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The effects of seismic blasting on shallow water wells and aquifers in western North Dakota

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THE EFFECTS OF SEISMIC BLASTING ON SHALLOW WATER WELLS AND AQUIFERS IN WESTERN NORTH DAKOTA

by
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This thesis submitted by Frank W. Beaver, Jr., P. E. in partial fulfillment of the requirements for the Degree of Master of Science from the University of North Dakota is hereby approved by the Faculty Advisory Committee under whom the work has been done.

Alan E. Kehew

John R. Reid

This thesis meets the standards for appearance and conforms to the style and format requirements of the Graduate School of the University of North Dakota, and is hereby approved.

A. William Johnson 5/2/84

Title THE EFFECTS OF SEISMIC BLASTING ON SHALLOW WATER WELLS AND AQUIFERS IN WESTERN NORTH DAKOTA

Department Geology

Degree Master of Science

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Signature ______________________________

Date ______________________________

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The North American Coal Corporation deserves special consideration for their willingness to let us use their land holdings as an experimental site. Site consolidation made the logistics much more manageable than they would have been with multiple sites. Jim Brown, Director of Environmental Control, was instrumental in obtaining permission within the company and Terry Zich, Hydrologist, served as a cooperative and helpful liaison.

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ABSTRACT

Seismographic petroleum exploration throughout North Dakota has generated concern over the effects of blasting on groundwater supplies and wells. A preliminary investigation revealed complaints alleging declining productivity and decreased water quality in regions where coal aquifers are extensively used. Unplugged shotholes were frequently cited as a source of problems.

Experimental results indicate that long term physical changes due to blasting occur within the aquifers rather than in specific water wells. Pumping tests conducted in a sand and coal aquifer system showed no apparent physical effects when shots were detonated one quarter mile away from the pumping wells. Shots 500 feet distant resulted in no permanent effects. Shots 100 feet or closer increased the yield from wells finished in the sand aquifer and decreased the yield from the coal aquifer. Fracturing of the poorly indurated sandstone aquifer is suggested as a mechanism for the increase. Collapse of fractures is suggested as the failure mechanism in the coal aquifer. Well casings remained intact after 25 pound charges were detonated as close as 10 feet from a well screen. Currently available methods for evaluating pump test data do not adequately

address coal fracture permeability. Consequently, values for transmissivity, storativity, and specific yield were unobtainable.

During the pumping tests, no significant long term chemical or mineralogical equilibrium changes were observed which could be attributed to the blasting. Water quality changes resulted from pumping during the early time segments of the pump tests. Immediately following a shot 100 feet from a pumping well finished in coal, a short term increase in most chemical parameters was noted. Shots farther away had no apparent effect on chemical quality.

Well owners and explorers are advised to collect water quality and pumping drawdown data before any exploration is conducted. The relative productivity of any well can be determined by pumping the well and noting the drawdown with time. If done prior to exploration, these measures provide an excellent basis for evaluation of the effects of blasting.

Chapter I

INTRODUCTION

1.1 HISTORY

Seismographic exploration in North Dakota began with oil development approximately thirty years ago. Seismic exploration has been occurring, for the most part, in the western two-thirds of North Dakota. However, through the years, the most concentrated exploration activity generally has occurred in the oil producing counties. In many parts of western North Dakota, repeated seismic surveys have crisscrossed the countryside with networks of shotlines. This has resulted in extensive perforation of the nearsurface strata. During that time, various governmental agencies and law firms received reports of damage to water supply systems allegedly caused by nearby seismographic blasting. No definitive data were available and speculations and claims were numerous. The absence of a regulatory framework prevented the development of standardized procedures to deal with such cases. Generally, the only practicable recourse available was a civil action, a solution which has not been extensively utilized in rural North Dakota.

As oil development increased, so did the number of complaints, many of which were apparently reported to legislators. In 1981, the 47th Legislative Assembly of North Dakota, through House Concurrent Resolution No. 3032, directed the Legislative Council to study the situation and report to the 48th Legislative Assembly in 1983. The Legislative Council asked the North Dakota State Water Commission and the North Dakota Geological Survey to investigate the problem during the following biennium and to submit a report to the 48th Legislative Assembly in 1983. The unfunded study was intended to be a compilation of existing information. The report to the 48th Legislative Assembly in 1983 was the result of the preliminary survey conducted for this thesis. The North Dakota Mining and Mineral Resources Research Institute, the North Dakota Geological Survey, and the North Dakota State Water Commission were instrumental in supporting the initial work. The experimental design was based in part on those findings.

1.2 LITERATURE SEARCH

There is an extensive body of literature on the effects of blasting vibrations on structures associated with mining and construction. There have been, however, very few investigations of their effects on the groundwater environment. Bond (1975) conducted an investigation in eastern Montana and concluded that blasting had no significant effect on the groundwater environment. Coal aquifers were not specifically addressed or considered. Eastern Montana is considerably less populated than most of North Dakota and the problem may therefore have received less attention. The work was carried out in the Tertiary Fort Union Formation, which is characterized by interlayered shale, sandstone, siltstone, lignite, and small beds of fresh water limestone. Rocks within the typical North Dakota setting may not be as well indurated as in the Montana study area, and, at least in the Underwood area, are dominated by extensive, poorly indurated sandstone. In many areas, lignite aquifers constitute the only useable water resource, a point not directly addressed by Bond. He further reported that interflow between aquifers through poorly installed wells or open shotholes was probably a more significant problem than blasting, with respect to aquifer degradation.

Sneddon (1981) summarized previous Canadian work and conducted a further investigation. Small changes in aquifer characteristics were noted and the overall results were essentially in agreement with those of Bond. The report includes an extensive section on blasting mechanics, but does not address coal aquifers or the chemical evolution of groundwater.

Berger (1980) investigated the effects of blasting on groundwater in Appalachia, where groundwater is obtained from glacial deposits, valley alluvium, sandstone aquifers, and low-yield water table fracture systems. Blasting was associated with nearby mining activities rather than seismic testing, and would therefore be on a larger scale. No direct changes in water quality were noted for properly constructed wells. Fracturing of the aquifer media from blasting and removal of lateral stress by mining increased the storage capacity, thereby lowering the static water level. The resulting permeability increase improved well performance. Most complaints were generated when pump intakes did not penetrate or did not extend below the new static water level.

Seismographic analysis has been used to observe the effects of blasting. The earth matrix oscillates in the manner of a wave in response to a shock. Seismograph instrumentation is able to resolve the particle velocity components resulting from blasting. Berger suggests that a peak particle velocity of 2.0 inches per second is insufficient to cause irreversible aquifer or well damage.

On-going research by the Wyoming Oil and Gas Commission suggests that unplugged or poorly plugged boreholes have a significant effect on water quality and that the degradation can be minimized with proper corrective plugging and drilling operations (Marvel, 1984).

Amoco Exploration determined that the number of damage complaints dropped when exploration activity was preceeded by water quality sampling (Whittemore, 1983).

1.3 PRELIMINARY SURVEY

In order to evaluate existing conditions in North Dakota, a preliminary investigation was carried out by the North Dakota Mining and Mineral Resources Research Institute (NDMMRRI) to identify any common factors or trends. A questionnaire requesting information on wells thought to have been affected by seismic testing was mailed to a number of organizations and individuals. County engineers, county auditors, county agents, the North Dakota State Department of Health (NDSDH), state district health units, selected law and engineering firms, the Soil Conservation Service, the U.S. Forest Service, certified water well contractors, the Rocky Mountain Oil and Gas Association, grazing associations, and environmental groups were contacted. A copy of the questionnaire is contained in Appendix A. A list of people was compiled from complaints received and records kept at the U.S. Geological Survey, N.D. Geological Survey, N.D. State Water Commission, U.S. Environmental Protection Agency, and the N.D. State Department of Health. Many of these people were contacted by phone or mail for additional information regarding this study.

A news release regarding this study was also distributed throughout North Dakota. The news release requested information on alleged effects of seismic exploration on groundwater and wells. A significant response developed in the form of personal letters in which such alleged effects were described. Follow-up resulted in more complete information. The data were initially tabulated and a field reconnaissance of selected sites was carried out during the summer of 1982. The field reconnaissance was undertaken to verify the allegations presented and to select tentative sites for further research. Approximately one-third of the cases reported were inspected to assess reported conditions. Information continued to come in through the summer and fall of 1982. Figure 1 illustrates the general geographical distribution of complaints. Table 1 categorizes alleged changes in wells as a result of seismic blasting.

A considerably longer list of possible cases has not been included in table 1 because of inadequate documentation; the information reported in the returned questionnaires was incomplete in most cases. Very few people have good records of their wells with respect to production and water quality. Many wells have passed through numerous owners and historical data have been lost in the transactions. Because of the lack of background information, it is usually not possible to draw definitive conclusions regarding changes in water quality and production. All of the problems reported

Complaints originated from the western half of North Dakota, the oil production district.

Figure 1. Geographical Distribution of Complaints

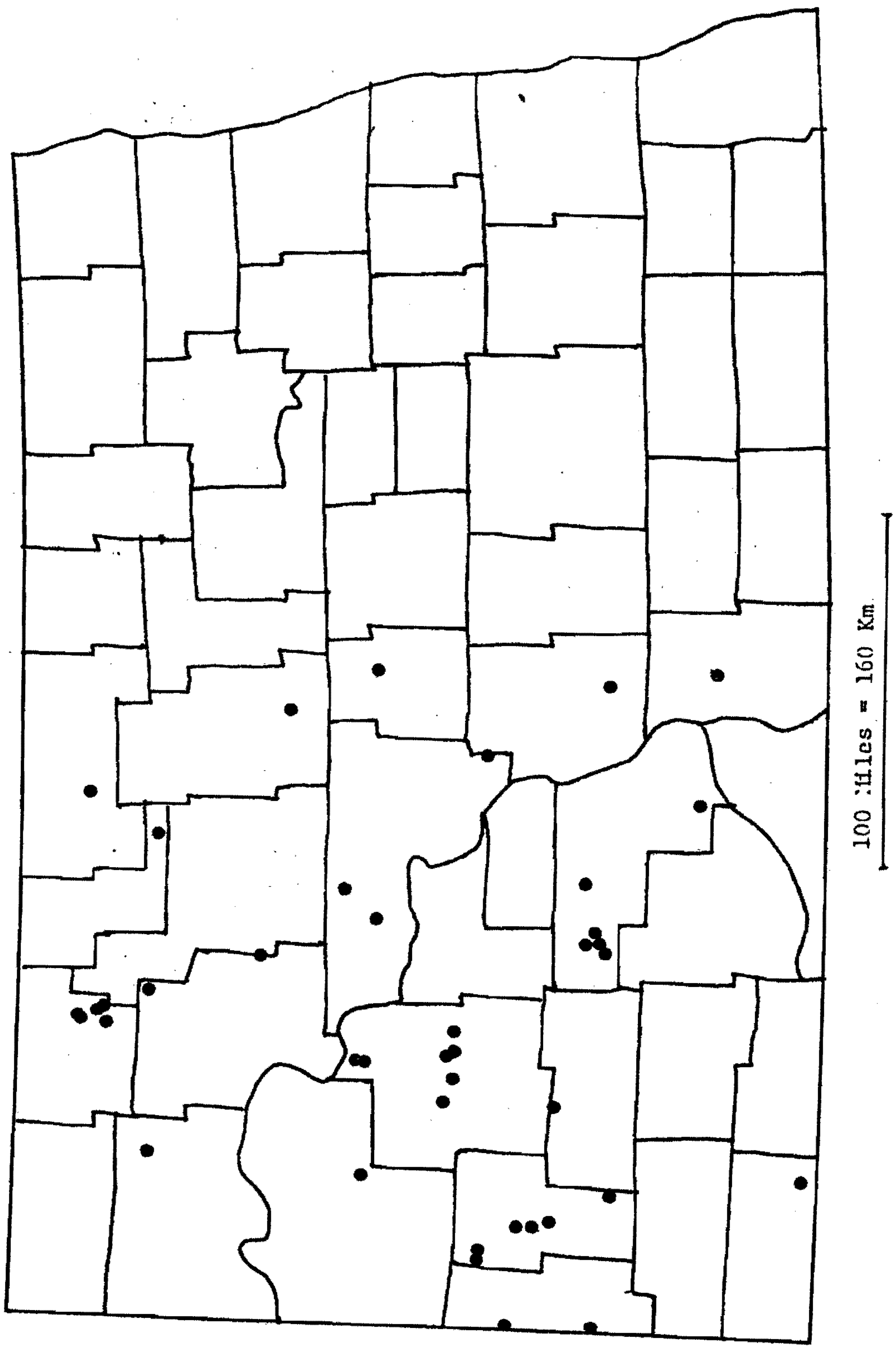

100 Miles = 160 Km

TABLE 1

Summary of Reported Blasting Effects

Key to reported problems: sediment produced = S; color = C; decreased yield = Y; well failed = F; odor = O; lignite produced = L; taste problems = T. Field inspection indicated by * (metres = ft x 0.3048)

Location	Age (yr)	Depth (ft)	Pumped or Flowing	Type of Problem:
Anamoose				T
Balfour*	14	290	pumped	S, L, Y
Balfour*	20	342	pumped	S, L, T
Balfour				L, iron, Y
Beach*	40	127	pumped	L, T, O
Beach*		spring	flowing	F
Belfield*		deep	flowing	Y
Belfield*	7	1300	flowing	F
Belfield*	20	315	flowing	L, Y, C
Beulah			pumped	L, Y
Bottineau			pumped	F
Bowbells			flowing	Y
Bowbells	12	100	pumped	S, L
Bucyrus				Y, T, O
Burt	40	240	pumped	L
Denhoff			pumped	L, T, O
Denhoff	38	310	pumped	S, L, T
Dickinson			pumped	Y
Dickinson	5	15	pumped	T, O
Donnybrook*	15	185	pumped	C, Y
Douglas*	30	250	pumped	L, Y, T
Douglas			pumped	L, Y
Dunn Center*	35	157	flowing	F
Dunn Center*	25	120	flowing	L, Y, C, T
Dunn Center		138	flowing	L, Y
Dunn Center			flowing	L, Y
Dunn Center*			flowing	F
Dunn Center*			pumped	L, Y
Dunn Center	26	130	flowing	L, Y
Elgin	3		pumped	S
Emmet*	45	186	pumped	S, C, Y
Flasher	30	120	pumped	Y, T, C
Glenburn*	78	18	pumped	L, T, O
Glen Ullin		55		S, Y
Glen Ullin		55		Y
Glen Ullin				S
Golva*	5	300	pumped	L, Y, O
Golva			pumped	L, Y
Halliday*	25	180	flowing	L, Y, C
Haynes			pumped	L, Y

TABLE 1 (Continued)

Summary of Reported Blasting Effects

Key to reported problems: sediment produced = S; color = C; decreased yield = Y; well failed = F; odor = O; lignite produced = L; taste problems = T. Field inspection indicated by * (metres = ft x 0.3048)

Location	Age (yr)	Depth (ft)	Pumped or Flowing	Type of Problem:
Hettinger	15	350	pumped	L, Y
Kenmare	25		pumped	S, L, Y
Kenmare*	10	32	pumped	S, L, Y, O
Kenmare*	60	50	pumped	L, Y
Kenmare*	25	86	flowing	S, L, Y, T, O
Killdeer*		spring	flowing	Y
Linton	6	184	pumped	L
Linton			pumped	T
Martin				Y
Maxbass	54	78	pumped	T
McKenzie	8	139	pumped	F
McClusky	26	11	pumped	Y
McGregor	60	190	pumped	L
Medora*	45	450	flowing	Y
Medora*	20		flowing	Y
Mott	16	91	pumped	F
Mott	70		pumped	F
New Salem		140	pumped	Y, T
New Salem		150	pumped	S
New Town		spring	flowing	F
New Town*		spring	flowing	F
New Town*		spring	flowing	Y
Plaza*	54	118	pumped	S, L
Powers Lake			pumped	S, Y
Raleigh	30	200	pumped	T, O
Ray	10	160	pumped	C, L, Y
Regent	20	50		S, Y
Rhame			pumped	Y
Scranton	11	110	pumped	C, S, Y, T
Tioga	18	200	pumped	L, C, O
Towner			pumped	Y
Watford City*	4	250	pumped	L, Y, T
White Earth	6	60	pumped	L
Wilton	3	240	pumped	S, L, C, Y

have allegedly occurred during or after seismic testing in an area. Both old and new wells have allegedly been affected. In the cases reported in table 1, 18 wells were under 20 years old and 25 wells were over 20 years old. The lack of correlation between well age and reported damage indicates that the problem is not restricted to old deteriorated wells which were on the verge of collapse before the seismic blasting. Problems originating within the aquifer are therefore more likely than problems with wells. Site specific chemical, hydrologic, and geologic information is not available in most cases, although many users have an intuitive understanding of the hydrogeologic setting of their well.

1.3.1 Shotline Orientation

The shotline orientation was rather vaguely described by most people interviewed. Because of the large number of shotholes, it is impossible to determine a direct cause and effect relationship between a given well and shothole. When the direction of groundwater flow could be determined, seismic activity upgradient was usually indicated as that which had caused the problem. At one location near Douglas, repeated shots as close as 500 feet downgradient caused no effect, while activity upgradient, approximately one mile away, resulted in immediate sediment production from a well finished in sand and lignite. A similar case occurred near the Underwood research site when a piezometer hole was drilled upgradient from a farmstead well screened in lignite. Soon afterwards, the well began producing sediment (Groenewold, 1983). Sediment may have been liberated by the drilling, and subsequently transported through coal fractures between the borehole and the well. The borehole was oriented approximately N 40 degrees W of the well, which corresponds well with the regional primary coal fracture direction. Reported distances between the well(s) in question and the shothole(s)/shotline ranged from several hundred feet to several miles.

1.3.2 Water Quality

Many respondents noted a "long term decline" in their water quality, where the alleged damage has been a gradual transition over several years. In other cases, the alleged damage occurred within hours and was abrupt.

The production of water from lignite aquifers is quite common in western North Dakota. In some areas, lignite aquifers are the most economical source of water or the only source. Wells may be screened in lignite or through several strata, including lignite beds. The wells completed in lignite commonly produce small fragments of lignitic material. Sediment production and the need for the installation of filter systems was frequently mentioned by those surveyed. Typically, water from a well completed in lignite has a brown to black color from organic matter that has been leached out of the coal and is locally known as "black water" in comparison to clear or "white" water.

1.3.3 Water Quantity

Fifty-three of the 76 cases reported in table 1 indicated a decreased yield from wells. The reported decrease in yield ranges from barely perceptible to a total loss of production. The yield did recover in a few wells. However, many people reported the need to find replacement or supplemental water supplies. Background static water-well levels and pump-test data are generally nonexistent. Declines have been reported either in the water level in pumped wells, or in the flow rate from flowing wells and developed springs. The effects are more easily observable on a flowing well, especially if it is used to capacity. A decline in the water level in a pumped well is less readily noticed as long as the pumping demand does not exceed the productive capacity of the well. There is a greater apparent concern over the decline of water level in a flowing well than the decline of the water level in a pumped well. It was not commonly known that a gradual water level or pressure decline in a flowing well is a naturally occurring result of usage.

1.3.4 Unplugged Shotholes

A somewhat unique aspect of alleged effects on groundwater is related to shotholes which are left unplugged or are abandoned. With few exceptions, the reported cases are from shallow wells less than 300 feet deep. Seismic shotholes are in the 200 foot depth range which places them in the same subsurface regime as most rural wells. Unplugged shotholes were commonly mentioned as a point of concern by many landowners. Most people surveyed believed present plugging practices are inadequate.

1.3.5 Legal Actions

There have been very few legal actions in North Dakota relating to alleged damage to ground-water supplies by seismic testing. Some people surveyed indicated they had considered legal action but had not followed through. Few plaintiffs have had sufficient background data and records to prepare a winning case. Some respondents claim to have replaced wells and/or equipment at their own expense.

Chapter II

RESEARCH SITE

2.1 OBJECTIVES

The essence of this research was to determine the qualitative and quantitative effects of seismic exploration blasting on the groundwater environment in western North Dakota. A carefully designed experiment was intended to evaluate effects of blasting in a geologic setting common to the Great Plains by observing the response of wells finished in coal and sandstone aquifers. Submitting an existing farmstead well to simulated exploration blasting was considered to be an important aspect of this investigation.

Features to be addressed included the effects on sand and lignite coal aquifers, the influence of fractures, the orientation and distance between shots and wells, water quality, well yield, and the physical effects on wells. The characteristics of fractured coal aquifers and their response to blasting have not previously been investigated. The influence of fractures on groundwater hydrology has not been widely recognized or completely understood. The concept is particularly important when coal aquifers constitute the major groundwater resource as they do in parts of North Dakota. The project was undertaken with the intention of addressing issues from a practical user's viewpoint based on good scientific practice.

2.2 LOCATION

The logistics of an extensive testing program required a consolidated test site which would be remote enough to prevent possible damage to existing domestic facilities and yet be large enough to minimize coordination problems with landowners. Potential sites throughout western North Dakota were evaluated and systematically eliminated. The site ultimately selected is on a large landholding of the North American Coal Corporation near Underwood, N. D. (Figure 2). The study area detail is shown in figure 3. Extensive hydrogeological research has been conducted in this area in preparation to planned coal mining. The area contains an extensive, poorly indurated sandstone aquifer overlying the coal deposits, thus allowing for evaluation of the effects of blasting on both sand and lignite aquifers. One site, located in the S1/2 SW1/4 S20 T146N R82W, is hereafter referred to as the pump test site. The company also acquired a 160 acre farm one mile west of the pump test site in the NW1/4 S30 T146N R82W. The farmstead had been used until 1983 and the well was typical of old steel-cased installations. It was an ideal situation around which to simulate an actual seismic survey and to record the results as they affected the well. This site is hereafter referred to as the farmstead site.

Figure 2. Study Area General Location

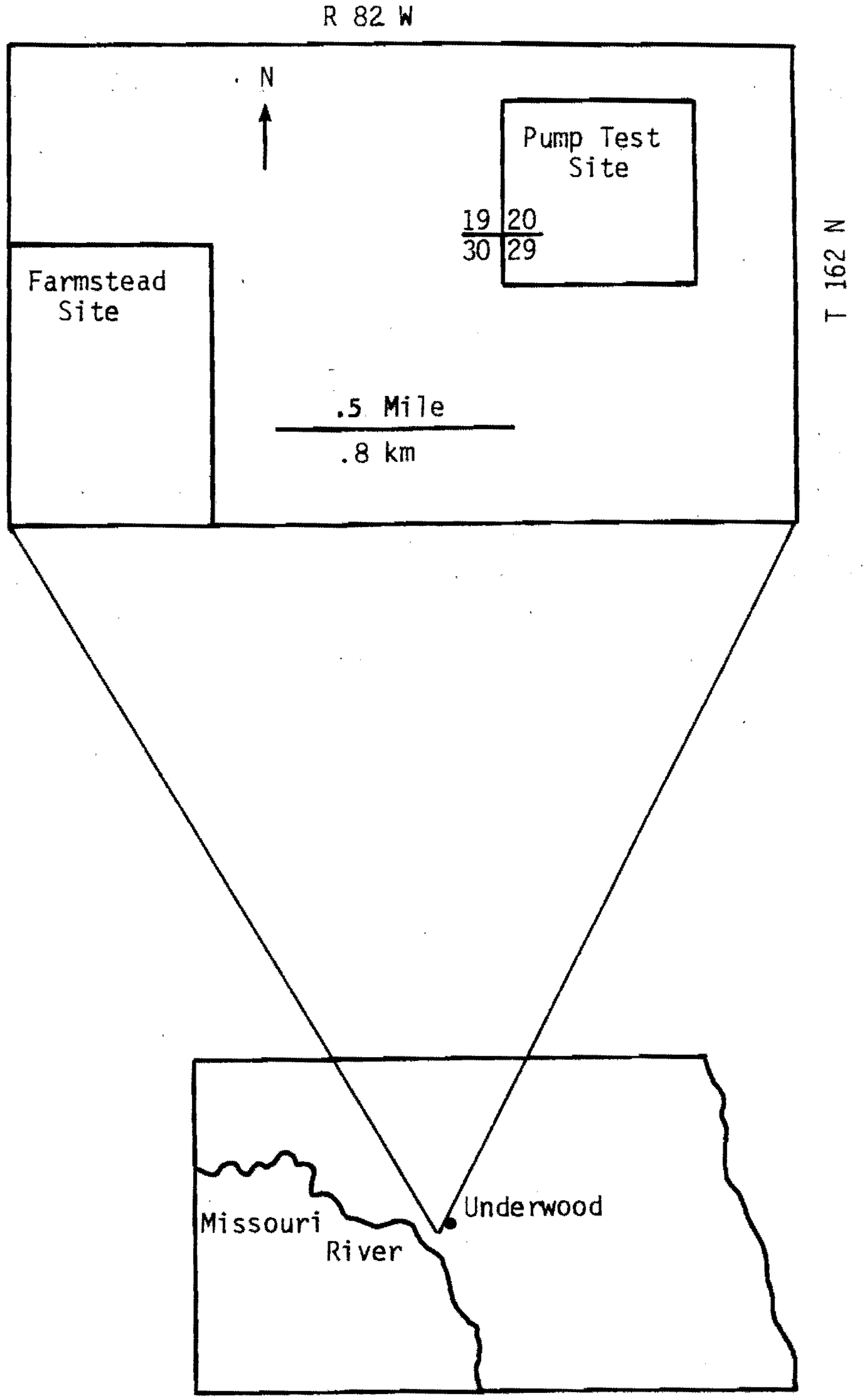
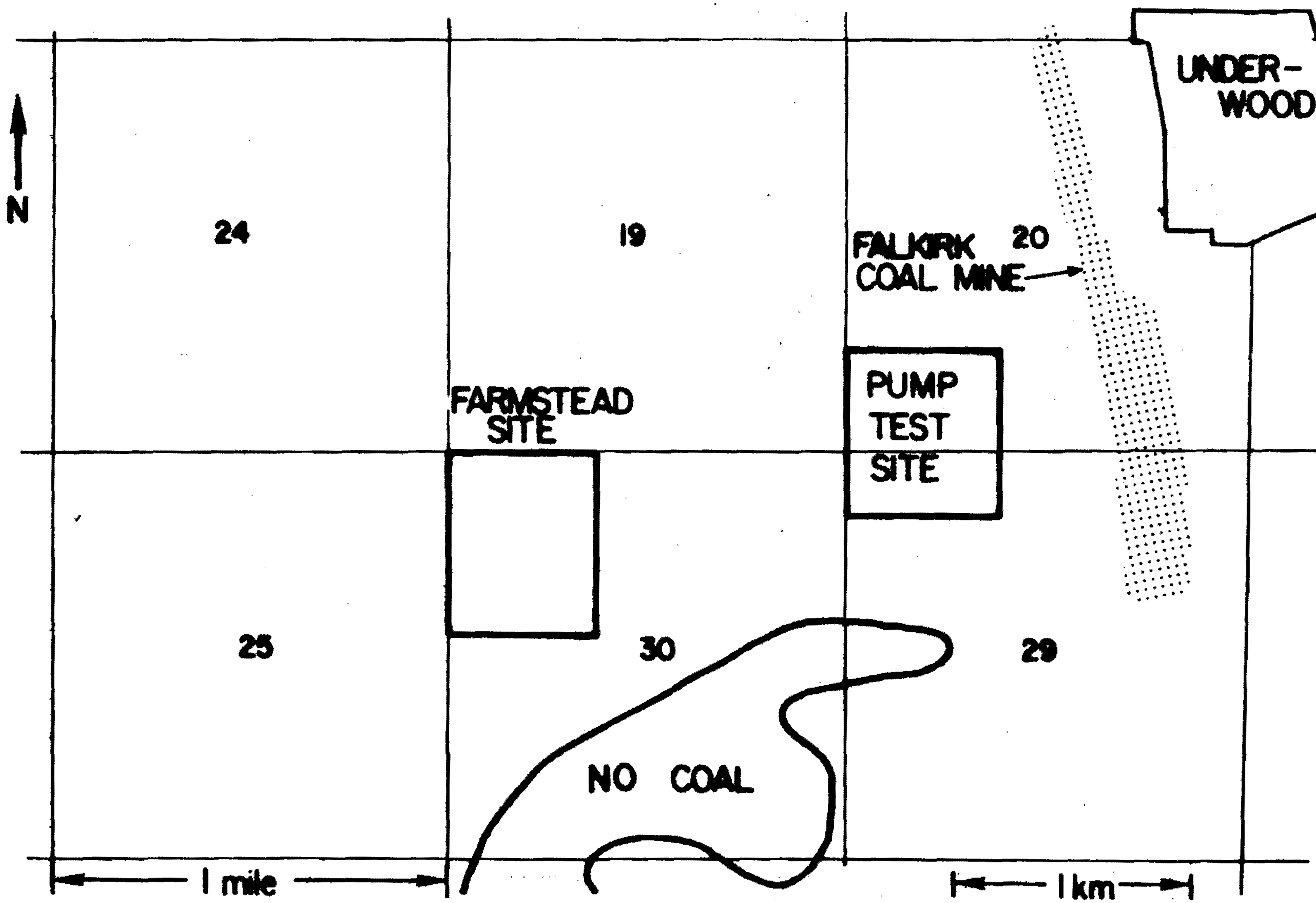

R 82 W
N
Pump Test Site
19 20
30 29
T 162 N
Farmstead Site
.5 Mile
.8 km
Underwood
Missouri River

Figure 3. Study Area Detail

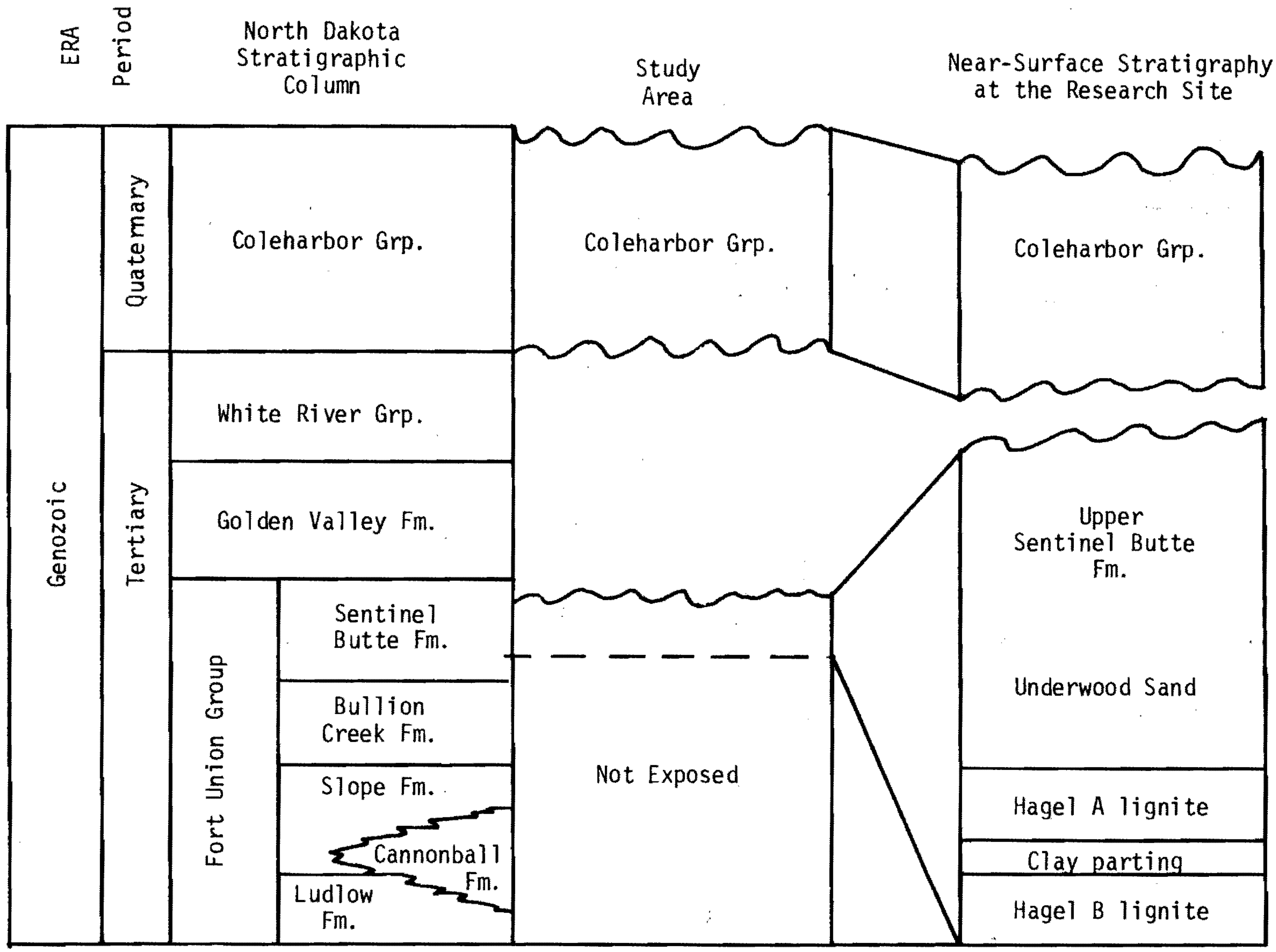

N
24
19
20
FALKIRK
COAL MINE
UNDER-
WOOD
FARMSTEAD
SITE
PUMP
TEST
SITE
25
30
29
NO COAL
1 mile
1 km

2.3 STRATIGRAPHY

The research site is located within the glaciated portion of the Williston Basin. Figure 4 shows the relationship between the site stratigraphy and the regional stratigraphic setting. The uppermost strata of the area consist of approximately forty feet of Coleharbor Group till. Several tills are exposed in the highwall exposures of the Falkirk Mine at a site within one mile of the pump test site.

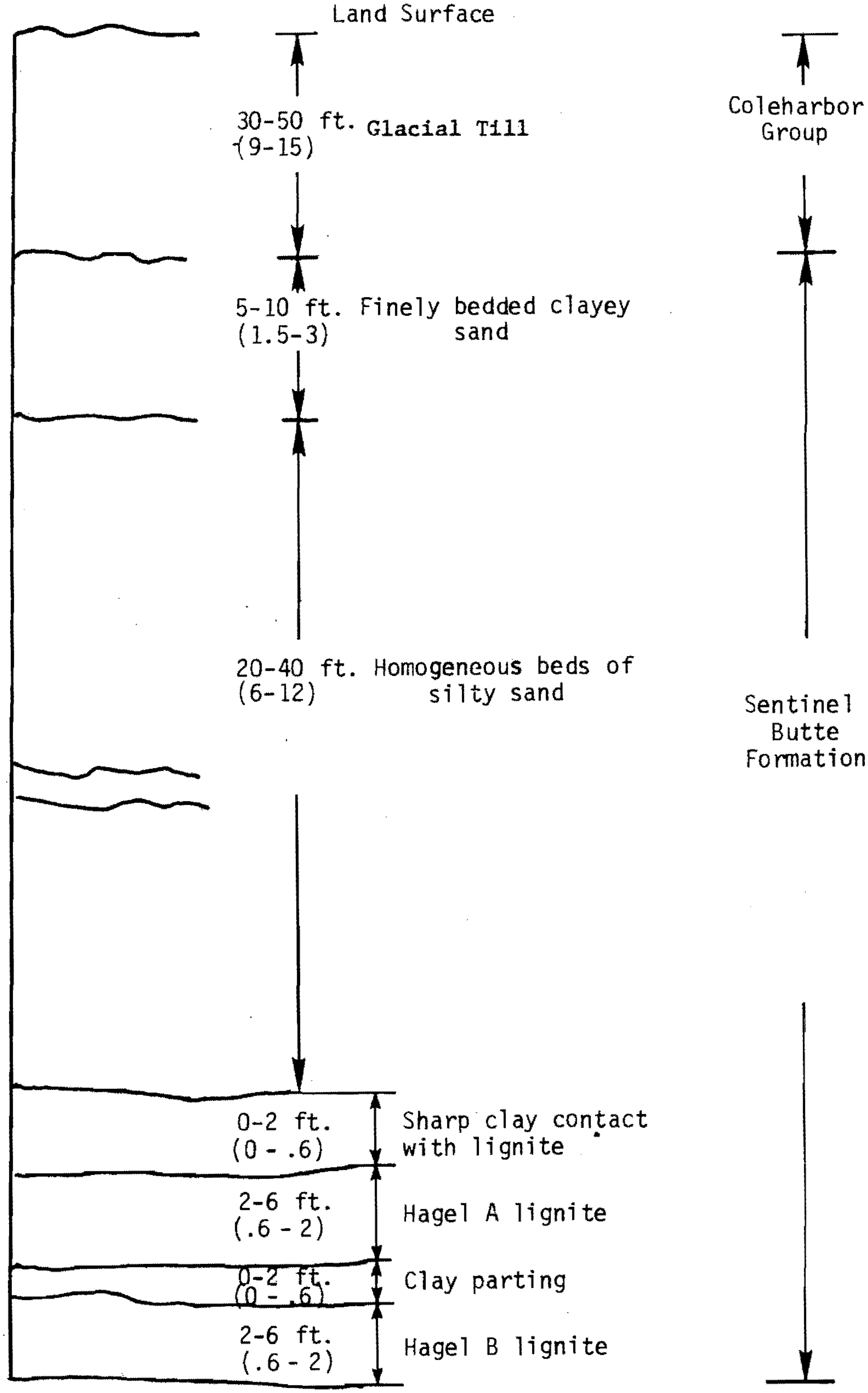
Directly underlying the till is the local bedrock which consists of moderately to poorly indurated sand and silt of the Sentinel Butte Formation (Paleocene). The Fort Union Group, which includes the Sentinel Butte Formation, consists of marine transgressional and non-marine lignite-bearing sediments deposited in a cyclic manner (Royse, 1972). The non-lignitic interval below the till and above the Hagel Lignite has been named the Kinneman Creek Interval (Groenewold et al., 1979). This unit consists, in part, of the Underwood Sand, a relatively thick sand aquifer which was instrumented at the pump test site. The Underwood Sand consists of poorly indurated fine sand and silt, 40 to 60 feet thick, in the vicinity of the pump test site. The thickness of the Kinneman Creek Interval varies considerably; the upper surface of this interval is a preglacial and/or glacial erosional surface.

Figure 4. Stratigraphic Position of Research Site


ERA
Period
North Dakota Stratigraphic Column
Study Area
Near-Surface Stratigraphy at the Research Site
Genozoic
Quaternary
Tertiary
Coleharbor Grp.
White River Grp.
Golden Valley Fm.
Fort Union Group
Sentinel Butte Fm.
Bullion Creek Fm.
Slope Fm.
Cannonball Fm.
Ludlow Fm.
Coleharbor Grp.
Not Exposed
Coleharbor Grp.
Upper Sentinel Butte Fm.
Underwood Sand
Hagel A lignite
Clay parting
Hagel B lignite

A thin bed of carbonaceous clay separates the Underwood Sand and the underlying lignite. In places the till directly overlies the lignite but there is little evidence of erosion of the lignite. This may be the result of high fluid pressure which developed in the lignite aquifer during glaciation. The brittle nature of the lignite resulted in slippage and removal of overlying sediments by the ice mass. The Hagel lignite A and B beds comprise the lowest lignite strata of the Sentinel Butte Formation and are the beds of economic interest at the Falkirk Mine. Figure 5 illustrates the idealized stratigraphic column of the study area. Figure 6 is a northwest cross section through the pump test site which was constructed after the site was instrumented. Figure 7 is a northeast cross section through the pump test site, constructed after the site was instrumented. Figure 8 is a north-south cross section of the farmstead site which was constructed from drilling logs on file with the NDMMRRI.

Figure 5. Study Area Stratigraphic Column


Land Surface
30-50 ft. (9-15) Glacial Till
Coleharbor Group
5-10 ft. (1.5-3) Finely bedded clayey sand
20-40 ft. (6-12) Homogeneous beds of silty sand
Sentinel Butte Formation
0-2 ft. (0 - .6) Sharp clay contact with lignite
2-6 ft. (.6 - 2) Hagel A lignite
0-2 ft. (0 - .6) Clay parting
2-6 ft. (.6 - 2) Hagel B lignite

(not to scale)

Figure 6. Northwest Pump Test Site Cross Section

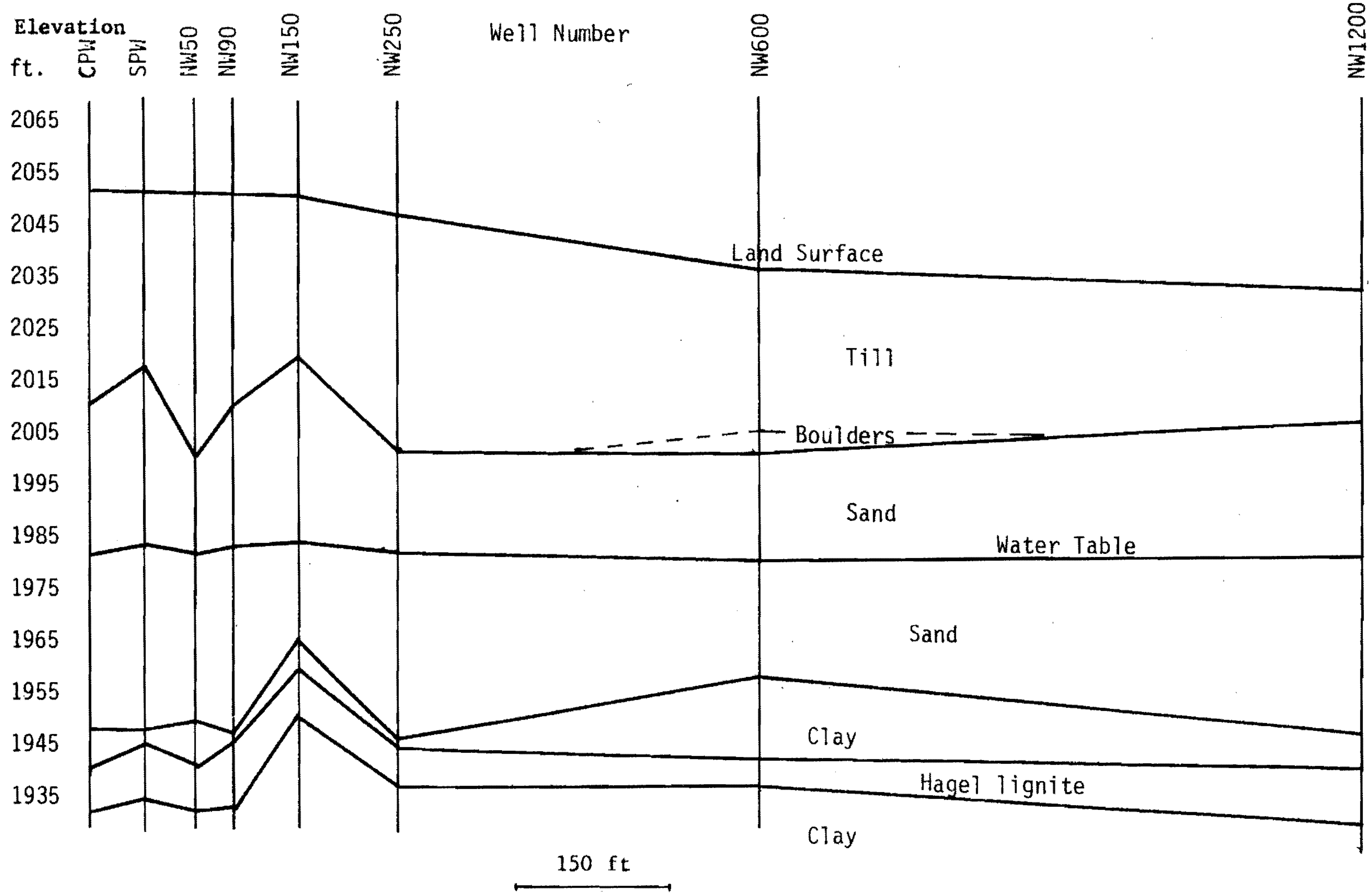

Elevation
ft.
Well Number
CPW
SPW
NW50
NW90
NW150
NW250
NW600
NW1200
2065
2055
2045
2035
2025
2015
2005
1995
1985
1975
1965
1955
1945
1935
Land Surface
Till
Boulders
Sand
Water Table
Sand
Clay
Hagel lignite
Clay
150 ft

Figure 7. Northeast Pump Test Site Cross Section

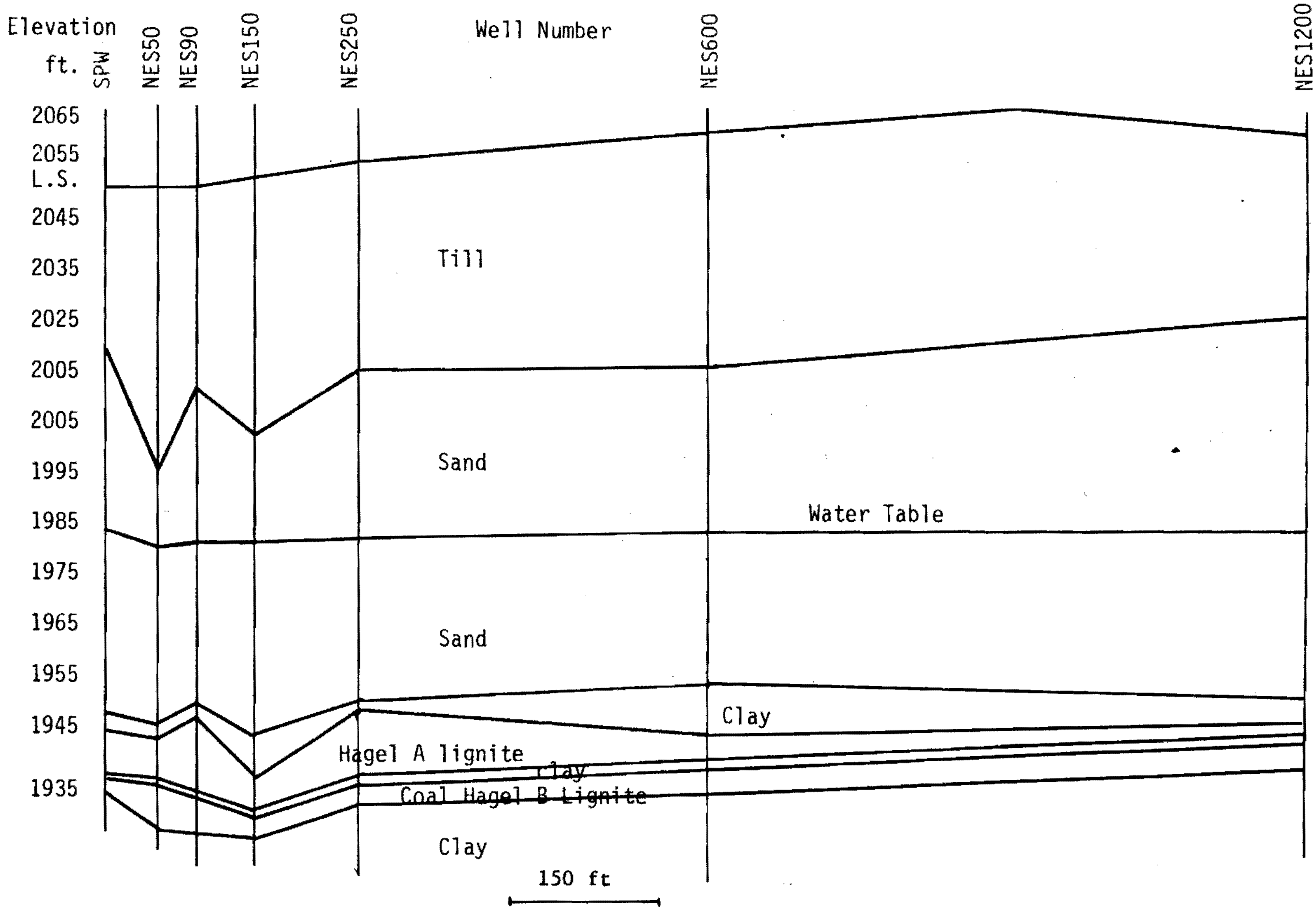
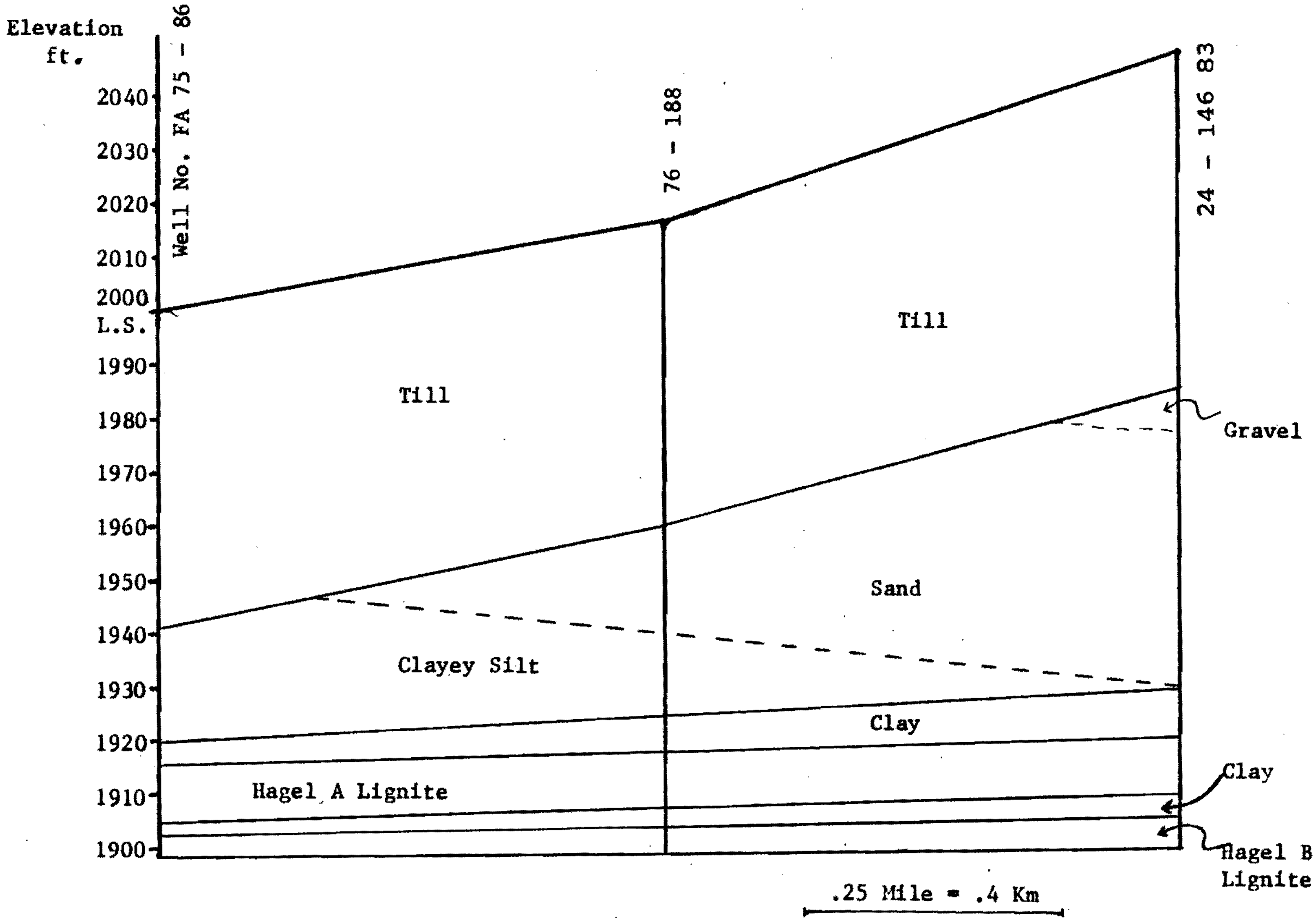

Elevation ft.
Well Number
SPW
NES50
NES90
NES150
NES250
NES600
NES1200
2065
2055
L.S.
2045
2035
2025
2005
2005
1995
1985
1975
1965
1955
1945
1935
Till
Sand
Water Table
Sand
Clay
Hagel A lignite
clay
Coal Hagel B Lignite
Clay
150 ft

Figure 8. North-South Farmstead Site Cross Section



Elevation
ft.
2040
2030
2020
2010
2000
L.S.
1990
1980
1970
1960
1950
1940
1930
1920
1910
1900
Well No. FA 75 - 86
76 - 188
24 - 146 83
Till
Till
Gravel
Sand
Clayey Silt
Clay
Clay
Hagel A Lignite
Hagel B
Lignite
.25 Mile = .4 Km

2.4 LITHOLOGY

2.4.1 Pump Test Site

Drilling logs from the instrumentation of the site and inspections of the Falkirk Mine highwall adjacent to the pump test site indicate that the uppermost till contains granitic boulders and grades downward into more locally derived material. Glacial lake sediments are present as layers within the till. The lithology of the Kinneman Creek Interval, between the till and the lignite, is poorly indurated, laterally continuous, blue gray to yellow reddish-brown, sandy silt and fine sand with interbedded clay beds. The sand appears to exist in two distinct states: a yellow reddish-brown, apparently oxidized component and a light blue-gray, apparently reduced component. Massive volumes of each are juxtaposed and may extend from the coal to the till with no apparent relationship to the present water table. Small scale mottling is also evident. Bedforms include climbing ripples, rhythmites, trough-shape ripples, and ungraded and unlaminated massive sands. The red sand is better indurated than the gray sand. When slumping occurs in the mine, it is usually in the gray sand areas (Zich, 1984). Irregular stringers of organic material are evident throughout the massive sand. A thin stratum of carbonaceous clay lies beneath the sand, directly over the Hagel Lignite. The lignite is a highly-fractured, low rank coal. The Hagel A and B beds are generally separated by a thin bed of clay. The coal is extensively fractured and it has been shown that in this region the primary fracture direction is approximately N40W, with a secondary set perpendicular to the primary set.

2.4.2 Farmstead Site

The lithology at the farmstead site is based on drilling logs on file at the NDMMRRI. The Underwood Sand pinches out west of the pump test site and is much thinner at the farmstead site. The till consists of dark brown clayey sand, concretions, lignite chips, gravel, and lacustrine sediments. Sand and gravel is found at some sites. Reddish-brown to gray-brown clayey sand and silt lies beneath the till. Carbonaceous clay overlies the Hagel lignite as at the pump test site.

2.5 PETROGRAPHY

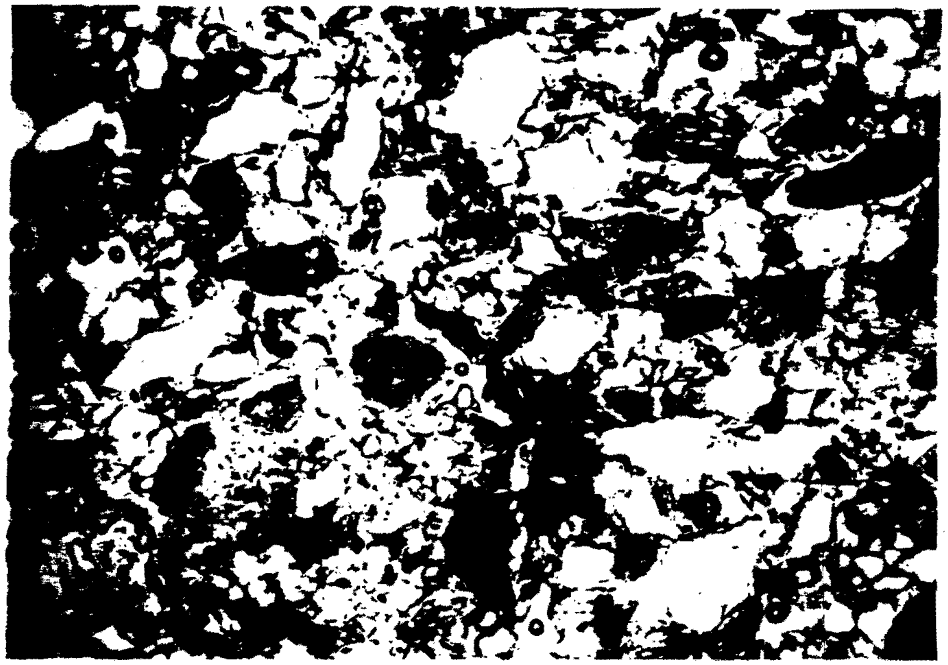
Permeability is affected by aquifer structural characteristics and water chemistry is affected by aquifer mineralogy. A survey of the aquifer mineralogy was considered essential to identify structural and mineralogical characteristics which could be affected by blasting. Undisturbed samples of the gray and red sand from the lower Kinneman Creek Interval, exposed in the Falkirk

Mine, were subjected to X-ray diffraction (XRD) analysis in the NDMMRRI Natural Materials Analytical Laboratory (NMAL). Quartz, feldspars, biotite and clay minerals were indicated. Gypsum was suggested by the XRD profiles but could not be definitively identified. Pyrite was not identified, but is known to commonly occur in these sediments at concentrations below the level of detection by XRD analysis (¼1%) (Groenewold, et al., 1983). Similar analyses were conducted on borehole cuttings from the sites at NW1200, CPW, and NE1200. Quartz, feldspars, biotite and clay minerals were again indicated. The use of bore hole cuttings is not desirable because of the likelihood of washing the clays out and oxidizing framboidal pyrite. It should be noted that the cuttings had been subjected to washing, subsequent desiccation, and oxidation while in storage, and any trace mineralogy may have been lost.

XRD analysis of an undisturbed highwall lignite sample, with no apparent mineralization, revealed only the characteristic lignite pattern. Fracture mineralization of a second lignite sample was determined to be pure pyrite by XRD analysis. The pyrite appears to be preferentially precipitated near fractures, the avenues of groundwater movement in lignite. Euhedral gypsum crystals have been reported in the coal along fractures in the lignite and along clay partings (Logan, 1981).

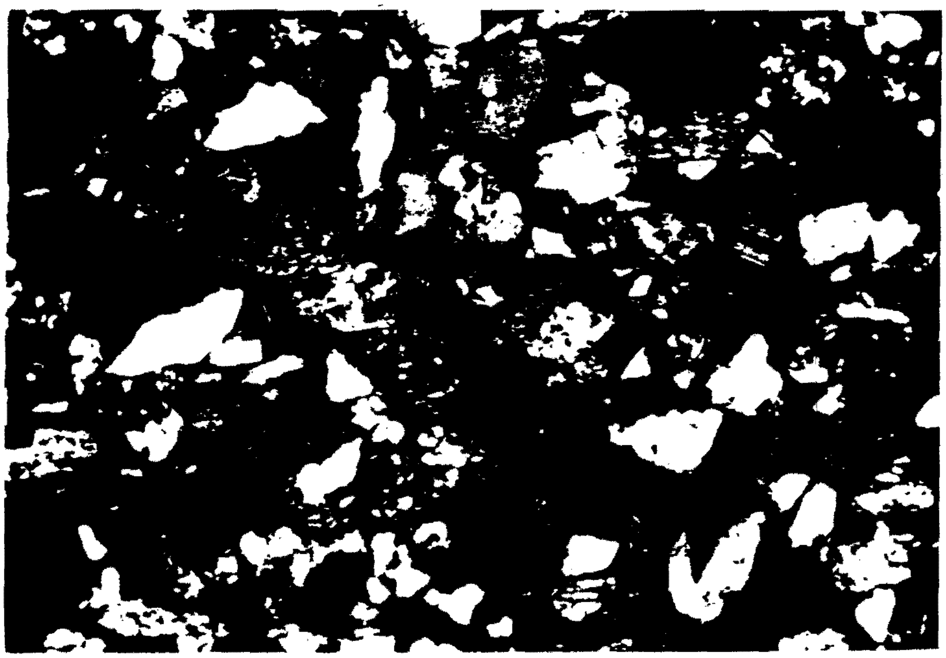
Polished thin sections were also prepared from undisturbed samples of red and gray sand obtained from the Falkirk Mine highwall. Figures 9 and 10 are approximately 15X photomicrographs of the red sand under plane and cross polarized lighting. Figures 11 and 12 are approximately 15X photomicrographs of the gray sand under plane and cross polarized lighting. A distinct reddish brown coating can be seen on the grains of the red sand, imparting the reddish overall color. Less matrix material is present in the gray sand, which explains its lesser degree of induration.

Further analyses of the thin sections with the scanning electron microscope/microprobe in the NDMMRRI NMAL revealed the character of the material more clearly than other methods. The general mineralogy of the area includes quartz, feldspars, biotite, pyrite, dolomite, clay minerals, gypsum and hematite. The origin and distribution of the two distinct lithologies is not apparent at this time. Figures 13 through 22 further illustrate the grain-matrix relationships of the two lithologies. These poorly indurated Tertiary sandstones are transitional between unconsolidated sediments and sandstone. A knowledge of the matrix relationships and mineralogy is essential to understanding structural and geochemical changes within the aquifer matrix. Trace amounts of pyrite are confirmed as the sulfur source for gypsum formation and sulfate. The poorly indurated sandstone constitutes an easily fractured aquifer medium. Samples can be crushed between the fingers.



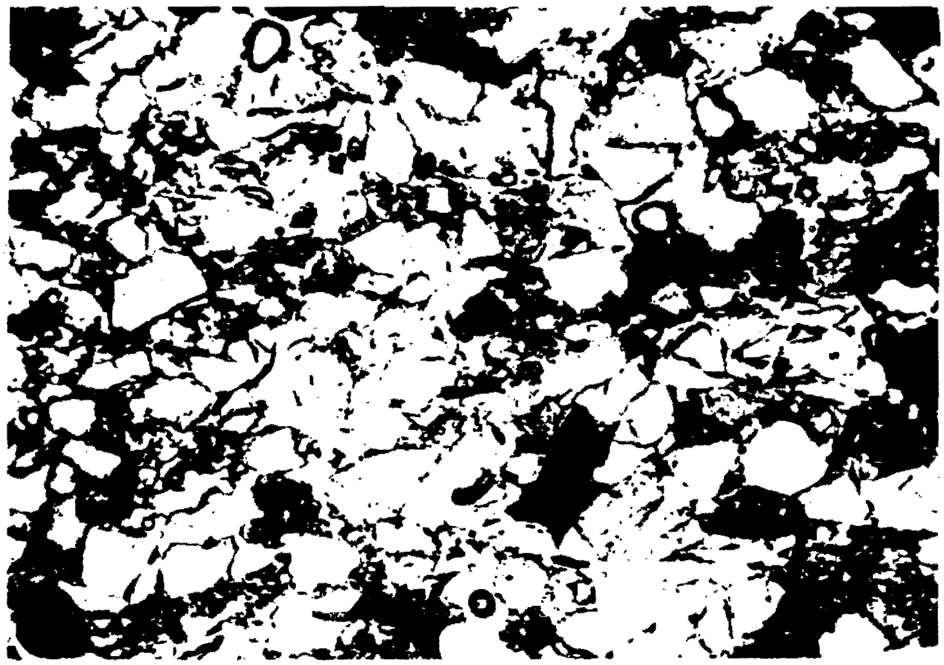
Grain-matrix relationships are visible. The reddish color is a result of the matrix coloration, not the grain mineralogy.

Figure 9. Red Sand at 15X Under Plane Polarized Light



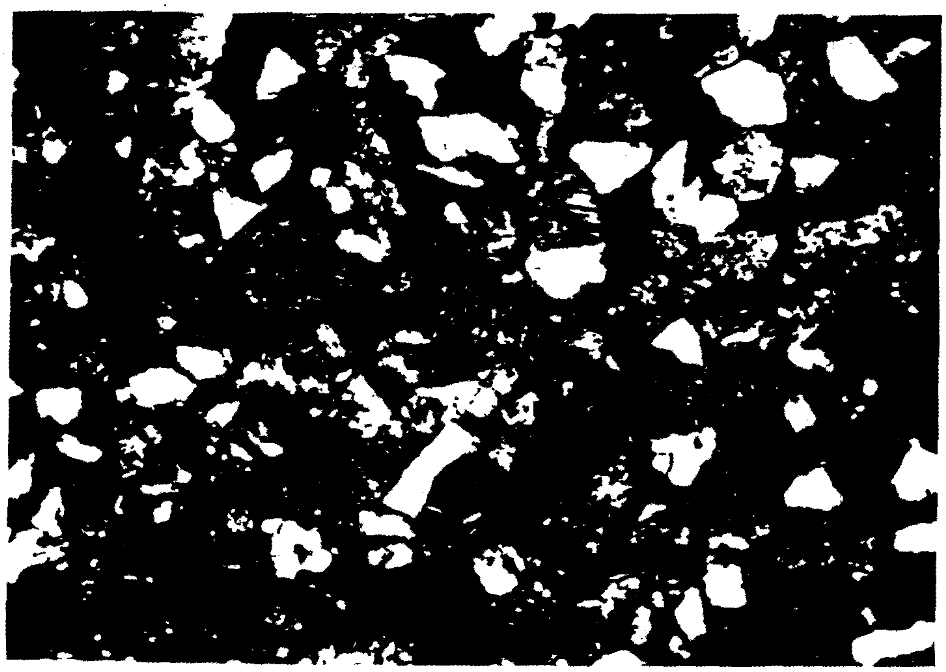
The porosity voids are apparent as black areas between the matrix and the grains.

Figure 10. Red Sand at 15X Under Cross Polarized Light



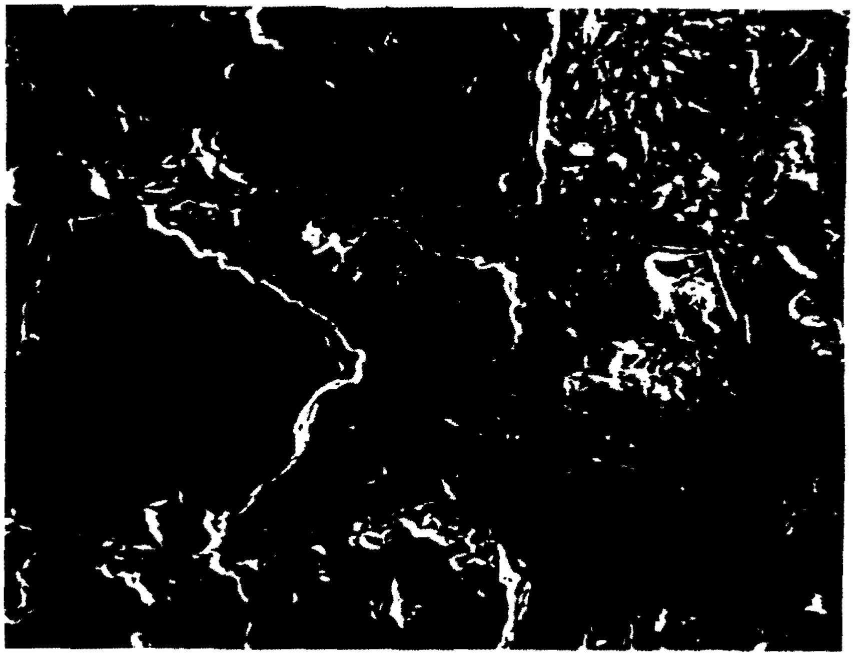
The sand grains appear to be slightly more angular than those found in the red sand. There is less matrix material in the gray sand which explains its lesser degree of induration. The gray color is imparted by matrix rather than the grain mineralogy.

Figure 11. Gray Sand at 15X Under Plane Polarized Light



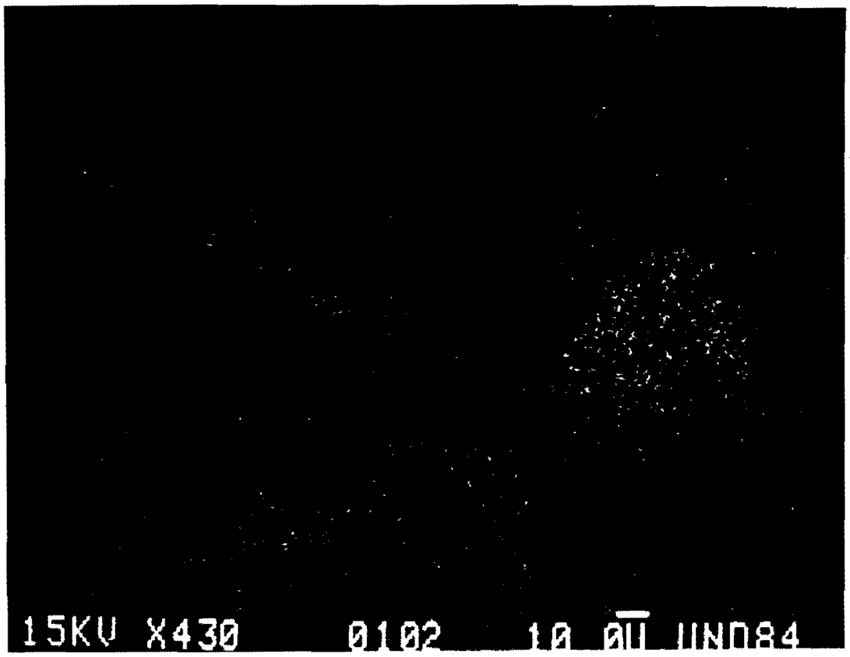
The relatively large porosity voids and paucity of matrix material is readily apparent.

Figure 12. Gray Sand at 15X Under Cross Polarized Light



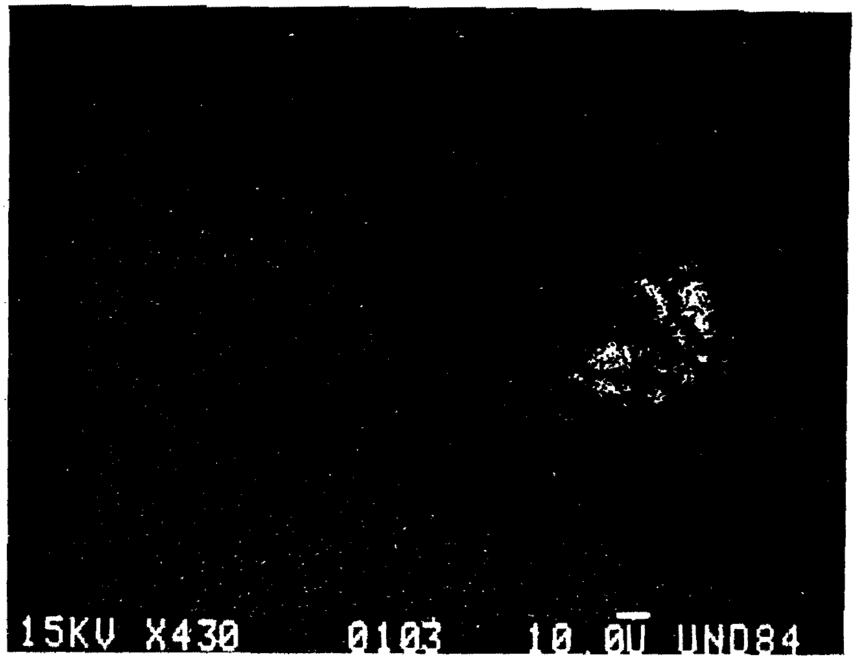
The cementing matrix is clearly indicated. Disintegrating feldspar is apparent in the upper right corner. Voids appear as the darkest spaces. The two large grains on the left are quartz and the large grain on the bottom is feldspar. An angular pyrite grain is at the right center.

Figure 13. Secondary Electron Image of the Red Sand



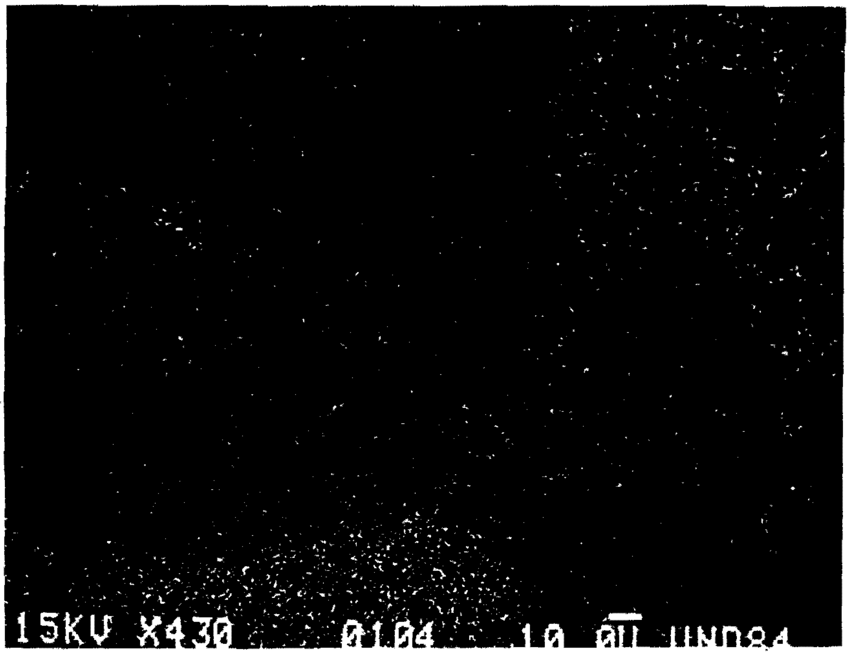
SEM/microprobe analysis clearly reveals the iron content in the cementing matrix and the pyrite grain. An oxidized iron mineral such as hematite may account for the red color of the matrix.

Figure 14. Iron Dot Map of Figure 13



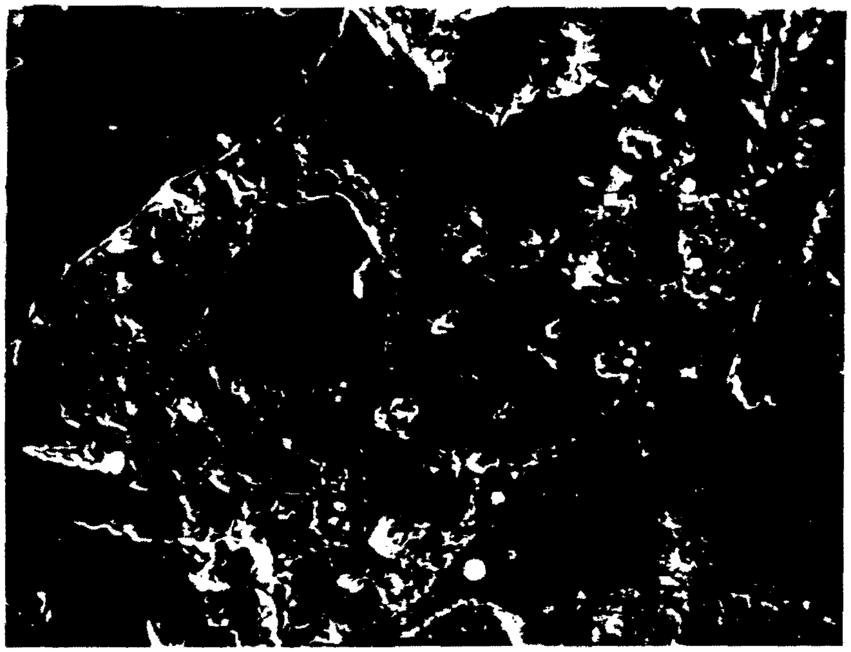
The sulfur distribution in the pyrite grain is readily apparent. It may be oxidizing to hematite or sulfate, providing a sulfur source for gypsum or selenite.

Figure 15. Sulfur Dot Map of the Area of Figure 13



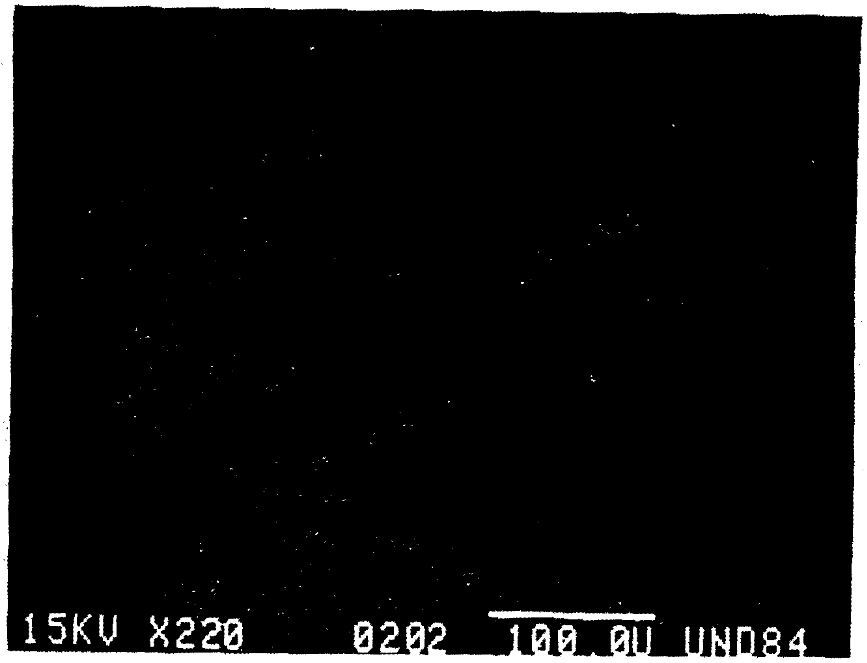
The aluminum distribution in the feldspar and matrix is readily seen. The feldspar and pyrite may be altering to form a cementing matrix of hematite and clay minerals. The hematite may enhance the degree of induration and account for the red color.

Figure 16. Aluminum Dot Map of the Area of Figure 13



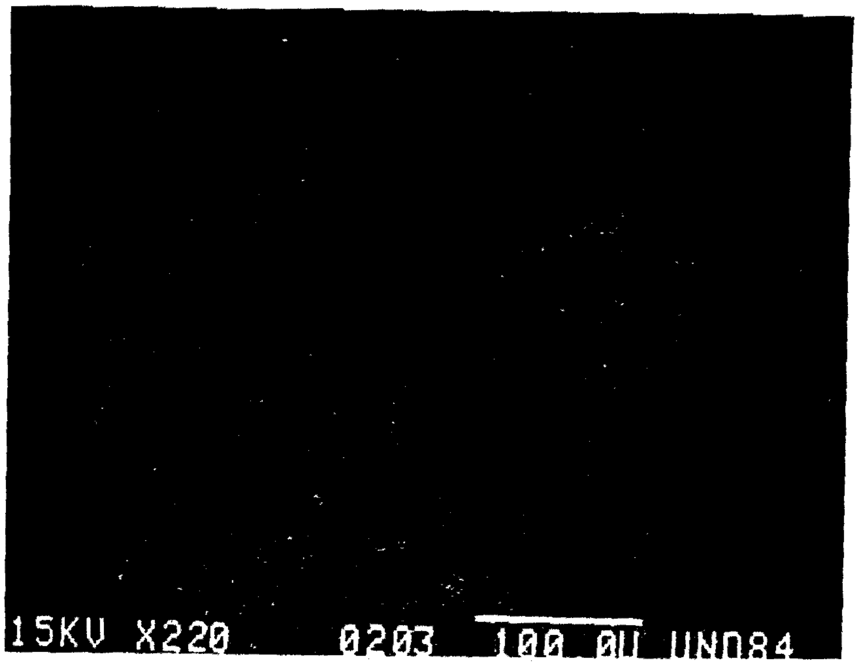
A rock fragment, center left, quartz grain, upper left, centrally located coal fragment containing pyrite stringers, and voids are apparent. A relative paucity of cementing matrix is evident. Angular grains are apparent.

Figure 17. Secondary Electron Image of the Gray Sand



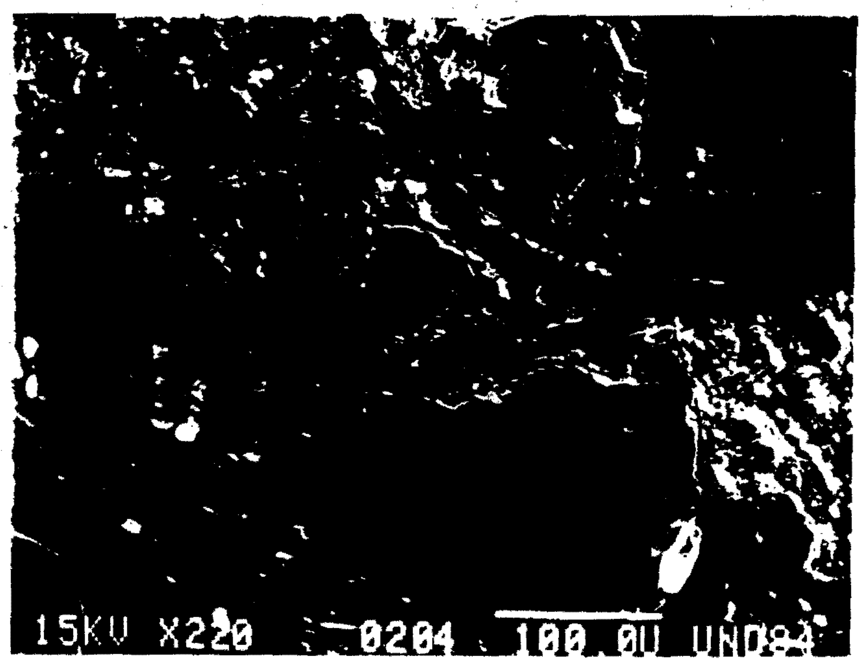
The concentration of dots indicates the presence of pyrite or oxidized iron minerals in the matrix.

Figure 18. Iron Dot Map of the Area of Figure 17



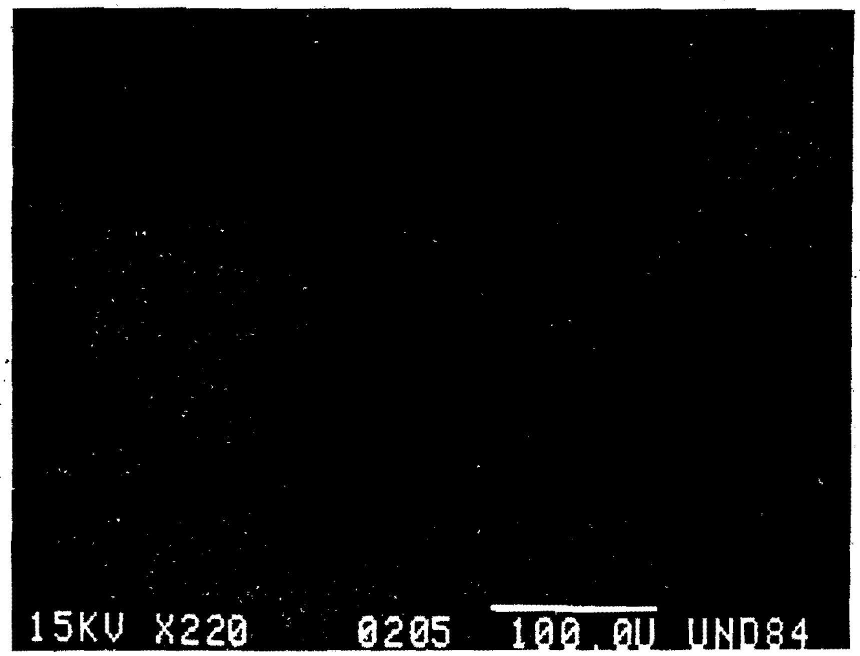
The concentration of dots indicates a source of sulfur in pyrite and oxidized matrix minerals.

Figure 19. Sulfur Dot Map of the Area of Figure 17



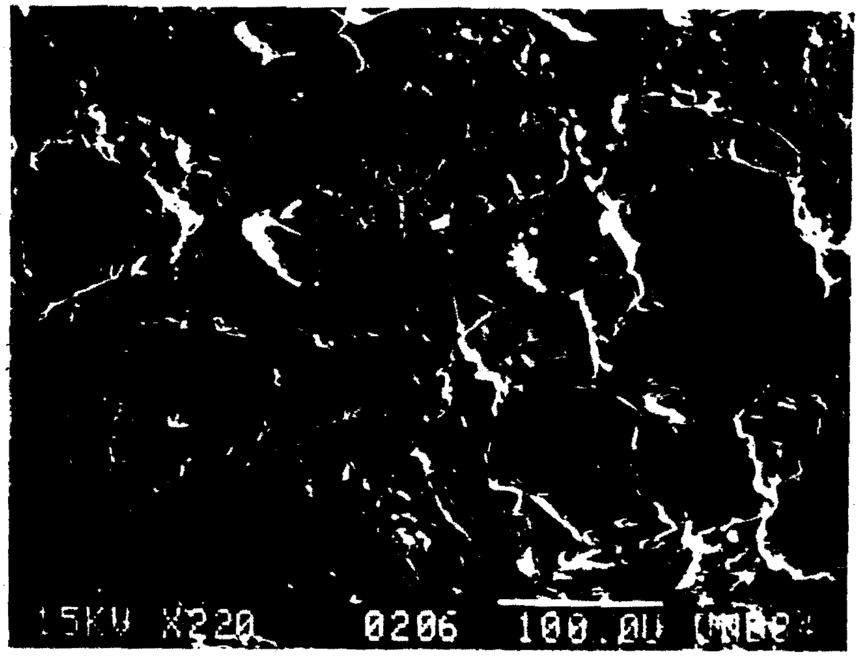
An unaltered biotite grain is at the lower left corner. The area between the grains is filled by matrix which may be forming from the biotite and feldspars and may impart the gray color and poor induration observed in the gray sand.

Figure 20. Gray Sand Secondary Electron Image



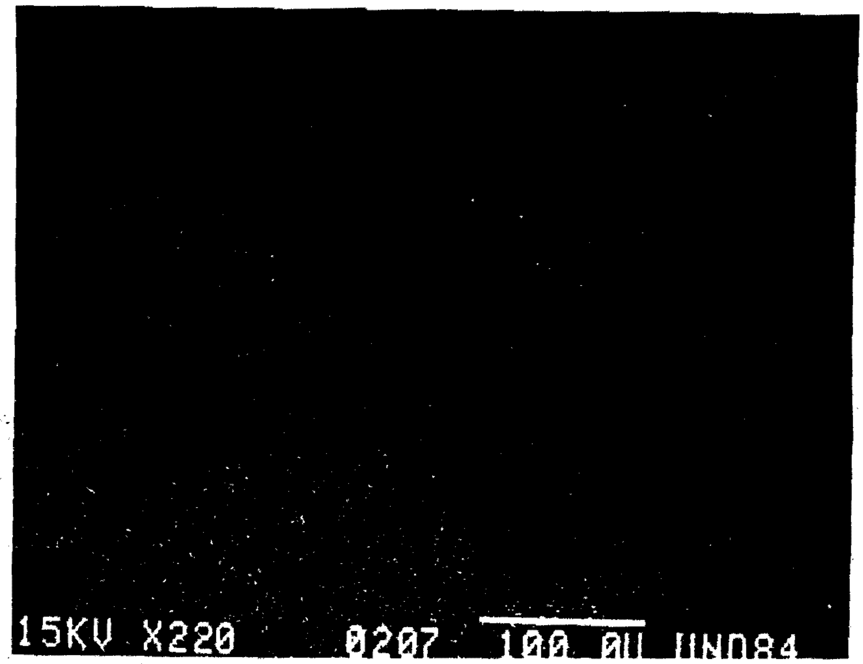
Alteration of biotite and feldspars to a clay mineral cementing matrix is suggested here.

Figure 21. Iron Dot Map of the Area of Figure 19



This biotite in the lower left corner may be altering to a clay mineral matrix which would account for the gray color of the sand.

Figure 22. Secondary Electron Image of Biotite Grain



The iron concentration in the biotite grain at the lower left corner and the associated matrix indicates that the biotite is altering to clay minerals.

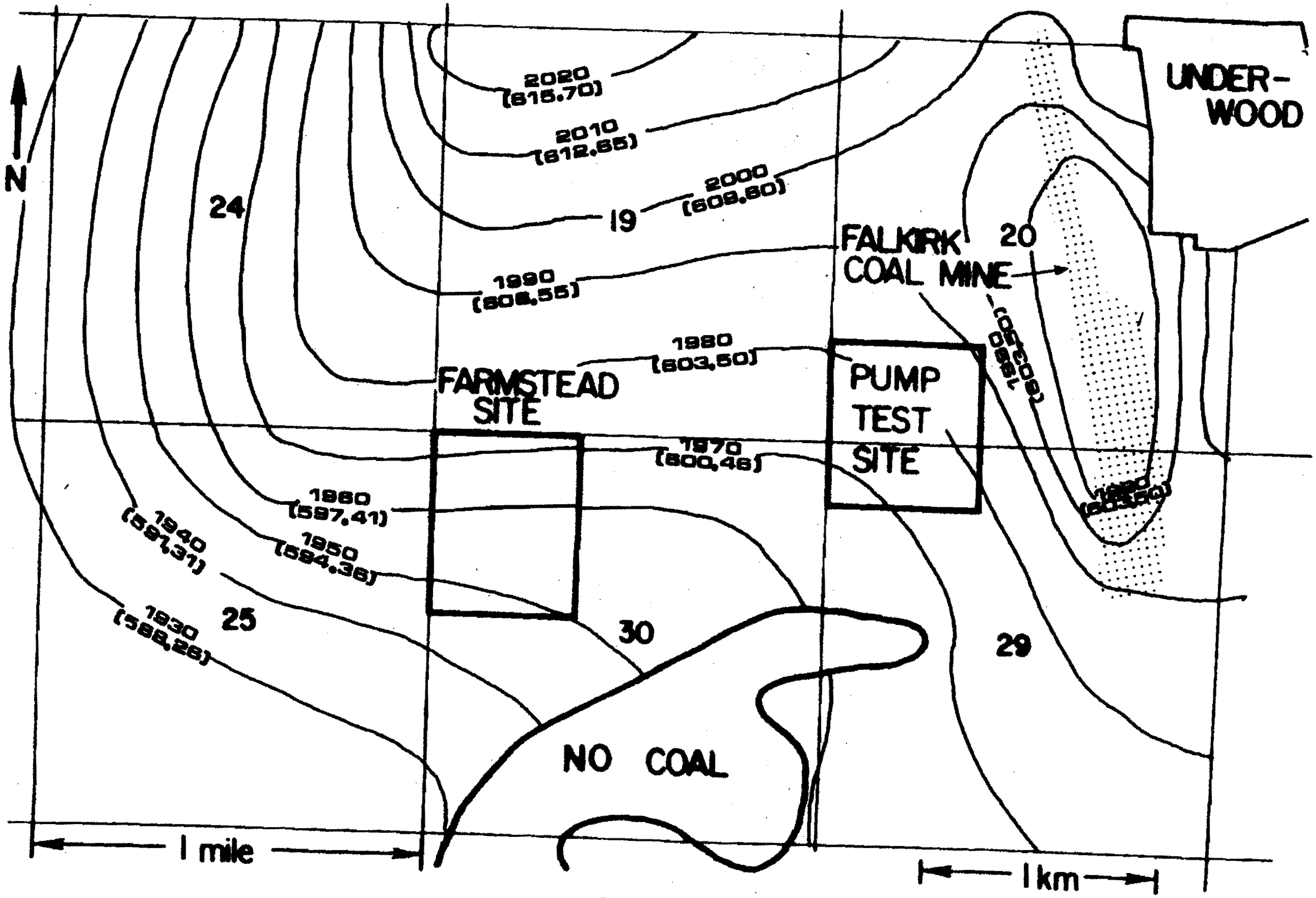
Figure 23. Iron Dot Map of the Area of Figure 22

2.6 HYDROGEOLOGY

The North Dakota Mining and Mineral Resources Research Institute (NDMMRRI) and the North American Coal Corporation have an extensive array of monitoring wells in the study area allowing for detailed characterization of the occurrence, flow, and quality of groundwater in the area. The water table lies within the massive Underwood Sand, and most wells are finished in the Underwood Sand or underlying lignite strata. Regional groundwater flow in deeper aquifers is from the northeast to the southwest toward the Missouri River. The Underwood region is a groundwater recharge area (Groenewold et al., 1979). Figure 24 is a water table contour map which reveals a general gradient to the southwest toward the Missouri River. Figure 25 is a potentiometric surface map of the Underwood Sand which shows a general gradient to the southwest. Figures 26 and 27 indicate the potentiometric surfaces of the Hagel A and B lignite beds, respectively, and again indicate a general southwesterly direction of groundwater movement. It is apparent that some local differences in flow direction exist. This could conceivably complicate aquifer analysis. Detailed discussion of the geohydrology in the Underwood area can be found in Groenewold, et al. (1979) and Rehm, et al. (1980).

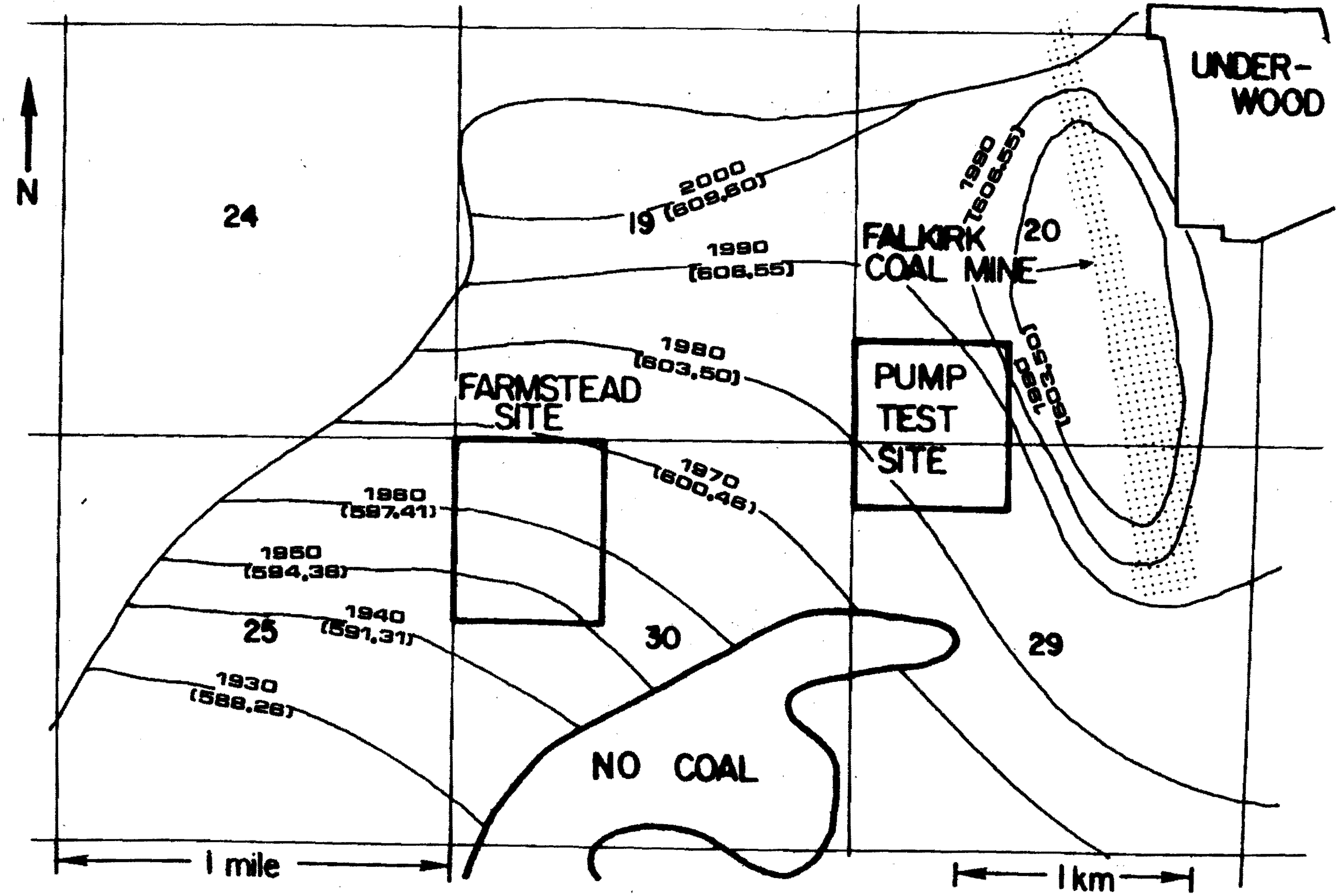
Groundwater flow is generally to the southwest toward the Missouri River. Heads are measured in feet (metres).

Figure 24. Study Area Water Table Contour Map


N
24
19
20
25
30
29
2020 (615.70)
2010 (612.65)
2000 (609.60)
1990 (606.55)
1980 (603.50)
1970 (600.46)
1960 (597.41)
1950 (594.36)
1940 (591.31)
1930 (588.26)
FARMSTEAD SITE
PUMP TEST SITE
FALKIRK COAL MINE
UNDER-WOOD
NO COAL
1 mile
1 km

The Underwood Sand constitutes the major sand aquifer at the study area pump test site. The general gradient is to the southwest. Head is measured in feet (metres).

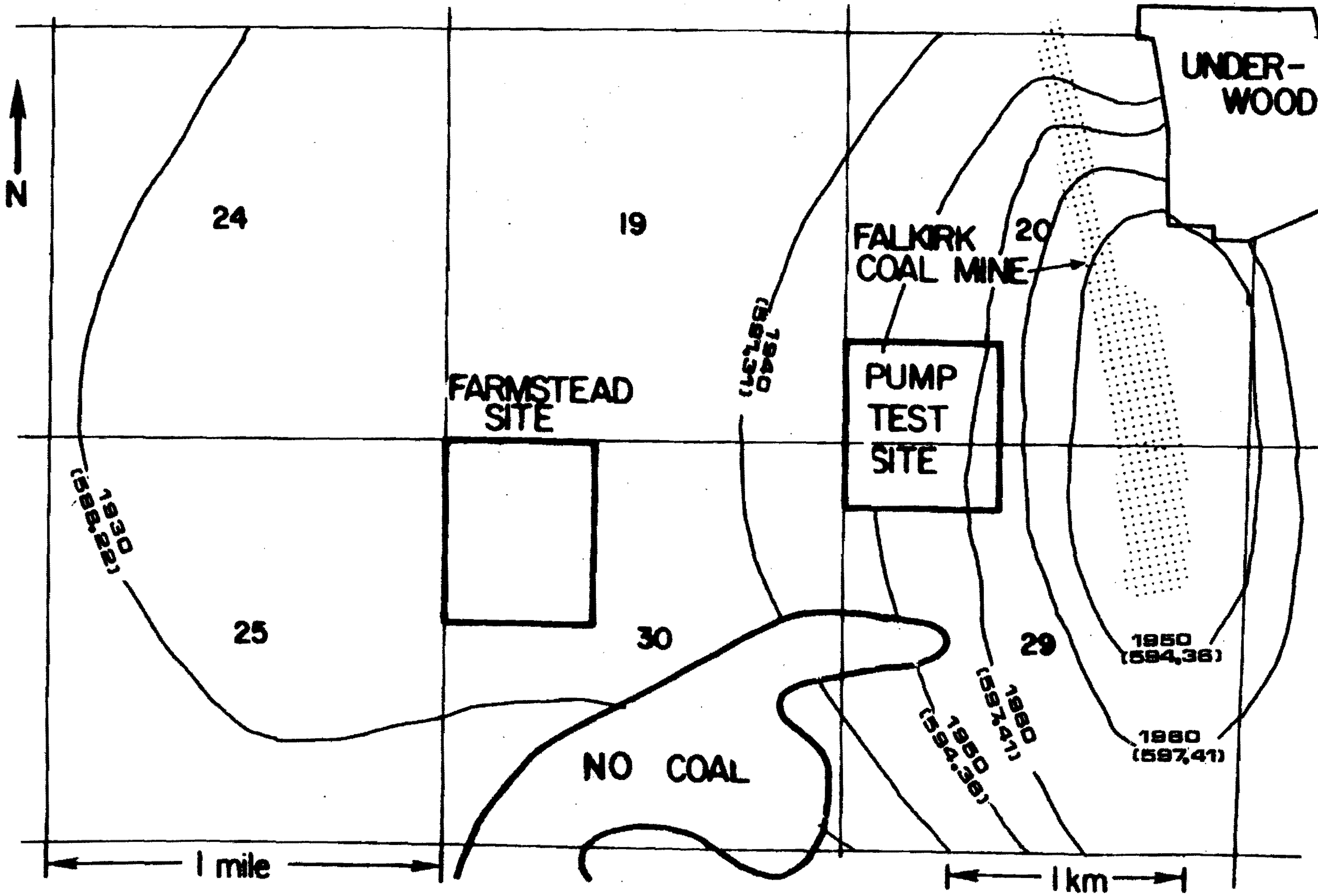
Figure 25. Underwood Sand Potentiometric Surface Map



N
24
19
20
25
30
29
UNDER-
WOOD
2000
(609.60)
1990
(606.55)
1980
(603.50)
1970
(600.46)
1960
(597.41)
1950
(594.36)
1940
(591.31)
1930
(588.26)
FALKIRK
COAL MINE
PUMP
TEST
SITE
FARMSTEAD
SITE
NO COAL
1 mile
1 km

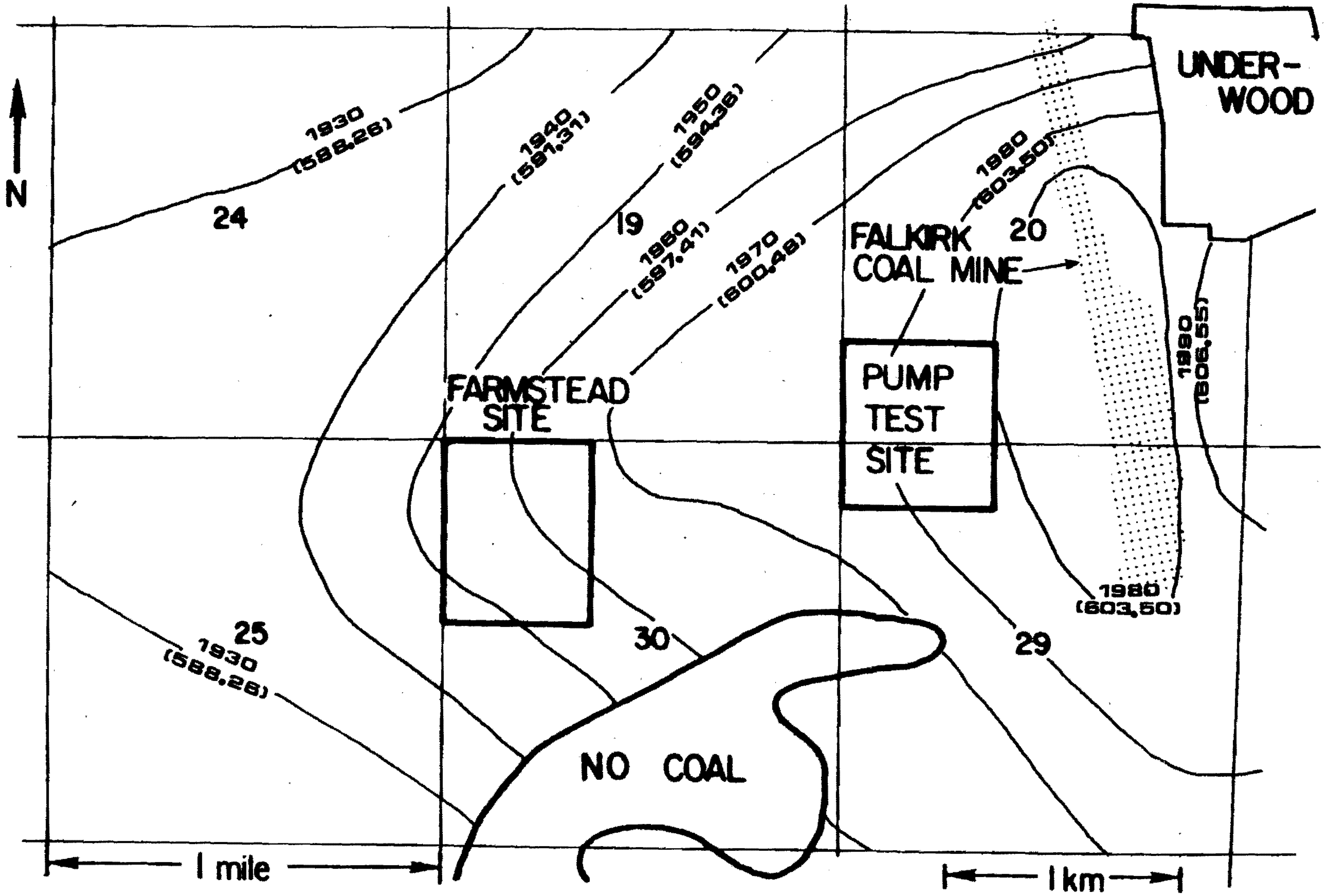
The Hagel lignite constitutes the study area lignite aquifer. Flow is west toward the Missouri River. Head is measured in feet (metres).

Figure 26. Hagel A Lignite Potentiometric Surface Map


N
24
19
20
25
30
29
UNDER-
WOOD
FALKIRK
COAL MINE
PUMP
TEST
SITE
FARMSTEAD
SITE
NO COAL
1930
(588,22)
1940
(597,31)
1950
(594,36)
1960
(597,41)
1950
(594,36)
1960
(597,41)
1 mile
1 km

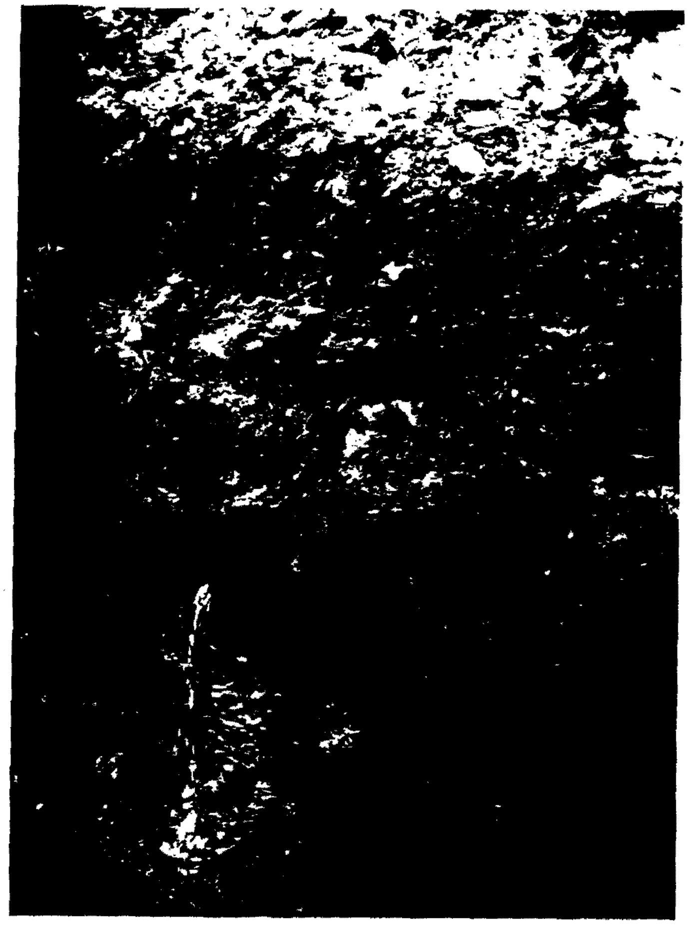
The Hagel lignite constitutes the study area lignite aquifer. Flow is to the southwest toward the Missouri River. Head is measured in feet (metres).

Figure 27. Hagel B Lignite Potentiometric Surface Map


N
UNDER-
WOOD
FALKIRK
COAL MINE
PUMP
TEST
SITE
FARMSTEAD
SITE
NO COAL
1930
(588.26)
1940
(591.31)
1950
(594.36)
1960
(597.41)
1970
(600.46)
1980
(603.50)
1990
(606.55)
24
19
20
25
30
29
1 mile
1 km

Observations of the Falkirk Mine north pit highwall revealed little seepage out of the massive sand overlying the lignite. Where the sand overlies an impervious clay stratum, however, increased seepage is evident at the base of the sand and out of fractures in the sand overlying the clay. Water has been observed flowing from individual fractures up to 1/2 inch (1.3 cm) wide in coal at the rate of several gallons per minute (Figure 28). The fractures serve as groundwater conduits and appear to provide the primary avenue of water movement through the coal (Groenewold, et al., 1979; Rehm, et al., 1980). Fractures are readily apparent in the high wall. It is common knowledge among well drillers of the region that the yield from wells finished in coal varies significantly within short distances. This may be explained in terms of whether or not fractures are intersected by the well.

Large values of apparent transmissivity have been reported for the coal at a site several miles east of the pump test site (Rehm, 1979). Pump tests conducted by the Falkirk Mining Company have yielded a wide range of values and have indicated that well construction and development technique in lignite is especially important. The fractured character of the coal aquifer makes determination of traditional aquifer parameters such as transmissivity, storativity, and specific yield questionable; calculated values are apparent values. Turbulent flow in irregular



The highwall of the Falkirk Coal Mine located directly east of the pump test site provided an opportunity to observe the sand and coal aquifer in cross section. The fracture is oriented northwest into the highwall. The vertical dimension is approximately 10 feet (3 metres).

Figure 28. Water Flow From Coal Fracture

conduits would probably need to be addressed in order to adequately evaluate the hydraulic characteristics of the fractured lignite.

Chapter III

EXPERIMENTAL DESIGN AND METHODOLOGY

English and SI units have been used throughout this thesis. It is recognized that SI units are scientifically preferred. Most of the equipment, however, was calibrated in English units, which are preferred by the industry. The primary units herein are therefore English. SI units are included where appropriate in parentheses or a conversion factor is supplied. (Multiply measurements in feet by .3048 to obtain metres.)

3.1 OBJECTIVES

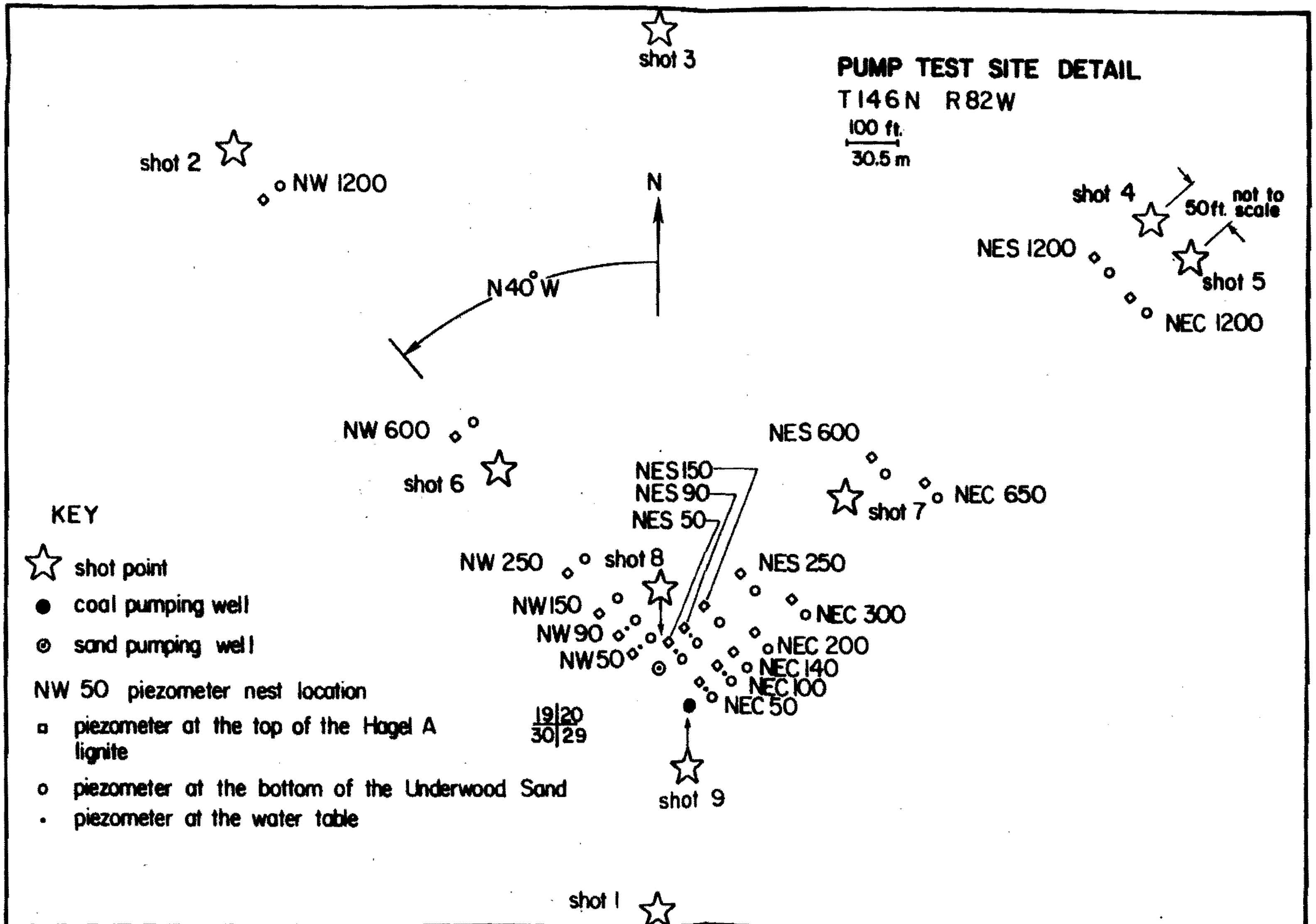
Complete assessment of the effects of seismic blasting on aquifers and wells required consideration of the hydrogeology and hydrogeochemistry of the study area. Comparison of chemical parameters, mineral saturation, storativity, transmissivity, and specific yield before and after blasting was considered to be a valid means of comparing the pre- and post- blast state of the coal and sand aquifers. The pump test site provided an opportunity to design and instrument a carefully controlled experiment. The farmstead site allowed a long-term characterization of an existing facility. The regional groundwater flow and coal fracture direction were considered in laying out the experiment. The primary regional fracture direction of the lignite is approximately 40 degrees west of north, with a secondary set perpendicular.

3.2 PUMP TEST SITE

The detailed experimental layout (Figure 29) was designed to test the response of two production wells, one finished in the Hagel lignite aquifer and the other finished in the Underwood Sand aquifer, to seismic blasts detonated at varying orientations and distances up to one-quarter mile away from the pumping wells. Piezometers were installed in the coal, sand, and at the water table to isolate the physical and chemical response of the system to blasting. One piezometer arm was oriented to parallel the primary regional fracture direction which is 40 degrees west of north. Two piezometer arms were installed parallel to the regional secondary fracture direction, one extending from the sand production well (SPW), and one extending from the coal production well (CPW). The northwest (NW) arm extends from the coal pumping well (CPW), through the sand pumping well (SPW), to the end of the northwest arm (NW1200), which designates a position 1200 feet from the SPW along the northwest arm. The suffix S is added to indicate a piezometer finished in the Underwood Sand. C designates a piezometer finished at the top of the Hagel A lignite, and

WT designates a piezometer finished at the water table. The arm radiating northeastward from the SPW is designated NES with position and piezometer nest identification indicated by the distance from the SPW and the suffix, S, C, or WT. The arm radiating northeast from the coal pumping well is designated NEC. The piezometer in the coal, located 300 feet from the sand pumping well, along the northeast piezometer arm, radiating from the sand pumping well, is designated NES300C. This identification system is used throughout this thesis.

Figure 29. Pump Test Site Detail


PUMP TEST SITE DETAIL
T146N R82W
100 ft.
30.5 m
N
N40°W
shot 1
shot 2
shot 3
shot 4
shot 5
shot 6
shot 7
shot 8
shot 9
50ft. not to scale
NW 1200
NW 600
NW 250
NW150
NW90
NW50
NES 1200
NEC 1200
NES 600
NEC 650
NES150
NES90
NES 50
NES 250
NEC 300
NEC 200
NEC140
NEC100
NEC50
19|20
30|29
KEY
shot point
coal pumping well
sand pumping well
NW 50 piezometer nest location
piezometer at the top of the Hagel A lignite
piezometer at the bottom of the Underwood Sand
piezometer at the water table

3.2.1 Pumping Well Installation

A 4-inch diameter production well was installed in the sand overlying the coal and another 4-inch production well was installed in the coal, 50 feet away from the production well finished in sand, as illustrated in figure 29. Both wells were constructed in the same manner to facilitate comparison. The coal pumping well was screened through the Hagel lignite. The sand pumping well was screened through the saturated thickness of the Underwood Sand above the coal. Both were screened with 0.020 inch slotted screen. The wells were capped at the bottom, sand-packed with washed sand, and developed by the drilling contractor. The coal well was grouted to the surface. Complete details of installation are shown in figures 30 and 31.

Figure 30. Coal Pumping Well Construction Detail

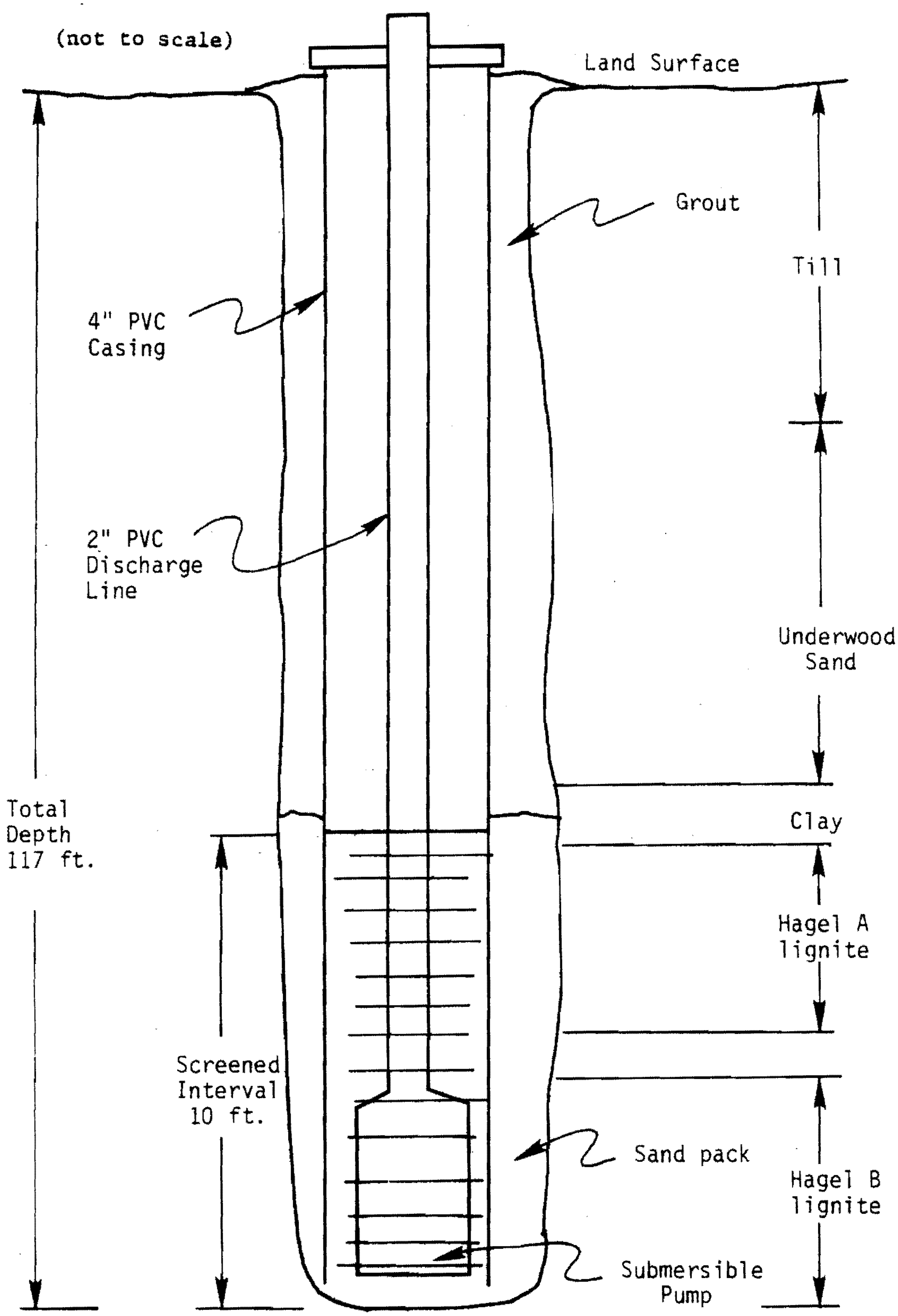
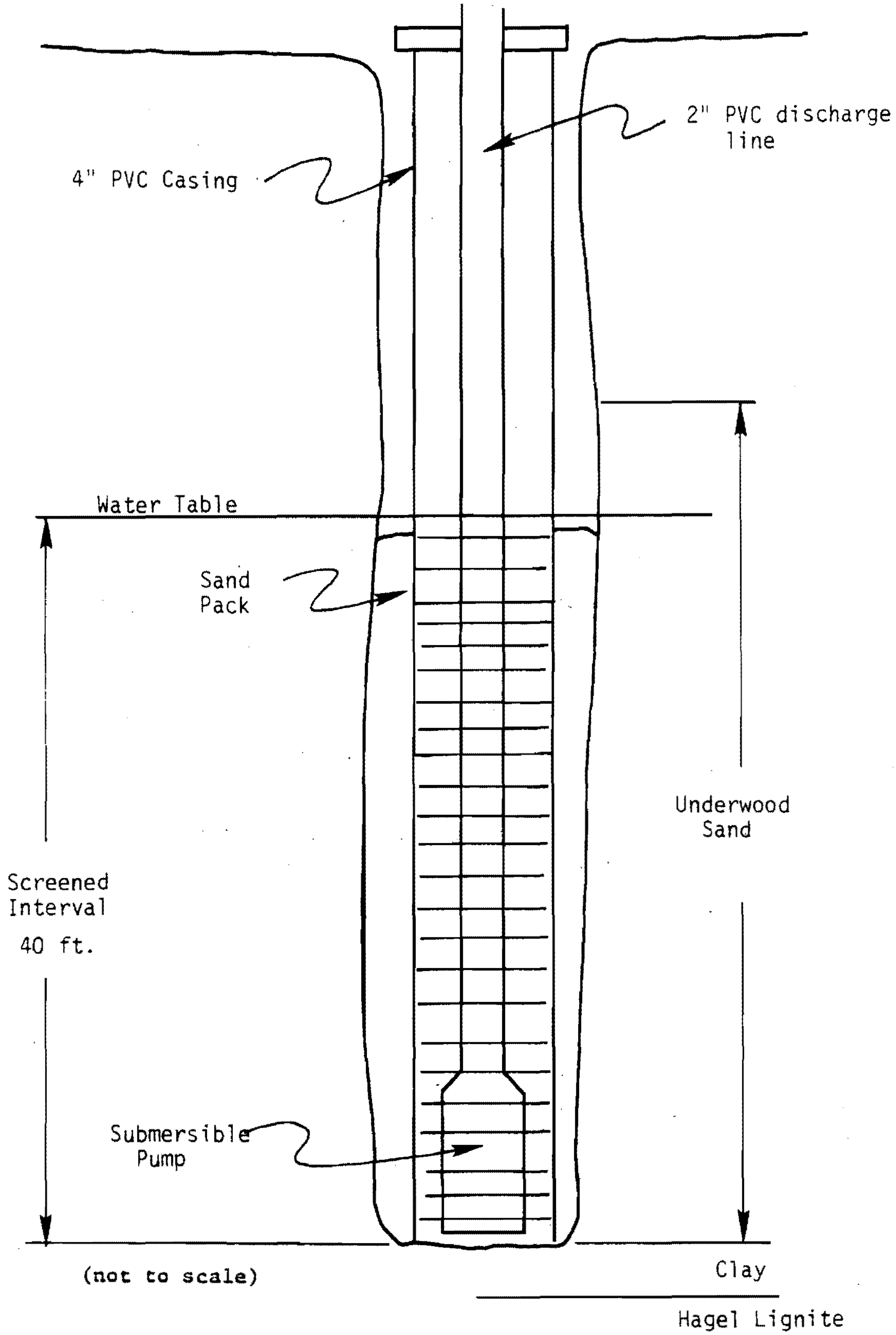

(not to scale)
Land Surface
Grout
Till
4" PVC Casing
2" PVC Discharge Line
Underwood Sand
Total Depth 117 ft.
Clay
Hagel A lignite
Screened Interval 10 ft.
Sand pack
Hagel B lignite
Submersible Pump

Figure 31: Sand Pumping Well Construction Detail

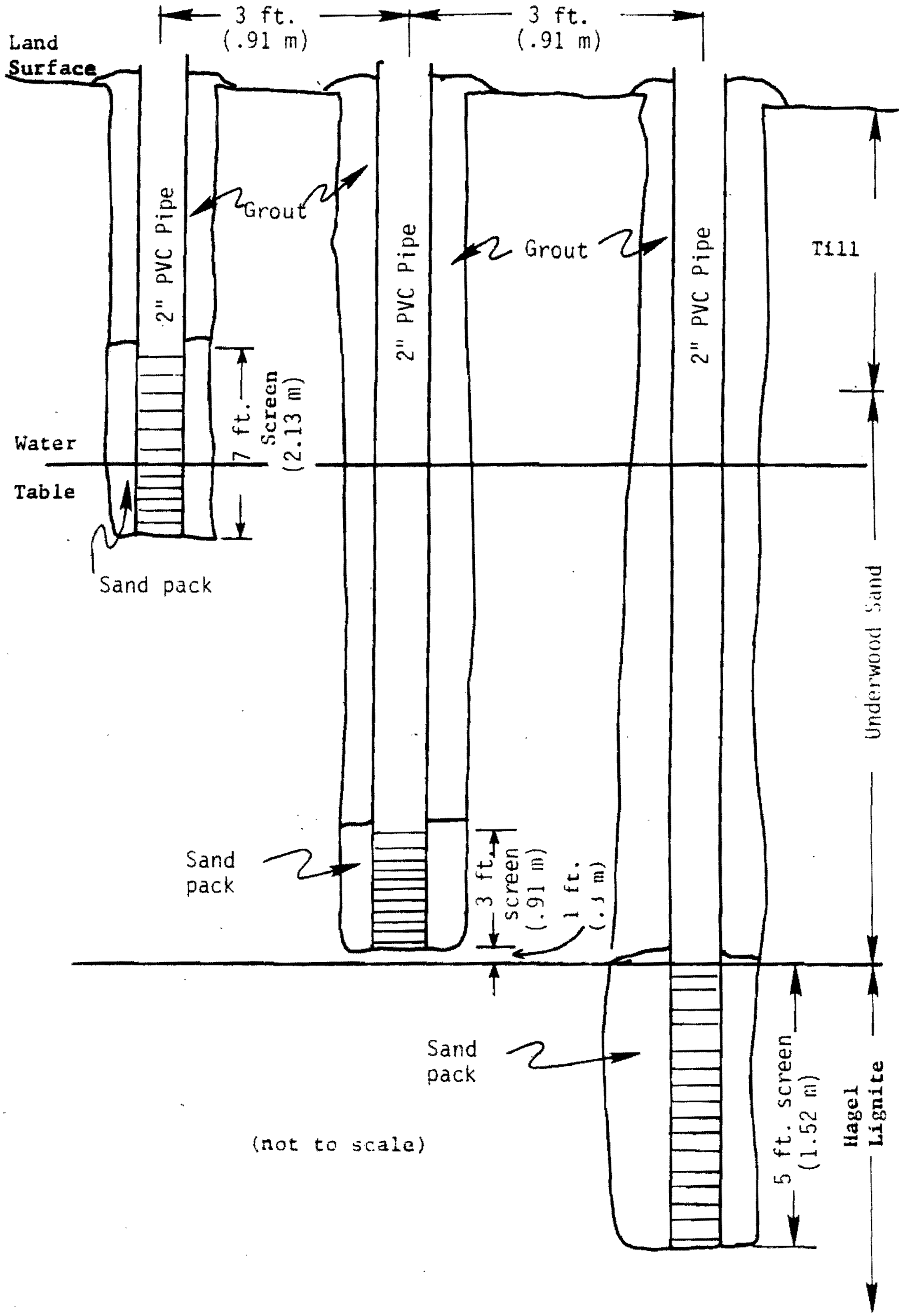

2" PVC discharge line
4" PVC Casing
Water Table
Sand Pack
Underwood Sand
Screened Interval
40 ft.
Submersible Pump
(not to scale)
Clay
Hagel Lignite

3.2.2 Piezometer Installation

Three arms of piezometers were installed and oriented to coincide with the regional fracture direction (Figure 29) in order to maximize the possibility of observing response through the coal fractures. The length of the piezometer array arms was designed to extend 1/4 mile, a distance which is arbitrarily considered by some governmental agencies and companies to be a safe distance, beyond which no effects from blasting will be detected. Piezometer nest construction detail is shown in figure 32. Drilling of the holes for the piezometers was done with a contracted reverse rotary rig using compressed air as the drilling fluid. This was done to minimize contamination of the aquifers with drilling fluid. Cutting samples from the deepest hole at each drilling site were taken at appropriate intervals, and changes in lithology were noted on a field log. The tabulated results are included in Appendix B. Geophysical logs were obtained from the deepest hole at each drilling site with the NDGS logging unit. Table 2 illustrates depth of placement.

The piezometers installed for this study were screened in near-surface units which are part of the local flow system. The static head data for the piezometer array indicate a downward flow at the pumping well site which is a local topographic high and recharge area. The groundwater flow

Figure 32. Piezometer Nest Construction Detail



3 ft.
(.91 m)
3 ft.
(.91 m)
Land Surface
2" PVC Pipe
Grout
2" PVC Pipe
Grout
2" PVC Pipe
Till
7 ft. Screen (2.13 m)
Water Table
Sand pack
Underwood Sand
Sand pack
3 ft. screen (.91 m)
1 ft.
Sand pack
5 ft. screen (1.52 m)
Hagel Lignite
(not to scale)

TABLE 2

Piezometer Installation Depths

(measured in feet)
(to obtain metres multiply by 0.3048)

Site Number	Water Table	Hagel A Bed	Hagel B Bed	Bottom of Sand Piezometer	Bottom of Coal Piezometer
SPW	67.5	108-113	114-117	107	113
NW50	69	108-112	114-117	106	113
NW90	68	108-111	113-116	106	111
NW150	66	107-112	113-116	105	112
NW250	64	99-105	106-111	98	110
NW600	55	92-96	97-100	91	95
NW1200	51	81-86	87-91	80	85
NES50	70	109-114	116-119	108	114
NES90	69	111-116	117-121	110	115
NES150	71	114-119	121-124	113	118
NES250	74	113-119	121-124	112	118
NES600	78	116-*	*-126	115	120
NES1200	77	112-117	118-121	111	117
CPW	69	107-113	114-117	106	113
NEC50	69	109-115	116-119	108	114
NEC100	70	111-116	117-121	110	115
NEC140	71	114-119	120-124	113	118
NEC200	74	116-121	122-125	115	120
NEC300	76	114-120	122-126	113	119
NEC650	82	117-124	125-128	116	122
NEC1200	80	111-117	118-121	110	116

The Hagel A and B beds are generally separated by a thin clay stratum. No clay parting is indicated by an *.

gradient is upward at the distant ends of the piezometer arms, as shown in table 3. These discharge areas correspond to a natural drainage at the end of the northwest arm and an internally drained pothole at the end of the northeast arms. The pothole may serve as a site for depression-focused recharge when the standing water is deep enough to overcome the slight upward gradient.

TABLE 3

Piezometer Array Elevations

Site Number	Land Surface (ft.)	Measuring Point (ft.)	Water Level (ft.)	Head (ft.)
NW50WT	2049.69	0.21	68.25	1981.65
NW50S	2049.66	0.65	68.83	1981.48
NW50C	2049.94	0.65	72.35	1978.24
NW90S	2049.30	0.77	68.65	1981.42
NW90C	2049.09	1.09	71.95	1978.33
NW150S	2048.54	0.74	67.70	1981.58
NW150C	2048.43	0.79	69.06	1980.16
NW250S	2044.52	0.92	63.81	1981.63
NW250C	2044.52	1.01	64.01	1981.52
NW600S	2033.27	1.23	54.59	1979.91
NW600C	2033.33	1.24	62.53	1972.04
NW1200S	2029.56	1.18	50.10	1980.64
NW1200C	2029.64	1.10	50.00	1980.74
SPW	2049.67	0.80	68.52	1981.95
SPWC	2049.83	0.76	75.23	1975.36
CPW	2049.67	0.67	69.36	1980.98
NES50WT	2050.41	0.88	69.50	1981.79
NES50S	2050.13	0.96	69.29	1981.80
NES50C	2050.17	1.05	69.56	1981.66
NES90S	2050.04	0.98	69.32	1981.70
NES90C	2050.22	0.89	69.79	1981.32
NES150S	2052.64	0.80	72.47	1980.97
NES150C	2052.53	0.54	71.75	1981.32
NES250S	2055.68	0.69	74.77	1981.60
NES600S	2061.03	1.11	79.30	1982.84
NES600C	2061.03	0.96	81.20	1980.79
NES1200S	2060.70	0.69	78.44	1982.95
NES1200C	2060.75	0.54	77.82	1983.47
NEC50WT	2050.12	0.56	69.03	1981.65
NEC50S	2050.46	0.63	69.62	1981.47
NEC50C	2050.56	0.85	70.21	1981.20
NEC100WT	2051.17	1.03	70.28	1981.92
NEC100S	2051.01	1.07	70.37	1981.71
NEC100C	2051.08	0.71	71.95	1979.84
NEC140S	2052.07	1.04	71.33	1981.78
NEC140C	2052.28	0.65	71.49	1981.44
NEC200S	2055.00	0.97	74.31	1981.66
NEC200C	2055.13	0.69	77.26	1978.56
NEC300S	2057.34	1.00	76.77	1981.57
NEC300C	2057.11	1.33	77.46	1980.98
NEC650S	2064.65	0.86	81.86	1983.65
NEC650C	2064.74	0.36	84.51	1980.59
NEC1200S	2062.55	1.28	80.97	1982.86
NEC1200C	2062.30	1.20	80.51	1982.99

The piezometers were installed by lowering each one, section by section, into the hole with the aid of a pipe vise supported on an improvised wooden support stand. The piezometer screens were positioned as shown in table 2 using the total hole depths, electric logs, and measuring tapes. Backfilling where necessary and/or the use of blank stub ends of pipe below the screens allowed for precise vertical placement. The screened sections were backfilled with washed sand obtained locally. The correct depth of sandpack was determined by the use of a one-piece tremie rod and with a set of fiberglass loading poles. The use of the fiberglass loading poles proved to be infinitely safer, quicker, and more convenient than the long flexible rod.

The piezometers finished at the water table and in sand were schedule 60 PVC bell-end sections joined with solvent cement. The screen length at the water table was 10 feet; the screen length for the sand piezometers was 3 feet. The piezometers finished in the coal had 5-foot screens and were constructed of schedule 80 PVC threaded pipe sections which were screwed together with threaded couplings. Even though it was more costly to use threaded pipe, it was deemed necessary to avoid contamination by glue solvents when collecting total organic carbon (TOC) samples from the coal well.

When all the piezometers had been installed, the holes were grouted to the surface. The piezometers were cut to convenient lengths and protective threaded caps were installed. Wells were numbered and measuring points established. The elevation of the measuring point was established with standard leveling practices using a dumpy level. Prior to experimental testing, the piezometers were developed by bailing on two separate occasions. A period of one month elapsed between the final installation and the commencement of testing to allow for the system to stabilize.

3.2.3 Shot Placement

The shothole orientation is also illustrated in figure 29. After the piezometer array and pumping wells were in place, the shothole sites were located. Shot 1 was placed 500 feet downgradient to the south. A simulated shotline was run from west to east, with shot 2 being placed at one-quarter mile along the northwest arm. Shot 3 was placed one-quarter mile north of the production wells. Shots 4 and 5 were placed at one-quarter mile along the two northeast arms. Shots 6 and 7 were placed along the arms 500 feet from the production wells. Shot 8 was placed 50 feet north of the sand production well. Shot 9 was placed 10 feet downgradient of the coal production well.

3.2.4 Shothole Charging

Twenty-five pound charges of Atlas Petrogel were placed forty feet below the water table, but not within the coal. The energy transmitting characteristics of coal are relatively inefficient and therefore do not make coal a good seismographic medium. Consequently, the shot charges were placed at the 100-foot level or the top of the coal, whichever was encountered first. The charges were placed as soon as the hole was cleared. The five-pound sections were screwed together, double capped, and placed down the hole. The holes were stemmed with cuttings to prevent the charges from floating and to provide maximum energy transmission to the surrounding strata. No problems were encountered with the detonation of any of these charges. A six-volt lantern battery was used to detonate them.

3.2.5 Pump Test Instrumentation

The pumps were submersible units powered by a Honda portable generator. The water pumped during the tests was diverted into a 55-gallon drum. The discharge rate was determined by measuring the time it took to fill the drum with an electronic stop watch. During non-measurement times, the flow was directed into a sediment trap to measure the amount of suspended solids collected over the course of the testing. The water was ultimately directed to a nearby road ditch and to natural drainage to avoid recharge problems in the vicinity of the wells. The water levels in the piezometers and pumping wells were recorded with steel tapes, Ott electric tapes, and continuous water level recorders. The recorders consisted of Stevens water level recorders, combined with Keck automatic water level sensing units. Thirteen of these devices were available and working most of the time.

3.2.6 Barometric Background

Pump test drawdown data must be corrected for barometric effects. Background barometric data were collected for four days prior to pump testing with a microbarograph installed at the pump test site. A longer pre-test period of background information may have been useful in determining if the system water levels were stable or undergoing long-term fluctuations. This consideration becomes even more critical with the small drawdowns experienced here. The barometric fluctuations are best considered as a set of minor variations superimposed upon the average water level. Water level recorders were installed on a water table piezometer, on a piezometer finished at the bottom of the Underwood Sand, and on a piezometer finished at the top of the Hagel lignite A bed. The system is unconfined, making a mathematical correlation procedure difficult when trying to determine barometric efficiency.

The water table well responded the most directly to relatively rapid changes in atmospheric pressure. The response in the Underwood Sand was more attenuated. The least response was observed in the Hagel lignite aquifer. The lignite apparently is more confined. During periods of constant pressure, the water levels in the water table and sand well tended to recover to their equilibrium values. The water table well responded slightly faster than the sand well. The coal well responded to long term changes and did not attenuate noticeably, indicating confined behavior.

It is apparent from the raw data that there is considerable individual variation between wells. This further compounds the difficulty of arriving at a correction technique for an entire set of wells. When there was a period of stable barometric pressure the drawdown values were used directly. In some cases an intuitive judgement had to be made based on a comparison of the recorder strip charts for barometric pressure and water level.

3.2.7 Pump Test Sequence

A preliminary pump test on the sand production well was conducted, shut in, and allowed to recover. This is referred to as the sand pumping well or SPW test. The flow rate for the sand pumping well test was 8.2 gpm and was considered reasonably typical. A pump test was then conducted on the coal production well; this is referred to as the coal pumping well or CPW test. The flow rate of 3.2 gpm for the coal well was less than desired but the high cost of installing production wells precluded further search which may have been futile in any case. This exemplifies the character of wells finished in coal at the test site. The shots were executed during the coal pumping well (CPW) test and the sequence is listed in table 4. Table 4 is keyed to the plotted data in the appendices. After shots 1 through 8 had been detonated, the test was shut in and allowed to recover. This is known as the coal production well recovery or CPWR test. The sand production well was tested again and is described as the sand production well post-blast or SPWPB test. The flow rate was set at 8.2 gpm, a stable pumping rate.

TABLE 4

Shot Detonation and Sampling Sequence

for the Coal Pumping Well Test (CPW)

Event	Date	Day	Clock Time	Elapsed Time (minutes)
sample 4698	7-26-83			
test started	8-4-83	0	0800	0
sample 5007	8-5-83	1		1440
sample 5058	8-6-83	2		2880
shot 1	8-7-83		1145	4545
sample 5058	8-7-83	3	1200	
shot 2	8-8-83		1127	5960
shot 3	8-8-83		1143	5985
shot 4	8-8-83		1230	6030
shot 5	8-8-83		1300	6075
sample 5202	8-8-83	4		
shot 6	8-8-83		1945	6465
shot 7	8-8-83		2045	6525
sample 5203	8-8-83	4.9	2100	
sample 5204	8-9-83	5.46	1030	
shot 8	8-9-83		1305	7515
sample 5205	8-9-83	5.6	1305	7515
sample 5206	8-9-83	5.7	1335	8208
sample 5207	8-10-83		0950	9187
sample 5602	8-26-83	22	1800	31680

(Shot 9 was not part of the CPW blasting sequence.)

3.2.8 Anaysis of Pump Test Data

The physical data for all the pumping tests were tabulated with the intention of calculating transmissivity, storativity, and specific yield for the aquifers before and after they had been subjected to blasting. The piezometer response data were tabulated as (time divided by the radius squared) versus drawdown on log log graph paper, where t = time in minutes, r = radius in feet, and drawdown = feet.

Because of the unconfined layered aquifer system, it was determined that the analytical solution most appropriate was that prepared by Boulton (Kruseman and DeRidder 1970). This was suggested by the NDSWC hydrology staff with the admonition that, although it may be the best available model, it may be entirely inadequate.

3.2.9 Fracture Experiment

Shot 9 was a fracture test conducted on the coal production well to determine the effects of a shot located 10 feet away from the screen. This was a short-term test as the well failed to produce water after the blast.

3.2.10 Seismograph Analysis

A small, portable seismograph was used to record the shock waves of some of the blasts. The amplitude of the shock wave at the well location was recorded for each of the shots. The tapes were analyzed by Vibra-Tech Engineers, the firm which donated the use of the instrument.

The analyses provide the peak particle velocity of the ground movement in three mutually perpendicular planes. Particle velocity measurements represent the rate of motion in inches per second that the ground surface was moving at the geophone location as a result of each blast. A particle velocity of less than 2.0 inches per second probably does not have an adverse effect on any structure (Berger 1980).

3.2.11 Specific Capacity Tests

Specific capacity tests were carried out on selected piezometers to assess the effects of blasting on individual wells in addition to the pumping wells. The depth of the wells and their rapid recovery precluded the use of slug and bail tests. Comparative "mini pump tests" were used instead (Strausberg 1982). This consists of using a sampling pump with a fixed discharge to determine drawdown versus time in a piezometer. Tests were run on the piezometers prior to any of the blasting and again after the blasting, for comparison.

A Johnson-Keck SP-81 submersible sampling pump was used to pump the piezometers. The static water level was measured prior to the test. All water level measurements were made with the same A. Ott electronic tape. The pump was lowered into the well until the water level was encountered. The pump was further lowered until the top of the intake was 3 metres below the static water level. The water level was allowed to return to static conditions before pumping commenced.

Because the pump is extremely sensitive to power levels, it was always hooked into the electrical system of a running vehicle in order to insure a constant voltage level. This was intended to minimize output fluctuations.

After the pump was turned on, the water level was measured at one- minute intervals for ten minutes. The entire procedure was repeated for each of the 18 piezometers tested. The before and after results are overlain on the same graph for each well for comparison.

The underlying assumption is that the specific capacity relationship, C= pumping rate/change in head, can be used to make gross predictions about the well behavior. The well behavior can be assessed before and after the shots, assuming a constant pumping rate, based on relative changes in head/drawdown. The initial static water levels were constant and it can reasonably be assumed that the pumping rate for each well for each test was constant.

3.2.12 Hydrogeochemistry

Hydrogeochemical characterization is necessary in order to assess adequately the potential for environmental degradation and potential deleterious effects on the biosphere. The site chosen had not, to the best knowledge of all concerned, been subjected to previous blasting disturbances. The hydrogeochemical characteristics of the Underwood area have been extensively studied and described by Groenewold et al. (1979, 1981, 1983) and Moran et al. (1978). The geochemistry of the unsaturated zone was not addressed in this study. This investigation focused on the changes that occurred in the water in the saturated zone below the water table and in stratigraphically lower aquifers. The water in these units had already undergone its major natural chemical evolutionary changes from the standpoint of this experiment. Only the subsequent changes resulting from blasting were of interest to this study.

3.2.12.1 Water Quality Parameters

Complete chemical and mineralogical characterization of the water was considered necessary to properly assess any potentially deleterious water quality degradations. The chemical parameters of the Federal Drinking Water Standards, as adopted by the NDSDH, specify limitations for the inorganic chemicals listed in table 5. Organic chemical criteria consist of two groups. One group includes synthetic compounds such as herbicides and pesticides which are introduced into the environment through human activity and include Endrin, Lindane, Methoxychlor, Toxaphene, 2, 4-D, and 2, 4 5-TP Silvex. The second group includes trihalomethanes which result from the chlorination of water containing naturally occurring organic compounds, conceivably of the type found in lignite aquifers. Background TOC increases in a municipal water supply could conceivably result in increased exposure to trihalomethanes, if proper treatment is not practiced prior to chlorination.

TABLE 5

Inorganic Chemical Drinking Water Standards

Contaminant	Concentration (mg/l)
Arsenic	0.05
Barium	1.00
Cadmium	0.010
Chromium	0.05
Lead	0.05
Mercury	0.002
Nitrate (as N)	10.0
Selenium	0.01
Silver	0.05
Fluoride	2.4

(Christianson, 1982)

Breakdown products from blasting are recognized but have not been specifically addressed here. Information provided by Atlas, Inc. indicated that Petrogel leaves no chemical residues. Further investigation is necessary to confirm this claim. No information is available on the breakdown products of the plastic material used to contain the charges.

Complete geochemical characterization of the water requires a more extensive analysis than required by the drinking water standards. The samples collected during the experiment were analyzed for total alkalinity, arsenic, barium, bicarbonate, cadmium, calcium, carbonate, chloride, chromium, copper, fluoride, total hardness, iron, lead, magnesium, manganese, selenium, field pH, field temperature, potassium, silver, sodium, sulfate, total dissolved solids (TDS), zinc, conductivity, nitrate, and total organic carbon (TOC). Trace element analysis was conducted because lignites are known to contain substantial amounts of these elements, presumably from concentration of the original organic constituents (Karner, 1983). The analyses for iron, manganese, and arsenic were made for total species and no determination of the oxidation states of iron and manganese was made. Although no dissolved oxygen readings were taken in the field, previous work has shown the value to be low, but greater than zero (Groenewold, 1983). TOC samples were taken to indicate gross changes in organic chemistry as a result of blasting. It should be noted that these TOC values do not reflect volatile components, for which a special sampling technique is necessary. Samples were not taken for specific synthetic organic compounds because of cost and time considerations and the assumption that there was probably little usage of synthetic organic compounds in the area.

3.2.12.2 Sampling Methods and Laboratory Analyses

All samples were taken, preserved, and analyzed in accordance with standardized methods as recommended by the U.S. Environmental Protection Agency and the NDSDH Laboratory. At the pump test site, one complete suite of water samples was taken prior to any pumping or blasting. A second complete suite was taken after all the blasting was completed. Samples taken from piezometers were collected with the use of the Johnson-Keck SP-81 sampling pump. Prior to collecting the sample, the pump was run long enough to purge at least three volumes of water from the piezometer. Samples were taken from the pumping wells during the pump tests, and before and after shot detonation, to note any immediate changes. Field temperature, pH, and conductivity were taken immediately upon collection of the sample. The samples, filtered with a 0.45 micron filter, were packed and transported in ice on a regular basis to the laboratory for analysis. Samples for metals and TOC were taken in separate containers and those for trace metals were acidified with nitric acid. The TOC samples were analyzed by the U. S. Geological Survey Laboratory in Denver, Colorado. All other analyses were analyzed by the NDSDH Laboratories in Bismarck, North Dakota.

The uncertainty limits for each parameter are listed with the data contained in the appendices. They are especially significant at the low reported levels observed for the trace metals. The uncertainty for total organic carbon is 0.2. These analyses provide a thorough assessment of the water quality.

3.2.13 Computer Analysis

The data were analyzed with the aid of two computer programs. The first to be used was the U.S. Geological Survey WATEQF model, designed for calculating chemical equilibrium of natural waters (Plummer et al., 1976). The WATEGM-SE model for hydrogeochemical processes, presently used by the NDMMRRI, was also utilized (Palmer, 1983). The WATEGM-SE model has the additional feature of being able to simulate reactions between solids and a given water chemistry to determine the ultimate evolution of the water when it comes in contact with a given mineralogy. Initial comparison of the results for the data showed no differences; subsequently, only the WATEGM-SE model was used. Calculation of mineral saturation indices was the most useful aspect for this investigation. The WATEGM-SE program allows for consideration of oxidized or reduced states of iron and manganese. If the reduced state of iron and manganese is used, the resultant mineralogy does not agree with field observations. The oxidized state yields mineralogy compatible with field observations and was used for all analyses.

3.2.13.1 Heat and Pressure Induced Chemistry Changes

The reactions governing chemical equilibrium are functions of temperature, pressure, and species activity.

In the vicinity of a blast, both the heat and pressure are elevated and conceivably produce a new short-term environment. Theoretically, changes in mineral solution equilibrium could occur if the reaction kinetics are favorable. Chemical reactions are generally reversible, so it is probable that, with cooling and return to normal pressures, the chemical equilibrium would return to the previous normal levels. Any long-term or irreversible trends should show up as changes in water chemistry. The high specific heat and heat of vaporization of water would probably limit the range of influence of temperature changes. The pressure increase, however, would be felt much farther from the blast. Atlas Inc. reports a peak borehole pressure of 150 kilobars which is rapidly attenuated radially (Longhan, 1984).

In order to predict the effects of blast-induced temperature and pressure changes, the pre-blast data for piezometer number NW50S was subjected to WATEGM-SE analysis at three pressure-temperature combinations. Water at ambient conditions was subjected to increased heat and pressure during blasting and to reduced pressure during pumping. Ambient condition mineralogy was calculated and used as a reference. The same data were subjected to a decrease in pressure to 0.75 bars, and finally to a temperature rise to 150 degrees C at a pressure of 1000 bars. These conditions are assumed to be representative of conditions near a blast. The saturation indices for the predicted mineralogy are compared in table 6. The potential effects of decreasing the pressure by pumping, or raising the temperature and pressure by blasting are thereby effectively simulated. Mineralogy remained the same but the saturation indices changed by several orders of magnitude for some minerals. Both increases and decreases were noted. No exotic or esoteric mineral species were predicted. Gypsum was the only mineral which changed from undersaturated to significantly oversaturated at the higher temperature and pressure.

A closely associated mechanism by which blasting may affect water quality is by the introduction of new reaction surfaces. If the newly fractured aquifer medium is not in chemical and mineralogical equilibrium with the pore water, then the water quality should change in response to the new conditions and be detectable as above.

3.2.13.2 Flow Induced Water Chemistry Changes

Groundwater is a product of its environment and reflects the mineralogy of the medium. The groundwater environment is dynamic, usually anisotropic, and nonhomogeneous. It is reasonable, therefore, to expect spatial and temporal variation in groundwater chemistry. Even if an aquifer is of fairly constant quality, leakage from other aquifers and aquitards may alter the water quality being observed.

TABLE 6

Projected Mineral Saturation Indices

Well no. NW50S

TEMPERATURE (DEG.C)	12.5	12.5	150
PRESSURE (atm.)	.75	1.0	1000
magnesite	0.07624	0.07613	-27.31531
dolomite	0.76343	0.76319	-73.45419
calcite	0.48923	0.48909	-27.99590
anhydrite	-0.68345	-0.68367	2.90439
gypsum	-0.49815	-0.49834	-4.06639
brucite	-5.51401	-5.51404	-68.09242
aragonite	0.32874	0.32862	-27.93779
hydromagnesite	-112.87654	-112.87703	-282.87508
nahcolite	-4.10873	-4.10880	-7.16404
trona	-15.13581	-15.13592	-46.85645
natron	-8.76277	-8.76266	-43.08587
thermonatrite	-10.79188	-10.79177	-40.50150
fluorite	-2.89889	-2.89909	-9.28815
halite	-7.83048	-7.83053	-9.14784
thenardite	-7.59390	-7.59408	-12.32300
mirabilite	-7.25346	-7.25359	-5.64544
goethite	6.92746	6.92712	-88.95570
amorphous Fe(OH)3	3.82261	3.02271	-78.85741
huntite	-1.66484	-1.66532	-142.45401
barite	1.44401	1.44378	-5.79715
witherite	2.21185	2.21169	-27.51219
nesqehonite	-2.54040	-2.54048	-36.90553
artinite	-6.58776	-6.58785	-103.79650
epsomite	-2.91459	-2.91471	-6.96335
MgSO4*6H2O	-3.48812	-3.48812	-3.19838
MgSO4*H2O	-6.96621	-6.96620	-3.38050
MgSO4*H2O amorph	-11.35385	-11.35384	-6.15108
sylvite	-8.18530	-8.18535	-10.34883
2CaSO4*H2O alpha	-8.94866	-8.94866	-6.16260
2CaSO4*H2O beta	-9.13271	-9.13271	-6.22226
Hematite	18.80270	18.80198	-173.32176
maghemite	6.82776	6.82796	-148.50180
Fe(OH)Cl	6.49846	6.49853	-62.80697
Na-jarosite	4.26828	4.26826	-156.06730
K-jarosite	6.88322	6.88319	-154.68962
H-jarosite	-0.08632	-0.08645	-124.71311
Fe2(SO4)3	-40.82918	-40.83042	-36.33381
vaterite	-0.12573	-0.12587	-35.94268
portlandite	-11.70892	-11.70898	-73.67649
monohydrocalcite	-0.38917	-0.38928	-36.48841

Pumping a well lowers the pressure and creates an hydraulic gradient which causes the water to flow toward the well. The WATEGM-SE simulation at a pressure of 0.75 atmospheres and at ambient temperature resulted in a change in saturation indices shown in table 6. Precipitation of minerals with an increased saturation index is likely because the solution is supersaturated to a greater degree. This may be the mechanism by which some mineral encrustation occurs in pipes. The observed result would be a decrease in subsequent solution concentration. It may be impossible to determine which of the mechanisms is responsible for any changes in species concentration. Municipal wells are generally pumped at substantial rates over long periods of time and tend to show changes in water quality with time, to such an extent that engineering for water treatment plants is sometimes difficult (Francis, 1984).

3.3 FARMSTEAD SITE

The farmstead owned by the North American Coal Corporation presented a typical rural North Dakota water supply system and a unique opportunity to study an existing system. This was considered an essential supplement to the detailed pump test site experiment described previously. The test was a long term observation of chemical quality changes in response to blasting.

The exact age of the well is unknown but, based upon local recollection, it is between 30 and 50 years old. It was originally equipped with a windmill, and was later converted to a working head. Recently, a small diameter submersible unit had been installed at a depth of 86 feet. Total depth as measured was 113 feet. It is allegedly screened throughout the sand and coal, as is common of farmstead wells. The casing, which is 3-inch highly corroded steel, has been capped with a piece of 4-inch PVC pipe for the submersible pump head to rest on. The well was used as it was found, with no modifications.

3.3.1 Experimental Description

The well was pumped continuously for 70 days, during which time seven shots were detonated. The shot layout (Figure 33) was intended to simulate an upgradient shotline at one-quarter mile and another at 500 feet. The first shot fired was downgradient 500 feet. The two shots at one-quarter mile were fired next, followed by the two shots at 500 feet. The final two shots were 50 feet from the well, one upgradient, and one down gradient. They were intended to stress the well structure. Shot installation procedures were the same as used at the pump test site.

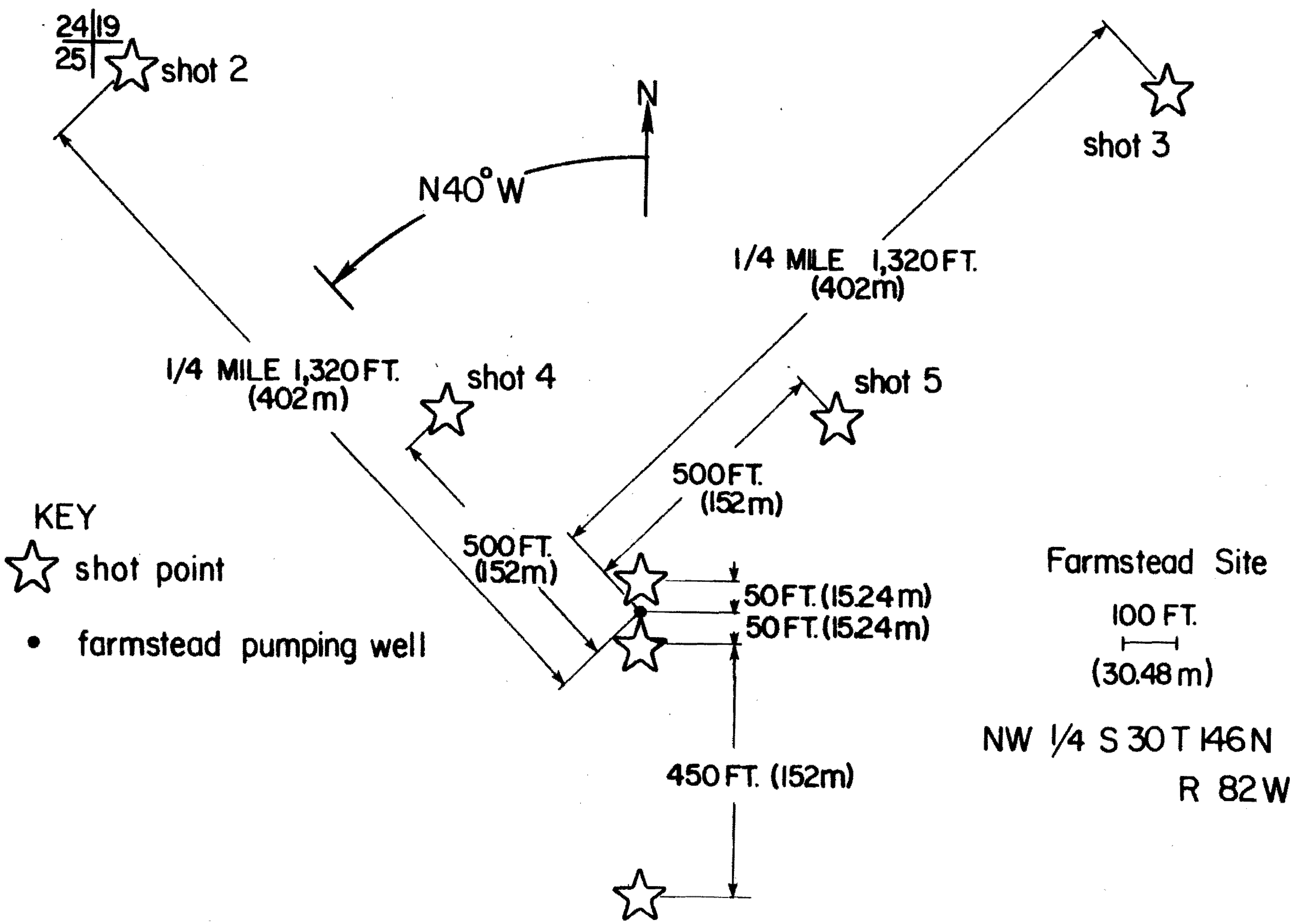
Water quality samples were taken periodically in order to create a water quality profile related to blasting.

Sampling and analysis procedures were the same as for the pump test site. The seismograph was also used here to measure shock wave intensity.

The water discharged during the prolonged pumping was directed away from the site to natural drainage with a hose. The determination of drawdown with time was not possible because the small diameter casing, large discharge line, and general installation made determination of water levels impractical.

The location of the pumping well and the shot orientation is illustrated. The north 40 degrees west orientation of the shotline was intended to maximize the possibility of observing a response along the primary fracture direction.

Figure 33: Farmstead Site Experimental Detail



24 19
25
shot 2
N
N40° W
shot 3
1/4 MILE 1,320 FT.
(402m)
1/4 MILE 1,320 FT.
(402 m)
shot 4
shot 5
500 FT.
(152m)
500 FT.
(152m)
KEY
shot point
farmstead pumping well
50 FT. (15.24 m)
50 FT. (15.24 m)
Farmstead Site
100 FT.
(30.48 m)
NW 1/4 S 30 T 146 N
R 82 W
450 FT. (152m)

Chapter IV

EXPERIMENTAL RESULTS

4.1 PUMP TEST SITE

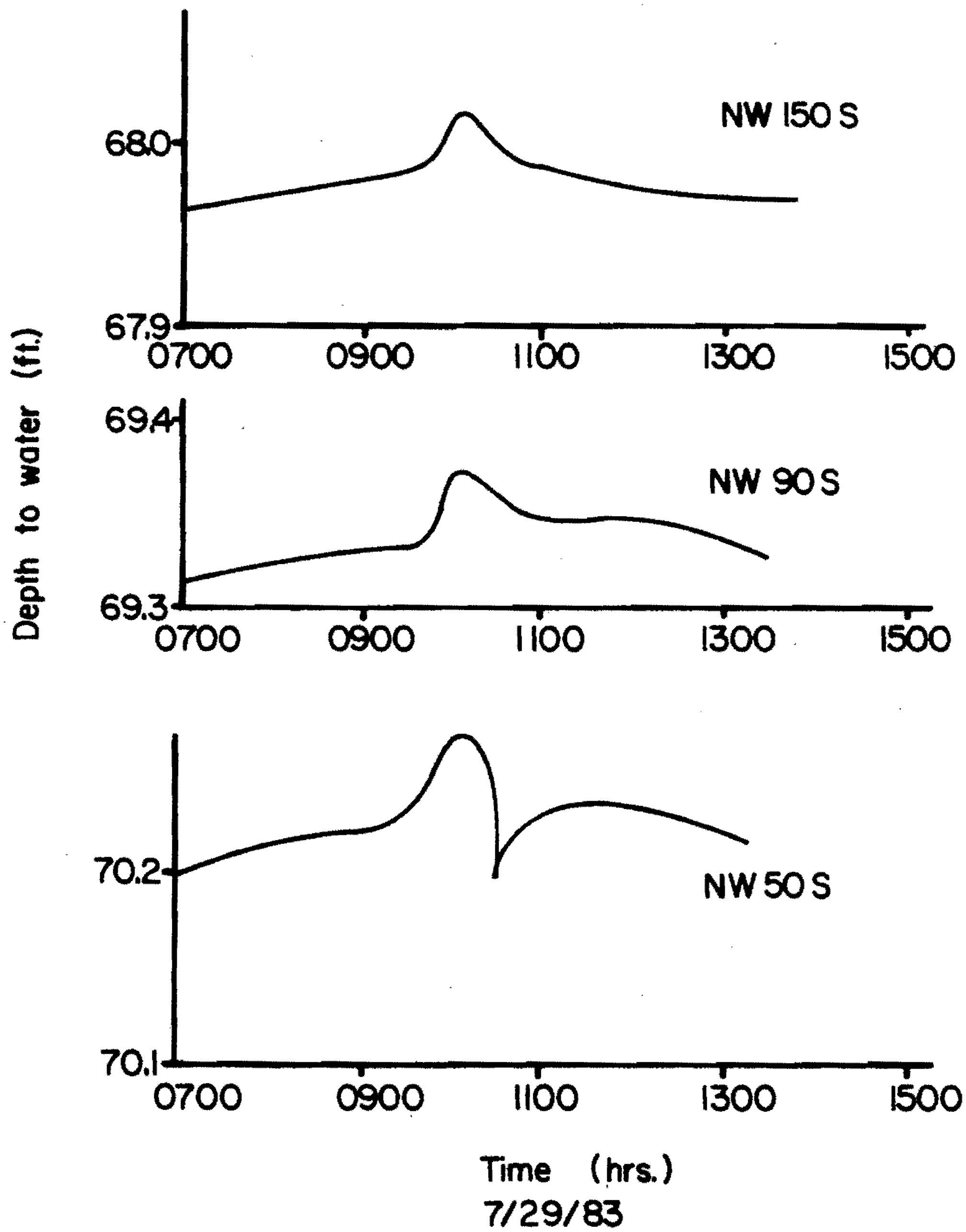
4.1.1 Effects of Drilling

During the drilling of the shotholes, an opportunity arose to compare the method of drilling with water to drilling with air. Shothole number 8, 50 feet away from the sand production well, was drilled after water level recorders had been installed on the nearby piezometers. At approximately 60 feet into the hole the driller was unable to maintain circulation with air and began to inject water. There was an initial drop in the water levels of surrounding piezometers while drilling with air. The shothole was being pumped. At the time injection of water began, an abrupt reversal in the water levels of the piezometers became apparent. Water was being added to the system and the effects were being observed at distances greater than 50 feet. The graphic response can be seen in figures 34 and 35.

Well numbers NES50WT, NES50S, NW50S, NES90S, and NES90C all showed water level changes due to pumping of and injection of water into the formation by the drilling

The water level changes in response to drilling with air and water indicate that injection of drilling water can significantly influence the surrounding hydrogeology.

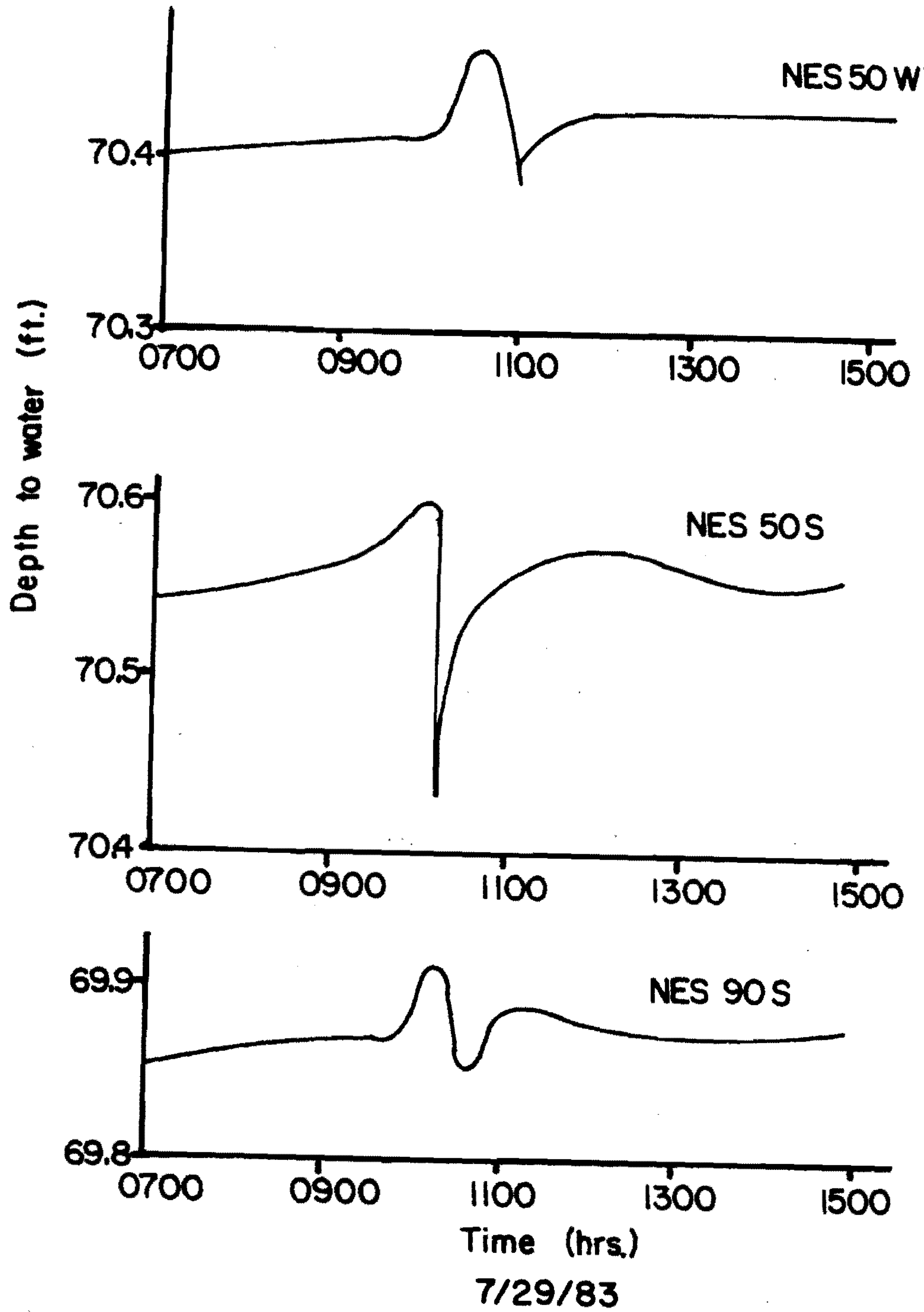
Figure 34. Piezometer Response to Drilling



NW 150 S
68.0
67.9
0700
0900
1100
1300
1500
NW 90 S
69.4
69.3
0700
0900
1100
1300
1500
70.2
70.1
NW 50 S
0700
0900
1100
1300
1500
Depth to water (ft.)
Time (hrs.)
7/29/83

The water level changes in response to drilling with air and water indicate that injection of drilling water can significantly influence the surrounding hydrogeology.

Figure 35. Piezometer Response to Drilling

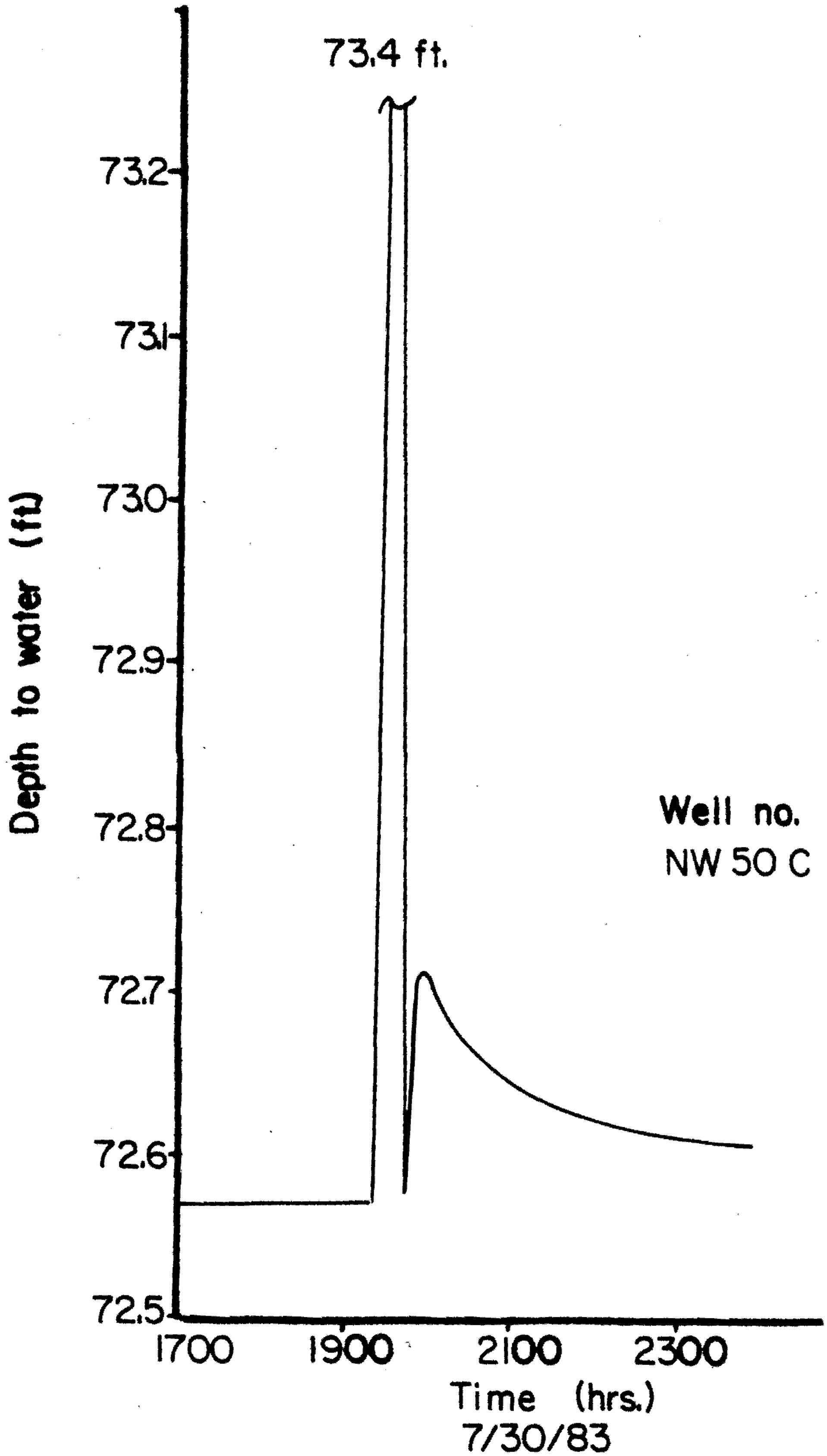

NES 50 WT
70.4
70.3
0700
0900
1100
1300
1500
Depth to water (ft.)
NES 50 S
70.6
70.5
70.4
0700
0900
1100
1300
1500
NES 90 S
69.9
69.8
0700
0900
1100
1300
1500
Time (hrs.)
7/29/83

operations. As soon as water was injected, the level of the nearest piezometer began to rise, and continued to do so until injection ceased after approximately 300 gallons of water had been injected into the hole. The piezometer levels then returned to former levels. Had this been a sampling well, one can only speculate upon the effect this would have had on the validity of the water quality analyses taken from this hole. Development of a piezometer would rarely purge 300 gallons from the well. Drilling with air should be regarded as an absolute necessity when installing piezometers from which water quality samples are recovered.

When the shothole 10 feet away from the coal pumping well was drilled and cleared by pumping with air, there was an immediate and substantial drawdown in certain wells. Less response was seen during the actual pumping tests. The water level in well NW50C dropped 0.9 feet within minutes after the pumping began and recovered fully within 2 hours after pumping ceased. Well NES50S experienced a barely perceptible fluctuation, as did well NES90S. The remaining wells showed no response at all. Prior to this there had been no fluctuations of the nearby water level recorders. The closest one was approximately fifty feet away from the shothole, but the large response was seen at more than 100 feet. Figures 36 and 37 illustrates the water level response. From this behavior, it is probably safe to infer that the coal system is fractured and that the primary fracture direction is northwest along the NW piezometer arm.

The water level in piezometer NW50C dropped immediately in response to pumping the hole for shot 9, located 110 feet from the hole. Other piezometers only half as far away showed little or no response to pumping of the shothole.

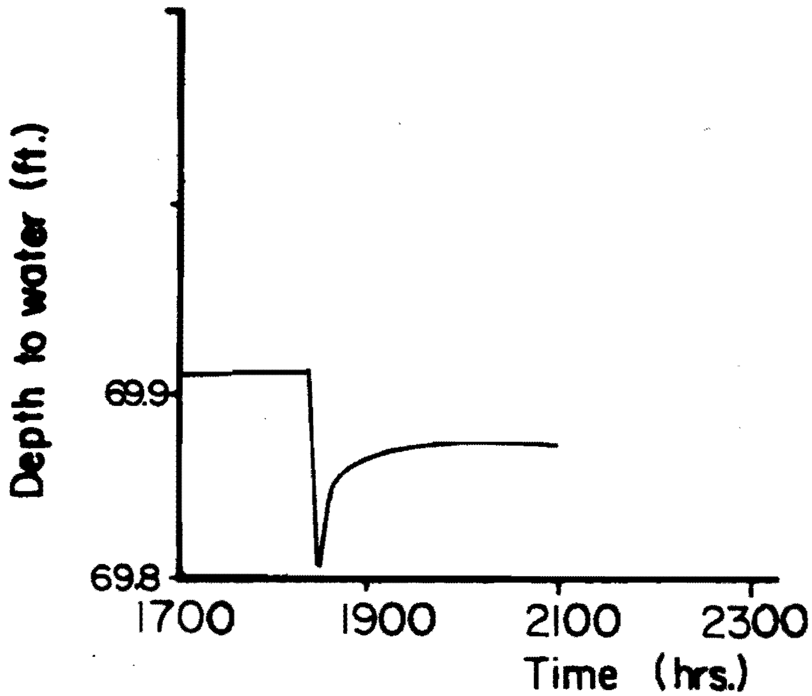
Figure 36. Piezometer Response to Pumping


73.4 ft.
73.2
73.1
73.0
72.9
72.8
72.7
72.6
72.5
Depth to water (ft)
Well no.
NW 50 C
1700
1900
2100
2300
Time (hrs.)
7/30/83

Wells NES90S and NES50S are the only other piezometers which responded to pumping of shothole 9. Other piezometers closer to the shot hole showed no response.

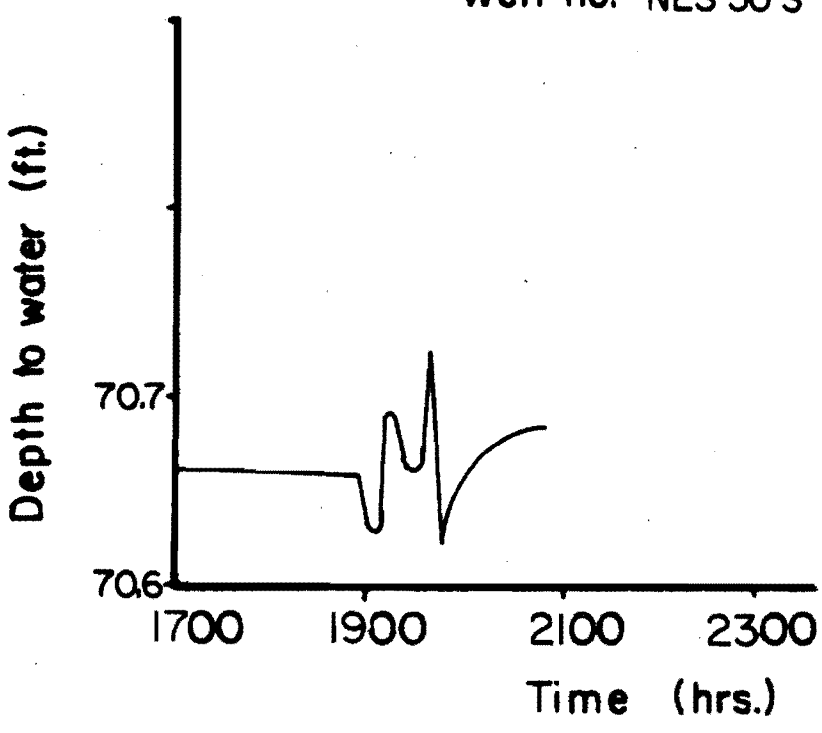
Figure 37. Piezometer Response to Pumping

Well no. NES 90S



7/30/83

Well no. NES 50 S



4.1.2 Physical Response to Blasting

The blasting sequence occurred during the coal well pumping test. The water level response was rapid and could not be recorded with tapes, so only those wells with recorders are represented. The physical responses of the various piezometers are best represented by the plotted results, included in Appendix C. The effects with respect to distance are readily apparent. The distances between shots and wells/piezometers are listed in table 7.

4.1.2.1 Piezometer Response

Well NW90C showed a 0.7-foot rise and recovery in water level at shot 1. Shots 2 through 5 caused no response in water level. Shot 6 caused a 0.8-foot rise followed by recovery. Shot 7 had no effect. Shot 8 caused a 0.4-foot rise which remained as a long-term effect on the water level, which may be inferred to be a change in aquifer characteristics at that point.

Well NES50C was uneffected by shots 1 through 7, but shot 8 caused a 1.3-foot rise in water level and two wave-like reverberations. The water level quickly returned to the previous level.

Well NES50S was also uneffected by shots 1 through 7, but experienced a 2.1-foot rise in water level and two

TABLE 7

Distance Between Shots and Wells/Piezometers

(feet)
(to obtain metres multiply by 0.3048)

WELL SITE	SHOT NUMBER 1	2	3	4	5	6	7	8
NW1200	1790	120	970	1790	1820	700	1350	1160
NW600	920	720	990	1450	1470	100	1820	570
NW250	640	1070	1160	1350	1360	250	580	220
NW150	570	1170	1220	1330	1330	350	540	120
NW90	530	1230	1260	1320	1330	410	520	65
NW50	520	1270	1290	1320	1330	450	510	40
SPW	490	1320	1320	1320	1320	500	500	50
NES50	540	1320	1290	1270	1270	500	450	40
NES90	580	1330	1270	1230	1230	510	410	65
NES150	630	1330	1220	1170	1180	520	350	120
NES250	230	1350	1160	1070	1070	560	250	220
NES600	1070	1450	990	720	720	780	110	570
NES1200	1660	1790	980	120	130	1300	700	1170
CPW	480	1370	1360	1325	1320	550	510	90
NEC50	520	1370	1330	1270	1270	550	400	85
NEC100	570	1370	1290	1220	1220	560	400	110
NEC140	610	1375	1265	1175	1175	565	360	140
NEC200	270	1380	1230	1120	1120	580	300	190
NEC300	770	1400	1170	1020	1020	630	200	280
NEC650	1110	1520	1020	720	720	850	150	620
NEC1200	1650	1820	1020	130	120	1325	700	1170

reverberations in response to shot 8. Recovery to the previous level was rapid.

Well NW90S showed a 0.05-foot rise in water level at shot 1 and recovered within 5 hours. Shots 2 through 5 showed no effect. Shot 6 caused a 0.08-foot rise and shot 7 caused no apparent response. Shot 8 caused a 1.5-foot rise in water level which returned to previous levels within 4 hours.

Well SPWC experienced a slight rise followed by an immediate drop and recovery of the water level at shot 1. Shot 2 caused a barely perceptible rise and shots 3 through 5 caused no apparent changes in water level. Shots 6 and 7 each caused a 0.05-foot drop followed by recovery to the previous level. Shot 8 caused a 0.3 foot rise followed by a sharp 0.65-foot drop, at which water level it remained.

Well NES90S experienced a 0.03-foot water level drop at shot 1 and recovered within 6 hours. Shots 2 through 4 failed to effect the water levels. Shot 5 caused a slight drop which was quickly recovered. Shots 6 and 7 caused no effect. Shot 8 caused a 1.6-foot rise and two reverberations of the water level followed by a return to the former level.

Well NEC50S responded only to shot 8 with a 0.4-foot rise and instant recovery of the water level.

Well NEC100S showed a 0.04-foot water level rise which recovered within 4 hours at shot 1. Shots 2 through 7 caused no effects. Shot 8 caused a 0.15-foot rise in water level followed by immediate recovery.

Well NES90C showed a 0.04-foot water level drop at shot 1 and recovered within 4 hours. Shots 2 through 5 caused no effects. Shot 6 caused a 0.12-foot water level rise. Shot 7 caused no effect. Water levels recovered to the previous level. Shot 8 caused a 0.3-foot water level drop followed by recovery.

Well NEC50C showed a 0.1-foot water level drop and recovery at shot 1. Shots 2 through 5 caused no effects. Shot 6 caused a 0.15-foot water level rise and recovery. Shot 7 caused no effect. Shot 8 caused a 0.4-foot water level rise followed by rapid recovery.

Well NW50S showed no response to shots 1 through 5. Shot 6 showed a hint of water level rise. Shot 7 caused no effect. Shot 8 caused a 1.6-foot water level rise and two reverberations followed by rapid recovery.

Well NW50C showed a 0.04-foot water level drop at shot 1 and appears not to have recovered. Shots 2 through 5 caused no effects. Shot 6 caused a 0.1-foot rise and drop in water level. Shot 7 had no apparent effect. Shot 8 caused a 0.32-foot rise followed by a drop in water level.

Well NEC100C showed a 0.06-foot rise and slow water level recovery at shot 1. Shots 2 through 5 caused no effects. Shot 6 caused a water level drop of 0.1-feet. Shot 7 caused a 0.8-foot drop and recovery of water level. Shot 8 caused a 0.1-foot rise followed by recovery to the former water level.

As expected, the shots at one-quarter mile had very little, if any, physical effect. In general, shots 2 through 5 at one-quarter mile from the observed well produced no response in any of the piezometers. The shots at 500 feet produced more pronounced water level changes and shot 8 caused significant disturbances. Shot 1, 500 feet downgradient, caused a response of approximately 0.05-feet in all the wells it affected. All the coal wells but one were affected. Three of the sand wells were affected and three were not. The 500 foot upgradient shots caused water level fluctuations in the range of 0.1-foot and the responses were irregular in expression. Shot 8 at 50 feet from the sand production well caused water level changes of over 1.0-foot.

Some of the effects appear to be permanent. No regular response pattern is evident, which may indicate an irregular fracture pattern. Some of the response in the sand wells may be enhanced by pressure peaks transmitted through coal fractures. Some water levels rose and some dropped, which indicates a complex system of interconnections, probably through the coal fracture system. An irregular fracture pattern is indicated both by this display and by the pump test response data.

4.1.2.2 Coal Well Response

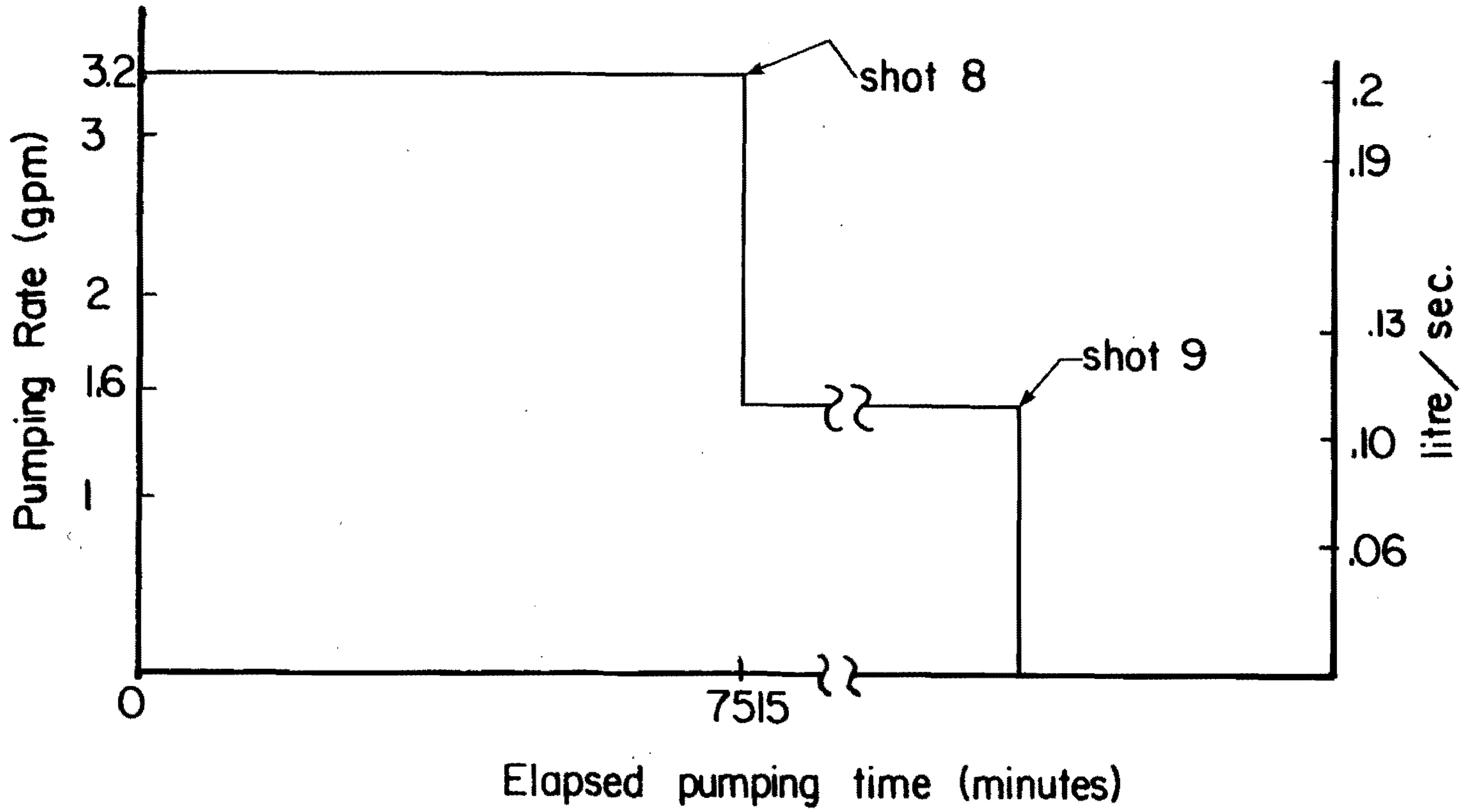
The water from the coal production well was closely monitored during the blasting sequence. Shots 500 feet or farther away produced no visible increases in turbidity or detectable change in pumping rate. The water pumped from the coal production well became temporarily turbid and the flow rate permanently dropped from 3.2 gpm to 1.6 gpm when shot 8, 100 feet from the coal production well, was detonated. Water level fluctuation of the coal production well was not determined because of the turbulence. Figure 38 illustrates the pumping rate versus time for the test.

4.1.2.3 Sand Well Response

The sand production well (SPW) test was intended to demonstrate the condition of the sand production well system before and after all the blasting had been completed. This was a two part test, the first part having been conducted prior to the blasting sequence in order to define the pre-blast system. The second test was carried out in the same manner. The duration was not as long as the first test but the result was very informative. The same 8.2 gpm pumping rate was used as in the previous test, but the drawdown was substantially less when equilibrium had been established. Figure 39 illustrates the two drawdown versus time curves generated by this test. It would appear that the blasting effectively fractured the sand aquifer, resulting in greater transmissivity, and a shallower but more extensive drawdown cone of depression. The apparent result is the same as that desired when fracturing of an oil

The pumping rate remained at 3.2 gpm until shot 8 was detonated, at which time the pumping rate dropped by one-half, to 1.6 gpm where it remained until shot 9 was detonated during the fracture test.

Figure 38. Coal Well Pumping Rate

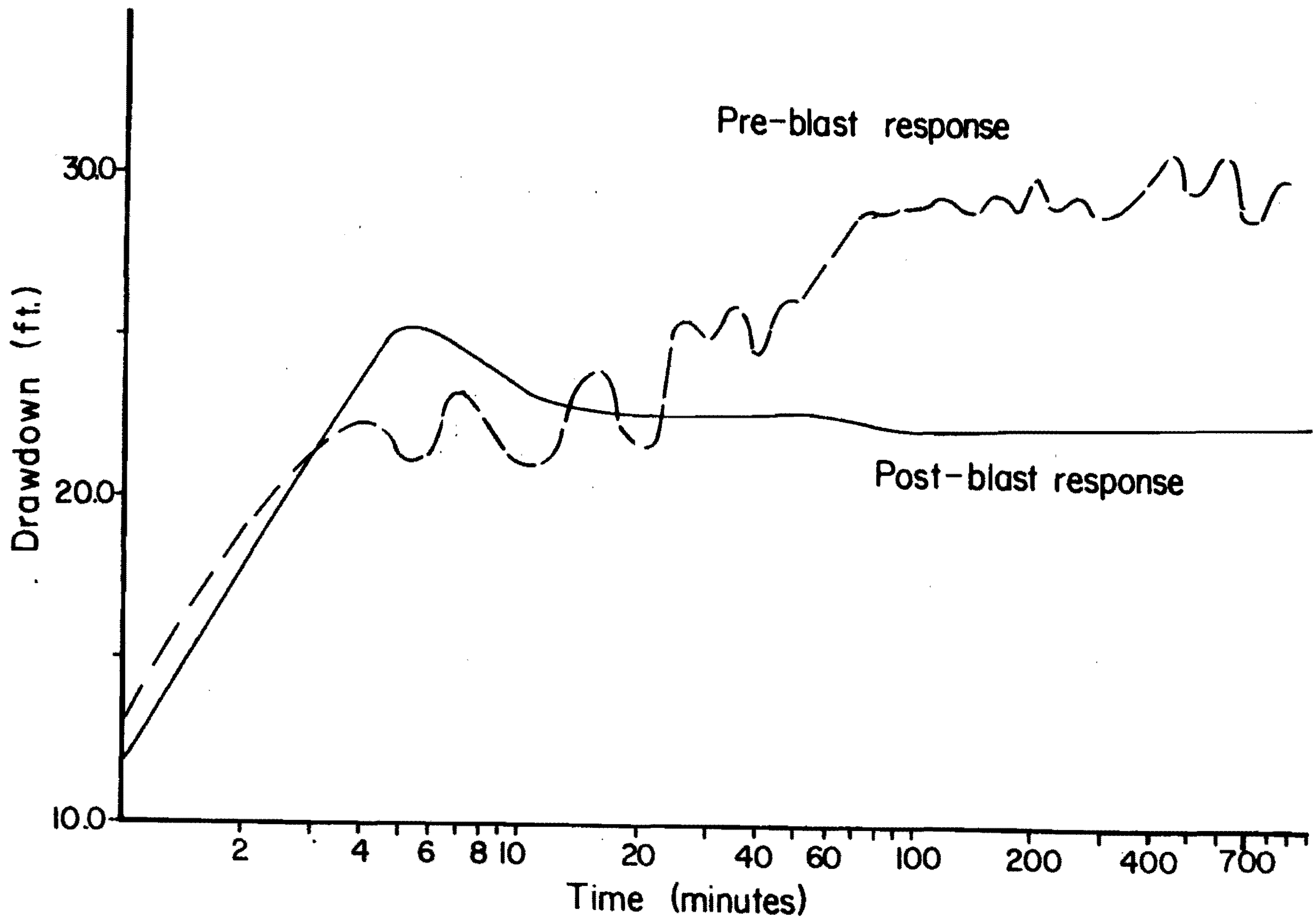


Pumping Rate (gpm)
3.2
3
2
1.6
1
0
7515
shot 8
shot 9
.2
.19
.13
.10
.06
litre/sec.
Elapsed pumping time (minutes)

bearing stratum is attempted. In a practical situation, the only evidence available may be the decreased drawdown of the production well, and would probably not be noticed by a well owner at all. The sand well was not pumped during the blasting, but it did produce turbid water for a short time at the beginning of the second phase. The turbidity may be the only apparent indication of change to the typical well owner.

At a fixed pumping rate of 8.2 gpm, the drawdown after the blasting is significantly less, indicating an increase in permeability in the poorly indurated sandstone aquifer.

Figure 39. Sand Well Drawdown


Pre-blast response
Post-blast response
Drawdown (ft.)
30.0
20.0
10.0
2
4
6
8
10
20
40
60
100
200
400
700
Time (minutes)

4.1.3 Pump Test Results

Initial calculations of transmisivity resulted in a wide range of seemingly meaningless values. The plotted data for the pump tests are included in Appendix D. Future models may be developed which would approximate the flow in a fractured system. Presently available methods of aquifer analysis are probably inadequate to describe characteristics of fractured coal and associated aquifers. The shape of the curves did not allow even an approximate match with the type curves (Kruseman and DeRidder, 1970).

The tentative conclusion from interpretation of the data is that there is a difference in the aquifer media, as expected, because of the vertical offset between many of the curves in the long time segment. Values for the pumping wells were not calculated because the questions of appropriate radius, efficiency, and turbulent flow render those data questionable in analysis of aquifers for transmissivity, storativity, and specific yield. Turbulent flow may be involved and recharge from the overlying and underlying aquifers may be concentrated in the fracture regions of the coal, thereby creating erratic flow conditions in the non-coal aquifers. These phenomena are not addressed in presently available solutions and may not be solvable considering the uncertainty involved. Response of the sand pumping well test was a relatively uniform concentric drawdown. The response to the coal pumping well showed a preferred directional drawdown response to the NNE. This suggests a distinctly directional drawdown response. Coal fracture permeability is probably the mechanism. It does not correspond, however, with the assumed regional NW fracture direction.

The small drawdowns in most of the piezometers increase the chances of error in both measurement and barometric corrections and make definitive conclusions even more difficult. The drawdown in the sand pumping well approached the saturated thickness of the sand aquifer. The water level in the coal aquifer dropped below the upper confining boundary of the lignite aquifer. More piezometers closer to the pumping wells may be important in describing the cone of depression more completely.

Probably the most valuable measurement, and certainly the one most easily obtained, is the time-drawdown curve of the pumping well. But, these data are normally not used in aquifer evaluation. The correct effective radius is difficult to determine and the effects of turbulence create problems in the analytical solutions presently available. Gross changes in aquifer characteristics can, however, be readily observed and therefore the time-drawdown curve may be the only presently available technique for assessing damage. In order to utilize this technique, a time drawdown curve must be established prior to any blasting if there is to be any hope of successful litigation. Time-drawdown data provides information which can be understood easily by the layman even though it is not as immediately obvious as an instantaneous decrease in the output from a flowing artesian well.

4.1.4 Seismograph Results

The shot at fifty feet from the sand production well produced a vertical particle velocity of 2.48 inches per second and was the only one to exceed the recommended 2.0 inches per second limit. The use of a seismograph may be an economically effective way to monitor seismic blasting.

4.1.5 Specific Capacity Results

Comparative specific capacity test results are obtained by overlaying the pre-blast and post-blast time-drawdown curves on the same graph. Wells that level off at 9.84 feet (3 m) indicate a decrease and stabilization of the water at the level of the pump intake. Increased or decreased productivity can easily be noted by comparisons of the two superimposed curves for each site, contained in Appendix E. In all but two, the productivity of the well increased to some extent, presumably as a result of fracturing the aquifer medium. In two cases the productivity decreased.

Collapse of fractures in the coal may be the responsible mechanism. There was no apparent correlation between distances from shots, orientation, vertical position of the well screen in the aquifer, or the aquifer lithology. It may be possible that the wells with decreased production became partially plugged by particles driven into the screens. An alternative explanation is the nonhomogeneity of the aquifer medium. Observation of the aquifer materials in the nearby coal mine highwall indicate differences in structure, composition, depth, and mineralization, all of which ultimately may affect the productivity of a given well.

It can be concluded that the productivity of these wells in general was changed by nearby seismic blasting. The mechanism may be fracturing of the sand aquifer medium. Collapse of coal fractures may be the mechanism of decrease. The shapes of the curves themselves provide more insight than specific capacity values calculated at any given time.

4.1.6 Coal Fracturing Experiment

Shot 9, installed 10 feet away from the coal pumping well, was expected to fracture the aquifer and increase the yield. Shot 9 consisted of 25 pounds of petrogel placed in the coal 10 feet away from and parallel to the pumping well screen. When the experiment was executed, the well output had already been decreased from 3.2 to 1.6 gpm as a result of the shot 100 feet away. Because the shot was so close to the well, it was deemed advisable to remove the pump from the well. As soon as the pump was removed, shot 9 was fired, and the pump was immediately reinstalled. The pump had only one-quarter inch of clearance in the well casing and it was effortlessly reinstalled to its former depth of 117 feet. When the pump was turned on, the water pumped out of the casing was very turbid. When the water level dropped to the pump level it began to draw air and continued to run, but without producing water. The pump was left on for several minutes but no more water was produced. Two hours later the water level was only 3.0 feet above the pump. The blast had effectively destroyed the productivity. Because the casing apparently remained intact, the change must have occurred in the aquifer and decreased the permeability. The mechanism of well failure may involve plugging of the fractures during the expansion of material near the blast zone. Perhaps the blast was too powerful to merely fracture the coal, and instead, effectively sealed all the fractures in the area. A smaller charge or greater distance may have given different results. If the heat generated by the blast had been sufficient to melt the screen openings, the deformation should have prevented reinsertion of the pump after the shot.

4.1.7 Piezometer-Field Hydrogeochemistry

Comparison of the chemical analyses for each piezometer before and after the blasting sequence revealed no significant changes in observed species concentrations. Mineral saturation also was compared but no significant changes were observed, as would be expected from similar waters. Total organic carbon exhibited both small increases and decreases after blasting, with no apparent correlation to distance from the shot or direction from the shot. These data reflect pre-blasting ambient conditions and post-blast conditions after a return to equilibrium and suggest no permanent effects. The analytical data are included in Appendix F.

4.1.8 Sand Well Hydrogeochemistry

Samples for chemical analyses were taken during the sand well pump test and after the coal well pump test. No samples were taken from the sand production well during the coal well test because the withdrawal of an adequate sample volume from the well could have disturbed the small drawdowns experienced. The results reflect a before and after state of the system. The concentrations versus time are plotted for each parameter and are included in appendix G.

It should be noted that there is an initial increase in some of the parameters which apparently is a result of pumping. Conductivity, total dissolved solids, total hardness, sulfate, magnesium, manganese, and nitrate all show a general rise during early pumping time which implies that changes can be expected from pumping alone. Nitrate ranged from 0.4 to 1.75 mg/l, showing an early increase with pumping. Fluoride remained constant at 0.2 mg/l through the entire test and was a good indicator of analytical stability. Iron remained near zero except for a peak near 2.5 mg/l after the blasting, followed by a return to near zero. Potassium ranged from 5.1 to 5.6 mg/l. Chloride remained below 3.0 mg/l. Conductivity remained between 650 and 760 micromhos/cm. Sulfate ranged from 42 to 90 mg/l. Total dissolved solids ranged from 390 to 490 mg/l. Alkalinity dropped from 350 to nearly zero; no explanation is immediately apparent. Hardness ranged between 350 and 450 mg/l. Sodium and calcium remained between 16 and 20 mg/l and displayed an inverse relationship, which reflects a sodium and calcium exchange reaction on Na-montmorillonite sites as a result of blasting disturbance. The mechanism may be a physical dislodging of the ions. The trend is a return toward initial conditions with time. Manganese remained between 0.48 and 0.70 mg/l. Magnesium ranged from 34 to 43 mg/l. Bicarbonate ranged from 414 to 434 mg/l. Trace metals remained at barely detectable levels. TOC showed an overall but perhaps insignificant decrease. It is apparent that no significant long term changes can be attributed to the blasting sequence. No significant changes in mineralogy or saturation indices are evident, either.

4.1.9 Coal Well Hydrogeochemistry

Samples for chemical analyses were taken before, during, and after the coal well pump test. The shot sequence was executed during the pump test. Concentrations over time have been plotted for each parameter and are included in Appendix H. Table 4, the blasting sequence, is keyed to the data in Appendix H in order to show any immediate changes in the water chemistry as a function of blasting. In general, a rise due to pumping is seen for some parameters. The only effects attributable to blasting are the peaks after shot 8 which are superimposed upon the already slightly elevated values apparently induced by pumping. Fluoride remained constant at 0.2 mg/l, indicating good experimental technique and analysis.

The trace metals, barium, arsenic, cadmium, chromium, lead, silver, and zinc remained at less than 1 mg/l. Chromium and barium remained at a steady level and ultimately dropped to zero. Barium remained below 100 ug/l. Silver remained below 2.5 ug/l. Arsenic, chromium, and lead remained below 3.0 ug/l. These levels are so low that they may be considered negligible, with respect to the confidence limits of the analyses. No definitive response was evident in the trace elements.

Major cations and anions showed more response to the blast at 100 feet. Potassium remained below 5.2 mg/l except for a peak to 8.2 following shot 8. Manganese remained below 0.36 mg/l except for a peak to 1.75 after shot 8. Chloride remained below 1.1 mg/l, except for a brief rise to 1.5 mg/l after shot 8. Sodium remained between 35.0 and 45.0 mg/l for the duration of the test except for a small rise after shot 8. Calcium remained between 52.5 and 62.5 mg/l except for a peak of 130 mg/l following shot 8. Total iron remained below 0.05 mg/l except for a brief rise to 0.125 mg/l following shot 8. Both calcium and iron remained in a fixed range. Magnesium ranged from 26.5 to 32.0 mg/l with a peak of 53 after shot 8. Nitrate remained below 0.4 mg/l. TOC remained below 20.0 mg/l, except for a brief rise to 40.0 after the shot sequence. TOC showed a rise from a background of slightly less than 10.0 to near 40.0 mg/l after the shot sequence and an immediate return to background conditions. Sulfate remained between 28 and 31 mg/l. Total dissolved solids, a general quality indicator, remained below 390 mg/l, except for a brief rise to 510 mg/l after shot 8. Conductivity, another general quality indicator, ranged from 590 mg/l to a small peak of 630 mg/l. Bicarbonate rose from a background of 120 mg/l to slightly over 400 mg/l with a 480 mg/l peak after shot 8. The rise appears to be a response to pumping rather than blasting. Total alkalinity remained between 333 and 347 mg/l with a peak to 390 mg/l after shot 8. Total hardness ranged from 242 to 285 mg/l with a peak of 540 after shot 8.

Total iron, chloride, total dissolved solids, total alkalinity, bicarbonate, total hardness, magnesium, calcium, manganese, and potassium all showed distinct concentration peaks in response to shot 8. Sulfate, nitrate, sodium, and conductivity showed less distinctive peaks. Conductivity, sodium, sulfate, nitrate, magnesium, bicarbonate, and TDS show a slight initial increase, possibly a result of pumping. Saturation indices showed only slight shifts and no difference in mineralogy was noted.

4.2 FARMSTEAD SITE RESULTS

4.2.1 Flow Rate

The flow rate remained constant at 5.2 gpm through the first 50 days of the 70-day test. The final flow was 3.0 gpm and the pump was drawing air at that time. This constant pumping stressed the system far beyond normal usage. At approximately 100 gallons per day, this represents approximately fifteen years of usage.

The two final shots at 50 feet were intended to subject the well structure to extreme stress. The well was pumping at a reduced rate prior to these close shots and continued to do so after the shots. The pump was removed prior to the two close shots and was reinstalled without difficulty. The structural integrity had been retained even though loosened scale could be heard falling down the casing. The plaster on the inside of an abandoned basement 75 feet south of the well and 25 feet south of the close downgradient shot was blown off the wall and small fractures could be noted. The original quality of the concrete appeared to be very poor, having been prepared with high clay/shale content sand.

4.2.2 Hydrogeochemistry

The farmstead shot sequence is listed in table 8. The sequence is keyed to the plotted data in Appendix I.

TABLE 8

Farmstead Shot Detonation Sequence

SHOT NUMBER	DATE	DAY	CLOCK TIME
Test started	8-4-83	0	0800
Shot 1	8-5-83	1	1230
Shot 2	8-6-83	1.25	1230
Shot 3	8-6-83	1.26	1300
Shot 4	8-28-83	22	1130
Shot 5	8-28-83	22	1200
Shot 6	10-9-83	69	1130
Shot 7	10-9-83	69	1145

The water chemistry here should reflect both the coal and sand aquifers through which it is screened. Changes in one environment may be masked by changes in the other. The net result should be apparent in the analyses. Water quality samples were taken prior to and throughout the test. Parameter values versus time in days were plotted and are included in Appendix I. A lengthy pre-blast test was not conducted at the farmstead, so it is impossible to determine if the effects are due solely to pumping or blasting. But, based on the early pumping time increases seen at the sand pumping well site, the initial rise is probably due to pumping.

A general concentration rise occurred during the first 15 days of the test and might be attributed to shots 1, 2, and 3. There were no spike peaks so it is probably safe to conclude that the general rise was due to pumping. This is in agreement with the results from the pump test site, where no effect was seen at 500 feet. Shots 4 and 5 caused no obvious increase and were 500 feet from the pumping well. There was an increasing trend in sulfate and conductivity, but only within approximately one order of magnitude. In general, the trends indicated no major changes in the water chemistry.

Trace metals remained essentially stable, except immediately following the two shots 50 feet away from the well. Iron and manganese increased dramatically, possibly a result of scale from the pipe changing the water quality for a short term. Iron remained near zero until the last shots were fired. Similarly, manganese remained below 0.05 mg/l until the last shots, which presumably loosened iron and manganese encrustations in the well casing. Iron scale, however, is not necessarily soluble. Connate water with relatively low pE and therefore higher levels of iron and manganese may have been released upon fracturing.

Total dissolved solids exhibited a sharp rise following the first two shots. The total range of values was from 830 to 1050 mg/l. Sulfate showed a general rise from 325 to 475 mg/l, with a sharp rise and drop at the last two close shots. Sodium remained between 15 and 24 mg/l throughout the test. Calcium showed a slight increase from 160 mg/l to slightly under 200 mg/l. Barium ranged between 0.0 and 100 ug/l. Chloride ranged from 8 to 12 mg/l. Bicarbonate ranged between 370 and 440 mg/l. Potassium ranged from 3.6 to 6.0 mg/l. Barium ranged from 50 to 175 ug/l. Arsenic remained under 6.0 ug/l. Chromium remained under 3.0 mg/l. Cadmium remained under 0.6 ug/l. Fluoride remained at 0.2 mg/l. Zinc ranged from approximately 10 to 90 ug/l. Lead remained below 1.8 ug/l. Potassium ranged from 3.5 to 6.0 mg/l. Magnesium ranged from 70 to 90 mg/l. Nitrate ranged from 8 to 16 mg/l. Total organic carbon remained under 10 mg/l except for a peak of almost 60 following shots 1 through 3. Sulfate and bicarbonate are the dominant anions.

4.2.3 Mineral Saturation

The saturation indices for those minerals near equilibrium, according to the WATEGM-SE program, were plotted against time and are included in Appendix J. Magnesite fluctuated between being slightly oversaturated to slightly undersaturated. Gypsum remained slightly undersaturated, as did anhydrite. Aragonite varied from slightly undersaturated to slightly oversaturated. Calcite and dolomite varied from slightly undersaturated to slightly oversaturated.

Chapter V

CONCLUSIONS

This research has shown that some change in water quality and aquifer characteristics result from seismic blasting within 500 feet and that the effects are confined to the aquifer rather than the wells themselves. The coal aquifer at the pump test site is more sensitive to disturbance than the sand aquifer. The site is sufficiently representative of the Great Plains geological setting to allow limited inference to other areas. This experiment stressed the system more than a normal encounter with seismic blasting. Chemical effects are small and reversible. Short range physical effects in coal and sand are significant and permanent.

5.1 EFFECTS OF BLASTING ON WELL STRUCTURES

It is apparent from this study that both PVC and even badly corroded steel casings can withstand substantial impact without structural failure, even though none of the well casings in this study were extracted and inspected visually. It can be concluded that the effects of blasting on the structures themselves are minimal and that apparent effects are within the aquifer(s).

Two blasts of 25 pounds of Petrogel, each 50 feet from the old farmstead well, failed to collapse the casing. A substantial amount of scale was loosened, and which fell down the hole when the submersible pump was reinserted. The detonation of 25 pounds of petrogel, 10 feet away from the coal pumping well screen, failed to collapse the screen or casing. The closely fitting submersible pump was effortlessly reinstalled after the shot, although not without some reservations about its becoming irretrievably wedged in place.

None of the piezometers experienced any detectable damage. The closely fitting submersible sampling pump was used to sample all the piezometers after all the blasting was completed and no problems were encountered.

5.2 WATER LEVEL CHANGES

Permanent changes in static water level may be the result of increasing or decreasing the aquifer storage capacity. The shots at one-quarter mile caused no changes in water levels. Shots at 500 feet caused a response of approximately 0.1-foot rise or drop with little apparent residual effect. The shot located 100 feet from the coal production well caused water level changes of approximately 1.0-foot, part of which remained as an apparently permanent residual effect in the aquifer. If the amount of water level rise is taken to be a measure of physical impact, the critical distance is between 500 and 100 feet. No residual change was noted in any well or piezometer finished in sand.

5.3 PERMEABILITY CHANGES

Coal porosity and permeability are apparently reduced when fractures collapse from blasting. The weight of the overlying strata may serve to compact the freshly fractured coal. The permeability of the overlying strata may be increased by the disturbance. Any physical disturbance should increase the permeability by fracturing the cementing matrix of the overlying strata. The bulk density of sandstone is not likely to increase because of the grain to grain contact. The bulk density of fractured coal could increase when fractures are closed, therefore reducing permeability. Coal permeability is not structurally protected. There may be a critical distance at which the blast merely fractures the coal but does not cause collapse.

The pump test site Underwood Sand aquifer contains a significant amount of matrix which could be fractured upon impact, thereby increasing the permeability. If matrix fracturing is the mechanism of increase, then no increase should be observed in clean sand after blasting.

5.4 PUMPING RATE

Changes in pumping rate of a given well or a change in the flow rate of a flowing artesian well are readily noticed and may be a valuable indicator of change. Significant changes were noted during the experiment and suggest that blasting can have a permanent significant effect on the physical environment of the aquifer.

5.4.1 Coal Production Well

The coal production well system was stressed by continuous pumping during the blasting sequence in order to sensitize the system. No effect was felt until the blast at 100 feet was detonated. The critical distance is apparently between 500 and 100 feet. The flow rate remained at 3.2 gpm until shot 8, 100 feet north of the well, at which time the rate dropped to 1.6 gpm and remained there until the fracture test. The pump was not drawing air at 3.2 gpm but was pumping small air bubbles at the 1.6 gpm rate, after the shot.

Prior to the fracture test, the well continued to produce at 1.6 gpm. After shot 9, 10 feet away, the well failed to produce any water although the pump could be heard running and was indeed working when later tested. The blast reduced the effective permeability of the aquifer, instead of increasing it as anticipated. The drawdown was the same for both pumping rates, indicating a decrease in permeability.

5.4.2 Sand Production Well

The sand production well produced 8.2 gpm before and after the blasting sequence. The drawdown in the pumping well was substantially less after the blasting. One can infer that the system had experienced an increase in permeability, the result essentially being a fracturing of the aquifer medium as practiced in the petroleum industry for increasing yields. Increased yield is possible with the same drawdown after the blast. This result would not have been demonstrated by the pump test analysis quite so graphically, if at all, and supports the contention that the time-drawdown curve of the pumping well is the most valuable pumping test data, even though it is not generally used in the analysis.

5.4.3 Farmstead Well

The pumping rate at the farmstead remained at 5.2 gpm through most of the test and decreased to 3 gpm at the end, apparently because of the excessive drawdown and extended pumping time. The well still produced water at a domestically usable rate after the last shots at 69 days. It was not possible to obtain definitive drawdown data. Pumping was terminated shortly after the final two shots. Within two hours, the static water level had returned to within approximately 5 feet of the pre-test value, indicating no significant changes in overall productivity of the well had occurred. The well was screened through coal and sand, consequently the net effect was observed.

5.5 WATER QUALITY

Water from the farmstead site and the pump test site was used by the research crew for drinking, and no change in palatibility was noted at either the farmstead site or the pump test site. Although no large permanent changes in chemistry were noted, there were some increases, which may be due in part to continued pumping. It is impossible at this time to separately identify any effects of leakage from aquitards and other aquifers on water quality.

The short term peaks noted during the coal pumping well test are obviously blast-related. The results at the pump test site showed no significant changes following any of the shots except number 8, 100 feet north of the coal pumping well. Readsorption would cause the levels to drop, as is suggested by the data. The behavior of sodium and calcium in the coal and sand, described earlier, suggests an adsorption interrelationship within the coal and clay mineralogy. Short term chemical changes are apparently quickly reversible and are contained within a short distance of the shot. The general chemistry of the systems remained unchanged and the chemical environment was characterized by concentration changes of extant species.

It is readily apparent that no large long- term changes in the water chemistry resulted from the blasting sequence. The only blast-related rises are in response to shot 8 and they are not permanent. Continued pumping should have stressed the system and have revealed any long-term effects. Desorption/readsorption is suggested as a mechanism by which the high peak values may appear and disappear. The inverse relationship seen in the sand between sodium and calcium indicates an exchange process with a clay mineral such as illite or Na-montmorillonite. The inverse relationship is not seen in the coal where there is minimal clay but ample adsorption sites for trace metals. Trace metals in sand and coal apparently remain at low levels, and are relatively unaffected by blasting. Even though an increase is suggested, it is too small to be significant when the confidence limits are considered. The range at which such effects are felt is between 100 and 500 feet from a 25-pound charge of petrogel detonated above the coal.

Plots of mineral saturation indices for selected minerals near equilibrium versus time revealed small-scale oscillations but no large or long-term changes that can be attributed to the blasting sequence. This is in agreement with computer generated predictions. Heat and pressure increases caused only changes in saturation indices. New species did not become stable. It may be concluded that the heat and pressure effects of blasting on groundwater chemistry and mineralogy are minimal and short-term.

5.6 SEDIMENT PRODUCTION

Muddy water was commonly noted by respondents as a result of nearby shots. This would be particularly unnerving when discovered in the washing machine or at the drinking water faucet. The fractured character of lignite and other media in the Great Plains accounts for relatively high permeability in some locations. Fracture channels may provide avenues for the rapid movement of naturally occurring sediment, or water with naturally changing chemical quality. These same fractures may also provide avenues for transport of sediments jarred loose during seismic exploration. If a borehole penetrates a fractured coal aquifer, the disturbance alone may be enough to dislodge sediment, which could follow the fracture permeability. The coal itself is rather brittle and friable and may be easily broken into fragments which may clog well screens. Lignite has a relatively low density, which facilitates transport of fragments by flowing water. Water moving into the well may carry the dislodged sediment into the screen openings or, in the case of wells without screens, into the pump. Sediment plugging the screen openings of a well or entering the well may cause the efficiency of the well to drop. In some cases, large quantities of sediment have been pumped out of wells and partial recovery has been achieved.

Turbidity increases were noted for several of the shots at 500 feet and for all of the closer shots. In all cases the turbidity disappeared within ten minutes of pumping. The discharge line was directed into a sediment trap for the entire test, during which time less than 500 ml of sediment were collected. This supports the observation that some allegedly damaged wells had "cleared up" upon continued pumping. The sediment probably resulted from fines loosened by the blast vibrations, which were then swept into the well. This does not appear to be as significant a problem as it is annoying to the domestic user. Rehabilitation of a water system may be quite costly, however.

Even though a sand aquifer may be fractured and disturbed during blasting, it also serves as a filter which would minimize the transportation of fines. The sand continues to act as a filter in much the same way as a water treatment plant sand filter. Coal permeability is essentially fracture permeability, and there is little filtering capability to remove dislodged fines. The fractured coal provides a less stable medium and may provide avenues of rapid transport. The effective difference between blasting and vibration technology has not been defined.

5.7 SHOT DISTANCE AND ORIENTATION

It may be concluded from this research that the immediate effective radius of influence of a shot is less than 500 feet. It is obvious that the farther away the shot, the less likelihood there is that deleterious changes may occur. Sediment can be dislodged by drilling and blasting, and if an avenue of transport is available the results of an immediate disturbance within the area of the hole may be felt as an indirect effect at some distance from the hole, beyond the range of immediate influence.

This research has demonstrated the distinct directional character of coal aquifer transmissivity. The effects on transported sediment have not been quantified. There is a directional effect which is enhanced by a groundwater gradient parallel to the fracture direction. If perpendicular, the effect should be minimized. Physical dislodgement and movement through fractures is suggested as the principal mechanism by which sediment is liberated and transported.

5.8 PUMP TESTS

An attempt to calculate transmissivity, storativity, and specific yield values for the coal and sand aquifers resulted in apparently meaningless numbers. The assumptions inherent in the solutions differ too greatly from the field situation to allow a meaningful interpretation. Nonhomogeneity and anisotropy were evident throughout the site. Fracturing of the media, especially of the coal, further reduced the applicability of the available solutions.

The most valuable data obtained from the pump tests were the time-drawdown curves for the pumping wells. These data essentially provide a comparison of specific capacities and, for a given well, relate before and after conditions. It may be concluded that the traditional aquifer testing of coal and associated aquifers is not justifiable because of the effects of fracture permeability. A much simpler and more meaningful interpretation can be made using the time-drawdown curve.

5.9 OPEN SHOTHOLES

Open shotholes were peripherally investigated during this research. Flowing artesian conditions do exist in North Dakota and open shotholes may be one of the most insidious aspects of exploration by seismic blasting. Unplugged and flowing shotholes are a concern among those surveyed and many open holes were observed during the fieldwork. Some were flowing freely at the surface. Under appropriate conditions, water may flow out of a shothole in the same manner as a flowing well. Because shotholes are not cased, flowing conditions may lead to erosion and development of a quagmire near the hole. An unchecked flow from a seismic shothole could lower the head in an aquifer and could thereby impact local wells completed in the same aquifer. This mechanism may be partially responsible for some of the pressure head declines reported in the Dunn Center and Halliday areas.

Any improperly plugged hole or improperly installed well casing can provide a direct cross-connection between aquifers or between the surface and subsurface. Contaminated water may enter the subsurface. The potential for cross-connection contamination exists with each penetration of the aquifer systems. The relatively shallow systems associated with river valleys, such as Spring Creek, are more sensitive because of population concentrations in the valleys and increased use of the resource. These relatively shallow aquifers are in the same subsurface regime in which shotholes are drilled. Deeper aquifers, such as the Dakota and Foxhills would rarely be penetrated by seismic drilling.

Even if there were a tendency for most shotholes to eventually seal themselves by bridging and collapse, there still would be a period of time in which interaquifer flow could occur. Repeated exposure to drilling and improper plugging could allow for incremental changes in water quality. Water eventually reaching a well may reflect a quality change which would be only casually associated with a given drilling event, if at all. Any wasteful activity decreases the value of the natural resource.

5.10 WELL INSTALLATION

Considerable debate exists over the proper method of installation of wells in coal. Some drillers recommend an open hole through the coal with the casing resting on the top of the coal. Others backfill the open hole with coarse gravel. The use of a screen with/without gravel is also recommended in some situations. Exploding a small charge in the coal has resulted in phenomena ranging from total failure of the well to marked improvement.

5.11 PIEZOMETER INSTALLATION

Drilling for piezometer installation must be done with air to avoid contamination with injection water. If this is not possible, the piezometers must be thoroughly developed and purged of all introduced fluids if the water quality results are to be meaningful.

5.12 WORKING GUIDELINES

A working distance of one quarter mile between wells and seismic testing has been used as an empirically derived distance. This arbitrary value may be adequate in some cases but is probably a poor overall choice because coal transmissivity has distinctly directional character which is further complicated by the groundwater gradient. A gradient parallel to the fractures would enhance sediment transport and a perpendicular gradient would probably hinder sediment transport. Some of the reports of increased turbidity were allegedly caused by activity at distances greater than 1 mile. The groundwater gradient should be determined, especially if a coal aquifer is involved, and upgradient disturbances should be avoided. This must be taken into account when planning drilling operations upgradient from existing wells. The influence of gradient was not adequately resolved here but it is obviously important, especially in a fractured system. Fracture direction and groundwater gradient may be the governing considerations in determining safe working distances.

Corrective measures, better regulation, and improved understanding can improve the general situation. Well owners, exploration companies, and governmental agencies should support the development of a background data bank. Attempts at regulation must address shothole plugging, type of exploration, the presence of coal, and should emphasize monitoring to determine cause and effect. Each case is somewhat unique and needs to be addressed with reasonable, professional, scientific, and intuitive judgement based on the situation in question.

5.13 RECOMMENDATIONS

The prudent well owner and explorer would be well advised to know as much about the background environment as possible and to collect background information wherever possible. A full scale pump test is completely impractical for the typically encountered well problem. A much more practical approach, and one more readily understandable to the layman, is the specific capacity test. It can be easily conducted with whatever pump is already installed and comparisons between two tests can be used to infer changes in the aquifer environment. There must be two tests for a comparison to be valid, so testing must be done on wells prior to alleged damage.

Although this research indicates that long-term chemical effects are unlikely, periodic water quality sampling by well owners is strongly recommended. Water samples should be collected and analyzed on a regular basis. A continuous record of water quality is infinitely more valuable than a single sample, taken after the fact. Trends in changing water quality can be noted only with regular periodic data.

5.14 FURTHER RESEARCH NEEDS

Not all of the reported phenomena have been addressed here and not all of the phenomena observed during the first season of field work can be explained on the basis of these experimental results. This reflects the site-specific character of the experiment.

Production well installation techniques for coal aquifers need to be investigated to ensure efficient installations. The change in water quality from pumping should be thoroughly investigated. The breakdown products of explosives and plastics need to be studied to determine if any potentially dangerous compounds are being introduced into the groundwater environment by practices considered by many to be completely benign. The use of vibration methods for seismic exploration has increased in recent years, as a result of complaints about the effects of blasting. The effects are not known and need to be investigated. Subjecting an aquifer to extended vibration, which reportedly can be felt at distances of over 1 mile, for extended periods of time, may be more harmful than a single blast impulse. Further research on hole plugging and corrective technology is needed. The water quality in lignite aquifers, with respect to organic chemistry needs to be addressed in general. Wells finished in till were not addressed here, but probably should be examined in future studies. The relationships between fracture orientation and gradient and time of flow need to be investigated. It may be revealing to sample the water quality continuously after a close shot to more clearly define the mechanism of liberation and recapture of various chemical species.

APPENDICES

Appendix A

PRELIMINARY SURVEY QUESTIONNAIRE

WELL SURVEY

IF YOU HAVE A WATER WELL THAT YOU FEEL HAS BEEN AFFECTED BY SEISMIC TESTING PLEASE ANSWER THE FOLLOWING QUESTIONS AS COMPLETELY AS YOU CAN.

NAME:______________________________ DATE:__________

ADDRESS:______________________________ PHONE NO.:__________

LOCATION OF WELL: SECTION_____ TOWNSHIP_____ RANGE_____ COUNTY__________

PRIMARY USE: DOMESTIC_____ STOCK WATERING_____ IRRIGATION_____ OTHER__________

DEPTH:__________ SIZE OF CASING:__________ CASING MATERIAL:__________

TYPE OF WELL(DUG, DRIVEN, BORED, ETC.):______________________________

AGE:__________ REPAIRS:______________________________

INSTALLATION:______________________________

PUMP TYPE (SUBMERSIBLE, ETC.):______________________________

SCREEN TYPE:__________ GRAVEL PACK:__________ GROUTED:__________

IS THIS A FLOWING WELL OR HAS IT EVER FLOWED FREELY AT THE SURFACE?

HAVE YOU EVER CONDUCTED A PUMP TEST ON THIS WELL?_______ WHEN:__________

BY WHOM:______________________________ YIELD:__________

HAS THIS WELL ALWAYS PROVIDED AN ADEQUATE SUPPLY OF WATER FOR YOUR NEEDS?

ARE THERE ANY SPRINGS IN THE AREA?

WHAT IS THE SURFACE OF THE LAND LIKE?

WHAT DO YOU KNOW ABOUT THE LOCAL GEOLOGY?

WHAT IS THE NATURE OF THE AQUIFER THE WELL IS IN? (SAND, LIGNITE, ETC.)

IS THE AQUIFER FRACTURED?

HOW LONG AFTER SEISMIC TESTING DID YOU NOTICE CHANGES IN THE WELL?

HAVE YOU NOTICED ANY CHANGE IN THE QUANTITY OF WATER PRODUCED SINCE SEISMIC TESTING? - SPECIFY

WAS SAND PRODUCED IN THE WATER <u>BEFORE</u> SEISMIC TESTING____________________;
AFTER SEISMIC TESTING?______________________________

HOW WOULD YOU DESCRIBE THE WATER <u>BEFORE</u> SEISMIC TESTING?
HARD OR SOFT__________ SALTY OR FRESH_______ COLORLESS OR COLORED__________
IF COLORED, WHAT COLOR______________ CLEAR OR TURBID______________
TASTE______________________________

HOW WOULD YOU DESCRIBE THE WATER <u>AFTER</u> SEISMIC TESTING?
HARD OR SOFT__________ SALTY OR FRESH_______ COLORLESS OR COLORED__________
IF COLORED, WHAT COLOR______________ CLEAR OR TURBID______________

HAVE YOU EVER HAD THE WATER TESTED SINCE SEISMIC ACTIVITIES?__________
IF SO, BY WHOM?______________________________

WHAT WERE THE REASONS FOR TESTING THE WATER AND WHEN WERE THE TESTS CONDUCTED?

(continued on back)

DID THE TESTS SHOW SIGNIFICANT CHANGES IN WATER QUALITY RELATIVE TO CONDITIONS PRIOR TO SEISMIC ACTIVITIES?

RESULTS OF WATER TESTING:
INORGANIC: ORGANIC:

IN THE SPACE BELOW SKETCH A MAP SHOWING THE WELL AND SHOT LINE DIMENSIONS:

SEISMOGRAPH COMPANY:
DATE OF TESTING:
AMOUNT OF CHARGE:
NUMBER OF SHOTS:
EXPLOSIVE TYPE:
WAS THE HOLE PLUGGED?
ADDRESS OF THE COMPANY:

HAS ANY LEGAL ACTION BEEN TAKEN?

WHAT WAS THE RESULT OF LEGAL ACTION, IF ANY?

WHAT WAS THE RESPONSE BY THE COMPANY RESPONSIBLE FOR THE SEISMIC WORK?

DO YOU KNOW OF ANYONE ELSE WHO IS HAVING SIMILAR PROBLEMS?

DO YOU KNOW OF ANYTHING ELSE YOU THINK MAY BE SIGNIFICANT TO THIS STUDY?

DO YOU OWN THE MINERAL RIGHTS ON THE LAND THE WELL IS LOCATED ON?

YOUR COOPERATION IN FILLING OUT THIS QUESTIONNAIRE IS SINCERELY APPRECIATED!

PLEASE RETURN THIS FORM TO:

FRANK BEAVER
UNIVERSITY OF NORTH DAKOTA
GEOLOGY DEPARTMENT
GRAND FORKS, NORTH DAKOTA 58202

Appendix B

DRILLING AND GEOPHYSICAL LOGS

WELL NUMBER: CPW
LAND SURFACE ELEVATION (feet): 2049.67
WATER TABLE (feet): 69.0
0 to 40 feet yellow to brown silty, pebbly till
40 to 65
brown to gray silty clay
65 to 74
yellow to brown silt and sand
74 to 103
yellow to brown fine grained sand
103 to 110
carbonaceous clay
110 to 114
lignite
114 to 114.5
clay parting
114.5 to 117
lignite

WELL NUMBER: SPWC
LAND SURFACE ELEVATION (feet): 2049.67
WATER TABLE (feet): 67.5
0 to 32 feet
yellow, gray, to olive brown, silty, pebbly, clayey till
32 to 55
light red clayey silt and fine grained sand
55 to 93
fine grained brown and yellow sand with concretions and traces of dark bluish-gray sand
93 to 103
silty gray clay
103 to 105
dark gray carbonaceous clay
105
lignite

WELL NUMBER: NES50C
LAND SURFACE ELEVATION (feet): 2050.17
WATER TABLE (feet): 69.0
0 to 55 feet
brown to gray pebbly till with clay content increasing with depth
55 to 75
gray to brown clayey fine grained sand
75 to 105
very fine grained red to brown sand
105 to 107
dark gray carbonaceous clay
107 to 115
lignite
115 to 116
clay parting
116 to 125
lignite

WELL NUMBER: NW90C
LAND SURFACE ELEVATION (feet): 2049.09
WATER TABLE (feet): 68.00
0 to 40 feet
gray to brown pebbly till
40 to 75
fine grained gray sand
75 to 102.5
fine grained red to brown sand
102.5 to 103
carbonaceous clay
103 to 116
lignite

WELL NUMBER: NW150C LAND SURFACE ELEVATION (feet): 2048.43
WATER TABLE (feet): 66
0 to 50 feet
gray to brown pebbly till
50 to 85
fine grained dark red to brown clayey sand
85 to 89
dark gray carbonaceous clay
89 to 97
lignite

WELL NUMBER: NW250C
LAND SURFACE ELEVATION (feet): 2044.52
WATER TABLE (feet): 64.0
0 to 45 feet
gray to brown pebbly till
45 to 100
very fine grained yellow to brown sand
100 to 101
dark gray carbonaceous clay
101 to 107
107 to 108
clay parting
108 to 111
lignite

WELL NUMBER: NW600C
LAND SURFACE ELEVATION (feet): 2033.33
WATER TABLE (feet): 55.0
0 to 35 feet
dark brown bouldery till
35 to 75
boulder pavement
37 to 78
red to brown fine grained sand
78 to 94
carbonaceous clay
94 to 98
lignite

WELL NUMBER: NW1200C
LAND SURFACE ELEVATION (feet): 2029.64
WATER TABLE (feet): 51.0
0 to 25 feet
light brown clayey pebbly till
25 to 85
yellow to brown fine grained sand
85 to 93
black carbonaceous clay
93 to 103
lignite

WELL NUMBER: NES90C
LAND SURFACE ELEVATION (feet): 2050.22
WATER TABLE (feet): 69.0
0 to 42 feet
yellow to brown silty pebbly till
42 to 45
brown silty clay
45 to 52
fine grained brown sand
52 to 60
gray to brown silty clay
60 to 80
fine grained yellow to brown sand
80 to 85
brown clayey silt
85 to 113
113 to 115
dark gray carbonaceous clay
115 to 125
lignite

WELL NUMBER: NEC150C
LAND SURFACE ELEVATION (feet): 2052.53
WATER TABLE (feet): 71.0
0 to 50 feet
yellow to brown silty pebbly till
50 to 58
yellow to brown fine grained sand
58 to 75
75 to 109
yellow to brown fine grained sand
109 to 117
gray to brown carbonaceous clay
117 to 123
lignite
123 to 124
clay parting
124 to 127
lignite

WELL NUMBER: NES250C
LAND SURFACE ELEVATION (feet): 2055.58

WATER TABLE (feet): 74.0
0 to 40 feet
brown silty pebbly till
40 to 116
red to brown sand
116 to 117
dark gray carbonaceous clay
117 to 123
lignite
123 to 124
clay parting
124 to 128
lignite

WELL NUMBER: NES600C
LAND SURFACE ELEVATION (feet): 2061.03
WATER TABLE (feet): 78.0
0 to 45
yellow to brown gravelly till
45 to 70
yellow to brown silty sand
70 to 117
yellow to brown fine grained silty sand
117 to 118.5
dark gray carbonaceous clay
118.5 to 127
lignite
127 to 129
clay parting
129 to 131
lignite

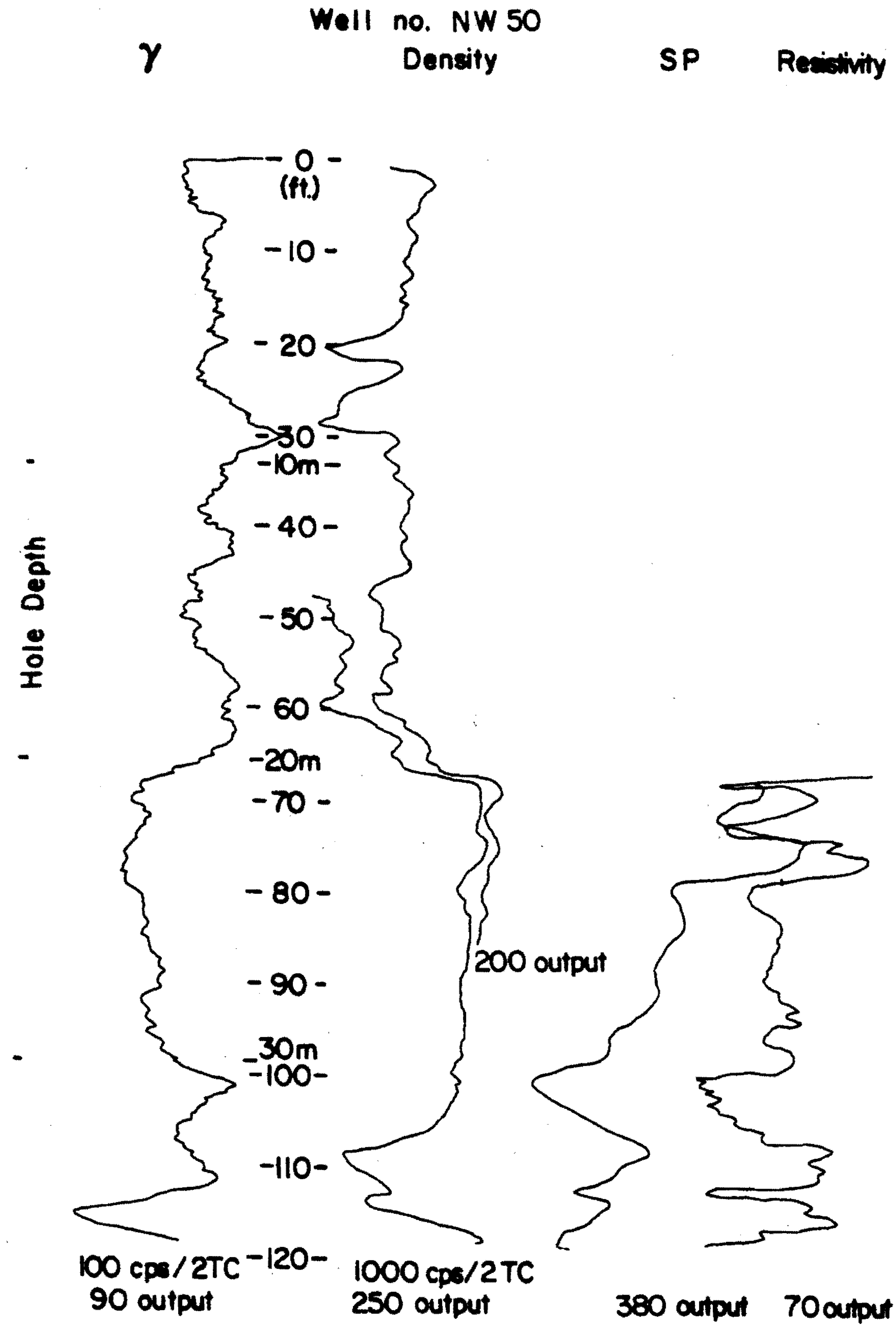
WELL NUMBER: NES1200C
LAND SURFACE ELEVATION (feet): 2060.70
WATER TABLE (feet): 77.0
0 to 35 feet
gray to brown clayey to pebbly till
35 to 110
red to brown fine grained clayey sand
110 to 114
carbonaceous clay
114 to 118
lignite
118 to 119
clay parting
119 to 123
lignite

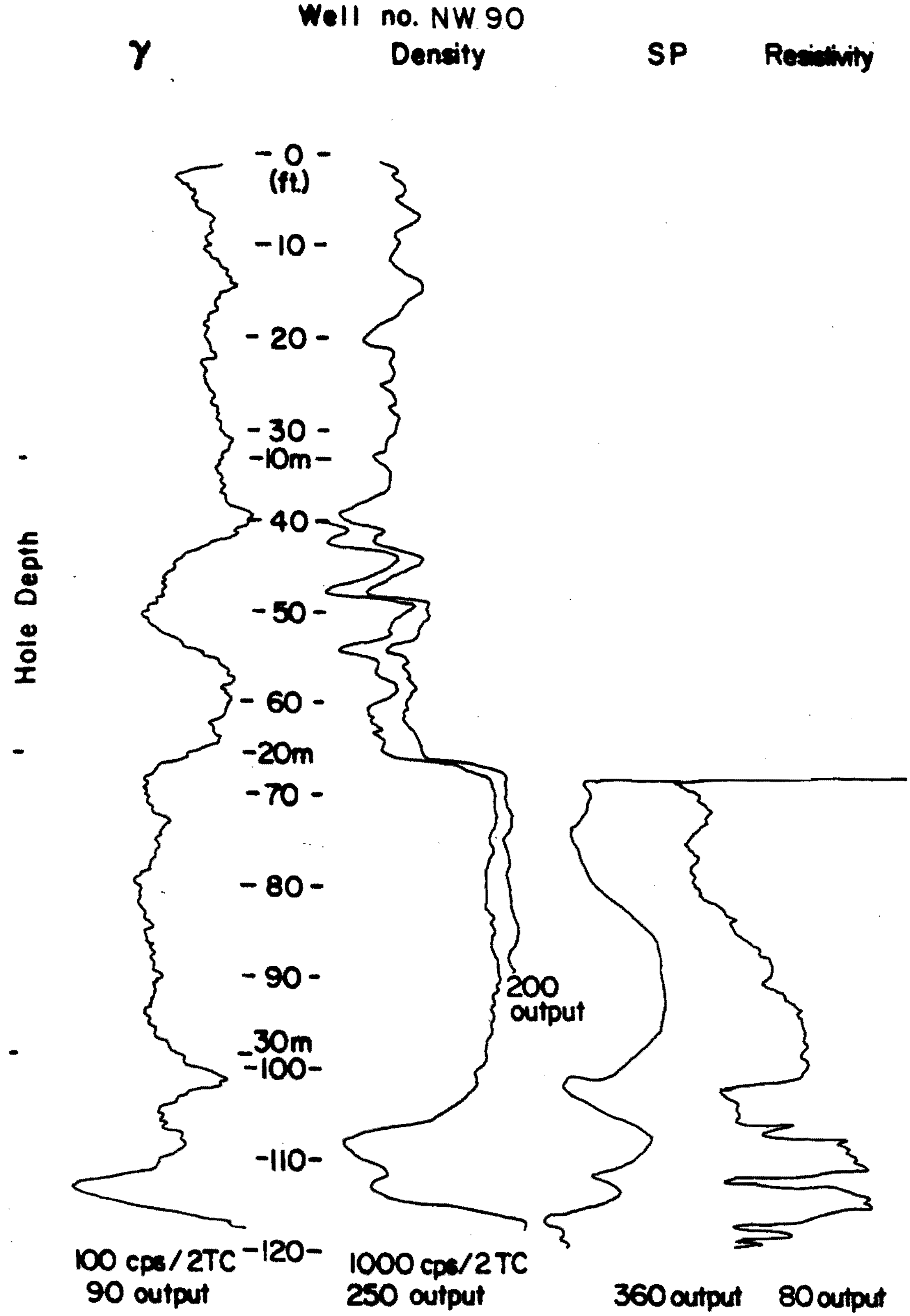
WELL NUMBER: FA 75-86 148-82-30 CCC
LAND SURFACE ELEVATION (feet): 2000.00
0 to 58 feet
dark brown clayey till containing lignite chips, pebbles, concretions, gravel, and lacustrine sediments
58 to 80

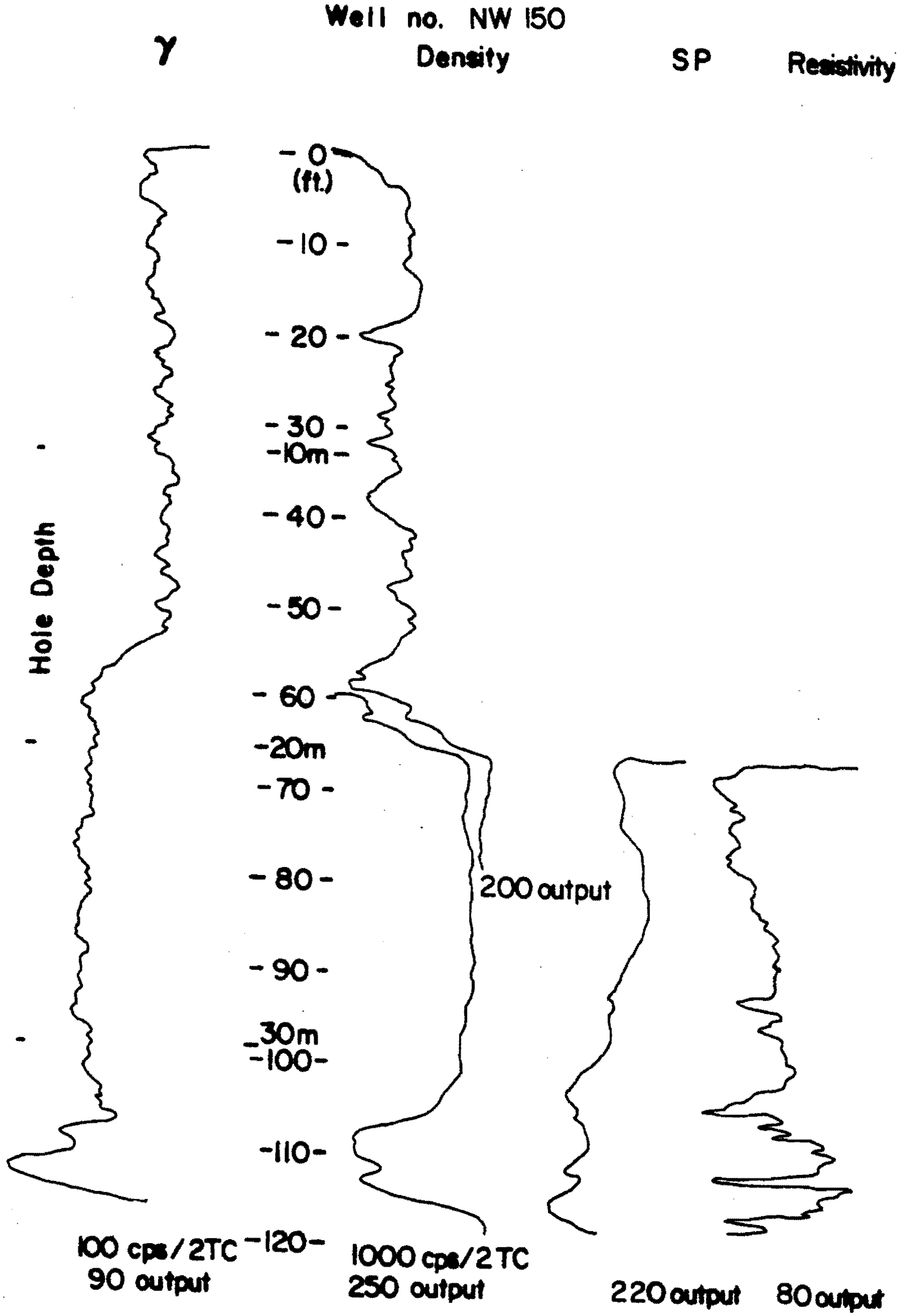
yellow to brown clayey silt
80 to 84
carbonaceous clay
84 to 94
lignite
94 to 97
clay parting
97 to 101

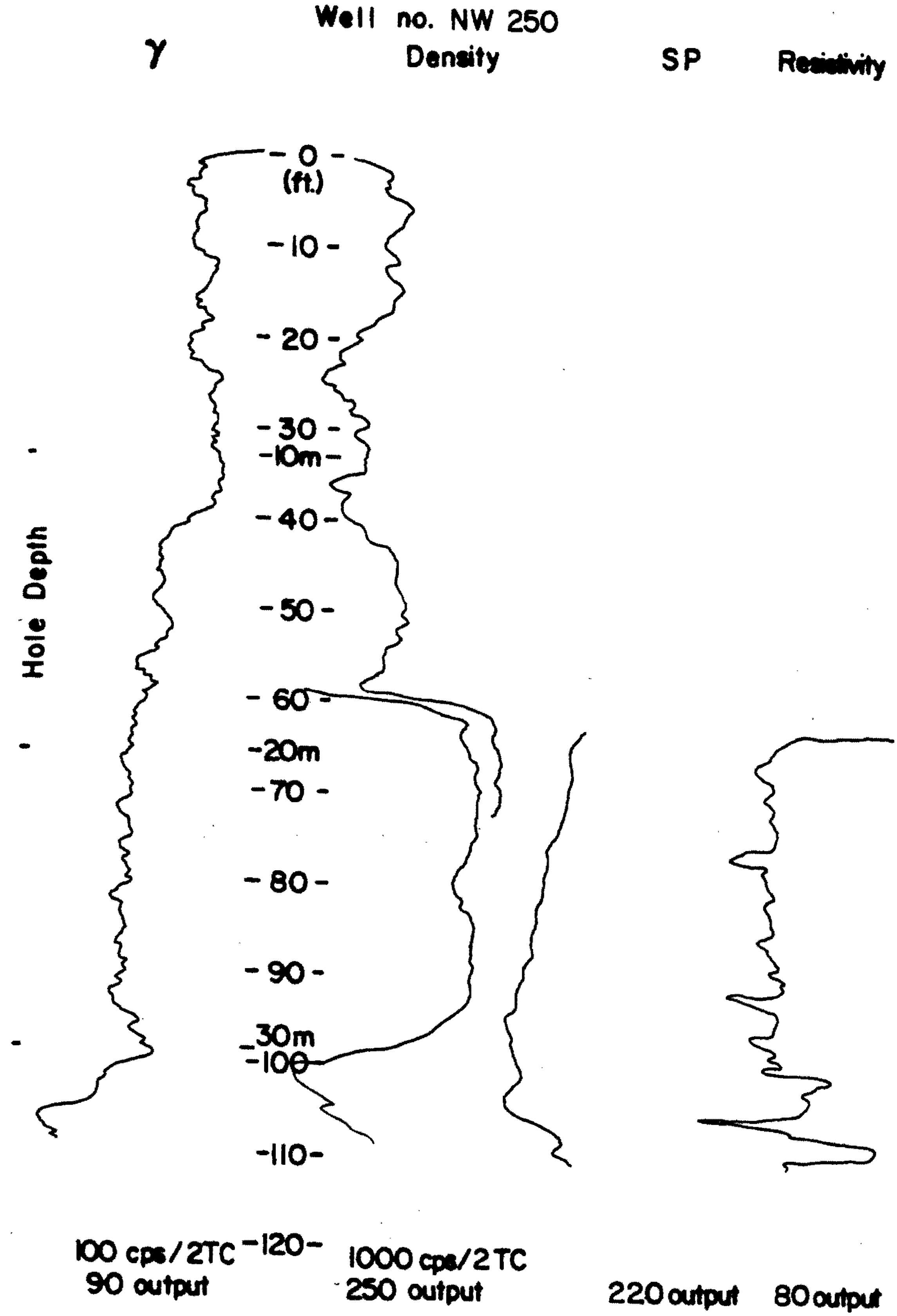
WELL NUMBER: FA 76-183 NE1/4 SE SE 24 146 83
0 TO 60 feet
gray to brown pebbly till
60 to 75
brown silt and sand
75 to 115
silt and clay
115 to 126
lignite

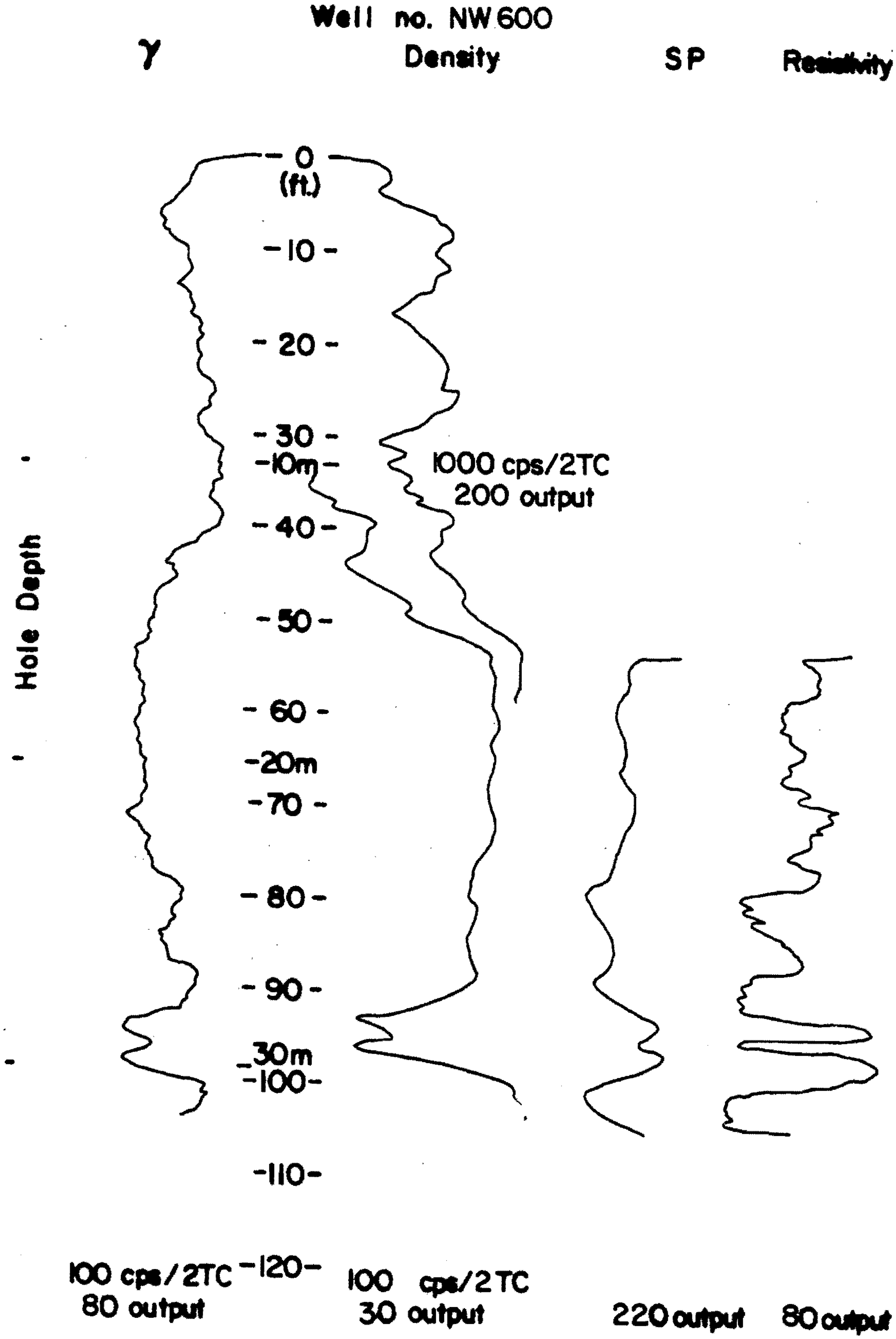
WELL NUMBER: FA 24-146-83 DDD
LAND SURFACE ELEVATION (feet): 2050
WATER TABLE (feet): 14
0 to 63
gray pebbly till
63 to 70
sand and gravel
70 to 120
gray sand
120 to 130
carbonaceous clay
130 to 140
lignite
140 to 143
clay parting
143 to 148
lignite

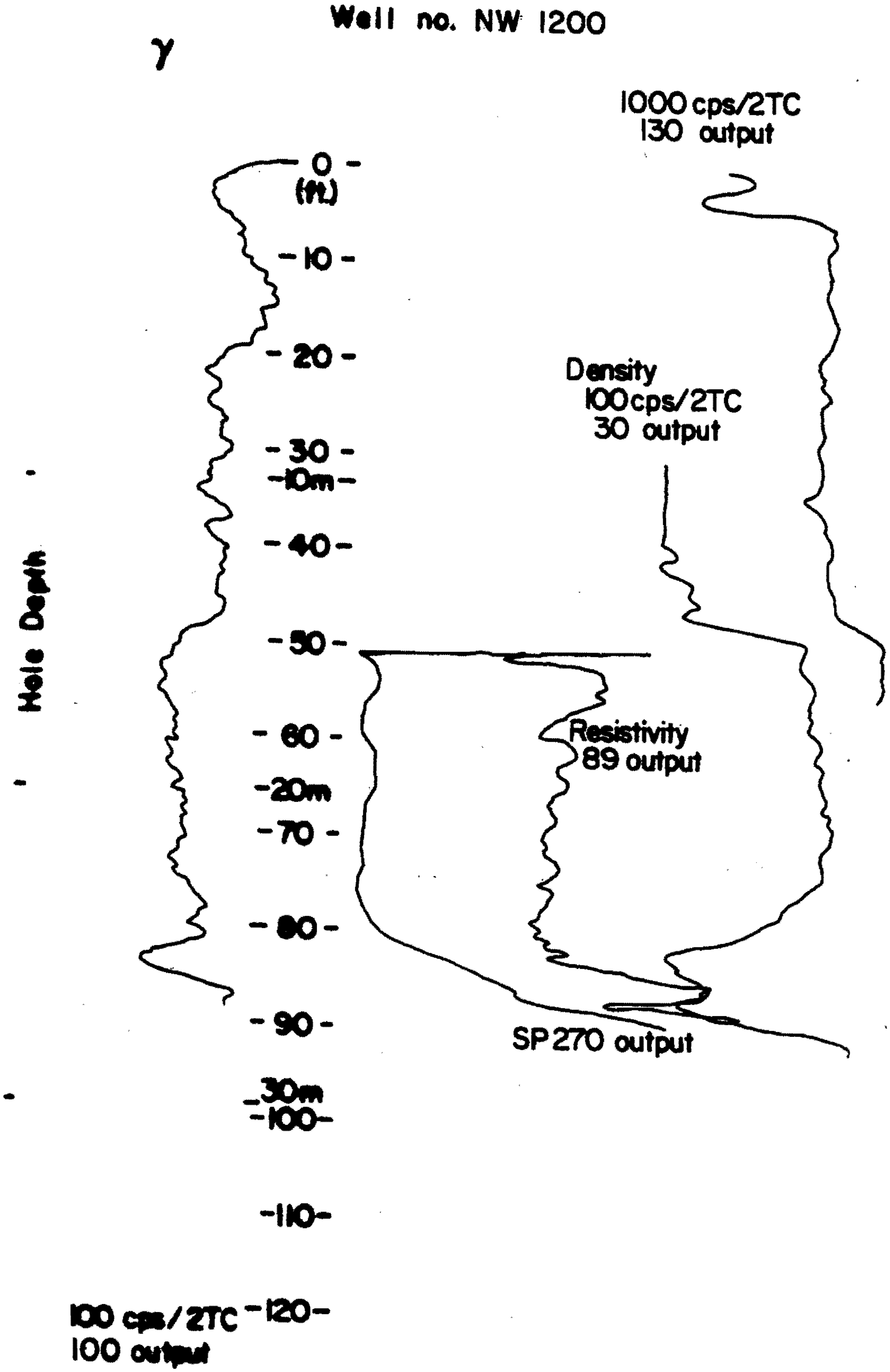

Well no. NW 50
γ
Density
SP
Resistivity
Hole Depth
0
(ft.)
10
20
30
10m
40
50
60
20m
70
80
90
30m
100
110
120
200 output
100 cps/2TC
90 output
1000 cps/2 TC
250 output
380 output
70 output

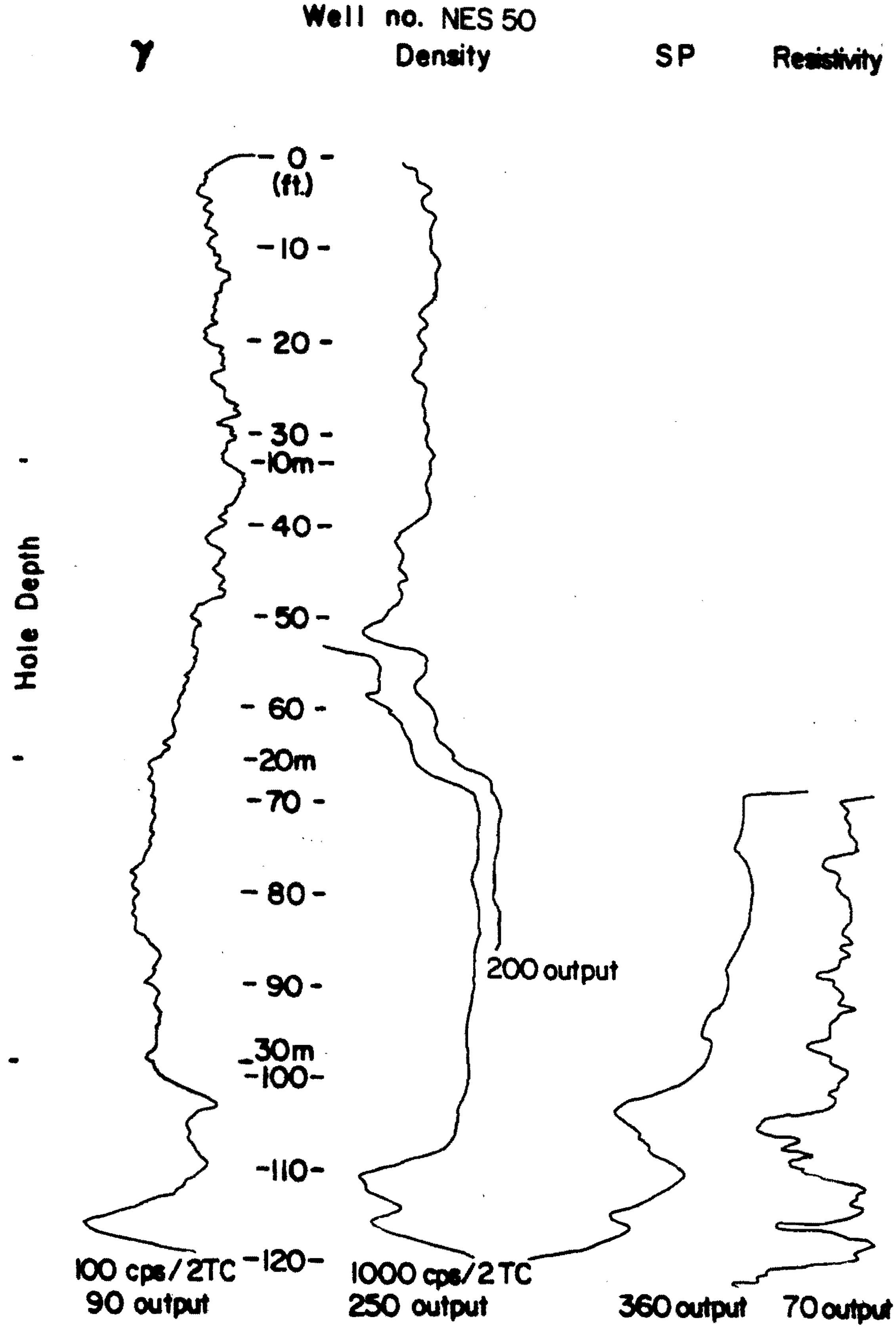

Well no. NW 90
γ
Density
SP
Resistivity
- 0 -
(ft.)
- 10 -
- 20 -
- 30 -
-10m-
- 40 -
Hole Depth
- 50 -
- 60 -
-20m
- 70 -
- 80 -
- 90 -
200
output
30m
-100-
-110-
-120-
100 cps/2TC
90 output
1000 cps/2TC
250 output
360 output
80 output


Well no. NW 150
γ
Density
SP
Resistivity
Hole Depth
- 0 -
(ft.)
- 10 -
- 20 -
- 30 -
-10m -
- 40 -
- 50 -
- 60 -
-20m
- 70 -
- 80 -
- 90 -
30m
-100-
-110-
-120-
200 output
100 cps/2TC
90 output
1000 cps/2TC
250 output
220 output
80 output

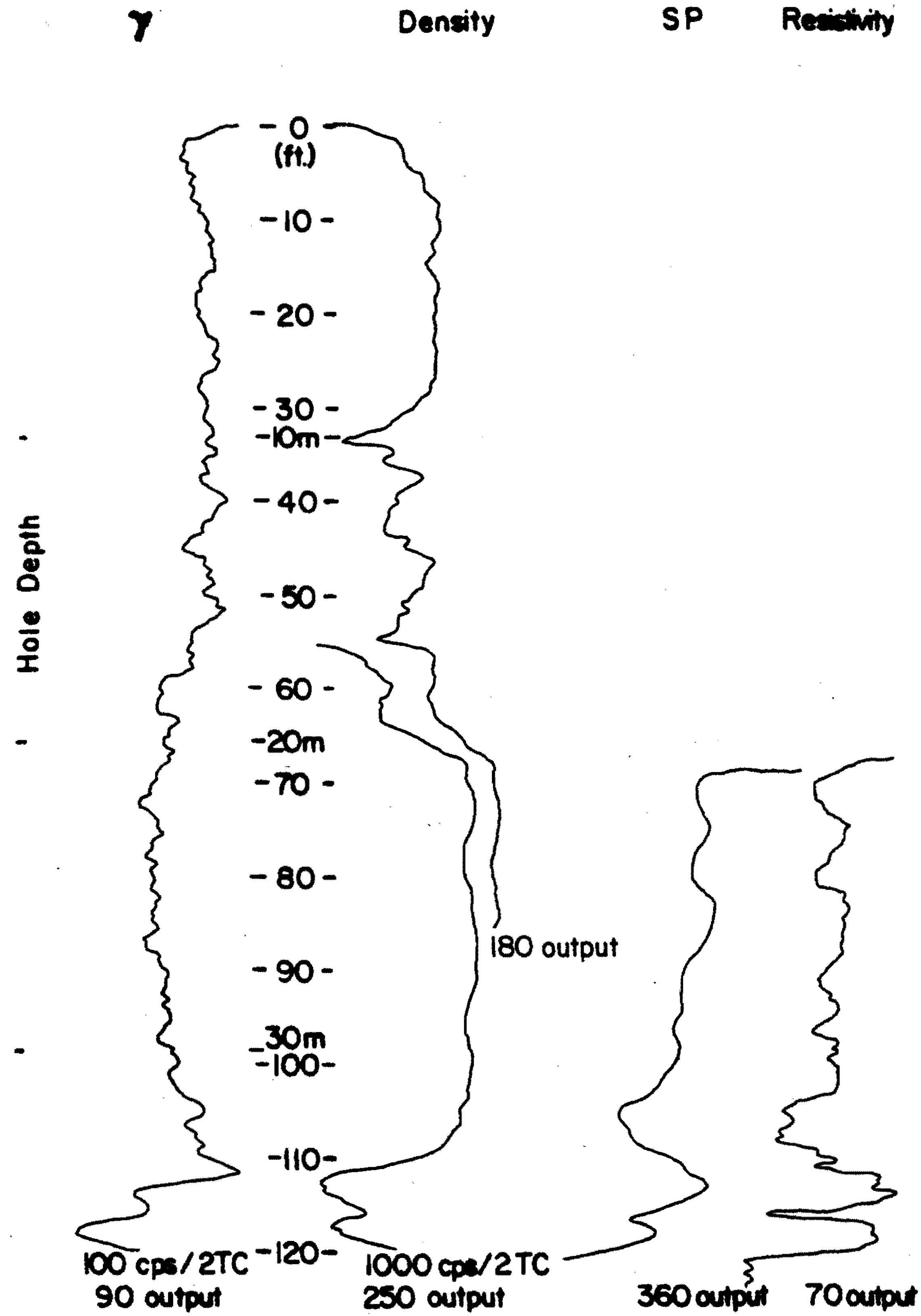

Well no. NW 250
γ
Density
SP
Resistivity
- 0 -
(ft.)
- 10 -
- 20 -
- 30 -
-10m-
- 40 -
- 50 -
- 60 -
-20m
- 70 -
- 80 -
- 90 -
30m
-100
-110-
-120-
Hole Depth
100 cps/2TC
90 output
1000 cps/2 TC
250 output
220 output
80 output

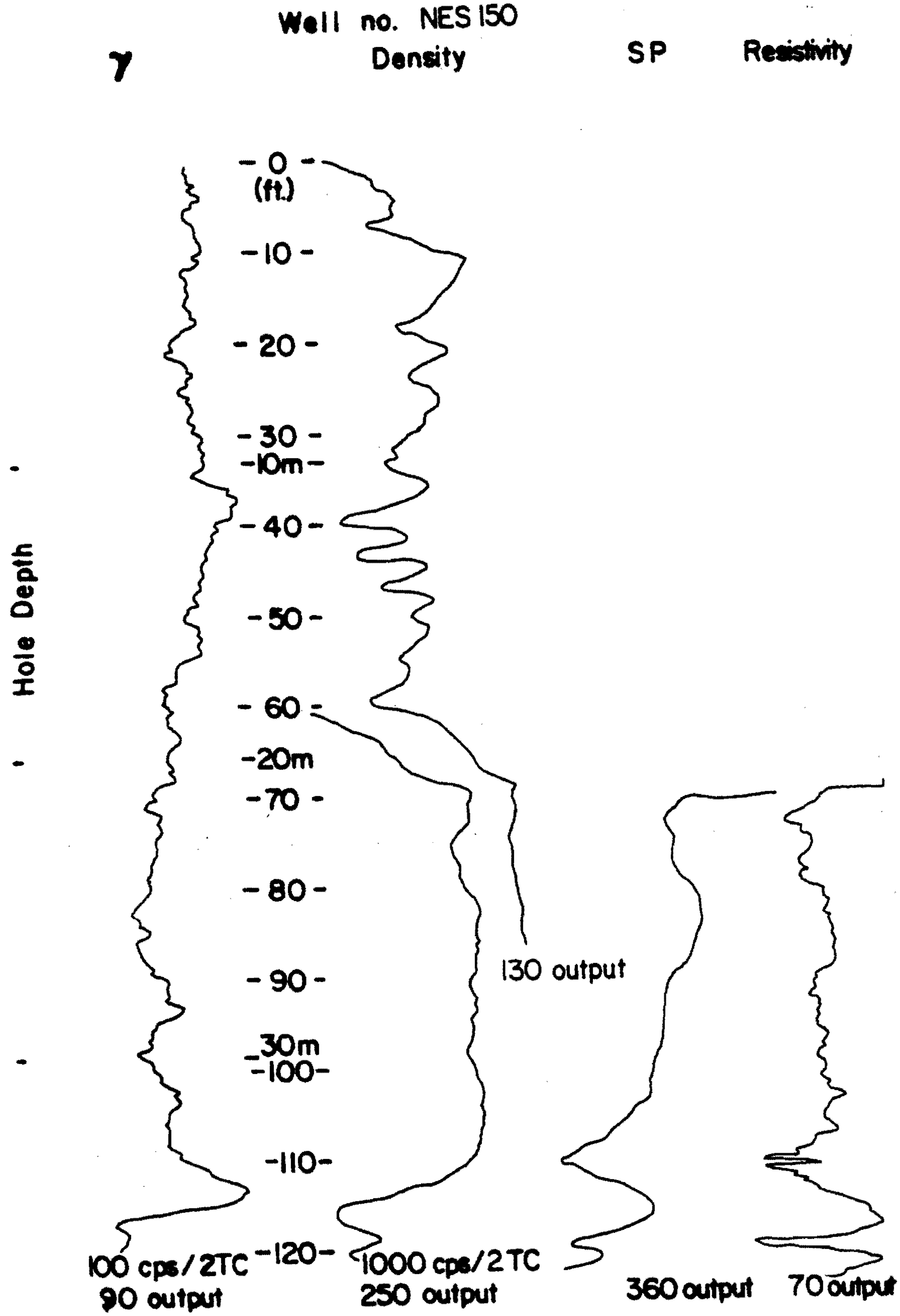

Well no. NW 600
γ
Density
SP
Resistivity
Hole Depth
0
(ft.)
-10-
-20-
-30-
-10m-
-40-
-50-
-60-
-20m
-70-
-80-
-90-
30m
-100-
-110-
-120-
1000 cps/2TC
200 output
100 cps/2TC
80 output
100 cps/2TC
30 output
220 output
80 output

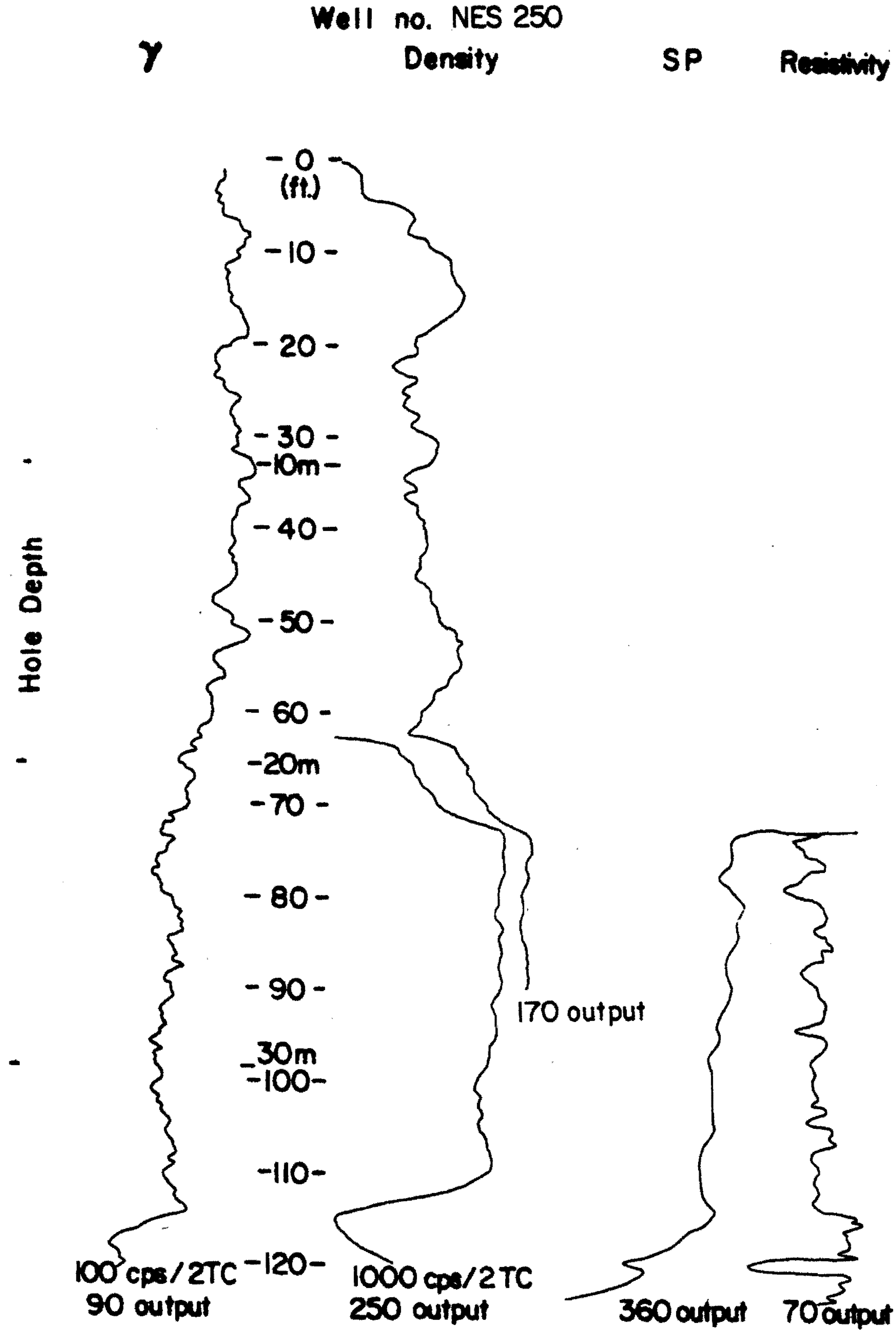

Well no. NW 1200
γ
1000 cps/2TC
130 output
0
(ft.)
-10-
-20-
Density
100cps/2TC
30 output
-30-
-10m-
-40-
Hole Depth
-50-
-60-
Resistivity
89 output
-20m
-70-
-80-
-90-
SP 270 output
-30m
-100-
-110-
100 cps/2TC
100 output
-120-


Well no. NES 50
γ
Density
SP
Resistivity
Hole Depth
- 0 -
(ft.)
-10-
- 20 -
- 30 -
-10m-
- 40 -
- 50 -
- 60 -
-20m
- 70 -
- 80 -
- 90 -
30m
-100-
-110-
-120-
200 output
100 cps/2TC
90 output
1000 cps/2 TC
250 output
360 output
70 output

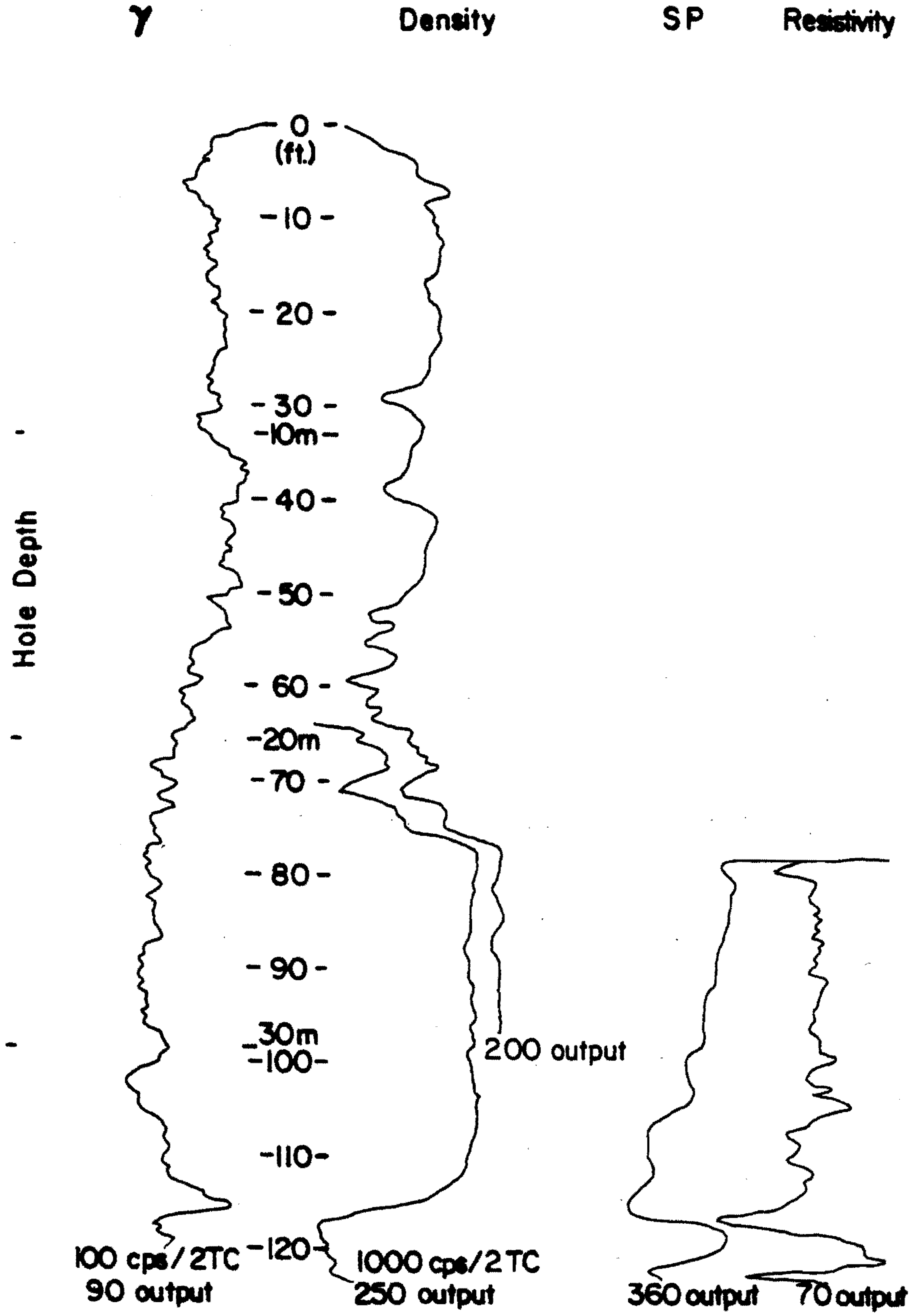
Well no. NES 90



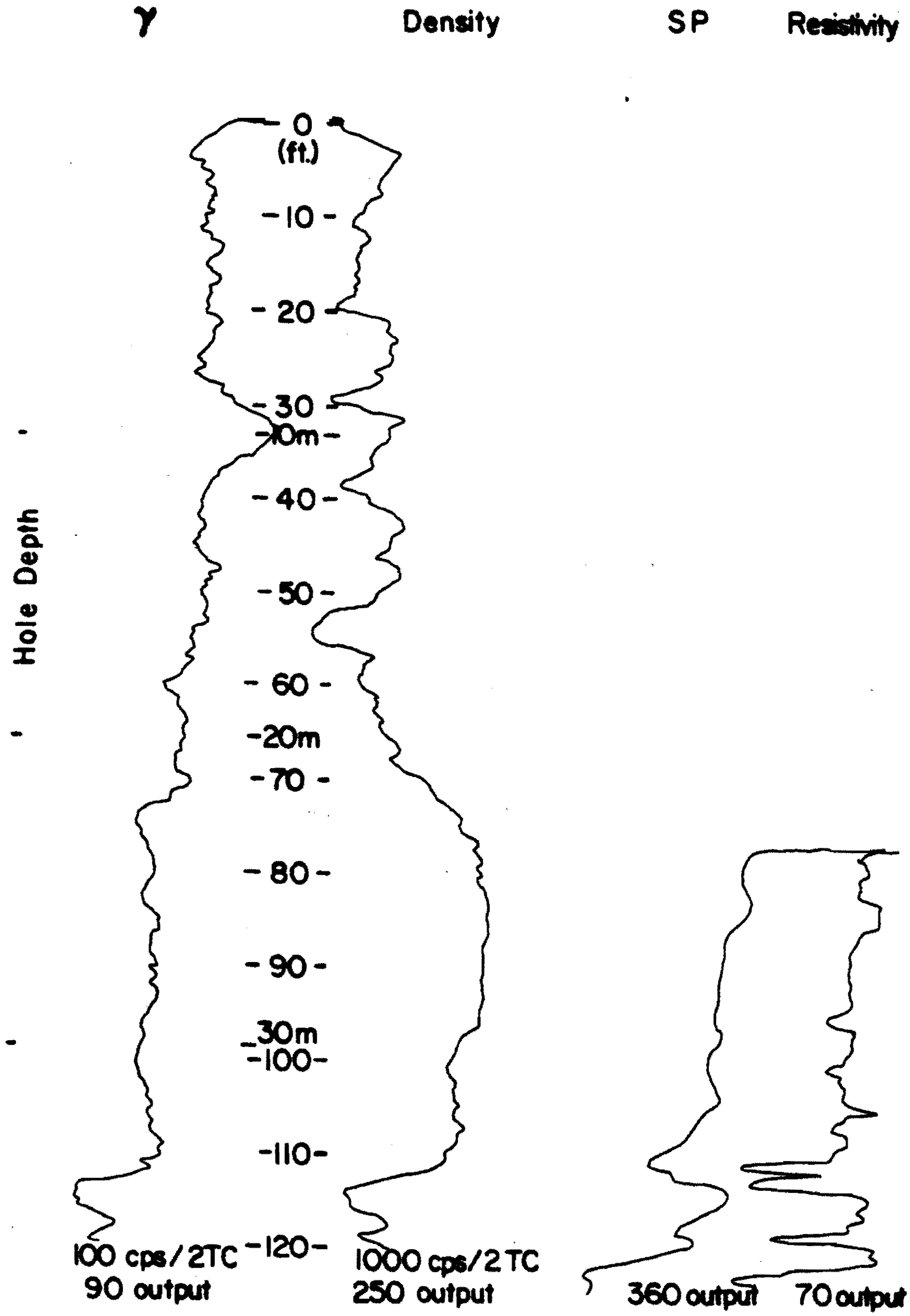

Well no. NES 150
γ
Density
SP
Resistivity
Hole Depth
- 0 -
(ft.)
- 10 -
- 20 -
- 30 -
-10m-
- 40 -
- 50 -
- 60 -
-20m
- 70 -
- 80 -
- 90 -
30m
-100-
-110-
-120-
100 cps/2TC
90 output
1000 cps/2TC
250 output
130 output
360 output
70 output


Well no. NES 250
γ
Density
SP
Resistivity
Hole Depth
- 0 -
(ft.)
-10 -
- 20 -
- 30 -
-10m -
- 40 -
- 50 -
- 60 -
-20m
- 70 -
- 80 -
- 90 -
170 output
30m
-100-
-110-
-120-
100 cps/2TC
90 output
1000 cps/2TC
250 output
360 output
70 output

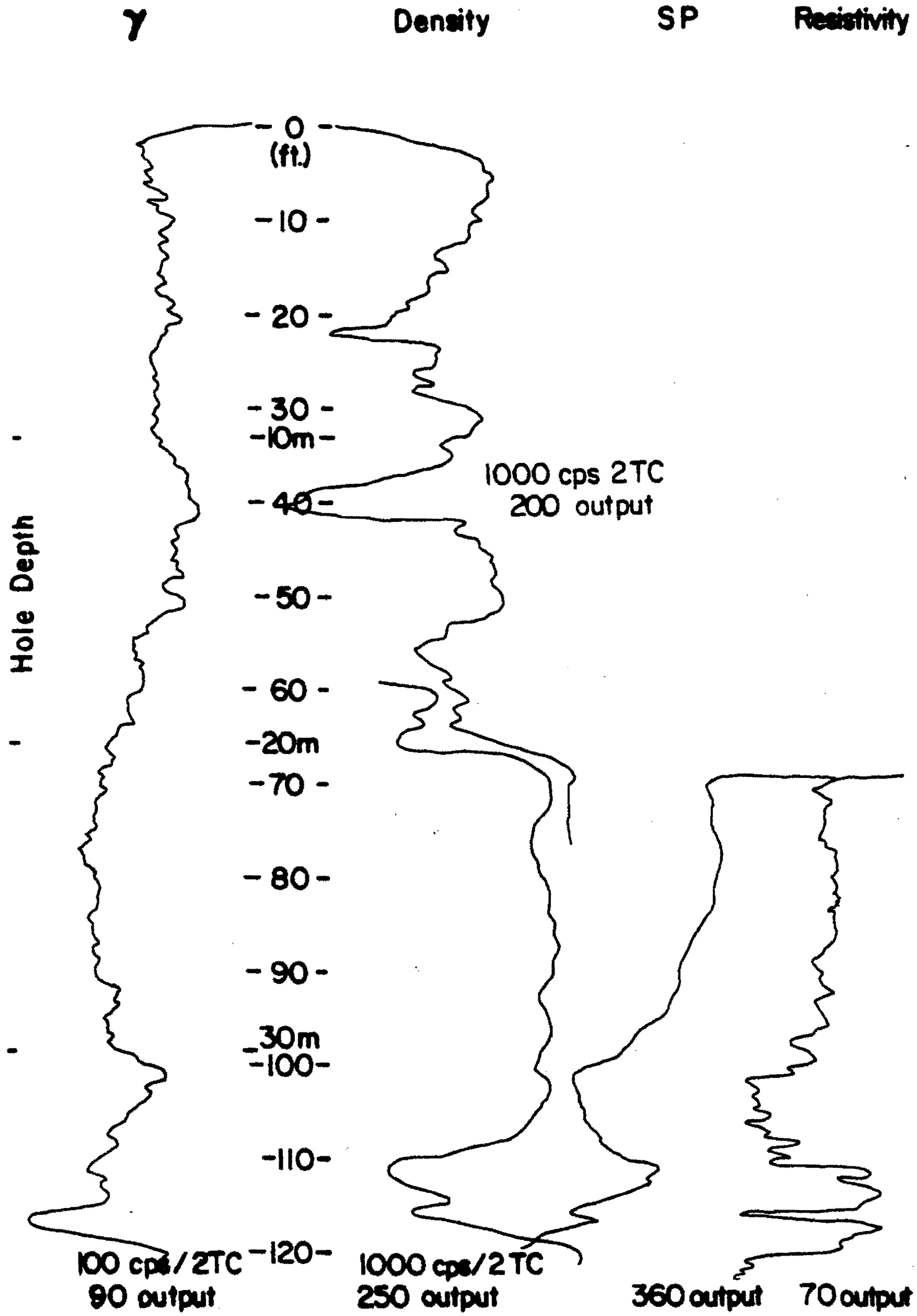
Well no. NES 600



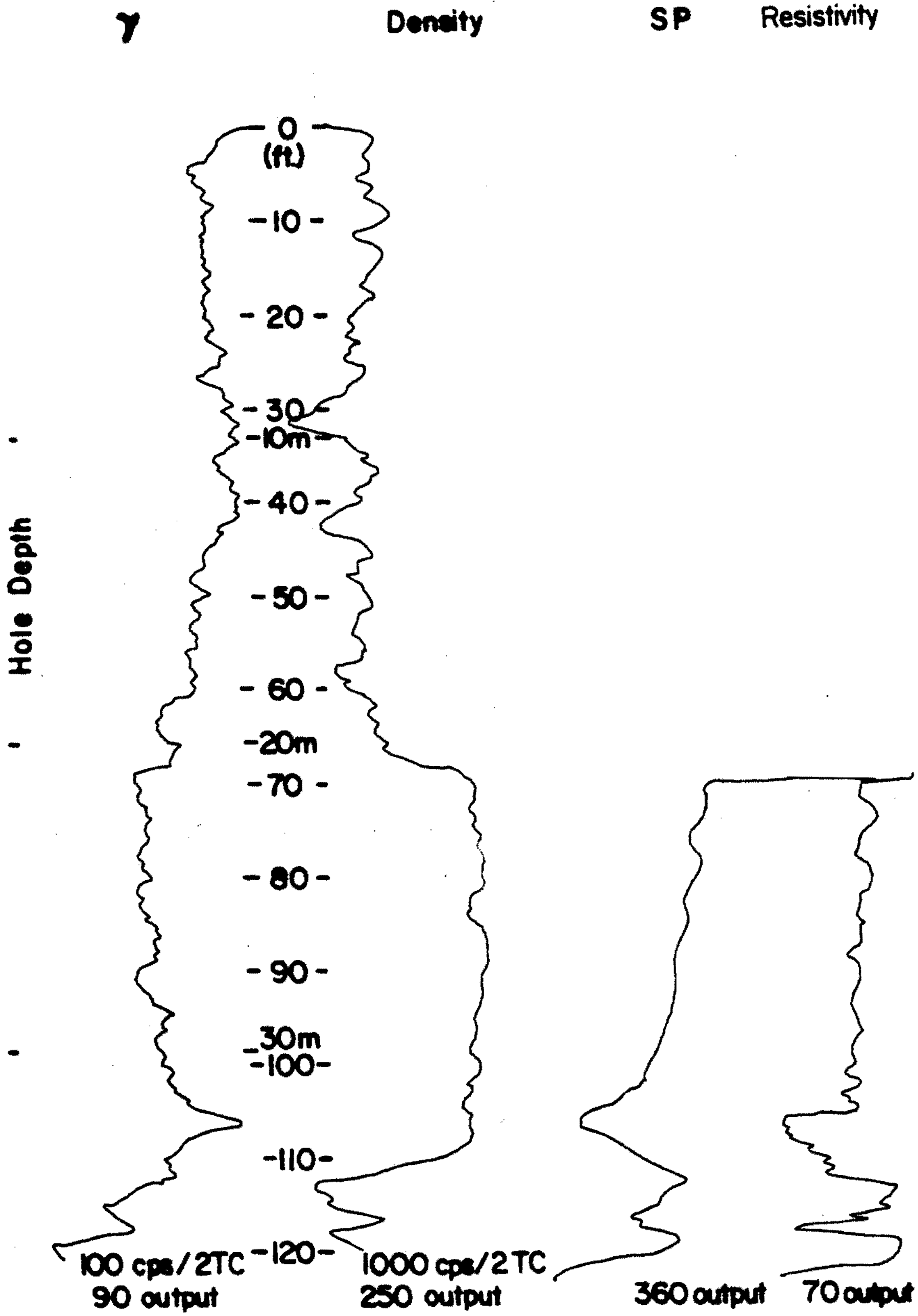
Well no. NES 1200

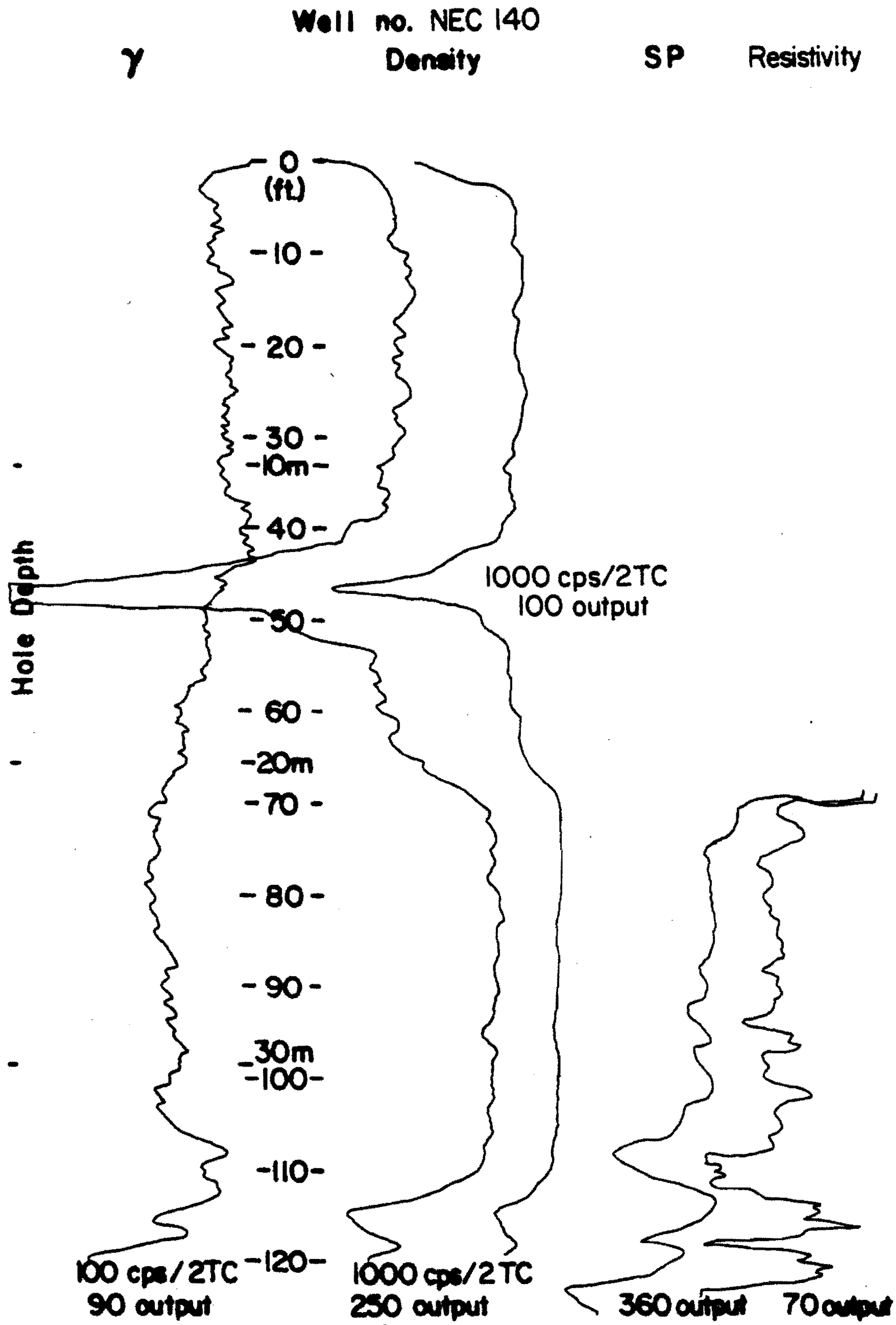


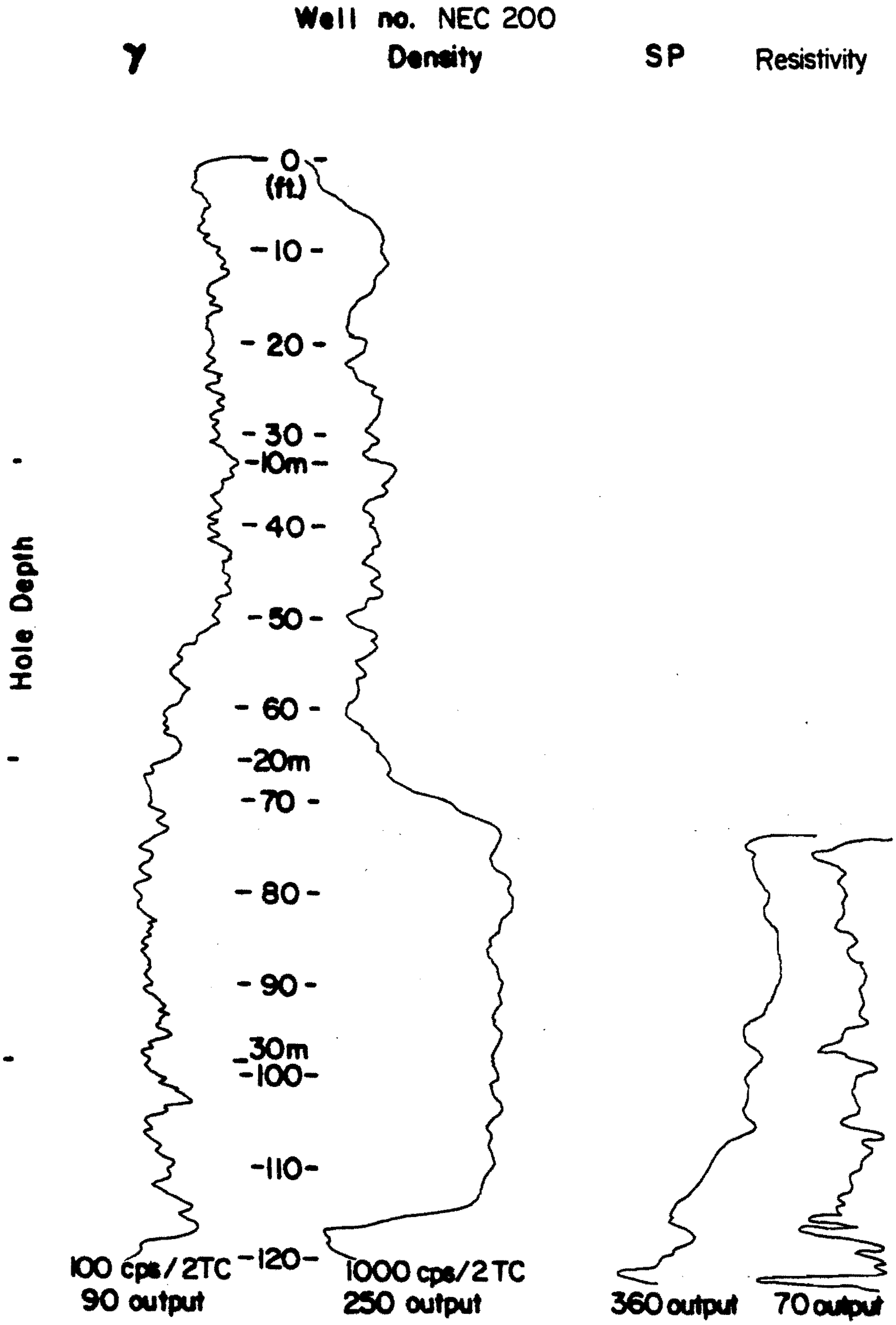
Well no. NEC 50

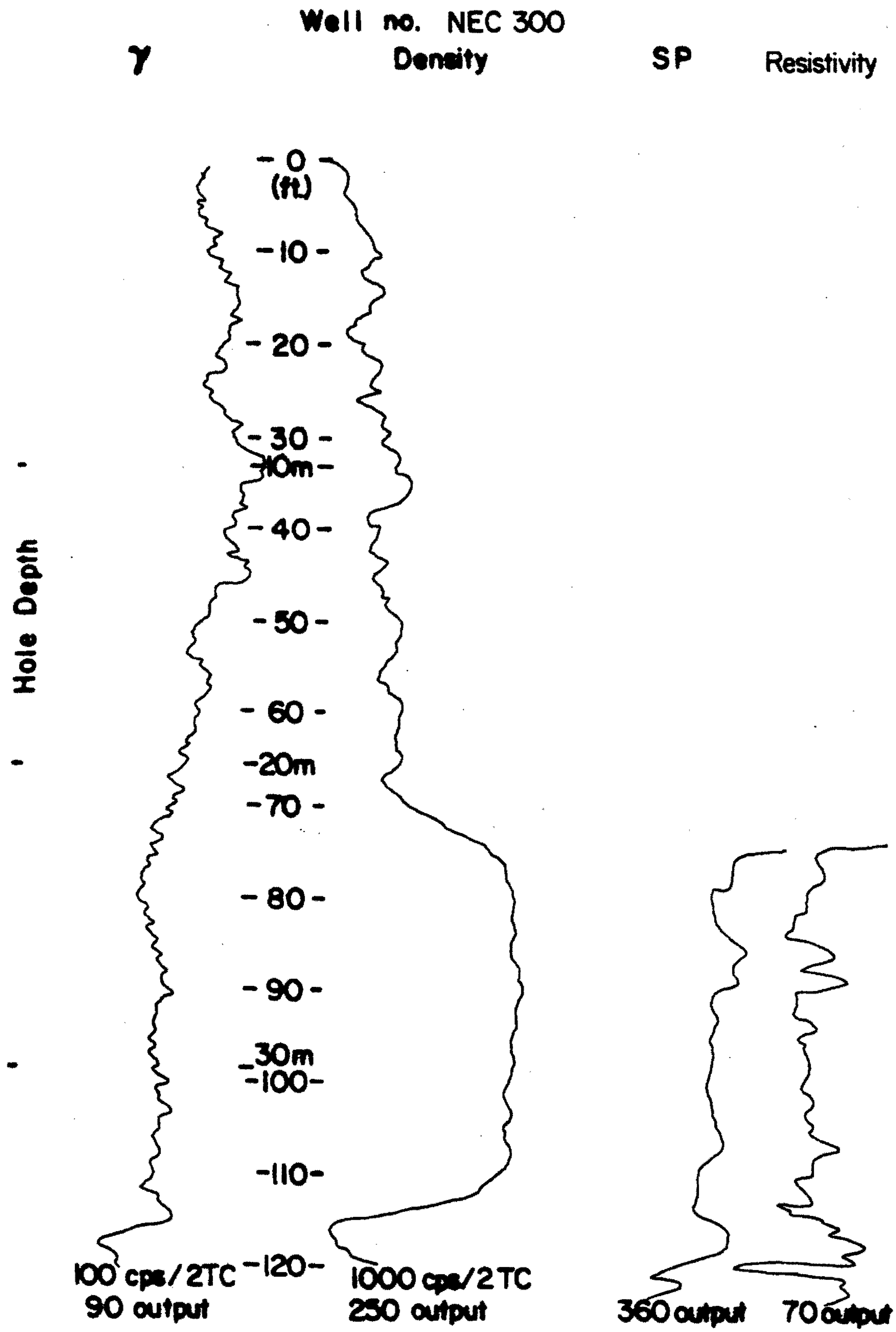


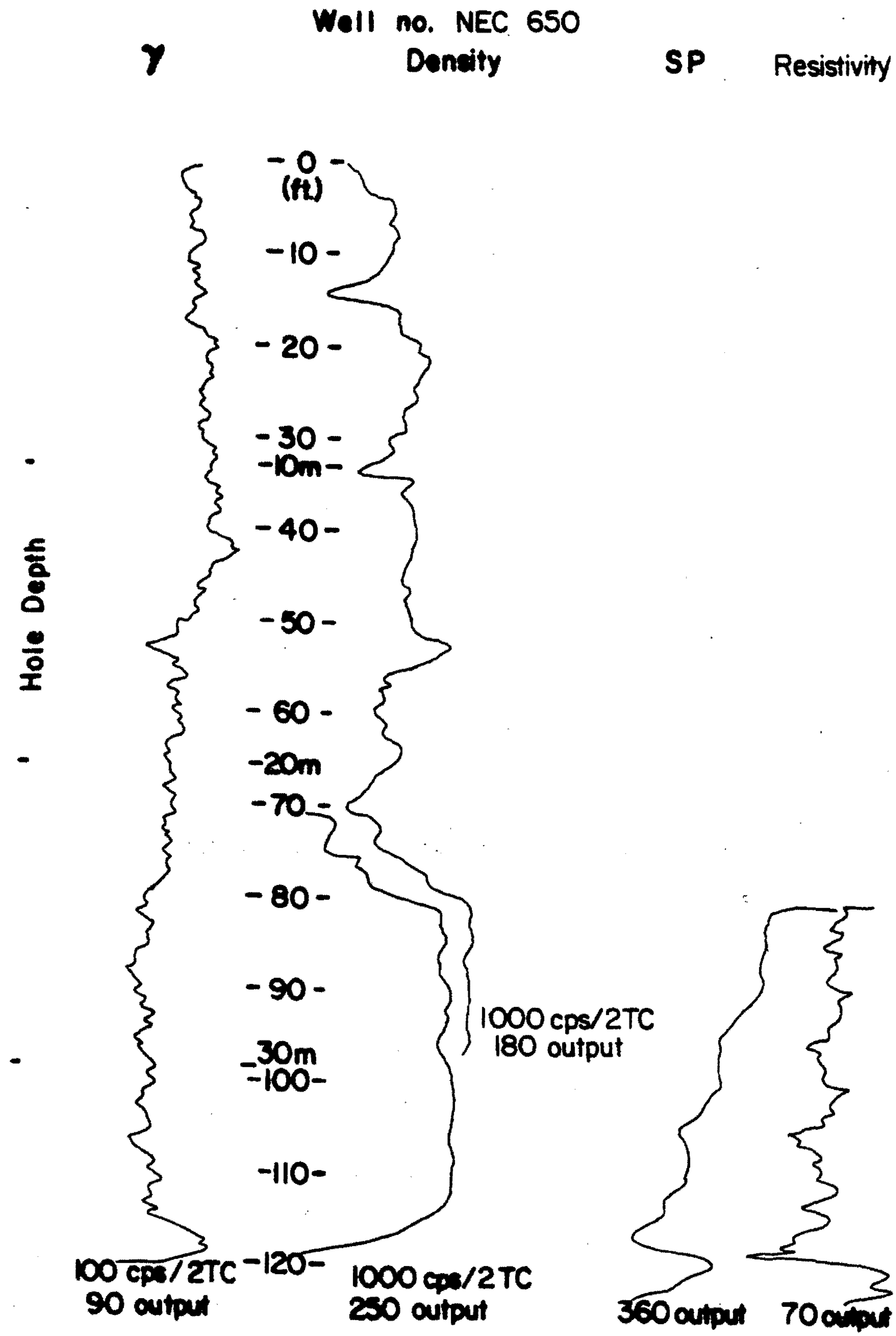
Well no. NEC 100




Well no. NEC 140
γ
Density
SP
Resistivity
0
(ft.)
-10-
-20-
-30-
-10m-
-40-
-50-
-60-
-20m
-70-
-80-
-90-
30m
-100-
-110-
-120-
Hole Depth
1000 cps/2TC
100 output
100 cps/2TC
90 output
1000 cps/2TC
250 output
360 output
70 output

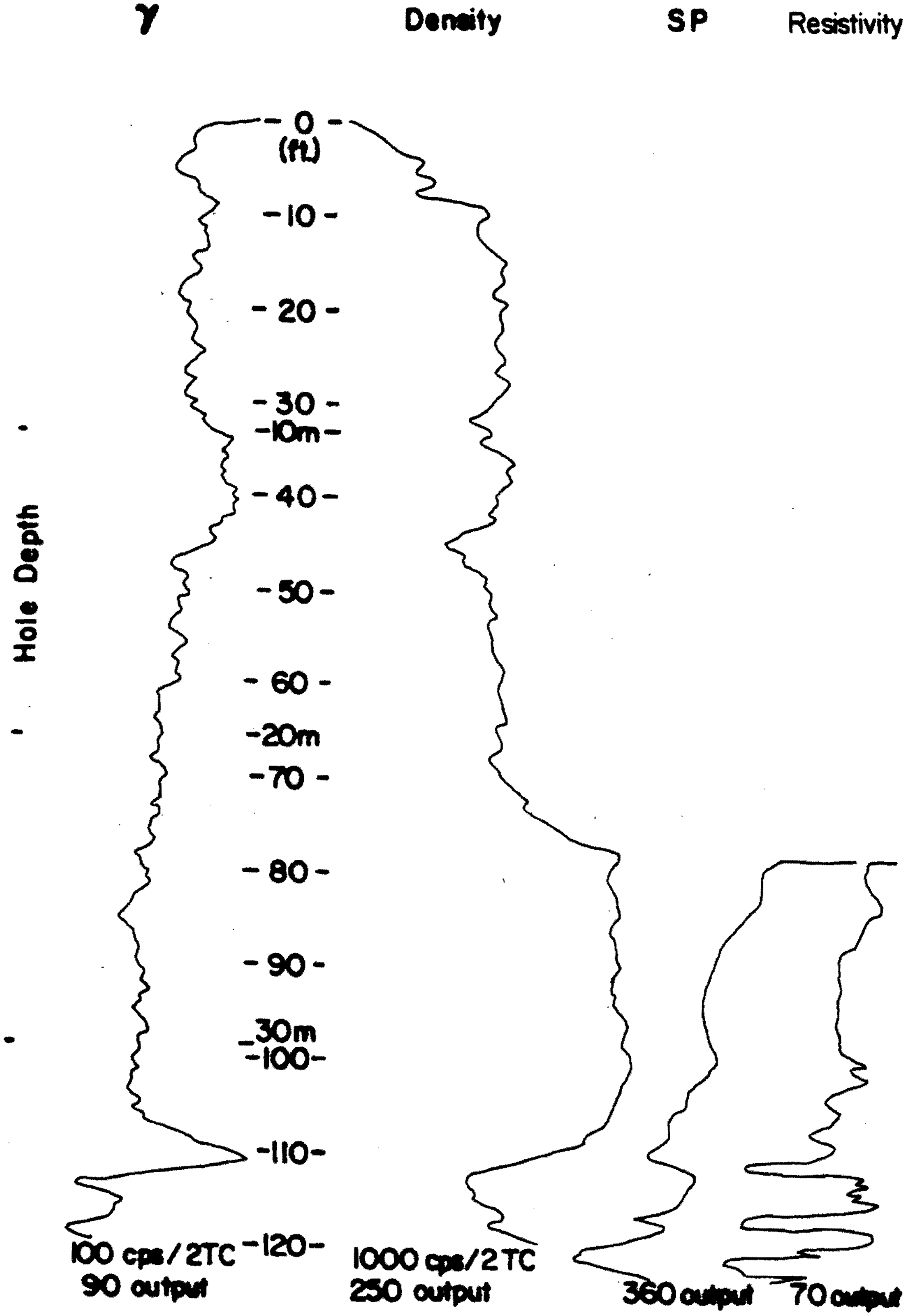

Well no. NEC 200
γ
Density
SP
Resistivity
Hole Depth
0
(ft.)
-10-
-20-
-30-
-10m-
-40-
-50-
-60-
-20m
-70-
-80-
-90-
30m
-100-
-110-
-120-
100 cps/2TC
90 output
1000 cps/2TC
250 output
360 output
70 output

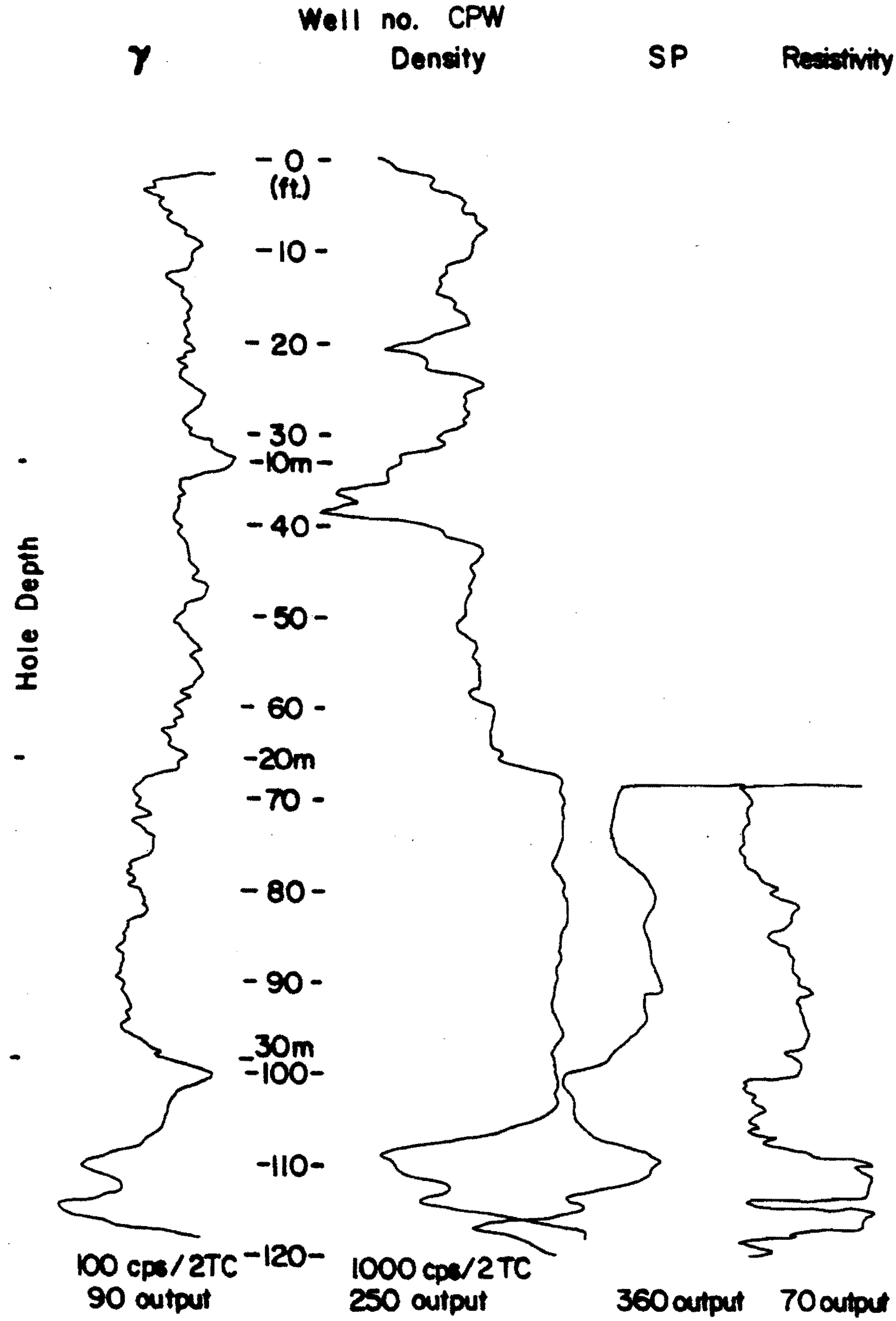

Well no. NEC 300
γ
Density
SP
Resistivity
Hole Depth
- 0 -
(ft.)
-10-
-20-
-30-
-10m-
-40-
-50-
-60-
-20m
-70-
-80-
-90-
30m
-100-
-110-
-120-
100 cps/2TC
90 output
1000 cps/2TC
250 output
360 output
70 output

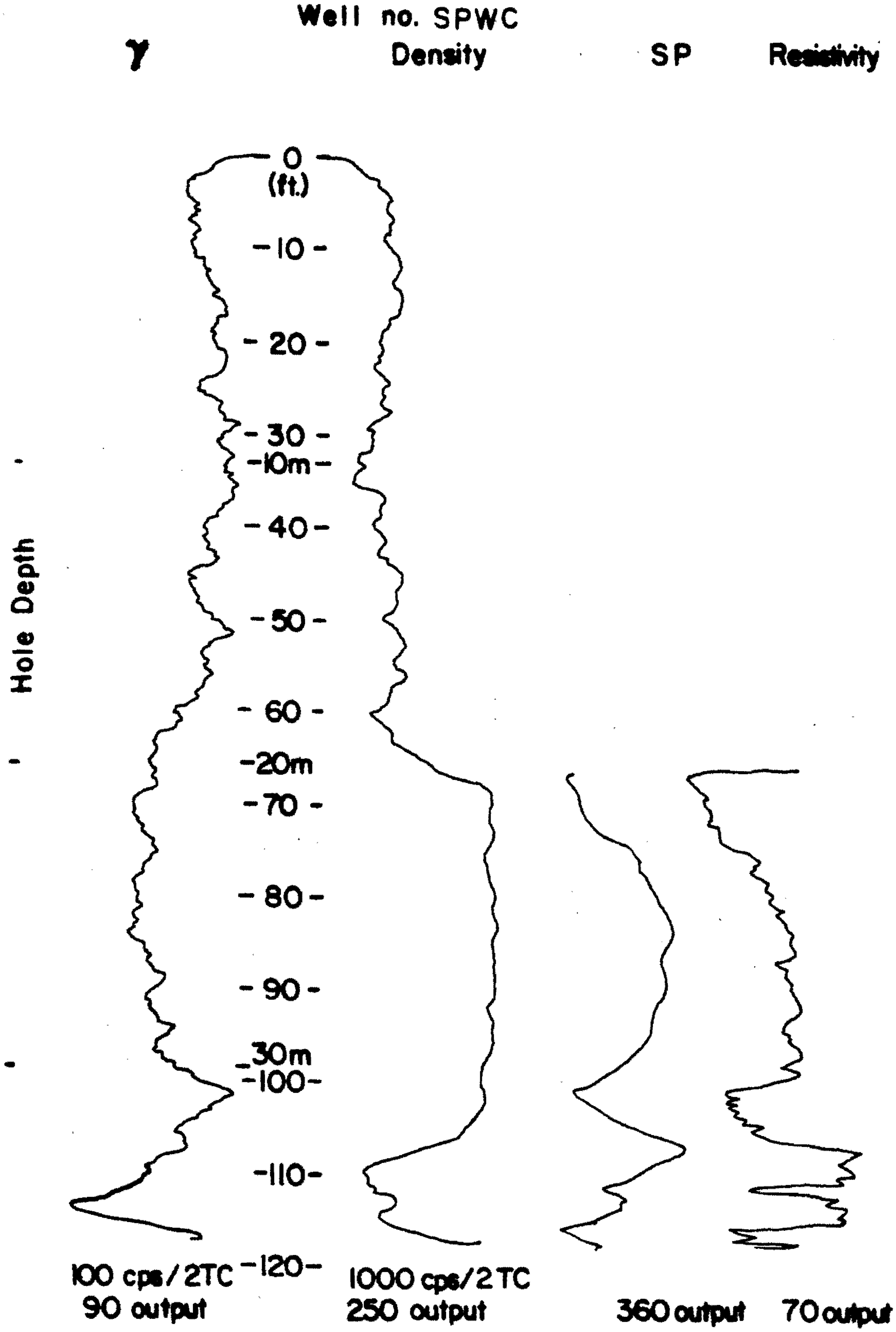


Well no. NEC 650
γ
Density
SP
Resistivity
Hole Depth
0 (ft)
10
20
30
10m
40
50
60
20m
70
80
90
30m
100
110
120
1000 cps/2TC
180 output
100 cps/2TC
90 output
1000 cps/2TC
250 output
360 output
70 output

Well no. NEC 1200

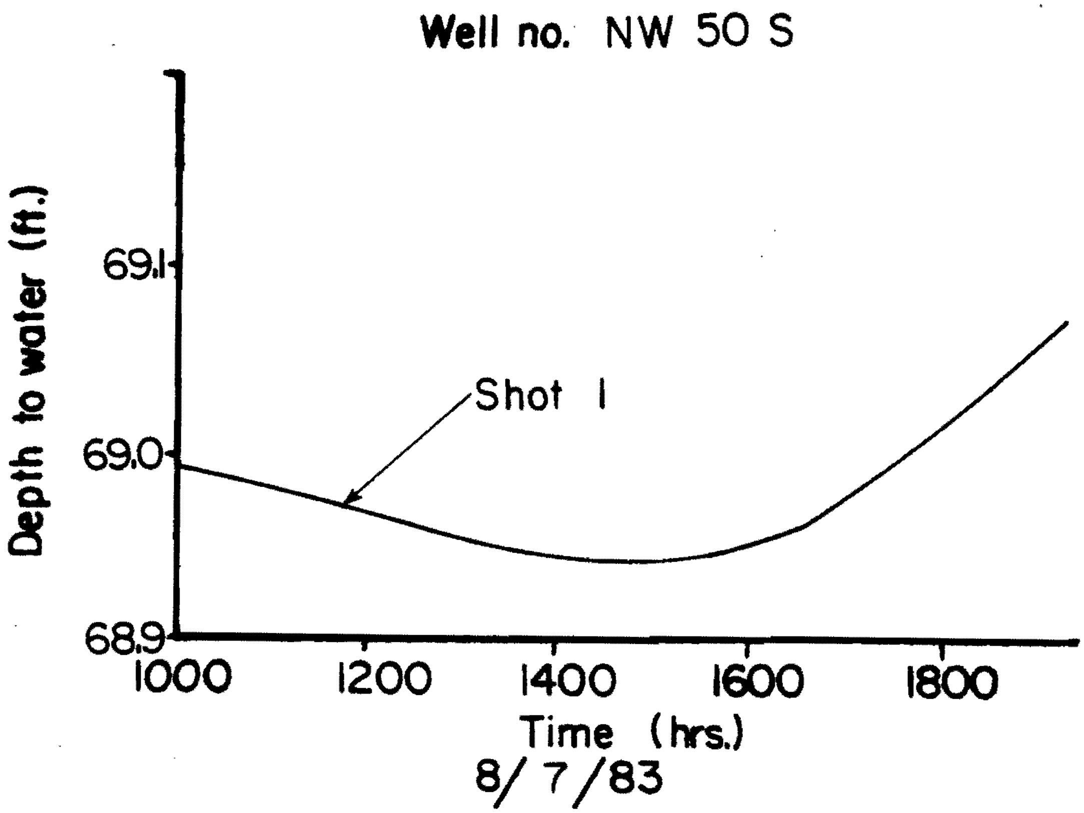


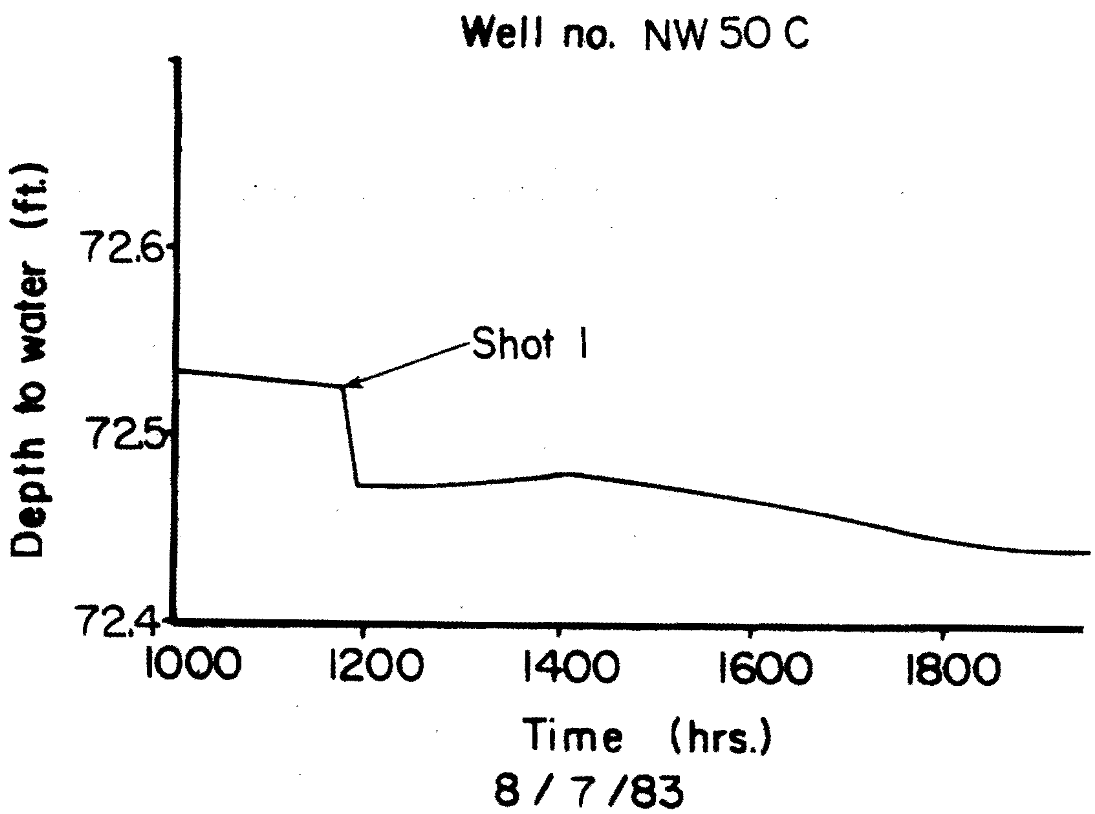

Well no. CPW
γ
Density
SP
Resistivity
Hole Depth
- 0 -
(ft.)
- 10 -
- 20 -
- 30 -
-10m-
- 40 -
- 50 -
- 60 -
-20m
- 70 -
- 80 -
- 90 -
30m
-100-
-110-
-120-
100 cps/2TC
90 output
1000 cps/2TC
250 output
360 output
70 output


Well no. SPWC
γ
Density
SP
Resistivity
Hole Depth
0
(ft.)
-10-
-20-
-30-
-10m-
-40-
-50-
-60-
-20m
-70-
-80-
-90-
-30m
-100-
-110-
-120-
100 cps/2TC
90 output
1000 cps/2TC
250 output
360 output
70 output

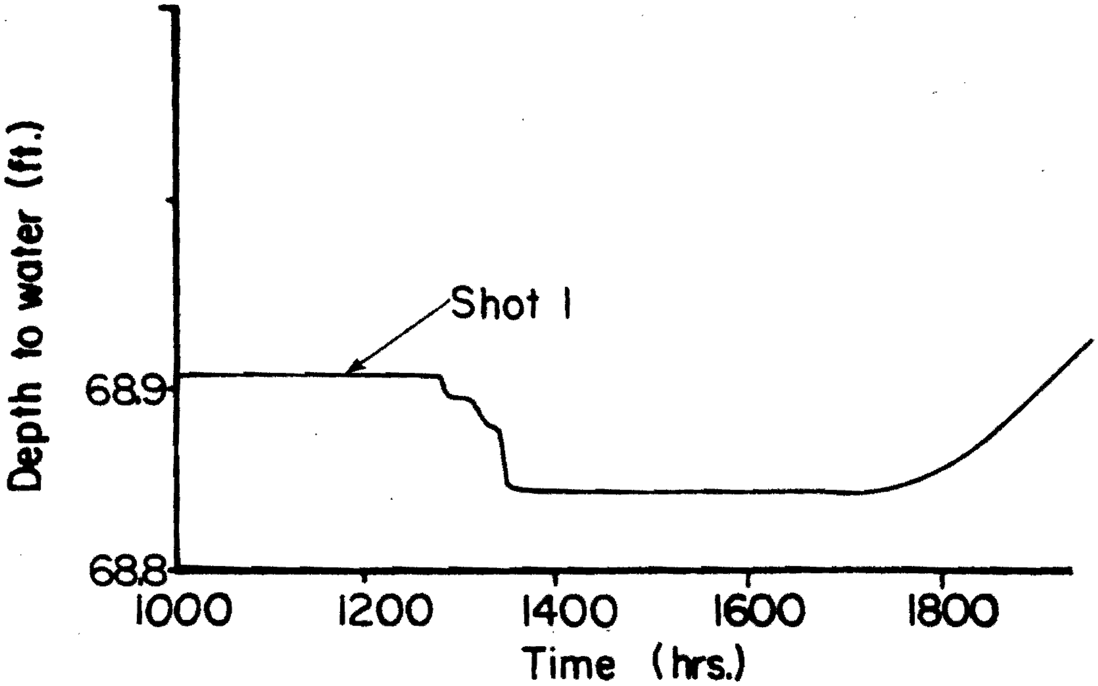
Appendix C

WATER LEVEL RESPONSE TO BLASTING


Well no. NW 50 S
Depth to water (ft.)
69.1
69.0
68.9
Shot 1
1000
1200
1400
1600
1800
Time (hrs.)
8/7/83

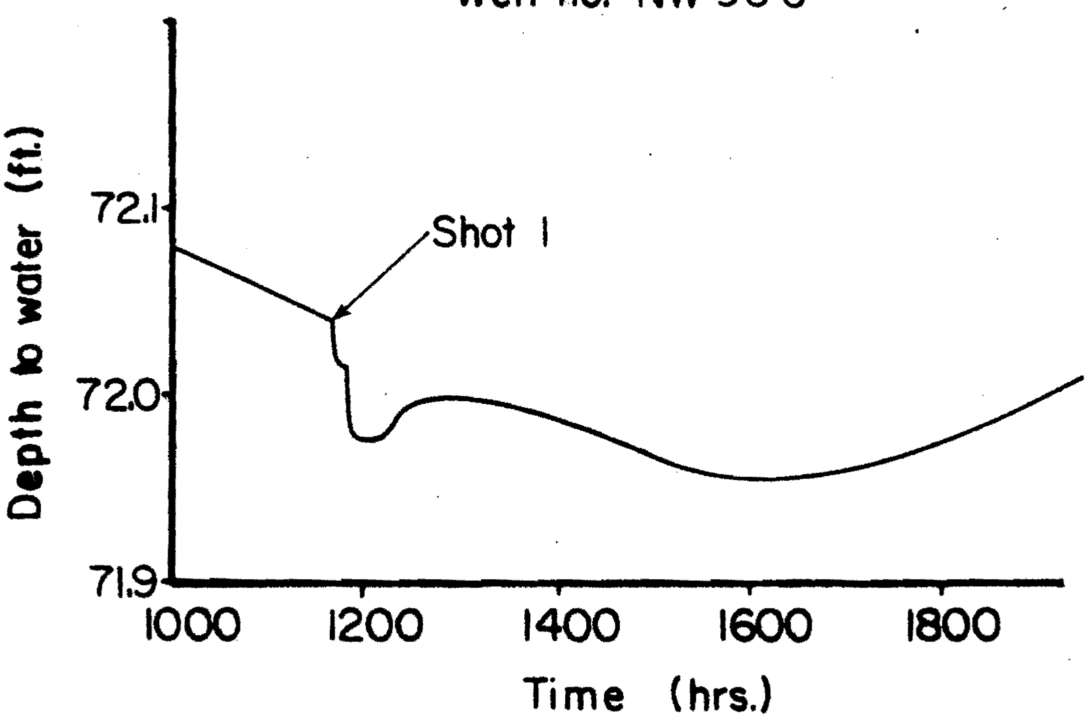

Well no. NW 50 C
Depth to water (ft.)
72.6
72.5
72.4
Shot 1
1000
1200
1400
1600
1800
Time (hrs.)
8/7/83

Well no. NW 90 S

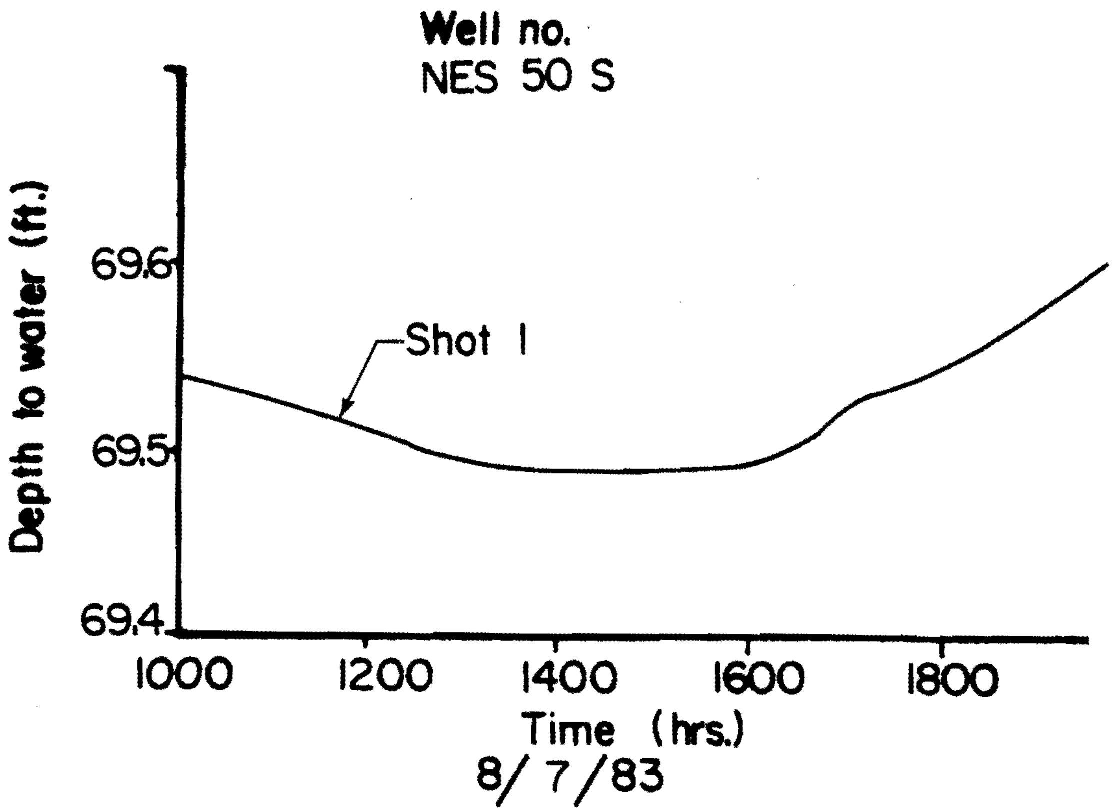


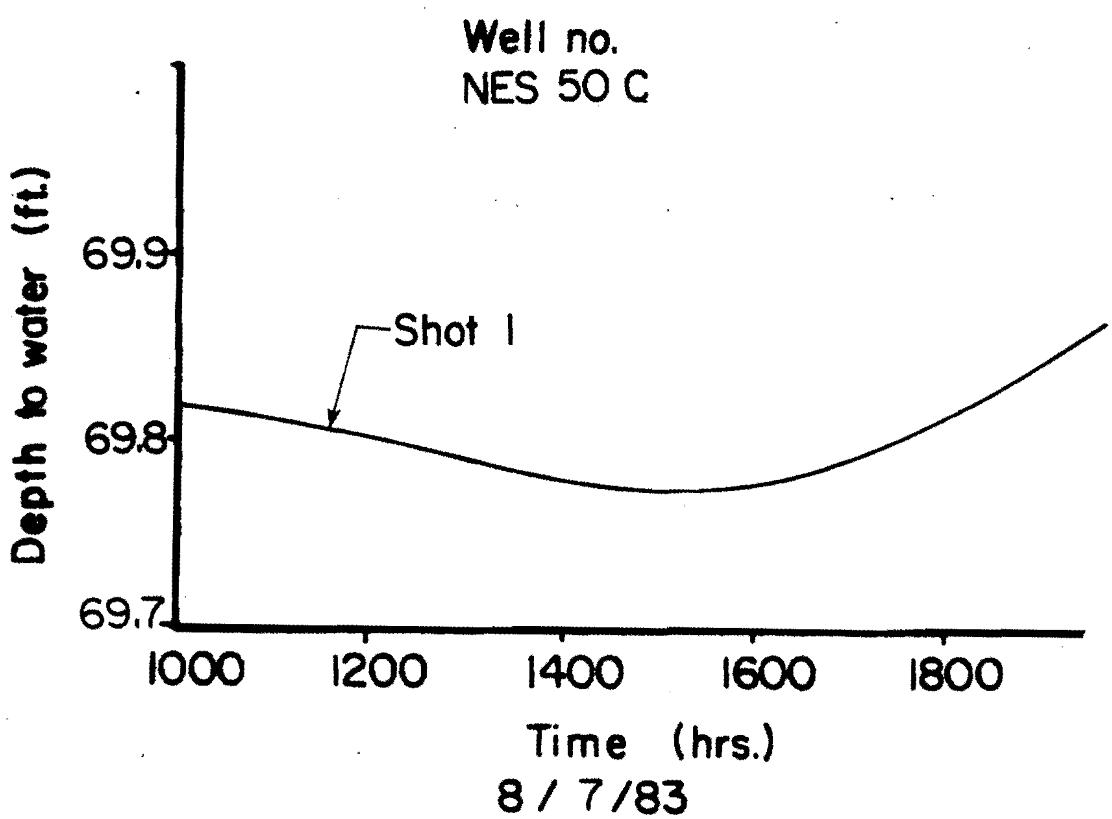
8/7/83

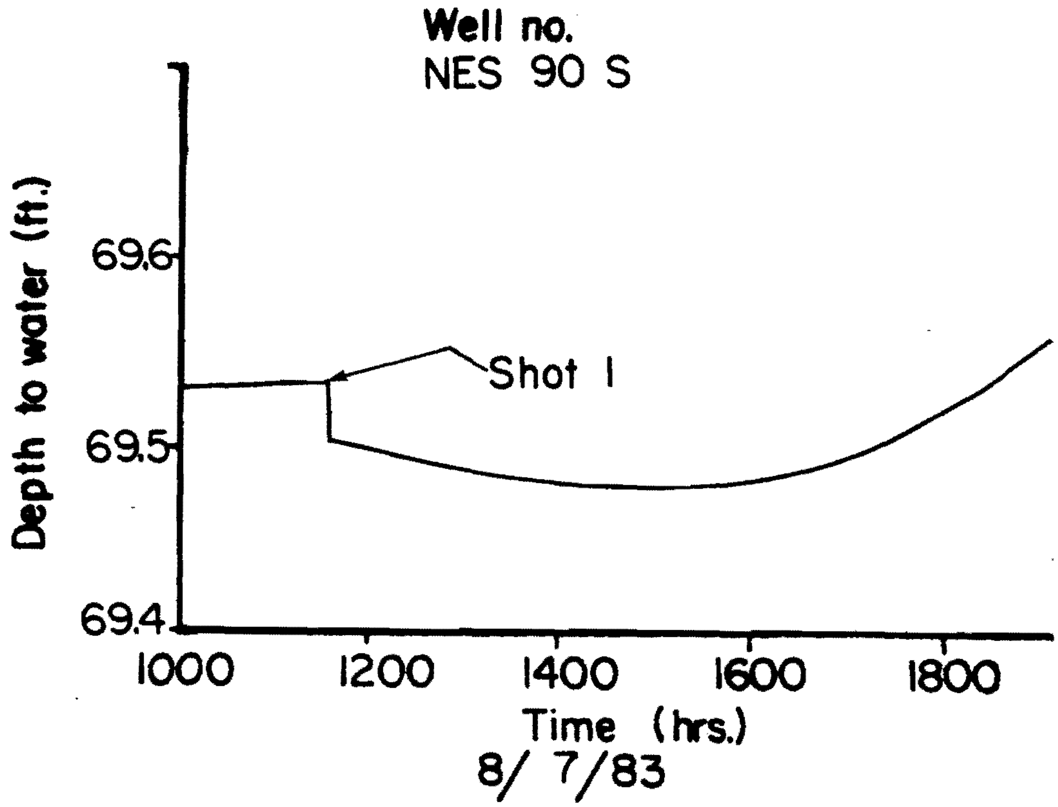
Well no. NW 90C

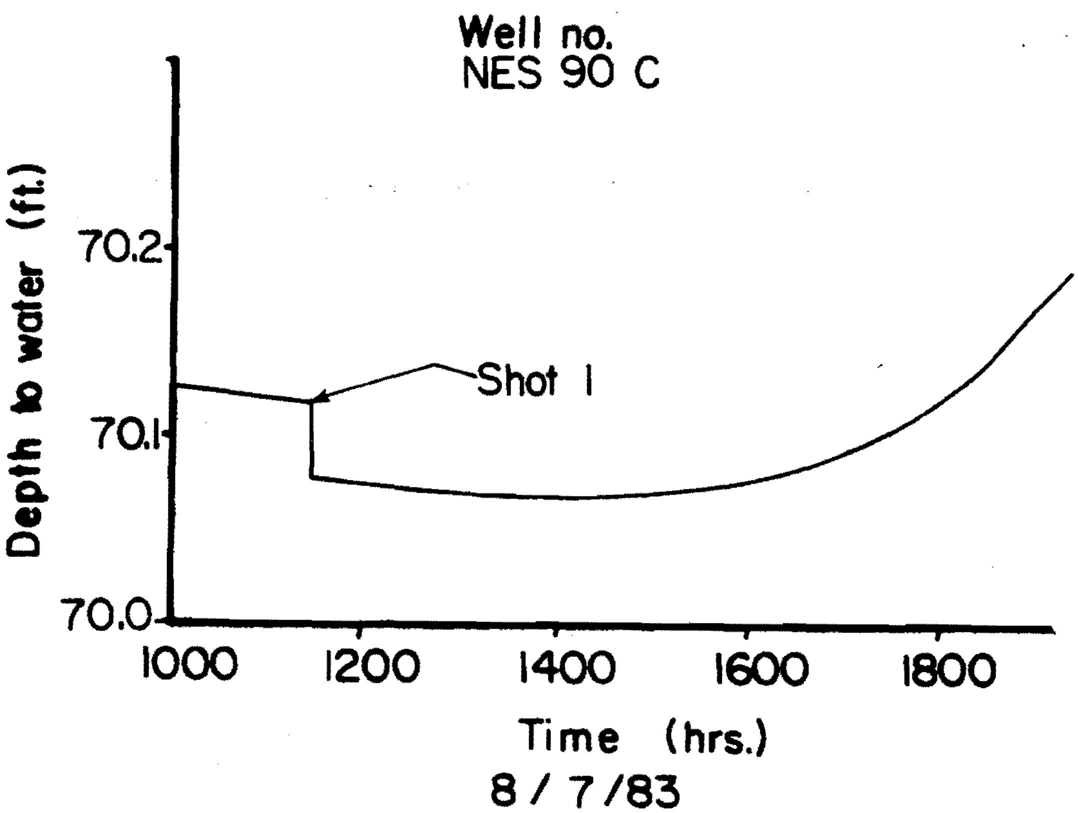


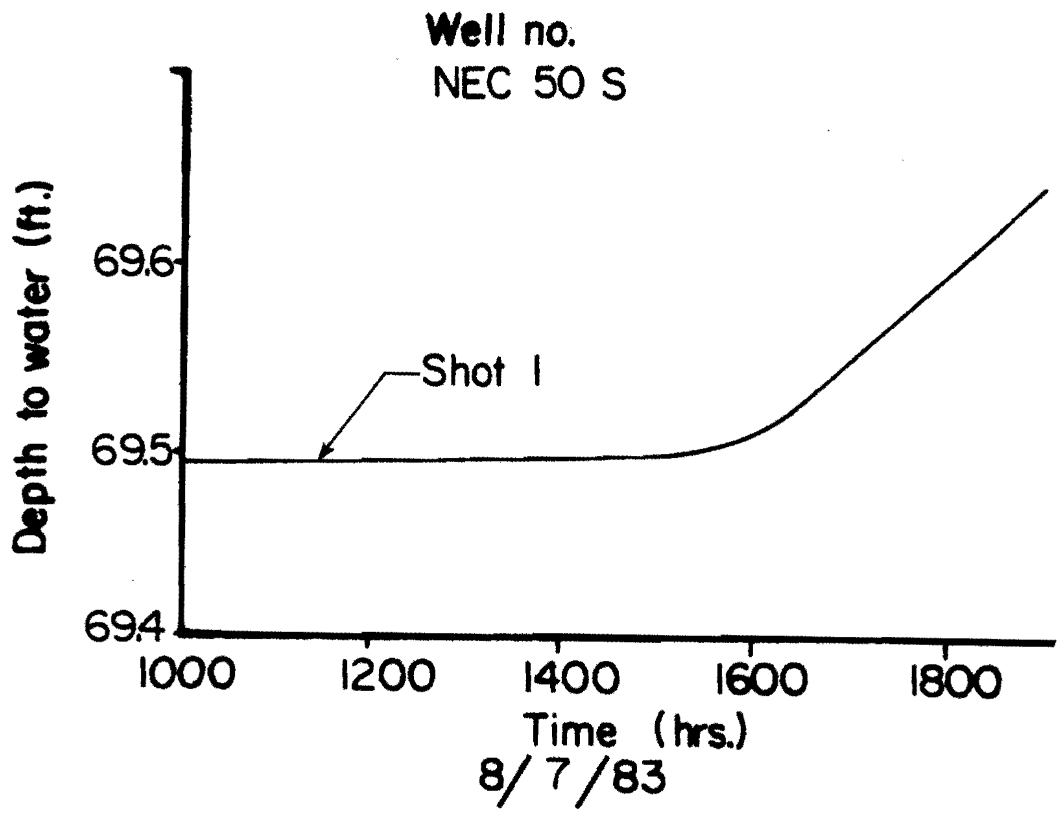
8/7/83


Well no.
NES 50 S
Depth to water (ft.)
69.6
69.5
69.4
Shot 1
1000
1200
1400
1600
1800
Time (hrs.)
8/7/83

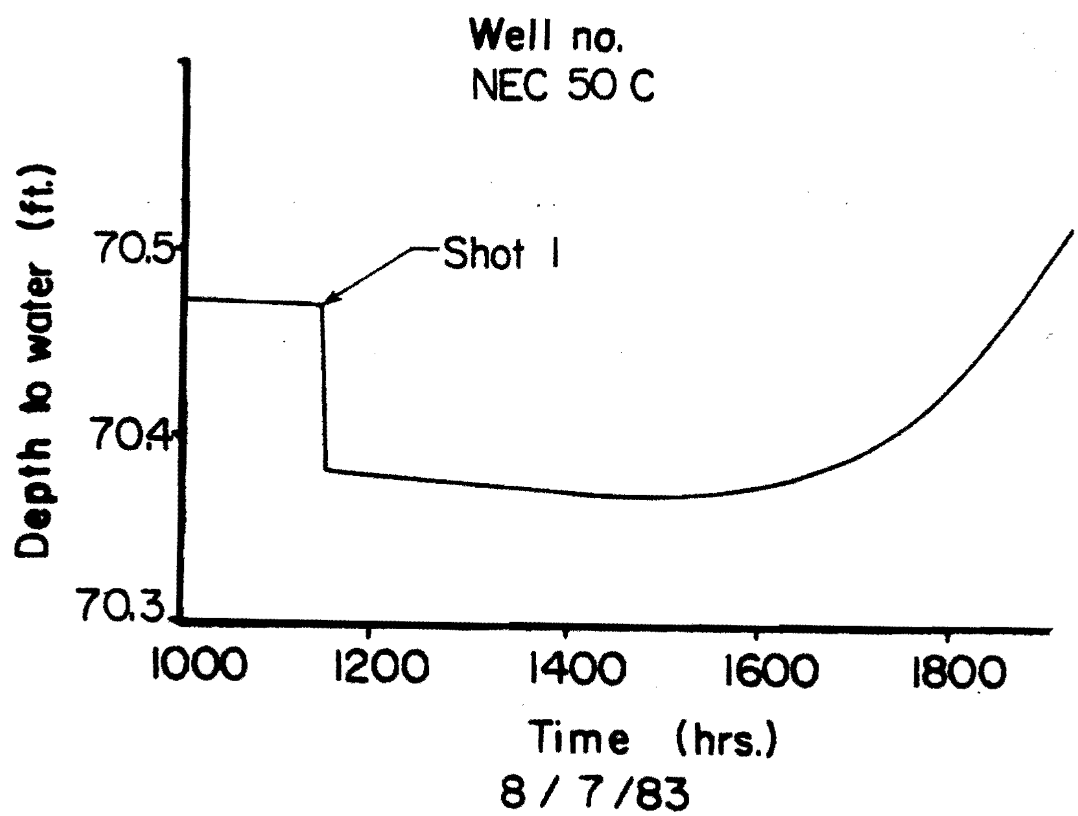

Well no.
NES 50 C
Depth to water (ft.)
69.9
69.8
69.7
Shot 1
1000
1200
1400
1600
1800
Time (hrs.)
8/7/83


Well no.
NES 90 S
Depth to water (ft.)
69.6
69.5
69.4
Shot I
1000
1200
1400
1600
1800
Time (hrs.)
8/ 7/83

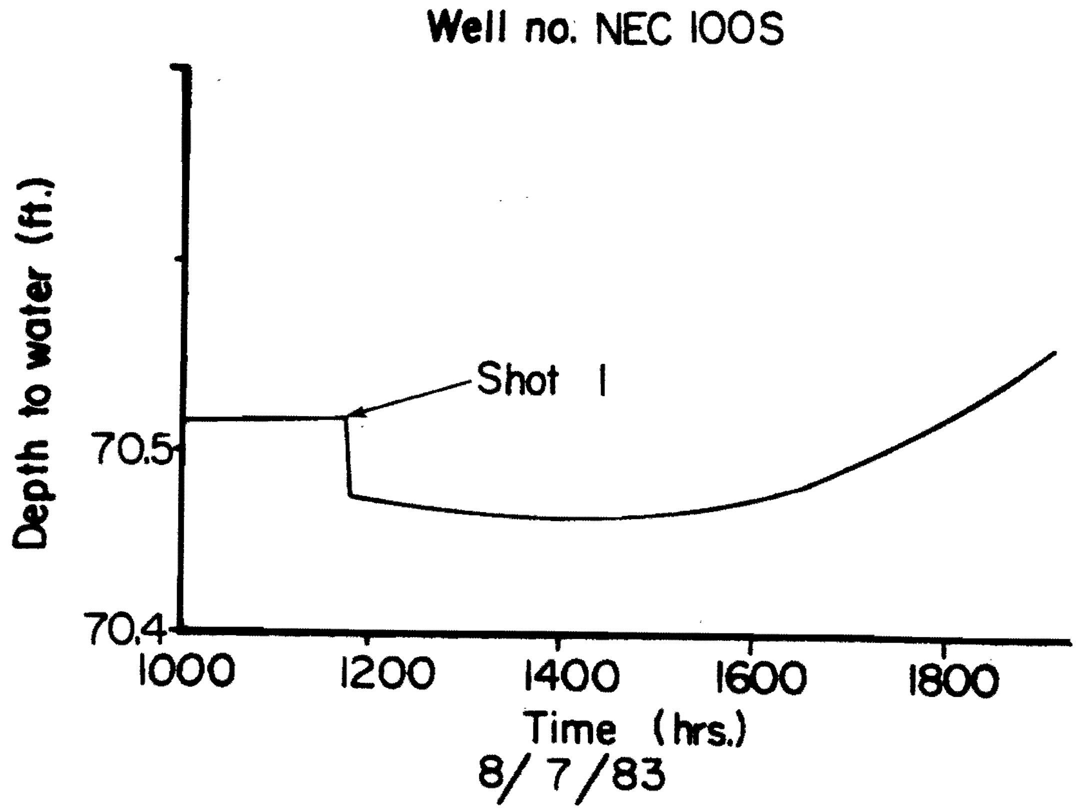

Well no.
NES 90 C
Depth to water (ft.)
70.2
70.1
70.0
Shot I
1000
1200
1400
1600
1800
Time (hrs.)
8 / 7 /83

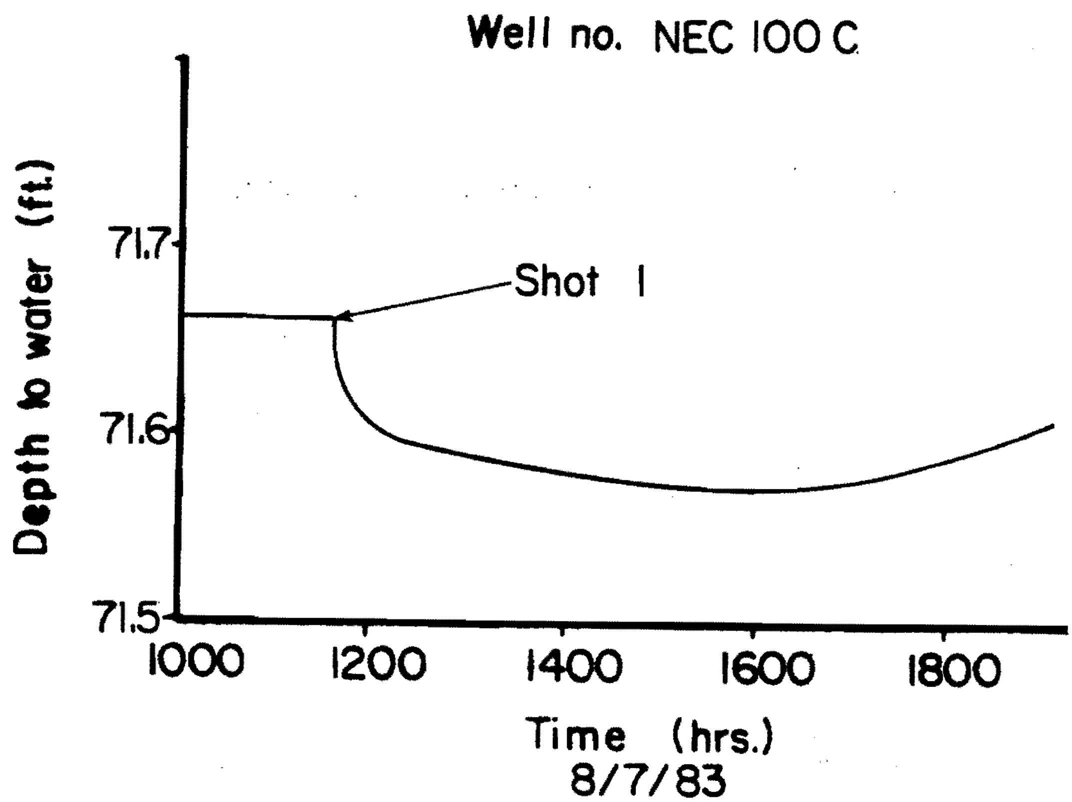


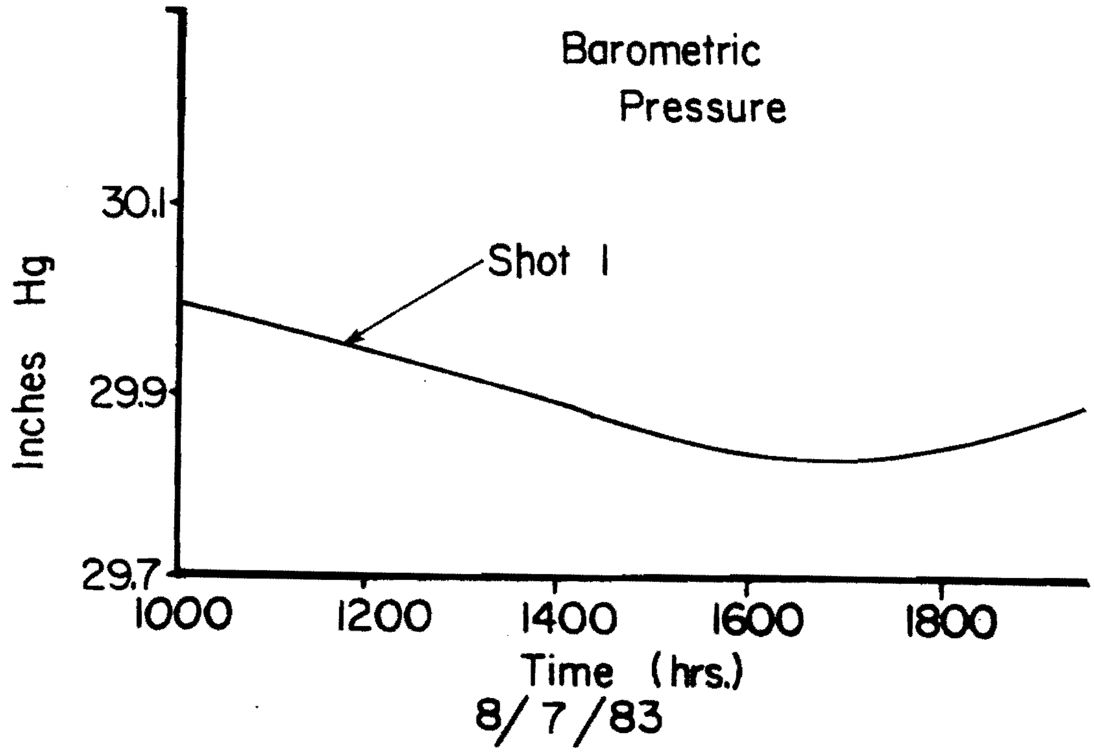
Well no.
NEC 50 S
Depth to water (ft.)
69.6
69.5
69.4
Shot 1
1000
1200
1400
1600
1800
Time (hrs.)
8/7/83

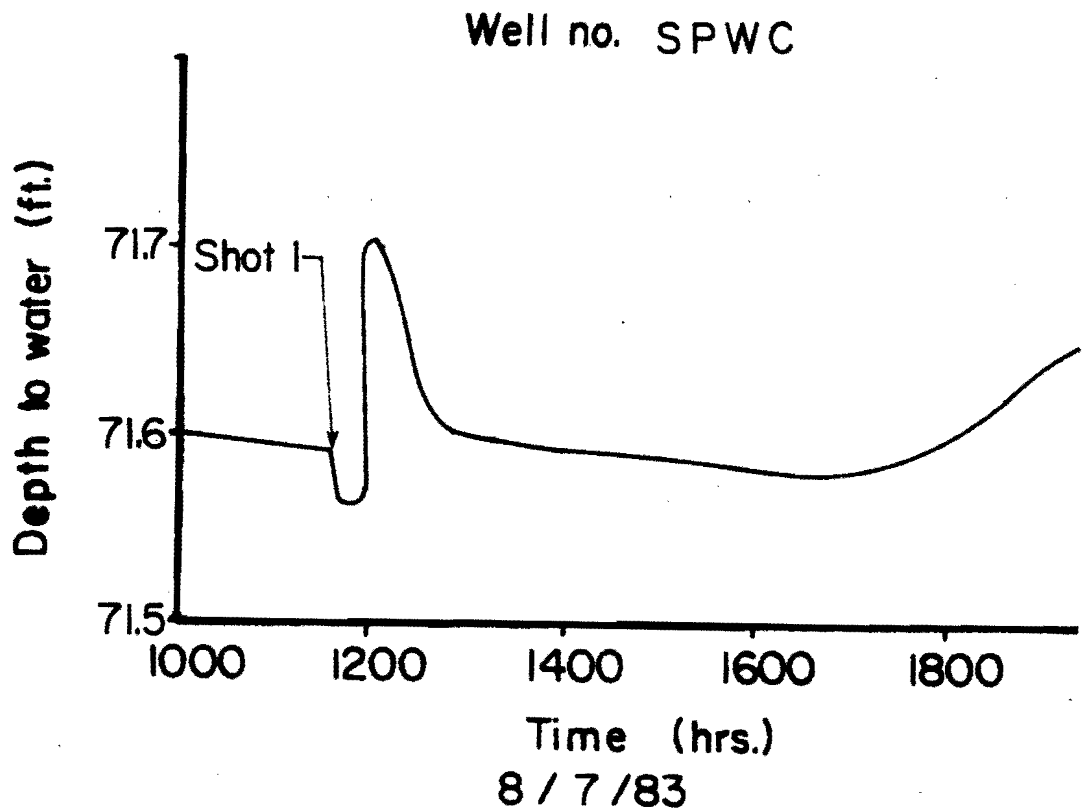


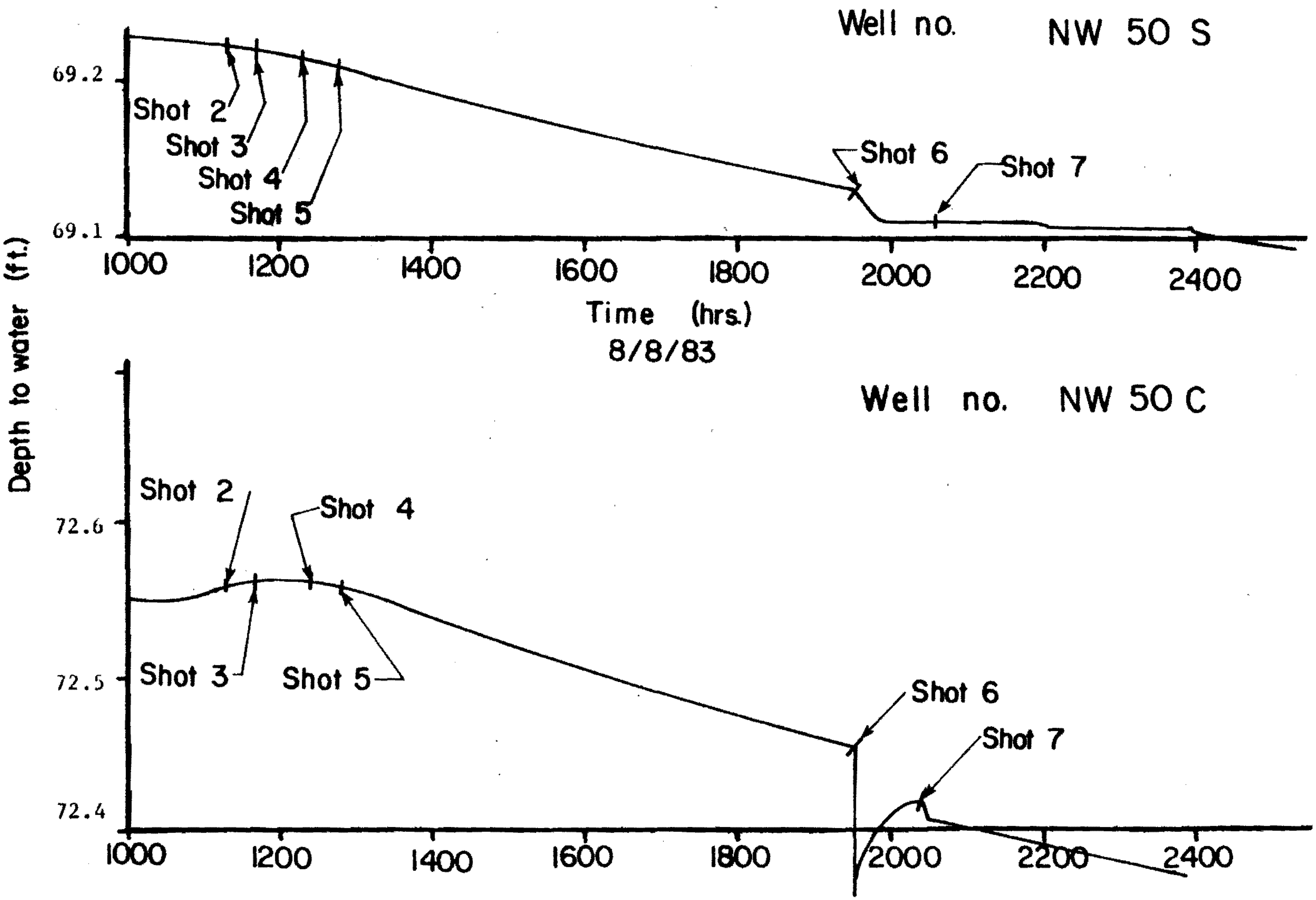
Well no.
NEC 50 C
Depth to water (ft.)
70.5
70.4
70.3
Shot 1
1000
1200
1400
1600
1800
Time (hrs.)
8/7/83


Well no. NEC 100S
Depth to water (ft.)
70.5
70.4
Shot 1
1000
1200
1400
1600
1800
Time (hrs.)
8/7/83

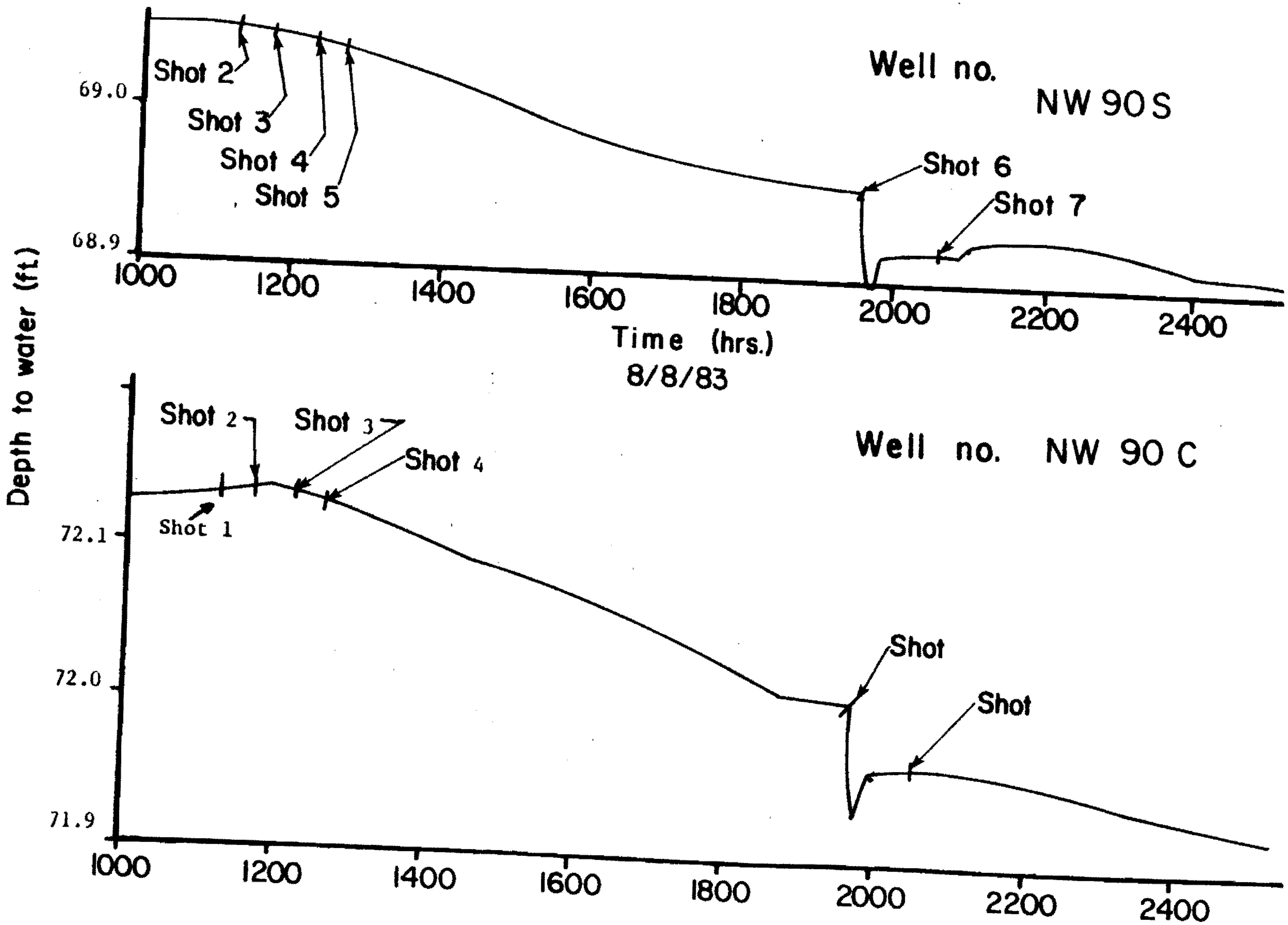

Well no. NEC 100 C
Depth to water (ft.)
71.7
71.6
71.5
Shot 1
1000
1200
1400
1600
1800
Time (hrs.)
8/7/83

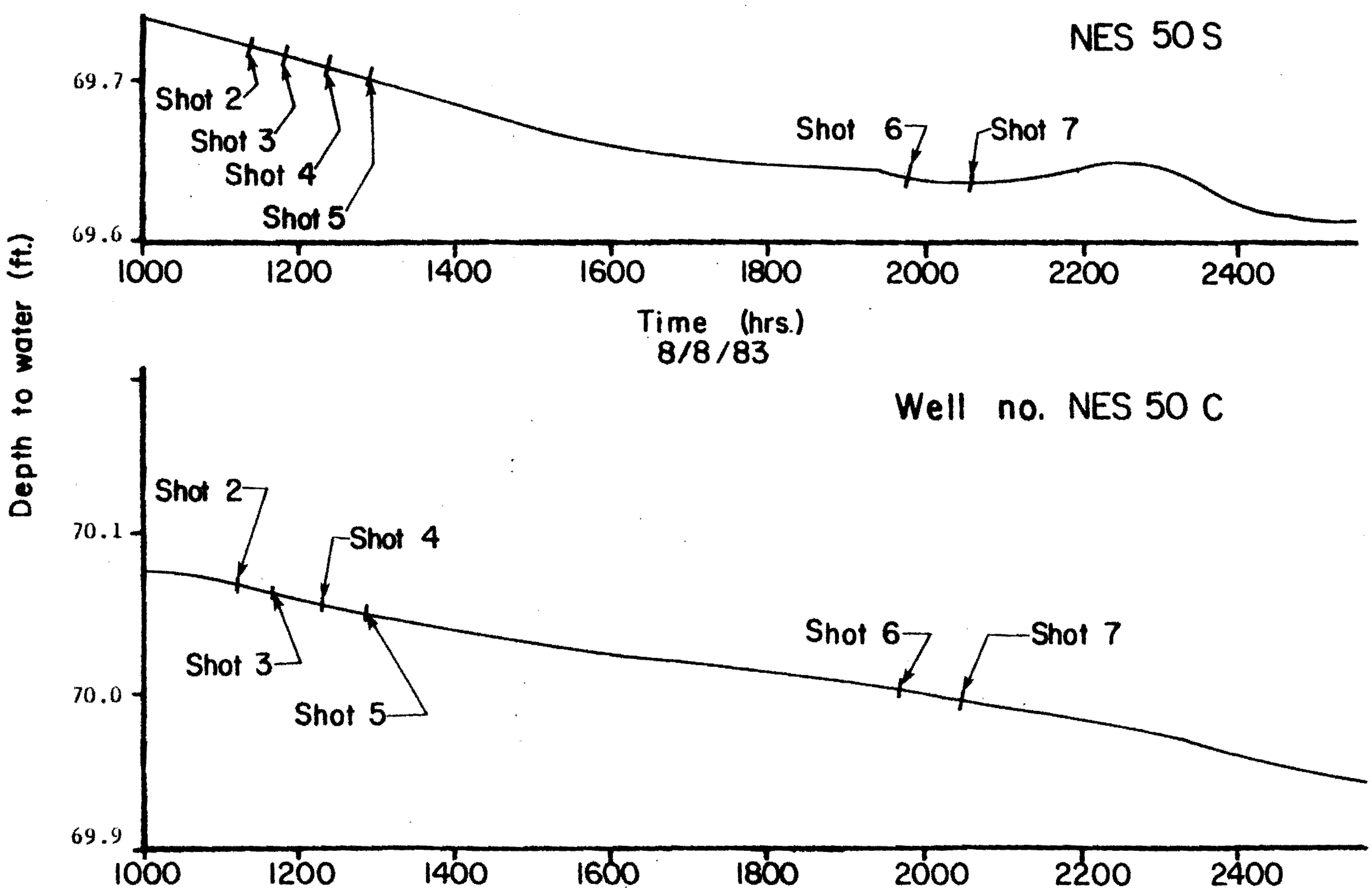

Barometric Pressure
Inches Hg
30.1
29.9
29.7
Shot 1
1000
1200
1400
1600
1800
Time (hrs.)
8/7/83

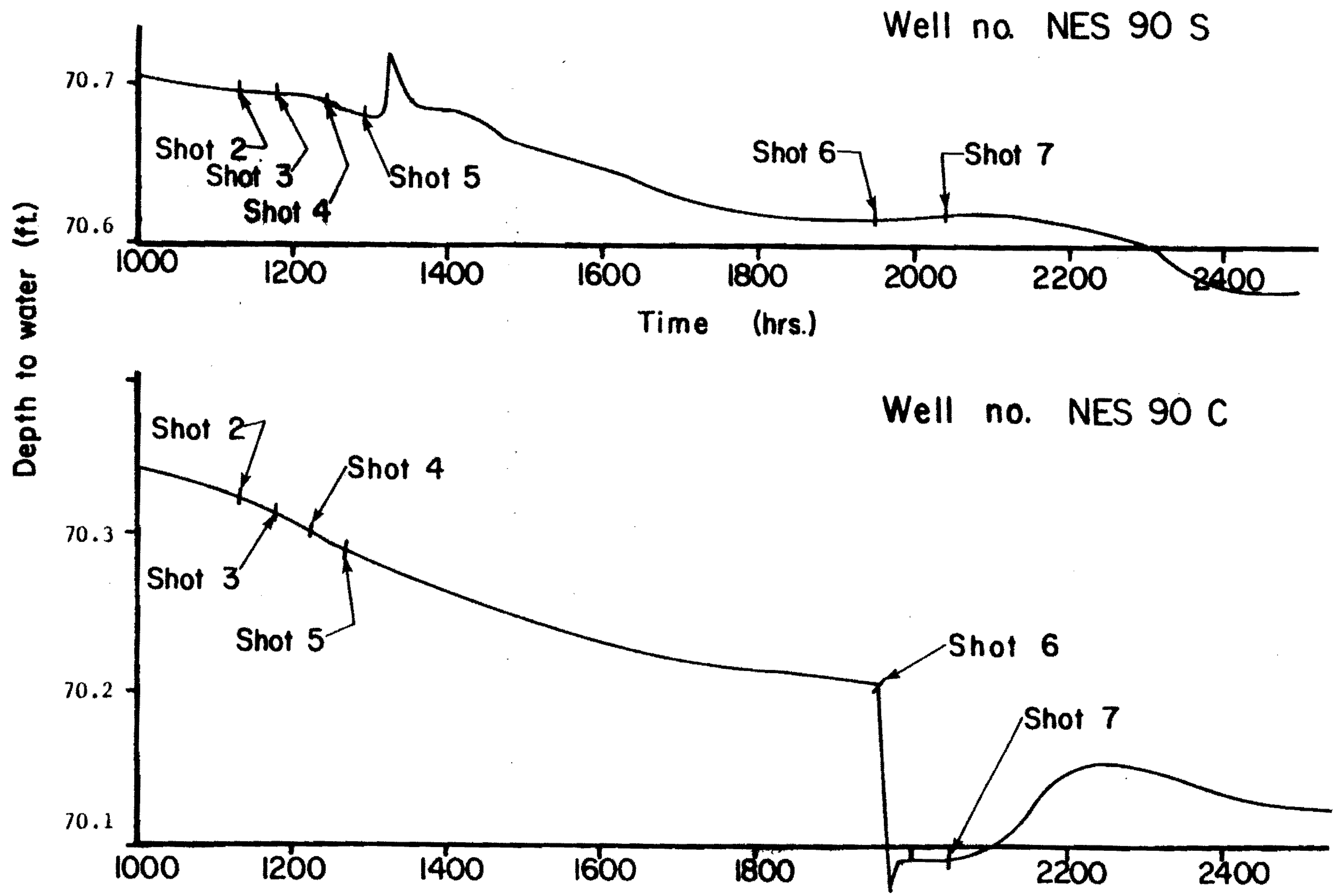

Well no. SPWC
Depth to water (ft.)
71.7
71.6
71.5
Shot 1
1000
1200
1400
1600
1800
Time (hrs.)
8/7/83

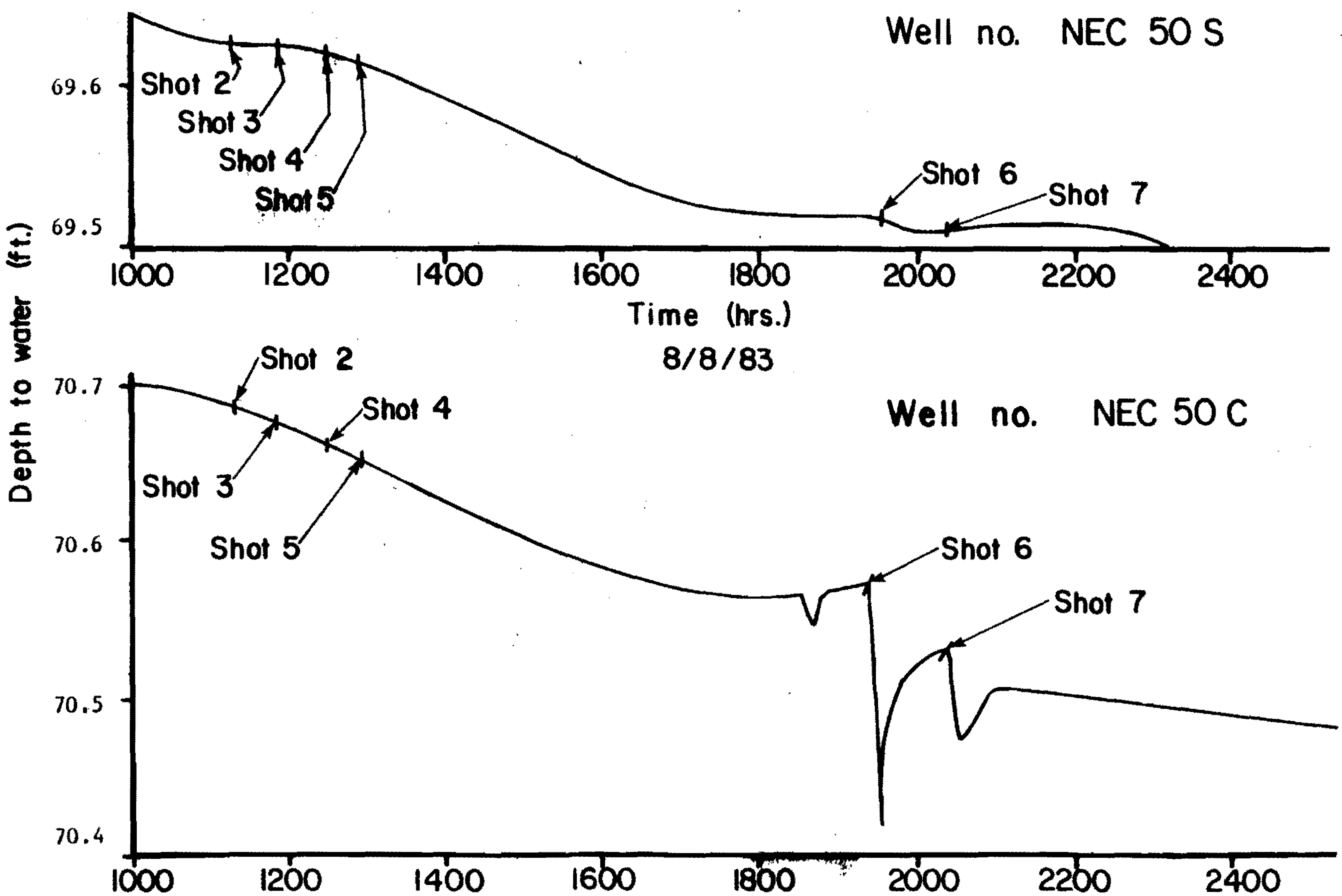


Well no. NW 50 S
69.2
69.1
Shot 2
Shot 3
Shot 4
Shot 5
Shot 6
Shot 7
1000
1200
1400
1600
1800
2000
2200
2400
Time (hrs.)
8/8/83
Depth to water (ft.)
Well no. NW 50 C
72.6
72.5
72.4
Shot 2
Shot 3
Shot 4
Shot 5
Shot 6
Shot 7
1000
1200
1400
1600
1800
2000
2200
2400

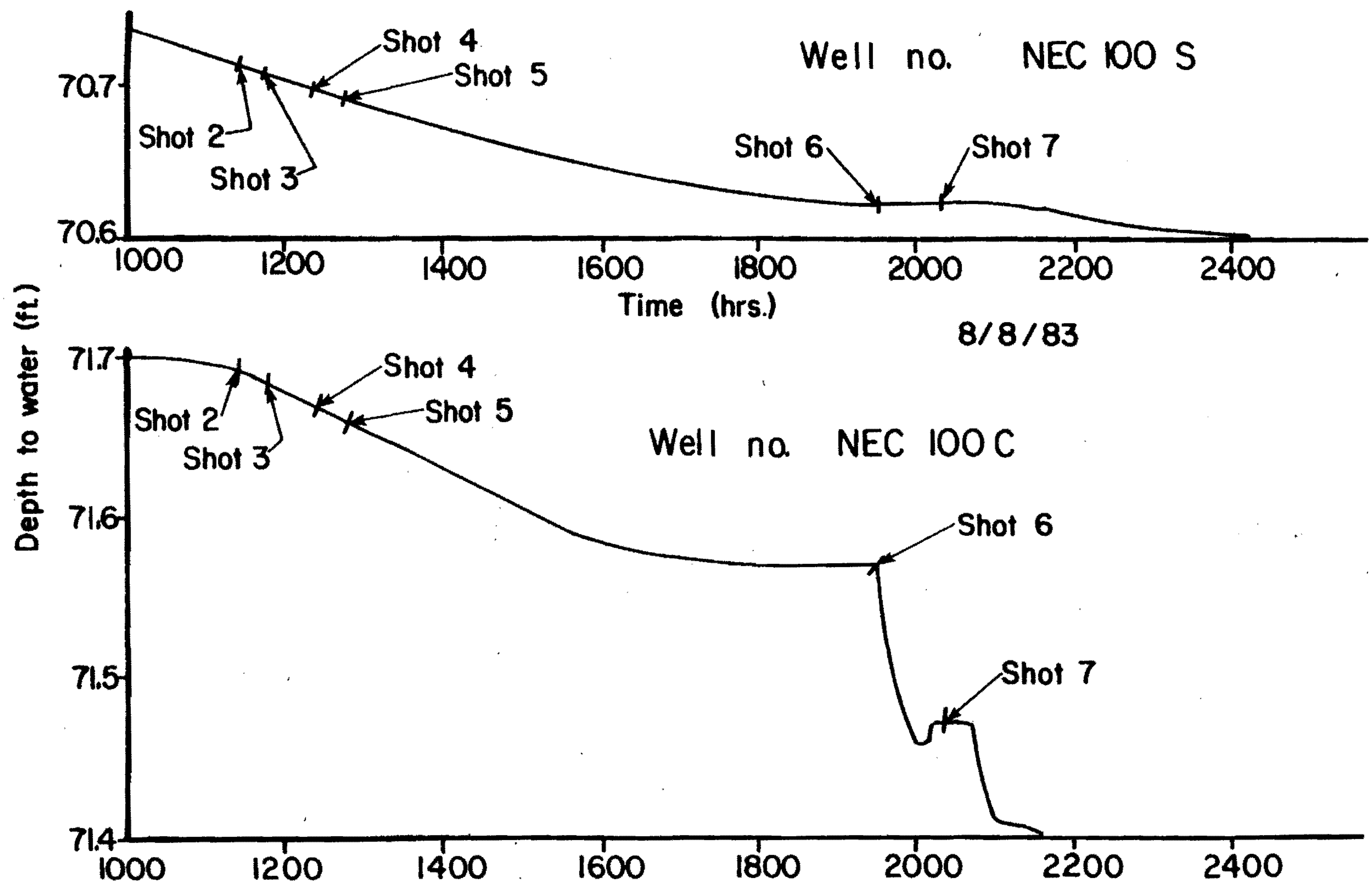

Well no. NW 90 S
Shot 2
Shot 3
Shot 4
Shot 5
Shot 6
Shot 7
69.0
68.9
1000
1200
1400
1600
1800
2000
2200
2400
Time (hrs.)
8/8/83
Depth to water (ft.)
Well no. NW 90 C
Shot 1
Shot 2
Shot 3
Shot 4
Shot
Shot
72.1
72.0
71.9
1000
1200
1400
1600
1800
2000
2200
2400


NES 50 S
Shot 2
Shot 3
Shot 4
Shot 5
Shot 6
Shot 7
69.7
69.6
1000
1200
1400
1600
1800
2000
2200
2400
Time (hrs.)
8/8/83
Depth to water (ft.)
Well no. NES 50 C
Shot 2
Shot 3
Shot 4
Shot 5
Shot 6
Shot 7
70.1
70.0
69.9
1000
1200
1400
1600
1800
2000
2200
2400

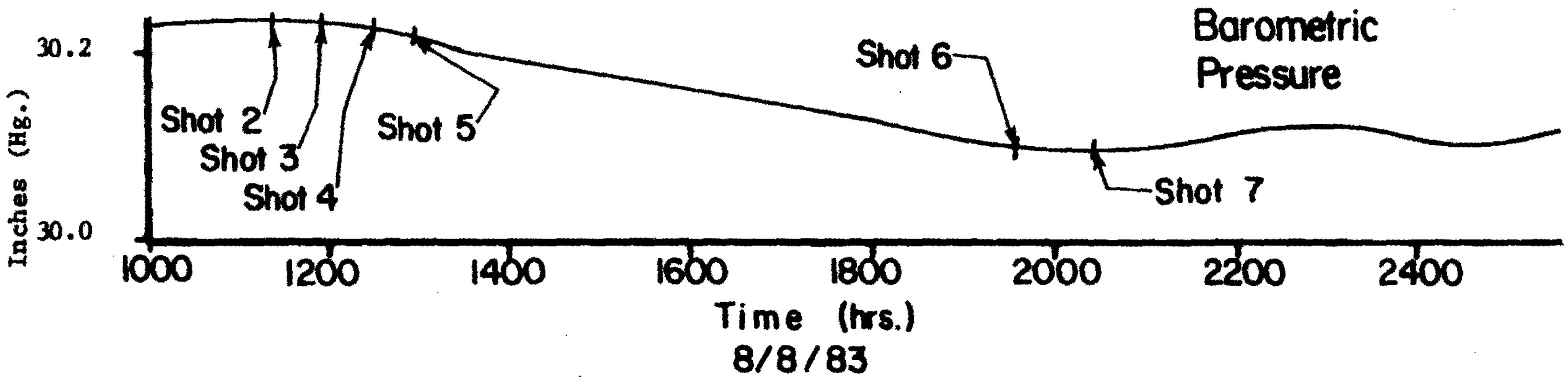

Well no. NES 90 S
70.7
70.6
Shot 2
Shot 3
Shot 4
Shot 5
Shot 6
Shot 7
1000
1200
1400
1600
1800
2000
2200
2400
Time (hrs.)
Depth to water (ft.)
Well no. NES 90 C
70.3
70.2
70.1
Shot 2
Shot 3
Shot 4
Shot 5
Shot 6
Shot 7
1000
1200
1400
1600
1800
2200
2400

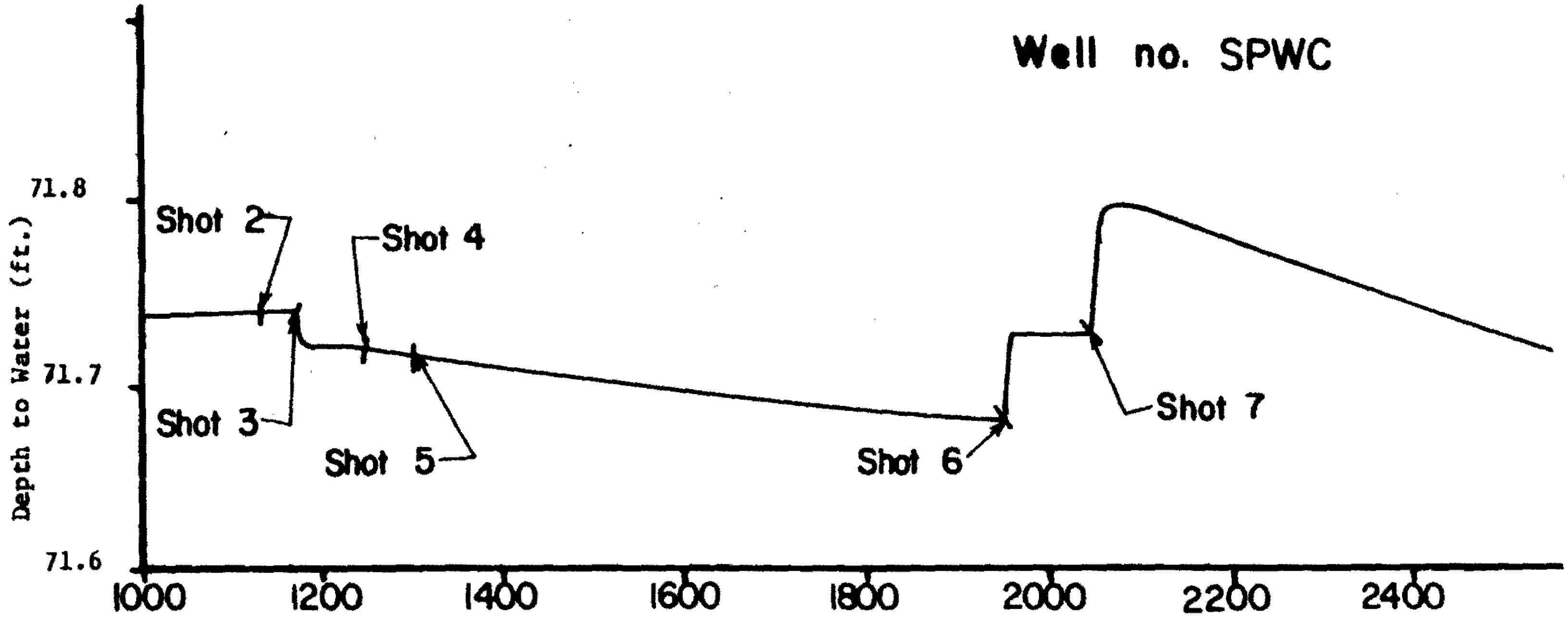


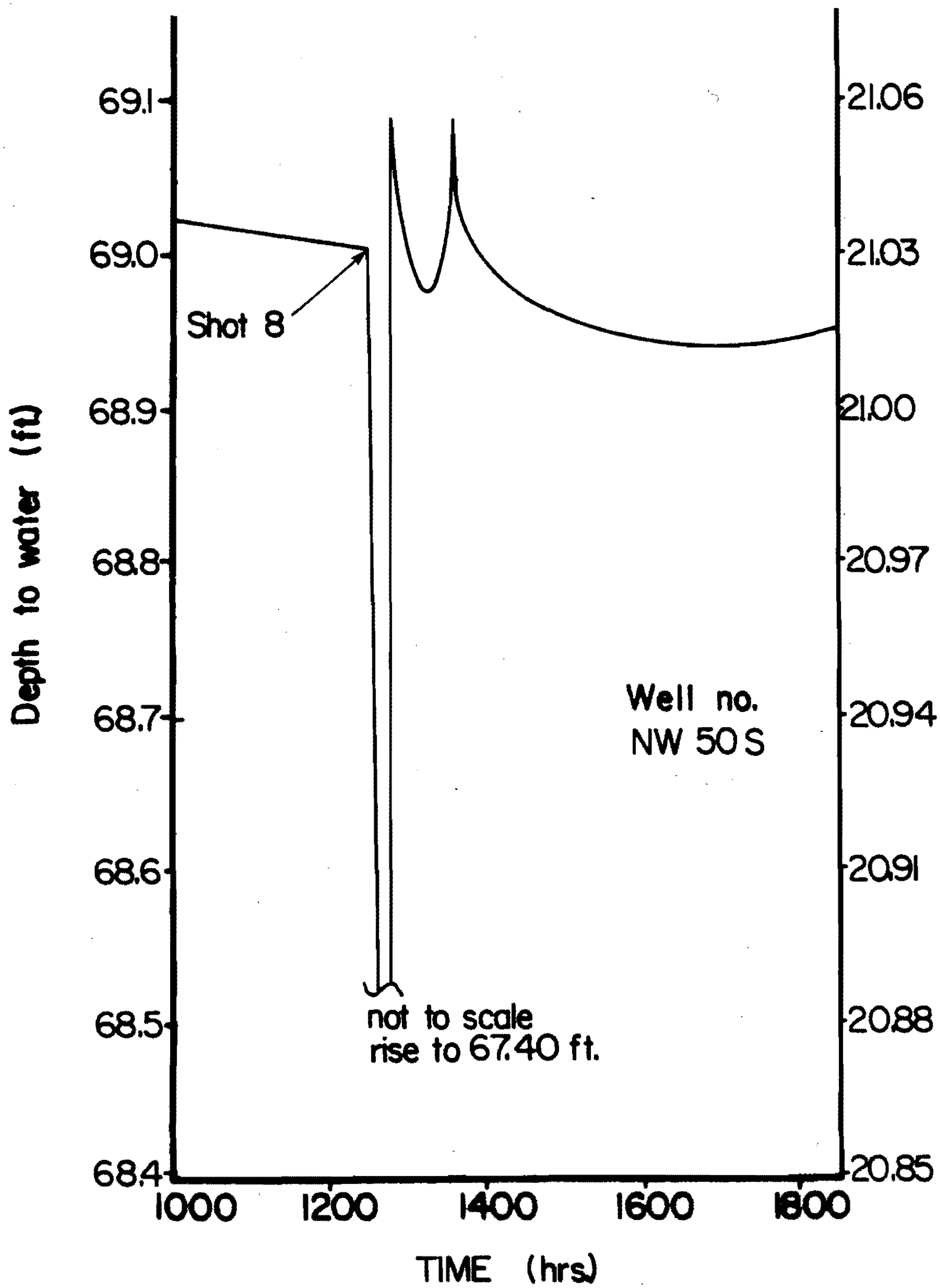
Well no. NEC 50 S
69.6
69.5
Shot 2
Shot 3
Shot 4
Shot 5
Shot 6
Shot 7
1000
1200
1400
1600
1800
2000
2200
2400
Time (hrs.)
8/8/83
Depth to water (ft.)
Well no. NEC 50 C
70.7
70.6
70.5
70.4
Shot 2
Shot 3
Shot 4
Shot 5
Shot 6
Shot 7
1000
1200
1400
1600
1800
2000
2200
2400



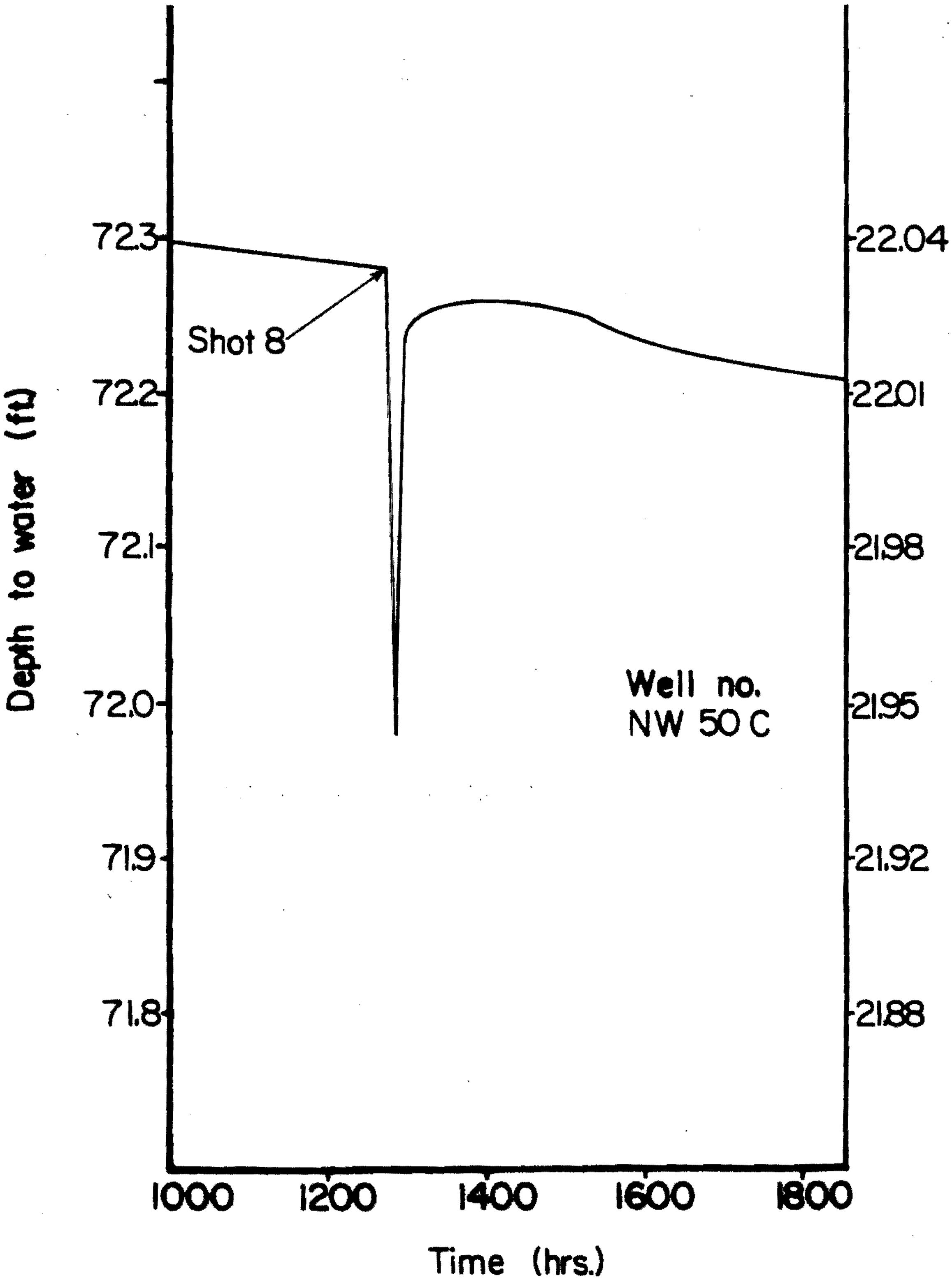
Well no. NEC 100 S
70.7
70.6
Shot 2
Shot 3
Shot 4
Shot 5
Shot 6
Shot 7
1000
1200
1400
1600
1800
2000
2200
2400
Time (hrs.)
8/8/83
Depth to water (ft.)
71.7
71.6
71.5
71.4
Well no. NEC 100 C
Shot 2
Shot 3
Shot 4
Shot 5
Shot 6
Shot 7
1000
1200
1400
1600
1800
2000
2200
2400


Barometric
Pressure
Inches (Hg.)
30.2
30.0
Shot 2
Shot 3
Shot 4
Shot 5
Shot 6
Shot 7
1000
1200
1400
1600
1800
2000
2200
2400
Time (hrs.)
8/8/83

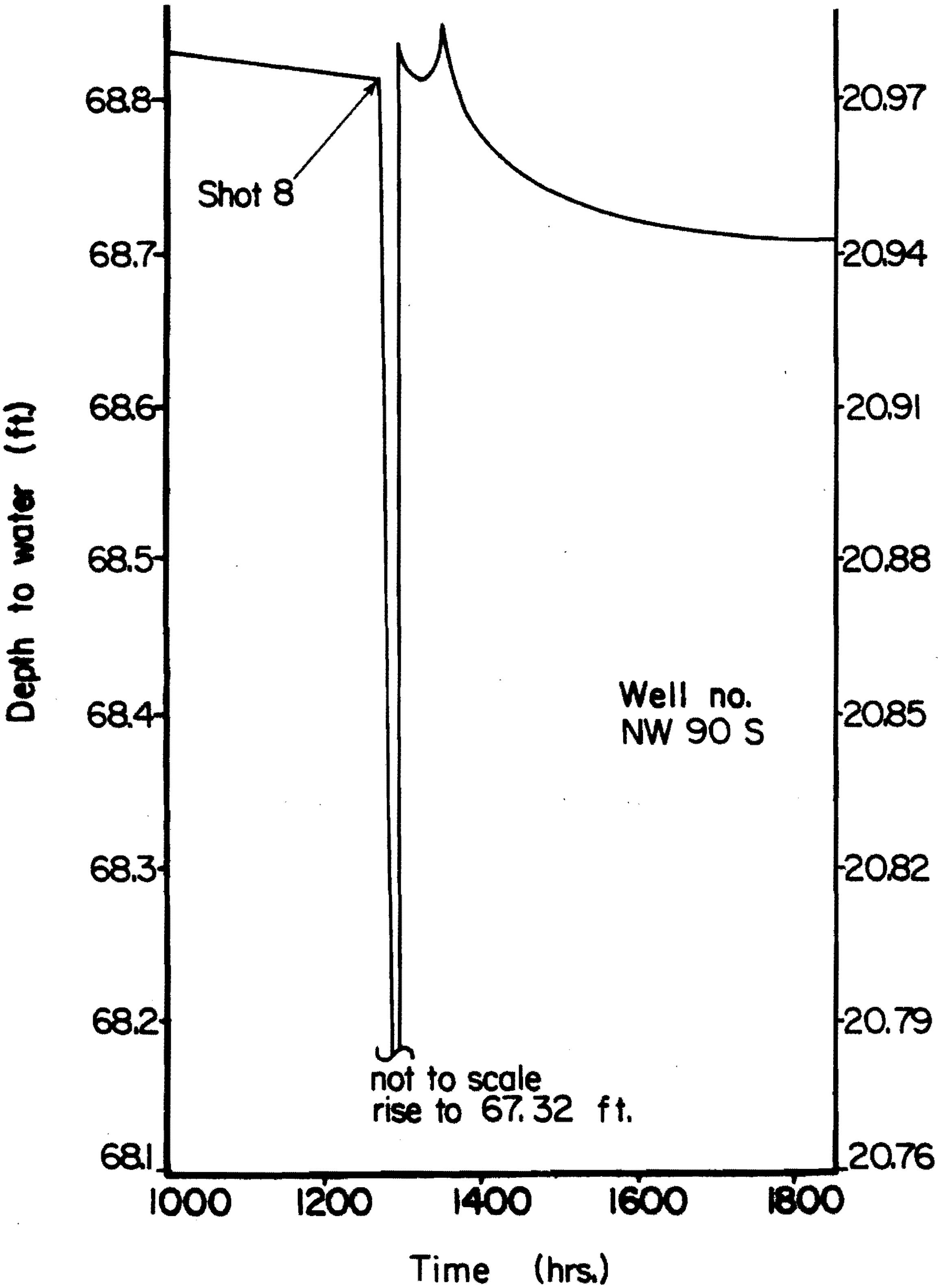

Well no. SPWC
Depth to Water (ft.)
71.8
71.7
71.6
Shot 2
Shot 3
Shot 4
Shot 5
Shot 6
Shot 7
1000
1200
1400
1600
1800
2000
2200
2400



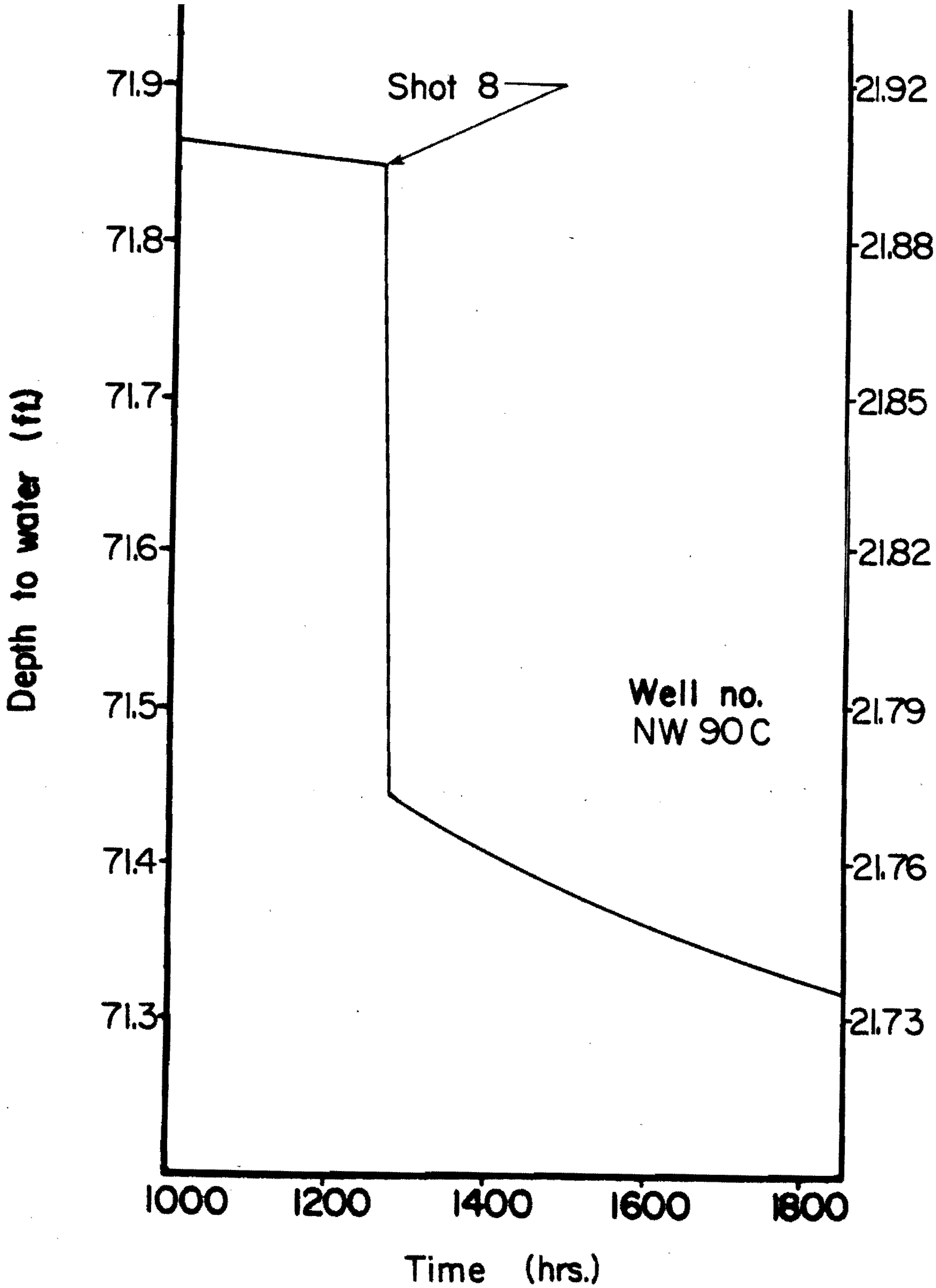
69.1
69.0
68.9
68.8
68.7
68.6
68.5
68.4
21.06
21.03
21.00
20.97
20.94
20.91
20.88
20.85
Shot 8
not to scale
rise to 67.40 ft.
Well no.
NW 50 S
Depth to water (ft)
1000
1200
1400
1600
1800
TIME (hrs)

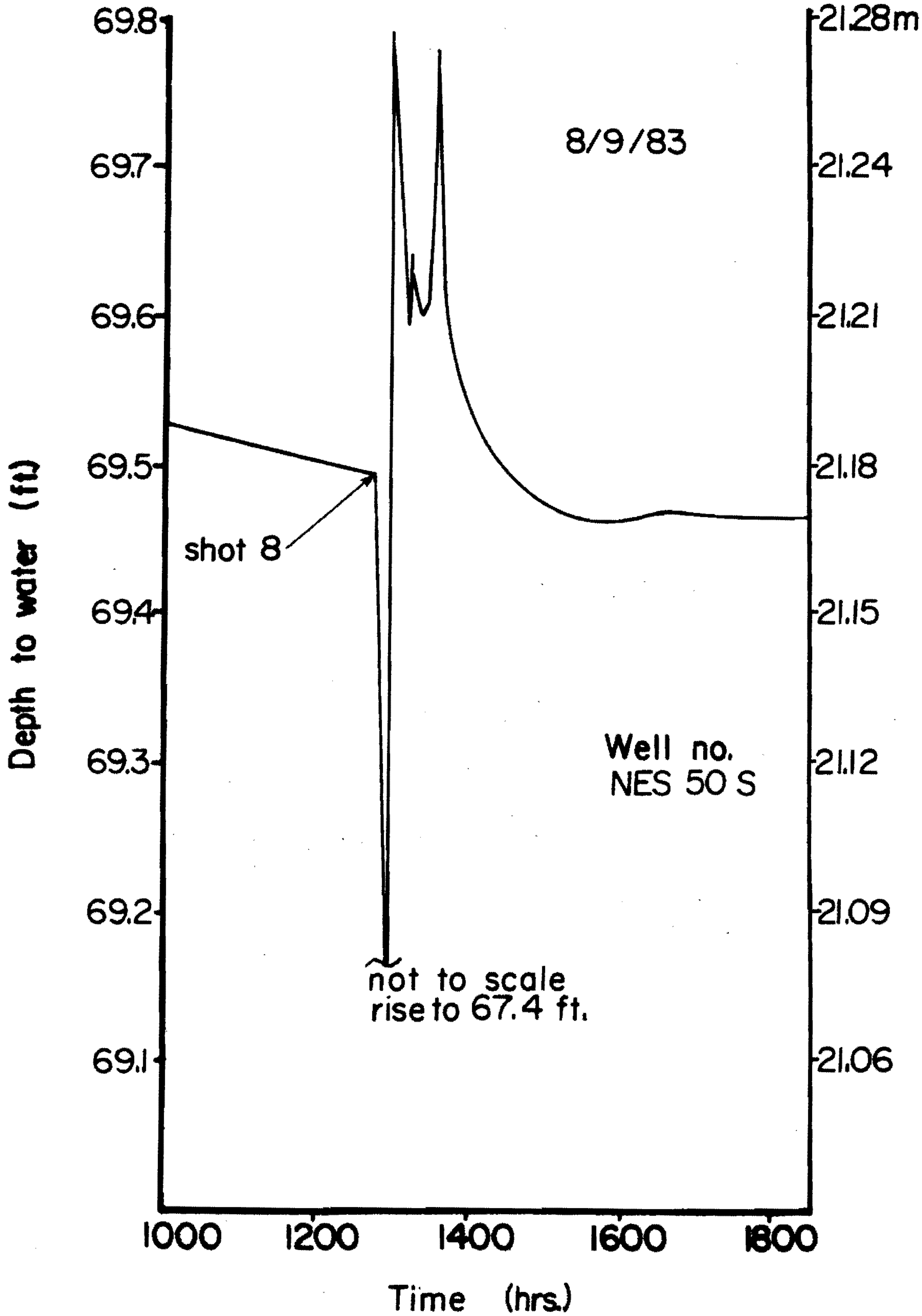


72.3
72.2
72.1
72.0
71.9
71.8
22.04
22.01
21.98
21.95
21.92
21.88
Shot 8
Depth to water (ft.)
Well no.
NW 50 C
1000
1200
1400
1600
1800
Time (hrs.)

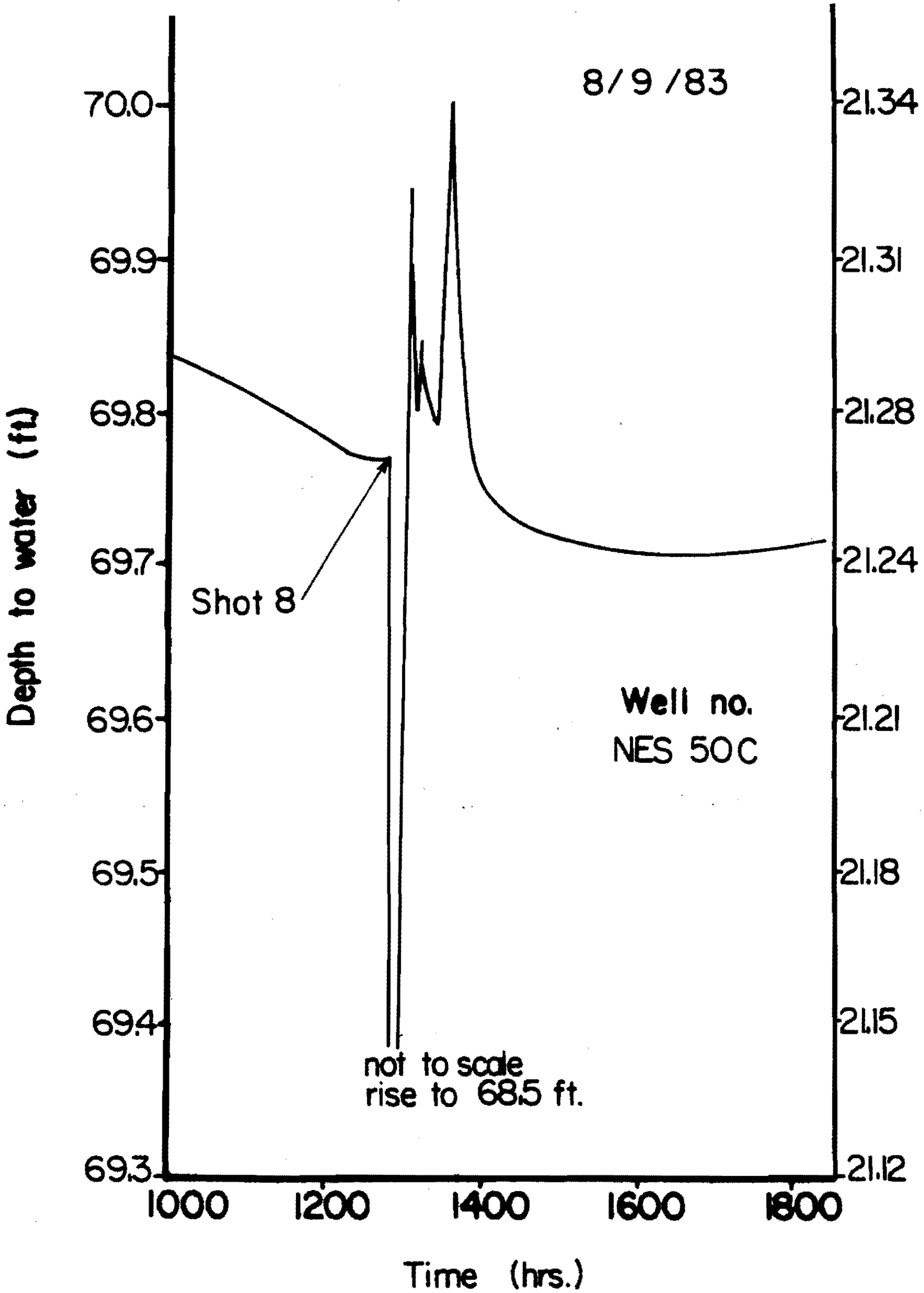


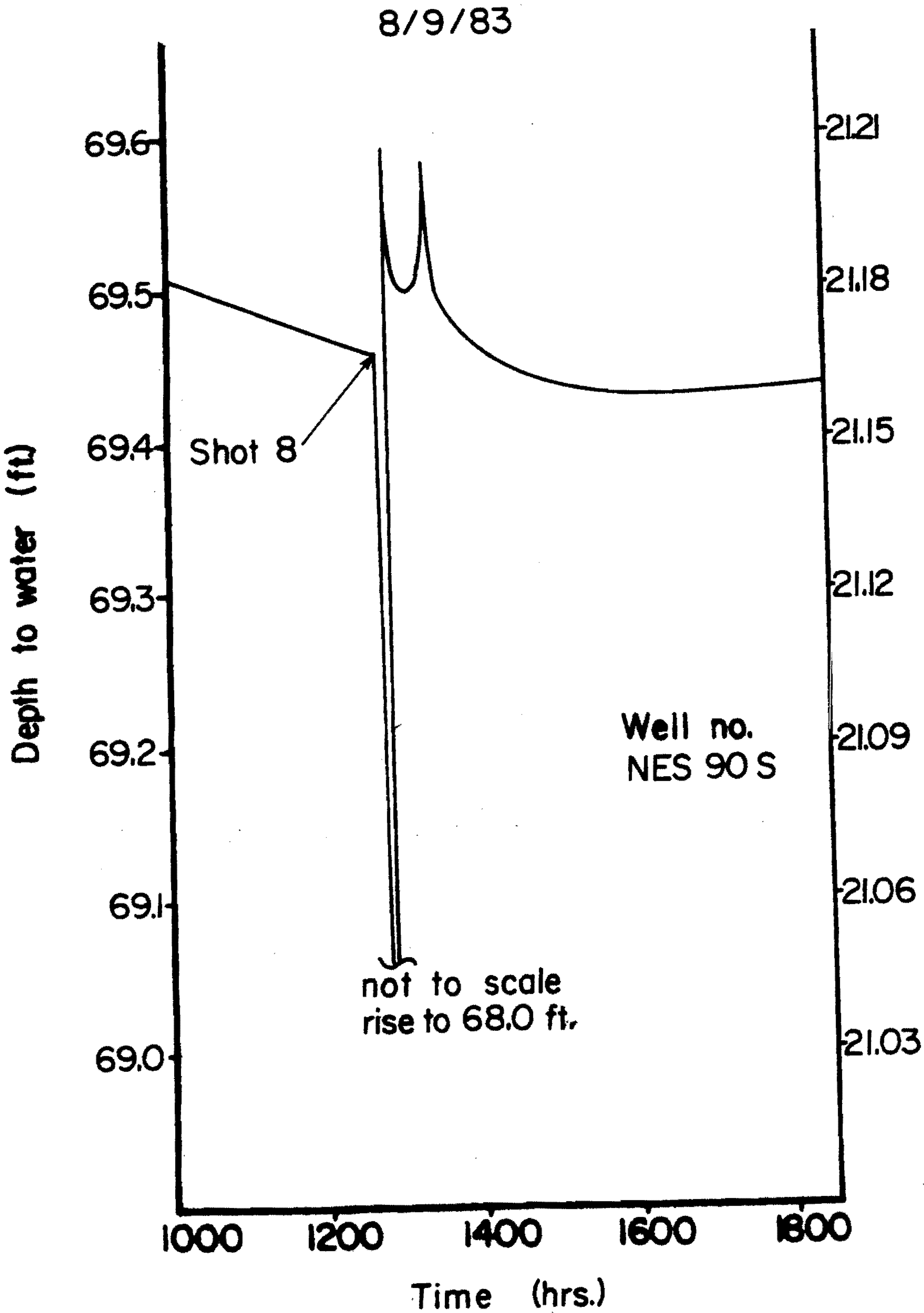
Shot 8
68.8
68.7
68.6
68.5
68.4
68.3
68.2
68.1
20.97
20.94
20.91
20.88
20.85
20.82
20.79
20.76
Depth to water (ft.)
Well no.
NW 90 S
not to scale
rise to 67.32 ft.
1000
1200
1400
1600
1800
Time (hrs.)

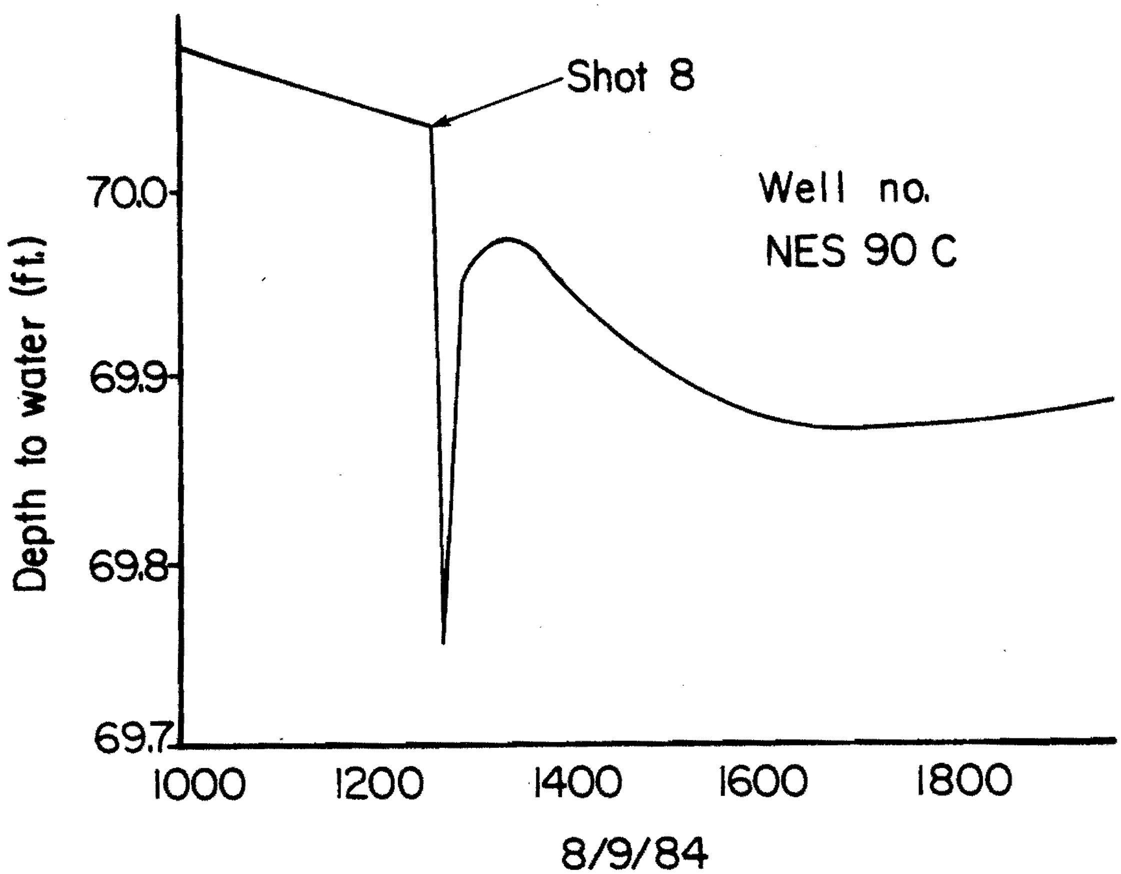

Shot 8
71.9
71.8
71.7
71.6
71.5
71.4
71.3
21.92
21.88
21.85
21.82
21.79
21.76
21.73
Depth to water (ft)
Well no.
NW 90C
1000
1200
1400
1600
1800
Time (hrs.)

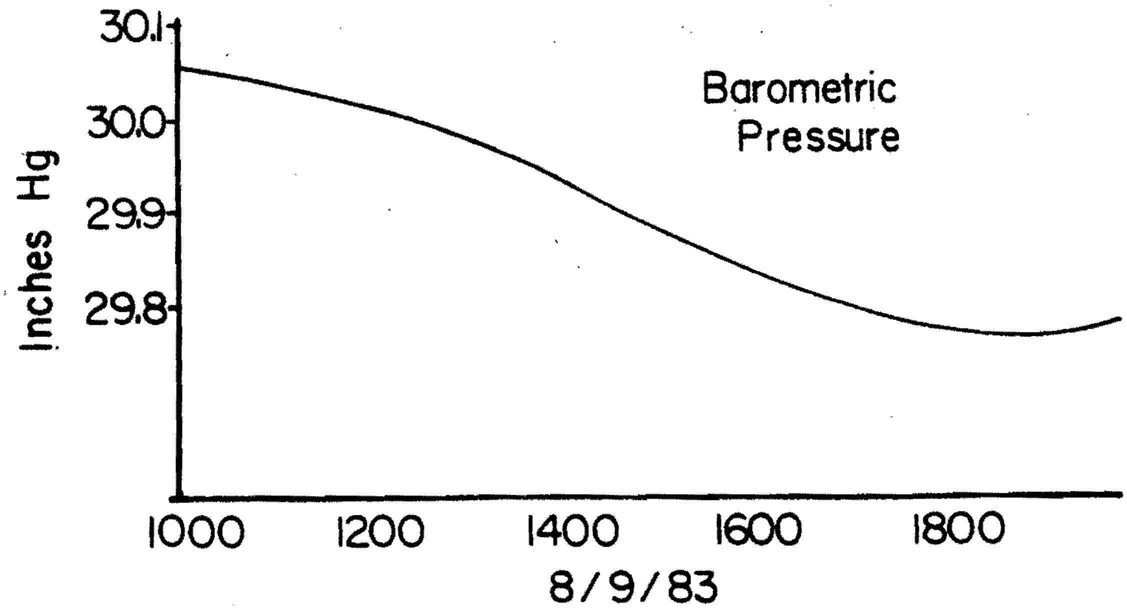


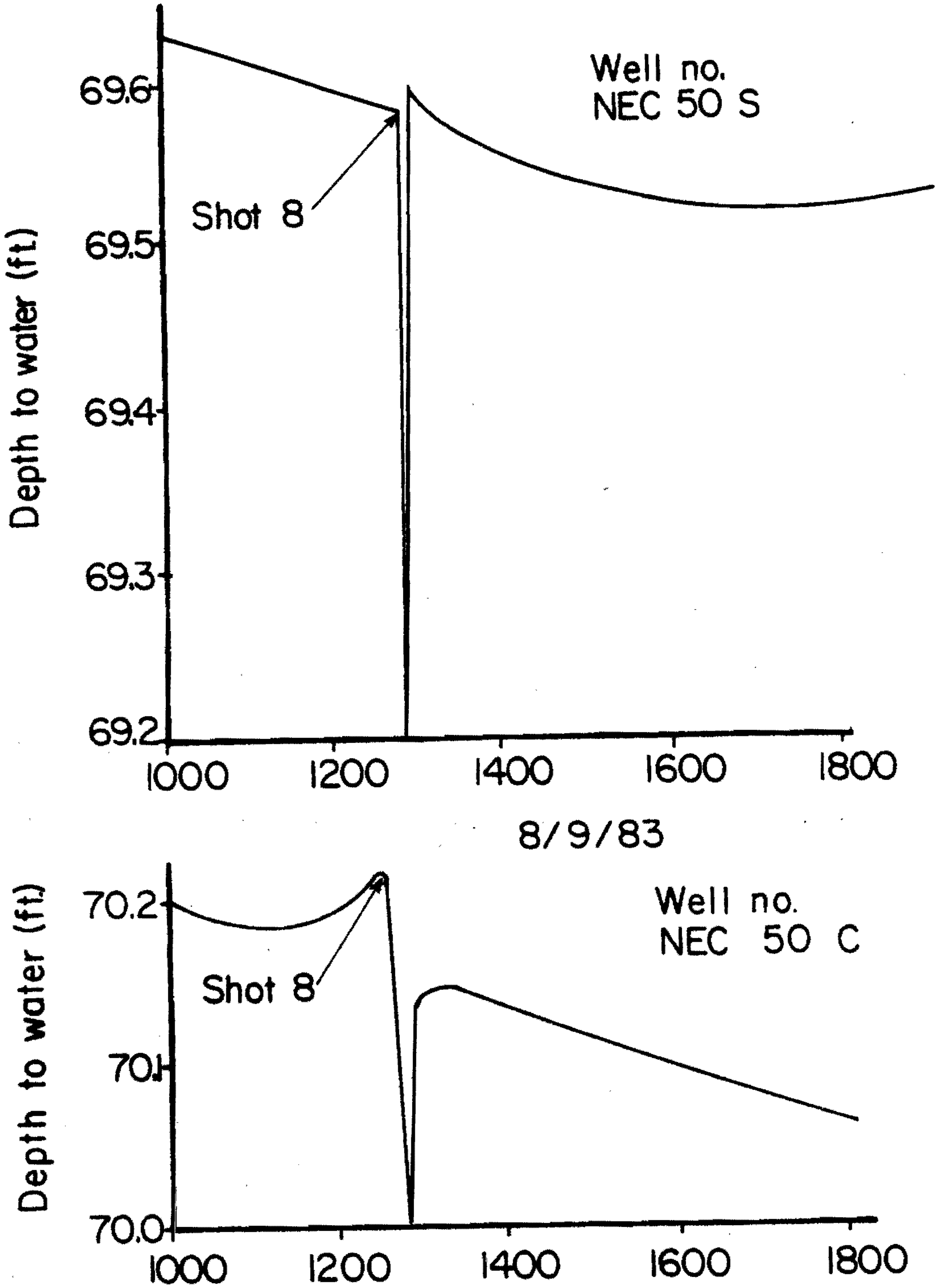
69.8
69.7
69.6
69.5
69.4
69.3
69.2
69.1
Depth to water (ft)
21.28m
21.24
21.21
21.18
21.15
21.12
21.09
21.06
8/9/83
shot 8
Well no.
NES 50 S
not to scale
rise to 67.4 ft.
1000
1200
1400
1600
1800
Time (hrs.)


8/9/83
70.0
69.9
69.8
69.7
69.6
69.5
69.4
69.3
21.34
21.31
21.28
21.24
21.21
21.18
21.15
21.12
Depth to water (ft)
Shot 8
Well no.
NES 50C
not to scale
rise to 68.5 ft.
1000
1200
1400
1600
1800
Time (hrs.)

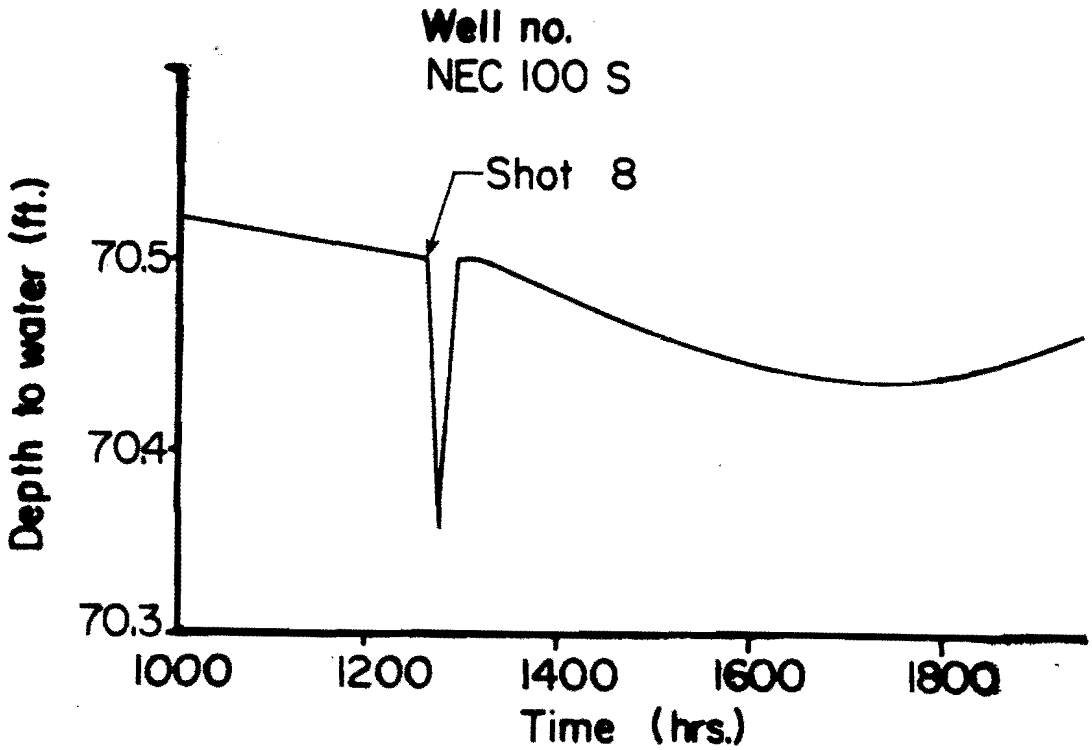

8/9/83
69.6
69.5
69.4
69.3
69.2
69.1
69.0
Depth to water (ft.)
21.21
21.18
21.15
21.12
21.09
21.06
21.03
Shot 8
not to scale
rise to 68.0 ft.
Well no.
NES 90 S
1000
1200
1400
1600
1800
Time (hrs.)


Shot 8
Well no.
NES 90 C
Depth to water (ft.)
70.0
69.9
69.8
69.7
1000
1200
1400
1600
1800
8/9/84

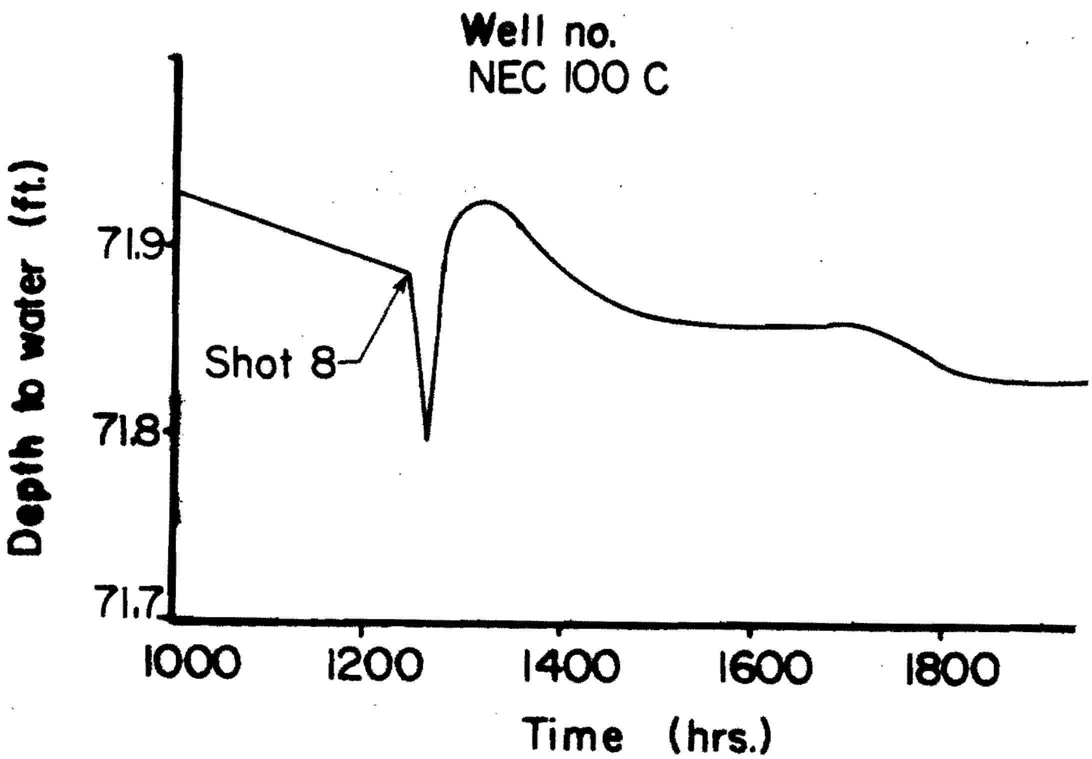

Barometric
Pressure
Inches Hg
30.1
30.0
29.9
29.8
1000
1200
1400
1600
1800
8/9/83

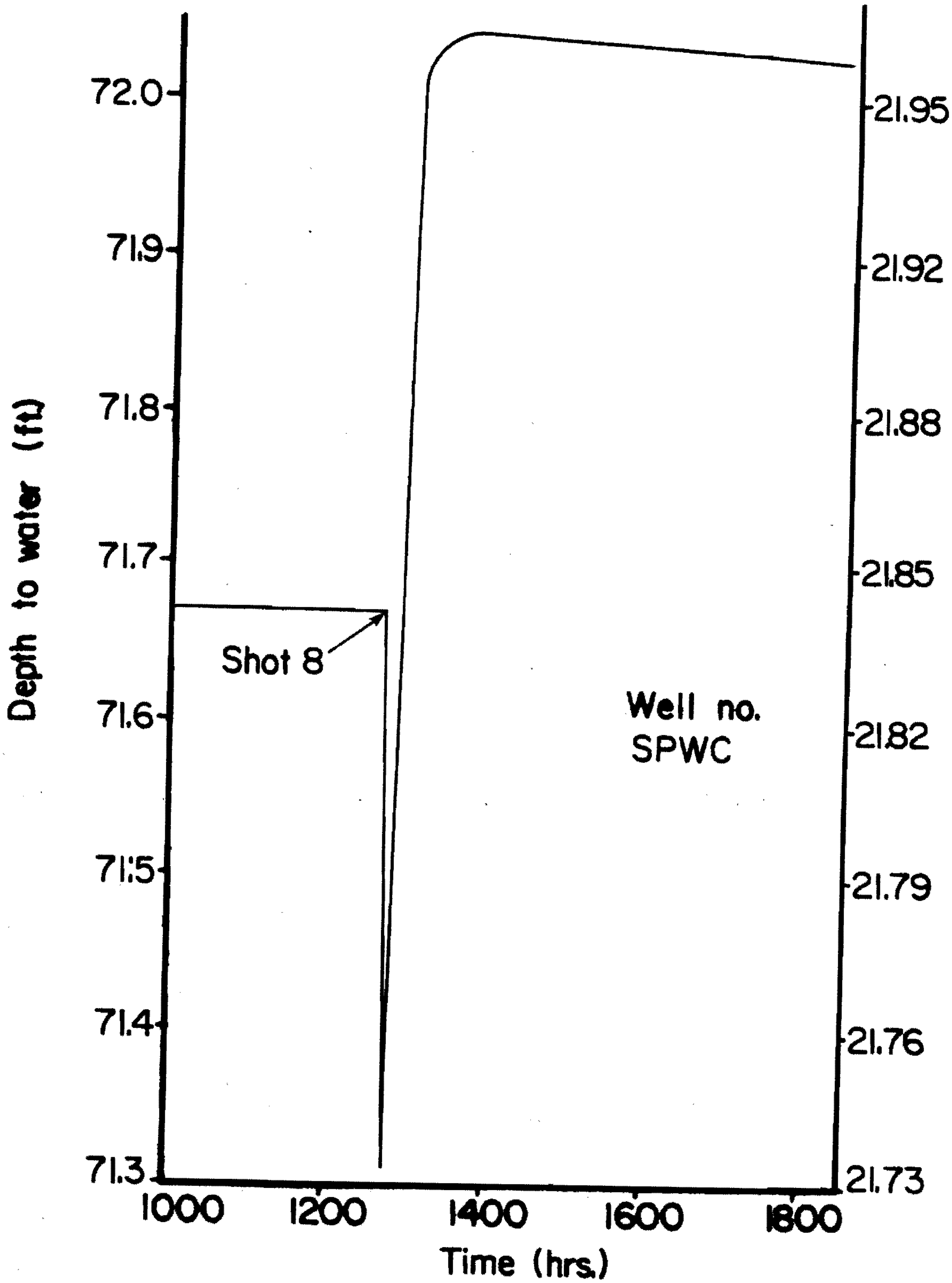


Well no.
NEC 50 S
Shot 8
Depth to water (ft)
69.6
69.5
69.4
69.3
69.2
1000
1200
1400
1600
1800
8/9/83
Well no.
NEC 50 C
Shot 8
Depth to water (ft)
70.2
70.1
70.0
1000
1200
1400
1600
1800


Well no.
NEC 100 S
Shot 8
Depth to water (ft.)
70.5
70.4
70.3
1000
1200
1400
1600
1800
Time (hrs.)

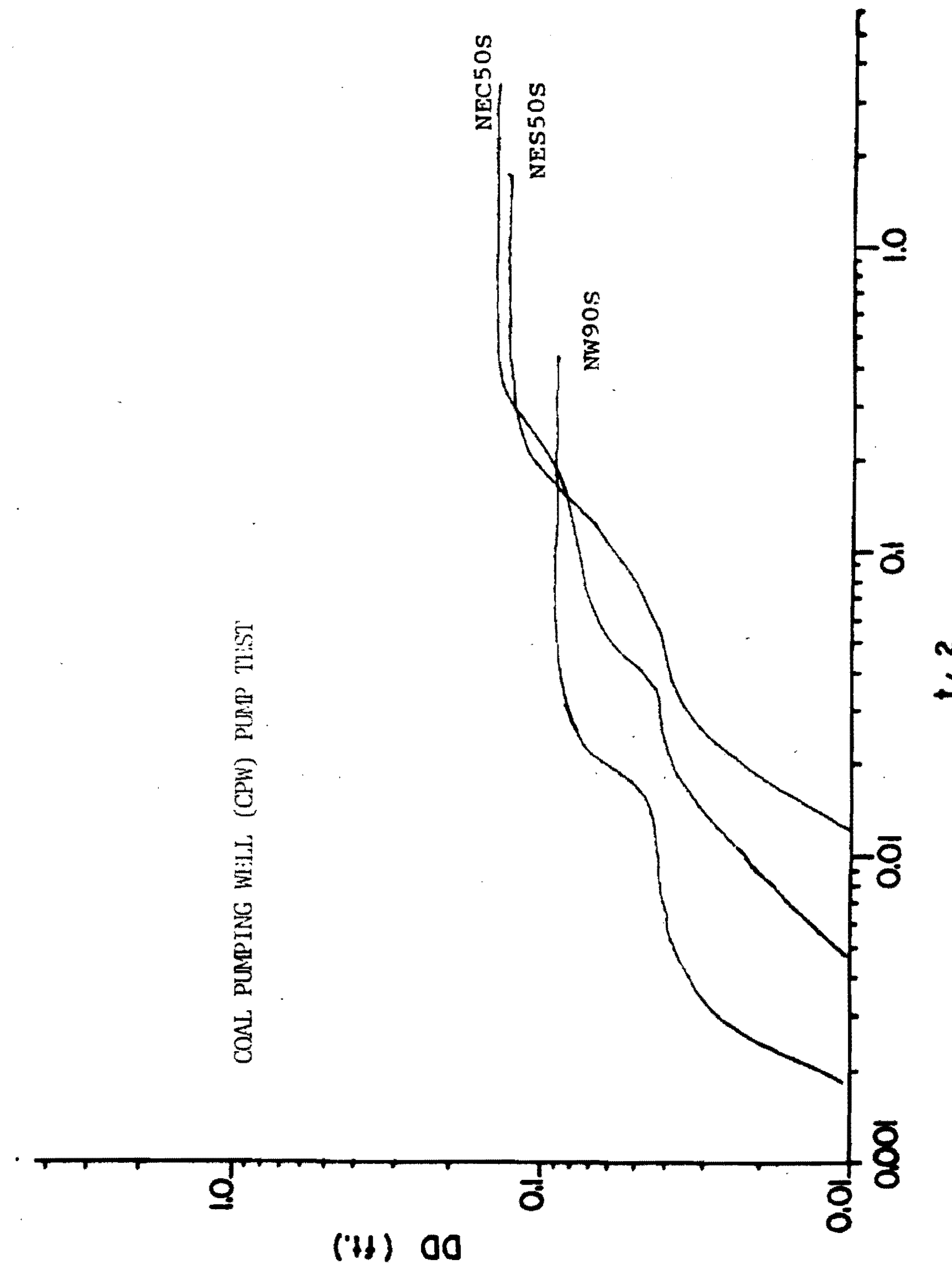
8/9/83

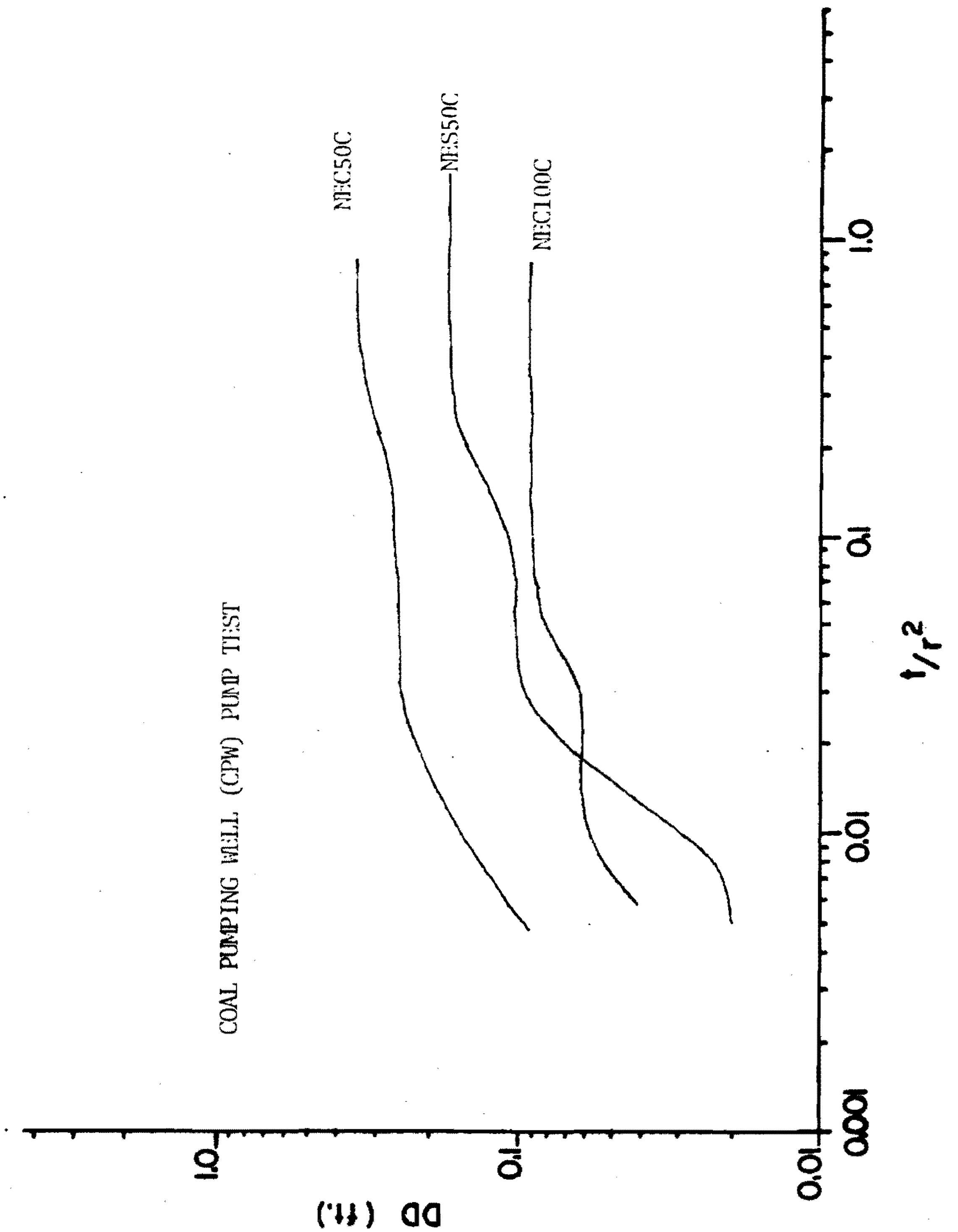

Well no.
NEC 100 C
Shot 8
Depth to water (ft.)
71.9
71.8
71.7
1000
1200
1400
1600
1800
Time (hrs.)


72.0
71.9
71.8
71.7
71.6
71.5
71.4
71.3
Depth to water (ft)
21.95
21.92
21.88
21.85
21.82
21.79
21.76
21.73
Shot 8
Well no.
SPWC
1000
1200
1400
1600
1800
Time (hrs.)

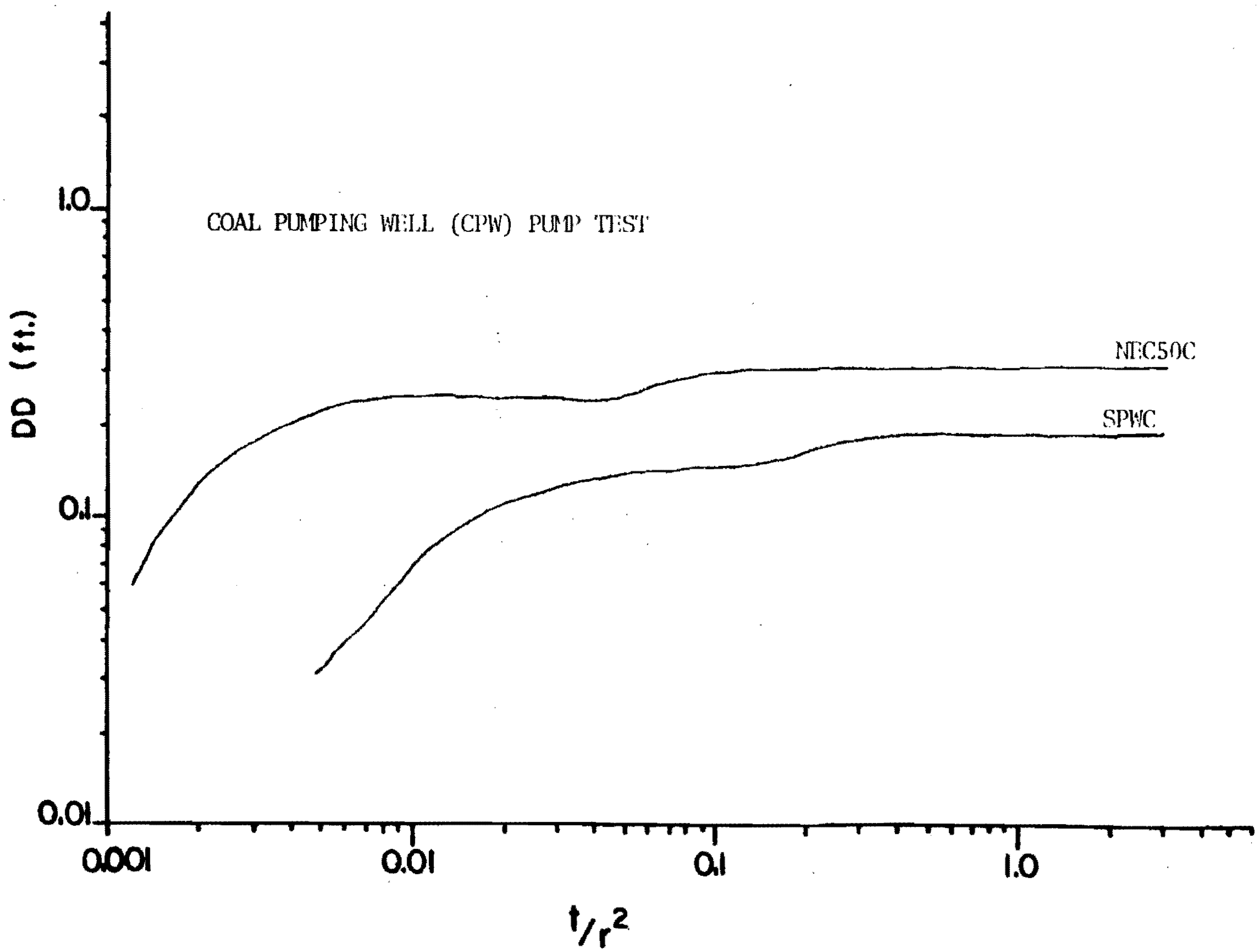
Appendix D

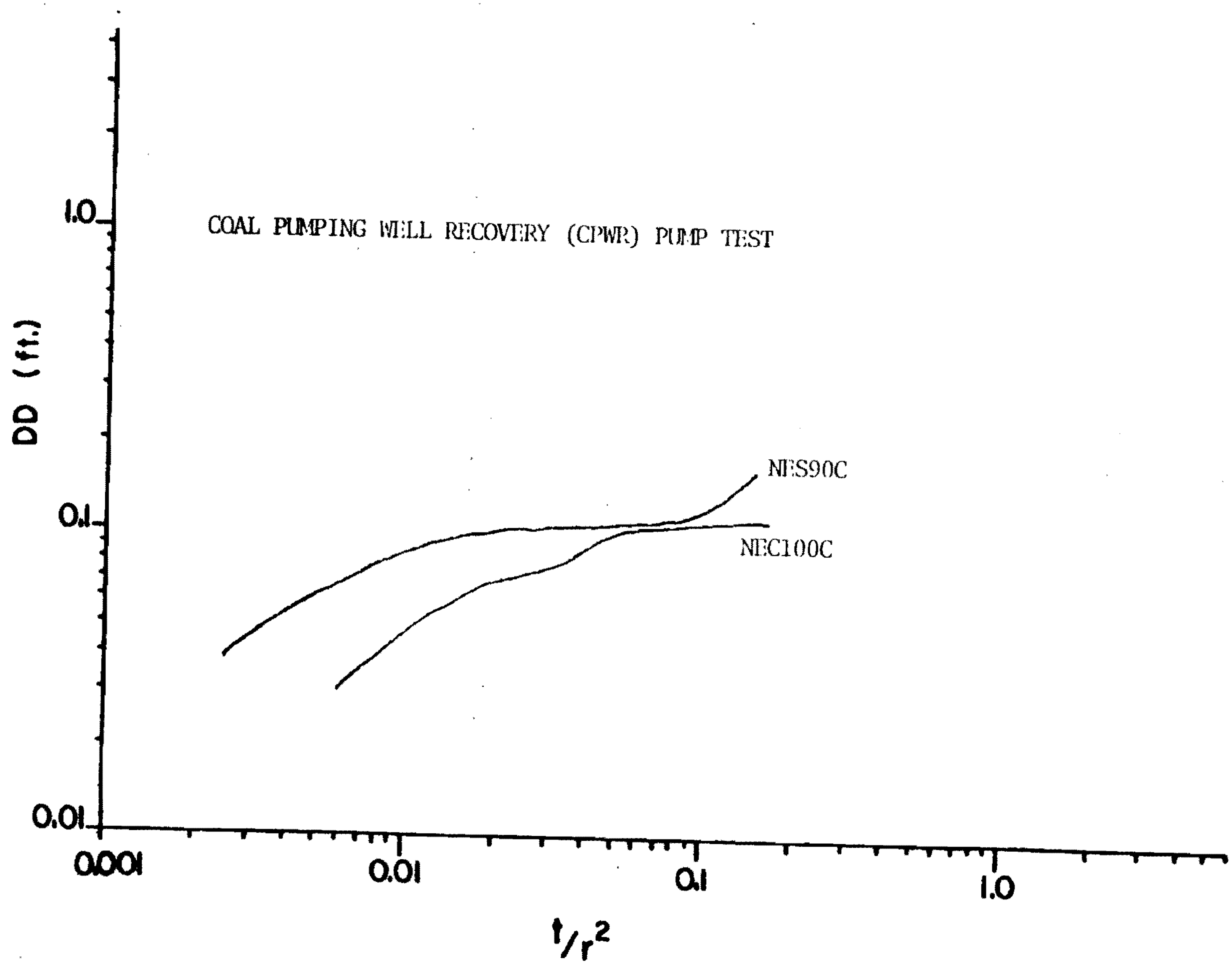
PLOTTED PUMP TEST DATA

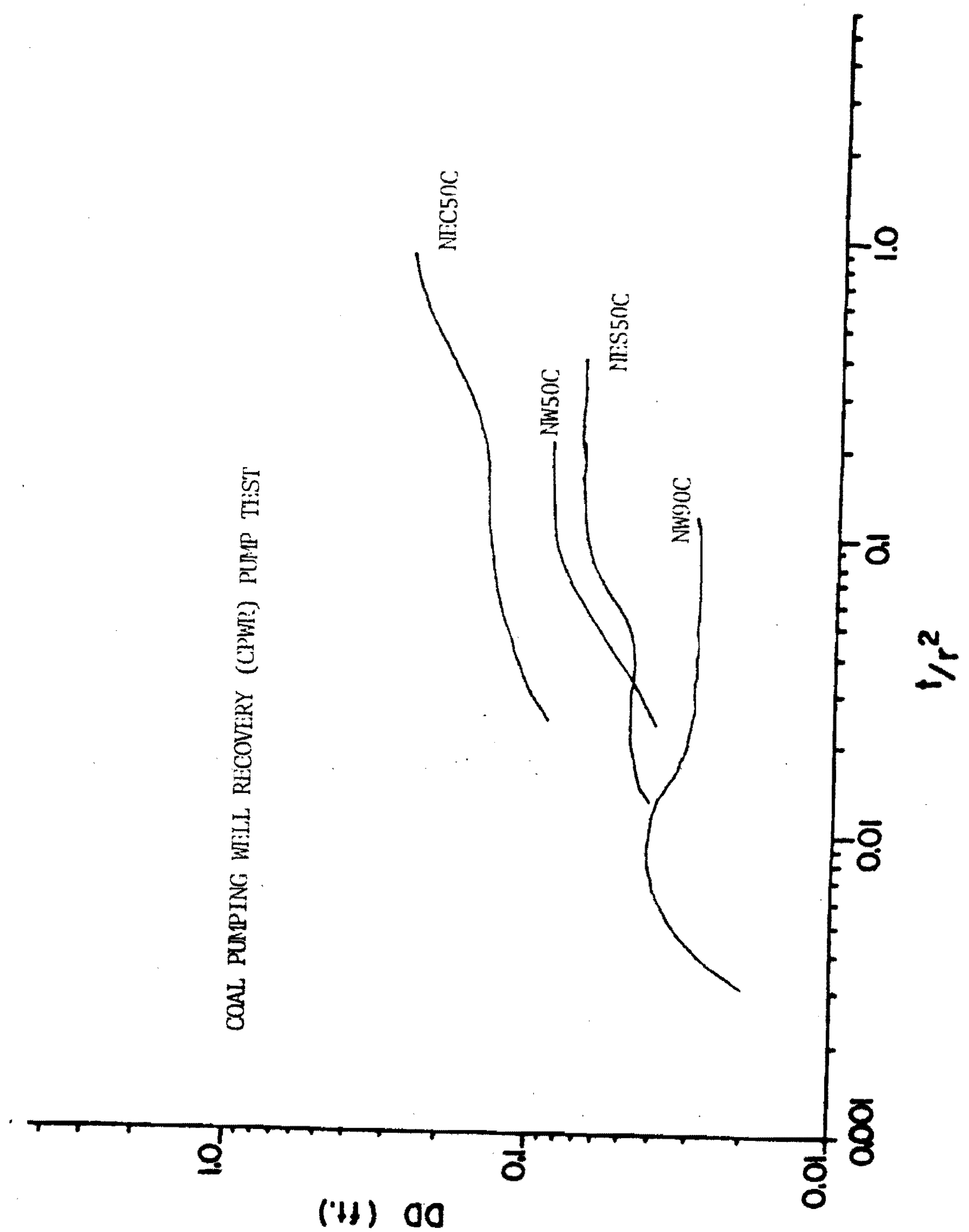

COAL PUMPING WELL (CPW) PUMP TEST
NEC50S
NES50S
NW90S
DD (ft.)
1.0
0.1
0.01
0.001
0.01
0.1
1.0
t/r²

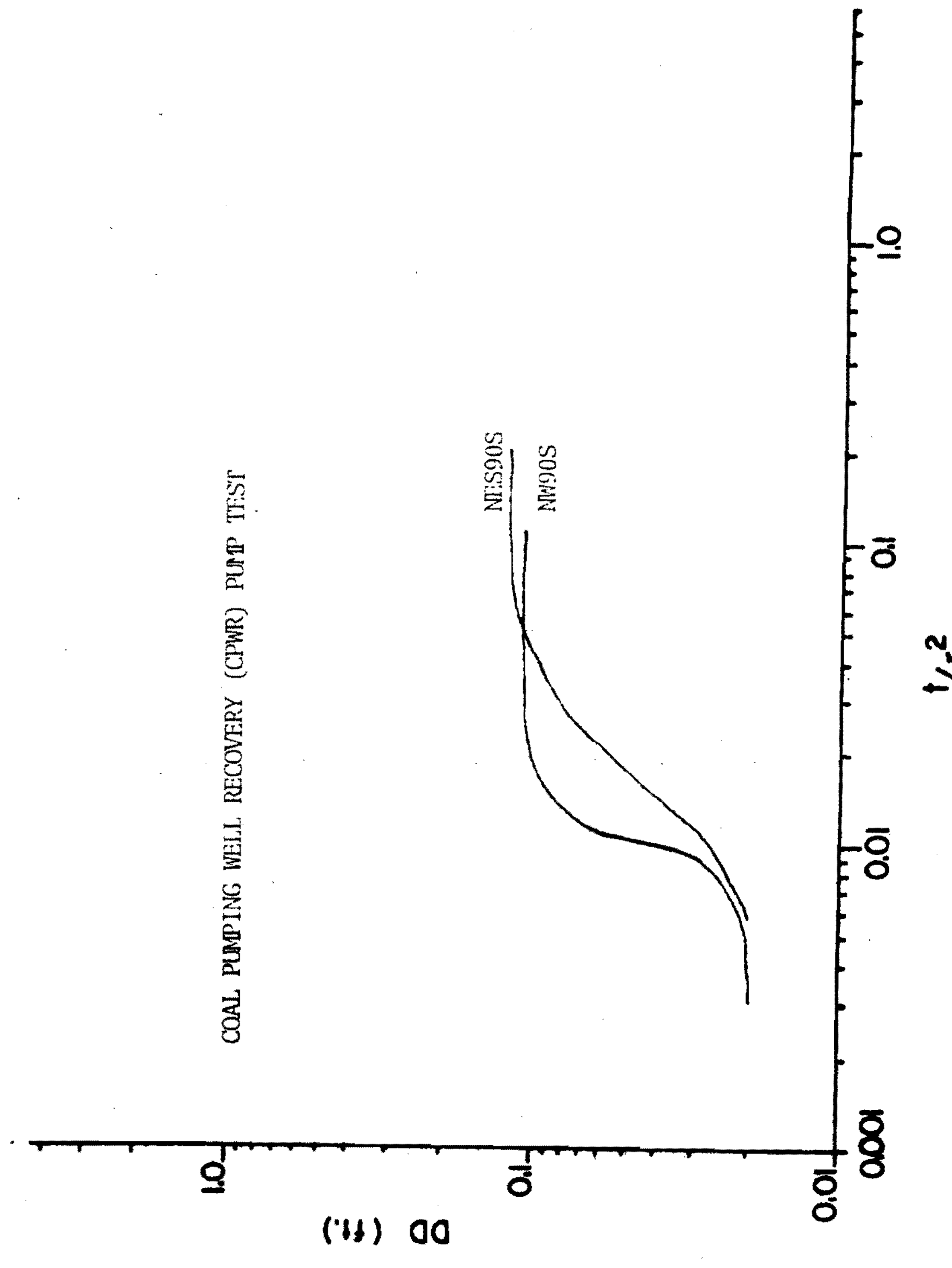


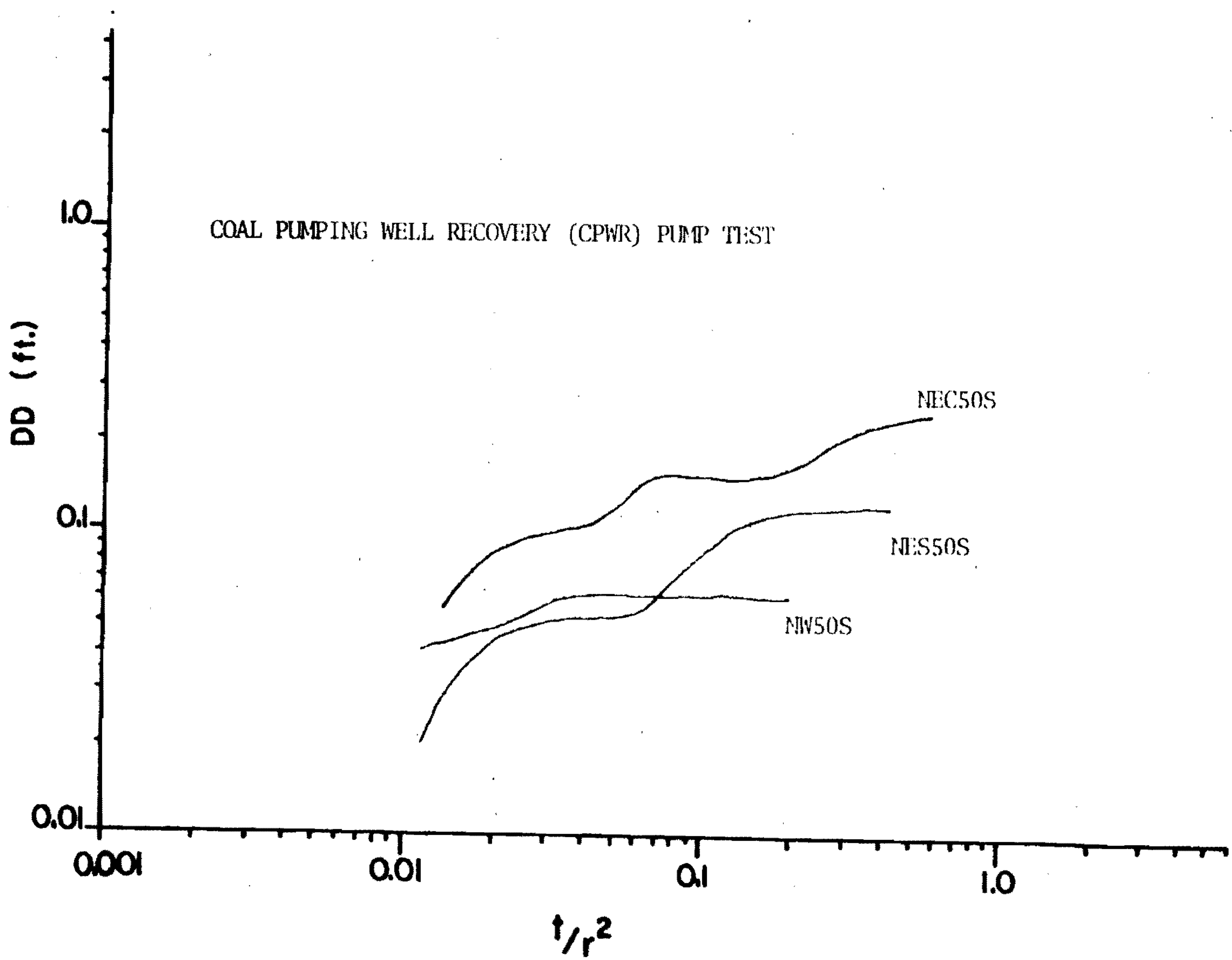
COAL PUMPING WELL (CPW) PUMP TEST
NEC50C
NES50C
NEC100C
DD (ft.)
1.0
0.1
0.01
0.001
0.01
0.1
1.0
t/r²

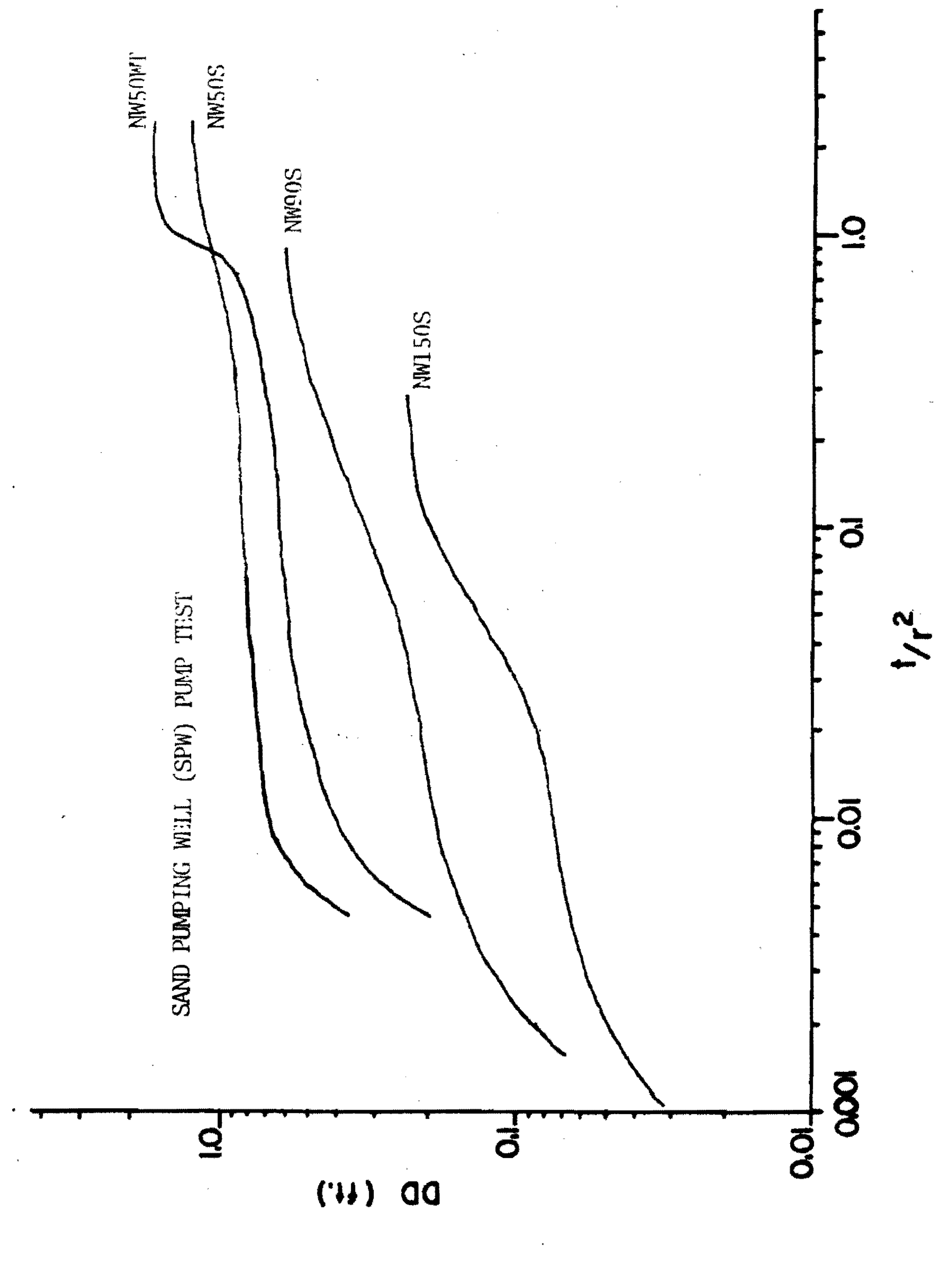

COAL PUMPING WELL (CPW) PUMP TEST
NEC50C
SPWC
DD (ft.)
1.0
0.1
0.01
0.001
0.01
0.1
1.0
t/r2

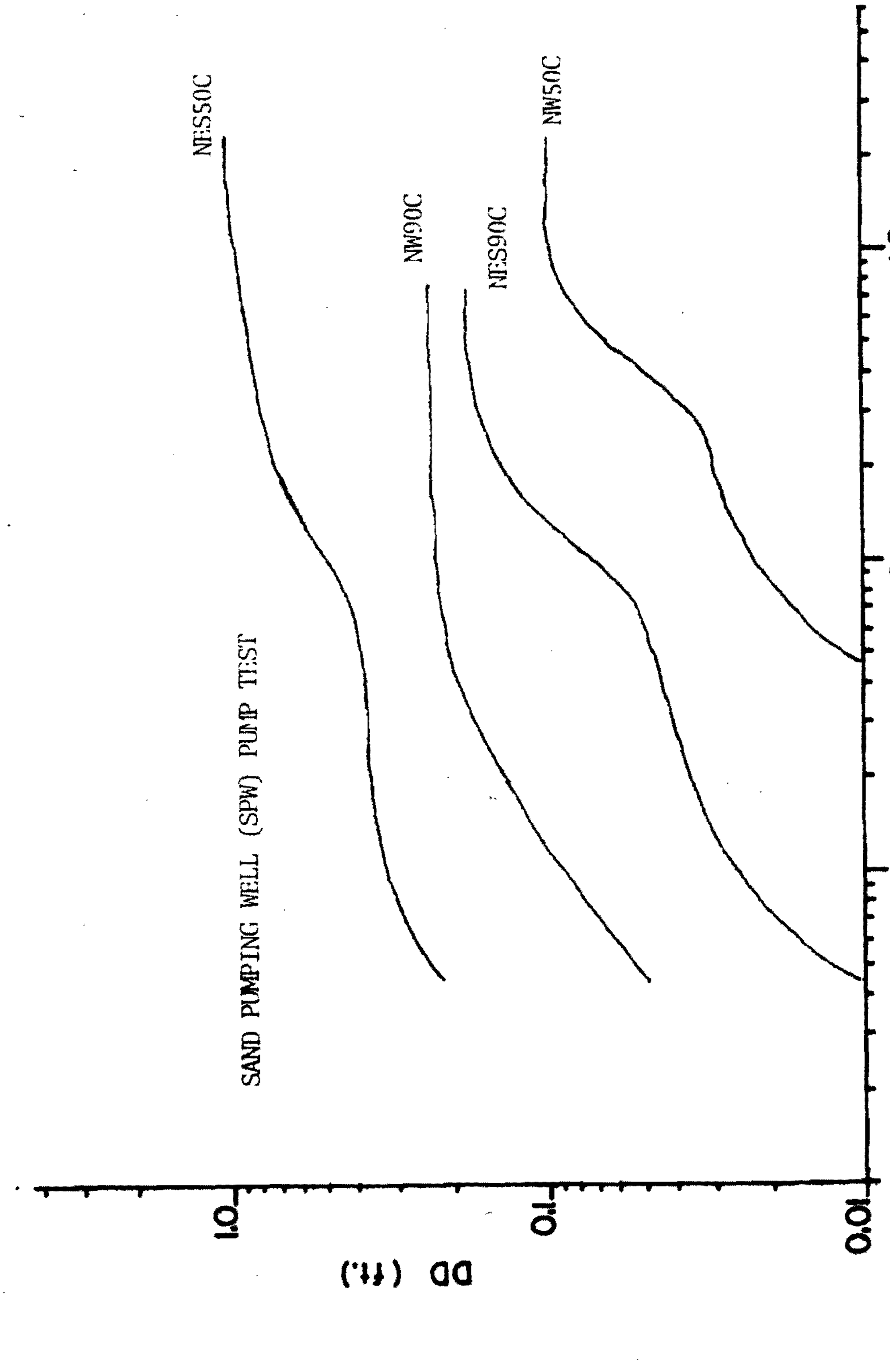

COAL PUMPING WELL RECOVERY (CPWR) PUMP TEST
NES90C
NEC100C
DD (ft.)
1.0
0.1
0.01
0.001
0.01
0.1
1.0
t/r²


COAL PUMPING WELL RECOVERY (CPWR) PUMP TEST
NEC50C
NES50C
NW50C
NW90C
DD (ft.)
0.01
0.1
1.0
0.001
0.01
0.1
1.0
t/r²

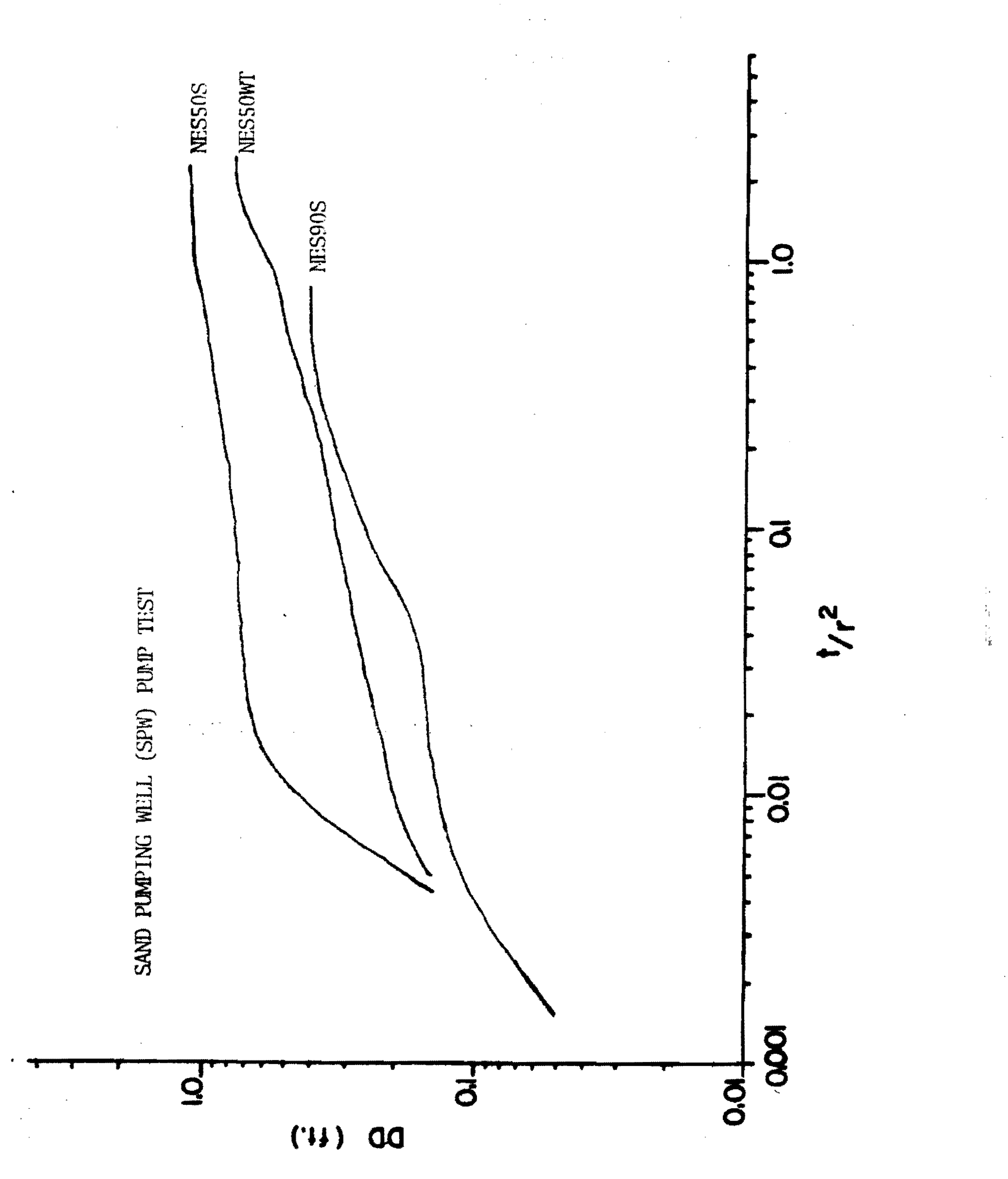

COAL PUMPING WELL RECOVERY (CPWR) PUMP TEST
NES90S
NW90S
DD (ft.)
1.0
0.1
0.01
0.001
0.01
0.1
1.0
t/r²

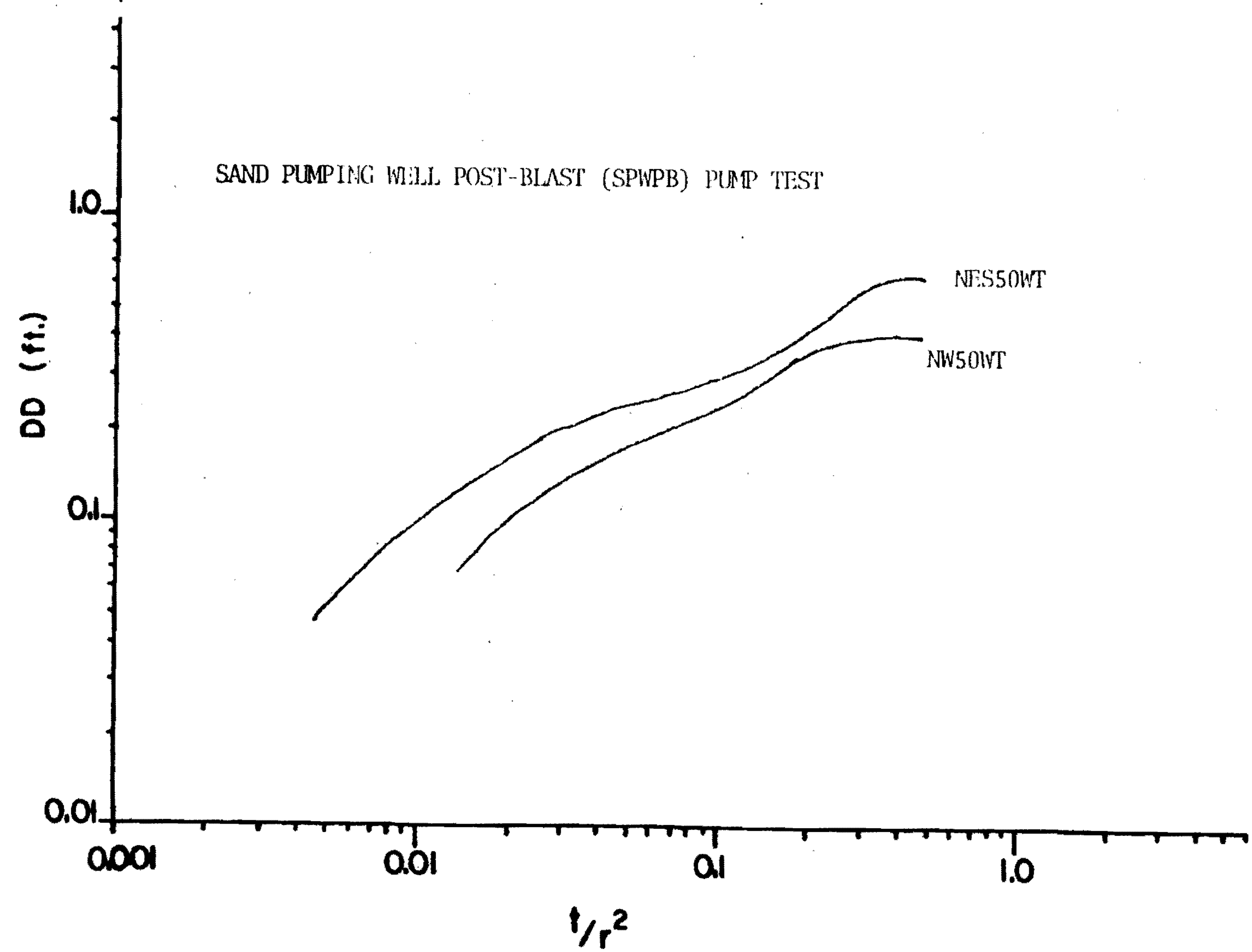

COAL PUMPING WELL RECOVERY (CPWR) PUMP TEST
DD (ft.)
1.0
0.1
0.01
0.001
0.01
0.1
1.0
t/r²
NEC50S
NES50S
NW50S

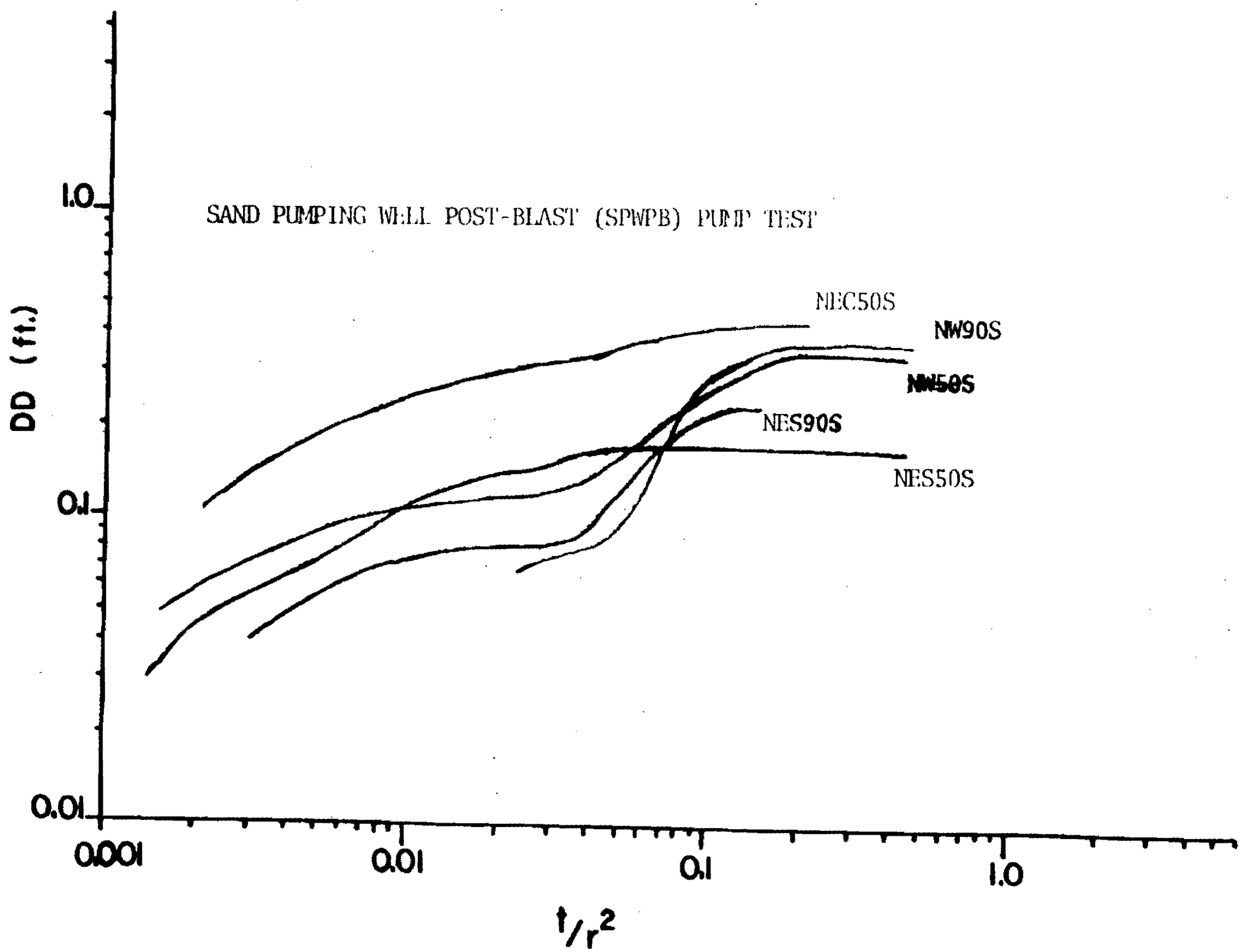

SAND PUMPING WELL (SPW) PUMP TEST
NW50WT
NW50S
NW90S
NW150S
DD (ft.)
1.0
0.1
0.01
0.001
0.01
0.1
1.0
t/r2

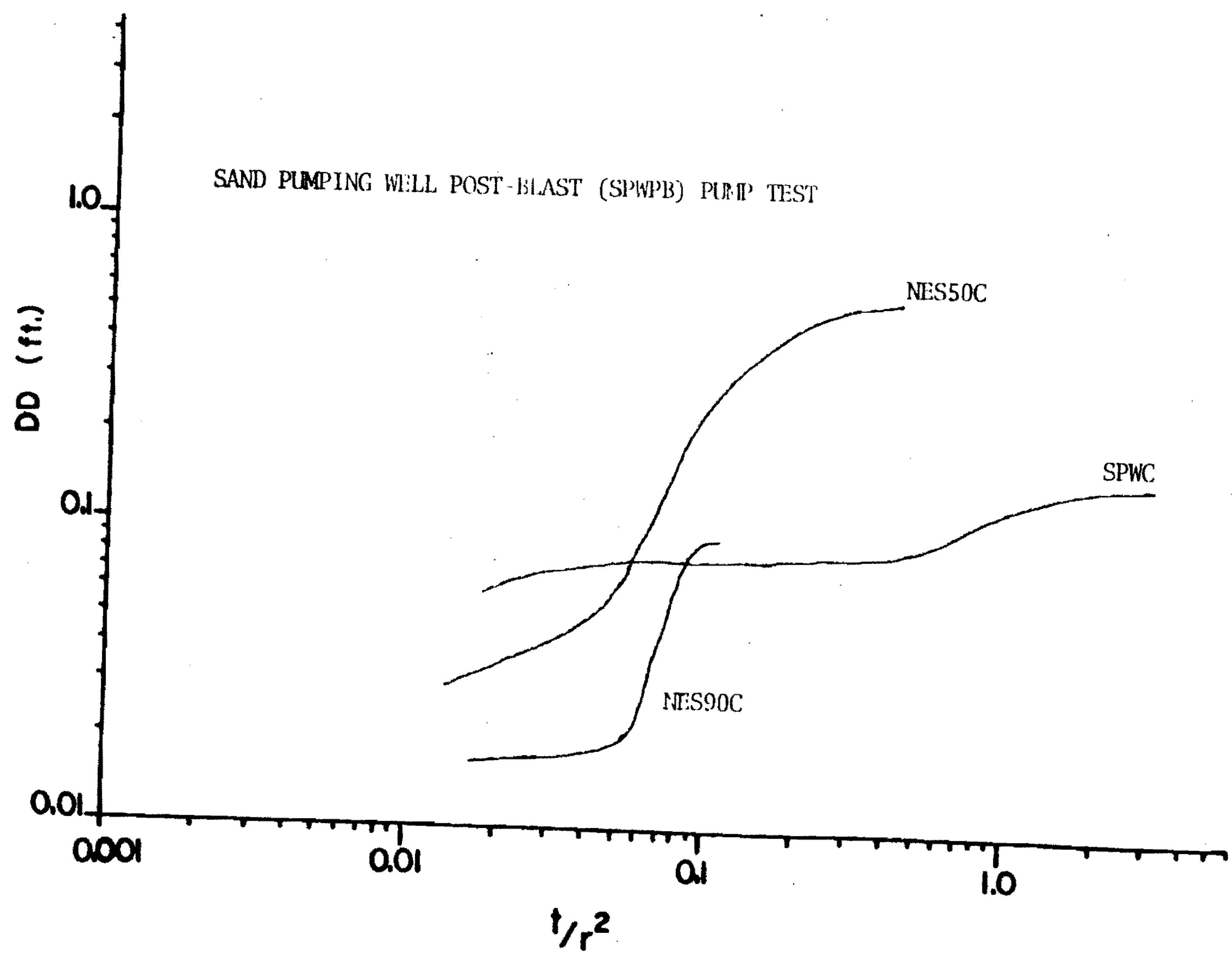


SAND PUMPING WELL (SPW) PUMP TEST
NES50C
NW90C
NES90C
NW50C
DD (ft.)
1.0
0.1
0.01
0.001
0.01
0.1
1.0
t/r²


SAND PUMPING WELL (SPW) PUMP TEST
NES50S
NES50WT
NES90S
DD (ft.)
1.0
0.1
0.01
0.001
0.01
0.1
1.0
t/r²


SAND PUMPING WELL POST-BLAST (SPWPB) PUMP TEST
DD (ft.)
1.0
0.1
0.01
0.001
0.01
0.1
1.0
t/r²
NES50WT
NW50WT


SAND PUMPING WELL POST-BLAST (SPWPB) PUMP TEST
NEC50S
NW90S
NW50S
NES90S
NES50S
DD (ft.)
1.0
0.1
0.01
0.001
0.01
0.1
1.0
t/r²



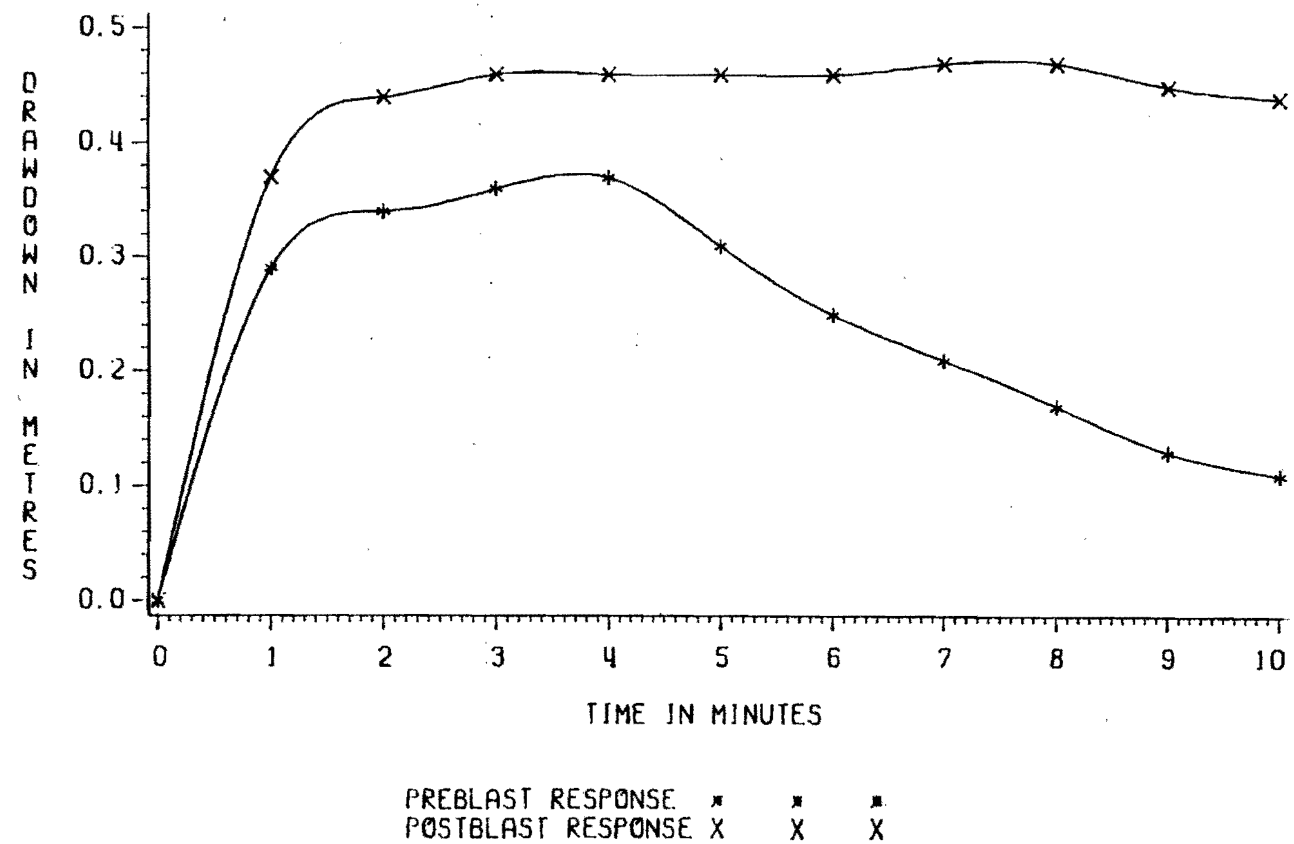
SAND PUMPING WELL POST-BLAST (SPWPB) PUMP TEST
DD (ft.)
1.0
0.1
0.01
0.001
0.01
0.1
1.0
t/r²
NES50C
SPWC
NES90C

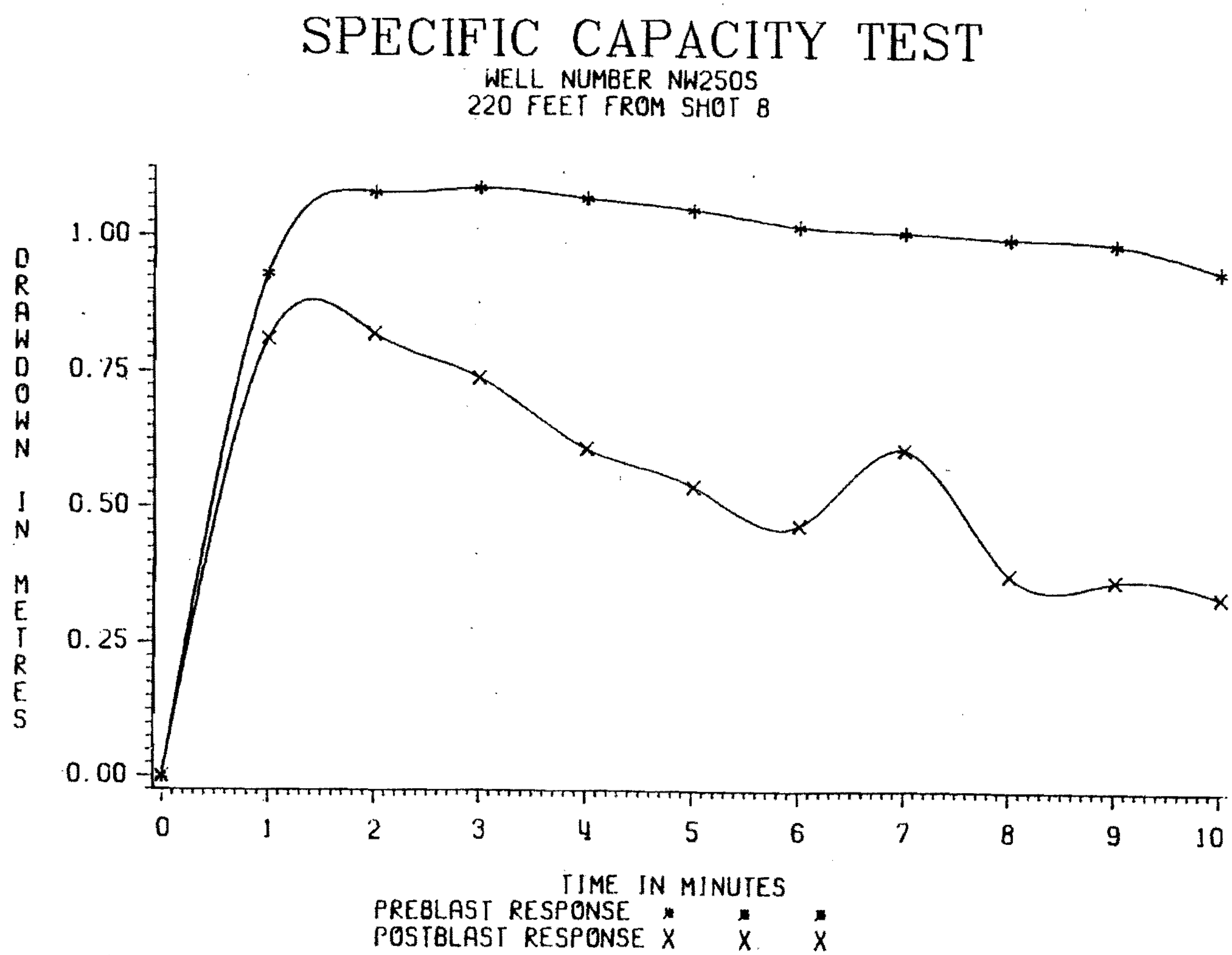
Appendix E

SPECIFIC CAPACITY TEST RESULTS

SPECIFIC CAPACITY TEST

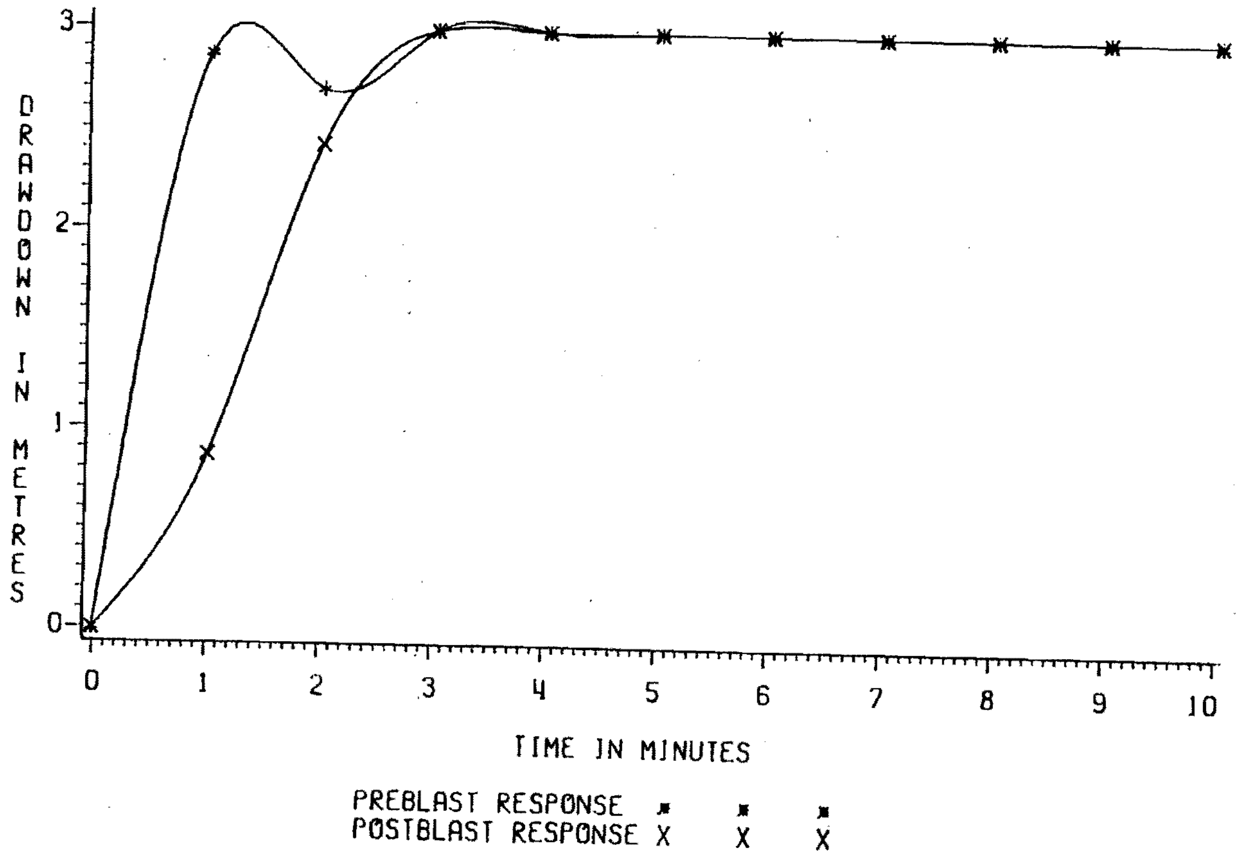
WELL NUMBER NW250C
220 FEET FROM SHOT 8




SPECIFIC CAPACITY TEST
WELL NUMBER NW250S
220 FEET FROM SHOT 8
DRAWDOWN IN METRES
1.00
0.75
0.50
0.25
0.00
0
1
2
3
4
5
6
7
8
9
10
TIME IN MINUTES
PREBLAST RESPONSE * * *
POSTBLAST RESPONSE X X X

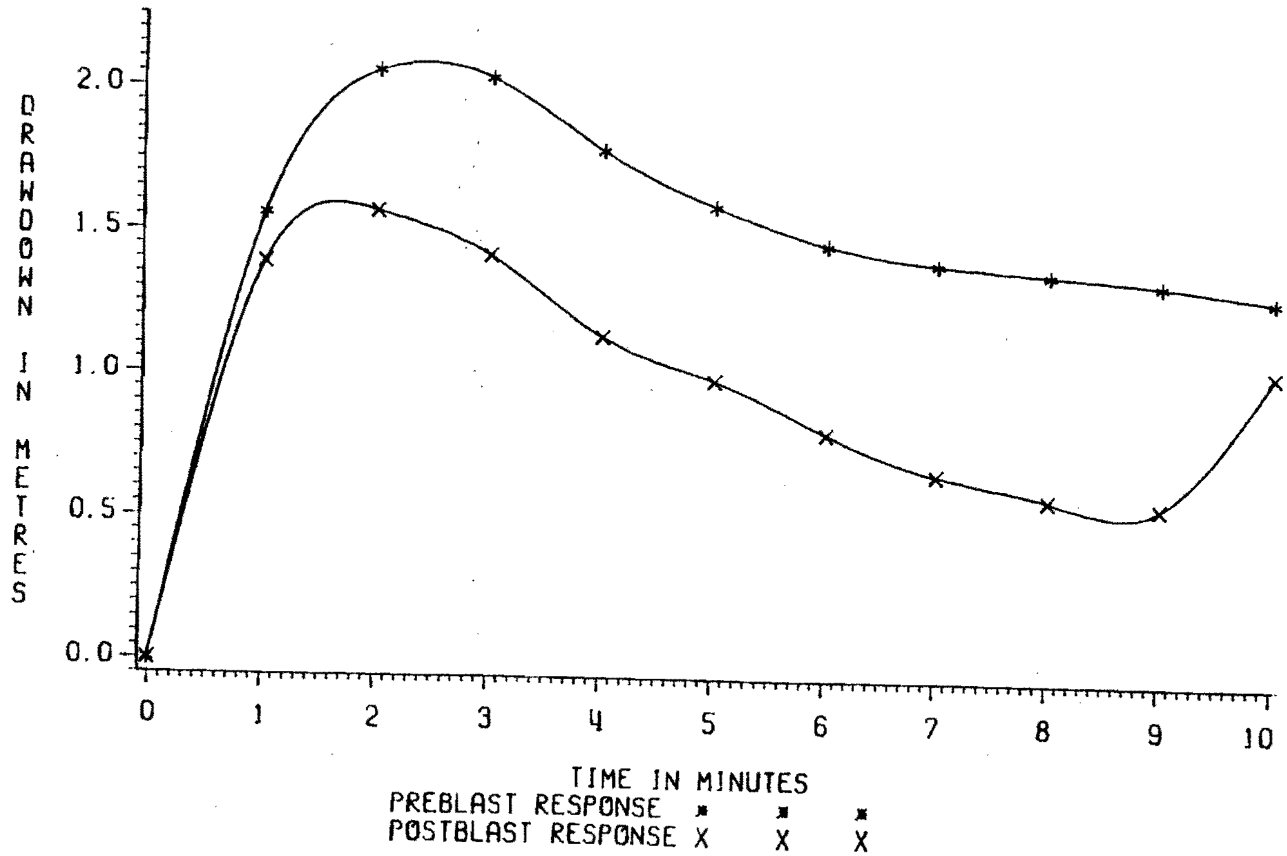
SPECIFIC CAPACITY TEST

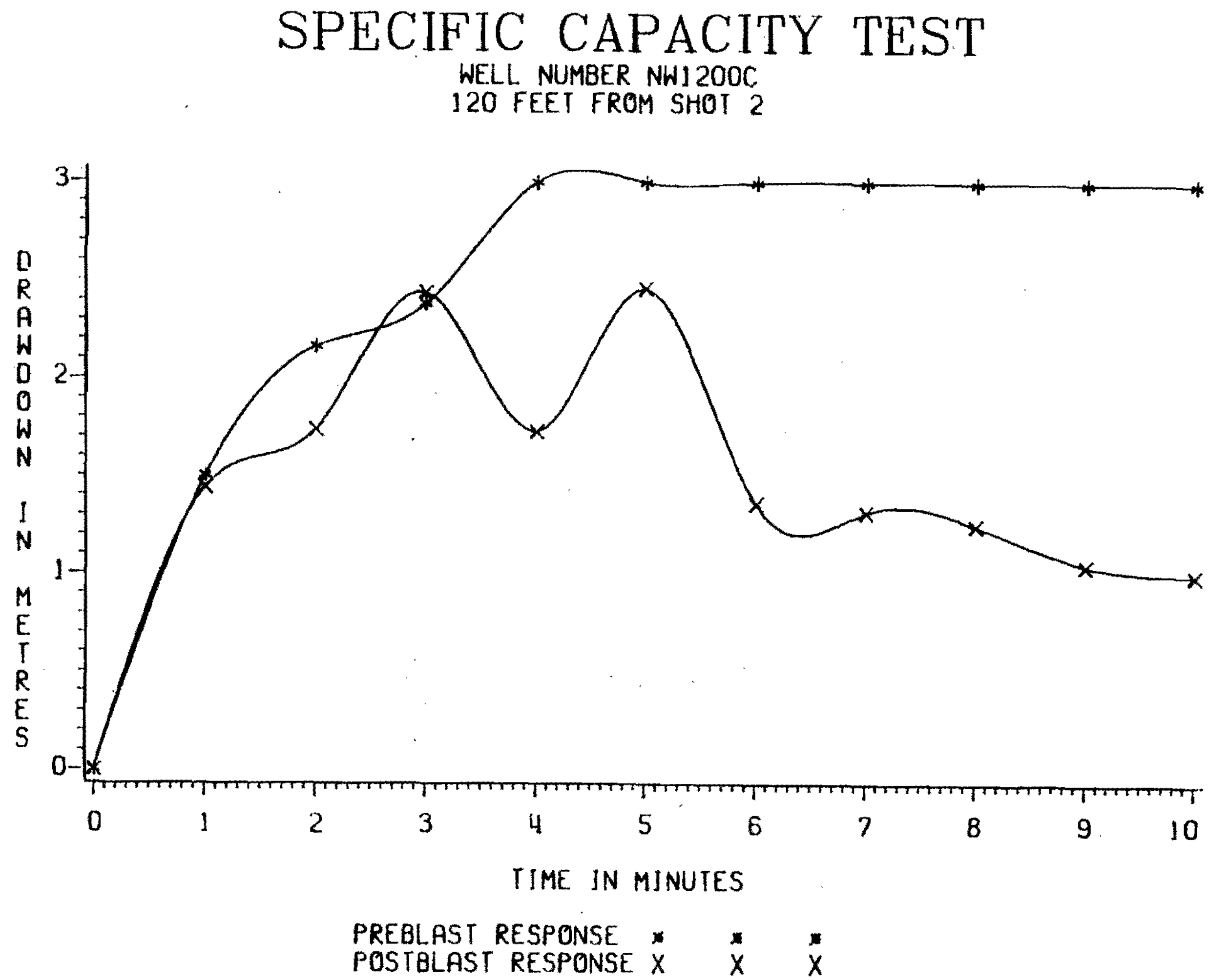
WELL NUMBER NW600C
100 FEET FROM SHOT 6



SPECIFIC CAPACITY TEST

WELL NUMBER NW600S
100 FEET FROM SHOT 6

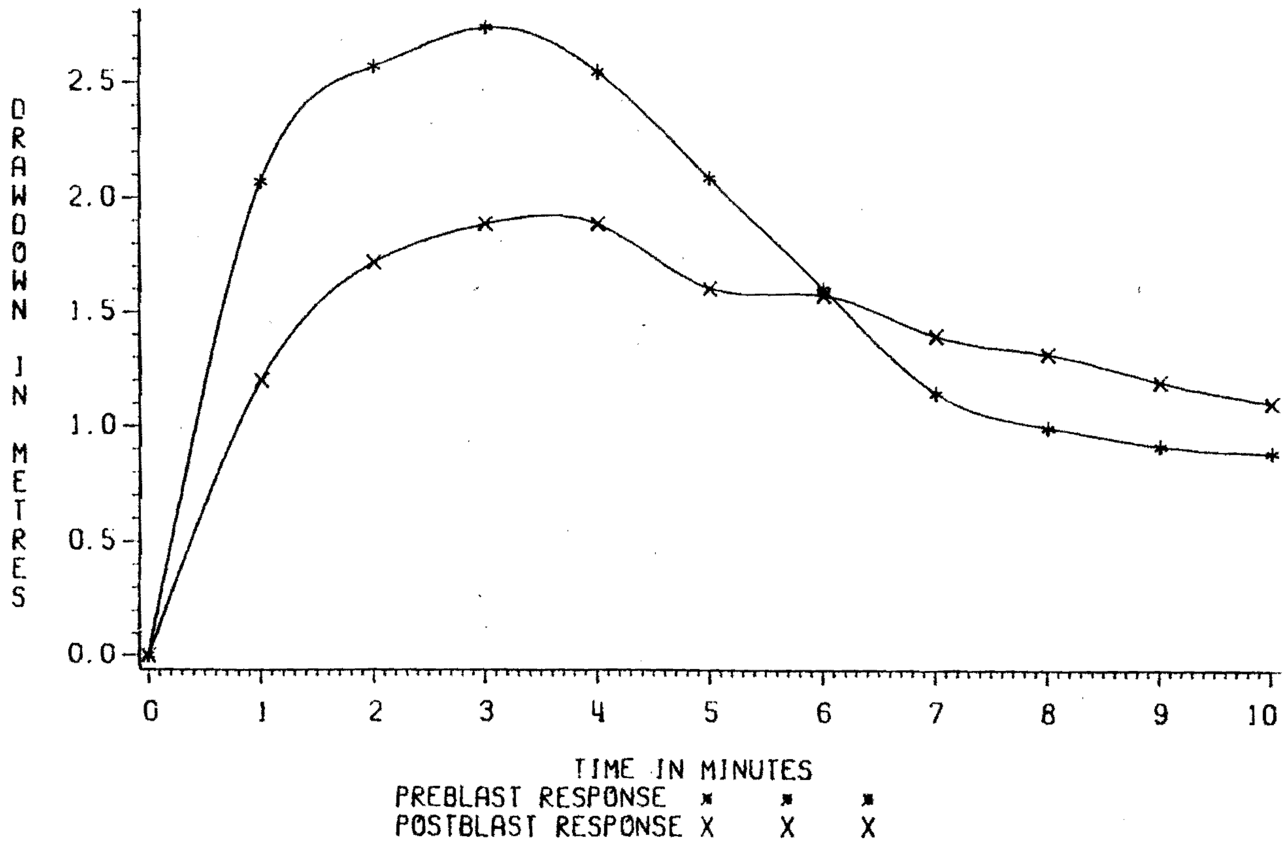




SPECIFIC CAPACITY TEST
WELL NUMBER NW1200C
120 FEET FROM SHOT 2
DRAWDOWN IN METRES
0
1
2
3
0
1
2
3
4
5
6
7
8
9
10
TIME IN MINUTES
PREBLAST RESPONSE * * *
POSTBLAST RESPONSE X X X

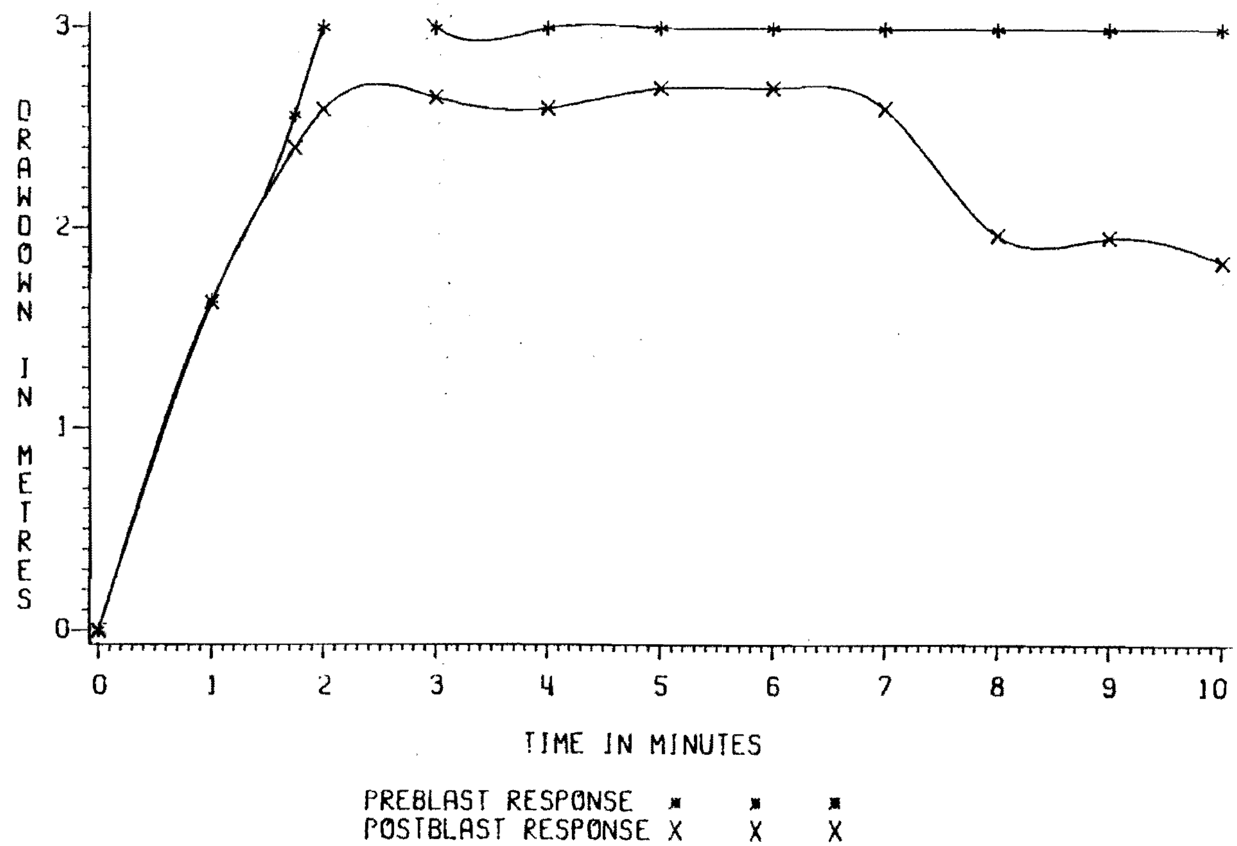
SPECIFIC CAPACITY TEST

WELL NUMBER NW1200S
120 FEET FROM SHOT 2



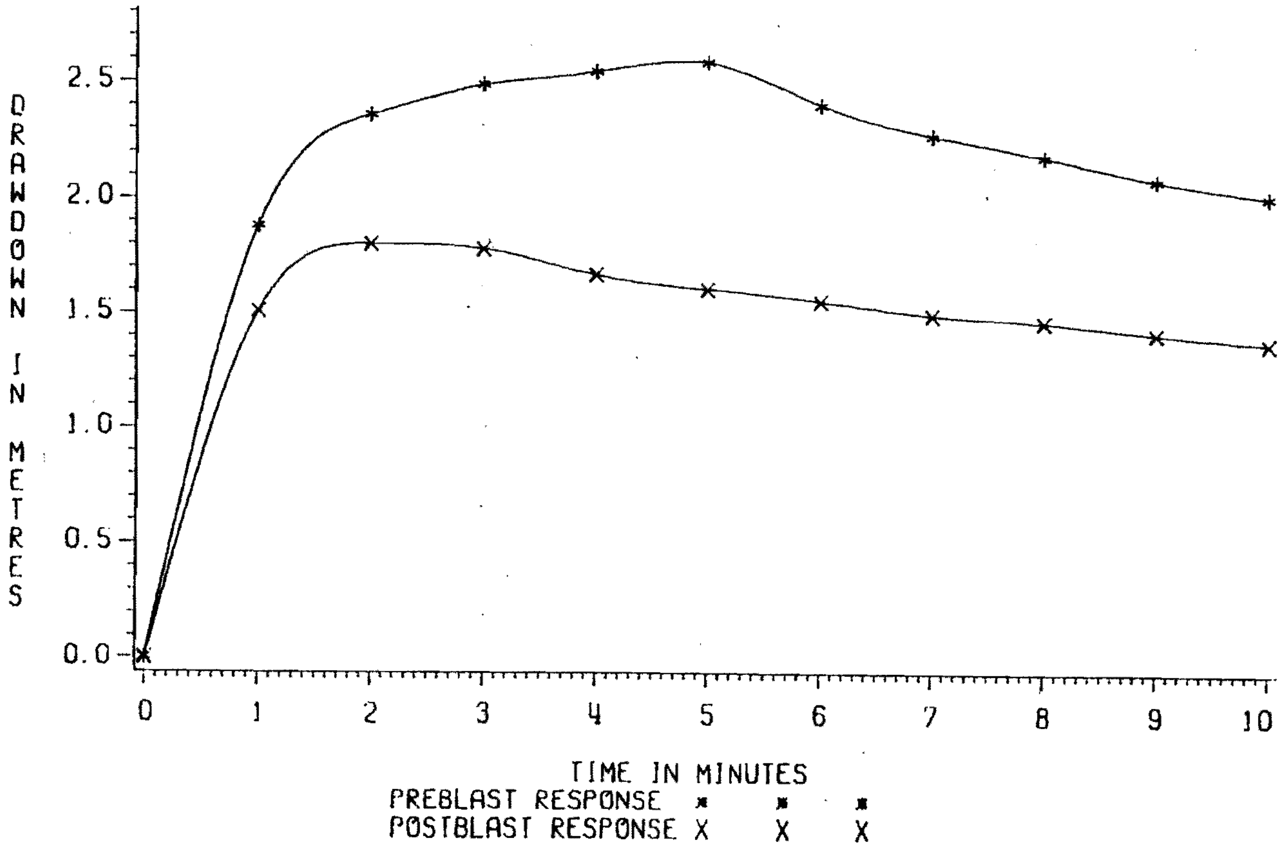
SPECIFIC CAPACITY TEST

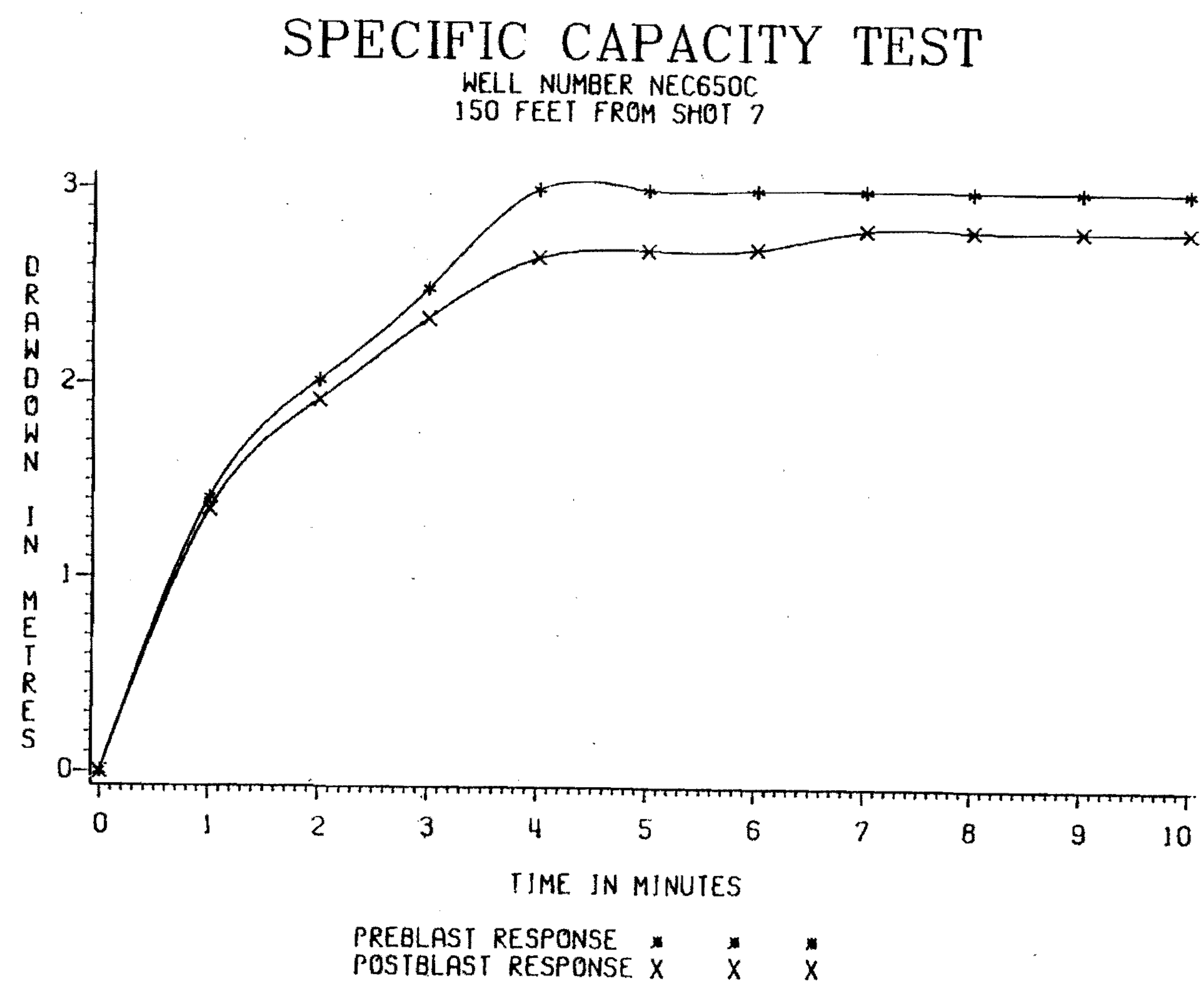
WELL NUMBER NEC300C
200 FEET FROM SHOT 7



SPECIFIC CAPACITY TEST

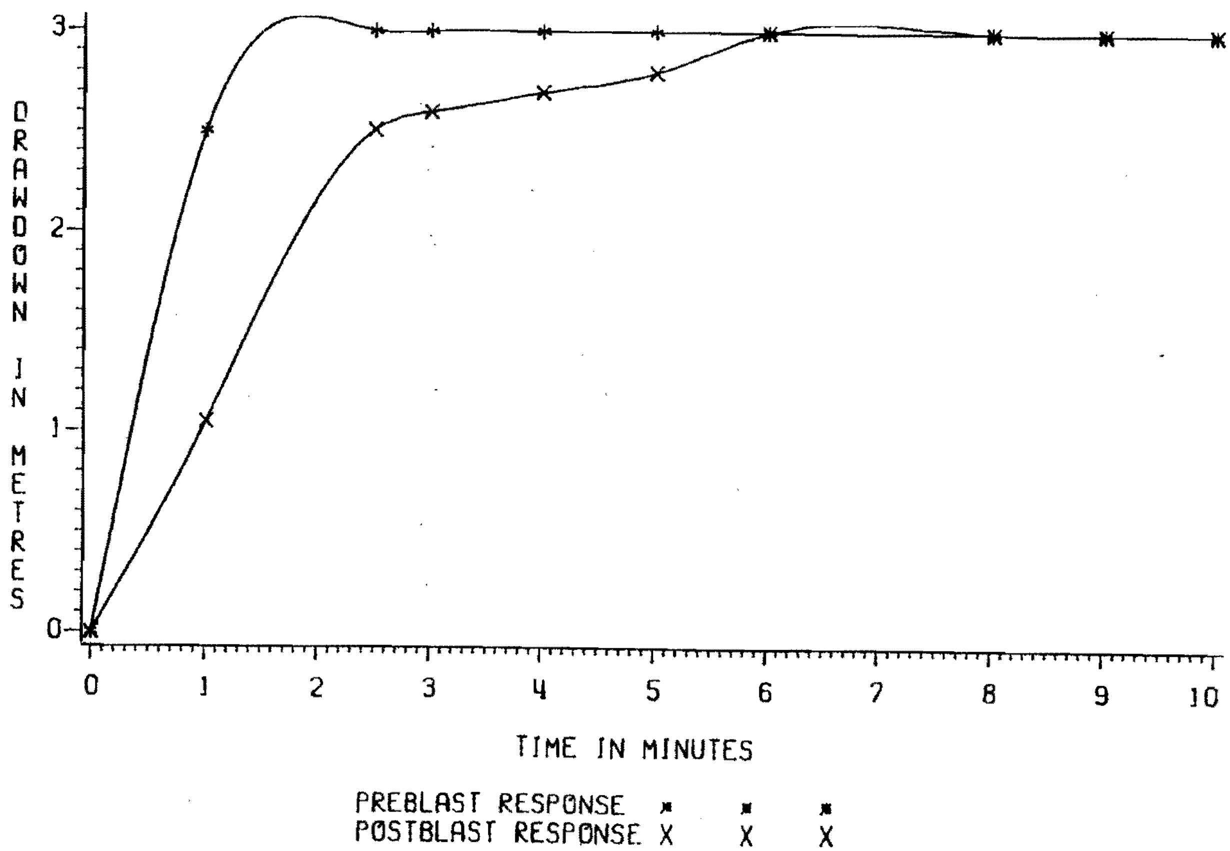
WELL NUMBER NEC300S
200 FEET FROM SHOT 7




SPECIFIC CAPACITY TEST
WELL NUMBER NEC650C
150 FEET FROM SHOT 7
DRAWDOWN IN METRES
0
1
2
3
0
1
2
3
4
5
6
7
8
9
10
TIME IN MINUTES
PREBLAST RESPONSE * * *
POSTBLAST RESPONSE X X X

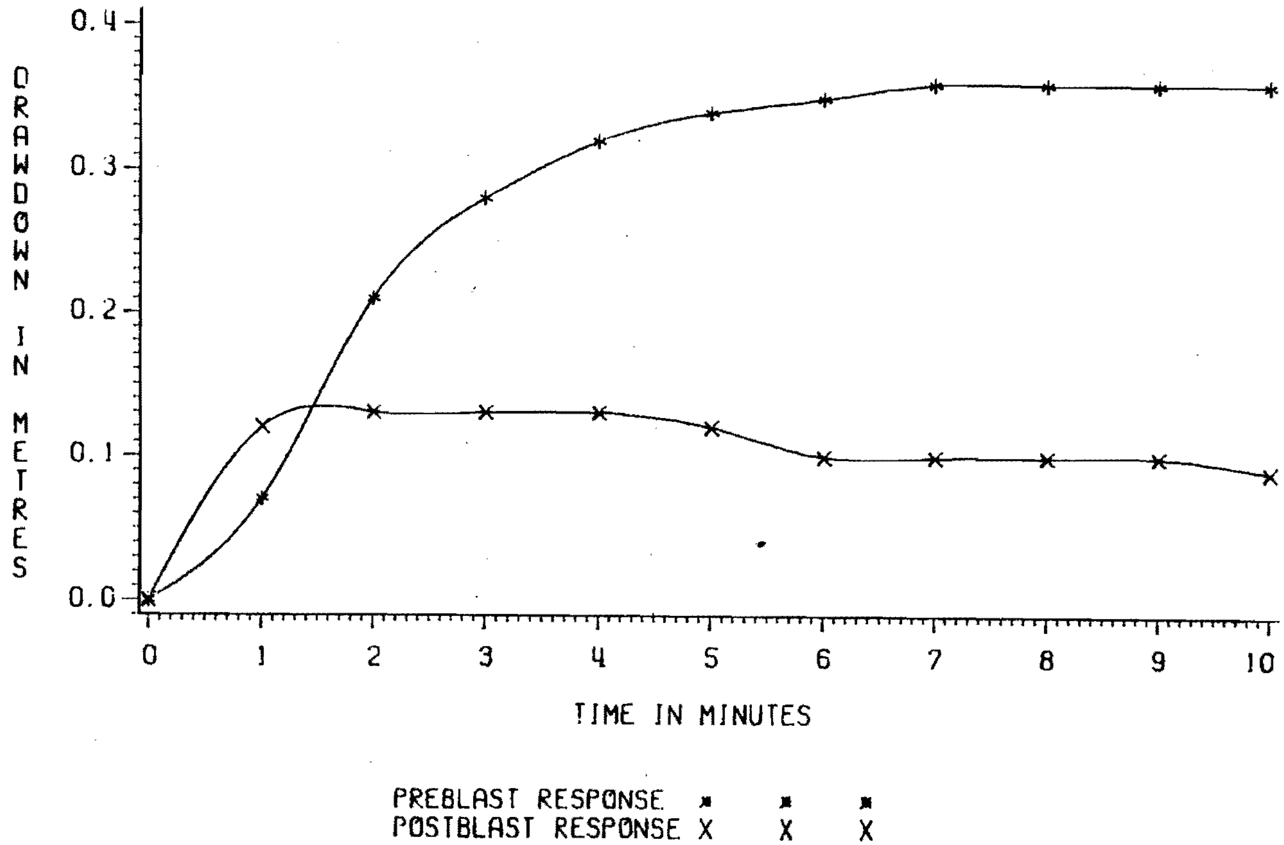
SPECIFIC CAPACITY TEST

WELL NUMBER NEC650S
150 FEET FROM SHOT 7



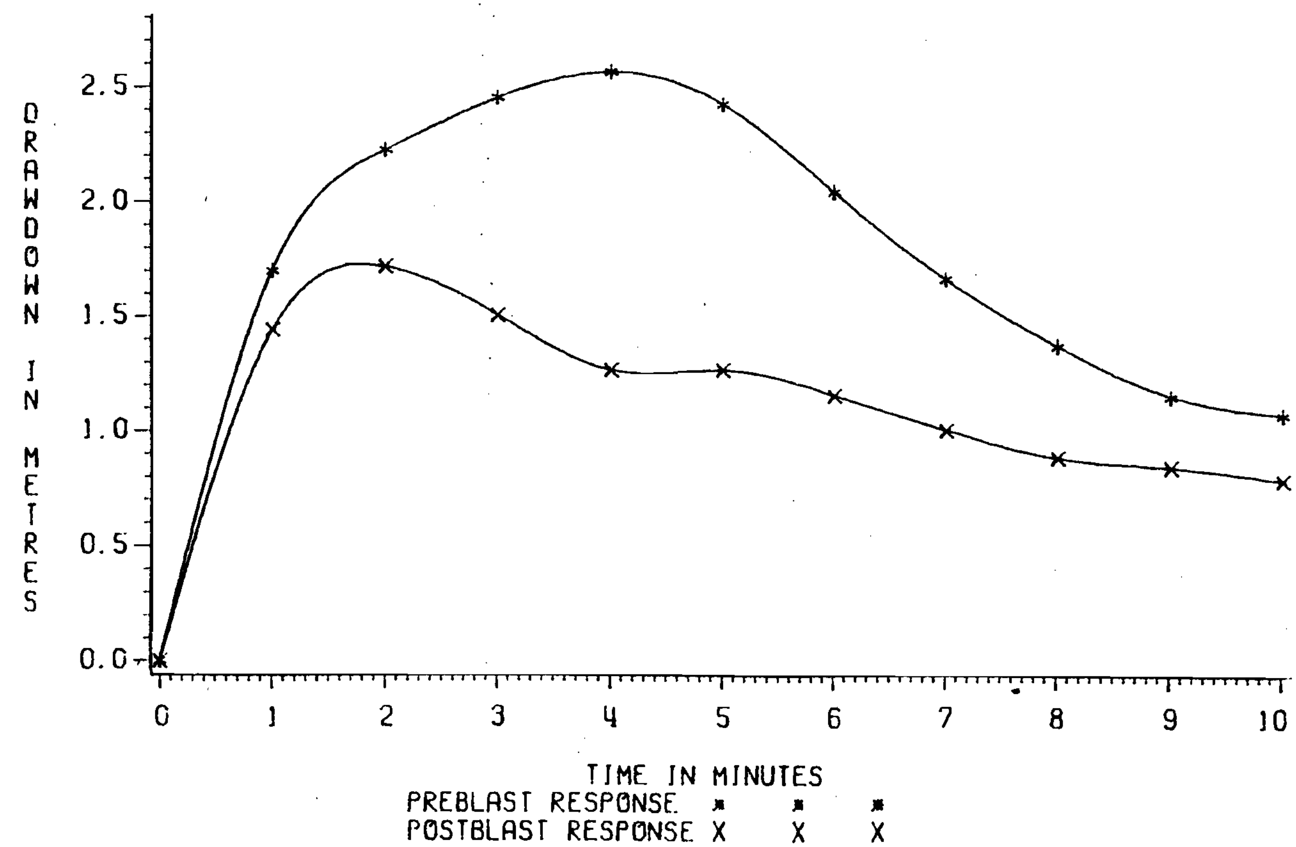
SPECIFIC CAPACITY TEST

WELL NUMBER NEC1200C
120 FEET FROM SHOT 5



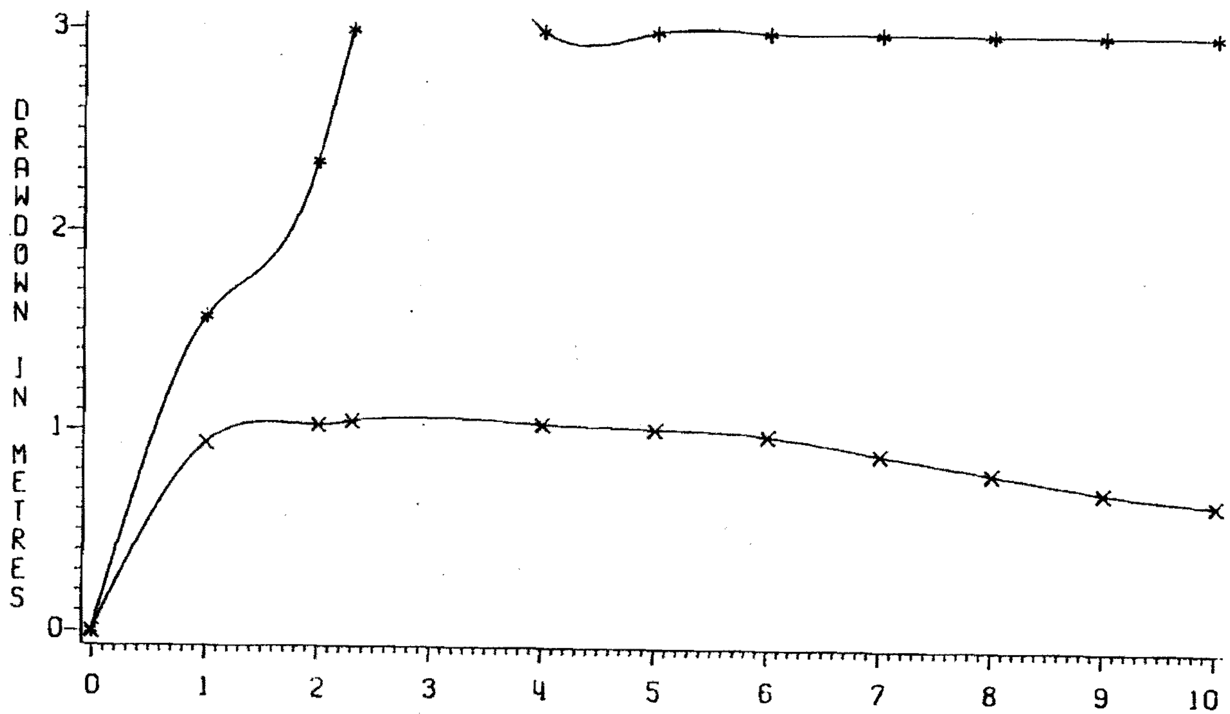
SPECIFIC CAPACITY TEST

WELL NUMBER NEC1200S
120 FEET FROM SHOT 5



SPECIFIC CAPACITY TEST

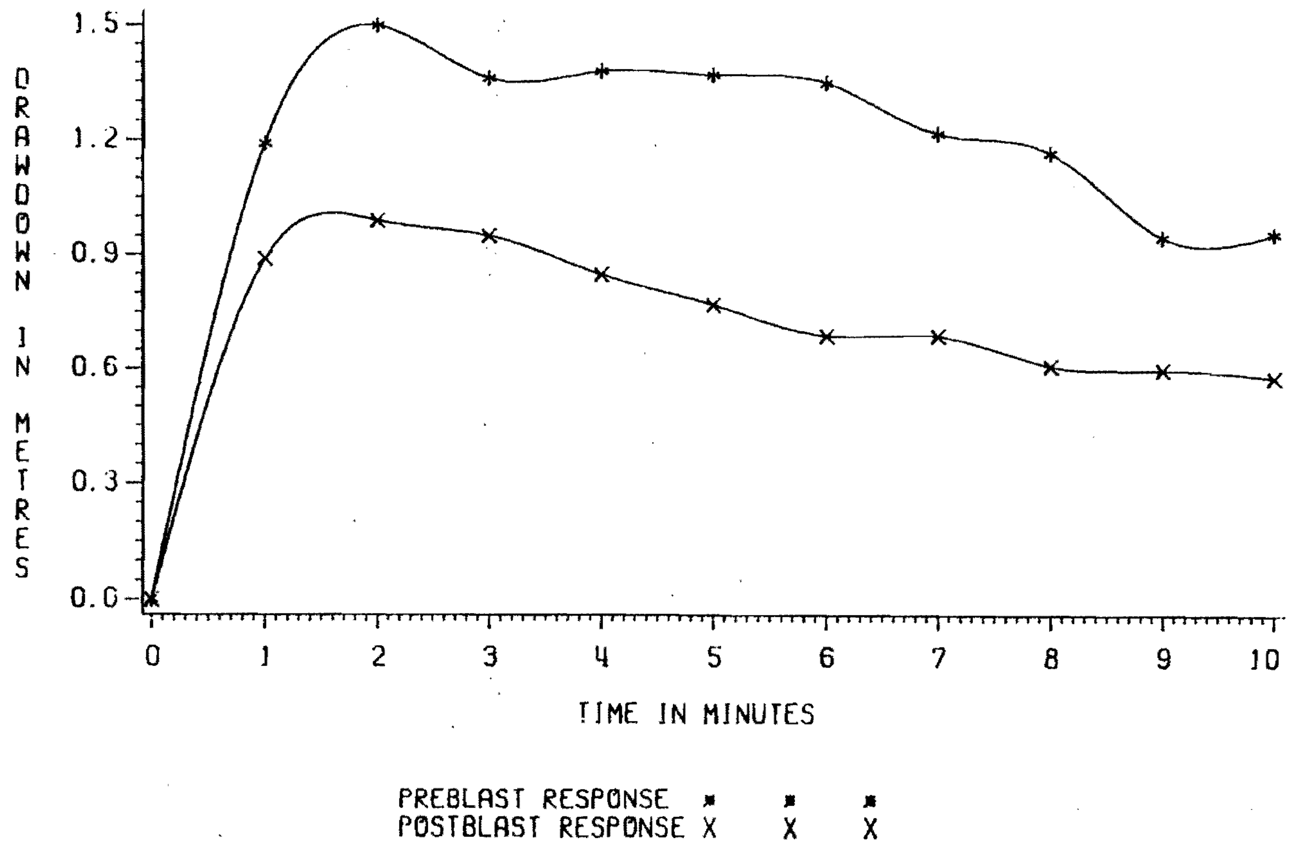
WELL NUMBER NES250C
220 FEET FROM SHOT 8



PREBLAST RESPONSE * * *
POSTBLAST RESPONSE X X X

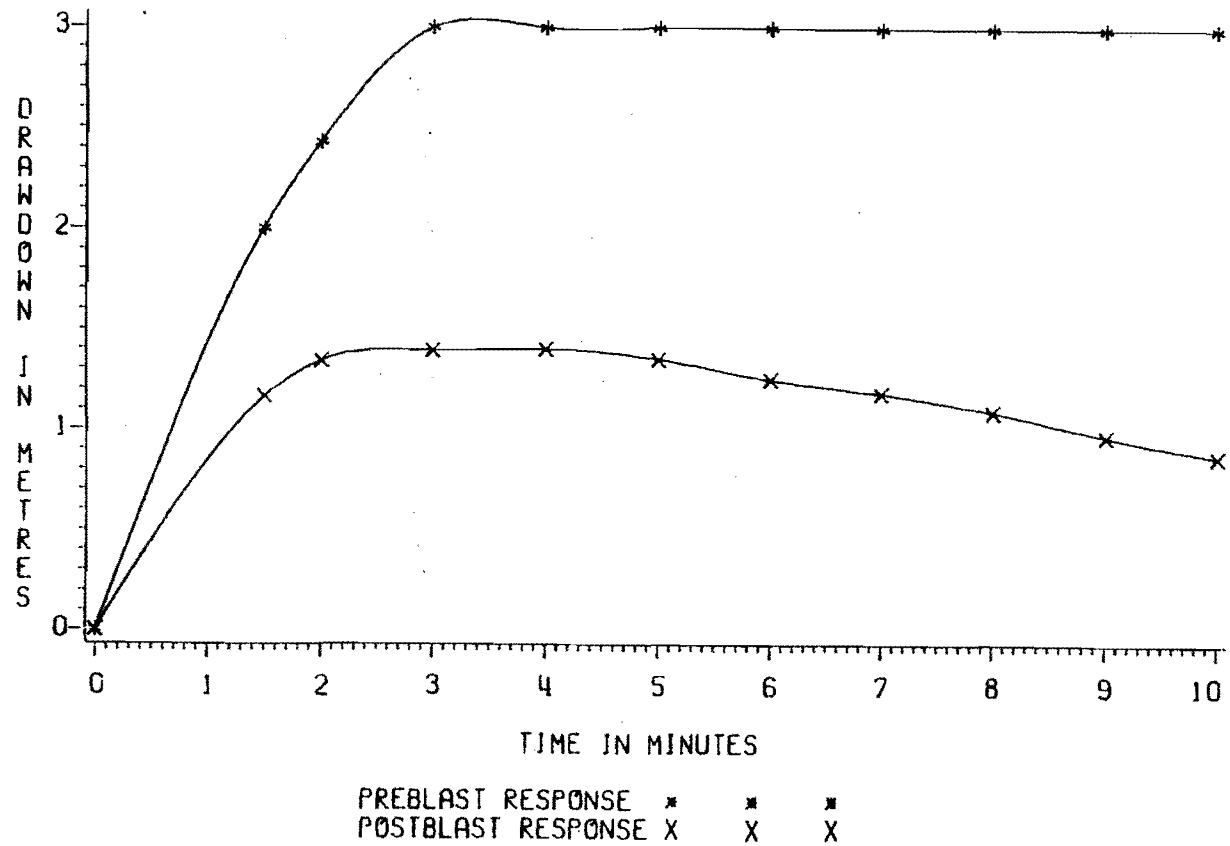
SPECIFIC CAPACITY TEST

WELL NUMBER NES250S
220 FEET FROM SHOT 8



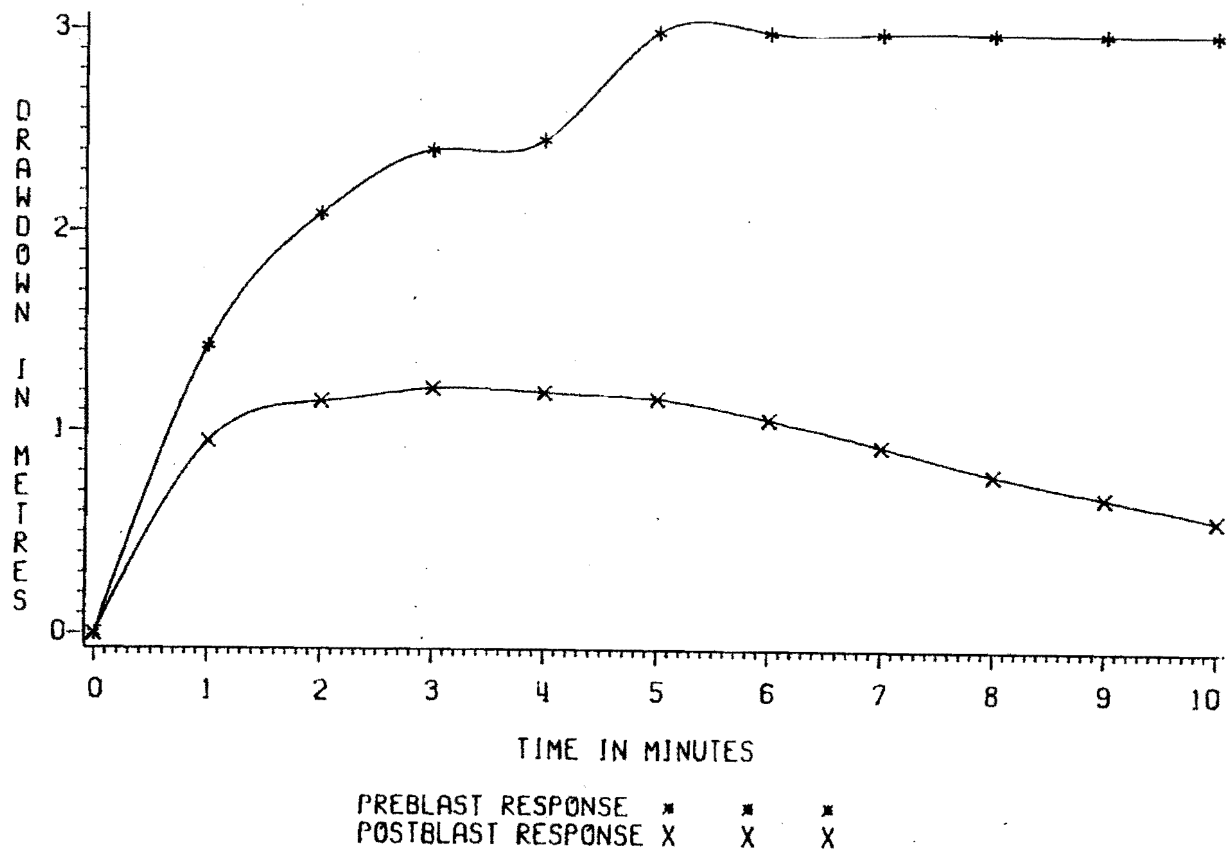
SPECIFIC CAPACITY TEST

WELL NUMBER NES600C
110 FEET FROM SHOT 7



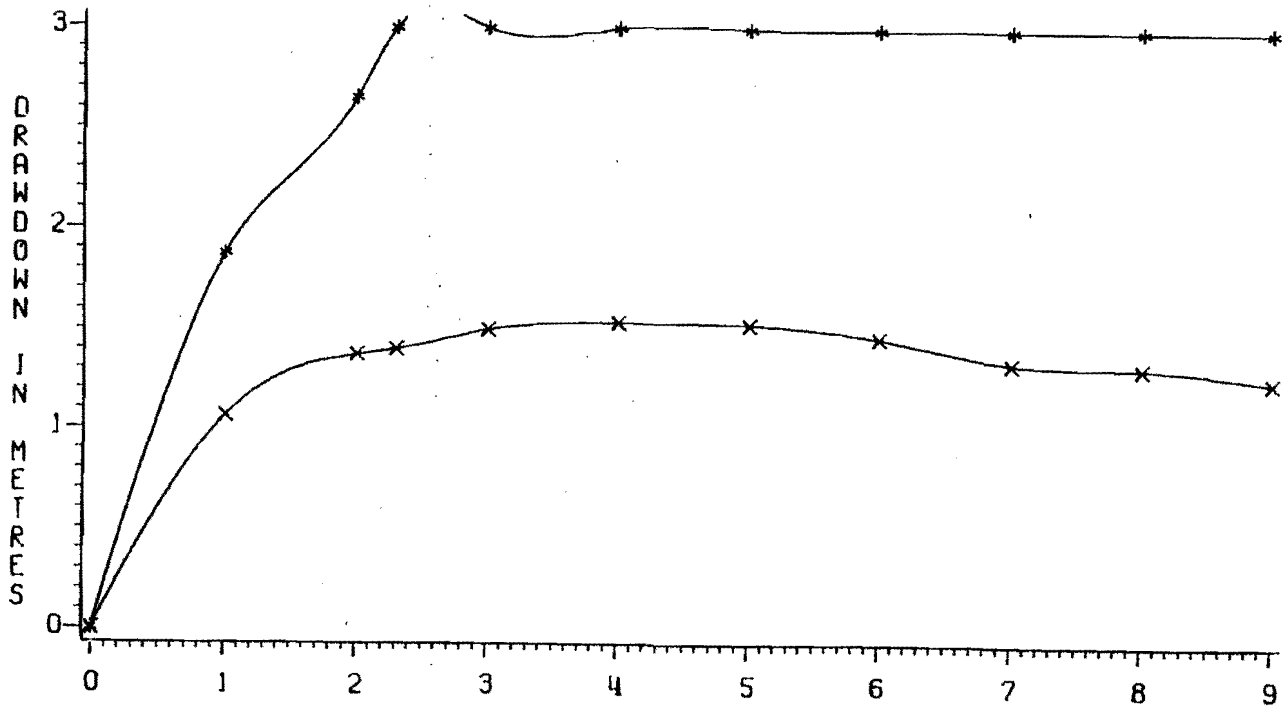
SPECIFIC CAPACITY TEST

WELL NUMBER NES600S
110 FEET FROM SHOT 7



SPECIFIC CAPACITY TEST

WELL NUMBER NES1200C
120 FEET FROM SHOT 4



PREBLAST RESPONSE * * *
POSTBLAST RESPONSE X X X

Appendix F

PIEZOMETER-FIELD CHEMISTRY DATA

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C4699
WELL NUMBER: NEC50C
DATE: 7/26/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	65.	mg/l	10.	mg/l
Arsenic	11.5	ug/l	3.0	ug/l
Barium	50.	ug/l	100.	ug/l
Bicarbonate	70.	mg/l	10.	mg/l
Cadmium	1.24	ug/l	0.20	ug/l
Calcium	19.0	mg/l	2.3	mg/l
Carbonate	5.0	mg/l	10.0	mg/l
Chloride	.10	mg/l	2.00	mg/l
Chromium	3.27	ug/l	0.50	ug/l
Copper	0.0	ug/l	10.0	ug/l
Fluoride	0.3	mg/l	0.1	mg/l
Total Hardness	78.	mg/l	-	-
Iron	0.01	mg/l	0.03	mg/l
Lead	0.0	ug/l	1.0	ug/l
Magnesium	7.50	mg/l	1.00	mg/l
Manganese	0.018	mg/l	0.010	mg/l
Selenium	0.67	ug/l	0.2	ug/l
pH	8.6	units	-	-
Potassium	2.65	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	13.0	mg/l	2.50	mg/l
Percent Sodium	26.4	-	-	-
Sulfate (SO4)	50.	mg/l	5.	mg/l
Total Dissolved Solids	137.	mg/l	-	-
Turbidity	1.	NTU	-	-
Zinc	6.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.64	-	-	-
Conductivity	241.	umhos/cm	-	-
Nitrate	1.01	mg/l	0.02	mg/l
TOC	4.2	mg/l	-	-

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5607
WELL NUMBER: NEC50C
DATE: 8/26/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	190.	mg/l	10.	mg/l
Arsenic	7.	ug/l	3.0	ug/l
Barium	120.	ug/l	100.	ug/l
Bicarbonate	232.	mg/l	10.	mg/l
Cadmium	0.80	ug/l	0.20	ug/l
Calcium	43.5	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	1.	mg/l	2.00	mg/l
Chromium	3.39	ug/l	0.50	ug/l
Copper	12.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	185.	mg/l	-	-
Iron	0.20	mg/l	0.03	mg/l
Lead	10.2	ug/l	1.0	ug/l
Magnesium	18.5	mg/l	1.00	mg/l
Manganese	0.095	mg/l	0.010	mg/l
Selenium	2.12	ug/l	0.2	ug/l
pH	7.8	units	-	-
Potassium	4.80	mg/l	0.30	mg/l
Silver	0.22	ug/l	0.20	ug/l
Sodium	16.0	mg/l	2.50	mg/l
Percent Sodium	15.8	-	-	-
Sulfate (SO4)	46.	mg/l	5.	mg/l
Total Dissolved Solids	245.	mg/l	-	-
Turbidity	3.00	NTU	-	-
Zinc	1940	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.51	-	-	-
Conductivity	424.	umhos/cm	-	-
Nitrate	0.201	mg/l	0.02	mg/l
TOC	4.8	mg/l	-	-

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C4701
WELL NUMBER: NEC50WT
DATE: 7/26/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	389.	mg/l	10.	mg/l
Arsenic	0.0	ug/l	3.0	ug/l
Barium	300.	ug/l	100.	ug/l
Bicarbonate	475.	mg/l	10.	mg/l
Cadmium	0.94	ug/l	0.20	ug/l
Calcium	130.	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	2.00	mg/l	2.00	mg/l
Chromium	1.16	ug/l	0.50	ug/l
Copper	2.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	525.	mg/l	-	-
Iron	0.02	mg/l	0.03	mg/l
Lead	0.6	ug/l	1.0	ug/l
Magnesium	49.0	mg/l	1.00	mg/l
Manganese	0.043	mg/l	0.010	mg/l
Selenium	0.00	ug/l	0.2	ug/l
pH	7.5	units	-	-
Potassium	4.50	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	10.0	mg/l	2.50	mg/l
Percent Sodium	4.0	-	-	-
Sulfate (SO4)	201.	mg/l	5.	mg/l
Total Dissolved Solids	664.	mg/l	-	-
Turbidity	1.00	NTU	-	-
Zinc	40.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.19	-	-	-
Conductivity	987.	umhos/cm	-	-
Nitrate	7.85	mg/l	0.02	mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5606
WELL NUMBER: NEC50WT
DATE: 8/26/83

ANALYTE	RESULT		UNCERTAINTY
Total Alkalinity	384.	mg/l	10. mg/l
Arsenic	0.0	ug/l	3.0 ug/l
Barium	200.	ug/l	100. ug/l
Bicarbonate	469.	mg/l	10. mg/l
Cadmium	1.30	ug/l	0.20 ug/l
Calcium	127.	mg/l	2.3 mg/l
Carbonate	0.	mg/l	10.0 mg/l
Chloride	2.00	mg/l	2.00 mg/l
Chromium	2.38	ug/l	0.50 ug/l
Copper	12.	ug/l	10.0 ug/l
Fluoride	0.2	mg/l	0.1 mg/l
Total Hardness	529.	mg/l	- -
Iron	1.33	mg/l	0.03 mg/l
Lead	1.4	ug/l	1.0 ug/l
Magnesium	51.5	mg/l	1.00 mg/l
Manganese	0.128	mg/l	0.010 mg/l
Selenium	0.06	ug/l	0.2 ug/l
pH	7.6	units	- -
Potassium	5.65	mg/l	0.30 mg/l
Silver	0.00	ug/l	0.20 ug/l
Sodium	10.5	mg/l	2.50 mg/l
Percent Sodium	4.1	-	- -
Sulfate (SO4)	146.	mg/l	5. mg/l
Total Dissolved Solids	605.	mg/l	- -
Turbidity	50.0	NTU	- -
Zinc	149.	ug/l	130. ug/l
Sodium Adsorption Ratio	0.20	-	- -
Conductivity	909.	umhos/cm	- -
Nitrate	7.05	mg/l	0.02 mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C4703
WELL NUMBER: NEC100S
DATE: 7/26/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	223.	mg/l	10.	mg/l
Arsenic	6.7	ug/l	3.0	ug/l
Barium	90.	ug/l	100.	ug/l
Bicarbonate	272.	mg/l	10.	mg/l
Cadmium	0.75	ug/l	0.20	ug/l
Calcium	40.5	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	0.10	mg/l	2.00	mg/l
Chromium	2.61	ug/l	0.50	ug/l
Copper	1.	ug/l	10.0	ug/l
Fluoride	0.3	mg/l	0.1	mg/l
Total Hardness	184.	mg/l	-	-
Iron	0.00	mg/l	0.03	mg/l
Lead	0.6	ug/l	1.0	ug/l
Magnesium	20.0	mg/l	1.00	mg/l
Manganese	0.035	mg/l	0.010	mg/l
Selenium	0.09	ug/l	0.2	ug/l
pH	8.2	units	-	-
Potassium	10.2	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	17.0	mg/l	2.50	mg/l
Percent Sodium	16.7	-	-	-
Sulfate (SO4)	37.	mg/l	5.	mg/l
Total Dissolved Solids	260.	mg/l	-	-
Turbidity	1.	NTU	-	-
Zinc	5.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.55	-	-	-
Conductivity	444.	umhos/cm	-	-
Nitrate	0.300	mg/l	0.02	mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5621
WELL NUMBER: NEC200S
DATE: 8/28/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	198.	mg/l	10.	mg/l
Arsenic	6.2	ug/l	3.0	ug/l
Barium	110.	ug/l	100.	ug/l
Bicarbonate	242.	mg/l	10.	mg/l
Cadmium	0.48	ug/l	0.20	ug/l
Calcium	44.5	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	1.00	mg/l	2.00	mg/l
Chromium	2.03	ug/l	0.50	ug/l
Copper	7.	ug/l	10.0	ug/l
Fluoride	0.3	mg/l	0.1	mg/l
Total Hardness	191.	mg/l	-	-
Iron	0.13	mg/l	0.03	mg/l
Lead	6.4	ug/l	1.0	ug/l
Magnesium	19.5	mg/l	1.00	mg/l
Manganese	0.087	mg/l	0.010	mg/l
Selenium	0.18	ug/l	0.2	ug/l
pH	7.8	units	-	-
Potassium	7.15	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	13.0	mg/l	2.50	mg/l
Percent Sodium	12.8	-	-	-
Sulfate (SO4)	40.	mg/l	5.	mg/l
Total Dissolved Solids	245.	mg/l	-	-
Turbidity	3.00	NTU	-	-
Zinc	840.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.41	-	-	-
Conductivity	426.	umhos/cm	-	-
Nitrate	0.000	mg/l	0.02	mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C4702
WELL NUMBER: NEC100C
DATE: 7/26/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	360.	mg/l	10.	mg/l
Arsenic	2.8	ug/l	3.0	ug/l
Barium	140.	ug/l	100.	ug/l
Bicarbonate	439.	mg/l	10.	mg/l
Cadmium	0.74	ug/l	0.20	ug/l
Calcium	56.5	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	1.00	mg/l	2.00	mg/l
Chromium	2.9	ug/l	0.50	ug/l
Copper	0.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	265.	mg/l	-	-
Iron	0.01	mg/l	0.03	mg/l
Lead	0.9	ug/l	1.0	ug/l
Magnesium	30.0	mg/l	1.00	mg/l
Manganese	0.216	mg/l	0.010	mg/l
Selenium	0.10	ug/l	0.2	ug/l
pH	7.4	units	-	-
Potassium	4.9	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	37.5	mg/l	2.50	mg/l
Percent Sodium	23.5	-	-	-
Sulfate (SO4)	37.	mg/l	5.	mg/l
Total Dissolved Solids	383.	mg/l	-	-
Turbidity	1.	NTU	-	-
Zinc	8.	ug/l	130.	ug/l
Sodium Adsorption Ratio	1.00	-	-	-
Conductivity	645.	umhos/cm	-	-
Nitrate	0.064	mg/l	0.02	mg/l
TOC	4.2	mg/l	-	-

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5620
WELL NUMBER: NEC100C
DATE: 8/28/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	347.	mg/l	10.	mg/l
Arsenic	0.0	ug/l	3.0	ug/l
Barium	120.	ug/l	100.	ug/l
Bicarbonate	424.	mg/l	10.	mg/l
Cadmium	0.00	ug/l	0.20	ug/l
Calcium	56.0	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	2.00	mg/l	2.00	mg/l
Chromium	1.66	ug/l	0.50	ug/l
Copper	6.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	276.	mg/l	-	-
Iron	0.14	mg/l	0.03	mg/l
Lead	1.5	ug/l	1.0	ug/l
Magnesium	33.0	mg/l	1.00	mg/l
Manganese	0.317	mg/l	0.010	mg/l
Selenium	0.04	ug/l	0.2	ug/l
pH	7.5	units	-	-
Potassium	5.2	mg/l	0.30	mg/l
Silver	0.79	ug/l	0.20	ug/l
Sodium	38.5	mg/l	2.50	mg/l
Percent Sodium	23.2	-	-	-
Sulfate (SO4)	32.	mg/l	5.	mg/l
Total Dissolved Solids	375.	mg/l	-	-
Turbidity	7.00	NTU	-	-
Zinc	310.	ug/l	130.	ug/l
Sodium Adsorption Ratio	1.01	-	-	-
Conductivity	635.	umhos/cm	-	-
Nitrate	0.019	mg/l	0.02	mg/l
TOC	1.8	mg/l	-	-

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C4704
WELL NUMBER: NEC100WT
DATE: 7/26/83

ANALYTE	RESULT		UNCERTAINTY
Total Alkalinity	392.	mg/l	10. mg/l
Arsenic	0.0	ug/l	3.0 ug/l
Barium	370.	ug/l	100. ug/l
Bicarbonate	479.	mg/l	10. mg/l
Cadmium	0.67	ug/l	0.20 ug/l
Calcium	108.	mg/l	2.3 mg/l
Carbonate	0.	mg/l	10.0 mg/l
Chloride	2.00	mg/l	2.00 mg/l
Chromium	2.30	ug/l	0.50 ug/l
Copper	0.	ug/l	10.0 ug/l
Fluoride	0.2	mg/l	0.1 mg/l
Total Hardness	454.	mg/l	- -
Iron	0.03	mg/l	0.03 mg/l
Lead	3.6	ug/l	1.0 ug/l
Magnesium	44.5	mg/l	1.00 mg/l
Manganese	0.045	mg/l	0.010 mg/l
Selenium	0.00	ug/l	0.2 ug/l
pH	7.7	units	- -
Potassium	4.00	mg/l	0.30 mg/l
Silver	0.00	ug/l	0.20 ug/l
Sodium	12.0	mg/l	2.50 mg/l
Percent Sodium	5.4	-	- -
Sulfate (SO4)	130.	mg/l	5. mg/l
Total Dissolved Solids	552.	mg/l	- -
Turbidity	2.00	NTU	- -
Zinc	52.	ug/l	130. ug/l
Sodium Adsorption Ratio	0.24	-	- -
Conductivity	846.	umhos/cm	- -
Nitrate	3.43	mg/l	0.02 mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5622
WELL NUMBER: NEC100WT
DATE: 8/28/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	363.	mg/l	10.	mg/l
Arsenic	1.3	ug/l	3.0	ug/l
Barium	160.	ug/l	100.	ug/l
Bicarbonate	443.	mg/l	10.	mg/l
Cadmium	0.35	ug/l	0.20	ug/l
Calcium	116.	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	3.00	mg/l	2.00	mg/l
Chromium	2.50	ug/l	0.50	ug/l
Copper	8.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	485.	mg/l	-	-
Iron	0.00	mg/l	0.03	mg/l
Lead	1.8	ug/l	1.0	ug/l
Magnesium	47.5	mg/l	1.00	mg/l
Manganese	0.037	mg/l	0.010	mg/l
Selenium	0.03	ug/l	0.2	ug/l
pH	7.6	units	-	-
Potassium	5.10	mg/l	0.30	mg/l
Silver	0.05	ug/l	0.20	ug/l
Sodium	10.0	mg/l	2.50	mg/l
Percent Sodium	4.3	-	-	-
Sulfate (SO4)	172.	mg/l	5.	mg/l
Total Dissolved Solids	593.	mg/l	-	-
Turbidity	1.	NTU	-	-
Zinc	95.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.20	-	-	-
Conductivity	872.	umhos/cm	-	-
Nitrate	4.90	mg/l	0.02	mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C4706
WELL NUMBER: NEC140S
DATE: 7/26/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	381.	mg/l	10.	mg/l
Arsenic	0.0	ug/l	3.0	ug/l
Barium	190.	ug/l	100.	ug/l
Bicarbonate	465.	mg/l	10.	mg/l
Cadmium	0.43	ug/l	0.20	ug/l
Calcium	89.0	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	2.00	mg/l	2.00	mg/l
Chromium	1.91	ug/l	0.50	ug/l
Copper	0.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	367.	mg/l	-	-
Iron	0.04	mg/l	0.03	mg/l
Lead	0.9	ug/l	1.0	ug/l
Magnesium	35.0	mg/l	1.00	mg/l
Manganese	0.499	mg/l	0.010	mg/l
Selenium	0.00	ug/l	0.2	ug/l
pH	7.6	units	-	-
Potassium	4.70	mg/l	0.30	mg/l
Silver	2.52	ug/l	0.20	ug/l
Sodium	9.50	mg/l	2.50	mg/l
Percent Sodium	5.3	-	-	-
Sulfate (SO4)	29.	mg/l	5.	mg/l
Total Dissolved Solids	400.	mg/l	-	-
Turbidity	1.	NTU	-	-
Zinc	32.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.22	-	-	-
Conductivity	660.	umhos/cm	-	-
Nitrate	0.358	mg/l	0.02	mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5624
WELL NUMBER: NEC140S
DATE: 8/28/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	371.	mg/l	10.	mg/l
Arsenic	1.8	ug/l	3.0	ug/l
Barium	40.	ug/l	100.	ug/l
Bicarbonate	453.	mg/l	10.	mg/l
Cadmium	0.00	ug/l	0.20	ug/l
Calcium	85.5	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	2.00	mg/l	2.00	mg/l
Chromium	2.05	ug/l	0.50	ug/l
Copper	6.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	354.	mg/l	-	-
Iron	0.01	mg/l	0.03	mg/l
Lead	1.4	ug/l	1.0	ug/l
Magnesium	34.0	mg/l	1.00	mg/l
Manganese	0.024	mg/l	0.010	mg/l
Selenium	0.00	ug/l	0.2	ug/l
pH	7.6	units	-	-
Potassium	4.45	mg/l	0.30	mg/l
Silver	0.79	ug/l	0.20	ug/l
Sodium	9.00	mg/l	2.50	mg/l
Percent Sodium	5.2	-	-	-
Sulfate (SO4)	27.	mg/l	5.	mg/l
Total Dissolved Solids	387.	mg/l	-	-
Turbidity	1.	NTU	-	-
Zinc	36.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.21	-	-	-
Conductivity	661.	umhos/cm	-	-
Nitrate	0.339	mg/l	0.02	mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C4705
WELL NUMBER: NEC140C
DATE: 7/26/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	364.	mg/l	10.	mg/l
Arsenic	0.0	ug/l	3.0	ug/l
Barium	90.	ug/l	100.	ug/l
Bicarbonate	445.	mg/l	10.	mg/l
Cadmium	0.33	ug/l	0.20	ug/l
Calcium	75.5	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	0.00	mg/l	2.00	mg/l
Chromium	1.97	ug/l	0.50	ug/l
Copper	0.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	310.	mg/l	-	-
Iron	0.00	mg/l	0.03	mg/l
Lead	1.0	ug/l	1.0	ug/l
Magnesium	29.5	mg/l	1.00	mg/l
Manganese	0.439	mg/l	0.010	mg/l
Selenium	0.06	ug/l	0.2	ug/l
pH	7.6	units	-	-
Potassium	4.6	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	19.0	mg/l	2.50	mg/l
Percent Sodium	11.7	-	-	-
Sulfate (SO4)	37.	mg/l	5.	mg/l
Total Dissolved Solids	385.	mg/l	-	-
Turbidity	1.	NTU	-	-
Zinc	8.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.47	-	-	-
Conductivity	650.	umhos/cm	-	-
Nitrate	0.189	mg/l	0.02	mg/l
TOC	35.0	mg/l	-	-

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5623
WELL NUMBER: NEC140C
DATE: 8/28/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	352.	mg/l	10.	mg/l
Arsenic	3.2	ug/l	3.0	ug/l
Barium	60.	ug/l	100.	ug/l
Bicarbonate	430.	mg/l	10.	mg/l
Cadmium	0.00	ug/l	0.20	ug/l
Calcium	75.5	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	1.50	mg/l	2.00	mg/l
Chromium	1.83	ug/l	0.50	ug/l
Copper	6.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	314.	mg/l	-	-
Iron	0.12	mg/l	0.03	mg/l
Lead	1.0	ug/l	1.0	ug/l
Magnesium	30.5	mg/l	1.00	mg/l
Manganese	0.609	mg/l	0.010	mg/l
Selenium	0.01	ug/l	0.2	ug/l
pH	7.6	units	-	-
Potassium	5.3	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	19.0	mg/l	2.50	mg/l
Percent Sodium	11.6	-	-	-
Sulfate (SO4)	29.	mg/l	5.	mg/l
Total Dissolved Solids	372.	mg/l	-	-
Turbidity	4.00	NTU	-	-
Zinc	60.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.47	-	-	-
Conductivity	635.	umhos/cm	-	-
Nitrate	0.015	mg/l	0.02	mg/l
TOC	46.0	mg/l	-	-

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C4708
WELL NUMBER: NEC200S
DATE: 7/26/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	358.	mg/l	10.	mg/l
Arsenic	0.0	ug/l	3.0	ug/l
Barium	170.	ug/l	100.	ug/l
Bicarbonate	437.	mg/l	10.	mg/l
Cadmium	0.85	ug/l	0.20	ug/l
Calcium	79.0	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	1.00	mg/l	2.00	mg/l
Chromium	2.21	ug/l	0.50	ug/l
Copper	0.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	325.	mg/l	-	-
Iron	0.01	mg/l	0.03	mg/l
Lead	0.2	ug/l	1.0	ug/l
Magnesium	31.0	mg/l	1.00	mg/l
Manganese	0.336	mg/l	0.010	mg/l
Selenium	0.02	ug/l	0.2	ug/l
pH	7.6	units	-	-
Potassium	4.55	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	14.5	mg/l	2.50	mg/l
Percent Sodium	8.8	-	-	-
Sulfate (SO4)	30.	mg/l	5.	mg/l
Total Dissolved Solids	376.	mg/l	-	-
Turbidity	1.	NTU	-	-
Zinc	26.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.35	-	-	-
Conductivity	630.	umhos/cm	-	-
Nitrate	0.158	mg/l	0.02	mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5630
WELL NUMBER: NEC200S
DATE: 8/28/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	288.	mg/l	10.	mg/l
Arsenic	3.4	ug/l	3.0	ug/l
Barium	40.	ug/l	100.	ug/l
Bicarbonate	352.	mg/l	10.	mg/l
Cadmium	0.59	ug/l	0.20	ug/l
Calcium	68.5	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	1.00	mg/l	2.00	mg/l
Chromium	1.72	ug/l	0.50	ug/l
Copper	4.	ug/l	10.0	ug/l
Fluoride	0.3	mg/l	0.1	mg/l
Total Hardness	280.	mg/l	-	-
Iron	0.12	mg/l	0.03	mg/l
Lead	1.6	ug/l	1.0	ug/l
Magnesium	26.5	mg/l	1.00	mg/l
Manganese	0.519	mg/l	0.010	mg/l
Selenium	0.19	ug/l	0.2	ug/l
pH	7.6	units	-	-
Potassium	4.9	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	13.0	mg/l	2.50	mg/l
Percent Sodium	9.1	-	-	-
Sulfate (SO4)	27.	mg/l	5.	mg/l
Total Dissolved Solids	314.	mg/l	-	-
Turbidity	7.00	NTU	-	-
Zinc	41.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.34	-	-	-
Conductivity	651.	umhos/cm	-	-
Nitrate	0.005	mg/l	0.02	mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C4707
WELL NUMBER: NEC200C
DATE: 7/26/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	347.	mg/l	10.	mg/l
Arsenic	0.0	ug/l	3.0	ug/l
Barium	90.	ug/l	100.	ug/l
Bicarbonate	424.	mg/l	10.	mg/l
Cadmium	0.44	ug/l	0.20	ug/l
Calcium	51.5	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	1.00	mg/l	2.00	mg/l
Chromium	2.08	ug/l	0.50	ug/l
Copper	0.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	244.	mg/l	-	-
Iron	0.07	mg/l	0.03	mg/l
Lead	0.04	ug/l	1.0	ug/l
Magnesium	28.0	mg/l	1.00	mg/l
Manganese	0.364	mg/l	0.010	mg/l
Selenium	0.00	ug/l	0.2	ug/l
pH	7.6	units	-	-
Potassium	4.75	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	46.5	mg/l	2.50	mg/l
Percent Sodium	29.2	-	-	-
Sulfate (SO4)	24.	mg/l	5.	mg/l
Total Dissolved Solids	365.	mg/l	-	-
Turbidity	1.	NTU	-	-
Zinc	6.	ug/l	130.	ug/l
Sodium Adsorption Ratio	1.29	-	-	-
Conductivity	606.	umhos/cm	-	-
Nitrate	0.111	mg/l	0.02	mg/l
TOC	3.7	mg/l	-	-

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5629
WELL NUMBER: NEC200C
DATE: 8/28/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	337.	mg/l	10.	mg/l
Arsenic	0.0	ug/l	3.0	ug/l
Barium	130.	ug/l	100.	ug/l
Bicarbonate	412.	mg/l	10.	mg/l
Cadmium	0.35	ug/l	0.20	ug/l
Calcium	53.5	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	1.	mg/l	2.00	mg/l
Chromium	1.79	ug/l	0.50	ug/l
Copper	4.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	253.	mg/l	-	-
Iron	0.05	mg/l	0.03	mg/l
Lead	1.4	ug/l	1.0	ug/l
Magnesium	29.0	mg/l	1.00	mg/l
Manganese	0.393	mg/l	0.010	mg/l
Selenium	0.03	ug/l	0.2	ug/l
pH	7.5	units	-	-
Potassium	5.40	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	45.5	mg/l	2.50	mg/l
Percent Sodium	28.0	-	-	-
Sulfate (SO4)	25.0	mg/l	5.	mg/l
Total Dissolved Solids	362.	mg/l	-	-
Turbidity	4.00	NTU	-	-
Zinc	34.	ug/l	130.	ug/l
Sodium Adsorption Ratio	1.24	-	-	-
Conductivity	622.	umhos/cm	-	-
Nitrate	0.009	mg/l	0.02	mg/l
TOC	3.1	mg/l	-	-

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C4710
WELL NUMBER: NEC300S
DATE: 7/26/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	146.	mg/l	10.	mg/l
Arsenic	5.5	ug/l	3.0	ug/l
Barium	30.	ug/l	100.	ug/l
Bicarbonate	178.	mg/l	10.	mg/l
Cadmium	0.48	ug/l	0.20	ug/l
Calcium	23.0	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	0.10	mg/l	2.00	mg/l
Chromium	2.78	ug/l	0.50	ug/l
Copper	0.	ug/l	10.0	ug/l
Fluoride	0.3	mg/l	0.1	mg/l
Total Hardness	103.	mg/l	-	-
Iron	0.01	mg/l	0.03	mg/l
Lead	0.3	ug/l	1.0	ug/l
Magnesium	11.0	mg/l	1.00	mg/l
Manganese	0.040	mg/l	0.010	mg/l
Selenium	0.47	ug/l	0.2	ug/l
pH	8.2	units	-	-
Potassium	6.70	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	22.5	mg/l	2.50	mg/l
Percent Sodium	32.2	-	-	-
Sulfate (SO4)	23.	mg/l	5.	mg/l
Total Dissolved Solids	175.	mg/l	-	-
Turbidity	1.	NTU	-	-
Zinc	13.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.97	-	-	-
Conductivity	305.	umhos/cm	-	-
Nitrate	0.079	mg/l	0.02	mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5636
WELL NUMBER: NEC300S
DATE: 8/28/83

ANALYTE	RESULT		UNCERTAINTY
Total Alkalinity	275.	mg/l	10. mg/l
Arsenic	0.0	ug/l	3.0 ug/l
Barium	70.	ug/l	100. ug/l
Bicarbonate	336.	mg/l	10. mg/l
Cadmium	0.46	ug/l	0.20 ug/l
Calcium	49.5	mg/l	2.3 mg/l
Carbonate	0.	mg/l	10.0 mg/l
Chloride	1.	mg/l	2.00 mg/l
Chromium	1.71	ug/l	0.50 ug/l
Copper	3.	ug/l	10.0 ug/l
Fluoride	0.2	mg/l	0.1 mg/l
Total Hardness	233.	mg/l	- -
Iron	0.27	mg/l	0.03 mg/l
Lead	1.6	ug/l	1.0 ug/l
Magnesium	26.5	mg/l	1.00 mg/l
Manganese	0.305	mg/l	0.010 mg/l
Selenium	0.03	ug/l	0.2 ug/l
pH	7.7	units	- -
Potassium	7.30	mg/l	0.30 mg/l
Silver	0.06	ug/l	0.20 ug/l
Sodium	24.0	mg/l	2.50 mg/l
Percent Sodium	18.2	-	- -
Sulfate (SO4)	23.	mg/l	5. mg/l
Total Dissolved Solids	297.	mg/l	- -
Turbidity	9.00	NTU	- -
Zinc	28.	ug/l	130. ug/l
Sodium Adsorption Ratio	0.68	-	- -
Conductivity	526.	umhos/cm	- -
Nitrate	0.008	mg/l	0.02 mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C4709
WELL NUMBER: NEC300C
DATE: 7/26/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	275.	mg/l	10.	mg/l
Arsenic	3.7	ug/l	3.0	ug/l
Barium	90.	ug/l	100.	ug/l
Bicarbonate	336.	mg/l	10.	mg/l
Cadmium	0.69	ug/l	0.20	ug/l
Calcium	35.0	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	0.10	mg/l	2.00	mg/l
Chromium	2.30	ug/l	0.50	ug/l
Copper	0.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	186.	mg/l	-	-
Iron	0.01	mg/l	0.03	mg/l
Lead	0.5	ug/l	1.0	ug/l
Magnesium	24.0	mg/l	1.00	mg/l
Manganese	0.053	mg/l	0.010	mg/l
Selenium	0.10	ug/l	0.2	ug/l
pH	8.0	units	-	-
Potassium	7.50	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	39.5	mg/l	2.50	mg/l
Percent Sodium	31.5	-	-	-
Sulfate (SO4)	24.	mg/l	5.	mg/l
Total Dissolved Solids	296.	mg/l	-	-
Turbidity	1.	NTU	-	-
Zinc	4.	ug/l	130.	ug/l
Sodium Adsorption Ratio	1.26	-	-	-
Conductivity	499.	umhos/cm	-	-
Nitrate	0.131	mg/l	0.02	mg/l
TOC	5.7	mg/l	-	-

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5635
WELL NUMBER: NEC300C
DATE: 8/28/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	324.	mg/l	10.	mg/l
Arsenic	0.0	ug/l	3.0	ug/l
Barium	150.	ug/l	100.	ug/l
Bicarbonate	396.	mg/l	10.	mg/l
Cadmium	0.40	ug/l	0.20	ug/l
Calcium	46.5	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	1.00	mg/l	2.00	mg/l
Chromium	1.81	ug/l	0.50	ug/l
Copper	13.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	236.	mg/l	-	-
Iron	0.16	mg/l	0.03	mg/l
Lead	1.3	ug/l	1.0	ug/l
Magnesium	29.0	mg/l	1.00	mg/l
Manganese	0.309	mg/l	0.010	mg/l
Selenium	0.00	ug/l	0.2	ug/l
pH	7.5	units	-	-
Potassium	5.65	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	45.0	mg/l	2.50	mg/l
Percent Sodium	29.3	-	-	-
Sulfate (SO4)	24.	mg/l	5.	mg/l
Total Dissolved Solids	346.	mg/l	-	-
Turbidity	3.00	NTU	-	-
Zinc	31.	ug/l	130.	ug/l
Sodium Adsorption Ratio	1.27	-	-	-
Conductivity	609.	umhos/cm	-	-
Nitrate	0.017	mg/l	0.02	mg/l
TOC	3.5	mg/l	-	-

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5354
WELL NUMBER: NEC650S
DATE: 7/26/83

ANALYTE	RESULT		UNCERTAINTY
Total Alkalinity	360.	mg/l	10. mg/l
Arsenic	0.0	ug/l	3.0 ug/l
Barium	150.	ug/l	100. ug/l
Bicarbonate	440.	mg/l	10. mg/l
Cadmium	0.67	ug/l	0.20 ug/l
Calcium	66.5	mg/l	2.3 mg/l
Carbonate	0.	mg/l	10.0 mg/l
Chloride	1.00	mg/l	2.00 mg/l
Chromium	2.46	ug/l	0.50 ug/l
Copper	0.	ug/l	10.0 ug/l
Fluoride	0.3	mg/l	0.1 mg/l
Total Hardness	306.	mg/l	- -
Iron	0.00	mg/l	0.03 mg/l
Lead	0.0	ug/l	1.0 ug/l
Magnesium	34.0	mg/l	1.00 mg/l
Manganese	0.430	mg/l	0.010 mg/l
Selenium	0.01	ug/l	0.2 ug/l
pH	7.5	units	- -
Potassium	5.65	mg/l	0.30 mg/l
Silver	0.00	ug/l	0.20 ug/l
Sodium	34.0	mg/l	2.50 mg/l
Percent Sodium	19.4	-	- -
Sulfate (SO4)	33.	mg/l	5. mg/l
Total Dissolved Solids	392.	mg/l	- -
Turbidity	1.	NTU	- -
Zinc	22.	ug/l	130. ug/l
Sodium Adsorption Ratio	0.84	-	- -
Conductivity	664.	umhos/cm	- -
Nitrate	0.169	mg/l	0.02 mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5642
WELL NUMBER: NEC650S
DATE: 8/27/83

ANALYTE	RESULT		UNCERTAINTY
Total Alkalinity	332.	mg/l	10. mg/l
Arsenic	3.5	ug/l	3.0 ug/l
Barium	120.	ug/l	100. ug/l
Bicarbonate	405.	mg/l	10. mg/l
Cadmium	0.39	ug/l	0.20 ug/l
Calcium	62.0	mg/l	2.3 mg/l
Carbonate	0.	mg/l	10.0 mg/l
Chloride	1.	mg/l	2.00 mg/l
Chromium	1.77	ug/l	0.50 ug/l
Copper	6.	ug/l	10.0 ug/l
Fluoride	0.2	mg/l	0.1 mg/l
Total Hardness	278.	mg/l	- -
Iron	0.67	mg/l	0.03 mg/l
Lead	0.8	ug/l	1.0 ug/l
Magnesium	30.0	mg/l	1.00 mg/l
Manganese	0.562	mg/l	0.010 mg/l
Selenium	0.04	ug/l	0.2 ug/l
pH	7.6	units	- -
Potassium	5.75	mg/l	0.30 mg/l
Silver	0.14	ug/l	0.20 ug/l
Sodium	29.5	mg/l	2.50 mg/l
Percent Sodium	18.7	-	- -
Sulfate (SO4)	24.	mg/l	5. mg/l
Total Dissolved Solids	352.	mg/l	- -
Turbidity	32.0	NTU	- -
Zinc	48.	ug/l	130. ug/l
Sodium Adsorption Ratio	0.77	-	- -
Conductivity	608.	umhos/cm	- -
Nitrate	0.066	mg/l	0.02 mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C4711
WELL NUMBER: NEC650C
DATE: 7/26/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	316.	mg/l	10.	mg/l
Arsenic	0.0	ug/l	3.0	ug/l
Barium	80.	ug/l	100.	ug/l
Bicarbonate	386.	mg/l	10.	mg/l
Cadmium	0.86	ug/l	0.20	ug/l
Calcium	32.5	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	1.00	mg/l	2.00	mg/l
Chromium	2.37	ug/l	0.50	ug/l
Copper	0.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	166.	mg/l	-	-
Iron	0.04	mg/l	0.03	mg/l
Lead	0.7	ug/l	1.0	ug/l
Magnesium	20.5	mg/l	1.00	mg/l
Manganese	0.192	mg/l	0.010	mg/l
Selenium	0.08	ug/l	0.2	ug/l
pH	7.4	units	-	-
Potassium	4.15	mg/l	0.30	mg/l
Silver	0.11	ug/l	0.20	ug/l
Sodium	64.0	mg/l	2.50	mg/l
Percent Sodium	45.5	-	-	-
Sulfate (SO4)	26.	mg/l	5.	mg/l
Total Dissolved Solids	338.	mg/l	-	-
Turbidity	1.	NTU	-	-
Zinc	6.	ug/l	130.	ug/l
Sodium Adsorption Ratio	2.16	-	-	-
Conductivity	577.	umhos/cm	-	-
Nitrate	0.070	mg/l	0.02	mg/l
TOC	4.9	mg/l	-	-

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5641
WELL NUMBER: NEC650C
DATE: 8/27/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	323.	mg/l	10.	mg/l
Arsenic	3.9	ug/l	3.0	ug/l
Barium	110.	ug/l	100.	ug/l
Bicarbonate	394.	mg/l	10.	mg/l
Cadmium	0.27	ug/l	0.20	ug/l
Calcium	45.5	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	1.0	mg/l	2.00	mg/l
Chromium	1.77	ug/l	0.50	ug/l
Copper	7.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	221.	mg/l	-	-
Iron	0.20	mg/l	0.03	mg/l
Lead	1.2	ug/l	1.0	ug/l
Magnesium	26.0	mg/l	1.00	mg/l
Manganese	0.196	mg/l	0.010	mg/l
Selenium	0.10	ug/l	0.2	ug/l
pH	7.5	units	-	-
Potassium	5.05	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	51.0	mg/l	2.50	mg/l
Percent Sodium	33.3	-	-	-
Sulfate (SO4)	26.	mg/l	5.	mg/l
Total Dissolved Solids	349.	mg/l	-	-
Turbidity	8.00	NTU	-	-
Zinc	36.	ug/l	130.	ug/l
Sodium Adsorption Ratio	1.49	-	-	-
Conductivity	602.	umhos/cm	-	-
Nitrate	0.090	mg/l	0.02	mg/l
TOC	2.5	mg/l	-	-

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5056
WELL NUMBER: NEC1200S
DATE: 7/27/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	366.	mg/l	10.	mg/l
Arsenic	0.0	ug/l	3.0	ug/l
Barium	190.	ug/l	100.	ug/l
Bicarbonate	447.	mg/l	10.	mg/l
Cadmium	0.65	ug/l	0.20	ug/l
Calcium	68.0	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	2.00	mg/l	2.00	mg/l
Chromium	2.91	ug/l	0.50	ug/l
Copper	0.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	316	mg/l	-	-
Iron	0.00	mg/l	0.03	mg/l
Lead	0.0	ug/l	1.0	ug/l
Magnesium	35.5	mg/l	1.00	mg/l
Manganese	0.383	mg/l	0.010	mg/l
Selenium	0.11	ug/l	0.2	ug/l
pH	7.5	units	-	-
Potassium	5.45	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	32.0	mg/l	2.50	mg/l
Percent Sodium	18.0	-	-	-
Sulfate (SO4)	29.	mg/l	5.	mg/l
Total Dissolved Solids	393.	mg/l	-	-
Turbidity	1.	NTU	-	-
Zinc	26.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.78	-	-	-
Conductivity	663.	umhos/cm	-	-
Nitrate	0.116	mg/l	0.02	mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5646
WELL NUMBER: NEC1200S
DATE: 8/27/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	334.	mg/l	10.	mg/l
Arsenic	2.5	ug/l	3.0	ug/l
Barium	180.	ug/l	100.	ug/l
Bicarbonate	408.	mg/l	10.	mg/l
Cadmium	0.53	ug/l	0.20	ug/l
Calcium	67.0	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	1.	mg/l	2.00	mg/l
Chromium	1.81	ug/l	0.50	ug/l
Copper	6.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	303.	mg/l	-	-
Iron	0.35	mg/l	0.03	mg/l
Lead	1.2	ug/l	1.0	ug/l
Magnesium	33.0	mg/l	1.00	mg/l
Manganese	0.449	mg/l	0.010	mg/l
Selenium	0.04	ug/l	0.2	ug/l
pH	7.6	units	-	-
Potassium	5.80	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	30.0	mg/l	2.50	mg/l
Percent Sodium	17.6	-	-	-
Sulfate (SO4)	29.	mg/l	5.	mg/l
Total Dissolved Solids	367.	mg/l	-	-
Turbidity	14.0	NTU	-	-
Zinc	58.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.75	-	-	-
Conductivity	655.	umhos/cm	-	-
Nitrate	0.107	mg/l	0.02	mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5055
WELL NUMBER: NEC1200C
DATE: 7/27/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	356.	mg/l	10.	mg/l
Arsenic	0.0	ug/l	3.0	ug/l
Barium	210.	ug/l	100.	ug/l
Bicarbonate	435.	mg/l	10.	mg/l
Cadmium	1.12	ug/l	0.20	ug/l
Calcium	88.5	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	3.00	mg/l	2.00	mg/l
Chromium	2.81	ug/l	0.50	ug/l
Copper	0.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	363.	mg/l	-	-
Iron	0.00	mg/l	0.03	mg/l
Lead	0.0	ug/l	1.0	ug/l
Magnesium	34.5	mg/l	1.00	mg/l
Manganese	0.195	mg/l	0.010	mg/l
Selenium	0.05	ug/l	0.2	ug/l
pH	7.5	units	-	-
Potassium	4.80	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	8.50	mg/l	2.50	mg/l
Percent Sodium	4.8	-	-	-
Sulfate (SO4)	21.	mg/l	5.	mg/l
Total Dissolved Solids	381.	mg/l	-	-
Turbidity	1.	NTU	-	-
Zinc	9.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.19	-	-	-
Conductivity	646.	umhos/cm	-	-
Nitrate	1.50	mg/l	0.02	mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5645
WELL NUMBER: NEC1200C
DATE: 8/27/83

ANALYTE	RESULT		UNCERTAINTY
Total Alkalinity	359.	mg/l	10. mg/l
Arsenic	2.2	ug/l	3.0 ug/l
Barium	290.	ug/l	100. ug/l
Bicarbonate	438.	mg/l	10. mg/l
Cadmium	0.55	ug/l	0.20 ug/l
Calcium	88.5	mg/l	2.3 mg/l
Carbonate	0.	mg/l	10.0 mg/l
Chloride	2.00	mg/l	2.00 mg/l
Chromium	2.10	ug/l	0.50 ug/l
Copper	7.	ug/l	10.0 ug/l
Fluoride	0.2	mg/l	0.1 mg/l
Total Hardness	357.	mg/l	- -
Iron	0.20	mg/l	0.03 mg/l
Lead	1.50	ug/l	1.0 ug/l
Magnesium	33.0	mg/l	1.00 mg/l
Manganese	0.243	mg/l	0.010 mg/l
Selenium	0.04	ug/l	0.2 ug/l
pH	7.5	units	- -
Potassium	5.20	mg/l	0.30 mg/l
Silver	0.18	ug/l	0.20 ug/l
Sodium	18.0	mg/l	2.50 mg/l
Percent Sodium	9.8	-	- -
Sulfate (SO4)	24.	mg/l	5. mg/l
Total Dissolved Solids	392.	mg/l	- -
Turbidity	10.	NTU	- -
Zinc	58.	ug/l	130. ug/l
Sodium Adsorption Ratio	0.41	-	- -
Conductivity	655.	umhos/cm	- -
Nitrate	1.38	mg/l	0.02 mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C4676
WELL NUMBER: NES50S
DATE: 7/24/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	354.	mg/l	10.	mg/l
Arsenic	0.0	ug/l	3.0	ug/l
Barium	300.	ug/l	100.	ug/l
Bicarbonate	432.	mg/l	10.	mg/l
Cadmium	0.29	ug/l	0.20	ug/l
Calcium	74.0	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	2.00	mg/l	2.00	mg/l
Chromium	2.37	ug/l	0.50	ug/l
Copper	4.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	319.	mg/l	-	-
Iron	0.04	mg/l	0.03	mg/l
Lead	0.0	ug/l	1.0	ug/l
Magnesium	32.5	mg/l	1.00	mg/l
Manganese	0.345	mg/l	0.010	mg/l
Selenium	0.20	ug/l	0.2	ug/l
pH	7.5	units	-	-
Potassium	4.65	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	20.5	mg/l	2.50	mg/l
Percent Sodium	12.2	-	-	-
Sulfate (SO4)	31.	mg/l	5.	mg/l
Total Dissolved Solids	379.	mg/l	-	-
Turbidity	1.00	NTU	-	-
Zinc	71.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.50	-	-	-
Conductivity	631.	umhos/cm	-	-
Nitrate	0.145	mg/l	0.02	mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5610
WELL NUMBER: NES50S
DATE: 8/28/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	350.	mg/l	10.	mg/l
Arsenic	2.9	ug/l	3.0	ug/l
Barium	140.	ug/l	100.	ug/l
Bicarbonate	427.	mg/l	10.	mg/l
Cadmium	0.33	ug/l	0.20	ug/l
Calcium	75.0	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	1.	mg/l	2.00	mg/l
Chromium	2.02	ug/l	0.50	ug/l
Copper	7.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	313.	mg/l	-	-
Iron	0.17	mg/l	0.03	mg/l
Lead	0.0	ug/l	1.0	ug/l
Magnesium	30.5	mg/l	1.00	mg/l
Manganese	0.125	mg/l	0.010	mg/l
Selenium	0.06	ug/l	0.2	ug/l
pH	7.8	units	-	-
Potassium	4.8	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	15.0	mg/l	2.50	mg/l
Percent Sodium	9.4	-	-	-
Sulfate (SO4)	25.	mg/l	5.	mg/l
Total Dissolved Solids	361.	mg/l	-	-
Turbidity	1.	NTU	-	-
Zinc	2110.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.37	-	-	-
Conductivity	620.	umhos/cm	-	-
Nitrate	0.006	mg/l	0.02	mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C4689
WELL NUMBER: NES90S
DATE: 7/25/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	360.	mg/l	10.	mg/l
Arsenic	3.7	ug/l	3.0	ug/l
Barium	290.	ug/l	100.	ug/l
Bicarbonate	439.	mg/l	10.	mg/l
Cadmium	0.54	ug/l	0.20	ug/l
Calcium	80.5	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	8.00	mg/l	2.00	mg/l
Chromium	2.49	ug/l	0.50	ug/l
Copper	0.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	327.	mg/l	-	-
Iron	0.04	mg/l	0.03	mg/l
Lead	1.2	ug/l	1.0	ug/l
Magnesium	30.5	mg/l	1.00	mg/l
Manganese	0.577	mg/l	0.010	mg/l
Selenium	0.04	ug/l	0.2	ug/l
pH	7.7	units	-	-
Potassium	4.60	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	28.0	mg/l	2.50	mg/l
Percent Sodium	15.6	-	-	-
Sulfate (SO4)	37.	mg/l	5.	mg/l
Total Dissolved Solids	406.	mg/l	-	-
Turbidity	1.00	NTU	-	-
Zinc	50.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.67	-	-	-
Conductivity	659.	umhos/cm	-	-
Nitrate	0.173	mg/l	0.02	mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5619
WELL NUMBER: NES90S
DATE: 8/28/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	354.	mg/l	10.	mg/l
Arsenic	0.0	ug/l	3.0	ug/l
Barium	100.	ug/l	100.	ug/l
Bicarbonate	432.	mg/l	10.	mg/l
Cadmium	0.37	ug/l	0.20	ug/l
Calcium	73.0	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	8.00	mg/l	2.00	mg/l
Chromium	1.71	ug/l	0.50	ug/l
Copper	3.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	312.	mg/l	-	-
Iron	2.02	mg/l	0.03	mg/l
Lead	2.1	ug/l	1.0	ug/l
Magnesium	31.5	mg/l	1.00	mg/l
Manganese	0.658	mg/l	0.010	mg/l
Selenium	0.03	ug/l	0.2	ug/l
pH	7.6	units	-	-
Potassium	5.55	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	27.5	mg/l	2.50	mg/l
Percent Sodium	16.0	-	-	-
Sulfate (SO4)	35.	mg/l	5.	mg/l
Total Dissolved Solids	394.	mg/l	-	-
Turbidity	14.	NTU	-	-
Zinc	3560	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.68	-	-	-
Conductivity	661.	umhos/cm	-	-
Nitrate	0.009	mg/l	0.02	mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C4688
WELL NUMBER: NES90C
DATE: 7/25/83

ANALYTE	RESULT		UNCERTAINTY
Total Alkalinity	309.	mg/l	10. mg/l
Arsenic	0.0	ug/l	3.0 ug/l
Barium	170.	ug/l	100. ug/l
Bicarbonate	377.	mg/l	10. mg/l
Cadmium	0.77	ug/l	0.20 ug/l
Calcium	55.0	mg/l	2.3 mg/l
Carbonate	0.	mg/l	10.0 mg/l
Chloride	2.00	mg/l	2.00 mg/l
Chromium	1.90	ug/l	0.50 ug/l
Copper	0.	ug/l	10.0 ug/l
Fluoride	0.2	mg/l	0.1 mg/l
Total Hardness	247.	mg/l	- -
Iron	0.03	mg/l	0.03 mg/l
Lead	0.7	ug/l	1.0 ug/l
Magnesium	26.5	mg/l	1.00 mg/l
Manganese	0.470	mg/l	0.010 mg/l
Selenium	0.49	ug/l	0.2 ug/l
pH	7.6	units	- -
Potassium	5.05	mg/l	0.30 mg/l
Silver	0.00	ug/l	0.20 ug/l
Sodium	31.5	mg/l	2.50 mg/l
Percent Sodium	21.7	-	- -
Sulfate (SO4)	25.	mg/l	5. mg/l
Total Dissolved Solids	333.	mg/l	- -
Turbidity	1.00	NTU	- -
Zinc	35.	ug/l	130. ug/l
Sodium Adsorption Ratio	0.87	-	- -
Conductivity	563.	umhos/cm	- -
Nitrate	0.507	mg/l	0.02 mg/l
TOC	5.4	mg/l	- -

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5618
WELL NUMBER: NES90C
DATE: 8/28/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	334.	mg/l	10.	mg/l
Arsenic	0.0	ug/l	3.0	ug/l
Barium	100.	ug/l	100.	ug/l
Bicarbonate	408.	mg/l	10.	mg/l
Cadmium	0.52	ug/l	0.20	ug/l
Calcium	50.5	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	1.00	mg/l	2.00	mg/l
Chromium	1.74	ug/l	0.50	ug/l
Copper	6.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	239.	mg/l	-	-
Iron	0.04	mg/l	0.03	mg/l
Lead	1.9	ug/l	1.0	ug/l
Magnesium	27.5	mg/l	1.00	mg/l
Manganese	0.270	mg/l	0.010	mg/l
Selenium	0.23	ug/l	0.2	ug/l
pH	7.6	units	-	-
Potassium	5.45	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	43.0	mg/l	2.50	mg/l
Percent Sodium	28.0	-	-	-
Sulfate (SO4)	19.	mg/l	5.	mg/l
Total Dissolved Solids	348.	mg/l	-	-
Turbidity	2.00	NTU	-	-
Zinc	3600	ug/l	130.	ug/l
Sodium Adsorption Ratio	1.21	-	-	-
Conductivity	593.	umhos/cm	-	-
Nitrate	0.009	mg/l	0.02	mg/l
TOC	2.5	mg/l	-	-

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C4691
WELL NUMBER: NES150S
DATE: 7/25/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	367	mg/l	10.	mg/l
Arsenic	0.0	ug/l	3.0	ug/l
Barium	170.	ug/l	100.	ug/l
Bicarbonate	448.	mg/l	10.	mg/l
Cadmium	0.48	ug/l	0.20	ug/l
Calcium	77.5	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	5.00	mg/l	2.00	mg/l
Chromium	2.96	ug/l	0.50	ug/l
Copper	0.	ug/l	10.0	ug/l
Fluoride	0.3	mg/l	0.1	mg/l
Total Hardness	317.	mg/l	-	-
Iron	0.01	mg/l	0.03	mg/l
Lead	0.8	ug/l	1.0	ug/l
Magnesium	30.0	mg/l	1.00	mg/l
Manganese	0.419	mg/l	0.010	mg/l
Selenium	0.10	ug/l	0.2	ug/l
pH	7.7	units	-	-
Potassium	4.45	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	25.5	mg/l	2.50	mg/l
Percent Sodium	14.8	-	-	-
Sulfate (SO4)	37.	mg/l	5.	mg/l
Total Dissolved Solids	401.	mg/l	-	-
Turbidity	1.	NTU	-	-
Zinc	31.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.62	-	-	-
Conductivity	664.	umhos/cm	-	-
Nitrate	0.087	mg/l	0.02	mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C4690
WELL NUMBER: NES150C
DATE: 7/25/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	261.	mg/l	10.	mg/l
Arsenic	2.7	ug/l	3.0	ug/l
Barium	140.	ug/l	100.	ug/l
Bicarbonate	319.	mg/l	10.	mg/l
Cadmium	0.00	ug/l	0.20	ug/l
Calcium	34.0	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	0.10	mg/l	2.00	mg/l
Chromium	2.45	ug/l	0.50	ug/l
Copper	0.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	151.	mg/l	-	-
Iron	0.03	mg/l	0.03	mg/l
Lead	0.8	ug/l	1.0	ug/l
Magnesium	16.0	mg/l	1.00	mg/l
Manganese	0.144	mg/l	0.010	mg/l
Selenium	0.09	ug/l	0.2	ug/l
pH	7.6	units	-	-
Potassium	6.05	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	46.0	mg/l	2.50	mg/l
Percent Sodium	39.8	-	-	-
Sulfate (SO4)	26.	mg/l	5.	mg/l
Total Dissolved Solids	286.	mg/l	-	-
Turbidity	1.00	NTU	-	-
Zinc	28.	ug/l	130.	ug/l
Sodium Adsorption Ratio	1.63	-	-	-
Conductivity	493.	umhos/cm	-	-
Nitrate	0.065	mg/l	0.02	mg/l
TOC	5.2	mg/l	-	-

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5627
WELL NUMBER: NES150C
DATE: 8/28/83

ANALYTE	RESULT		UNCERTAINTY
Total Alkalinity	244.	mg/l	10. mg/l
Arsenic	3.7	ug/l	3.0 ug/l
Barium	120.	ug/l	100. ug/l
Bicarbonate	298.	mg/l	10. mg/l
Cadmium	0.00	ug/l	0.20 ug/l
Calcium	31.0	mg/l	2.3 mg/l
Carbonate	0.	mg/l	10.0 mg/l
Chloride	1.	mg/l	2.00 mg/l
Chromium	1.74	ug/l	0.50 ug/l
Copper	2.	ug/l	10.0 ug/l
Fluoride	0.2	mg/l	0.1 mg/l
Total Hardness	145.	mg/l	- -
Iron	0.09	mg/l	0.03 mg/l
Lead	1.7	ug/l	1.0 ug/l
Magnesium	16.5	mg/l	1.00 mg/l
Manganese	0.106	mg/l	0.010 mg/l
Selenium	0.02	ug/l	0.2 ug/l
pH	7.9	units	- -
Potassium	10.5	mg/l	0.30 mg/l
Silver	0.00	ug/l	0.20 ug/l
Sodium	44.5	mg/l	2.50 mg/l
Percent Sodium	39.8	-	- -
Sulfate (SO4)	26.	mg/l	5. mg/l
Total Dissolved Solids	276.	mg/l	- -
Turbidity	4.00	NTU	- -
Zinc	42.	ug/l	130. ug/l
Sodium Adsorption Ratio	1.60	-	- -
Conductivity	474.	umhos/cm	- -
Nitrate	0.019	mg/l	0.02 mg/l
TOC	2.8	mg/l	- -

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C4693
WELL NUMBER: NES250S
DATE: 7/25/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	364.	mg/l	10.	mg/l
Arsenic	0.0	ug/l	3.0	ug/l
Barium	330.	ug/l	100.	ug/l
Bicarbonate	444.	mg/l	10.	mg/l
Cadmium	0.56	ug/l	0.20	ug/l
Calcium	75.5	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	2.00	mg/l	2.00	mg/l
Chromium	2.17	ug/l	0.50	ug/l
Copper	0.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	316.	mg/l	-	-
Iron	0.00	mg/l	0.03	mg/l
Lead	4.8	ug/l	1.0	ug/l
Magnesium	31.0	mg/l	1.00	mg/l
Manganese	0.228	mg/l	0.010	mg/l
Selenium	0.32	ug/l	0.2	ug/l
pH	7.6	units	-	-
Potassium	3.75	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	19.0	mg/l	2.50	mg/l
Percent Sodium	11.5	-	-	-
Sulfate (SO4)	24.	mg/l	5.	mg/l
Total Dissolved Solids	375.	mg/l	-	-
Turbidity	2.00	NTU	-	-
Zinc	55.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.46	-	-	-
Conductivity	629.	umhos/cm	-	-
Nitrate	0.199	mg/l	0.02	mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5634
WELL NUMBER: NES250S
DATE: 8/28/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	343.	mg/l	10.	mg/l
Arsenic	0.0	ug/l	3.0	ug/l
Barium	140.	ug/l	100.	ug/l
Bicarbonate	419.	mg/l	10.	mg/l
Cadmium	0.79	ug/l	0.20	ug/l
Calcium	77.5	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	1.00	mg/l	2.00	mg/l
Chromium	1.94	ug/l	0.50	ug/l
Copper	5.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	323.	mg/l	-	-
Iron	0.16	mg/l	0.03	mg/l
Lead	1.6	ug/l	1.0	ug/l
Magnesium	31.5	mg/l	1.00	mg/l
Manganese	0.298	mg/l	0.010	mg/l
Selenium	0.39	ug/l	0.2	ug/l
pH	7.4	units	-	-
Potassium	4.90	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	17.0	mg/l	2.50	mg/l
Percent Sodium	10.2	-	-	-
Sulfate (SO4)	23.	mg/l	5.	mg/l
Total Dissolved Solids	361.	mg/l	-	-
Turbidity	6.00	NTU	-	-
Zinc	60.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.41	-	-	-
Conductivity	641.	umhos/cm	-	-
Nitrate	0.150	mg/l	0.02	mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C4692
WELL NUMBER: NES250C
DATE: 7/25/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	220.	mg/l	10.	mg/l
Arsenic	0.0	ug/l	3.0	ug/l
Barium	140.	ug/l	100.	ug/l
Bicarbonate	269.	mg/l	10.	mg/l
Cadmium	0.37	ug/l	0.20	Tg/l
Calcium	35.0	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	0.10	mg/l	2.00	mg/l
Chromium	2.61	ug/l	0.50	ug/l
Copper	0.	ug/l	10.0	ug/l
Fluoride	0.3	mg/l	0.1	mg/l
Total Hardness	151.	mg/l	-	-
Iron	0.01	mg/l	0.03	mg/l
Lead	0.4	ug/l	1.0	ug/l
Magnesium	15.5	mg/l	1.00	mg/l
Manganese	0.026	mg/l	0.010	mg/l
Selenium	0.21	ug/l	0.2	ug/l
pH	8.0	units	-	-
Potassium	5.30	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	29.0	mg/l	2.50	mg/l
Percent Sodium	29.3	-	-	-
Sulfate (SO4)	25.	mg/l	5.	mg/l
Total Dissolved Solids	243.	mg/l	-	-
Turbidity	1.	NTU	-	-
Zinc	20.	ug/l	130.	ug/l
Sodium Adsorption Ratio	1.03	-	-	-
Conductivity	420.	umhos/cm	-	-
Nitrate	0.116	mg/l	0.02	mg/l
TOC	5.8	mg/l	-	-

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5633
WELL NUMBER: NES250C
DATE: 8/28/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	298.	mg/l	10.	mg/l
Arsenic	2.7	ug/l	3.0	ug/l
Barium	140.	ug/l	100.	ug/l
Bicarbonate	364.	mg/l	10.	mg/l
Cadmium	0.94	ug/l	0.20	ug/l
Calcium	38.0	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	1.	mg/l	2.00	mg/l
Chromium	2.12	ug/l	0.50	ug/l
Copper	11.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	192.	mg/l	-	-
Iron	0.23	mg/l	0.03	mg/l
Lead	1.2	ug/l	1.0	ug/l
Magnesium	23.5	mg/l	1.00	mg/l
Manganese	0.082	mg/l	0.010	mg/l
Selenium	0.00	ug/l	0.2	ug/l
pH	7.6	units	-	-
Potassium	8.65	mg/l	0.30	mg/l
Silver	100.	ug/l	0.20	ug/l
Sodium	54.0	mg/l	2.50	mg/l
Percent Sodium	37.9	-	-	-
Sulfate (SO4)	27.	mg/l	5.	mg/l
Total Dissolved Solids	332.	mg/l	-	-
Turbidity	10.0	NTU	-	-
Zinc	44.	ug/l	130.	ug/l
Sodium Adsorption Ratio	1.70	-	-	-
Conductivity	578.	umhos/cm	-	-
Nitrate	0.018	mg/l	0.02	mg/l
TOC	3.2	mg/l	-	-

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C4695
WELL NUMBER: NES600S
DATE: 7/25/83

ANALYTE	RESULT		UNCERTAINTY
Total Alkalinity	378.	mg/l	10. mg/l
Arsenic	0.0	ug/l	3.0 ug/l
Barium	130.	ug/l	100. ug/l
Bicarbonate	461.	mg/l	10. mg/l
Cadmium	3.04	ug/l	0.20 ug/l
Calcium	59.5	mg/l	2.3 mg/l
Carbonate	0.	mg/l	10.0 mg/l
Chloride	1.00	mg/l	2.00 mg/l
Chromium	2.50	ug/l	0.50 ug/l
Copper	0.	ug/l	10.0 ug/l
Fluoride	0.2	mg/l	0.1 mg/l
Total Hardness	266.	mg/l	- -
Iron	0.01	mg/l	0.03 mg/l
Lead	0.7	ug/l	1.0 ug/l
Magnesium	28.5	mg/l	1.00 mg/l
Manganese	0.243	mg/l	0.010 mg/l
Selenium	0.07	ug/l	0.2 ug/l
pH	7.6	units	- -
Potassium	4.40	mg/l	0.30 mg/l
Silver	0.29	ug/l	0.20 ug/l
Sodium	44.0	mg/l	2.50 mg/l
Percent Sodium	26.4	-	- -
Sulfate (SO4)	23.	mg/l	5. mg/l
Total Dissolved Solids	389.	mg/l	- -
Turbidity	1.	NTU	- -
Zinc	16.	ug/l	130. ug/l
Sodium Adsorption Ratio	1.17	-	- -
Conductivity	658.	umhos/cm	- -
Nitrate	0.182	mg/l	0.02 mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5638
WELL NUMBER: NES600S
DATE: 8/27/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	369.	mg/l	10.	mg/l
Arsenic	0.0	ug/l	3.0	ug/l
Barium	140.	ug/l	100.	ug/l
Bicarbonate	451.	mg/l	10.	mg/l
Cadmium	0.57	ug/l	0.20	ug/l
Calcium	62.0	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	1.	mg/l	2.00	mg/l
Chromium	1.89	ug/l	0.50	ug/l
Copper	7.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	278.	mg/l	-	-
Iron	0.17	mg/l	0.03	mg/l
Lead	1.6	ug/l	1.0	ug/l
Magnesium	30.0	mg/l	1.00	mg/l
Manganese	0.253	mg/l	0.010	mg/l
Selenium	0.03	ug/l	0.2	ug/l
pH	7.5	units	-	-
Potassium	5.70	mg/l	0.30	mg/l
Silver	0.03	ug/l	0.20	ug/l
Sodium	42.5	mg/l	2.50	mg/l
Percent Sodium	24.8	-	-	-
Sulfate (SO4)	23.	mg/l	5.	mg/l
Total Dissolved Solids	386.	mg/l	-	-
Turbidity	7.00	NTU	-	-
Zinc	60.	ug/l	130.	ug/l
Sodium Adsorption Ratio	1.11	-	-	-
Conductivity	658.	umhos/cm	-	-
Nitrate	0.062	mg/l	0.02	mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C4694
WELL NUMBER: NES600C
DATE: 7/25/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	364.	mg/l	10.	mg/l
Arsenic	0.0	ug/l	3.0	ug/l
Barium	160.	ug/l	100.	ug/l
Bicarbonate	444.	mg/l	10.	mg/l
Cadmium	2.04	ug/l	0.20	ug/l
Calcium	81.5	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	0.10	mg/l	2.00	mg/l
Chromium	2.50	ug/l	0.50	ug/l
Copper	0.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	327.	mg/l	-	-
Iron	0.05	mg/l	0.03	mg/l
Lead	0.4	ug/l	1.0	ug/l
Magnesium	30.0	mg/l	1.00	mg/l
Manganese	0.247	mg/l	0.010	mg/l
Selenium	0.01	ug/l	0.2	ug/l
pH	7.8	units	-	-
Potassium	3.95	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	8.50	mg/l	2.50	mg/l
Percent Sodium	5.3	-	-	-
Sulfate (SO4)	23.	mg/l	5.	mg/l
Total Dissolved Solids	369.	mg/l	-	-
Turbidity	1.	NTU	-	-
Zinc	23.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.20	-	-	-
Conductivity	640.	umhos/cm	-	-
Nitrate	0.737	mg/l	0.02	mg/l
TOC	3.8	mg/l	-	-

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5637
WELL NUMBER: NES600C
DATE: 8/27/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	338.	mg/l	10.	mg/l
Arsenic	0.0	ug/l	3.0	ug/l
Barium	170.	ug/l	100.	ug/l
Bicarbonate	413.	mg/l	10.	mg/l
Cadmium	0.45	ug/l	0.20	ug/l
Calcium	69.5	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	1.00	mg/l	2.00	mg/l
Chromium	1.94	ug/l	0.50	ug/l
Copper	7.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	295.	mg/l	-	-
Iron	0.26	mg/l	0.03	mg/l
Lead	1.4	ug/l	1.0	ug/l
Magnesium	29.5	mg/l	1.00	mg/l
Manganese	0.211	mg/l	0.010	mg/l
Selenium	0.21	ug/l	0.2	ug/l
pH	7.5	units	-	-
Potassium	5.30	mg/l	0.30	mg/l
Silver	3.49	ug/l	0.20	ug/l
Sodium	28.5	mg/l	2.50	mg/l
Percent Sodium	17.3	-	-	-
Sulfate (SO4)	25.	mg/l	5.	mg/l
Total Dissolved Solids	364.	mg/l	-	-
Turbidity	11.0	NTU	-	-
Zinc	52.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.72	-	-	-
Conductivity	635.	umhos/cm	-	-
Nitrate	0.361	mg/l	0.02	mg/l
TOC	3.2	mg/l	-	-

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C4697
WELL NUMBER: NES1200S
DATE: 7/25/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	375.	mg/l	10.	mg/l
Arsenic	4.8	ug/l	3.0	ug/l
Barium	370.	ug/l	100.	ug/l
Bicarbonate	458.	mg/l	10.	mg/l
Cadmium	0.42	ug/l	0.20	ug/l
Calcium	64.5	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	2.00	mg/l	2.00	mg/l
Chromium	1.76	ug/l	0.50	ug/l
Copper	0.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	299.	mg/l	-	-
Iron	0.03	mg/l	0.03	mg/l
Lead	0.7	ug/l	1.0	ug/l
Magnesium	33.5	mg/l	1.00	mg/l
Manganese	0.450	mg/l	0.010	mg/l
Selenium	0.02	ug/l	0.2	ug/l
pH	7.9	units	-	-
Potassium	6.15	mg/l	0.30	mg/l
Silver	0.03	ug/l	0.20	ug/l
Sodium	41.5	mg/l	2.50	mg/l
Percent Sodium	23.1	-	-	-
Sulfate (SO4)	38.	mg/l	5.	mg/l
Total Dissolved Solids	412.	mg/l	-	-
Turbidity	2.00	NTU	-	-
Zinc	55.	ug/l	130.	ug/l
Sodium Adsorption Ratio	1.04	-	-	-
Conductivity	683.	umhos/cm	-	-
Nitrate	0.142	mg/l	0.02	mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5648
WELL NUMBER: NES1200S
DATE: 8/27/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	358.	mg/l	10.	mg/l
Arsenic	4.0	ug/l	3.0	ug/l
Barium	170.	ug/l	100.	ug/l
Bicarbonate	437.	mg/l	10.	mg/l
Cadmium	0.55	ug/l	0.20	ug/l
Calcium	64.5	mg/l	2.3	mg/l
Carbonate	0.0	mg/l	10.0	mg/l
Chloride	1.	mg/l	2.00	mg/l
Chromium	1.65	ug/l	0.50	ug/l
Copper	4.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	301.	mg/l	-	-
Iron	.32	mg/l	0.03	mg/l
Lead	2.0	ug/l	1.0	ug/l
Magnesium	34.0	mg/l	1.00	mg/l
Manganese	0.236	mg/l	0.010	mg/l
Selenium	0.00	ug/l	0.2	ug/l
pH	7.5	units	-	-
Potassium	5.80	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	35.0	mg/l	2.50	mg/l
Percent Sodium	20.1	-	-	-
Sulfate (SO4)	35.	mg/l	5.	mg/l
Total Dissolved Solids	391.	mg/l	-	-
Turbidity	13.	NTU	-	-
Zinc	63.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.88	-	-	-
Conductivity	666.	umhos/cm	-	-
Nitrate	0.033	mg/l	0.02	mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C4696
WELL NUMBER: NES1200C
DATE: 7/25/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	391.	mg/l	10.	mg/l
Arsenic	0.0	ug/l	3.0	ug/l
Barium	290.	ug/l	100.	ug/l
Bicarbonate	478.	mg/l	10.	mg/l
Cadmium	1.23	ug/l	0.20	ug/l
Calcium	91.0	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	1.00	mg/l	2.00	mg/l
Chromium	2.00	ug/l	0.50	ug/l
Copper	0.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	365.	mg/l	-	-
Iron	0.01	mg/l	0.03	mg/l
Lead	0.7	ug/l	1.0	ug/l
Magnesium	33.5	mg/l	1.00	mg/l
Manganese	0.164	mg/l	0.010	mg/l
Selenium	0.07	ug/l	0.2	ug/l
pH	7.6	units	-	-
Potassium	4.55	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	6.00	mg/l	2.50	mg/l
Percent Sodium	3.4	-	-	-
Sulfate (SO4)	24.	mg/l	5.	mg/l
Total Dissolved Solids	405.	mg/l	-	-
Turbidity	1.	NTU	-	-
Zinc	44.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.14	-	-	-
Conductivity	696.	umhos/cm	-	-
Nitrate	2.03	mg/l	0.02	mg/l
TOC	6.8	mg/l	-	-

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5647
WELL NUMBER: NES1200C
DATE: 8/27/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	366.	mg/l	10.	mg/l
Arsenic	3.2	ug/l	3.0	ug/l
Barium	170.	ug/l	100.	ug/l
Bicarbonate	447.	mg/l	10.	mg/l
Cadmium	0.36	ug/l	0.20	ug/l
Calcium	97.5	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	1.00	mg/l	2.00	mg/l
Chromium	1.94	ug/l	0.50	ug/l
Copper	4.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	392.	mg/l	-	-
Iron	0.12	mg/l	0.03	mg/l
Lead	1.0	ug/l	1.0	ug/l
Magnesium	36.0	mg/l	1.00	mg/l
Manganese	0.024	mg/l	0.010	mg/l
Selenium	0.08	ug/l	0.2	ug/l
pH	7.6	units	-	-
Potassium	5.55	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	8.50	mg/l	2.50	mg/l
Percent Sodium	4.5	-	-	-
Sulfate (SO4)	26.	mg/l	5.	mg/l
Total Dissolved Solids	401.	mg/l	-	-
Turbidity	3.0	NTU	-	-
Zinc	92.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.19	-	-	-
Conductivity	705.	umhos/cm	-	-
Nitrate	1.54	mg/l	0.02	mg/l
TOC	3.0	mg/l	-	-

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C4673
WELL NUMBER: NW50S
DATE: 7/24/83

ANALYTE	RESULT		UNCERTAINTY
Total Alkalinity	457.	mg/l	10. mg/l
Arsenic	4.2	ug/l	3.0 ug/l
Barium	240.	ug/l	100. ug/l
Bicarbonate	558.	mg/l	10. mg/l
Cadmium	0.21	ug/l	0.20 ug/l
Calcium	238.	mg/l	2.3 mg/l
Carbonate	0.	mg/l	10.0 mg/l
Chloride	10.0	mg/l	2.00 mg/l
Chromium	9.55	ug/l	0.50 ug/l
Copper	5.	ug/l	10.0 ug/l
Fluoride	0.1	mg/l	0.1 mg/l
Total Hardness	1110	mg/l	- -
Iron	0.07	mg/l	0.03 mg/l
Lead	5.1	ug/l	1.0 ug/l
Magnesium	126.	mg/l	1.00 mg/l
Manganese	1.06	mg/l	0.010 mg/l
Selenium	3.22	ug/l	0.2 ug/l
pH	7.2	units	- -
Potassium	7.85	mg/l	0.30 mg/l
Silver	0.02	ug/l	0.20 ug/l
Sodium	63.5	mg/l	2.50 mg/l
Percent Sodium	11.0	-	- -
Sulfate (SO4)	898.	mg/l	5. mg/l
Total Dissolved Solids	1640	mg/l	- -
Turbidity	1.	NTU	- -
Zinc	137.	ug/l	130. ug/l
Sodium Adsorption Ratio	0.83	-	- -
Conductivity	1944	umhos/cm	- -
Nitrate	5.04	mg/l	0.02 mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5615
WELL NUMBER: NW50S
DATE: 8/28/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	455.	mg/l	10.	mg/l
Arsenic	3.6	ug/l	3.0	ug/l
Barium	80.	ug/l	100.	ug/l
Bicarbonate	555.	mg/l	10.	mg/l
Cadmium	0.83	ug/l	0.20	ug/l
Calcium	225.	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	8.50	mg/l	2.00	mg/l
Chromium	1.90	ug/l	0.50	ug/l
Copper	16.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	1070	mg/l	-	-
Iron	0.32	mg/l	0.03	mg/l
Lead	1.6	ug/l	1.0	ug/l
Magnesium	123.	mg/l	1.00	mg/l
Manganese	0.871	mg/l	0.010	mg/l
Selenium	2.32	ug/l	0.2	ug/l
pH	7.6	units	-	-
Potassium	9.10	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	66.0	mg/l	2.50	mg/l
Percent Sodium	11.8	-	-	-
Sulfate (SO4)	787.	mg/l	5.	mg/l
Total Dissolved Solids	1490	mg/l	-	-
Turbidity	5.00	NTU	-	-
Zinc	-	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.88	-	-	-
Conductivity	1843.	umhos/cm	-	-
Nitrate	0.035	mg/l	0.02	mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C4672
WELL NUMBER: NW50C
DATE: 7/24/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	342.	mg/l	10.	mg/l
Arsenic	4.6	ug/l	3.0	ug/l
Barium	80.	ug/l	100.	ug/l
Bicarbonate	418.	mg/l	10.	mg/l
Cadmium	0.00	ug/l	0.20	ug/l
Calcium	62.5	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	3.00	mg/l	2.00	mg/l
Chromium	14.5	ug/l	0.50	ug/l
Copper	2.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	292.	mg/l	-	-
Iron	5.24	mg/l	0.03	mg/l
Lead	18.1	ug/l	1.0	ug/l
Magnesium	33.0	mg/l	1.00	mg/l
Manganese	0.443	mg/l	0.010	mg/l
Selenium	14.6	ug/l	0.2	ug/l
pH	7.4	units	-	-
Potassium	5.50	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	76.5	mg/l	2.50	mg/l
Percent Sodium	36.2	-	-	-
Sulfate (SO4)	154.	mg/l	5.	mg/l
Total Dissolved Solids	541.	mg/l	-	-
Turbidity	34.0	NTU	-	-
Zinc	108.	ug/l	130.	ug/l
Sodium Adsorption Ratio	1.95	-	-	-
Conductivity	826.	umhos/cm	-	-
Nitrate	0.120	mg/l	0.02	mg/l
TOC	11.0	mg/l	-	-

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5614
WELL NUMBER: NW50C
DATE: 8/28/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	377.	mg/l	10.	mg/l
Arsenic	0.0	ug/l	3.0	ug/l
Barium	30.	ug/l	100.	ug/l
Bicarbonate	460.	mg/l	10.	mg/l
Cadmium	0.67	ug/l	0.20	ug/l
Calcium	100.	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	5.50	mg/l	2.00	mg/l
Chromium	1.67	ug/l	0.50	ug/l
Copper	6.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	543.	mg/l	-	-
Iron	3.06	mg/l	0.03	mg/l
Lead	0.0	ug/l	1.0	ug/l
Magnesium	71.0	mg/l	1.00	mg/l
Manganese	0.400	mg/l	0.010	mg/l
Selenium	1.88	ug/l	0.2	ug/l
pH	7.6	units	-	-
Potassium	7.00	mg/l	0.30	mg/l
Silver	0.19	ug/l	0.20	ug/l
Sodium	78.0	mg/l	2.50	mg/l
Percent Sodium	23.7	-	-	-
Sulfate (SO4)	331.	mg/l	5.	mg/l
Total Dissolved Solids	819.	mg/l	-	-
Turbidity	22.0	NTU	-	-
Zinc	483.	ug/l	130.	ug/l
Sodium Adsorption Ratio	1.45	-	-	-
Conductivity	1161.	umhos/cm	-	-
Nitrate	0.019	mg/l	0.02	mg/l
TOC	4.5	mg/l	-	-

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C4674
WELL NUMBER: NW50WT
DATE: 7/24/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	482.	mg/l	10.	mg/l
Arsenic	2.7	ug/l	3.0	ug/l
Barium	290.	ug/l	100.	ug/l
Bicarbonate	589.	mg/l	10.	mg/l
Cadmium	0.38	ug/l	0.20	ug/l
Calcium	234.	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	10.0	mg/l	2.00	mg/l
Chromium	2.44	ug/l	0.50	ug/l
Copper	4.	ug/l	10.0	ug/l
Fluoride	0.1	mg/l	0.1	mg/l
Total Hardness	959.	mg/l	-	-
Iron	0.02	mg/l	0.03	mg/l
Lead	0.8	ug/l	1.0	ug/l
Magnesium	91.0	mg/l	1.00	mg/l
Manganese	0.257	mg/l	0.010	mg/l
Selenium	0.02	ug/l	0.2	ug/l
pH	7.3	units	-	-
Potassium	7.45	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	43.0	mg/l	2.50	mg/l
Percent Sodium	8.8	-	-	-
Sulfate (SO4)	612.	mg/l	5.	mg/l
Total Dissolved Solids	1320	mg/l	-	-
Turbidity	1.	NTU	-	-
Zinc	77.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.60	-	-	-
Conductivity	1662.	umhos/cm	-	-
Nitrate	7.38	mg/l	0.02	mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5613
WELL NUMBER: NW50WT
DATE: 8/27/83

ANALYTE	RESULT		UNCERTAINTY
Total Alkalinity	494.	mg/l	10. mg/l
Arsenic	3.4	ug/l	3.0 ug/l
Barium	170.	ug/l	100. ug/l
Bicarbonate	603.	mg/l	10. mg/l
Cadmium	1.46	ug/l	0.20 ug/l
Calcium	254.	mg/l	2.3 mg/l
Carbonate	0.	mg/l	10.0 mg/l
Chloride	13.0	mg/l	2.00 mg/l
Chromium	1.88	ug/l	0.50 ug/l
Copper	27.	ug/l	10.0 ug/l
Fluoride	0.2	mg/l	0.1 mg/l
Total Hardness	1100	mg/l	- -
Iron	0.24	mg/l	0.03 mg/l
Lead	11.8	ug/l	1.0 ug/l
Magnesium	114.	mg/l	1.00 mg/l
Manganese	0.343	mg/l	0.010 mg/l
Selenium	0.21	ug/l	0.2 ug/l
pH	7.5	units	- -
Potassium	10.2	mg/l	0.30 mg/l
Silver	0.00	ug/l	0.20 ug/l
Sodium	53.0	mg/l	2.50 mg/l
Percent Sodium	9.4	-	- -
Sulfate (SO4)	737.	mg/l	5. mg/l
Total Dissolved Solids	1500	mg/l	- -
Turbidity	11.	NTU	- -
Zinc	-	ug/l	130. ug/l
Sodium Adsorption Ratio	0.69	-	- -
Conductivity	1859.	umhos/cm	- -
Nitrate	5.89	mg/l	0.02 mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C4679
WELL NUMBER: NW90S
DATE: 7/24/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	365.	mg/l	10.	mg/l
Arsenic	4.3	ug/l	3.0	ug/l
Barium	280.	ug/l	100.	ug/l
Bicarbonate	446.	mg/l	10.	mg/l
Cadmium	2.17	ug/l	0.20	ug/l
Calcium	100.	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	5.00	mg/l	2.00	mg/l
Chromium	5.93	ug/l	0.50	ug/l
Copper	13.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	459.	mg/l	-	-
Iron	0.03	mg/l	0.03	mg/l
Lead	8.1	ug/l	1.0	ug/l
Magnesium	50.5	mg/l	1.00	mg/l
Manganese	0.219	mg/l	0.010	mg/l
Selenium	6.73	ug/l	0.2	ug/l
pH	7.5	units	-	-
Potassium	5.30	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	34.0	mg/l	2.50	mg/l
Percent Sodium	13.8	-	-	-
Sulfate (SO4)	187.	mg/l	5.	mg/l
Total Dissolved Solids	605.	mg/l	-	-
Turbidity	1.00	NTU	-	-
Zinc	78.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.69	-	-	-
Conductivity	908.	umhos/cm	-	-
Nitrate	0.552	mg/l	0.02	mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5617
WELL NUMBER: NW90S
DATE: 8/27/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	345.	mg/l	10.	mg/l
Arsenic	0.0	ug/l	3.0	ug/l
Barium	160.	ug/l	100.	ug/l
Bicarbonate	421.	mg/l	10.	mg/l
Cadmium	0.63	ug/l	0.20	ug/l
Calcium	65.5	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	1.00	mg/l	2.00	mg/l
Chromium	2.04	ug/l	0.50	ug/l
Copper	43.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	287.	mg/l	-	-
Iron	0.42	mg/l	0.03	mg/l
Lead	2.5	ug/l	1.0	ug/l
Magnesium	30.0	mg/l	1.00	mg/l
Manganese	0.446	mg/l	0.010	mg/l
Selenium	0.01	ug/l	0.2	ug/l
pH	7.6	units	-	-
Potassium	5.40	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	29.5	mg/l	2.50	mg/l
Percent Sodium	18.2	-	-	-
Sulfate (SO4)	22.	mg/l	5.	mg/l
Total Dissolved Solids	361.	mg/l	-	-
Turbidity	6.00	NTU	-	-
Zinc	985.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.76	-	-	-
Conductivity	613.	umhos/cm	-	-
Nitrate	0.038	mg/l	0.02	mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C4678
WELL NUMBER: NW90C
DATE: 7/24/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	439.	mg/l	10.	mg/l
Arsenic	3.7	ug/l	3.0	ug/l
Barium	180.	ug/l	100.	ug/l
Bicarbonate	536.	mg/l	10.	mg/l
Cadmium	0.00	ug/l	0.20	ug/l
Calcium	230.	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	12.0	mg/l	2.00	mg/l
Chromium	0.48	ug/l	0.50	ug/l
Copper	5.	ug/l	10.0	ug/l
Fluoride	0.1	mg/l	0.1	mg/l
Total Hardness	967.	mg/l	-	-
Iron	0.02	mg/l	0.03	mg/l
Lead	0.0	ug/l	1.0	ug/l
Magnesium	95.5	mg/l	1.00	mg/l
Manganese	0.488	mg/l	0.010	mg/l
Selenium	0.16	ug/l	0.2	ug/l
pH	7.4	units	-	-
Potassium	6.65	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	29.5	mg/l	2.50	mg/l
Percent Sodium	6.2	-	-	-
Sulfate (SO4)	584.	mg/l	5.	mg/l
Total Dissolved Solids	1260	mg/l	-	-
Turbidity	1.	NTU	-	-
Zinc	11.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.41	-	-	-
Conductivity	1595.	umhos/cm	-	-
Nitrate	9.8	mg/l	0.02	mg/l
TOC	7.2	mg/l	-	-

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5616
WELL NUMBER: NW90C
DATE: 8/27/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	434.	mg/l	10.	mg/l
Arsenic	1.6	ug/l	3.0	ug/l
Barium	120.	ug/l	100.	ug/l
Bicarbonate	530.	mg/l	10.	mg/l
Cadmium	0.42	ug/l	0.20	ug/l
Calcium	214.	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	13.0	mg/l	2.00	mg/l
Chromium	1.94	ug/l	0.50	ug/l
Copper	11.	ug/l	10.0	ug/l
Fluoride	0.1	mg/l	0.1	mg/l
Total Hardness	944.	mg/l	-	-
Iron	0.00	mg/l	0.03	mg/l
Lead	1.2	ug/l	1.0	ug/l
Magnesium	99.0	mg/l	1.00	mg/l
Manganese	0.527	mg/l	0.010	mg/l
Selenium	0.07	ug/l	0.2	ug/l
pH	7.5	units	-	-
Potassium	7.25	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	29.0	mg/l	2.50	mg/l
Percent Sodium	6.2	-	-	-
Sulfate (SO4)	539.	mg/l	5.	mg/l
Total Dissolved Solids	1210	mg/l	-	-
Turbidity	1.	NTU	-	-
Zinc	194.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.41	-	-	-
Conductivity	1557.	umhos/cm	-	-
Nitrate	10.0	mg/l	0.02	mg/l
TOC	4.8	mg/l	-	-

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C4681
WELL NUMBER: NW150S
DATE: 7/24/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	354.	mg/l	10.	mg/l
Arsenic	0.0	ug/l	3.0	ug/l
Barium	580.	ug/l	100.	ug/l
Bicarbonate	432.	mg/l	10.	mg/l
Cadmium	0.32	ug/l	0.20	ug/l
Calcium	75.5	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	3.00	mg/l	2.00	mg/l
Chromium	2.21	ug/l	0.50	ug/l
Copper	0.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	322.	mg/l	-	-
Iron	0.05	mg/l	0.03	mg/l
Lead	1.5	ug/l	1.0	ug/l
Magnesium	32.5	mg/l	1.00	mg/l
Manganese	0.592	mg/l	0.010	mg/l
Selenium	0.22	ug/l	0.2	ug/l
pH	7.6	units	-	-
Potassium	4.70	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	22.0	mg/l	2.50	mg/l
Percent Sodium	12.9	-	-	-
Sulfate (SO4)	41.	mg/l	5.	mg/l
Total Dissolved Solids	394.	mg/l	-	-
Turbidity	2.00	NTU	-	-
Zinc	87.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.53	-	-	-
Conductivity	648.	umhos/cm	-	-
Nitrate	0.425	mg/l	0.02	mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C2526
WELL NUMBER: NW150S
DATE: 8/27/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	350.	mg/l	10.	mg/l
Arsenic	0.0	ug/l	3.0	ug/l
Barium	80.	ug/l	100.	ug/l
Bicarbonate	427.	mg/l	10.	mg/l
Cadmium	0.38	ug/l	0.20	ug/l
Calcium	71.0	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	2.00	mg/l	2.00	mg/l
Chromium	1.64	ug/l	0.50	ug/l
Copper	5.	ug/l	10.0	ug/l
Fluoride	0.1	mg/l	0.1	mg/l
Total Hardness	311.	mg/l	-	-
Iron	0.00	mg/l	0.03	mg/l
Lead	1.8	ug/l	1.0	ug/l
Magnesium	32.5	mg/l	1.00	mg/l
Manganese	0.141	mg/l	0.010	mg/l
Selenium	0.05	ug/l	0.2	ug/l
pH	7.6	units	-	-
Potassium	4.95	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	19.0	mg/l	2.50	mg/l
Percent Sodium	11.7	-	-	-
Sulfate (SO4)	27.	mg/l	5.	mg/l
Total Dissolved Solids	366.	mg/l	-	-
Turbidity	1.	NTU	-	-
Zinc	166.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.47	-	-	-
Conductivity	628.	umhos/cm	-	-
Nitrate	0.010	mg/l	0.02	mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C4680
WELL NUMBER: NW150C
DATE: 7/24/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	332.	mg/l	10.	mg/l
Arsenic	2.8	ug/l	3.0	ug/l
Barium	240.	ug/l	100.	ug/l
Bicarbonate	405.	mg/l	10.	mg/l
Cadmium	0.33	ug/l	0.20	ug/l
Calcium	42.0	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	1.00	mg/l	2.00	mg/l
Chromium	3.59	ug/l	0.50	ug/l
Copper	8.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	210.	mg/l	-	-
Iron	0.03	mg/l	0.03	mg/l
Lead	5.2	ug/l	1.0	ug/l
Magnesium	25.5	mg/l	1.00	mg/l
Manganese	0.195	mg/l	0.010	mg/l
Selenium	0.18	ug/l	0.2	ug/l
pH	7.6	units	-	-
Potassium	4.50	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	57.0	mg/l	2.50	mg/l
Percent Sodium	37.0	-	-	-
Sulfate (SO4)	31.	mg/l	5.	mg/l
Total Dissolved Solids	361.	mg/l	-	-
Turbidity	1.	NTU	-	-
Zinc	28.	ug/l	130.	ug/l
Sodium Adsorption Ratio	1.71	-	-	-
Conductivity	595.	umhos/cm	-	-
Nitrate	0.072	mg/l	0.02	mg/l
TOC	3.7	mg/l	-	-

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5625
WELL NUMBER: NW150C
DATE: 8/27/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	327.	mg/l	10.	mg/l
Arsenic	3.2	ug/l	3.0	ug/l
Barium	110.	ug/l	100.	ug/l
Bicarbonate	399.	mg/l	10.	mg/l
Cadmium	0.70	ug/l	0.20	ug/l
Calcium	38.5	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	2.00	mg/l	2.00	mg/l
Chromium	2.31	ug/l	0.50	ug/l
Copper	8.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	207.	mg/l	-	-
Iron	0.00	mg/l	0.03	mg/l
Lead	2.5	ug/l	1.0	ug/l
Magnesium	27.0	mg/l	1.00	mg/l
Manganese	0.283	mg/l	0.010	mg/l
Selenium	0.02	ug/l	0.2	ug/l
pH	7.7	units	-	-
Potassium	5.10	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	58.0	mg/l	2.50	mg/l
Percent Sodium	37.7	-	-	-
Sulfate (SO4)	30.	mg/l	5.	mg/l
Total Dissolved Solids	357.	mg/l	-	-
Turbidity	2.00	NTU	-	-
Zinc	57.	ug/l	130.	ug/l
Sodium Adsorption Ratio	1.75	-	-	-
Conductivity	604.	umhos/cm	-	-
Nitrate	0.013	mg/l	0.02	mg/l
TOC	3.5	mg/l	-	-

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C4683
WELL NUMBER: NW250S
DATE: 7/24/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	364.	mg/l	10.	mg/l
Arsenic	0.0	ug/l	3.0	ug/l
Barium	170.	ug/l	100.	ug/l
Bicarbonate	444.	mg/l	10.	mg/l
Cadmium	0.46	ug/l	0.20	ug/l
Calcium	58.5	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	2.00	mg/l	2.00	mg/l
Chromium	2.11	ug/l	0.50	ug/l
Copper	0.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	276.	mg/l	-	-
Iron	0.03	mg/l	0.03	mg/l
Lead	0.4	ug/l	1.0	ug/l
Magnesium	31.5	mg/l	1.00	mg/l
Manganese	0.474	mg/l	0.010	mg/l
Selenium	0.03	ug/l	0.2	ug/l
pH	7.5	units	-	-
Potassium	4.95	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	39.5	mg/l	2.50	mg/l
Percent Sodium	23.7	-	-	-
Sulfate (SO4)	29.	mg/l	5.	mg/l
Total Dissolved Solids	385.	mg/l	-	-
Turbidity	1.00	NTU	-	-
Zinc	46.	ug/l	130.	ug/l
Sodium Adsorption Ratio	1.03	-	-	-
Conductivity	642.	umhos/cm	-	-
Nitrate	0.140	mg/l	0.02	mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5632
WELL NUMBER: NW250S
DATE: 8/27/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	343.	mg/l	10.	mg/l
Arsenic	4.0	ug/l	3.0	ug/l
Barium	70.	ug/l	100.	ug/l
Bicarbonate	419.	mg/l	10.	mg/l
Cadmium	0.45	ug/l	0.20	ug/l
Calcium	55.0	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	1.00	mg/l	2.00	mg/l
Chromium	1.85	ug/l	0.50	ug/l
Copper	5.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	277.	mg/l	-	-
Iron	0.01	mg/l	0.03	mg/l
Lead	2.4	ug/l	1.0	ug/l
Magnesium	34.0	mg/l	1.00	mg/l
Manganese	0.256	mg/l	0.010	mg/l
Selenium	0.06	ug/l	0.2	ug/l
pH	7.6	units	-	-
Potassium	5.55	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	35.5	mg/l	2.50	mg/l
Percent Sodium	21.7	-	-	-
Sulfate (SO4)	24.	mg/l	5.	mg/l
Total Dissolved Solids	362.	mg/l	-	-
Turbidity	2.00	NTU	-	-
Zinc	29.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.93	-	-	-
Conductivity	638.	umhos/cm	-	-
Nitrate	0.010	mg/l	0.02	mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C4682
WELL NUMBER: NW250C
DATE: 7/24/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	332.	mg/l	10.	mg/l
Arsenic	0.0	ug/l	3.0	ug/l
Barium	400.	ug/l	100.	ug/l
Bicarbonate	405.	mg/l	10.	mg/l
Cadmium	.00	ug/l	0.20	ug/l
Calcium	41.0	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	1.00	mg/l	2.00	mg/l
Chromium	18.7	ug/l	0.50	ug/l
Copper	3.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	207.	mg/l	-	-
Iron	0.03	mg/l	0.03	mg/l
Lead	1.6	ug/l	1.0	ug/l
Magnesium	25.5	mg/l	1.00	mg/l
Manganese	0.254	mg/l	0.010	mg/l
Selenium	0.19	ug/l	0.2	ug/l
pH	7.4	units	-	-
Potassium	4.15	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	54.5	mg/l	2.50	mg/l
Percent Sodium	36.3	-	-	-
Sulfate (SO4)	30.	mg/l	5.	mg/l
Total Dissolved Solids	356.	mg/l	-	-
Turbidity	1.	NTU	-	-
Zinc	9.	ug/l	130.	ug/l
Sodium Adsorption Ratio	1.65	-	-	-
Conductivity	596.	umhos/cm	-	-
Nitrate	0.074	mg/l	0.02	mg/l
TOC	5.7	mg/l	-	-

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5631
WELL NUMBER: NW250C
DATE: 8/27/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	320.	mg/l	10.	mg/l
Arsenic	2.0	ug/l	3.0	ug/l
Barium	50.	ug/l	100.	ug/l
Bicarbonate	391.	mg/l	10.	mg/l
Cadmium	0.92	ug/l	0.20	ug/l
Calcium	39.0	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	1.00	mg/l	2.00	mg/l
Chromium	1.69	ug/l	0.50	ug/l
Copper	7.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	211.	mg/l	-	-
Iron	0.13	mg/l	0.03	mg/l
Lead	1.6	ug/l	1.0	ug/l
Magnesium	27.5	mg/l	1.00	mg/l
Manganese	0.500	mg/l	0.010	mg/l
Selenium	0.00	ug/l	0.2	ug/l
pH	7.5	units	-	-
Potassium	5.4	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	54.0	mg/l	2.50	mg/l
Percent Sodium	35.7	-	-	-
Sulfate (SO4)	27.	mg/l	5.	mg/l
Total Dissolved Solids	347.	mg/l	-	-
Turbidity	4.0	NTU	-	-
Zinc	35.	ug/l	130.	ug/l
Sodium Adsorption Ratio	1.62	-	-	-
Conductivity	605.	umhos/cm	-	-
Nitrate	0.017	mg/l	0.02	mg/l
TOC	8.0	mg/l	-	-

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C4685
WELL NUMBER: NW600S
DATE: 7/24/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	408.	mg/l	10.	mg/l
Arsenic	0.0	ug/l	3.0	ug/l
Barium	170.	ug/l	100.	ug/l
Bicarbonate	498.	mg/l	10.	mg/l
Cadmium	0.00	ug/l	0.20	ug/l
Calcium	97.0	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	3.00	mg/l	2.00	mg/l
Chromium	2.50	ug/l	0.50	ug/l
Copper	0.	ug/l	10.0	ug/l
Fluoride	0.1	mg/l	0.1	mg/l
Total Hardness	411.	mg/l	-	-
Iron	0.01	mg/l	0.03	mg/l
Lead	35.4	ug/l	1.0	ug/l
Magnesium	41.0	mg/l	1.00	mg/l
Manganese	0.275	mg/l	0.010	mg/l
Selenium	0.22	ug/l	0.2	ug/l
pH	7.4	units	-	-
Potassium	5.15	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	20.5	mg/l	2.50	mg/l
Percent Sodium	9.7	-	-	-
Sulfate (SO4)	75.	mg/l	5.	mg/l
Total Dissolved Solids	488.	mg/l	-	-
Turbidity	1.	NTU	-	-
Zinc	6.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.44	-	-	-
Conductivity	772.	umhos/cm	-	-
Nitrate	0.365	mg/l	0.02	mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5640
WELL NUMBER: NW600S
DATE: 8/27/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	380.	mg/l	10.	mg/l
Arsenic	0.0	ug/l	3.0	ug/l
Barium	70.	ug/l	100.	ug/l
Bicarbonate	464.	mg/l	10.	mg/l
Cadmium	0.91	ug/l	0.20	ug/l
Calcium	89.0	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	2.00	mg/l	2.00	mg/l
Chromium	1.98	ug/l	0.50	ug/l
Copper	7.	ug/l	10.0	ug/l
Fluoride	0.1	mg/l	0.1	mg/l
Total Hardness	389.	mg/l	-	-
Iron	0.09	mg/l	0.03	mg/l
Lead	3.1	ug/l	1.0	ug/l
Magnesium	40.5	mg/l	1.00	mg/l
Manganese	0.273	mg/l	0.010	mg/l
Selenium	1.36	ug/l	0.2	ug/l
pH	7.5	units	-	-
Potassium	5.25	mg/l	0.30	mg/l
Silver	0.18	ug/l	0.20	ug/l
Sodium	20.5	mg/l	2.50	mg/l
Percent Sodium	10.2	-	-	-
Sulfate (SO4)	66.	mg/l	5.	mg/l
Total Dissolved Solids	453.	mg/l	-	-
Turbidity	5.00	NTU	-	-
Zinc	34.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.45	-	-	-
Conductivity	748.	umhos/cm	-	-
Nitrate	0.262	mg/l	0.02	mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C4684
WELL NUMBER: NW600C
DATE: 7/24/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	360.	mg/l	10.	mg/l
Arsenic	0.0	ug/l	3.0	ug/l
Barium	0.	ug/l	100.	ug/l
Bicarbonate	440.	mg/l	10.	mg/l
Cadmium	0.25	ug/l	0.20	ug/l
Calcium	65.5	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	1.00	mg/l	2.00	mg/l
Chromium	2.86	ug/l	0.50	ug/l
Copper	0.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	308.	mg/l	-	-
Iron	0.00	mg/l	0.03	mg/l
Lead	1.1	ug/l	1.0	ug/l
Magnesium	35.0	mg/l	1.00	mg/l
Manganese	0.475	mg/l	0.010	mg/l
Selenium	0.06	ug/l	0.2	ug/l
pH	7.5	units	-	-
Potassium	5.70	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	75.0	mg/l	2.50	mg/l
Percent Sodium	34.5	-	-	-
Sulfate (SO4)	138.	mg/l	5.	mg/l
Total Dissolved Solids	537.	mg/l	-	-
Turbidity	1.	NTU	-	-
Zinc	10.	ug/l	130.	ug/l
Sodium Adsorption Ratio	1.86	-	-	-
Conductivity	818.	umhos/cm	-	-
Nitrate	0.182	mg/l	0.02	mg/l
TOC	5.0	mg/l	-	-

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5639
WELL NUMBER: NW600C
DATE: 8/27/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	349.	mg/l	10.	mg/l
Arsenic	4.1	ug/l	3.0	ug/l
Barium	30.	ug/l	100.	ug/l
Bicarbonate	426.	mg/l	10.	mg/l
Cadmium	0.71	ug/l	0.20	ug/l
Calcium	49.5	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	2.00	mg/l	2.00	mg/l
Chromium	1.94	ug/l	0.50	ug/l
Copper	6.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	245.	mg/l	-	-
Iron	0.05	mg/l	0.03	mg/l
Lead	1.4	ug/l	1.0	ug/l
Magnesium	29.5	mg/l	1.00	mg/l
Manganese	0.501	mg/l	0.010	mg/l
Selenium	0.00	ug/l	0.2	ug/l
pH	7.5	units	-	-
Potassium	5.75	mg/l	0.30	mg/l
Silver	0.07	ug/l	0.20	ug/l
Sodium	70.0	mg/l	2.50	mg/l
Percent Sodium	38.2	-	-	-
Sulfate (SO4)	68.	mg/l	5.	mg/l
Total Dissolved Solids	435.	mg/l	-	-
Turbidity	1.	NTU	-	-
Zinc	31.	ug/l	130.	ug/l
Sodium Adsorption Ratio	1.94	-	-	-
Conductivity	717.	umhos/cm	-	-
Nitrate	0.083	mg/l	0.02	mg/l
TOC	36.	mg/l	-	-

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C4687
WELL NUMBER: NW1200S
DATE: 7/24/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	383.	mg/l		
Arsenic	0.0	ug/l	10.	mg/l
Barium	90.	ug/l	3.0	ug/l
Bicarbonate	468.	mg/l	100.	ug/l
Cadmium	1.2	ug/l	10.	mg/l
Calcium	85.0	mg/l	0.20	ug/l
Carbonate	0.	mg/l	2.3	mg/l
Chloride	4.00	mg/l	10.0	mg/l
Chromium	2.98	ug/l	2.00	mg/l
Copper	0.	ug/l	0.50	ug/l
Fluoride	0.2	mg/l	10.0	ug/l
Total Hardness	392.	mg/l	0.1	mg/l
Iron	0.04	mg/l	-	-
Lead	0.7	ug/l	0.03	mg/l
Magnesium	43.5	mg/l	1.0	ug/l
Manganese	0.414	mg/l	1.00	mg/l
Selenium	1.12	ug/l	0.010	mg/l
pH	7.3	units	0.2	ug/l
Potassium	5.6	mg/l	-	-
Silver	0.00	ug/l	0.30	mg/l
Sodium	26.5	mg/l	0.20	ug/l
Percent Sodium	12.8	-	2.50	mg/l
Sulfate (SO4)	84.	mg/l	-	-
Total Dissolved Solids	480.	mg/l	5.	mg/l
Turbidity	1.	NTU	-	-
Zinc	37.	ug/l	-	-
Sodium Adsorption Ratio	0.58	-	130.	ug/l
Conductivity	752.	umhos/cm	-	-
Nitrate	0.122	mg/l	-	-
			0.02	mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5644
WELL NUMBER: NW1200S
DATE: 8/27/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	370.	mg/l	10.	mg/l
Arsenic	0.6	ug/l	3.0	ug/l
Barium	70.	ug/l	100.	ug/l
Bicarbonate	452.	mg/l	10.	mg/l
Cadmium	1.78	ug/l	0.20	ug/l
Calcium	73.5	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	2.00	mg/l	2.00	mg/l
Chromium	1.36	ug/l	0.50	ug/l
Copper	4.	ug/l	10.0	ug/l
Fluoride	0.3	mg/l	0.1	mg/l
Total Hardness	340.	mg/l	-	-
Iron	0.16	mg/l	0.03	mg/l
Lead	1.4	ug/l	1.0	ug/l
Magnesium	38.0	mg/l	1.00	mg/l
Manganese	0.355	mg/l	0.010	mg/l
Selenium	0.08	ug/l	0.2	ug/l
pH	7.5	units	-	-
Potassium	4.80	mg/l	0.30	mg/l
Silver	0.61	ug/l	0.20	ug/l
Sodium	19.0	mg/l	2.50	mg/l
Percent Sodium	10.8	-	-	-
Sulfate (SO4)	34.	mg/l	5.	mg/l
Total Dissolved Solids	395.	mg/l	-	-
Turbidity	6.00	NTU	-	-
Zinc	35.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.45	-	-	-
Conductivity	678.	umhos/cm	-	-
Nitrate	0.023	mg/l	0.02	mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C4686
WELL NUMBER: NW1200C
DATE: 7/24/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	383.	mg/l	10.	mg/l
Arsenic	3.3	ug/l	3.0	ug/l
Barium	120.	ug/l	100.	ug/l
Bicarbonate	468.	mg/l	10.	mg/l
Cadmium	0.00	ug/l	0.20	ug/l
Calcium	78.5	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	2.00	mg/l	2.00	mg/l
Chromium	2.38	ug/l	0.50	ug/l
Copper	0.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	349.	mg/l	-	-
Iron	0.05	mg/l	0.03	mg/l
Lead	0.8	ug/l	1.0	ug/l
Magnesium	37.0	mg/l	1.00	mg/l
Manganese	0.267	mg/l	0.010	mg/l
Selenium	0.31	ug/l	0.2	ug/l
pH	7.3	units	-	-
Potassium	4.70	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	21.5	mg/l	2.50	mg/l
Percent Sodium	11.8	-	-	-
Sulfate (SO4)	39.	mg/l	5.	mg/l
Total Dissolved Solids	414.	mg/l	-	-
Turbidity	1.00	NTU	-	-
Zinc	7.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.50	-	-	-
Conductivity	695.	umhos/cm	-	-
Nitrate	0.163	mg/l	0.02	mg/l
TOC	5.2	mg/l	-	-

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5643
WELL NUMBER: NW1200C
DATE: 8/27/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	356.	mg/l	10.	mg/l
Arsenic	3.8	ug/l	3.0	ug/l
Barium	0.	ug/l	100.	ug/l
Bicarbonate	435.	mg/l	10.	mg/l
Cadmium	1.51	ug/l	0.20	ug/l
Calcium	70.5	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	1.00	mg/l	2.00	mg/l
Chromium	2.09	ug/l	0.50	ug/l
Copper	7.	ug/l	10.0	ug/l
Fluoride	0.3	mg/l	0.1	mg/l
Total Hardness	322.	mg/l	-	-
Iron	0.31	mg/l	0.03	mg/l
Lead	1.1	ug/l	1.0	ug/l
Magnesium	35.5	mg/l	1.00	mg/l
Manganese	0.306	mg/l	0.010	mg/l
Selenium	0.15	ug/l	0.2	ug/l
pH	7.5	units	-	-
Potassium	5.55	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	24.0	mg/l	2.50	mg/l
Percent Sodium	13.9	-	-	-
Sulfate (SO4)	30.	mg/l	5.	mg/l
Total Dissolved Solids	381.	mg/l	-	-
Turbidity	20.0	NTU	-	-
Zinc	51.	ug/l	130.	ug/l
Sodium Adsorption Ratio	0.58	-	-	-
Conductivity	642.	umhos/cm	-	-
Nitrate	0.024	mg/l	0.02	mg/l
TOC	1.9	mg/l	-	-

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C4671
WELL NUMBER: SPWC
DATE: 7/24/83

ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	337.	mg/l	10.	mg/l
Arsenic	3.8	ug/l	3.0	ug/l
Barium	550.	ug/l	100.	ug/l
Bicarbonate	411.	mg/l	10.	mg/l
Cadmium	0.38	ug/l	0.20	ug/l
Calcium	46.5	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	1.00	mg/l	2.00	mg/l
Chromium	24.2	ug/l	0.50	ug/l
Copper	0.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	221.	mg/l	-	-
Iron	0.06	mg/l	0.03	mg/l
Lead	2.9	ug/l	1.0	ug/l
Magnesium	25.5	mg/l	1.00	mg/l
Manganese	0.259	mg/l	0.010	mg/l
Selenium	0.42	ug/l	0.2	ug/l
pH	7.3	units	-	-
Potassium	4.25	mg/l	0.30	mg/l
Silver	0.00	ug/l	0.20	ug/l
Sodium	51.0	mg/l	2.50	mg/l
Percent Sodium	33.3	-	-	-
Sulfate (SO4)	27.	mg/l	5.	mg/l
Total Dissolved Solids	358.	mg/l	-	-
Turbidity	1.	NTU	-	-
Zinc	29.	ug/l	130.	ug/l
Sodium Adsorption Ratio	1.49	-	-	-
Conductivity	501.	umhos/cm	-	-
Nitrate	0.090	mg/l	0.02	mg/l

NORTH DAKOTA STATE DEPARTMENT OF HEALTH LOG NUMBER: 83-C5612
WELL NUMBER: SPWC
DATE: 8/28/83

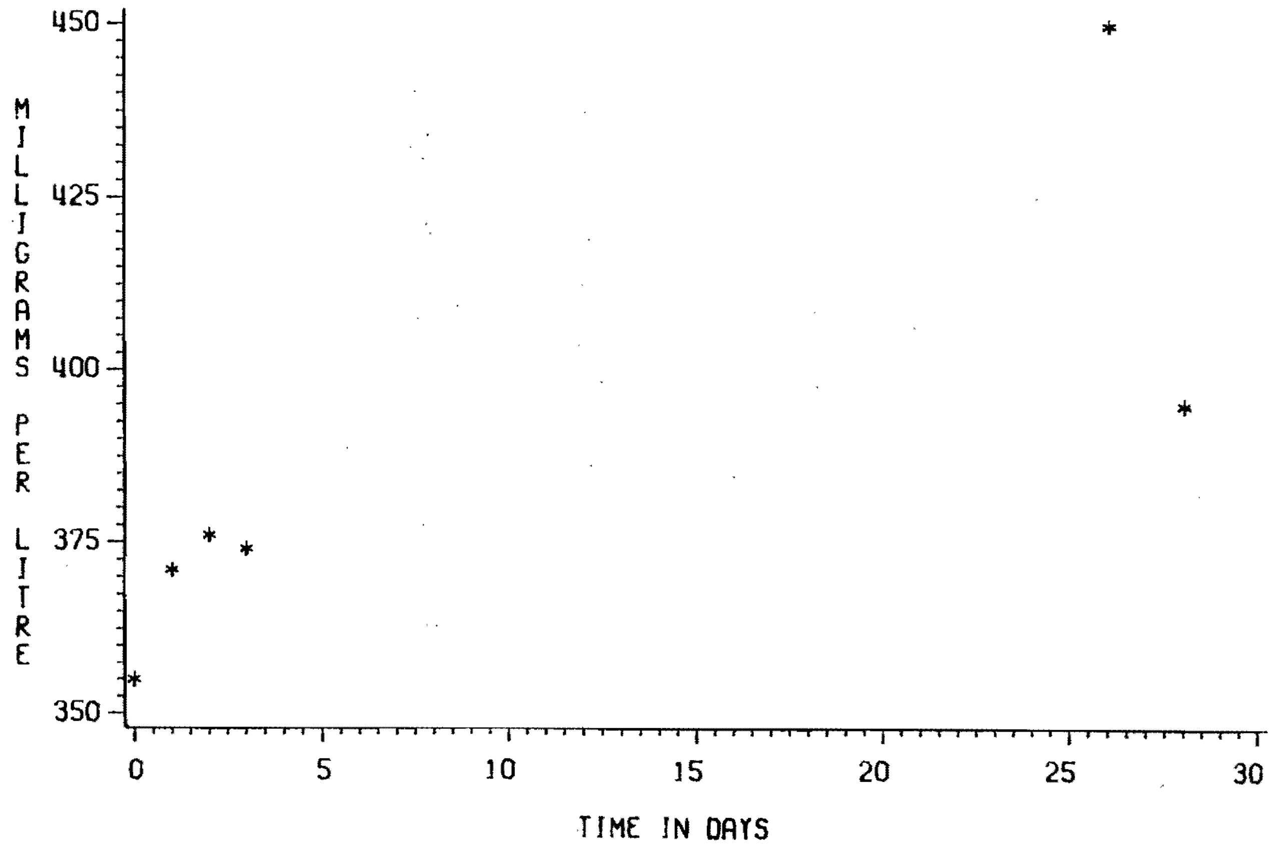
ANALYTE	RESULT		UNCERTAINTY	
Total Alkalinity	337.	mg/l	10.	mg/l
Arsenic	0.0	ug/l	3.0	ug/l
Barium	130.	ug/l	100.	ug/l
Bicarbonate	411.	mg/l	10.	mg/l
Cadmium	0.00	ug/l	0.20	ug/l
Calcium	45.5	mg/l	2.3	mg/l
Carbonate	0.	mg/l	10.0	mg/l
Chloride	1.00	mg/l	2.00	mg/l
Chromium	2.21	ug/l	0.50	ug/l
Copper	6.	ug/l	10.0	ug/l
Fluoride	0.2	mg/l	0.1	mg/l
Total Hardness	231.	mg/l	-	-
Iron	0.05	mg/l	0.03	mg/l
Lead	0.5	ug/l	1.0	ug/l
Magnesium	28.5	mg/l	1.00	mg/l
Manganese	0.295	mg/l	0.010	mg/l
Selenium	0.00	ug/l	0.2	ug/l
pH	7.7	units	-	-
Potassium	5.10	mg/l	0.30	mg/l
Silver	0.38	ug/l	0.20	ug/l
Sodium	52.5	mg/l	2.50	mg/l
Percent Sodium	33.0	-	-	-
Sulfate (SO4)	26.	mg/l	5.	mg/l
Total Dissolved Solids	361.	mg/l	-	-
Turbidity	1.	NTU	-	-
Zinc	414.	ug/l	130.	ug/l
Sodium Adsorption Ratio	1.50	-	-	-
Conductivity	606.	umhos/cm	-	-
Nitrate	0.014	mg/l	0.02	mg/l

Appendix G

SAND PRODUCTION WELL CHEMISTRY DATA

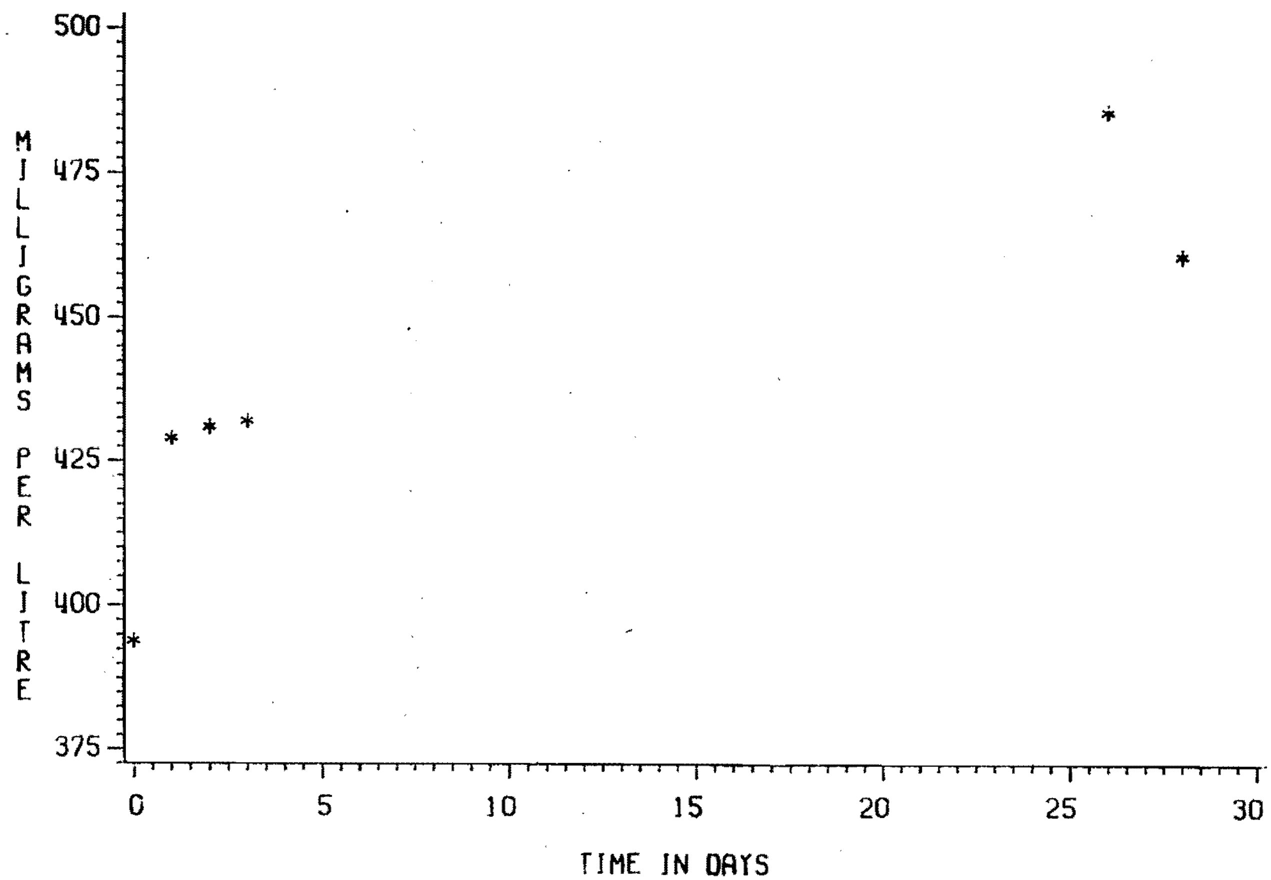
SAND PUMPING WELL

HARDNESS AS CALCIUM CARBONATE



SAND PUMPING WELL

TOTAL DISSOLVED SOLIDS



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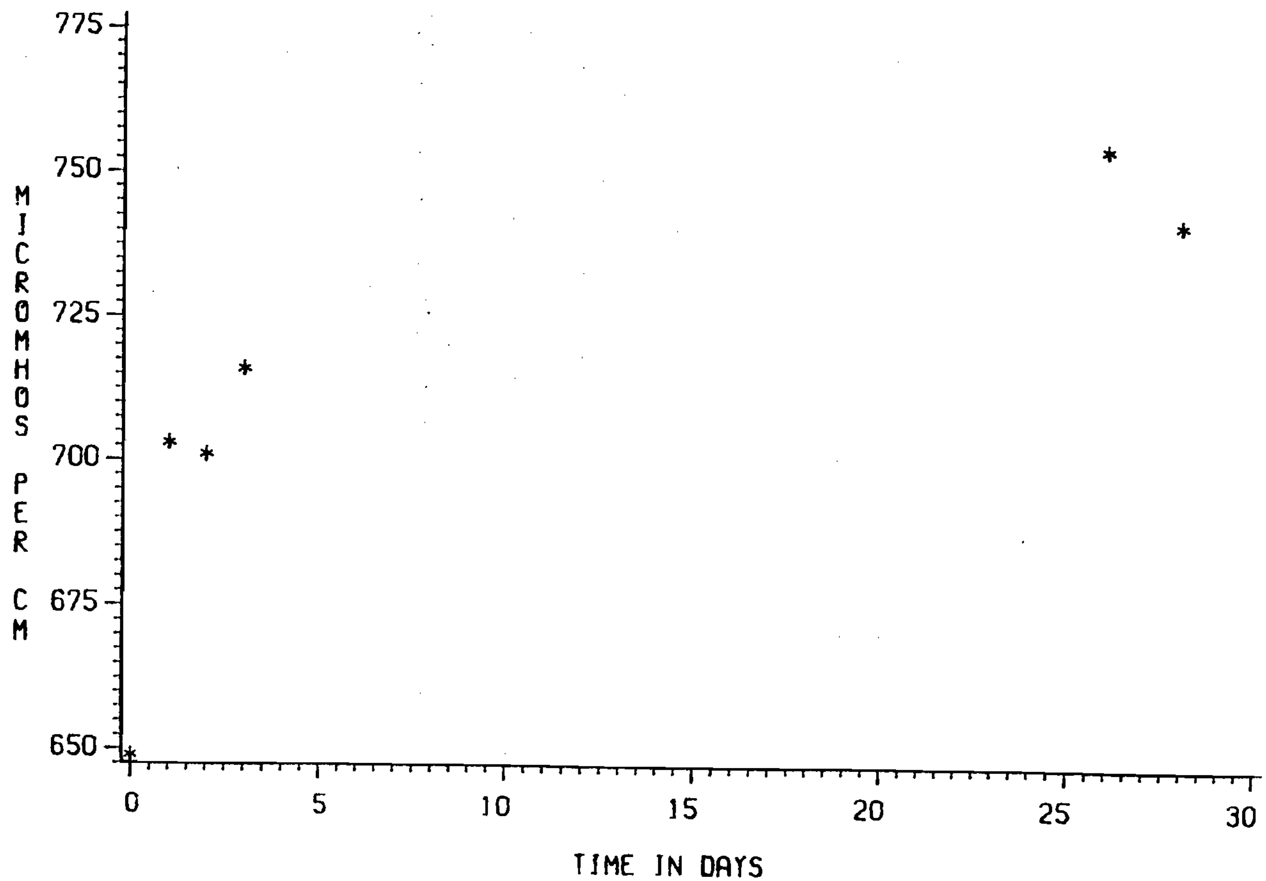
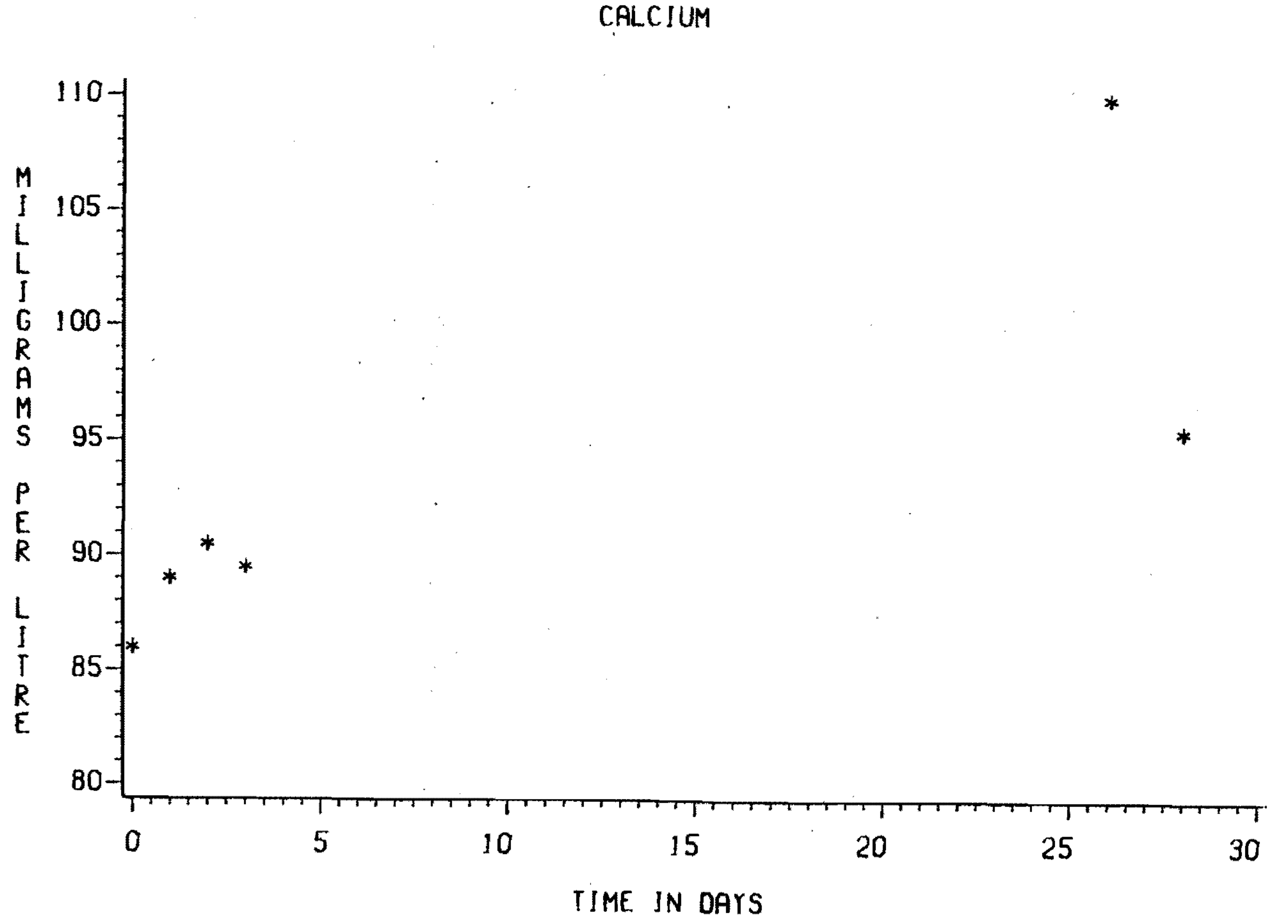
SAND PUMPING WELL

CONDUCTIVITY

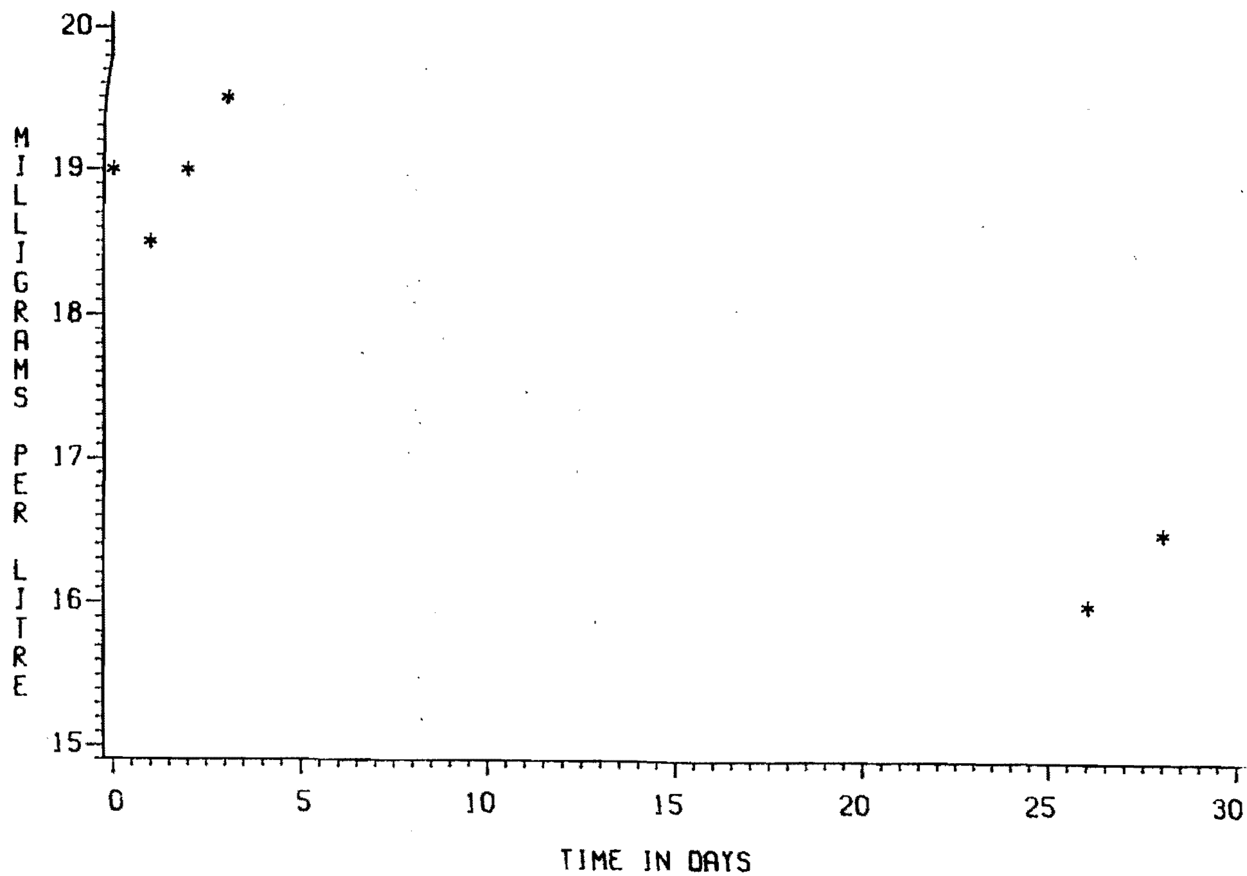


SAND PUMPING WELL



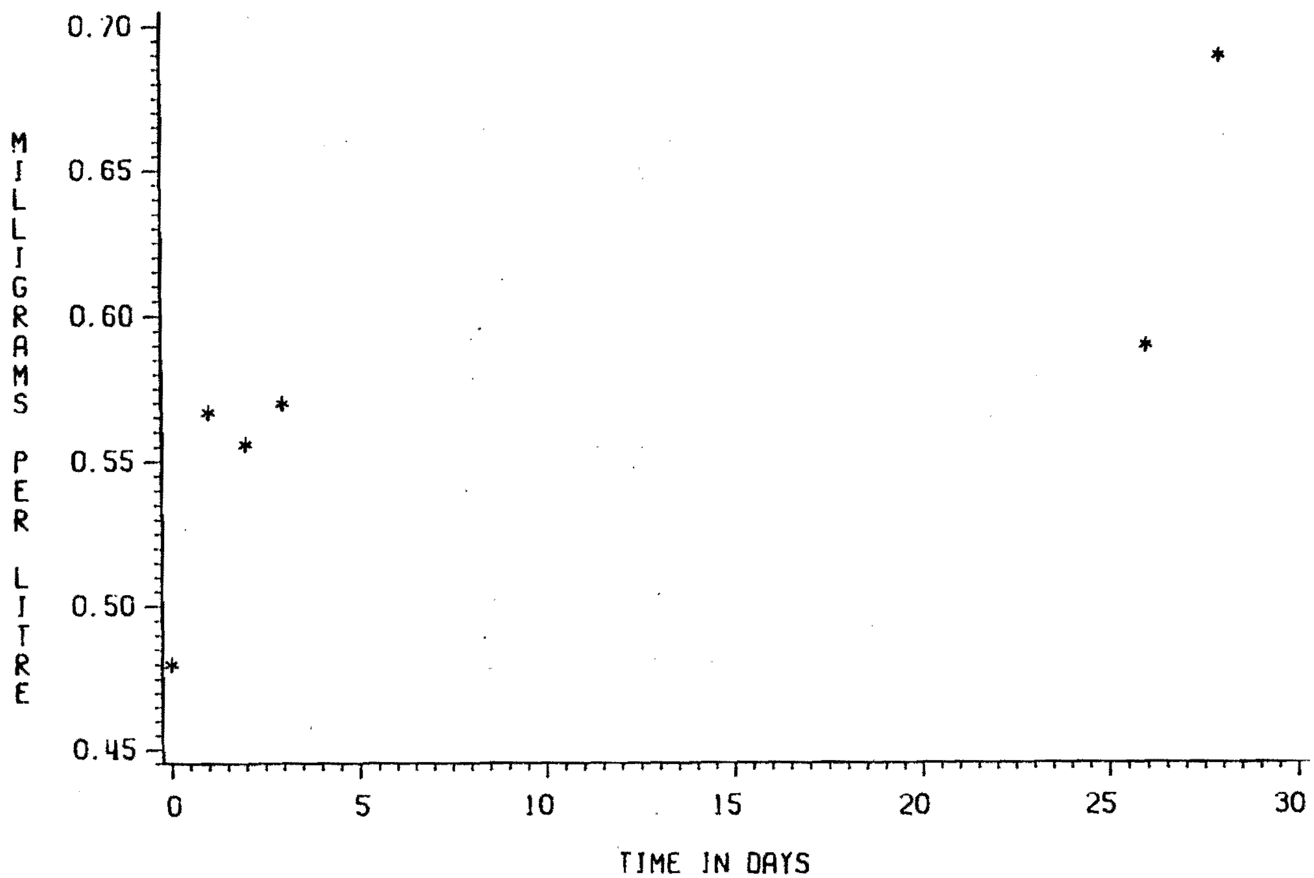
SAND PUMPING WELL

SODIUM



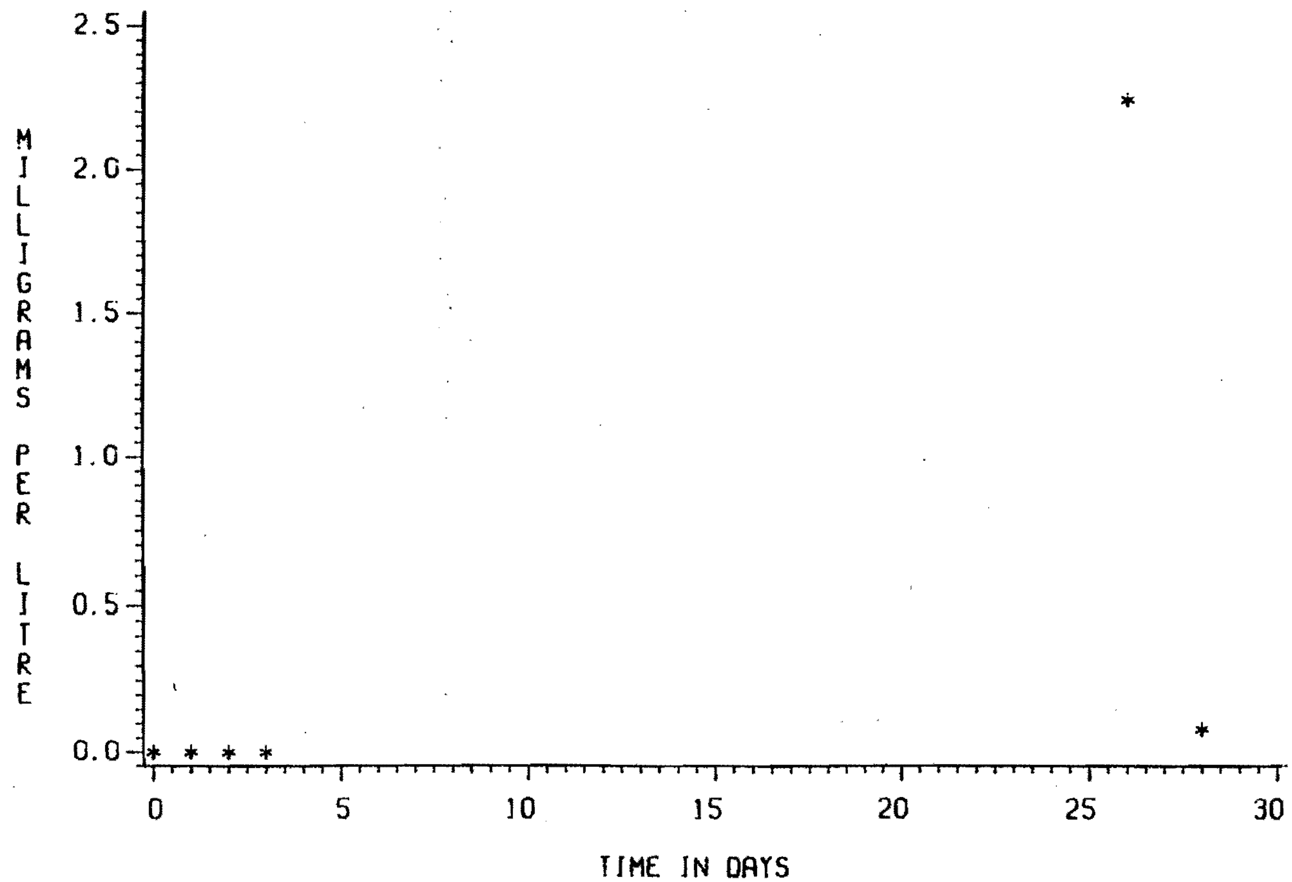
SAND PUMPING WELL

MANGANESE



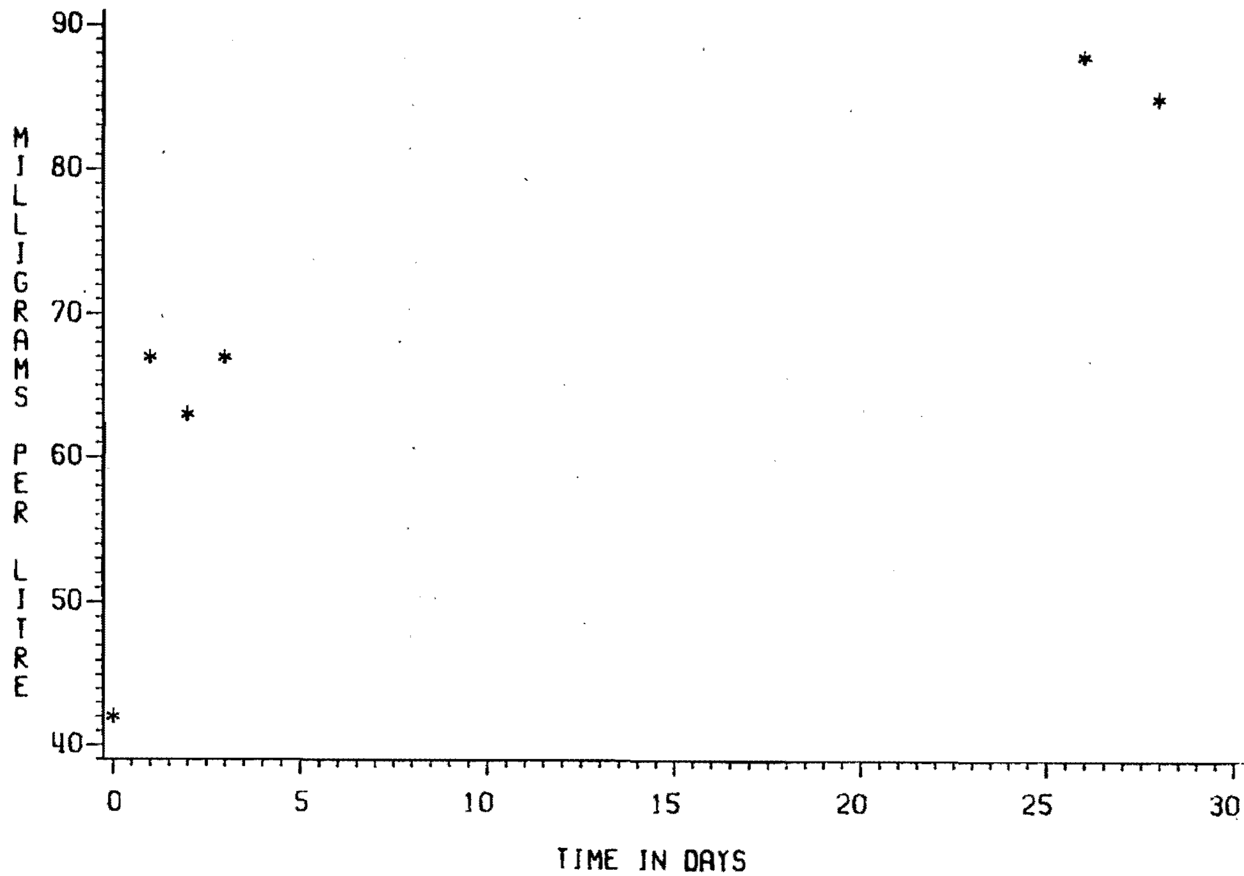
SAND PUMPING WELL

IRON

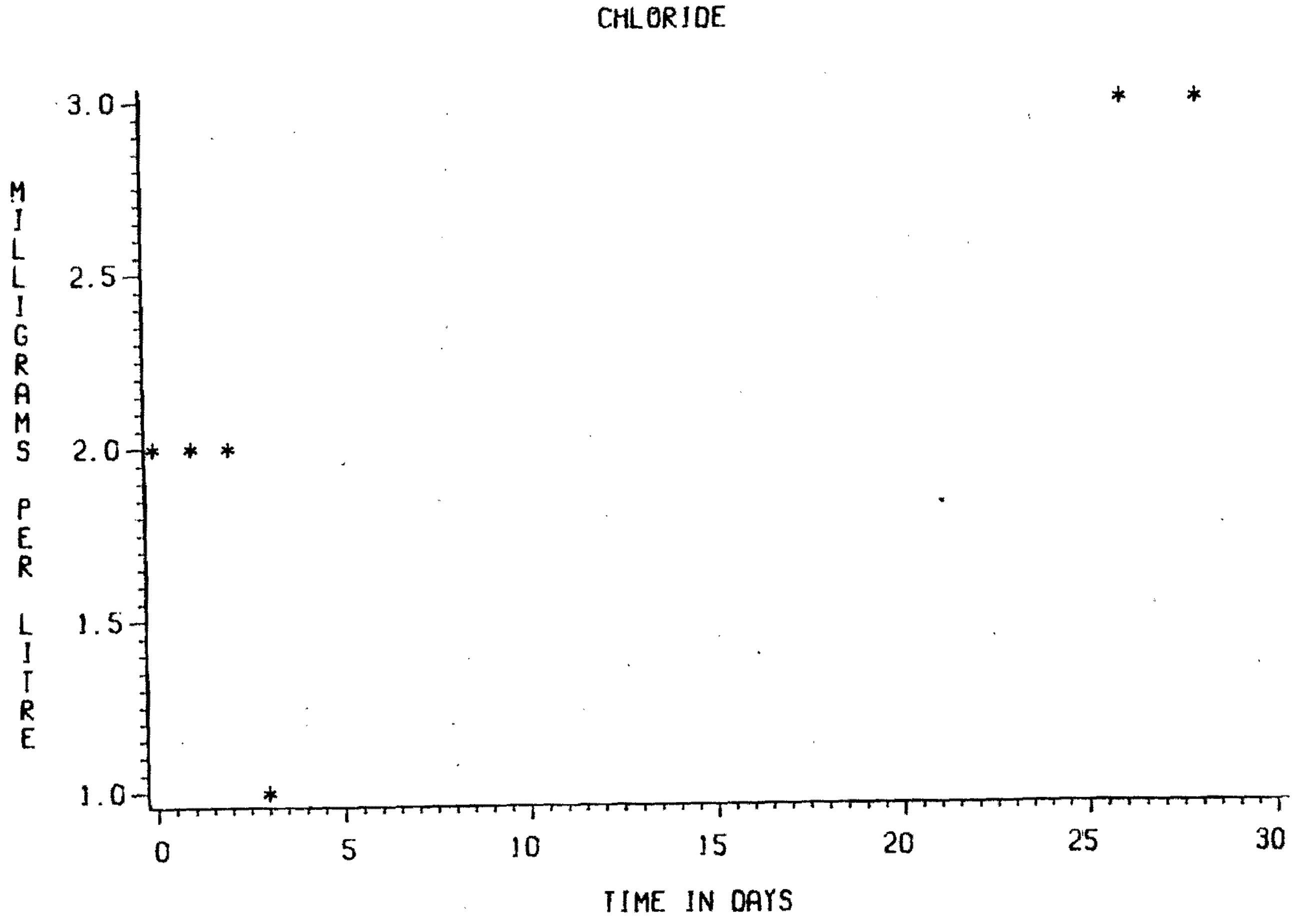


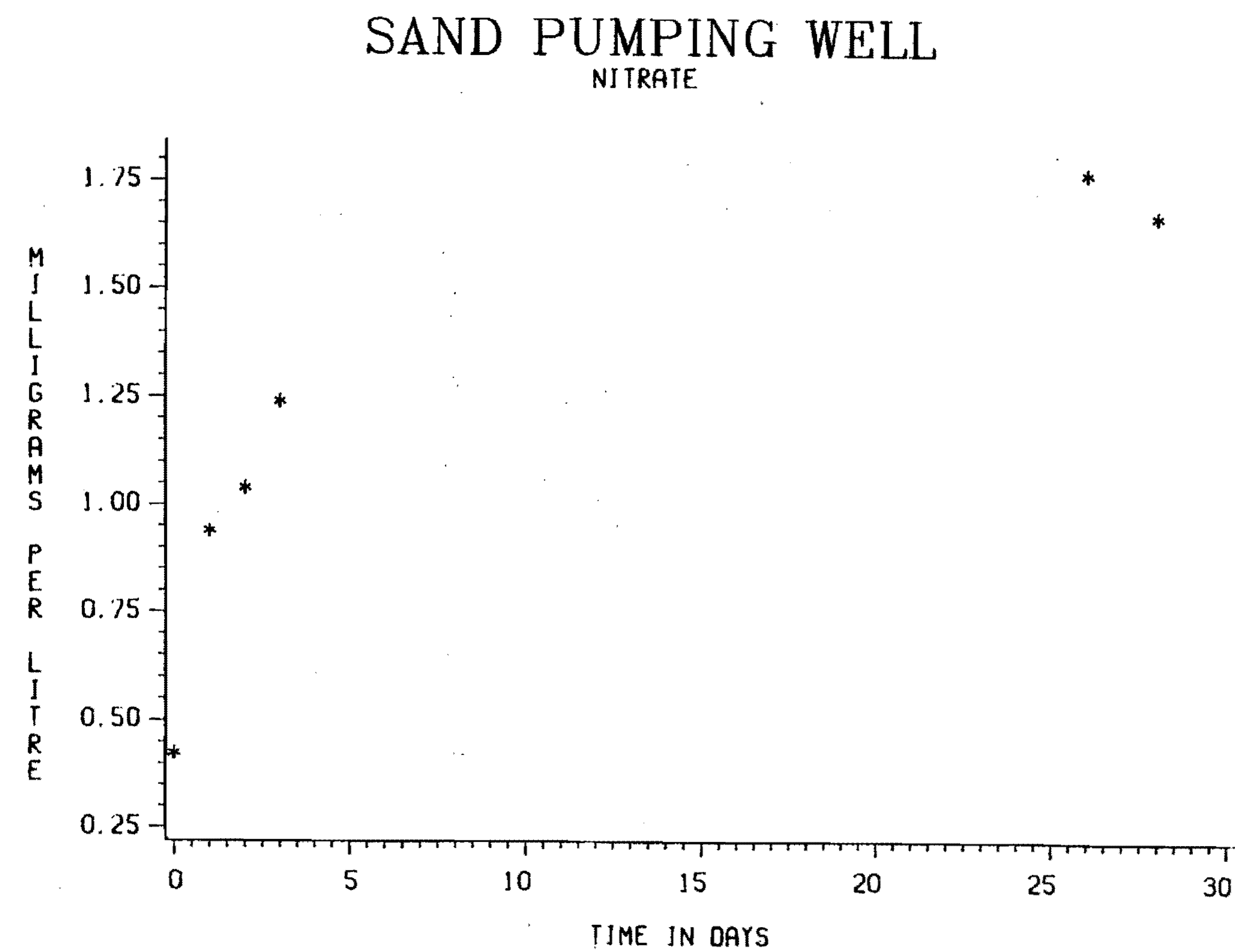
SAND PUMPING WELL

SULFATE

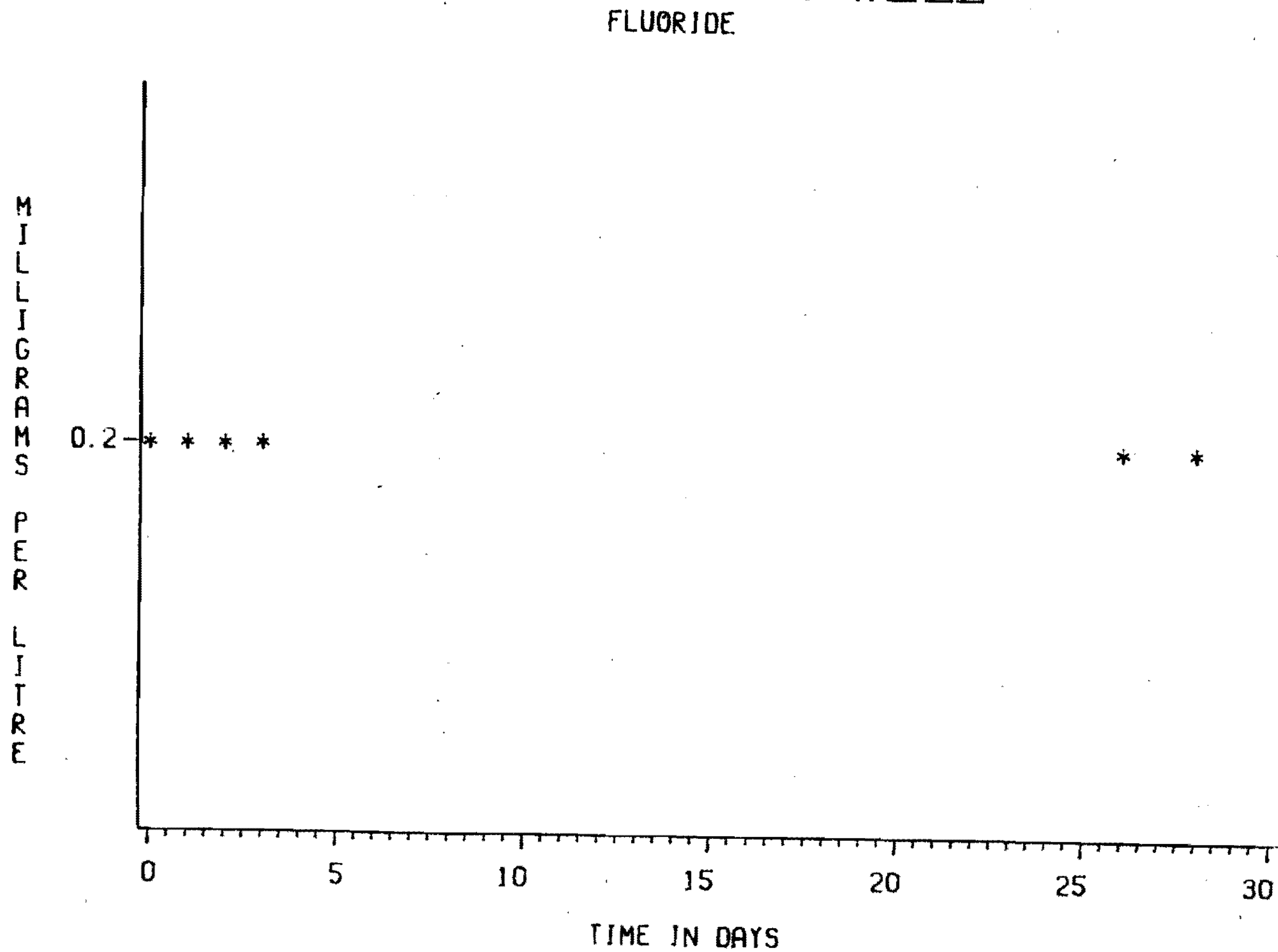


SAND PUMPING WELL



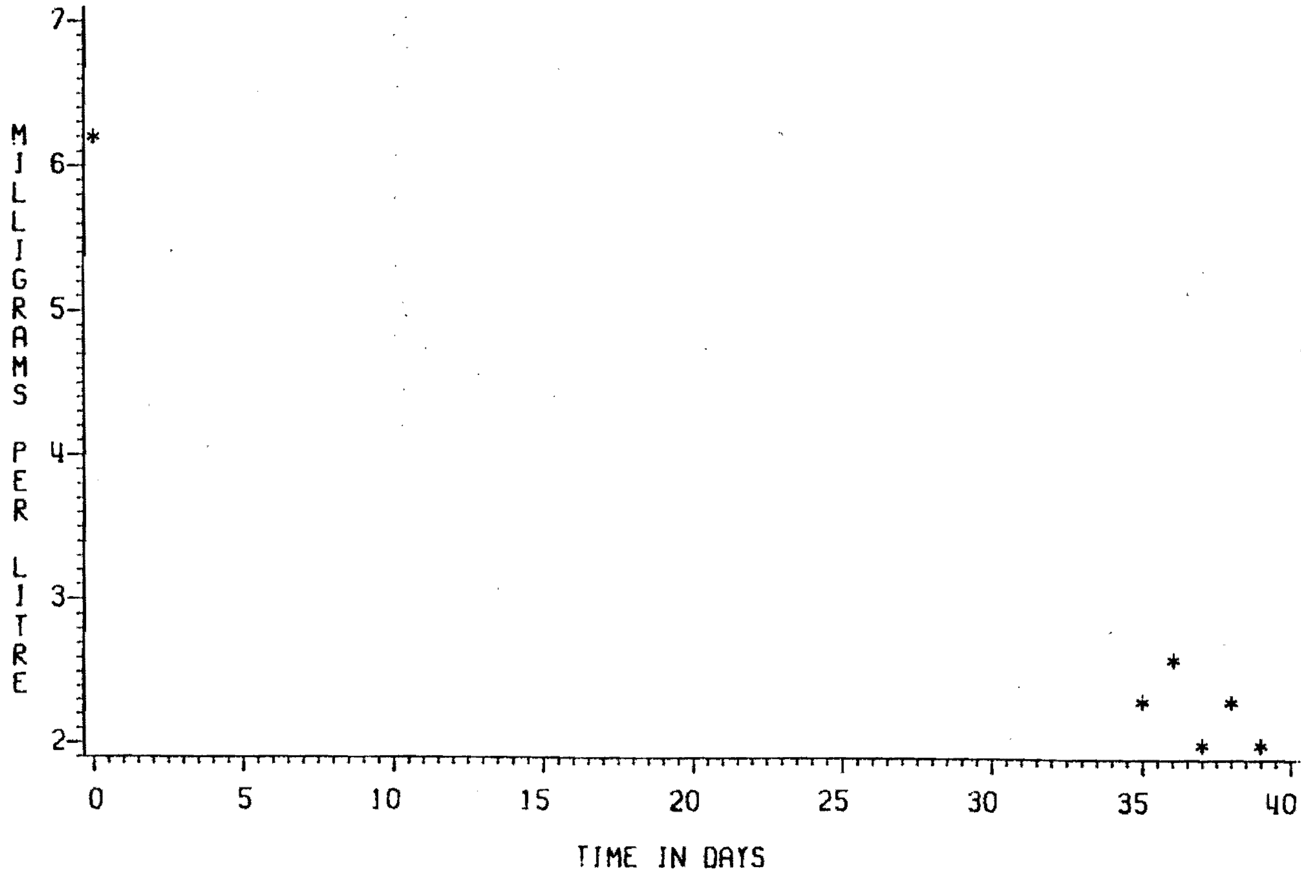

SAND PUMPING WELL
NITRATE
MILLIGRAMS PER LITRE
0.25
0.50
0.75
1.00
1.25
1.50
1.75
0
5
10
15
20
25
30
TIME IN DAYS

SAND PUMPING WELL



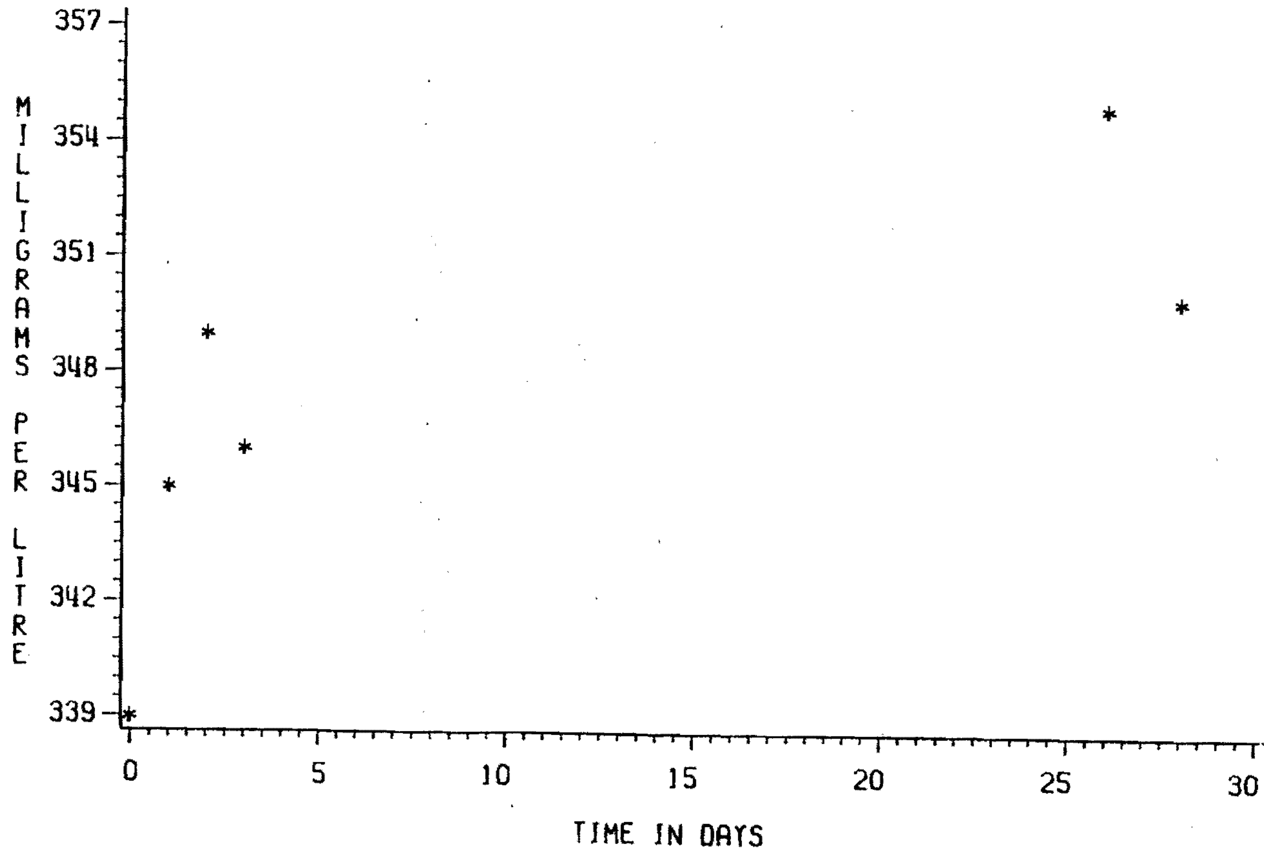
SAND PUMPING WELL

TOTAL ORGANIC CARBON

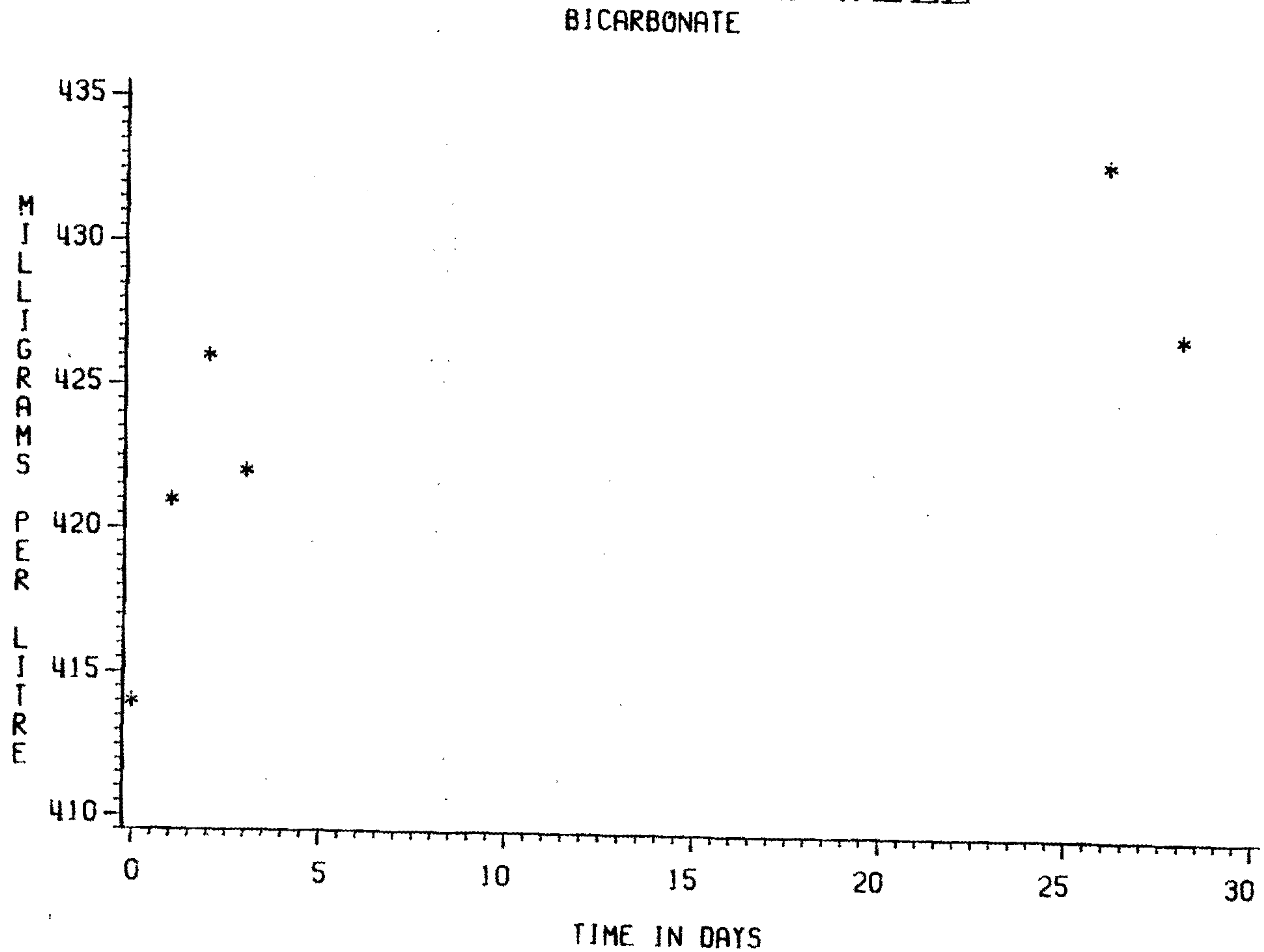


SAND PUMPING WELL

ALKALINITY



SAND PUMPING WELL

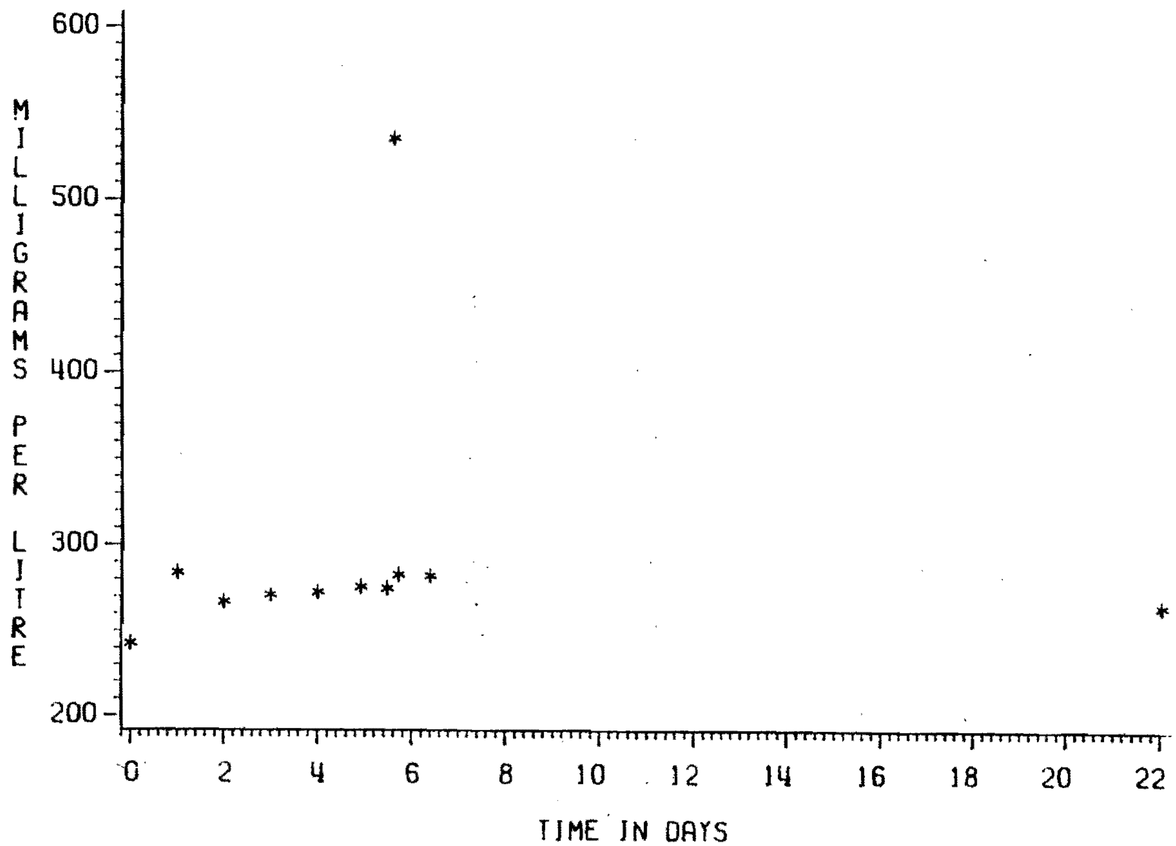


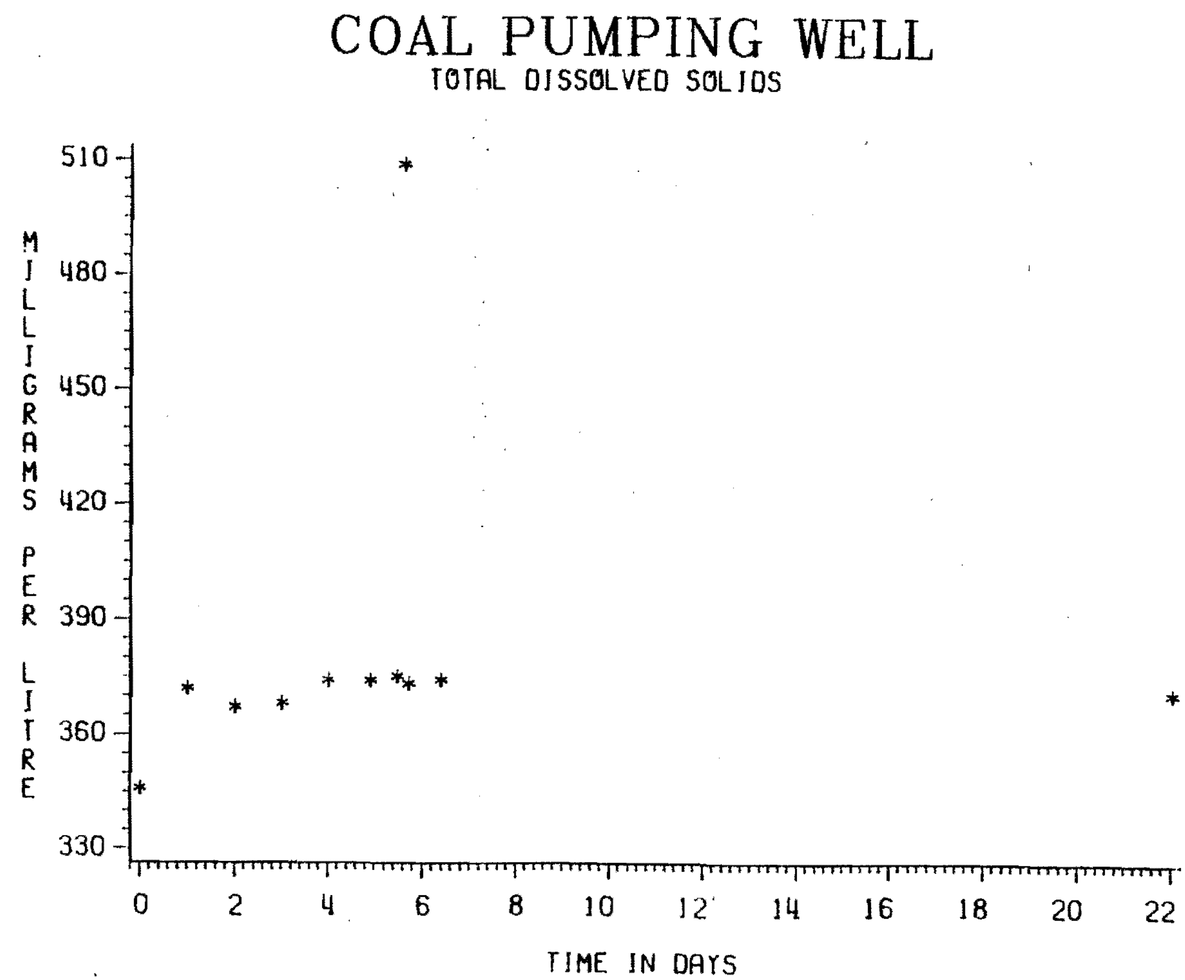
Appendix H

COAL PRODUCTION WELL CHEMISTRY DATA

COAL PUMPING WELL

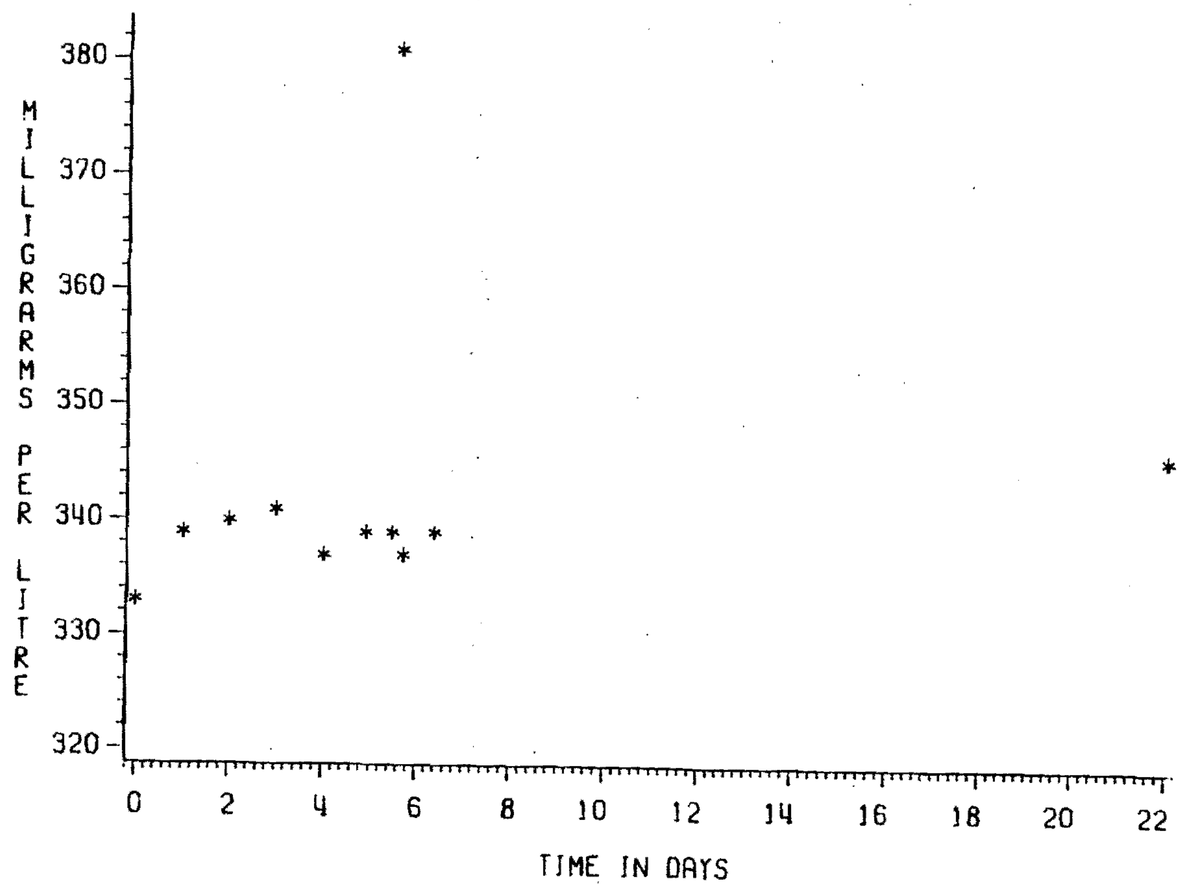
TOTAL HARDNESS AS CALCIUM CARBONATE



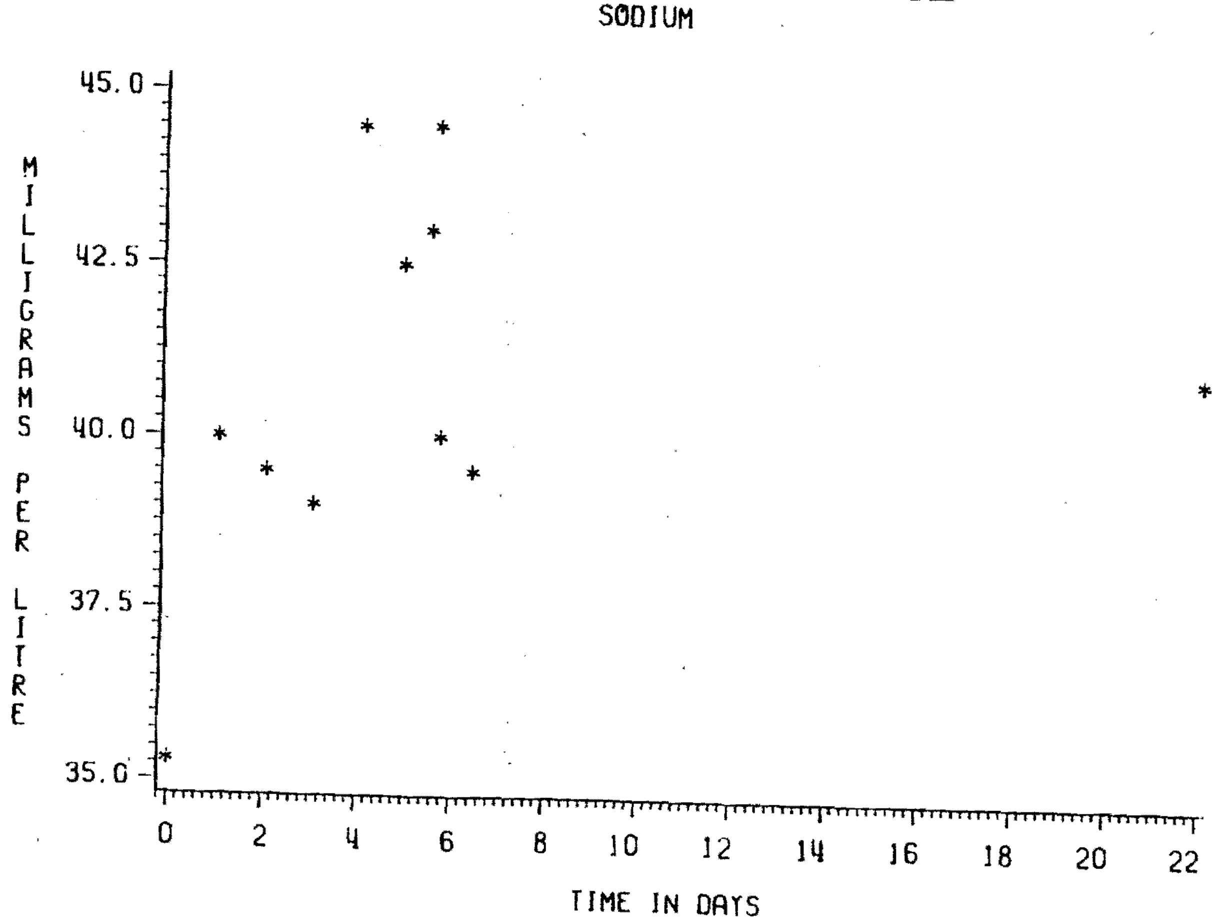

COAL PUMPING WELL
TOTAL DISSOLVED SOLIDS
MILLIGRAMS PER LITRE
510
480
450
420
390
360
330
0
2
4
6
8
10
12
14
16
18
20
22
TIME IN DAYS

COAL PUMPING WELL

TOTAL ALKALINITY

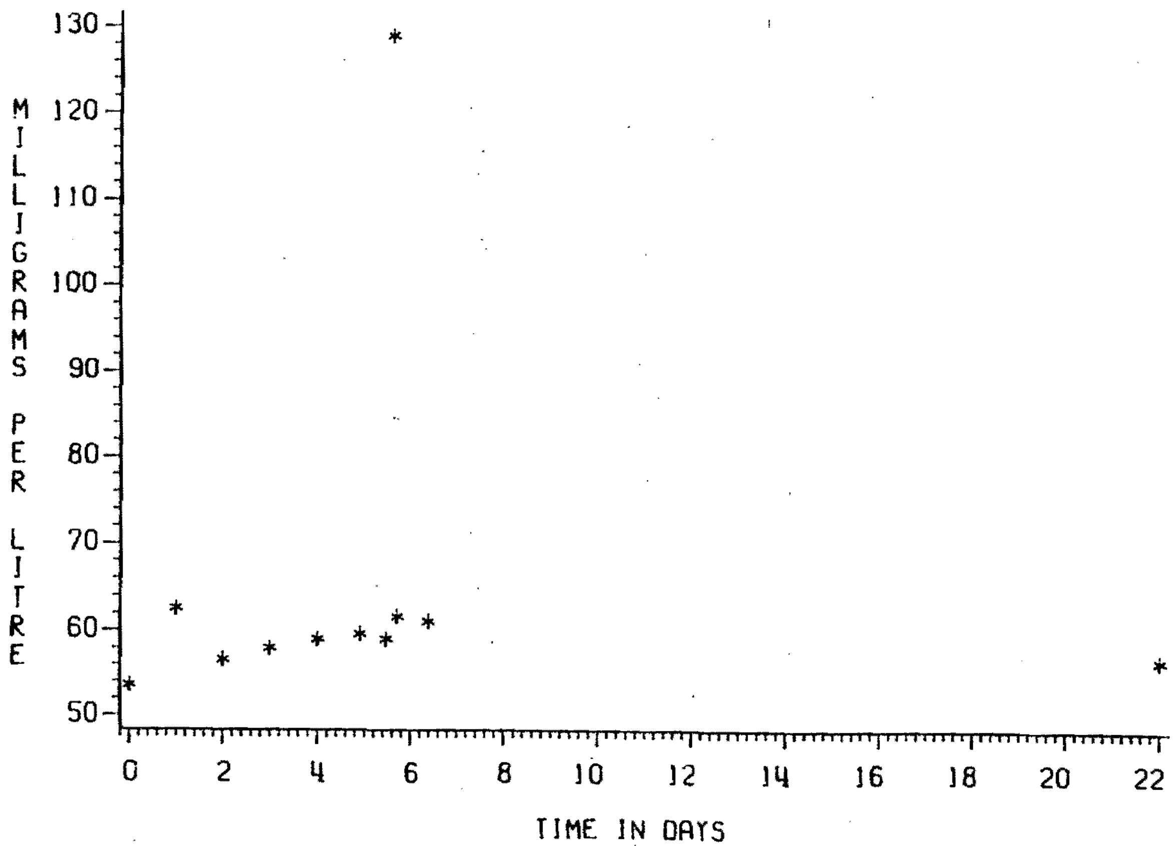


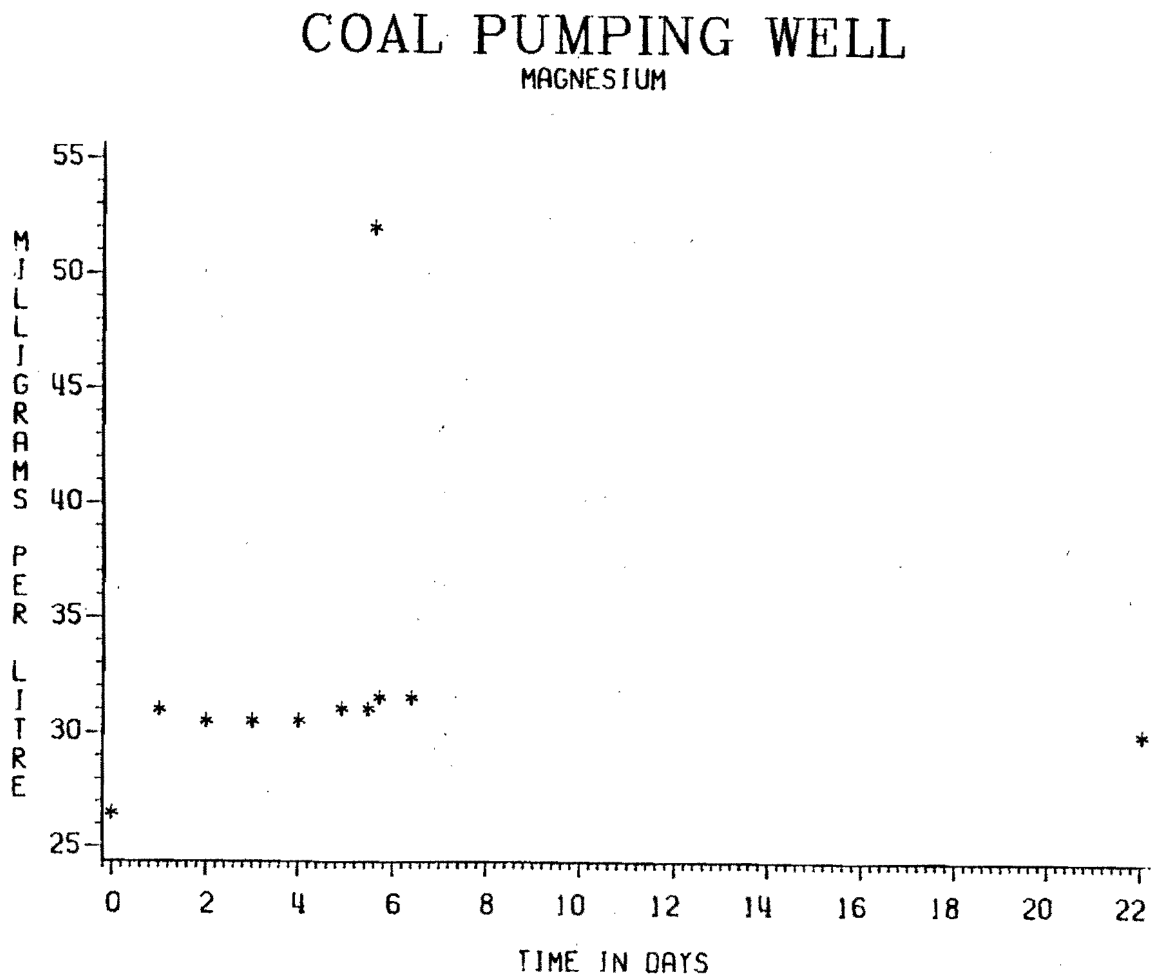
COAL PUMPING WELL



COAL PUMPING WELL

CALCIUM

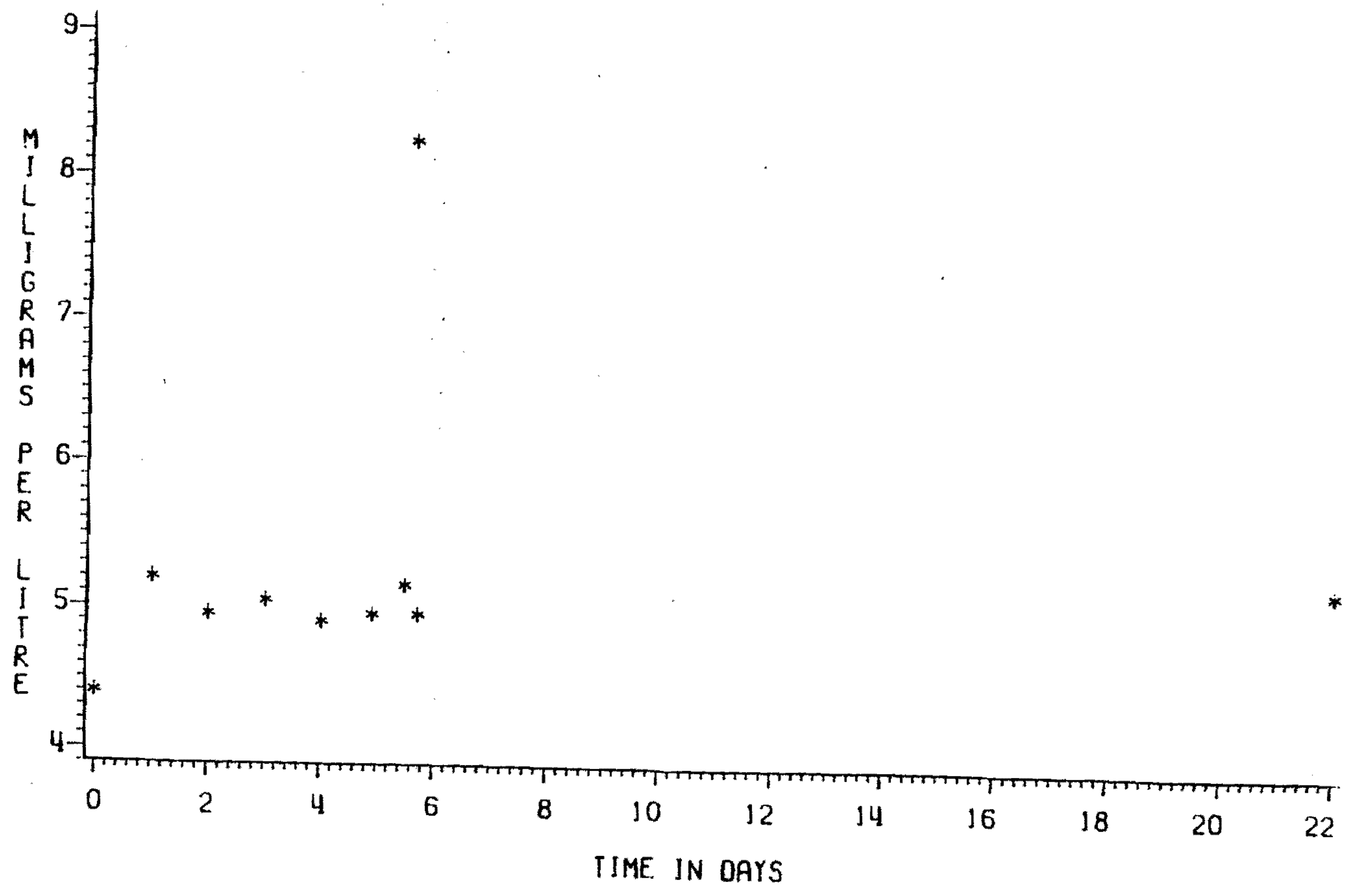




COAL PUMPING WELL
MAGNESIUM
MILLIGRAMS PER LITRE
55
50
45
40
35
30
25
0
2
4
6
8
10
12
14
16
18
20
22
TIME IN DAYS

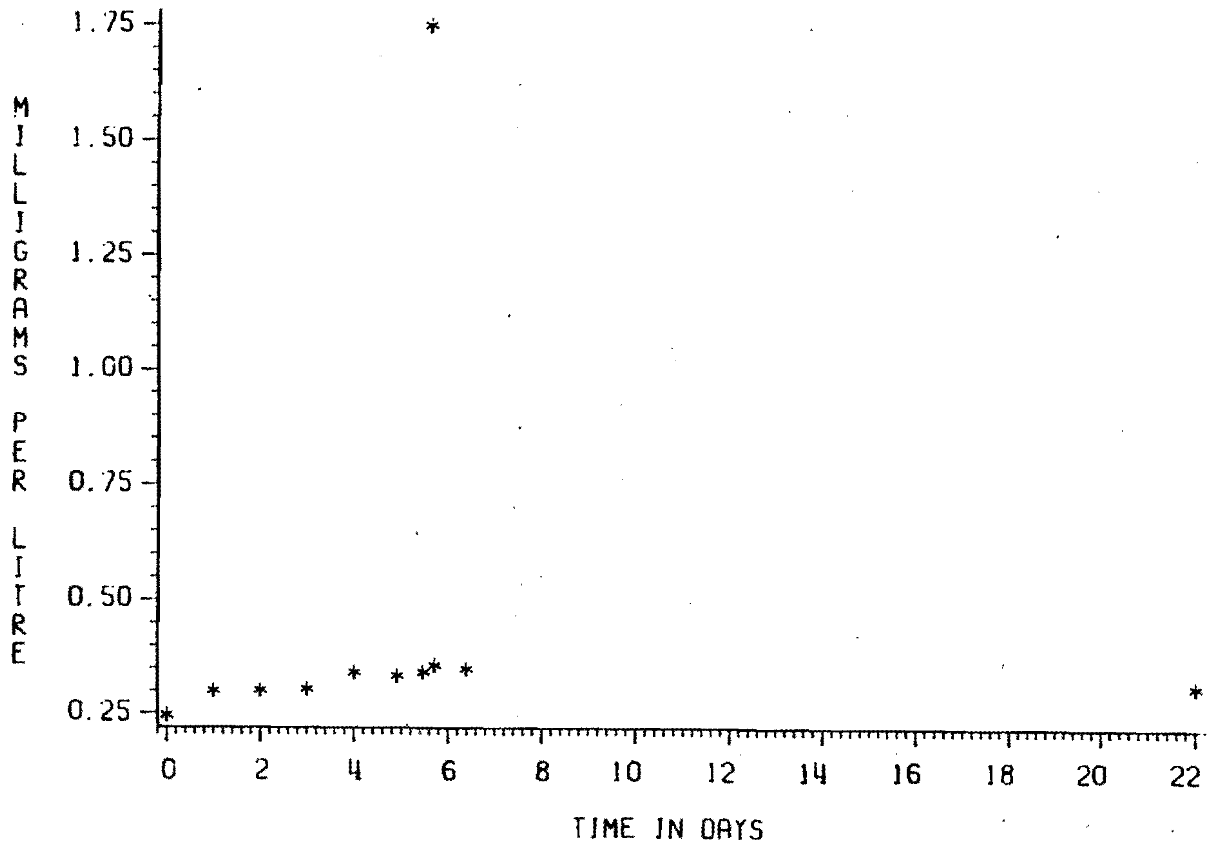
COAL PUMPING WELL

POTASSIUM

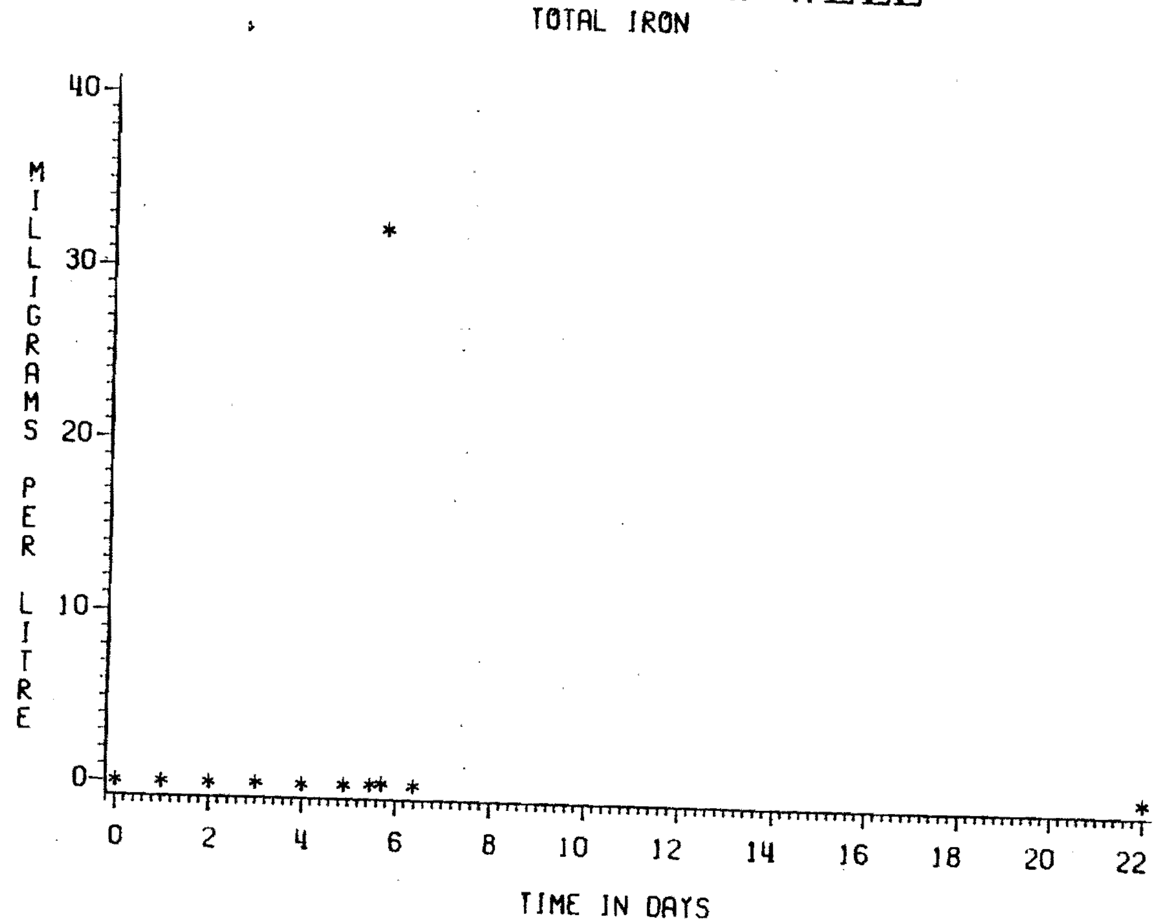


COAL PUMPING WELL

MANGANESE

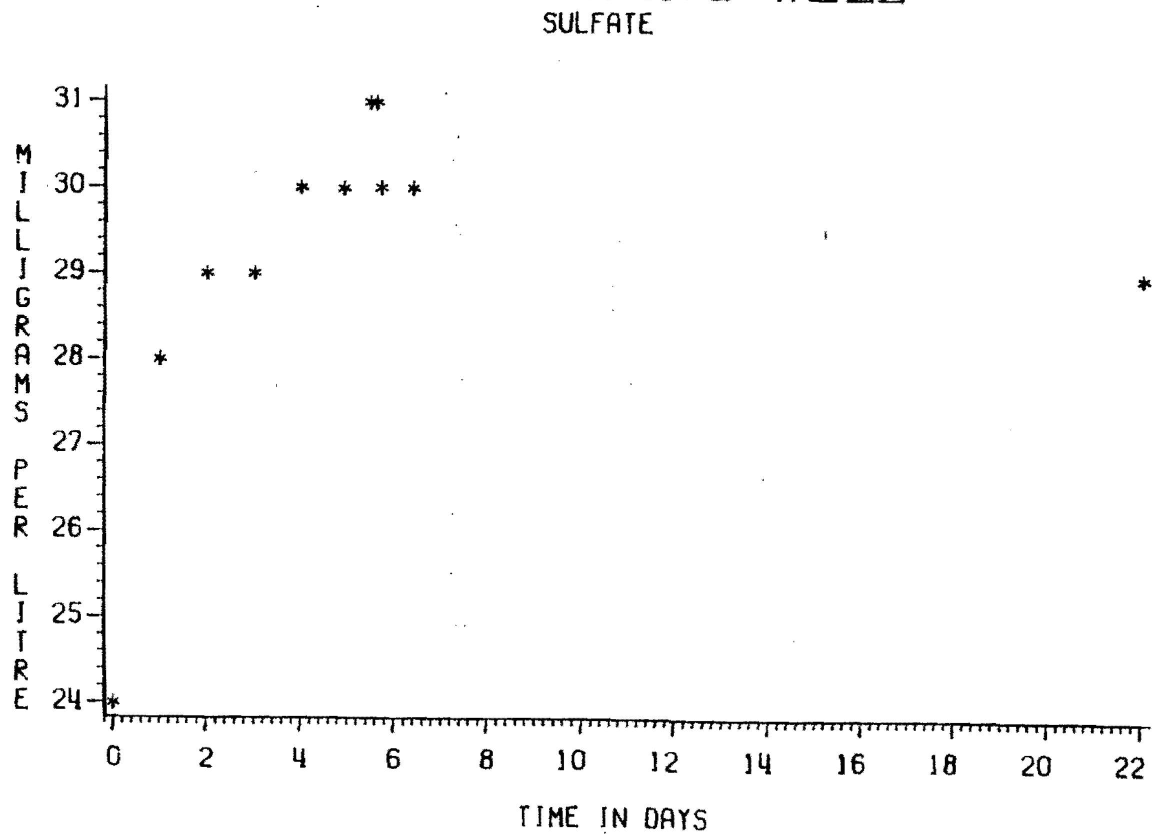


COAL PUMPING WELL



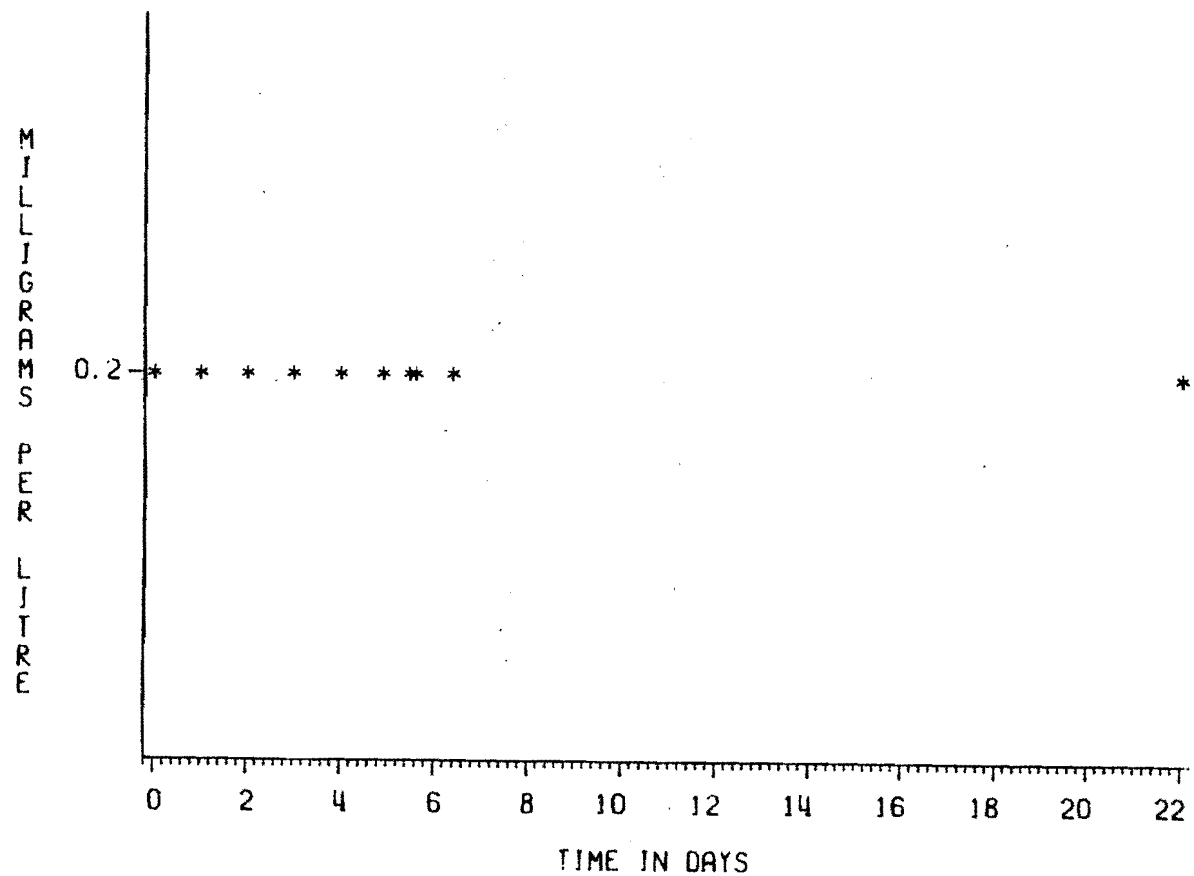
351

COAL PUMPING WELL



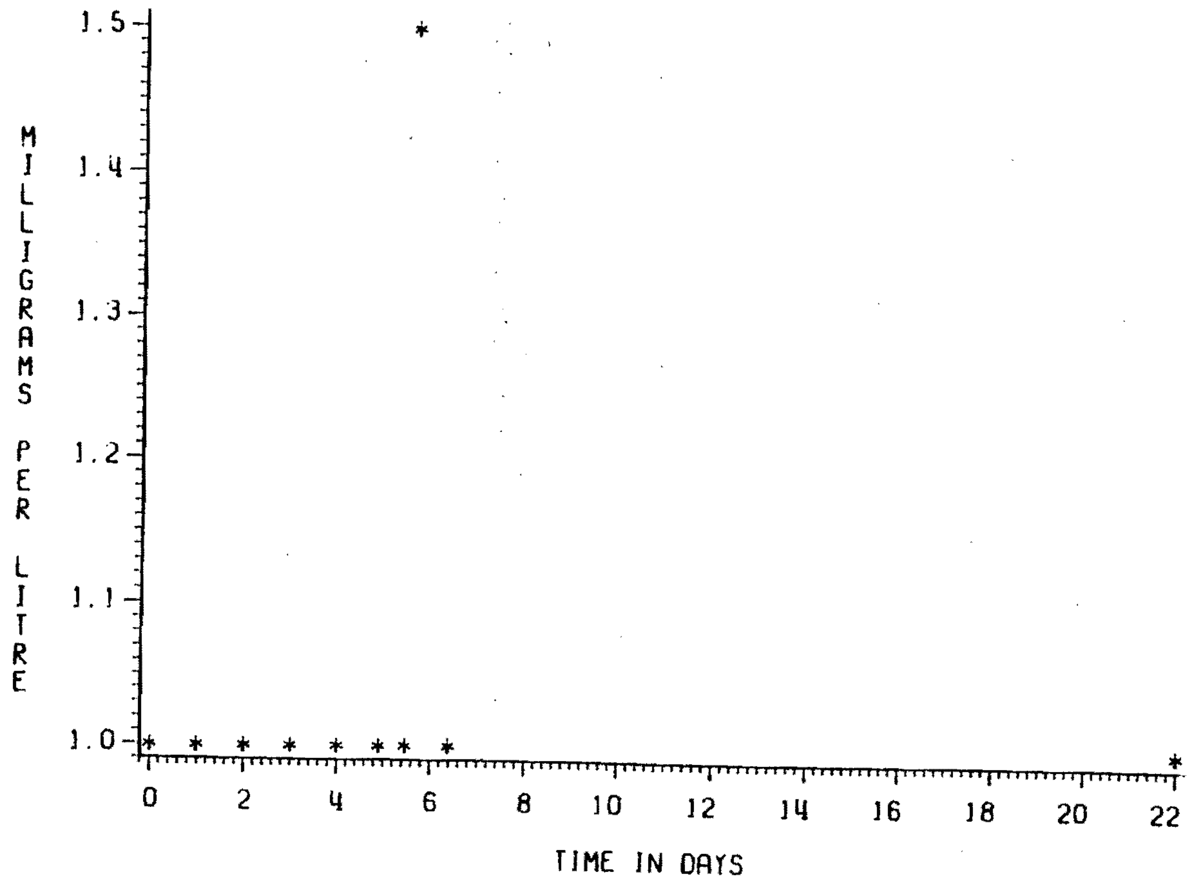
COAL PUMPING WELL

FLUORIDE



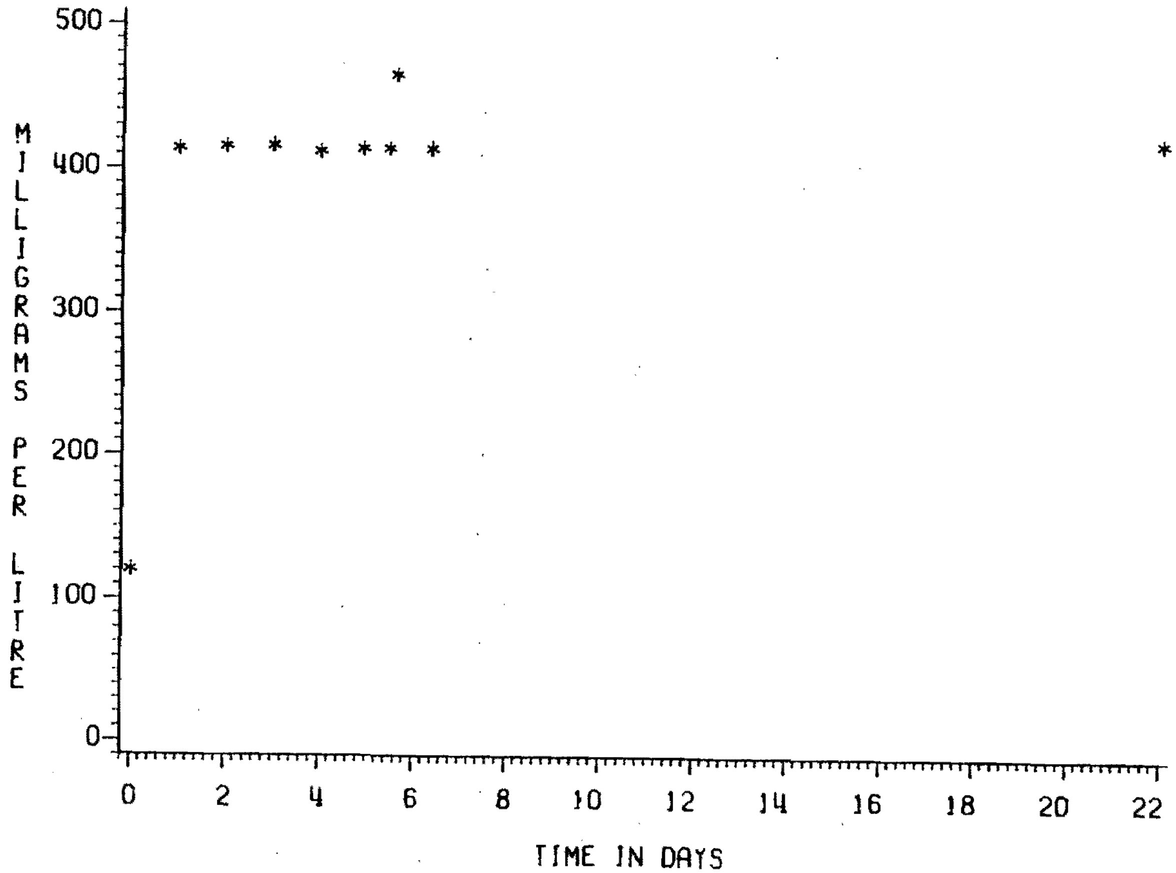
COAL PUMPING WELL

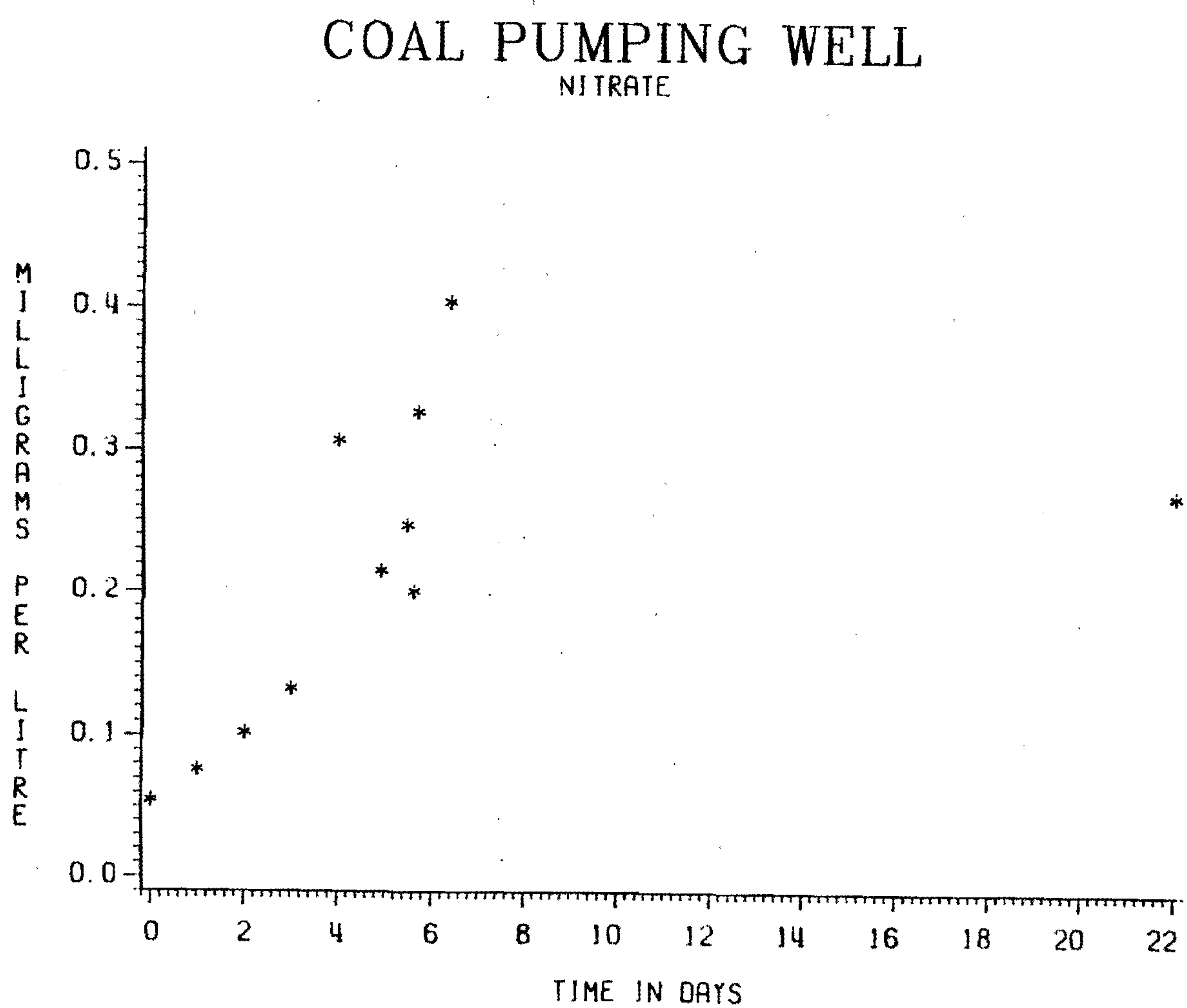
CHLORIDE



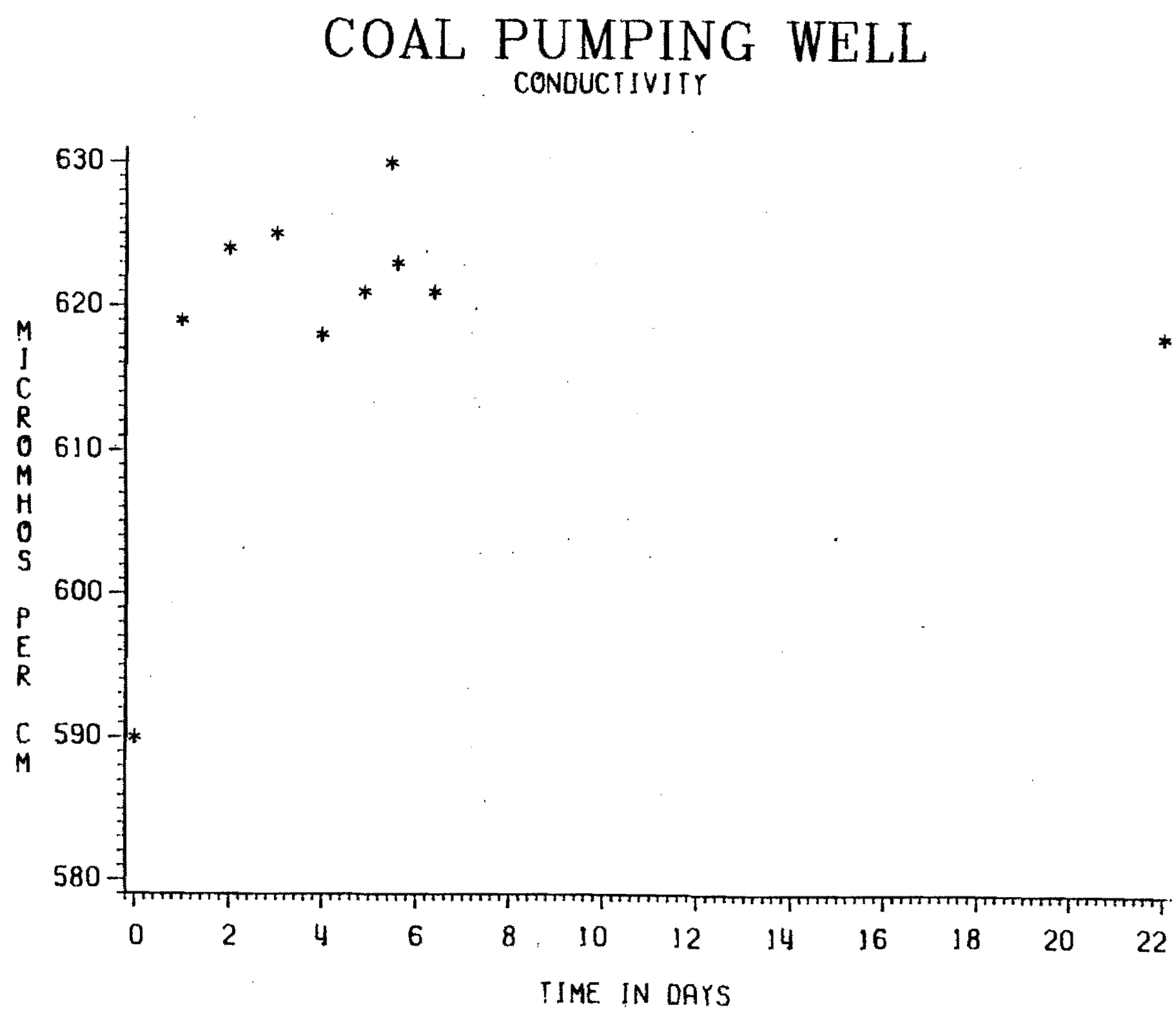
COAL PUMPING WELL

BICARBONATE



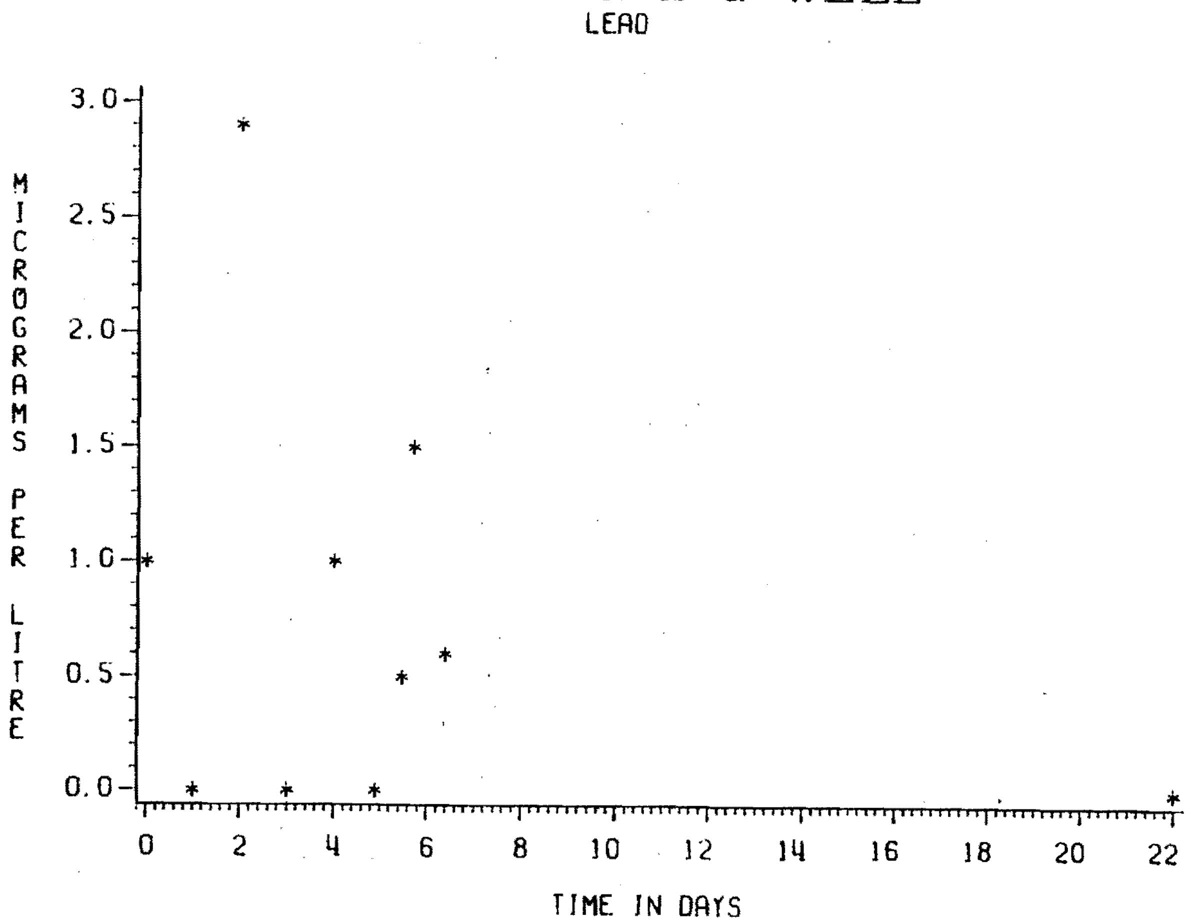


COAL PUMPING WELL
NITRATE
MILLIGRAMS PER LITRE
0.0
0.1
0.2
0.3
0.4
0.5
0
2
4
6
8
10
12
14
16
18
20
22
TIME IN DAYS



COAL PUMPING WELL
CONDUCTIVITY
MICROMHOS PER CM
630
620
610
600
590
580
0
2
4
6
8
10
12
14
16
18
20
22
TIME IN DAYS

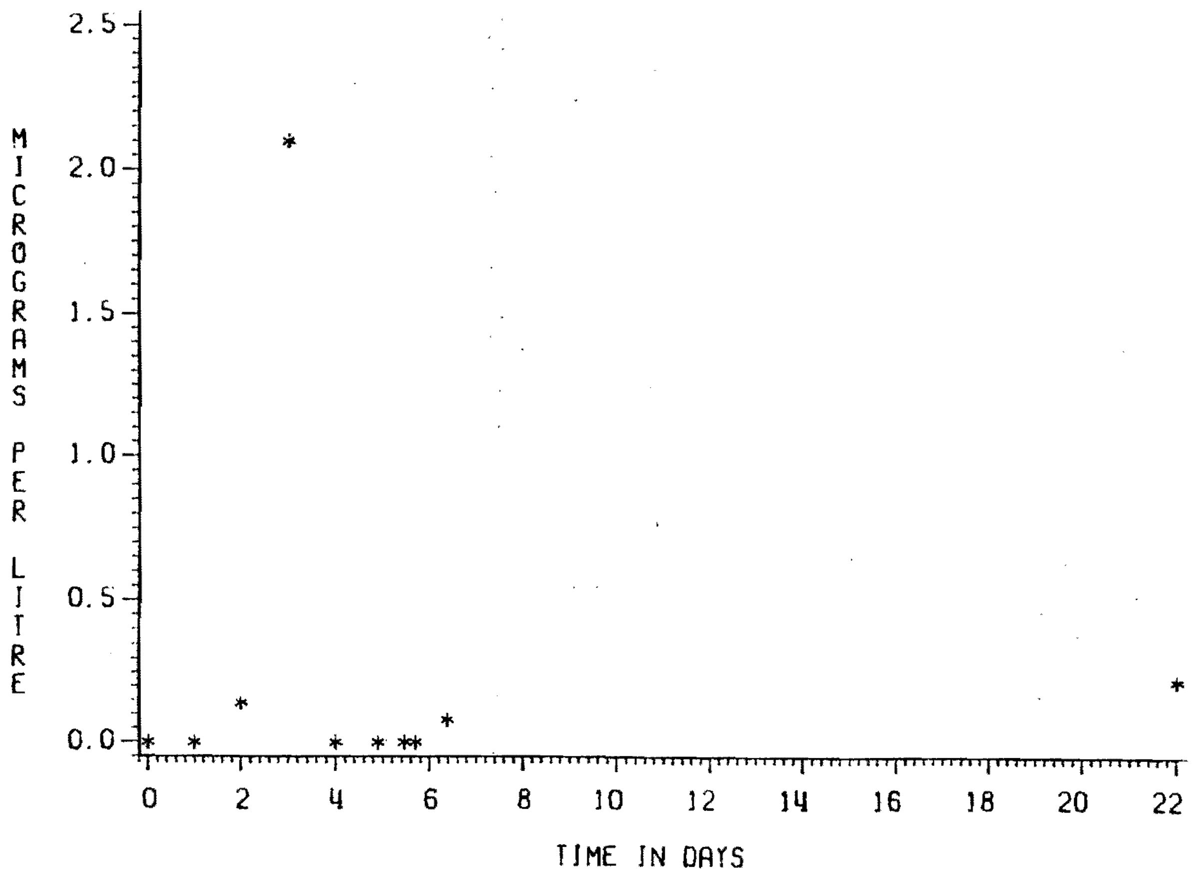
COAL PUMPING WELL



358

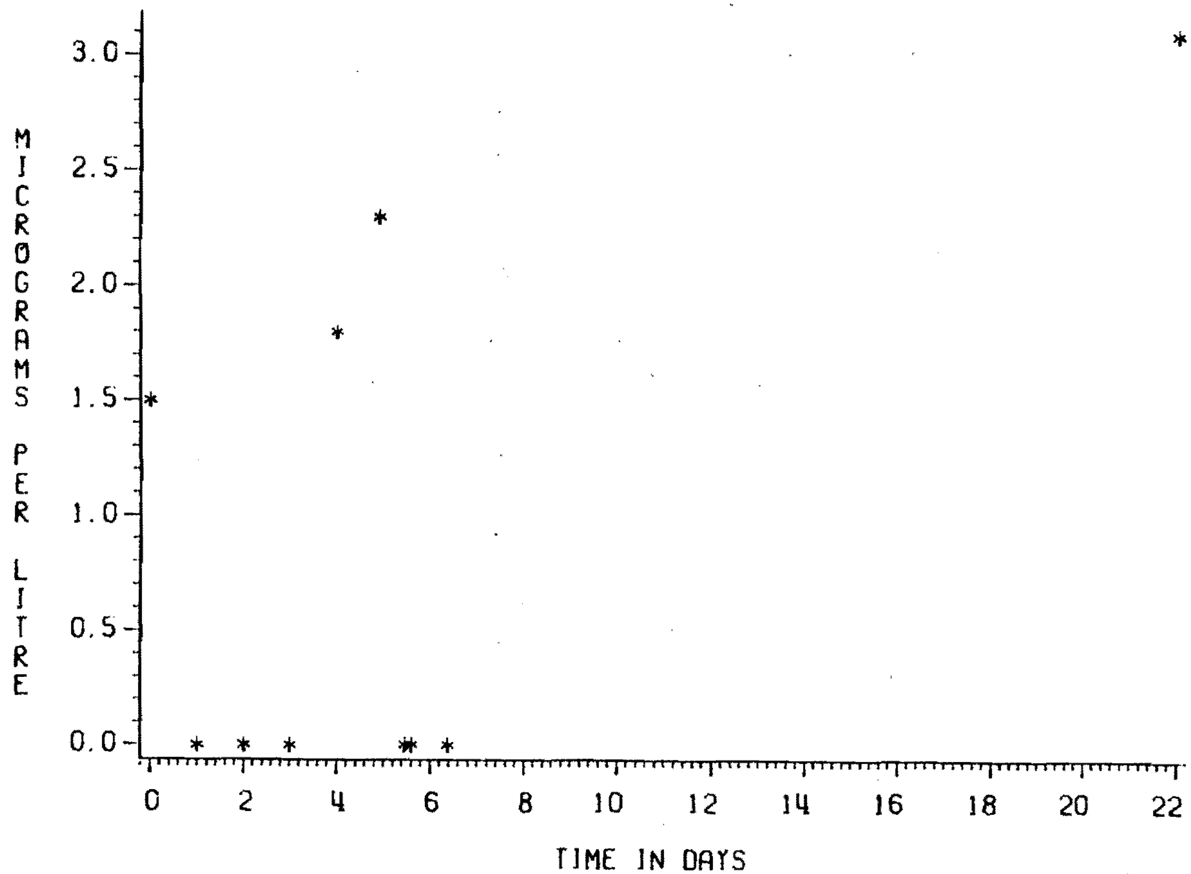
COAL PUMPING WELL

SILVER

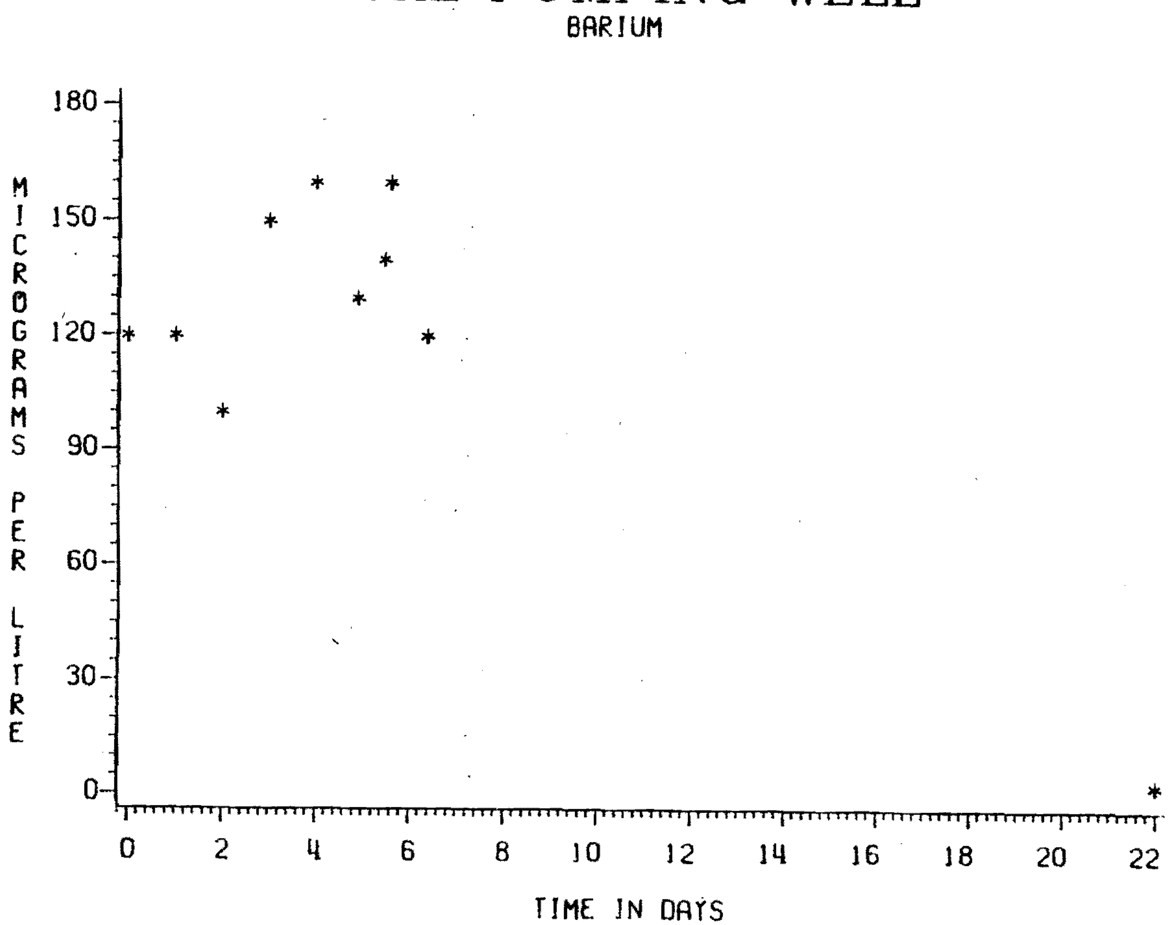


COAL PUMPING WELL

ARSENIC

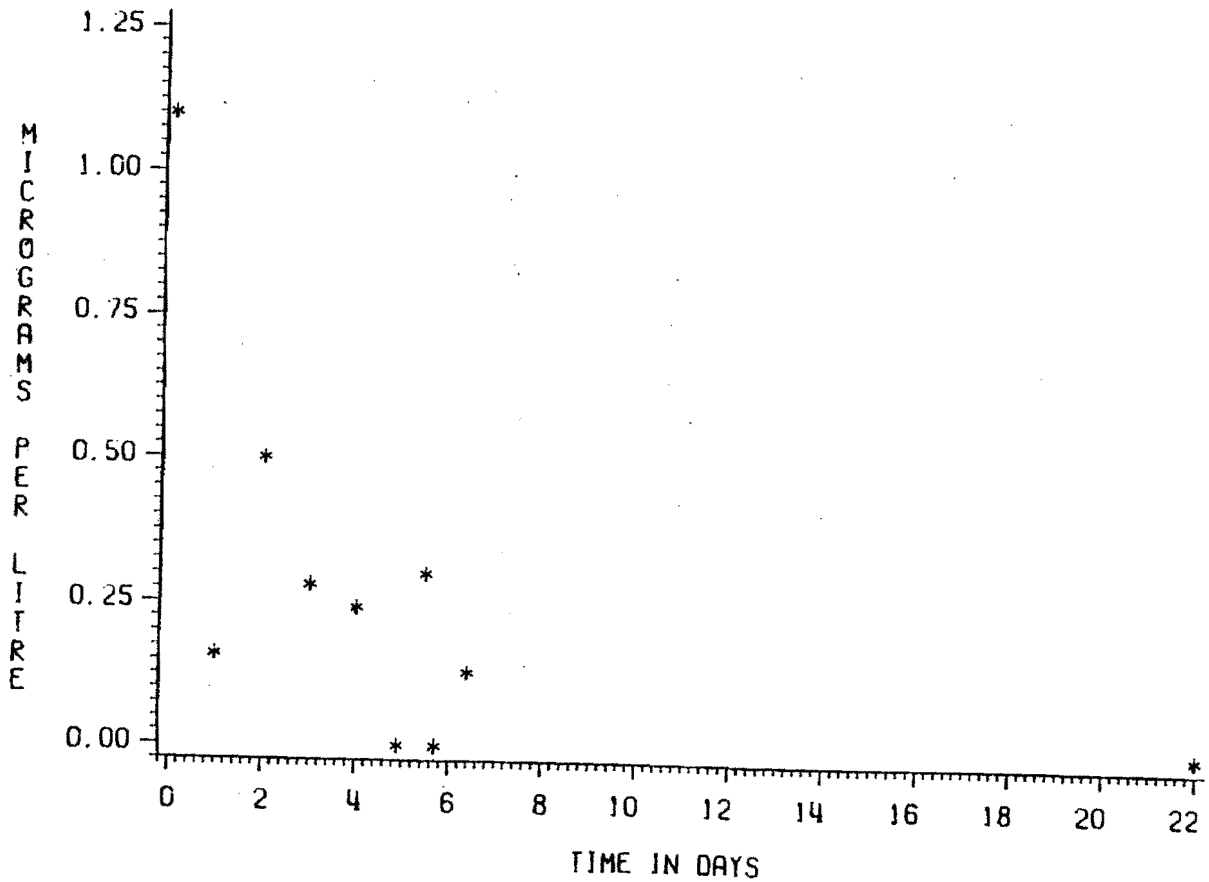


COAL PUMPING WELL



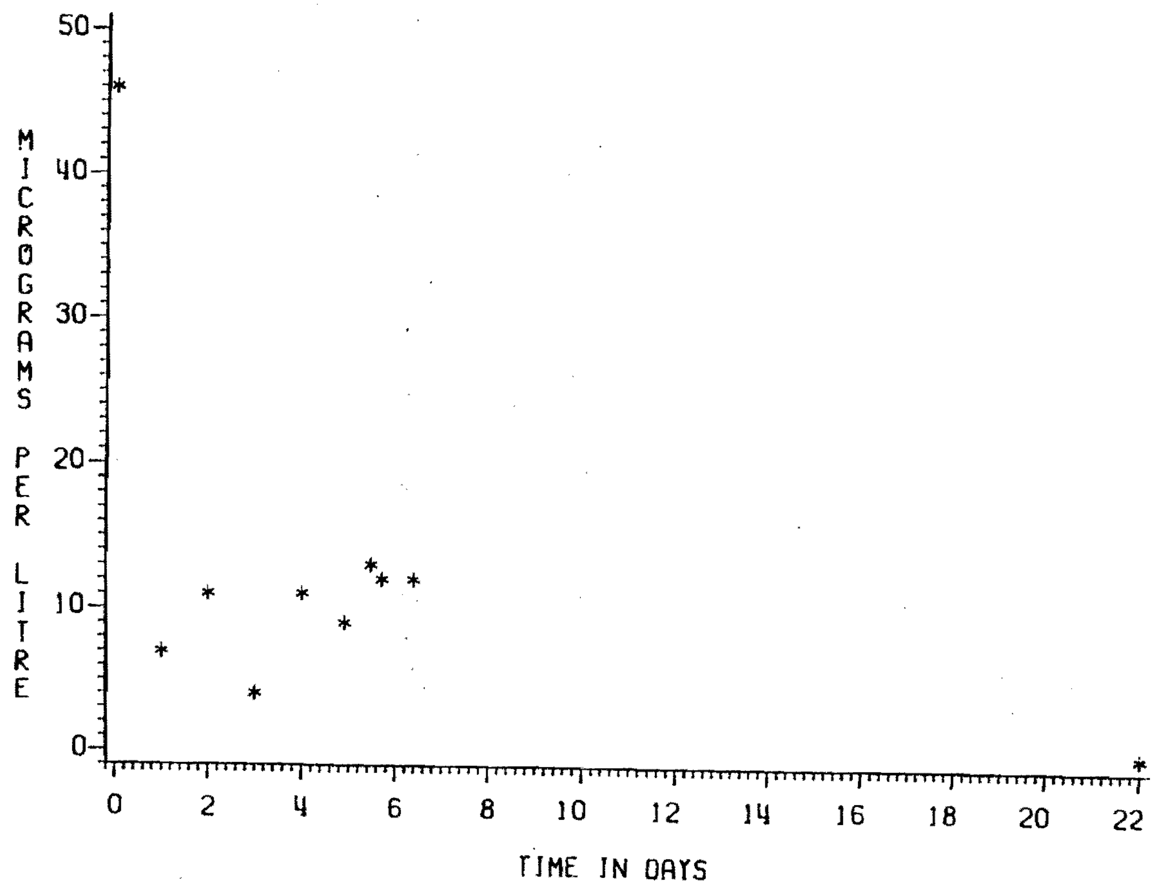
COAL PUMPING WELL

CADMIUM



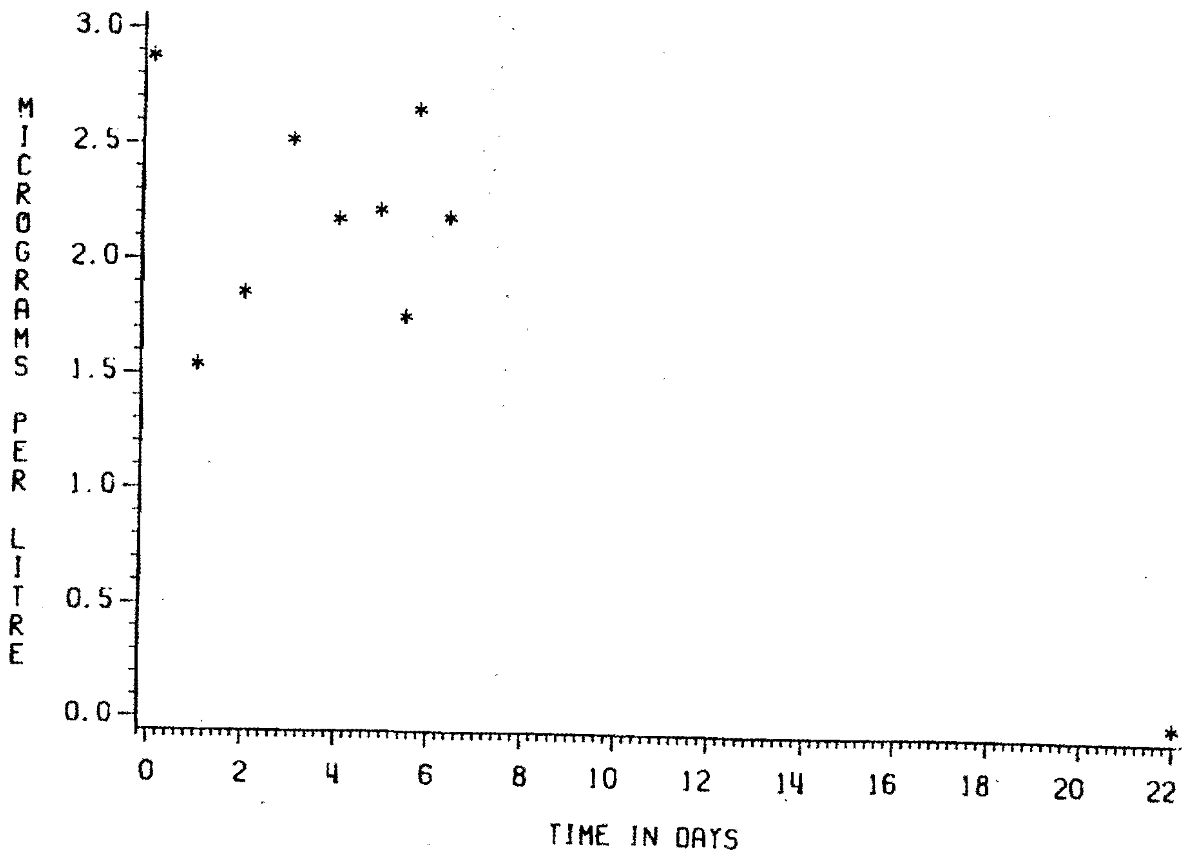
COAL PUMPING WELL

ZINC



COAL PUMPING WELL

CHROMIUM

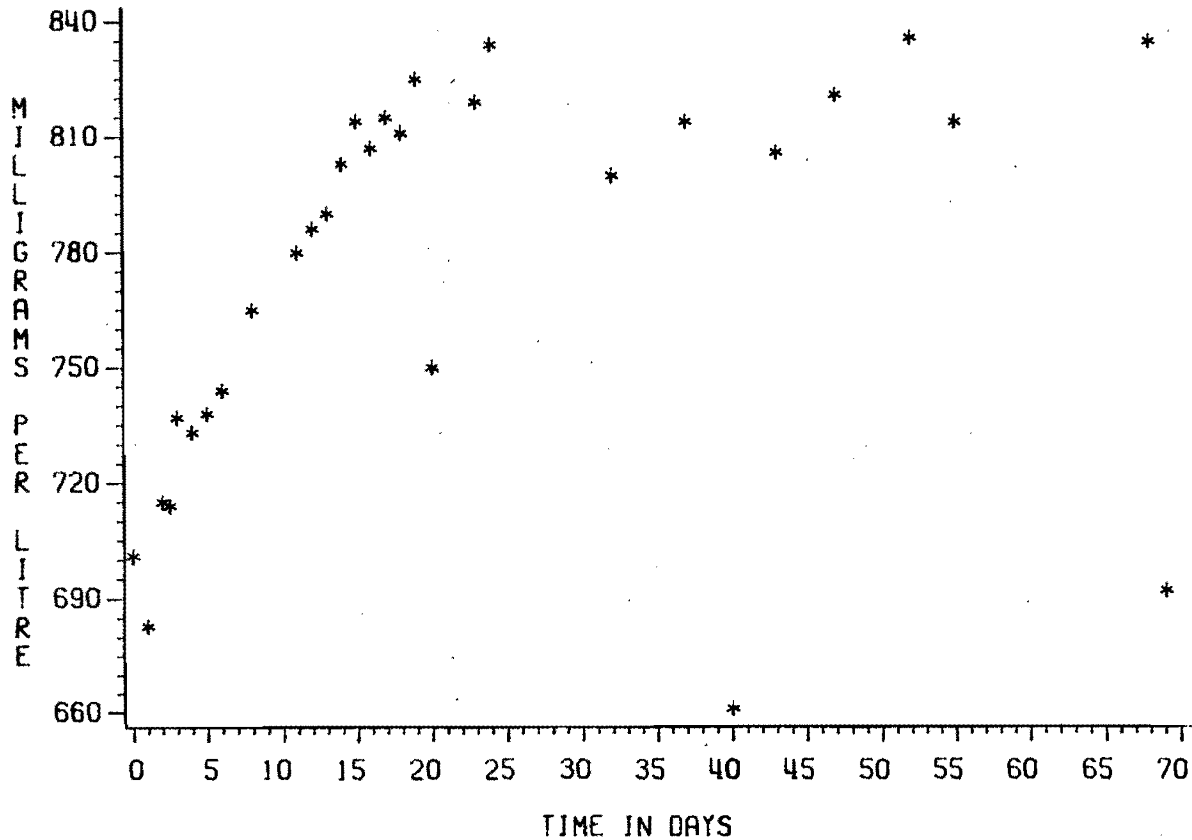


Appendix I

FARMSTEAD CHEMISTRY DATA

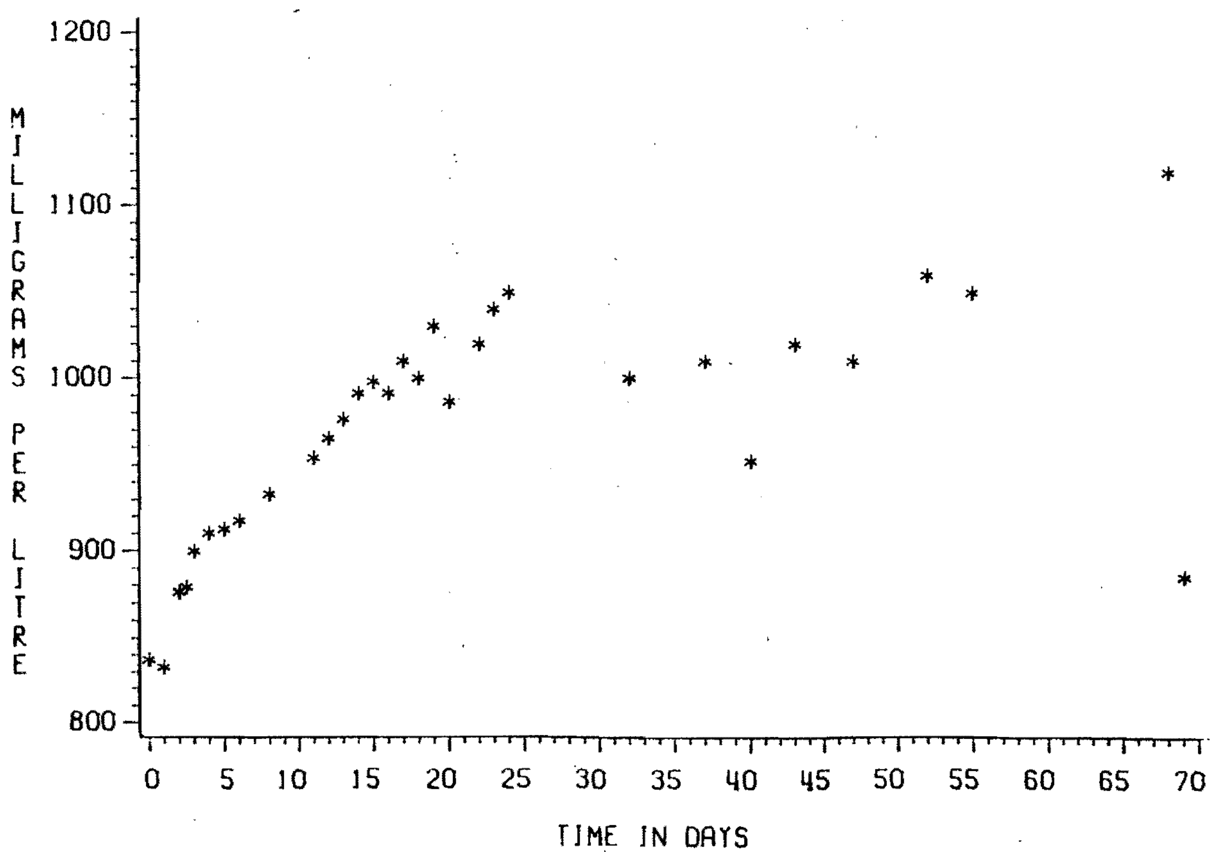
FARMSTEAD CONTINUOUS PUMPING TEST

HARDNESS AS CALCIUM CARBONATE



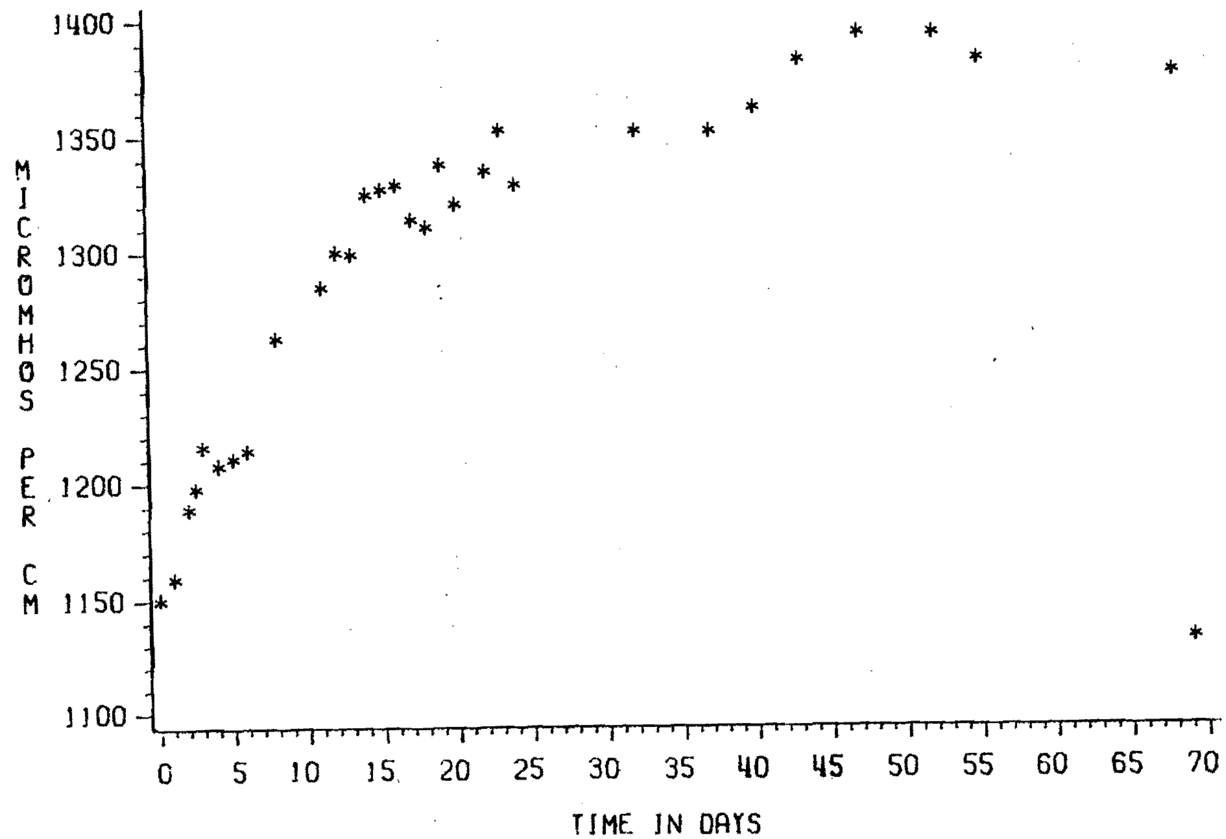
FARMSTEAD CONTINUOUS PUMPING TEST

TOTAL DISSOLVED SOLIDS



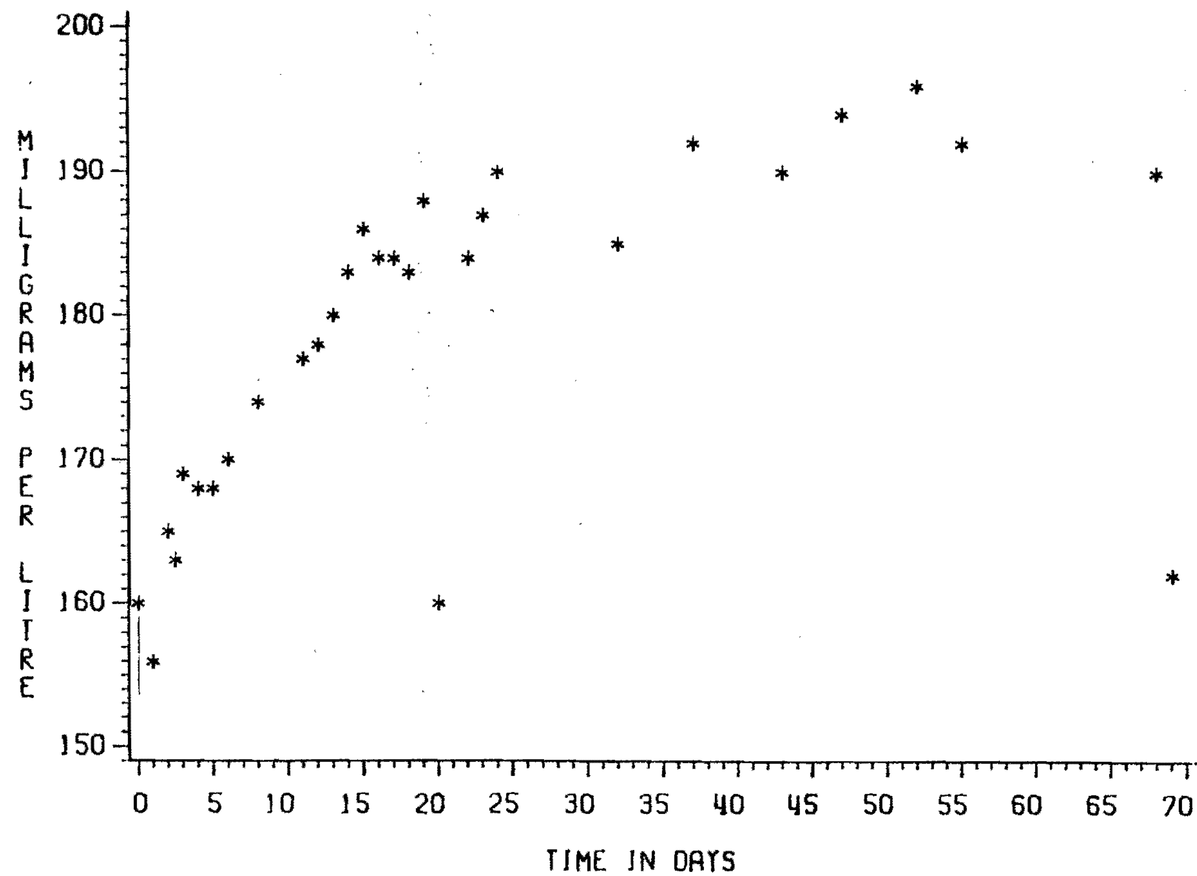
FARMSTEAD CONTINUOUS PUMPING TEST

CONDUCTIVITY

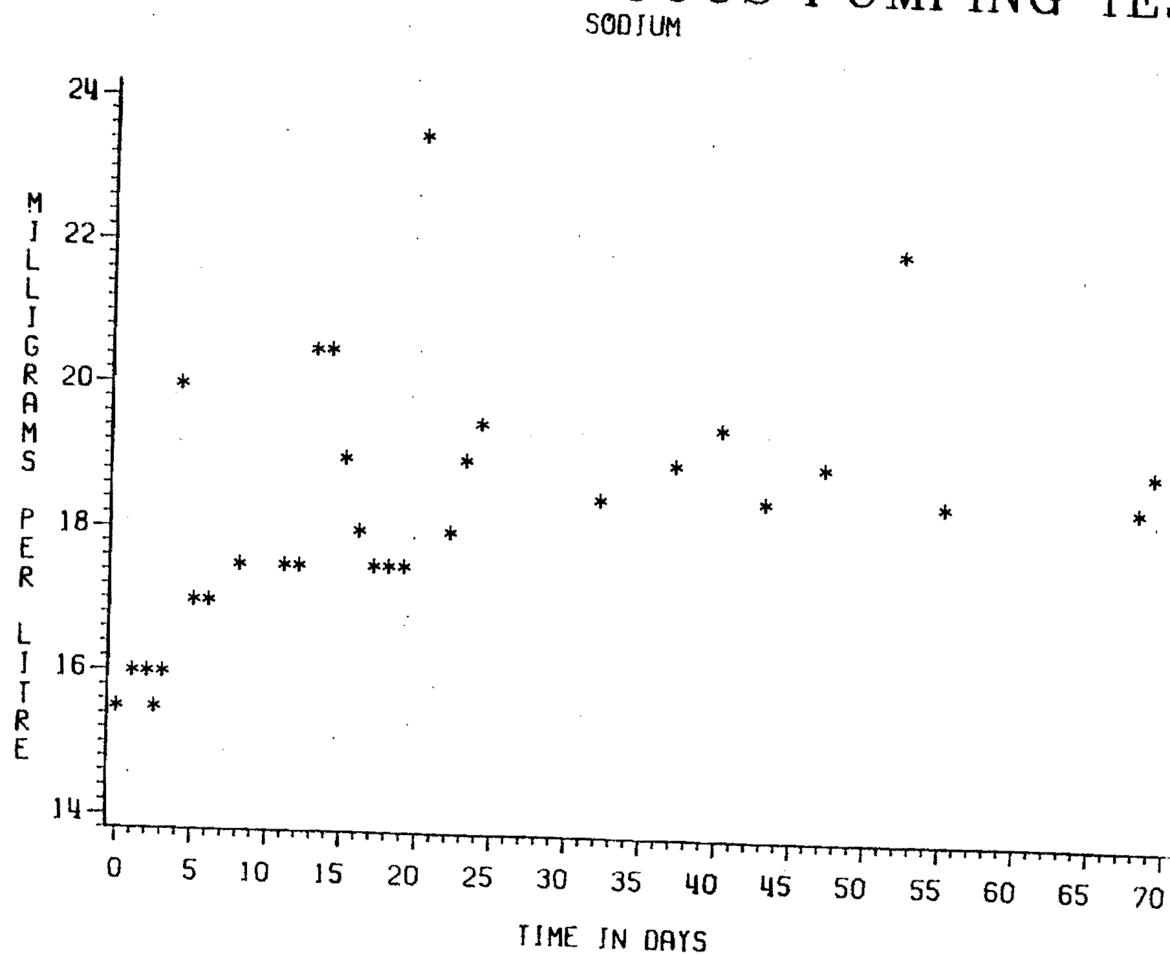


FARMSTEAD CONTINUOUS PUMPING TEST

CALCIUM

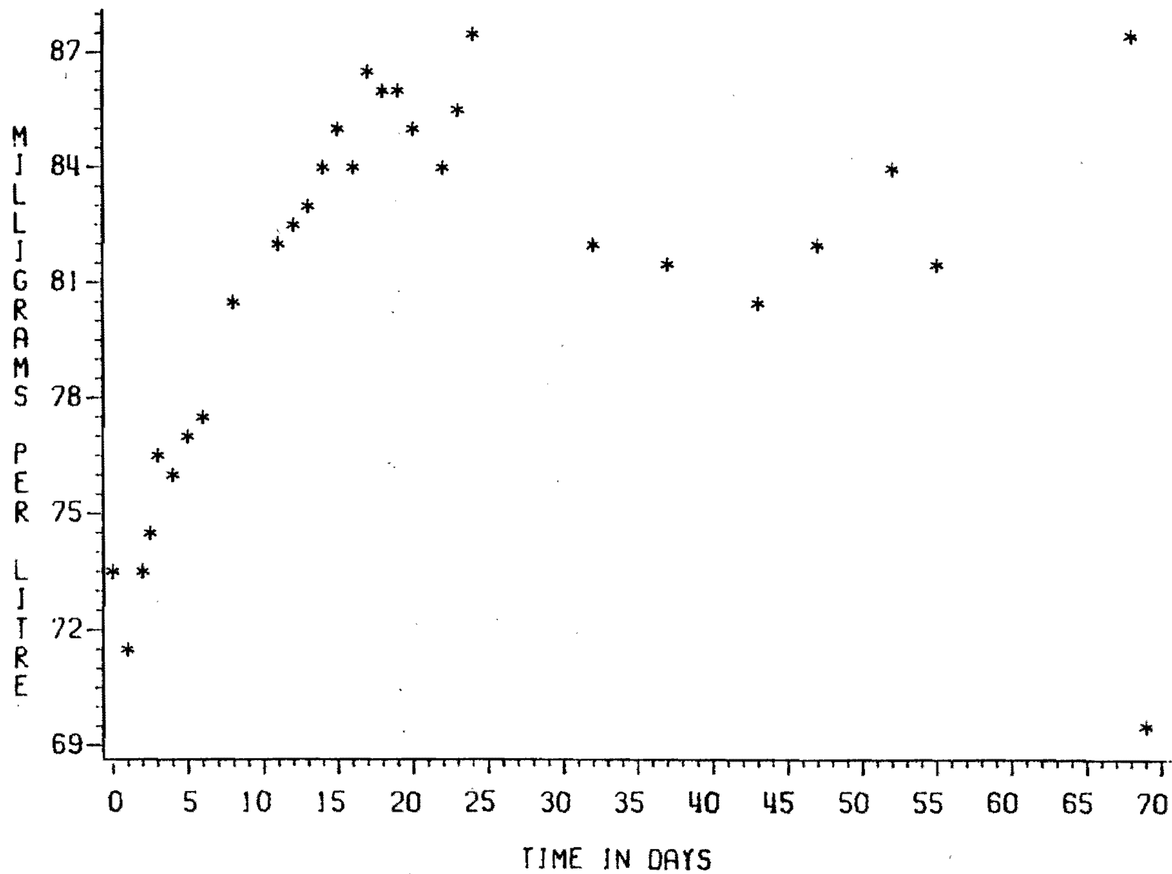


FARMSTEAD CONTINUOUS PUMPING TEST



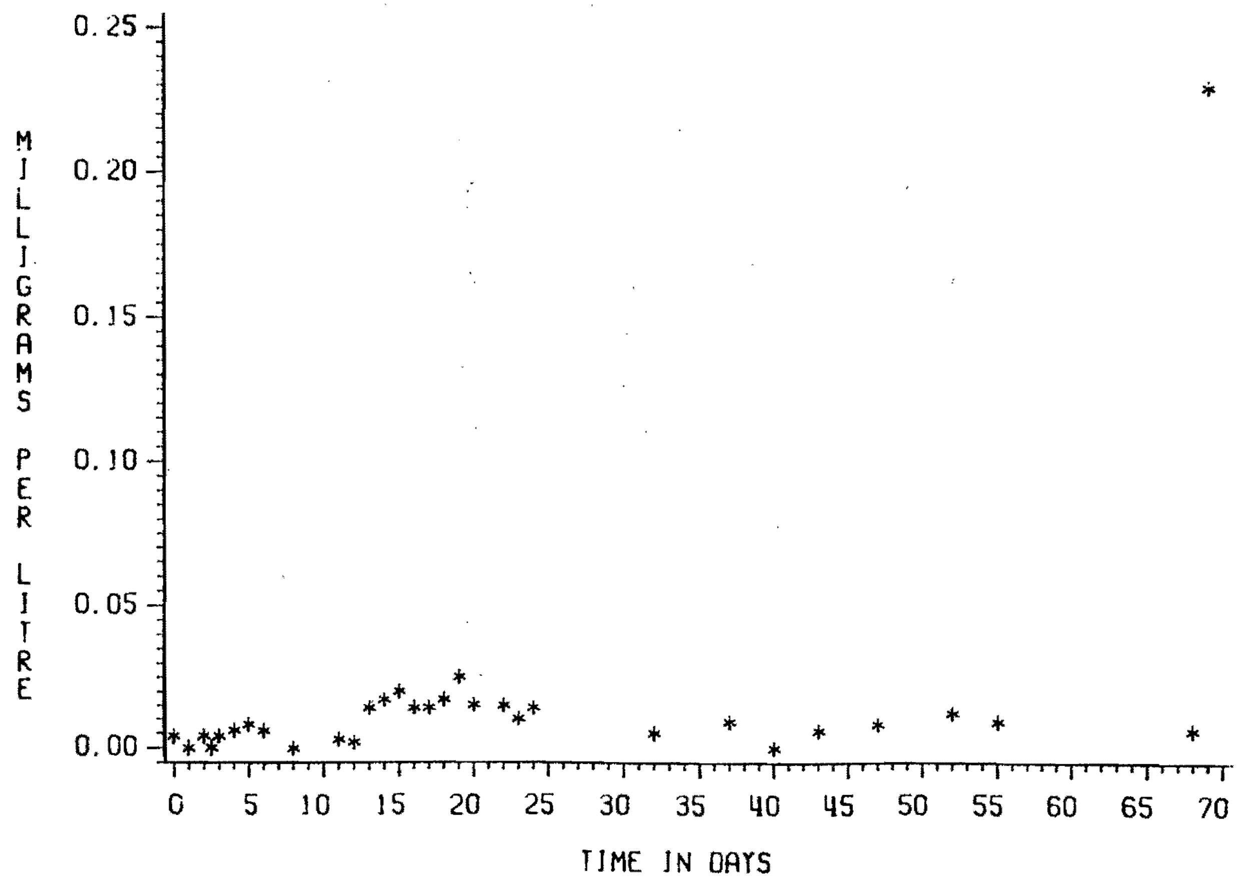
FARMSTEAD CONTINUOUS PUMPING TEST

MAGNESIUM



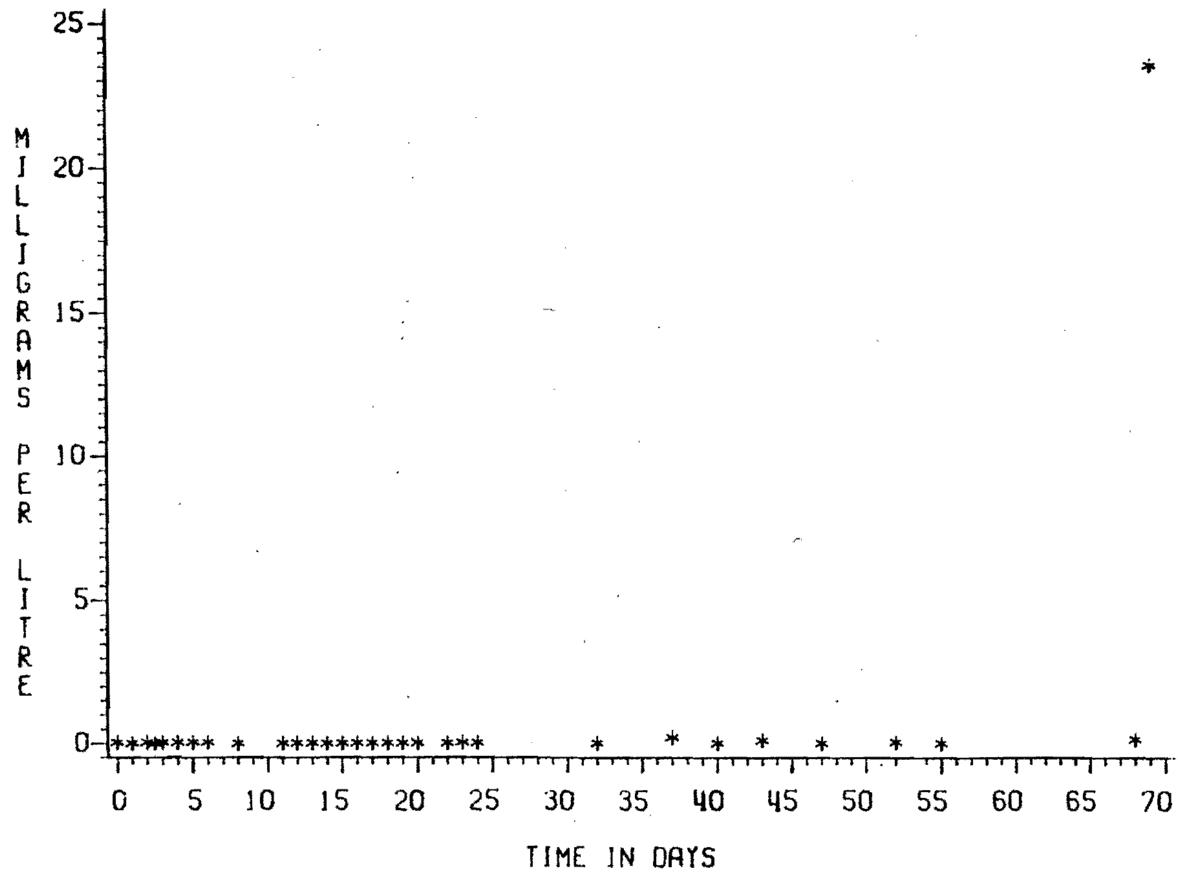
FARMSTEAD CONTINUOUS PUMPING TEST

MANGANESE



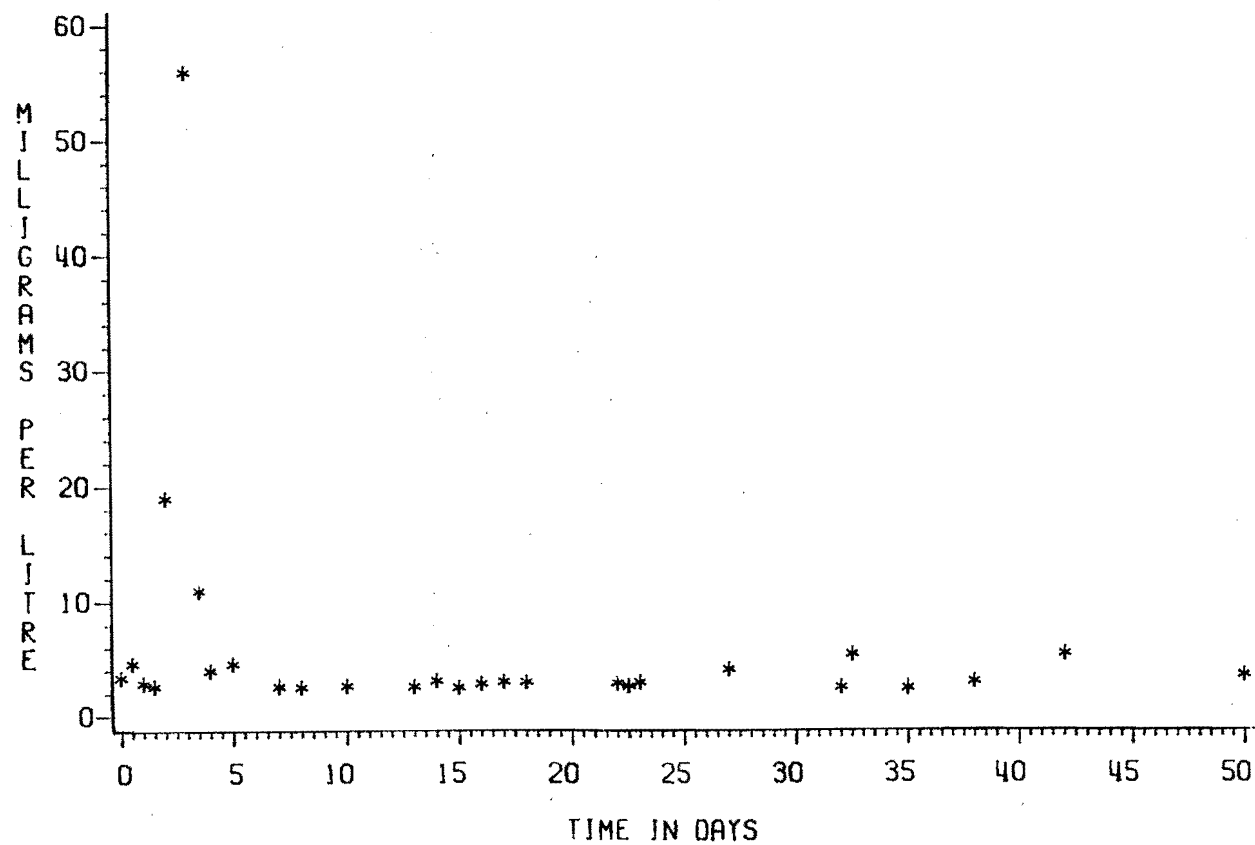
FARMSTEAD CONTINUOUS PUMPING TEST

IRON

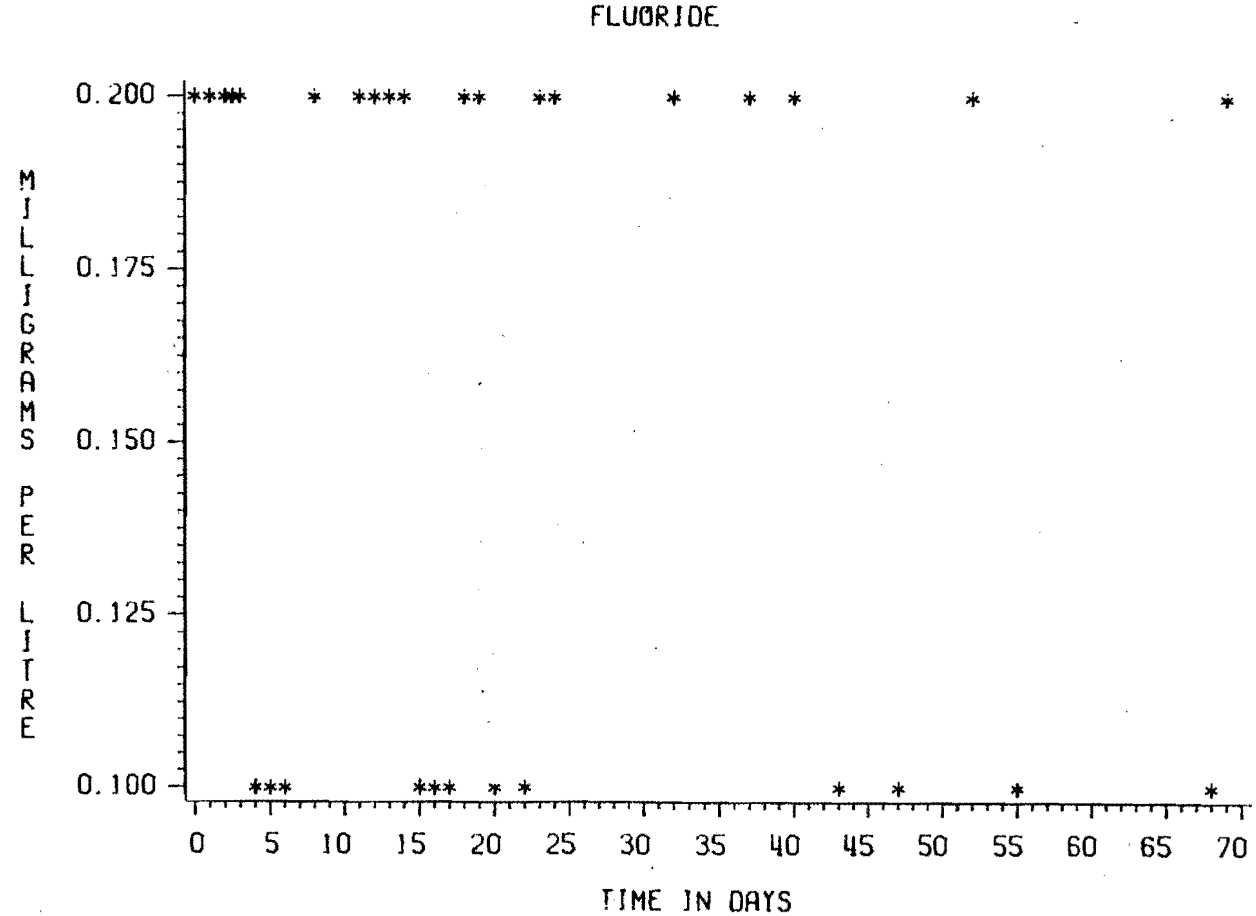


FARMSTEAD CONTINUOUS PUMPING TEST

TOTAL ORGANIC CARBON

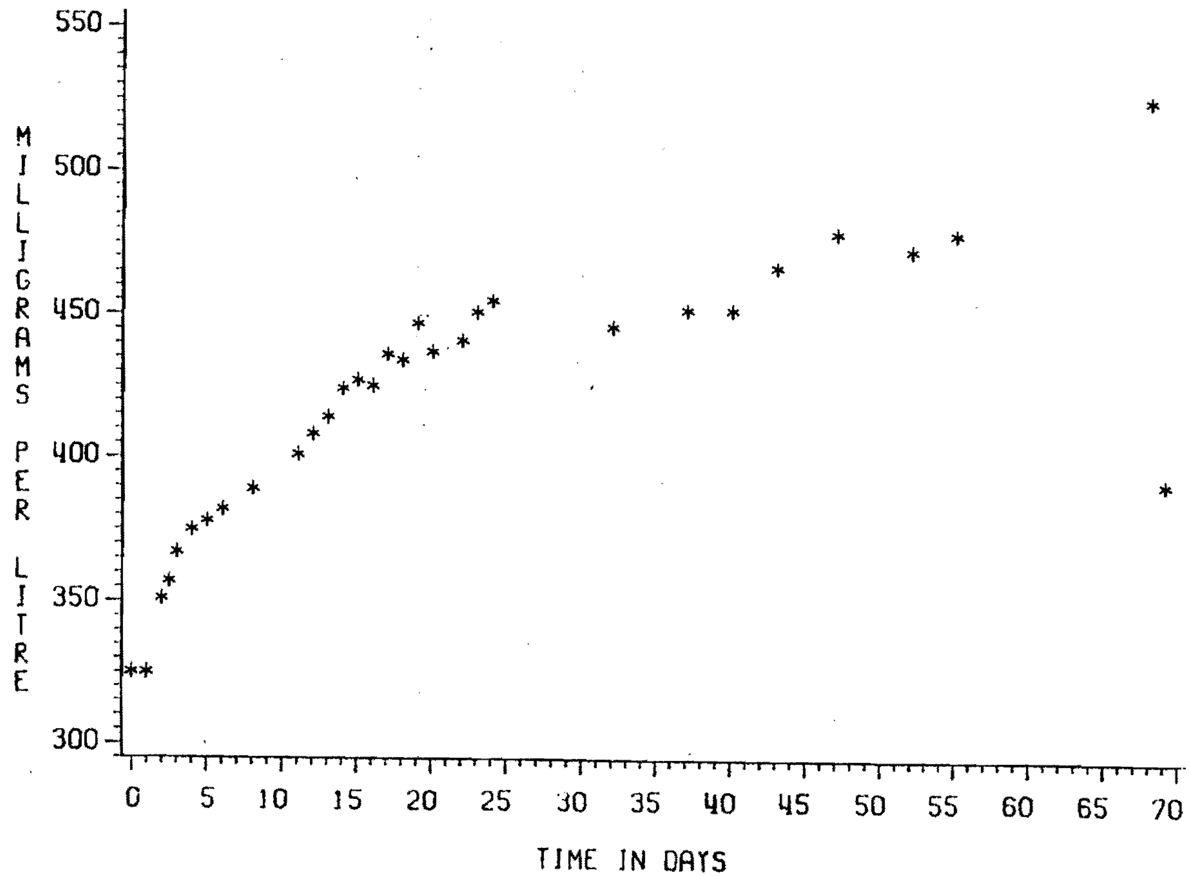


FARMSTEAD CONTINUOUS PUMPING TEST



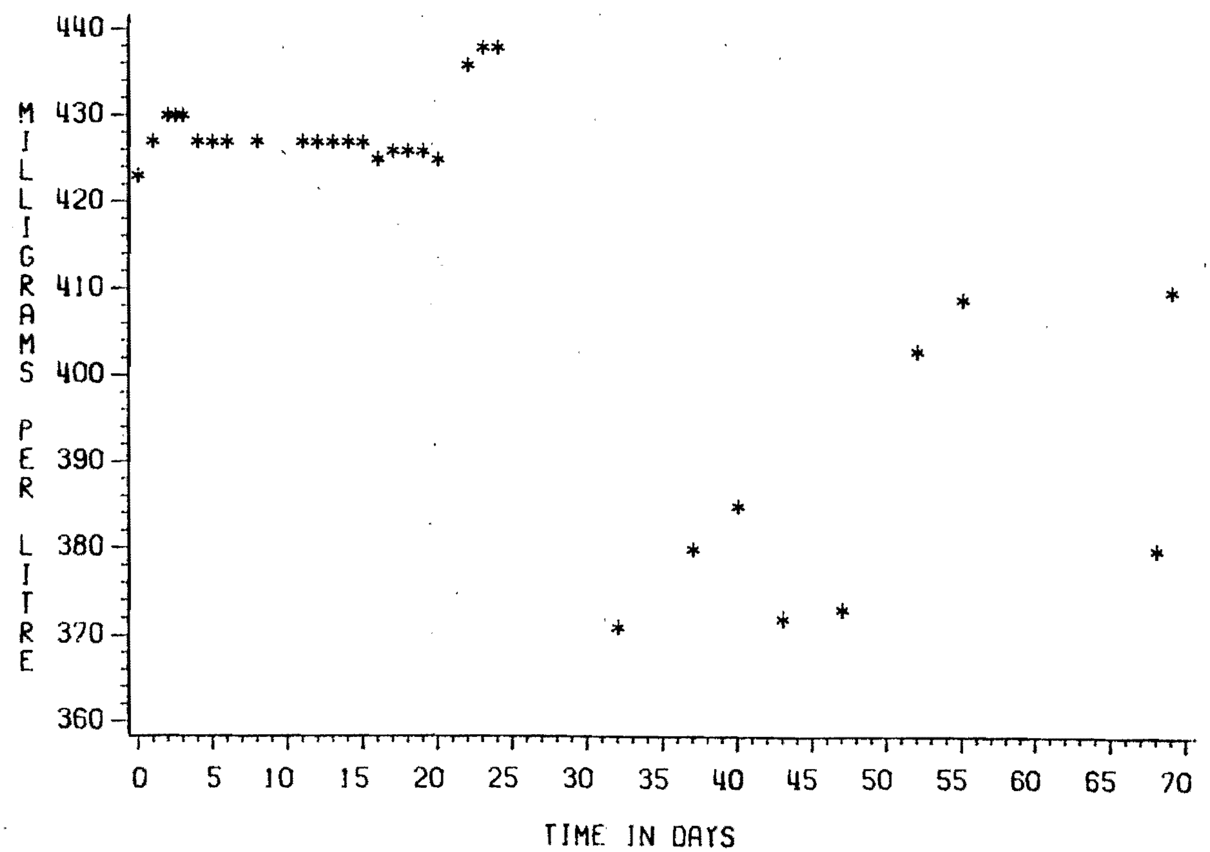
FARMSTEAD CONTINUOUS PUMPING TEST

SULFATE



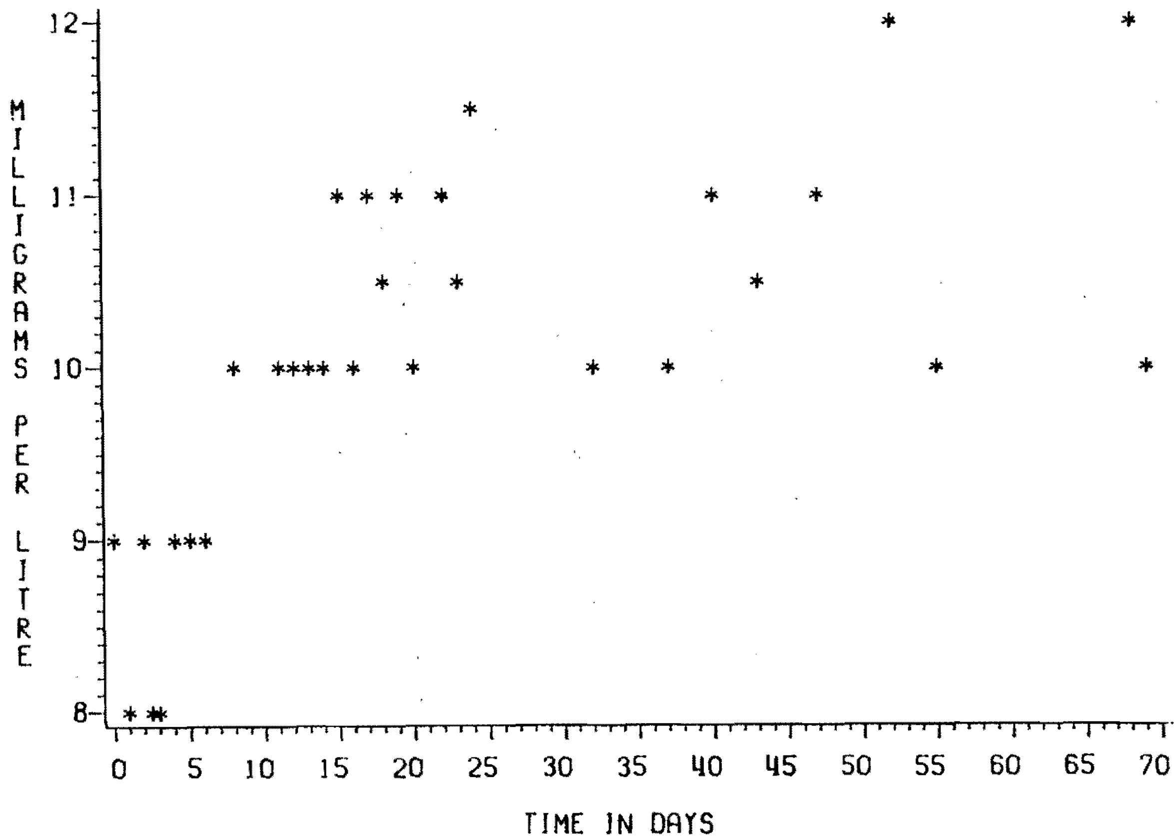
FARMSTEAD CONTINUOUS PUMPING TEST

BICARBONATE



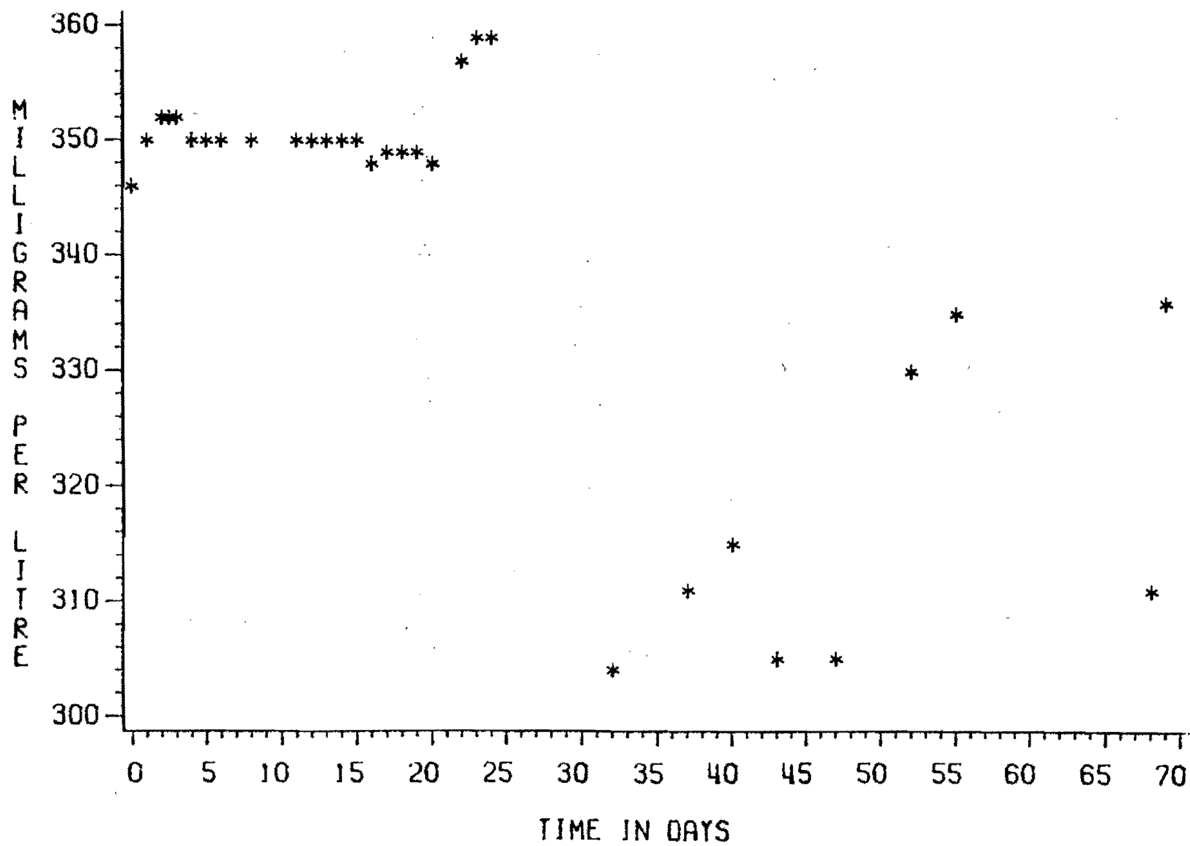
FARMSTEAD CONTINUOUS PUMPING TEST

CHLORIDE



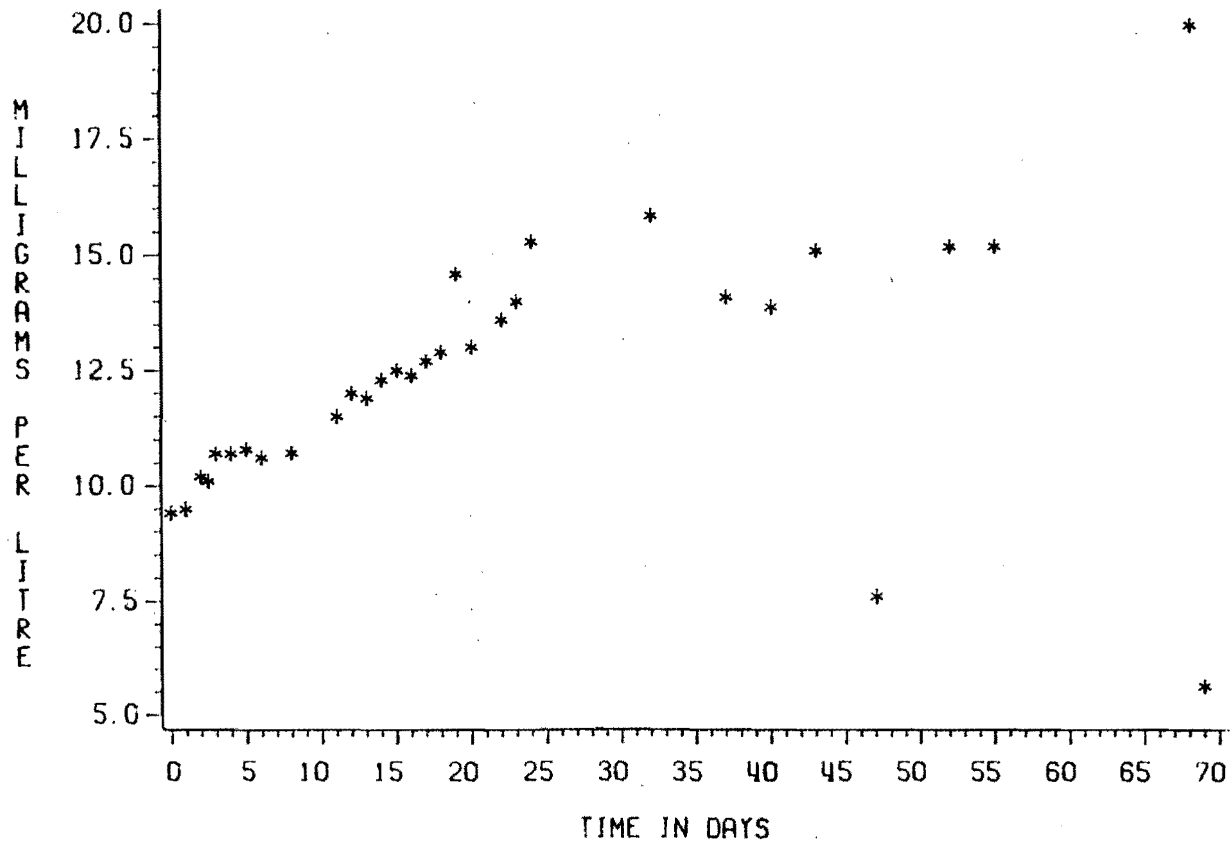
FARMSTEAD CONTINUOUS PUMPING TEST

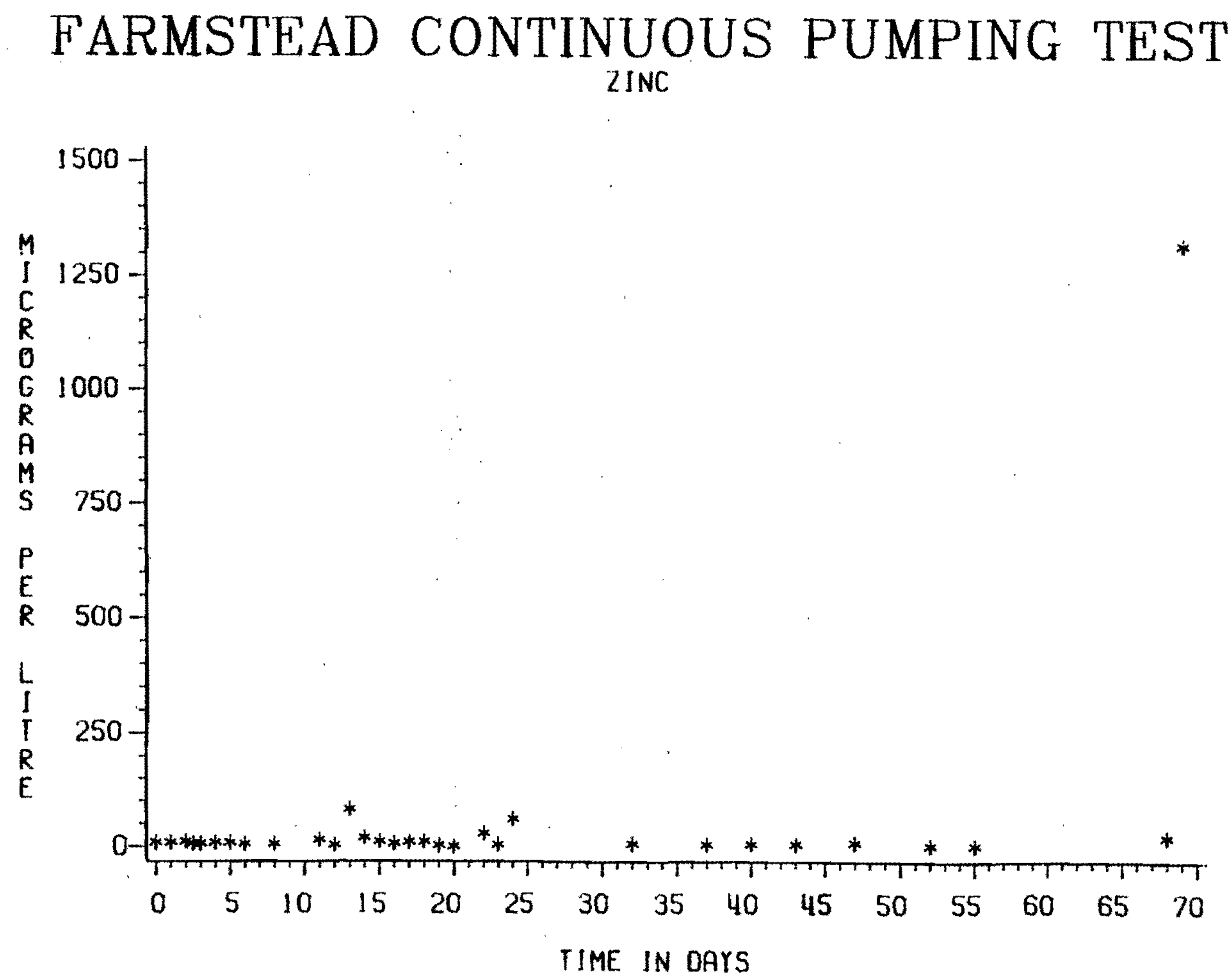
TOTAL ALKALINITY



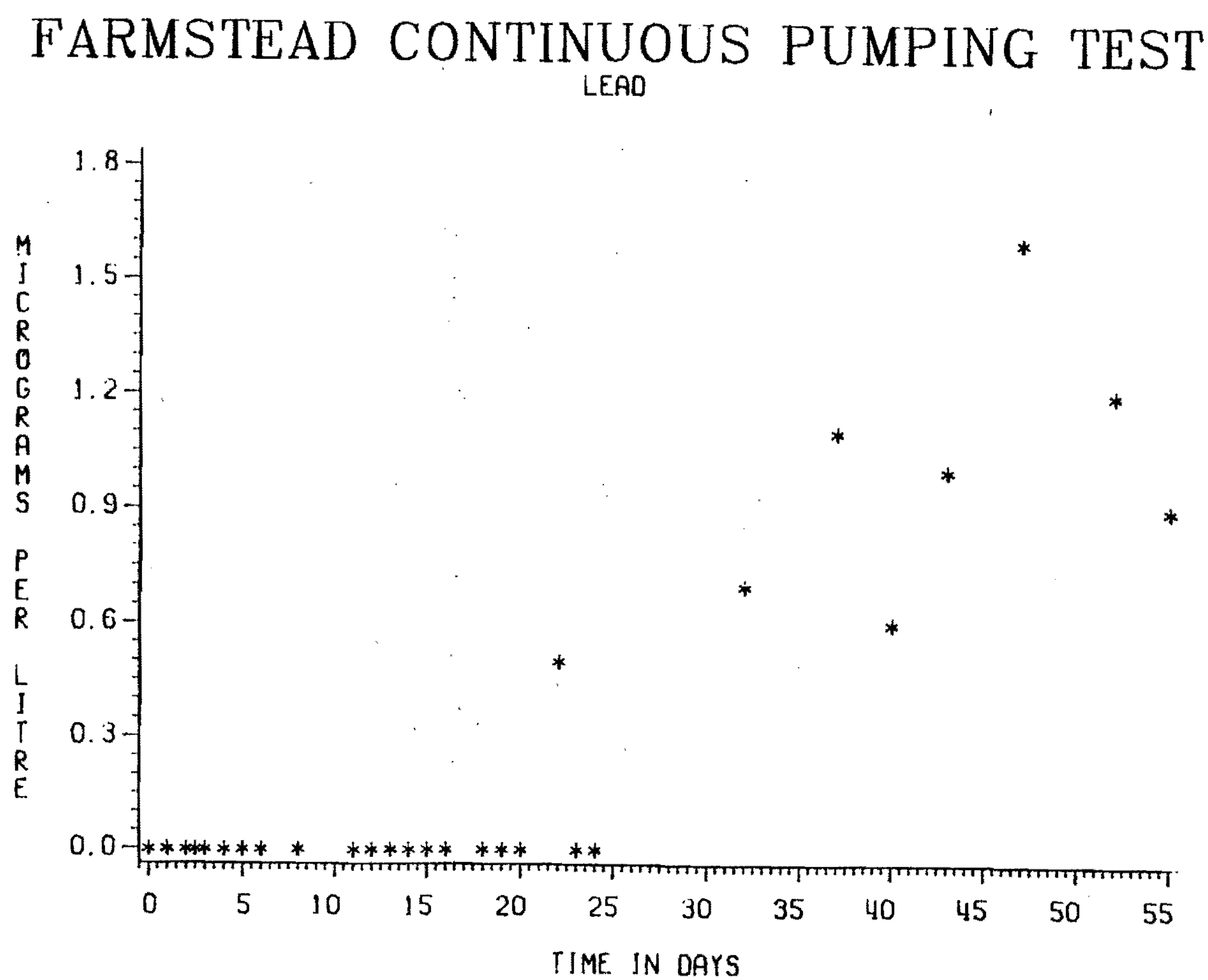
FARMSTEAD CONTINUOUS PUMPING TEST

NITRATE



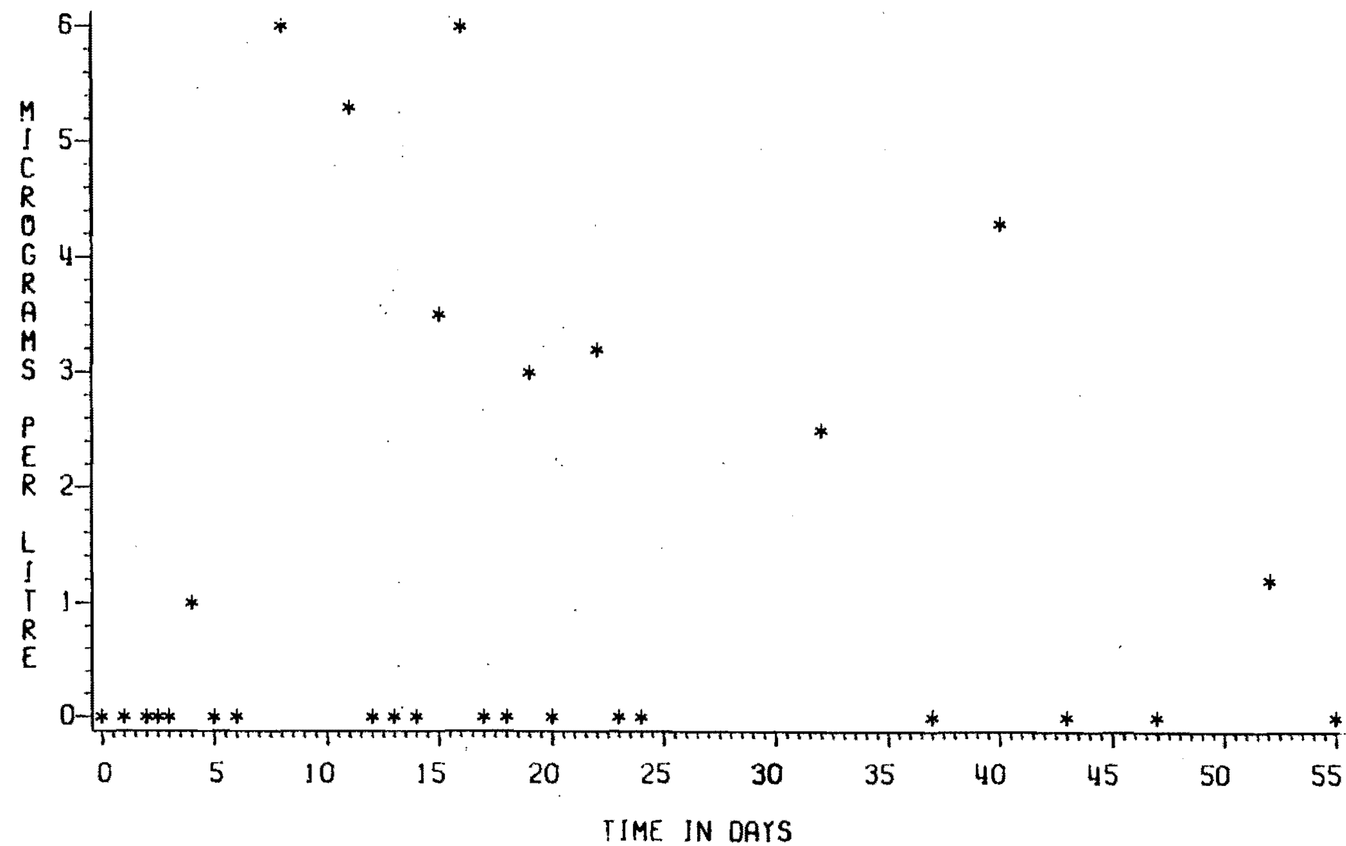


FARMSTEAD CONTINUOUS PUMPING TEST
ZINC
MICROGRAMS PER LITRE
1500
1250
1000
750
500
250
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70
TIME IN DAYS

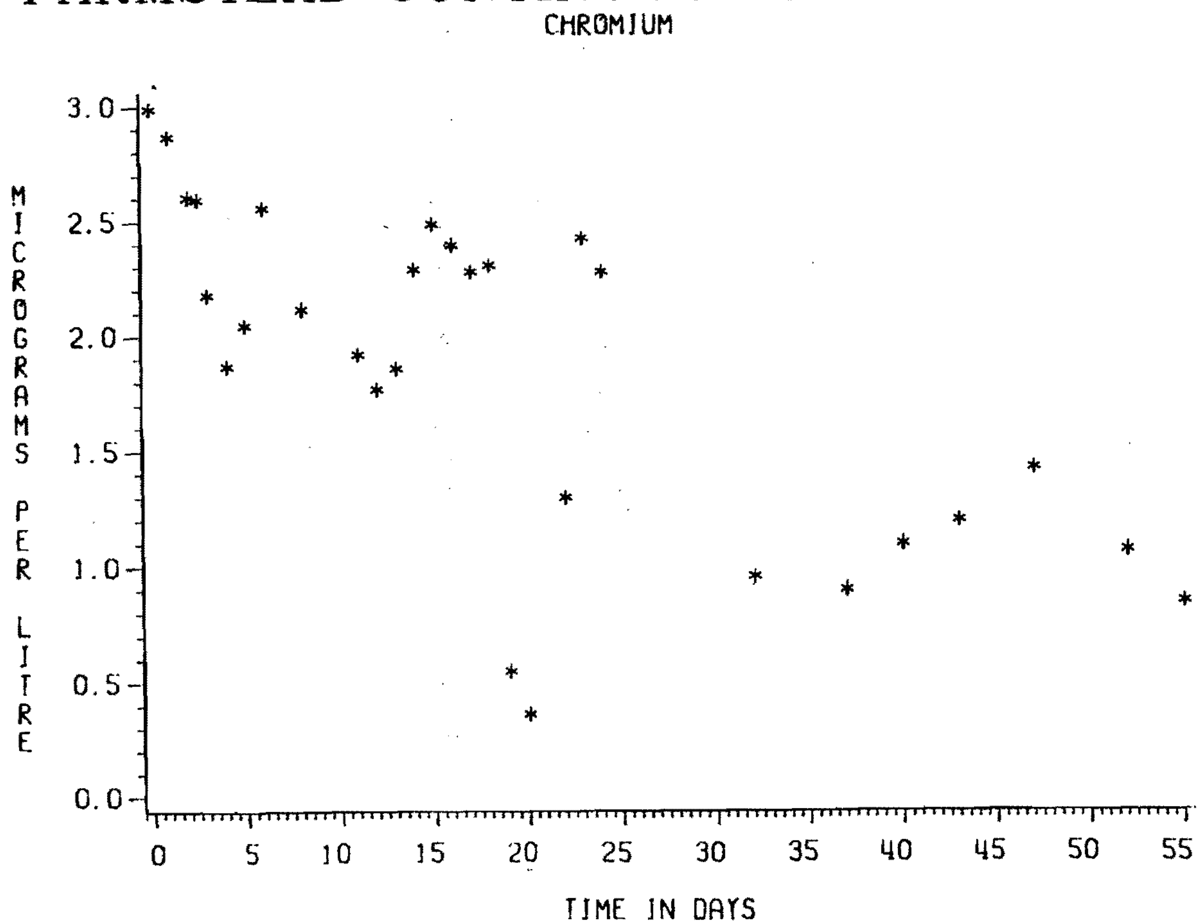

FARMSTEAD CONTINUOUS PUMPING TEST
LEAD
MICROGRAMS PER LITRE
1.8
1.5
1.2
0.9
0.6
0.3
0.0
0
5
10
15
20
25
30
35
40
45
50
55
TIME IN DAYS

FARMSTEAD CONTINUOUS PUMPING TEST

ARSENIC



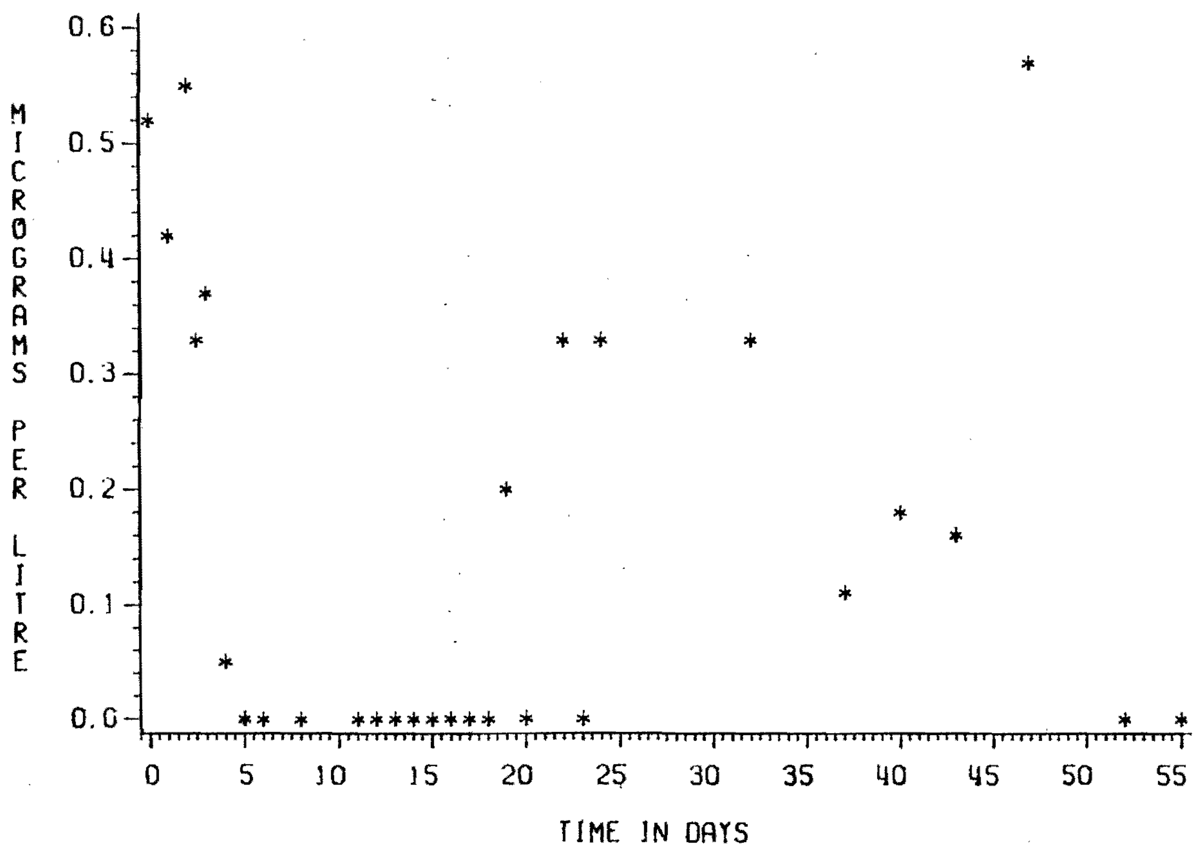
FARMSTEAD CONTINUOUS PUMPING TEST



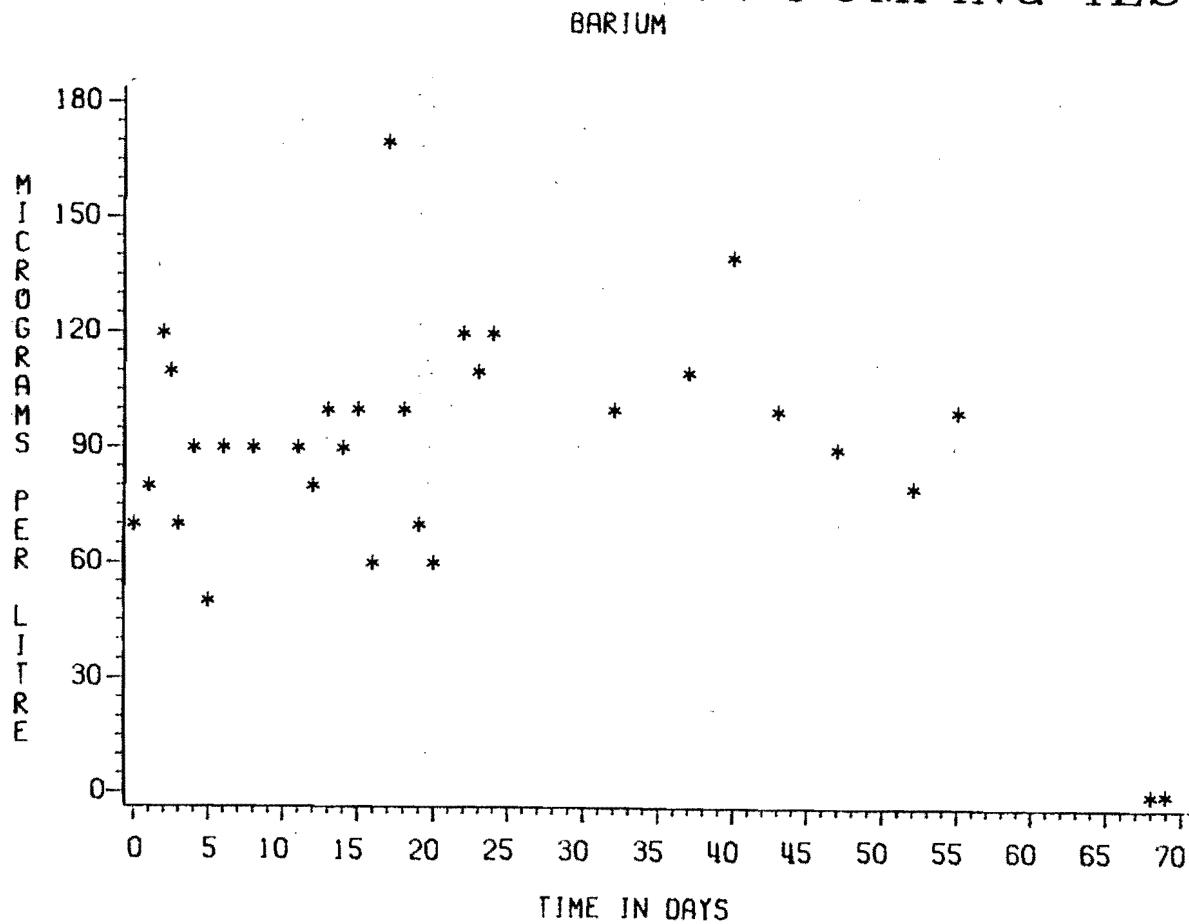
384

FARMSTEAD CONTINUOUS PUMPING TEST

CADMIUM

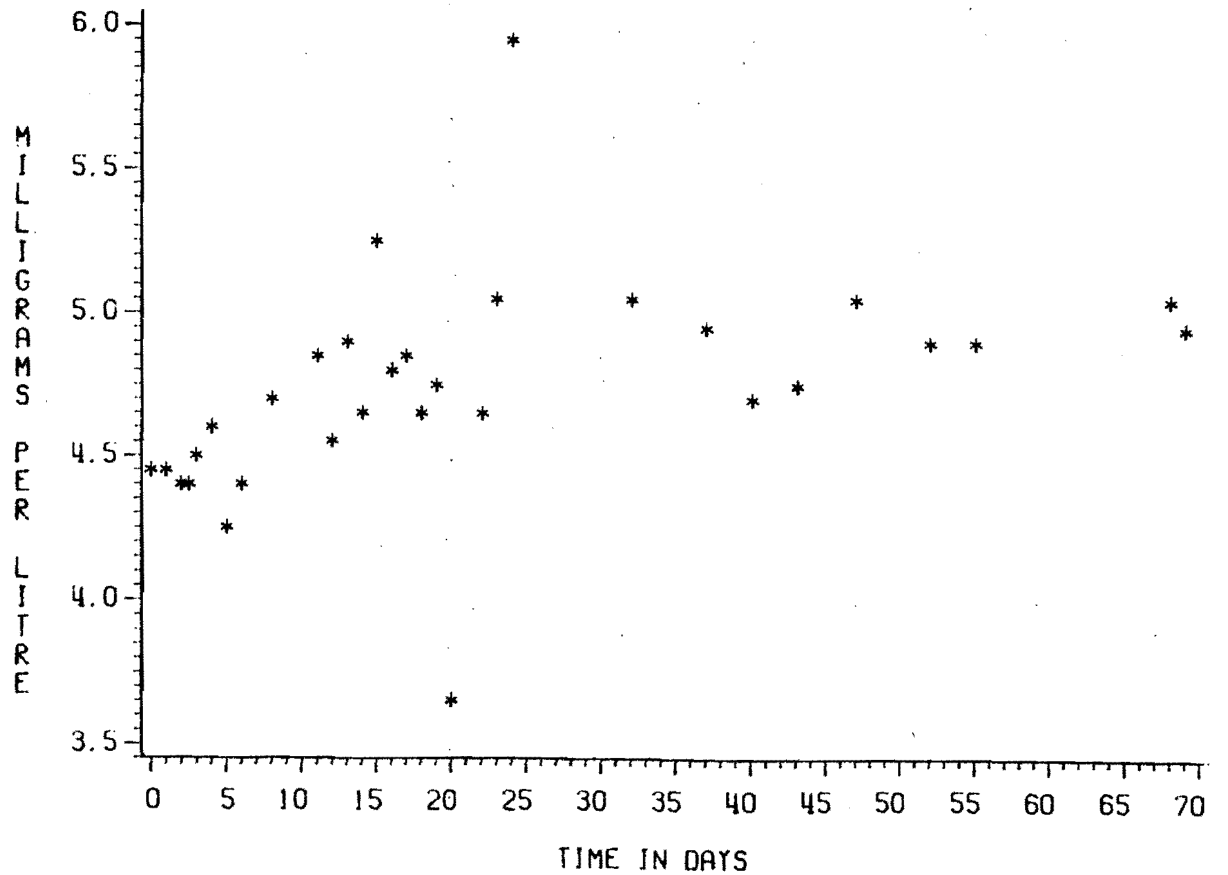


FARMSTEAD CONTINUOUS PUMPING TEST



FARMSTEAD CONTINUOUS PUMPING TEST

POTASSIUM

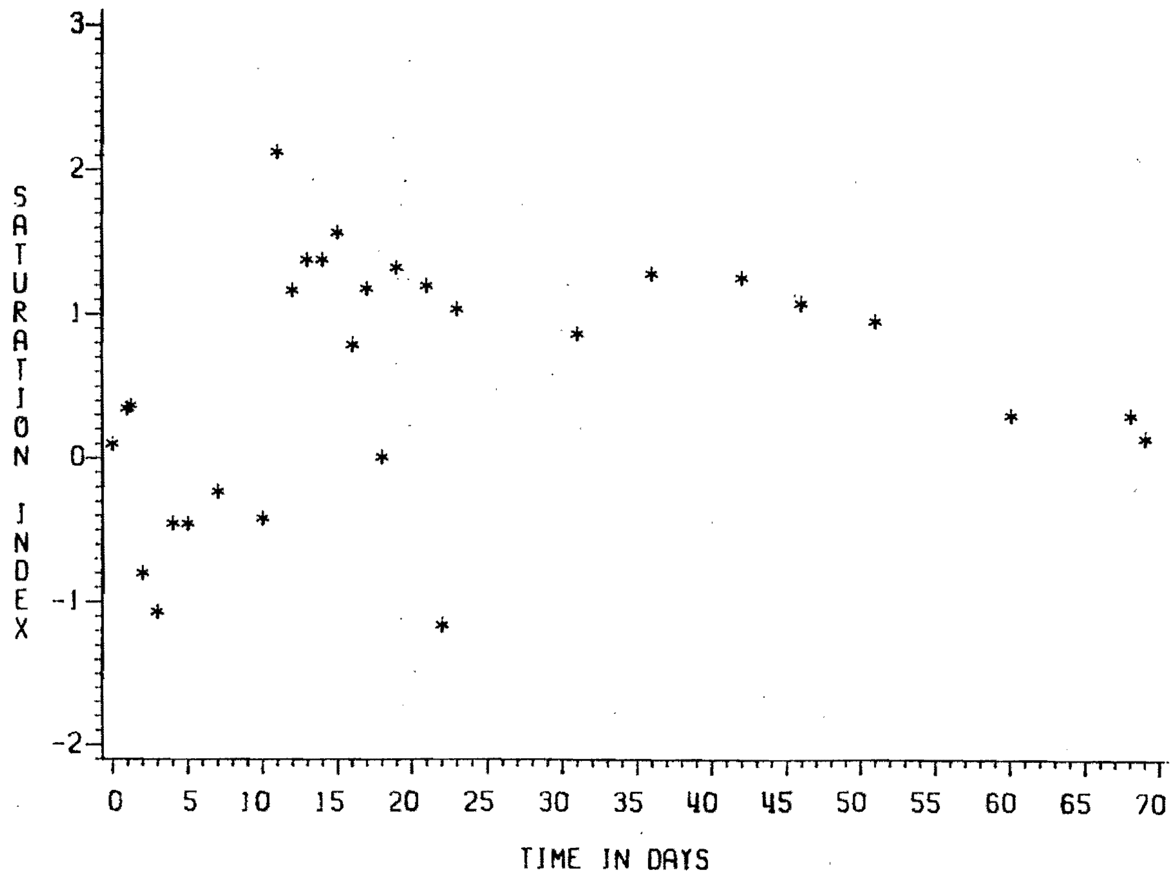


Appendix J

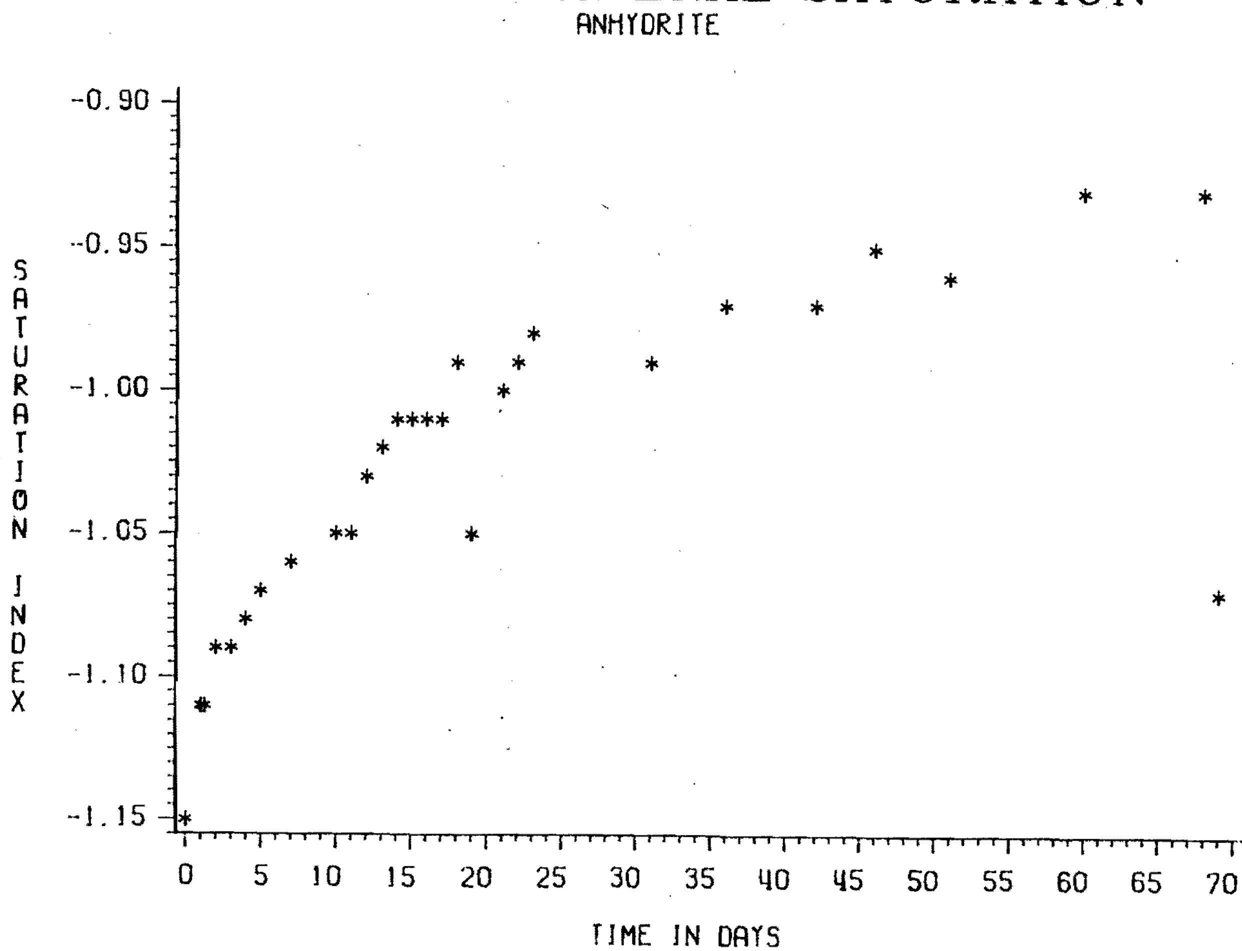
FARMSTEAD MINERAL SATURATION DATA

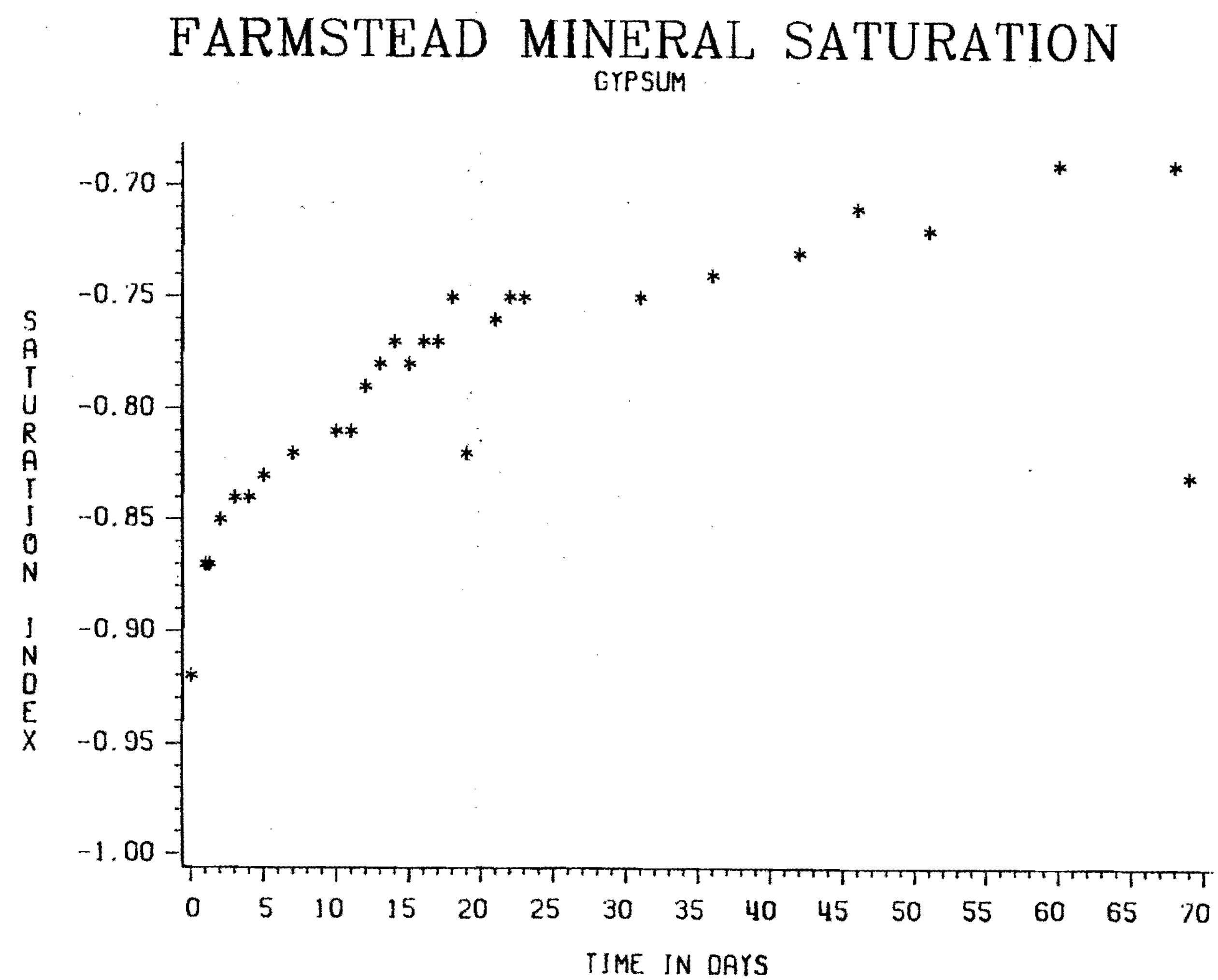
FARMSTEAD MINERAL SATURATION

DOLOMITE

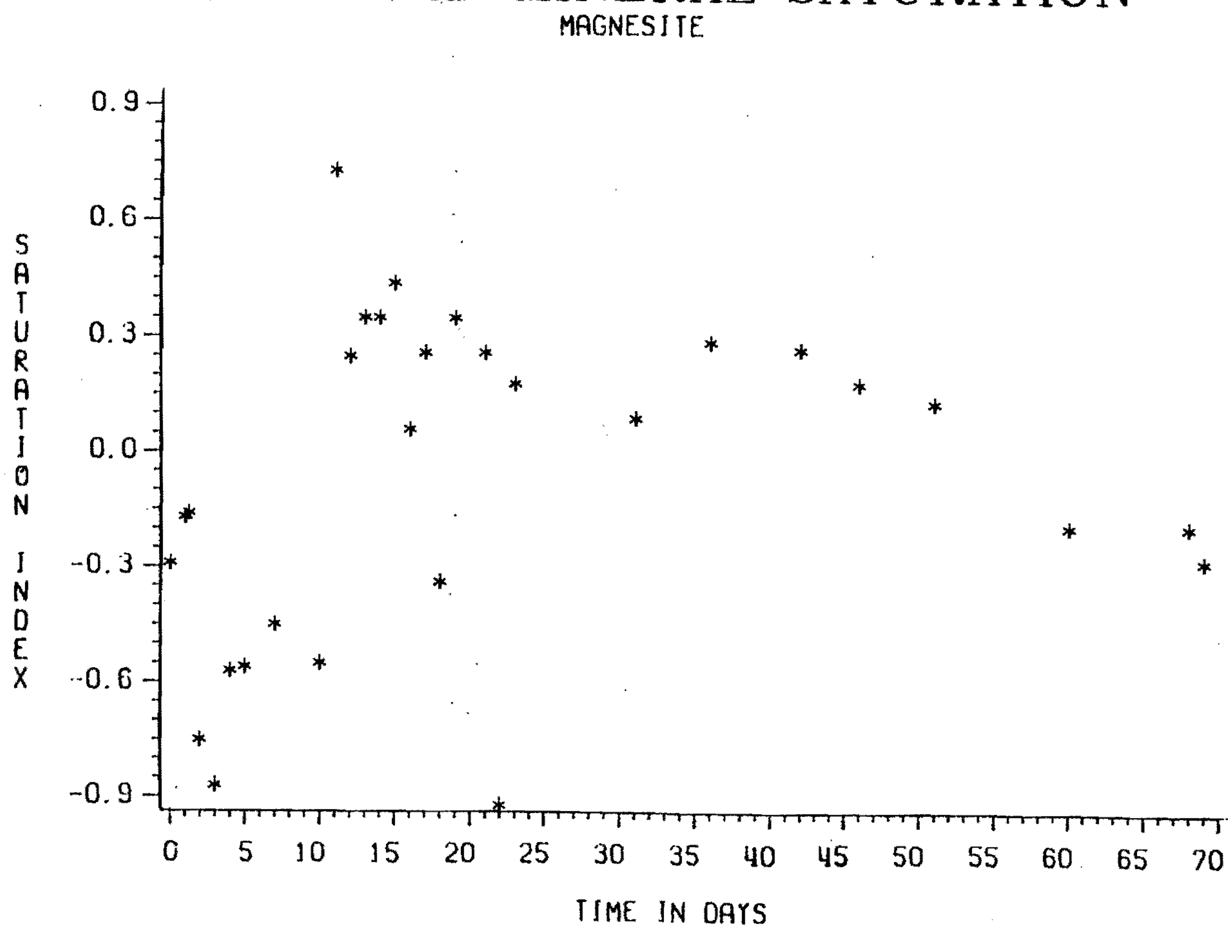


FARMSTEAD MINERAL SATURATION

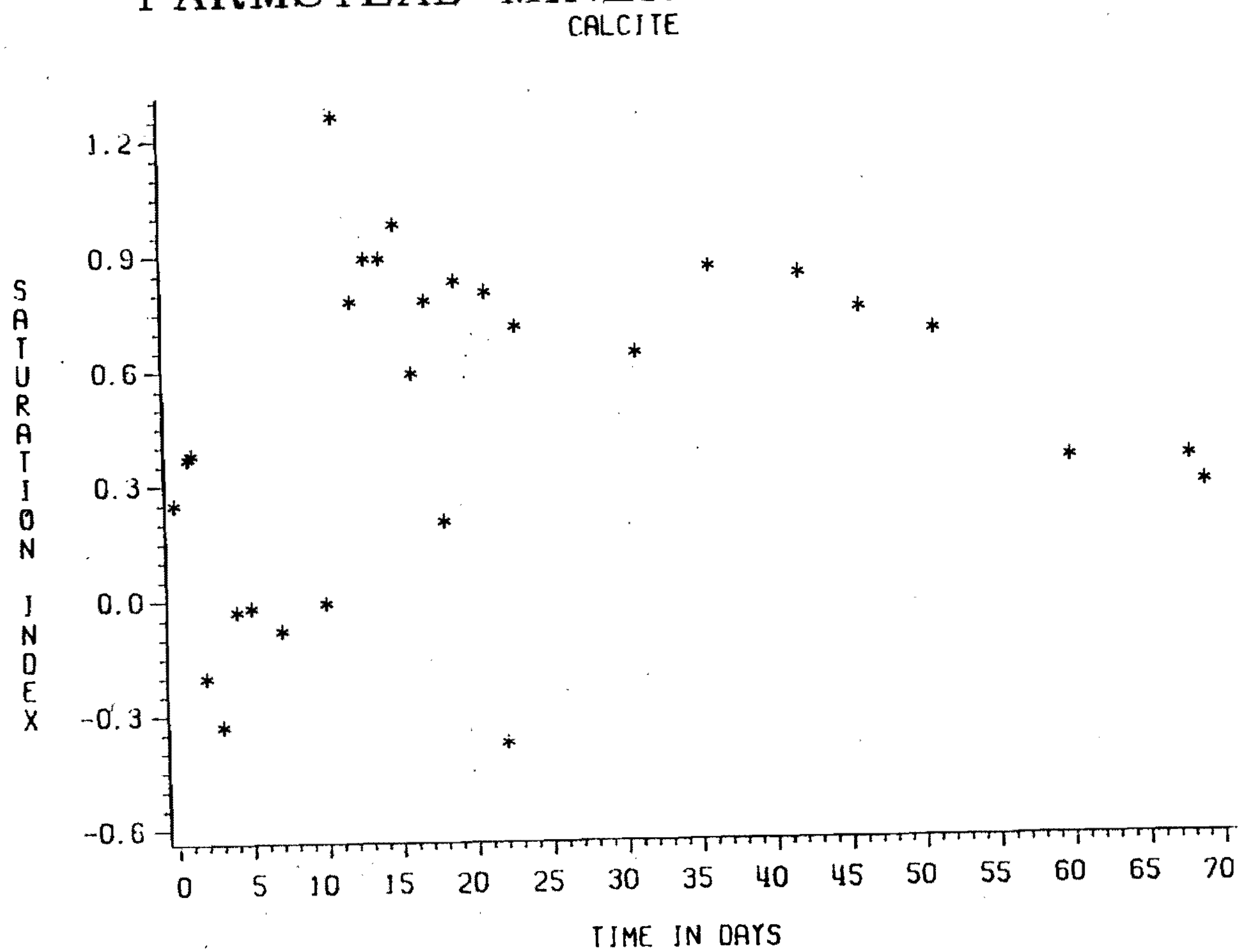



FARMSTEAD MINERAL SATURATION
GYPSUM
-0.70
-0.75
-0.80
-0.85
-0.90
-0.95
-1.00
SATURATION INDEX
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
TIME IN DAYS

FARMSTEAD MINERAL SATURATION

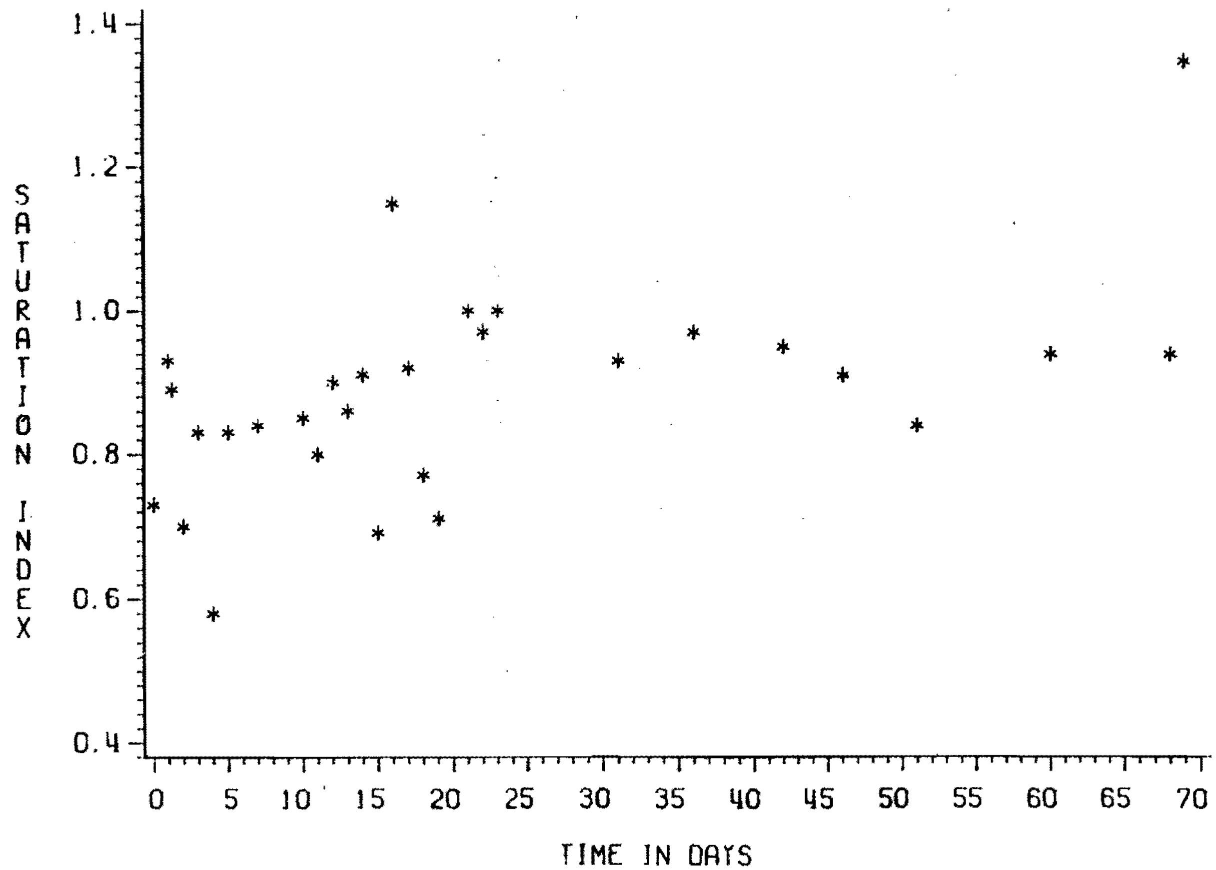


FARMSTEAD MINERAL SATURATION

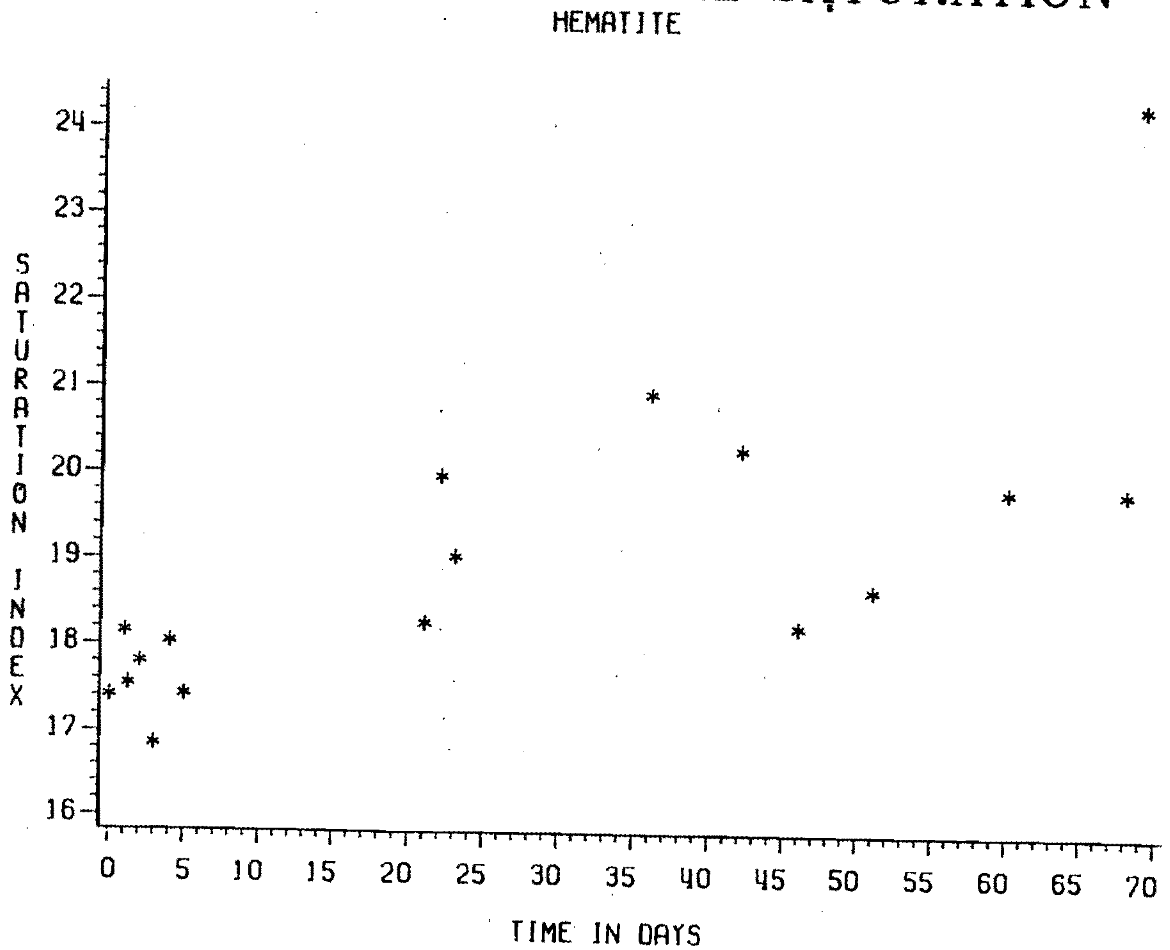


FARMSTEAD MINERAL SATURATION

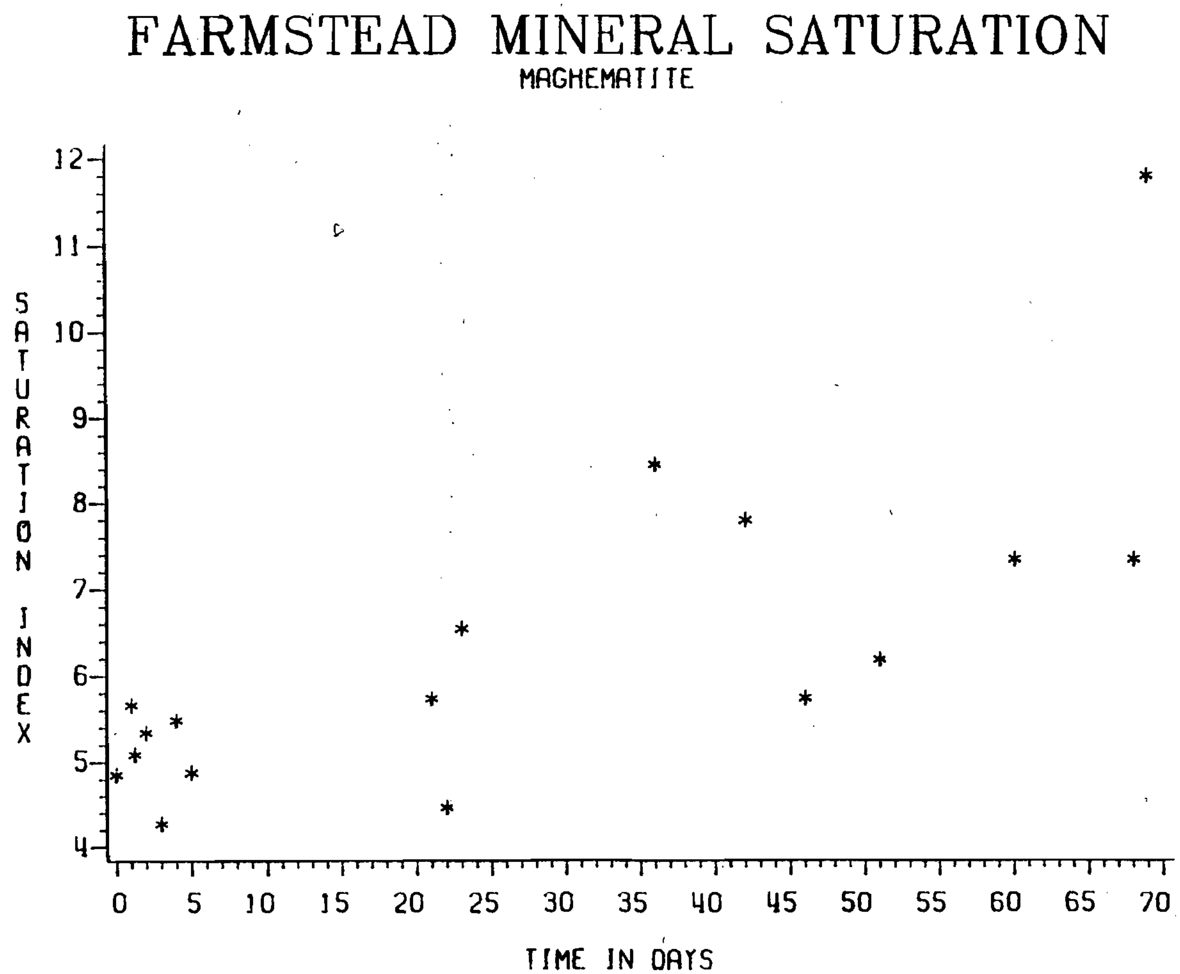
BARITE



FARMSTEAD MINERAL SATURATION



395


FARMSTEAD MINERAL SATURATION
MAGHEMATITE
SATURATION INDEX
TIME IN DAYS
12
11
10
9
8
7
6
5
4
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70

Appendix K

FIELD CHEMISTRY DATA

WELL NUMBER	TIME	DATE	TEMPERATURE degrees C.	pH	CONDUCTIVITY umhos/m
NEC50C		8-26-83	14.3	7.6	
NEC50S		8-26-83	10.	7.3	
NEC50WT		8-26-83	8.8	7.3	
CPW	1800	8-26-83	9.8	7.2	
FS		8-27-83	16.	6.6	1200
NW1200S		8-27-83	8.5	7.3	775
NW1200C		8-27-83	8.8	7.3	750
NW600C		8-27-83	9.5	7.6	800
NW600S		8-27-83	9.5	7.7	840
NW250C		8-27-83	9.	8.	650
NW250S		8-27-83	9.3	8.	700
NW150C		8-27-83	8.6	8.2	700
NW150S		8-27-83	9.	8.2	725
NW90C		8-27-83	9.5	8.	1650
NW90S		8-27-83	9.5	7.8	700
NW50WT		8-27-83	10.	7.8	1725
NES1200C		8-27-83	9.8	7.6	800
NES1200S		8-27-83	9.3	7.7	760
NEC1200C		8-27-83	9.	7.6	690
NEC1200S		8-27-83	9.5	7.7	750
NES600C		8-27-83	10.	7.8	740
NES600S		8-27-83	9.	7.8	760
NEC650C		8-27-83	9.5	7.7	700
NEC650S		8-27-83	9.5	7.6	710
NES250C		8-28-83	8.5	6.3	625
NES250S		8-28-83	8.5	6.3	725
NEC300C		8-28-83	8.2	6.6	700
NEC300S		8-28-83	8.3	6.9	600
NEC200C		8-28-83	8.	6.7	700
NEC200S		8-28-83	9.2	6.9	650
NES150C		8-28-83	8.5	7.3	550
NES150S		8-28-83	8.	7.	750
NEC140C		8-28-83	8.5	7.	725
NEC140S		8-28-83	8.2	7.	760
NEC100C		8-28-83	8.7	7.	725
NEC100S		8-28-83	8.5	7.1	500
NEC100WT		8-28-83	9.	7.1	975
NES90C		8-28-83	9.	7.1	700
NES90S		8-28-83	9.	7.	700
NES50C		8-28-83	8.8	7.1	660
NES50S		8-28-83	9.5	7.1	700
NES50WT		8-28-83	9.	7.2	800
SPWC		8-28-83	9.5	7.3	700
NW50C		8-28-83	8.8	7.5	1175
NW50S		8-28-83	9.5	7.3	1600
FS	1400	8-28-83	8.5	7.7	1350
SPWC		7-24-83	9.5	7.2	65
NW50WT		7-24-83	11.5	7.2	157
NW50S		7-24-83	12.5	7.3	185
NW50C		7-24-83	9.	7.4	81

NW90S		7-24-83	9.2	7.3	74
NW90C		7-24-83	10.	7.2	133
NW150S		7-24-83	11.	7.4	70
NW150C		7-24-83	11.5	7.4	65
NW250S		7-24-83	10.5	7.5	70
NW250C		7-24-83	10.5	7.3	66
NW600S		7-24-83	9.5	7.4	75
NW600C		7-24-83	11.5	7.6	87
NW1200S		7-24-83	12.	7.4	79
NW1200C		7-24-83	10.	7.3	72
NES50C		7-24-83	10.	7.3	60
NES50S		7-24-83	9.	7.5	58
NES50WT		7-24-83	9.	7.4	74
NES90S		7-25-83	9.5	7.3	70
NES90C		7-25-83	9.5	7.3	60
NES150S		7-25-83	10.5	7.4	73
NES150C		7-25-83	12.5	7.4	53
NES250S		7-25-83	11.	7.3	69
NES250C		7-25-83	10.	7.7	48
NES600C		7-25-83	10.	7.7	70
NES600C		7-25-83	10.5	7.3	62
NES1200S		7-25-83	14.	7.2	65
NES1200C		7-25-83	10.5	7.2	67
CPW		7-26-83	9.5	7.4	63
NEC50C		7-26-83	9.5	8.3	28
NEC50S		7-26-83	9.3	7.5	88
NEC50WT		7-26-83	11.	7.3	102
NEC100C		7-26-83	9.5	7.3	66
NEC100S		7-26-83	9.2	7.9	51
NEC100WT		7-26-83	9.5	7.3	87
NEC140C		7-26-83	9.5	7.2	67
NEC140S		7-26-83	9.5	7.2	65
NEC200C		7-26-83	9.2	7.1	64
NEC200S		7-26-83	9.2	7.1	70
NEC300C		7-26-83	9.8	7.5	58
NEC300S		7-26-83	9.2	7.9	37
NEC650C		7-26-83	9.	7.2	56
NEC650S		7-26-83	9.2	7.2	73
NEC1200C		7-26-83	8.5	7.3	70
NEC1200S		7-26-83	9.	7.2	72
SPW		7-27-83	8.5	7.4	67
SPW		7-28-83	8.4	7.2	77
SPW		7-29-83	8.4	7.4	74
SPW		7-30-83	8.6	6.8	75
FS	1130	8-5-83	8.1	7.3	115
FS	1230	8-5-83	7.8	7.3	108
CPW		8-5-83	10.	7.3	60
FS	1144	8-6-83	8.5	7.4	115
FS	1905	8-6-83	8.8	7.4	120
CPW		8-6-83	11.	7.	68
CPW		8-7-83	10.7	6.8	67
FS	1730	8-7-83	8.8	6.8	115
CPW	1930	8-8-83	8.8	6.6	67
FS	1945	8-8-83	8.	6.7	118

CPW	2100	8-8-83	8.5	6.7	68
CPE	1030	8-9-83	9.5	6.9	68
CPW	1305	8-9-83	15	7.7	61
CPW	1335	8-9-83	11.5	7.6	67
FS	1355	8-9-83	8.	7.6	169
CPW	0950	8-10-83	10.8	7.1	68
FS	1030	8-10-83	8.2	7.	121
NEC50C		8-26-83	14.3	7.6	
NEC50S		8-26-83	10.	7.3	
NEC50WT		8-26-83	8.8	7.3	
CPW	1800	8-26-83	9.8	7.2	
FS		8-27-83	16	6.6	1200
NW1200S		8-27-83	8.5	7.3	775
NW1200C		8-27-83	8.8	7.3	750
NW600C		8-27-83	9.5	7.6	800
NW600S		8-27-83	9.5	7.7	740
NW250C		8-27-83	9.	8.	650
NW250S		8-27-83	9.3	8.	700
NW150C		8-27-83	8.6	8.2	700
NW150S		8-27-83	9.	8.2	725
NW90C		8-27-83	9.5	8.	1650
NW90S		8-27-83	9.5	7.8	700
NW50WT		8-27-83	10.	7.8	1725
NES1200C		8-27-83	9.8	7.6	800
NES1200S		8-27-83	9.3	7.7	760
NEC1200C		8-27-83	9.	7.6	690
NEC1200S		8-27-83	9.5	7.7	750
NES600C		8-27-83	10.	7.8	740
NES600S		8-27-83	9.	7.8	760
NEC650C		8-27-83	9.5	7.7	700
NEC650S		8-27-83	9.5	7.6	710
NES250C		8-28-83	8.5	6.3	625
NES250S		8-28-83	8.5	6.3	725
NEC300C		8-28-83	8.2	6.6	700
NEC300S		8-28-83	8.3	6.9	600
NEC200C		8-28-83	8.	6.7	700
NEC200S		8-28-83	9.2	6.9	650
NES150C		8-28-83	8.5	7.3	550
NES150S		8-28-83	8.	7.	550
NEC140C		8-28-83	8.5	7.	725
NEC140S		8-28-83	8.2	7.	760
NEC100C		8-28-83	8.7	7.	725
NEC100S		8-28-83	8.5	7.1	500
NEC100WT		8-28-83	9.	7.1	975
NES90C		8-28-83	9.	7.1	700
NES90S		8-28-83	9.	7.	700
NES50C		8-28-83	8.8	7.1	660
NES50S		8-28-83	9.5	7.1	700
NES50WT		8-28-83	9.	7.2	800
SPWC		8-28-83	9.5	7.3	700
NW50C		8-28-83	8.8	7.5	1175
NW50S		8-28-83	9.5	7.3	1600
FS	1400	8-28-83	8.5	7.7	1350

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