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POR-2285
(WT-2285)

Operation

SUN BEAM

SHOT JOHNIE BOY

PROJECT OFFICERS REPORT—PROJECT 1.11

SOILS SURVEY (U)

T. B. Goode, Project Officer

A. L. Mathews

U. S. Army Engineer
Waterways Experiment Station
Vicksburg, Mississippi

Issuance Date: May 17, 1963

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ABSTRACT

A soil survey was conducted in the vicinity of ground zero prior to the Johnie Boy Event to provide data for Program 1 projects on the physical and mineralogical characteristics of the subsurface soils to a depth of 50 feet and to provide holes for the installation of instruments and sand columns to depth of 80 feet.

Field and laboratory tests were conducted to determine the water content, gradation, density, and mineralogical composition of the natural soils and the compaction characteristics of the soil used for backfill around the detonation device.

Drilling and testing procedures used in conducting the soil survey and the results obtained are presented in this report. The results indicate the soil to be typical alluvial fan deposits of gravelly sand containing some silt and occasional cobbles and boulders.

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CHAPTER 1

INTRODUCTION

1.1 OBJECTIVES

The overall objectives of Project 1.11, Soils Survey, were to: (1) obtain preshot data on the character and certain physical properties of the natural soil to a depth of 80 feet in the vicinity of ground zero for the Johnie Boy Event at the Nevada Test Site, (2) provide compaction control on the backfill material placed around the detonation device, and (3) provide holes for the installation of instruments and sand columns. The soils data were to be used by agencies participating in Projects 1.2, 1.5, 1.9, 1.13, and 9.1 in analyzing blast effects as related to: earth motion, mass throwout, shock spectra, crater studies, earth rotation motion studies, and device emplacement.

Specific objectives of the soils survey were to: (1) provide 5 5/8-inch diameter and 3-inch diameter holes ranging from 10 to 80 feet deep for instrument and sand column installations, (2) determine stratification, type, water content, and mineral content of the subsurface soils in the vicinity of ground zero and at the instrument locations for Projects 1.2, 1.9, and 1.13, (3) determine by field and laboratory tests the type, water content, and density of the in situ soil at ground zero from the surface to the depth of emplacement of the detonation device, (4) design and install backfill around the device having the same density as the in situ density of the soil excavated from the device emplacement pit for Project 9.1, and (5) determine by laboratory tests the size distribution of throwout material collected after the shot by Project 1.5.

The specific objectives were accomplished by: (1) drilling holes by rotary drilling methods for the installation of instruments and sand columns, (2) obtaining soil samples from borings and a test pit, making visual classification of the samples, and performing desired laboratory tests on some of the samples, (3) performing compaction control during the placement of backfill around the detonation device, and (4) performing sieve analyses on mass throwout samples collected by Project 1.5.

1.2 BACKGROUND

Representatives of all agencies participating in the projects were contacted to establish specific soils survey requirements and to exchange ideas on the best possible methods for drilling, sampling, and testing the soils.

1.2.1 Correspondence and Conferences. The soils survey program conducted by the U. S. Army Engineer Waterways Experiment Station (WES) was initiated and formulated through the following conferences: (1) Johnie Boy coordination meeting, 6 June 1962, Nevada Test Site (NTS), Mercury, Nevada, and (2) informal conferences at NTS with Program Directors and Project Officers before and during construction to determine the soil survey requirements of each project and to arrange schedules, methods, and procedures to accomplish the requirements of each project on schedule.

1.2.2 Projects and Requirements. A list of projects and agencies and their requirements for soils survey work are shown in Table 1.1. The requirements fall into three groups: (1) holes, instrumented and backfilled; (2) holes backfilled with colored sand only; and (3) emplacement of detonation device assembly and backfilling around and over the assembly.

The sampling and testing accomplished to fulfill the soils survey requirements of the projects listed in Table 1.1 are summarized in Table 1.2.

1.2.3 Soils Survey Plan. Soils data, available prior to this investigation, on the characteristics of the subsurface soils in the area consisted only of general lithographic logs of borings made previously in the general vicinity of the test site. Therefore, a reconnaissance of the area in the immediate vicinity of the test site was made by WES engineers during the latter part of May and first part of June 1962. At this time, some excavations had been made for installations by other projects and visual inspections of the subsurface soils were made in these excavations. As a result of these inspections and from information derived from the lithographic logs of borings previously made in the vicinity, it was concluded that the subsurface soils consisted of typical alluvial fan deposits of gravelly sand containing some silt and occasional cobbles and boulders. Also, it appeared that the general stratification and properties of the soils were fairly uniform over the area and to the depth of primary interest to projects requiring subsurface soils data. It was concluded from the results of the preliminary study of the general soil conditions and from conferences with the agencies participating in the program requiring soils data that adequate data for all projects could be obtained from tests on the samples from one general sample boring and one test pit and from comparison of these data with visual observation of material from some of the holes drilled for the installation of instruments and sand columns.

Sampling operations were conducted during the boring of holes for the installation of instruments and sand columns. The in situ density of the soil in the vicinity of the detonation device was determined in advance of the installation so that backfill material of closely matching density could be prepared. The location of all borings and the test pit are shown in Figure 1.1.

TABLE 1.1 PROJECTS, AGENCIES, AND REQUIREMENTS

Project	Agency	Requirements
1.13	Air Force Special Weapons Center (AFSWC)	6 holes, 5 5/8-inch diameter, 11 feet deep, instrumented and backfilled
1.2	Waterways Experiment Station (WES)	6 borings, 8-inch diameter, 11 feet deep, instrumented and backfilled
1.5	WES	100 mass distribution throwout samples collected
1.9	WES	14 holes, 5 5/8-inch diameter, 10 to 57.5 feet deep, backfilled with colored sand
9.1	Sandia Corporation (SC)	Detonation device assembly emplacement in pit approximately 3 feet by 6 feet by 3 feet deep, and backfilled

TABLE 1.2 SUMMARY OF SAMPLING AND TESTING REQUIREMENTS

Projects	Phase	Field Sampling and In Situ Testing	Field Laboratory Testing	WES Laboratory Testing
All projects	Initial	General samples from boring JB-1 to depth of 50 feet	None required	9 sieve analyses 9 water content determinations 9 mineralogical analyses
1.13	Installation	None required	None required	None required
1.2	Installation	None required	None required	None required
1.5	Posttest	None required	100 sieve analyses	None required
1.9	Installation	None required	None required	None required
9.1	Preliminary	1 test pit, approximately 2 feet by 2 feet by 2 1/2 feet deep, 20 feet NE of GZ with all excavated material retained for density determinations	1 density determination	1 water content 1 classification 1 sieve analysis
		1 sack sample of concrete sand	3 compaction tests 2 water content determinations	
	Installation	1 density sample of compacted backfill at GZ	1 density determination	1 sieve analysis

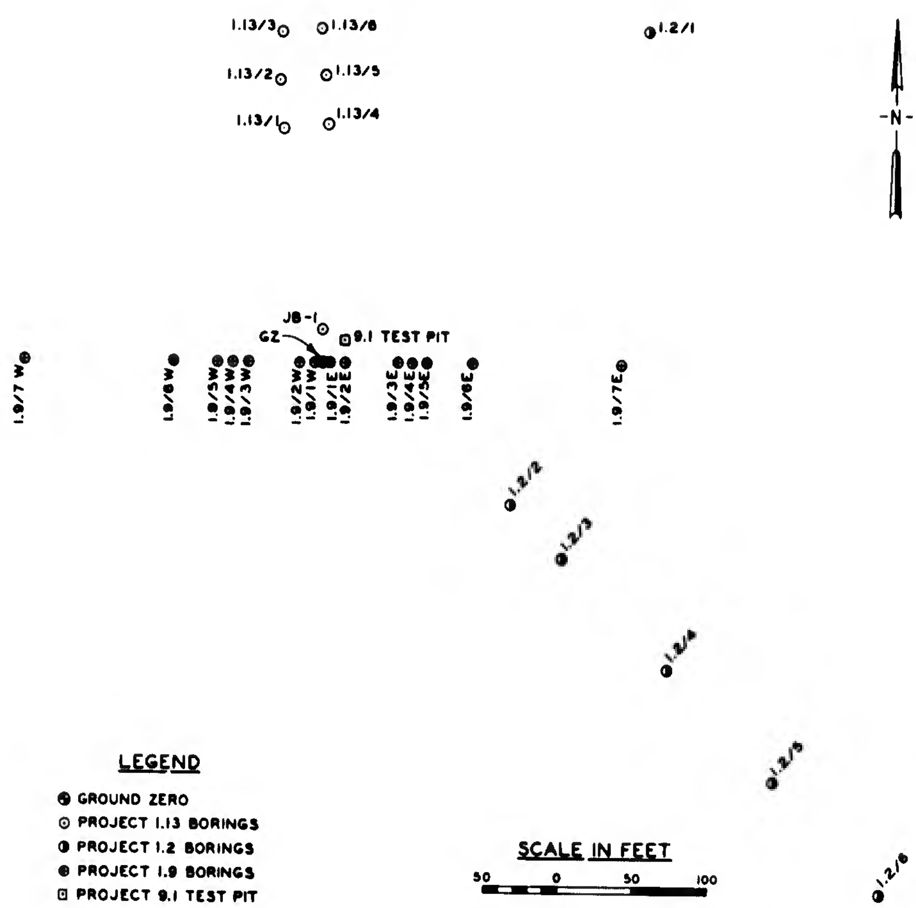


Figure 1.1 Plan of borings and test pit location.

CHAPTER 2

PROCEDURES

The soil survey project officer, drill crews, and all soil exploration and testing equipment were furnished by WES. A headquarters operations office and field soils laboratory had been set up previously at Camp Mercury, NTS, for soil survey work on other projects. These facilities were used for the soils survey for this project. Field exploration and testing equipment used on the project included: (1) two truck-mounted, rotary drill rigs with accessory drilling equipment, and (2) apparatus for determining in-place density of soil. The field laboratory was equipped with the necessary apparatus for the determination of water content, density, grain size, and compaction characteristics of soils. Field operations were started at the Johnie Boy site on 27 June 1962.

2.1 BORING AND SAMPLING

General samples for classification, water content, and mineralogical analysis were obtained from boring JB-1.

2.1.1 Borings. Boring JB-1, instrumentation holes, and holes for sand columns were bored with truck-mounted rotary drill rigs, using tricone roller bits to advance the holes and compressed air to remove cuttings from the holes. Some of the instrumentation and sand column holes required casing to prevent sloughing of the side walls. The casing was withdrawn during backfilling operations.

2.1.2 Sampling. General samples were taken from boring JB-1 with a split-spoon sampler from the surface to a depth of 21.5 feet. The split-spoon samples were obtained by driving a 1 3/8-inch ID by 2-inch OD split-spoon sampler 18 inches into the soil for each sample by means of a 300-pound drive hammer with a drop of 30 inches, operated by means of a cathead on the drill rig. From a depth of 25 feet to a depth of 50 feet, general samples were obtained by catching the cuttings ejected by compressed air from the holes as the holes were advanced with a tricone roller bit. In this latter method of sampling, all of the material removed from each 5-foot increment of depth was caught; then a representative sample was taken from the mass. After visual classification had been made in the field, the samples were sealed in pint glass jars for further testing. As will be discussed under Chapter 3, Results, sampling operations caused changes in in situ soil gradations by fracturing and pulverizing gravel and cobble sizes.

2.2 TESTS IN THE FIELD

Tests performed in the field included classification, water content, density, and compaction.

2.2.1 Classification of Soils. All samples were classified in the field by means of visual descriptions based on the Corps of Engineers Unified Soil Classification System (see Reference 1).

2.2.2 Water Content. All water content determinations were made by standard procedures, using an electric oven.

2.2.3 Density. Satisfactory undisturbed samples of the soils could not be taken, due to cobbles and gravel in the soil which is predominantly a gravelly sand. Therefore, the density of the soil was determined by the sand-displacement method in a test pit approximately 2 feet square and 2 1/2 feet deep, located 20 feet northeast of ground zero. The test pit was excavated carefully by hand and all of the soil loosened in excavating the pit was saved and weighed and the water content determined. The pit was then backfilled under controlled conditions with concrete sand and the weight of sand required to fill the holes was determined. The density of the sand backfill was determined by sampling with a box density sampler which had been previously calibrated with the same sand, and thus the volume of the pit could be computed. The in situ unit weight of the soil was then computed by dividing the weight of the soil removed from the pit by the computed volume of the pit.

2.2.4 Design of Backfill. A sample of concrete sand was obtained from the stockpile at well 5-B, Area 5, NTS, for the basic material for backfilling around the detonation device. Compaction tests showed that the sand alone could not be compacted to the density of the in situ soil. Experiments were then performed with a sand and Baroid (ground barite) mixture to obtain a backfill material with the desired density. The experiments were performed in a calibrated steel mold about 23 inches in diameter and 13 inches deep. The sand-Baroid mixture was placed in about 3-inch lifts and compacted by rodding each lift for two complete coverages with a 1 1/2-inch wooden rod, 5 feet long, which weighed 3 1/2 pounds.

2.2.5 Shipment of Samples. Samples were transported by truck to WES for testing after processing through RAD-SAFE and the DOD support group. Samples of the soil excavated from the test pit and samples of the sand used for backfill were sealed in 5-gallon cans, and samples from boring JB-1 were sealed in glass jars.

2.3 LABORATORY TESTS

Certain soil testing was performed by the WES soils and concrete laboratories. Tests performed included classification, sieve analysis, water content, and mineralogical analysis.

2.3.1 Classification and Water Content. Water content determinations were made using standard oven-drying procedures. The classification of the samples was based on results of the sieve analyses, using the Corps of Engineers Unified Soil Classification System (see Reference 1).

2.3.2 Mineralogical Analyses. The mineralogical analyses were performed using petrographic techniques.

Each of nine soil samples from boring JB-1 was separated by sieving into size ranges suitable for petrographic analysis. The sieved samples were examined in varying detail visually and with stereomicroscopes to determine their general composition and to detect any differences between samples.

Selected particles of the several rock varieties in the 1/2 inch to No. 4 sieve sizes were ground and then examined on the X-ray diffractometer. Representative specimens of the fractions retained on the No. 8 sieve, No. 50 sieve, and that fraction passing No. 200 sieve, of the odd-numbered samples (1, 3, 5, 7, 9), and a single composite sample of the even-numbered samples (2, 4, 6, 8), were ground and examined by X-ray diffraction and X-ray emission spectroscopy. X-ray diffraction patterns of all of the samples examined were made on an XRD-5 diffractometer, using nickel-filtered copper radiation; most of the patterns were made at 50 kvp and 16 ma, but when clay minerals were expected to be present, the tube was operated at 30 kvp and 27 ma. Scanning speeds, collimation, and time constants were varied as appropriate. X-ray emission scans were made for all elements of atomic numbers above 13 (aluminum) in a helium atmosphere with a chromium target X-ray tube at 50 kvp and 50 ma, using an EDT (Ethylene Diamine Ditartrate) analyzing crystal.

The sodium and potassium contents of a composite of each sample were determined, using appropriate fusion techniques to render the alkali metals soluble, and a flame spectrophotometer.

CHAPTER 3

RESULTS

3.1 PROJECTS 1.13, 1.2, and 1.9

<u>3.1.1 Borings</u>. A total of 26 holes for the installation of instruments and sand columns were bored for Projects 1.13, 1.2, and 1.9, and one hole, JB-1, was bored to obtain samples for testing. A tabulation of the holes is shown in Table 3.1.

<u>3.1.2 Field Classification</u>. The field classification of the soil removed from Projects 1.13 and 1.9 holes showed gravelly sand with cobbles to depths of 3 feet to 20 feet underlain by sand with occasional gravel cobbles to the maximum depths of the holes. The depth of the uppermost stratum containing the greater percentage of cobbles in the Projects 1.13 and 1.9 holes varied irregularly but generally was deepest near ground zero. This compared very well with the stratification in boring JB-1, as shown in Table 3.2, which showed that the greater percentage of cobbles was encountered in the upper 20 feet of the hole.

<u>3.1.3 Laboratory Classification and Water Content</u>. Sieve analyses and water content determinations were made in the WES soils laboratory on the soil samples from boring JB-1. The gradation and water content of these samples are shown in Figures 3.1 through 3.3. The gradation curves show

that the largest particles were about 1 inch size in the samples from a depth of 4.2 feet to a depth of 30.0 feet; however, the driller's log (Table 3.2) shows that gravel and cobbles were encountered to a depth of 20 feet and occasional cobbles from a depth of 20 feet to the bottom of the hole. Therefore, samples obtained above a depth of 30 feet are not truly representative of the in situ soils, as a considerable quantity of the coarse fraction of the samples is undoubtedly composed of fragments of gravel and cobbles fractured during drilling operations. The gradation curves for the samples below a depth of 30 feet are considered more representative of in situ soils, as only occasional gravel and cobbles were encountered below 30 feet. Consequently, fractured particles in the samples constitute a very small proportion of the material tested. The water content of the samples obtained from cuttings may be slightly lower than in situ soils, as some drying of the samples probably occurred during drilling operations with compressed air.

3.1.4 Mineralogical Analysis. Stereomicroscope examination of the larger sieve sizes of the nine samples indicated that they were composed of dense light gray to pink cryptocrystalline and glassy porphyritic volcanic rocks, vesicular porphyries, and tan, highly weathered, somewhat fragile glassy particles exhibiting flow structure. The tan, glassy particles had highly weathered soft surfaces and white, more dense interiors. Highly weathered, glassy particles increased in number in the lower part of the hole, particularly in the cutting samples that were collected at the surface as they were being blown from the hole with compressed air. Almost all the particles were coated with a dusty, calcareous caliche-like coating. Part of the coating could be removed by washing with water, but diluted hydrochloric acid was needed to remove it completely. Selected particles, crushed and examined as immersion mounts under the petrographic microscope, were composed of small quartz and feldspar phenocrysts in exceedingly fine-grained cryptocrystalline to glassy matrices. Some contained numerous small magnetite, biotite, green amphibole, and other mineral grains as inclusions. Immersion mounts of the finer sizes were composed of rock fragments, glass shards, devitrified glass, quartz, feldspar, and accessory mineral grains, together with many extremely small secondary calcite grains from the coatings on the surfaces. The index of refraction of the glass was very close to 1.500; based on George's (see Reference 2) curves on index of refraction versus silica content, the silica content of the glass was about 73 percent.

X-ray diffraction patterns of selected particles of representative samples of the fractions retained on No. 8 and No. 50 sieves, and the fraction passing No. 200 sieve of the odd-numbered samples and of composite samples of the even-numbered samples, indicated that all were similar. All were composed of quartz, plagioclase and potassium feldspars, and calcite, with very minor to trace amounts of amphibole, ortho-pyroxene, biotite, and magnetite. Plagioclase feldspar was more abundant than potassium feldspar in every case. Minor amounts of very poorly crystalline montmorillonite, traces of chlorite, and a possible zeolite mineral of the Heulandite group were detected in the fine silt and clay size ranges but were not definitely detected in the patterns of the whole samples. A pattern of the caliche-like coating scraped from some of the larger particles indicated that it consisted of calcite and amorphous material, possibly opal or volcanic glass, and traces of quartz and feldspar. No clay minerals were detected. Calcite in the whole samples increased with decreasing particle size because the dusty caliche accumulated in the finer sizes. Although one of the large particles examined contained a considerable amount of cristobalite, cristobalite was not found in any of the patterns of the finer material, probably because the main cristobalite lines are interfered with by feldspar lines, making it impossible to detect small amounts of cristobalite when feldspars are major constituents. Most of the patterns show lower-than-normal intensities of the quartz and feldspar lines and a broad, poorly defined halo in the region extending from about 4.5 to 2.5 A; such patterns indicate igneous rocks that contain fairly high amounts of glass.

The emission patterns, like the diffraction patterns, were very similar to one another. The elements detected were silicon, potassium, titanium, calcium, and iron. None of the heavier elements that are sometimes present in trace amounts in volcanic rocks were detected. The X-ray tube and analyzing crystal used were most efficient for the lighter elements, but the diffraction patterns did not indicate significant amounts of minerals high in the heavier elements. The intensities of the analytical lines for silicon, potassium, and iron were relatively constant both within a given sample and from sample to sample throughout the depth of the hole. The intensities of the titanium and calcium analytical lines generally increased with decreasing particle size, indicating an increase in amounts of material containing these elements. The increase in the calcium content was due to the increase in the amount of calcite ($CaCO_3$) in the finer sizes, as shown in the diffraction patterns. The increase in the titanium content was probably due to the increase in the amount of highly weathered material that was associated with the fines. Although no titanium minerals were identified in the diffraction patterns, small amounts of titanium are known to substitute in the structures of clays, iron minerals, micas, and glass, which were all present in varying amounts in the samples.

The sodium and potassium oxide contents of the nine samples are shown in Table 3.3. The chemical results agree with the optical and X-ray indications that plagioclase was more abundant than potassium feldspar in most of the samples.

A summary of the mineralogical analyses follows:

a. All nine samples were similar, consisting principally of rocks ranging from soda dacite to rhyolite, with textures ranging from porphyries to tuffs and highly glassy rocks with flow structure shown by elongated bubbles. Most of the rocks examined contained some glass, with the amount increasing from the partially devitrified groundmass of the porphyries, to the tuffs, and to the almost entirely glassy rocks; the glasses were highly siliceous, about 73 percent SiO_2 as judged by index of refraction. Sodic plagioclase, quartz, glass, and potassium feldspar were the most abundant phases in the rocks.

b. The samples contained rocks and minerals in varying stages of weathering, ranging from relatively fresh to highly weathered, friable, spongy particles. Samples from depths below 21.5 feet appeared to be more weathered than samples from nearer the surface, and highly weathered glassy particles increased with increasing depth in the hole. The actual physical condition of the rock particles was, in most cases, masked by dusty, caliche-like coatings made up of calcite with some opal.

c. Because of the close relation among all of the samples from this series in chemical composition and physical condition, granting the minor variations from highly glassy to less glassy rocks, a complete mineralogical analysis was not made of each sample. Both sodium and iron were present in the rocks; on the average, sodium amounted to about 3.4 percent of each sample; iron amounted to considerably less, judging by the X-ray emission results and mineralogy. Magnesium-containing minerals were probably less abundant than the iron-bearing ones.

3.2 PROJECT 9.1

3.2.1 Test Pit. The density test performed in the test pit gave an average in situ density of the soil of 115.3 pcf and a water content of 2.9 percent. The gradation curve for a composite sample of the soil excavated from the test pit is shown in Figure 3.4. The field classification of the excavated pit is shown below:

Depth, ft	Classification and Remarks
0.0 - 0.7	Silt with roots, gravel, and cobbles to 6-inch size, medium loose
0.7 - 1.5	Silty sand and gravel, compact and hard
1.5 - 1.8	Silty sand and gravel with occasional cobbles, compact and hard
1.8 - 2.5	Silty sand and gravel with occasional cobbles, hard and slightly cemented

3.2.2 Backfill. The backfill material placed around the detonation device consisted of a dry mixture of 92 percent concrete sand and 8 percent Baroid by weight. The material was placed and compacted in 3-inch lifts to a density of 115.2 pcf with a 1 1/2-inch-diameter wooden rod, 5 feet long and weighing 3 1/2 pounds. The gradation curve for the sand used in the backfill material is shown in Figure 3.5.

3.3 PROJECT 1.5

Gradation curves of the 100 samples of throwout material collected after the shot were furnished to the Project 1.5 Project Officer for inclusion in the Project 1.5 POR (Reference 3) and therefore are not presented herein.

TABLE 3.1 SUMMARY OF SOIL BORINGS

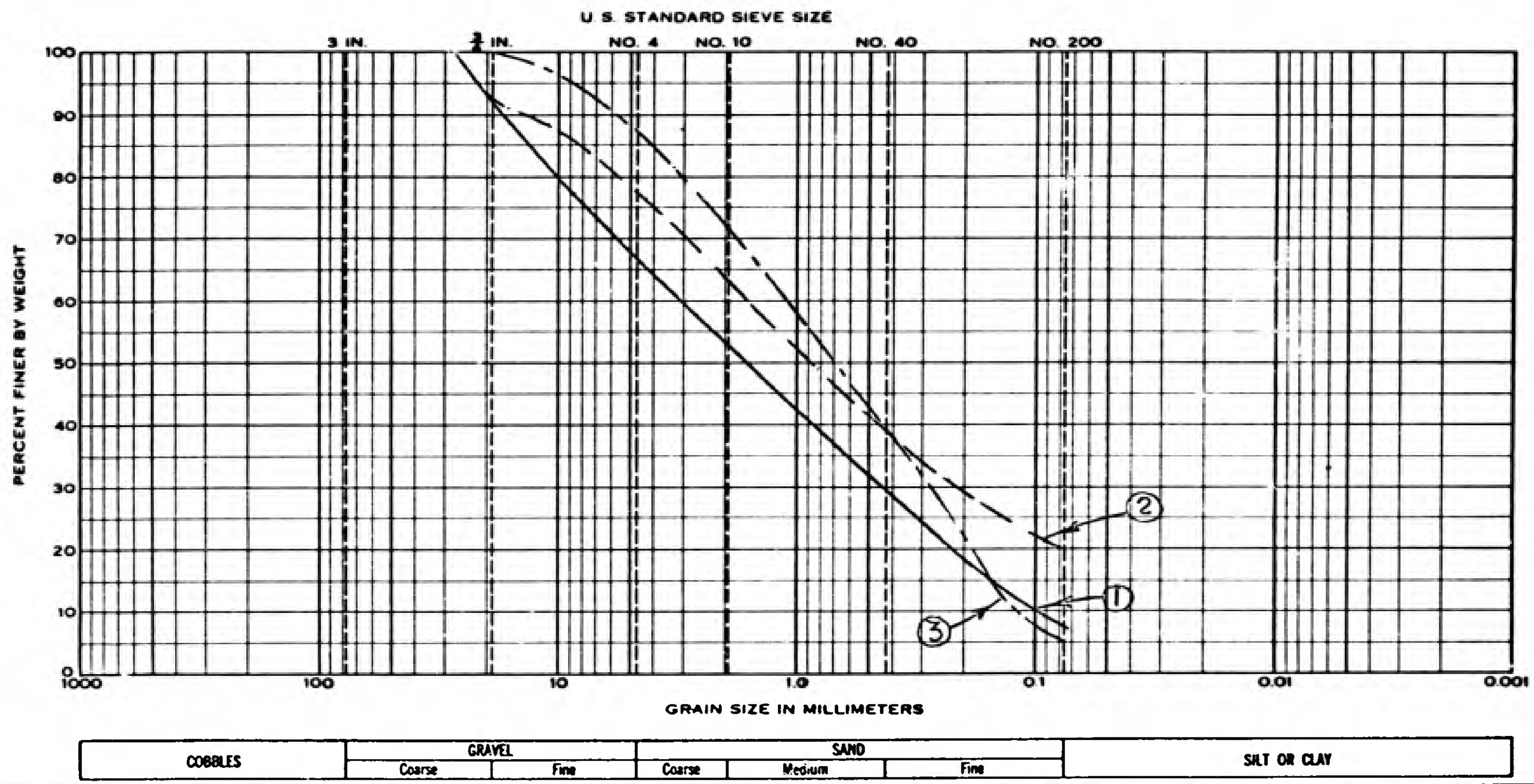
Project	Boring No.	Location: Distance from GZ in feet	Location: Bearing from GZ	Diameter in inches	Total Depth in feet
1.13	1.13/1	150.4	N 10°44'W	5 5/8	75
	1.13/2	180.8	N 9°47'W	5 5/8	77
	1.13/3	209.9	N 7°45'W	5 5/8	77
	1.13/4	150.8	N 0°40'E	5 5/8	80
	1.13/5	180.7	N 0°14'W	5 5/8	77
	1.13/6	210.3	N 0°57'W	5 5/8	77
1.2	1.2/1	300.1	N 46°12'33"E	8	11
	1.2/2	152.3	S 54°57'26"E	8	11
	1.2/3	201.7	S 52°30'04"E	8	11
	1.2/4	301.1	S 50°01'00"E	8	11
	1.2/5	400.9	S 48°45'58"E	8	11
	1.2/6	500.7	S 48°00'34"E	8	11
1.9	1.9/1-E	5	East	5 5/8	50
	1.9/2-E	15	East	5 5/8	40
	1.9/3-E	50	East	5 5/8	30
	1.9/4-E	60	East	5 5/8	30
	1.9/5-E	70	East	5 5/8	30
	1.9/6-E	100	East	5 5/8	20
	1.9/7-E	200	East	5 5/8	10
	1.9/1-W	5	West	5 5/8	50
	1.9/2-W	15	West	5 5/8	40
	1.9/3-W	50	West	5 5/8	30
	1.9/4-W	60	West	5 5/8	30
	1.9/5-W	70	West	5 5/8	30
	1.9/6-W	100	West	5 5/8	20
	1.9/7-W	200	West	5 5/8	10
All Projects	JB-1	20	North	5 5/8	50

TABLE 3.2 SOIL CLASSIFICATION, BORING JB-1

Sample No.	Depth of Sample, feet	Sampling Method	Laboratory Classification	Field Classification
1	4.2 - 5.7	Split spoon	Gravelly sand, SP-SM	Silty sand, gravel and cobbles from surface to depth of 20 feet
2	10.0 - 11.5	Split spoon	Gravelly silty sand, SP	
3	15.0 - 16.5	Split spoon	Gravelly sand, SP	
4	20.0 - 21.5	Split spoon	Gravelly silty sand, SM	Gravelly sand with occasional cobbles from 20 feet to 30 feet
5	25.0 - 30.0	From cuttings	Gravelly silty sand, SP-SM	
6	30.0 - 35.0	From cuttings	Sand, SP	Sand with occasional gravel and cobbles from 30 feet to 50 feet
7	35.0 - 40.0	From cuttings	Sand, SP	
8	40.0 - 45.0	From cuttings	Sand, SP	
9	45.0 - 50.0	From cuttings	Sand, SP	

TABLE 3.3 RESULTS OF DETERMINATIONS OF Na_2O AND K_2O

Sample	Na_2O %	K_2O %	Moles Na_2O	Moles K_2O	Moles K_2O/Na_2O
1	3.68	4.15	0.0594	0.0440	0.74
2	4.17	4.38	0.0673	0.0465	0.69
3	3.80	4.48	0.0613	0.0476	0.78
4	3.09	4.81	0.0498	0.0511	1.03
5	3.47	4.13	0.0560	0.0438	0.78
6	3.22	4.46	0.0519	0.0473	0.91
7	2.86	4.35	0.0461	0.0462	1.00
8	3.06	4.29	0.0494	0.0455	0.92
9	3.18	4.12	0.0513	0.0437	0.85
Average	3.39	4.36	0.0547	0.0462	0.86

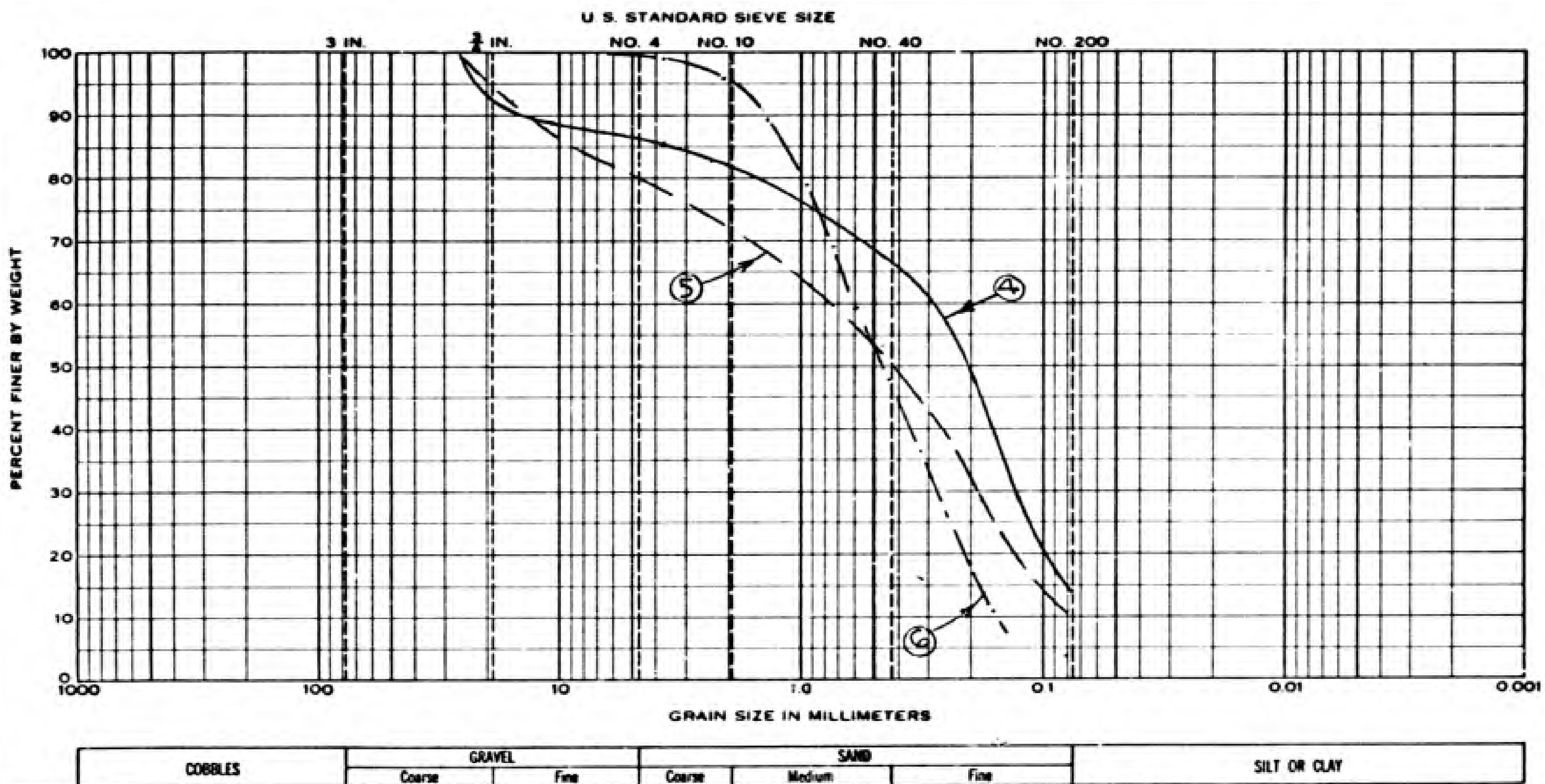


Sample No.	Elev or Depth	Classification	NatWC	LL	PL	PI	
1	4.2'-5.7'	GRAVELLY SAND, SP-SM	4.4	–	–	–	
2	10.0'-11.5'	GRAVELLY SILTY SAND, SP	1.6	–	-	–	
3	15.0'-16.5'	GRAVELLY SAND, SP	1.3	–	-	–	

Project	JOHNNIE BOY NTS
Area	18
Boring No.	JB-1
Date	AUG 1962

GRADATION CURVES

Figure 3.1 Gradation curves, Boring JB-1, Samples 1, 2, and 3.

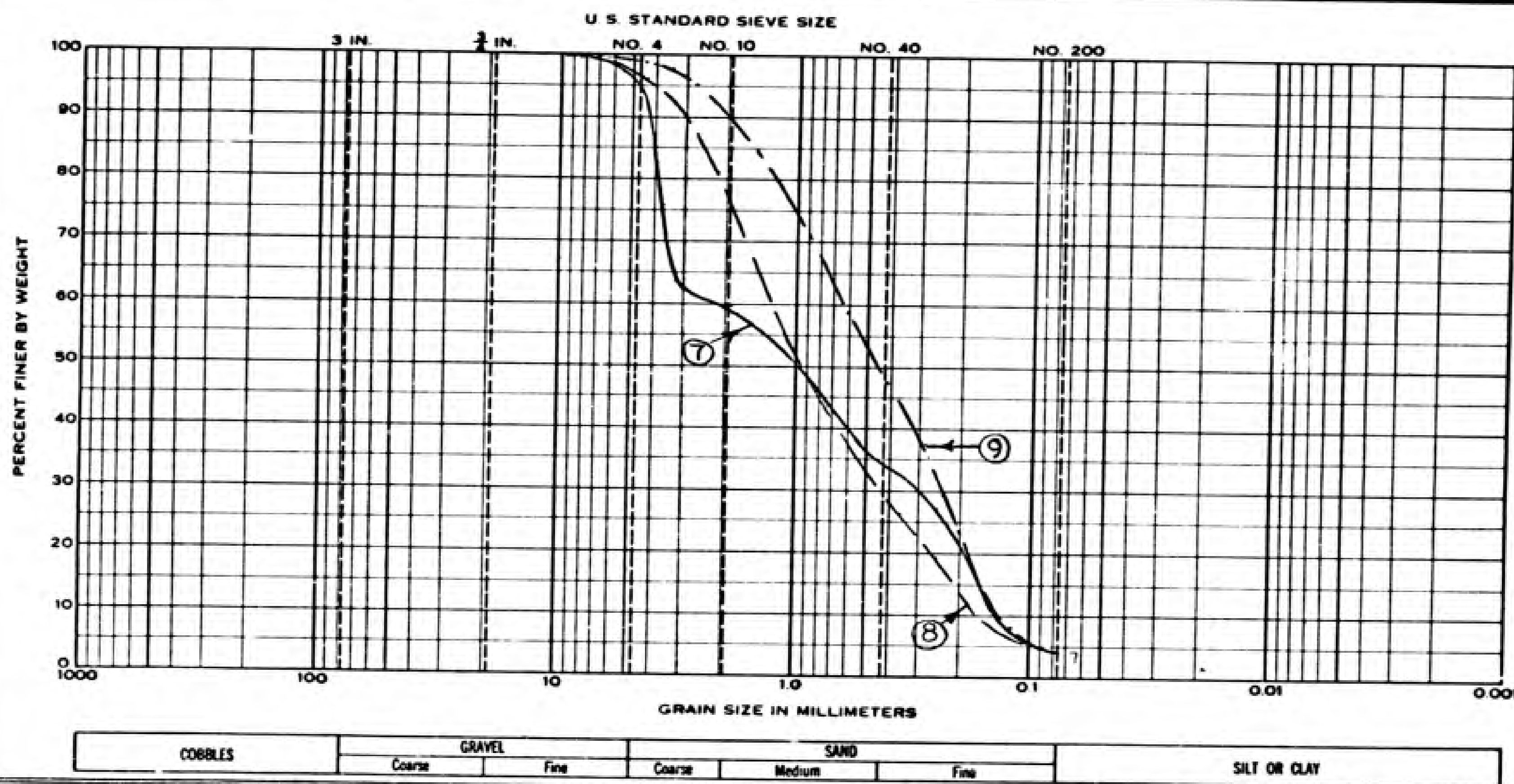


Sample No.	Elev or Depth	Classification	Nat WC	LL	PL	PI
4	20.0'-21.5'	GRAVELLY SILTY SAND, SM	10.1	–	–	–
5	25.6'-30.0'	GRAVELLY SILTY SAND, SP-SM	3.7	–	–	–
6	30.0'-35.0'	SAND, SP	6.5	–	–	–

Project JOHNIE BOY
NTS
Area 18
Boring No. JB-1
Date AUG 1962

GRADATION CURVES

Figure 3.2 Gradation curves, Boring JB-1, Samples 4, 5, and 6.



Sample No.	Elev or Depth	Classification	Nat W/C	LL	PL	PI
7	35.0'-40.0'	SAND, SP	5.6	–	–	–
8	40.0'-45.0'	SAND, SP	5.4	–	–	–
9	45.0'-50.0'	SAND, SP	2.4	–	–	–

Project: JOHNIE BOY NTS

Area: 18

Boring No. JB-1

Date: AUG 1962

GRADATION CURVES

Figure 3.3 Gradation curves, Boring JB-1, Samples 7, 8, and 9.

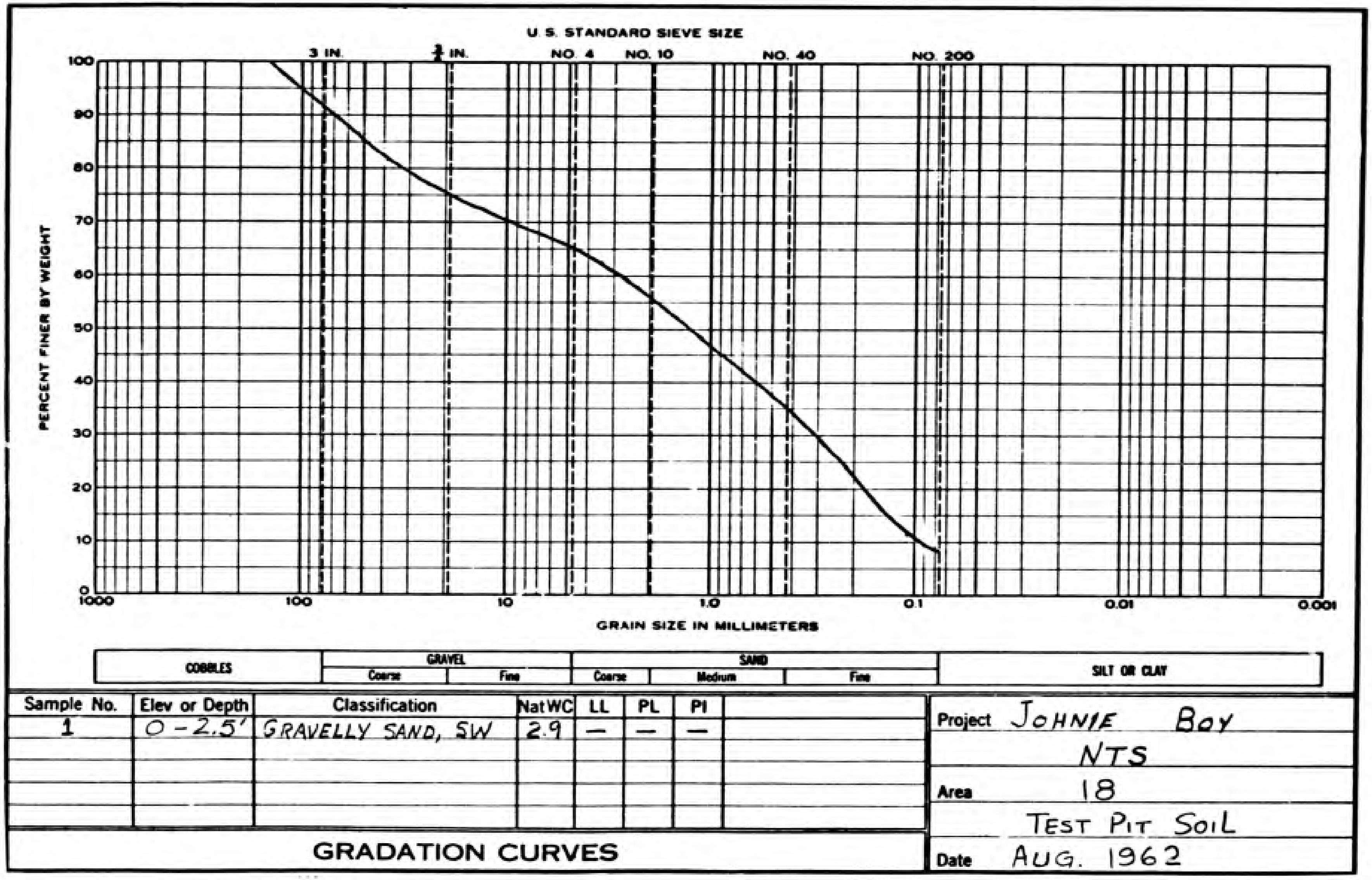


Figure 3.4 Gradation curve, test pit soil.

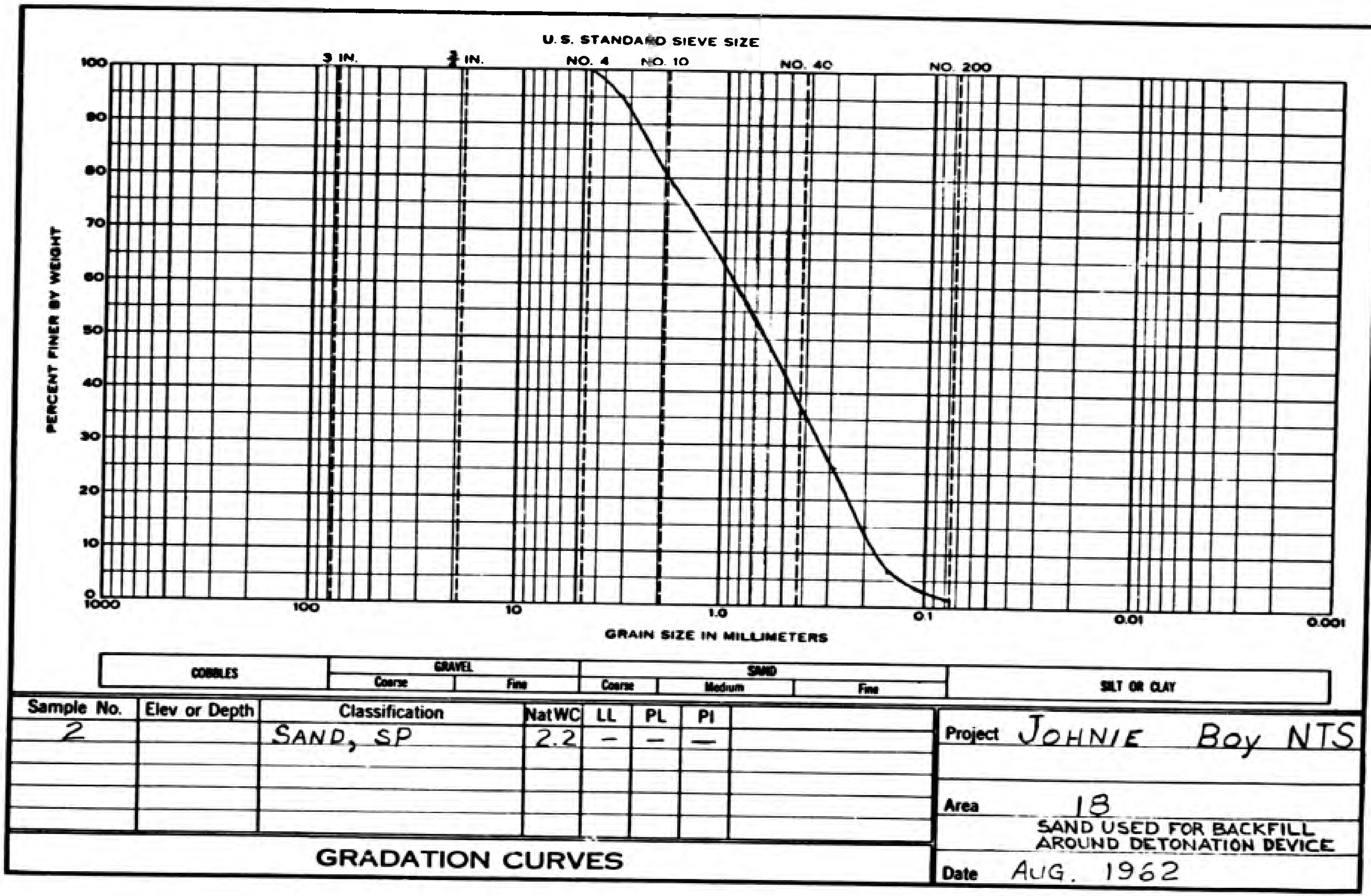


Figure 3.5 Gradation curve, sand used for backfill around detonation device.

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1. "The Unified Soil Classification System"; Corps of Engineers, U.S. Army, TM 3-357, March 1953; U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi; Unclassified.

2. W. O. George; "Relation of the Physical Properties of Natural Glasses to Their Chemical Composition"; Jour. Geology, Vol 32, pp 352-372, 1924.

3. A. D. Rooke, Jr.; "Mass Distribution Measurements"; Project 1.5, Operation Sun Beam, Shot Johnie Boy; POR-2282, U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi; Confidential Formerly Restricted Data.

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