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EVALUATION OF THE REHABILITATION PROGRAM FOR RELIEF WELLS AT LEESVILLE DAM, OHIO

by

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At a relief well and drainage system rehabilitation workshop held in April 1985, it was determined that maintenance methods varied between Districts and that no attempt had been made to document results versus the method used. The Huntington District was planning the rehabilitation of 12 wells at Leesville Dam, Ohio, and agreed to use a composite of the various "common" Corps of Engineer (CE) cleaning methods along with the extra verification procedures needed to document the results. Therefore, the objectives of the study were to document a commonly used CE well rehabilitation procedure, to provide the needed pre- and post-verification data, and to evaluate the results.

For the study, encrustant, bacterial, and water analyses were conducted for use in planning the rehabilitation procedure. Recommended procedures and the final selected procedures for rehabilitation are presented. Planning criteria required that the chemicals be industry accepted and commonly used with economics

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being the final governing factor. The procedure used at this site incorporated a long linear phosphate and sodium hypochlorite as chemicals with mechanical agitation using a surge block.

Several factors were considered during the evaluation: (a) the lake level was lowered between some of the pre- and post-pump tests; (b) there was no bacterial growth in two wells; and (c) there were hydrogeologic boundary conditions that altered groundwater quality, flow, and available bacterial nutrients from well to well. Although there were immediate benefits, post-bacterial analysis showed regrowth had started within 4 months of the rehabilitation. There was no "as installed" specific capacity on record to evaluate overall results. Comparison of before and after pump tests indicated an increase in specific capacity for the eight central wells (W-4 through W-11) considered to be representative of the well system that ranged from 35 to 714 percent with an average value of 236 percent. The remaining four wells are not included in the average values because they are at the end of the system, have less screen length, and appear to be founded in finer sediments.

PREFACE

This report was prepared at the US Army Engineer Waterways Experiment Station (WES), Vicksburg, MS, and was sponsored by Headquarters, US Army Corps of Engineers (HQUSACE), under the Work Unit 32313, "Rehabilitation of Relief Wells and Drainage Systems" of the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program. The HQUSACE technical monitor was Mr. Arthur H. Walz. This part of the study under REMR Work Unit 32313 was conducted from May 1986 through June 1987 by the Soil and Rock Mechanics Division (S&RMD) of the WES Geotechnical Laboratory (GL).

The research was conducted and the report was written by Mr. Glen Hackett, formerly with the National Ground Water Association, and Mr. Roy E. Leach, S&RMD. Mr. Gene P. Hale, GL, was the Problem Area Leader. The study was under the supervision of Dr. Don Banks, Chief, S&RMD, and Mr. Milton Myers, Chief, Soil Mechanics Branch (SMB). The work was conducted under the general supervision of Dr. William F. Marcuson III, Director, GL. The REMR Program Manager was Mr. William F. McCleese, WES, and the Directorate of Research and Development (DRD) Coordinator, HQUSACE, was Mr. Jesse A. Pfeiffer. Mr. James E. Crews and Dr. Tony C. Liu served as the REMR Overview Committee.

The field study was conducted at Leesville Dam, Ohio, in the US Army Engineer District, Huntington, under the coordination of Messrs. L. W. Franks and T. Plummer. The study would not have been possible without the District's cooperation and support in allowing the research to be incorporated into one of its ongoing rehabilitation projects. Dodson-Lindblom Associates, Inc., performed the actual well rehabilitation to Corps specifications.

At the time of the publication of this report, Director of WES was Dr. Robert W. Whalin. Commander and Deputy Director was COL Leonard G. Hassell, EN.

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
feet	0.3048	meters
inches	25.4	millimeters
gallons	0.264	liters

EVALUATION OF THE REHABILITATION PROGRAM FOR RELIEF WELLS AT LEESVILLE DAM, OHIO

PART I: INTRODUCTION

Background

1. From a Repair, Evaluation, Maintenance, and Rehabilitation (REMR) program survey of United States Army Corps of Engineers (CE) district and division practice, it was determined that rehabilitation of relief wells and drains was a major maintenance item. The CE owns more than 5,000 relief wells with related drain systems (piping, outlet valves, and regular sand drains beneath soil and concrete structures). A REMR workshop held to discuss maintenance problems revealed a diversity of rehabilitation procedures ranging from severe neglect to state-of-the-art procedures with most programs relying on availability of money and manpower or emergency management to trigger rehabilitation. Guidance for rehabilitation exists in Engineering Manuals and Regulations, but there is no set procedure and again economics is the governing factor for most CE well rehabilitation activity.

2. To be able to compare current cleaning procedures used by the CE with any new methods that might be developed required merging of the several procedures, determined at the workshop (which differed in detail), into a "commonly used" CE method. The method chosen could not include all available chemical or mechanical treatments; therefore, the adopted procedure was to use industry "standard" chemicals and economical mechanical treatments. Once a rehabilitation method was selected, its application required a presently funded project where extra pre- and post-tests and documentation could be conducted. The United States Army Engineer District, Huntington (ORH), was planning the rehabilitation of 12 relief wells at Leesville Dam, Ohio, and agreed to incorporate the extra work into the project.

Objectives

3. The primary objectives of this study were to:

a. Evaluate a basic rehabilitation procedure that is presently being used in some form by a number of CE Districts.

b. Determine the type of data collection required to conduct and evaluate a successful relief well rehabilitation program.

c. Collect and evaluate data from the rehabilitation work at Leesville Dam.

4. A secondary objective is to compile the results of this study for comparison with the results of other methods developed in the overall rehabilitation program. The documentation includes representative photos (1-28) which will supply visual instruction for delineation of future problems.

Scope

5. This report provides the information necessary to plan, conduct, and evaluate a relief well rehabilitation project using a procedure that has been merged from several procedures used by CE Districts. Both the chemical and mechanical cleaning aspects are discussed. The information presented is site specific, and some minor adjustments would have to be made to adapt the procedure to other sites.

PART II: PROBLEM DEFINITION

Site Description

6. Leesville Dam is an earthen embankment constructed by the United States Army Corps of Engineers from 1935 to 1937 (Photos 1 and 2). The dam is located in Orange Township, Carroll County, Ohio, at the confluence of the South Fork and the North Fork of McGuire Creek (Figure 1). Leesville Lake was created by damming McGuire Creek. McGuire Creek continues downstream from the dam and discharges into Conotton Creek, which flows into Dover Reservoir and the Tuscarawas River. Maintenance of the dam, as well as structures appurtenant to the dam, is overseen by personnel from ORH.

7. Consequent to the construction of Leesville Dam, underseepage at the downstream toe of the dam created swampy conditions below the site of the dam. To alleviate the wet surface conditions, a 4- to 8-ft*-thick filter blanket, composed of coarse granular material enveloping a network of drainage tiles, was installed below the damsite in November and December of 1975. In addition, 12 relief wells, at 75-ft horizontal spacings, were installed along the length of the dam in late 1976 and early 1977 to lessen the hydrostatic pressure beneath the dam. These wells were drilled through the filter blanket and the rock toe of the dam, and into the underlying alluvial deposits. Figure 2 is a plan view of the downstream side of the dam showing the location of the 12 relief wells.

8. The relief wells terminate 4 to 7 ft below the surface of the filter blanket and are individually housed within a 48-in.-diam corrugated metal casing, with a hinged lid that is lock-bolted for security (Photo 3). A general cross-sectional view of the housing for the individual relief wells is shown in Figure 3. The relief wells are designed as uncapped, flowing wells (Photo 4). The overflow from each well drains by gravity, through subsurface drains in the filter blanket, and discharges into a collector ditch downstream of the toe of the dam.

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* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 4.

Problem Description

9. Pursuant to a request from personnel at the Waterways Experiment Station (WES) and ORH, an inspection of the relief wells at Leesville Dam was made in July, 1986, to determine whether the performance of the wells was being impaired by iron bacteria. A visual inspection of the top of the relief well casings and the floors of the well housings revealed the presence of substantive amounts of reddish-brown, mucilaginous deposits characteristic of iron-precipitating bacteria (Photo 5). Based on this presumptive visual evidence of iron bacteria, the relief wells at Leesville Dam were selected for study and inclusion in the well rehabilitation project. At that time, however, the reduction in hydraulic performance of the relief wells, from the apparent growth of iron bacteria, could not be determined because of the absence of historic pumping test data for the wells. In general, it can be stated that, before cleaning, wells 1, 2, 3, 11, and 12 did not flow and wells 4 - 10 did flow when the lake level was at elevation 963 ft. Also, the risers for the nonflowing wells are 0.3 to 1.0 ft higher than the highest riser for a flowing well. Wells 1, 2, 3, and 12 can only sustain very low pump rates and are considered to be at the outer fringes of the water-bearing aquifer.

PART III: METHOD OF STUDY

General

10. The methodology for this study and subsequent well rehabilitation project included the following items:

a. Site characterization.

b. Analysis of encrustant material.

c. Vertical profile of iron bacteria in the wells.

d. Analysis of groundwater quality.

e. Developing and conducting a chemical treatment program.

f. Evaluation of the chemical treatment program.

Each item is discussed in some detail below.

Site Characterization

11. Characterization of the site involved evaluating the hydrogeology, based on published information, and reviewing the design and construction of the relief wells. Published reports, maps, and borehole logs were reviewed to obtain information on the geology of the site. Borehole logs from the relief wells and piezometers, as well as applicable engineering reports on previous geotechnical studies conducted at Leesville Dam, were obtained from the ORH. Information on the groundwater resources at the site was also obtained from the Ohio Department of Natural Resources. These data primarily consisted of driller's logs for domestic water wells drilled in the drainage basin of McGuire Creek and Conotton Creek.

12. Specifications for the design and construction of the relief wells at Leesville Dam were also received from the ORH. Technical critical criteria for the design and installation of the filter pack, intake, and casing for the relief wells were reviewed. The bid specifications for developing and pump testing the relief wells, at the time of their initial installation, were also reviewed. Records of the original pumping test results, however, were not present in the files of the ORH.

Analysis of Encrusting Material

13. During the initial phase of this study, the reddish-brown, mucilaginous deposits occurring around the top of the majority of the relief well casings were sampled in order to confirm the presence of iron bacteria. These samples were collected by gently scraping the encrusting material away from the surface of the well casing. This material was immediately placed in a Nasco Whirl-Pak™ containing water from the well (Photo 6), and the sample was kept cool until analyzed at the contract laboratory.

14. The samples of the encrusting material were analyzed for the presence of iron bacteria in accordance with Part 918 A. of the Standard Methods for the Examination of Water and Wastewater (American Public Health Association 1985). This procedure involves placing a small portion of the material on a microscope slide, covering the material with a cover slip, and examining the material under a low-power microscope for iron-encrusted bacterial filaments.

Vertical Profile of Iron Bacteria in the Wells

15. An attempt also was made to determine the vertical distribution of iron bacteria within the relief wells. The purpose for determining the vertical profile of iron bacteria in the relief wells was two-fold: (a) to establish the presence or absence of iron bacteria, at depth, in the wells; and (b) to identify any tendency for iron bacteria to occur at specific vertical depths or zones in the wells. An empirical technique was used to determine the presence of iron bacteria, at depth, in the relief wells. This technique involved suspending solid surfaces in the wells, at fixed depths, for a prescribed period of time. The solid surfaces, informally termed "in-well collectors," served as sites for the attachment of iron bacteria. These surfaces were subsequently retrieved from the wells and examined for the presence of a biofilm containing iron bacteria.

16. The in-well collectors used in this study were fabricated by cutting a one-eighth-inch-thick sheet of clear Plexiglas into 1- by 3-in. rectangles, and then drilling a small hole at one end of each rectangle. The Plexiglas rectangles were identical in size to commercially available glass microscope slides; however, the Plexiglas material eliminated concerns about

the potential breakage and loss of slides down in the wells. In order to suspend the Plexiglas slides in the relief wells, monofilament line was used. The monofilament line was measured and cut for each relief well, based on the total depth of the well. Weights were tied to one end of the monofilament line to anchor the line in the relief well. Brass, snap swivels were then attached to the monofilament line at depths corresponding to the top, midsection, and bottom of the intake of the relief well. An exception to this procedure, however, was made for relief wells W-1, -2, and -12. Due to the short length of intake for each of these wells, snap swivels were attached to the monofilament line at depths corresponding to the top and bottom of the intake. Prior to attaching the Plexiglas slides to the weighted, monofilament line for each relief well, the slides were immersed in a 50-mg/l chlorine solution for 30 min. The slides were then rinsed with distilled water and dried. Cotton string was threaded through the hole in each Plexiglas slide, and the string was knotted forming a loop. The plexiglass slides were attached to the weighted, monofilament line by hooking the cotton string through the snap swivel (Photo 7). Each slide was labeled with the well number and depth setting, and each weighted, monofilament line with attached slides was placed in a sealed bag (Photo 8).

17. The in-well collectors were installed by slowly lowering the weighted, monofilament line, with attached Plexiglas slides, through the center of each relief well (Photo 9). Once the weighted end of the monofilament line reached the bottom of the well, the top of the line was hooked around a rung of the stationary ladder in each well housing to hold the in-well collector in place (Photo 10). The in-well collectors were left in the relief wells for a period of 19 days. The Plexiglas slides were then retrieved by slowly raising the weighted, monofilament line from the relief well (Photo 11) and carefully removing each slide from the snap swivel. The individual Plexiglas slides were immediately immersed in distilled water in a Nasco Whirl-Pak (Photo 12), and the slides were kept cool until analyzed at the contract laboratory. The Plexiglas slides were directly analyzed for the presence of iron bacteria by placing a cover slip on the plexiglass slide and examining the slide using light microscopy.

Analysis of Groundwater Quality

18. During the course of this study, groundwater samples from the 12 relief wells were collected and analyzed for parameters considered important to the growth of iron bacteria in groundwater. These parameters included ph, temperature, oxidation-reduction potential, dissolved oxygen, ferrous iron, and chemical oxygen demand (COD).

19. Temperature and pH measurements were made onsite using an Orion SA 250 portable meter with a Ross Combination Epoxy Body pH electrode and automatic temperature compensation probe (Photo 13). An Orion redox electrode, Model 96-78, was also used in the field with the SA 250 portable meter for measuring the oxidation-reduction potential of the groundwater samples, and an Orion Model 97-08 dissolved oxygen electrode was used with the SA 250 portable meter for dissolved oxygen determinations. Unfiltered, acid-preserved groundwater samples were collected and taken to the contract laboratory for COD and ferrous iron analyses. These two analyses were conducted in accordance with Standard Methods for the Examination of Water and Wastewater (American Public Health Association 1985).

20. Groundwater samples were collected from each relief well at a depth of approximately 12 in. below the static or flowing water level. Samples were collected and analyzed twice prior to the development and recommendation of a chemical treatment program for controlling iron bacteria in the relief wells. Groundwater samples were also collected and analyzed once after the treatment program was completed.

Developing and Conducting a Treatment Program

21. The following information was reviewed prior to developing a chemical treatment program to control iron bacteria in the relief wells at Leesville Dam: (a) the hydrogeology of the site, (b) the design of the relief wells, (c) the analysis of the encrusting material from the top of the relief wells, (d) the results from the in-well collectors, and (e) the analysis of the groundwater samples. Based on this information, a chemical treatment program was recommended to the ORH. The recommended treatment program included: (a) the type of chemicals to be used, (b) chemical concentrations, (c) contact time for the chemicals in the well, (d) method for introducing the

chemicals in the well, and (e) method for surging the chemicals in the well. Details of the recommended chemical treatment program, as well as the actual treatment program used, are given in Part IV.

22. Prior to conducting the chemical treatment program in each relief well, a temporary 5- to 6-ft length of casing had to be added to the well to maintain a static water level inside the casing, above the floor of the relief well housing. Maintaining the static water level inside the casing was necessary in order to properly introduce, contain, and surge the chemicals in the well. A 10-in.-diam PVC well casing was used for the temporary casing extension. A neoprene sleeve was used to join the PVC riser pipe to the fiberglass relief well casing (Photos 14 and 15). The neoprene sleeve was secured to each pipe with stainless steel bands. Vertical support for the PVC riser pipe was provided by extending the PVC pipe through a plywood platform placed over the relief well housing (Photo 16).

Evaluation of the Treatment Program

23. During the final phase of the well rehabilitation project, the effectiveness of the chemical treatment program was evaluated in two ways: (a) by performing a pumping test on each relief well, both before and after the chemical treatment program; and (b) by placing in-well collectors in the relief wells after the treatment program was completed.

24. A step-drawdown pumping test was performed on the relief wells. The test was conducted by setting a submersible turbine pump in the well and pumping the well at three different rates, where possible, for a period of 2 hr at each rate (Photo 17). Riser pipe extensions were added to the wells prior to the pumping tests allowing an initial static water level to be measured for use as a basis for computing drawdowns. That some of the wells were flowing prior to the rehabilitation pumping tests is evident from the fact that water levels in the riser pipe extensions, except for wells W-1, -3, -11, and -12, were higher than the tops of the well risers without the extension. The elevations of the tops of risers for wells W-1, -2, -3, -11, and -12, at the ends of the well line, are about a foot or so higher than that of the remaining wells. Thus, in addition to the fact that W-1, -2, -3, and -12 are low-producing wells, this increase in the elevations may account for the absence of flow before the extensions. The scope of this study, however,

did not provide for a detailed analysis of the impact of hydrogeologic boundary conditions and lake pool elevations on the pumping test results.

25. In-well collectors were placed in the relief wells, approximately 4 months after the chemical treatment program, to determine whether regrowth of iron bacteria was occurring in the wells. Any regrowth of iron bacteria in the relief wells was used as a long-term measurement of the effectiveness of the treatment program.

PART IV: SITE CHARACTERIZATION AND INITIAL SAMPLING RESULTS

Site Geology and Hydrogeology

26. The study site is located in the Unglaciated Plateau section of the Allegheny physiographic province (Figure 4). The Unglaciated Plateau is the hilliest part of Ohio and is characterized by narrow ridges and steep-sided valleys with narrow floodplains. Ridges are typically capped with resistant sandstone, and the region has been maturely dissected by areal streams. Bedrock is commonly exposed in the valley walls.

27. At the site of Leesville Dam, the valley floodplain of McGuire Creek is approximately 1,000 ft wide and is approximately 930 ft above mean sea level (Figure 1). The valley walls slope moderately upward for about 500 ft toward the maturely dissected upland. A geologic cross section along the downstream toe of the dam is shown in Figure 5. Boring logs for the 12 relief wells are included in Appendix B.

28. Based on information from the boring logs for the relief wells, the unconsolidated deposits within the valley of McGuire Creek range in thickness from approximately 25 ft, near the sides of the valley, to approximately 95 ft, in the deepest part of the valley. The unconsolidated material overlying the bedrock consists of alluvial deposits which are characterized as predominantly silty to clayey sand (Figure 5). It appears that the alluvial deposits close to the valley walls are generally less permeable than the deposits near the center of the valley.

29. Bedrock at the site consists of a predominantly shale-sandstone sequence with minor amounts of coal and underclay. Based on general stratigraphic information for bedrock in the McGuire Creek and Conotton Creek basins, these rocks represent formations from the Pennsylvanian Period. Cyclothems of alternating sandstones and shales of the Conemaugh and underlying Allegheny formations reportedly outcrop along the higher ridges. Interbedded sandstones and shales of the older Pottsville formation occur beneath the floodplain of McGuire Creek (US Army Corps of Engineers 1978).

30. The principal water-bearing formations in the area are the more permeable sandstones and sandy shales. These formations, however, are not consistent in thickness, character, and areal extent, and well yields typically range from 5 to 10 gpm (ODNR 1962). Alluvial deposits in the major

stream valleys may also serve as a local source of groundwater. These deposits consist principally of clay, silt, fine sand, and some gravel and generally yield adequate amounts of water for domestic supplies.

Relief Well Description

31. Figure 6 is a cross section of the valley of McGuire Creek showing the relative depths of the 12 relief wells. Table 1 (US Army Corps of Engineers 1976) lists elevations and lengths of various components of each relief well. Based on the information provided in Table 1, the depths of the relief wells, as measured from the floor of the well housings, range from 19.39 ft for relief well W-12 to 69.88 ft for relief well W-7.

32. The twelve relief wells at Leesville Dam are similar in design and construction. The upper 8 to 10 ft of each well consist of solid, fiberglass casing with an inner diameter of 10 in. (Figure 3). Below this length, the fiberglass casing is perforated. The perforated casing serves as the well "screen" and extends to the bottom of the well. The approximate length of the intake for each relief well is given in Table 1. The only exception to the standard design is relief well W-3, where a 10-ft, solid length of casing was installed through an apparent alluvial clay deposit between elevations 895 and 905 ft above mean sea level (see Figure 6 and boring log for relief well W-3 in Appendix B).

33. The written design specifications for the relief wells state that the perforations in the fiberglass pipe are machine-cut slots with a width of one-sixteenth inch and a length of approximately 1-3/4 in. The slots provide for a minimum total open area of 42 sq. in. per linear foot of the 10-in.-diam pipe. This minimum open area represents approximately 11 percent of the total surface area of the pipe. The slots are distributed in a uniform pattern around the periphery of the pipe, and the openings are oriented with the length of the slot normal to the axis of the pipe.

34. The 10-in. fiberglass casing and screen are centered in a 24-in. -diam borehole that is "filter packed" from the bottom of the well to an approximate elevation of 920 ft above mean sea level. The filter pack around the intake of each well is approximately 7 in. thick. The written design specifications for the relief wells specify that the filter pack material is a noncarbonaceous stone with less than 3 percent by weight of soft, friable,

thin, or elongated particles. Gradation of the material is as follows:

US Standard Sieve Opening	Percent by Weight Passing
No. 4	95-100
No. 8	70-90
No. 16	30-70
No. 30	15-50
No. 50	5-15
No. 100	0-5

Encrustant and Bacterial Sampling

35. The laboratory analysis of the samples of reddish-brown, mucilaginous deposits collected from the surface of the relief well casings on July 31, 1986, confirmed the presence of filamentous iron-precipitating bacteria. With the exception of relief well W-1, the sampled deposits from every well contained significant amounts of iron-encrusted bacterial sheaths. Photomicrographs of these bacterial sheaths were taken and used to tentatively classify this filamentous form of iron bacteria as *Leptothrix* (Photo 18).

36. Table 2 lists the findings from the in-well collectors that were placed in relief wells throughout the 19-day period from July 31, 1986, to August 19, 1986. The in-well collectors confirmed that 10 out of the 12 relief wells had iron bacteria occurring, at depth, in the well. These iron bacteria were tentatively classified as species of the genera Leptothrix-Sphaerotilus. Growth on the plexiglass slides was generally moderate to heavy. Where iron bacteria were present in a well, they typically occurred at all depths along the intake.

Groundwater Quality Sampling

37. Table 3 contains the results of groundwater quality samples collected from the 12 relief wells. Samples were collected and analyzed for temperature, pH, oxidation-reduction potential, and dissolved oxygen on July 31, 1986, and August 19, 1986. Samples also were collected on July 31, 1986, for COD and ferrous iron and taken to the contract laboratory for analysis. Values listed in Table 3 for these chemical parameters indicate that the

quality of the groundwater varied from slightly acidic to slightly alkaline and that the water was typically low in dissolved oxygen with a correspondingly low oxidation-reduction potential. In relief well W-1, however, where the dissolved oxygen concentration was higher, the water had a higher oxidation-reduction potential. The reported values for COD indicated appreciable organic matter in the groundwater, with the exception of samples collected from relief wells W-1, -3, and -10. Significant amounts of iron were found in all relief wells except wells W-1, -4, and -5. In general, the values for the water-quality parameters fell within the general ranges acknowledged as suitable for the occurrence and growth of various iron-precipitating bacteria in groundwater (Hackett and Lehr 1985).

PART V: TREATMENT SELECTION

Recommended Program

38. Based on the characterization of the site and the initial biological and chemical sampling results, a three-step chemical treatment program for the relief wells at Leesville Dam was recommended to personnel at the ORH. The recommended three-step treatment program for each well involved the sequential use of the following chemicals:
(a) a long-linear phosphate, (b) hydroxyacetic acid, and (c) sodium hypochlorite.

39. Long-linear phosphates were recommended for the first step of the treatment program for two reasons: (a) phosphates are sequestering agents that are capable of forming soluble complexes with iron, thereby preventing dissolved iron in groundwater from precipitating out of solution when using strong oxidants, like chlorine, during latter steps in the treatment program; and (b) phosphates have detergent capabilities that disperse the mucilaginous deposits resulting from the growth of iron bacteria, thereby enhancing the subsequent use of a disinfectant to kill the living bacterial cells within these deposits. The second step of the recommended chemical treatment program included the use of hydroxyacetic acid for three reasons: (a) hydroxyacetic acid is an organic acid that acts as a systemic biocide against some iron bacteria; (b) hydroxyacetic acid has a moderate capability to chemically dissolve encrusting iron surrounding the bacterial sheaths and living bacterial cells; and (c) hydroxyacetic acid is a chelating agent that can form soluble complexes with iron and maintain the iron in solution. The third and final step of the recommended chemical treatment involved the use of sodium hypochlorite because chlorine is an effective disinfectant against the diverse group of bacteria, collectively known as iron-precipitating bacteria.

Selected Program

40. After reviewing the recommended chemicals for use in the treatment program, the Huntington, West Virginia District Office authorized a two-step chemical treatment program using long-linear phosphates and sodium hypochlorite. Acids were not used because of a concern by personnel in the

district office that the acid might affect the structural integrity of the fiberglass casing.

41. Details of the actual chemical procedures used to clean and rehabilitate each relief well at Leesville Dam included two steps:

Step 1

42. A commercially available long-linear phosphate solution, known as Aqua-Mag™, was obtained in 55-gal drums (Photo 19). A small electrical, metering pump was used to measure and dispense a predetermined volume of the phosphate solution into an empty 55-gal drum (Photos 20, 21, and 22). The predetermined volume of phosphate solution was equivalent to 3 percent of the well volume. The well volume was calculated as the volume inside the casing and intake plus the volume in the filter pack (using a porosity value of 40 percent), multiplied by an empirical factor of 1.5. The premeasured volume of phosphate solution was then pumped from the 55-gal drum, through a flexible 1-1/2-in.-diam hose, into the relief well (Photo 23). The discharge end of the flexible hose was initially positioned at the bottom of the well screen and was slowly raised to the top of the well screen as the phosphate solution was pumped into the well. Immediately after adding the long-linear phosphates to the well, the phosphates were surged in the well using a mechanical surge block (Photos 24 and 25). Surging started at the top of the well intake and continued downward to the bottom of the intake, at a rate of 15 ft/hr. The length of the stroke of the surge block was approximately 36 in., and the measured rate of fall of the surge block was about 3 ft/sec. The phosphates were surged in the well for a period of 2 to 4 hr. (Note: An initial attempt was made to surge the wells by hand using a cathead as shown in Photo 26. This technique was found to be inadequate for sustaining the required surging action over the prescribed period of 2 to 4 hr. A mechanically powered drill rig was subsequently used to surge the relief wells throughout the chemical treatment program). As surging progressed, each well was periodically bailed to remove accumulated sediment in the well (Photo 27).

43. After the phosphates were surged in the well, a premeasured volume of commercial grade sodium hypochlorite, containing 12 percent available chlorine, was added to the well (Photo 28). The amount of sodium hypochlorite added to the well was equivalent to a 50-mg/l concentration, by weight, of chlorine. This chlorine solution was added to suppress any immediate growth of iron bacteria that may have been stimulated by the addition of the

phosphates to the well. The chlorine solution was surged in the well for 2 hr using the same surging technique as previously described for the phosphates. After surging the chlorine solution, the chemicals were left in the well overnight. The following morning, the well was surged for 30 min, and the chemicals were then pumped from the well.

Step 2

44. Immediately after pumping the well and removing the chemicals from Step 1, a second 3 percent concentration, by volume, of phosphate solution was pumped into the well. The phosphate solution was surged in the well for 2 to 4 hr using the same surging techniques as previously described in Step 1.

45. After the phosphates were surged in the well, a premeasured volume of sodium hypochlorite was added to the well to obtain a 1,000-mg/l concentration, by weight, of chlorine in the well. The chlorine was surged in the well for 4 hr using the same surging technique as previously described in Step 1, and the chemicals were left in the well overnight. Throughout the night the chlorine residual was periodically checked using a Hach Model CN-DT chlorine test kit with a digital titrator. Additional sodium hypochlorite was added to the well, when necessary, to maintain a 1,000-mg/l concentration of total chlorine in the well. The following morning the well was surged for 30 min, and the chemicals were then pumped from the well.

PART VI: POST-PUMPING TEST AND SAMPLING RESULTS

Pumping Test Results

46. Drawdown curves from the pumping tests performed on each relief well, before and after treatment, are included in Appendix A. These curves were provided by the contract engineering firm that conducted the pumping tests. The wells were pumped at three pumping rates, with the exception of relief wells W-1, -2, -3, and -12. Pumping tests run on relief wells W-1, -2, -3, and -12 were limited to one pumping rate because of the high amount of drawdown in the well relative to the depth of the well. The proportionately higher drawdown, at low pumping rates, in these four relief wells may be attributed to the proximate location of these wells to the hydrogeologic boundaries in the McGuire Creek valley and to the installation of these wells in the less permeable alluvial deposits near the valley walls.

47. As the riser pipe extensions were added prior to the pumping tests, the specific capacities were properly calculated on the basis of an initial static head and thus were not affected by flow from adjacent wells. Specific capacities of an artesian well adjacent to an infinite line source are given by the expression:

$$\frac{Q_w}{DD} = 2\pi kD \qquad (1)$$

where

Q_w = discharge from a single well

DD = well drawdown

k = coefficient of permeability of pervious substratum

D = thickness of pervious substratum

In the case of Leesville Dam, it is also necessary to include the assumption of an infinite line sink as the static heads at the well line are substantially less than pool elevations. The specific capacity of an artesian well adjacent to an infinite line source with a parallel downstream line sink is given by the expression:

$$\frac{Q_w}{DD} = \frac{2\pi kD}{ln\left[\frac{2(S + x_3)^2 \left(1 - \cos \frac{2\pi s}{s + x_3}\right)}{\pi^2 r_w^2}\right]^{1/2}} \qquad (2)$$

where

S = distance from effective seepage entry to the well

x_3 = distance from landside toe of levee to effective seepage exit

In both cases it is apparent that the specific capacity, neglecting well losses, is a constant, independent of the head at the source, depending only on the aquifer characteristics and boundary conditions. Thus, the effects of different reservoir pools during the pumping period can be ignored.

48. The specific capacities shown in Appendix A were based on the final pumping rates and drawdown for each well. In some cases the final drawdowns were well below the top of the screen and represent gravity flow conditions instead of smaller drawdowns representative of artesian flow. It appears more reasonable for comparative purposes to calculate the specific capacities from plots of drawdown versus pumping rate using a common drawdown representing artesian flow. Plots of drawdown versus pumping rate are shown in Figures 7-17. A drawdown of 5 ft was selected for a common drawdown as it reflects similar flow conditions for all wells and is a reasonable value for the maximum drawdown for the condition of well flow at maximum pool. Specific capacities for each well before and after cleaning based on a drawdown of 5 ft are shown on Table 4.

49. It may be noted in Table 4 that wells W-1, -2, -3, and -12 have specific capacities generally less than 10 gpm/ft. As stated earlier, these wells are at the ends of the well system, have less screen length, and appear to be founded in somewhat finer sediments; consequently, they are not representative of the well system as a whole. The percentage increase in specific capacity for the eight central wells (W-4 through W-11) with specific capacities greater than 10 gpm/ft ranges from 35 to 714 percent with an average value of 236 percent. As stated earlier, the absence of pumping test data at the time of installation prevents a determination of the increase in specific capacity with respect to the wells as installed. Nevertheless, it can be concluded that the surging and chemical treatment resulted in substantial improvement.

Sanding of Wells

50. The surging which accompanied the well cleaning operations produced relatively large amounts of sand in the wells. The average rate of sand produced, as indicated by soundings in the wells, varied from 0.02 ft/hr at well W-1 to 0.74 ft/hr at well W-8. Except for well W-1, all wells produced sand at or in excess of 0.25 ft/hr. A rate of 0.25 ft/hr in a 10-in.-diam well translates into approximately 8 pt/hr. The period of surging varied from 4 to 10 hr with no indications of reduced sand production with time. A well that continues to produce sand in excess of 2 pt/hr is generally considered unacceptable. Consequently, it appears that the wells may not have been effectively developed at the time of installation. This fact is born out by the large rocks measuring 2-1/2 to 3-1/2 in. that were found in well W-2 during the surging and chemical treatment. Furthermore, the size of the screen slots, one-sixteenth inch or 1.58 mm, appears to be overly large with respect to the specified filter gradation. Thus, it is possible that the mechanical surging in itself may have produced significant increases in specific capacity. If true, these increases would account for lack of correlation between improvements in specific capacity and the presence or lack of filamentous iron bacteria in the well before testing.

In-Well Bacterial Sampling Results

51. Table 5 presents the results from the in-well collectors that were reset in the relief wells approximately 4 months after the chemical treatment program was completed. The in-well collectors were placed in the wells throughout the 19-day period from April 16, 1987, to May 5, 1987. Results from the in-well collectors showed that 7 of the 12 relief wells had growth of iron bacteria reoccurring, at depth, in the well. These iron bacteria were tentatively classified as species of the genera Gallionella and Leptothrix-Sphaerotilus, and growth on the plexiglass slides was generally reported as "few." Where iron bacteria were present in a well, they were present at all depths along the screen, except for relief wells W-3, -5, -8, and -10. In these four wells, the results from the in-well collectors indicate that the iron bacteria had a general tendency to occur only at shallower depths along the well screen.

Groundwater Quality Results

52. The results from the groundwater samples collected from the 12 relief wells after chemical treatment are listed in Table 6. Samples were collected on April 16, 1987, and analyzed for COD and ferrous iron. In addition, samples for temperature, pH, oxidation-reduction potential, and dissolved oxygen were collected and analyzed on May 5, 1987. No determination of dissolved oxygen in the groundwater sample from relief well W-2 was made because the dissolved oxygen probe could not provide a stable reading.

53. Values for the groundwater quality parameters listed in Table 6 indicate that the quality of the groundwater continued to be slightly acidic to slightly basic. The groundwater contained low levels of dissolved oxygen, with the exception of samples from relief wells W-1 and -11, and was generally characterized by lower oxidation-reduction potentials. Reported values, however, for COD and dissolved iron concentrations indicate substantive change from the previous samples collected before the chemical treatment program. Iron mineralization in the groundwater had increased significantly. However, the dissolved iron concentrations in relief wells W-1, -2, -4, and -5 remained relatively lower than values from the other wells. A noticeable drop had also occurred in the organic matter content in the groundwater, as measured by the COD values, with the exception of samples collected from relief wells W-9 and -12.

PART VII: DISCUSSION

Treatment Performance

54. Based on the median value for the percent increase in specific capacity for the wells at Leesville Dam with greater than 10 gpm/ft of drawdown (i.e. 236 percent for wells W-4 through W-11), the chemical treatment program appeared to have an immediate beneficial effect on the hydraulic performance of the wells. The degree of benefit is difficult to interpret because there are no historic pumping test data for the wells. Without historic pumping test data, the specific capacity for each relief well after chemical treatment cannot be compared to the specific capacity of the well at the time of the initial installation of the well. Nevertheless, the specific capacity values, before and after chemical treatment, for 6 of the 12 relief wells increased by at least 166 percent (Table 4).

55. With regard to relief well W-12, a comparison between Table 2 and Table 5 shows that the chemical treatment program was successful in removing the iron bacteria, at depth, in the well. However, the increase in the specific capacity of relief well W-12 after chemical treatment was negligible (Table 4). In this instance, it can be hypothesized that the hydraulic performance of relief well W-12 is limited to a greater extent by the proximate location of the well to the hydrogeologic boundary of the valley (Figure 6), rather than by clogging with iron bacteria. The results from relief well W-12 provide a good illustration that the comparison of specific capacity alone, calculated before and after treatment, is a cursory indication of the effectiveness of the chemical treatment program. Factors such as the well depth and construction, hydrogeologic boundary conditions, and the varying characteristics of the alluvial valley-fill deposits may have an overriding influence on the hydraulic performance of the well.

56. The information in Table 5 indicates the chemical treatment program was not successful in preventing the reoccurrence of iron bacteria in the relief wells. Within 4 months after the completion of the treatment program, iron bacteria were confirmed growing, at depth, in 7 of the 12 relief wells. A comparison between Table 2 and Table 5 shows, however, that the predominant types of iron bacteria identified in the relief wells, before and after the chemical treatment program, were different. Before the chemical treatment

program, the species of iron bacteria identified most often on the in-well collectors belonged to the genus Leptothrix. After the treatment program, the species of iron bacteria identified most often on the in-well collectors belonged to the genus Gallionella. This finding suggests that the chemical treatment program was generally capable of removing the iron bacteria that were in the relief wells at the time of cleaning, but that the wells may have been recolonized by different organisms after the chemical treatment program. If this assumption is correct, then the possibility must be considered of a continuing source of iron bacteria within the alluvial deposits, as well as a pathway through which these organisms gain access to the wells.

57. The more abundant growth of Gallionella, versus Leptothrix, in the relief wells after the chemical treatment program may also be a result of changes in the quality of the groundwater. Gallionella reportedly occur most often in nonorganic, iron-bearing waters characterized by a low oxidation-reduction potential (Hackett and Lehr 1985). Conversely, Leptothrix exhibit more abundant growth in groundwater containing higher concentrations of organic material. A comparison of values for COD and ferrous iron listed in Tables 3 and 6 indicate that the organic content in the groundwater was appreciably lower and that iron mineralization of the groundwater was significantly higher after the chemical treatment program. Both of these changes in groundwater quality appear to favor the growth of Gallionella, as opposed to Leptothrix. As a result, the presence of Gallionella in the relief wells after the chemical treatment program may not necessarily indicate that these organisms are from a continuing source of iron bacteria. Gallionella may have been present in the relief wells prior to the treatment program. However, their growth may have been suppressed, at that time, by the quality of the groundwater.

58. A final significant finding of this study is that relief wells W-4 and -6 did not contain iron bacteria growing, at depth, in the well either before or after the treatment program. A review of the hydrogeologic information and groundwater quality data obtained during this study does not provide a reasonable explanation of why these two relief wells remained free of iron bacteria, despite the fact that adjacent relief wells contained significant growth of these organisms. Further study and comparison of relief wells W-4 and -6 to the other 10 relief wells at Leesville Dam may provide important insights into the environmental conditions and processes which promote the

colonization of wells with iron bacteria.

Economics

59. The selection of a rehabilitation procedure is often based primarily on the economics that exist at the time a decision must be made. Any number of chemicals or mechanical procedures (air-lifting, surge block, or jetting) could be used in combinations that would exhaust any budget. The Leesville Dam rehabilitation plan was based on a combination of economics which included extra tests to verify the results and well screen material interaction with the treatment chemicals. For Leesville, the CE wanted a record of performance for future reference, so extra pump tests and bacterial determinations were added and thus conservatively increased the total costs 15 percent. If acid treatment had been used, another 30 percent would have been added to the cost. The acid was not chosen because a literature and industry search did not identify any data that would verify use of acid in any dilution on fiberglass screens. The final cost, which includes strict adherence to the adopted procedure and was considered state of the art for the procedure chosen, was between $7K and $8K per well.

PART VIII: SUMMARY AND RECOMMENDATIONS

Summary

60. Based on the findings of this study and the well rehabilitation project, the following summary can be made regarding the chemical treatment program used to evaluate the control of iron bacteria in relief wells at Leesville Dam, Ohio:

a. The chemical treatment program had an immediate beneficial effect on the hydraulic performance of the relief wells. Based on pumping tests performed on each well before and after the chemical treatment program, the median value for the percent increase in the specific capacity for the eight relief wells with specific capacities greater than 10 gpm/ft was 236 percent.

b. The amount of sand produced by the wells may indicate that the wells were not effectively developed initially, and this fact in turn could be part of the increase in specific capacities.

c. The chemical treatment program was not successful in preventing regrowth of iron bacteria in the relief wells. The source of the iron bacteria recolonizing the wells is unknown.

d Long-term control of the iron bacteria in the relief wells at Leesville Dam, by the chemical treatment method used in this study, will require repeated chemical treatments at regular intervals.

Recommendations

61. An effective treatment strategy for the control of iron bacteria in the relief wells at Leesville Dam, Ohio, should include the following:

a. Perform supplemental pumping tests on the relief wells to measure the hydraulic performance of the wells. Results from the pumping tests should be kept on file and used to identify the decline of individual well efficiencies.

b. Establish a critical percent reduction in relief well efficiency that will serve as an administrative "action level." The action level will define the need for implementing a well rehabilitation program.

c. Continue to study the iron bacteria populations in the 12 relief wells, as well as the groundwater quality in the alluvial deposits, to define those factors unique to relief wells W-4 and W-6 which limit the growth of iron bacteria in these wells. The additional study should include:

(1) Quanitifying the growth on in-well collectors.

(2) Downhole measuring of groundwater temperature, pH, dissolved oxygen, and oxidation-reduction potential (Eh).

(3) Developing Eh/pH diagrams for iron, and correlating the presence of iron bacteria with the stability of ionic species of iron.

(4) Culturing groundwater samples from specific well depths to determine "total plate counts" and to identify the presence of other organisms which may contribute to encrusting problems.

d. Review of the effects, if any, of hydroxyacetic acid on the structural integrity of the fiberglass well casing and screen.

e. Reevaluate a chemical treatment program, based on the information collected in items c and d, to determine if a more effective chemical treatment program can be developed.

f. Review the use of steam cleaning in conjunction with the use of chemicals to determine if this method would be a more effective long-term rehabilitation technique.

g. Implement a well rehabilitation procedure, based on information collected in items c through f, when the action level, described in item b, is reached.

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Table 1

Elevations and Lengths of Components of Relief Wells

(US Army Corps of Engineers 1976)

No.	Station	Approximate Elevation Top of Blanket	Approximate Elevation Bottom of Well Screen	Approximate Length of Well Screen	No. of Well Screen Joints	Minimum Length of Fiberglass Riser	Elevation Top of Riser	Maximum Elevation Top of Gravel Pack	Elevation Top of Sand Pack	Elevation Top of Impervious Material	Elevation Top of Concrete	Approximate Length of Housing Pipe (Ft.)	Invert Elevation Collector Pipe (BCCMP)
W-1	23+85	903.8	906	14.0	1	8.0	928.34	921.0	-	-	927.34	5.0±	926.50
W-2	23+25	931.2	902	17.7	1	8.0	928.02	920.7	-	-	927.02	5.5±	926.21
W-3*	22+50	930.7	890	27.4	2	10.0	927.71	920.4	-	-	926.71	5.5±	925.83
W-4	21+75	930.8	878	39.0	2	10.0	927.37	920.0	-	-	926.37	6.0±	925.48
W-5	21+00	931.3	86*	52.6	3	10.0	926.51	919.6	-	-	925.51	7.0±	925.11
W-6	20+25	931.2	858	58.2	3	10.0	926.24	919.2	-	-	925.24	7.0±	924.75
W-7	19+50	931.2	856	60.0	3	10.0	926.88	919.1	-	-	925.88	7.0±	924.62
W-8	18+75	931.*	856	60.0	3	10.0	927.08	919.5	-	-	926.08	7.0±	925.00
W-9	18+00	931.1	856	59.9	3	10.0	927.48	919.9	-	-	926.48	6.5±	925.38
W-10	17+25	931.7	856	60.0	3	10.0	927.43	920.2	-	-	926.43	6.5±	925.75
W-11	16+50	931.8	856	60.0	3	10.0	928.13	920.6	-	-	927.13	6.5±	926.12
W-12	15+75	931.7	908	12.0	1	8.0	928.39	921.0	-	-	927.39	6.0±	926.50

* Solid Casing as noted on section A-A is included as "well screen" approximately between elevations 895 to 905.

Table 2
Presence of Filamentous Iron Bacteria on In-Well Collectors Placed in Relief Wells at Leesville, Dam, from 7-31-86 to 8-19-86 Before Chemical Treatment Program*

	Relief Well No.											
Depth Range in Feet **	1	2	3	4	5	6	7	8	9	10	11	12
5-15 + +	(L) +	-(L)	(L)	-	+	+	(L) +	(L) +	(L,S) +	(L)	(L)	(L) +
16-25 + +	(L) +	(L)	(L)									(L) +
26-35		-										
36-45	+		(L)	-	+	+	(L) +	(L) +	(L,S) +	(L)	(L)	
46-55		-										
56-65			+ (few)		(L)							
66-75				-	+	+ (few)	(L)	(L)	(L,S) + +	(L,S) +		

* "+" Indicates filamentous iron bacteria present on slide (tentatively identified as species of the genera: L - Leptothrix; S - Sphaerotilus).

"-" Indicates filamentous iron bacteria not present on slide.

** Depth measured from floor elevation of relief well housing.

Table 3

Results of Groundwater Samples Collected from Relief Wells Prior to Chemical Treatment Program

Well No.	Temperature		pH		Eh (mv)		Dissolved Oxygen (mg/l)		Chemical Oxygen Demand (mg/l)	Dissolved Iron (mg/l)
	7-31-86	8-19-86	7-31-86	8-19-86	7-31-86	8-19-86	7-31-86	8-19-86	7-31-86	7-31-86
1	25.7	24.5	7.49	7.67	+238.0	+151.3	3.16	3.56	26.91	0.03
2	22.2	21.4	7.17	7.22	-58.3	-100.3	0.37	0.47	68.46	1.04
3	20.5	17.8	7.38	7.41	-72.3	-126.5	0.16	0.35	<5.00	0.86
4	19.9	17.0	7.33	7.35	+51.3	+30.0	0.18	0.39	47.69	0.05
5	19.2	17.6	7.03	7.06	+71.7	+42.3	0.15	0.18	47.69	0.05
6	17.7	15.6	6.75	6.77	+55.5	+22.5	0.13	0.12	37.30	0.68
7	17.7	13.6	6.76	6.78	+123.3	+44.5	0.35	0.18	78.85	0.29
8	17.6	13.8	6.80	6.82	-26.7	-52.0	0.30	0.23	58.08	0.84
9	17.3	13.5	6.98	6.93	-46.0	-45.0	0.25	0.17	37.30	0.78
10	18.0	14.9	6.94	6.96	-27.0	+12.7	0.25	0.20	16.53	0.74
11	20.3	15.1	7.13	7.14	-93.0	-93.5	0.23	0.13	99.62	3.22
12	25.1	23.7	6.93	6.96	-123.3	-132.0	0.39	0.23	68.46	3.29

Table 4
Specific Capacity Values Before and After Treatment

Well No.	Screen Length ft	Specific Capacity cpm/ft*		Percent Increase in Specific Capacity After Chemical Treatment**
		Before Treatment	After Treatment	
W-1	14.0	<10	<10	--
W-2	17.7	<10	<10	--
W-3	27.4	<10	<10	--
W-4	39.0	15	45	200
W-5	52.6	75	208	177
W-6	58.2	155	210	35
W-7	60.0	27	220	714
W-8	60.0	120	162	35
W-9	59.9	40	140	250
W-10	60.0	45	120	166
W-11	60.0	15	62	313
W-12	12.0	<10	<10	--
			Mean (8 wells)	236

* Calculated at a drawdown of 5 ft, interpolated from data in Appendix A.

** Percentage is determined as the difference between the specific capacity, before and after treatment, divided by the value for the specific capacity before treatment multiplied by 100.

Table 5

Presence of Filamentous Iron Bacteria on In-Well Collectors Placed in Relief Wells at Leesville Dam from 4-16-87 to 5-5-87 After Chemical Treatment Program*

Depth Range in Feet **	Relief Well No. 1	2	3	4	5	6	7	8	9	10	11	12
5-15	-	(G,L) +	(G,L) + (few)	-	(G) + (few)	-	-	(L) + (few)	(G,L) +	(G) + (few)	(G,L) +	-
16-25	-	(G,L) + (few)	(L) + (few)									-
26-35				-								
36-45			-		-	-	-	-	(G,L) +	-	(G,S) +	
46-55				-								
56-65					-							
66-75						-	-	(G) + (few)	(G) + (few)	-	(G) + (few)	

* "+" Indicates filamentous iron bacteria present on slide (tentatively identified as species of the genera: G-Gallionella; L-Leptothrix; S-Sphaerotilus).

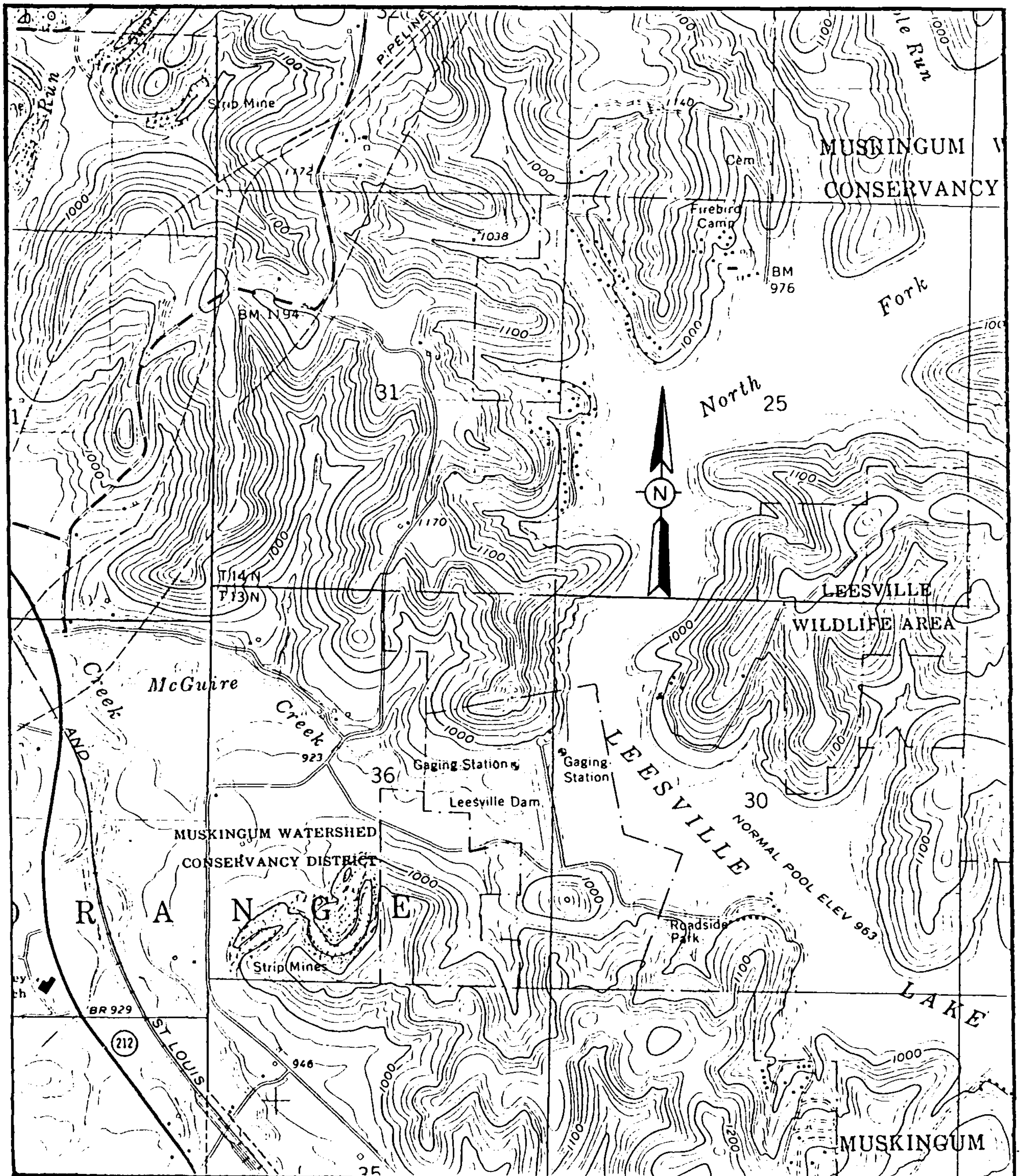
"-" Indicates filamentous iron bacteria not present on slide.

** Depth measured from floor elevation of relief well housing.

Table 6

Results of Groundwater Samples Collected from Relief Wells After Chemical Treatment Program

	Temperature	pH	Eh (mv)	Dissolved Oxygen (mg/l)	Chemical Oxygen Demand (mg/l)	Dissolved Iron (mg/l)
Well No.	5-5-87	5-5-87	5-5-87	5-5-87	4-16-87	4-16-87
1	14.3	7.15	147.5	2.05	<22	0.12
2	12.9	6.92	-36.0	-	<22	0.26
3	12.2	7.05	-60.0	0.20	<22	10.16
4	12.2	7.14	85.5	0.14	31	0.10
5	11.6	6.98	17.5	0.22	<22	0.51
6	11.7	6.67	20.5	0.13	<22	49.56
7	11.5	6.67	7.7	0.14	<22	10.73
8	11.5	6.70	-58.3	0.15	<22	31.29
9	11.3	6.77	-48.5	0.19	48	38.14
10	11.3	6.87	-56.7	0.46	<22	9.60
11	12.9	6.72	-42.7	2.66	<22	35.86
12	12.0	7.37	62.5	0.19	436	32.43



0 2000 4000

scale feet

CONTOUR INTERVAL = 20 FEET

SITE LOCATION MAP

Figure 1. Site location map, Leesville Dam, Carroll Co., Ohio

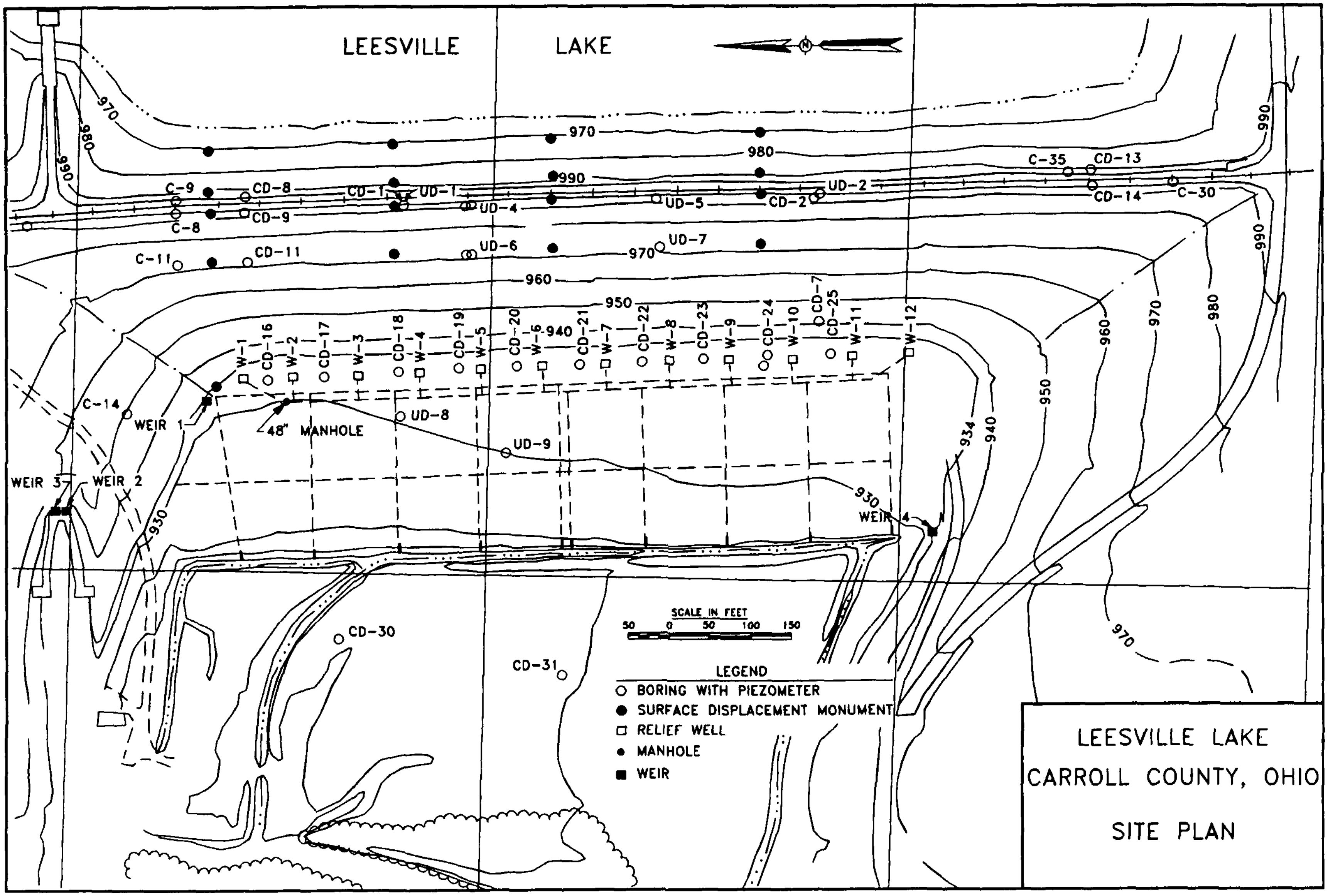
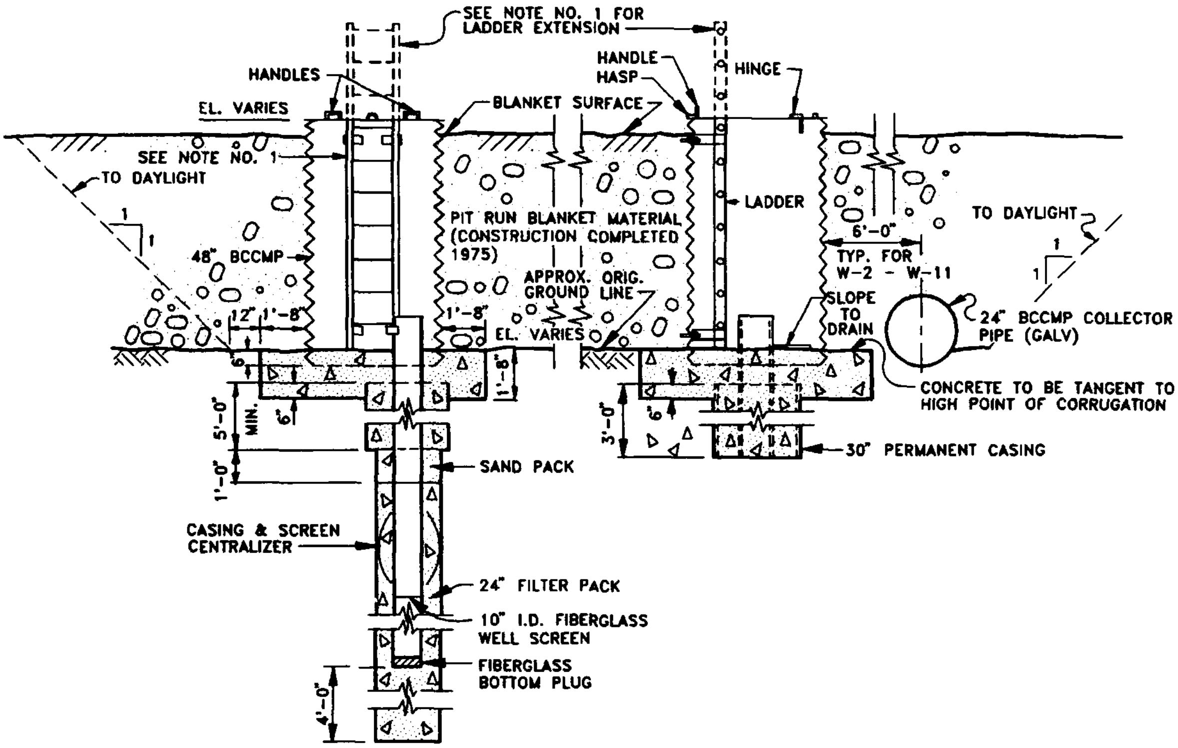


Figure 2. Plan view of damsite showing location of relief wells (US Army Corps of Engineers 1978)



LEGEND

1. SEE APPLICABLE SECTION OF SPECIFICATIONS FOR LADDER AND EXTENSION REQUIREMENTS.
2. SAFETY CHAIN REQUIRED TO PREVENT WIND FROM CLOSING LID WHEN OPEN.
3. COVERS TO BE LOCKED WITH MASTER LOCK NO. 6, A 406, KEYED ALIKE.
4. ELEVATIONS FOR ABOVE COMPONENTS ARE SHOWN IN RELIEF WELL TABLE DRAWING NO. 82/1.
5. FOR MANHOLE DETAIL SEE DRAWING NO. 82/1.
6. FOR 60" DIAMETER MANHOLE USE 1/2" TREAD PLATE.

Figure 3. Cross-sectional view of relief well housing (US Army Corps of Engineers 1976)

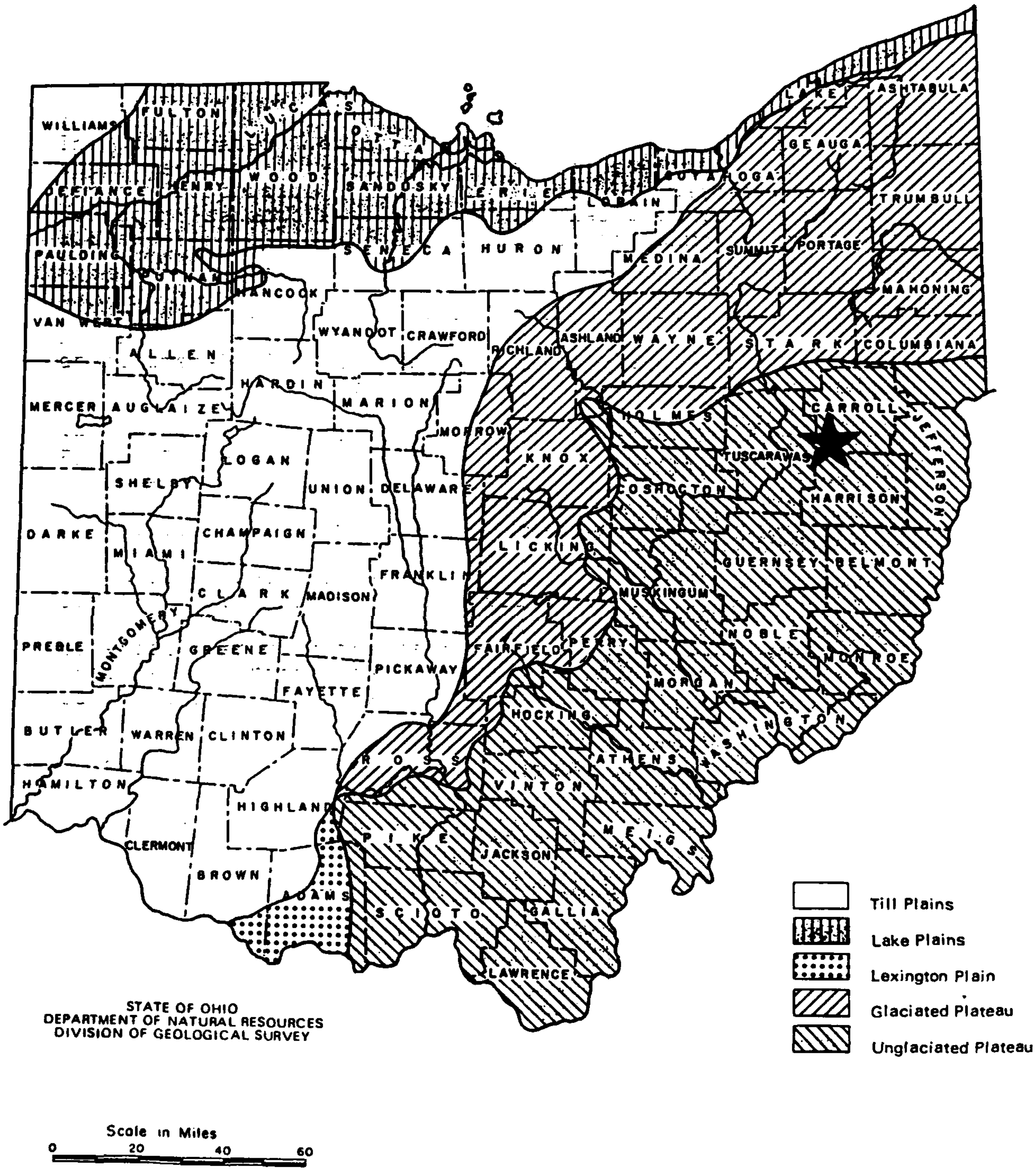


Figure 4. Physiographic sections of Ohio

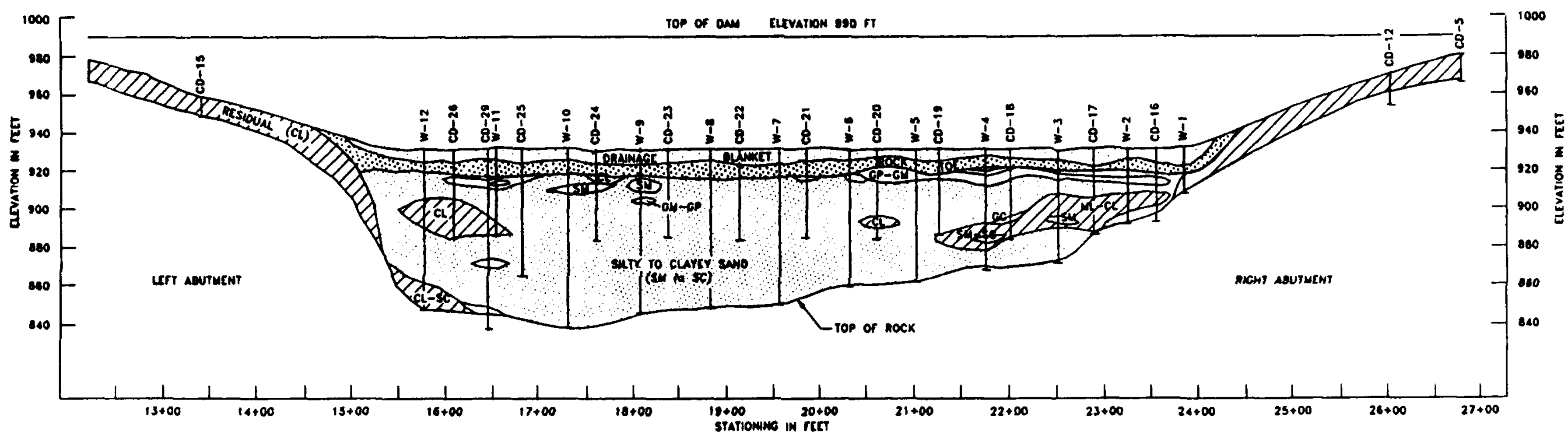


Figure 5. Geologic cross section along toe of Leesville Dam
(US Army Corps of Engineers 1978)

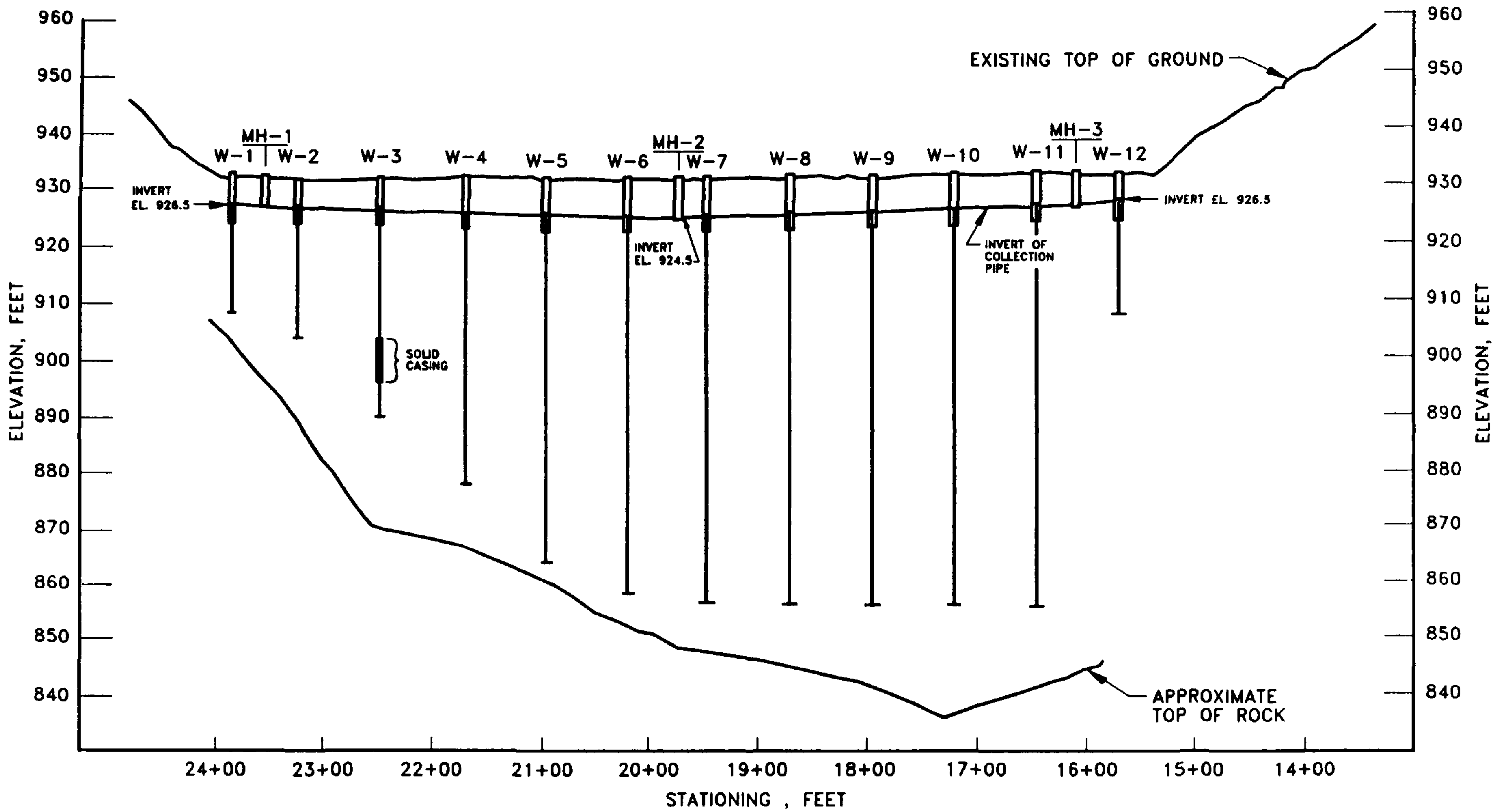


Figure 6. Cross section of McGuire Creek valley showing depths of relief wells (US Army Corps of Engineers 1976)

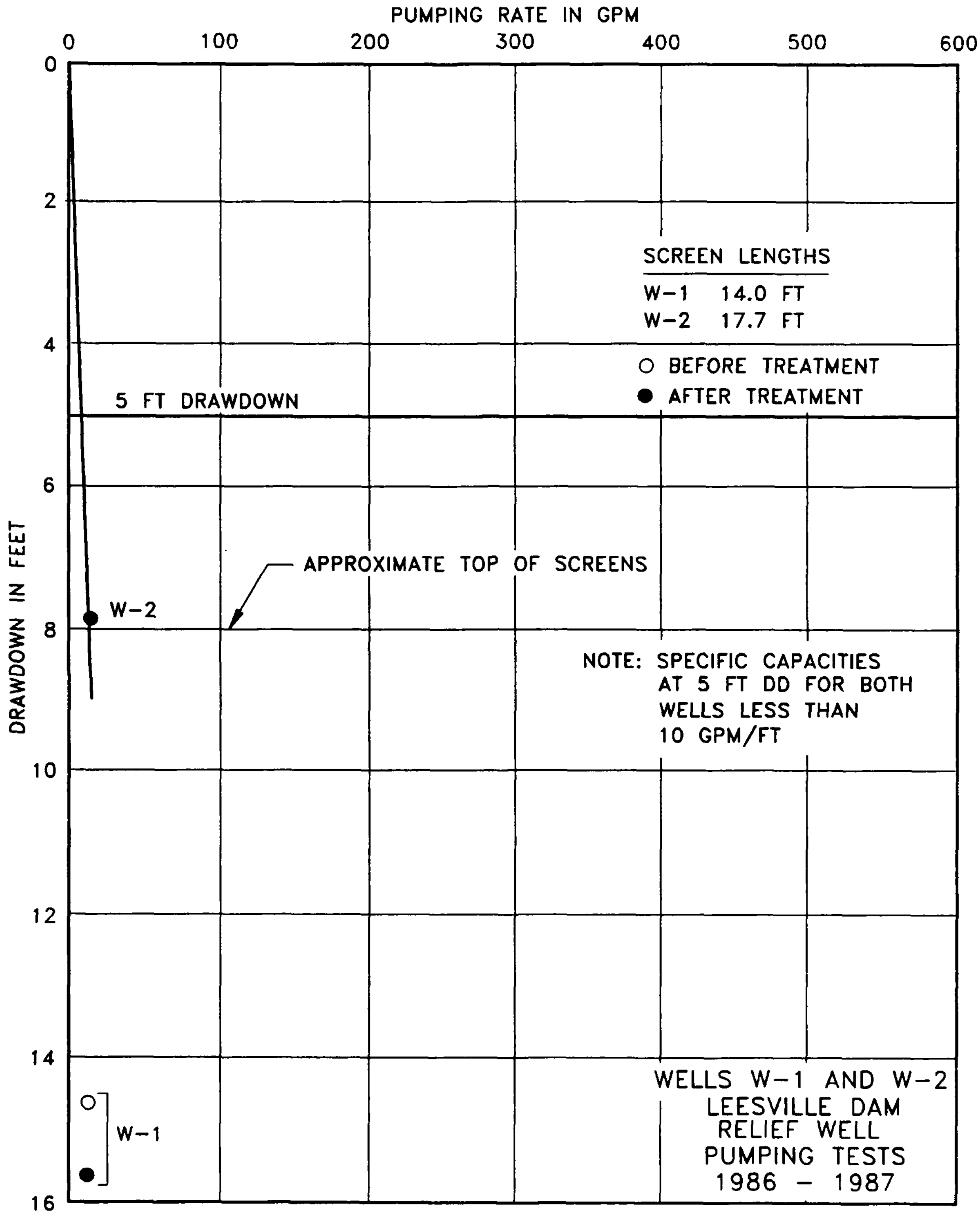


Figure 7. Drawdown versus pumping rate for wells W-1 and W-2

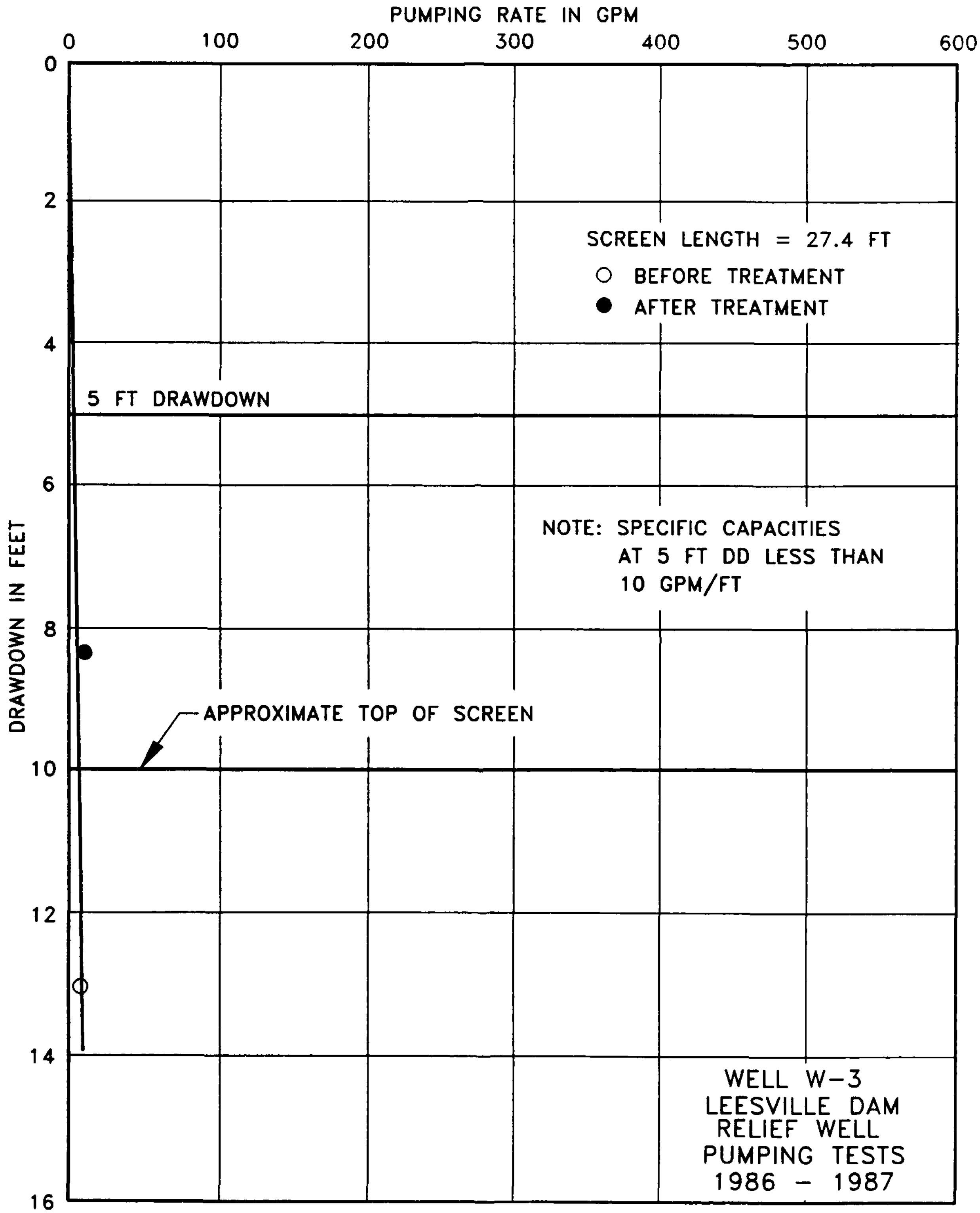


Figure 8. Drawdown versus pumping rate for well W-3

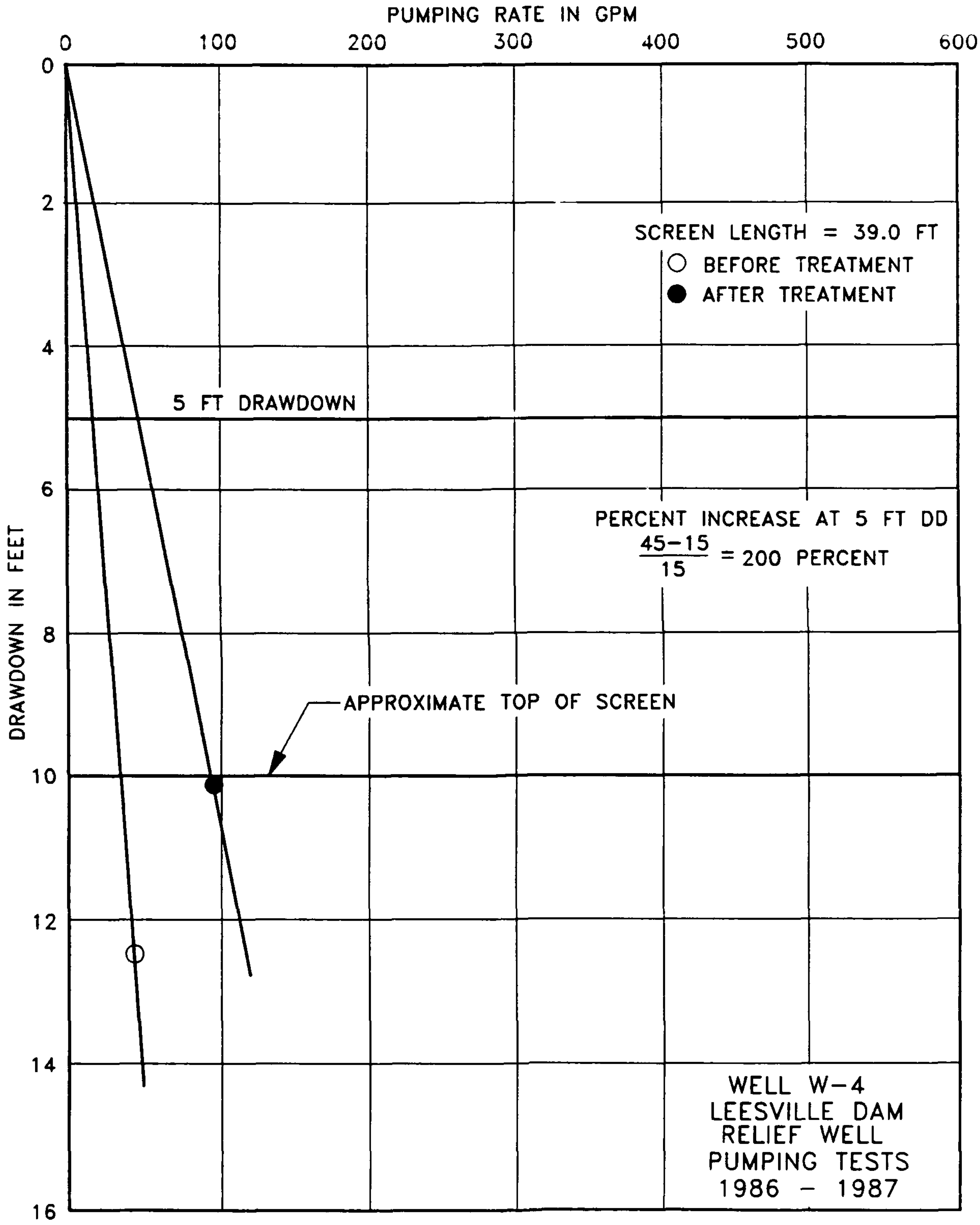


Figure 9. Drawdown versus pumping rate for well W-4

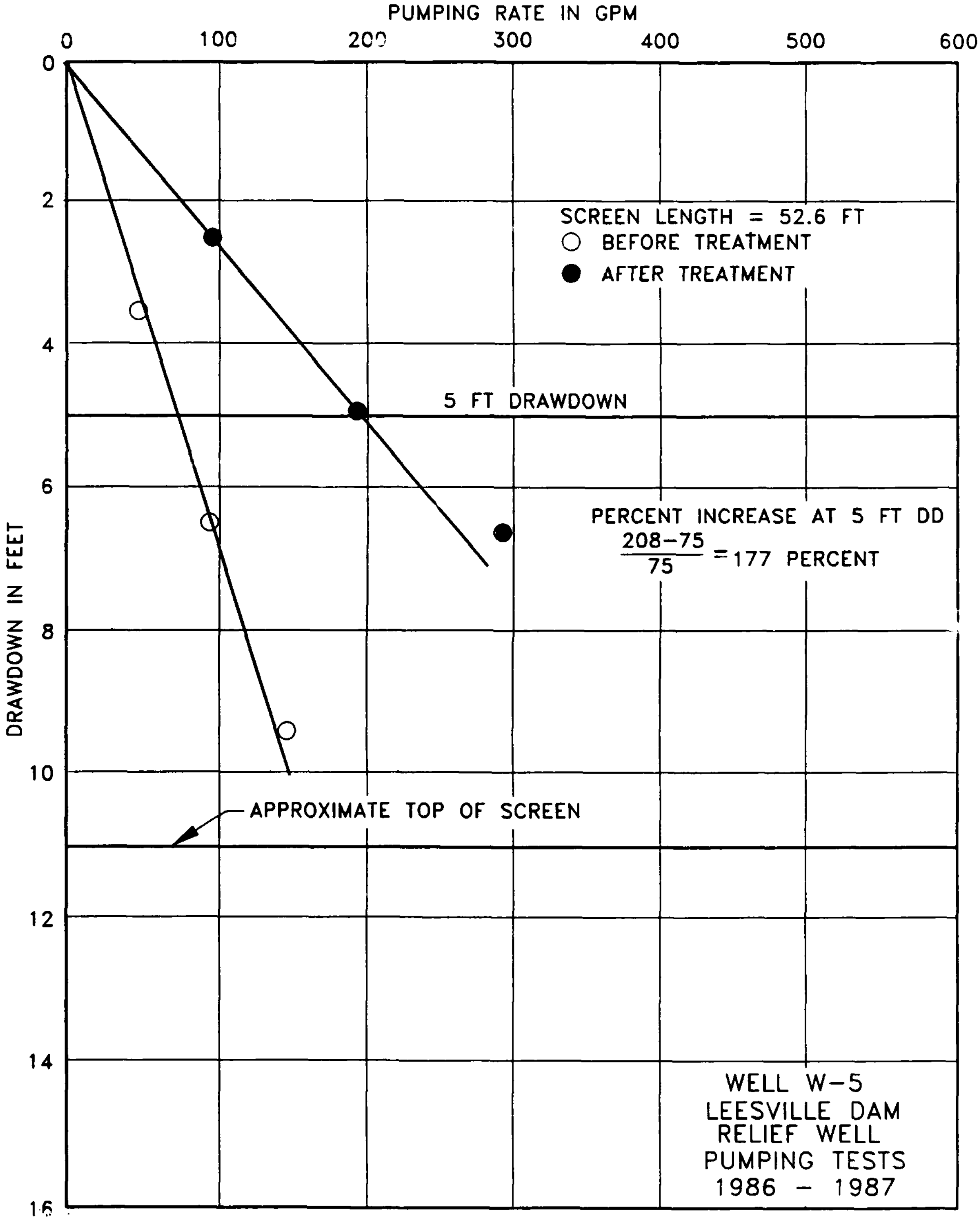


Figure 10. Drawdown versus pumping rate for well W-5

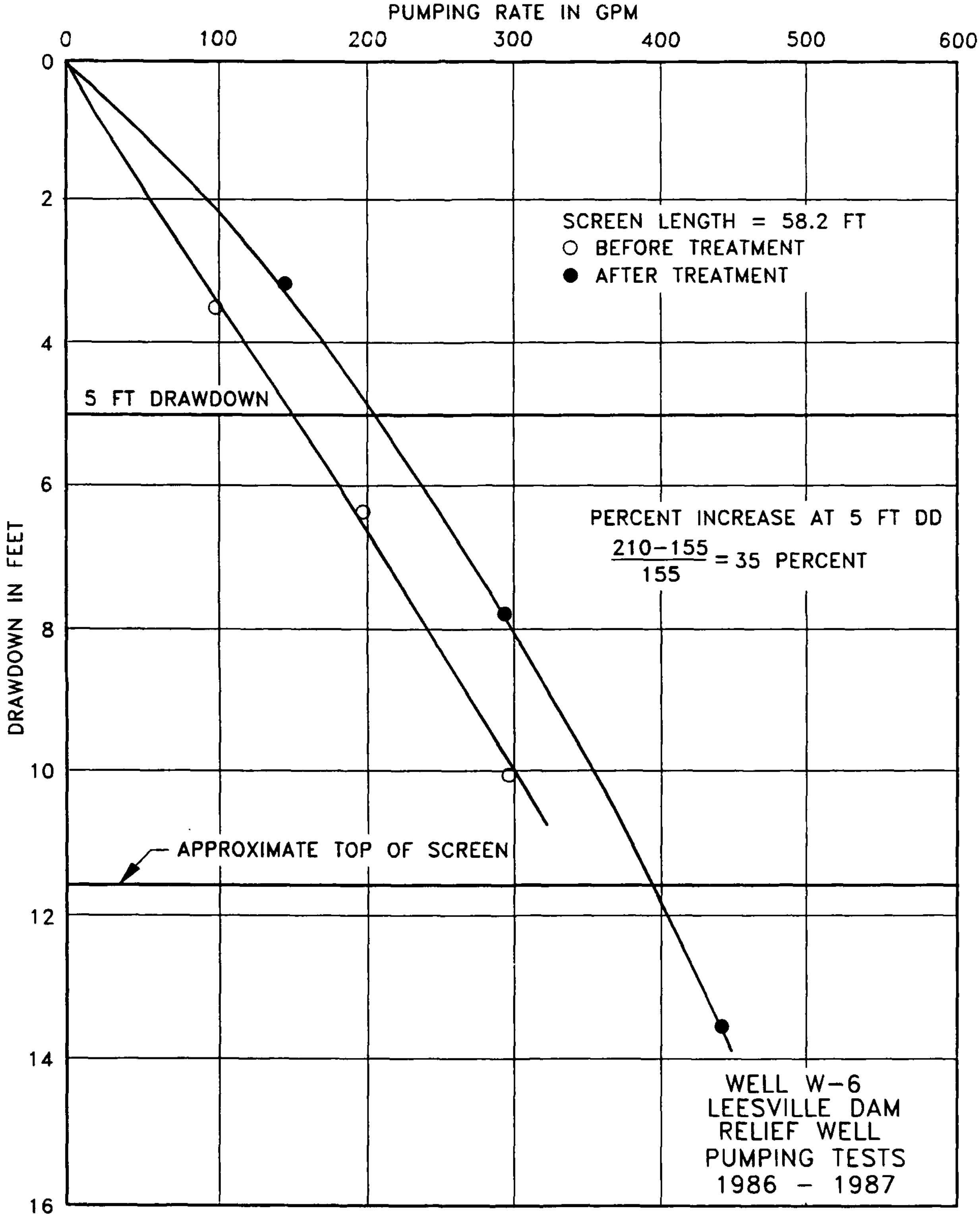


Figure 11. Drawdown versus pumping rate for well W-6

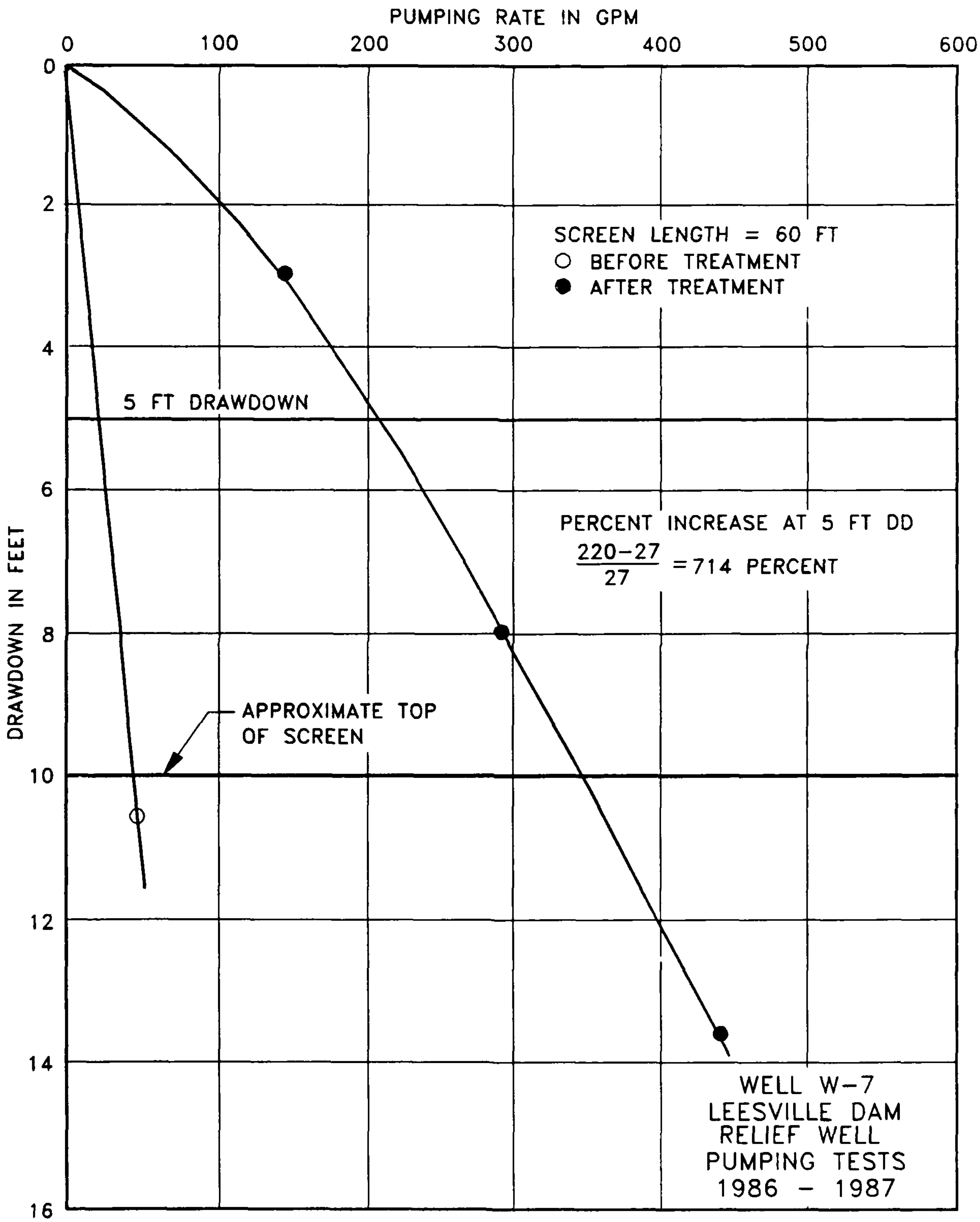


Figure 12. Drawdown versus pumping rate for well W-7

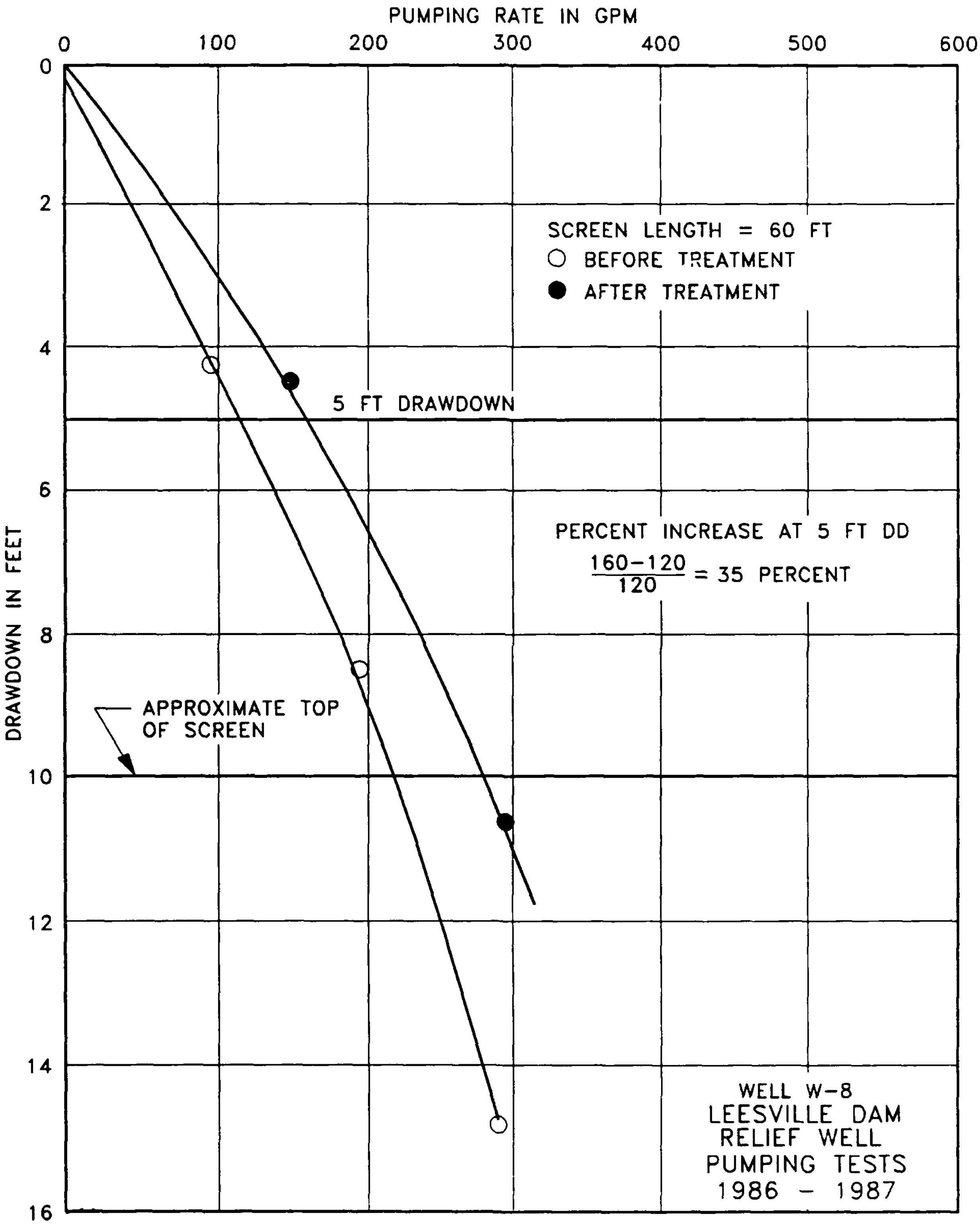


Figure 13. Drawdown versus pumping rate for well W-8

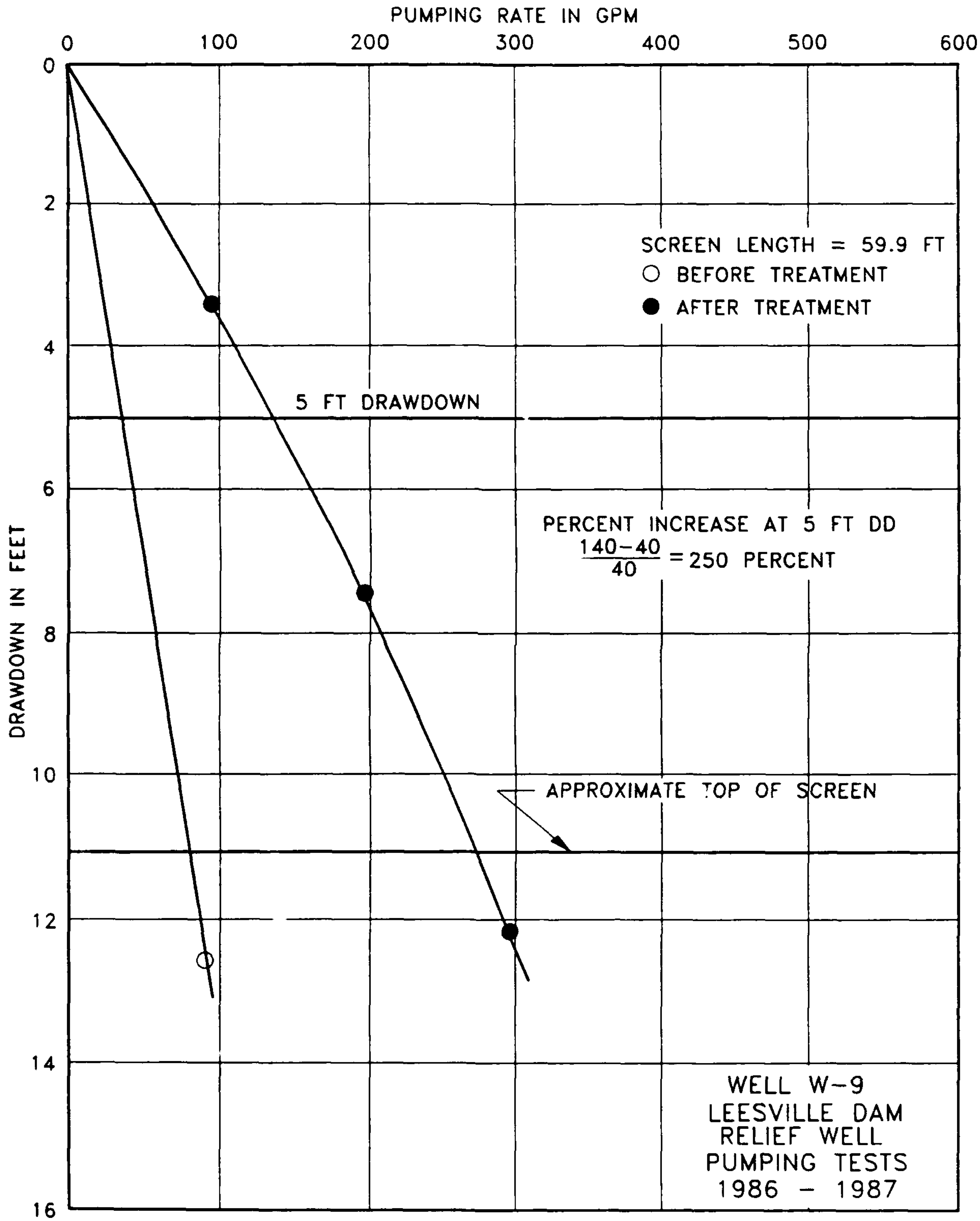


Figure 14. Drawdown versus pumping rate for well W-9

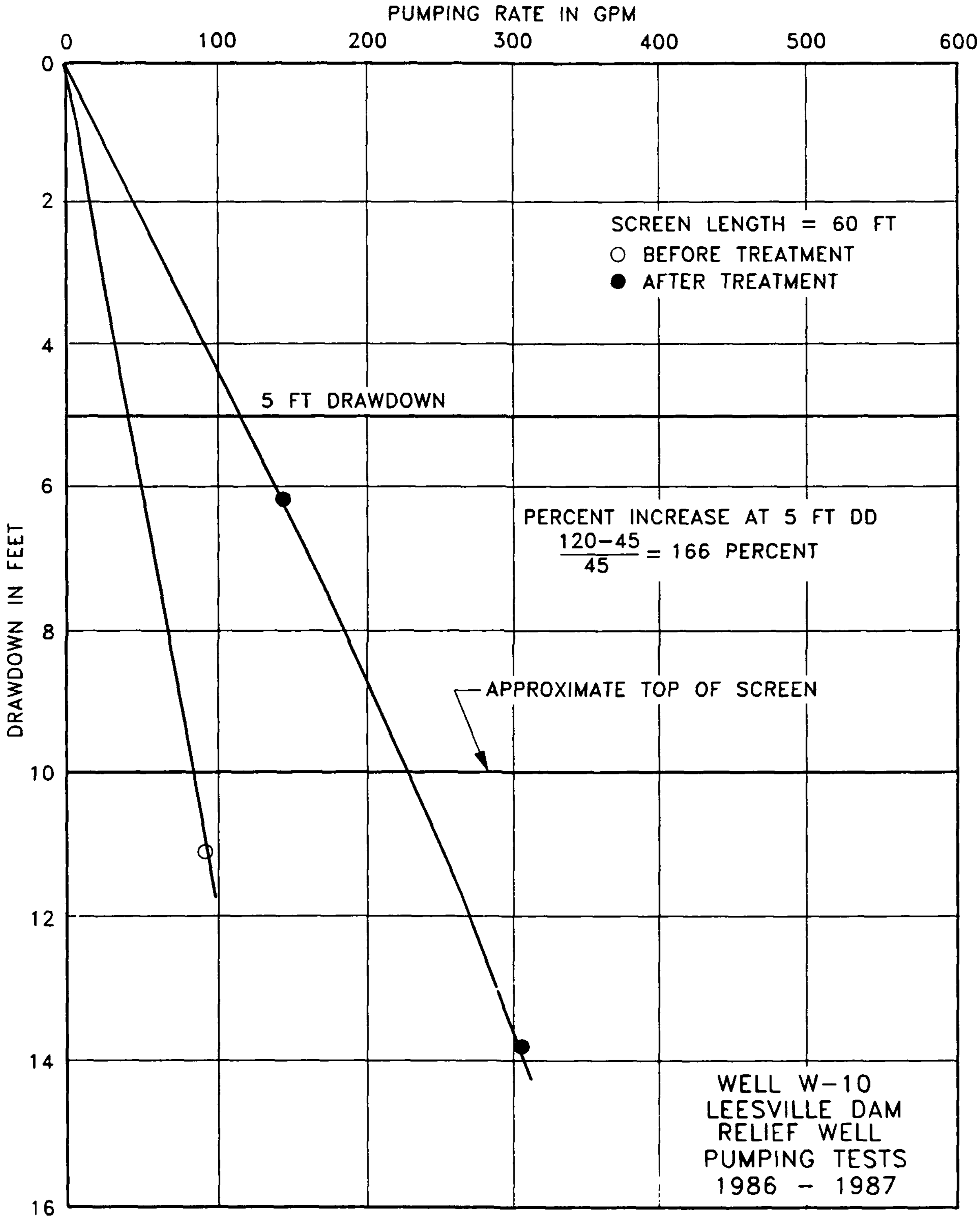


Figure 15. Drawdown versus pumping rate for well W-10

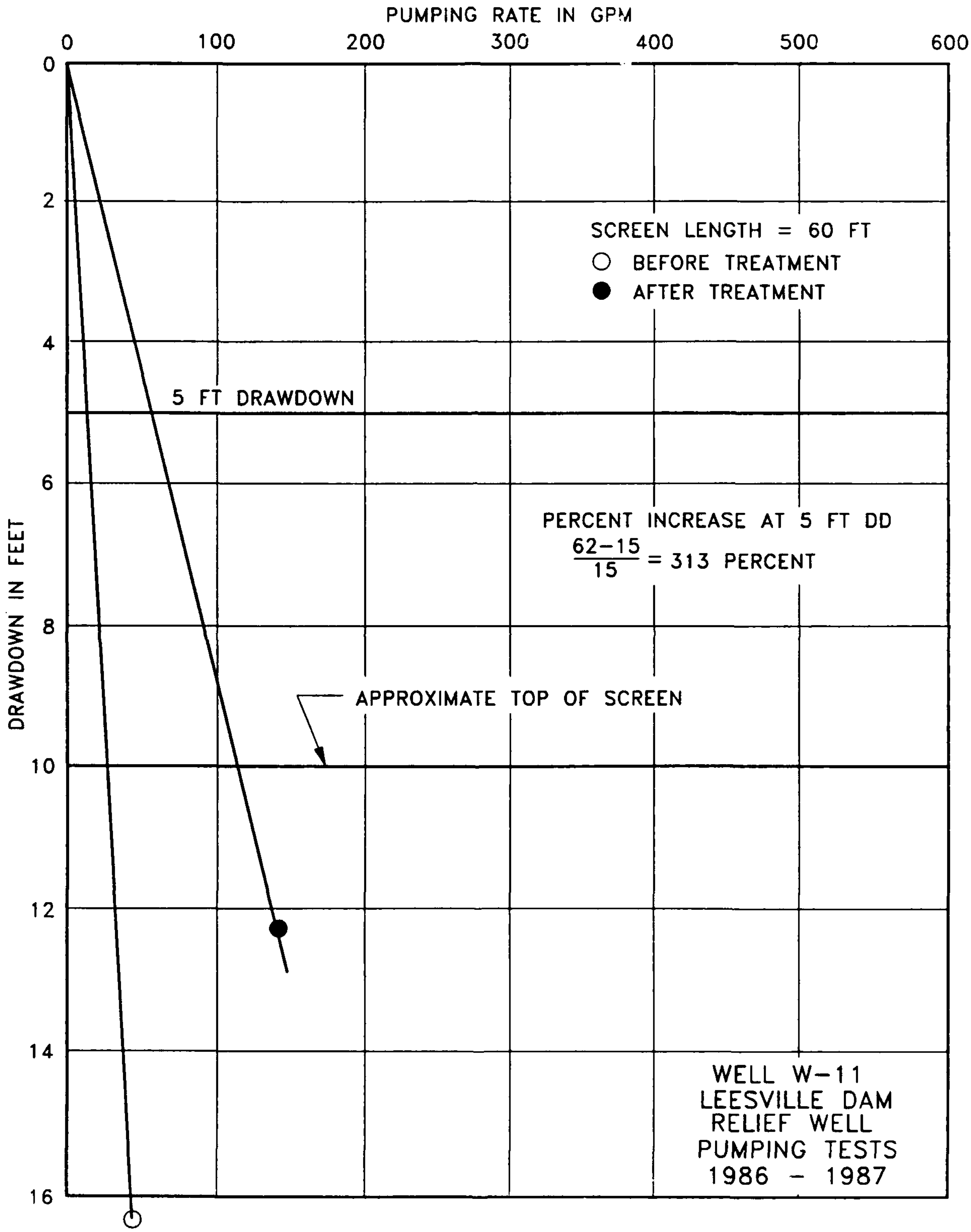


Figure 16. Drawdown versus pumping rate for well W-11

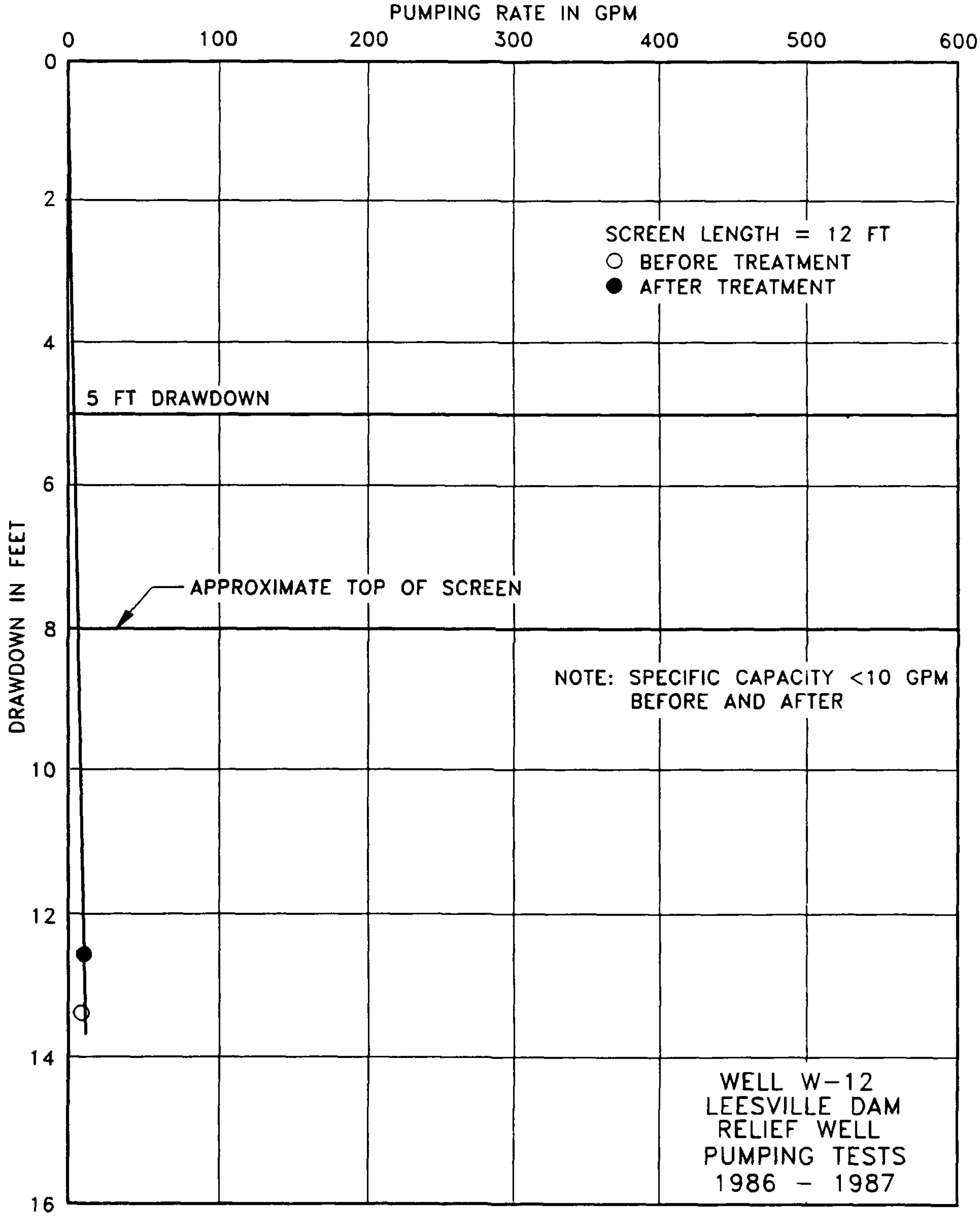


Figure 17. Drawdown versus pumping rate for well W-12

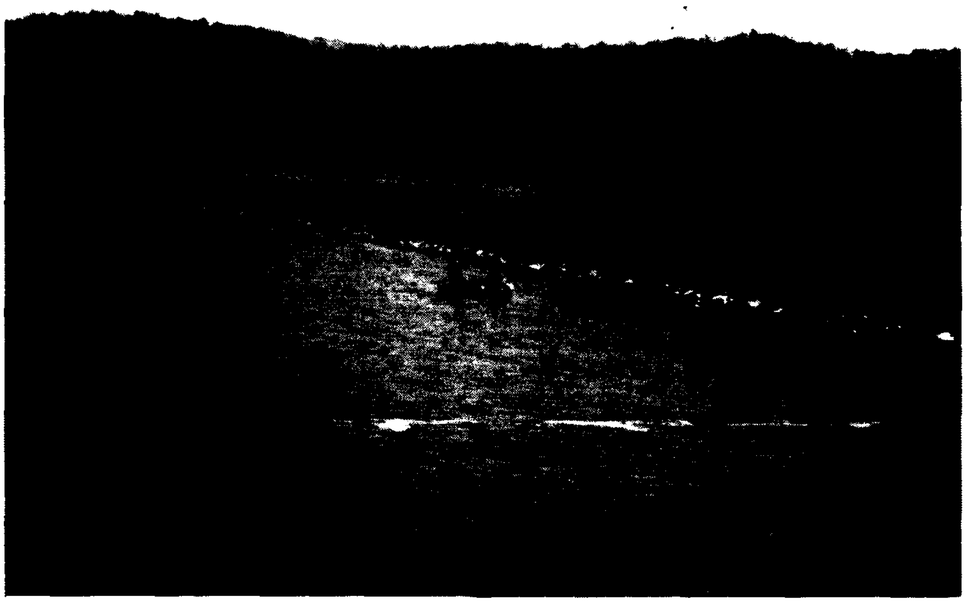


Photo 1. Leesville Dam, Ohio - lakeside

Photo 2. Leesville Dam, Ohio - downstream toe

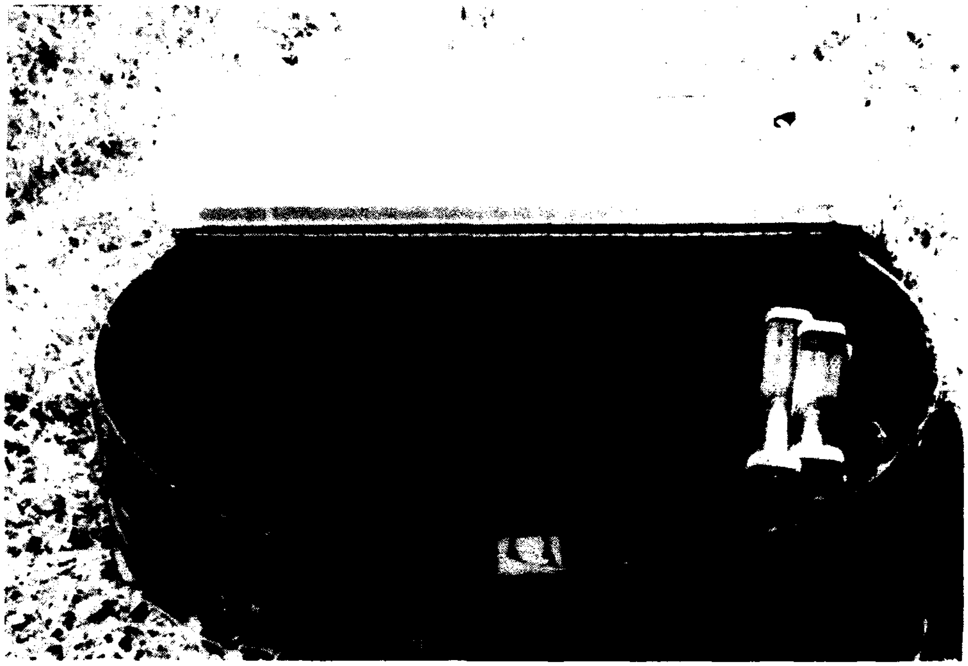


Photo 3. Corrugated casing for individually housed relief wells

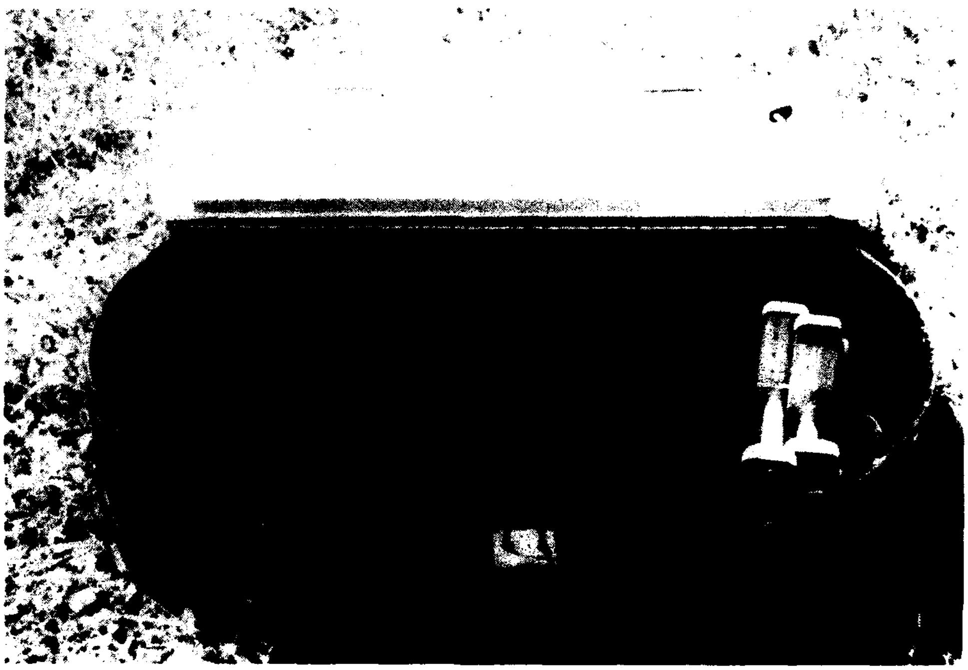
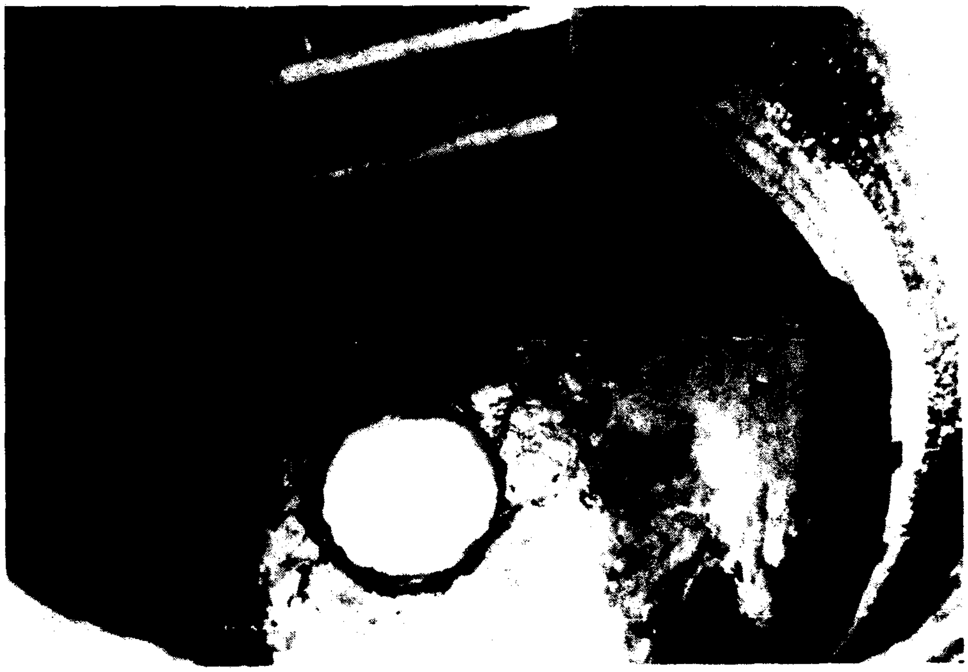


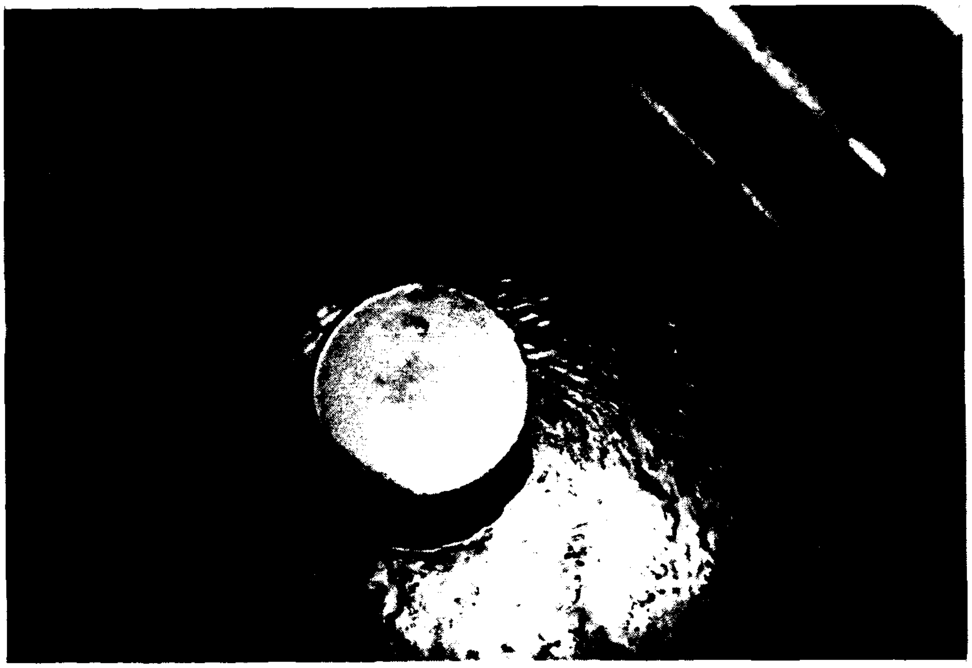
Photo 4. Relief wells designed as uncapped, flowing wells



a.

b.

Photo 5. Reddish-brown, mucilaginous deposits in well characteristic of iron-precipitating bacteria (Continued)



c.
Photo 5. (Concluded)

Photo 6. Nasco Whirl-Pak containing water from well

Photo 7. Plexiglas slides attached to weighted, monofilament line

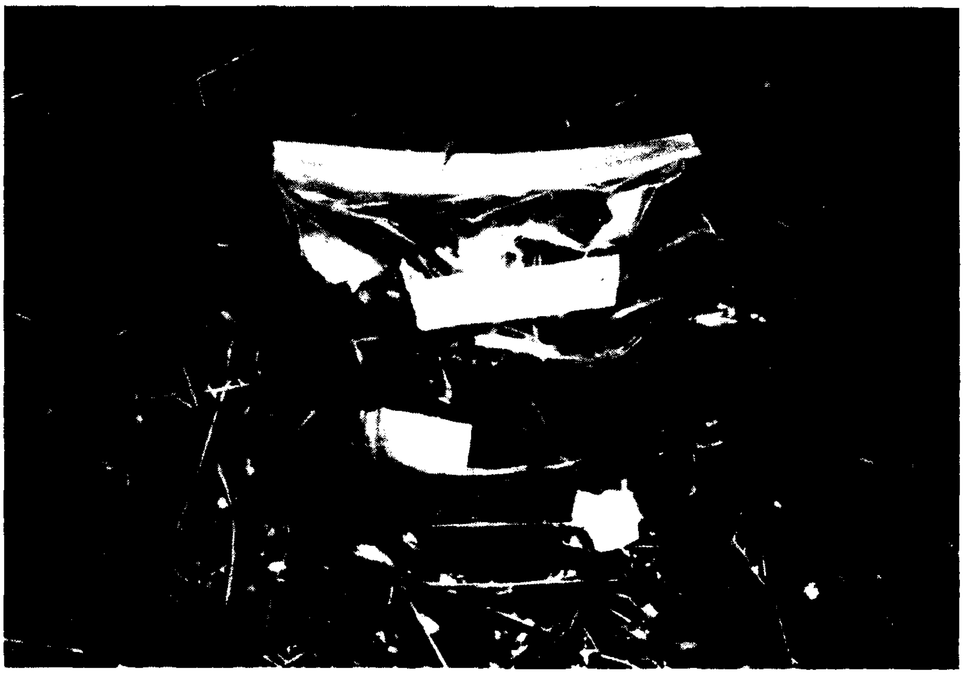


Photo 8. Plexiglas slides labeled and placed in sealed bag

Photo 9. Lowered weighted, monofilament line with attached slides into each relief well

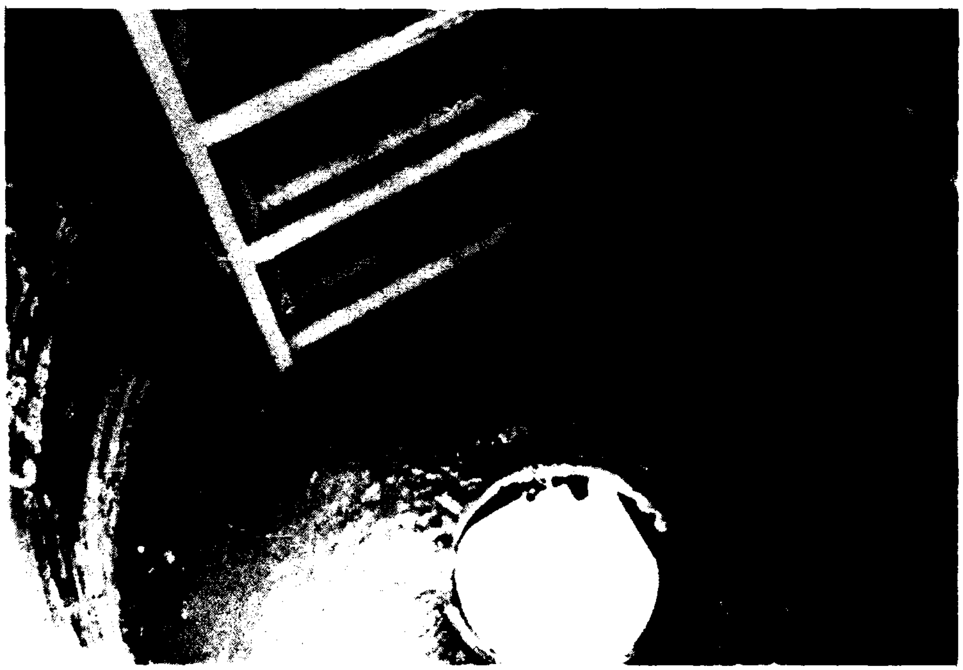


Photo 10. Monofilament line anchored to a rung on the stationary ladder

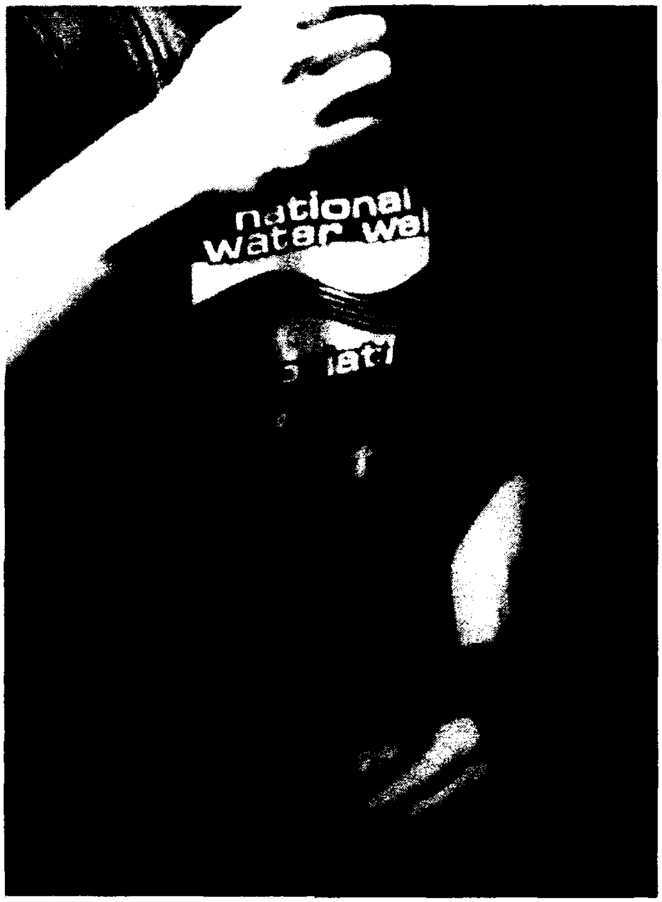


Photo 11. Retrieval of Plexiglas slides

Photo 12. Slides immersed in distilled water in a Nasco Whirl-Pak

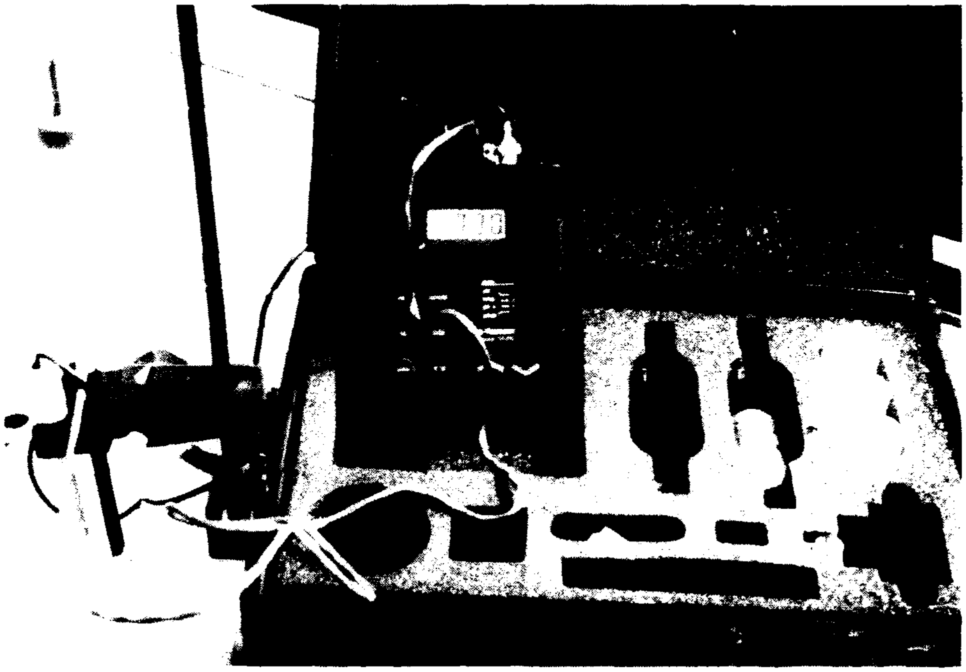


Photo 13. Orion SA 250 portable meter with pH electrode and automatic temperature compensation probe

Photo 14. Neoprene sleeve used to join the PVC riser pipe to the fiberglass relief well casing, before placement

Photo 15. Neoprene sleeve used to join the PVC riser pipe to the fiberglass relief well casing, installed

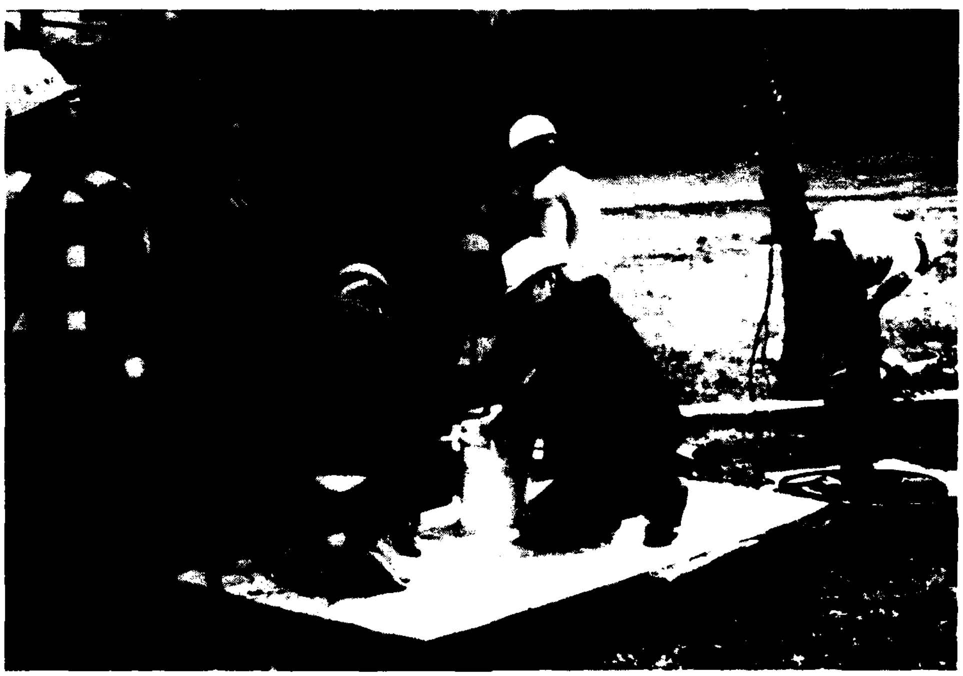


Photo 16. Vertical support for PVC riser pipe; plywood platform placed over the relief well housing

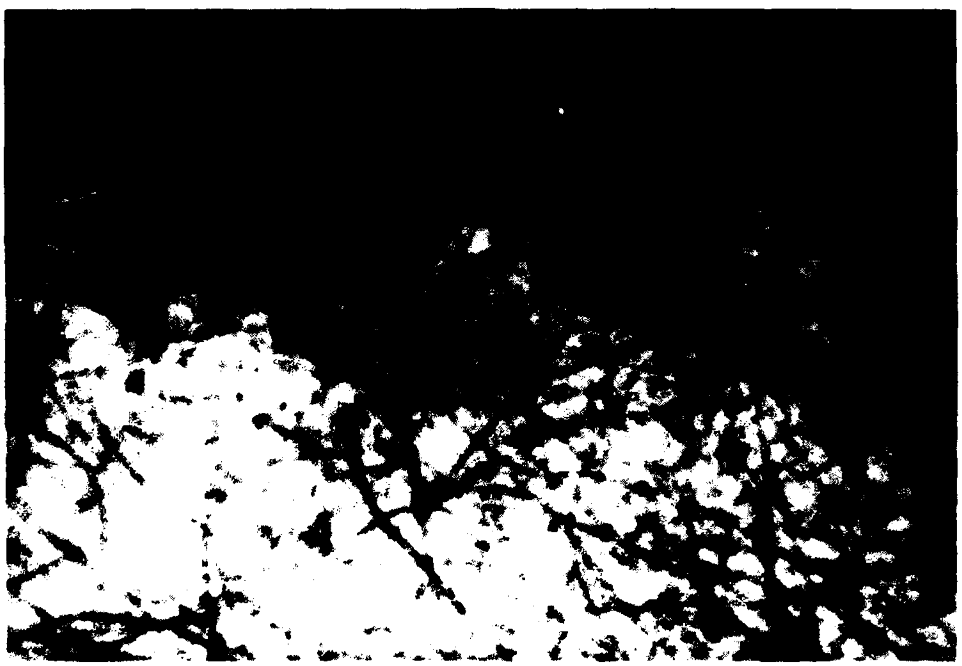
a.

b.

Photo 17. Pump test conducted using a submersible turbine pump and pumping at three different rates (Continued)

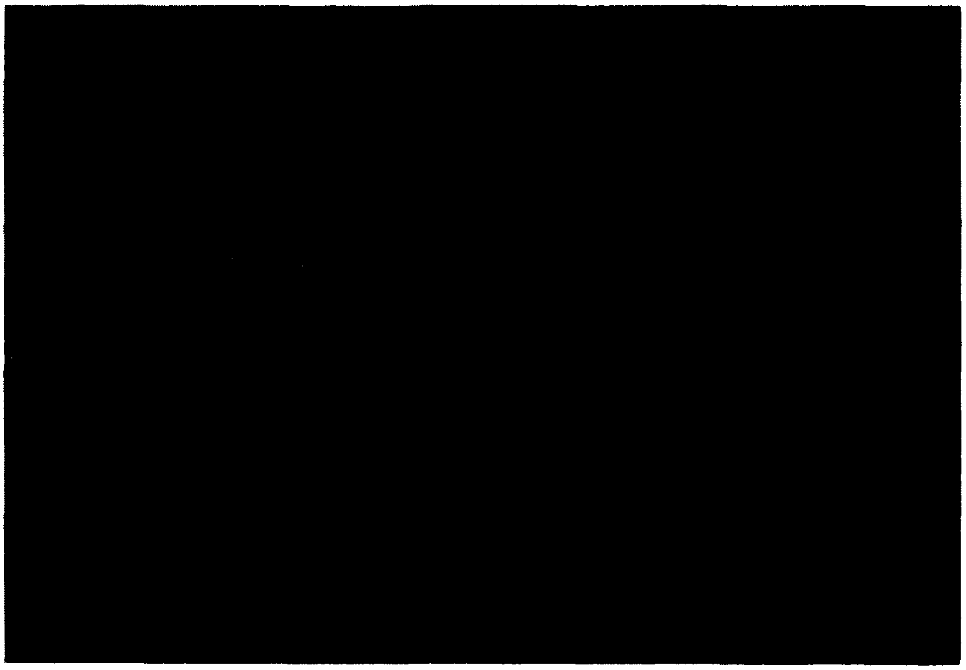
c.

Photo 17. (Concluded)



a.

Photo 18. Photomicrographs of bacterial sheaths, *Lepothrix* (Continued)



b.

c.

Photo 18. (Concluded)

Photo 19. A commercially available long-linear phosphate solution obtained in 55-gal drums

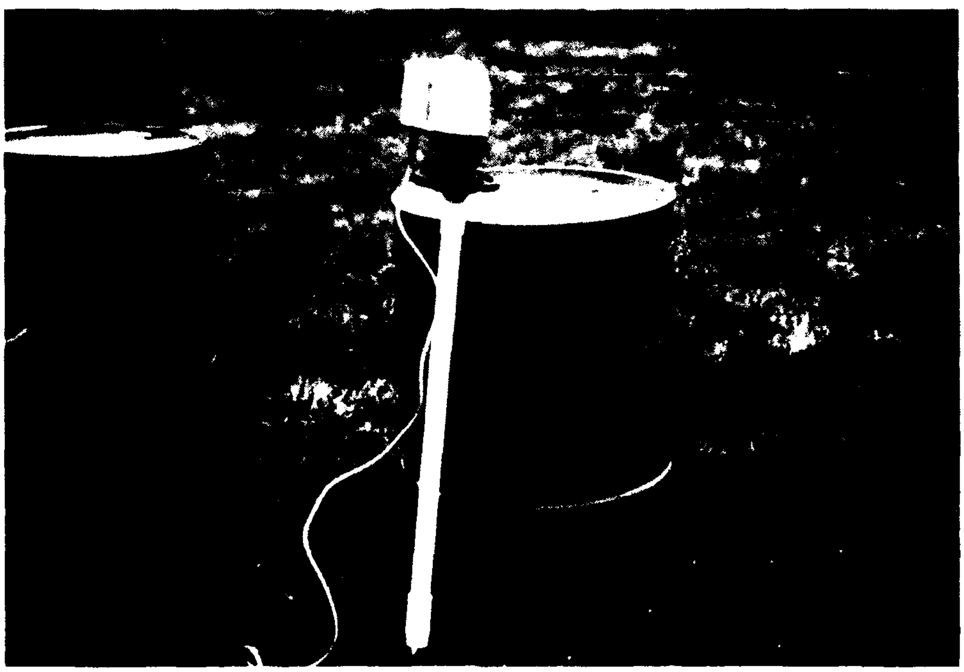


Photo 20. Chemical mixing operation - small electrical, metering pump

Photo 21. Chemical mixing operation - small electrical, metering pump transfer-ring solution from the chemical supply drum to 55-gal barrel

Photo 22. Chemical mixing operation - small electrical, metering pump measuring long-linear phosphate solution

Photo 23. Premeasured volume of phosphate solution pumped into relief well

Photo 24. Phosphates surged in the well using a mechanical surge block

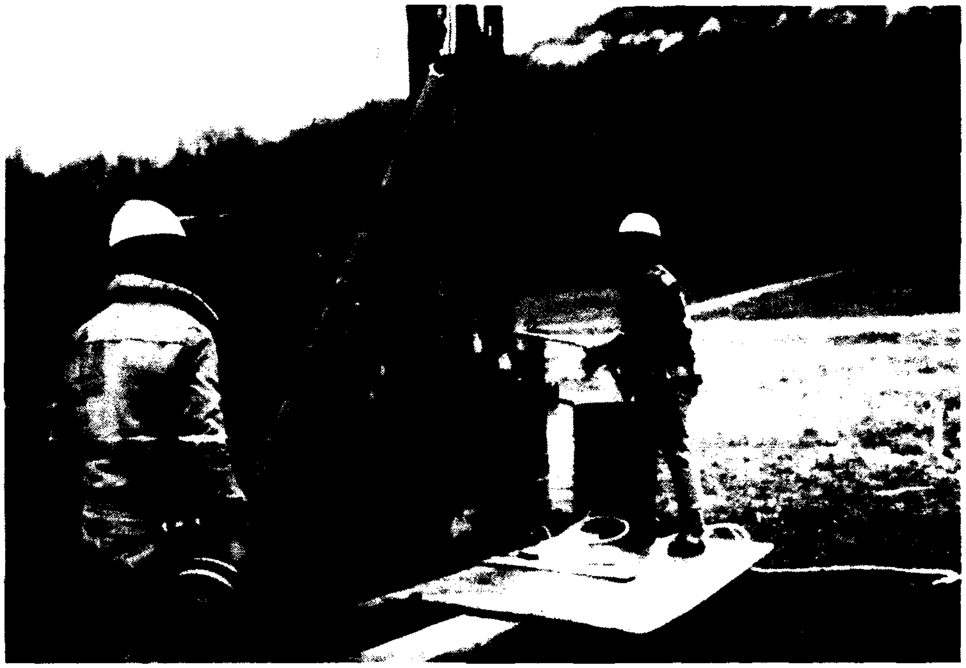


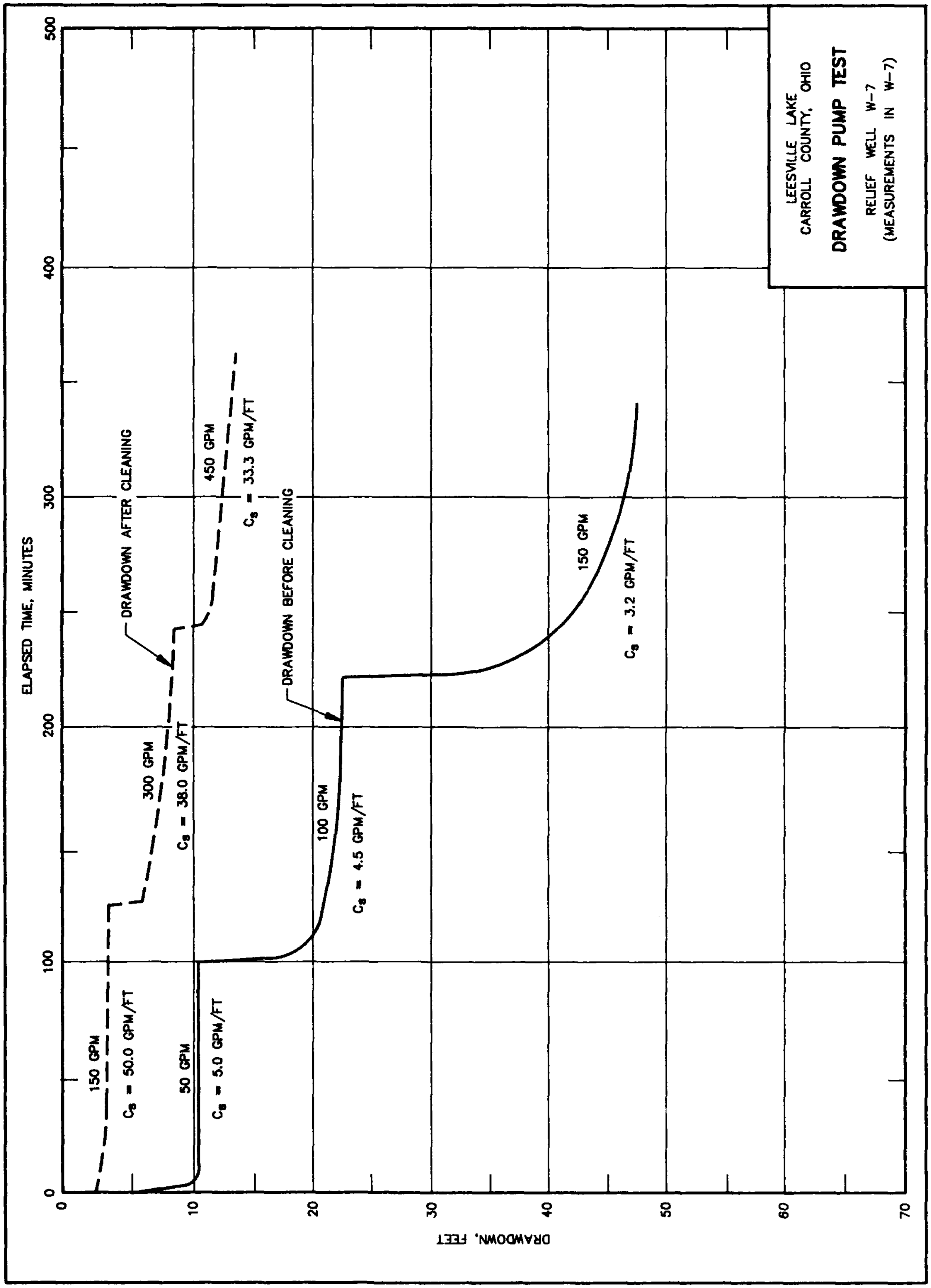
Photo 25. Surge block

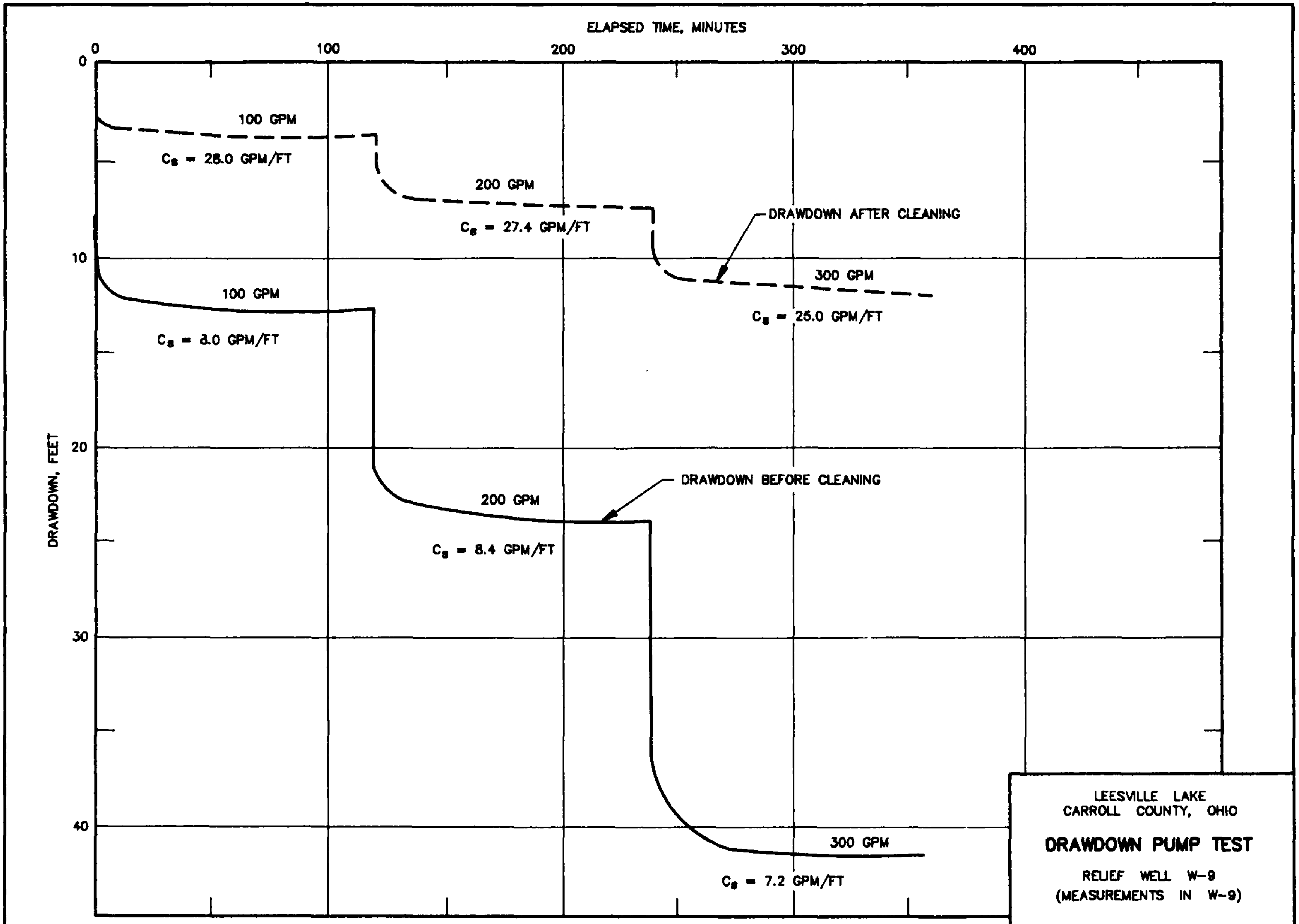
Photo 26. Unsuccessful attempt to surge the wells by hand, using a cathead

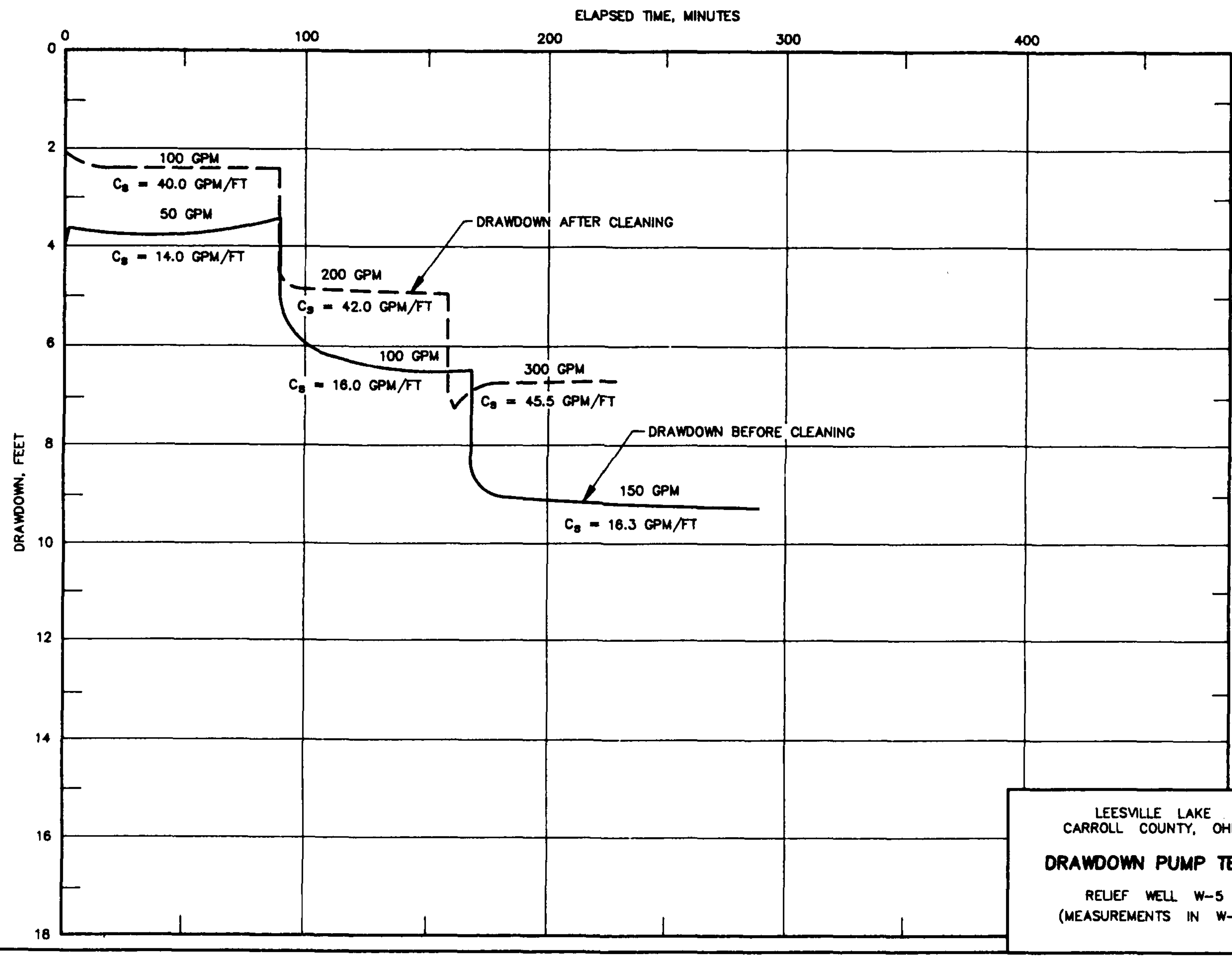
Photo 27. Bailing well to remove accumulated sediment

Photo 28. Sodium hypochloride added to the well

APPENDIX A: CONTRACTOR FURNISHED PUMP TEST DRAWDOWN CURVES


LEESVILLE LAKE
CARROLL COUNTY, OHIO
DRAWDOWN PUMP TEST
RELIEF WELL W-7
(MEASUREMENTS IN W-7)
ELAPSED TIME, MINUTES
DRAWDOWN, FEET
DRAWDOWN AFTER CLEANING
DRAWDOWN BEFORE CLEANING
150 GPM
C_s = 50.0 GPM/FT
50 GPM
C_s = 5.0 GPM/FT
300 GPM
C_s = 38.0 GPM/FT
100 GPM
C_s = 4.5 GPM/FT
450 GPM
C_s = 33.3 GPM/FT
150 GPM
C_s = 3.2 GPM/FT
0
100
200
300
400
500
0
10
20
30
40
50
60
70

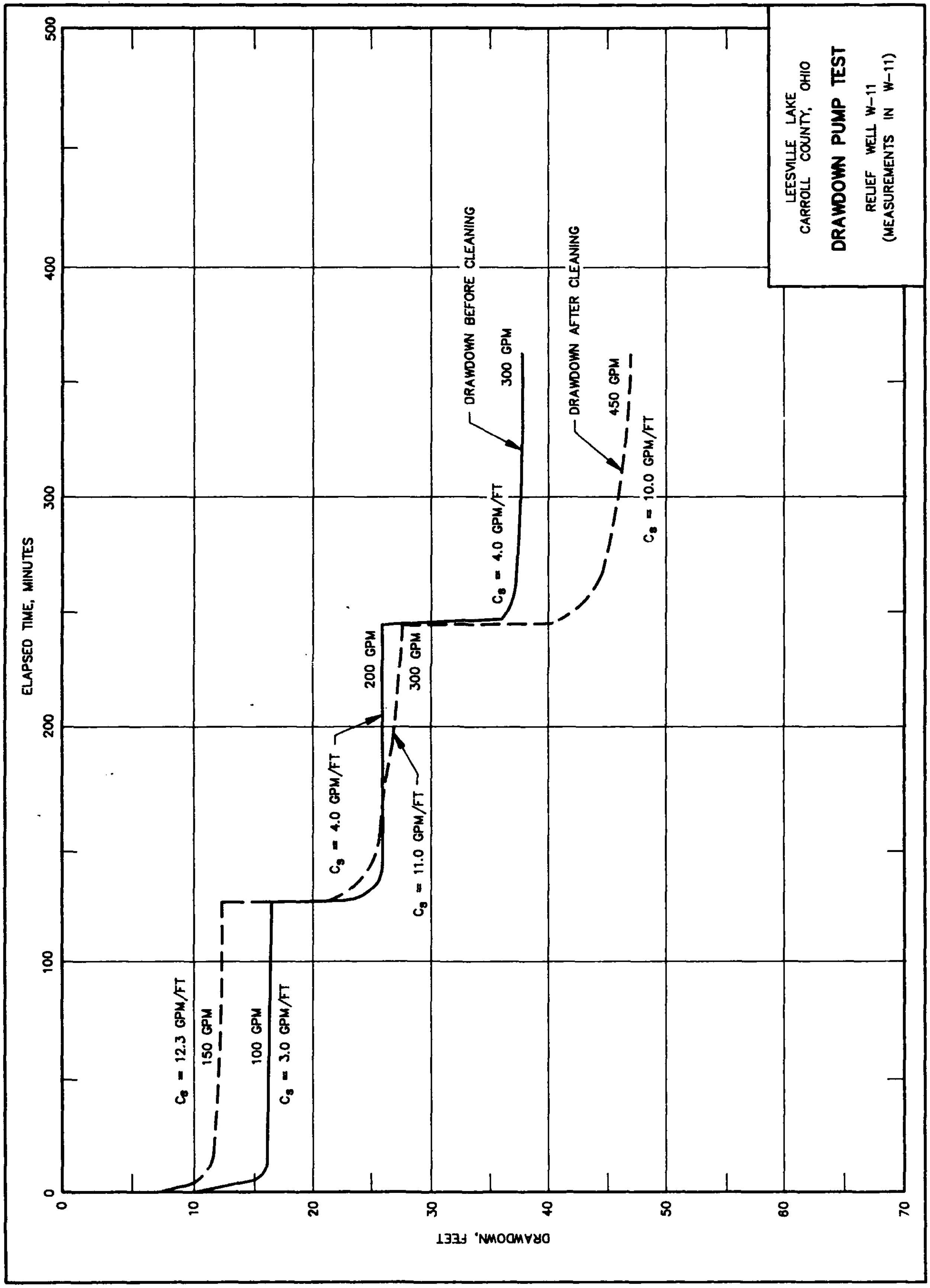

ELAPSED TIME, MINUTES
0
100
200
300
400
DRAWDOWN, FEET
0
10
20
30
40
100 GPM
C_s = 28.0 GPM/FT
200 GPM
C_s = 27.4 GPM/FT
DRAWDOWN AFTER CLEANING
300 GPM
C_s = 25.0 GPM/FT
100 GPM
C_s = 8.0 GPM/FT
DRAWDOWN BEFORE CLEANING
200 GPM
C_s = 8.4 GPM/FT
300 GPM
C_s = 7.2 GPM/FT
LEESVILLE LAKE
CARROLL COUNTY, OHIO
DRAWDOWN PUMP TEST
RELIEF WELL W-9
(MEASUREMENTS IN W-9)

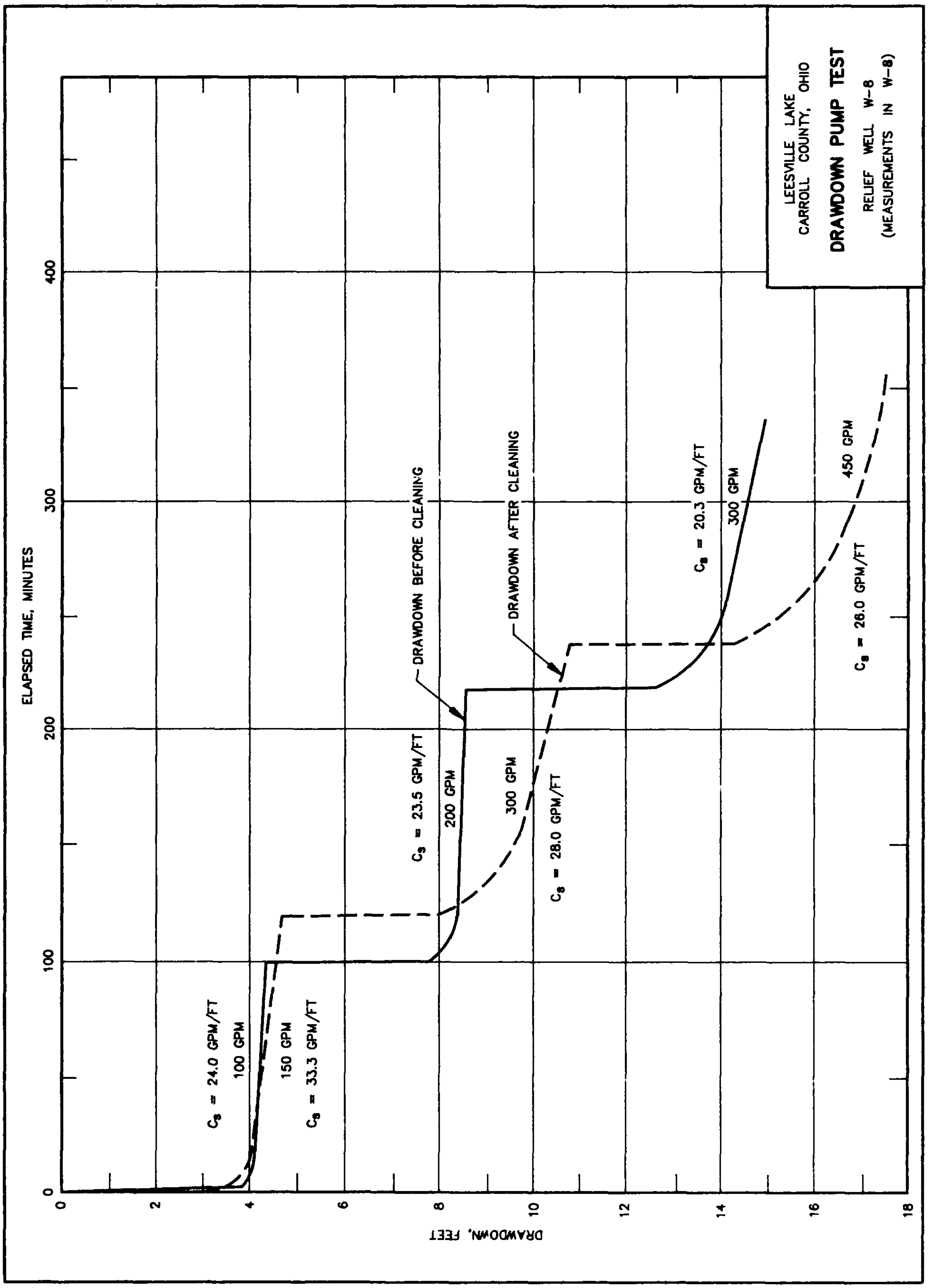


LEESVILLE LAKE
CARROLL COUNTY, OHIO

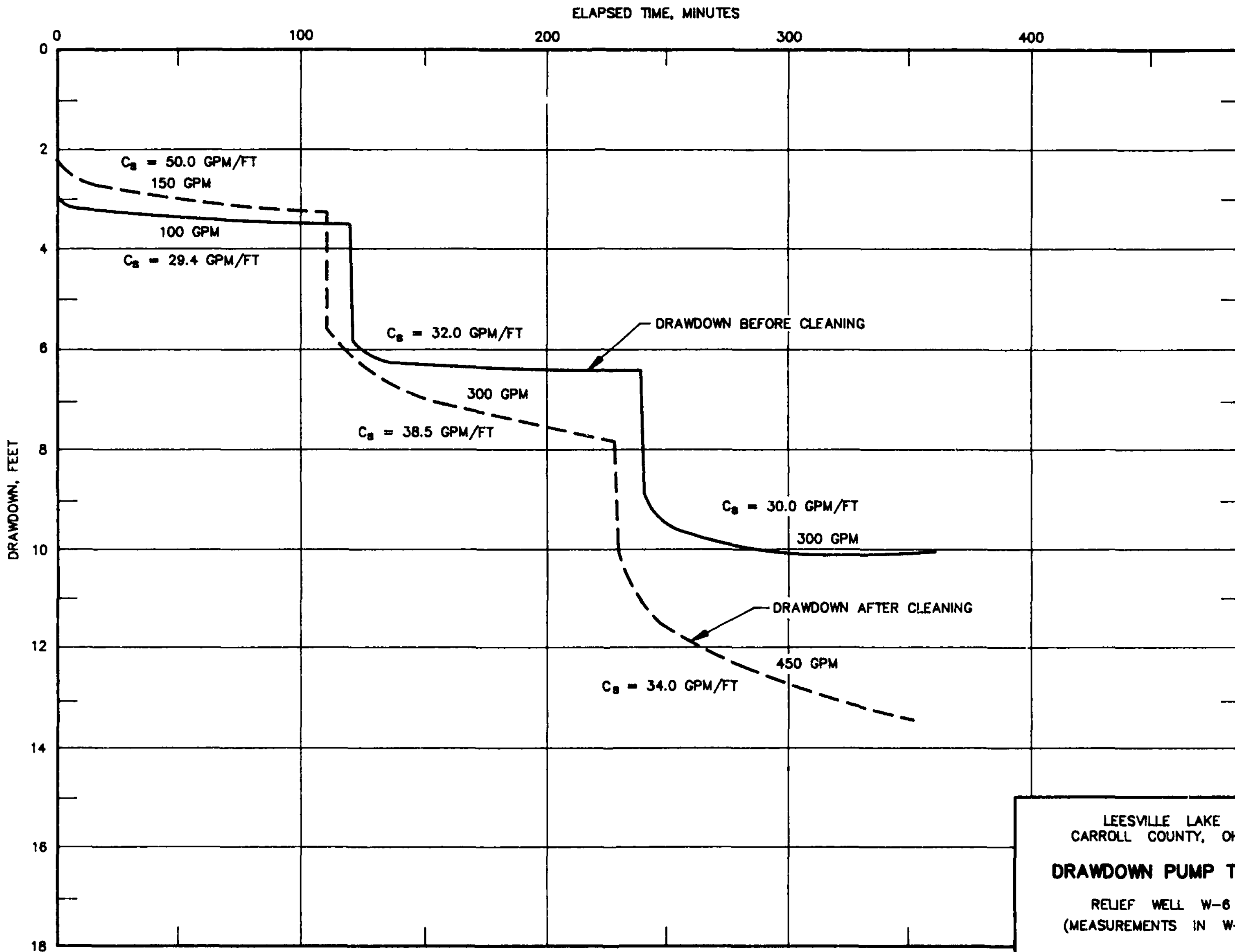
DRAWDOWN PUMP TEST

RELIEF WELL W-5
(MEASUREMENTS IN W-5)


LEESVILLE LAKE
CARROLL COUNTY, OHIO
DRAWDOWN PUMP TEST
RELIEF WELL W-11
(MEASUREMENTS IN W-11)
ELAPSED TIME, MINUTES
DRAWDOWN, FEET
DRAWDOWN BEFORE CLEANING
DRAWDOWN AFTER CLEANING
300 GPM
450 GPM
C_s = 4.0 GPM/FT
C_s = 10.0 GPM/FT
200 GPM
300 GPM
C_s = 4.0 GPM/FT
C_s = 11.0 GPM/FT
C_s = 12.3 GPM/FT
150 GPM
100 GPM
C_s = 3.0 GPM/FT
0
100
200
300
400
500
0
10
20
30
40
50
60
70



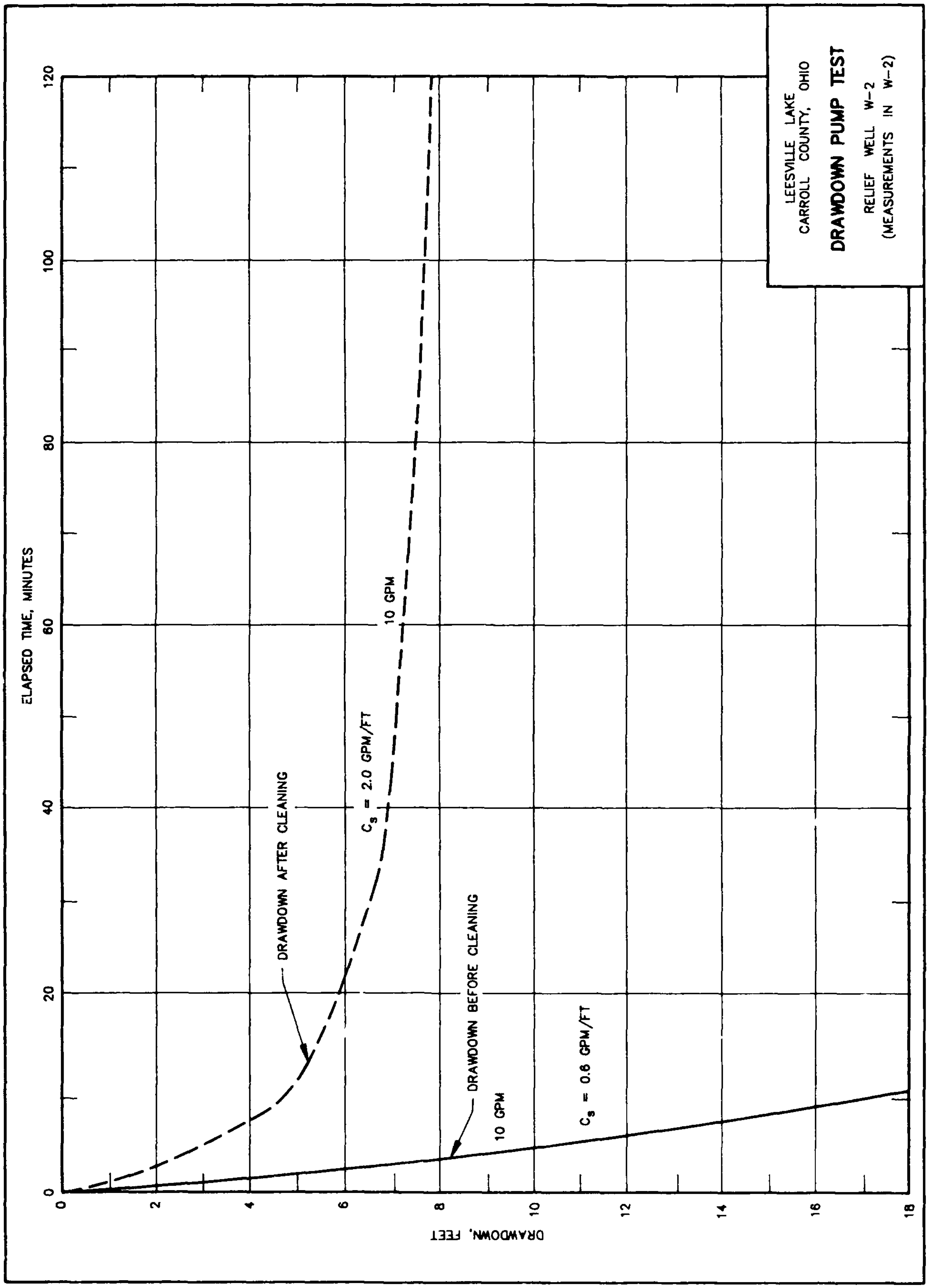
LEESVILLE LAKE
CARROLL COUNTY, OHIO
DRAWDOWN PUMP TEST
RELIEF WELL W-8
(MEASUREMENTS IN W-8)
ELAPSED TIME, MINUTES
DRAWDOWN, FEET
DRAWDOWN BEFORE CLEANING
DRAWDOWN AFTER CLEANING
C_s = 24.0 GPM/FT
100 GPM
150 GPM
C_s = 33.3 GPM/FT
C_s = 23.5 GPM/FT
200 GPM
300 GPM
C_s = 28.0 GPM/FT
C_s = 20.3 GPM/FT
300 GPM
450 GPM
C_s = 26.0 GPM/FT
0
100
200
300
400
0
2
4
6
8
10
12
14
16
18

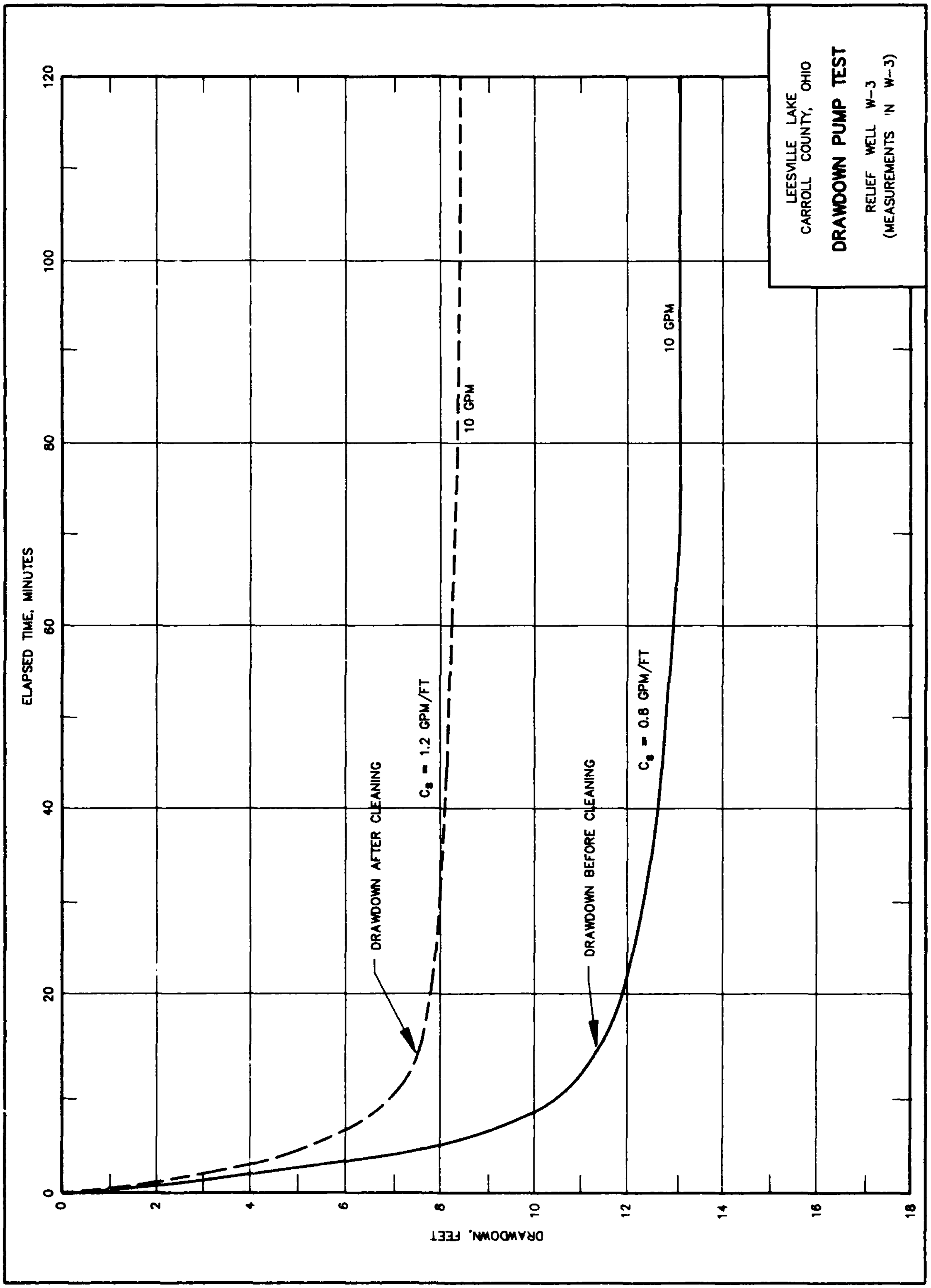


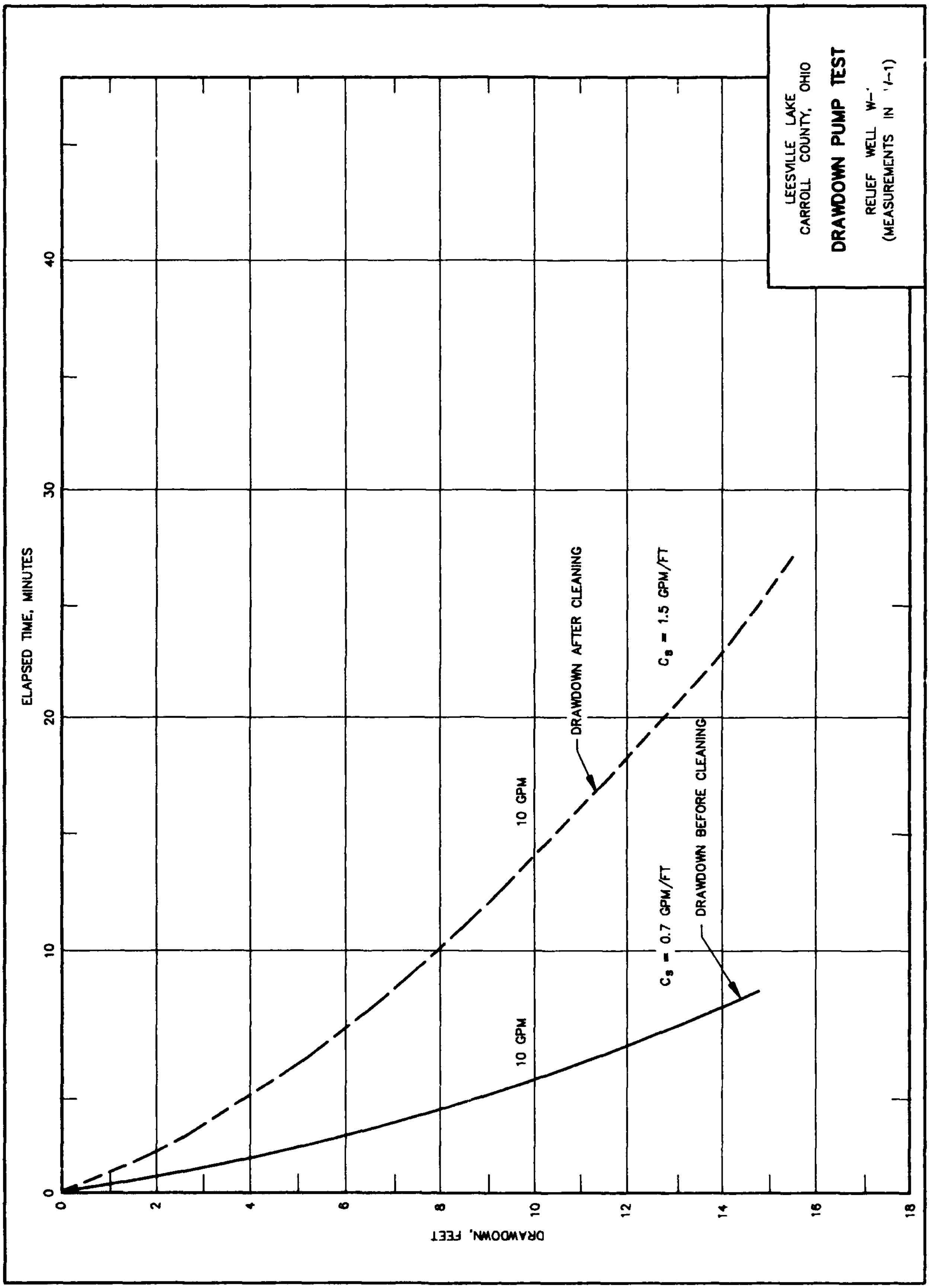
LEESVILLE LAKE
CARROLL COUNTY, OHIO

DRAWDOWN PUMP TEST

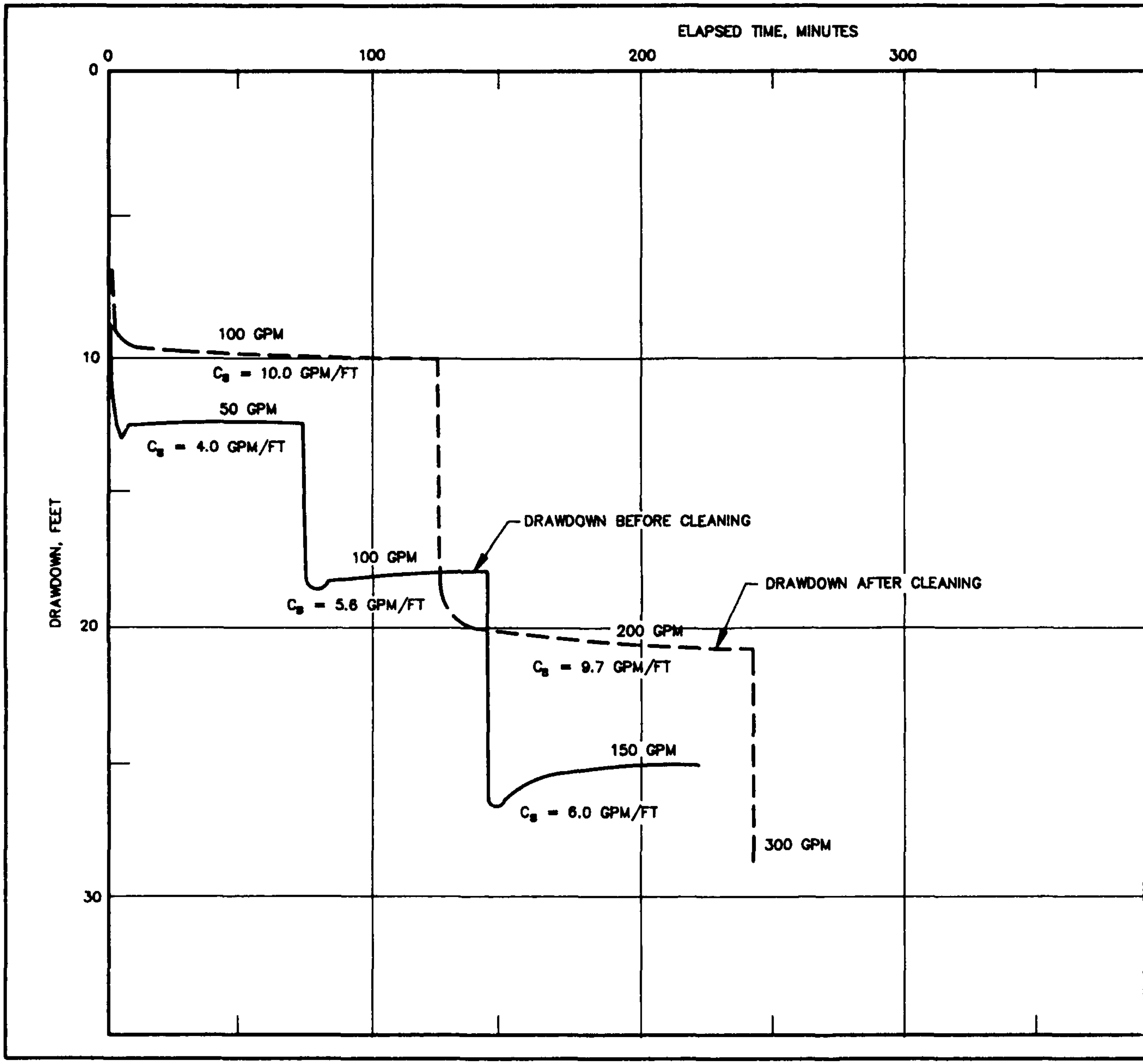
RELIEF WELL W-6
(MEASUREMENTS IN W-6)


LEESVILLE LAKE
CARROLL COUNTY, OHIO
DRAWDOWN PUMP TEST
RELIEF WELL W-2
(MEASUREMENTS IN W-2)
ELAPSED TIME, MINUTES
DRAWDOWN, FEET
DRAWDOWN AFTER CLEANING
C_s = 2.0 GPM/FT
10 GPM
DRAWDOWN BEFORE CLEANING
C_s = 0.6 GPM/FT
10 GPM
0
20
40
60
80
100
120
2
4
6
8
10
12
14
16
18


LEESVILLE LAKE
CARROLL COUNTY, OHIO
DRAWDOWN PUMP TEST
RELIEF WELL W-3
(MEASUREMENTS 'N W-3)
ELAPSED TIME, MINUTES
DRAWDOWN, FEET
0
20
40
60
80
100
120
0
2
4
6
8
10
12
14
16
18
10 GPM
10 GPM
C_s = 1.2 GPM/FT
C_s = 0.8 GPM/FT
DRAWDOWN AFTER CLEANING
DRAWDOWN BEFORE CLEANING



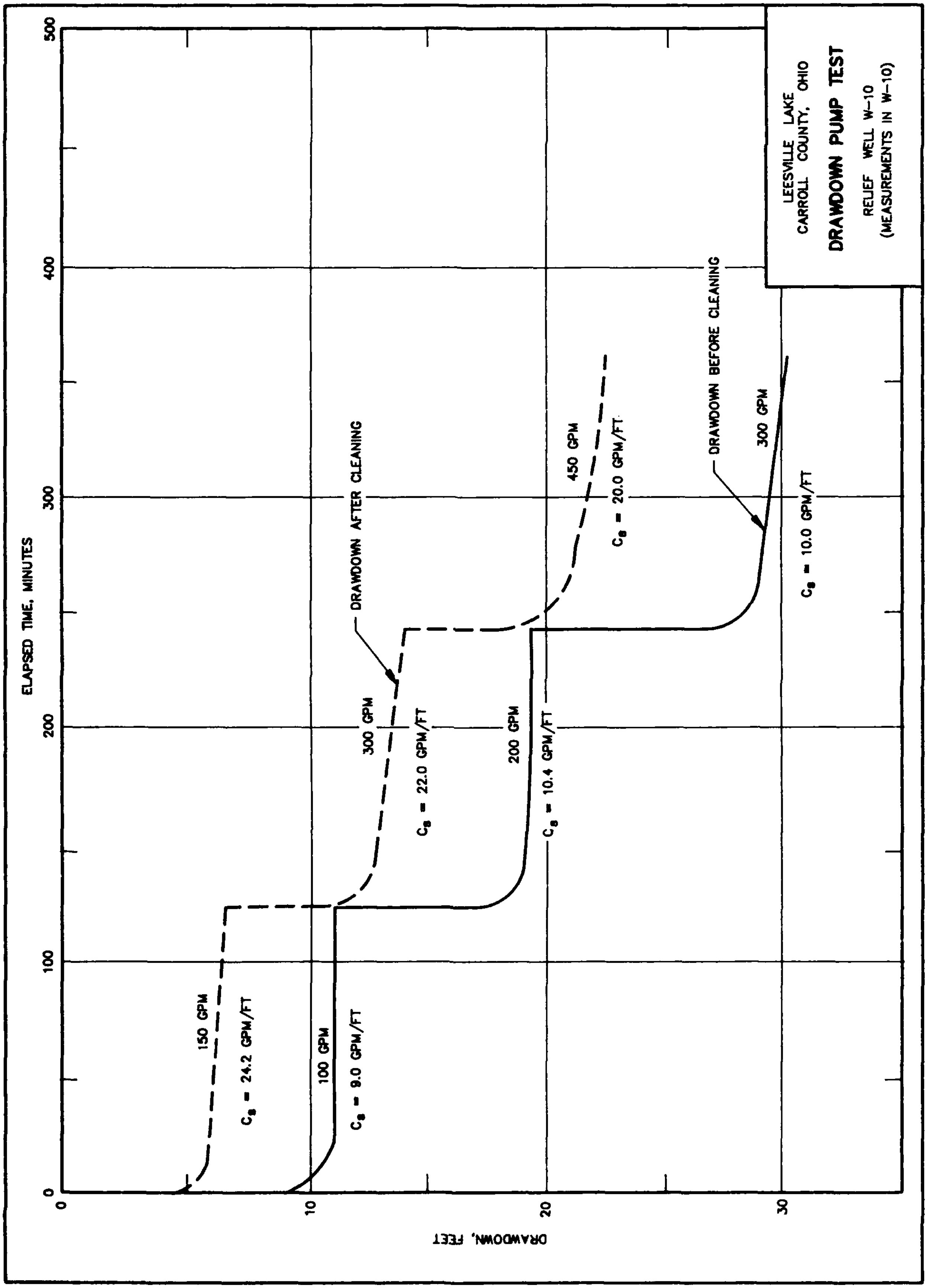
LEESVILLE LAKE
CARROLL COUNTY, OHIO
DRAWDOWN PUMP TEST
RELIEF WELL W-
(MEASUREMENTS IN
ELAPSED TIME, MINUTES
DRAWDOWN, FEET
DRAWDOWN AFTER CLEANING
DRAWDOWN BEFORE CLEANING
10 GPM
10 GPM
C_s = 1.5 GPM/FT
C_s = 0.7 GPM/FT
0
10
20
30
40
0
2
4
6
8
10
12
14
16
18

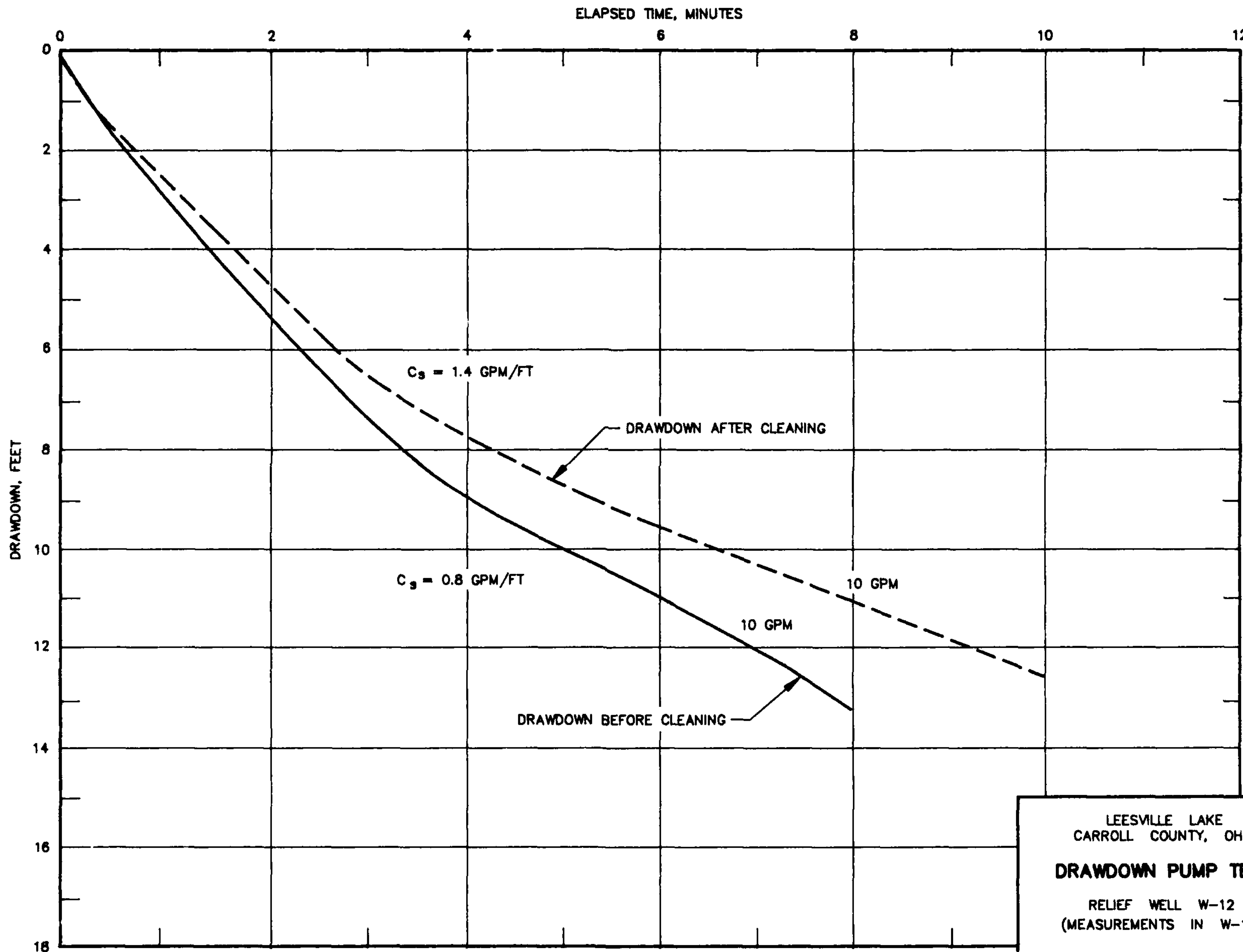


LEESVILLE LAKE
CARROLL COUNTY, OHIO

DRAWDOWN PUMP TEST

RELIEF WELL W-4
(MEASUREMENTS IN W-4)


LEESVILLE LAKE
CARROLL COUNTY, OHIO
DRAWDOWN PUMP TEST
RELIEF WELL W-10
(MEASUREMENTS IN W-10)
ELAPSED TIME, MINUTES
DRAWDOWN, FEET
0
100
200
300
400
500
0
10
20
30
DRAWDOWN AFTER CLEANING
DRAWDOWN BEFORE CLEANING
150 GPM
C_s = 24.2 GPM/FT
100 GPM
C_s = 9.0 GPM/FT
300 GPM
C_s = 22.0 GPM/FT
200 GPM
C_s = 10.4 GPM/FT
450 GPM
C_s = 20.0 GPM/FT
300 GPM
C_s = 10.0 GPM/FT



LEESVILLE LAKE
CARROLL COUNTY, OHIO

DRAWDOWN PUMP TEST

RELIEF WELL W-12
(MEASUREMENTS IN W-12)

APPENDIX B: BORING LOGS FOR RELIEF WELLS, *LEESVILLE DAM, OHIO*

HOLE NO.
W-1

DATE 20 Jan 76 N. ______

ELEV. 930.8 DIRECTION Vertical E. ______

ELEV.	SYM.	CLASSIFICATION	BLOWS	REMARKS
930.8				
928.8	NS	NO SAMPLE (WATER)		Sampler: 6" Barrel 900# Hammer 30" Drop
926.8	SP	GRAVELLY SAND (SP), br., f. to c.g., GRAVEL f.& c., fines non-pl.	44	
924.8	GP	SANDY GRAVEL(GP),br.,f.& c.,SAND f.to c.g.,fines non-pl.	42	
922.8	GM GP	SILTY SANDY GRAVEL(GM-GP),br.,c.& f.,SAND c.to f.g.,fines non-pl	48	SEEPAGE BLANKET FROM TOP OF GROUND TO EL. 920.8
920.8	GC GM	CLAYEY SANDY GRAVEL(GC-GM),br., f.& c., SAND c.to f.g.	72	Changed to 4" barrel
		ROCK TOE-SANDSTONE COBBLES & BOULDERS	74	
916.8			78	
914.8	CL	SANDY GRAVELLY CLAY(CL),gr. br. c.& f.GRAVEL(mos.SS.frags)SAND c.to f.	44	
	CL	GRAVELLY SANDY CLAY(CL),gr.br./f.to c.g.SAND,f.& c.GRAVEL,med. pl.	32	
910.8			34	
908.8	SC	CLAYEY SAND(SC),gr.br.,c.to f.g c.& f.GRAVEL(mos.SS.frags.)low pl	130	
906.8	CL	SANDY GRAVELLY CLAY(CL),gr.br., c& f.GRAVEL(mos.SS.frags),SAND c.to f.g.,low pl.	220	
		Bottom of Hole		

SIZE 6" & 4" PROJECT LEESVILLE LAKE, OHIO SHEET 1 OF 1 SHEETS

HOLE NO.
W-2

DATE 18 Mar. 76 N. ________

ELEV. 931.2 DIRECTION Vertical E. ________

ELEV	SYM	CLASSIFICATION	BLOWS	REMARKS
931.2				
927.2	SP	GRAVELLY SAND(SP),dk.br.,f. to c.g.,GRAVEL f.& c./tr.of SS. frags.	14 52	Sampler: 6" Barrel 900# Hammer 30" Drop
925.2	SM SP	SILTY GRAVELLY SAND(SM-SP),dk.br. f. to c.g.	61	
923.2		ROCK TOE-SANDSTONE COBBLES & BOULDERS	72	SEEPAGE BLANKET FROM TOP OF GROUND TO EL.925.2
917.2	GM	SILTY SANDY GRAVEL(GM),dk.br.,f. & c./num.SS.frags,,SAND f. to c.g., GRAVEL f.& c.,non pl.	68 72 68	Changed to 4" Barrel
915.2	SM	GRAVELLY SILTY SAND (SM),dk.br., f to m. g./tr.c.,GRAVEL f.& c.(mos. SS frags.)	52	
913.2	GM	SILTY SANDY GRAVEL(GM),gr.br.,f.& c. /num.SS.frags.,SAND f.to c.g.,sli.pl.	29	
909.2	SC	CLAYEY SAND (SC),br.gr.& gr.,f.to c.g.,GRAVEL f.& c.(mos.SS frags.), low pl.	48 52	
907.2	SC SM	CLAYEY SAND(SC-SM),gr.br., f.to m.g./ tr.c.,f.GRAVEL/tr.SS.frags.	29	
905.2	CL	SANDY CLAY(CL),gr.br.,f. to c.g. SAND, f.GRAVEL/tr.SS frags.,low pl.	38	
899.2	CL	SANDY CLAY(CL),br.gr.,f. to c.g. SAND/f.& c. GRAVEL, m.pl.	32 36 38	
897.2	CL	SANDY CLAY (CL),br.gr.,SAND f.to c.g. GRAVEL f.& c.(mos.SS.frags)low pl.	42	
895.2	SC	CLAYEY SAND(SC),gr.gr.,SAND f.to c.g. GRAVEL f.& c.(mos.SS.frags)low pl.	72	
893.2	SC	CLAYEY SAND(SC) br.gr.,SAND f.to c.g., low pl.	102	
892.5	NS	NO SAMPLE	325	
		Bottom of Hole		

SIZE 6"& 4" PROJECT LEESVILLE LAKE, OHIO SHEET 1 OF 1 SHEETS

HOLE NO. W -3

DATE 18 Feb. 1976 N. ________

ELEV. 930.7 DIRECTION Vertical E. ________

ELEV.	SYM.	CLASSIFICATION	BLOWS	REMARKS
930.7				
	GP	SANDY GRAVEL (GP), br., f.& c., SAND f. to c.g.	24	Sampler: 6" Barrel 900# Hammer 30" Drop
924.7			26	
922.7	GP GM	SANDY GRAVEL(GP-GM),br.,f. & c. SAND f. to c.g.	48	SEEPAGE BLANKET FROM TOP OF GROUND TO EL. 922.7
		ROCK TOE-SANDSTONE COBBLES & BOULDERS	110	Changed to 4" Barrel
918.7			26	
916.7	SM-SP	SILTY GRAVELLY SAND(SM-SP), br., f. to c.g. GRAVEL f.& c./few SS.frags.	26	
914.7	SM	GRAVELLY SILTY SAND(SM),br.,f.to c.g. GRAVEL f.& c.,+4 SS.frags.	28	
912.7	SM	SILTY GRAVELLY SAND(SM),br., f.to m.g. GRAVEL f. & c.	30	
910.7	SM-SP	SILTY GRAVELLY SAND(SM-SP),br., f. to m.g., GRAVEL f.& c.(approx.50% frags.)	32	
908.7	SM	SILTY GRAVELLY SAND(SM),br.,f.to c.g. GRAVEL f. & c.	75	
906.7	SM	GRAVELLY SILTY SAND(SM),br.,f.g./tr. m.& c.,GRAVEL f.& c.(30%SS.frags.)	70	
904.7	CL	GRAVELLY SANDY CLAY(CL),br.f. to m.g. SAND,GRAVEL f.& c.(15% SS.frags.)	72	
902.7	CL	GRAVELLY CLAY(CL),br.,f to m.g.SAND GRAVEL f. & c.	72	
900.7	CL	GRAVELLY SANDY CLAY(CL),br., f. to m.g.SAND,GRAVEL-num.SS.frags.	38	
	CL	SANDY CLAY (CL), br.,f. to m.g.SAND GRAVEL.num.SS.frags. & tr. of s. SH. frags.	72	
896.7			66	
894.7	SC	GRAVELLY CLAYEY SAND(SC),br.,f. to m.g.,GRAVEL-wd.SH. & SS.	68	
892.7	SM	SILTY GRAVELLY SAND (SM),br., f. to m. g./wd. SH. & SS.	72	
890.7	SM	SILTY GRAVELLY SAND(SM),br.,f.to m. g.,GRAVEL f.& c.(mos.SS.& SH.frags.)	130	
888.7	CL	SANDY CLAY(CL),br.,f.to m.g.SAND, GRAVEL f. & c.	62	
886.7	SC	CLAYEY SAND(SC),br., f. to m.g., GRAVEL f.& c.,num.SS. & SH. frags.	70	
884.7	SC	GRAVELLY CLAYEY SAND(C),br.,f. to m. g.,GRAVEL f.& c.(mos.SS.& SH.frags.)	68	
	SC	CLAYEY SAND(SC), br.,f. to m.g., GRAVEL, f. & c.(mos. SS.)	108	
880.7			110	

SIZE 6" & 4" PROJECT LEESVILLE LAKE, OHIO SHEET 1 OF 2 SHEETS

CONTD.
W-3

ELEV.	SYM.	CLASSIFICATION	REMARKS (BLOWS)	
880.7			BLOWS	
878.7	SC	CLAYEY SAND(SC),br.,f. to c.g., GRAVEL f. & c., SS. & SH. frags.	130	
	SC	CLAYEY SAND (SC), br., f. to m.g., GRAVEL mos. SS. frags.	136	
874.7			180	
	SC	CLAYEY SAND(SC), br., f. to c.g., GRAVEL mos. wd. SS. frags.	182	
871.5			300	
		Bottom of Hole		

SIZE 4" | PROJECT LEESVILLE LAKE, OHIO | SHEET 2 OF 2 SHEETS

HOLE NO.
W -4

DATE 22 Mar. 76   N. ______

ELEV. 930.8   DIRECTION Vertical   E. ______

ELEV.	SYM	CLASSIFICATION	BLOWS	REMARKS
930.8				
926.8	SP	GRAVELLY SAND(SP), br., f. to c.g., GRAVEL f. & c.	67	Sampler: 6" Barrel 900# Hammer 30" Drop
922.8		ROCK TOE - SANDSTONE COBBLES & BOULDERS	80 168	SEEPAGE BLANKET FROM TOP OF GROUND TO EL. 926.8
920.8	GP GM	SANDY GRAVEL(GP-GM), br.,f. & c., SAND f. to c.g.	102	Changed to 4" Barrel
918.8	SP	GRAVELLY SAND (SP), lt.br., f.to c.g./num. SS. frags.(soft)	168	
916.8	SP SM	GRAVELLY SAND(SP-SM),lt.br., f. to c.g., GRAVEL f.& c.(mos.SS. frags.)	225	
914.8	GP GM	SANDY GRAVEL(GP-GM),lt.br., f.to c.g. SAND, GRAVEL c. to f.,sli. pl.	104	
912.8	SM SP	SILTY GRAVELLY SAND(SM-SP), br.,f.to m.g., GRAVEL c. to f.	62	
910.8	SP SM	SAND(SP-SM), gr.br., f.to c.g./tr. f. GRAVEL & SS. frags.	14	
906.8	SM SP	SILTY GRAVELLY SAND(SM-SP),lt.br. f. to c.g., GRAVEL f. to c./num. SS. frags.	12 28	
904.8	SM	SILTY SAND(SM), dk.br., f. to c.g., GRAVEL f. to c./tr.SS.frags.	57	
900.8	SM	SILTY SAND (SM), gr.br. & br.,f. to c. g., GRAVEL f. to c./num. SS. frags.	32 53	
896.8	SM	SILTY SAND(SM), br.,f. to c.g., GRAVEL f. to c./SS. frags.	168 151	
894.8	SM SC	SILTY SAND(SM-SC), gr.br., f.to c.g. GRAVEL f.to c.(mos.SS.frags)sli.pl.	101	
892.8	SM SC	GRAVELLY SILTY SAND(SM-SC),gr.br.,f. to c.g.,GRAVEL f.to c./num.SS.frags.	48	
890.8	SM SC	SILTY SAND(SM-SC),gr.br.,f.to c.g., GRAVEL f.to c.(mos.SS.frags.)sli.pl.	55	
888.8	SC	CLAYEY SAND(SC),gr.br.,f.to c.g.,f. GRAVEL/tr.SS.frags., low pl.	49	
886.8	CL	SANDY CLAY(CL),br.gr.,SAND f.to c.g. tr.f.to c.GRAVEL & SS.frags,low pl.	55	
884.8	SC	CLAYEY SAND(SC),br.gr.,f.to c.g., GRAVEL f.to c.(mos.SS.frags),low pl.	59	
882.8	SM SC	SILTY SAND(SM-SC),lt.br.,f.g./tr. m.g., sli.pl.	52	
880.8	SM	SILTY SAND(SM),lt.br., f. to c.g.,f. GRAVEL/num.SS. frags., v.sli.pl.	38	

SIZE 6" & 4"   PROJECT LEESVILL LAKE, OHIO   SHEET 1 OF 2 SHEETS

CONTD.
W-4

ELEV.	SYM.	CLASSIFICATION	BLOWS	REMARKS
880.8				
876.8	CL	SANDY CLAY (CL), br.gr., SAND f. to c.g., GRAVEL f. & c./SS. frags., low pl.	39 39	
874.8	SC	CLAYEY SAND (SC), gr.br., f. to c.g., GRAVEL f. to c. (mos. SS. frags.), low pl.	52	
872.8	SC	GRAVELLY CLAYEY SAND (SC) br.gr., f. to c.g., GRAVEL f. to c. (mos. SS.), low pl.	72	
870.8	SM	SILTY SAND (SM), dk.br., f. to m./tr.c., GRAVEL f. (mos. SS. frags), v.sli.pl.	82	
868.8	SC	CLAYEY SAND (SC), br., f. to c.g., tr. f. & c. GRAVEL & SS. frags., low pl.	72	
868.4	NS	NO SAMPLE	300	
		Bottom of Hole		

SIZE 4" | PROJECT LEESVILLE LAKE, OHIO | SHEET 2 OF 2 SHEETS

HOLE NO.
W - 5

DATE 15 Mar. 76 N. ______

ELEV. 931.3 DIRECTION Vertical E. ______

ELEV.	SYM	CLASSIFICATION	BLOWS	REMARKS
931.3				
	SP	GRAVELLY SAND(SP), br., f. to c.g., GRAVEL f. to c.	71	Sampler: 6" Barrel 900# Hammer 30" Drop
925.3			72	SEEPAGE BLANKET FROM TOP OF GROUND TO EL. 925.3
		ROCK TOE - SANDSTONE COBBLES & BOULDERS	69	
			78	Changed to 4" Barrel
919.3			110	
917.3	GP	SANDY GRAVEL(GP),br.,SAND f. to c.g., GRAVEL c. to f.	87	
915.3	GM	SILTY SANDY GRAVEL(GM), br., c. & f., SAND f. to c.g.	82	
913.3	GP-GM	SANDY GRAVEL(GP-GM), br., f. & c., SAND f. to c.g.	57	
911.3	SP	GRAVELLY SAND(SP), br., f. to m.g./ tr. c., GRAVEL f., so. org. mat.	52	
909.3	SM	GRAVELLY SILTY SAND(SM), br., f.g., GRAVEL f.	42	
907.3	SM	SILTY GRAVELLY SAND(SM), br., f. to c g., GRAVEL f. & c., non. pl.	27	
905.3	SP-SM	SILTY GRAVELLY SAND(SM-SP), br., f. to c.g., GRAVEL f. & c.	52	
903.3	SM	SILTY SAND(SM), br., f.g./tr. m. & c., tr. f. GRAVEL	56	
	SM	SILTY SAND (SM), br., f. to c. g., f. GRAVEL size frags.	62	
			72	
897.3			72	
895.3	SM-SP	SILTY SAND (SM-SP), br., f. to m.g., GRAVEL f. & c./num.SS. frags.	68	
893.3	SM-SC	SILTY SAND (SM-SC), br., f. to c.g., f. GRAVEL	72	
891.3	SC	GRAVELLY CLAYEY SAND (SC), br., f. to c.g., GRAVEL f.& c., low pl. CLAY	68	
	SC	CLAYEY SAND (SC), br., f. to c.g., GRAVEL f. & c., low pl.	167	
887.3			117	
885.3	SC	CLAYEY SAND (SC), br., f.g./so.m. & c., tr. GRAVEL size SS. & SLS.frags.	175	
883.3	SC	CLAYEY SAND (SC), br., f. to c.g., num.f. GRAVEL size SS. frags.	172	
881.3	SC	CLAYEY SAND (SC), br., GRAVEL f. & c.	94	

SIZE 6" & 4" PROJECT LEESVILLE LAKE, OHIO SHEET 1 OF 2 SHEETS

CONTD.
W-5

ELEV.	SYM.	CLASSIFICATION	REMARKS (BLOWS)
881.3			
879.3	SM-SP	SILTY SAND(SM-SP),br., f. to c.g., f. GRAVEL-num. SS. frags.	62
875.3	SC-SM	CLAYEY SAND (SC-SM), br., f. to m. g., f. GRAVEL (mos. SS. frags.)	68 58
873.3	SC	CLAYEY SAND (SC), br., f. to m.g., f. GRAVEL (mos. SS. frags.)	62
871.3	SM	SILTY SAND (SM), br., f. to m.g.,/tr c., GRAVEL f./SLS. & SS. frags.	58
865.3	SC	CLAYEY SAND (SC), lt. br., f. to m.g., /tr.c., GRAVEL f. & c./so.wd. frags., low pl.	59 58 71
863.3	SC	CLAYEY SAND (SC), mot.lt.br. & gr.,f. to m.g., f.GRAVEL size SS. frags.	86
862.8	SM-SC	SILTY SAND (SM-SC),gr. & tan, f.g., /tr. c. & m.g., GRAVEL size SH. frags., wd., las./tr mica	300

Bottom of Hole

SIZE 4" | PROJECT LEESVILLE LAKE, OHIO | SHEET 2 OF 2 SHEETS

HOLE NO.
W - 6

DATE 9 Feb. 76 N. ______

ELEV. 931.2 DIRECTION Vertical E. ______

ELEV.	SYM	CLASSIFICATION	BLOWS	REMARKS
931.2				
	SP	GRAVELLY SAND(SP), br., f. to c. g., GRAVEL f. & c.	22	Sampler: 6" Barrel 900# Hammer 30" Drop
925.2			48	SEEPAGE BLANKET FROM TOP OF GROUND TO EL. 925.2
		ROCK TOE - SANDSTONE COBBLES & BOULDERS	85	
			128	Changed to 4" Barrel
			118	
917.2			128	
915.2	SP	SAND (SP), br., f. to c.g., GRAVEL f. & c./few SS. frags.	12	
913.2	SC	CLAYEY GRAVELLY SAND (SC), f. to c.g./few SS. frags.	42	
911.2	SP	GRAVELLY SAND (SP), br., f. to c.g., GRAVEL f. & c.	24	
909.2	SM-SP	SILTY GRAVELLY SAND (SM-SP), br., f. to c.g., GRAVEL f. & c., wd.	22	
	SP-SM	GRAVELLY SAND (SP-SM), br., f. to c. g., GRAVEL f. & c.	22	
905.2			22	
	SM	SILTY GRAVELLY SAND (SM), br., f. to c.g., GRAVEL f. & c.	60	
901.2			70	
	SM-SP	SILTY GRAVELLY SAND (SM-SP), br., f. to c.g., GRAVEL f. & c.	48	
897.2			48	
	SM-SP	SILTY GRAVELLY SAND (SM-SP), br., f. to c.g., GRAVEL f. & c.	42	
			55	
891.2			65	
889.2	SC	CLAYEY GRAVELLY SAND (SC), br., f. to c.g., GRAVEL f. & c.	55	
887.2	SM-SP	SILTY GRAVELLY SAND (SM-SP), br., f. to c.g., GRAVEL f. & c.	56	
	SM	SILTY GRAVELLY SAND (SM), br., f. to c. g., GRAVEL f. & c.	68	
			77	
881.2			78	

SIZE 6" & 4" PROJECT LEESVILLE LAKE, OHIO SHEET 1 OF 2 SHEETS

CONTD.
W-6

ELEV.	SYM.	CLASSIFICATION	BLOWS	REMARKS
881.2				
875.2	SM-SP	SILTY GRAVELLY SAND(SM-SP), br., f. to c.g., GRAVEL f. & c., tr. CLAY	72 69 67	
873.2	SM	SILTY GRAVELLY SAND (SM), br., f. to c.g., GRAVEL f. & c.	54	
871.2	SM-SP	SILTY GRAVELLY SAND (SM-SP), br., f. to m.g./tr.c., GRAVEL f. & c.	58	
869.2	SM	SILTY GRAVELLY SAND (SM), br., f. to c.g., GRAVEL f. & c.	72	
865.2	SM-SC	SILTY SAND (SM-SC), br., f. to c.g., GRAVEL f. & c.	49 66	
863.2	SM	SILTY SAND (SM), br., f. to c.g., so. sm. GRAVEL & frags.	68	
861.2	SM	SILTY SAND (SM), br., f. to c.g./tr. of c. & f. GRAVEL	40	
859.2	SM	GRAVELLY SILTY SAND (SM), br., f. to m.g., GRAVEL f. & c.	54	
857.2	SC	CLAYEY SAND (SC), br., f. to m.g., so. GRAVEL(mos.frags)/tr. of SILT	44	
855.2	SM-SC	GRAVELLY SILTY SAND(SM-SC), br., f. to c.g., GRAVEL f. & c./SS.& SH.frags	315	
		Bottom of Hole		

SIZE 4"	PROJECT LEESVILLE LAKE, OHIO	SHEET 2 OF 2 SHEETS

HOLE NO.
W-7

DATE 12 Mar 76 N. ______

ELEV. 931.2 DIRECTION Vertical E. ______

ELEV	SYM	CLASSIFICATION	BLOWS	REMARKS
931.2				
	GP-GM	SANDY GRAVEL(GP-GM), lt.br., c. to f.g./tr. of SS. frags. f. to c.g. SAND	62	Sampler: 6" Barrel Hammer: 900# Drop: 30"
925.2			64	SEEPAGE BLANKET FROM TOP OF GROUND TO EL. 921.2
923.2	GM	SILTY SANDY GRAVEL(GM),lt.br.,c.to f.g.,f.to c.g.SAND (mos.SS.frags.)	64	
		ROCK TOE - SANDSTONE COBBLES AND BOULDERS	114	Changed to 4" Barrel
			175	
917.2			42	
	SM	GRAVELLY SILTY SAND(SM),gr.br., f. to c.g.,f.g. GRAVEL/tr. SS. frags.	32	
913.2			36	
911.2	SM	SILTY GRAVELLY SAND(SM),lt.br.,f.to c.g.SAND,f.to c.g.GRAVEL/tr.SS frags	34	
909.2	SC	GRAVELLY CLAYEY SAND(SC),dk.gr.f. to c.g.,f.to c.g.GRAVEL/tr.SS.frags.	19	
	SM	SILTY GRAVELLY SAND(SM),gr.br. f.to c.g., f.to c.g. GRAVEL/num. SS. frags.	24	
905.2			38	
903.2	SM	SILTY SAND(SM),lt.br.,f.to c.g./num. SS. frags./f.GRAVEL	48	
	SM	SILTY GRAVELLY SAND(SM),lt.br. f. to c.g., f. to c.g.GRAVEL/num. SS. frags.	28	
			44	
897.2			44	
895.2	SM	SILTY SAND(SM),lt.br., f.to c.g., f.to c.g. GRAVEL/num.SS. frags.	46	
893.2	SM	GRAVELLY SILTY SAND(SM),lt.br., f. to c.g., f.to c.g.GRAVEL/num.SS.frags	48	
891.2	SM	SILTY GRAVELLY SAND(SM),gr.br. f. to c.g., f.to c.g.GRAVEL/num.SS.frags.	53	
889.2	SM	SILTY SAND(SM),gr.br.,f.to c.g.,f. to c.g.GRAVEL/num.SS. frags.	104	
887.2	SM	SILTY SAND(SM),dk.br., f. to c.g./tr f. GRAVEL	120	
885.2	SM	GRAVELLY SILTY SAND(SM), gr.br. f. to c.g., f. to c.g.GRAVEL(mos.SS. frags.)	60	
883.2	SM	SILTY GRAVELLY SAND(SM),gr.br.,f.to c.g.GRAVEL(mos.SS.frags.)	87	
881.2	SM	SILTY GRAVELLY SAND(SM),dk.br.	46	

SIZE 6" & 4" PROJECT LEESVILLE LAKE, OHIO SHEET 1 OF 2 SHEETS

CONTD.
W-7

ELEV.	SYM.	CLASSIFICATION	BLOWS	REMARKS
881.2				
879.2		f.to c.g., f.to c.g. GRAVEL/tr. SS. frags.	52	
875.2	SM-SW	SILTY GRAVELLY SAND(SM-SP), dk.br., f. to c.g., f. to c.g.GRAVEL /so SS frags.	48 58	
873.2	SM	SILTY SAND(SM),dk.br.,f. to c.g./ f. to c.g.GRAVEL/num.SS. frags.	62	
869.2	SM	GRAVELLY SILTY SAND (SM), dk. br. f. to c.g., f. to c.g. GRAVEL/num. SS. frags.	78 118	
965.2	SM	SILTY GRAVELLY SAND(SM), br. f. to c.g., f. to c.g. GRAVEL (mos. SS. frags.)	125 200	
863.2	SM	SILTY SAND(SM),lt.br.,f.to c.g.,f.to c.g. GRAVEL(mos.SS.frags.)	68	
861.2	SM	SILTY GRAVELLY SAND(SM),lt.br.,f.to c.g.,f.to c.g.GRAVEL/num.SS.frags.	41	
859.2	SM-SP	SILTY GRAVELLY SAND(SM-SP), lt.br., f.to c.g.,f.to c.g.GRAVEL/num.SS.frags	38	
857.2	SM	GRAVELLY SILTY SAND(SM),gr.br.,f.to c.g.,f.to c.g.GRAVEL/num.SS.frags.	300	
853.2	SM	SILTY SAND(SM),gr.br.,f.to c.g., f. to c.g. GRAVEL/num.SS.frags.	72 75	
851.2	SM	SILTY GRAVELLY SAND(SM),gr.br.f.to c.g.,f. to c.g.GRAVEL/num.SS.frags.	80	
849.2	SC	GRAVELLY CLAYEY SAND(SC),gr.br.f. to c.g.,f.to s.g.GRAVEL(mos.SS.frags.)	275	
848.9		SHALE, gr.h.	300	
		Bottom of Hole		

SIZE 6"& 4"	PROJECT LFESVILLE LAKE, OHIO	SHEET 2 OF 2 SHEETS

HOLE NO.
W-8

DATE 30 Jan 76 N. ________

ELEV. 931.4 DIRECTION Vertical E. ________

ELEV	SYM	CLASSIFICATION	BLOWS	REMARKS
931.4				
927.4	NS	NO SAMPLE		Sampler: 6" Barrel Hammer: 900# Drop: 30"
925.4	GP-GM	SANDY GRAVEL (GP-GM), dk.br.	72	SEEPAGE BLANKET FROM TOP OF GROUND TO EL. 925.4
923.4		ROCK TOE-SANDSTONE COBBLES AND BOULDERS	68	
921.4	GC	CLAYEY SANDY GRAVEL(GC),gr.br.,f.to c.g.,f.toc.g.SAND/so.SS.frags.	76	Changed to 4" Barrel
917.4	GM-GP	SILTY SANDY GRAVEL(GM-GP), lt. br. f.to c.g.,f.to c.g. SAND/tr. SS. frags.	50 112	
915.4	SP-SM	SAND(SP-SM),lt.br.,f. to c.g.,/f.to c.g. GRAVEL & num. SS. frags.	88	
913.4	CL	GRAVELLY SANDY CLAY(CL),br.gr.,f.to c.g.,f.to c.g.GRAVEL/mos.SS. frags.	72	
911.4	GM	SILTY SANDY GRAVEL(GM),dk.br.,f. to c.g.,f.to c.g.SAND(mos.SS.frags.)	87	
909.4	SM	SILTY SAND(SM),dk.br.,f.to c.g./ f. to c.g.GRAVEL & tr.SS. frags.	24	
907.4	SM	GRAVELLY SILTY SAND(SM),dk.br. f.to c.g., f. to c.g.GRAVELLY/tr.SS.frags.	30	
905.4	SM	SILTY SAND(SM),gr.br.,f.to c.g.,/ f.GRAVEL (mos.SS.frags.)	72	
901.4	SM-SC	SILTY SAND(SM-SC), gr.br., f. to c.g./f. GRAVEL & num.SS. frags.	48 68	
897.4	SM	SILTY SAND(SM), dk.br.,f. to c.g. /f.to c.g. GRAVEL(mos.SS.frags.)	48 46	
895.4	SM	SILTY SAND(SM), dk.br.,f. to c.g./ f. to c.g.GRAVEL & num.SS. frags.	42	
893.4	SM	SILTY GRAVELLY SAND(SM),dk.br. f.to c.g.,f.to c.g.GRAVEL(mos.SS.frags:)	46	
891.4	SM	GRAVELLY SILTY SAND(SM),dk.br. f.to c.g.,f.to c.g.GRAVEL(mos.SS.frags.)	48	
889.4	SM	SILTY GRAVELLY SAND(SM),dk.br. f.to c.g.,f.to c.g.GRAVEL(mos. SS frags.)	46	
887.4	SM-SP	SILTY GRAVELLY SAND(SM-SP),dk.br.f. to c.g.,f.& c.g.GRAVEL(mos.SS.frags.)	54	
885.4	SM	SILTY GRAVELLY SAND(SM),dk.br.f.to c.g.,f.& c.g.GRAVEL/num.SS.frags.	58	
883.4	SM-SP	SILTY GRAVELLY SAND(SM-SP),lt.br. f. to c.g., f.& c.g.GRAVEL(mos.SS.frags)	52	
881.4	SM	SILTY GRAVELLY SAND(SM),lt.br.,f.to c.g.,f.& c.g.GRAVEL(so.SS.frags.)	54	

SIZE 6"& 4" PROJECT LEESVILLE LAKE, OHIO SHEET 1 OF 2 SHEETS

CONTD.
W-8

ELEV.	SYM.	CLASSIFICATION	BLOWS	REMARKS
881.4				
879.4	SM-SP	SILTY GRAVELLY SAND(SM-SP),lt.br.,f. to c.g.,f. & c.g.GRAVEL(mos.SS.frags)	60	
871.4	SM	SILTY GRAVELLY SAND,(SM), br. f. to c.g., f. & c.g.GRAVEL/ num. SS. frags.	49 145 142 225	
867.4	SM	SILTY GRAVELLY SAND, dk. br. f. to c.g., f.g. GRAVEL/num. SS. frags.	186 185	
865.4	SM	GRAVELLY SILTY SAND(SM), dk.br. f.to c.g.,f.& c.g.GRAVEL/num.SS.frags	182	
863.4	SM	SILTY SAND(SM),dk.br.,f.to c.g.,f.& c.g.GRAVEL (so.SS.frags.)	152	
861.4	SM	SILTY GRAVELLY SAND(SM), dk.gr., c. to c.g., f.& c.g.GRAVEL(so.SS.frags.)	145	
859.4	SM	SILTY SAND(SM), dk.br.f.to c.g., f.& c.g.GRAVEL(so.SS.frags.)	58	
857.4	SM	SILTY GRAVELLY SAND(SM),dk.br.,f.to c.g.,f.& c.g.GRAVEL(so.SS.frags.)	116	
853.4	SM	SILTY SAND(SM),gr.br.,f.to c.g., f.& c.g. GRAVEL,(so.SS.frags.)	108 116	
851.4	SM	SILTY SAND(SM),dk.br.,f.to c.g., f. & c.g.GRAVEL (so.SS.frags.)	118	
849.4	SC	CLAYEY SAND(SC),gr.br.,f.to c.g./tr. f.& c.g.GRAVEL(so.SS.frags.)	180	
847.4	CL	SANDY CLAY(CL),dk.gr.,f. to c.g.SAND/ tr. f.& c.g.GRAVEL(mos.SS.frags)	330	
		Bottom of Hole		

SIZE 6"& 4" | PROJECT LEESVILLE LAKE, OHIO | SHEET 2 OF 2 SHEETS

HOLE NO.
W - 9

DATE 24 Mar. 76 N. ______

ELEV. 931.1 DIRECTION Vertical E. ______

ELEV	SYM	CLASSIFICATION	BLOWS	REMARKS
931.1				
929.1	NS	NO SAMPLE	-	Sampler: 6" Barrel Hammer: 1800# Drop: 24"
925.1	SP	GRAVELLY SAND (SP), br., f. to c.g., f. & c.g. GRAVEL	6 23	
923.1	GP	SANDY GRAVEL (GP), br., f. & c.g., c. to f.g. SAND	21	SEEPAGE BLANKET FROM TOP OF GROUND TO EL. 923.1
921.1	SP-SM	GRAVELLY SAND (SP-SM), br., c. to f.g., c. & f.g. GRAVEL	28	RIPRAP PRESENT BUT NOT NOTED ON FIELD LOG
919.1	GC-GP	CLAYEY SANDY GRAVEL (GC-GP), br., c. & f.g. GRAVEL, c. to f.g. SAND	47	
917.1	SP-SM	GRAVELLY SAND (SP-SM), br., f. to c.g. f. & c.g. GRAVEL	38	
915.1	SP	GRAVELLY SAND (SP), br., f. to c.g., f. to c.g. GRAVEL	17	
913.1	SP-SM	GRAVELLY SAND(SP-SM), br., f. to c.g., f. to c.g. GRAVEL	38	
911.1	SM-SP	SILTY GRAVELLY SAND(SM-SP), br., f. to c.g., f. & c.g. GRAVEL	60	
909.1	SP	GRAVELLY SAND(SP), br.f. to c.g., f. & c.g. GRAVEL	21	
907.1	GP	SANDY GRAVEL(GP), br., f. & c.g., f. to c.g. SAND	33	
905.1	SC	CLAYEY GRAVELLY SAND(SC), br., f. to c.g., f. & c.g. GRAVEL	34	
903.1	GM-GP	CLAYEY SANDY GRAVEL (GM-GP), br. f. & c.g., f. to c.g. SAND	29	
901.1	SC	CLAYEY GRAVELLY SAND (SC), br., f. to c.g., f. & c.g. GRAVEL	17	
897.1	SC	CLAYEY SAND(SC), br., f. to c.g. SAND/f. & c.g. GRAVEL, few frags.	9 23	
893.1	SM-SC	SILTY SAND (SM-SC), br., f. to c.g. SAND/f. & c.g. GRAVEL frags. @ 34.0'	19 29	
889.1	SM	SILTY SAND (SM), br. f. to c.g./ f. & c.g. GRAVEL	10 28	
885.1	SM-SC	SILTY SAND (SM-SC), br., f. to c.g. /f. & c.g. GRAVEL	20 32	
881.1	SC	CLAYEY SAND (SC), br., f. to c.g. f. & c.g. GRAVEL	49 16	

SIZE 6" & 4" PROJECT LEESVILLE LAKE, OHIO SHEET 1 OF 2 SHEETS

CONTD.
W-9

ELEV.	SYM	CLASSIFICATION	BLOWS	REMARKS
881.1				
879.1	SM	GRAVELLY SILTY SAND(SM), br. f. to c. g./num.frags.	19	
873.1	SC	CLAYEY SAND (SC), br., f. to c.g. /num. frags.	31 89 119	
871.1	NS	NO SAMPLE	-	
869.1	SC	GRAVELLY CLAYEY SAND(SC), br. f.g. to c.g., f. & c.g. GRAVEL	21	
865.1	SC	CLAYEY SAND (SC), br., f. to c.g. f. & c.g. GRAVEL	100 142	
863.1	SC	GRAVELLY CLAYEY SAND (SC), br. f. to c.g., f. & c.g. GRAVEL	178	
853.1	SC	CLAYEY SAND (SC), br., f. to c.g., f. & c.g. GRAVEL/tr. wood frags. @ 68.0'/frags. @ 68.0' & 70.0'	185 147 47 65 66	
847.1	SC	GRAVELLY CLAYEY SAND (SC), br. f. to c.g., f. & c.g. GRAVEL	69 86 112	
843.1	SC	CLAYEY SAND (SC), br. f. to c.g. /f. & c.g. GRAVEL	120 255	
		Bottom of Hole		

SIZE 6" & 4" PROJECT LEESVILLE LAKE, OHIO SHEET 2 OF 2 SHEETS

HOLE NO.
W - 10

DATE 4 Mar 76 | N. ______
ELEV. 931.7 | DIRECTION Vertical | E. ______

ELEV	SYM	CLASSIFICATION	BLOWS	REMARKS
931.7				
929.7	NS	NO SAMPLE	0	Sampler: 6" Barrel Hammer: 900# Drop: 30"
927.7	SP	GRAVELLY SAND(SP), br., f. to c.g., c. to c.g. GRAVEL	0	
925.7	NS	NO SAMPLE	72	SEEPAGE BLANKET FROM TOP OF GROUND TO EL. 925.7
		ROCK TOE - SANDSTONE COBBLES & BOULDERS	100	
			137	Changed to 4" Drive BBL
919.7			162	
917.7	GP	SANDY GRAVEL (GP), br., f. to c.g. f. to c.g. sand/SS. frags	78	
915.7	SP-SM	GRAVELLY SAND (SP-SM), br. f. to c.g./SS. frags.	72	
913.7	SM-SP	SILTY GRAVELLY SAND (SM-SP), lt.br. f. to c.g., f. & c.g. GRAVEL	75	
911.7	SC	CLAYEY GRAVELLY SAND (SC), br.f. to c.g., f. to c.g. GRAVEL	38	
	SP-SC	GRAVELLY SAND (SP-SC), br. f. to c. g., f. to c.g. GRAVEL	34	
907.7			42	
905.7	SP-SM	GRAVELLY SAND (SP-SM), br. f. to c.g., f.g. GRAVEL/frags.	82	
903.7	SM	SILTY SAND, br., f. to c.g./ frags.	86	
901.7	SC	CLAYEY SAND (SC), br., f. to c.g. /f. to c. g. GRAVEL	72	
899.7	SM	SILTY SAND (SM), br., f. to c.g. /frags.	38	
897.7	SC	CLAYEY SAND (SC), br., f. to c.g. /ro. frags. wd.	49	
	SM	SILTY SAND (SM), br. f. to c. g.,/f. to c. g. GRAVEL /frags.	38	
			32	
			42	
			44	
			42	
			32	
883.7			37	
881.7	SC	CLAYEY SAND (SC), br., f. to c.g., f. to c.g. GRAVEL/frags.	58	

SIZE 6" & 4" | PROJECT LEESVILLE LAKE, OHIO | SHEET 1 OF 2 SHEETS

CONTD.
W - 10

ELEV.	SYM	CLASSIFICATION	BLOWS	REMARKS
881.7				
879.7	SM	SILTY SAND (SM), br., f. & c.g.,/ f. & c.g. GRAVEL & SS. frags.	78	
877.7	SM	SILTY SAND (SM), br., f. to c.g./ f.g. GRAVEL	106	
875.7	SP-SM	~~SILTY GRAVELLY SAND (SP-SM), br.~~	98	
873.7	SC	CLAYEY SAND (SC), br., f. to c.g.,/ f.g. GRAVEL & frags.	92	
869.7	SP-SM	SILTY GRAVELLY SAND (SP-SM), br.. f. to c.g. GRAVEL/frags. @ 58.0'/num. frags. @ 60.0'	89 108	
867.7	SM-SP	SILTY GRAVELLY SAND (SM-SP), br., f. to c.g., f. to c.g.GRAVEL/num. frags.	68	
863.7	SC	CLAYEY GRAVELLY SAND (SC), br. f. to c.g., f. to c.g. GRAVEL/tr. COAL @ 64.0'	108 72	
859.7	SP-SM	SILTY GRAVELLY SAND (SP-SM), br. f. to c.g., f. to c.g. GRAVEL/few frags.	46 62	
857.7	SM	SILTY SAND (SM), br., f. to c.g./ GRAVEL & frags.	66	
853.7	SC	GRAVELLY CLAYEY SAND (SC), br. f. to c.g., f. to c.g. GRAVEL & frags. wd.	90 92	
851.7	SC	CLAYEY SAND (SC), br., f. to c.g. (mos. f. num. frags).	102	
847.7	SC	GRAVELLY CLAYEY SAND (SC), br. f. to c.g., f. to c.g. GRAVEL/ frags. @ 80.0'	118 92	
845.7	SC	CLAYEY GRAVELLY SAND (SC), br.,f. to c.g., f. to c.g. GRAVEL/few frags.	200	
839.7	SC	GRAVELLY CLAYEY SAND (SC), br. f. to c.g., f. to c.g. GRAVEL/ frags.	215 225 302	
837.7	SM	SILTY GRAVELLY SAND (SM), br.,f. to c.g.,f. to c.g.GRAVEL/few frags.	235	
836.7	SC	GRAVELLY CLAYEY SAND (SC), br.,f.to c.g.,f.g. GRAVEL/frags.	325	
		Bottom of Hole		

SIZE 6" & 4" | PROJECT LEESVILLE LAKE, OHIO | SHEET 2 OF 2 SHEETS

HOLE NO.
W-11

DATE 1 Mar 76 N. ______

ELEV. 931.7 DIRECTION Vertical E. ______

ELEV	SYM	CLASSIFICATION	BLOWS	REMARKS
931.7				
925.7	SP	GRAVELLY SAND (SP), dk. br. f. to c.g., c. to f.g. GRAVEL/tr. SS. frags. (10% of SAMPLE DECAYED WOOD)	0 14 23	Sampler: 6" Barrel Hammer: 900# Drop: 30" SEEPAGE BLANKET FROM TOP OF GROUND TO EL. 923.7
923.7	GP-GM	SANDY GRAVEL(GP-GM), dk.br f.g. to c.g./tr.SS.frags.f. to c.g.SAND, rts	48	
919.7		ROCK TOE - SANDSTONE COBBLES AND BOULDERS	70 58	Changed to 4" Barrel
917.7	SM	GRAVELLY SILTY SAND(SM), gr.,f. to c.g., f.& c.g.GRAVEL/tr.SS. frags.	64	
915.7	SM-SC	SILTY SAND(SM-SC),gr.br., f.to c.g., f.g. GRAVEL/tr. SS. frags.	72	
913.7	SM	SILTY GRAVELLY SAND(SM),gr.br., f.to c.g., f.to c.g.GRAVEL/tr.SS.frags.	78	
911.7	SM	SILTY GRAVELLY SAND(SM), dk.br.,f.to c.g.,f. to c.g.GRAVEL/tr.SS.frags.	66	
907.7	SM	SILTY SAND(SM), gr.br.,f. to c.g./tr.f.to c.g.GRAVEL & so.SS. frags.	62 64	
905.7	SC-SM	CLAYEY SAND (SC-SM),br.gr., f. to c.g./tr. f.g. GRAVEL	66	
903.7	CL	SANDY CLAY(CL),br.,gr., f. to c.g. SAND/tr.f.to c.g. GRAVEL(mos.SS.frags)	68	
889.7	CL	SANDY CLAY (CL), dk. gr. f. to c.g. SAND, (mos. SS. frags @ 28.0') /c. to f. g. GRAVEL (mos. SS. frags. @ 32.0', 34.0') /tr. SS. frags. @ 36.0' (mos. SS. frags. @ 40.0')	62 64 72 74 64 62 110	
887.7	SC	CLAYEY SAND(SC),dk.gr., f.to c.g. /c.& f.GRAVEL (mos.SS. frags.)	80	
883.7	CL	SANDY CLAY (CL), dk. gr., f. to c.g. SAND,/f. & c.g. GRAVEL /tr. SS. frags. @ 44.0'	92 58	
881.7	CL	SANDY CLAY(CL),br.gr., f. to c.g.SAND (mos.SS. frags.)/f.g.GRAVEL	72	

SIZE 4" & 4" PROJECT LEESVILLE LAKE, OHIO SHEET 1 OF 2 SHEETS

CONTD.
W-11

ELEV	SYM	CLASSIFICATION	BLOWS	REMARKS
881.7				
879.7	CL	SANDY CLAY(CL), dk.gr.f.& c.g. SAND	76	
877.7	SC-SM	CLAYEY SAND(SC-SM),gr.br.,f.to c.g./ f.&c.g.GRAVEL(mos.SS. frags.)	66	
871.7	SM	SILTY SAND(SM),gr.br., f. to c.g. (mos. SS. frags. 54.0' to 58.0')/f.& c.g. GRAVEL 54.0'to 58.0'	68 72 72	
867.7	SM	SILTY SAND(SM), lt.br.f. to c.g. SAND/f.g.GRAVEL & tr. SS.frags.	72 77	
865.7	SM	SILTY SAND(SM), gr.br. f. to c.g. /tr. f. & c.g. GRAVEL & num.SS.frags	68	
861.7	SM	GRAVELLY SILTY SAND(SM), gr. br., f. to c.g.,f.& c.g.GRAVEL/ num.SS. frags. @ 68.0' & tr.SS.@66.0'	72 76	
857.7	SC	CLAYEY SAND(SC),br.gr. f to c.g. /f.& c.g.GRAVEL/num.SS.frags. @ 70.0'/tr.SS.frags.@ 72.0'	108 112	
855.7	NS	NO SAMPLE	172	
853.7	SC	CLAYEY SAND(SC), br.gr.,f. to c.g. /f.g. GRAVEL & tr. SS. frags.	170	
851.7	CL	SANDY CLAY(CL),br.gr. f. to c.g. SAND/f.to c.g.GRAVEL & tr.SS.frags.	257	
849.7	SC	CLAYEY SAND(SC), lt.gr.,f. to c.g. /f. to c.g.GRAVEL & num.SS. frags.	178	
846.4	SC	GRAVELLY CLAYEY SAND(SC), lt. gr., f. to c.g.SAND, f. to c.g. GRAVEL (mos. SS. frags. & wd. SH.)	112 225	
		Bottom of Hole		

SIZE 6"& 4" | PROJECT LEESVILLE LAKE, OHIO | SHEET 2 OF 2 SHEETS

HOLE NO.
W-12

DATE 19 Mar 76 N. ______

ELEV. 931.8 DIRECTION Vertical E. ______

ELEV.	SYM	CLASSIFICATION	BLOWS	REMARKS
931.8				
929.8	NS	NO SAMPLE	-	Sampler: 6" Barrel Hammer: 1800# Drop: 24"
925.8	SP	GRAVELLY SAND,(SP),br.,f.to c.g. f. & c.g. GRAVEL/tr.SILT @ 4.0'	5 10	SEEPAGE BLANKET FROM TOP OF GROUND TO EL. 923.8
923.8	GP	SANDY GRAVEL(GP), f. & c.g. f.to c.g. SAND	18	
921.8	GP-GM	SANDY GRAVEL(GP-GM), br., f.& c.g. f. to c.g.SAND	29	RIPRAP PRESENT BUT NOT NOTED ON FIELD LOG.
919.8	GM-GP	SILTY SANDY GRAVEL(GM-GP), br. c. & f.g. SS. frags. f.to c.g. SAND/few GRAVEL	38	
917.8	GP-GM	SANDY GRAVEL(GP-GM),br.f.to c.g. f. to c.g. SAND	46	
915.8	SM	SILTY GRAVELLY SAND(SM), br., f. to c.g., f. to c.g. GRAVEL	43	
913.8	GM-GP	SILTY SANDY GRAVEL(GM-GP), br.,f.g. f. to c.g. SAND/SS. frags.	38	
911.8	SM	SILTY GRAVELLY SAND(SM), br. f. to c.g.SAND, f. & c.g. GRAVEL	29	Changed to 4" Barrel
909.8	GP	SANDY GRAVEL(GP), br., f. to c.g., f. to c.g.SAND/few SS. frags.	26	
907.8	SM	SILTY GRAVELLY SAND(SM), br., f. to c.g., c.& f.g.GRAVEL/tr.bk.lignite	16	
905.8	SC	CLAYEY SAND(SC),br. f. to m.g. /so. f.g. GRAVEL	16	
903.8	SM	SILTY GRAVELLY SAND(SM), br. f. to m.g.,f.g. GRAVEL	21	
901.8	SM	SILTY SAND(SM), br., f. to m.g., /f.g. GRAVEL	19	
899.8	SM	SILTY GRAVELLY SAND(SM), lt.br. f. to c.g., c.& f.g. GRAVEL	58	
897.8	SM	SILTY SAND(SM)/tr.f.g.GRAVEL	25	
895.8	SM	SILTY SAND (SM),gr.,f. to m.g. /tr. f. SS. frags.	34	
893.8	SM	SILTY GRAVELLY SAND(SM),br.,f. to c.g., f.g. GRAVEL	38	
891.8	SM	GRAVELLY SILTY SAND (SM),gr. f. to c.g., f.g. GRAVEL	30	
889.8	CL	SANDY CLAY,(CL), br.,f.g. to c.g. SAND/tr. f. GRAVEL	98	
887.8	SC	CLAYEY SAND(SC) gr., f. to c.g. /GRAVEL f.g.& c.g.	106	
885.8		SHALE, gr., wd. to SILTY SAND, SAND f. to m.g./sevr. s,.rusty iron frags.	134	
		Bottom of Hole		

SIZE 6"& 4" PROJECT LEESVILLE LAKE, OHIO SHEET 1 OF 1 SHEETS

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