CONSOLIDATING FINE-GRAINED DREDGED MATERIAL WITH VACUUM WELLPOINTS

By

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PREFACE

This study is concerned with the feasibility of utilizing a vacuum wellpoint system to consolidate fine-grained materials. The primary application would be for use in dredge disposal areas. The research was conducted as part of the Dredged Material Research Program which was administered by the Waterways Experiment Station, U.S. Army Corps of Engineers. An ever increasing need for dredged material disposal space and continually decreasing land space prompted the need for this research program.

The author wishes to express his appreciation to his major adviser, Dr. T. Allan Haliburton, for his guidance and assistance throughout this study.

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Finally, special gratitude is expressed to my wife, Sheila, our daughter, Dawn, and our son, Michael, for their understanding, encouragement, and sacrifices.

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CHAPTER I

INTRODUCTION

Dredging

For the purpose of this study and report, the term "dredging" will infer the removal of sediment and other materials from the bottom of rivers, bays, and other bodies of water. Dredging is traditionally conducted for the purpose of deepening and/or widening these bodies of water to accommodate navigation. In many instances, waterways utilized for navigation are associated with major drainage courses. Therefore, maintenance for navigation is often a repetitive requirement.

Most dredging in the United States is conducted by the U.S. Army Corps of Engineers. In recent years, the Corps of Engineers has averaged dredging 300 million yd^3 (290 million m^3) of material annually at a cost of approximately $170 million per year (16).

The by-product of dredging is usually large quantities of waste material. This by-product often consists of fine grained soils. Bishop and Vaughn (1) have indicated that "organic silty clay of high plasticity is a general and consistent product of maintenance dredging." This waste material has been traditionally dumped into open water or into containment areas. However, increasing environmental concern has greatly reduced or negated open water disposal. This concern is usually based on the turbidity effect of dumping fine grained materials. Therefore, the future of dredge disposal would appear to rest with on-land containment ponds. However, several problems exist with land disposal. The most basic problem is the difficulty of acquiring new disposal sites. It is estimated that approximately 7,000 acres (2,800 hectares) of new land will be required annually to contain material generated from maintenance dredging. Other aspects of land disposal are outlined by Boyd et al. (3).

> . . . confined land disposal sites receive the poorest quality spoil (from the engineering point of view) and . . . the quality will likely get worse before it gets better. Consequently, problems associated with spoil drainage . . . containment area management, and subsequent utilization will become more acute.
>
> Behavioral characteristics of dredge soil in containment areas have not been thoroughly investigated. It is apparent that most dredge spoils improve with time if drainage is provided, and at some point in time these materials can be used as foundation or building materials. There is a need for research on the characteristics of dredge spoil which will enable it to play a more positive role in urban and regional development projects.
>
> Dewatering techniques must be developed to allow full utilization of the capacity of diked containment areas and/or the reuse of such areas. Research is needed on . . . techniques to speed consolidation of material in the confined area. . . .
>
> Efforts to make useful products such as building materials from spoils have been few and have met with mixed success (p. 121).

Another dimension of the problem which is of concern to federal agencies, such as the Corps of Engineers, is discussed by Montgomery and Palermo (14):

> Confined land disposal of dredged material fulfills one short-term Corps need (i.e., disposal of dredged material); however, it often creates rather than alleviates problems in land utilization and management. This, in turn, is of direct significance to the Corps since the problems created quickly influence public opinion and public acceptance of land disposal. The manifestation of this is in the increasing difficulty, by the Corps and its project sponsors, to acquire easements for additional land disposal sites (p. 142).

In summary, there appears to be an obvious need for improvement in land containment area management. Existing containment areas and those developed in the future must be utilized to the maximum extent possible.

The Dredged Material Research Program

The need for addressing dredge disposal problems resulted in a congressionally authorized and funded research and development program (20). The study and development program was assigned to the Waterways Experiment Station, U.S. Army Corps of Engineers. Preliminary study was initiated in May 1971. Funding for a full scale research program was authorized in February 1973. WES initiated the Dredged Material Research Program (DMRP) in March 1973. The stated objective of the DRMP is:

> To provide, through research, definitive information on the environmental impact of dredging and dredged material disposal operations and to develop technically satisfactory, environmentally compatible, and economically feasible dredging and disposal alternatives, including consideration of dredged material as a manageable resource (22, p. 115).

Much of the DMRP effort has been aimed at developing techniques for dewatering and consolidating fine-grained dredged material. Dredged material is initially in a slurry state. Although a significant amount of water is removed from containment ponds through overflow weirs, the resulting pond sediment possesses extremely high water contents (several hundred percent). These extremely high water contents make the dredged material unsuitable or undesirable for commercial use. Also, the volume of space occupied by the liquid portion of dredged material greatly reduces available disposal space. Task 5A of the DMRP was developed to study various methods of accomplishing dewatering and consolidation of fine-grained dredged material. The stated objective of the DMRP Task 5A is:

> . . . to develop and test promising techniques for dewatering or densifying dredged material using mechanical, biological, and/or chemical techniques prior to, during, and after placement in containment areas. . . (22, p. 101).

The Task 5A effort has been divided into a series of work units, each unit devoted to studying various alternatives of dewatering and consolidation. A summary list of work units is provided in Table I.

Hopefully, various economically acceptable and technically viable alternatives will be developed from these study units. If technology of this nature is developed, the serious crunch on dredging disposal may be relieved. Such technology may also be valuable in other fields. Disposal of certain industrial wastes and waste treatment sludge is an acute problem faced by industry and municipalities. Techniques developed for handling fine-grained dredged material should also find application in these other areas.

Task unit 5A09 has consisted of conducting a field demonstration of consolidating fine-grained dredged material with windmill-powered vacuum wellpoints. This thesis will cover available background information, describe the field experiment, and present and discuss results of the experiment. Discussion on the power system will be held to a minimum as this will be discussed in detail in a separate report (5).

TABLE I

DREDGED MATERIAL RESEARCH PROJECTS
TASK 5A WORK UNITS

Work Unit	Title
5A01	Methodology for Dredged Material Reclamation and Drainage
5A02	Mechanical Slurry Agitation
5A03	Survey of Conventional Dewatering Techniques
5A04	Electro-Osmotic Dewatering Feasibility
5A05	Aeration Dewatering Feasibility
5A06	Crust Management
5A07	Freeze-Thaw Dewatering Feasibility
5A08*	Progressive Trenching
5A09.1*	Vacuum Wellpoints
5A09.2	Windmill Power Feasibility
5A10	Capillary Wick Dewatering
5A11*	Sand Slurry Injection
5A12*	Remote Weather Station
5A13	Containment Area Management
5A14*	Crust Mechanical Stabilization
5A15.1*	Gravity Underdrainage
.2	Vacuum Underdrainage
.3	Seepage Consolidation
.4	Seepage + Vacuum Consolidation
5A16*	Electro-Osmotic Dewatering
5A17	Crust Management
5A18*	Vegetation Dewatering
5A19*	Interior Borrow Development and Mining

*Field demonstration conducted at Upper Polecat Bay containment area, Mobile, Alabama.

CHAPTER II

A REVIEW OF WELLPOINT DEVELOPMENT

Conventional Wellpoints

Initial uses of wellpoints date to the turn of the century. These early dewatering systems were moderately successful when used to lower the groundwater within a small area. Also, initial uses of wellpoints were confined to lowering the groundwater in clean sands, which are free-draining.

Tremendous advances have been made in the development of wellpoint dewatering equipment. Modern conventional wellpoint systems consist of one or more stages of wellpoints. The wellpoint or tip is a small screen constructed of brass or stainless steel mesh, slotted brass, or plastic pipe. Well screens are usually 2 to 4 inches (5.1 to 10.2 cm) in diameter and 2 to 5 feet (0.6 to 1.5 m) in length. Wellpoints may include a special tip for jetting the wellpoint into position. Riser pipes are generally 1.5 to 2.0 inches (3.8 to 5.1 cm) in diameter. A series of riser pipes and wellpoints are interconnected by a header system. The header system is connected to a wellpoint pump. These pumps generally have both a vacuum and centrifugal component to remove water that drains to the wellpoint (see Figure 1).

Despite advances in equipment development, conventional wellpoint systems are primarily utilized to dewater free-draining granular materials. It is suggested in some literature that silts and sandy silts with

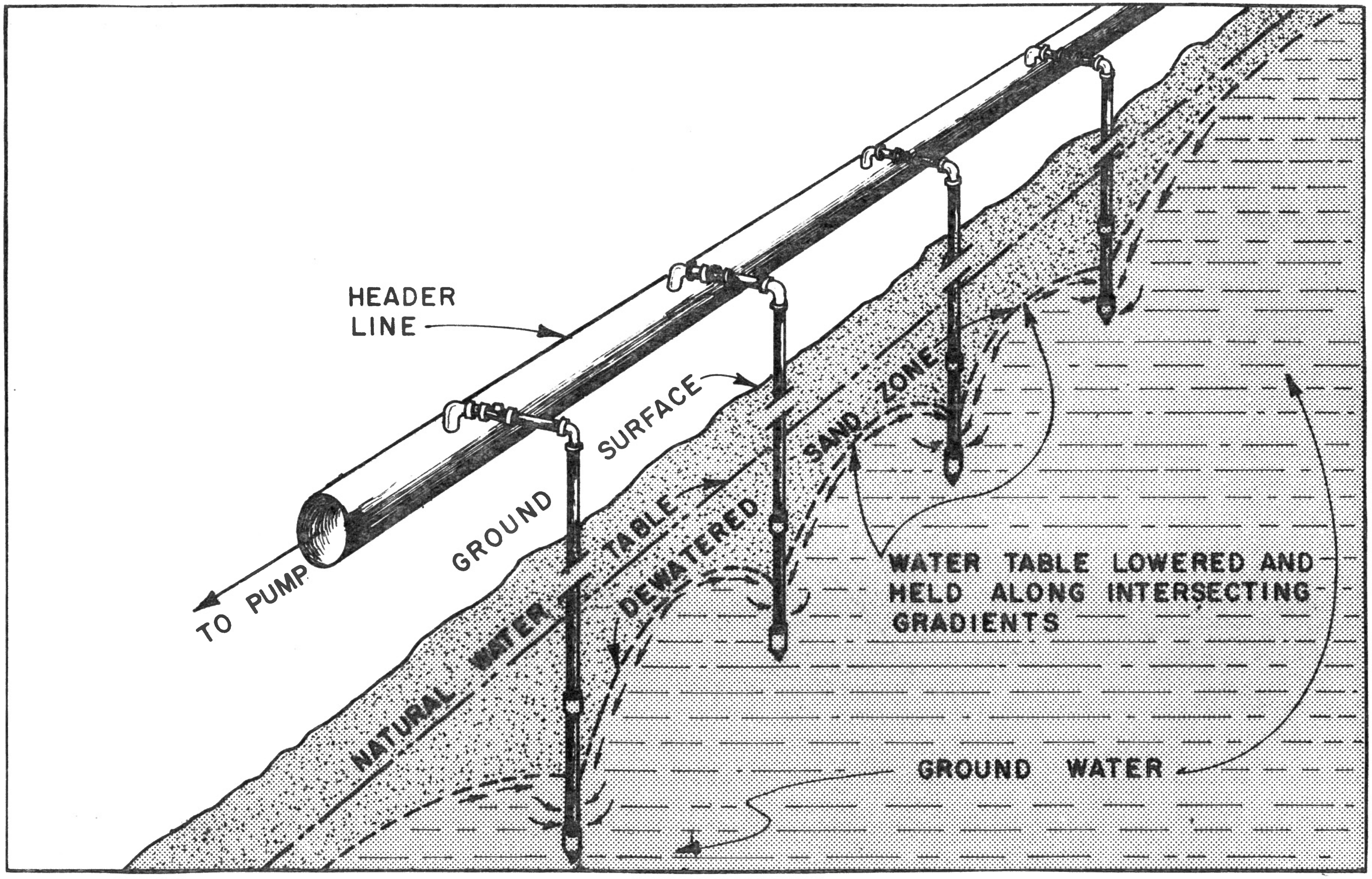


Figure 1. Typical Wellpoint System

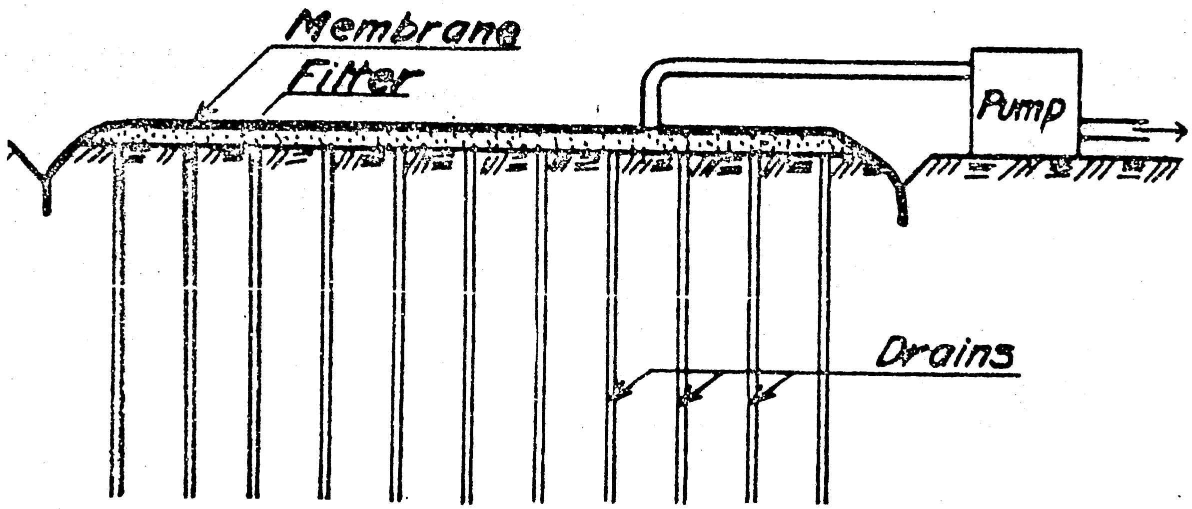
permeability coefficient (K) of approximately 10^{-4} cm/sec cannot be drained by gravity methods (4). This literature suggests vacuum wellpoint systems may be successful in dewatering materials with a permeability of approximately 10^{-4} cm/sec. By establishing a partial vacuum at the wellpoint, the hydraulic gradient producing flow to the wellpoint is increased.

Vacuum Wellpoints in Fine-Grained Material--Two Case Studies

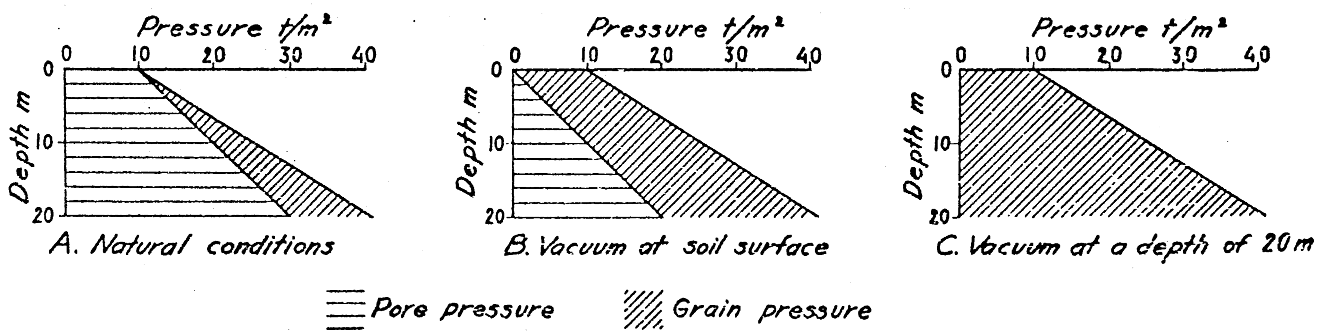
Dewatering and consolidation of fine-grained materials (with permeability coefficient $K = 10^{-6}$ cm/sec) is normally accomplished by means other than conventional wellpoints or vacuum wellpoints. These methods do not produce the rapid drawdown of groundwater in fine-grained material that is required on modern construction projects. However, there are at least two known references in which dewatering and consolidation of fine-grained materials with vacuum wellpoints are suggested or actually utilized. These references are considered worthy of mention.

The use of vacuum pumps to consolidate fine-grained materials was suggested by Kjellman (11). This recommendation was presented after field tests were conducted on a soft clay material. Briefly, this field test required installing a series of vertical sand drains in the soft clay. The drained area was covered with a sand filter. A membrane was placed over the horizontal filter. A suction pipe was placed through the membrane (with a tight seal) and was connected to the vacuum pump. By applying a vacuum to the horizontal filter and vertical drains, the pore pressure in the soft clay is gradually decreased. This allows atmospheric pressure at the surface to act as a surcharge. The resulting increase in soil grain pressure (or increase in effective stress) produces consolidation and removal of soil void water. A maximum settlement of approximately 21 inches (54 cm) was achieved after pumping for 110 days. An average vacuum of (8 t/m^2) was developed. This is equivalent to the surcharge weight of a sand fill approximately 16.5 feet (5 m) thick (see Figure 2).

Vacuum wellpoints were used to consolidate soft clay subgrade materials prior to extending a runway at Philadelphia International Airport (10). The airport had been constructed on marginal property adjacent to reclaimed marshlands. These reclaimed marshlands were used as disposal areas for maintenance dredging of the Delaware River. The arrival of the jet age necessitated extending a runway approximately 2300 ft (701 m). The extension was to be constructed over the old disposal area. Construction restraints included maintaining operation of the existing runway. This prohibited using high fills to surcharge the soft subgrade. In addition, an extremely short construction schedule was required. Therefore, it was decided to stabilize the subgrade with a system which combined vacuum dewatering and sand drains. Vertical sand drains, capped at the surface with bentonite clay, were placed through the soft material into an underlying granular layer. Deep wells connected to the vacuum system were placed around the site. These wells also extended into the underlying granular layer. A vacuum of 15 inches (38 cm) Hg was developed and maintained for 18 days. Settlements during stabilization and after paving are summarized in Figure 3.

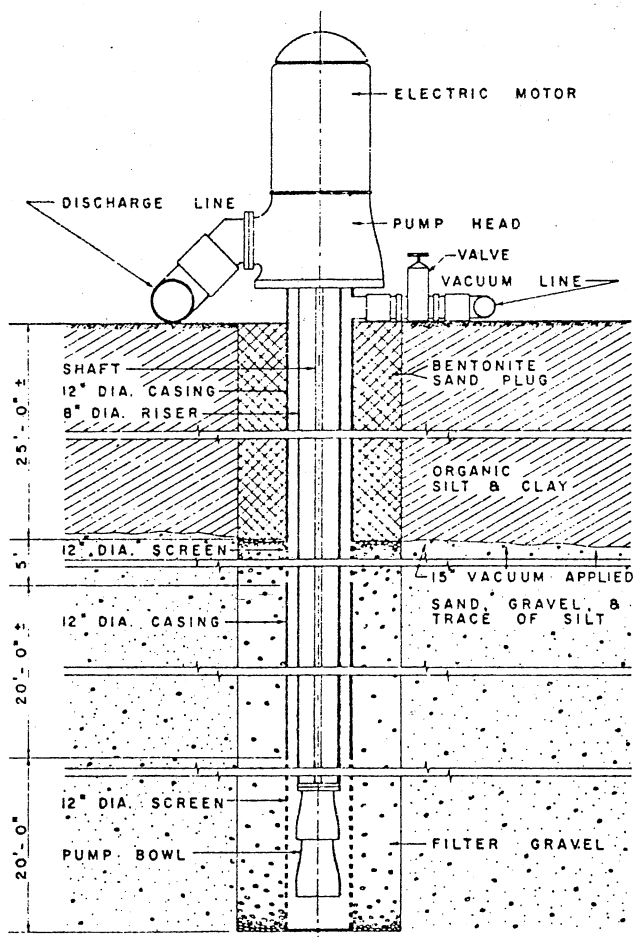


(a) Principle of Swedish Vacuum Method

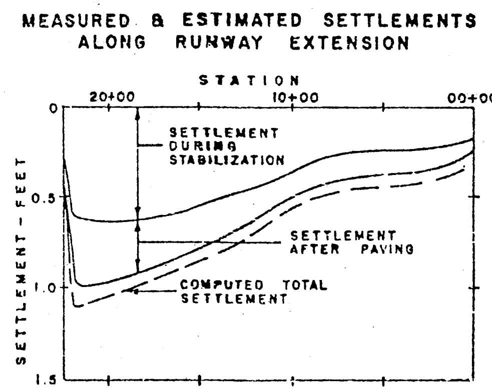


(b) Grain Pressure and Pore Pressure in the Ground After Complete Consolidation

Figure 2. Consolidation of Clay Soil by Means of Atmospheric Pressure



Detail of Deep Well and Vacuum Connection



Comparison of Settlements--
Along Center Line

Figure 3. Vacuum Wellpoints at Philadelphia International Airport (After Reference (10))

CHAPTER III

PROPOSED APPLICATION OF VACUUM WELLPOINTS

As indicated in Chapter II, dewatering and consolidating fine-grained materials with vacuum systems is not a new concept. In fact, the potential use of vacuum systems in consolidating fine-grained dredged material is discussed by Bishop and Vaughn (1). Their article references prior discussions on this subject.

However, previous use of vacuum wellpoints in fine-grained soils has incorporated close centered vertical sand drains and/or pumping from a granular subdrain layer. Traditionally, conventional wellpoints have been used to develop rapid draw-down of the groundwater for construction purposes. Rapid dewatering and consolidation of soft subgrade materials was the objective of the case studies cited in Chapter II. Without the aid of sand drains and subdrains, rapid dewatering of fine-grained dredge material would be impossible.

In many instances, dredging is accomplished on a periodic cycle of several years. Therefore, the dredged material is often deposited and left unattended for several years. If a vacuum could be established in the dredged material, the potential for volume reduction could be significant on a long-term basis. The volume reduction would be caused by increases in effective stress from lowering the groundwater table and from atmospheric pressure surcharge. Volume reduction could be achieved in the deposited material and from the foundation material. Preliminary calculations based on consolidation test data from typical dredge material indicate a surcharge of 1 tsf (95.8 K pa) (equivalent to atmospheric pressure) could produce volume reductions on the order of 100 percent (9). The consolidated material would occupy approximately half the volume occupied by the dredge slurry.

Other problems must be addressed if vacuum wellpoints are to represent a viable solution. The cost of installing wellpoint systems of conventional materials over large disposal areas would be enormous. In addition, dredge disposal sites are often located in coastal areas. Therefore, non-corrosive materials would be required for constructing the vacuum system.

Dredge disposal sites are often located in remote areas. Supplying power to such sites to drive vacuum systems would be excessive. This problem could possibly be overcome by utilizing natural resources such as wind power. The use of windmills for power development in coastal areas would appear promising. Past studies have indicated that for wind generators to be practical, a minimum average wind velocity of 6 mph (9.7 Kph) must be maintained (9). Records indicate many coastal and inland waterway areas experience average wind velocities in excess of 6 mph. A summary of long-term average wind velocities at selected locations in indicated in Table II.

With these various considerations in mind, Task 5A09 of the DMRP was commissioned. A field demonstration was considered necessary. Specific questions that would hopefully be answered by the field demonstration included:

a. Will vacuum wellpoints produce long-term densification/

dewatering in soils of lower permeability than currently are considered suitable for short-term application of the method?

b. Will variable wind power operate the vacuum system successfully?

c. Can plastic pipe be used to successfully construct the vacuum system?

If a small-scale field demonstration can successfully overcome these obstacles and at a reasonable cost, then great potential would exist for vacuum consolidation in existing and future disposal areas.

TABLE II

AVERAGE WIND VELOCITIES AT SELECTED CITIES

City	Average Wind Velocity (mph)
Pensacola, FL	10.1
Mobile, AL	9.5
Galveston, TX	10.8
Savannah, GA	9.0
Miami, FL	12.6
Boston, MA	11.8
New York, NY	14.6
Philadelphia, PA	10.1
Buffalo, NY	14.6
Detroit, MI	10.6
Chicago, IL	10.7
Cleveland, OH	12.7
San Francisco, CA	10.5
Spokane, WA	8.4
New Orleans, LA	7.7
Memphis, TN	9.9
St. Louis, MO	11.0

CHAPTER IV

VACUUM WELLPOINT FIELD STUDY

Upper Polecat Bay Test Site

In selecting a site for Task 5A field demonstrations, the DMRP considered several factors. Utilization of a single test site for all field demonstrations would offer several advantages. Comparing test results of individual dewatering techniques would be easier if all tests were conducted on similar dredged material. In addition, administration and management costs would be reduced by utilizing a single site. Another consideration in site selection was assuring the tests were conducted in some of the most difficult dredged material to dewater. Conducting field demonstrations in such conditions would lend confidence to recommending successful techniques at other sites.

Mutual interest in dewatering dredged material resulted in an agreement between the Mobile District, Corps of Engineers, and the DMRP to conduct field testing at the Upper Polecat Bay disposal area in Mobile, Alabama. This disposal site is located adjacent to the Mobile River at the north end of Mobile Harbor. A site location map is indicated in Figure 4.

The Upper Polecat Bay disposal area was created by the Mobile District in 1970. The disposal area was constructed in a marsh area adjacent to the Mobile River. Containment dikes were constructed by end dumping sand fill. Natural ground elevations prior to construction

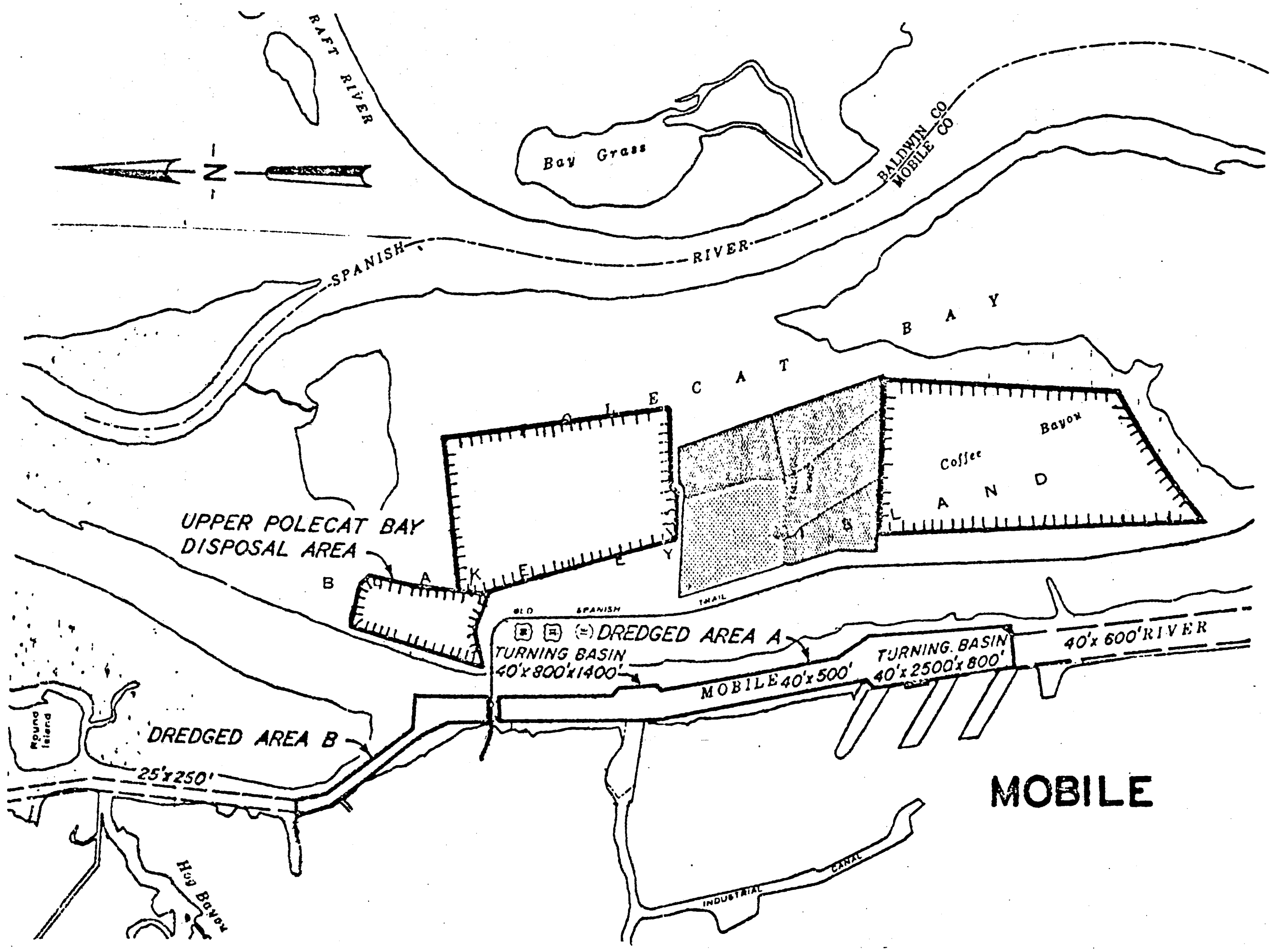


Figure 4. Upper Polecat Bay Location Map

averaged 2.0 to 3.0 feet (0.6 to 0.9 m) MLW. After construction, dike crown elevations varied between elevation 14.0 and 16.0 feet (4.3 to 4.9 m) MLW.

Initial disposal of dredged material into the containment area was accomplished between December, 1971 and March, 1972. The material was dredged from the upper Mobile River and Chickasaw Creek. This material consisted primarily of fine-grained clays and silts with small percentage of sands. The coarse material was deposited near the southeast corner of the disposal area. The fine-grained material settled toward the north end of the disposal site. A second disposal operation was conducted between January and March, 1973, when dredging operations were again performed in the upper Mobile River. From this second dredging operation, coarse-grained materials and find-grained clays were pumped into the disposal area. In addition, significant amounts of wood chips and bark were pumped into the containment area. As with the first disposal operation, the coarse-grained material and wood chips settled near the south end, or discharge end, of the disposal area. The fine-grained clays and silts settled toward the north end of the disposal area. After the second disposal operation, a surface elevation of approximately 9 feet (2.7 m) was established over the northern half of the containment area. Surface elevations in the southwest section ranged from 10 to 11 feet (3.0 to 3.4 m). In the southeast corner of the site, elevations ranged from 10 to 20 feet (3.0 to 6.0 m).

Prior to constructing dikes for the UPB containment area, a subsurface investigation was conducted to verify foundation conditions at the site. These borings revealed that the foundation at upper Blakeley Island consisted of marsh deposits composed of soft organic clays and silts (OH) underlain by alternating strata of plastic clays (CH), silty sands (SM), and clayey sands (SC). Additional investigations were conducted after dike construction to determine the displacement pattern of the sand dikes.

After selection of the UPB containment area as a test site, additional investigations were undertaken. This investigation was aimed at primarily establishing the characteristics of the dredged material. Twenty-six borings were taken during July and August of 1975. Sampling was accomplished by hand-pushing a 3-inch (7.6 cm) ID piston-type sampler. Observation wells were installed at 24 locations. These observation wells were seated at a depth of approximately 10 feet (3.0 m) below the surface.

A laboratory testing program was conducted utilizing the 3-inch undisturbed samples obtained from the dredged material. This program included classification (Unified Soil Classification System) and water content determinations on all samples. Certain samples were selected for density, gradation, specific gravity, Atterberg Limits, vane shear, consolidation, and laboratory shrinkage tests. The testing program was conducted by the WES Soils and Pavements Laboratory.

The laboratory testing program indicates a majority of the dredged material sampled is a dark grey to black, fine-grained, high liquid limit clay. According to the Unified Soil Classification System, this materials classifies as (CH). A small percentage of the samples classified as silty sand (SM), clayey sand (SC), or poorly graded sand (SP). Some of the samples taken from the underlying foundation classified as organic clay (OH).

Grain size analyses on selected samples indicated the fine-grained materials generally contain over 80 percent minus No. 200 (.073 mm) sieve size material. For most samples, 30 to 40 percent of the material is smaller than one micron. Approximately 5 percent organic material is contained within the dredge material. Those materials on which Atterberg Limits were conducted were classified as (CH). Liquid limit values ranged from 52 to approximately 175 percent. Petrographic analyses indicated the clay minerals of the dredged material are Montmorillonitic and Chloritic.

Consolidation tests were performed from 20 selected samples of fine-grained dredged material. The samples were loaded incrementally to a load of 1.28 tsf (13.7 t/m^2). Values of the compression index, C_c, varied between 0.60 and 1.26 for the clay (CH) dredged material, with an average value of 0.916 (18). A study by Salem and Krizek (20) analyzed the consolidation characteristics of dredged material in the Toledo, Ohio area. A series of consolidation tests, conducted as part of that study, produced a compression index of 0.94. This suggests the consolidation characteristics of the Upper Polecat Bay dredged material is typical of fine-grained dredged material.

Reference is made to "Background Information and Laboratory Test Data for Upper Polecat Bay Disposal Area" (18) for additional information on site history and results of subsurface and laboratory investigations.

Installation of Vacuum Wellpoint System

An approximate one acre (0.4 hectares) site, located in the northwest corner of Upper Polecate Bay, was selected for conducting the vacuum wellpoint demonstration (see Figure 5 for the general layout of UPB test sites).

The proposed site was divided into four sections. Two sections, designated Sections B and D on Figure 6, were established as "control" sections. These sections were to be monitored to establish a basis for comparison between vacuum stabilized and nonstabilized dredged material. Sections A and C (see Figure 6) were established to evaluate the dewatering/consolidation effects of applying vacuum of different wellpoint spacings. Wellpoints were to be placed on 20-foot (6 m) centers in Section A, 40-foot (12 m) centers in Section C. These wellpoints are probably wide spaced in comparison to conventional wellpoint applications. However, in order for vacuum dewatering/consolidation to be economically feasible, wellpoint spacings of these orders would be required.

It was decided to use plastic (PVC) pipe (Sch. 40) for constructing the wellpoints and header system. Several advantages exist with using plastic pipe. The piping is light and easy to handle. This is important since installation of the wellpoint system had to be accomplished entirely with manual labor. The soft dredged material would not support heavy equipment. The pipe can be easily cut to accommodate varying length requirements. However, one uncertainty was how well the glued pipe system would hold a vacuum. Another reason for using plastic pipe was to verify its durability in a corrosive environment. It is also a relatively inexpensive material.

The vacuum wellpoints were installed according to the following procedure. The surface crust, to a depth of approximately one foot (0.3 m), was excavated by shovel. Metal casing, 5 inch (12.7 cm) OD, was manually pushed into the dredged material to a depth of approximately 9 feet

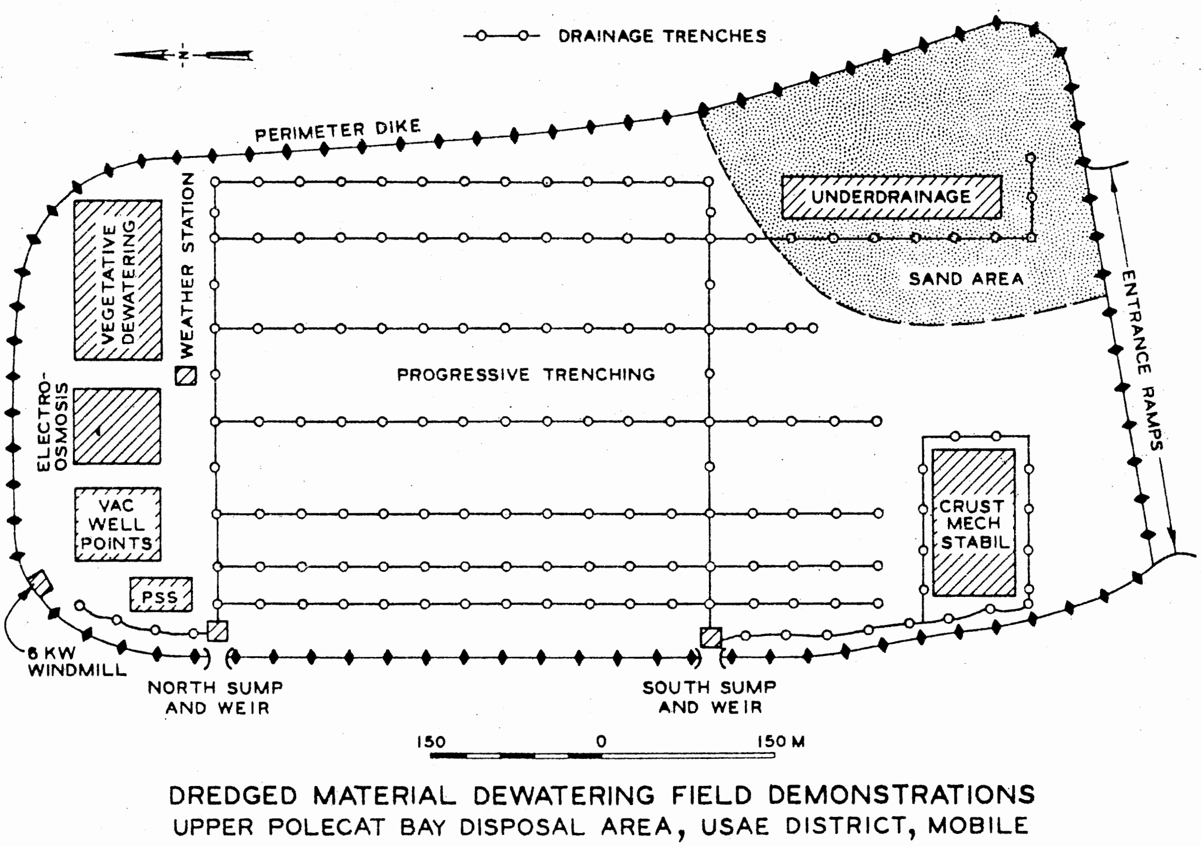


Figure 5. Layout of Upper Polecat Bay Test Sites

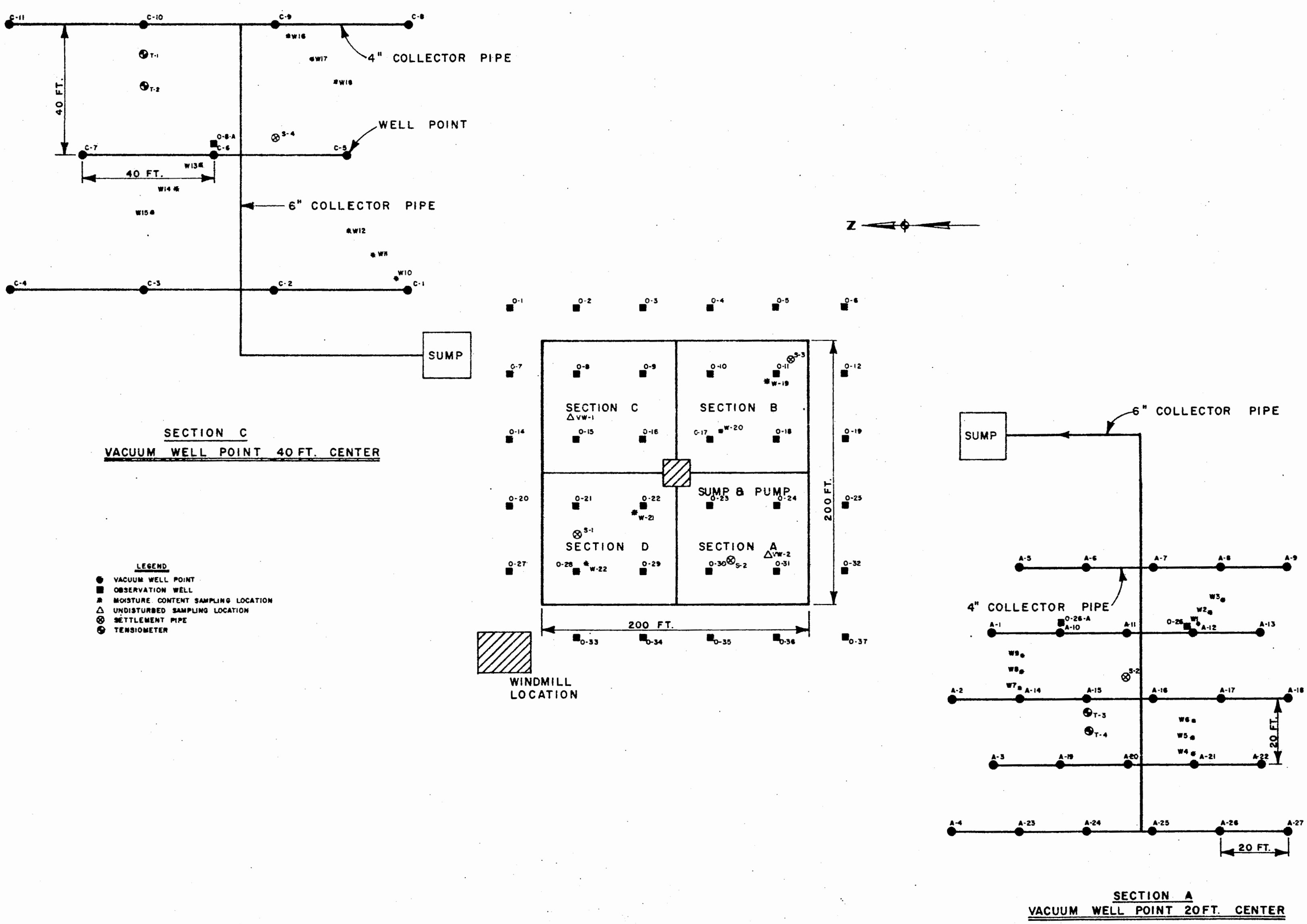


Figure 6. Layout of Vacuum Wellpoint Experiment

(2.7 m). This was considered to be the approximate depth of the dredged material. The dredged material within the metal casing was washed out by a water jet. The vacuum wellpoint riser pipe, with a slotted tip, was placed inside the metal casing. Sand was placed between the riser pipe and metal casing to a height of approximately one foot (0.3 m) above the slotted section. The slotted section had been previously wrapped with Filter X filter cloth. The bottom 2.5 feet (0.76 m) of the riser pipe was slotted to form a previous tip section. The tip section was slotted to .008 inch (.02 cm) openings. A 2.0-foot (0.6 m) thick bentonite clay section was placed above the sand fill to form a seal. Dredged material was then used to backfill to the surface. The metal casing was then manually extracted, leaving the wellpoint in place (see Figure 7).

A deviation in wellpoint installation procedure was used to install wellpoints A-1, A-2, A-3, and A-4. These wellpoints were installed according to procedures outlined in Figure 8. The wellpoint tips were inserted in a sand-filled burlap bag. After breaking the surface crust, the sand bag and riser pipe were manually shoved through the soft dredged material to the required depth.

The wellpoint riser pipes were connected to a 4-inch (10.2 cm) header pipe by a flexible hose. The 4-inch header pipes were connected to a 6-inch (15.2 cm) collector pipe which was connected to a water collection sump. See Figures 9, 10, and 11 for illustration of the header system and collection sump. (The header system was later modified to supply vacuum to the Sand Slurry Injection Study.)

Vacuum was supplied by a model D1500 vacuum pump manufactured by the Precision Scientific Company. The vacuum pump was driven by a 3 hp

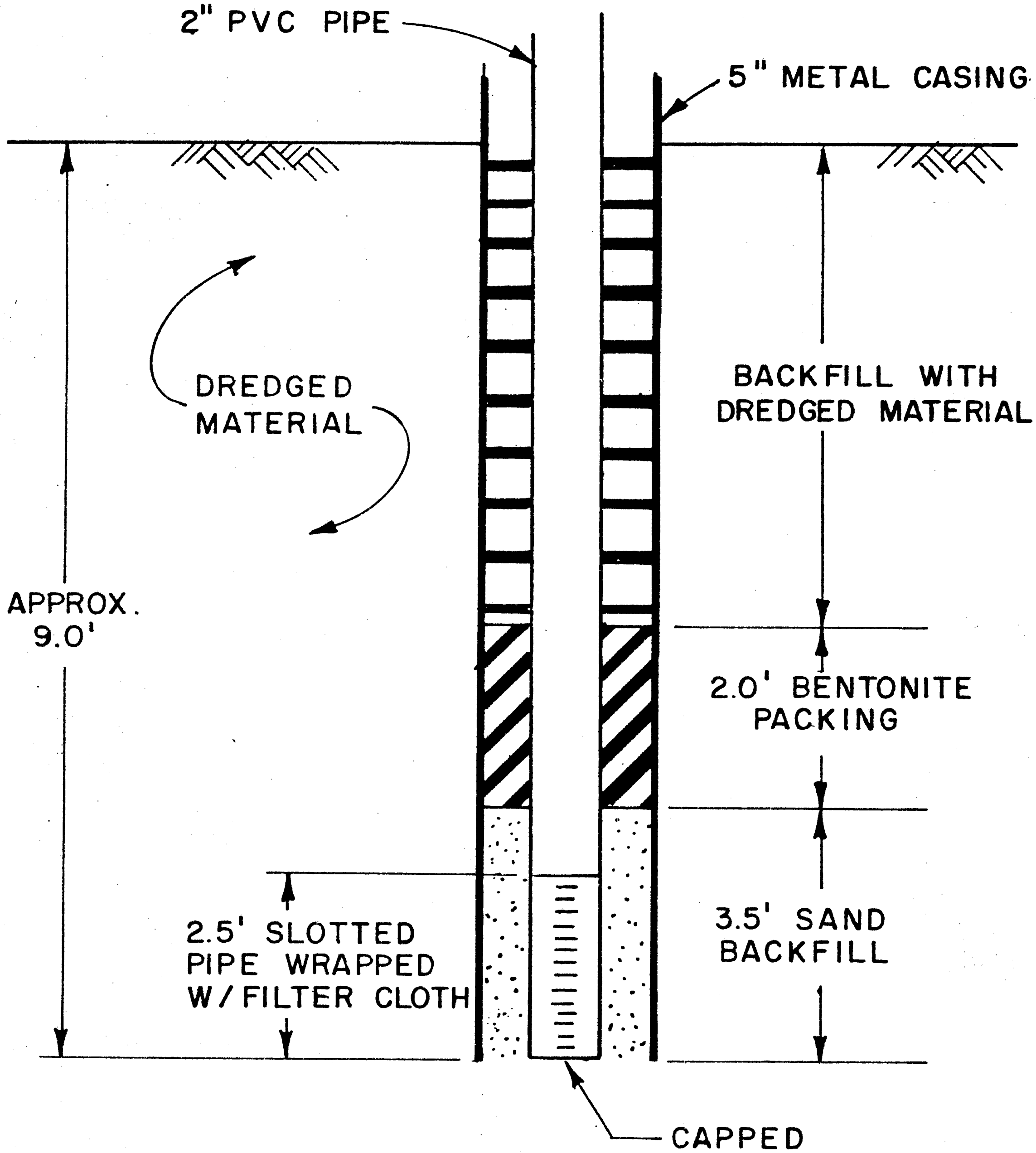


Figure 7. Typical Section, Vacuum Wellpoint Installation

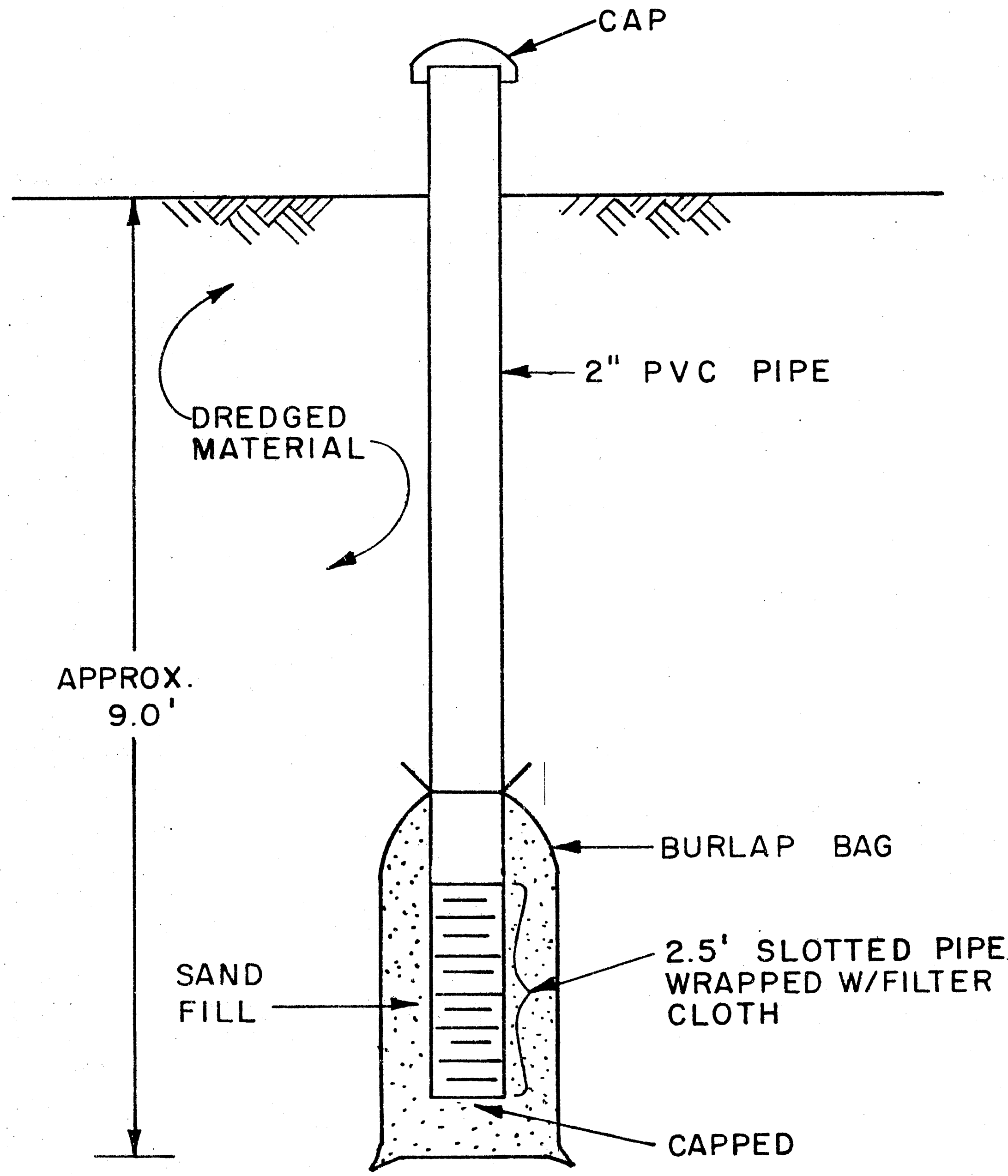


Figure 8. Typical Section, Observation Well

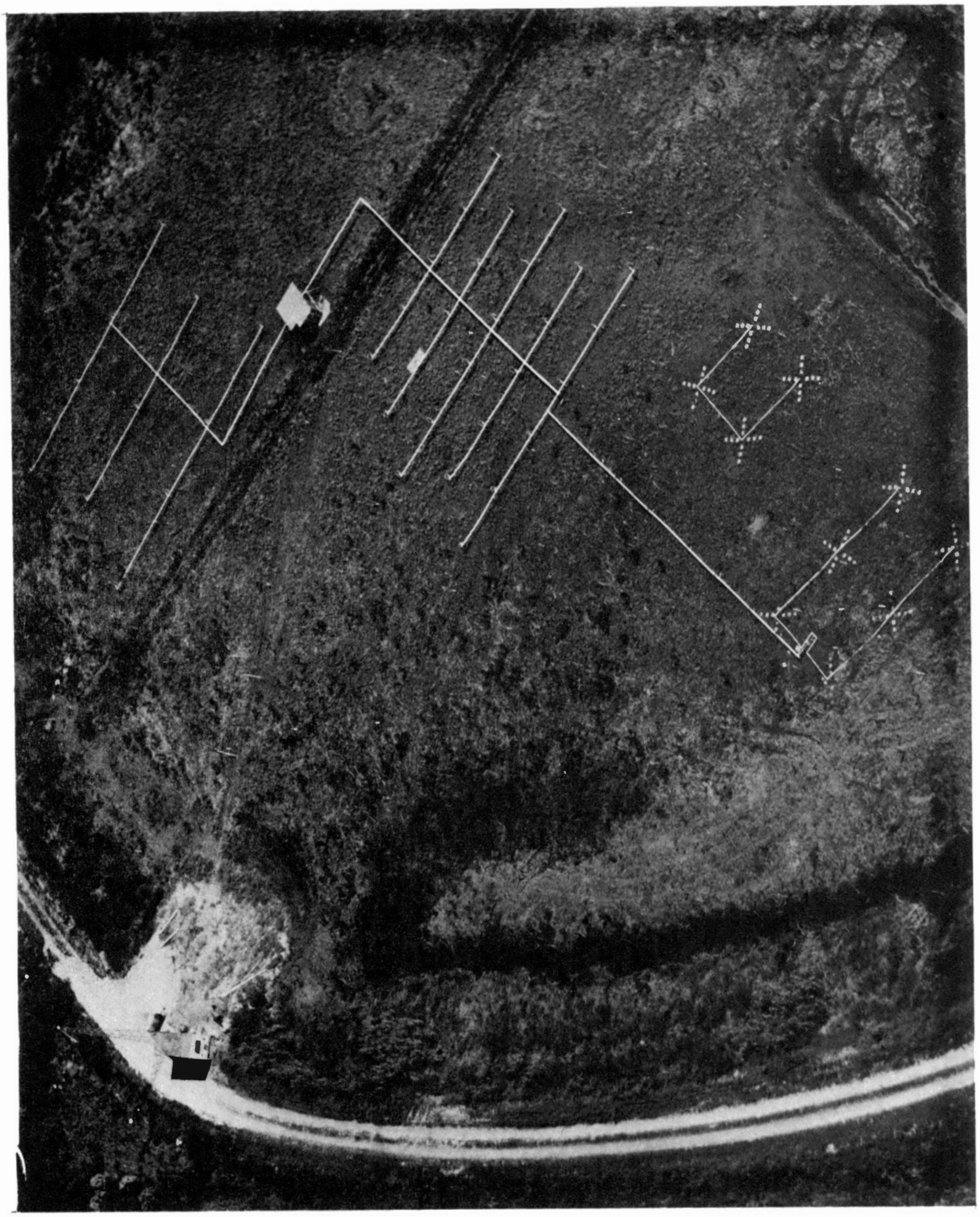
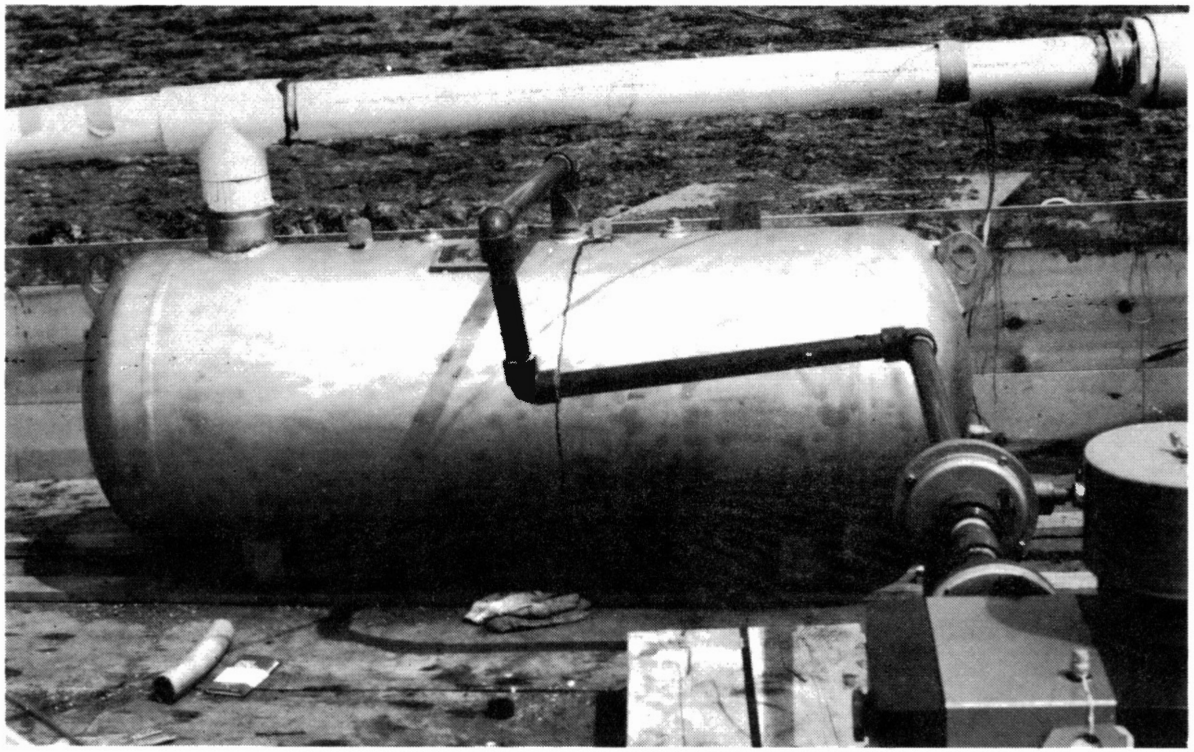
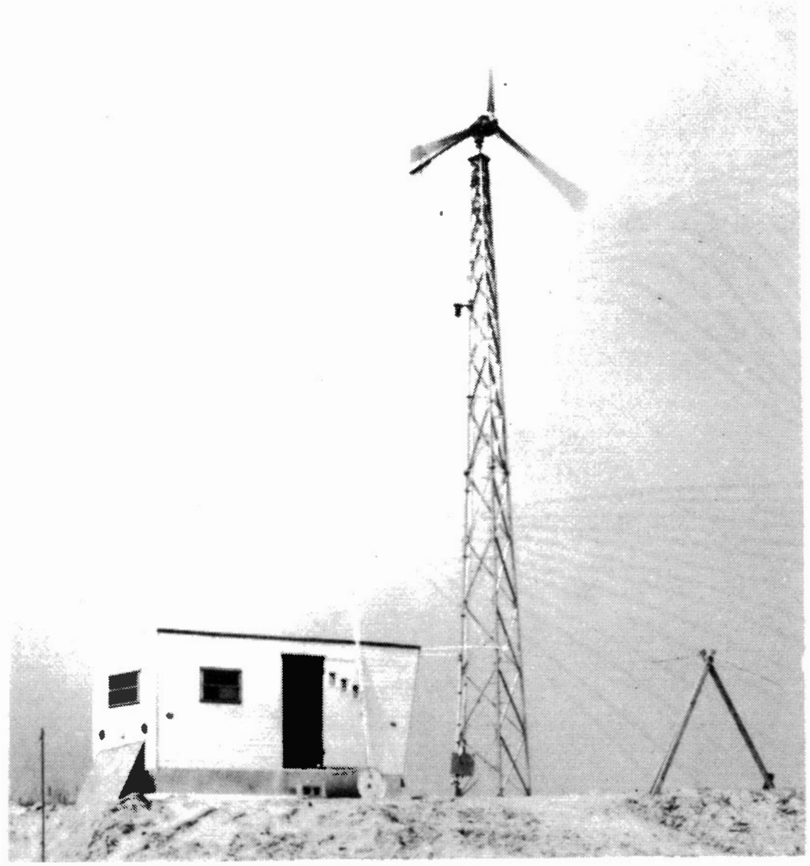


Figure 9. Vacuum Wellpoint Header System



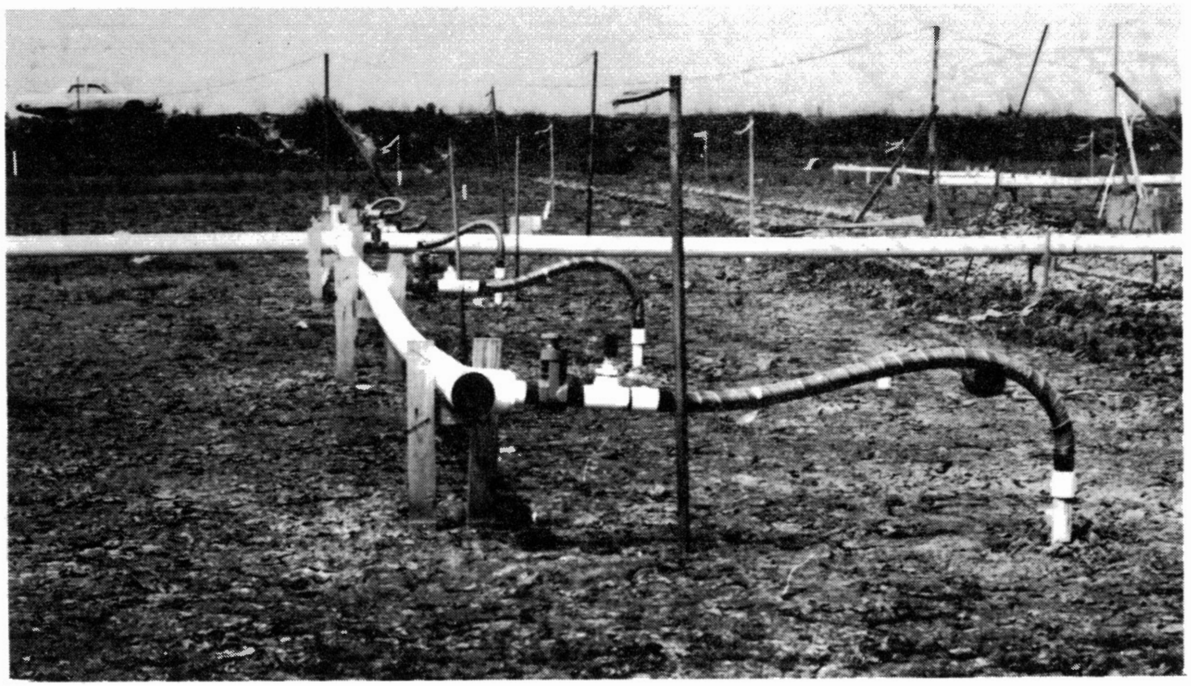
(a) Vacuum Wellpoint Collection Sump

Figure 10. Vacuum Wellpoint Collection Sump and Windmill



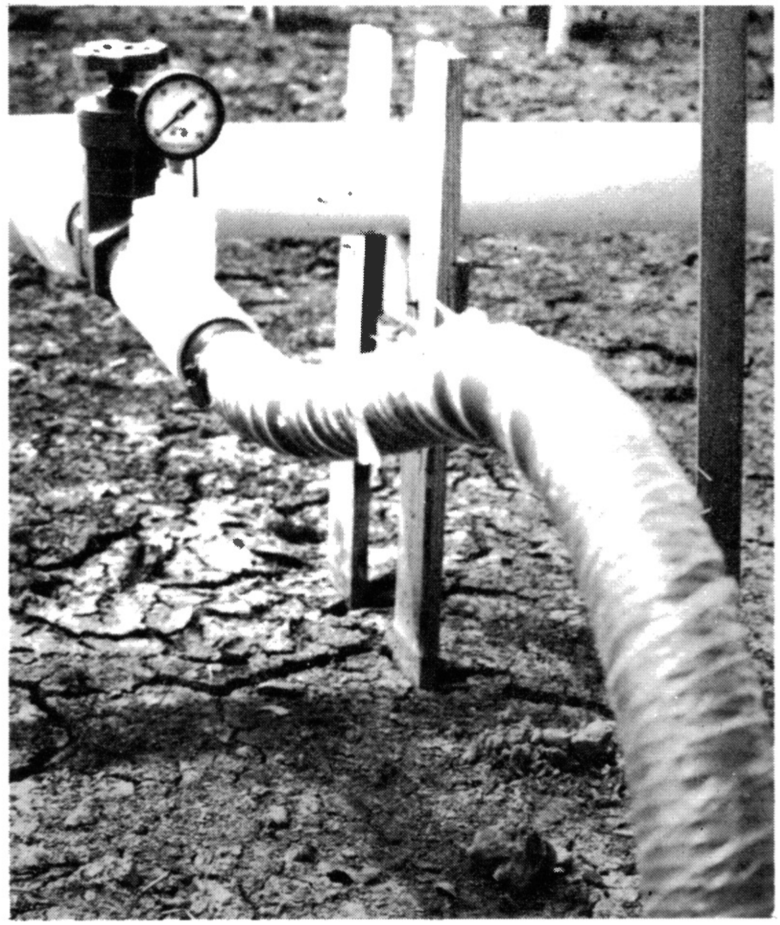
(b) Windmill

Figure 10. (Continued)



(a) Vacuum Wellpoint Header Pipe

Figure 11. Vacuum Wellpoint Header Pipe and Vacuum Gage



(b) Vacuum Gage

Figure 11. (Continued)

electric motor. At various phases of the experiment, electric power was developed from a windmill generator, gasoline-powered generator and diesel-powered generator.

Utilizing a four-man crew, approximately ten work days were required to install 38 wellpoints. Approximately five work days were required to install the vacuum header system.

Instrumentation

Open tube piezometers were installed to record variations in the groundwater table. Initially, 37 piezometers were installed. These piezometers were installed by the procedure indicated in Figure 8. Piezometer tips were placed at a depth of approximately 9 feet (2.7 m). During the operations phase of the test, additional piezometers (designated 0-38 through 0-57) were installed. These piezometers utilized a 0.5-inch (12.7 mm) riser pipe and porous tip. The porous tip was placed in a sand-filled burlap bag. These piezometers were placed by manually pushing the riser pipe and tip through the soft dredged material to depths of 4 feet (1.2 m) and 8 feet (2.4 m). Piezometer locations are shown in Figure 6. See Appendix D for depths of piezometers 0-38 through 0-57.

Vacuum gages were installed in the header system at each wellpoint location. Cutoff valves were placed at each wellpoint location to avoid vacuum loss over the whole system in case of isolated leaks.

Soil moisture tensiometers were installed at locations indicated in Figure 6. At each location tensiometers were installed to depths of 2, 5, and 8 feet (0.6, 1.5, 2.4 m) below the surface. These instruments have been primarily used in conjunction with agriculture irrigation studies. Tensiometers are used to indicate hydraulic heads without regard to whether soil water pressures are positive or negative (19). Various tensiometer models are commercially available. Tensiometers used in this experiment were Model 2710 instruments manufactured by the Soilmoisture Equipment Corporation.

Operation and Data Gathering

The vacuum wellpoint system was designed to draw collected water to a main sump. Water collected at each wellpoint was carried through the 4-inch (10.2 cm) header pipe, to the 6-inch (15.2 cm) collector pipe, to the collection sump. One collection sump served for both Sections A and C. Through a series of electrodes, an automatic pumping and discharge cycle was achieved. Continuous operation of the vacuum pump would periodically fill the sump with water. At this point the vacuum pump would be shut down. Atmospheric pressure would be re-established in the sump. Check valves in the 6-inch collector pipe would close to maintain vacuum in the header system. Water in the collection sump would then be discharged by a centrifugal pump. A discharge line carried water away from the test site. The vacuum pump would then renew pumping.

The vacuum pump was driven by a 3 hp electric motor. Electrical power was initially supplied by windmill generation. However, this power source was inadequate during the calm summer months. The windmill was later declared inoperable due to lightning damage. Windmill power was replaced by a 10 hp gasoline-driven generator. This power source performed satisfactorily for a short period. However, down time for generator repair eventually became excessive. The gasoline generator was replaced by a diesel generator. The diesel generator was the most reliable power source during the experiment. For additional information on design and performance of power systems, see Reference (5) (5A09.2 report).

During operation of the vacuum system, vacuum gages, piezometers, tensiometers, and the water meter were periodically monitored. A remote weather station was established and maintained by WES for recording meteorological information such as rainfall, wind speeds, and temperature. Moisture samples were periodically taken from locations indicated in Figure 6. In addition, samples were obtained at distances of 1, 2, and 3 feet (0.3, 0.6, 0.9 m) from wellpoints A-11, A-21, C-2, and C-9. A hand-operated piston sampler was used to retrieve the samples. A summary of moisture test results is attached as Appendix A. Surface elevations were frequently taken on 10-foot (3 m) centers. These elevations were furnished by survey crews assigned to the Mobile District's Mobile Area Office. A summary of surface elevations is attached as Appendix B. Elevations are referenced to the grid system indicated in Figure 6. Two series of cone penetrometer measurements were taken at selected locations. Approximate testing locations are indicated in the test data summary sheets in Appendix E.

A laboratory testing program was conducted utilizing samples from the vacuum wellpoint site. As indicated above, the moisture content of the dredged material was periodically determined from samples taken at various locations and depths. The initial set of samples were visually classified according to the Unified Soil Classification System. Eleven moisture samples were used in performing liquid limit, plastic limit, shrinkage limit, and sieve and hydrometer analyses. A series of relatively undisturbed samples were obtained at locations indicated in

Figure 6. Five samples were obtained by hand-pushing a 5-inch (12.7 cm) Shelby tube. Tube densities and moisture contents were obtained from these samples. One sample was selected for consolidation testing. This sample was incrementally loaded to 1.0 tsf (10.7 t/m^2). Testing was conducted in accordance with the Corps of Engineers testing procedure (17). Testing was conducted by the Corps of Engineers' South Atlantic Division Laboratory.

Installation of the vacuum system, including wellpoints and header systems, vacuum pump and sump, and windmill power source, was completed in May of 1976. The vacuum system was contantly plagued by mechanical and electrical failures. Pumping equipment often required repair as did the electrical control system. In addition, nature was not always cooperative. During the summer months, the average wind speed was not sufficient to drive the windmill. During January of 1977, record low temperatures froze the discharge line and centrifugal pump. The most productive and consistent pumping was achieved during the periods of 23 November to 31 December 1976, and 28 January to 20 March 1977. Operation of the vacuum system was terminated on 20 March due to mechanical failure of the vacuum pump. A log of operation, highlighting daily operational problems, is attached as Appendix F.

CHAPTER V

SUMMARY OF FIELD STUDY RESULTS

Laboratory Test Results

As outlined in Chapter IV, a laboratory testing program was conducted on samples obtained from the vacuum wellpoint test site. This testing program was aimed toward two objectives. One, to verify through classification and density testing, that the dredged material at the test site is comparable to the material at other test sites. In addition, periodic water content determinations were conducted to evaluate the effectiveness of vacuum wellpoint dewatering.

Visual classifications were made of the initial moisture samples. Selected samples were used in Atterberg Limits and shrinkage limit testing as well as gradation analyses. Shelby tube samples were obtained for density determinations and consolidation testing. A summary of test results on these selected samples is indicated in Table III.

The dredged material at the test site is typically a dark grey fat clay (CH) with a trace of sand sizes. The sampled material generally contains from 90 to 99 percent minus No. 200 grain size particles (see Figure 12). Results of plasticity tests indicate a range in liquid limit from 69 to 165 percent. The corresponding plasticity index ranged from 44 to 96 percent (see Figure 13). A comparison of these results with results of similar tests over the entire Upper Polecat Bay (UPB) test site indicates material at the vacuum wellpoint site is rather typical of the

TABLE III

SUMMARY OF CLASSIFICATION AND DENSITY TESTS

Location	Depth (ft)	Classification	LL	PL	PI	SL	Percent Finer No. 200 Sieve	Dry Density (pcf)	Moisture Content
VW-1*	0.5-1.5	Black and Grey Fat Clay (CH)						28.9	158.1
VW-1*	1.5-2.5	Black and Grey Fat Clay (CH)	130	34	96		97	31.9	142.6
VW-1*	4.0-5.5	Black and Grey Fat Clay (CH)						35.5	123.6
VW-1*	8.0-9.0	Black and Grey Fat Clay (CH)						32.3	123.3
VW-2*	1.0-2.5	Black and Grey Fat Clay (CH)						30.1	134.7
VW-2*	4.0-5.0	Dark Grey Fat Clay (CH) with a Trace of Sand Sizes	119	33	86	21	98		
VW-4*	7.0-8.0	Dark Grey Fat Clay (CH) with a Trace of Sand Sizes	84	26	58	18	90		
VW-8*	1.0-2.0	Dark Grey Fat Clay (CH) with a Trace of Sand Sizes	114	35	79	24	91		
VW-10*	4.0-5.0	Dark Grey Fat Clay (CH) with a Trace of Sand Sizes	114	36	78	21	99		
VW-13*	7.0-8.0	Dark Grey Fat Clay (CH) with a Trace of Sand Sizes	100	31	69	18	98		
VW-17*	1.0-2.0	Dark Grey Fat Clay (CH) with a Trace of Sand Sizes	131	41	90	20	99		
VW-19*	4.0-5.0	Dark Grey Fat Clay (CH) with a Trace of Sand Sizes	111	33	78	21	99		
VW-22*	4.0-5.0	Dark Grey Fat Clay (CH) with a Trace of Sand Sizes	116	34	82	19	99		

TABLE III (Continued)

Location	Sample	Classification	LL	PL	PI	SL	Percent Finer No. 200 Sieve	Dry Density (pcf)	Moisture Content
BI-8†	1	Black Plastic Clay (CH) with Sand	165	52	113		92		
BI-8†	2	Plastic Clay (CH)	98	32	66		95	40.4	115.3
BI-8†	3	Plastic Clay (CH) with Sand	78	25	53		92		
BI-8†	4	Black Sandy Fat Clay (CH)	69	25	44		85		

*Testing performed by South Atlantic Division Laboratory, Corps of Engineers.

†Testing performed by Waterways Experiment Station, Corps of Engineers.

Note: See Appendix for additional test data.

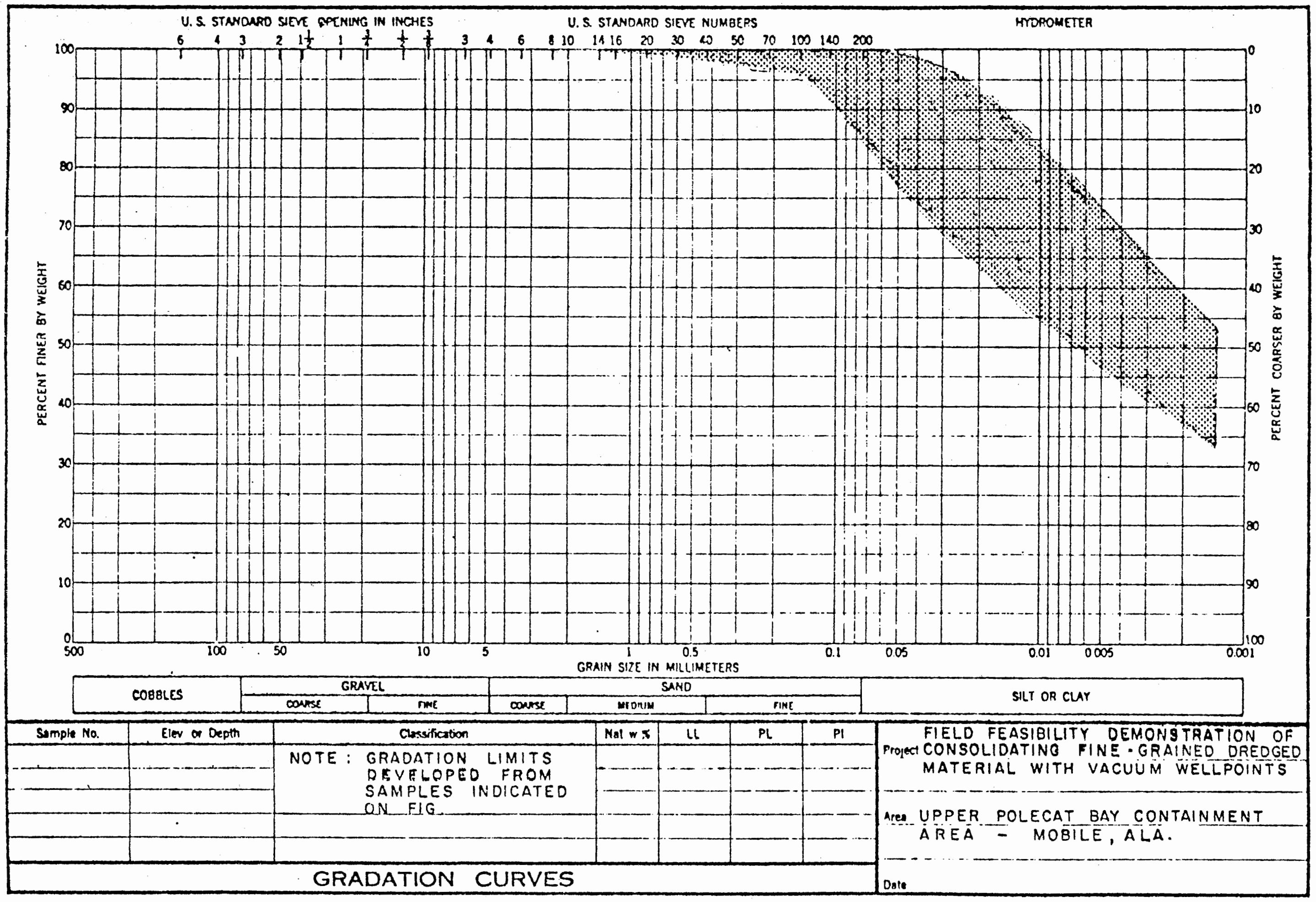


Figure 12. Composite Grain-Size Curve

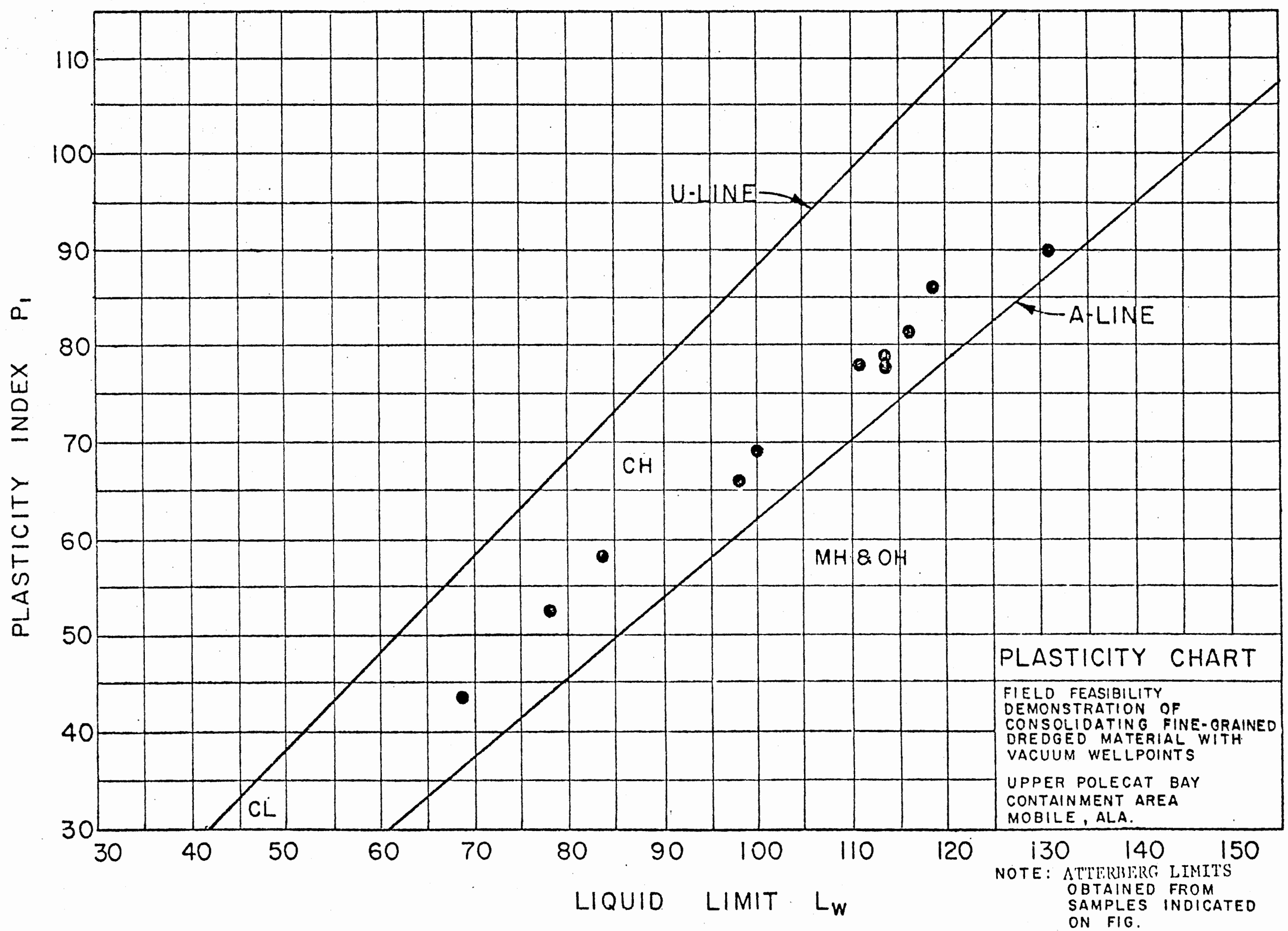


Figure 13. Composite Plasticity Chart

very fine-grained material at UPB. Inplace densities, as determined from 5-inch (12.7 cm) Shelby tubes, averaged approximately 32 pcf (512.6 Kg/m^3) at the vacuum wellpoint site. This is slightly lower than those values summarized in the report by Palermo (18).

Vacuum System

As indicated previously, a Precision Scientific Model D1500 vacuum pump was used to develop a vacuum throughout the header and wellpoint system. Vacuum gages were installed within the header system at each wellpoint location to determine the applied vacuum. An average gage reading of 24.8 inches vacuum was obtained at Section A. Similarly, an average reading of 26.5 inches vacuum was obtained at Section C. These average measurements correspond to pressures of 9.4 t/m^2 and 10.1 t/m^2, respectively. Gage readings are recorded in Appendix C.

The vacuum pump utilized in the field study appears adequate for developing high vacuums over a large area. This opinion is based on the vacuum readings summarized above and the similar readings obtained at the Sand Slurry Injection Site. However, constant attention and frequent maintenance is required. A disadvantage of using this equipment for production purposes would be the shortage of stock items and the mechanical sophistication which would probably necessitate returning the pump to the manufacturer for major repairs.

The header and wellpoint systems were constructed of sch. 40 pvc pipe. This material was not affected by the corrosive environment of UPB. Glued connections were satisfactory for maintaining the vacuum. The only noticeable leak was observed after the header pipe was cut to extend the vacuum system to the SSI site. However, deflections in the header pipes were very noticeable after the header system became filled with water. The original connection between the header pipe and wellpoint was a light weight flexible hose. This hose collapsed under full vacuum. The light weight hose was replaced with a heavy duty hose. This heavy duty hose performed satisfactorily under full vacuum. However, after approximately one year in service, the hose appeared to be developing cracks from exposure.

Tensiometers were installed at locations indicated in Figure 6. Tensiometer readings are summarized in Appendix E. Unfortunately, these instruments were sited outside the apparent zone of influence of the wellpoints. In addition, it is suspected these instruments may have been damaged during severe cold weather in January of 1977. Therefore, these measurements were not considered in the final analysis.

Dewatering

A primary objective of this field demonstration was to determine if vacuum wellpoints could effectively dewater fine-grained dredged material. Hopefully, this would be accomplished by lowering the groundwater table and by consolidating dredged material adjacent to the wellpoint tip.

A total of 59 observations wells (piezometers) were installed to record variations in the groundwater table. Observation well locations are indicated in Figure 6. Observation well readings are summarized in Appendix D. Water table measurements were recorded periodically between April 1976 and April 1977 for observation wells 0-1 through 0-37. Measurements were recorded periodically between February 1977 and April 1977 for observation wells 0-38 through 0-57.

In analyzing the observation well readings, the readings on certain dates were considered more appropriate in determining the results of the vacuum wellpoints in lowering the groundwater table. The primary production pumping was achieved between the periods of 23 November to 31 December 1976, and 28 January to 20 March 1977. Therefore, observation well readings developed during these periods were compared with readings developed before and after these periods.

Observation wells located in control areas indicated variations in piezometric levels ranging from reductions of 0 to 1.0 foot (0.3 m) and increases of 0 to 1.7 feet (0.52 m). Observation wells located within the pumping areas indicated variations in piezometric levels ranging from reductions of 0 to 3.0 feet (0.9 m) to increases of 0 to 0.3 feet (.09 m). Significant reductions in piezometric level were recorded at observations wells located close to wellpoints. Typical drawdown curves, developed from a composite of observation well readings, are indicated in Figure 14.

A flowmeter was installed at the end of the collection sump discharge line to record flow rates developed from the vacuum wellpoints. Flowmeter readings are recorded in Appendix E. Readings were obtained for the period of 22 February to 20 March 1977. During this period, the vacuum system operated for 22 days. A total discharge of 3,990 gallons (15.2×10^3 l.) was recorded during this period or an average daily discharge of 181 gallons/day (688 l./day). In an effort to differentiate the flow rate of the vacuum wellpoint system and that of the sand slurry injection system, the shutoff valve to the sand slurry injection system was closed for a period of three days. Mysteriously, the flow rate of

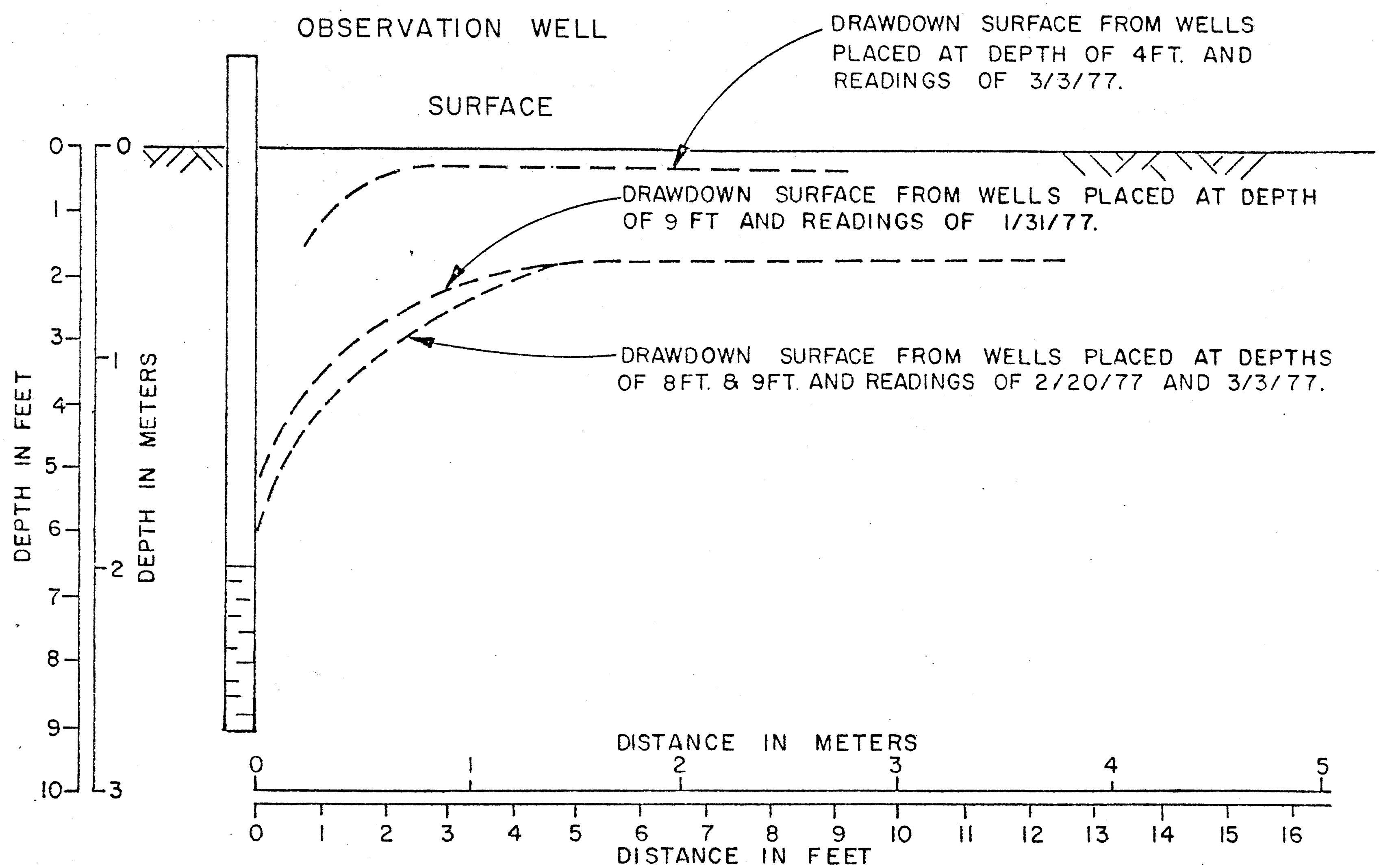


Figure 14. Typical Drawdown Curves

the vacuum wellpoint system averaged approximately 225 gallons/day (855 l./day) for this period.

A total of 38 wellpoints were installed for the vacuum wellpoint system. If equal water flow is assumed from all wellpoints (this is probably not the actual case), and a total daily discharge of 181 gallons/day is achieved, then a daily discharge of approximately 5 gallons (19 l.) per wellpoint can be assumed.

Moisture content samples were obtained periodically to evaluate the effect of pumping on the water content of the dredged slurry. Sampling locations VW-1 through VW-22 are indicated in Figure 6. Additional moisture samples were taken at distances of 1, 2, and 3 feet (0.3, 0.6, 0.9 m) from wellpoints A-11, A-21, C-2, and C-9. Moisture content results are summarized in Appendix A.

Extreme variations in moisture content were obtained for samples taken at depths of 1 to 2 feet (0.3 to 0.6 m). It is assumed most of this variation can be attributed to variations in rainfall and surface ponding. Shrinkage cracks allow ponding which allows infiltration of surface water to recharge the underlying material. The most noticeable reduction in moisture contents was achieved for samples taken close to wellpoints and at the 7 to 8 foot (2.1 to 2.4 m) depth. This conclusion was based on comparing the moisture contents of samples taken during the period of 2 November 1976 to 29 March 1977, and at locations VW-1 through VW-22. In Section A the maximum water content reduction approached 20 percent and averaged approximately 9 percent. During the same period samples taken from Sections B, C, and D registered increases in moisture contents at this same depth. A comparison of test results obtained from samples taken close to wellpoints A-11, A-21, C-2, and C-9 supports the conclusions reached above. Samples taken 1 foot (0.3 m) from wellpoints (at the 7 to 8 foot depth) averaged reductions in moisture content of 24 percent during the period of 24 February to 29 March 1977. However, samples taken 2 and 3 feet (0.6 and 0.9 m) from wellpoints actually recorded increases in moisture content for the same period.

Cone penetration measurements were obtained at many of the moisture sampling locations. These measurements are recorded in Appendix E and summarized in Table IV. These measurements reflect a general increase in penetration resistance with depth. In addition, penetration measurements taken close to wellpoints A-11, A-21, C-2, and C-9 reflect significantly higher resistances within 3 feet (0.9 m) of the wellpoints. As indicated by Frizek and Salem (12, p. 133), these measurements should be considered "as a rough approximation to the undrained shear strength" and are submitted for relative comparison purposes.

Site Consolidation

The primary objective of the field demonstration was to determine the effect of vacuum wellpoints on consolidation of the dredged material. Hopefully, consolidation would be achieved from two conditions. First, the groundwater table would be lowered. Second, the vacuum system would create negative pore pressures in the dredged material, thereby allowing atmospheric pressure at the surface to act as a surcharge. If successful, the effective stress in the dredged material and underlying foundation would be increased with resulting consolidation of the dredged material. This consolidation would create storage space for additional dredged material.

TABLE IV

SUMMARY OF CONE PENETRATION READINGS

Distance From Wellpoint	Average Penetration Reading at Depth of 3 ft	4 ft	5 ft	6 ft	7 ft	8 ft
Date: 2/10/77; Cone Size: 2 in.						
1 ft	42	50	64	79	100	129
2 ft	36	41	50	66	84	107
3 ft	33	36	50	63	72	94
4 ft	31	37	46	59	74	87
Date: 3/9/77; Cone Size: 1 in.						
1 ft	35	46	52	64	74	89
2 ft	32	35	42	51	60	68
3 ft	28	34	39	45	53	63
4 ft	27	32	39	45	53	57

A series of level readings were taken at the test site to determine the actual site consolidation. Level readings were taken on 10-foot (3 m) centers over the area indicated in Figure 6. The readings are recorded in Appendix B.

A comparison of elevations taken in April 1976 and March 1977 indicates the test site has consolidated approximately 5 inches (12.7 cm). This consolidation has been rather uniform over the whole site. It is assumed most of this consolidation can be attributed to natural consolidation of the dredged material. A comparison of elevations taken 5 November 1976 and 29 March 1977 should reflect any site consolidation that can be attributed to pumping with vacuum wellpoints. For this purpose, changes in elevation (between these dates) for Sections A, B, C, and D were averaged. The average consolidation for Section A during this period was 1.46 inches (3.71 cm). Similarly, the consolidation at Sections B, C, and D averaged 0.56 inches (1.42 cm), 0.86 inches (2.18 cm), and 0.79 inches (2.01 cm), respectively. The average consolidation for control Sections B and D was 0.67 inches (1.70 cm). Therefore, the net gain in consolidation for Section C was 0.19 inches (0.48 cm).

Based on the measured average net consolidation for Section A, approximately 25.4 yd^3 (17.8 m^3) of space was created for each 0.25 acre (0.1 ha) of surface area. Similarly, for Section C, approximately 8.1 yd^3 (5.9 m^3) of space was created. The approximate volume of water removed from Section A during the period 22 February to 20 March 1977 was 15.5 yd^3 (11.3 m^3). For Section C, approximately 6.3 yd^3 (4.6 m^3) of water was removed. Although not directly comparable, these independent volume calculations are considered to be within the same order of magnitude.

Installation and Operational Costs

Wellpoint system installation and operational charges have been summarized in Table IV. The cost analysis has been developed based on varying wellpoint centers and method of installation. The estimates are based on the use of 2-inch (5.1 cm) pvc wellpoints and header pipes and 4-inch (10.2 cm) pvc collector pipes. Two methods of wellpoint installations were analyzed (Table V). The "casing" and "sandbag" methods were described in detail earlier. These costs estimates have been computed from data developed during installation of the test site.

TABLE V

SUMMARY OF COST ESTIMATES

Wellpoint Spacing (ft)	Method of Installing Wellpoints	Cost/Acre Materials and Installation
10	Casing	$22,800
10	Sandbag	$14,000
20	Casing	$ 8,500
20	Sandbag	$ 6,000
40	Casing	$ 3,900
40	Sandbag	$ 3,250

In addition to costs for buying and installing the vacuum system, current costs of pumping equipment and power sources are also summarized (Table VI). It is assumed that operation of a vacuum wellpoint system on a production basis would require constant attention. Therefore, the cost of maintaining a technician on site should be included in any cost analysis.

TABLE VI

MISCELLANEOUS COSTS

Item	Cost
Vacuum Pump	$2,000
Electric Motor	$ 400
Diesel Generator	$3,500
Gasoline	$15/day

If the rate of storage capacity development can be projected for a period of one year, approximately 1300 yd^3/acre or 2500 m^3/ha of capacity would be created. For a wellpoint spacing of 20 ft (6.1 m), material and installation costs would be approximately $6,000/acre (14,800/ha). Thus, unit costs for creating storage volume would be $4.61/$yd^3$ ($5.92/$m^3$). However, these costs do not reflect operational costs which must be considered in any detailed cost analysis.

CHAPTER VI

ANALYSIS AND CONCLUSIONS

Technical Feasibility

A review of published reports on the subject and data gathered from this field study tend to support the conclusion that vacuum wellpoints are technically feasible for consolidating fine-grained materials. A major deviation between this field study and previous applications was an attempt to employ wide-spaced wellpoints in achieving long-term consolidation of the dredged material. Previous applications cited utilized horizontal and vertical sand drain to increase the consolidation rate.

Field observations and vacuum gage measurements indicate pvc pipe can be reliably used to construct the vacuum header system. This material has the advantages of being light weight, relatively inexpensive, and easy to assemble. During the testing period, some deflections of the header system were noted. However, these deflections did not result in any noticeable breaks in the vacuum system.

Results of periodic moisture tests and observation well readings indicate dewatering was primarily confined within 3 to 5 feet (0.9 to 1.5 m) of the wellpoint. However, as reflected in Figure 14, dewatering appears to be time-dependent. This information, combined with results of the cone penetration measurements, suggests the radius of influence of the wellpoints is approximately 3 to 5 feet. Dewatering of the surface material was hampered by a lack of surface drainage. During dry weather, shrinkage cracks developed in the surface of the dredged material. However, surface ponding during wet weather appeared to recharge the dredged material. Surface ponding was generally noticeable at wellpoint locations. Saucer-shaped depressions developed at several wellpoints and collected surface water.

Results of surface elevation measurements indicate pumping with vacuum wellpoints did produce additional consolidation above that amount measured at the control sites. This consolidation should be attributable to atmospheric surcharge and lowering of the groundwater table. Considering the organic content of many dredged materials, some advantage may be gained by even minor reductions in the groundwater table. According to a report by Stephens (19), the largest long-term consolidation of organic soils is due to biochemical oxidation.

Economic Feasibility

The magnitudes of deflection developed and the estimated costs of installation indicate vacuum wellpoints would not be economically feasible as proposed by this field study. Reductions in cost of materials could be realized by utilizing smaller diameter pipe, such as 0.5-inch (1.27 cm) wellpoints and 2.0-inch (5.08 cm) header pipe. The cheaper "sandbag" method should be satisfactory for installing wellpoints.

A potential cost savings might be realized by re-using light weight header systems in shallow lifts of 4 to 5 feet (1.2 to 1.5 m). Vacuum consolidation could be conducted during the period between disposals. This is often several years. Prior to additional disposals, the header systems could be removed and then reinserted after placement of additional dredged material.

Operational Problems

Certain operational problems must be faced prior to production use of a vacuum wellpoint system. First, a reliable power source must be established for driving vacuum pumps. The usual remote locations of containment areas often will require an independent power source. For this field study, diesel generators proved to be the most reliable power source.

Maintenance of pumping equipment was another major problem in conducting this field demonstration. Vacuum pumps of sufficient capacity for large-scale pumping projects are not easily obtained. In addition, mechanical expertise for repairing these pumps may not always be locally available. Therefore, a major production use of vacuum wellpoints should not be initiated without developing a stock-pile of pumps and replacement parts.

Operational problems were also experienced with the electrical system which controlled cycling of the vacuum pump and discharge pump. The control system was designed to allow continuous operation of the vacuum pump system. This system was improved upon during the course of the experiment. However, production pumping operations should not be dependent upon sophisticated control systems.

Any production use of vacuum wellpoints should include constant attention by competent personnel. Generators and pumps require frequent maintenance and are subject to breakdowns.

Recommendations

The following recommendations should be considered and evaluated prior to utilizing vacuum wellpoints to consolidate fine-grained dredged materials:

1. Wellpoint spacings should not exceed 10 to 20 feet (3 to 6 m).
2. Underdrains should be utilized to increase the drainage surface.
3. Ditching will be necessary to control surface water.
4. A vacuum wellpoint system should not be considered unless the user is prepared to provide equipment and personnel to maintain operation of the system.

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APPENDIX A

SUMMARY OF MOISTURE TEST RESULTS

TABLE VII

SUMMARY OF MOISTURE CONTENT SAMPLES

Location	Depth	DATE SAMPLED						
		5/8/76	9/29/76	11/2/76	12/7/76	12/29/76	2/21/77	3/29/77
VW-1	1-2	160.2	82.4	143.1	126.5	159.6	141.6	145.6
"	4-5	108.2	120.4	118.8	126.1	126.2	122.5	125.9
"	7-8	73.2	101.5	118.7	110.6	97.9	92.4	98.7
VW-2	1-2	118.6	111.5	131.6	146.2	144.7	136.8	145.3
"	4-5	118.5	128.3	126.9	136.7	123.9	109.7	129.9
"	7-8	78.1	109.4	97.8	123.1	92.1	90.7	87.5
VW-3	1-2	119.1	106.8	152.8	128.4	157.3	142.7	132.7
"	4-5	92.4	112.9	118.3	118.9	129.4	119.6	124.4
"	7-8	70.4	98.3	89.6	94.2	82.8	89.9	95.5
VW-4	1-2	104.1	66.9	93.9	107.0	144.1	133.6	102.7
"	4-5	94.3	102.2	120.2	116.9	110.6	106.4	122.1
"	7-8	81.5	88.0	98.9	96.3	85.1	103.3	99.4
VW-5	1-2	125.7	101.3	87.4	112.6	135.9	143.2	137.5
"	4-5	96.5	99.3	118.8	122.9	122.1	119.7	129.0
"	7-8	66.6	84.1	115.0	97.9	93.8	93.0	86.2
VW-6	1-2	109.6	106.6	92.7	124.3	125.0	133.7	132.9
"	4-5	92.6	103.7	120.0	136.8	125.5	111.1	117.4
"	7-8	72.7	98.4	117.6	88.7	80.2	88.2	100.6

TABLE VII (Continued)

Location	Depth	DATE SAMPLED 5/8/76	9/29/76	11/2/76	12/7/76	12/29/76	2/21/77	3/29/77
VW-7	1-2	106.9	110.8	82.7	127.2	127.9	133.6	119.2
"	4-5	81.9	105.4	124.9	113.4	152.6	117.7	104.2
"	7-8	67.8	101.2	91.3	87.2	86.4	80.4	87.5
VW-8	1-2	134.8	126.2	96.3	131.8	131.2	129.5	106.3
"	4-5	91.9	116.7	105.7	115.5	108.6	107.9	107.4
"	7-8	71.1	88.7	95.0	86.8	86.1	78.3	93.9
VW-9	1-2	149.4	112.6	78.8	128.2	124.6	130.5	132.0
"	4-5	98.2	109.8	115.7	114.7	122.7	107.2	105.8
"	7-8	78.3	114.8	100.7	96.8	82.4	82.9	93.9
VW-10	1-2	106.6	77.4	133.6	159.1	131.5	129.7	152.6
"	4-5	98.6	128.3	129.9	137.2	136.0	109.1	135.3
"	7-8	81.3	100.0	112.7	117.2	102.4	97.4	103.5
VW-11	1-2	147.4	112.1	144.0	145.9	135.9	134.6	133.9
"	4-5	123.0	109.0	117.9	118.3	127.7	122.3	119.6
"	7-8	92.1	105.5	113.5	119.6	112.4	131.5	130.1
VW-12	1-2	146.2	105.5	133.6	149.6	161.7	155.2	143.4
"	4-5	112.6	112.8	109.4	136.0	117.1	125.9	112.5
"	7-8	90.4	96.3	97.3	119.2	106.9	102.8	117.0
VW-13	1-2	164.1	88.2	145.5	132.3	192.1	130.6	143.7
"	4-5	108.4	112.6	113.3	117.5	112.7	121.8	127.1
"	7-8	100.6	102.8	98.8	115.7	103.5	108.1	111.5

TABLE VII (Continued)

Location	Depth	DATE SAMPLED						
		5/8/76	9/29/76	11/2/76	12/7/76	12/29/76	2/21/77	3/29/77
VW-14	1-2	142.5	88.5	135.5	153.2	133.0	134.3	125.6
"	4-5	102.3	117.2	118.1	120.7	134.6	131.9	124.7
"	7-8	99.9	99.8	99.1	119.8	107.8	107.0	120.7
VW-15	1-2	132.4	96.0	148.5	141.9	166.3	135.2	123.3
"	4-5	113.2	112.8	110.3	133.4	124.6	111.0	128.9
"	7-8	87.4	99.9	98.6	137.1	105.2	108.4	108.8
VW-16	1-2	136.7	101.2	141.1	133.0	138.8	152.9	132.5
"	4-5	117.9	124.4	117.1	127.6	116.4	127.4	140.2
"	7-8	92.7	103.8	108.8	115.7	108.2	107.8	113.7
VW-17	1-2	156.5	130.9	133.5	149.0	141.2	130.2	128.4
"	4-5	127.5	107.2	114.1	124.4	125.7	115.1	130.1
"	7-8	107.2	87.4	113.3	124.1	111.0	109.3	109.8
VW-18	1-2	131.5	91.6	136.6	145.3	154.0	132.3	136.5
"	4-5	109.0	107.6	119.3	138.2	114.6	122.9	126.2
"	7-8	87.4	102.8	111.0	122.8	114.1	109.9	115.6
VW-19	1-2	128.6	106.9	151.2	152.8	154.8	128.6	166.3
"	4-5	109.5	128.3	114.1	135.5	123.4	117.6	128.7
"	7-8	90.3	87.9	106.3	120.3	104.0	106.7	118.3
VW-20	1-2	136.7	89.3	146.7	154.1	153.8	134.5	147.4
"	4-5	115.3	95.9	118.4	128.5	134.0	119.6	139.0
"	7-8	86.1	103.8	114.0	111.5	105.3	98.3	118.0

TABLE VII (Continued)

Location	Depth	DATE SAMPLED						
		5/8/76	9/29/76	11/2/76	12/7/76	12/29/76	2/21/77	3/29/77
VW-21	1-2	140.2	101.1	142.7	147.9	143.4	138.0	143.8
"	4-5	118.1	114.5	133.7	138.9	131.5	119.1	138.4
"	7-8	80.3	91.9	112.2	110.9	92.9	106.7	108.3
VW-22	1-2	158.3	124.4	146.2	134.9	149.2	149.4	157.5
"	4-5	140.6	127.3	120.2	125.1	133.6	115.8	125.9
"	7-8	89.0	92.3	81.5	105.8	86.9	78.6	90.9
		2/24/77	3/29/77					
A-11-1	1-2	113.0	139.1					
"	4-5	134.4	129.6					
"	7-8	117.8	102.4					
A-11-2	1-2	121.0	117.3					
"	4-5	119.4	129.2					
"	7-8	81.7	95.8					
A-11-3	1-2	119.9	125.2					
"	4-5	121.0	126.1					
"	7-8	83.5	90.0					
A-21-1	1-2	118.3	121.7					
"	4-5	135.9	117.0					
"	7-8	121.7	99.7					
A-21-2	1-2	118.3	130.1					
"	4-5	107.9	103.7					
"	7-8	84.0	85.3					

TABLE VII (Continued)

Location	Depth	DATE SAMPLED 2/24/77	3/29/77
A-21-3	1-2	108.0	118.7
"	4-5	118.4	122.0
"	7-8	100.3	78.7
C-2-1	1-2	117.6	135.9
"	4-5	145.8	137.6
"	7-8	131.5	103.9
C-2-2	1-2	161.1	127.3
"	4-5	111.4	121.6
"	7-8	105.9	100.2
C-2-3	1-2	147.3	134.9
"	4-5	98.8	124.3
"	7-8	108.5	113.6
C-9-1	1-2	133.5	135.0
"	4-5	157.5	130.0
"	7-8	134.9	103.4
C-9-2	1-2	140.9	145.1
"	4-5	118.6	140.5
"	7-8	104.7	110.1
C-9-3	1-2	139.7	124.7
"	4-5	114.8	123.4
"	7-8	118.3	125.2

APPENDIX B

SUMMARY OF SURFACE ELEVATIONS

TABLE VIII

SUMMARY OF SURVEY READINGS*

Sta.	Dist.	4/8/76	5/6/76	8/4/76	11/5/76	12/23/76	3/29/77
0+00	0	8.4	8.2	8.05	8.04	7.98	7.97
	10	8.3	8.2	7.95	7.90	7.87	7.87
	20	8.3	8.0	7.85	7.81	7.79	7.87
	30	8.3	8.0	7.90	7.86	7.99	7.87
	40	8.2	8.0	7.83	7.75	7.80	7.77
	50	8.1	7.9	7.72	7.70	7.70	7.67
	60	8.1	7.9	7.76	7.69	7.70	7.67
	70	8.1	7.9	7.75	7.67	7.72	7.67
	80	8.1	7.9	7.72	7.61	7.68	7.67
	90	8.1	7.8	7.67	7.63	7.68	7.67
	100	8.0	7.9	7.71	7.62	7.64	7.67
	110	8.1	7.8	7.75	7.63	7.68	7.67
	120	8.0	7.8	7.68	7.57	7.67	7.57
	130	8.1	7.8	7.63	7.60	7.60	7.57
	140	8.0	7.8	7.57	7.63	7.59	7.57
	150	8.0	7.8	7.69	7.62	7.64	7.57
	160	8.0	7.8	7.59	7.62	7.62	7.57
	170	8.1	7.8	7.65	7.57	7.68	7.57
	180	8.1	7.8	7.65	7.65	7.70	7.67
	190	8.0	7.8	7.62	7.63	7.64	7.67
	200	8.1	7.8	7.72	7.66	7.69	7.67
	210	8.1	7.8	7.72	7.65	7.63	7.57
	220	8.0	7.8	7.69	7.61	7.62	7.57
	230	8.0	7.8	7.71	7.66	7.70	7.57
	240	8.0	7.8	7.71	7.66	7.69	7.57
	250	8.1	7.8	7.75	7.69	7.71	7.77
	260	8.1	7.8	7.74	7.68	7.75	7.67
	270	8.1	7.8	7.75	7.66	7.73	7.67
	280	8.1	7.8	7.73	7.72	7.74	7.77
	290	8.2	7.8	7.81	7.76	7.83	7.77
	300	8.2	7.9	7.81	7.78	7.84	7.77
0-10W	0	8.4	8.1	8.10	7.98	8.00	7.97
	10	8.3	8.1	7.95	7.89	7.90	7.97
	20	8.2	8.0	7.88	7.87	7.88	7.87
	30	8.2	8.0	7.93	7.82	7.88	7.77
	40	8.2	8.0	7.82	7.70	7.78	7.77
	50	8.1	7.9	7.81	7.74	7.74	7.67
	60	8.1	7.9	7.74	7.72	7.72	7.67
	70	8.1	7.9	7.74	7.69	7.73	7.67
	80	8.1	7.9	7.74	7.65	7.62	7.57
	90	8.1	7.8	7.73	7.68	7.62	7.67
	100	8.0	7.8	7.69	7.61	7.68	7.67
	110	8.0	7.8	7.64	7.60	7.68	7.57
	120	8.0	7.8	7.70	7.62	7.66	7.57
	130	8.0	7.8	7.63	7.66	7.60	7.57
	140	8.0	7.8	7.67	7.57	7.64	7.57
	150	7.9	7.8	7.62	7.61	7.65	7.67
	160	7.9	7.8	7.67	7.55	7.60	7.37
	170	8.0	7.8	7.69	7.56	7.62	7.57
	180	8.0	7.7	7.63	7.61	7.61	7.57
	190	8.0	7.8	7.66	7.62	7.68	7.47
	200	8.0	7.7	7.62	7.53	7.58	7.47
	210	8.0	7.8	7.68	7.62	7.59	7.57
	220	8.0	7.8	7.69	7.59	7.64	7.57
	230	8.0	7.8	7.69	7.61	7.70	7.57
	240	8.0	7.8	7.71	7.63	7.68	7.57
	250	8.1	7.9	7.70	7.64	7.72	7.67
	260	8.1	7.9	7.74	7.68	7.74	7.67
	270	8.1	7.9	7.74	7.69	7.76	7.67
	280	8.1	7.9	7.75	7.66	7.70	7.67
	290	8.2	7.9	7.80	7.72	7.79	7.77
	300	8.2	7.9	7.72	7.73	7.72	7.77

TABLE VIII (Continued)

Sta.	Dist.	4/8/76	5/6/76	8/4/76	11/5/76	12/23/76	3/29/77
0+20W	0	8.4	8.1	8.04	7.94	7.98	7.97
	10	8.3	8.1	7.94	7.89	7.92	7.87
	20	8.2	8.0	7.91	7.81	7.87	7.87
	30	8.2	8.0	7.83	7.78	7.74	7.67
	40	8.1	8.0	7.77	7.69	7.72	7.67
	50	8.0	7.9	7.75	7.65	7.71	7.57
	60	8.1	7.9	7.76	7.70	7.71	7.67
	70	8.1	7.8	7.76	7.48	7.67	7.63
	80	8.0	7.8	7.73	7.62	7.70	7.62
	90	8.0	7.9	7.70	7.60	7.67	7.61
	100	8.0	7.9	7.67	7.58	7.64	7.58
	110	7.9	7.8	7.67	7.58	7.64	7.59
	120	8.0	7.8	7.64	7.59	7.61	7.52
	130	8.0	7.7	7.65	7.63	7.59	7.54
	140	8.0	7.8	7.67	7.60	7.60	7.55
	150	8.0	7.8	7.70	7.59	7.61	7.53
	160	8.0	7.8	7.65	7.57	7.60	7.57
	170	7.9	7.7	7.62	7.55	7.60	7.56
	180	7.9	7.8	7.64	7.55	7.60	7.53
	190	8.0	7.9	7.65	7.49	7.63	7.58
	200	7.9	7.9	7.66	7.57	7.61	7.63
	210	8.0	7.8	7.67	7.60	7.62	7.58
	220	8.0	7.8	7.66	7.52	7.60	7.61
	230	8.0	7.8	7.69	7.53	7.64	7.52
	240	8.0	7.9	7.70	7.64	7.69	7.56
	250	8.1	7.9	7.70	7.58	7.73	7.67
	260	8.1	7.9	7.73	7.67	7.74	7.67
	270	8.1	7.9	7.73	7.65	7.71	7.66
	280	8.1	7.9	7.74	7.65	7.72	7.72
	290	8.2	7.9	7.76	7.67	7.71	7.77
	300	8.2	7.9	7.81	7.70	7.74	7.75
0+30W	0	8.3	7.9	7.96	7.89	7.91	7.90
	10	8.2	8.0	7.83	7.76	7.84	7.82
	20	8.1	7.9	7.85	7.78	7.78	7.77
	30	8.1	7.9	7.71	7.75	7.74	7.69
	40	8.1	7.9	7.78	7.64	7.72	7.61
	50	8.0	7.9	7.73	7.64	7.68	7.61
	60	8.0	7.8	7.73	7.60	7.63	7.60
	70	8.0	7.8	7.73	7.61	7.60	7.55
	80	8.0	7.8	7.74	7.52	7.58	7.51
	90	8.0	7.8	7.68	7.60	7.58	7.58
	100	8.0	7.9	7.68	7.49	7.61	7.60
	110	7.9	7.8	7.69	7.59	7.63	7.59
	120	8.0	7.8	7.66	7.56	7.61	7.59
	130	8.0	7.8	7.66	7.57	7.56	7.55
	140	8.0	7.8	7.65	7.58	7.61	7.44
	150	8.0	7.8	7.71	7.60	7.61	7.57
	160	8.0	7.8	7.68	7.58	7.59	7.55
	170	8.0	7.8	7.61	7.55	7.60	7.57
	180	7.9	7.8	7.65	7.57	7.58	7.58
	190	7.9	7.8	7.62	7.55	7.49	7.53
	200	7.9	6.8	7.58	7.50	7.60	7.54
	210	8.0	7.8	7.67	7.57	7.63	7.55
	220	8.0	7.8	7.72	7.64	7.63	7.62
	230	8.0	7.8	7.57	7.59	7.64	7.52
	240	8.0	7.8	7.68	7.58	7.70	7.60
	250	8.0	7.8	7.71	7.66	7.71	7.66
	260	8.1	7.8	7.64	7.56	7.71	7.65
	270	8.1	7.9	7.72	7.69	7.73	7.72
	280	8.1	7.9	7.77	7.71	7.75	7.73
	290	8.1	7.9	7.79	7.72	7.79	7.70
	300	8.2	7.9	7.81	7.77	7.80	7.76

TABLE VIII (Continued)

Sta.	Dist.	4/8/76	5/6/76	8/4/76	11/5/76	12/23/76	3/29/77
0+40W	0	8.3	8.0	7.98	7.92	7.87	7.87
	10	8.2	7.9	7.90	7.79	7.78	7.77
	20	8.2	8.0	7187	7178	7.68	7.75
	30	8.1	7.9	7.70	7.65	7.67	7.59
	40	8.1	8.0	7.74	7.65	7.64	7.62
	50	8.0	7.8	7.73	7.64	7.60	7.51
	60	8.0	7.8	7.58	7.59	7.58	7.53
	70	8.0	7.8	7.67	7.61	7.55	7.51
	80	8.0	7.8	7.62	7.56	7.50	7.50
	90	7.9	7.8	7.64	7.50	7.56	7.44
	100	8.0	7.8	7.64	7.56	7.59	7.40
	110	8.0	7.8	7.64	7.56	7.64	7.55
	120	7.9	7.8	7.68	7.61	7.55	7.55
	130	8.0	7.9	7.65	7.59	7.57	7.52
	140	7.9	7.8	7.65	7.57	7.60	7.51
	150	8.0	7.8	7.64	7.58	7.64	7.51
	160	8.0	7.8	7.70	7.57	7.60	7.55
	170	8.0	7.8	7.66	7.58	7.60	7.53
	180	8.0	7.8	7.64	7.56	7.61	7.52
	190	7.9	7.8	7.65	7.55	7.60	7.50
	200	7.9	7.8	7.63	7.57	7.61	7.56
	210	7.9	7.7	7.65	7.58	7.56	7.46
	220	7.9	7.7	7.59	7.50	7.66	7.53
	230	7.9	7.8	7.68	7.60	7.67	7.59
	240	7.9	7.8	7.69	7.58	7.65	7.53
	250	8.0	7.8	7.70	7.59	7.68	7.55
	260	8.1	7.8	7.71	7.64	7.67	7.64
	270	8.1	7.9	7.74	7.64	7.73	7.60
	280	8.1	7.8	7.75	7.66	7.71	7.69
	290	8.1	7.8	7.78	7.69	7.77	7.71
	300	8.2	7.9	7.82	7.67	7.75	7.72
0+50W	0	8.3	8.0	7.94	7.82	7.88	7.84
	10	8.2	7.9	7.81	7.74	7.78	7.72
	20	8.1	7.8	7.77	7.74	7.71	7.65
	30	8.0	7.7	7.66	7.60	7.55	7.37
	40	8.0	7.8	7.68	7.64	7.65	7.55
	50	8.0	7.7	7.70	7.65	7.64	7.59
	60	8.0	7.7	7.66	7.55	7.53	7.46
	70	8.0	7.8	7.67	7.49	7.41	7.37
	80	8.0	7.7	7.62	7.58	7.57	7.43
	90	8.0	7.7	7.64	7.52	7.51	7.44
	100	7.9	7.7	7.56	7.45	7.43	7.33
	110	7.9	7.7	7.62	7.54	7.55	7.51
	120	8.0	7.8	7.60	7.55	7.53	7.51
	130	8.0	7.7	7.66	7.64	7.48	7.48
	140	7.9	7.7	7.61	7.50	7.49	7.35
	150	8.0	7.8	7.69	7.59	7.62	7.58
	160	8.0	7.8	7.65	7.49	7.55	7.53
	170	8.0	7.8	7.62	7.55	7.51	7.47
	180	7.9	7.7	7.63	7.59	7.57	7.51
	190	8.0	7.8	7.68	7.59	7.51	7.44
	200	7.9	7.8	7.67	7.53	7.67	7.46
	210	8.0	7.8	7.68	7.59	7.58	7.55
	220	8.0	7.8	7.71	7.58	7.63	7.59
	230	8.0	7.8	7.70	7.51	7.59	7.56
	240	7.9	7.8	7.62	7.56	7.60	7.59
	250	8.0	7.8	7.67	7.59	7.60	7.59
	260	8.0	7.8	7.71	7.66	7.67	7.62
	270	8.1	7.9	7.74	7.63	7.68	7.52
	280	8.1	7.9	7.74	7.67	7.65	7.62
	290	8.1	7.9	7.83	7.71	7.79	7.72
	300	8.1	7.9	7.80	7.69	7.70	7.69

TABLE VIII (Continued)

Sta.	Dist.	4/8/76	5/6/76	8/4/76	11/5/76	12/23/76	3/29/77
0+60W	0	8.3	7.8	7.78	7.80	7.81	7.75
	10	8.1	7.9	7.84	7.80	7.74	7.65
	20	8.1	7.9	7.78	7.74	7.72	7.51
	30	8.0	7.9	7.75	7.63	7.67	7.50
	40	8.0	7.8	7.71	7.65	7.65	7.59
	50	8.0	7.8	7.67	7.50	7.60	7.56
	60	8.0	7.8	7.66	7.55	7.60	7.47
	70	8.0	7.7	7.67	7.54	7.53	7.44
	80	7.8	7.6	7.62	7.51	7.52	7.41
	90	8.0	7.7	7.63	7.51	7.57	7.43
	100	7.9	7.7	7.62	7.52	7.53	7.43
	110	8.0	7.7	7.58	7.54	7.53	7.43
	120	8.0	7.8	7.67	7.59	7.63	7.46
	130	8.0	7.6	7.68	7.58	7.60	7.54
	140	7.9	7.7	7.61	7.56	7.54	7.42
	150	8.0	7.7	7.64	7.56	7.64	7.53
	160	7.9	7.7	7.59	7.54	7.58	7.47
	170	7.9	7.7	7.59	7.49	7.58	7.52
	180	7.9	7.7	7.64	7.58	7.61	7.49
	190	7.9	7.7	7.63	7.56	7.59	7.48
	200	7.9	7.7	7.62	7.56	7.61	7.53
	210	8.0	7.7	7.61	7.52	7.60	7.52
	220	7.9	7.7	7.67	7.56	7.58	7.47
	230	8.0	7.8	7.65	7.57	7.60	7.39
	240	8.0	7.8	7.66	7.60	7.66	7.55
	250	8.0	7.8	7.67	7.59	7.62	7.52
	260	8.0	7.7	7.71	7.61	7.67	7.59
	270	8.0	7.8	7.74	7.62	7.70	7.55
	280	8.1	7.8	7.73	7.69	7.74	7.64
	290	8.1	7.8	7.69	7.52	7.69	7.62
	300	8.2	7.9	7.85	7.75	7.80	7.72
0+70W	0	8.2	8.0	7.91	7.77	7.84	7.75
	10	8.2	7.9	7.79	7.70	7.72	7.51
	20	8.1	7.9	7.81	7.70	7.70	7.62
	30	8.1	7.8	7.74	7.63	7.65	7.56
	40	8.0	7.8	7.67	7.61	7.61	7.47
	50	8.0	7.8	7.70	7.60	7.61	7.44
	60	7.9	7.7	7.66	7.52	7.55	7.50
	70	7.9	7.7	7.57	7.52	7.51	7.46
	80	8.0	7.7	7.63	7.55	7.55	7.49
	90	7.9	7.7	7.61	7.53	7.54	7.44
	100	8.0	7.7	7.61	7.56	7.55	7.40
	110	7.9	7.7	7.59	7.48	7.55	7.39
	120	8.0	7.7	7.64	7.55	7.55	7.58
	130	7.9	7.6	7.63	7.58	7.54	7.47
	140	7.9	7.7	7.63	7.54	7.57	7.55
	150	7.9	7.7	7.65	7.58	7.55	7.44
	160	7.9	7.7	7.53	7.40	7.48	7.37
	170	8.0	7.7	7.64	7.59	7.60	7.52
	180	7.9	7.8	7.65	7.56	7.56	7.49
	190	7.9	7.8	7.64	7.54	7.53	7.48
	200	7.9	7.9	7.60	7.56	7.54	7.46
	210	7.9	7.8	7.61	7.53	7.60	7.47
	220	7.9	7.7	7.64	7.69	7.59	7.56
	230	8.0	7.7	7.62	7.67	7.60	7.49
	240	8.0	7.8	7.65	7.62	7.58	7.42
	250	8.0	7.8	7.68	7.62	7.65	7.42
	260	8.0	7.8	7.68	7.61	7.65	7.61
	270	8.0	7.9	7.70	7.62	7.68	7.57
	280	8.0	7.9	7.71	7.59	7.70	7.62
	290	8.1	7.8	7.81	7.70	7.71	7.63
	300	8.1	7.9	7.82	7.71	7.81	7.76

TABLE VIII (Continued)

Sta.	Dist.	4/8/76	5/6/76	8/4/76	11/5/76	12/23/76	3/29/77
0+80W	0	8.2	8.0	7.76	7.68	7.69	7.69
	10	8.2	7.9	7.81	7.74	7.75	7.72
	20	8.1	7.9	7.76	7.69	7.67	7.60
	30	8.0	7.9	7.70	7.63	7.63	7.55
	40	8.0	7.8	7.63	7.50	7.57	7.49
	50	7.9	7.8	7.64	7.59	7.55	7.51
	60	8.0	7.8	7.65	7.58	7.60	7.51
	70	8.0	7.7	7.61	7.49	7.56	7.49
	80	7.9	7.7	7.55	7.47	7.52	7.43
	90	7.9	7.7	7.60	7.49	7.54	7.47
	100	7.9	7.7	7.64	7.55	7.53	7.46
	110	7.9	7.7	7.63	7.51	7.54	7.55
	120	7.9	7.8	7.62	7.51	7.55	7.48
	130	8.0	7.8	7.58	7.49	7.54	7.44
	140	7.9	7.8	7.58	7.51	7.60	7.48
	150	7.9	7.7	7.59	7.49	7.56	7.48
	160	7.9	7.8	7.50	7.53	7.53	7.41
	170	7.9	7.8	7.64	7.57	7.55	7.56
	180	8.0	7.8	7.61	7.54	7.56	7.52
	190	7.9	7.7	7.62	7.47	7.56	7.47
	200	7.9	7.8	7.59	7.52	7.56	7.51
	210	7.9	7.7	7.60	7.46	7.54	7.57
	220	7.9	7.8	7.64	7.55	7.56	7.47
	230	8.0	7.8	7.64	7.58	7.59	7.54
	240	8.0	7.8	7.69	7.59	7.62	7.57
	250	8.0	7.8	7.68	7.59	7.64	7.62
	260	8.0	7.9	7.69	7.61	7.66	7.59
	270	8.1	8.0	7.72	7.63	7.69	7.66
	280	8.1	8.0	7.74	7.66	7.73	7.68
	290	8.1	7.8	7.75	7.72	7.72	7.75
	300	8.2	8.0	7.81	7.71	7.68	7.62
0+90W	0	8.3	7.9	7.92	7.80	7.71	7.80
	10	8.2	8.0	7.80	7.70	7.64	7.59
	20	8.1	7.9	7.73	7.69	7.69	7.59
	30	8.1	7.9	7.74	7.62	7.68	7.35
	40	8.1	7.8	7.62	7.51	7.41	7.50
	50	8.0	7.7	7.68	7.56	7.52	7.55
	60	7.9	7.8	7.59	7.54	7.56	7.44
	70	7.9	7.7	7.55	7.47	7.49	7.39
	80	7.8	7.6	7.60	7.46	7.50	7.43
	90	7.9	7.6	7.57	7.47	7.51	7.39
	100	7.9	7.7	7.47	7.38	7.41	7.46
	110	7.9	7.7	7.61	7.50	7.49	7.36
	120	7.9	7.7	7.58	7.48	7.41	7.33
	130	7.9	7.5	7.57	7.41	7.39	7.32
	140	7.9	7.8	7.57	7.47	7.48	7.41
	150	7.9	7.8	7.59	7.52	7.55	7.46
	160	7.9	7.7	7.55	7.53	7.52	7.49
	170	7.9	7.8	7.62	7.51	7.64	7.43
	180	7.9	7.8	7.59	7.53	7.44	7.53
	190	7.9	7.8	7.63	7.57	7.59	
	200	8.0	7.8	7.56	7.53	7.54	7.50
	210	7.9	7.9	7.63	7.57	7.58	7.51
	220	8.0	7.8	7.63	7.50	7.62	7.57
	230	8.1	7.8	7.71	7.63	7.64	7.59
	240	8.0	7.9	7.72	7.59	7.66	7.59
	250	8.0	7.8	7.61	7.54	7.60	7.55
	260	8.0	7.9	7.69	7.62	7.66	7.65
	270	8.0	7.9	7.69	7.64	7.69	7.57
	280	8.1	7.9	7.74	7.69	7.73	7.59
	290	8.1	7.9	7.81	7.75	7.79	7.73
	300	8.1	7.9	7.85	7.73	7.79	7.70

TABLE VIII (Continued)

Sta.	Dist.	4/8/76	5/6/76	8/4/76	11/5/76	12/23/76	3/29/77
1+00W	0	8.2	7.9	7.86	7.77	7.74	7.72
	10	8.1	7.9	7.78	7.71	7.79	7.73
	20	8.0	7.9	7.74	7.67	7.68	7.63
	30	8.0	7.8	7.72	7.62	7.57	7.56
	40	8.0	7.8	7.51	7.52	7.56	7.46
	50	8.0	7.8	7.68	7.55	7.54	7.45
	60	8.0	7.8	7.62	7.54	7.53	7.41
	70	7.9	7.6	7.59	7.49	7.45	7.43
	80	7.8	7.7	7.58	7.44	7.50	7.38
	90	7.9	7.7	7.55	7.49	7.50	7.42
	100	7.9	7.7	7.57	7.51	7.50	7.40
	110	7.9	7.7	7.62	7.50	7.48	7.45
	120	7.9	7.7	7.60	7.52	7.54	7.44
	130	7.9	7.7	7.60	7.50	7.54	7.46
	140	7.9	7.7	7.58	7.51	7.53	7.47
	150	7.9	7.7	7.57	7.51	7.55	7.37
	160	7.9	7.7	7.59	7.51	7.53	7.45
	170	7.9	7.7	7.61	7.59	7.56	7.48
	180	7.9	7.7	7.65	7.54	7.53	7.49
	190	7.9	7.8	7.64	7.53	7.60	7.47
	200	7.9	7.8	7.64	7.59	7.61	7.47
	210	7.9	7.7	7.65	7.54	7.69	7.46
	220	8.0	7.8	7.73	7.66	7.64	7.63
	230	8.0	7.8	7.67	7.60	7.62	7.56
	240	8.0	7.8	7.64	7.60	7.66	7.55
	250	8.0	7.8	7.70	7.66	7.67	7.59
	260	8.0	7.9	7.71	7.62	7.68	7.59
	270	8.0	7.8	7.72	7.65	7.72	7.53
	280	8.0	7.9	7.78	7.70	7.76	7.62
	290	8.1	7.9	7.79	7.72	7.80	7.67
	300	8.1	7.9	7.83	7.75	7.80	7.73
1+10W	0	8.2	7.9	7.79	7.76	7.76	7.67
	10	8.1	7.9	7.77	7.72	7.70	7.62
	20	8.1	7.9	7.76	7.68	7.70	7.66
	30	8.0	7.8	7.68	7.61	7.60	7.46
	40	7.9	7.9	7.66	7.50	7.50	7.48
	50	7.9	7.8	7.57	7.49	7.51	7.46
	60	7.9	7.7	7.55	7.57	7.43	7.47
	70	7.9	7.6	7.57	7.48	7.45	7.37
	80	7.9	7.7	7.61	7.52	7.46	7.43
	90	7.9	7.7	7.56	7.49	7.47	7.42
	100	7.9	7.7	7.56	7.48	7.45	7.43
	110	7.9	7.8	7.57	7.51	7.42	7.43
	120	7.9	7.7	7.54	7.47	7.55	7.43
	130	7.9	7.7	7.67	7.57	7.56	7.47
	140	7.9	7.8	7.59	7.51	7.47	7.45
	150	7.9	7.7	7.59	7.51	7.48	7.41
	160	7.9	7.7	7.63	7.58	7.50	7.48
	170	7.9	7.8	7.61	7.50	7.48	7.49
	180	7.9	7.8	7.62	7.60	7.60	7.54
	190	7.9	7.7	7.66	7.60	7.58	7.56
	200	7.9	7.7	7.64	7.53	7.58	7.49
	210	8.0	7.9	7.69	7.63	7.58	7.56
	220	7.9	7.9	7.74	7.68	7.64	7.58
	230	7.9	7.8	7.69	7.63	7.62	7.58
	240	8.0	7.9	7.74	7.61	7.61	7.57
	250	8.0	7.9	7.75	7.69	7.68	7.59
	260	8.0	7.9	7.74	7.71	7.70	7.59
	270	8.1	7.8	7.74	7.70	7.67	7.59
	280	8.1	7.8	7.73	7.68	7.65	7.63
	290	8.1	7.9	7.80	7.72	7.72	7.67
	300	8.1	7.9	7.78	7.70	7.70	7.65

TABLE VIII (Continued)

Sta.	Dist.	4/8/76	5/6/76	8/4/76	11/5/76	12/23/76	3/29/77
1+20W	0	8.2	7.9	7.76	7.69	7.62	7.56
	10	8.1	7.9	7.75	7.64	7.67	7.65
	20	8.1	7.9	7.77	7.66	7.64	7.52
	30	8.0	7.9	7.71	7.61	7.61	7.52
	40	8.0	7.9	7.61	7.52	7.52	7.45
	50	7.9	7.9	7.52	7.44	7.48	7.42
	60	7.9	7.6	7.56	7.50	7.52	7.46
	70	7.8	7.7	7.57	7.50	7.40	7.42
	80	7.9	7.6	7.48	7.46	7.47	7.45
	90	7.9	7.6	7.62	7.53	7.51	7.44
	100	7.9	7.7	7.60	7.49	7.49	7.43
	110	7.9	7.7	7.54	7.41	7.43	7.37
	120	7.9	7.7	7.56	7.45	7.45	7.43
	130	7.9	7.7	7.63	7.56	7.52	7.45
	140	7.9	7.8	7.59	7.48	7.51	7.47
	150	7.9	7.7	7.60	7.51	7.56	7.46
	160	7.9	7.7	7.60	7.52	7.55	7.46
	170	8.0	7.7	7.61	7.53	7.57	7.46
	180	7.9	7.7	7.66	7.57	7.61	7.52
	190	7.9	7.7	7.64	7.58	7.56	7.37
	200	8.0	7.7	7.64	7.57	7.55	7.49
	210	8.0	7.9	7.70	7.62	7.65	7.64
	220	8.0	7.8	7.74	7.66	7.70	7.62
	230	8.0	7.8	7.74	7.64	7.66	7.57
	240	8.0	7.9	7.74	7.65	7.70	7.61
	250	8.0	7.9	7.81	7.66	7.69	7.62
	260	8.0	7.9	7.86	7.67	7.70	7.64
	270	8.1	7.9	7.76	7.69	7.76	7.71
	280	8.1	7.9	7.80	7.67	7.74	7.73
	290	8.1	7.9	7.72	7.64	7.77	7.72
	300	8.1	7.9	7.72	7.64	7.69	7.72
1+30W	0	8.1	7.9	7.84	7.73	7.75	7.74
	10	8.1	7.9	7.74	7.77	7.75	7.73
	20	8.1	7.7	7.71	7.55	7.76	7.53
	30	8.1	7.7	7.64	7.49	7.66	7.38
	40	8.0	7.8	7.66	7.51	7.56	7.46
	50	7.9	7.7	7.60	7.40	7.56	7.41
	60	7.8	7.7	7.58	7.47	7.50	7.39
	70	7.8	7.7	7.50	7.39	7.49	7.36
	80	7.9	7.7	7.62	7.45	7.49	7.37
	90	7.8	7.7	7.52	7.36	7.51	7.38
	100	7.9	7.5	7.58	7.38	7.47	7.33
	110	7.8	7.7	7.60	7.46	7.36	7.42
	120	7.8	7.7	7.59	7.50	7.44	7.37
	130	7.9	7.6	7.58	7.37	7.50	7.38
	140	7.8	7.6	7.52	7.43	7.38	7.32
	150	7.9	7.7	7.56	7.45	7.50	7.40
	160	7.9	7.7	7.56	7.49	7.51	7.47
	170	8.0	7.7	7.65	7.54	7.56	7.52
	180	7.9	7.8	7.66	7.56	7.58	7.44
	190	7.9	7.8	7.56	7.55	7.54	7.44
	200	8.0	7.8	7.67	7.56	7.59	7.57
	210	8.0	7.7	7.71	7.59	7.64	7.56
	220	8.0	7.8	7.73	7.62	7.70	7.61
	230	8.1	7.9	7.74	7.72	7.75	7.66
	240	8.0	7.9	7.72	7.59	7.71	7.53
	250	8.1	7.9	7.78	7.67	7.75	7.62
	260	8.1	7.9	7.76	7.65	7.69	7.61
	270	8.0	7.9	7.75	7.62	7.75	7.66
	280	8.1	7.9	7.78	7.67	7.69	7.72
	290	8.1	7.9	7.83	7.74	7.80	7.69
	300	8.1	7.8	7.84	7.74	7.77	7.69

TABLE VIII (Continued)

Sta.	Dist.	4/8/76	5/6/76	8/4/76	11/5/76	12/23/76	3/29/77
1+40W	0	8.1	7.9	7.79	7.76	7.75	7.73
	10	8.1	7.9	7.73	7.75	7.65	7.63
	20	8.1	7.9	7.67	7.70	7.66	7.62
	30	7.9	7.9	7.67	7.58	7.58	7.47
	40	7.9	7.8	7.62	7.56	7.57	7.48
	50	8.1	7.6	7.57	7.51	7.53	7.42
	60	7.9	7.7	7.56	7.49	7.48	7.42
	70	7.9	7.7	7.59	7.48	7.49	7.42
	80	7.9	7.7	7.46	7.39	7.41	7.37
	90	7.8	7.7	7.56	7.46	7.48	7.38
	100	7.9	7.6	7.53	7.45	7.46	7.37
	110	7.8	7.6	7.56	7.45	7.49	7.36
	120	7.8	7.7	7.56	7.48	7.50	7.40
	130	7.8	7.6	7.57	7.44	7.49	7.38
	140	7.9	7.7	7.50	7.43	7.45	7.41
	150	7.4	7.7	7.71	7.56	7.52	7.42
	160	8.1	7.7	7.70	7.70	7.60	7.72
	170	7.9	7.6	7.62	7.55	7.54	7.56
	180	8.0	7.5	7.62	7.57	7.52	7.54
	190	8.0	7.9	7.64	7.54	7.59	7.56
	200	8.0	7.8	7.70	7.64	7.63	7.58
	210	8.0	7.8	7.72	7.62	7.63	7.59
	220	8.0	7.8	7.75	7.67	7.69	7.64
	230	8.1	7.9	7.77	7.68	7.68	7.61
	240	8.0	7.9	7.72	7.63	7.67	7.62
	250	8.0	7.9	7.73	7.67	7.63	7.60
	260	8.1	7.8	7.68	7.61	7.61	7.59
	270	8.1	7.9	7.71	7.60	7.68	7.62
	280	8.1	7.8	7.73	7.64	7.72	7.61
	290	8.1	7.8	7.78	7.71	7.76	7.68
	300	8.1	7.8	7.79	7.72	7.73	7.69
1+50W	0	8.0	7.9	7.30	7.35	7.39	7.33
	10	7.6	7.8	7.30	7.40	7.31	7.12
	20	8.1	7.8	7.58	7.67	7.17	7.46
	30	8.0	7.8	7.42	7.67	6.95	7.66
	40	8.0	7.7	7.68	7.75	7.31	7.54
	50	8.3	7.7	7.67	7.53	7.71	7.49
	60	8.1	7.6	7.62	7.45	7.55	7.47
	70	7.8	7.7	7.72	7.53	7.66	7.38
	80	8.0	7.6	7.54	7.48	7.46	7.36
	90	7.8	7.7	7.54	7.42	7.43	7.38
	100	8.0	7.7	7.53	7.43	7.46	7.38
	110	8.0	7.7	7.55	7.49	7.45	7.41
	120	8.0	7.7	7.51	7.43	7.51	7.37
	130	7.9	7.7	7.53	7.43	7.45	7.38
	140	7.7	7.2	7.52	7.36	7.46	7.41
	150	7.4	7.5				
	160	7.6	7.7	7.43	7.48	7.46	7.50
	170	8.0	7.8	7.68	7.52	7.54	7.47
	180	8.0	7.8	7.61	7.58	7.57	7.53
	190	8.0	7.8	7.68	7.60	7.64	7.58
	200	8.0	7.8	7.71	7.67	7.60	7.62
	210	8.0	7.8	7.76	7.62	7.64	7.62
	220	8.0	7.8	7.72	7.62	7.65	7.60
	230	8.0	7.8	7.71	7.67	7.64	7.58
	240	8.0	7.8	7.72	7.64	7.64	7.59
	250	8.1	7.9	7.77	7.62	7.65	7.62
	260	8.1	7.9	7.74	7.66	7.69	7.67
	270	8.0	7.9	7.73	7.66	7.67	7.64
	280	8.1	7.9	7.80	7.73	7.69	7.63
	290	8.1	7.9	7.81	7.74	7.77	7.69
	300	8.1	7.9	7.85	7.73	7.83	7.73

TABLE VIII (Continued)

Sta.	Dist.	4/8/76	5/6/76	8/4/76	11/5/76	12/23/76	3/29/77
1+60W	0	7.8	7.7	7.48	7.44	7.44	7.41
	10	7.9	7.7	7.40	7.38	7.38	7.39
	20	7.8	7.7	7.41	7.44	7.43	7.33
	30	7.5	7.7	7.56	7.27	7.46	7.11
	40	7.4	7.6	7.24	7.18	7.14	7.12
	50	7.5	7.1	7.21	7.03	7.04	7.40
	60	7.9	7.8	7.18	7.09	7.10	7.13
	70	7.9	7.4	7.66	7.43	7.49	7.48
	80	7.7	7.7	7.53	7.44	7.45	7.33
	90	7.8	7.6	7.53	7.42	7.21	7.22
	100	7.8	7.5	7.44	7.35	7.36	7.30
	110	7.8	7.4	7.40	7.44	7.43	7.31
	120	7.9	7.2	7.33	7.27	7.26	7.27
	130	7.6	7.4	7.31	6.97	7.10	7.20
	140	7.4	7.4	7.24	7.43	7.13	7.13
	150	7.9	7.5	7.50		7.41	7.51
	160	7.8	7.7	7.53	7.44	7.29	7.27
	170	7.6	7.6	7.54	7.44	7.47	7.54
	180	8.0	7.5	7.53	7.42	7.46	7.45
	190	7.8	7.8	8.01	7.72	7.55	7.72
	200	7.7	8.0	7.99	7.84	7.88	7.87
	210	7.9	7.9	8.12	7.80	7.80	7.72
	220	7.8	8.0	7.84	7.82	7.76	7.65
	230	8.0	7.9	7.66	7.62	7.57	7.56
	240	7.9	7.8	7.72	7.62	7.59	7.56
	250	8.0	7.9	7.66	7.62	7.60	7.65
	260	8.1	7.9	7.75	7.66	7.70	7.62
	270	8.1	7.9	7.79	7.65	7.67	7.65
	280	8.1	7.9	7.79	7.71	7.69	7.67
	290	8.1	7.9	7.78	7.69	7.75	7.67
	300	8.1	7.9	8.00	7.90	7.88	7.82
1+70W	0	8.2	8.0	7.86	7.79	7.81	7.77
	10	8.3	7.9	7.79	7.72	7.68	7.71
	20	8.1	7.9	7.78	7.72	7.68	7.64
	30	8.1	7.8	7.72	7.60	7.67	7.59
	40	8.0	7.8	7.70	7.56	7.56	7.53
	50	8.0	7.7	7.62	7.56	7.50	7.50
	60	8.0	7.7	7.64	7.51	7.48	7.49
	70	8.0	7.7	7.64	7.45	7.46	7.42
	80	7.8	7.6	7.53	7.42	7.44	7.38
	90	7.9	7.6	7.57	7.45	7.56	7.52
	100	7.9	7.7	7.61	7.41	7.44	7.52
	110	7.8	7.7	7.60	7.56	7.63	7.42
	120	7.9	7.7	7.68	7.51	7.73	7.47
	130	8.0	7.9	7.68	7.27	7.32	7.49
	140	7.9	7.8	7.60	7.17	7.44	7.38
	150	8.0	7.9	7.38	7.04	6.92	7.55
	160	7.6	7.8	7.17	7.10	7.09	7.31
	170	7.5	7.4	7.22	7.11	7.01	7.15
	180	7.7	7.6	7.53	7.41	7.09	7.21
	190	7.5	7.6	7.44	7.31	7.38	7.11
	200	7.6	7.4	7.32	7.13	7.28	7.17
	210	7.8	7.6	7.36	7.35	7.16	7.37
	220	7.7	7.5	7.48	7.23	7.48	7.22
	230	7.9	7.6	7.22	7.25	7.58	7.42
	240	7.9	7.6	7.25	7.52	7.54	7.46
	250	7.9	7.4	7.33	7.22	7.25	7.15
	260	7.7	7.4	7.31	7.14	7.26	7.17
	270	7.8	7.3	7.30	7.28	7.45	7.15
	280	7.7	7.4	7.24	7.28	7.44	7.17
	290	7.5	7.5	7.40	7.15	7.77	7.32
	300	7.8	7.6	7.70	7.56	7.89	7.37

TABLE VIII (Continued)

Sta.	Dist.	4/8/76	5/6/76	8/4/76	11/5/76	12/23/76	3/29/77
1+80W	0	8.3	8.0	7.78	7.82	7.70	7.77
	10	8.1	7.9	7.77	7.71	7.68	7.62
	20	8.0	7.9	7.68	7.60	7.57	7.52
	30	8.0	7.9	7.70	7.70	7.67	7.53
	40	8.1	7.8	7.65	7.61	7.63	7.58
	50	8.0	7.7	7.59	7.40	7.44	8.41
	60	7.8	7.7	7.62	7.53	7.43	7.46
	70	7.9	7.7	7.67	7.54	7.45	7.42
	80	7.9	7.7	7.45	7.43	7.41	7.39
	90	7.9	7.7	7.53	7.42	7.45	7.42
	100	7.9	7.7	7.60	7.44	7.46	7.41
	110	7.9	7.7	7.58	7.36	7.47	7.37
	120	7.9	7.7	7.60	7.47	7.46	7.45
	130	7.9	7.8	7.57	7.45	7.40	7.37
	140	7.9	7.7	7.57	7.47	7.50	7.45
	150	7.9	7.7	7.57	7.46	7.47	7.42
	160	7.9	7.7	7.63	7.54	7.55	7.45
	170	7.9	7.7	7.63	7.54	7.48	7.39
	180	7.9	7.7	7.60	7.52	7.46	7.36
	190	7.9	7.7	7.63	7.52	7.55	7.46
	200	7.9	7.7	7.65	7.53	7.56	7.45
	210	7.9	7.7	7.61	7.59	7.48	7.55
	220	7.9	7.7	7.70	7.71	7.60	7.56
	230	7.9	7.7	7.73	7.81	7.97	7.74
	240	8.0	7.8	7.78	7.75	7.74	7.61
	250	8.1	7.8	7.77	7.92	7.76	7.71
	260	8.3	7.8	7.58	7.56	7.54	7.55
	270	8.3	7.9	7.62	7.49	7.55	7.67
	280	8.3	7.7	7.39	7.30	7.31	7.26
	290	8.1	7.6	7.29	7.32	7.63	7.47
	300	8.4	7.7	7.28	7.20	7.24	7.32
1+90W	0	8.2	8.0	7.92	7.86	7.84	7.89
	10	8.0	7.9	7.80	7.77	7.78	7.80
	20	8.1	7.9	7.75	7.77	7.70	7.74
	30	8.1	7.9	7.77	7.70	7.65	7.58
	40	8.0	7.8	7.64	7.58	7.55	7.61
	50	8.0	7.7	7.61	7.58	7.59	7.55
	60	7.9	7.7	7.57	7.54	7.48	7.57
	70	7.9	7.7	7.60	7.55	7.61	7.47
	80	7.9	7.7	7.57	7.52	7.50	7.45
	90	7.9	7.7	7.40	7.48	7.46	7.55
	100	7.9	7.6	7.51	7.32	7.45	7.46
	110	7.9	7.7	7.57	7.44	7.41	7.42
	120	7.9	7.9	7.55	7.44	7.43	7.37
	130	7.9	7.7	7.57	7.54	7.41	7.37
	140	7.9	7.6	7.60	7.39	7.49	7.47
	150	7.9	7.8	7.53	7.39	7.49	7.32
	160	7.9	7.7	7.60	7.46	7.37	7.37
	170	7.9	7.7	7.56	7.52	7.45	7.35
	180	7.9	7.7	7.59	7.44	7.35	7.52
	190	7.9	7.7	7.59	7.48	7.49	7.38
	200	7.9	7.7	7.64	7.47	7.44	7.45
	210	8.0	7.7	7.63	7.52	7.51	7.27
	220	8.0	7.8	7.63	7.50	7.45	7.41
	230	7.9	7.8	7.68	7.51	7.47	7.31
	240	8.0	7.8	7.68	7.56	7.43	7.57
	250	8.0	7.8	7.70	7.62	7.61	7.59
	260	8.0	7.8	7.71	7.57	7.63	7.57
	270	8.0	7.8	7.70	7.66	7.65	7.58
	280	8.0	7.8	7.74	7.59	7.64	7.67
	290	8.1	7.9	7.73	7.65	7.70	7.67
	300	8.1	7.9	7.82	7.73	7.71	7.27

TABLE VIII (Continued)

Sta.	Dist.	4/8/76	5/6/76	8/4/76	11/5/76	12/23/76	3/29/77
2+00W	0	8.2	8.0	7.96	7.87	7.79	7.87
	10	8.1	7.9	7.74	7.74	7.65	7.74
	20	8.1	7.9	7.75	7.68	7.66	7.64
	30	8.1	7.8	7.78	7.71	7.69	7.67
	40	8.0	7.8	7.64	7.58	7.55	7.52
	50	8.0	7.7	7.66	7.60	7.60	7.57
	60	7.9	7.8	7.55	7.43	7.48	7.42
	70	7.9	7.7	7.59	7.54	7.54	7.46
	80	7.9	7.6	7.60	7.58	7.54	7.47
	90	7.9	7.7	7.63	7.51	7.48	7.39
	100	7.9	7.7	7.51	7.48	7.45	7.41
	110	7.8	7.7	7.54	7.51	7.45	7.35
	120	7.9	7.6	7.59	7.47	7.47	7.35
	130	7.9	7.5	7.59	7.53	7.51	7.37
	140	7.9	7.7	7.48	7.44	7.44	7.36
	150	7.9	7.7	7.58	7.54	7.48	7.41
	160	7.8	7.8	7.57	7.48	7.43	7.42
	170	8.0	7.7	7.31	7.51	7.44	7.37
	180	7.9	7.7	7.31	7.53	7.48	7.35
	190	7.9	7.7	7.64	7.57	7.53	7.45
	200	7.9	7.7	7.64	7.49	7.51	7.44
	210	7.9	7.7	7.63	7.52	7.51	7.41
	220	7.9	7.7	7.59	7.56	7.53	7.35
	230	8.0	7.7	7.85	7.58	7.52	7.32
	240	8.0	7.9	7.61	7.52	7.52	7.36
	250	8.0	7.8	7.67	7.60	7.63	7.55
	260	8.0	7.8	7.70	7.59	7.65	7.47
	270	8.0	7.8	7.68	7.60	7.64	7.58
	280	8.1	7.8	7.72	7.58	7.66	7.56
	290	8.0	7.8	7.70	7.63	7.64	7.61
	300	8.1	7.8	7.71	7.64	7.72	7.61
2+10W	0	8.3	8.1	7.93	7.81	7.83	7.79
	10	8.1	7.8	7.69	7.70	7.69	7.69
	20	8.1	7.8	7.79	7.67	7.67	7.62
	30	8.1	7.8	7.81	7.72	7.71	7.67
	40	8.1	7.8	7.74	7.67	7.64	7.59
	50	8.0	7.8	7.72	7.58	7.61	7.61
	60	8.0	7.7	7.54	7.42	7.31	7.27
	70	8.0	7.7	7.67	7.64	7.59	7.45
	80	7.9	7.7	7.61	7.52	7.49	7.41
	90	7.9	7.8	7.57	7.48	7.48	7.35
	100	7.9	7.7	7.58	7.47	7.41	7.35
	110	7.9	7.7	7.56	7.50	7.45	7.37
	120	7.9	7.7		7.47	7.48	7.39
	130	7.9	7.6		7.49	7.42	7.37
	140	7.9	7.6		7.46	7.43	7.28
	150	7.9	7.7		7.43	7.37	7.19
	160	7.9	7.7		7.48	7.41	7.31
	170	7.8	7.7		7.47	7.39	7.36
	180	7.9	7.6		7.52	7.50	7.37
	190	7.9	7.7		7.56	7.44	7.37
	200	7.9	7.7		7.55	7.50	7.40
	210	8.0	7.7		7.57	7.42	7.41
	220	7.9	7.7		7.56	7.53	7.47
	230	7.9	7.7		7.52	7.49	7.57
	240	8.0	7.8		7.59	7.56	7.51
	250	8.0	7.8		7.67	7.64	7.58
	260	8.0	7.8		7.65	7.63	7.59
	270	8.0	7.8		7.64	7.61	7.58
	280	8.0	7.7		7.67	7.60	7.60
	290	8.0	7.8		7.65	7.68	7.61
	300	8.0	7.8		7.62	7.67	7.56

TABLE VIII (Continued)

Sta.	Dist.	4/8/76	5/6/76	8/4/76	11/5/76	12/23/76	3/29/77
2+20W	0	8.3	8.0	7.89	7.83	7.82	7.72
	10	8.2	7.9	7.72	7.66	7.70	7.58
	20	8.1	7.9	7.65	7.65	7.55	7.52
	30	8.1	7.8	7.74	7.64	7.70	7.47
	40	8.0	7.8	7.75	7.67	7.63	7.55
	50	8.0	7.7	7.65	7.55	7.50	7.47
	60	8.0	7.8	7.54	7.48	7.44	7.49
	70	8.0	7.7	7.65	7.49	7.56	7.42
	80	8.0	7.8	7.63	7.53	7.56	7.49
	90	8.0	7.7	7.61	7.57	7.53	7.42
	100	7.9	7.7	7.61	7.55	7.54	7.42
	110	7.9	7.7	7.54	7.55	7.46	7.44
	120	7.9	7.7	7.57	7.52	7.50	7.43
	130	8.0	7.7	7.56	7.48	7.48	7.42
	140	7.9	7.6	7.55	7.43	7.42	7.34
	150	7.9	7.7	7.57	7.51	7.43	7.27
	160	7.9	7.5	7.59	7.50	7.46	7.14
	170	7.9	7.7	7.58	7.34	7.43	7.31
	180	7.9	7.6	7.55	7.52	7.45	7.38
	190	7.9	7.7	7.62	7.49	7.49	7.32
	200	7.9	7.7	7.65	7.54	7.55	7.47
	210	7.9	7.7	7.63	7.50	7.49	7.37
	220	8.0	7.7	7.61	7.51	7.47	7.32
	230	7.9	7.7	7.65	7.57	7.48	7.45
	240	8.0	7.8	7.53	7.57	7.54	7.47
	250	8.0	7.7	7.57	7.53	7.58	7.42
	260	8.0	7.8	7.65	7.57	7.75	7.55
	270	8.0	7.8	7.70	7.57	7.54	7.57
	280	8.0	7.8	7.72	7.62	7.65	7.61
	290	8.0	7.7	7.71	7.58	7.65	7.55
	300	8.1	7.8	7.76	7.67	7.71	7.65
2+30W	0	8.3	8.0	7.93	7.84	7.79	7.75
	10	8.1	7.9	7.80	7.71	7.68	7.77
	20	8.1	7.8	7.79	7.42	7.48	7.59
	30	8.1	7.8	7.62	7.61	7.58	7.56
	40	8.0	7.8	7.69	7.56	7.61	7.45
	50	8.0	7.8	7.62	7.50	7.56	7.52
	60	8.0	7.7	7.64	7.54	7.57	7.46
	70	8.0	7.7	7.65	7.56	7.57	7.49
	80	8.0	7.8	7.62	7.59	7.55	7.49
	90	8.0	7.7	7.63	7.57	7.58	7.51
	100	7.9	7.8	7.66	7.54	7.56	7.42
	110	7.9	7.7	7.54	7.47	7.50	7.25
	120	7.9	7.7	7.58	7.43	7.44	7.32
	130	7.9	7.7	7.58	7.44	7.37	7.31
	140	7.9	7.7	7.58	7.42	7.33	7.32
	150	7.9	7.6	7.55	7.47	7.35	7.35
	160	7.9	7.5	7.54	7.41	7.39	7.31
	170	7.9	7.6	7.56	7.67	7.41	7.38
	180	7.9	7.7	7.54	7.38	7.46	7.49
	190	7.9	7.6	7.57	7.47	7.49	7.39
	200	7.8	7.6	7.56	7.51	7.48	7.36
	210	7.9	7.6	7.56	7.47	7.51	7.35
	220	7.9	7.6	7.60	7.50	7.54	7.25
	230	8.0	7.7	7.62	7.51	7.55	7.51
	240	7.9	7.7	7.60	7.50	7.52	7.37
	250	8.0	7.6	7.64	7.46	7.57	7.55
	260	8.0	7.7	7.68	7.57	7.58	7.36
	270	7.9	7.8	7.61	7.47	7.52	7.32
	280	8.0	7.8	7.69	7.58	7.61	7.52
	290	8.1	7.7	7.67	7.61	7.67	7.57
	300	8.1	7.8	7.74	7.68	7.70	7.65

TABLE VIII (Continued)

Sta.	Dist.	4/8/76	5/6/76	8/4/76	11/5/76	12/23/76	3/29/77
2+40W	0	8.4	8.1	7.78	7.67	7.69	7.59
	10	8.1	7.9	7.80	7.68	7.67	7.58
	20	8.0	7.8	7.72	7.65	7.55	7.56
	30	8.1	7.8	7.71	7.64	7.57	7.57
	40	8.0	7.7	7.61	7.57	7.56	7.52
	50	8.0	7.7	7.63	7.55	7.56	7.46
	60	7.9	7.8	7.62	7.55	7.54	7.48
	70	8.0	7.7	7.66	7.56	7.55	7.53
	80	8.0	7.8	7.51	7.50	7.50	7.50
	90	8.0	7.7	7.63	7.53	7.55	7.45
	100	7.9	7.7	7.59	7.54	7.50	7.44
	110	7.8	7.7	7.60	7.47	7.48	7.37
	120	7.9	7.6	7.56	7.46	7.50	7.34
	130	7.8	7.6	7.56	7.47	7.44	7.36
	140	7.9	7.6	7.60	7.47	7.48	7.33
	150	7.9	7.6	7.52	7.48	7.41	7.30
	160	7.8	7.7	7.56	7.45	7.44	7.36
	170	7.9	7.7	7.46	7.47	7.43	7.32
	180	7.9	7.6	7.60	7.48	7.50	7.33
	190	7.9	7.7	7.61	7.50	7.51	7.35
	200	7.9	7.7	7.58	7.50	7.47	7.35
	210	7.9	7.6	7.57	7.45	7.43	7.36
	220	7.9	7.7	7.57	7.53	7.51	7.38
	230	7.9	7.7	7.59	7.45	7.42	7.40
	240	7.9	7.7	7.66	7.54	7.55	7.45
	250	8.0	7.7	7.63	7.44	7.55	7.46
	260	8.0	7.7	7.68	7.56	7.53	7.35
	270	8.1	7.8	7.67	7.55	7.58	7.47
	280	8.0	7.7	7.73	7.61	7.65	7.57
	290	8.1	7.8	7.64	7.59	7.65	7.55
	300	8.0	7.8	7.74	7.69	7.72	7.59
2+50W	0	8.1	7.6	7.75	7.64	7.53	7.48
	10	7.9	7.7	7.59	7.54	7.58	7.51
	20	7.9	7.8	7.67	7.62	7.68	7.39
	30	7.9	7.8	7.70	7.62	7.65	7.56
	40	7.9	7.7	7.57	7.54	7.57	7.43
	50	7.9	7.7	7.56	7.46	7.45	7.47
	60	8.0	7.7	7.60	7.62	7.55	7.50
	70	8.0	7.7	7.63	7.51	7.52	7.52
	80	8.0	7.8	7.65	7.57	7.57	7.56
	90	7.9	7.7	7.69	7.62	7.61	7.55
	100	7.9	7.7	7.57	7.49	7.50	7.42
	110		7.7	7.60	7.50	7.52	7.30
	120	7.9	7.6	7.54	7.46	7.45	7.41
	130	7.9	7.6	7.52	7.46	7.41	7.33
	140	7.7	7.6	7.44	7.36	7.33	7.19
	150	7.8	7.6	7.57	7.43	7.24	7.17
	160	7.9	7.6	7.56	7.50	7.41	7.30
	170	7.8	7.5	7.48	7.44	7.34	7.24
	180	7.9	7.6	7.56	7.43	7.40	7.29
	190	7.9	7.6	7.52	7.50	7.38	7.26
	200	7.8	7.6	7.57	7.43	7.47	7.31
	210	7.8	7.7	7.56	7.39	7.28	7.18
	220	7.9	7.7	7.58	7.47	7.48	7.33
	230	7.9	7.6	7.65	7.50	7.48	7.36
	240	7.9	7.6	7.64	7.47	7.54	7.40
	250	7.9	7.7	7.65	7.60	7.59	7.38
	260	8.0	7.8	7.63	7.59	7.62	7.52
	270	8.0	7.8	7.68	7.58	7.63	7.56
	280	8.0	7.8	7.72	7.63	7.65	7.47
	290	8.0	7.8	7.70	7.59	7.61	7.53
	300	8.0	7.8	7.73	7.64	7.71	7.58

TABLE VIII (Continued)

Sta.	Dist.	4/8/76	5/6/76	8/4/76	11/5/76	12/23/76	3/29/77
2+60W	0	9.2	9.1	7.96	7.90	7.79	7.77
	10	7.8	7.4	7.47	7.32	7.27	7.24
	20	8.1	7.6	7.57	7.55	7.54	7.63
	30	8.0	7.8	7.70	7.64	7.65	7.41
	40	8.0	7.8	7.67	7.59	7.59	7.53
	50	7.9	7.7	7.66	7.56	7.55	7.50
	60	7.9	7.8	7.58	7.54	7.50	7.48
	70	7.9	7.8	7.62	7.54	7.50	7.47
	80	7.9	7.7	7.63	7.54	7.54	7.53
	90	7.7	7.7	7.63	7.58	7.58	7.41
	100	7.7	7.7	7.56	7.52	7.45	7.40
	110	7.9	7.8	7.58	7.52	7.46	7.42
	120	7.9	7.7	7.62	7.47	7.37	7.31
	130	7.9	7.7	7.49	7.54	7.36	7.25
	140	7.9	7.6	7.52	7.38	7.35	7.27
	150	7.9	7.6	7.57	7.42	7.36	7.26
	160	7.9	7.6	7.55	7.43	7.36	7.26
	170	7.9	7.6	7.56	7.35	7.37	7.28
	180	7.8	7.6	7.52	7.42	7.40	7.32
	190	7.8	7.6	7.57	7.45	7.41	7.34
	200	7.8	7.6	7.56	7.45	7.43	7.30
	210	7.9	7.7	7.57	7.50	7.45	7.32
	220	7.9	7.7	7.60	7.49	7.42	7.38
	230	7.9	7.7	7.69	7.47	7.41	7.36
	240	7.9	7.7	7.54	7.49	7.50	7.35
	250	7.9	7.7	7.54	7.51	7.49	7.31
	260	7.9	7.8	7.60	7.49	7.61	7.43
	270	7.9	7.8	7.67	7.60	7.61	7.56
	280	7.9	7.8	7.69	7.61	7.68	7.57
	290	7.9	7.8	7.73	7.63	7.62	7.54
	300	8.0	7.8	7.74	7.58	7.62	7.51
2+70W	0	8.8	8.5	8.24	8.10	7.94	8.02
	10	8.5	8.0	7.41	7.50	7.34	7.43
	20	7.6	7.6	7.37	7.23	7.33	7.24
	30	7.9	7.5	7.61	7.63	7.56	7.47
	40	8.0	7.8	7.64	7.57	7.55	7.48
	50	8.0	7.8	7.64	7.56	7.53	7.45
	60	7.9	7.7	7.45	7.52	7.50	7.39
	70	7.9	7.8	7.55	7.57	7.53	7.43
	80	7.9	7.6	7.56	7.54	7.49	7.41
	90	7.9	7.7	7.62	7.56	7.51	7.42
	100	7.9	7.7	7.54	7.48	7.46	7.43
	110	7.9	7.7	7.58	7.53	7.49	7.40
	120	7.8	7.7	7.52	7.39	7.40	7.29
	130	7.9	7.7	7.50	7.53	7.38	7.31
	140	7.9	7.7	7.33	7.34	7.28	7.16
	150	7.9	7.6	7.47	7.38	7.36	7.26
	160	7.8	7.6	7.55	7.39	7.29	7.17
	170	7.8	7.6	7.56	7.41	7.41	7.24
	180	7.8	7.5	7.52	7.38	7.32	7.26
	190	7.9	7.5	7.57	7.40	7.29	7.22
	200	7.9	7.6	7.56	7.39	7.37	7.25
	210	7.9	7.7	7.57	7.45	7.45	7.33
	220	7.8	7.6	7.60	7.43	7.39	7.26
	230	7.9	7.6	7.69	7.45	7.41	7.29
	240	7.9	7.8	7.54	7.39	7.35	7.28
	250	7.9	7.7	7.54	7.46	7.53	7.44
	260	7.9	7.7	7.60	7.53	7.54	7.43
	270	7.9	7.8	7.67	7.54	7.51	7.47
	280	7.9	7.8	7.69	7.51	7.58	7.47
	290	7.9	7.7	7.73	7.57	7.64	7.48
	300	8.0	7.7	7.74	7.56	7.62	7.51

TABLE VIII (Continued)

Sta.	Dist.	4/8/76	5/6/76	8/4/76	11/5/76	12/23/76	3/29/77
2+80W	0	8.6	8.1	8.22	8.11	7.65	7.99
	10	8.1	8.0	7.47	7.28	7.34	7.28
	20	7.6	7.4	7.33	7.18	7.37	7.26
	30	8.0	7.7	7.61	7.56	7.55	7.53
	40	7.9	7.8	7.60	7.56	7.56	7.39
	50	8.0	7.8	7.60	7.49	7.51	7.31
	60	7.9	7.8	7.54	7.46	7.48	7.33
	70	7.9	7.8	7.50	7.46	7.44	7.39
	80	7.9	7.7	7.56	7.52	7.53	7.34
	90	7.9	7.7	7.54	7.50	7.54	7.48
	100	7.9	7.7	7.58	7.50	7.48	7.41
	110	7.9	7.6	7.61	7.52	7.52	7.46
	120	7.9	7.7	7.44	7.36	7.36	7.36
	130	7.9	7.7	7.51	7.32	7.37	7.26
	140	7.8	7.6	7.53	7.38	7.39	7.31
	150	7.8	7.6	7.52	7.46	7.40	7.42
	160	7.8	7.6	7.46	7.32	7.36	7.27
	170	7.8	7.6	7.55	7.37	7.39	7.34
	180	7.8	7.6	7.53	7.44	7.42	7.32
	190	7.8	7.6	7.53	7.32	7.45	7.27
	200	7.8	7.5	7.56	7.44	7.42	7.35
	210	7.8	7.6	7.52	7.45	7.43	7.33
	220	7.9	7.7	7.56	7.44	7.48	7.36
	230	7.9	7.7	7.57	7.43	7.45	7.27
	240	7.8	7.7	7.54	7.42	7.43	7.31
	250	7.9	7.7	7.61	7.44	7.51	7.37
	260	7.9	7.7	7.56	7.43	7.51	7.41
	270	7.9	7.7	7.58	7.51	7.55	7.41
	280	7.9	7.7	7.66	7.39	7.45	7.38
	290	8.0	7.8	7.59	7.49	7.55	7.33
	300	7.9	7.8	7.69	7.52	7.59	7.44
2+90W	0	8.7	8.5	8.48	7.37	7.35	8.23
	10	8.0	7.4	7.51	7.46	7.48	7.29
	20	8.1	7.7	7.66	7.63	7.64	7.62
	30	7.8	7.7	7.59	7.60	7.55	7.52
	40	8.0	7.7	7.58	7.49	7.46	7.18
	50	7.9	7.8	7.60	7.52	7.49	7.43
	60	8.0	7.8	7.63	7.53	7.54	7.47
	70	7.9	7.8	7.56	7.49	7.48	7.45
	80	7.9	7.8	7.61	7.47	7.52	7.47
	90	7.9	7.7	7.61	7.44	7.51	7.35
	100	7.9	7.9	7.51	7.45	7.46	7.30
	110	7.9	7.7	7.52	7.41	7.47	7.39
	120	7.9	7.7	7.51	7.48	7.44	7.38
	130	7.9	7.7	7.58	7.46	7.48	7.32
	140	7.8	7.7	7.50	7.48	7.42	7.26
	150	7.8	7.7	7.55	7.43	7.55	7.36
	160	7.9	7.7	7.52	7.43	7.43	7.30
	170	7.9	7.7	7.51	7.47	7.40	7.31
	180	7.8	7.7	7.54	7.48	7.49	7.28
	190	7.8	7.7	7.50	7.47	7.45	7.29
	200	7.8	7.7	7.55	7.48	7.48	7.30
	210	7.9	7.7	7.45	7.49	7.47	7.35
	220	7.9	7.7	7.54	7.41	7.49	7.27
	230	7u.9	7.6	7.55	7.51	7.54	7.33
	240	7.9	7.6	7.51	7.42	7.45	7.31
	250	7.9	7.6	7.59	7.47	7.48	7.33
	260	7.9	7.6	7.59	7.50	7.44	7.36
	270	7.8	7.6	7.56	7.51	7.48	7.32
	280	7.9	7.6	7.56	7.58	7.54	7.35
	290	7.9	7.8	7.61	7.48	7.56	7.47
	300	7.7	7.2	7.67	7.54	7.58	7.30

TABLE VIII (Continued)

Sta.	Dist.	4/8/76	5/6/76	8/4/76	11/5/76	12/23/76	3/29/77
3+00W	0	8.1	8.0	7.66	7.61	7.64	7.51
	10	8.0	7.9	7.74	7.74	7.71	7.70
	20	8.1	7.9	7.78	7.73	7.74	7.62
	30	8.0	7.8	7.59	7.57	7.56	7.49
	40	7.9	7.7	7.55	7.49	7.49	7.45
	50	7.9	7.6	7.54	7.52	7.45	7.40
	60	7.9	7.7	7.52	7.46	7.46	7.40
	70	8.0	7.8	7.63	7.57	7.52	7.46
	80	7.9	7.8	7.62	7.54	7.56	7.44
	90	7.9	7.8	7.54	7.46	7.46	7.43
	100	7.9	7.7	7.55	7.47	7.50	7.44
	110	7.9	7.7	7.58	7.49	7.48	7.38
	120	7.9	7.7	7.61	7.53	7.47	7.45
	130	7.9	7.7	7.57	7.48	7.43	7.37
	140	7.8	7.7	7.50	7.48	7.42	7.39
	150	7.8	7.6	7.47	7.40	7.41	7.38
	160	7.8	7.6	7.51	7.47	7.46	7.38
	170	7.9	7.6	7.57	7.45	7.51	7.38
	180	7.8	7.6	7.58	7.50	7.40	7.42
	190	7.9	7.7	7.54	7.43	7.46	7.38
	200	7.8	7.7	7.54	7.46	7.48	7.25
	210	7.8	7.6	7.54	7.44	7.49	7.35
	220	7.8	7.6	7.54	7.50	7.49	7.32
	230	7.9	7.6	7.51	7.41	7.39	7.39
	240	7.8	7.6	7.50	7.39	7.40	7.33
	250	7.8	7.7	7.45	7.38	7.53	7.31
	260	7.8	7.6	7.59	7.54	7.46	7.40
	270	7.9	7.7	7.56	7.44	7.43	7.38
	280	7.9	7.6	7.50	7.38	7.44	7.32
	290	7.8	7.6	7.26	7.19	7.53	7.12
	300	8.1	7.6	7.58	7.49	7.53	7.24

*Surface elevation on date shown.

APPENDIX C

SUMMARY OF VACUUM GAGE READINGS

TABLE IX

SUMMARY OF VACUUM GAGE READINGS

Gage No.	DATE 5/4/76 *	5/4/76 †	12/4/76 2 p.m.	1/11/77 2 p.m.	1/13/77 3 p.m.	1/31/77 1:30 p.m.*	2/20/77	Ave. Vacuum Reading	Gage Rdging. With Zero Vacuum	Net Ave. Vacuum
A-1	7	30+	0	30+	30+	7.0	30+	30	7	23
A-2	0	24.5	28	28.5	28.5	0.0	28.5	28	0	28
A-3	1.5	15.5	29	28.6	29.0	2.0	28.5	29	2	27
A-4	2	24.5	27	27.4	27.5	2.0	27.0	27	2	25
A-5	0	21.5	26	26	26.0	0.0	25.5	26	0	26
A-6	3	27.5	0	30	30+	4.5	30+	30	4	26
A-7	0	18	21	21.5	21.5	0.0	21.5	21	0	21
A-8	0	20.5	0	30	30+	3.0	30.0	30	3	27
A-9	0	19.5	24	24	24.0	0.0	24.0	24	0	24
A-10	2	28.5	0	30+	30+	3.0	30+	30	3	27
A-11	2	25.5	29	29.5	29.5	2.5	29.0	29	2	27
A-12	0	23.0	27	27.5	27.5	0.0	27.5	27	0	25
A-13	0	18.5	21	21	21.0	0.0	21.0	21	0	21
A-14	0	23.5	27	27.3	27.5	0.0	27.0	27	0	27
A-15	0	20.5	25	25.0	24.5	0.0	24.5	25	0	25
A-16	9.5	30+	0	30+	30+	0.0	30+	30	0	30
A-17	4	29.5	0	30+	30+	4.5	30+	30	4	26
A-18	0	19.5	24	24	23.5	0.0	23	24	0	24

TABLE IX (Continued)

Gage No.	DATE 5/4/76 *	5/4/76 †	12/4/76 2 p.m.	1/11/77 2 p.m.	1/13/77 3 p.m.	1/31/77 1:30 p.m.*	2/20/77	Ave. Vacuum Reading	Gage Rdging. With Zero Vacuum	Net Ave. Vacuum
A-19	0	20.5	25	18.6	18.0	0.0	22.5	20	0	20
A-20	24	7.5	12	11.5	11.5	0.0	11.5			
A-21	0	24.5	25	28	28.0	0.0	28.0	28	0	28
A-22	5.5	30+	0	30+	30+	11.0	30+	30	11	19
A-23	0	22.0	11	0	6.0	5.0	15.0			
A-24	3.5	28.0	0	0	0	0.0	0.0			
A-25	4	27.0	28	30.0	30.0	3.5	13.5	28	4	24
A-26	0	24.0	26	26.2	26.5	0.0	26.0	26	0	26
A-27	0	22.5	25	26.5	22.5	4.5	23.0	24	4	20
C-1	0	23.5	27	27.0	27.0	0.0	27.0	27	0	27
C-2	0	24.0	28	28.0	28.0	0.5	28.0	28	0	28
C-3	0	19.0	23	23.0	23.0	0.0	23.0	23	0	23
C-4	2.5	26.5	30	30.0	30+	2.0	30.0	30	2	28
C-5	0	24.5	28	28.0	28.0	0.5	28.5	28	0	28
C-6	2	24.0	28	27.5	27.5	1.5	28.5	28	2	26
C-7	0	17.5	20	22.0	19.0	0.0	18.5	20	0	20
C-8	0	24.0	28	28.0	28.0	0.0	28.5	28	0	28
C-9	0	23.0	27	26.5	27.0	0.0	27.0	27	0	27
C-10	1	27.5	0	30+	30+	1.5	30+	30	1	29
C-11	0	24.5	28	27.5	28.0	0.0	14.5	28	0	28

*Readings taken before turning vacuum system on.

†Readings taken after turning vacuum system on.

APPENDIX D

SUMMARY OF OBSERVATION WELL READINGS

TABLE X

SUMMARY OF OBSERVATION WELL READINGS

Well No.	DATE									
	4/16/76	5/4/76	7/16/76	10/7/76	12/2/76	1/11/77	1/14/77	1/31/77	2/20/77	3/29/77	4/12/77
0-1	3.6 (1.7)	3.1	3.9	3.4	3.7		3.6	3.9	3.9	3.90	3.95
0-2	2.5 (1.1)	2.0	2.5	2.4	2.6		2.7	2.9	2.9	2.89	3.0
0-3	3.2 (1.1)	2.3	2.8	2.8	3.0		3.0	3.2	3.3	3.16	3.2
0-4	4.7 (0.9)	3.9	2.3	2.2	2.0		2.0	2.1	2.1	2.00	2.15
0-5	2.3 (1.1)	1.8	2.2	2.0	2.2		2.2	2.5	2.5	2.51	
0-6	2.6 (1.2)	2.2	3.8	2.8	2.9		3.0	3.1	3.2	3.08	
0-7	2.9 (1.4)	2.2	2.8	2.8	2.9	3.5	3.3	3.7	3.3	3.23	
0-8	2.1 (1.1)	1.8	5.1	2.9	2.6		2.7	2.9	2.8	2.82	2.85
0-8A	3.5 (0.4)	3.4	4.8	3.2	5.8	5.6	3.5	4.7	6.0	3.81	3.65
0-9	5.7 (1.2)	5.5	5.3	4.7	4.4	4.2	4.2	4.4	4.2	4.12	
0-10	3.1 (1.2)	2.2	2.8	3.7	2.8		3.1	3.2	3.1	3.08	3.10
0-11	3.2 (1.2)	2.2	2.8	3.1	2.9		2.9	3.1	3.1	3.10	
0-12	2.3 (1.0)	2.1	2.7	3.0	3.0		2.8	3.1	3.1	3.02	3.10
0-13	1.3 (1.0)	1.5	1.8	2.3	2.5		2.3	2.5	2.5	2.86	2.55
0-14	3.3 (1.2)	2.7	3.0	3.2	3.4	3.5	3.5	3.6	4.1	3.86	3.65
0-15	2.0 (1.0)	1.8	2.0	2.2	2.3	2.6	2.5	2.6	2.6	2.57	2.75
0-16	1.2 (1.0)	1.4	1.9	1.9	1.7	2.1	2.1	2.3	2.4	2.37	2.40
0-17	5.6 (0.9)	5.1	3.5	2.7	2.5		2.5	2.6	2.5	2.39	2.40
0-18	3.1 (1.0)	2.2	2.4	2.5	2.9		2.8	3.0	3.0	2.97	
0-19	2.6 (1.0)	2.2	2.5	3.2	3.1		2.8	3.1	3.1	3.03	3.15
0-20	3.9 (1.3)	2.7	3.3	3.3	4.4		2.7	3.7	3.7	3.72	3.70
0-21	2.6 (1.1)	1.9	2.7	2.5	2.7		2.8	2.9	2.9	2.89	3.00

TABLE X (Continued)

Well No.	DATE 4/16/76	5/4/76	7/16/76	10/7/76	12/2/76	1/11/77	1/14/77	1/31/77	2/20/77	3/29/77	4/12/77
0-22	2.3 (0.9)	1.9	2.8	4.3	2.6		2.7	2.9	2.8	2.81	2.90
0-23	2.2 (0.9)	2.0	1.6	1.4	1.2		1.3	1.5	1.6	1.46	1.55
0-24	2.2 (1.0)	1.9	2.5	1.5	1.5		1.6	1.8	1.8	1.74	1.85
0-25	1.8 (1.1)	2.0	2.4	2.5	2.8		2.8	3.1	3.1	3.05	3.05
0-26	2.6 (1.1)	2.1	2.3	2.6	2.9	3.0	3.6	3.2	3.4	3.34	
0-26A	1.8 (0.6)	4.1	3.5	2.9	6.0	6.3	5.7	4.8	8.3	3.61	3.40
0-27	3.3 (1.4)	2.6	3.1	3.1	3.4		3.4	3.6	3.6	3.55	
0-28	2.4 (1.1)	2.1	2.5	2.7	3.0		3.0	3.2	3.2	3.10	3.25
0-29	3.1 (1.2)	2.5	2.7	2.8	3.1		3.1	3.3	3.5	3.34	3.30
0-30	2.9 (1.0)	2.5	2.7	2.9	3.2	3.4	3.3	3.5	3.7	3.47	3.35
0-31	2.7 (1.1)	2.2	2.5	2.8	3.0	3.1	3.1	3.3	3.4	3.35	3.25
0-32	2.6 (0.9)	2.1	2.3	2.4	3.2		2.7	2.9	3.0	2.92	
0-33	2.7 (1.2)	2.1	2.4	2.6	2.7		2.9	3.0	3.0	3.0	3.10
0-34	2.6 (1.1)	1.9	3.2	2.3	2.5		2.6	2.8	2.8	2.82	2.90
0-35	2.8 (1.0)	2.3	2.5	2.8	3.0		3.0	3.1	3.4	3.16	3.20
0-36	3.0 (1.1)	2.2	2.7	3.0	3.0	3.1	3.1	3.3	3.4	3.34	3.35
0-37	2.8 (1.0)	2.3	2.7	2.7	2.9		2.9	3.2	3.2	3.18	

TABLE X (Continued)

Well No.	DATE					Depth of Tip Below Ground Surface (ft.)
	2/16/77	2/18/77	3/3/77	3/29/77	4/12/77	
0-38	Dry (3.0)	4.35	3.43	3.52	3.80	4
0-39	Dry (2.6)	8.15	6.82	6.24	4.90	8
0-40	2.3 (3.0)	3.5	3.36	3.15	3.65	4
0-41	5.3 (2.5)	5.0	4.83	4.54	4.35	8
0-42	3.9 (3.3)	5.5	5.20	5.09		8
0-43	Dry (3.3)	8.25	5.85	3.45	4.40	8
0-44	5.75 (3.5)	5.5	5.10	4.69	4.95	8
0-45	5.4 (3.1)	5.1	4.51	4.53	4.45	4
0-46	3.45 (3.0)	3.25	3.27	3.36	3.45	8
0-47	5.45 (2.9)	4.9	4.67	4.53	4.45	8
0-48	Dry (3.6)	8.1	4.71	5.01	4.90	8
0-49	Dry (2.8)	4.3	3.71	2.91	3.65	4
0-50	Dry (2.95)	4.2	3.22	2.91	3.45	4
0-51	Dry (3.1)	8.5	5.62	3.58	4.45	8
0-52	3.2 (3.0)	3.1	3.16	3.30	3.40	4
0-53	4.75 (2.75)	4.45	4.26	4.23	4.25	8
0-54	3.3 (3.1)	3.25	3.35	3.04	3.65	4
0-55	5.65 (3.0)	5.35	4.74	4.45	4.45	8
0-56	5.25 (2.7)	4.9	4.22	2.31	3.5	8
0-57	5.5 (2.9)	5.2	4.39	3.60	4.0	8

APPENDIX E

FLOWMETER, TENSIOMETER, AND CONE PENETRATION READINGS

TABLE XI

SUMMARY OF FLOWMETER READINGS

Date	Meter Reading (gals)
2/22/77	0
3/2/77 (0800)	1,400
3/2/77 (1600)	1,500
3/4/77	1,649*
3/7/77	3,323*
3/20/77	3,990

*Vacuum shut off to Sand Slurry Injection Study for three days.

Note: Flowmeter installed 2/22/77 at end of discharge line.

TABLE XII

SUMMARY OF TENSIOMETER READINGS

Tensiometer No.	Tip Depth (ft.)	DATE 12/4/76	1/4/77	2/4/77	4/15/77
T-1	2	0	0	100+	100+
T-1	5	0	42*	0	0
T-1	8	0	0	50	54
T-2	2	0	0†	15	15
T-2	5	0	60	100+	100+
T-2	8	0	0	100+	100+
T-3	2	0	0	100+	100+
T-3	5	0	0†	100+	100+
T-3	8	0	0	74	74
T-4	2	0	51	100+	100+
T-4	5	0	20	100+	100+
T-4	8	10	8	40	44

*Rezeroed.

†No reaction to pumping.

TABLE XIII

SUMMARY OF CONE PENETRATION MEASUREMENTS

Location	Cone Index at Depth of							
	1 ft	2 ft	3 ft	4 ft	5 ft	6 ft	7 ft	8 ft
Date: 2/10/77; Cone Size: 2 in.								
W-1	20	30	30	40	58	70	82	87
W-2	20	22	30	40	50	70	85	92
W-3	25	27	32	42	52	60	75	90
W-4	25	30	32	35	47	60	77	100
W-5	22	33	30	40	45	60	70	105
W-6	20	20	25	30	40	52	75	92
W-7	15	20	22	30	20	35	60	70
W-8	20	30	30	20	30	42	65	80
W-9	20	27	36	40	50	60	60	65
W-10	15	20	25	34	45	55	77	85
W-11	15	25	35	40	55	70	80	85
W-12	20	30	30	37	50	68	77	90
W-13	15	22	27	35	45	55	67	85
W-14	15	22	25	30	37	45	62	77
W-15	15	25	27	40	45	60	80	95
W-16	20	22	22	35	40	55	65	80
W-17	22	35	37	40	55	62	75	90
W-18	15	25	35	40	45	60	75	90
W-19	18	28	35	37	54	65	84	95
W-20	20	28	35	40	47	65	90	97
W-21	15	22	33	33	40	43	55	80
W-22	38	45	45	62	66	80	95	90
A-11 1' from W.P.*	24	40	44	50	60	82	107	140
A-11 2' from W.P.	20	23	30	37	48	65	80	105
A-11 3' from W.P.	20	30	37	44	62	73	75	97
A-21 1' from W.P.	25	45	50	55	75	93	120	145
A-21 2' from W.P.	20	36	38	40	53	72	96	110
A-21 3' from W.P.	25	30	32	35	47	60	77	100
C-2 1' from W.P.	20	37	42	50	60	72	85	130
C-2 2' from W.P.	22	35	40	47	50	60	75	105
C-2 3' from W.P.	20	25	30	30	40	55	65	85
C-9 1' from W.P.	19	30	30	45	60	70	87	100
Date: 3/9/77; Cone Size: 1 in.								
W-4	20	30	30	40	40	55	70	70
W-5	30	30	32	40	50	60	70	70
W-6	20	25	30	35	45	56	65	65
W-16	15	15	10	15	25	28	32	38
W-17	18	22	22	30	35	40	45	50
W-18	16	22	25	30	45	50	60	70
W-19	12	12	20	22	30	33	40	45
W-20	18	20	25	30	38	40	52	62

TABLE XIII (Continued)

Location	Cone Index at Depth of 1 ft	2 ft	3 ft	4 ft	5 ft	6 ft	7 ft	8 ft
W-21	30	40	40	45	48	50	55	55
W-22	20	30	33	35	30	40	40	45
A-11 1' from W.P.	26	30	40	40	40	55	60	65
A-11 2' from W.P.	25	30	30	30	35	44	50	65
A-11 3' from W.P.	25	25	20	30	35	40	50	65
A-21 1' from W.P.	22	32	35	55	65	80	100	120
A-21 2' from W.P.	20	25	28	30	40	48	58	60
A-21 3' from W.P.	20	22	25	30	35	40	50	62
C-2 1' from W.P.	20	28	30	42	50	58	55	75
C-2 2' from W.P.	20	30	35	40	45	53	65	75
C-2 3' from W.P.	20	25	28	38	43	50	55	60
C-9 1' from W.P.	20	28	35	48	55	65	80	95
C-9 2' from W.P.	20	30	35	40	50	60	65	70
C-9 3' from W.P.	20	25	38	39	43	50	58	65

*Wellpoint.

APPENDIX F

LOG OF OPERATION

TABLE XIV

LOG OF OPERATION

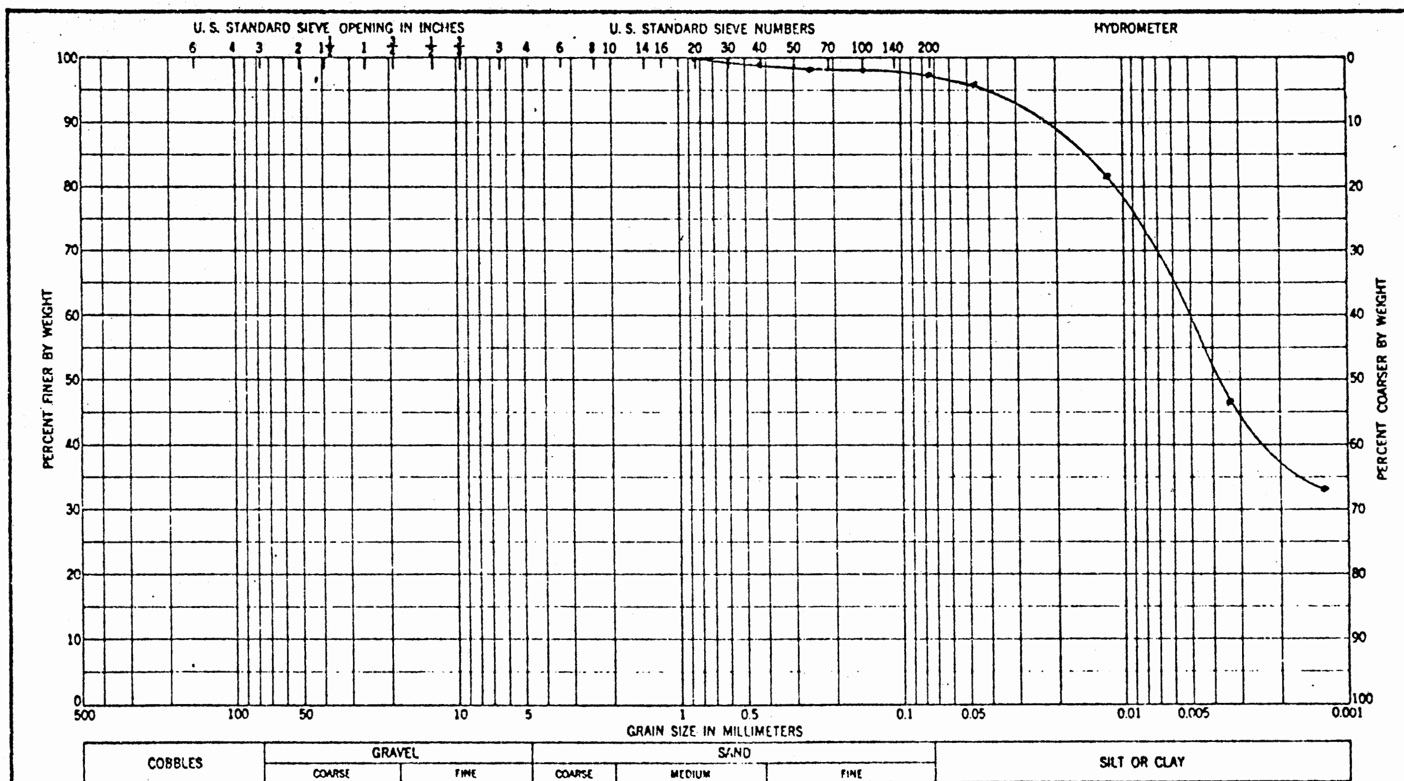
Date	Note
3/8/76	Start installation of wellpoints (4 man crew).
3/19/76	Finish installing wellpoints, start putting header pipe together.
3/30/76	Finish putting header pipe together and installing observation wells.
4/16/76	Installation of vacuum system completed. Vacuum system turned on. Flexible hoses collapsed (to be replaced).
5/4/76	Flexible hoses replaced. Vacuum system turned on.
5/5/76	Vacuum system turned off. Small water pump came apart.
5/11/76	Start connecting "SSI" experiment to vacuum system.
5/16/76	Finish connecting "SSI" experiment to vacuum system.
5/19/76	Vacuum system turned on. Oil leak developed in vacuum pump. Vacuum system turned off.
6/25/76	Vacuum pump repaired. Waiting for batteries to be charged by windmill.
9/30/76	Portable gasoline generator installed and vacuum system turned on.
10/1/76	Vacuum system turned off. (Pump turning slow.)
10/11/76	Vacuum system turned on.
10/12/76	Electric motor and vacuum pump found not running.
10/14/76	Electrical relay repaired. Vacuum system turned on.
10/15/76	Vacuum system turned off because of inadequate gas supply for generator.
10/21/76	Load of gas delivered. Vacuum system turned on.
10/23/76	Vacuum system turned off. Small water pump came apart.
10/27/76	Water pump replaced. System tested.

TABLE XIV (Continued)

Date	Note
10/29/76	Switching system not operating properly. Vacuum system turned off.
11/4/76	Vacuum system turned on.
11/6/76	Vacuum system turned off. Electrical problem.
11/23/76	Electrical problem repaired. Vacuum system turned on.
11/28/76	Generator ran out of gas. Vacuum system stopped.
11/30/76	Vacuum system turned on.
12/17/76	Vacuum system turned off (generator failure).
12/21/76	Generator repaired. Vacuum system turned on.
12/31/76	Vacuum system turned off (generator failure).
1/11/77	Generator repaired. Vacuum pump turned on.
1/14/77	Vacuum system turned off (generator failure). Extreme cold weather has frozen discharge line.
1/28/77	Vacuum system turned on. Power being supplied by diesel generator.
2/3/77	Vacuum system shut down due to damage to electrical wiring.
2/4/77	Electrical wires repaired and vacuum system turned on.
3/11/77	Vacuum system turned off (water pump failure).
3/16/77	Vacuum system turned on.
3/20/77	Vacuum system turned off (vacuum pump failure).

APPENDIX G

LABORATORY TEST DATA



Sample No.	~~Elev or~~ Depth	Classification	Nat w %	LL	PL	PI
2	1.5-2.5'	Black & gray fat clay(CH)	147.7	130	34	96

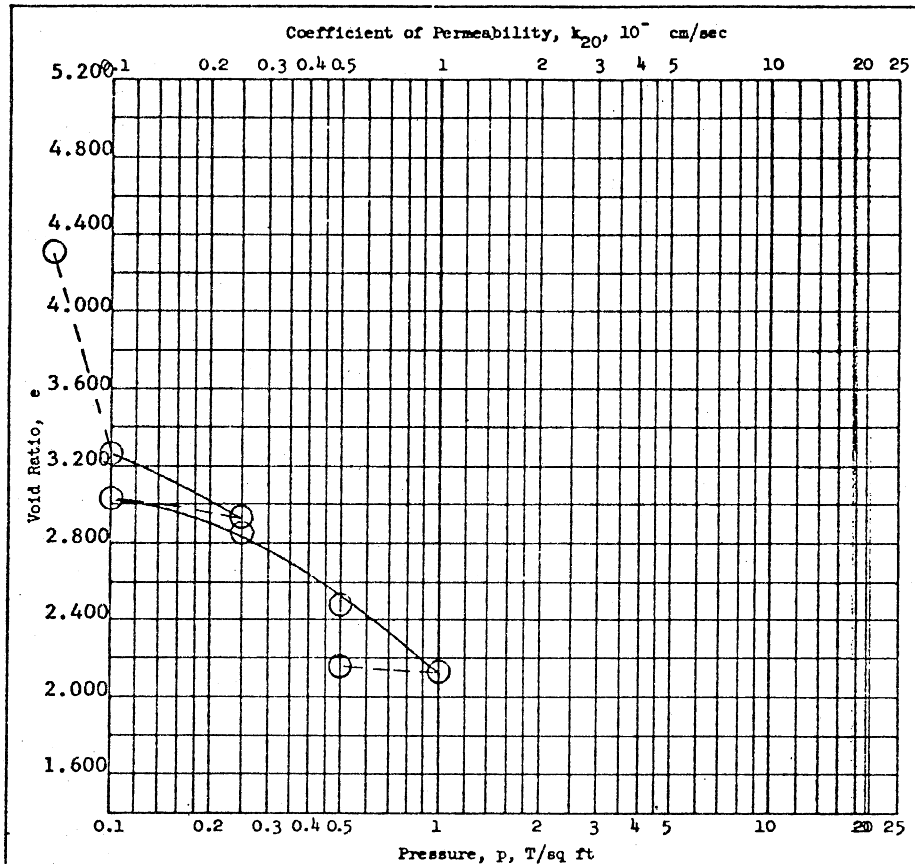
GRADATION CURVES

Project: MOBILE DISTRICT
Vacuum Well Point Experiment
Lab. No. 57/7599

Area: Pole Cat Bay

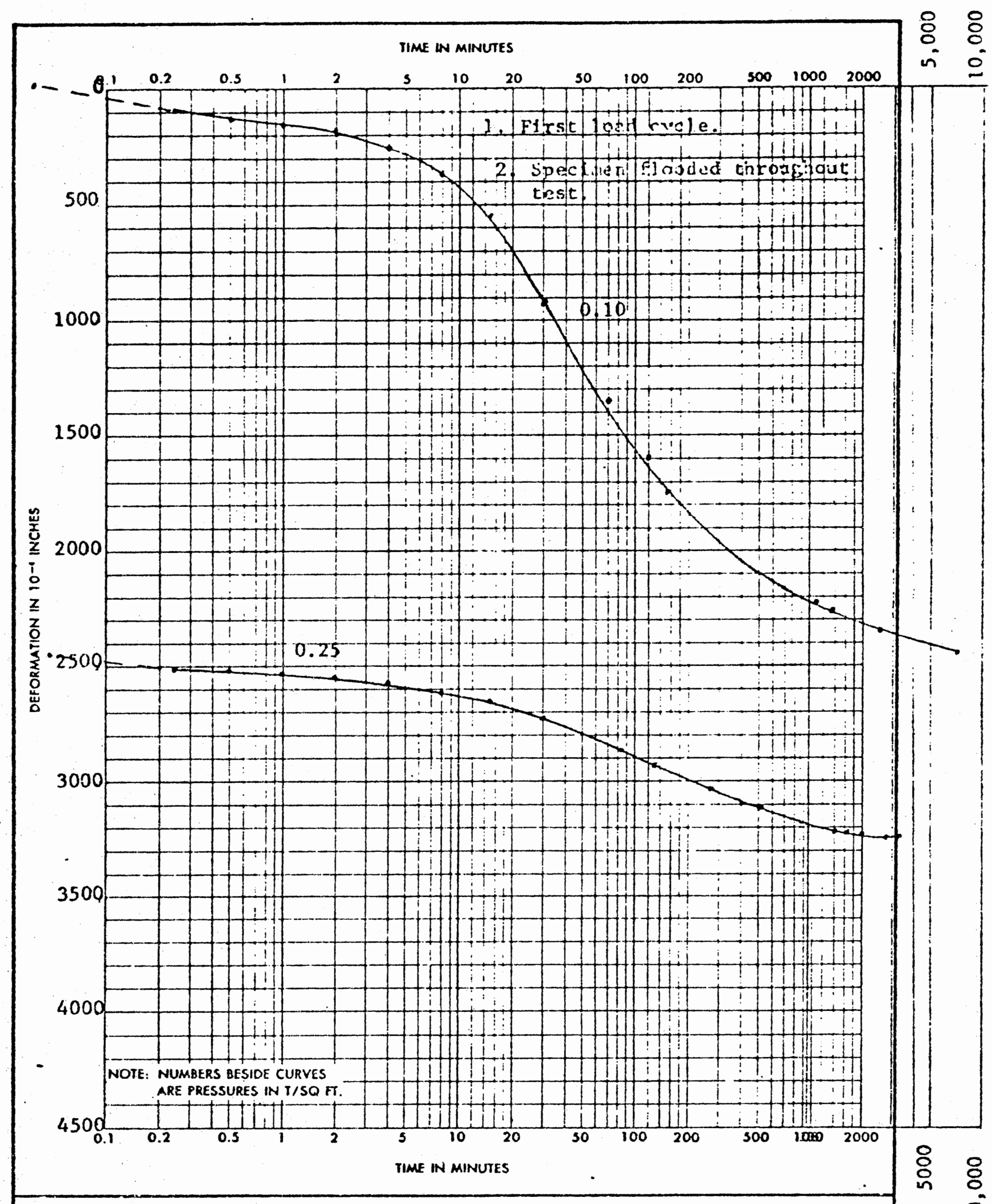
Boring No. VW-1, Sample No. 2

Date: 30 July 1976

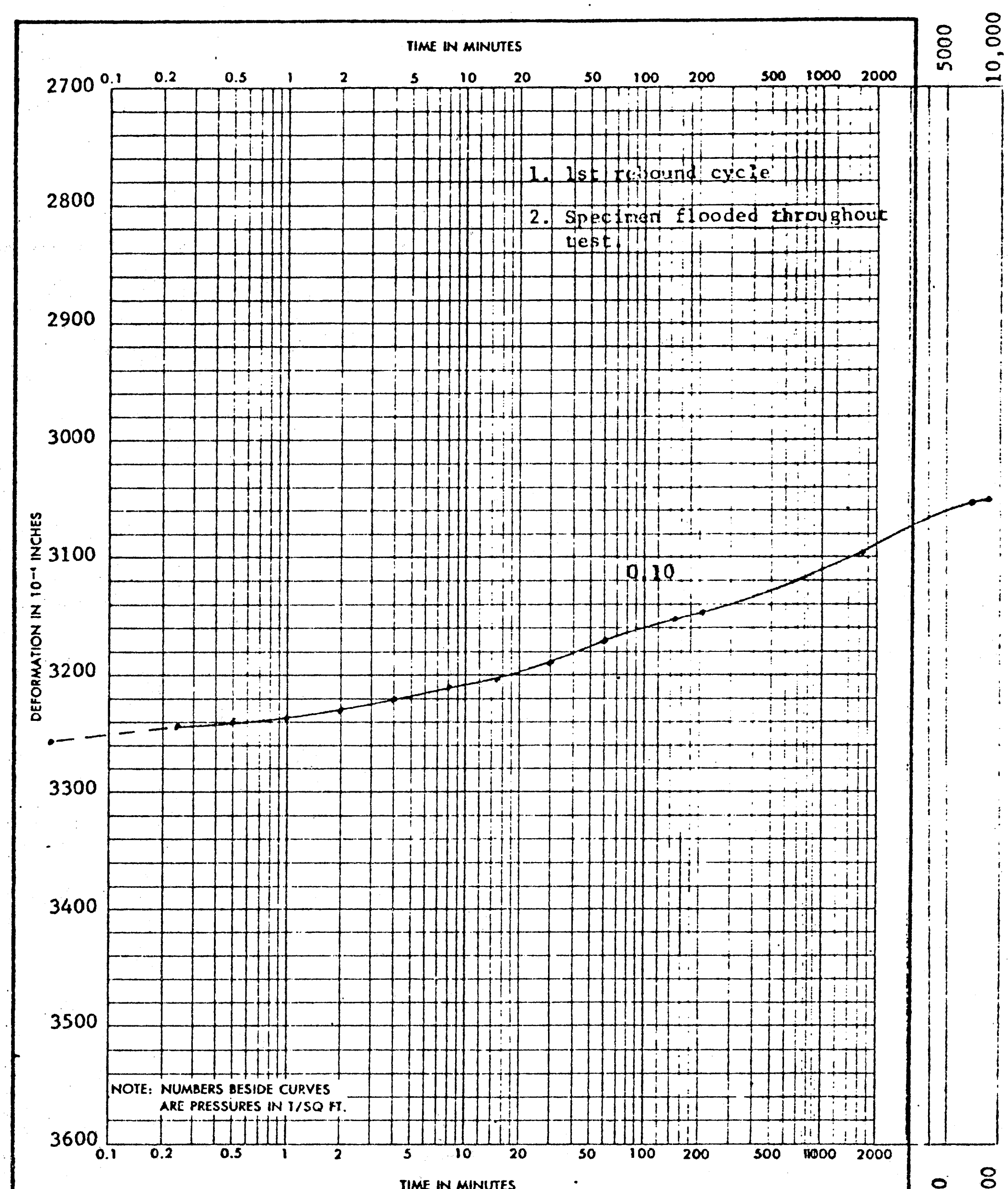


Type of Specimen Undisturbed		Before Test		After Test	
Diam 3.99 in.	Ht 1.25 in.	Water Content, w_o	147.7 %	w_f	79.1 %
Overburden Pressure, p_o -- T/sq ft		Void Ratio, e_o	4.303	e_f	2.153
Preconsol. Pressure, p_c -- T/sq ft		Saturation, S_o	93.4 %	S_f	100.0 %
Compression Index, C_c --		Dry Density, γ_d	32.0 lb/ft^3		
Classification Black and gray fat clay (CH)		k_{20} at e_o = -- x 10^{-} cm/sec			

LL 130	G_s 2.72	Project MOBILE DISTRICT Vacuum Well Point Experiment	
PL 34	D_{10} < .001mm	Lab. No. 57/7599	
Remarks See lab classification data on ENG Form 2087.		Area Pole Cat Bay	
		Boring No. VW-1	Sample No. 2
		Depth 1.5-2.5'	Date 30 July 1976
		CONSOLIDATION TEST REPORT	



PROJECT MOBILE DISTRICT - Vacuum Well Point Experiment			Lab.No.57/7599
AREA Pole Cat Bay			
BORING NO. VW-1	SAMPLE NO. 2	DEPTH 1.5-2.5'	DATE 30 July 1976
ENG FORM 1 MAY 63 2088	PREVIOUS EDITIONS ARE OBSOLETE.	CONSOLIDATION TEST—TIME CURVES	(TRANSLUCENT)

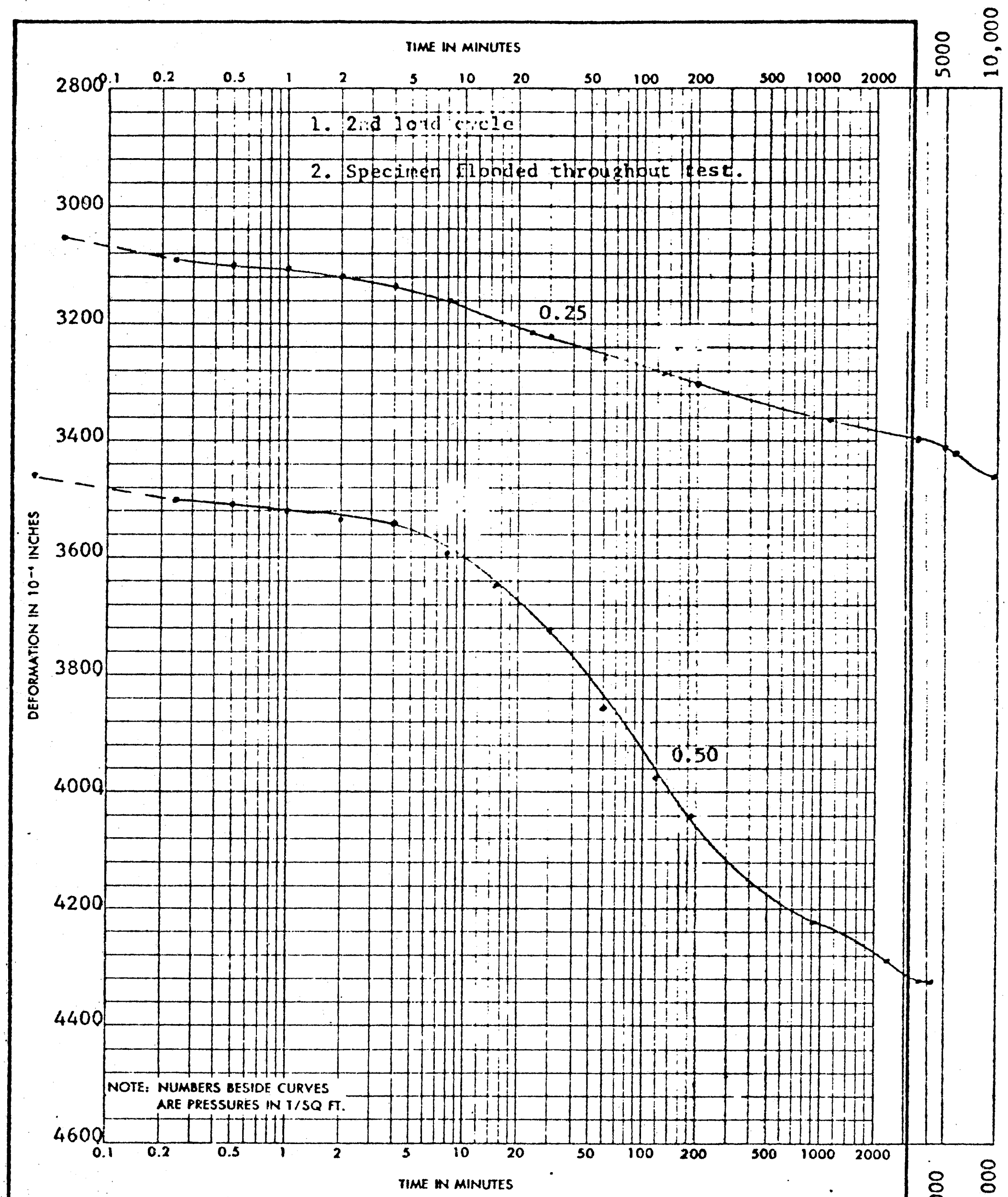


PROJECT MOBILE DISTRICT, Vacuum Well Point Experiment

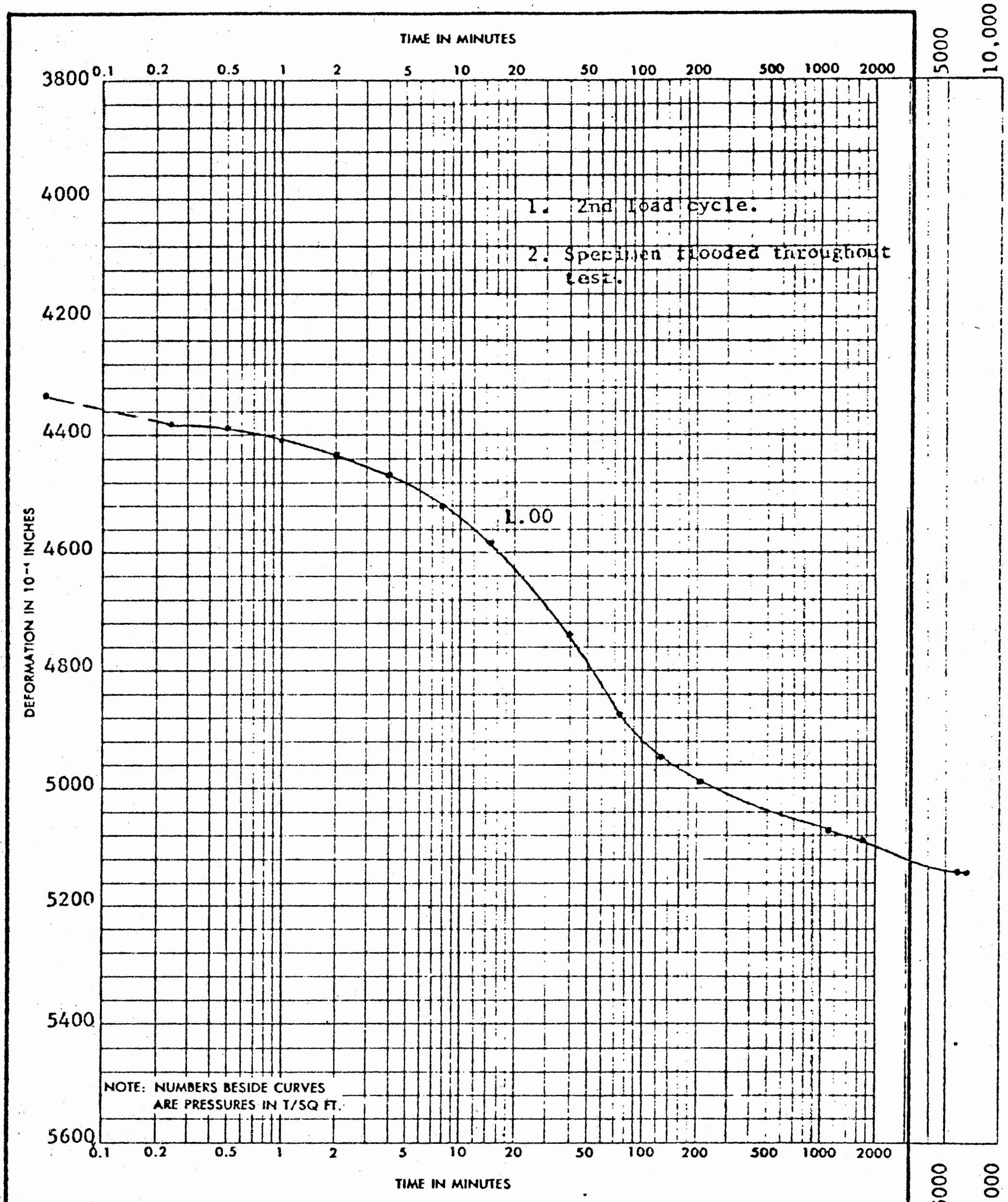
AREA Pole Cat Bay Lab. No. 57/7599

BORING NO. VW-1 SAMPLE NO. 2 DEPTH 1.5-2.5' DATE 30 July 1976

ENG FORM 1 MAY 63 2088 PREVIOUS EDITIONS ARE OBSOLETE. **CONSOLIDATION TEST—TIME CURVES** (TRANSLUCENT)



PROJECT MOBILE DISTRICT Vacuum Well Point Experiment			
AREA Pole Cat Bay Lab. No. 57/7599			
BORING NO. VW-1	SAMPLE NO. 2	DEPTH 1.5-2.5'	DATE 30 July 1976
ENG FORM 2088 1 MAY 63 PREVIOUS EDITIONS ARE OBSOLETE.	CONSOLIDATION TEST—TIME CURVES		(TRANSLUCENT)

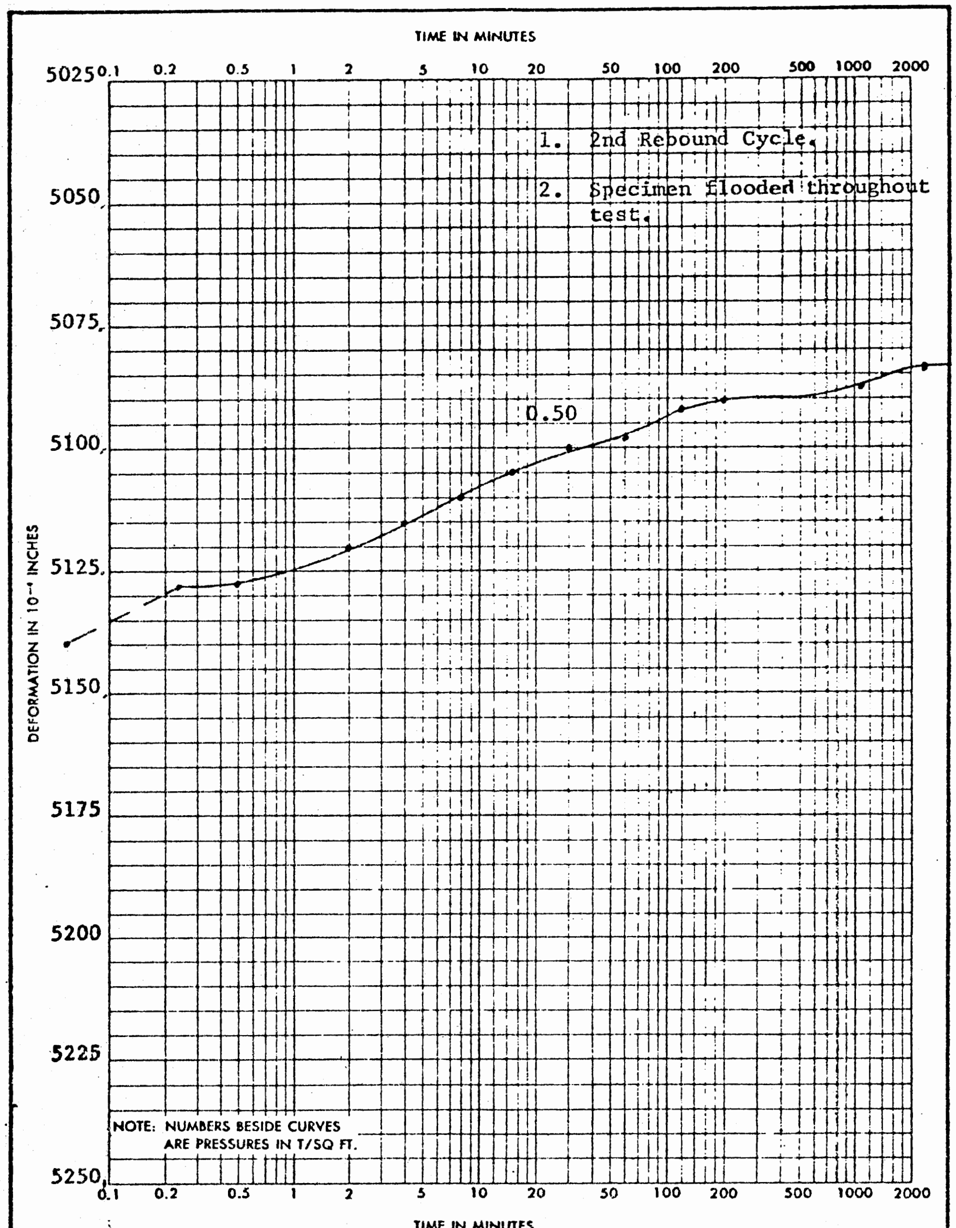


PROJECT MOBILE DISTRICT Vacuum Well Point Experiment

AREA Pole Cat Bay Lab. No. 57/7599

BORING NO. VW-1	SAMPLE NO. 2	DEPTH 1.5-2.5'	DATE 30 July 1976

ENG FORM 2088 1 MAY 63 PREVIOUS EDITIONS ARE OBSOLETE. **CONSOLIDATION TEST—TIME CURVES** (TRANSLUCENT)

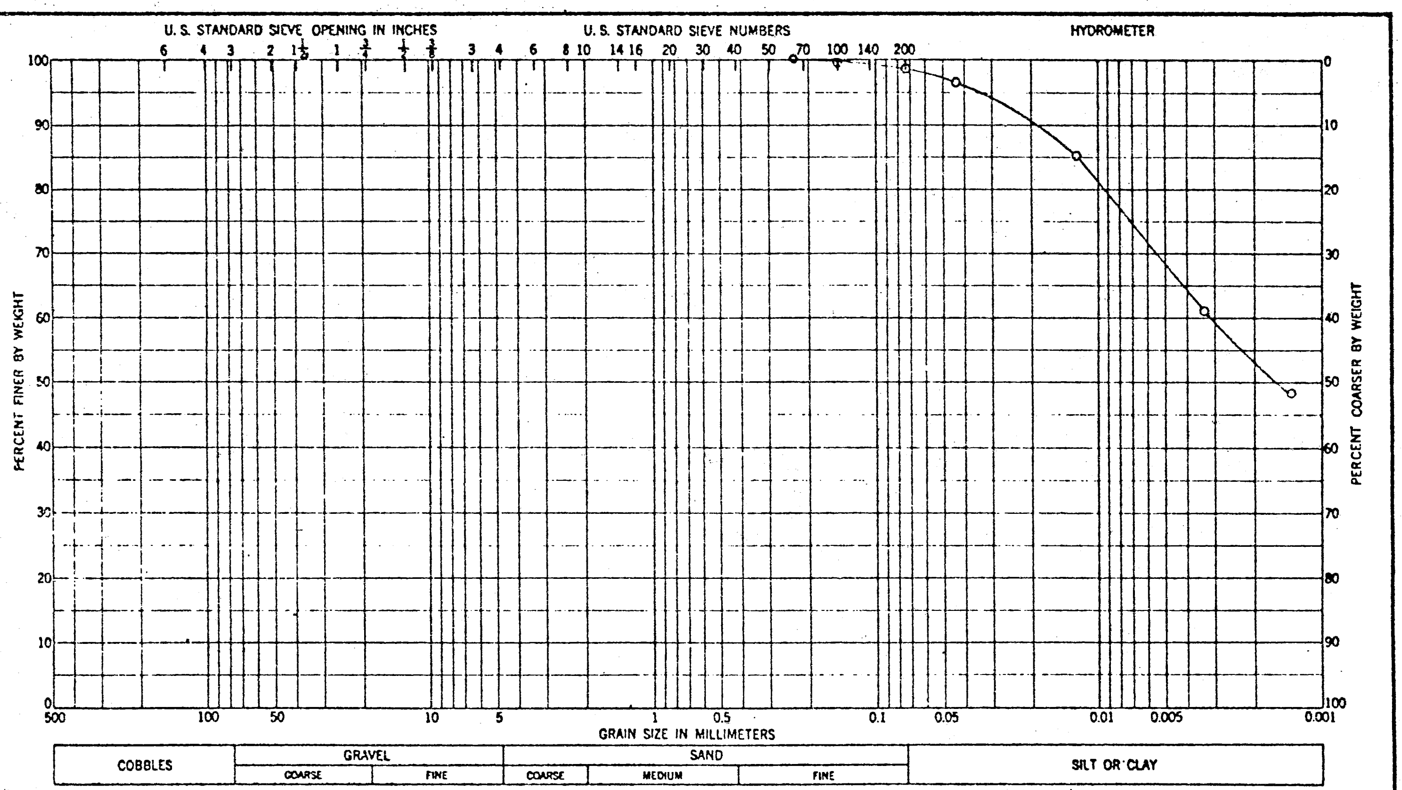


PROJECT MOBILE DISTRICT Vacuum Well Point Experiment

AREA Pole Cat Bay Lab. No. 57/7599

BORING NO. VW-1	SAMPLE NO. 2	DEPTH 1.5-2.5'	DATE 30 July 1976

ENG FORM 2088 1 MAY 63 PREVIOUS EDITIONS ARE OBSOLETE. **CONSOLIDATION TEST—TIME CURVES** (TRANSLUCENT)



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
2	4.0-5.0'	Dark gray fat clay (CH) with a trace of sand sizes	128.3	119	33	86
		Sample taken 9-29-76				

Project: MOBILE DISTRICT, Polecat Bay Vacuum Well Point Experiment

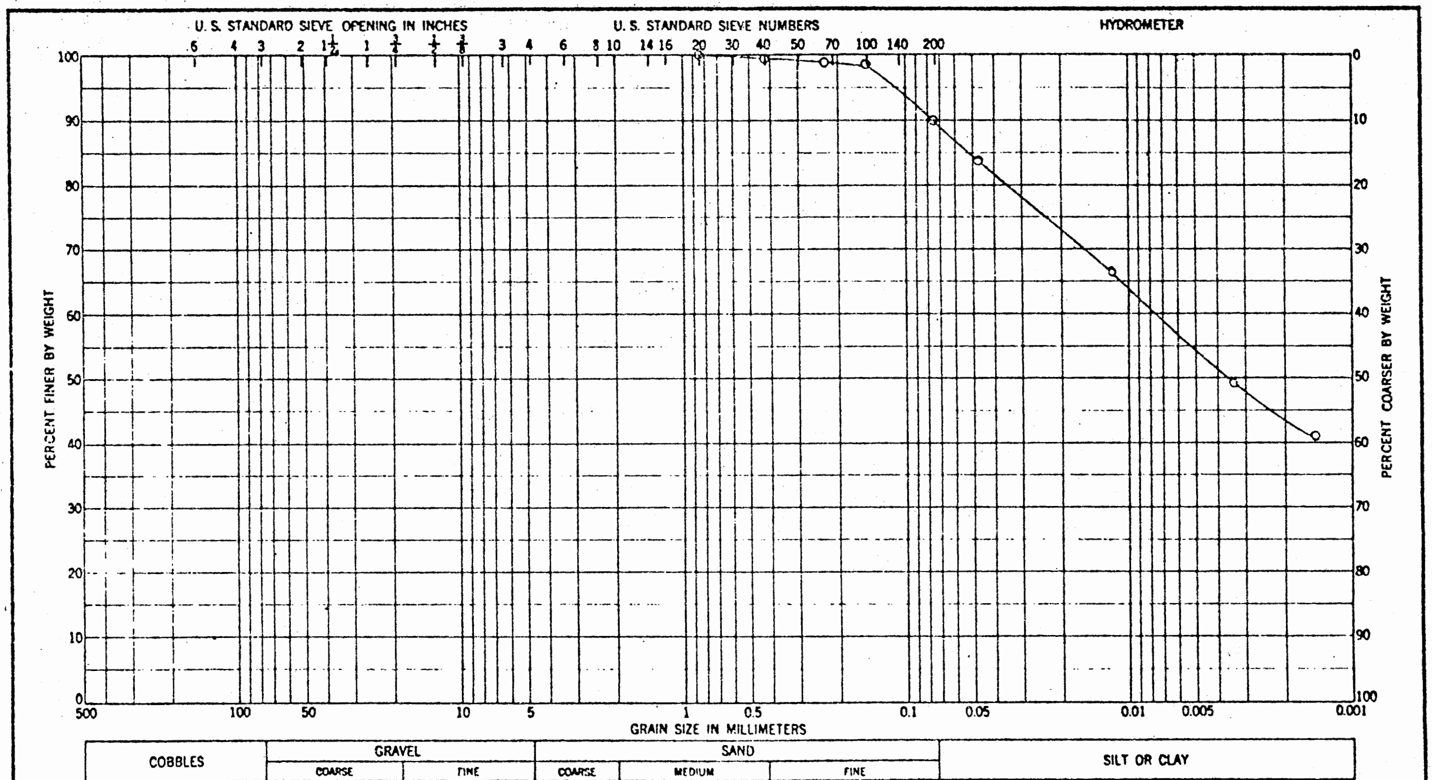
Lab. No. 57/8054

Area: --

Boring No. VW-2-76, Sample No. 2

Date: 16 December 1976

GRADATION CURVES



Sample No.	Depth	Classification	Nat w %	LL	PL	PI
3	7.0-8.0'	Dark gray fat clay (CH) with a trace of sand sizes	88.0	84	26	58
		Sample taken 9-29-76				

GRADATION CURVES

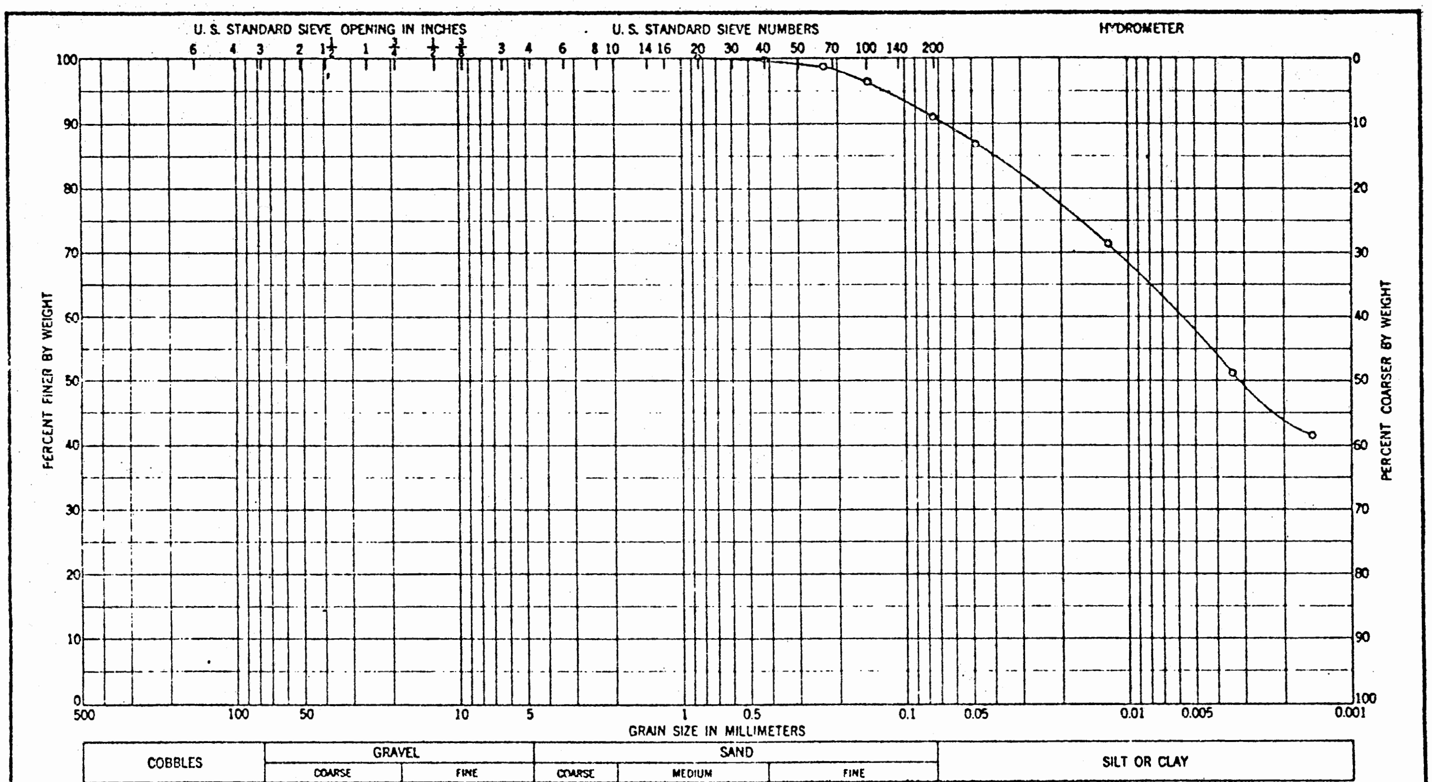
MOBILE DISTRICT, Polecat Bay

Project: Vacuum Well Point Experiment
Lab. No. 57/8061

Area: --

Boring No. VW-4-76, Sample No. 3

Date: 16 December 1976



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
1	1.0-2.0'	Dark gray fat clay (CH) with a trace of sand sizes	126.2	114	35	79
		Sample taken 9-29-76				

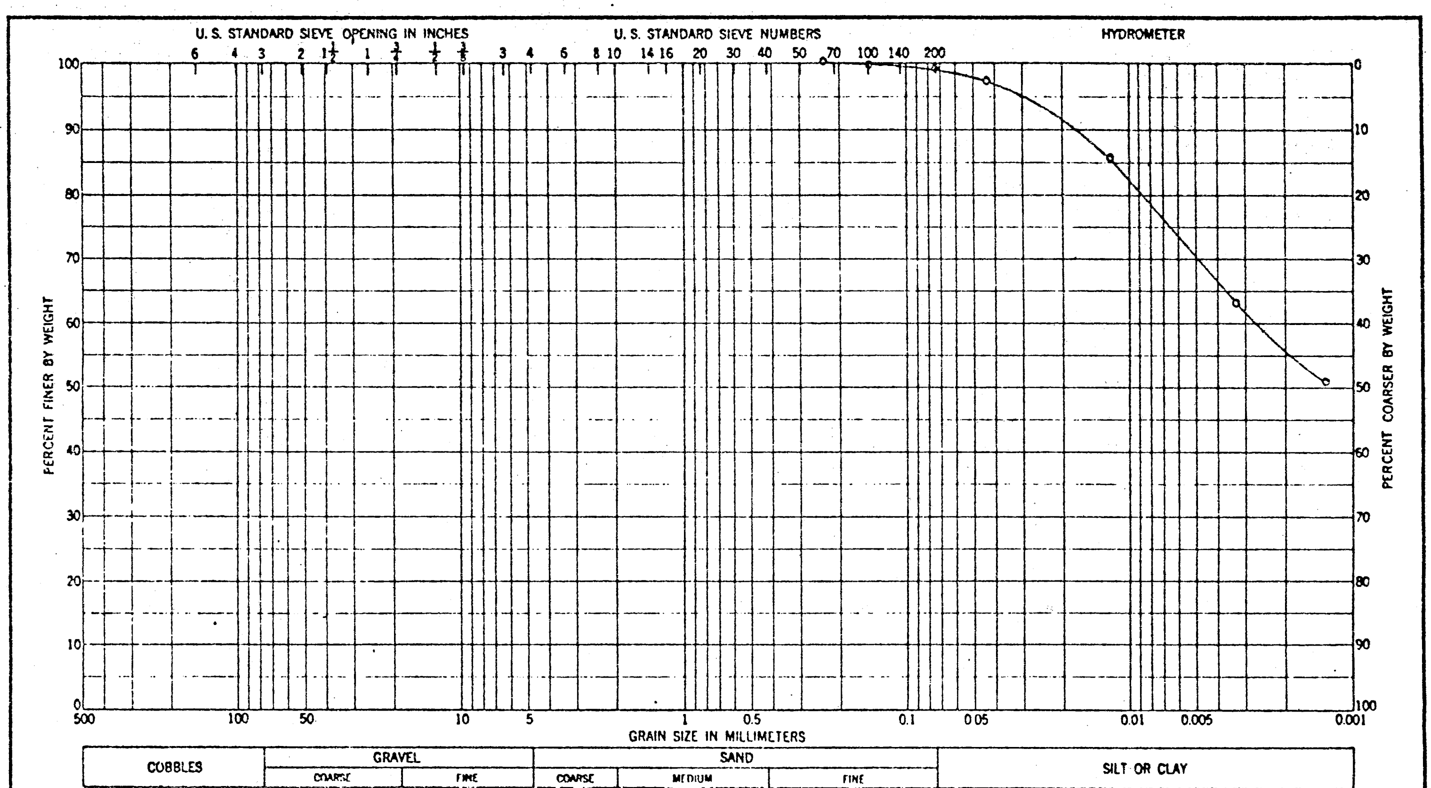
GRADATION CURVES

Project MOBILE DISTRICT, Polecat Bay Vacuum Well Point Experiment
Lab. No. 57/8071

Area --

Boring No. VW-8-76, Sample No. 1

Date 16 December 1976



Sample No.	Depth	Classification	Nat w %	LL	PL	PI
2	4.0-5.0'	Dark gray fat clay (CH) with a trace of sand sizes	128.3	114	36	78
		Sample taken 9-29-76				

GRADATION CURVES

MOBILE DISTRICT, Polecat Bay

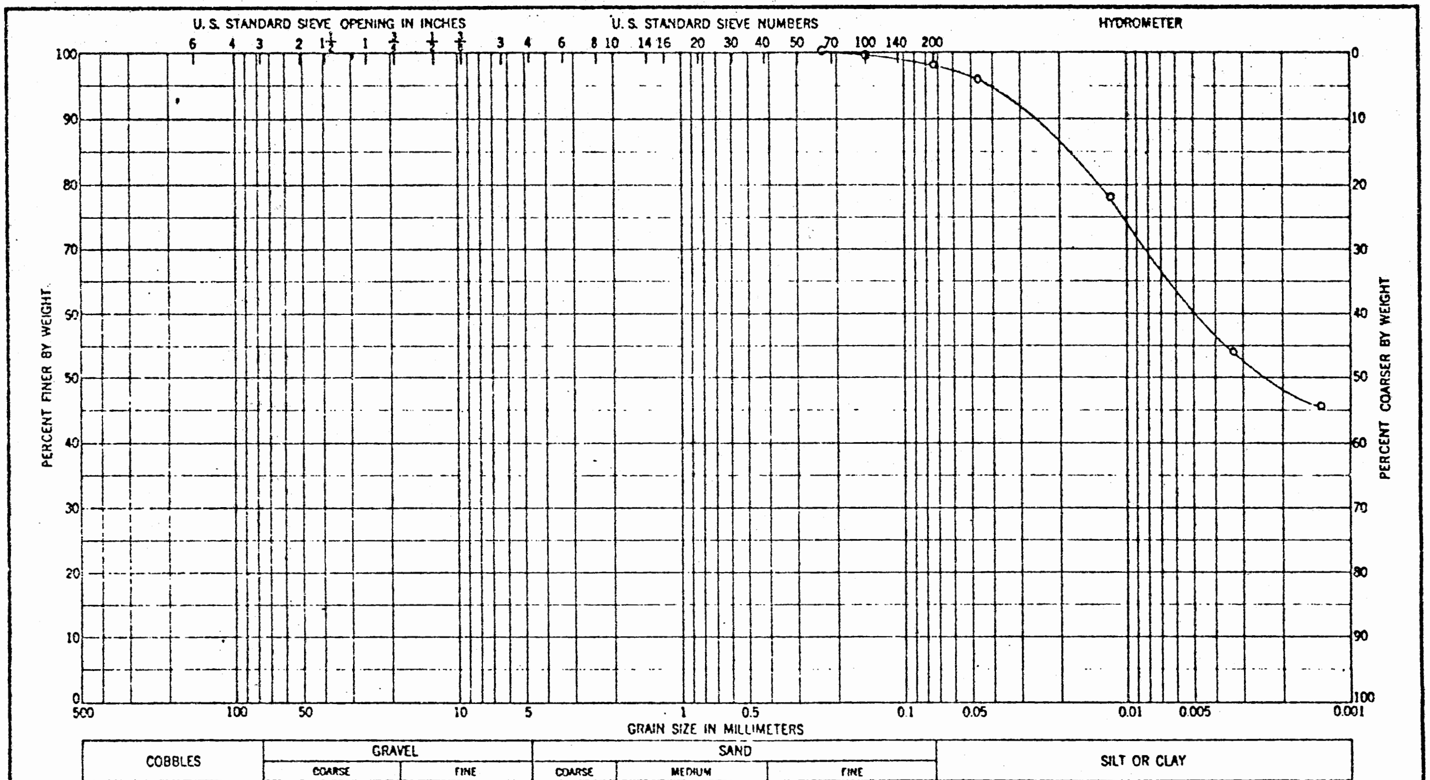
Project: Vacuum Well Point Experiment

Lab. No. 57/8078

Area: --

Boring No.: VW-10-76, Sample No. 2

Date: 16 December 1976



Sample No.	Depth	Classification	Nat w %	LL	PL	PI
3	7.0-8.0'	Dark gray fat clay (CH) with a trace of sand sizes	102.8	100	31	69
		Sample taken 9-29-76				

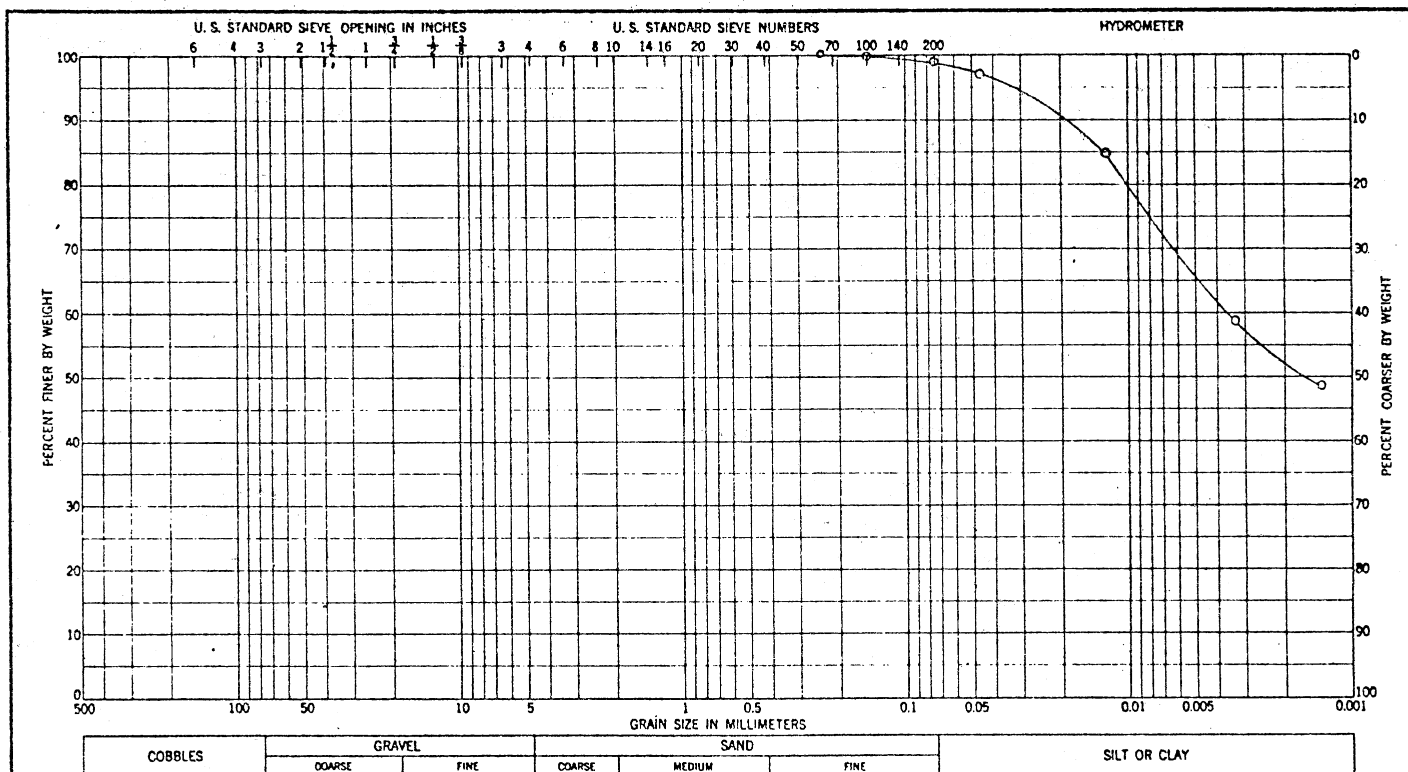
Project: MOBILE DISTRICT, Polecat Bay
Vacuum Well Point Experiment
Lab. No. 57/8088

Area: --

Boring No. VW-13-76, Sample No. 3

Date: 16 December 1976

GRADATION CURVES



Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI
1	1.0-2.0'	Dark gray fat clay (CH) with a trace of sand sizes	130.9	131	41	90
		Sample taken 9-29-76				

Project: MOBILE DISTRICT, Polecat Bay Vacuum Well Point Experiment

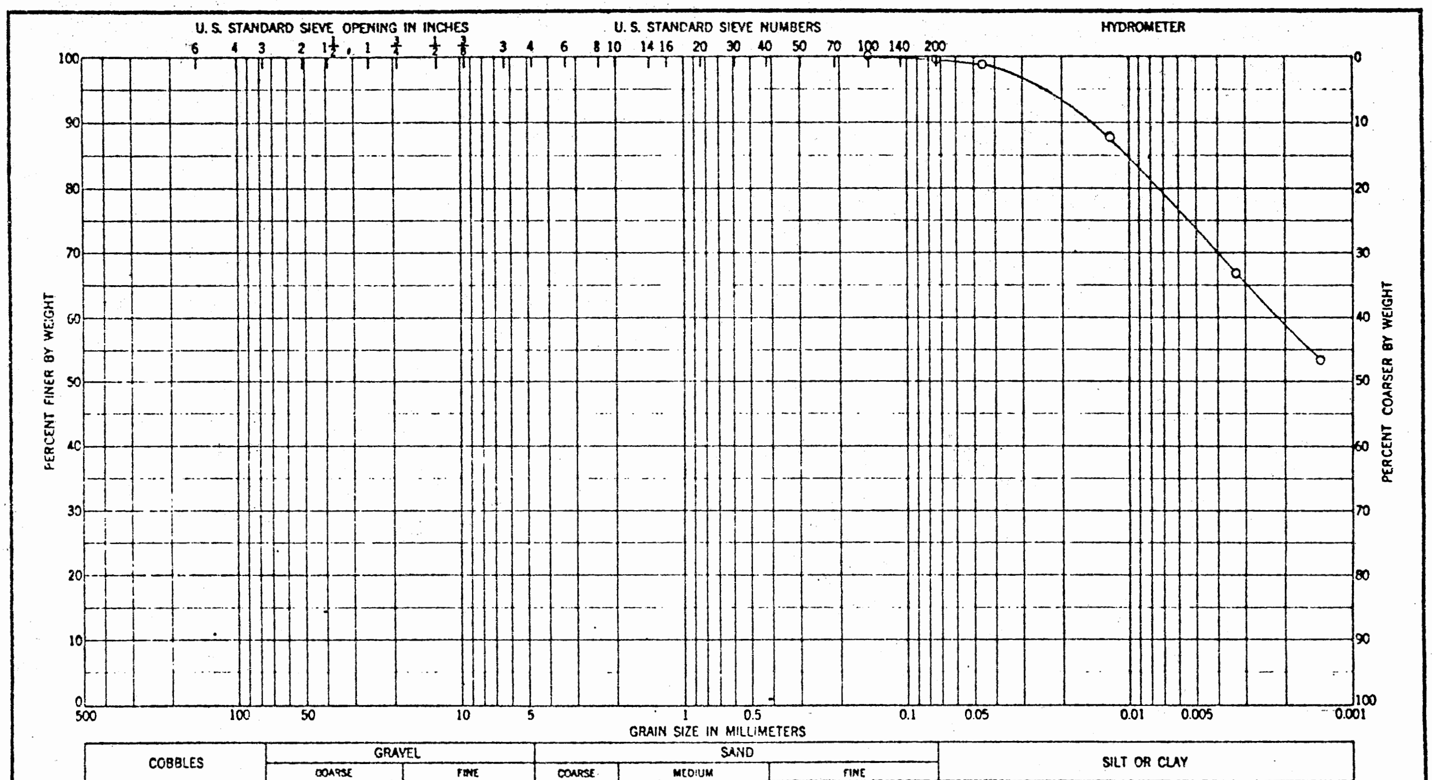
Lab. No. 57/8098

Area --

Boring No. VW-17-76, Sample No. 1

Date 16 December 1976

GRADATION CURVES



Sample No.	Depth	Classification	Nat w %	LL	PL	PI
2	4.0-5.0'	Dark gray fat clay (CH) with a trace of sand sizes	128.3	111	33	78
		Sample taken 9-29-76				

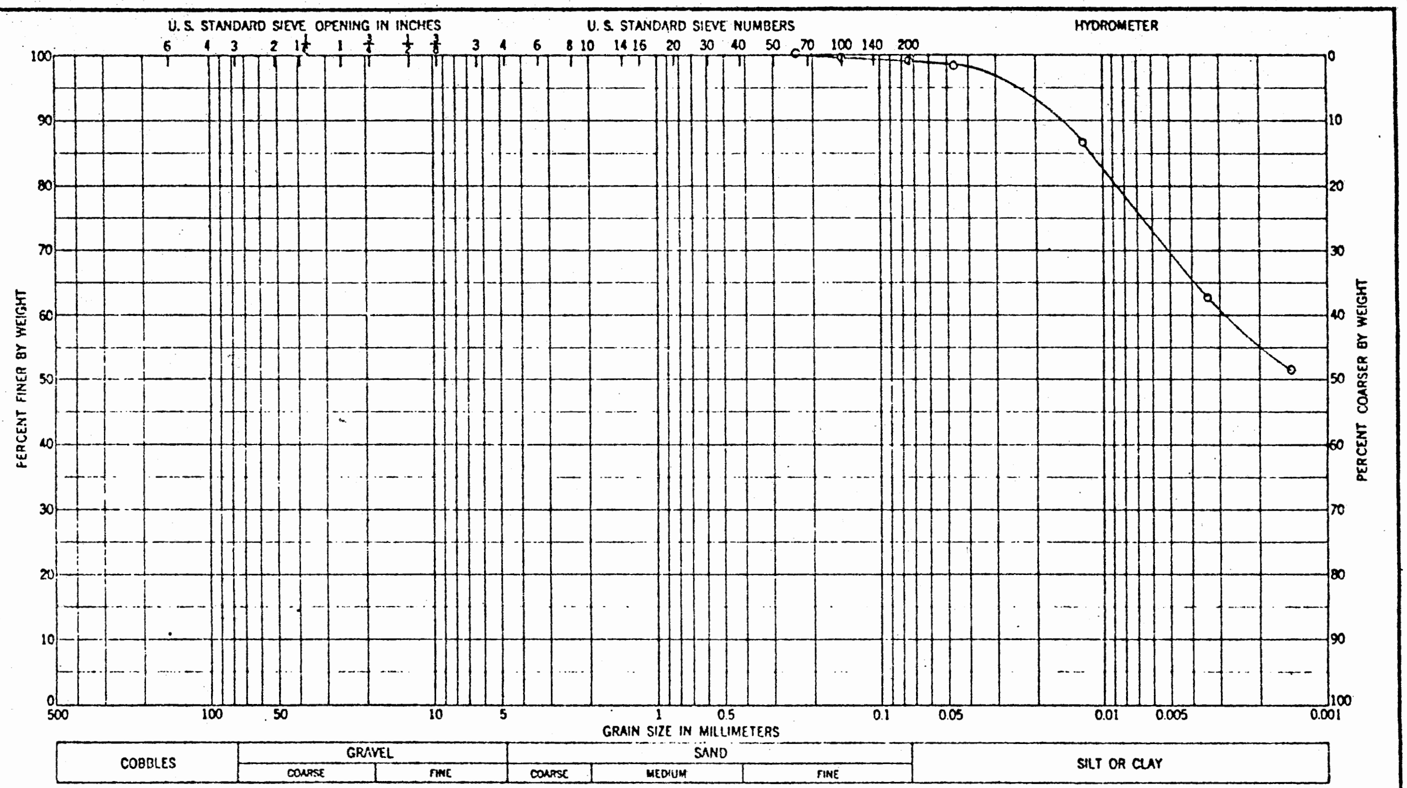
GRADATION CURVES

Project: MOBILE DISTRICT, Polecat Bay Vacuum Well Point Experiment
Lab. No. 57/8105

Area: --

Boring No. VW-19-76, Sample No. 2

Date: 16 December 1976



Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI
2	4.0-5.0'	Dark gray fat clay (CH) with a trace of sand sizes	127.3	116	34	82
		Sample taken 9-29-76				

MOBILE DISTRICT, Polecat Bay

Project Vacuum Well Point Experiment

Lab. No. 57/8114

Area --

Boring No. VW-22-76, Sample No. 2

Date 16 December 1976

GRADATION CURVES

VITA [2]

Robert William Chamlee

Candidate for the Degree of

Master of Science

Thesis: CONSOLIDATING FINE-GRAINED DREDGED MATERIAL WITH VACUUM WELLPOINTS

Major Field: Civil Engineering

Biographical:

Personal Data: Born in Atlanta, Georgia, April 28, 1947, the son of Mr. and Mrs. John H. Chamlee.

Education: Graduated from Perry High School, Perry, Georgia, 1965; received the Bachelor of Civil Engineering degree from the Georgia Institute of Technology, Atlanta, Georgia, in 1970; completed the requirements for the Master of Science degree at Oklahoma State University in May, 1979.

Professional Experience: Co-operative Student Trainee, U.S. Army Corps of Engineers, South Atlanta Division Laboratory, 1966-1968; Civil Engineer, Geotechnical and Materials Branch, U.S. Army Corps of Engineers, Mobile, Alabama, 1970-1978; Civil Engineer, Geotechnical and Materials Branch, U.S. Army Corps of Engineers, South Atlantic Division Office, Atlanta, Georgia, 1979 to present.