G-000-107.9

GROUNDWATER STUDY TASK C REPORT
JULY 1985

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Department of Energy
Feed Materials Production Center

GROUNDWATER STUDY
TASK C REPORT

Prepared By:

Dames & Moore

White Plains, New York

For:

NLO, Inc.

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July 29, 1985

Mr. Robert B. Weidner
Director
Health, Safety, and Environmental Division
NLO Inc.
7400 Willey Road
Fernald, Ohio 45030

Re: NLO Subcontract S-1094
Groundwater Study at the FMPC and Vicinity

Dear Mr. Weidner:

We are pleased to herewith transmit two hundred (200) copies of the Task C Final Report under the referenced contract. This report incorporates revisions and comments made in our review meeting of July 17, 1985.

As you know, the purpose of the Task C work was to identify the source or sources for the above-background concentrations of uranium detected in three offsite wells near the FMPC.

Our work has concluded that the sources of these above-background concentrations are runoff from the Plant Production Area and the Waste Pit Storage Area. We have recommended short-term actions to mitigate this condition and longer term options to enhance environmental protection.

The monitoring activities established under this program will be continuing and constitute a significant component of comprehensive site monitoring.

Sincerely yours
DAMES & MOORE

Robert P. Blauvelt
Principal Investigator

Les Skoski, PhD
Project Manager

John M. Heckard
Project Director

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EXECUTIVE SUMMARY

This Task C Report, prepared by Dames & Moore under a subcontract with NLO, Inc., a prime contractor for the Department of Energy, identifies the sources of above-background concentrations of uranium which have been detected in three offsite wells. These wells are downgradient of the Feed Materials Production Center, a uranium metal processing facility, which is managed by NLO, Inc. for the Department of Energy.

This Report presents:

- Field and laboratory data collected during the drilling, aquifer testing, and water sampling tasks of this project;

- Evaluation of site geologic and hydrogeologic conditions based on recently collected and previously published data;

- The basis for the identification of sources for the above-background concentrations of uranium in the three offsite wells;

- The identification of sources for above-background concentrations of uranium in the three offsite wells;

- Recommended short- and long-term alternative actions to reduce the contribution of uranium to groundwater and/or to mitigate its potential impacts.

The FMPC is located on a 1050-acre site in a rural agricultural area about 20 miles northwest of downtown Cincinnati, Ohio. The site is in a two-mile wide valley filled with about 200 feet of permeable sand and gravel. Overlying this sand and gravel is 30 to 50 feet of impermeable silty clay till.

The sand and gravel deposit is the principal aquifer for the site area. Flow directions in this aquifer generally follow surface topography and groundwater flows generally towards the south. The three offsite wells with above-background uranium concentrations are completed within this sand and gravel aquifer and are located to the south of the FMPC.

Surface drainage at the FMPC is generally southward via Paddy's Run. Part of the runoff from the Plant Production Area flows to the Storm Sewer Outfall Ditch and subsequently to Paddy's Run; the remainder goes to the Great Miami River.

Two sources for the above-background concentrations of uranium in the offsite wells have been identified. They are, in order of importance:

- Water flowing into the Storm Sewer Outfall Ditch via the Storm Sewer Outfall.

- Water flowing into Paddy's Run from the Waste Pit Storage Area.

These two sources were identified based upon the following information which was collected and analyzed by Dames & Moore during the course of this study:

- Above-background uranium concentrations in runoff water from the Plant Production Area which flows into the Storm Sewer Outfall Ditch.

- Previously collected NLO water quality data that confirm the presence of above-background concentrations of uranium in the Storm Sewer Outfall Ditch.

- Above-background concentrations of uranium in runoff water from the Waste Pit Storage Area which flows into Paddy's Run.

- Above-background concentrations of uranium in water seeping from the Waste Pit Storage Area which flows into Paddy's Run.

- Previously collected NLO water quality analytical data that confirm the presence of above-background concentrations of uranium in downstream surface water of Paddy's Run.

- Results of downgradient groundwater quality sampling which support the conclusion that uranium is not migrating from the FMPC to the offsite wells via a groundwater pathway at concentrations high enough to account for the above-background levels.

Uranium in surface water from the two identified sources is transported toward the three offsite wells by flowing down Paddy's Run and the Storm Sewer Outfall Ditch to an area where the relatively impermeable glacial till grades into permeable sand and gravel. Surface water percolates into the groundwater aquifer at an area near the confluence of Paddy's Run and the Storm Sewer Outfall Ditch and follows natural (and, in part, pumping induced) groundwater flow patterns toward the offsite wells. Surface water containing above-background concentrations of uranium entering the groundwater flow regime in this area is estimated to take approximately 0.25 years to 5.5 years to reach the offsite wells.

All concentrations reported in the three offsite wells are below the Department of Energy guidelines and U.S. Public Health Service recommendations for uranium in drinking water.

Dames & Moore recommends the following five short-term actions to reduce the contribution of uranium to groundwater and/or to mitigate its potential impacts:

- Storm Water Retention
- Surface Runoff Control
- Excavation of Uranium-bearing Sediment
- Expansion of Groundwater Monitoring System
- Substitution of Drinking Water

In addition to these short-term action recommendations, the following long-term conceptual alternatives should be evaluated for their remedial effectiveness and applicability at the FMPC site:

- Waste Pit Management Alternatives
- Material Relocation
- Provide Alternate Water Supplies
- Active Plume Control
- Partial Plume Control

1.0 INTRODUCTION

On April 1, 1984, Dames & Moore entered into a subcontract with NLO Inc. (NLO), a prime contractor for the Department of Energy (DOE), to perform a study at the DOE's Feed Materials Production Center (FMPC) in Fernald, Ohio. The main purpose of the study was to identify the source or sources of above-background* concentrations of uranium which had been detected in three offsite wells.

This Report presents:

- Field and laboratory data collected during the drilling, aquifer testing, and water sampling tasks of this project;

- An evaluation of site geologic and hydrogeologic conditions based on recently collected and previously published data;

- The basis for the identification of sources for the above-background concentrations of uranium in the three offsite wells;

- Identification of sources for these concentrations;

- Recommended short-term and long-term actions to remediate above-background concentrations of uranium in groundwater.

1.1 Project Background

As part of the NLO/DOE environmental monitoring program at the FMPC, thirteen monitoring wells, drilled over a twenty year period and located principally in the Waste Pit Storage Area, and three production wells have been routinely sampled and analyzed for various water quality indicators.

* Underlined words are defined in the Glossary presented in the back of the Report.

This monitoring started in 1952 with the installation of the FMPC's first production well. Beginning in December of 1981, the monitoring program was expanded and now includes both the onsite wells and over 22 offsite wells located up and downgradient of the site.

Laboratory analysis of NLO samples (collected since 1981) has demonstrated that the maximum uranium concentration of 0.578 mg/L in the water of three offsite wells (OS-1, OS-2, and OS-3; Figure 1-1) is above-background but below (by approximately 67%) the maximum permissible concentration (MPC) of 1.8 mg/L allowable for water released to an uncontrolled area as per DOE guidelines (Reference 1). That concentration is also below (by approximately 90 %) the upper limit of 5 mg/L recommended by the U.S. Public Health Service (Reference 2). Table 1-1 provides a summary of water quality data for these three wells.

Although the uranium concentrations were below MPC and remain below MPC, concerns about the potential source(s) of this uranium led to a regional groundwater study (Reference 3) performed in 1982 for NLO/DOE by the United States Geological Survey (USGS). That study collected additional data in the area and served as a basis for the Dames & Moore groundwater study reported herein.

In April, 1984 Dames & Moore was retained to:

- Identify the source or sources of the above-background concentrations of uranium in the offsite wells, and

- Recommend remedial measures if it is concluded that the FMPC facility is the source of the above-background concentrations of uranium in the groundwater in the offsite wells.

1.2 Scope of Dames & Moore's Work

The Dames & Moore study consisted of three tasks. The results of Tasks A and B are summarized below. The objective of the Task C study is to identify the source(s) for the above-background concentrations of uranium reported in the offsite wells and to recommend remedial measures, if necessary. Groundwater characterization, water quality, pathways analyses, and geologic interpretation have therefore been performed only to the extent necessary to provide data to accomplish this objective. The Dames & Moore work scope did not include the characterization or monitoring of other waste management facilities at the FMPC.

To identify the source(s) of the above-background uranium concentrations in the offsite wells, Dames & Moore developed a three-task program to accomplish the work summarized below.

TASK A

Dames & Moore completed the first task of the groundwater study with the submission of the Task A Draft Report (Reference 4) which reviewed and evaluated relevant file information, data collected by and on file with federal and state agencies, and generally available published literature on the facility and its operations.

On the basis of this information, the Task A Draft Report preliminarily identified five potential sources (Figure 1-2) for the above-background uranium concentrations in the three offsite wells. Three principal criteria were used to make this preliminary identification: the known or estimated amounts of leachable uranium present at the potential source, the detection of uranium in the environment near these sources by the NLO monitoring

system, and the availability of an effective transport mechanism to introduce this uranium into the groundwater. The potential sources were identified as:

(1) Water flowing into and uranium-bearing stream sediments in Paddy's Run and the Storm Sewer Outfall Ditch.
(2) Waste Pit Storage Area.
(3) Fly Ash Piles.
(4) Plant Production Area.
(5) Scrap Metal Pile.

The Task A Draft Report also presented a preliminary characterization of the site hydrogeologic conditions and briefly described the outline for the proposed field program to be conducted under Task B.

Task B

The principal objective of the Task B work was to provide the necessary data to confirm or repudiate the contribution of uranium to groundwater from each of the potential sources listed in the Task A Report. This second task of the groundwater study was divided into two phases: preparation of a work plan (Task B Report) describing field activities to be performed, and implementation of that work.

Work described in the Task B Draft Report (Reference 5) was implemented on December 9, 1984 and field work was completed on March 6, 1985. The draft work plan described protocols and procedures for drilling, installing, and developing 23 new monitoring wells in various areas of the FMPC site. The draft plan also provided a rationale for the location of these wells, described formation and groundwater sampling methodologies, laboratory analytical procedures, and outlined the scope of the aquifer testing program.

Task C

The Task C Report interprets site geologic and hydrogeologic conditions at the FMPC utilizing data gathered in the field as well as previously published information. Water quality and geologic characteristics are interpreted and their effect on uranium migration from the site is discussed. A computer model of the site has been prepared to illustrate current groundwater contours and quality and to predict their future condition. The sources of the above-background concentrations of uranium in the offsite wells are identified and several potential conceptual action alternatives are presented.

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2.0 DESCRIPTION OF STUDY AREA

2.1 Setting

The FMPC is located on a 1050-acre site in a rural agricultural area about 20 miles northwest of downtown Cincinnati, Ohio (Figure 2-1). Most of the site is located within Hamilton County but approximately two hundred acres lie in southern Butler County. The villages of Fernald, Ross, and Shandon are within a few miles of the site. The Great Miami River is about three-quarters of a mile to the east.

The production facilities are oriented in a north/south direction and occupy about 136 acres in roughly the center of the site. Topographically, the production facilities rest on a relatively level plain at about 580 feet above sea level. North of the production area the land surface rises to an elevation of about 700 feet at the northern site boundary. Elevations decrease along the western and southern edges of the site towards Paddy's Run to approximately 550 feet.

The main drainage channel for the western portion of the site is Paddy's Run, a tributary of the Great Miami River. Paddy's Run originates just north of the FMPC and flows south. Flow in this stream is typically constant only between January and May. Flows range from 0.2 cubic feet per second to 4.0 cubic feet per second. For the balance of the year it is a dry stream bed with occasional flows of a few hours' duration following heavy rains. (Reference 6).

2.2 Process Description

A wide variety of chemical and metallurgical process steps are used at the FMPC to convert uranium compounds into either uranium oxide for

shipment to gaseous diffusion plants or machined uranium ingots and billets for extrusion into tubular form for fabricating fuel cores and target fuel elements. These FMPC products are used in defense programs of the Department of Energy (Reference 7).

Large-scale chemical operations at the FMPC consist of dissolving uranium-bearing materials in nitric acid to produce a uranyl nitrate hexahydrate (UNH) feed solution for solvent extraction purification (Reference 7). Purified UNH solution is concentrated by evaporation and then thermally denitrated to uranium trioxide (UO_3), commonly called orange oxide. Orange oxide is converted to uranium tetrafluoride (UF_4), commonly called green salt, for reduction to metal.

Metal processing steps begin with the conversion of green salt to elemental uranium metal by reducing UF_4 with magnesium metal. Metallic scrap and briquettes, recycled from subsequent fabrication operations, are combined with uranium metal and melted in a graphite crucible. At the proper temperature, the melt is bottom-poured to a preheated graphite mold to form ingots that vary in weight and size depending on their ultimate use.

A description of the waste disposal operations at the FMPC is provided in Reference 8.

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3.0 HYDROGEOLOGIC SETTING

This section of the Report describes the hydrogeologic setting of the FMPC. Information has been drawn from the available geologic literature (as indicated) as well as from the Dames & Moore site-specific field program.

3.1 Site Geologic Conditions

The FMPC is located in a two-mile wide valley filled with glacial deposits (Figure 3-1). This valley parallels the Great Miami River between the towns of Ross and Hooven, Ohio (Reference 9). A generalized geologic cross-section for the FMPC site area is presented in Figure 3-2.

The geologic history of the site area (as compiled from References 9, 10, and 11) can be summarized as follows:

- In Late Ordovician time (approximately 450 million years ago) sediments which would become a predominantly flat-lying shale with thin interbedded limestone were deposited in a shallow sea. This shale (a part of the Cincinnatian Series) is the relatively impermeable bedrock which now underlies the FMPC site area.

- Sometime prior to, or perhaps contemporaneous with, Pleistocene glaciation, a large watercourse (larger than the present-day Great Miami River) cut its channel into this shale bedrock to a level of more than 200 feet below that of the present-day Great Miami River. This approximately two-mile wide channel (informally called the New Haven Trough) may be an abandoned course of the ancestral Ohio River.

- During subsequent Pleistocene glacial advances and retreats across the site area (Illinoisan-approximately 300,000 years to 400,000 years ago and Wisconsinan- approximately 100,000 years ago) the New Haven Trough was filled with about 200 feet of glacial sediments. These sediments were deposited by water running from the margins of the glaciers and consisted mainly of well sorted sand and gravel. Deposited on top of these sediments was a blanket of clay-rich, relatively impermeable glacial till from a more recent glacial event.

- Erosion by the Great Miami River and its tributaries then removed significant portions of the glacial till and left terrace remnants which stand topographically higher than surrounding bottom lands. The FMPC site lies on top of one of these terrace remnants.

3.2 Shale Bedrock - Geology and Hydrology

The bedrock underlying the FMPC consists of a predominantly flat-lying, grayish olive (10Y4/2)* shale with interbedded thin limestone layers. The bedrock surface slopes generally to the northwest and forms the floor and walls of the New Haven Trough as well as the hills rising above the glacial till north and south of the valley. In these upland areas, the shale bedrock is overlain by up to 60 feet of glacial till (Reference 11). At well 12 (Figure 1-1), drilled north of the Production Area, the shale is within approximately 65 feet of the land surface. To the south, along Paddy's Run Road and near the center of the New Haven Trough, shale was encountered in well 15 (Figure 1-1) at a depth of approximately 214 feet below the land surface.

* Color designations are based on The Geological Society of America's Rock Color Chart (Reference 13)

Shales of this type typically have a low (0.003 ft/day to 0.00003 ft/day) hydraulic conductivity (Reference 11). Water occurs primarily in joints and cracks in the shale which have an irregular distribution. Transmissivity of the shale is usually too low to provide a reliable supply of water for domestic or agricultural purposes (Reference 12).

3.3 Glacial Outwash - Geology and Hydrology

Unconformably overlying the shale bedrock is a sequence of highly permeable sand and gravel glacial outwash deposits laid down by the meltwaters of receding continental ice sheets.

These outwash deposits generally consist of an unconsolidated medium to coarse grained, olive brown (5Y4/4), 200 foot thick layer of sand and gravel. They are overlain by till. Occurring approximately 100 to 125 feet below grade in some areas of the site is a 10 to 20 foot thick layer of greenish black (5G2/1) silty clay. This deeper silty clay layer has been previously referred to by several authors as the "blue clay".

A series of 4 cross-sections (Figures 3-4 through 3-7) have been prepared using site drilling data. Locations of these cross sections are shown on Figure 3-3. The cross-sections indicate that:

- The bottom of the surficial silty clay till layer occurs at about elevation 540 ft MSL relatively uniformly across the site.

- The sand and gravel deposits underlying the FMPC site are approximately 150 to 200 feet thick. They consist of irregularly alternating layers of silty sand, medium to coarse sand, and medium to coarse gravel. In the vicinity

of the Waste Pit Storage Area, this layer is separated into two units by a 10 to 20 foot thick layer of greenish-black silty clay. The FMPC production wells are completed below this "blue clay" layer.

- Figure 3-8 illustrates the areal extent of this "blue clay" layer as determined by the onsite boring data. This layer underlies about 360 acres of the site and occurs only in the vicinity of the Waste Pit Storage Area and the production wells. It was probably deposited in an ice marginal lake or as a backwater deposit of a glacial stream (Reference 14). The top of this "blue clay" layer lies at about 125 feet below the land surface.

- Glacial outwash deposits show only gross tendencies towards stratification.

Hydrologically, the sand and gravel above and below the "blue clay" layer acts as a single unit. The "blue clay" layer is not sufficiently extensive to act as an aquitard (Reference 14) and no significant head differences exist between wells completed above and below this layer (Table 3-1).

The hydraulic conductivity of the "blue clay" has been estimated (using temperature differences and pumping test results) to be about 0.4 ft/day (References 8 and 14). The discontinuous distribution of the "blue clay," as well as lateral variations in its thickness and consistency, apparently allow it to transmit water between the two sand layers despite its relatively low permeability.

Transmissivities and hydraulic conductivities for the sand and gravel have been measured by several authors (References 11, 12, and 14) and are reported to range from 35,000 gpd/ft to 300,000 gpd/ft and 270 ft/day to 370 ft/day respectively. Total porosities have been estimated at 25% Refer-

ence 14). Average hydraulic gradients for the area measured by the USGS (Reference 3) from water level measurements made in August, 1982 are low and were calculated to range from 0.001 ft/ft to 0.005 ft/ft. Using these data, the rate of groundwater movement (horizontal groundwater velocity) is calculated to range between 1.1 ft/day and 9.3 ft/day (Appendix 1).

Figure 3-9 is a Dames & Moore water level contour map for the western portion of the sand and gravel aquifer. This map shows that groundwater movement is generally to the south and east in this area. Figure 5-2 is the USGS water level contour map which shows that flow for the area is generally to the south.

The upper 20 to 30 feet of the sand and gravel deposits are not saturated and water in this aquifer occurs approximately 60 to 90 feet below land surface depending upon surface elevation and thickness of till. A more detailed discussion of groundwater flow patterns for the area is presented in Section 5.0-Groundwater Modeling.

3.4 Glacial Till

At the surface of the site and overlying the sand and gravel outwash deposits is a 20 to 50 foot thick layer of glacial till composed of a dense, olive-gray (5Y3/2) silty clay. The till varies in texture and composition both laterally and vertically and contains lenses of poorly sorted fine to medium grained sand and gravel. The base of the till occurs at about elevation of 540 ft MSL and overlies the sand and gravel outwash deposits.

To the west and south of the site, the silty clay till laterally grades into a sequence of silty sand and silt with some layers of silty clay. The silty clay till remains continuous to the north and east of the site and directly

overlies the bedrock in these areas. In the lower reaches of Paddy's Run and the Storm Sewer Outfall Ditch, the silty clay till has been eroded away and the underlying sand and gravel are exposed.

A saturated zone occurs within the silty clay till approximately 4 to 9 feet below land surface in some areas of the FMPC site. This saturated zone was encountered in five shallow wells (19TP, 20TP, 21TP, 22TP, and OB-1) and is probably recharged by precipitation. It was not detected in test pits near well clusters 13 and 18. This saturated zone may be present because of the vertical variations of composition and texture of the till, or near-surface weathering or desiccation induced fracturing of the till itself.

Dames & Moore's aquifer testing of this saturated zone has measured hydraulic conductivities of 0.2 ft/day to 2.5 ft/day with associated transmissivities of 3.5 gpd/ft to 150 gpd/ft (Appendix 1).

4.0 INVESTIGATION OF POTENTIAL SOURCE AREAS

This section of the Report provides the basis for the identification of sources for the above-background concentrations of uranium in the three offsite wells. The sources are identified and transport pathways are described.

The Dames & Moore field program at the FMPC consisted primarily of the following tasks:

- Drilling, constructing, and installing 23 new monitoring wells. During drilling, 93 formation samples were collected and a representative number of samples was submitted for laboratory analysis of hydraulic conductivity and grain size distribution. Results of laboratory testing are presented in Appendix 2.

- Purging monitoring wells to improve well yield and to collect representative water quality samples. In addition, short-term pumping/recovery tests were conducted on 12 wells to measure/confirm critical aquifer characteristics.

- Surveying the top of well casings to the nearest 0.01 of a foot to relate accurately water levels to a common datum.

- Collecting 41 groundwater samples from the wells installed by Dames & Moore as well as those installed previously by NLO/DOE. The three offsite wells were also included in this sampling program. All groundwater samples were split with NLO/DOE and analytical results are compared in Table 4-2. Environmental Analysis Laboratory (EAL-the Dames & Moore subcontracted laboratory) test data results have been used for data analysis in this Report.

- Collecting and analyzing 21 surface water samples from the Waste Pit Storage Area, Plant Production Area, and one offsite location.

4.1 Area-Specific Background Uranium Concentrations

Before any sources were identified, an area-specific background value for uranium in the groundwater of the sand and gravel aquifer was established. This was necessary to estimate the FMPC's contribution, if any, to the above-background uranium concentrations reported in the offsite wells. This background value was also needed to conduct statistical comparisons.

As shown on Table A3-1 (Appendix 3), the background concentrations for naturally-occurring uranium in groundwater upgradient of the FMPC range from 0.0001 mg/L to 0.0027 mg/L. This range is lower than the typical groundwater range reported in the literature of 0.001 mg/L to 0.01 mg/L (Reference 15). An average background value of 0.0008 mg/L was calculated by computing the geometric mean of 228 samples and was used for statistical comparisons. These samples were collected by NLO over a two year period from February, 1982 to December, 1983.

Table 4-3 lists onsite monitoring wells in the sand and gravel aquifer which contain statistically significant above-background concentrations of uranium. The Wilcoxon Two-Sample Rank Sum Test was used to measure whether there was a significant statistical difference between the average background value and those reported in the onsite wells. This method was used (instead of the Student's t-test) because of the tested non-normal distribution of the groundwater quality data. These tests are described in more detail in Appendix 3.

4.2 Identification Methodology

Before performing any field work, Dames & Moore identified five potential sources for the above-background concentrations of uranium in the three offsite wells based on data collected during the review of available information (Task A - Reference 4). These potential sources were:

- Water flowing into and uranium-bearing stream sediments in Paddy's Run and the Storm Sewer Outfall Ditch.
- Waste Pit Storage Area.
- Fly Ash Piles.
- Plant Production Area.
- Scrap Metal Pile.

These potential sources were preliminarily identified using three principal criteria: the known or estimated amounts of leachable uranium present at the potential source, the detection of uranium near these sources by the NLO monitoring system, and the availability of an effective transport mechanism to introduce this uranium into the groundwater.

Dames & Moore's Task B field program (Reference 5) was designed to monitor the movement of water from each of these potential sources towards the three offsite wells. In addition, surface waters were sampled and their flow patterns characterized in critical areas of the site where overland flow was thought to be a possible contributing factor to the above-background concentrations of uranium reported in the three offsite wells. The results of all laboratory analyses of ground and surface water samples collected during the Task B program are presented in Table 4-2.

4.3 Source Identification

An investigative program was implemented to identify the sources of the above-background concentrations of uranium in the three offsite wells. The following sub-sections describe that program.

4.3.1 Sampling Results of Runoff Water In Storm Sewer Outfall Ditch

During a two day period in early March, 1985, 19 samples of runoff water were collected from various locations within the Waste Pit Storage Area (Figure 4-1) and two runoff water samples were collected from the Storm Sewer Outfall Ditch (Figure 4-2). Samples were collected from drainage ditches and from natural swales in the topography within a few hours after an approximate 0.5 inch overnight rainfall.

Runoff from roofs, uncontrolled pads, and the open ground of the Plant Production Area of the FMPC drains southward and is collected at the Storm Sewer Lift Station (Figure 1-1). This lift station pumps the collected runoff water through the process effluent line to the combined outfall in the Great Miami River. During periods of high-intensity rainfall, runoff may exceed the pumping capacity of the Storm Sewer Lift Station. This excess runoff is diverted through a pipeline to the Storm Sewer Outfall which empties into a natural gully which discharges to Paddy's Run.

In addition, groundwater contained within the glacial till is apparently entering the Storm Sewer pipelines. A flow of water (less than 2 gpm) empties almost continuously from the mouth of this pipe into the Storm Sewer Outfall Ditch. This occurs even during periods of prolonged dryness (Reference 16).

Laboratory analyses of uranium in water samples taken from the Storm Sewer Outfall Ditch, both at the mouth of the Storm Sewer Outfall (Sample OD-1; 0.3 mg/L-Table 4-2), and further downstream near its inter-

section with Paddy's Run (OD-2; 0.01 mg/L-Table 4-2) demonstrate that uranium is migrating via surface flow from the FMPC site along these drainage channels. Previous NLO testing of this water has also confirmed the presence of above-background concentrations of uranium (Table 4-5).

4.3.2 Previous NLO Sampling Data - Storm Sewer Outfall Ditch

Samples of runoff water flowing into the Storm Sewer Outfall Ditch have been collected and analyzed by NLO on a regular basis. Results of sampling conducted since 1975 are summarized in Table 4-5. Average annual concentrations of uranium in this water have ranged from 0.34 mg/L to 3.8 mg/L.

Average annual concentrations of uranium reported in the two offsite wells closest to the Storm Sewer Outfall Ditch (OS-1 and OS-2-Table 4-6) are approximately one-half the average annual concentration of uranium flowing to the Storm Sewer Outfall Ditch (except for OS-2 in 1983 when the average concentrations were nearly identical). The similarity of these concentrations supports the conclusion that uranium-bearing water flowing in the Storm Sewer Outfall Ditch enters the groundwater system and migrates to the offsite wells. Therefore, a source for the above-background concentrations of uranium reported in the three off-site wells is water flowing from the Storm Sewer Outfall.

4.3.3 Sampling Results of Runoff Water From The Waste Pit Storage Area

Drainage patterns in the Waste Pit Storage Area are illustrated in Figure 4-3. The majority of surface runoff from the pits, pads, and berms in this area is routed into the Clearwell where it is held prior to discharge to the Great Miami River. Water from three of the four small drainage basins in the Waste Pit Storage Area is conveyed to Paddy's Run at three points as shown on Figure 4-3; the fourth drainage basin empties into the Clearwell.

Samples of runoff water in these drainage ditches taken in March, 1985 within the Waste Pit Storage Area have uranium concentrations ranging from 0.007 mg/L (water from an area east of the pits) to 24 mg/L (water from the berm surrounding pit 5). Samples of runoff water from the Waste Pit Storage Area collected by NLO in June, 1985 contained concentrations of uranium ranging from 0.005 mg/L to 1.9 mg/L. Weekly NLO sampling of water in Paddy's Run has also confirmed the presence of above-background concentrations of uranium (Table 4-4) ranging from 0.003 mg/L to 1.2 mg/L at Willey Road.

4.3.4 Results of Seep Sampling

During the surface water sampling program, two seeps were observed. One seep (Sample RO-9; 3.0 mg/L of uranium-Table 4-2) originated at the northwestern corner of the closed pit area and was flowing at approximately 0.3 gpm into a drainage ditch which empties into Paddy's Run. The second seep (RO-6; 4.6 mg/L of uranium-Table 4-2) was observed flowing into the north side of the Clearwell at the rate of approximately 0.5 gpm. This second seep flowed directly into the Clearwell.

These seeps are probably related to the saturated zone in the glacial till. Other seeps of similar character may drain into Paddy's Run along the heavily vegetated western margins of the Waste Pit Storage Area although none were observed during the field program.

4.3.5 Previous NLO Sampling Data - Paddy's Run

NLO has conducted an extensive environmental sampling and monitoring program of Paddy's Run since 1955. Table 4-4 summarizes the data collected by NLO since 1975.

The average annual concentration of uranium present upstream from the FMPC ranges between 0.002 mg/L and 0.008 mg/L. Average annual downstream concentrations in Paddy's Run at Willey Road Bridge range from

0.014 mg/L to 0.027 mg/L. Willey Road Bridge data have consistently shown above-background concentrations of uranium in Paddy's Run; however, at no time were reported concentrations greater than DOE guidelines (Reference 1).

4.3.6 Downgradient Groundwater Quality Sampling Results

Figure 4-4 illustrates the approximate extent of groundwater that is thought to contain above-background concentrations of uranium. As can be seen from this figure, the distribution of the above-background concentrations of uranium generally coincides with the channel of Paddy's Run.

The southern portion of the plume has uranium concentrations ranging from 0.010 mg/L to 0.350 mg/L (Figure 4-4). These concentrations appear to be caused principally by recharge of uranium-bearing runoff released via the Storm Sewer Outfall Ditch. This water percolates directly into the exposed portions of the sand and gravel aquifer (Section 4.4 -Transport Mechanism).

The northern part of the plume exhibits lower concentrations of uranium (0.001 mg/L to 0.009 mg/L-Figure 4-4). These concentrations are related to the flow of uranium-bearing runoff and seepage water from the Waste Pit Storage Area to Paddy's Run and the subsequent infiltration of that water into the groundwater system. Recharge probably takes place through sand and gravel lenses in the till which appear to be hydrologically connected to the sand and gravel aquifer (Reference 4).

Previous sampling since 1975 by NLO in Paddy's Run upstream of Willey Road has shown that concentrations of uranium ranging from 0.003 mg/L to 1.2 mg/L are present in this recharge area (Table 4-4). The wide range of values (three orders of magnitude) is probably related to the amount of uranium mobilized by individual runoff events.

Analytical results of samples collected in March, 1985, from eight wells located upgradient of the three offsite wells and downgradient of the Production Area and Waste Pit Storage Area sources (Well numbers P-1, P-2, P-3, 1D, 8S, 8D, 20S, as shown in Figure 1-1) do not show above-background concentrations of uranium. Other onsite wells in this area show concentrations at background or lower than those found in the three offsite wells. This indicates that uranium is not being transported offsite from the Waste Pit Storage Area and Production Area via a groundwater pathway at concentrations high enough to account for the above-background levels in the three offsite wells.

4.3.7 Conclusions

Based on the analysis described above, two sources for the above-background concentrations of uranium in the three offsite wells have been identified. They are:

- Water flowing into the Storm Sewer Outfall Ditch via the Storm Sewer Outfall from the Production Area.

- Water flowing into Paddy's Run from the Waste Pit Storage Area.

The identification of these two sources is based upon the following information which was collected and analyzed by Dames & Moore:

- Above-background uranium concentrations in runoff from the Production Area which flows into the Storm Sewer Outfall Ditch.

- Previous NLO water quality analytical data that confirm the presence of above-background concentrations of uranium (Table 4-5) in the Storm Sewer Outfall Ditch.

- Above-background concentrations of uranium in runoff and seepage water from the Waste Pit Storage Area which flows into Paddy's Run (Table 4-7).

- Above-background concentrations of uranium in water seeping from the Waste Pit Storage Area which flows into Paddy's Run.

- Previous NLO water quality analytical data that confirm the presence of above-background concentrations of uranium (Table 4-4) in downstream surface water of Paddy's Run.

- Results of downgradient groundwater sampling which indicate that uranium is not migrating via a groundwater pathway from the Waste Pit Storage Area and Plant Production Area at concentrations high enough to account for the above-background levels in the three offsite wells.

The Storm Sewer Outfall Ditch has been designated as the more important source for the following reasons:

- Similarity in uranium concentrations between the water released from it and those in the three offsite wells;

- Consistency of those values over the past two years as shown on Table 1-1;

- Nearness of the Outfall Ditch to the transport mechanisms described in Section 4.4-Transport Mechanism.

Results of groundwater sampling (Table 4-2) downgradient of the Scrap Metal and Fly Ash Piles have indicated that these are not sources for the above-background concentrations reported in the offsite wells.

4.4 Transport Mechanism

Uranium-bearing water generated from the sources described above is transported toward the three offsite wells via the following mechanism:

- Precipitation-induced runoff water from both the Plant Production Area and Waste Pit Storage Area flows via natural and man-made drainage channels into the Storm Sewer Outfall Ditch and Paddy's Run.

- Once in the surface water system, the water mixes with upstream water and travels via channel flow to an area near the intersection of the Storm Sewer Outfall Ditch and Paddy's Run (Area A on Figure 4-5).

- Within this area, the relatively impervious glacial till grades into more permeable sand and gravel. Surface water thus percolates into the sand and gravel aquifer and follows the natural (and, in part, pumping induced) groundwater flow pattern toward the three offsite wells.

Surface water containing above-background concentrations of uranium entering the groundwater flow regime in this area takes approximately 0.25 years to 5.5 years to reach the three offsite wells. This is based on the calculations provided in Appendix 1.

The above-background concentrations in the three offsite wells are representative of the quality of surface water recently released from the site. Given the environmental improvements made by NLO/DOE over the past several years, it is likely that the above-background concentrations in the three offsite wells will not increase. In addition, environmental programs currently underway will probably result in an overall decrease in the above-background concentrations reported in the three offsite wells.

5.0 GROUNDWATER MODELING

Computer modeling of the groundwater system at the FMPC site was performed to confirm the interpretation of the hydrogeologic conditions to the extent necessary to assist in verifying the location of uranium transport to the aquifer. Modeling the hydrogeologic system in plan view as a two dimensional system using Dames & Moore's TARGET computer code was selected as an efficient way of achieving these goals. The USGS potentiometric surface map (Reference 3) was used as the base map for this phase of the work. The area modeled in this study and the portion of the USGS potentiometric surface map in the modeled area are shown on Figures 5-1 and 5-2, respectively.

5.1 Description of Model

Dames & Moore's TARGET-2DH ("Transient Analyzer of Reactive Groundwater Effluent Transport") finite difference computer code was used to model the FMPC site. The 2DH indicates that the version of the computer code which was used is applicable to two dimensional modeling of a horizontal (plan view) hydraulic system. The mathematical formulation of the code is based upon the depth-averaged formulation of the differential equations governing flow and mass transfer in saturated porous media. Particular computational advantages accrue from the present formulation in which the governing equations are expressed in generalized, conservative forms. Such forms take computational advantage of the similarity in the equations as well as of the non-dimensional terms contained therein.

Modeling of groundwater flow using the TARGET computer code requires the following data inputs for each grid point shown on Figure 5-1 within the modeled system: hydraulic conductivity, depth to bedrock, infiltration rate, and effective porosity. Table 5-1 and Figure 5-3 show the material properties used to model the system and the location of each type of

material within the system. The elevations of any hydraulically fixed locations (boundaries), and the location of no-flow boundaries are also required. The model assumes that the material properties are homogeneous in the vertical direction throughout the saturated thickness, as is the case in all plan view, 2-D models.

5.2 Data And Assumptions

The potentiometric surface map developed by the USGS (Reference 3) was used as the base map in the modeling because it covered the entire groundwater flow system surrounding the site. Additionally, the potentiometric surface data collected during the Dames & Moore program were consistent with the potentiometric surface mapped by the USGS. That is, the water levels gathered as part of Dames & Moore's drilling program were generally within a few feet of those shown on the map prepared by the USGS.

Data input assumptions are based on the general geology of the site area as well as available data. Modeling results showed good agreement with the measured physical system operating at the FMPC.

5.2.1 Hydraulic Conductivity

During Dames & Moore's drilling program, soil samples were obtained using a 2" inside-diameter split spoon sampler. Twelve remolded samples from the aquifer were tested in the laboratory using a falling head permeability test to measure their hydraulic conductivity. Measured conductivities of samples from the sand and gravel aquifer ranged from 2.3 ft/day to 31.2 ft/day. Other reported hydraulic conductivities (Reference 8) of 300 ft/day have been based on pump testing of the lower aquifer. These test data compare with the hydraulic conductivity value of 60 ft/day which was used in the model for the portions of the aquifer beneath the site. The differences between the laboratory and field values are not at all

unusual since the laboratory test cannot take into account large-scale inhomogeneities in the hydraulic system and is affected by remolding of the sample.

Hydraulic conductivity data were available only for the area included in the drilling program. The model was therefore used to help estimate the likely hydraulic conductivity values in areas where data were lacking. Except for well MW-12, the data from the various onsite drilling programs indicated relatively consistent material properties in the sand and gravel aquifer. It was therefore initially assumed that the offsite portion of the aquifer would have approximately the same hydraulic conductivities. To match the USGS potentiometric map in areas with no data, hydraulic conductivities which varied from 0.06 ft/day to 300 ft/day were used.

5.2.2 Depth to Bedrock

The depth to bedrock beneath the site was estimated from the Dames & Moore drilling program, the USGS cross-section of the site (Reference 11), and several onsite boring logs. Bedrock crops out to the north, west, southeast, and southwest of the site, and the depth to bedrock surface is not uniform throughout the modeled area. For the modeling, it was assumed that in areas without nearby subsurface information the bedrock was at elevation 370 feet above MSL. However, near the bedrock outcrops, it was assumed the rock was closer to the ground surface. The assumed elevations of the bedrock surface are provided in Table 5-2.

Minor changes in the bedrock surface elevation had little effect on the modeling results. Variations caused by changes in hydraulic conductivity were so much more significant than those caused by varying the aquifer thickness that any small error (20-30 feet) in estimated elevation on the bedrock will cause only a minor change in the potentiometric surface map.

5.2.3 Recharge

Direct recharge of precipitation through the surficial soils into the

aquifer is the major source of water present in the sand and gravel aquifer beneath the site. In addition, some water is derived from recharge into the aquifer from the upgradient areas to the north and from recharge of runoff along the various surface water drainages in the area. The amount of recharge which was assumed at each point in the modeled area is shown on Figure 5-4.

The soil at the site is a silty clay till. This type of soil generally has a low hydraulic conductivity, in the range of 0.003 ft/day to 0.00003 ft/day, which limits groundwater recharge to a small percentage of the total rainfall. A test for hydraulic conductivity from Well 13s, near the interface of the till and sand and gravel aquifer had a measured value of 0.0004 ft/day. For modeling purposes, recharge through the till was assumed to be about 0.5 inches per year. This number was estimated by assuming a hydraulic conductivity of 0.0003 ft/day, a hydraulic gradient of 0.5 ft/ft, and a continuous source of water.

USGS cross-sections of the site (Reference 11) indicate that west of Paddy's Run the surficial soils are sandier (and, therefore, probably have higher hydraulic conductivities) than the onsite till. South of the site, the till has been eroded away leaving sandy soils exposed at the surface. In these two areas, a recharge rate of 1.04 inches per year was assumed. Recharge may be somewhat higher at some locations, particularly in Paddy's Run.

5.2.4 Effective Porosity

The effective porosity of a soil is determined by the interconnected pore space available for fluid transmission and is typically less than total porosity. For the model, an effective porosity of 20% was assumed, except for the soils with the highest and lowest hydraulic conductivities. For the soils with lower hydraulic conductivities, an effective porosity of 15% was assumed. For the soils with higher hydraulic conductivities, a value of 25% was assumed (Table 5-1).

5.2.5 Model Boundaries

Two types of hydrologic boundaries were used in the model: fixed head and no flow. At fixed head locations, the hydraulic head in the aquifer is provided as input data. Water is allowed to freely flow into or out of these locations into surrounding areas. At no flow boundaries, no water is allowed to enter or leave the system. These boundaries are placed at locations such as groundwater divides beyond which no flow will occur.

The area within Row 1, Columns 2 through 14; and the area within Row 22, Columns 10 through 20 (Figure 5-1) were chosen as fixed head boundaries. The USGS potentiometric surface map showed these to be areas where flow would occur through the model boundaries.

The remaining boundary areas were chosen as no flow boundaries. Along the east and west boundaries of the model, they correspond to groundwater divides. Along the portions of the north and south boundaries which were not fixed head, they correspond to bedrock outcrops through which little flow occurs (Section 3.2 - Shale Bedrock-Geology and Hydrology).

5.2.6 Other Input Assumptions

The model used steady-state conditions. These are conditions which would occur at an indeterminate time in the future assuming that no remedial actions will take place. The modeling program also assumed that no radioactive decay of the uranium will occur and that no geochemical processes are attenuating the uranium concentrations in the groundwater. These are both conservative assumptions. Since uranium is radioactive, some slight decay will occur over time.

Geochemical processes could significantly affect the uranium migration and travel time through the aquifer. By assuming steady-state conditions and no geochemical attenuation of the uranium, the areal extent and relative concentrations of uranium in the aquifer are maximized. The fact that no

concentrations of uranium in the aquifer are maximized. The fact that no above-background concentration of uranium has been detected in any other wells south and east of the site may indicate that some geochemical or hydraulic process is occurring which has thus far prevented the uranium from reaching that location.

The area of assumed uranium recharge is shown on Figure 5-4 as the area with a recharge rate of 2.1 inches/year. The actual recharge area may extend further south than shown on the figure.

5.3 Results

Above-background concentrations of uranium have been detected in most of the onsite wells. The highest reported above-background concentrations of uranium are confined to an area just south of the site boundary, near Paddy's Run. The source of these higher concentrations is recharge of uranium-bearing water from the Storm Sewer Outfall Ditch and Paddy's Run to the underlying sand and gravel (See Section 4.0-Investigation of Potential Sources). To assist in verifying these as the sources, uranium transport was modeled using the 2.1 inches/year recharge area shown on Figure 5-4 as the source area. As Figure 5-5 illustrates, transport from Paddy's Run to wells OS-1, OS-2, and OS-3 is shown to be a viable transport mechanism.

To test the hypothesis that groundwater emanating from the Waste Pit Storage Area might be the primary source of the above-background concentrations of uranium in the three offsite wells, a computer run was made with the Waste Pit Storage Area as the source of the uranium-bearing recharge to the aquifer. The resulting plume indicated a much larger area with uranium in groundwater than has been observed. This lends additional support to the conclusion that groundwater emanating from the Waste Pit Storage Area is not the primary source for the above-background concentrations of uranium in the three offsite wells, but rather that

recharge via the surface water is the mechanism for the occurrence of above-background concentrations in the offsite wells.

The modeling showed that the potentiometric surface map drawn by the USGS is consistent with the hydraulic conductivity data gathered as part of Dames & Moore's exploration program, and that the groundwater flow system can be duplicated using the existing data or reasonable assumptions where data are lacking. The potentiometric surface as developed by the modeling is shown on Figure 5-7.

5.4 Interpretation of Data

For several areas, such as the areas to the east and west of well OS-2, data on the sediments and their hydrologic properties are not available. The assumptions made to model the flow system in these areas do not contradict any observations which have been made to date.

Water levels measured by the USGS at OS-2 and verified during the Dames & Moore study indicate that a potentiometric high exists at that location. The elevation of the water level measured at the well is approximately 10 feet higher than at wells OS-1 and OS-3 which are north and south of OS-2. To duplicate the potentiometric high in the modeling, it is necessary to assume that the sediments in this area have a much lower hydraulic conductivity than those observed under the FMPC site.

Well OS-2 may be partially completed in a saturated portion of the glacial till. If this is the case, the groundwater flow directions may be different than those shown on Figure 5-6. Also, some of the groundwater from the modeled area may be moving eastward towards the Great Miami River in addition to moving southward as indicated in Figure 5-6. However, given the existing data on uranium concentrations in the groundwater, it appears that even if some of the water is flowing eastward, the migration

of uranium in the groundwater is to the south since no uranium has been detected in offsite wells to the east.

In several areas besides the area surrounding the OS-2 well, it was found that to duplicate the USGS potentiometric surface map, it was necessary to assume hydraulic conductivities similar to those used in the vicinity of the OS-2 well. This lends some support to the existence of isolated zones of lower hydraulic conductivity in the aquifer system. Given the complex history of glacial and fluvial changes known to have occurred in this area, areas with lower hydraulic conductivity should not be unexpected.

6.0 RECOMMENDATIONS

Dames & Moore's recommendations for further work at the FMPC can be broken down into three categories: (1) Short-Term Action Recommendations (Section 6.1), (2) Recommendations for Additional Studies (Section 6.2), and (3) Conceptual Long-Term Action Alternatives (Section 6.3).

6.1 Short-Term Action Recommendations

Short-term actions that can be implemented to reduce the contribution of uranium to groundwater and/or to mitigate potential impacts are:

- Storm Water Retention - Completion of the lined storm water retention basin now under construction will minimize the flow of runoff water from the Production Area into the Storm Sewer Outfall Ditch and Paddy's Run.

- Surface Water Runoff Control - Divert, by regrading, surface water runoff originating in the Waste Pit Storage Area to the Clearwell. As part of this action, runoff from other areas of the site should be diverted away from the Waste Pit Storage Area. Before regrading, the capacity of the Clearwell should be re-assessed so that it is not exceeded. This action will minimize the flow of surface water from the Waste Pit Storage Area to Paddy's Run.

- Excavation of Uranium-Bearing Sediment - A closely spaced survey and sampling program of both the Storm Sewer Outfall Ditch and Paddy's Run can be used to identify zones of sediments which may be acting as intermediate uranium sources for the groundwater. If such zones of sediment are found, they should then be excavated for subsequent disposal.

- Expansion of Groundwater Monitoring System - The current offsite groundwater monitoring program should be expanded to include wells, if any, southeast of the site and adjacent to Paddy's Run which are not currently being monitored by NLO/DOE. These are the areas that will most likely be influenced by the sources identified in the report.

- Substitution of Drinking Water - If it is found that water from the offsite wells is being used for drinking purposes, an alternate water supply (such as a bottled water system) should be provided to the users of offsite wells OS-2 and OS-3 (OS-1 already has an alternate supply).

6.2 Recommendations For Additional Studies

Several recommendations for additional studies necessary for the selection of appropriate Long-Term Actions are:

- Downgradient Wells - Additional wells to the south and east of the plume are required to better delineate the extent of the plume. Specifically, these wells should confirm the existence of high groundwater elevations around OS-2 and west of OS-2 across Paddy's Run. They should also be located to delineate the full extent of the plume to the east and south.

- Eastern Boundary Wells - The USGS potentiometric surface map (Figure 5-2) implies a groundwater divide east of the site boundary. This divide would prevent groundwater flow to the east towards the Great Miami River. To verify the existence of this divide, 1 to 3 wells should be drilled east or southeast of well cluster 13. Verification of the groundwater divide would virtually preclude the possibility of any uranium being transported eastward via a groundwater pathway.

- Surface Water Flow - The surface water flow directions and quantities for each drainage basin onsite can be identified based on the topography of the site and storm records available from the National Oceanographic and Atmospheric Administration. This analysis will be necessary for the design of any long-term surface water flow modifications. In addition, a water balance for the site should be developed to provide necessary flow and infiltration and/or recharge data.

- Uranium Transport - The transport of uranium in groundwater is controlled by the movement of the groundwater and by geochemical processes. The rate of movement can be changed by processes such as sorption, where the uranium may become temporarily bound to the soil. The sorption process can slow the movement of uranium to some fraction of the rate of movement of the water. Uranium precipitation may also occur. This would cause the uranium to change from a soluble to an insoluble form preventing and/or retarding additional migration. This might explain why no uranium has been detected south of OS-3. The chemistry of the uranium, groundwater, and soils should be studied to determine what geochemical processes are active in the groundwater transport system.

6.3 Conceptual Long-Term Actions

This section presents a set of long-term alternative actions in addition to the action recommendations described in Section 6.1-Short-Term Action Recommendations. Each of these long-term actions should be thoroughly evaluated to provide quantitative information on their effectiveness and applicability. It is recognized that some of these actions (upon more in-depth analysis) may be judged not to be appropriate. As part of this evaluation, criteria included in the National Contingency Plan (40CFR Part 300), and any other applicable regulations, must be taken into consideration.

These long-term actions should not be considered as final recommended actions; rather, they are proposed for an evaluation of their applicability to the FMPC situation.

For the purposes of these conceptual long-term actions, it is assumed that groundwater monitoring will be continued by NLO/DOE. Also, data regarding both onsite and offsite groundwater quality will be collected on a regular basis and impacts assessed.

Several of the alternative actions discussed below could be combined to reduce further the contribution of uranium to the groundwater and/or mitigate its potential impacts:

- Waste Pit Management Alternatives - The covers on the waste pits need to be improved to control more effectively infiltration. The long-term permeability of the covers should be greater than that of the underlying liners to prevent the pits from filling with water and overflowing at the surface. It may also be desirable to provide some sort of coarse drainage layer within the covers as an additional guard against infiltration. The cover and surrounding areas should be graded to eliminate any surface water run-on to the waste pit covers. Numerous materials and designs of covers are available for consideration.

  Several test pits dug by Dames & Moore in the vicinity of the waste pits demonstrated that the till was saturated in places. If this is the case (which can be more fully evaluated by longer-term testing), groundwater may be flowing laterally into and out of the waste pits. A system to control more effectively groundwater on a long-term basis will require additional data on the hydraulic properties of the till.

- Material Relocation - Materials in the Waste Pit Storage Area and Production Area which are contributing uranium to water

flowing into Paddy's Run could be relocated to some other location. Prior to moving the materials, a suitable disposal location (either on or offsite) would need to be selected.

- Provide Alternate Water Supply - If it is determined that alternative water supplies are needed, such water could be supplied by the installation of new wells and pipelines as necessary, by wellhead treatment, or by provision of bottled water. Because wellhead treatment requires continued maintenance, providing an alternate water supply may be preferable unless wellhead treatment is used as a temporary solution. Bottled water is generally used only as a temporary supply because of the long-term inconvenience to the users.

- Active Plume Control - Active plume control involves the placement of pumping wells downgradient of the site to withdraw groundwater with above-background concentrations of uranium. Assuming no other control measures were implemented, this system might need to operate well into the future.

- Partial Plume Control - This action would be viable only in conjunction with other previously mentioned conceptual long-term action alternatives. It would be instituted prior to or along with another control alternative, depending on the final goals of the long-term action program.

The amount of plume control used at a site should be selected to fulfill specific clean-up needs. To remove and treat all groundwater beneath the site would require pumping and handling of at least 6.5 billion gallons. If any geochemical processes are affecting the transport of uranium in groundwater (which is likely), the volume of water which would have to be pumped to restore groundwater to background levels could be much higher. In contrast, the

groundwater with the highest concentrations could be removed by pumping less than 0.5 billion gallons of water assuming no geochemical retardation of the uranium. If the plume is larger than currently mapped, or if the uranium has sorbed to the soil in a reversible reaction, more water may have to be pumped and treated to significantly decrease concentrations.

TABLES

TABLE 1-1

WATER QUALITY DATA FOR OFFSITE WELLS WITH ABOVE-BACKGROUND URANIUM CONCENTRATIONS

URANIUM CONCENTRATION (mg/L)*

DATE	OS-1	OS-2	OS-3
11-81	0.190	---	---
12-81	0.160	0.320	0.054
1-82	---	---	---
2-82	0.240	0.520	0.050
3-82	0.240	0.410	0.069
4-82	0.280	0.450	0.071
5-82	0.310	0.450	0.075
6-82	0.250	0.440	0.078
7-82	0.270	0.440	0.099
8-82	0.234	0.470	0.046
9-82	0.238	0.480	0.061
10-82	0.280	0.490	---
11-82	0.220	0.502	0.054
12-82	0.230	0.554	0.066
1-83	0.255	0.539	0.065
2-83	0.306	0.578	0.055
3-83	0.239	0.483	0.045
4-83	0.225	0.460	0.060
5-83	0.249	0.419	0.057
6-83	0.287	0.416	0.066

TABLE 1-1 (Cont'd)

WATER QUALITY DATA FOR OFFSITE WELLS WITH ABOVE-BACKGROUND URANIUM CONCENTRATIONS

URANIUM CONCENTRATION (mg/L)*

DATE	OS-1	OS-2	OS-3
7-83	0.275	0.370	0.056
8-83	0.287	0.376	0.059
9-83	0.274	0.379	0.068
10-83	0.260	0.390	0.062
11-83	0.252	0.393	0.053
12-83	0.230	0.363	0.041
1-84	---	0.360	0.053
2-84	0.235	0.358	0.045
3-84	0.256	0.355	0.052
4-84	0.270	0.348	0.050
5-84	0.266	0.318	0.051
6-84	0.270	0.311	0.059
7-84	0.255	0.298	0.055
8-84	0.236	0.286	0.048
9-84	0.257	0.292	---
10-84	0.222	0.312	0.068
11-84	0.240	0.355	0.058
12-84	0.190	0.304	0.054
1-85	0.189	0.360	0.048
2-85	0.240	0.290	0.041

--- Analysis Not Available

* DOE Guideline for Uranium in water released to Uncontrolled Areas =1.8 mg/L

TABLE 3-1
HYDROSTATIC LEVELS RECORDED IN WELLS
SCREENED ABOVE AND BELOW
THE BLUE CLAY LAYER

Well No.	Elevation of Water Level (ft)	Screened above (A) or below (B) Blue Clay	Differences in Water Level Elevation (ft) (Shallow-Deep)
1s	524.38	A	-0.57
1d	524.81	B	
8s	523.37	A	0.58
8d	522.37	B	
20d	522.70	A	0.10
P-2	522.60	B	

- o Water Levels Recorded in April, 1984.
- o Production Well #2 (P-2) is outside the cone of influence for Production Well P-3. Water level recorded is probably true static level.

TABLE 4-1

MONITORING WELL SUMMARY SHEET

Well No.	Installed By	Location	Installation Order	Surface Elevation (ft)	Approximate Elevation at Top of Screen (ft)	Water Level Elevation (ft)	Aquifer Monitored
1d	NLO	Waste Pit Storage Area	1	585.31	410	524	Deeper sand and gravel aquifer (below the blue clay layer)
1s	NLO	Waste Pit Storage Area	2	585.55	510	524	Upper sand and gravel aquifer (above the blue clay layer)
3	NLO	West of Waste Pit Storage Area	3	560.86	520	526	Upper sand and gravel aquifer (above the blue clay layer)
4	NLO	Southwest of Waste Pit Storage Area	4	556.85	524	526	Upper sand and gravel aquifer (above the blue clay layer)
5	NLO	Southwest of Waste Storage Pit Area	5	577.09	557	526	Upper sand and gravel aquifer (above the blue clay layer)
8s	NLO	Southeast Waste Pit Area	6	576.60	446	523	Upper sand and gravel aquifer (above the blue clay layer)

TABLE 4-1 (Cont'd)

MONITORING WELL SUMMARY SHEET

Well No.	Installed By	Location	Installation Order	Surface Elevation (ft)	Approximate Elevation at Top of Screen (ft)	Water Level Elevation (ft)	Aquifer Monitored
8d	NLO	Southeast Waste Pit Area	7	576.62	401	523	Deeper sand and gravel aquifer (below the blue clay layer)
9	NLO	South of Waste Pit Storage Area and east of Paddy's run	8	557.23	460	526	Deeper sand and gravel aquifer (below the blue clay layer)
10	NLO	East of Waste Pit Storage area west of Production Area	9	580.00	460	520	Upper sand and gravel aquifer (above the blue clay layer
11	NLO	West of Waste Pit Storage Area	10	585.78	510	526	Upper sand and gravel aquifer (above the blue clay layer
12	D&M	North (upgradient) of Production Area	11	639.67	580	610	Interface between glacial till and shale bedrock
13s	D&M	East of Production Area and west of North Access road	24	590.37	503	522	Upper portion of sand and gravel aquifer

TABLE 4-1 (Cont'd)

MONITORING WELL SUMMARY SHEET

Well No.	Installed By	Location	Installation Order	Surface Elevation (ft)	Approximate Elevation at Top of Screen (ft)	Water Level Elevation (ft)	Aquifer Monitored
13d	D&M	Same as 13s	23	590.36	466	522	Deeper portion of sand and gravel aquifer
14s	D&M	Intersection of Paddy's Run and Storm Sewer Outfall Ditch	13	535.79	524	524	Upper portion of sand and gravel aquifer
14d	D&M	Same as 14s	12	535.81	492	524	Deeper portion of sand and gravel aquifer
15s	D&M	Southern boundary of site along Willey Road	22	579.65	502	521	Upper portion of sand and gravel aquifer
15d	D&M	Fifty feet east offsite well #2	33	579.41	394	521	Deeper portion of sand and gravel aquifer
16s	D&M	Paddy's Run south of inactive Fly Ash pile	15	542.28	508	525	Upper portion of sand and gravel aquifer
16d	D&M	Paddy's Run south of inactive Fly Ash pile	14	542.13	475	525	Lower portion of sand and gravel aquifer

TABLE 4-1 (Cont'd)

MONITORING WELL SUMMARY SHEET

Well No.	Installed By	Location	Installation Order	Surface Elevation (ft)	Approximate Elevation at Top of Screen (ft)	Water Level Elevation (ft)	Aquifer Monitored
17s	D&M	West of Paddy's Run near Willey Road bridge	21	536.19	513	523	Upper portion of sand and gravel aquifer
17d	D&M	Same as 17s	20	536.35	466	523	Lower portion of sand and gravel aquifer
18s	D&M	Southwest of Production Area north of inactive Fly Ash pile	17	536.35	514	525	Upper portion of sand and gravel aquifer (above blue clay layer)
18d	D&M	Same as 18s	16	573.88	454	525	Deeper portion of sand and gravel aquifer (above blue clay layer)
19TP	D&M	East side of Waste pit #4	30	584.96	578	580	Saturated portion of glacial till
19s	D&M	Same as 19TP	26	585.38	497	524	Upper portion of sand and gravel aquifer (above blue clay layer)

TABLE 4-1 (Cont'd)

MONITORING WELL SUMMARY SHEET

Well No.	Installed By	Location	Installation Order	Surface Elevation (ft)	Approximate Elevation at Top of Screen (ft)	Water Level Elevation (ft)	Aquifer Monitored
19d	D&M	Same as 19TP	25	585.25	453	524	Deeper portion of sand and gravel aquifer (above blue clay layer)
20TP	D&M	Southwest corner of Production Area outside security fence	29	574.73	568	572	Saturated portion of glacial till
20s	D&M	Same as 20TP	19	574.44	507	523	Upper portion of sand and gravel aquifer (above blue clay layer)
20d	D&M	Same as 20TP	18	574.71	455	523	Deeper portion of sand and gravel aquifer (above blue clay layer)
21TP	D&M	South side waste pit #4	31	585.61	579	582	Saturated portion of glacial till

TABLE 4-1 (Cont'd)

MONITORING WELL SUMMARY SHEET

Well No.	Installed By	Location	Installation Order	Surface Elevation (ft)	Approximate Elevation at Top of Screen (ft)	Water Level Elevation (ft)	Aquifer Monitored
21s	D&M	Same as 21 TP	27	586.02	504	524	Upper portion of sand and gravel aquifer (above blue clay layer)
22TP	D&M	West side of waste pit #4	32	588.91	582	582	Saturated portion of glacial till
22s	D&M	Same as 22 TP	28	587.95	499	525	Upper portion of upper sand and gravel aquifer (above blue clay layer)
P-1	NLO	Northernmost well - east side of Production Area	---	578.66	393	523	Deeper sand and gravel aquifer-below blue clay
P-2	NLO	South of P-1	---	579.16	390	523	Deeper sand and gravel aquifer-below blue clay layer
P-3	NLO	Southernmost well west side of production area	---	579.36	390	523	Deeper sand and gravel aquifer-below blue clay layer

TABLE 4-1 (Cont'd)

MONITORING WELL SUMMARY SHEET

Well No.	Installed By	Location	Installation Order	Surface Elevation (ft)	Approximate Elevation at Top of Screen (ft)	Water Level Elevation (ft)	Aquifer Monitored
OB-1	NLO	South of main parking lot west side of storm water retention basin	---	577.59	558	565	Saturated portion of glacial till
OS-1	Private Party	Willey Road	---	581.83	507.83	520	Sand and Gravel Aquifer
OS-2	Private Party	Paddy's Run Road	---	555*	465*	---	Sand and Gravel Aquifer
OS-3	Private Party	Paddy's Run Road	---	530*	470*	---	Sand and Gravel Aquifer

* Estimated

TABLE 4-2

LABORATORY RESULTS FOR GROUND AND SURFACE WATER SAMPLES COLLECTED BY DAMES & MOORE DURING TASK B FIELD WORK*

Sample #	EAL Uranium Concentration mg/L	NLO Uranium Concentration mg/L	EAL Iron Concentration mg/L
MW1s	0.0089	0.0085	0.4
MW1d	0.0000	0.0005	5.5
MW3	0.0024	0.0029	0.8
MW4	0.0092	0.0096	0.2
MW5	0.0042	0.0051	3.0
MW8s	0.0006	0.0010	1.1
MW8d	0.0000	0.0003	3.2
MW9	0.0015	0.0015	<0.2
MW10	0.0190	0.0277	0.5
MW11	0.0039	0.0004 (1)	3.6
MW12	0.0000	0.0006	0.3
MW13s	0.0150	0.0400	3.3
MW13d	0.0100	0.0222	6.6
MW14s	0.1200	0.1250	<0.2
MW14d	0.1400	0.0300 (1)	<0.2
MW15s	0.1400	0.1240	<0.2
MW15d	0.0018	0.0009	4.0
MW16s	0.0310	0.0290	<0.2
MW16d	0.0250	0.0202	<0.2
MW17s	0.0033	0.0200 (1)	<0.2

TABLE 4-2 (Cont'd)

LABORATORY RESULTS FOR GROUND AND SURFACE WATER SAMPLES
COLLECTED BY DAMES & MOORE DURING TASK B FIELD WORK*

Sample #	EAL Uranium Concentration mg/L	NLO Uranium Concentration mg/L	EAL Iron Concentration mg/L
MW17d	0.0015	0.0032	0.4
MW18s	0.0018	0.0221 (1)	<0.2
MW18d	0.0033	0.0085	<0.2
MW19tp	0.2900	0.4960	1.6
MW19s	0.0021	0.0350 (1)	0.4
MW19d	0.0240	0.0320	<0.2
MW20tp	0.0410	0.0532	0.7
MW20s	0.0006	0.0009	<0.2
MW20d	0.0021	0.0133 (1)	0.7
MW21tp	1.50	1.4200	1.9
MW21s	0.0140	0.0211	<0.2
MW22tp	2.10	1.2200	<1.2
MW22s	0.015	0.0181	0.2
P-1	0.0006	0.0065 (1)	5.9
P-2	0.0006	0.0069 (1)	3.6
P-3	0.0000	0.0012 (1)	2.6
OB-1	0.0053	0.0149	1.4
OD-1	0.2700	0.2710	0.5
OD-2	0.0080	0.0150	3.5
OS-1	0.3000	0.2270	<0.2
OS-1A	0.0030	0.0028	<0.2

TABLE 4-2 (Cont'd)

LABORATORY RESULTS FOR GROUND AND SURFACE WATER SAMPLES COLLECTED BY DAMES & MOORE DURING TASK B FIELD WORK*

Sample #	EAL Uranium Concentration mg/L	NLO Uranium Concentration mg/L	EAL Iron Concentration mg/L
OS-2	0.3500	0.3020	<0.2
OS-3	0.0430	0.0410	1.4
RO-1	0.0270	---	<0.2
RO-2	12.0	---	<0.2
RO-3	0.0068	---	1.5
RO-4	28.0	---	0.6
RO-5	24.0	---	1.0
RO-6**	4.6	---	0.8
RO-7	0.3100	---	<0.2
RO-8	34.0	---	0.5
RO-9**	3.0	---	6.3
RO-10	3.6	---	2.0
RO-11	0.8300	---	0.2
RO-12	0.3400	---	<0.2
RO-13	0.5400	---	1.1
RO-14	0.4800	---	<0.2
RO-15	0.7100	---	<0.2
RO-16	0.6200	---	0.6
RO-17	11.0	---	<0.2
RO-18	0.5300	---	<0.2
RO-19	0.0018	---	<0.2

TABLE 4-2 (Cont'd)

LABORATORY RESULTS FOR GROUND AND SURFACE WATER SAMPLES
COLLECTED BY DAMES & MOORE DURING TASK B FIELD WORK*

NOTES:

EAL (Environmental Analysis Laboratory) was subcontracted by Dames & Moore to perform analytical services.

Iron was analyzed for use as a possible uranium indicator. Results show no correlation between Iron and Uranium values.

See Figures 1-1, 4-1, and 4-2 for well, seep, and runoff sampling locations

MW: Monitor Well

P: Production Well

OB: Observation Well (on west side of storm water retention basin)

OD: Storm Sewer Outfall Ditch

OS: Offsite Wells (OS-1A-shallow dug well)

RO: Runoff Sample

* DOE Guide for Uranium in water released to Uncontrolled Areas = 1.8 mg/L

** Surface Seep Samples

--- Samples Not Split with NLO

(1) Indicates an order of magnitude difference between EAL and NLO values. EAL values were used in data analysis and interpretation.

See Table 4-1 for Well Specifications

TABLE 4-3

ABOVE-BACKGROUND CONCENTRATIONS OF URANIUM
IN GROUNDWATER SAMPLES FROM ONSITE WELLS
IN THE SAND AND GRAVEL AQUIFER

WELL #	SCREENED ZONE	VALUE* (U in mg/L)
MW 1s	B	0.009
MW 3	B	0.002
MW 4	B	0.009
MW 5	B	0.004
MW 9	B	0.002
MW 10	B	0.019
MW 11	B	0.004
MW 13s	A	0.015
MW 13d	B	0.010
MW 14s	A	0.120
MW 14d	B	0.140
MW 15s	A	0.140
MW 15d	B	0.002
MW 16s	A	0.031
MW 16d	B	0.025
MW 17s	A	0.003
MW 17d	B	0.002
MW 18s	A	0.002
MW 18d	B	0.003
MW 19s	A	0.002
MW 19d	B	0.024
MW 20d	B	0.002
MW 21s	A	0.014
MW 22s	A	0.015

NOTES

A: Screened above Blue Clay Layer, in upper part of Upper Sand and Gravel Aquifer.
B: Screened above Blue Clay Layer, in lower part of Upper Sand and Gravel Aquifer.

Samples taken March, 1985 by Dames & Moore

Background ranges from 0.0001 mg/L to 0.0027 mg/L. Average value of 0.0008 mg/L was used for statistical comparisons.

*DOE Guideline for Uranium in water released to Uncontrolled Areas = 1.8 mg/L.

TABLE 4-4

SUMMARY OF NLO WATER SAMPLING DATA
FOR URANIUM FROM
PADDY'S RUN*

Upgradient samples collected at intersection of Paddy's Run and SR 126.

Downgradient samples collected at intersection of Paddy's Run and Willey Road.

YEAR	UPGRADIENT		DOWNGRADIENT	
	AVERAGE CONCENTRATION (mg/L)	RANGE (mg/L)	AVERAGE CONCENTRATION (mg/L)	RANGE (mg/L)
1975	0.006	0.001-0.026	0.027	0.007-0.140
1976	0.004	0.001-0.014	0.016	0.005-1.10
1977	0.008	0.001-0.120	0.014	0.007-0.310
1978	0.008	0.001-0.120	0.022	0.006-1.20
1979	0.003	0.001-0.014	0.015	0.009-0.052
1980	0.003	0.001-0.009	0.015	0.008-0.090
1981	0.004	0.002-0.010	0.020	0.004-0.400
1982	0.004	0.002-0.008	0.022	0.003-0.170
1983	0.002	0.001-0.006	0.027	0.003-0.908
1984	0.002	0.001-0.010	0.023	0.008-0.249

* DOE Guideline for Uranium in water released to Uncontrolled Areas = 1.8 mg/L.

TABLE 4-5

SUMMARY OF NLO WATER SAMPLING DATA
FOR URANIUM FROM
STORM SEWER OUTFALL DITCH

YEAR	AVERAGE CONCENTRATION* (mg/L)	TOTAL QUANTITY DISCHARGED (kg)
1975	1.40	375
1976	2.60	88
1977	3.80	145
1978	1.00	43
1979	1.07	70
1980	0.74	15
1981	0.34	4
1982	0.83	11
1983	0.47	44
1984	0.63	56

* This is an onsite discharge and the DOE Guidelines for Uranium in water released to Uncontrolled Areas (1.8 mg/L) does not apply at this location.

TABLE 4-6

COMPARISON OF AVERAGE URANIUM CONCENTRATIONS IN THE THE OFFSITE WELLS WITH ABOVE-BACKGROUND CONCENTRATIONS OF URANIUM RELEASED TO THE STORM SEWER OUTFALL DITCH

YEAR	OFFSITE WELLS AVERAGE URANIUM CONCENTRATIONS			AVERAGE URANIUM CONCENTRATION RELEASED TO STORM SEWER OUTFALL DITCH
	OS-1 (mg/L)	OS-2 (mg/L)	OS-3 (mg/L)	(mg/L)
1982	0.25	0.47	0.07	0.83
1983	0.26	0.43	0.06	0.47
1984	0.25	0.33	0.05	0.63

TABLE 4-7

CONCENTRATIONS OF URANIUM IN DRAINAGE DITCHES WITHIN THE WASTE PIT STORAGE AREA

Samples Collected in March, 1985 by Dames & Moore.

SAMPLE	DRAINAGE BASIN/CONCENTRATION (mg/L)	CONCENTRATION AT DISCHARGE PT* (mg/L)
RO-1	A/0.03	0.030
RO-2	B/12.0	0.048
RO-3	C/0.007	Clearwell
RO-4	C/28.0	Clearwell
RO-5	B/24.0	0.048
RO-6	C/4.6	Clearwell
RO-7	C/0.31	Clearwell
RO-8	C/34.0	Clearwell
RO-9	B/3.0	0.048
RO-10	D/3.6	0.340
RO-11	D/0.83	0.340
RO-12	D/0.34	0.340
RO-13	B/0.54	0.048
RO-14	B/0.48	0.048
RO-15	B/0.71	0.048
RO-16	B/0.62	0.048
RO-17	D/11.0	0.340
RO-18	D/0.53	0.340

*DOE Guidelines for Uranium in water released to Uncontrolled Areas =1.8 mg/L

TABLE 5-1
MATERIAL PROPERTIES

(SEE FIGURE 5-3 FOR MATERIAL LOCATIONS)

MATERIAL PROPERTY	1	2	3	4	5	6
Hydraulic Conductivity (ft/day)	0.06	1.0	8.0	60.0	300.0	0.5
Effective Porosity	0.15	0.2	0.2	0.2	0.25	0.2

TABLE 5-2

ELEVATION OF BASE OF AQUIFER
AT EACH GRID POINT

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	430	430	430	430	400	400	400	400	400	440	430	430	460	480
2	430	430	430	430	400	400	400	400	400	440	430	430	460	480
3	430	430	430	430	400	410	380	380	380	380	380	400	430	430
4	430	430	430	430	410	380	370	370	370	370	380	400	430	430
5	430	430	430	430	410	380	370	370	370	370	370	370	400	400
6	430	430	430	430	410	380	370	370	370	370	370	370	380	380
7	430	430	430	410	380	370	370	370	370	370	370	370	370	370
8	440	400	400	380	370	370	370	370	370	370	370	370	370	370
9	410	410	380	370	370	370	370	370	370	370	370	370	370	370
10	380	380	370	370	370	370	370	370	370	370	370	370	370	370
11	370	370	370	370	370	370	370	370	370	370	370	370	370	370
12	370	370	370	370	370	370	370	370	370	370	370	370	370	370
13	370	370	370	370	370	370	370	370	370	370	370	370	370	370

TABLE 5-2 (CONT'D)

ELEVATION OF BASE OF AQUIFER (Cont'd)
AT EACH GRID POINT

	15	16	17	18	19	20	21
1	480	480	480	490	490	490	490
2	480	480	480	490	490	490	490
3	430	430	430	430	430	430	430
4	430	430	430	430	430	430	430
5	400	400	400	400	400	400	400
6	380	380	380	380	380	380	380
7	370	370	370	370	370	370	370
8	370	370	370	370	370	370	370
9	370	370	370	370	400	430	430
10	370	370	370	400	400	430	430
11	370	370	400	400	400	430	430
12	370	370	400	400	400	430	430
13	370	370	400	400	400	400	430

TABLE 5-2 (CONT'D)

ELEVATION OF BASE OF AQUIFER
AT EACH GRID POINT

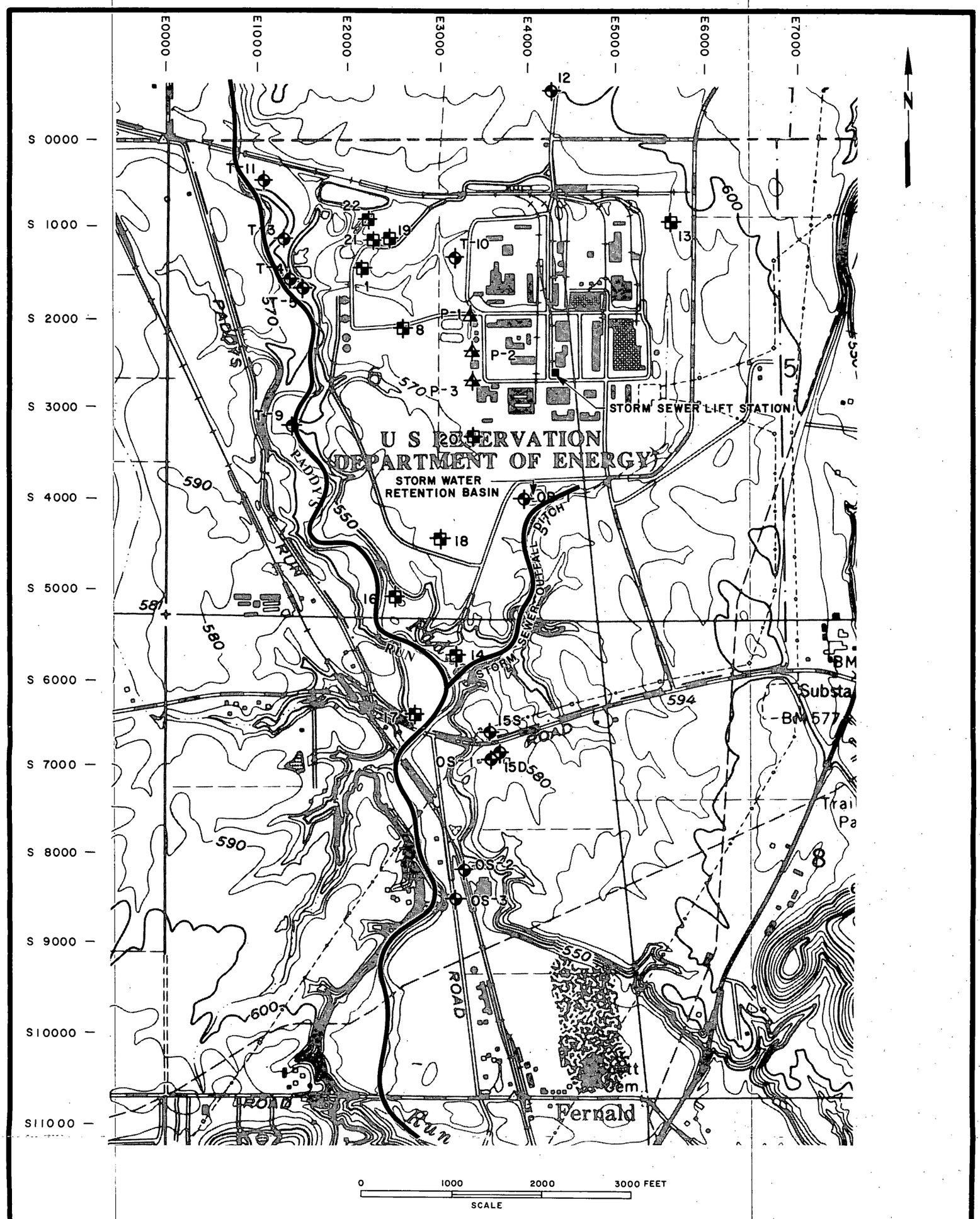
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
14	370	370	370	370	370	370	370	370	370	370	370	370	370	370
15	370	370	370	370	370	370	370	370	370	370	370	370	370	370
16	370	370	370	370	370	370	370	370	370	370	370	370	370	370
17	370	370	370	370	370	370	370	370	370	370	370	370	370	370
18	370	370	370	370	370	370	370	370	370	370	370	370	370	370
19	380	380	380	380	380	380	380	380	380	380	370	370	370	370
20	430	430	430	430	430	430	430	430	430	380	370	370	370	370
21	470	470	470	470	470	470	430	430	400	400	370	370	370	370
22	470	470	470	470	470	470	430	430	400	400	370	370	370	370

TABLE 5-2 (CONT'D)

ELEVATION OF BASE OF AQUIFER (Cont'd)
AT EACH GRID POINT

	15	16	17	18	19	20	21
14	370	370	400	400	400	400	430
15	370	370	370	370	370	370	370
16	370	370	370	370	370	370	370
17	370	370	370	400	400	400	400
18	370	370	370	400	430	430	400
19	370	370	370	400	430	430	430
20	370	370	400	430	430	430	430
21	370	370	370	400	400	400	400
22	370	370	370	400	400	400	400

FIGURES



EXPLANATION:

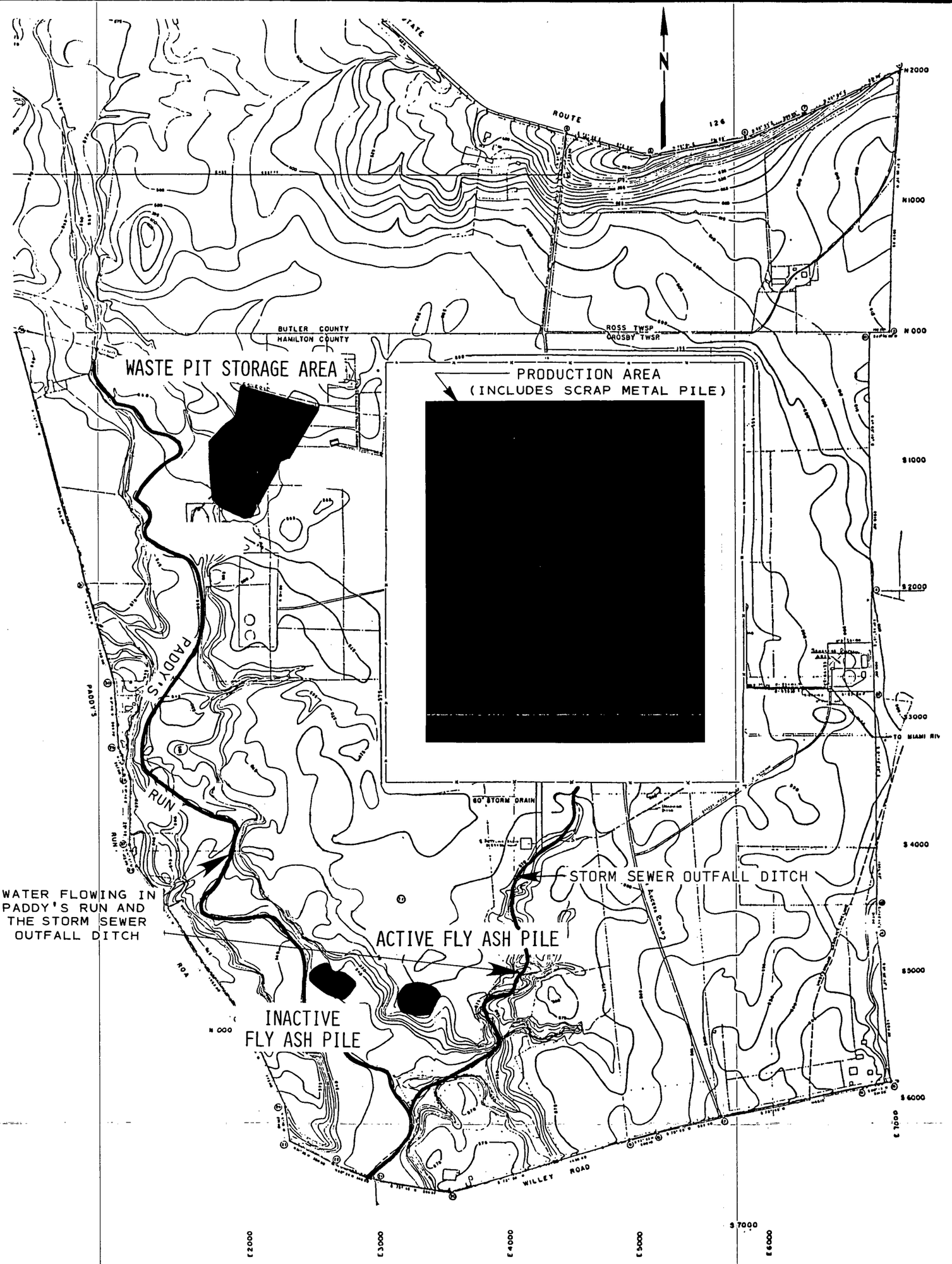
- SINGLE WELL LOCATION
- CLUSTER WELL LOCATION
- PRODUCTION WELL LOCATION
- S2000 - PLANT COORDINATE SYSTEM

REFERENCE: BASE MAP TAKEN FROM U.S.G.S. 7.5' TOPOGRAPHIC MAP, SHANDON, OHIO (1981) QUADRANGLE

WELL LOCATIONS

DAMES & MOORE

FIGURE 1-1



EXPLANATION:

POTENTIAL SOURCE AREA

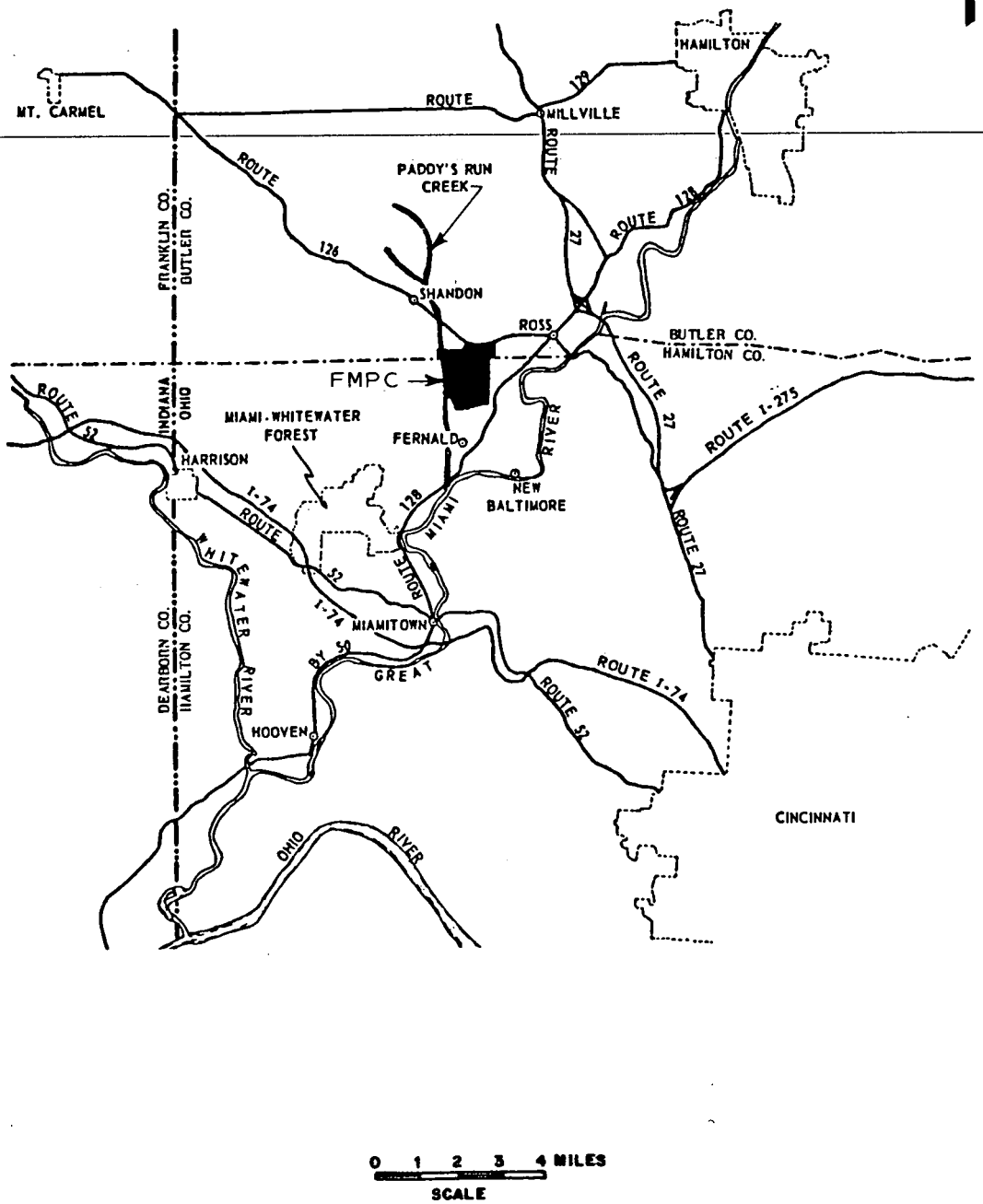
0 500 1000 FEET
SCALE

THE POTENTIAL SOURCE AREAS SHOWN REPRESENT AN EVALUATION OF THE MOST PROBABLE CONDITIONS BASED UPON INTERPRETATION OF PRESENTLY AVAILABLE DATA. VARIATIONS FROM THESE CONDITIONS MAY OCCUR.

FIGURE 1-2

PRELIMINARY IDENTIFICATION OF POTENTIAL SOURCES
FOR THE ABOVE-BACKGROUND CONCENTRATIONS
IN THE THREE OFFSITE WELLS

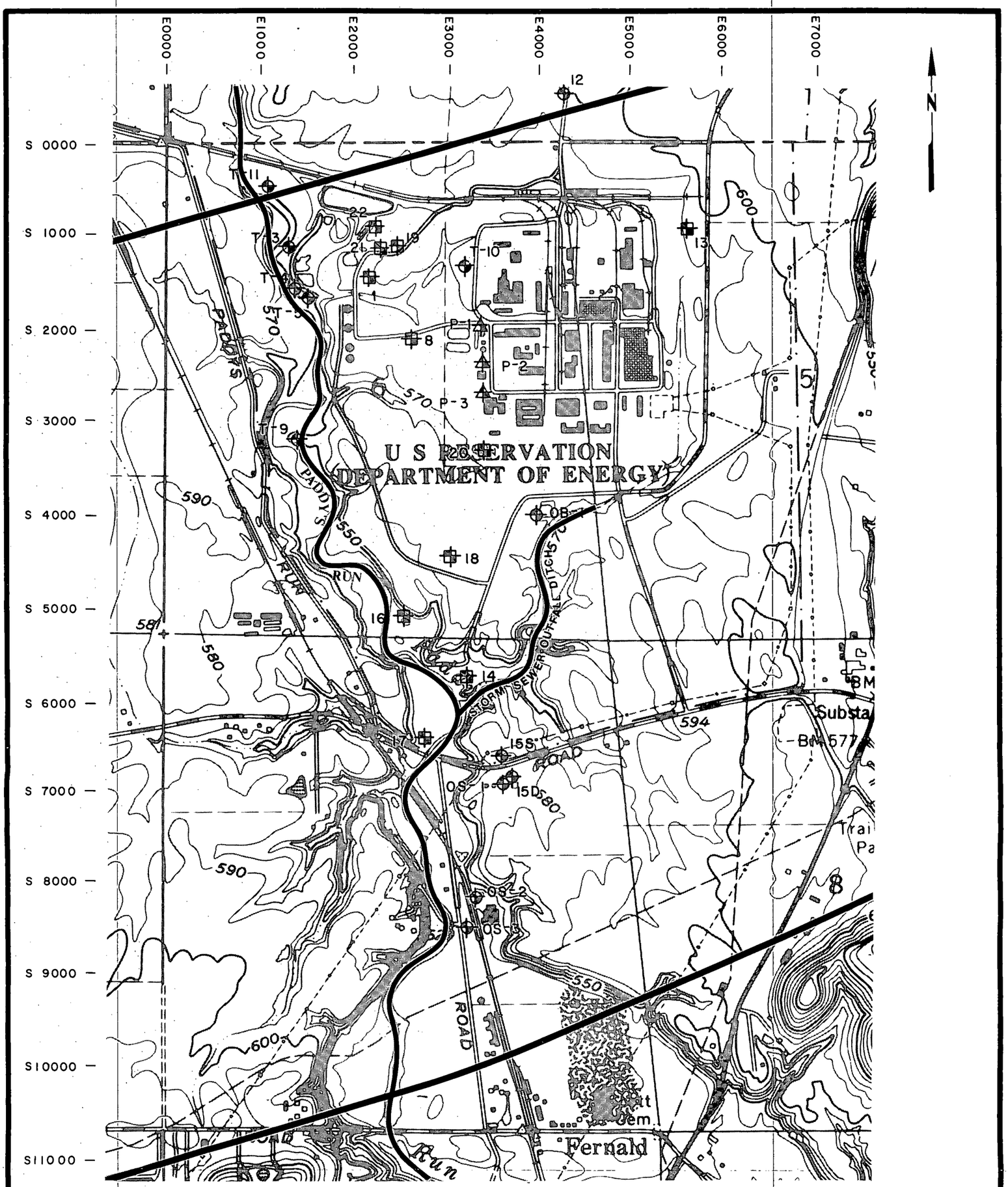
DAMES & MOORE



SITE LOCATION MAP

DAMES & MOORE

FIGURE 2-1



0 1000 2000 3000 FEET
SCALE

EXPLANATION:

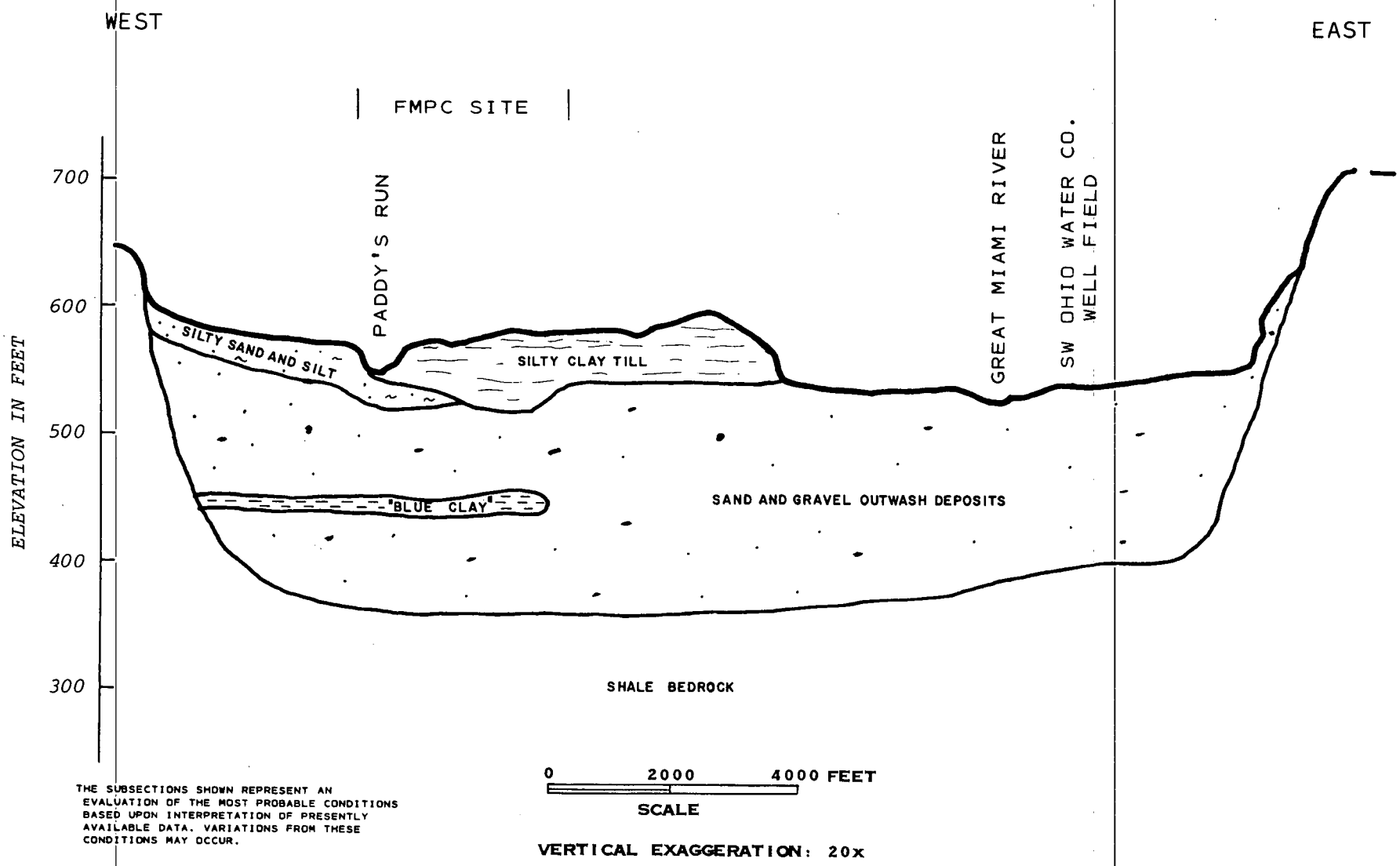
- APPROXIMATE BOUNDARY OF NEW HAVEN TROUGH
- SINGLE WELL LOCATION
- CLUSTER WELL LOCATION
- PRODUCTION WELL LOCATION

REFERENCE: BASE MAP TAKEN FROM U.S.G.S. 7.5' TOPOGRAPHIC MAP, SHANDON, OHIO (1981) QUADRANGLE

NEW HAVEN TROUGH BOUNDARIES

DAMES & MOORE

FIGURE 3-1

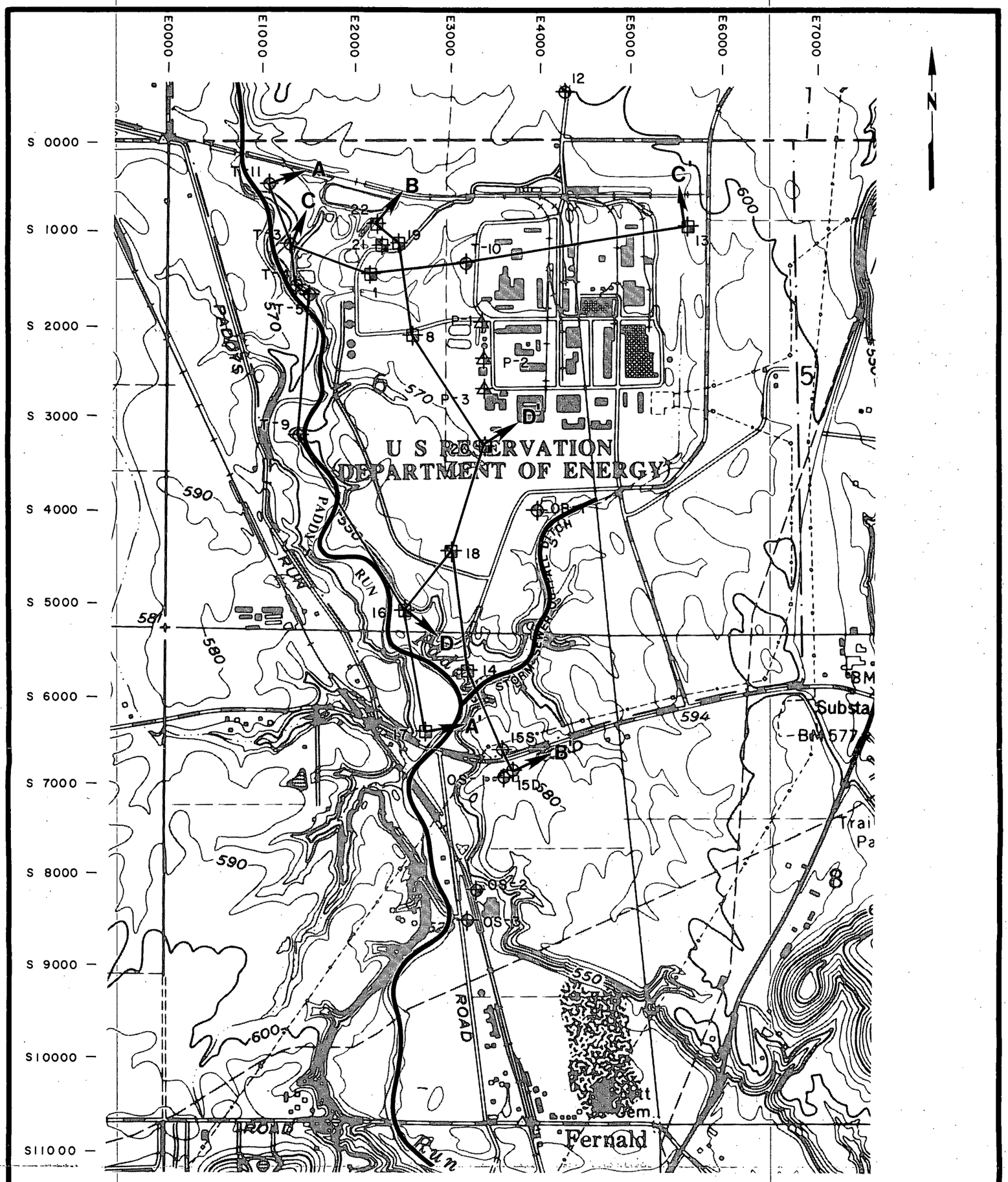


THE SUBSECTIONS SHOWN REPRESENT AN EVALUATION OF THE MOST PROBABLE CONDITIONS BASED UPON INTERPRETATION OF PRESENTLY AVAILABLE DATA. VARIATIONS FROM THESE CONDITIONS MAY OCCUR.

GENERALIZED GEOLOGIC CROSS SECTION OF NEW HAVEN TROUGH

DAMES & MOORE

FIGURE 3-2



EXPLANATION:

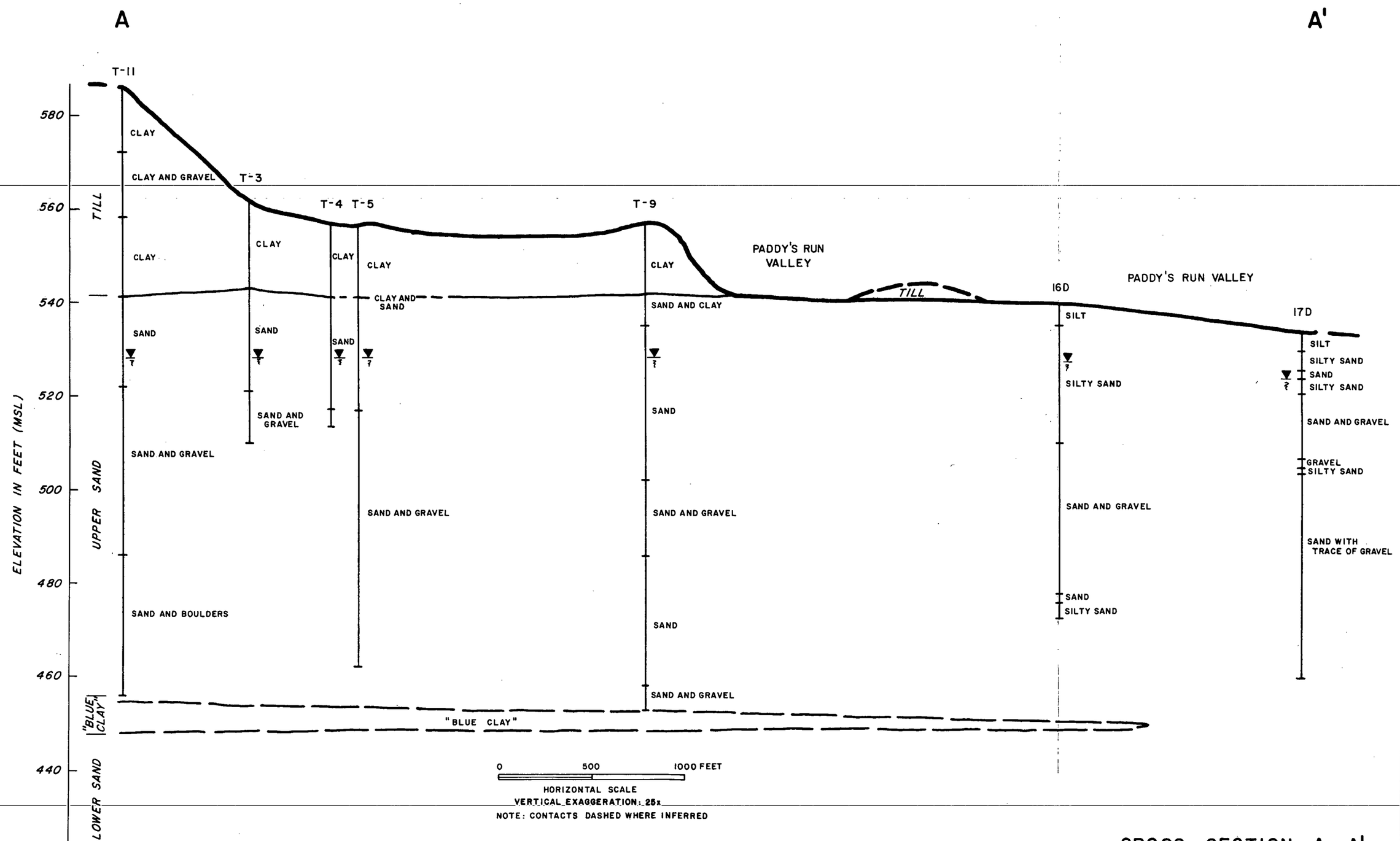
- SINGLE WELL LOCATION
- CLUSTER WELL LOCATION
- PRODUCTION WELL LOCATION
- A A' CROSS SECTION LOCATION

REFERENCE: BASE MAP TAKEN FROM U.S.G.S. 7.5' TOPOGRAPHIC MAP, SHANDON, OHIO (1981) QUADRANGLE

CROSS SECTION LOCATION MAP

DAMES & MOORE

FIGURE 3-3



THE SUBSECTIONS SHOWN REPRESENT AN EVALUATION OF THE MOST PROBABLE CONDITIONS BASED UPON INTERPRETATION OF PRESENTLY AVAILABLE DATA. VARIATIONS FROM THESE CONDITIONS MAY OCCUR.

CROSS SECTION A - A'

DAMES & MOORE

FIGURE 3-4

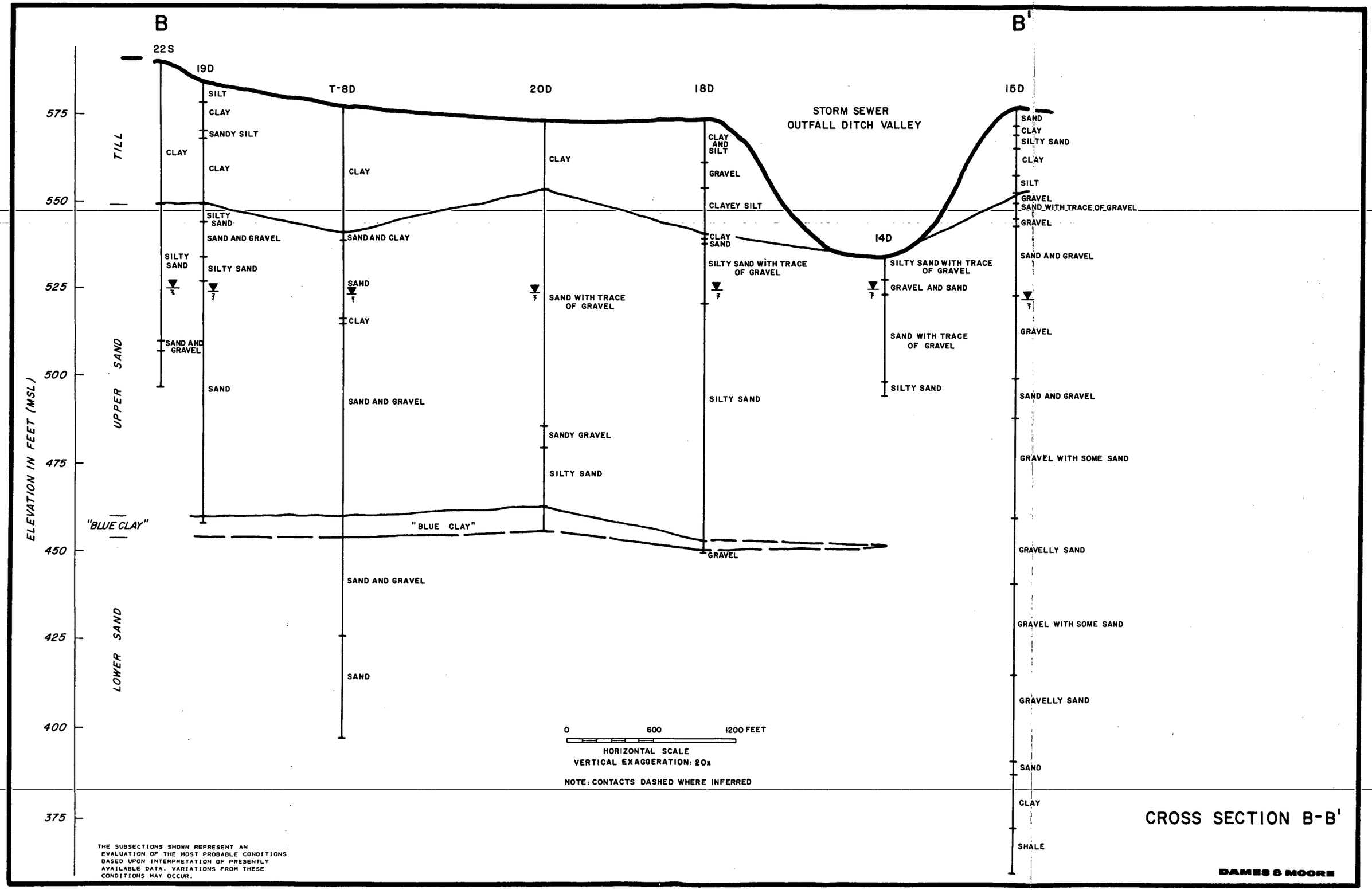

B
B'
22S
19D
T-8D
20D
18D
15D
14D
STORM SEWER
OUTFALL DITCH VALLEY
ELEVATION IN FEET (MSL)
575
550
525
500
475
450
425
400
375
TILL
UPPER SAND
LOWER SAND
"BLUE CLAY"
SILT
CLAY
SANDY SILT
CLAY
SILTY SAND
SAND AND GRAVEL
SILTY SAND
SILTY SAND
SAND AND GRAVEL
SAND
CLAY
SAND AND CLAY
SAND
CLAY
SAND AND GRAVEL
SAND
CLAY
SAND WITH TRACE OF GRAVEL
SANDY GRAVEL
SILTY SAND
CLAY AND SILT
GRAVEL
CLAYEY SILT
CLAY SAND
SILTY SAND WITH TRACE OF GRAVEL
SILTY SAND
GRAVEL
SILTY SAND WITH TRACE OF GRAVEL
GRAVEL AND SAND
SAND WITH TRACE OF GRAVEL
SILTY SAND
SAND
CLAY
SILTY SAND
CLAY
SILT
GRAVEL
SAND WITH TRACE OF GRAVEL
GRAVEL
SAND AND GRAVEL
GRAVEL
SAND AND GRAVEL
GRAVEL WITH SOME SAND
GRAVELLY SAND
GRAVEL WITH SOME SAND
GRAVELLY SAND
SAND
CLAY
SHALE
"BLUE CLAY"
GRAVEL
0
600
1200 FEET
HORIZONTAL SCALE
VERTICAL EXAGGERATION: 20x
NOTE: CONTACTS DASHED WHERE INFERRED
THE SUBSECTIONS SHOWN REPRESENT AN EVALUATION OF THE MOST PROBABLE CONDITIONS BASED UPON INTERPRETATION OF PRESENTLY AVAILABLE DATA. VARIATIONS FROM THESE CONDITIONS MAY OCCUR.
CROSS SECTION B-B'
DAMES & MOORE

FIGURE 3-5

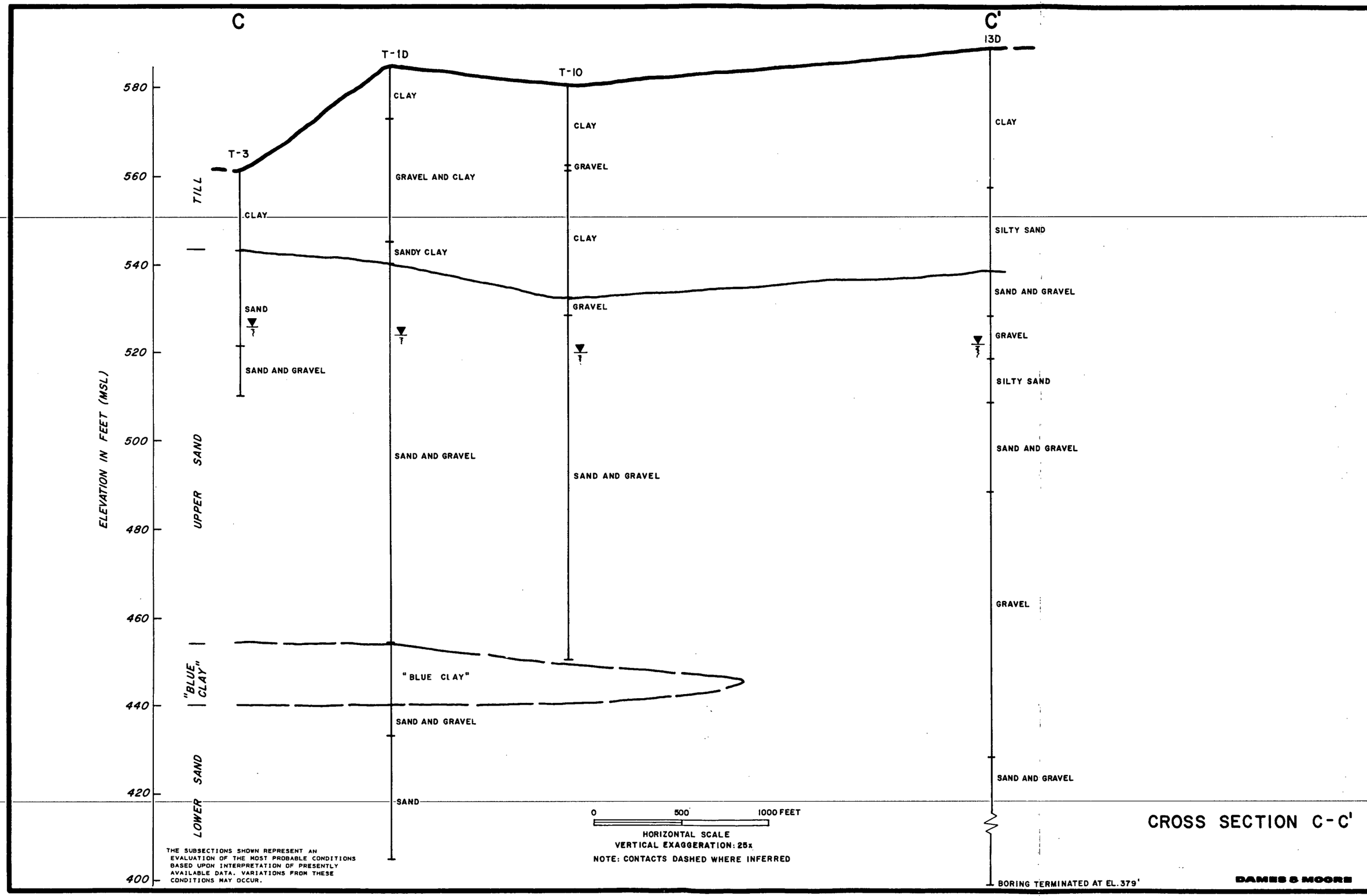
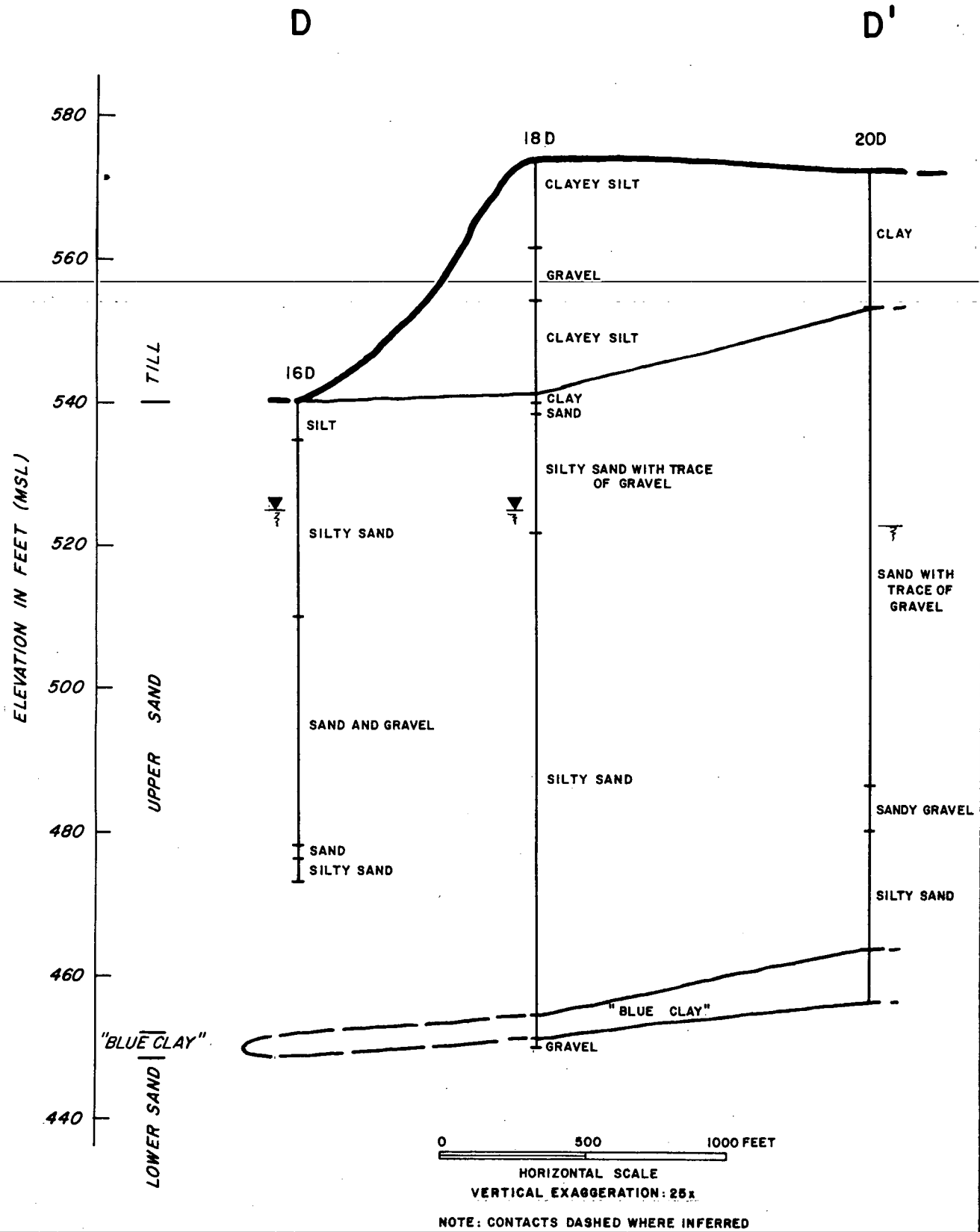

C
C'
T-3
T-1D
T-10
13D
580
560
540
520
500
480
460
440
420
400
ELEVATION IN FEET (MSL)
TILL
UPPER SAND
"BLUE CLAY"
LOWER SAND
CLAY
SAND
SAND AND GRAVEL
CLAY
GRAVEL AND CLAY
SANDY CLAY
SAND AND GRAVEL
"BLUE CLAY"
SAND AND GRAVEL
SAND
CLAY
GRAVEL
CLAY
GRAVEL
SAND AND GRAVEL
CLAY
SILTY SAND
SAND AND GRAVEL
GRAVEL
SILTY SAND
SAND AND GRAVEL
GRAVEL
SAND AND GRAVEL
BORING TERMINATED AT EL. 379'
0
500
1000 FEET
HORIZONTAL SCALE
VERTICAL EXAGGERATION: 25x
NOTE: CONTACTS DASHED WHERE INFERRED
THE SUBSECTIONS SHOWN REPRESENT AN EVALUATION OF THE MOST PROBABLE CONDITIONS BASED UPON INTERPRETATION OF PRESENTLY AVAILABLE DATA. VARIATIONS FROM THESE CONDITIONS MAY OCCUR.
CROSS SECTION C-C'
DAMES & MOORE

FIGURE 3-6

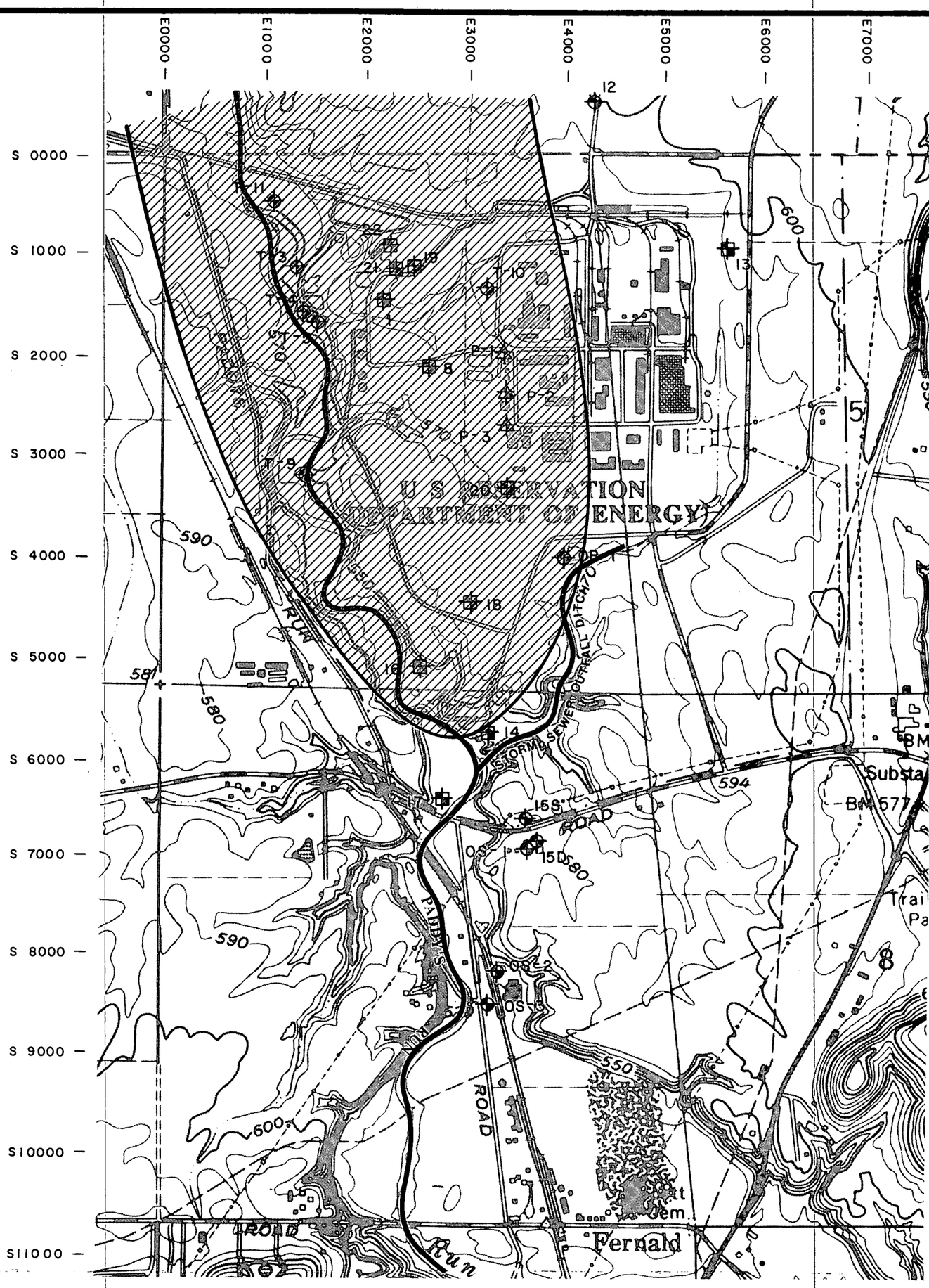


CROSS SECTION D-D'

THE SUBSECTIONS SHOWN REPRESENT AN EVALUATION OF THE MOST PROBABLE CONDITIONS BASED UPON INTERPRETATION OF PRESENTLY AVAILABLE DATA. VARIATIONS FROM THESE CONDITIONS MAY OCCUR.

DAMES & MOORE

FIGURE 3-7



EXPLANATION:

- ESTIMATED LIMIT OF "BLUE CLAY
  BASED ON DATA FROM WELLS SHOWN ON FIGURE
  APPROXIMATE ELEVATION 460'
- SINGLE WELL LOCATION
- CLUSTER WELL LOCATION
- PRODUCTION WELL LOCATION

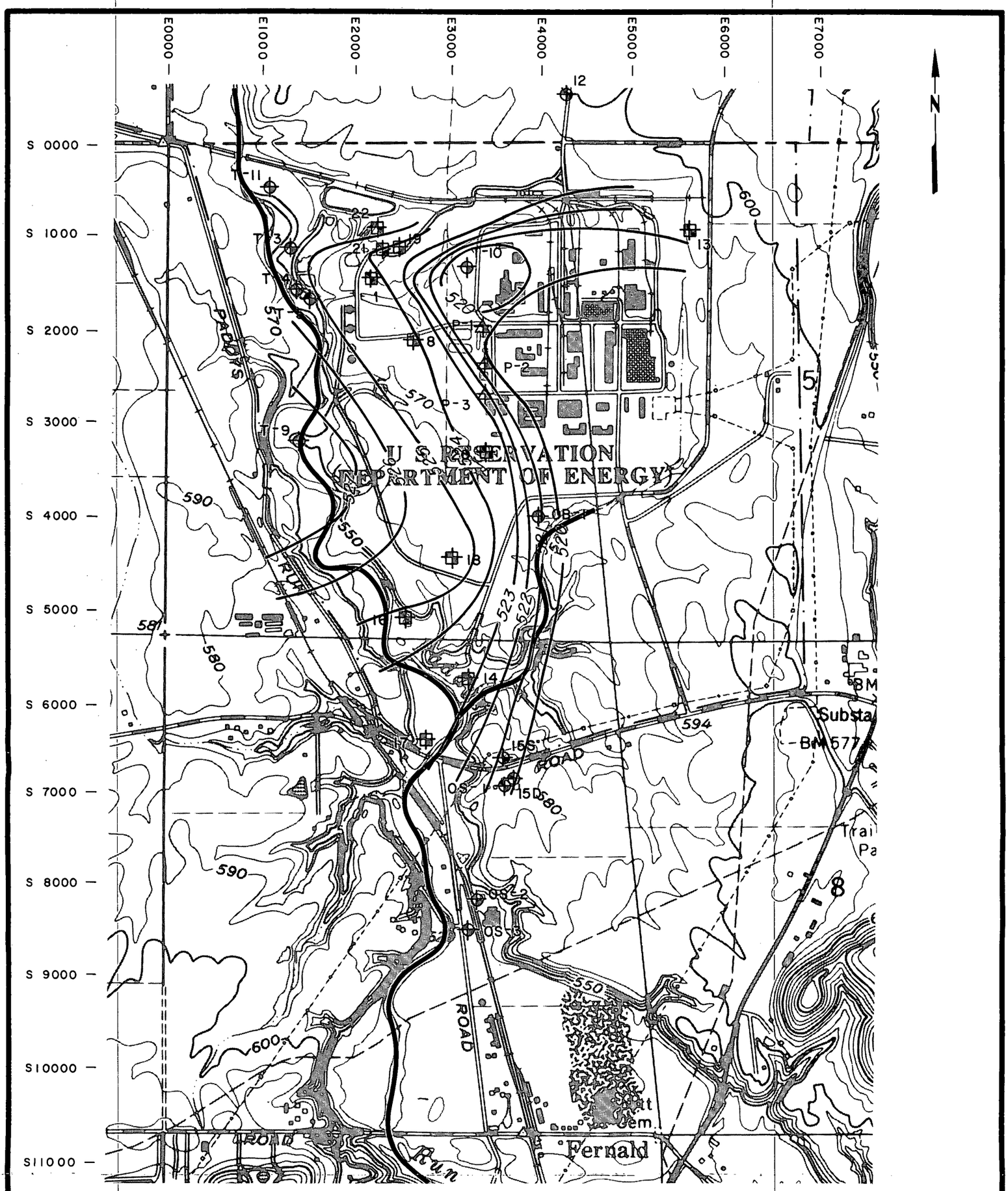
REFERENCE: BASE MAP TAKEN FROM U.S.G.S. 7.5' TOPOGRAPHIC MAP, SHANDON, OHIO (1981) QUADRANGLE

THE ESTIMATED LIMITS SHOWN REPRESENT AN EVALUATION OF THE MOST PROBABLE CONDITIONS BASED UPON INTERPRETATION OF PRESENTLY AVAILABLE DATA. VARIATIONS FROM THESE CONDITIONS MAY OCCUR.

AREAL EXTENT OF THE "BLUE CLAY" LAYER

DAMES & MOORE

FIGURE 3-8



EXPLANATION:

— 520 — WATER LEVEL CONTOUR (IN FEET)

SINGLE WELL LOCATION

CLUSTER WELL LOCATION

PRODUCTION WELL LOCATION

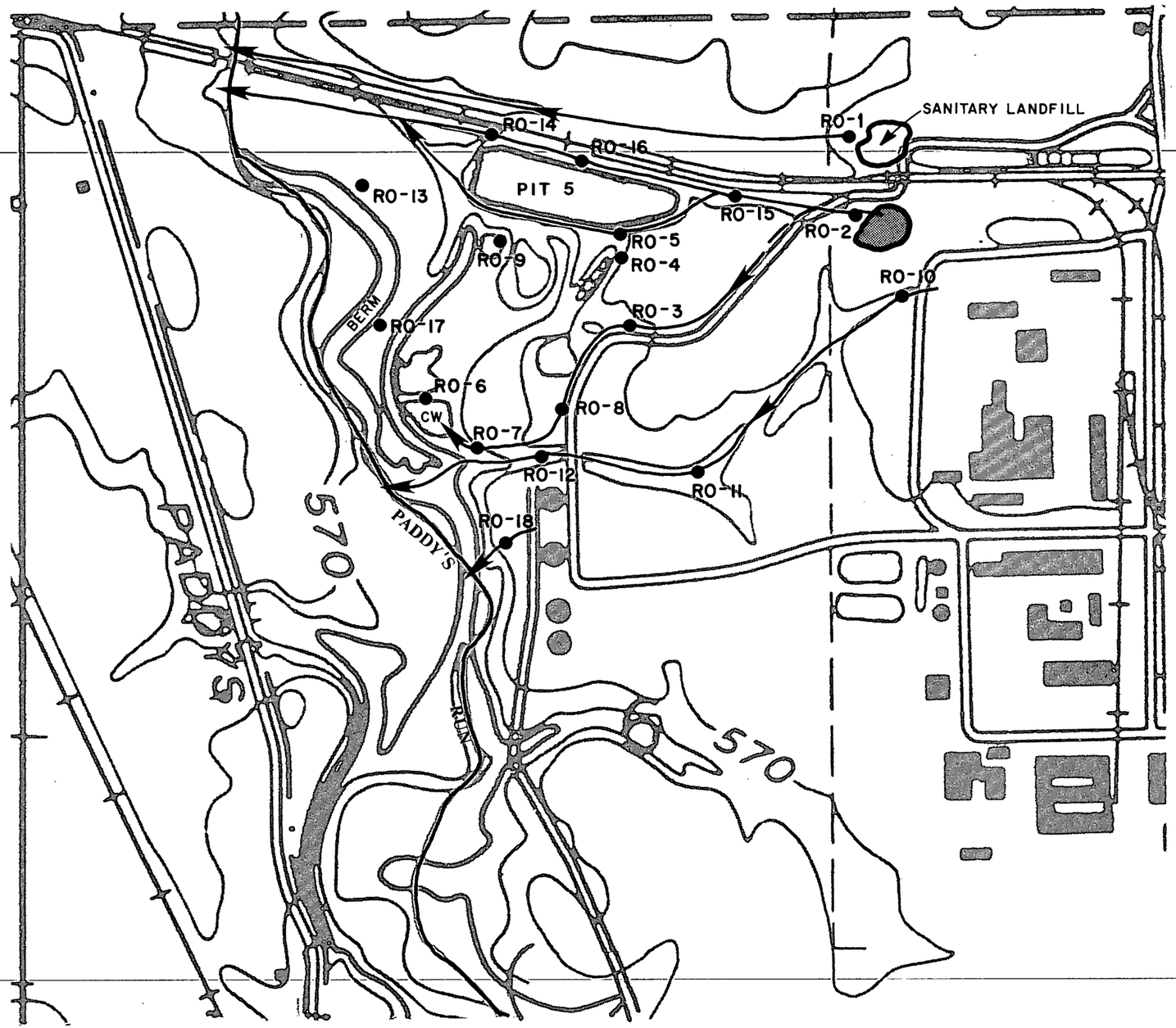
REFERENCE: BASE MAP TAKEN FROM U.S.G.S. 7.5' TOPOGRAPHIC MAP, SHANDON, OHIO (1981) QUADRANGLE

THE WATER LEVEL CONTOURS SHOWN REPRESENT AN EVALUATION OF THE MOST PROBABLE CONDITIONS BASED UPON INTERPRETATION OF PRESENTLY AVAILABLE DATA. VARIATIONS FROM THESE CONDITIONS MAY OCCUR.

DAMES & MOORE
WATER LEVEL CONTOUR MAP
FOR THE SAND AND GRAVEL AQUIFER

DAMES & MOORE

FIGURE 3-9



N

0 500 1000 FEET
SCALE

EXPLANATION:

PILE OF CLEAN SOILS REMOVED FOR CONSTRUCTION PURPOSES FROM VICINITY OF RO-11

CW — LIQUID IN THE CLEARWELL IS DISCHARGED FROM THE FMPC'S PERMITTED OUTFALL

DIRECTION OF FLOW IN SURFACE DRAINAGES

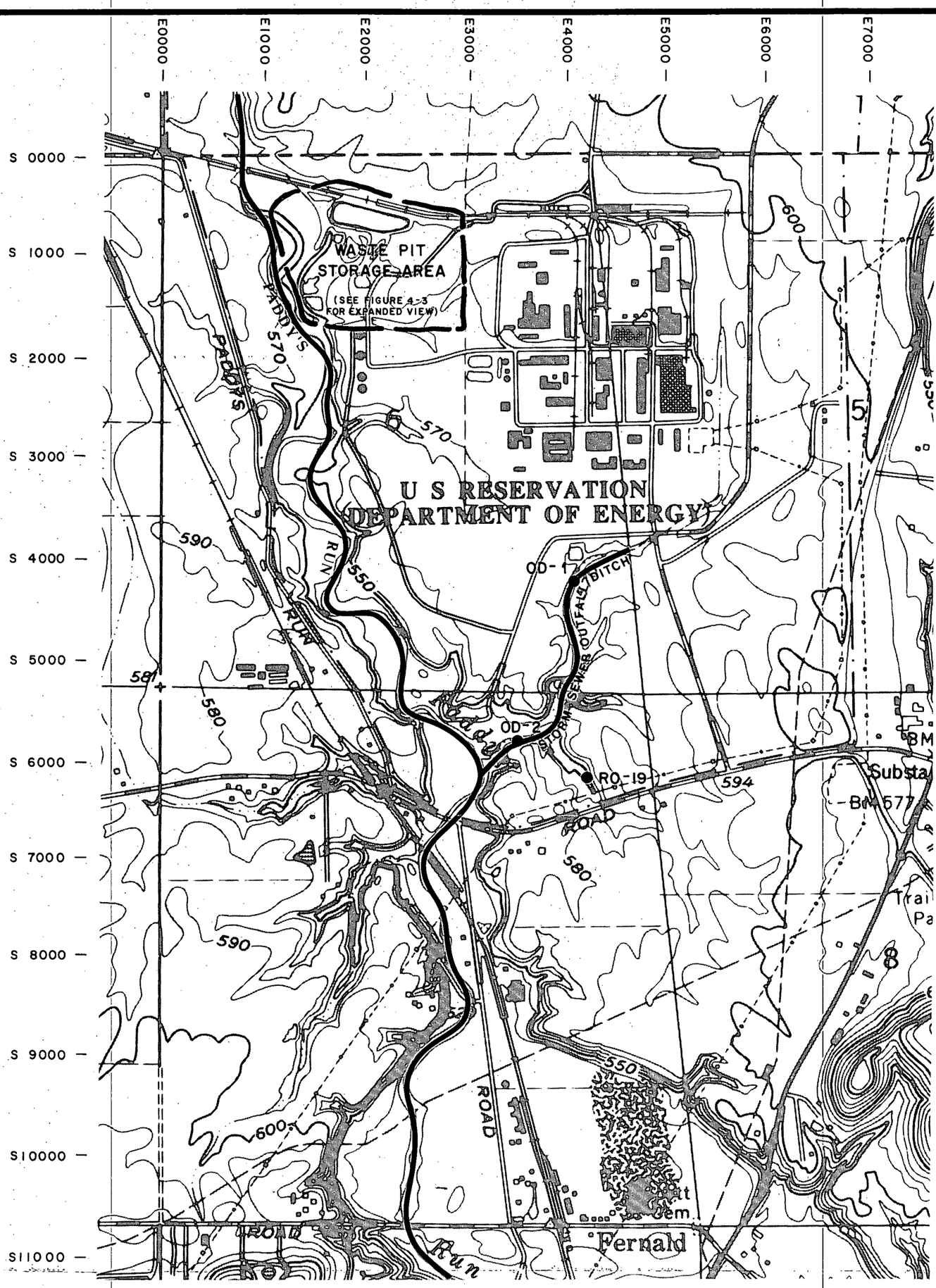
SURFACE WATER SAMPLE

REFERENCE: BASE MAP TAKEN FROM U.S.G.S. 7.5' TOPOGRAPHIC MAP, SHANDON, OHIO (1981) QUADRANGLE

SURFACE WATER SAMPLING LOCATIONS
WASTE PIT STORAGE AREA

DAMES & MOORE

FIGURE 4-1



0 1000 2000 3000 FEET
SCALE

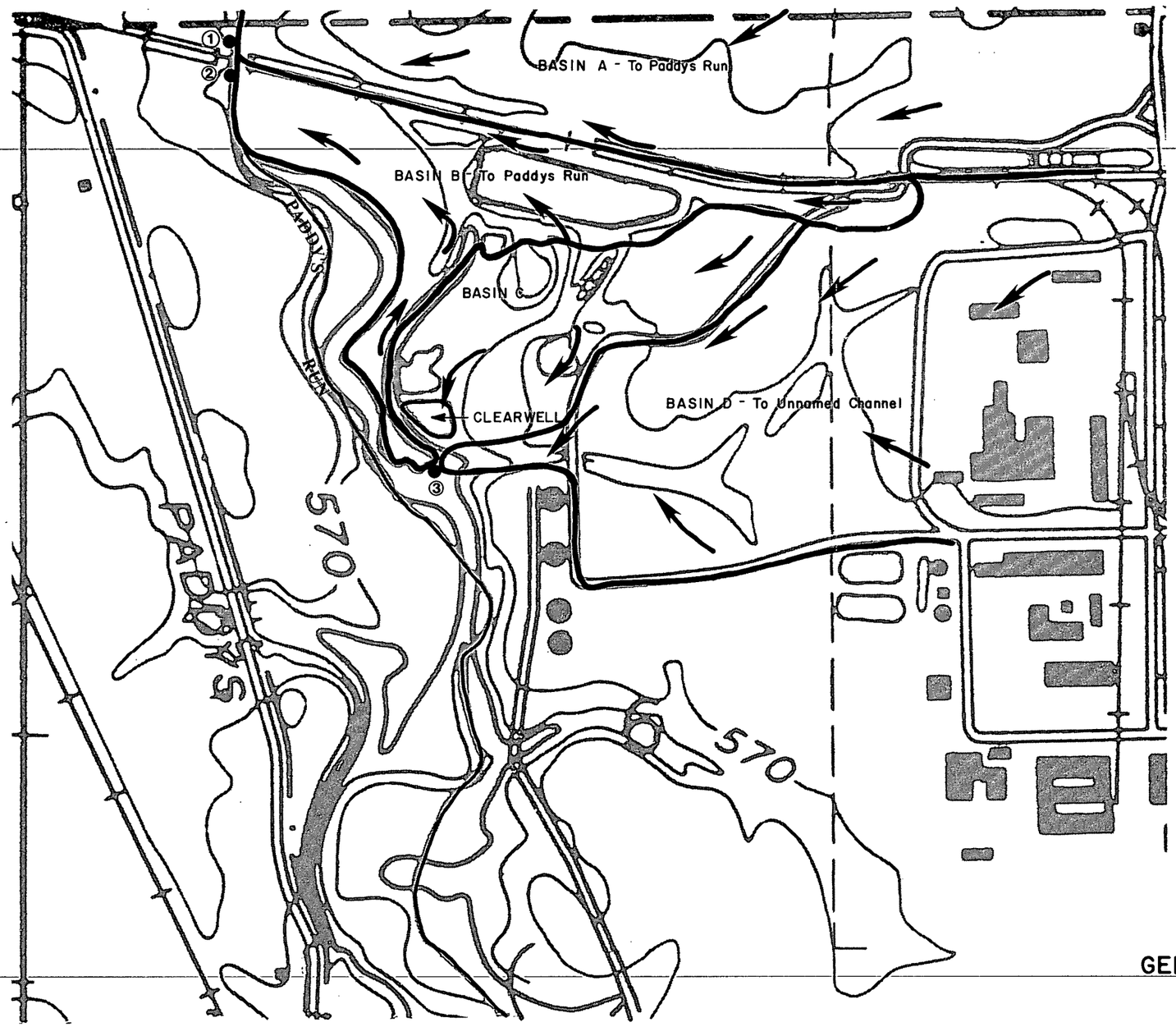
REFERENCE: BASE MAP TAKEN FROM U.S.G.S. 7.5' TOPOGRAPHIC MAP, SHANDON, OHIO (1981) QUADRANGLE

SURFACE WATER SAMPLING LOCATIONS

OUTSIDE OF WASTE PIT STORAGE AREA

DAMES & MOORE

FIGURE 4-2



N

0 500 1000 FEET
SCALE

EXPLANATION:

① ● DISCHARGE POINT FOR BASIN A
② ● DISCHARGE POINT FOR BASIN B
③ ● DISCHARGE POINT FOR BASIN D

NOTE: Basin C discharge point is to clearwell.

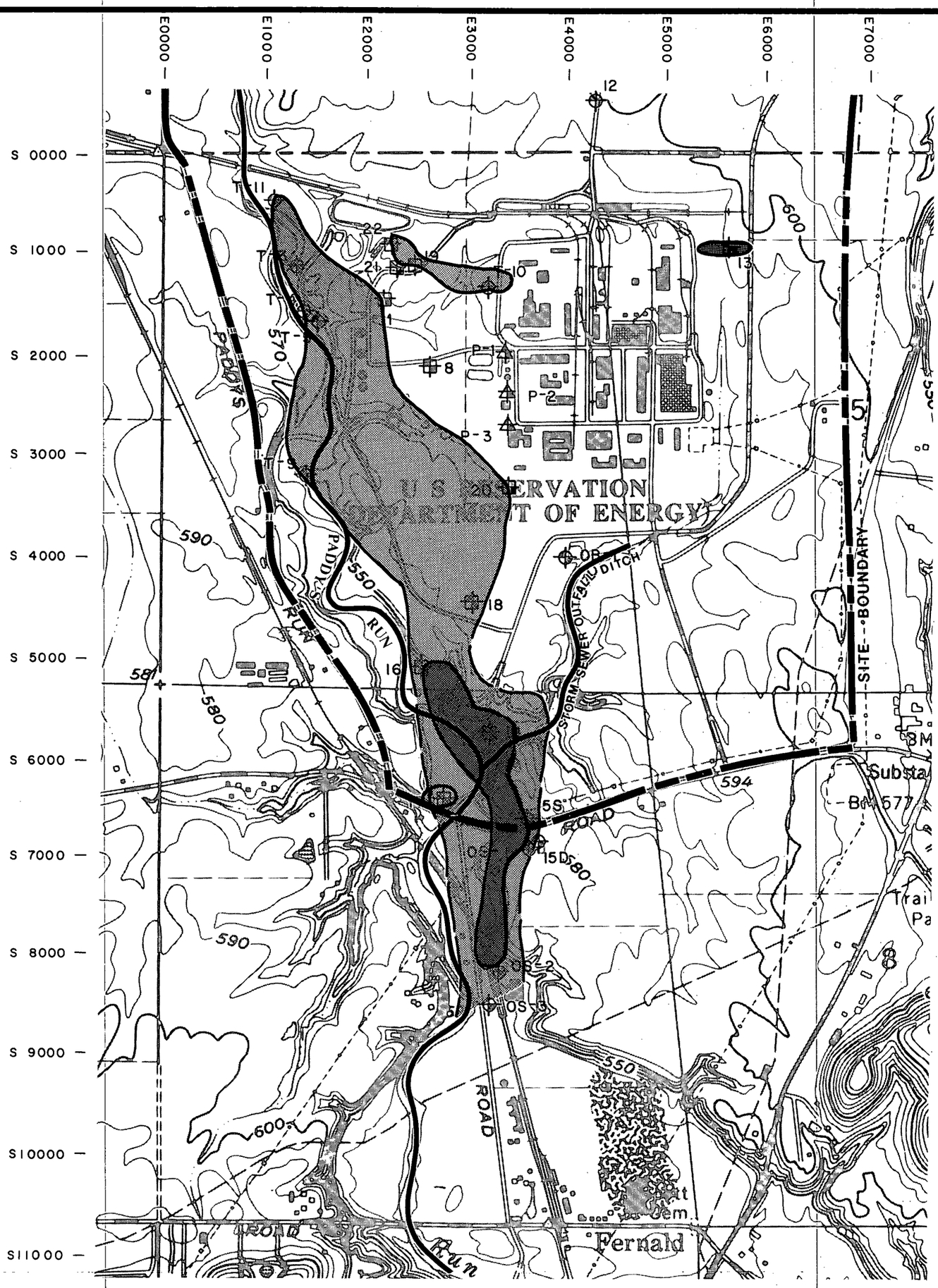
GENERALIZED SURFACE WATER FLOW PATTERNS
WASTE PIT STORAGE AREA

REFERENCE: BASE MAP TAKEN FROM U.S.G.S. 7.5' TOPOGRAPHIC MAP, SHANDON, OHIO (1981) QUADRANGLE

THE SURFACE WATER FLOW PATTERNS SHOWN REPRESENT AN EVALUATION OF THE MOST PROBABLE CONDITIONS BASED UPON PRESENTLY AVAILABLE DATA. VARIATIONS FROM THESE CONDITIONS MAY OCCUR.

DAMES & MOORE

FIGURE 4-3



EXPLANATION:

0 1000 2000 3000 FEET
SCALE

URANIUM CONCENTRATION BETWEEN 0.001 - 0.009 mg/l

URANIUM CONCENTRATION BETWEEN 0.010 - 0.350 mg/l

SINGLE WELL LOCATION

CLUSTER WELL LOCATION

PRODUCTION WELL LOCATION

NOTE: URANIUM CONCENTRATIONS IN NON SHADED AREAS ARE AT OR BELOW BACKGROUND LEVEL OF 0.0008 mg/l

REFERENCE: BASE MAP TAKEN FROM U.S.G.S. 7.5' TOPOGRAPHIC MAP, SHANDON, OHIO (1981) QUADRANGLE

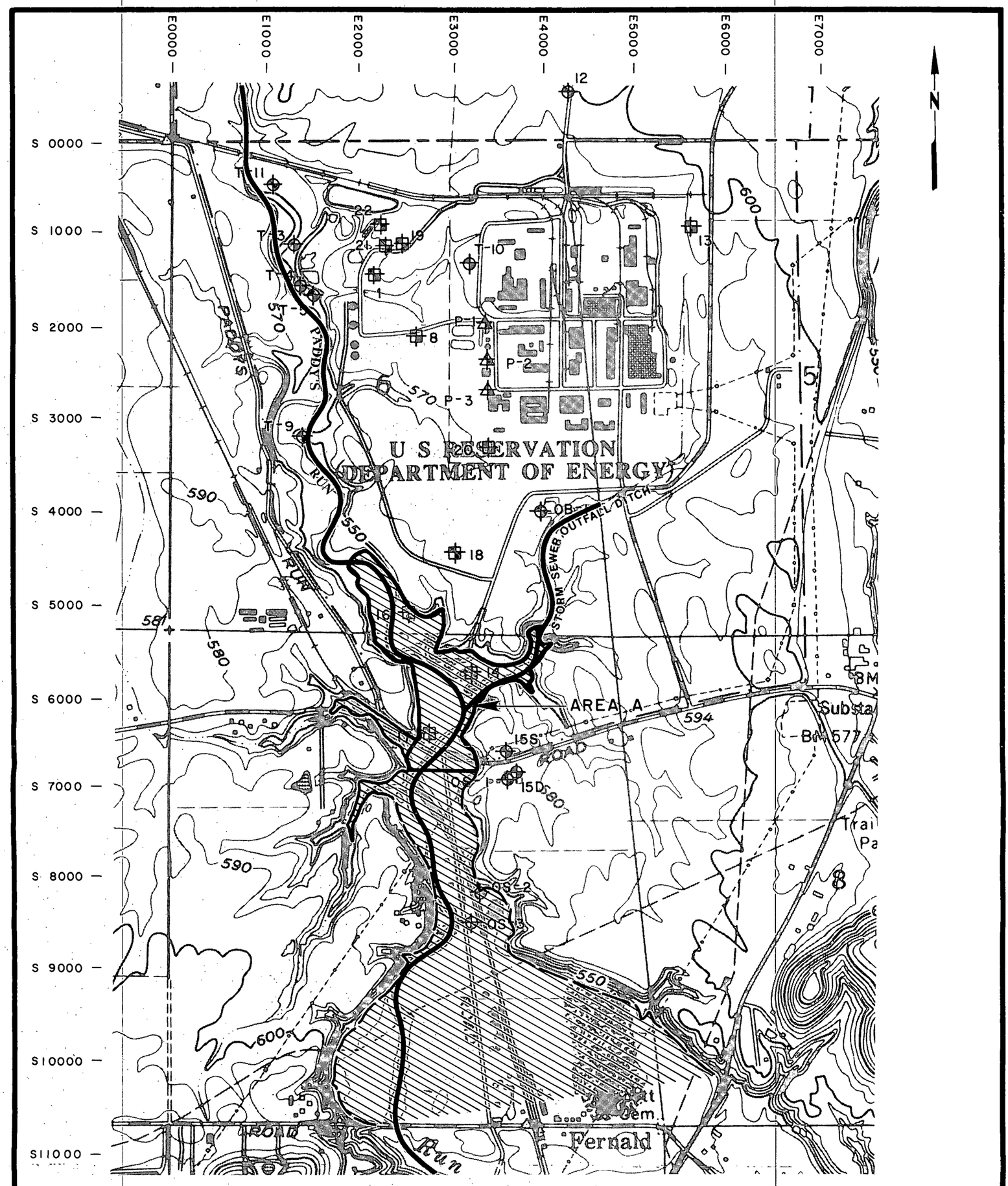
THE EXTENT OF CONCENTRATIONS SHOWN REPRESENT AN EVALUATION OF THE MOST PROBABLE CONDITIONS BASED UPON INTERPRETATION OF PRESENTLY AVAILABLE DATA. VARIATIONS FROM THESE CONDITIONS MAY OCCUR.

APPROXIMATE EXTENT OF ABOVE-BACKGROUND URANIUM CONCENTRATIONS

IN UPPER PORTION OF SAND AND GRAVEL AQUIFER ABOVE "BLUE CLAY" LAYER

DAMES & MOORE

FIGURE 4-4



EXPLANATION:

- UPPER SAND AQUIFER OUTCROP
- TILL OUTCROP
- INFERRED CONTACT BETWEEN UPPER SAND AND TILL
- SINGLE WELL LOCATION
- CLUSTER WELL LOCATION
- PRODUCTION WELL LOCATION

0 1000 2000 3000 FEET
SCALE

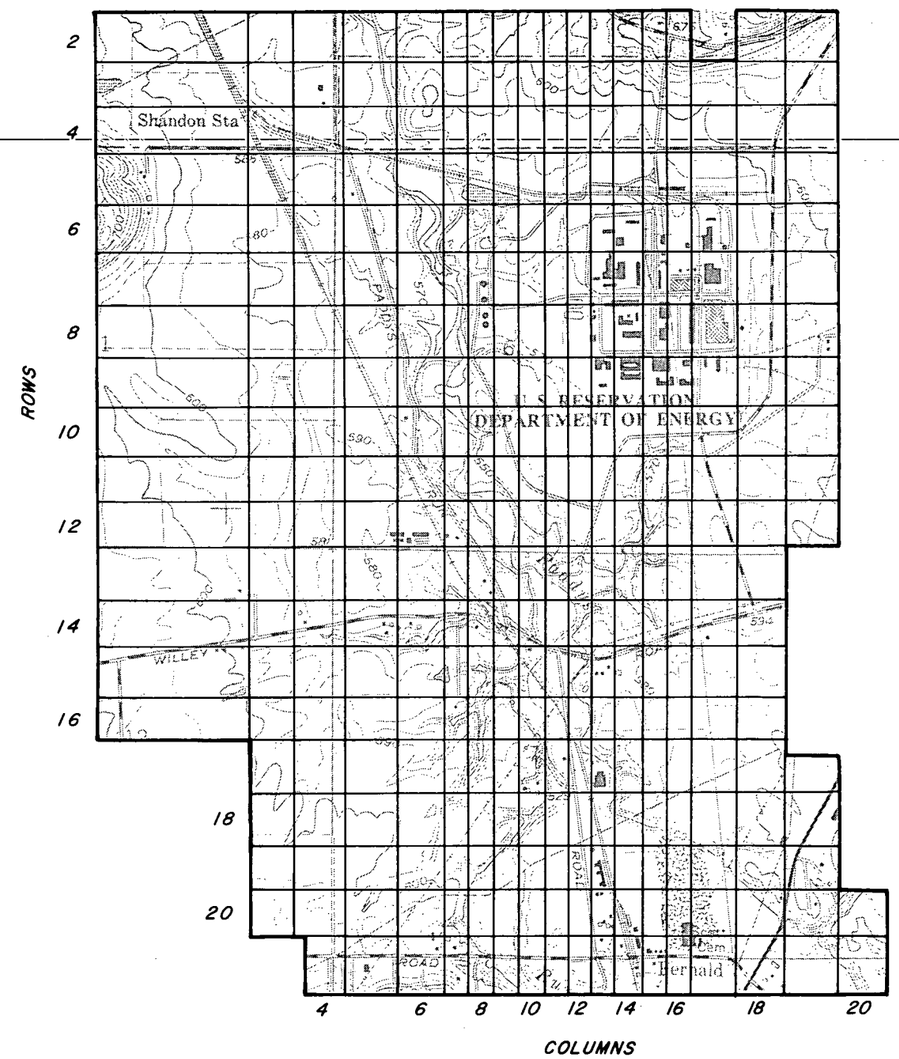
REFERENCE: BASE MAP TAKEN FROM U.S.G.S. 7.5' TOPOGRAPHIC MAP, SHANDON, OHIO (1981) QUADRANGLE

THE SURFICIAL GEOLOGY SHOWN REPRESENTS AN EVALUATION OF THE MOST PROBABLE CONDITIONS BASED UPON INTERPRETATION OF PRESENTLY AVAILABLE DATA. VARIATIONS FROM THESE CONDITIONS MAY OCCUR.

SURFICIAL GEOLOGY

DAMES & MOORE

FIGURE 4-5



N

0 2000 4000 FEET
SCALE

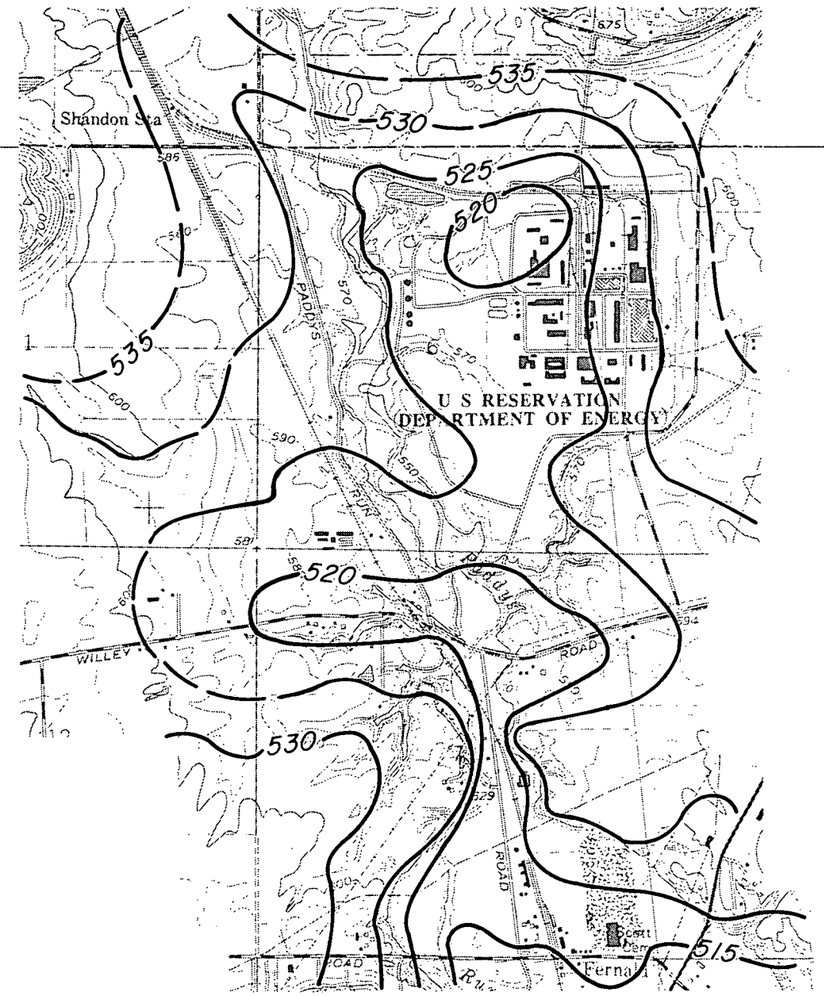
MODELED AREA

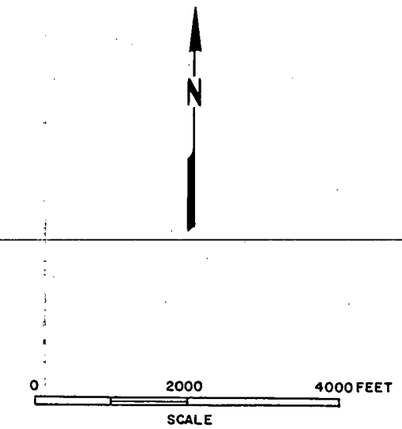
FMPC, FERNALD, OHIO

REFERENCE: BASE MAP TAKEN FROM U.S.G.S. 7.5' TOPOGRAPHIC MAP, SHANDON, OHIO (1981) QUADRANGLE

DAMES & MOORE

FIGURE 5-1





EXPLANATION:

— 525 — WATER LEVEL CONTOUR IN FEET
DASHED WHERE INFERRED
(NATIONAL GEODETIC VERTICAL DATUM OF 1929)

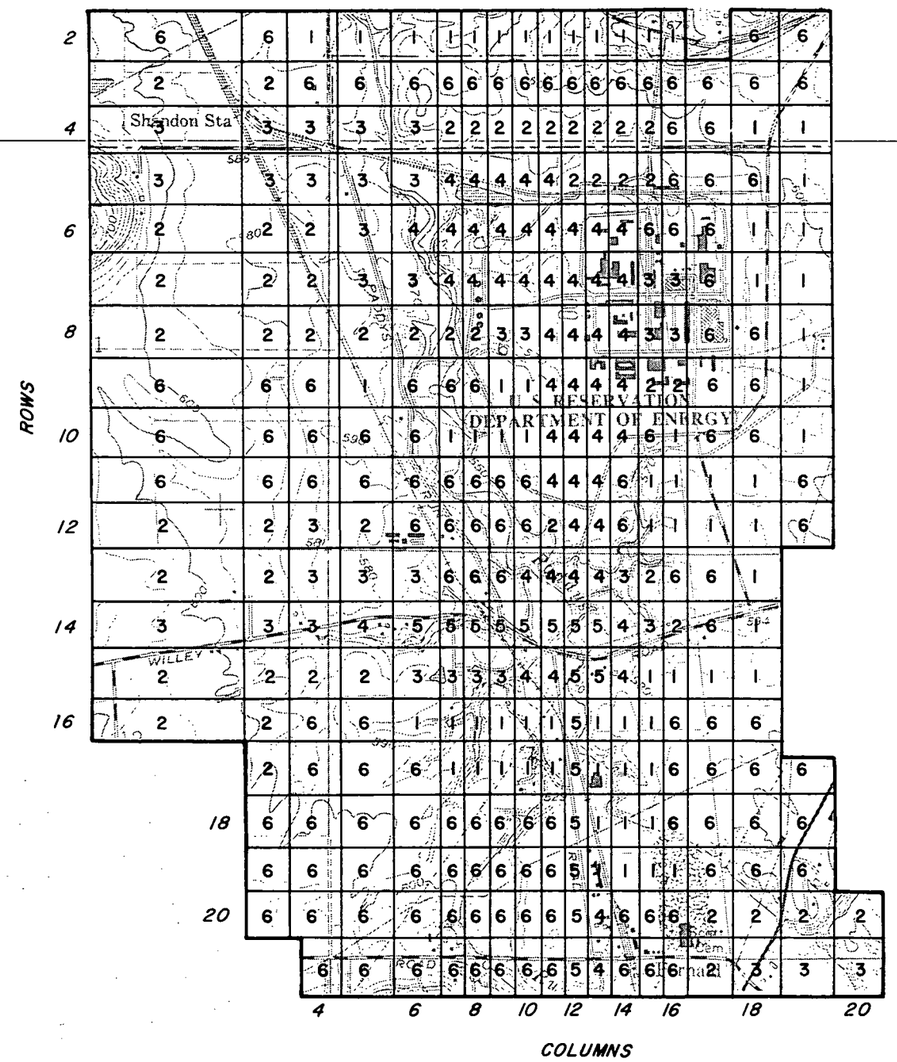
U.S.G.S. POTENTIOMETRIC SURFACE MAP

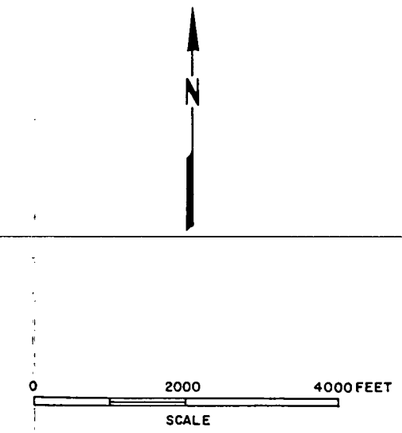
REFERENCE: BASE MAP TAKEN FROM U.S.G.S. 7.5' TOPOGRAPHIC MAP, SHANDON, OHIO (1981) QUADRANGLE

ADAPTED FROM REFERENCE 3

DAMES & MOORE

FIGURE 5-2





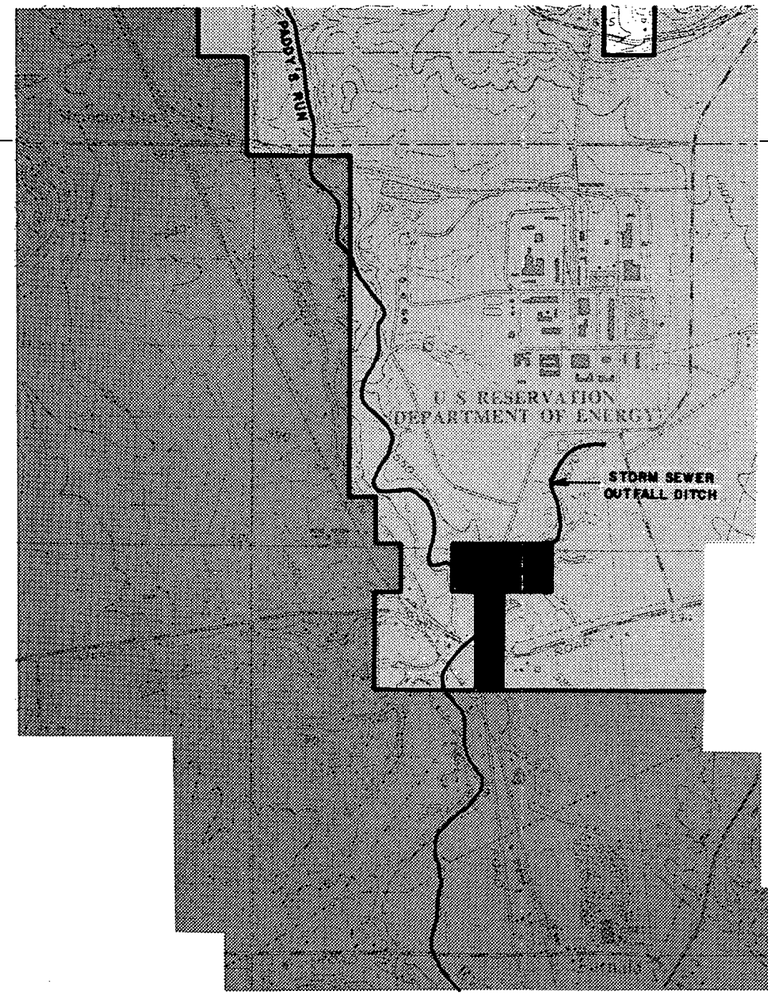
REFERENCE: BASE MAP TAKEN FROM U.S.G.S. 7.5' TOPOGRAPHIC MAP, SHANDON, OHIO (1981) QUADRANGLE

MATERIAL PROPERTIES

(DATA USED FOR TARGET MODEL)

DAMES & MOORE

FIGURE 5-3



N

0 2000 4000 FEET
SCALE

EXPLANATION:

RECHARGE RATE

0.44 in./yr.

1.05 in./yr.

2.10 in./yr.

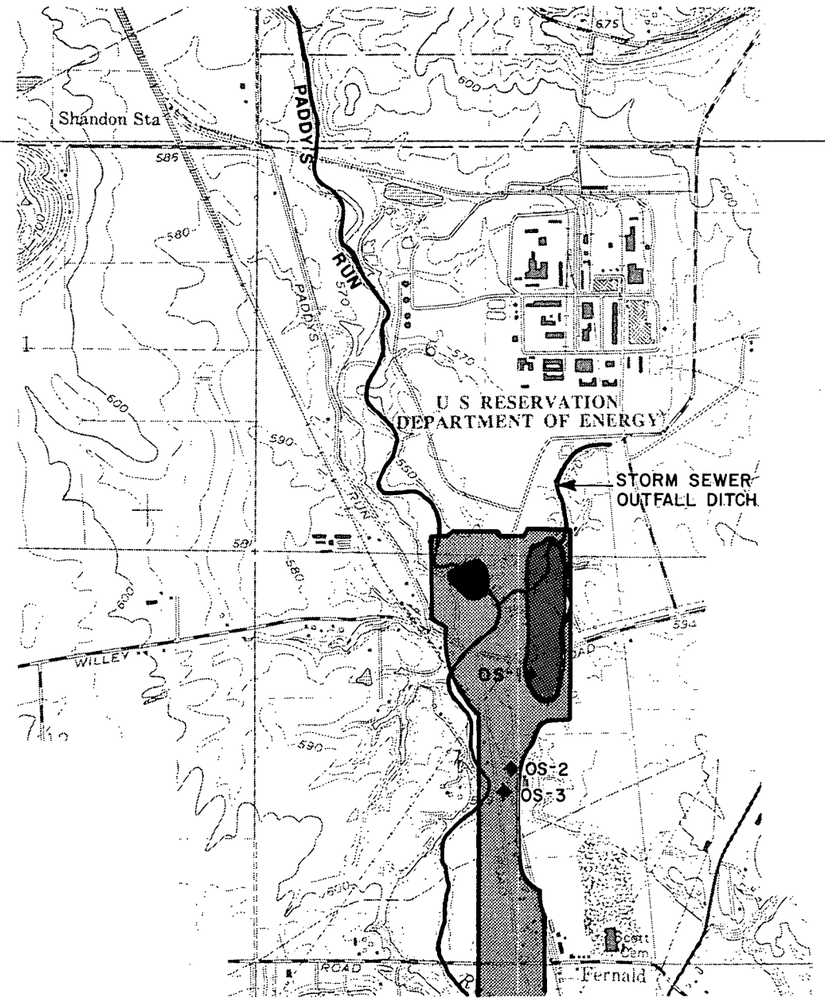
REFERENCE: BASE MAP TAKEN FROM U.S.G.S. 7.5' TOPOGRAPHIC MAP, SHANDON, OHIO (1981) QUADRANGLE

RECHARGE AREAS - BOUNDARY PLOT

(DERIVED FROM TARGET MODEL)

DAMES & MOORE

FIGURE 5-4



N

0 2000 4000 FEET
SCALE

EXPLANATION:

AREAS WITH HIGHEST URANIUM CONCENTRATIONS

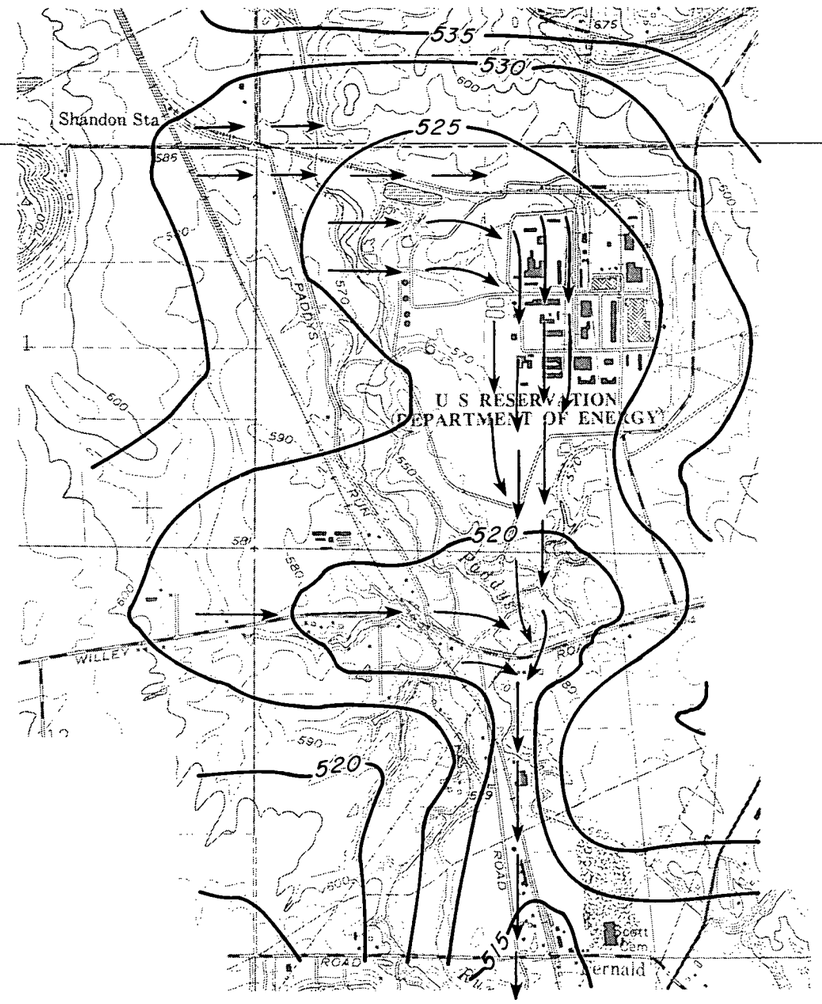
EXTENT OF URANIUM PLUME, NO ATTENUATION

RELATIVE CONCENTRATION OF URANIUM
(DERIVED FROM TARGET MODEL)

REFERENCE: BASE MAP TAKEN FROM U.S.G.S. 7.5' TOPOGRAPHIC MAP, SHANDON, OHIO (1981) QUADRANGLE

DAMES & MOORE

FIGURE 5-5



N

0 2000 4000 FEET
SCALE

EXPLANATION:

525 WATER LEVEL CONTOUR IN FEET

FLOW DIRECTION

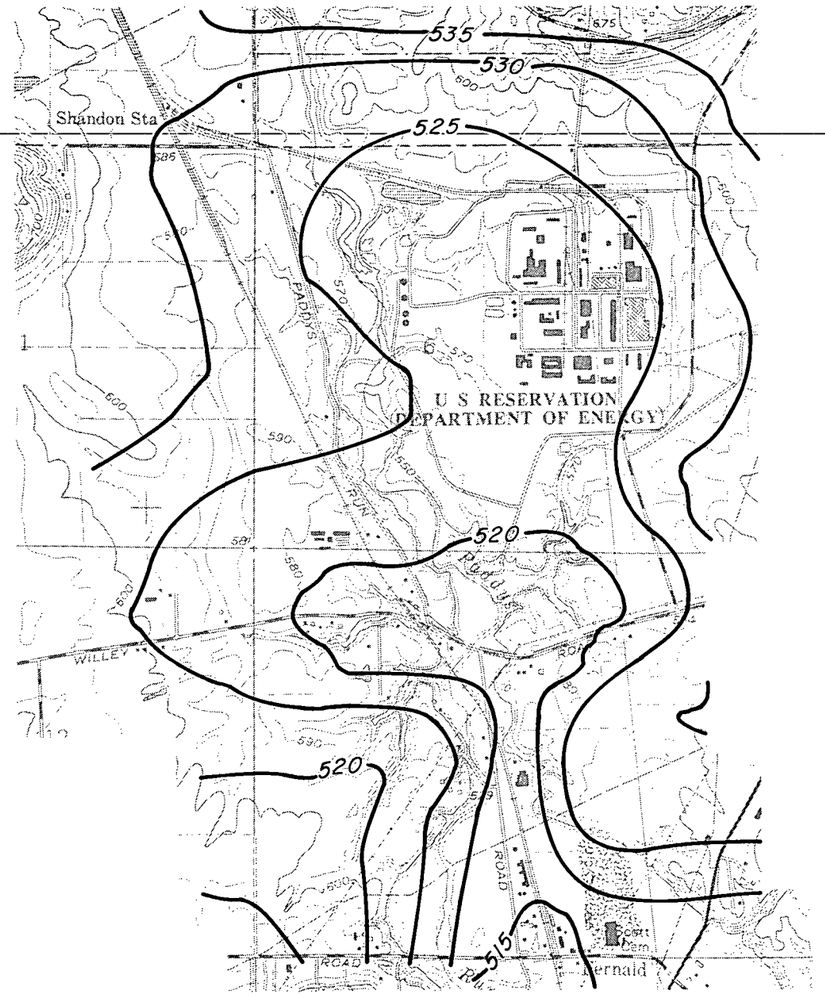
GROUNDWATER FLOW DIRECTIONS

(DERIVED FROM TARGET MODEL)

REFERENCE: BASE MAP TAKEN FROM U.S.G.S. 7.5' TOPOGRAPHIC MAP, SHANDON, OHIO (1981) QUADRANGLE

DAMES & MOORE

FIGURE 5-6



N

0 2000 4000 FEET
SCALE

EXPLANATION:

525 WATER LEVEL CONTOUR IN FEET

POTENTIOMETRIC SURFACE MAP

(DERIVED FROM TARGET MODEL)

REFERENCE: BASE MAP TAKEN FROM U.S.G.S. 7.5' TOPOGRAPHIC MAP, SHANDON, OHIO (1981) QUADRANGLE

DAMES & MOORE

FIGURE 5-7

REFERENCES CITED

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2) U.S. Public Health Service, 1970, Community Water Supply Study: National Survey Findings, U.S. Department of Health, Education, and Welfare, Washington, D.C., as cited in Doull, John; Klaasen, Curtis D.; Andur, Mary O., 1980, Toxicology, Macmillan Publishing Company, New York.

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10) Dove, George D., Norris, Stanley E., 1951, Conditions Governing the Occurrence of Groundwater in the Fernald Area, Ohio with Reference to the Possibilities of Contamination by Disposal of Chemical Wastes, U.S. Geological Survey-Ground Water Branch.

11) Spieker, A.M., 1968, Groundwater Hydrology and Geology of the Lower Great Miami River Valley, Ohio, U.S. Geological Survey, Professional Paper 605-A.

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13) Goddard, E.N., Trask, Parker D., DeFord, Ronald K., Olaf, N. Rove, Singewald, Joseph T., Overbeck, R.M., 1975, Rock Color Chart, Distributed by The Geological Society of America.

14) Spieker, A.M., Norris, Stanley E., 1962, Groundwater Movement and Contamination at the AEC Feed Materials Production Center Located Near Fernald, Ohio, A Report Prepared by the U.S. Geological Survey for the U.S. Atomic Energy Commission, Dated September, 1962.

15) Hem, John D., 1970, Study and Interpretation of the Chemical Characteristics of Natural Water, U.S. Geological Survey Water-Supply Paper 1473.

16) Personal Communication, 1985, NLO Health Safety & Environmental Division Staff.

17) Remington, R.D. and M. Schork, 1982, Statistics with Applications to the Biological and Health Sciences, Prentice-Hall, Inc., N.J.

18) U.S. Department of Interior, 1981, Groundwater Manual, United States Government Printing Office, Washington, D.C.

GLOSSARY

AQUITARD: A confining bed that retards but does not prevent the flow of the water to or from an adjacent aquifer.

ATTENUATION: A reduction or lessening in concentration.

BACKGROUND: Ambient or naturally present.

CLEARWELL: Receiving basin for Pit 5 supernatant and runoff from the Waste Pit Storage Area.

CLOSED PIT AREA: The northwest corner of the Waste Pit Storage Area which includes pits 1, 2, 3 and the Burn Pit, which are not operating.

CONE OF INFLUENCE: A cone-shaped depression in the potentiometric surface of a body of groundwater that has the shape of an inverted cone and develops around a well from which water is being withdrawn

CONFINING BED: A body of relatively low permeability material stratigraphically adjacent to one or more aquifers. In nature, however, its hydraulic conductivity may range from nearly zero to some value distinctly lower than that of the aquifer.

DESICCATION INDUCED FRACTURING: Cracks in sediment produced by drying.

EFFECTIVE POROSITY: The amount of interconnected pore space available for fluid transmission.

ft/day (feet per day): A measure of hydraulic conductivity. Reduced from the volumetric units of $ft^3/ft^2/day$.

ft/ft (feet per foot): A measure of hydraulic gradient.

gpd/ft (gallons per day per foot): A measure of transmissivity.

gpd/ft.^{2} (gallons per day per square foot): A measure hydraulic conductivity.

gpm (gallons per minute): A measure of flow rate.

GLACIAL OUTWASH: Stratified detritus (chiefly sand and gravel) removed or "washed out" from a glacier by meltwater streams and deposited in front of or beyond the end of the margin of an active glacier.

GLACIAL TILL: Dominantly unsorted and unstratified material, generally unconsolidated, deposited directly by and underneath a glacier without subsequent reworking by meltwater and consisting of a heterogeneous mixture of clay, silt, sand and gravel and boulders ranging in size and shape.

HEAD: The height above a standard datum (for this Report, Mean Sea Level) of the surface of a column of water.

HYDRAULIC CONDUCTIVITY: (Permeability Coefficient) If a porous medium is isotropic and the fluid is homogeneous, the hydraulic conductivity of the medium is the volume of water at the existing kinematic viscosity that will move in unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of that movement.

HYDRAULIC GRADIENT: The change in hydraulic head (level) per unit of distance in the direction perpendicular to hydraulic head contour lines.

LEACHABLE: Able to be dissolved and washed out by a percolating liquid.

mg/L (milligrams per liter - often used interchangeably with parts per million (ppm)): A method of expressing concentrations. The number of grams

of solute per million grams of solution. One part per million is approximately equal to one teaspoon of sugar in 10,420 eight ounce cups of coffee.

MPC (MAXIMUM PERMISSIBLE CONCENTRATION): The concentration of a radioactive substance which, when ingested or inhaled for an extended period of time will give the maximum allowable dose to an individual.

MSL (MEAN SEA LEVEL): Sea level or sea level datum - as a standard datum for heights or elevation, based on tidal observation over many years at various tide stations along the coast.

NON-NORMAL DISTRIBUTION: A set of variable data which is not distributed symetrically about the mean.

OUTCROP: That part of a geologic formation or structure that appears at the surface of the earth.

POROSITY: The percentage of the bulk volume of a rock or soil that is occupied by interstices (openings), whether isolated or connected.

POTENTIOMETRIC SURFACE: An imaginary surface representing the total head of groundwater and defined by the level to which water with the same density and viscosity will rise in a well (e.g. the water table).

RECHARGE: The process involved in the absorption and addition of water to the zone of saturation.

REMEDIATE: The process of relieving, curing, or correcting an environmental concern.

SEEP: An area, generally small, where water percolates slowly to the land surface.=

STATISTICALLY SIGNIFICANT: Numerical data having or expressing a mathematically demonstrable difference from other numerical data.

STEADY STATE: In equilibrium, a stable, balanced, or unchanging system.

TERRACE: Any long, narrow, relatively level or gently inclined surface, generally less broad than a plain, bounded along one edge by a steeper descending slope and along the other by a steeper ascending slope.

TRANSMISSIVITY: The rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of a confined aquifer under a unit hydraulic gradient.

UNCONFORMABLY: Not succeeding the underlying rocks in immediate order of age. A break in the geologic record.

UNCONTROLLED AREA: An area of unlimited public access.

UNCONTROLLED PADS: A pad on which material is stored and runoff from it is not collected as part of the surface water recovery system.

URANIUM (NATURAL): A combination of U-238, U-235 and U-234, by mass U-238 = 99.27%, U-235 = 0.72 % AND U-234 = 0.006%.

APPENDIX 1

HYDROLOGIC TEST DATA

A1.1 EXPLANATION OF HYDRAULIC TEST ANALYSIS.

Dames & Moore's testing of selected monitoring wells was conducted to:

- Confirm already well established hydraulic charactertistics of the sand and gravel aquifer;

- Gather data on the saturated portions of the glacial till, and;

- Evaluate these data as they are related to source identification.

Testing of these wells consists of pumping the well at a constant rate until steady state conditions were reached. Pumping is then stopped and the water level is measured as it rises (recovers) in the well. Data are subsequently analyzed in accordance with the assumptions and calculations inherent in the recovery analysis method as described in Reference 18.

Wells screened in the sand and gravel aquifer had yields too high to allow for short term testing. Therefore, laboratory tests for hydraulic conductivity were performed on representative sediment samples from this aquifer. Results of this testing are provided in Appendix 2.

A1.2 MONITOR WELL RECOVERY TEST ANALYSIS

A1.2.1 Recovery Test for MW #12

STATIC WATER LEVEL = 31.96 ft
PUMPING RATE (Q) = 6 gpm (0.80 ft^3/min)

DATE	TIME	t (min)	t' (min)	t/t'	DEPTH TO WATER (ft) s	RESIDUAL DRAWDOWN s' (ft)	REMARKS
1-15	0900	16.00	0	0.0	54.33	22.37	Pump-off
		16.42	0.42	39.10	51.33	19.37	
		17.33	1.33	13.03	43.50	11.54	
		18.00	2.00	9.00	42.25	10.29	
		20.00	4.00	5.00	40.08	8.12	
		21.50	5.50	3.91	36.96	5.00	
		23.00	7.00	3.29	36.37	4.41	
		25.00	9.00	2.78	34.00	2.04	

Data plotted on Figure A1-1
$\Delta s' = 1.4$ ft.

$$\text{Transmissivity} = \frac{2.303Q}{4\pi\Delta s'}$$

$$= \frac{(2.303)(0.80\ ft^3/min)}{(12.56)(1.4\ ft)}$$

$$= 150\ ft^2/day \text{ or } 1130\ gal/day/ft$$

$$\text{Hydraulic Conductivity} = \frac{150\ ft^2/day}{60\ ft.}$$

$$= 2.5\ ft/day$$

A1.2.2 Recovery Test for MW-19TP

STATIC WATER LEVEL = 5.73 ft
PUMPING RATE (Q) = 3 gpm (0.41 ft^3/min)

DATE	TIME	t (min)	t' (min)	t/t'	DEPTH TO WATER (ft) s	RESIDUAL DRAWDOWN s' (ft)	REMARKS
3-3	1035	20.00	0	0.00	11.00	5.27	Pump-off
		23.00	3.00	7.7	10.33	4.60	
		25.00	5.00	5.0	9.73	4.00	
		27.00	7.00	3.9	9.56	3.83	
		30.00	10.00	3.0	9.35	3.62	
		35.00	15.00	2.3	9.00	3.27	
		40.00	20.00	2.0	8.73	3.00	

Data plotted on Figure A1-1
$\Delta s'$ = 3.95 ft

$$\text{Transmissivity} = \frac{(2.303)(Q)}{4\pi\Delta s'}$$

$$= \frac{(2.303)(0.41\ ft^3/min)}{(12.56)(3.95\ ft)}$$

$$= 30\ ft^2/day \text{ or } 220\ gal/day/ft$$

$$\text{Hydraulic Conductivity} = \frac{30\ ft^2/day}{15\ ft.}$$

$$= 2\ ft/day$$

A1.2.3 Recovery Test for MW-20 TP

STATIC WATER LEVEL = 3.63 ft
PUMPING RATE (Q)= 4 gpm (0.55 ft^3/min)

DATE	TIME	t (min)	t' (min)	t/t'	DEPTH TO WATER (ft) s	RESIDUAL DRAWDOWN s' (ft)	REMARKS
3-3	1720	25.00	0	0.00	10.00	6.37	Pump-off
		26.50	1.50	17.67	9.67	6.04	
		26.75	1.75	15.29	9.56	5.93	
		27.00	2.00	13.50	9.50	5.87	
		27.25	2.25	12.11	9.46	5.83	
		27.50	2.50	11.0	9.40	5.77	
		28.00	3.00	9.33	9.31	5.68	
		29.00	4.00	7.25	9.00	5.37	
		30.00	5.00	6.00	8.71	5.08	
		35.00	10.00	3.50	7.83	4.20	

Data plotted on Figure A1-1
$\Delta s' = 6.65$ ft

$$\text{Transmissivity} = \frac{(2.303)(Q)}{4\pi\Delta s'}$$

$$= \frac{(2.303)(0.55\ ft^3/min)}{(12.56)(6.65\ ft)}$$

$$= 20\ ft^2/day \quad \text{or } 160\ gal/day/ft$$

$$\text{Hydraulic Conductivity} = \frac{20\ ft^2/day}{15\ ft}$$

$$= 1.3\ ft/day$$

A1.2.4 Recovery Test for MW - 21 TP

STATIC WATER LEVEL = 4.33 ft
PUMPING RATE (Q) = 4 gpm (0.55 ft^3/min)

DATE	TIME	t (min)	t' (min)	t/t'	DEPTH TO WATER (ft) s	RESIDUAL DRAWDOWN s' (ft)	Remarks
3-4	1230	18.00	0	0.0	7.00	2.67	Pump-off
		19.50	1.5	13.0	6.88	2.55	
		21.00	3.0	7.0	6.79	2.46	
		30.00	12.0	2.5	6.77	2.44	
		33.00	15.0	2.2	6.71	2.38	
		38.00	20.0	1.9	6.69	2.36	

Data plotted on Figure A1-1
$\Delta s'$ = 40.91 ft.

$$\text{Transmissivity} = \frac{2.303\,(Q)}{4\pi\Delta s'}$$

$$= \frac{(2.303)\,(0.55\ ft^3/min)}{(12.56)(40.91\ ft)}$$

$$= 3.5\ ft^2/day \quad \text{or} \quad 30\ gal/day/ft$$

$$\text{Hydraulic Conductivity} = \frac{3.5\ ft^2/day}{15\ Ft.}$$

$$= 0.2\ ft/day$$

A1.3 Calculation of Hydraulic Gradients

$$i = \frac{h1-h2}{L}$$

Where:

i = hydraulic gradient (ft/ft)

h1,h2 = head difference (ft)

L = distance between equipotential lines (ft)

Line A-A' (see Figure A1-2)

$$\frac{520-515}{4920} = 0.001 \text{ ft/ft}$$

Line B-B'

$$\frac{530-525}{1850} = 0.003 \text{ ft/ft}$$

Line C-C'

$$\frac{535-525}{1860} = 0.005 \text{ ft/ft}$$

A1.4 Estimate of Groundwater Travel Times

$$V = \frac{Ki}{n}$$

Where:

V = Groundwater Flow Velocity
K = Hydraulic Conductivity (ft/day)
i = Hydraulic Gradient (ft/ft)
n = Effective Porosity (%)

Case 1 - Minimum (fastest) estimated groundwater travel time from recharge area (Area A - Figure 4-5) to the offsite wells

(a) Approximate distance from recharge area to:
OS-1 = 800 ft
OS-2 = 1500 ft
OS-3 = 2200 ft

(b) Steepest hydraulic gradient = 0.005 ft/ft

(c) Highest hydraulic conductivity = 370 ft/day

(d) Lowest estimated effective porosity = 20 %

(e) Flow Velocity (v) = $\frac{(370\ ft/day)(0.005\ ft/ft)}{0.20}$

= 9.25 ft/day

(f) Estimated time to reach offsite wells

OS-1: $\frac{800\ ft}{9.25\ ft/day}$ = 90 days (0.25 years)

OS-2: $\frac{1500 \text{ ft}}{9.25 \text{ ft/day}}$ = 160 days (0.40 years)

OS-3: $\frac{2200 \text{ ft}}{9.25 \text{ ft/day}}$ = 240 days (0.70 years)

Case 2 - Maximium (slowest) estimated groundwater travel time from recharge area (Area A - Figure 4-5) to the offsite wells

(a) Approximate distance from recharge area to:
OS-1 = 800 ft
OS-2 = 1500 ft
OS-3 = 2200 ft

(b) Shallowest hydraulic gradient = 0.001 ft/ft

(c) Lowest hydraulic conductivity = 270 ft/day

(d) Highest estimated effective porosity = 25 %

(e) Flow velocity (v) = $\frac{(270 \text{ ft/day})(0.001 \text{ ft/ft})}{0.25}$

= 1.1 ft/day

(f) Estimated time to reach wells:

OS-1: $\frac{800 \text{ ft}}{1.1 \text{ ft/day}}$ = 730 days (2.0 years)

OS-2: $\frac{1500 \text{ ft}}{1.1 \text{ ft/day}}$ = 1360 days (3.7 years)

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OS-3: $\frac{2200 \text{ ft}}{14.1 \text{ ft/day}}$ = 2000 days (5.5 years)

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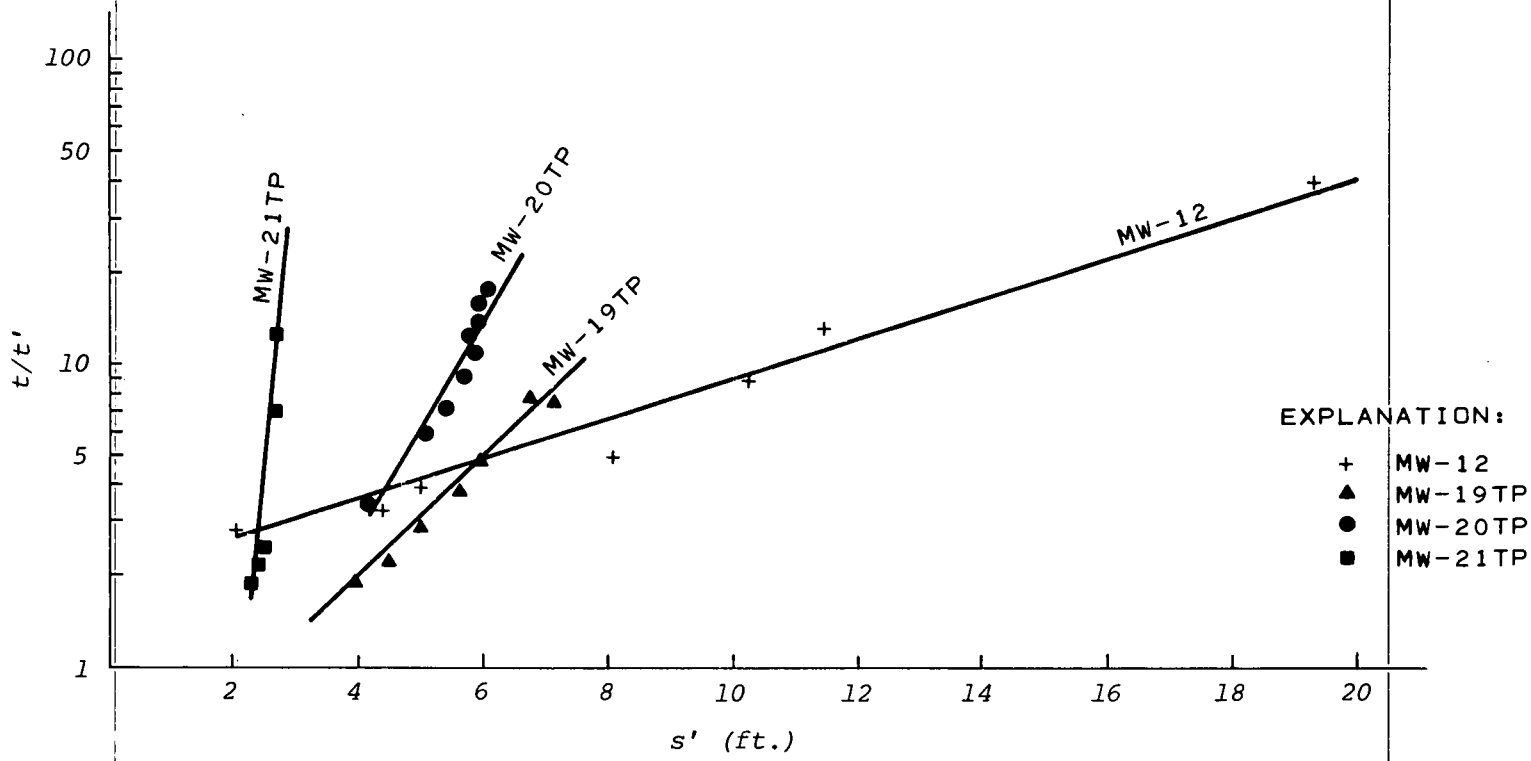
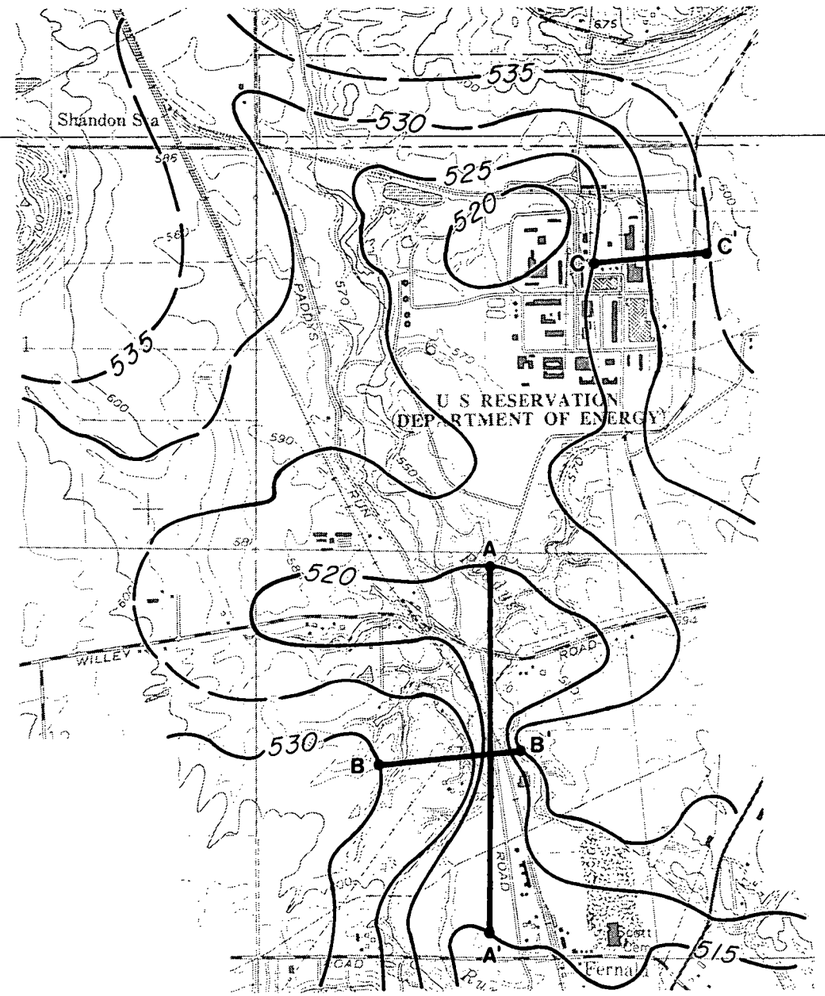


PLOT OF RECOVERY TEST DATA

DAMES & MOORE

FIGURE A1-1



N

0 2000 4000 FEET
SCALE

EXPLANATION:

—525— WATER LEVEL CONTOUR IN FEET
DASHED WHERE INFERRED
(NATIONAL GEODETIC VERTICAL DATUM OF 1929)

HYDRAULIC GRADIENT LINE LOCATION MAP

REFERENCE: BASE MAP TAKEN FROM U.S.G.S. 7.5' TOPOGRAPHIC MAP, SHANDON, OHIO (1981) QUADRANGLE

ADAPTED FROM REFERENCE 3

DAMES & MOORE

FIGURE A1-2

APPENDIX 2

SEDIMENT TEST DATA

SUMMARY OF TEST DATA

Boring #	Sample #	Depth (ft.)	TEST: Grain Size	TEST: Hydrometer	TEST: Hydraulic Conductivity	TEST: Specific Gravity	RESULTS: Grain Size	RESULTS: Hydraulic Conductivity (cm/sec)	RESULTS: Specific Gravity
13s	1-2	36	X	---	X	---	SW-SC	1.50E-7	---
	NLO-15	80	---	---	X	---	---	1.05E-3	---
	NLO-16	80	---	---	X	---	---	1.96E-3	---
13d	10	55	---	---	X	---	---	2.57E-3	---
	19								
	NLO-19-20	80	X	---	X	---	GP	2.58E-3	---
14s	2	22	X	---	X	---	SP	5.15E-3	---
14d	11	55	X	---	X	---	GP	4.79E-3	---
15s	S-11	32	X	---	X	---	SP	8.41E-4	---
	NLO-18	35	---	---	X	---	---	3.70E-2	---
	NLO-17	80	---	---	X	---	---	6.78E-3	---
15d	S-14	55	X	---	X	---	GP	4.02E-3	---
16d	NLO-2	35	X	---	---	---	SP	---	---
16s	NLO-1	35	---	---	X	---	---	3.33E-3	---

SUMMARY OF TEST DATA (Cont'd)

Boring #	Sample #	Depth (ft.)	TEST: Grain Size	TEST: Hydrometer	TEST: Hydraulic Conductivity	TEST: Specific Gravity	RESULTS: Grain Size	RESULTS: Hydraulic Conductivity (cm/sec)	RESULTS: Specific Gravity
17s	NLO-13	35	X	---	---	---	GW	---	---
	NLO-14	80	---	---	X	---	---	6.10E-2	
18s	NLO-5-6	55	X	---	X	---	SW	1.10E-2	---
18d	NLO-3	120	X	X	---	X	CL	---	2.76
19d	NLO-21	20	X	X	---	X	CL	---	2.81
20s	NLO-8	5	X	X	---	X	ML	---	2.79
20d	NLO-7	5	---	---	X	---	---	5.7E-4	---
	NLO-9	119	X	X	---	X	CL		2.79
	NLO-11	20	X	---	---	---	SW	---	---
22s	NLO-23	10	X	X	---	X	CL	---	2.79
	NLO-25	15	X	X	---	X	CL	---	2.71
	NLO-27	20	X	X	---	X	CL	---	2.73

X : Test performed

---: Test not performed

DAMES & MOORE
SIEVE ANALYSIS

Job No. 10805-161
Owner NLO
Location FERNALD
Date 10-15-84
By JDJ

dry

Boring No. 15-d Sample No. S-14 Depth 55'

Sieve No.	Wt. Grams	Percent Retained	Cumulative Percent passing
Pan	653.49	100	0
200	651.87	99.75	.25
100	651.35	99.67	.33
60	650.77	99.58	.42
40	650.05	99.47	.53
20	649.39	99.37	.63
10	647.88	99.14	.86
4	637.00	97.48	2.52
3/8	597.35	91.41	8.59
1/2	503.83	77.10	22.90
3/4	196.38	30.05	69.95
1	76.68	11.73	88.27
1.5	0	0	100.00

$\frac{D_{60}}{D_{10}} = \frac{17}{10} = 1.7$

$\frac{D_{30}^2}{17 \times 10} = \frac{(14)^2}{17 \times 10} = 1.15$

washed

Boring No. 13-5 Sample No. 1 Depth 36'

Sieve No.	Wt. Grams	Percent Retained	Cumulative Percent passing
Pan	300.81	100	0
200	268.87	89.38	10.62
100	258.07	85.79	14.21
60	226.03	75.14	24.86
40	182.93	60.81	39.19
20	128.59	42.75	57.25
10	70.02	23.28	76.72
4	24.46	8.13	91.87
3/8	7.48	2.49	97.51
1/2	5.64	1.87	98.13
3/4	0	0	100.00

$\frac{D_{60}}{D_{10}} = \frac{.95}{.08} = 11.9$

$\frac{D_{30}^2}{D_{60} \times D_{10}} = \frac{(.32)^2}{.95 \times .08} = 1.35$

SW-SC

dry

Boring No. 14-5 Sample No. 2 Depth 22'

Sieve No.	Wt. Grams	Percent Retained	Cumulative Percent passing
Pan	413.88	100	0
200	400.55	96.78	3.22
100	396.03	95.69	4.31
60	387.08	93.52	6.48
40	352.36	85.14	14.86
20	163.68	39.55	60.45
10	55.08	13.31	86.69
4	13.67	3.30	96.70
3/8	4.46	1.08	98.92
1/2	235	0.57	99.43
3/4	0	0	100.00

$\frac{D_{60}}{D_{10}} = \frac{.85}{.35} = 2.4$

$\frac{D_{30}^2}{.85 \cdot .35} = \frac{.5^2}{} = .84$

DAMES & MOORE

FALLING HEAD PERMEABILITY TEST

PROJECT: NLO PROJECT NO.: 10805-161 LOCATION: FERNALD BORING: 13S SAMPLE: 2 DEPTH: 36 FT.

SAMPLED: / / TESTED: JDT 4 23 / 84 COMPUTED: JDT 10/24/84 CHECKED: / / NOTES: remolded samples

SOIL CLASSIFICATION: SW-SC

DIAMETER OF STANDPIPE (d) 1.97 in. (19.63 cm) AREA OF STANDPIPE (a) 3.05 in.^{2} (19.63 cm^2) DIAMETER OF SAMPLE (D) 2.40 in. (6.10 cm) AREA OF SAMPLE (A) 4.54 in.^{2} (29.26 cm^2)

TEST SURCHARGE: _____ lbs/sq. ft. _____ in. of _____ SPRING GRADE OF STONE USED: medium

SATURATION DATA

DATE	TIME	ELAPSED TIME MIN.	LOAD DIAL	DEFL. DIAL	HEIGHT OF SAMPLE (L) IN.	% DEFL. OR EXPANSION
			0 =			
			=			
		after saturation =				
		after test =				

PERMEABILITY RESULTS

$$K_{20^oC} = \left(2.3 \frac{aL}{A(t_1 - t_0)} \log_{10} \frac{H_0}{H_1}\right)\left(\frac{\mu T}{\mu 20^oC}\right)$$

K_{20^oC} at min.	inches/min.	cm/sec	ft./yr
6:30 P	2.36×10^{-6}	1.00×10^{-7}	0.103
8:00 A	4.84×10^{-6}	2.05×10^{-7}	0.212

MOISTURE AND DENSITY DATA

DISH # 15	FIELD	AFTER SATURATION	AFTER TEST
Weight of sample (wet) lbs			.924
wet wt + dish (gm)			104.58
dry wt + dish (gm)			94.90
wt of moisture (gm)			9.68
wt of dish (gm)			24.14
wt of dry soil (gm)			70.76
moisture content (%)			13.68
wet density (pcf)			142.94
dry density (pcf)			125.74

PERMEABILITY DATA

DATE	TIME	ELAPSED TIME MIN.	TEMP °C (T)	HEAD AT START (H_0) ~~IN.~~ cm	HEAD AT END (H_1) ~~IN.~~ cm	ΔH
10/23	6:30 P	1530	18	48.2	48.1	0.1
10/24	8:00 A	1500	18	47.6	47.4	0.2

123

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FALLING HEAD PERMEABILITY TEST

Sample No: NLO 15 : Boring 13s

Date: May 23rd

Description:

Tested By: Nonlhi'

Diameter of Stand Pipe: ~~146.00~~ 0.7.
(cm)

Location: Drop area, 13s.

Diameter of Permeameter: 3.3.
(cm)

Depth: 80' - 82'

Sample Length: 7.2.
(cm)

Wt. of Pan & Soil (g):

Wt. of Permeameter & Soil (g): 503.3.

Wt. of Pan & Dry Soil (g):

Wt. of Permeameter (g): 392.0

Wt. of Pan:

%Wt. of Soil (g): 111.3.

Temperature (%): 18°

Elapsed Time (sec)	Head at Start (cm)	Head at End (cm)	Permeability at 20°C (cm/sec)	Permeability at 20°C (cm/sec)
49.6.	80	70	8.72×10^{-4}	9.16×10^{-4}
58.9	60	50	10.00×10^{-4}	10.50×10^{-4}
74.2	45	35	10.97×10^{-4}	11.52×10^{-4}
60.9	30	25	9.64×10^{-4}	10.12×10^{-4}

Permeability of the Soil (No.): 1.05×10^{-3} cm/sec

Initial Test Density: 111.2 pcf

Initial Moisture Content: 10.3%.

Remarks:

Harvard miniature apparatus was used as sample was not enough to run a standard permeameter test.

FALLING HEAD PERMEABILITY TEST

Sample No: NL016 · Boring 13s

Date: May 21st

Description: Gravel with sand

Tested By: Nonthi

Diameter of Stand Pipe: (cm) 1.46

Location: 13S

Diameter of Permeameter: (cm) 6.29

Depth: 80-82'

Sample Length: (cm) 7.0'

Wt. of Pan & Soil (g):

Wt. of Permeameter & Soil (g): 632.1

Wt. of Pan & Dry Soil (g):

Wt. of Permeameter (g): 285.2

Wt. of Pan:

%Wt. of Soil (g): 346.9

Temperature (%): 16°

Elapsed Time (sec)	Head at Start (cm)	Head at End (cm)	Permeability at 20°C (cm/sec)	Permeability at 20°C (cm/sec)
30.0	99.0	87.1	1.61×10^{-3}	1.75×10^{-3}
30.8	93.0	81.1	1.68×10^{-3}	1.86×10^{-3}
28.3	95.4	83.5	1.78×10^{-3}	1.97×10^{-3}
28.0	96.6	84.7	1.77×10^{-3}	1.96×10^{-3}

Permeability of the Soil (No.): 1.96×10^{-3} cm/sec

Initial Test Density: 99.5 pcf.

Initial Moisture Content:

Remarks:

DAMES & MOORE

SIEVE ANALYSIS

Job No. 10805-161
Owner NLO
Location FERNALD
Date 10-15-84
By JDJ

Boring No. 15-S Sample No. S-11 Depth 32-34'

Sieve No.	Wt. Grams	Percent Retained	Cumulative Percent passing
Pan	399.78	100	0
200	387.20	96.85	3.15
100	381.38	95.40	4.60
60	361.15	90.34	9.66
40	296.49	74.16	25.84
20	199.12	49.81	50.19
10	118.00	29.52	70.48
4	53.20	13.31	86.69
3/8	16.96	4.24	95.76
1/2	10.00	2.50	97.50
3/4	0	0	100.00

$\frac{D_{60}}{D_{10}} = \frac{1.2}{0.25} = 4.8$

$\frac{D_{30}^2}{1.2 \times .25} = \frac{.411^2}{} = .77$

Boring No. 13-d Sample No. 9 Depth 55'

Sieve No.	Wt. Grams	Percent Retained	Cumulative Percent passing
Pan	745.87	100	0
200	721.77	96.77	3.23
100	713.18	95.62	4.38
60	695.22	93.21	6.79
40	668.08	89.57	10.43
20	633.38	84.92	15.08
10	597.73	80.14	19.86
4	536.14	71.88	28.12
3/8	350.85	47.04	52.96
1/2	206.76	27.72	72.28
3/4	41.07	5.51	94.49
1	0	0	100.00

$\frac{D_{60}}{D_{10}} = \frac{11}{.4} = 27.5$

$\frac{D_{30}^2}{11 \times .4} = \frac{.25}{} = 5.68$

Boring No. _____ Sample No. _____ Depth _____

Sieve No.	Wt. Grams	Percent Retained	Cumulative Percent
Pan			
200			
100			
50			
30			
20			
16			
10			
8			

DAMES & MOORE

FALLING HEAD PERMEABILITY TEST

PROJECT: NLO PROJECT NO.: 10805-161 LOCATION: FERNALD BORING: 13d SAMPLE: 10 DEPTH: 55 FT.

SAMPLED: / / TESTED: JJ 10/17/84 COMPUTED: JJ 10/21/84 CHECKED: [illegible] 10/26/84 NOTES: remolded samples

SOIL CLASSIFICATION: GP L = 62.50 mm = 2.46 inches

DIAMETER OF STANDPIPE (d) 1.97 in. AREA OF STANDPIPE (a) 3.05 in.^{2} DIAMETER OF SAMPLE (D) 3.06 in. AREA OF SAMPLE (A) 7.35 in.^{2}

TEST SURCHARGE: _____ lbs/sq. ft. _____ in. of _____ SPRING GRADE OF STONE USED: medium

SATURATION DATA

DATE	TIME	ELAPSED TIME MIN.	LOAD DIAL	DEFL. DIAL	HEIGHT OF SAMPLE (L) IN.	% DEFL. OR EXPANSION
			0 =			
			=			
		after saturation =				
		after test =				

PERMEABILITY DATA

DATE	TIME	ELAPSED TIME MIN.	TEMP °C (T)	HEAD AT START (H_0) – IN.	HEAD AT END (H_1) – IN.	ΔH
10/17	7:56	6.0	24	49.6	33.3	16.3
10/17	8:17	6.0	24	47.8	31.6	16.2
10/17	8:39	5.0	24	44.0	32.5	11.5

PERMEABILITY RESULTS

$$K_{20°C} = \left(2.3 \frac{aL}{A(t_1 - t_0)} \log_{10} \frac{H_0}{H_1}\right)\left(\frac{\mu T}{\mu 20°C}\right)$$

$K_{20°C}$ at min.	inches/min.	cm/sec	ft./yr
7:56	6.17×10^{-2}	2.61×10^{-3}	2.70×10^{3}
8:17	6.40×10^{-2}	2.71×10^{-3}	2.80×10^{3}
8:39	5.62×10^{-2}	2.38×10^{-3}	2.46×10^{3}

MOISTURE AND DENSITY DATA

DISH # 12	FIELD	AFTER SATURATION	AFTER TEST
weight of sample (in.)			1.04
wet wt + dish (gm)			232.56
dry wt + dish (gm)			227.80
wt of moisture (gm)			4.76
wt of dish (gm)			25.31
wt of dry soil (gm)			202.49
moisture content (%)			2.35
wet density (pcf)			99.43
dry density (pcf)			98.41

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56

Job. No. 10805-161
Owner NLO
Location Fremont
Date 1-23-85
By E.S.

Dames & Moore Sieve Analysis

Boring = 13d Sample = NLO-17 Depth (ft) 80-82

Sieve #	Wt. Grams	% Retained	Cumulative % Pasing
	0	0	100.00
	32.2	7.52	92.48
	57.9	13.52	78.96
3	8.4	1.96	77.00
4	8.1	1.89	75.11
6	6.9	1.61	73.50
8	12.1	2.83	70.61
12	17.7	4.13	66.54
20	81.6	19.06	47.48
40	93.9	21.93	25.55
60	48.6	11.35	14.20
100	23.9	5.58	8.62
140	8.1	1.89	6.73
200	6.3	1.47	5.26
PAN	22.4	5.23	0.03
	Σ 428.1		

Initial Wt. 429.0

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FALLING HEAD PERMEABILITY TEST

Sample No: NLO 20 : Boring 13d

Date: May 24th

Description:

Tested By: Northi

Diameter of Stand Pipe: 1.46 (cm)

Location: 19S

Diameter of Permeameter: 6.29 (cm)

Depth: 80'-82'

Sample Length: 10.1 (cm)

Wt. of Pan & Soil (g):

Wt. of Permeameter & Soil (g): 983.5

Wt. of Pan & Dry Soil (g):

Wt. of Permeameter (g): 358.4

Wt. of Pan:

Wt. of Soil (g): 625.1

Temperature (%): 17°

Elapsed Time (sec)	Head at Start (cm)	Head at End (cm)	Permeability at 20°C (cm/sec)	Permeability at 20°C (cm/sec)
13.3	63.8	60.2	2.36×10^{-3}	2.54×10^{-3}
14.8	57.9	54.3	2.42×10^{-3}	2.61×10^{-3}
16.2	51.2	48.2	2.40×10^{-3}	2.59×10^{-3}
20.1	42.4	38.8	2.33×10^{-3}	2.56×10^{-3}

Permeability of the Soil (No.): 2.58×10^{-3} cm/sec

Initial Test Density: 124.3 pcf

Initial Moisture Content: —

Remarks:

DAMES & MOORE

SIEVE ANALYSIS

Job No. 10805-161
Owner NLO
Location FERNALD
Date 10-15-84
By JDJ

dry

Boring No. 15-d Sample No. S-14 Depth 55'

Sieve No.	Wt. Grams	Percent Retained	Cumulative Percent passing
Pan	653.49	100	0
200	651.87	99.75	.25
100	651.35	99.67	.33
60	650.77	99.58	.42
40	650.05	99.47	.53
20	649.39	99.37	.63
10	647.88	99.14	.86
4	637.00	97.48	2.52
3/8	597.35	91.41	8.59
1/2	503.83	77.10	22.90
3/4	196.38	30.05	69.95
1	76.68	11.73	88.27
1.5	0	0	100.00

$\frac{D_{60}}{D_{10}} = \frac{17}{10} = 1.7$

$\frac{D_{30}^2}{17 \times 10} = \frac{(14)^2}{17 \times 10} = 1.15$

washed

Boring No. 13-S Sample No. 1 Depth 36'

Sieve No.	Wt. Grams	Percent Retained	Cumulative Percent passing
Pan	300.81	100	0
200	268.87	89.38	10.62
100	258.07	85.79	14.21
60	226.03	75.14	24.86
40	182.93	60.81	39.19
20	128.59	42.75	57.25
10	70.02	23.28	76.72
4	24.46	8.13	91.87
3/8	7.48	2.49	97.51
1/2	5.64	1.87	98.13
3/4	0	0	100.00

$\frac{D_{60}}{D_{10}} = \frac{.95}{.08} = 11.9$

$\frac{D_{30}^2}{D_{60} \times D_{10}} = \frac{(.32)^2}{.95 \times .08} = 1.35$

SW-SC

dry

Boring No. 14-S Sample No. 2 Depth 22'

Sieve No.	Wt. Grams	Percent Retained	Cumulative Percent passing
Pan	413.88	100	0
200	400.55	96.78	3.22
100	396.03	95.69	4.31
60	387.08	93.52	6.48
40	352.36	85.14	14.86
20	163.68	39.55	60.45
10	55.08	13.31	86.69
4	13.67	3.30	96.70
3/8	4.46	1.08	98.92
1/2	2.35	0.57	99.43
3/4	0	0	100.00

$\frac{D_{60}}{D_{10}} = \frac{.85}{.35} = 2.4$

$\frac{D_{30}^2}{.85 \times .35} = \frac{.5^2}{} = .24$

DAMES & MOORE

FALLING HEAD PERMEABILITY TEST

PROJECT: NLO PROJECT NO.: 10805-161 LOCATION: FERNALD BORING: 145 SAMPLE: 1 DEPTH: 20 FT.

SAMPLED: / / TESTED: JDJ / 10/17/84 COMPUTED: JDJ 10/21/84 CHECKED: / / NOTES: remolded samples

SOIL CLASSIFICATION: SP 1 = 7.46 in.

DIAMETER OF STANDPIPE (d) 1.97 in. (5.0 cm) AREA OF STANDPIPE (a) 3.05 in.^{2} (19.63 cm^2) DIAMETER OF SAMPLE (D) 3.06 in. (7.768 cm) AREA OF SAMPLE (A) 7.35 in. (47.39 cm^2)

TEST SURCHARGE: _____ lbs/sq. ft. _____ in. of _____ SPRING GRADE OF STONE USED: medium

SATURATION DATA

DATE	TIME	ELAPSED TIME MIN.	LOAD DIAL	DEFL. DIAL	HEIGHT OF SAMPLE (L) IN.	% DEFL. OR EXPANSION
			0 =			
			=			
		after saturation =				
		after test =				

PERMEABILITY RESULTS

$$K_{20^oC} = \left(2.3 \frac{aL}{A(t_1 - t_0)} \log_{10} \frac{H_0}{H_1}\right)\left(\frac{\mu T}{\mu 20^oC}\right)$$

K_{20^oC} at min.	Inches/min.	cm/sec	ft./yr
	0.104	4.42×10^{-3}	4,573.13
	0.150	6.36×10^{-3}	6,580.35
	0.110	4.67×10^{-3}	4,831.80

MOISTURE AND DENSITY DATA

DISH # 65	FIELD	AFTER SATURATION	AFTER TEST
weight of sample (dry) lbs			1.27
wet wt + dish (gm)			196.16
dry wt + dish (gm)			180.34
wt of moisture (gm)			15.82
wt of dish (gm)			19.83
wt of dry soil (gm)			160.51
moisture content (%)			9.86 %
wet density (pcf)			121.42
dry density (pcf)			110.52

PERMEABILITY DATA

DATE	TIME	ELAPSED TIME MIN.	TEMP °C (T)	HEAD AT START (H_0) ~~IN.~~ cm	HEAD AT END (H_1) ~~IN.~~ cm	ΔH
10/17	7:53	5.0	24	55.1	31.4	23.7
10/17	8:14	3.0	24	48.3	29.7	18.6
10/17	8:35	5.0	24	50.0	27.6	22.4

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DAMES & MOORE

FALLING HEAD PERMEABILITY TEST

PROJECT: NLO PROJECT NO.: 10805-161 LOCATION: FERNALD BORING: 14d SAMPLE: 12 DEPTH: 55 FT.

SAMPLED: / / TESTED: JJ 10/17/84 COMPUTED: JJ 10/29/84 CHECKED: GH / / NOTES: remolded sample

SOIL CLASSIFICATION:

DIAMETER OF STANDPIPE (d) 1.97 in. AREA OF STANDPIPE (a) 3.05 in.^{2} DIAMETER OF SAMPLE (D) 3.06 in. AREA OF SAMPLE (A) 7.35 in.^{2}

TEST SURCHARGE: _____ lbs/sq. ft. _____ in. of _____ SPRING GRADE OF STONE USED: medium

SATURATION DATA

DATE	TIME	ELAPSED TIME MIN.	LOAD DIAL	DEFL. DIAL	HEIGHT OF SAMPLE (L) IN.	% DEFL. OR EXPANSION
			0 =			
			=			
		after saturation =				
		after test =				

PERMEABILITY DATA

DATE	TIME	ELAPSED TIME MIN.	TEMP °C (T)	HEAD AT START (H_0) – IN.	HEAD AT END (H_1) – IN.	ΔH
10/24	8:06	5.0	18	49.0	27.2	21.8
10/24	8:16	4.0	18	53.0	30.5	22.5
10/29	8:00	4.0	22	55.0	37.3	17.7
10/29	8:07	4.0	22	52.2	35.5	16.7
10/29	8:14	5.0	22	55.3	32.4	22.9

PERMEABILITY RESULTS

$$K_{20^\circ C} = \left(2.3 \frac{aL}{A(t_1 - t_0)} \log_{10} \frac{H_0}{H_1}\right)\left(\frac{\mu T}{\mu 20^\circ C}\right)$$

$K_{20^\circ C}$ at min.	inches/min.	cm/sec	ft./yr
8:06	1.26×10^{-1}	5.34×10^{-3}	5.52×10^{3}
8:16	1.48×10^{-1}	6.26×10^{-3}	6.48×10^{3}
8:00	9.43×10^{-2}	3.99×10^{-3}	4.13×10^{3}

continued

K_{20}	inches/min	cm/sec	ft/year
8:07	9.36×10^{-2}	3.96×10^{-3}	4.10×10^{3}
8:14	1.04×10^{-1}	4.40×10^{-3}	4.55×10^{3}

MOISTURE AND DENSITY DATA

DISH # 25	FIELD	AFTER SATURATION	AFTER TEST
weight of sample (in.)			1.04
wet wt + dish (gm)			204.65
dry wt + dish (gm)			199.06
wt of moisture (gm)			5.59
wt of dish (gm)			24.18
wt of dry soil (gm)			174.88
			3.20

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DAMES & MOORE

SIEVE ANALYSIS

Job No. 10805-161
Owner NLO
Location FERNALD
Date 10-15-84
By JDJ

Boring No. 15-S Sample No. S-11 Depth 32-34'

Sieve No.	Wt. Grams	Percent Retained	Cumulative Percent passing
Pan	399.78	100	0
200	387.20	96.85	3.15
100	381.38	95.40	4.60
60	361.15	90.34	9.66
40	296.49	74.16	25.84
20	199.12	49.81	50.19
10	118.00	29.52	70.48
4	53.20	13.31	86.69
3/8	16.96	4.24	95.76
1/2	10.00	2.50	97.50
3/4	0	0	100.00

$\frac{D_{60}}{D_{10}} = \frac{1.2}{0.25} = 4.8$

$\frac{D_{30}^2}{1.2 \times .25} = \frac{(.42)^2}{} = .77$

Boring No. 13-d Sample No. 9 Depth 55'

Sieve No.	Wt. Grams	Percent Retained	Cumulative Percent passing
Pan	745.87	100	0
200	721.77	96.77	3.23
100	713.18	95.62	4.38
60	695.22	93.21	6.79
40	668.08	89.57	10.43
20	633.38	84.92	15.08
10	597.73	80.14	19.86
4	536.14	71.88	28.12
3/8	350.85	47.04	52.96
1/2	206.76	27.72	72.28
3/4	41.07	5.51	94.49
1	0	0	100.00

$\frac{D_{60}}{D_{10}} = \frac{11}{.4} = 27.5$

$\frac{D_{30}^2}{11 \times .4} = \frac{25}{} = 5.68$

Boring No. _____ Sample No. _____ Depth _____

Sieve No.	Wt. Grams	Percent Retained	Cumulative Percent	
Pan				
200				
100				
50				
30				
20				
16				
10				
8				

DAMES & MOORE

FALLING HEAD PERMEABILITY TEST

PROJECT: NLO PROJECT NO.: 10805-161 LOCATION: FERNALD BORING: 15S SAMPLE: 10 DEPTH: ~~30-32~~ 32-34 FT.

SAMPLED: / / TESTED: JJ 10/17 /84 COMPUTED: JJ 10/21 /84 CHECKED: [illegible] / / NOTES: remolded samples

SOIL CLASSIFICATION: SP [illegible]

DIAMETER OF STANDPIPE (d) 1.97 in. AREA OF STANDPIPE (a) 3.05 in.^{2} DIAMETER OF SAMPLE (D) 3.06 in. AREA OF SAMPLE (A) 7.35 in.

TEST SURCHARGE: _____ lbs/sq. ft. _____ in. of _____ SPRING GRADE OF STONE USED: medium

SATURATION DATA

DATE	TIME	ELAPSED TIME MIN.	LOAD DIAL	DEFL. DIAL	HEIGHT OF SAMPLE (L) IN.	% DEFL. OR EXPANSION
			0 =			
			=			
		after saturation =				
		after test =				

PERMEABILITY RESULTS

$$K_{20^oC} = \left(2.3 \frac{aL}{A(t_1 - t_0)} \log_{10} \frac{H_0}{H_1}\right)\left(\frac{\mu T}{\mu 20^oC}\right)$$

K_{20^oC} at min.	inches/min.	cm/sec	ft./yr
7:52	2.26×10^{-2}	9.56×10^{-4}	9.89×10^{2}
8:13	2.04×10^{-2}	8.62×10^{-4}	8.92×10^{2}
8:37	1.66×10^{-2}	7.04×10^{-4}	7.28×10^{2}

MOISTURE AND DENSITY DATA

DISH # 7	FIELD	AFTER SATURATION	AFTER TEST
height of sample (in.)			1.11
wet wt + dish (gm)			188.95
dry wt + dish (gm)			165.44
wt of moisture (gm)			23.51
wt of dish (gm)			25.41
wt of dry soil (gm)			140.03
moisture content (%)			16.79
wet density (pcf)			118.54
dry density (pcf)			101.54

PERMEABILITY DATA

DATE	TIME	ELAPSED TIME MIN.	TEMP °C (T)	HEAD AT START (H_0) – IN.	HEAD AT END (H_1) – IN.	ΔH
10/17	7:52	8.0	24	50.1	40.3	9.8
10/17	8:13	8.0	24	44.9	36.9	8.0
10/17	8:37	5.0	24	46.2	41.8	4.4

FALLING HEAD PERMEABILITY TEST

Sample No: NLO 17 : Boring 15s

Date: May 21st

Description: Coarse gravel

Tested By: Nanlh

Diameter of Stand Pipe: 1.46 (cm)

Location: 155'

Diameter of Permeameter: 6.09 (cm)

Depth: 80-82'

Sample Length: 12.0' (cm)

Wt. of Pan & Soil (g):

Wt. of Permeameter & Soil (g): 969.7

Wt. of Pan & Dry Soil (g):

Wt. of Permeameter (g): 332.1

Wt. of Pan:

%Wt. of Soil (g): 637.6

Temperature (%): 20°C

Elapsed Time (sec)	Head at Start (cm)	Head at End (cm)	Permeability at 20°C (cm/sec)	Permeability at 20°C (cm/sec)
14.79	78.8	31.4		4.0×10^{-2}
16.60	75.2	27.9		3.9×10^{-2}
16.50	77.0	30.3		3.7×10^{-2}
16.79	76.0	29.1		3.7×10^{-2}

Permeability of the Soil (No.): 3.7×10^{-2} cm/sec

Initial Test Density: 106.7 pcf

Initial Moisture Content: –

Remarks:

FALLING HEAD PERMEABILITY TEST

Sample No: NLO 18 : Boring 15s

Date: May 21st

Description:

Tested By: Nanth.

Diameter of Stand Pipe: 1.46 (cm)

Location: PASTURE

Diameter of Permeameter: 6.29 (cm)

Depth: 35-37'

Sample Length: 12.4 (cm)

Wt. of Pan & Soil (g):

Wt. of Permeameter & Soil (g): 931.8

Wt. of Pan & Dry Soil (g):

Wt. of Permeameter (g): 328.6

Wt. of Pan:

%Wt. of Soil (g): 603.6

Temperature (%): 20°C

Elapsed Time (sec)	Head at Start (cm)	Head at End (cm)	Permeability at 20°C (cm/sec)	Permeability at 20°C (cm/sec)
5.93	107.4	59.0		6.75×10^{-2}
5.90	105.0	56.6		7.00×10^{-2}
5.66	111.0	82.5		6.75×10^{-2}
5.95	108.5	60.1		6.63×10^{-3}

Permeability of the Soil (No.): 6.75×10^{-3} cm/sec

Initial Test Density: 97.7 pcf

Initial Moisture Content:

Remarks:

DAMES & MOORE

SIEVE ANALYSIS

Job No. 10805-161
Owner NLO
Location FERNALD
Date 10-15-84
By JDJ

dry

Boring No. 15-d Sample No. S-14 Depth 55'

Sieve No.	Wt. Grams	Percent Retained	Cumulative Percent passing
Pan	653.49	100	0
200	651.87	99.75	.25
100	651.35	99.67	.33
60	650.77	99.58	.42
40	650.05	99.47	.53
20	649.39	99.37	.63
10	647.88	99.14	.86
4	637.00	97.48	2.52
3/8	597.35	91.41	8.59
1/2	503.83	77.10	22.90
3/4	196.38	30.05	69.95
1	76.68	11.73	88.27
1.5	0	0	100.00

$\frac{D_{60}}{D_{10}} = \frac{17}{10} = 1.7$

$\frac{D_{30}^2}{17 \times 10} = \frac{(14)^2}{17 \times 10} = 1.15$

washed

Boring No. 13-S Sample No. 1 Depth 36'

Sieve No.	Wt. Grams	Percent Retained	Cumulative Percent passing
Pan	300.81	100	0
200	268.87	89.38	10.62
100	258.07	85.79	14.21
60	226.03	75.14	24.86
40	182.93	60.81	39.19
20	128.59	42.75	57.25
10	70.02	23.28	76.72
4	24.46	8.13	91.87
3/8	7.48	2.49	97.51
1/2	5.64	1.87	98.13
3/4	0	0	100.00

$\frac{D_{60}}{D_{10}} = \frac{.95}{.08} = 11.9$

$\frac{D_{30}^2}{D_{60} \times D_{10}} = \frac{(.32)^2}{.95 \times .08} = 1.35$

SW-SC

dry

Boring No. 14-S Sample No. 2 Depth 22'

Sieve No.	Wt. Grams	Percent Retained	Cumulative Percent passing
Pan	413.88	100	0
200	400.55	96.78	3.22
100	396.03	95.69	4.31
60	387.08	93.52	6.48
40	352.36	85.14	14.86
20	163.68	39.55	60.45
10	55.08	13.31	86.69
4	13.67	3.30	96.70
3/8	4.46	1.08	98.92
1/2	235	0.57	99.43
3/4	0	0	100.00

$\frac{D_{60}}{D_{10}} = \frac{.85}{.35} = 2.4$

$\frac{D_{30}^2}{.85 \cdot .35} = \frac{.5^2}{} = .84$

DAMES & MOORE

FALLING HEAD PERMEABILITY TEST

PROJECT: NLO PROJECT NO.: 10805-161 LOCATION: Fremont BORING: 15d SAMPLE: S-13 DEPTH: 55 FT.

SAMPLED: / / TESTED: JT 10/17 /84 COMPUTED: JT 10/21 /84 CHECKED: / / NOTES: remolded samples

SOIL CLASSIFICATION: GP L = 2.46 in.

DIAMETER OF STANDPIPE (d) 1.97 in. AREA OF STANDPIPE (a) 3.05 in.^{2} DIAMETER OF SAMPLE (D) 3.06 in. AREA OF SAMPLE (A) 7.35 in.^{2}

TEST SURCHARGE: _____ lbs/sq. ft. _____ in. of _____ SPRING GRADE OF STONE USED: medium

SATURATION DATA

DATE	TIME	ELAPSED TIME MIN.	LOAD DIAL	DEFL. DIAL	HEIGHT OF SAMPLE (L) IN.	% DEFL. OR EXPANSION
			0 =			
			=			
		after saturation =				
		after test =				

PERMEABILITY DATA

DATE	TIME	ELAPSED TIME MIN.	TEMP °C (T)	HEAD AT START (H_0) – IN.	HEAD AT END (H_1) – IN.	ΔH
10/17	7:55	4.0+10s	24	44.6	29.2	15.4
10/17	8:16	6.0	24	48.8	26.5	22.3
10/17	8:36	4.0	24	45.9	30.3	15.6

PERMEABILITY RESULTS

$$K_{20^oC} = \left(2.3 \frac{aL}{A(t_1 - t_0)} \log_{10} \frac{H_0}{H_1}\right)\left(\frac{\mu T}{\mu 20^oC}\right)$$

K_{20^oC} at min.	inches/min.	cm/sec	ft./yr
7:55	9.43×10^{-2}	3.99×10^{-3}	4.13×10^{3}
8:16	9.43×10^{-2}	3.99×10^{-3}	4.13×10^{3}
8:36	9.64×10^{-2}	4.08×10^{-3}	4.22×10^{3}

MOISTURE AND DENSITY DATA

DISH # 17	FIELD	AFTER SATURATION	AFTER TEST
weight of sample (in.)			1.02
wet wt + dish (gm)			265.72
dry wt + dish (gm)			257.74
wt of moisture (gm)			7.98
wt of dish (gm)			24.71
wt of dry soil (gm)			233.03
moisture content (%)			3.42
wet density (pcf)			97.51
dry density (pcf)			94.28

Job. No. 10805-161
Owner NLO
Location Fernald
Date 1-22-85
By E.S.

Dames & Moore Sieve Analysis

Boring # 16d Sample # NLO-2 Depth (ft) 35-37

Sieve #	Wt. Grams	% Retained	Cumulative % Pasing
	53.3	18.00	100.00
	0	0	100.00
	15.7	5.30	76.70
3	2.8	0.95	75.75
4	3.4	1.15	74.60
6	1.0	0.34	74.26
8	0.5	0.17	74.09
12	0.4	0.14	73.95
20	2.8	0.95	73.00
40	39.6	13.38	59.62
60	126.4	42.69	16.93
100	26.9	9.08	7.85
140	5.4	1.82	6.03
200	3.5	1.18	4.85
PAN	14.4	1.86	0
	Σ 296.1		

Initial wt. 298.0

FALLING HEAD PERMEABILITY TEST

Sample No: NLO 1 : Borwg 18s

Date: May 22nd.

Description: Sand.

Tested By: NANTHIKESAN

Diameter of Stand Pipe: 1.46. (cm)

Location: Old fly ash pile

Diameter of Permeameter: 6.29. (cm)

Depth: 35-37'

Sample Length: 11.9. (cm)

Wt. of Pan & Soil (g):

Wt. of Permeameter & Soil (g): 1230.6

Wt. of Pan & Dry Soil (g):

Wt. of Permeameter (g): 559.6.

Wt. of Pan:

%Wt. of Soil (g): 671.0.

Temperature (°C): 18.5°.

Elapsed Time (sec)	Head at Start (cm)	Head at End (cm)	Permeability at 20°C (cm/sec)	Permeability at 20°C (cm/sec)
30.5	83.6.	71.6	3.26×10^{-3}	3.38×10^{-3}
32.8	77.5	65.8	3.20×10^{-3}	3.32×10^{-3}
44.0	67.1	53.8	3.21×10^{-3}	3.33×10^{-3}

Permeability of the Soil (No.): 3.33×10^{-3} cm/sec.

Initial Test Density: 113.2 pcf

Initial Moisture Content: 10.8%.

Remarks:

The tests on sands of this high permeability would be an underestimate of the k values ie. k actl may be much higher than this.

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Job. No. 10805-161
Owner NLO
Location Fernald
Date 1-30-85
By E.S.

Dames & Moore Sieve Analysis

Boring # 17s Sample # NLO-13 Depth (ft) 35-37

Sieve #	Wt. Grams	% Retained	Cumulative % Pasing
	64.9	17.45	82.35
	105.2	28.29	54.26
4	158.1	42.51	11.75
6	23.8	6.40	5.35
8	10.0	2.69	2.66
20	6.4	1.72	0.94
40	1.7	0.45	0.49
PAN	1.8	0.48	0
	Σ 371.9		

Initial wt. 3721.1

FALLING HEAD PERMEABILITY TEST

Sample No: NLO 14 · Boring 17s

Date: May 20th.

Description:

Tested By: Nanthi

Diameter of Stand Pipe: 1.46. (cm)

Location: 80-82' 15S

Diameter of Permeameter: 6.29 (cm)

Depth:

Sample Length: 12.6. (cm)

Wt. of Pan & Soil (g):

Wt. of Permeameter & Soil (g):

Wt. of Pan & Dry Soil (g):

Wt. of Permeameter (g):

Wt. of Pan:

%Wt. of Soil (g): 643.7

Temperature (%): 20

Elapsed Time (sec)	Head at Start (cm)	Head at End (cm)	Permeability at 20°C (cm/sec)	Permeability at 20°C (cm/sec)
6.00	117.5	69.5		5.94×10^{-2}
6.08	109.6	62.0		6.36×10^{-2}
5.90	114.0	66.7		6.17×10^{-2}
5.25	111.5	69.5		6.11×10^{-2}

Permeability of the Soil (No.): 6.1×10^{-2} cm/sec.

Initial Test Density: 102.6 pcf

Initial Moisture Content: 3.4%

Remarks:

Job. No. 10805-161
Owner NLO
Location FERWALD
Date 1-24-85
By E.S.

Dames & Moore Sieve Analysis

Boring # 18s Sample # NL-5 Depth (ft) 55-57

Sieve #	Wt. Grams	% Retained	Cumulative % Pasing
8	110.3	19.03	80.97
20	163.7	28.26	52.73
40	184.7	31.81	20.92
60	40.1	6.92	14.00
100	52.6	9.07	4.93
150	10.4	1.74	2.14
200	6.3	1.09	2.05
PAN	11.6	2.00	0
	Σ 579.7		

FALLING HEAD PERMEABILITY TEST

Sample No: NLO:6 - Boring 18s

Date: May 22nd

Description: Sand with Gravel.

Tested By: Nanlbc

Diameter of Stand Pipe: 1.46 (cm)

Location: 18S

Diameter of Permeameter: 6.29 (cm)

Depth: 55'-57'

Sample Length: 14.3 (cm)

Wt. of Pan & Soil (g):

Wt. of Permeameter & Soil (g): 1294.4

Wt. of Pan & Dry Soil (g):

Wt. of Permeameter (g): 391.3

Wt. of Pan:

%Wt. of Soil (g): 903.1

Temperature (%): 18.5

Elapsed Time (sec)	Head at Start (cm)	Head at End (cm)	Permeability at 20°C (cm/sec)	Permeability at 20°C (cm/sec)
11.10	83.6	71.60	0.0108	0.0112
11.85	77.5	65.80	0.0106	0.0110
18.30	86.0	67.10	0.0104	0.0108
16.90	67.1	53.8	0.0104	0.0105

Permeability of the Soil (No.): 1.1×10^{-2} cm/sec

Initial Test Density: 126.8 pcf

Initial Moisture Content: 4.71 %

Remarks:

GRAIN SIZE ANALYSIS-HYDROMETER METHOD Data Sheet 7

Project Dames & Moore Job No. 10805-161

Location of Project NLO Boring No. 18d Sample No. NL03

Description of Soil Silty-clay Depth of Sample 120-122

Tested By Omar Date of Testing 6/1/85 (Sat)

Hydrometer analysis

Hydrometer no. H 152 G_s of solids = 2.76 a = 0.976

Dispersing agent Na PO_3 Amount 4% in 125 ml Wt. of soil, W_s 50.0 gm

Zero correction 0.0 Meniscus correction +1.0

Date	Time of reading	Elapsed time, min	Temp., °C	Actual Hyd. reading R_a	Corr. Hyd. reading R_r	% Finer	Hyd. Corr. only for meniscus, R	L from Table 6-5	$\frac{L}{t}$	K from Table 6-4	D, mm
6/1	3.48	0	23°	49	✓						
	3.49	1		45	45.7	89.2	46	8.8	8.8	0.01276	0.038
	3.50	2		42.5	43.2	84.3	43.5	9.15	4.575		0.027
	3.51	3		41	41.7	81.4	42	9.4	3.13		0.023
	3.52	4		39	39.7	77.5	40	9.7	2.43		0.020
	3.56	8		36	36.7	71.6	37	10.2	1.275		0.014
	4.04	16		32.5	33.2	64.8	33.5	10.8	0.675		0.011
	4.18	30		30	30.7	59.9	31	11.2	0.373		0.0078
	4.48	60		27	27.7	54.0	28	11.7	0.195		0.0056
	5.48	120	23	24	24.7	48.2	25	12.2	0.102	0.01276	0.0041
	10.48	420	23.5	21	21.7	42.4	22	12.7	0.03	0.01267	0.0022
6/2	12.48	1260	23	18.5	19.2	37.5	19.5	13.1	0.01	0.01276	0.0013
	2.18	1350	23.5	18	18.7	36.5	19	13.2	0.0097	0.01267	0.00125
	3.48	1440	23.5	18	18.7	36.5	19	13.2	0.0092	0.01267	0.0012
										✓	

$R_r = R_{actual}$ − zero correction + C_T % finer = $R_r(a)/W_s$ $D = K\sqrt{L/t}$

SPECIFIC GRAVITY OF SOIL SOLIDS (G_s) Data Sheet 8

Project Dames & Moore Job No. 10805-161

Location of Project NLO Boring No. 18d Sample No. NLO 3

Description of Soil Silty-clay Depth of Sample 120 – 122

Tested By Omar Date of Testing 6/16/85

Test no.	1			
Vol. of flask at 20°C	500 ml.			
Method of air removal[a]	Vacumn			
Wt. flask + water + soil = W_{bw}	728.7			
Temperature, °C	20.0 °C			
Wt. flask + water[b] = W_{bw}	661.1			
Evap. dish no.	2			
Wt. evap. dish + dry soil	636.4			
Wt. of evap. dish	530.4			
Wt. of dry soil = W_s	106.0			
$W_w = W_s + W_{bw} - W_{bws}$	38.4			
$G_s = \alpha W_s / W_w$	2.76	✓		

[a]Indicate vacuum or aspirator for air removal.

[b]W_{bw} is the weight of the flask filled with water at same temp. ± 1° C as for W_{bws} or value from calibration curve at T of W_{bws}.

Remarks $\alpha = 1.0$ ✓

Average specific gravity of soil solids (G_s) =

GRAIN SIZE ANALYSIS-HYDROMETER METHOD Data Sheet 7

Project Dames & Moore Job No. 10805-161

Location of Project NLO Boring No. 19d Sample No. NLO 21

Description of Soil Silty-clay Depth of Sample 20-22 Ft

Tested By Omar Date of Testing 5/27/85 (Mon)

Hydrometer analysis

Hydrometer no. H 152 G_s of solids = 2.81 a = 0.97

Dispersing agent Na PO_3 Amount 125ml. 4% Wt. of soil, W_s 50 gm

Zero correction 0 Meniscus correction +1.0

Date	Time of reading	Elapsed time, min	Temp., °C	Actual Hyd. reading R_a	Corr. Hyd. reading R_r	% Finer	Hyd. Corr. only for meniscus, R	L from Table 6-5	$\frac{L}{t}$	K from Table 6-4	D, mm
5/27	1.25pm	0	25	47.5	48.8		48.5				
	1.26	1		45	46.3	89.8	46	8.8	8.8	0.0123	0.036
	1.27	2		44	45.3	87.9	45	8.9	4.45		0.026
	1.28	3		43	44.3	85.9	44	9.1	3.03		0.021
	1.29	4		42	43.3	84.	43	9.2	2.3		0.019
	1.33	8		39	40.3	78.2	40	9.7	1.21		0.014
	1.41	16		35.5	36.8	71.4	36.5	10.3	0.64		0.010
	1.55	30	25	33	34.3	66.5	34	10.7	0.36	0.0123	0.0074
	2.25	60	24.5	29	30.15	58.5	30	11.4	0.19	0.0124	0.0054
	3.25	120	24.5	26	27.15	52.7	27	11.9	0.099	0.0124	0.0039
	6.28	303	24.5	22	23.15	44.9	23	12.5	0.04	0.0124	0.0025
	7.25	360	25.5	21	22.5	43.7	22	12.7	0.035	0.01225	0.0023
	11.25	600	25	19.5	20.8	40.4	20.5	12.95	0.022	0.0123	0.0018
5/28	11.25	1320	24	19	20	38.8	20	13.0	0.010	0.0125	0.0013
	1.25	1440	25.5	18	19.5	37.8	19	13.2	0.009	0.01225	0.0012
	4.35	1530	25.5	17	18.5	35.9	18	13.3	0.0086	0.01225	0.0011

$R_r = R_{actual}$ − zero correction + C_T % finer = $R_r(a)/W_s$ $D = K\sqrt{L/t}$

SPECIFIC GRAVITY OF SOIL SOLIDS (G_s) Data Sheet 8

Project Dames & Moore Job No. 10805-161

Location of Project NLO Boring No. 19-d Sample No. NLO-21

Description of Soil Silty-clay Depth of Sample 20-22 Ft

Tested By Omar Date of Testing 6/15/85

Test no.	1			
Vol. of flask at 20°C	500 ml.			
Method of air removal[a]	Vacum			
Wt. flask + water + soil = W_{bws}	727.1			
Temperature, °C	18.5°C			
Wt. flask + water[b] = W_{bw}	660.2			
Evap. dish no.	1			
Wt. evap. dish + dry soil	578.8			
Wt. of evap. dish	474.9			
Wt. of dry soil = W_s	103.9			
$W_w = W_s + W_{bw} - W_{bws}$	37.0			
$G_s = \alpha W_s / W_w$	2.81			

[a]Indicate vacuum or aspiration for air removal.

[b]W_{bw} is the weight of the flask filled with water at same temp. ± 1°C as for W_{bws} or value from calibration curve at T of W_{bws}.

Remarks $\alpha = 1.0003$

Average specific gravity of soil solids (G_s) = 2.81

Job. No. 10805-161
Owner NLO
Location FERNALD
Date 1-25-85
By D.S.

Dames & Moore Sieve Analysis

Boring # 20S Sample # NLO-8 Depth (ft) 5-7

Sieve #	Wt. Grams	% Retained	Cumulative % Pasing
8	21.4	4.44	95.56
20	12.9	2.67	92.85
40	2.8	0.58	92.31
60	7.2	1.49	90.82
100	47.0	9.74	81.08
140	58.6	12.14	68.94
200	82.8	17.16	51.78
PAN	249.7	51.76	
	Σ 482.4		

initial weight 591.5

GRAIN SIZE ANALYSIS-HYDROMETER METHOD Data Sheet 7

Project Dames & Moore Job No. 10805-161

Location of Project NLO Boring No. 205 Sample No. NLO 8

Description of Soil SILTY CLAY Depth of Sample 5-7 ft

Tested By Omar Date of Testing 6/12/85 (Wed)

Hydrometer analysis

Hydrometer no. H 152 G_s of solids = 2.795 a = 0.97

Dispersing agent $Na\ PO_3$ Amount 125 ml. 4% Wt. of soil, W, 50.0 gm

Zero correction 0 Meniscus correction 1

Date	Time of reading	Elapsed time, min	Temp., °C	Actual Hyd. reading R_a	Corr. Hyd. reading R_r	% Finer	Hyd. Corr. only for meniscus, R	L from Table 6-5	$\frac{L}{t}$	K from Table 6-4	D, mm
6/12	3.24	0	23	36	36.7		37				
	3.25	1		27	27.7	53.7	28	11.7	11.7	0.0126	0.043
	3.26	2		22	22.7	44.	23	12.5	6.25		0.032
	3.27	3		19	19.7	38	20	13.0	4.33		0.026
	3.28	4		17	17.7	34	18	13.3	3.33		0.023
	3.32	8		12.5	13.2	25.6	13.5	14.1	1.76		0.017
	3.40	16		10	10.7	20.8	11	14.5	0.91		0.012
	3.54	30		9	9.7	18.8	10	14.7	0.49		0.009
	4.24	60	23	8	8.7	16.9	9	14.8	0.25		0.006
	5.24	120	23	7	7.7	14.9	8	15.0	0.125		0.0045
6/13	12.54	1290	23	6	6.7	13.0	7	15.2	0.012		0.0014
	3.24	1440	23	6	6.7	13.0	7	15.2	0.01	0.0126	0.0013

$R_r = R_{actual}$ − zero correction + C_T % finer = $R_r(a)/W_s$ $D = K\sqrt{L/t}$

SPECIFIC GRAVITY OF SOIL SOLIDS (C_s) Data Sheet 8

Project Dames & Moore Job No. 10805-161

Location of Project NLO Boring No. 205 Sample No. NLO 8

Description of Soil SILTY CLAY Depth of Sample 5-7 ft

Tested By Omar Date of Testing 6/15/85 (Sat)

Test no.	1			
Vol. of flask at 20°C	500 ml.			
Method of air removal*	Vacum			
Wt. flask + water + soil = W_{bws}	735.4			
Temperature, °C	18.5°C			
Wt. flask + water[b] = W_{bw}	663.6			
Evap. dish no.	2			
Wt. evap. dish + dry soil	530.4			
Wt. of evap. dish	642.2			
Wt. of dry soil = W_s	111.8			
$W_w = W_s + W_{bw} - W_{bws}$	40			
$C_s = \alpha W_s / W_w$	2.795			

*Indicate vacuum or aspirator for air removal.

[b]W_{bw} is the weight of the flask filled with water at same temp. ± 1°C as for W_{bws} or value from calibration curve at T of W_{bws}.

Remarks $\alpha = 1.0003$

Average specific gravity of soil solids (C_s) =

56

Job. No. 10805-161
Owner NLO
Location Furnald
Date 1-25-85
By E.S.

Dames & Moore Sieve Analysis

Boring # 20d Sample # NLO-9 Depth (ft) 20-22

Sieve #	Wt. Grams	% Retained	Cumulative % Pasing
8	50.9	9.37	90.63
20	121.4	22.34	68.29
40	162.5	29.91	38.38
60	143.8	26.47	11.91
100	44.6	8.21	3.70
140	5.2	0.96	2.74
200	4.1	0.76	1.98
PAN	10.8	1.99	0
	Σ 543.3		

Initial wt. 544.7

152

5e

GRAIN SIZE ANALYSIS-HYDROMETER METHOD Data Sheet 7

Project Dames & Moore Job No. 10805-161

Location of Project NLO Boring No. 20d Sample No. NLO 11

Description of Soil Silty-clay Depth of Sample 119 - 121

Tested By Omar Date of Testing 6/1/85 (Sat)

Hydrometer analysis

Hydrometer no. H 152 G_s of solids = 2.79 a = 0.97

Dispersing agent $Na\ PO_3$ Amount 125ml. 4% Wt. of soil, W_s 50. gm

Zero correction 0.0 Meniscus correction +1.0

Date	Time of reading	Elapsed time, min	Temp., °C	Actual Hyd. reading R_a	Corr. Hyd. reading R_r	% Finer	Hyd. Corr. only for meniscus, R	L from Table 6-5	$\frac{L}{t}$	K from Table 6-4	D, mm
6/1	5.21	0	24	50							
	5.22	1		47.5	48.5	94.1	48.5	8.35	8.35	0.01252	0.036
	5.23	2		46	47	91.2	47	8.6	4.3		0.026
	5.24	3		45	46	89.2	46	8.8	2.93		0.021
	5.25	4		44	45	87.3	45	8.9	2.23		0.019
	5.29	8		41.5	42.5	82.5	42.5	9.3	1.163		0.0135
	5.37	16		39	40	77.6	40	9.7	0.606		0.0097
	5.51	30		36.2	37.2	72.8	37.2	10.2	0.34		0.0073
	6.21	60		33.5	34.5	66.9	34.5	10.6	0.177		0.0053
	7.21	120	24	30.5	31.5	61.1	31.5	11.15	0.093	0.01252	0.0038
	10.51	330	23.5	28	28.85	56.	29	11.5	0.035	0.01258	0.0024
6/2	12.51	1170	23.5	25	25.85	50.1	26	12.0	0.013	0.01258	0.0014
	2.21	1260	23.5	24.5	25.35	49.2	25.5	12.1	0.0096	0.01258	0.0012
	5.21	1440	24	24.0	25.0	48.5	25.0	12.2	0.0084	0.01252	0.0011

$R_r = R_{actual}$ − zero correction + C_T % finer = $R_r(a)/W_s$ $D = K\sqrt{L/t}$

SPECIFIC GRAVITY OF SOIL SOLIDS (C_s)

Data Sheet 8

Project Dames & Moore

Job No. 10805-161

Location of Project NLO

Boring No. 20d Sample No. NLO 11

Description of Soil Silty-clay

Depth of Sample 119-121

Tested By Omar

Date of Testing 6/16

Test no.	1			
Vol. of flask at 20°C	500. ml.			
Method of air removal*	Vacumn			
Wt. flask + water + soil = W_{bcw}	724.4			
Temperature, °C	20.0			
Wt. flask + water[b] = W_{bw}	662.9			
Evap. dish no.	1			
Wt. evap. dish + dry soil	570.8			
Wt. of evap. dish	474.9			
Wt. of dry soil = W_s	95.9			
$W_w = W_s + W_{bw} - W_{bcw}$	34.4			
$C_s = \alpha W_s / W_w$	2.79			

*Indicate vacuum or aspirator for air removal.

[b] W_{bw} is the weight of the flask filled with water at same temp. ± 1°C as for W_{bcw} or value from calibration curve at T of W_{bcw}.

Remarks $\alpha = 1.0$

Average specific gravity of soil solids (C_s) =

FALLING HEAD PERMEABILITY TEST

Sample No: NL07 : Boring 20d

Date: May 23rd

Description: Weathered Hill (Yellowish Uniform Sand)

Tested By: Nanthi

Diameter of Stand Pipe: (cm) 1.46

Location: Fence line ; 20S.

Diameter of Permeameter: (cm) 6.29

Depth: 5-7'

Sample Length: (cm) 12.9

Wt. of Pan & Soil (g):

Wt. of Permeameter & Soil (g): 1162.3

Wt. of Pan & Dry Soil (g):

Wt. of Permeameter (g): 390.9

Wt. of Pan:

%Wt. of Soil (g): 771.4

Temperature (%): 17

Elapsed Time (sec)	Head at Start (cm)	Head at End (cm)	Permeability at 20°C (cm/sec)	Permeability at 20°C (cm/sec)
46.3	96.1	92.5	5.68×10^{-4}	6.12×10^{-4}
33.0	91.3	89.0	5.56×10^{-4}	5.99×10^{-4}
36.2	87.8	85.4	5.32×10^{-4}	5.73×10^{-4}
58.7	81.8	78.3	5.28×10^{-4}	5.69×10^{-4}

Permeability of the Soil (No.): 5.7×10^{-4} cm/sec

Initial Test Density: 120.1 pcf

Initial Moisture Content: 18.9%

Remarks:

GRAIN SIZE ANALYSIS-HYDROMETER METHOD Data Sheet 7

Project Dames & Moore Job No. 10805-161

Location of Project NLO Boring No. 225 Sample No. NLO 23

Description of Soil Silty-clay Depth of Sample 10-12 Ft

Tested By Omar Date of Testing 5/27/85 (Mon.)

Hydrometer analysis

Hydrometer no. H 152 G_s of solids = 2.786 a = 0.97

Dispersing agent Na PO_3 Amount 125 ml. 4% Wt. of soil, W_s 50. gm

Zero correction 0.0 Meniscus correction +1.0

Date	Time of reading	Elapsed time, min	Temp., °C	Actual Hyd. reading R_a	Corr. Hyd. reading R_r	% Finer	Hyd. Corr. only for meniscus, R	L from Table 6-5	$\frac{L}{t}$	K from Table 6-4	D, mm
5/27	5.23	0	25	49			50				
	5.24	1		46	47.3	91.8	47	8.6	8.6	0.01236	0.036
	5.25	2		44.5	45.8	88.9	45.5	8.85	4.425		0.026
	5.26	3		43	44.3	85.9	44	9.1	3.03		0.022
	5.27	4		42.5	43.8	85.	43.5	9.15	2.288		0.019
	5.31	8		40.	41.3	80.1	41	9.6	1.2		0.014
	5.39	16		38	39.3	76.2	39	9.9	0.619		0.010
	5.53	30		36	37.3	72.4	37	10.2	0.34		0.007
	6.23	60		33	34.3	66.5	34	10.7	0.178		0.005
	7.23	120		30.5	31.8	61.7	31.5	11.15	0.093		0.0038
	11.23	360	25	28.0	29.3	56.8	29	11.5	0.032	0.01236	0.0022
5/28	11.23	1080	24	26.0	27.3	53.0	27	11.9	0.011	0.01253	0.0013
	1.23	1200	25	25.0	26.3	51.0	26	12.0	0.01	0.01236	0.0012
	5.23	1440	26.5	24.0	25.3	49.1	25	12.2	0.0085	0.01216	0.0011

$R_r = R_{actual}$ − zero correction + C_T % finer = $R_r(a)/W_s$ $D = K\sqrt{L/t}$

SPECIFIC GRAVITY OF SOIL SOLIDS (C_s)

Data Sheet 8

Project Dames & Moore

Job No. 10805-161

Location of Project NLO

Boring No. 225 Sample No. NLO 23

Description of Soil Silty-clay

Depth of Sample 10-12 ft

Tested By Omar

Date of Testing 6/14/85

Test no.	1			
Vol. of flask at 20°C	500 ml.			
Method of air removal*	Vacum			
Wt. flask + water + soil = W_{bws}	733.2			
Temperature, °C	18°			
Wt. flask + water† = W_{bw}	662.7			
Evap. dish no.	2			
Wt. evap. dish + dry soil	530.4			
Wt. of evap. dish	640.4			
Wt. of dry soil = W_s	110.0			
$W_w = W_s + W_{bw} - W_{bws}$	39.5			
$C_s = \alpha W_s / W_w$	2.786			

*Indicate vacuum or aspirator for air removal.

†W_{bw} is the weight of the flask filled with water at same temp. ± 1° C as for W_{bws} or value from calibration curve at T of W_{bws}.

Remarks $\alpha = 1.0004$

Average specific gravity of soil solids (C_s) =

GRAIN SIZE ANALYSIS-HYDROMETER METHOD

Data Sheet 7

Project Dames & Moore

Job No. 10805-161

Location of Project NLO

Boring No. 22S Sample No. NLO 25

Description of Soil Silty-clay

Depth of Sample 15-17 Ft

Tested By Omar & Nanthi

Date of Testing 5/26/85 (Sun)

Hydrometer analysis

Hydrometer no. H 152 G_s of solids = 2.71 a = 0.987

Dispersing agent Na PO_3 Amount 125ml 4% Wt. of soil, W_s 50.36

Zero correction 0.0 Meniscus correction +1.0

Date	Time of reading	Elapsed time, min	Temp., °C	Actual Hyd. reading R_a	Corr. Hyd. reading R_c	% Finer	Hyd. Corr. only for meniscus, R	L from Table 6-5	$\frac{L}{t}$	K from Table 6-4	D, mm
5/26	3.54	0	23.5°	48.5	49.35		49.5	8.2			
	3.55	1	23.5	43	43.85	85.9	44	9.1	9.1	0.01286	0.039
	3.56	2	23.5	41.5	42.35	83.0	42.5	9.3	4.65		0.028
	3.57	3	23.5	39.5	40.35	79.1	40.5	9.65	3.22		0.023
	3.58	4	23.5	38	38.85	76.1	39	9.9	2.475		0.02
	4.02	8	23.5	33.5	34.35	67.3	34.5	10.6	1.325		0.015
	4.10	16	23.5	30.5	31.35	61.4	31.5	11.15	0.697		0.011
	4.25	31	23.5	27	27.85	54.6	28	11.7	0.377		0.0079
	4.54	60	23.5°	24	24.85	48.7	25	12.2	0.203	0.01286	0.0058
	5.54	120	24	21	22	43.1	22	12.7	0.106	0.01276	0.0042
	8.0	246	25	18.5	19.8	38.8	19.5	13.1	0.053	0.01266	0.0029
5/27	12.24	1230	25	15.5	16.8	32.9	16.5	13.6	0.011	0.01266	0.0013
	3.54	1440	26	14.5	16.15	31.7	15.5	13.75	0.0096	0.01245	0.0012
	5.44	1550	26	14.0	15.65	30.7	15	13.8	0.0089	0.01246	0.0012

$R_c = R_{actual}$ − zero correction + C_T % finer = $R_c(a)/W_s$ $D = K\sqrt{L/t}$

SPECIFIC GRAVITY OF SOIL SOLIDS (G_s) Data Sheet 8

Project Dames & Moore Job No. 10805-161

Location of Project NLO Boring No. 225 Sample No. NLO 25

Description of Soil Silty-clay Depth of Sample 15-17

Tested By Omar Date of Testing 6/11/85 (Tue)

Test no.	1			
Vol. of flask at 20°C	500 ml.			
Method of air removal*	Vacum			
Wt. flask + water + soil = W_{bws}	736.3			
Temperature, °C	21° C			
Wt. flask + water† = W_{bw}	665.0			
Evap. dish no.	1			
Wt. evap. dish + dry soil	587.8			
Wt. of evap. dish	474.9			
Wt. of dry soil = W_s	112.9			
$W_w = W_s + W_{bw} - W_{bws}$	41.6			
$G_s = \alpha W_s / W_w$	2.71			

*Indicate vacuum or aspirator for air removal.

†W_{bw} is the weight of the flask filled with water at same temp. ± 1°C as for W_{bws} or value from calibration curve at T of W_{bws}.

Remarks $\alpha = 0.9998$

Average specific gravity of soil solids (G_s) = _____

GRAIN SIZE ANALYSIS-HYDROMETER METHOD Data Sheet 7

Project Dames & Moore Job No. 10805-161

Location of Project NLO Boring No. 225 Sample No. NL027

Description of Soil Silty-clay Depth of Sample 20-22 Ft

Tested By Omar Date of Testing 5/27/85 (Mon)

Hydrometer analysis

Hydrometer no. H 152 G_s of solids = 2.725 a = 0.98

Dispersing agent Na PO_3 Amount 125 ml 4% Wt. of soil, W_s 50 gm

Zero correction 0.0 Meniscus correction +1.0

Date	Time of reading	Elapsed time, min	Temp., °C	Actual Hyd. reading R_a	Corr. Hyd. reading R_r	% Finer	Hyd. Corr. only for meniscus, R	L from Table 6-5	$\frac{L}{t}$	K from Table 6-4	D, mm
5/27	4.49	0	25	48	49.3		49			0.0124	
	4.50	1		45.5	46.8	91.7	46.5	8.7	8.7		0.037
	4.51	2		44	45.3	88.8	45	8.9	4.45		0.026
	4.52	3		43	44.3	86.8	44	9.1	3.03		0.022
	4.53	4		41.5	42.8	83.9	42.5	9.3	2.33		0.019
	4.57	8		38.5	39.8	78.	39.5	9.8	1.225		0.014
	5.05	16		35.5	36.8	72.1	36.5	10.3	0.64		0.01
	5.19	30		32.5	33.8	66.3	33.5	10.8	0.36		0.0074
	5.49	60		29	30.3	59.4	30	11.4	0.19		0.0054
	6.49	120		25.5	26.8	52.5	26.5	11.95	0.1		0.0039
	10.49	360	25	22	23.3	45.7	23	12.5	0.035	0.0124	0.0023
5/28	10.49	1080	23.5	19.5	20.35	39.9	20.5	12.95	0.012	0.01278	0.0014
	1.49	1260	25	19.0	20.3	39.8	20	13.0	0.01	0.0124	0.00124
	4.49	1440	26	18.0	19.65	38.5	19	13.2	0.009	0.0123	0.0012

$R_r = R_{actual}$ − zero correction + C_T % finer = $R_r(a)/W_s$ $D = K\sqrt{L/t}$

SPECIFIC GRAVITY OF SOIL SOLIDS (G_s) Data Sheet 8

Project Dames & Moore Job No. 10805-161

Location of Project NLO Boring No. 225 Sample No. NLO 27

Description of Soil Silty-clay Depth of Sample 20-22 Ft

Tested By Omar Date of Testing 6/14/85

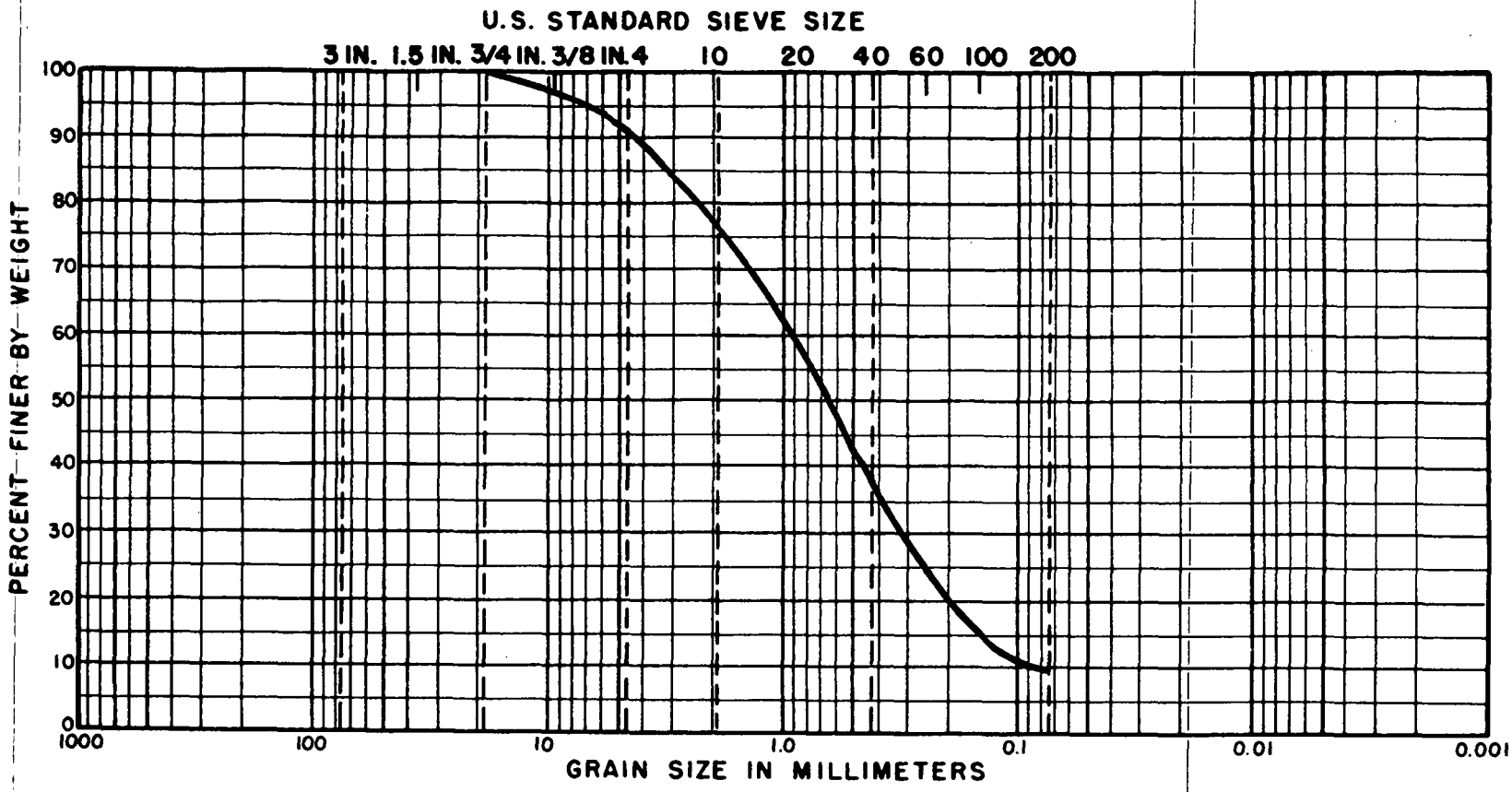
Test no.	1			
Vol. of flask at 20°C	500 ml.			
Method of air removal*	Vacum			
Wt. flask + water + soil = W_{bcw}	721.8			
Temperature, °C	18°C			
Wt. flask + water[b] = W_{bw}	661.1			
Evap. dish no.	1			
Wt. evap. dish + dry soil	570.8			
Wt. of evap. dish	474.9			
Wt. of dry soil = W_s	95.9			
$W_w = W_s + W_{bw} - W_{bcw}$	35.2			
$G_s = \alpha W_s / W_w$	2.725			

*Indicate vacuum or aspirator for air removal.

[b]W_{bw} is the weight of the flask filled with water at same temp. ± 1°C as for W_{bcw} or value from calibration curve at T of W_{bcw}.

Remarks $\alpha = 1.0004$

Average specific gravity of soil solids (G_s) =



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

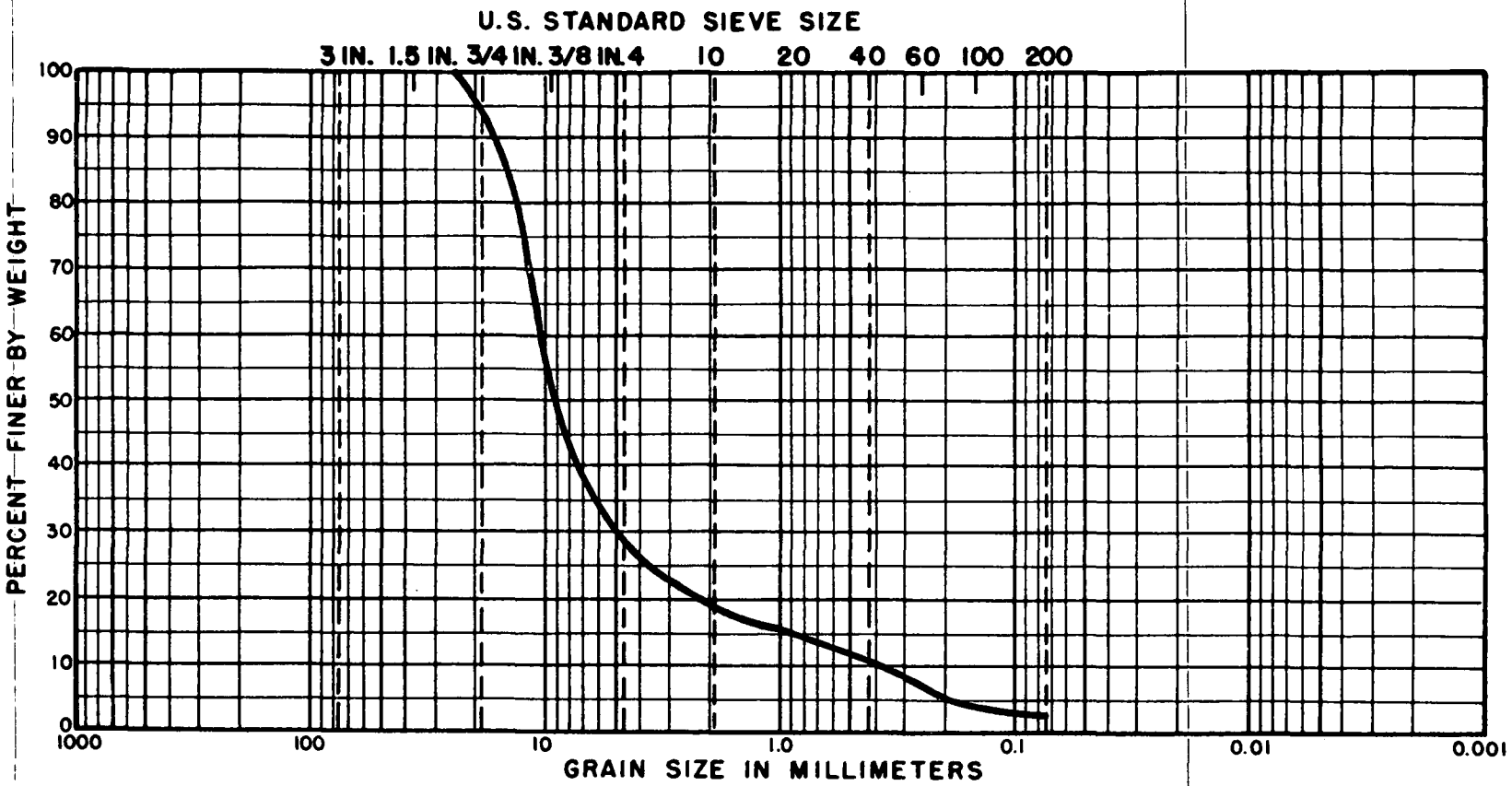
SAMPLE	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
NLO-1	36-38'	SW-SC						

DAMES & MOORE

FIGURE A2-1

GRADATION CURVE

BORING 13s



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
NLO-9	55-57'	GP						

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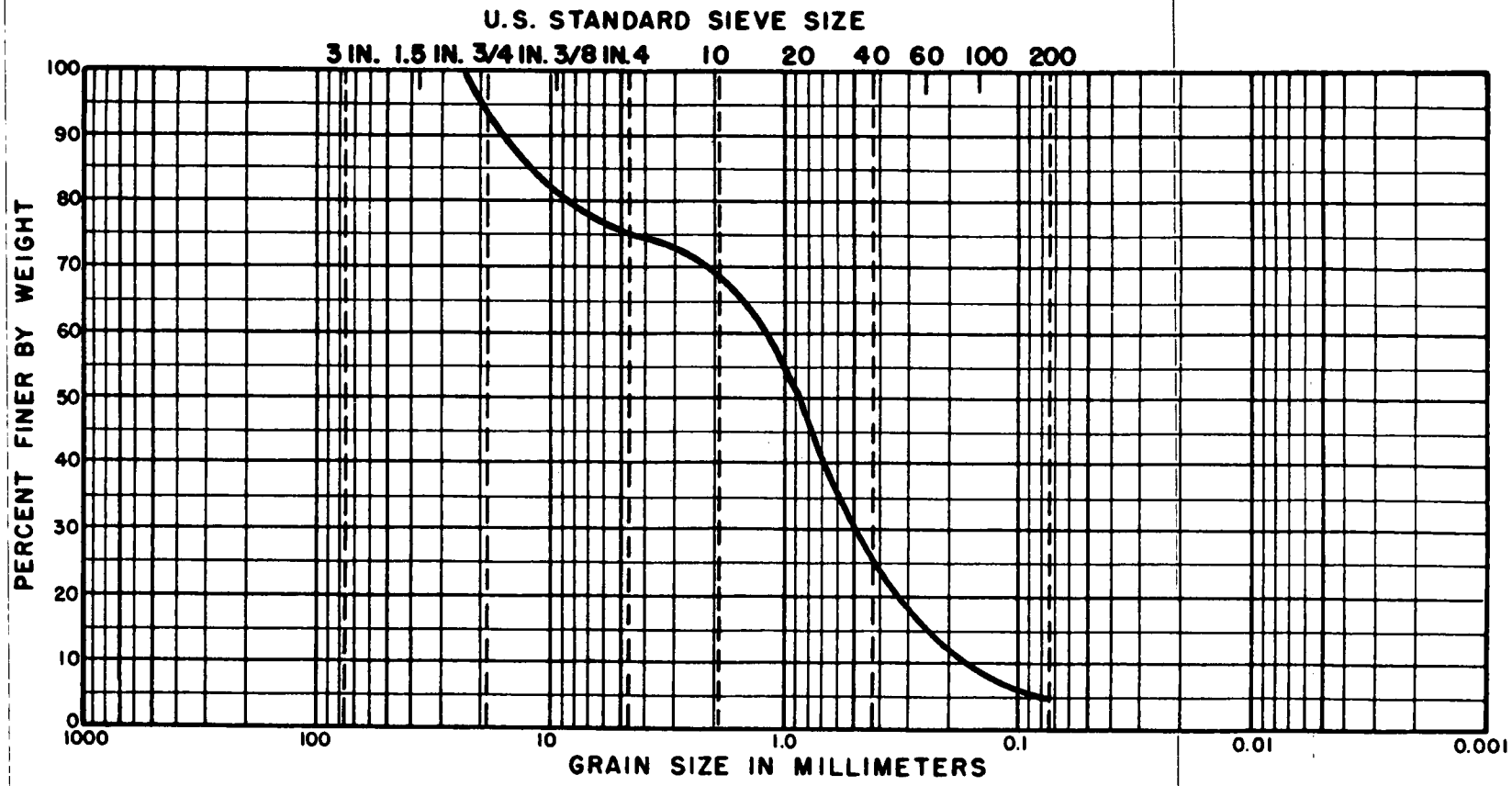
GRADATION CURVE

BORING 13d

FIGURE A2-2

163



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI
NLO-19	80-82'	GP	SANDY GRAVEL				

DAMES & MOORE

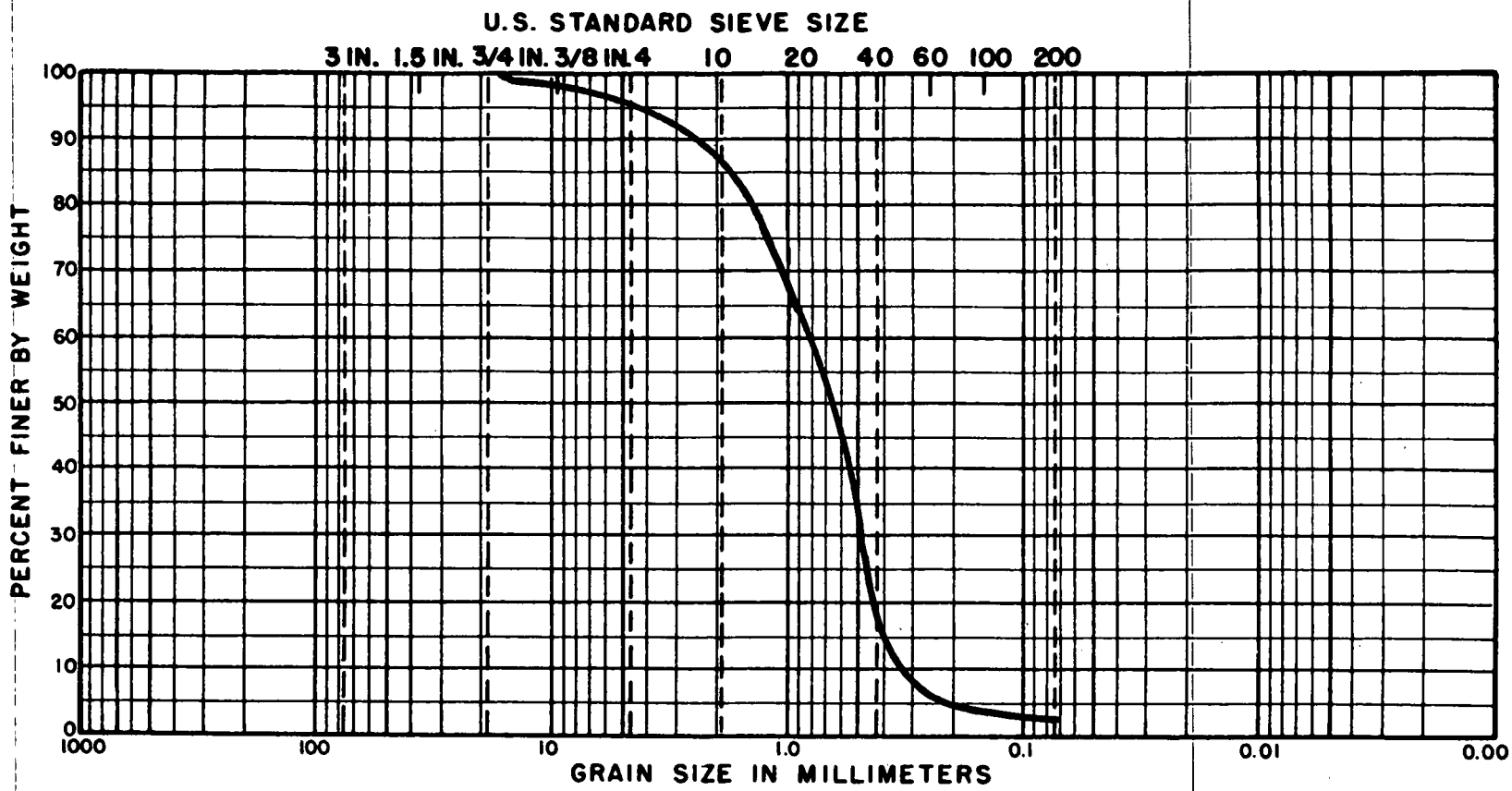
FIGURE A2-3

GRADATION CURVE

BORING 13d

164

56



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
NLO-2	22-24'	SP						

DAMES & MOORE

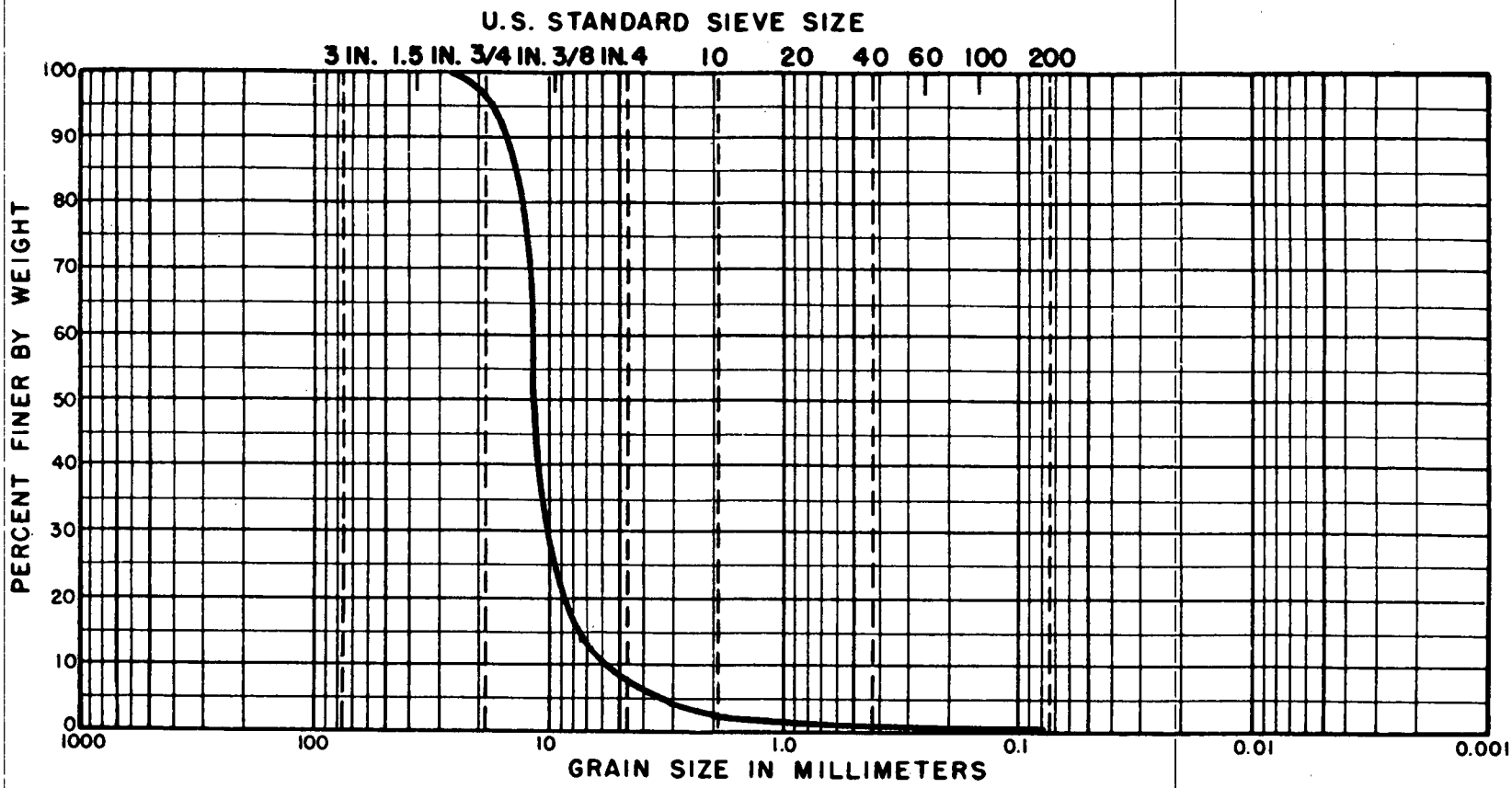
FIGURE A2-4

GRADATION CURVE

BORING 14s

145

56



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
NLO-11	55-57'	GP						

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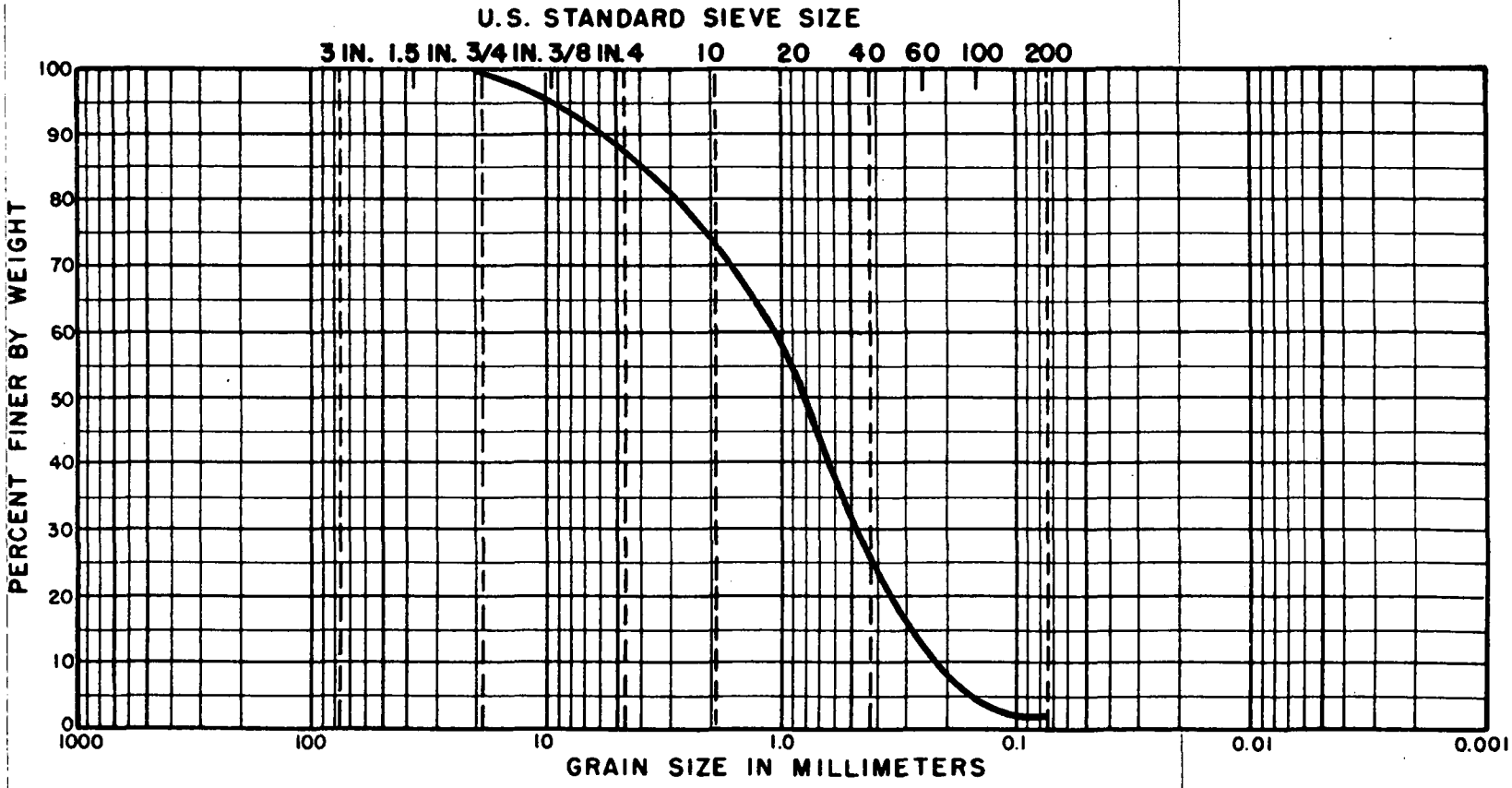
GRADATION CURVE

BORING 14d

FIGURE A2-5

166

56



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
NLO-S11	32-34'	SP						

DAMES & MOORE

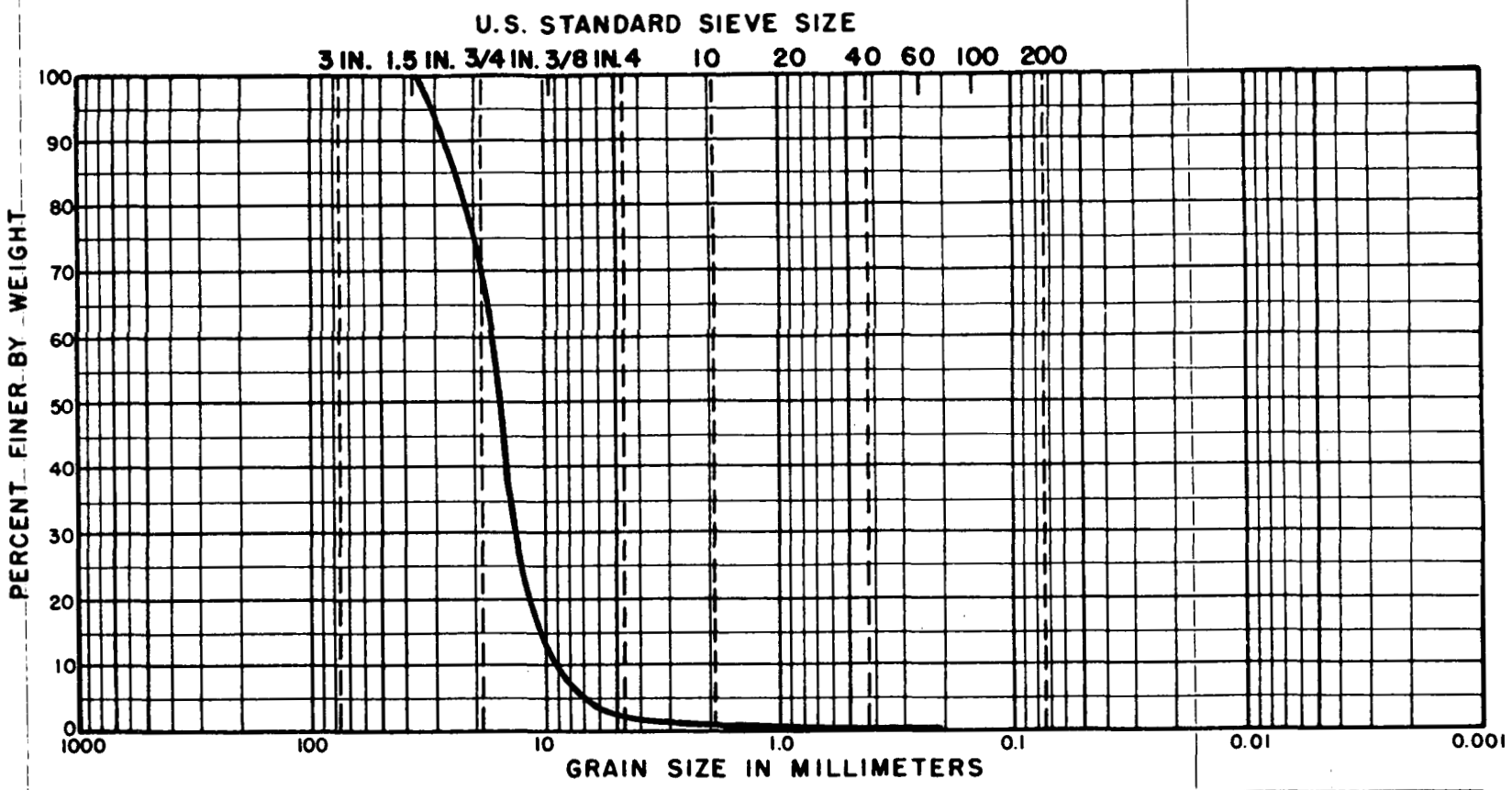
GRADATION CURVE

BORING 15s

FIGURE A2-6

167

56



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
NLO-14s	55-57'	GP						

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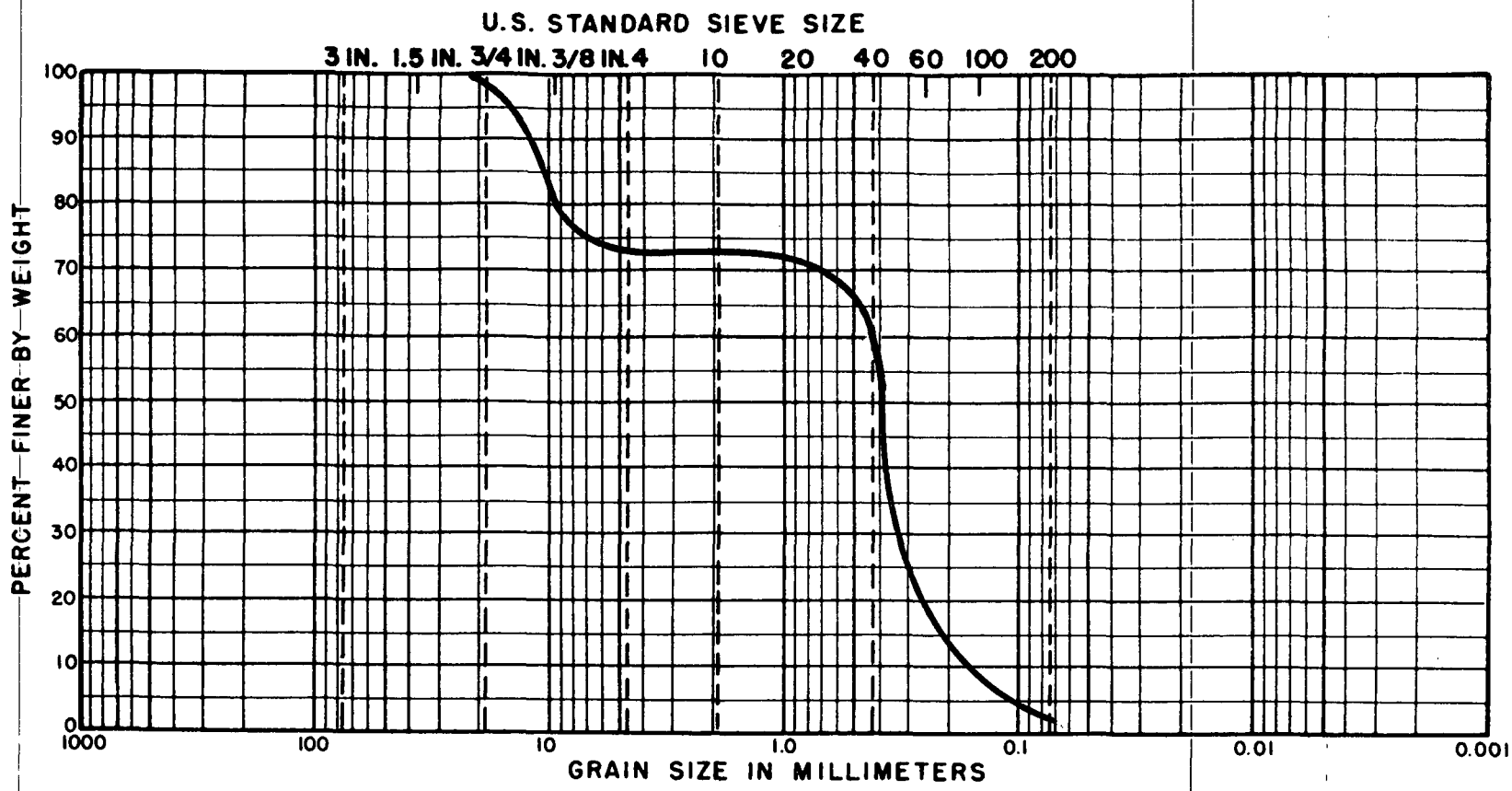
FIGURE A2-7

GRADATION CURVE

BORING 15d

168

56



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
NLO-2	35-37'	SP	GRAVELLY SAND					

DAMES & MOORE

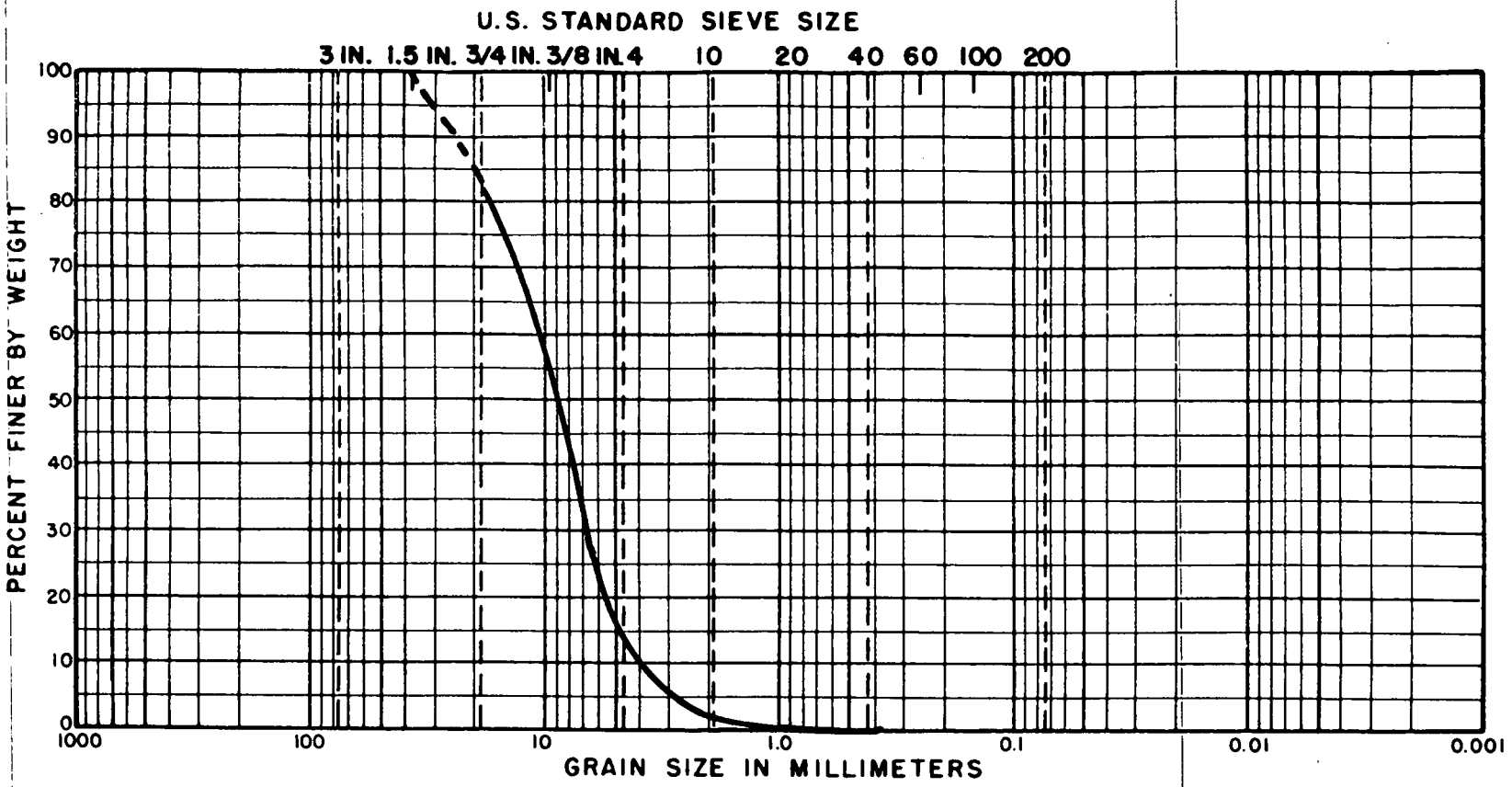
FIGURE A2-8

GRADATION CURVE

BORING 16d

169

56



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
NLO-13	35-37'	GW						

DAMES & MOORE

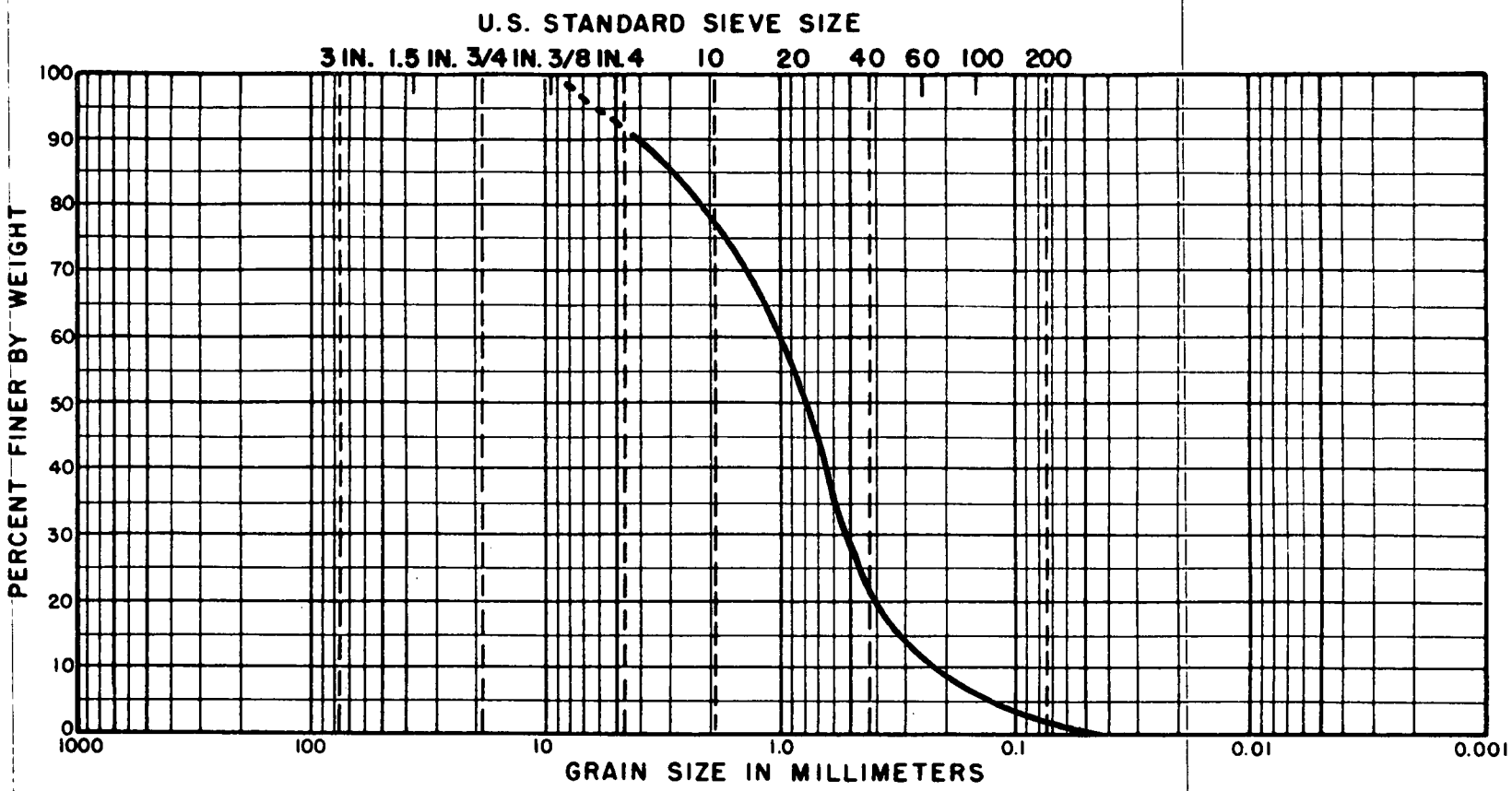
FIGURE A2-9

GRADATION CURVE

BORING 17s

170

56



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

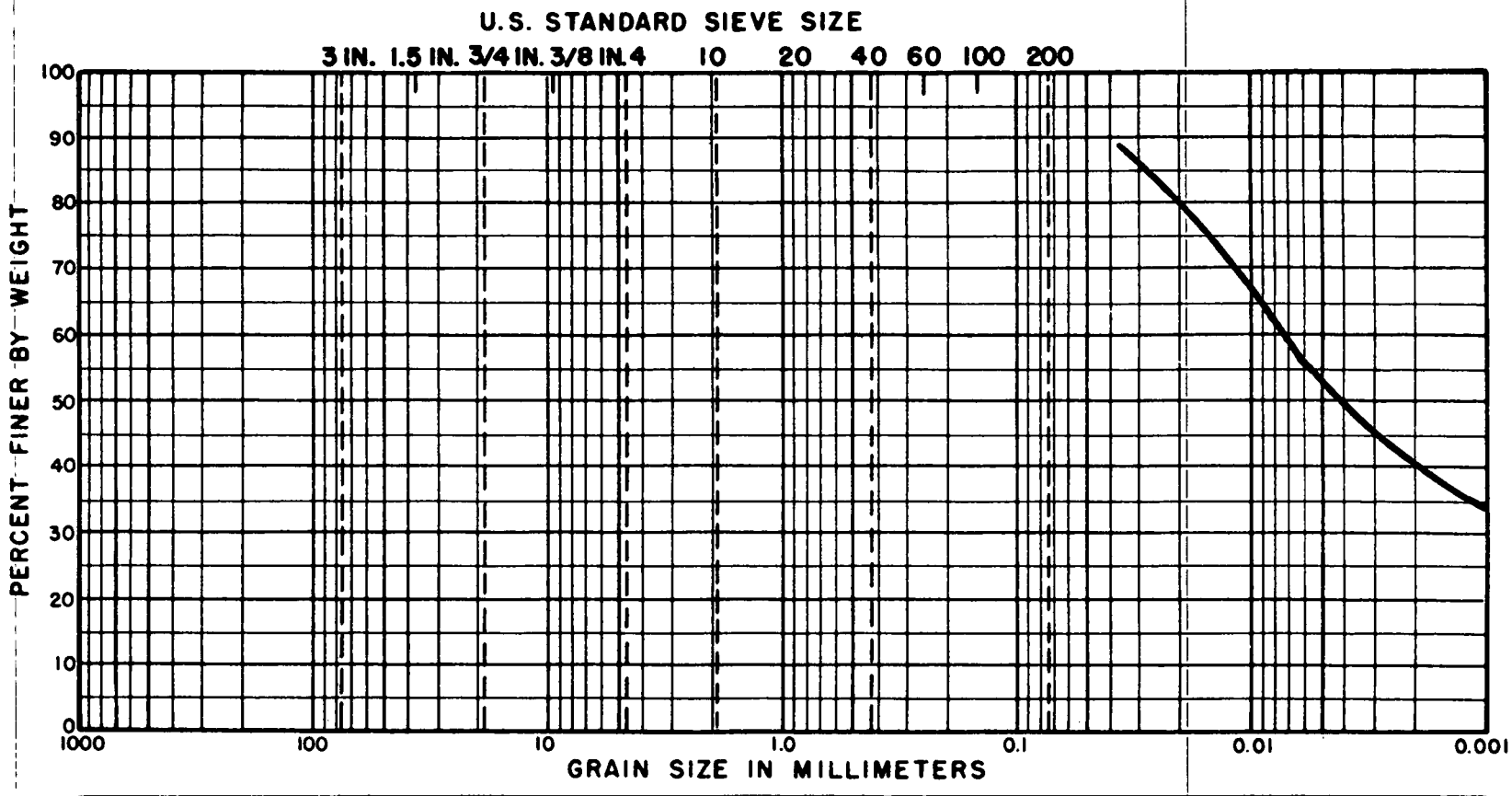
SAMPLE	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
NLO-5	55-57'	SW						

DAMES & MOORE

FIGURE A2-10

GRADATION CURVE

BORING 18s



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
NLO-3	120-122'	CL						

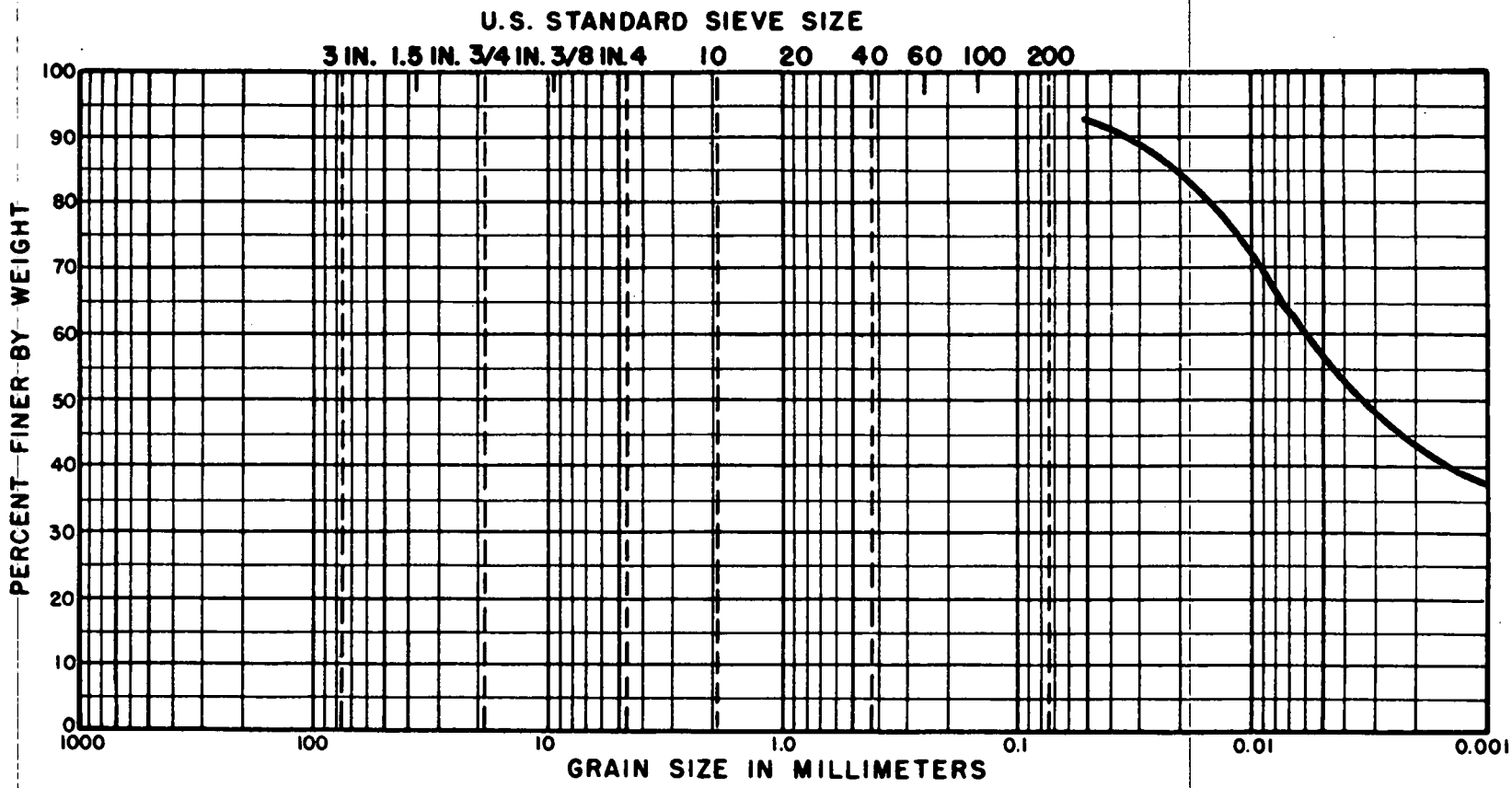
DAMES & MOORE

GRADATION CURVE

BORING 18d

FIGURE A2-11

112



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

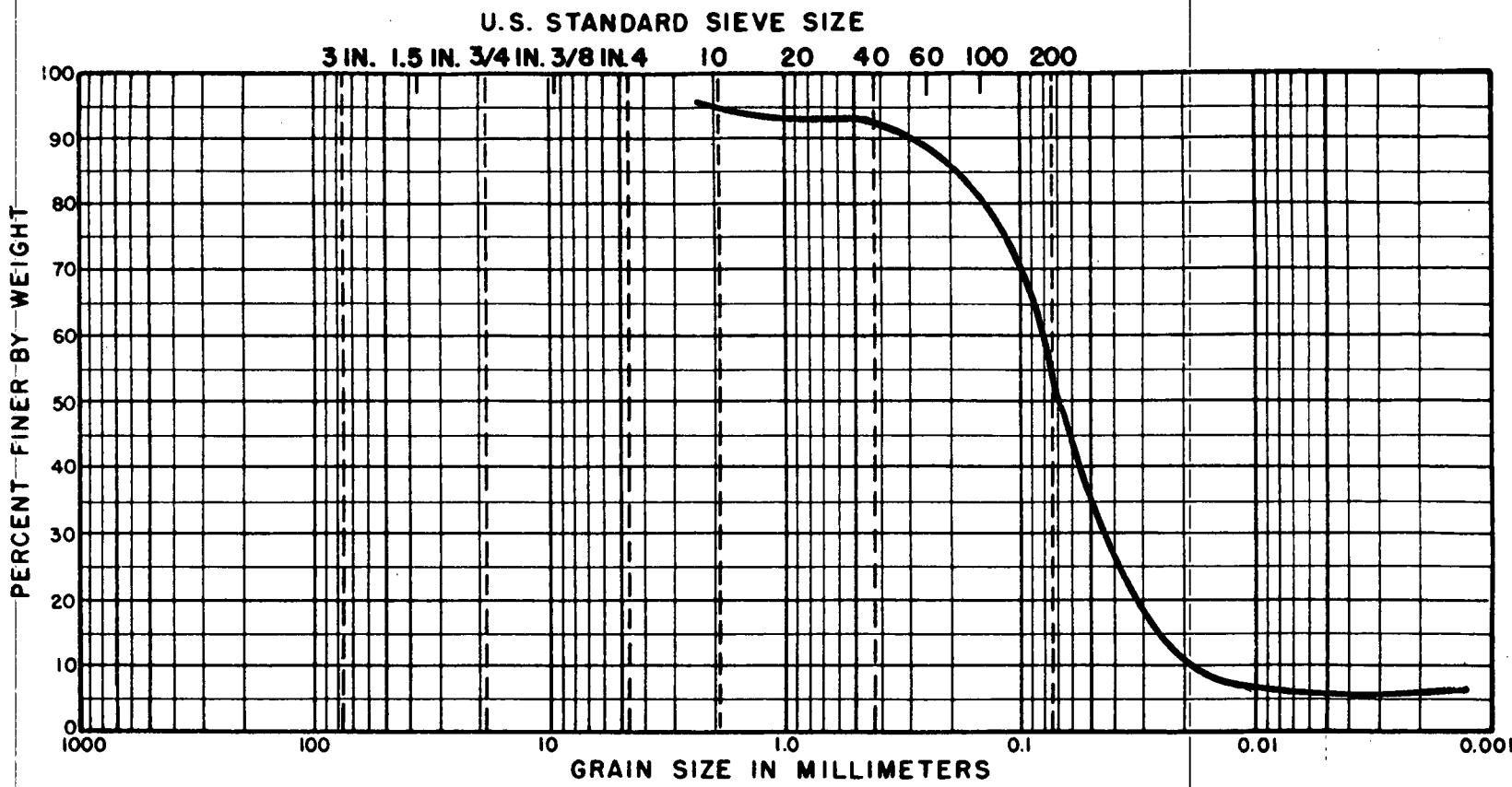
SAMPLE	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
NLO-21	20-22'	CL						

DAMES & MOORE

GRADATION CURVE

BORING 19d

FIGURE A2-12



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

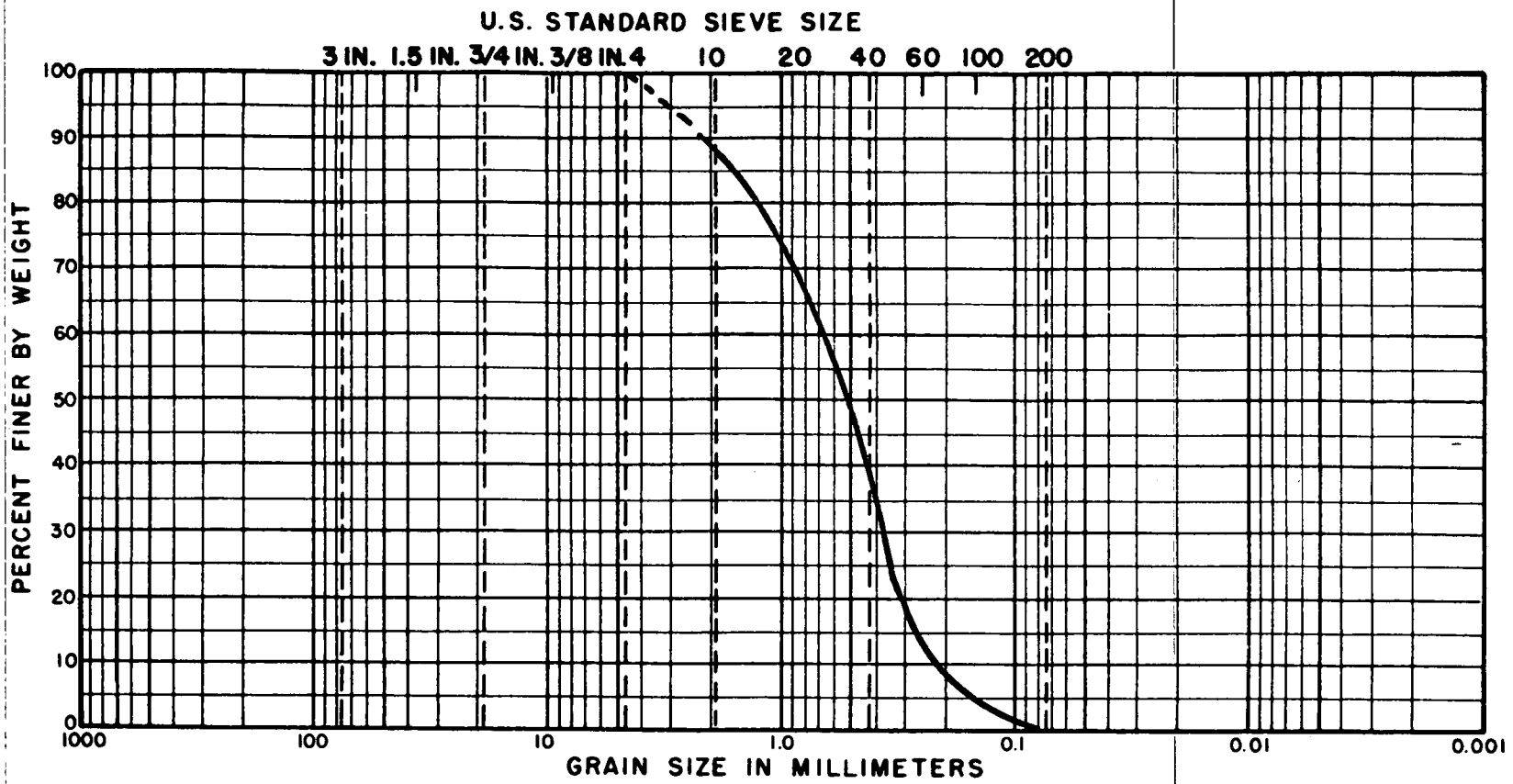
SAMPLE	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
NLO-8	5-7'	ML						

DAMES & MOORE

GRADATION CURVE

BORING 20s

FIGURE A2-13



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

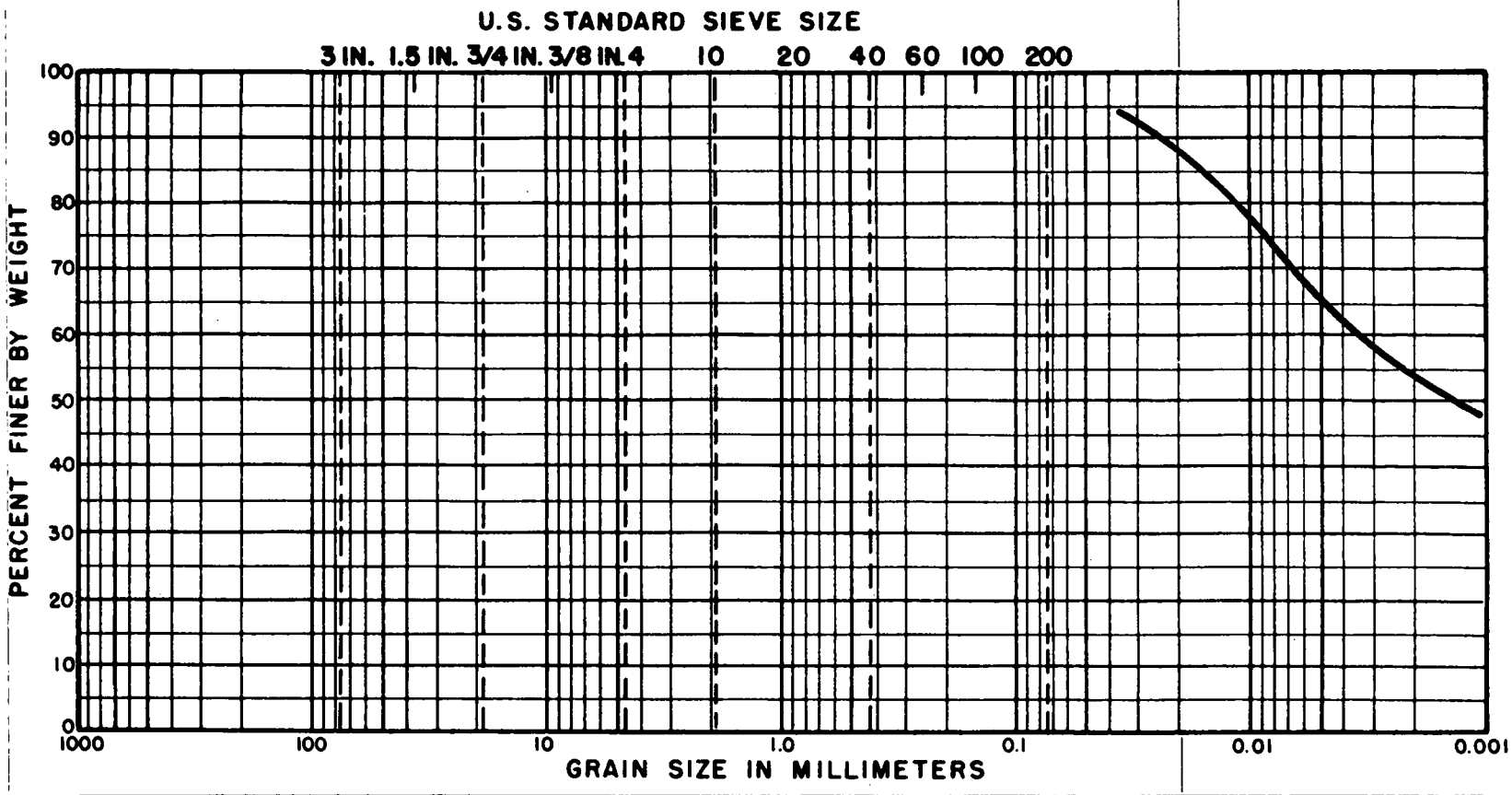
SAMPLE	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI
NLO-9	20-22'	SW					

DAMES & MOORE

FIGURE A2-14

GRADATION CURVE

BORING 20d



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
NLO-11	119-121'	CL						

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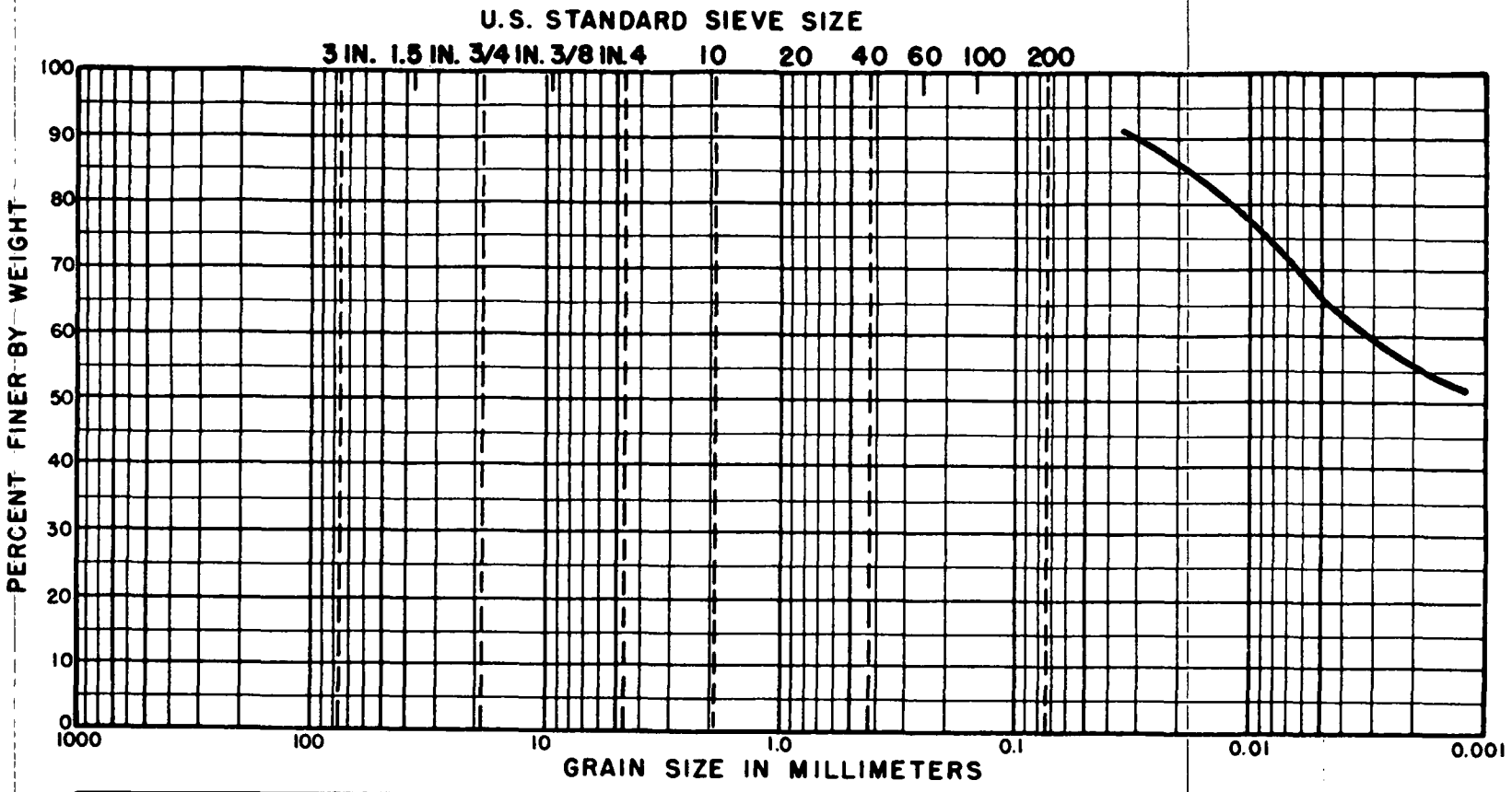
GRADATION CURVE

BORING 20d

FIGURE A2-15



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

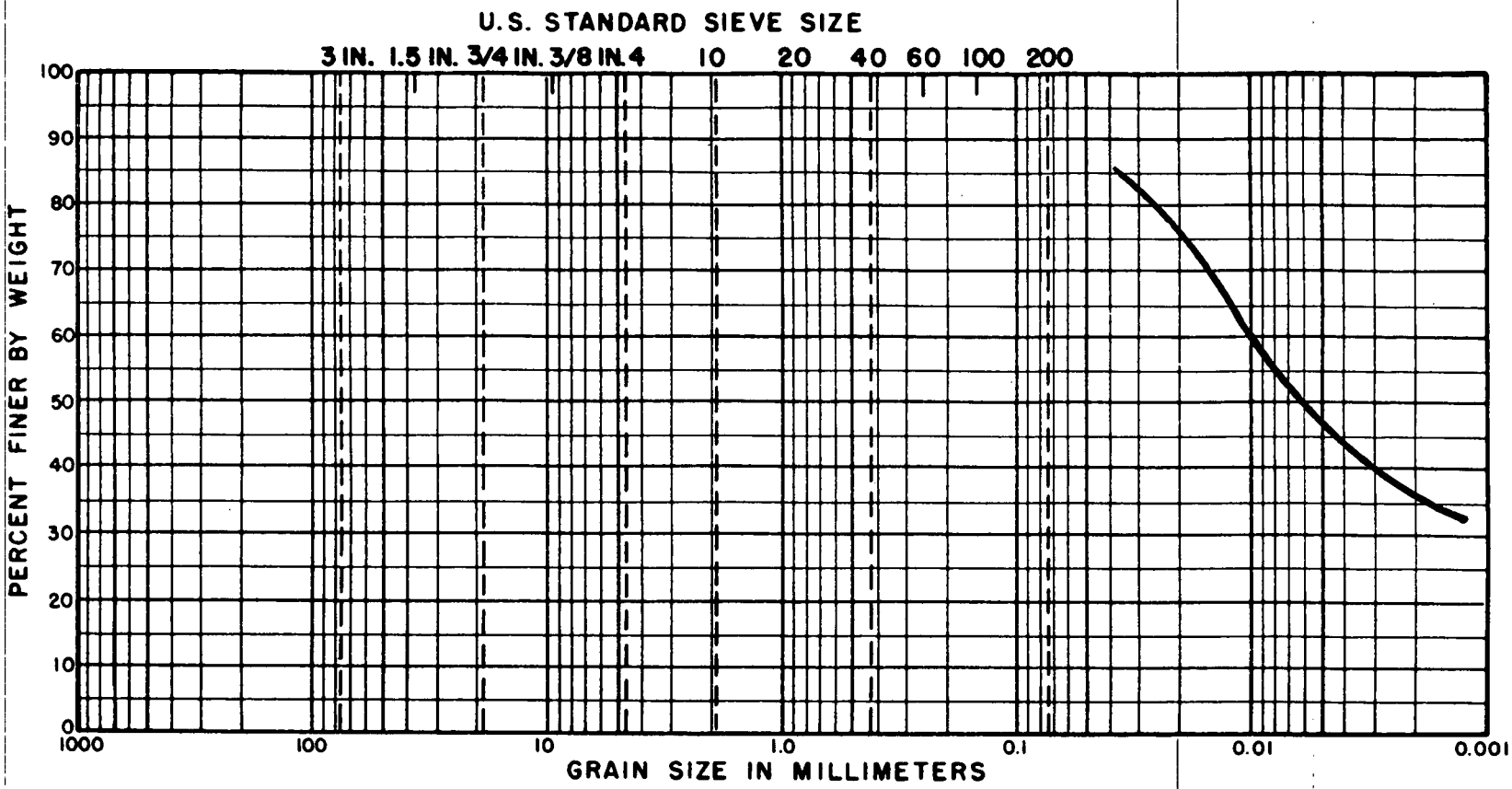
SAMPLE	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
NLO-23	10-12'	CL						

DAMES & MOORE

GRADATION CURVE

BORING 22s

FIGURE A2-16



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
NLO-25	15-17'	CL						

GRADATION CURVE

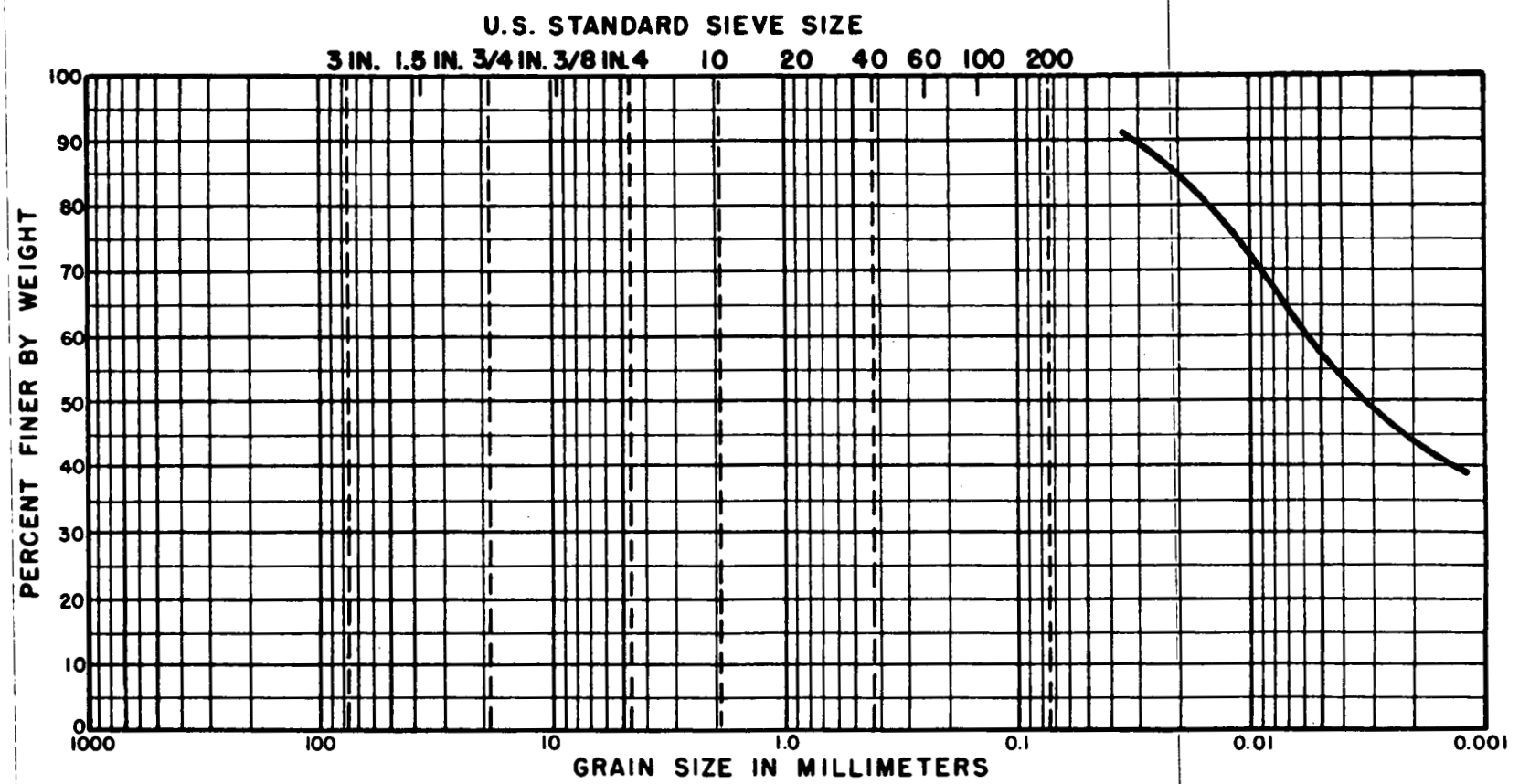
BORING 22s

DAMES & MOORE

FIGURE A2-17

178

54



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE	DEPTH	CLASSIFICATION		NAT. WC	LL	PL	PI	
NLO-27	20-22'	CL						

DAMES & MOORE

FIGURE A2-18

GRADATION CURVE

BORING 22s

179

56

APPENDIX 3

STATISTICAL CALCULATIONS

A3.1 BACKGROUND CONCENTRATIONS OF URANIUM

A total of 228 samples from 16 upgradient wells has been collected and analyzed by NLO in the past and uranium values in these wells have been used to establish background concentrations of uranium in the groundwater. Table A3-1 lists the range of the uranium concentrations for each of the wells. Geometric averaging was used to determine background uranium concentrations for each of the wells. Table A3-1 also lists the geometric mean of the uranium concentrations for each background well. The use of geometric means rather than arithmetic means allows representative estimates to be made from sets of data that contain a few data points which are several orders of magnitude greater than the majority in the set and which would dominate the average if arithmetic means were used. The geometric mean of the uranium concentrations for upgradient well X is defined as:

$$U_X = [(U_X1)(U_X2)..(U_Xn)]^{1/n}$$

Where:

U_X = Geometric mean of the uranium concentrations for well X;

U_{X1} = Uranium concentration of sample 1 taken from well X;

U_{X2} = Uranium concentration of sample 2 taken from well X; and

n = The number of samples taken from well X.

The geometric mean of the uranium concentrations for the 16 wells, a total of 228 measurements, was 0.0008 mg/L. This value is the best estimate of a background concentration for this site.

A3.2 STATISTICAL EVALUATION OF THE DATA

The Wilcoxon Two-Sample Rank Sum test was used to determine if there was a statistical difference between the upgradient and downgradient wells. The test *does not assume* that the data are from normal populations. The test does assume that the data consists of two independent random samples, sample 1 from population 1 and sample 2 from population 2. It also assumes that u^1 denotes the mean of population 1 and u^2 denotes the mean of population 2. The null hypothesis asserts that the two populations are equivalent, and thus under this hypothesis u1 = u2. This test is relatively insensitive to outliers (a value which is several orders of magnitude lower or higher than the majority of values in a set).

Well number OS-4 was selected as containing uranium concentrations which are representative of background values for this site. The geometric mean of the uranium concentrations for well OS-4 was 0.0007 mg/L which is in good agreement with the overall geometric mean of the 16 wells, 0.0008 mg/L (See Table A3-1). Well numbers OS-6 and OS-7 have uranium concentrations ranging from 0.0006 mg/L to 0.114 mg/L and 0.0005 mg/L to 0.0080 mg/L. The two values 0.114 mg/L and 0.0080 mg/L appear to be outliers. The second largest values for both of the wells are 0.0012 mg/L and 0.0011 mg/L respectively.

The value 0.0012 mg/L is about two orders of magnitude smaller than 0.114 mg/L and the value 0.0011 mg/L is about a factor of 8 smaller than 0.0080 mg/L. If these two values are discarded the range of uranium concentrations in Table A3-1 is from 0.0001 mg/L to 0.0027 mg/L. A well containing uranium concentrations with a similar range is OS-4 which had a range from 0.0003 mg/L to 0.0020 mg/L. This well was chosen as containing uranium concentrations which are representative of background values for this site.

A3.3 TEST FOR NORMALITY

The Student's T-test is used to determine if there is a statistical difference between upgradient and downgradient wells. The Student's t-test assumes that the data sets are random samples from normally distributed populations. A kurtosis test can be used to test if a set of data is a random sample from a normally distributed population. The kurtosis of a distribution describes its degree of peakedness or, more exactly, its peakedness relative to the length and size of its tails. A distribution that is relatively flat and has short tails is of low kurtosis and is said to be platykurtic. A distribution with a sharp peak and long tapering tails is of high kurtosis and is termed leptokurtic. The normal distribution is considered to be of intermediate kurtosis, and is said to be mesokurtic.

A series of kurtosis tests, the Geary test (Reference 17), was used for determining if the sets of data for the downgradient wells were random samples from normally distributed populations. The tests (Tables A3-2 through A3-6) indicated that some of the data sets were not random samples from a normally distributed population. In particular, the data from wells P-3, MW-1D, MW-3, MW-8S, and MW-9 were not normally distributed. The null hypothesis, that the observations (uranium concentrations) are a random sample from a normally distributed population, was rejected for these five wells using a two-sided, five percent level test. Since some of the downgradient water data sets were not normally distributed the Student's t-test was not used. The Geary test indicated that the distributions of the data sets for wells P-3, MW-3, MW-8S, and MW-9 were leptokurtic, and the distribution of the data set for well MW-1D was platykurtic.

TABLE A3-1

UPGRADIENT (BACKGROUND) WELL DATA

Well #	n	Geometric Mean (mg/L)	Range (mg/L)
OS-4	22	0.0007	0.0003-0.002
OS-5	22	0.0010	0.0003-0.0018
OS-6	23	0.0009	0.0006-0.114
OS-7	22	0.0007	0.0005-0.0080
OS-8	21	0.0002	0.0001-0.0005
OS-9	21	0.0014	0.0010-0.0020
OS-10	23	0.0005	0.0003-0.0010
OS-11	22	0.0002	0.0001-0.0007
OS-12	21	0.0007	0.0005-0.0016
OS-13	4	0.0004	0.0002-0.0008
OS-14	4	0.0003	0.0002-0.0004
OS-15	4	0.0003	0.0003
OS-16	5	0.0018	0.0013-0.0024
OS-17	5	0.0024	0.0020-0.0027
OS-18	5	0.0020	0.0018-0.0024
OS-19	4	0.0014	0.0014-0.0015
	228		

Geometric Mean = 0.0008 mg/L

Number of Measurements (n) = 228

TABLE A3-2

Test Of Well P3 for kurtosis

$\bar{x}$=0.0025 (Arithmetic Mean)
S.D.=0.0040
n=18

Geary Test $g = \dfrac{\sum_{i=1}^{n} |xi-\bar{x}|}{s\sqrt{n(n-1)}}$

$$\sum_{i=1}^{n} |xi-\bar{x}| = 0.0023+0.0023+0.0023$$
$$+0.0021+0.0021+0.0020$$
$$+0.0020+0.0019+0.0015$$
$$+0.0014+0.0005+0.0005$$
$$+0.0005+0.0005+0.0005$$
$$+0.0005+0.0013+0.0155$$
$$=0.0397$$

$$g = \frac{0.0397}{(0.0040)\sqrt{18(17)}} = 0.5674$$

Ho: Observations are a random sample from a normally distributed population.

Reject Ho using a two-sided 5 percent level test.
if $g \leq g0.025$
or $g \geq g0.975$
for this case $g \leq 0.7080$
$g \geq 0.8948$

Ho Rejected

TABLE A3-3

Test Of Well MW-1D for kurtosis

$\bar{x}$=0.0017 (Arithmetic Mean)
S.D.=0.0012
n=16

Geary Test $g=\dfrac{\sum_{i=1}^{n}|xi-\bar{x}|}{s\sqrt{n(n-1)}}$

$$\sum_{i=1}^{n}|xi-\bar{x}|=0.0014+0.0014+0.0012$$

+0.0011+0.0009+0.0009

+0.0009+0.0007+0.0002

+0.0003+0.0013+0.0013

+0.0013+0.0013+0.0013

+0.0023= 0.0178

$$g=\frac{0.0178}{(0.0012)\sqrt{(16)(15)}}=0.9575$$

Ho: observations are a random sample from a normally distributed population.

Reject Ho using a two-sided 5 percent level test if $g \leq g0.025$
or $g \geq g0.975$

for this case $g \leq 0.7033$
$g \geq 0.9011$

Ho Rejected

TABLE A3-4

Test of Well MW-3 for Kurtosis

$\bar{x}$=0.0036 (Arithmetic Mean)
S.D.=0.0021
n=17

Geary Test $g=\dfrac{\sum_{i=1}^{n}|xi-\bar{x}|}{s\sqrt{n(n-1)}}$

$$\sum_{i=1}^{n}|xi-\bar{x}|=0.0030+0.0028+0.0017$$
$$+0.0010+0.0006+0.0006$$
$$+0.0006+0.0005+0.0005$$
$$+0.0005+0.0001+0.0004$$
$$+0.0004+0.0004+0.0014$$
$$+0.0024+0.0064$$
$$= 0.0233$$

$$g=\frac{0.0233}{(0.0021)\sqrt{(17)\ (16)}}=0.6727$$

Ho: observations are a random sample from a normally distributed population.

Reject Ho using a two-sided 5 percent level test if $g \leq g0.025$ or $g \geq g0.975$

for this case $g \leq 0.7033$
$g \geq 0.9011$

Ho Rejected

TABLE A3-5

Test Of Well MW-8S for kurtosis

$\bar{x}$=0.0030 (Arithmetic Mean)
S.D.=0.0034
n=16

Geary Test $g=\dfrac{\sum_{i=1}^{n}|xi-\bar{x}|}{s\sqrt{n(n-1)}}$

$\sum_{i=1}^{n}|xi-\bar{x}|$=0.0027+0.0022+0.0021

+0.0021+0.0019+0.0018

+0.0018+0.0014+0.0010

+0 +0 +0

+0 +0.0010+0.0050

+0.011

= 0.034

$$g=\frac{0.034}{(0.0034)\sqrt{(16)(15)}}=0.6455$$

Ho: observations are a random sample from a normally distributed population.

Reject Ho using a two-sided 5 percent level test if $g \leq g_{0.025}$
or $g \geq g_{0.975}$

for this case $g \leq 0.7033$
$g \geq 0.9011$

Ho Rejected

APPENDIX 4

BORING LOGS AND MONITOR WELL CONSTRUCTION SPECIFICATIONS

MAJOR DIVISIONS			GRAPH SYMBOL	LETTER SYMBOL	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
				GP	POORLY-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
	MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES
MORE THAN 50% OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE	SAND AND SANDY SOILS	CLEAN SAND (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
				SP	POORLY-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
	MORE THAN 50% OF COARSE FRACTION PASSING NO. 4 SIEVE	SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND-SILT MIXTURES
				SC	CLAYEY SANDS, SAND-CLAY MIXTURES
FINE GRAINED SOILS	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
MORE THAN 50% OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
				OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS.

SOIL CLASSIFICATION CHART

UNIFIED SOIL CLASSIFICATION SYSTEM

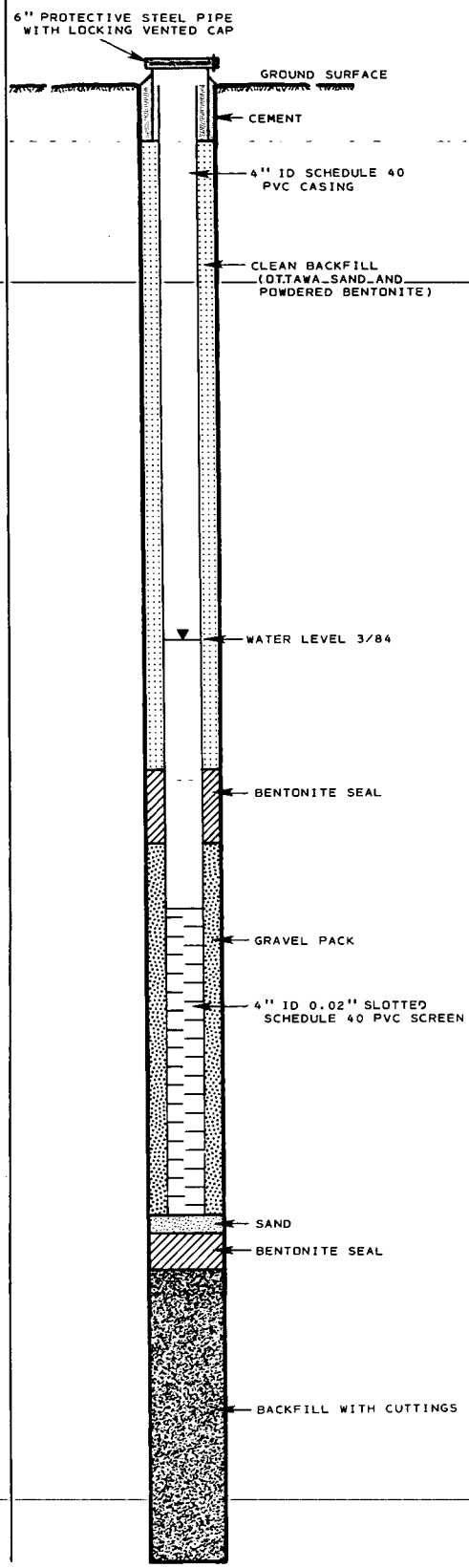
NOTE: Color designations are based on
The Geological Society of America's
Rock Color Chart (Reference 13).

DAMES & MOORE

FIGURE A4-1

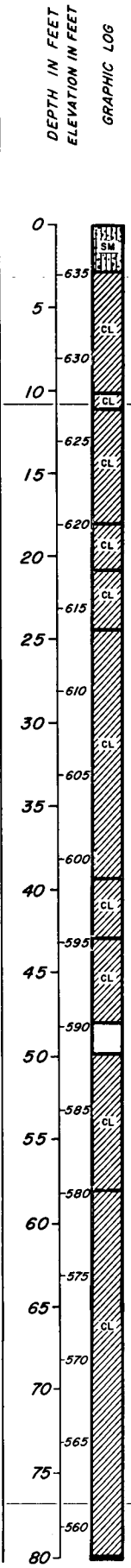
WELL SCHEMATICS

12D



BORING 12

SURFACE ELEVATION 637.0'



DESCRIPTIVE GEOLOGIC NOTES

- GRASS, SILTY SAND WITH UNDERLYING RIP-RAP LIMESTONE COBBLES
- PALE OLIVE (10Y6/2) MASSIVE CLAY WITH SOME IRON STAINED FRACTURES
- MEDIUM BLUISH-GRAY CLAY (5B5/1) MASSIVE, DENSE, DRY, NO FRACTURES
- MEDIUM BLUISH-GRAY CLAY (5B5/1) WITH SOME GRAVEL, IRON OXIDE STAINING
- MEDIUM BLUISH-GRAY CLAY (5B5/1) WITH SOME SAND
- MEDIUM BLUISH-GRAY CLAY (5B5/1) MORE FRIABLE THAN ABOVE
- MEDIUM BLUISH-GRAY CLAY (5B5/1), MASSIVE, VARVED, FRIABLE
- OLIVE GRAY (5Y3/2) CLAY WITH SILT
- DARK GREENISH-GRAY (5GY4/1) CLAY WITH THIN GRAVEL LENS (~1/4" THICK) OF IRON STAINED QUARTZ, A FEW SHALE FRAGMENTS 1/2" DIAMETER PRESENT
- DRILL BIT CHATTERING, CUTTINGS SHOW LIMESTONE FRAGMENTS, POSSIBLE BOULDERS OR BEDROCK
- DARK GREENISH-GRAY (5GY4/1) CLAY, VERY DENSE, THINLY BEDDED, DRY, ALMOST A SHALE
- NO SAMPLE, SOFT GREENISH-GRAY SHALE
- BORING TERMINATED AT A DEPTH OF 80 FEET

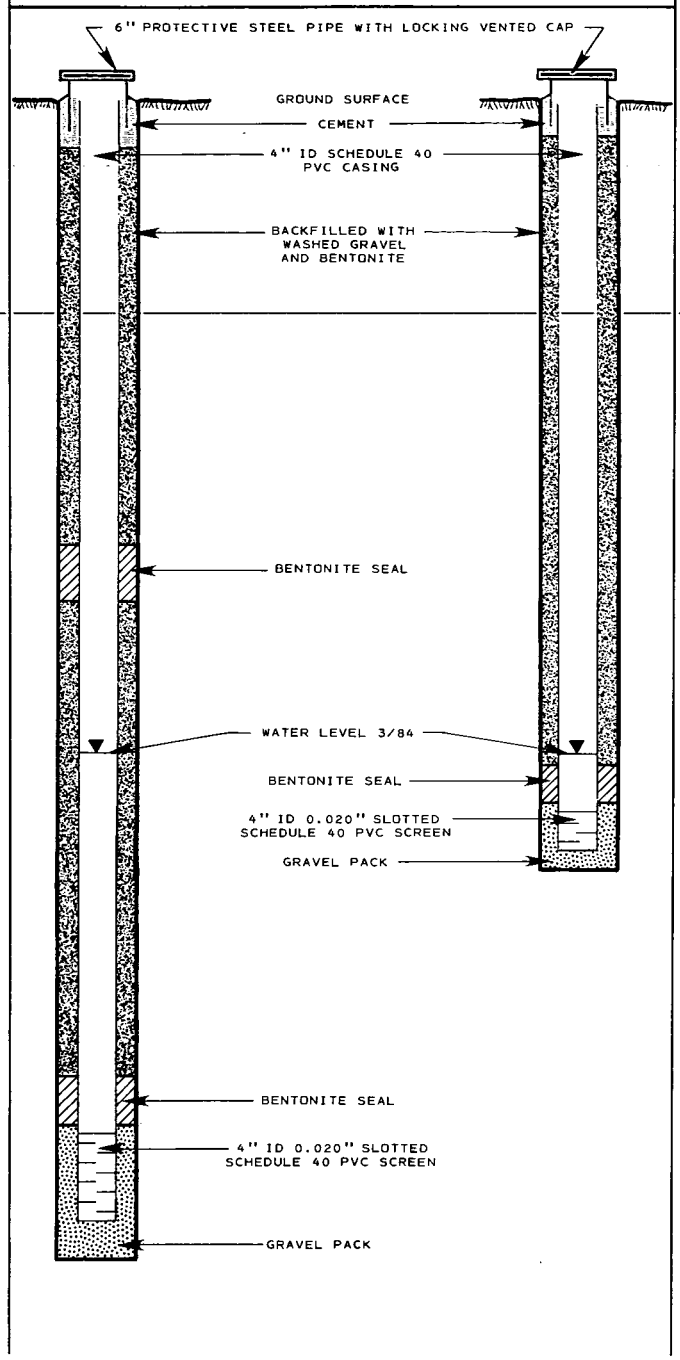
DAMES & MOORE

FIGURE A4-2

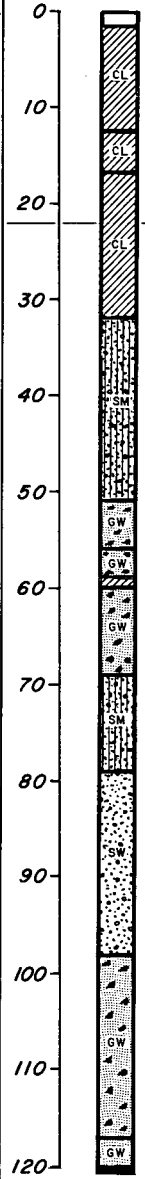
BORING 13

SURFACE ELEVATION 13D 588.52'
13S 588.73'

WELL SCHEMATICS



DEPTH IN FEET | *GRAPHIC LOG* | *DESCRIPTIVE GEOLOGIC NOTES*



LIMESTONE RIP-RAP
OLIVE GRAY (5Y3/2) CLAY WITH SOME SILT, LESS THAN 3% GRAVEL, SLIGHT YELLOWISH OXIDATION PARTICLES IN UPPER 2", CLAY IS PLASTIC, DENSE

ALMOST PURE CLAY AS ABOVE, LITTLE TO NO SILT OR GRAVEL

OLIVE GRAY (5Y3/2) SILTY CLAY WITH UP TO 5% GRAVEL, LARGE FRAGMENTS OF LIMESTONE AND QUARTZ (UP TO 2" IN DIAMETER)

LIGHT OLIVE GRAY (5Y5/2) MEDIUM TO COARSE GRAINED, MOIST WELL SORTED SILTY SAND, GRAVEL UP TO 2%

COARSE GRAVEL (QUARTZ AND LIMESTONE FRAGMENTS)

BROWN CLAY
COARSE GRAVEL

SILTY SAND WITH SOME GRAVEL

SAND-GRAVEL

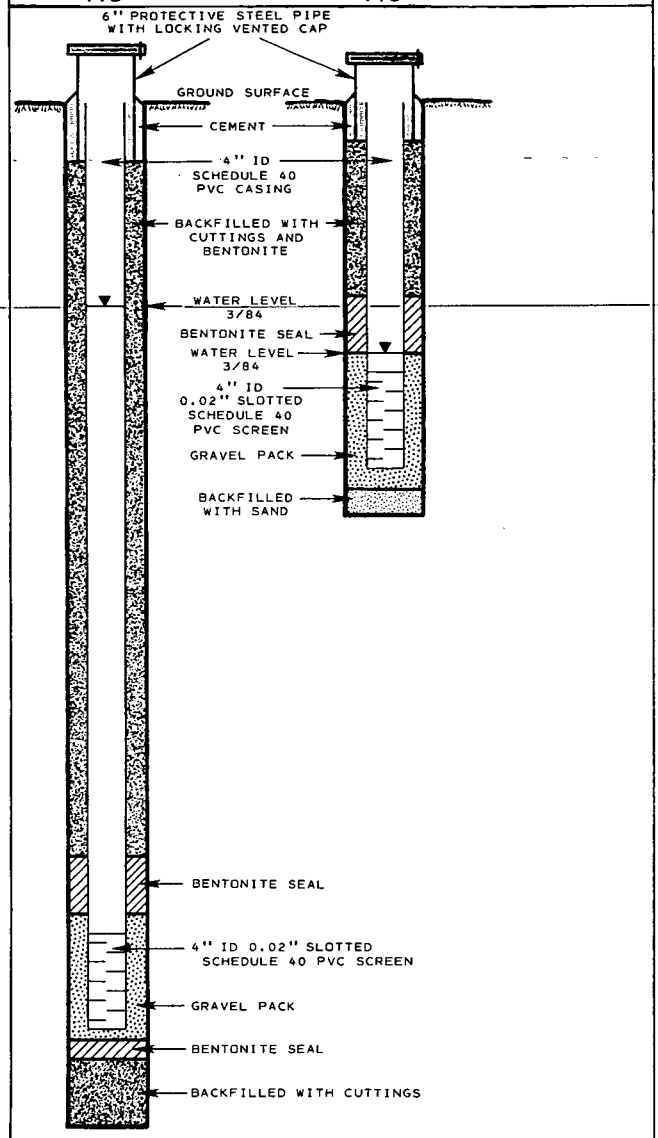
GRAVEL

COARSE GRAVEL
BORING TERMINATED AT A DEPTH OF 120.0' ON 2/4/85

DAMES & MOORE

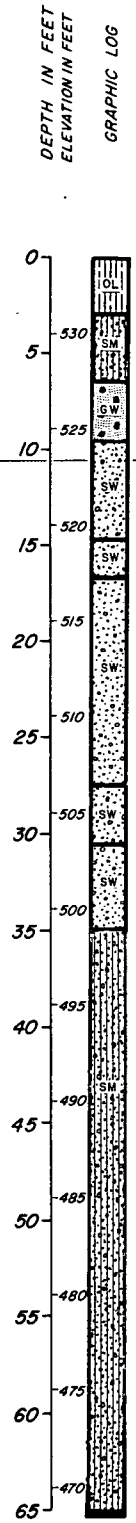
FIGURE A4-3

WELL SCHEMATICS



BORING 14

SURFACE ELEVATION 14D 533.71'
14S 533.79'



DESCRIPTIVE GEOLOGIC NOTES

GRASS OVER SILTY LOAM

OLIVE GRAY (5Y3/2) SILTY SAND WITH UP TO 10% GRAVEL, BLEACHED CLAY PODS PRESENT

OLIVE BROWN (5Y4/4) COARSE GRAVEL IN MEDIUM SAND MATRIX

OLIVE BROWN (5Y4/4) MEDIUM TO COARSE GRAINED SAND, 3-10% GRAVEL

OLIVE BROWN (5Y4/4) FINE TO MEDIUM GRAINED SAND, LESS THAN 1% GRAVEL

OLIVE BROWN (5Y4/4) MEDIUM TO COARSE SAND WITH UP TO 3% GRAVEL

CONTAINS SEVERAL LARGE (1.5" DIAMETER) PEBBLES OF LIMESTONE AND QUARTZ

OLIVE BROWN (5Y4/4) COARSE SAND WITH SOME GRAVEL

OLIVE BROWN (5Y4/4) COARSE SAND WITH SILT, LESS THAN 1% GRAVEL

BORING TERMINATED AT A DEPTH OF 65.0' ON 8/10/84

DAMES & MOORE

FIGURE A4-4

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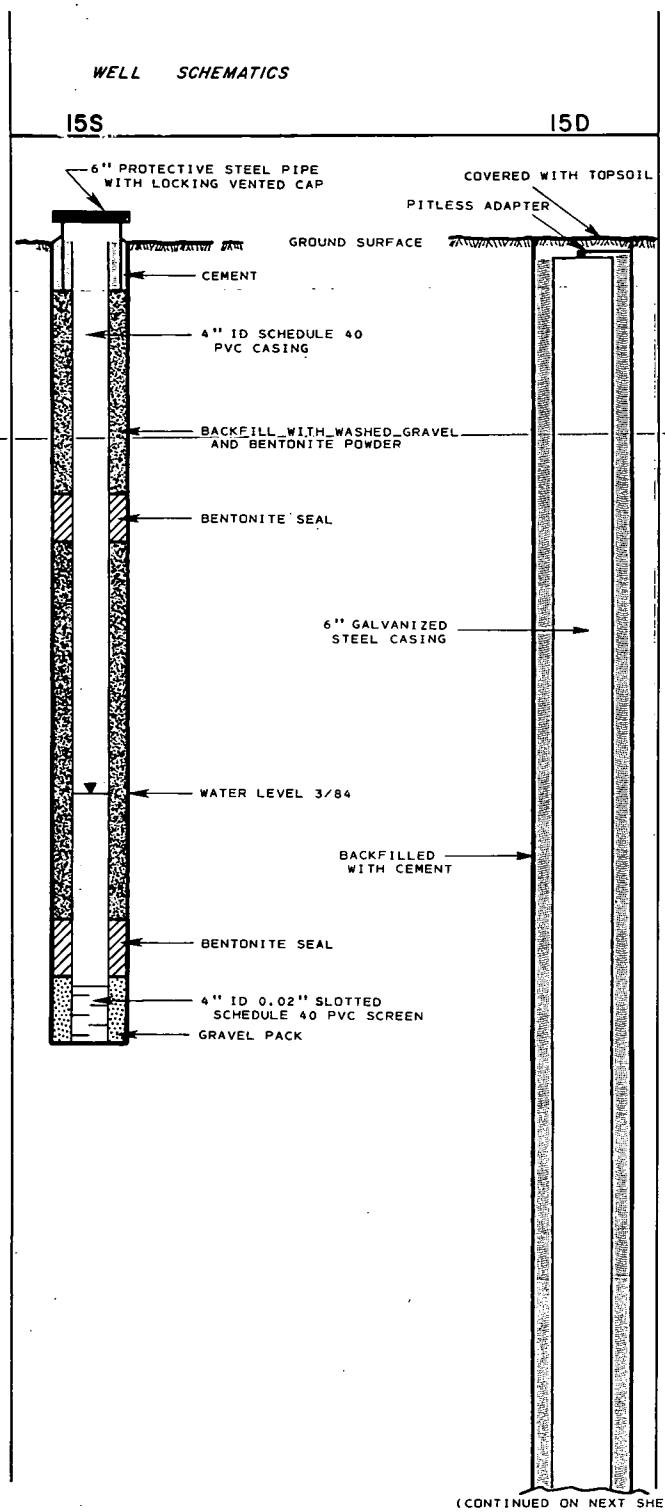
BORING 15

SURFACE ELEVATION 15S 579.41'
15D 577.80'

WELL SCHEMATICS



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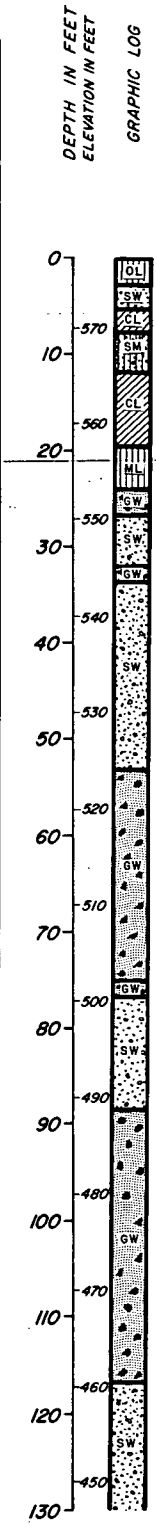

DESCRIPTIVE GEOLOGIC NOTES

CLAYEY LOAM TOPSOIL

MEDIUM TO FINE GRAINED SAND

LIGHT OLIVE BROWN (5Y5/6) SILTY CLAY WITH IRON STAINS AND BLEACHED PODS

LIGHT OLIVE BROWN (5Y5/6) SILTY SAND AND SANDY SILT, WELL GRADED

GRAYISH OLIVE (10Y4/2) MASSIVE LENSE OF SILTY CLAY WITH SOME GRAVEL (UP TO 5-7%)

DENSE DRY CLAYEY SILT

MEDIUM TO COARSE GRAVEL

LIGHT OLIVE BROWN (5Y5/6) COARSE SAND WITH SOME GRAVEL (QUARTZ AND LIMESTONE FRAGMENTS)

GRAVEL WITH SOME CLAY

OLIVE BROWN (5Y5/6) MEDIUM TO COARSE SAND WITH SOME GRAVEL

COARSE WELL SORTED GRAVEL, LESS THAN 1% SILT OR CLAY

LIGHT OLIVE BROWN SANDY GRAVEL

LIGHT OLIVE BROWN GRAVELLY SAND

LIGHT OLIVE BROWN GRAVEL WITH SOME SAND

GRAYISH-BROWN GRAVELLY SAND

DAMES & MOORE

FIGURE A4-5A

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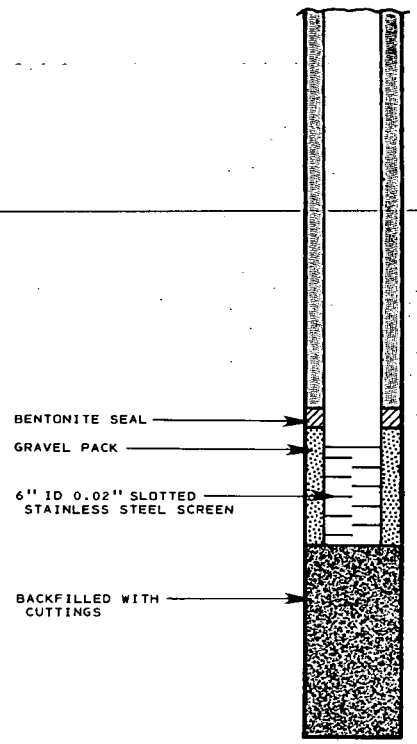
BORING 15

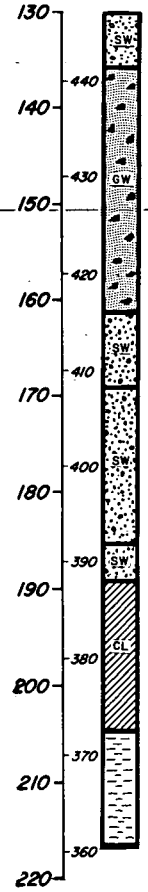
WELL SCHEMATICS

15D
(CONTINUED)



DEPTH IN FEET
ELEVATION IN FEET
GRAPHIC LOG

DESCRIPTIVE GEOLOGIC NOTES



GRAYISH-BROWN GRAVELLY SAND

GRAVEL WITH SOME SAND

GRAVELLY SAND

OLIVE GRAY SAND WITH UP TO 10% GRAVEL
SAND, NO GRAVEL

SAND, NO GRAVEL

GRAY CLAY GRADING INTO GREENISH-BLACK
("BLUE CLAY") SILTY CLAY, LARGE COBBLES
ON TOP OF CLAY LAYER

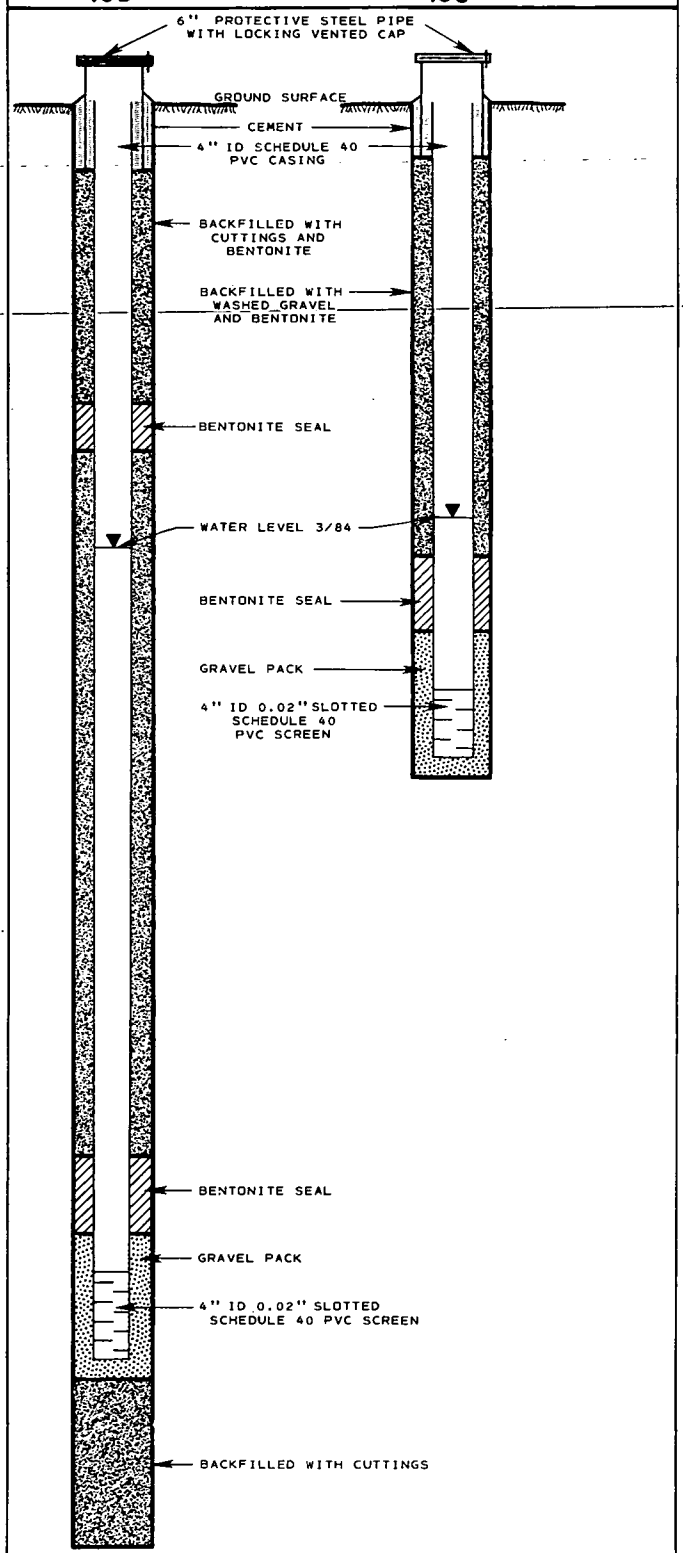
SHALE

BORING TERMINATED AT A DEPTH OF 217.0' ON 8/9/84

DAMES & MOORE

FIGURE A4-5B

WELL SCHEMATICS



BORING 16

SURFACE ELEVATION 16D 540.47'
16S 540.50'

DEPTH IN FEET	ELEVATION IN FEET	GRAPHIC LOG	DESCRIPTIVE GEOLOGIC NOTES
0	540	ML	0-9" BLACK SILTY FILL MATERIAL (PROBABLY FLYASH)
		ML	DARK YELLOWISH BROWN (10YR5/4) CLAYEY SILT
5	535	SM	LIGHT OLIVE BROWN (5Y5/6) MEDIUM TO COARSE GRAINED SILTY SAND, CONTAINS LIMESTONE FRAGMENTS UP TO 3" AND PEBBLES OF QUARTZ (SUBROUNDED TO ANGULAR) DECREASING IN QUANTITY WITH DEPTH
10	530		
		SM	LIGHT OLIVE BROWN (5Y5/6) SILTY SAND, NO PEBBLES WELL SORTED, DECREASING IN GRAIN SIZE WITH DEPTH
15	525	SM	
20	520	SM	
25	515	SM	DUSKY YELLOW (5Y6/4) FINE GRAINED SILTY SAND
30	510		LIGHT OLIVE BROWN (5Y5/6) MEDIUM TO COARSE GRAINED SANDY GRAVEL WITH PEBBLES OF QUARTZ (UP TO 1/2" DIAMETER) AND LIMESTONE (ROUNDED TO SUBROUNDED)
35	505	GW	
40	500		LIGHT OLIVE BROWN (5Y5/6) MEDIUM TO COARSE GRAINED SAND WITH GRAVEL, WELL SORTED
		SW	
45	495		LIGHT OLIVE BROWN (5Y5/6) COARSE GRAINED SANDY GRAVEL WITH SUBANGULAR TO SUBROUNDED PEBBLES OF QUARTZ AND LIMESTONE
50	490	GW	
55	485		
60	480		OLIVE BROWN (5Y4/4) MEDIUM TO COARSE GRAINED SAND
		SW	
65	475	SM	DARK OLIVE BROWN (5Y4/4) TO LIGHT OLIVE BROWN (5Y5/6) SILTY SAND
70	470		
75	465		BORING TERMINATED AT A DEPTH OF 75.0' ON 1/17/85

DAMES & MOORE

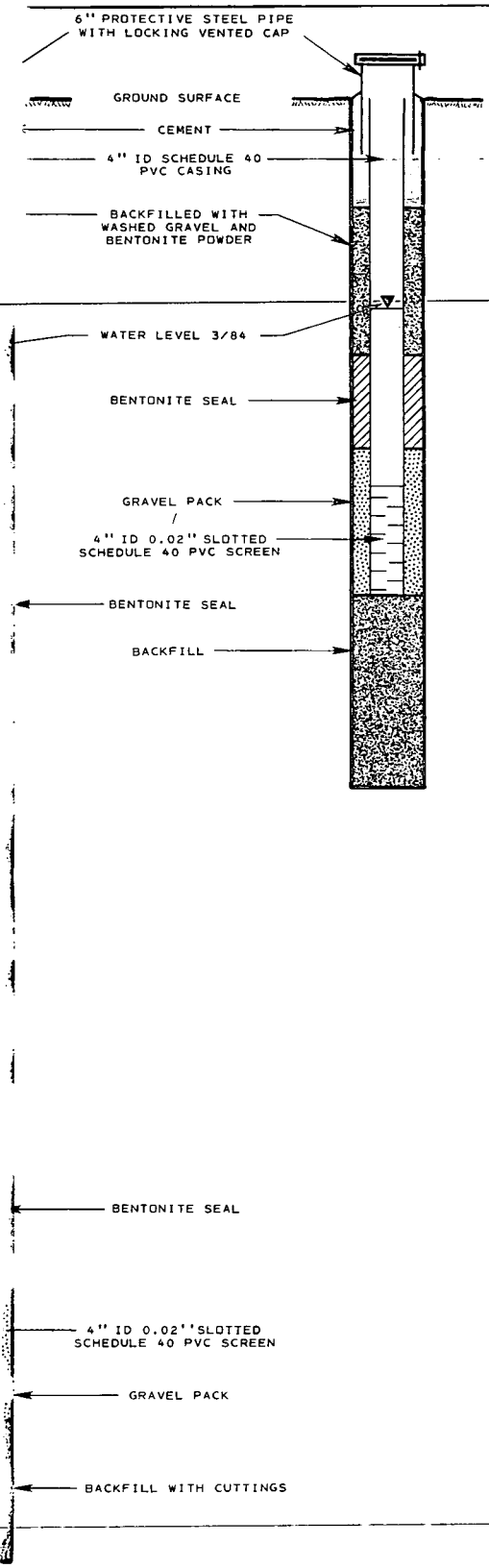
FIGURE A4-6

BORING 17

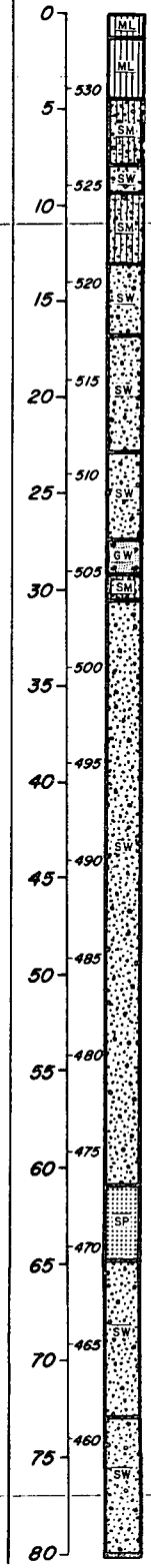
SURFACE ELEVATION 17D 534.28'
17S 534.43'

SCHEMATICS

17S



DEPTH IN FEET / *ELEVATION IN FEET* / *GRAPHIC LOG*



DESCRIPTIVE GEOLOGIC NOTES

BROWN CLAYEY SILT

PALE BROWN (5YR5/2) CLAYEY SILT, SOME ROOTS CONTACT IS SHARP AND WELL DEFINED

LIGHT OLIVE BROWN (5Y5/6) SILTY SAND WITH SMALL AMOUNT OF GRAVEL, DRY LOOSE, SOME YELLOW LIMONITE STAINING NEAR CONTACT WITH CLAYEY SILT

LIGHT OLIVE BROWN (5Y5/6) GRAVELLY SAND, CONTACT IS SHARP AND WELL DEFINED

MEDIUM TO FINE GRAINED LIGHT OLIVE BROWN (5Y5/6) SILTY SAND, WELL SORTED

LIGHT OLIVE BROWN (5Y5/6) COARSE GRAVELLY SAND, CONTACT IS GRADATIONAL

LIGHT OLIVE BROWN (5Y5/6) FINE TO MEDIUM WELL SORTED SAND, MODERATE OLIVE BROWN (5Y4/4) COARSE TO MEDIUM WELL SORTED SAND

LIGHT OLIVE GRAY (5Y5/2) TO LIGHT OLIVE BROWN (5Y5/6) GRAVELLY SAND WITH SOME SILT AND PEBBLES UP TO 1" IN DIAMETER, CONTACT IS SHARP AND WELL DEFINED

COARSE GRAVEL, WELL SORTED CONSISTING OF LIMESTONE AND QUARTZ PEBBLES, CONTACT IS GRADATIONAL WITH GRAVEL GOING TO A MEDIUM TO COARSE SAND

LIGHT OLIVE BROWN (5Y5/6) MEDIUM TO COARSE GRAINED, WELL SORTED SILTY SAND

LIGHT OLIVE BROWN (5Y5/6) MEDIUM TO COARSE SAND WITH UP TO 5% GRAVEL

DARK OLIVE BROWN (5Y4/4) SAND WITH UP TO 1% GRAVEL, COARSER GRAINED AND NOT AS WELL SORTED AS ABOVE

DARK YELLOWISH BROWN (10YR6/6) MEDIUM TO COARSE SAND WITH 5% GRAVEL

DARK YELLOWISH BROWN (10YR6/6) FINE TO MEDIUM GRAINED SAND

BORING TERMINATED AT A DEPTH OF 80.0' ON 1/29/85

DAMES & MOORE

FIGURE A4-7

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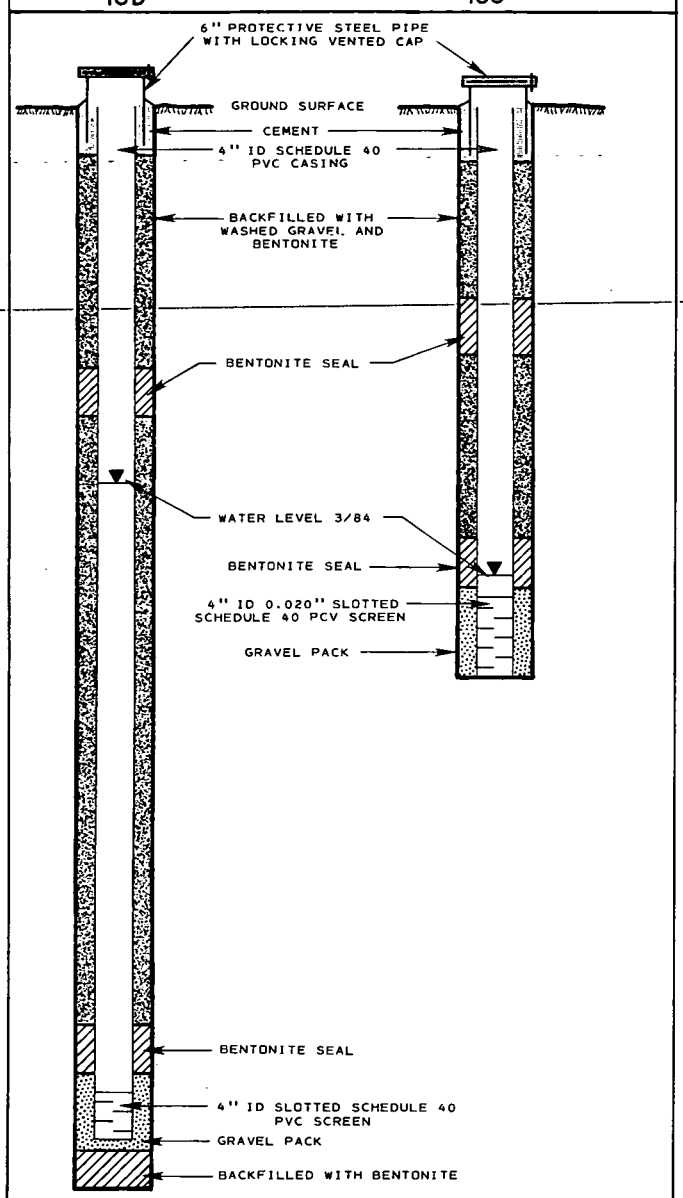
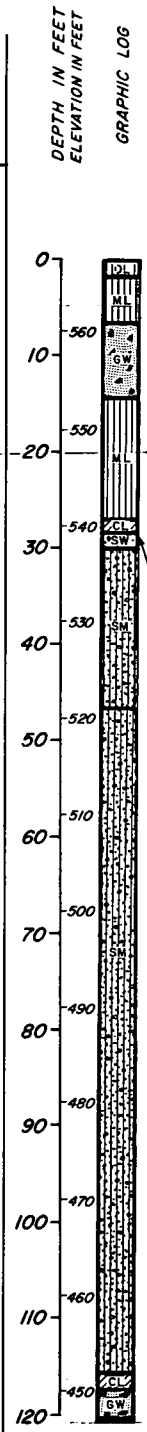
56

WELL SCHEMATICS



BORING 18

SURFACE ELEVATION 18D 521.56'
18S 521.31'



DESCRIPTIVE GEOLOGIC NOTES

FROZEN SOIL TO 1.3' MEDIUM TO COARSE SANDY LOAM

DUSKY YELLOW (5Y6/4) CLAYEY SILT, CONTAINS THIN BANDS OF LIGHT OLIVE BROWN CLAYEY SILT

LIGHT OLIVE GRAY (5Y5/2) CLAYEY SILT, CONTAINS LESS THAN 1% ANGULAR TO SUBANGULAR QUARTZ AND LIMESTONE FRAGMENTS, SILTY SAND ENCOUNTERED AT BOTTOM

LIGHT OLIVE GRAY (5Y5/2) SILTY CLAY WITH UP TO 10% GRAVEL CONSISTING OF QUARTZ AND LIMESTONE FRAGMENTS (0.5" IN DIAMETER)

LIGHT OLIVE BROWN (5Y5/6) SAND, WELL SORTED

LIGHT OLIVE GRAY (5Y5/2) SILTY SAND WITH SOME GRAVEL (1-4%)

LIGHT OLIVE BROWN (5Y5/6) SILTY SAND, FINER GRAINED THAN ABOVE, NO NOTICEABLE GRAVEL

GREENISH-BLACK ("BLUE CLAY") SILTY CLAY (5G2/1)

COARSE GRAVEL 1/4-1/2" IN DIAMETER

BORING TERMINATED AT A DEPTH OF 120.0' ON 1/23/85

DAMES & MOORE

FIGURE A4-8

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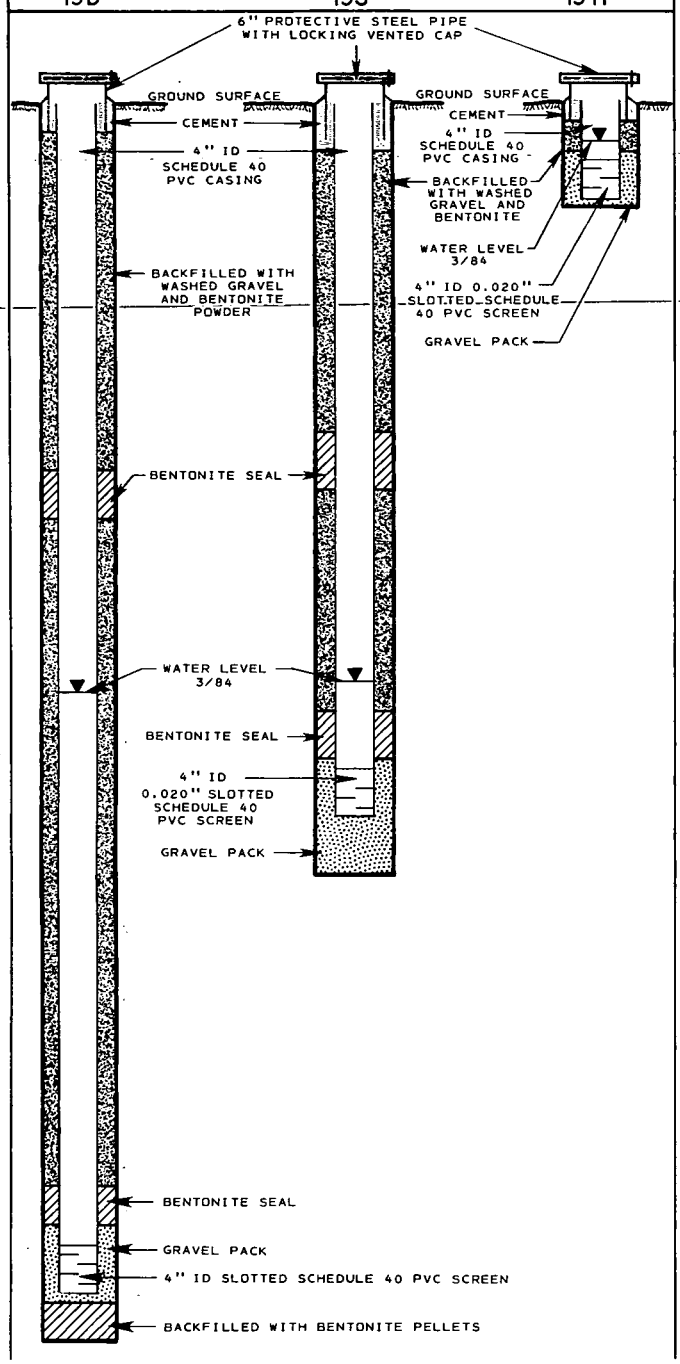
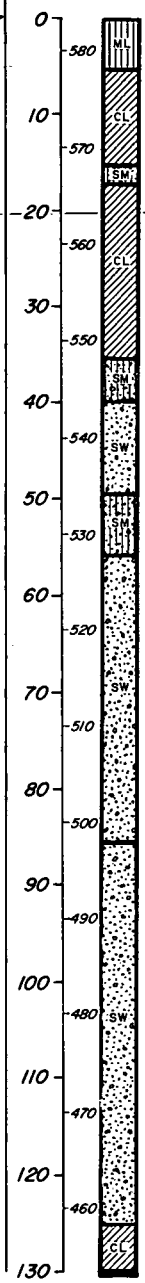
BORING 19

SURFACE ELEVATION 19D 583.20'
19S 583.26'
19TP 582.98'

WELL SCHEMATICS



DEPTH IN FEET | *GRAPHIC LOG* | *DESCRIPTIVE GEOLOGIC NOTES*



LIGHT OLIVE BROWN (5Y5/6) CLAYEY SILT, CONTAINS STREAKS OF DUSKY YELLOW SILT, SOME GRAVEL

LIGHT OLIVE GRAY (5Y5/2) SILTY CLAY, CONTAINS DUSKY YELLOW SILT, NO GRAVEL

LIGHT OLIVE BROWN (5Y5/6) SANDY SILT WITH UP TO 5% GRAVEL, CONTACT IS SHARP AND WELL DEFINED

LIGHT OLIVE GRAY (5Y5/2) SILTY CLAY WITH 2% GRAVEL

LIGHT OLIVE BROWN (5Y5/6) SILTY SAND WITH 3% GRAVEL

MODERATE OLIVE BROWN (5Y4/4) GRAVELLY SAND MEDIUM TO COARSE GRAINED, SOME GRAVEL, CONTACT IS GRADATIONAL

LIGHT OLIVE BROWN (5Y5/6) FINE TO MEDIUM GRAINED WELL SORTED SILTY SAND

OLIVE GRAY (5Y3/2) MEDIUM TO COARSE GRAINED WELL SORTED SAND

LIGHT OLIVE BROWN (5Y5/6) MEDIUM TO COARSE GRAINED WELL SORTED SAND

GREENISH-BLACK ("BLUE CLAY") (5G2/1) SILTY CLAY

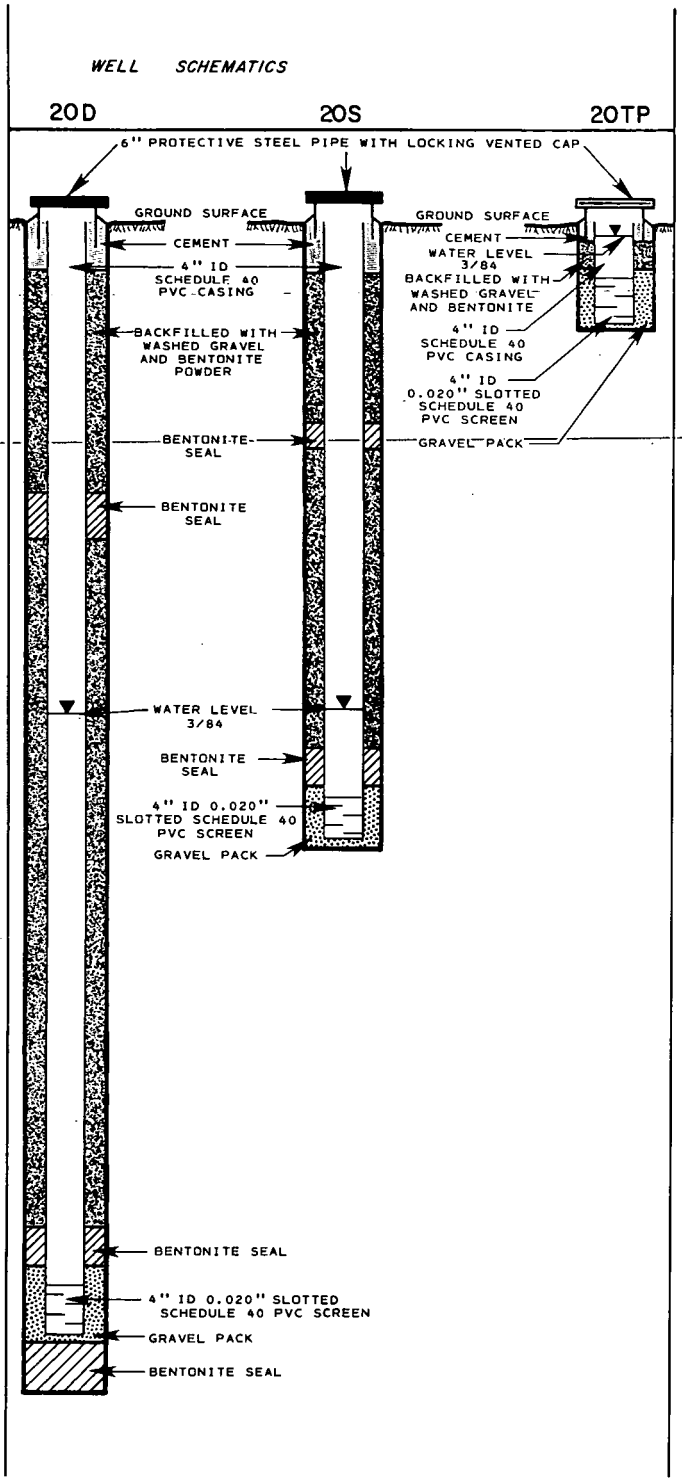
BORING TERMINATED AT A DEPTH OF 130.0' ON 2/6/85

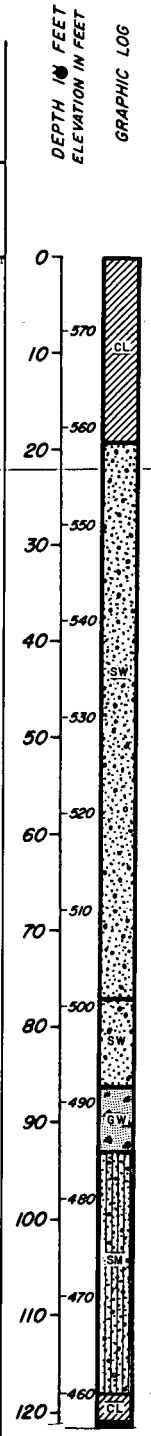
DAMES & MOORE

FIGURE A4-9

BORING 20

SURFACE ELEVATION 20D 573.31'
20S 573.42'
20TP 573.21'





DESCRIPTIVE GEOLOGIC NOTES

LIGHT OLIVE BROWN (5Y5/6) SILTY CLAY, DRY, DENSE, STIFF

LIGHT OLIVE BROWN (5Y5/6) SAND WITH UP TO 10% GRAVEL

LIGHT OLIVE GRAY (5Y5/2) COARSE SAND WITH GRAVEL

GRAY SANDY GRAVEL

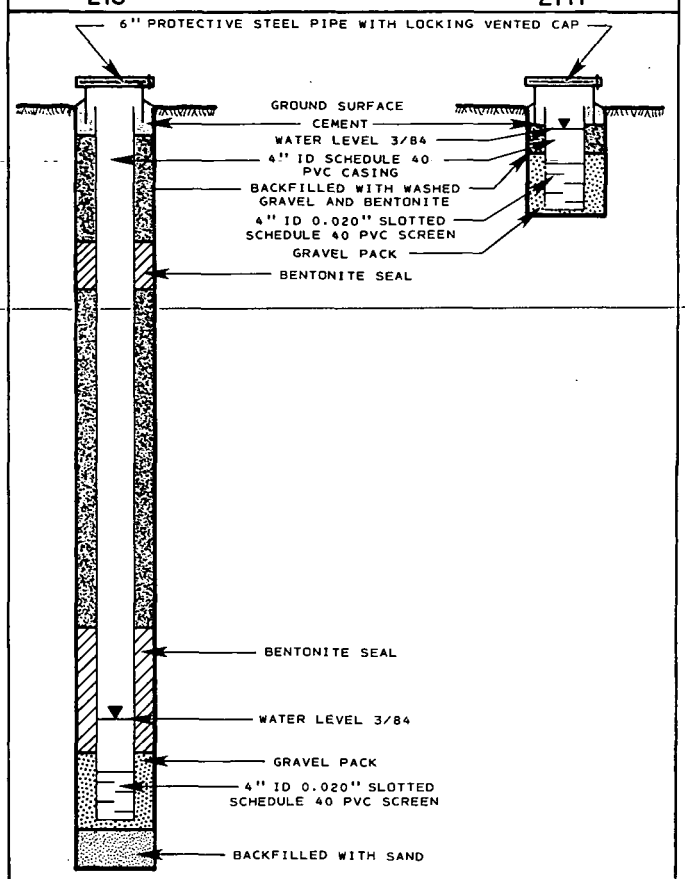
GRAYISH OLIVE (10Y4/2) MEDIUM TO COARSE WELL SORTED SILTY SAND

GREENISH-BLACK ("BLUE CLAY") (5G2/1) SILTY CLAY
BORING TERMINATED AT A DEPTH OF 121.0' ON 1/28/85

DAMES & MOORE

FIGURE A4-10

WELL SCHEMATICS



BORING 21

SURFACE ELEVATION 21S 584.42'
21TP 584.06'

DEPTH IN FEET	ELEVATION IN FEET	GRAPHIC LOG	DESCRIPTIVE GEOLOGIC NOTES
0			ROAD FILL, COARSE GRAVEL
		ML	DARK YELLOWISH BROWN (10YR4/2) CLAYEY SILT UP TO 5% SAND AND GRAVEL
10	575	ML	LIGHT OLIVE GRAY (5Y5/2) CLAYEY SILT, WITH UP TO 5% SAND OR GRAVEL
20	565	GM	LIGHT OLIVE GRAY (5Y5/2) SILTY GRAVEL
30	555	ML	LIGHT OLIVE GRAY (5Y5/2) SILTY GRAVEL
40	545	ML	MIXTURE OF DARK YELLOWISH BROWN (10YR4/2) AND LIGHT OLIVE GRAY (5Y5/2) CLAYEY SILT, UP TO 5% GRAVEL, MEDIUM TO COARSE GRAINED SAND ENCOUNTERED AT 40.5'
50	535	SW	LIGHT OLIVE GRAY (5Y5/2) MEDIUM TO CAORSE GRAINED WELL SORTED SAND, UP TO 3% GRAVEL
60	525	SW	LIGHT OLIVE GRAY (5Y5/2) MEDIUM TO COARSE GRAINED SAND, SOME GRAVEL, CONTAINS THIN LAYER OF BROWNISH-YELLOW FINE SAND
70	515	SW	LIGHT OLIVE BROWN (5Y5/6) MEDIUM TO COARSE GRAINED SAND (LESS THAN 1% GRAVEL) WITH SOME SILT
80	505	GW	COARSE GRAVEL WITH SOME SAND BORING TERMINATED AT A DEPTH OF 80.0' ON 2/13/85

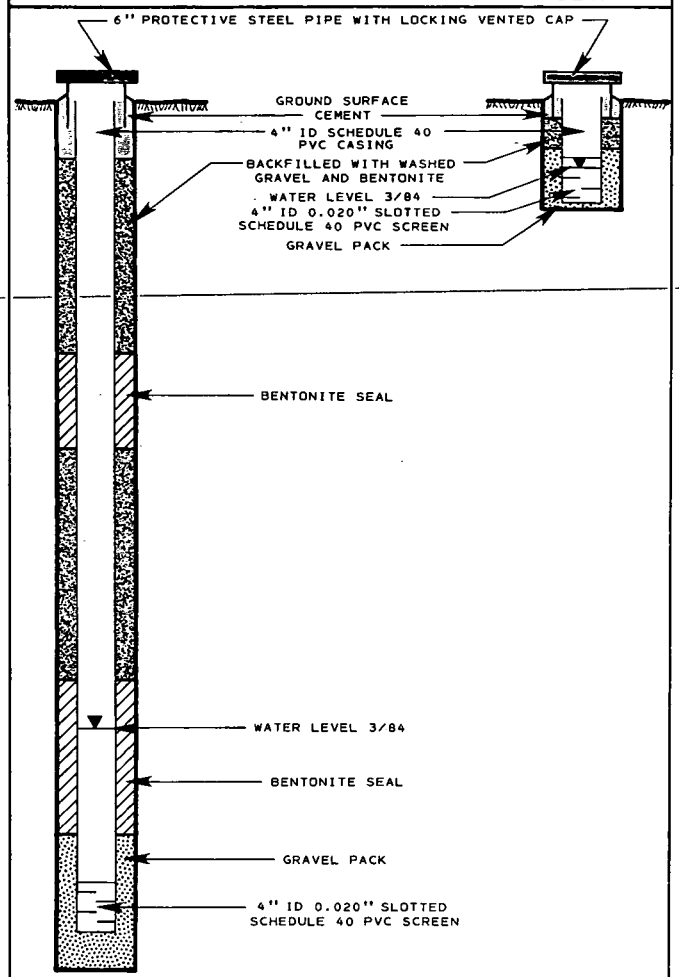
DAMES & MOORE

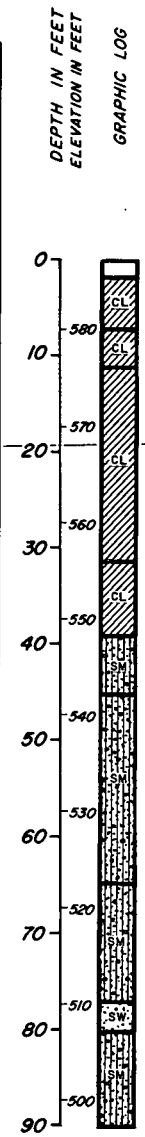
FIGURE A4-11

BORING 22

SURFACE ELEVATION 22S 582.93'
22TP 582.93'

WELL SCHEMATICS





DESCRIPTIVE GEOLOGIC NOTES

COARSE GRAVEL IN SILT MATRIX ON BERM

OLIVE GRAY (5Y3/2) SILTY CLAY, LESS THAN 1% VERY COARSE GRAVEL

DARK YELLOWISH BROWN (10Y4/2) SILTY CLAY, DRY, DENSE, STIFF

LIGHT OLIVE GRAY (5Y5/2) SILTY CLAY, STIFF, DRY, LESS THAN 1% GRAVEL

LIGHT OLIVE GRAY (5Y5/2) GRAVELLY SILTY CLAY

LIGHT OLIVE BROWN (5Y5/6) MEDIUM TO FINE GRAINED WELL SORTED SILTY SAND, GRADES INTO MEDIUM TO COARSE GRAINED SILTY SAND

LIGHT OLIVE BROWN (5Y5/6) MEDIUM TO FINE GRAINED SILTY SAND WITH SOME OLIVE BROWN CLAY

LIGHT OLIVE BROWN (5Y5/6) SILTY SAND, UP TO 15% GRAVEL

COARSE SAND AND GRAVEL, UP TO 15% SILT

LIGHT OLIVE BROWN (5Y5/6) SILTY SAND, UP TO 15% GRAVEL

BORING TERMINATED AT A DEPTH OF 90.0' ON 2/14/85

DAMES & MOORE

FIGURE A4-12