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CLAY LINER TEST PAD CONSTRUCTION STUDY

ALLEN PARK CLAY MINE LANDFILL

Prepared For

FORD MOTOR COMPANY

Dearborn, Michigan

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REPORT ON CLAY LINER TEST PAD CONSTRUCTION STUDY

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1.0 INTRODUCTION

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At the request of Ford Motor Company, three test pads were constructed at the Allen Park Clay Mine (APCM) Landfill to develop correlations between construction methodology and the soil engineering properties of moisture content, degree of compaction, field permeability and shear strength. Each test pad was constructed according to a pre-determined procedure and was subjected to a battery of tests, both during and following construction. The test results were evaluated to determine which construction methodologies could be expected to produce results which meet project specifications and produce field permeabilities of 1×10^{-7} cm/sec or less.

Three different clay sources were evaluated in this study and a test pad was constructed for each clay source. The test pads are identified as follows:

Test Pad TP-1	I-696 clay
Test Pad TP-2	London Michigan clay
Test Pad TP-3	Ann Arbor Sand and Gravel clay

This report contains a description of the test pad construction methodology, the soil tests performed, a summary of the data obtained, and our evaluations and conclusions concerning the viability of the proposed construction materials and techniques.

1.1 Purpose of a Test Pad

Based on permit requirements, the clay liner at APCM landfill must be constructed from compacted soil having a maximum permeability coefficient of 1×10^{-7} cm/sec. Recent research indicates that field measurements of permeability in compacted soils are frequently greater than permeabilities obtained from laboratory tests on the same material. Differences between field and laboratory permeabilities are believed to be due to the ability of the in-situ field permeability tests to account for the effects of secondary permeability features such as fractures, macropores, and fissures which are frequently not sufficiently represented in the smaller samples utilized for laboratory testing.

The purpose of constructing a test pad is, therefore, to develop the methodologies to be employed during construction of the clay liner that are capable of yielding field permeability coefficients equal to or less than 1×10^{-7} cm/sec, as well as meeting project specifications for moisture, density, and shear strength.

2.0 TEST PAD CONSTRUCTION

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Three test pads were constructed, one from each clay source. Each test pad was divided into three test fills. The test fills were constructed by placing soil from the appropriate stockpile using either a Cat 631B tractor-scraper (test pad TP-1) or a Cat 140G grader (test pads TP-2 and TP-3), spreading each lift of soil using either a Cat D-8K dozer (test pad TP-1) or a Cat D-8L dozer (test pads TP-2 and TP-3), and compacting each layer with a specific number of passes using a self-propelled Cat 825B 33-ton sheepsfoot compactor. Each test pad consisted of five 9-inch thick loose lifts. The methodology used to construct the test pad was discussed with the project Construction Quality Assurance (CQA) Officer prior to the start of construction of the test pads.

Each test pad has overall dimensions of 150 feet by 75 feet, with the dimensions of each test fill being approximately 50 feet by 75 feet. The test fill dimensions were established primarily on the size of the tractor-scrapers planned to be used for the construction of the clay liner. These dimensions represent a test pad width (50 feet) of approximately four times the width of a tractor-scraper (i.e., 12 feet) and a length (75 feet) of approximately three times the length of a tractor-scraper (i.e., 15 feet), plus an additional 15 feet on either end of the test pad to allow room for turning.

The compactive effort was varied for each test fill by changing the number of passes per lift of soil. The number of passes made with the Cat 825B sheepsfoot compactor are presented below for each 9-inch lift for the three test pads.

RANGE OF COMPACTIVE EFFORT FOR 9-INCH LIFT THICKNESS

TEST PAD	SOURCE	NO. OF PASSES
TP-1	I-696 Clay	2 4 6
TP-2	London Michigan Clay	6 8 10
TP-3	Ann Arbor Sand & Gravel Clay	10 12 14

Plate Nos. I through 3 show the approximate location of the test pad permeameters, the three test fills comprising a given test pad and the compactive effort applied to each test fill.

3.0 MONITORING OF TEST PAD CONSTRUCTION

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Test pad TP-1 was constructed between August 28, 1989 and September 5, 1989, by C. J. Rogers, Inc., the earthwork contractor for the Cell II construction project in 1989 and 1990. Test pads TP-2 and TP-3 were constructed by C. J. Rogers, Inc. between June 21, 1990 and July 5, 1990. A representative from NTH (Independent Testing Engineer) monitored the fill placement operations during the construction of each test pad.

During construction of the test fills, field moisture/density tests were taken on each lift at the permeameter locations. These tests provided a basis for correlating field permeabilities with compactive effort in each of the test fills. The clay fill was tested to determine in-place dry density and water content for comparison with maximum dry density and optimum water content, as determined by ASTM D1557. Additionally, Torvane shear strength tests were performed at each moisture/density location.

4.0 PERMEAMETERS

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4.1 Permeameter Description

The hydraulic conductivity of the test fills was determined using the Boutwell-type permeameter. The permeameters for test pad TP-1 were installed between September 6, 1989 and September 14, 1989 and the permeameters for test pads TP-2 and TP-3 were installed between July 17, 1990 and October 4, 1990, by the ITE.

The Boutwell permeameter test is a two-stage, field hydraulic conductivity test performed in a shallow borehole. The method allows both the vertical and horizontal coefficients of permeability (k_v and k_h) to be determined. The Boutwell permeameter is easily installed, economical, and allows for rapid measurements of permeability.

The first stage of the test consists of measuring the coefficient of permeability, k_1, when water is allowed to permeate the base of the permeameter casing. After a stabilized permeability value is obtained for the first stage, the borehole is extended below the base of the casing. For the second stage of the test, water is allowed to permeate through the sides and the base of the borehole. The test proceeds until a stabilized permeability value, k_2, is obtained for the second stage. Values

of k_v and k_h are calculated from k_1 and k_2 values, using the procedures described later in this report.

4.2 Permeameter Installation

Each permeameter was seated in a hole dug approximately 12 inches in diameter and 12 inches deep. Within each hole a 4-inch diameter PVC pipe was driven approximately 1 inch into the clay to seat the casing and ensure a sound hydraulic seal. The permeameters were sealed in place with a cement grout. The grout consisted of approximately 8 gallons of water to 94 pounds of Portland cement and approximately 3 pounds of bentonite (approximately 3% by weight) for TP-2 and TP-3, and approximately 7 pounds of bentonite (approximately 6% by weight) for TP-1. The grout mixture was allowed to set overnight before testing proceeded. The permeameters were observed during filling for water leakage around the grout pack; grout packs were replaced for any permeameters that leaked.

Each permeameter casing was sealed with a threaded PVC cap containing a rubber O-ring and a bleeder valve with a T-fitting. A 36-inch long, 1/2-inch diameter acrylic tube was affixed to the top of each fitting. A portion of a steel tape rule was affixed to the acrylic tube. All connections were sealed with epoxy. A sketch of the first stage Boutwell permeameter is presented in Plate No. 4.

A total of 27 permeameters were installed - nine per test pad or three per test fill. A set of three permeameters per test fill was installed in a triangular formation, as presented in Plate Nos. 1 through 3. Moisture and density tests were conducted in the proximate location of each permeameter. After the first stage of testing a 4-inch hole, equal to the inside diameter of the permeameter casing, was excavated below the base of the casing. The depth of the holes ranged between 8 to 14 inches. The total depth of the permeameter for the second stage ranged between 20 to 27 inches below the surface.

The holes in test pad TP-1 were extended for the second stage using a 3-inch diameter Shelby tube pushed by a bulldozer blade. The holes were then enlarged to the same diameter as the 4-inch PVC permeameter casing using a reaming device constructed from a Shelby tube. The holes in test pads TP-2 and TP-3 were extended using a 4-inch diameter extraction tube pushed through the interior of the 4-inch PVC permeameter casing. The tubes were removed with the enclosed cylinder of soil. The extraction tube and Shelby tube soil samples were marked and transported to the ITE laboratory for testing. The sides of the clay annular space, created by the removal of the soil samples, were scratched using a wire brush to minimize smearing effects. A sketch of the second stage Boutwell permeameter is presented in Plate No. 5.

During the period of study of test pad TP-1 the soil at the surface of the test fills was losing moisture. Desiccation cracks were observed throughout test pad TP-1. Therefore, the base of each permeameter for test pads TP-2 and TP-3 (constructed approximately 9 months after test pad TP-1) was covered with 10 feet square geosynthetic liner to minimize surface desiccation and to better model soil conditions of an actual clay liner.

Permeameter ST-3 of test pad TP-1 was abandoned prior to second stage permeability testing. A large diameter rock that could not be removed was encountered at a depth 4 inches below the permeameter base. Permeameters that did not function properly in test pads TP-2 and TP-3 were replaced. Approximately one third of the permeameters for test pads TP-2 and TP-3 were replaced due to leaks at the fittings or grout seal.

5.0 DATA COLLECTION

5.0 DATA COLLECTION

First stage testing of the Boutwell permeameter method was run from October 4, 1989 through October 13, 1989 for test pad TP-1 and from July 17, 1990 through August 29, 1990 for test pads TP-2 and TP-3. Second stage testing was run from November 1, 1989 through November 16, 1989 for test pad TP-1 and from August 29, 1990 through October 20, 1990 for test pads TP-2 and TP-3.

The test method consists of filling the permeameter with water and measuring the total distance of head drop in the stand pipe for a given time interval. The distance of head drop, the corresponding time interval, and the permeameter dimensions are used to calculate k_1 and k_2 permeability values.

Each stage of the test method generates a coefficient of permeability for the soil - k_1 from the first stage and k_2 from the second stage. Coefficients k_1 and k_2 are used to compute the vertical (k_v) and horizontal (k_h) coefficients of permeability.

Each stage of the test proceeds until a stabilized condition is attained. Once the permeability stabilizes, measurements in head drop continue to be taken for some time to confirm equilibrium. Thereafter, the individual stages are considered complete.

6.0 PERMEABILITY COMPUTATION

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Values for the observed field permeabilities are calculated, during the course of each stage of the test, using equations based on formulas derived by Hvorslev (Lambe, T. William and Robert V. Whitman, 1969). First and second stage coefficients k_1 and k_2, respectively, are computed for every field reading. After a period of time the permeameters stabilize. A single k_1 and k_2 value for each test location is computed by taking a weighted average of the permeability with respect to time after the permeability stabilized.

To compute the coefficient of permeability for the first stage (k_1), the raw permeameter readings are converted to actual hydraulic head (H_n) and the corresponding times are tabulated. First stage k_1 permeabilities are calculated using one of two different equations.

Equation (1) is used to calculate the k_1 coefficient for a soil surface which is flush with the bottom of the permeameter casing (i.e., for a permeameter with a seating depth of b=o).

$$k_1 = \frac{d^2 \pi}{11 D (t_2 - t_1)} \ln\left(\frac{H_1}{H_2}\right) \qquad \text{Eq. (1)}$$

where,

d = diameter of pipette

D = diameter of casing

H_1 = hydraulic head at beginning of measurement

H_2 = hydraulic head at end of measurement

t_1 = time at beginning of measurement

t_2 = time at end of measurement

Equation (2) is used to calculate the k_1 coefficient for a soil surface that is above the bottom of the permeameter casing (i.e., for a permeameter with a finite seating depth of b > o).

$$k_1 = \frac{d^2\left(\frac{D\pi}{11} + b\right)}{D^2\,(t_2 - t_1)} \ln\left(\frac{H_1}{H_2}\right) \qquad \text{Eq. (2)}$$

where, b = seating depth

Permeameter readings for second stage testing and their corresponding times are tabulated to calculate k_2. The readings are converted to actual hydraulic head (H_n) and substituted into Equation 3.

$$k_2 = \frac{A}{B} \ln\left(\frac{H_1}{H_2}\right) \qquad \text{Eq. (3)}$$

where,

$$A = d^2 \ln\left(\frac{L}{D} + \sqrt{1 + \left(\frac{L}{D}\right)^2}\right)$$

and

$$B = 8L(t_2 - t_1)(1 - 0.526\, EXP^{\left(-1.57 \frac{L}{D}\right)})$$

where, L = length of the uncased section of the permeameter

The soil anisotropy transformation coefficient, m, is calculated (e.g., by means of a computer program), using one of Equations (4) through (6).

Equation (4) uses coefficient k_1 from Equation (1) for permeameter casings having zero seating depth (b = 0); transformation coefficient, m, is computed using Equation (4) for such cases (i.e., test pad TP-1).

$$\frac{k_2}{k_1} = \frac{m \ln\left(\frac{L}{D} + \sqrt{1 + \left(\frac{L}{D}\right)^2}\right)}{\ln\left(\frac{mL}{D} + \sqrt{1 + \left(\frac{mL}{D}\right)^2}\right)} \qquad \textbf{Eq. (4)}$$

Equation (5) uses coefficient k_1 from Equation (2) for permeameter casings having finite seating depth (b > 0); transformation coefficient, m, is computed using Equation (5) for such cases (i.e., test pads TP-2 and TP-3 excluding permeameter ST-8 of TP-3).

$$\frac{k_2}{k_1} = \frac{m^2\left(\frac{D\pi}{11m}+b\right)\ln\left(\frac{L}{D}+\sqrt{1+\left(\frac{L}{D}\right)^2}\right)}{\left(\frac{D\pi}{11}+b\right)\ln\left(\frac{mL}{D}+\sqrt{1+\left(\frac{mL}{D}\right)^2}\right)} \qquad \text{Eq. (5)}$$

Equation (6) uses coefficient k_1 from Equation (2) for one permeameter casing having finite seating depth (b > 0) and a smeared annular space; transformation coefficient, m, is computed using Equation (6) for one such case (i.e., station ST-8 of test pad TP-3). Following extraction of the soil sample for the second stage of the test, the annular space was observed to have been excessively smeared even after scouring with a wire brush. Equation (6) is used to compute an m value that compensates for the reduction in permeability attributed to this smearing effect. The coefficient of permeability for the smear zone is k_a.

$$\frac{k_2}{k_1} = \frac{m\ln\left(\frac{L}{D}+\sqrt{1+\left(\frac{L}{D}\right)^2}\right)}{\ln A + P\ln B} \qquad \text{Eq. (6)}$$

where,

$$A = \frac{mL}{D+2T} + \sqrt{1+\left(\frac{mL}{D+2T}\right)^2}$$

and

$$B = 1 + 2\frac{T}{D}$$

where, T = smear thickness

P = ratio of the actual k_h and k_a of the smear zone

Once m is computed, coefficients of permeability k_h and k_v are calculated from the following equations:

$$k_v = \frac{k_1}{m}$$

$$k_h = mk_1$$

Values for horizontal and vertical permeabilities (k_h and k_v) are presented in Table Nos. 1 through 3.

7.0 TESTING AND RESULTS

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7.1 Field Testing

Field density, moisture, and torvane tests were taken at each permeameter location. A summary of the field data obtained during construction is presented in Table Nos. 4 through 6.

7.2 Laboratory Testing

A total of 9 soil samples were obtained from test pad TP-1, 12 soil samples from test pad TP-2, and 12 soil samples from test pad TP-3. Soil samples recovered from second stage field permeability testing were laboratory tested for permeability, in a falling head test method detailed in USEPA Publication SW-925. In addition, soil samples were analyzed for grain-size distribution (ASTM D422), Atterberg limits (ASTM D4318), moisture content (ASTM D4959), and dry density. Additionally, the soil samples were planned to be tested for unconfined compressive strength as determined by ASTM D2166. However, during the sampling process, most of the samples were disturbed and could not be tested. Soil samples from test pad TP-1, ST-4 and ST-5 and test pad TP-2, ST-6, ST-9, and ST-9.2 were tested for unconfined compressive strength.

Laboratory results are presented in Table Nos. 7 and 8. Grain Size Distribution Curves are plotted for soils at each permeameter location in Figure Nos. 1 through 34.

Laboratory permeability results (k_{lab}), ranged from 6.1×10^{-9} cm/sec to 7.1×10^{-8} cm/sec for the permeameter locations.

7.3 Results

In general, field vertical coefficient of permeability k_v shows good correlation with laboratory coefficient of permeability k_{lab}, differing from approximately one-half order of magnitude less than k_{lab} to approximately one-half order of magnitude greater than k_{lab}. This fluctuation is considered a normal distribution of data and would be predicted inasmuch as k_{lab} only measures and accounts for vertical permeability. Field horizontal coefficient of permeability k_h however, demonstrates consistently greater permeabilities than laboratory coefficient of permeability k_{lab}, differing approximately two orders of magnitude greater than k_{lab}. The higher k_h values are most likely the result of secondary permeability features (e.g., dessication cracks, fissures, lift demarcations, etc.) that influence k_h in the field. The laboratory permeability test is performed on a relatively small soil sample and measures only vertical permeability; secondary permeability features do not affect measured k_{lab} values. Field and laboratory coefficients of permeability are presented in Tables 1 through 3.

All soils were identified as CL material, as determined by Unified Soil Classification ASTM D2487; results of Atterberg Limit testing were consistent within each test pad.

Clay used for the construction of test pad TP-1 exhibited maximum dry densities ranging from 130.6 to 133.9 pcf and optimum moisture contents ranging from 9.0 to 10.4 percent, as determined by the Modified Proctor ASTM D1557. Laboratory test results indicate that clay from test pad TP-1 had in-place moisture contents approximately 1 to 3 percent greater than their optimum moisture contents. The average laboratory percent-compaction of the 2, 4 and 6 pass fills was 96.4 percent, 96.7 percent and 97.1 percent, respectively. These values compare to average field percent-compaction of the 2, 4 and 6 pass fills of 92.0 percent, 93.2 percent and 93.4 percent, respectively.

Clay used for the construction of test pad TP-2 exhibited a maximum dry density of 127.3 pcf and an optimum moisture content of 10.6 percent, as determined by the Modified Proctor ASTM D1557. Laboratory test results indicate that clay from test pad TP-2 had in-place moisture contents approximately 1 to 6 percent greater than the optimum moisture content, determined by the Modified Proctor. The average laboratory percent-compaction of the 6, 8 and 10 pass fills was 96.7 percent, 98.7 percent and 99.1 percent, respectively. These values compare to average field percent-

compaction of the 6, 8 and 10 pass fills of 94.2 percent, 94.6 percent and 94.2 percent, respectively.

Clay used for the construction of test pad TP-3 exhibited a maximum dry density of 134.0 pcf and an optimum moisture content of 8.9 percent, as determined by the Modified Proctor ASTM D1557. Laboratory test results indicate that clay from test pad TP-3 had in-place moisture contents approximately 0 to 4 percent greater than the optimum moisture content, as determined by the Modified Proctor. The average laboratory percent-compaction of the 10, 12 and 14 pass fills was 97.5 percent, 97.8 percent and 97.5 percent, respectively. These values compare to average field percent-compaction of the 10, 12 and 14 pass fills of 92.7 percent, 94.2 percent and 92.3 percent, respectively.

8.0 CONCLUSIONS

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The "Construction Quality Assurance Plan", dated January 11, 1990, for the APCM Cell II landfill requires test fills be compacted to greater than 90% of the maximum dry density and at minus 2% to plus 3% of optimum moisture content, as determined by ASTM D1557. The plan also requires shear strength of 2500 pounds per square foot (psf) as determined by either field vane shear methods or laboratory strength tests performed on Shelby tube samples.

All field test results for percent compaction as determined by ASTM D3017 met the above requirements. However, field moisture content test results, as determined by ASTM D2922, range from plus 0.5% to plus 5.3% of the optimum moisture content which is slightly outside the above specified range.

All laboratory test results for moisture content and percent compaction performed on soil samples taken at the permeameter locations met the above requirements. However, 4 of 12 laboratory moisture contents within test pad TP-2 were slightly greater than +3% of the optimum moisture content.

All field torvane shear strength test results were greater than the required 2500 psf. Limited laboratory unconfined compressive strength tests were performed due to disturbed soil samples. Two laboratory tests failed the shear strength requirement. However,

both failed at low strains, which indicate the samples may have been disturbed during the sampling process.

Test fills (set of three permeameters) that yielded field permeabilities less than 1 x 10^{-7} cm/sec, in accordance with the "Construction Quality Assurance Plan" are: test pad TP-1, 6 pass fill; test pad TP-2, 8 pass and 10 pass fills; and test pad TP-3, 14 pass fill. The following test fills had one or more permeameters that did not meet the maximum allowed field permeability: test pad TP-1, 2 pass and 4 pass fills; test pad TP-2, 6 pass fill; and test pad TP-3, 10 pass and 12 pass fills.

All laboratory permeability tests resulted in coefficient of permeabilities less than 1 x 10^{-7} cm/sec.

Field permeability testing results indicate that vertical and horizontal coefficients of permeability generally decrease as the compactive effort increases. This investigation did not evaluate the correlation between in-place moisture content and permeability, nevertheless research indicates that an increase in the degree of saturation or dry density, in general, decreases the permeability (Boutwell and Hedges, 1989).

Based on test results and references for this study, it is recommended that clay proposed for the Cell II liner be placed 1 to

5 percent above the optimum moisture content to attain field coefficients of permeability equal to or less than 1×10^{-7} cm/sec.

APPENDIX

LIST OF TABLES

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TABLE 1

I-696 CLAY TEST PAD TP-1										
Station	Roller Passes	k1 (cm/sec)	k2 (cm/sec)	M	L (Inches)	b (Inches)	kh (cm/sec)	kv (cm/sec)	klab (cm/sec)	Comments
ST-1	2	3.79E-08	8.57E-08	4.34	9.00	0.00	1.64E-07	8.72E-09	1.60E-08	NO SEAT
ST-2	2	2.80E-07	1.61E-07	0.52	8.88	0.00	1.46E-07	5.39E-07	8.70E-09	NO SEAT
ST-3	2	3.33E-08	ABANDON			0.00				NO SEAT
ST-4	4	4.44E-08	8.58E-08	3.42	8.88	0.00	1.52E-07	1.30E-08	1.30E-08	NO SEAT
ST-5	4	3.69E-08	7.99E-08	4.11	8.64	0.00	1.52E-07	8.98E-09	1.60E-08	NO SEAT
ST-6	4	3.22E-08	4.52E-08	2.02	8.52	0.00	6.50E-08	1.59E-08	1.50E-08	NO SEAT
ST-7	6	8.20E-08	8.21E-08	1.00	8.4	0.00	8.20E-08	8.20E-08	9.50E-09	NO SEAT
ST-8	6	3.20E-08	5.34E-08	2.77	8.28	0.00	8.88E-08	1.16E-08	7.60E-09	NO SEAT
ST-9	6	3.87E-08	4.93E-08	1.67	8.88	0.00	6.47E-08	2.32E-08	1.10E-08	NO SEAT

TABLE 2

LONDON MICHIGAN CLAY TEST PAD TP-2										
Station	Roller Passes	k1 (cm/sec)	k2 (cm/sec)	M	L (Inches)	b (Inches)	kh (cm/sec)	kv (cm/sec)	klab (cm/sec)	Comments
ST-1	6	6.00E-08	1.46E-07	2.06	14.06	1.54	1.24E-07	2.92E-08	7.60E-09	FULL SEAT DEPTH
ST-2	6	6.79E-08	2.65E-07	3.30	9.62	0.94	2.24E-07	2.06E-08	8.10E-09	FULL SEAT DEPTH
ST-3	6	3.45E-08	7.05E-08	1.98	9.98	0.94	6.84E-08	1.74E-08	8.20E-09	FULL SEAT DEPTH
ST-4	8	4.41E-08	5.31E-08	1.20	9.50	1.30	5.31E-08	3.66E-08	1.00E-08	FULL SEAT DEPTH
ST-5	8	3.92E-08	4.95E-08	1.35	9.62	0.46	5.29E-08	2.91E-08	1.10E-08	FULL SEAT DEPTH
ST-6	8	4.22E-08	7.59E-08	1.65	7.56	2.52	6.98E-08	2.55E-08	1.10E-08	FULL SEAT DEPTH
ST-7	10	3.15E-08	4.95E-08	1.68	9.02	0.58	5.29E-08	1.87E-08	1.20E-08	FULL SEAT DEPTH
ST-8	10	2.58E-08	4.96E-08	2.11	9.62	0.46	5.43E-08	1.22E-08	1.10E-08	FULL SEAT DEPTH
ST-9	10	6.30E-08	9.61E-08	1.46	8.54	1.99	9.18E-08	4.32E-08	1.40E-08	FULL SEAT DEPTH

TABLE 3

ANN ARBOR SAND AND GRAVEL CLAY TEST PAD TP-3										
Station	Roller Passes	k1 (cm/sec)	k2 (cm/sec)	M	L (Inches)	b (Inches)	kh (cm/sec)	kv (cm/sec)	klab (cm/sec)	Comments
ST-1	10	3.97E-08	7.61E-07	1.88	9.98	0.94	7.45E-08	2.12E-08	7.50E-09	FULL SEAT DEPTH
ST-2	10	2.71E-08	4.68E-08	1.69	9.74	1.06	4.59E-08	1.60E-08	7.40E-09	FULL SEAT DEPTH
ST-3	10	8.39E-08	1.06E-07	1.36	8.04	0.46	1.14E-07	6.16E-08	6.20E-09	FULL SEAT DEPTH
ST-4	12	3.87E-08	1.33E-07	2.90	7.92	1.30	1.12E-07	1.33E-08	1.30E-08	FULL SEAT DEPTH
ST-5	12	1.11E-07	9.43E-08	0.80	9.98	0.58	8.84E-08	1.39E-07	1.00E-08	FULL SEAT DEPTH
ST-6	12	3.25E-08	2.46E-08	0.68	9.00	0.82	2.22E-08	4.76E-08	1.50E-08	FULL SEAT DEPTH
ST-7	14	5.60E-08	5.88E-08	1.07	8.40	0.58	5.98E-08	5.25E-08	1.10E-08	FULL SEAT DEPTH
ST-8	14	6.95E-08	2.38E-08	0.86	10.10	0.82	5.96E-08	8.10E-08	1.20E-08	FULL SEAT DEPTH W/ SMEAR
ST-9	14	2.52E-08	7.53E-08	3.32	10.10	0.34	8.37E-08	7.58E-09	7.10E-08	FULL SEAT DEPTH

TABLE 4
TABULATION OF FIELD TEST DATA
I-696 CLAY TEST PAD TP-1

TEST FILL AREA	IN-PLACE MOISTURE CONTENT (%)	PERCENT MAX DRY DENSITY	TORVANE COHESION (PSF)
2 Pass Area	11.7	92.0	2500+
	11.1	93.9	2500+
	11.2	90.1	2500+
	14.3	91.6	2500+
	12.0	91.2	2500+
	12.8	90.3	2500+
	12.6	91.3	2500+
	12.4	91.9	2500+
	11.6	92.6	2500+
	12.3	93.1	2500+
	10.9	94.4	2500+
	12.4	91.5	2500+
4 Pass Area	12.8	94.7	2500+
	9.9	90.0	2500+
	11.4	92.9	2500+
	10.7	93.4	2500+
	10.7	94.9	2500+
	10.0	93.7	2500+
	13.6	93.3	2500+
	12.7	93.7	2500+
	11.4	95.5	2500+
	13.6	90.1	2500+
6 Pass Area	13.1	92.7	2500+
	11.0	95.0	2500+
	11.8	90.6	2500+
	12.3	92.4	2500+
	12.3	93.4	2500+
	10.5	95.7	2500+
	13.4	90.9	2500+
	11.0	93.6	2500+
	13.0	90.0	2500+
	13.7	94.9	2500+
	13.9	98.6	2500+

TABLE 5
TABULATION OF FIELD TEST DATA
LONDON CLAY TEST PAD TP-2

TEST FILL AREA	IN-PLACE MOISTURE CONTENT (%)	PERCENT MAX DRY DENSITY	TORVANE COHESION (PSF)
6 Pass Area	13.6	94.1	2950
	13.3	95.3	4000
	14.3	93.2	3175
	13.4	94.2	3750
	12.4	94.2	3150
	15.9	90.6	4300
	15.6	90.5	3575
	13.1	95.9	3450
	13.3	94.5	3300
	13.8	94.4	3875
	13.0	92.8	3425
	13.0	96.1	3325
	12.3	96.2	3150
	12.6	96.3	3325
8 Pass Area	14.6	94.0	3300
	12.7	94.5	3600
	12.9	94.5	3650
	13.9	95.8	4175
	15.0	93.3	3400
	12.0	98.6	3375
	14.5	94.5	4425
	13.7	92.9	3875
	14.0	95.0	3625
	14.5	92.5	3675
	12.4	96.6	3575
	13.9	92.2	3675
	13.7	94.7	3650
	13.0	96.2	3225
	12.7	95.3	3425
10 Pass Area	14.7	93.6	3075
	11.8	96.3	3700
	13.2	95.0	3625
	12.4	96.5	3000
	14.8	93.3	3025
	13.0	92.8	3450
	13.8	95.0	4025
	13.8	94.9	2650
	12.8	95.4	3700
	12.2	95.2	3675
	14.2	92.5	3650
	14.6	92.4	3025
	13.4	95.8	3900
	15.4	92.0	3575
	13.5	92.0	4075

TABLE 6
TABULATION OF FIELD TEST DATA
ANN ARBOR TEST PAD TP-3

TEST FILL AREA	IN-PLACE MOISTURE CONTENT (%)	PERCENT MAX DRY DENSITY	TORVANE COHESION (PSF)
10 Pass Area	13.1	93.4	3000
	11.8	90.8	2850
	13.2	90.6	3650
	13.2	92.5	3025
	12.4	94.0	2775
	12.9	90.5	3375
	11.1	93.2	2700
	10.6	94.6	2900
	13.3	91.9	3000
	11.8	94.8	3100
	12.4	94.0	3400
	13.1	93.2	3700
	11.2	92.1	3500
	12.2	92.5	3250
	12.2	93.2	2950
12 Pass Area	12.2	94.5	3425
	12.3	92.5	2850
	11.8	93.4	2950
	10.7	95.7	3500
	10.9	94.3	3700
	11.2	93.5	3600
	11.8	94.9	3075
	11.5	93.0	3450
	12.1	95.6	3850
	12.6	94.3	4925
	12.0	94.2	3572
	11.6	95.1	2850
	12.0	94.3	2900
	12.0	93.6	3150
14 Pass Area	13.8	90.4	2725
	13.0	90.1	3625
	12.6	93.2	2750
	11.8	93.6	2900
	11.3	92.3	4125
	11.8	92.8	4025
	11.2	93.7	3850
	11.4	95.6	3325
	11.2	90.5	3300
	10.8	96.2	3900
	12.7	93.9	3725
	11.0	94.8	4050
	12.5	90.4	3450
	10.3	92.1	2725
	12.0	94.6	3350

PROJECT NO. 89365 OW

NTH Consultants, Ltd.

TABULATION OF LABORATORY TEST DATA

Test Pad	Sample Number	Depth of Sample Tip (Inch)	Elevation of Sample Tip	Unconfined Compressive Strength (PSF)	Failure Strain (Percent)	Natural Water Content (Percent of Dry Weight)	In-Place Dry Density (Pounds per Cubic Foot)	Permeability (Centimeters per Second)	Particle Size Distribution: Colloids (Percent)	Clay (Percent)	Silt (Percent)	Fine Sand (Percent)	Medium Sand (Percent)	Coarse Sand (Percent)	Gravel (Percent)	Atterberg Limits: Liquid Limit (Percent)	Plastic Limit (Percent)	Plasticity Index (Percent)	Apparent Specific Gravity	Torvane Cohesion c (Tons per Square Foot)
TP-01	ST-1		-	-	-	11.2	128.5	1.6×10^{-8}	<--	33	36	22	6	2	1	27	15	12	-	-
	ST-2		-	-	-	13.1	126.3	8.7×10^{-9}	<--	33	32	20	6	2	7	26	15	11	-	-
	ST-4		-	7790	-	11.7	128.6	1.3×10^{-8}	<--	31	33	22	7	3	4	25	14	11	-	-
	ST-5		-	3310	-	11.5	127.0	1.6×10^{-8}	<--	31	35	23	8	2	1	25	14	11	-	-
	ST-6		-	-	-	12.0	128.3	1.5×10^{-8}	<--	30	30	22	5	2	11	25	14	11	-	-
	ST-7		-	-	-	13.1	121.6	9.5×10^{-9}	<--	33	35	22	6	3	1	26	15	11	-	-
	ST-8		-	-	-	12.4	128.2	7.6×10^{-9}	<--	30	33	22	7	2	6	25	14	11	-	-
	ST-9		-	-	-	11.5	128.5	1.1×10^{-8}	<--	30	35	23	7	2	3	26	15	11	-	-
TP-02	ST-1SP		-	-	-	16.7	120.6	1.4×10^{-8}	<--	39	38	13	5	2	3	29	16	13	-	-
	ST-1	26.3	-	-	-	12.1	125.2	7.6×10^{-9}	<--	48	34	11	4	2	1	33	17	16	-	6.8
	ST-2	22.6	-	-	-	13.8	99.8	8.1×10^{-9}	<--	44	37	11	4	2	2	30	16	14	-	7.75
	ST-3	22.5	-	-	-	14.7	123.7	8.2×10^{-9}	<--	41	36	12	5	3	3	30	17	13	-	7.5
	ST-4	21.1	-	-	-	13.4	125.5	1.0×10^{-8}	<--	41	36	13	6	2	2	29	16	13	-	6.75
	ST-5	21.3	-	-	-	13.6	126.5	1.1×10^{-8}	<--	45	37	11	4	2	1	31	16	15	-	3.75
	ST-6	22.0	-	9970	15.0	13.5	127.7	1.1×10^{-8}	<--	37	39	11	5	2	6	31	18	13	-	-
	ST-7	20.9	-	-	-	13.0	126.9	1.2×10^{-8}	<--	43	38	12	5	1	1	32	17	15	-	-
	ST-8	21.6	-	-	-	13.2	127.0	1.1×10^{-8}	<--	42	35	12	5	2	4	30	17	13	-	3.8
	ST-9	21.9	-	8810	14.6	13.7	130.0	1.4×10^{-8}	<--	43	39	13	3	1	1	30	17	13	-	-
	ST-9.2	20.8	-	1660	11.9	13.2	123.3	1.1×10^{-8}	<--	45	34	11	6	2	2	31	16	15	-	3.5
	ST-6.2	18.4	-	-	-	12.8	123.1	1.1×10^{-8}	<--	49	34	10	5	1	1	32	16	16	-	-

TABLE 7

PROJECT NO. 89365 OW

NTH Consultants, Ltd.

TABULATION OF LABORATORY TEST DATA

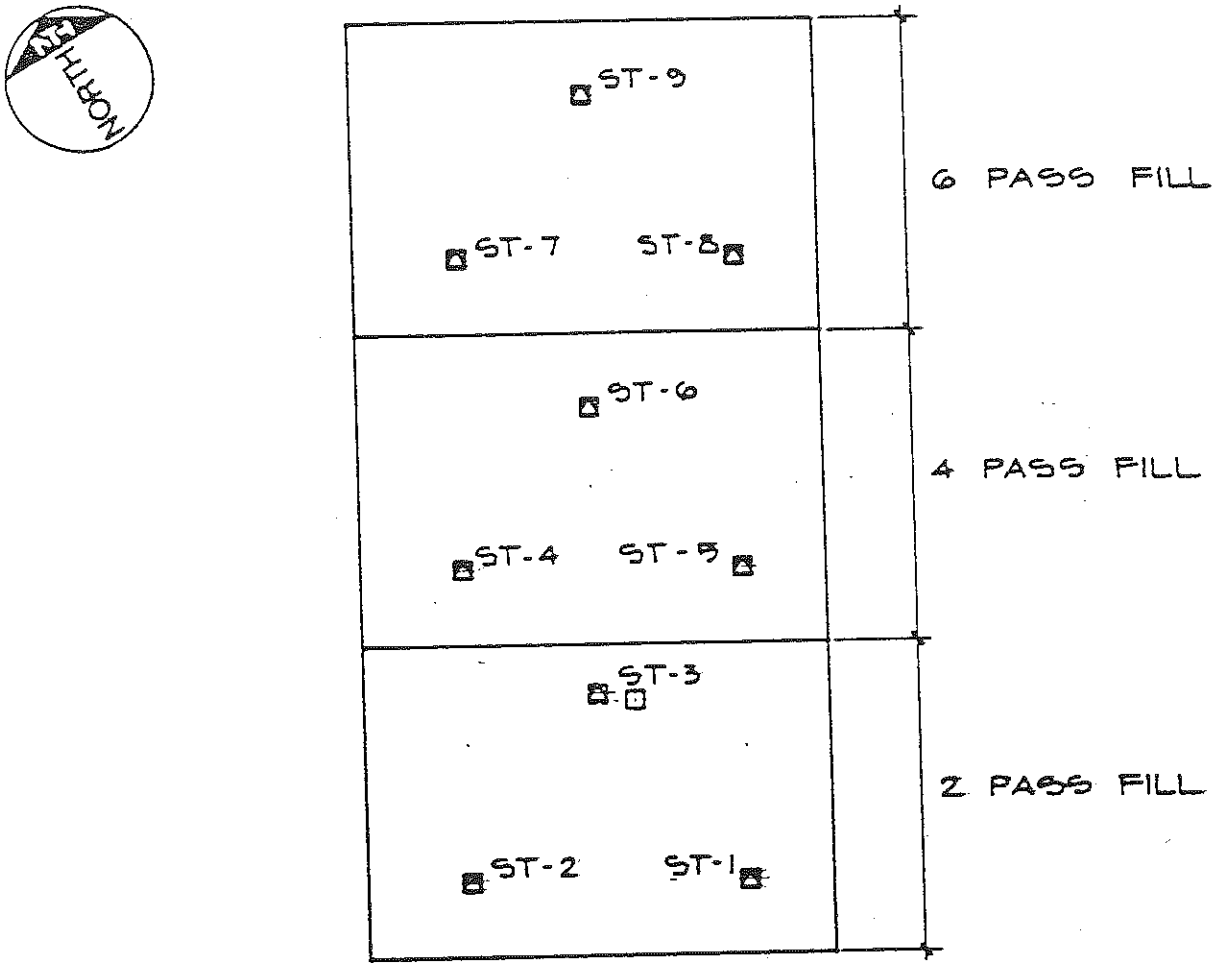
Test Pad	Sample Number	Depth of Sample Tip (Inch)	Elevation of Sample Tip	Unconfined Compressive Strength (PSF)	Failure Strain (Percent)	Natural Water Content (Percent of Dry Weight)	In-Place Dry Density (Pounds per Cubic Foot)	Permeability (Centimeters per Second)	Particle Size Distribution: Colloids (Percent)	Clay (Percent)	Silt (Percent)	Fine Sand (Percent)	Medium Sand (Percent)	Coarse Sand (Percent)	Gravel (Percent)	Atterberg Limits: Liquid Limit (Percent)	Plastic Limit (Percent)	Plasticity Index (Percent)	Apparent Specific Gravity	Torvane Cohesion c (Tons per Square Foot)
TP-03	ST-1	22.5	-	-	-	10.4	133.1	7.5×10^{-9}	<--	33	45	13	5	2	2	26	15	11	-	4.5
	ST-2	23.7	-	-	-	9.9	133.2	7.4×10^{-9}	<--	34	45	13	5	2	1	26	15	11	-	2.9
	ST-3	24.4	-	-	-	13.2	127.5	6.2×10^{-9}	<--	32	47	12	5	2	2	27	14	13	-	-
	ST-4	21.3	-	-	-	11.1	130.7	1.3×10^{-8}	<--	33	47	12	5	2	1	28	15	13	-	2.25
	ST-5	23.3	-	-	-	10.8	143.1	1.0×10^{-8}	<--	32	46	12	5	2	3	27	15	12	-	4.5
	ST-6	24.4	-	-	-	10.7	137.2	1.5×10^{-8}	<--	34	45	13	5	2	1	28	14	14	-	8.75
	ST-7	22.6	-	-	-	9.3	136.1	1.1×10^{-8}	<--	31	47	12	5	1	4	27	14	13	-	11.25
	ST-8	22.0	-	-	-	11.4	130.4	1.2×10^{-8}	<--	33	47	12	5	2	1	27	15	12	-	10.75
	ST-9	23.4	-	-	-	10.3	130.0	7.1×10^{-8}	<--	32	47	13	5	2	1	28	14	14	-	10.00
	ST-1.2	19.2	-	-	-	11.6	127.4	7.4×10^{-9}	<--	32	48	12	4	2	2	25	14	11	-	4.5
	ST-3.2	18.2	-	-	-	10.1	132.2	1.0×10^{-8}	<--	32	48	12	4	2	2	29	16	13	-	1.9
	ST-4.2	19.8	-	-	-	10.4	129.0	6.1×10^{-9}	<--	33	46	12	5	2	2	26	15	11	-	3.5
	ST-6.2	20.6	-	-	-	11.6	127.7	7.9×10^{-9}	<--	32	47	13	5	2	1	27	15	12	-	2.2
	ST-7.3	19.6	-	-	-	11.2	128.2	2.5×10^{-8}	<--	33	46	12	5	2	2	25	15	10	-	2.4

TABLE 7 (continued)

LIST OF PLATES

I-696 CLAY TP-1 PERMEAMETER LOCATIONS	PLATE 1
LONDON CLAY TP-2 PERMEAMETER LOCATIONS	PLATE 2
ANN ARBOR CLAY TP-3 PERMEAMETER LOCATIONS	PLATE 3
PERMEAMETER FIRST STAGE	PLATE 4
PERMEAMETER SECOND STAGE	PLATE 5

I-696 CLAY
TEST PAD TP-1



LEGEND:

△ FIRST STAGE PERMEAMETER

⊡ TERMINATED SECOND STAGE PERMEAMETER

□ SECOND STAGE PERMEAMETER

I-696 CLAY PERMEAMETER TEST LOCATION PLAN

ALLEN PARK CLAY MINE

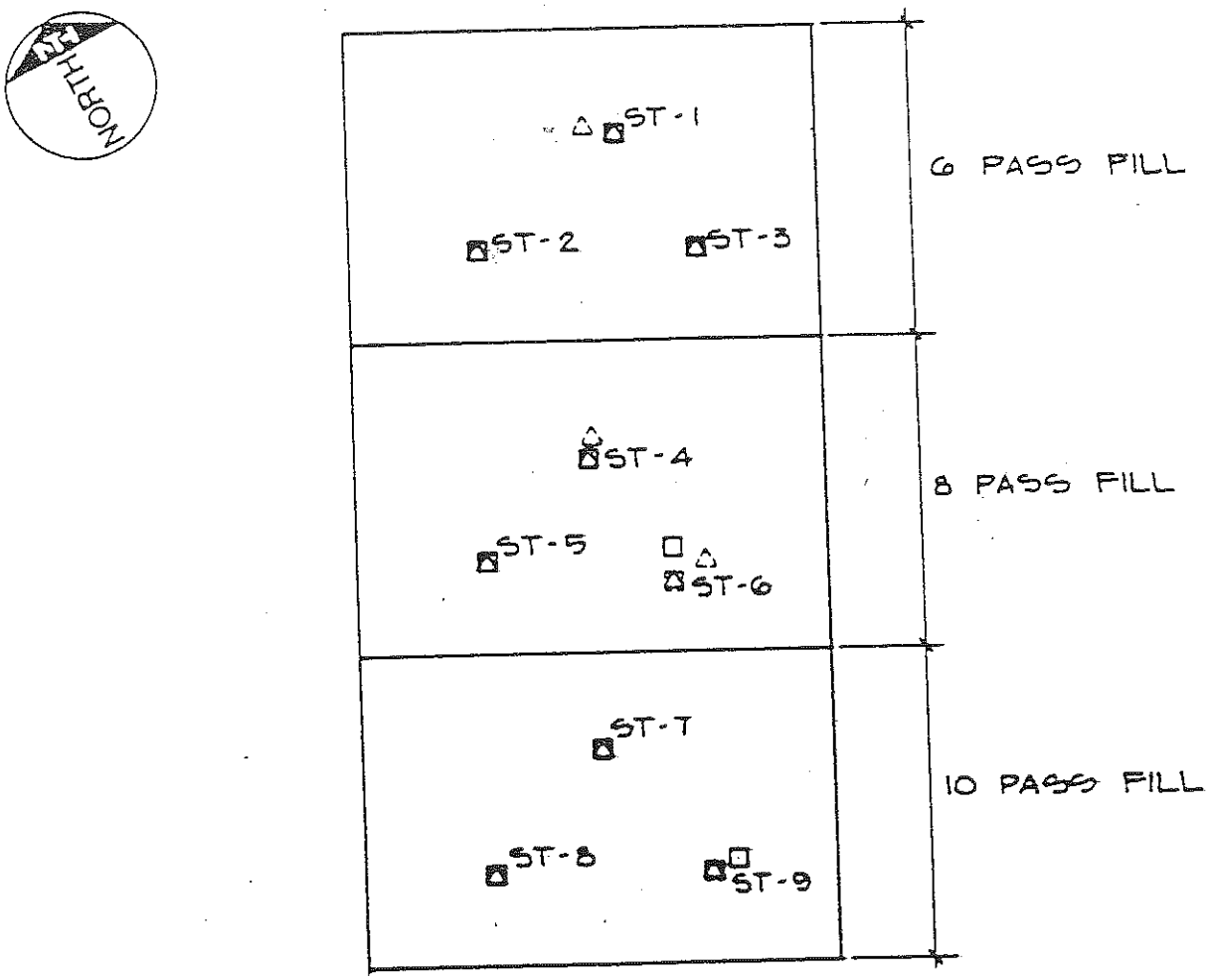
ALLEN PARK, MICHIGAN

NTH CONSULTANTS, LTD.
Professional Engineering & Environmental Services
Farmington Hills, Michigan

PROJECT NO:	DRAWN BY:	DATE:
89365 OW	RK	10-25-90
SCALE: 1" = 30'	CHECKED BY:	SHEET 1 OF 1

PLATE 1

LONDON CLAY
TEST PAD TP-2



LEGEND:

- △ TERMINATED FIRST STAGE PERMEAMETER
- △ FIRST STAGE PERMEAMETER
- □ TERMINATED SECOND STAGE PERMEAMETER
- □ SECOND STAGE PERMEAMETER

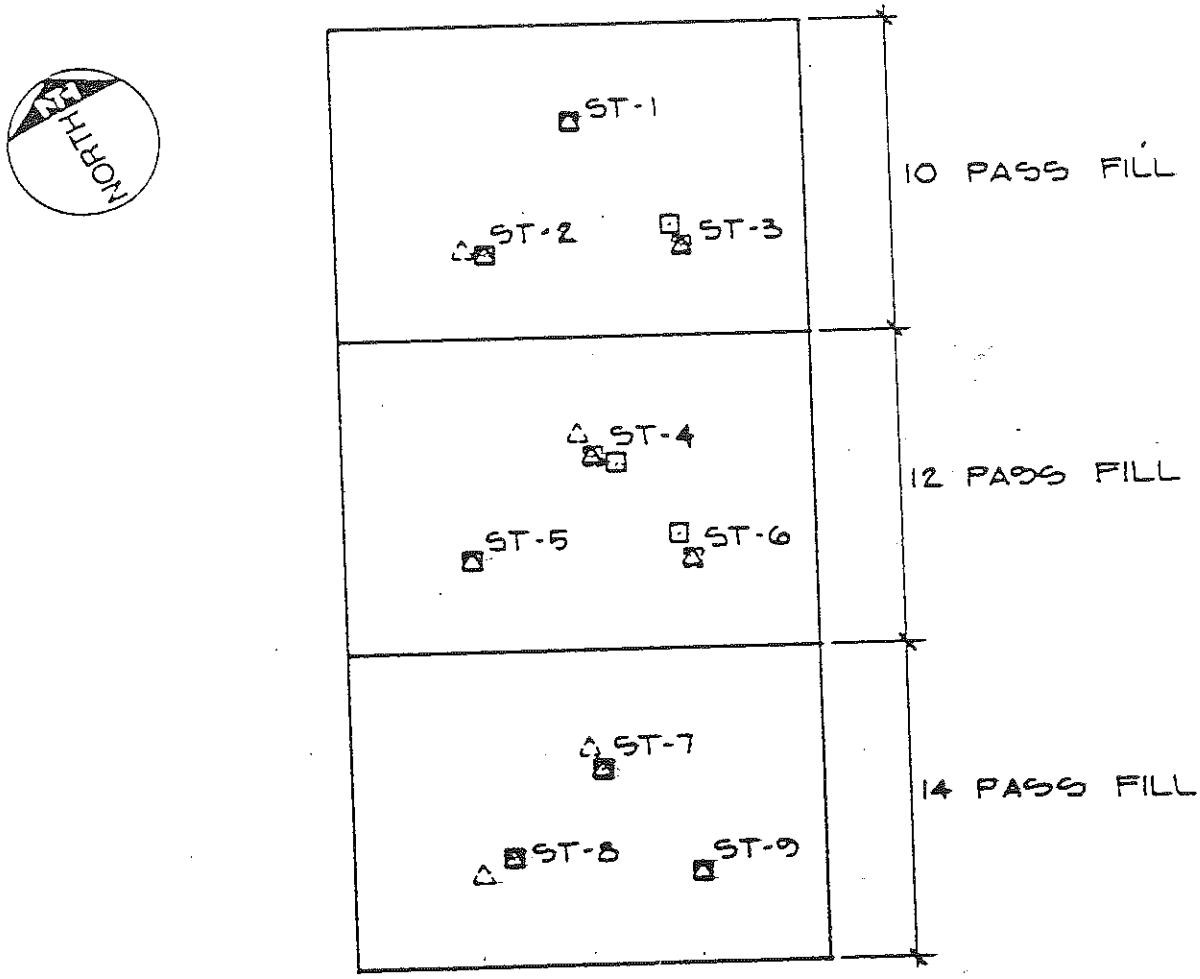
LONDON CLAY PERMEAMETER TEST LOCATION PLAN
ALLEN PARK CLAY MINE
ALLEN PARK, MICHIGAN

NTH CONSULTANTS, LTD.
Professional Engineering & Environmental Services
Farmington Hills, Michigan

PROJECT NO: 89365 OW	DRAWN BY: RK	DATE: 10-25-90
SCALE: 1" = 30'	CHECKED BY:	SHEET 1 of 1

PLATE 2

ANN ARBOR SAND & GRAVEL
TEST PAD TP-3



LEGEND:

- △ TERMINATED FIRST STAGE PERMEAMETER
- △ FIRST STAGE PERMEAMETER
- ⊡ TERMINATED SECOND STAGE PERMEAMETER
- □ SECOND STAGE PERMEAMETER

ANN ARBOR SAND & GRAVEL PERMEAMETER TEST LOCATION PLAN

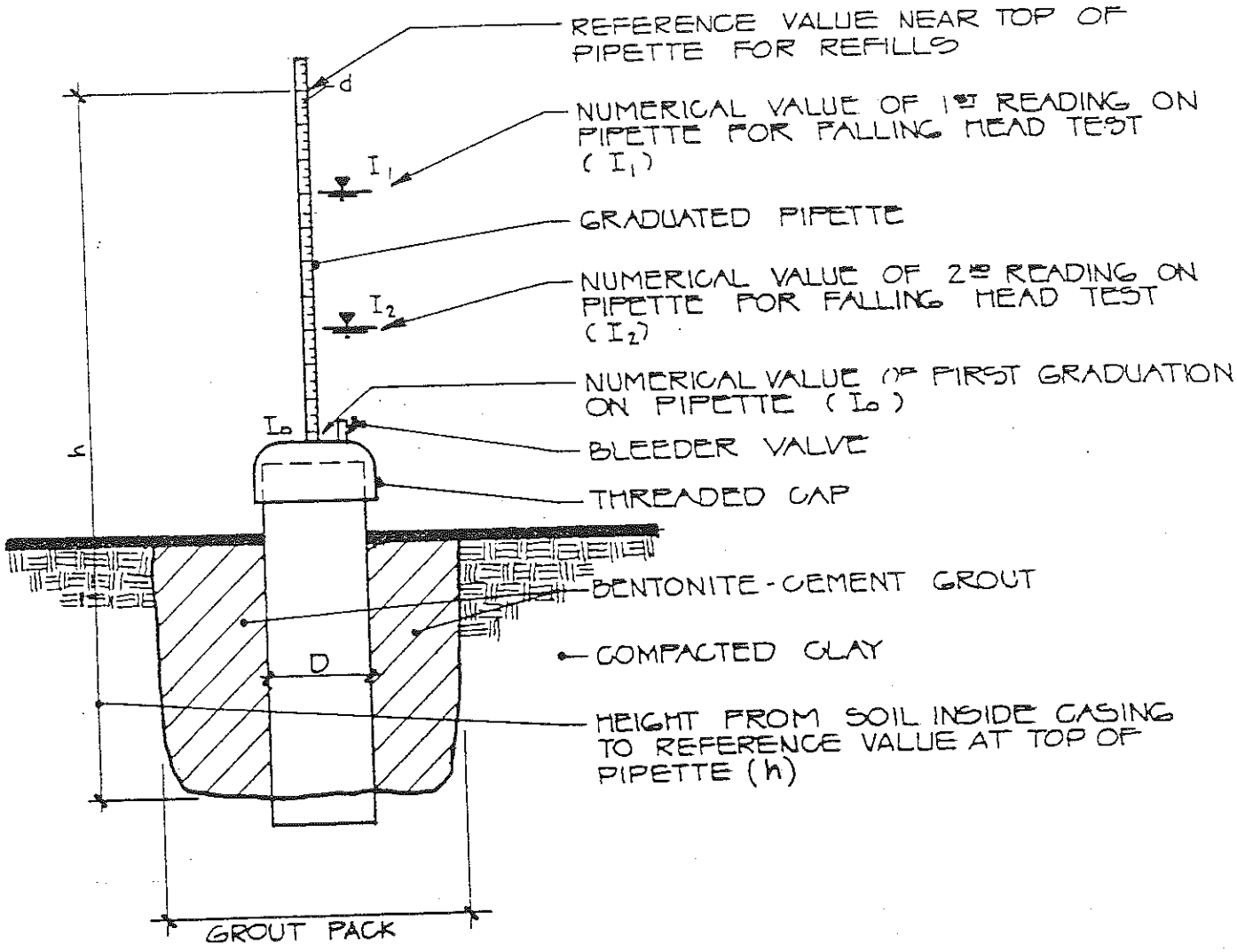
ALLEN PARK CLAY MINE

ALLEN PARK, MICHIGAN

NTH CONSULTANTS, LTD.
Professional Engineering & Environmental Services
Farmington Hills, Michigan

PROJECT NO: 89365 OW	DRAWN BY: RK	DATE: 10-25-90
SCALE: 1" = 30'	CHECKED BY:	SHEET 1 OF 1

PLATE 3



FOR ALL PEREAMETERS

TO OBTAIN H_1 AND H_2 FOR BOUTWELL EQUATION ;

$H_1 = (I_1 - I_0) + h$

$H_2 = (I_2 - I_1) + h$

FIRST STAGE PERMEAMETER SET-UP

ALLEN PARK CLAY MINE LANDFILL

ALLEN PARK, MICHIGAN

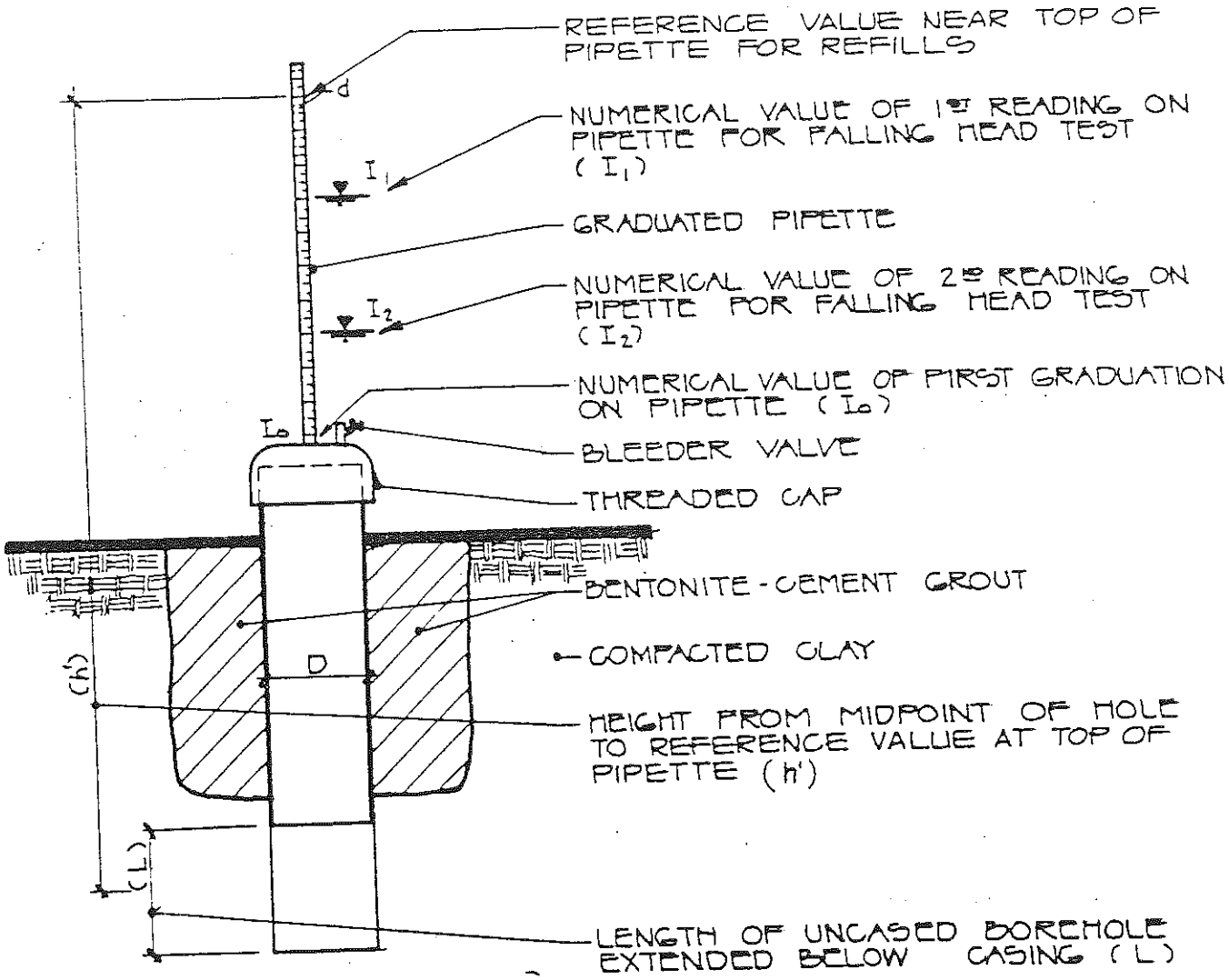
NTH CONSULTANTS, LTD.

Professional Engineering & Environmental Services

Farmington Hills, Michigan

PROJECT NO:	DRAWN BY:	DATE:
39365 OW	GUY	2-27-90
SCALE: NOT TO SCALE	CHECKED BY: DHH	SHEET 1 OF 1

PLATE 4



FOR ALL PEREAMETERS

TO OBTAIN H_1 AND H_2 FOR BOUTWELL EQUATION ;

$H_1 = (I_1 - I_0) + h'$

$H_2 = (I_2 - I_1) + h'$

SECOND STAGE PERMEAMETER SET-UP

ALLEN PARK CLAY MINE LANDFILL

ALLEN PARK, MICHIGAN

NTH CONSULTANTS, LTD.

Professional Engineering & Environmental Services

Farmington Hills, Michigan

PROJECT NO:	DRAWN BY:	DATE:
890365 OW	GUY	2-27-90
SCALE:	CHECKED BY:	SHEET
NOT TO SCALE	DHH	1 OF 1

PLATE 5

LIST OF FIGURES

I-696 CLAY TP-1 GRAIN SIZE DISTRIBUTION CURVES	FIGURES 1 - 8
LONDON CLAY TP-2 GRAIN SIZE DISTRIBUTION CURVES	FIGURES 9 - 20
ANN ARBOR CLAY TP-3 GRAIN SIZE DISTRIBUTION CURVES	FIGURES 21 - 34

NTH Consultants, Ltd.

GRAIN SIZE DISTRIBUTION CURVE

Project No. 89305-OW Lab Sample No. 39 Source I-696 Excavation

Project Location Allen Park, Michigan For As-built Characteristics

Boring No. TP-1 Field Sample No. ST-1 Sample Depth 24" Sample Elev. (Tip) ---

Sample Description Gray silty clay with some sand and trace of gravel

Sampled By DHH Date 10-31-89 Tested By D.V. Date 1-9-90

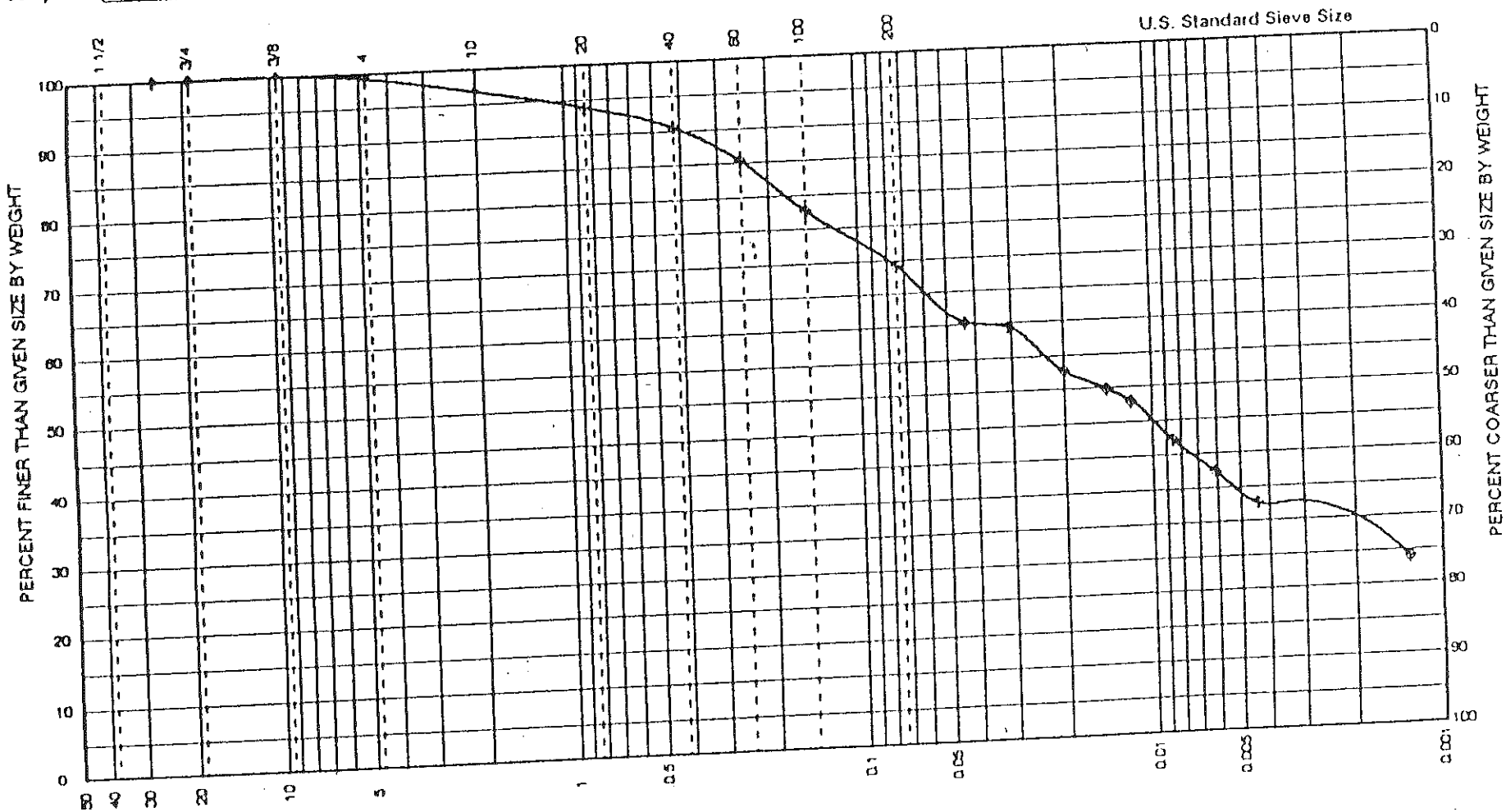


FIGURE 1

NTH Consultants, Ltd.

GRAIN SIZE DISTRIBUTION CURVE

Project No. 89365-OW Lab Sample No. 41 Source I-696 Excavation

Project Location Allen Park, Michigan For As-built Characteristics

Boring No. TP-1 Field Sample No. ST-2 Sample Depth 24" Sample Elev. (Tip) --

Sample Description Gray silty clay with some sand and trace of gravel

Sampled By DHH Date 10-31-89 Tested By D.V. Date 1-9-90

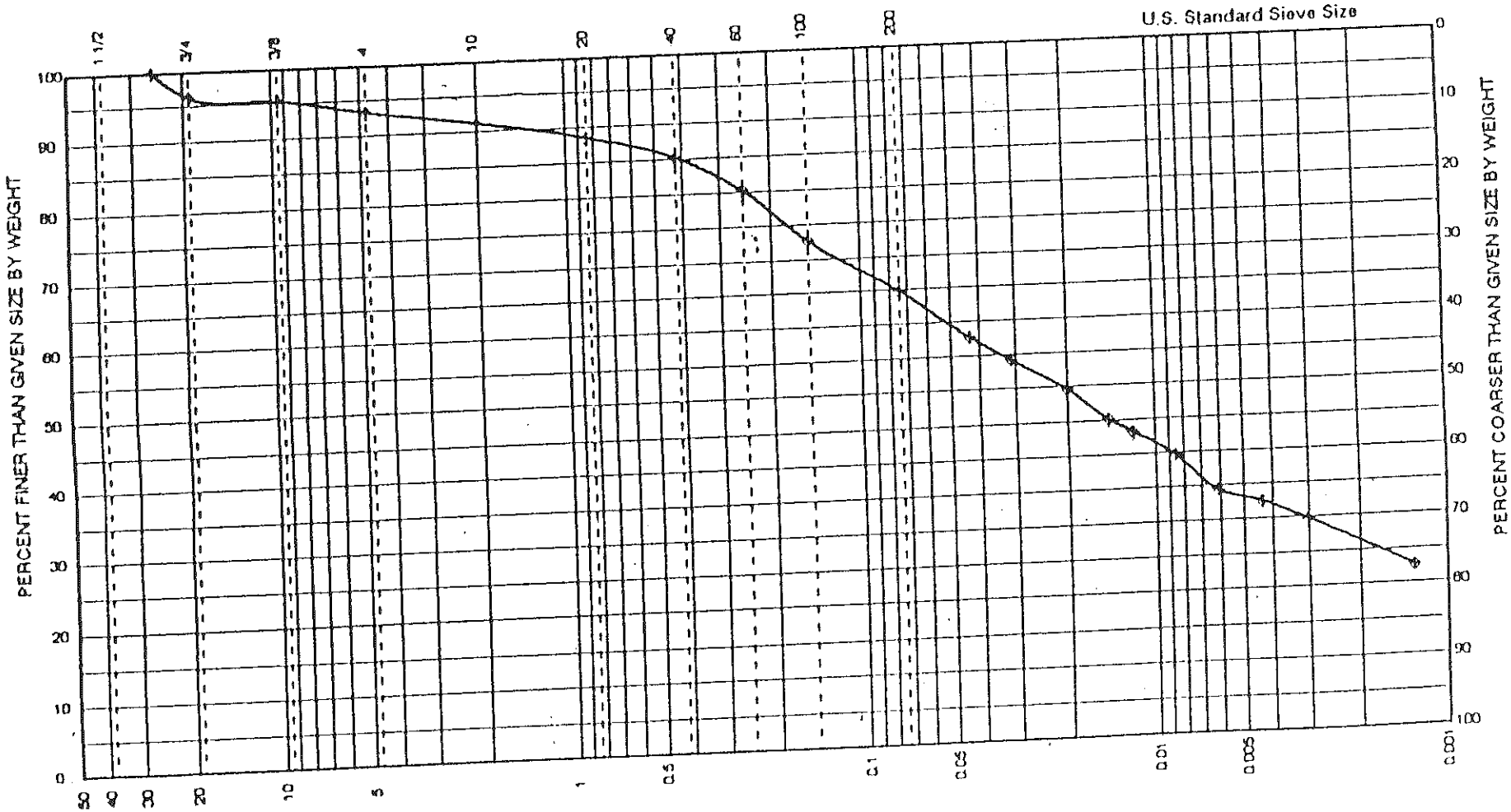


FIGURE 2

NTH Consultants, Ltd.

GRAIN SIZE DISTRIBUTION CURVE

Project No. 89365-OW Lab Sample No. 40 Source I-696 Excavation

Project Location Allen Park, Michigan For As-built Characteristics

Boring No. TP-1 Field Sample No. ST-4 Sample Depth 27" Sample Elev. (Tip) --

Sample Description Gray silty clay with some sand and trace of gravel

Sampled By DHH Date 11-1-89 Tested By D.V. Date 1-9-90

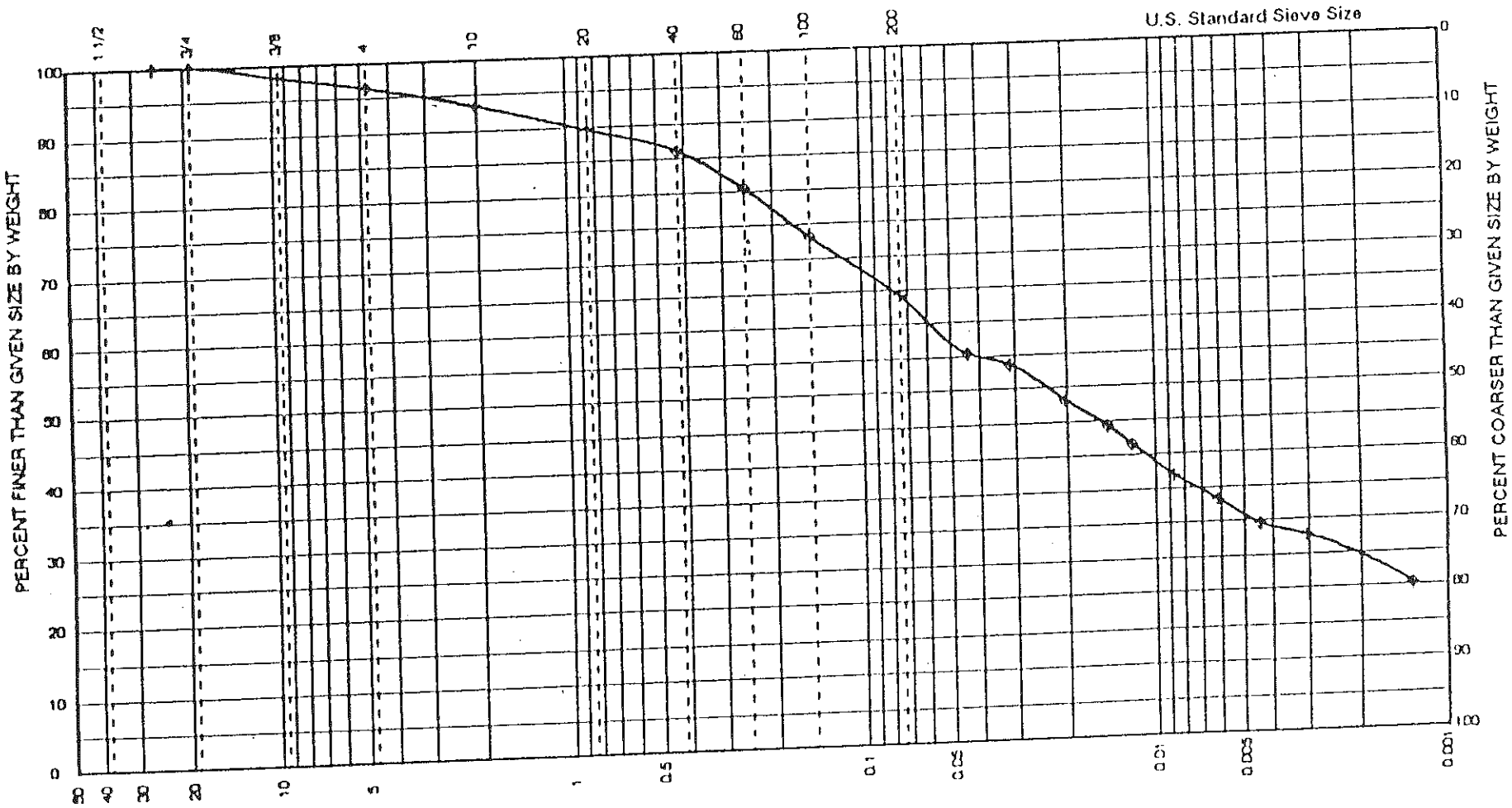


FIGURE 3

NTH Consultants, Ltd.

GRAIN SIZE DISTRIBUTION CURVE

Project No. 89365-OW Lab Sample No. 30 Source I-696 Excavation

Project Location Allen Park, Michigan For As-built Characteristics

Boring No. TP-1 Field Sample No. ST-5 Sample Depth 27" Sample Elev. (Tip) --

Sample Description Gray silty clay with some sand and trace of gravel

Sampled By DHH Date 11-1-89 Tested By D.V. Date 1-9-90

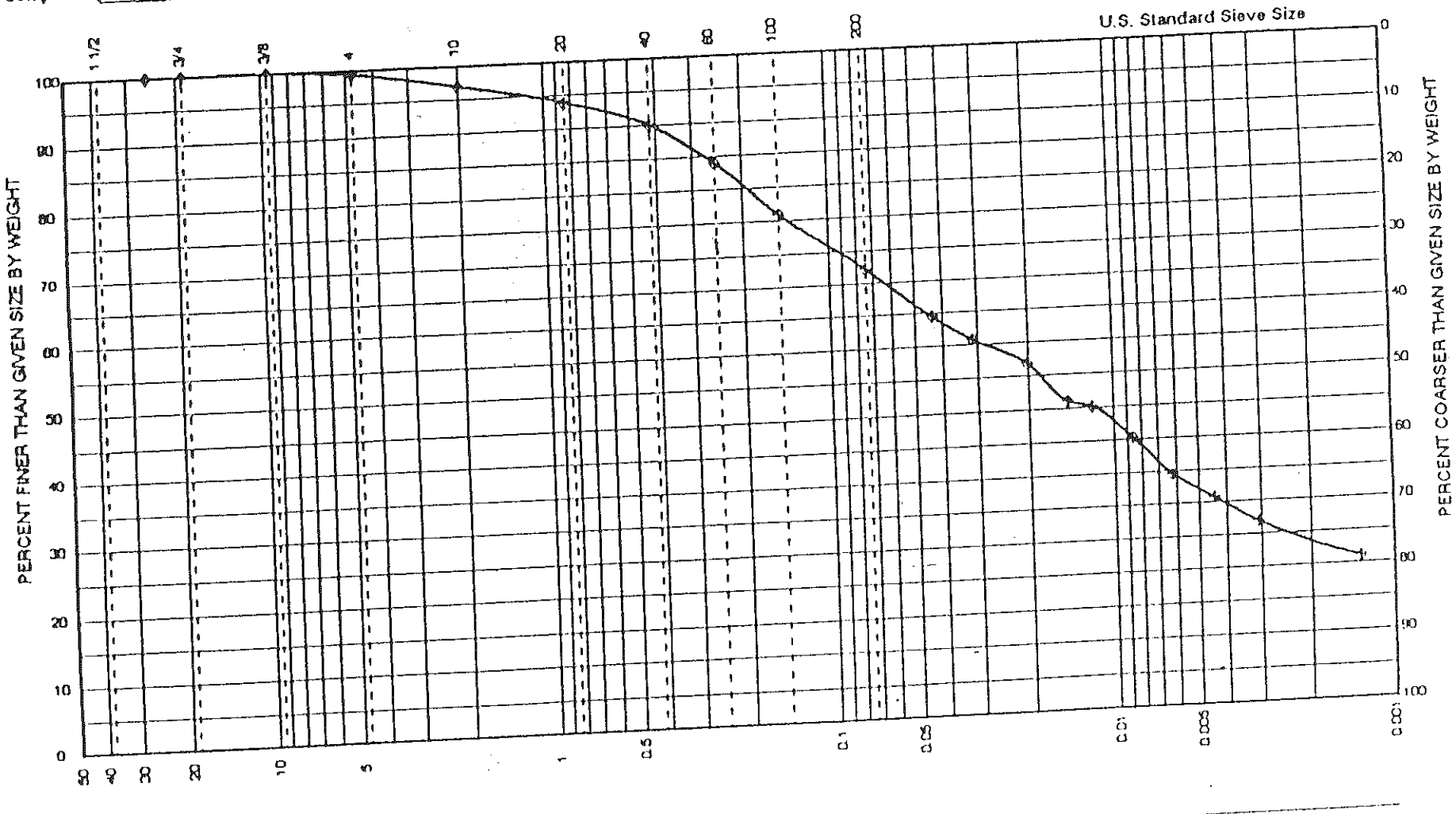


FIGURE 4

NTH Consultants, Ltd.

GRAIN SIZE DISTRIBUTION CURVE

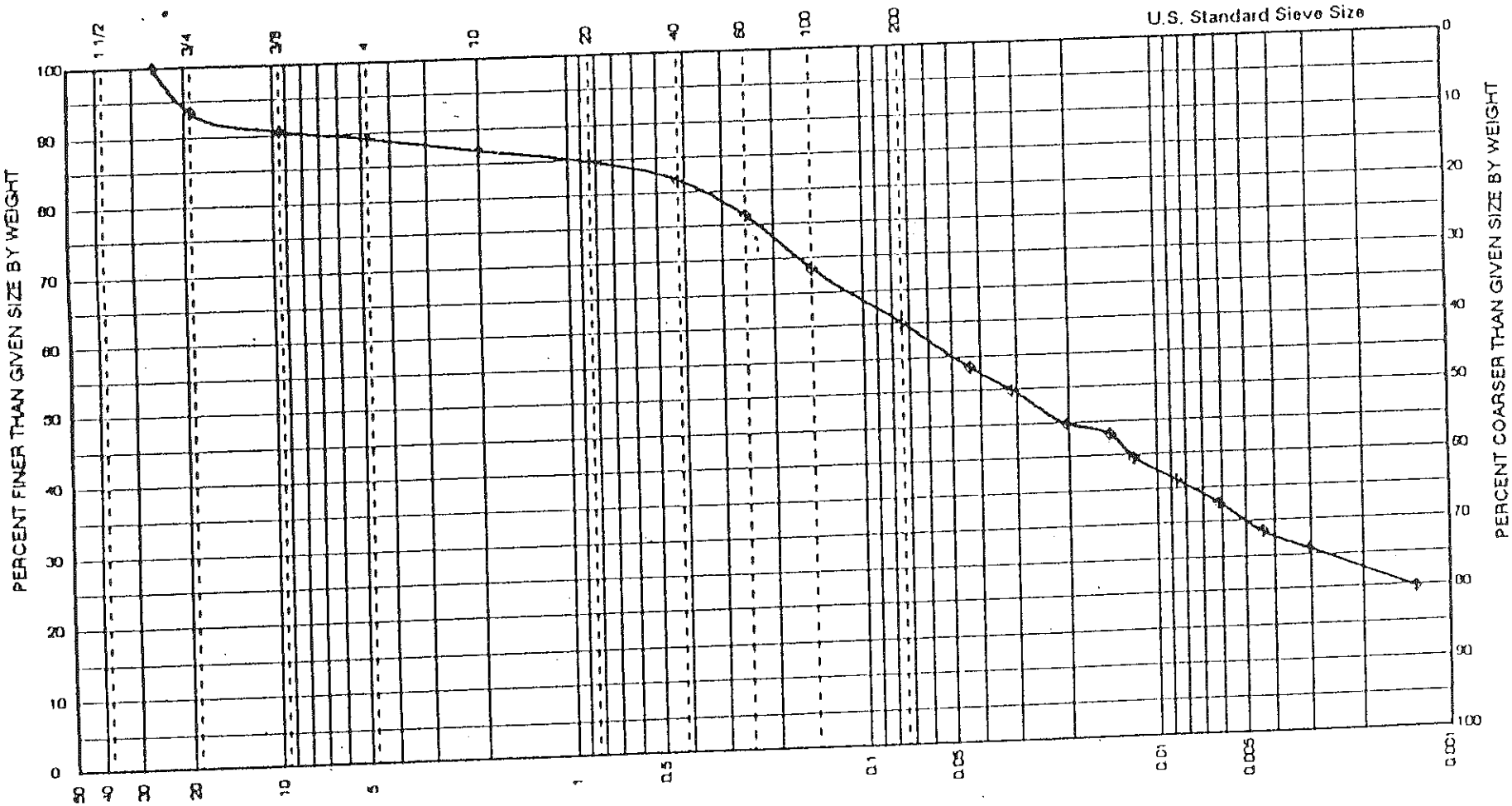
Project No. 89305-OW Lab Sample No. 37 Source I-696 Excavation

Project Location Allen Park, Michigan For As-built characteristics

Boring No. TP-1 Field Sample No. ST-6 Sample Depth 27" Sample Elev. (Tip) --

Sample Description Gray silty clay with some sand and trace of gravel

Sampled By DIIII Date 11-1-89 Tested By D.V. Date 1-9-90



Grain Size in MM.

Gravel		Sand			Fines		
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	Colloids

FIGURE 5

NTH Consultants, Ltd.

GRAIN SIZE DISTRIBUTION CURVE

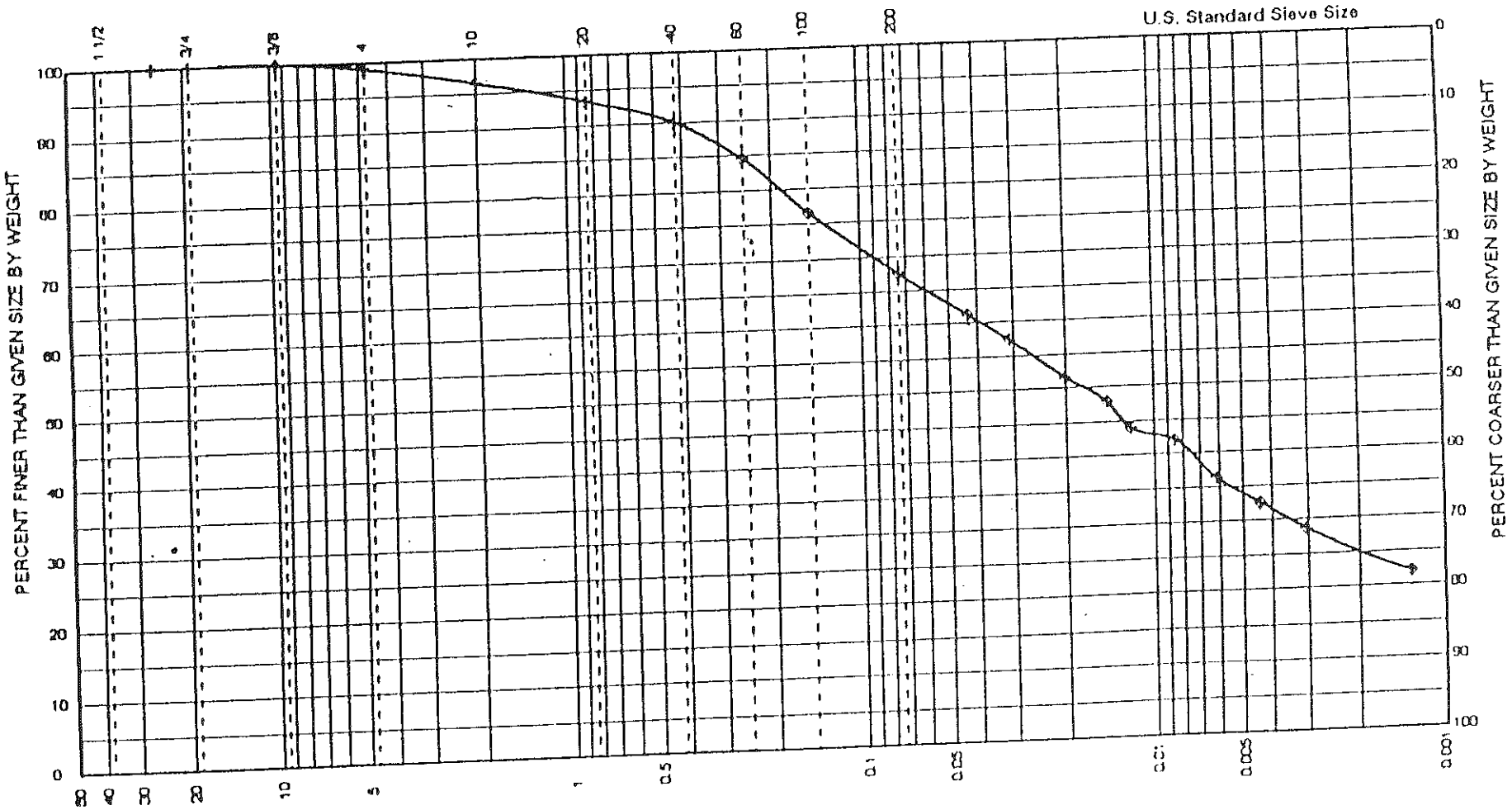
Project No. 09365-OW Lab Sample No. 34 Source I-696 Excavation

Project Location Allen Park, Michigan For As-built Characteristics

Boring No. TP-1 Field Sample No. ST-7 Sample Depth 27" Sample Elev. (Tip) -

Sample Description Gray silty clay with some sand and trace of gravel

Sampled By DHH Date 11-1-89 Tested By D.V. Date 1-9-90



Gravel		Sand			Fines		
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	Colloids

FIGURE 6

NTH Consultants, Ltd.

GRAIN SIZE DISTRIBUTION CURVE

Project No. 89365-OW Lab Sample No. 35 Source I-696 Excavation

Project Location Allen Park, Michigan For As-built Characteristics

Boring No. TP-1 Field Sample No. ST-8 Sample Depth 27" Sample Elev. (Tip) --

Sample Description Gray silty clay with some sand and trace of gravel

Sampled By DIIII Date 11-1-89 Tested By D.V. Date 1-9-90

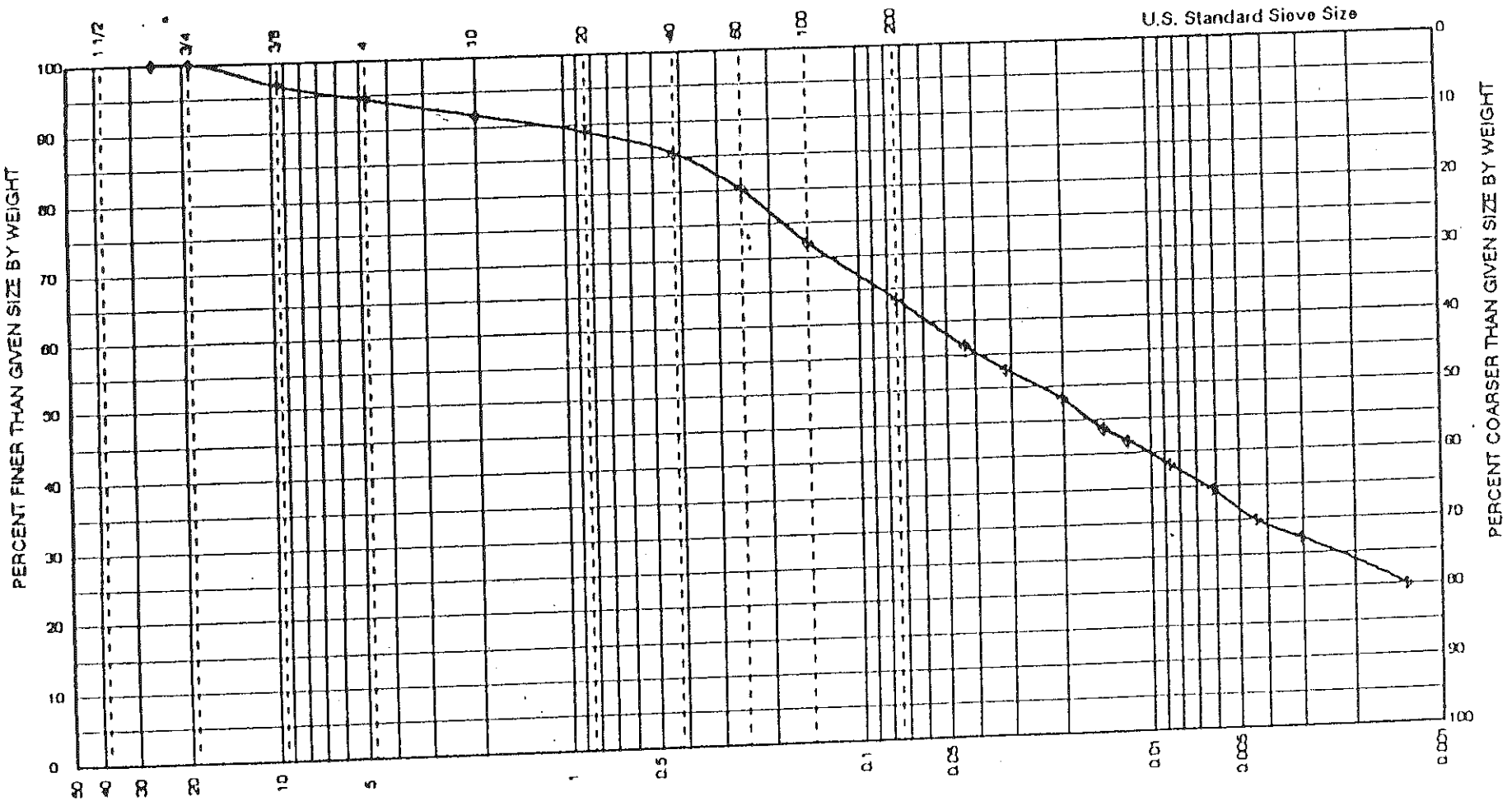


FIGURE 7

NTH Consultants, Ltd.

GRAIN SIZE DISTRIBUTION CURVE

Project No. 89365-OW Lab Sample No. 38 Source I-696 Excavation

Project Location Allen Park, Michigan For As-built Characteristics

Boring No. TP-1 Field Sample No. ST-9 Sample Depth 27" Sample Elev. (Tip) --

Sample Description Gray silty clay with some sand and trace of gravel

Sampled By DHH Date 11-1-89 Tested By D.V. Date 1-9-90

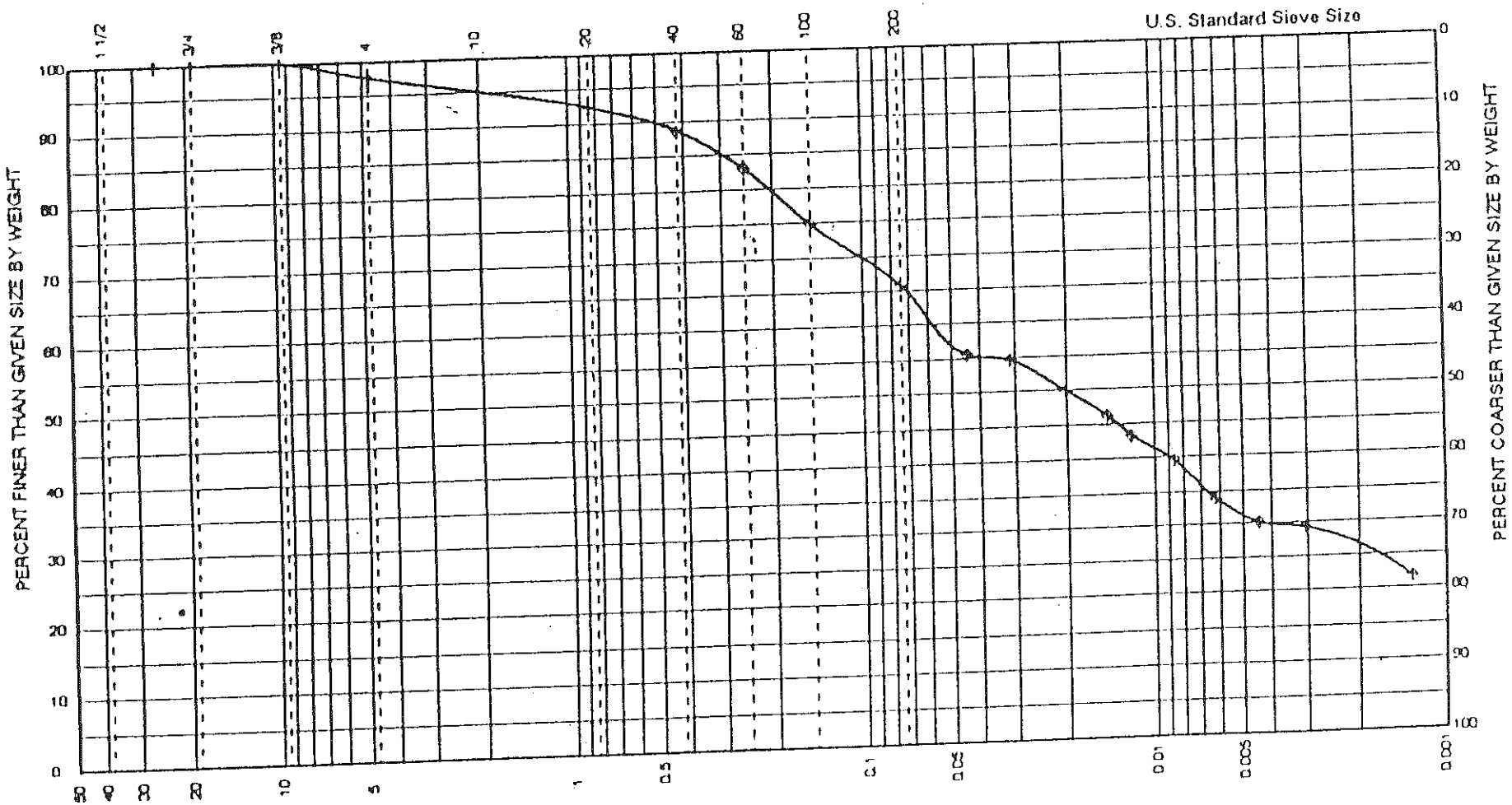


FIGURE 8

NTH Consultants, Ltd.

GRAIN SIZE DISTRIBUTION CURVE

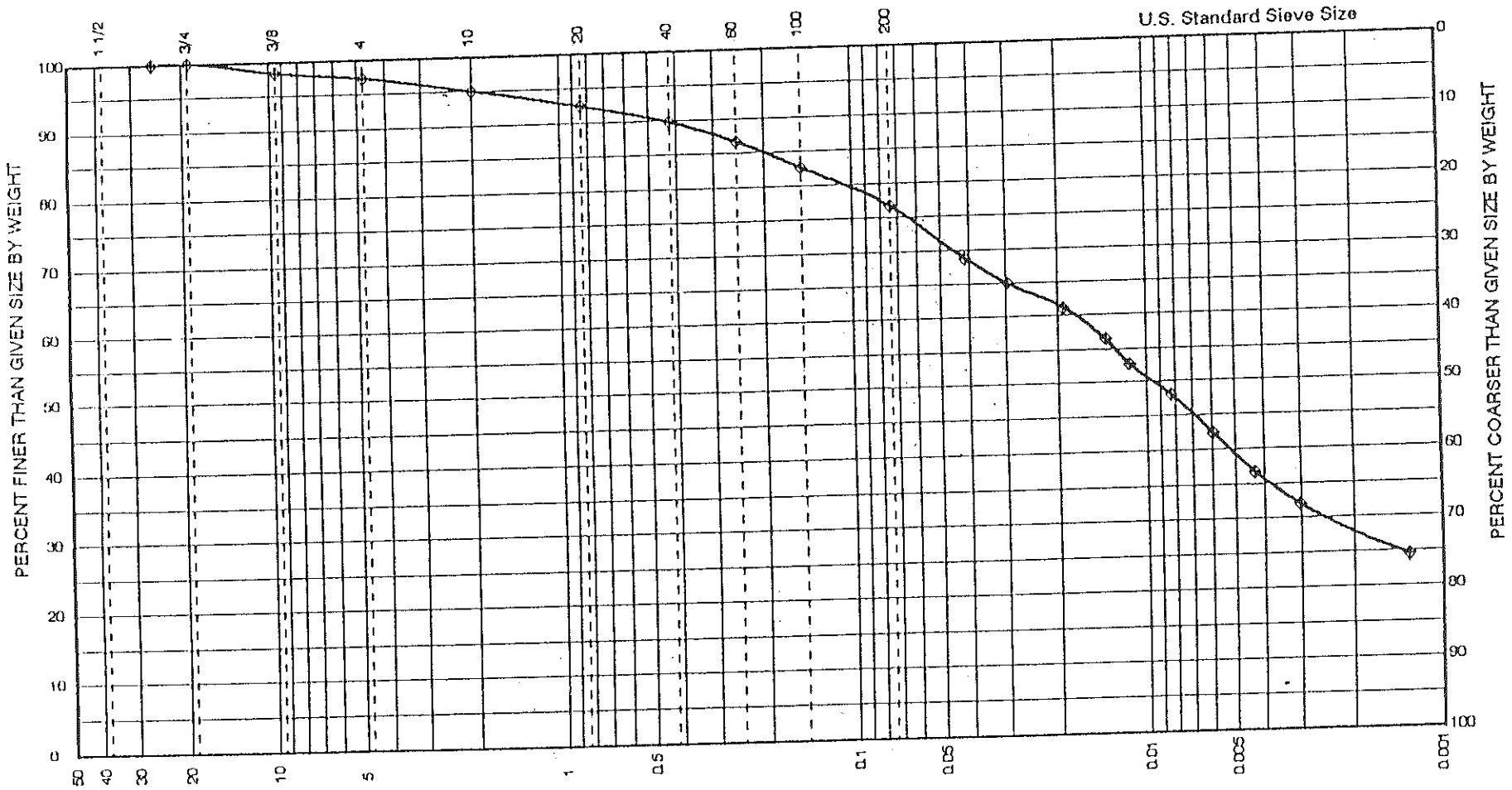
Project No. 89365-OW Lab Sample No. 7 Source London Borrow Source

Project Location Allen Park, Michigan For Allen Park Clay Mine

Boring No. TP-2 Field Sample No. ST-1 SPR Sample Depth Sample Elev. (Tip)

Sample Description Gray SILTY CLAY with Little Sand and Trace of Gravel

Sampled By J.R. Date 8/28/90 Tested By R.O. Date 8-31-90



Gravel		Sand			Fines		
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	Colloids

FIGURE 9

NTH Consultants, Ltd.

GRAIN SIZE DISTRIBUTION CURVE

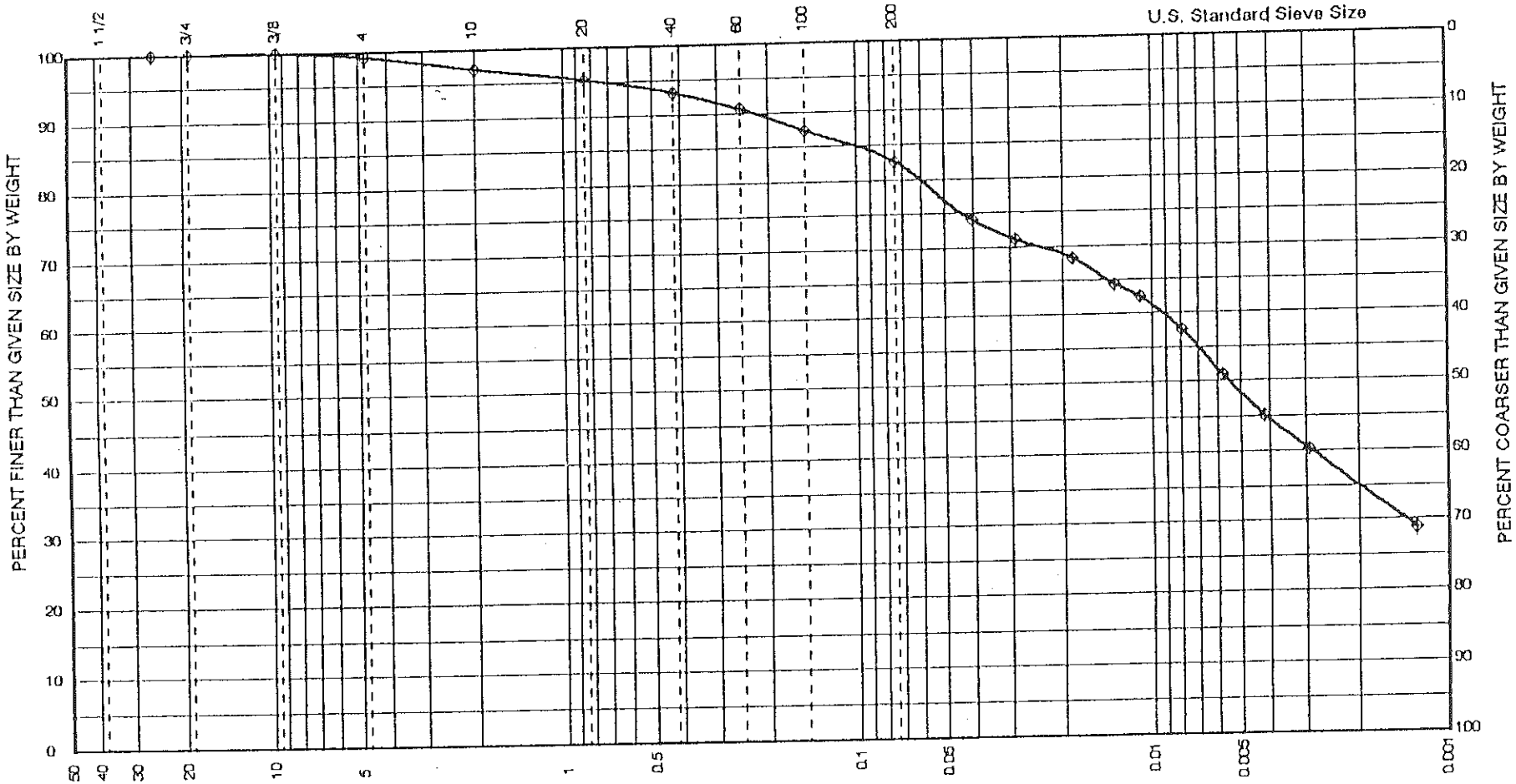
Project No. 89365-OW Lab Sample No. 6 Source London Borrow Source

Project Location Allen Park, Michigan For Allen Park Clay Mine

Boring No. TP-2 Field Sample No. ST-1 Sample Depth 26.3" Sample Elev. (Tip)

Sample Descriptio Gray SILTY CLAY with Little Sand and Trace of Gravel

Sampled By J.R. Date 8/27/90 Tested By R.O. Date 8-31-90



Grain Size in MM.

Gravel		Sand			Fines		
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	Colloids

FIGURE 10

NTH Consultants, Ltd.

GRAIN SIZE DISTRIBUTION CURVE

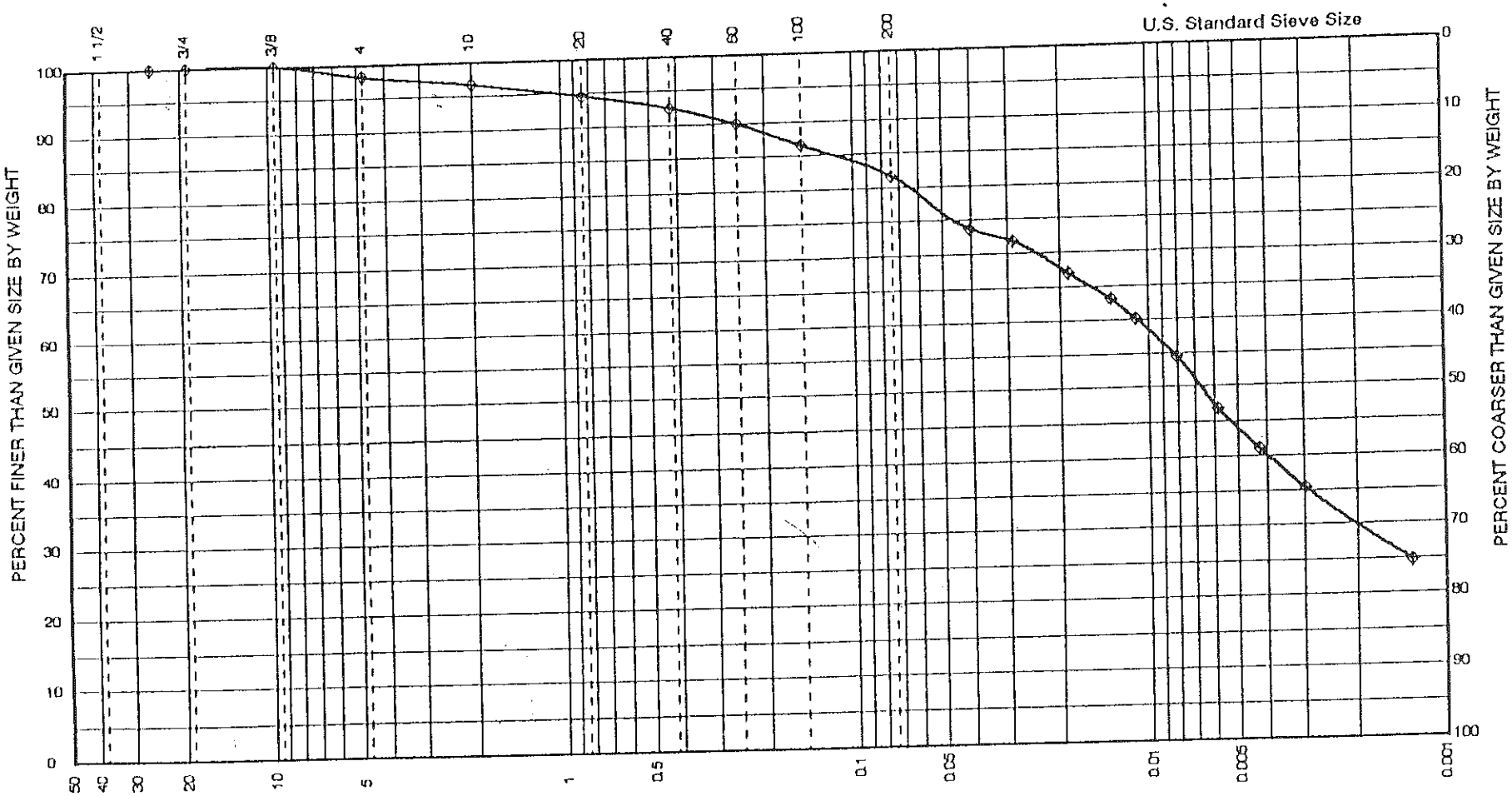
Project No. 89365-OW Lab Sample No. 8 Source London Borrow Source

Project Location Allen Park, Michigan For Allen Park Clay Mine

Boring No. TP-2 Field Sample No. ST-2 Sample Depth 22.6" Sample Elev. (Tip)

Sample Description Gray SILTY CLAY with Little Sand and Trace of Gravel

Sampled By J.R. Date 8/27/90 Tested By R.O. Date 8-31-90



Gravel		Sand			Fines		
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	Colloids

FIGURE 11

NTH Consultants, Ltd.

GRAIN SIZE DISTRIBUTION CURVE

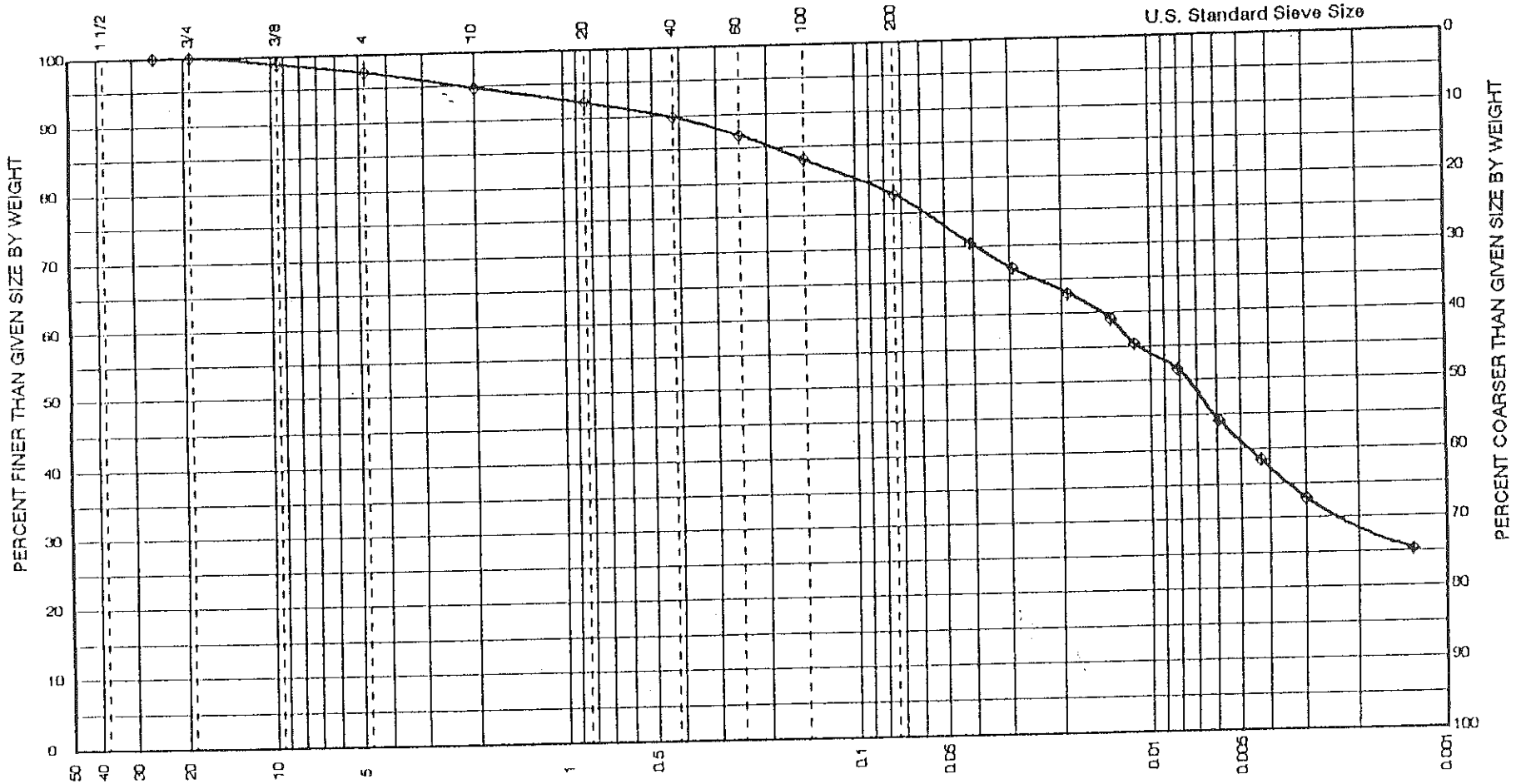
Project No. 89365-OW Lab Sample No. 9 Source London Borrow Source

Project Location Allen Park, Michigan For Allen Park Clay Mine

Boring No. TP-2 Field Sample No. ST-3 Sample Depth 22.5" Sample Elev. (Tip)

Sample Description Gray SILTY CLAY with Little Sand and Trace of Gravel

Sampled By J.R. Date 8/27/90 Tested By R.O. Date 8-31-90



Grain Size in MM.

Gravel		Sand			Fines		
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	Colloids

FIGURE 12

NTH Consultants, Ltd.

GRAIN SIZE DISTRIBUTION CURVE

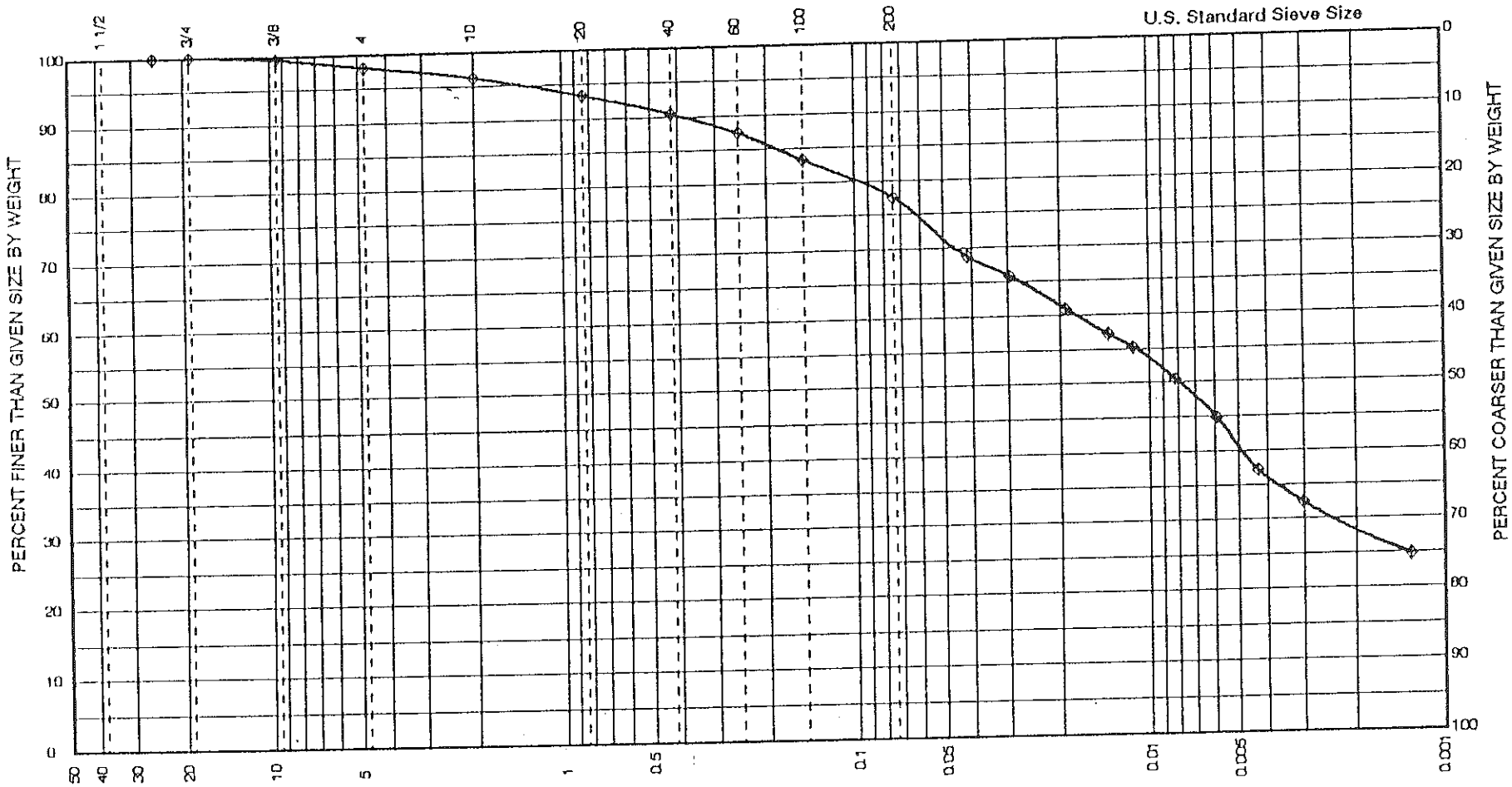
Project No. 89365-OW Lab Sample No. 10 Source London Borrow Source

Project Location Allen Park, Michigan For Allen Park Clay Mine

Boring No. TP-2 Field Sample No. ST-4 Sample Depth 21.1" Sample Elev. (Tip)

Sample Description Gray SILTY CLAY with Little Sand and Trace of Gravel

Sampled By J.R. Date 8/27/90 Tested By R.O. Date 8-31-90



Gravel		Sand			Fines		
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	Colloids

FIGURE 13

NTH Consultants, Ltd.

GRAIN SIZE DISTRIBUTION CURVE

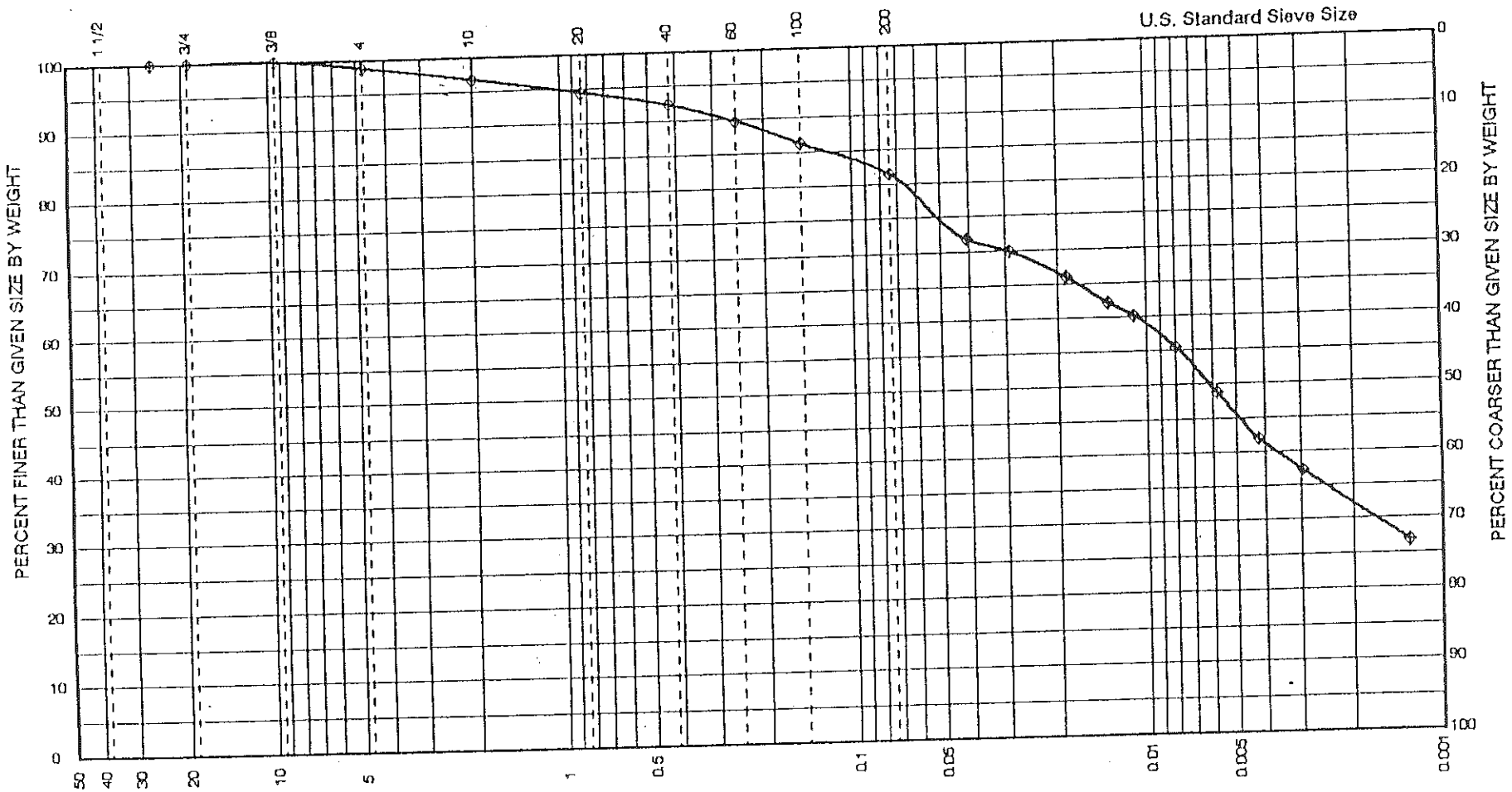
Project No. 89365-OW Lab Sample No. 11 Source London Borrow Source

Project Location Allen Park, Michigan For Allen Park Clay Mine

Boring No. TP-2 Field Sample No. ST-5 Sample Depth 21.3" Sample Elev. (Tip)

Sample Description Gray SILTY CLAY with Little Sand and Trace of Gravel

Sampled By J.R Date 8/27/90 Tested By R.O. Date 8-31-90



Gravel		Sand			Fines		
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	Colloids

FIGURE 14

NTH Consultants, Ltd.

GRAIN SIZE DISTRIBUTION CURVE

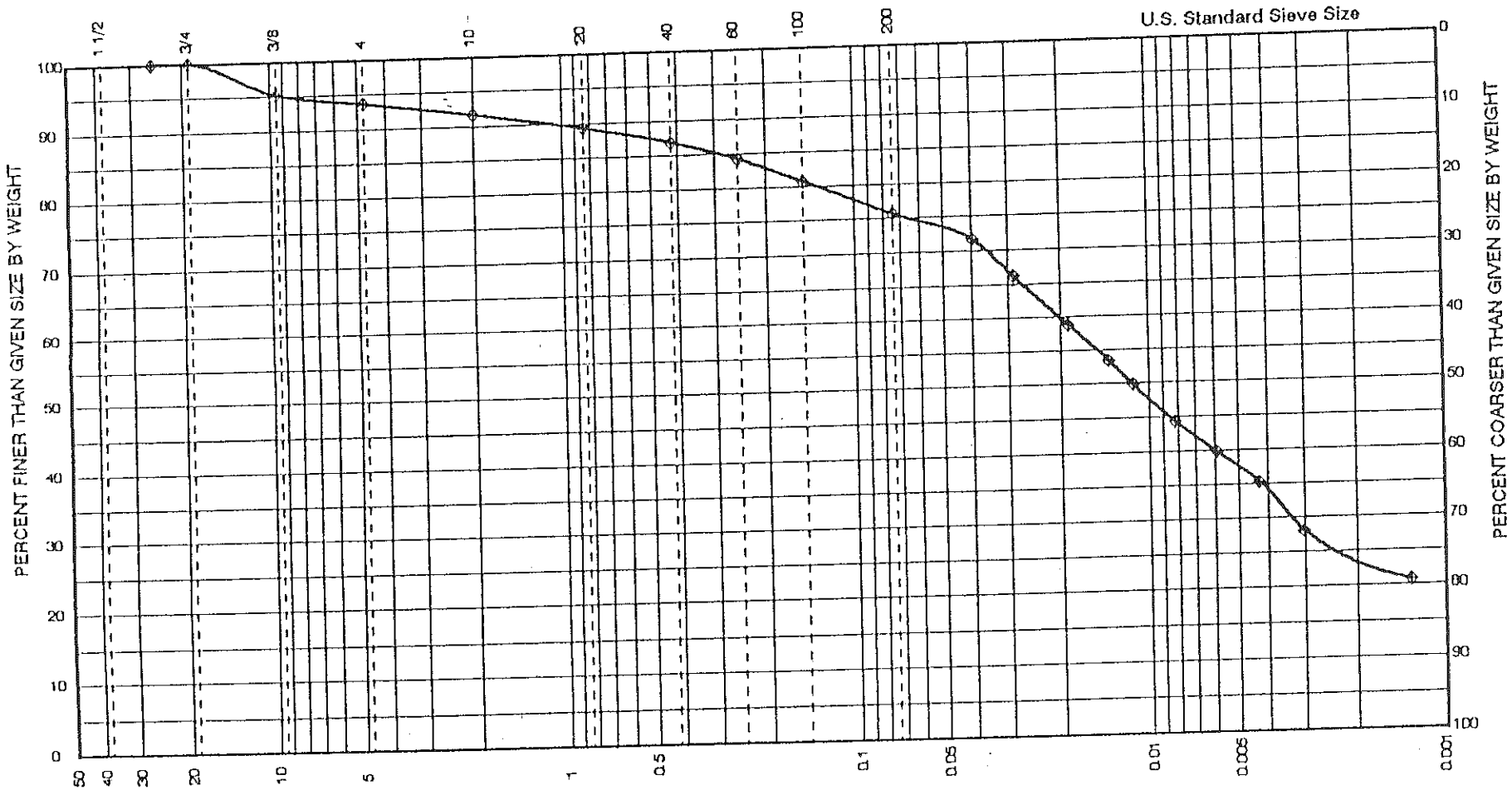
Project No. 89365-OW Lab Sample No. 12 Source London Borrow Source

Project Location Allen Park, Michigan For Allen Park Clay Mine

Boring No. TP-2 Field Sample No. ST-6 Sample Depth 21.2" Sample Elev. (Tip)

Sample Description Grey SILTY CLAY with Little Sand and Trace of Gravel

Sampled By J.R Date 8/27/90 Tested By R.O. Date 9-7-90



Gravel		Sand			Fines		
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	Colloids

FIGURE 15

NTH Consultants, Ltd.

GRAIN SIZE DISTRIBUTION CURVE

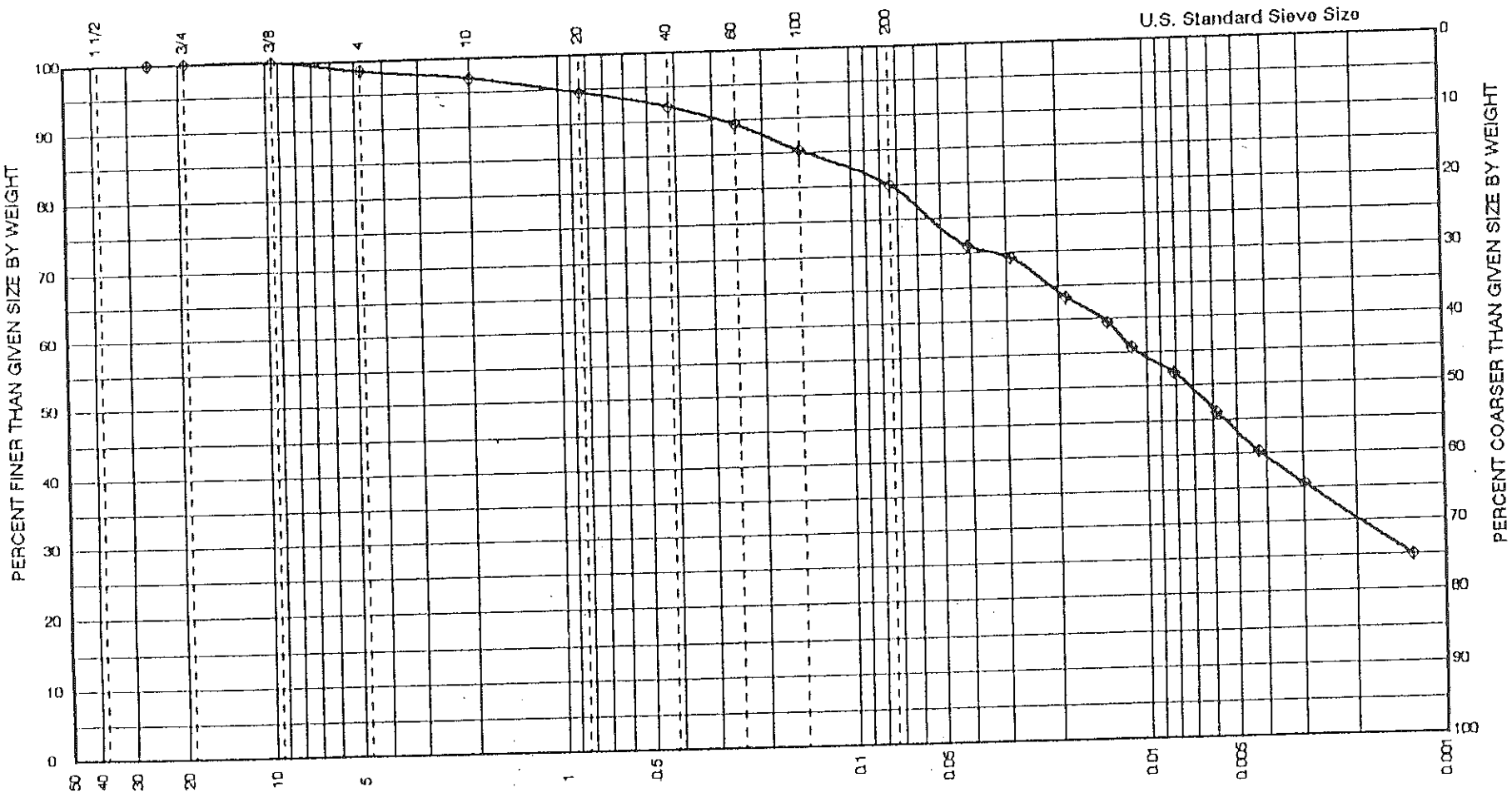
Project No. 89365-OW Lab Sample No. 15 Source London Borrow Source

Project Location Allen Park, Michigan For Allen Park Clay Mine

Boring No. TP-2 Field Sample No. ST-7 Sample Depth 20.8" Sample Elev. (Tip)

Sample Description Gray SILTY CLAY with Little Sand and Trace of Gravel

Sampled By J.R. Date 8/28/90 Tested By R.O. Date 9-10-90



Gravel		Sand			Fines		
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	Colloids

FIGURE 16

NTH Consultants, Ltd.

GRAIN SIZE DISTRIBUTION CURVE

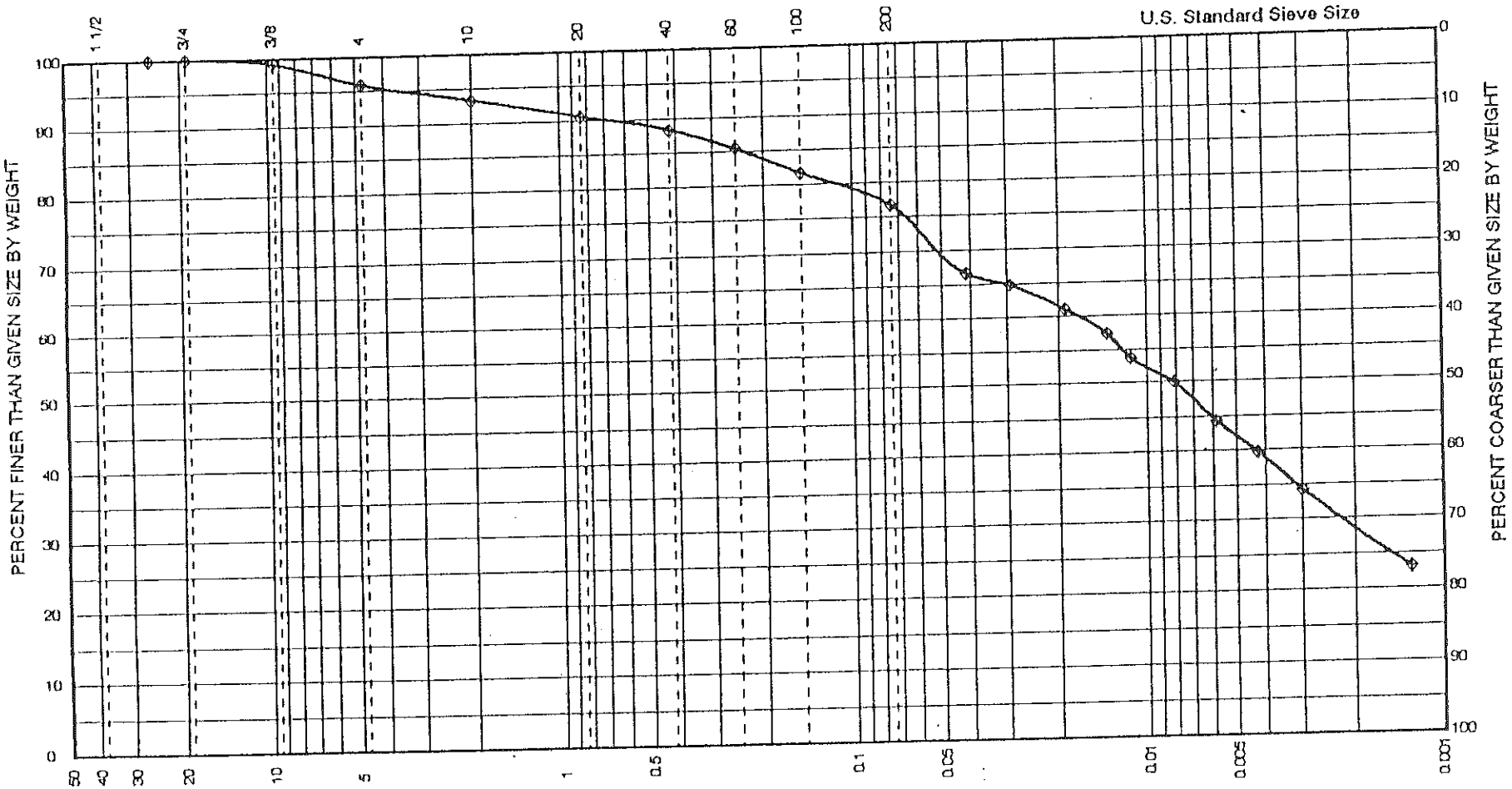
Project No. 89365-OW Lab Sample No. 16 Source London Borrow Source

Project Location Allen Park, Michigan For Allen Park Clay Mine

Boring No. TP-2 Field Sample No. ST-8 Sample Depth 21.6" Sample Elev. (Tip)

Sample Description Gray SILTY CLAY with Little Sand and Trace of Gravel

Sampled By J.R. Date 8/28/90 Tested By R.O. Date 9-10-90



Gravel		Sand			Fines		
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	Colloids

FIGURE 17

NTH Consultants, Ltd.

GRAIN SIZE DISTRIBUTION CURVE

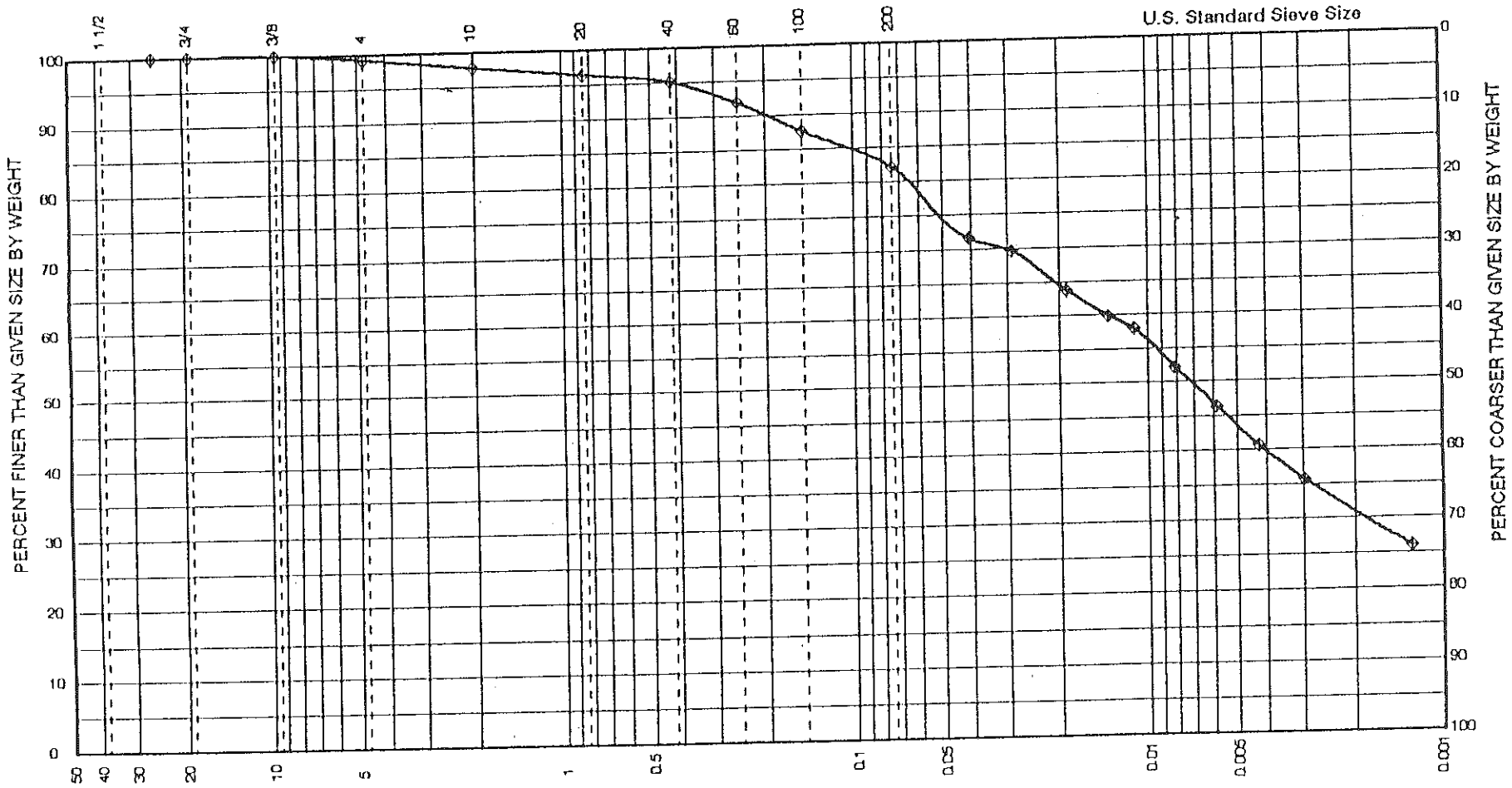
Project No. 89365-OW Lab Sample No. 17 Source London Borrow Source

Project Location Allen Park, Michigan For Allen Park Clay Mine

Boring No. TP-2 Field Sample No. ST-9 Sample Depth 21.9" Sample Elev. (Tip)

Sample Description Gray SILTY CLAY with Little Sand and Trace of Gravel

Sampled By J.R. Date 8/28/90 Tested By R.O. Date 9-10-90



Gravel		Sand			Fines		
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	Colloids

FIGURE 18

NTH Consultants, Ltd.

GRAIN SIZE DISTRIBUTION CURVE

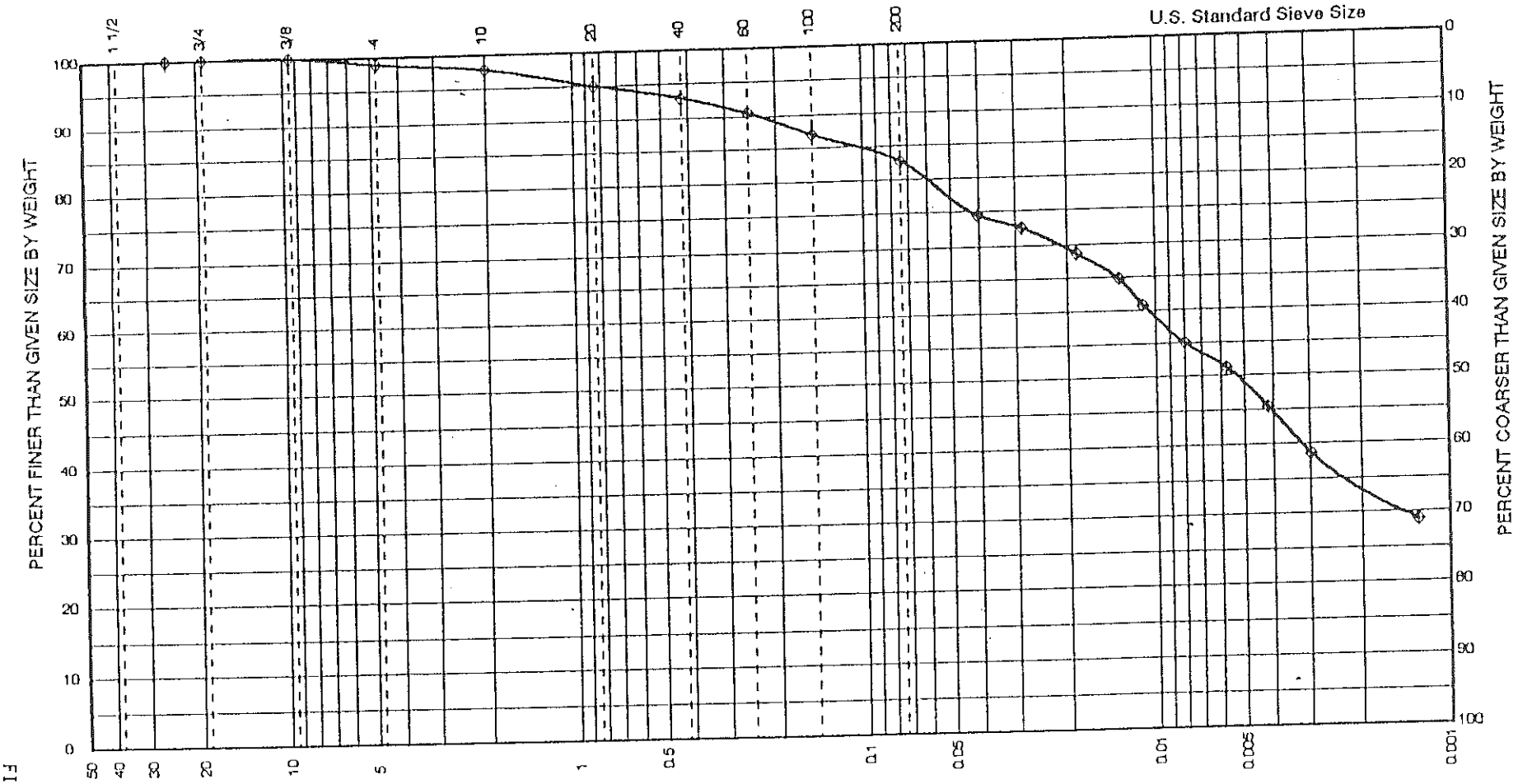
Project No. 89365-OW Lab Sample No. 26 Source London Borrow Source

Project Location Allen Park, Michigan For Allen Park Clay Mine

Boring No. TP-2 Field Sample No. ST 6.2 Sample Depth 18.4" Sample Elev. (Tip)

Sample Descriptio Gray SILTY CLAY with Little Sand and Trace of Gravel

Sampled By J.R. Date 9/17/90 Tested By R.O. Date 9-28-90



Gravel		Sand			Fines		
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	Colloids

FIGURE 19

NTH Consultants, Ltd.

GRAIN SIZE DISTRIBUTION CURVE

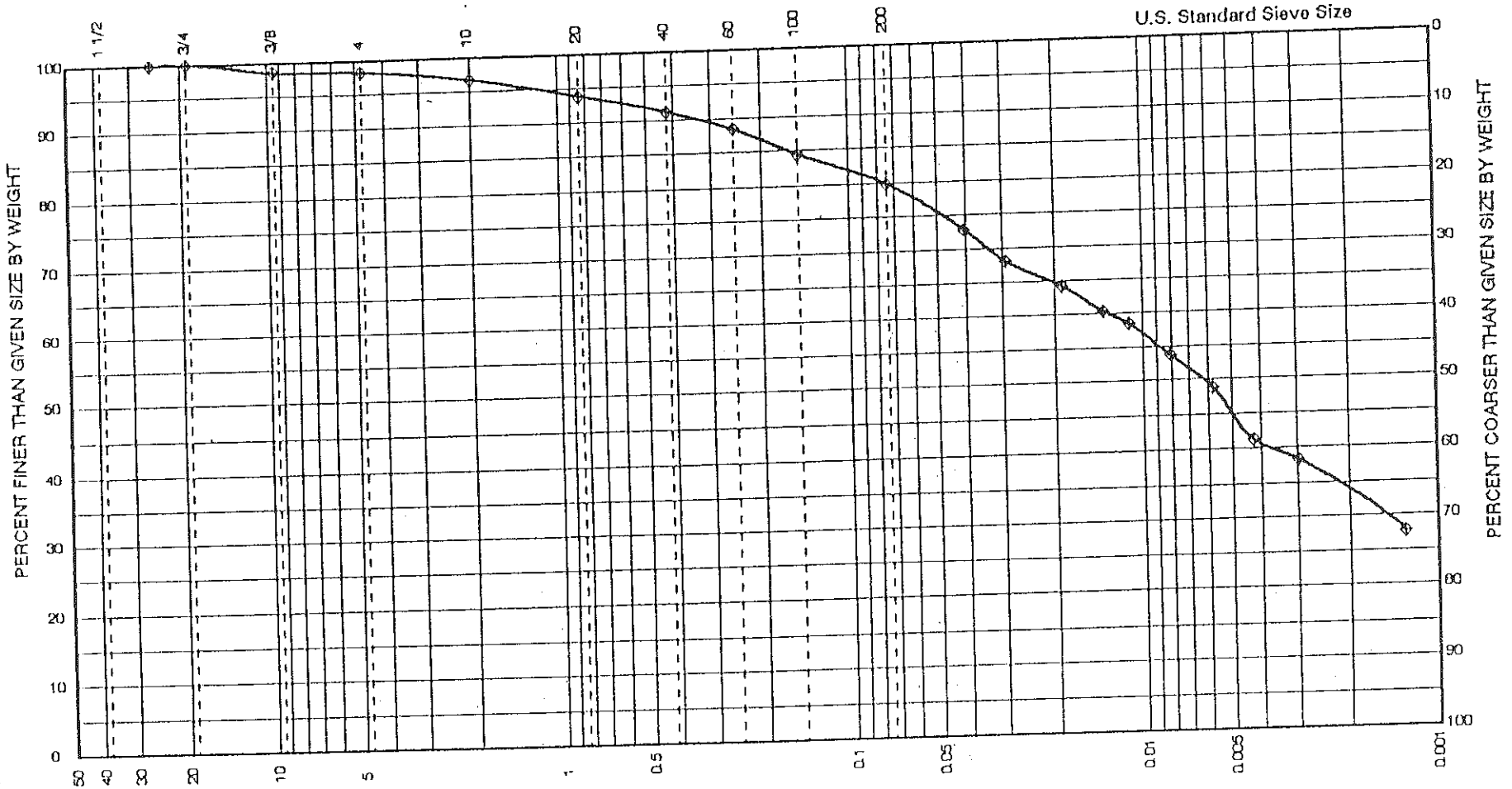
Project No. 89365-OW Lab Sample No. 25 Source London Borrow Source

Project Location Allen Park, Michigan For Allen Park Clay Mine

Boring No. TP-2 Field Sample No. ST-9.2 Sample Depth 20.8" Sample Elev. (Tip)

Sample Description Gray SILTY CLAY with Little Sand and Trace of Gravel

Sampled By J.R. Date 9/13/90 Tested By R.O. Date 9-28-90



Gravel		Sand			Fines			
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	Colloids	

FIGURE 20

NTH Consultants, Ltd.

GRAIN SIZE DISTRIBUTION CURVE

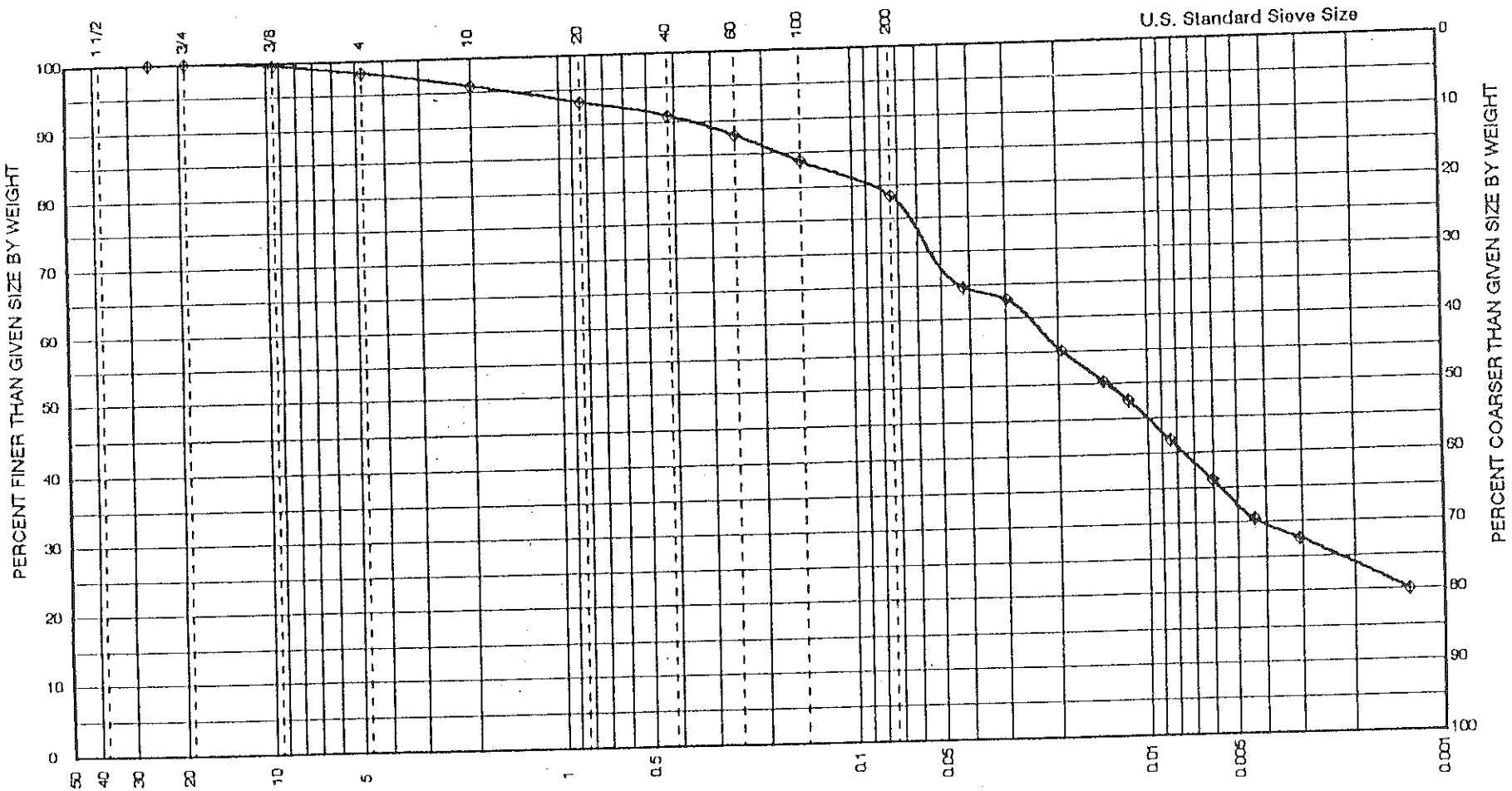
Project No. 89365-OW Lab Sample No. 13 Source Ann Arbor Sand and Gravel

Project Location Allen Park, Michigan For Allen Park Clay Mine

Boring No. TP-3 Field Sample No. ST-1 Sample Depth 22.5" Sample Elev. (Tip)

Sample Description Gray SILTY CLAY with Little Sand and Trace of Gravel

Sampled By J.R. Date 8/28/90 Tested By R.O. Date 9-10-90



Gravel		Sand			Fines		
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	Colloids

FIGURE 21

NTH Consultants, Ltd.

GRAIN SIZE DISTRIBUTION CURVE

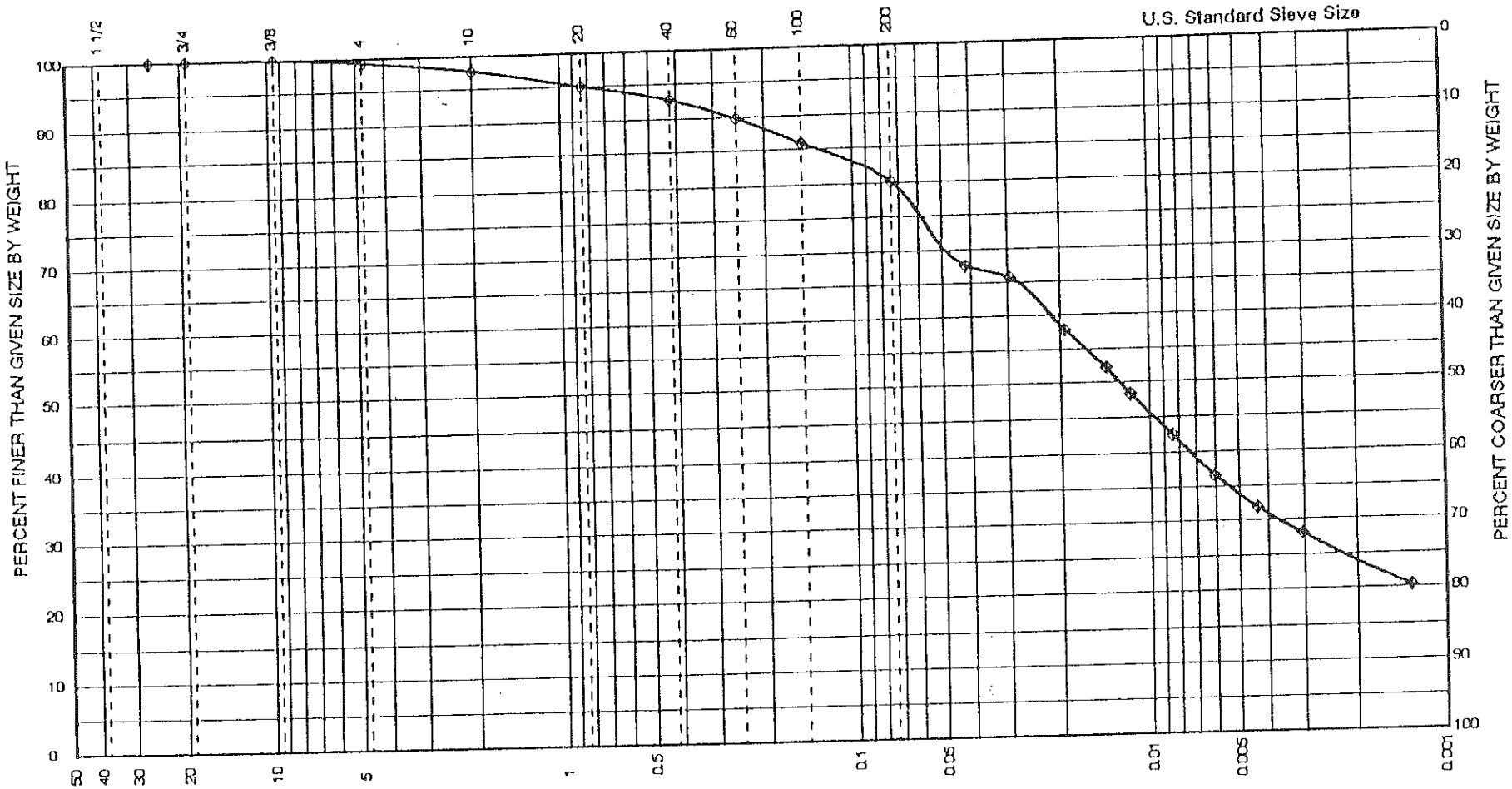
Project No. 89365-OW Lab Sample No. 14 Source Ann Arbor Sand and Gravel

Project Location Allen Park, Michigan For Allen Park Clay Mine

Boring No. TP-3 Field Sample No. ST-2 Sample Depth 23.7" Sample Elev. (Tip)

Sample Description Gray SILTY CLAY with Little Sand and Trace of Gravel

Sampled By J.R. Date 8/28/90 Tested By R.O. Date 9-10-90



Grain Size in MM.

Gravel		Sand			Fines		
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	Colloids

FIGURE 22

NTH Consultants, Ltd.

GRAIN SIZE DISTRIBUTION CURVE

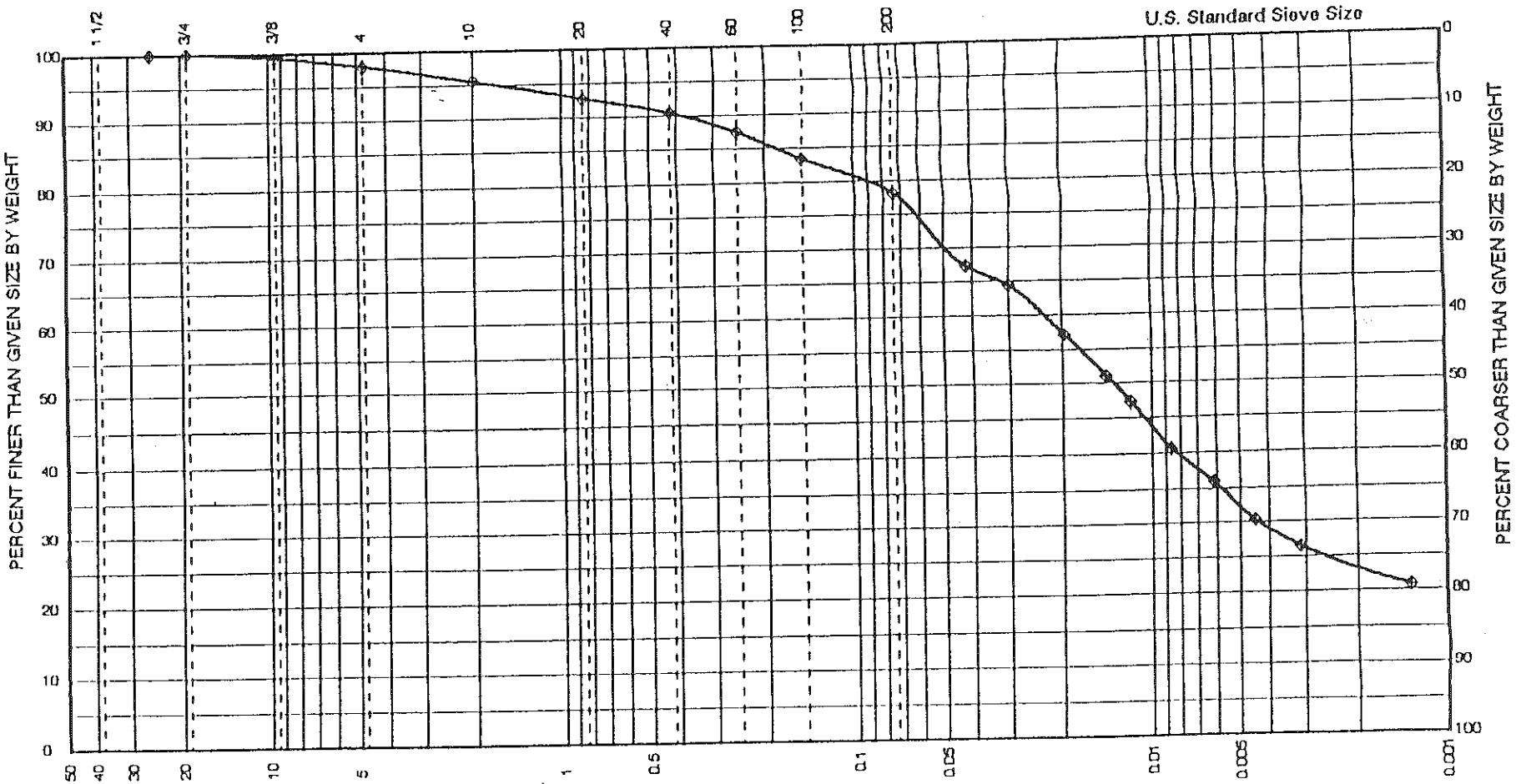
Project No. 89365-OW Lab Sample No. 18 Source Ann Arbor Sand and Gravel

Project Location Allen Park, Michigan For Allen Park Clay Mine

Boring No. TP 3 Field Sample No. ST-3 Sample Depth 24.4" Sample Elev. (Tip)

Sample Description Gray SILTY CLAY with Little Sand and Trace of Gravel

Sampled By J.R. Date 8/29/90 Tested By S.R. Date 9-17-90



Grain Size in MM.

Gravel		Sand			Fines		
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	Colloids

FIGURE 23

NTH Consultants, Ltd.

GRAIN SIZE DISTRIBUTION CURVE

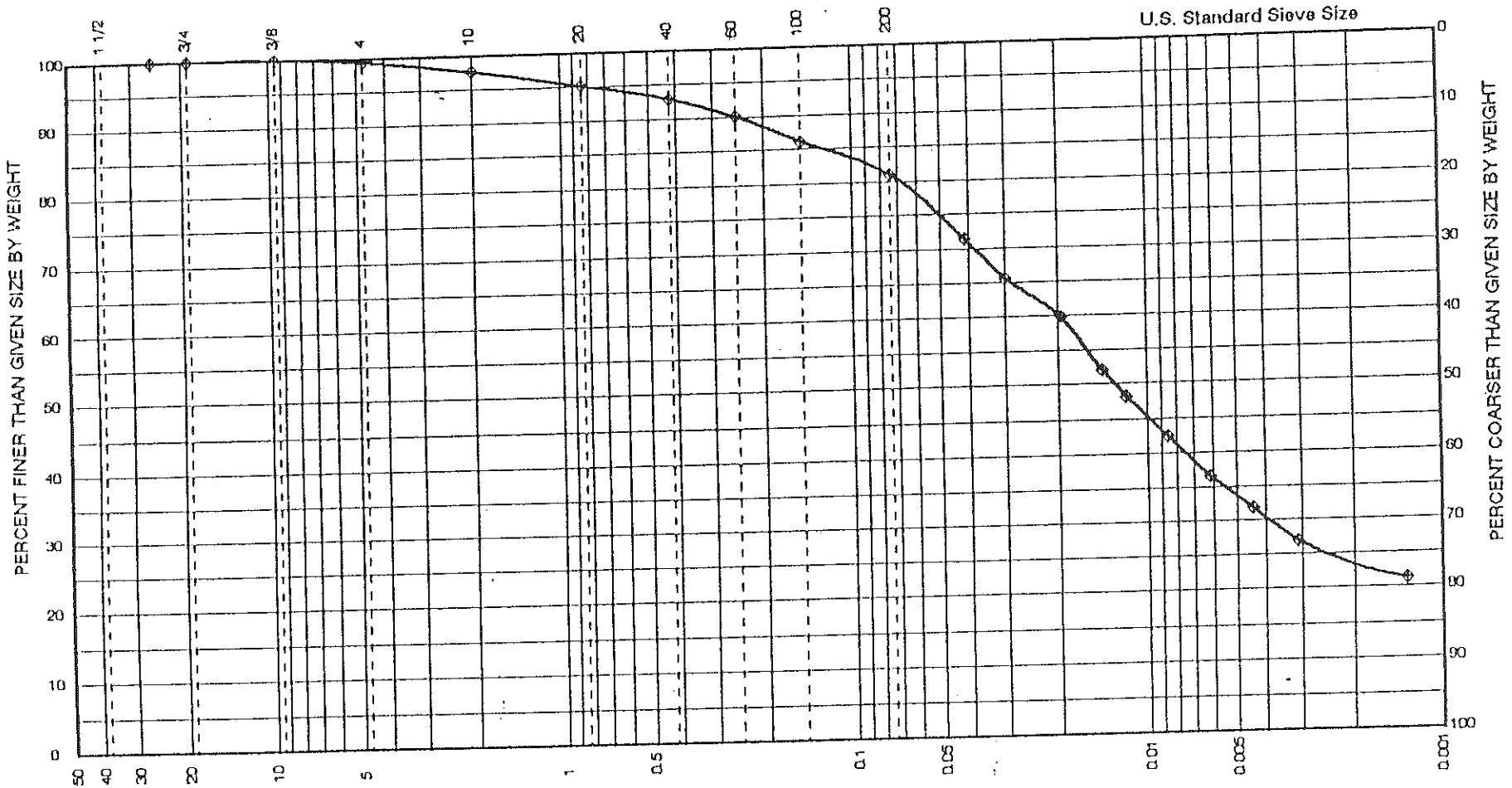
Project No. 89365-OW Lab Sample No. 19 Source Ann Arbor Sand and Gravel

Project Location Allen Park, Michigan For Allen Park Clay Mine

Boring No. TP 3 Field Sample No. ST-4 Sample Depth 21.3" Sample Elev. (Tip)

Sample Descriptio Gray SILTY CLAY with Little Sand and Traces of Gravel

Sampled By J.R. Date 8/29/90 Tested By S.R. Date 9-17-90



Gravel		Sand			Fines		
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	Colloids

FIGURE 24

NTH Consultants, Ltd.

GRAIN SIZE DISTRIBUTION CURVE

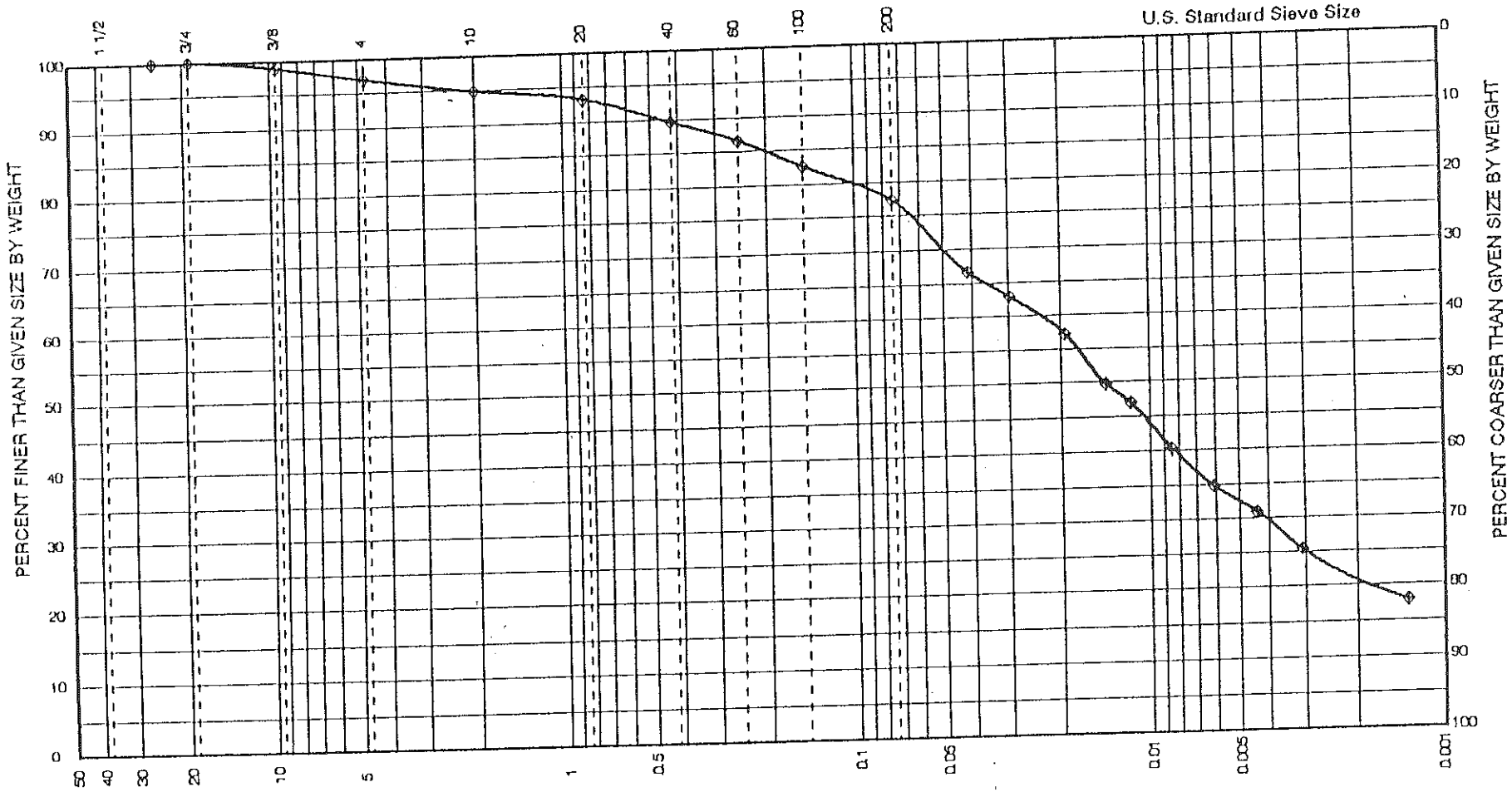
Project No. 89365-OW Lab Sample No. 20 Source Ann Arbor Sand and Gravel

Project Location Allen Park, Michigan For Allen Park Clay Mine

Boring No. TP-3 Field Sample No. ST-5 Sample Depth 23.3" Sample Elev. (Tip)

Sample Description Gray SILTY CLAY with Little Sand and Trace of Gravel

Sampled By J.R. Date 8/29/90 Tested By R.O. Date 9-20-90



Gravel		Sand			Fines		
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	Colloids

FIGURE 25

NTH Consultants, Ltd.

GRAIN SIZE DISTRIBUTION CURVE

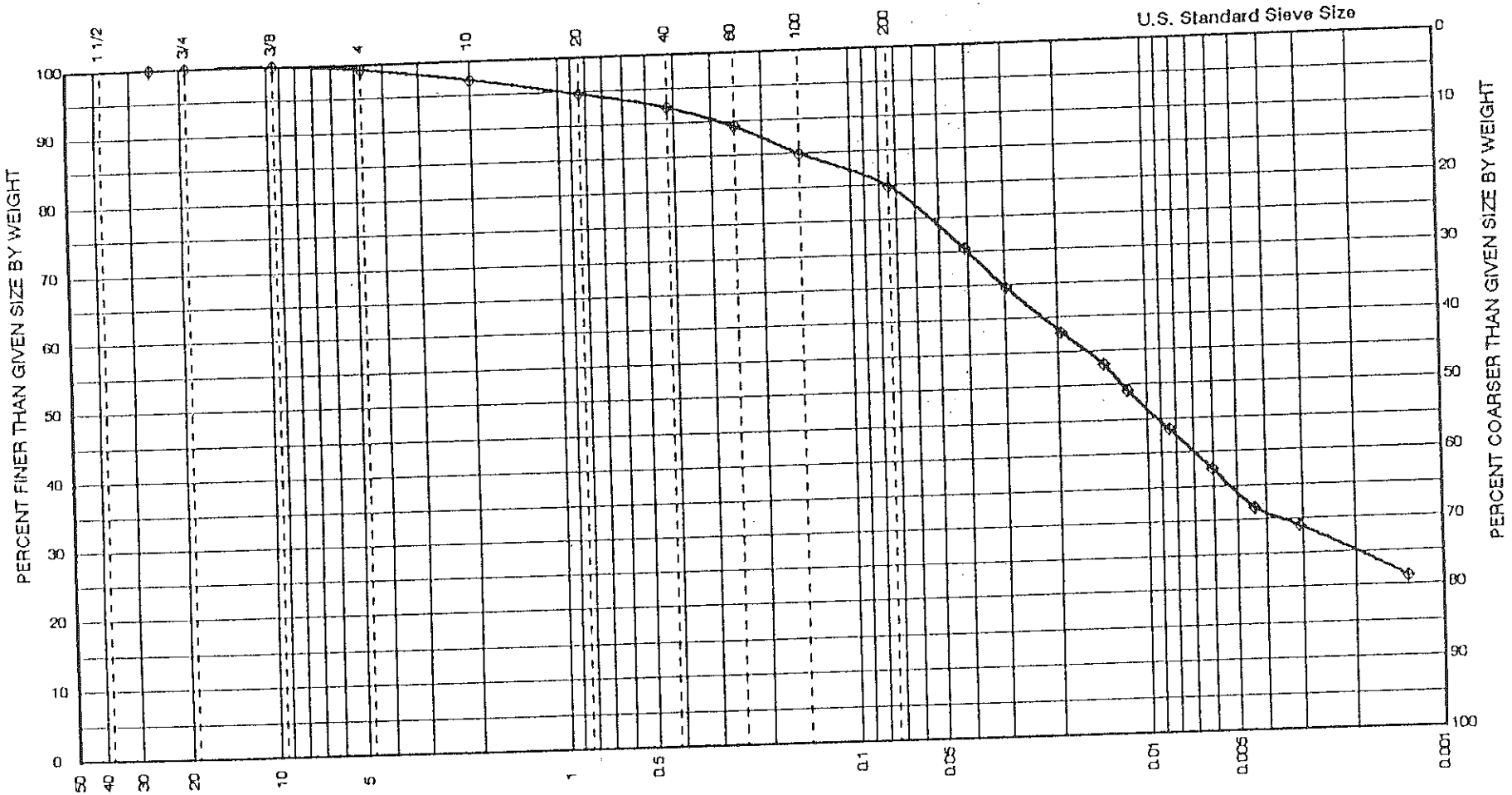
Project No. 89365-OW Lab Sample No. 21 Source Ann Arbor Sand and Gravel

Project Location Allen Park, Michigan For Allen Park Clay Mine

Boring No. TP-3 Field Sample No. ST-6 Sample Depth 24.4" Sample Elev. (Tip)

Sample Description Gray SILTY CLAY with Little Sand and Trace of Gravel

Sampled By J.R. Date 8/29/90 Tested By R.O. Date 9-20-90



Gravel		Sand			Fines		
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	Colloids

FIGURE 26

NTH Consultants, Ltd.

GRAIN SIZE DISTRIBUTION CURVE

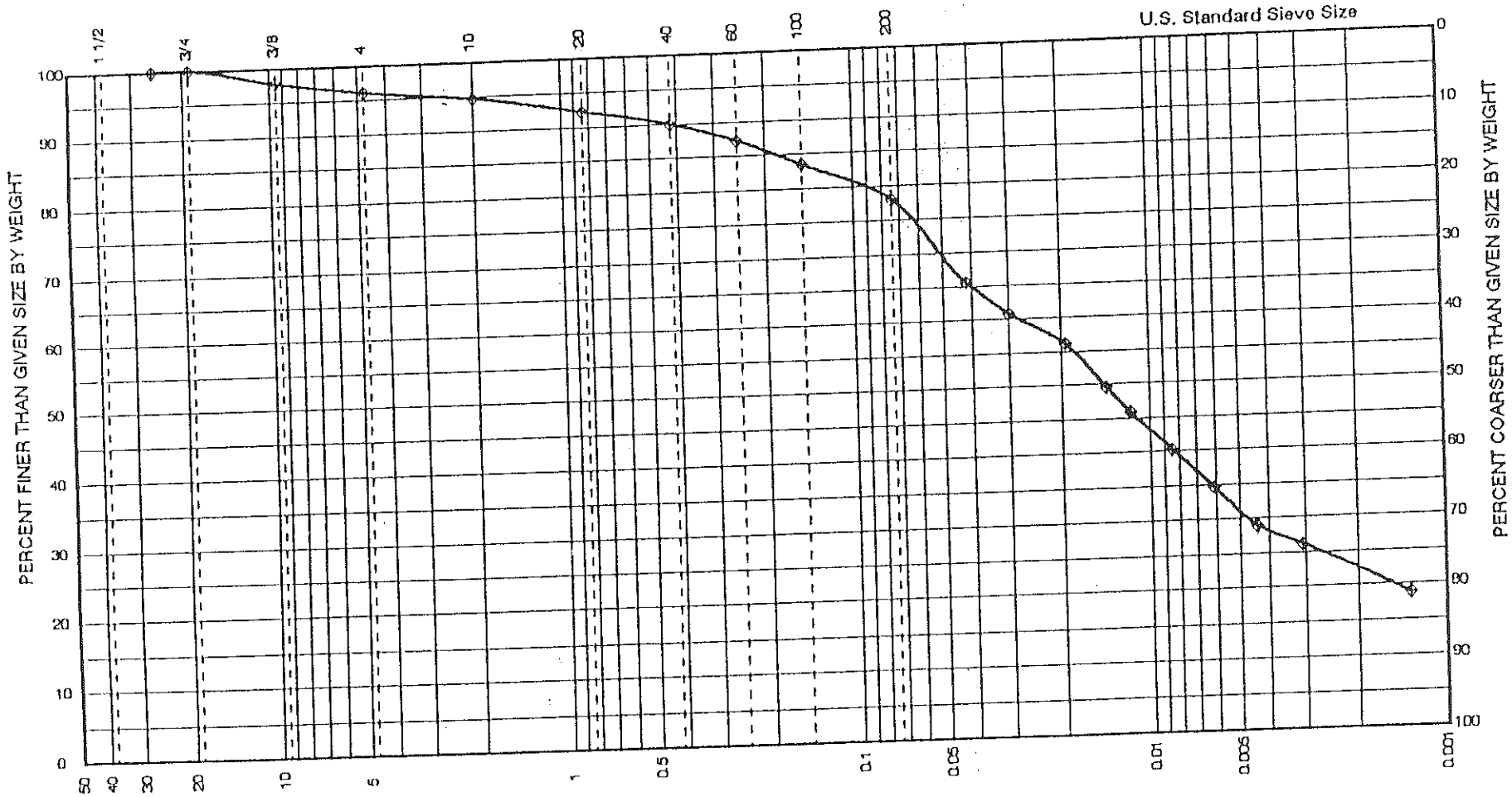
Project No. 89365-OW Lab Sample No. 22 Source Ann Arbor Sand and Gravel

Project Location Allen Park, Michigan For Allen Park Clay Mine

Boring No. TP-3 Field Sample No. ST-7 Sample Depth 22.6" Sample Elev. (Tip)

Sample Description Gray SILTY CLAY with Little Sand and Trace of Gravel

Sampled By J.R. Date 8/29/90 Tested By R.O. Date 9-20-90



Grain Size in MM.

Gravel		Sand			Fines		
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	Colloids

FIGURE 27

NTH Consultants, Ltd.

GRAIN SIZE DISTRIBUTION CURVE

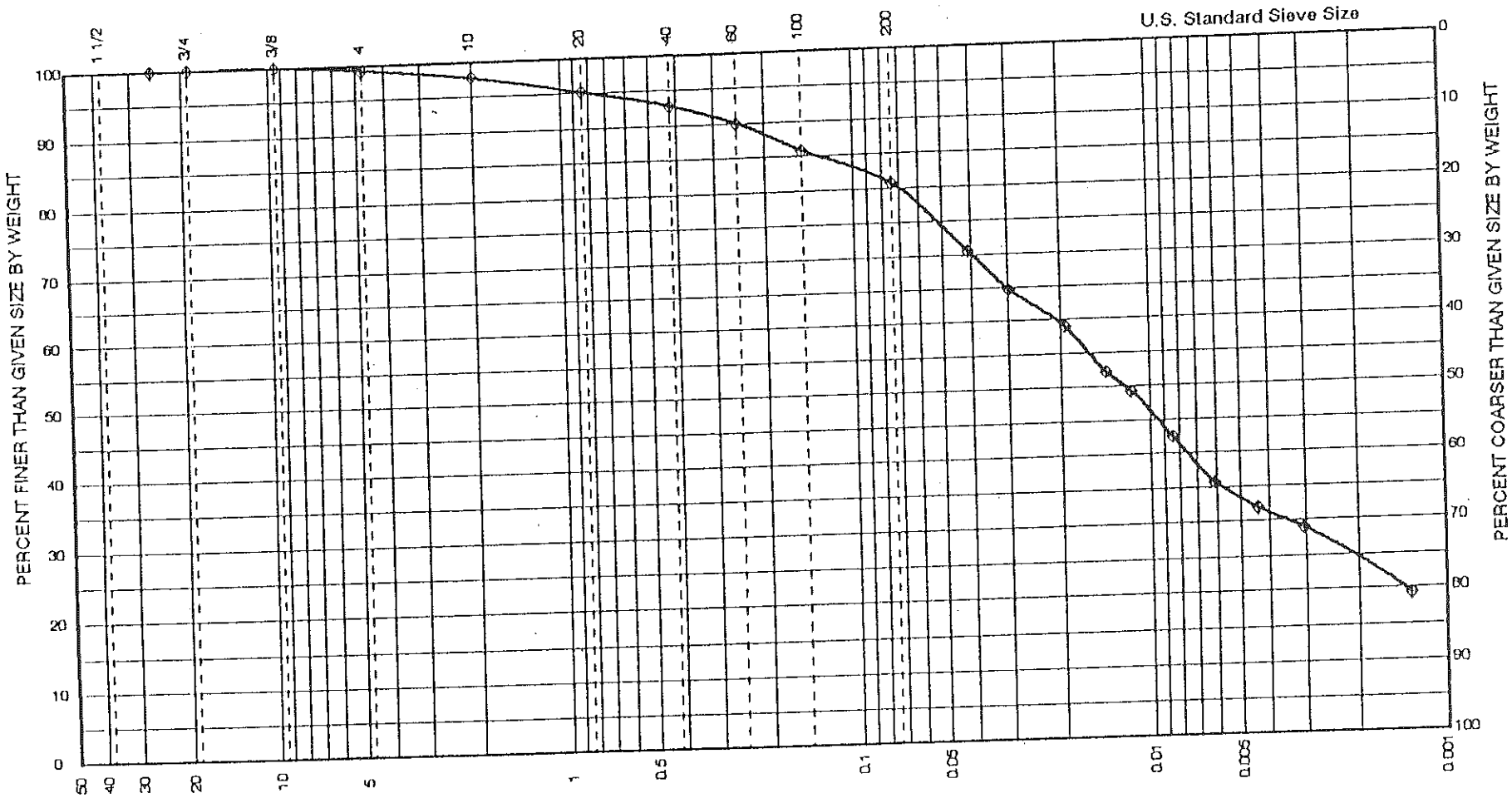
Project No. 89365-OW Lab Sample No. 23 Source Ann Arbor Sand and Gravel

Project Location Allen Park, Michigan For Allen Park Clay Mine

Boring No. TP-3 Field Sample No. ST-8 Sample Depth 22.0" Sample Elev. (Tip)

Sample Description Gray SILTY CLAY with Little Sand and Trace of Gravel

Sampled By J.R. Date 8/29/90 Tested By R.O. Date 9-20-90



Grain Size in MM.

Gravel		Sand			Fines		
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	Colloids

FIGURE 28

NTH Consultants, Ltd.

GRAIN SIZE DISTRIBUTION CURVE

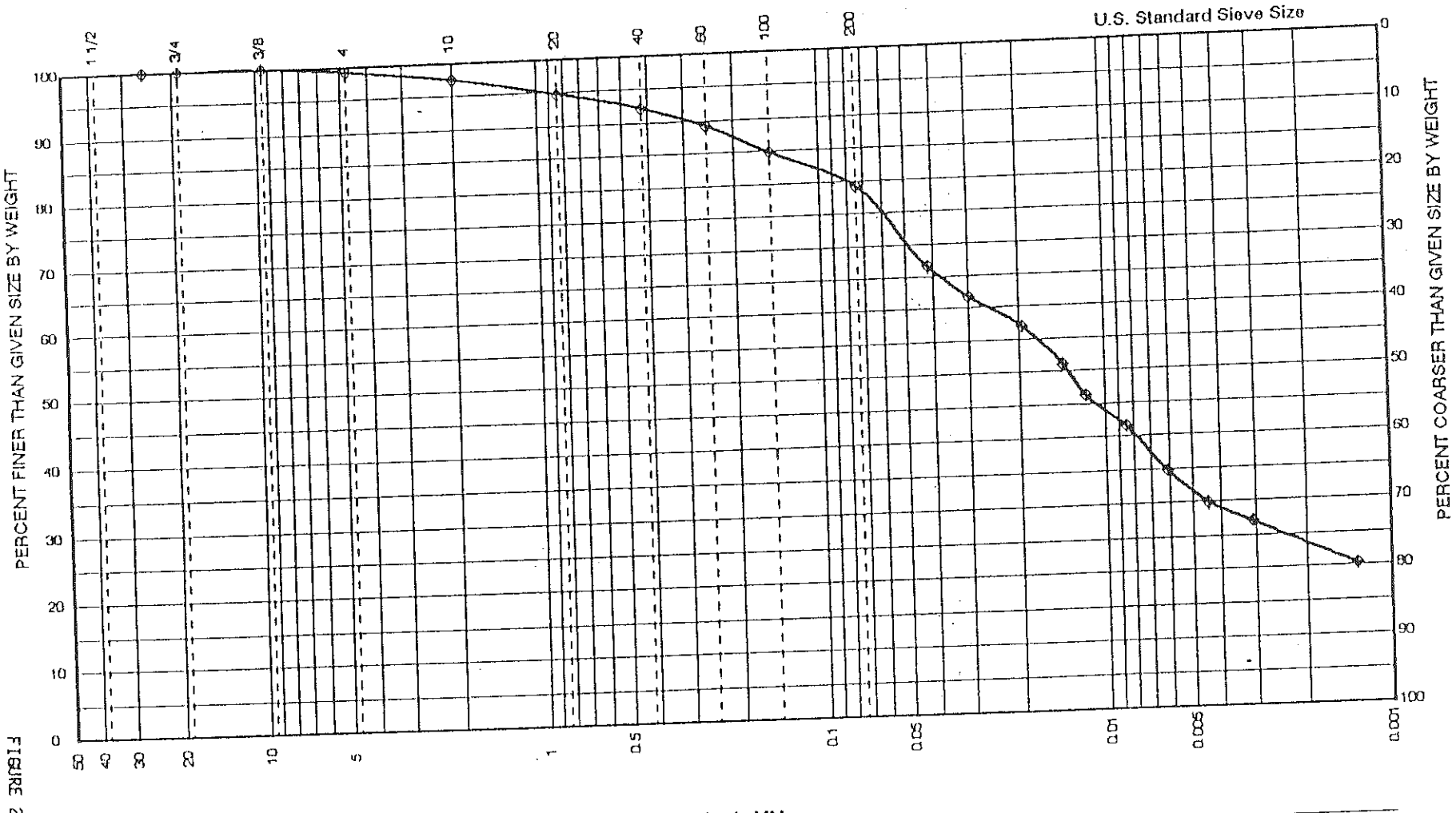
Project No. 89365-OW Lab Sample No. 24 Source Ann Arbor Sand and Gravel

Project Location Allen Park, Michigan For Allen Park Clay Mine

Boring No. TP-3 Field Sample No. ST-9 Sample Depth 23.4" Sample Elev. (Tip)

Sample Description Gray SILTY CLAY with Little Sand and Trace of Gravel

Sampled By J.R. Date 8/29/90 Tested By R.O. Date 9-20-90



Gravel		Sand			Fines		
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	Colloids

FIGURE 29

NTH Consultants, Ltd.

GRAIN SIZE DISTRIBUTION CURVE

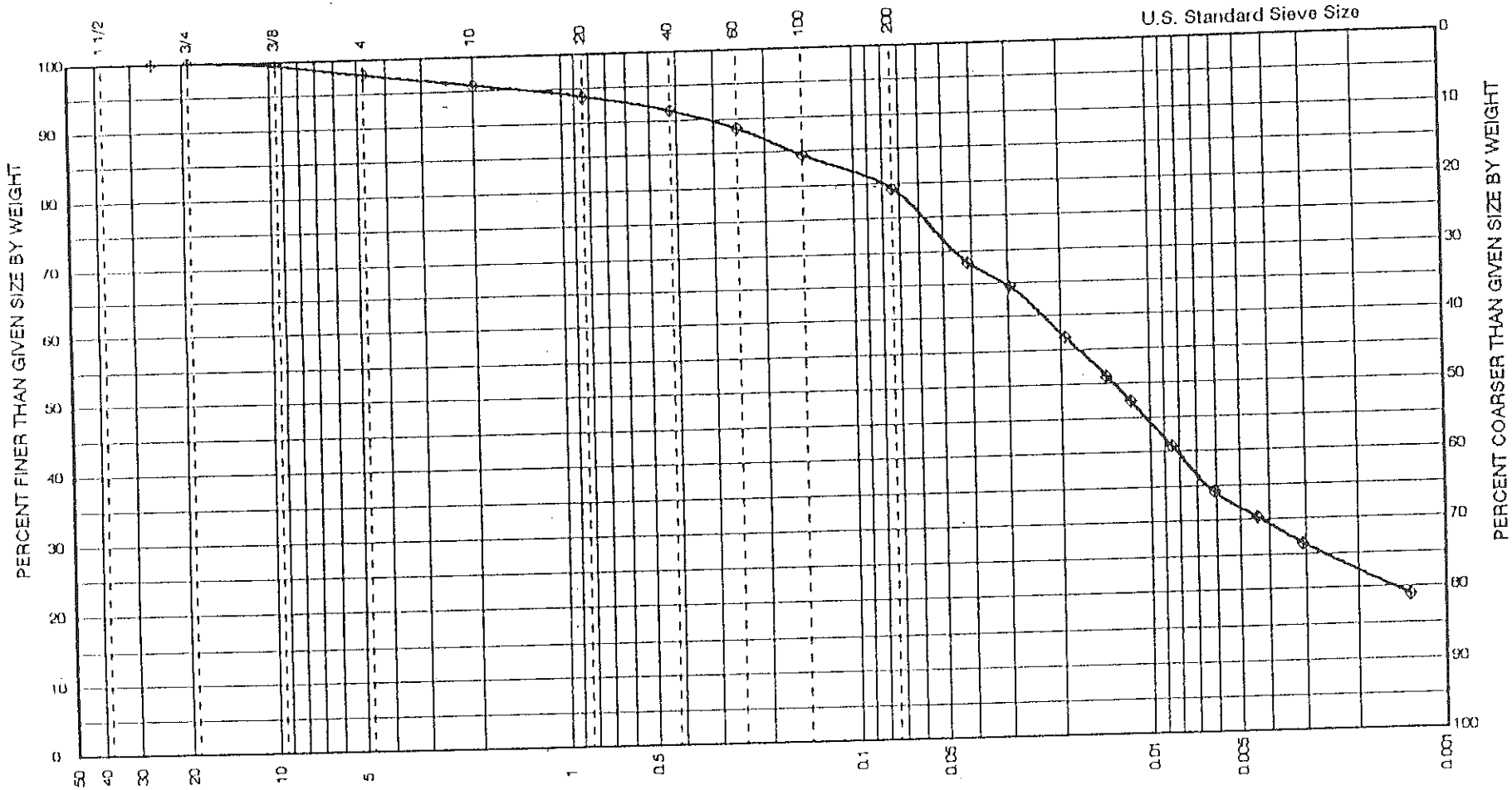
Project No. 89365-OW Lab Sample No. 29 Source Ann Arbor Sand and Gravel

Project Location Allen Park, Michigan For Allen Park Clay Mine

Boring No. TP-3 Field Sample No. ST 1.2 Sample Depth 19.2" Sample Elev. (Tip)

Sample Description Gray SILTY CLAY with Little Sand and Trace of Gravel

Sampled By J.R. Date 10/4/90 Tested By S.R. Date 10-8-90



Gravel		Sand			Fines		
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	Colloids

FIGURE 30

NTH Consultants, Ltd.

GRAIN SIZE DISTRIBUTION CURVE

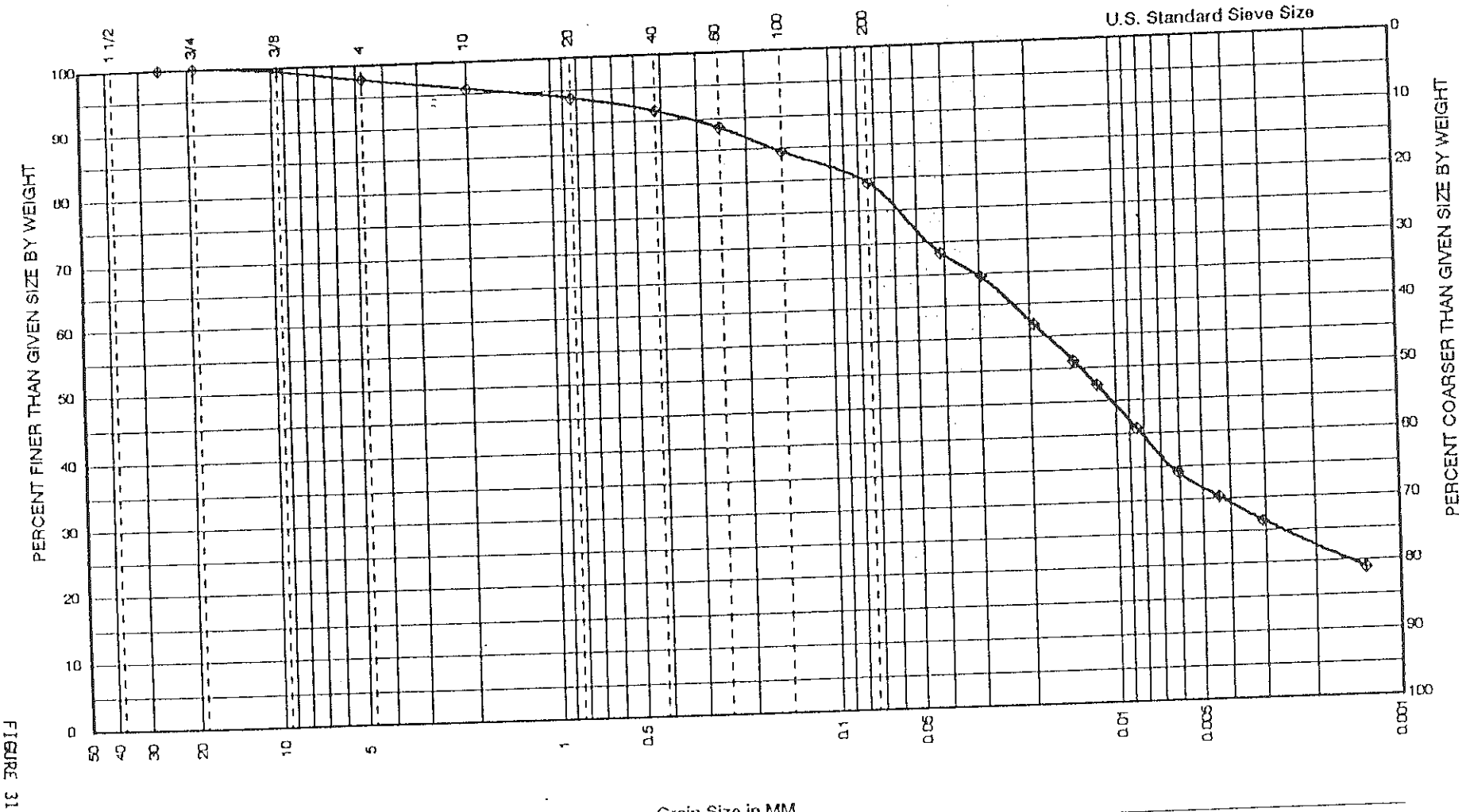
Project No. 89365-OW Lab Sample No. 29 Source Ann Arbor Sand and Gravel For Allen Park Clay Mine

Project Location Allen Park, Michigan Sample Elev. (Tip)

Boring No. TP-3 Field Sample No. ST 3.2 Sample Depth 16.2"

Sample Description Gray SILTY CLAY with Little Sand and Trace of Gravel

Sampled By J.R. Date 9/17/90 Tested By S.R. Date 10-8-90



Gravel		Sand			Fines		
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	Colloids

FIGURE 31

NTH Consultants, Ltd.

GRAIN SIZE DISTRIBUTION CURVE

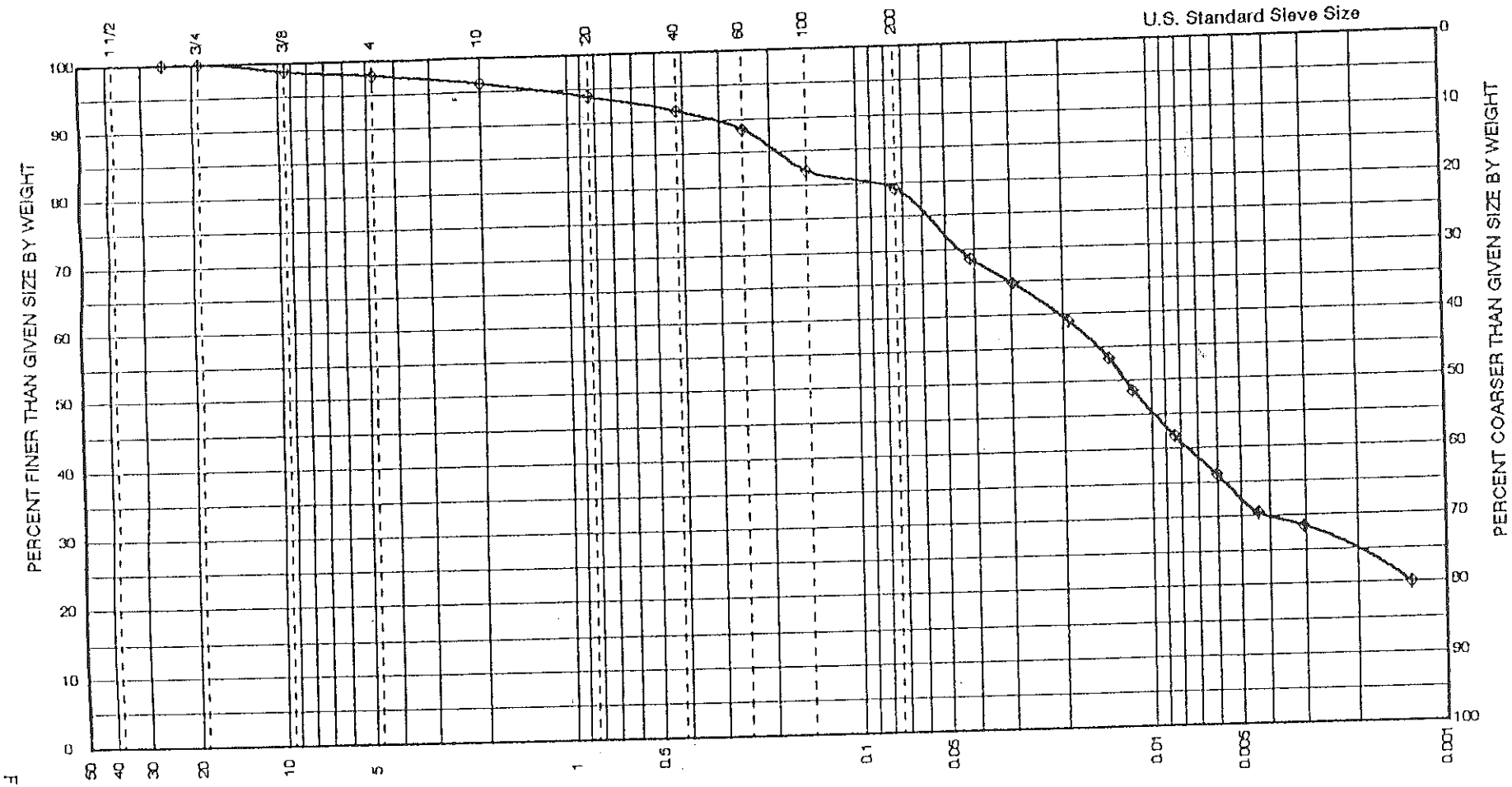
Project No. 89365-OW Lab Sample No. 27 Source Ann Arbor Sand and Gravel

Project Location Allen Park, Michigan For Allen Park Clay Mine

Boring No. TP-3 Field Sample No. ST 4.2 Sample Depth 18.0" Sample Elev. (Tip)

Sample Description Gray SILTY CLAY with Little Sand and Trace of Gravel

Sampled By J.R. Date 9/25/90 Tested By S.R. Date 10-8-90



Gravel		Sand			Fines		
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	Colloids

FIGURE 32

NTH Consultants, Ltd.

GRAIN SIZE DISTRIBUTION CURVE

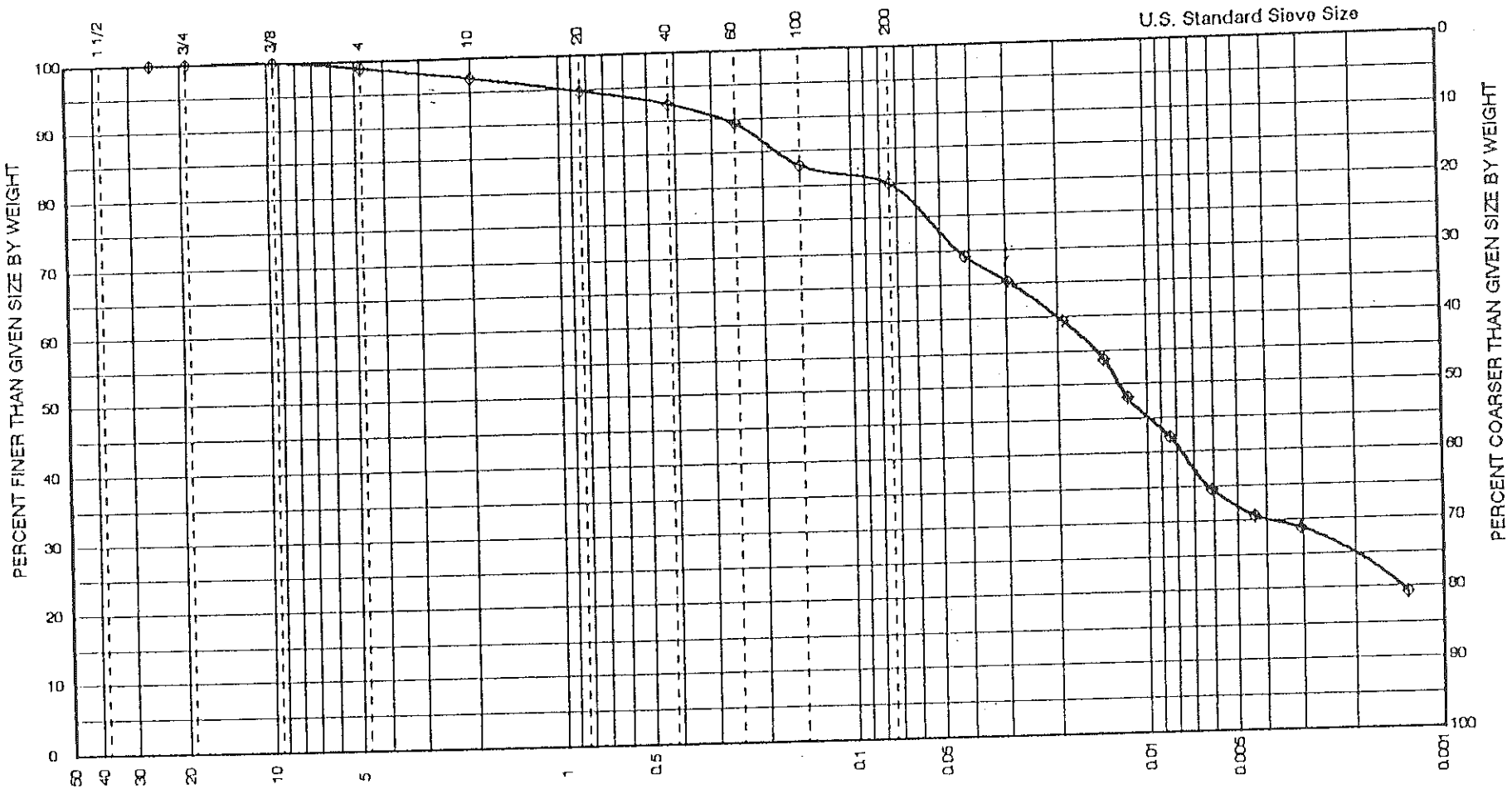
Project No. 89365-OW Lab Sample No. 28 Source Ann Arbor Sand and Gravel

Project Location Allen Park, Michigan For Allen Park Clay Mine

Boring No. TP-3 Field Sample No. ST 6.2 Sample Depth 20.6" Sample Elev. (Tip)

Sample Description Gray SILTY CLAY with Little Sand and Trace of Gravel

Sampled By J.R. Date 9/25/90 Tested By S.R. Date 10-8-90



Gravel		Sand			Fines		
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	Colloids

FIGURE 33

NTH Consultants, Ltd.

GRAIN SIZE DISTRIBUTION CURVE

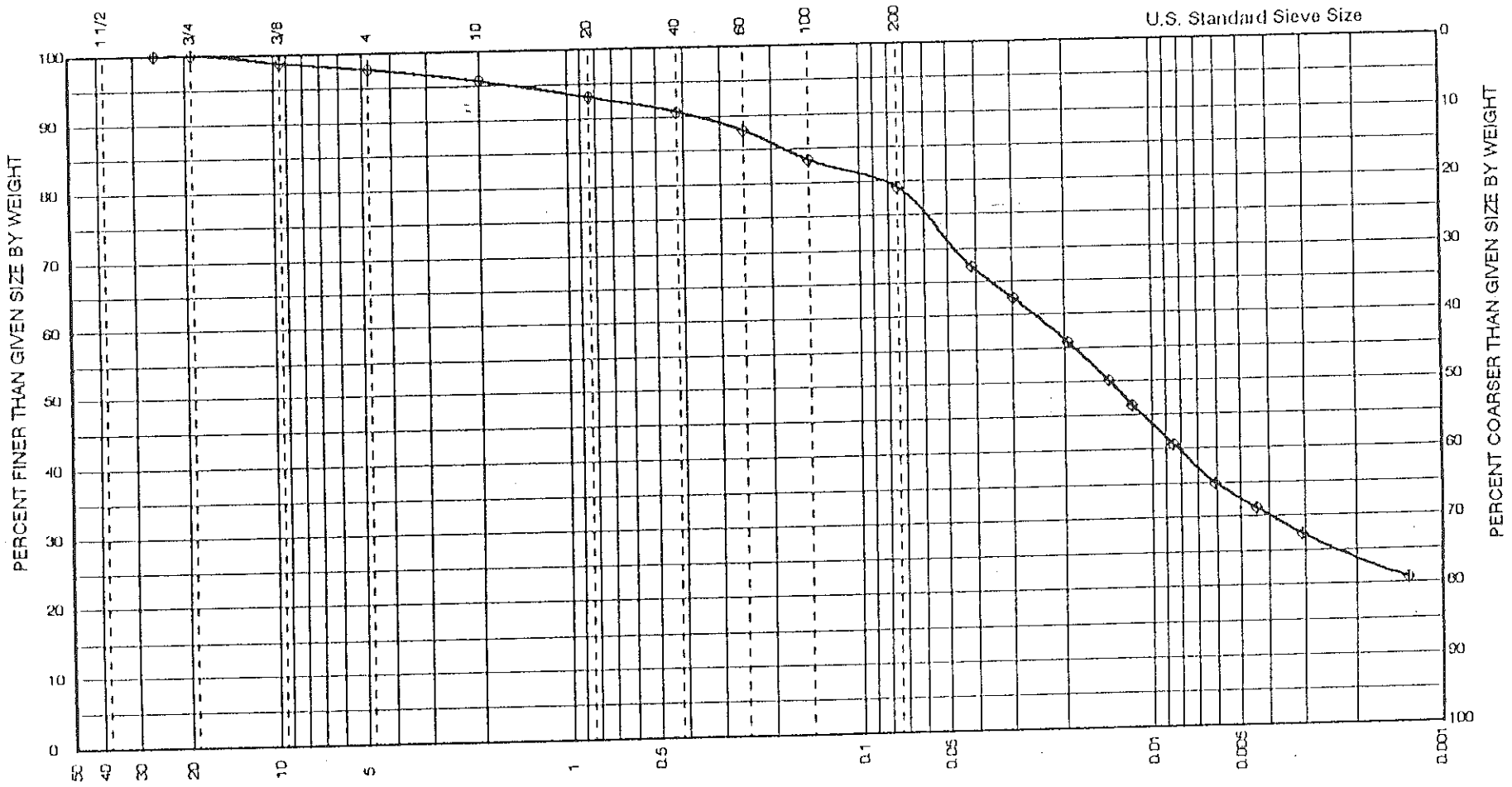
Project No. 89365-OW Lab Sample No. 31 Source **Ann Arbor Sand and Gravel**

Project Location Allen Park, Michigan For Allen Park Clay Mine

Boring No. TP-03 Field Sample No. ST-7.3 Sample Depth **19.6"** Sample Elev. (Tip)

Sample Description **Gray SILTY CLAY with Little Sand and Trace of Gravel**

Sampled By **J.R.** Date **10/3/90** Tested By D.A. Date 10-11-90



Gravel		Sand			Fines		
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	Colloids

FIGURE 34

TEST PAD #2

LONDON SOURCE STOCKPILE

TEST PAD #2
LONDON SOURCE STOCKPILE

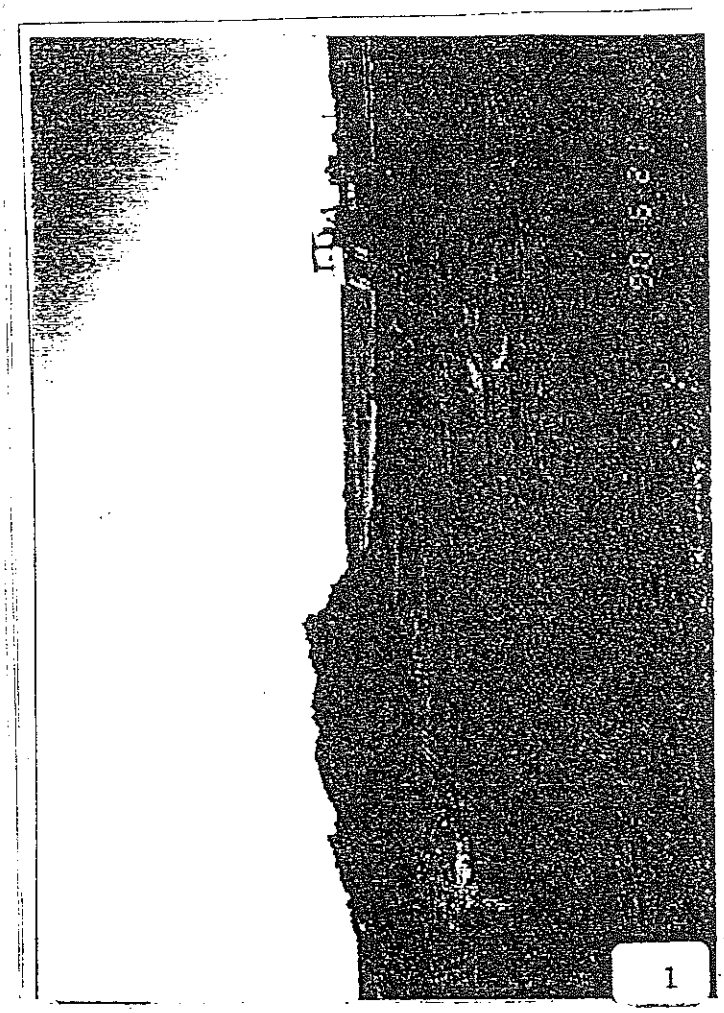
PHOTOGRAPH DESCRIPTION

PHOTOGRAPH 1	LIFTS #1-2 - LIFT #1 IN PLACE. LIFT #2 STARTING. TEST SITES VISIBLE.
PHOTOGRAPH 2	LIFT #2 - LIFT #2 BACKBLADED. LOOSE AND COMPACTION. STARTING FOR 10 PASSES.
PHOTOGRAPH 3	LIFT #2 - 10 PASSES COMPACT.
PHOTOGRAPH 4	LIFT #2 - 8 PASSES COMPACT. 3 TEST SITES OPEN.
PHOTOGRAPH 5	LIFT #2 - 6 PASSES COMPACT.
PHOTOGRAPH 6	LIFT #3 - LIFT PROFILE.
PHOTOGRAPH 7	LIFT #3 - FINISHING PLACING AND STARTING COMPACTION.
PHOTOGRAPH 8	LIFT #3 - 10 PASSES COMPACT.
PHOTOGRAPH 9	LIFT #3 - 8 PASSES COMPACT.
PHOTOGRAPH 10	LIFT #3 - 6 PASSES COMPACT.
PHOTOGRAPH 11	LIFT #3 - TYPICAL TEST SITE.
PHOTOGRAPH 12	LIFT #3 - SITE PRIOR TO WORK AFTER RAINS (HOW TRANQUIL).
PHOTOGRAPH 13	LIFT #4 - LIFT BEING WORKED INTO PLACE.
PHOTOGRAPH 14	LIFT #4 - FINISHING GRADING PRIOR TO COMPACTION.
PHOTOGRAPH 15	CAT 140G GRADER.
PHOTOGRAPH 16	LIFT #4 - 10 PASSES COMPACT.
PHOTOGRAPH 17	LIFT #4 - 8 PASSES COMPACT.
PHOTOGRAPH 18	LIFT #4 - 6 PASSES COMPACT.
PHOTOGRAPH 19	LIFT #4 - TEST SITES (TYPICAL).
PHOTOGRAPH 20	LIFT #5 - COMPLETING FILL PLACEMENT.

TEST PAD #2
LONDON SOURCE STOCKPILE

PHOTOGRAPH DESCRIPTION
(CONTINUED)

PHOTOGRAPH 21	LIFT #5 - DOZER FINISHING PLACING ROLLER COMPACTING.
PHOTOGRAPH 22	LIFT #5 - 10 PASSES COMPACT.
PHOTOGRAPH 23	LIFT #5 - 8 PASSES COMPACT.
PHOTOGRAPH 24	LIFT #5 - 6 PASSES COMPACT.
PHOTOGRAPH 25	6/26/90 - LONDON SOURCE TEST PAD COVERED IN AVAILABLE TARPING.



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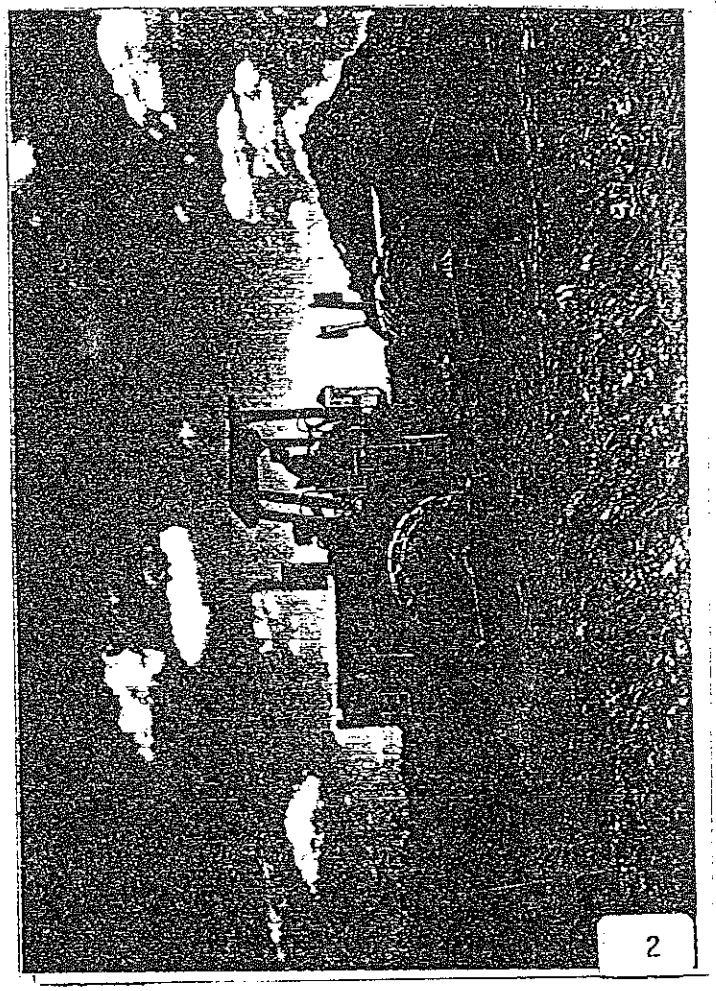

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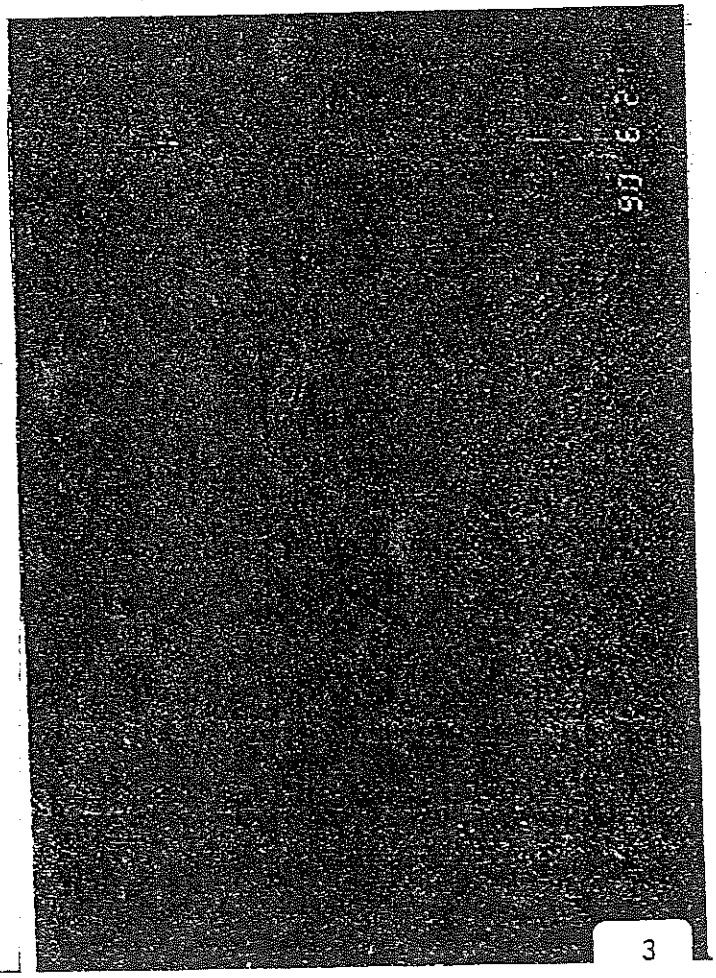

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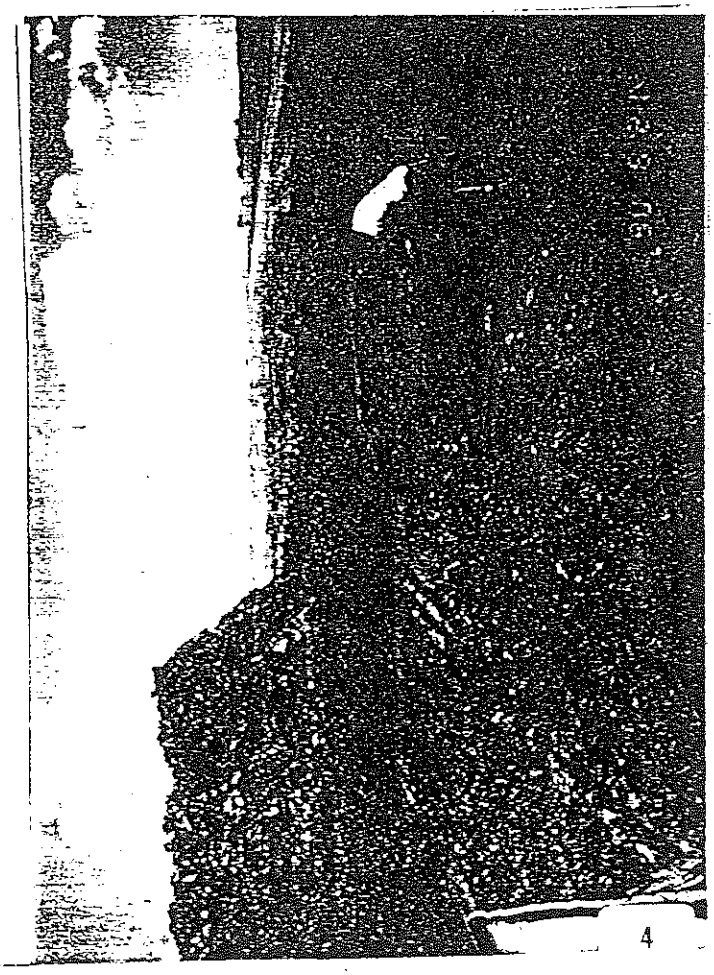

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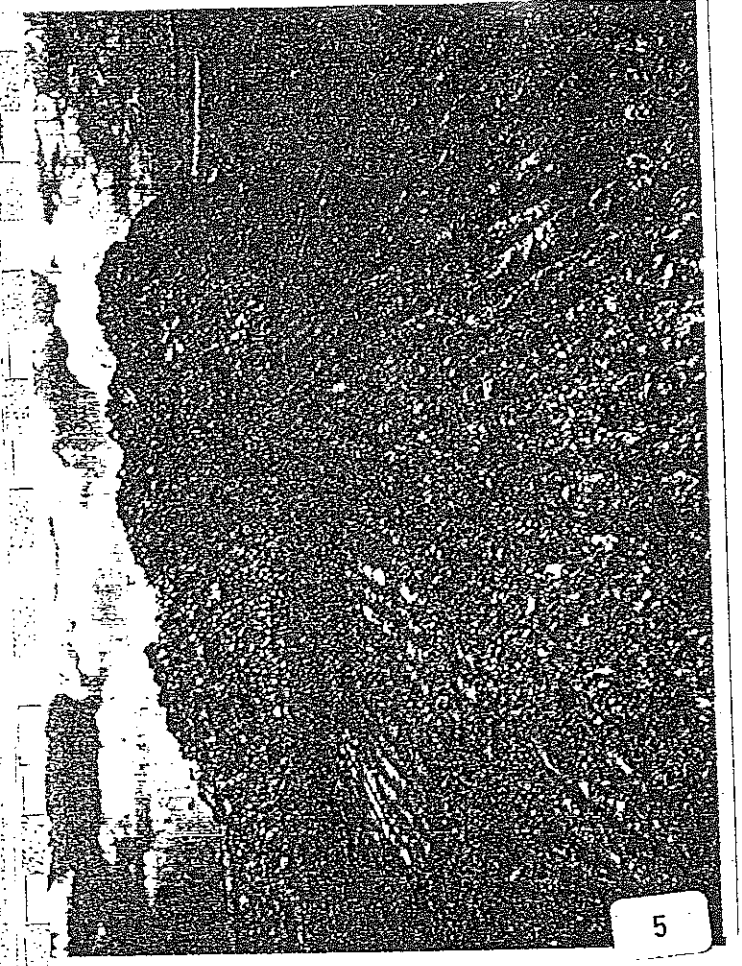

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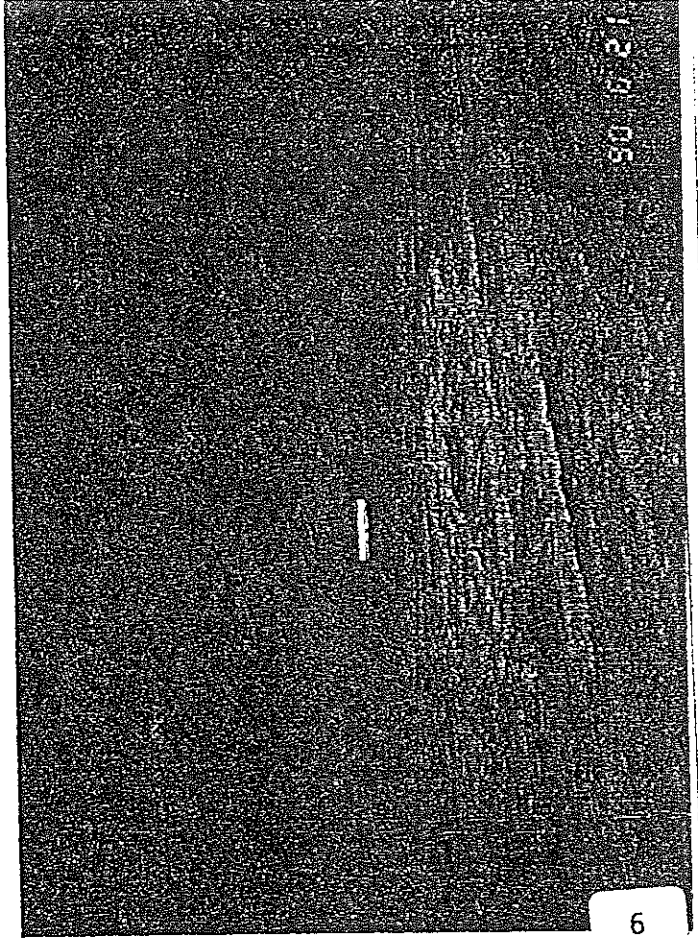

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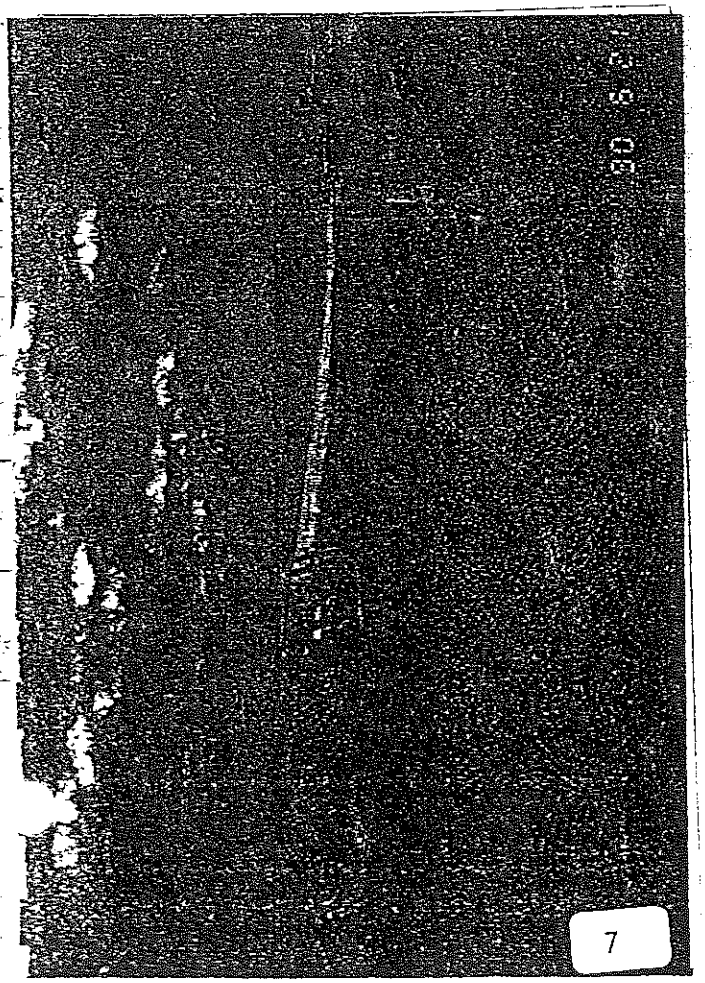

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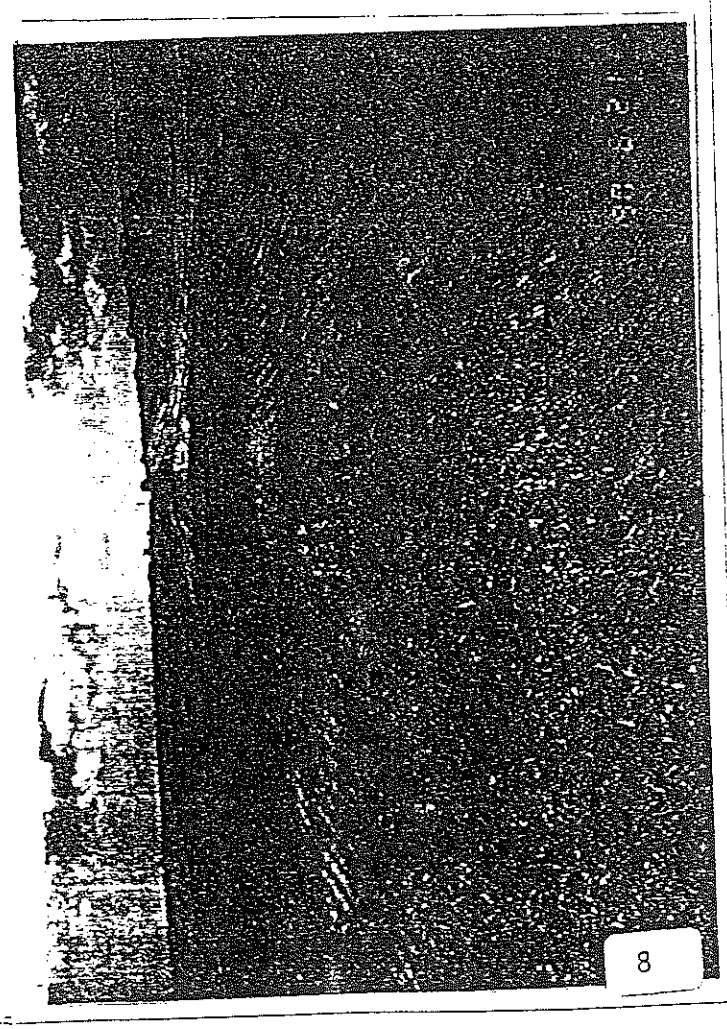

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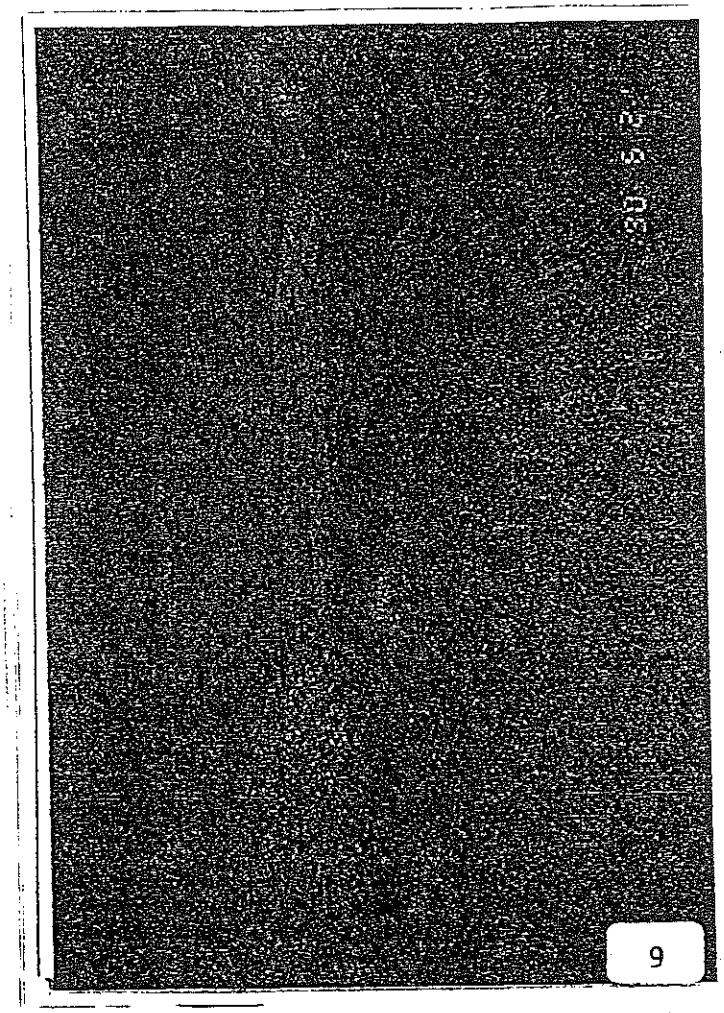
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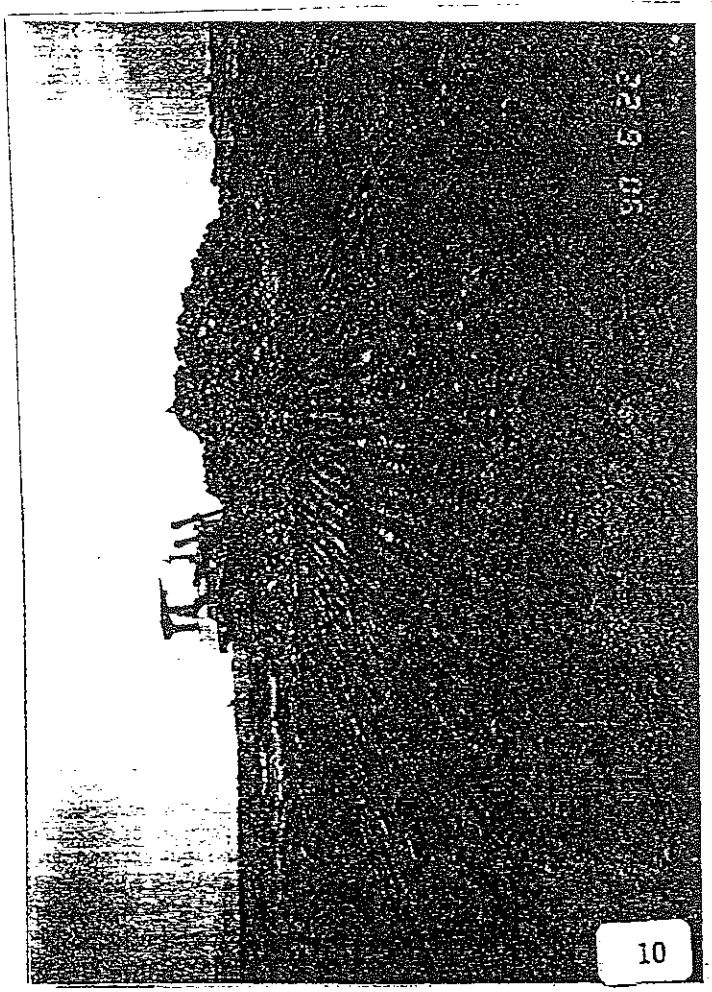
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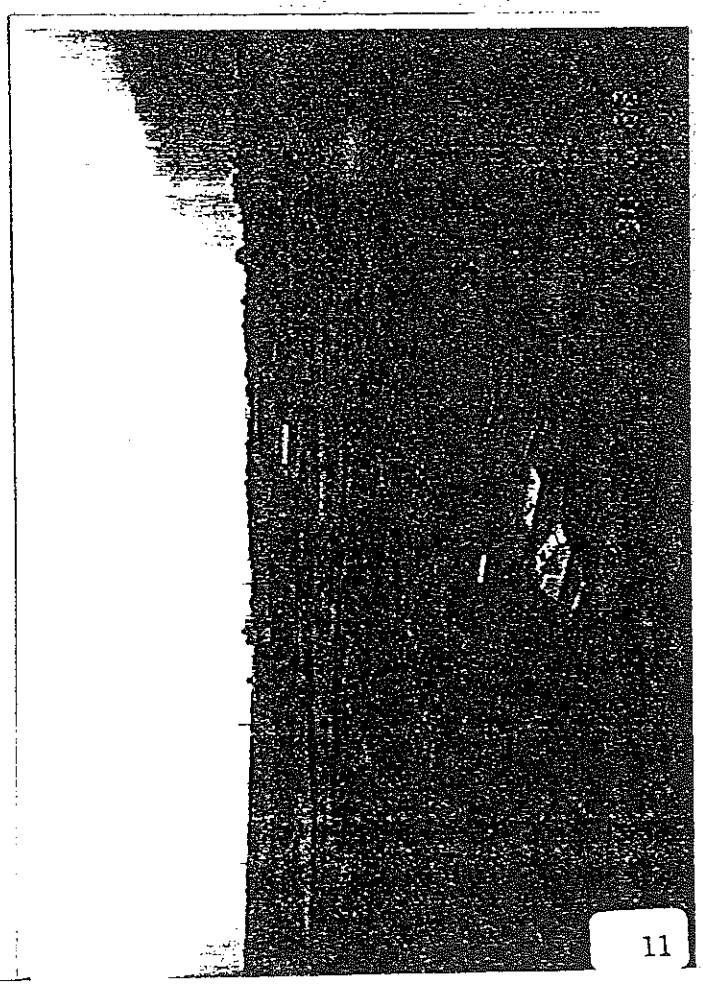
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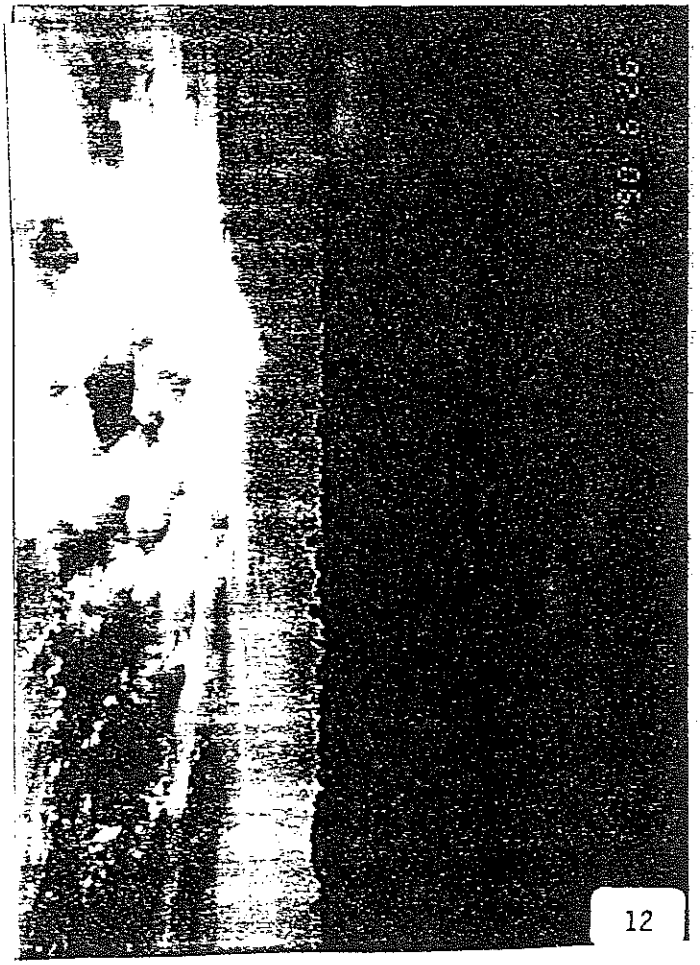
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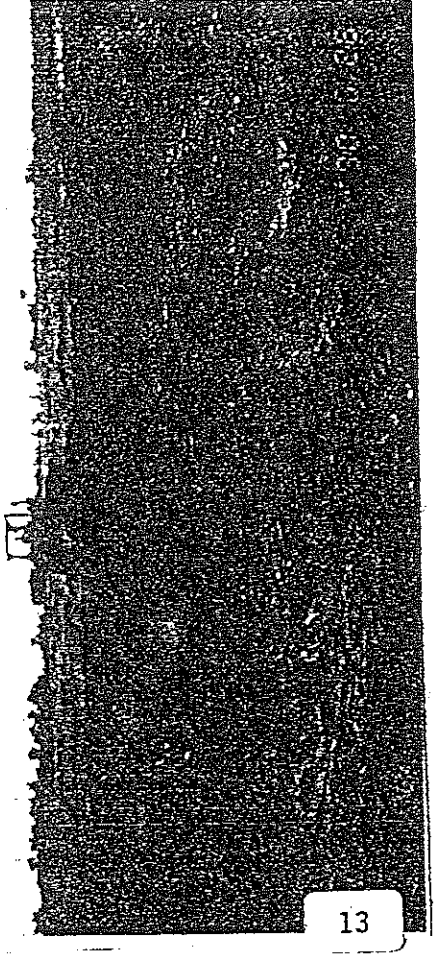

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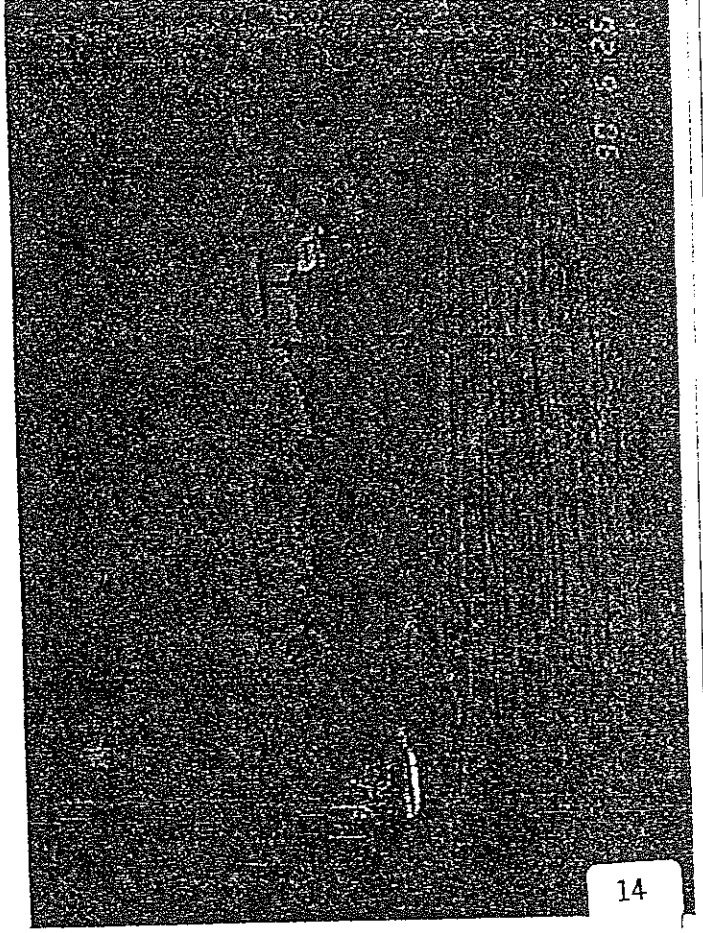

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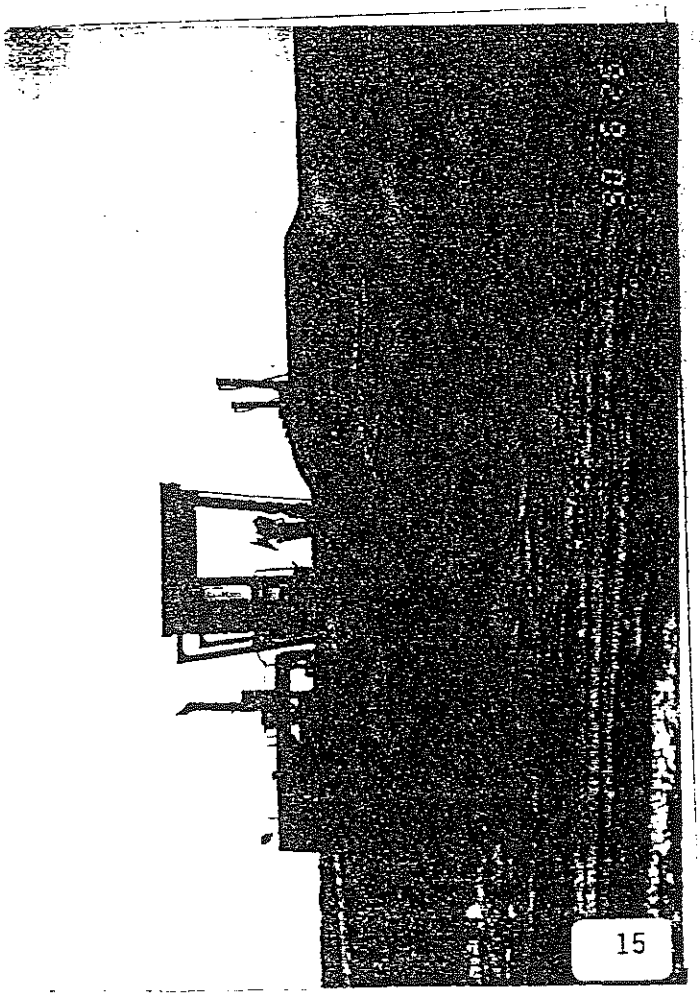

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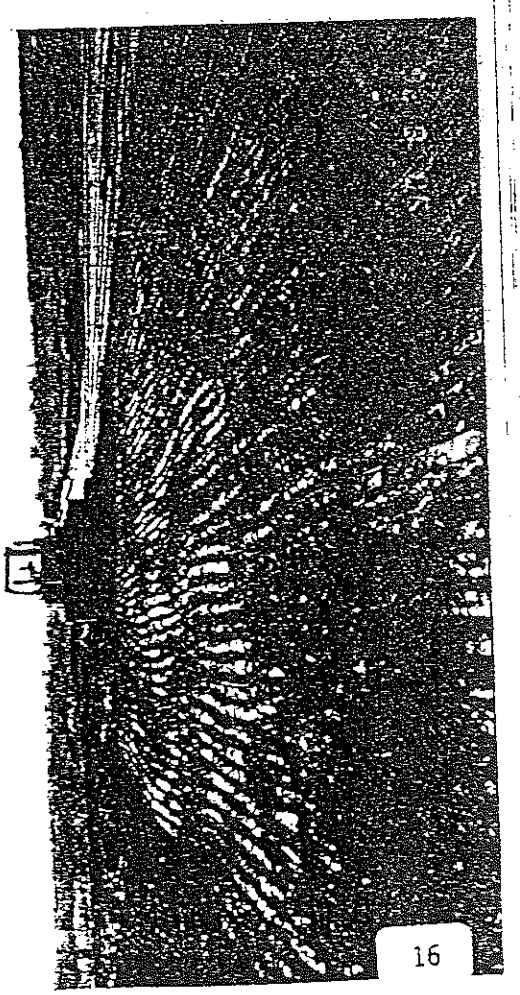

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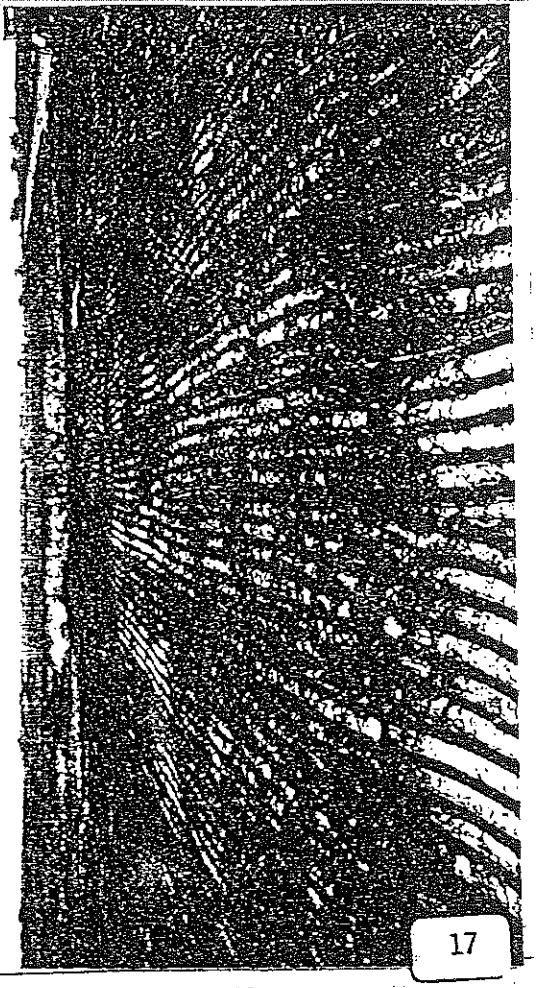

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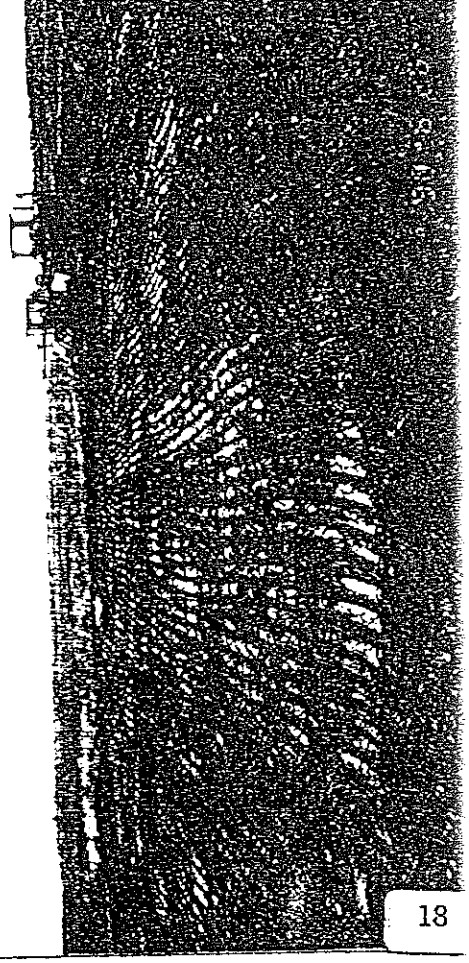

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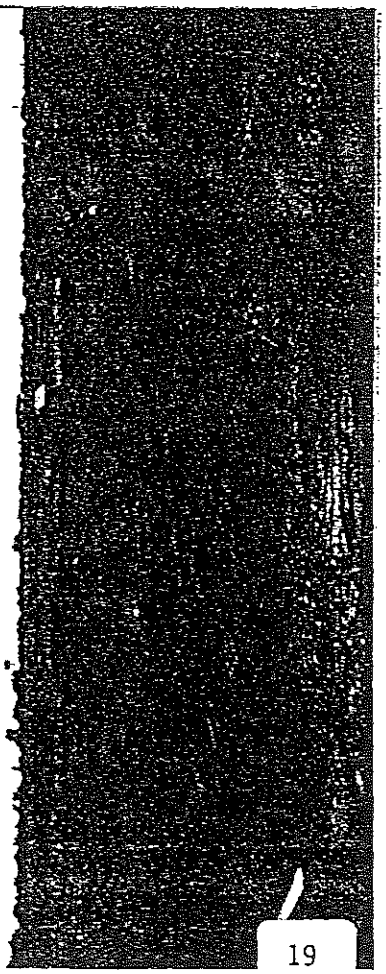

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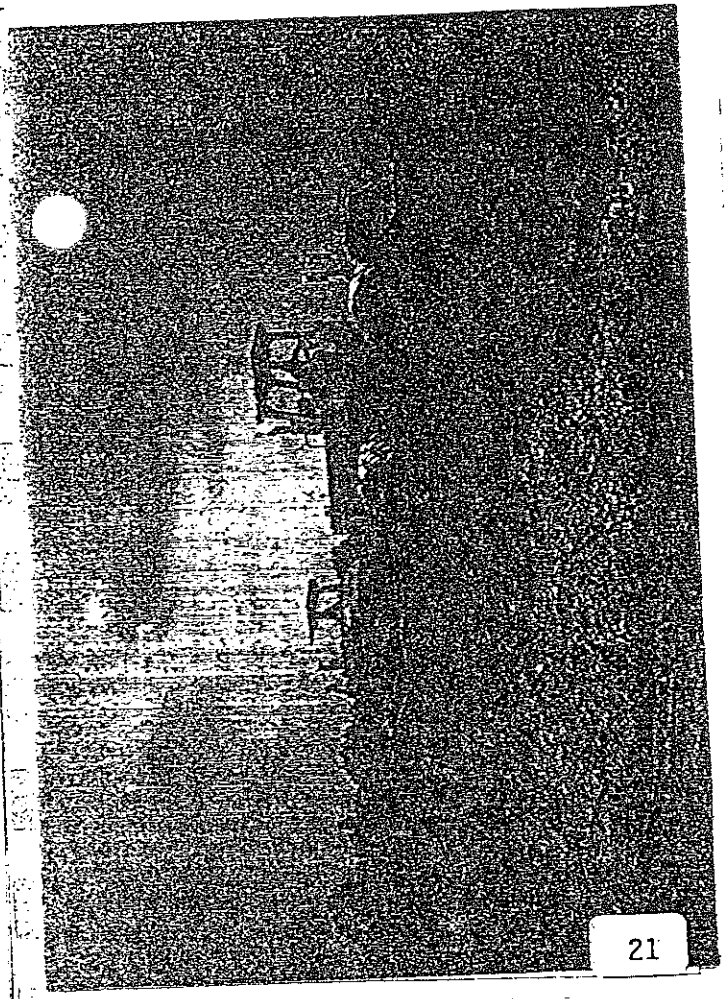

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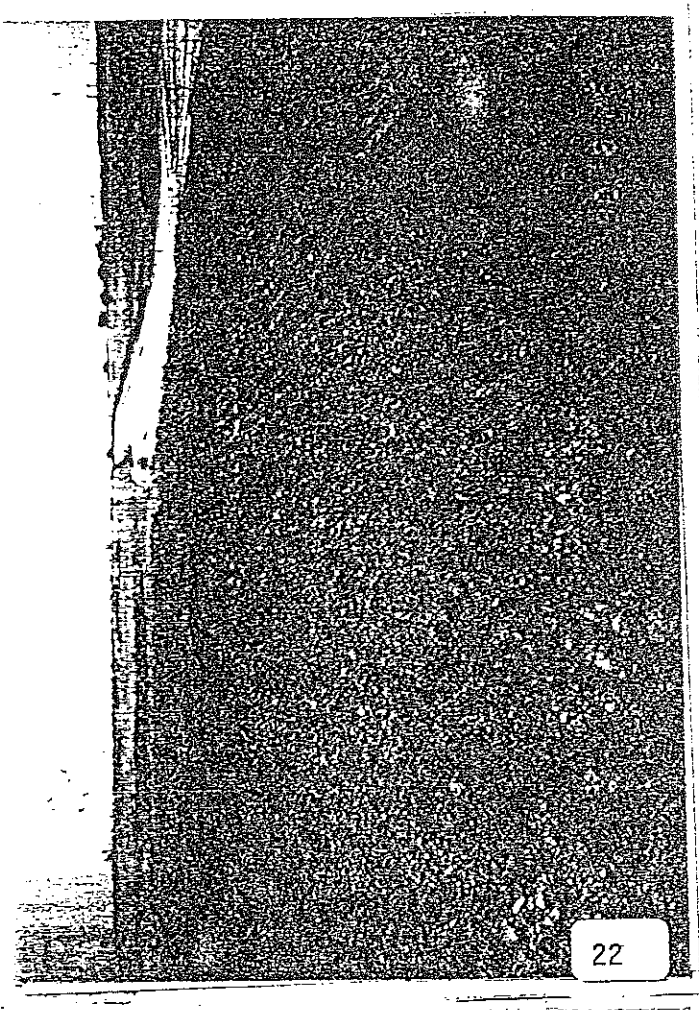

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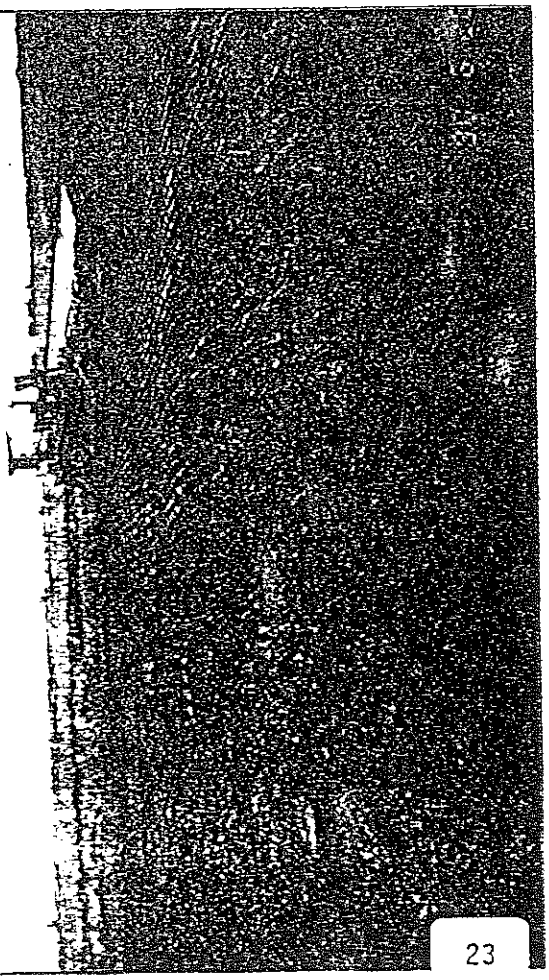

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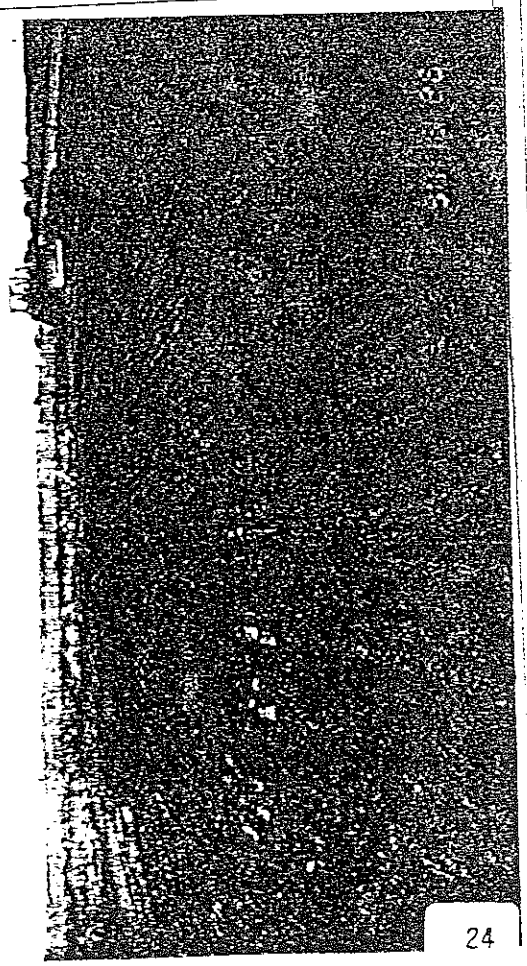

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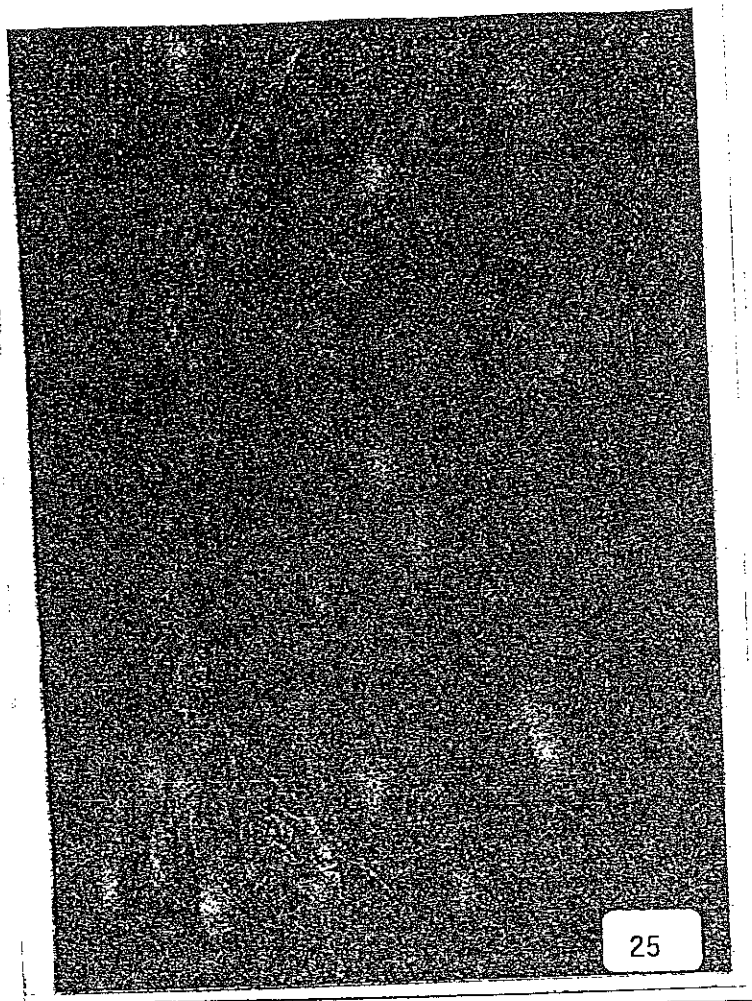


TEST PAD #3

ANN ARBOR SAND & GRAVEL SOURCE STOCKPILE

TEST PAD #3
ANN ARBOR SAND & GRAVEL SOURCE STOCKPILE

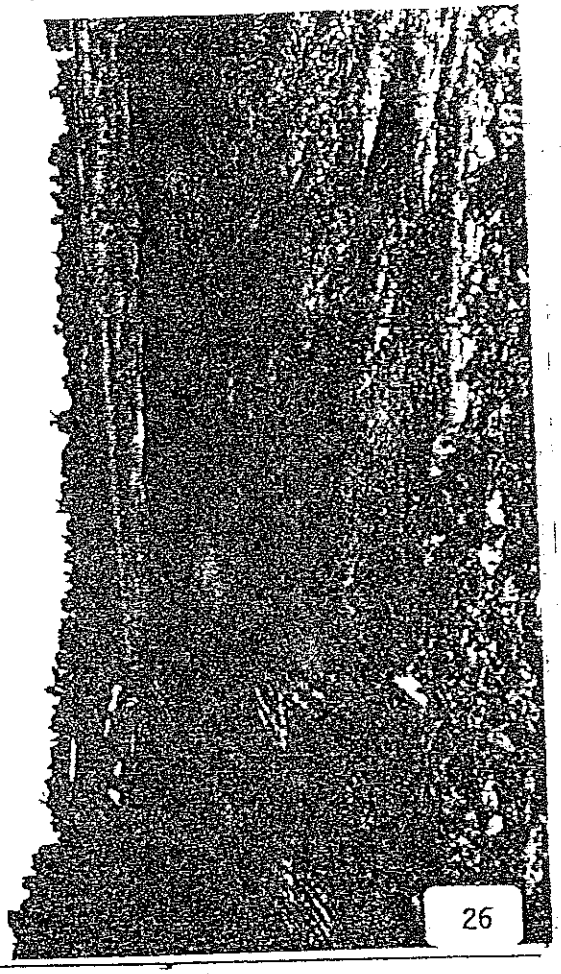
PHOTOGRAPH DESCRIPTION

PHOTOGRAPH 26	LIFT #1 - SUBSURFACE AND PLACEMENT OF LIFT.
PHOTOGRAPH 27	LIFT #1 - PRIOR TO REMEDIATION EFFORTS. . . SOIL CONDITIONS TOO WET.
PHOTOGRAPH 28	LIFT #1 - SCARIFICATION OF LIFT FOR AERATION.
PHOTOGRAPH 29	LIFT #1 - CLOSE UP OF DISC ROLLER.
PHOTOGRAPH 30	LIFT #1 - SCARIFICATION COMPLETE. SCARIFIED BORROW SOURCE VISIBLE AT FRONT.
PHOTOGRAPH 31	LIFT #1 - TESTING 10 PASS AREA WITH MARGINALLY PASSING RESULTS. . . 10,8,6 → 14,12,10.
PHOTOGRAPH 32	LIFT #1 - 8,6 → 12,10 PASS FILL AREAS SCARIFIED SECOND TIME (LEFT OPEN TO AERATE).
PHOTOGRAPH 33	LIFT #1 - 14 PASSES COMPACT (FORMERLY 10 PASSES).
PHOTOGRAPH 34	LIFT #1 - 12 PASSES COMPACT (FORMERLY 8 PASSES).
PHOTOGRAPH 35	LIFT #1 - 10 PASSES COMPACT (FORMERLY 6 PASSES).
PHOTOGRAPH 36	LIFT #2 - CAPPING OPERATION DUE TO RAIN THREAT.
PHOTOGRAPH 37	LIFT #2 - SCARIFYING LIFT FOR AERATION.
PHOTOGRAPH 38	LIFT #2 - POST AERATION EFFORTS/ON SET OF COMPACTION.
PHOTOGRAPH 39	LIFT #2 - 14 PASSES COMPACT.
PHOTOGRAPH 40	LIFT #2 - 12 PASSES COMPACT.
PHOTOGRAPH 41	LIFT #2 - 10 PASSES COMPACT.
PHOTOGRAPH 42	LIFT #3 - FINISHING PLACING/BACKBLADING AND START OF COMPACTION.
PHOTOGRAPH 43	LIFT #3 - 14 PASSES COMPACT.

TEST PAD #3
ANN ARBOR SAND & GRAVEL SOURCE STOCKPILE

PHOTOGRAPH DESCRIPTION
(CONTINUED)

PHOTOGRAPH 44	LIFT #3 - 12 PASSES COMPACT.
PHOTOGRAPH 45	LIFT #3 - 10 PASSES COMPACT.
PHOTOGRAPH 46	LIFT #4 - CAPPING NEWLY PLACED LIFT.
PHOTOGRAPH 47	LIFT #4 - MATERIAL FOR LIFT #5 STOCKPILED TOGETHER AGAINST RAIN THREAT.
PHOTOGRAPH 48	LIFT #4 - PLASTIC TARP COVERING LIFT AFTER COMPLETION OF CAPPING OPERATIONS.
PHOTOGRAPH 49	LIFT #4 - SCARIFYING CAPPED LIFT SURFACE.
PHOTOGRAPH 50	LIFT #4 - BACKBLADING SCARIFIED SURFACE PRIOR TO COMPACTION.
PHOTOGRAPH 51	LIFT #4 - 14 PASSES COMPACT.
PHOTOGRAPH 52	LIFT #4 - 12 PASSES COMPACT.
PHOTOGRAPH 53	LIFT #4 - 10 PASSES COMPACT.
PHOTOGRAPH 54	LIFT #5 - 14 PASSES COMPACT.
PHOTOGRAPH 55	LIFT #5 - 12 PASSES COMPACT.
PHOTOGRAPH 56	LIFT #5 - 10 PASSES COMPACT.
PHOTOGRAPH 57	LIFT #5 - BACKBLADING AND SMOOTH ROLLING DURING CAPPING OPERATIONS.
PHOTOGRAPH 58	PLASTIC TARPING COVERING COMPLETED TEST PADS.



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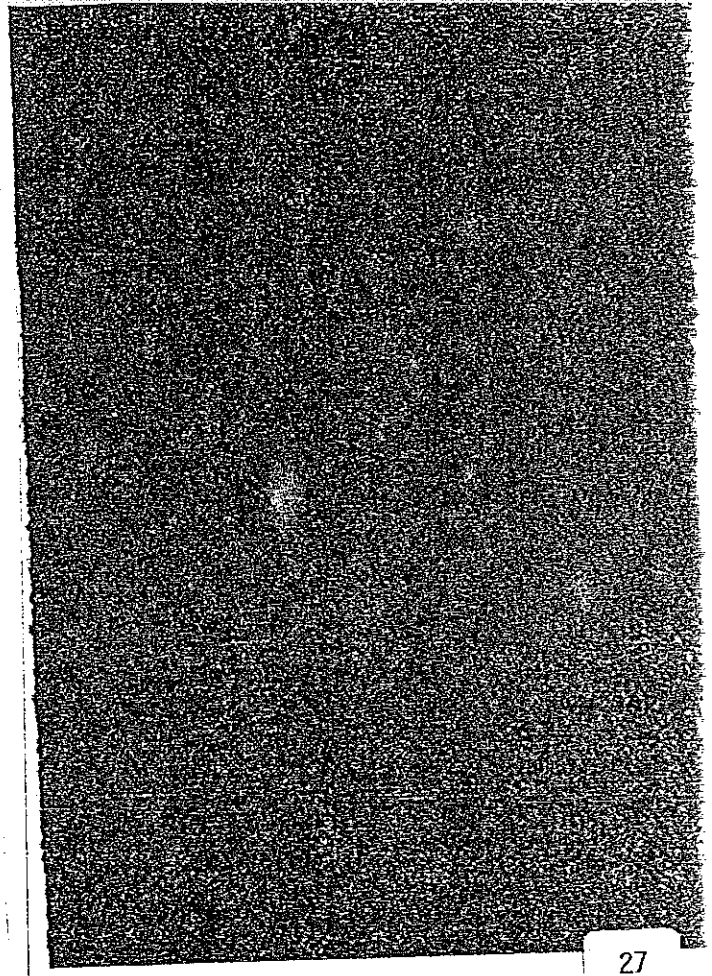

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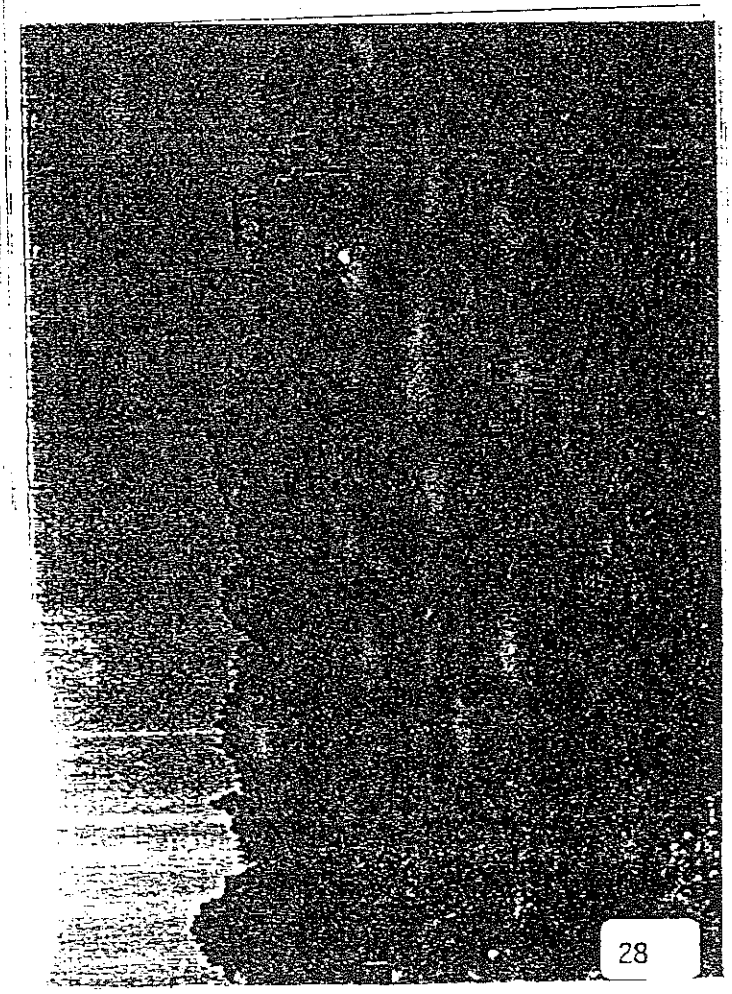

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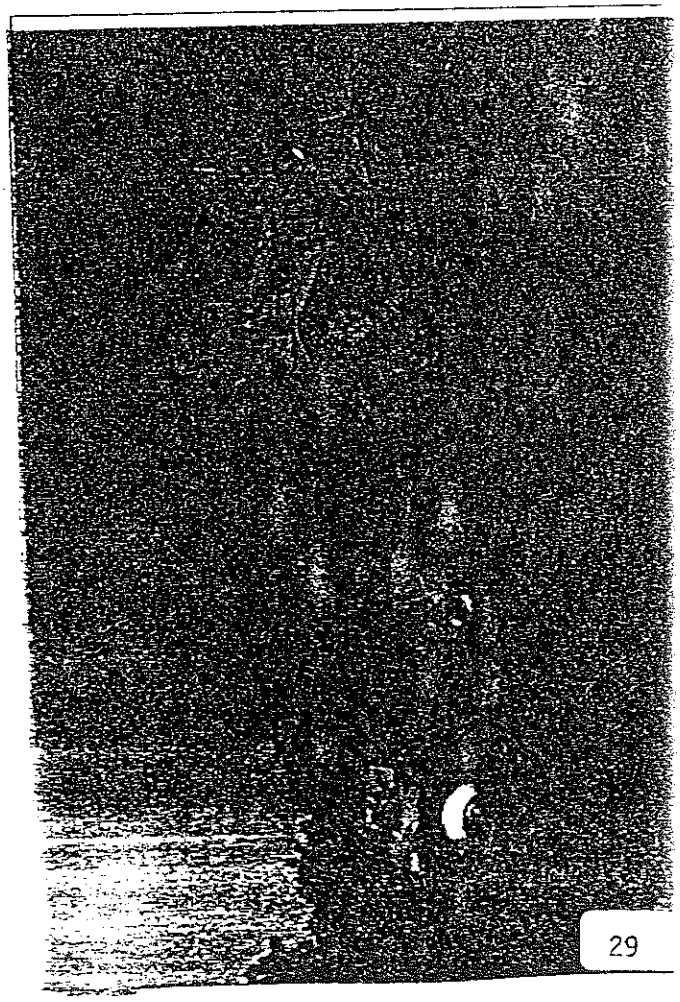

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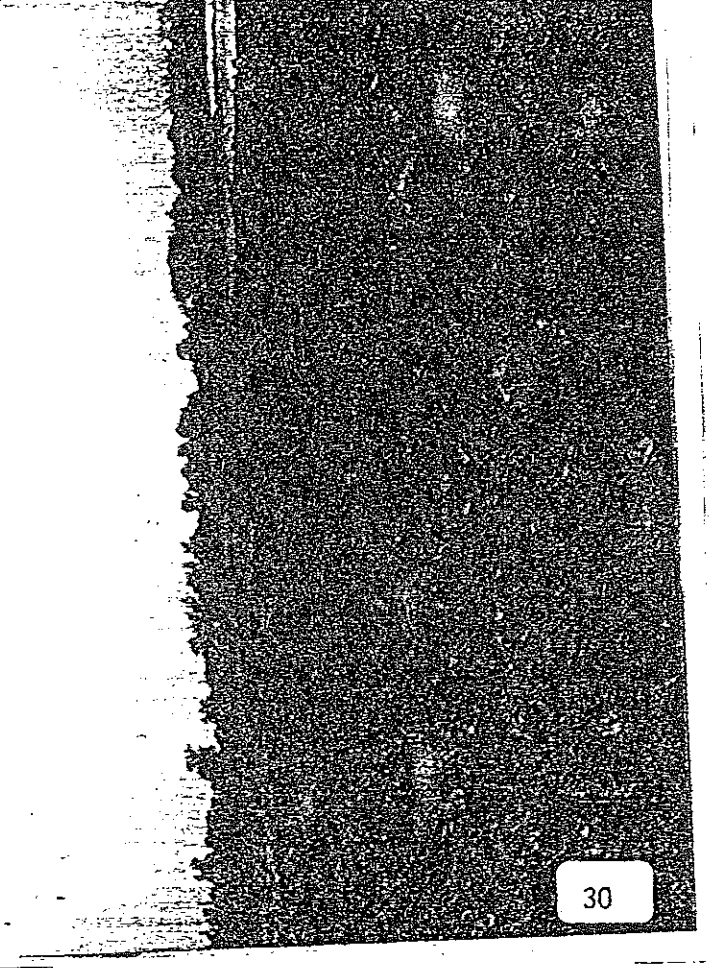

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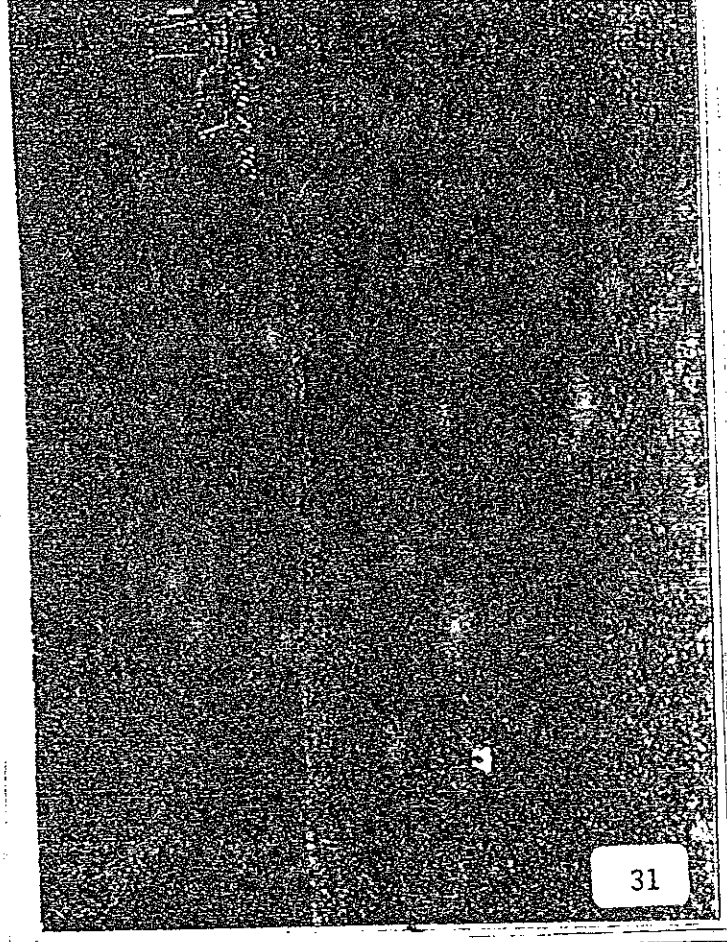

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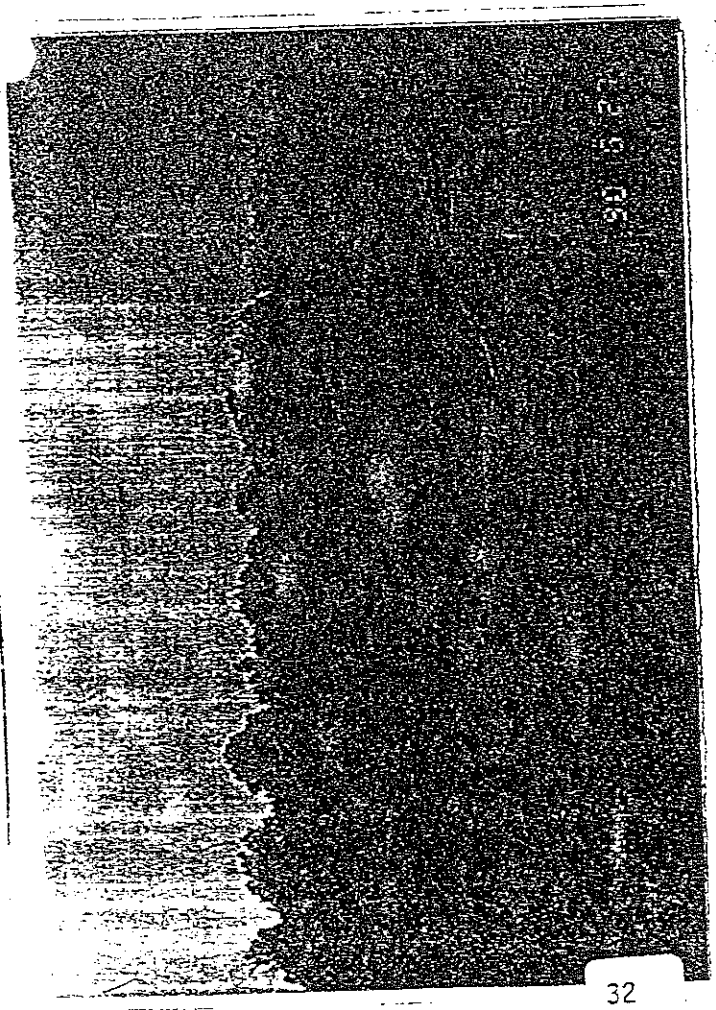

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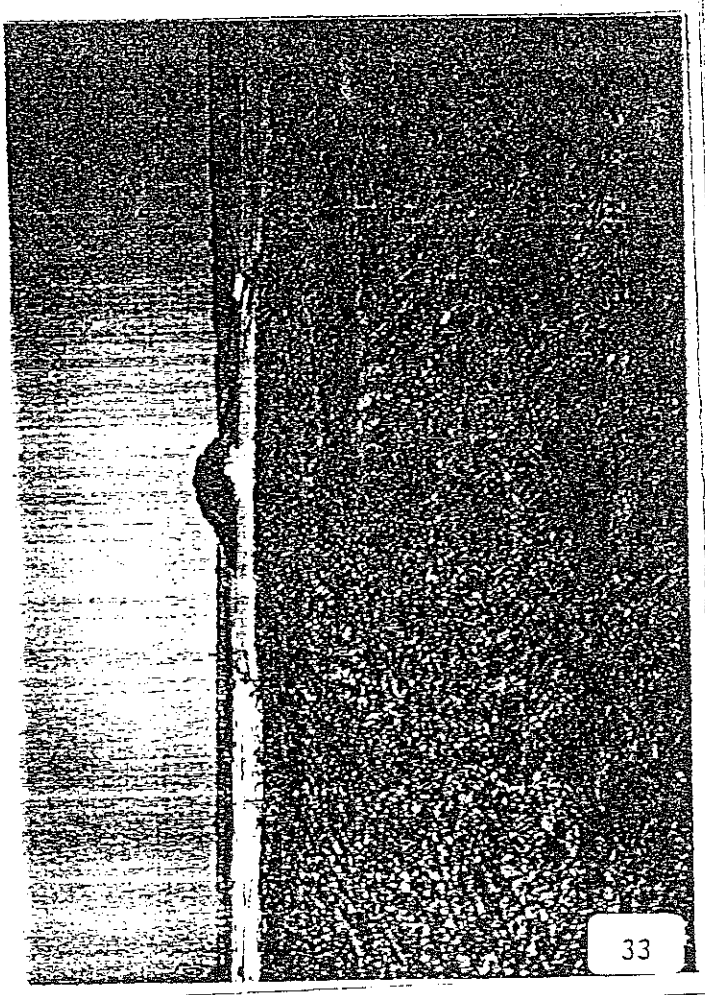

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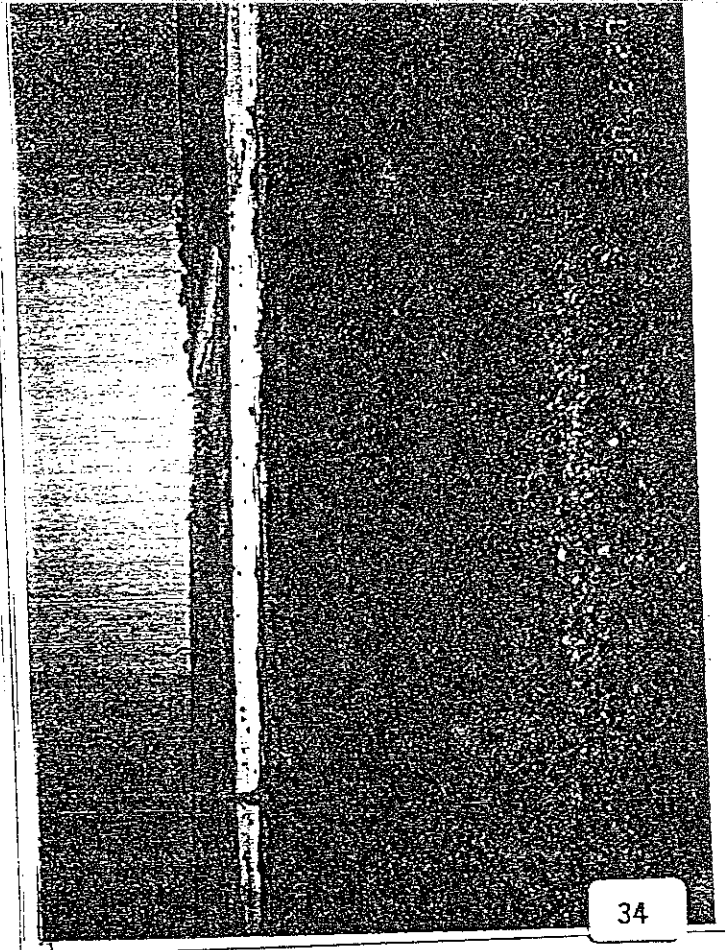

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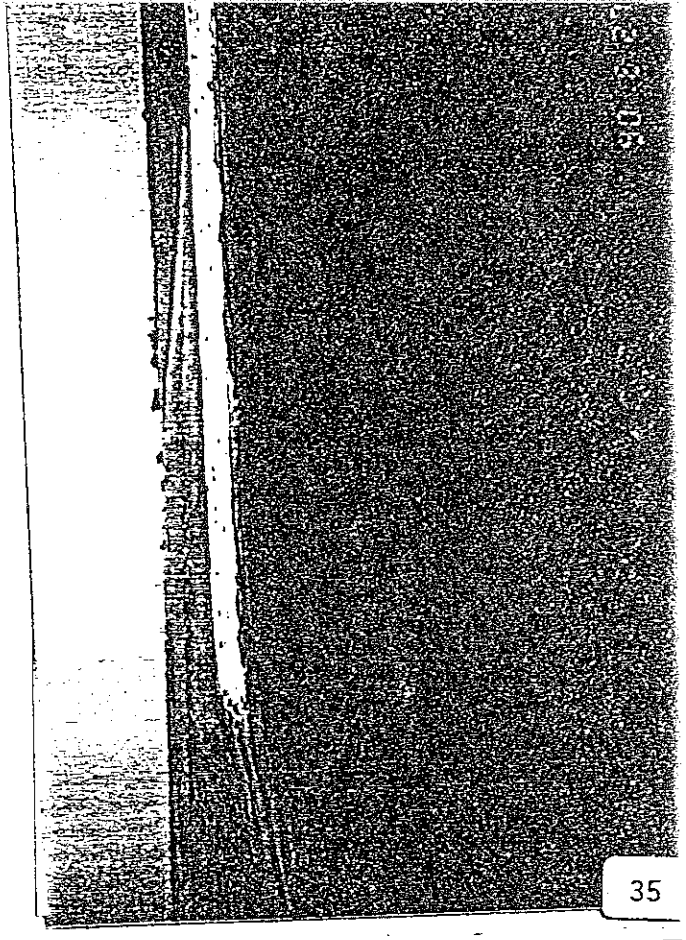

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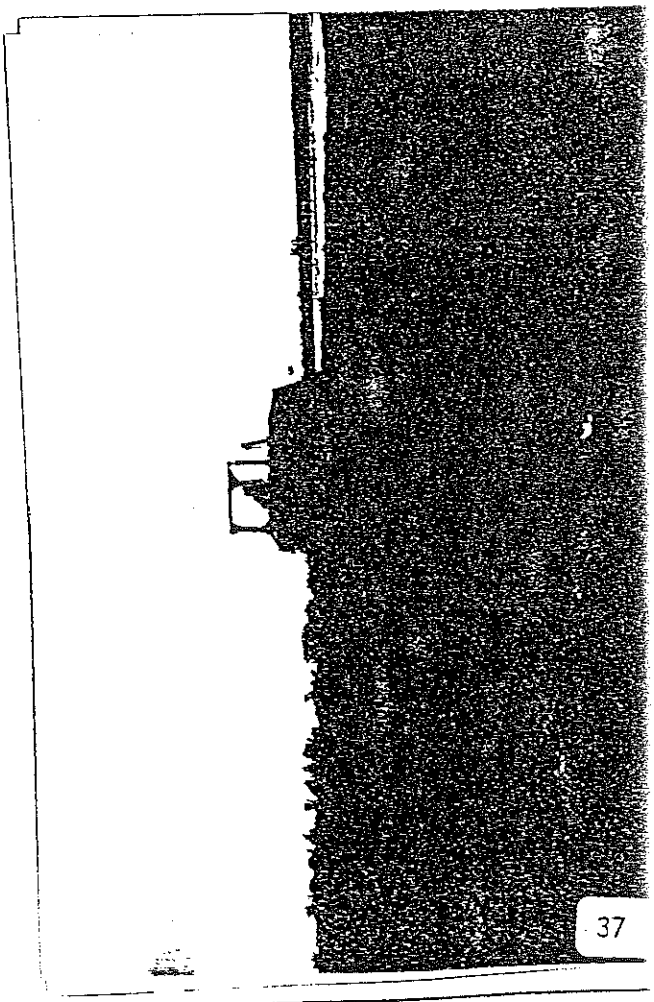

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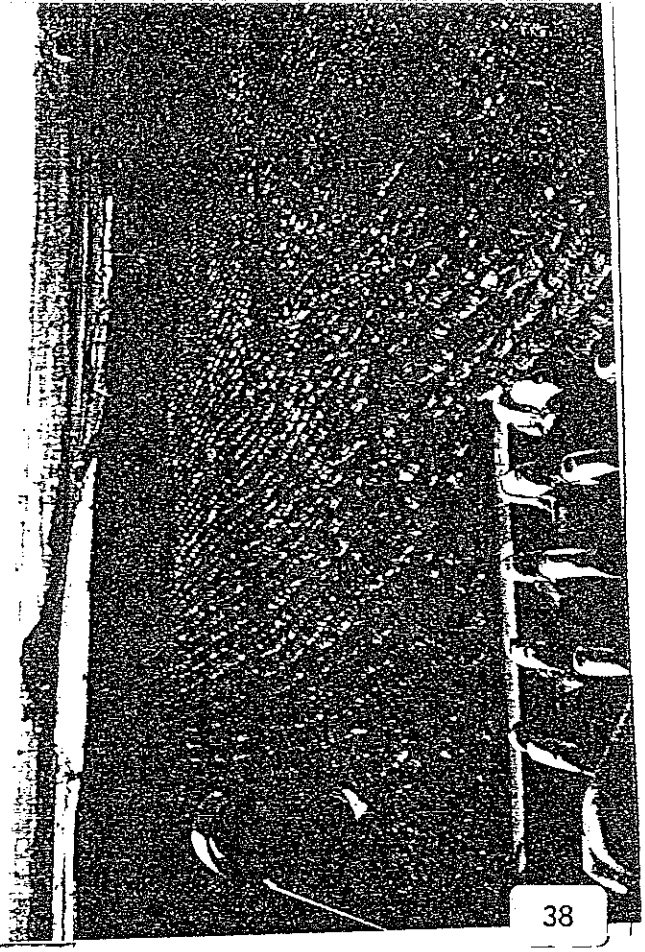

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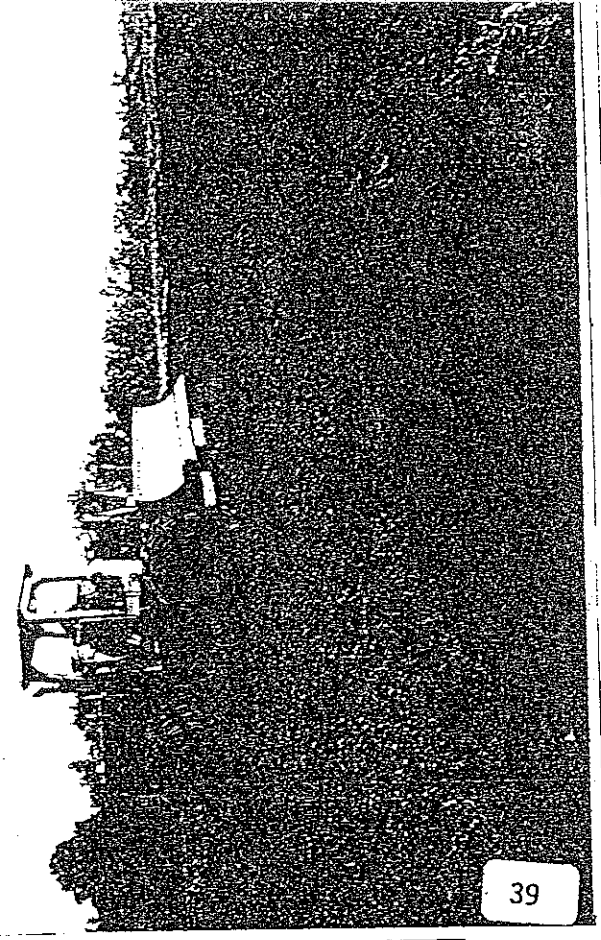

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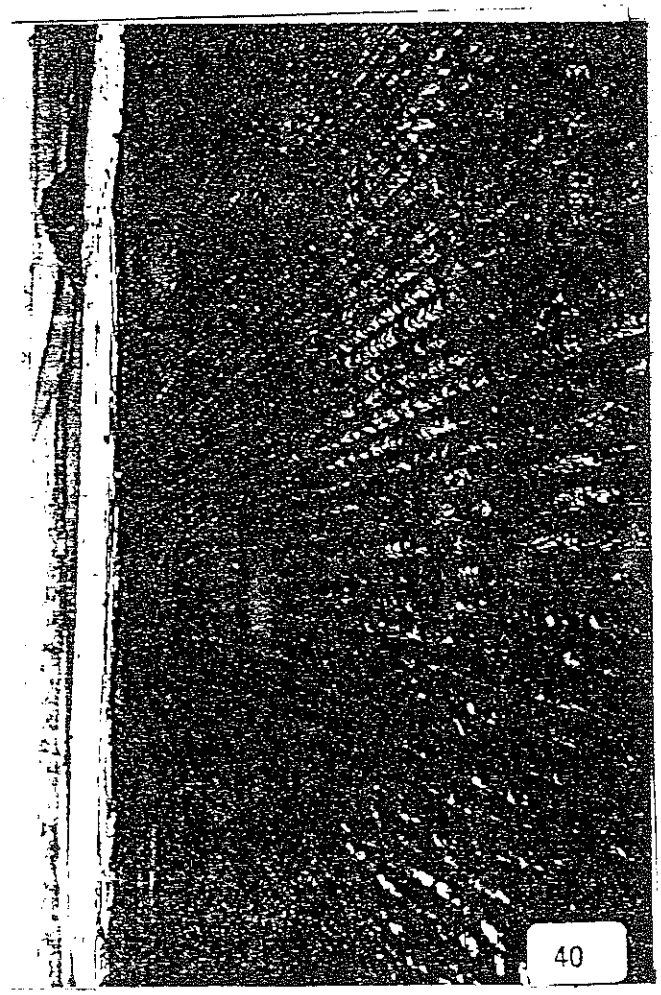

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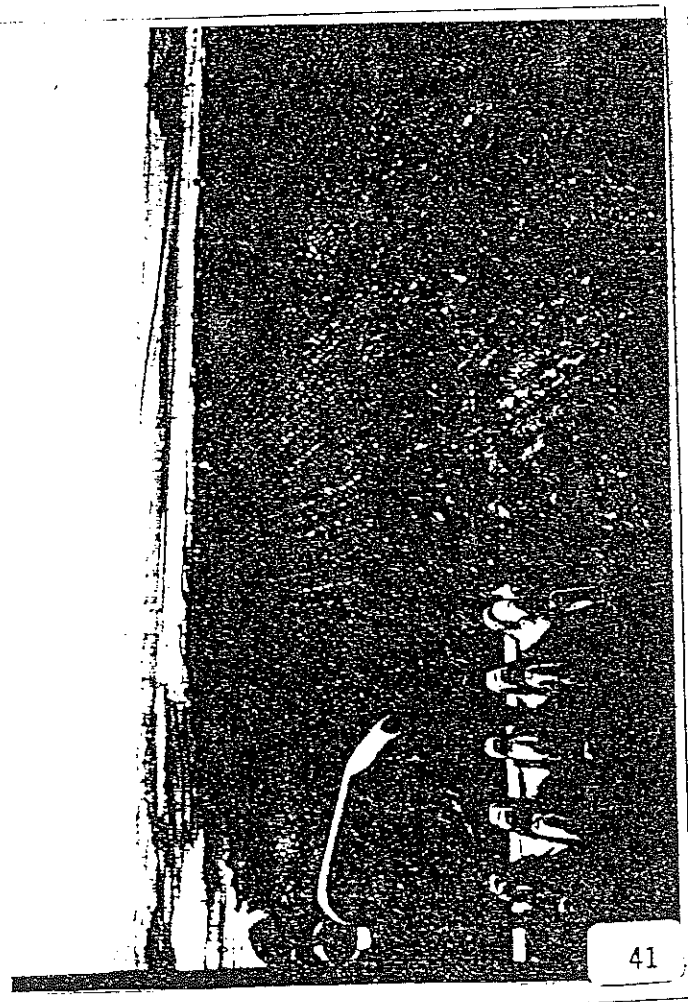

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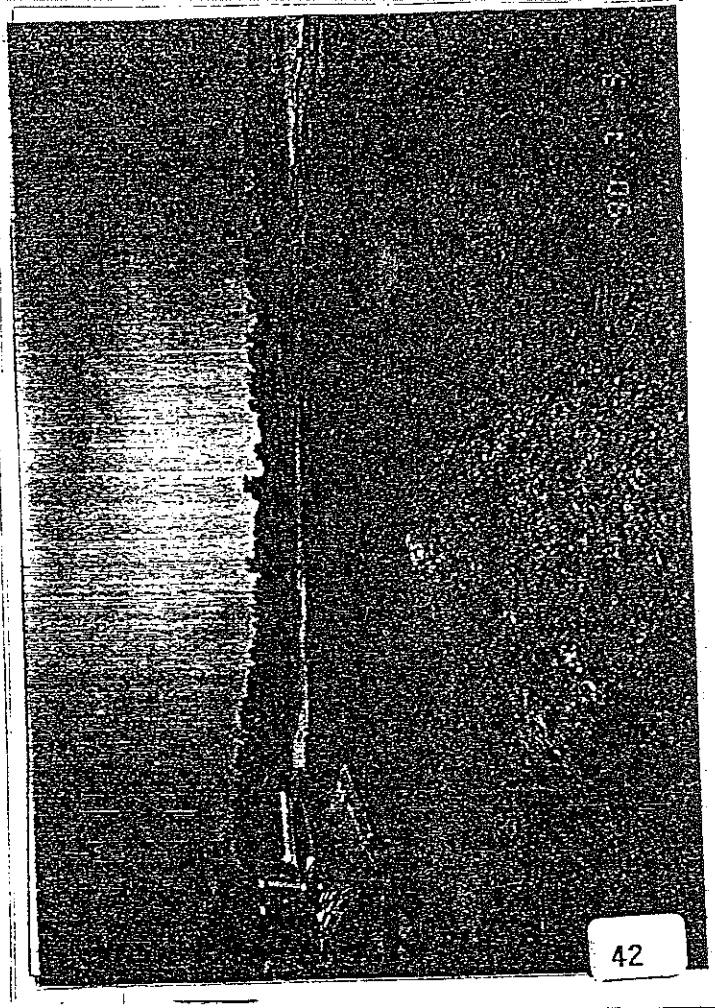

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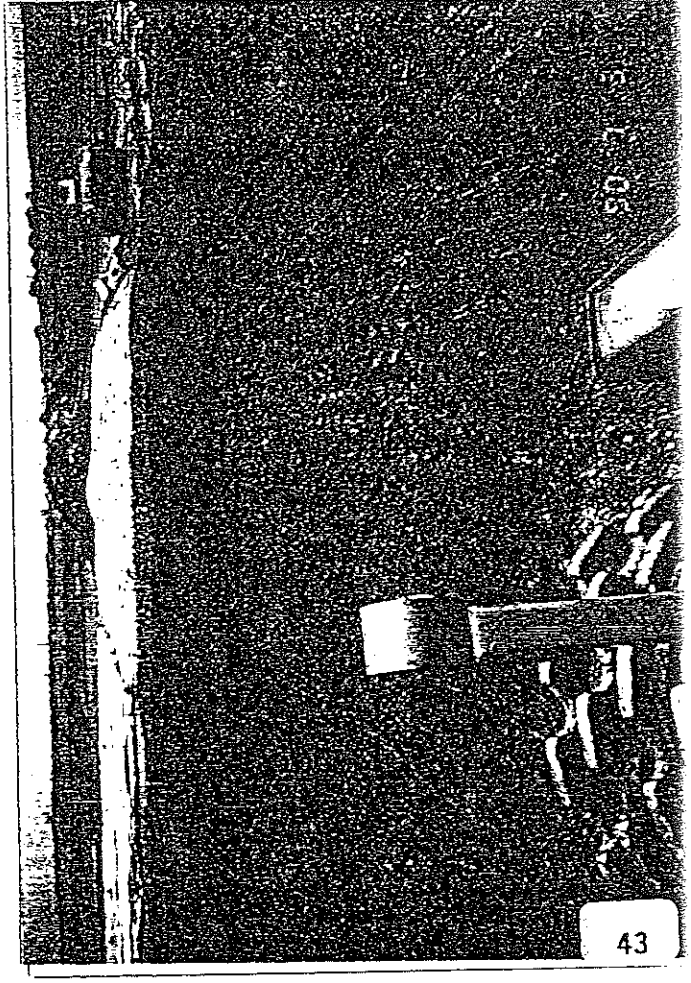

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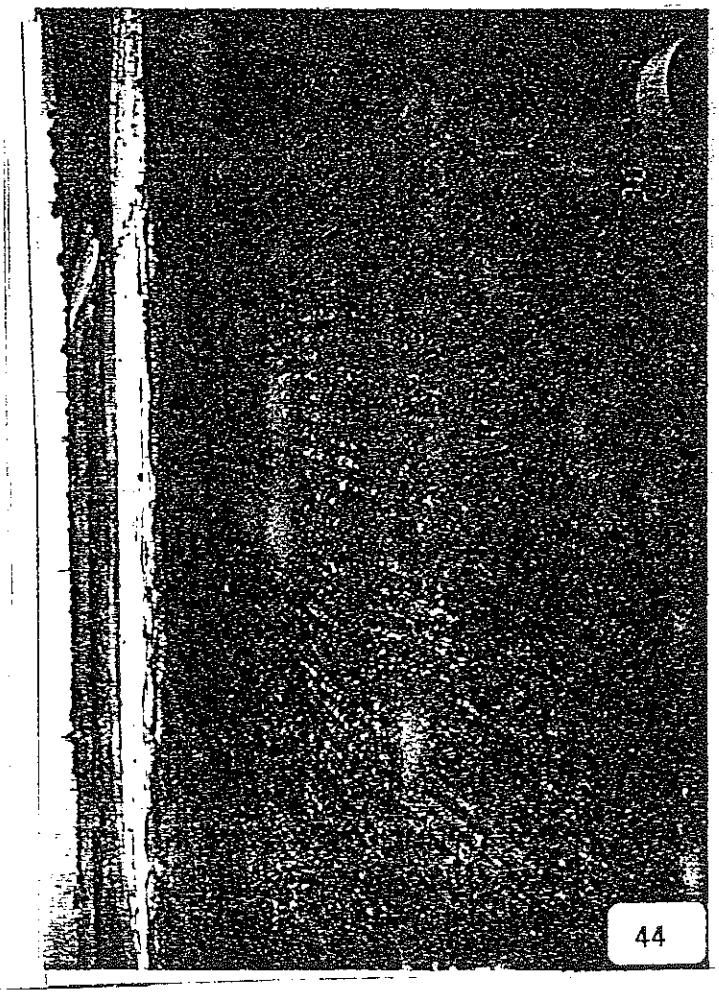

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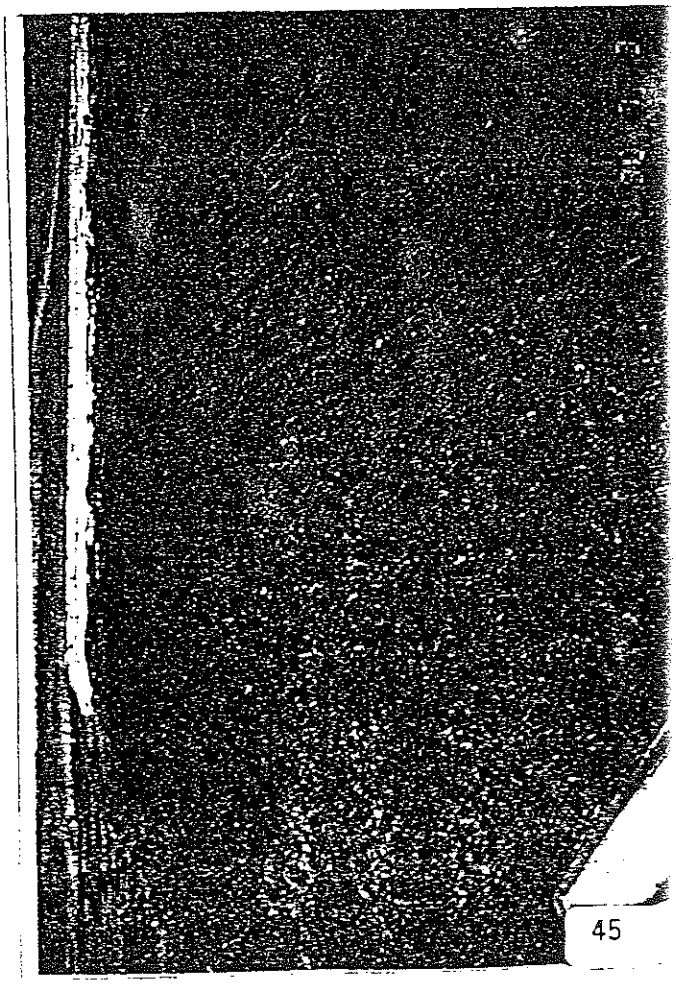

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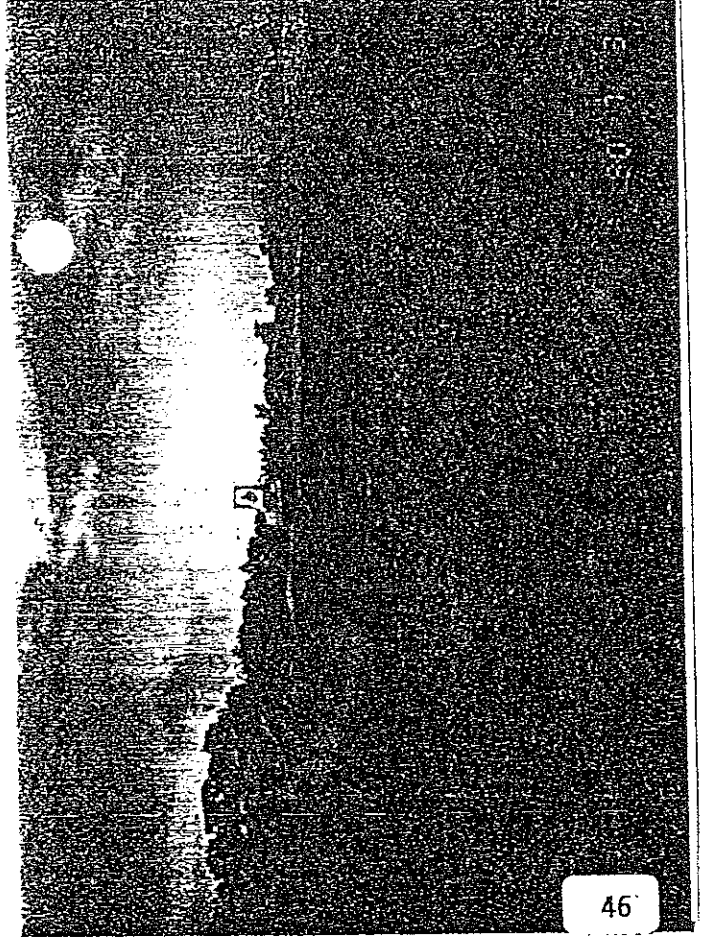

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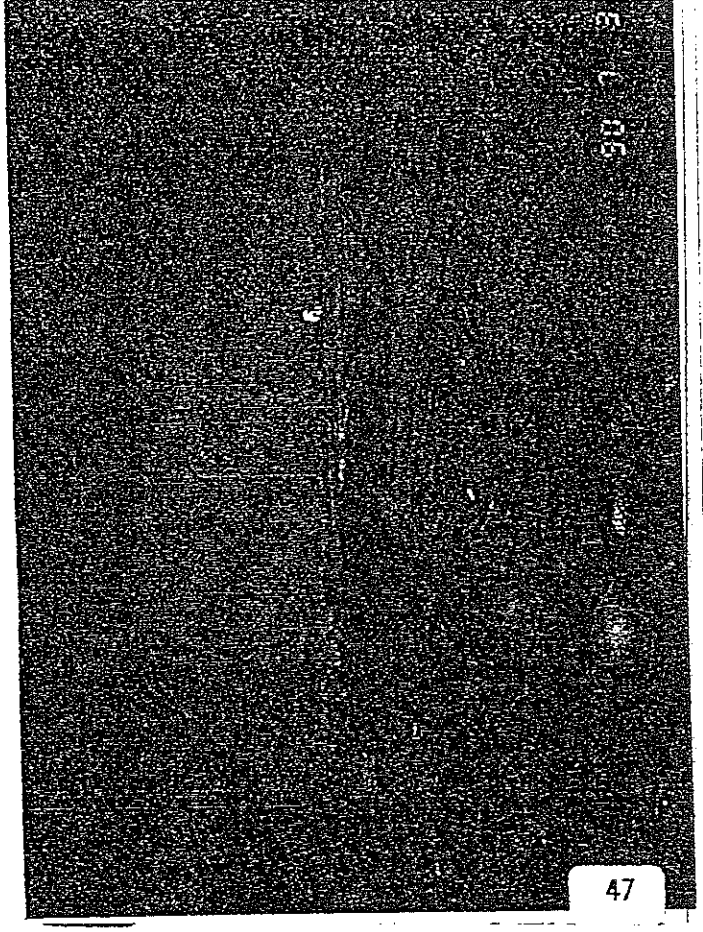

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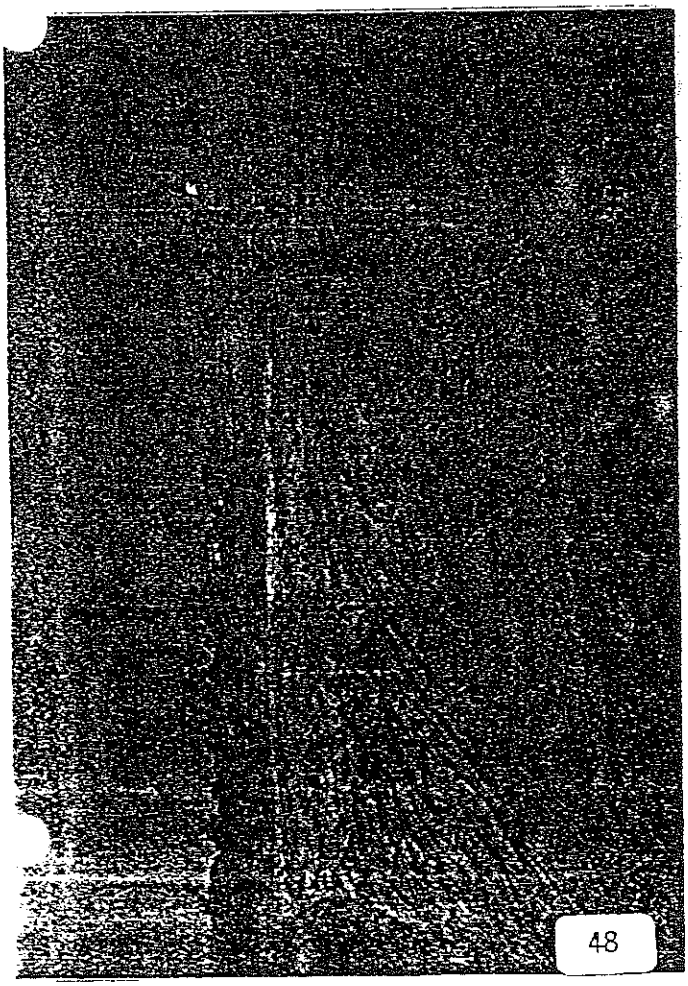

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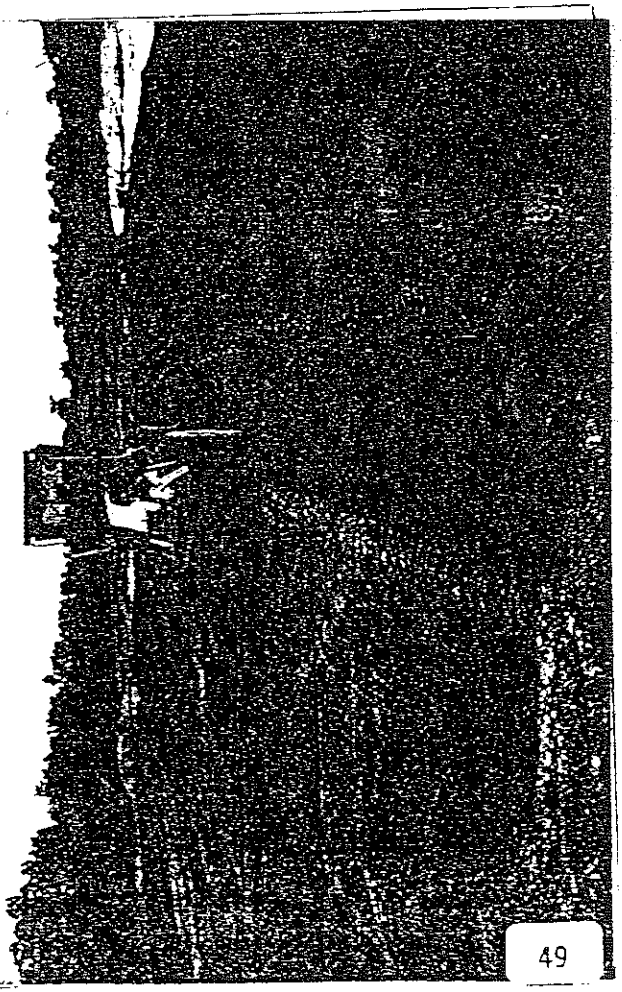

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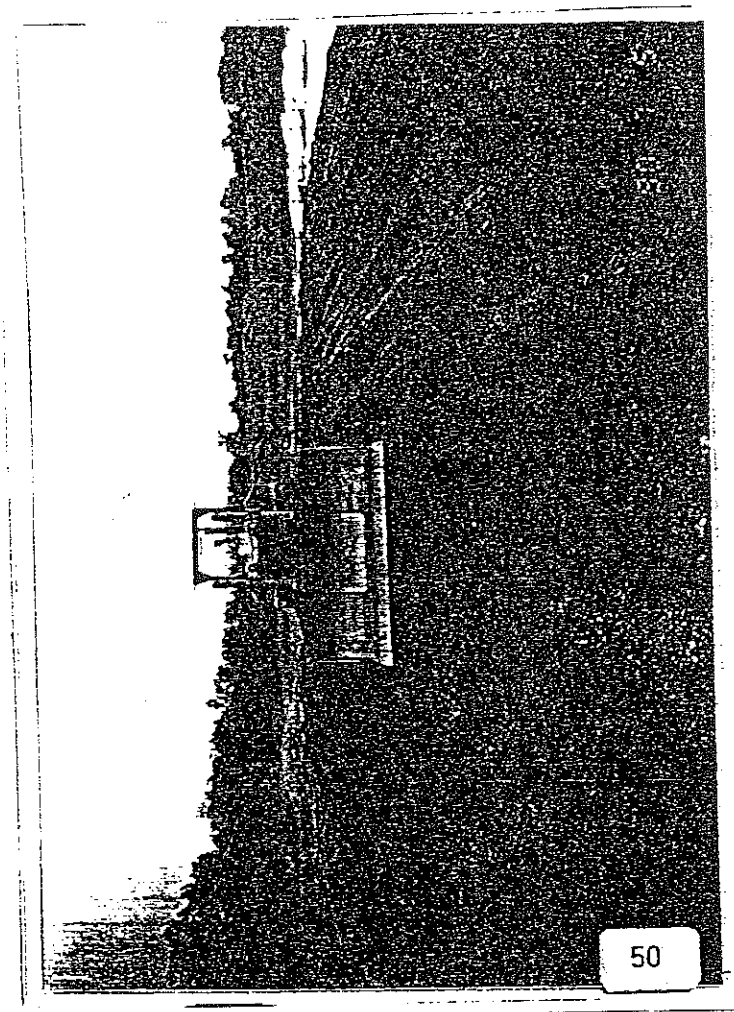

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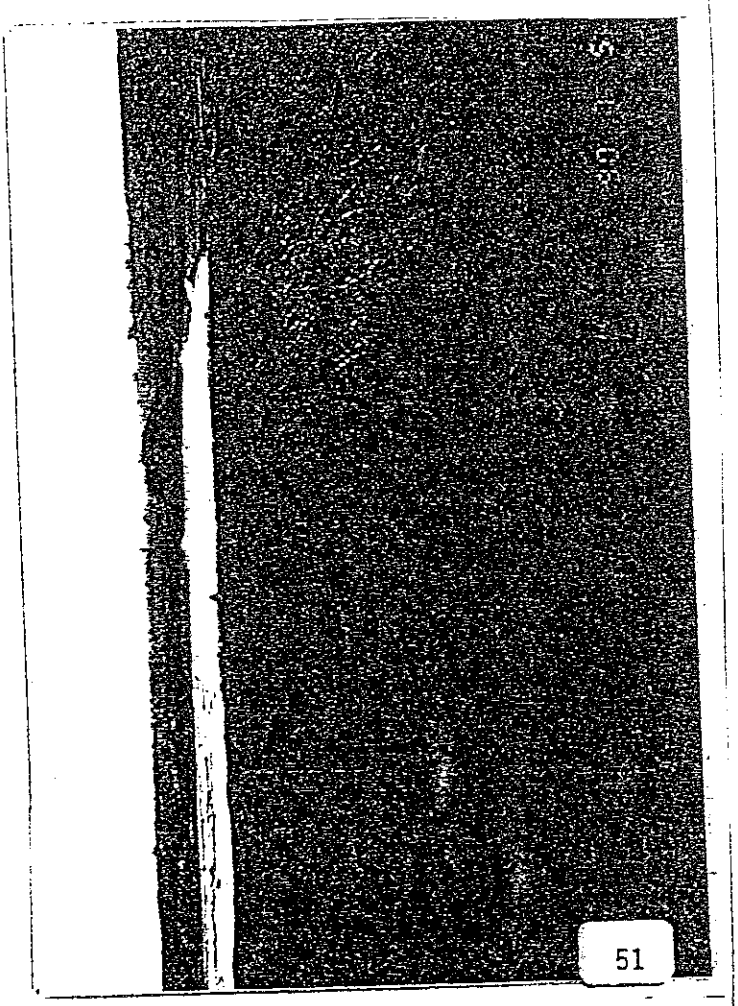

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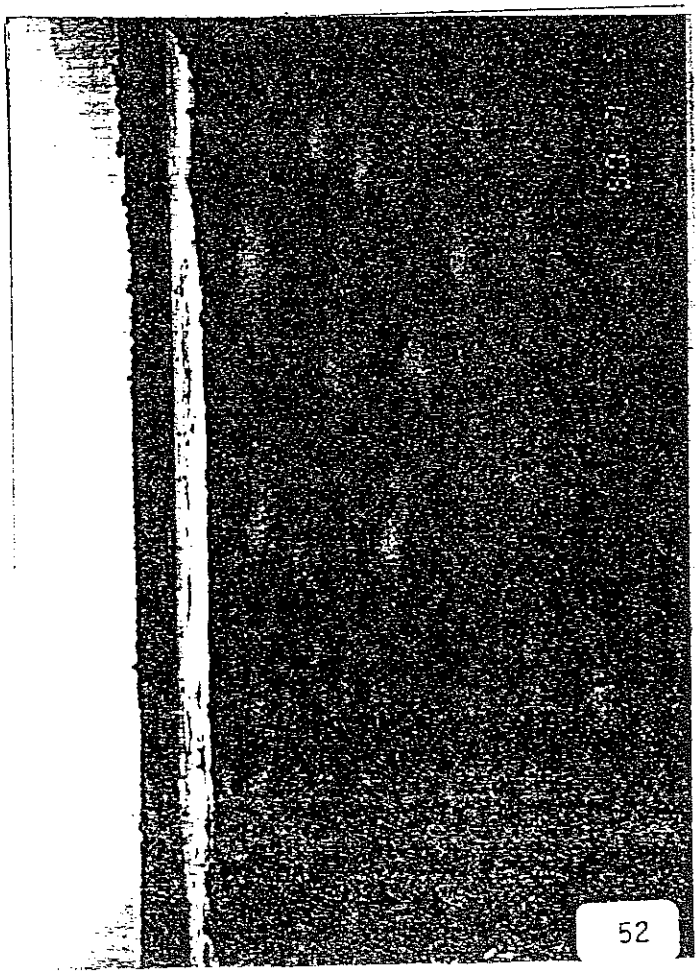

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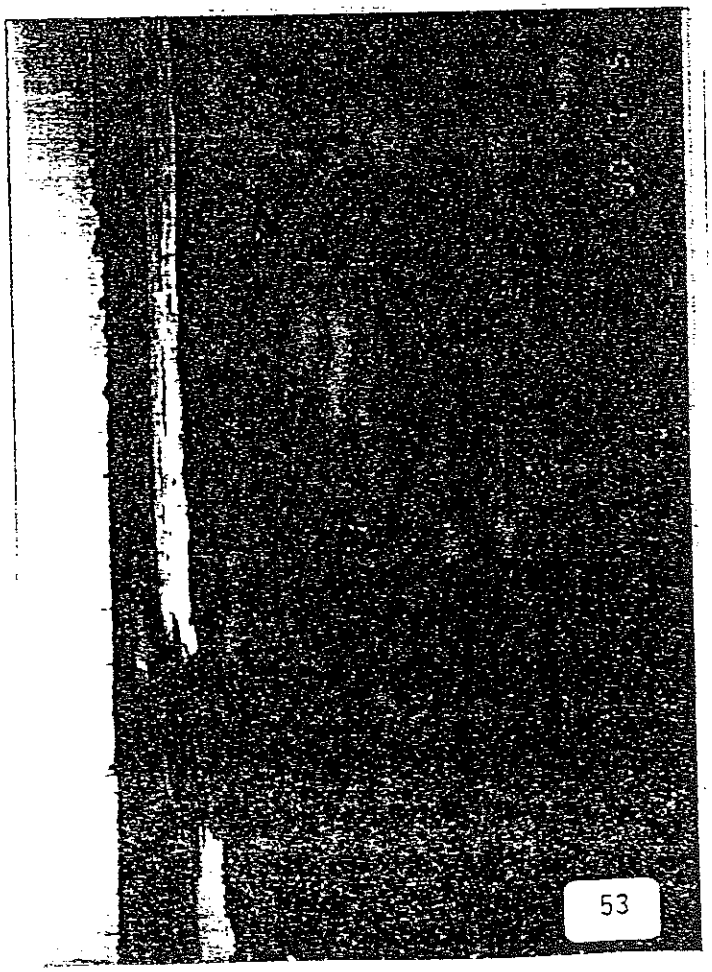

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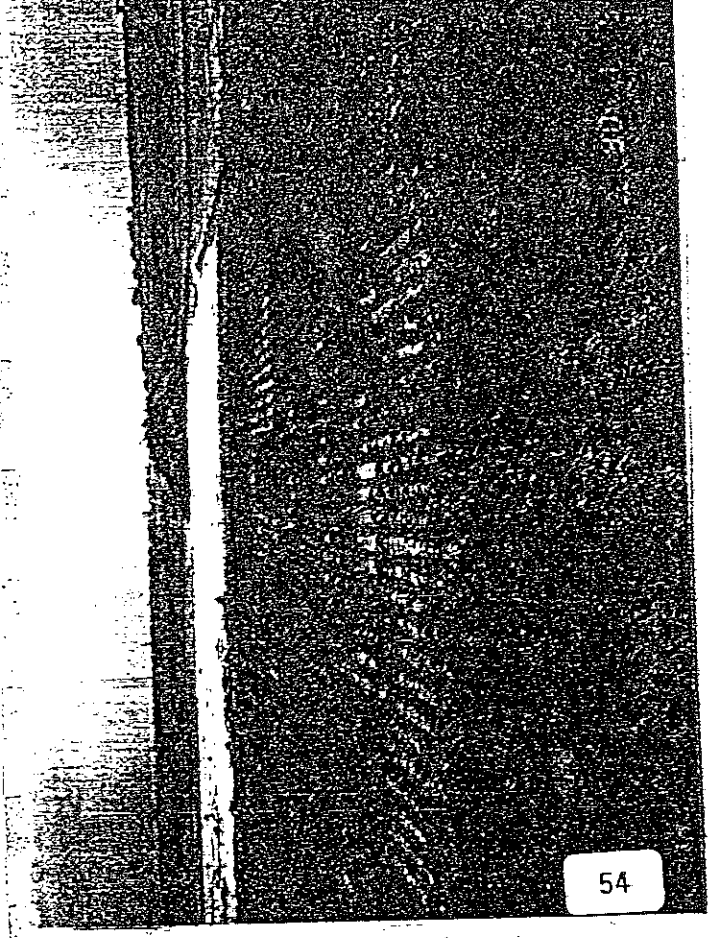

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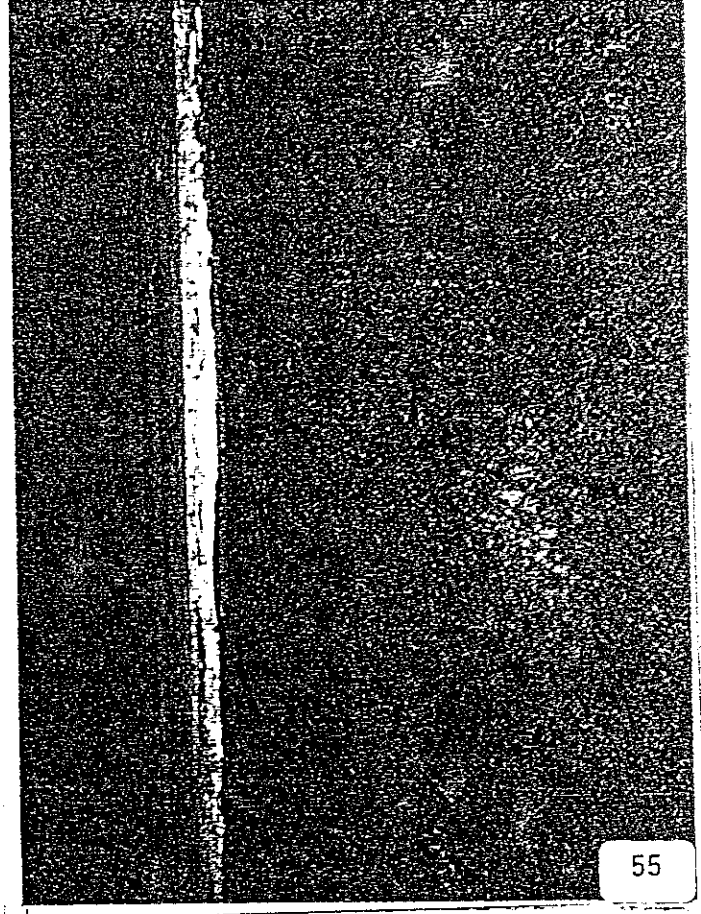

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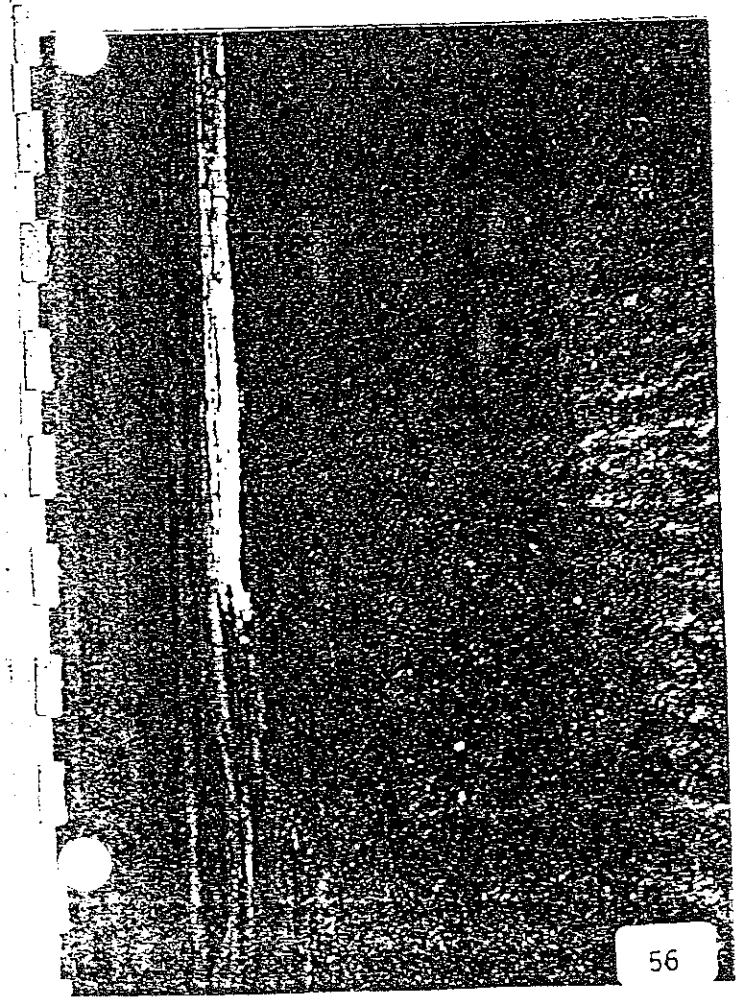

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