to the stage of the river while water tables approximately 10 ft higher than river stage were recorded for borings with thicker top strata, such as borings 2U and 3U. It is believed that this latter condition represents a lag in drainage time of less pervious soils following a fall in river elevation.

Stability Conditions

Shear type failures

19. Three typical bank profiles for the site are shown on plate 11. A stability analysis of the existing bank, using soil conditions encountered at boring 4U and the bank profile for range 725.3, was made. The water table was taken at elevation 183 ft msl which is the average standard low water elevation for the site. The analysis is based on conservatively estimated shear strength values of $\phi = 25°$ for fine sand, $\phi = 30°$ for coarse sand, and c = 0 for both sands. It was assumed that the top stratum would crack, and no shear strength was assigned to the fine-grained top stratum soil. A safety factor of 1.29 against shear failure of the bank was obtained and this safety factor was reduced to 1.13 by applying sudden drawdown conditions. Application of sudden drawdown conditions to the sandy soils encountered is a rather severe test, as it is believed that truly sudden drawdown conditions never will occur at this site. The safety factors obtained are believed to be conservative and adequate, and therefore the bank is considered safe from shear-type failures.

Possibility of liquefaction

20. Investigations of soil conditions at such sites as Reid Bedford Bend, Hardscrabble Bend, Morville, and Free Nigger Point, where large-scale flow failures have occurred, have shown that the top stratum soils generally are comparatively thin and are underlain with continuous, relatively thick or massive deposits of clean fine sand, which overlie deposits of graveliferous sands at depth. Studies of these flow failures have presented no evidence that any of the failures extended into the graveliferous sands,

which are free-draining. Thus, it is believed that flow failures are the result of liquefaction of the thick, fine sand strata and owing to the thickness of the strata pore-water pressures cannot be dissipated rapidly enough to maintain stability.

21. The upper sand series at Bauxippi-Wyanoke is comparatively thin, and relative densities obtained are numerically equal to or slightly higher than those obtained at the Morville and Free Nigger Point sites. It is believed that ample drainage is provided by the underlying coarse sand series and should liquefaction of the fine sand occur, the condition would be localized and excess pore-water pressures rapidly dissipated.

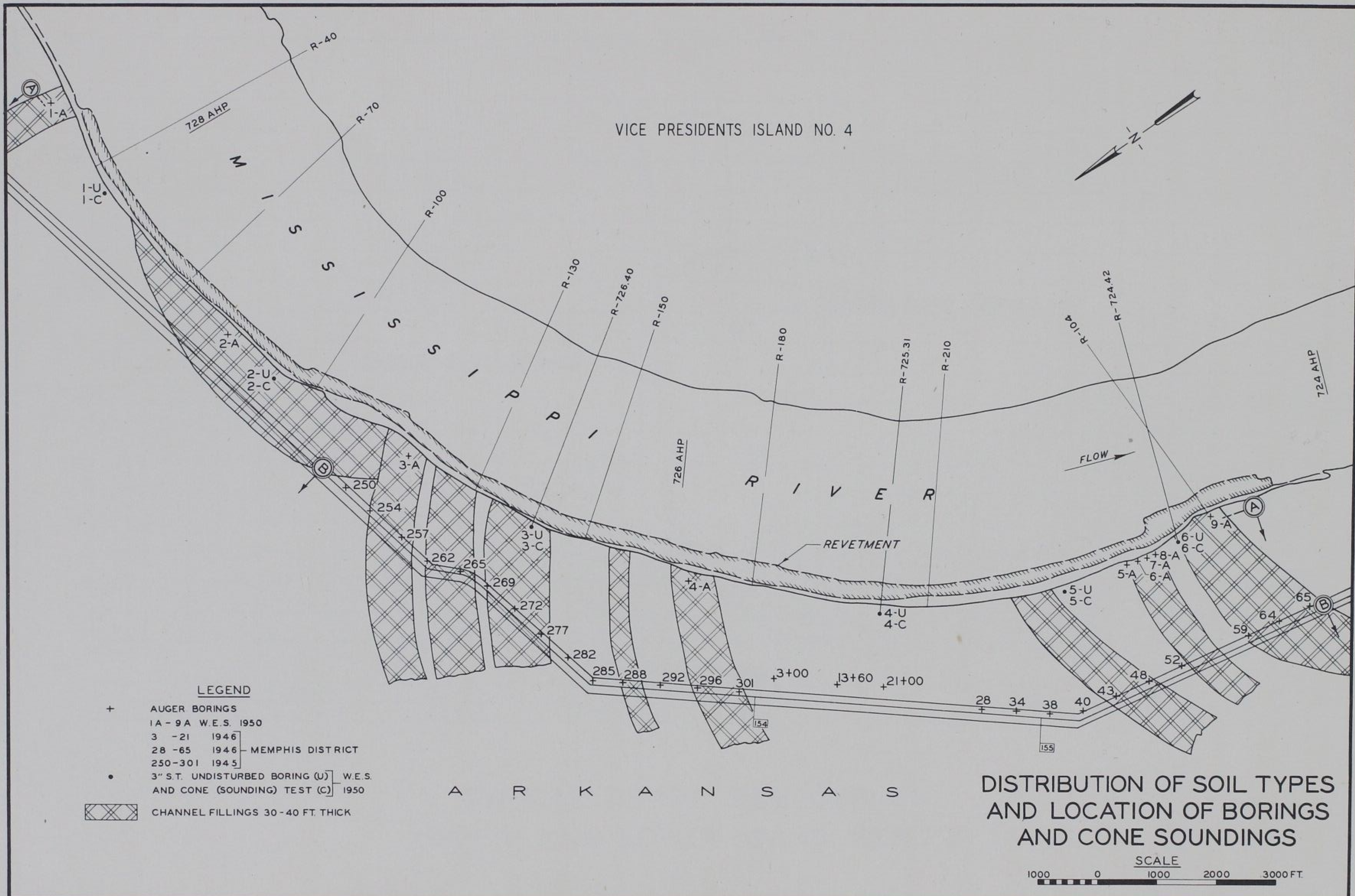
Conclusions

22. The following conclusions are believed warranted based on the information obtained in the investigations at this site:

a. The bank slopes existing at the time of investigation are considered stable from the standpoint of shear failure.

b. Relative densities of the underlying sands at this site are of the same order of magnitude as those encountered at other sites where failures have occurred.

c. The possibility of a liquefaction failure is considered remote, principally because of the comparative thinness of the upper sand series.



DISTRIBUTION OF SOIL TYPES AND LOCATION OF BORINGS AND CONE SOUNDINGS

PLATE 1

TYPICAL GRAIN SIZE CURVES
UPPER AND LOWER SAND SERIES

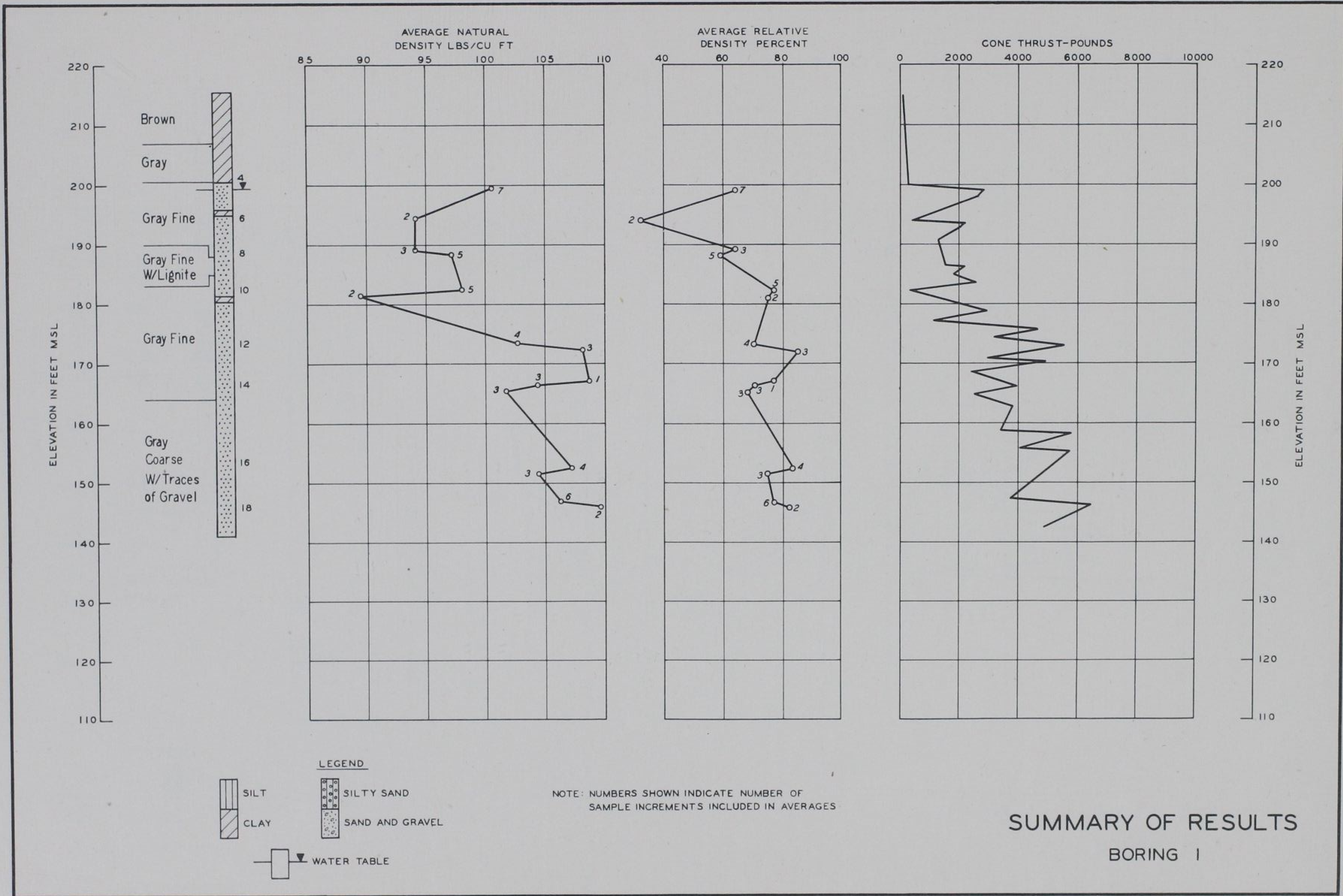
PLATE 2

LEGEND

- SILT
- CLAY
- SILTY SAND
- SAND AND GRAVEL
- WATER TABLE

LOG OF BORINGS
SECTION A-A

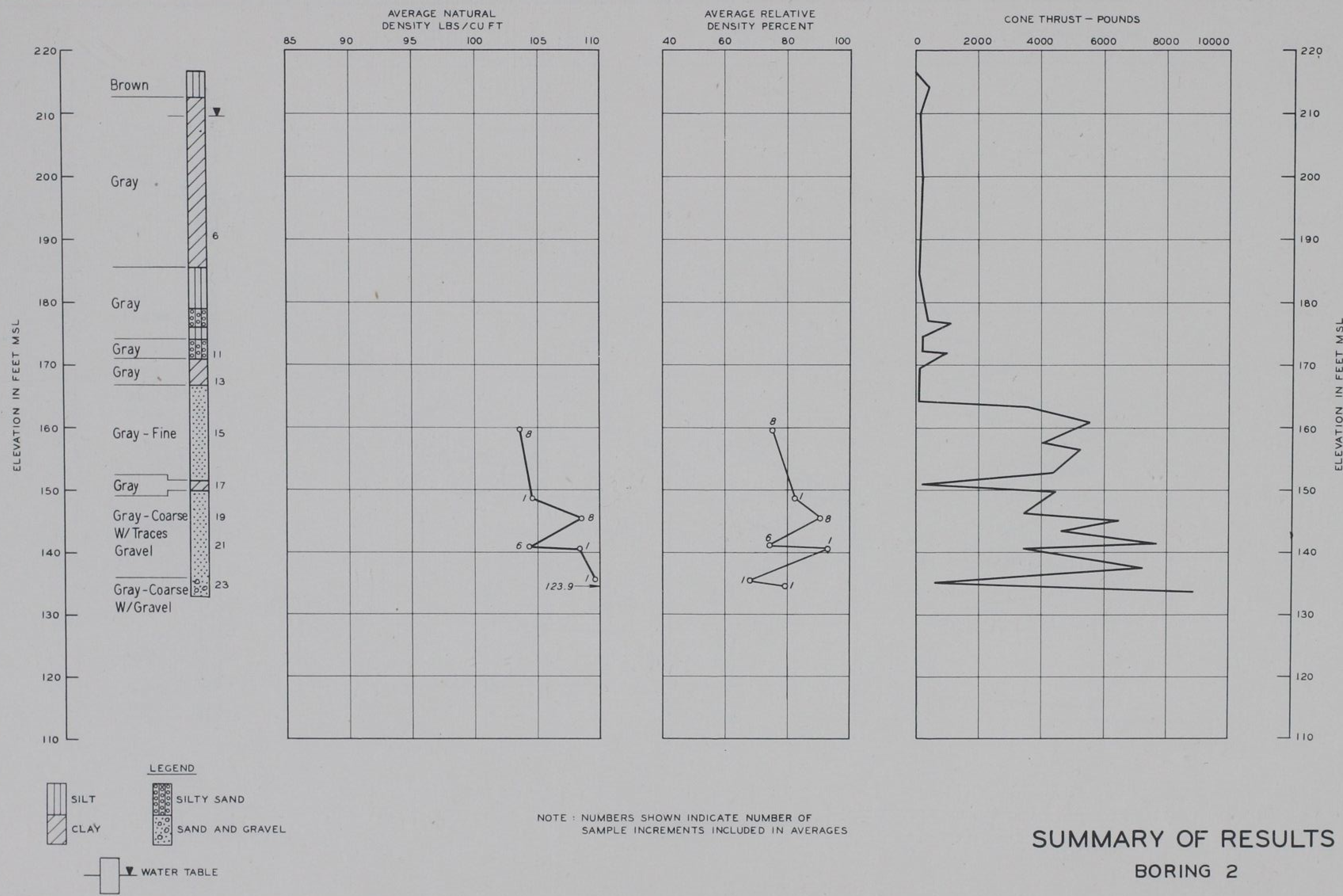
LOG OF BORINGS
SECTION B-B



SUMMARY OF RESULTS

BORING 1

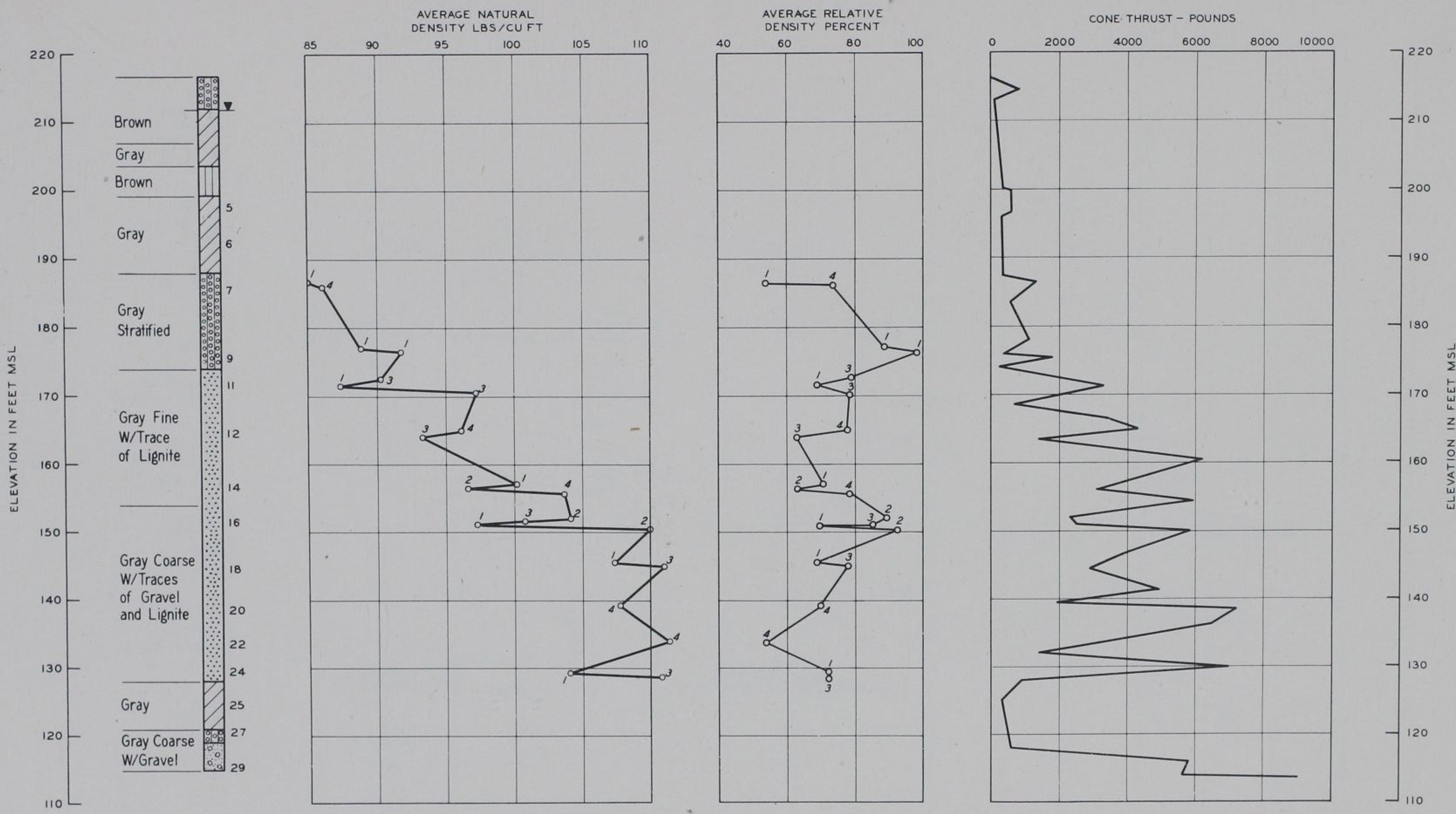
PLATE 5



NOTE : NUMBERS SHOWN INDICATE NUMBER OF SAMPLE INCREMENTS INCLUDED IN AVERAGES

SUMMARY OF RESULTS
BORING 2

PLATE 6



LEGEND

SILT
CLAY
SILTY SAND
SAND AND GRAVEL
WATER TABLE

NOTE : NUMBERS SHOWN INDICATE NUMBER OF SAMPLE INCREMENTS INCLUDED IN AVERAGES

SUMMARY OF RESULTS
BORING 3

PLATE 7

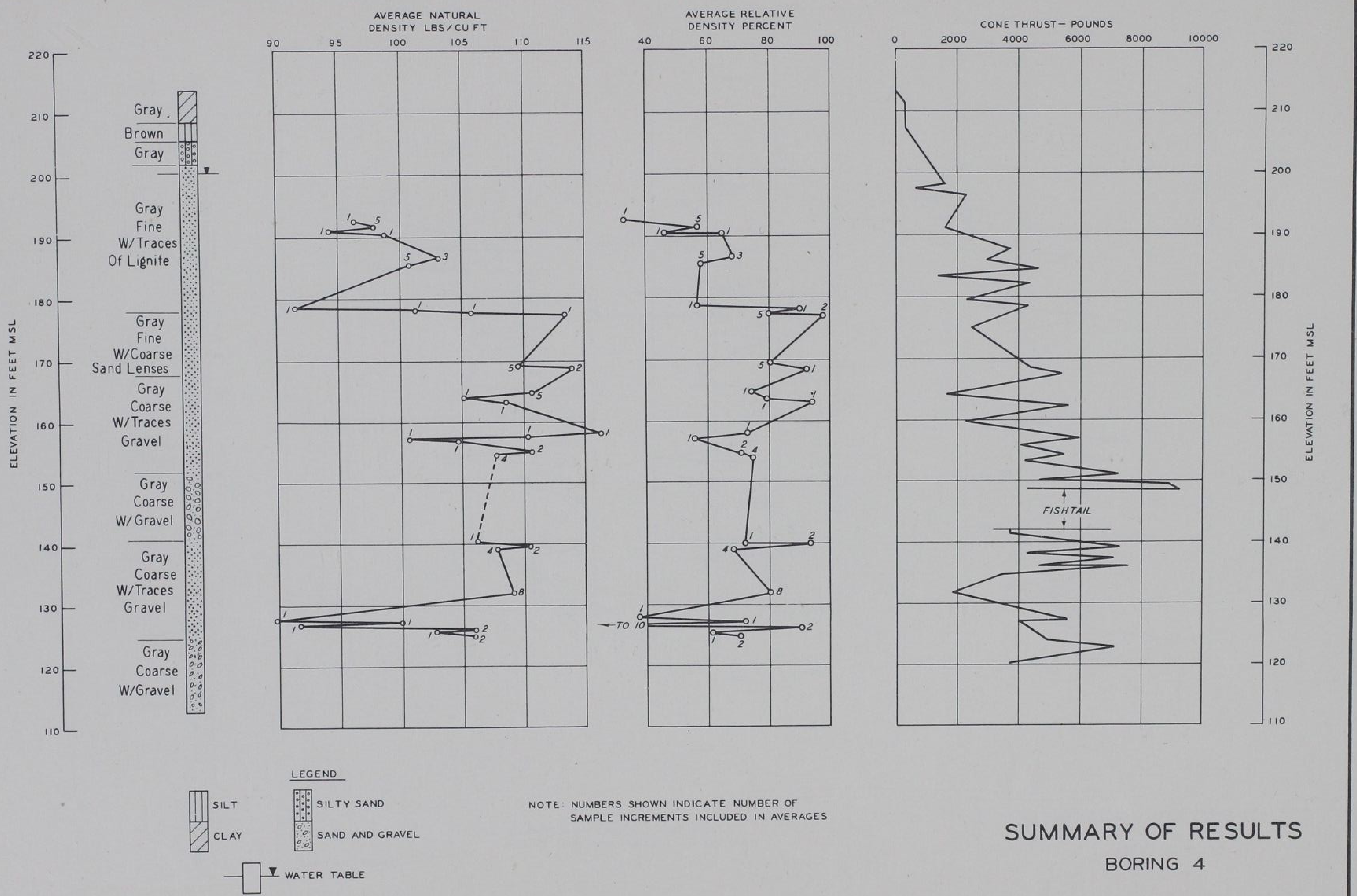
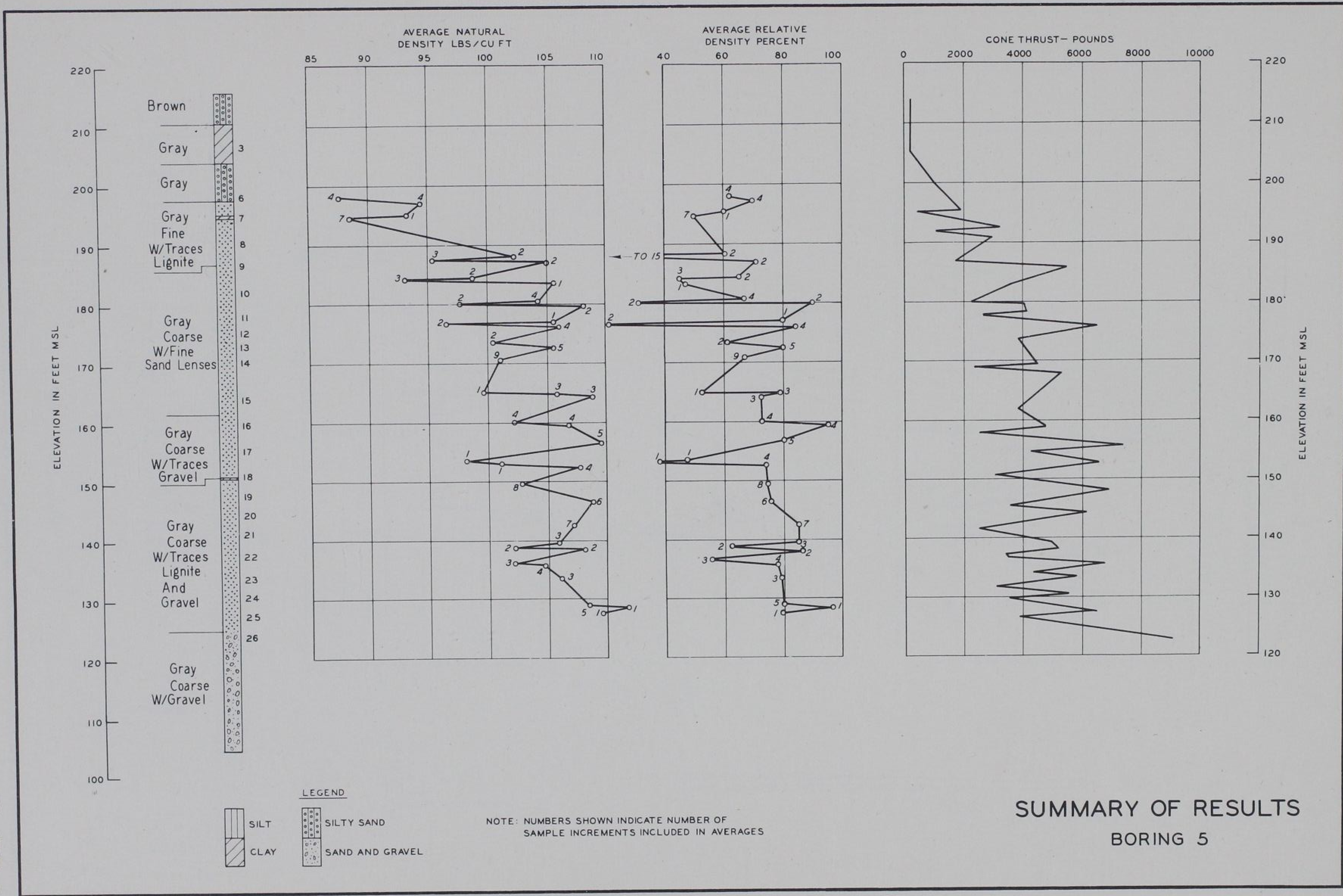


PLATE 8

SUMMARY OF RESULTS

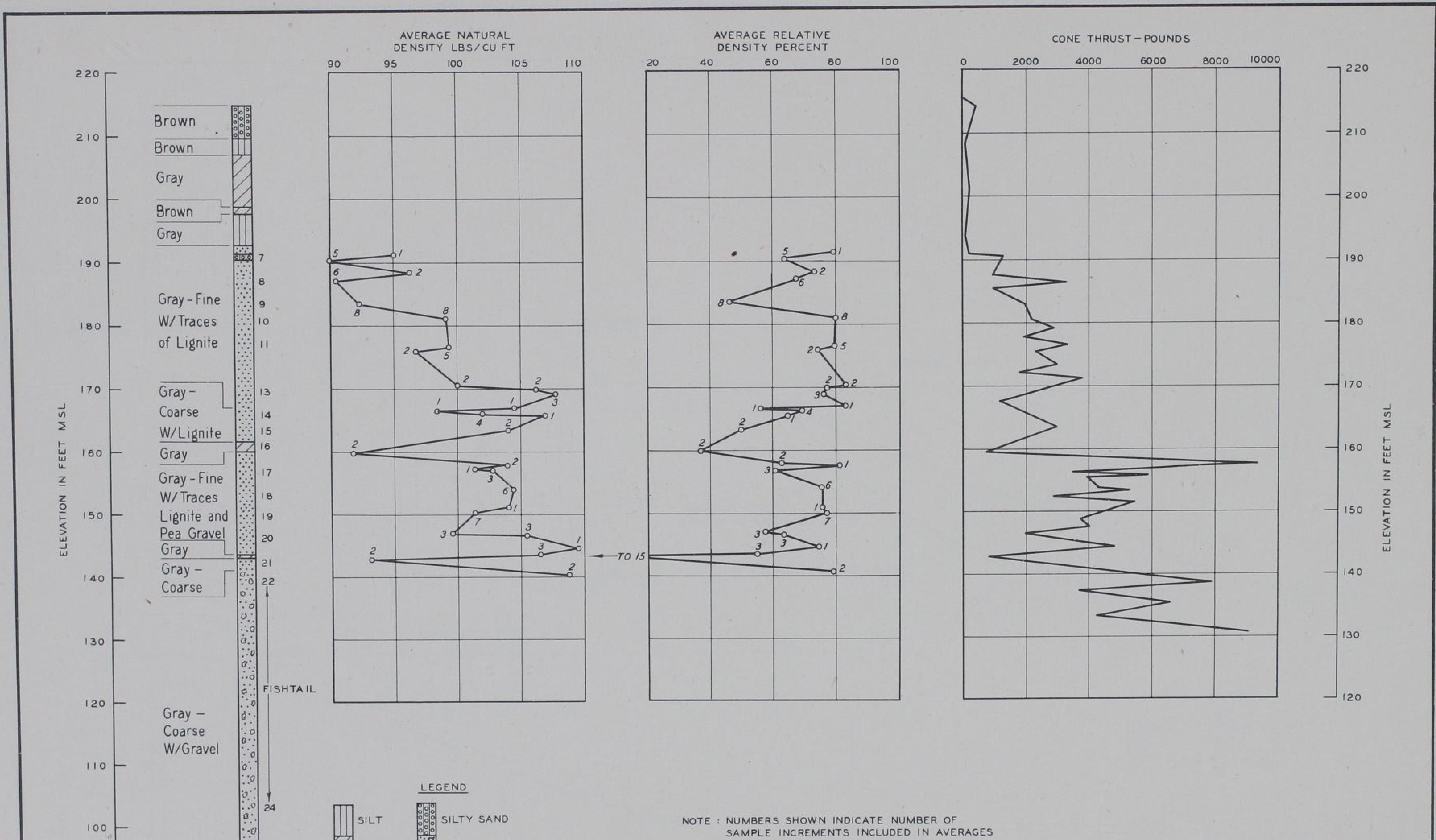
BORING 4



SUMMARY OF RESULTS

BORING 5

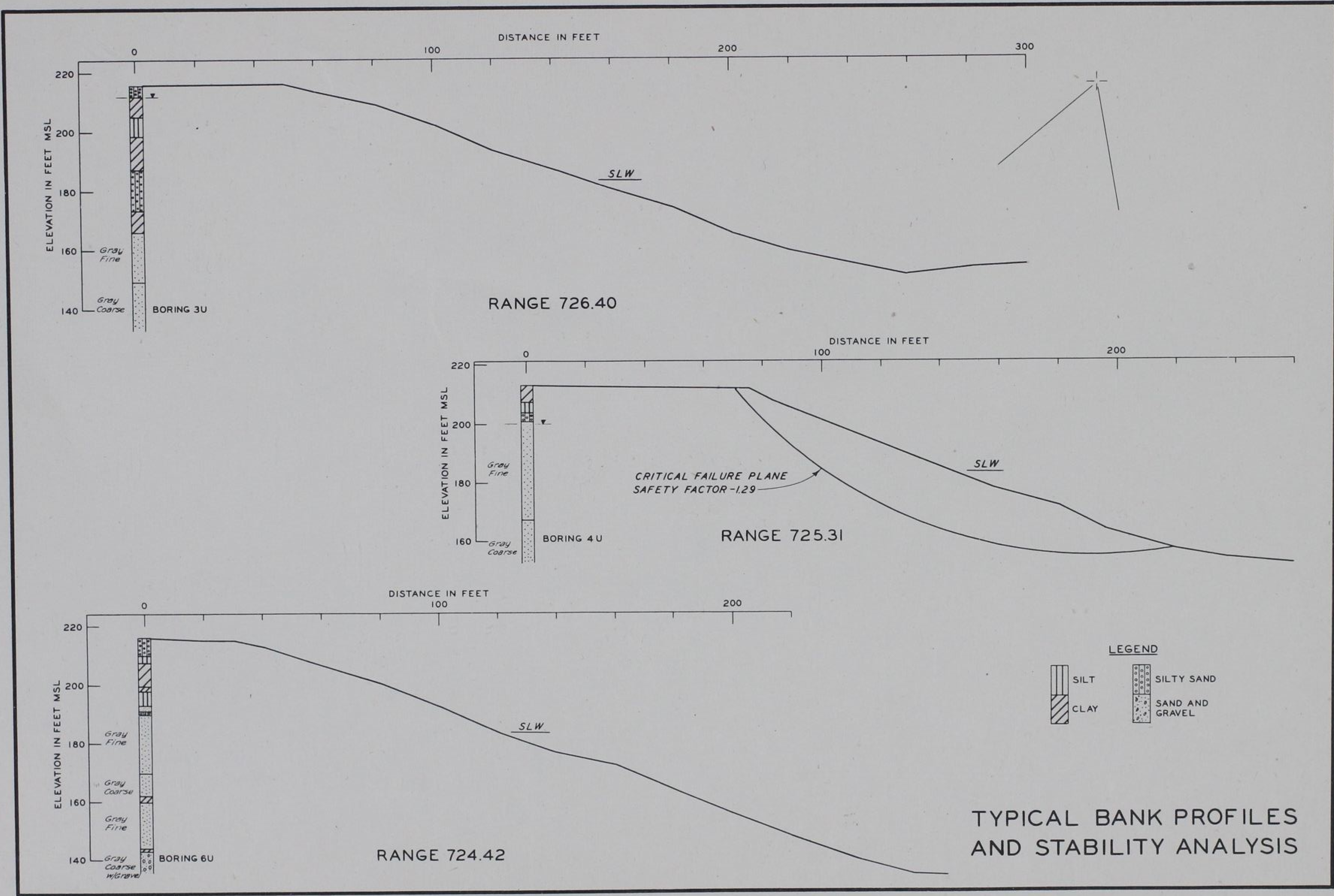
PLATE 9



SUMMARY OF RESULTS

BORING 6

PLATE 10



TYPICAL BANK PROFILES AND STABILITY ANALYSIS