THE SUPPORTING VALUE OF MARL FOR HIGHWAY EMBANKMENTS

THESIS FOR THE DEGREE OF M. S.

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THESIS

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To Mr. F. R. Olmstead, State Highway Laboratory, who made the chemical analysis of the marl samples collected.

INTRODUCTION

Michigan swamps range in depth from a few inches to sixty feet or more. All soft materials such as muck, peat, marl and lacustrian clay found in these swamps were, until recently, considered unsuitable for supporting highway embankments. They were therefore usually removed and the cut filled with suitable materials. Needless to say this practice added materially to the cost of highway construction. It was finally observed, however, that occasionally road fills would become perfectly stable despite the fact that very little of the underlying soft material had been disturbed. Investigation disclosed that there are three groups of swamp materials which more or less successfully support highway embankments. These materials are marl, mixtures of peat and sand, and soft lacustrian clay.

Marl deposits may be larger, occur more frequently, and include greater variations in composition and position than the other groups of materials mentioned, and consequently offer more of a problem to the highway engineer. This paper deals with the supporting value of marl.

The term "marl" as used in this report refers only to fresh water deposits of lime carbonate ($CaCO_3$). Such deposits are never absolutely pure, but usually contain varying amounts of fine sand, clay, or peat. Sand improves the supporting value of marl by its contribution to the internal friction and unit weight of the marl body. The influence of clay may be beneficial or detrimental depending on its position, distribution and amount.

Unlike sand and clay, peat, because of its small volume, weight, great water retaining capacity, and coefficient of expansion upon wetting, is far more important than percentage figures based on dried weight would indicate. The two tables that follow illustrate how the weights of marl and peat compare (1) to other soil materials and (2) to each other.

1. The weight of one cubic foot of (1) (3) (4)*

Water		62.42 pounds
Dry sand	Approx.	100.00 "
Dry clay	"	85.00 "
Air dry marl	"	55.00 "
Dry muck	"	40.00 "
Air dry peat	"	15.00 "

2. The peat and marl content of a single sample under different conditions. ** (1) (4)

Basis of comparison	Peat	Marl
Air dried. Figures based on volume.	50%	50%
Saturated condition. Figures based on volume.	76%	24%
Air dried. Figures based on weight	15%	85%

* Numbers in parenthesis refers to literature cited on P. 31

** Figures are approximate and based on weight and shrinkage factors contained in the literature cited.

Numerous tests, results of which appear in table page 26 , containing enough lime to be recognized as marl by visual field inspection may contain from 90 to 99 percent $CaCO_3$ provided, of course, that the impurities are organic rather than sand or clay.

Marl has certain physical properties which are of considerable assistance in distinguishing it from other swamp materials. Marl and peat, for instance, are quite easily separated on the basis of color alone. When moist, peats range from various shades of green and brown to black, while marl varies from almost pure white to dull gray or slate. After these materials have dried, however, peat becomes dark brown or black and marl, gray or white.

The inexperienced investigator often has considerable difficulty in distinguishing marl from clay. Color is of assistance since the most common color of lacustrian clay is a blue to bluish gray instead of the gray or white of marl. Plasticity is another property by which clay can be distinguished from marl. Wet clay feels very sticky when tested between the thumb and fingers while marl shows very little or no cohesive properties when tested in this manner. There is also a difference in the way marl and clay are deposited relative to position. The lacustrian clays are always found at the bottom of the deposit and are usually thickest in the deepest part of the swamp. Marls, on the other hand, may occur anywhere in the swamp profile with the purest samples coming from the shallower portions of the swamp.

Aside from color, probably the easiest way to distinguish marl is by its texture, variations of which depend upon the mode of formation. In all the deposits encountered in this study the bulk of the marl was so fine grained that individual grains could not be recognized by the unaided eye. However it always had a decidedly "chalky" feel. In most cases some material with a finely granular texture was present and could be recognized by rubbing a small amount of marl between the thumb and fingers. Some shell material was generally present and on close examination the fine cylinders deposited by Chara usually could be found.

REVIEW OF LITERATURE

Marl is described by C. A. Davis (6) as follows: "Marl, when dry and pure, is white or slightly cream colored, nodular, coarsely granular to finely powdery, very loosely coherent and effervescing freely with acids."

It is not the purpose of this paper to discuss the geology of marl deposits, but as a matter of interest it may be in order to quote a summary contained in a paper written by Dr. R. A. Smith, State Geologist. (5).

"The facts so far stated may be summarized as follows: Spring or stream water, carrying lime carbonate in solution, deposits it in lakes in the form of marl, this deposition being caused by:

1. Escape of carbon dioxide, owing to decrease in pressure.
2. Supersaturation, owing to rise in temperature.
3. Abstraction of carbon dioxide by plants.
4. Freeing of oxygen by plants, resulting in the formation of carbonates from bicarbonates.

5. Direct abstraction and crystallization of lime salts by Chara.

6. Abstraction of lime by molluscs and formation of shell deposits."

No studies dealing directly or indirectly with the supporting value of marl for highway or other embankments have come to the attention of the writer.

EXPERIMENTAL

Much of the investigational work on which this paper is based has been carried on over a period of four years. The field work has consisted mainly of sounding, boring, sketching, collecting samples, making settlement studies, and obtaining pictures. Follow up inspections have been made to check the behavior of pavements where surfacing has been laid. Soundings have been made by means of the Davis peat sampler. Borings were made by means of a hydraulic drilling outfit. The laboratory work has consisted of determining the moisture content and complete analysis of a number of peat and marl samples.

Out of a large number of so-called "sink holes" where fills have been made, seven have been chosen for the particular information that each may contribute to this study. Some of these marl deposits show almost perfect support of the highway fill while others have apparently afforded little support. This difference in behavior reflects the effects of various peat and clay impurities in the marl.

Each deposit is designated by a project number under which heading the location, cross sections, records of work done and results observed will be recorded and discussed.

Project 063 - 21

This marl deposit lies about four miles south of Pontiac on the Telegraph Road, Oakland County. It is surrounded by hills of morainic origin which are composed of sand, gravel and clay more or less segregated. The hills to the north, especially, are very springy along the base and at one location furnishes water for an artificial lake which occupies part of the depression in which this deposit lies.

The profile and cross sections (Figures 1, 2 and 3) show that the marl is covered by a very thin layer of muck. Borings also indicate that while the deposit varies greatly in depth it is very uniform in composition both vertically and horizontally. Some aquatic peat has been deposited with the marl, mainly in the deeper portion of the swamp at station 547/50.

063-21 Telegraph Rd. Sta 546 - 554
Looking N. Marl deposit in foreground
Stokstad 4-26-33

Figure 1.

A longitudinal profile showing a deposit of marl supporting a highway fill. Note the small extent to which the fill and underlying muck has settled into the marl.

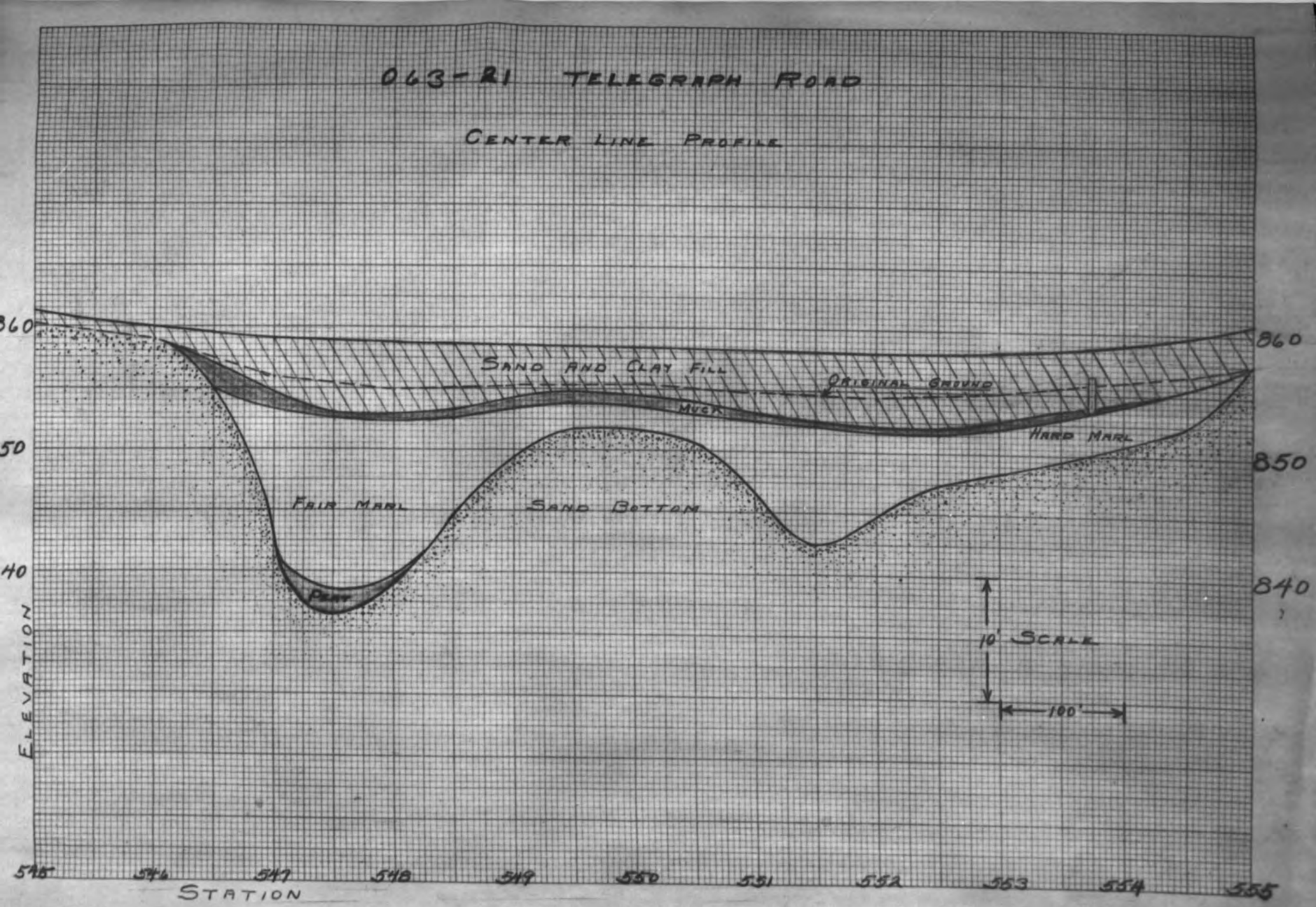

063-R1 TELEGRAPH ROAD
CENTER LINE PROFILE
SAND AND CLAY FILL
ORIGINAL GROUND
MUCK
HARD MARL
FAIR MARL
SAND BOTTOM
PEAT
10' SCALE
100'
ELEVATION
STATION
860
850
840
545
546
547
548
549
550
551
552
553
554
555

FIG. 1

Figure 2.

A cross section taken at station 547+50 of the profile shown in Figure 1.

Under modern construction procedures the muck between the clay fill and marl would have been excavated. The muck seems to be largely responsible for what fill penetration has been obtained at this point.

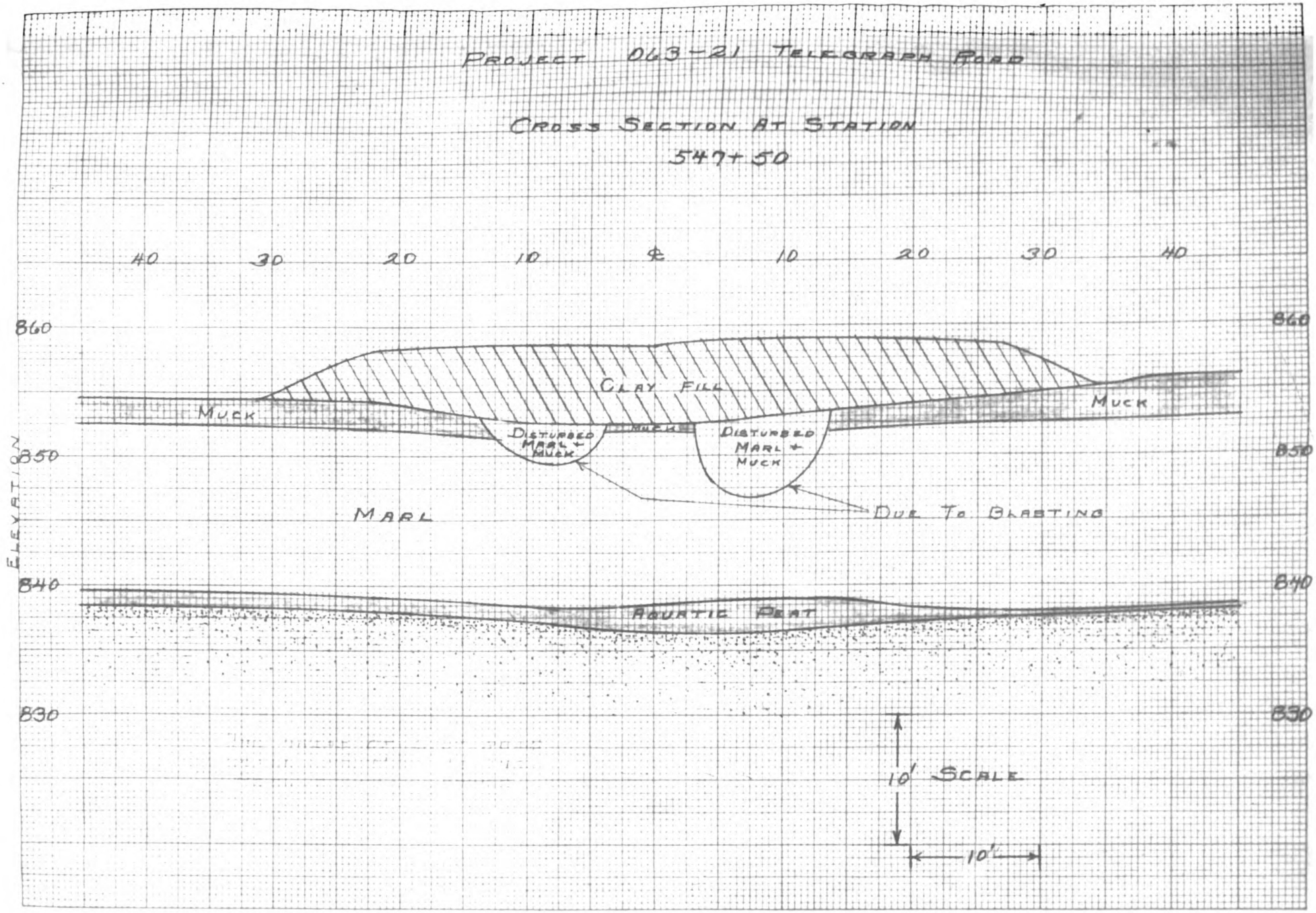

PROJECT 063-21 TELEGRAPH ROAD
CROSS SECTION AT STATION
547+50
40
30
20
10
℄
10
20
30
40
860
850
840
830
ELEVATION
CLAY FILL
MUCK
MUCK
DISTURBED MARL + MUCK
MUCK
DISTURBED MARL + MUCK
MARL
DUE TO BLASTING
AQUATIC PEAT
10' SCALE
10'

FIG. 2

Figure 3.

A cross section taken at station 550+50 of the profile shown in Figure 1.

Note again the efficiency with which marl supports highway embankments. There does not seem to be much difference in the amount of penetration at the two locations illustrated by figures 2 and 3.

PROJECT 063-21 TELEGRAPH ROAD

CROSS SECTION STATION
550+50

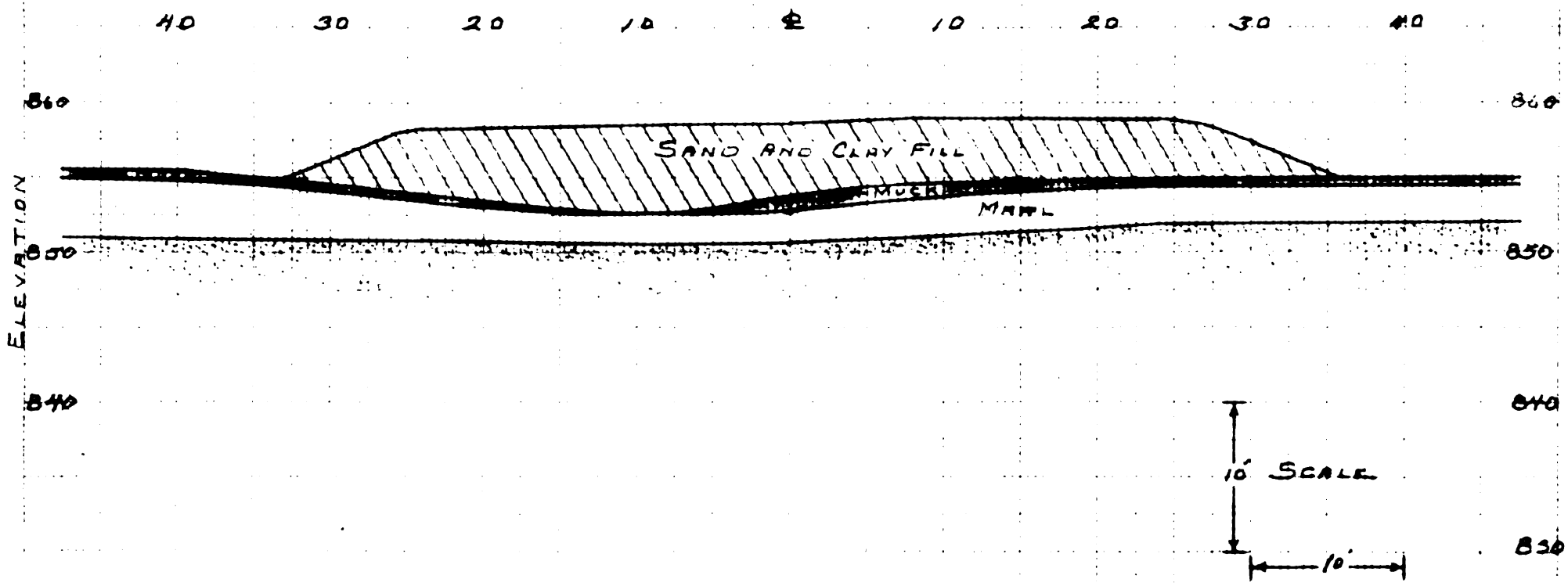


FIG. 3

When the original survey was made at this location ordinary rod soundings indicated soft unstable foundation conditions. It was assumed that the peat visible on the surface extended the entire depth of the soundings, consequently plans were prepared for sinking the fill and displacing the peat by the use of dynamite. The construction operations of filling and blasting were carried on in July and August, 1928. Field engineers were somewhat puzzled to find that in spite of their efforts they obtained very little settlement of the fill into the soft underlying material. A soil study was therefore made. The results obtained are illustrated by figures 1, 2 and 3. This project was the first to emphasize the extent to which marls would support highway embankments.

The pavement has been in place at this location for four years with very little apparent settlement. There is a slight dip between stations 546+50 and 548 that reaches a maximum of about six inches. This dip is not sudden, however, and the average driver does not notice it.

Some observations made while studying this deposit are:

1. The aquatic peat present has been deposited below the marl and is located about 16 feet beneath the surface.
2. Marl that is relatively free from organic impurities is capable of supporting a highway fill.

3. Dynamite charges left cavities in the marl and fill into which water drained from the fill surface.
4. Very little settlement has resulted on this deposit despite the fact that no adequate surcharge* was used to compact the marl.

*When an embankment is built especially high in order to compact underlying peat or marl, the portion of the fill that rests above the final grade line is referred to as surcharge.

Project 063 - 22

This deposit is located about one mile north of Ortonville on M-15. The poor alignment on the old gravel road was corrected at this location and necessitated a 25 foot cut immediately south of the swamp. This cut extends thru uniform sand and gravel (Bellefontaine sandy loam) and is of particular interest because of the very large number of lime concretions found below the weathered portion of the soil. This observation helps to explain the unusual centerline profile of the deposit illustrated by figure 4.

063-22 Ortonville N. Sta 563 to 571
Peat & marl deposit in foreground.
Bellefontaine hill in background
Stokstad 1-24-33

The gravelly hill at station 560 to 564 evidently has been the source of both moisture and lime as proven by the fact that the marl deposit is thickest and purest next to the hill. A bench swamp has also developed above the marl and up the hillside which could only take place under quite uniform seepage.

Figure 4.

A profile view showing adjoining cut and fill sections. The surface peat was excavated six feet deep before placing the sand fill. The sand influence between station 568 and 569 undoubtedly helped to support the fill thru the area of aquatic peat in that part of the swamp. The main stabilizing influence throughout the deposit, however, is marl.

CENTER LINE PROFILE

063-22 ORTONVILLE NORTH

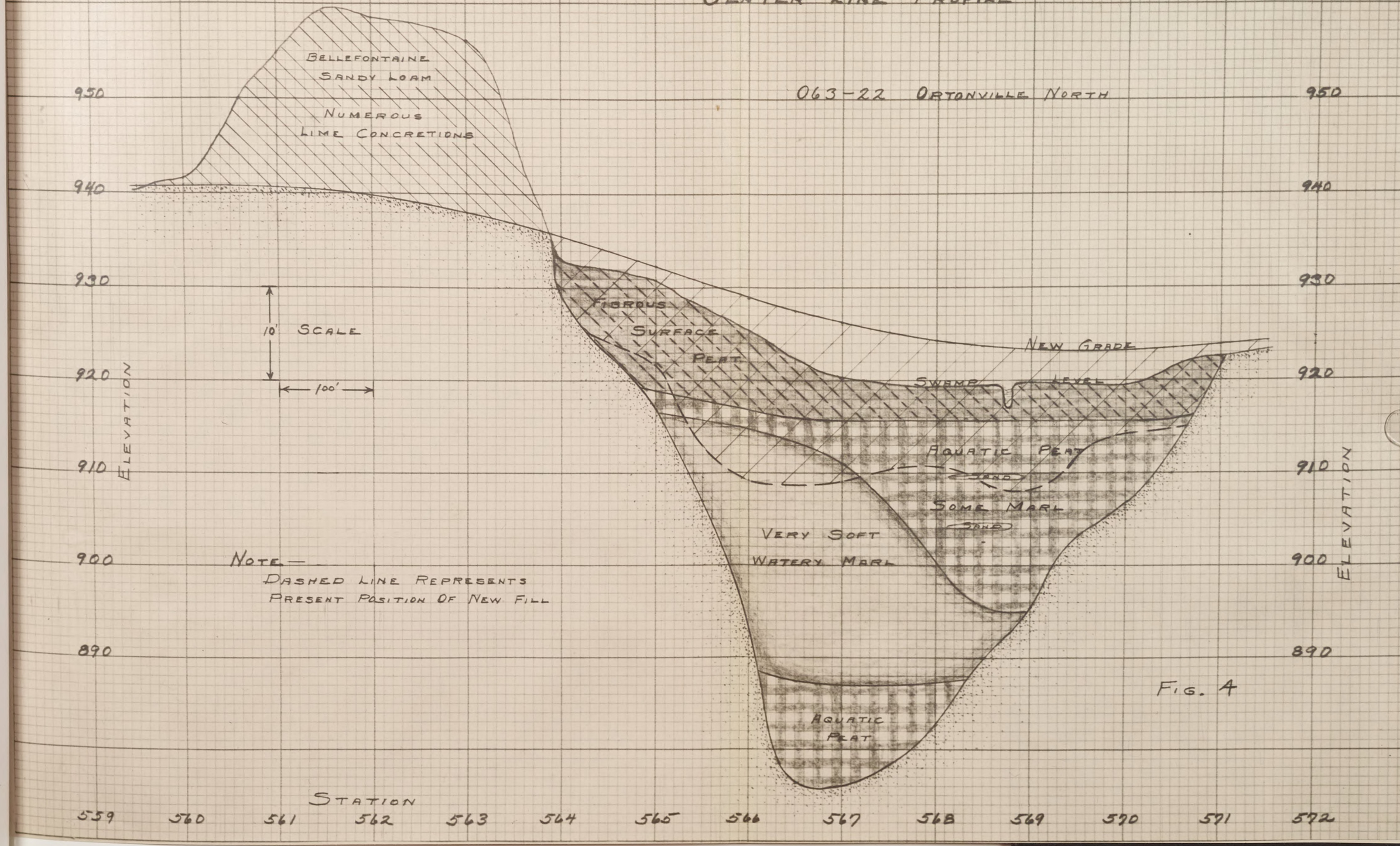


FIG. 4

The marl in this deposit was very soft and watery when investigations were first started. So soft, in fact, that the Davis peat sampler would slowly sink into it without the application of pressure (Station 566/50)*. It was with considerable interest, therefore, that the behavior of this material was watched to learn if so soft a marl would flow or compact when subjected to the weight of a heavy sand fill. An examination of this location after the fill was in place indicated that there had been practically no latteral flow in the marl and that it had become compacted.

067-22 North of Ortonville Sta. 564 to 571 OLS 12/13/32. Gen. view of highway over marl deposi from high sandy hill.

The original study of the location at station 568/50 failed to reveal any very pronounced marl influence. After the fill was in place, however, and the material had become compacted a strong marl influence made its appearance. This phenomenon is probably explained as follows:

*50 feet beyond station 566 in figure 4.

As the load or fill is applied to the marly peat, water is squeezed out of the material causing a much greater shrinkage in the volume of the peat than in the volume of the marl. The marl influence would, therefore, appear much stronger after than before compaction.

The fill across this swamp was placed during the fall of 1929 and the concrete surfacing was built the following summer. Considerable attempt was made to force the fill to settle thru the marl to solid bottom. The following is a quotation from the Engineer's weekly construction report for the period between October 17 and October 31, 1929:

"The contractor is dynamiting the fill from station 565 to 570 after the second loading. As result of the first loading and dynamiting the fill settled from 6 to 12 feet. As soon as the second dynamiting is complete the fill will be brought back to surcharge grade and settlement observations taken."

The method used in dynamiting at this location consisted of placing 40 sticks of explosives 2 to 3 feet below the bottom of the fill, 5 feet right and left of centerline, and every 10 feet longitudinally. This means that each time the swamp was dynamited 400 pounds of explosives were used per 100 feet of roadway. Before any filling or blasting was done, however, the surface peat was excavated 44 feet wide and 6 feet deep. The uniform compaction of the marl was greatly facilitated by this excavation which removed the mat of living roots as well as a large amount of fairly well preserved wood.

After two years of service the pavement over this deposit has not become appreciably warped. The only noticeable settlement is located at station 567. This settlement, however, is not serious enough to be apparent to the average driver.

Project 059 - 24

The third deposit of marl and peat to be considered is located on trunkline M-14 about one half mile north of Sheridan in Montcalm County. The original road across the swamp was built of sawdust and slabs. When this road began to fail another corduroy road was built and as this deteriorated and traffic demands increased the logs were covered more and more deeply with sand and gravel.

Sta 558 - Looking [illegible] across sink hole

The profile study (Figure 5) shows two points in the swamp that evidently gave former road builders considerable trouble. Note the amount of corduroy, boulders and fill material at stations 549 to 551 and 556 to 558. At the time the profile study was made the fill at station 548 to 551 was settling at a rate that demanded constant maintenance. The interesting feature about this profile study is the relationships that exist between the troublesome sections of the road and the marl areas of the swamp. The old gravel road never

M059-24. 8-8-28. HLB
Sta 553 - Sounding in sink hole

[illegible]
Sta 559 - Looking North.
[illegible] shows sink hole

059-24

059-21 Sheridan-Stanton Sta 541-566 OLS 12-1-32
General view of highway over marl deposit
looking N.

Figure 5.

A longitudinal profile showing one-half mile of highway construction across a swamp of varying depth and composition. Note the supporting value of marl as compared to that of peat and marly peat. The old fill, corduroy, and surface were excavated before any new fill was placed.

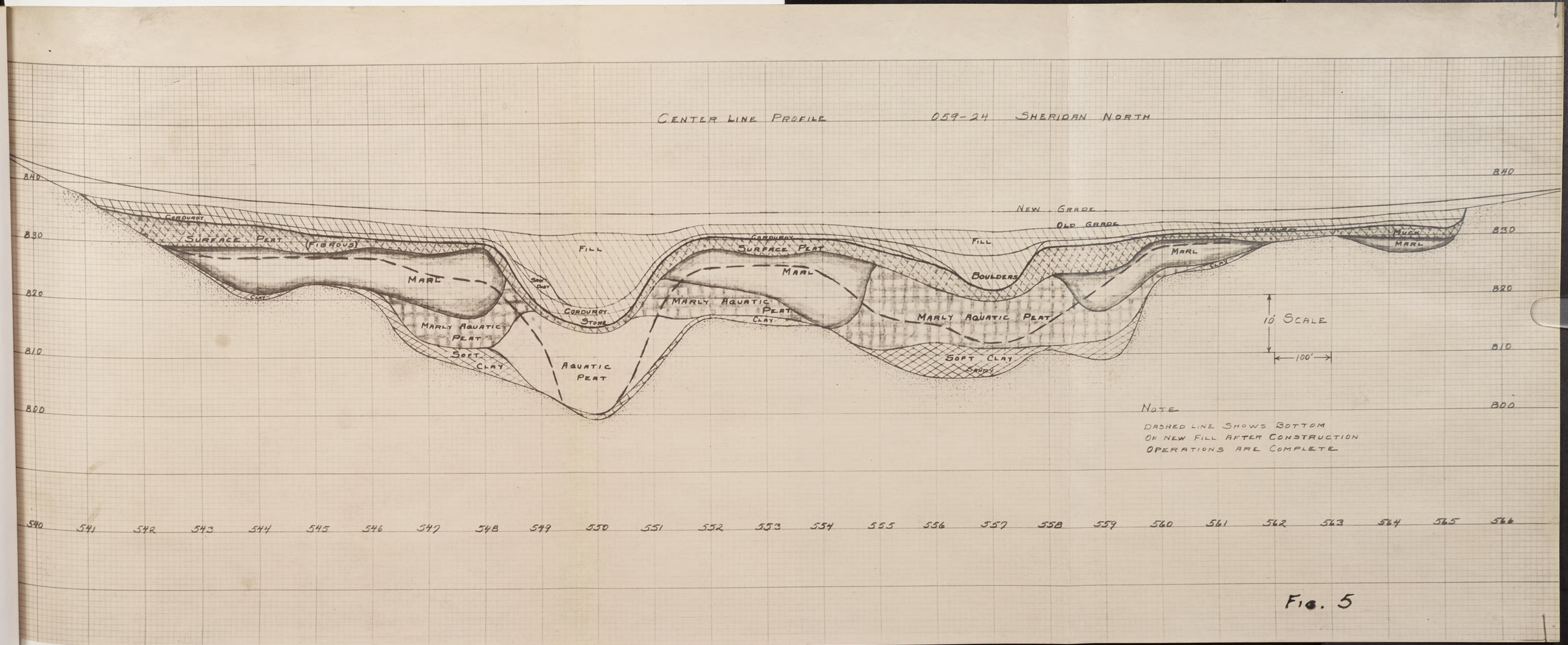

CENTER LINE PROFILE
059-24 SHERIDAN NORTH
840
830
820
810
800
CORDUROY
SURFACE PEAT (FIBROUS)
MARL
CLAY
FILL
SAND
CORDUROY
STONE
MARLY AQUATIC PEAT
SOFT CLAY
AQUATIC PEAT
CORDUROY
SURFACE PEAT
MARL
MARLY AQUATIC PEAT
CLAY
FILL
NEW GRADE
OLD GRADE
BOULDERS
MARLY AQUATIC PEAT
SOFT CLAY
SANDY
CORDUROY
MARL
CLAY
MUCK
MARL
10' SCALE
100'
NOTE
DASHED LINE SHOWS BOTTOM
OF NEW FILL AFTER CONSTRUCTION
OPERATIONS ARE COMPLETE
540 541 542 543 544 545 546 547 548 549 550 551 552 553 554 555 556 557 558 559 560 561 562 563 564 565 566

Fig. 5

Figure 6.

A cross section taken at station 546+00 of the profile shown by figure 5. The supporting value of marl is again illustrated by this section.

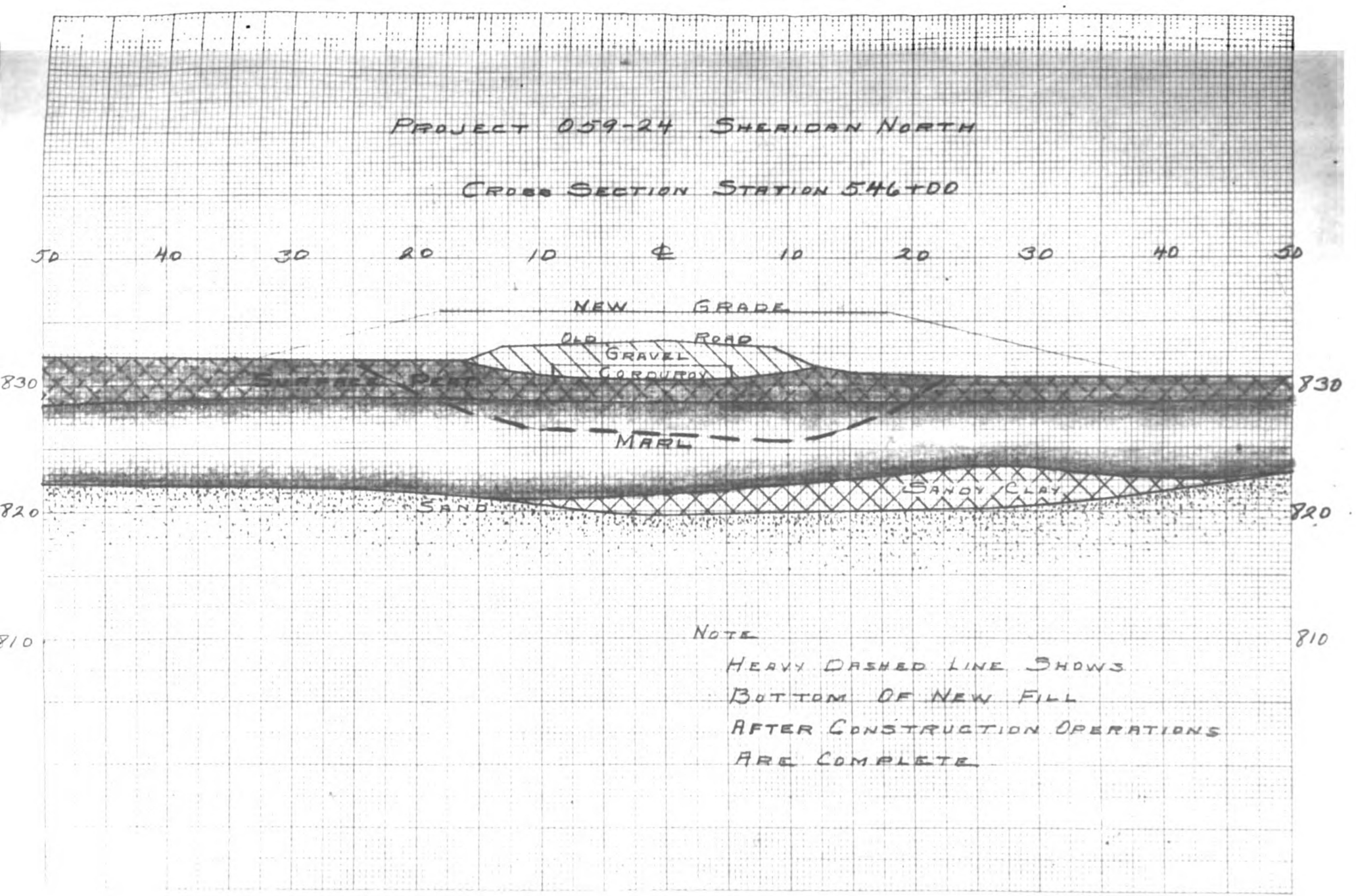

PROJECT 059-24 SHERIDAN NORTH
CROSS SECTION STATION 546+00
50
40
30
20
10
℄
10
20
30
40
50
NEW GRADE
OLD ROAD
GRAVEL
CORDUROY
SURFACE PEAT
MARL
SANDY CLAY
SAND
830
820
810
NOTE
HEAVY DASHED LINE SHOWS
BOTTOM OF NEW FILL
AFTER CONSTRUCTION OPERATIONS
ARE COMPLETE

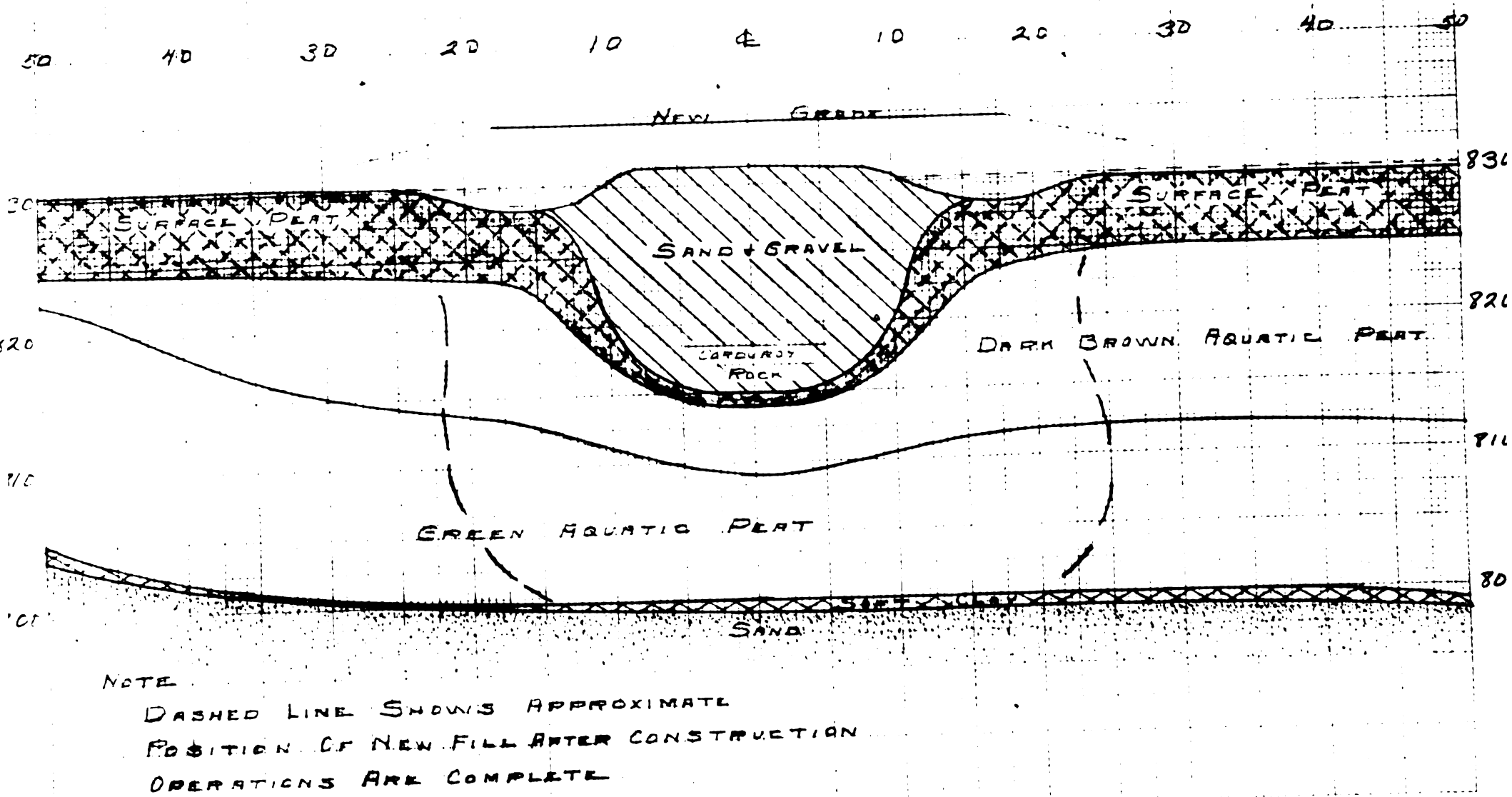
FIG. 6

Figure 7.

A cross section taken at station 550+00 of the profile illustrated by figure 5. There is no marl influence at this point. The new fill, consequently, settled to firm bottom.

PROJECT 069-24 SHERIDAN NORTH

CROSS SECTION STATION 550+00



NOTE

DASHED LINE SHOWS APPROXIMATE POSITION OF NEW FILL AFTER CONSTRUCTION OPERATIONS ARE COMPLETE

FIG. 7

Figure 8.

A cross section taken at station 556+00 of the profile illustrated by figure 5. There is enough marl in the aquatic peat at this point to prevent total peat displacement. Note the influence of the marl at the left on fill penetration.

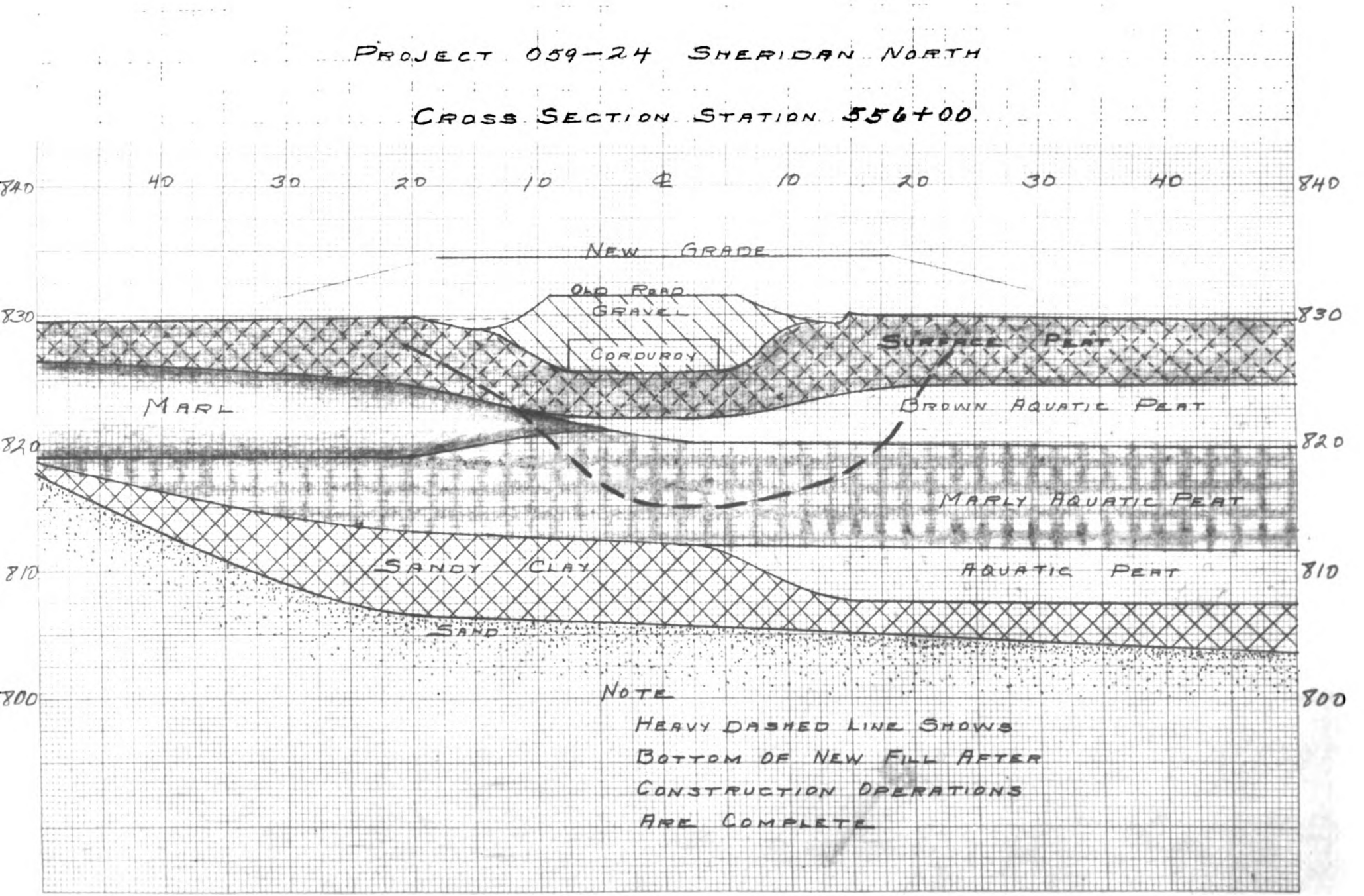

PROJECT 059-24 SHERIDAN NORTH
CROSS SECTION STATION 556+00
840
40
30
20
10
℄
10
20
30
40
840
NEW GRADE
OLD ROAD GRAVEL
CORDUROY
830
830
SURFACE PEAT
MARL
BROWN AQUATIC PEAT
820
820
MARLY AQUATIC PEAT
SANDY CLAY
AQUATIC PEAT
810
810
SAND
800
800
NOTE
HEAVY DASHED LINE SHOWS
BOTTOM OF NEW FILL AFTER
CONSTRUCTION OPERATIONS
ARE COMPLETE.

FIG. 8

Very little action was obtained. Practically all the additional settlement occurred at the two points where the marl influence is the weakest, namely, stations 548 to 552 and 554 to 559. Figures 6, 7 and 8 show in detail the relative supporting value of marl, peat and a mixture of the two materials.

The pavement across this swamp was constructed during the summer of 1931 and to date no settlement is apparent to the casual observer.

Some facts observed in studying this location:

1. The best marl is located in the shallower portions of the swamp.
2. No amount of dynamiting or jetting would cause the good marl to move out from below the new embankment.
3. The old road had been giving trouble from the first over the two short sections of the swamp in which there was no, or very little, marl influence. The most troublesome spot was located at station 550.

Project 059-27

The twin deposit of marl, peat and clay considered in the following few pages is located on Trunk Line M-14 about three miles south of Sheridan in Montcalm County.

The upland soils to the north of this deposit are largely sand and gravel, while the soils to the south seem to consist of several feet of till clay underlain by sand and gravel. Both of these soil conditions permit a springy condition at the base of slopes as is shown by the accompanying photographs. The marl found in this deposit undoubtedly has its source in the waters seeping from the uplands surrounding the swamp.

The first glance at the sketches of this deposit (Figures 9, 10, 11 and 12) would lead one to suspect that the supporting value of marl is very low or no better than that of peat. The reason for including this swamp in the study is to show the influence of a soft lake deposited clay on the supporting value of overlying materials. It had been observed on several locations that this soft lacustrian clay accelerates the movement of peat under load and sometimes even causes the highway embankments to assume unusual cross sections. In other words, this clay acts as a lubricant and is efficient enough in this respect to permit marl to move laterally when subjected to unusual pressure from above. See Figure 12.

A study of the swamp profile reveals the fact that, here again, the better marl has been deposited in the shallower

059-27 Sheridan So. 2-23-33 Stokstad
Sta 327 R. Boggy condition of side hill
indicates seepage.

[illegible]-27 Sheridan So. Stokstad 2-23-33
Spring at base of hill left of Sta 327

[illegible]-27 Sheridan So. Stokstad 2-23-33
Boggy Condition on side hill indicates
seepage - Sta 336 R.

Figure 9

A longitudinal profile showing highway construction across a twin deposit of peat, marl and lacustrian clay. The heavy dashed line indicates the depth to which the new fill penetrated. Note that the marl is almost completely displaced. For explanation see pages 16 and 17.

CENTER LINE PROFILE PROJECT 059-27 SHERIDAN SOUTH

SHOWING THE INFLUENCE OF UNDERLYING SOFT CLAY
ON THE SUPPORTING VALUE OF MARL

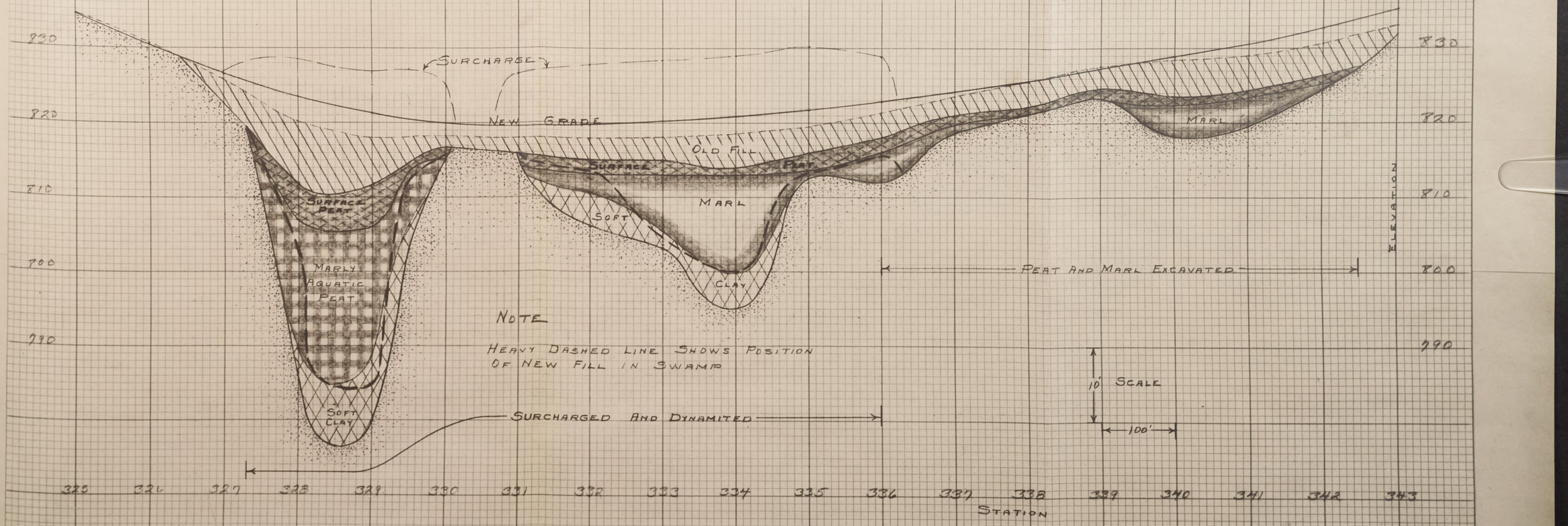


FIG. 9

Figure 10.

A cross section taken at station 328+50 of the profile shown in figure 9. The marl influence in the aquatic peat is enough to prevent lateral flow in the lower portion of the clay fill.

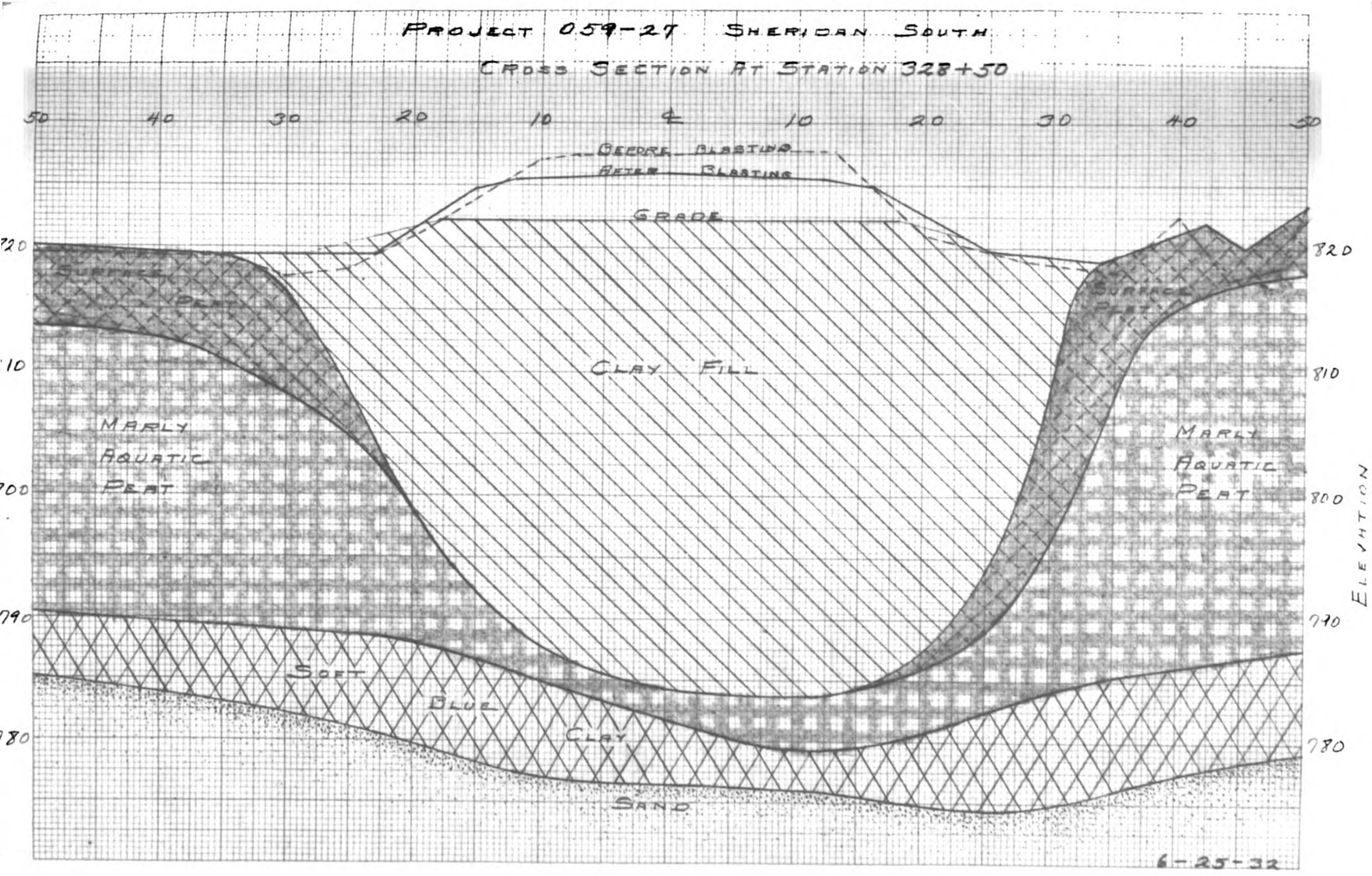

PROJECT 059-27 SHERIDAN SOUTH
CROSS SECTION AT STATION 328+50
50
40
30
20
10
℄
10
20
30
40
50
BEFORE BLASTING
AFTER BLASTING
GRADE
820
810
800
790
780
SURFACE PEAT
CLAY FILL
MARLY AQUATIC PEAT
SOFT BLUE CLAY
SAND
ELEVATION
6-25-32

FIG. 10

Figure 11.

A cross section taken at station 332+00 of the profile illustrated by figure 9. The marl has been only partially displaced in this shallower portion of the swamp.

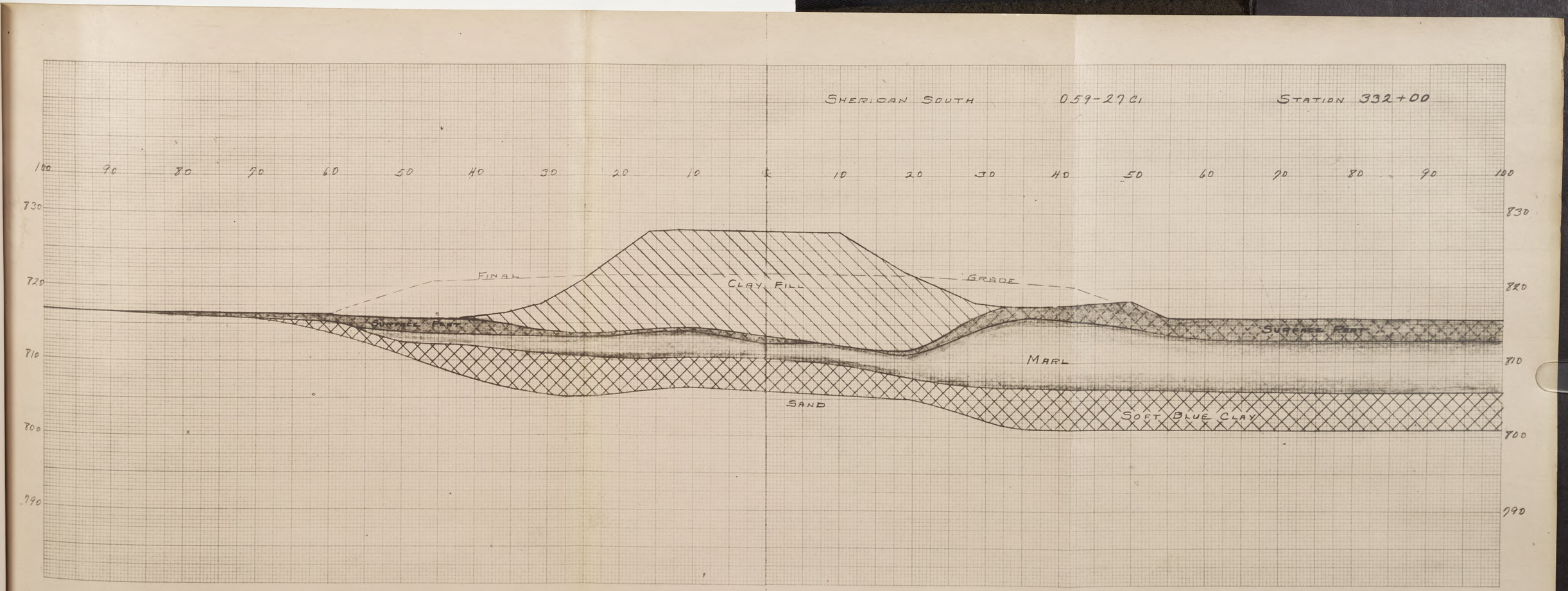

SHERIDAN SOUTH 059-27 C1 STATION 332+00
100 90 80 70 60 50 40 30 20 10 0 10 20 30 40 50 60 70 80 90 100
830
820
810
800
790
FINAL GRADE
CLAY FILL
SUBFILL PEAT
SUBFILL PEAT
MARL
SAND
SOFT BLUE CLAY

FIG. 11

Figure 12.

A cross section at station 334+00 of the profile sketch, figure 9. The marl has been completely displaced on centerline. The lubricating influence of the blue clay seems to have facilitated lateral flow in the marl.

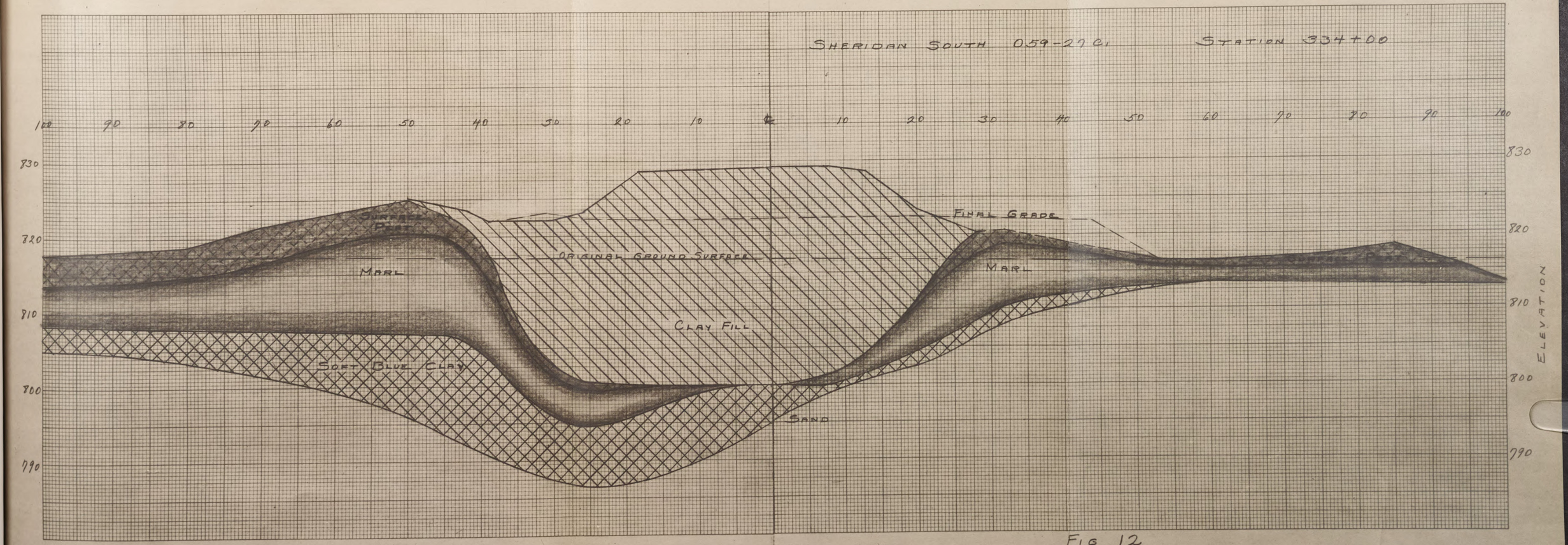

SHERIDAN SOUTH 059-27 Cl
STATION 334+00
100 90 80 70 60 50 40 30 20 10 ℄ 10 20 30 40 50 60 70 80 90 100
830
820
810
800
790
ELEVATION
FINAL GRADE
ORIGINAL GROUND SURFACE
MARL
MARL
CLAY FILL
SOFT BLUE CLAY
SAND

FIG. 12

portions of the swamp. The aquatic peat between stations 327+50 and 328+50 does not contain enough marl to support the fill on centerline, but it does contain enough to prevent the complete displacement of the peat at the sides. A clay fill displacing pure peat over lacustrian clay would tend to displace all the peat, much of the underlying clay, and often spread out to unusual widths on the bottom. In other words, the marly aquatic peat, shown in figure 10, offers enough resistance to flow so as to confine the embankment even tho it does not completely support it.

The marl displacement, shown by figure 12, is very unusual. It can be accounted for only by the combined effect of the clay fill and the soft clay layer between the marl and the sand bottom. A wet clay fill has a tendency to flow laterally. As stated before, the underlying lacustrian clay aids this tendency by acting as a lubricant.

The rebuilding of the road across this swamp was started during February, 1932. The swamp was excavated and backfilled from station 336 to 342+50 and surcharged and dynamited from 327+30 to 336. The heavy dashed line on the profile shows the depth to which the new fill penetrated the swamp. The section between stations 327 and 330 was blasted after the original filling was completed in order to obtain more thorough displacement of the marly peat. Very little additional settlement was obtained, however.

The pavement across this swamp was opened to traffic August, 1932. To date the only settlement apparent is located at station 328+75. It is of interest to note that this settlement has occurred in the deepest part of the swamp where the fill rests directly on the underlying lacustrian clay. No settlement has occurred from station 327+50 to 328+00 where there is a maximum of 12 feet of marly aquatic peat below the fill.

059-27 Sheridan S. Sta 327-340 OLS 12-1-32
Adjoining deposits - one is marl and the other peat.

059-27 Sheridan So. Stolstad 8-27-33
Looking N. over swamp from sta 326

Project 041-37

The next swamp considered is one-half mile long and is located on the new West Belt Road of Grand Rapids about 1½ miles south of the intersection with M-50. The swamp is timbered to a considerable extent with elm and maple. The soil survey of Kent County classifies the swamp area as Carlisle Muck, and the surrounding mineral soils as Plainfield, Coloma and Bellefontaine. Here again is a high-lime swamp surrounded by sandy upland soils.

The work of constructing a satisfactory grade across this swamp was accomplished in two stages. Most of the work was done between March 1 and November 8, 1929. On this contract the fill was placed 4 feet above plan grade and 32 feet wide. Next the "sink hole" was blasted using 260 pounds of dynamite per station and then reloaded.

Borings taken to study peat displacement after construction work was completed indicated that considerable soft material still remained below the fill. It was decided that another attempt would be made to more completely displace underlying unstable peat and marl. In order to give a clear picture of the work performed, and results obtained, the Project Engineer's weekly construction reports will be quoted.

"12-10-31. First overload complete. (Overload consists of building fill 5 feet above grade). Started driving pipe for blasting.

12-17-31. Settlement of from 2 to 6 feet obtained on blasting.

Figure 13

A profile view of a highway embankment across one-half mile of swamp. Centerline soundings on which this profile is based would indicate that practically all of the marl and peat has been displaced. The influence of the marl is best shown by figures 14 and 15.

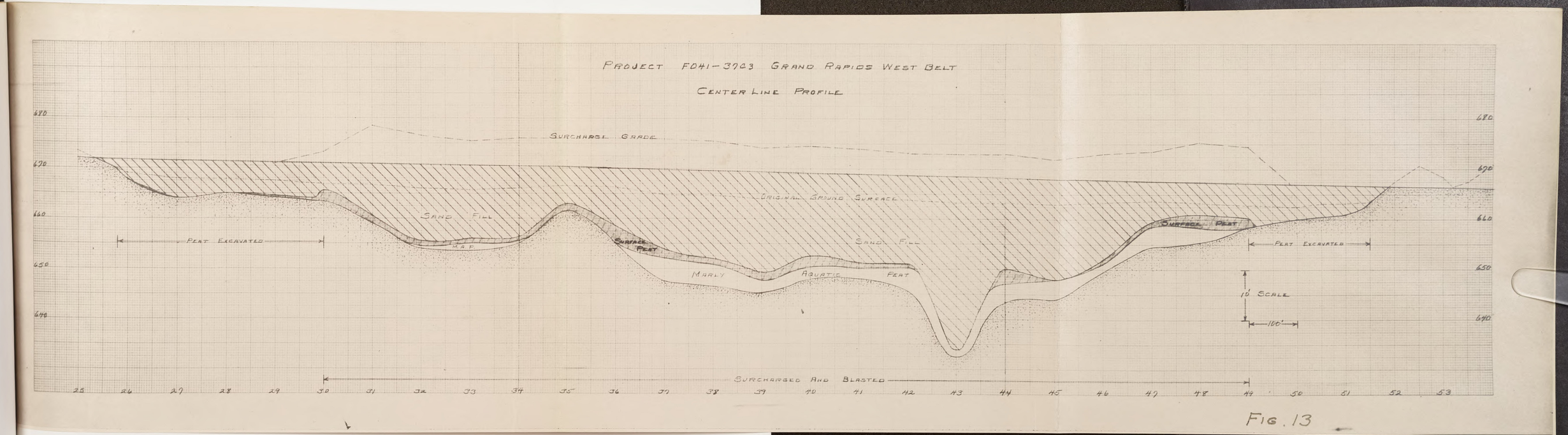

PROJECT FDHI-3903 GRAND RAPIDS WEST BELT
CENTER LINE PROFILE
SURCHARGE GRADE
ORIGINAL GROUND SURFACE
SAND FILL
MAR
PEAT EXCAVATED
SURFACE PEAT
MARLY
AQUATIC PEAT
SAND FILL
SURFACE PEAT
PEAT EXCAVATED
10' SCALE
100'
SURCHARGED AND BLASTED
680
670
660
650
640
25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53

FIG. 13

Figure 14.

A cross section at station 37+00 of figure 13. The marl influence in the aquatic peat has prevented total displacement.

PROJECT 041-37 GRAND RAPIDS WEST BELT

CROSS SECTION AT STATION 37+00

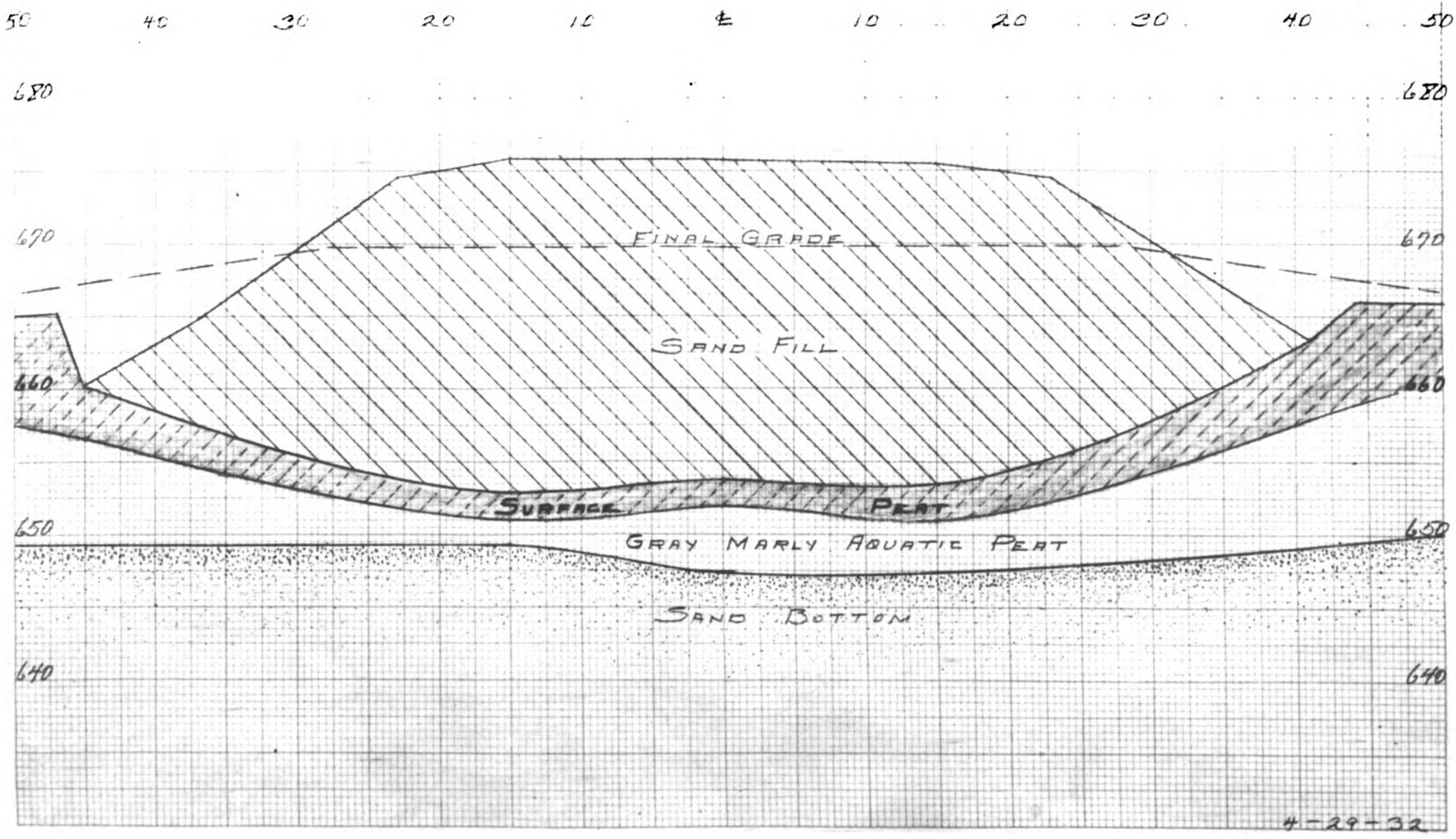


FIG. 14

Figure 15.

A cross section at station 43+00 of figure 13. A boring on centerline does not truly portray the influence of the marl at this point. The marl content in this deposit is only strong enough to partially support the highway fill.

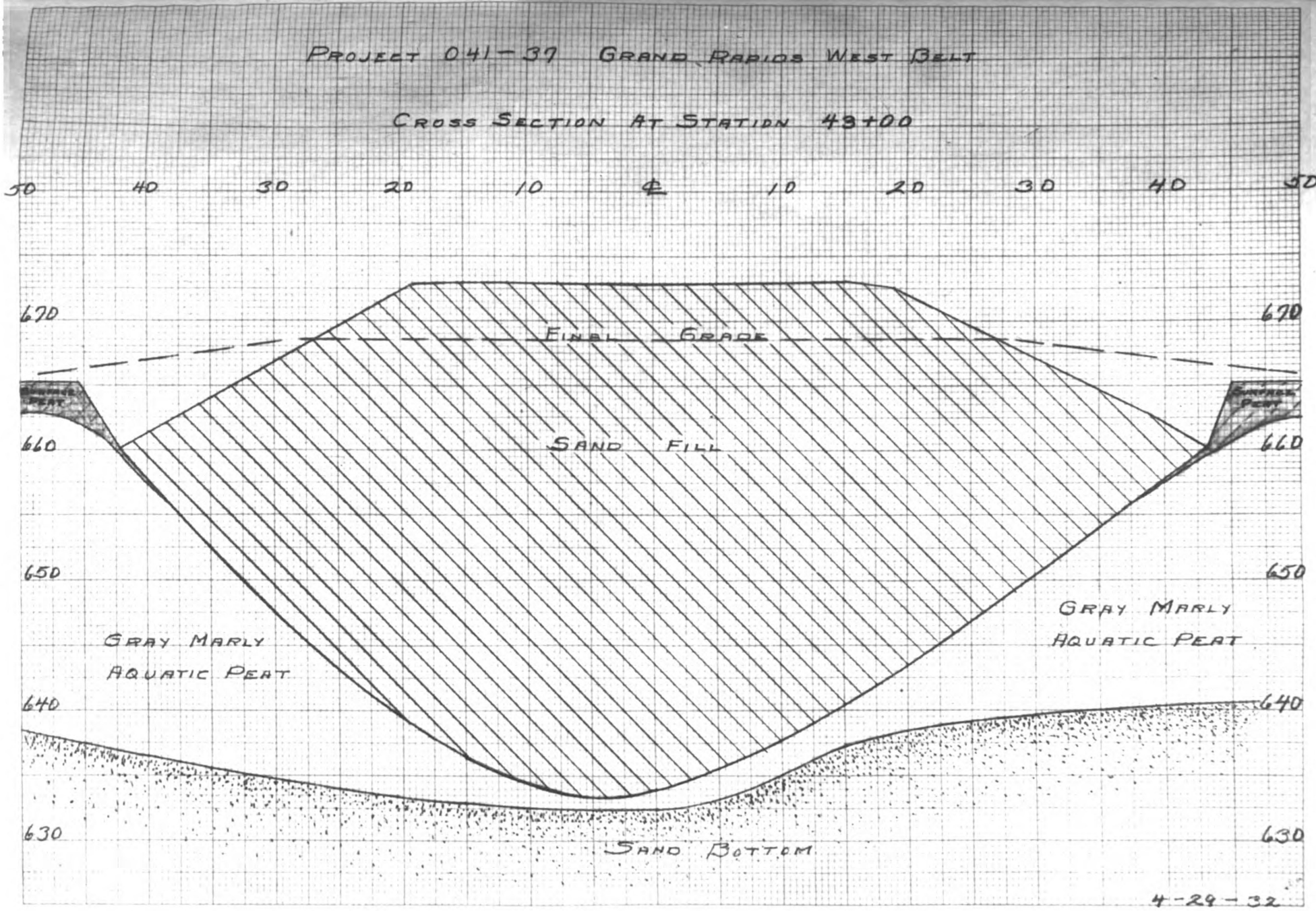

PROJECT 041-37 GRAND RAPIDS WEST BELT
CROSS SECTION AT STATION 43+00
50
40
30
20
10
℄
10
20
30
40
50
670
660
650
640
630
FINAL GRADE
SAND FILL
GRAY MARLY
AQUATIC PEAT
GRAY MARLY
AQUATIC PEAT
SAND BOTTOM
4-29-32

FIG. 15

12-31-31 First blasting complete. Drag line excavating trench along sides of fill to provide space for peat displacement.
Second loading and blasting to follow soon.

1-7-32 Peat excavation complete by end of week.
Second overload started.

2-19-32 Second overload complete. Second blasting started.

2-26-32 Second blasting complete, Settlement of from 3 to 4 feet obtained.

3-4-32 Started third overload. Considerable settlement obtained because of additional fill weight.

3-16-32 Third overload complete.

4-25-32 Surcharge removal in progress.

5-20-32 Surcharge removed. Grade raised one foot to provide for waste peat.

7-11-32 Highway paved and open to traffic."

When the filling operations were complete for the second time, borings were taken again by means of a hydraulic drilling outfit to determine the position of the new fill. These borings showed that peat displacement was incomplete in spite of all efforts to displace it. These borings also showed that since the peat had become compacted a fairly strong marl influence had made its appearance. Again compaction of the peat and loss of water in the compacted material resulted in a change in the volume differential between the peat and marl. In other words, the marl occupied a larger percentage of the volume after compaction than before compaction.

After discovering the presence of marl in the peat no attempts were made to widen the fill at the bottom. A check-up on the behavior of the road to date indicates that absolute stability had been reached before surfacing was placed. Much of this stability is undoubtedly due to the time factor involved. Grading over this swamp took place over a period of two years during which time the swamp was blasted three times and the surcharge brought back up to surcharge grade five times. This tremendous amount of work, excellent fill material (sand), and ample time for settlement have combined to produce an unusually stable grade.

041-37 Gr. Rapids W. Belt. Sta 28-52 CLS
General view of highway over marl deposit
looking S. from sta 53

Project 030-19

The new highway grade between Hillsdale and Osseo crosses a small swamp located about two miles southeast of Hillsdale between Baw Beese Lake and Boot Lake. The surrounding upland soils are sandy and gravelly, consisting mainly of the Hillsdale, Bellefontaine, Plainfield and Fox Series.

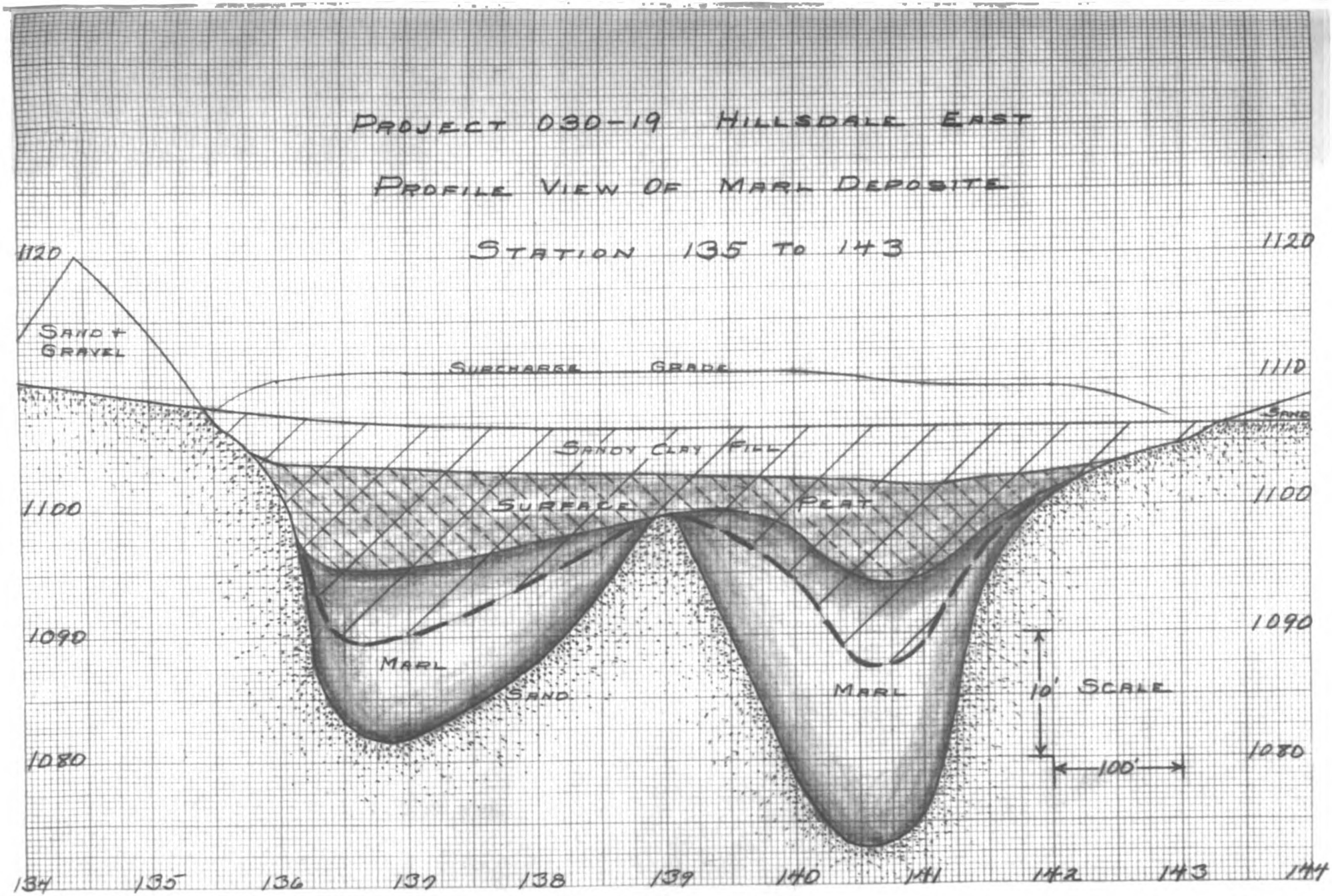
The marl content of this swamp seemed small at the time the survey was made. In fact, it was thought the construction procedure would not be seriously affected by it. The road plans were consequently set up for total excavation from station 136 to 139+40 and from station 141+70 to 142+50. The balance of the swamp was to be surcharged and blasted. The swamp at station 137 proved to be too deep to excavate, consequently the construction procedure was changed. The new plan called for excavation 8 feet deep and 24 feet wide throughout the entire swamp; then loading to 5 feet above grade to compact or displace the marl and aquatic peat below the 8 foot depth.

Excavation thru this swamp was started May 28, 1931 and the filling was completed by the middle of June of the same season. No surfacing has been placed on this grade up to this time. It is expected, however, that the finished road will prove to be stable. There are two important factors combined in the construction across this swamp that usually result in an excellent finished job. These factors are (1) the use of a sand and gravel fill material and (2) ample time for proper settlement.

Figures 16 and 17 are sketches showing a profile and cross section of the highway embankment and its relation to the underlying peat and marl.

-19 Hillsdale M. Sta 136-143 OLS 11-30-3
Looking E. Marl deposit in foreground. Sandy gravelly hills in background

-19 Hillsdale M. Sta 136-143 OLS 11-30-3
Looking E. Marl deposit in foreground and sand plain in distance.



DISCUSSION ON PAGE 22 AND 23

FIG. 16

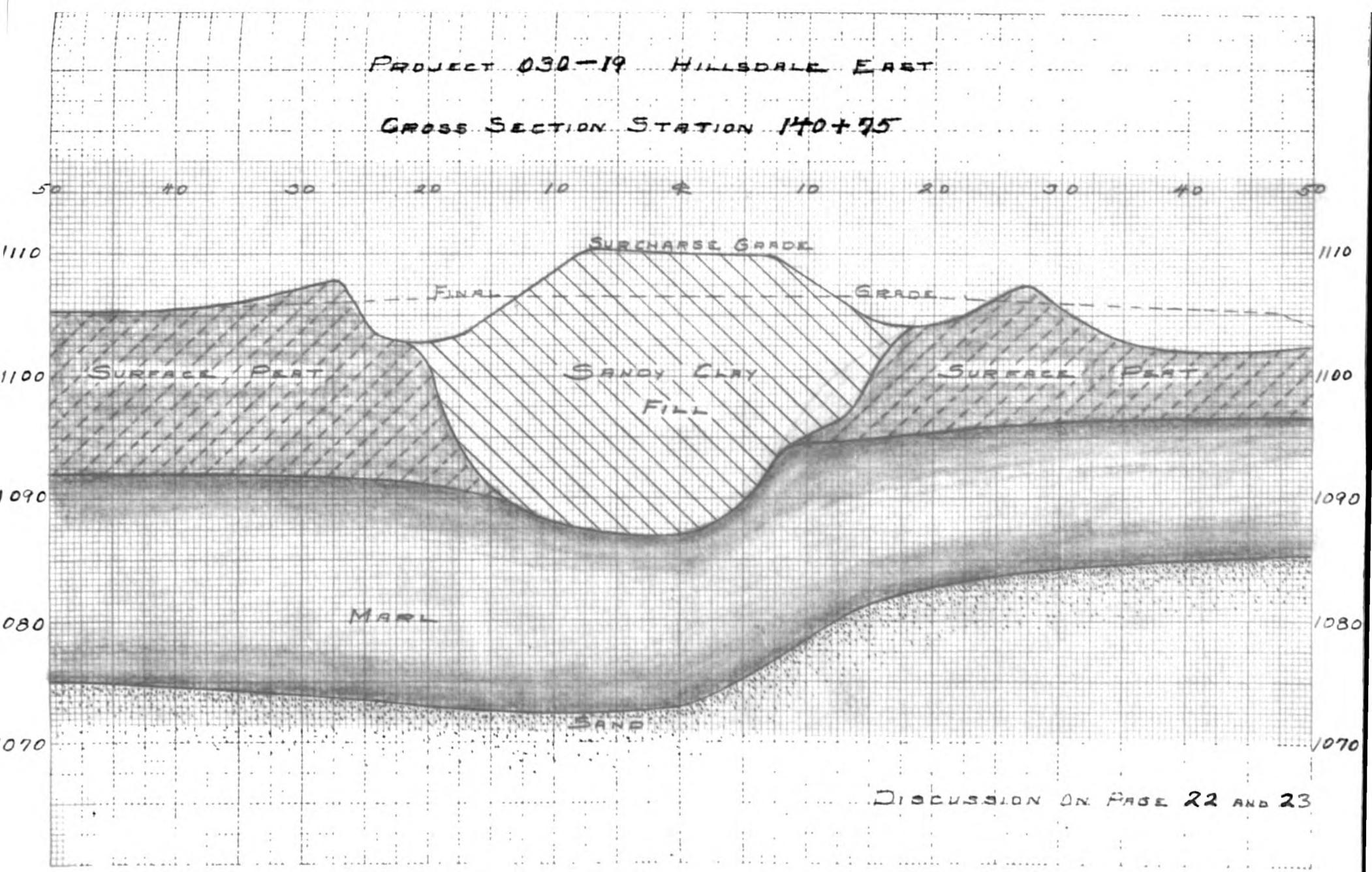

PROJECT 030-19 HILLSDALE EAST
CROSS SECTION STATION 140+75
50
40
30
20
10
0
10
20
30
40
50
1110
1100
1090
1080
1070
SURCHARGE GRADE
FINAL
GRADE
SURFACE PEAT
SANDY CLAY
FILL
SURFACE PEAT
MARL
SAND
DISCUSSION ON PAGE 22 AND 23

FIG. 17

Project 039-7

The new highway crosses this swamp just off the east end of Sugarloaf Lake about three miles north of the Village of Schoolcraft in Kalamazoo County. The swamp at this crossing is almost 3000 feet wide, has a maximum depth of about 36 feet, consists principally of marl, and is part of a long chain of lakes and swamps. The mineral soil uplands surrounding this area belong to the Fox, Plainfield and Warsaw Series.

The thin mat of surface peat over the marl in this deposit ranges from 6 inches in thickness thru the central portion to a maximum of about 5 feet near the edges of the swamp. The surface of the marl remains at a fairly constant elevation, whereas the elevation of the peat surface increases as the edges of the swamp are approached. This change in surface elevation is also reflected in the type of vegetation growing on the peat.

The principal reason for locating the highway across this swamp was to eliminate two railroad crossings and two right angle turns. A preliminary study of the swamp was made during the winter of 1930 and 1931. By this time considerable knowledge had been gained regarding the value of marl as a supporting material. When it was found that the swamp consisted largely of marl, it was decided to study the deposit in detail to see if the marl might be of such quality as to properly support a road bed. Preliminary soundings were obtained during March, 1931. Three different lines were studied before accepting the final highway location. The first line included 5300 feet of

08 -7 Kalamazoo South -1"-32 Rudolph
Sta 79 - Looking N. Showing N. end of Swamp

-7 Reloc. N of Schooler ft. Rudolph
Sta 54 Looking N. along centerline. 2-17-52

-7 Kalamazoo South 2-17-52 Rudolph
Sta 67. Looking N. along centerline

[illegible] 54. Looking N. along centerline

F 39-7 C1 Reloc. N of Schoolcraft 4-6-32 CLS
General View

[illegible] Reloc. [illegible] Detour
[illegible], [illegible] [illegible]
[illegible] operations. [illegible]

[illegible]

03 -701 Schoolcraft Reloc. Sta 63 3½' sand fill on 3½' marl. No heaving ahead or at side of fill. 3-20-32 Rudolph

F[illegible]-7 01 Schoolcraft Reloc. 3-10-32 Stokstad Sta 69. Placing surcharge accelerated settlement here. 4th lift across in 2 days.

[illegible]-7 C1 Schoolcraft Reloc. 8-10-32 Stokstad
Looking north from sta 55.

F[illegible]9-7 C1 Schoolcraft Reloc. 8-10-32 Stokstad
Sugar-loaf Lake from station 59

[illegible]9-7 C1 Schoolcraft Reloc. Sta 60 Stokstad
Dry boring thru fill to sample marl. Tarleg's
outfit. 9-22-32

swamp, ranged in depth from 4 to 12 feet, and contained no marl. The line chosen included only 2800 feet of swamp, but had a maximum depth of 36 feet of which 6 inches to 5 feet was peat.

Grading operations thru the swamp were started in February, 1932, and were completed to surcharge grade by August, 1932. The procedure followed is illustrated by figure 18. Sand and gravel obtained from special borrow pits at each end of the swamp fill was used as fill material. During the course of construction gradual settlement took place at all times, more rapidly at first, but gradually slowed up as the marl became compacted. At times, certain sections settled faster than others, but there were no sudden breaks causing the fill to disappear below water, such as characterizes filling operations over swamps consisting of peat alone.

Figures 19 and 20 are cross sections taken after settlement had stopped and before the surcharge was removed. Figure 21 is a longitudinal profile study showing the position of the fill at the highway centerline. The shaded profile near the top of figure 21 shows graphically the fill settlement that has taken place during the three months period between August 27 and November 30, 1932. The maximum settlement during that time was 0.70 feet which occurred at station 68. Note, however, the uniformity of the settlement.

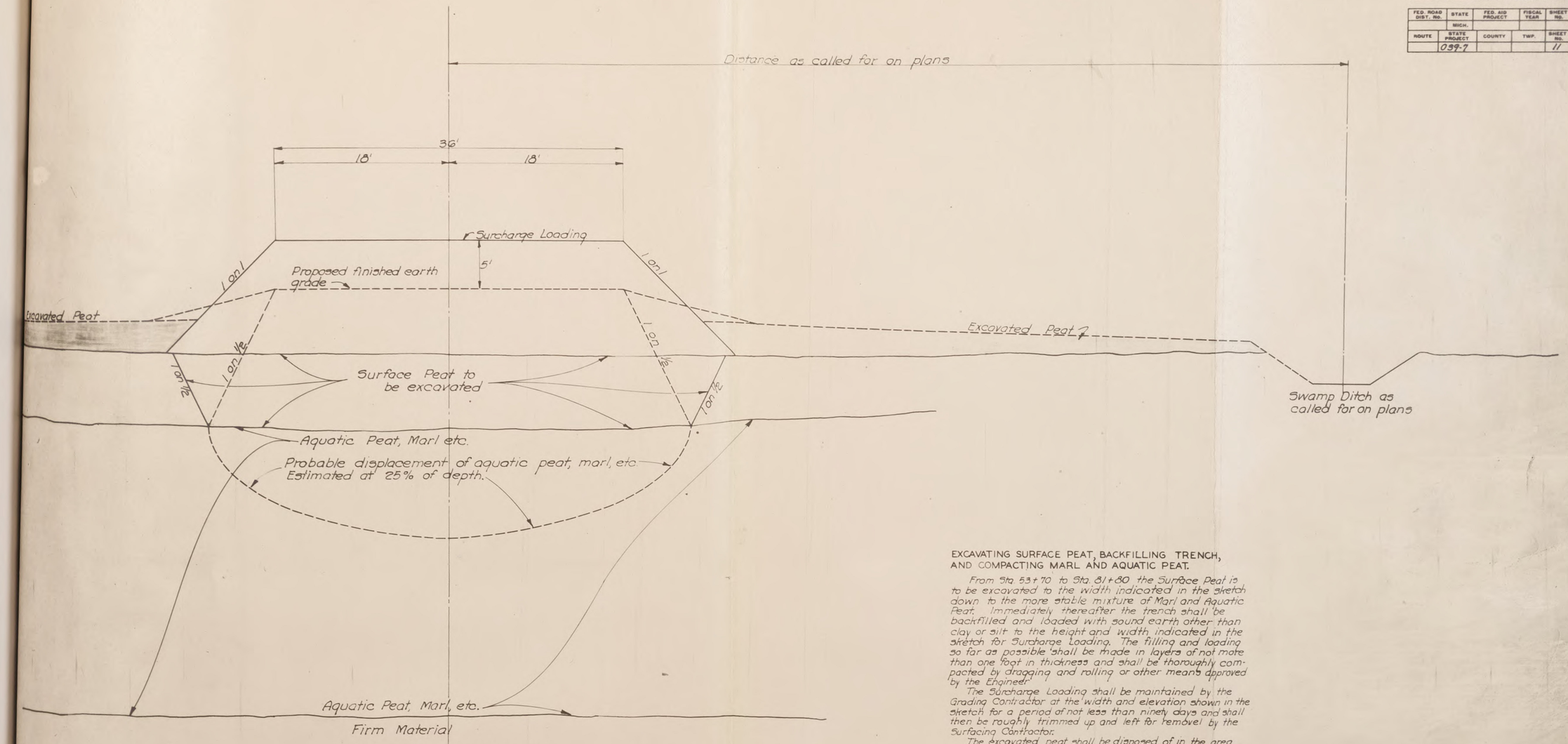
By November 30 the settlement had practically stopped. It was decided to remove the surcharge immediately in order that the finished cross section might have ample time to arrive

Figure 18.

This figure is a detail showing the construction procedure used in grading across the swamp. The amount of fill needed was underestimated by about 19 percent.

FED. ROAD DIST. No.	STATE	FED. AID PROJ. No.	FISCAL YEAR	SHEET No.	TOTAL SHEETS
7	MICH.	160 A		11	
ROUTE	STATE PROJECT	COUNTY	TWP.	SHEET No.	TOTAL SHEETS
	039-7	KALAMAZOO	PORTAGE SCHOOLCRAFT	11	

FED. ROAD DIST. No.	STATE	FED. AID PROJECT	FISCAL YEAR	SHEET No.	TOTAL SHEETS
	MICH.				
ROUTE	STATE PROJECT	COUNTY	TWP.	SHEET No.	TOTAL SHEETS
	039-7			11	



DETAIL SHOWING METHOD OF EXCAVATION AND LOADING SWAMP STA 53+70 TO STA. 81+80

EXCAVATING SURFACE PEAT, BACKFILLING TRENCH, AND COMPACTING MARL AND AQUATIC PEAT.

From Sta 53+70 to Sta. 81+80 the Surface Peat is to be excavated to the width indicated in the sketch down to the more stable mixture of Marl and Aquatic Peat. Immediately thereafter the trench shall be backfilled and loaded with sound earth other than clay or silt to the height and width indicated in the sketch for Surcharge Loading. The filling and loading so far as possible shall be made in layers of not more than one foot in thickness and shall be thoroughly compacted by dragging and rolling or other means approved by the Engineer.

The Surcharge Loading shall be maintained by the Grading Contractor at the width and elevation shown in the sketch for a period of not less than ninety days and shall then be roughly trimmed up and left for removal by the Surfacing Contractor.

The excavated peat shall be disposed of in the area between the Surcharge Loading and the Swamp Ditches or between the Surcharge Loading and the R.O.W. lines where no ditches are called for, and shall be uniformly spread and leveled so as to drain naturally away from the Fill.

The Contractor shall maintain drainage by ditches, temporary culverts, or other methods satisfactory to the Engineer during all operations of grading thru the peat marsh.

FIG. 18

FILE No. USE No. 250 STENCIL	J-3-C-3	PROJECT	SEC.	SHEET No.
		039-7		11

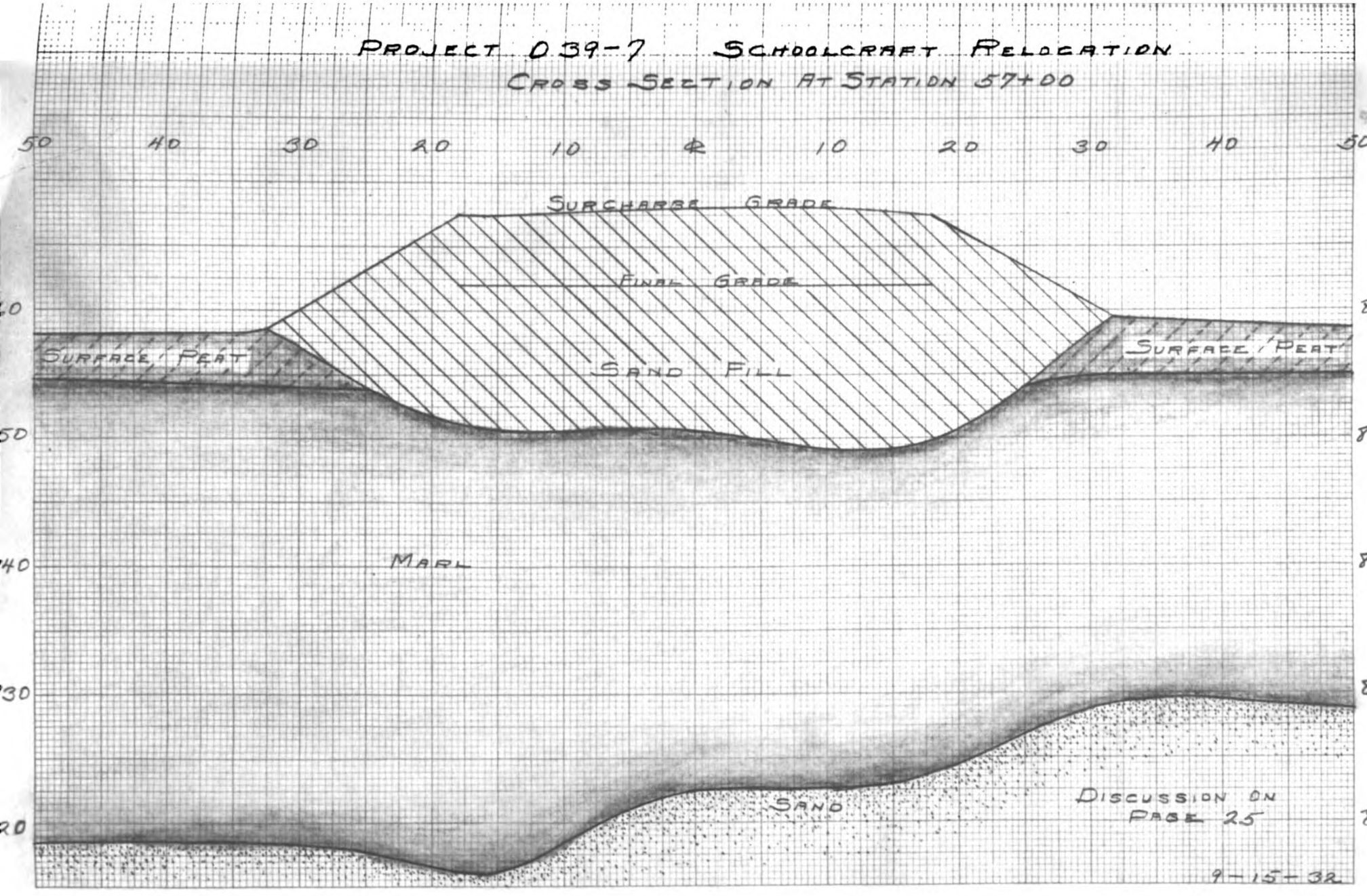

PROJECT 039-7 SCHOOLCRAFT RELOCATION
CROSS SECTION AT STATION 57+00
50
40
30
20
10
℄
10
20
30
40
50
SURCHARGE GRADE
FINAL GRADE
SURFACE PEAT
SAND FILL
SURFACE PEAT
MARL
SAND
DISCUSSION ON PAGE 25
860
850
840
830
820
9-15-32

FIG. 19

PROJECT 0694-0

SECTION AT STATION 61+00

NOTE: SEE SHEET #1 FOR LEGEND

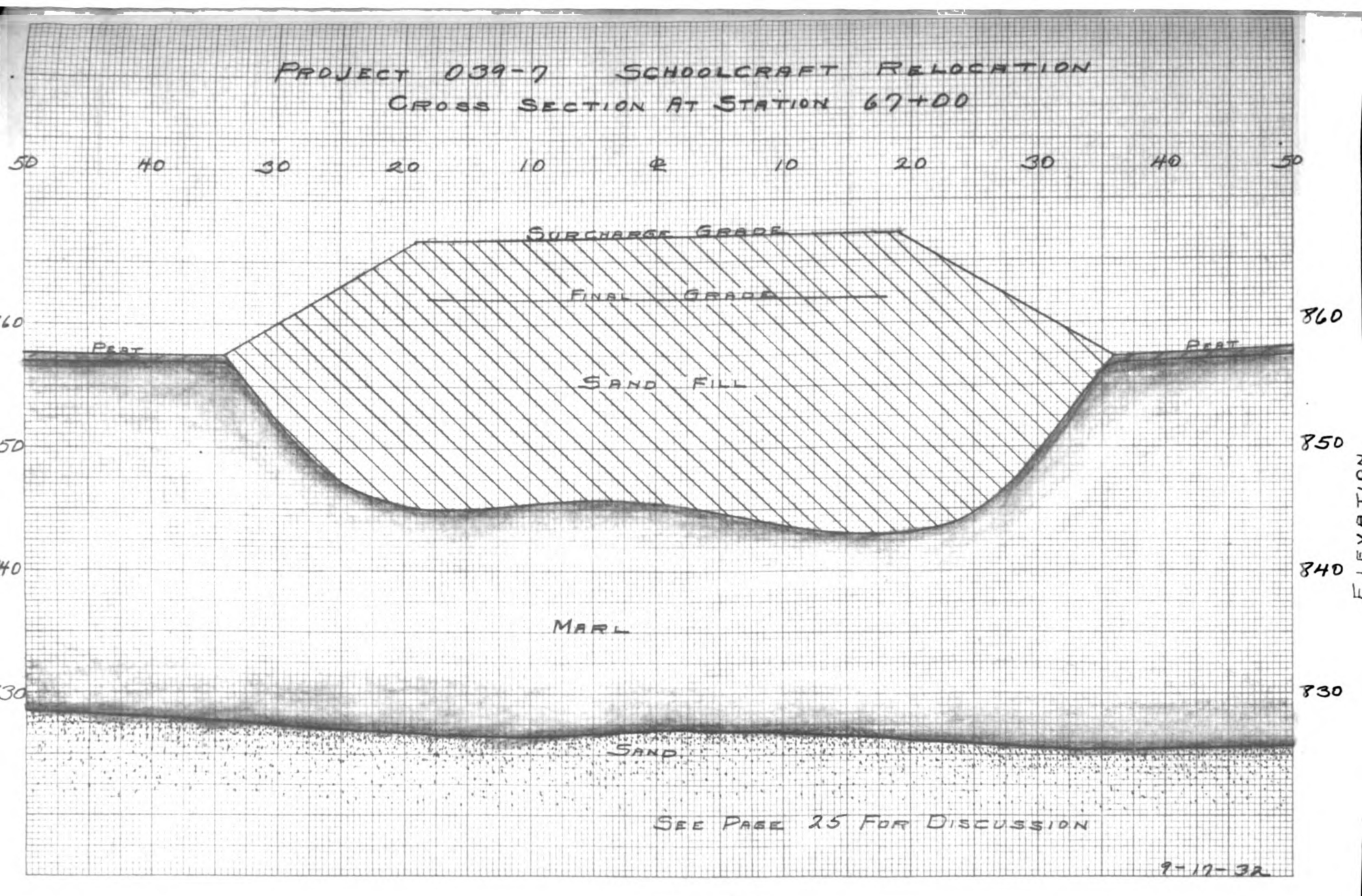

PROJECT 039-7 SCHOOLCRAFT RELOCATION
CROSS SECTION AT STATION 67+00
50
40
30
20
10
℄
10
20
30
40
50
SURCHARGE GRADE
FINAL GRADE
860
850
840
830
PEAT
PEAT
SAND FILL
MARL
SAND
SEE PAGE 25 FOR DISCUSSION
9-12-32

FIG. 20

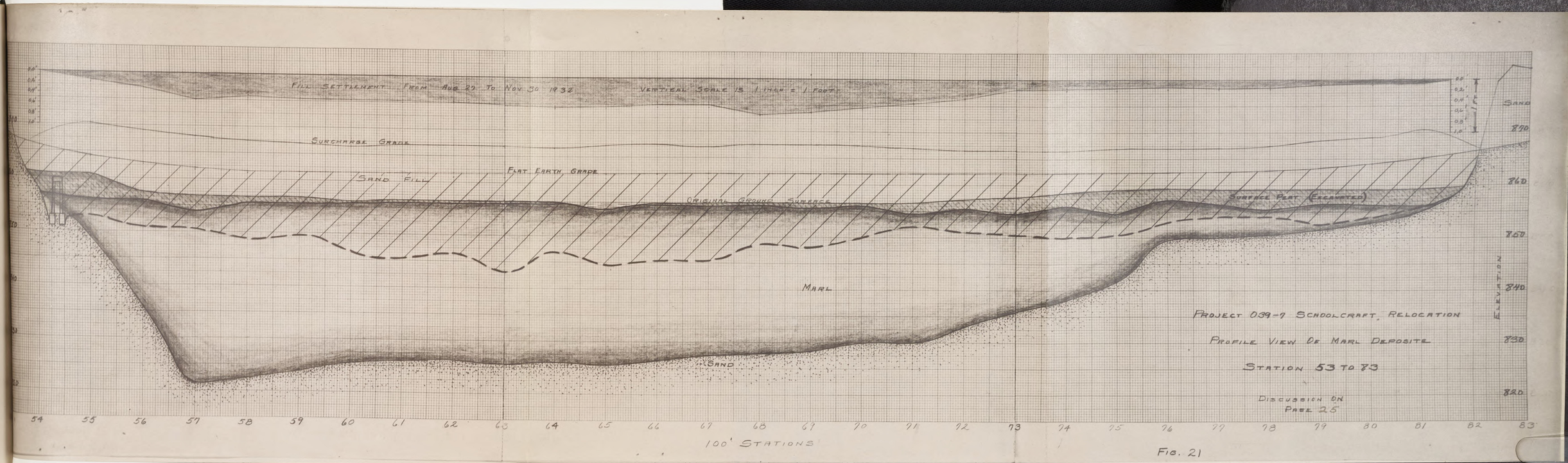

Fill Settlement From Aug 29 To Nov 30 1932
Vertical Scale is 1 inch = 1 foot
Surcharge Grade
Sand Fill
Flat Earth Grade
Original Ground Surface
Surface Peat (Excavated)
Marl
Sand
Sand
Project 039-1 Schoolcraft Relocation
Profile View Of Marl Deposite
Station 53 to 83
Discussion On Page 25
Elevation
100' Stations
54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83

Fig. 21

at a new equilibrium before construction is started on the concrete pavement. The pavement must be in place by July 1, 1933.

During the process of construction samples were collected of the marl to study its uniformity. Table 1 shows the results of analyses performed according to the outline accompanying the table. There are a few things of interest to be learned from a study of Table 1. For instance, note the relationship that exists between the $CaCO_3$ content and the field classification of the sample as listed under Field Notes. When the $CaCO_3$ percent falls below 90 the sample is usually classified as peat. The samples classified as marl with only a slight peat influence range in $CaCO_3$ content from 92 to 96 percent. The material described as compact aquatic peat occurring near the bottom of the deposit proved to contain from 7 to 39 percent clay as well as a considerable amount of $CaCO_3$. The organic content of the samples collected ranged from 0.1 to 9.0 percent and mineral content ranged from 91.0 to 99.9 percent. These figures are not a true index of the importance of the organic influence in the marl. See page 2 for the discussion of this subject.

A special attempt was also made on this swamp to determine what had happened to the marl over which the highway embankment had been built. Numerous samples for moisture tests were taken. It was assumed that some information regarding the relative compaction of the marl below and beyond the fill could be gained by studying the moisture content of samples taken to form a cross section. Figures 22 and 23 show the results at the two sections studied in this manner.

PROCEDURE

FOR THE ANALYSIS OF SAMPLES

Dry sample at 105°C to 110°C until the water is removed.

Pulverize sample taking care not to break the mineral particles.

CO_2 determination (A.Marshall's improved Scheibler's Calcimeter)

Loss on ignition at 900°C will be CO_2 evolved from carbonates and organic matter.

Organic matter obtained by subtracting CO_2 evolved by acids from loss on ignition

Wash sample thru 270 mesh sieve (.053 mm opening).

Retained

Sand

Pass

Soluble salts such as $Ca(OH)_2$, $Mg(OH)_2$, PO_4 plus clay and silt.

TABLE NO. 1

LABORATORY ANALYSIS OF MARL SAMPLES PROJECT 039-7

Station	Depth Sampled	Loss on Ignition	CO_2	% Organic	% Mineral	Composition of Mineral			Field Notes Taken When Samples Were Collected
						% Ca CO_3	% Sand	% Clay Silt	
55	8.5-11.0	28.95	26.24	2.71	97.29	58.46	15.00	23.80	Sample of peat. Sand influence.
57	3.7-4.5	44.65	41.70	2.95	97.05	93.50	Trace	3.55	Marl with peat influence.
	7.0-8.0	43.05	42.70	0.35	99.65	97.00	0.0	2.65	Aquatic peat, strong marl influence
	11.0-12.0	43.30	42.46	0.84	99.16	96.00	1.4	1.76	Peat and marl
	15.0-16.0	41.8	41.3	0.5	99.5	92.0	0.3	7.2	" " "
	19.0-20.0	42.0	40.1	1.9	98.1	89.6	1.4	7.1	" " "
	23.0-24.0	43.0	42.6	0.4	99.6	95.0	1.4	3.2	Fair marl. Small percent peat
	27.0-28.0	44.2	41.2	3.0	97.0	92.0	0.5	4.5	" " " " "
	31.0-32.0	43.8	41.5	2.3	97.7	92.7	0.4	4.6	" " " " "
	34.5-36.0	39.4	38.5	0.9	99.1	85.7	0.5	12.9	Marly aquatic peat.
59	3.5-4.5	44.6	42.2	2.4	97.6	94.2	0.4	3.0	Marl with some peat.
	7.0-8.0	45.0	42.0	3.0	97.0	93.7	0.2	4.1	" " " "
	11.0-12.0	43.4	41.9	1.5	98.5	93.5	0.5	4.5	" " " "
	15.0-16.0	44.5	43.0	1.5	98.5	95.8	0.1	2.6	" " " "
	19.0-20.0	43.0	42.9	0.1	99.9	95.6	0.5	3.8	" " " "
	23.0-24.0	43.0	38.1	4.9	95.1	85.0	0.6	9.5	Aquatic peat with some marl
	27.0-28.0	41.5	37.4	4.1	95.9	83.5	0.8	11.6	" " " " "
59	30.0-31.0	19.5	14.6	4.9	95.1	32.6	23.1	39.4	Hard aquatic peat.
63	1.0-1.8	45.7	42.4	3.3	96.7	94.5	1.0	1.2	Surface of deposit
	3.5-4.5	45.4	3917	5.7	94.3	88.5	0.5	5.3	Marl and surface peat.
	7.0-8.0	44.8	42.0	2.8	97.2	93.7	0.1	3.4	Marl and some peat.
	11.0-12.0	45.8	40.5	5.3	94.7	90.5	0.2	4.0	" " " "
	15.0-16.0	46.1	38.6	7.5	92.5	86.2	0.1	6.2	Aquatic peat with some marl.
	19.0-20.0	45.9	37.4	8.5	91.5	83.5	0.2	7.8	" " " " "
	23.0-24.0	39.2	38.0	1.2	98.8	84.6	1.0	13.2	Compact aquatic peat.
	27.0-28.0	42.0	40.8	1.2	98.8	91.0	0.5	7.3	" " "
	30.0	6.8	5.0	1.8	98.2	11.4	86.8	0.0	Bottom
67	3.5-4.5	46.2	38.8	7.4	92.6	86.5	0.3	5.8	Peaty Marl.
	7.0-8.0	45.6	39.1	6.5	93.5	87.2	0.2	6.1	" "
	11.0-12.0	46.0	40.3	5.7	94.3	89.8	0.3	4.2	" "
	15.0-16.0	46.9	39.2	7.7	92.3	87.5	0.2	4.6	Aquatic peat and some marl.
	18.5-20.0	45.3	36.3	9.0	91.0	81.0	0.5	9.5	" " " " "

The first set of samples was collected at station 60+00 (Figure 22). To obtain marl below the fill, holes were first put thru the sand by means of a hydraulic drill; then the samples were collected with the Davis peat sampler. Subsequent moisture tests indicated that water from the drilling equipment had affected the moisture content of the marl immediately below the fill. In order to check this indication another hole was bored on centerline by means of augers, and samples were collected. The moisture content of the sample immediately below the fill proved to be 85.8 percent instead of 123 percent as shown by the sample collected when the hydraulic drill was used. The other two check samples on centerline coincided approximately with the original samples.

The percentage of water in the first 10 feet of marl, immediately below the fill, suffered a reduction of about 47 percent (from an average of 161% to about 85%.) The moisture content of the more compact marl near the bottom does not seem to have been affected by the highway embankment.

At station 75+00 (Figure 23) an interesting contract is shown in the difference between the moisture percentages of the peat and marl. This peat was excavated before placing any fill material. In collecting marl samples below the fill for moisture tests at this station, the holes thru the fill were bored by hand in order to avoid the error made at station 60. The marl immediately below the fill at this location has had its moisture content reduced from about 94 percent to 76 percent. This is

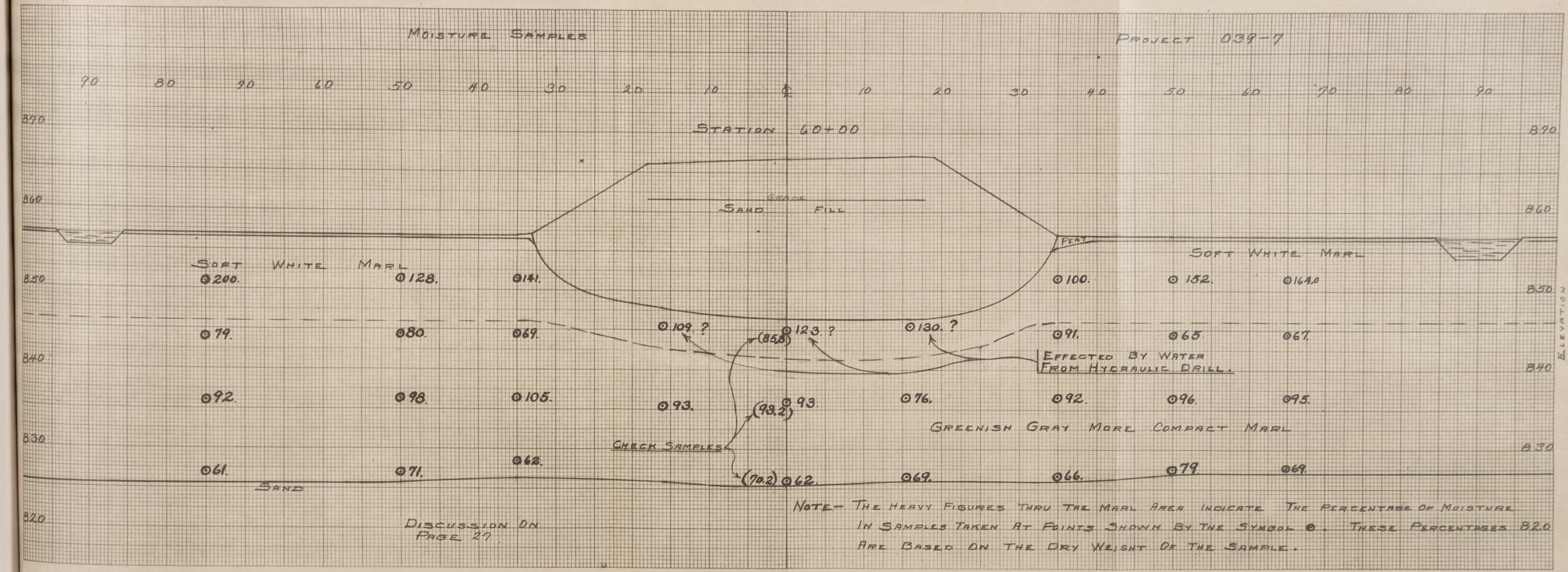
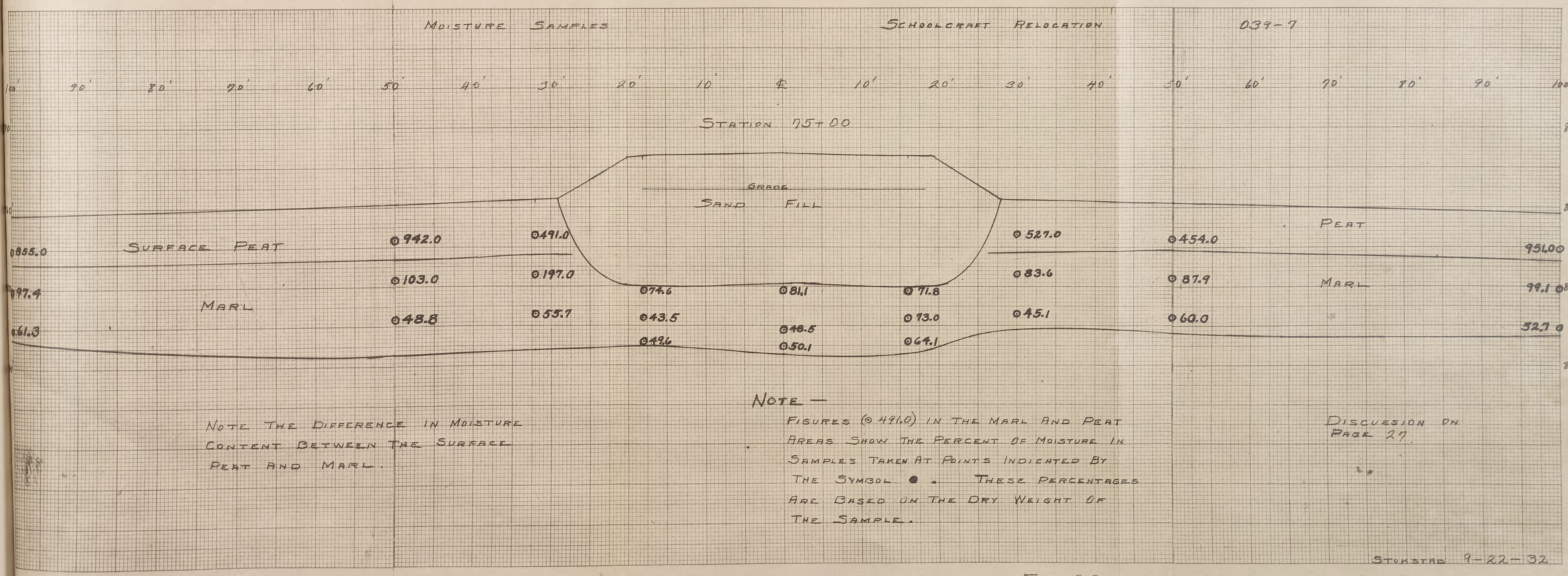

Moisture Samples
Project 039-7
90 80 70 60 50 40 30 20 10 ℄ 10 20 30 40 50 60 70 80 90
Station 60+00
870
860
850
840
830
820
Grade
Sand Fill
Peat
Soft White Marl
Soft White Marl
200. 128. 141. 100. 152. 164.0
79. 80. 69. 109. ? (85.8) 123. ? 130. ? 91. 65. 67.
Effected By Water From Hydraulic Drill.
92. 98. 105. 93. 93. (93.2) 76. 92. 96. 95.
Greenish Gray More Compact Marl
Check Samples
61. 71. 62. (70.2) 62. 69. 66. 79. 69.
Sand
Discussion On Page 27
Note- The heavy figures thru the marl area indicate the percentage of moisture in samples taken at points shown by the symbol ⊙. These percentages are based on the dry weight of the sample.
Elevation

Fig. 22

MOISTURE SAMPLES — SCHOOLCRAFT RELOCATION — 039-7



NOTE THE DIFFERENCE IN MOISTURE CONTENT BETWEEN THE SURFACE PEAT AND MARL.

NOTE —

FIGURES (491.0) IN THE MARL AND PEAT AREAS SHOW THE PERCENT OF MOISTURE IN SAMPLES TAKEN AT POINTS INDICATED BY THE SYMBOL ●. THESE PERCENTAGES ARE BASED ON THE DRY WEIGHT OF THE SAMPLE.

DISCUSSION ON PAGE 27.

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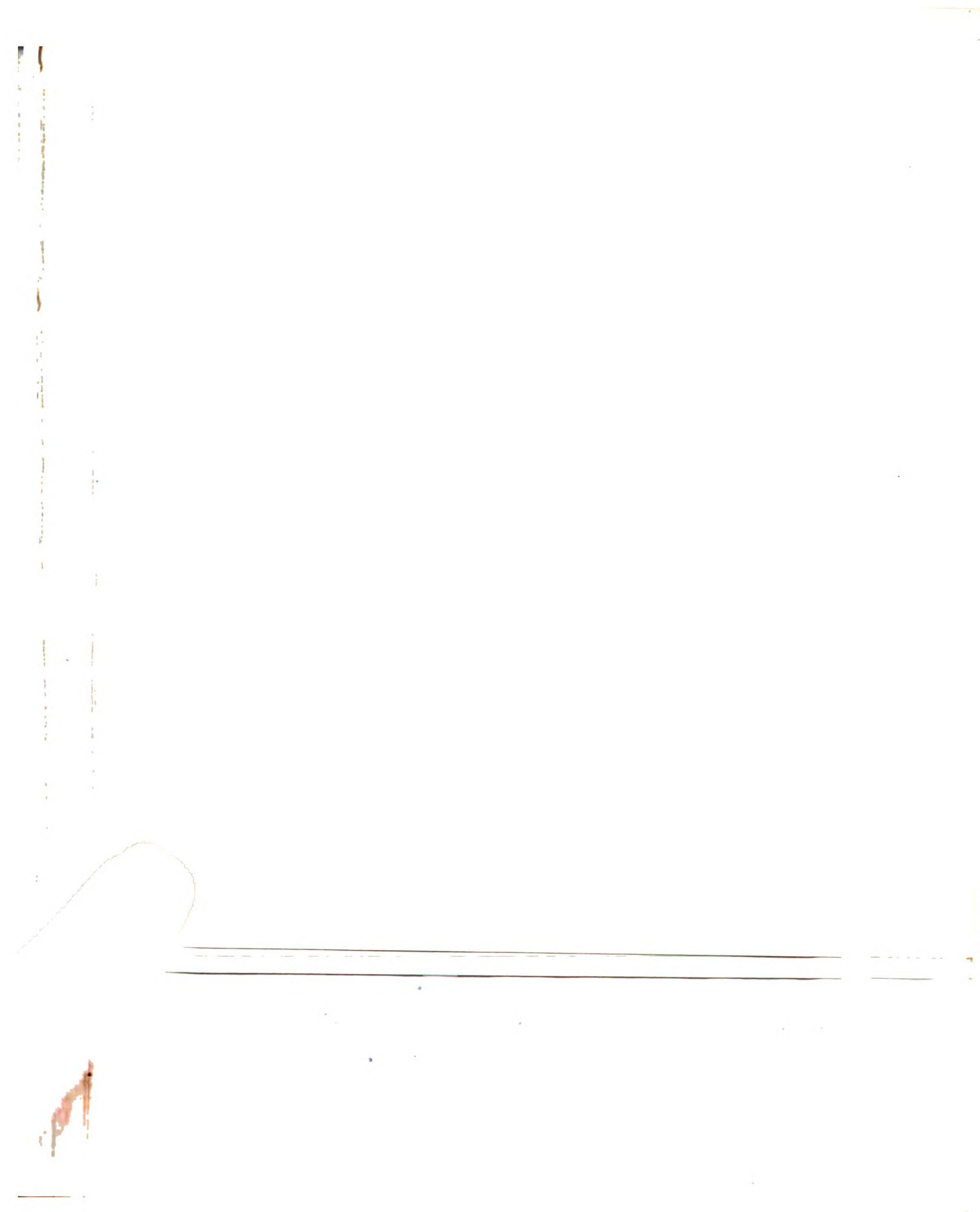
FIG. 23



a loss of only 19 percent. (In arriving at these figures the abnormal reading of 197.0 at the left of the fill was disregarded.) Here again the weight of the fill does not seem to have affected the moisture content of the marl near the bottom of the deposit.

CONCLUSIONS

1. Good marl will support a highway embankment with approximately 25 percent compaction of the marl. In other words, the fill will penetrate the marl to about 25 percent of the thickness of the marl. See the preceding table.
2. The disturbing effects of excavating machines in removing peat lying on top of the marl causes a loss as high as 50 percent of the marl in shallow deposits.
3. Highway fills will penetrate a marly peat as high as 90 percent of the thickness of the deposit on centerline. The marl influence will show its effects, however, in supporting the fill at the sides, thus saving a considerable amount of fill material. See figure 15.
4. Deposits of soft lacustrian clay below marl may have a very detrimental influence on the bearing value of the overlying marl, because they permit the latter to flow when subjected to heavy loading.
5. The moisture content of the marl does not have an influence on the supporting powers of the marl, but it does affect the volume change that occurs in marl subjected to loads.
6. Explosives may be justified to speed up compaction of marl on a rush project. There is a tendency, however, to blow "shell holes" which do not immediately fill.
7. Time allowed for settling is an important factor except in comparatively shallow deposits (up to about 10 feet). A project such as shown by figure 21 should rest from 1 to 2 years under surcharge grade before surfacing is placed.

8. The supporting value of marl is due to a possible combination of four factors:

   a. Internal friction due to the more or less granular structure of the marl.

   b. The volume weight of marl is considerably greater than that of peat.

   c. Water moves thru the marl quite freely which permits the marl to compact as the load is being applied.

   d. There is enough cohesion in a marl body to exert a considerable influence on its bearing value.

9. Fill penetration in marl or marly peat.

Percentages based on original depth of marl

Material	Percent penetration		
	Min.	Average	Max.
Good marl (shallow)	8	37	80*
(deep)	10	25	42
Marl with some peat	20	30	46
Peat with some marl	56	77	91

The figures given in this table summarize the information on penetration shown by the profiles and cross sections contained in this report.

In excavating peat from the surface of the marl some of the latter may be removed with the peat. This accounts for part of the loss of the marl. Excavating equipment also has a tendency to disturb the marl and cause it to flow ahead of the backfill as the latter is being placed.

* This figure represents penetration plus loss of marl.

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