AUGUSTINE BEACH BREAKWATER

SHOALING STUDY

NOVEMBER 1989

FOR

THE DELAWARE DEPARTMENT OF NATURAL RESOURCES
AND ENVIRONMENTAL CONTROL

DIVISION OF FISH AND WILDLIFE

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A. INTRODUCTION AND STUDY PURPOSE

Augustine Beach is located on the Delaware River in New Castle County, Delaware, about 18 miles southeast of Newark, Delaware and about 20 miles south of Wilmington, Delaware. The area is a popular site for swimming, fishing and boating activities.

In 1987, the construction of a stone breakwater was completed immediately south of the boat launching ramp at Augustine Beach. The purpose of the breakwater was to 1) protect the existing boat launching ramp from excessive wave activity from the southeasterly direction, 2) provide walkway access to deeper waters of the Delaware River for fishing and sightseeing and 3) prevent northerly transport of littoral drift into the launch ramp area. Following construction of the breakwater, shoaling was reported immediately offshore of the boat launching ramp. The extent of the shoaling area is shown in Figure 1. As a result of the shoaling, boaters using the ramp encountered navigation difficulties immediately after leaving the boat ramp.

As a result of this problem, the Delaware Department of Natural Resources and Environmental Control, Division of Fish and Wildlife authorized Andrews, Miller & Associates, Inc. to conduct a study of the shoaling problem. The purpose of the study is to identify the source of the shoaling material and to develop conceptual alternative plans to reduce/eliminate the shoaling.

B. EXISTING CONDITIONS

General

The Delaware Estuary is one of several major embayments along the Atlantic Coastal Plain and extends from the Atlantic Ocean to the head of tide at Trenton, New Jersey. The upper part of the estuary consists of the Delaware River and the lower part consists of the Delaware Bay.

The coastal zone in the estuary is characterized as a lagoon-barrier-marsh shoreline. The lower Delaware River and upper Delaware coast is a shoreline of broad marsh with isolated sandy barriers. Near the mouth of the Chesapeake and Delaware Canal and further south, the tidal marshes have become relatively broad with nearshore waters composed of soft muddy sediments. Immediately north of Augustine Beach near Port Penn, marsh muds reach a thickness of greater than 80 feet. Figure 2 is a photograph of the marsh shoreline north of Augustine Beach. The growth of the marsh, which is building bayward in parts, is dependent upon a supply of fine-grained material from the Bay and tidal creeks. The area immediately south of Augustine Beach is characterized by muds up to 60 feet in thickness.

Sources of sediments reaching Augustine Beach are erosion of the shorelines north and south of the area, contributions from the Delaware River and smaller tributaries, and erosion or resuspension of bottom sediments.

The major sources of energy influencing sedimentation in the Delaware Estuary include tides, winds, waves, density driven currents and fluvial discharge. The combination of these forces controls the overall estuarine circulation and thus the distribution of the sediments within the system.

The Delaware Estuary is considered a classic example of a tidally dominated estuary, despite the presence of large areas of shallow water and long fetches. The tides of the Delaware Estuary are semi-diurnal with two high tides and two low tides occurring over a 24 hour and 50 minute period. The tidal range increases in an up bay direction from 4.3 feet at the bay mouth to 6.7 feet at the head of tide.

In general, currents flow parallel to the axes of tidal channels. Current velocities are highest in tidal channels in the deeper parts of the bay, and decrease towards shore, in response to increasing bottom friction. Ebb tidal current velocities are higher than those of flood tides, in part because of the discharge of the Delaware River. The average speed of the maximum tidal currents at Reedy Island (east of Augustine Beach) are 2.4 knots and 2.6 knots for the flood and ebb currents, respectively.

Surface Sediments

Weil (1977) made a detailed study of the character and distribution of surface sediments in the Delaware Bay and found a distinctive pattern of progressive sorting related to bathymetry with grain size decreasing in an up bay direction and towards shore. In general, sediments become coarser-grained with increasing water depth: the tidal channels are floored with coarse to medium-grained sands, the adjacent linear shoals consist of fine and very fine sand, and muds make up the tidal marshes at the bay margins. Weil (1977) attributes this sediment distribution almost entirely to the action of tides. Other investigators have also concluded that tidal currents exert a major influence on the distribution and concentration of suspended sediments , as well as on the distribution and textural properties of surficial bottom sediments in the Delaware Bay.

Stumpf (1984) conducted a study based on satellite imagery of variations of suspended sediments within the waters of Delaware Bay. He found that highly turbid water (high sediment concentration) occurs inshore of the 10 foot contour while clearer water occurs bayward of the 30 foot contour. A comparison of variations in suspended sediment concentration with mean wind stress showed a remarkable correlation of $r = 0.98$. He concluded that wind is the dominant factor controlling suspended sediment concentration in surface waters of the Delaware Bay, accounting for over 88 percent of the observed variation.

C. FIELD INVESTIGATIONS

Hydrographic Surveys

June - July 1989 - A detailed hydrographic/topographic survey was conducted between June 20 and July 3, 1989 to define the extent and characteristics of the shoal area. This survey, shown in Map 1, extended from about 1,600 feet north and 700 feet south of the breakwater out to a depth of about - 5.0 feet mean low water. The channel dredged in May 1989 is clearly shown on Map 1. The shoaled area appears to begin about 600 feet north of the boat ramp and extends in the offshore direction about 550 feet from the shoreline.

July 1989 - A second survey was conducted on July 26, 1989 and is shown on Map 2. This survey was conducted as part of the sediment sampling program and also for comparison with the earlier survey to determine if any shoaling had occurred during the period between surveys. The recently dredged channel is also shown in this survey. The extent of the shoaled area is about the same as the previous survey.

Survey Comparison - Comparison of the surveys indicates that the location of the channel dredged in June 1989 has remained about the same between surveys. It appears that the depths in the channel have decreased on the order of 1 to 2 feet between surveys. Overall, comparison of the two surveys indicates some apparent shoaling between surveys in the area to the north of the dredged channel. However, quantification of this shoaling is difficult due to the difficulties experienced in precisely locating the bottom during the surveys. This difficulty was due to the soft bottom in the area which allowed the survey rod to penetrate the bottom easily.

To gain an insight into the shoaling that has occurred in the area since the breakwater construction, the preconstruction survey (conducted by Tetra Tech - Richardson) was compared to the surveys conducted during this study. Figures 3-5 show this comparison for 5 profiles located north and south of the boat launching ramp. The location of these profiles are shown on Map 1. Analysis of Figures 3-5 indicates that there has been considerable shoaling in the area to the north of the launching ramp and breakwater while there has been little change in the profile south of the breakwater. Specifically, Figures 3-5 indicate that the area north of the breakwater has decreased in depth by about 2 to 3 feet since the breakwater was constructed. Profile 5, south of the breakwater, shows only negligible changes in depth between the two surveys.

The implications of the changes in these areas is that the primary source of the shoaling material is from the north. It is possible that sediment from the south side of the breakwater could be transported along the offshore edge of the breakwater and around the tip of the breakwater and into the shoal area. However, if this transport was occurring, some accretion on the south side of the breakwater would be evident. This is clearly not the case as shown in Figure 5.

Sediment Sampling

In order to identify the source of the shoaling material, 28 sediment samples were obtained from the bottom from about 1,000 feet north of the breakwater to about 800 feet south of the breakwater. The locations of the samples are shown on Map 3. The samples were obtained in 1 quart jars by a diver.

Fourteen of the samples were analyzed in the laboratory to determine their classification and grain size distribution. Sieve analysis and Atterberg Limits were performed on each of the samples. In general, the samples consisted of dark gray to black organic clays and silts with sand.

The purpose of the laboratory analyses was to identify any trends in material classification and grain size characteristics that would indicate whether the source of the shoal was north or south of the breakwater. The anticipated trend was for the material to be finer in size moving from south to north along the study area shoreline.

The results of the laboratory analyses for each sample are presented in Appendix 1. In order to analyze any trends in the samples, the grain size distributions of samples north of the shoal area, in the shoal area, and south of the shoal area were plotted on one graph as shown in Figure 6 (blue = north samples, red = shoal samples, black = south samples). Analysis of Figure 6 indicates an apparent trend in finer grain size characteristics moving from south to north in the study area. The median grain size for the various samples are shown in Table 1.

TABLE 1
MEDIAN GRAIN SIZE

SAMPLE		d50 (mm.)
North Area		
S-20		.0042
S-22		.0360
S-23		.0033
	Average = .0145	
Shoal Area		
S-6		.0120
S-7		.0032
S-10		.0040
S-13		.0055
	Average = .0062	
South Area		
S-2		.0570
S-3		.0350
S-24		.0130
S-25		.0170
S-26		.0280
	Average = .0300	

From the data in Table 1 and Figure 6, it appears that the grain size characteristics of the samples to the north of the shoal area are more similar to the characteristics of the samples from the shoal as compared to the samples from south of the breakwater.

Fluorescent Dye Tracing

To gain insight into the typical sediment transport patterns in the area, particularly suspended sediment transport, fluorescent dye packets were deployed in the area and observed on August 30, 1989.

At about 1230 hours, the tide was still high as evidenced by the waterline on the breakwater. The predicted high tide was at 1015 hours and the predicted low tide was at 1645 hours. The wind direction was offshore i.e., from the west, at about 15 miles per hour.

The first dye packet was deployed at about 1400 hours at Location 1 shown on Figure 7. The packet was observed to move offshore first quickly , then in a downshore direction. The dye dispersed quickly and could not be observed after 15 minutes.

The second set of dye packets was deployed at 1415 hours in Location 2 as shown on Figure 7. The general movement of the packets is shown on Figure 7. Both of the offshore packets moved offshore and downriver much quicker than the onshore packets. A water-filled milk jug deployed at the same time moved in the same general direction and with the same relative speed as the offshore dye packets. After 30 minutes, all of the dye packets had moved in the offshore direction in a direction away from the shoal area.

The third set of dye packets were deployed at 1500 hours in Location 3 as shown in Figure 7. The packet nearest to shore remained somewhat stationary for the first 3-5 minutes and then began to move in an offshore direction towards the south. The offshore packets moved offshore quickly and eventually moved in a southeast direction that would miss the shoal area.

During the course of the dye tracing, the tidal elevation was decreasing and ebb currents were flowing in a general south to southeast direction. Although the dye packets dispersed in a direction away from the shoal area, an important process was observed; the influence of the wind on the direction of the dye packets. As soon as the dye packets were deployed, they moved in an offshore direction due to the influence of the wind. This observation supports the findings of Stumpf (1984) that the wind is a dominant influence on the concentration and movement of suspended sediment in the Delaware Estuary.

D. COASTAL PROCESSES

As an aid in determining the source of the shoal offshore of the boat launching ramp, an analysis of the coastal processes occurring following the construction of the breakwater was conducted. This analysis is discussed in the following paragraphs.

Wind Conditions

Hourly observations of the wind speed and direction from January 1987 to December 1988 from Wilmington Airport were obtained. These data were obtained from the National Climatic Center in Asheville, North Carolina on 5 1/4 inch floppy disks. The data were read into Lotus 123 and then translated to a RBASE 5000 database file. This file was then manipulated to develop a wind climatology for the period; i.e., percentage of occurrence of various wind speed groups for the different directions. This climatology is shown in Figure 8 for both years separately and for both years combined in Figure 9. Analysis of these figures indicates that the winds that would be expected to direct suspended sediment transport downriver towards the shoal area (N, NNE, NE, ENE, E, WNW, NW, and NNW) occurred about 54.6 percent of the time as compared to 29.7 percent for winds expected to direct sediment transport upriver towards the shoal area (ESE, SE, SSE, S, SSW, and SW).

Wave Conditions

Coughanowr (1985) concluded that while tides exert the major control on sedimentation in the northern part of the Delaware Bay on a day to day basis, occasional strong winds create waves capable of resuspending significant quantities of clay and silt. These resuspended sediments could then be transported by surface wind currents and tidal currents. For the period of interest, the higher percentage of higher velocity winds from the general NW directions would tend to have resuspended sediments more often during conditions conducive to transport towards the shoal area from upriver.

Tidal Currents

Although no records of tidal currents were available during the period of interest, the typical maximum tidal currents experienced in the area are 2.4 knots and 2.6 knots for the flood and ebb currents, respectively. The generally higher velocities of the ebb currents would be expected to result in a net transport of sediment in a downriver direction during a typical tidal cycle. Although no data is available regarding the current velocity along the river bottom (the above velocities are surface velocities), it would be expected that the bottom velocities would be sufficient to erode and transport the very fine-grained bottom sediments.

E. CONCLUSIONS ON THE SOURCE OF SHOALING

Based on the preceding analyses, it is concluded that the material that has shoaled in the area opposite the boat launching ramp has been transported to the area from north of the site. This conclusion is supported by the hydrographic surveys which indicate a significant accretion of sediment immediately north of the breakwater following its construction while little sediment has accreted on the south side of the breakwater. Comparison of the pre-breakwater survey with the surveys conducted as part of this study indicate that the hydrography south of the breakwater has not changed significantly.

The trend in the sediment characteristics toward finer material in the shoal and the area to the north as opposed to the area to the south of the breakwater also supports this conclusion.

The dye tracing observations indicate that surface wind currents play a significant role in the transport of suspended sediments in the area. Analysis of wind data during the two year period following the breakwater construction indicates a predominance of winds that would be conducive to sediment transport towards the shoal area from the north. Combining those findings with the predominance of wave conditions from the NW direction and the predominance of the ebb tidal current in the area also supports the conclusions.

The source of the material is presumed to be a combination of sediments eroded from the marsh shorelines, resuspension of the fine-grained bottom sediments north of the area and suspended sediment being transported downriver from Delaware River. It appears that this sediment is transported to the shoal area by these mechanisms and then deposited as the transporting currents are decreased in velocity by the effects of the breakwater.

The primary transport mechanisms for transport of this material are tidal currents, surface wind currents and wave action that resuspends bottom sediments periodically.

F. ALTERNATIVE SOLUTIONS

Assuming the shoaling material is being transported to the shoal from the north, there are a number of alternative plans that could significantly reduce the shoaling in addition to the alternative of periodically dredging the channel opposite the boat launching ramp. The following paragraphs discuss these conceptual alternatives.

Alternative 1 - Channel Dredging. This alternative consists of the periodic dredging of the channel opposite the boat launching ramp as shown in Figure 10. Following dredging of the channel in May 1989, the channel remained relatively stable as evidenced by the surveys conducted in June and July 1989. However, due to the short time period between dredging and the surveys, the long-term stability of the channel is unknown. However, on the positive side, the dredging in May has provided an adequate channel for the major recreational period.

It is possible that dredging the channel on an annual basis could provide an adequate channel for the subsequent recreational period. The estimated costs for this alternative are $5,300 per year based on dredging unit costs of $6.00 per cubic yard and assuming disposal along the shoreline south of the breakwater.

Alternative 2 - Breakwater Modification at the Outer End. According to the design report (Tetra Tech - Richardson 1986), the primary purposes for the breakwater were to protect the existing boat ramp from excessive wave activity from the southeasterly direction, provide fishing and sightseeing access, and to prevent northerly transport of littoral drift into the launch ramp area. Although it appears that the breakwater is satisfying these initial purposes, it appears that the structure is also resulting in the trapping of fine-grained sediments being transported from north of the area.

One potential solution to this problem is the removal of part of the outer section of the breakwater as shown on Figure 11. This modification would allow the fine-grained sediment from the north to be transported past the boat launching area by tidal and wind currents. One disadvantage of this alternative is the resulting reduction in wave protection from the southeasterly direction. To regain wave protection, the stone removed from the existing outer end could be placed further offshore in a detached breakwater segment as shown in Figure 11. The actual location and orientation of this segment would have to be selected to minimize diffracted wave energy through the gap between the segment and the new offshore end of the existing breakwater and also to insure that the sediment transporting currents would not be reduced to allow deposition of the sediment.

Due to deeper water depths offshore of the existing offshore end of the existing breakwater, additional stone would be required for construction of the breakwater segment. The estimated construction cost for this alternative is $450,000, based on a unit cost for stone of $ 30.00 per ton core/bedding stone and $46.00 per ton for armor stone (1987 breakwater construction costs adjusted to 1989) and assuming 3 foot of settlement into the bottom.

Alternative 3 - Breakwater Modification at the Mid-Section. This alternative consists of the removal of a section of the existing breakwater near its mid-section as shown in Figure 12. This modification would provide a "flow channel" between the inner and outer ends of the breakwater that would allow the sediment from north of the area to be transported through the shoal area. Selection of the size of the gap in the existing structure would have to consider potential scouring at the base of the structures and diffracted wave energy through the gap.

One disadvantage of this alternative, similar to Alternative 2, is the elimination of access to the offshore end of the breakwater for fishing purposes. In addition, the stone removed from the existing breakwater would have to be removed off-site unless some use could be made of it on-site. One possibility would be to use it for shoreline protection along the eroding shoreline sections in the area. The estimated cost for this alternative (assuming on-site use of the excess stone) is $221,800.

Alternative 4 - Stone Jetty North of the Boat Launching Ramp. This alternative consists of the construction of a stone jetty north of the existing boat launching ramp as shown in Figure 13. The purpose of this structure would be to trap the sediment being transported from the north before it reaches the boat launching area. Due to the fine-grained characteristics of the sediment and the transport processes, i.e., tidal and surface wind currents, the structure would have to extend a significant distance offshore as shown in Figure 13.

The estimated construction cost for this alternative is $198,300, based on a unit cost of stone of $30.00 per ton for core/bedding and $46.00 per ton for armor stone and assuming 3 feet of settlement into the bottom.

Alternative 5 - Steel-Sheetpile Jetty North of the Boat Launching Ramp. This alternative consists of the construction of a steel sheetpile jetty as shown in Figure 14. The purpose of this structure would be the same as Alternative 4. Based on the soft bottom conditions existing at the site, the stability of this structure is questionable and would require extremely long sheeting.

The estimated construction cost of this alternative is $600,000, based on a unit cost of $1,500 per linear foot of bulkhead.

Alternative 6 - Timber-Sheetpile Jetty North of the Boat Launching Ramp. This alternative consists of the construction of a timber sheetpile jetty as shown in Figure 15. The purpose of this structure is the same as Alternatives 4 and 5. This alternative actually consists of the construction of two parallel timber sheetpile walls that would be connected to each other for stability and then backfilled with material. Due to the soft bottom conditions in the area and the potential for ice damage, the use of a single sheetpile wall as a jetty is not possible. Backfill could be either stone, dirt or a combination of the two. It is possible that some of the material dredged from the shoal area could be used as backfill.

The estimated construction cost for this alternative is $539,400, based on a unit cost of $600 per linear foot of bulkhead and $20.00 per c.y. for fill material.

G. EVALUATION OF ALTERNATIVE PLANS

Based on preliminary evaluation, all of the above plans would provide solutions to the shoaling problem and would provide an adequate channel opposite the boat launching ramp. **Alternative 1 - Channel Dredging** would be the least costly plan, but would require continual action to maintain the channel and would require an approved disposal site. Continued disposal of the dredged material along the shoreline may be objectionable to environmental agencies; particularly since it was reported that the material was lost from the area within two weeks.

The remaining alternatives would reduce the channel shoaling but would be more costly to construct initially. However, over a designated project life, these alternatives may be attractive; particularly considering the continuous effort required to keep the channel open through periodic dredging and potential environmental concerns. For example, assuming a project life of 25 years, the annual cost of Alternative 4 is $18,600 versus an annual cost of $5,300 for Alternative 1. However, the annual cost for Alternative 1 does not include engineering and administrative costs associated with each dredging event and assumes that the channel will only have to be dredged one time each year. The actual shoaling rate and storms may require dredging more frequently. The costs for the alternatives are shown in Table 2.

TABLE 2
ANNUAL COSTS OF ALTERNATIVE PLANS

	CONSTRUCTION COST	AVERAGE ANNUAL COST (@ 8% Interest)
Alternative 1	$ 5,300	$ 5,300
Alternative 2	$450,000	$42,200
Alternative 3	$221,800	$20,800
Alternative 4	$198,300	$18,600
Alternative 5	$600,000	$56,200
Alternative 6	$539,400	$50,500

H. RECOMMENDATION

In consideration of the above, particularly the high cost of construction of the various alternatives, it is recommended that the shoal area be resurveyed in about 4 months to determine if the channel dredged in May 1989 has remained open. If the channel has remained open to a sufficient degree, then periodic monitoring of the channel should be conducted and maintenance dredging should be considered as the solution to the shoaling problem. However, if the resurvey indicates that the channel has shoaled significantly, a maintenance dredging operation should be scheduled as soon as possible to dredge the channel for the 1990 boating season.

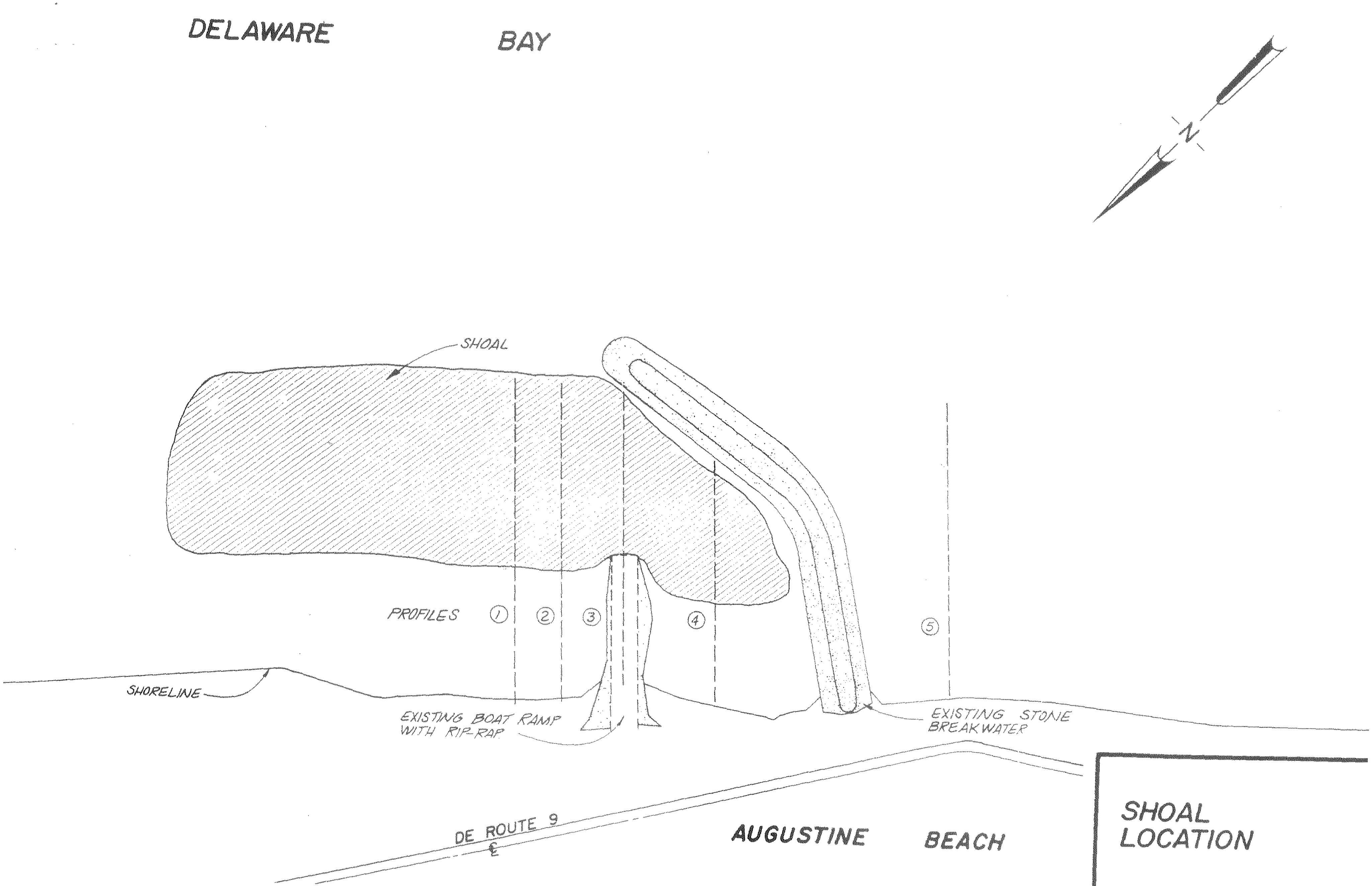
At the same time, depending on the budget and policy of the Department, a decision should be made to continue periodic maintenance dredging of the channel or to initiate detailed evaluation and design of one of the alternatives presented above. Based on preliminary evaluation, Alternative 4 is the most cost-effective structural solution to the shoaling problem.

REFERENCES

Coughanowr, C.A., 1985, The Effects of Wind Waves on Sedimentation in Northeastern Delaware Bay. M.S. Thesis, University of Delaware, 153 pp.

Stumpf, R.P., 1984, Analysis of Suspended Sediment Distribution in Surface Waters of the Delaware Bay. Ph.D. dissertation, University of Delaware, 123 pp.

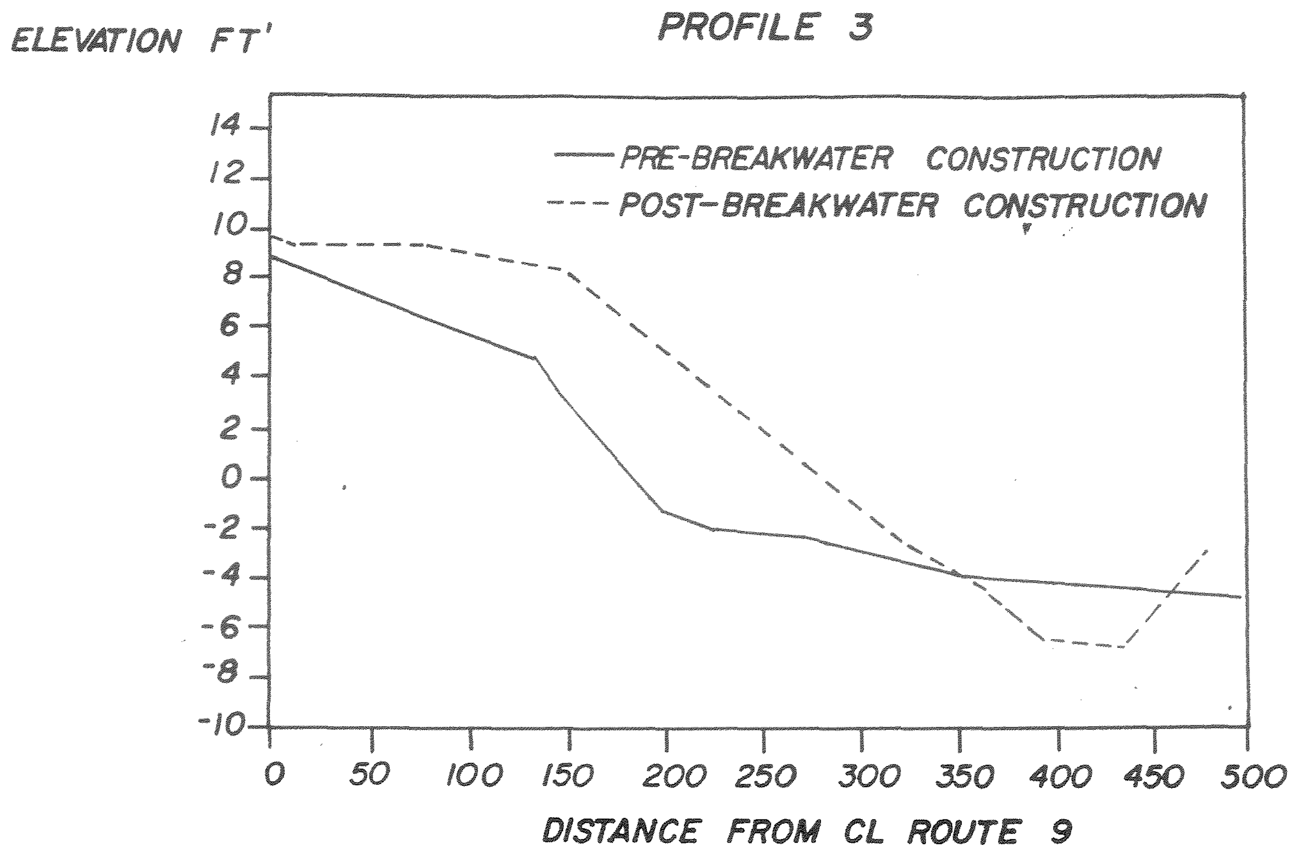
Weil, C.B., 1977, A Model for the Distribution, Dynamics and Evaluation of Holocene Sediments and Morphologic Features of Delaware Bay. Ph.D. dissertation, University of Delaware.



SHOAL
LOCATION

FIGURE 1

AUGUSTINE BEACH BREAKWATER



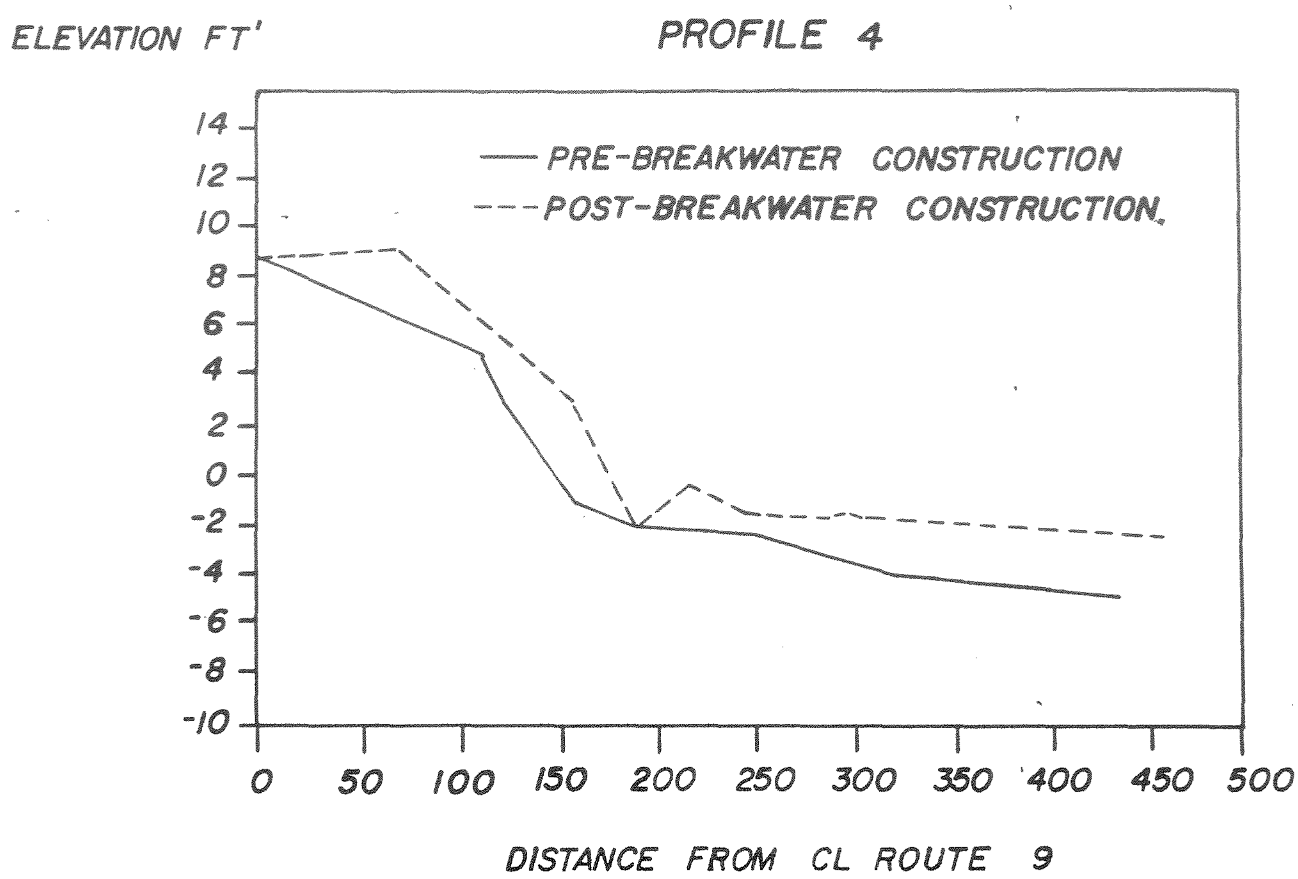


FIGURE 4

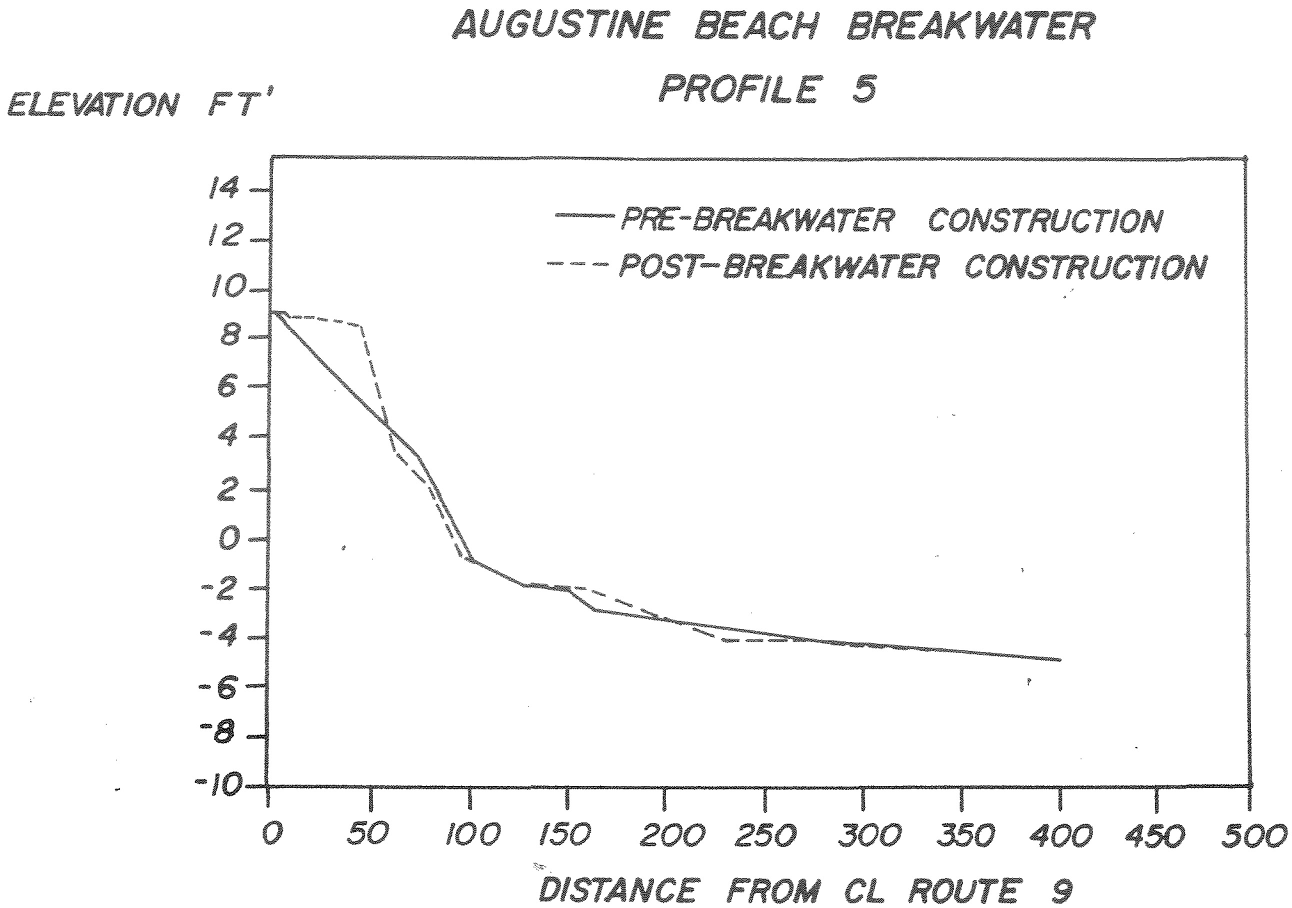

AUGUSTINE BEACH BREAKWATER
PROFILE 5
ELEVATION FT'
PRE-BREAKWATER CONSTRUCTION
POST-BREAKWATER CONSTRUCTION
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
0
50
100
150
200
250
300
350
400
450
500
DISTANCE FROM CL ROUTE 9

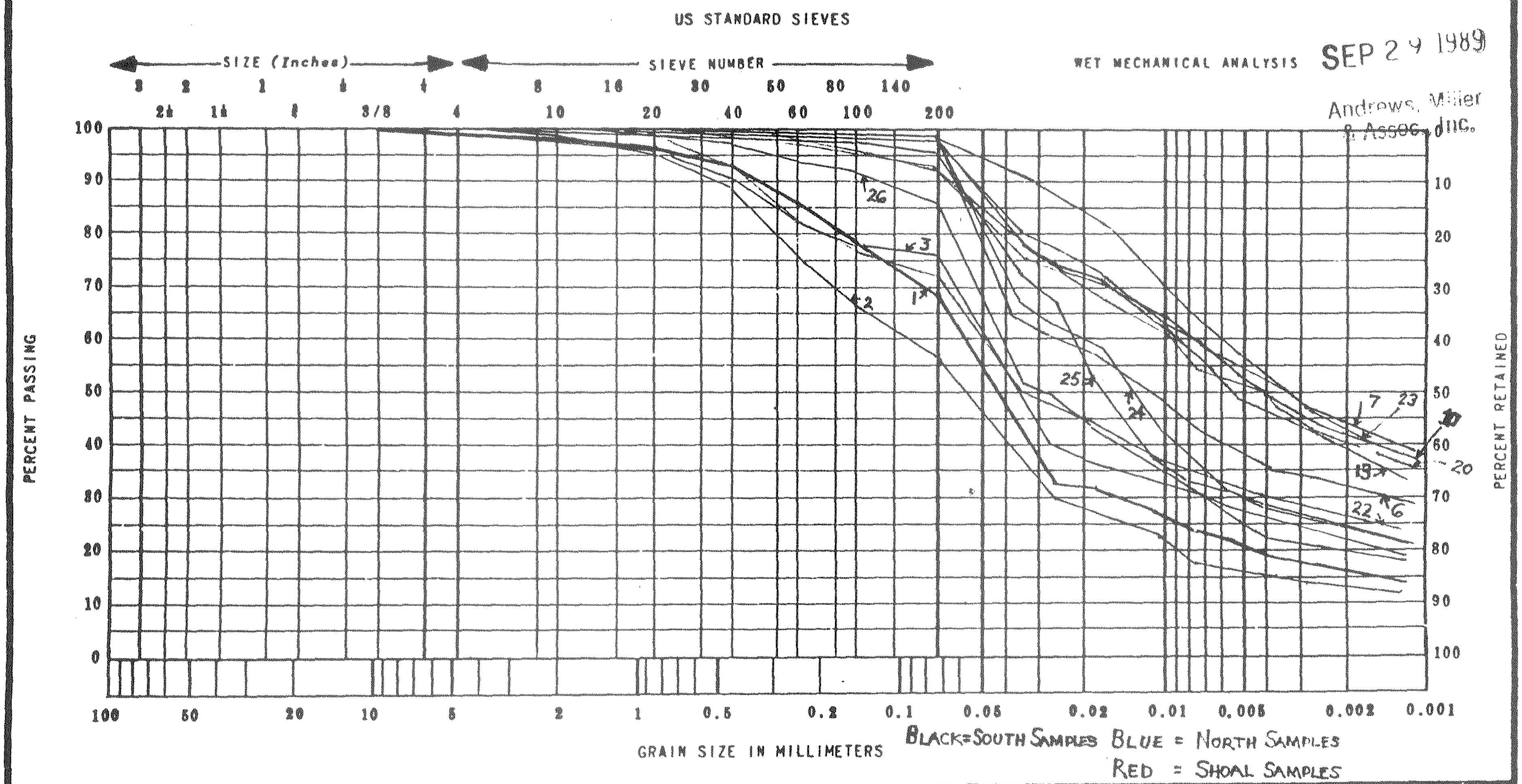
FIGURE 5

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES • ENGINEERS & CHEMISTS

GRAIN SIZE DISTRIBUTION GRAPH - AGGREGATE GRADING CHART

DATE: 9-22-89

PROJECT: AUGUSTINE BREAKWATER F & R PROJECT NO. Q-73-319

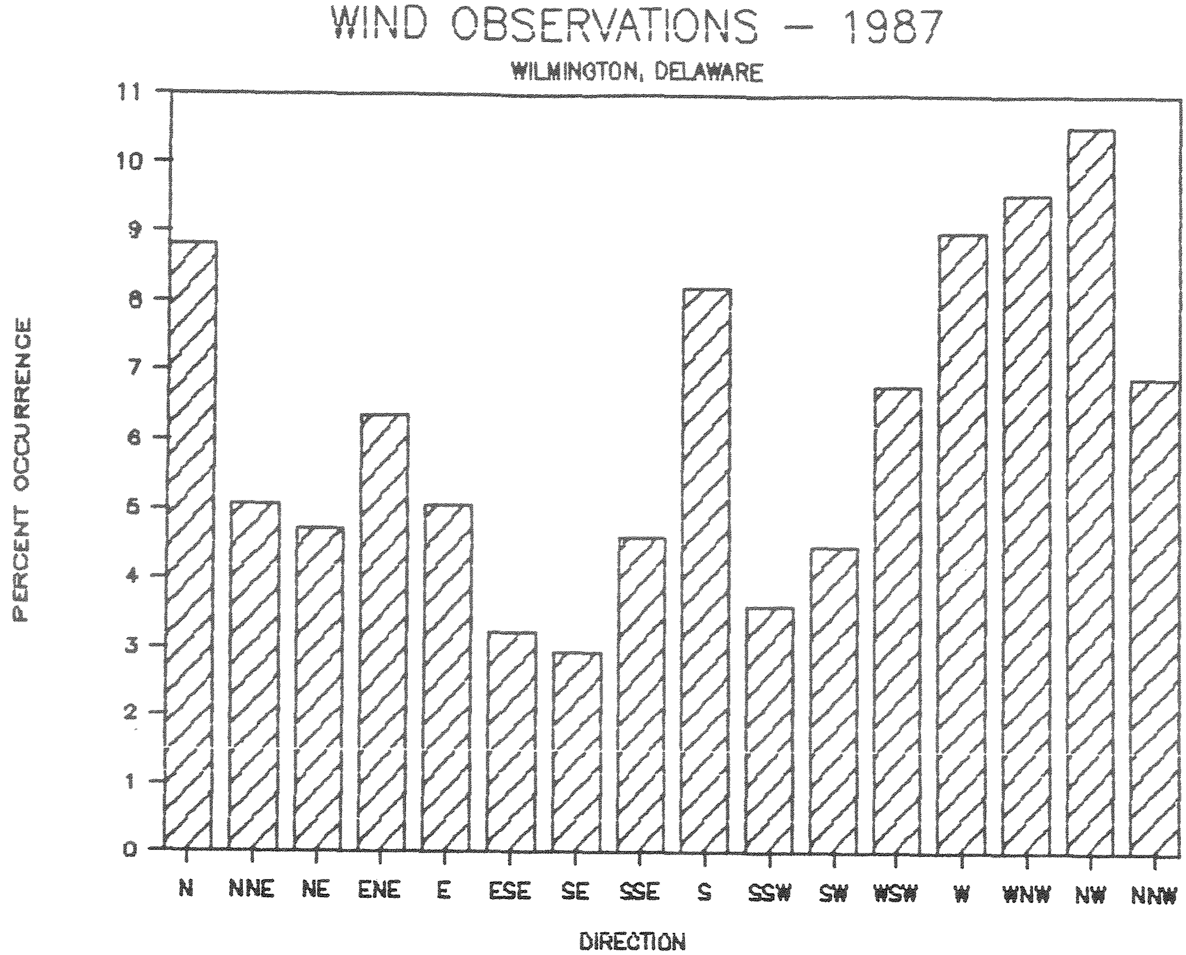


EXCAVATION NUMBER	SAMPLE NUMBER	NATURAL % MOISTURE	w_L	w_P	I_P	CLASSIFICATION	REMARKS
CONTROL NO.	S-1	---	48	21	27	DK GRAY, LEAN CLAY	
26727						WITH SAND	
						(CL)	

TECHNICIAN (Signature): L.A.T.
PLOTTED BY (Signature): M.T.F.
CHECKED BY (Signature): [signature]

FIGURE 6

Form No: 110


WIND OBSERVATIONS — 1987
WILMINGTON, DELAWARE
PERCENT OCCURRENCE
0
1
2
3
4
5
6
7
8
9
10
11
N
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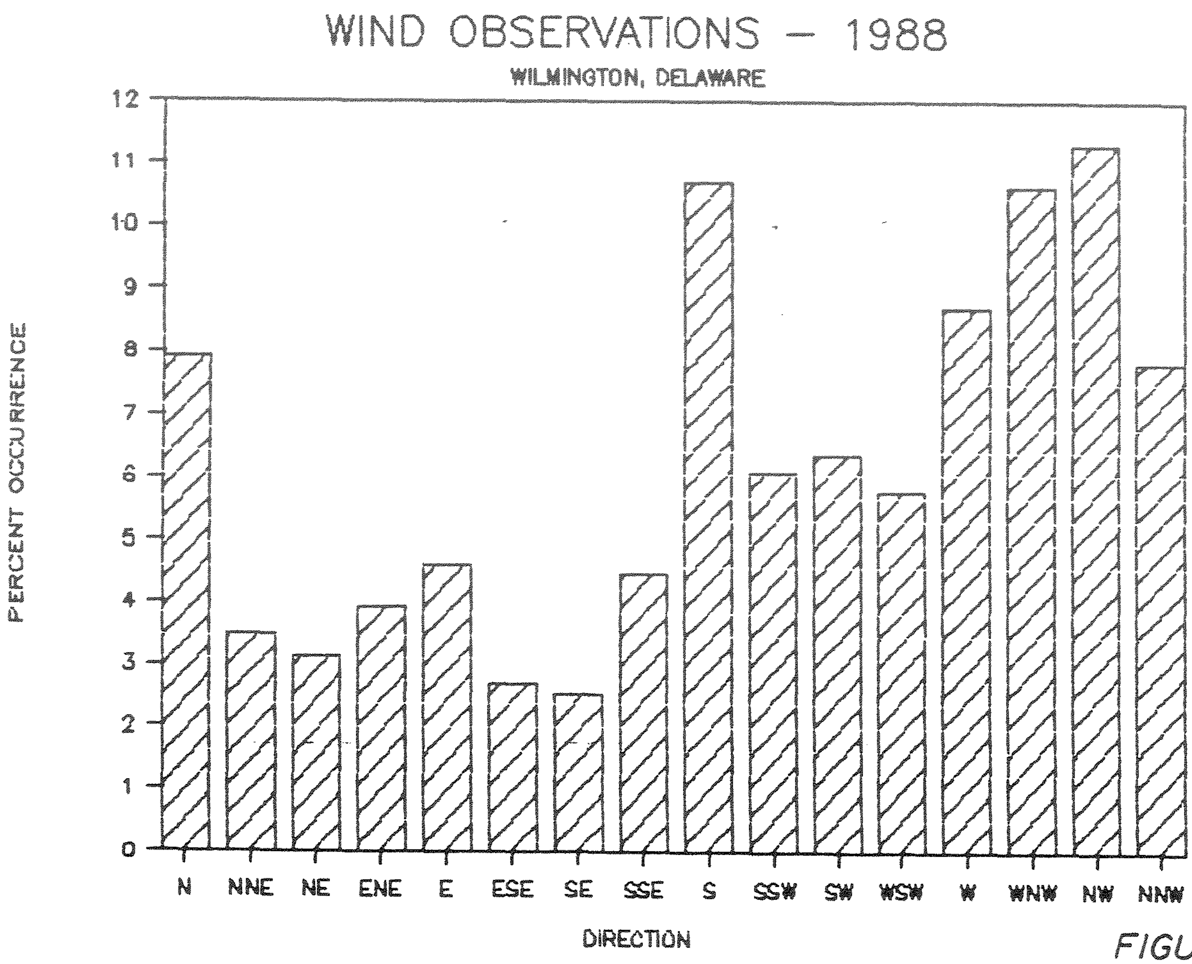
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
DIRECTION


WIND OBSERVATIONS — 1988
WILMINGTON, DELAWARE
PERCENT OCCURRENCE
0
1
2
3
4
5
6
7
8
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10
11
12
N
NNE
NE
ENE
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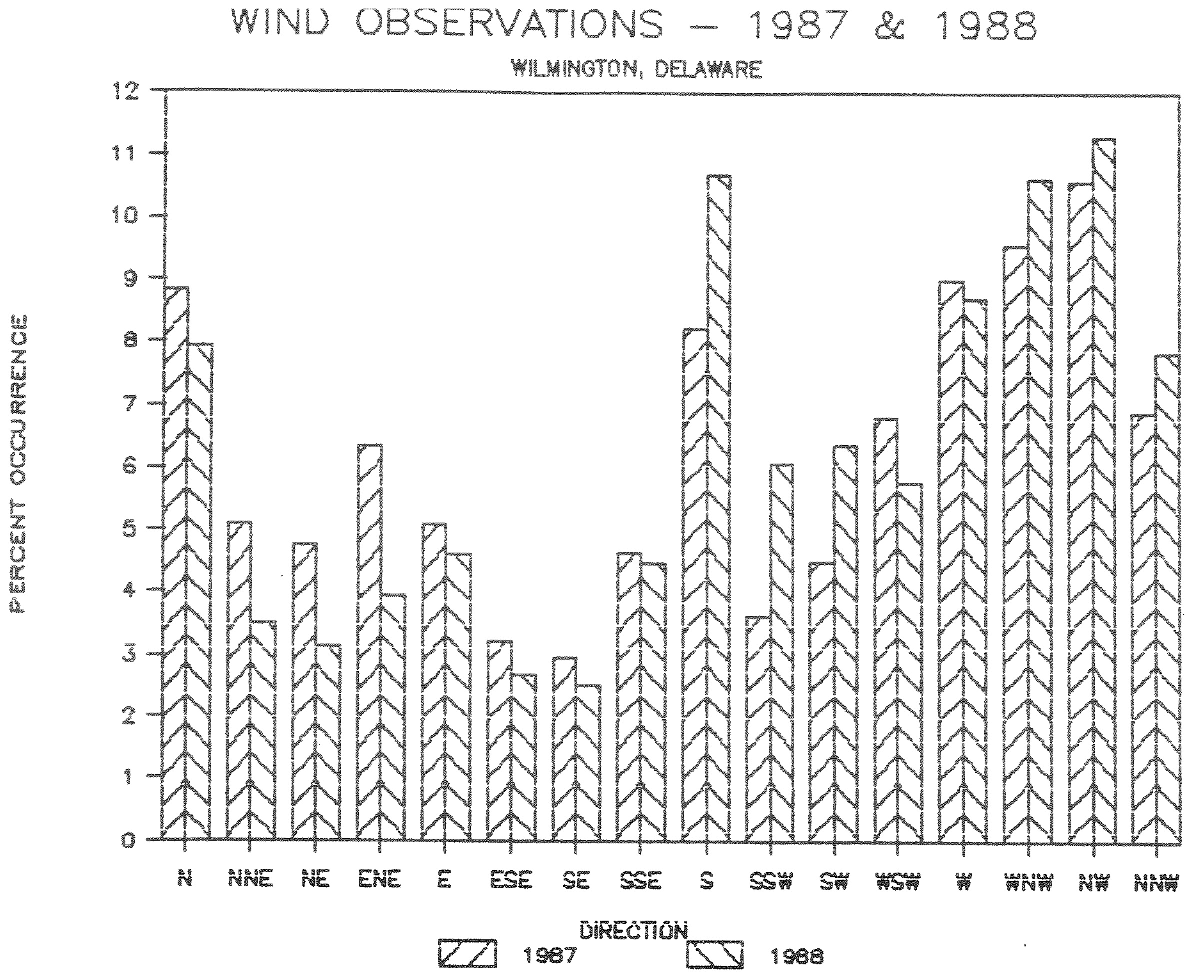
SW
WSW
W
WNW
NW
NNW
DIRECTION

FIGURE 8


WIND OBSERVATIONS — 1987 & 1988
WILMINGTON, DELAWARE
PERCENT OCCURRENCE
0
1
2
3
4
5
6
7
8
9
10
11
12
N
NNE
NE
ENE
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ESE
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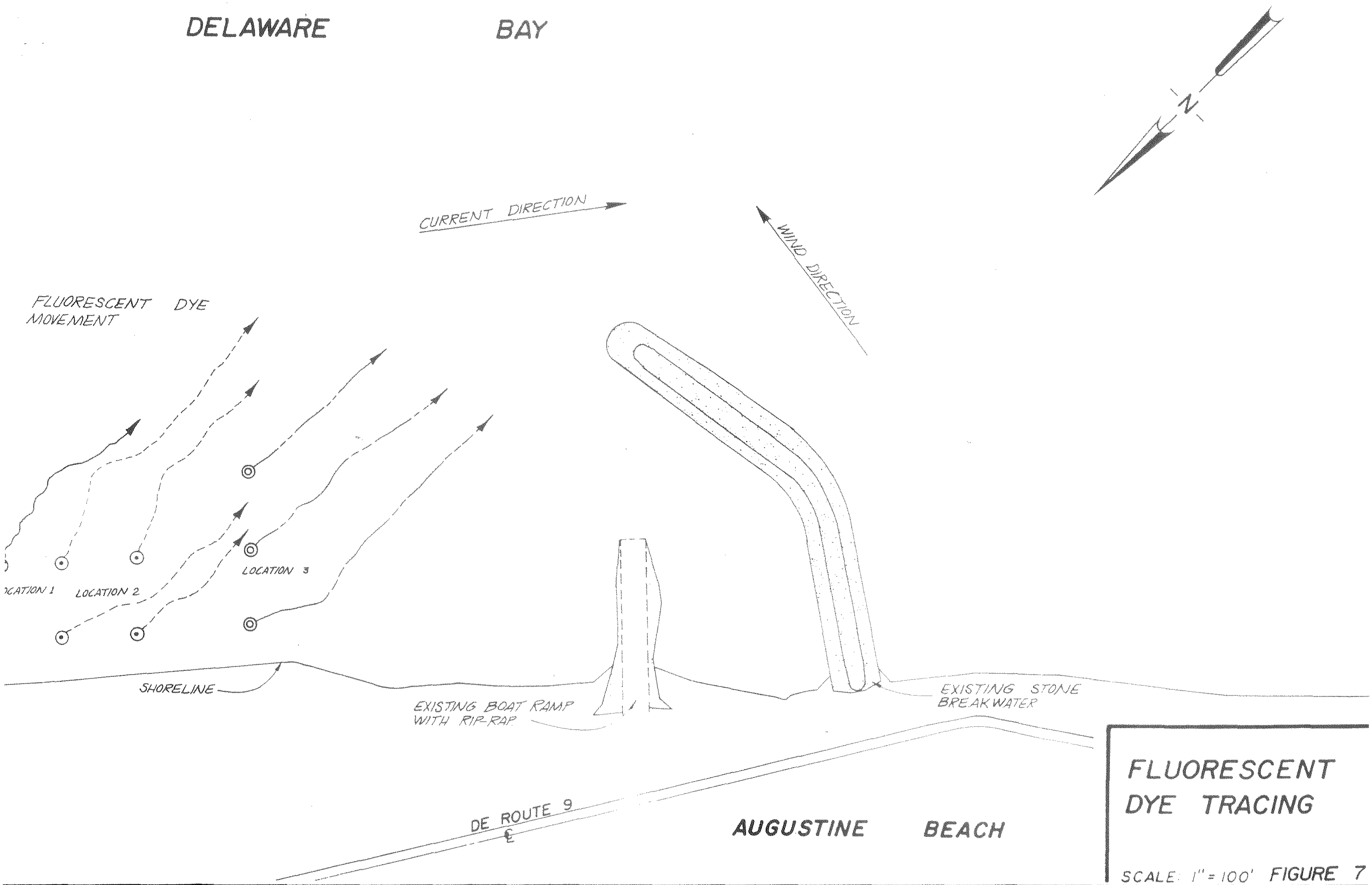
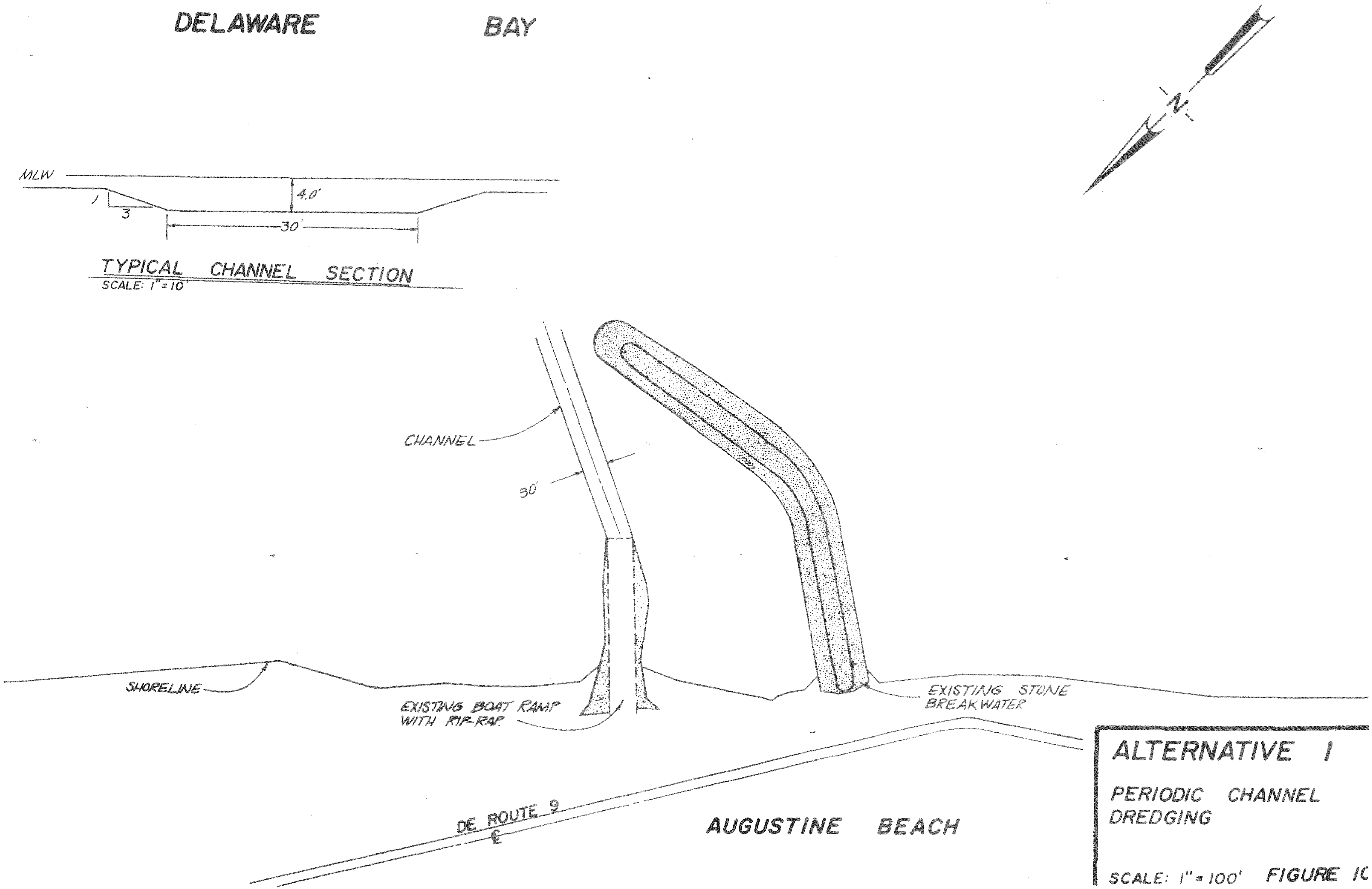
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
DIRECTION
1987
1988

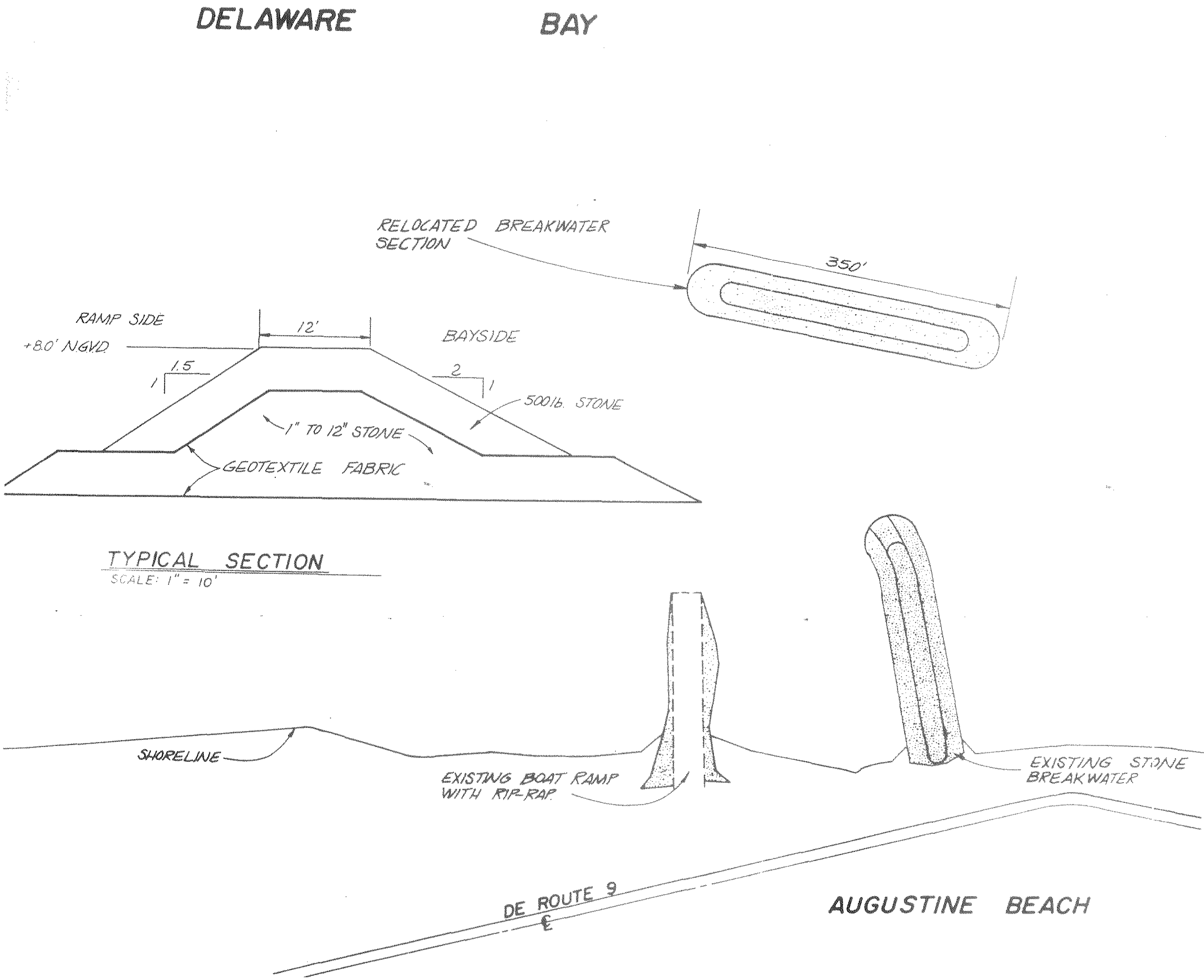
FIGURE 9



FLUORESCENT DYE TRACING

SCALE: 1" = 100' FIGURE 7

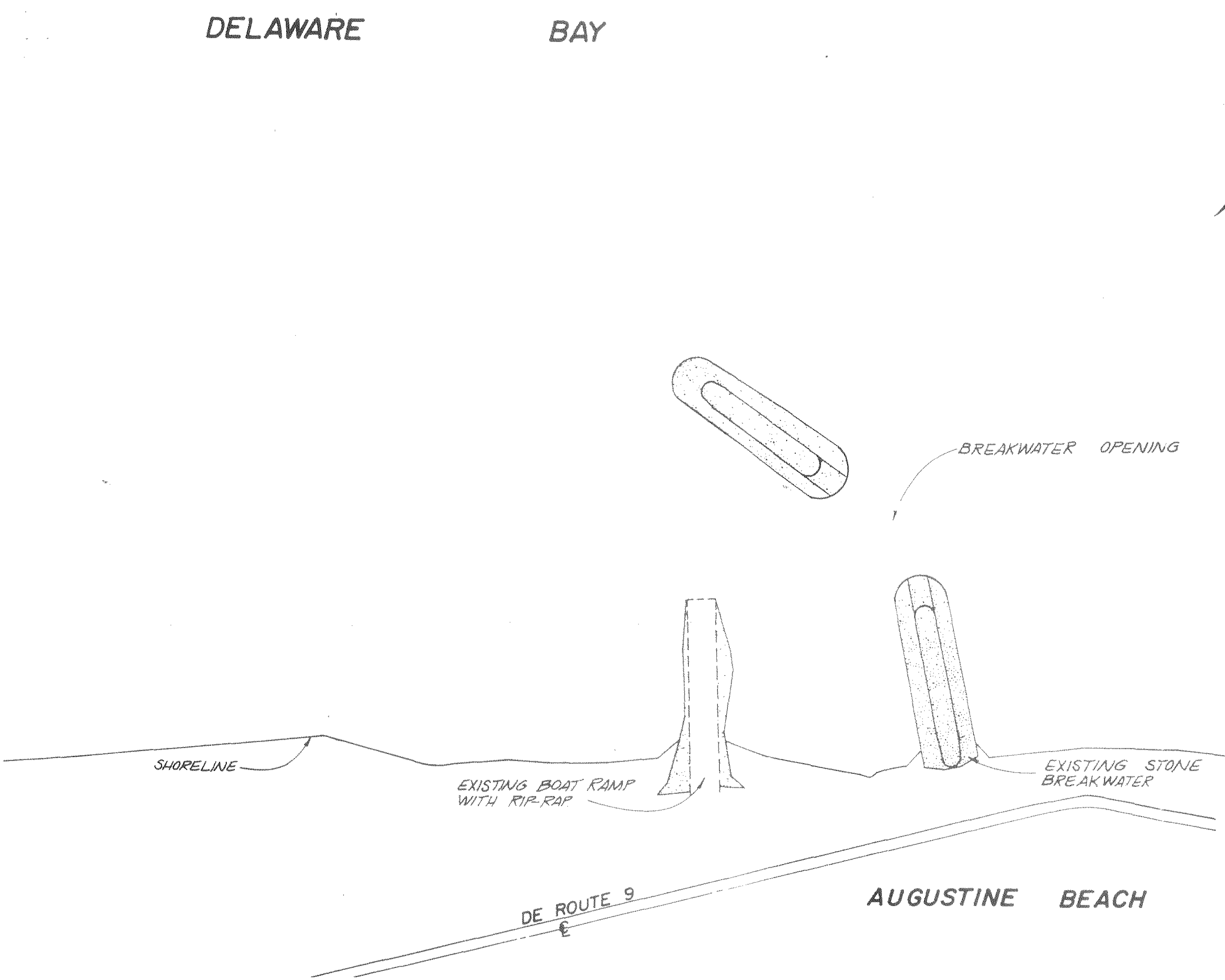

DELAWARE BAY
MLW
4.0'
1
3
30'
TYPICAL CHANNEL SECTION
SCALE: 1" = 10'
CHANNEL
30'
SHORELINE
EXISTING BOAT RAMP WITH RIP-RAP
EXISTING STONE BREAKWATER
DE ROUTE 9
AUGUSTINE BEACH
ALTERNATIVE 1
PERIODIC CHANNEL DREDGING
SCALE: 1" = 100'
FIGURE 1C



ALTERNATIVE 2

BREAKWATER MODIFICATION AT THE OUTER END

SCALE: 1" = 100'   FIGURE 11

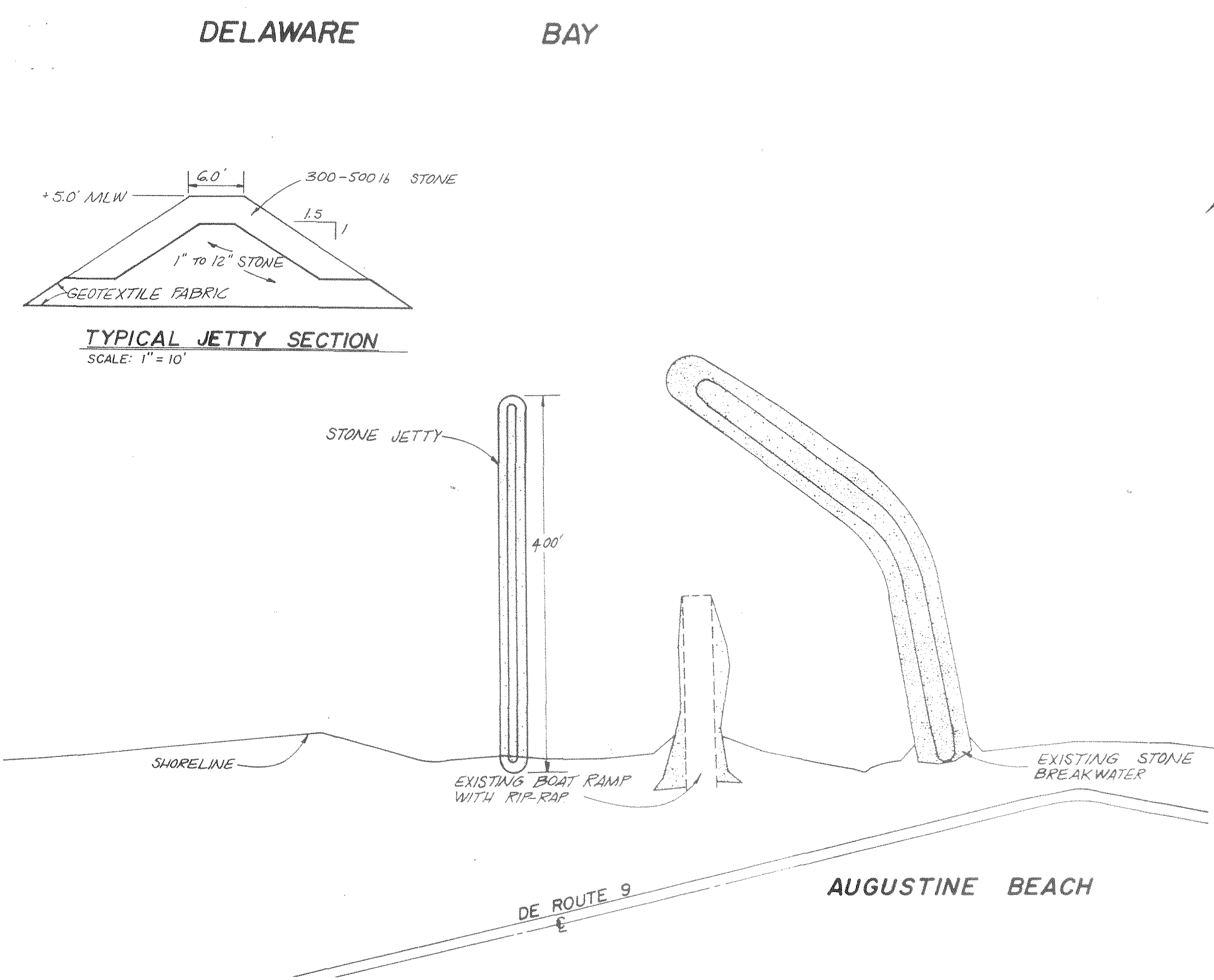


ALTERNATIVE 3

BREAKWATER MODIFICATION AT THE MID-SECTION

SCALE: 1" = 100'

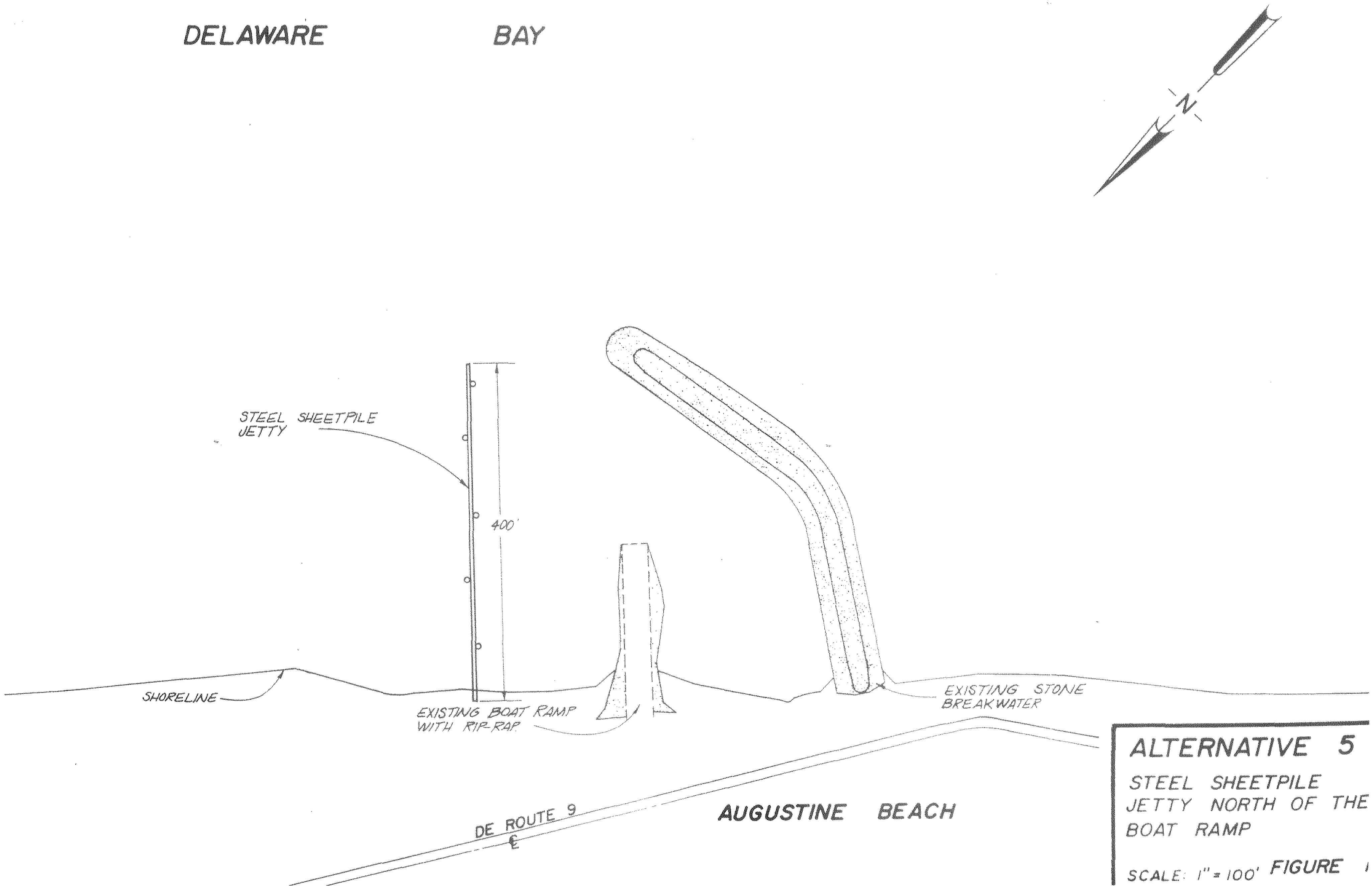
FIGURE 1.



ALTERNATIVE 4

STONE JETTY NORTH OF THE BOAT RAMP

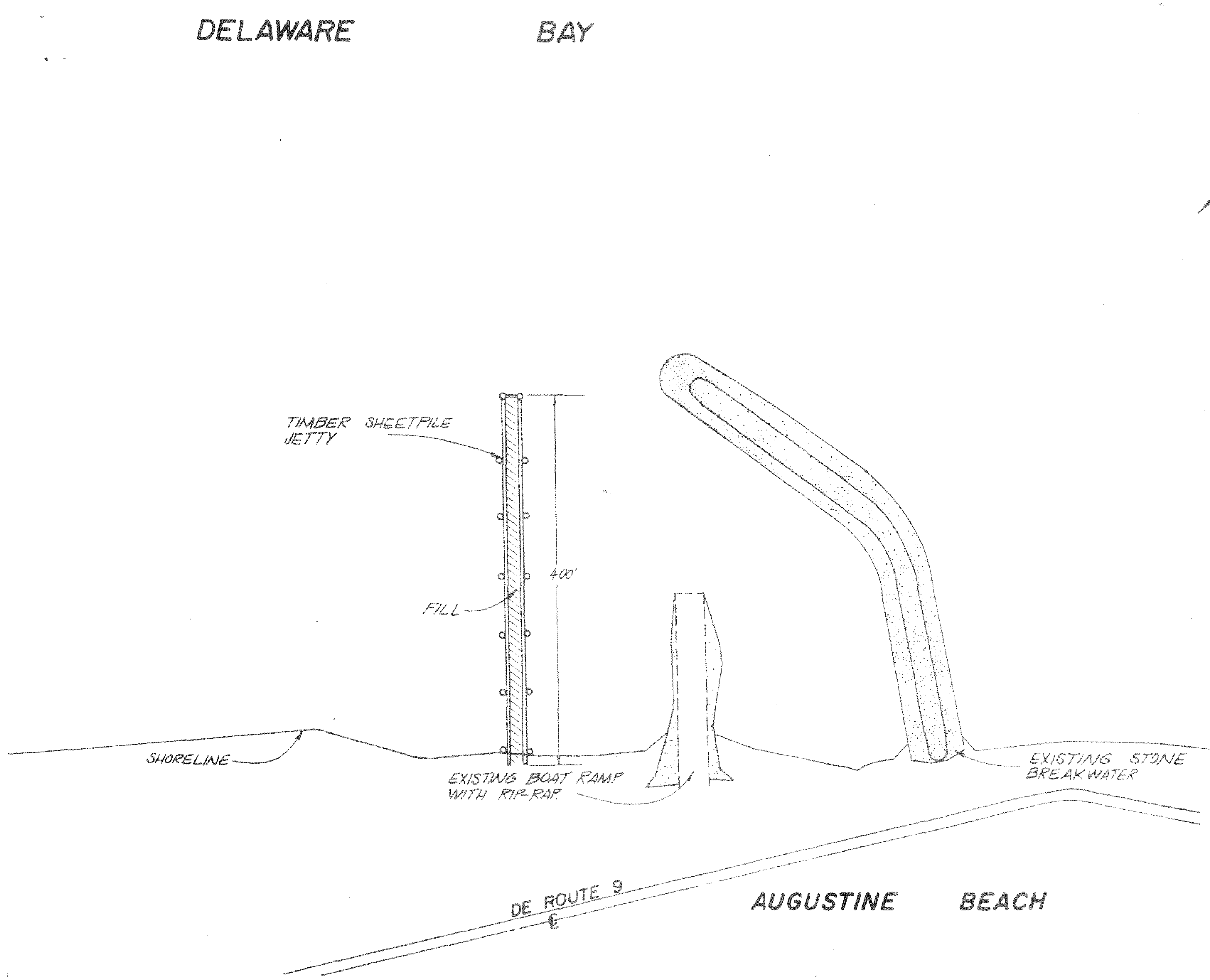
SCALE: 1" = 100' **FIGURE 1.**



ALTERNATIVE 5

STEEL SHEETPILE JETTY NORTH OF THE BOAT RAMP

SCALE: 1" = 100' FIGURE



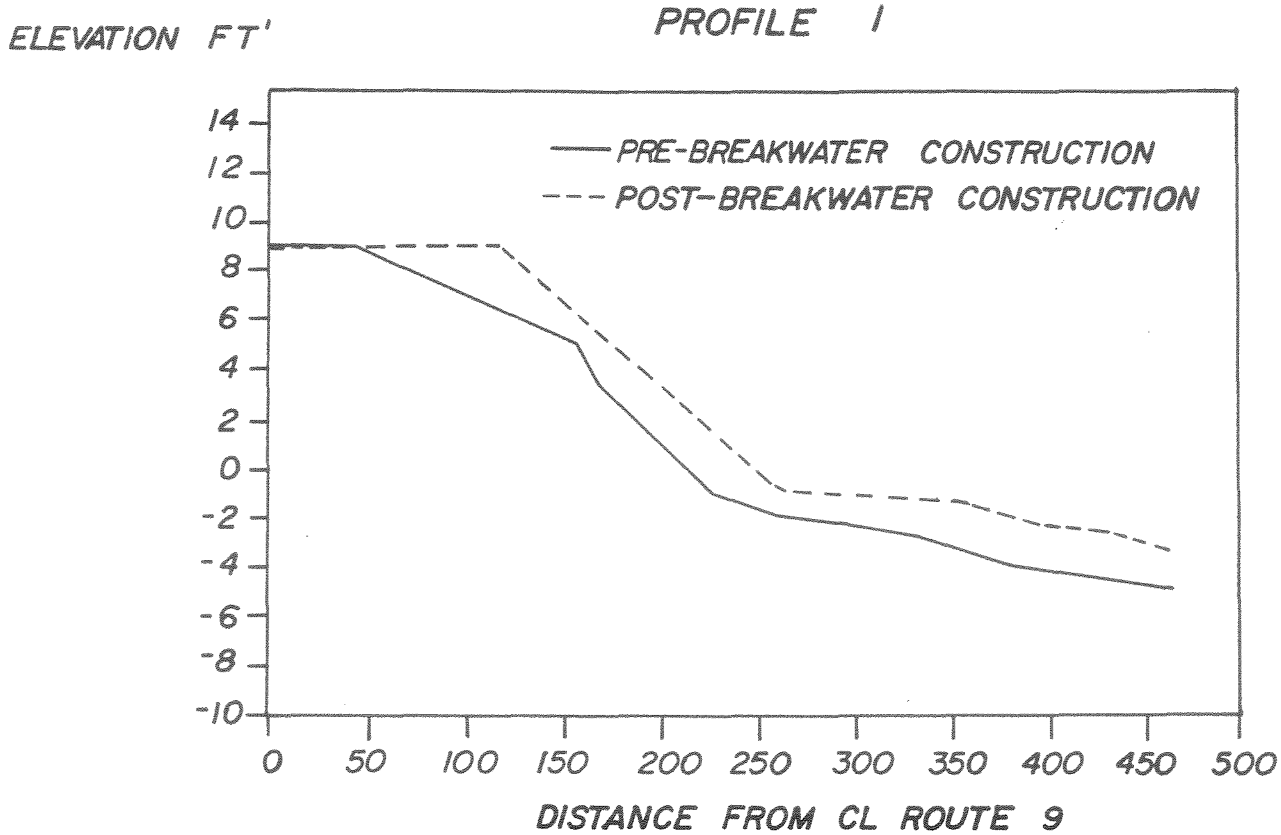
ALTERNATIVE 6

TIMBER SHEETPILE JETTY NORTH OF THE BOAT RAMP

SCALE: 1" = 100' FIGURE 15

MARSH SHORELINE NORTH OF AUGUSTINE BEACH

FIGURE 2


PROFILE 1
ELEVATION FT'
PRE-BREAKWATER CONSTRUCTION
POST-BREAKWATER CONSTRUCTION
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
0
50
100
150
200
250
300
350
400
450
500
DISTANCE FROM CL ROUTE 9

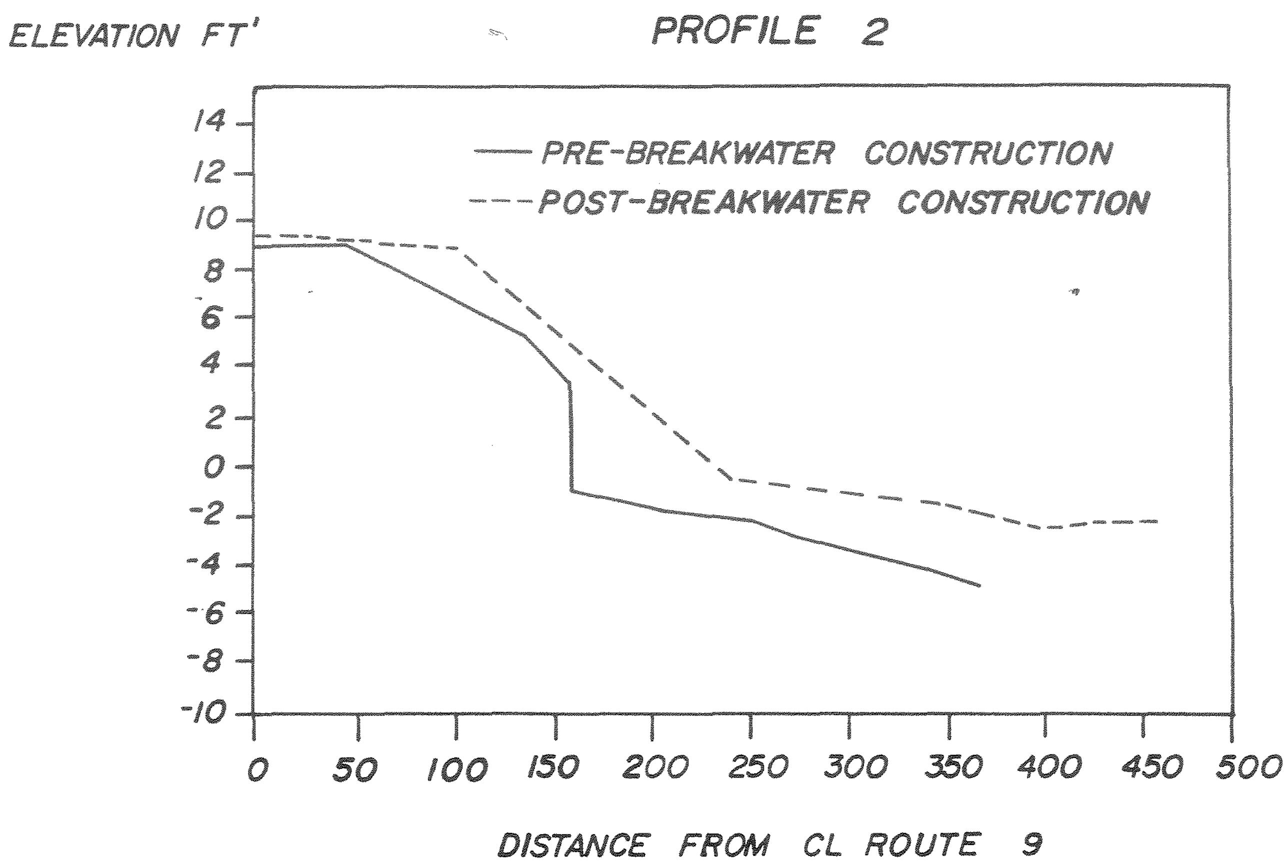

PROFILE 2
ELEVATION FT'
PRE-BREAKWATER CONSTRUCTION
POST-BREAKWATER CONSTRUCTION
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
0
50
100
150
200
250
300
350
400
450
500
DISTANCE FROM CL ROUTE 9

FIGURE 3

APPENDIX 1

RESULTS OF SEDIMENT ANALYSES

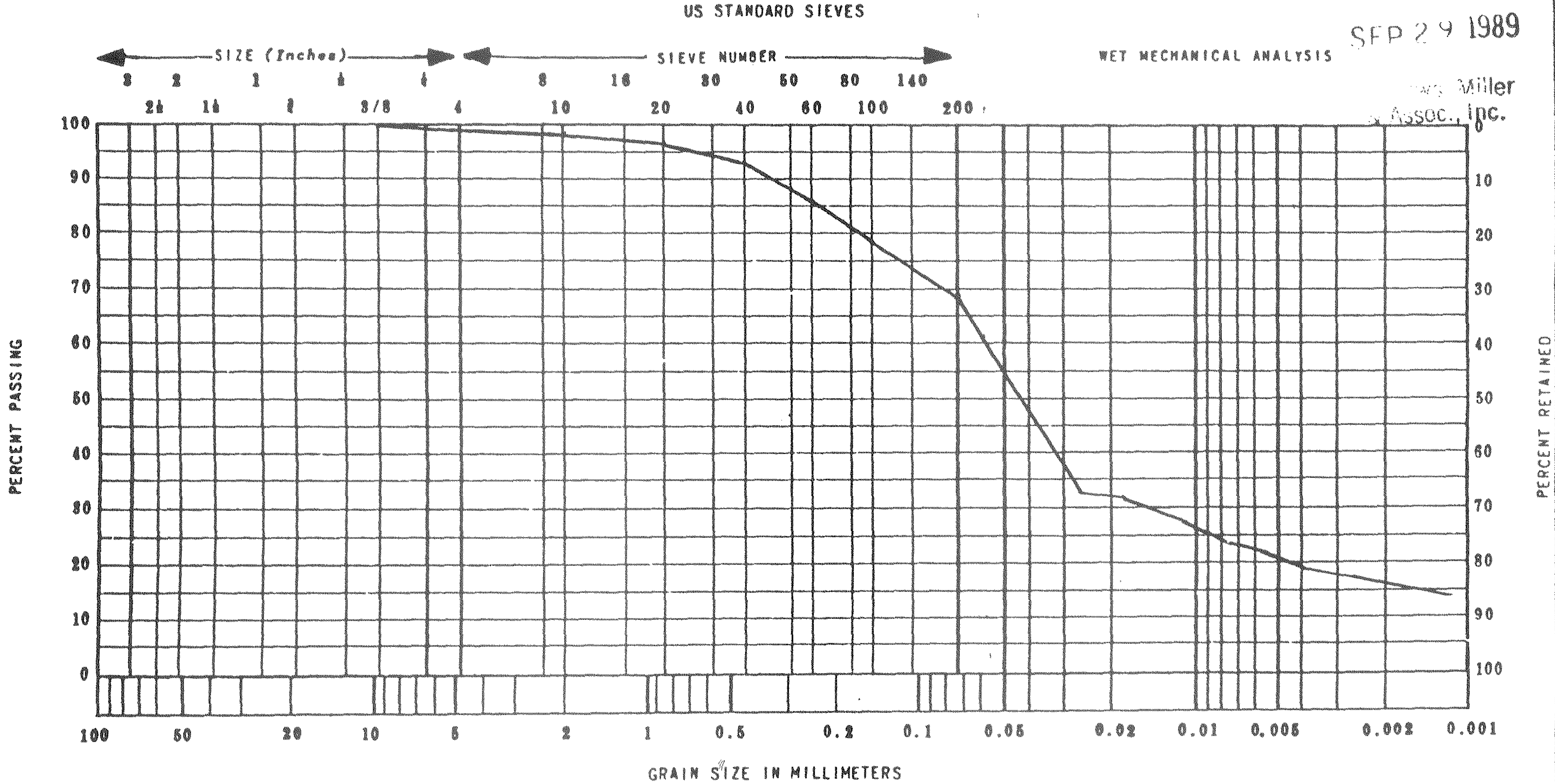
FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES • ENGINEERS & CHEMISTS

GRAIN SIZE DISTRIBUTION GRAPH - AGGREGATE GRADING CHART

DATE 9-22-89

PROJECT AUGUSTINE BREAKWATER F & R PROJECT NO. Q-73-319

Received SEP 29 1989 Miller Assoc., Inc.



EXCAVATION NUMBER	SAMPLE NUMBER	NATURAL % MOISTURE	w_L	w_P	I_P	CLASSIFICATION	REMARKS
CONTROL NO.	S-1	---	48	21	27	DK GRAY, LEAN CLAY	
26727						WITH SAND	
						(CL)	

TECHNICIAN (Signature) L.A.T.

PLOTTED BY (Signature) M.T.F.

CHECKED BY (Signature) [signature]

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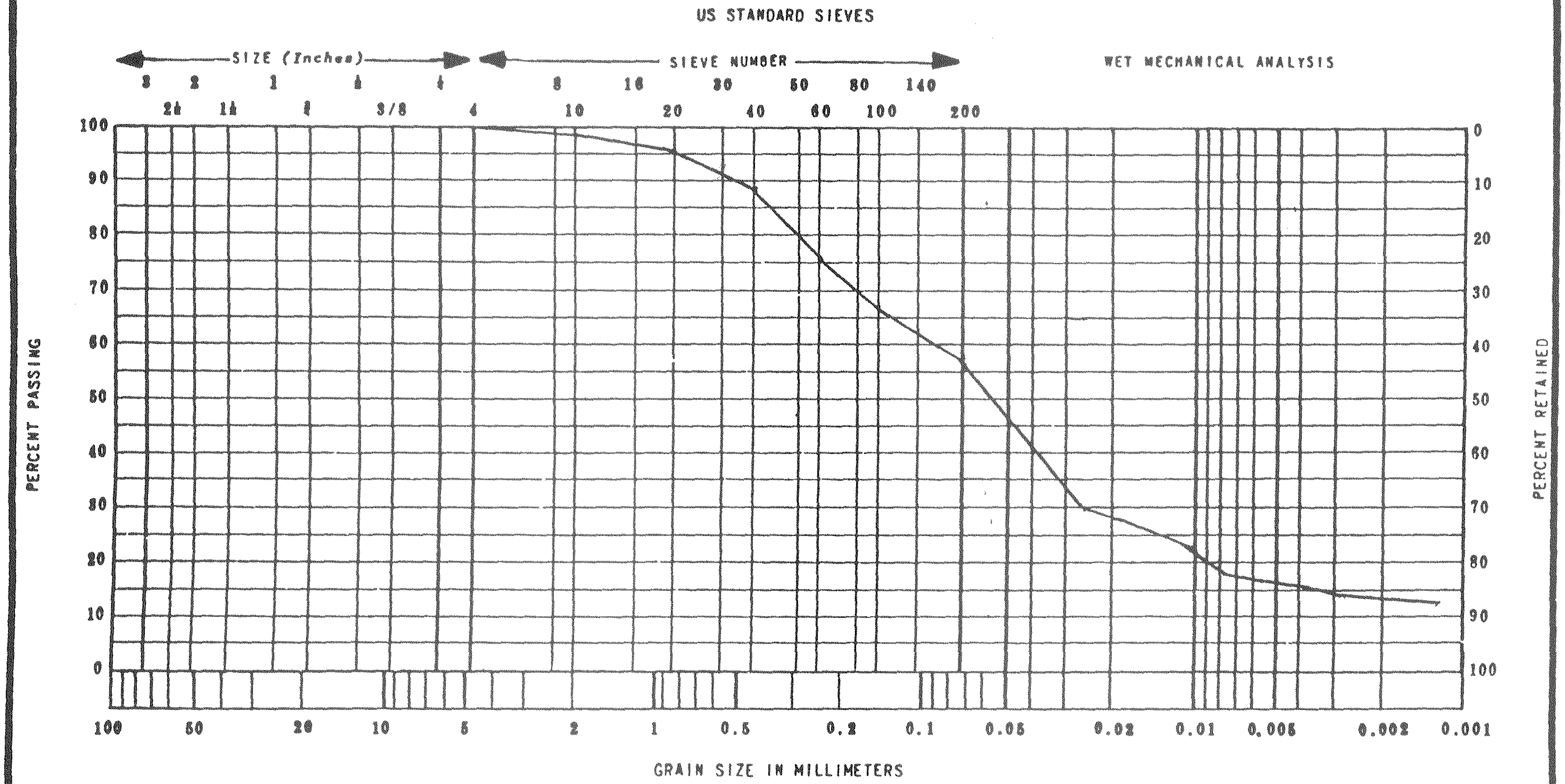
DATE: 9-22-89

PROJECT: AUGUSTINE BREAKWATER   F & R PROJECT NO. Q-73-319



EXCAVATION NUMBER	SAMPLE NUMBER	NATURAL % MOISTURE	w_L	w_P	I_P	CLASSIFICATION	REMARKS
CONTROL NO.	S-2	----	41	20	21	DK GRAY, SANDY	
26727						LEAN CLAY	
						(CL)	

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DATE: 9-22-89

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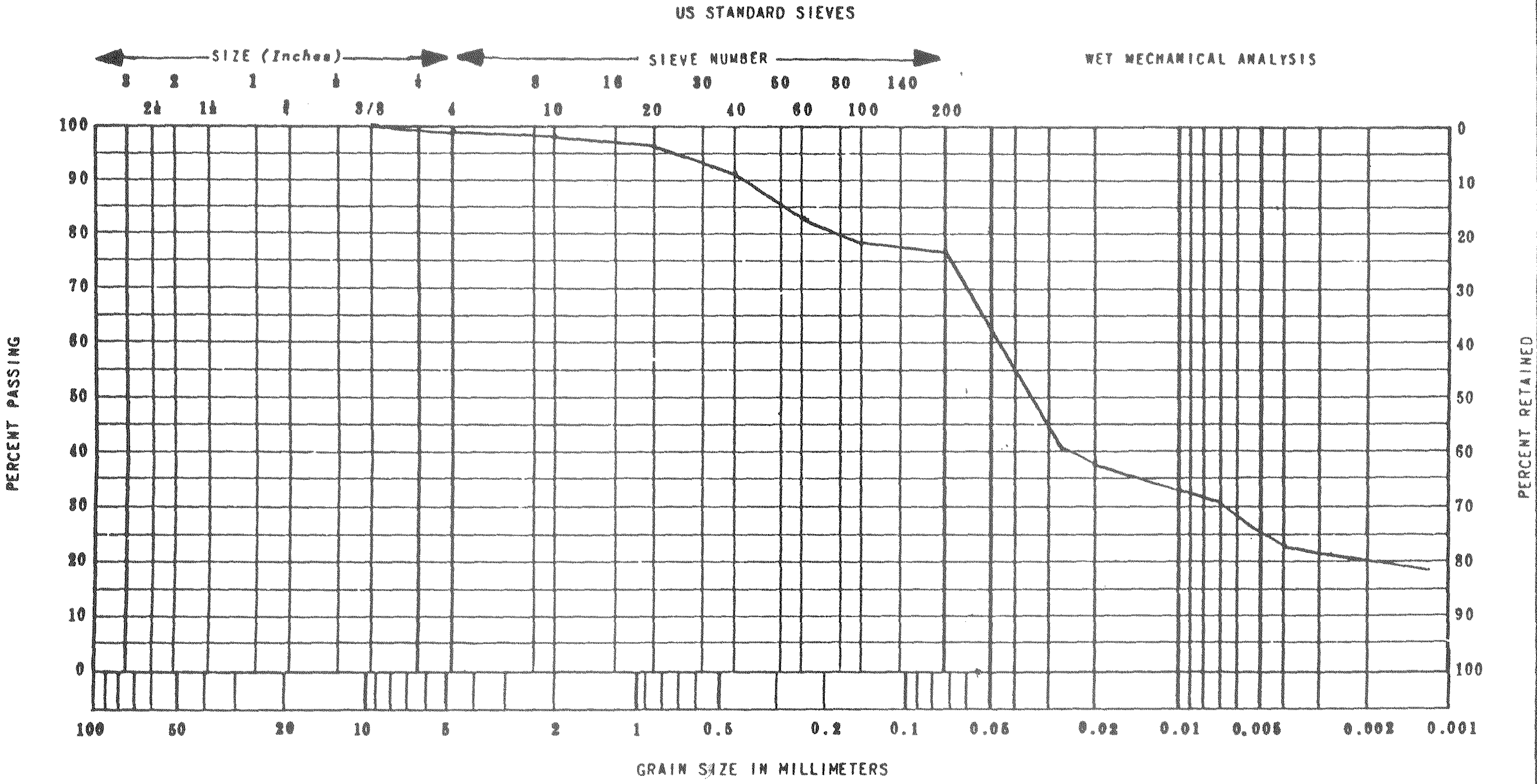

EXCAVATION NUMBER	SAMPLE NUMBER	NATURAL % MOISTURE	w_L	w_P	I_P	CLASSIFICATION	REMARKS
CONTROL NO. 26727	S-3	---	59	34	25	DK GRAY TO BLACK, ORGANIC SILT WITH SAND (OH)	

TECHNICIAN (Signature)	PLOTTED BY (Signature)	CHECKED BY (Signature)
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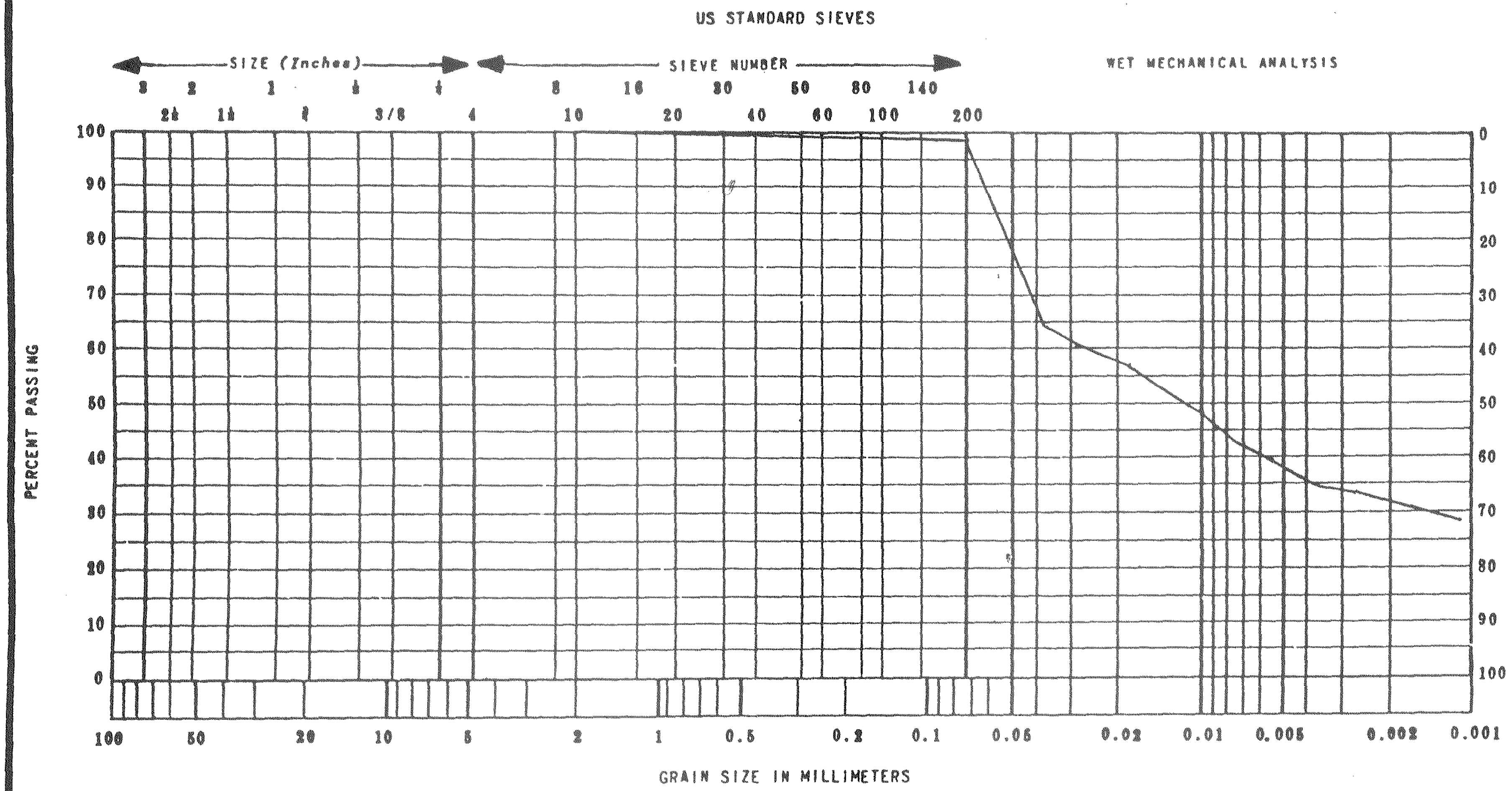
DATE 9-22-89

PROJECT SUGUSTINE BREAKWATER F & R PROJECT NO. Q-73-319



EXCAVATION NUMBER	SAMPLE NUMBER	NATURAL % MOISTURE	w_L	w_P	I_P	CLASSIFICATION	REMARKS
CONTROL NO.	S-6	---	91	45	46	DK GRAY TO BLACK,	
26727						ORGANIC SILT	
						(OH)	

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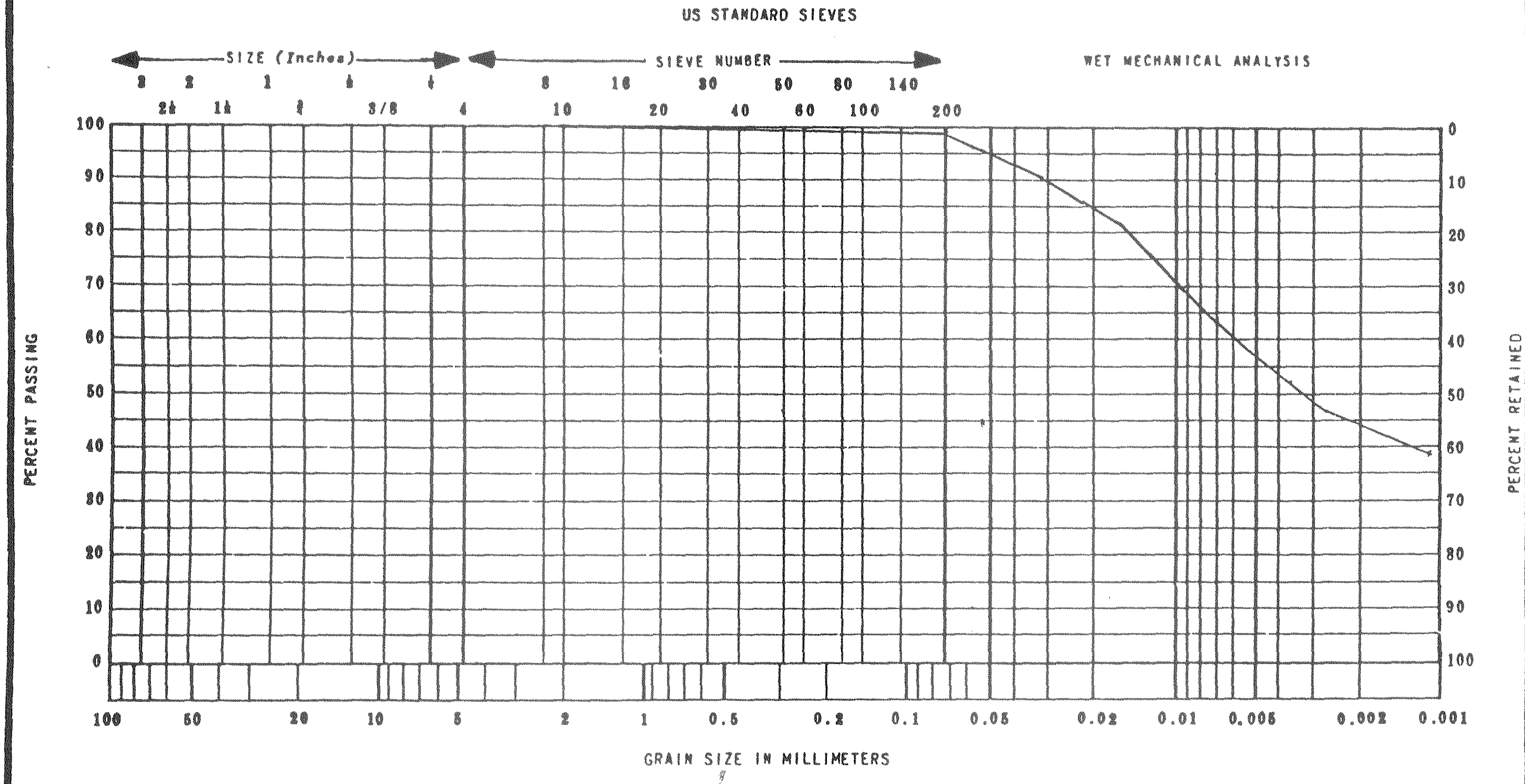
DATE: 9-22-89

PROJECT: AUGUSTINE BREAKWATER   F & R PROJECT NO. Q-73-319



EXCAVATION NUMBER	SAMPLE NUMBER	NATURAL % MOISTURE	w_L	w_P	I_P	CLASSIFICATION	REMARKS
CONTROL NO.	S-7	---	104	47	57	DK GRAY TO BLACK,	OVEN DRIED LIQUID LIMIT -- 66
26727						ORGANIC SILT	
						(OH)	

TECHNICIAN (Signature): L.A.T.   PLOTTED BY (Signature): M.T.F.   CHECKED BY (Signature): [signature]

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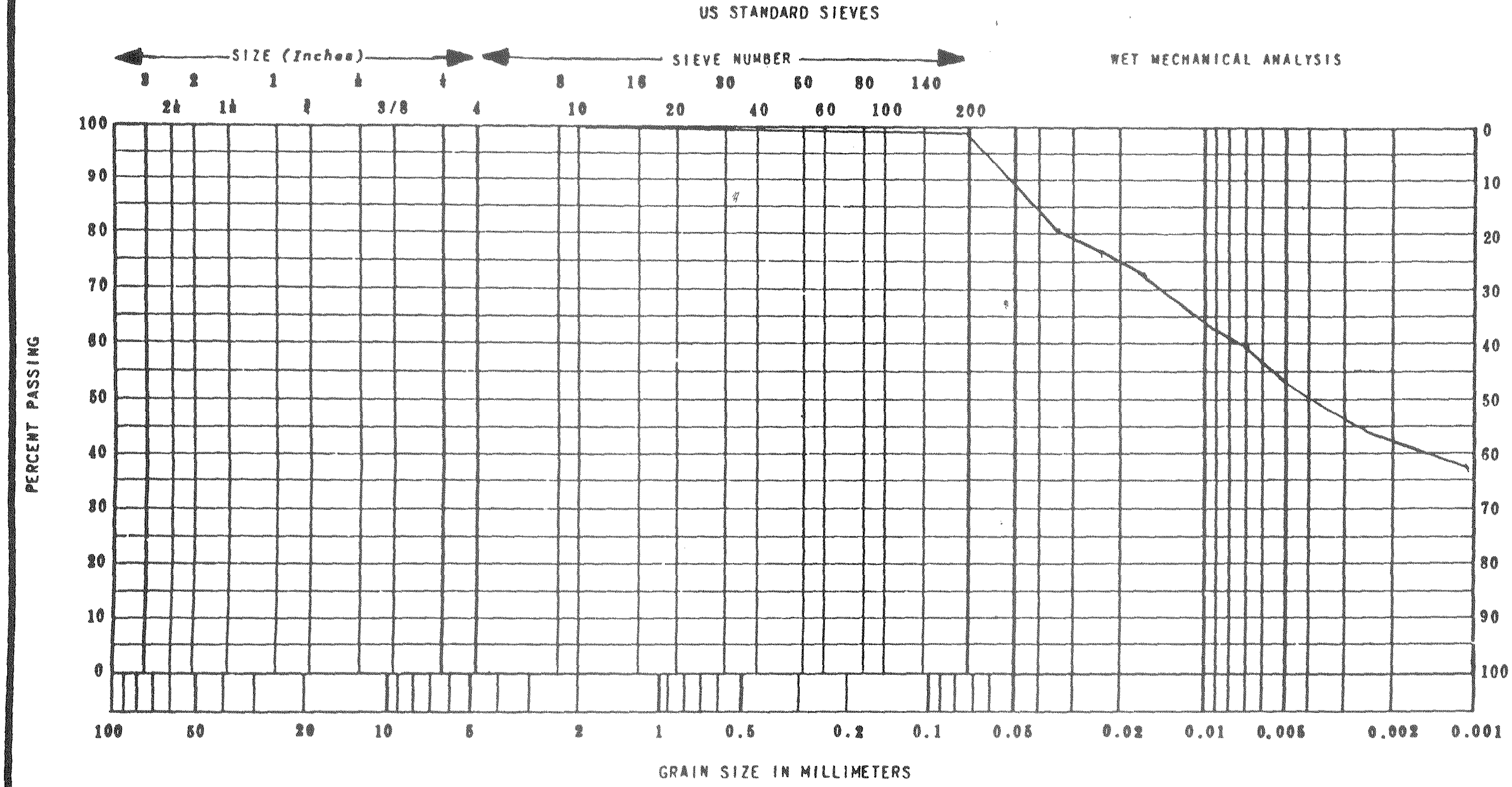
DATE 9-22-89

PROJECT AUGUSTINE BREAKWATER F & R PROJECT NO. Q-73-319



EXCAVATION NUMBER	SAMPLE NUMBER	NATURAL % MOISTURE	w_L	w_P	I_P	CLASSIFICATION	REMARKS
CONTROL NO.	S-10	----	127	43	84	DK GRAY TO BLACK,	
26727						ORGANIC **CLAY**	
						(OH)	

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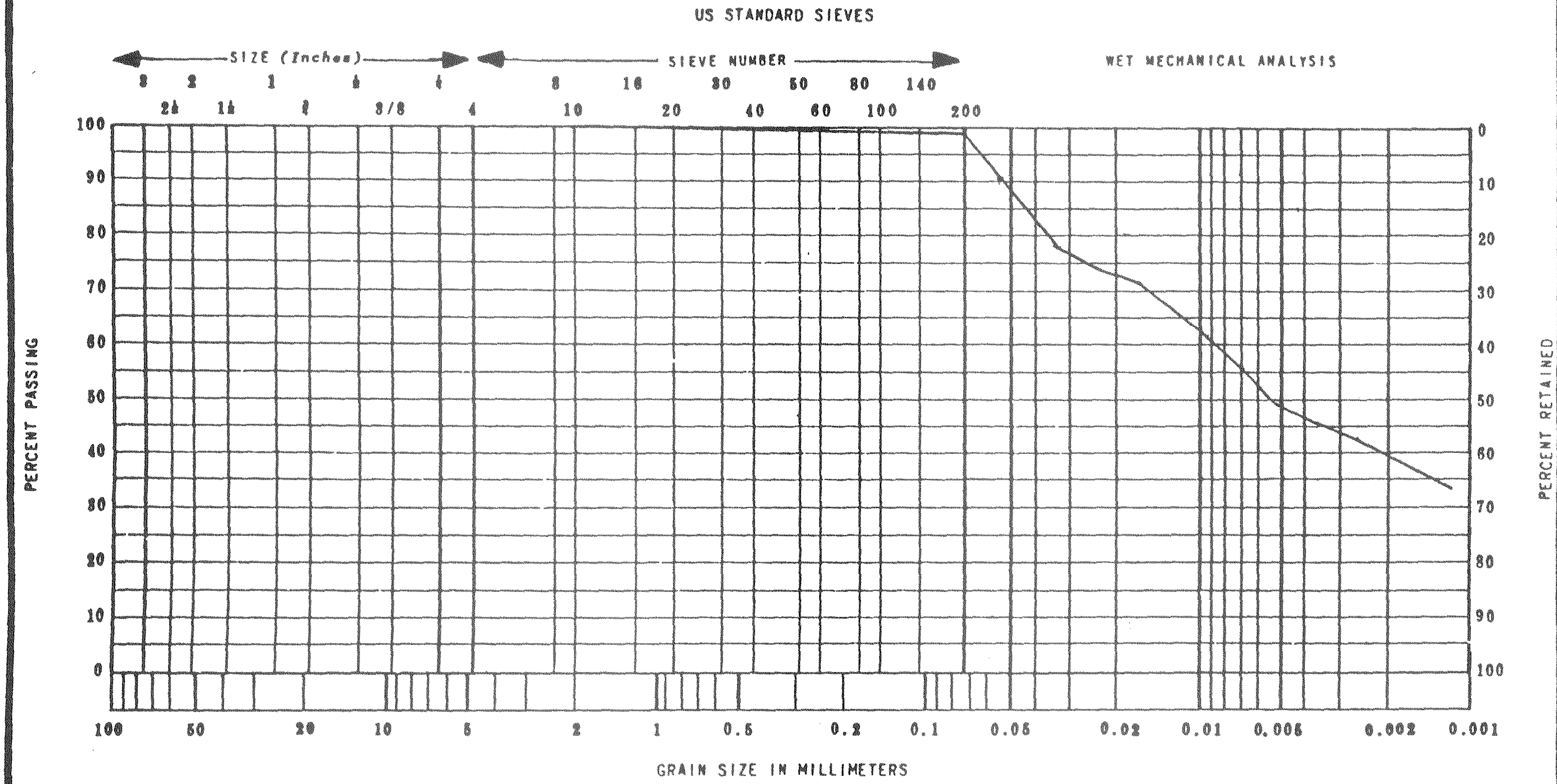
PROJECT

AUGUSTINE BREAKWATER F & R PROJECT NO. Q-73-319



EXCAVATION NUMBER	SAMPLE NUMBER	NATURAL % MOISTURE	w_L	w_P	I_P	CLASSIFICATION	REMARKS
CONTROL NO.	S-13	----	100	49	51	DK GRAY TO BLACK,	
26727						ORGANIC SILT	
						(OH)	

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L.A.T.	M.T.F.	[signature]

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DATE 9-22-89

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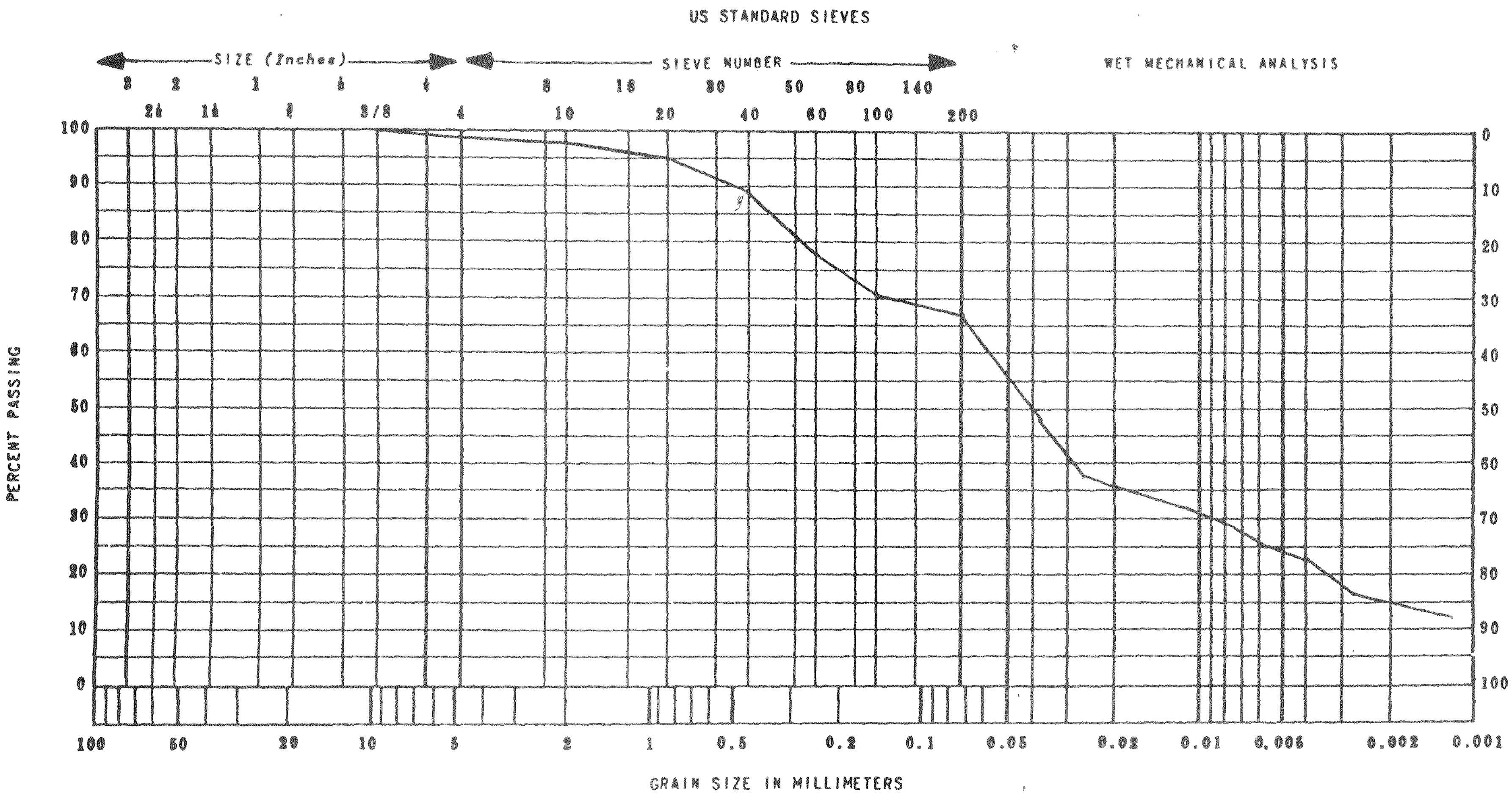
AUGUSTINE BREAKWATER F & R PROJECT NO. Q-73-319



EXCAVATION NUMBER	SAMPLE NUMBER	NATURAL % MOISTURE	w_L	w_P	I_P	CLASSIFICATION	REMARKS
CONTROL NO.	S-17	----	64	23	41	DK GRAY TO BLACK,	
26726						SANDY ORGANIC CLAY	
						(OH)	

TECHNICIAN (Signature) L.A.T.

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CHECKED BY (Signature) [signature]

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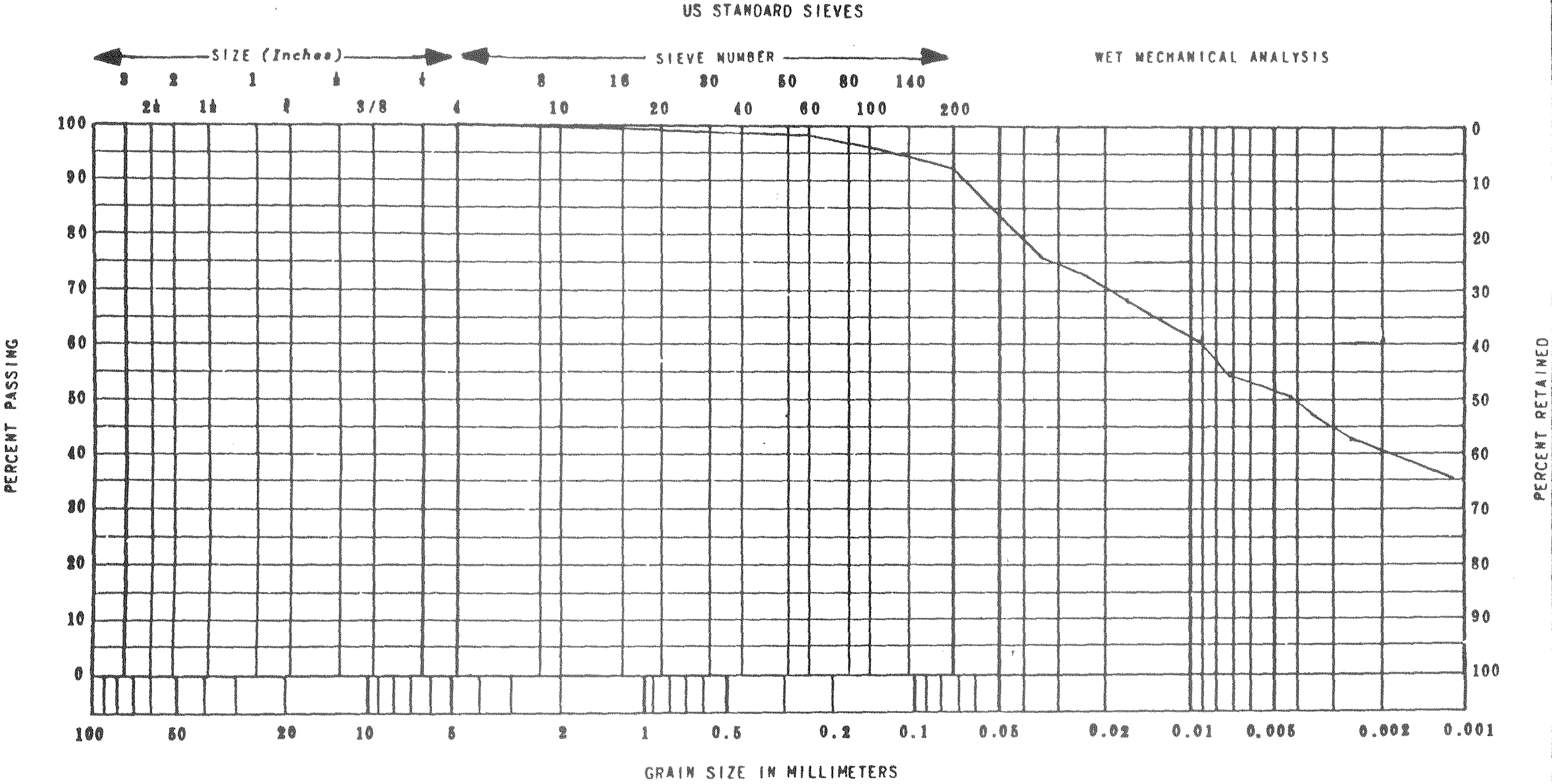
DATE 9-22-89

PROJECT
AUGUSTINE BREAKWATER F & R PROJECT NO. Q-73-319



EXCAVATION NUMBER	SAMPLE NUMBER	NATURAL % MOISTURE	w_L	w_P	I_P	CLASSIFICATION	REMARKS
CONTROL NO.	S-20	---	79	35	44	DK GRAY TO BLACK,	
26726						ORGANIC **CLAY**	
						(OH)	

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L.A.T.	M.T.F.	[signature]

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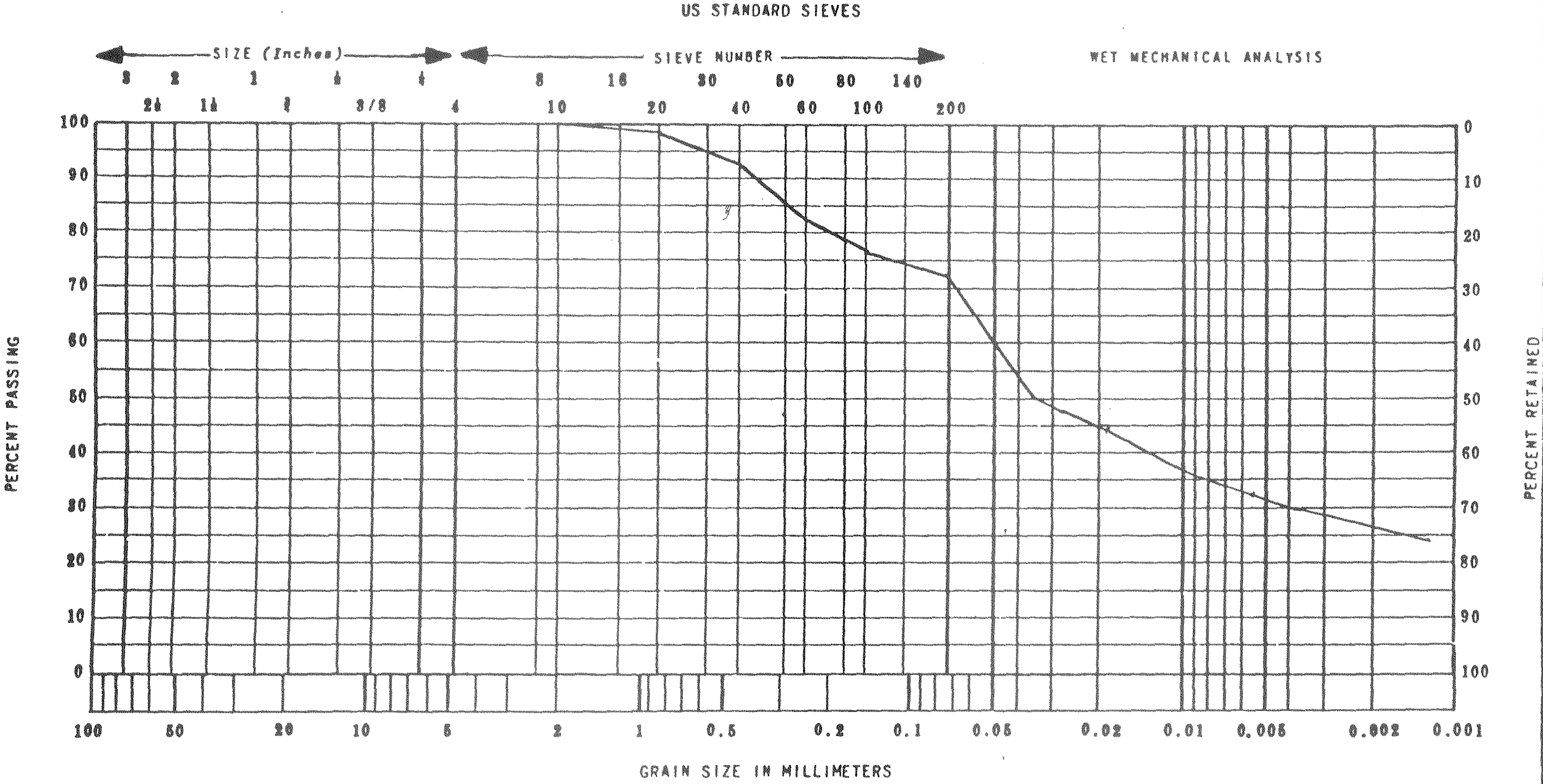
PROJECT

AUGUSTINE BREAKWATER F & R PROJECT NO. Q-73-319



EXCAVATION NUMBER	SAMPLE NUMBER	NATURAL % MOISTURE	w_L	w_P	I_P	CLASSIFICATION	REMARKS
CONTROL NO.	S-22	---	68	34	34	DK GRAY TO BLACK,	OVEN DRIED LIQUID LIMIT = 44
26727						ORGANIC **SILT** WITH	
						SAND (OH)	

TECHNICIAN (Signature)	PLOTTED BY (Signature)	CHECKED BY (Signature)
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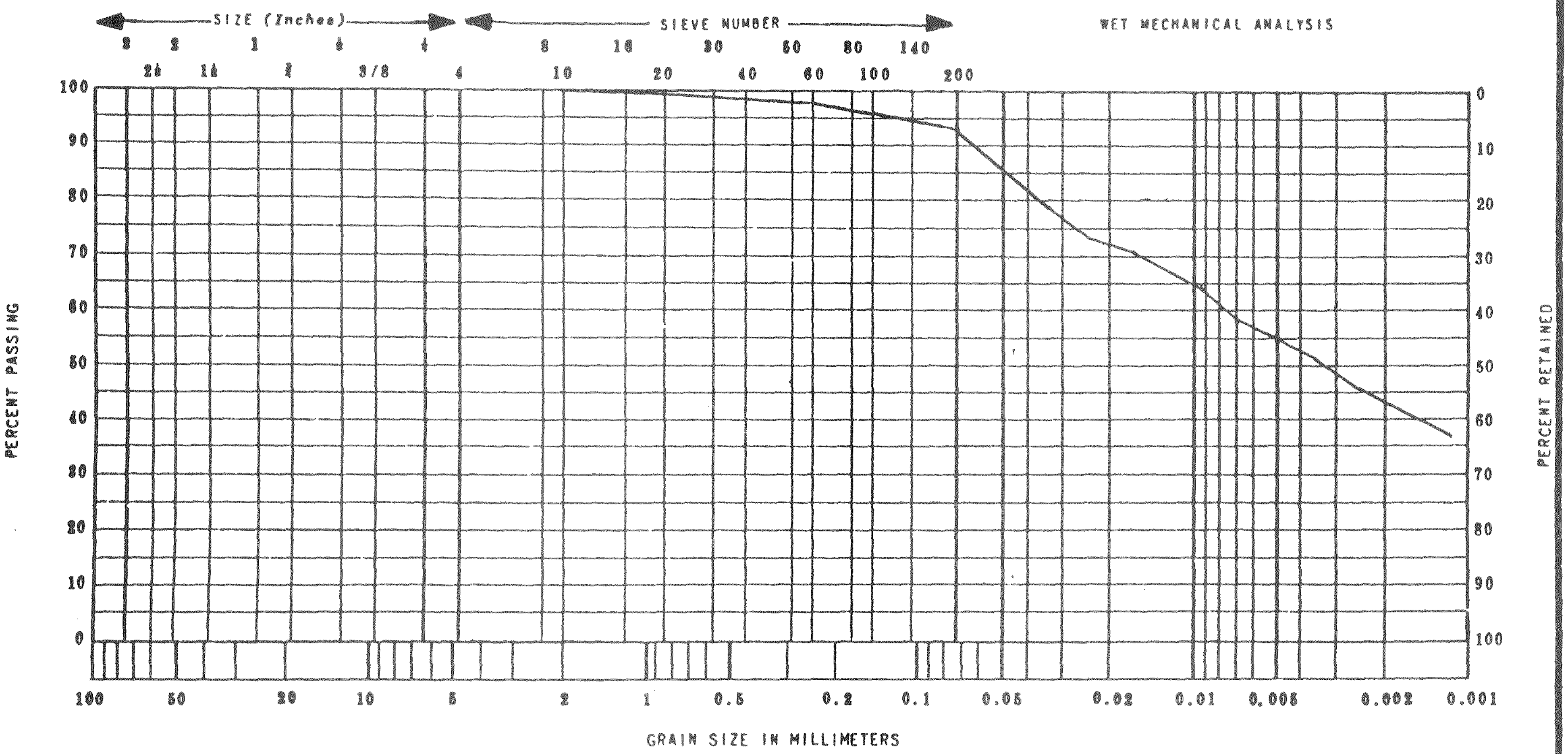

EXCAVATION NUMBER	SAMPLE NUMBER	NATURAL % MOISTURE	w_L	w_P	I_P	CLASSIFICATION	REMARKS
CONTROL NO.	S-23	---	102	38	64	DK GRAY TO BLACK,	
						ORGANIC **CLAY**	
						(OH)	

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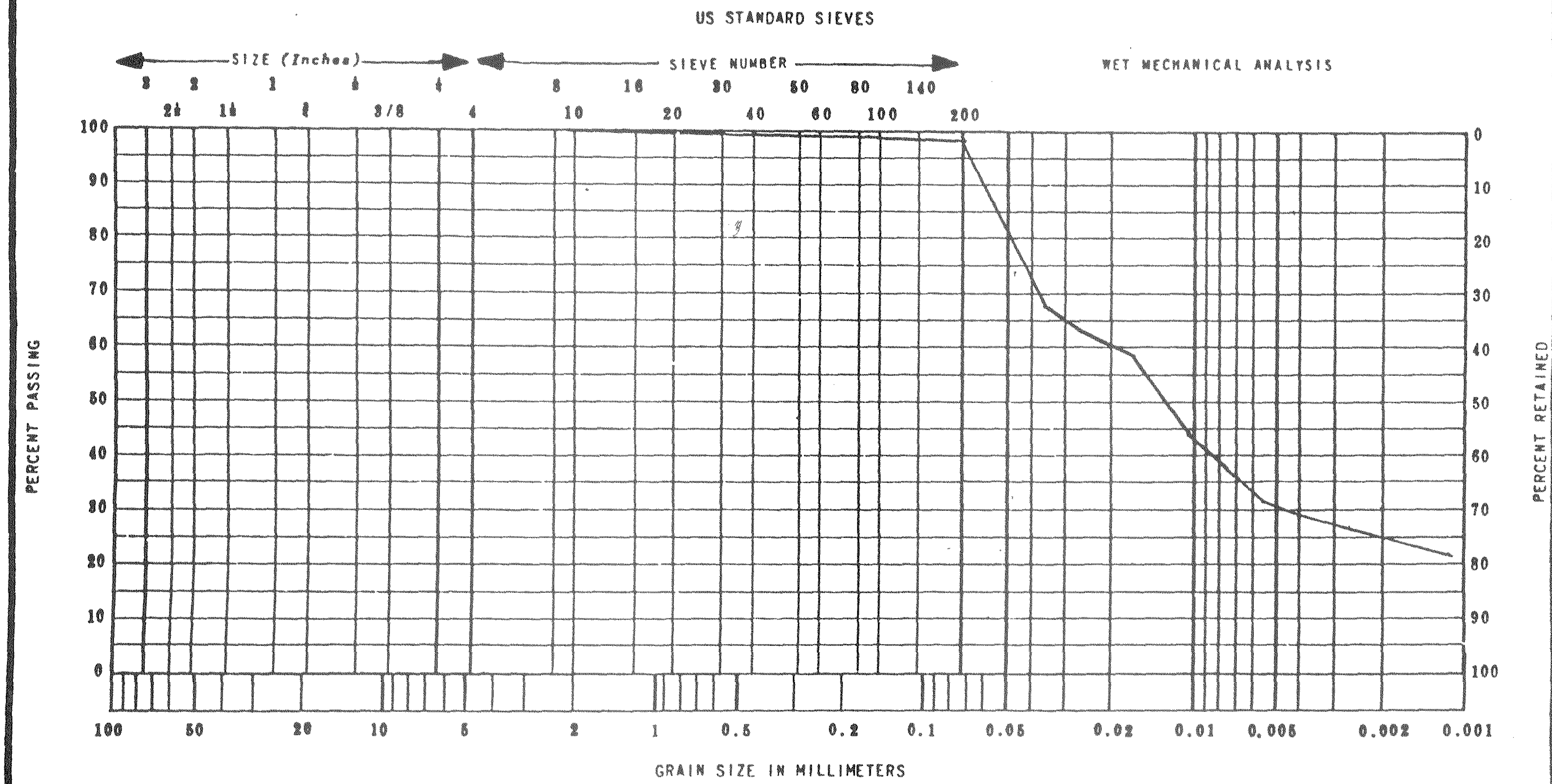

EXCAVATION NUMBER	SAMPLE NUMBER	NATURAL % MOISTURE	w_L	w_P	I_P	CLASSIFICATION	REMARKS
CONTROL NO.	S-24	---	62	33	29	DK GRAY TO BLACK,	
26726						ORGANIC SILT	
						(OH)	

TECHNICIAN (Signature)	PLOTTED BY (Signature)	CHECKED BY (Signature)
L.A.T.	M.T.F.	[signature]

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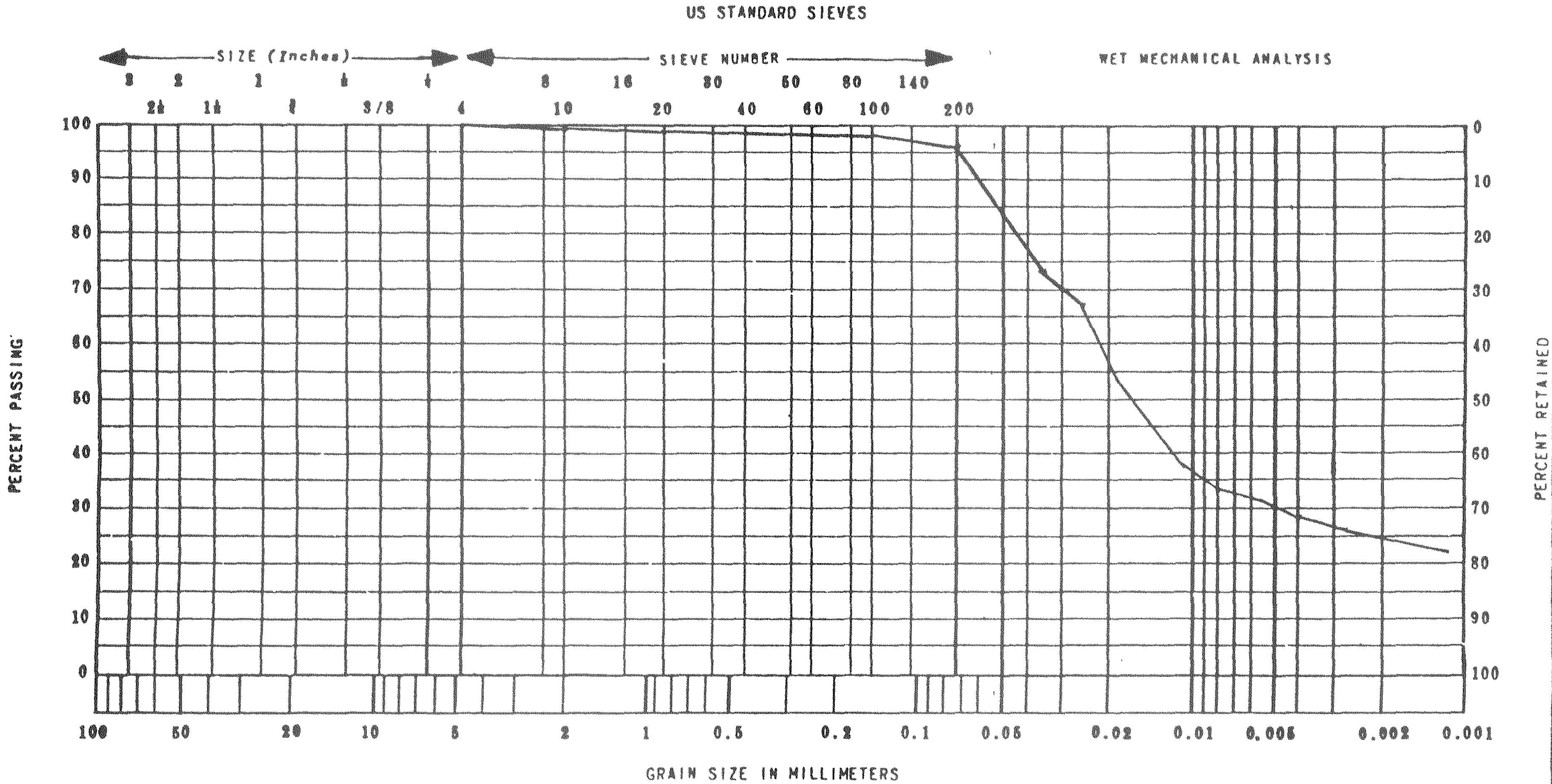

EXCAVATION NUMBER	SAMPLE NUMBER	NATURAL % MOISTURE	w_L	w_P	I_P	CLASSIFICATION	REMARKS
CONTROL NO.	S-25	---	45	27	18	GRAY, SILT	
26726							

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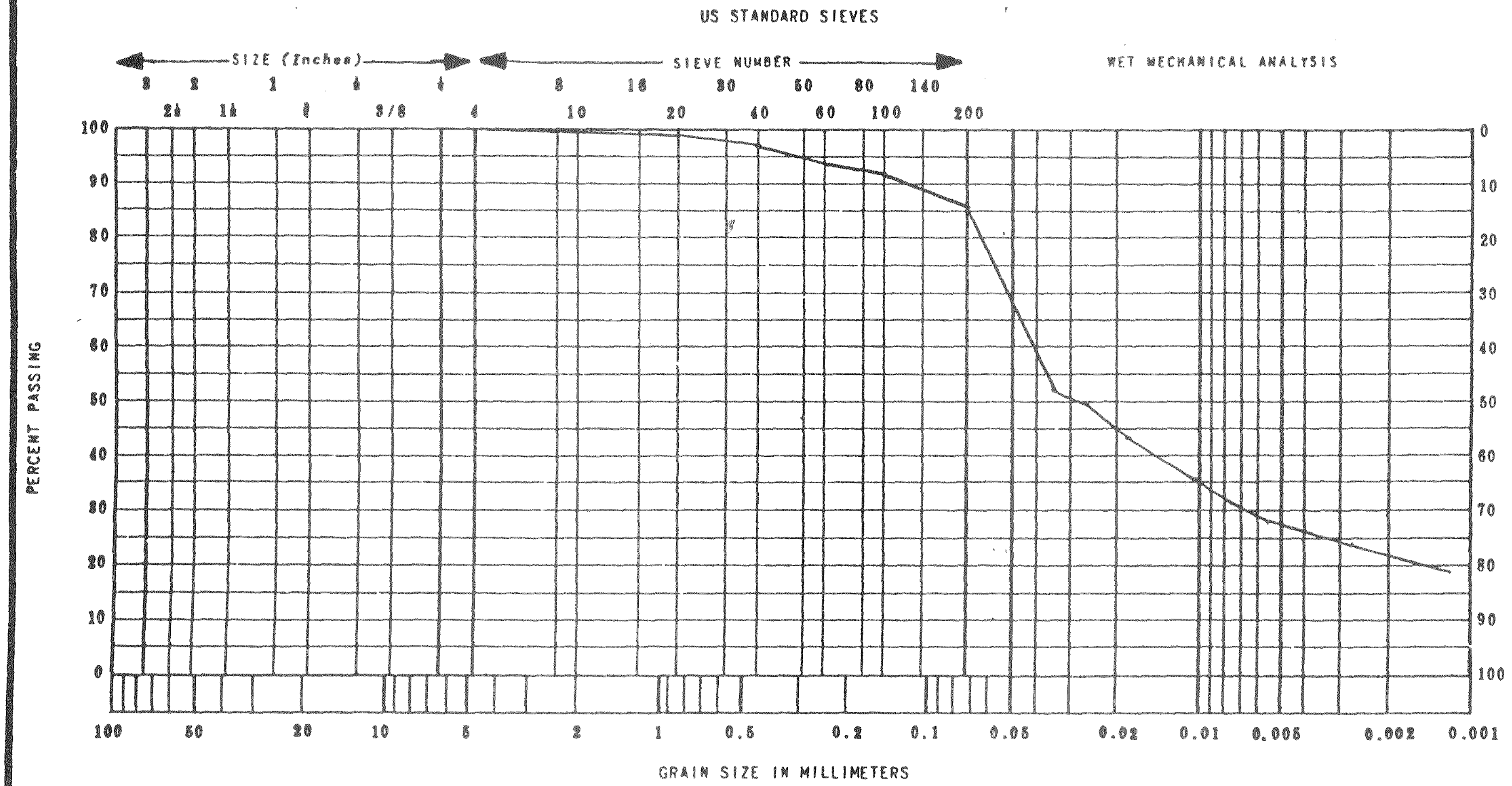

EXCAVATION NUMBER	SAMPLE NUMBER	NATURAL % MOISTURE	w_L	w_P	I_P	CLASSIFICATION	REMARKS
CONTROL NO.	S-26	----	60	31	29	DARK GRAY TO BLACK	OVEN DRIED LIQUID = 39
26727						ORGANIC **CLAY**	
						(OH)	

TECHNICIAN (Signature): L.A.T.

PLOTTED BY (Signature): M.T.F.

CHECKED BY (Signature): [signature]

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