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July 29, 1976

Thomas M. Schwarberg, Jr.
Regional Director
State Water Control Board
Northern Virginia Regional Office
P. O. Box 307
Springfield, Virginia 22150

Re: Bogle Matter

Dear Mr. Schwarberg:

Forwarded herewith is the final report of Dames and Moore which coversall of those items required of them and of the R. H. Bogle Company in the proposed consent order.

You will note that in addition to detailing the ground water studies, the report deals with a final solution to isolation of contaminated soils by Bogle in the event that the property is not sold. The signing of a contract for the sale of the property is imminent and the report also deals with the proposed development of the property for residential townhouses.

I believe that by the filing of this report, the R. H. Bogle Company has now complied fully with all the requirements of the proposed consent order even though that order has not yet been signed by the State Water Control Board.

Sincerely yours,

A. Hugo Blankingship, Jr.

AHB:ps

Enclosure

cc: David E. Evans,
Assistant Attorney General

RECEIVED
JUL 30 1976
BY
NORTHERN REGIONAL
OFFICE

DAMES & MOORE

July 29, 1976

The R.H. Bogle Company
Post Office Box 588
Alexandria, Virginia 22313

Attention: Mr. R.H. Bogle, President

Subject: Transmittal of Report
Evaluation of Groundwater
Contamination at the
R.H. Bogle Company Property,
Alexandria, Virginia

Gentlemen:

Attached are six copies of the subject report. We would be pleased to provide additional copies if needed.

This report presents the results of the groundwater study requested by your company in March, 1976. The report also presents our recommendations for permanently isolating the arsenic at the site from further human contact. It is still our opinion that this can effectively be accomplished by developing the site in the manner proposed by Development Resources, Incorporated. However, an alternative approach is proposed in the event that the sale of the property to Development Resources is not consumated prior to August 1, 1976. Specifically, this report is intended to respond to the three items in the proposed consent order signed by your company on June 25, 1976.

We appreciate the opportunity to serve your company on this project. Please contact me if you have any questions on the contents of this report.

Very truly yours,

DAMES & MOORE

A.D. Pernichele
Associate

RECEIVED
JUL 30 1976
BY
NORTHERN REGIONAL
OFFICE

ADP/ls

Enclosure

EVALUATION OF
GROUND-WATER CONTAMINATION AT
THE R.H. BOGLE COMPANY PROPERTY
ALEXANDRIA, VA.

9930-001-27

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1.0 SUMMARY

The State of Virginia Water Control Board has noted the occurrence of abnormally high concentrations of arsenic in surficial soils on and adjacent to the R.H. Bogle plant in Alexandria, Va.

The Company has been employed in the manufacture of herbicides at the site for over 40 years. However, arsenic has not been utilized on the site since about 1968. Spillage and washing of railroad cars has been the primary source of arsenic in the surficial soils at the site. Stormwater runoff has deposited contaminated soils in the nearby Potomac River and on adjacent property.

Arsenic used in the manufacture of herbicides is in a soluble form, hence leaching of arsenic spilled at the site has no doubt occurred. In all likelihood, all arsenic presently contained in the soil profile is in a relatively insoluble form, having been fixed through reactions with organics, clays, iron and other natural soil constitutents. However, some arsenic has reached the underlying ground-water system. Potentially, ground-water transport can result in wide distribution of contaminates.

The primary purpose of the study described in this report is to define the magnitude and areal extent of ground-water contamination in the vicinity of the Bogle plant and to assess the possibility that ground-water contamination may adversely affect the natural and human environment. Methods of minimizing or eliminating possible adverse impacts are also addressed in this study. This report also discusses methods which could be used to preclude possible future human contact with arsenic at the site. The study was carried out at the request of and funded by the R.H. Bogle Company.

The site and adjacent area are underlain by up to 15 feet of fill consisting of soil, construction materials, and other debris. The fill is underlain by clay and silty sand layers varying between 10 and 20 feet in thickness. A coarse sand and gravel formation, ranging between 10 and 25 feet in thickness, underlies the silty sand strata. The coarse sand is underlain by pervasive, stiff blue clay.

Surficial soils in the plant site contain up to about 30,000 mg/ℓ arsenic. Outside the plant site, concentrations range between 51 mg/ℓ to 340 mg/ℓ. Concentrations of up to 245 mg/ℓ were discovered in Founders Park, which is located about 300 feet from the plant site. Arsenic in Founders Park may have been introduced in the fill used to develop the park or as sediment eroded from the Bogle property. Below about 15 feet both in and surrounding the plant site, the arsenic levels are 100 mg/ℓ in all strata and commonly less than 30 mg/ℓ.

Ground water in the deeper sand and gravel strata is under some artesian head. Ground water from this strata is discharged upward into the overlying silty sand and/or into the Potomac River. The higher pressure and tendency for upward movement of ground water has precluded downward migration of contaminants into this zone. Excessive local pumping of water from the deep zone, could reverse the ground-water gradient and result in the introduction of contaminants. Withdrawal of water from this zone in the immediate site area should be avoided. The only two nearby wells produce water from strata below the blue clay. Therefore they will not be affected by contaminants from the Bogle site.

No trace of arsenic contamination was detected in the deeper sand and gravel zone. Arsenic concentrations in the upper silty sand and in the overlying fill range up to a maximum of 120 mg/ℓ in the plant site. Off site, the maximum arsenic concentration in this zone was on the order of 0.5 mg/ℓ.

Ground water in all strata above the blue clay discharges into the Potomac River. The total amount of contaminated ground water discharged into the River is on the order of 0.21 cubic feet per minute. This discharge occurs along a 200 to 400 foot section of the Potomac River. The total inflow of arsenic via contaminated ground water is on the order of 2.5 lbs/year. This, in our opinion, is insignificant. The above volume of discharge does not include discharge from the lower sand and gravel zone which is considered to be uncontaminated.

We conclude that contamination of ground water in the vicinity of the Bogle plant is relatively minor and poses no significant health or environmental problem. However, ground-water withdrawal from all strata above the blue clay in the immediate vicinity of the Bogle plant should not be allowed, since this could result in more wide-spread migration of arsenic than that which has occured to date.

Current plans for development of the property in townhouses incorporate measures which would effectively preclude further movement of arsenic from the site, except for almost trace amounts in ground water. The plans would also ensure that opportunity for human contact would be minimal. If plans for development do not materialize, placement of a minimum of 18 inches of compacted, iron-rich clay over the contaminated, surficial soils, would also effectively eliminate the possibility of future human contact or movement of arsenic from the site. Gravel or vegetation must be established over the clay blanket to ensure that the blanket is not breached by erosion.

2.0 INTRODUCTION

Sampling by the Virginia State Water Control Board in late 1975 and early 1976 indicated that abnormally high concentrations of arsenic exist in soils on the R.H. Bogle plant, and, to a lesser extent, in areas adjacent to the plant site. Higher than normal concentrations were also found in sediments in Oronoco Bay, an embayment of the Potomac River adjacent to the Bogle plant. As a result, the R.H. Bogle Company was requested by the State to undertake certain studies bearing on identification and rectification of this potential health problem.

Mr. Ralph Bogle, President of the R.H. Bogle Company, requested that Dames & Moore perform studies to define the extent of contamination at the plant site and adjacent area and to develop methods of controlling any potentially harmful effects which might result therefrom. A three-phase study was undertaken by Dames & Moore. This report covers the Phase 2 study which was designed to delineate the extent and magnitude of ground-water contamination in the area, to identify potentially harmful impacts which might result from this contamination and to develop methods of isolating or otherwise reducing hazards, if any, which could result from ground-water contamination.

The R.H. Bogle plant is located in Alexandria, Virginia, at the intersection of Oronoco and North Lee Streets. The plant is located near the Potomac River, about 6,000 feet upstream from the Woodrow Wilson Memorial Bridge. The plant site covers approximately 2 acres. See Plate 1.

The plant has been formulating herbicides, primarily for control of brush along railroad right-of-ways, for over 40 years. Until about 7 years ago, arsenic compounds, primarily sodium arsenite and arsenic trioxide, were used in the preparation of herbicides. The arsenic compounds were received from various suppliers in dry form in railroad cars.

Over the years, spillage of arsenic during unloading and during preparation of the herbicides resulted in accumulation of arsenic in the soil at the plant site. Water washing of railroad cars after unloading was probably the major source of the arsenic in the soils. Spillage was concentrated on the north end of the property, where railroad cars were unloaded and washed. (See Plate 2).

Since late 1975, stormwater runoff from the plant site has been through three vertical drains located on the north side of the property. The drains are connected to a stormwater drain which parallels Pendleton Street and discharges into Oronoco Bay within a few hundred feet from the junction with the drains from the Bogle property. This new drain was constructed by the City of Alexandria. In the past, stormwater runoff form a small part of the south end of the property may have flowed toward Founders Park.

Prior to construction of the new drain, a single horizontal drain pipe from the Bogle property conveyed stormwater runoff from the plant site into the old storm drain on Pendleton Street.

Abnormally high concentrations of arsenic have been found in sediments in Oronoco Bay, where the Pendleton Street storm drain discharges into the Potomac River; in sediments of the Potomac River for a short distance downstream from Oronoco Bay; in soils on the R.H. Bogle Company property, and to a lesser extent, on the property east of the plant, and in soils in isolated areas in Founders Park. (See Plate 2). The specific arsenic compounds present have not been identified.

The only significant movement of arsenic from the Bogle property is due to erosion and transport of soil from the site. Sediments through the storm drain system on the north side of the plant has resulted in accumulations of arsenic in Oronoco Bay. Minor amounts may have been washed into Founders Park, and other areas immediately adjacent to the plant site. However, some have speculated that the arsenic in Founders Park may have been introduced in fill used in landscaping.

Since no new arsenic has been introduced into the area for about 7 years, it appears extremely likely that arsenic present in the surficial soils in the area, and certainly in the river sediments, is present in compounds having very low solubility in water. Arsenic from the readily soluble compounds used in preparation of herbicides apparently has been percipitated or otherwise fixed by organics, clays, iron and/or other natural soil constitutents.

The water front area of Alexandria, where the Bogle plant is located, has been industrialized for well over 100 years. A fertilizer plant, which manufactured sulfuric acid on site, and a water-gas plant adjacent to the present Bogle property have existed in the past These operations could well have contributed to contamination of soil and possibly ground-water in the area. Iron salts originating from the water-gas plant were distributed on the present Bogle plant site. These salts may have contributed to precipitation of arsenic in the soil profile.

It should also be mentioned that traces of mercury have been detected in surficial soils at the site. However, studies by the State of Virginia and City of Alexandria Department of Health indicate that the mercury originates from the coal-fired power plant located upwind from the Bogle plant.

3.0 CLIMATE, PHYSIOGRAPHY AND GENERAL GEOLOGY

The site is in an area of continental, humid, temperate climate. National Airport, located about 3 miles north of the site, reports annual average precipitation of 38.89 inches based on records from 1941 to 1975. Most rain falls during the spring and summer. Snow cover is rare and remains only over a period of a few days. Ground is frozen only to shallow depths in winter.

The area has low relief with flat to very gently undulating topography. Surface drainage is dependent on man's activities, since the site is in a highly developed urban setting. Exposed and vegetated soil cover occupies only a minor percent of the total land surface in the site area.

The site is located on coastal plain sediments varying in age from Cretaceous to Holocene. Fill material has been emplaced over most of the area to depths up to 15 feet. The upper 40 to 60 feet of the coastal plain sediments consist of an upper zone of fine to medium sands with interlayed silts and minor clay underlain by a coarser lower zone consisting of sand, gravel and cobbles. A stiff blue clay underlies this lower unit at a depth of about 42 to 60 feet beneath the site. The clay layer increases in thickness and becomes continuous beneath the Potomac River to depths of about 70 feet west of the plant site.

4.0 METHODS OF INVESTIGATION

This section briefly summarizes the methods, and data used in the ground-water investigation.

4.1 REVIEW OF EXISTING INFORMATION

4.1.1 Literature and Data Review

The pertinent geologic, hydrologic, and geochemical literature were reviewed to obtain background information on the site area. All available boring logs and arsenic analyses for soil and ground-water samples taken in the site area by the State and others were reviewed.

4.1.2 Well Inventory

Based on information provided by the State Water Control Board (SWCB), (Young, verbal communication, 1976), there are only two wells actively withdrawing ground water in the site area. Both wells are located several hundred yards north of the site and belong to Norton and Company, 127 Madison Street, Alexandria, Virginia. Both are approximately 430 feet deep. Based on existing geologic data, the wells are withdrawing water from aquifers hydraulically isolated from the upper quifers which may have been subjected to ground-water contamination at the R.H. Bogle Company site. Prior to this investigation, no other monitor wells had been installed at the site although some other borehole information is available from foundation investigations in the area.

4.2 FIELD INVESTIGATIONS

4.2.1 Area Reconnaissance

A preliminary reconnaissance of the problem area was made by Dames & Moore with R.H. Bogle Company personnel. Background data on the history of plant operations was obtained through discussion with R.H. Bogle personnel. Following this reconnaissance and review of plant operations, the investigative program was recommended and monitor well locations were tentatively identified.

4.2.2 Drilling and Sediment Sampling

Borehole drilling was done using a rotary drilling rig equipped with hollow stem augers having a 3-5/8 inch inside diameter (I.D.) and 7-1/2 inch outside diameter (O.D.). Sediment samples were taken through the hollow stem using a 2-3/8 inch O.D. standard split spoon (ASTM D-1586-67) or a 3-3/8 inch O.D. Dames & Moore U-type Sampler (see Appendix B). Selected sediment samples were split for arsenic and grain size analyses. Results of these are given in Table 1 and Appendix C, respectively.

4.2.3 Installation of Monitor Wells

A total of 11 monitor wells were installed on and near the R.H. Bogle Company property. The wells were installed for the purpose of accurately determining the ground-water levels and collecting ground-water samples from specific depths for chemical analysis. Table 2 lists details of monitor well construction. Plate 2 shows the location of the monitoring wells. The location of the monitor wells was selected after discussion with the SWCB.

At each of four locations, three or four wells were drilled, each screened at a specific depth. This was done to allow assessment of contamination and pressure conditions as a function of depth at each site. At each location, the first hole was drilled into the blue clay strata. Sediment and water samples were taken every 5 and 10 feet, respectively. Lithologic descriptions of the sediments encountered in these deep borings are given on Plates 3A and 3B. The blue clay was considered to be the deepest possible extent of ground-water contamination.

Arsenic analyses of sediment and water samples and examination and correlation of the strata encountered served as the basis for determining the depth and number of additional monitor wells to be installed at each location. In total, five monitor wells were installed in the lower coarse sand and gravel zone above the clay layer. Six wells were installed in the upper fill and silty sand zone overlying the coarse zone.

Installation of the deep monitoring wells at each of the four locations was completed in the following manner:

1. Sediment lithologies and permeabilities were evaluated from samples taken during drilling;

2. After penetrating and sampling the clay zone, the auger flights were raised to about 3 feet above the top of the clay and the borehole allowed to backfill with natural materials or filter sand was poured into the augers to provide a base for the well screen at the depth desired;

3. The monitoring well screen and casing was placed in the boring. The boring was backfilled with filter sand or naturally backfilled to 3 feet above the screen;

4. A thick mixture of bentonite and cement was poured or pumped into the augers to seal and thereby isolate, the zone of the monitoring well and preventing leakage around the PVC casing;

5. The augers were removed, natural backfill emplaced to about 2 to 3 feet below grade and a protector pipe installed approximately level with ground surface; and,

6. Using clear drilling water, the well was flushed of fines.

Subsequently, an air compressor and drilling water were used to alternately flush and purge fines from the formation adjacent to the gravel-pack or natural backfill material. Wells in shallower zones at each of the four locations were installed in a similar manner.

4.2.4 Water Level Measurements

Water levels in the monitoring wells were initially measured upon completion of each well. On May 24, 1976, additional measurements were made and are shown in Table 2. Water levels were measured from the top of the protector pipe at each well using a Soiltest, M-Probe type electric tape.

These data were later reduced to elevations above mean sea level based on protector pipe elevations provided by the Public Works Department, City of Alexandria (Table 2). Horizontal control was established to about ± one foot based on map-plotted locations.

4.2.5 Ground-Water Sampling

4.2.5.1 Borehole Sampling

A thief-type sampler was used to collect 16 water samples from the four boring locations. At three locations, material came up inside the augers during drilling and water was used to flush the augers clean. In most instances, the hole was bailed to the point that formation water rather than drilling water was present in the borehole. However, since this could not be definitely ascertained, results of samples taken after washing are specifically noted in the results (Table 3). Samples were collected in untreated plastic containers, stored in a cold ice chest and transported to a commercial laboratory where the samples were filtered and acidified. This was done within 2 to 4 hours after recovery of the samples. The samples were then analyzed by the same laboratory, Versar, Inc., of Springfield, Virginia.

4.2.5.2 Well Sampling

Samples were taken from wells immediately after development, and again on May 11, 1976, and June 7, 1976. Samples on May 7 and May 11, 1976, were taken using an air compressor adapted with a T-fitting at ground surface to facilitate sample collection. Samples were collected in untreated one-quart plastic containers, stored in a cold ice chest and transported to Versar, Inc., laboratory for preparation and preservation within 1 to 4 hours of sampling. Results of these analyses are given in Table 4.

Conductivity and temperature readings were made at the time of sampling in an attempt to help ensure the well had been fully developed and that any drilling water used during installation was removed prior to sampling. Results of analyses of samples taken on May 7, 1976 and May 11, 1976 (Table 4) indicated that at location 1 and Well 2A, drilling fluids may still have been present as suggested by the variation in these analyses. However, another possible source of these variations in analyses may have been the high amount of sediment in the samples. The analyses appear to vary according to the degree of filtration prior to acidification.

To clarify these discrepancies, samples were retaken from all wells on June 7, 1976. A vacuum pump and 2-litre trap flask were used to collect samples from the wells.

Prior to taking the sample, the well was pumped dry or a volume of water, greater than that standing in the well prior to sampling, was removed. This helped ensure that formation water was sampled. Samples were collected in high grade polyethylene reagent bottles and hand carried to a portable laboratory on site for immediate determination of pH, conductivity, and temperature and for filtration and acidification. Samples containing high amounts of sediment were first filtered through a medium speed Watman 3 filter paper using a Buchner funnel under suction. The filtrate was then filtered two times through a 0.45 micron millipore filter under suction. Relatively clear samples were twice run through the micropore system for filtration prior to acidification. Samples were acidified to a pH of 2.0 using redistilled, concentrated nitric acid.

Samples were split and sent to different laboratories to check analytical accuracy. Aliquots of each well sample were given to Versar, Inc., laboratory and Texas Instrument laboratory in Dallas, Texas. Results are given in Table 4. Three samples were given to the SWCB for control analyses but at this time their results are not available.

4.3 LABORATORY ANALYSES

4.3.1 Sediment Samples

Total arsenic concentrations were determined by Versar, Inc., for selected sediment samples taken from the monitor well borings. Samples were dried at 55° to 60°, passed through an 80 mesh seive and subsequently ground and passed through a 40 mesh seive and thoroughly mixed. One to two grams of the sample was digested with a mixture of 5 milliliters of concentrated nitric acid and concentrated sulfuric acid and heated until the appearance of heavy white fumes of SO_3. The mixture was cooled and another 5 ml of nitric acid added and again heated to fumes of SO_3. The samples were cooled, diluted to either 50 or 100 milliliters and then further diluted prior to analysis.

This technique utilizes only that part of the sample passing through an 80 mesh seive. Thus, depending on the percent of coarse material, the analyses will give higher values than are actually present. This is particularly true of the lower sand and gravel aquifer zone in which from 60 to 80 percent of the sample was more coarse than the 80 mesh seive (Appendix C).

Mechanical grain size analyses were run on a selected number of samples by the Dames & Moore soils laboratory in Park Ridge, Illinois. Procedures used were those prescribed by ASTM D422-72. Results of the analyses are given in Appendix C.

4.3.2 Ground-Water Samples

Total arsenic and in some instances, total mercury concentrations in ground water samples were determined by Versar, Inc. Samples taken on June 7, 1976, were also sent out to Texas Instruments Laboratory in Dallas for verification analyses. The procedure utilized was as follows:

1. Upon receipt in the laboratory, samples were filtered through a 0.45 micron millipore filter to remove sediment. Samples were then preserved by acidifying with redistilled concentrated nitric acid to a pH of 2 and stored for analysis.

2. Analysis for total arsenic in the ground water was done using the graphite furnace on a Perkin Elmer Model 306 Atomic Absorption Spectrophotometer.

3. Analysis for total mercury in the ground water was also done using a Perkin Elmer Model 306 Atomic Absorption Spectrophotometer.

Measurements of pH and conductivity were made using a Fisher-Accumet Model 150 pH meter and a YSI-Model 33 conductivity bridge, respectively. Results of all analyses are given in Table 3 for the bore-hole samples and in Table 4 for the well samples.

5.0 RESULTS AND DISCUSSION

5.1 SURFICIAL GEOLOGY

Strata were identified at the site and in the surrounding area based on borings by different contractors and the observation well borings installed by Dames & Moore. Boring logs used in this investigation are shown on Plates 3A and 3B.

Fill material is present at the site and surrounding area to a depth of up to about 15 feet. The fill consists of sand, silt, organics, chemical wastes, and coarser cinder, glass, brick and gravel fragments. The history of fill placement is unknown. The thickness of the fill varies considerably. The fill represents filling of depressions, wetland areas, burial of waste and debris and excavation for foundations.

A sandy layer varying in thickness between 10 and 20 feet underlies the fill material. Discontinuous, interbedded, silt and clay layers in this zone account for confinement of the ground water in the unerlying coarser sand and gravel zone. The sand is fine to medium, sub-rounded to angular, and has varying degrees of uniformity and density. In this report, the layer is referred to as the upper sand zone.

The lower sand and gravel zone generally varies in thickness from about 10 to 25 feet. It consists of varying amounts of coarse sand, gravel and cobbles, is angular to rounded and has minor amounts of fine to medium sand. The presence of mica within the unit was noted on all borings. A predominantly medium grained sand about 5 feet thick was encountered at the base of this unit at all boring locations except 5A where it is absent. This basal portion of this zone included minor gravel and some cobbles. This coarse fraction was not identified to a depth of about

80 feet in one of four borings drilled offshore in Oronoco Bay northeast of the site (Dames & Moore, 1975). It is likely that this unit pinches out towards Oronoco Bay or grades laterally in places to a more silty and clayey marine clay deposit.

A blue-gray, very stiff clay underlies the lower sand and gravel aquifer over the site and most of the surrounding area. The clay was not completely penetrated by borings during this investigation. This clay unit is believed to be continuous over the area and acts as a confining unit for the deeper Cretaceous age sands and gravels which are supplying water to the Norton and Company wells north of the plant.

5.2 GROUND-WATER LEVELS AND FLOW PATTERN

Ground-water levels measured by Dames & Moore personnel on May 24, 1976 (Table 2), were used to construct a water table contour map for upper sand and fill material zone (Plate 4) and a potentiometric contour map for the lower sand and gravel zone (Plate 5) in and surrounding the Bogle site. Water level measurements taken from borings by others northwest of the site were used in constructing the potentiometric map for the lower unit. A schematic illustration of the flow system in a cross-section approximately parallel to the main direction of flow is shown in Plate 6.

The local shallow water table system is probably influenced by surface topography, the regional ground-water flow system, nonuniform recharge, penetration below the water table by foundations of structures, and tidal fluctuations in the Potomac River. Non-uniform recharge may be caused by the presence of buildings and pavements and discharges from drain pipes and possibly leakage from sewer lines.

Water levels in the lower sand and gravel aquifer, except in the plant site, were 1.5 to 3.3 feet higher than the water levels in the water table system at the same locations. This indicates artesian conditions exist in the lower sand and gravel aquifer and that silt and/or clay layers encountered in the upper fill and sandy zones are acting as semi-confining or retarding units. A boring about 500 feet northwest of the plant site at an elevation of about 16 feet above MSL encountered artesian conditions in the sand and gravel aquifer. Water flowed above ground surface from a depth of about 35 feet below grade.

In the plant area itself, the water levels in the water table wells (1c, 1d) is about 0.5 feet higher than in the deep aquifer. Confining clay and silt units were encountered in drilling at this location. The higher water levels in the upper aquifer in this area are likely the result of localized infiltration from precipitation occurring in an open (undeveloped) area up-gradient (west) of the plant site (Plate 4). By contrast, the other areas surrounding the site are developed with houses, buildings, and pavement, thus restricting infiltration of water into the subsurface.

The water table contours indicate that the direction of groundwater movement in the upper zone is from west to east in the site vicinity. Hydraulic gradients are highest from the plant northeast towards Oronoco Bay. Directly east of the plant, the gradients flatten towards the Potomac River. This is probably due to limited recharge to the upper zone because of building and pavement cover. Fluctuations in the near-shore water table levels are expected to result from tidal fluctuations in the Potomac River.

This cyclic tidal fluctuation would tend to dampen the magnitude of the overall hydraulic gradient towards the river from the water table zone.

The artesian conditions in the lower sand and gravel aquifer provide a potential for movement of ground water upward into the overlying sediments in the area and laterally into the sediments underlying the Potomac River and eventually into the river itself. The potentiometric contours in this zone indicate ground-water movement is from west to east in the site vicinity with the strongest hydraulic gradients north of the site towards Oronoco Bay. Similar to the water table, the gradient in the lower zone appears somewhat flatter to the south and east of the site (see Plate 5).

The artesian head in the deeper aquifer increases toward the river. At well 4A3 which is furthest from the river, the head in the lower zone is about 1.5 feet above the water table. At well 5A, the head about 2.0 above water table and at well 2A, less than 50 feet from Oronoco Bay, the head in the lower aquifer was about 3.3 feet above the water table. This change in the magnitude of artesian conditions over less than 1000 feet may in part be the result of an increase in the thickness and clay content of the confining layers in the upper zone and the pinching out of the sand and gravel zone toward the northeast.

Based on the flow patterns in the upper and lower zones, it is apparent that ground-water recharge to both zones is occurring to the west of and to a limited degree in the plant site area. Ground-water discharge is into the Potomac River from the upper zone and into the upper zone and directly into the Potomac River from the lower sand and gravel zone. The amount of discharge to the upper zone from the lower zone is likely to be negligible compared to lateral flow that is taking place towards the Potomac River. This is based on the apparent two to three order of magnitude higher permeability in the lower sand and gravel zone compared to the upper sand zone containing silt and clay layers.

The artesian condition in the lower sand and gravel zone effectively precludes the downward movement of contaminated ground water into this zone. This accounts for the low concentrations of arsenic in the sediments and ground water of the lower zone. See analyses in Appendix.

In the plant area, the higher water level in the upper unit compared to the hydraulic head in the lower artesian zone is believed to be a localized condition which may be seasonal. During dryer periods, it is likely this condition in the site area is reversed, becoming consistent with the other areas.

Only in the event of lowering the hydraulic heads in the lower aquifer would there be a potential for appreciable downward leakage from the upper sand zone into the lower sand and gravel. Even in this instance, the total amount of leakage from the upper zone, because of its relatively low permeability, would be small. The potential degree of movement is also dependent on the magnitude and duration of change in head in the lower zone. Pumping of water from the lower zone could reverse the existing flow system, resulting in vertical movement of contaminants.

5.3 SEDIMENT ARSENIC CONCENTRATIONS

Arsenic concentrations in the sediments varied from <5 mg/ℓ in some samples from the lower sand and gravel zone and underlying clay zone to between 10,300 mg/ℓ at locations in the plant site area.

The profile of arsenic concentrations from ground surface to 10 feet at TB-2 and TB-3 (Appendix A) shows arsenic levels decreasing with depth to about 5 to 10 percent of the surface concentration. Below 15 feet in all borings both in and surrounding the plant site, the arsenic levels are generally less than 100 mg/ℓ in all strata and commonly less than 30 mg/ℓ. Walsh and Keeney (1975, p. 36) report that natural soils in the United State show total natural arsenic concentrations ranging between 0.2 and 40 mg/ℓ.

Distribution of arsenic in the surficial material over the plant site indicates considerable variation. For example, the surface sample at location 1A had an arsenic level of 83.3 mg/ℓ while at 1D about 30 feet away the arsenic concentration was 24,131 mg/ℓ. Similar variablity in results have been reported by the SWCB based on their sampling program within the property area (SWCB, written communication, March, 1976).

Outside the plant site, surficial soils contained arsenic concentrations varying from about 51 mg/ℓ at boring 4A-1 to 245 mg/ℓ at boring 5A in Founders Park. Surficial arsenic concentration at boring 2A, next to Oronoco Bay, was 341 mg/ℓ.

At each of these locations, the surface and underlying material to depths from about 4 to 13 feet was artificial fill, the origin of which is not known. In Founders Park, location 5, the two samples of fill at 10 and 11.5 feet had arsenic concentrations of 245 mg/ℓ and 180 mg/ℓ, respectively. The underlying sand and gravel have concentrations of 10 mg/ℓ and 7.3 mg/ℓ. Location 5 is about 200 feet southeast of the plant site (Plate 2). No known arsenic dumping or washing related to activity at the Bogle plant took place in this area. Fill material at this location may have contained arsenic prior to its being moved to the area.

Knowledge of the mechanism of arsenic transport and its mobility in sediments and ground water is important to an understanding of the observed distribution of arsenic in the area. Sediments were analyzed for total arsenic which includes amounts of arsenic which have been complexed and/or formed precipitates with a variety of mineral or organic compounds in the soil. Walsh and Keeney, 1975, have reviewed research and case histories of theirs and of other workers on the chemistry of arsenic in soils.

They report that arsenic is generally in the form of arsenate in most soil systems, particularly those in oxygenated environments such as typically found in zones above the water table. When the iron contained in the soil is not highly reactive, Woolson et al, (in Walsh and Keeney, 1975) report that the dominant form of arsenic is controlled by relative proportions of exchangeable Ca and reactive Al. Visual examination of the sediment samples indicates a substantial amount of iron-rich compounds and aluminosilicate minerals in the clay and silt fraction in the fill material found over most of the area.

Sorption of arsenic by soils is reported to be time dependent and reversion of arsenic to less soluble forms have been obtained in field, greenhouse and laboratory studies (Walsh and Keeney, 1975). Woolson et al, 1973, reported that soluble arsenic decreased to a constant value after about 4 months but that the rate of decrease was dependent on the soil type and mineralogic composition. Iron-bound arsenic continued forming after the aluminum-bound fraction had reached a maximum level and began to decline.

Walsh and Keeney (1975, p. 41) indicate that in one study, leaching of arsenic in a sandy profile continued with time but that the degree of loss of arsenic from the surface soil had decreased significantly with time.

The last use of arsenic at the plant site was about 1968. Soil arsenic levels in the site area are therefore related to incidents which occurred over eight years ago. The persistent high total arsenic levels in the upper 10 feet with signficantly lower levels in the underlying sediments suggest that the current leaching rate is low and will decrease in future. This is further supported by the levels of arsenic which were found in the ground water which is discussed in more detail below.

5.4 GROUND-WATER ARSENIC CONCENTRATIONS

Samples of ground water taken from the borehole during drilling (Table 3) showed levels ranging from <0.001 mg/ℓ to 1.04 mg/ℓ. Values were highest in the plant site boring 1A. At this location, arsenic concentrations decreased from 1.04 mg/ℓ at 15 feet to 0.088 mg/ℓ at 55 feet. Down-gradient, at location 2A, the arsenic level was 0.052 mg/ℓ at 20 feet. At 5A, in Founders Park, and 4A a background location gradient from the site arsenic concentrations were less than 0.008 mg/ℓ.

These results suggest the ground-water concentrations in the strata vary naturally over a fairly widespread area with higher concentrations present in ground water in the fill and upper sandy zones directly beneath the site.

Samples were taken from the monitor wells on three occasions (Table 4). Results from the first sampling, i.e., the sampling done during drilling, indicate the wells may not have been adequtely developed and drilling water may have been mixed with formation water at some of the wells. We believe the results from all wells sampled on June 7, 1976, to be representative of arsenic concentrations in the ground water.

Arsenic concentrations in the five wells in the lower sand and gravel zone varied from <0.001 mg/ℓ to 0.021 mg/ℓ. The highest value occurring at 2A. The lowest values, all <0.008 mg/ℓ occurring in 1A, 4A, and 5A.

In the upper zone, six wells showed arsenic concentrations varying from 0.004 mg/ℓ to 120 mg/ℓ, the highest levels at the shallow wells 1C and 1D in the plant site, the lowest levels at well 5B in Founders Park, and well 4A, southwest from the site.

Any arsenic leached from the surficial sediments into the ground-water regime will be susceptible to further sorption on organics, silts or clay particles in the aquifer. Some of the arsenic will be sorbed to these particles forming tightly held complexes or relatively insoluble precipitates whereas other arsenic, because of the near saturation of sorptive particles, particularly in the upper 10 feet of sediment, will be only loosely held or attached. Similar results to these have been reported by Dames & Moore in a study of arsenic and chloride contamination at an industrial site in northeastern Wisconsin, (Dames & Moore, 1975).

5.5 SEDIMENT PERMEABILITIES

Grain size curves for selected samples taken during drilling were used to estimate permeabilities of the sediments in the lower sand and gravel and upper fill and silty sand zone. (See Appendix C). Results of grain size analyses were plotted and compared to curves published by the Department of Navy (U.S. Dept. of Navy, 1962). This method was used to estimate permeability of the sediments in the site vicinity. Permeability estimates were needed to estimate the amount of arsenic entering the Potomac River via the ground-water system.

Estimated permeabilities for the sediments are given in Table 5. Values for the upper zone range from < 1×10^{-5} ft/min (≈1.08×10^{-1} gpd/ft^2) to 1×10^{-2} ft/min (= 1.08×10^{2} gpd/ft^2) with an average for 7 samples of about 0.006 ft/min (65 gpd/ft^2).

Values in the lower sand and gravel zone varied from ≈5×10^{-3} ft/min (≈54 gpd/ft^2) for a silty sand zones directly above the clay layers to about 5.4 ft/min (≈5.83×10^{4} gpd/ft^2) for the sand, gravel and cobble layer. Permeability of the coarser gravel generally ranged from about 1×10^{-2} ft/min (≈1.08×10^{2} gpd/ft^2) to 5.4 ft/min (5.83×10^{4} gpd/ft^2) with an average of about 0.13 ft/min (≈1400 gpd/ft^2).

5.6 DISCHARGE OF CONTAMINATED GROUND WATER TO THE POTOMAC RIVER

The discharge of contaminated ground water from the plant site into the Potomac River can be calculated using a modification of the Darcy equation (Walton, 1970, p. 118):

$$q = k\ i\ a$$

where:

q = volume of flow (gallons per day)
k = permeability (gallons per day per sq. ft)
i = hydraulic gradient (ft/ft)
A = cross-sectional area (sq. ft.)

Ground water gradients are determined by the slope of the water table or potentiometric surface in the direction of ground-water movement. Ground water ideally moves down-slope and perpendicular to lines of equal head. An average gradient of 0.012 ft/ft was assigned to the water table over the area along the estimated discharge zone on the shoreline shown on Plate 4.

The cross sectional area of the unit along this shoreline was calculated from borings in that vicinity. The top of the saturated interval was assumed to be one foot above mean sea level elevation at the shoreline. The base of the saturated thickness was based on examination of boring logs from this investigation and those done by Dames & Moore in July, 1975 for a proposed stormwater retention basin in Oronoco Bay (Dames & Moore, 1975a).

The permeability assigned to this upper unit was selected as 65 gpd/ft^2 based on the grain size analysis curve estimates. We believe that, in light of the soils description from the borings in Oronoco Bay, this value is a representative maximum value and therefore would provide the conservative estimate, i.e., the maximum flow, into the Potomac River.

The total calculated discharge towards the Potomac River in the area shown on the map for the above conditions is about 2250 gallons per day or about 0.21 cubic feet per minute (cfm).

A similar approach was used to calculate the volume flowing from the lower sand and gravel zone towards the Potomac River from the plant site. An average gradient of 0.004 ft/ft to the area along the estimated discharge zone. Saturated thickness along this area was calculated based on all available boring log information. The permeability assigned to this unit was conservatively estimated as about 1400 gpd/ft^2 again resulting in what we believe to be a representative maximum flow rate towards the Potomac River. The total calculated discharge towards the Potomac River from the lower zone along the discharge zone is about 17250 gallons per day or about 1.6 cfm.

Total discharge towards the Potomac River from combining the upper and lower zones is estimated at about 19500 gpd or about 1.8/cfm. However, only the flow in the upper zone is considered to be contaminated with arsenic.

The amount of arsenic in ground water discharging to the Potomac River from the site can be calculated based on the concentrations observed in the ground waters and the volumes of flow in the two zones. Concentrations used in the calculations are those based on results from the wells at location 2 since they would most closely approximate, although they are likely higher than, the actual concentrations in the ground water along the interface between ground water in the sediments underlying the Potomac River water itself.

Wells 2B and 2C in the upper sand zone and fill material had maximum arsenic concentratons of 0.353 mg/ℓ. A factor of 6.25×10^{-5} was used to convert concentrations to lb/cubic foot. This value multiplied by the flow rate in cubic foot per minute times 5.256×10^{5} minutes per year yields a value of 2.43 lb/year of arsenic. This represents the estimated weight of arsenic discharged in contaminated ground water from the site area into the Potomac River from the upper sand zone and fill material. By comparison, the ground water in the lower zone, which is uncontaminated from arsenic at the Bogle property has a concentration of 0.021 mg/ℓ at well 2A and discharges an estimated 1.1 lb/year towards the Potomac River from the site.

6.0 PROPOSED DEVELOPMENT PLAN

The R.H. Bogle Company is presently negotiating with Development Resources, Inc., for sale of their property located at Oronoco and Lee Streets, Alexandria, Va. Development Resources, Inc., plans to construct townhouses on the site. The proposed contract, dated July 27, 1976, is being given serious consideration by both parties. However, it is not possible at this time, to determine whether a final sale can be consummated prior to August 1. The intent of this section of the report is to present a plan designed to achieve permanent control of contaminated soils on and in the vicinity of the Bogle plant and to eliminate the possibility of further human contact with these soils. Specifically, this section is intended to respond to questions 2 and 3 in Appendix A of the proposed consent order signed by Mr. Bogle on June 25, 1976. Response to these questions is required should the sale fail to be consummated prior to August 1.

We are confident that permanent control of the problem can readily be achieved by placing a minimum of 18 inches of compacted, iron-rich clay over all contaminated soils. Clays of this type are readily available in the area. This approach has been discussed at some length with Dr. Woolson, of the Dept. of Agriculture, Beltsville, Md., a world expert in the chemistry of arsenic in soils. Dr. Woolson agrees that the clay blanket will provide the required permanent solution from a chemical standpoint.

Although the arsenic in the surficial soils is no doubt in a form which has very low solubility in water, the iron in the clay blanket will readily react with and permanently fix any soluble arsenic which might tend to migrate upward in the soil column. The clay blanket will eliminate the possibility of the liberation of arsenic-bearing dust from the property, preclude human contact and with certain other precautions, will eliminate further erosion and transport of contaminated soils from the property.

Provision must be made to ensure that erosion does not breach the clay blanket. Depending on the intended use of the property, this can be accomplished by placing a minimum of 6 inches of well-graded, coarse gravel over the site, or placing a minimum of 4 inches of good top soil over the blanket and sodding or seeding the site. In addition, raising the elevation of the three vertical drains in the plant site would be highly desirable to compensate for increasing the elevation of the site.

The site should be graded to ensure flow toward the three existing vertical drains to the extent practical. The compacted clay blanket will also reduce vertical seepage of precipitation to the ground-water table and hence will reduce the leaching and transport of arsenic into the ground-water system.

The public need not be restricted from the site after placement of the clay blanket.

Dames & Moore has met with principals of Development Resources, Inc. to discuss their plan for development of the property. In particular, we emphasized those precautions which must be taken to preclude the possibility of further human contact with contaminated soils at the site after construction. Precautions to be taken during construction were also discussed in our meetings.

The letter from Development Resources, Inc., dated June 17, and addressed to Mr. Bogle, summarizes the precautions to be taken to ensure that the contaminated soils will be isolated from human contact after construction. We agree with the plan presented in this letter.

Further, Dames & Moore has reviewed the proposed sale contract between the R.H. Bogle Company, and Development Resources, Inc., dated July 26, 1976. We see no stipulation in the proposed contract which would preclude development of the property as outlined in the letter from Development Resources, Inc., dated June 17, 1976.

7.0 REFERENCES

Dames & Moore, 1975a, Geotechnical Investigation - Proposed Pendleton Street Retention Basin for City of Alexandria, Virginia

Dames & Moore, 1975, Geohydrologic and Aquatic Studies, Ansul Site, Final Report

U.S. Department of Navy, 1962, Navdocks DM-7, Design Manual, Soil Mechanics, Foundations, and Earth Structures, Bureau of Yards and Docks, Washington, 25, D.C.

Walsh, L.M., and Keeney, D.R., 1975, Behavior and Phytotoxicty of Inorganic Arsenicals in Soils: In Arsenical Pesticides, Ed. by E.A. Woolson, American Chemical Society, Washington, D.C. pp. 35-52.

Walton, W.C., 1970, Ground-Water Resource Evaluation, McGraw-Hill, New York, p. 118

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LIST OF TABLES

TABLE 1

ARSENIC CONCENTRATIONS IN SEDIMENT SAMPLES
TAKEN DURING BOREHOLE DRILLING

Boring	Sample	Depth[a]	Lithology	Arsenic (mg/ℓ)	Date
1A	1	0 to 1.5	Fill, Silty Sandy	83.3	4/29/76
1A	2	5 to 6.5	Fill, Sandy and Clayey	54.2	4/29/76
1A	3	10 to 11.5	Fill, Silty, Sandy	27.8	4/29/76
1A	4	15 to 16.5	Sand	24.7	4/29/76
1A	5	20 to 21.5	Silt, Sand	12.4	4/29/76
1A	6	25 to 26.5	Sand, Gravel	10.9	4/29/76
1A	7	30 to 31.5	Sand, Gravel	16.0	4/29/76
1A	8	35 to 36.5	Sand	14.3	4/29/76
1A	9	40 to 41.5	Sand	4.4	4/29/76
1A	10	45 to 46.5	Sand, Gravel	20.3	4/29/76
1A	11	50 to 51.5	Sand	17.4	4/29/76
1D	1	0 to 1.5	Fill, Silty Sand	24131	5/06/76
1D	2	5.5 to 7	Sand, Silt	118	5/06/76
2A	1	0 to 1.5	Fill, Sandy	341	5/05/76
2A	3	10 to 11.5	Fill, Sandy	63	5/05/76
2A	4A	15 to 16	Sand, Organics	16.6	5/05/76
2A	4B	16 to 17	Clay	26.7	5/05/76
2A	6	25 to 26.5	Sand, Gravel	9.9	5/05/76
2A	8	35 to 36.5	Sand, Gravel	20.0	5/05/76
2A	9	40 to 41	Sand	10.2	5/05/76

TABLE 1 - continued

Boring	Sample	Depth[a]	Lithology	Arsenic (mg/ℓ)	Date
4A1	1	0 to 1.5	Fill, Sandy	51.25	4/30/76
4A1	1A	1 to 1.5	Fill, Sandy, Gravel	27.25	4/30/76
4A1	2	5 to 6.5	Sand, Clay	9.0	4/30/76
4A1	3	10 to 11.5	Sand	19.0	4/30/76
4A1	5	15.5 to 17.5	Sand	17.25	4/30/76
4A1	6	20 to 21.5	Sand	18.60	4/30/76
4A1	7	25 to 26.5	Sand	13.80	4/30/76
4A1	8	30 to 31	Gravel, Sand	10.77	4/30/76
4A1	9	35 to 36.5	Gravel, Sand	3.82	4/30/76
4A1	11	45 to 46.5	Gravel	13.22	4/30/76
5A	1	0 to 1.5	Fill, Sandy	245	5/06/76
5A	3	10 to 11.5	Fill, Sandy	180	5/06/76
5A	4	15 to 16.5	Sand, Silty	10.7	5/06/76
5A	6	25 to 26.5	Sand, Gravel	7.3	5/06/76
5A	9	40 to 41.5	Clay	221	5/06/76

NOTE:

[a]Depths given in feet below approximate ground surface

TABLE 2

MONITOR WELL DESCRIPTIONS

Materials

Screen:	2-inch I.D. PVC SCH.80 0.010 slot width
Casing:	2-inch I.D. PVC SCH.80
Filter Sand:	A.N.D. Sand, Uniformity Coefficient 1.2, Effective Size 1.0 mm.
Seal Material:	Zeogel (Bentonite Mud-Baroid Chemicals)
Cement:	Standard Portland Type
Protector Pipe:	4-inch cast iron casing, 30 inches long, locking caps (manufactured by Temple Foundry, Alexandria, Virginia)

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LOCATION #1

	Well 1A	Well 1B	Well 1C	Well 1D
Filter Sand	58.5 to 52.5	-	-	-
Screen	52.5 to 46.5	31.5 to 25.5	15 to 9	11 to 7
Filter Sand	-	-	15 to 5	11 to 4.5
Natural Backfill	52.5 to 43	33 to 23	-	-
Bentonite Seal	43 to ≈ 15	23 to 5	5 to 4	4.5 to 1
Filter Sand	-	-	-	-
Natural Backfill	≈ 15 to 2.5	5 to 2.5	-	-
Cement and Sand	2.5 to G.S.	2.5 to G.S.	4 to G.S.	1 to G.S.
Protector Pipe	2.5 to G.S.	2.5 to G.S.	2.5 to G.S.	2.5 to G.S.
Protector Pipe Elevation*	12.90	13.10	13.27	13.41

	Water Level*	Elevation*	Time	Date
1A	7.88'	5.02	0836	5/24/76
1B	8.09	5.01	0837	5/24/76
1C	7.63	5.64	0838	5/24/76
1D	7.93	5.48	0839	5/24/76

LOCATION #2

	Well 2A	Well 2B	Well 2C
Filter Sand	-	-	-
Screen	41 to 35	20 to 14	12 to 6
Filter Sand	-	-	-
Natural Backfill	44.5 to 27	20 to 10	12 to 3
Bentonite Seal	27 to 10	10 to 4	3 to 2
Filter Sand	-	-	-
Natural Backfill	10 to 3	4 to 2	-
Cement and Sand	3 to G.S.	2 to G.S.	2 to G.S.
Protector Pipe	2.5 to G.S.	2.5 to G.S.	2.5 to G.S.
Protector Pipe Elevation*	10.51	10.62	10.78

	Water Level*	Elevation*	Time	Date
2A	5.93	4.58	0826	5/24/76
2B	9.13	1.49	0828	5/24/76
2C	9.64	1.14	0830	5/24/76

LOCATION #4

	Well 4A3	Well 4B
Filter Sand	-	-
Screen	46 to 40	23 to 17
Filter Sand	-	15 to 5
Natural Backfill	50 to 15	23 to 15
Bentonite Seal	15 to 5	5 to 2
Filter Sand	-	-
Natural Backfill	5 to 2	-
Cement and Sand	2 to G.S.	2 to G.S.
Protector Pipe	2.5 to G.S.	2.5 to G.S.
Protector Pipe Elevation*	15.80	15.95

	Water Level*	Elevation*	Time	Date
4A3	8.57	7.23	0821	5/24/76
4B	10.25	5.70	0820	5/24/76

LOCATION #5

	Well 5A	Well 5B
Filter Sand	-	-
Screen	35 to 29	12 to 6
Filter Sand	-	12 to 5
Natural Backfill	41.5 to 22	-
Bentonite Seal	22 to 6	5 to 2
Filter Sand	-	-
Natural Backfill	6 to 2	-
Cement and Sand	2 to G.S.	2 to G.S.
Protector Pipe	2.5 to G.S.	2.5 to G.S.
Protector Pipe Elevation*	8.90	8.79

	Water Level*	Elevation*	Time	Date
5A	3.70	5.2	0812	5/24/76
5B	5.62	3.17	0815	5/24/76

NOTES:

1. All dimensions in feet referenced to approximate Ground Surface (G.S.) unless otherwise noted.

* Water level depths referenced to top of protector pipe cap. Elevations referenced to mean sea level.

TABLE 3

ARSENIC CONCENTRATIONS IN WATER SAMPLES

TAKEN DURING BOREHOLE DRILLING

Boring	Sample	Depth[a]	Arsenic (mg/ℓ)	Time	Date
1A	1	15'	1.04	1120	4/29/76
1A	2	25'	0.26	1140	4/29/76
1A	3	35'	0.175	1245	4/29/76
1A	4	45'	0.113[b]	1330	4/29/76
1A	5	55'	0.088	1430	4/29/76
2A	1	20'	0.052	0820	5/05/76
2A	2	30'	0.005[b]	0845	5/05/76
2A	3	40'	0.007[b]	0920	5/05/76
4A1	1	15'	0.012	0845	4/30/76
4A1	2	25'	0.044	0925	4/30/76
4A1	3	35'	0.005[b]	1015	4/30/76
4A1	4	45'	0.042	1110	4/30/76
4A1	5	55'	0.006[b]	1225	4/30/76
5A	1	10'	<0.001	0930	5/06/76
5A	2	20'	<0.001	1000	5/06/76
5A	3	30'	<0.001	1110	5/06/76

NOTES:

[a] Depths given in feet below approximate ground surface.

[b] Hole was washed with drilling water prior to sampling. Arsenic concentrations may not be indicative of formation water.

TABLE 4

ARSENIC AND RELATED ANALYSIS RESULTS

FROM MONITOR WELL GROUND-WATER SAMPLES

Well [a]	Aquifer Zone [b]	May 7, 1976 Arsenic (mg/ℓ)	May 11, 1976 Arsenic (mg/ℓ)	June 7, 1976 Arsenic (mg/ℓ)		pH	Conductivity (μmhos/cm)	Temperature (°C)
1A	lower	0.009	0.10	0.005[c]	.0036[d]	6.9	280	20
1B	lower	< 0.001	0.32	0.008[c]	.0048	6.6	295	18
1C	upper	5.78	172.5	102	195.	6.5	4700	20
1D	upper	9.34	97.6	120	255	6.5	3900	23
2A	lower	< 0.001	0.46	0.021	.0041	6.7	260	21
2B	upper	0.487	0.32	0.353	3.9[e]	6.2	3500	22
2C	upper	No sample	No sample	0.096	.22	6.3	3200	21
4A	lower	0.267	0.17	<0.001	.0015	6.3	600	22
4B	upper	Not installed	0.04	0.004	.0018	6.0	600	20
5A	lower	< 0.001	< 0.005	0.004	.0042	6.8	280	19
5B	upper	Not installed	< 0.005	0.007	.0068	6.8	330	24

a - Well descriptions given in Table 2

b - Upper aquifer zone includes fill material and upper sand zone as outlined in text.
Lower aquifer zone includes sand and gravel zone overlying clay unit as outlined in text.

c - Results provided by Versar, Inc. Laboratory

d - Results provided by Texas Instruments Laboratory

e - Value questionable

TABLE 5

ESTIMATES OF SEDIMENT PERMEABILITIES

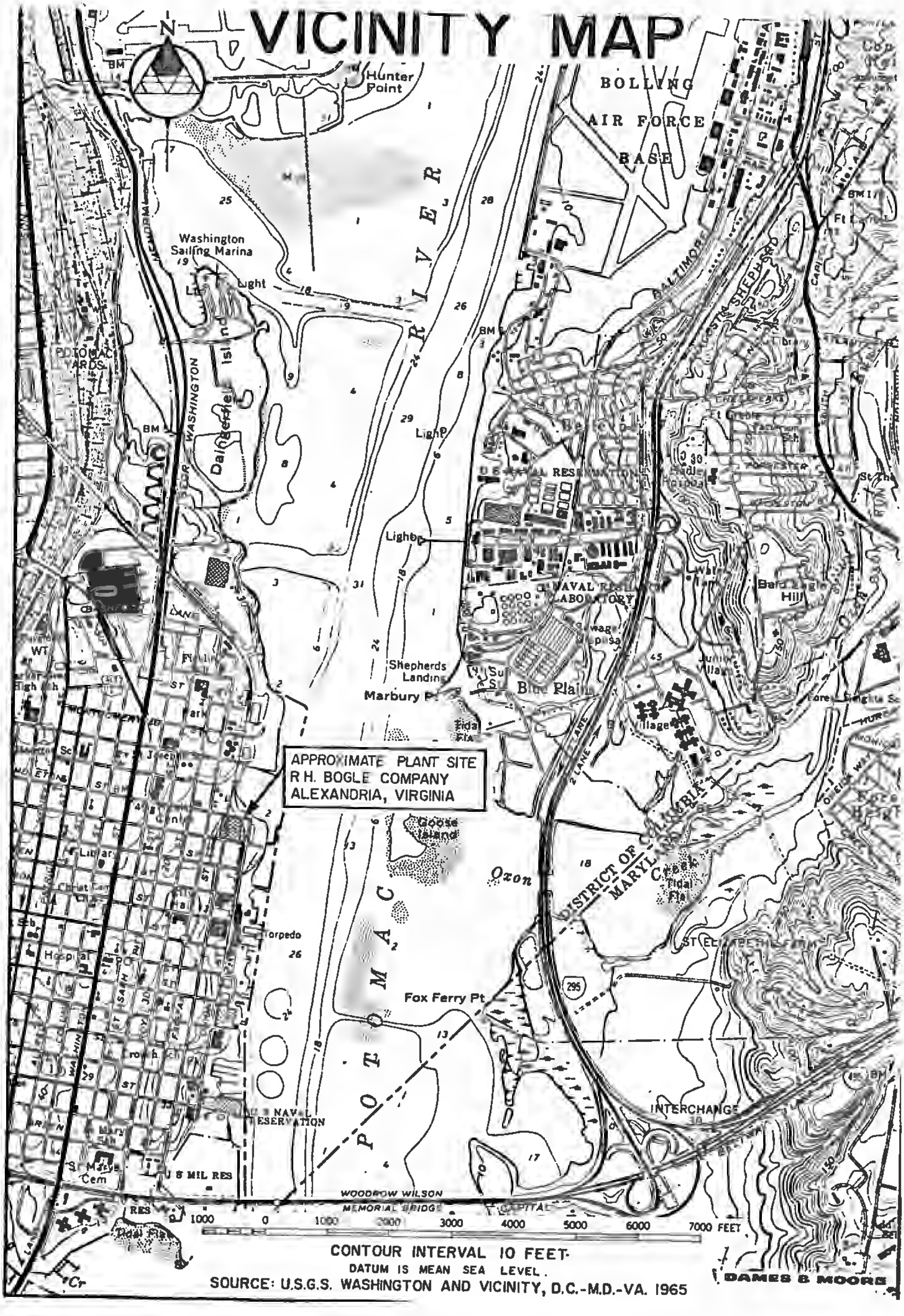
BASED ON GRAIN SIZE ANALYSIS CURVES

	Boring	Sample	Permeability Based on Grain Size Plot[a] (ft/min)	Permeability Based on D_{10} Correlation[b] (ft/min)
Upper Fill and Sand Unit	1A	3	< 0.0001	-
	1A	4	< 0.00001	
	2A	2	< 0.01	-
	2A	3	< 0.01	< 0.005
	2A	4A	< 0.001	-
	4A1	3	< 0.0001	-
	5A	3	< 0.01	-
	5A	4	< 0.01	< 0.01
Lower Sand and Gravel Unit	1A	7	0.13 to 5.41	0.023
	1A	8	≈ 0.13	-
	1A	9	≈ 0.13	0.032
	1A	10	0.13 to 5.41	-
	1A	11	≈ 0.13	0.01
	2A	6	≈ 0.13	< 0.01
	2A	7	0.01 to 0.13	< 0.01
	2A	8	≈ 0.22	< 0.01
	4A1	8	0.01 to 0.08	0.03 to 0.06
	4A1	10	0.08 to 0.22	0.34 to 0.58
	4A1	12	≈ 0.01	< 0.01
	5A	5	≈ 0.01	0.013
	5A	6	≈ 0.005	< 0.01
	5A	8	0.01 to 0.13	0.01 to 0.18

[a] Reference Figure 8-5 Department of Navy, 1962.

[b] Reference Figure 3-2 Department of Navy, 1962.

LIST OF PLATES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Hunter Point
BOLLING AIR FORCE BASE
Washington Sailing Marina
Light
Daingerfield Island
POTOMAC YARDS
WASHINGTON
BM
RIVER
POTOMAC
Shepherds Landing
Marbury Pt
Blue Plains
NAVAL RESEARCH LABORATORY
Bald Eagle Hill
SHEPHERD
BALTIMORE
APPROXIMATE PLANT SITE
R H. BOGLE COMPANY
ALEXANDRIA, VIRGINIA
Goose Island
Oxon Creek
DISTRICT OF MARYLAND
Tidal Flat
Torpedo
Fox Ferry Pt
295
ST ELIZABETHS FARM
INTERCHANGE
Hospital
Library
U S NAVAL RESERVATION
U S MIL RES
St Marys Cem
WOODROW WILSON MEMORIAL BRIDGE
CAPITAL
Tidal Flat
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL.
SOURCE: U.S.G.S. WASHINGTON AND VICINITY, D.C.-M.D.-VA. 1965
DAMES & MOORE

PLOT
PLAN

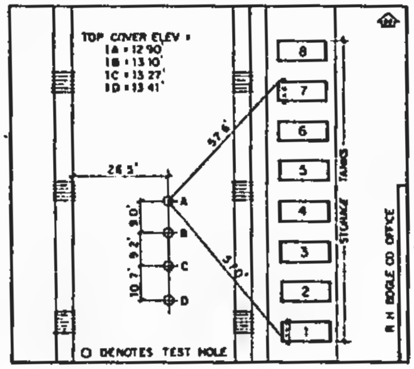
PLATE 2.

Map has been removed.
Map can be found in Contaminated Land Folder.

BY ______ DATE ______ PLATE # ______ OF ______

CHECKED BY ______ DATE ______

BORING 1A

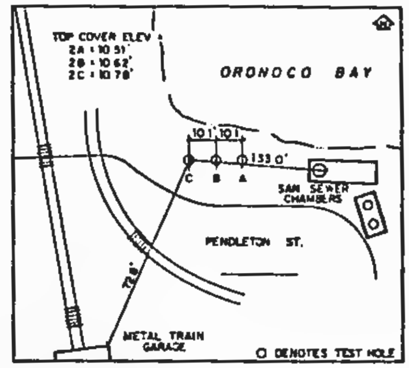


SURFACE ELEVATION: 13.0'
LOCATION: SEE MAP

DEPTH IN FEET	SAMPLES	SOIL TYPE	DESCRIPTIONS
0	1	SM	FILL MATERIAL, DARK GRAY TO BLACK AND DARK BROWN MIXTURE OF SAND, FINE TO MEDIUM WITH SOME COARSE SAND AND MINOR GRAVEL, AND SILT, WITH TRACE CLAY, OXIDIZED IN SOME LAYERS WITH IRON STAINING.
5	2	SW	
10	*3	SM / WC	
15	*4	CL	INTERLAYERED SAND, FINE TO MEDIUM, SUB-ROUNDED TO ANGULAR AND SILT, MODERATE UNIFORMITY, YELLOW BROWN TO LIGHT BROWN.
20	*5	SP	
25	6	SP	SAND, MEDIUM BROWN, FINE TO COARSE, AND GRAVEL, SUB-ROUNDED TO ANGULAR, MIXED LITHOLOGY LOW TO MODERATE UNIFORMITY.
30	*7	SP	
35	*8	SM / SP	SAND, MEDIUM BROWN, FINE TO MEDIUM WITH MINOR COARSE, TRACE VERY FINE AND SILT, SUB-ROUNDED TO ANGULAR, UNIFORM, MICACEOUS (JUVENILE).
40	*9	SP	
45	*10	SW	SAND, MEDIUM GRAY BROWN, MEDIUM TO COARSE AND GRAVEL, SUB-ROUNDED TO SUB-ANGULAR, LOW UNIFORMITY, WITH MINOR FINE SAND.
50	*11	SP	SAND, MEDIUM GRAY, MEDIUM TO FINE WITH MINOR GRAVEL AND COARSE SAND, SUB ANGULAR TO ANGULAR, UNIFORM.
55	12	CL	CLAY, BLUE GRAY, VERY STIFF.

DRILLING TERMINATED AT 56.5' AFTER SAMPLE 12 TAKEN: 1430 HR, APRIL 29, [illegible], MONITORING WELL CONSTRUCTION DETAILS GIVEN IN APPENDIX.

BORING 2A



SURFACE ELEVATION: 10.3'
LOCATION: SEE MAP

DEPTH IN FEET	SAMPLES	SOIL TYPE	DESCRIPTIONS
0	1	SP	FILL MATERIAL, BLACK, DARK BROWN AND REDDISH BROWN MIXTURE OF SAND, FINE TO MEDIUM WITH MINOR SILT, COARSE SAND AND GRAVEL, SUB-ROUNDED TO ANGULAR, LOW UNIFORMITY.
5	*2	SM	
10	*3	SM / SP	
15	*4	SM / CL	INTERLAYERED SAND, MEDIUM TO DARK GRAY MEDIUM TO COARSE WITH GRAVEL, TRACE SILT AND ORGANICS AND CLAY LIGHT BROWN TO GRAY, SILTY AND MODERATELY STIFF.
20	*5	SM / CL	
25	*6	SW	SAND, MEDIUM GRAY, MEDIUM TO COARSE WITH TRACE SILT AND GRAVEL, WITH MINOR COBBLES, SUB-ROUNDED TO ANGULAR, MODERATE UNIFORMITY.
30	*7	SW	
35	*8	GW	SAND, MEDIUM TO DARK GRAY, MEDIUM TO FINE WITH SOME COARSE, SUB-ROUNDED TO ANGULAR, UNIFORM.
40	9	SP / CL	CLAY, BLUE GRAY, VERY STIFF.
	10	CL	
45			

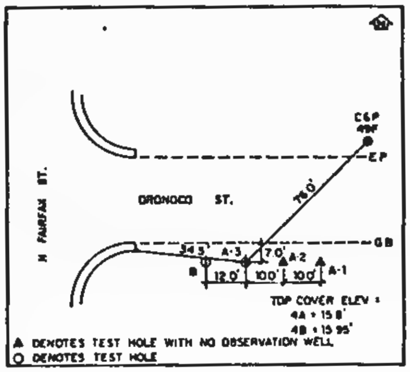
DRILLING TERMINATED AT 44.5' AFTER TAKING SAMPLE 10: 1000 HR, MAY 5, 1976, MONITORING WELL CONSTRUCTION DETAILS GIVEN IN APPENDIX.

LOG OF BORINGS

DAMES & MOORE

*GRAIN SIZE ANALYSIS CURVE SHOWN IN APPENDIX.

BORING 4A-B

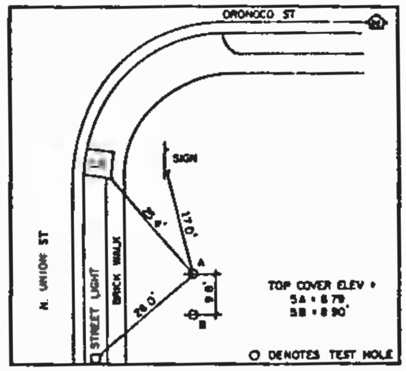


SURFACE ELEVATION: 15.9'
LOCATION: SEE MAP

DEPTH IN FEET	SAMPLES	SOIL TYPE	DESCRIPTIONS
0	1	SP	FILL MATERIAL, SAND, BLACK TO DARK GRAY, FINE TO MEDIUM WITH SOME COARSE AND GRAVEL, ROUNDED TO ANGULAR, MODERATE UNIFORMITY.
5	2	CL/SM	INTERLAYERED SILT, MEDIUM BROWN AND CLAY, LIGHT TO MEDIUM BROWN WITH TRACE SAND.
10	*3	SM	SAND, MEDIUM GRAY, FINE TO MEDIUM WITH SILT AND MINOR COARSE SAND AND GRAVEL, SUB-ROUNDED TO ANGULAR, MODERATE UNIFORMITY, MINOR LIMONITE STAINING TO 16'.
15	4, *5	SM	
20	6	SM	
25	*7	ML	
30	*8	SW	GRAVEL, COBBLES, AND SAND, MEDIUM TO COARSE, SUB ROUNDED TO ANGULAR, LOW UNIFORMITY, VARIABLE LITHOLOGY, MICACEOUS IN PART (JUVENILE).
35	9	GP	
40	*10	SW	
45	11	GW	
50	*12	SW	
55	13	SP	SAND, MEDIUM GRAY, MEDIUM WITH MINOR GRAVEL LAYERS, SUB-ROUNDED TO ANGULAR, UNIFORM.
60	14	CL	CLAY, DARK BLUE BLACK, VERY STIFF.

DRILLING TERMINATED AT 60.5' AFTER SAMPLE 14 TAKEN 1300 HR, MAY 3, 1976, MONITORING WELL CONSTRUCTION DETAILS GIVEN IN APPENDIX.

BORING 5A



SURFACE ELEVATION: 8.8'
LOCATION: SEE MAP

DEPTH IN FEET	SAMPLES	SOIL TYPE	DESCRIPTIONS
0	1	SM	FILL MATERIAL, SAND, MEDIUM TO DARK GRAY, FINE WITH SOME MEDIUM TO COARSE INCLUDING BRICK AND WOOD FRAGMENTS.
5	2	SP	
10	*3	SM	
15	*4	SM	SAND, MEDIUM GRAY BROWN, FINE TO MEDIUM AND SOME COARSE AND SILT AND TRACE GRAVEL.
20	*5	SW	GRAVEL AND SAND, MEDIUM TO COARSE WITH MINOR FINE AND TRACE SILT SUB-ROUNDED TO ANGULAR, MODERATELY UNIFORM, VARIABLE LITHOLOGY.
25	*6	SM	
30	7	GP	
35	*8	SW	CLAY, MEDIUM BLUE GRAY, MOTTLED, VERY STIFF.
40	9	CL	

DRILLING TERMINATED AT 41.5' AFTER SAMPLE 9 TAKEN: 1200 HR, MAY 6, 1976, MONITORING WELL CONSTRUCTION DETAILS GIVEN IN APPENDIX.

LOG OF BORINGS

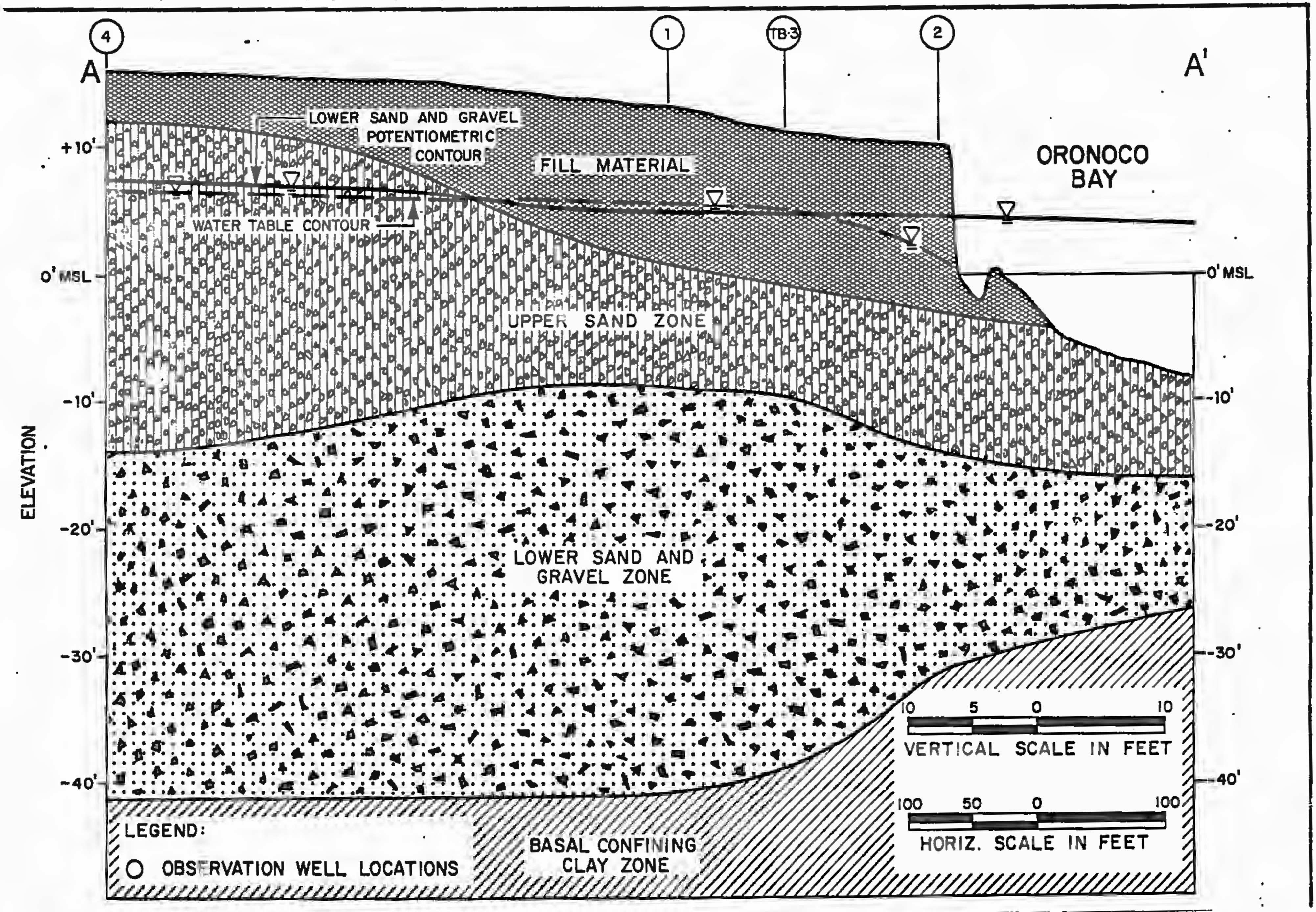
DAMES & MOORE

*GRAIN SIZE ANALYSIS CURVE SHOWN IN APPENDIX.

CHECKED BY ____ DATE ____
BY ____ DATE ____ PLATE ____

CHECKED BY ______ FILE 4430 001-27 REVISIONS BY ______ DATE 7/29/7

SCHEMATIC CROSS-SECTION OF GEOLOGY AND GROUND-WATER LEVELS IN THE SITE VICINITY



APPENDIX A

PHASE I - SEDIMENT ARSENIC

AND MERCURY CONCENTRATIONS FOR TB-BORINGS

PHASE I - SEDIMENT ARSENIC AND MERCURY CONCENTRATIONS FOR TB-BORINGS

Boring	Sample Number	Sample Depth (ft.)	Lithology	Arsenic in PPM	Mecury in PPM
TB-1	6	7.5 - 9.0	Sandy Silt	9.9	<0.25
TB-1	10	25.0 - 26.5	"	6.6	<0.25
TB-1	11	35.0 - 36.5	Sandy & Gravel	44.5	<0.25
TB-1	15	54.0 - 55.5	Clay	5.0	<0.25
TB-1	20	79.0 - 80.5	Sandy Clay	14.2	<0.25
TB-1	23	94.0 - 94.8	Silty Clay	5.0	<0.25
TB-2	1	0.0 - 1.0	Fill	10,300.0	70.00
TB-2	2	1.0 - 2.0	"	4,650.0	2.80
TB-2	3	2.0 - 3.0	"	1,870.0	0.67
TB-2	4	3.0 - 4.0	"	1,880.0	2.15
TB-2	5	4.0 - 5.0	"	1,400.0	1.10
TB-2	6	5.0 - 6.0	Sand	1,700.0	<0.25
TB-2	7	6.0 - 7.0	"	735.0	1.55
TB-2	8	7.0 - 8.0	Silty Clay	683.0	0.30 0.25*
TB-2	9	8.0 - 9.0	Silty Clay	780.0	0.25
TB-2	10	9.0 - 10.0	Sand	515.0	0.25
TB-2	11	24.0 - 25.5	Sand & Gravel	10.0	0.30
TB-2	12	29.0 - 29.3	" "	41.4	0.30
TB-2	13	34.0 - 35.5	" "	15.5	0.30
TB-2	14	39.0 - 40.5	" "	7.5 <5.0*	0.30
TB-2	15	44.0 - 45.5	" "	18.4	0.45
TB-2	16	49.0 - 50.5	Silty Sand	<5.0	0.45
TB-2	17	54.0 - 55.5	Silty Clay	<5.0	<0.25 0.25*
TB-2	18	59.0 - 60.5	Silty Clay	6.8 5.1*	0.40
TB-2	19	64.0 - 65.5	" "	7.0	<0.25
TB-2	20	69.9 - 70.5	Clayey Sand	8.8	<0.25

*Additional analysis results from same sample. .

PHASE I - SEDIMENT ARSENIC AND MERCURY CONCENTRATIONS FOR TB-BORINGS

Boring	Sample Number	Sample Depth (ft.)	Lithology	Arsenic in PPM	Mecury in PPM
TB-2	21	74.0 - 75.5	Clayey Sand	96.4 82.5*	1.10 <0.25*
TB-3	1	0.0 - 1.0	Fill	29,800.0	24.75
TB-3	2	1.0 - 2.0	Fill	15,300.0	147.50
TB-3	3	2.0 - 3.0	"	16,500.0	19.50
TB-3	4	3.0 - 4.0	"	2,500.0	2.54
TB-3	5	4.0 - 5.0	"	1,760.0	6.20
TB-3	6	5.0 - 6.0	"	1,210.0 1,130.0*	5.00
TB-3	7	6.0 - 7.0	"	4,060.0	11.80
TB-3	8	7.0 - 8.0	"	3,560.0	1.13
TB-3	9	8.0 - 9.0	"	5,686.0	0.60
TB-3	10	9.0 - 10.0	"	2,900.0	2.00
TB-3	11	14.0 - 15.5	Silty Sand	24.8	<0.25 0.30*
TB-3	12	19.0 - 20.5	Silty Sand	9.9	0.45
TB-3	13	24.0 - 25.5	Sand & Gravel	24.3	<0.25
TB-3	14	29.0 - 30.5	" "	28.6	0.55
TB-3	15	34.0 - 35.5	" "	27.5 16.3*	0.45
TB-3	16	39.0 - 40.5	" "	21.3	<0.25
TB-3	17	44.0 - 45.5	" "	22.0	0.30 0.40*
TB-3	18	54.0 - 55.5	Silty Clay	<5.0	<0.25
TB-3	19	59.0 - 60.5	Silty Clay	<5.0	<0.25
TB-3	20	64.0 - 65.5	" "	<5.0	0.45
TB-3	21	69.0 - 70.5	" "	37.9 27.0*	0.95 0.73*
TB-3	22	74.0 - 75.5	" "	<5.0	0.25
TB-4	1 & 2	0.0 - 2.0	Fill	4,740.0	12.50
TB-4	9	8.0 - 9.0	Fill	1,310.0	0.93

*Additional analysis results from same sample.

9930-001-27
R.H. Bogle Co.

PHASE I - SEDIMENT ARSENIC
AND MERCURY CONCENTRATIONS FOR TB-BORINGS

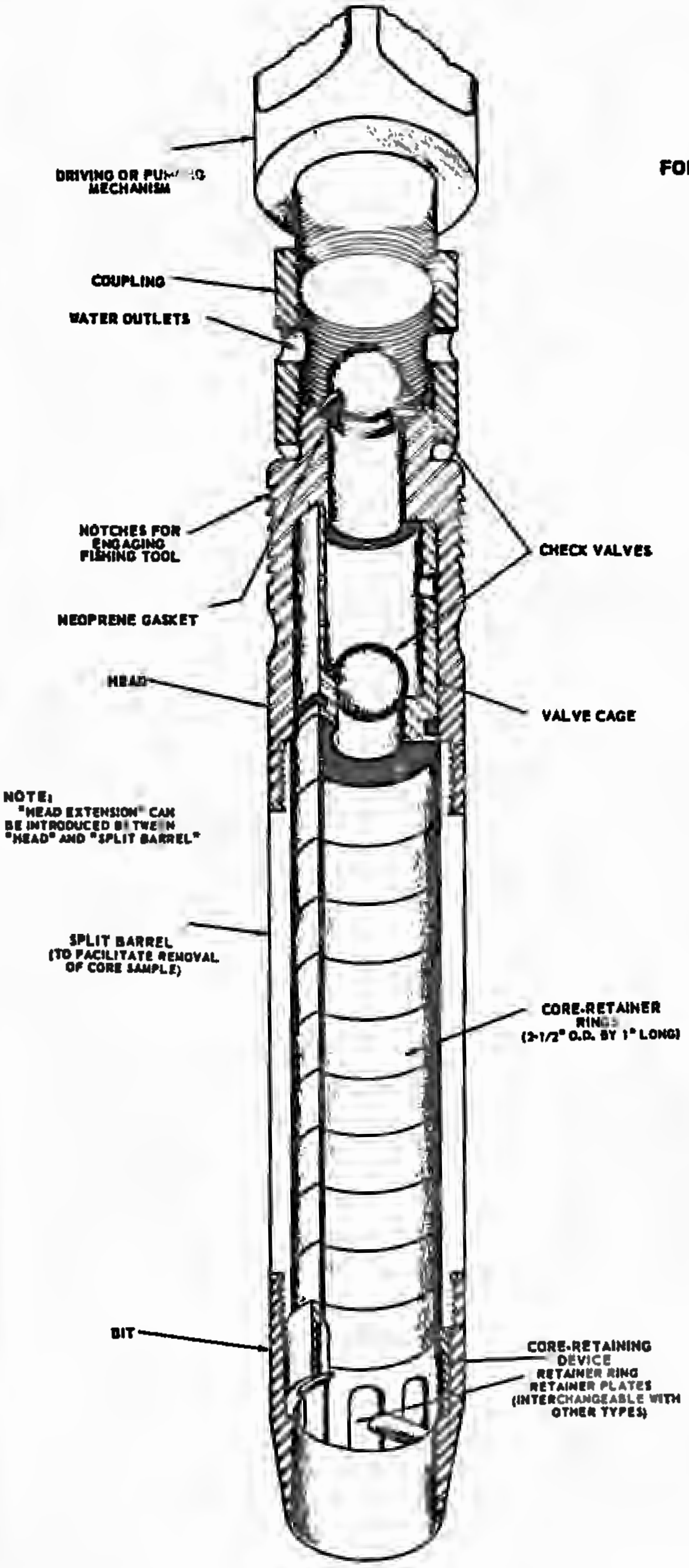
Boring	Sample Number	Sample Depth (ft.)	Lithology	Arsenic in PPM	Mecury in PPM
TB-4	13	24.0 - 25.5	Sand & Gravel	15.0	0.25
TB-4	18	54.0 - 55.5	Silty Clay	7.0	0.25
TB-4	21	69.0 - 70.5	Silty Clay	<5.0	<0.25
TB-5	3	2.0 - 3.0	Fill	76.8	<0.25
TB-5	6	5.0 - 6.0	Fill	30.3	<0.25
TB-5	11	14.0 - 15.5	Silty Sand	12.4	0.25
TB-5	14	29.0 - 30.5	Sand & Gravel	<5.0	<0.25
TB-5	19	54.0 - 55.5	Silty Clay	23.5	<0.25
TB-5	23	74.0 - 75.5	Silty Clay	6.4	<0.25

APPENDIX B

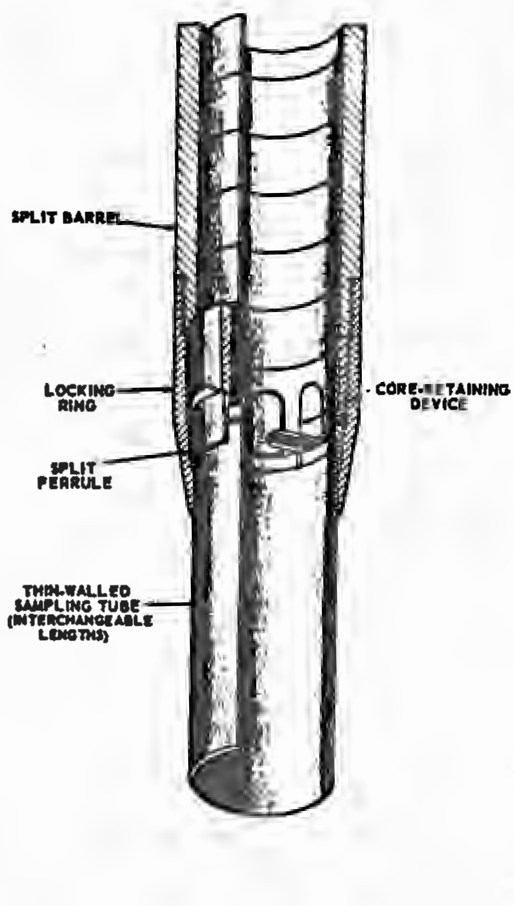
DAMES & MOORE U-TYPE SAMPLER

SOIL SAMPLER TYPE U

FOR SOILS DIFFICULT TO RETAIN IN SAMPLER

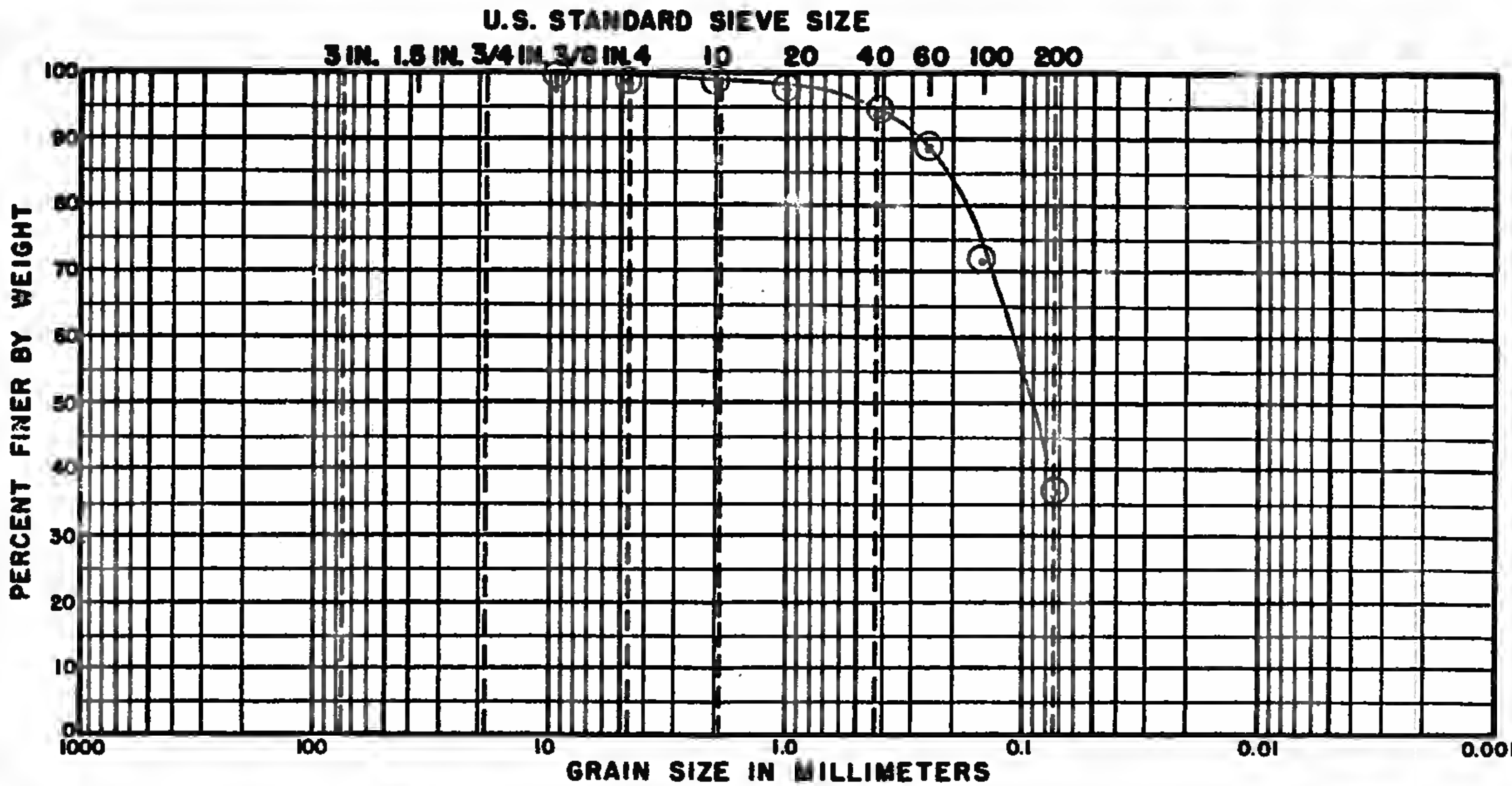


ALTERNATE ATTACHMENTS



APPENDIX C

GRAIN SIZE CURVES

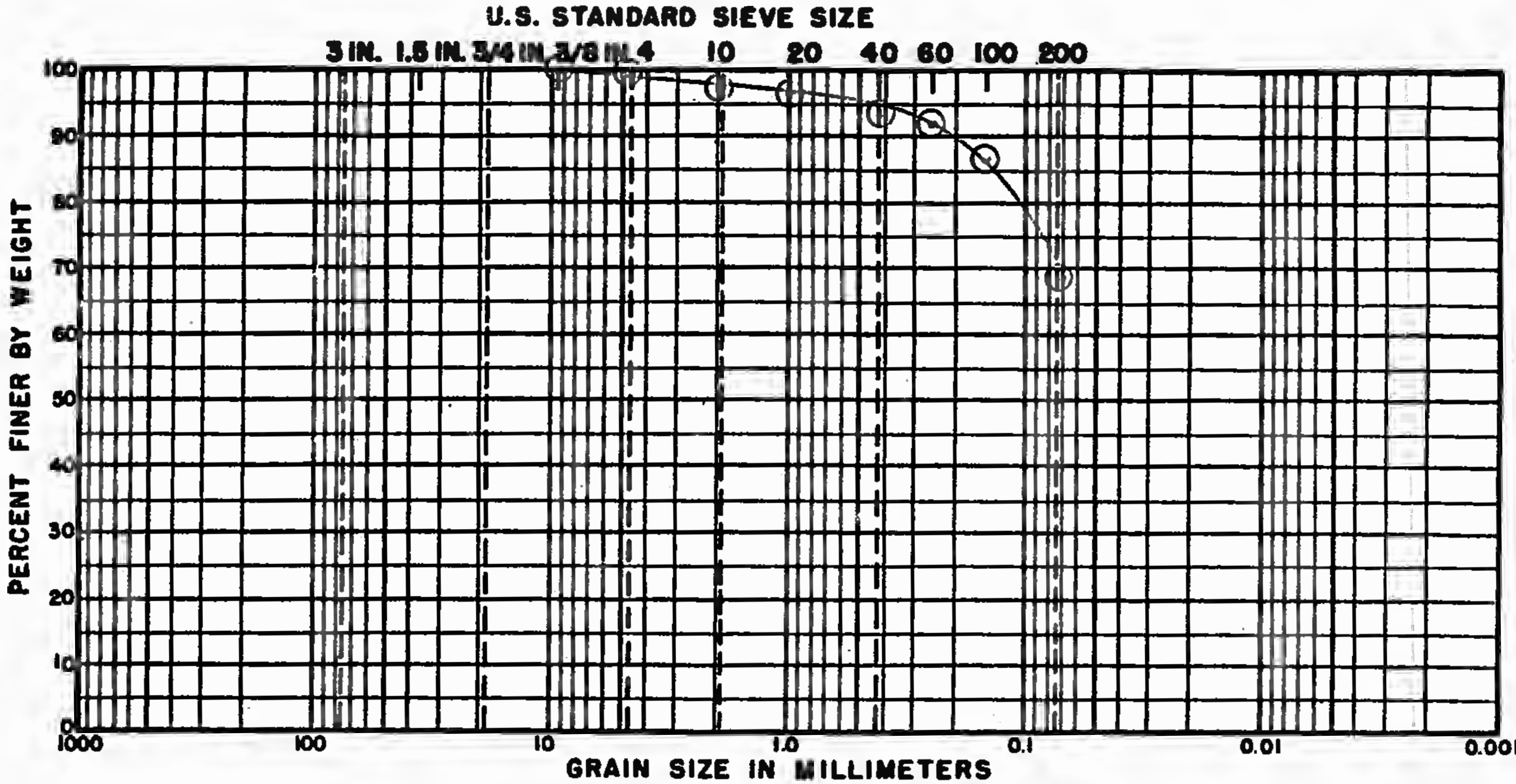


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
1A S-3	10-11.5	SM	w/ Clayey silt	20.4	—	—	—	

65% SAND
35% SILT-CLAY

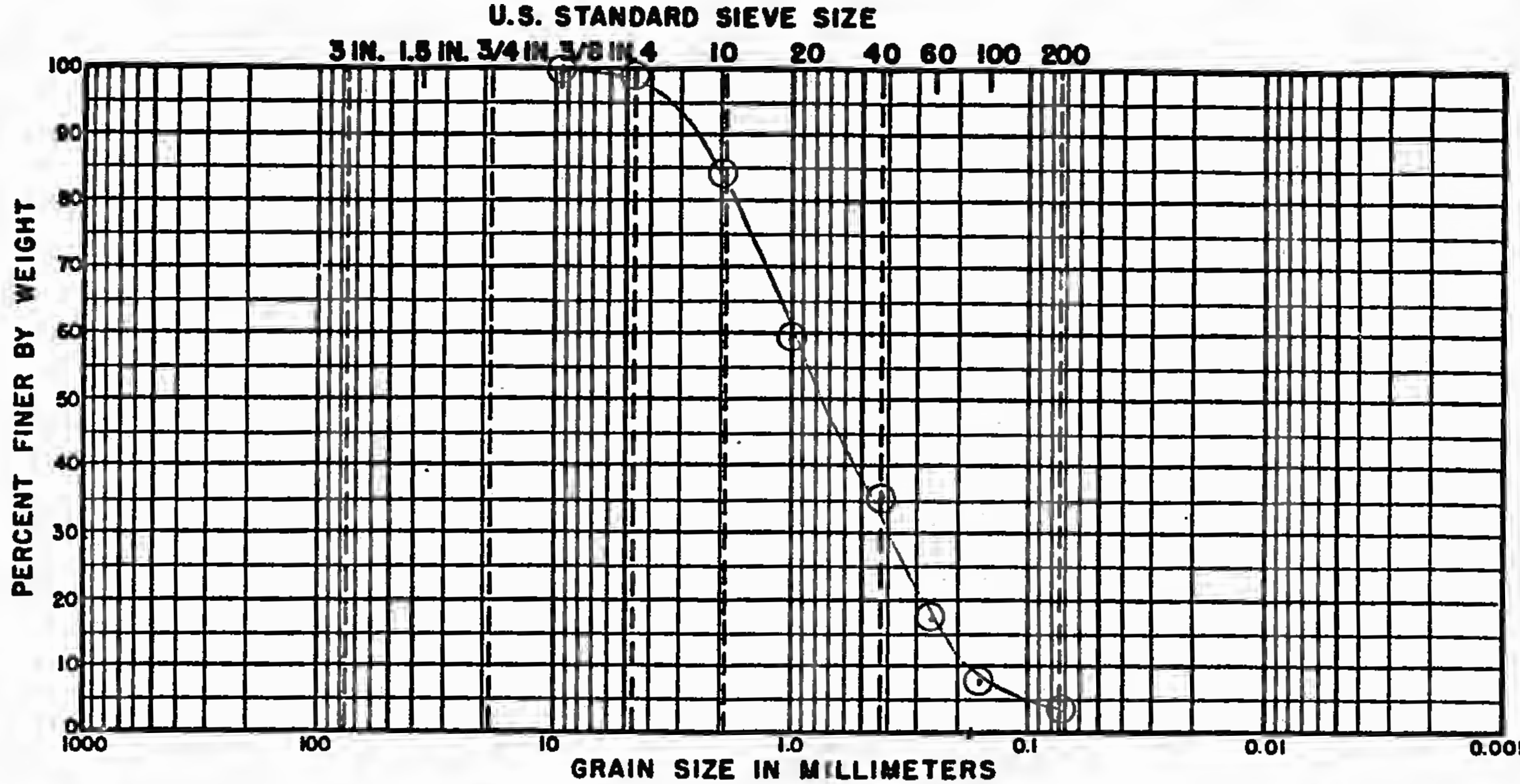
GRADATION CURVE



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION		NAT WC	LL	PL	PI	
1A 4	15.0-16.5	CL		21.8	—	—	—	

GRADATION CURVE

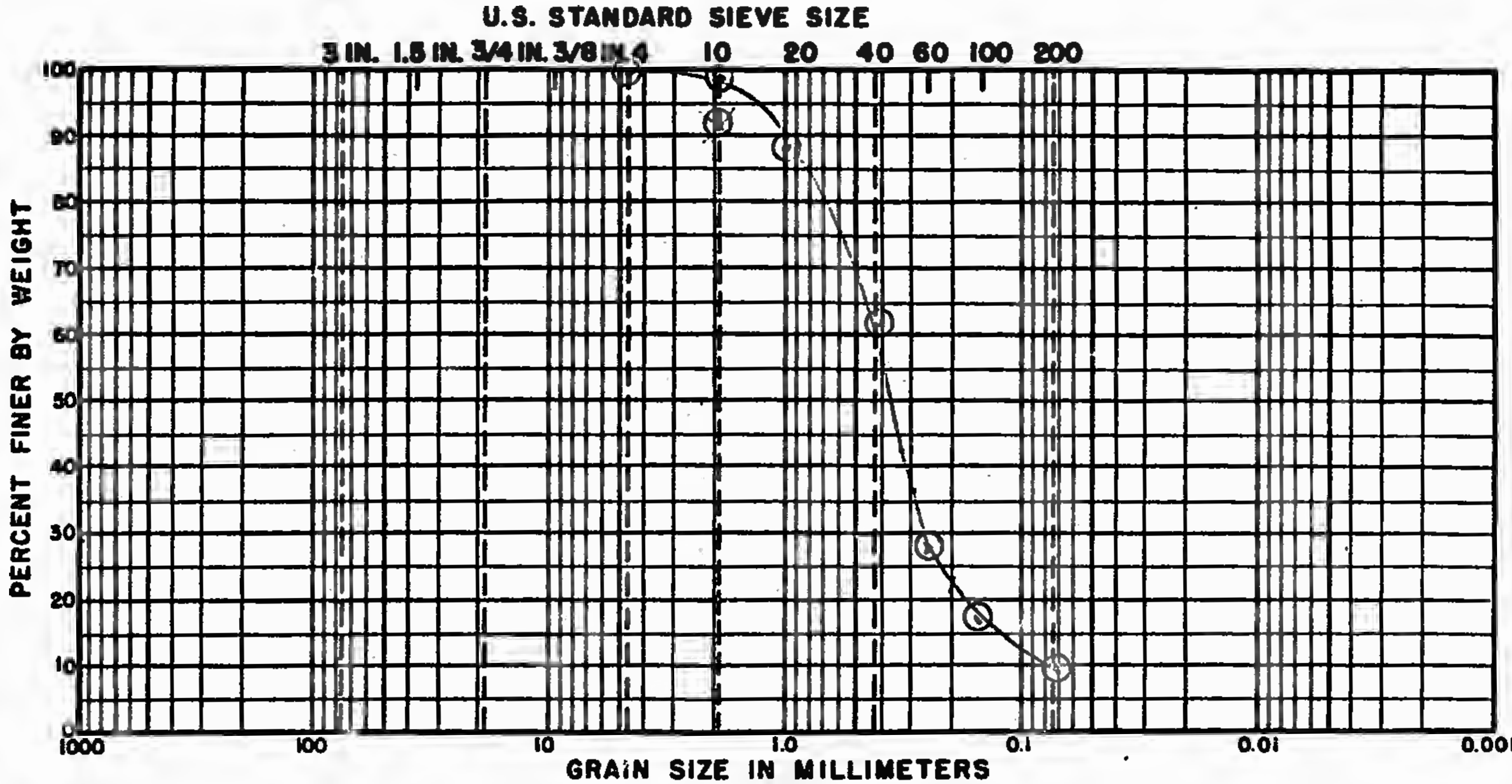


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION	NAT. WC	LL	PL	PI	
1A 7	30 - 31.5	SP	17.3				

2% GRAVEL
94% SAND
4% SILT

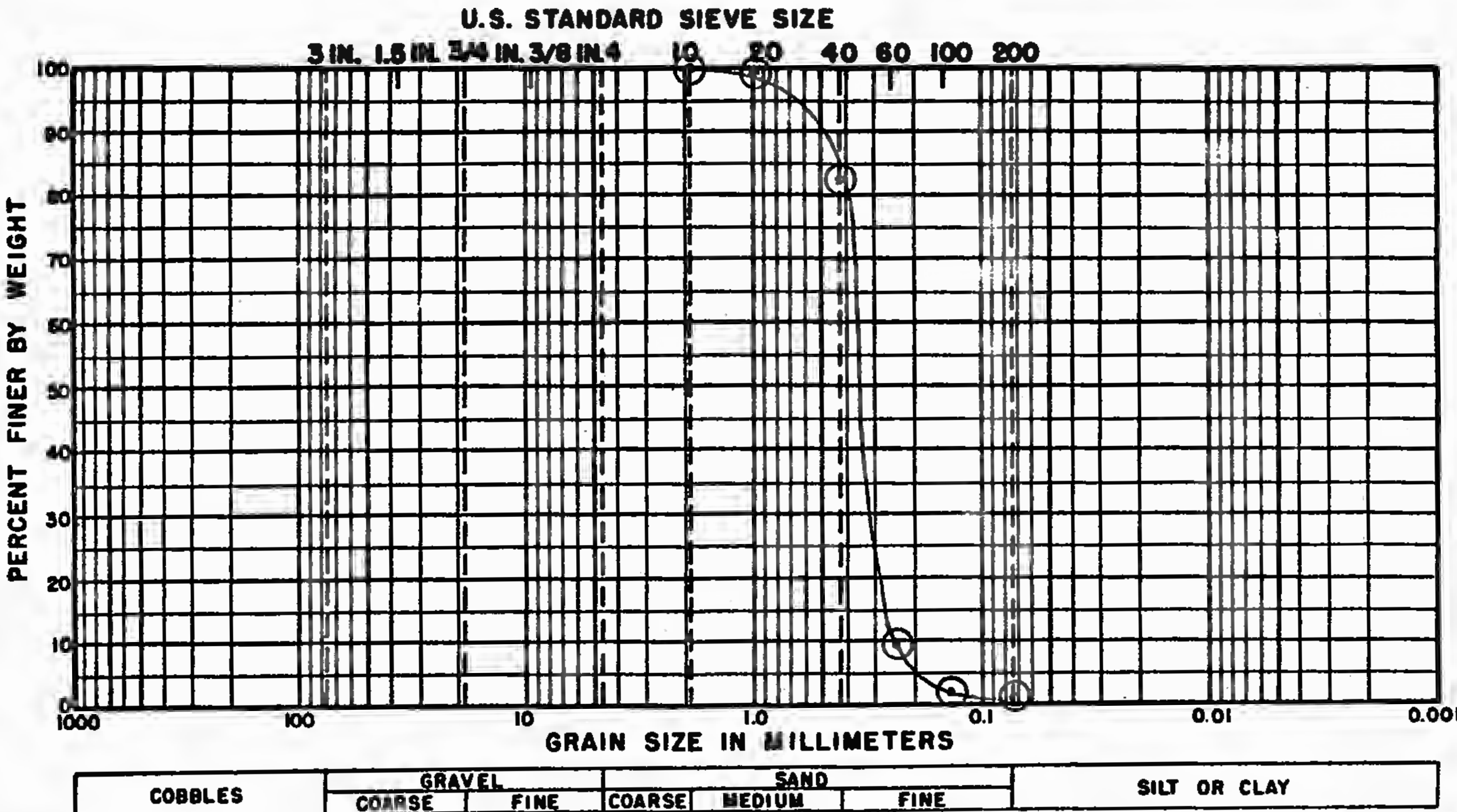
GRADATION CURVE



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

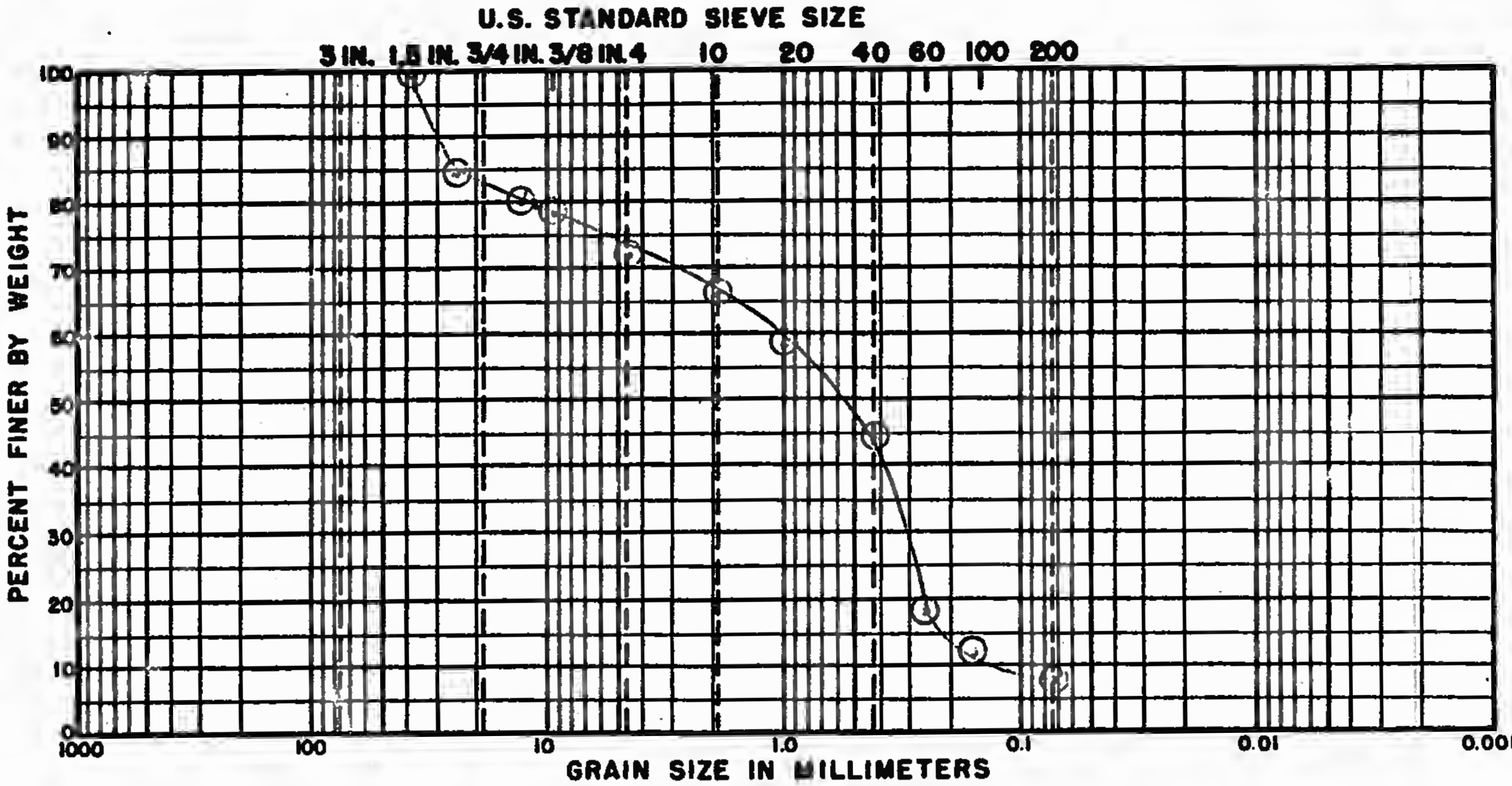
	DEPTH	CLASSIFICATION	NAT. WC	LL	PL	PI	
1A 8	35-36.5	SM/SP	16.0				

GRADATION CURVE



	DEPTH	CLASSIFICATION		NAT WC	LL	PL	PI	
1A[9]	40.0-41.5	SP	Fi @ Si. MED SA.	25.3	—	—	—	

GRADATION CURVE

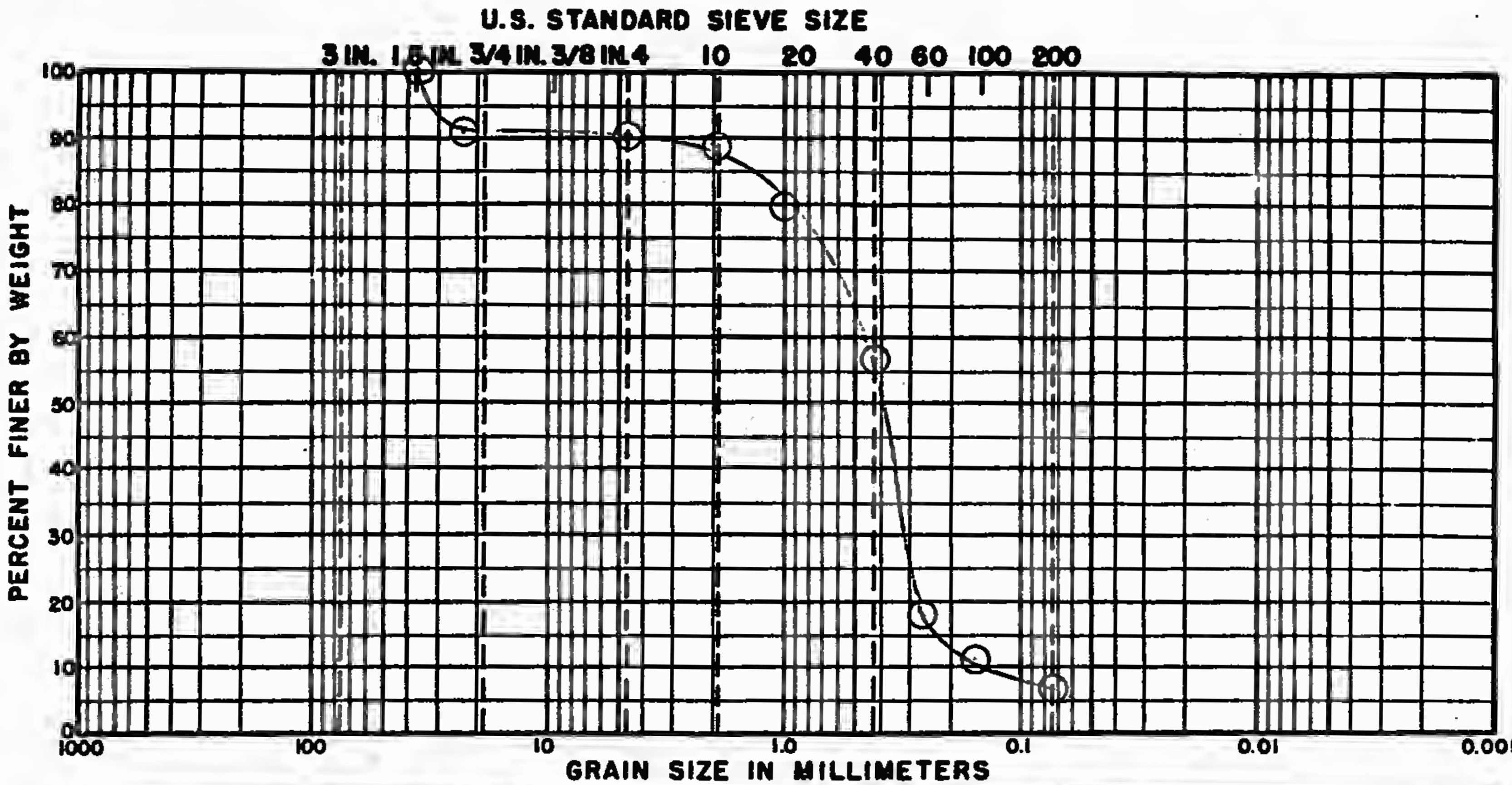


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION	NAT. WC	LL	PL	PI	
1A 10	45 - 46.5	Soil	13.0	—	—	—	

29% GRAVEL
64% SAND
7% SILT

GRADATION CURVE

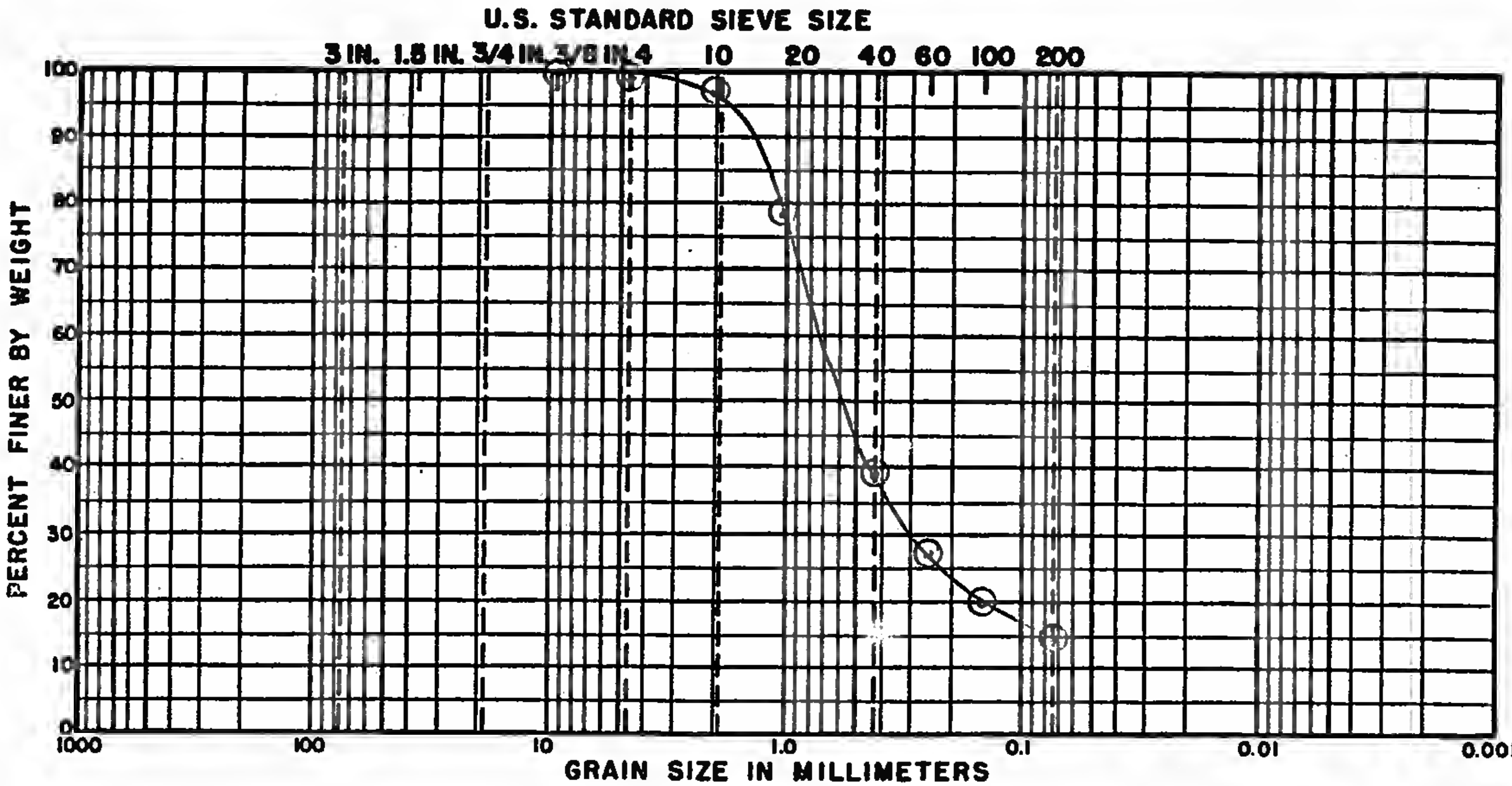


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
1A "	50 - 51.5	SP	WITH GRAVEL	16.4	—	—	—	

10% GRAVEL
83% SAND
7% SILT

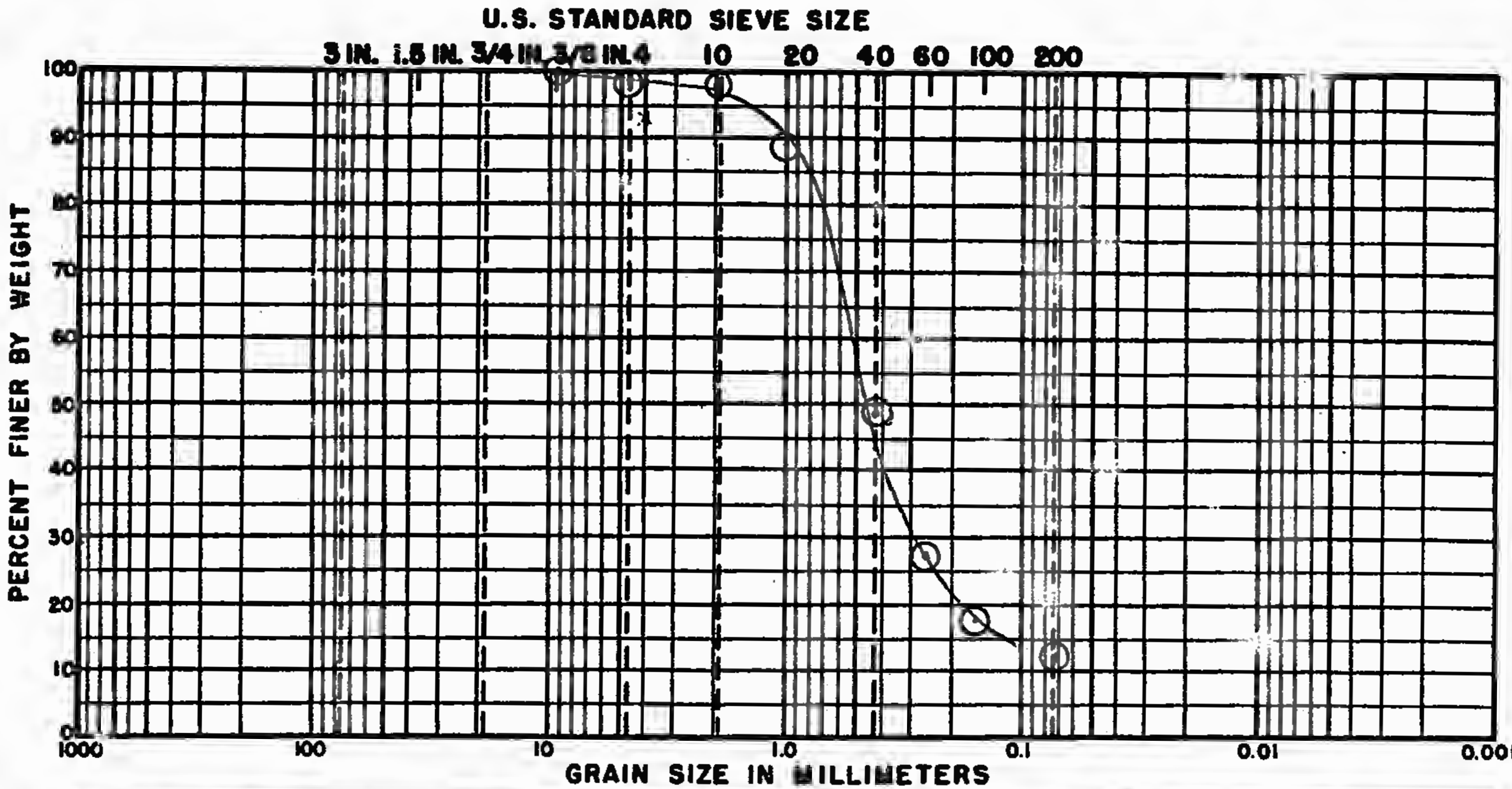
GRADATION CURVE



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
2A 2	5 - 6.5	SM		25.0	—	—	—	

GRADATION CURVE

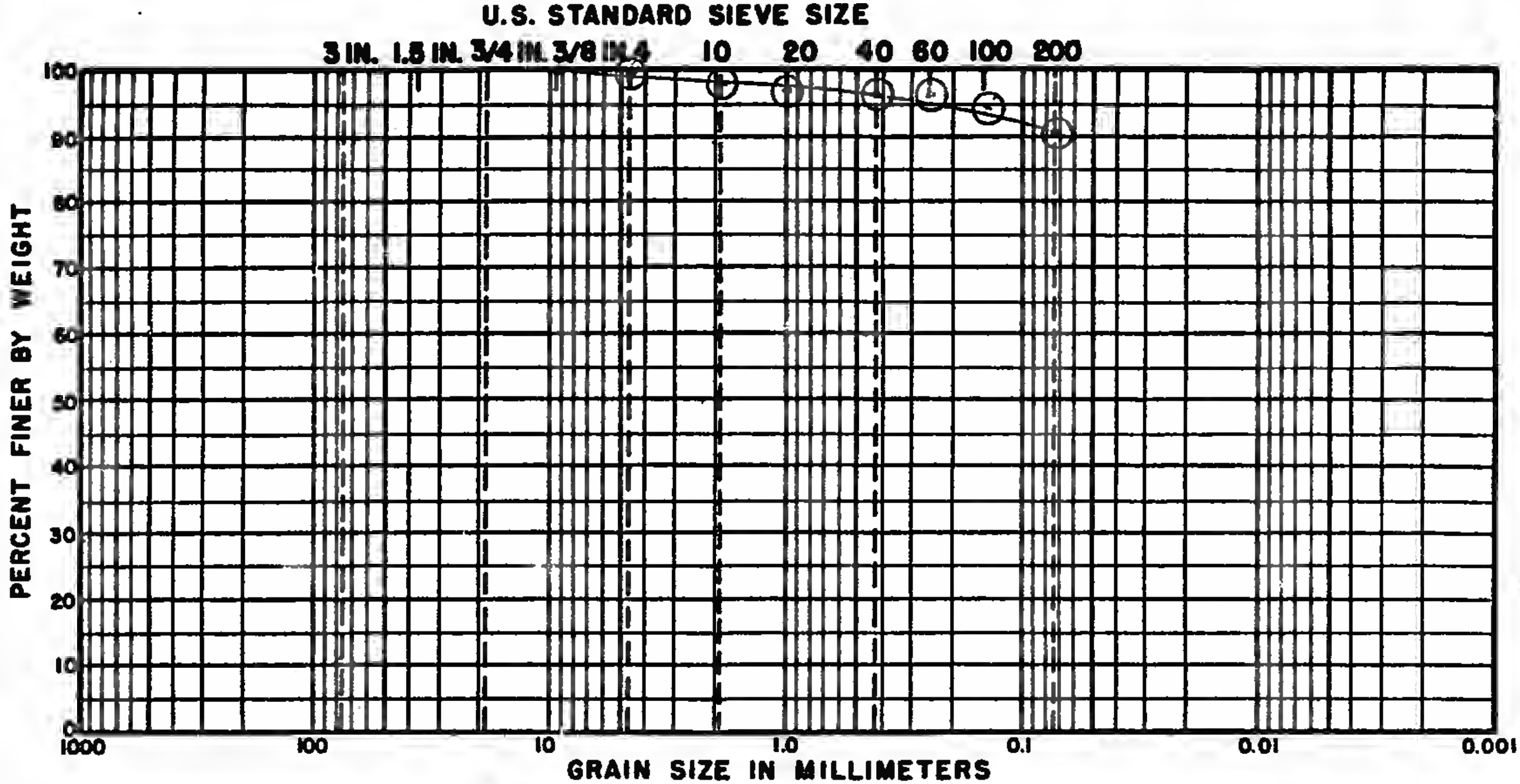


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION	NAT. WC	LL	PL	PI	
2A 3	10 - 11.5	SM/SP	37.8	—	—	—	

1% GRAVEL
87% SAND
12% SILT

GRADATION CURVE

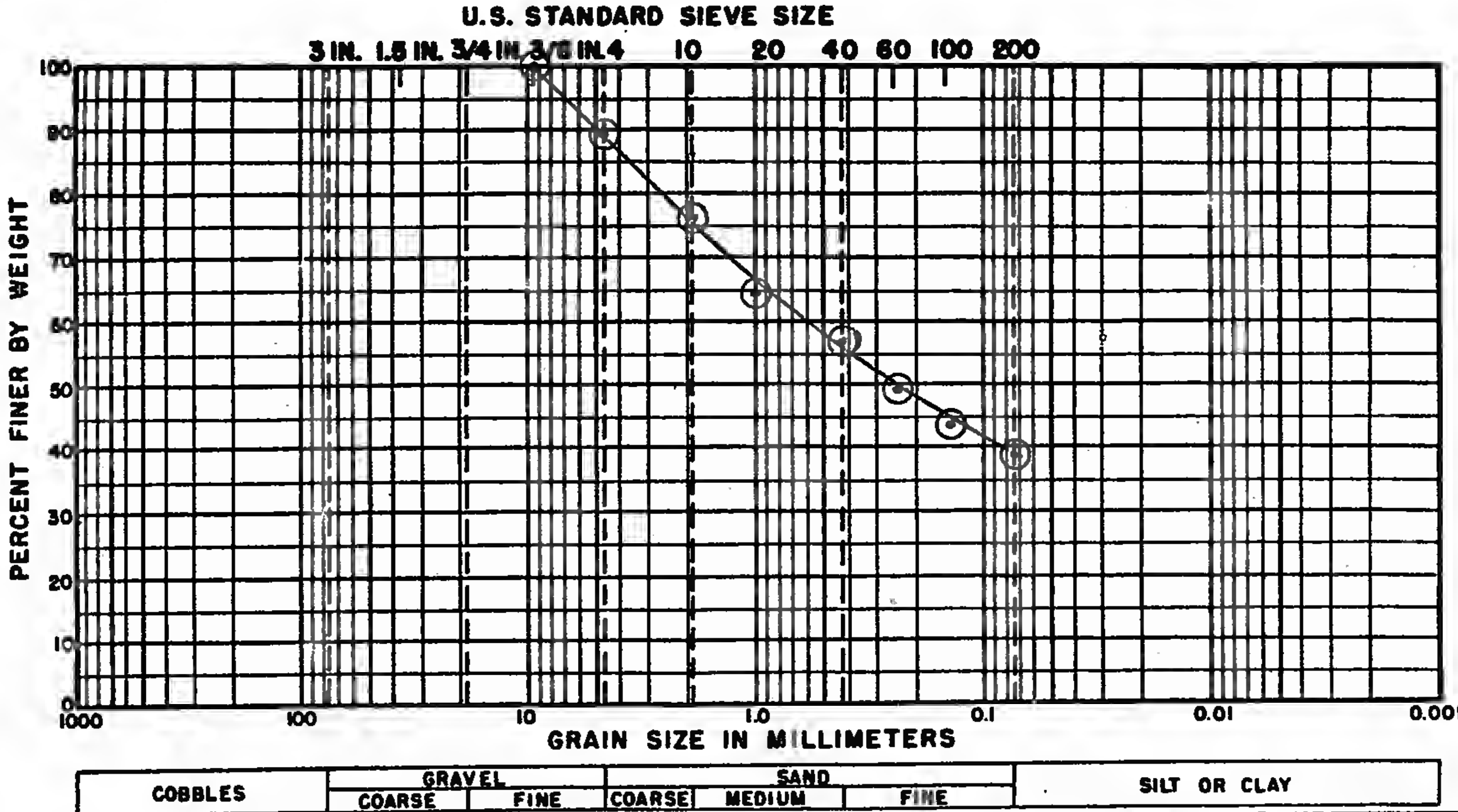


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
2A+A	15-16.5	CL-		24.7	—	—	—	

GRADATION CURVE

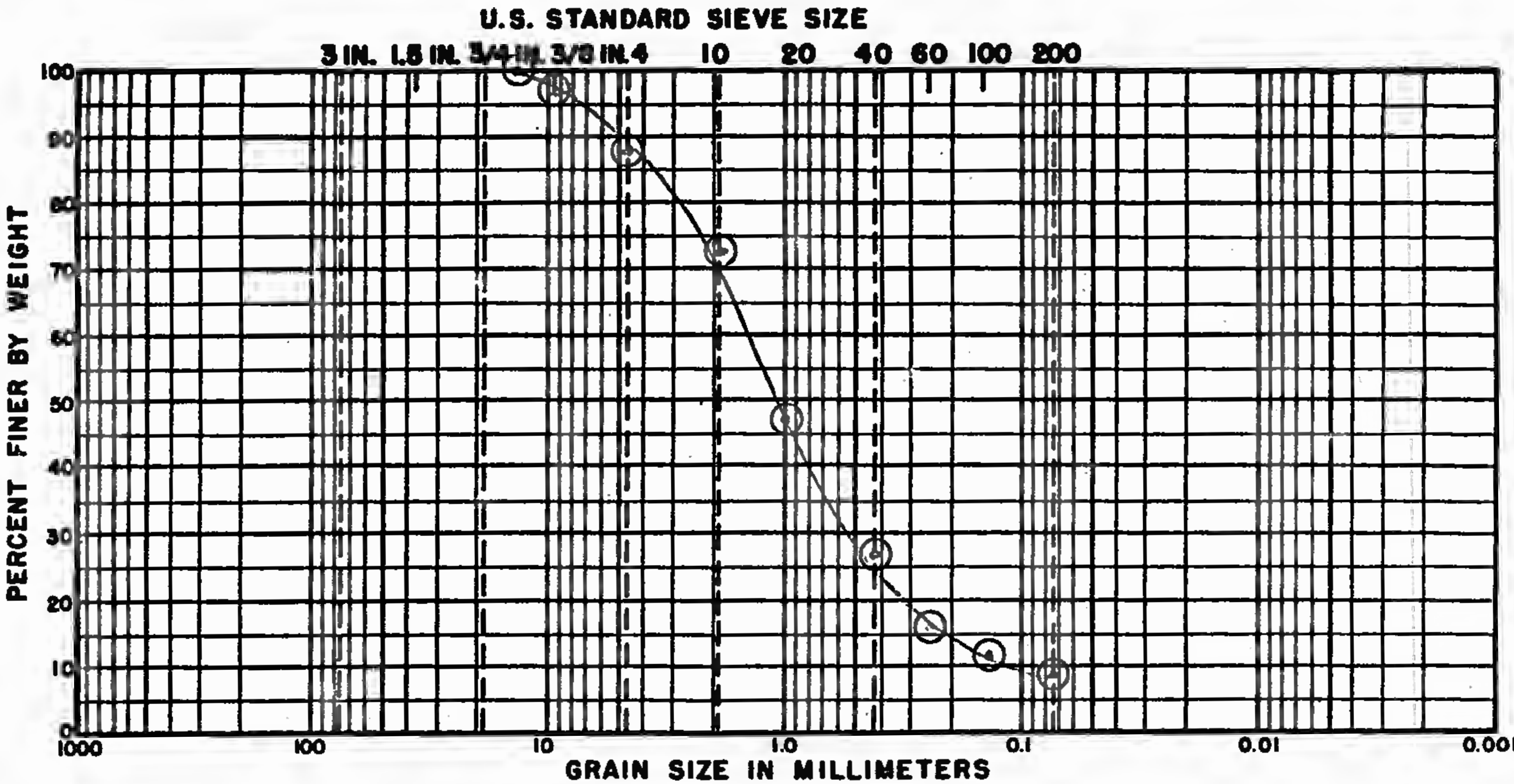
NOT PLOTTED.



	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
2A 4A	15-16.5	SM	CLAY/SILTY SA	24.7	—	—	—	

11% GRAVEL
50% SAND
39% SILT CLAY

GRADATION CURVE

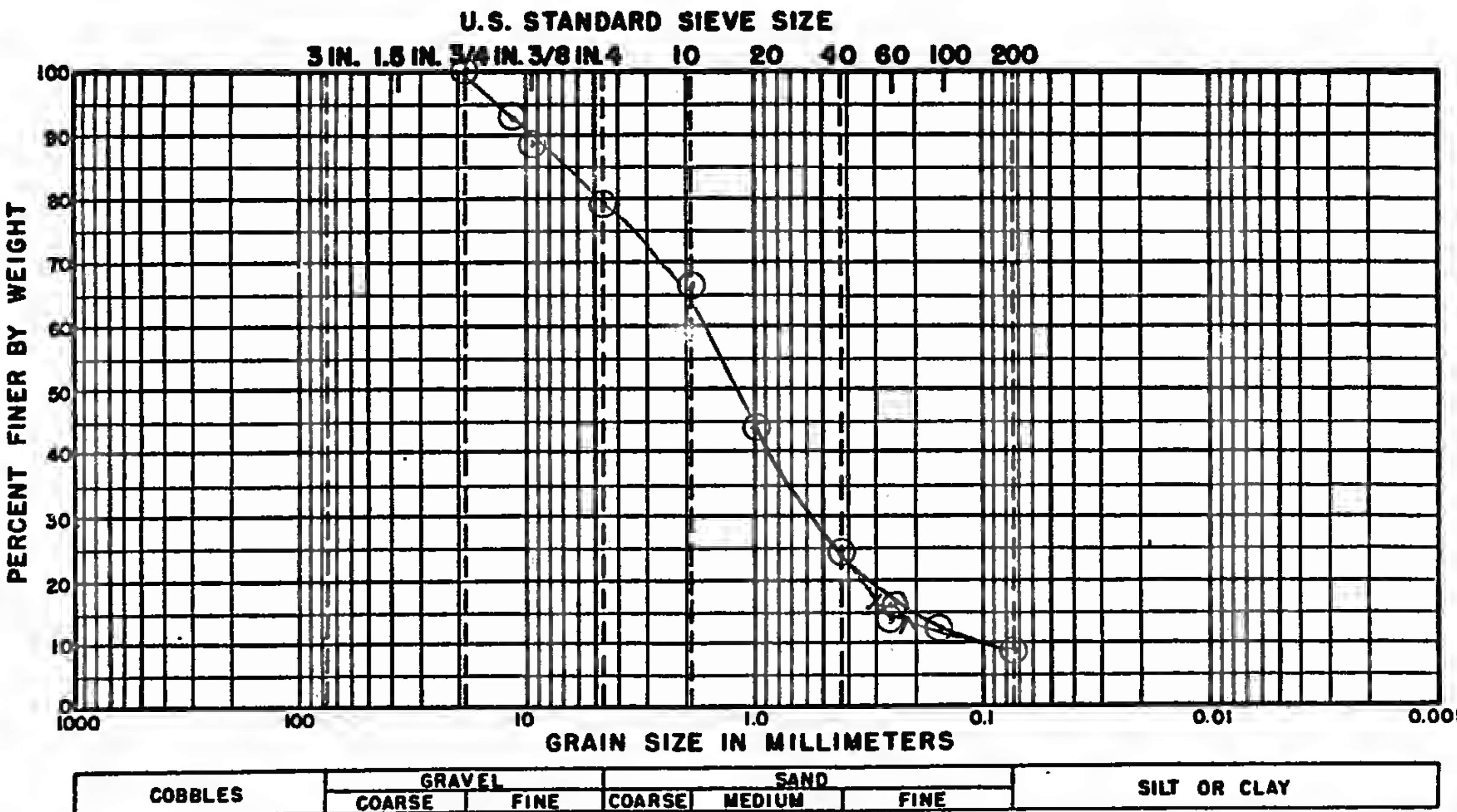


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION	NAT. WC	LL	PL	PI	
2AG	25.0-26.5	SW	15.0	—	—	—	

12% GV
79% SAND
9% SILT-CLAY

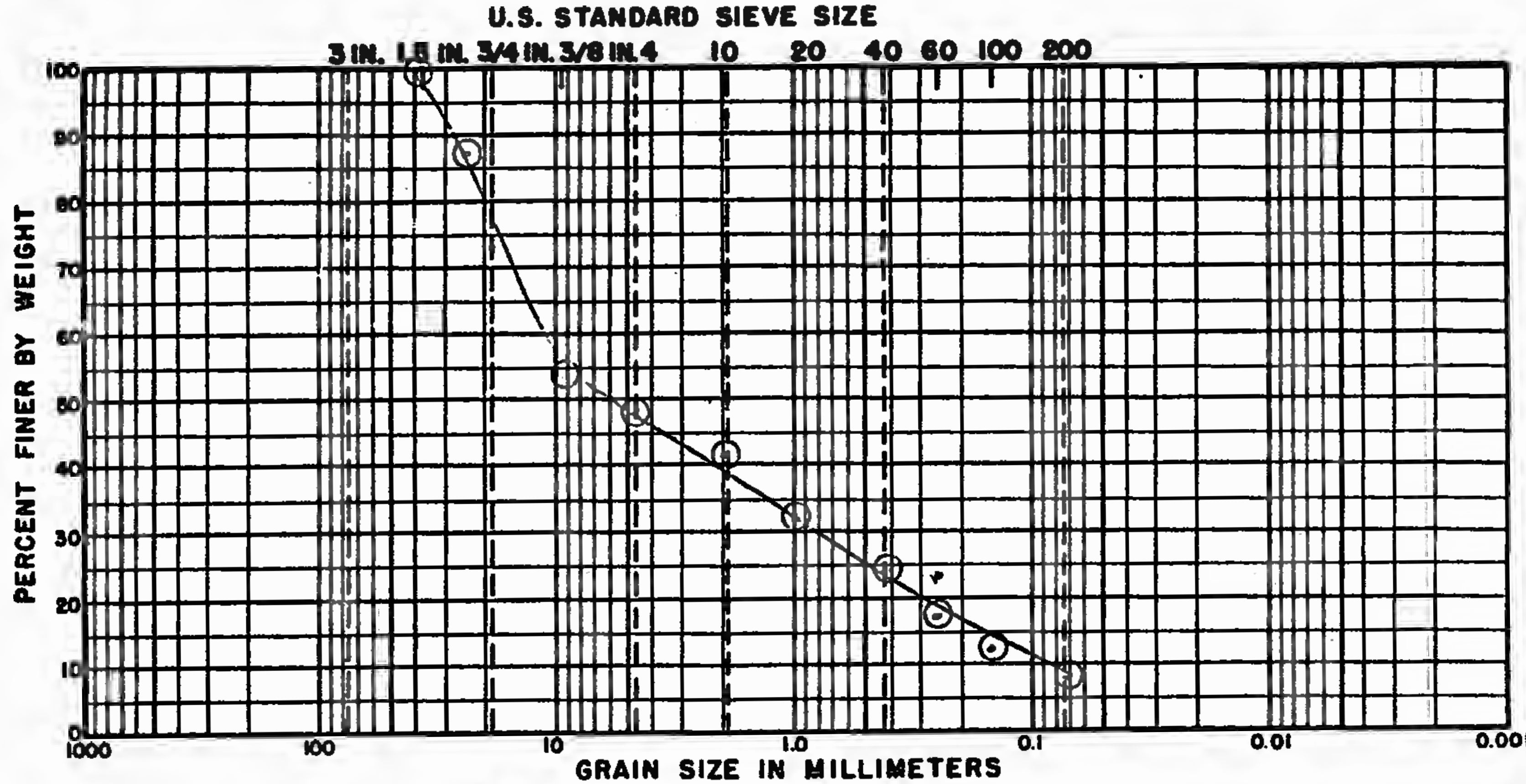
GRADATION CURVE



	DEPTH	CLASSIFICATION	NAT. WC	LL	PL	PI	
2A 7	30-31.5	SW	12.2	—	—	—	

21% GRAVEL
71% SAND
8% SILT CLAY

GRADATION CURVE

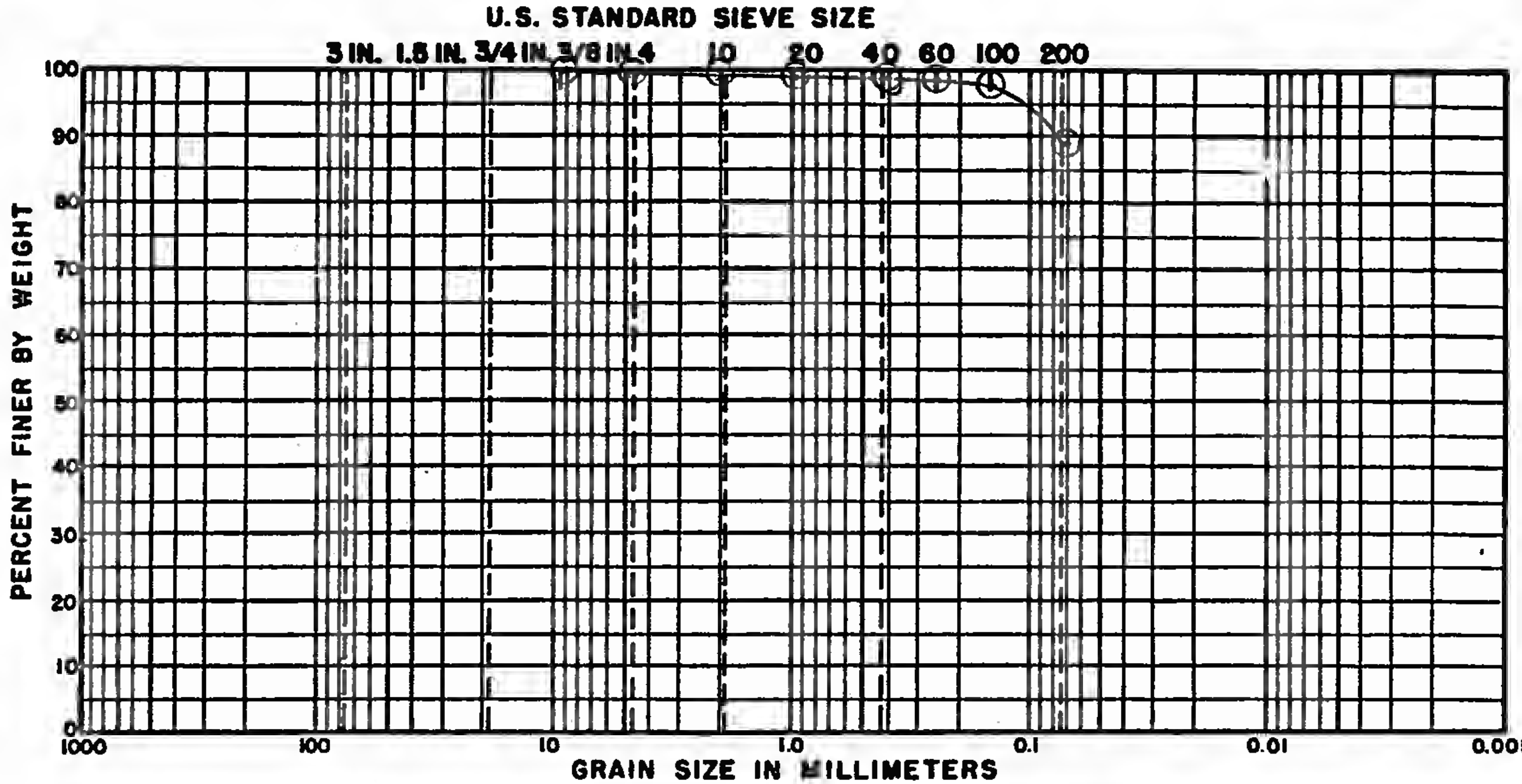


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION	NAT WC	LL	PL	PI	
2A ?	35 - 36.5	GW	7.5	—	—	—	

52% GRAVEL
41% SAND
7% SILT

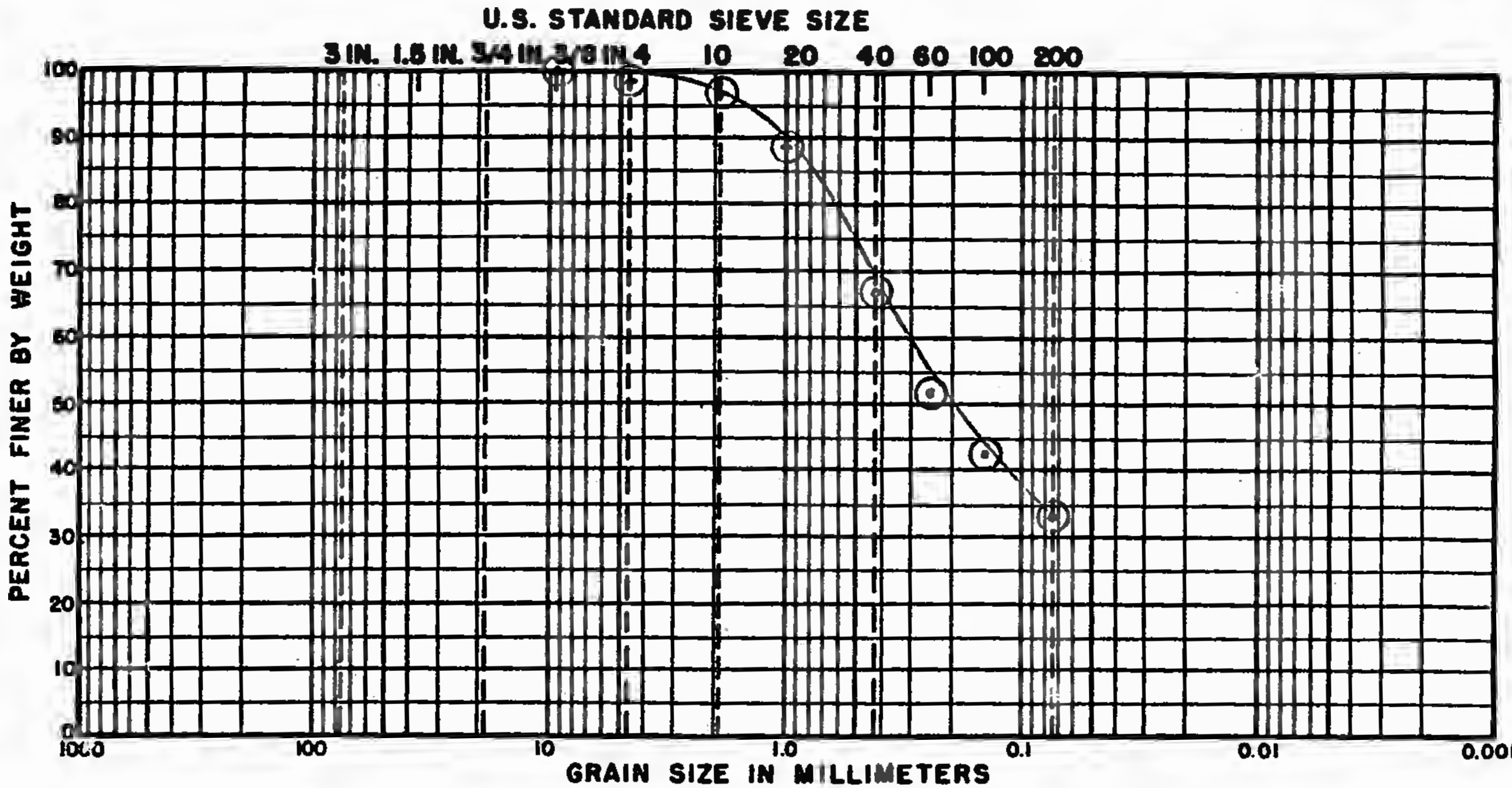
GRADATION CURVE



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
4A-1[2]	5-6.5	CL		24.6				

GRADATION CURVE

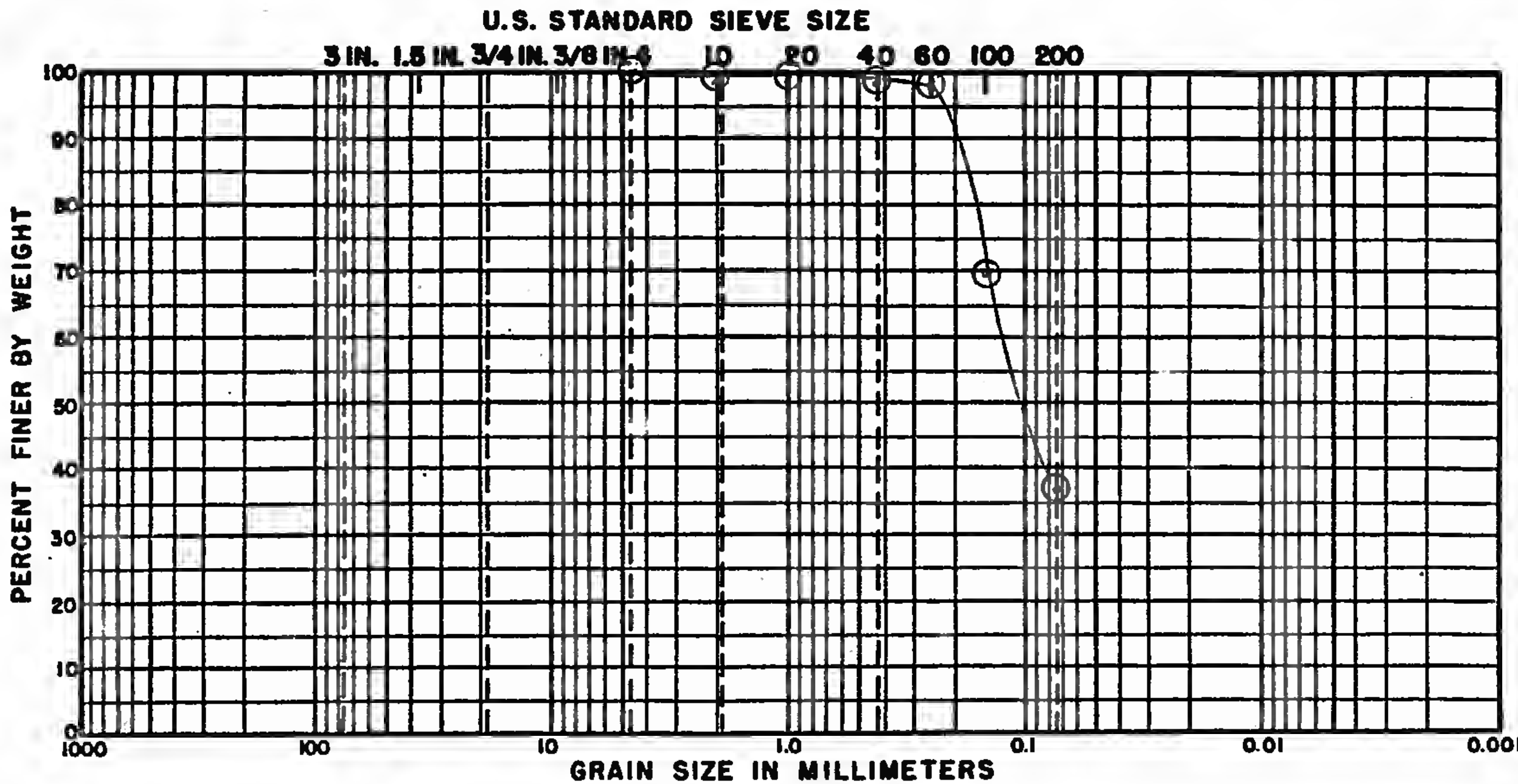


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
HA-1^{3}	10 - 11.5'	SM		19.6	—	—	—	

1% GRAVEL
65% SAND
34% SILT-CLAY

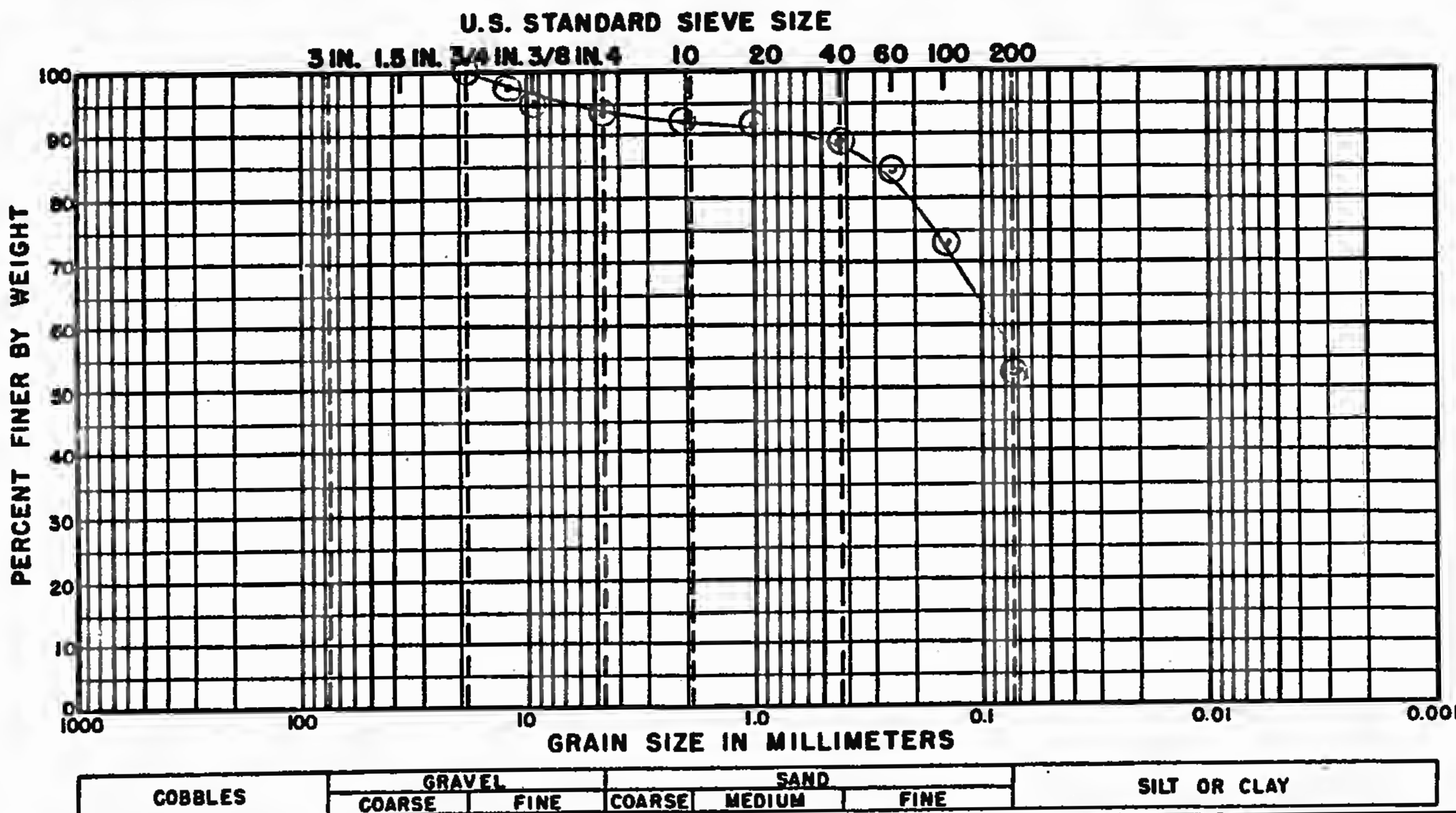
GRADATION CURVE



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION	NAT. WC	LL	PL	PI	
4n-1[5]	15.5 -17.0	S[illegible] F.-Med Sa w/si	16.8	—	—	—	

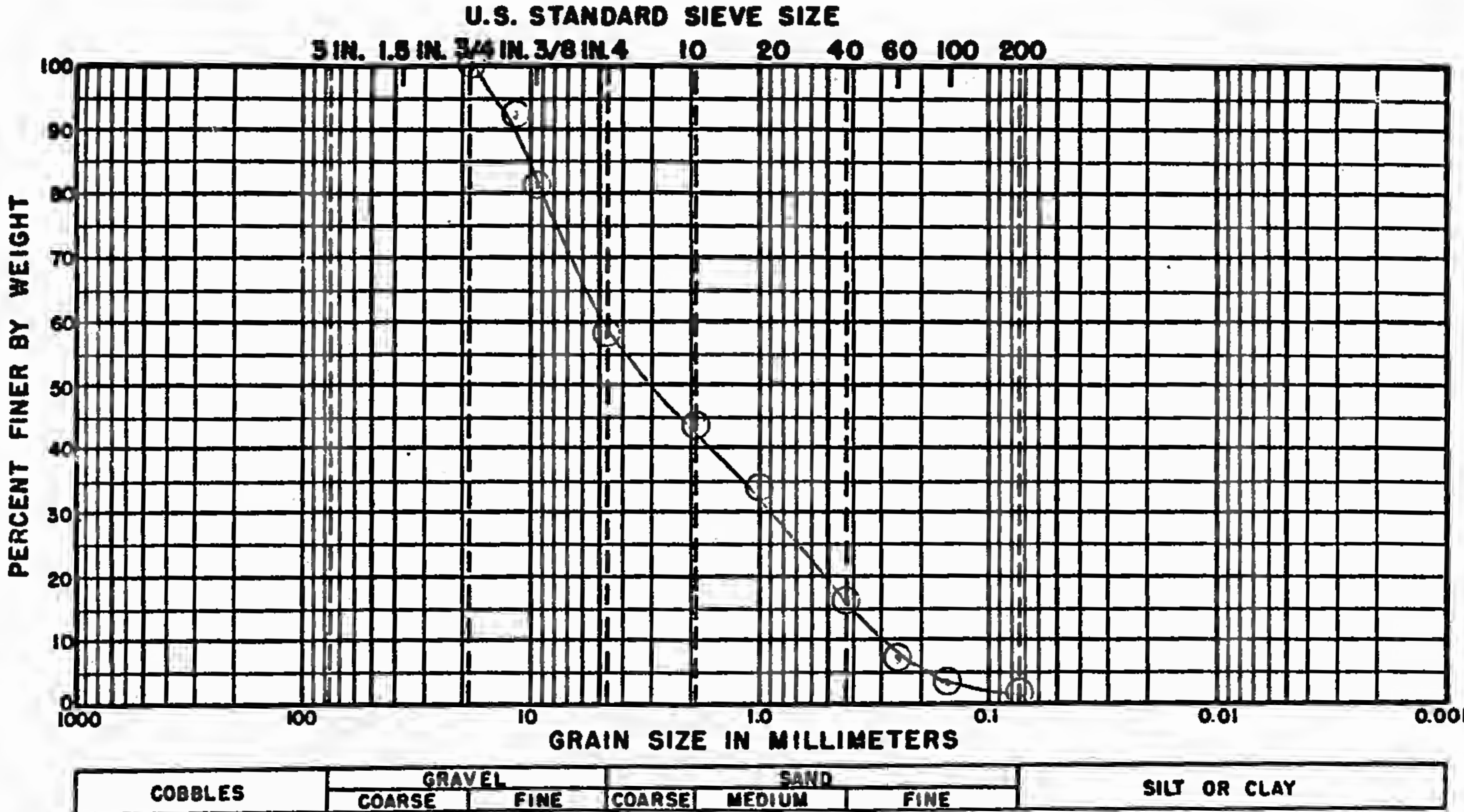
GRADATION CURVE



	DEPTH	CLASSIFICATION		NAT WC	LL	PL	PI	
4A-1 7	25 - 26.5	ML	w/SA & Fi Gv	20.0	—	—	—	

6% GRAVEL
42% SAND
52% SILT - CLAY

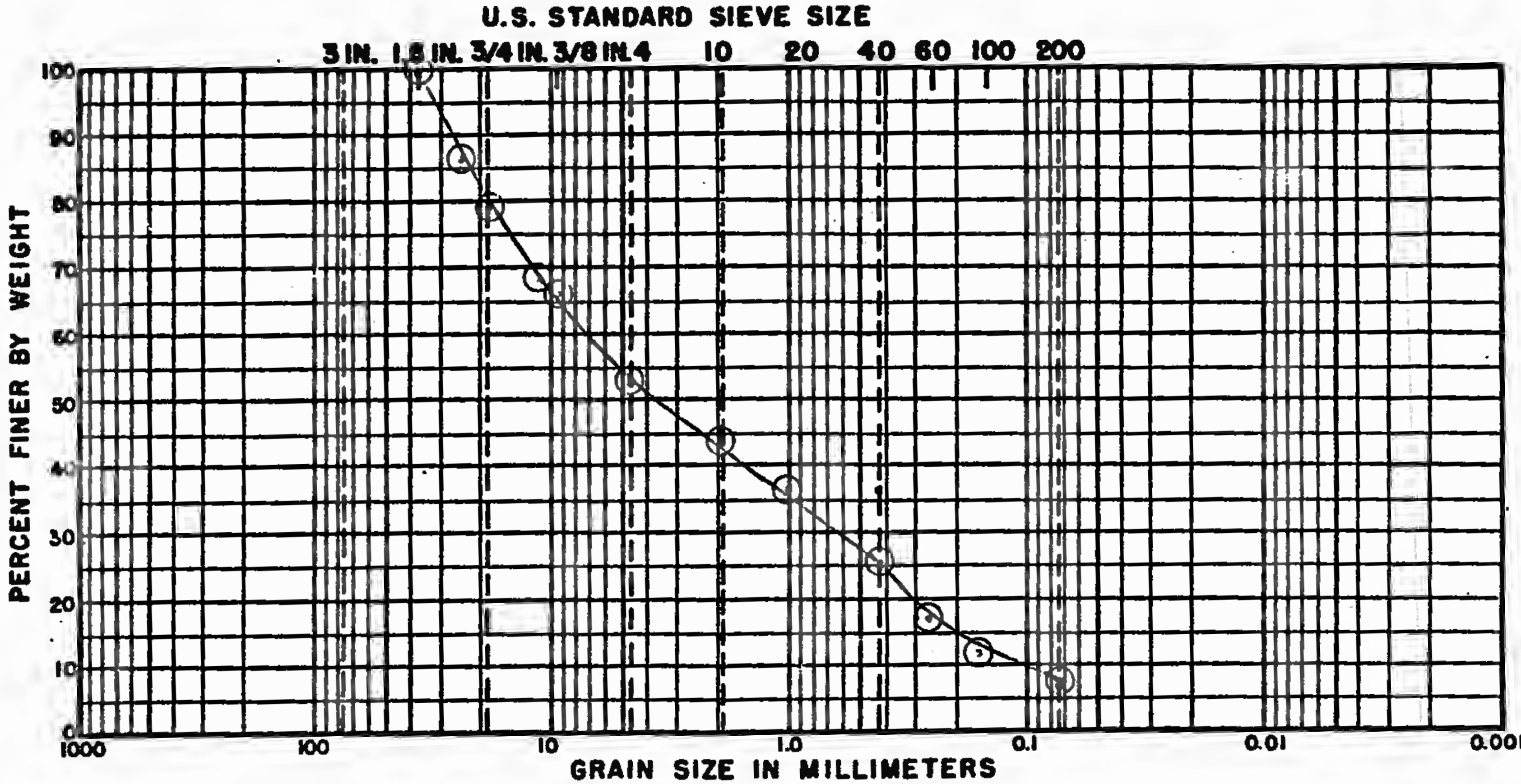
GRADATION CURVE



	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
4A-1 8	30-31.5	SW		9.9	—	—	—	

41% GRAVEL
57% SAND
2% SILT

GRADATION CURVE

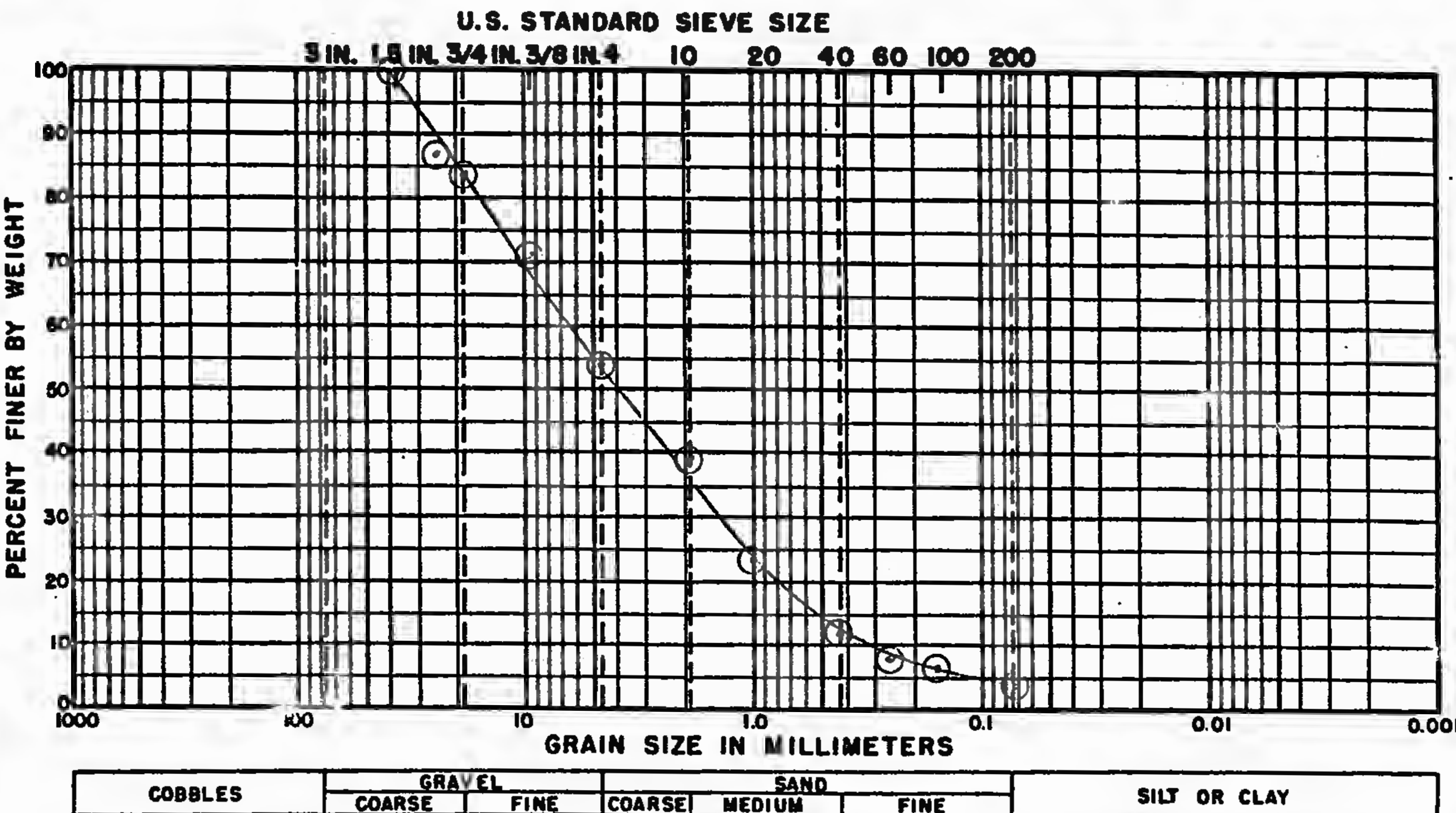


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION	NAT WC	LL	PL	PI	
4A-1 [12]	50 - 51.5	SW	9.4	–	–	–	

47% GRAVEL
47% SAND
6% SILT

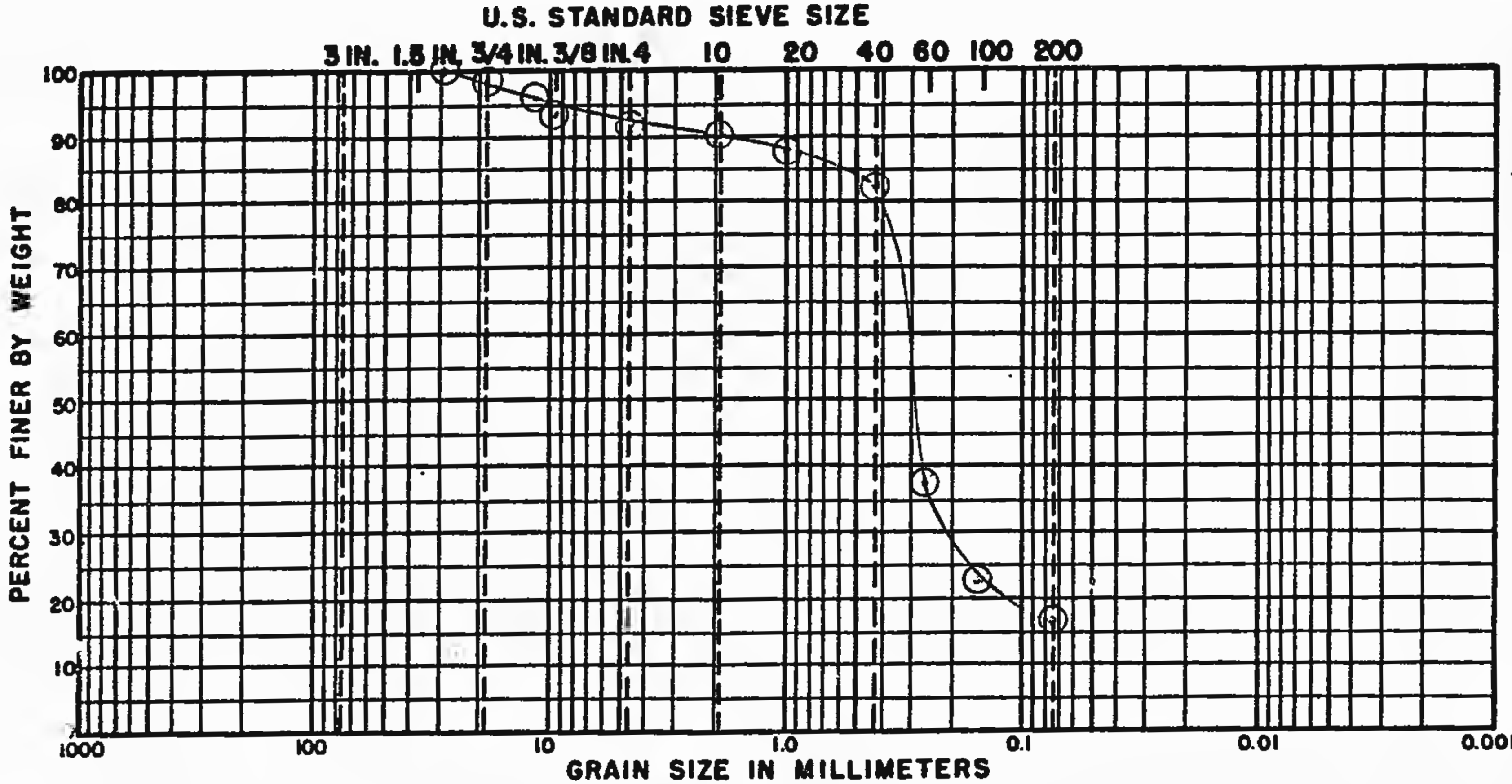
GRADATION CURVE



	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
4A-1[10]	40-41.5	SW		9.7	—	—	—	

45% GRAVEL
50% SAND
4% SILT CLAY

GRADATION CURVE

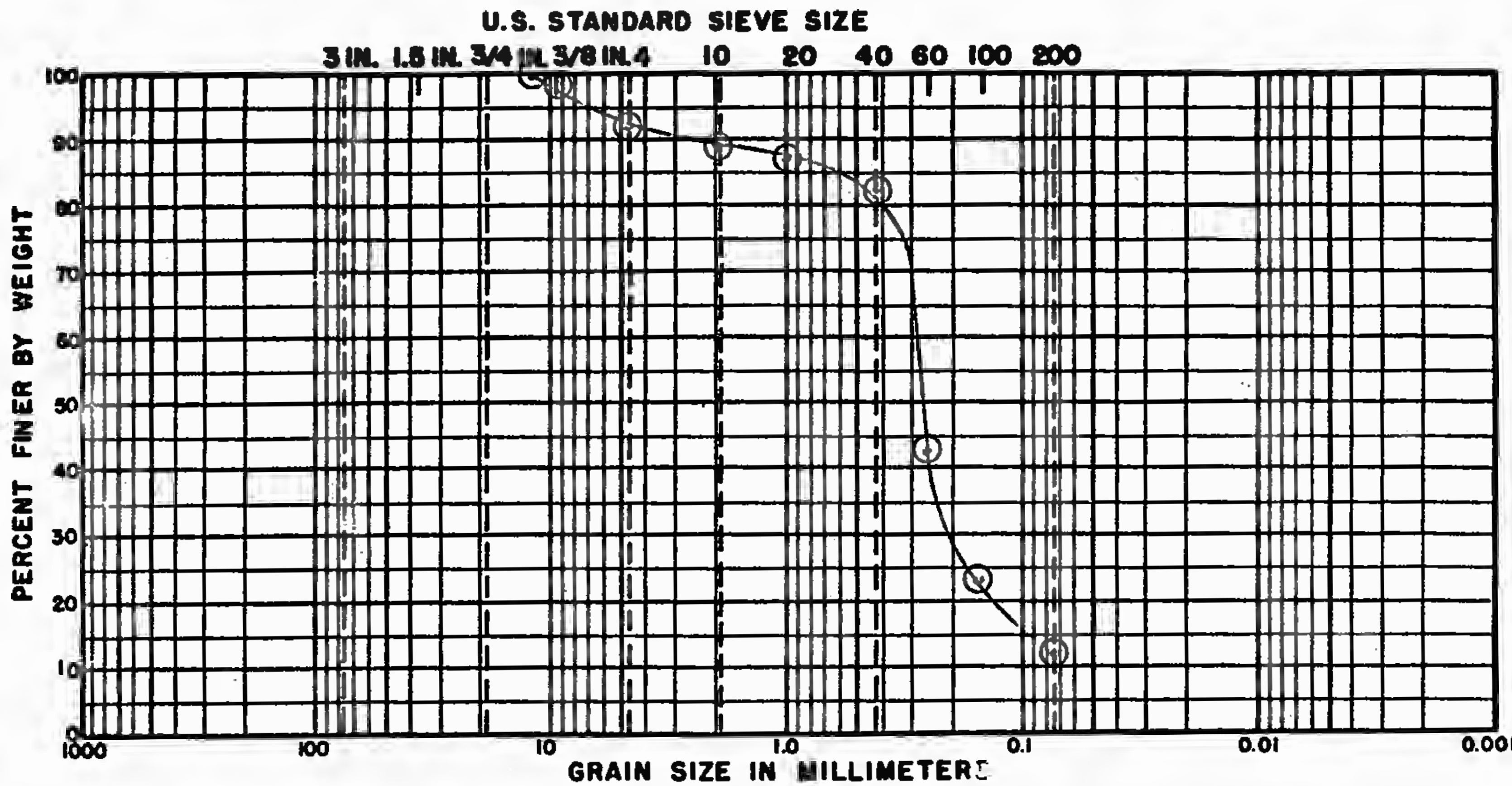


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
5A 3	10 - 11.5	SM		22.3	—	—	—	

8% GRAVEL
70% SAND
16% SILT CLAY

GRADATION CURVE

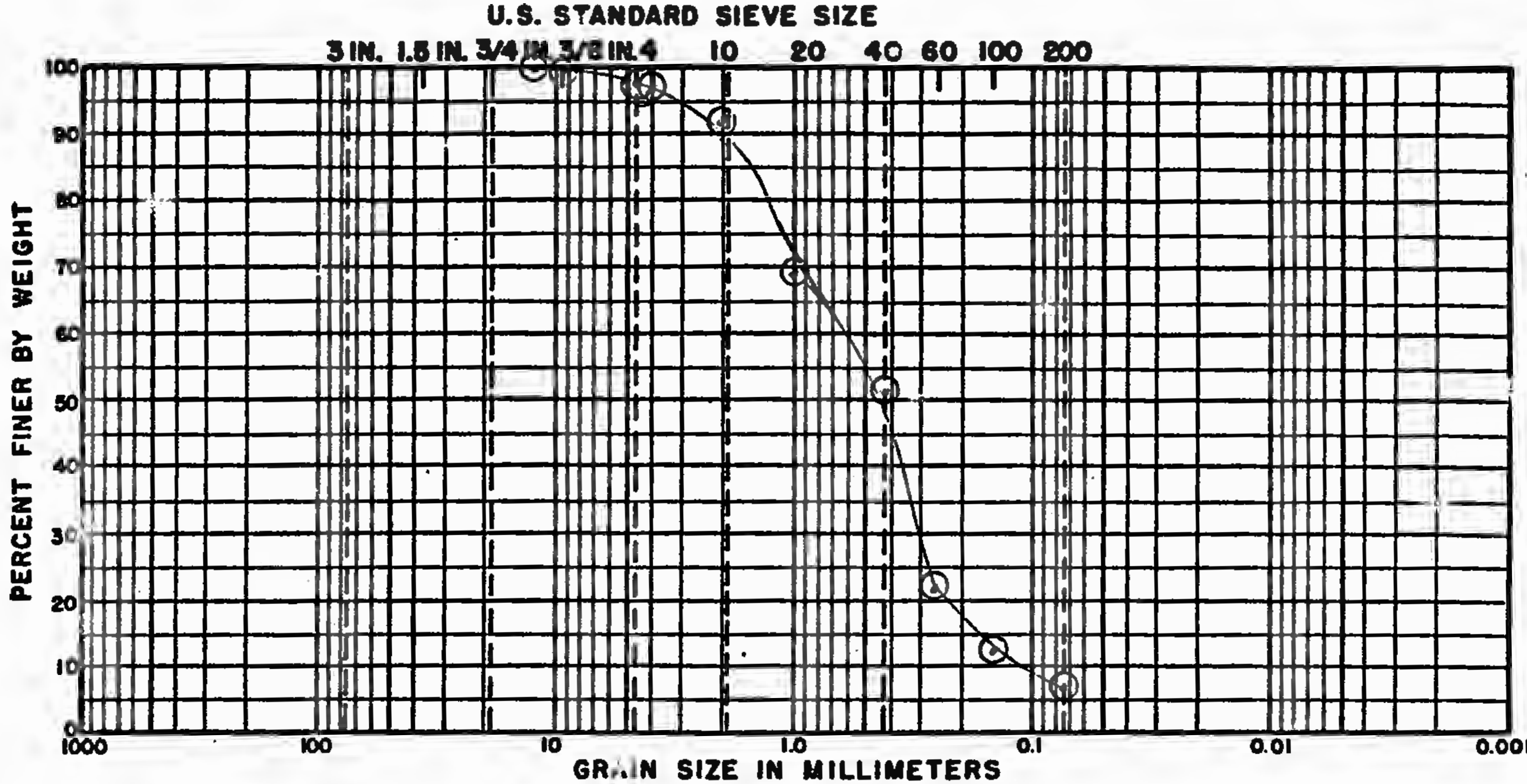


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
5A 4	15 - 16.5	SM	WITH SO GRAVEL	20.7	—	-	—	

8% GRAVEL
80% SAND
12% SILT

GRADATION CURVE

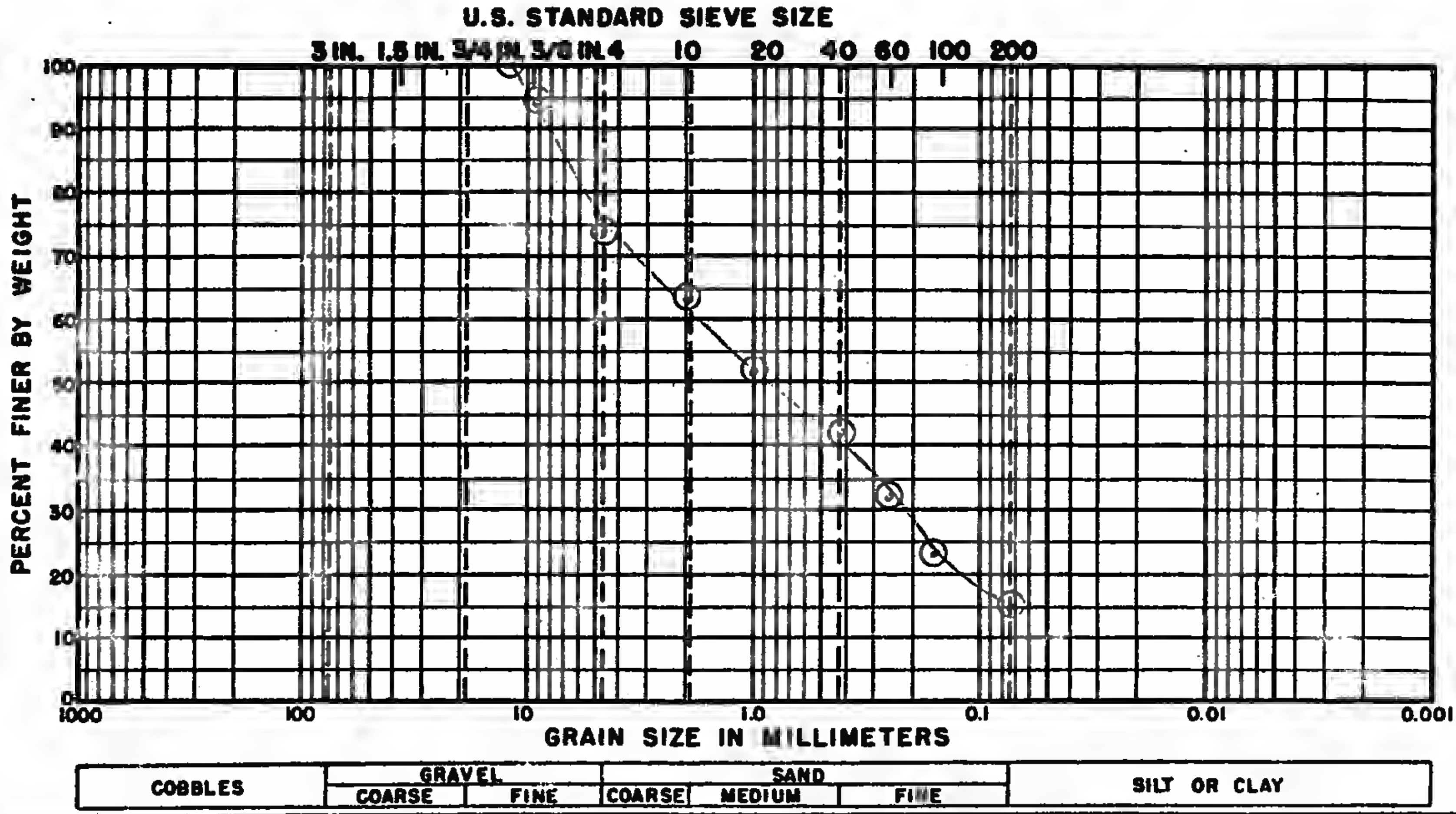


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

	DEPTH	CLASSIFICATION	NAT WC	LL	PL	PI	
5A 5	20-21.5	SW/NM	18.6				

3% GRAVEL
90% SAND
7% SILT

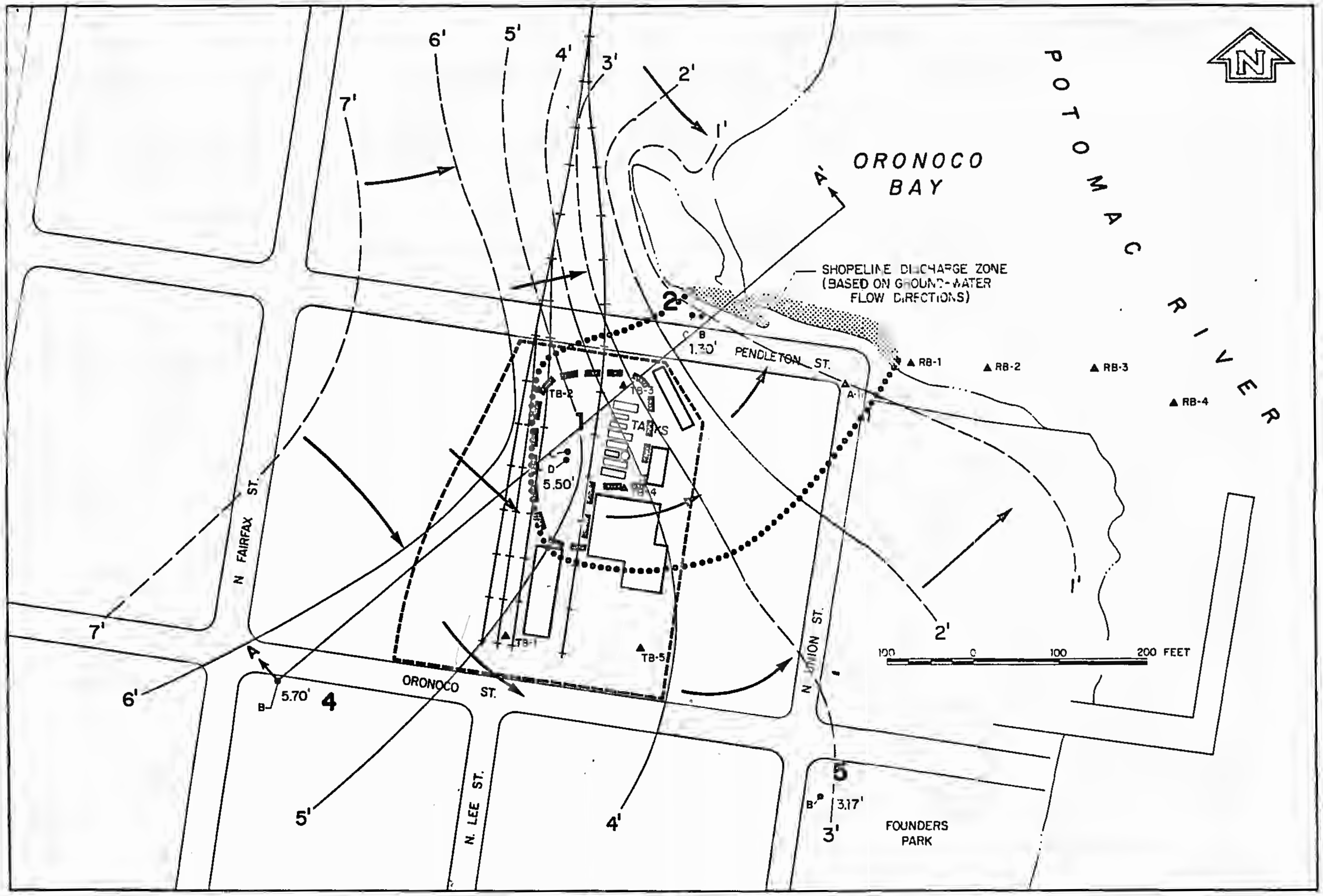
GRADATION CURVE



	DEPTH	CLASSIFICATION	NAT WC	LL	PL	PI	
5A 6	25-26.5	~~[illegible]~~ w/so Sc SM	8.7	—	—	—	

25% GRAVEL
60% SAND
15% SILT-CLAY

GRADATION CURVE



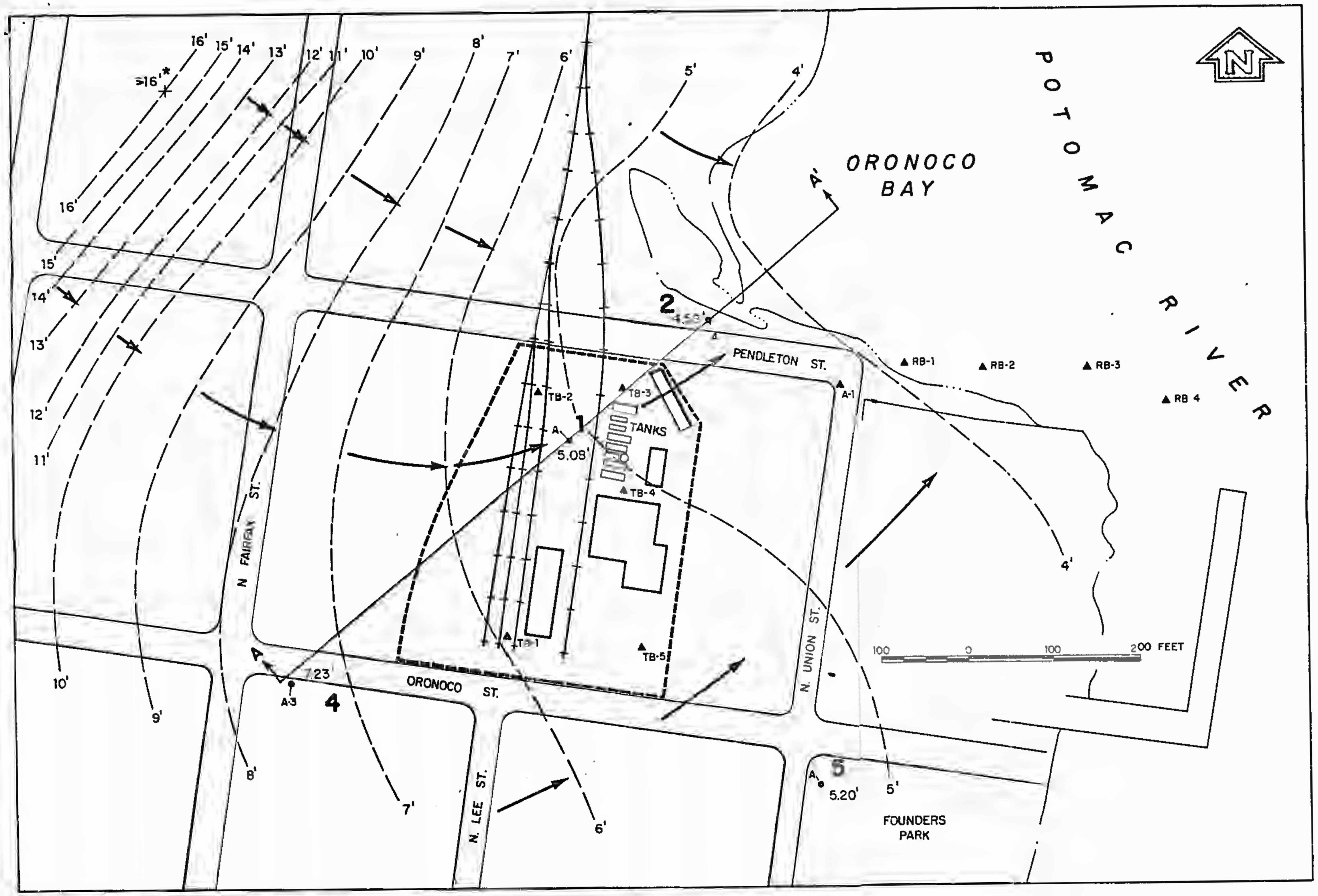
NOTE: WATER LEVEL ELEVATIONS BASED ON MEASUREMENTS TAKEN 5/24/76

KEY TO DRAWING

- 1 A — LOCATION NUMBER AND DESIGNATION OF OBSERVATION WELL INSTALLED IN DRILL HOLE, WITH WATER LEVEL ELEVATION ABOVE MSL (DETAILS IN TABLE 2)
- ▲ — DRILL HOLE WITHOUT OBSERVATION WELL
- RAILROAD TRACKS (LOCATION REFERENCE)
- APPROXIMATE OUTLINE OF R.H. BOGLE CO. PROPERTY
- APPROXIMATE WATERLINE (VARIES WITH TIDAL FLUCTUATIONS)
- AREA OF POSSIBLE GROUND WATER CONTAMINATION
- 5' — WATER LEVEL ELEVATION CONTOURS (DASHED WHERE APPROXIMATE OR ESTIMATED)
- DIRECTION OF GROUND WATER MOVEMENT
- CONTAMINATED AREA

WATER TABLE CONTOURS IN FILL MATERIAL AND UPPER SAND ZONE

PLATE 4



KEY TO DRAWING

- 1 A — LOCATION NUMBER AND DESIGNATION OF OBSERVATION WELL INSTALLED IN DRILL HOLE, WITH WATER LEVEL ELEVATION ABOVE MSL (DETAILS IN TABLE 2)
- ▲ — DRILL HOLE WITHOUT OBSERVATION WELL
- RAILROAD TRACKS (LOCATION REFERENCE)
- APPROXIMATE OUTLINE OF R.H. BOGLE CO. PROPERTY
- APPROXIMATE WATERLINE (VARIES WITH TIDAL FLUCTUATIONS)
- 5' — WATER LEVEL ELEVATION CONTOURS (DASHED WHERE APPROXIMATE OR ESTIMATED)
- DIRECTION OF GROUND WATER MOVEMENT

NOTE: WATER LEVEL ELEVATION BASED ON MEASUREMENTS TAKEN 5/24/76

*BORING LOCATION REFERENCE FORTUNE ENGINEERING ASSOCIATES. DRILLING CONTRACTOR INDICATED ARTESIAN FLOW ABOVE GROUND SURFACE FROM SAND STRATA AT 37' BELOW GROUND SURFACE, CASING AT 35'.

POTENTIOMETRIC CONTOURS OF LOWER SAND AND GRAVEL AQUIFER ZONE

PLATE 5

DAMES & MOORE

JULY 29, 1976