ADDITIONAL SUBSOIL INVESTIGATION

SEWERAGE AND WATER BOARD OF NEW ORLEANS

METAIRIE RELIEF CANAL

STATION 617+50 TO STATION 663+00

ORLEANS AND JEFFERSON PARISHES, LOUISIANA

3

FOR
MODJESKI AND MASTERS
CONSULTING ENGINEERS
NEW ORLEANS, LOUISIANA

By
Eustis Engineering Company
Metairie, Louisiana

23 August 1982

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23 August 1982

Modjeski and Masters
Consulting Engineers
John Hancock Building
1055 St. Charles Avenue
New Orleans, Louisiana 70113

Attention Mr. Barney Martin

Gentlemen:

Additional Subsoil Investigation
Sewerage and Water Board of New Orleans
Metairie Relief Canal
Station 617+50 to Station 663+00
Orleans and Jefferson Parishes, Louisiana

Transmitted is our engineering report for an additional subsoil investigation for the subject project.

Thank you for asking us to perform this work.

Yours very truly,

EUSTIS ENGINEERING COMPANY

By J. Bres Eustis
J. Bres Eustis

ADDITIONAL SUBSOIL INVESTIGATION

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METAIRIE RELIEF CANAL

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TABLE OF CONTENTS

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INTRODUCTION

1. This report contains the results of an additional subsoil investigation performed for proposed improvements to the existing Metairie Relief Canal located between Stations 617+50 and 663+00 in Orleans and Jefferson Parishes, Louisiana. The investigation was performed in accordance with Eustis Engineering Company's letter of estimated cost for professional engineering services dated 25 March 1982. Authorization to proceed with the investigation was received on 5 May 1982 from Mr. Barney T. Martin of Modjeski and Masters, Consulting Engineers for the project.

2. This report has been prepared in accordance with generally accepted soil and foundation engineering practice for the exclusive use of Modjeski and Masters and their representatives for specific application to the proposed improvements to the Metairie Relief Canal between Stations 617+50 and 663+00 in Orleans and Jefferson Parishes, Louisiana. In the event that any changes in the nature, design or location of the improvements are planned, the conclusions and

recommendations contained in this report shall not be considered valid unless the changes are reviewed and the conclusions of this report are modified or verified in writing.

3. The analyses and recommendations contained in this report are based in part on data obtained from the soil borings. The nature and extent of variations that may exist between boring locations may not become evident until construction. If variations then appear evident, it will be necessary to re-evaluate the recommendations contained in this report.

SCOPE

4. The scope of the investigation included the drilling of undisturbed and auger type soil borings to determine subsoil conditions and stratification. Information regarding subsoil conditions was also obtained from borings previously drilled at the site and for other projects in the general area of the site. Piezometers were installed to periodically determine the ground water conditions and hydrostatic conditions on both sides of the canal. Soil mechanics laboratory tests were performed on samples obtained from borings previously drilled at the site to evaluate their physical properties. Engineering analyses were made to determine the stability of the levees adjacent to the canal and to determine the potential for a "blow-out" at the landside toe due to hydrostatic uplift.

SOIL BORINGS

5. Soil borings were drilled during the period 5-10 May 1982 at the locations shown on Figure 1. All survey work necessary to determine the ground surface elevation at the boring locations was performed by Modjeski and Masters. Boring coordinates were estimated using survey data previously developed by Modjeski and Masters. Detailed descriptive logs of the individual borings are shown in both tabular and graphical form on Figures 2 through 9.

6. Two of the undisturbed borings (Borings 5 and 12) previously drilled at the site to a depth of 50 feet were each deepened to 70 feet below the existing ground surface using a truck mounted rotary type drill rig. These borings were extended to verify the thickness of the underlying sand stratum. After first washing to a depth of 40 feet with a fishtail bit, cohesive and semi-cohesive soils were obtained at intervals of 5 feet using a 3-in. diameter Shelby tube sampling barrel. Cohesionless soils were sampled during performance of in situ Standard Penetration Tests.

7. A total of nine (9) auger type borings were drilled to depths ranging between 10 and 17.5 feet below existing ground surface using a power-operated auger. These borings were drilled for the purpose of determining the thickness of the clay cover at and beyond the landside toe of the levee. Samples were obtained at close intervals, visually classified and placed in

glass jars for preservation. The auger borings are designated as Borings 101 through 103, 201 through 203 and 301 through 303.

8. Three (3) borings, designated as Borings 100, 200 and 300, were drilled in the canal to depths of 18, 19.5 and 24 feet below the water surface, respectively. Samples were obtained at close intervals using a piston-type sampler, visually classified and placed in moisture proof containers for preservation. These borings were necessary to determine the thickness and composition of the sediment at the bottom of the canal and to determine the depth to the underlying sand stratum.

9. The results of soil borings previously drilled at the site are contained in Eustis Engineering Company's report entitled "Subsoil Investigation, Sewerage and Water Board of New Orleans, Metairie Relief Canal, Station 554+00 to Station 670+00, Orleans and Jefferson Parishes, Louisiana," dated 3 November 1981. Information regarding subsoil conditions was also obtained from borings previously drilled for other projects in the general area of the site. The approximate location of these borings is shown on Figure 1.

PIEZOMETERS

10. A total of five (5) piezometers were installed on 10 and 31 May 1982 at the locations shown on Figure 1. The elevation of the ground surface and riser pipe at the three locations on the Jefferson side were surveyed by Modjeski and Masters, and, at the two locations on the Orleans side, were

estimated from survey data previously developed. These elevations and the estimated ground coordinates are tabulated on Figure 18. Measurements of the water level were made periodically and the results are tabulated on Figure 19.

LABORATORY TESTS

11. Permeability tests were performed on samples of cohesive soils obtained from borings previously drilled at the site and the results are summarized in tabular form on Figure 10. Grain size analyses were performed on samples of granular soils that were also previously obtained. The results of these tests are shown graphically in the form of grain size distribution curves on Figures 11 through 17.

DESCRIPTION OF SUBSOIL CONDITIONS

12. The surface of the underlying sand stratum varies from el 15 C.D. to el 3 C.D. and may extend as deep as el -25 C.D. to el -30 C.D. The coefficient of permeability (k) of this stratum estimated from the grain size distribution curves ranges from 2×10^{-4} to 200×10^{-4} cm/sec.

13. The landside clay cover consists primarily of soft to medium stiff clay with a coefficient of permeability (k) ranging between 3.6×10^{-8} to 7.2×10^{-7} cm/sec. The thickness of the clay is generally uniform in a direction perpendicular to the levee centerline.

14. Sediment at the canal bottom appears to be 4.5 to 6.5 feet thick and consists of soft clay and loose sandy soil. The elevation of the underlying sand stratum is 8 to 10 feet lower at the canal indicating that the bottom may have been deeper at one time in the past than at present.

Ground Water Conditions

15. Readings shown on Figure 19 indicate a relatively horizontal piezometric head in the underlying sand stratum generally between el 12 C.D. and el 13 C.D. on the Jefferson side and generally between el 11 C.D. and el 12 C.D. on the Orleans side. Considering that the water level in the canal is generally between el 22 C.D. and el 23 C.D., it appears that a seal has formed on the canal bottom and side slopes preventing the development of excess hydrostatic head in the sand stratum. Therefore, the piezometric readings should reflect the true ground water level adjacent to the canal and levees.

FOUNDATION ANALYSIS

Stability Analysis

16. Analyses were made to determine the stability of the levee with respect to a potential failure toward the landside toe during high water conditions in the canal. The computations were based on furnished cross-sections of the final levee configuration and assumed a high water level one foot below the levee crown or sheetpile floodwall.

17. The "Method of Planes" analysis was used wherein horizontal potential failure surfaces are varied along with active and passive wedge locations to arrive at the lowest numerical value of safety factor. Soil parameters developed from the previous investigation at the site were used, and for conservative purposes, computations were based on full hydrostatic uplift pressures in the underlying sand stratum. Although excess hydrostatic pressures are not presently evident in the sand stratum, the planned improvements to deepen and enlarge the canal may remove the seal that has apparently developed on the bottom and side slopes, thereby allowing a buildup of such pressures in the sand stratum.

18. The cross-sections and soil parameters along with typical computations for the critical, active and passive wedge locations are shown on Figure 20. The results of the computations indicate a minimum factor of safety of 1.38 which occurs at Station 646+00 on the Jefferson side. This factor of safety is considered acceptable. Computations for cross-sections located just beyond the north and south ends of the study area indicate factors of safety of 2.13 and 2.28, respectively.

Uplift Analysis

19. Analyses were made to determine the potential for a blow-out at the landside toe of the levee due to hydrostatic uplift pressure from high water in the canal. The computations were based on the assumption that the planned improvements may

allow development of excess hydrostatic pressure in the underlying sand stratum.

20. The magnitude of hydrostatic pressure at the levee toe will depend on the amount of material sealing the canal removed during enlargement of the canal cross-section, the area of the sand stratum that becomes exposed, the duration of the high water level, and the head loss that occurs between the levee toe and seepage entrance point. For conservative purposes, the full hydrostatic uplift pressure was used to determine the theoretical factor of safety against a blow-out. Also, the resistance of the clay cover at the toe was based on the dead weight of the soil only without consideration of the soil shear strength. Under these conditions, a theoretical factor of safety slightly greater than 1.0 is considered acceptable since the actual safety factor should be higher.

21. Based on the results of the computations shown on Figure 20, it is believed that a blow-out on the landside levee toe should not occur north of Station 617+50 or south of Station 663+00. Between Stations 617+50 and 663+00, computations indicate the possibility of a blow-out during extreme high water in the canal. Unless more definitive information can be developed regarding the potential hydrostatic uplift pressure at the levee toe through this reach, measures should be taken to prevent a blow-out during extreme high water conditions.

Test Section

22. Consideration should be given to the excavation of a segment of the canal to the planned cross-section prior to finalization of design plans to determine more definitive information regarding the potential for a blow-out at the land-side toe. The test section should be located between Station 659+00 and Station 660+50 in order to utilize five piezometers installed in this area. Installation of several additional piezometers will be required to augment the existing piezometers in order to closely monitor changes in the hydrostatic pressures in the sand stratum.

Preventative Measures

23. In the event that it is not practical or economically feasible to accomplish the test section previously described, measures must be taken to prevent a blow-out. Preventative measures include the installation of a seepage cutoff through the levee crown, installation of pressure relief wells near the landside toe of the levee, and sealing the canal bottom.

24. Seepage Cutoff. The most positive measure to minimize the possibility of a blow-out is the installation of a seepage cutoff through the levee crown. To provide an effective seepage cutoff, steel sheetpiling and/or a slurry wall should penetrate the sand stratum. Considering that the bottom of the sand stratum is at or near el -30 C.D., a 65-ft long cutoff wall would be required. General experience indicates that the use of steel sheetpiling should be more economical and

practical than the installation of a slurry wall. Additional computations will be necessary to determine the stability of the levee during the installation of a slurry wall.

25. Relief Wells. Consideration should also be given to installation of pressure relief wells near the landside to of the levee. To be effective, relief wells should penetrate close to the bottom of the sand, and, therefore, wells approximately 50 feet deep will be required. For planning purposes, it is estimated that a well spacing of 30 to 45 feet may be necessary. However, detailed analyses should be performed to determine the exact spacing required. The use of pumps will not be necessary and seepage into the wells can be collected in header pipes buried a few feet below ground surface for discharge into the drainage system.

26. Dry Bottom Seal. The canal bottom may be sealed to minimize seepage by placement of a concrete liner, an impervious membrane, or a ler of cohesive type soil. To insure a positive seal, placement of these materials should be accomplished on a dry canal bottom. This will require stage construction to maintain continuous operation of the pump station. All liner materials should extend from the canal bottom up the side slopes to at least el 20 C.D. If the liner is constructed of cohesive soil, a minimum thickness of 18 inches is required. Cohesive soil must be placed in layers and each layer compacted to the degree necessary to provide a relatively impervious blanket.

27. Underwater Seal. Concrete and membrane liners have been successfully placed under water; however, this type of installation must be closely supervised by qualified and experienced divers. If a soil liner is to be placed under water, the feasibility of this operation should be verified prior to initiation of construction. Bentonite (trade name Volclay) has been successfully deposited under water to seal the bottom of shallow ponds and lakes in other areas. In pellet form, the bentonite can be deposited by loose dumping from the side of marine equipment. Bentonite may be available in panel form which may permit greater control of placement. The placement of bentonite in gradual form will probably be the most difficult to control, if deposited by loose dumping. Probably the most practical means for using granular bentonite is to form a slurry which can be pumped through discharge tubes to the canal bottom. Continuous supervision during placement must be maintained by qualified and experienced divers to insure complete coverage is obtained. Information from a local supplier of bentonite indicates that an estimate of the quantity of material required should be based on 1.5 pounds per square foot of area to be covered.

CONCLUSIONS

28. Unless a test section can be dredged to develop more definitive information regarding the potential hydrostatic pressure at the landside levee toe, measures should be taken

between Stations 617+50 and 663+00 to prevent a possible blow-out indicated by theoretical analysis. The most positive method is installation of a seepage cutoff. Use of steel sheetpiling will be very costly, but should be more economical and practical than installation of a slurry wall.

29. Placement of a dry bottom seal using a concrete liner, impervious membrane or a layer of cohesive soil is the most favorable alternate to the use of a seepage cutoff. Considering that stage construction will be required to maintain continous operation of the station, the cost of this method may also be prohibitive.

30. Pressure relief wells have been successfully used for similar conditions in this area and are considered to be an acceptable alternate method. The initial cost may be less than steel sheetpiling or a dry bottom seal. However, periodic inspection is necessary because wells may become clogged and must be flushed to remain functional. In some area, particularly on the Orleans side, it may be necessary to locate wells at or near the levee crown due to insufficient right-of-way at the landside toe.

31. Concrete, membrane liners and bentonite have been successfully placed under water, but, because control and inspection are difficult, an underwater seal is not as positive an alternate as the preceding methods. If bentonite is used, the most practical means probably will be to form a slurry which can be pumped through tubes to the canal bottom. If construction will extend through the hurricane season, a stage operation

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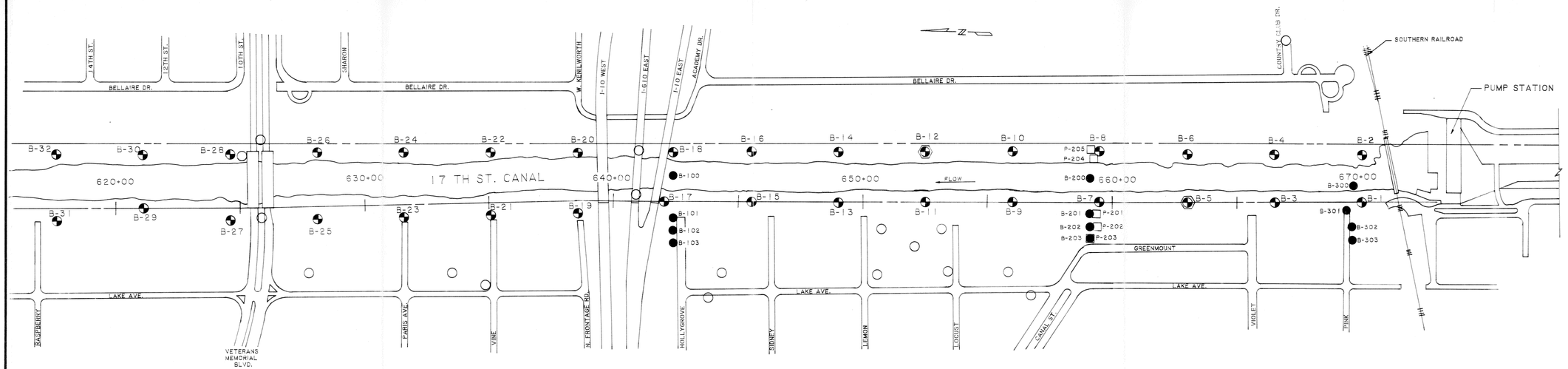
is necessary to avoid the possibility of a high water condition occurring before the sealing material can be placed. If dredging can be completed before the approach of hurricane season, placement of the seal may be delayed in order to investigate the potential hydrostatic pressure and determine the necessity for placing the seal. In this event, several additional piezometers will be required to augment the existing piezometers in order to closely monitor changes in the hydrostatic pressure before and after dredging operations.

EUSTIS ENGINEERING COMPANY

By J. Bres Eustis
J. Bres Eustis

L. J. Napolitano:bh



LOCATION OF BORINGS

SCALE: 1"= 20'

- UNDISTURBED BORING: DRILLED DURING PERIOD 14 MAY - 22 JULY 1981.
- UNDISTURBED BORING: DEEPENED TO 70' BELOW GROUND SURFACE.
- UNDISTURBED BORING: DRILLED FOR OTHER PROJECTS BETWEEN 1957 AND 1976.
- AUGER BORING: DRILLED DURING PERIOD 6 - 11 MAY 1982.
- PIEZOMETER: INSTALLED DURING PERIOD 6 - 31 MAY 1982.

ADDITIONAL SUBSOIL INVESTIGATION
SEWERAGE AND WATER BOARD OF NEW ORLEANS
METAIRIE RELIEF CANAL
STATION 617+50 TO STATION 663+00
ORLEANS AND JEFFERSON PARISHES, LOUISIANA

LOCATION OF BORINGS

FOR
MODJESKI AND MASTERS
CONSULTING ENGINEERS
NEW ORLEANS, LOUISIANA

EUSTIS ENGINEERING COMPANY
SOIL AND FOUNDATION CONSULTANTS
JULY, 1982 METAIRIE, LA.

FIGURE

LOG OF BORING

EUSTIS ENGINEERING COMPANY
SOIL AND FOUNDATION CONSULTANTS
METAIRIE, LA.

Name of Project: Sewerage and Water Board of New Orleans
Metairie Relief Canal, Station 617+50 to Station 663+00
Orleans and Jefferson Parishes, Louisiana
For: Modjeski and Masters, Consulting Engineers, New Orleans, Louisiana

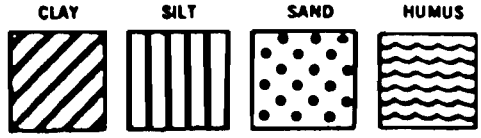
Boring No. 5A Soil Technician George Hardee Date 5 May 1982
Ground Elev. 33 (Est.) Datum Cairo Gr. Water Depth

Sample No.	SAMPLE Depth — Feet From	To	DEPTH STRATUM Feet From	To	VISUAL CLASSIFICATION	*STANDARD PENETRATION TEST	
			0.0	40.0	Wash		
1	40.0	41.5	40.0		Very dense gray fine sand	6	53
2	43.5	45.0		48.0	Ditto	16	50=9"
3	48.5	50.0	48.0		Medium dense gray fine sand w/silt	6	27
4	53.5	55.0		58.0	Medium dense gray fine sand	5	22
5	58.5	60.0	58.0		Medium stiff gray clay	2	3
6	63.5	64.0			Medium stiff gray clay w/sand pockets & shells		
7	68.5	69.0		70.0	Ditto		

*Number in first column indicates number of blows of 140-lb. hammer dropped 30 in. required to seat 2-in. O. D splitspoon sampler 6 in. Number in second column indicates number of blows of 140-lb. hammer dropped 30 in. required to drive 2-in. O. D. splitspoon sampler 1 ft. after seating 6 in.

WHILE THIS LOG OF BORING IS CONSIDERED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT ITS RESPECTIVE LOCATION ON THE DATE SHOWN, IT IS NOT WARRANTED THAT IT IS REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

Remarks: Boring located on west side of canal @ Sta. 663+00 in crown of levee.



Predominant type shown heavy. Modifying type shown light.

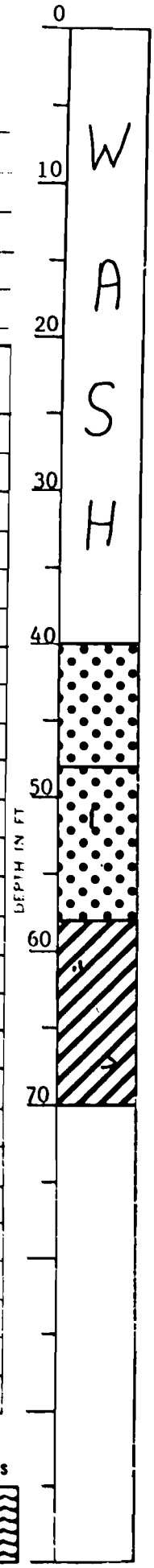


Fig. 2

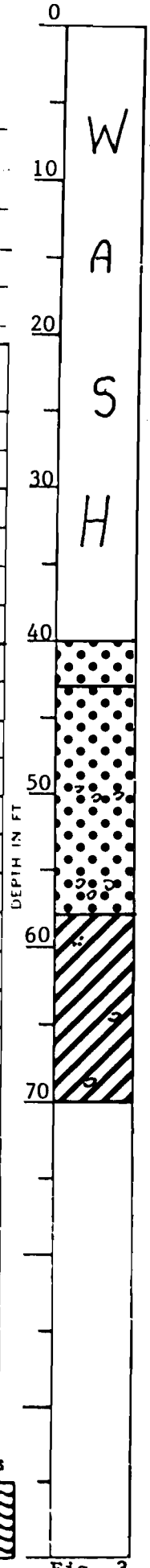
LOG OF BORING

EUSTIS ENGINEERING COMPANY
SOIL AND FOUNDATION CONSULTANTS
METAIRIE, LA.

Name of Project: Sewerage and Water Board of New Orleans
Metairie Relief Canal, Station 617+50 to Station 663+00
Orleans and Jefferson Parishes, Louisiana
For: Modjeski and Masters, Consulting Engineers, New Orleans, Louisiana

Boring No. 12A Soil Technician George Hardee Date 6 May 1982
Ground Elev. 30.5 (Est.) Datum Cairo Gr. Water Depth

Sample No.	SAMPLE Depth — Feet From	To	DEPTH STRATUM Feet From	To	VISUAL CLASSIFICATION	*STANDARD PENETRATION TEST	
			0.0	40.0	Wash		
1	40.0	41.5	40.0	43.0	Very dense gray fine sand	18	50=10"
2	43.5	45.0	43.0		Dense gray fine sand	14	36
3	48.5	50.0			Dense gray fine sand w/shell fragments	13	41
					& small clay		
4	53.5	55.0		58.0	Dense gray fine sand w/shell fragments	11	31
5	58.5	60.0	58.0		Medium stiff gray clay w/sand pockets	1	3
					& shell fragments		
6	63.5	64.0			Ditto		
7	68.5	69.0		70.0	Ditto		



*Number in first column indicates number of blows of 140-lb. hammer dropped 30 in. required to seat 2-in. O. D. splitspoon sampler 6 in. Number in second column indicates number of blows of 140-lb. hammer dropped 30 in. required to drive 2-in. O. D. splitspoon sampler 1 ft. after seating 6 in.

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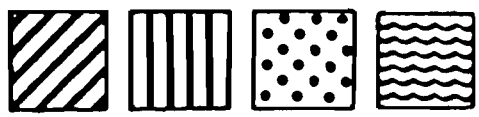


Predominant type shown heavy. Modifying type shown light.

Remarks: Boring located on east side of canal @ Sta. 652+50 in crown of levee.

Fig. 3

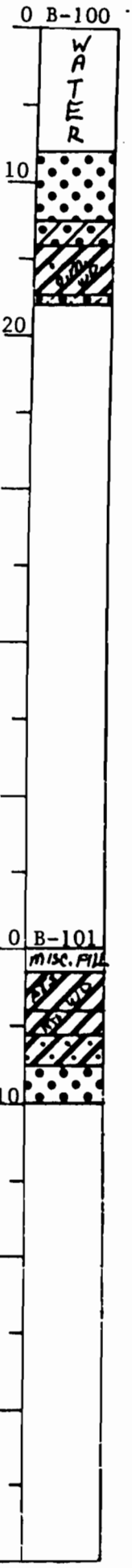
LOG OF BORING

EUSTIS ENGINEERING COMPANY
SOIL AND FOUNDATION CONSULTANTS
METAIRIE, LA.

Name of Project: Sewerage and Water Board of New Orleans
Metairie Relief Canal, Station 617+50 to Station 663+00
Orleans and Jefferson Parishes, Louisiana
For: Modjeski and Masters, Consulting Engineers, New Orleans, Louisiana

Boring No. _____ Soil Technician G. Hardee & R. Courtiade Date 7 & 10 May 1982
Ground Elev. _____ Datum Cairo Gr. Water Depth _____

Sample No.	SAMPLE Depth — Feet From	To	DEPTH STRATUM Feet From	To	VISUAL CLASSIFICATION	*STANDARD PENETRATION TEST	
					BORING 100 (Water Surface @ el. 21.6)		
			0.0	8.0	Water		
1	8.5	9.0	8.0		Loose black sand w/oil (Sediment)		
2	10.5	11.0		12.5	Ditto		
3	13.5	14.0	12.5	14.0	Loose dark gray clayey sand (Sediment)		
4	15.0	15.5	14.0		Soft gray clay w/organic matter		
5	16.5	17.0			Soft gray clay w/organic matter & wood		
6	17.0	17.5		17.5	Soft gray clay w/trace of sand		
7	17.5	18.0	17.5	18.0	Medium dense gray sand w/clay layers		
			NOTE:		Boring located near ℄ of canal.		
					BORING 101 (Ground Surface @ el. 19.2)		
			0.5	1.5	Miscellaneous fill		
1	2.5	3.0	1.5	4.0	Medium stiff tan & gray clay w/roots & wood		
2	5.0	5.5	4.0	5.5	Medium stiff gray clay w/roots		
3	7.0	7.5	5.5	7.5	Soft gray sandy clay		
			7.5	10.0	Medium dense gray fine sand		
			NOTE:		Boring located at landside toe of west side levee.		



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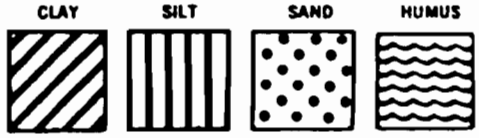


Predominant type shown heavy. Modifying type shown light.

Remarks: Borings located @ Sta. 642+50.

Fig. 4

LOG OF BORING

EUSTIS ENGINEERING COMPANY
SOIL AND FOUNDATION CONSULTANTS
METAIRIE, LA.

Name of Project: Sewerage and Water Board of New Orleans
Metairie Relief Canal, Station 617+50 to Station 663+00
Orleans and Jefferson Parishes, Louisiana
For: Modjeski and Masters, Consulting Engineers, New Orleans, Louisiana

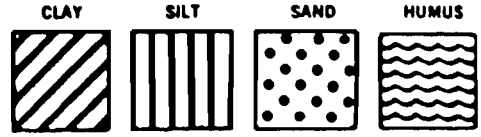
Boring No. _____ Soil Technician G. Hardee Date 7 May 1982
Ground Elev. _____ Datum Cairo Gr. Water Depth _____

Sample No.	SAMPLE Depth — Feet From	To	DEPTH STRATUM Feet From	To	VISUAL CLASSIFICATION	*STANDARD PENETRATION TEST	
					BORING 102 (Ground Surface @ el. 18.6)		
			0.0	1.0	Miscellaneous fill		
1	2.5	3.0	1.0	5.5	Medium stiff gray clay w/organic matter & roots		
2	5.5	6.0	5.5	6.5	Soft gray clay w/roots & sand pockets		
3	9.5	10.0	6.5	10.0	Medium dense gray fine sand		
			NOTE:		Boring located 50' from landside toe of west side levee.		
					BORING 103 (Ground Surface @ el. 18.4)		
			0.0	1.0	Medium dense gray & tan sand w/shells & clay pockets		
1	2.5	3.0	1.0	5.0	Medium stiff gray clay w/organic matter & roots		
2	5.5	6.0	5.0	6.0	Soft gray clay w/roots & sand pockets		
3	9.5	10.0	6.0	10.0	Medium dense gray fine sand		
			NOTE:		Boring located 100' from landside toe of west side levee.		

*Number in first column indicates number of blows of 140-lb. hammer dropped 30 in. required to seat 2-in. O. D. splitspoon sampler 6 in. Number in second column indicates number of blows of 140-lb. hammer dropped 30 in. required to drive 2-in. O. D. splitspoon sampler 1 ft. after seating 6 in.

WHILE THIS LOG OF BORING IS CONSIDERED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT ITS RESPECTIVE LOCATION ON THE DATE SHOWN, IT IS NOT WARRANTED THAT IT IS REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

Remarks: Borings located @ Sta. 642+50.



Predominant type shown heavy. Modifying type shown light.

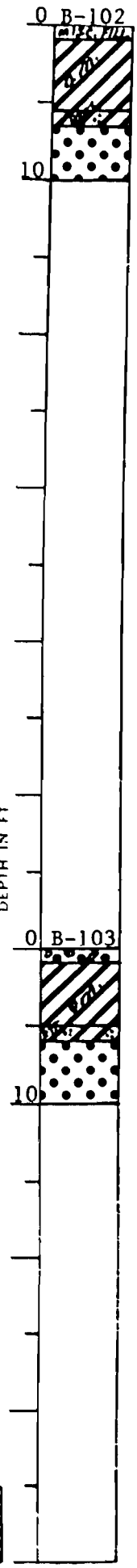


Fig. 5

LOG OF BORING

EUSTIS ENGINEERING COMPANY
SOIL AND FOUNDATION CONSULTANTS
METAIRIE, LA.

Name of Project: Sewerage and Water Board of New Orleans
Metairie Relief Canal, Station 617+50 to Station 663+00
Orleans and Jefferson Parishes, Louisiana
For: Modjeski and Masters, Consulting Engineers, New Orleans, Louisiana

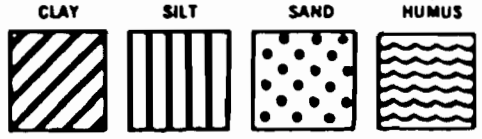
Boring No. _____ Soil Technician G. Hardee & R. Courtiade Date 6 & 10 May 1982
Ground Elev. _____ Datum Cairo Gr. Water Depth _____

Sample No.	SAMPLE Depth — Feet From	To	DEPTH STRATUM Feet From	To	VISUAL CLASSIFICATION	*STANDARD PENETRATION TEST	
					BORING 200 (Water Surface @ el. 21.6)		
			0.0	8.0	Water		
1	8.5	9.0	8.0	9.0	Loose black sand w/oil (Sediment)		
2	9.5	10.0	9.0	10.0	Soft dark gray clay w/vegetation (Sediment)		
3	11.5	12.0	10.0	12.5	Loose black sand w/miscellaneous materials (Sediment)		
4	13.5	14.0	12.5	14.0	Medium stiff gray clay w/organic matter		
5	15.5	16.0	14.0	16.5	Soft gray clay w/organic matter		
6	17.5	18.0	16.5	18.0	Very soft gray clay		
7	18.5	19.0	18.0	19.0	Medium stiff gray clay		
8	19.0	19.5	19.0	19.5	Loose gray silty sand		
			NOTE:		Boring located near ℄ of canal.		
					BORING 201 (Ground Surface @ el. 22.3)		
1	2.0	2.5	0.0	3.0	Stiff tan, gray & brown sandy clay		
2	3.0	3.5	3.0	4.0	Loose tan & gray clayey sand w/shells, bricks, roots & wood		
3	6.5	7.0	4.0	9.0	Medium stiff tan & gray clay w/silt pockets & roots		
4	9.5	10.0	9.0	10.0	Medium dense gray & white fine sand		
			NOTE:		Boring located at landside toe of west side levee.		

*Number in first column indicates number of blows of 140-lb. hammer dropped 30 in. required to seat 2-in. O. D splitspoon sampler 6 in. Number in second column indicates number of blows of 140-lb. hammer dropped 30 in. required to drive 2-in. O. D. splitspoon sampler 1 ft. after seating 6 in.

WHILE THIS LOG OF BORING IS CONSIDERED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT ITS RESPECTIVE LOCATION ON THE DATE SHOWN, IT IS NOT WARRANTED THAT IT IS REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

Remarks: Borings located @ Sta. 659+30.



Predommant type shown heavy. Modifying type shown light

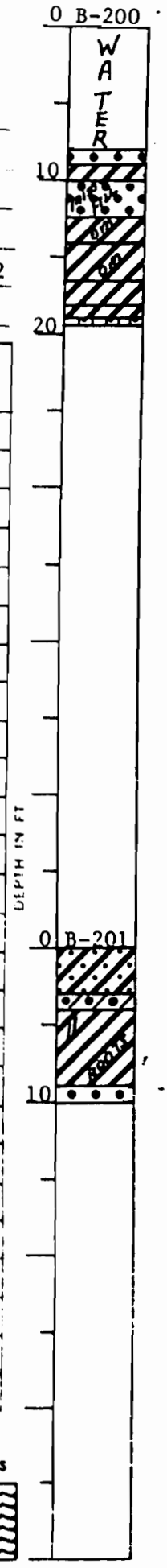


Fig. 6

LOG OF BORING

EUSTIS ENGINEERING COMPANY
SOIL AND FOUNDATION CONSULTANTS
METAIRIE, LA

Name of Project: Sewerage and Water Board of New Orleans
Metairie Relief Canal, Station 617+50 to Station 663+00
Orleans and Jefferson Parishes, Louisiana
For: Modjeski and Masters, Consulting Engineers, New Orleans, Louisiana

Boring No. _____ Soil Technician G. Hardee Date 6 May 1982
Ground Elev. _____ Datum Cairo Gr. Water Depth _____

Sample No.	SAMPLE Depth — Feet From	To	DEPTH STRATUM Feet From	To	VISUAL CLASSIFICATION	*STANDARD PENETRATION TEST	
					BORING 202 (Ground Surface @ el. 19.9)		
			0.0	1.0	Miscellaneous fill		
1	2.5	3.0	1.0		Medium stiff tan & gray clay w/roots		
2	5.5	6.0		9.0	Medium stiff tan & gray clay w/silt		
					pockets		
3	9.5	10.0	9.0	10.0	Medium dense gray & tan fine sand		
			NOTE:		Boring located 50' from landside toe of west side levee.		
					BORING 203 (Ground Surface @ el. 19.6)		
1	2.5	3.0	0.0	3.0	Miscellaneous fill		
2	5.5	6.0	3.0		Medium stiff tan & gray clay		
3	8.0	8.5		8.5	Ditto		
4	9.5	10.0	8.5	10.0	Medium dense gray fine sand w/organic		
					matter		
			NOTE:		Boring located 100' from landside toe of west side levee.		

*Number in first column indicates number of blows of 140-lb. hammer dropped 30 in. required to seat 2-in. O. D. splitspoon sampler 6 in. Number in second column indicates number of blows of 140-lb. hammer dropped 30 in. required to drive 2-in. O. D. splitspoon sampler 1 ft. after seating 6 in.

WHILE THIS LOG OF BORING IS CONSIDERED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT ITS RESPECTIVE LOCATION ON THE DATE SHOWN, IT IS NOT WARRANTED THAT IT IS REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

Remarks: Borings located @ Sta. 659+30.

CLAY SILT SAND HUMUS

Predominant type shown heavy. Modifying type shown light.

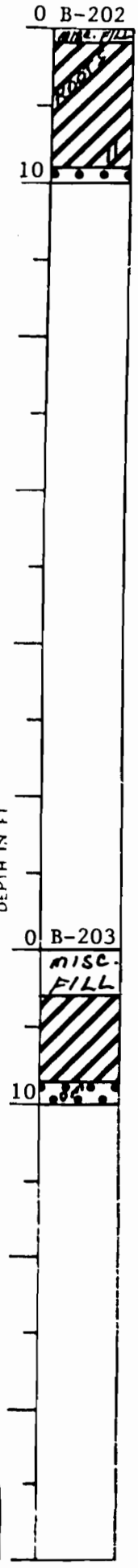


Fig. 7

LOG OF BORING

EUSTIS ENGINEERING COMPANY
SOIL AND FOUNDATION CONSULTANTS
METAIRIE, LA.

Name of Project: Sewerage and Water Board of New Orleans
Metairie Relief Canal, Station 617+50 to Station 663+00
Orleans and Jefferson Parishes, Louisiana
For: Modjeski and Masters, Consulting Engineers, New Orleans, Louisiana

Boring No. _____ Soil Technician G. Hardee & R. Courtiade Date 6 & 10 May 1982
Ground Elev. _____ Datum Cairo Gr. Water Depth _____

Sample No.	SAMPLE Depth — Feet From	To	DEPTH STRATUM Feet From	To	VISUAL CLASSIFICATION	*STANDARD PENETRATION TEST	
					BORING 300 (Water Surface @ el. 21.6)		
			0.0	12.0	Water		
1	13.0	13.5	12.0	14.0	Very soft gray clay w/organic matter & vegetation		
2	15.0	15.5	14.0		Soft gray clay w/organic matter & vegetation		
3	17.0	17.5		18.5	Soft gray clay		
4	19.0	19.5	18.5	20.0	Medium stiff gray clay w/organic matter		
5	21.0	21.5	20.0	22.5	Very soft gray clay		
6	22.5	23.0	22.5	23.5	Medium compact gray clayey silt		
7	23.5	24.0	23.5	24.0	Medium compact gray silty sand w/clay lenses		
			NOTE:		Boring located 30' from west bank of canal.		
					BORING 301 (Ground Surface @ el. 22.9)		
			0.0	3.0	Miscellaneous fill		
1	5.5	6.0	3.0		Medium stiff tan & gray clay		
2	8.5	9.0			Ditto		
3	11.5	12.0		12.0	Ditto		
4	14.5	15.0	12.0	15.0	Medium stiff gray clay w/roots		
5	17.0	17.5	15.0	17.5	Soft gray clay w/roots & organic matter		
			17.5	18.0	Loose to medium dense gray sand		
			NOTE:		Boring located at landside toe of west side levee.		

*Number in first column indicates number of blows of 140-lb. hammer dropped 30 in. required to seat 2-in. O. D. splitspoon sampler 6 in. Number in second column indicates number of blows of 140-lb. hammer dropped 30 in. required to drive 2-in. O. D. splitspoon sampler 1 ft. after seating 6 in.

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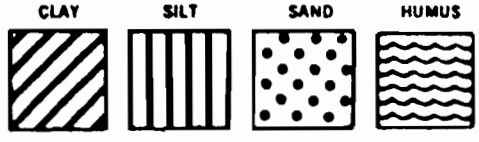
Remarks: Borings located @ Sta. 669+80.



Predominant type shown heavy. Modifying type shown light.

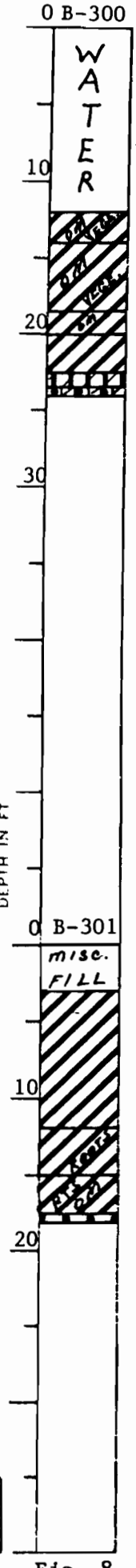


Fig. 8

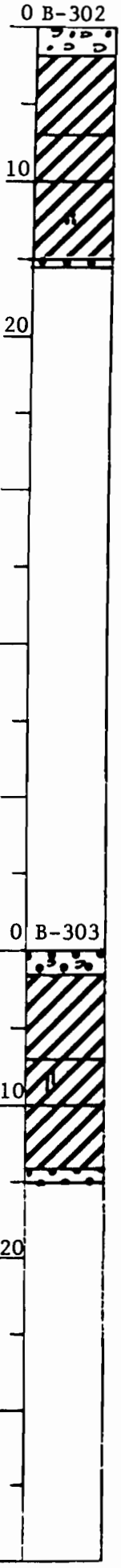
LOG OF BORING

EUSTIS ENGINEERING COMPANY
SOIL AND FOUNDATION CONSULTANTS
METAIRIE, LA.

Name of Project: Sewerage and Water Board of New Orleans
Metairie Relief Canal, Station 617+50 to Station 663+00
Orleans and Jefferson Parishes, Louisiana
For: Modjeski and Masters, Consulting Engineers, New Orleans, Louisiana

Boring No. _____ Soil Technician G. Hardee Date 6 & 7 May 1982
Ground Elev. _____ Datum Cairo Gr. Water Depth _____

Sample No.	SAMPLE Depth — Feet From	SAMPLE Depth — Feet To	DEPTH STRATUM Feet From	DEPTH STRATUM Feet To	VISUAL CLASSIFICATION	*STANDARD PENETRATION TEST	
					BORING 302 (Ground surface @ el. 21.0)		
			0.0	2.0	Shells w/sand		
1	3.0	3.5	2.0		Medium stiff tan & gray clay		
2	5.5	6.0		7.0	Ditto		
3	8.5	9.0	7.0	10.0	Stiff tan & gray clay		
4	11.5	12.0	10.0	15.0	Medium stiff gray clay w/sand pockets		
			15.0	15.5	Loose to medium dense gray sand		
			NOTE:		Boring located 50' from landside toe of west side levee.		
					BORING 303 (Ground Surface @ el. 20.6)		
			0.0	1.5	Medium dense tan sand w/shells		
1	2.5	3.0	1.5		Medium stiff tan & gray clay		
2	5.0	5.5		7.0	Ditto		
3	8.0	8.5	7.0	10.0	Stiff tan & gray clay w/silt pockets		
4	11.0	11.5	10.0	14.0	Medium stiff gray & tan clay		
5	14.5	15.0	14.0	15.0	Medium dense gray fine sand		
			NOTE:		Boring located 100' from landside toe of west side levee.		



*Number in first column indicates number of blows of 140-lb. hammer dropped 30 in. required to seat 2-in. O. D. splitspoon sampler 6 in. Number in second column indicates number of blows of 140-lb. hammer dropped 30 in. required to drive 2-in. O. D. splitspoon sampler 1 ft. after seating 6 in.

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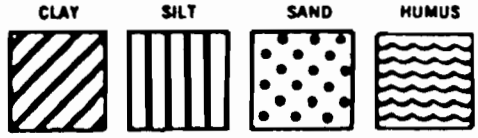


Predommant type shown heavy. Modifying type shown light.

Remarks: Borings located @ Sta. 669+80.

Fig. 9

Subsoil Investigation
Sewerage & Water Board of New Orleans
Metairie Relief Canal
Station 617+50 to Station 663+00
Orleans and Jefferson Parishes, Louisiana

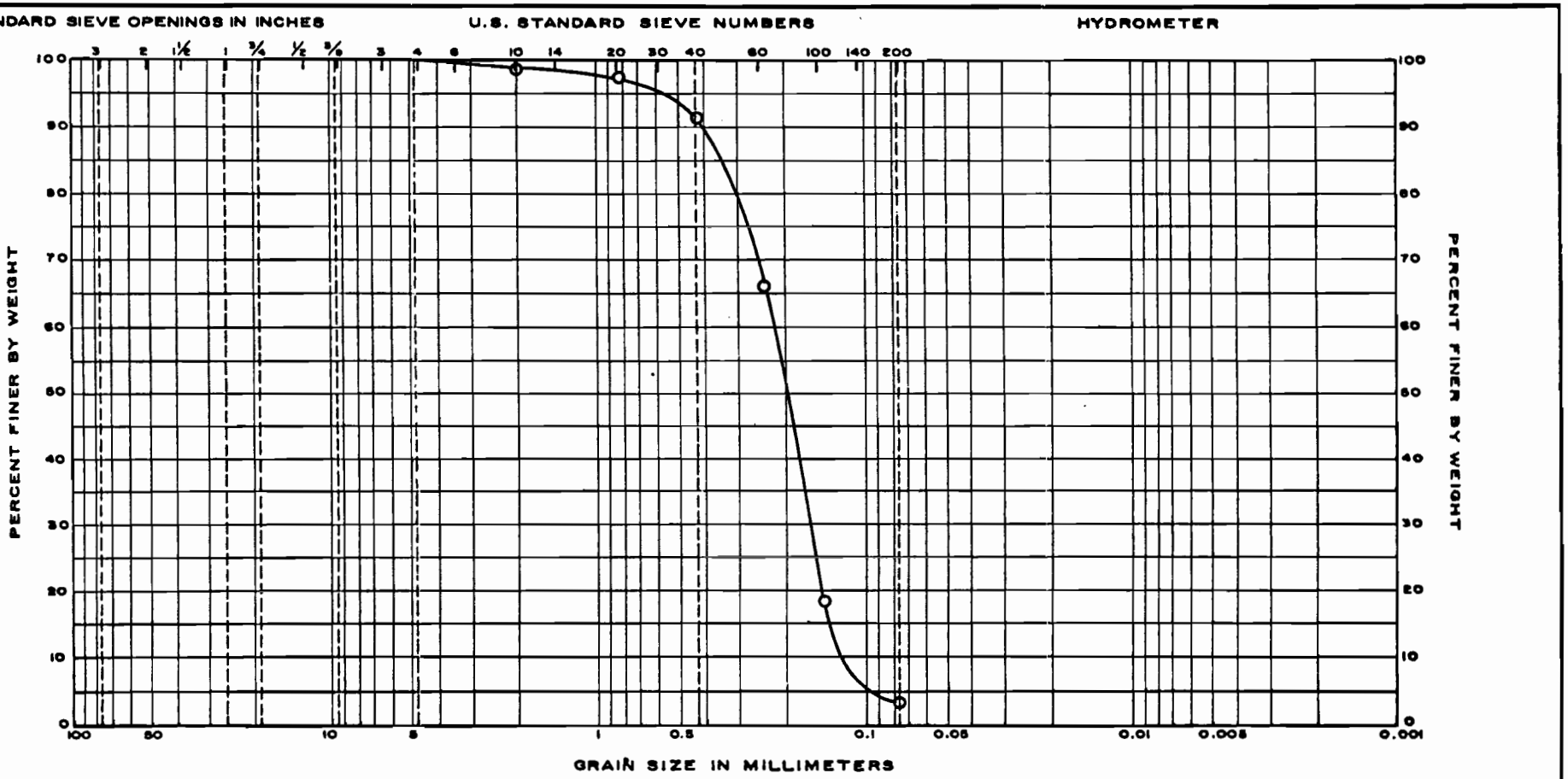
For: Modjeski and Masters, Consulting Engineers, New Orleans, Louisiana

SUMMARY OF LABORATORY PERMEABILITY TESTS

Sample No.	Depth in Feet	Classification	Moisture Content Percent		Density Lb/cu ft		Coefficient of Permeability in cm/sec
			Initial	Final	Dry	Wet	
		BORING 7					
8	19.5	Medium stiff gray sandy clay w/roots	26.3	28.4	95.9	121.2	7.2×10^{-7}
		BORING 12					
5	18.0	Very soft gray & tan clay w/sand pockets & roots	37.4	37.9	81.1	111.4	3.6×10^{-8}
		BORING 14					
5	14.0	Very soft gray clay w/sand pockets, wood & organic matter	49.3	51.1	69.3	103.4	4.1×10^{-8}
		BORING 20					
5	14.0	Soft dark gray organic silty clay w/sandy silt pockets, wood & roots	48.1	49.5	70.3	104.2	3.5×10^{-7}
		BORING 29					
5	14.0	Very soft gray clay w/roots	67.0	71.3	59.0	98.4	9.4×10^{-8}

Fig. 10

EUSTIS ENGINEERING COMPANY
SOIL AND FOUNDATION CONSULTANTS



UNIFIED	GRAVEL		SAND			SILT OR CLAY		
	COARSE	FINE	COARSE	MEDIUM	FINE			
AASHO	GRAVEL			SAND		SILT	CLAY	
	COARSE	MEDIUM	FINE	COARSE	FINE			

GRAIN SIZE ANALYSIS

CURVE NO.	BORING NO.	SAMPLE NO.	DEPTH IN FT.	NATURAL WATER CONTENT	ATTERBERG LIMITS		
					LL	PL	PI
	7	12	28.5				

PROJECT: Sewerage & Water Board of New Orleans

Metairie Relief Canal

Station 617+50 to Station 663+00

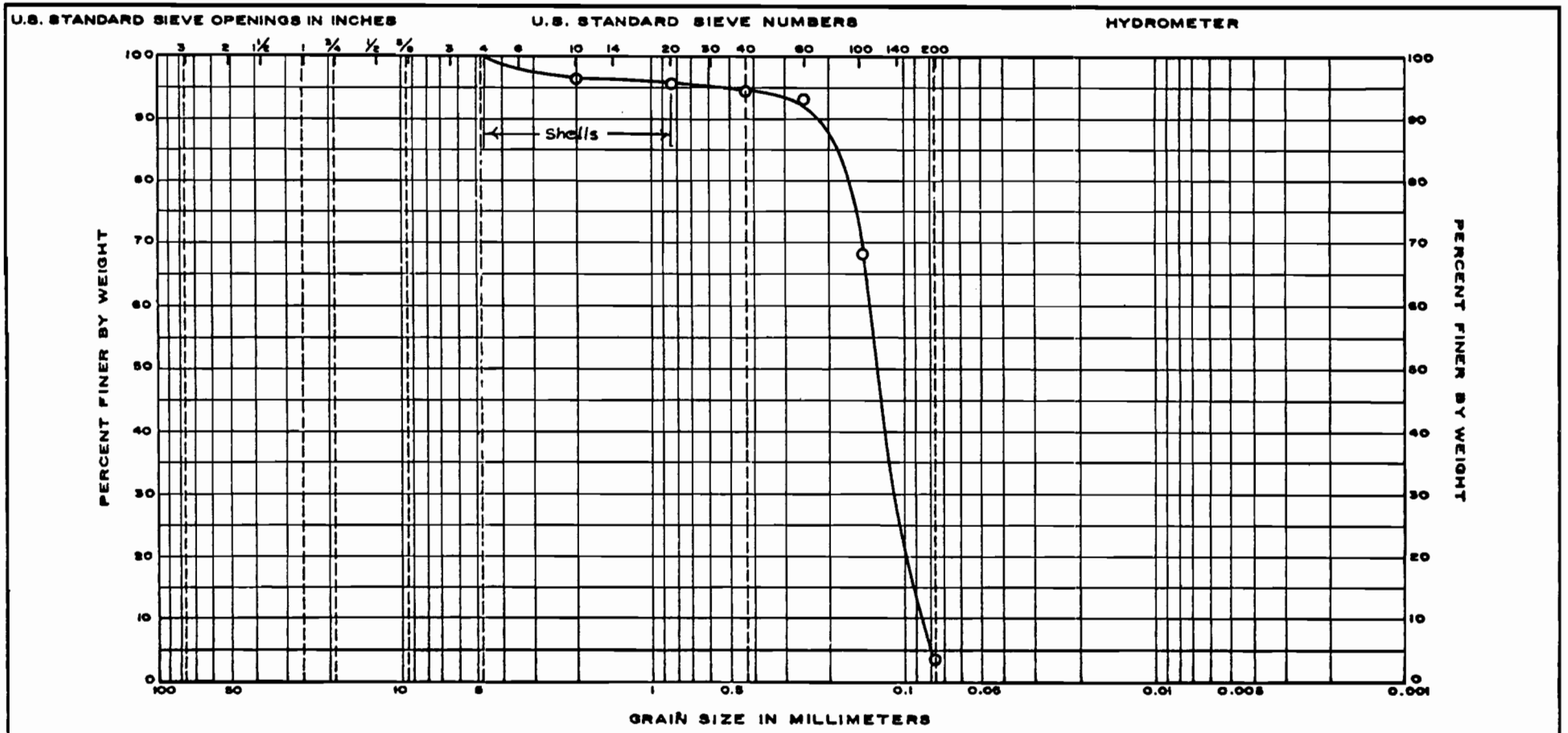
Orleans and Jefferson Parishes, Louisiana

For: Modjeski and Masters

Consulting Engineers, New Orleans, Louisiana

EUSTIS ENGINEERING COMPANY
CONSULTING FOUNDATION ENGINEERS
METAIRIE, LA.

Fig. 11



UNIFIED	GRAVEL			SAND			SILT OR CLAY	
	COARSE	FINE		COARSE	MEDIUM	FINE		
AASHO	GRAVEL			SAND			SILT	CLAY
	COARSE	MEDIUM	FINE	COARSE		FINE		

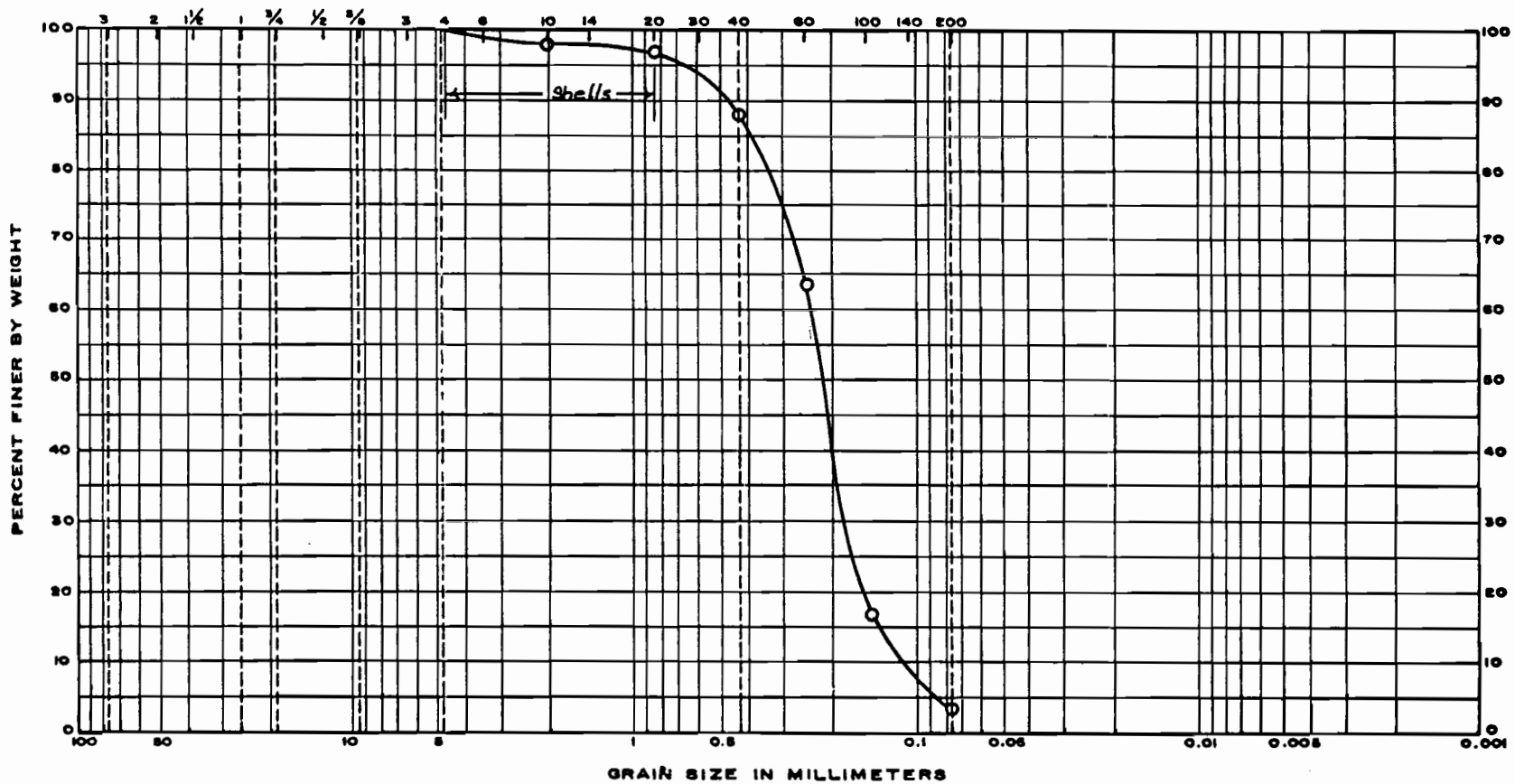
GRAIN SIZE ANALYSIS

CURVE NO.	BORING NO.	SAMPLE NO.	DEPTH IN FT.	NATURAL WATER CONTENT	ATTERBERG LIMITS LL	PL	PI
	12	10	38.5				

PROJECT: Sewerage & Water Board of New Orleans
Metairie Relief Canal
Station 617+50 to Station 663+00
Orleans and Jefferson Parishes, Louisiana
For: Modjeski and Masters
Consulting Engineers, New Orleans, Louisiana

EUSTIS ENGINEERING COMPANY
CONSULTING FOUNDATION ENGINEERS
METAIRIE, LA.

Fig. 12



UNIFIED	GRAVEL			SAND			SILT OR CLAY	
	COARSE		FINE	COARSE	MEDIUM	FINE		
AASHO	GRAVEL			SAND			SILT	CLAY
	COARSE	MEDIUM	FINE	COARSE		FINE		

GRAIN SIZE ANALYSIS

CURVE NO.	BORING NO.	SAMPLE NO.	DEPTH IN FT.	NATURAL WATER CONTENT	ATTERBERG LIMITS LL	PL	PI
	14	8	28.5				

PROJECT: Sewerage & Water Board of New Orleans

Metairie Relief Canal

Station 617+50 to Station 663+00

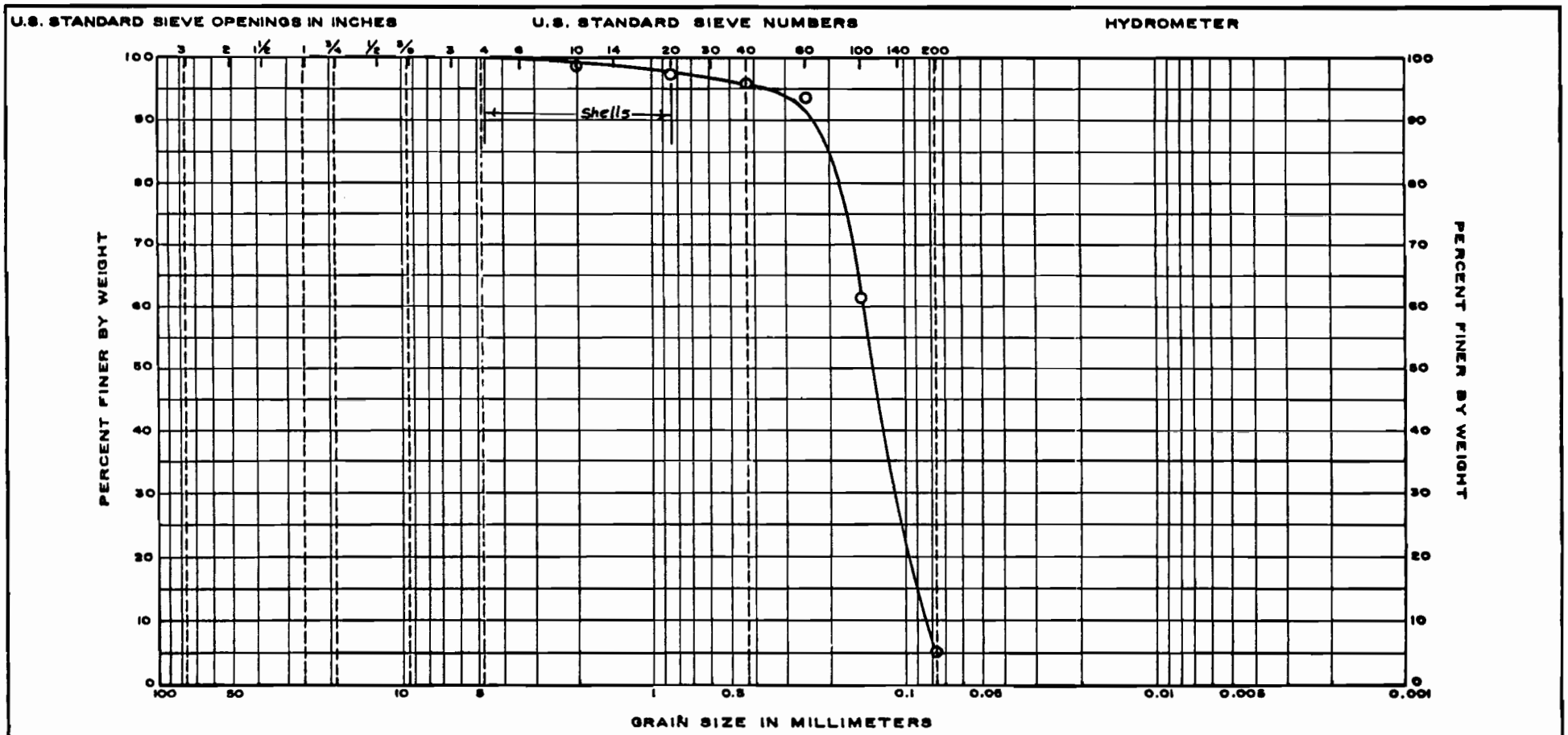
Orleans and Jefferson Parishes, Louisiana

For: Modjeski and Masters

Consulting Engineers, New Orleans, Louisiana

EUSTIS ENGINEERING COMPANY
CONSULTING FOUNDATION ENGINEERS
METAIRIE, LA.

Fig. 13



UNIFIED	GRAVEL		SAND			SILT OR CLAY		
	COARSE	FINE	COARSE	MEDIUM	FINE			
AASHO	GRAVEL			SAND		SILT	CLAY	
	COARSE	MEDIUM	FINE	COARSE	FINE			

GRAIN SIZE ANALYSIS

CURVE NO.	BORING NO.	SAMPLE NO.	DEPTH IN FT.	NATURAL WATER CONTENT	ATTERBERG LIMITS		
					LL	PL	PI
	16	11	38.5				

PROJECT: Sewerage & Water Board of New Orleans

Metairie Relief Canal

Station 617+50 to Station 663+00

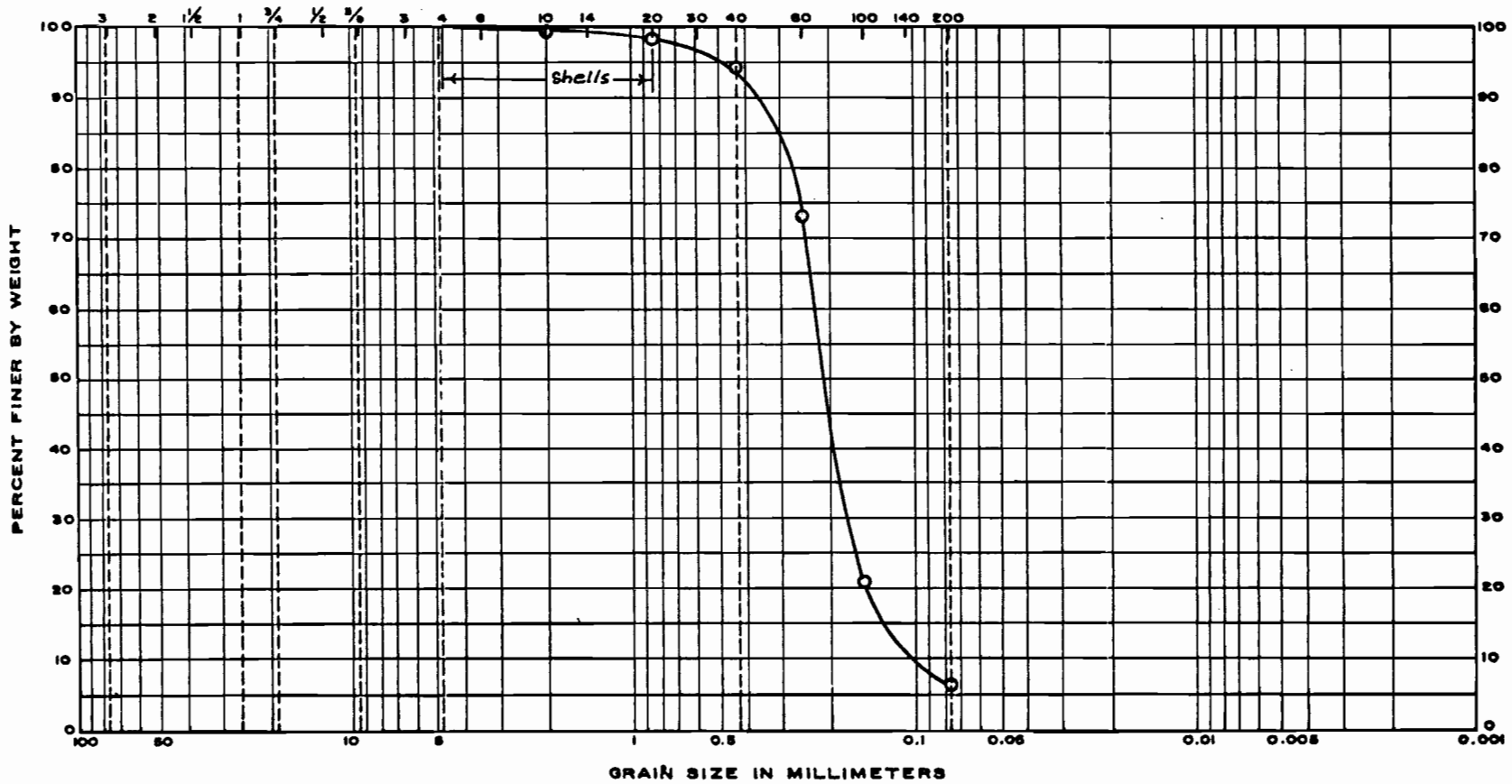
Orleans and Jefferson Parishes, Louisiana

For: Modjeski and Masters

Consulting Engineers, New Orleans, Louisiana

EUSTIS ENGINEERING COMPANY
CONSULTING FOUNDATION ENGINEERS
METAIRIE, LA.

Fig. 14



UNIFIED	GRAVEL		SAND			SILT OR CLAY		
	COARSE	FINE	COARSE	MEDIUM	FINE			
AASHO	GRAVEL			SAND		SILT	CLAY	
	COARSE	MEDIUM	FINE	COARSE	FINE			

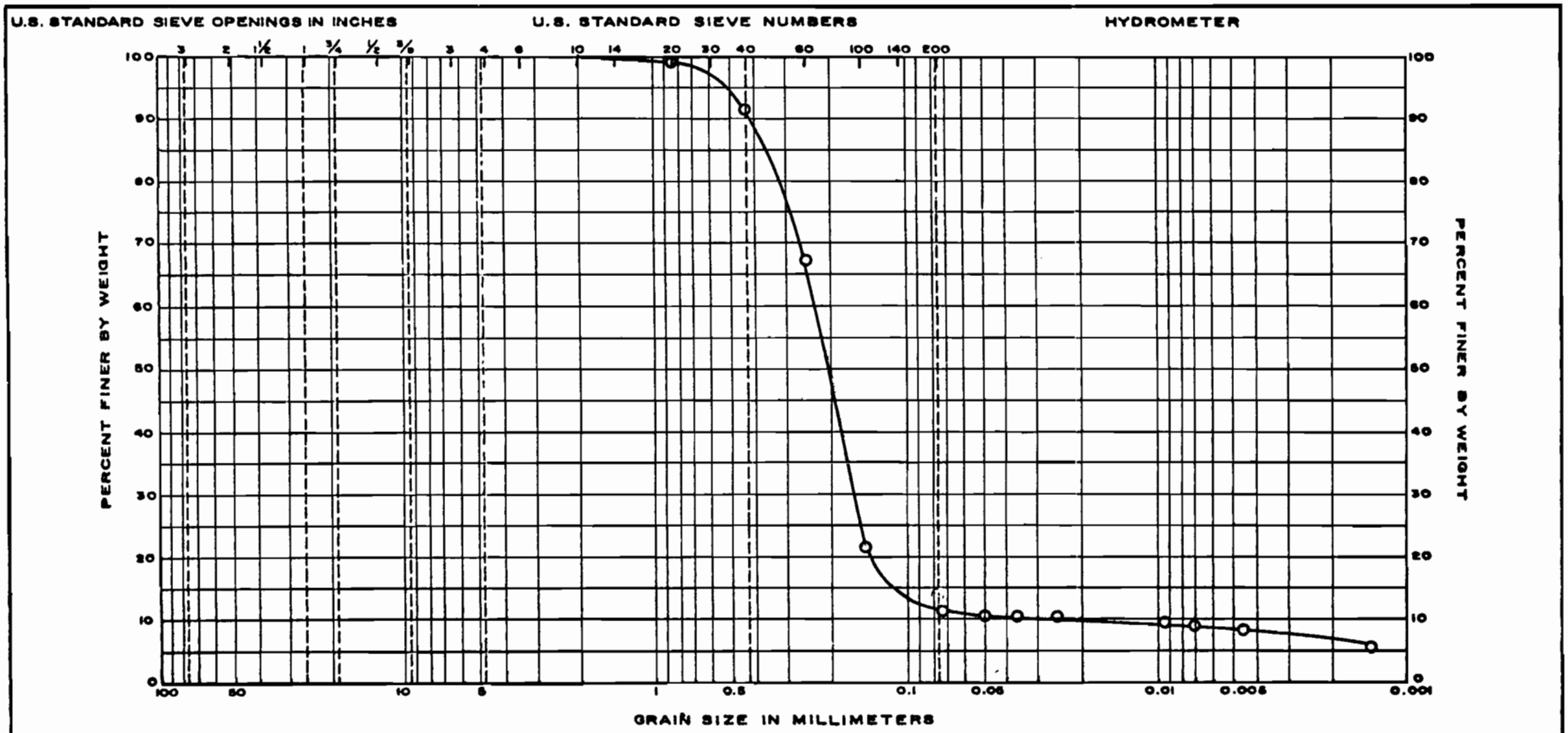
GRAIN SIZE ANALYSIS

CURVE NO.	BORING NO.	SAMPLE NO.	DEPTH IN FT.	NATURAL WATER CONTENT	ATTERBERG LIMITS		
					LL	PL	PI
	20	8	28.5				

PROJECT: Sewerage & Water Board of New Orleans
Metairie Relief Canal
Station 617+50 to Station 663+00
Orleans and Jefferson Parishes, Louisiana
For: Modjeski and Masters
Consulting Engineers, New Orleans, Louisiana

EUSTIS ENGINEERING COMPANY
CONSULTING FOUNDATION ENGINEERS
METAIRIE, LA.

Fig. 15



UNIFIED	GRAVEL		SAND			SILT OR CLAY		
	COARSE	FINE	COARSE	MEDIUM	FINE			
AASHO	GRAVEL			SAND		SILT	CLAY	
	COARSE	MEDIUM	FINE	COARSE	FINE			

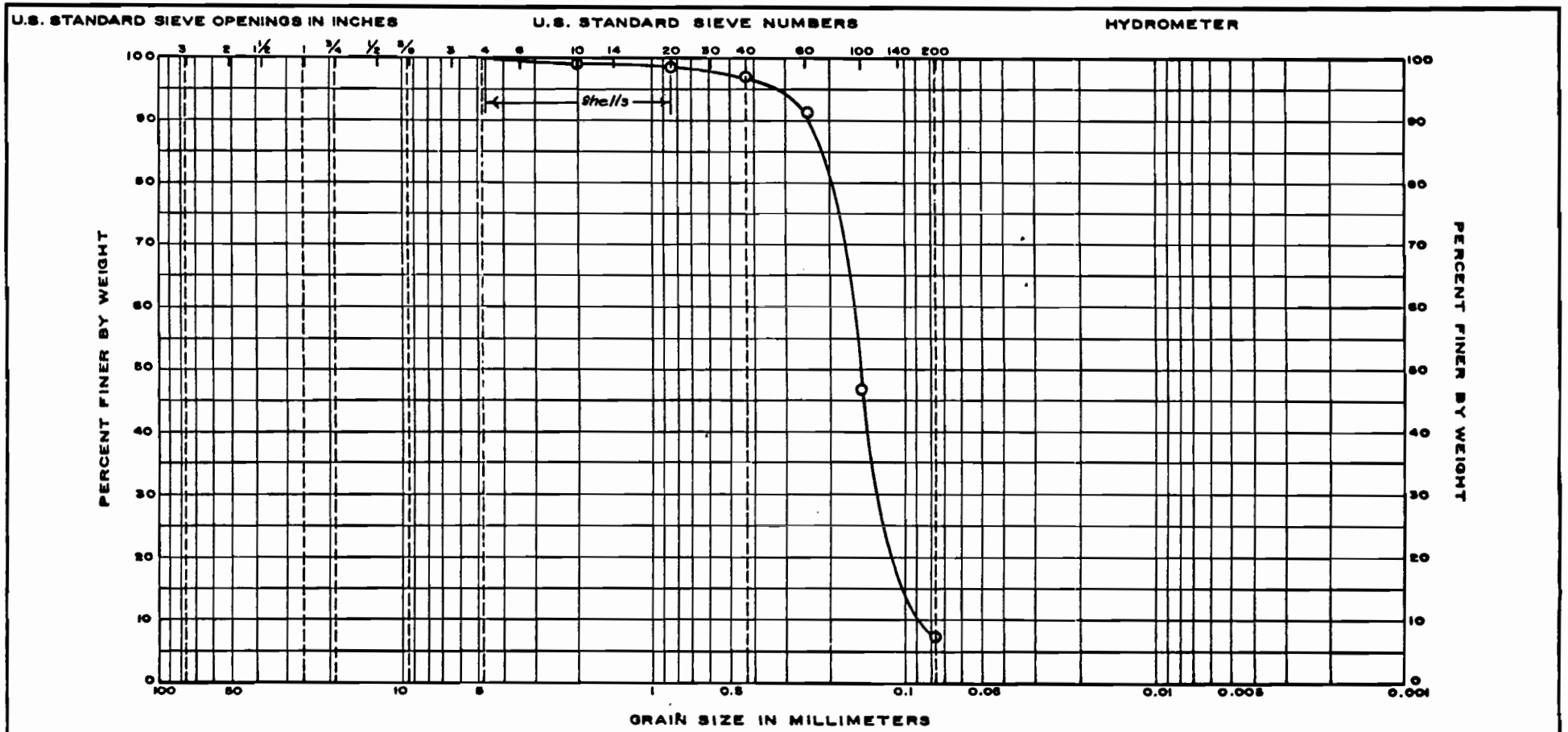
GRAIN SIZE ANALYSIS

CURVE NO.	BORING NO.	SAMPLE NO.	DEPTH IN FT.	NATURAL WATER CONTENT	ATTERBERG LIMITS		
					LL	PL	PI
	26	8	23.5				

PROJECT: Sewerage & Water Board of New Orleans
Metairie Relief Canal
Station 617+50 to Station 663+00
Orleans and Jefferson Parishes, Louisiana
For: Modjeski and Masters
Consulting Engineers, New Orleans, Louisiana

EUSTIS ENGINEERING COMPANY
CONSULTING FOUNDATION ENGINEERS
METAIRIE, LA.

Fig. 16



UNIFIED	GRAVEL		SAND			SILT OR CLAY	
	COARSE	FINE	COARSE	MEDIUM	FINE		
AASHO	GRAVEL			SAND		SILT	CLAY
	COARSE	MEDIUM	FINE	COARSE	FINE		

GRAIN SIZE ANALYSIS

CURVE NO.	BORING NO.	SAMPLE NO.	DEPTH IN FT.	NATURAL WATER CONTENT	ATTERBERG LIMITS LL	PL	PI
	29	9	26.0				

PROJECT: Sewerage & Water Board of New Orleans

Metairie Relief Canal

Station 617+50 to Station 663+00

Orleans and Jefferson Parishes, Louisiana

For: Modjeski and Masters

Consulting Engineers, New Orleans, Louisiana

EUSTIS ENGINEERING COMPANY
CONSULTING FOUNDATION ENGINEERS
METAIRIE, LA.

Fig. 17

Additional Subsoil Investigation
Sewerage and Water Board of New Orleans
Metairie Relief Canal
Station 617+50 to Station 663+00
Orleans and Jefferson Parishes, Louisiana

For: Modjeski and Masters, Consulting Engineers, New Orleans, Louisiana

PIEZOMETER INSTALLATIONS

No.	Location	Elevations - Cairo Datum		
		Top of Riser	Ground Surface	Bottom of Screen
P 201	Landside toe of west side levee near Sta. 659+50	25.6	22.5	10.5
P 202	50" from landside toe of west side levee near Sta. 659+40	22.1	19.8	9.8
P 203	100' from landside toe of west side levee near Sta. 659+30	22.6	19.6	8.6
P 204	Canalside toe of east side levee near Sta. 660+00	26.2	23.2	7.7
P 205	Crown of east side levee near Sta. 660+00	31.0	31.0	6.0

NOTE: P 201, P 202 & P 203 set on 7 May 1982.
P 204 & P 205 set on 31 May 1982.

EUSTIS ENGINEERING COMPANY
SOIL AND FOUNDATION CONSULTANTS
METAIRIE, LOUISIANA

Additional Subsoil Investigation
Sewerage and Water Board of New Orleans
Metairie Relief Canal
Station 617+50 to Station 663+00
Orleans and Jefferson Parishes, Louisiana

For: Modjeski and Masters, Consulting Engineers, New Orleans, Louisiana

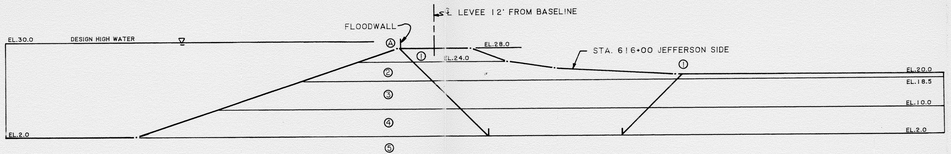
PIEZOMETER READINGS

Date of Reading	Elevation of Water Surface - Cairo Datum					
	P 201	P 202	P 203	P 204	P 205	Canal*
10 May 1982	14.4	13.0	12.7	----	----	21.6
17 May 1982	12.9	12.8	13.0	----	----	22.5
31 May 1982	14.0	12.9	13.3	12.2	11.9	22.2
10 Jun 1982	13.4	12.2	12.6	11.4	11.5	21.8
24 Jun 1982	13.6	12.5	12.7	11.5	11.2	**

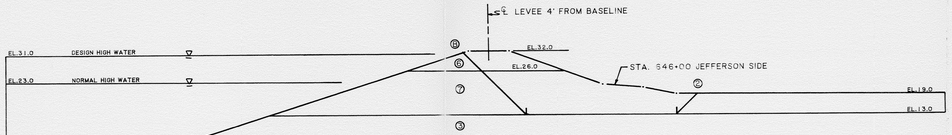
*Benchmark set at water's edge on west side near Sta. 659+50. Elevation of red line on stake is 23.5.

**Stake uprooted.

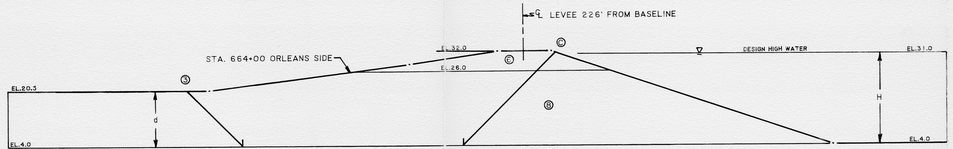
Fig. 19



LAKE PONTCHARTRAIN TO STA. 617+50



STA. 617+50 TO STA. 663+00



STA. 663+00 TO PUMP STATION

SOIL PARAMETERS

ST. No.	γ' PCF	ϕ DEG.	C_A PSF	C_{RB} PSF
1	120	0	500	500
2	120	0	500	500
3	103	0	280	280
4	103	0	320	360
5	122	30	0	0
6	117	0	600	300
7	107	0	360	420
8	107	0	410	520

STABILITY ANALYSIS

SLIP SURFACE		DRIVING FORCE			RESISTING FORCE				FACTOR OF SAFETY
No.	EL.	D_A	D_P	ΣD	R_A	R_B*	R_P	ΣR	
A-1	2.0	36100	17410	18690	19380	9086	11380	39846	2.132
B-2	13.0	19770	1920	17850	16560	3800	4320	24680	1.383
C-3	4.0	42498	15228	27270	24640	24005	13530	62176	2.280

* INCLUDES FULL HYDROSTATIC UPLIFT AT SURFACE OF SAND STRATUM.

UPLIFT ANALYSIS

$FS = \frac{d(\gamma')+H(62.5)}{}$

FS= FACTOR OF SAFETY AGAINST BLOWOUT. (A VALUE OF 1.0 IS ACCEPTABLE CONSIDERING THAT HEAD LOSS AND SOIL SHEAR STRENGTH IS NEGLECTED.)

d= THICKNESS OF CLAY COVER ABOVE SURFACE OF SAND IN FEET.

γ'= SATURATED UNIT WEIGHT OF CLAY COVER ABOVE SURFACE OF SAND IN PCF.

H= HYDROSTATIC HEAD ABOVE SURFACE OF SAND IN FEET.

STA. 616+00 $FS = \frac{18\,(103)}{28\,(62.5)} = 1.06$ OK (DESIGN HIGH WATER).

STA. 646+00 $FS = \frac{6\,(107)}{18\,(62.5)} = 0.57$ NO GOOD (DESIGN HIGH WATER).

$FS = \frac{6\,(107)}{10\,(62.5)} = 1.03$ OK (NORMAL HIGH WATER).

STA. 664+00 $FS = \frac{16.5\,(107)}{27\,(62.5)} = 1.05$ OK (DESIGN HIGH WATER).

ADDITIONAL SUBSOIL INVESTIGATION
SEWERAGE AND WATER BOARD OF NEW ORLEANS
METAIRIE RELIEF CANAL
STATION 617+50 TO STATION 663+00
ORLEANS AND JEFFERSON PARISHES, LOUISIANA

STABILITY ANALYSIS

FOR
MODJESKI AND MASTERS
CONSULTING ENGINEERS
NEW ORLEANS, LOUISIANA

EUSTIS ENGINEERING COMPANY
SOIL AND FOUNDATION CONSULTANTS
JULY, 1962 METAIRIE, LA.

FIGURE 20