RESULTS OF

AQUIFER TESTS

IN SANDS OF THE POTOMAC GROUP

IN THE FRANKLIN AREA,

SOUTHEASTERN VIRGINIA

(1949 - 1950)

By

Allen Sinnott

U.S. GEOLOGICAL SURVEY OPEN-FILE REPORT

Prepared in cooperation with the Virginia ~~Division of Mineral~~ Geological Survey Resources

1968

Submitted 10/14/68 to closed file by Allen Sinnott. J Kaiser

Open file Feb. 1969

CONTENTS

	Manuscript page
Abstract	1
Introduction	3
Purpose and scope	3
Acknowledgments	5
Well numbers	6
Geographic setting	7
General geology and hydrology of the Franklin area	9
Deposits of the Potomac Group	10
Large-yield wells in the Franklin area	15
Definitions of the aquifer constants	20
Aquifer tests at Franklin	22
Introduction	22
Methods used	24
Distances between wells	25
Yield of pumped well	25
Brief descriptions of the tests	26
Case 1.--Recorder hydrograph: December 1945	27
Case 2.--Aquifer test: July 1949 (I)	30
Case 3.--Aquifer test: July 1949 (II)	33
Case 4.--Aquifer test: April 1950 (I)	35
Case 5.--Aquifer test: April 1950 (II)	38
Case 6.--Aquifer test: April 1950 (III)	41
Case 7.--Recorder hydrograph: October 1950 (I)	43
Case 8.--Recorder hydrograph: October 1950 (II)	47

CONTENTS--Continued

	Manuscript page
Summary and application of results	49
References	55
Appendix	57

ILLUSTRATIONS

Figure		Manuscript Page
1.	Map of eastern Virginia showing location of the Franklin area	8
2.	Graphic generalized geologic section at Franklin, Va., from data by J. R. McLane and Layne-Atlantic Company. (After Cederstrom, 1945, plate 32)	11
3.	Map of the Franklin area showing location of selected wells	12
4.	Diagrammatic section showing selected wells in the Franklin area, Southampton and Isle of Wight Counties, Va.	13
5.	Projected decline of water level in three wells in the Franklin area caused by pumping an additional industrial well	52

TABLES

		Manuscript Page
1.	Records of selected wells in the Franklin area, Southampton and Isle of Wight Counties, Virginia	14
2.	Summary of determinations of aquifer constants	50

RESULTS OF AQUIFER TESTS IN SANDS OF THE POTOMAC GROUP IN THE FRANKLIN AREA, SOUTHEASTERN VIRGINIA (1949 - 1950)

By

Allen Sinnott [1/]

Abstract

Two water wells of large yield were in operation at a pulp and paper mill in the town of Franklin, in southeastern Virginia, from late 1941 and early 1942 through 1950, when these wells together withdrew about 7,000,000 gallons of ground water per day, chiefly from sands of the Potomac Group of ~~Lower~~ Early Cretaceous age. That part of the group that occurs from about 250 to more than 800 feet below sea level in this area was tested in 1949 and 1950 to determine aquifer constants; the results of these tests are summarized.

The sands receive much of their ground water from rainwater and stream infiltration along the western edge of the Coastal Plain at the Fall Zone, where they crop out at the surface; also, a considerable amount of water probably is derived from vertical leakage through clays above and below the productive sands.

The operation of the wells at the paper mill was controlled
2 during a program of water-level measurements in order to evaluate the important aquifer constants, the coefficients of transmissibility and storage. Using the methods of Cooper and Jacob and of Theis, computations based on the data collected yielded coefficients of

1/ Geologist, U.S. Geological Survey.

2 transmissibility ranging from 144,000 to 425,100 gpd/ft (gallons per day per foot), and coefficients of storage ranging from 1.13×10^{-3} to 1.59×10^{-3}. These values were computed from measurements extending over periods of about 4 to 70 hours. Pending further studies, the values tentatively adopted as reasonable are 200,000 gpd/ft for the coefficient of transmissibility, and 1.4×10^{-3} for the coefficient of storage. These figures are considered to be representative for sands of the Potomac Group in this part of southeastern Virginia, for the depth range between about 230 feet and about 600 feet below sea level. They indicate that these sands have a relatively high transmissibility, ~~compared with other aquifers in the Virginia Coastal Plain.~~

INTRODUCTION

Purpose and scope

This report presents the results of quantitative tests of certain artesian sands in the vicinity of Franklin in southeastern Virginia. The work was undertaken in 1949 and 1950 by the U.S. Geological Survey, in cooperation with the Virginia Geological Survey (now the Virginia Division of Mineral Resources), as a part of a program of investigation of the ground-water conditions in Virginia. When the field tests were made, the program was under the general direction of the late A. Nelson Sayre, former Chief of the Branch of Ground Water of the Survey, and the late William M. McGill, former State Geologist. This report was prepared in 1968 under the general direction of George E. Ferguson, Regional Hydrologist, and J. Wyatt Gambrell, District Chief, Water Resources Division, U.S. Geological Survey; and Marvin M. Sutherland, Director, Virginia Department of Conservation and Economic Development, and James L. Calver, State Geologist and Commissioner of the Virginia Division of Mineral Resources.

The basic data for the tests were obtained by controlling the operation of one of two large-diameter wells at a large industrial plant--the pulp and paper mill operated by the Camp Manufacturing Company--and making measurements of the fluctuations of the water levels in these and other wells in the vicinity. Combined with other pertinent information, these measurements were used to compute certain aquifer constants--the coefficients of transmissibility and storage.

3

These aquifer constants are important for estimating the amount of decline in water level that would take place, after selected periods of time, caused by operation of additional wells in the area, and thus are of value in planning new developments involving additional withdrawals of ground water.

4 Important earlier studies include the geologic work of Clark and Miller (1912) and the ground-water reports by Sanford (1913) and Cederstrom (1945). The latter report is a detailed reconnaissance of that part of the Coastal Plain in Virginia that lies south of James River, and includes discussion of the Franklin area in considerable detail based on field studies carried on from 1937 to 1942.

Acknowledgments

The writer is indebted to William F. Guyton, formerly with the U.S. Geological Survey, who assisted in the organization of the tests in the field, and to Russell H. Brown and Robert W. Stallman of the Survey for advice on the methods for determining the results. G. Chase Tibbitts, Jr., then of the Charlottesville office of the Survey, assisted with the water-level measuring program. W. C. Coker, Chief Engineer for the Camp Manufacturing Company, R. E. L. Wheless, Chief Chemist, A. J. Sweitzer, Power Engineer, and E. T. Rogers, Associate Engineer, assisted in making arrangements for the tests. E. K. Nissen, R. F. Traver, and J. R. Sinclair, all with the Camp Manufacturing Company, assisted at various times with water-level measurements and with the operation of the water stage recorder on the observation well.

The writer also is indebted to the following town officials
5 who were imcumbent at the times the tests were made: E. N. Wilkinson, Town Manager of Franklin, C. H. Dougherty, Water Superintendent, and S. Malik, plant technician, for assisting in arrangements for the measurements of water levels in some of the municipal wells.

Mrs. Nauvoo M. Ragland of the Charlottesville office assisted in various ways with the preparation of the data for release.

Well numbers

In order to facilitate coordination with Cederstrom's (1945) Bulletin 63, published by the Virginia Geological Survey, the well numbers used in that report have been retained. Because the Franklin area lies on both sides of the Blackwater River, which is the boundary between Southampton and Isle of Wight Counties, the well numbers have been given appropriate prefixes, S- and IW- respectively. Additional information on the wells in this report, and on other wells in the vicinity of Franklin, may be found in Cederstrom's report in the chapters for each of these counties.

GEOGRAPHIC SETTING

The town of Franklin lies in the southeastern part of the Virginia Coastal Plain province, about 75 miles southeast of Richmond, 60 miles west of Virginia Beach, and about 10 miles north of the North Carolina-Virginia State boundary. (See Fig. 1.) Franklin is on the west bank of the Blackwater River, a tributary of the Chowan River, which is an important stream in northeastern North Carolina. Franklin proper is in Southampton County, but adjacent to it across the Blackwater is the East Franklin industrial district which lies in Isle of Wight County. The pulp and paper mill, where the tests described in this study were conducted, is in East Franklin.

During the early history of the area, the community was reached by water transportation from Albemarle Sound by way of the Chowan River. The Blackwater River is rarely used now locally for transportation, however, because Franklin is readily accessible by modern highways, by rail, and by air.

Figure 1.--Index map of eastern Virginia, showing location of the Franklin area in Southampton and Isle of Wight counties.

9a

GENERAL GEOLOGY AND HYDROLOGY OF THE FRANKLIN AREA

Most of the area is mantled by Pleistocene deposits, consisting of yellowish sands and clays of the Columbia Group. The upper surface of these deposits, modified somewhat by the effects of vegetation and by soil-forming processes, is the typical gently undulating surface characteristic of the Coastal Plain province.

The Pleistocene deposits furnish small supplies to domestic dug wells or driven wells. These wells are shallow, with maximum depths of about 30 feet. Except for iron from some of the wells, the quality is generally good, and the water is soft.

9b Underlying the Columbia Group are deposits of Miocene age. Although at least three formations have been distinguished in the Miocene section, they are not readily differentiated in drill cuttings in this area. They are thus here designated only as the Chesapeake Group. Cederstrom (1945, p. 228) notes that at Franklin the lower Miocene deposits consist of fairly tough blue clays containing a very little shell marl, but "higher in the section sandy marls seem to be characteristic." They are not important as sources

10a of ground water in this general area, although they furnish small supplies to a few wells. Water from the Miocene marl beds is likely to be hard because of the high proportion of shell fragments in them.

Underlying the Miocene deposits are sandy beds with characteristically abundant black glauconite. These deposits range in age from Paleocene through Late Eocene. The Paleocene through middle Eocene beds constitute the Pamunkey Group which in this area probably is represented entirely by the Aquia Formation of Paleocene age. The Pamunkey Group is only about 45 feet in thickness in the Franklin

area, and probably only a few wells derive water from these deposits. The quality of the ground water from the Pamunkey is likely to be generally good, and relatively soft.

Cederstrom assigns about 90 feet of the section penetrated by the deep well at the paper mill (IW-160) to the Upper Cretaceous. (See Figure 2.) On the basis of later published work by Cederstrom (1957, p. 17-21) the writer has assigned tentatively this part of the geologic column to the Mattaponi Formation, which Cederstrom named and described in the report cited. (See Figures 2 and 4 in the present report.) Although not tapped by the large industrial and municipal wells under discussion in this report, these deposits are locally water-bearing and may provide moderate supplies to a few wells.

Deposits of the Potomac Group

The principal water-bearing deposits in the Franklin area are the thick sands in the Potomac Group of Cretaceous age. The depth to the basement bedrock surface at Franklin is believed to be on the order of 1,500 feet (DeBuchananne, 1968, Sheet 1). Thus, the total thickness of the Potomac Group is probably at least 1,000 feet and may be more than 1,200 feet.

As of the early 1950's, four deep wells had been drilled in the Franklin area--one for the town, completed in 1944 (S-207-b) and three for the Camp Manufacturing Co. (IW-160, -161, and-162). (See figures 2, 3, and 4, and Table 1.) The deepest of these, Camp well no. 1, reached 800 feet in depth, or about 780 feet below sea level. (See generalized graphic log, figure 2, after Cederstrom, 1945, plate 32).

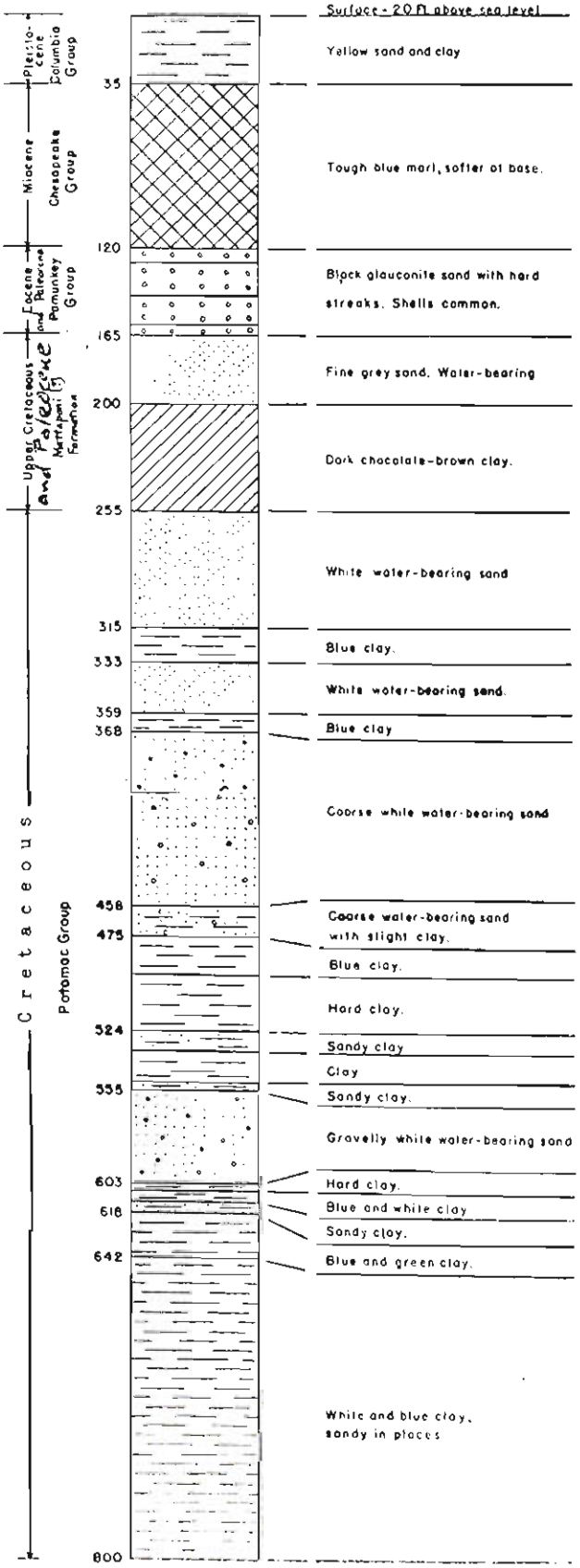


Fig. 2.— Graphic generalized geologic section at Franklin, Va.; from data by J. R. McLane and Layne-Atlantic Company.

(After Cederstrom, 1945, plate 32)

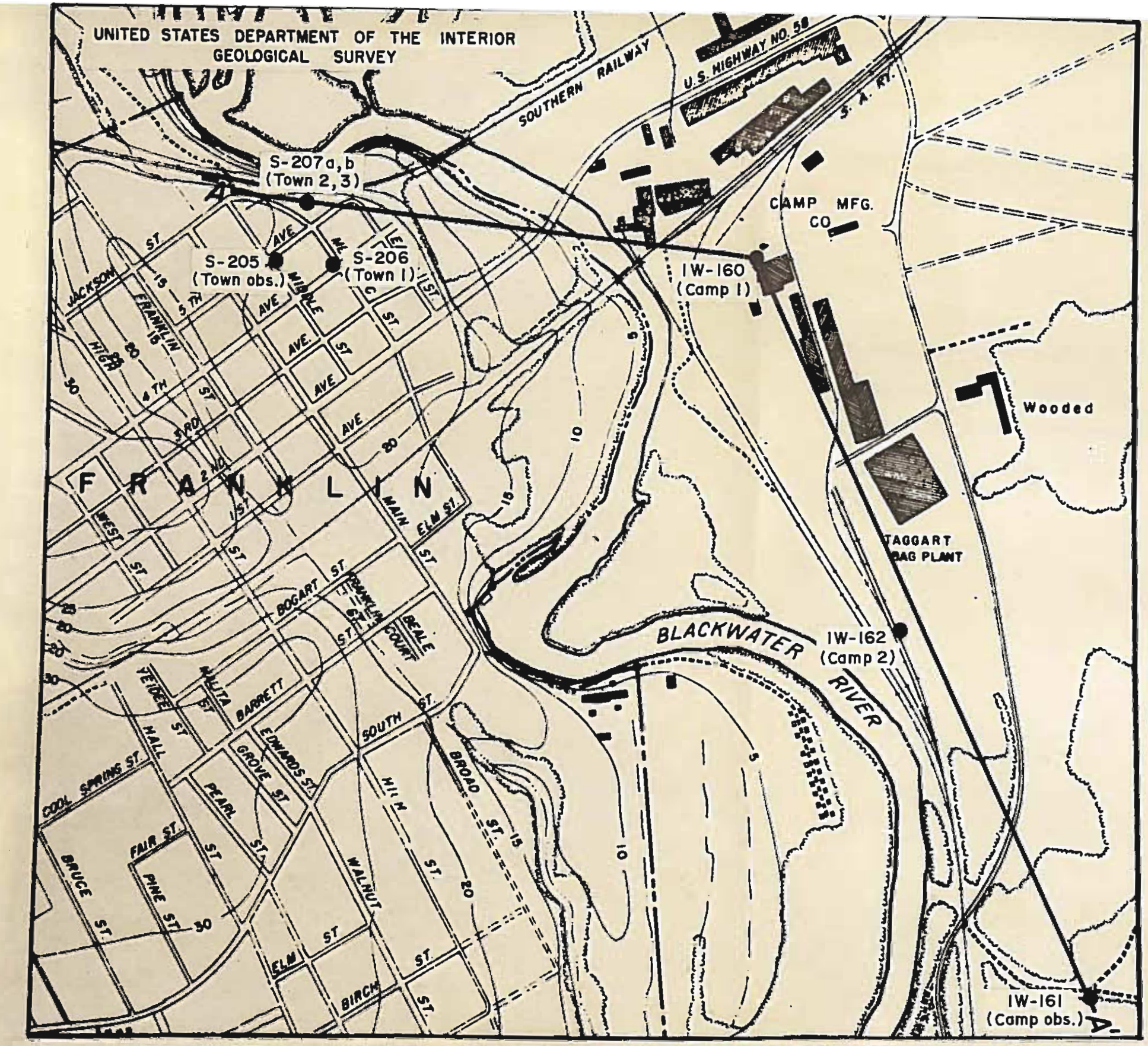


Figure 3.--MAP SHOWING LOCATIONS OF SELECTED WELLS IN THE FRANKLIN AREA AND THE LOCATION OF THE GEOLOGIC SECTION ON FIGURE 4.

600 0 600 1200 1800 2400 FEET

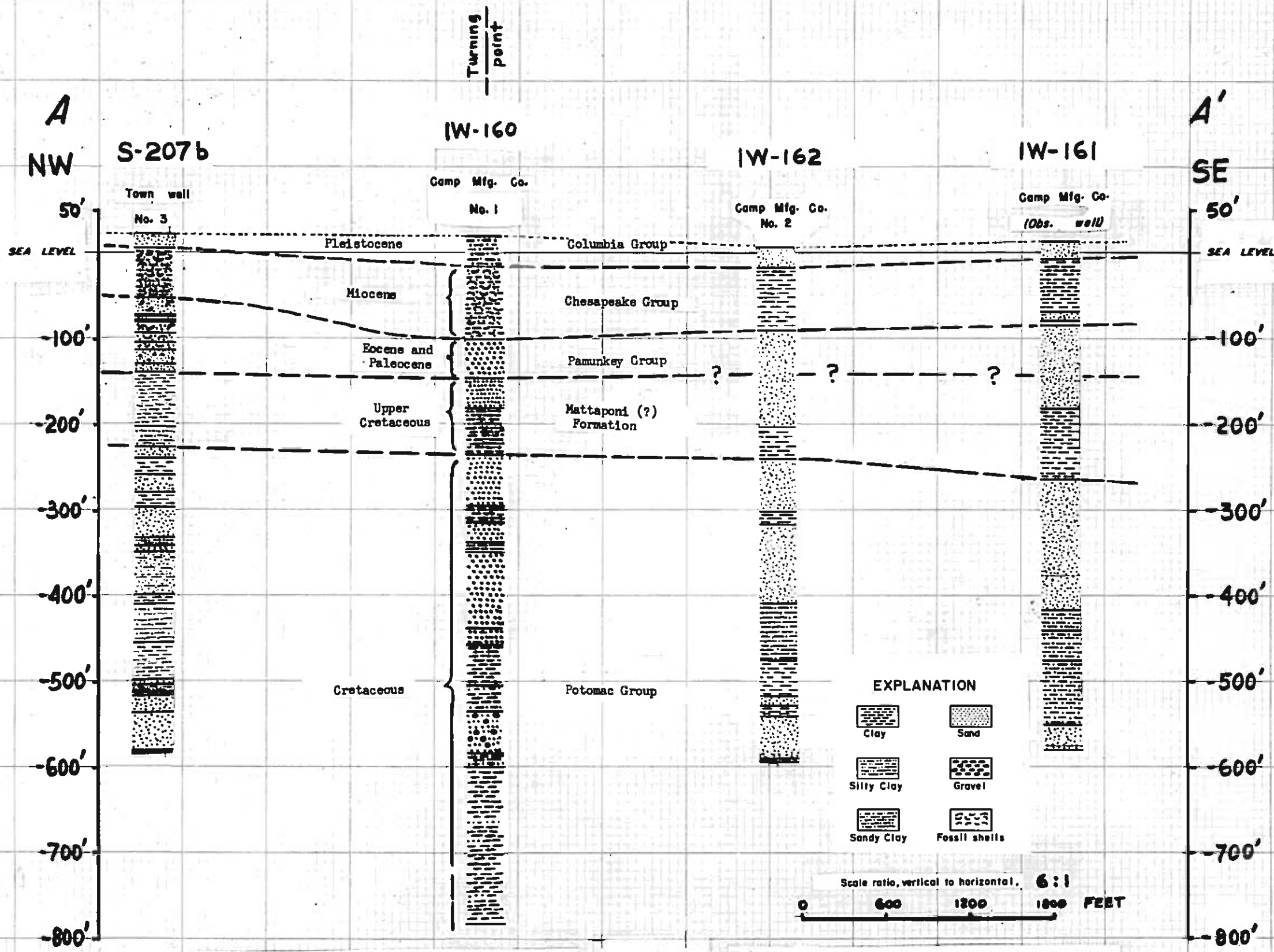


Fig. 4.-- DIAGRAMMATIC SECTION SHOWING SELECTED WELLS IN THE FRANKLIN AREA, SOUTHAMPTON AND ISLE OF WIGHT COUNTIES, VA.

Table 1.--Records of selected wells in the Franklin Area, Southampton and Isle of Wight Counties, Virginia

[Numbers are those used in Virginia Geological Survey Bulletin 63; prefixes have been added to identify the county in which well is located: S-, Southampton County; IW-, Isle of Wight County]

No.	Location	Owner or tenant	Driller	Year completed	Approximate altitude above sea level (feet)	Type of well	Depth of well (feet)	Diameter of well (inches)	Principal water-bearing zone: Geologic age	Principal water-bearing zone: Stratigraphic unit or named aquifer	Approximate water level above (+) or below (-) land surface (feet)	Approximate yield (gpm)	Use of water	Remarks	No.
S-205	Fifth Ave. and Middle St., Franklin	Town of Franklin	J. H. McLane	1930	21	J	354	[illegible]	Cretaceous	Potomac Group	(-)	—	Obs.	Town of Franklin, observation well	S-205
S-206	Fourth Ave. and Mechanic St., Franklin	Town of Franklin	Sydnor Pump & Well Co.	1931	21	[illegible]	364	10-8	Cretaceous	Potomac Group	(-)	1,000	PS	Town of Franklin, well no. 1	S-206
S-207a	Fifth Ave. and Mechanic St., Franklin	Town of Franklin	J. H. McLane	1935	21	[illegible]	339	6	Cretaceous	Potomac Group	(-)	—	PS	Town of Franklin, well no. 2	S-207a
S-207b	Fifth Ave. and Mechanic St., Franklin	Town of Franklin	Layne-Atlantic Co.	1944	21	[illegible]	604		Cretaceous	Potomac Group	(-)	1,650	PS	See log, p. 19. Town of Franklin, well no. 3. Used as a stand-by supply.	S-207b
IW-160	East Franklin, at pulp and paper mill	Camp Manufacturing	Layne-Atlantic Co.	1941	20[illegible]	[illegible]	800	18-10	Cretaceous	Potomac Group	(-)	2,000	Ind.	See graphic log, Figure 2, p. 11. Camp Mfg. Co., well no. 1. For construction details see Appendix (item 1).	IW-160
IW-161	do.	do.	do.	1941	15	[illegible]	405	[illegible]	Cretaceous	Potomac Group	(-)		Obs.	See log, p. 18. Used as observation well. For construction details, see Appendix (item 1).	IW-161
IW-162	do.	do.	do.	1941	6	[illegible]	410	18-10	Cretaceous	Potomac Group	(-)	2,100	Ind.	See log, p. 19. Camp Mfg. Co., well no. 2. For construction details, see Appendix (item 1).	IW-162

1/ Hm-- Drilled by hydraulic-rotary method
Dc-- Drilled by cable-tool method
J-- Drilled by jetting method

2/ PS-- Public supply well
Ind.-- Industrial supply well
Obs.-- Observation well

In the Franklin area, deposits of the upper 350 feet of the Potomac Group consist of several white sands, each 50 feet or more in thickness. They are generally coarse-textured, and yield ample supplies of ground water. Interbedded with these sands are blue clays.

Cederstrom (1945, p. 22-23) has ascribed the origin of the sediments of the Potomac Group to deltaic deposition. The character of the Virginia deposits is closely similar in internal structure to the sediments of the Mississippi delta region described by Russell and Russell (1939).

These upper water-bearing sands were the primary source of the ground water pumped at the pulp and paper mill at Franklin in the early 1950's, and the tests described in this report were made on wells tapping them.

Large-yield wells in the Franklin area

Cederstrom (op. cit., p. 276 ff.) also has discussed in some detail the large-yield wells at Franklin that tap this part of the Potomac Group. Because the hydraulic factors governing these wells are the subject of this report, portions of his description are quoted here as background information.

14b

"The Chesapeake-Camp Corporation mill at Franklin was built in 1937-38. It produces kraft paper from wood pulp. Large quantities of water were needed in the manufacture of paper, and for a time the water used was pumped from the near-by Blackwater River. However, during the drought which began in the spring of 1941, difficulties were encountered in the use of this supply. During low-water stages flow in Blackwater River was very small and not sufficient to carry downstream the waste liquids from the mill and, in fact; incoming tides would occasionally carry waste waters upstream. For a time it was necessary to bring water to the mill from Nottoway River (where it joined the Blackwater below Franklin) by barge.

15a "It was decided to drill large-diameter wells in the hope of alleviating this situation, and in November 1941 a test well was drilled by the hydraulic rotary method * * * to a depth of 800 feet. In addition to previously known water-bearing strata occurring above a depth of 367 feet * * *, thick sand strata between 367 and 603 feet were penetrated. A 107-foot thickness of permeable sand was found at from 368 to 475 feet and a 48-foot thickness at from 555 to 603 feet (Pl. 32). Sandy strata were absent from 603 to 800 feet."

Cederstrom's plate 32, referred to in the quotation above, is reproduced in this report, with certain modifications, as Figure 2. The details of construction of this well (IW-160) are shown in the drilling contractor's well log in the Appendix.

15 "A second large diameter well was constructed 2,200 feet south of the first well in December, 1941. A 35-foot thickness of sand at from 281 to 316 feet was not developed in the finished well. Deeper sands, a 93-foot thickness at from 330 to 423 feet, a 67-foot thickness of clayey sand at from 423 to 490 feet, an 11-foot stratum at from 531 to 542 feet and a 49-foot thickness at from 558 to 607 feet, were developed. * * * It proved to yield about as much water as the first well."

The yields from these two wells was more than 2,000 gpm (gallons per minute) each. Detailed specifications in the construction of the second well (IW-162) is given in the Appendix.

16 At Cederstrom's suggestion an observation well (IW-161) was constructed by the company. "Sands were penetrated at from 285 to 440 feet, and from 575 to 605 feet * * *." Details of its construction are shown on the driller's log in the Appendix.

"The well was completed with the casing extending 10 feet above the surface in order that the flow might be checked and to make possible the use of a water-level recorder activated by a float. When completed, the water stood inside the extended casing 6½ feet above the surface. * * * The rate of flow was about 10 gallons a minute.

"A platform and shelter were built, and a recorder was installed over the extended casing * * * and put into operation November 27, 1941. It has proved to be an excellent observation well and immediately sensitive to all changes in operation of wells 160 and 162 * * *."

The decline in the regional piezometric surface was great enough by about the mid-1950's that the Camp Manufacturing Co. lowered the recorder shelter so that the instrument could be serviced more conveniently at about ground level.

17 Logs of wells used in the aquifer tests described in this report are given in the following pages, except that for well IW-160, a generalized log for which has already appeared as figure 2.

Well IW-161, Camp Manufacturing Co., observation well
(Log by Layne-Atlantic Company)
Altitude, 15 feet

	Thickness (feet)	Depth (feet)
Fine white sand	20	20
Blue clay	63	83
Fine black sand	12	97
Rock	3	100
Fine black sand[a]	100	200
Blue clay	85	285
Medium to coarse sand, water	165	440
Clayey sand	25	465
Sandy clay	35	500
Hard sticky clay	75	575
Sand, water	30	605

[a]Black sand probably does not extend below about 150 feet. In drilling this stratum caved badly.

Well IW-162, Camp Manufacturing Co., well no. 2
(Log by Layne-Atlantic Company)
Altitude, 7 feet

	Thickness (feet)	Depth (feet)
White sand	25	25
Blue clay	75	100
Fine black sand[b]	116	216
Hard blue clay	65	281
Sand, water	35	326
Blue clay	14	330
Soft sand, water	93	423
Clayey sand; probably water bearing	67	490
Hard clay	41	531
Sand, water	11	542
Hard clay	16	558
Sand, water	49	607
Sandy clay	3	610

[b]Black sand probably does not extend below about 140 feet. In drilling this stratum caved badly.

Well S-207b, Town of Franklin,
municipal well no. 3

((Log[a] by D. J. Cederstrom, paleontological determinations by
H. G. Richards and J. A. Cushman)
Altitude, 20 feet

	Thickness (feet)	Depth (feet)
Columbia group (Pleistocene):		
Fine yellow sand	18	18
Chesapeake group (Miocene):		
Sandy gray marl, becoming shelly at 45 feet, dark olive-green at base	57	75
Aquia formation, Pamunkey Group (~~Eocene)~~ Paleocene):		
Marly black glauconite sand with subordinate shell; *Gryphacostrea vomer*	22	97
Rock	½	97½
Glauconite sand	3½	101
Rock	1	102
Marly glauconite sand, some shell; *Gryphacostrea vomer*, and *Rouvigerina excavata*, *Dentalina calei*, *Globorotalia wilcoxensis*, and numerous Naheola and Wilcox species of foraminifera	15	117
Fine marly glauconite; same fossils as above with *Spiroplectammina wilcoxensis*	11	128
Marly glauconite sand; same fossils as above with *Robulus midwayensis* and *Lamarckina limbata*	10	138
Small gravel and glauconite sand; very few foraminifera	16	154
Undifferentiated (Upper Cretaceous?):		
Fine glauconitic quartz sand, no shells	10	164
Dark gray micaceous clay, showing faint mottling in places; unfossiliferous	63	227
Dark-gray micaceous clay, becoming increasingly sandy with depth; unfossiliferous	23	250
Potomac group (Lower Cretaceous):		
Gray sand, medium texture but coarse at base, water	13	263
Light olive-green clay with brown and light-gray mottling	19	282
Gray sand, fine to medium texture, water	20	302
Mottled olive-green clay	18	320
Light-gray sand, medium texture, water	35	355
Dark clayey sand	15	365
Fine gray sand, water ?	8	373
Sand, varying in texture from coarse to small gravelly, alternating with thin clay streaks, water	50	423
Light-green hard clay	10	433
Sandy clay	14	477
White and blue mottled clay	73	520
Moderately coarse sand, water	5	525
Sandy blue clay	9	534
Blue clay	4	538
Fine sand, water	18	556
Moderately coarse sand, water	45	601
Black clay	3	604

[a]Well drilled by rotary method by Layne-Atlantic Co.

Note: The section assigned to the Upper Cretaceous (?) probably represents the Mattaponi Formation. See discussion in text. (The Mattaponi Formation now is assigned to the Upper Cretaceous and Paleocene Series.)

DEFINITIONS OF AQUIFER CONSTANTS

The aquifer constants determined during the tests described in this report are (1) the coefficient of transmissibility and (2) the coefficient of storage.

The coefficient of transmissibility, T, was introduced by Theis (1935), and is expressed as the rate of flow of water, at the prevailing water temperature, in gallons per day, through a vertical strip of the aquifer 1 foot wide extending the full saturated height of the aquifer under a hydraulic gradient of 100 percent. (A hydraulic gradient of 100 percent means a 1-foot drop in head in 1 foot of flow distance.) For further discussion of this coefficient, see Ferris and others (1962, p. 72-74); their definition of it is given above.

The coefficient of storage, S, is defined as the volume of water that an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface. (Ferris and others, 1962, p. 74.)

As the definition of this second coefficient is difficult to render in simple terms and yet maintain proper rigor, a few explanatory remarks will not be out of place here. They have been
21 adapted largely from Ferris and others (1962), to which the reader is referred for additional discussion of the concept.

In the Franklin area, the coefficient of storage may be visualized by considering the sands of the Potomac Group as a single aquifer that is essentially horizontal, of uniform thickness, and elastic in character. Decreasing the head or pressure of water in that aquifer will result in the release of some finite volume of water from storage that is proportional to the change in head. The volume of water released from storage in a vertical prism in the aquifer, divided by the product of the prism's cross-section area and the change in head caused by pumping, results in a dimensionless number which is the coefficient of storage--usually expressed as a decimal fraction.

22 Under artesian conditions, as is the case with the Potomac Group under discussion in this report, this coefficient is very small, because the aquifer remains filled with water during the fluctuations of the piezometric surface caused by pumping operations.

23 As already mentioned, these constants can be used to provide guides to well field development. Their application to a typical problem in the Franklin area is discussed in a later section.

AQUIFER TESTS AT FRANKLIN

Introduction

In the spring of 1949 it was learned that the Camp Manufacturing Company's pulp and paper mill was to be shut down "cold" for a period of about one week during the July 4 holiday, beginning about July 3. The large-yield wells at the mill (IW-160 and IW-162, fig. 3) were to be turned off on July 2, and arrangements were completed to make a series of pumping level and recovery measurements beginning about July 1. Only one of the two wells (IW-162) was to be turned off on July 2 for at least a reasonable time before the second well (IW-160) would be turned off; thus the effects of recovery caused by the first well could be measured at the observation well (IW-161). Although measurements were continued after the second well was turned off, they have not been used for determination of aquifer constants because of the complications involved and also because later arrangements were made during the following spring that allowed for additional tests to be conducted
25 in a manner that proved more satisfactory for the purpose.

In the spring of 1950 the second formal test was conducted by the writer by arranging with the Camp Manufacturing Co. to turn off well IW-162, affording an opportunity to obtain an extended series of measurements both at this well and at the observation well (IW-161).

In addition to these two formal aquifer tests, informal supplementary determinations were made from hydrographs obtained during the routine operation of the water-stage recorder on the observation well (IW-161). Information was furnished from time to

time by the engineering staff of the paper mill regarding the operation of the two production wells (IW-160 and IW-162) then in use. The reported time when one or the other of the wells was turned on or off was used in conjunction with the resulting drawdown or recovery as shown on the recorder hydrograph, resulting in an informal aquifer test. While in several respects this procedure is not as accurate as a formal controlled pumping test, by selecting for computation those occasions when relatively long periods of drawdown
26 or recovery occurred it was found that the results were in reasonable agreement with determinations made from the formal tests. Accordingly, they were regarded as essentially valid, and two such cases have been selected for inclusion in this report with those based on the formal tests. Each of these cases involved the operation of well IW-162.

Of these two cases the first was a period of recovery during early December, 1945. (See later description of Case 1.) The second was a period of drawdown during October, 1950. (See Cases 7 and 8.)

The remaining cases are based on the formal aquifer tests of 1949 (Cases 2 and 3), and 1950 (Cases 4, 5, and 6) in each of which more accurate times and water levels could be recorded during the test periods.

Methods used

Two principal methods were followed in analyzing the test results, (1) the non-equilibrium method developed by Theis (1935), and (2) the simplified modification of it developed by Cooper and Jacob (1946). Each of these methods has been fully described in many articles in the literature in addition to the
27 original papers cited above. Among these articles, Wenzel (1942) presents a good summary of the Theis non-equilibrium method in U.S. Geological Survey Water-Supply Paper 887 (p. 87 ff.), and Brown (1953) describes both the Theis method and that of Cooper and Jacob in a review article in the Journel of the American Water Works Association. Among other articles discussing these and other methods are those by Bruin and Hudson (1955), Ferris and others (1962), and Lang (1966).

Although these two methods are based on the same theoretical considerations, and thus the results should be essentially indentical, some subjective variation is involved in determining the best fit of the plotted data points with the type curve (Theis method), or in judging the best position for the straight line through the plotted data points (Cooper and Jacob method). By analyzing the results, using both methods where convenient, some of the subjective error
28 may be eliminated. Accordingly, as discussed later, reasonable values for the coefficients of transmissibility and storage were selected on the basis of the results of the several tests analyzed by either or both methods.

Distances between wells

For the computations in this report, the distances used are those determined by the writer from information available at the offices of the Camp Manufacturing Company at about the time the first of the two formal tests was conducted.

Subsequent study by the Camp engineering staff, made in connection with plans for increasing the number of wells in the Camp Co.'s well field, indicated that slight revisions should be made. In recent years the company (now the Union-Bag Camp-Paper Corporation) has done test drilling and has completed wells tapping water-bearing sands deeper than those for which information was available in the early 1950's. When the opportunity presents itself, additional quantitative tests in this area would be desirable. If this is done, the distances should be revised where necessary in order to insure the greatest possible validity of the results.

The distance (r) between Camp well no. 2 (IW-162) and the observation well in the Camp Co.'s well field, IW-161, is taken as 2,135 feet.

Yield of pumped well

The pumping rate, Q, for the Camp Co.'s production well no. 2 (IW-162) has been taken as 2,180 gallons per minute. It is used for the computations in this report given in the several Cases discussed in the following section. This pumping rate was furnished by Mr. W. C. Coker, the plant engineer, who made the determination volumetrically when the first formal test was conducted.

BRIEF DESCRIPTIONS OF THE TESTS

The results of the computations to determine preliminary values for the aquifer constants are presented briefly in this section. Each result is discussed as a separate case, with accompanying illustrations and tabulations, as appropriate.

Case 1.--Recorder hydrograph: December 1945

In December, 1945, well IW-162 (Camp well no. 2) was reported to have been shut off for more than 50 hours. The measurements of the recovery of water level at the observation well (IW-161) were taken from the chart on the Lietz recording gage installed at the well, and plotted on the semilogarthmic coordinate paper for solution by the Cooper and Jacob method. (See accompanying table and graph.)

The aquifer constants determined from this recovery record are as follows:

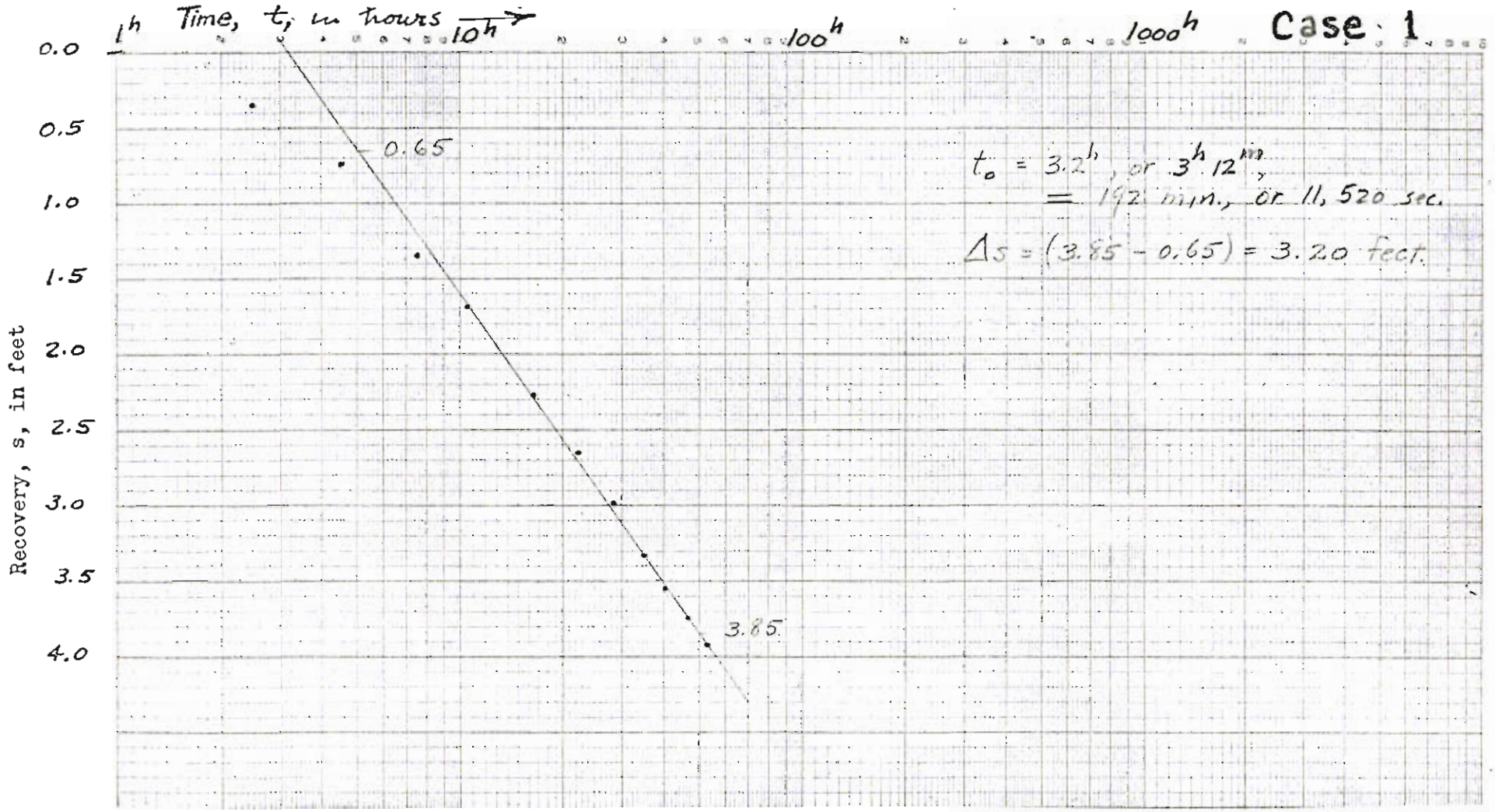
$$T = 178{,}200 \text{ gpd/ft}$$

$$\text{and} \quad S = 1.56 \times 10^{-3}$$

Water-level measurements (Case 1)

Pumping level (wells IW-160 and IW-162 in operation) assumed to have stabilized at 28.55 feet below measuring point. Pump on well IW-162 reported turned off at 7:30 a.m. December 1, 1945. Measurements are from chart, from Lietz recording gage maintained on observation well (IW-161).

Date 1945	Time	Depth to water, ft	Recovery, ft	Elapsed time
Dec. 1	7^h 30^m	28.55	--	0^h 00^m
	10 00	28.20	0.35	2 30
	12 00	27.81	.74	4 30
	15 00	27.20	1.35	7 30
	18 00	26.86	1.69	10 30
	24 00	26.27	2.28	16 30
Dec. 2	6 00	25.88	2.67	22 30
	12 00	25.56	2.99	28 30
	18 00	25.22	3.33	34 30
	24 00	25.01	3.54	40 30
Dec. 3	6 00	24.81	3.74	46 30
	12 00	24.63	3.92	52 30


Case: 1
Time, t, in hours
1h
10h
100h
1000h
Recovery, s, in feet
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
0.65
3.85
t_o = 3.2h, or 3h 12min,
= 192 min., or 11,520 sec.
Δs = (3.85 - 0.65) = 3.20 feet.

Case 2.--Aquifer test: July 1949 (I)

As discussed earlier, a formal test was conducted in the field in the summer of 1949 when the Camp Manufacturing Co. pulp and paper mill was shut down during the July 4 holiday period. The accompanying table presents the basic information collected at the observation well (IW-161) when Camp well no. 2 (IW-162) was turned off at the beginning of the shut-down early in the morning of July 2. Measurements of recovery, as shown, were continued for a little more than 3 hours before the second well (IW-160; owner's well no. 1) was shut down.

The recovery was plotted on semilogarithmic coordinate paper for solution by the Cooper and Jacob method. (See accompanying table and graph.)

The aquifer constants were determined as follows:

$$T = 425{,}100 \text{ gpd/ft}$$

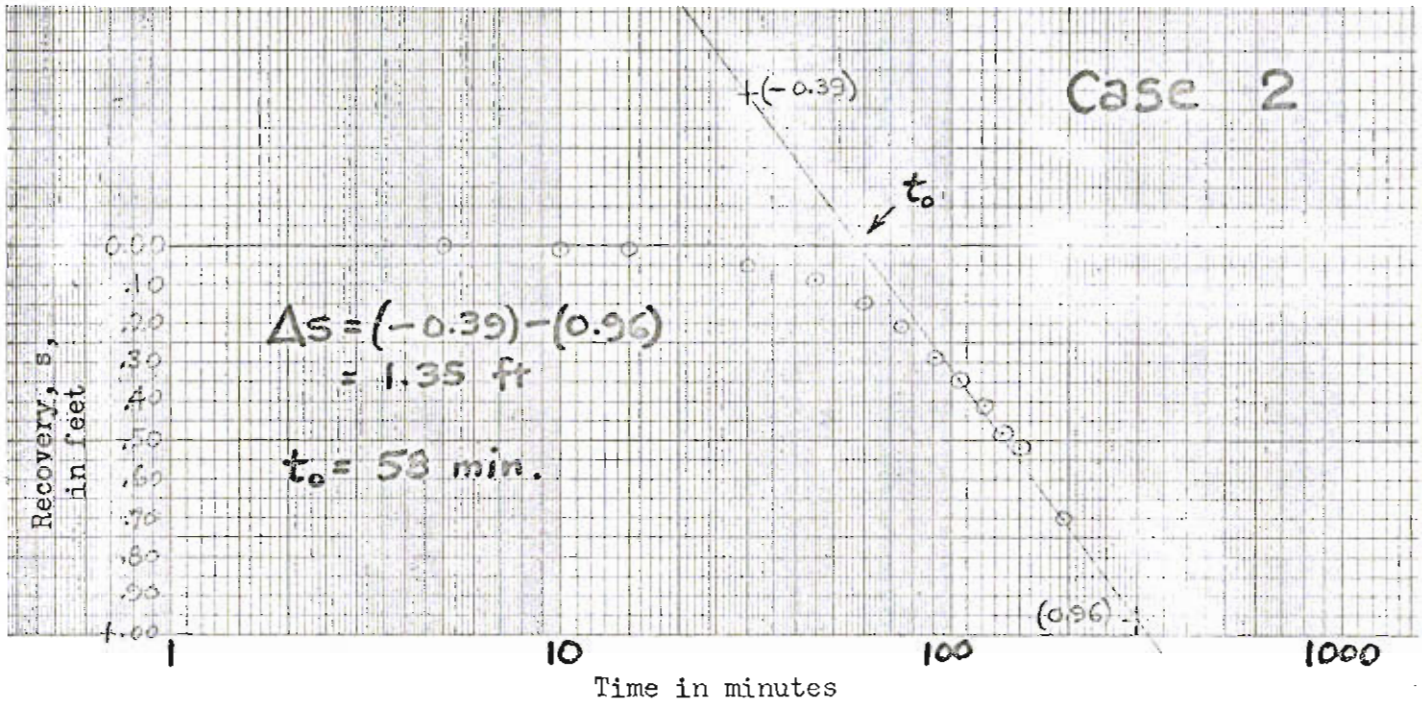
$$\text{and} \quad S = 1.13 \times 10^{-3}$$

In this instance, the value for T is believed to be considerably out of line, in part probably because of the short time duration for the test.

Water-level measurements (Cases 2 and 3)

Pumping level (wells IW-160 and IW-162 in operation) taken as 29.76 feet below measuring point. Pump on well IW-162 turned off at 4:00 a.m. July 2, 1949. Measurements of recovery of water level at observation well (IW-161).

Date 1949	Time	Depth to water, ft	Recovery, ft	Elapsed time	Reciprocal of elapsed time in minutes (1/t)
July 1	10^h 30^m	29.66		-	
	17 15	29.72		-	
	20 55	29.77		-	
	23 48	29.76		-	
July 2	3 15	29.75		-	
	3 50	29.76		-	
	4 00	29.76	0.00	0^h 00^m	--
	4 05	29.76	.00	05	0.2
	4 10	29.75	.01	10	.1
	4 15	29.75	.01	15	.067
	4 30	29.71	.05	30	.033
	4 45	29.67	.09	45	.022
	5 00	29.61	.15	1^h 00	.0167
	5 15	29.55	.21	1 15	.0133
	5 31	29.47	.29	1 31	.0110
	5 45	29.42	.34	1 45	.0095
	6 01	29.35	.41	2 01	.0083
	6 17	29.28	.48	2 17	.0073
	6 30	29.24	.52	2 30	.0067
	7 14	29.06	.70	3 14	.0052


Case 2
(-0.39)
t_o
(0.96)
$\Delta s = (-0.39) - (0.96)$
$= 1.35$ ft
$t_o = 58$ min.
Recovery, s, in feet
0.00
.10
.20
.30
.40
.50
.60
.70
.80
.90
1.00
1
10
100
1000
Time in minutes

Case 3. Aquifer test--July 1949 (II)

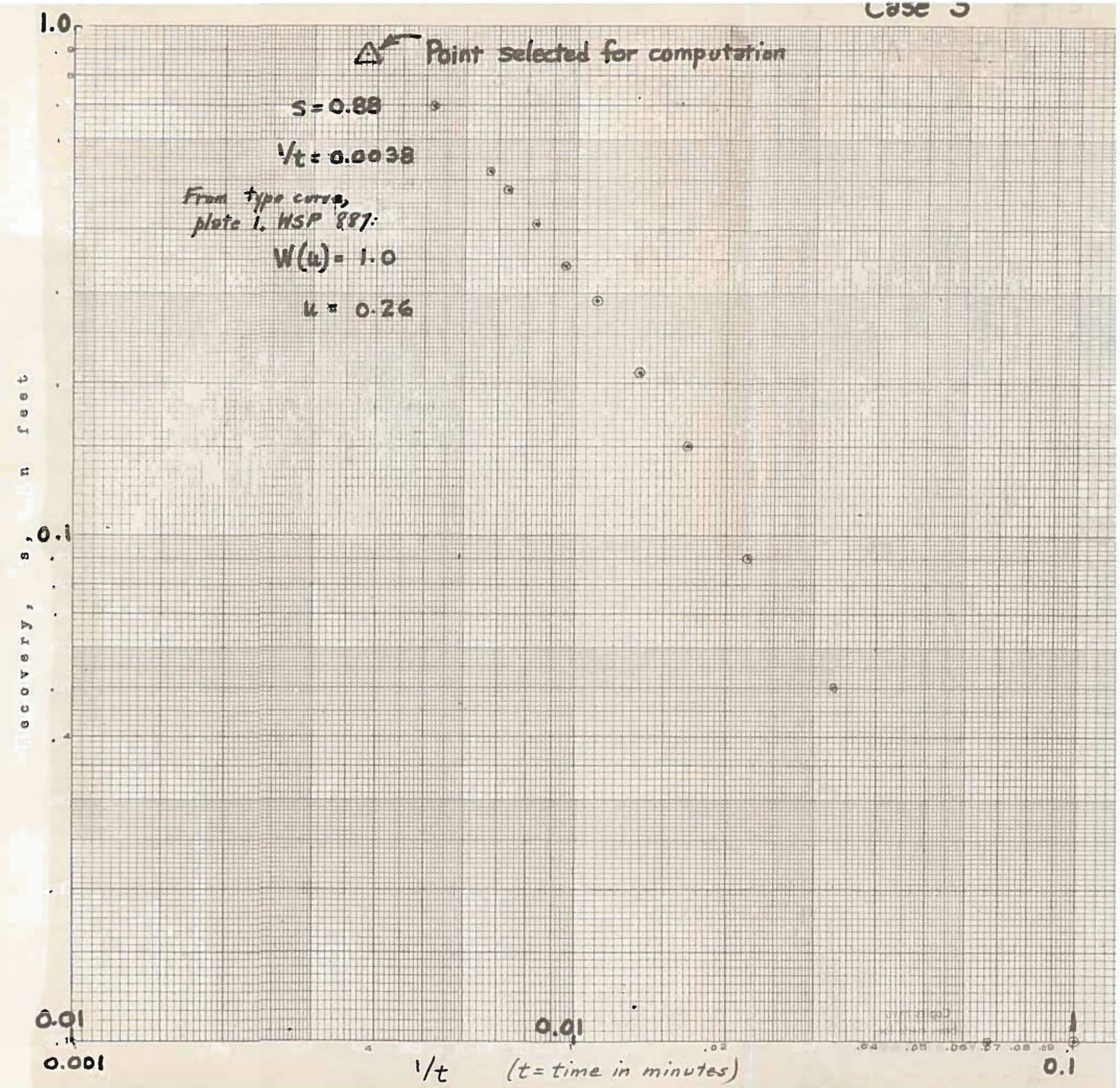
The recovery data obtained from the recorder hydrograph during the aquifer test of July 1949 also were analyzed using the Theis method. The recovery measurements were plotted against the reciprocal of the time in minutes (1/t) on logarithmic coordinate paper and the plotted points matched with the type curve. (See graph on next page; data from table accompanying Case 2.)

The aquifer constants determined during the recovery period of more than 3 hours are:

$$T = 284{,}000 \text{ gpd/ft}$$

$$\text{and} \quad S = 1.59 \times 10^{-3}$$

Case 3


Point selected for computation
s = 0.88
1/t = 0.0038
From type curve, plate 1, WSP 887:
W(u) = 1.0
u = 0.26
1.0
0.1
0.01
0.001
0.01
0.1
1/t
(t = time in minutes)
s, in feet

Case 4.--Aquifer test: April 1950 (I)

The second formal aquifer test conducted at the Camp Manufacturing Co.'s pulp and paper mill took place in April 1950. On this occasion, the water requirements at the mill could be satisfied--at least for a period of several days--by operating only one of the two production wells then in operation. Accordingly, arrangements were completed to conduct the test by turning off well IW-162 (Camp well no. 2), and making measurements of the recovery of the water level in that well, while a Lietz water-stage recorder was continued in operation on the observation well (IW-161) .

Measurements of recovery were made in well IW-162 with chalked steel tape. (See accompanying table and graph.)

The coefficient of transmissibility determined from the recovery in the pumped well, using the Cooper and Jacob method, is:

$$T = 144{,}000 \text{ gpd/ft}$$

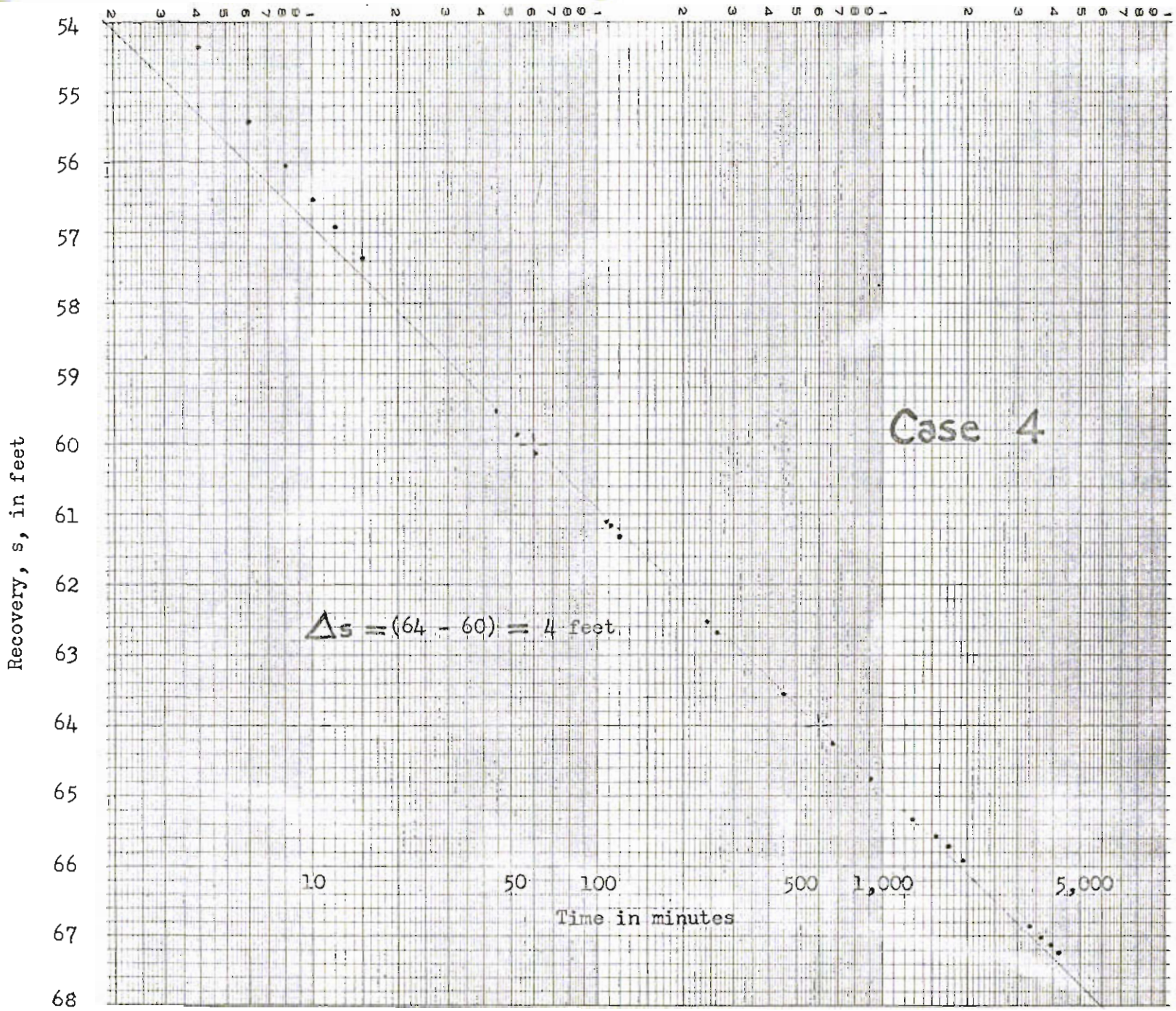
It should be noted that the coefficient of storage can not be obtained from measurements at the pumped well.

Water-level measurements (Case 4)

Recovery of water level in pumped well (IW-162; Camp well no. 2) when pump turned off at 4:30 p.m. April 12, 1950. Measurements by chalked steel tape. Valve closed on line to plant, to shut off back pressure, at same time that pump was turned off. Pumping level (average of several readings) determined as 85.56 feet below measuring point.

Date 1950	Time	Depth to water, ft	Recovery, ft	Elapsed time, minutes	1/t [1/]
April 12	16^h 30^m	85.56	0	0	--
	16 34	31.17	54.39	4	360
	16 36	30.15	55.41	6	240
	16 38	29.48	56.08	8	180
	16 40	29.01	56.55	10	144
	16 42	28.64	56.92	12	120
	16 45	28.18	57.38	15	96
	17 14	26.04	59.52	44	32.7
	17 23	25.70	59.86	53	27.2
	17 31	25.44	60.12	61	23.6
	18 18	24.43	61.13	108	13.2
	18 21	24.38	61.18	111	13.0
	18 30	24.24	61.32	120	12.0
	20 34	23.02	62.54	244	5.9
	20 54	22.88	62.68	264	5.45
	23 58	21.97	63.59	448	3.21
April 13	3 37	21.32	64.24	667	2.15
	7 48	20.78	64.78	918	1.57
	13 45	20.22	65.34	1275	1.13
	18 01	19.98	65.58	1531	.94
	20 52	19.85	65.71	1702	.85
April 14	0 21	19.64	65.92	1911	.75
	23 37	18.71	66.85	3307	.44
April 15	4 52	18.55	67.01	3622	.39
	10 43	18.40	67.16	3973	.36
	14 13	18.34	67.22	4183	.34

1/ Reciprocal of the elapsed time, t, where t is expressed in days. (1/t = 1440/t, where t is expressed in minutes, from previous column)


Case 4
Δs = (64 - 60) = 4 feet
Recovery, s, in feet
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
10
50
100
500
1,000
5,000
Time in minutes

Case 5.--Aquifer test: April 1950 (II)

The recovery of water level in the observation well (IW-161), caused by turning off well IW-162, also was recorded, taken from the chart on the Lietz recording gage maintained on the well. The recovery was plotted on semilogarithmic coordinate paper for solution by the Cooper and Jacob method. (See accompanying table and graph.)

The aquifer constants were determined as follows:

$$T = 195{,}000 \text{ gpd/ft}$$

$$\text{and} \quad S = 1.19 \times 10^{-3}$$

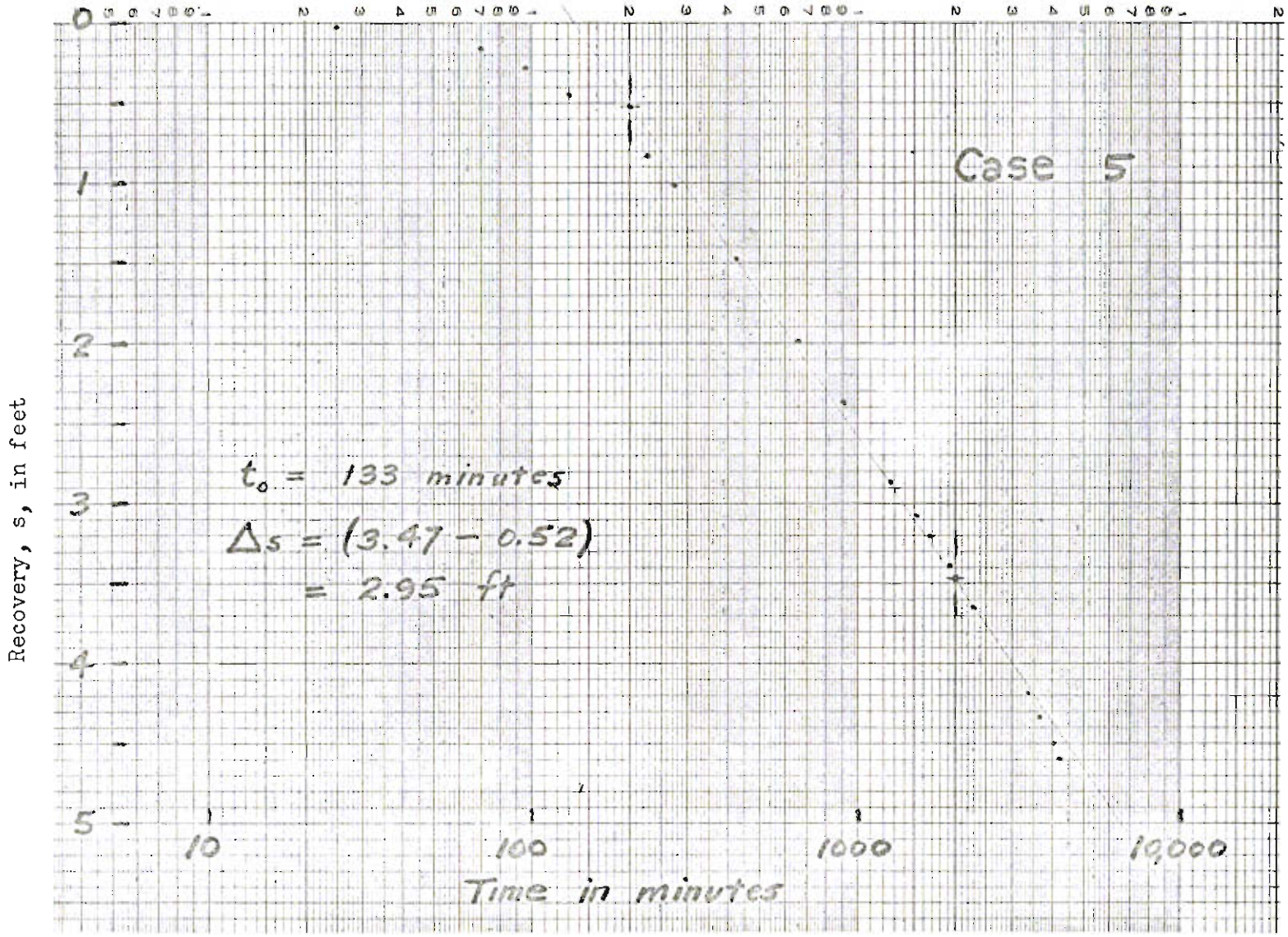
Water-level measurements (Cases 5 and 6)

Recovery of water level in observation well (IW-161) when pump in well IW-162 was turned off at 4:30 p.m. April 12, 1950. Measurements taken from Lietz recorder chart.

Date 1950	Time	Depth to water, ft	Recovery, ft	Elapsed time, minutes	r^2/t 1/
April 12	16^h 30^m	29.78	--	0	--
	16 55	29.77	0.01	25	2.6×10^8 2/
	17 40	29.62	.16	70	9.4×10^7
	18 05	29.49	.29	95	6.9×10^7
	18 40	29.34	.44	130	5.05×10^7
	20 16	28.95	.83	226	2.9×10^7
	21 03	28.77	1.01	273	2.4×10^7
	23 37	28.30	1.48	427	1.54×10^7
April 13	3 27	27.80	1.98	657	1.05×10^7
	7 30	27.40	2.38	900	7.3×10^6
	13 35	26.91	2.87	1,265	5.2×10^6
	17 47	26.70	3.08	1,517	4.3×10^6
	20 39	26.58	3.20	1,689	3.9×10^6
April 14	0 30	26.39	3.39	1,920	3.3×10^6
	6 24	26.15	3.63	2,274	2.9×10^6
	23 53	25.59	4.19	3,323	1.9×10^6
April 15	5 05	25.45	4.33	3,635	1.8×10^6
	11 57	25.28	4.50	4,047	1.6×10^6
	14 33	25.19	4.59	4,203	1.56×10^6

1/ r (distance between IW-162 and IW-161) = 2,135 feet; $r^2 = 4.56 \times 10^6$ ft
t = time, in days, since pump was turned off.
$r^2/t = 4.56 \times 10^6 \times 1{,}440 / t$ (minutes, from previous column)

2/ Plots out of range of graph accompanying Case 6 discussion.


Case 5
t_o = 133 minutes
Δs = (3.47 − 0.52)
= 2.95 ft
Recovery, s, in feet
0
1
2
3
4
5
10
100
1000
10,000
Time in minutes

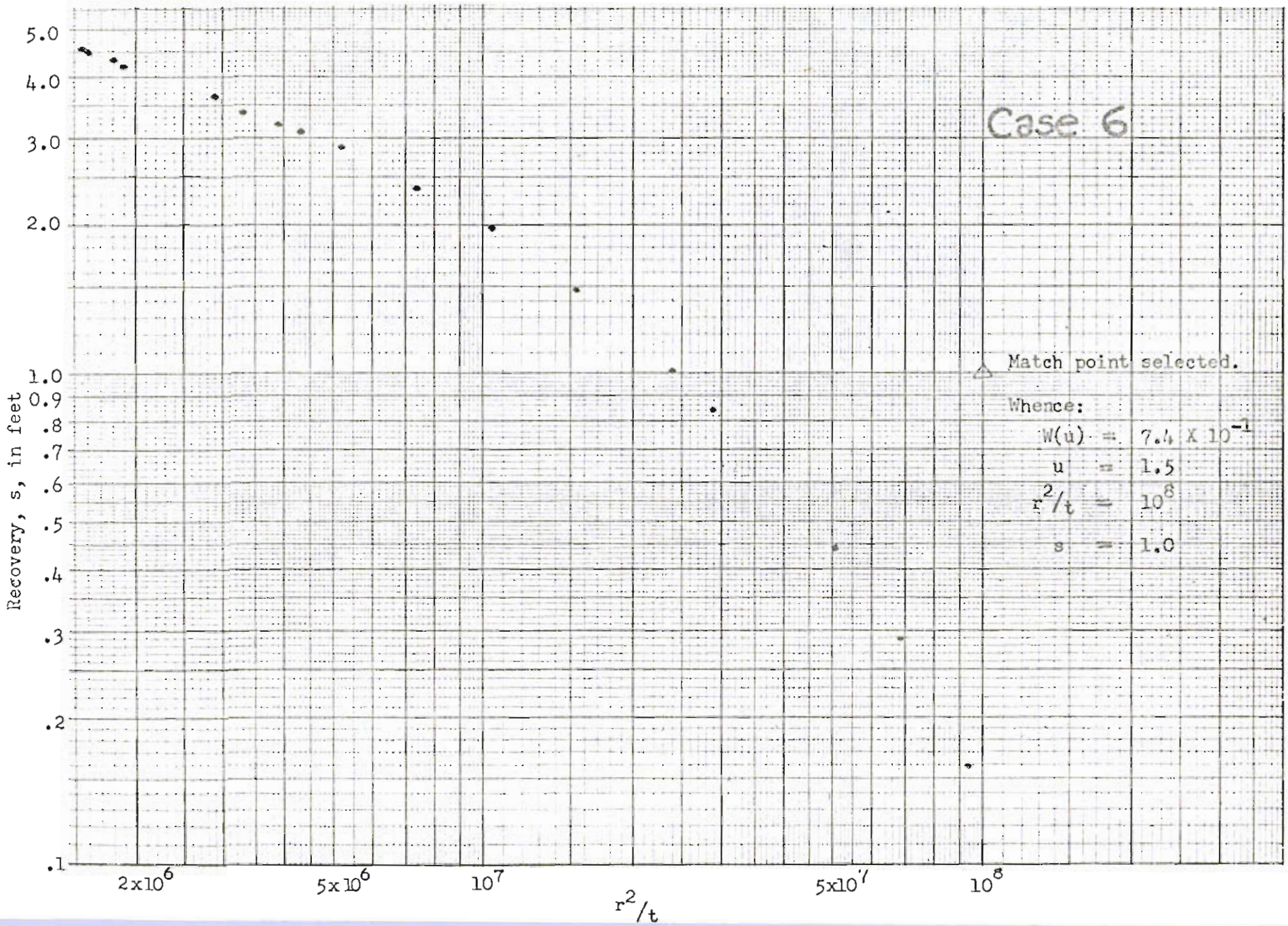
Case 6.--Aquifer test: April 1950 (III)

The record of recovery of water level at well IW-161, after well IW-162 was turned off (Case 5) also was plotted on logarithmic coordinate paper, using the Theis method. (See graph on next page, and table accompanying Case 5.)

The aquifer constants determined by this procedure are as follows:

$$T = 185{,}000 \text{ gpd/ft}$$

$$\text{and} \quad S = 1.48 \times 10^{-3}$$


Case 6
Match point selected.
Whence:
W(u) = 7.4 X 10^-1
u = 1.5
r^2/t = 10^8
s = 1.0
Recovery, s, in feet
5.0
4.0
3.0
2.0
1.0
0.9
.8
.7
.6
.5
.4
.3
.2
.1
2x10^6
5x10^6
10^7
5x10^7
10^8
r^2/t

Case 7.--Recorder hydrograph: October 1950 (I)

As with Case 1, data were obtained from one of the weekly Lietz recorder charts obtained at observation well (IW-161) in October 1950, when it was learned that the pump on well IW-162 (Camp well no. 2) had been turned on. Information as to the period of time that the pump had been idle is not readily available but it probably was on the order of several days. The results as shown below, are in reasonable agreement with those obtained by several of the other tests. The data were plotted on semilogarithmic coordinate paper for solution by the Cooper and Jacob method. (See accompanying table and graph.)

The aquifer constants determined from this chart record are as follows:

$$T = 193{,}000 \text{ gpd/ft}$$

$$\text{and} \quad S = 1.32 \times 10^{-3}$$

Water-level measurements (Cases 7 and 8)

Water level in observation well (IW-161) assumed to have become stabilized after pump in well IW-162 (Camp well no. 2) shut down (probably for repairs). When pump in IW-162 turned on, drawdown recorded on chart on Lietz recording gage maintained on IW-161 shown in first column. Well IW-160 (Camp well no. 1) pumping continuously during entire period.

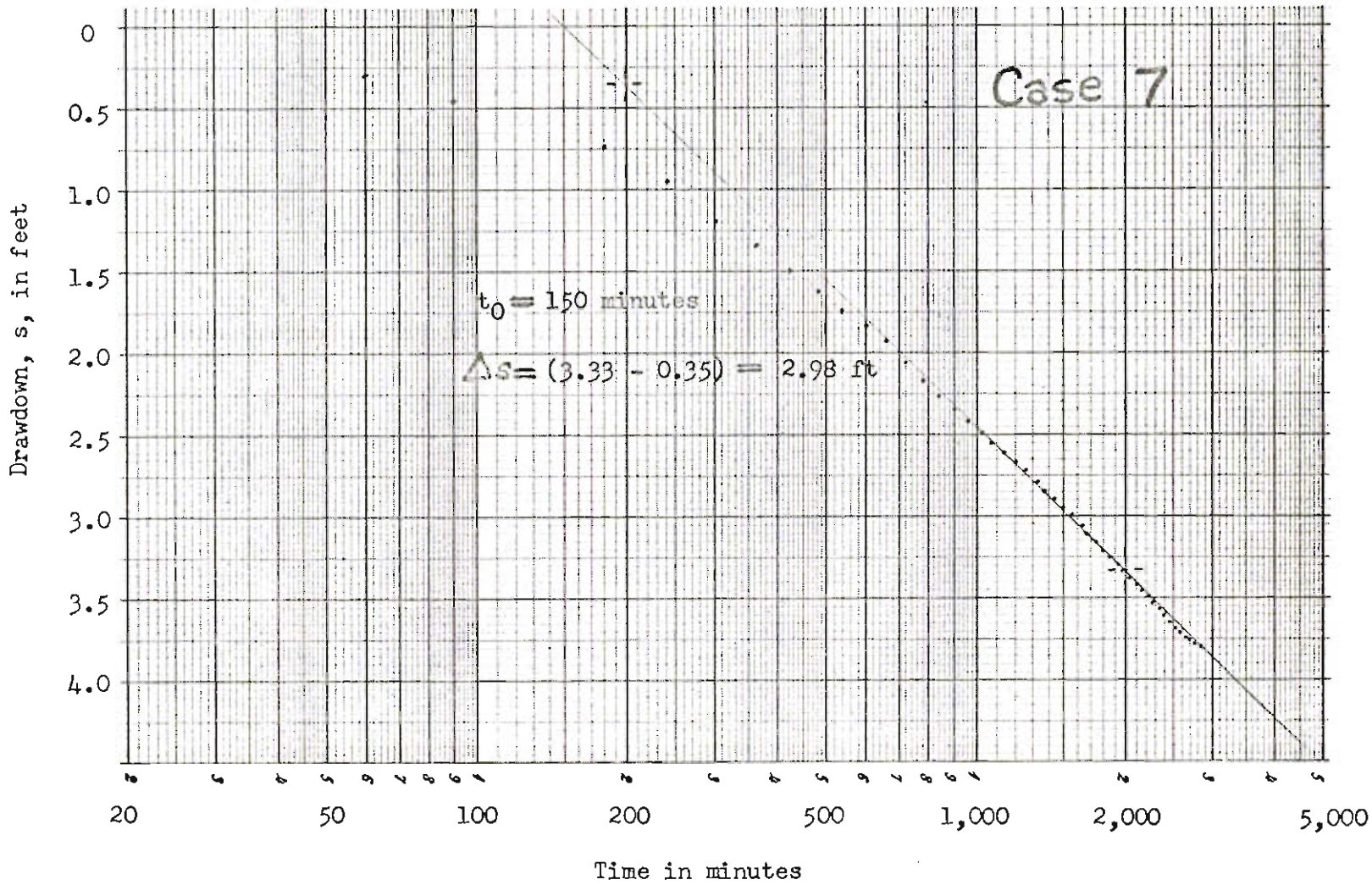
Drawdown, ft	Elapsed time, minutes	r^2/t 1/
0.30	60	1.1×10^8
.45	90	7.3×10^7
.74	180	3.7×10^7
.95	240	2.7×10^7
1.19	300	2.2×10^7
1.35	360	1.82×10^7
1.50	420	1.56×10^7
1.62	480	1.37×10^7
1.75	540	1.21×10^7
1.84	600	1.09×10^7
1.94	660	9.9×10^6
2.07	720	9.1×10^6
2.18	780	8.4×10^6
2.26	840	7.8×10^6
2.35	900	7.3×10^6
2.42	960	6.8×10^6
2.49	1020	6.4×10^6
2.55	1080	6.07×10^6
2.61	1140	5.8×10^6
2.67	1200	5.47×10^6
2.72	1260	5.21×10^6
2.79	1320	4.97×10^6
2.84	1380	4.76×10^6
2.89	1440	4.56×10^6
2.95	1500	4.38×10^6
3.00	1560	4.21×10^6
3.06	1620	4.05×10^6
3.11	1680	3.91×10^6
3.16	1740	3.78×10^6
3.21	1800	3.65×10^6

Water-level measurements (Cases 7 and 8).--Continued

Drawdown, ft	Elapsed time, minutes	r^2/t [1/]
3.25	1860	3.53×10^6
3.29	1920	3.42×10^6
3.33	1980	3.32×10^6
3.38	2040	3.22×10^6
3.42	2100	3.12×10^6
3.46	2160	3.04×10^6
3.50	2220	2.96×10^6
3.53	2280	2.88×10^6
3.57	2340	2.81×10^6
3.61	2400	2.74×10^6
3.65	2460	2.67×10^6
3.68	2520	2.6×10^6
3.71	2580	2.55×10^6
3.74	2640	2.49×10^6
3.75	2700	2.43×10^6
3.78	2760	2.38×10^6
3.80	2820	2.33×10^6

1/ r^2/t = distance between IW-161 and IW-162 squared, divided by the time in days since pumping began.

Computation: $\frac{(2135)^2\ (24 \times 60)}{\text{elapsed time in minutes}}$, or $\frac{6.56 \times 10^9}{\text{elapsed time in minutes}}$


Case 7
t_0 = 150 minutes
Δs = (3.33 - 0.35) = 2.98 ft
Drawdown, s, in feet
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
20
50
100
200
500
1,000
2,000
5,000
Time in minutes

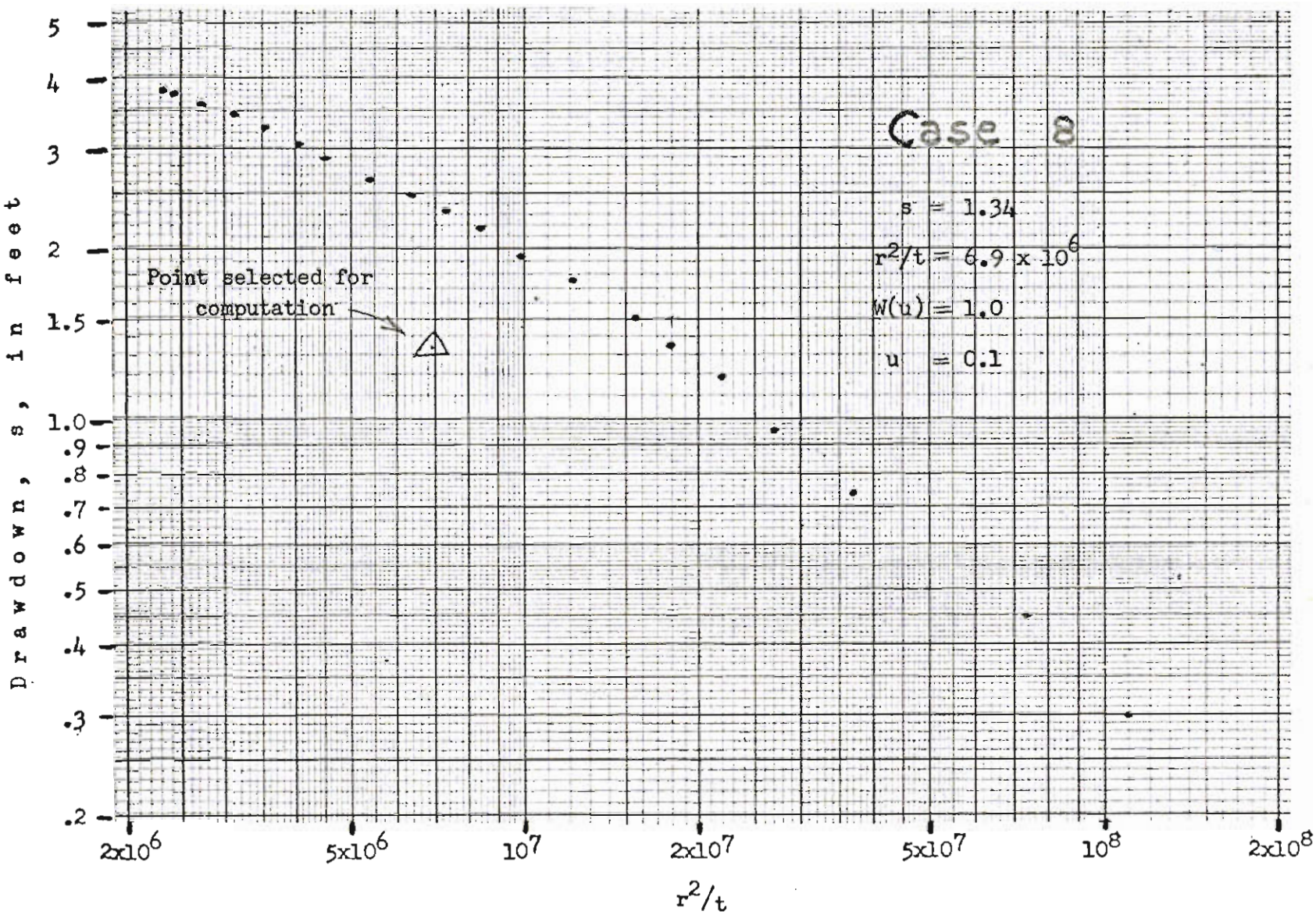
Case 8.--Recorder hydrograph: October 1950 (II)

The drawdown data obtained at the observation well (IW-161) in October 1950, discussed previously (Case 7) also were plotted on logarithmic coordinate paper for determination of the coefficients of transmissibility and storage by the Theis method. (See graph on next page, and data from table accompanying Case 7.)

The aquifer constants, determined during the period of drawdown after the pump at well IW-162 (Camp well no. 2) was turned on, are as follows:

$$T \doteq 186{,}000$$

$$\text{and} \quad S = 1.44 \times 10^{-3}$$


Case 8
s = 1.34
r²/t = 6.9 x 10⁶
W(u) = 1.0
u = 0.1
Point selected for computation
Drawdown, s, in feet
5
4
3
2
1.5
1.0
.9
.8
.7
.6
.5
.4
.3
.2
2x10⁶
5x10⁶
10⁷
2x10⁷
5x10⁷
10⁸
2x10⁸
r²/t

SUMMARY AND APPLICATION OF RESULTS

Table 2 (p. 50) summarizes the results of the tests. On the basis of the several determinations of the coefficients of transmissibility (T) and storage (S), the round values of T=200,000 gpd/ft and $S=1.4x10^{-3}$ have been selected as reasonable. It is believed that by employing these values for the aquifer constants, fairly reliable estimates can be made, by substituting the coefficients in the Theis (1935) formula, for the effect of additional production wells tapping these sands in this area.

The practical application of the use of these coefficients is shown by calculations made by the writer some years ago (Sinnott, 1950) at a time when the construction of a third production well at the paper mill was getting under way, and shortly after the tests described in this report were made.

An estimate of the amount of decline of the water levels in the three largest production wells (as of 1950) in the Franklin area, caused by pumping the new well when it would be placed in production, was desired. This decline was computed for periods of one
S-3 year and ten years for each of the three wells, assuming that the new well would be pumped at a constant rate of 2,500 gallons per minute. The theoretical effects on the water levels in several important wells in the area, at the approximate distances indicated, are shown in the accompanying table. (See p. 51.)

Table 2.--Summary of determinations of aquifer constants

Case no.	Date	Brief description	Method of analysis	Coefficient of transmissibility = T (gpd/ft)	Coefficient of storage = S
1	Dec. 1-3, 1945	Data from routine recorder chart on IW-161; recovery from shutdown of well IW-162.	Cooper and Jacob	178,200	1.56×10^{-3}
2	July 2, 1949	Formal aquifer test. Recovery at at IW-161 from shutdown of IW-162; from recorder chart.	Cooper and Jacob	425,100	1.13×10^{-3}
3	do.	do.	Theis	284,000	1.59×10^{-3}
4	April 12-15, 1950	Formal aquifer test. Recovery at pumped well, IW-162; from manual measurements after shutdown.	Cooper and Jacob	144,000	—
5	do.	Formal aquifer test. Recovery at IW-161 from shutdown of IW-162; from recorder chart.	Cooper and Jacob	195,000	1.19×10^{-3}
6	do.	do.	Theis	185,000	1.48×10^{-3}
7	October 16-18 1950	Data from routine recorder chart on IW-161; drawdown caused by turning on pump at well IW-162.	Cooper and Jacob	193,000	1.32×10^{-3}
8	do.	do.	Theis	186,000	1.44×10^{-3}

S-3

Well	Approximate distance from new well, in feet	Decline in water level, in feet, caused by discharge of new well	
		After 1 year	After 10 years
Town of Franklin well no. 3	4,500	9.4	12.8
Paper mill well no. 1	2,100	11.7	15.0
Paper mill well no. 2	2,400	11.3	14.6

Figure 5 shows the same information plotted graphically. The small circles represent points corresponding to the calculated amounts of decline in water level listed in the table above. The lines in the graph may be used to determine the estimated amount of drawdown in either direction for periods of time from 10 days to 10,000 days--or ~~nearly~~ about 27 years.

It may be noted here that the actual decline in water levels, experienced after the new well began pumping at about the rate assumed for the computations, was found to be closely similar to these estimates. This suggests (1) that the mathematical model on which the Theis formula is based, and the Cooper and Jacob approximation of it, represents a reasonable approximation to the actual hydrologic conditions in the well field, and (2) that the formation constants finally selected from the several individual cases provide a basis for meaningful estimates of the effect of additional production wells in this area tapping these sands in that portion of the Potomac Group between about 255 and 800 feet below sea level.

S-4

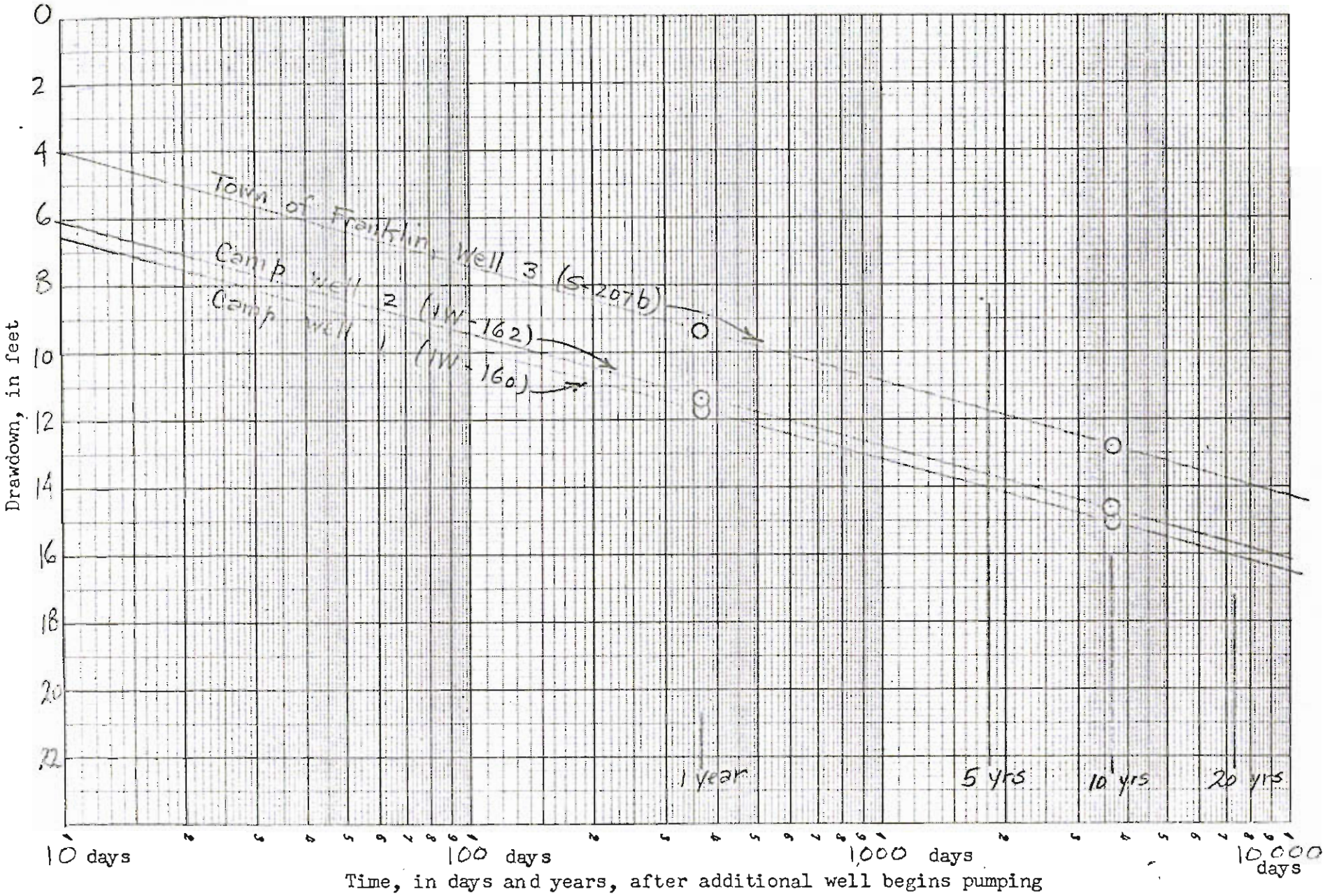


Figure 5.--Projected decline of water level in three wells in the Franklin area caused by pumping an additional industrial well. (See discussion in text.)

Since these tests were made, systematic expansion has taken place at the pulp and paper mill, which is now a subsidiary of the Union Bag-Camp Paper Corporation. In addition to several additional wells tapping this upper part of the Potomac section, it is understood that at least one well withdraws water from deeper water-bearing beds. Specific information on these more recent developments, however, is not available to the writer.

On the basis of the general character of the Potomac Group in this area, as pointed out in the section on the geology of the area, and considering that these sands have a relatively high transmissibility [redacted], it is believed that there is ample available ground water in the area. Increased aggregate withdrawals from properly spaced wells, up to a maximum of on the order of 50,000,000 gpd (gallons per day), can probably be safely accomplished before the decline in artesian head is likely to progresss deeply enough to reach the uppermost of the water-bearing units in the Potomac Group in this area. This would be at about 230 feet below sea level. After this point is reached, the immediate effect of pumping at large scale in this area from these sands will begin to dewater this uppermost water-bearing stratum, and thus begin to "mine" ground water from it.

S-5

Careful monitoring of the water levels in the area should be continued in order to prevent dewatering of the upper sand. If this condition is permitted to happen, at the moment it does so the withdrawal of ground water from the upper sands of the Potomac Group--that is, from 230 to about 600 feet below sea level--will have exceeded the rate of replenishment. Although the rate of decline in water levels

will be reduced, it will continue and the cone of depression of the water table in the aquifer will continue to widen rather than

S-6 to become stabilized. Possible deterioration of ground-water quality in nearby municipalities in northeastern North Carolina, that are supplied by ground water, will become a continuing threat, further complicated by possible legal action. As of 1968, awareness of this possible effect of increased withdrawals in the Franklin area has resulted in some preliminary study.

It has been the purpose of this report not only to point out a convenient and reliable method of estimating the potential effects of additional withdrawals of ground water in the Franklin area, but also to call attention to some of the potential dangers of local overdraft of the ground water supplies available to this growing municipal-industrial complex.

REFERENCES

Brown, R. H., 1953, Selected procedures for analyzing aquifer test data: Jour. Am. Water Works Assoc., vol. 45, no. 8, August, p. 844-866.

Bruin, Jack, and Hudson, H. E., Jr., 1955, Selected methods for pumping test analysis: Illinois State Water Survey Report of Investigation no. 25, 51 p.

Cederstrom, D. J., 1945, Geology and ground-water resources of the Coastal Plain in southeastern Virginia: Va. Geol. Survey Bull. 63, 384 p.

_____, 1957, Geology and ground-water resources of the York-James peninsula, Virginia: U.S. Geol. Survey Water-Supply Paper 1361, 237 p.

Clark, W. B., and Miller, B. L., 1912, The physiography and geology of the Coastal Plain province of Virginia: Va. Geol. Survey Bull. 4, 274 p.

Cooper, H. H., Jr., and Jacob, C. E., 1946, A generalized graphical method for evaluating formation constants and summarizing well-field history: Am. Geophys. Union Trans., vol. 27, no. 4, p. 526-534.

DeBuchananne, G. D., 1968, Ground-water resources of the Eastern Shore of Virginia and the James, York, and Rappahannock River basins of Virginia east of the Fall Line: U.S. Geol. Survey Hydrologic Investigations Atlas HA-284, 2 sheets (maps, tables, and text).

Ferris, J. G., Knowles, D. B., Brown, R. H., and Stallman, R. W., 1962, Theory of aquifer tests: U.S. Geol. Survey Water-Supply Paper 1536-E, 174 p.

Lang, S. M., 1966, Pumping test methods for determining aquifer characteristics (Advance copy of paper no. 192 presented at the Sixty-Ninth Annual Meeting of the American Society for Testing and Materials): U.S. Geol. Survey open-file report, 19 p., 13 figs.

Russell, R. J., and Russell, R. D., 1939, Mississippi River delta sedimentation: in Recent marine sediments, P. D. Trask, ed.: Tulsa, Okla., Am. Assoc. Petroleum Geologists, p. 153-177.

Sanford, Samuel, 1913, The underground water resources of the Coastal Plain province of Virginia: Va. Geol. Survey Bull. 5, 361 p.

Sinnott, Allen, 1950, Coefficients of transmissibility and storage determined for sands of the Potomac Group in the Franklin area, Virginia: U.S. Geol. Survey open-file report, 3 p.

Theis, C. V., 1935, Relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using ground-water storage: Am. Geophys. Union Trans., pt. 2, p. 519-524; dupl. as U.S. Geol. Survey Ground Water Note 5, 1952.

Wenzel, L. K., 1942, Methods for determining permeability of water-bearing materials, with special reference to discharging-well methods: U.S. Geol. Survey Water-Supply Paper 887, 192 p.

APPENDIX

Ap-1 Additional information is presented here that supplements the basic information given in the body of the report.

Included are the following:

(1) Facsimile copies of the drilling contractor's specifications of the three active wells (as of 1949-1950) owned by the Camp Manufacturing Co.

These wells are: IW-160 (Camp well no. 1), IW-161 (Camp observation well), and IW-162 (Camp well no. 2). In addition to the log of materials penetrated, these records provide graphically the details of construction, and give information on the equipment used in each installation.

Ap-2 (2) Record of water-level measurements at the observation well (IW-161) during the 1949 formal aquifer test.

This record includes (a) recovery after turning off the pump on Camp well no. 2 (IW-162), discussed in Cases 2 and 3 in the report, and (b) in addition, further recovery for about 9 days after the pump on the other Camp production well, no. 1 (IW-160), was turned off. (The effect of turning off this second well--IW-160--was not studied in the present report.)

Ap-3 (3) Measurements of water level at Camp well no. 1 (IW-160), July 1-3, 1949.

These measurements were not employed for the present report, but are given here for the record in order to provide basic data for possible later additional study of the test program.

A-

(4) Measurements of water level at Camp well no. 2 (IW-162), July 1-8, 1949.

Because the valve could not be closed when the pump at this well was turned off on July 2, at the beginning of the 1949 test, water

Ap-4 drained back into well for half an hour during its initial period of recovery. This of course would adversely affect the results, at least during the early phases of the test; therefore, these data were not used in the computations discussed in this report. These measurements are included, for the record, because of the extended period of time during which they were made, and their consequent value for additional analysis of the test program in connection with other studies that may be made in the Franklin area.

Ap-5 (5) Measurements of water level at town well no. 3 (S-207b) during the period July 1-11, 1949.

Although some notes have been entered under "remarks" on the operation of certain other municipal wells--mostly recorded by the well reader from advice from water plant personnel--a complete schedule of the operation of these other wells is given in this Appendix. (See Item 7.)

(6) Measurements of water level at the town observation well (S-205) during the period July 1-11, 1949.

Like town wells 1 and 2 (S-206 and S-207a, respectively), the observation well at the east corner of Fifth Avenue and Middle Street, near the municipal water plant, taps the uppermost sand beds in the Potomac Group. Water levels were measured in this well during the formal test in July 1949 as part of the program of measurements made in order to monitor the regional recovery during the shut-down of the Camp Manufacturing Company's pulp and paper mill, although the production wells at the mill obtain water from several deeper water-bearing sands in addition to the uppermost sands tapped by the observation well.

(7) Pumping schedule of wells operated by the town of Franklin, July 1-11, 1949.

Three municipal wells were active in July 1949. (See table 1 and figure 4.) The schedule of their pumping is given in order to provide as much information as possible for any later analysis that might be attempted of the later part of the recovery period of the July shut-down beyond the first few hours that were studied in this report. It was not possible, because of the needs of the town, to avoid pumping town well no. 2 (S-207a), nor even well no. 3 (S-207b) in which the regional recovery was being recorded by tape measurements of water level. (It was understood and expected that town well no. 1 (S-206) would continue intermittent pumping, however.)

Although the distances of these wells from town well no. 3 (S-207b) are only approximately known, they readily may be obtained for later study from the town records. Well no. 1 (S-206) was a little more than 300 feet distant from well no. 3, and pumping it had only a moderate effect on the water level in the latter. Well no. 2 (S-207a) however, although equipped with a relatively small capacity pump, was only a few feet away, in the same building as well no. 3, and consequently had considerable effect on the water level, as can be seen by inspection of the table for well no. 3. (See Appendix, Item 5)

(1a)

455

#1

LAYNE ATLANTIC COMPANY

NORFOLK, VA.

Ivan Higgerson

LOG OF WELL For Chesapeake Camp Corp.

Located at Franklin in County, State Virginia

Date Drilling Started 10-14-41 19 Date Started 9-22-41 19

Finished Drilling 11-10-41 19 Finished 11-24-41 19

USGS

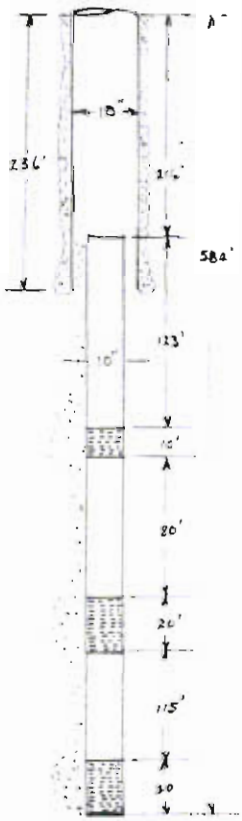
IW-160

FORMATIONS AND DEPTH OF WELL No. 1

TOTAL DEPTH OF ALL STRATA FT.	IN.	DEPTH OF EACH STRATUM FT.	IN.	FORMATION FOUND AT EACH STRATUM
15		15		Fill and fine sand
25		10		Sand
102		77		Soft blue clay
106		4		Rock
112		6		Fine sand and shell mixed in clay
306		194		Blue clay and fine sand - hard
				and soft spots
317		11		Water bearing sand
333		16		Hard blue clay
359		26		Water bearing sand
368		9		Hard blue clay
475		107		Water Bearing sand
555		80		Hard sandy blue clay
603		48		Water bearing sand
800		197		Hard sandy clay

DIMENSIONS OF CASING AND SCREEN

TOTAL LENGTH OF ALL SCREENS and CASINGS FT.	IN.	LENGTH OF EACH SEC. OF SCREEN OR CASING FT.	IN.	SPECIFY SCREEN OR CASING	SIZE OF SCREEN OR CASING IN.	GAUGE OF SCREEN	
236		236		Casing	18	5/16	Armco
10" casing commences at 216' below surface							
123		123		Casing	10	40#	Steel #7 opening
133		10		Screen	10	6	Armco
213		80		Casing	10	40#	Steel #7 opening
233		20		Screen	10	6	Armco
348		115		Casing	10	40#	Steel #7 opening
368		20		Screen	10	6	Armco



WELL DATA:

Preliminary Test

Date Tested 19 Static Level

Production GPM Pumping Level

Permanent Test

Date Tested 11-15 19 41 Static Level Flows

Production GPM Active St. Level

Drawdown 68' Pumping Level 68'

Remarks: Estimate 3000 GPM on test

PUMP DATA:

Shop No. 11578 Type Lubr.

Type Head T11 Size Suction 8"

Depth Setting 99' (BP to MB)

Size Column 10x1-15/16x8 Length Suction

Type Bowl 15"DRHO Length Air Line 108'

No. Stages 2 Discharge-

Cap'y and Head Pressure

MOTOR DATA:

Horsepower 100 Voltage

RPM 1750 Phase

Type Cycles

Make Westinghouse Frame No. [illegible]

(1b)

456

LAYNE ATLANTIC COMPANY

NORFOLK, VA.

Ivan Higgerson

(Observation Well)

LOG OF WELL For Chesapeake Camp Corp.

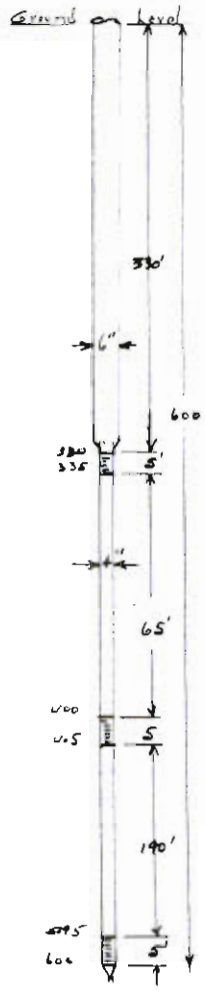
Located at Franklin In County, State Virginia

Date Drilling Started 11-14-41 19 Date Started 9-29-41 19

Finished Drilling 19 Finished 11-24-41 19

USGS IW-161

FORMATIONS AND DEPTH OF WELL NOTE (Observation Well)					DIMENSIONS OF CASING AND SCREEN						
TOTAL DEPTH OF ALL STRATA		DEPTH OF EACH STRATUM		FORMATION FOUND AT EACH STRATUM	TOTAL LENGTH OF ALL SCREENS and CASINGS		LENGTH OF EACH SEC. OF SCREEN OR CASING		APERTURE SCREEN OR CASING	SIZE OF SCREEN OR CASING	GAUGE OF SCREEN
FT.	IN.	FT.	IN.		FT.	IN.	FT.	IN.		IN.	
20		20		Fine white sand							
160		140		Blue clay							
252		92		Soft sandy blue clay							
285		33		Hard blue clay							
438		153		Coarse water bearing sand							
		Hole caved in over weekend									
440		2		Sand							
500		60		Sandy clay							
575		75		Hard stiff blue clay							
605		30		Water bearing sand							



WELL DATA:

Preliminary Test

Date Tested 19 Static Level

Production GPM Pumping Level

Permanent Test

Date Tested 19 Static Level

Production GPM Active St. Level

Drawdown Pumping Level

Remarks: Well flows 8 GPM 2' above ground. Rises about 5½' above surface.

PUMP DATA:

Shop No. Type Lubr.

Type Head Size Suction

Depth Setting (BP to MB)

Size Column Length Suction

Type Bowl Length Air Line

No. Stages Discharge-

Cap'y and Head Pressure

MOTOR DATA:

Horsepower Voltage

RPM Phase

Type Cycles

Make Frame No.

(1c)

489 LAYNE ATLANTIC COMPANY 489

NORFOLK, VA. Ivan Hirgerson

LOG OF WELL For Chesapeake - Camp Corporation #2

Located at Franklin in Virginia County, State

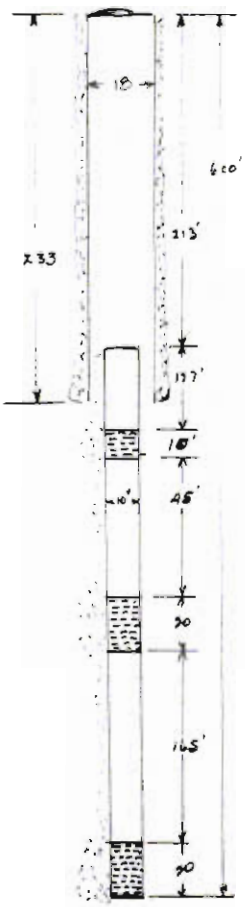
Date Drilling Started 12-12-41 19 Date Started 12-8-41 19

Finished Drilling 12-24-41 19 Finished 6-20-42 19

USGS IW-162

FORMATIONS AND DEPTH OF WELL No. 2 — DIMENSIONS OF CASING AND SCREEN

	TOTAL DEPTH OF ALL STRATA FT.	IN.	DEPTH OF EACH STRATUM FT.	IN.	FORMATION FOUND AT EACH STRATUM	TOTAL LENGTH OF ALL SCREENS and CASINGS FT.	IN.	LENGTH OF EACH SEC. OF SCREEN OR CASING FT.	IN.	SPECIFY SCREEN OR CASING	SIZE OF SCREEN OR CASING IN.	GAUGE OF SCREEN
Armco	95		95		White sand	233		233		Casing	18	5/16
	50		25		Blue mud and sand	10" casing starts about 213' below surface						
	100		50		Blue clay - med. drilling							
Steel #7 opening	186		86		Fine black sand	127		127		Casing	10	40#
Armco	200		14		Blue clay - med. drilling	137		10		Screen	10	6
Steel #7 opening	235		35		Hard blue clay	182		45		Casing	10	40
Armco	248		13		Blue clay	202		20		Screen	10	6
Steel #7 opening	281		33		Red clay and mud	367		165		Casing	10	40#
Armco	316		35		Water bearing sand	387		20		Screen	10	6
	330		14		Sandy blue clay							
	423		93		Loose water bearing sand							
	485		62		Sand with clay							
	550		65		Hard clay							
	607		57		Water bearing sand							
	610		3		Sandy clay							



WELL DATA:

Preliminary Test

Date Tested 19 Static Level

Production GPM Pumping Level

Permanent Test

Date Tested 19 Static Level

Production GPM Active St. Level

Drawdown Pumping Level

Remarks:

PUMP DATA:

Shop No. 11458 Type Lubr.

Type Head TA1 Size Suction

Depth Setting 100' (BP to MB)

Size Column 10x1-15/16x3 Length Suction

Type Bowl 17" DSHC Length Air Line

No. Stages 1 Discharge-

Cap'y and Head Pressure

MOTOR DATA:

Horsepower 100 Voltage

RPM 1750 Phase

Type Cycles

Make Westinghouse Frame No. 7M607X

(2) Water-level measurements, Camp observation well (IW-161)

t = tape measurement
r = recorder chart

Date (1949)	Time	Depth to water, feet
July 1	10:30 a.m.	29.66 t
	5:15 p.m.	29.72 t
	8:55 p.m.	29.77 t
	11:48 p.m.	29.76 t
July 2	3:15 a.m.	29.75 t
	3:50 a.m.	29.76 t
	4:00 a.m.	29.76 r
	4:05 a.m.	29.76 t
	4:10 a.m.	29.75 r
	4:15 a.m.	29.75 t
	4:30 a.m.	29.71 t
	4:45 a.m.	29.67 t
	5:00 a.m.	29.61 t
	5:15 a.m.	29.55 r
	5:31 a.m.	29.47 t
	5:45 a.m.	29.42 r
	6:01 a.m.	29.35 r
	6:17 a.m.	29.28 t
	6:30 a.m.	29.24 r
	7:14 a.m.	29.06 t
--Camp well no. 1 (IW-160) off at 7:52.5 a.m.--		
	8:35 a.m.	28.77 t
	9:00 a.m.	28.68 r
	9:15 a.m.	28.63 r
	11:26 a.m.	28.17 t
	12:40 p.m.	27.94 r
	2:30 p.m.	27.57 t
	5:05 p.m.	27.12 t
	8:10 p.m.	26.67 t
	10:30 p.m.	26.32 t
	11:45 p.m.	26.21 t
July 3	2:37 a.m.	25.84 t
	5:00 a.m.	25.62 r
	8:48 a.m.	25.23 t
	11:30 a.m.	24.99 t
	3:16 a.m.	24.69 t
	8:05 p.m.	24.38 r
	11:05 p.m.	24.19 r

(2) Water-level measurements, Camp observation well (IW-161)--Continued

Date (1949)	Time	Depth to water, feet
July 4	8:41 a.m.	23.63 t
	3:52 p.m.	23.28 r
	10:24 p.m.	23.01 r
July 5	9:24 a.m.	22.55 t
	2:58 p.m.	22.38 r
July 6	9:00 a.m.	21.84 t
	3:10 p.m.	21.68 t
	9:05 p.m.	21.56 r
July 7	9:12 a.m.	21.24 t
	10:00 p.m. (approx.)	20.94 r
	10:30 p.m.	21.14 r
July 8	12:05 a.m. (approx.)	21.38 r 1/
	8:46 a.m.	20.91 t
	11:55 p.m.	20.82 t
July 9	2:09 a.m.	21.30 r
	9:57 a.m.	23.14 t
	11:25 a.m.	23.36 r
	2:18 p.m.	23.74 r
	3:03 p.m.	23.84 r
	3:47 p.m.	23.93 r
	4:29 p.m.	24.02 r
	5:09 p.m.	24.10 r
	5:39 p.m.	24.16 r
	6:00 p.m.	24.21 r
	7:42 p.m.	24.38 r
	9:32 p.m.	24.59 t
July 10	10:00 a.m.	25.37 r
	1:20 p.m.	25.53 r
	5:57 p.m.	25.72 r
July 11	10:58 a.m.	26.36 r
	4:13 p.m.	26.60 t
	8:10 p.m.	26.71 r
July 12	9:34 a.m.	27.01 r

1/ Brief reversal caused by pumping well 2 (IW-162)

(3) Water-level measurements, Camp well no. 1 (IW-160)

Date (1949)	Time	Depth to water, feet
July 1	11:35 a.m.	- - a
	5:30 p.m.	- - a
July 2	3:00 p.m.	28.97
	4:15 p.m.	28.58
	5:23 p.m.	28.25
	8:45 p.m.	27.76
	10:55 p.m.	26.57
July 3	12:06 a.m.	26.47
	12:00 noon	24.91
	3:47 p.m.	24.52
	8:32 p.m.	24.07
	11:17 p.m.	23.84
July 4	8:53 a.m.	23.07
	4:45 p.m.	22.88
	10:55 p.m.	22.38
July 5	10:00 a.m.	21.63
	3:30 p.m.	21.72
	9:37 p.m.	21.52
July 6	9:30 a.m.	20.95
	3:35 p.m.	20.90
	9:28 p.m.	20.63
	9:58 p.m.	20.23
July 7	3:11 p.m.	20.18
	10:11 p.m.	20.33
July 8	9:34 a.m.	- - b
	4:06 p.m.	20.21
(Found pumping at 11:00 p.m. on July 8)		
	11:12 p.m.	- - a
July 11	2:30 p.m.	- - a

a False water level was measured at this time--between 10 and 11 feet below measuring point. Measurement was made by steel tape in air line; water probably was being forced up into air line by pressure near discharge while pumping.

b False water level, as (a) above. Well may have been pumping although no record of it was made.

(4) Water-level measurements, Camp well no. 2 (IW-162)

Date (1949)	Time	Depth to water, feet	Remarks
July 1	11:07 a.m.	75.39	
	11:10 a.m.	75.58	
	11:13 a.m.	75.54	
	4:50 p.m.	76.24	
	4:55 p.m.	77.20	
	9:15 p.m.	76.78	
	9:20 p.m.	76.59	
	9:25 p.m.	76.51	
July 2	12:01 a.m.	77.41	
	12:04 a.m.	77.00	
	3:40 a.m.	77.13	
	3:43 a.m.	77.08	
	4:00 a.m.		well off, running backward.
	4:13 a.m.	12.40	
	4:15 a.m.		Stopped running backward.
	4:17 a.m.		water still draining back into well.
	4:20 a.m.		
	4:30 a.m.		Stopped draining entirely.
	4:30 a.m.	25.23	
	4:33.5 a.m.	25.13	
	4:36 a.m.	25.07	
	4:40 a.m.	24.97	
	4:46 a.m.	24.80	
	4:50 a.m.	24.69	
	4:55 a.m.	24.57	
	5:00.5 a.m.	24.44	
	5:10 a.m.	24.24	
	5:20 a.m.	24.07	
	5:30 a.m.	23.92	
	5:40 a.m.	23.77	
	5:50 a.m.	23.63	
	6:00 a.m.	23.52	
	6:15 a.m.	23.35	
	6:30 a.m.	23.20	
	6:45 a.m.	23.06	
	7:00 a.m.	22.95	
	7:20.5 a.m.	22.78	

(4) Water-level measurements, Camp well no. 2 (IW-162)--Continued

Date (1949)	Time	Depth to water, feet	Remarks
July 2	7:36 a.m.	22.68	
	8:00 a.m.	22.52	
	8:15 a.m.	22.36	
	8:29 a.m.	22.16	
	8:45 a.m.	21.93	
	9:00 a.m.	21.71	
	9:15 a.m.	21.49	
	9:30 a.m.	21.30	
	9:45 a.m.	21.11	
	10:00 a.m.	20.95	
	10:15 a.m.	20.79	
	10:30 a.m.	20.63	
	10:50 a.m.	20.45	
	11:13 a.m.	20.26	
	11:54 a.m.	19.93	
	12:20 p.m.	19.73	
	1:27 p.m.	19.37	
	2:42 p.m.	18.85	
	4:07 p.m.	18.42	
	5:16 p.m.	18.11	
	8:30 p.m.	17.72	
	10:45 p.m.	16.83	
	11:59 p.m.	16.67	
July 3	3:06 a.m.	16.12	
	5:14 a.m.	15.82	
	9:03 a.m.	15.33	
	11:45 a.m.	14.58	
	3:40 p.m.	14.70	
	8:10 p.m.	14.30	
	11:09 p.m.	14.06	
July 4	8:43 a.m.	13.34	
	4:24 p.m.	13.02	
	10:43 p.m.	12.66	
July 5	9:50 a.m.	12.08	
	3:16 p.m.	11.99	
	9:23 p.m.	11.81	
July 6	9:19 a.m.	11.30	
	3:22 p.m.	11.20	
	9:19 p.m.	11.00	

(4) Water-level measurements, Camp well no. 2 (IW-162)--Continued

Date (1949)	Time	Depth to water, feet	Remarks
July 7	9:47 a.m.	10.60	
	3:23 p.m.	10.50	
	10:00 p.m.	79.75	
July 8	9:12 a.m.	11.11	
	4:16 p.m.	10.50	
	10:50 p.m.	10.75	
--Camp well no. 1 (IW-160) reported on at about 10:50 p.m. --			
	11:30 p.m.	10.89	
July 9	12:05 a.m.	Pump reported on.	

(5) Water-level measurements at town well no. 3 (S-207b), Franklin

Date (1949)	Time	Depth to water, feet	Remarks
July 1	1:32 p.m.	33.36	(Depth to water from top of airline)
	5:45 p.m.	33.07	
	10:11 p.m.	33.17	
	11:08 p.m.	33.05	
July 2	12:29 a.m.	33.07	
	2:10 a.m.	33.07	
	3:10 a.m.	33.03	
	3:46 a.m.	32.79	
	3:52 a.m.	32.79	
	4:02 a.m.	32.03	
	4:07 a.m.	32.98	
	4:12 a.m.	32.93	
	4:18 a.m.	32.88	
	4:23 a.m.	32.84	
	4:28 a.m.	32.83	
	4:34 a.m.	32.78	
	4:39 a.m.	32.78	
	4:44 a.m.	32.77	
	4:49 a.m.	32.88	
	4:54 a.m.	32.89	
	5:05 a.m.	32.88	
	5:10 a.m.	32.79	
	5:15 a.m.	32.74	
	5:20 a.m.	32.69	
	5:26 a.m.	32.65	
	5:38 a.m.	32.60	
	5:43 a.m.	32.69	
	5:48 a.m.	32.74	
	5:58 a.m.	32.79	
	6:10 a.m.	32.60	
	6:15 a.m.	32.53	
	6:20 a.m.	32.46	
	6:25 a.m.	32.44	
	6:35 a.m.	32.58	
	6:40 a.m.	32.63	
	6:45 a.m.	32.60	
	6:55 a.m.	32.61	
	7:05 a.m.	32.44	
	7:10 a.m.	32.38	
	7:15 a.m.	32.34	
	7:25 a.m.	32.34	

(5) Water-level measurements at town well no. 3 (S-207b), Franklin--Continued

Date (1949)	Time	Depth to water, feet	Remarks
July 2	7:35 a.m.	32.43	
	7:45 a.m.	32.43	
	7:55 a.m.	32.39	
	8:10 a.m.	32.35	
	8:20 a.m.	32.25	
	8:25 a.m.	32.22	
	8:35 a.m.	32.08	
	8:45 a.m.	31.93	
	8:50 a.m.	31.88	
	8:55 a,m.	31.73	
	9:05 a.m.	31.65	
	9:15 a.m.	31.44	
	9:25 a.m.	31.39	
	9:30 a.m.	31.35	
	9:35 a.m.	31.30	
	9:40 a.m.	31.26	
	9:46 a.m.	31.16	
	9:51 a.m.	31.10	
	9:55 a.m.	31.07	
	10:00 a.m.	30.99	
	10:05 a.m.	30.95	Town well no. 2 (with small pump) on at 10:05 a.m.
	10:12 a.m.	32.82	
	10:16 a.m.	32.98	
	10:25 a.m.	33.14	
	10:40 a.m.	33.04	
	10:50 a.m.	32.96	
	11:00 a.m.	32.90	
	11:10 a.m.	32.89	
	11:20 a.m.	32.90	

--Town wells turned off: well no. 1 at 11:20 a.m., and well no. 2 at 11:30 a.m.--

	11:40 a.m.	30.04	
	11:45 a.m.	30.37	
	11:55 a.m.	30.04	
	12:15 p.m.	30.81	Town well no. 1 turned on at 12:15 p.m.
	12:40 p.m.	31.19	
	1:00 p.m.	31.24	
	1:34 p.m.	31.92	
	2:04 p.m.	31.75	

(5) Water-level measurements at town well no. 3 (S-207b), Franklin--Continued

Date (1949)	Time	Depth to water, feet	Remarks
July 2	2:55 p.m.	31.43	
	4:26 p.m.	31.06	
	5:35 p.m.	28.93	
	5:36 p.m.	28.82	
	5:37 p.m.	28.72	
	7:42 p.m.	27.75	
	10:10 p.m.	27.06	
	11:35 p.m.	26.57	
July 3	3:34 a.m.	25.85	
	5:30 a.m.	25.49	
	9:25 a.m.	25.31	
	12:15 p.m.	24.74	
	4:07 p.m.	24.66	
	8:19 p.m.	24.13	
	11:48 p.m.	23.70	
July 4	9:05 a.m.	23.28	
			Town well no. 1 off at 10:10 a.m.
	10:17 a.m.	23.15	
	10:29 a.m.	23.00	
	10:38 a.m.	22.94	
			Town well no. 3 on at 10:40 a.m.
	11:06 a.m.	62.25	
			Town well no. 3 off at 11:08 a.m.
	11:15 a.m.	25.70	
	11:18 a.m.	25.04	
	11:21 a.m.	24.76	
	11:23 a.m.	24.50	Town well no. 3 on at 11:23 a.m.
			Town well no. 3 off at 11:29 1/4 p.m. (pumping rate, 1600 gpm)
	11:32 1/4 a.m.	25.68	
	11:34 1/4 a.m.	25.14	
	11:38 1/4 a.m.	24.56	
	11:41 1/4 a.m.	24.33	
			Town well no. 3 on at 11:45 a.m.
			Town well no. 3 off at 11:50 3/4 a.m.

(5) Water-level measurements at town well no. 3 (S-207b), Franklin--Continued

Date (1949)	Time	Depth to water, feet	Remarks
July 4	12:25 p.m.	23.52	
	12:28 p.m.	23.46	
	12:30 p.m.	23.43	
	12:35 p.m.	23.35	
	12:40 p.m.	23.29	
	12:53 p.m.	23.15	
	12:59 p.m.	23.11	
			Town well no. 3 on at 1:00 p.m.
	1:20 p.m.	62.10	
			(Drawdown, 38.99 ft, at 1600 gpm; sp. cap. = 41 gpm/ft)
	1:25 p.m.	62.05	
			Town well no. 3 off at 1:26 p.m.
	1:33 p.m.	25.58	
	1:35 p.m.	25.20	
	1:37 p.m.	24.92	
	1:39 p.m.	24.70	
	1:41 p.m.	24.54	
	1:43 p.m.	24.39	
	1:45 p.m.	24.26	
	1:47 p.m.	24.15	
	1:49 p.m.	24.05	
	1:51 p.m.	23.98	
	1:53 p.m.	23.91	
	1:55 p.m.	23.85	
	2:00 p.m.	23.71	
	2:05 p.m.	23.58	
	2:10 p.m.	23.49	
	2:15 p.m.	23.40	
	2:20 p.m.	23.32	
	2:25 p.m.	23.25	
	2:30 p.m.	23.20	
	2:35 p.m.	23.17	
	2:40 p.m.	23.09	
	2:45 p.m.	23.05	
			Town well no. 3 on at 2:48 p.m.

(5) Water-level measurements at town well no. 3 (S-207b), Franklin--Continued

Date (1949)	Time	Depth to water, feet	Remarks
July 4	11:11 p.m.	22.40	
July 5	10:19 a.m.	24.57	
	9:56 p.m.	21.68	
July 6	8:47 a.m.	21.22	
	9:50 p.m.	20.81	
July 7	8:47 a.m.	20.50	
	10:37 p.m.	20.17	
July 8	8:15 a.m.	20.38	
			Camp well no. 1 on at 10:50 p.m.
July 9			Camp well no. 2 on at 12:06 a.m.
	12:40 a.m.	21.20	
	12:43 a.m.	21.25	
	12:45 a.m.	21.30	
	12:51 a.m.	21.38	
	12:56 a.m.	21.36	
	12:58 a.m.	21.35	
	1:06 a.m.	21.34	
	1:08 a.m.	21.36	
	1:15 a.m.	21.38	
	1:20 a.m.	21.40	
	1:25 a.m.	21.47	
	1:30 a.m.	21.61	
	1:44 a.m.	21.86	
	9:05 a.m.	24.77	
	6:13 p.m.	26.93	
	9:53 p.m.	27.00	
July 10	2:12 p.m.	28.05	
July 11	10:45 a.m.	32.08	
	6:35 p.m.	29.72	

(6) Water-level measurements in town observation well (S-205), Fifth Avenue and Middle Street, Franklin, Va.

Date (1949)	Time	Depth to water, feet
July 1	1:54 p.m.	28.36
	5:55 p.m.	27.38
	10:00 p.m.	27.49
	11:03 p.m.	27.30
July 2	12:18 a.m.	27.90
	12:20± a.m.	27.80
	12:22± a.m.	27.70
	2:05 a.m.	27.65
	3:25 a.m.	27.08
	3:30 a.m.	27.07
	3:57 a.m.	27.54
	4:30 a.m.	26.95
	4:57 a.m.	27.55
	5:36 a.m.	26.77
	6:05 a.m.	27.09
	6:30 a.m.	27.10
	7:00 a.m.	27.24
	7:30 a.m.	27.18
	8:00 a.m.	27.25
	8:30 a.m.	27.15
	9:10 a.m.	26.96
	9:45 a.m.	26.73
	10:35 a.m.	27.40
	11:05 a.m.	27.25
	11:35 a.m.	27.19
	2:15 p.m.	26.40
	3:02 p.m.	26.15
	4:30 p.m.	25.87
	5:40 p.m.	24.64
	5:41 p.m.	24.56
	5:42 p.m.	24.51
	7:35 p.m.	24.20
	9:45 p.m.	23.51
	11:30 p.m.	22.74
July 3	3:25 a.m.	22.48
	5:25 a.m.	21.79
	9:16 a.m.	22.17
	12:10 p.m.	21.07
	4:15 p.m.	21.65
	8:25 p.m.	21.13
	11:33 p.m.	20.35

(6) Water-level measurements in town observation well (S-205)--Continued

Date (1949)	Time	Depth to water, feet
July 4	8:55 a.m.	20.46
	10:10 a.m.	20.55
	10:20 a.m.	19.60
	10:30 a.m.	19.74
	10:40 a.m.	19.59
	10:45 a.m.	20.37
	10:50 a.m.	21.23
	10:55 a.m.	21.74
	11:00 a.m.	22.14
	11:05 a.m.	22.39
	11:09 a.m.	22.53
	11:15 a.m.	21.47
	11:20 a.m.	20.94
	11:25 a.m.	20.67
	11:30 a.m.	21.55
	11:35 a.m.	21.08
	11:40 a.m.	20.64
	11:45 a.m.	20.35
	11:50 a.m.	20.75
	11:55 a.m.	21.12
	12:00 noon	20.57
	12:45 p.m.	19.47
	1:09 p.m.	20.73
	3:21 p.m.	20.75
	11:23 p.m.	19.05
July 5	10:15 a.m.	21.00
	10:03 p.m.	18.67
July 6	8:40 a.m.	18.76
	9:55 p.m.	18.39
July 7	8:38 a.m.	18.15
	10:33 p.m.	17.78
July 8	8:19 a.m.	17.85
July 9	1:57 a.m.	17.89
	8:55 a.m.	20.75
	5:25 p.m.	23.68
	9:45 p.m.	22.71
July 10	2:27 p.m.	23.70
July 11	9:50 a.m.	24.65
	7:52 p.m.	25.23

(7) Pumping schedule of town wells
Franklin, Virginia

Date (1949)	No. 1 On	No. 1 Off	No. 2 On	No. 2 Off	No. 3 On	No. 3 Off
July 1		6:00 a	9:50 a	11:20 a		
	6:25 a	7:02	12:25 p	4:30 p		
	7:20	11:30	4:45	5:25		
	11:45	5:25 p				
	6:10 p	8:30				
	9:10	9:40				
	10:05	10:35				
	11:00	11:30				
	11:55					
July 2		12:15 a	10:05 a	10:25 a		
	12:50 a	1:10	11:05	11:25		
	1:45	2:10	12:10 p	1:00 p		
	2:45	3:05	3:05	3:20		
	3:45	4:05	5:15	5:30		
	4:40	5:00				
	5:35	6:00				
	6:20	7:00				
	7:15	11:30				
	12:15 p	5:30 p				
	6:10	8:25				
	8:45	9:20				
	9:40	10:10				
	10:30	11:10				
	11:30	12:00 p				
July 3	12:25 a	12:50 a	7:30 a	10:20 a		
	1:20	1:40	10:35	11:30		
	2:15	2:35	12:10 p	1:45 p		
	3:05	3:30	2:05	3:30		
	4:00	4:20	3:45	5:00		
	4:50	5:15	5:15	5:30		
	5:45	6:10				
	6:35	7:05				
	7:15	7:25				
	7:30	5:30 p				
	6:10 p	7:50				
	8:10	8:45				
	9:10	9:35				
	9:55	10:25				
	10:50	11:20				
	11:45					
July 4		12:05 a			10:40 a	11:08 a
	12:35 a	1:00			11:22	11:29
	1:30	1:50			11:45	11:50
	2:25	2:45			1:00 p	1:26 p
	3:25	3:45			2:45	3:12
	4:20	4:40				
	5:15	5:35				
	6:10	6:30				
	6:50	7:30				

(7) Pumping schedule of town wells, Franklin, Va.--Continued

Date (1949)	No. 1 On	No. 1 Off	No. 2 On	No. 2 Off	No. 3 On	No. 3 Off
July 4	7:50 a	10:10 a				
	3:20 p	5:25 p				
	6:10	8:15				
	8:35	9:10				
	9:30	10:00				
	10:20	10:55				
	11:20	11:45				
July 5	12:15 a	12:35 a	9:50 a	11:30 a		
	1:05	1:30	1:40	2:05		
	2:00	2:20	3:10	3:45		
	2:55	3:15	4:30 p	5:00 p		
	3:45	4:10	6:25	7:15		
	4:40	5:05				
	5:30	6:00				
	6:20	6:55				
	7:15	11:30				
	11:45	5:30 p				
	6:10 p	7:45				
	8:05	8:50				
	9:10	9:30				
	10:05	10:50				
	11:10	11:35				
July 6	12:05 a	12:25 a	8:50 a	10:05 a		
	12:55	1:20	10:05	11:30		
	1:50	2:10	1:05 p	4:15 p		
	2:40	3:05				
	3:35	3:55				
	4:25	4:50				
	5:15	5:45				
	6:00	6:40				
	7:00	11:30				
	12:00 m	4:40 p				
	6:10 p	6:55				
	8:30	9:20				
	9:40	10:25				
	10:45	11:20				
	11:40					
July 7		12:10 a	9:10 a	10:40 a		
	12:35 a	1:00	12:20 p	1:50 p		
	1:25	1:45	3:00	5:30		
	2:15	2:40				
	3:10	3:30				
	4:00	4:25				
	4:50	5:15				
	5:40	6:15				
	6:35	11:30				
	11:45	2:05 p				
	4:10 p	5:10				
	5:45	6:45				
	7:05	8:00				
	8:20	8:50				

(7) Pumping schedule of town wells, Franklin, Va.--Continued

Date (1949)	No. 1 On	No. 1 Off	No. 2 On	No. 2 Off	No. 3 On	No. 3 Off
July 7	9:10 p	9:45 p				
	10:05	10:35				
	11:00	11:20				
	11:50					
July 8		12:15 a	7:40 a	12:45 p		
	12:45 a	1:05	4:00 p	4:25		
	1:35	2:00				
	2:30	2:50				
	3:25	3:45				
	4:15	4:40				
	5:05	5:30				
	6:00	6:15				
	6:35	7:25				
	7:40	11:00				
	11:35	12:45 p				
	1:00 p	2:30				
	2:45	5:15				
	5:30	6:20				
	6:40	7:30				
	7:50	8:20				
	8:45	9:10				
	9:35	10:05				
	10:30	11:00				
	11:25	11:50				
July 9	12:20 a	12:40 a				
	1:10	1:30				
	2:05	2:25				
	3:05	3:20				
	4:00	4:20				
	4:50	5:15				
	5:45	6:20				
	6:45	8:25				
	8:40	11:30				
	11:45	12:35 p				
	1:55 p	2:10				
	3:20	3:40				
	4:10	4:30				
	5:30	7:00				
	7:15	8:05				
	8:20	9:00				
	9:20	9:50				
	10:10	10:45				
	11:10	11:40				
July 10	12:10 a	12:30 a				
	1:05	1:25				
	2:00	2:20				
	3:00	3:15				
	3:55	4:15				
	4:50	5:15				
	5:45	6:00				
	6:10	6:35				

(7) Pumping schedule of town wells, Franklin, Va.--Continued

Date (1949)	No. 1 On	No. 1 Off	No. 2 On	No. 2 Off	No. 3 On	No. 3 Off
July 10	6:40 a	7:05 a				
	7:25	8:05				
	8:20	9:30				
	9:45	10:45				
	11:05	11:35				
	12:15 p	2:00 p				
	2:10	3:40				
	4:00	4:40				
	5:00	5:30				
	6:15	7:30				
	7:50	8:25				
	8:45	9:15				
	9:40	10:10				
	10:35	11:00				
	11:30	11:50				
July 11	12:25 a	12:45 a	9:45 a	11:30 a		
	1:20	1:40	12:10 p	1:30 p		
	2:20	2:40				
	3:20	3:40				
	4:20	4:40				
	5:15	5:35				
	6:00					
	6:45	11:30				
	12:20 p	1:30 p				
	1:45	5:30				
	5:50	7:50				