EWR 860438
FOUNDATION INVESTIGATION
BUILDING 241F
ADDITIONAL HIGH LEVEL
WASTE STORAGE TANKS
PROJECT 9S 1493 FY75
TANKS NOS. 25 THROUGH 28
PROJECT FY77
TANKS NOS. 44 THROUGH 47
SAVANNAH RIVER PLANT

E. I. DuPont de Nemours & Co., Inc.
Engineering Department
Louviers Building
Wilmington, Delaware 19898

Mueser, Rutledge, Wentworth & Johnston
Consulting Engineers
415 Madison Avenue
New York, New York 10017

May 19, 1975

MUESER - RUTLEDGE - WENTWORTH - & - JOHNSTON
Consulting Engineers

WILLIAM H. MUESER
PHILIP C. RUTLEDGE
PAUL M. WENTWORTH
ROBERT C. JOHNSTON
SALVATORE V. DESIMONE
JAMES P. GOULD
ELMER A. RICHARDS
EDMUND M. BURKE
Partners

415 MADISON AVENUE
NEW YORK, N. Y. 10017

212 ELDORADO 5-4800

DANAROMIEL, NEW YORK

JAMES D. PARSONS
NICHOLAS W. KOZIAKIN
MAX BERNHEIMER
GEORGE L. MOORE
Senior Associates

DOMINIC A. ZARRELLA
PETER H. EDINGER
PHILIP L. CALDWELL
VYTAUTAS ANONIS
WALTER WALCHUK
HUGH S. LACY
Associates

May 19, 1975

E. I. DuPont de Nemours & Co., Inc.
Engineering Department
Louviers Building
Wilmington, Delaware 19898

Attention: Mr. George M. Vroman

Re: Building 241-F
New High Level Waste Storage Tanks
Nos. 25 Through 28 and 44 Through 47
Savannah River Plant

Gentlemen:

During a meeting held in your office on August 8, 1974, you requested us to perform foundation investigations for eight new tanks to be constructed in Area F of the Savannah River Plant. Our proposal letter for this portion of the investigation is dated September 18, 1974 and the work was authorized by a letter dated October 1, 1974. The work has been performed under Modifications Nos. 17 and 18 of Consulting Agreement AXC-25567-1/2 for our services in connection with SRP projects. We report to you herein the results of our investigation and our recommendations for foundation support of the above mentioned tanks.

EXHIBITS

The following exhibits have been prepared to illustrate the subsurface conditions in the area of the proposed waste storage tanks and the results of the laboratory tests performed on samples obtained from the borings. These exhibits are included following the text.

Drawing No. GS-1	Location Plan and Geologic Section A-A
Drawing No. GS-2	Geologic Section B-B
Drawing No. GS-3	Geologic Section C-C
Drawing No. 1	Location of Sinks in Area "F"
Drawing No. 2	Existing Topography in Area "F"
Drawing No. 3	Elevations of Top and Bottom of Calcareous Zone
Drawing No. 4	Mud Losses, Rod Drops and Grouting in Boreholes
Table No. I	Summary of Borings Made in 1974 - Building 241F - Tanks Nos. 25 Through 28 and 44 Through 47, Savannah River Plant
Table No. II	Summary of Borings Made Prior to 1974 - Building 241F - Tanks Nos. 1 Through 8, 17 Through 20, 33 and 34, Savannah River Plant
Table No. III	Summary of Laboratory Test Data
Plate No. 1	Plasticity Chart, Borings 14F-1 to 14F-9
Plate No. 2	Soil Properties Profile, Borings Nos. 3U, 5U & 7U
Plate No. 3	Consolidation Test, Boring 14F-5U, Sample 21U
Plate No. 4	Consolidation Test, Boring 14F-5U, Sample 24U
Plate No. 5	Summary of Settlement Analysis
Plate No. 6	Proposed Grout Hole Locations
Appendix A	Grouting Records in Boreholes, Sheets Nos. 1 Through 15
Appendix B	MRW&J Letter Dated April 12, 1963 & Attachments

AVAILABLE INFORMATION

The following reports and drawings were utilized during our work on this project:

1. Report No. 1, Volume 1 and Volume 2, entitled "Report of Preliminary Studies-Foundation Investigations, Savannah River Plant," dated March 1951, by Charleston District Corps of Engineers, U.S. Army.

2. Report, Volume 1 and Volume 2, entitled "Geologic Engineering Investigations, Savannah River Plant," dated March 1952, by Charleston District Corps of Engineers, U.S. Army.

3. Report entitled, "Foundation Grouting Operations, Savannah River Plant," dated June 1952, by Charleston District Corps of Engineers, U.S. Army.

4. Drawing No. W449600 showing the layout of the proposed waste storage tanks, revised August 22, 1974

5. Drawings Nos. MAP3302, Sheets 853 and 854 showing general layout of structures in Area F.

6. Drawing No. MAP3406, Sheet 854, showing locations of existing borings in Area 200F.

7. Drawing No. W239379 showing logs of Borings 11F-1 through 11F-5 made at the site of Building 241-11F.

8. Drawing No. W239396 showing logs of Borings 11F-6 through 11F-12 made at the site of Building 241-11F.

9. Raymond International, Inc. logs of Borings 11F-1 through 11F-12 made at the site of Building 241-11F.

10. Drawing No. W238698 showing logs of Borings F-1 through F-6 made in Area 200F.

11. Drawing No. W238699 showing logs of Borings F-7 and F-8 made in Area 200F.

12. Corps of Engineers Drawing No. SRP-F-8 showing logs of Borings F-25 through F-27 and F-29 through F-32 made in Area F for alternate No. 2.

13. Drawing No. W234538 showing logs of Borings 1 through 13 made at the site of Building 241-F.

14. Drawing No. W238163 showing the general arrangement and construction details of proposed waste storage tanks.

DESCRIPTION OF THE FACILITIES

You have provided us with prints of your Drawing No. W449600 showing the plot plan and grading plan for the tanks. There will be 8 tanks in two rows spaced approximately 120 feet on centers in a north-south direction and 185 feet on centers in an east-west direction. Each tank will have a concrete encasement 95 feet in outside diameter with a height of about 41'-4" from bottom of base slab to top of roof slab. Each tank will have a central concrete core column 6'-4" in diameter. The bottom of the base slab except for the central dropped slab will bear at Elev. 245.63 for tanks Nos. 26, 27, 45 and 46 and at Elev. 244.28 for tanks Nos. 25, 28, 44 and 47. These elevations are approximately 42 feet below present ground. The tops of the roofs for these two groups of tanks will be at Elev. 287.00 and Elev. 285.65, respectively. A 4-inch lean concrete mat is to be placed under these bearing levels.

We have used your Drawing No. W238163, previously submitted to us in connection with a subsurface investigation in 200H Area for computing the weight of the tank contents assuming a final specific gravity of 1.8. These calculations indicate that each tank filled to a depth of 31.0 feet will have an average bearing pressure of 4.7 ksf. The top of the surrounding ground will be one foot below the top of the concrete roof slab of the tanks. Using an estimate damp unit weight for the soil of 125 pcf, we compute that the total excavated soil load removed to the base of the tanks is equal to 5.3 ksf. Therefore, the total net load at subgrade level after the tanks are in place and filled with liquid will be an unloading of the underlying soil of 0.6 ksf.

RESULTS OF BORING OPERATIONS

Nine borings, Nos. 241-14F-1 through 241-14F-9, were made to investigate the subsurface conditions at the locations of the proposed tanks. The locations of the borings, relative to the planned locations of the tanks, are shown on plan on Drawing No. GS-1. The borings were made by Soil and Materials Engineers during the period of October 9 through November 23, 1974, under contract negotiated by the DuPont Construction Division. The field work was inspected by Andrew Schechter and Richard Conolly of our office. Copies of field records prepared during the work have been submitted to you.

Six of the borings were exploratory "dry sample" type borings extending to depths ranging from 163.7 feet to 180.0 feet. Three borings for recovery of undisturbed samples were carried to depths between 140 feet to 174.5 feet. The results of the borings are shown in the form of geological sections on Drawings Nos. GS-1 through GS-3. All borings were grouted at the completion of work and records of the grout acceptance are included as Appendix A.

Thirteen split-spoon samples and fishtail borings were made in 1963 as part of an investigation of a portion of this site. Two wellpoint piezometers were installed during that investigation. The locations of these explorations are indicated on Drawing No. GS-1 and the results are discussed in attached Appendix B.

GENERAL SUBSURFACE CONDITIONS

General subsurface conditions are shown in the form of three geological sections on Drawings Nos. GS-1 through GS-3. The locations of these sections are shown on the Boring Location Plan, Drawing No. GS-1. The boring logs on the geologic sections include individual sample descriptions. Outlines for the base of the foundations for the tanks are shown by dash lines on these drawings. The subsoils encountered at the site have been divided into seven principal strata, as shown on the sections and described in sequence with depth as follows:

Stratum F - Fill. Fill encountered at the site is classified as medium to compact brown and red fine to medium sand, trace to some clay, cinders and rock fragments. This stratum was encountered in all the borings and is fill from excavations of other areas within the plant. The northern portion of Section B-B shows the greatest thickness of fill which was placed at the location of the ramp built in 1956 in connection with the construction of the group of tanks north of Building 241-14F. The Boring Location Plan shows the outline of this ramp. The average thickness of fill outside the limits of the ramp is 5 feet.

Stratum C1 - Silty Clay. Beneath the fill was found a stratum of stiff mottled red brown and purple silty clay to fine sandy clay, trace gravel which varies between 5 and 22 feet in thickness with its base elevation not below Elev. +255. Penetration resistances vary between 7 and 56 blows per foot. Water contents range between 13 and 30 per cent of dry weight.

Stratum S1 - Sand with some clay layers. A stratum of medium compact to compact brown, white and purple fine to medium sand and clayey fine to medium sand with some clay lenses was encountered in all borings. Penetration resistances in this layer vary between 14 and 90 blows per foot. This stratum varies in thickness between 8 and 32 feet and extends to as low as Elev. 230 in Boring No. 14F-2.

(S1)

Stratum S2 - Sand. A thick deposit of medium compact to very compact red and brown and orange fine to medium sand, trace silt and clay exists beneath the entire site with the greatest thickness on the western side. It varies in thickness between 24 feet at Boring No. 241-14F-2 and 72 feet at Boring No. 241-14F-7U. The standard penetration resistance of the stratum ranges between 11 and 80 blows per foot.

(S2)

Stratum C2 - Clay. Stratum C2 consists of layers of stiff to hard brown and green clay, trace fine to medium sand lenses that occur within Stratum S2. Stratum C2 clays vary up to 11 feet in thickness. Natural water contents are between 35 and 85 per cent of dry weight.

(C2)

Stratum S3 - Clayey Sand. Clayey sands classified as loose to very compact brown, gray and yellow clayey sand to fine to medium sand, trace to some clay, trace gravel and organic material were found above and below the calcareous zone at this site. All of the borings were terminated below the calcareous zone in this stratum. Water contents vary between 20 and 68 per cent of dry weight. Standard penetration resistances vary between 6 to over 157 blows per ft.

(S3)

Stratum S4 - Calcareous Clayey Sand. Medium compact to very compact light gray, white and brown calcareous clayey fine to coarse sand, trace to some shell fragments was encountered in all borings with stratum thickness varying between 5 and 30 feet. As this stratum is calcareous, it is susceptible to solution by ground water. Its occurrence was confirmed by reaction of samples to dilute hydrochloric acid. Six of the 1974 borings encountered zones of apparent cavities varying in size between 1.5 feet to 9.5 feet. Standard penetration resistance ranges between a low of 12 blows per foot and a high of 100 blows per inch. Stratum S4 generally occurs with its base above Elev. +140.

GROUND WATER OBSERVATIONS

Ground water levels were observed in Piezometer No. 1. This piezometer was installed in 1963 and has its tip approximately at Elev. 215. Several readings were taken in this piezometer between October 10 and November 23, 1974. All of these observations indicate that the ground water level is at Elev. 226.7 which is at the same level recorded on March 11, 1963 or about 18 feet below the proposed foundation bearing level. Piezometer No. 2, also installed in 1963, with tip at Elev. 242 was found to be dry. Water levels observed in the recent borings are shown on the geologic sections but may not be indicative of the stabilized ground water table due to the presence of drilling mud in the hole from the boring operations.

GEOLOGIC CONDITIONS

General. As the results of the borings indicated zones of extremely loose or soft material within the calcareous zone located approximately 115 feet below the ground surface and approximately 75 feet below the base of the proposed tanks, we reviewed available geologic information and results of previous borings in F Area in order to determine whether conditions beneath adjacent structures are similar. Numerous investigations have been conducted at the site of the Savannah River Plant. The initial foundation investigation program at the plant was conducted by the Corps of Engineers in 1951. In March 1952, the Corps of Engineers published in two volumes the results of their geologic and engineering investigations.

The Savannah River Plant is located near the east boundary of the Atlantic Coastal Plain which extends from New Jersey to Florida. The Corps of Engineers listed the principal sediments encountered at the plant site in order of depth as follows:

Formation	Period	Thickness	Description
Hawthorne	Miocene	0-80	Red to purple sands with extensive lenses of gray clay and gravel lenses.
Barnwell	Eocene	50-80	Red and brown sand with layer of red, white and purple clay and sandy clay.

Formation	Period	Thickness	Description
McBean	Eocene	100-200	Tan to brown and green sands with beds of marl, laminated clays and lenses of silicified limestone.
Tuscaloosa	Upper Cretaceous	600-700	Light gray, white or buff coarse sands with inter-fingering lenses of clay.

The engineering and geologic studies of 1951 and 1952 disclosed that the plant site is covered with numerous sinks. The sinks resulted from solution of calcareous materials in the McBean Formation at depths of about 100 to 200 feet. The studies disclosed that these sinks developed during geological time and only one of the sinks within the general plant area can possibly have occurred in recent history. Area studies of sink occurrence seem to indicate that they are oval-shaped areas generally aligned perpendicular to the strikes of the underlying bedrock and soil formations which bear N 73° E. Often, sinks are found at the head of drainage depressions or streams suggesting that the streams are working their way upland as the sinks form as a result of underground drainage beneath the stream and sink areas.

As part of the studies by the Corps, borings were made in the center and edges of representative sinks which confirmed that the sinks had resulted from removal of material from the calcareous zone since the surface of the formation showed a depression in elevation across the sink corresponding to the depression in the ground surface. The results of the borings also showed that the calcareous zone was denser in the center of the sink than at its edges as the material had densified during the settlement process following the leaching of calcareous material. Often, the zone of apparent voids was overlain by sand of less compactness which is believed to result from loss of material into the void zone. It was concluded that the apparent voids in the calcareous zone are not open caverns, but a mass of spongy material supported by a skeleton of more resistant material. This is reasonable as the calcareous material is not rock but a dense soil of a granular nature that cannot support large roof spans. As ground water flow through the clayey soils is relatively slow, it is reasonable to conclude that the development of surface sinks is a very gradual process and this conclusion is confirmed by the lack of evidence of recent surface settlement.

Area F. Attached Drawing No. 1 reproduced from the Corps studies shows the mapped sinks and drainage depressions in the vicinity of the project. We have added to this drawing the locations of structures now existing and waste tanks for this project. This comparison indicates that the site of the proposed tanks was formerly crossed by a drainage depression leading from a mapped sink approximately 200 feet west of the site. The drawing also shows that tanks Nos. 1 through 8 were constructed within an area partially covered by a former sink.

The general location of the proposed tanks in reference to the entire Area F complex is shown on Drawing No. 2. This drawing was made up by utilizing your Drawings Nos. MAP3302, Sheet 853 and MAP3302, Sheet 854. Original ground contours shown on this drawing show the sink west of the proposed site and the regrading which relocated the former drainage depression into a ditch crossing the south corner of the site.

Zone of Apparent Voids. Drawings Nos. 3 and 4, and Tables Nos. I and II summarize information obtained during the drilling work relative to the limits of the calcareous zone and the extent of apparent voids or cavities encountered during drilling. Included are data from the recent borings and the borings made prior to 1974. All borings were grouted at the completion of work in order to eliminate the possibility of surface water flow directly into the calcareous zone. As approximately 15 cubic feet of grout is the computed minimum quantity required to fill up the hole made by the boring operations, a grout acceptance quantity many times larger indicates that voids or zones of semi-liquid material exist that are being filled or displaced by the grout.

The examination of the above data indicates that the subsoils of Building 241-14F contain more apparent cavities than the rest of Area F. In terms of numbers of voids, Borings Nos. 241-14F-2, 241-14F-4, 241-14F-6, 241-14F-7U and 241-14F-9 proved to be the most critical. Following is a summary of the drilling mud losses, rods and casing drops in these borings.

In Boring No. 241-14F-2, a soft zone was encountered below a 128.5 foot depth. Approximately 100 gallons of drilling mud was lost between 131.0 and 133.0 feet. It took a total of 112.9 cubic feet of grout to fill the completed hole. No grout return was obtained until the hole was allowed to sit overnight permitting the grout that had been pumped to solidify.

Apparent voids were encountered during sampling in Boring No. 241-14F-4 at depths between 123.5 to 124.5 feet, 148.5 to 150.0 feet and 153.5 to 155.0 feet. The hole collapsed at 80 feet overnight. Loss of mud return occurred between 111 feet and 115 feet and again between 121 feet and 130 feet. Complete drilling mud loss took place between 111.0 and 115.0 ft. depth. Casing was lowered to 130 ft. depth to minimize drilling mud loss and to be able to advance the hole to completion. Some drilling mud was lost during drilling below 140 feet for the remainder of the hole. The hole collapsed at 117 ft. depth during grouting. It was then redrilled to 135 ft. depth and grouting continued. A total of 151.5 cubic feet of grout was pumped into the hole to fill it to the ground surface. Three days were spent grouting this hole.

During the drilling of Boring No. 241-14F-6 an apparent cavity was encountered between 114.5 to 124.0 ft. depth as the rods fell between these depths. Casing was lowered to 125 ft. depth to be able to advance the hole to completion. A total of 94.5 cubic feet of grout was pumped into the hole indicating that some interconnecting cavities exist at this location. Grouting during two days failed to obtain a return and the hole did not stabilize until after the second overnight shutdown.

The drilling operations of Boring No. 241-14F-7U experienced difficulties at 120 ft. depth. As the driller was pulling up the rods from this depth, the hole kept caving on top of the rods. In order to advance the hole below 120 ft. depth, it was necessary to drive casing to 139 ft. depth. The casing dropped between 132 to 137 ft. depth indicating the presence of a cavity. Upon redrilling to 130 ft. depth, a total of 220 gallons of drilling mud was lost. A total of 71.1 cubic feet of grout was needed to fill this hole and it was grouted during one day's work.

In Boring No. 241-14F-9 an extremely soft zone was encountered between 106 and 123 ft. depth. During drilling between 93.5 to 123.0 ft. depth, a total of 700 gallons of drilling mud was lost.

Some cement was mixed with the drilling mud in an attempt to stabilize the hole overnight. Casing was inserted to 138.5 feet in order to advance the hole to completion. A total of 170.9 cubic feet of grout was pumped into the hole during a period of three days in order to fill it.

Extensive drilling difficulties were not experienced in Borings Nos. 241-14F-1, 241-14F-5U and 241-14F-8. There was no loss of drilling mud and the grout take was about the same magnitude as the volume of the holes.

We believe the data assembled concerning the 1974 borings and the borings made at earlier dates within the F Area show that conditions beneath proposed tanks Nos. 44 through 47 along the southwesterly side of the project are more severe than encountered beneath areas of previous construction. Although the data available for the old borings are meager as compared with that for the recent program, we believe more detailed information would have been recorded if problems similar to the recent ones occurred.

RESULTS OF LABORATORY TESTS

All the dry samples and undisturbed samples of Borings Nos. 241-14F-1 through 241-14F-9 were shipped to our laboratory for classification. These classifications are shown in geological sections A-A, B-B and C-C on Drawings Nos. GS-1 through GS-3. A total of 14 undisturbed samples were recovered from Borings Nos. 241-14F-3U, 241-14F-5U and 241-14F-7U. Results of all laboratory testing performed on the undisturbed samples are shown on Table No. III.

The results of the borings have shown that the soil profile beneath the tanks is largely sand except for occasional thin clay layers. Plasticity limits were obtained for sections of the undisturbed samples and for the clay layers from the split-spoon samples. The results are shown on Plate No. 1 and are within the range of values obtained from other areas within the plant, confirming that the clays are similar even though they occur less extensively at this location. The wide range of plasticity values is caused by the sand present within some of the samples.

Plate No. 2 is a Soil Properties Profile presenting graphically the results of all the testing performed in the undisturbed samples. On the left-hand panel are also plotted the vertical stresses due to weight of existing overlying materials and vertical stresses in the soil after the tanks have been completed, backfilled and filled with liquid. Four consolidated-undrained triaxial tests were performed on samples located above the base of the proposed tanks. These tests indicate that the clay soils above the base of the tanks possess a minimum shearing strength value of 2.0 ksf. These values can be utilized in determining safe slopes in the clay portion of the excavation for the tanks.

Only Samples Nos. 21U and 24U of Boring No. 241-14F-5U obtained from beneath the base of the proposed tanks contained clay. Consolidation tests were performed on these samples to determine the compression characteristics of the clay. As the remaining undisturbed samples located beneath the proposed tanks were found to contain sand, no testing was scheduled for them. On the left-hand panel of the Soil Properties Profile, Plate No. 2, we have indicated the preconsolidation values determined from the tests. Plates Nos. 3 and 4 show in detail the results of the tests. Sample No. 21U indicates a preconsolidation greatly in excess of existing overburden stresses. Sample No. 24U was performed on a clayey sand and a clear definition of past preconsolidation was not obtained. We judge from the relationship of the natural water content of the sample to its plasticity limits and the compactness of the sample that this material has also been preloaded in excess of existing overburden stresses.

FOUNDATION ANALYSES

The borings have shown that materials below the subgrade of the proposed waste storage tanks are essentially granular with thin layers of stiff clay. A stratum of calcareous sand exists between 70 and 100 feet below subgrade that contains zones of loose and soft material remaining from leaching of calcareous material by the ground water. The effect of these conditions on the performance of the tanks has been evaluated as described below.

Effect of Clay Layers on Tank Performance

The tank construction will require excavation of soil weight approximately equal to the gross weight of the tank and contained fluid. Therefore, stresses created in the subsoils by the completed structures are no greater than existing overburden stresses. Some settlements of the tanks will occur because of the clay zones within the subsoils as a result of expansion and recompression during the excavation construction cycle. We have made an analysis of this settlement assuming that 20 feet of clay may exist beneath the tanks and find that the settlement will not exceed one-half inch. As the clay layers are distributed over a considerable depth below the tank, any settlement that occurs will affect the entire tank structure and no detrimental differential settlements are anticipated. The results of this analysis are shown on Plate No. 5.

Effect of Voids in Calcareous Stratum on Tank Performance

The geologic investigations and boring results have shown that Stratum S4 includes zones of material of very low supporting capacity created by solution of calcareous material by moving ground water. It is believed that these zones consist of a sponge-like structure of sufficient strength to support the overlying overburden soil with the voids filled with semi-fluid soil material. The numerous ancient sinks which are apparent in the ground topography of the plant are areas where the sponge-like structure deteriorated to a point where it was no longer capable of supporting the overburden weight and downward movement of the overlying soils occurred. We believe the surface movement was preceded by gradual loss of granular material into the calcareous zone. As the proposed structures will not increase vertical stresses within the calcareous zone, we do not believe that the construction of the waste storage tanks will accelerate any sink hole activity. However, as the base of the structures are within 80 feet of the poor zone of material and the structures have diameters of approximately 95 feet, sink hole activity which causes loss of ground during the life of these structures could cause gradual settlement of the structures.

CONCLUSIONS AND RECOMMENDATIONS

As a result of the foundation investigation made for the proposed eight waste storage tanks to be constructed in F Area, we conclude as follows:

1. The subsurface investigation has shown that the tank subgrades are underlain by medium compact to compact granular materials containing layers of clay and a stratum of calcareous material with zones of voids filled with soft or semi-liquid material. Drilling records indicate that the void zones in the calcareous stratum are more extensive at this site than at other locations within F Area.

2. Geologic investigations made prior to initial construction of the Savannah River Plant show that the site selected for the proposed tanks is approximately 200 feet from a surface depression believed to be evidence of an ancient sink hole. A drainage depression leading from the sink crosses the proposed tank construction site. We believe that the extent of the void soft zones and the proximity of the site to the former sink and drainage depressions indicates that the site is one of potential future sink hole activity. The geologic history of the site shows that sink hole activity is an extremely slow process and there is no means of establishing whether or not a sink could develop during the life of the proposed structure.

3. Materials existing at subgrade are suitable for support of the proposed tank base. Ground water is approximately 18 feet below subgrade and should not influence tank construction. A backfilled former ramp for construction of tanks to the north exists in the area of tanks Nos. 25 and 26 and backfill may exist below subgrade of tank No. 25. This fill should be examined when subgrade for tank No. 25 is exposed in order to determine if it has been suitably compacted or if it should be removed and replaced with compacted fill before tank base construction.

4. Estimates of settlement of the proposed tanks due to the clay layers in the overburden soils indicate that settlements should not exceed one-half inch. This settlement is less than has been estimated for other waste storage tanks within the Savannah River Plant as less clay exists beneath the tanks and they are to be constructed below existing ground.

5. The void zones in the calcareous material at this location are not open caverns but consist of zones of sponge-like nature with openings filled with soft or semi-fluid material. Since the void zones are within a soil mass that is uncemented or partly cemented, collapse of the soil structure occurs as the voids develop and large unsupported openings which could collapse and cause sudden ground surface settlements are unlikely. Because of

the possibility that some sink hole activity may be developing at the location selected for the proposed tanks, it is possible that tank settlement of an unpredictable magnitude may develop. Therefore, we believe it would be prudent to strengthen the void zones within the calcareous stratum by low pressure grouting of these zones prior to tank construction to reduce the possibility of settlement. We believe that the basic grouting program for the site should consist of holes spaced approximately 50 feet on centers within the tank areas. Supplementary grouting of holes at closer spacing may be necessary if the field work indicates that large quantities of grout are accepted in certain areas.

6. Laboratory tests on the clay stratum within the zone of excavation indicate that the clay is of sufficient strength to support temporary excavation slopes of 1 vertical to 1 horizontal. A considerable portion of the excavation will be in granular soil that will stand initially at a similar slope; however, some ravelling and loss of surface material into the excavation may develop with time. It would be advisable to excavate a bench midway in the excavation slope to reduce the amount of slope wash which actually reaches the base of the excavation.

7. We recommend that settlement points be installed around the rim of the tank foundation and the elevations be transferred to points on the roof of the tanks after construction is complete. Determination of elevation of these points should be made during construction and at periodic intervals after the tank walls are backfilled and the tanks put in service. As all settlement due to tank load and stored material should occur as construction loads and tank waste loads are applied, long-term settlements should be followed closely to confirm that no loss of ground into voids beneath the tanks is taking place.

Very truly yours,

MUESER, RUTLEDGE, WENTWORTH & JOHNSTON

By Elmer A Richards

Elmer A. Richards

EAR:SLT:mr

SUMMARY OF BORINGS MADE PRIOR TO 1974 - BUILDING 241F - TANKS NOS. 1 THROUGH 8, 17 THROUGH 20, 33 AND 34, SAVANNAH RIVER PLANT

Boring No.	Type of Boring	Surface Elev.	Depth of Boring	Bottom Elev. Of Boring	Ground Water Level-Depth	Rod, Casing Droppings or Settling-Depths	Drilling Mud Losses Depths	Calcareous Material Depths	Grout Required To Fill Hole Cubic Feet	Remarks
241-11F-1	split spoon	+283.6	160.0 Ft.	123.6	60.0 Ft.	112.5 to 115.5 Ft.	112.5 to 115.5 Ft.	111.0 to 147.5 Ft.	not reported	Casing lowered to 120' depth to maintain hole open.
241-11F-2	do	+281.4	149.5	131.9	56.6	none	none	107.0 to 142.0	do	
241-11F-3	do	+285.5	150.0	135.5	60.0	none	none	119.0 to 131.0	do	
241-11F-4	do	+284.6	155.0	129.6	not given	none	none	---------	do	
241-11F-5	do	+284.6	75.0	209.6	59.0	none	none	58.0 to 69.0	do	Only calcareous lenses noted between 58' to 69' depth.
241-11F-6	do	+282.1	150.0	132.1	55.0	none	none	117.0 to 131.5	do	
241-11F-7	do	+283.9	155.0	128.9	61.0	none	45.5 to 153.5 (slight loss)	121.5 to 126.6	do	
241-11F-8	do	+284.1	150.0	134.1	58.5	none	----	117.0 to 131.5	do	
241-11F-10	fishtail	+283.6	118.5	165.1	59.0	none	98.0 to 98.5 (complete mud loss)	112.5 to 118.5	do	
241-11F-11	do	+283.7	118.5	165.2	64.0	none	40.0 to 118.5 (slight loss)	112.0 to 118.5	do	
241-11F-12	do	+285.4	85.0	200.4	59.0	none	none	---------	do	Piezometer installed in this hole. Shallow boring, did not reach calcareous zone.
F-24	split spoon	+286.4	81.0	205.4	not given	none	none	---------	do	Shallow boring, did not reach calcareous zone.
F-25	do	+285.9	163.9	122.0	do	none	none	---------	do	No sampling below 80' depth.
F-26	do	+282.6	81.0	201.6	do	none	none	---------	do	Shallow boring, did not reach calcareous zone.
F-27	do	+287.3	168.9	118.4	do	none	none	121.0 to 135.0	do	Caved between 164.0 to 168.9 ft.
F-29	do	+281.1	149.6	131.5	do	none	none	118.0 to 134.0	do	No sampling below 82' depth.
F-30	do	+281.5	153.5	128.0	do	none	none	107.7 to 147.0	do	No sampling below 81' depth.
F-31	do	+283.3	154.0	129.3	do	none	none	125.5 to 137.0	do	No sampling below 81' depth.
F-32	do	+282.8	155.0	127.8	do	not given	not given	105.0 to 108.0	do	
241-F-1	split spoon	+292.2	125.9	166.3	do	none	122' (lost 1,200 gallons of drilling mud)	124.9 to 125.9	do	Boring apparently discontinued because of lack of drilling mud circulation.
241-F-2	do	+289.6	141.5	148.1	do	none	none	125.6 to 141.6	do	
241-F-3	do	+292.0	140.1	151.9	do	none	none	125.0 to 140.0	do	
241-F-4	do	+291.8	140.9	150.9	do	none	none	124.8 to 140.8	do	
241-F-5	do	+289.7	141.5	148.2	do	none	none	none	do	
241-F-6	do	+293.2	51.5	241.7	do	none	none	none	do	Shallow boring, did not reach calcareous zone.
241-F-7	do	+291.4	125.8	165.6	do	none	none	none	do	
241-F-8	do	+291.0	126.5	164.5	do	none	none	none	do	
FF-4	do	+291.7	179.0	112.7	do	not given	not given	125.0 to 176.0	do	

TABLE NO. II

TABLE NO. III

SUMMARY OF LABORATORY TEST DATA

Sample Identification: Boring No.	Sample No.	Depth Ft.	Stratum Designation	Classification Properties: Natural Water Content %(W) Average of Entire Sample	Liquid Limit (W_L)	Plasticity Index (I_p)	Natural Water Content of Limit Sample %(W)	Specific Gravity of Solids (G)	Unified Classification System: Soil Type	% Sand (<#4,>#200 Sieve)	% Fines (<#200 Sieve)	Strength – Unconfined Compression: Compressive Strength TSF	Water Content at End of Test %	Strain at Failure %	Strength – Triaxial Compression: Type of Test	Deviator Stress ($\sigma_1 - \sigma_3$) TSF	Confining Pressure (σ_3) TSF	Natural Water Content %	Water Content at End of Test %	Consolidation: Natural Water Content %	Existing Overburden Stress TSF	Estimated Probable Preconsolidation Stress - TSF	Compression Index C_c	Swelling Index C_s	Void Ratio at Start of Swell, e_r
241-14F-1	18D	79.3	C2	57	157	124	63																		
	19D	84.3	C2	47	93	73	37																		
241-14F-2	10D	39.3	S1	33	96	59	35																		
	19D	84.3	C2	40	108	78	41																		
241-14F-3U	8U	28.5	C1	28	56	28	21								Qc	3.30	1.30	24	23						
	20D	84.3	C2	66	137	93	56																		
241-14F-4	13D	55.8	S2	14	30	9	14																		
241-14F-5U	4U	9.8	C1	20											Qc	2.39	0.50	20	19						
	6U	19.8	C1&S1	15											Qc	2.17	1.00		15						
	12U	50.0	S1	16																					
	14U	60.0	S2	17																					
	16U	69.5	S2	26																					
	19D	84.3	C2	85	69	34																			
	21U	100.0	S3	68	136	73	73	2.77												64	6.0	14.0	1.20	0.28	1.020
	24U	114.3	S3	26	65	41	24	2.68												27	5.4	5.4	0.22	0.030	0.489
	28U	134.2	S3	33																					
241-14F-6	7D	24.2	C1	22	65	38	22																		
	18D	79.3	C2	74	125	77	74																		
	20D	89.3	C2	30	66	42	30																		
241-14F-7U	9U	25.8	C1	19											Qc	2.78	1.30	23	21						
241-14F-8	3D	7.2	C1	21	46	18	21																		
241-14F-9	21D	84.3	C2	95	160	104	95																		

DESCRIPTION OF SOIL TYPES

(C1) **SILTY CLAY**
Stiff mottled red, brown and purple silty clay to fine sandy clay, trace gravel.

(S1) **SAND WITH SOME CLAY LAYERS**
Medium compact to compact brown, white and purple fine to medium sand and clayey fine to medium sand with some clay lenses.

(S2) **SAND**
Medium compact to very compact red, brown and orange fine to medium sand, trace silt and clay.

(C2) **CLAY**
Stiff to hard brown and green clay, trace fine to medium sand lenses.

(S3) **CLAYEY SAND**
Loose to very compact brown, gray and yellow clayey sand, fine to medium sand, trace to some clay, trace gravel and organic material.

NOTES

1. All tests summarized above were performed in the soils laboratory of Mueser, Rutledge, Wentworth & Johnston.
2. The sample depth listed above is the average depth of the sample recovered.
3. Ground surface elevations at borings are as follows:

Boring No.	Elevation	Boring No.	Elevation
241-14F-1	+283.7	241-14F-6	+286.4
241-14F-2	+288.2	241-14F-7U	+285.2
241-14F-3U	+287.9	241-14F-8	+287.0
241-14F-4	+289.8	241-14F-9	+288.5
241-14F-5U	+286.7		

4. "Natural water content of entire sample" is a weighted average of all material types recovered.
5. The triaxial compression tests performed were:
   Qc - Consolidated Quick Tests (CU - Consolidated Undrained Tests)
6. Strength tests were performed on samples approximately 2-7/8 inches in diameter. The ratio of height to diameter of all strength test specimens was approximately 2.0.
7. The strength tests were performed at a rate of strain of 1 per cent per minute.
8. Compression Index C_c - Straight line portion of the virgin curve of consolidation test $e = e_o - C_c \log P/P_o$
9. Swelling Index C_s - Straight line portion of the rebound curve of consolidation test $e = e_o - C_s \log P/P_o$

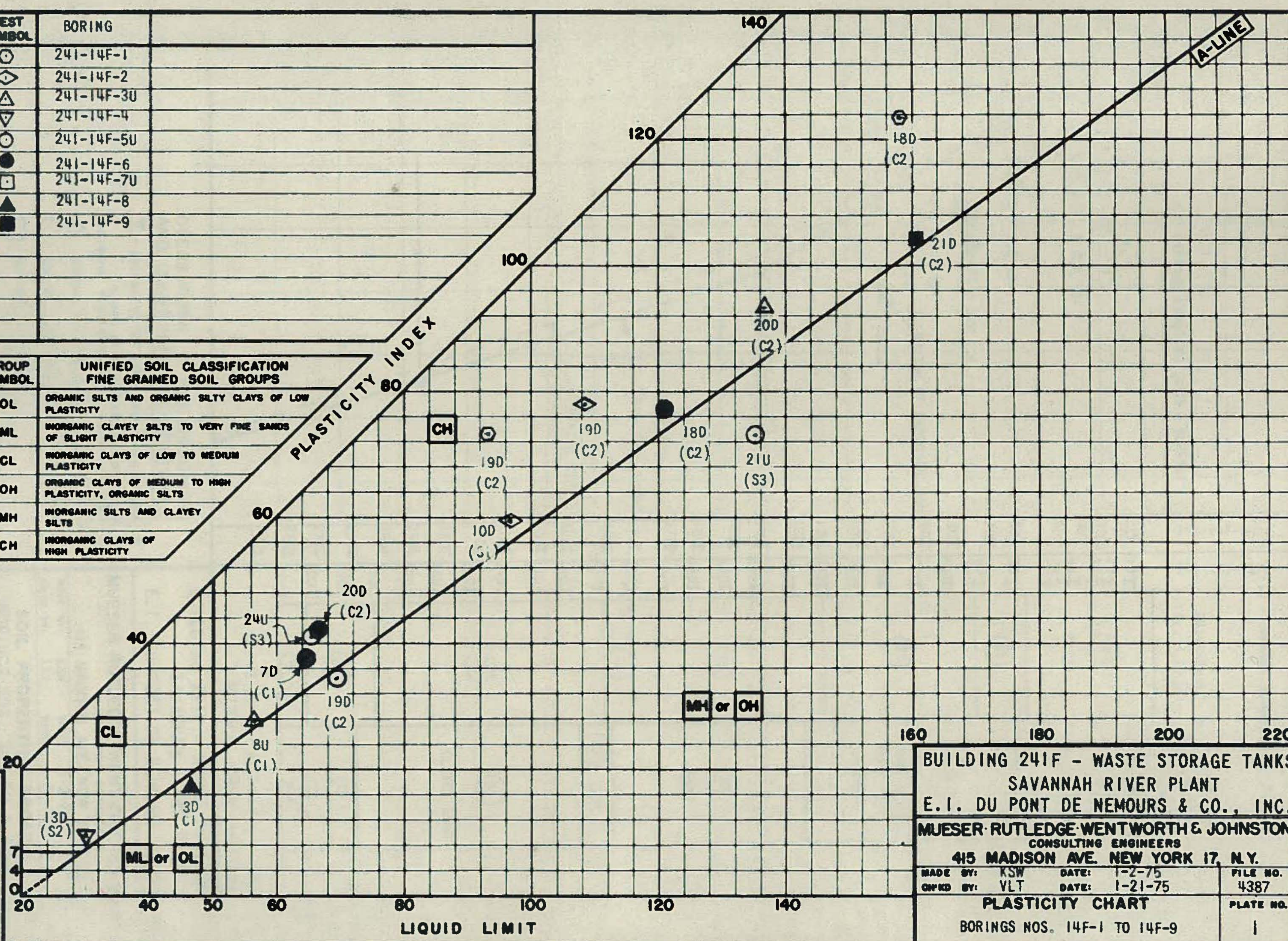
MUESER, RUTLEDGE, WENTWORTH & JOHNSTON
CONSULTING ENGINEERS
415 MADISON AVENUE
NEW YORK, N.Y. 10017

BUILDING 241F · WASTE STORAGE TANKS
SAVANNAH RIVER PLANT
E. I. DU PONT DE NEMOURS & CO., INC.

DATE January 28, 1975 | FILE NO. 4387 | SHEET NO. 1 OF 1 | TABLE NO. III

TEST SYMBOL	BORING
⬡	241-14F-1
◇	241-14F-2
△	241-14F-3U
▽	241-14F-4
⊙	241-14F-5U
●	241-14F-6
⊡	241-14F-7U
▲	241-14F-8
■	241-14F-9

GROUP SYMBOL	UNIFIED SOIL CLASSIFICATION FINE GRAINED SOIL GROUPS
OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
ML	INORGANIC CLAYEY SILTS TO VERY FINE SANDS OF SLIGHT PLASTICITY
CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY
OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
MH	INORGANIC SILTS AND CLAYEY SILTS
CH	INORGANIC CLAYS OF HIGH PLASTICITY



BUILDING 241F - WASTE STORAGE TANKS
SAVANNAH RIVER PLANT
E. I. DU PONT DE NEMOURS & CO., INC.

MUESER · RUTLEDGE · WENTWORTH & JOHNSTON
CONSULTING ENGINEERS
415 MADISON AVE. NEW YORK 17, N.Y.

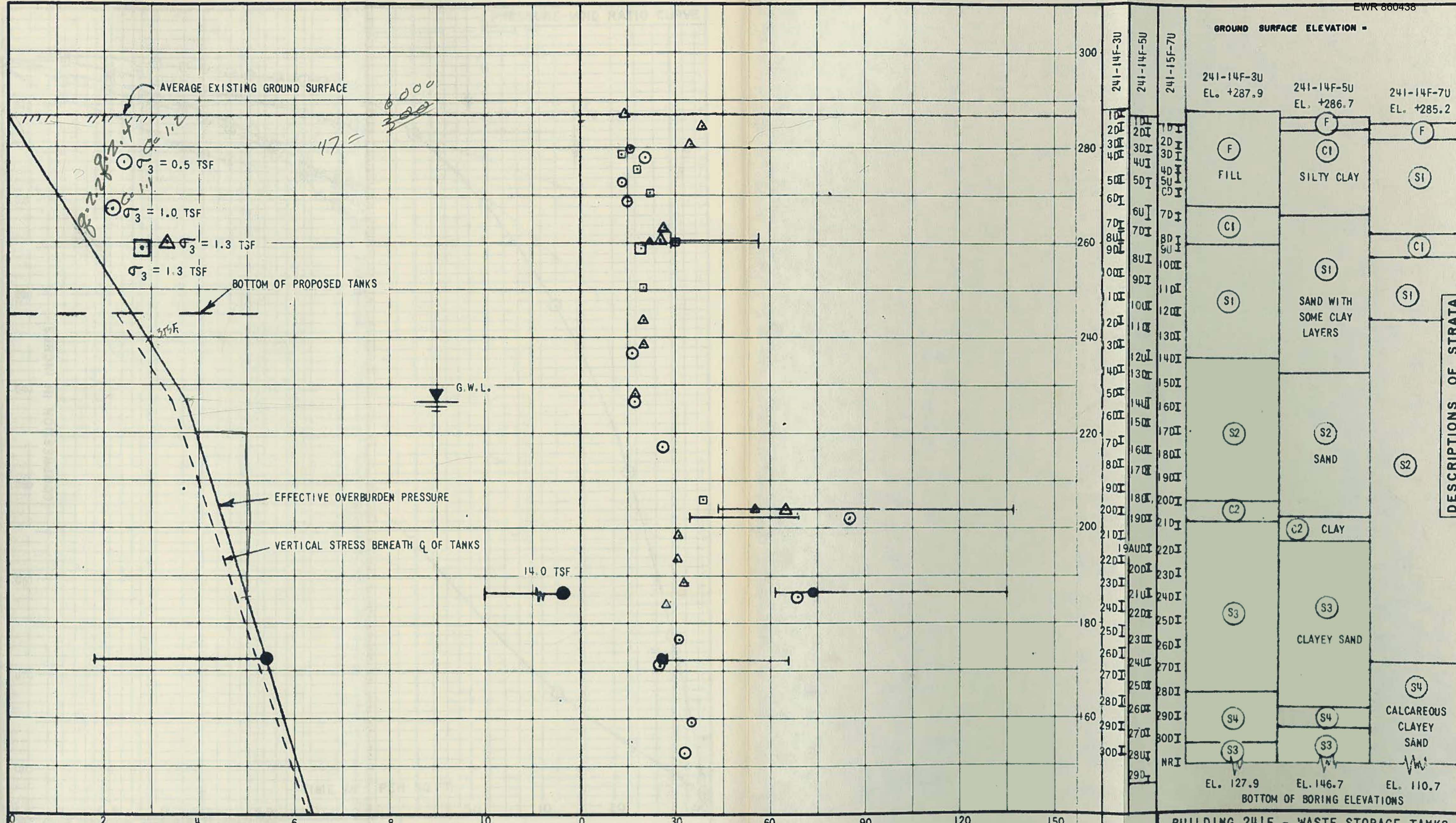
MADE BY:	KSW	DATE:	1-2-75	FILE NO. 4387
CH'KD BY:	VLT	DATE:	1-21-75	

PLASTICITY CHART
BORINGS NOS. 14F-1 TO 14F-9

PLATE NO. 1

PLATE NO. 1

EWR 860438



- GROUND WATER LEVEL OBSERVED IN BORING

RANGE OF PRECONSOLIDATION STRESS VALUES: MINIMUM POSSIBLE — MOST PROBABLE (BORING 5U)

△ BORING 241-14F-3U
⊙ BORING 241-14F-5U
□ BORING 241-14F-7U
→ CONSOLIDATED UNDRAINED TEST

⊙ AVERAGE NATURAL WATER CONTENT OF ENTIRE UNDISTURBED SAMPLE
⊙ NATURAL WATER CONTENT OF DRY SAMPLE OR NATURAL WATER CONTENT OF PORTION OF UNDISTURBED SAMPLE

PLASTIC LIMIT — LIQUID LIMIT
NATURAL WATER CONTENT OF LIMIT SPECIMEN

□ □ BORING 241-14F-7U
○ ⊙ ● BORING 241-14F-5U
△ ▲ ▲ BORING 241-14F-3U

BUILDING 241F - WASTE STORAGE TANKS
SAVANNAH RIVER PLANT
E.I. DU PONT DE NEMOURS & CO., INC.

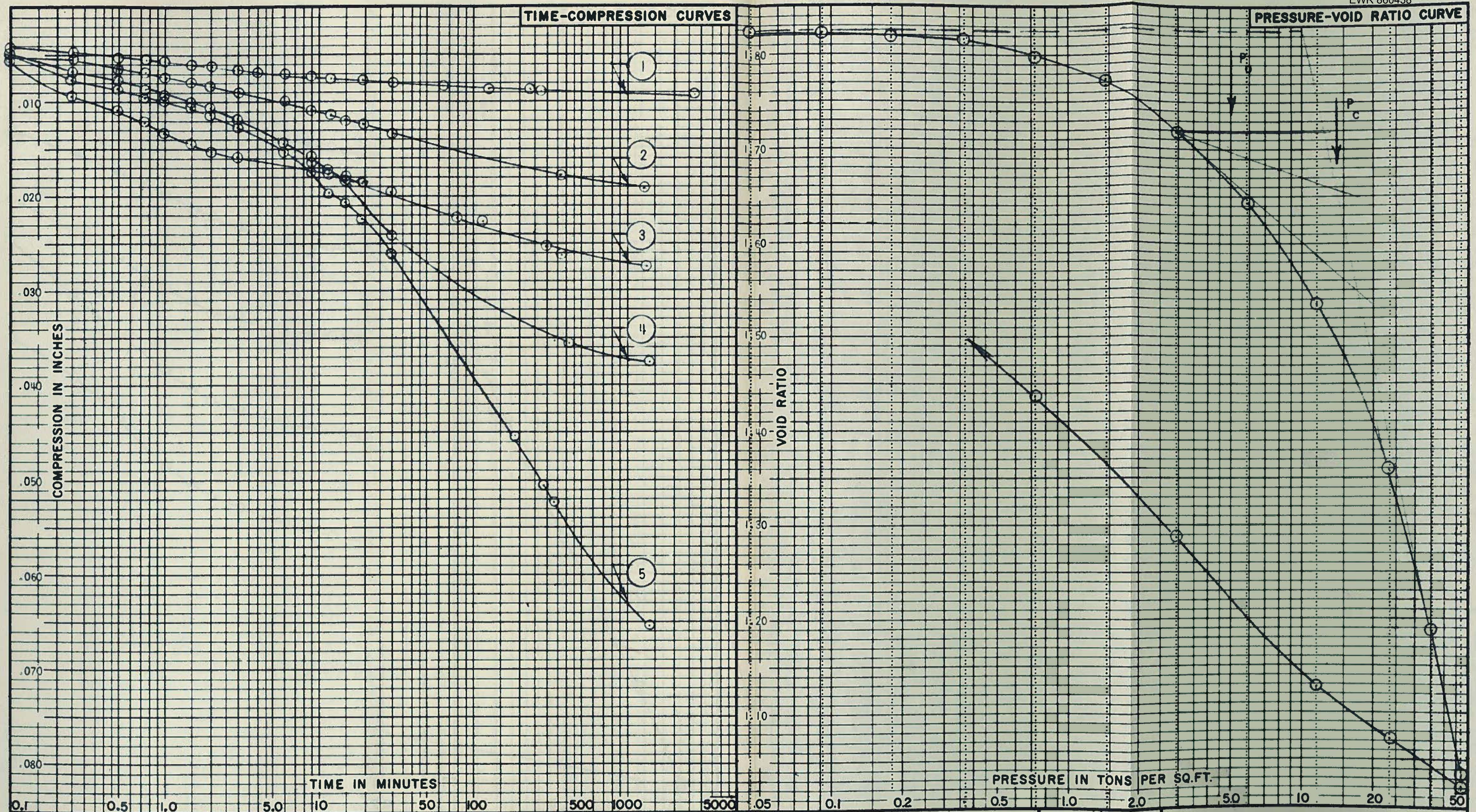
MUESER·RUTLEDGE·WENTWORTH & JOHNSTON
CONSULTING ENGINEERS
415 MADISON AVE. NEW YORK 17, N.Y.

MADE BY:	KSW	DATE:	1-2-75	FILE NO. 4387
CH'KD BY:	AAK	DATE:	1-24-75	

SOIL PROPERTIES PROFILE
BORINGS NOS. 3U, 5U & 7U

PLATE NO. 2

EWR 860438



PRESSURE INCREMENTS OF TIME-COMPRESSION CURVES: CURVE NUMBER	PRESSURE INCREMENT FROM (TSF)	TO (TSF)
①	0.733	1.47
②	1.47	2.93
③	2.93	5.87
④	5.87	11.7
⑤	11.7	23.5
⑥		
⑦		
⑧		

DESCRIPTION OF SPECIMEN: STIFF LIGHT BROWN CLAYEY SILT, SOME FINE SAND POCKETS

STRATUM: S3

PROPERTIES OF PLASTICITY LIMIT SPECIMEN	
UNIFIED CLASSIFICATION	MH
LIQUID LIMIT (w_L)	135.0
PLASTIC LIMIT (w_p)	61.8
PLASTICITY INDEX (I_p)	73.2
NATURAL WATER CONT. % (w)	72.5
LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	0.15
SPECIFIC GRAVITY (G)	2.77

PROPERTIES OF CONSOLIDATION SPECIMEN	
ELEVATION OF SPECIMEN	+186.7
DEPTH OF SPECIMEN (FT.)	100.0
DIAMETER OF SPECIMEN (IN.)	2.50
INITIAL THICKNESS OF SPECIMEN (IN.)	1.009
INITIAL WATER CONTENT %	63.6
FINAL WATER CONTENT %	62.0
INITIAL DEGREE SATURATION %	96.6
FINAL DEGREE SATURATION %	105.5

INITIAL VOID RATIO (e_o), SHOWN THUS: ——— ———	1.826
FINAL VOID RATIO (e_f), SHOWN THUS: - - - - - -	1.630
MOST PROBABLE PRECONSOLIDATION STRESS (TSF) SHOWN THUS: P_c↓	14.0
EXISTING OVERBURDEN STRESS (TSF) SHOWN THUS: P_o↓	5.0
COMPRESSION INDEX (C_c)	1.20
SWELLING INDEX (C_s), REBOUND FROM e = 1.020	0.28

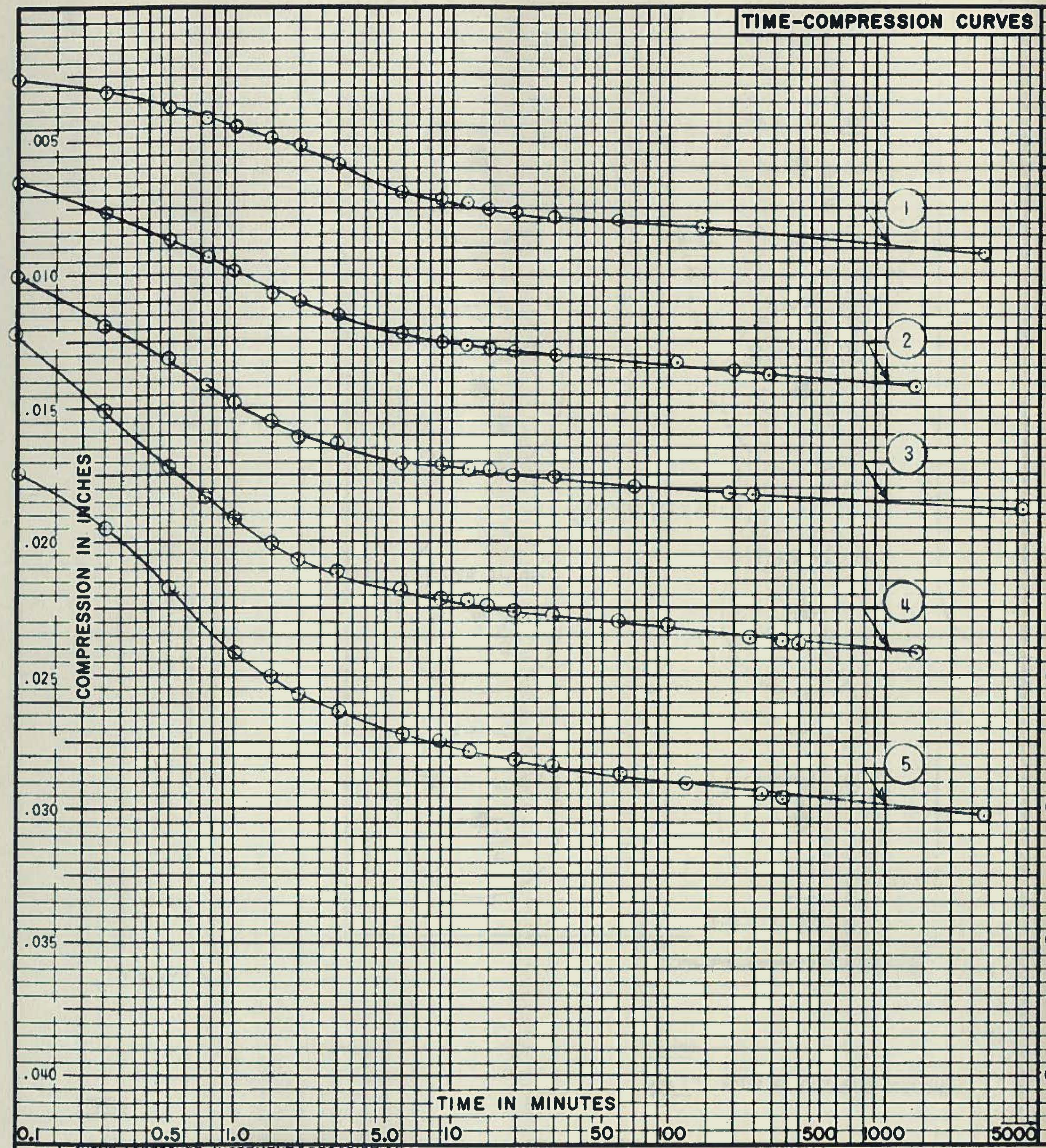
BUILDING 241F - WASTE STORAGE TANKS
SAVANNAH RIVER PLANT
E. I. DU PONT DE NEMOURS & CO., INC.

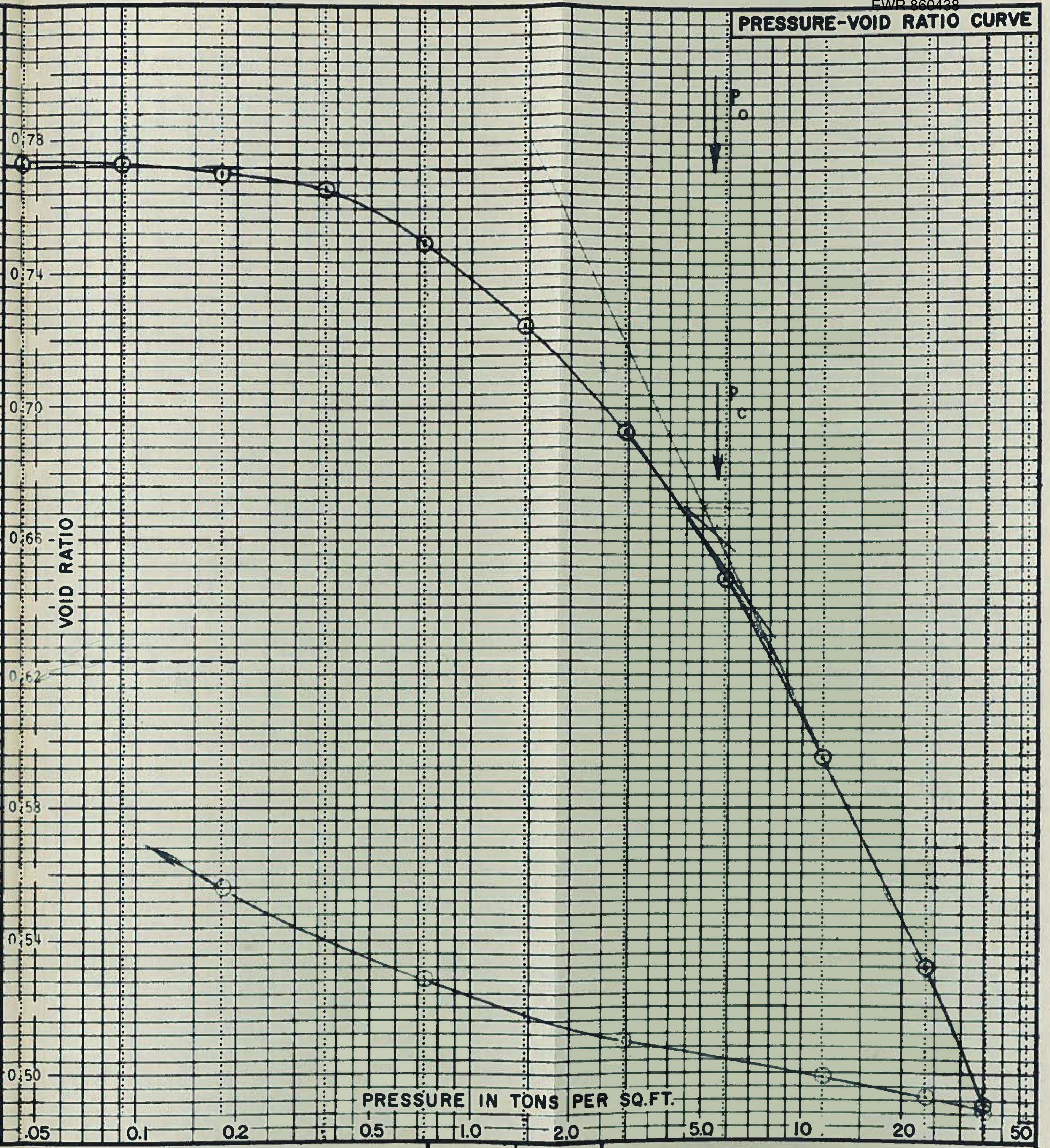
MUESER·RUTLEDGE·WENTWORTH & JOHNSTON
CONSULTING ENGINEERS
415 MADISON AVE, NEW YORK, N.Y. 10017

MADE BY: KSW DATE: 1-22-75
CH'KD BY: AAK DATE: 1-22-75
FILE NO. 4387

CONSOLIDATION TEST
BORING 241-14F 5U SAMPLE NO. 21U
PLATE NO. 3

EWR 860438





PRESSURE INCREMENTS OF TIME-COMPRESSION CURVES: CURVE NUMBER	PRESSURE INCREMENT FROM (TSF)	TO (TSF)
①	0.367	0.733
②	0.733	1.47
③	1.47	2.93
④	2.93	5.87
⑤	5.87	11.7
⑥		
⑦		
⑧		

DESCRIPTION OF SPECIMEN: YELLOW-GRAY CLAYEY MEDIUM TO COARSE SAND, TRACE FINE SAND AND GRAVEL

STRATUM: S3

PROPERTIES OF PLASTICITY LIMIT SPECIMEN	
UNIFIED CLASSIFICATION	SC
LIQUID LIMIT (w_L)	65.0
PLASTIC LIMIT (w_p)	23.9
PLASTICITY INDEX (I_p)	41.1
NATURAL WATER CONT. % (w)	24.3
LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	0.01
SPECIFIC GRAVITY (G)	2.68

PROPERTIES OF CONSOLIDATION SPECIMEN	
ELEVATION OF SPECIMEN	+172.8
DEPTH OF SPECIMEN (FT.)	113.9
DIAMETER OF SPECIMEN (IN.)	2.50
INITIAL THICKNESS OF SPECIMEN (IN.)	1.005
INITIAL WATER CONTENT %	27.2
FINAL WATER CONTENT %	23.7
INITIAL DEGREE SATURATION %	94.3
FINAL DEGREE SATURATION %	102.0

INITIAL VOID RATIO (e_0), SHOWN THUS: ———	0.772
FINAL VOID RATIO (e_f), SHOWN THUS: - - - - - -	0.624
MOST PROBABLE PRECONSOLIDATION STRESS (TSF) SHOWN THUS: P_c↓	5.4
EXISTING OVERBURDEN STRESS (TSF) SHOWN THUS: P_o↓	5.4
COMPRESSION INDEX (C_c)	0.22
SWELLING INDEX (C_s), REBOUND FROM e =0.489	0.030

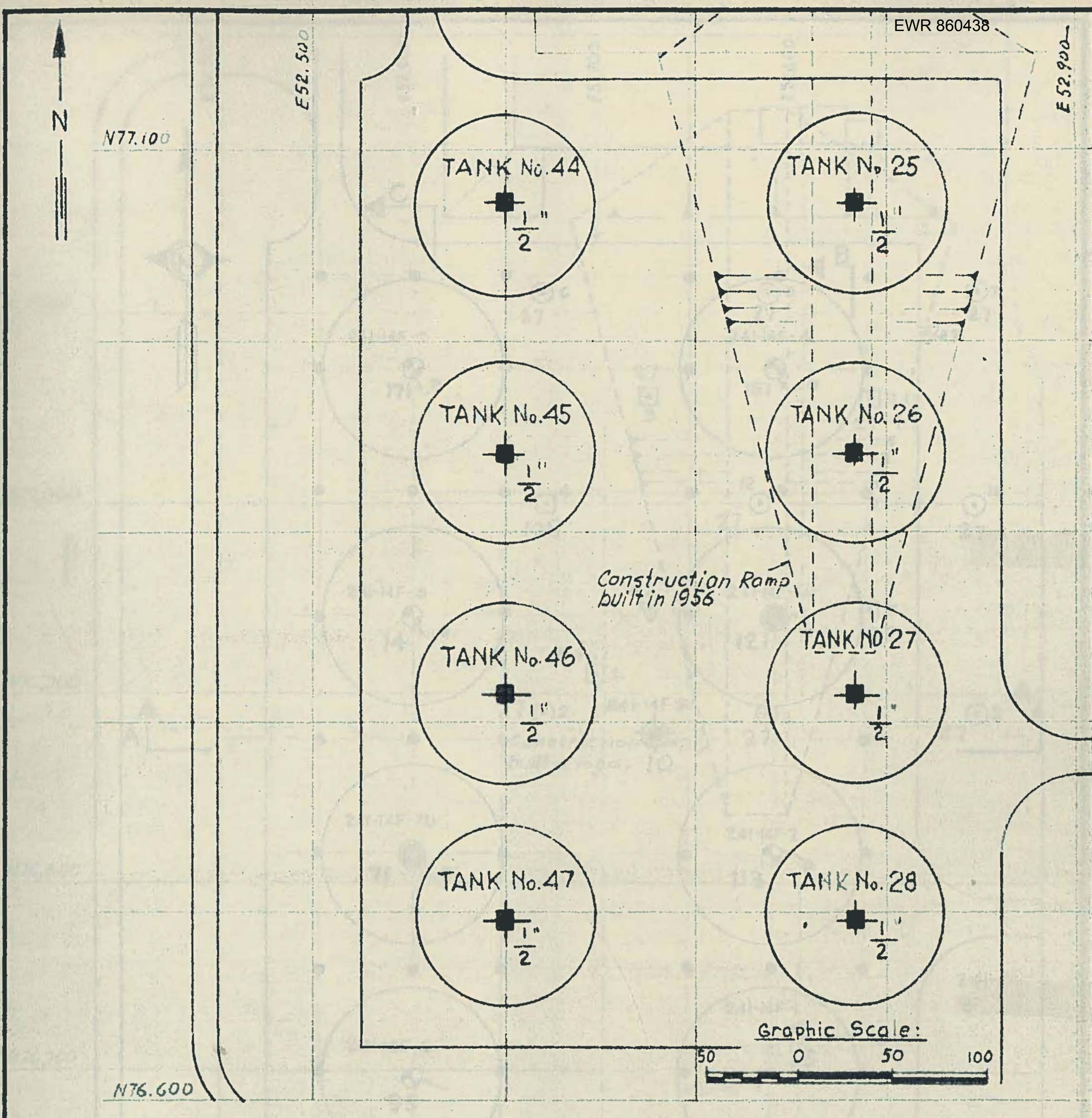
BUILDING 241F - WASTE STORAGE TANKS
SAVANNAH RIVER PLANT
E.I. DU PONT DE NEMOURS & CO., INC.

MUESER·RUTLEDGE·WENTWORTH & JOHNSTON
CONSULTING ENGINEERS
415 MADISON AVE, NEW YORK, N.Y. 10017

MADE BY: AAK DATE: 1-22-75
CH'KD BY: KSW DATE: 1-28-75
FILE NO. 4387

CONSOLIDATION TEST
BORING 241-14F-5U SAMPLE NO. 24U
PLATE NO. 4

EWR 860438



LEGEND

■ 1/2" INDICATES ESTIMATED SETTLEMENT

NOTES

1. THE TANKS ARE APPROXIMATELY 95 FEET IN DIAMETER AND 41 FEET IN HEIGHT.

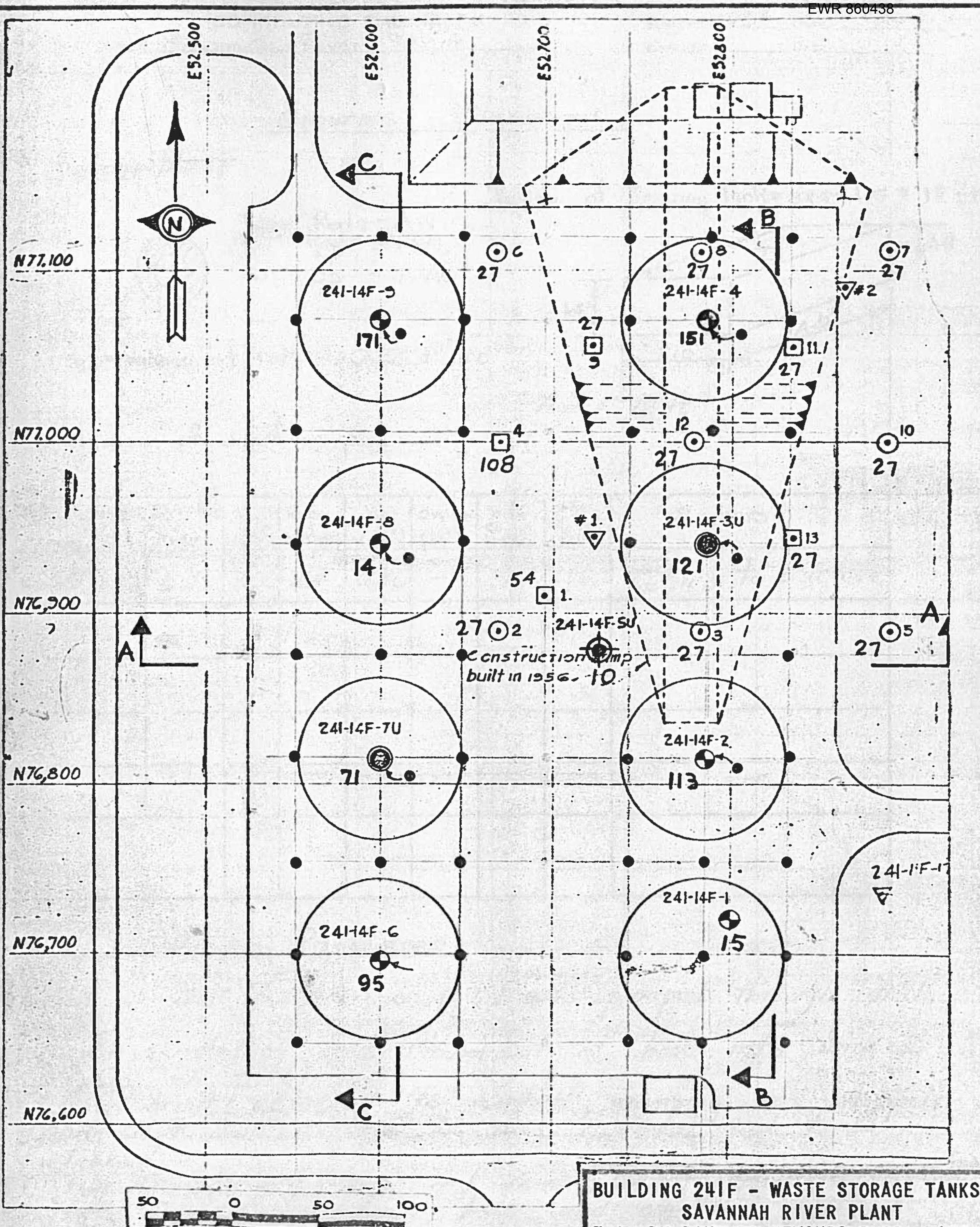
2. THE SETTLEMENTS ARE DUE TO THE CONSOLIDATION OF THE SOIL ABOVE THE CALCAREOUS STRATUM, ASSUMING THAT THE TANKS ARE FILLED WITH LIQUID AND BACK-FILLED WITH SOIL.

BUILDING 241F - WASTE STORAGE TANKS
SAVANNAH RIVER PLANT
E. I. DU PONT DE NEMOURS & CO., INC.

MUESER • RUTLEDGE • WENTWORTH & JOHNSTON
CONSULTING ENGINEERS
415 MADISON AVE., NEW YORK 17, N. Y.

MADE BY:	AR	DATE:	1-27-75	FILE NO. 4387
CH'KD BY:	SLT	DATE:	1-28-75	
SUMMARY OF SETTLEMENT ANALYSES				PLATE NO. 5

EWR 860438



BUILDING 241F - WASTE STORAGE TANKS
SAVANNAH RIVER PLANT
E. I. DU PONT DE NEMOURS & CO., INC.

MUESER • RUTLEDGE • WENTWORTH & JOHNSTON
CONSULTING ENGINEERS
415 MADISON AVE., NEW YORK 17, N. Y.

MADE BY: SLT	DATE: 1-22-75	FILE NO. 4387
CH'KD BY:	DATE:	
PROPOSED GROUT HOLE LOCATIONS		PLATE NO. 6

LEGEND

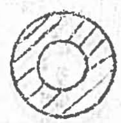
• - Proposed grout hole

121 - Actual vol. of grout take in borings in cubic feet.

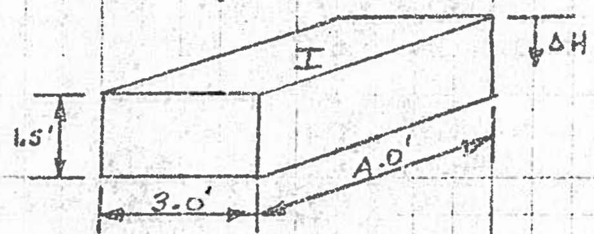
GROUTING OPERATIONS

B# 211-14F-1

Type Rods - AW
ID - 9 6/16
OD - 1 11/16



Volume of Grouting Tank = 3x4x1.5 = 18 ft³



V_R = Volume of rods = 0.52 ft³/100'

Area = 12 ft²

Volume of overflow pail =

Step	ΔH in Grout Tank (ft) Start	End	Diff	Vol (ft³)	Rods in Hole	V_R (ft³)	Overflow (ft³)	Bags Cement 94#/bag	Bags Bentonite 50#/bag	Remarks
①	0.34	1.05	0.71	8.5	164	0.86	—	4	1	Return to surface

Notes on Grouting Procedure

1) Grout in tank I (shown on pg 5) was pumped through drill rods.
2) Displaced drilling mud flowed out of hole into tank II (shown on pg 6).
3) When grout returned to surface, pumping was stopped and drill mud in tank II was removed and tank cleaned.
4) Pumping started again and remainder of grout in tank I pumped down hole and overflow directed into tank II.
5) Additional bentonite added to tank II to thicken mix, and circulated down hole.

MUESER, RUTLEDGE, WENTWORTH & JOHNSTON
CONSULTING ENGINEERS
FOR Savannah River Plant

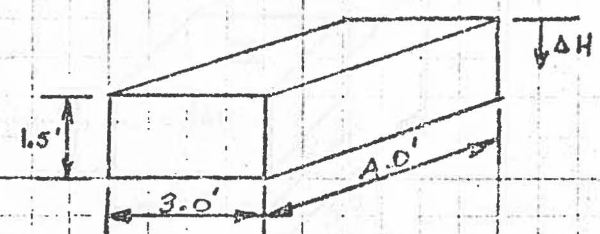
Made By RLS Date 10/17/74
Checked By ______ Date ______

GROUTING OPERATIONS

Boring # 241-14F-2

Volume of Grouting Tank = 3x4 x 1.5 = 18 ft³

Type Rods - AW
ID - 1 6/16
OD - 1 11/16



V_R = Volume of rods = 0.52 ft/100'

Volume of overflow pail =

ΔH in Grout Tank (ft) Start	End	Diff	Vol (ft³)	Rods in Hole	V_R (ft³)	Overflow (ft³)	Bags Cement 94#/bag	Bags Bentonite 50#/bag	Remarks	Date
0.39	1.31	0.92	11.0	170	0.88	0	4	1	No return to surface	10/16/74
0.33	1.30	0.97	11.6	170	0.88	"	4	1½	" " " "	
0.31	1.34	1.03	12.4	170	0.88	"	4	1	" " " "	
0.39	1.37	0.98	11.8	170	0.88	"	4	1	" " " "	
0.38	1.40	1.02	12.2	170	0.88	"	4	1	" " " "	
0.40	1.45	1.05	12.6	170	0.88	"	4	1	" " " "	
0.40	1.42	1.02	12.2	170	0.88	"	4	1	" " " "	
0.34	1.50	1.16	14.0	170	0.88	"	3	3/4	" " " "	
0.43	1.23	0.80	9.6	120	0.62	"	4	1	Return to surface	10/17/74
0.58	0.83	0.25	3.0	120	0.62	"	4	1½	" " "	
0.68	0.89	0.21	2.5	70	0.36	"			" " "	
1.05	1.05	0	0	10'	0.36	"			" " "	

Vol. grout = 112.9 ft³   39 bags cement   10¾ bags bentonite

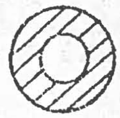
Total ... time 17 hrs

MUESER, RUTLEDGE, WENTWORTH & JOHNSTON
CONSULTING ENGINEERS
FOR Savannah River Plant.

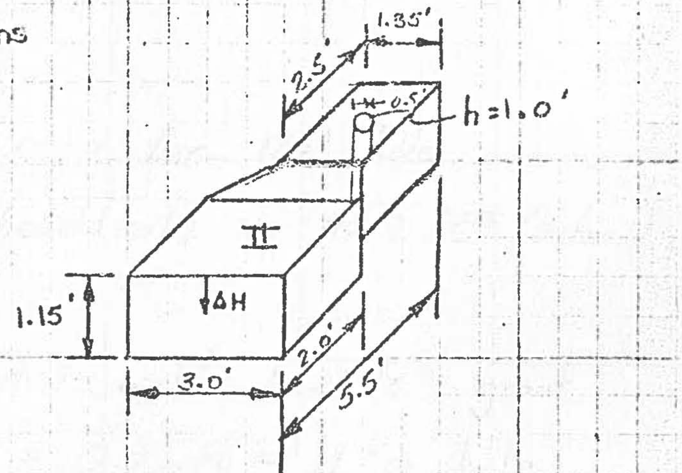
Sheet No. 2 Of 2
File 4387
EWR 860438
Made By APS Date
Checked By Date

GROUTING OPERATIONS

B#241-14F-1



Type Rods AW
ID = 1 6/16
OD = 1 11/16



V_R = Volume of Rods = 0.52 ft^3/100'

Volume of Overflow pail =

Area of tank = 3.0x2.0 + 1.35x2.5 + 1.35x1.0 + 0.83x1.0 = 11.56 ft^2

Step	ΔH in Grout Tank (ft) Start	End	Diff	Vol ft^3	Rods in Hole	V_R ft^3	Overflow ft^3	Bags Cement 94#/bag	Bags Bentonite 50#/bag	Remarks
②	0.28	0.33	0.05	0.6	164	0.86	–	0	1/2	Return to surface
③	0.28	0.43	0.15	1.7	110	0.57	–	0	0	"
④	0.43	0.67	0.24	2.8	0	–	–	0	0	"
Totals				5.1					1/2	

Total grout pumped into hole (pg 5 & 6) = 8.5 + 5.1 = 13.6 ft^3

Assuming 4" φ hole, theoretical amount grout req'd

$$= \frac{\pi (0.33)^2 (169)}{4} = 14.5\ ft^3$$

Totals – (pg 5 & 6) including 10/21

4 bags cement
1½ bags bentonite
4½ hrs grouting time
Vol. grout = 13.7 ft^3

NOTE: On 10/21/74 grout settled to 1½ ft below surface.

$$V = \frac{\pi (.33)^2}{4} (1.5) = 0.1\ ft^3$$

Time to mix cement & bentonite and pour on 10/21 = ½ hr

Boring #241-HF-2

Assuming 4"ϕ hole, quantity grout req'd for 170' hole

$$= \frac{\pi (0.33)^2 (170)}{4\ (12)} = 12.1\ ft^3\ (\text{theoretical})\ \text{vs}\ 112.9\ ft^3\ (\text{actual})$$

Diameter hole which can be grouted with 112.9 ft³ grout

$$D = \sqrt{\frac{V}{.785\,H}} = \sqrt{\frac{112.9}{.785(170)}} = \sqrt{0.847} = 0.92\ ft = 11"\phi\ \text{hole}$$

Grout was obviously lost in a permeable stratum or void which was undetected during drilling.

Notes on Grouting operation

1) On 10/16/74 approx. 98 ft³ of grout was pumped into hole with no return.

2) On 10/17/74 hole caved in to 29.5' overnight. Grout was encountered @ 125' below surface. Grout was recovered in split Spoon sampler driven from 125 to 127 ft.

MUESER, RUTLEDGE, WENTWORTH & JOHNSTON
CONSULTING ENGINEERS
FOR Savannah River Plant

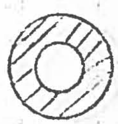
MADE BY RPS DATE 11/7/74 & 11/8/74
CHECKED BY ____ DATE ____

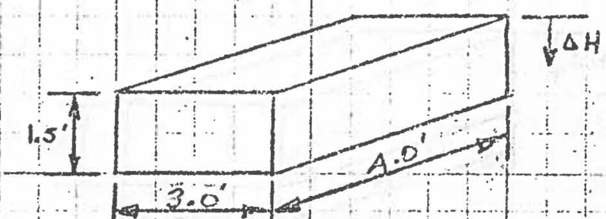
GROUTING OPERATIONS

Boring - 241-14F-3U

Volume of Grouting Tank = 3x4x1.5 = 18 ft³

Type Rods - AW
ID - 1 6/16"
OD - 1 11/16"





V_R = Volume of rods = 0.52 ft³/per 100 ft

Volume of overflow pail = ---

ΔH in Grout Tank (ft) Start	End	Diff	Vol (ft³)	Rods in Hole	V_R (ft³)	Overflow (ft³)	Bags Cement 94#/bag	Bags Bentonite 50#/bag	Remarks	
0.10	1.5	1.4	16.8	160	.86	--	7	1	No Return.	11/7/74
0.10	1.5	1.4	16.8	160	.86	--	7	1	No Return	
0.09	1.5	1.41	16.9	160	.86	--	7	1	No Return	
0.10	1.5	1.4	16.8	160	.86	-	7	1	No Return	
0.10	1.5	1.4	16.8	160	.86	--	7.	1	No Return	
0.08	1.5	1.42	17.0	160	.86	-	7	1	No Return	
0.10	1.5	1.4	16.8	160	.86	-	7	1	No Return	
0.06	0.3	.24	2.9	40	.21	-	7	1	Return immediately, hole filled to G.S.	11/8

1. 11/8/74 Grout at 25.0' no cave in spoon. Redrilled to 39.0' Chunks of grout in return.

2. 11/8/74 Pulled rods in 20' sections, continuous return.

3. Total Volume Grout 120.8 ft³
   56 bags cement   Grouting Time 7½ hrs
   8 bags Bentonite

MUESER, RUTLEDGE, WENTWORTH & JOHNSTON
CONSULTING ENGINEERS

M 3 20M

FOR Savannah River Plant

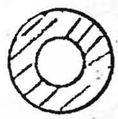
Made By als Date 10/30/74 to
Checked By ____ Date 11/1/74

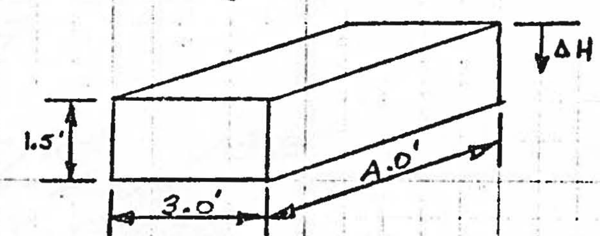
GROUTING OPERATIONS :

Boring 241-14F-4

Volume of Grouting Tank = 3x4x1.5 = 18 ft³

Type Rods - AW
ID - 1 5/16"
OD - 1 11/16"





V_R = Volume of rods = 0.52 ft³/100'

Volume of overflow pail =

ΔH in Grout Tank (ft) Start	End	Diff	Vol (ft³)	Rods in Hole	V_R (ft³)	Overflow (ft³)	Bags Cement 94#/bag	Bags Bentonite 50#/bag	Remarks	Date
0.15	1.45	1.30	15.6	160	0.83	—	5	2	Very slight Return	10/30/74
0.17	1.45	1.28	15.4	160	0.83	—	7	1	No Return	10/30/74
0.10	1.45	1.35	16.2	140	0.73	—	7	3/4	No Return pulled 10' csg.	10/30/74
0.15	1.48	1.33	16.0	140	0.73	—	7	1	No Return. pulled 10' csg.	10/30/74
0.20	1.48	1.28	15.4	123	0.64	—	7	1	No Return	10/31/74
0.15	1.48	1.33	16.0	123	0.64	—	7	1	No Return	10/31/74
0.12	1.48	1.36	16.3	123	0.64	—	7	1	No Return pulled 20' csg.	10/31/74
0.10	0.63	0.53	6.4	113	0.59	—	7	1	Return - used remainder in next tub	11/1/74
0.10	1.48	1.38	16.5	110	0.57	—	0	0	Return began at end of pumping	11/1/74
0.15	0.90	0.75	9.0	93	0.48	—	7	1	Stopped at Return pulled 10' csg	11/1/74
0.90	1.45	0.55	6.6	93	0.48	—	0	0	Stopped at return pull 20' csg.	11/1/74
1.0	.90	.10	1.2	93	0.48	—	2	1/2	Immed. Return beside casing	11/1/74
—	—	—	0.5	0	—	—	—	—	pulled all csg. filled hole.	11/1/74

Vol. Grout 151.1 ft³ — 63 bags cement — 10¼ bags mud

Grouting Time 71½

MADE BY RLC DATE 11/1/74

FOR Boring 241-145-4

CHECKED BY ______ DATE ______

Notes on Grouting Operations

1. 130' casing in place at start of operations. 10/30/74

2. Grout level 1300 10/30/74 132' with 130' casing in hole. Pulled 20' casing on 10/30

3. Grout level 0915 10/31/74 117' with 110' casing in hole Pulled 20' casing on 10/31

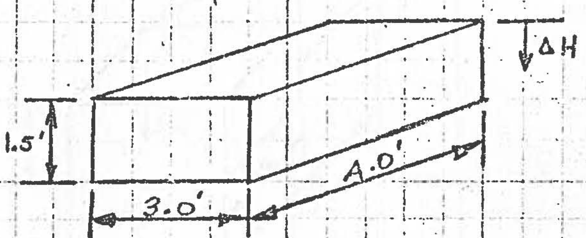
4. Grout level 0845 11/1/74 95' with 90' casing

GROUTING OPERATIONS

Boring 241-14F-5U

Volume of Grouting Tank = 3x4x1.5 = 18 ft³

Type Rods - AW
ID - 1 6/16"
OD - 1 11/16"



V_R = Volume of rods = 0.52/100ft

Volume of overflow pail = —

ΔH in Grout Tank (ft) START	End	DIFF	Vol (ft³)	Rods in Hole	V_R (ft³)	Overflow (ft³)	Bags Cement 94#/bag	Bags Bentonite 50#/bag	REMARKS
.10	.67	.57	6.8	137'	.71	—	7	1	Return after 6.2 ft³ pulled 30' rods
.67	.72	.05	0.6	107'	.55	—	0	0	Return — pulled 30' rods.
.72	.75	.03	0.4	77'	.40	—	0	0	Return — pulled 30' rods
.75	.80	.05	0.6	47'	.24	—	0	0	Return pulled 30' rods.
.80	.85	.05	0.6	17'	.08	—	0	0	Return pulled all rods
.85	.90	.05	0.6	0	0	—	0	0	Filled hole

11/23/74

Total Vol. Grout 9.6 ft³

7 bags Cement
1 bag Mud

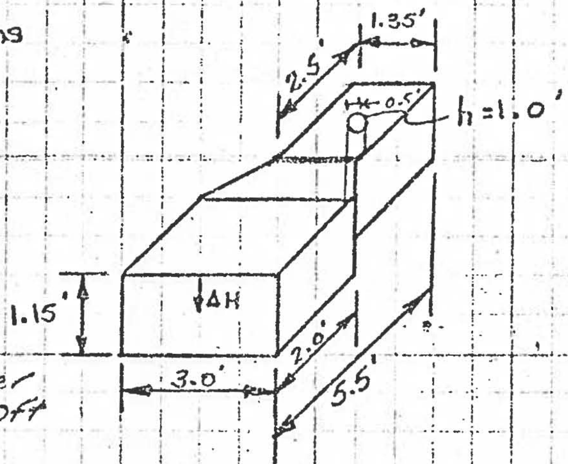
Grouting Time — 2½ hrs.

3 20M

GROUTING OPERATIONS

Boring 241-19F-6

Type Rods AW
ID = 1 9/16"
OD = 1 11/16"



V_R = Volume of Rods = 0.52 ft³/per 100ft

Volume of Overflow pail = —

A = 11.56 ft²

ΔH in Grout Tank (ft) START	END	DIFF	Vol ft³	Rods in Hose	V_R ft³	Overflow ft³	Bags Cement 94#/bag	Bags Bentonite 50#/bag	REMARKS
.20	.70	.50	5.8	177	.92	—	5	1	Return w/ 125' csg bas.
.15	.75	.60	6.9	177	.92	—	5	0	Pulled 20' csg. No Return
.15	.75	.60	6.9	177	.92	—	5	0	No Return.
.16	.77	.61	7.0	177	.92	—	5	0	No Return
.23	.78	.55	6.3	105	.55	—	5	1	No Return pulled all csg
.20	.75	.55	6.3	105	.55	—	5	½	No Return
.21	.68	.47	5.4	105	.55	—	5	½	No Return
.20	.70	.50	5.8	105	.55	—	5	½	No Return
.25	.60	.40	4.6	105	.55	—	5	½	No Return.
.25	.70	.45	5.2	105	.55	—	5	½	No Return.
.25	.70	.45	5.2	105	.55	—	5	0	No Return
.25	.75	.50	5.8	105	.55	—	5	0	No Return
.27	.78	.51	5.9	85	.44	—	5	0	No Return
.24	.75	.51	5.9	85	.44	—	5	0	No Return
.25	.75	.50	5.8	85	.44		5	½	No Return
.27	.60	.47	5.4	85	.44		5	0	No Return

11/9/74

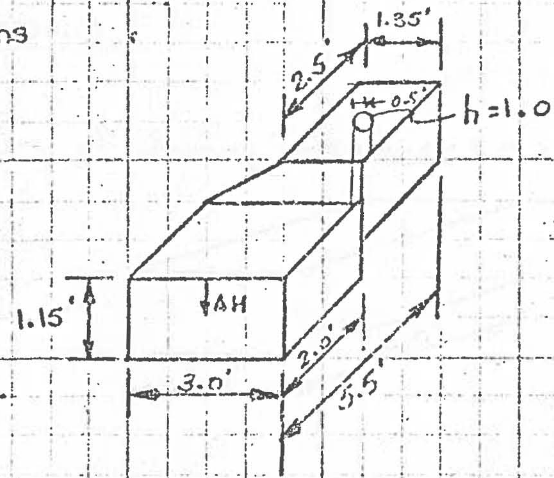
11/11/74

3 20M

GROUTING OPERATIONS

Boring Z41-14H-6

Type Rods AW
ID = 1 5/16"
OD = 1 11/16"



V_R = Volume of Rods = 0.52/100 ft

Volume of Overflow pail = —

ΔH in Grout Tank (ft) START	END	DIFF	Vol ft³	Rods in Hole	V_R ft³	overflow ft³	Bags Cement 94#/bag	Bags Bentonite 50#/bag	REMARKS
—	—	—	.3	15	.08	—	1	—	Grout at 5'
Totals			94.5				81	5	

11/12/79

Notes:

1. Grout at 80' 11/11/79 0815 with 125.0' casing bgs. Redrilled to 105' pulled all csg.

2. Grout at 5.0' 11/12/79 0815 redrilled to 15.0' & completed grouting.

3. 94.5 ft³ Total Vol. Grout

81 bags Cement
5 bags Bentonite.

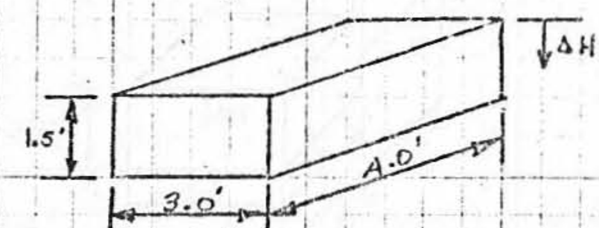
Grouting Time 13 1/4 hrs.

Grouting Operations :

Boring 241-14F-7U

Volume of Grouting Tank = 3x4x1.5 = 18 ft³

Type Rods - AW
ID - 1 6/16"
OD - 1 11/16"



V_R = Volume of rods = 0.52/100 ft

Volume of overflow pail = —

ΔH in Grout Tank (ft) Start	End	Diff	Vol (ft³)	Rods in Hole	V_R (ft³)	Overflow (ft³)	Bags Cement 94#/bag	Bags Bentonite 50#/bag	Remarks
0.10	.30	.20	2.4	173	.89	—	7	1/2	Return after 2.3 Csg. at 159
.30	1.30	1.00	12.0	173	.89	-	0	1/2	Pulled 20' csg No Return
.20	1.43	1.23	14.7	153	.79	--	7	1/2	Return after 14.1 pull 30' csg
.21	1.38	1.17	14.0	113	.59	—	7	1/2	Return after 13.2 pull 30' csg
.15	1.40	1.25	15.0	103	.53	—	7	1/2	Return immed. pulled 20' csg
.18	1.27	1.09	13.0	73	.38	—	7	-	Return immed. pulled 20' csg

11/12/74

Vol. Grout. 71.1 ft³

2½ bags Bentonite
35 bags Cement

1. After return csg. pulled 10' until return is established again. "Csg. pulled" in Remarks column represents total csg pulled during pumping of each tub of grout.
2. Broke rods after each csg. pull.
3. Started Grouting 0800. Completed 1630
4. Total Grouting Time 8½ hrs.

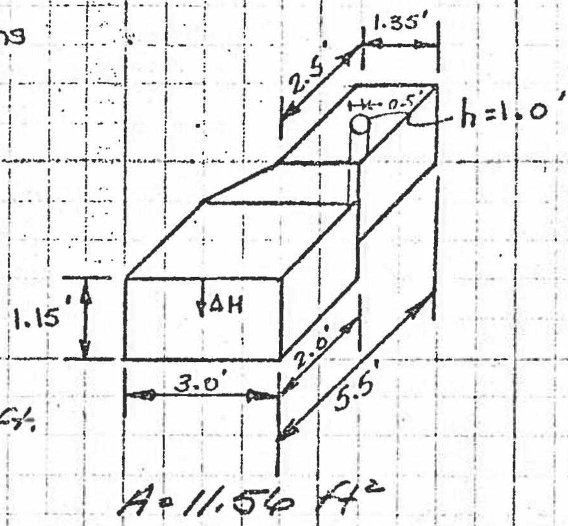
GROUTING OPERATIONS

Boring 241-14F-8

Type Rods AW
ID - 1 6/16"
OD - 1 11/16"

V_R = Volume of Rods = 0.52 ft³/per 100 ft.

Volume of Overflow pail :



ΔH in Grout Tank (ft) START	END	DIFF	Vol ft³	Rods in Hole	V_R ft³	Overflow ft³	Bags Cement 94#/bag	Bags Bentonite 50#/bag	Remarks
0.05	0.6	0.55	6.3'	170	.88	—	5	½	Return after 0.55
0.10	0.20	0.1	1.1	120	.62	—	2	-	Return - No Grout loss.
.20	.35	.15	1.7	70			0	0	Return
.35	.55	.20	2.3	20			0	0	Return
.55	.65	.10	1.1	0	0		0	0	Return
.65	.80	.15	1.7	0	0		0	0	Grout dropped approx 2.0' after 30 mins

Total Vol Grout 14.2 ft³

Remarks:

1. Return on 1st tub. Pulled rods in 50 ft increments.

2. There was no mud loss during drilling.

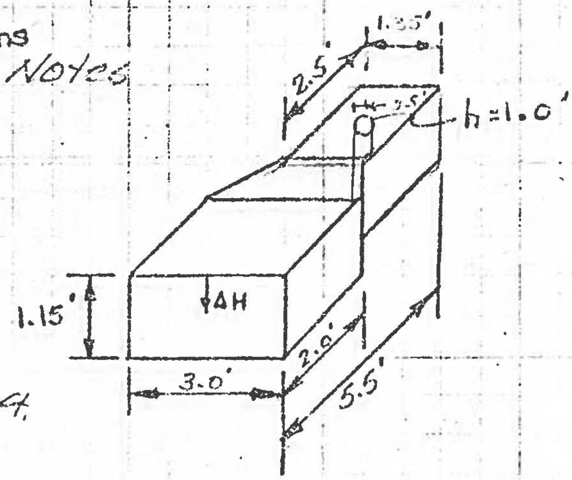
MUESER, RUTLEDGE, WENTWORTH & JOHNSTON
CONSULTING ENGINEERS

FORM 3 2CM

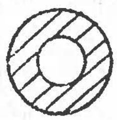
FOR Savannah River Plant.

GROUTING OPERATIONS

Boring 241-14F-9 see Notes



Type Rods
ID
OD



V_R = Volume of Rods = 0.52 ft³/100 ft.

Volume of Overflow pail =

Area tank = 11.56 ft².

ΔH in Grout Tank (ft) START	END	DIFF	Vol ft³	Rods in Hole	V_R ft³	Overflow ft³	Bags Cement 94#/bag	Bags Bentonite __#/bag	REMARKS
0.15	0.75	0.60	6.9	167	.87	—	5	1	No Return
0.05	0.80	0.75	8.7	167	.87	—	5	1	No Return
0.05	0.80	0.75	8.7	167	.87	—	5	1/4	No Return
0.05	0.72	0.67	7.7	167	.87	—	5	1/4	No Return
0.05	0.65	0.60	6.9	167	.87	—	5	1/4	No Return
0.05	0.65	0.65	7.5	167	.87	—	5	1/4	No Return
0.07	0.65	0.58	6.7	167	.87	—	5	1/3	No Return
0.05	0.70	0.65	7.5	167	.87	—	5	1/3	No Return
0.05	0.75	0.70	8.0	167	.87	—	5	1/3	No Return
0.05	0.70	0.65	7.5	167	.87	—	5	1/3	No Return
0.03	0.70	0.67	7.7	167	.87	—	5	1/3	No Return
0.03	0.75	0.72	8.3	167	.87	—	5	1/4	No Return
0.03	0.68	0.65	7.5	167	.87	—	5	1/4	No Return
0.06	0.75	0.69	8.0	167	.87	—	5	1/4	No Return
0.05	0.65	0.60	6.9	167	.87	—	5	1/4	No Return

10/28/74

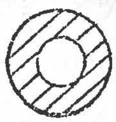
MUESER, RUTLEDGE, WENTWORTH & JOHNSTON
CONSULTING ENGINEERS
FOR Savannah River Plant.

Made By OPS Date
Checked By Date

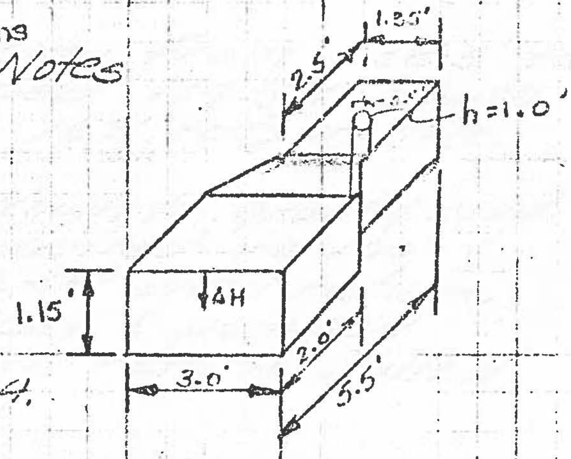
Form 3 20M

GROUTING OPERATIONS

Boring 241-14F-9 See Notes



Type Rods
ID
OD



V_R = Volume of Rods = 0.52ft³/100ft.

Volume of Overflow pail =

ΔH in Grout Tank (ft) Start	End	Diff	Vol ft³	Rods in Hole	V_R ft³	Overflow ft³	Bags Cement 94#/bag	Bags Bentonite 50#/bag	Remarks
0.05	.30	.25	2.9	90	.47	—	5	½	No Return
0.30	.67	.37	4.3	90	.47	—	5	½	Return pull 10' csg.
0.05	.75	.70	8.1	90	.47	—	5	½	No Return
0.02	.55	.53	6.1	90	.47	—	5	½	No Return
0.05	.70	.65	7.5	90	.47	—	4	0	No Return
0.05	.75	.70	8.1	90	.47	—	5	½	No Return
0.05	.75	.70	8.1	90	.47	—	5	½	No Return
0.05	.68	.63	7.3	90	.47	—	5	¾	No Return
0.03	.10	.07	0.8	90	.47	—	5	¼	Return pulled csg.
0.03	.40	.37	4.3	60	.31	—	5	½	Return
0.5	.65	.60	6.9	0.0	0.0	—	2	0	Return.

11/1/74
11/4/74

Total Grouting Time 20 hrs

12.6 94 lb bags cement

10.2 50 lb bags mud.

MUESER • RUTLEDGE • WENTWORTH & JOHNSTON

CONSULTING ENGINEERS

SHEET NO. ___ OF ___

FILE ~~9387~~ EWR 860438

MADE BY RLC DATE 11/4/74

FOR Notes Grouting 241-14F-9 CHECKED BY ______ DATE ______

1. 10/28/74 Pulled casing from 138.5' to 100'. Pumped 114.5 ft³ with no return. 167' rods in hole.

2. 11/1/74 Put spoon down to grout & mud at 88.5' Redrilled to 100' & pumped 7.2 ft³ until return. pulled 10' csg. & pumped 45.2 ft³ until return. Pulled all casing.

3. 11/4/74 Put spoon down to 47.5' grout & cave. Drilled down to 59.0' Immediate return with 11.2 ft³ pumped.

4. Total 170.9 ft³ to grout 241-14F-9

126 94 lb bags cement

10.2 50 lb bags Bentonite

20 hrs. Grouting Time.

For	Name	Read
	Proctor	
✓	EWR 860438	✓
	Rutledge	
	Wentworth	
	Johnston	
	Parsons	
	Kuss	
✓	Johnson	✓
	Gould	
	DeSimone	
	Koziakin	
	Richards	
	Bernheimer	
	Moore	
	2372	

April 12, 1963

E. I. Du Pont De Nemours & Company
Engineering Department
Louviers Building
Wilmington 98, Delaware

Attention: Mr. A. J. McCullin,
Design Division

RE: SAVANNAH RIVER PLANT
FOUNDATION INVESTIGATION
ADDITIONAL WASTE STORAGE TANKS
NO. 25 TO 28 INCLUSIVE
F AREA, PROJECT 981164-13

Gentlemen:

On April 11, 1963, Mr. A. J. McCullin requested a letter report summarizing our study of the logs of 13 borings and 2 piezometers located at the site of these proposed tanks. The purpose of our review was to determine if abnormal subsoil conditions at the proposed tank location are indicated by the borings and if grouting is required. The cause of possible abnormal subsoil conditions, solution of calcareous material in the McBean Formation, is discussed in detail in the report "Geologic-Engineering Investigations" dated March 1952. We understand that the tanks will be located largely beneath the existing ground surface. Fully loaded tanks will, therefore, not increase existing subsoil pressures in the "solution" zone.

The results of the borings are summarized on Table No. 1 and their locations are shown on Drawing No. 1, on which also is shown a simplified log for each boring showing depths at which calcareous material was encountered and location of drilling fluid losses, where these occurred. The borings penetrated the calcareous zone found throughout the plant area and in which rod droppings or slow settling and/or losses of water and drilling mud may occur. While calcareous material was encountered in all 13 borings at the approximate depths anticipated, a loss of drilling fluid occurred in only 2 borings (See Table No. 1) and in no boring did the drill rods drop rapidly or settle slowly, as has occurred elsewhere in the plant.

The 4 exploratory split spoon borings, Nos. 1, 9, 11 and 13, exhibited normal penetration resistances throughout their depths and high penetration resistances at depths where calcareous materials were encountered (See Drawing No. 1). The complete absence of either rapid dropping or slow settling of the drill rods; the high sampling penetration resistance in the calcareous materials, even at the depths at which drilling mud was lost; and the absence of drilling mud losses in all but two borings indicates that an open solution cavity condition does not exist beneath these tanks.

Each boring was grouted to prevent free seepage into the solution zone and as a test to measure the extent of voids within and above it. All but two borings required only the volume of grout required to fill the hole made by the borings. Borings 1 and 4, both of which lost drilling mud, see Table No. 1, required some additional grout but the quantity was small and is not considered significant. Grouting the borings constituted an important test of the solution zone and the results confirm data from the borings indicating that a condition of open voids does not exist beneath these tanks.

Because the tanks will not impose additional loads on underlying subsoils, and because of: (1) the reassuring conditions indicated by the borings, (2) the relatively close spacing of the borings, and (3) the 80 foot thick zone of intact soil between the bottom of the tanks and the top of the calcareous materials further exploration beneath these tanks is not indicated and we conclude that the site is suitable without additional testing or further grouting.

If there is any additional information you desire, please advise us accordingly.

Very truly yours,

MORAN, PROCTOR, MUESER & RUTLEDGE

By William H. Mueser
William H. Mueser

WHM:HC
encl

EWR 860438

NOTE: Incorrectly labelled Borings are in F Area. (MRW&J Jan.75)

TABLE NO. 1

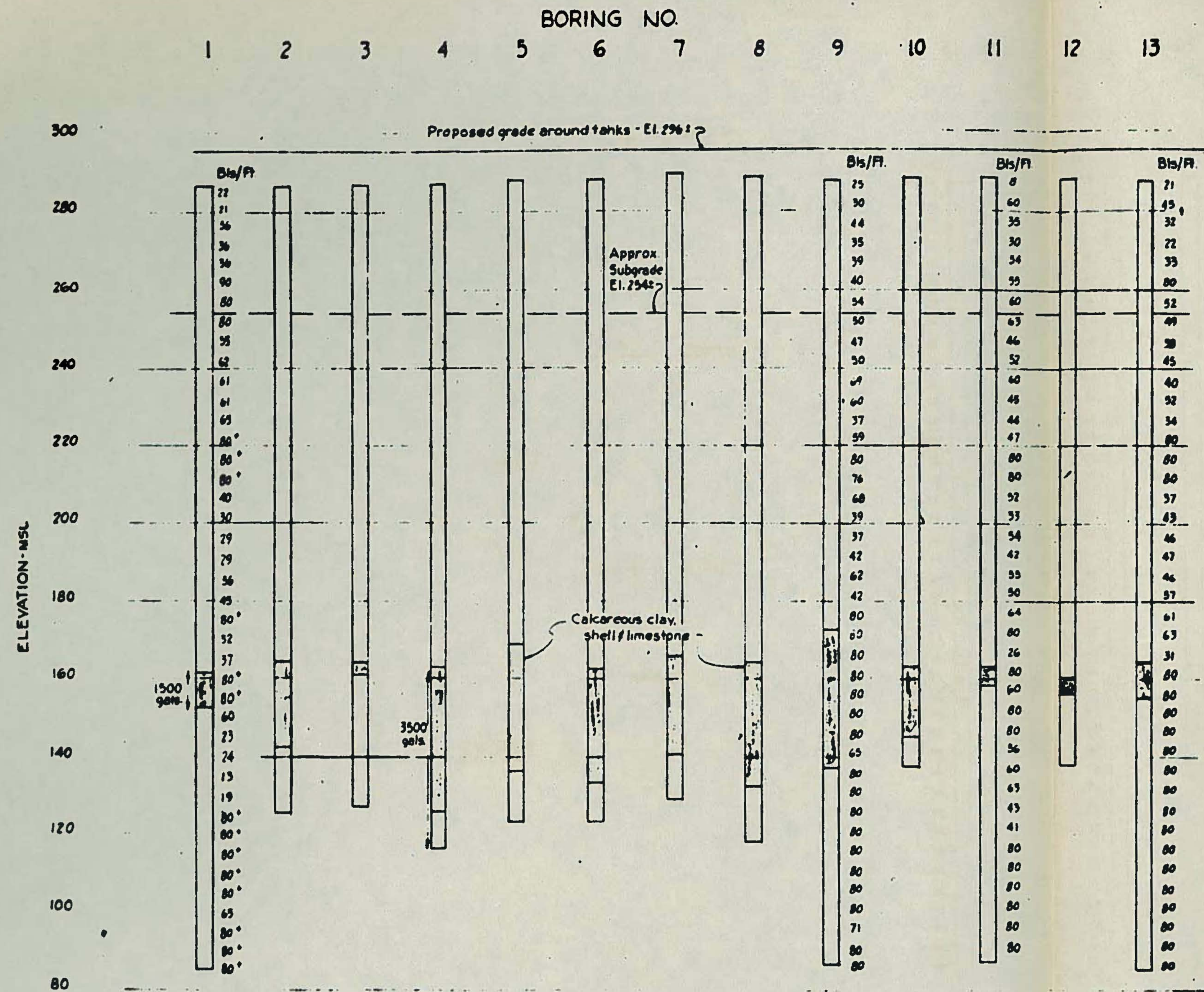
SUMMARY OF BORINGS FOR ADDITIONAL WASTE STORAGE TANKS - H-AREA
SAVANNAH RIVER PLANT - PROJECT 981164-13

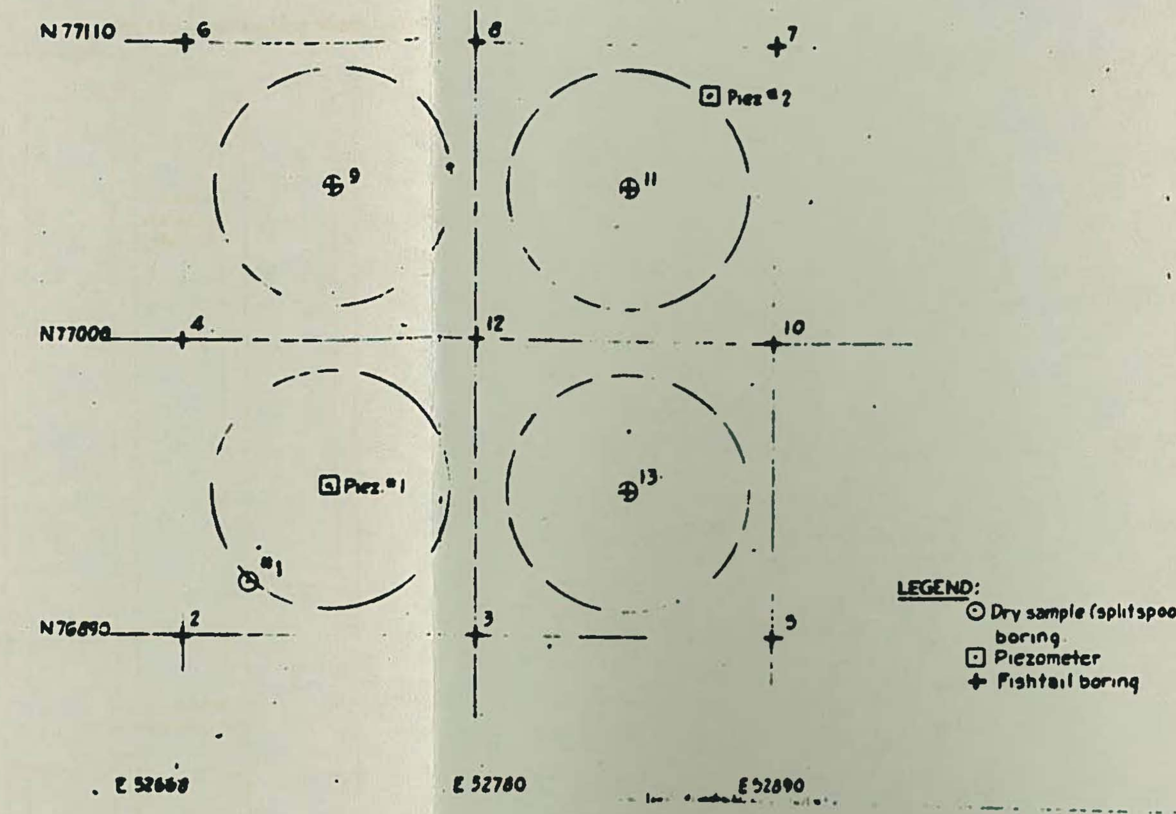
Boring	Coordinates N	Coordinates E	Type of Boring	Surface Elevation	Depth	Bottom Elevation	Ground Water Level	Rod Droppings or Settling	Drilling Mud Losses Depths	Calcareous Material Depth	Calcareous Material Description	Grout Required to Fill Hole - c. y.
F-11 ~~#1 Piez.~~	76944	52723		287.21	75.0	212.2	60.5' - 3/11/63	None	None	None		
F-12 ~~#2 Piez.~~	77090	52865		290.12	51.0	239.1	Piez at 50.0' - no water	"	"	"		
1	76910	52695	Split spoon	286.60	201.5	85.1	65'±	"	125'-134' - 1500 gals.	125-134	Calc. clay, shell and limestone	2
2	76890	52668	Fishtail	286.27	161.0	125.3	-	"	None	122-144	"	1
3	76890	52780	"	287.18	160.0	127.2	-	"	"	123-126	"	1
4	77000	52668	"	287.29	171.0	116.3	-	"	124 -171 - 3500 gals water and drilling mud	124-161	"	4
F-15 5	76890	52890	"	288.51	165.0	123.5	-	"	None	120-152	"	1
F-16 6	77110	52668	"	288.89	165.0	123.9	-	"	"	126-155	"	1
F-17 7	77110	52890	"	290.57	161.0	129.6	-	"	"	124-149	"	1
F-18 8	77110	52780	"	289.30	171.0	118.3	-	"	"	124-156	"	1
F-19 9	77056	52723	Split spoon	288.61	201.5	87.1	-	"	"	115-150	"	1
F-20 10	77000	52890	Fishtail	289.77	151.0	138.8	65'±	"	"	125-143	"	1
F-21 11	77056	52835	Split spoon	289.58	201.5	88.1	65'±	"	"	125-130	Calc. clay & shell	1
F-22 12	77000	52780	Fishtail	289.46	151.0	138.5	-	"	"	128-132	Calc. clay, shell and limestone	1
F-23 13	76944	52835	Split spoon	288.98	201.5	86.5	-	"	"	124-133	Calc. clayey sand with limestone	1

17 x 3 = 51 ft³

459 ft³

1cy 35.3 ft³





BORING LOCATION PLAN

NOTES:

1. Numbers to the right of boring are Blows / Foot of 140# hammer falling 30" on standard split spoon samples.
2. Calcareous zones are indicated by solid areas.
3. No dropping or settling of drill rods occured in any borings.
4. Drilling fluid was lost only in Borings 1 and 4 as indicated.

NOTE: Incorrectly labelled. Borings are in F Area (MRW&J Jan. 75)

E I DUPONT DE NEMOURS & COMPANY
ATOMIC ENERGY COMMISSION
SAVANNAH RIVER PLANT

ADDITIONAL WASTE STORAGE TANKS
IN H AREA
PROJECT 9811G4-13

MORAN, PROCTOR, MUESER & RUTLEDGE
CONSULTING ENGINEERS
415 MADISON AVE. NEW YORK 17, N. Y.

SCALE	MADE BY C.C.	DATE	FILE NO. 2572-7
	CH'KD BY	DATE	DRAWING NO.

STUDY OF SUBSURFACE
SOLUTION ZONE