EVALUATION OF SELECTED WELLS IN PENNSYLVANIA'S OBSERVATION-WELL PROGRAM AS OF 1993

by Randall W. Conger

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MULTIPLY	BY	TO OBTAIN
inch (in.)	25.40	millimeter
foot (ft)	0.3048	meter
gallon per minute (gal/min)	0.000063	cubic meter per second
gallon per minute per foot [(gal/min)/ft]	0.000207	cubic meter per second per meter
foot squared per day (ft^2/d)	0.0929	meter squared per day

Vertical datum: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Abbreviated water-quality units used in report:

micrograms per liter (µg/L)
microsiemens per centimeter at 25 degrees Celsius (µS/cm)
milligrams per liter (mg/L)

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ABSTRACT

In 1993, the U.S. Geological Survey operated 62 observation wells in 60 of Pennsylvania's 67 counties in cooperation with the Pennsylvania Department of Environmental Resources. These wells attempt to monitor an aerial extent of 45,000 square miles and penetrate 39 geologic formations or water-bearing units in 14 physiographic provinces. Some wells were drilled specifically for the observation-well program, some were drilled for other U.S. Geological Survey projects, and some were drilled for other purposes and were no longer used. Approximately 3 percent of the network wells have less than 5 years of record, 5 percent have 5 to 15 years of record, and 92 percent have greater than 15 years of record.

The older the observation well, the greater the possibility of water levels being affected by physical deterioration of the borehole. Therefore, it is necessary to periodically conduct a series of physical, chemical, and hydraulic tests to determine changes in the physical condition of the well and local land-use practices that may affect water-level response.

Nineteen wells were selected for evaluation on the basis of past questionable water-level responses. These wells were evaluated for functionality by analyzing historical water-level fluctuations, geophysical logs, single-well aquifer tests, and water-quality analyses. These parameters indicated that well Je-23 (Jefferson County) is affected by coal-mine pumpage, well Bt-311 (Butler County) is periodically affected by strip mine activities, wells Gr-118 (Greene County) and Mc-110 (McKean County) exhibit unexplained fluctuations not desirable for an observation well, and 15 wells show no obvious problems or degradation that would affect their functionality to monitor natural water-level fluctuations.

INTRODUCTION

The water-level data have many uses, but they are primarily needed to manage ground-water resources during periods of normal precipitation and drought. A primary objective of the observation-well program is to provide data to evaluate the effects of droughts on ground-water resources statewide. This objective can be achieved only with long-term water-level data from a regional network of observation wells. Because the physical condition of a well and surrounding land use can change over time, the well hydraulics and site conditions need periodic testing to insure valid long-term data.

The physical properties of a well and chemical characteristics of the water can be compared with previous measurements to detect changes in the well's function over the period of record. Degradation of the casing and open borehole or changes in land use of the surrounding area may affect the water-level response in the well. Detection of these changes could indicate a loss of observation-well functionality and data reliability and is the primary focus of this investigation.

PURPOSE AND SCOPE

This report presents results of an evaluation of 19 selected observation wells in Pennsylvania to verify the reliability of long-term, ground-water-level data. These wells were selected because of past unusual or questionable water-level responses. A series of tests were performed on the wells in 1992 to compare the physical properties of each well site and chemical characteristics of water from each well to previous measurements of these characteristics. These tests evaluate anomalies in available data that could indicate a deterioration of observation-well functionality. After the analysis of data for each well, an evaluation of its functionality is provided and needed improvements are discussed.

DESCRIPTION OF OBSERVATION-WELL PROGRAM

Currently (1993), the U.S. Geological Survey (USGS) operates 62 observation wells in 60 of Pennsylvania's 67 counties in cooperation with the Pennsylvania Department of Environmental Protection (fig. 1). Twenty wells are in the Ohio River Basin, 24 are in the Susquehanna River Basin, 15 are in the Delaware River Basin, and 1 is in the Potomac River Basin. The wells penetrate 39 geologic formations in 14 physiographic provinces. Some wells were drilled specifically for the observation-well program, some were drilled for other USGS projects, and some were drilled for other uses and were abandoned. The observation wells monitor water-level fluctuations that represent ground-water conditions throughout an area of 45,000 mi^2. The well-numbering system used by the USGS consists of a two-letter county abbreviation followed by a sequential number.

DELAWARE RIVER BASIN

The Delaware River Basin currently (1993) has 17 wells that penetrate 12 different geologic formations in 15 counties. Lackawanna County is the only county without a well in the program; most of the county is within the Susquehanna River Basin. Bucks, Delaware, and Montgomery Counties each have two wells. Satellite data-collection platforms (DCP's) are used to record water-level data at 12 wells, automated digital recorders (ADR's) are used at 5 wells, and 1 well has water levels measured manually once a day (table 1).

Periods of water-level record for wells in the Delaware River Basin range from 6 to 43 years. One well has 11 years of record, four wells have 10 to 20 years of record, seven wells have 20 to 30 years of record, and four wells have 30 to 40 years of record.

SUSQUEHANNA RIVER AND POTOMAC RIVER BASINS

The Susquehanna River Basin currently (1993) has 24 wells that penetrate 14 geologic formations in 24 counties. Columbia, Montour, and Northumberland Counties currently do not have observation wells. DCP's with ADR's as backups are installed on six wells. One well has an ADR. The remaining 16 wells have graphic recorders (table 1). The Franklin County observation well (Fr-322) is located in the Potomac River Basin has a DCP installed with an ADR backup.

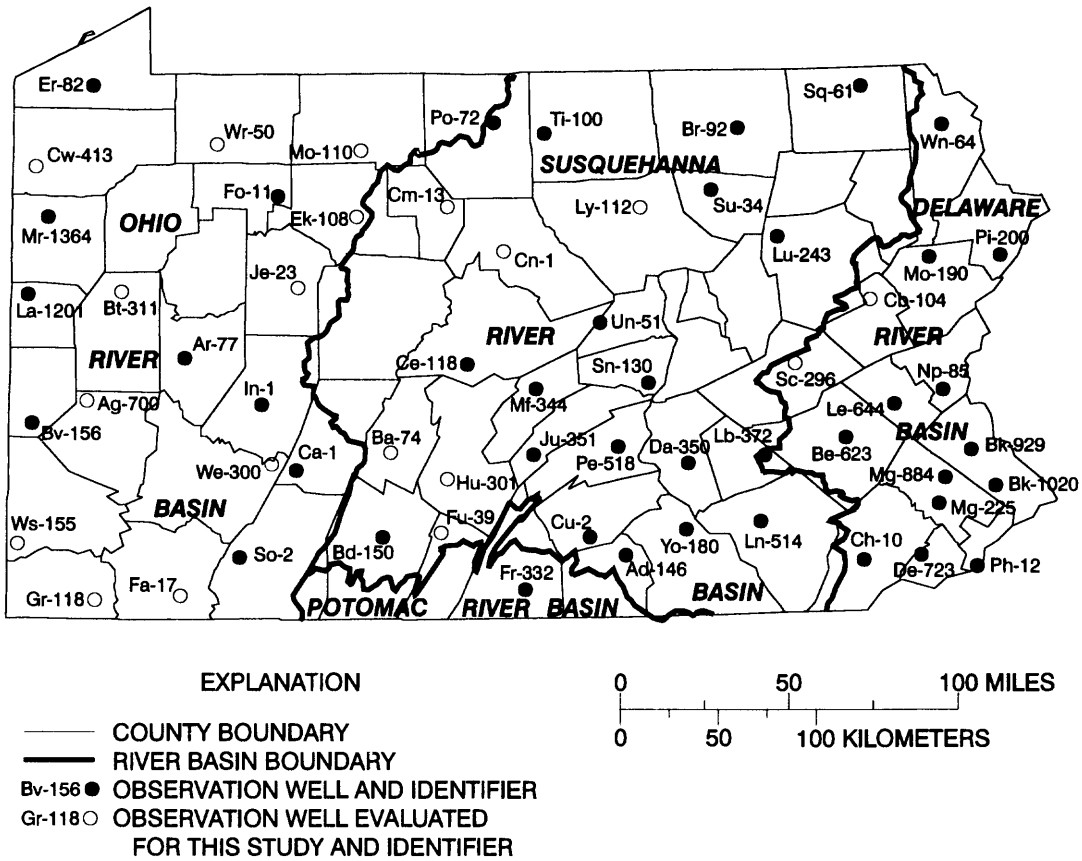

Figure 1. Approximate 1993 observation-well locations.

Periods of water-level record for wells in the Susquehanna River Basin range from 11 to 44 years. One well has 11 years of record, 1 well has 19 years of record, 5 wells have 20 to 25 years of record, 13 wells have 25 to 30 years of record, and 4 wells have greater than 30 years of record. Fr-322 has 19 years of record.

OHIO RIVER BASIN

The Ohio River Basin currently (1993) has 20 wells that penetrate 12 geologic formations in 20 counties. Clarion, Clearfield, and Venango Counties currently do not have observation wells. Thirteen wells have graphic recorders, three have ADR's, three have DCP's, and one well has water levels measured manually once a week (table 1).

Periods of water-level record for wells in the Ohio River Basin range from 19 to 57 years. One well has 19 years of record, seven wells have 20 to 25 years of record, nine wells have 25 to 30 years of record, two wells have 40 to 50 years of record, and one well has 57 years of record.

PREVIOUS INVESTIGATIONS

The observation-well program has been described in two reports since its establishment in 1931. Poth (1963) reported on the uses of water-level measurements and discussed the observation wells used in the program. H.J. McCoy and others (U.S. Geological Survey, written commun., 1981) described the observation wells and made recommendations for changes in the program.

Table 1. *Description of selected observation-well records in Pennsylvania*

[ADR, automated digital recorder; DCP, data-collection platform; Graphic, Leupold Stevens type F recorder; Daily, measured manually once a day; Weekly, measured manually once a week; --, no data]

Local well number	Number of water-quality samples	Current type of record	Length of record (years)
	Delaware River Basin		
Be-623	0	DCP	20
Bk-929	1	ADR	25
Bk-1020	0	DCP	17
Cb-104	3	DCP	24
Ch-10	0	DCP	41
De-3	0	Daily	41
De-723	1	ADR	9
Lb-372	0	DCP	19
Le-644	5	DCP	21
Mg-225	0	ADR	36
Mg-884	0	DCP	20
Mo-190	1	DCP	25
Np-83	0	ADR	4
Ph-12	3	ADR	40
Pi-200	0	DCP	11
Sc-296	1	DCP	18
Wn-64	1	DCP	25
	Susquehanna and Potomac River Basin		
Ad-146	0	DCP	24
Ba-74	2	Graphic	24
Bd-150	0	Graphic	27
Br-92	0	Graphic	26
Ce-118	0	Graphic	21
Cm-13	3	DCP	26
Cn-1	2	ADR	42
Cu-2	0	Graphic	41
Da-350	0	DCP	28
Fr-332	0	DCP	17
Fu-93	3	Graphic	28
Hu-301	2	DCP	24
Ju-351	0	Graphic	24
Ln-514	0	Graphic	28
Lu-243	0	Graphic	39
Ly-112	2	Graphic	26
Mf-344	0	Graphic	9
Pe-518	0	Graphic	17
Po-72	0	Graphic	25
Sn-130	0	Graphic	24
Sq-61	0	Graphic	30
Su-34	0	DCP	27
Ti-100	0	Graphic	30
Un-51	0	DCP	25
Yo-180	0	Graphic	30

Table 1. Description of selected observation-well records in Pennsylvania—Continued

[ADR, automated digital recorder; DCP, data-collection platform; Graphic, Leupold Stevens type F recorder; Daily, measured manually once a day; Weekly, measured manually once a week; --, no data]

Local well number	Number of water-quality samples	Current type of record	Length of record (years)
	Ohio River Basin		
Ag-700	2	DCP	26
Ar-77	0	Graphic	17
Bv-156	0	ADR	25
Bt-311	2	Graphic	23
Ca-1	0	Weekly	41
Cw-413	1	Graphic	12
Ek-108	3	Graphic	18
Er-82	0	Graphic	26
Fa-17	2	Graphic	26
Fo-11	0	Graphic	19
Gr-118	4	ADR	20
In-1	0	Graphic	42
Je-23	6	Graphic	25
La-1201	0	DCP	25
Mc-110	5	Graphic	20
Mr-1364	0	Graphic	28
So-2	0	Graphic	54
We-300	2	Graphic	25
Ws-155	3	ADR	22
Wr-50	2	DCP	21

EVALUATION METHODS

The characteristics of each well were determined from historical water-level fluctuations, geophysical logs, single-well pump tests, and water-quality analyses. Comparisons of these measurements with data from previous years were made to detect changes in the characteristics of the well that could indicate a change in its ability to function as a representative observation well. Water-level fluctuations define the ability of a well to respond to recharge and discharge and can be used to quantify changes in ground-water storage. Direct observation and geophysical logs were used to evaluate the construction characteristics of a well. The water-level drawdown caused by test-pumping the well gives estimates of specific capacity and indicates if water-bearing zones have become clogged over time. Water-quality samples were collected and analyzed for future reference.

WATER-LEVEL MEASUREMENTS

Visual evaluation of water-level hydrographs was used to identify changes in absolute water level as well as seasonal and other trends for each well. If ground-water levels deviate from established cycles for extended periods, a new stress on the local hydrologic system or physical change within the wellbore may be indicated. Some changes that may be evident from a hydrograph are periods of unusually low water levels or sudden fluctuations of water levels. A 31-day hydrograph covering approximately 15 days before and after pumping each well was evaluated to determine if water levels returned to previous trends or were otherwise affected by pumping. Long-term hydrograph data are derived from the lowest instantaneous water level (daily value) in a 24-hour day over the respective month.

GEOPHYSICAL LOGGING

Borehole-geophysical logs were collected at all selected wells. The logs may include caliper, natural gamma, single-point resistance, fluid resistance, fluid temperature, and fluid velocity (brine tracing). Borehole-geophysical logging is an effective and inexpensive way of defining a well's physical characteristics such as well depth, casing depth, fluid-producing or receiving zones, and lithology. The logs collected during this investigation were compared with previously collected logs and other data to evaluate changes in physical properties.

CALIPER LOG

Caliper logs provide a continuous record of average borehole diameter, which is related to fractures, lithology, and drilling technique. The tool is calibrated at land surface after each caliper log is run. Caliper logs are used to help correlate lithostratigraphy, identify fractures (changes in diameter) and possible fluid-bearing openings, and qualitatively correct other geophysical logs for changes in borehole diameter. Correlation of caliper logs with fluid-resistivity and fluid-temperature logs is used to identify fractures, fluid-producing zones, and fluid-receiving zones.

The term fracture used in association with the caliper-log interpretations might identify a change in borehole diameter that may not necessarily indicate a bedding-plane separation, lithologic contact, or fluid-producing or fluid-receiving zones but may simply indicate an enlargement of the borehole.

NATURAL-GAMMA LOG

The natural-gamma or gamma log is a record of the amount of natural-gamma radiation emitted by rock material surrounding a borehole as a function of depth. Most gamma radiation from earth materials is emitted by potassium-40 and daughter products of the uranium and thorium decay series. The gamma log can be recorded through casing, but the readings are dampened. Generally, clay and shale emit higher gamma radiation than sandstone or carbonate rock. The primary uses of gamma logs are correlation of rock units and general lithologic identification (Keys, 1988).

SINGLE-POINT-RESISTANCE LOG

Single-point-resistance logs record the electrical resistance between the borehole and an electrical ground at land surface. In general, resistance increases with grain size and decreases with borehole diameter, density of water-bearing fractures, and increasing dissolved-solids concentration of borehole fluid. A fluid-filled borehole is required for single-point-resistance logs, and they are run only for the saturated part of the formation below the casing. Single-point-resistance logs are used to correlate lithostratigraphy and may help to identify the location of water-bearing zones (Keys and MacCary, 1971).

FLUID-RESISTIVITY LOG

Fluid-resistivity logs measure the electrical resistance of fluid in the borehole. Fluid resistivity is the reciprocal of fluid conductivity. Fluid-resistivity logs reflect changes in the dissolved-solids concentration of the borehole fluid. Fluid-resistivity logs are used to identify water-producing and water-receiving zones and to determine intervals of vertical borehole flow. Water-producing and water-receiving zones usually are identified by sudden changes in resistivity, and intervals of borehole flow are identified by little or no resistivity gradient between water-producing and water-receiving zones.

FLUID-TEMPERATURE LOG

Fluid-temperature logs provide a continuous record of the temperature of the fluid in the borehole. Temperature logs are used to identify water-producing and water-receiving zones and to determine intervals of vertical borehole flow. Intervals of vertical borehole flow are identified by little or no temperature gradient (Williams and Conger, 1990).

BRINE-TRACE LOG

A brine-trace log measures the direction and amount of vertical flow in a borehole and helps identify fractures where fluid enters and exits the borehole. Vertical-borehole flow is measured by using the fluid-resistivity probe to monitor the movement of a brine slug (low resistance) injected at predetermined depth (Patten and Bennett, 1962).

SINGLE-WELL AQUIFER ANALYSIS

Each well was pumped for 1 hour or less at a discharge rate similar to the previous test conducted for that respective well. During and after pumping each well, water-level drawdown and recovery data were collected, and the drawdown data were used to calculate specific capacity of the well (table 2) (Driscoll, 1987).

ANALYSIS OF WATER-QUALITY DATA

The selected wells were pumped in order to purge the borehole and ensure that water representative of the aquifer was sampled. Three borehole volumes of water were typically pumped while specific conductance, pH, and temperature were monitored for stability. Samples were collected after these constituents stabilized, which indicates that the well was adequately purged. An unusual or gradual change in water quality in an observation well over time could be caused by changes in local land use or the physical deterioration of the casing or borehole. In order to determine if significant water-quality changes have occurred in an observation-well aquifer, analyses of the samples collected for this study were compared with previous analyses (tables 4-22).

Several possible problems arise when current water-quality data are compared to previous analyses. Proper purging, which would allow field constituents such as temperature, specific conductance, and pH to stabilize prior to sampling, may not have been conducted. Higher pumping rates produce more turbidity and larger particles; mineral particles such as clay have the ability to attach to dissolved metals in ground water, which would affect the analyses (Puls and Powell, 1992). Also, natural variability may cause the water quality to be different from one sampling date to another. Therefore, the concentrations of dissolved iron, aluminum, and manganese could vary even with similar sampling methods and conditions. Some chemical constituents, such as dissolved iron and dissolved manganese, can be altered simply by aeration (Stolzenburg and Nichols, 1985). Also, prior to 1975, not all samples collected were filtered if the discharge water was clear. Thus, analyses of some of the observation-well samples may report total concentrations rather than dissolved concentrations of constituents. Therefore, current data for iron and manganese may not be comparable to previous data.

Table 2. *Estimated specific capacity (after 1 hour) for selected Pennsylvania observation wells, from water-level drawdown and recovery data*

[(gal/min)/ft, gallons per minute per foot of drawdown; --, no data]

U.S. Geological Survey well number	Latitude	Longitude	Aquifer	Date	Depth to water below land surface	Specific capacity [(gal/min)/ft]	Total depth below land surface (feet)	Casing	
								Depth (feet)	Diameter (inches)
Ag-700	403734	800630	Glenshaw Formation	11/14/68		2.1	98	20	6
				04/10/92	6.51	2.3	100	20	6
Ba-74[1]	402452	782713	Brallier Formation	08/14/69		.07	150	20	6
				11/06/91	14.59	.07	148	14	6
Bt-311	410501	795244	Kittanning Formation	11/12/70		.5	--	10	6
				04/09/92	3.37	.3	87	10	6
Ca-1	401935	785506	Homewood S.S.	11/04/92	7.09	--	47.5	--	6
Cb-104	410123	754254	Mauch Chunk Formation	03/19/70		17	125	18.5	6
				12/05/91	53.42	17	120	18.5	6
Cm-13[1]	412732	780342	Catskill Formation	11/13/67		.31	101	53	6
				11/14/91	24.15	.23	101	53	6
Cn-1[1]	411424	774622	Huntley Formation	04/02/64		3.4	--	36	6
				11/15/91	53.96	3.2	75	36	6
Cw-413	413542	802450	Cussewago Formation	04/14/92	47.47	.5	97.5	19	6
Ek-108[1]	412458	783246	Pottsville group	04/09/74		5	--	--	--
				04/17/92	2.77	9.3	341.5	38	12
Fa-17	394843	793514	Glenshaw Formation	11/15/68		.3	100	19	6
				04/07/92	19.22	.3	99	19	6
Fu-93[1]	400302	780904	Pocono Formation	06/01/73		.9	198	45	6
				11/05/91	3.85	.8	191	45	6
Gr-118	394655	800143	Waynesburg Formation	07/11/73		2.7	--	20	6
				06/11/74		3.4	--	20	6
				04/08/92	29.35	10.5	103	20	6
Hu-301[1]	401843	780754	Pocono Formation	10/29/91	54.50	1.5	103	18	6
Je-23	410650	785758	Kittanning Formation	05/22/68		.5	--	33	6
				04/13/92	26.45	.2	100	33	6
Ly-112[1]	412427	765944	Catskill Formation	11/17/71		.1	200	19	6
				11/13/91	94.08	.14	200	19	6
Mc-110[1]	413852	783414	Pottsville Formation	10/24/73		.8	--	26	6
				04/16/92	27.49	.7	104	26	6
Sc-296[1]	404708	760707	Mauch Chunk Formation	11/21/91	51.29	.1	239	39	6
We-300[1]	402138	790318	Clarion Formation	04/06/92	14.52	.3	110	22	6
Wr-50	414159	792136	Venango Formation	04/15/92	42.21	.9	103	44	6
Ws-155	400233	802613	Washington Formation	07/01/71		.6	--	19	6
				04/09/92	35.65	.4	135	19	6

[1] Well pumped less than 1 hour.

EVALUATION OF SELECTED OBSERVATION WELLS

ALLEGHENY COUNTY OBSERVATION WELL (AG-700)

Historical water-level fluctuations.—Water-level data for the period of record indicate seasonal fluctuations and a minor upward trend (fig. 2).

Geophysical logging.—Borehole-geophysical data show the total depth of the borehole is 98 ft bls (feet below land surface) and that it is cased with 6-in. diameter casing to 20 ft bls. Several small fractures are seen on the caliper log between 20 and 70 ft bls; a single large fracture is located at 38 ft (fig. 3). The fluid-resistivity, fluid-temperature, and brine-trace logs show that under ambient conditions, 0.4 gal/min of water is produced through a fracture at 38 ft bls, moves vertically downward, and exits the borehole through a fracture at 86 ft bls.

Single-well pumping analysis.—A single-well aquifer test was conducted by pumping well Ag-700 for 1 hour at a rate of 11.5 gal/min on April 10, 1992. Analysis of water-level-drawdown data indicates the specific capacity of the well is 2.3 (gal/min)/ft. This value corresponds closely with the previous aquifer test data from November 14, 1968, when specific capacity was 2.1 (gal/min)/ft. Static water level on April 10, 1992, returned to within 0.22 ft of the original level within 1 hour after pumping stopped. No evidence of unusual or anomalous effects was produced by the well aquifer test.

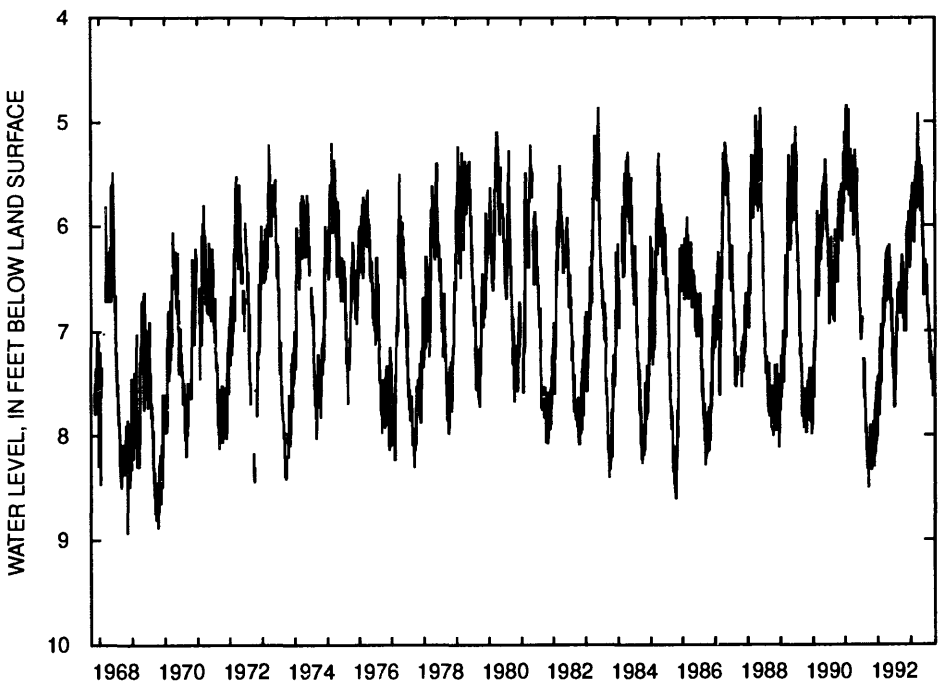

Figure 2. Hydrograph of Allegheny County observation well Ag-700 for period of record to September 30, 1993.

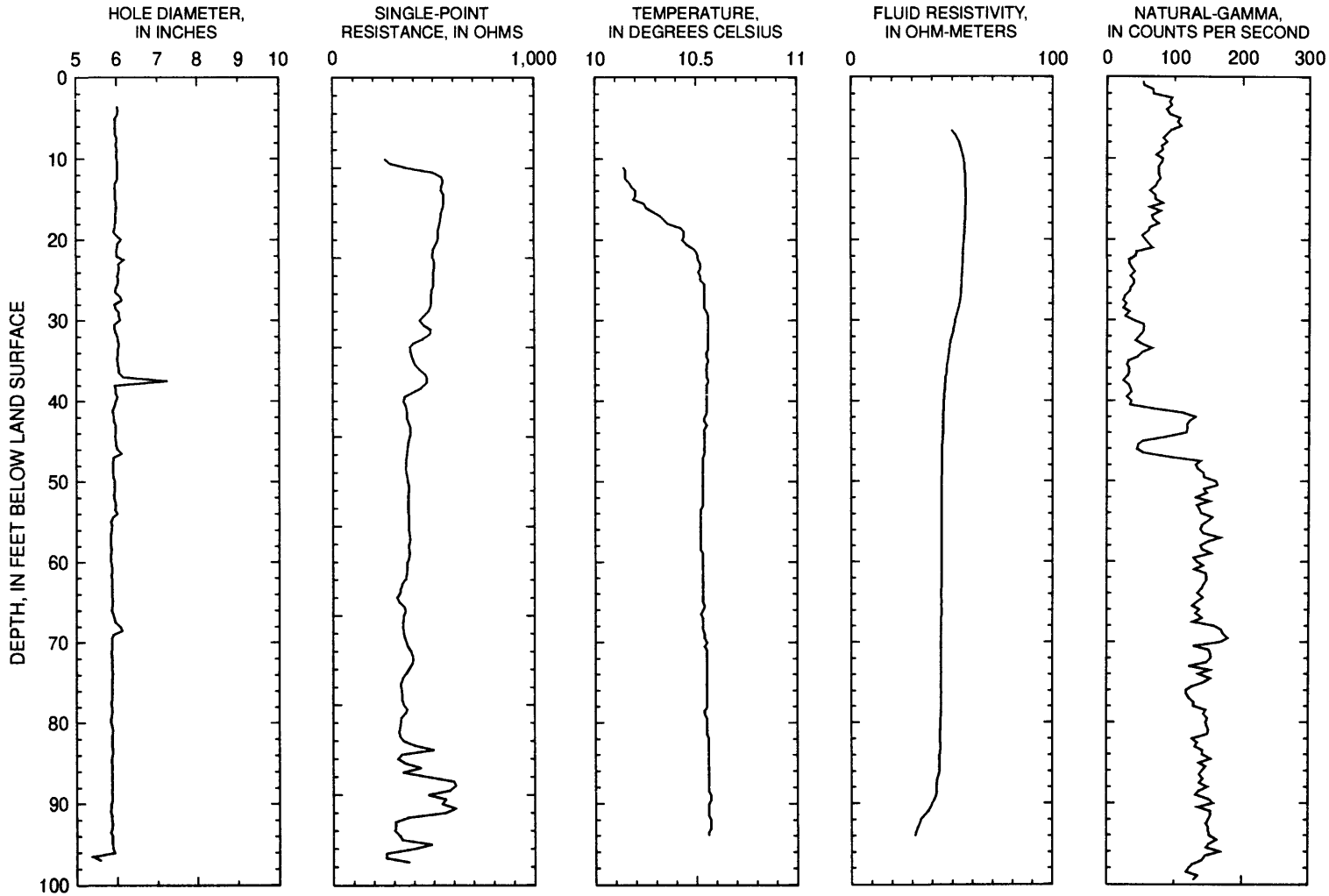

Figure 3. Geophysical logs for Allegheny County observation well Ag-700 collected on November 19, 1991.

Water-quality characteristics.—Concentrations of most constituents (for example, sodium, chloride, iron, and manganese) were lower on April 10, 1992 (improved), compared to November 14, 1968 (table 3). As a precautionary measure against iron clogging of water-bearing fractures, sufficient sodium hypochlorite was added to the well after testing to destroy any iron bacteria present in the borehole.

Evaluation.—Water-level fluctuations and specific capacity show slight variation from previous information. A noticeable reduction in several water-quality constituents may be attributed to different pumping and sampling techniques. Land use and geophysical, pumping, and water-level results are all similar to previous measurements and indicate little physical change has occurred. The well appears to be representative of the local aquifer conditions at its hilltop location.

Table 3. *Records of water quality for Allegheny County observation well Ag-700*

[All constituent concentrations are dissolved; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, no data]

Constituents	Date sample collected	
	Nov. 14, 1968	Apr. 10, 1992
Static water level	[1]8.94	[2]6.51
Specific conductance (µS/cm)	861	592
pH (standard units)	8.4	7.7
Water temperature (°C)	10	11.5
Dissolved oxygen (mg/L as O_2)	--	.5
Total hardness (mg/L as $CaCO_3$)	118	100
Noncarbonate hardness (mg/L as $CaCO_3$)	0	--
Calcium (mg/L as Ca)	24	26
Magnesium (mg/L as Mg)	14	8.4
Sodium (mg/L as Na)	120	88
Potassium (mg/L as K)	1	1.4
Alkalinity (mg/L as $CaCO_3$)	140	224
Sulfate (mg/L as SO_4)	4.8	2.3
Chloride (mg/L as Cl)	181	60
Fluoride (mg/L as F)	.3	.7
Silica (mg/L as SiO_2)	12	12
Dissolved solids, calculated, sum (mg/L)	442	334
Nitrogen, nitrite (mg/L as N)	--	.01
Nitrate plus nitrite (mg/L as N)	--	.05
Nitrogen ammonia (mg/L as N)	--	.01
Nitrogen, ammonia plus organic (mg/L as N)	--	.2
Phosphorus, ortho (mg/L as P)	0	.01
Aluminum (µg/L as Al)	--	20
Iron (µg/L as Fe)	1,100	330
Manganese (µg/L as Mn)	250	160
Zinc (µg/L as Zn)	--	10

[1] Daily value.
[2] Static water level before pumping.

BLAIR COUNTY OBSERVATION WELL (BA-74)

Historical water-level fluctuations.—Water-level data for the period of record reflect a continuous minor upward trend over the period of record from 1969 to 1990. The lack of recovery from the dry summer of 1991 can be seen on the hydrograph (fig. 4).

Geophysical logging.—Borehole-geophysical data show the total depth of the borehole has filled in from 150 to 148 ft bls and that the borehole is cased with 6.25-in. casing to 14 ft bls. The caliper log shows two fractures at 93 and 96 ft bls (fig. 5) and also shows little variation in borehole diameter with depth, indicating a competent geologic formation. The fluid-resistivity log shows a sharp decrease in resistivity (increase in dissolved solids) between 30 and 40 ft that correlates to a minor fracture on the caliper log, which may indicate a water-producing zone. The fluid-temperature log shows a change in fluid temperature at 49 and 93 ft bls that correlates to fractures on the caliper log, indicating possible water-producing zones. The fluid-temperature log shows a consistent geothermal gradient, indicating no vertical borehole flow.

Single-well pumping analysis.—A single-well aquifer test was conducted by pumping well Ba-74 for about 1/2-hour at a rate of 4.7 gal/min on November 19, 1991. The specific capacity was 0.07 (gal/min)/ft, exactly the same as that on August 14, 1969. The water level recovered in 10 days to within 0.25 ft of the original water level.

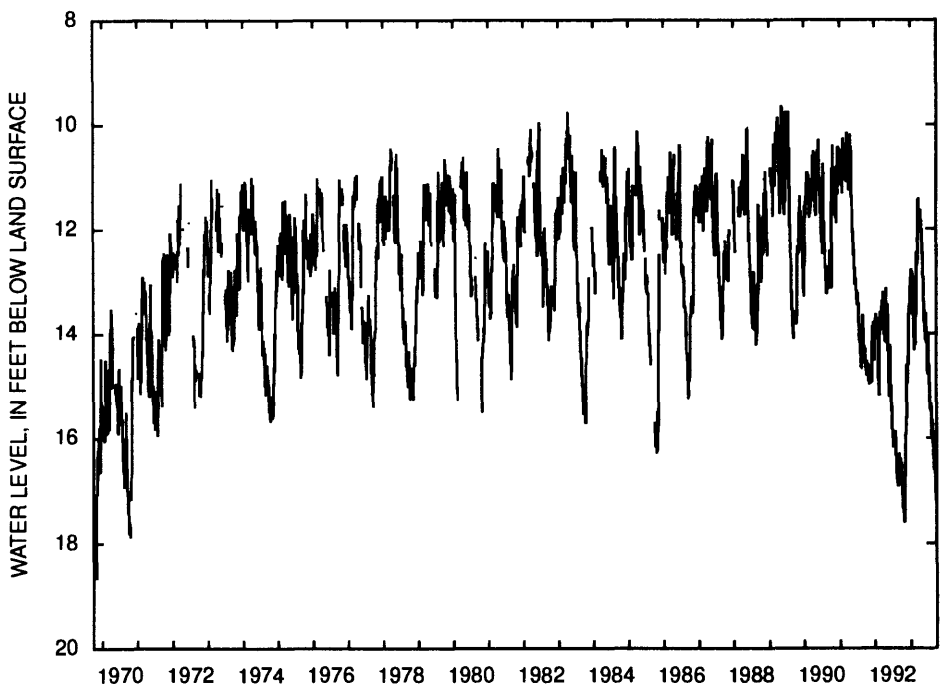

Figure 4. Hydrograph of Blair County observation well Ba-74 for period of record to September 30, 1993.

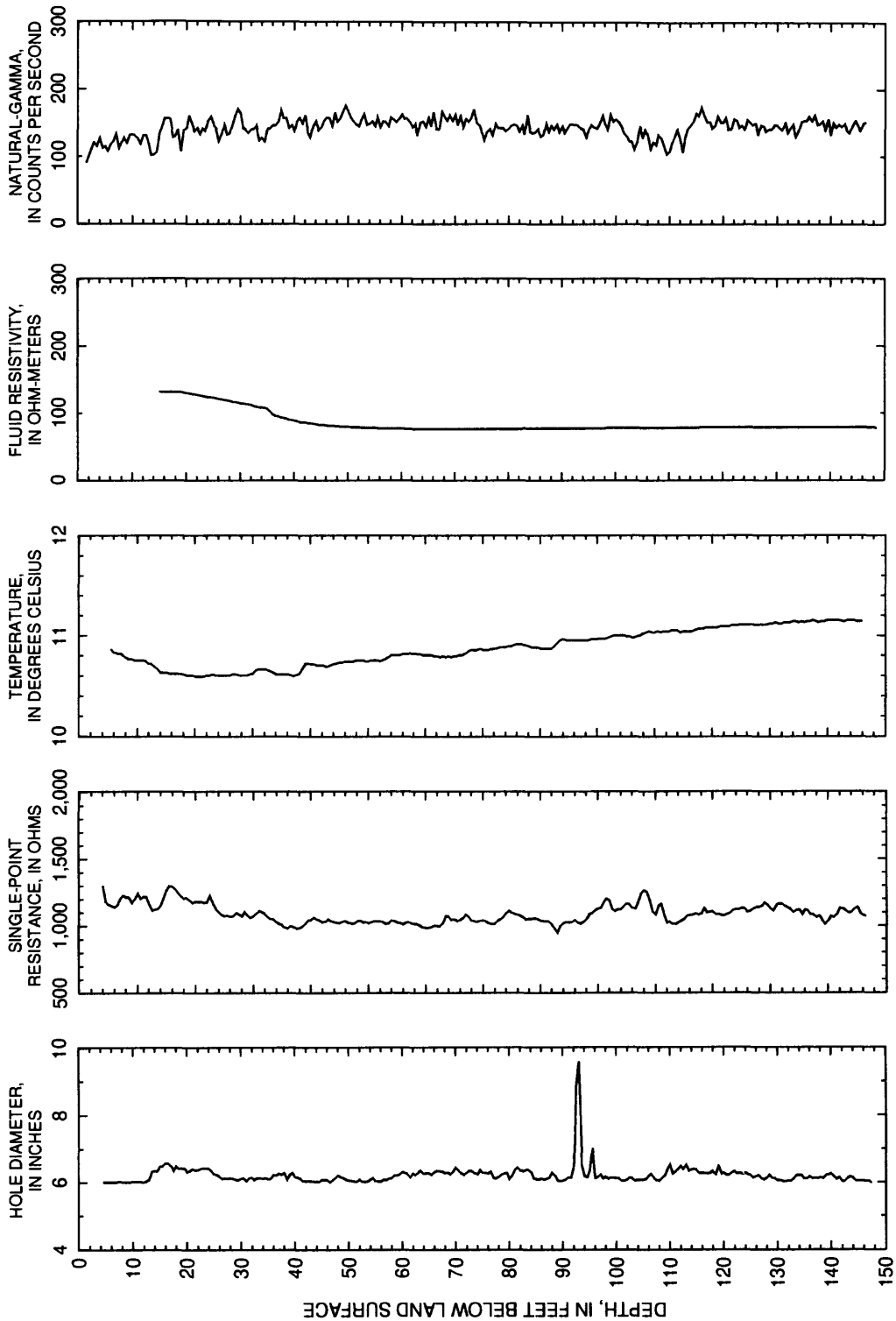

Figure 5. Geophysical logs for Blair County observation well Ba-74.

Water-quality characteristics.—The water-quality sample collected on November 19, 1991, showed a notable increase in concentrations of several constituents compared to data from August 13, 1969. Specific conductance, total hardness, and concentrations of calcium, dissolved solids, and dissolved iron approximately doubled, while concentrations of sulfate and manganese were six times original concentrations (table 4). The pump discharge rate during the aquifer test on November 19, 1991, was 4.7 gal/min compared to 2 gal/min on August 13, 1969. The difference in pumping rates increased turbidity, possibly producing more particles in the borehole, which elevated concentrations of dissolved solids and affected other concentrations (Puls and Powell, 1992). The increased pumping rate possibly withdrew water from different zones than the previous aquifer test, which resulted in different water chemistry.

Evaluation.—The specific capacity from the single-well pumping indicates the borehole is hydraulically tight. Therefore, a lag time between aquifer recharge and water-level changes in the well could occur. There is no apparent change in local land use.

Table 4. *Records of water quality for Blair County observation well Ba-74*

[All constituent concentrations are dissolved; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, no data]

Constituents	Date sample collected	
	Aug. 13, 1969	Nov. 19, 1991
Static water level	[1]16.71	[2]15.16
Specific conductance (µS/cm)	384	677
pH	8.3	7.6
Water temperature (°C)	--	10
Dissolved oxygen (mg/L as O_2)	--	3.2
Total hardness (mg/L as $CaCO_3$)	180	340
Noncarbonate hardness (mg/L as $CaCO_3$)	11	180
Calcium (mg/L as Ca)	44	110
Magnesium (mg/L as Mg)	17	16
Sodium (mg/L as Na)	18	1.9
Potassium (mg/L as K)	.7	1.4
Alkalinity (mg/L as $CaCO_3$)	170	160
Sulfate (mg/L as SO_4)	32	200
Chloride (mg/L as Cl)	3.9	5.7
Fluoride (mg/L as F)	.2	.2
Silica (mg/L as SiO_2)	15	6.9
Dissolved solids, calculated, sum (mg/L)	234	442
Nitrogen, nitrite (mg/L as N)	--	.01
Nitrate plus nitrite (mg/L as N)	--	.05
Nitrogen ammonia (mg/L as N)	--	.01
Nitrogen, ammonia plus organic (mg/L as N)	--	.2
Phosphorus, ortho (mg/L as P)	--	.01
Aluminum (µg/L as Al)	--	10
Iron (µg/L as Fe)	1,400	2, 500
Manganese (µg/L as Mn)	200	1, 200
Zinc (µg/L as Zn)	--	10

[1] Daily value.
[2] Static water level before pumping.

BUTLER COUNTY OBSERVATION WELL (BT-311)

Historical water-level fluctuations.—Ground-water levels for the period of record show fluctuations greater than 20 ft from June through December and then show an upward trend throughout winter and early summer that is related to ground-water pumping of a nearby strip mine. The hydrograph for the period of record shows increasing seasonal fluctuations with an overall upward trend (fig. 6).

Geophysical logging.—Borehole-geophysical data show the total depth of the borehole is 87 ft bls and that it is cased with 6-in. casing to 10 ft bls (fig. 7). The caliper log shows fractures at 11, 21, 44, 58, and 60 ft bls. The fracture at 44 ft bls corresponds to changes in slope on the gamma and single-point-resistance logs, indicating a lithologic contact. The fluid-temperature log indicates no vertical borehole flow (fig. 7).

Single-well pumping analysis.—A single-well aquifer test was conducted by pumping well Bt-311 for about 1 hour at a rate of approximately 12 gal/min on April 9, 1992. The specific capacity of the well was 0.3 (gal/min)/ft, very similar to 0.5 (gal/min)/ft calculated on November 11, 1970. The static water level took 9 days to recover to prepumping conditions.

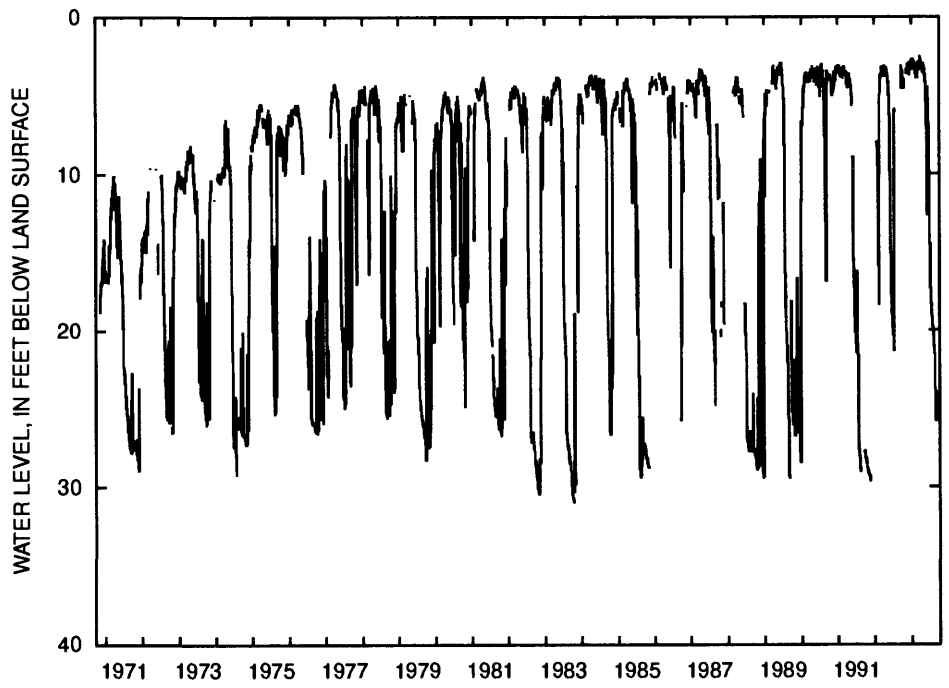

Figure 6. Hydrograph of Butler County observation well Bt-311 for period of record to September 30, 1993.

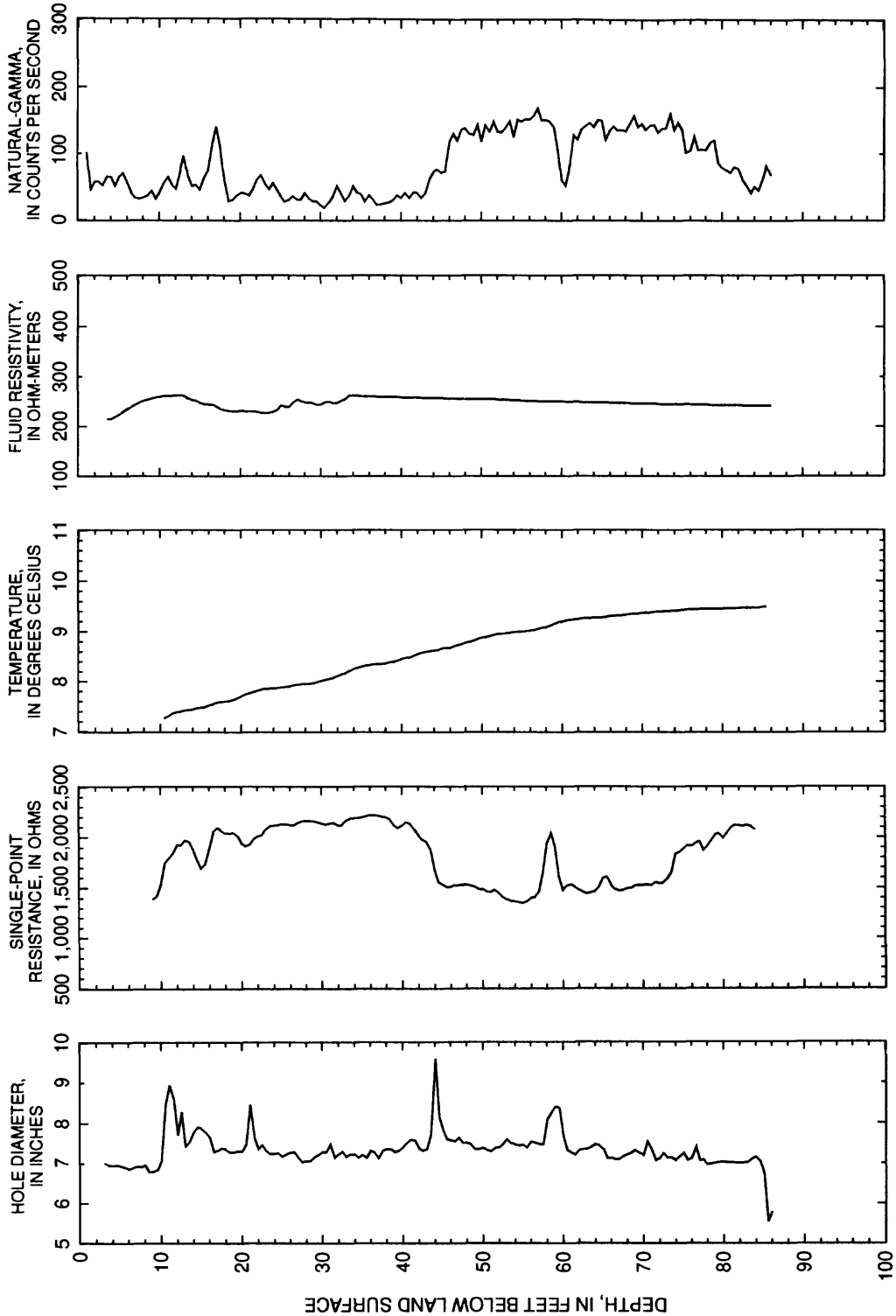

Figure 7. Geophysical logs for Butler County observation well Bt-311.

Water-quality characteristics.—The water quality of Bt-311 has improved for almost all constituents. Iron and manganese concentrations were greatly reduced since November 2, 1970 (table 5).

Evaluation.—Water-level fluctuations, which are superimposed on a gradual upward trend, show exaggerated seasonal variation of as much as 25 ft as a result of pumpage from local mine activities. Drawdown data show a low specific capacity, indicating a hydraulically tight aquifer. This data suggest well interference that affects water-level response. Thus, water-level fluctuations in this well are an unreliable indicator of aquifer response to climatic conditions.

Table 5. *Records of water quality for Butler County observation well Bt-311*

[All constituent concentrations are dissolved; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, no data]

Constituents	Date sample collected	
	Nov. 2, 1970	Apr. 9, 1992
Static water level	[1]27.00	[2]3.37
Specific conductance (µS/cm)	81	63
pH	5.5	5.2
Water temperature (°C)	--	7.5
Dissolved oxygen (mg/L as O_2)	--	9.4
Total hardness (mg/L as $CaCO_3$)	25	20
Noncarbonate hardness (mg/L as $CaCO_3$)	24	19
Calcium (mg/L as Ca)	5	3.9
Magnesium (mg/L as Mg)	3.1	2.6
Sodium (mg/L as Na)	3.5	.8
Potassium (mg/L as K)	.8	.7
Alkalinity (mg/L as $CaCO_3$)	1	1
Sulfate (mg/L as SO_4)	28	19
Chloride (mg/L as Cl)	1.9	2.1
Fluoride (mg/L as F)	.3	.1
Silica (mg/L as SiO_2)	7	5.3
Dissolved solids, calculated, sum (mg/L)	43	35
Nitrogen, nitrite (mg/L as N)	--	.01
Nitrate plus nitrite (mg/L as N)	--	.05
Nitrogen ammonia (mg/L as N)	--	.01
Nitrogen, ammonia plus organic (mg/L as N)	--	.2
Phosphorus, ortho (mg/L as P)	--	.01
Aluminum (µg/L as Al)	--	110
Iron (µg/L as Fe)	1,400	99
Manganese (µg/L as Mn)	330	75
Zinc (µg/L as Zn)	--	60

[1] Daily value.
[2] Static water level before pumping.

CAMBRIA COUNTY OBSERVATION WELL (CA-1)

Historical water-level fluctuations.—Water levels for the period of record show a continuous downward trend that began in 1959, stabilized in 1972, then showed little fluctuation to present (fig. 8).

Geophysical logging.—Depth soundings of the borehole were taken on November 4, 1992, and show the well has filled from 130 to 47.5 ft below top of casing. Database records show the well is cased to 45 ft, but no geophysical logs exist to confirm length of casing because the well is inaccessibly located in the basement of a building.

Single-well pumping analysis.—A single-well aquifer test was not conducted because the borehole was collapsed.

Water-quality characteristics.—No water-quality sample was collected because the borehole was collapsed; no previous water-quality data exist.

Evaluation.—Geophysical, water-quality, or aquifer-test data do not exist for Ca-1. The borehole has collapsed to 47.5 ft and is inaccessible to drilling equipment for cleaning. The upward water-level trend from 1959 to 1992 may be caused by gradual filling of the borehole. Because of filling, the well does not adequately repeat the aquifer response to climatic conditions.

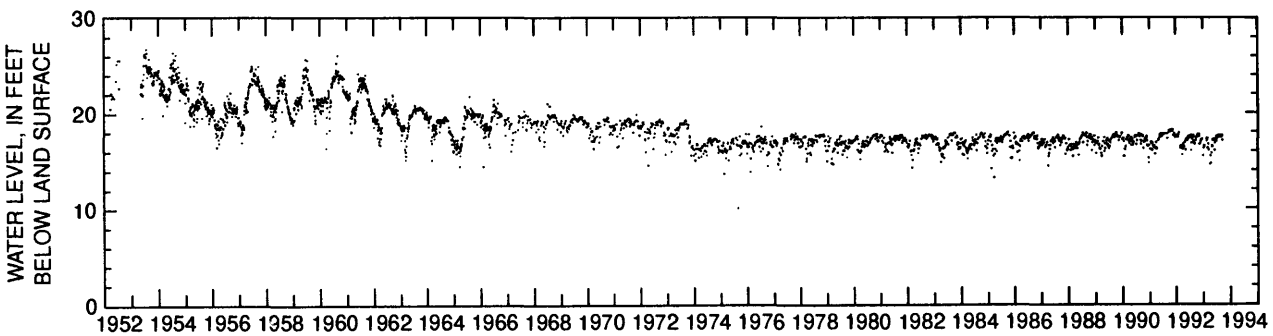

Figure 8. Hydrograph of Cambria County observation well Ca-1 for period of record to September 30, 1993.

CAMERON COUNTY OBSERVATION WELL (CM-13)

Historical water-level fluctuations.—Ground-water fluctuation over the period of record reflects seasonal trends (fig. 9). However, periodic and sudden recharge spikes shown on the hydrograph suggest over-land runoff from heavy precipitation may run directly into the well.

Geophysical logging.—Borehole-geophysical data confirm the total depth of the borehole is 101 ft and it is cased with 6-in. casing to 53 ft bls. The caliper log shows one notable fracture at 72 ft bls. The gamma log indicates a change in lithology at 58 ft bls, from probably a sandstone to a shale (fig. 10). The fluid-resistivity and fluid-temperature logs show a change in slope at approximately 60 ft bls that correlates to minor fractures on the caliper log and is in proximity to a change in lithology on the gamma log. This change in slope on the fluid logs may indicate lateral-borehole flow along the sandstone-shale contact. A slug of high-conductance fluid injected at 75 ft showed no measurable vertical borehole flow. No previous geophysical-log data are available for comparison.

Single-well pumping analysis.—A single-well aquifer test was conducted by pumping well Cm-13 for about 45 min at a rate of about 7 gal/min on November 14, 1991. The specific capacity of the well is 0.31 (gal/min)/ft, which is comparable to 0.23 (gal/min)/ft from the well aquifer test on November 13, 1967. A hydrograph shows static water level rose higher than prepumping levels by 0.85 ft within 24 hours. This higher static water level is probably because of the removal of sediment from fractures and bedding-plane separations (well development), allowing additional water to become available to the borehole (Driscoll, 1987).

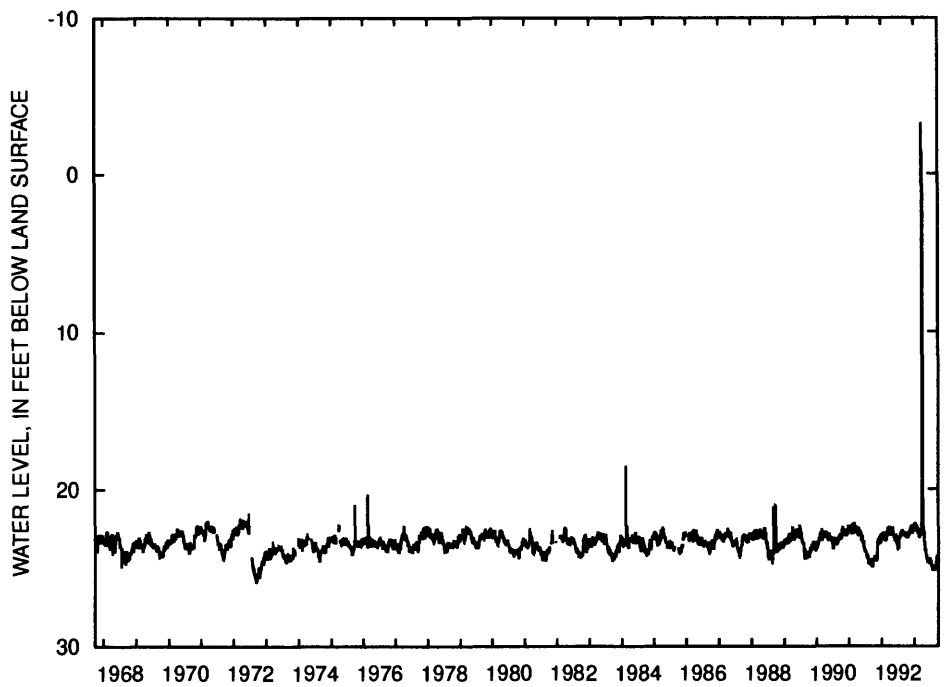

Figure 9. Hydrograph of Cameron County observation well Cm-13 for period of record to September 30, 1993.

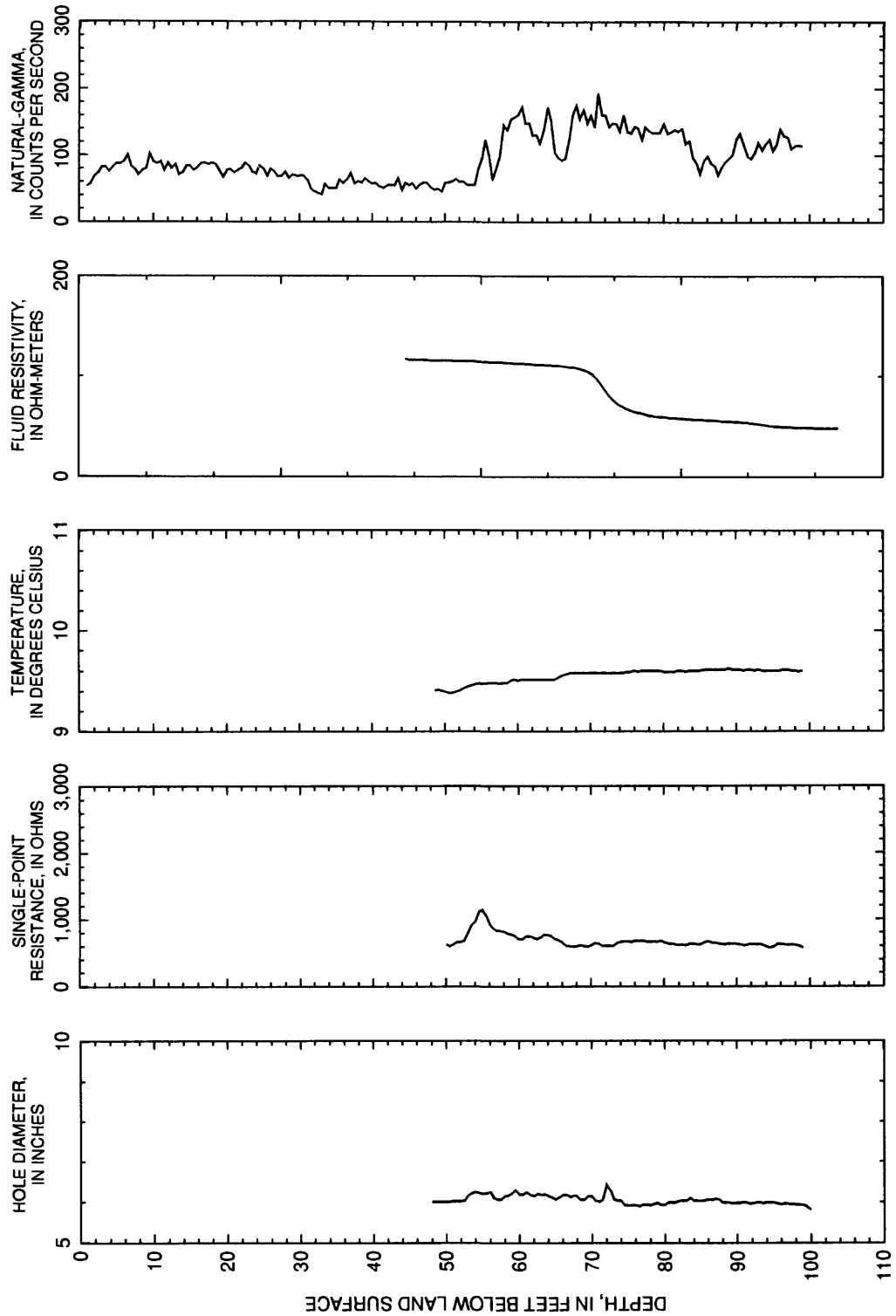

Figure 10. Geophysical logs for Cameron County observation well Cm-13.

Water-quality characteristics.—Concentrations of most chemical constituents were similar to previous sampling data (table 6). Concentrations of alkalinity and dissolved solids increased from 79 to 102 mg/L and 92 to 109 mg/L, respectively. Iron concentrations decreased from 580 to 74 µg/L, but manganese concentrations increased from 10 to 66 µg/L

Evaluation.—Specific capacity is low but consistent with previous data, indicating the formation penetrated by the borehole is hydraulically tight. Geophysical logs show the depth of the borehole and integrity of the casing is unchanged from original conditions. However, water-level data show some possible borehole development occurred during the well aquifer test on November 14, 1991, when static water levels rose and remained 0.85 ft above prepumping levels.

Table 6. *Records of water quality for Cameron County observation well Cm-13*

[All constituent concentrations are dissolved; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, no data]

Constituents	Date sample collected		
	Nov. 13, 1967	Apr. 10, 1968	Nov. 14, 1991
Static water level	--	[1]24.13	[2]24.15
pH	7.6	7.9	7.9
Water temperature (°C)	9	12	10
Dissolved oxygen (mg/L as O_2)	--	--	.3
Total hardness (mg/L as $CaCO_3$)	31	33	29
Noncarbonate hardness (mg/L as $CaCO_3$)	0	0	0
Calcium (mg/L as Ca)	8.5	8	7.6
Magnesium (mg/L as Mg)	2.4	3	2.5
Sodium (mg/L as Na)	24	21	24
Potassium (mg/L as K)	2	1.8	1.6
Alkalinity (mg/L as $CaCO_3$)	85	79	102
Sulfate (mg/L as SO_4)	1.5	.2	.6
Chloride (mg/L as Cl)	.5	.6	.8
Fluoride (mg/L as F)	--	0	.2
Silica (mg/L as SiO_2)	9.6	10	9.8
Dissolved solids, calculated, sum (mg/L)	101	92	109
Nitrogen, nitrite (mg/L as N)	--	--	.01
Nitrate plus nitrite (mg/L as N)	--	--	.05
Nitrogen ammonia (mg/L as N)	--	--	.171
Nitrogen, ammonia plus organic (mg/L as N)	--	--	.3
Phosphorus, ortho (mg/L as P)	--	--	.26
Aluminum (µg/L as Al)	--	0	.01
Iron (µg/L as Fe)	--	580	74
Manganese (µg/L as Mn)	80	10	66
Zinc (µg/L as Zn)	--	4	10

[1] Daily value.
[2] Static water level before pumping.

CARBON COUNTY OBSERVATION WELL (CB-104)

Historical water-level fluctuations.—Annual water levels show fluctuations of as much as 65 ft over the period of record. The average seasonal fluctuation is 45.94 ft. Wells, such as Cb-104, located on hilltops are subject to great changes in ground-water levels because they are located in a ground-water recharge area. Generally, ground-water levels for Cb-104 are lowest and fluctuate most from October through March, are higher and more stable from April through June, and steadily decline from July through September (fig. 11).

Geophysical logging.—Borehole-geophysical logs (fig. 12) show the depth of the borehole has decreased from 125 to 120 ft bls and that it is cased with 6-in. casing to 18.5 ft bls. Gamma and caliper logs suggest the lithology penetrated is a competent shale with sandstone interbeds from land surface down to 63 ft then changes to fissile shale down to the bottom of the borehole at 120 ft bls. Water-producing or water-receiving zones are not evident from the fluid-temperature log. The fluid-resistivity log could not be run because the conductance of the borehole fluid was less than the detection limit of the probe (50 µS/cm).

Single-well pumping analysis.—A single-well aquifer test was conducted by pumping well Cb-104 for about 1/2-hour at a rate of 9 gal/min on December 5, 1991. The approximate specific capacity of 17 (gal/min)/ft is the same as calculated on March 19, 1970. The water level in Cb-104 recovered in less than 24 hours.

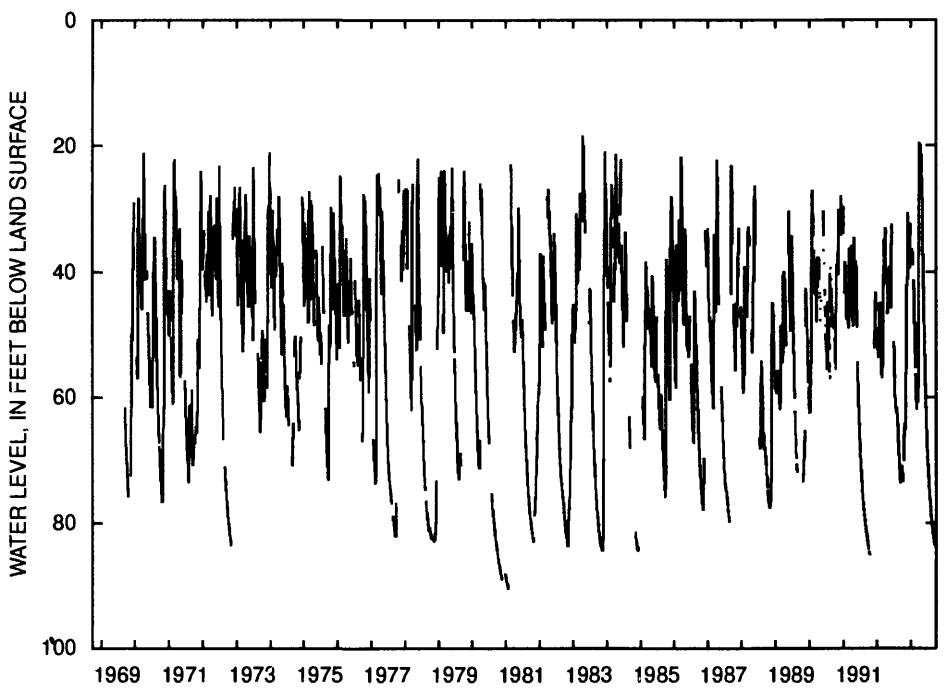

Figure 11. Hydrograph of Carbon County observation well Cb-104 for period of record to September 30, 1993.

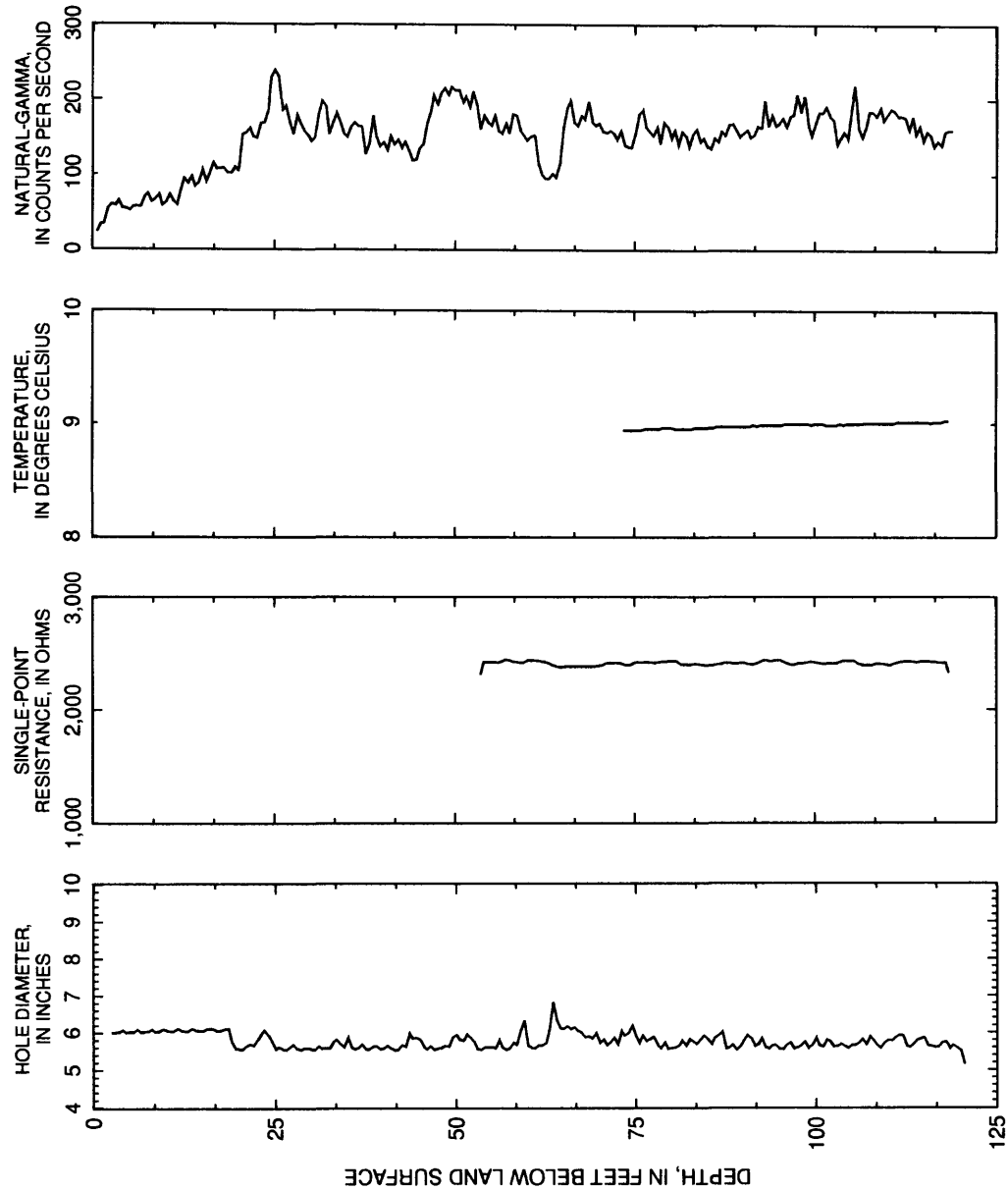

Figure 12. Geophysical logs for Carbon County observation well Cb-104.

Water-quality characteristics.—Water-quality characteristics are not consistent for most constituents over the period of record (table 7). Specific conductance and concentrations of dissolved solids, total hardness, sodium, calcium, and magnesium have all approximately doubled since last sampled. Noncarbonate hardness concentration has quadrupled, pH has consistently decreased, and chloride concentrations have increased sevenfold. However, even though the percentage changes are great, the concentration of total dissolved solids is very small, making the absolute changes in chemical characteristics very slight, possibly because of sampling procedures.

Evaluation.—The depth of the well on December 5, 1991, is 5 ft less than reported on the drilling log in June 1969. Either there was an original error in depth or loose material has filled in 5 ft of the borehole. Lack of previous geophysical logs prevent confirmation of initial borehole depth. Periodic depth measurements would determine if the borehole is slowly filling. Overall, the well appears to be representative of the local aquifer conditions at its hilltop location.

Table 7. *Records of water quality for Carbon County observation well Cb-104*

[All constituent concentrations are dissolved; μS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; μg/L, micrograms per liter; --, no data]

Constituents	Date sample collected		
	Sept. 16, 1969	Mar. 19, 1970	Dec. 5, 1991
Static water level	[1]61.75	[1]45.87	[2]54.09
Specific conductance (μS/cm)	15	15	46
pH	7.4	6.8	5.8
Water temperature (°C)	--	--	8
Dissolved oxygen (mg/L as O_2)	--	--	9.6
Total hardness (mg/L as $CaCO_3$)	4	5	9
Noncarbonate hardness (mg/L as $CaCO_3$)	--	2	8
Calcium (mg/L as Ca)	.6	.9	1.6
Magnesium (mg/L as Mg)	.6	.6	1.2
Sodium (mg/L as Na)	3	.6	3
Potassium (mg/L as K)	.4	.2	.6
Alkalinity (mg/L as $CaCO_3$)	4.0	2	1
Sulfate (mg/L as SO_4)	--	.20	.50
Chloride (mg/L as Cl)	1.5	1.4	9.4
Fluoride (mg/L as F)	--	.10	.2
Silica (mg/L as SiO_2)	5	4.9	4.8
Dissolved solids, calculated, sum (mg/L)	--	11	22
Nitrogen, nitrite (mg/L as N)	--	--	.01
Nitrate plus nitrite (mg/L as N)	--	--	.2
Nitrogen ammonia (mg/L as N)	--	--	.01
Nitrogen, ammonia plus organic (mg/L as N)	--	--	.2
Phosphorus, ortho (mg/L as P)	--	--	.01
Aluminum (μg/L as Al)	--	--	20
Iron (μg/L as Fe)	260	130	130
Manganese (μg/L as Mn)	10	--	12
Zinc (μg/L as Zn)	--	--	20

[1] Daily value.
[2] Static water level before pumping.

CLINTON COUNTY OBSERVATION WELL (CN-1)

Historical water-level fluctuation.—Water-level fluctuations over the period of record reflect seasonal and long-term trends. After 1982, the long-term trend becomes less discernible (fig. 13). A period of unusually low water levels exists from approximately October 1965 through February 1966 that was caused by less than normal precipitation (fig. 13).

Geophysical logging.—Borehole-geophysical data show the total depth of the borehole has decreased from 78 to 75 ft bls and that it is cased with 6-in. casing to 36 ft bls (fig. 14). Several fractures are present from 36 to 54 ft. The gamma log indicates alternating sandstone and shale lithology. The fluid-resistivity log was not run because the dissolved concentration was less than the detection limit of the probe.

Single-well pumping analysis.—A single-well aquifer test was conducted by pumping well Cn-1 for about 1/2-hour at a rate of 6.5 gal/min on November 15, 1991. The specific capacity of the penetrated formation is 3.2 (gal/min)/ft. This estimate is very similar to 3.4 (gal/min)/ft on April 2, 1964. Static water level recovered to prepumping levels in less than 1 day.

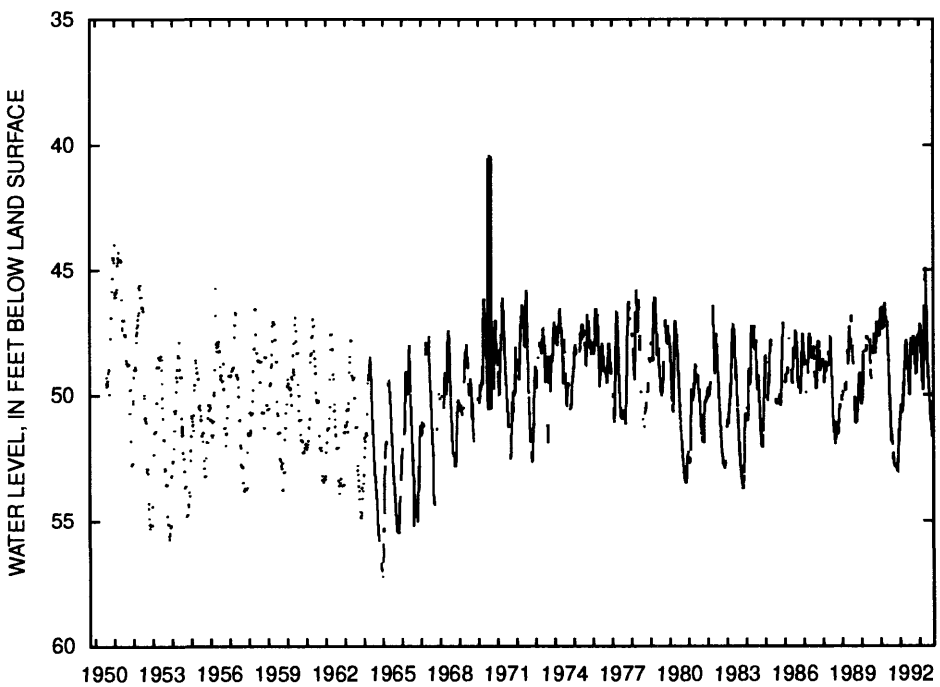

Figure 13. Hydrograph of Clinton County observation well Cn-1 for period of record to September 30, 1993.

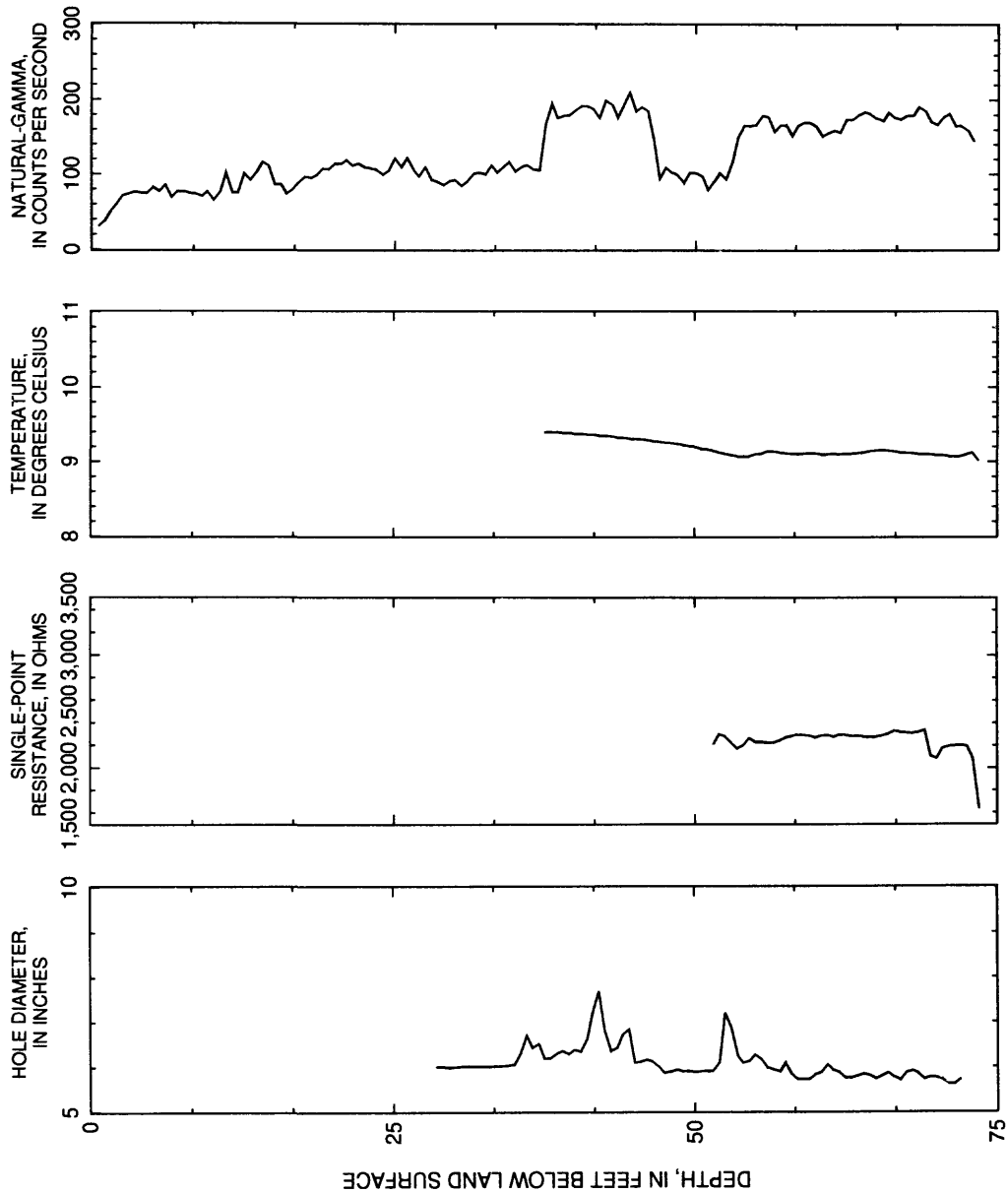

Figure 14. Geophysical logs for Clinton County observation well Cn-1.

Water-quality characteristics.—The concentrations of most constituents were similar to concentrations from the last sampling in 1971. Iron and manganese concentrations decreased from 0.92 to 0.023 µg/L and from 0.08 to 0.006 µg/L, respectively (table 8).

Evaluation.—Good well development is indicated by a constant specific capacity. Geophysical data show the physical condition of the well remains essentially unchanged. Previous and current water-quality data are consistent except for a reduction in iron and manganese concentrations that may be caused by differences in the sampling procedures. Overall, the well appears to be representative of the local aquifer conditions at its hilltop location.

Table 8. *Records of water quality for Clinton County observation well Cn-1*

[All constituent concentrations are dissolved; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, no data]

Constituents	Date sample collected	
	Nov. 18, 1971	Nov. 15, 1991
Static water level	[1]49.88	[2]53.96
Specific conductance (µS/cm)	17	20
pH	7.1	6.4
Water temperature (°C)	--	10
Dissolved oxygen (mg/L as O_2)	--	7.5
Total hardness (mg/L as $CaCO_3$)	9	6.
Noncarbonate hardness (mg/L as $CaCO_3$)	0	--
Calcium (mg/L as Ca)	2	1.6
Magnesium (mg/L as Mg)	1	.58
Sodium (mg/L as Na)	2.5	.9
Potassium (mg/L as K)	.7	.5
Alkalinity (mg/L as $CaCO_3$)	9	60
Sulfate (mg/L as SO_4)	1.8	1.3
Chloride (mg/L as Cl)	1	.8
Fluoride (mg/L as F)	.3	.2
Silica (mg/L as SiO_2)	6.4	7.1
Dissolved solids, calculated, sum (mg/L)	--	--
Nitrogen, nitrite (mg/L as N)	--	.01
Nitrate plus nitrite (mg/L as N)	--	.2
Nitrogen ammonia (mg/L as N)	--	.01
Nitrogen, ammonia plus organic (mg/L as N)	--	.02
Phosphorus, ortho (mg/L as P)	--	.02
Aluminum (µg/L as Al)	--	10
Iron (µg/L as Fe)	.92	.023
Manganese (µg/L as Mn)	.08	.006
Zinc (µg/L as Zn)	--	--

[1] Daily value.
[2] Static water level before pumping.

CRAWFORD COUNTY OBSERVATION WELL (CW-413)

Historical water-level fluctuations.—Ground-water levels for the period of record indicate seasonal variations with an upward trend. Unusually low periods in late 1983 and 1991 correspond to less than normal rainfall (fig. 15).

Geophysical logging.—Borehole-geophysical logs show the total depth of the borehole is 97.5 ft bls and that it is cased with 6-in. casing to 19 ft bls (fig. 16). The caliper log shows one notable fracture below static water level approximately 7.5 in. in diameter at 85 ft. The fluid-resistivity and fluid-temperature logs show no evidence of water-producing or water-receiving zones.

Single-well pumping analysis.—A single-well aquifer test was conducted by pumping well Cw-413 for about 1 hour at a rate of 14.5 gal/min on April 14, 1992. The specific capacity of the formation is 0.5 (gal/min)/ft. Hydrographs show static water level recovered to a prepumping trend in 18 days (fig. 17). Discharge water was dark red for approximately the first 5 min of pumping, perhaps because of the presence of iron bacteria. After tests were concluded, sodium hypochlorite was added to the borehole water to temporarily stop any bacteria growth. Monthly well treatment with sodium hypochlorite may be necessary to insure the borehole remains unclogged.

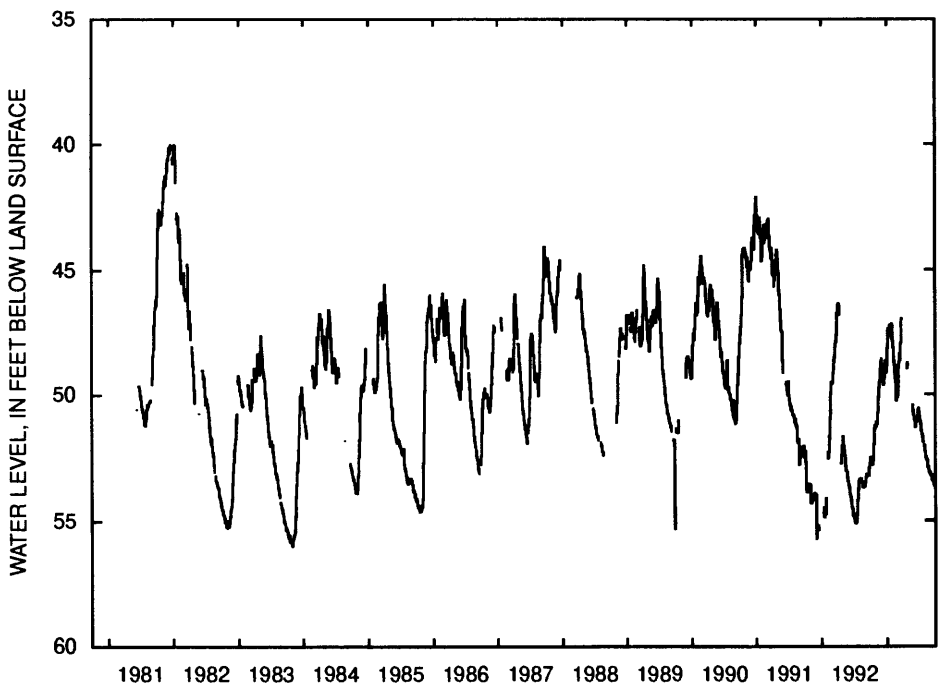

Figure 15. Hydrograph of Crawford County observation well Cw-413 for period of record to September 30, 1993.

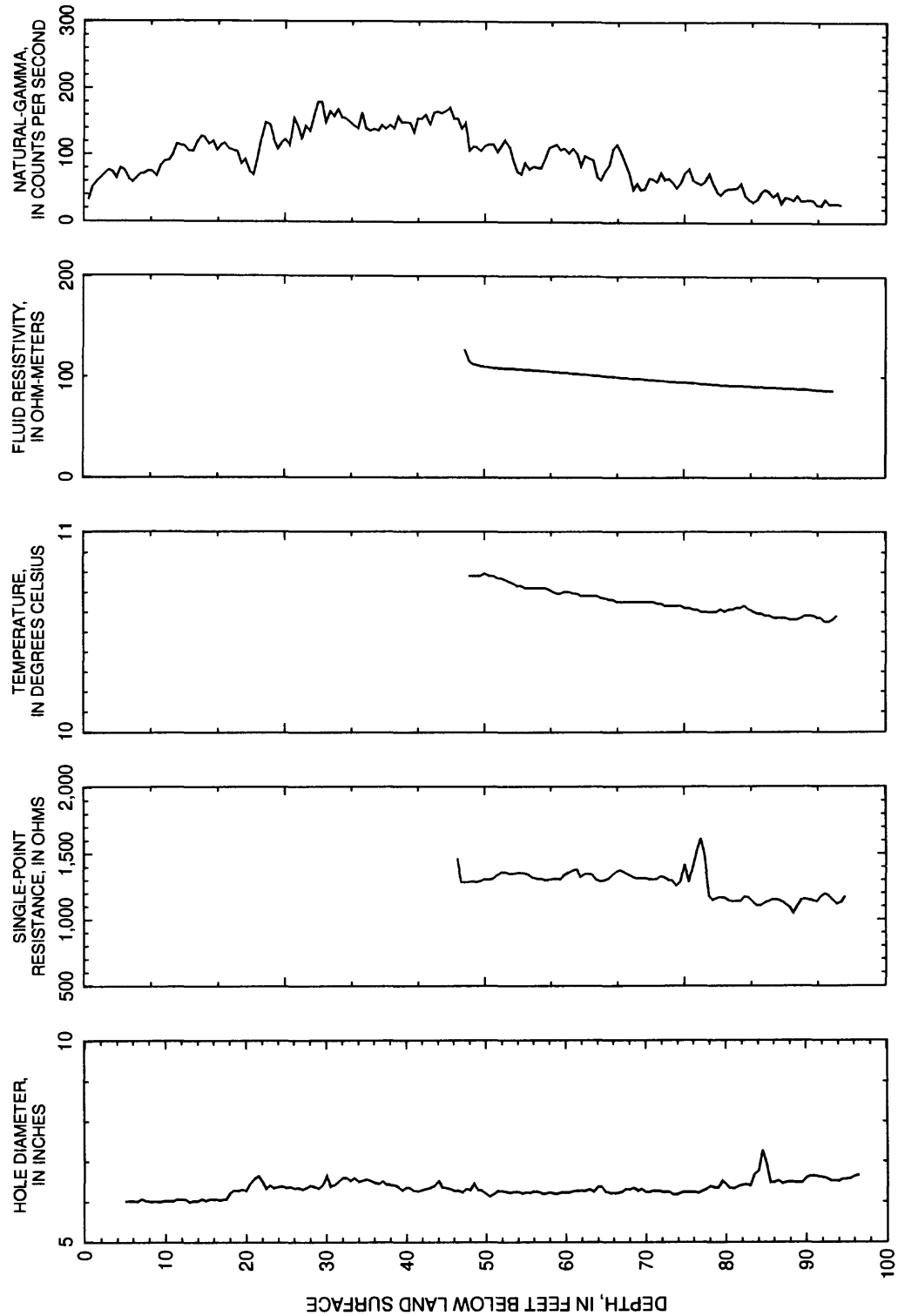

Figure 16. Geophysical logs for Crawford County observation well Cw-413.

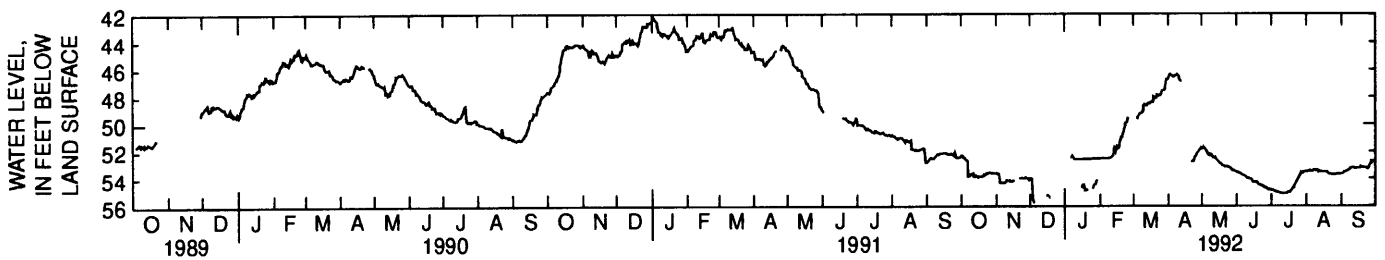

Figure 17. Hydrograph of Crawford County observation well Cw-413 showing seasonal fluctuations and recovery period of single-well aquifer test.

Water-quality characteristics.—The water quality was not analyzed prior to April 14, 1992; therefore, no comparisons of water-quality characteristics can be made (table 9). Constituents sampled on this date will be used as a background for future reference.

Evaluation.—A consistent rise in water levels over the period of record, combined with the suspected presence of iron bacteria, indicates the borehole is susceptible to clogging. This may affect water-level fluctuation response. Periodic pumping and chemical shocking may improve the water-level record for this well.

Table 9. *Records of water quality for Crawford County observation well Cw-413*

[All constituent concentrations are dissolved; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter]

Constituents	Date sample collected
	Apr. 14, 1992
Static water level	[1]47.47
Specific conductance (µS/cm)	416
pH	8
Water temperature (°C)	10
Dissolved oxygen (mg/L as O_2)	4
Total hardness (mg/L as $CaCO_3$)	170
Noncarbonate hardness (mg/L as $CaCO_3$)	0
Calcium (mg/L as Ca)	43
Magnesium (mg/L as Mg)	14
Sodium (mg/L as Na)	22
Potassium (mg/L as K)	2.6
Alkalinity (mg/L as $CaCO_3$)	185
Sulfate (mg/L as SO_4)	22
Chloride (mg/L as Cl)	7.8
Fluoride (mg/L as F)	.4
Silica (mg/L as SiO_2)	11
Dissolved solids, calculated, sum (mg/L)	234
Nitrogen, nitrite (mg/L as N)	.01
Nitrate plus nitrite (mg/L as N)	.05
Nitrogen ammonia (mg/L as N)	.02
Nitrogen, ammonia plus organic (mg/L as N)	.2
Phosphorus, ortho (mg/L as P)	.01
Aluminum (µg/L as Al)	10
Iron (µg/L as Fe)	10
Manganese (µg/L as Mn)	24
Zinc (µg/L as Zn)	10

[1] Static water level before pumping.

ELK COUNTY OBSERVATION WELL (EK-108)

Historical water-level fluctuations.—Water-level changes over the period of record indicate seasonal and long-term trends in which the extremes vary less than 4.0 ft (fig. 18).

Geophysical logging.—Borehole-geophysical data confirm the total depth of the borehole is 341.5 ft bls and that it is cased with 12-in. casing to 38 ft bls. Numerous fractures are located from 40 to 157 ft bls (fig. 19). Fluid-resistivity and fluid-temperature logs indicate water-producing zones are located near 40 to 60, 150, 250, and possibly 318 ft. One water-receiving zone is located near the bottom of casing between 38 and 43 ft. Brine tracing at 100 ft measured upward, vertical borehole flow at approximately 4.0 gal/min. The rates of water produced at 200 and 300 ft bls were not traceable because of borehole turbulence. Geophysical logs collected on October 16, 1974, match closely except for the brine-trace log, which was inconclusive.

Single-well pumping analysis.—A single-well aquifer test was conducted by pumping well Ek-108 for about 45 min at a rate of 37.5 gal/min on April 17, 1992. The specific capacity of the formation is 9.3 (gal/min)/ft. On the basis of drawdown data from the aquifer test on April 9, 1974, the specific capacity was 5.0 (gal/min)/ft when pumped at 479 gal/min. Recovery data from April 17, 1992, show that water levels returned to within 0.51 ft of prepumping conditions within 45 min.

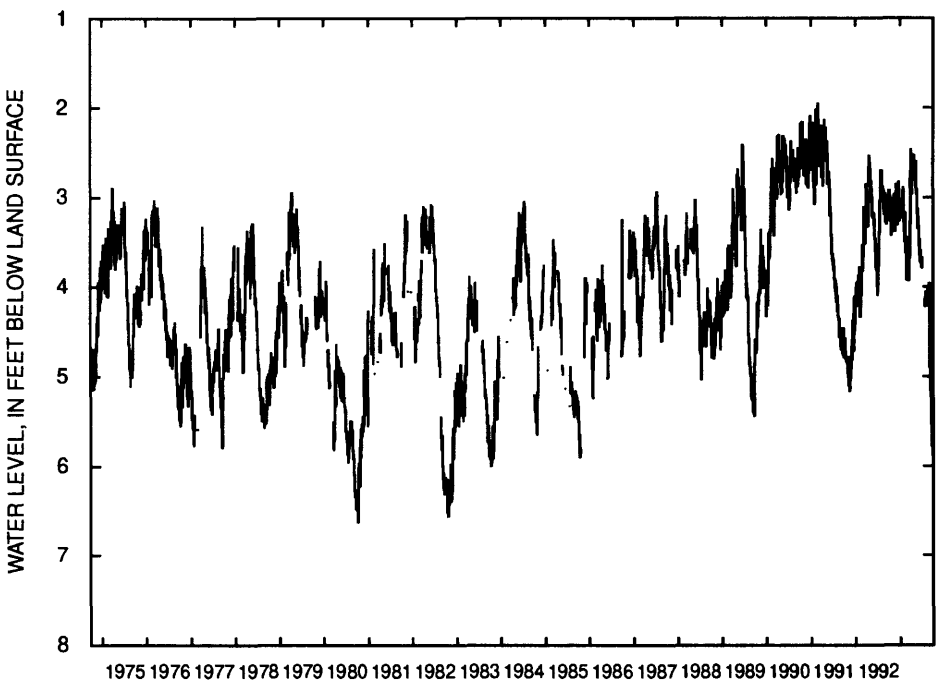

Figure 18. Hydrograph of Elk County observation well Ek-108 for period of record to September 30, 1993.

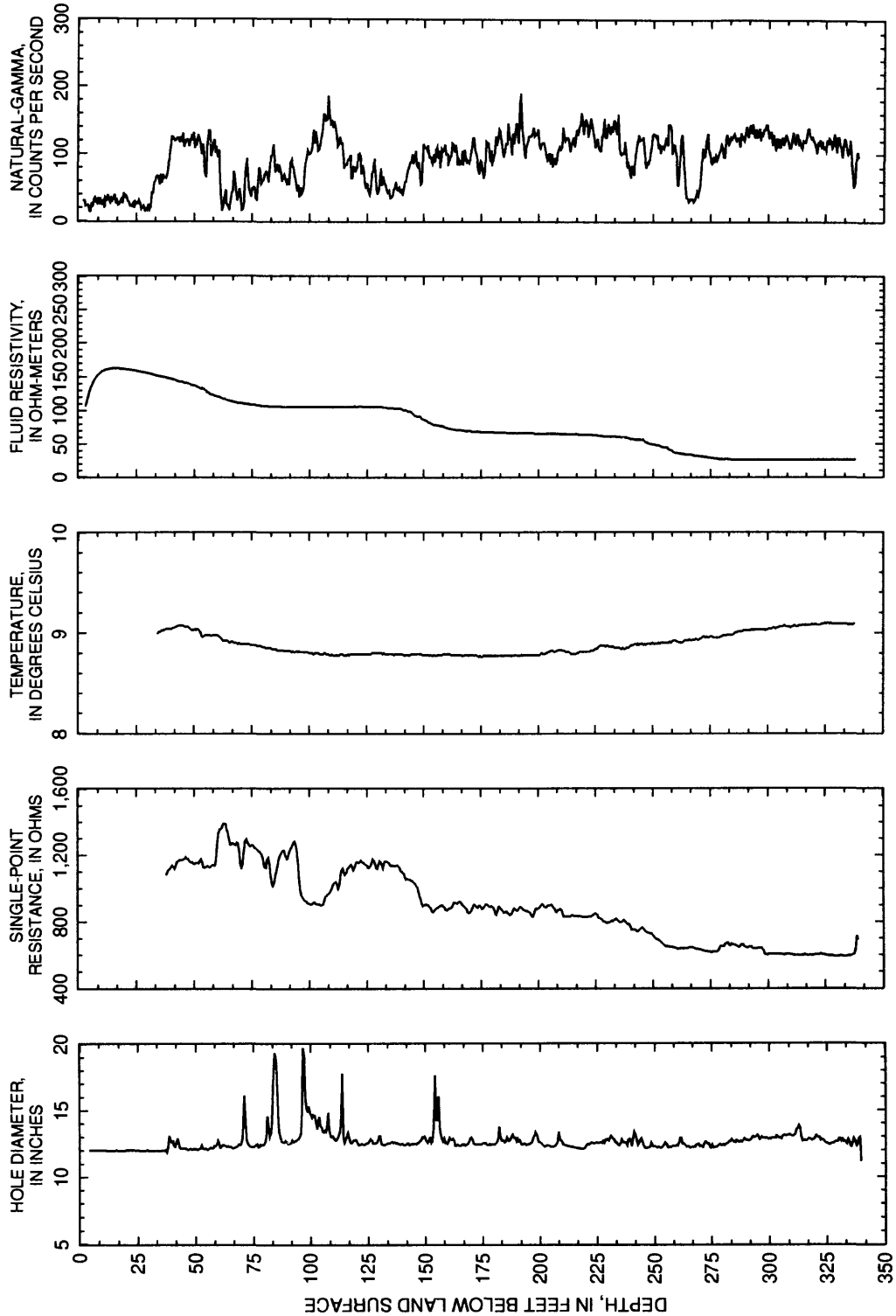

Figure 19. Geophysical logs for Elk County observation well Ek-108.

Water-quality characteristics.—The water-quality constituents sampled compare very closely with two previous data sets (table 10). Iron and manganese concentrations are notably high.

Evaluation.—Water-level analysis for Ek-108 reveals no unusual trends. The well appears to be a timely indicator of local and aerial changes in ground-water storage. Geophysical logs and water-quality data are consistent with previous data and show no obvious changes or degradation that would affect water-level statistics.

Table 10. *Records of water quality for Elk County observation well Ek-108*

[All constituent concentrations are dissolved; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, no data]

Constituents	Date sample collected		
	Nov. 18, 1974	May 21, 1975	Apr. 17, 1992
Static water level	[1]4.84	[1]3.46	[2]4.17
Specific conductance (µS/cm)	180	180	149
pH	6.8	6.1	6.4
Water temperature (°C)	9.2	11.9	10
Dissolved oxygen (mg/L as O_2)	--	--	0
Total hardness (mg/L as $CaCO_3$)	54	54	54
Noncarbonate hardness (mg/L as $CaCO_3$)	26	19	24
Calcium (mg/L as Ca)	12	13	13
Magnesium (mg/L as Mg)	5.8	5.2	5.3
Sodium (mg/L as Na)	2.2	2.7	2.7
Potassium (mg/L as K)	1.6	2.1	1.8
Alkalinity (mg/L as $CaCO_3$)	28	35	30
Sulfate (mg/L as SO_4)	20	20	17
Chloride (mg/L as Cl)	5.9	8.7	11
Fluoride (mg/L as F)	.2	.1	.1
Silica (mg/L as SiO_2)	5.7	6.2	6.2
Dissolved solids, calculated, sum (mg/L)	82	94	87
Nitrogen, nitrite (mg/L as N)	--	.01	.01
Nitrate plus nitrite (mg/L as N)	--	.1	.05
Nitrogen ammonia (mg/L as N)	--	--	.02
Nitrogen, ammonia plus organic (mg/L as N)	--	--	.2
Phosphorus, ortho (mg/L as P)	--	.01	.01
Aluminum (µg/L as Al)	--	--	10
Iron (µg/L as Fe)	11,000	14,000	11,000
Manganese (µg/L as Mn)	950	880	890
Zinc (µg/L as Zn)	50	--	40

[1] Daily value.
[2] Static water level before pumping.

FAYETTE COUNTY OBSERVATION WELL (FA-17)

Historical water-level fluctuations.—Water-level analysis shows an unusual low period near the beginning of record in 1967 when the water level was approximately 40 ft bls and may indicate slow recharge and passive well development after drilling. Transient pumpage may be responsible for several sudden unusually low water levels that occurred throughout the period of record. Seasonal cyclical ground-water recharge-discharge trends are evident (fig. 20).

Geophysical logging.—Borehole-geophysical data confirm the total depth of the borehole is 100 ft bls and that it is cased with 6-in. casing to 19 ft bls. The gamma log shows a clean sandstone to 37.5 ft underlain by shale (fig. 21). The fluid-resistivity and fluid-temperature logs indicate minor water-producing zones at 46-55, 65, and 95 ft. Comparison of current and previous logs shows no detectable physical change in the borehole.

Single-well pumping analysis.—A single-well aquifer test was conducted by pumping well Fa-17 for 1 hour at a rate of 1.5 gal/min on April 7, 1992. The specific capacity of the well is 0.3 (gal/min)/ft. This calculation is unchanged from the previous single-well aquifer test. The borehole penetrates a hydraulically tight aquifer. After the single-well aquifer test, the static water level returned to its prepumping trend in approximately 19 days (fig. 22).

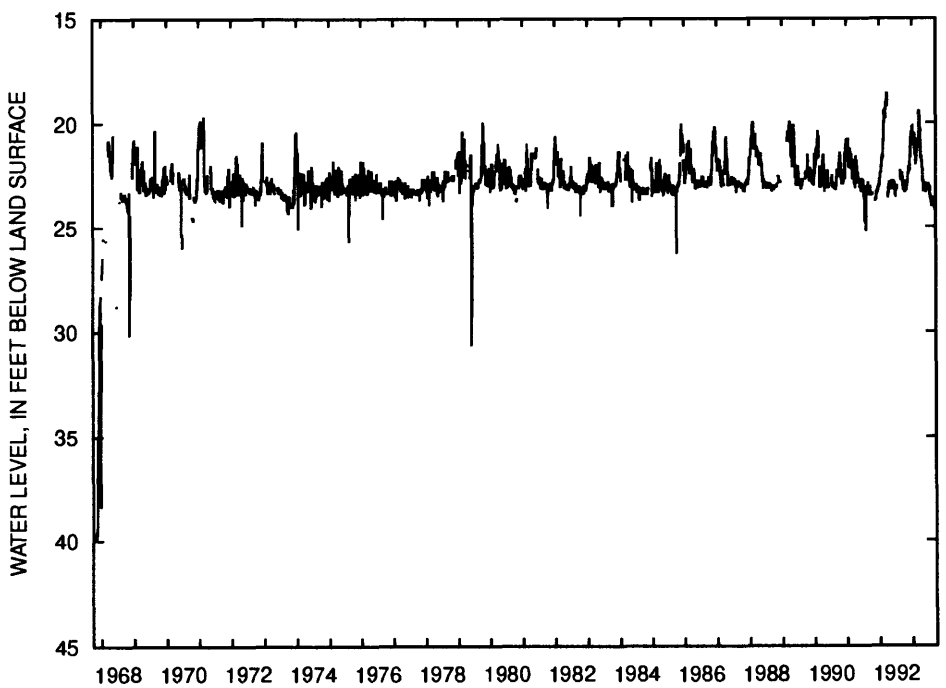

Figure 20. Hydrograph of Fayette County observation well Fa-17 for period of record to September 30, 1993.

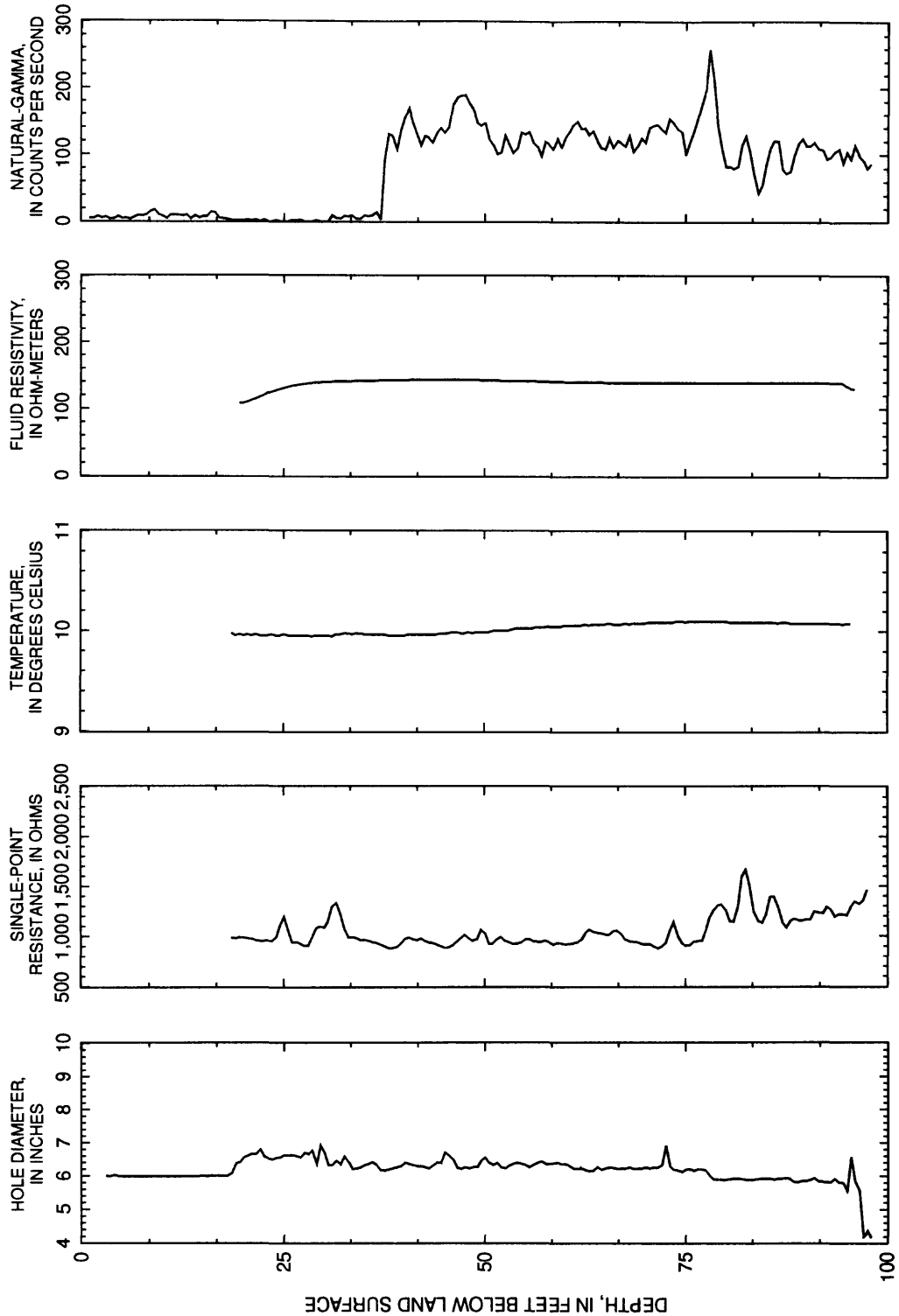

Figure 21. Geophysical logs for Fayette County observation well Fa-17.

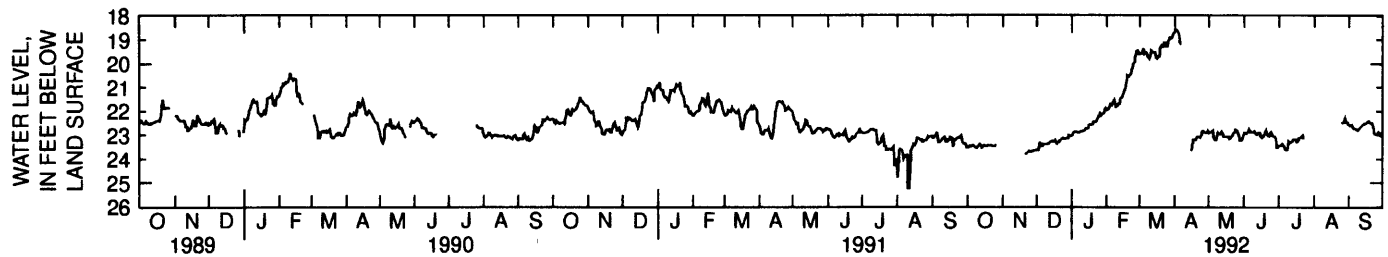

Figure 22. Hydrograph of Fayette County observation well Fa-17 showing seasonal fluctuations and recovery period of single-well aquifer test.

Water-quality characteristics.—Water quality in 1992 was similar to that in 1968 except for a small increase in chloride concentrations from 0.7 to 2.0 mg/L, a large decrease in iron concentrations from 14,000 to 5,600 µg/L, and an increase in manganese concentrations from 1,600 to 1,900 µg/L (table 11). As a precaution against iron encrustation, sodium hypochlorite was added to the well to destroy any iron bacteria present in the borehole.

Evaluation.—Postpumping hydrographs for well Fa-17 show water levels returned to prepumping conditions in about 19 days. Physical and chemical data show changes in some constituents from previous investigations that may be related to sampling procedures.

Table 11. *Records of water quality for Fayette County observation well Fa-17*

[All constituent concentrations are dissolved; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, no data]

Constituents	Date sample collected	
	Nov. 15, 1968	Apr. 7, 1992
Static water level	[1]24.26	[2]19.22
pH	7.6	7.4
Water temperature (°C)	11.66	12
Dissolved oxygen (mg/L as O_2)	--	4.2
Total hardness (mg/L as $CaCO_3$)	25	32
Noncarbonate hardness (mg/L as $CaCO_3$)	6	0
Calcium (mg/L as Ca)	6.4	7.8
Magnesium (mg/L as Mg)	2.2	3.0
Sodium (mg/L as Na)	.5	.8
Potassium (mg/L as K)	.8	1.3
Alkalinity (mg/L as $CaCO_3$)	19	39
Sulfate (mg/L as SO_4)	6.4	5.3
Chloride (mg/L as Cl)	.7	2
Fluoride (mg/L as F)	.2	.2
Silica (mg/L as SiO_2)	7.4	8.2
Dissolved solids, calculated, sum (mg/L)	87	60
Nitrogen, nitrite (mg/L as N)	--	--
Nitrate plus nitrite (mg/L as N)	--	--
Nitrogen ammonia (mg/L as N)	--	--
Nitrogen, ammonia plus organic (mg/L as N)	--	--
Phosphorus, ortho (mg/L as P)	--	--
Aluminum (µg/L as Al)	--	10
Iron (µg/L as Fe)	14,000	5,600
Manganese (µg/L as Mn)	1,600	1,900
Zinc (µg/L as Zn)	--	340

[1] Daily value.
[2] Static water level before pumping.

FULTON COUNTY OBSERVATION WELL (FU-93)

Historical water-level fluctuations.—Water-level fluctuations over the period of record reflect only seasonal trends. Approximately one-fourth of the time, the water level in the well is above land surface. The water level typically fluctuates between 1.75 ft above land surface and 2.5 ft bls. Only once (in 1966) did the water level decline below 4.0 ft bls (fig. 23).

Geophysical logging.—Borehole-geophysical data show the total depth of the borehole has decreased in 20 years from 198 to 191 ft and that it is cased with 6-in. casing to 45 ft bls (fig. 24). Numerous fractures are located from 69 to 81 ft bls. The caliper log shows the formation penetrated by the borehole is highly fractured from 45 to 122 ft bls. The fluid-resistivity and fluid-temperature logs show three apparent water-producing zones located at 122, 164, and 178 ft bls and one water-receiving zone at approximately 60 ft. Brine-trace logs show 7.4 gal/min upward borehole flow at 160 ft.

Single-well pumping analysis.—A single-well aquifer test was conducted by pumping well Fu-93 for approximately 1/2-hour at a rate of 30 gal/min on November 5, 1991. The specific capacity of Fu-93 is 0.8 (gal/min)/ft, which closely compares to 0.9 (gal/min)/ft estimated on June 1, 1973. The discharge water was dark red during pumping, possibly caused by iron bacteria. Its possible that a hydraulic connection exists between Fu-93 and an adjacent unnamed creek approximately 30 ft away. Water-level data show static water level recovered within 4 days after pumping. To prevent iron encrustation, sodium hypochlorite was added after testing to destroy any iron bacteria present in the borehole.

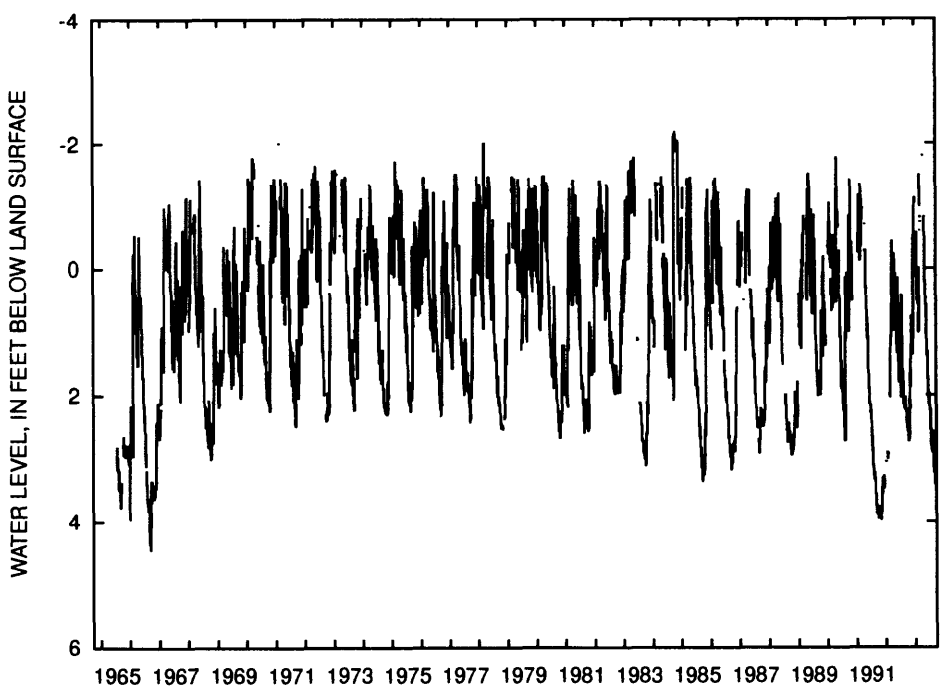

Figure 23. Hydrograph of Fulton County observation well Fu-93 for period of record to September 30, 1993.

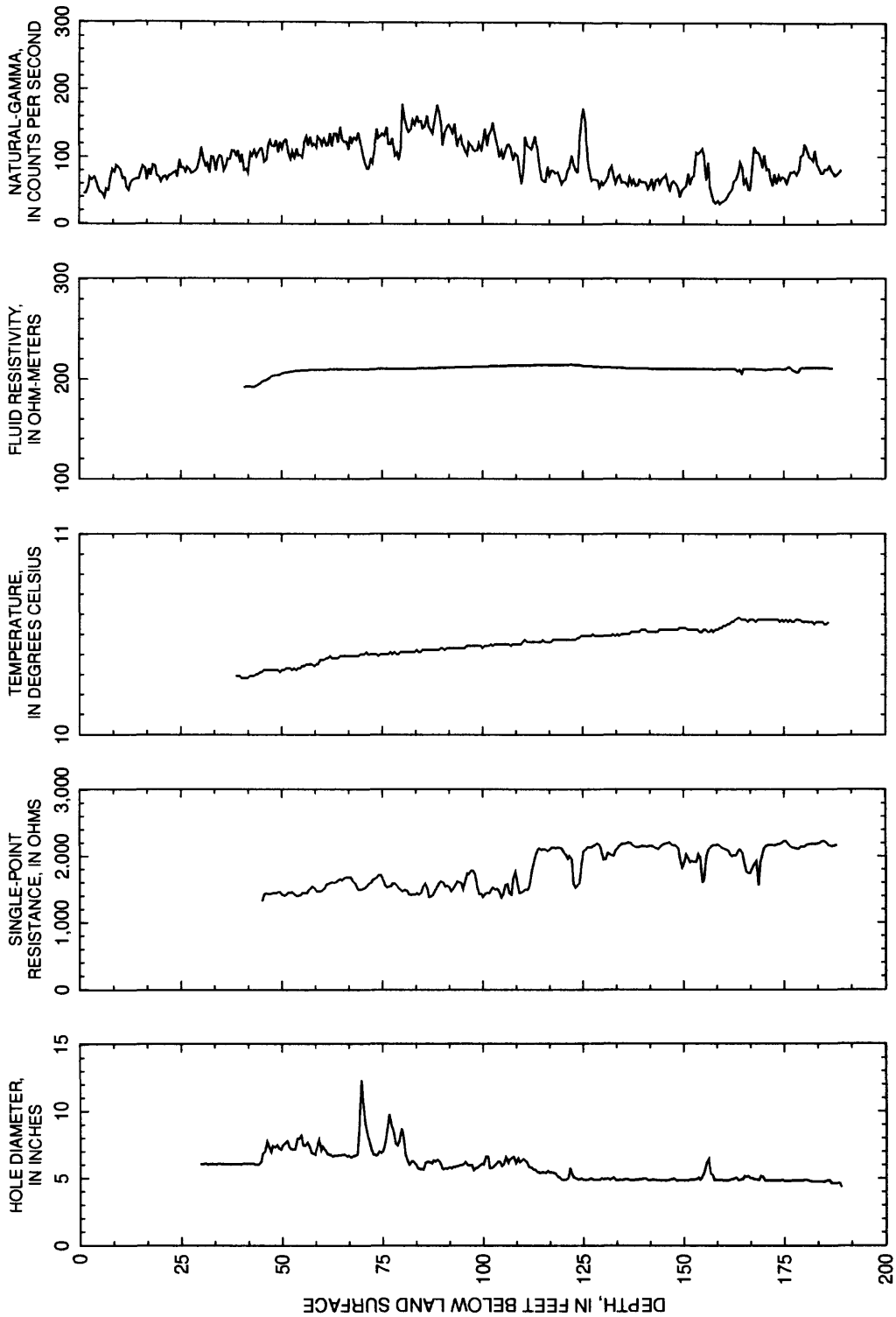

Figure 24. Geophysical logs for Fulton County observation well Fu-93.

Water-quality characteristics.—Except for an increase in concentrations of chloride from 0.3 to 3.8 mg/L and concentrations of manganese from 0.0 to 10.0 µg/L, concentrations of all analyzed constituents were essentially unchanged (table 12).

Evaluation.—Despite a reduction of 7 ft in the total depth of the borehole, the specific capacity and water-level and water-quality data indicate the well has experienced little change over the 20-year period of record. The dark red color of the discharge water suggests the presence of iron bacteria that could eventually clog the well. Periodic pumping and chemical shocking would extend the usefulness of this well.

Table 12. *Records of water quality for Fulton County observation well Fu-93*

[All constituent concentrations are dissolved; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, no data]

Constituents	Date sample collected		
	June 5, 1970	June 1, 1973	Nov. 5, 1991
Specific conductance (µS/cm)	68	65	78
pH	7	7.5	7.1
Water temperature (°C)	--	--	11
Dissolved oxygen (mg/L as O_2)	--	--	--
Total hardness (mg/L as $CaCO_3$)	30	31	35
Noncarbonate hardness (mg/L as $CaCO_3$)	0	0	3
Calcium (mg/L as Ca)	9.6	9.9	11
Magnesium (mg/L as Mg)	1.5	1.6	1.9
Sodium (mg/L as Na)	.8	.7	.9
Potassium (mg/L as K)	.7	.8	.9
Alkalinity (mg/L as $CaCO_3$)	--	0	32
Sulfate (mg/L as SO_4)	.8	0	1
Chloride (mg/L as Cl)	.5	.3	3.8
Fluoride (mg/L as F)	.2	.1	.1
Silica (mg/L as SiO_2)	7.4	7	6.8
Dissolved solids, calculated, sum (mg/L)	--	40	45
Nitrogen, nitrite (mg/L as N)	--	.004	.01
Nitrate plus nitrite (mg/L as N)	--	.019	.05
Nitrogen ammonia (mg/L as N)	--	--	.01
Nitrogen, ammonia plus organic (mg/L as N)	--	--	.2
Phosphorus, ortho (mg/L as P)	--	.008	.01
Aluminum (µg/L as Al)	--	--	.01
Iron (µg/L as Fe)	[1]50	[1]40	17
Manganese (µg/L as Mn)	.03	0	10
Zinc (µg/L as Zn)	--	--	10

[1] Total iron in µg/L as Fe.

GREENE COUNTY OBSERVATION WELL (GR-118)

Historical water-level fluctuations.—Water-level fluctuation increased dramatically in the early 1980's (fig 25). Ground-water pumping from a nearby coal mine may be responsible for the erratic water-level changes. Periods of pumpage that lasted several months are apparent throughout the 1980's, each lasting several months.

Geophysical logging.—Borehole-geophysical data show the total depth of the borehole is approximately 103 ft bls and that it is cased with 6-in. casing to 20 ft bls (fig. 26). The caliper log shows the borehole has several constrictions; a major one is located at 55 ft. Water cascades into the borehole probably from a small fracture at 21 ft bls. The fluid-temperature log indicates vertical flow. Water apparently enters the borehole at approximately 22 and 25 ft bls and moves downward. A small quantity of water exits the borehole through a fracture at 55 ft bls, and the remainder exits the borehole through a fracture at 71 ft bls. Brine tracing was inconclusive because of borehole turbulence.

Single-well pumping analysis.—A single-well aquifer test was conducted by pumping well Gr-118 for 1 hour at a rate of 11 gal/min on April 8, 1992. The specific capacity of the formation is 10.5 (gal/min)/ft, a threefold increase from 3.4 (gal/min)/ft since the last test on June 11, 1974, and almost four times the original of 2.7 (gal/min)/ft on July 11, 1973.

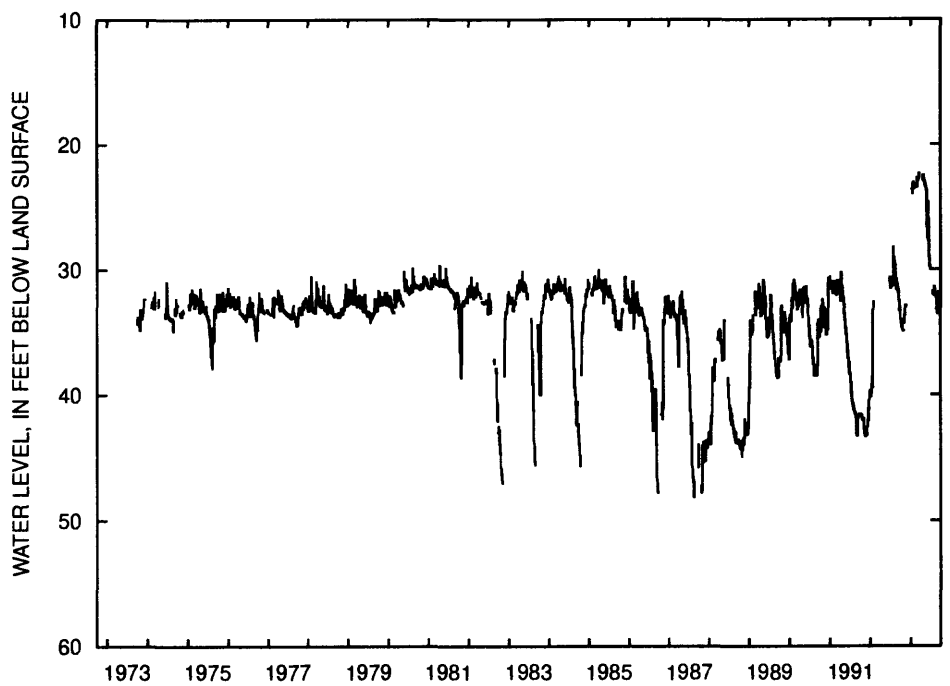

Figure 25. Hydrograph of Greene County observation well Gr-118 for period of record to September 30, 1993.

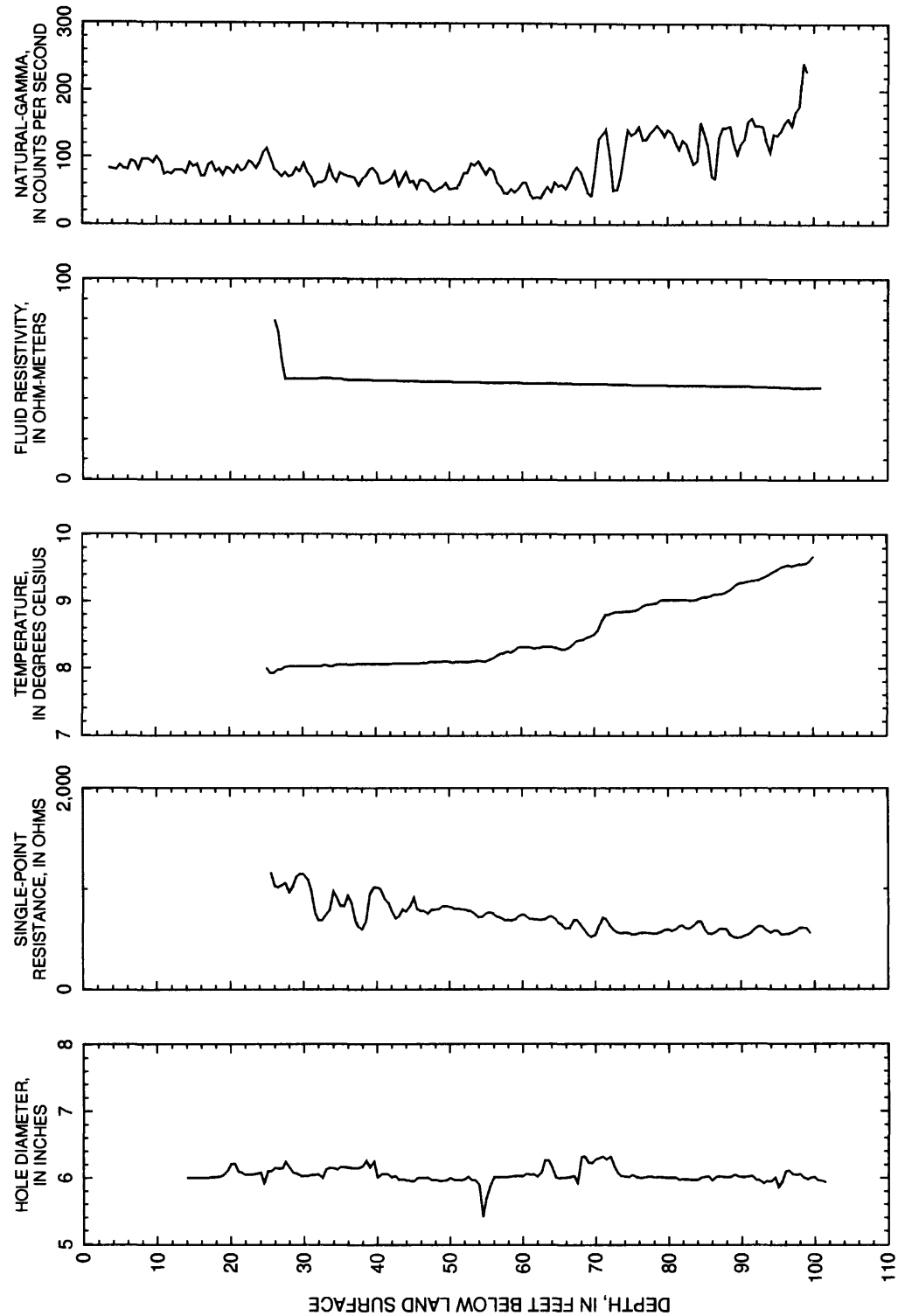

Figure 26. Geophysical logs for Greene County observation well Gr-118.

Water-quality characteristics.—Dissolved-solids and major ion concentrations show a increase with each successive sampling over the period of record. Concentrations of the other water-quality constituents are variable (table 13).

Evaluation.—Water quality in well Gr-118 has apparently degraded over time, although it's difficult to make conclusions from only four water-quality samples over a period of 20 years. The well has recently developed a cascading zone not reported in earlier field notes, suggesting local aquifer changes. The specific capacity has increased greatly from original values, and hydrographs show prolonged transient pumpage. These conditions are probably the effects of local coal mining, which make the water-level data nearly useless for determining aquifer response to climatic variations.

Table 13. *Records of water quality for Greene County observation well Gr-118*

[All constituent concentrations are dissolved; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, no data]

Constituents	Date sample collected			
	July 11, 1973	June 11, 1974	Oct. 19, 1979	Apr. 8, 1992
Specific conductance (µS/cm)	304	360	425	590
pH	7.9	6.8	7	6.85
Water temperature (°C)	--	10	12.5	9
Dissolved oxygen (mg/L as O_2)	--	--	--	2
Total hardness (mg/L as $CaCO_3$)	130	130	160	180
Noncarbonate hardness (mg/L as $CaCO_3$)	38	42	21	0
Calcium (mg/L as Ca)	38	40	47	53
Magnesium (mg/L as Mg)	7.8	8.5	10	11
Sodium (mg/L as Na)	13	15	20	64
Potassium (mg/L as K)	1.1	1.2	1.3	2.3
Alkalinity (mg/L as $CaCO_3$)	90	90	140	184
Sulfate (mg/L as SO_4)	46	51	45	110
Chloride (mg/L as Cl)	12	14	16	11
Fluoride (mg/L as F)	.2	.3	.1	.2
Silica (mg/L as SiO_2)	9.7	9.7	11	8.5
Dissolved solids, calculated, sum (mg/L)	182	199	240	371
Nitrogen, nitrite (mg/L as N)	.007	.01	--	.01
Nitrate plus nitrite (mg/L as N)	.17	.01	.42	.05
Nitrogen ammonia (mg/L as N)	--	--	--	.01
Nitrogen, ammonia plus organic (mg/L as N)	--	--	--	.2
Phosphorus, ortho (mg/L as P)	.01	.01	--	.01
Aluminum (µg/L as Al)	--	--	700	10
Iron (µg/L as Fe)	70	2,900	3,300	220
Manganese (µg/L as Mn)	190	280	350	500
Zinc (µg/L as Zn)	--	--	--	10

HUNTINGDON COUNTY OBSERVATION WELL (HU-301)

Historical water-level fluctuations.—Water-level hydrographs for the years of 1972, 1988, and 1989 were consistently above average and may be part of a long-term cycle (fig. 27).

Geophysical logging.—Borehole-geophysical data show the total depth of the borehole has decreased from 105 to 103 ft bls and that it is cased with 6-in. casing to 18 ft bls (fig. 28). The caliper log shows two notable fractures located at 38.5 and 85 ft bls. Water cascades into the borehole at approximately 38.5 ft bls, moves vertically downward, and exits the borehole through a fracture at 85 ft as indicated by the fluid-temperature log. This fluid-receiving zone correlates to a fracture shown on the caliper log and as a point of lowest resistance shown on the single-point-resistance log. Brine tracing at 65 ft was inconclusive, but some flow probably occurs at less than the detection limit of 0.5 gal/min.

Single-well pumping analysis.—A single-well aquifer test was conducted by pumping well Hu-301 for about 1/2-hour at a rate of 7.5 gal/min on October 29, 1991. The specific capacity of the well was 1.5 (gal/min)/ft. The data could not be compared to previous data because of a malfunctioning pump on October 17, 1969. The water level in well Hu-301 recovered to within 0.37 ft after 30 min.

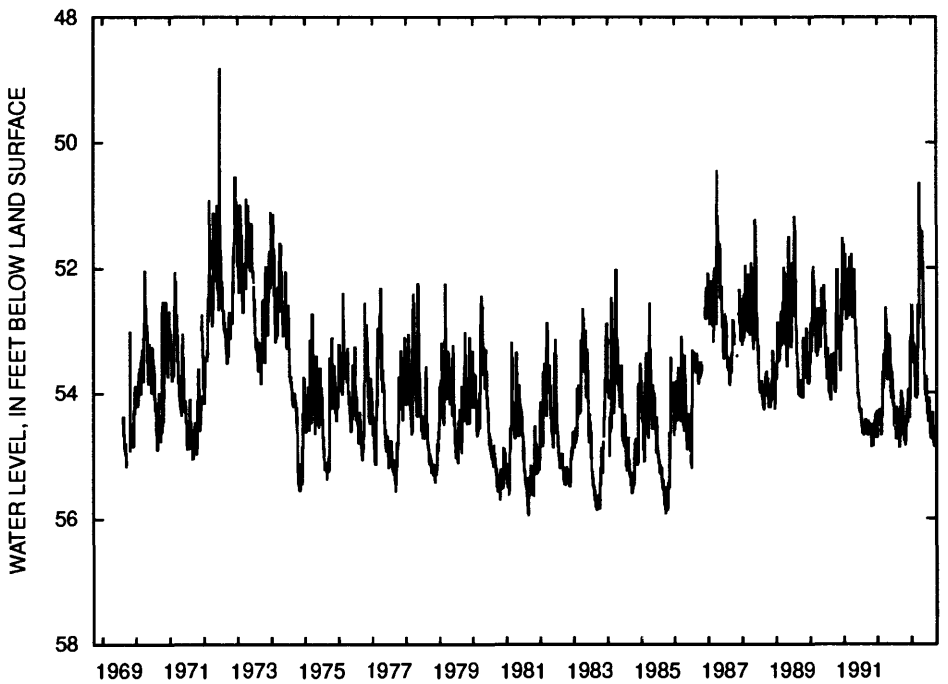

Figure 27. Hydrograph of Huntingdon County observation well Hu-301 for period of record to September 30, 1993.

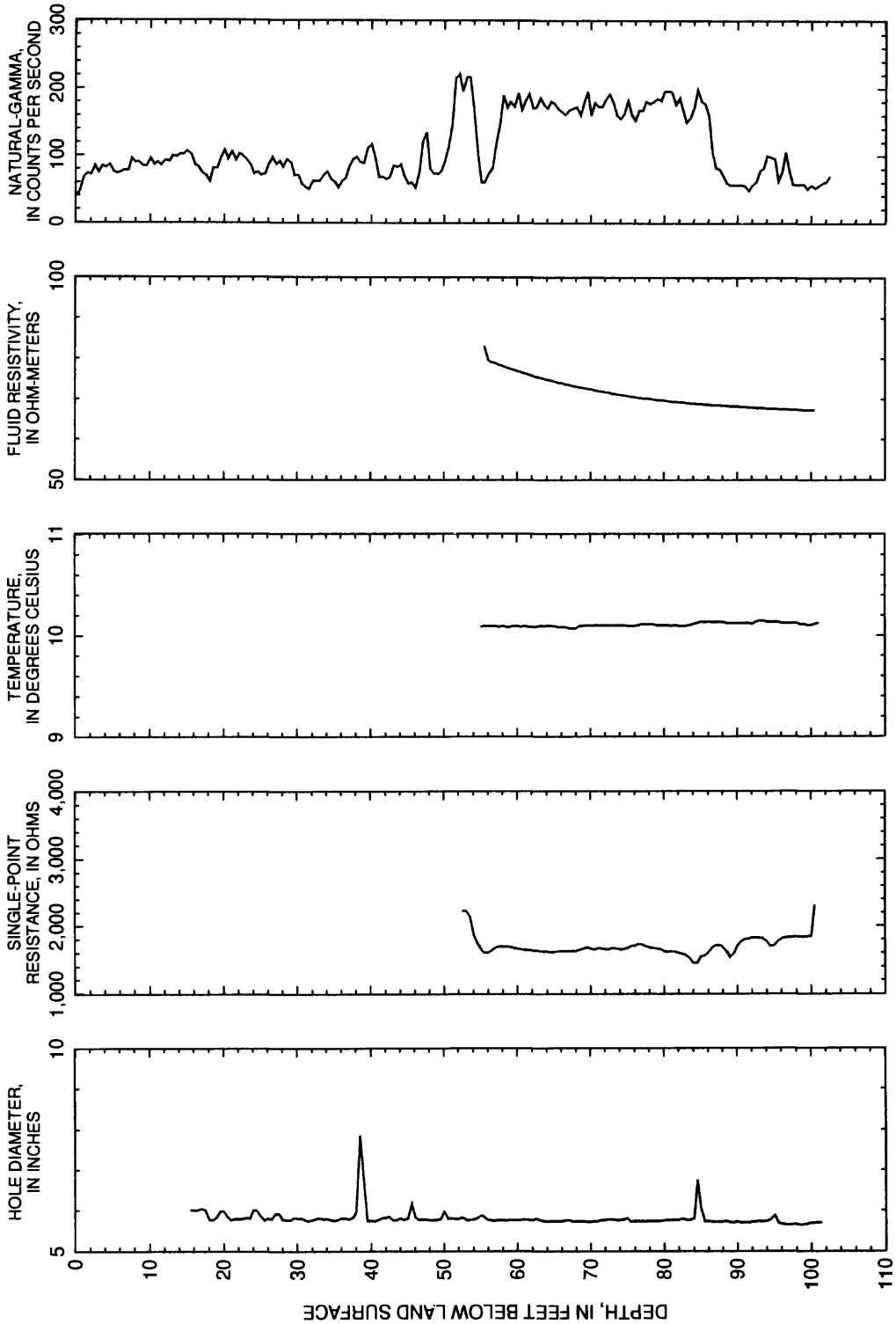

Figure 28. Geophysical logs for Huntingdon County observation well Hu-301.

Water-quality characteristics.—The water quality is very similar to that reported in a previous analysis (table 14). The concentrations of dissolved iron and manganese were considerably lower than the previous analysis. This reduction may be related to a difference in sampling equipment or technique.

Evaluation.—The current physical and chemical data from Hu-301 determined from geophysical logs and water-quality data are consistent with previous data in most respects, suggesting water-level data is representative of current local ground-water conditions.

Table 14. *Records of water quality for Huntingdon County observation well Hu-301*

[All constituent concentrations are dissolved; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, no data]

Constituents	Date sample collected	
	Sept. 17, 1969	Oct. 29, 1991
Specific conductance (µS/cm)	275	270
pH	8.2	7.8
Water temperature (°C)	--	11
Dissolved oxygen (mg/L as O_2)	--	5.8
Total hardness (mg/L as $CaCO_3$)	120	180
Noncarbonate hardness (mg/L as $CaCO_3$)	0	45
Calcium (mg/L as Ca)	30	65
Magnesium (mg/L as Mg)	11	3.6
Sodium (mg/L as Na)	12	2.8
Potassium (mg/L as K)	.6	1
Alkalinity (mg/L as $CaCO_3$)	135	132
Sulfate (mg/L as SO_4)	14	20
Chloride (mg/L as Cl)	1.7	12
Fluoride (mg/L as F)	.2	.10
Silica (mg/L as SiO_2)	13	5.9
Dissolved solids, calculated, sum (mg/L)	167	190
Nitrogen, nitrite (mg/L as N)	--	.010
Nitrate plus nitrite (mg/L as N)	--	2.6
Nitrogen ammonia (mg/L as N)	--	.01
Nitrogen, ammonia plus organic (mg/L as N)	--	.20
Phosphorus, ortho (mg/L as P)	--	.05
Aluminum (µg/L as Al)	--	10
Iron (µg/L as Fe)	2,900	9
Manganese (µg/L as Mn)	20	1
Zinc (µg/L as Zn)	--	10

JEFFERSON COUNTY OBSERVATION WELL (JE-23)

Historical water-level fluctuations.—Average water levels show seasonal variations from 1968 to mid-1972. In early 1974, water levels declined consistently to a depth approximately 12 ft below the established normal then stabilized to the present (1993) (fig. 29). This well is in close proximity to a coal strip mine area and apparently has been affected by that activity.

Geophysical logging.—Borehole-geophysical data show the total depth of the borehole is 100 ft bls and that it is cased with 6-in. casing to 33 ft bls. The caliper log shows three distinct fracture zones located at 34, 42, 53, 55, and 70-75 ft bls. Two fluid-resistivity logs run about 1 hour apart show a sudden decrease in concentrations of dissolved solids in the borehole water (increase in fluid resistivity) and a 2-ft rise in static water level. For an unknown reason, during geophysical logging, the aquifer apparently began to produce water into the borehole at the 34-ft fracture (from fluid-resistivity log) (fig. 30). This was probably caused by a nearby pump shutting off.

Single-well pumping analysis.—A single-well aquifer test was conducted by pumping well Je-23 for 90 min at a rate of about 9 gal/min on April 13, 1992. The specific capacity of the well was 0.2 (gal/min)/ft. Estimated specific capacity from data collected on May 22, 1968, is 0.5 (gal/min)/ft. The discharge water during the pumping test was black, possibly because of suspended coal particles, and did not become clear until 71 min into the test.

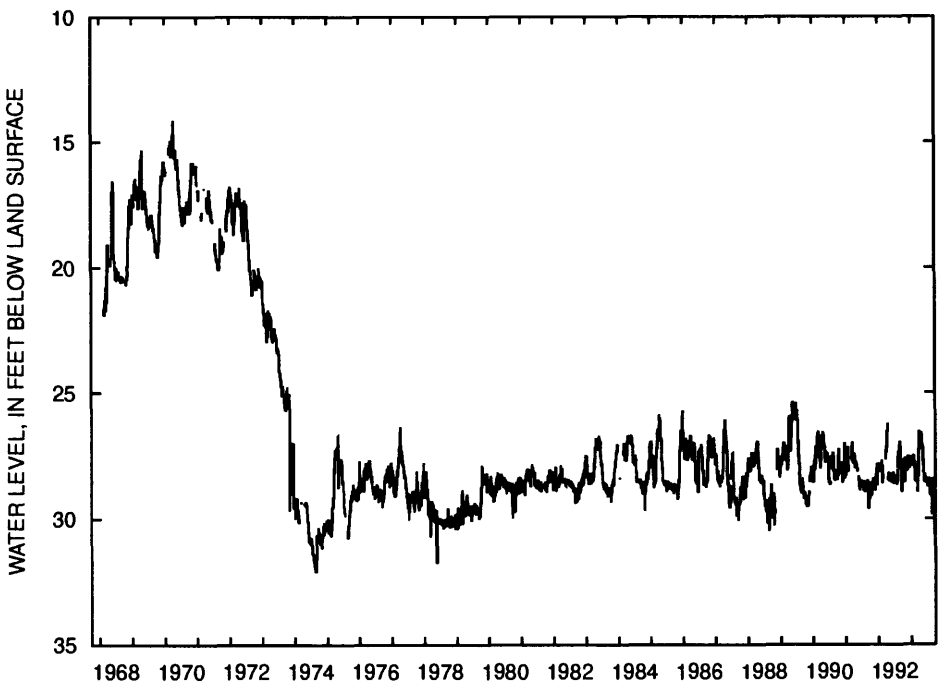

Figure 29. Hydrograph of Jefferson County observation well Je-23 for period of record to September 30, 1993.

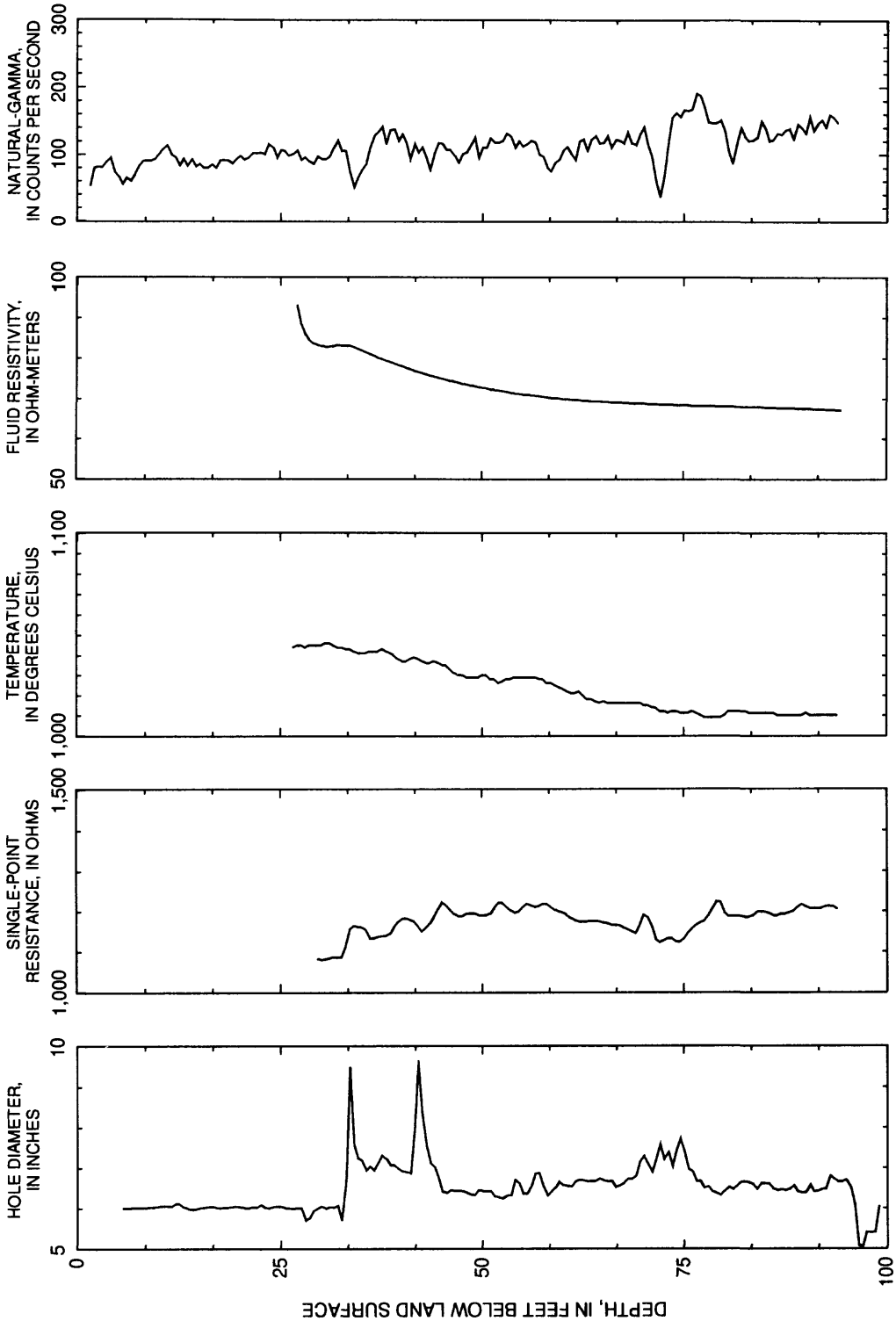

Figure 30. Geophysical logs for Jefferson County observation well Je-23.

Water-quality characteristics.—The water quality of Je-23 shows consistency, with minor variations over time, except for concentrations of iron, which range from 2,500 to 9,000 µg/L (table 15).

Evaluation.—Water-level fluctuations show an unusual decline from mid-1972 to early 1974 when a new local water-table equilibrium was established, probably caused by local coal strip mining operations. Also, geophysical logs and pumping data show changes in subsurface hydraulic conditions that indicate borehole clogging. This well may not be an accurate indicator of aquifer response to climatic variations.

Table 15. *Records of water quality for Jefferson County observation well Je-23*

[All constituent concentrations are dissolved; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, no data]

Constituents	Date sample collected					
	May 22, 1968	Nov. 7, 1973	May 7, 1974	Nov. 1, 1974	May 5, 1975	Apr. 13, 1992
Specific conductance (µS/cm)	575	512	530	516	420	677
pH	7.8	7.3	6.3	6.5	6.7	7.6
Water temperature (°C)	12	10	10	12.9	10.9	10
Dissolved oxygen (mg/L as O_2)	--	--	--	--	--	3.2
Total hardness (mg/L as $CaCO_3$)	280	240	290	260	270	340
Noncarbonate hardness (mg/L as $CaCO_3$)	200	110	200	140	150	180
Calcium (mg/L as Ca)	92	75	98	84	91	110
Magnesium (mg/L as Mg)	13	12	12	12	11	16
Sodium (mg/L as Na)	2	1.7	1.5	1.5	1.5	1.9
Potassium (mg/L as K)	.6	1.7	1.4	1.1	1.3	1.4
Alkalinity (mg/L as $CaCO_3$)	85	130	93	119	121	160
Sulfate (mg/L as SO_4)	201	130	160	140	160	200
Chloride (mg/L as Cl)	2.5	2.8	3.2	2.5	4.5	5.7
Fluoride (mg/L as F)	.2	.3	.2	.2	.1	.2
Silica (mg/L as SiO_2)	6.2	5.9	6.7	6.7	6.9	6.9
Dissolved solids, calculated, sum (mg/L)	369	318	344	326	356	442
Nitrogen, nitrite (mg/L as N)	--	.01	--	--	.01	.01
Nitrate plus nitrite (mg/L as N)	--	.04	--	--	.1	.05
Nitrogen ammonia (mg/L as N)	--	--	--	--	--	.01
Nitrogen, ammonia plus organic (mg/L as N)	--	--	--	--	--	.2
Phosphorus, ortho (mg/L as P)	--	.001	--	--	.01	.01
Aluminum (µg/L as Al)	--	1,500	--	--	--	10
Iron (µg/L as Fe)	--	9,000	4,700	5,100	6,200	2,500
Manganese (µg/L as Mn)	--	1,100	1,100	1,100	1,300	1,200
Zinc (µg/L as Zn)	--	14	--	--	--	10

LYCOMING COUNTY OBSERVATION WELL (LY-112)

Historical water-level fluctuations.—Water levels from 1968 to present reflect only seasonal variations; some low water levels from 1980 to 1984 and 1991 appear to be related to less than normal precipitation. The sharp recharge spike in 1972 is from heavy rains caused by hurricane Agnes (fig. 31).

Geophysical logging.—Borehole-geophysical data show the total depth of the borehole is 200 ft bls and that it is cased with 6-in. casing to 19 ft bls. The fluid-resistivity log shows a change in slope at 122 ft bls that correlates to a fracture shown on the caliper log, indicating a possible water-producing zone (fig. 32). However, the fluid-resistivity and fluid-temperature logs suggest no measurable vertical borehole flow.

Single-well pumping analysis.—A single-well aquifer test was conducted by pumping well Ly-112 for about 1/2-hour at a rate of about 5 gal/min on November 13, 1991. The specific capacity of the well is 0.14 (gal/min)/ft. This compares closely to the specific capacity of 0.1 (gal/min)/ft calculated from data collected on November 17, 1971. Water levels recovered within 10 days.

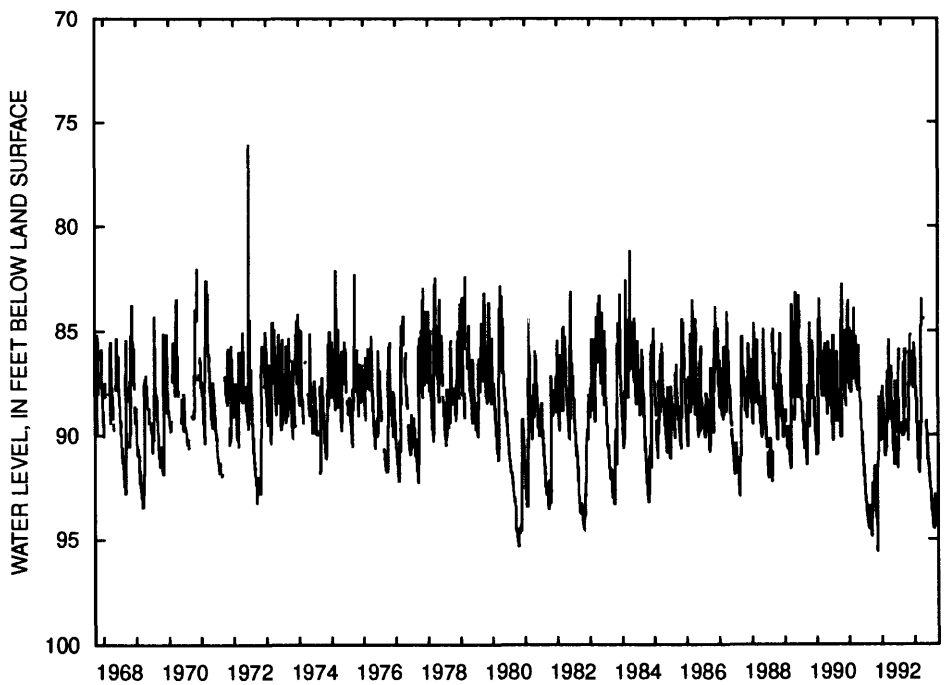

Figure 31. Hydrograph of Lycoming County observation well Ly-112 for period of record to September 30, 1993.

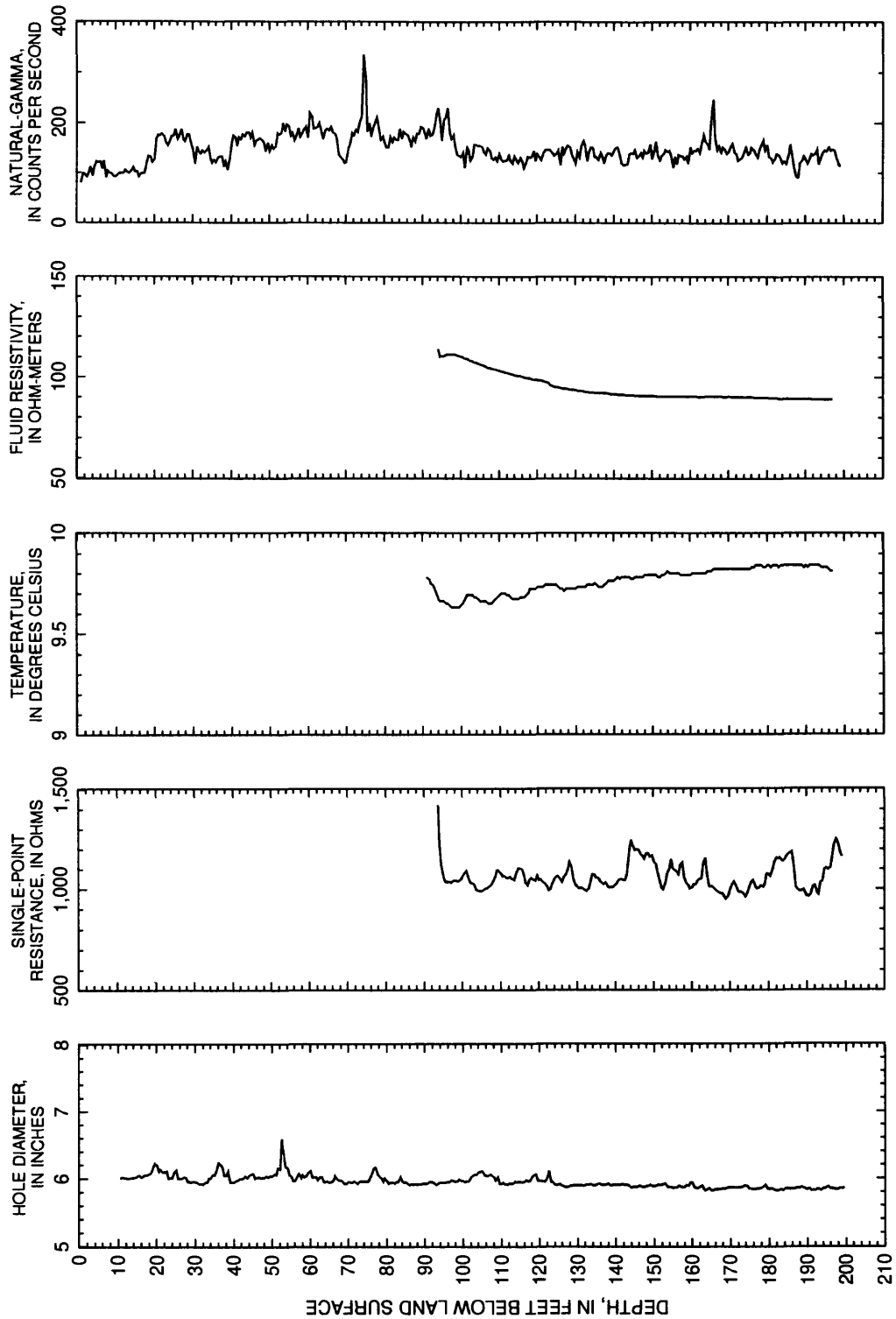

Figure 32. Geophysical logs for Lycoming County observation well Ly-112.

Water-quality characteristics.—Several water-quality constituents have changed slightly since the last sampling on November 19, 1968 (table 16). Prominent changes were reduced concentrations of iron and manganese, which may be attributed to sampling procedures such as filtration, length, and rate of pumping.

Evaluation.—The physical characteristics and observed ground-water fluctuations of Ly-112 are reasonably consistent over the 24-year period of record. Low nutrient concentrations and the rural setting indicate no changes in local land use. Therefore, the change in chemistry may be because of sampling or laboratory techniques or normal variability.

Table 16. *Records of water quality for Lycoming County observation well Ly-112*

[All constituent concentrations are dissolved; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, no data]

Constituent	Date sample collected	
	Nov. 19, 1968	Nov. 13, 1992
Specific conductance (µS/cm)	308	260
pH	7.9	7.7
Water temperature (°C)	--	10.5
Dissolved oxygen (mg/L as O_2)	--	9.2
Total hardness (mg/L as $CaCO_3$)	125	120
Noncarbonate hardness (mg/L as $CaCO_3$)	71	45
Calcium (mg/L as Ca)	44	42
Magnesium (mg/L as Mg)	3.5	3.5
Sodium (mg/L as Na)	6.7	7.9
Potassium (mg/L as K)	1.4	2.6
Alkalinity (mg/L as $CaCO_3$)	--	74
Sulfate (mg/L as SO_4)	11	17
Chloride (mg/L as Cl)	45	30
Fluoride (mg/L as F)	0	.10
Silica (mg/L as SiO_2)	9.4	10
Dissolved solids, calculated, sum (mg/L)	165	158
Nitrogen, nitrite (mg/L as N)	--	.01
Nitrate plus nitrite (mg/L as N)	--	1.4
Nitrogen ammonia (mg/L as N)	--	.03
Nitrogen, ammonia plus organic (mg/L as N)	--	.4
Phosphorus, ortho (mg/L as P)	--	.03
Aluminum (µg/L as Al)	--	10
Iron (µg/L as Fe)	290	23
Manganese (µg/L as Mn)	70	8
Zinc (µg/L as Zn)	--	90

McKean County Observation Well (Mc-110)

Historical water-level fluctuations.—A hydrograph of daily water levels for the period of record show a sudden rise in water levels in 1986 to the present, which may correspond to some water-receiving zones becoming clogged (fig. 33).

Geophysical logging.—Borehole-geophysical data show the total depth of the borehole is 104 ft bls and that it is cased with 6-in. casing to 26 ft bls. The caliper log shows numerous fractures from 26 to 72 ft bls. The gamma log shows a change in lithology at 62 ft bls and a sharp spike at 86.5 to 88.5 ft, possibly indicating a black shale bed. The fluid-resistivity and fluid-temperature logs indicate fluid-producing zones at 30, 45, and 65 ft bls, and a fluid-receiving zone at 103 ft bls. Brine tracing confirms vertical borehole flow at 50 and 80 ft at a rate of 0.6 and 1.3 gal/min, respectively (fig. 34).

Single-well pumping analysis.—A single-well aquifer test was conducted by pumping well Mc-110 for 1 hour at a rate of 9 gal/min on April 16, 1992. The specific capacity of the well is 0.7 (gal/min)/ft. This compares closely to 0.8 (gal/min)/ft calculated from an aquifer test on October 24, 1973. After the single-well pumping test on April 16, 1992, the static water level rose above prepumping levels by approximately 1.6 ft and slowly declined through June 1992 to approximate pre-test levels. The stress of pumping may have unclogged some water-producing fractures in the borehole with slightly greater hydraulic head than those that were open to the borehole before the test (fig. 35).

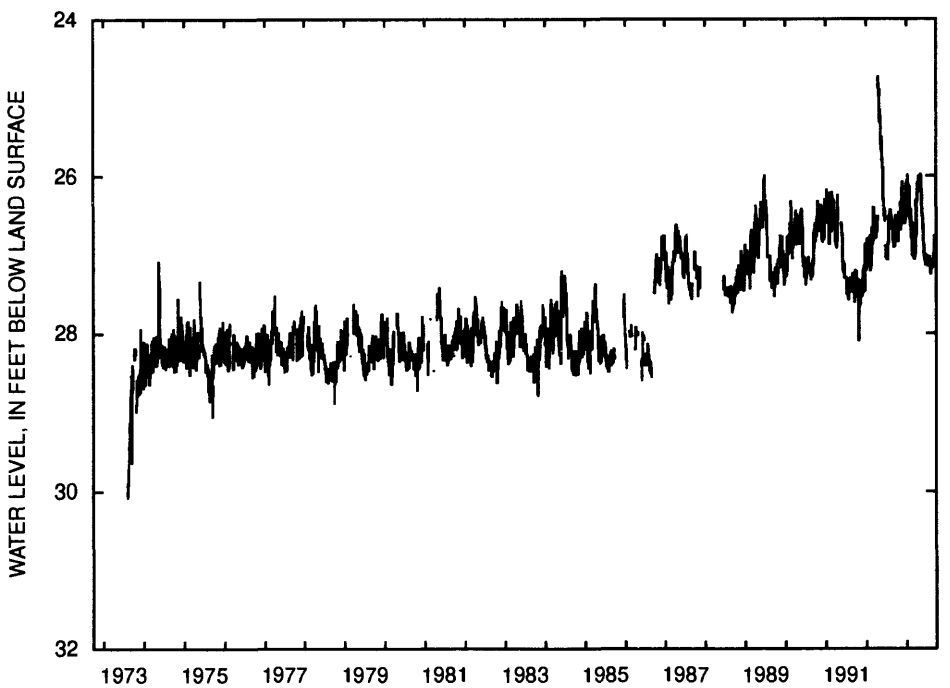

Figure 33. Hydrograph of McKean County observation well Mc-110 for period of record to September 30, 1993.

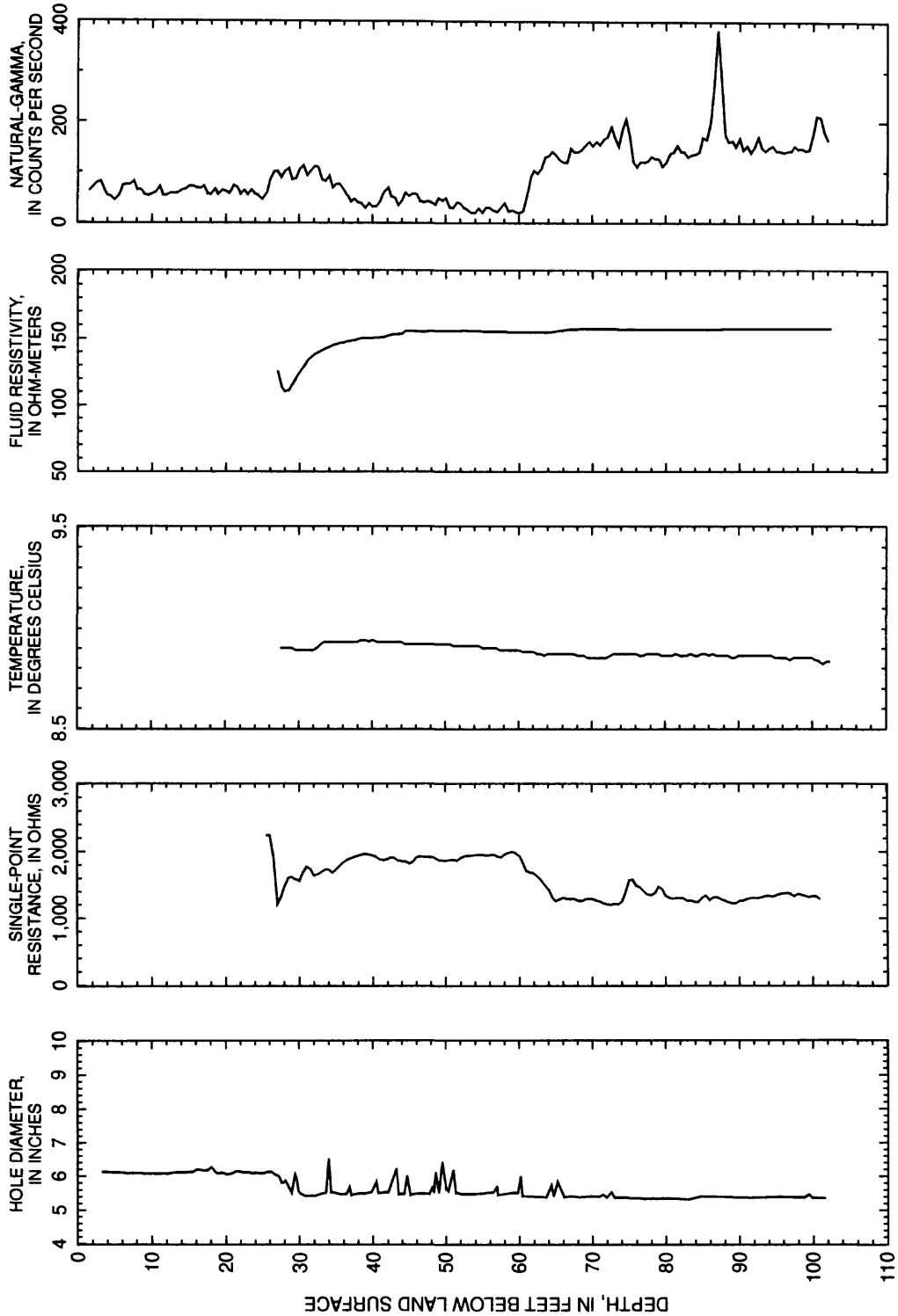

Figure 34. Geophysical logs for McKean County observation well Mc-110.

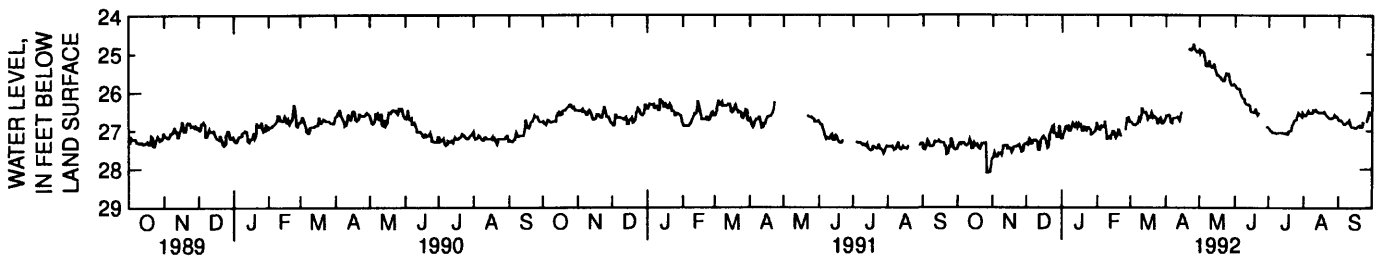

Figure 35. Hydrograph of McKean County observation well Mc-110 showing seasonal fluctuations and effect of single-well aquifer test on April 16, 1992.

Water-quality characteristics.—Mc-110 has been sampled five times over the period of record and concentrations of all water-quality constituents have remained nearly constant (table 17).

Evaluation.—Pumping and chemical analyses show change over a small range for the period of record. These data suggest that local aquifer conditions have remained relatively constant. However, an unknown condition has caused water levels to rise consistently from 1986 to the present.

Table 17. *Records of water quality for McKean County observation well Mc-110*

[All constituent concentrations are dissolved; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, no data]

Constituents	Date sample collected				
	Oct. 24, 1973	May 15, 1974	Nov. 4, 1974	May 20, 1975	Apr. 16, 1992
Specific conductance (µS/cm)	69	100	83	120	85
pH	6.8	7.5	6.4	6.5	7.8
Water temperature (°C)	--	11.5	9.9	12.6	9.5
Dissolved oxygen (mg/L as O_2)	--	--	--	--	0
Total hardness (mg/L as $CaCO_3$)	31	32	39	31	33
Noncarbonate hardness (mg/L as $CaCO_3$)	7	5	11	0	9
Calcium (mg/L as Ca)	8.9	9.1	12	9.2	9.2
Magnesium (mg/L as Mg)	2.2	2.2	2.3	2	2.5
Sodium (mg/L as Na)	.3	.4	.5	.2	.5
Potassium (mg/L as K)	1.5	1.4	1.1	1.3	1.1
Alkalinity (mg/L as $CaCO_3$)	24	27	29	33	24
Sulfate (mg/L as SO_4)	3.6	4.4	4.4	3.8	4.8
Chloride (mg/L as Cl)	.7	.6	1.1	1.1	5.3
Fluoride (mg/L as F)	.2	.2	.1	.1	.1
Silica (mg/L as SiO_2)	6.3	--	6.9	7.3	7.5
Dissolved solids, calculated, sum (mg/L)	46	52	53	46	54
Nitrogen, nitrite (mg/L as N)	.01	--	--	.01	.01
Nitrate plus nitrite (mg/L as N)	.1	--	--	.1	.05
Nitrcgen ammonia (mg/L as N)	--	--	--	--	.01
Nitrogen, ammonia plus organic (mg/L as N)	--	--	--	--	.2
Phosphorus, ortho (mg/L as P)	.002	--	--	.01	.01
Aluminum (µg/L as Al)	150	--	--	--	10
Iron (µg/L as Fe)	7,700	10,000	6,900	760	8,300
Manganese (µg/L as Mn)	110	550	570	580	670
Zinc (µg/L as Zn)	65	--	20	--	10

SCHUYLKILL COUNTY OBSERVATION WELL (SC-296)

Historical water-level fluctuations.—Ground-water levels reflect seasonal variations and a small consistent minor rise in water levels over the period of record (fig. 36).

Geophysical logging.—Borehole-geophysical data show the total depth of the borehole has decreased from 242 to 239 ft bls and that it is cased with 6-in. casing to 39 ft bls (fig. 37). The caliper log shows two notable fractures located at 42 and 64 ft bls. The fluid-resistivity log suggests that there are two possible water-producing zones located at 60-64 and 94 ft bls and a possible fluid-receiving zone at 159 ft bls. The caliper, gamma, single-point-resistance, and driller logs indicate a lithologic change between 160 to 170 ft bls where shale is underlain by sandstone. Brine tracing conducted on July 7, 1975, shows no vertical borehole flow at 60 or 200 ft bls and downward flow at 140 ft bls of 1 gal/min. The geophysical logs run on November 21, 1991, and July 1, 1975, are similar.

Single-well pumping analysis.—A single-well aquifer test was conducted by pumping well Sc-296 for about 1/2-hour at a rate of about 4 gal/min on November 21, 1991. The specific capacity of the well is 0.10 (gal/min)/ft. Static water level returned to normal 2 days after the single-well aquifer test. Previous drawdown data are not available for comparison.

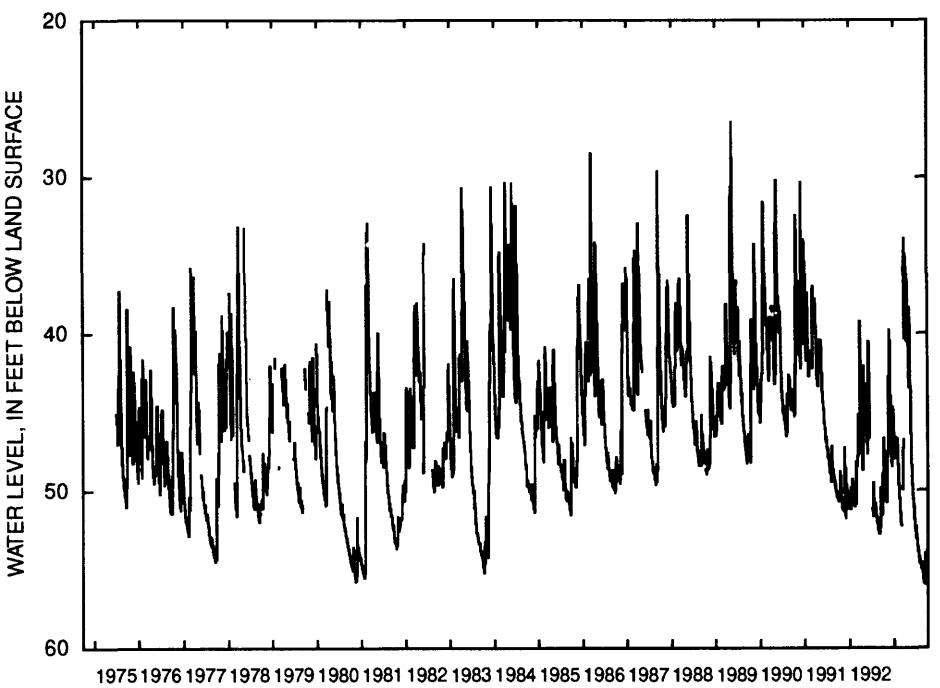

Figure 36. Hydrograph of Schuylkill County observation well Sc-296 for period of record to September 30, 1993.

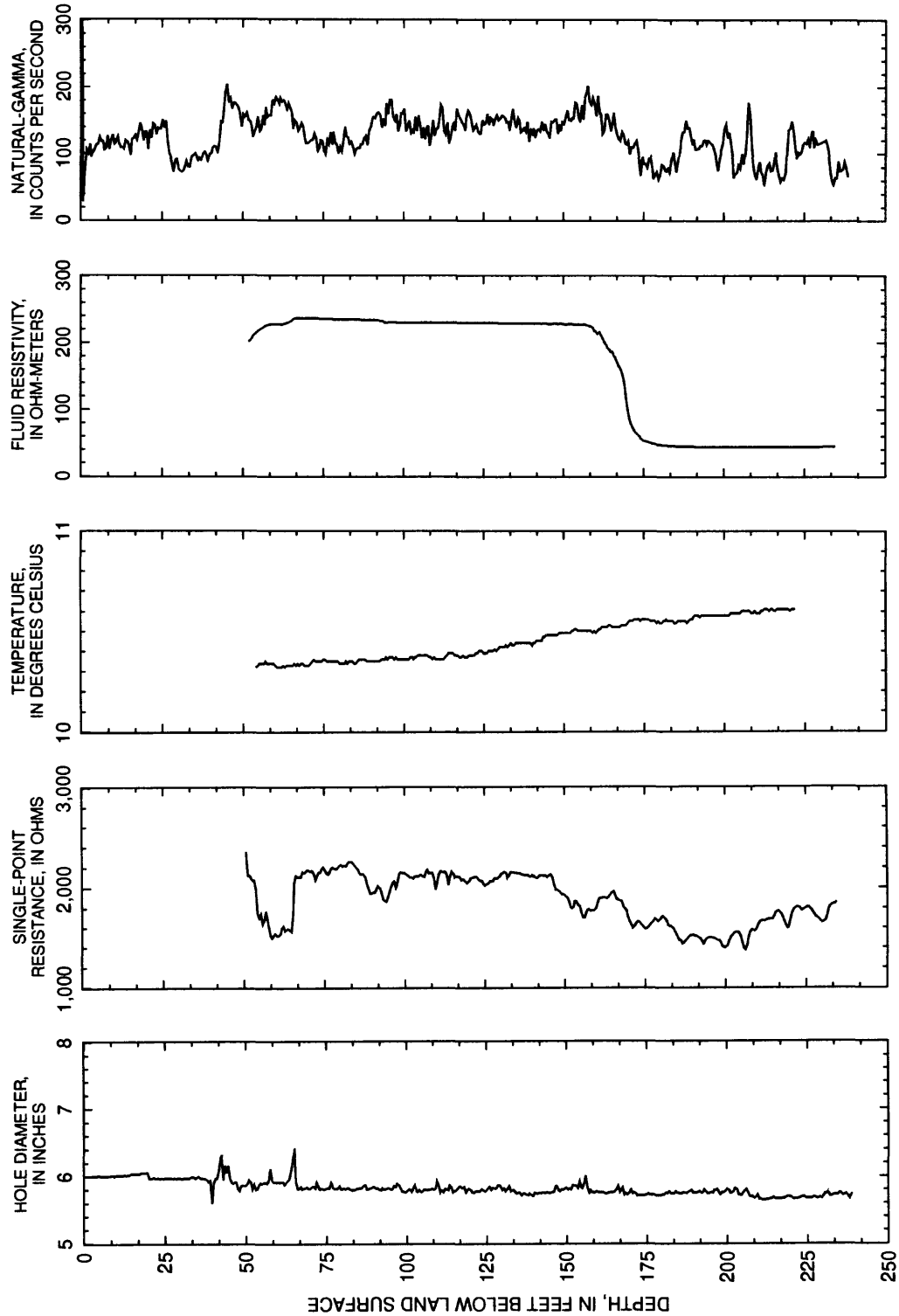

Figure 37. Geophysical logs for Schuylkill County observation well Sc-296.

Water-quality characteristics.—The water quality was not analyzed prior to November 21, 1991; therefore, no comparisons of water-quality characteristics can be made (table 18). Constituents sampled on this date will be used as a background for future reference.

Evaluation.—A minor consistent rise in water levels over the period of record currently appears to be the result of a long-term trend. The immediate area has no sign of development or change in land use. Comparison of current to previous geophysical data show the well's physical condition has not changed (except for an apparent 3-ft decrease in total depth) since the last logging. According to available data, this well is capable of being an accurate indicator of aquifer response to climatic variations.

Table 18. *Records of water quality for Schuylkill County observation well Sc-296*

[All constituent concentrations are dissolved; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter]

Constituents	Date sample collected
	Nov. 11, 1991
Specific conductance (µS/cm)	66
pH	6.1
Water temperature (°C)	12
Dissolved oxygen (mg/L as O_2)	7.2
Total hardness (mg/L as $CaCO_3$)	25
Noncarbonate hardness (mg/L as $CaCO_3$)	1
Calcium (mg/L as Ca)	7.4
Magnesium (mg/L as Mg)	1.5
Sodium (mg/L as Na)	1.8
Potassium (mg/L as K)	.9
Alkalinity (mg/L as $CaCO_3$)	24
Sulfate (mg/L as SO_4)	5.6
Chloride (mg/L as Cl)	1.8
Fluoride (mg/L as F)	.1
Silica (mg/L as SiO_2)	8.2
Dissolved solids, calculated, sum (mg/L)	42
Nitrogen, nitrite (mg/L as N)	.01
Nitrate plus nitrite (mg/L as N)	.39
Nitrogen ammonia (mg/L as N)	.021
Nitrogen, ammonia plus organic (mg/L as N)	.20
Phosphorus, ortho (mg/L as P)	.03
Aluminum (µg/L as Al)	10
Iron (µg/L as Fe)	130
Manganese (µg/L as Mn)	11
Zinc (µg/L as Zn)	130

Historical water-level fluctuations.—Average water level decreased from 1972 to 1976, then stabilized and reflected only seasonal fluctuations from 1977 to 1984. After 1984, average water levels became higher with increased fluctuations uncharacteristic of previous years, suggesting local ground-water interference or clogging of some receiving zones (fig. 38).

Geophysical logging.—Borehole-geophysical data show the depth of the borehole is 103 ft bls and that it is cased with 6-in. casing to 44 ft bls (fig. 39). The gamma log indicates lithology changes at 44, 58, and 70 ft bls. The brine-trace log shows no vertical borehole flow at 60 ft bls. The suite of geophysical logs run on September 11, 1986, is consistent with logs run on April 15, 1992.

Single-well pumping analysis.—A single-well aquifer test was conducted by pumping the well for 90 min at a rate of about 7 gal/min on April 15, 1992. The water-level drawdown caused by pumping indicates the well produces water from fractures that are bounded near the well. Specific capacity is 0.9 (gal/min)/ft. Water-level data shows well Wr-50 recovered to within 0.15 ft of the original water level in 1 hour.

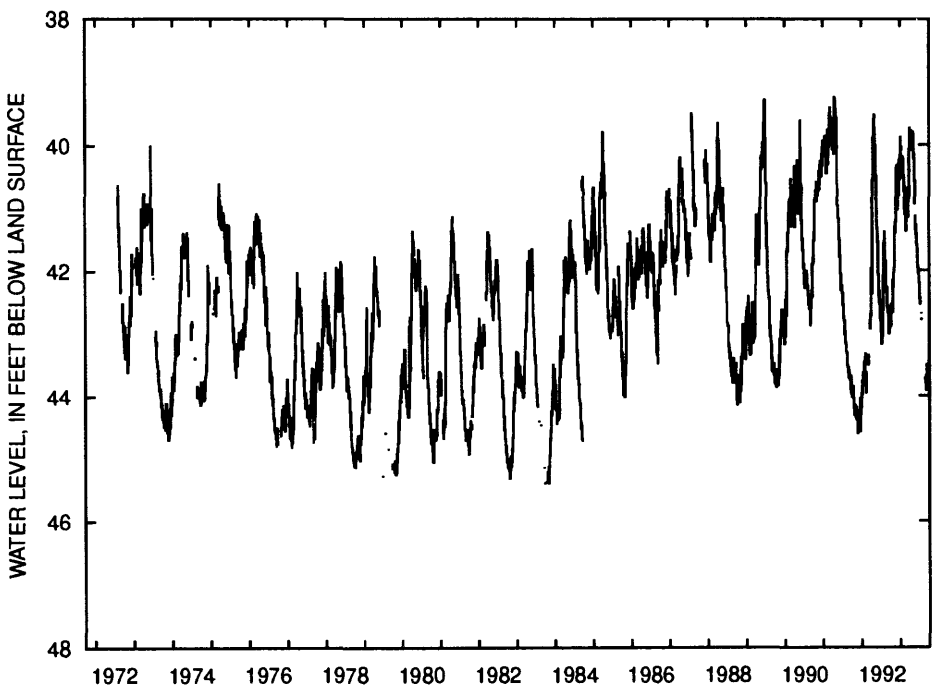

Figure 38. Hydrograph of Warren County observation well Wr-50 for period of record to September 30, 1993.

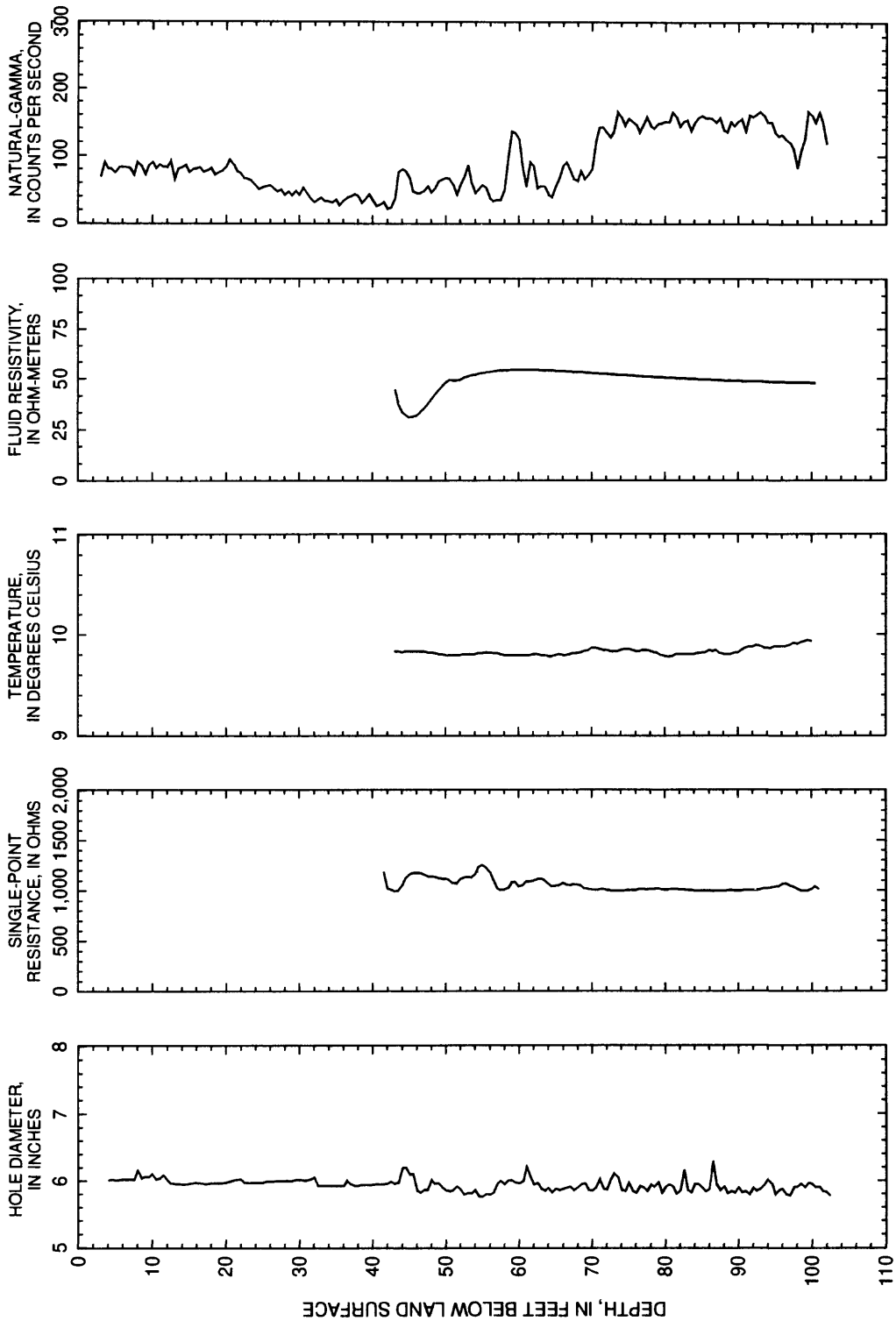

Figure 39. Geophysical logs for Warren County observation well Wr-50.

Water-quality characteristics.—Concentrations of water-quality constituents on April 15, 1992, are very similar to those from September 20, 1984, except for a slight increase in concentrations of sulfate and manganese (table 19).

Evaluation.—The changes in water-level fluctuations beginning in 1984 may be caused by local pumping interference or by clogging of some receiving zones. This well may not be an accurate indicator of local changes in ground-water storage.

Table 19. *Records of water quality for Warren County observation well Wr-50*

[All constituent concentrations are dissolved; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, no data]

Constituents	Date sample collected			
	Sept. 20, 1984	Aug. 28, 1985	July 28, 1987	Apr. 15, 1992
Specific conductance (µS/cm)	310	--	310	300
pH	7.4	--	5.2	7.8
Water temperature (°C)	11	--	--	9.5
Dissolved oxygen (mg/L as O_2)	--	--	--	1
Total hardness (mg/L as $CaCO_3$)	132	129	129	132
Noncarbonate hardness (mg/L as $CaCO_3$)	--	--	--	--
Calcium (mg/L as Ca)	38	36	36	38
Magnesium (mg/L as Mg)	8.9	9.4	9.4	9.1
Sodium (mg/L as Na)	13	9.8	9.8	10
Potassium (mg/L as K)	1.5	1.0	1.0	1.1
Alkalinity (mg/L as $CaCO_3$)	140	148	142	130
Sulfate (mg/L as SO_4)	13.0	11.0	15.0	16.0
Chloride (mg/L as Cl)	1.6	<1.0	2.0	1.4
Fluoride (mg/L as F)	.2	.2	.2	.3
Silica (mg/L as SiO_2)	15	--	--	15
Dissolved solids, calculated, sum (mg/L)	--	--	--	170
Nitrogen, nitrite (mg/L as N)	--	--	--	.01
Nitrate plus nitrite (mg/L as N)	--	.04	<.04	.05
Nitrogen ammonia (mg/L as N)	--	--	--	.02
Nitrogen, ammonia plus organic (mg/L as N)	--	--	--	.2
Phosphorus, ortho (mg/L as P)	--	.01	.15	.01
Aluminum (µg/L as Al)	--	--	--	<10
Iron (µg/L as Fe)	1,100	--	--	1,100
Manganese (µg/L as Mn)	260	--	--	320
Zinc (µg/L as Zn)	--	--	--	<10

WASHINGTON COUNTY OBSERVATION WELL (Ws-155)

Historical water-level fluctuations.—Water-level data reflect a consistent increase from the beginning of the period of record in 1971 until early 1974, a slight downward trend from 1974 until early 1982, then from 1982 to present, mid to late summer water-level spikes characteristic of transient pumpage (fig. 40).

Geophysical logging.—Borehole-geophysical data show the total depth of the well is 135 ft bls and that it is cased with 6-in. casing to 19 ft bls (fig. 41). The caliper log shows minor fractures at 66, 78, and 102 ft bls. The caliper log shows major fractures at 101 and 115-117 ft bls. The fluid-resistivity log shows almost no change between 40 and 100 ft bls, suggesting a zone of vertical borehole flow. However, the fluid-temperature log shows a geothermal gradient, which indicates no vertical borehole flow.

Single-well pumping analysis.—A single-well aquifer test was conducted by pumping well Ws-155 for about 1/4-hour at a rate of approximately 12 gal/min on April 9, 1992. The specific capacity of the well is 0.4 (gal/min)/ft, which is a close comparison to 0.6 (gal/min)/ft on July 1, 1971.

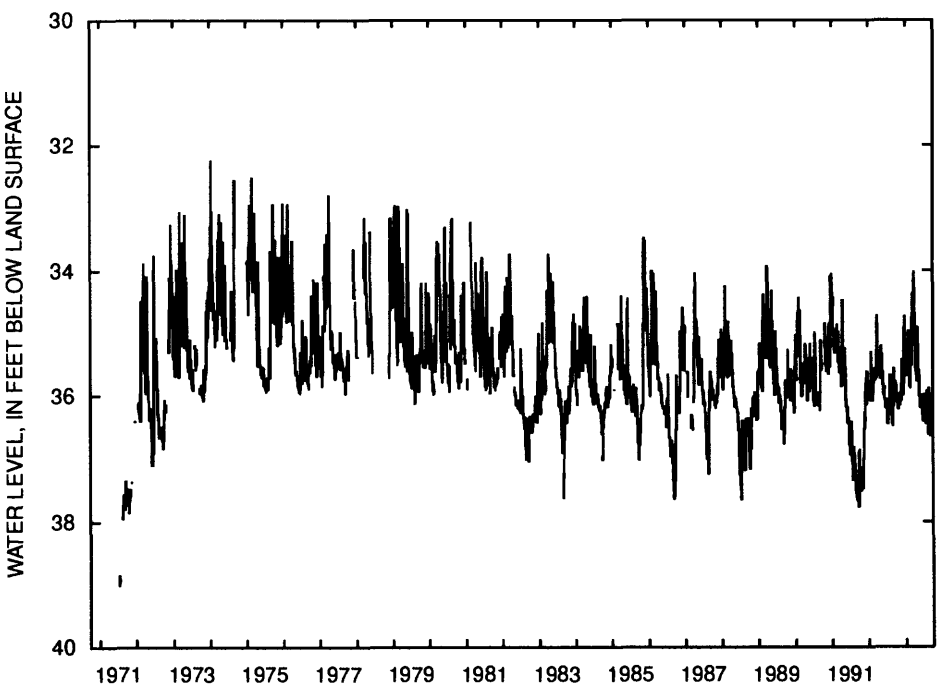

Figure 40. Hydrograph of Washington County observation well Ws-155 for period of record to September 30, 1993.

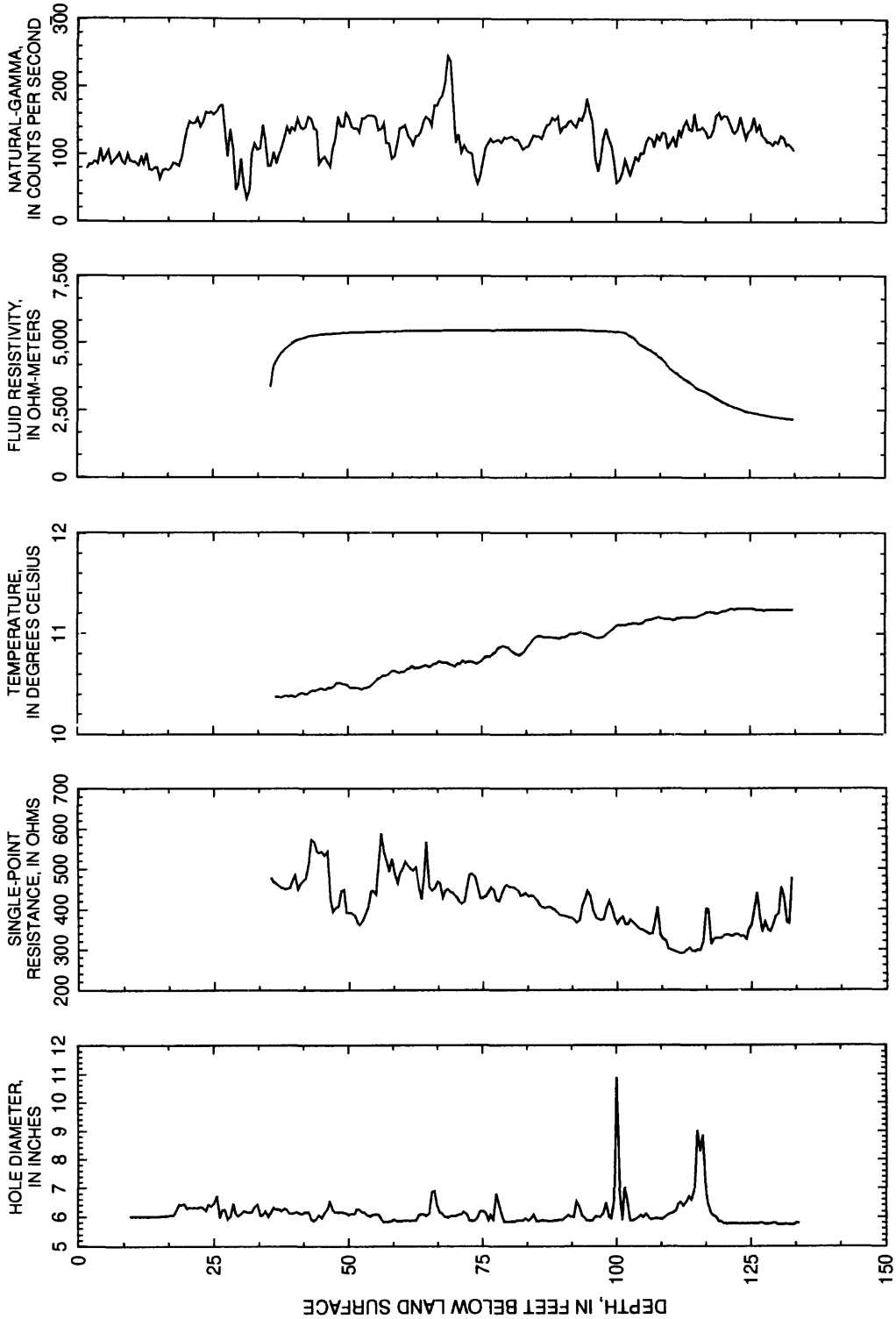

Figure 41. Geophysical logs for Washington County observation well Ws-155.

Water-quality characteristics.—Water-quality data show concentrations of total hardness doubled from July 1, 1971, to April 9, 1992; concentrations of calcium, magnesium, and sulfate have increased (table 20). Concentrations of sodium have decreased, concentrations of iron decreased from 500 to 21 µg/L, and the remaining constituents are similar to previous data. Even though the percentage of some constituents has greatly changed, the concentration of total dissolved solids is relatively low.

Evaluation.—The geophysical and aquifer-test data are consistent and the water-quality data are generally consistent. However, water-level fluctuations, beginning in 1982, suggest that local pumping of nearby wells may be affecting local aquifer storage.

Table 20. *Records of water quality for Washington County observation well Ws-155*

[All constituent concentrations are dissolved; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, no data]

Constituents	Date sample collected		
	July 1, 1971	Aug. 23, 1983	Apr. 9, 1992
Specific conductance (µS/cm)	518	490	470
pH	8.2	7.9	8.15
Water temperature (°C)	--	12	12
Dissolved oxygen (mg/L as O_2)	--	--	2.4
Total hardness (mg/L as $CaCO_3$)	55	--	120
Noncarbonate hardness (mg/L as $CaCO_3$)	0	--	0
Calcium (mg/L as Ca)	15	27	34
Magnesium (mg/L as Mg)	4.3	6.6	7.8
Sodium (mg/L as Na)	102	83	68
Potassium (mg/L as K)	1.7	1.2	1.2
Alkalinity (mg/L as $CaCO_3$)	268	250	230
Sulfate (mg/L as SO_4)	3.7	18	23
Chloride (mg/L as Cl)	1.5	3.2	1.6
Fluoride (mg/L as F)	.6	.3	.3
Silica (mg/L as SiO_2)	9.8	11	12
Dissolved solids, calculated, sum (mg/L)	300	--	286
Nitrogen, nitrite (mg/L as N)	--	--	.01
Nitrate plus nitrite (mg/L as N)	--	--	.05
Nitrogen ammonia (mg/L as N)	--	--	.01
Nitrogen, ammonia plus organic (mg/L as N)	--	--	.2
Phosphorus, ortho (mg/L as P)	.0163	--	.01
Aluminum (µg/L as Al)	--	10	10
Iron (µg/L as Fe)	500	17	21
Manganese (µg/L as Mn)	40	30	33
Zinc (µg/L as Zn)	--	9	10

WESTMORELAND COUNTY OBSERVATION WELL (WE-300)

Historical water-level fluctuations.—Ground-water-level data indicate an upward trend over the period of record, and unusually low water levels in late 1984 correspond to less than average precipitation for that year (fig. 42).

Geophysical logging.—Borehole-geophysical data show the total depth of the borehole is 110 ft bls and that it is cased with 6.25-in. casing to 22 ft bls (fig. 43). The caliper log shows numerous fractures throughout the open-hole interval. The fluid-resistivity and fluid-temperature logs indicate possible minor vertical borehole flow. No previous geophysical logs are available for comparison.

Single-well pumping analysis.—A single-well aquifer test was conducted by pumping the well for about 20 min at a rate of approximately 12 gal/min on April 6, 1992. The specific capacity of the well is 0.3 (gal/min)/ft.

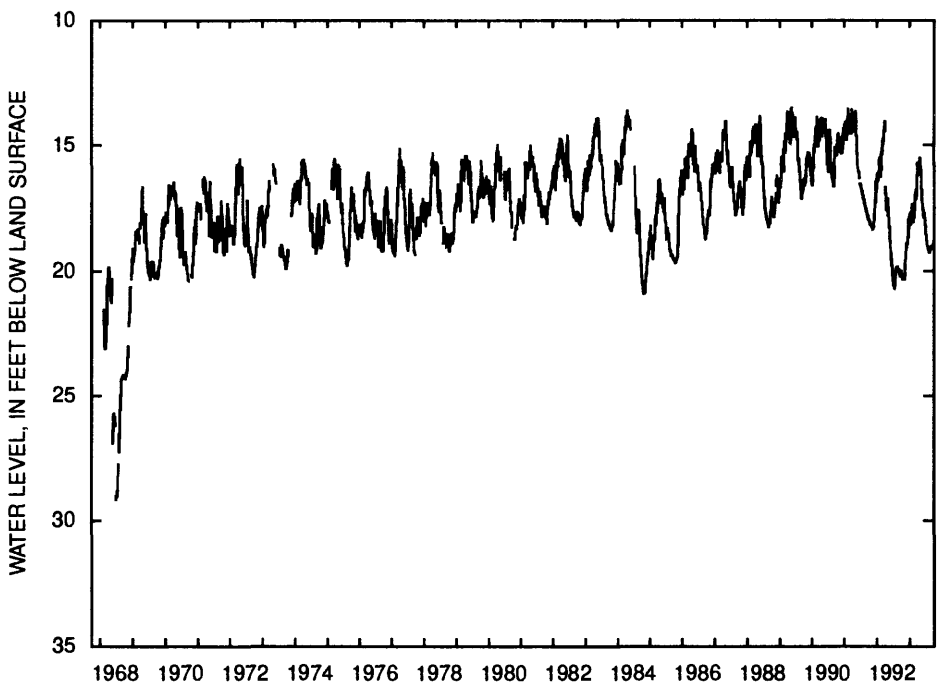

Figure 42. Hydrograph of Westmoreland County observation well We-300 for period of record to September 30, 1993.

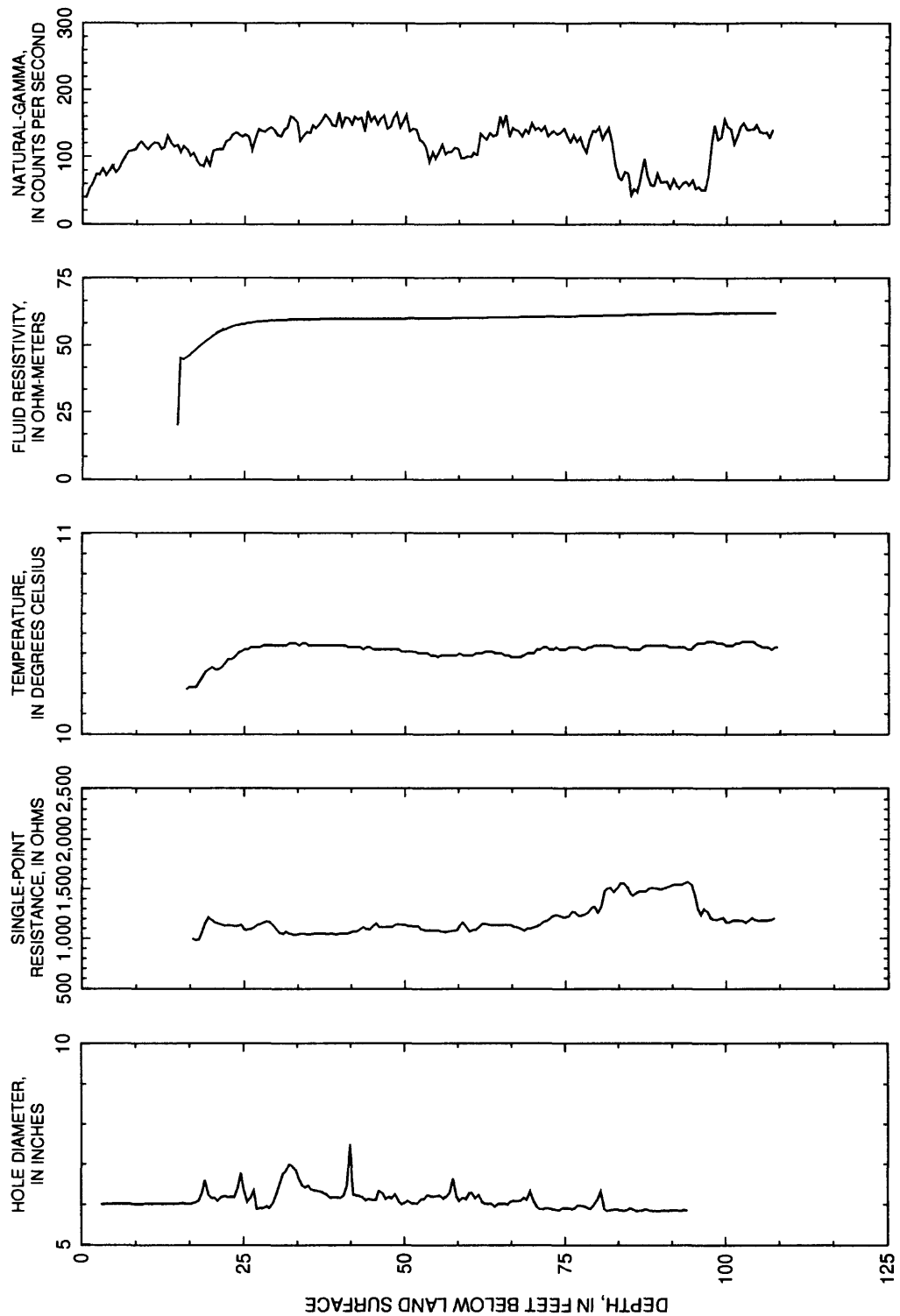

Figure 43. Geophysical logs for Westmoreland County observation well We-300.

Water-quality characteristics.—Water-quality data collected on April 6, 1992, are very similar to that from June 27, 1968 (table 21).

Evaluation.—After the aquifer test on April 6, 1992, water levels never returned to prepumping conditions. Some development of a zone under less hydraulic head is likely, which creates a zone of greater permeability allowing static water level to become and remain consistently lower.

Table 21. *Records of water quality for Westmoreland County observation well We-300*

[All constituent concentrations are dissolved; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, no data]

Constituents	Date sample collected	
	June 27, 1968	Apr. 6, 1992
Specific conductance (µS/cm)	282	260
pH	8.3	7.4
Water temperature (°C)	10	11
Dissolved oxygen (mg/L as O_2)	--	7.4
Total hardness (mg/L as $CaCO_3$)	120	140
Noncarbonate hardness (mg/L as $CaCO_3$)	10	5
Calcium (mg/L as Ca)	32	41
Magnesium (mg/L as Mg)	9.6	9.4
Sodium (mg/L as Na)	1.8	2
Potassium (mg/L as K)	.9	1.4
Alkalinity (mg/L as $CaCO_3$)	110	136
Sulfate (mg/L as SO_4)	9.6	9.9
Chloride (mg/L as Cl)	3	1.8
Fluoride (mg/L as F)	.1	.3
Silica (mg/L as SiO_2)	7.4	7.0
Dissolved solids, calculated, sum (mg/L)	130	155
Nitrogen, nitrite (mg/L as N)	--	.01
Nitrate plus nitrite (mg/L as N)	--	.05
Nitrogen ammonia (mg/L as N)	--	.01
Nitrogen, ammonia plus organic (mg/L as N)	--	.2
Phosphorus, ortho (mg/L as P)	--	.01
Aluminum (µg/L as Al)	--	10
Iron (µg/L as Fe)	0	41
Manganese (µg/L as Mn)	0	200
Zinc (µg/L as Zn)	--	30

Table 22. *Summary of anomalies, changes in physical characteristics, specific capacity, water quality, land use, and pertinent comments for selected wells in the Pennsylvania Observation-Well Program*

[no, no observed change; undetermined, no previous data]

U.S. Geological Survey well number	Hydrograph anomalies	Change in borehole (geophysics)	Percentage change in specific capacity (from last 2 tests)	Change in water quality	Change (apparent) in nearby land use	Comments
Ag-700	No	No	9.5	Yes, see comments	No	Possible iron bacteria; reduction in concentrations of sodium, chloride, iron, and manganese
Ba-74	No	3 ft decrease in well depth	No	Yes, see comments	No	Borehole hydraulically tight; 2-fold increase in specific conductance, total hardness, and concentrations of calcium and iron; 6-fold increase in concentrations of sulfate and manganese
Bt-311	Yes, see comments	No	-40	Yes, see comments		Increasing seasonal fluctuations with overall upward trend; most water-quality constituents showed improvement
Ca-1	Yes, see comments	Undetermined	Undetermined	Undetermined	No	Water level shows continues upward trend, borehole caved to bottom of casing
Cm-13	No	Undetermined	-25.8	Slight	No	Borehole hydraulically tight
Cb-104	Yes, see comments	Possible 5 ft decrease in well depth	No	Yes, see comments	No	Extreme water-level fluctuations; increase in specific conductance and concentrations of sodium, calcium, chloride, and manganese
Cn-1	Yes, see comments	3 ft decrease in well depth	-5.9	Similar	No	Unusually low period October 1965 to February 1966
Cw-413	Yes, see comments	No	Undetermined	Undetermined	No	Low period in 1991 caused by drought; possible iron bacteria in well
Ek-108	None	No	86	Similar	No	
Fa-17	Yes, see comments	No	No	Yes, see comments		Large increase in concentrations of iron and manganese; possible iron bacteria present
Fu-93	No	8 ft decrease in well depth	-11.1	Slight increase in concentrations of manganese	No	Well in proximity to lake which may influence water levels; possible iron bacteria present

Table 22. *Summary of anomalies, changes in physical characteristics, specific capacity, water quality, land use, and pertinent comments for selected wells in the Pennsylvania Observation-Well Program—Continued*

[no, no observed change; undetermined, no previous data]

U.S. Geological Survey well number	Hydrograph anomalies	Change in borehole (geophysics)	Percentage change in specific capacity (from last 2 tests)	Change in water quality	Change (apparent) in nearby land use	Comments
Gr-118	Yes, see comments	Major constriction at 55 ft	208.8	Data shows consistent increase in major ion concentrations	Local coal mining	Extreme water level fluctuation beginning in 1981, probably caused by nearby coal mining; not an effective indicator of aquifer response
Hu-301	1972, 1968, and 1989 were above average	No	Undetermined	Reduction in concentrations of iron and manganese	No	Data suggest water level-data is representative of local aquifer conditions
Je-23	Large change in water level in 1972-1974	No	-60	Concentrations of iron range from 2,500 to 9,000 µg/L	Local coal mining	Well possibly affected by local coal mining (pumping); not an effective indicator of local aquifer response to climatic conditions
Ly-112	Yes, see comments	No	No	Reduction in concentrations of iron and manganese	No	Recharge from rain from Hurricane Agnes shown in 1972
Mc-110	Sudden change in water level pattern in 1986 to present	No	-12.5	Very consistent	No	Unknown condition has caused water level to rise from 1986 to present
Sc-296	No	3 ft decrease in well depth	Undetermined	Undetermined	No	Available data indicates well is an accurate indicator of local aquifer conditions
Wr-50	Yes, see comments	No	Undetermined	Slight increase in concentrations of sulfate and manganese		Water level changes may indicate local pumping interference or borehole clogging; well may not be an accurate indicator of local aquifer conditions
Ws-155	Possibly affected by nearby pumping	No	-33.3	Increase in concentrations of calcium, manganese, and sulfate		Water level possibly affected by local pumping
We-300	Unusually low period at beginning of record	No	Undetermined	No	No	After pumping the well the water level never returned to prepumping trend/conditions

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