Geology, Hydrology, and Ground-Water Quality at the Byron Superfund Site Near Byron, Illinois

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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
inch (in.)	2.54	centimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
acre	4,047	square meter
gallon (gal)	3.785	liter
gallon per minute (gal/min)	0.06309	liter per second
foot per day (ft/d)[1]	0.3048	meter per day
foot per foot (ft/ft)	0.3048	meter per meter
foot per minute (ft/min)	0.3048	meter per minute
foot squared per day (ft^2/d)[2]	0.09290	meter squared per day
cubic foot per day (ft^3/d)	28.32	liter per day
pound per square inch (lb/in^2)	6.895	kilopascal

[1]Foot per day is the mathematically reduced term of cubic foot per day per square foot of aquifer cross-sectional area.
[2]Foot squared per day is the mathematically reduced term of cubic foot per day per square foot times foot of aquifer thickness $[(ft^3/d)/(ft^2)ft]$.

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

Abbreviated water-quality units used in this report: Chemical concentration is given in micrograms per liter (µg/L). Micrograms per liter is a unit expressing the concentration of chemical constituents in solution as weight (micrograms) of solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to one milligram per liter.

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By Robert T. Kay[1], Douglas J. Yeskis[2], William J. Bolen[2], James R. Rauman[1], *and* Scott T. Prinos[1]

Abstract

A study was conducted by the U.S. Geological Survey and the U.S. Environmental Protection Agency to define the geohydrology and contaminant distribution at a Superfund site near Byron, Illinois. Geologic units of interest beneath the site are the St. Peter Sandstone; the shale, dolomite and sandstone of the Glenwood Formation; the dolomite of the Platteville and Galena Groups; and sands, gravels, tills and loess of Quaternary age. The hydrologic units of interest are the unconsolidated aquifer, Galena-Platteville aquifer, Harmony Hill Shale semiconfining unit, and the St. Peter aquifer.

Ground-water flow generally is from the upland areas northwest and southwest toward the Rock River. Water levels indicate the potential for downward ground-water flow in most of the area except near the Rock River. The Galena-Platteville aquifer can be subdivided into four zones characterized by differing water-table altitudes, hydraulic gradients, and vertical and horizontal permeabilities. Geophysical, hydraulic, and aquifer-test data indicate that lithology, stratigraphy, and tectonic structures affect the distribution of primary and secondary porosity of dolomite in the Galena and Platteville Groups, which affects the permeability distribution in the Galena-Platteville aquifer.

The distribution of cyanide, chlorinated aliphatic hydrocarbons, and aromatic hydrocarbons in ground water indicates that these contaminants are derived from multiple sources in the study area. Contaminants in the northern part of this area migrate northwest to the Rock River. Contaminants in the central and southern parts of this area appear to migrate to the southwest in the general direction of the Rock River.

[1]U.S. Geological Survey.

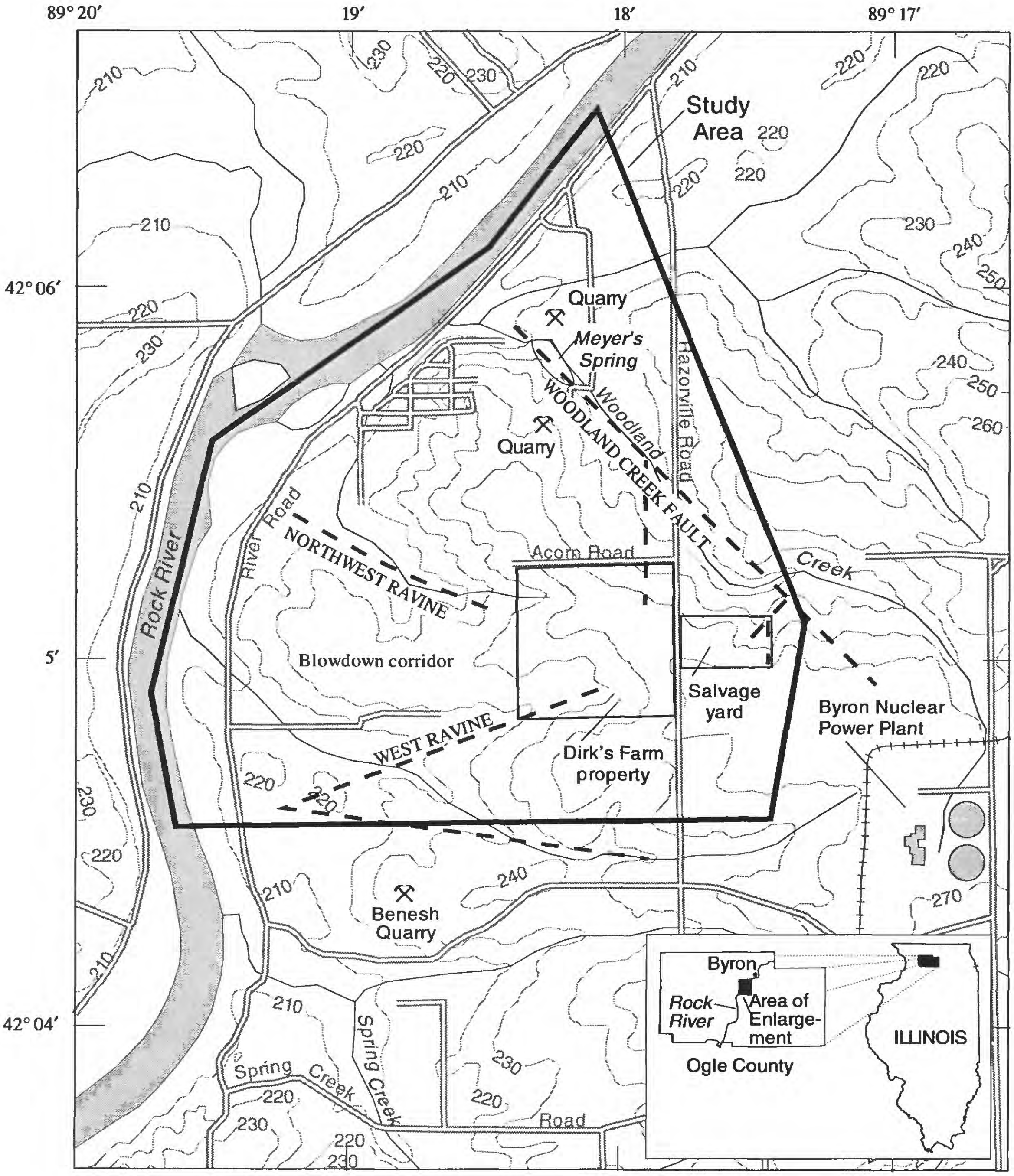
[2]U.S. Environmental Protection Agency.

INTRODUCTION

The U.S. Geological Survey (USGS), in cooperation with the U.S. Environmental Protection Agency (USEPA), conducted a study of the geology, hydrology, and distribution of contaminants at the Byron Superfund site (the site), near Byron, Ill., from August 1990 to March 1994. The site is located in rural Ogle County in northern Illinois, about 3 mi southwest of Byron (fig. 1).

The objectives of the study were to define the geologic and hydrologic properties that affect ground-water flow, and determine the type and extent of ground-water contamination in the study area. This information is required to assess options for ground-water remediation.

The study was divided into four components: geophysical logging, collection of static water-level measurements, aquifer tests, and water-quality sampling. Geophysical logging was conducted to determine stratigraphy, fracture orientation, and depths of ground-water flow. Static water-level measurements were collected to determine the vertical and horizontal directions of ground-water flow in the study area. Single- and multiple-well aquifer tests were conducted



Base from U.S. Geological Survey
1:100,000 Digital Line Graphs
Albers Equal-Area Conic Projection
Standard parallels 33° and 45°, central meridian -89°

0 0.5 1 MILE
0 0.5 1 KILOMETER

EXPLANATION

—220— TOPOGRAPHIC CONTOUR--Shows elevation of land surface, in meters. Contour interval 10 meters. Datum is sea level

— — — FRACTURE TRACE

Figure 1. Location of the study area, salvage yard, Dirk's Farm property, and fracture traces, Byron Superfund site.

to determine the hydraulic properties of the aquifers and identify spatial variations in hydraulic properties. Water-quality sampling was done to determine the type and spatial distribution of chemical constituents in ground water.

In this report, the salvage yard refers to a 20-acre area east of Razorville Road where wastes were disposed (fig. 1). The Dirk's Farm property (DFP) is bounded by Razorville Road to the east, Acorn Road to the north, the western limit of Acorn Road to the west, and an unnamed gravel road to the south (fig. 1). The study area is approximately bounded by Woodland Creek (an intermittent stream) to the north and east, well DF20 to the south, the Rock River to the north and west, and wells MW1 and MW2 to the south and east (figs. 1 and 2). The study is a part of the Byron Superfund site.

Purpose and Scope

This report describes the results of a study designed to determine the geohydrology and ground-water quality underlying a Superfund site near Byron, Ill. In addition to a description of the geology and hydrology of the study area, the results of a series of aquifer tests and two rounds of water-quality sampling in the study area are presented. The types and concentrations of selected chemical constituents in the ground-water system during the study are listed, and a number of processes that affect the type, concentration, and distribution of the chemical constituents in the study area are identified.

Site History

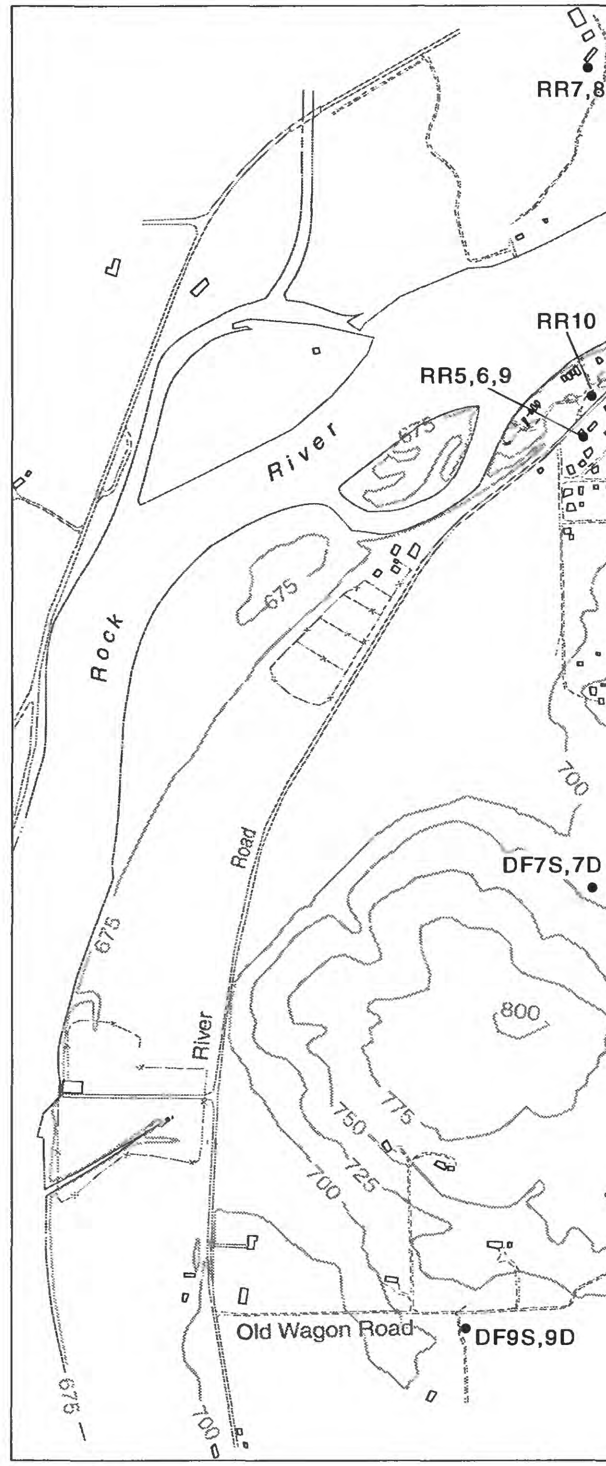
The study area was the location of a "junk" yard and nonpermitted landfill in the 1960's; at some later date, industrial and liquid wastes also were deposited within the study area. Waste disposal is known to have occurred at the salvage yard as well as the north disposal area, the east disposal area, the south disposal area, and the west disposal area of the DFP (fig. 3). Waste disposal is thought to have occurred in the central disposal area of the DFP (Dames and Moore, Inc., 1974; Ecology and Environment, Inc., 1976, p. 8–12; Dames and Moore, Inc., 1975; U.S. Environmental Protection Agency, 1994, p. 3:11 and fig. 3:3).

The Illinois Environmental Protection Agency (IEPA) began inspecting the salvage yard in 1970 and continued periodic inspections until 1972. In 1972, the IEPA ordered the waste-disposal activities at the salvage yard to cease following a fishkill in Woodland Creek, northwest of the salvage yard.

In May of 1974, three cattle were found dead on the DFP. Cyanide leachate from the DFP was determined to be the cause of these deaths (U.S. Environmental Protection Agency, 1994, p. 2:4). Consequently, an investigation of the contamination on the DFP was undertaken by Dames and Moore, Inc. Results of the investigation indicated that heavy metals and (or) cyanide were present in the wastes and soils in the north, south, east, and west disposal areas (Dames and Moore, Inc., 1974, figs. 5 and 6). Remedial cleanup measures, which included the removal of barrels of waste and soils contaminated with heavy metals and the treatment of cyanide-contaminated soils from the disposal areas on the DFP, were implemented in 1974 (Dames and Moore, Inc., 1976; CH2MHILL, Inc. and Ecology and Environment, Inc., 1984, p. 2:3). This remedial action was completed in 1975, prior to passage of the Comprehensive Environmental Response Compensation and Liability Act (commonly known as Superfund) of 1980. Because the laws governing regulation of hazardous-waste disposal had not been enacted in 1975, this early remedial action was not conducted with USEPA or IEPA oversight.

In 1982, the site was placed on the USEPA Superfund National Priority List. Remedial cleanup measures, including removal of known surface and buried drums and highly contaminated soils, were implemented at the salvage yard by the IEPA in 1986 (U.S. Environmental Protection Agency, 1994, p. 2:10). This remedial action was completed in 1987.

Subsequent to the remedial efforts at the salvage yard and the DFP, elevated levels of heavy metals and (or) cyanide were detected in soils at the salvage yard and the east, west, north, and south disposal areas of the DFP (Dames and Moore, Inc., 1976, p. 18–21; Camp Dresser & McKee, Inc., 1989, p. 4:3–4:44; Environmental Resources Management, 1990, p. 1:13). Volatile organic compounds (VOC's) were detected in soils at the salvage yard and the west and east disposal areas of the DFP (Camp Dresser & McKee, Inc., 1989, p. 4:3–4:44; Environmental Resources Management, 1990, p. 4:3–4:5). Cyanide, VOC's, and heavy metals have been detected in ground water beneath much of the study area (Camp Dresser & McKee Inc., 1989, p. 4:91–4:94; Environmental Resources Management, 1990, p. 5:5). The continued



EXPLANATION

APPROXIMATE SALVAGE YARD BOUNDARY

APPROXIMATE DIRK'S FARM PROPERTY BOUNDARY

775 TOPOGRAPHIC CONTOUR--Shows elevation of land surface, in feet. Contour interval 25 feet. Datum is sea level

•DF20 MONITORING WELL LOCATION AND NAME

0 2,000 FEET

0 500 METERS

Figure 2. Location of monitoring wells, salvage yard, and Dirk's Farm property, Byron Superfund site (from U.S. Environmental Protection Agency, 1994, figs. 2-5 and 3-4).

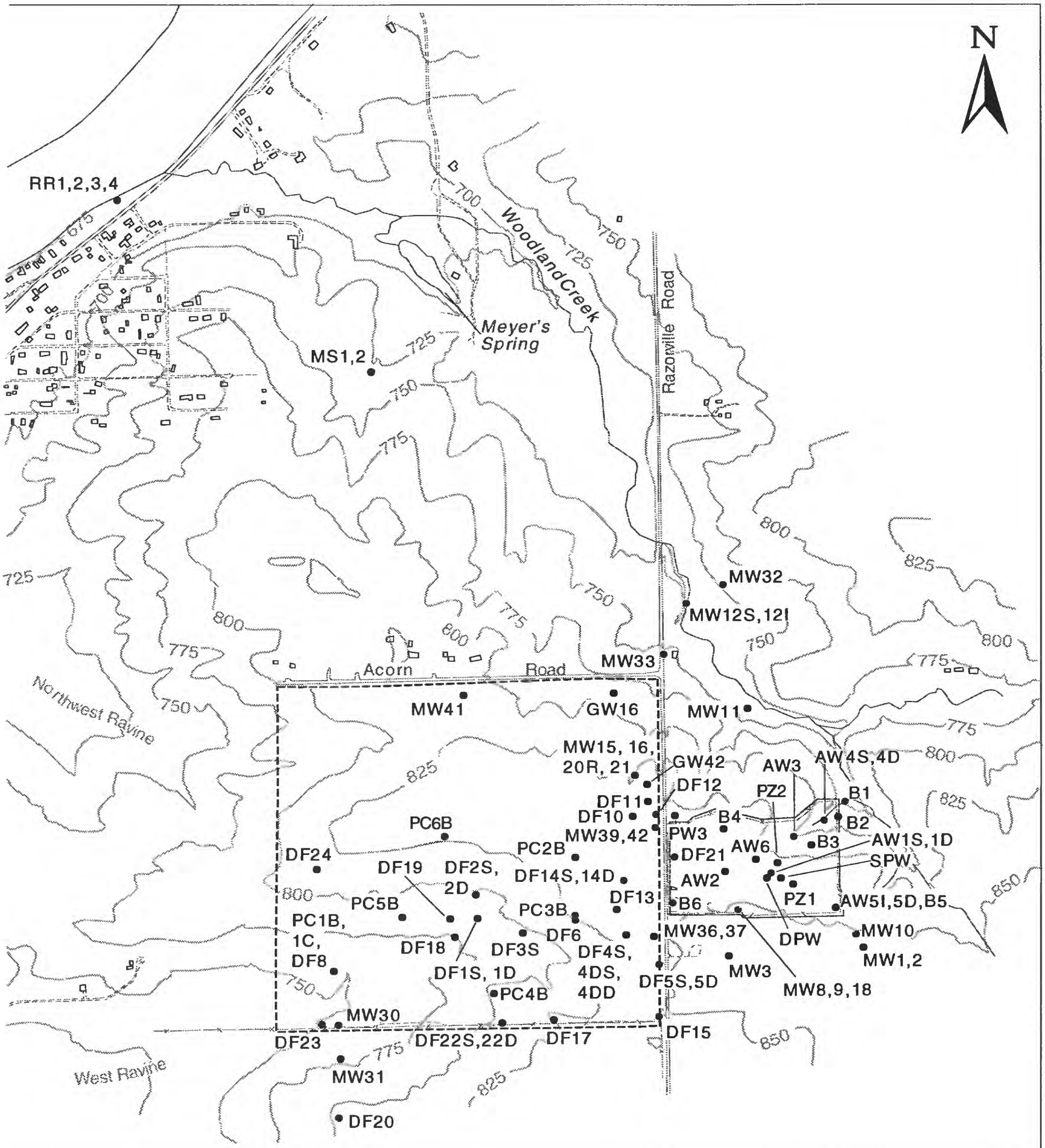
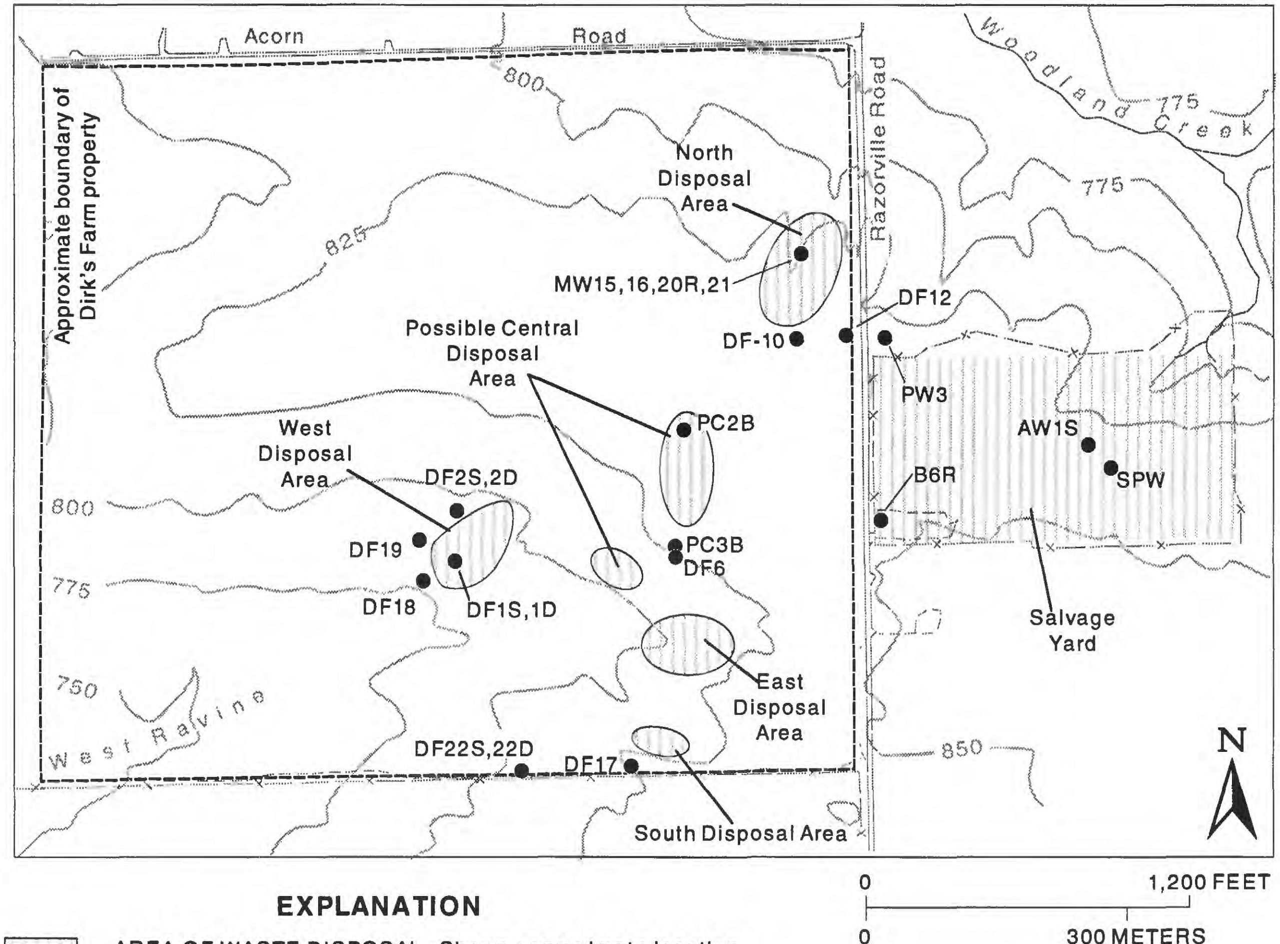


Figure 2. Continued.



EXPLANATION

AREA OF WASTE DISPOSAL--Shows approximate location of identified waste-disposal areas

—825— TOPOGRAPHIC CONTOUR--Shows elevation of land surface, in feet. Contour interval 25 feet. Datum is sea level

● DF17 MONITORING WELL LOCATION AND NAME

Figure 3. Location of identified waste-disposal areas, Byron Superfund site (modified from U.S. Environmental Protection Agency, 1994, figure 3:3.).

presence of contaminated soils and ground water at this site and the potential effect on human health and the environment necessitated additional investigation.

Methods

The geologic description of the study area is based on analysis of lithologic and geophysical logs contained in previous reports (Ecology and Environment, Inc., 1976, p. 14–22; Gilkeson and others, 1977, p. 19–24; D'Appolonia Waste Management Services, 1984, p. 77–88; Camp Dresser & McKee Inc., 1989, p. 3:1–3:10; Kay and others, 1989, p. 8–14; Environmental Resources Management, 1990, appendix H; U.S. Environmental Protection Agency, 1994, appendixes A and D), analysis of the lithologic and geophysical logs compiled during this study (Frederick Paillet, U.S. Geological Survey, written commun., 1991 and 1993), stratigraphic descriptions of cuttings and rock cores from ten borings drilled during the current and previous investigations, and observation of outcrops in and around the study area. The stratigraphic nomenclature used in this report is that of the Illinois State Geological Survey (ISGS) (Willman and others, 1975, p. 61–80 and 218–230) and does not necessarily follow the usage of the USGS.

The geophysical logs utilized in this investigation include natural-gamma, acoustic-televiewer, heat-pulse flowmeter, and three-arm caliper. These logs were used primarily for stratigraphic correlation and to characterize ground-water flow.

Natural-gamma logs were run by current or previous investigators in 49 wells or boreholes throughout the study area (U.S. Environmental Protection Agency, 1994, table 3:2). Natural-gamma logs measure the amount of natural-gamma radiation emitted by the rock, which typically is a function of its clay content. The ability to measure variations in clay content makes this log useful for stratigraphic correlation.

Acoustic-televiewer logs were run as part of the current investigation in boreholes DF4D, DF5D, DF12, DF13, DF17, DF24, PZ1, B6R, and SPW (fig. 2) prior to the installation of monitoring wells in the boreholes. Acoustic-televiewer logs run in boreholes GW16, GW42, PZ2, PZ3, DPW, and AW1S for other studies are not discussed specifically in this report. These boreholes are located at the salvage yard or the DFP. Acoustic-televiewer logs produce an oriented picture of the borehole wall and typically are used to identify the location and orientation of vugs, fractures, and solution openings intercepted by the borehole.

Three-arm caliper logs were run in the same boreholes as the acoustic-televiewer logs. Three-arm caliper logs measure the diameter of the borehole, which is often enlarged in areas of fractures and solution openings.

Heat-pulse flowmeter logging was conducted under conditions of natural flow in boreholes DF4D, DF5D, DF12, DF13, DF17, SPW, PZ1, and B6R. If vertical variations in head are present within the aquifer, then vertical flow within the borehole is induced (natural flow). Heat-pulse flowmeter logs measure the direction and rate of vertical flow at various depths in the borehole and identify the depths where measurable changes in the rate of flow are present. Inflow (flow into the borehole from the aquifer) is identified by an increase in flow rate along the direction of flow in the borehole. Outflow (flow out of the borehole to the aquifer) is identified by a decrease in flow rate along the direction of flow in the borehole. The depths where the flow rate changes are commonly intervals of increased aquifer permeability. Boreholes DF4D, DF12, and DF13 were pumped at between 2.0 and 3.5 gal/min with the pump intake set near the static water level in the borehole to verify the location of the flow intervals identified by flowmeter logging during conditions of natural flow. Heat-pulse flowmeter logs were compared with televiewer logs to identify the specific features (vuggy zones, fractures, and solution openings) through which water was flowing.

Bedrock stratigraphy was described by the ISGS from cores collected at the boreholes in which wells MW2, MW20, DF4D, DF11, AW1D, AW4S, and AW4D were installed (fig. 2) (Michael Sargent, Illinois State Geological Survey, written commun., 1992). Environmental Resources Management (1990, appendix C) also described bedrock stratigraphy from a core collected at the borehole in which well PC1C was installed and from cuttings of the boreholes in which wells PC2B and PC3B were installed.

The hydrologic description of the study area is based on analysis of static water-level measurements, flowmeter logs, slug tests, and constant-discharge aquifer tests. Each of these methods characterizes the aquifer at a different scale.

Water levels were measured from wells throughout the study area approximately every 3 months from August 1990 to January 1993. Water-level measurements were collected with a calibrated electric tape and are accurate to within about 0.02 ft. This report focuses on the water-level data collected from 84 wells on January 27, 1992, because conditions during that time are representative of the entire monitoring period (U.S. Environmental Protection Agency, 1994, appendix L) and because of the large number of wells measured on that date.

Discrete test intervals in boreholes DF2D, DF4D, DF5D, DF6, DF12, DF13, DF14D, DF17, SPW, AW1S, and PZ1 (fig. 2) were isolated using a packer assembly. The packer assembly consists of two 4-ft long inflatable neoprene packers separated by 10 ft of screened stainless steel or slotted aluminum pipe (fig. 4). The packer assembly was constructed so that ground-water levels (heads) could be measured above, below, and within the test interval after the packers were inflated and the water levels had equilibrated. The head above, within, and below the test intervals typically were not equal, which indicates that the packers were effectively isolating the test interval from the rest of the borehole. In addition to measuring the vertical distribution of head in the aquifer, slug testing and water-quality sampling were conducted in these test intervals.

Horizontal hydraulic conductivities were calculated from data collected during slug testing conducted in 55 discrete intervals isolated by the packer assembly at boreholes DF2D, DF4D, DF5D, DF6, DF12, DF13, DF14D, SPW, PZ1, and AW1S. Slug tests also were conducted in 61 monitoring wells located throughout the study area.

Slug tests involved insertion of a solid cylinder below the water level and measurement of water-level decline with time utilizing a pressure transducer, then removal of the cylinder from the well and measurement of water-level rise with time. Tests where the water-level decline is measured are referred to as falling-head tests. Tests where the water-level rise is measured are referred to as rising-head tests. If the water level is above the top of the screen in the well or packer assembly, both tests typically are analyzed to verify the results. If the water level is below the top of the screen, the effects of water drainage to the unsaturated zone on water levels are potentially large during the falling-head phase. The rising-head tests typically were analyzed if the water level was below the top of the well screen to eliminate potentially erroneous results. The results of the falling-head tests typically are presented for the discrete intervals isolated by the packer assembly.

Slug-test data for test intervals A and B of borehole DF12 and for wells DF24, MW16, B6R, PW3, and MW41 were analyzed utilizing the oscillatory response technique of van der Kamp (1976). This technique was developed for analysis of slug-test data from highly permeable aquifers where the effects of the inertia of water in the well dominate the aquifer response (underdampened response). A fully penetrating well in a confined aquifer where head loss resulting from friction is minimal is assumed with this technique. To achieve a solution to the aquifer transmissivity equation, aquifer storativity was assumed to be 0.005 when using the van der Kamp technique. When horizontal hydraulic conductivity was calculated from the transmissivity, the thickness of the aquifer was assumed to equal the length of the test interval of the packer assembly or the open interval of the monitoring well. Applying the van der Kamp technique to analyze slug-test data from a partially penetrating well in an unconfined aquifer is assumed to accurately estimate horizontal hydraulic conductivities.

Slug-test data for the remaining monitoring wells and test intervals isolated with the packer assembly were analyzed using the technique of Bouwer and Rice (1976). This technique was developed for use in unconfined aquifers with wells that fully or partially penetrate the aquifer.

The following conditions are assumed in the application of the van der Kamp and Bouwer and Rice techniques—

1. The water-level change in the vicinity of the well is negligible.
2. Flow above the water table can be ignored.
3. Head losses as the water enters the well are negligible.
4. The aquifer is homogeneous and isotropic.

These conditions were met or approximated in all of the aquifers at the scale measured by slug tests.

When analyzing the slug-test data, the following was assumed—

1. The radius of the casing is equal to the radius of the riser pipe if the water-level altitude measured before the start of the test is above the top of the screen. If this is not the case, the radius of the casing was calculated by applying the technique described by Bouwer and Rice (1976, p. 24).
2. The value for the length of the screen, through which water enters the aquifer, is equal to the length of the screened interval of the well or packer assembly if the water-level altitude measured before the start of

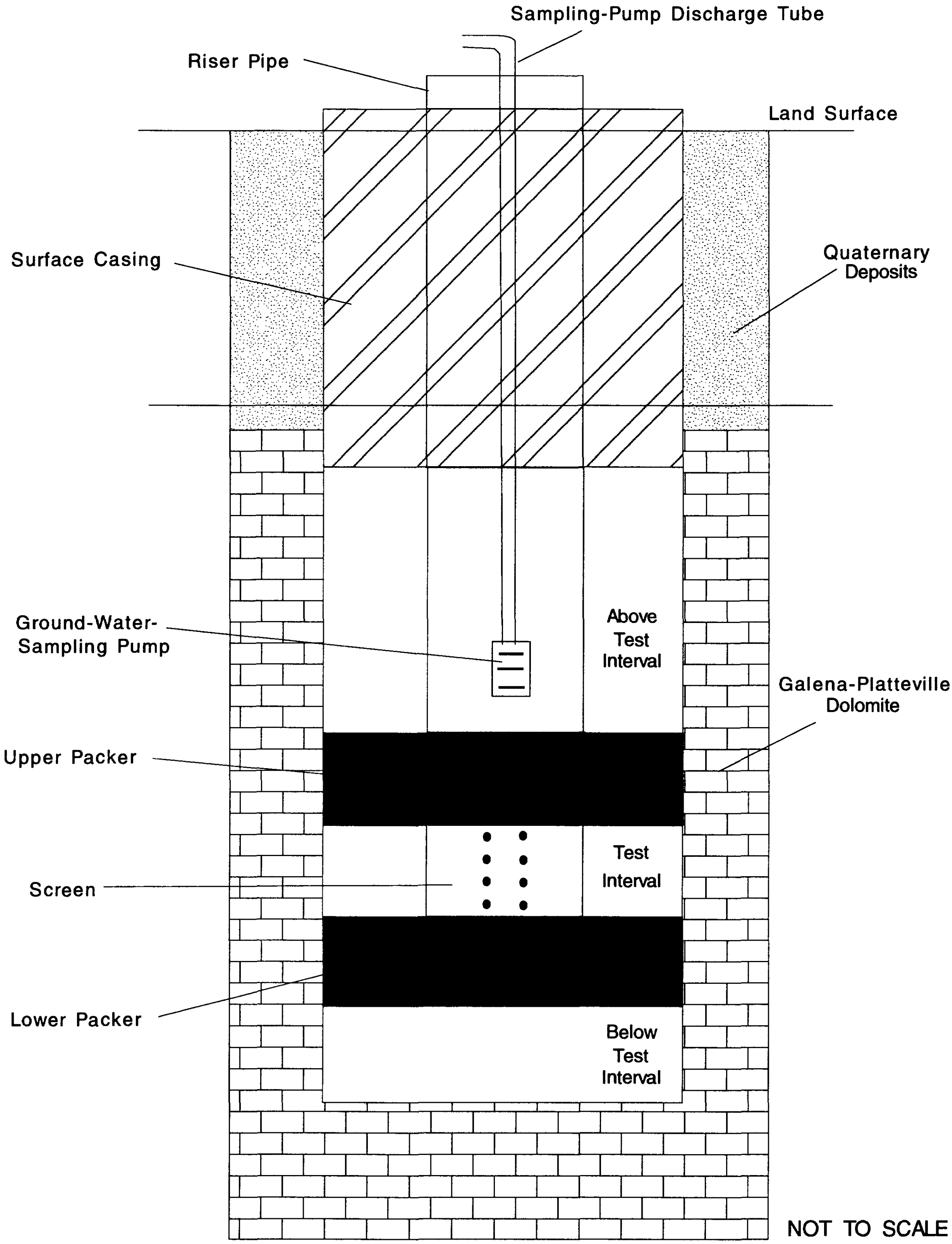


Figure 4. Packer assembly and ground-water-sampling pump in a borehole.

the test is above the altitude of the top of the screen. If this is not the case, the value is equal to the distance from the bottom of the screen in the well or packer assembly to the water level measured before the start of the test.

3. The aquifer is at steady state if the water-level change in the test interval is 0.01 ft/min or less.

These assumptions greatly simplified the analysis of the slug-test data and should not result in a substantial error in the calculated horizontal hydraulic conductivities.

Most of the slug tests resulted in clearly defined trends in water level with time that were easily matched to a straight-line fit (fig. 5) indicating that confidence can be placed on these values. Data were analyzed by applying the techniques recommended by Bouwer (1989) where a straight-line fit to the data could not be easily obtained.

A constant-discharge aquifer test was conducted in and around borehole DF4D from January 31 to February 5, 1992. Water was pumped from the borehole at a constant rate of 7.25 gal/min (1,447 ft^3/d) for 400 minutes while water levels were monitored in nearby wells. After the raw water-level data from the pumping phase were collected, corrections for the effects of changes in barometric pressure, background water-level fluctuations, partial penetration of the observation wells, and dewatering of borehole DF4D on the water-level data were considered. This was done so an accurate value for drawdown could be determined. After revision, the drawdown data were analyzed using the type-curve method of Papadopulos (1965). This technique was developed for analysis of homogeneous, anisotropic aquifers. The main conditions assumed in this method are the following:

1. The pumped well is fully penetrating.
2. The pumped well discharges at a constant rate, Q, beginning at time t = 0.
3. The radius of the pumped well is infinitesimal.
4. The aquifer is underlain by an impermeable boundary.
5. The aquifer is roughly homogeneous over the scale of the test with drawdown in the aquifer approximating an ellipse centered at the pumped well. The major axis of the ellipse is roughly parallel to the direction of maximum transmissivity.

The first four of these conditions were met or approximated. Attempts to calculate the transmissivity tensor from the aquifer test resulted in negative transmissivity values based on the type-curve and straight-line methods of Papadopulos (1965), graphical and analytical procedures (Allen Shapiro, U.S. Geological Survey, written commun., 1992), and the three-dimensional techniques of Hsieh and Neuman (1985). This indicates that the fifth condition was not met.

Aquifer-test data from borehole DF12 were analyzed by applying the specific-capacity method described by Walton (1962, p. 12). The following conditions are assumed in the specific-capacity method—

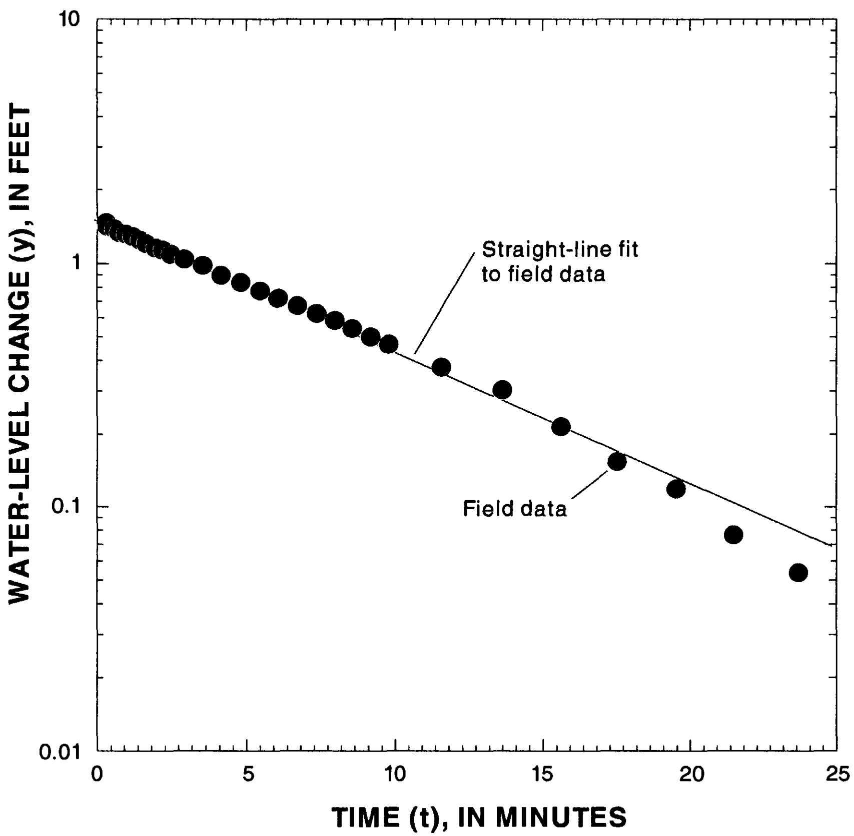
1. Well loss is negligible.
2. The well penetrates the entire saturated thickness of the aquifer.
3. The effective radius of the well has not been affected by well development and is equal to the nominal radius of the well.

The first two conditions are likely to be approximated at borehole DF12. Because of the large fractures and solution openings at borehole DF12, the effective radius of the well is likely to be greater than the nominal radius (6 in.). The underestimation of well radius should result in calculated values of transmissivity that are lower than the actual values. A value of 0.005 was assumed for the storage coefficient.

Water-quality samples were collected from test intervals in boreholes and from completed monitoring wells. Water-quality data were utilized in defining the pathways of ground-water flow.

Water-quality samples were collected from 57 test intervals in boreholes DF2D, DF4D, DF5D, DF6D, DF12, DF13, DF14D, DF17, SPW, and AW1S (fig. 2) using the packer assembly (fig. 4). These samples were analyzed for concentrations of VOC's. The test intervals in boreholes SPW and AW1S also were sampled for cyanide. Sampling from the test intervals was used as a screening device.

Each borehole was purged of at least three times the total volume of water in the borehole with a high-capacity submersible pump prior to insertion of the packer assembly. Purging was done to develop the borehole, remove water affected by the drilling process, and remove water affected by vertical flow within the borehole. Low-flow ground-water-sampling pumps were utilized to purge between two and four volumes from most of the test intervals prior to sampling to assure a representative sample. If permeability was to low too allow two volumes to be purged from the test interval in less than 8 hours, as was the case at borehole DF14D, then less than one volume was purged.



EXPLANATION

$$K = \frac{rc^2 \, ln(Re/rw)}{2L} \, \frac{1}{t} \, ln(yo/yt)$$

$$ln(Re/rw) = \left[\left(\frac{1.1}{ln(H/rw)} \right) + \left(\frac{A + \frac{B \, ln(D-H)}{rw}}{L/rw} \right) \right]^{-1}$$

rc = 0.086 foot
rw = 0.20 foot
L = 5.0 feet
t = 5.55×10^{-3} days
yo = 1.495 feet
yt = 0.56 foot
H = 31 feet
D = 94 feet
A = 2.25
B = 0.30

EXPLANATION OF SYMBOLS

K = Horizontal hydraulic conductivity, in feet per day
rc = Effective radius of the well casing, in feet
rw = Effective radius of the borehole, in feet
L = Length of the portion of the well through which water enters, in feet
t = Time since beginning of test, in minutes or days
yo = Water level at start of test, in feet
yt = Water level at some time during the test, in feet
Re = Effective radius of the aquifer, in feet
H = Height of the water table above the bottom of the well, in feet
D = Saturated thickness of the aquifer, in feet
A = Aquifer coefficient related to L/rw, dimensionless
B = Aquifer coefficient related to L/rw, dimensionless

Figure 5. Water-level change and time during slug testing, well DF4S, falling-head phase, Byron Superfund site.

The samples from boreholes DF4D, DF2D, and DF6D were initially analyzed with a portable gas chromatograph (GC). The detection limit of the portable GC was thought to be about 10 μg/L; however, the portable GC failed to detect concentrations of trichloroethene (TCE) as large as 30 μg/L in some of the samples collected for QA/QC. The portable GC did detect VOC's in the samples from test intervals C, E, and F in borehole DF6 at concentrations less than 10 μg/L. Boreholes DF2D and DF4D were resampled and reanalyzed.

Samples collected from the test intervals in boreholes AW1S, SPW, DF2D, DF4D, DF5D, DF12, DF13, DF14D, DF17, and test intervals A and B in borehole DF6 were analyzed by Central Regional Laboratory, a USEPA contract laboratory, or the USGS Water-Quality Laboratory in Arvada, Colo., using the gas chromatography and mass spectrometry (GCMS) method. The detection limit for the USGS laboratory generally was from 1 to 3 μg/L for all VOC's. The detection limit for the USEPA laboratories generally was from 1 to 3 μg/L, depending on the VOC. Duplicate samples analyzed based on the GCMS method gave results that generally were similar to the initial sample.

Over 115 ground-water samples were collected from 65 monitoring wells during two sampling periods. The first sampling period was in May 1991. The second sampling period was from November 1991 to April 1992. Ground-water samples were analyzed for a variety of constituents including VOC's and cyanide. Samples were collected, preserved, stored, and analyzed according to QA/QC guidelines outlined in the approved Quality Assurance Project Plan for the site (U.S. Environmental Protection Agency, 1990). Low-flow ground-water-sampling pumps were used to collect the samples. A minimum of three well volumes (volume of water in the well pipe or open borehole) were purged from each well prior to sample collection. Well purging was judged to be completed once stabilization (less than 10 percent variation between three successive half well-volume measurements) was reached for temperature, specific conductance, pH, and oxidation-reduction potential.

Samples collected from the monitoring wells were analyzed by a USEPA contract laboratory or the USEPA Region 5, Central Laboratory. The detection limit for VOC's typically was 10 μg/L, depending on the constituent. The detection limit for cyanide also was 10 μg/L. Only results deemed acceptable for use after QA/QC review are presented in this report.

GEOLOGY

The bedrock geologic units of primary interest in the study area are sandstone, shale, and dolomite of Ordovician age. From oldest to youngest, these units are the St. Peter Sandstone and Glenwood Formation of the Ancell Group, and the Platteville and Galena Groups. These bedrock deposits are unconformably overlain by Quaternary glacial, fluvioglacial, and alluvial deposits (fig. 6).

The St. Peter Sandstone is a coarse-to-medium grained quartz arenite, characterized by a high percentage of well-rounded quartz grains. Well logs obtained from the ISGS indicate that the St. Peter Sandstone is approximately 420 ft thick in this area (fig. 6).

The Glenwood Formation is a highly heterogeneous unit of sandstone, dolomite, and shale that overlies the St. Peter Sandstone. The base of the Glenwood Formation consists of a poorly sorted, well-rounded, dolomitic quartz sandstone, known as the Kingdom Sandstone Member (fig. 6). The Kingdom Sandstone Member typically is about 16 ft thick in the study area (Michael Sargent, Illinois State Geological Survey, written commun., 1993).

The Kingdom Sandstone Member grades upward into a massive argillaceous dolomite known as the Daysville Member of the Glenwood Formation. The Daysville Member is about 16 ft thick in most of the study area (Michael Sargent, Illinois State Geological Survey, written commun., 1993).

The uppermost unit of the Glenwood Formation is a gray-green shale known as the Harmony Hill Shale Member. The Harmony Hill Shale Member is about 5 ft thick in most of this area.

The Platteville and Galena Groups are the uppermost bedrock deposits in most of the study area and consist of fractured, partly cherty, partly argillaceous dolomite. Shale partings are common throughout these deposits. The two groups are subdivided into formations primarily based on subtle variations in clay and silt content (Willman and Kolata, 1978, p. 7). The primary porosity of the dolomite, which compose the Platteville and Galena Groups, was calculated to range from about 4 to 22 percent with a median value of about 10 percent at this site (Patrick Mills, U.S. Geological Survey, written commun., 1993; U.S. Environmental Protection Agency, 1994, p. 4:15).

SYSTEM	GROUP	FORMATION	MEMBER	LITHOLOGY	THICK-NESS, IN FEET	GEO-HYDRO-LOGIC UNIT	MEDIAN PRIMARY POROSITY, IN PERCENT
QUATERNARY				Alluvium, silty at top, grading downward to sand with occasional gravel	0-20	Un-consolidated aquifer	Unknown
				Loess, windblown silt, leached Sand and silt, windblown, leached Outwash, sand and gravel	0-15 0-15 0-180		
				Till, brown silty clay to clayey silt with few boulders, stiff	0-26		
				Silt, brown to gray, calcareous, stiff	0-10		
				Till, brown silty sand with few boulders, very stiff to hard	0-25		
ORDOVICIAN	GALENA	DUNLEITH		Dolomite, buff, finely crystalline, thin to medium bedded with white and gray chert nodules, green shale partings in lower portion	0-70	Galena-Platteville aquifer	10.3
		GUTTEN-BERG		Dolomite, vuggy, with red shale partings	0-5		6.4
	PLATTEVILLE	QUIMBYS MILL		Dolomite, buff and gray, occasional white chert, mottled with numerous shale partings	0-20		10.2
		NACHUSA		Dolomite, pure to slighty argillaceous, vuggy, thickly bedded to massive, occasional white chert	0-25		9.5
		GRAND DETOUR		Dolomite, mottled buff and dark gray, finely crystalline, medium to massive bedded, thin gray and reddish-brown shale partings	0-45		11.3
		MIFFLIN		Dolomite, mottled, thinly bedded, thin gray or green shale partings	0-15		9.4
		PECA-TONICA		Dolomite, mottled, medium bedded	0-33		9
	ANCELL	GLENWOOD	HAR-MONY HILL	Shale, green, gray, and brown, thinly laminated	0-5	Harmony Hill Shale semi-confining unit	Unknown
			DAYS-VILLE	Shale, brown and gray, sandy Dolomite, greenish-gray, fine-grained	0-16		18
			KING-DOM SAND-STONE	Dolomitic sandstone, greenish-gray	0-16	St. Peter aquifer	16
		ST. PETER SAND-STONE		Sandstone, white, coarse- to medium-grained, quartzose, friable	approximately 420		14

Figure 6. Generalized geologic column showing stratigraphy, geohydrologic units, and median primary porosity of Ordovician and Quaternary deposits, Byron Superfund site (modified from Gilkeson and others, 1977).

The Pecatonica Formation is the basal unit of the Platteville Group (fig. 6) and is composed of brown, finely vuggy, medium bedded, mottled dolomite. This deposit unconformably overlies the Harmony Hill Shale Member of the Glenwood Formation and is from 0 to 33 ft thick at the site.

The Mifflin Formation is composed of thinly bedded, mottled dolomite with numerous shale partings. The Mifflin Formation unconformably overlies the Pecatonica Formation and ranges from 0 to about 15 ft thick in the study area (fig. 6). The unconformity between the Pecatonica and Mifflin Formations is distinguished by a layer of iron-stained pyrite.

The Mifflin Formation is conformably overlain by the Grand Detour Formation. The Grand Detour Formation is composed of a lower, medium-grained, medium-bedded, mottled dolomite with little clay and an upper, thinly bedded, argillaceous dolomite with some fossils (fig. 6). The thickness of the Grand Detour Formation ranges from 0 to 45 ft (fig. 6).

The Nachusa Formation conformably overlies the Grand Detour Formation and is composed of a thickly bedded to massive, fine-to-medium grained, vuggy dolomite. The middle part of the Nachusa Formation is slightly argillaceous. The upper and lower parts of the formation are composed of pure dolomite. This formation is from 0 to 25 ft thick in the study area.

The Quimbys Mill Formation is the uppermost deposit of the Platteville Group. This formation unconformably overlies the Nachusa Formation and unconformably underlies the deposits of the Galena Group. The Quimbys Mill Formation is composed of mottled dolomite with numerous shale partings and ranges in thickness from 0 to 20 ft in this area.

The Guttenberg Formation, where present, is the basal unit of the Galena Group. The Guttenberg Formation is composed of vuggy dolomite with thin beds of red or brown shale. This deposit is absent in much of the study area, presumably because of erosion during the Ordovician System, and has a maximum thickness of about 5 ft.

The youngest bedrock deposit in the study area is the Dunleith Formation of the Galena Group (fig. 6). The Dunleith Formation is composed of alternating beds of pure and argillaceous dolomite. The pure dolomite deposits are medium-to-thick bedded and vuggy. The argillaceous dolomite deposits are medium to thinly bedded. The base of the Dunleith Formation conformably overlies the Guttenberg Formation where the Guttenberg occurs and unconformably overlies the Quimbys Mill Formation where the Guttenberg Formation is absent. The Dunleith Formation is from 0 to 70 ft thick in the study area.

A more detailed understanding of the bedrock stratigraphy at the site, particularly the stratigraphy of the Platteville and Galena Groups, was obtained from core descriptions and geophysical logging. The stratigraphic descriptions were compared to natural-gamma logs from wells MW2, MW20, and AW1D and boreholes DF4D, DF11, and AW4S (two examples are shown in figs. 7 and 8) so the natural-gamma signal of the bedrock formations could be identified. Natural-gamma logs from wells with stratigraphic descriptions were compared with natural-gamma logs from other wells and boreholes so the stratigraphy at these locations could be determined (examples are shown in figures 9–14, at end of report). Data from these wells and boreholes were then used to correlate stratigraphy throughout the study area (figs. 15–17, at end of report).

Natural-gamma logs at several locations, particularly boreholes DF12 and SPW, have intervals of high clay content that are not present at other locations (figs. 10 and 13). When the natural-gamma, acoustic-televiewer (figs. 10 and 13) and caliper data (not shown) for boreholes DF12 and SPW are compared, it is apparent that many intervals with high clay content correspond to fractured parts of the dolomite. Clays in the fractures indicate that infilling of fractures is obscuring the original stratigraphy at these locations.

Spectral-gamma logs run in borehole SPW indicated elevated amounts of uranium and thorium in the fractures. Potassium was the dominant source of gamma radiation in the unfractured dolomite at borehole SPW (Frederick Paillet, U.S. Geological Survey, written commun., 1991). The different elements in the clay minerals in the fractured and unfractured dolomite indicate that the clays in the fractures are from a different source than the clays in the dolomite matrix. This is further indication of infilling of fractures with clay minerals.

Because ground-water flow in the Platteville and Galena Groups is primarily through fractures, faults, and solution openings in the dolomite, a detailed understanding of these features is essential to understanding vertical and horizontal ground-water flow and contaminant transport. A study of fracture orientations in the Platteville and Galena dolomite was conducted at quarries, outcrops, and trenches in and around the study area by Sargent and Lundy, Inc., and Dames

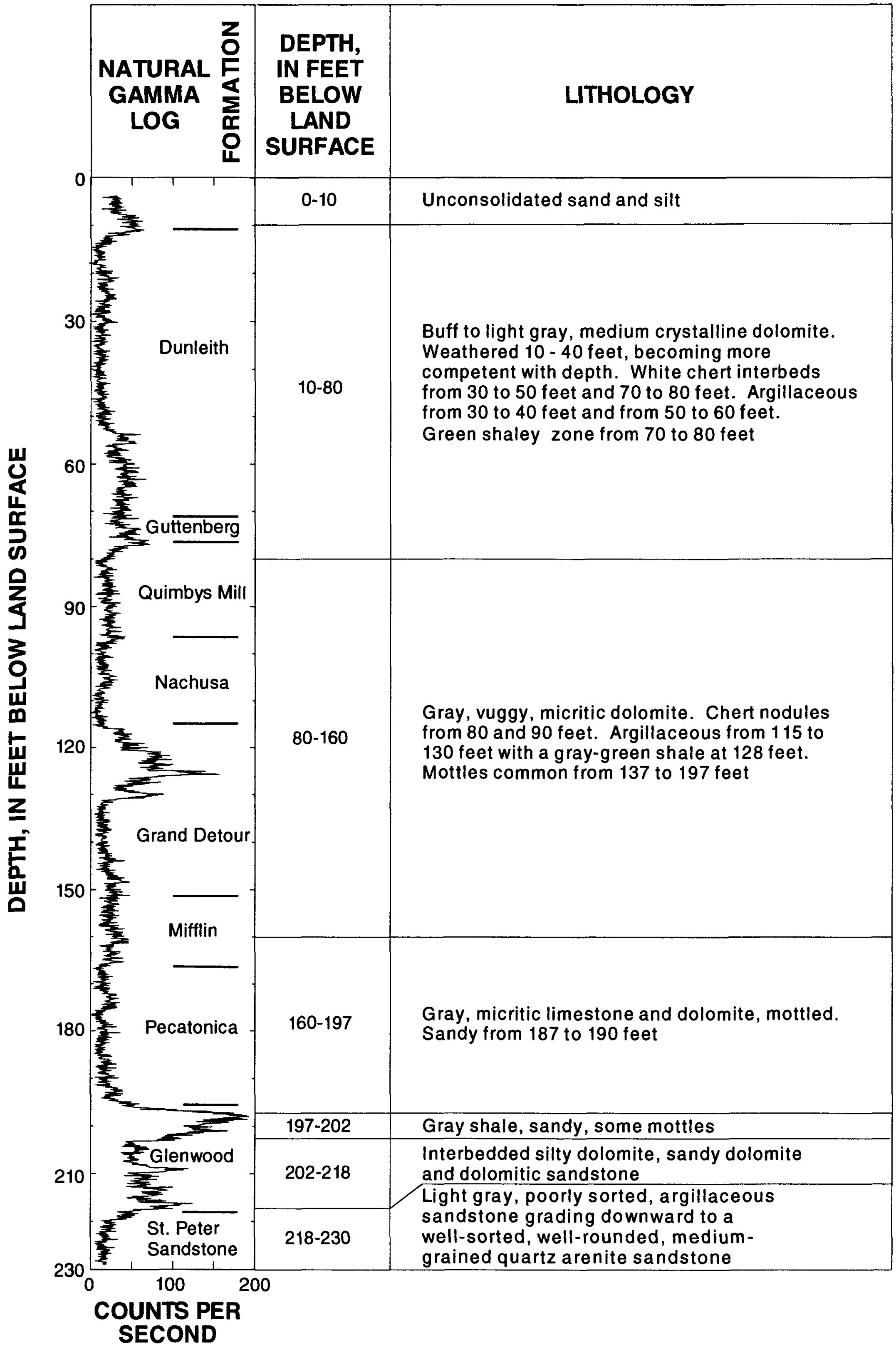


Figure 7. Natural-gamma log, lithologic log, and generalized stratigraphic section from well MW2, Byron Superfund site.

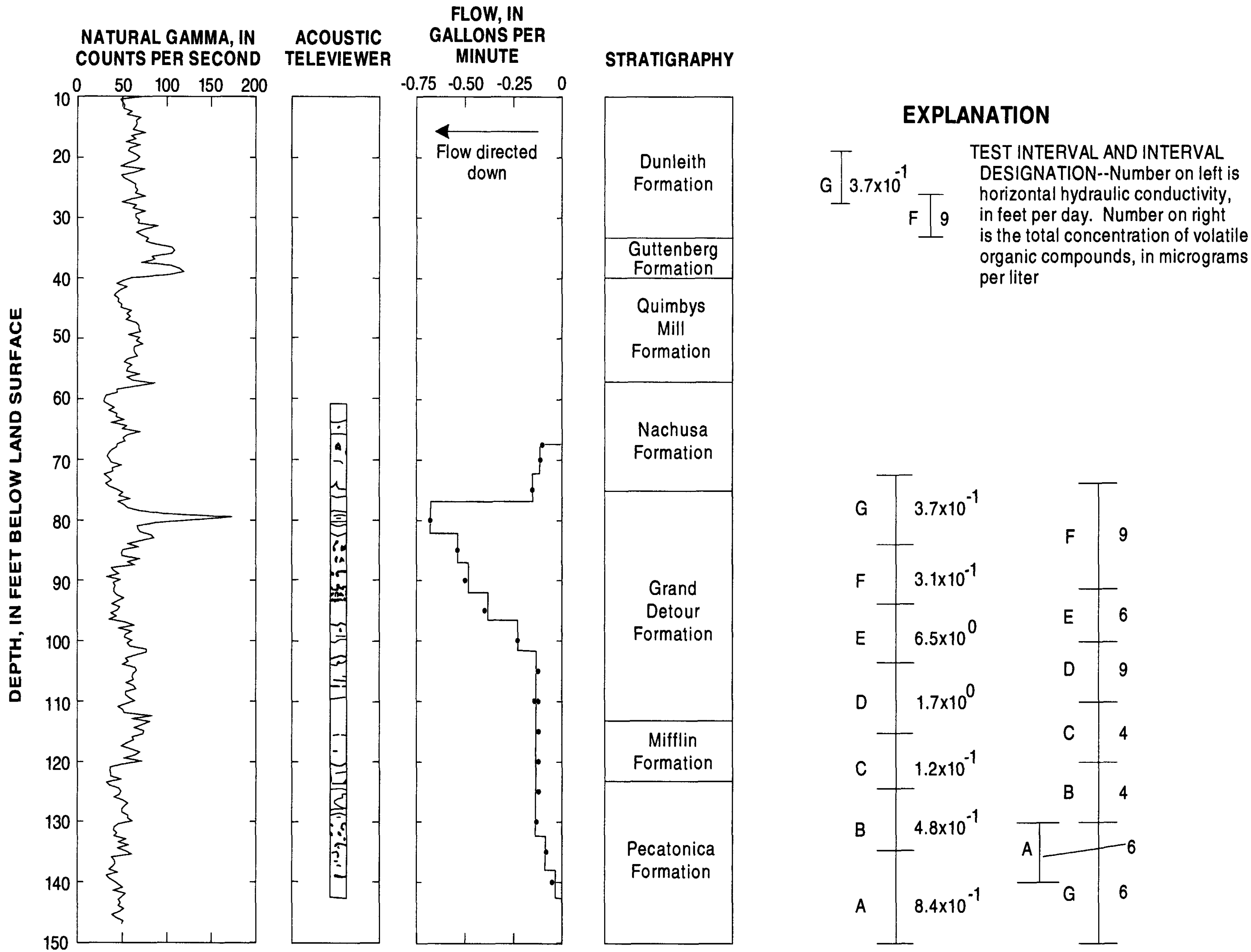


Figure 8. Natural-gamma, acoustic-televiewer, and flowmeter logs; stratigraphy; horizontal hydraulic conductivities; and total concentration of volatile organic compounds in the test intervals isolated with a packer assembly for borehole DF4D, Byron Superfund site.

and Moore, Inc. (1975). The results of this study indicate two main directions of strike to the vertical fractures in the Byron area: N. 60 W. to N. 75 W. and N. 15 E. to N. 30 E. The trend from N. 60 W. to N. 75 W. is the dominant structural trend. Clays have at least partially infilled some of the fractures. The report also noted the presence of a fault (measured displacement of 6 in.) associated with the topographic low at Woodland Creek (fig. 1). The report concluded that the faulting and fracturing in this area is related to movement along the Sandwich Fault zone, a part of which is 7 mi south of the site. Development of the Sandwich Fault zone occurred after deposition of the youngest bedrock in northern Illinois (Ordovician and Silurian age) but prior to deposition of the Pleistocene deposits.

Collapse features from 10 to 15 ft wide were observed by USGS, USEPA, and ISGS personnel at the Benesh Quarry south of the study area (fig. 1). The collapse features were formed by dissolution of dolomite in the upper, argillaceous part of the Grand Detour Formation (Dennis Kolata, Illinois State Geological Survey, oral commun., 1994). Collapse features do not appear to extend to the overlying deposits.

Acoustic-televiewer and three-arm caliper logs were run in selected boreholes to obtain a more complete characterization of the fractures and solution openings in the dolomite (Frederick Paillet, U.S. Geological Survey, written commun., 1991) (figs. 8–14). Televiewer logs show numerous small (typically less than 0.25 ft thick) subhorizontal fractures or solution openings through the entire thickness of all the boreholes that were logged. Vugs also were detected through the entire thickness of the dolomite in much of this area. Subhorizontal fractures and solution openings greater than 0.5 ft thick were detected in boreholes DF12, DF17 (figs. 10 and 12), DF24 (not shown), and B6R (not shown). This is consistent with the lithologic logs from boreholes DF12, DF24, and B6R, which indicate a rapid increase in drilling rate near the bottom of these boreholes and an absence of water and drill cuttings expelled from the borehole. The absence of water and drill cuttings expelled from the borehole typically indicates they are moving into very large fractures and solution openings in the rock. During three-arm caliper logging of borehole DF12, the 3-ft long probe fell on its side indicating a large solution opening. Large and small subhorizontal fractures and solution openings tend to be concentrated in the Grand Detour and Mifflin Formations, which is consistent with observations at the Benesh Quarry.

In addition to subhorizontal fractures and solution openings, acoustic-televiewer logs indicate inclined fractures in the dolomite. A large vertical fracture was identified at borehole SPW at depths of 72, 80.5, 92, 100, and 123 ft (fig. 13). Inclined fractures were observed in borehole DF4D at depths of about 82, 84, and 86.5 ft; in borehole DF5D at depths of about 96, 106, and 146.5 ft; in borehole DF12 at depths of about 79.5, 82, 88, and 91.5 ft; and in borehole DF13 at a depth of about 102 ft (figs. 8–11). The dip of the fractures in boreholes DF4D, DF5D, DF12, and DF13 is from 18 to 87 degrees below horizontal.

The small number of inclined fractures intercepted at a single borehole is most likely because of the difficulty in intercepting inclined fractures with a vertical well boring. Though the acoustic-televiewer logs indicate only a few inclined fractures at any borehole, the consistent interception of inclined fractures indicates a network of inclined fractures in the dolomite deposits. Inclined fractures are likely to be an important route by which ground water and ground-water contaminants migrate vertically through the dolomite.

The strike of the inclined fractures at boreholes DF5D and DF4D was about N. 90 E. This is roughly parallel to the orientation of the West Ravine (fig. 2) and indicates that these fractures are part of the same fracture network that affected the development of the West Ravine.

The strike of the inclined fractures in boreholes SPW and DF13 was from N. 58 W. to N. 72 W. This approximates the dominant fracture orientation in the dolomite identified by Sargent and Lundy, Inc., and Dames and Moore, Inc. (1975).

The strike of most of the inclined fractures at borehole DF12 was approximately due north-south. This strike is parallel to the orientation of the fracture trace near wells MW15 and MW16 (figs. 1, 2).

Acoustic-televiewer data collected by the USGS and data on fracture orientations collected by Sargent and Lundy, Inc. and Dames and Moore, Inc. (1975), indicate that the dominant orientation of the inclined fractures in the dolomite is in the N. 60 W. to N. 75 W. direction, especially in the topographically high areas away from the faults and fracture traces (fig. 1). In localized areas where fracture development has been extensive enough to affect surface topography (the areas near wells MW15 and MW16, Woodland Creek, and the West Ravine), the dominant orientation of the inclined fractures in the dolomite appears to parallel the orientation of the fracture trace.

Quaternary deposits lie unconformably on the bedrock throughout the study area (fig. 6). Alluvial sand and gravel deposits are present in the valley of the Rock River and along the lower reaches of Woodland Creek, the Northwest Ravine, and the West Ravine (fig. 1). Windblown sand and silt deposits (loess), underlain by outwash sand and gravel deposits, generally are located along the upper reaches of Woodland Creek, the Northwest Ravine, and the West Ravine. Windblown deposits and two underlying till units compose the surficial deposits along the topographic ridges. Quaternary deposits generally are less than 10 ft thick along the topographic ridges, but are usually greater than 20 ft thick in the ravines (figs. 15–17). The thickness of the Quaternary deposits at the Rock River is unknown but exceeds 130 ft at well RR10 (fig. 2).

A bedrock ridge trending southeast to northwest is between Woodland Creek and the West Ravine, and is reflected by a prominent topographic ridge. The bedrock consists of dolomites of the Platteville and Galena Groups in most of the study area (figs. 15–17). The Platteville and Galena Groups, and the Glenwood Formation have been eroded near the Rock River; and the bedrock is composed of the St. Peter Sandstone.

The bedrock in the study area dips to the south near Woodland Creek, but no consistent trend is indicated near the West Ravine. The altitude of the top of each stratigraphic unit along Woodland Creek (fig. 16, line of section A–A') decreases overall from northwest to southeast. Near the West Ravine, the altitude of the top of the stratigraphic units (fig. 17, line of section B–B') is highest in the vicinity of wells DF4D and DF1D, and decreases to the east and west.

HYDROLOGY

The geologic units in this area can be divided into four primary geohydrologic units—the unconsolidated aquifer, the Galena-Platteville aquifer, the Harmony Hill Shale semiconfining unit, and the St. Peter aquifer (fig. 6). These hydrologic units, particularly the Galena-Platteville aquifer, have been affected by waste-disposal activities at the site. Well records indicate that the unconsolidated, Galena-Platteville and St. Peter aquifers are utilized for water supply in the study area.

Water-level measurements collected from 84 wells on January 27, 1992 (table 1), were used to prepare maps of the altitude and configuration of the water table (fig. 18, at end of report), the potentiometric surface at the base of the Galena-Platteville aquifer (fig. 19, at end of report), and the potentiometric surface at the top of the St. Peter aquifer (fig. 20, at end of report). These maps indicate that ground-water flow at the water table, the base of the Galena-Platteville aquifer, and the St. Peter aquifer is from the salvage yard toward the Rock River with components of flow toward Woodland Creek and the West Ravine. Cursory examination of the maps also indicates that the water table typically is higher than the potentiometric surface at the base of the Galena-Platteville aquifer, which is higher than the potentiometric surface at the top of the St. Peter aquifer in much of the study area.

Unconsolidated Aquifer

The unconsolidated aquifer is composed of the saturated sand and gravel deposits along the Rock River and the saturated Quaternary deposits in the lower reaches of Woodland Creek, the West Ravine, and the Northwest Ravine (fig. 18). The unconsolidated aquifer is unconfined and, where present, is in good hydraulic connection with the underlying Galena-Platteville and St. Peter aquifers, except near the DF9 well cluster (fig. 2). A semiconfining unit composed of till is between the unconsolidated and Galena-Platteville aquifers in this area. The thickness of this semiconfining unit is about 15 ft. Lithologic logs from residential wells near the DF9 well cluster indicate that the till part of the semiconfining unit extends less than 200 ft from the DF9 well cluster. Therefore, the till is unlikely to have an appreciable effect on the hydrology of the study area.

Water Levels

Water-level data collected on January 27, 1992, from those wells open to the unconsolidated aquifer nearest the river (RR-1, 2, 3, 4) indicate that the head increases with increasing well depth (table 1). Head values in wells RR7 and RR8 north of the river also increase with increasing well depth. Although the stage of the Rock River was not measured in January 1992, head values in all these wells exceeded the river stage during most measurement periods (U.S. Environmental Protection Agency, 1994, appendix L) indicating that ground water typically has the potential to discharge to the Rock River. This is consistent with previous investigations, which documented ground-

Table 1. Monitoring well and water-level data, Byron Superfund site

[Well locations shown in figure 2]

Hydrologic unit well is open to: GPWT, well open to the water table in the Galena-Platteville aquifer; BGP, well open to the base of the Galena-Platteville aquifer; MGP, well open to the middle of the Galena-Platteville aquifer; UAWT, well open to the water table in the unconsolidated aquifer; UAM, well open to the middle of the unconsolidated aquifer; GPSS, well open to the entire thickness of the Galena-Platteville aquifer and the upper part of the St. Peter Sandstone aquifer; SS, well open to the St. Peter Sandstone aquifer; HHS, well open to the Harmony Hill Shale semiconfining unit; GP, well open to most or all of the Galena-Platteville aquifer

Water-level altitude: <, less than; NT, measurement not taken

Well name	Hydrologic unit well is open to	Depth of boring (feet below land surface)	Open interval (feet below land surface)	Measuring point altitude (feet above sea level)	Water-level altitude January 27, 1992 (feet above sea level)
AW1D	BGP	161	149–161	833.55	753.68
AW1S	GPWT	83	7–83	833.89	806.43
AW2	GPWT	71	10–71	843.13	787.73
AW4D	BGP	118	96–118	783.94	735.07
AW4S	GPWT	50	15–50	783.70	744.46
AW5D	BGP	172	159–172	845.81	753.74
AW5I	MGP	100	93–100	845.79	766.85
AW6	GPWT	35	9–35	828.70	806.61
B1	GPWT	35	14–35	771.81	<736.81
B2	GPWT	60	31–60	792.76	<732.76
B3	GPWT	50	32–50	819.85	775.12
B4	GPWT	90	63–90	834.03	753.76
B5	GPWT	40	21–40	846.82	809.12
B6	GPWT	95	76–95	850.48	NT
B6R	GPWT	102	15–102	851.69	753.68
DF1D	BGP	111	76–94	787.69	727.55
DF1S	GPWT	62	39–62	787.12	728.07
DF2D	BGP	112	104–112	796.24	729.38
DF2S	GPWT	75	52–75	795.29	728.74
DF3	GPWT	66	43-66	792.09	729.28
DF4DS	GPWT	151	41–64	833.22	NT
DF4DD	BGP	151	137–151	833.04	NT
DF4S	MGP	92	78–92	833.26	756.79
DF5D	MGP	168	98–109	844.75	753.97
DF5S	GPWT	65	13–65	844.29	803.72
DF6	BGP	151	113–125	828.11	744.17
DF7D	UAM	53	40–48	712.79	675.14
DF7S	UAWT	27	20–27	712.71	685.99
DF8	BGP	63	55–63	757.73	719.70
DF9D	BGP	51	41–51	707.38	677.12
DF9S	UAWT	20	7–20	707.61	688.22
DF10	GPWT	84	62–84	834.27	753.66
DF11	GPWT	84	65–84	834.38	753.60
DF12	BGP	134	122–134	834.74	753.70
DF13	MGP	158	101–112	839.24	753.92
DF14D	BGP	166	134–147	847.05	753.89
DF14S	GPWT	111	71–88	847.51	<762.11
DF15	GPWT	115	7–115	849.91	745.51
DF17	BGP	123	97–123	820.59	732.04
DF18	GPWT	63	36–63	780.51	727.57
DF19	GPWT	65	48–65	788.87	727.79
DF20	GPWT	80	9–80	804.91	729.01
DF21	GPWT	100	18–100	840.43	758.87
DF22D	BGP	135	99–109	811.77	728.17
DF22S	GPWT	135	67–90	812.06	727.86

Table 1. Monitoring well and water-level data, Byron Superfund site—Continued

Well name	Hydrologic unit well is open to	Depth of boring (feet below land surface)	Open interval (feet below land surface)	Measuring point altitude (feet above sea level)	Water-level altitude January 27, 1992 (feet above sea level)
DF23	BGP	65	53–65	755.66	719.09
DF24	GPWT	102	19–102	813.94	725.60
DPW	SS	310	190–310	837.06	NT
GW16	GPSS	133	16–133	788.79	NT
GW42	GPWT	101	5–101	838.58	753.16
MS1	BGP	47	34–47	729.27	694.79
MS2	SS	87	72–82	731.14	678.14
MW1	GPWT	71	13–71	862.15	806.50
MW2	SS	231	219–231	861.38	685.75
MW3	GPWT	76	14–76	858.82	789.28
MW8	BGP	180	170–180	853.40	753.56
MW9	GPWT	106	96–106	852.66	758.19
MW10	HHS	189	178–189	854.42	762.98
MW11	BGP	83	68–83	747.89	719.49
MW12I	UAM	52	43–52	726.99	713.44
MW12S	UAWT	33	22–33	728.55	712.58
MW15	GPWT	86	73–86	822.42	752.73
MW16	BGP	147	107–120	823.64	752.68
MW18	SS	237	227–237	853.09	NT
MW20R	SS	191	172–191	822.03	682.44
MW21	SS	234	215–234	821.88	682.47
MW30	GPWT	40	24–37	858.90	819.83
MW31	GPWT	63	50–63	772.96	719.04
MW32	GPWT	46	19–46	755.31	714.03
MW33	GPWT	58	22–58	759.21	712.50
MW36	BGP	156	136–156	843.99	753.93
MW37	SS	206	180–206	843.59	NT
MW39	SS	186	164–186	836.95	682.99
MW41	BGP	146	102–121	817.07	752.48
MW42	BGP	152	135–152	836.57	753.62
PC1B	GPWT	48	32–48	757.60	720.28
PC1C	SS	112	97–112	758.16	680.60
PC2B	GPWT	103	85–103	842.77	757.61
PC3B	GPWT	93	64–83	828.53	760.73
PC4B	GPWT	83	68–83	803.04	727.76
PC5B	GPWT	73	57–73	788.59	725.43
PC6B	GPWT	103	82–103	831.30	746.73
PW3	GPWT	91	8–91	833.38	753.64
PZ1	GP	165	20–165	838.51	NT
PZ2	GP	115	20–115	829.21	NT
RR1	UAM	55	40–53	679.99	672.14
RR2	UAM	25	9–25	678.55	NT
RR3	UAWT	15	4–15	679.90	672.11
RR4	UAM	88	70–88	678.24	672.18
RR5	UAM	40	31–40	689.61	672.11
RR6	UAWT	25	13–25	690.33	672.08
RR7	UAWT	44	28–44	709.00	672.71
RR8	UAM	100	87–100	710.19	672.76
RR9	UAM	58	50–58	689.28	672.00
RR10	UAM	123	103–113	676.27	NT
SPW	GP	150	20–150	836.43	NT

water discharge to the Rock River in the study area (Avery, 1994, p. 17).

Head values in the two wells open to the unconsolidated aquifer at Woodland Creek (MW12S, MW12I) increased with increasing well depth during most of the periods of measurement. This result is consistent with a ground-water discharge boundary near Woodland Creek.

Head values in the remainder of the wells open to the unconsolidated aquifer (RR5, RR6, RR9 and DF7S, DF7D clusters) (fig. 2) decreased with increasing well depth during most of the periods of measurement (table 1). This indicates the potential for flow from the water table deeper into the ground-water-flow system in much of the unconsolidated aquifer.

Aquifer Tests

Previous investigators attempted to calculate horizontal hydraulic conductivities from slug tests in wells RR1, RR2, RR5, and RR6. These wells are open to the unconsolidated aquifer near the Rock River (fig. 2). The high permeability of the aquifer at these wells prevented collection of sufficient data for analysis in every well except RR5, where a horizontal hydraulic conductivity of 2.1×10^{0} ft/d was calculated (Avery, 1994, p. 8).

Horizontal hydraulic conductivities calculated from three slug tests conducted during the current investigation in wells open to the unconsolidated aquifer ranged from 5.1×10^{-1} to 9.8×10^{0} ft/d (table 2). Though sparse, the data indicate that the unconsolidated aquifer is moderately to highly permeable throughout the study area.

Galena-Platteville Aquifer

The Platteville and Galena Groups are lithologically and hydrologically similar, and are considered a single hydrologic unit—the Galena-Platteville aquifer. The Galena-Platteville is an unconfined, double-porosity aquifer characterized by a primary porosity associated with the porous rock matrix and a secondary porosity associated with the fractures, joints, and solution openings in the dolomite. The elements of primary and secondary porosity are hydraulically connected. Most ground-water flow is through the fractures, joints, and solution openings, whereas most ground-water storage is in the porous matrix of the aquifer.

The water table is in the Galena-Platteville aquifer in most of the study area (fig. 18) and the Galena-Platteville is the uppermost aquifer beneath the disposal sites. The Galena-Platteville is the most contaminated aquifer in the study area, primarily because it is closest to the disposal sites. Because of the complex pathways of flow in this aquifer, extensive investigation is required to adequately characterize ground-water flow and contaminant transport.

Water Levels

The water-table configuration in the Galena-Platteville aquifer generally mirrors surface topography (fig. 18). The overall direction of ground-water flow in the aquifer is toward the Rock River with components of flow toward topographic lows at Woodland Creek and the West Ravine. The water-table contours and water-quality data, collected by previous investigators, indicate a hydraulic barrier to ground-water flow in the vicinity of Woodland Creek preventing flow across the creek (a no-flow boundary). It is unclear if a hydraulic barrier is associated with the West Ravine.

Closer analysis of the water-table configuration indicates that the Galena-Platteville aquifer underlying the salvage yard and DFP can be divided into four zones based on the altitude and configuration of the water table (fig. 21, at end of report). Each of these zones has distinctive hydraulic characteristics (table 3). Transitional areas are present between most zones. The exact location of the transitional areas and the boundaries between zones is somewhat arbitrary, but the transitional areas typically are characterized by large changes in the water-table altitude over short distances (high horizontal hydraulic gradient). Zones 1 through 4 typically have smaller changes in water-table altitude over larger distances (low horizontal hydraulic gradient).

Zone 1 corresponds primarily to the part of the water table above the 770-ft contour (fig. 21). Zone 1 underlies much of the central and southeastern parts of the salvage yard and the southeastern part of the DFP around wells B5, MW1, AW1S, AW6, AW2, MW3, DF5S, and DF4DS (fig. 2).

Zone 2 is characterized by a flat part of the water table from about 745 to 770 ft above sea level (fig. 21). Zone 2 underlies the western part of the salvage yard and the northern part of the DFP in the vicinity of wells PC6B, B4, DF21, MW15, MW41, GW42, MW9, and

Table 2. Horizontal hydraulic conductivities calculated from slug-test data from selected monitoring wells, Byron Superfund site

[NA, not applicable]

Aquifer zone: Shown in figure 21; T, transitional area between aquifer zones

Stratigraphic unit tested: P, Pecatonica Formation; QM, Quimbys Mill Formation; GD, Grand Detour Formation; N, Nachusa Formation; G, Galena Group; M, Mifflin Formation

Well name	Aquifer zone	Stratigraphic unit tested	Horizontal hydraulic conductivity (feet per day)
		Galena-Platteville Aquifer	
AW1D	1	P	2.2×10^{-2}
AW2	1	QM	3.6×10^{-2}
AW4S	4	GD	3.0×10^{0}
AW5D	1	P	2.4×10^{-1}
AW5I	1	N	6.4×10^{-1}
AW6	1	G	1.6×10^{-1}
B3	4	QM	1.5×10^{0}
B4	2	GD	7.6×10^{0}
B5	1	G	5.8×10^{-2}
B6	2	N	1.4×10^{3}
B6R	2	GD	3.2×10^{1}
DF1D	4	P	1.6×10^{1}
DF2D	4	P	1.0×10^{0}
DF2S	4	GD	8.1×10^{-3}
DF3	4	GD	3.3×10^{1}
DF4DD	1	P	5.3×10^{-1}
DF4DS	1	QM/N	1.2×10^{0}
DF4S	1	GD	2.7×10^{-1}
DF5D	1	GD	7.6×10^{0}
DF5S	1	G/QM	1.6×10^{-1}
DF6	T	M/P	2.4×10^{-2}
DF8	4	P	3.2×10^{1}
DF9D	T	P	5.8×10^{-1}
DF10	3	GD	4.0×10^{1}
DF11	3	GD	1.9×10^{1}
DF12	3	M/P	7.1×10^{2}
DF13	T	GD	1.4×10^{1}
DF15	4	GD	6.2×10^{1}
DF17	4	P	2.4×10^{1}
DF18	4	GD	4.0×10^{1}
DF19	4	GD	6.3×10^{0}
DF20	T	GD	1.0×10^{0}
DF21	2	GD	9.6×10^{0}
DF22S	4	GD	3.4×10^{1}
DF22D	4	M/P	1.1×10^{0}
		Galena-Platteville Aquifer—Continued	
DF23	4	M/P	1.2×10^{1}
DF24	4	GD	8.5×10^{3}
MW1	1	G	1.3×10^{-1}
MW3	1	G	3.3×10^{-1}
MW8	2	P	1.4×10^{0}
MW9	2	N/GD	2.7×10^{-2}
MW15	2	GD	2.3×10^{0}
MW16	2	M/P	9.9×10^{1}
MW31	4	GD/M	3.0×10^{-2}
MW33	4	M	3.6×10^{1}
MW36	1	P	1.4×10^{0}
MW41	2	P	2.3×10^{2}
MW42	2	P	7.1×10^{-2}
PC1B	4	GD/M	3.2×10^{1}
PC2B	T	GD	9.5×10^{0}
PC3B	T	N/GD	5.5×10^{0}
PC4B	4	GD	1.6×10^{1}
PC5B	4	GD	8.6×10^{1}
PC6B	2	GD	1.8×10^{-1}
PW3	3	GD	3.4×10^{3}
		Unconsolidated Aquifer	
DF7D	NA	NA	3.4×10^{0}
DF7S	NA	NA	5.1×10^{-1}
DF9S	NA	NA	9.8×10^{0}
		St. Peter Aquifer	
MW2	NA	NA	5.1×10^{0}
MW37	NA	NA	5.8×10^{0}
PC1C	NA	NA	2.8×10^{0}

B6R (fig. 2). Zone 3 is encompassed by zone 2 and corresponds to the area near wells PW3, DF10, DF11, and DF12 where the water-level altitudes are nearly identical (table 1).

Zone 4 is defined by water-table altitudes, typically less than 750 ft above sea level near Woodland Creek and typically less than 730 ft above sea level near the West Ravine. Zone 4 is an area of lower land surface elevation defined by water levels in wells B1, B2, B3, AW4S, DF1S, DF2S, DF3, DF15, DF17, DF18, DF19, DF22S, DF24, MW30, MW31, MW33, PC1B, PC4B and PC5B (fig. 2).

LeGrand and Stringfield (1971) noted that the water-table altitude in carbonate-rock aquifers tends to be low where the aquifer permeability is high, and the water-table altitude tends to be high where the aquifer permeability is low. If the altitude of the water table in the Galena-Platteville aquifer is affected by the permeability distribution in the aquifer, the following conclusions can be made—

1. The high water-table altitude associated with zone 1 indicates that zone 1 is an area of low permeability with a low degree of fracture interconnection. Lithologic and geophysical logs indicate competent,

Table 3. Water-level altitudes and horizontal hydraulic conductivity in zones 1–4 in the Galena-Platteville aquifer, Byron Superfund site
[>, greater than; <, less than]

Zone	Typical altitude of water table January 27, 1992 (feet above sea level)	Maximum difference in water level between bottom and top of aquifer January 27, 1992 (feet)	Median horizontal hydraulic conductivity (feet per day)
1	>770	55.4	3.1×10^{-1}
2	745–770	4.9	5.2×10^{0}
3	[1]753.6	[1].9	2.4×10^{2}
4	<745	10.8	8.0×10^{0}

[1]Approximately.

unfractured dolomite in the upper part of the aquifer at wells DF5S, DF4S, AW1S, AW2, AW6, MW1, and MW3 (fig. 2), which supports this conclusion. Lithologic and geophysical logs also indicate permeable zones in the deeper parts of the aquifer at boreholes DF4D, DF5D, PZ1 (figs. 8, 9, and 14), and at well AW5I. This indicates that the aquifer in zone 1 can be divided into a shallow, less-permeable unit and a deeper, more-permeable unit.

2. The intermediate water-table altitude in zones 2 and 3 indicate an area with little topographic variation and a well-developed system of permeable, interconnected fractures and solution openings. Ground-water flow in this area is primarily through fractures and solution openings, which are more prominent in zone 3 than in zone 2. Large fractures, caverns, and solution openings in the dolomite, identified from lithologic and geophysical logs at boreholes DF12, DF17 (figs. 10, 12), DF24, B6R, and PW3 (not shown), supports this conclusion.
3. The low water-table altitude in zone 4 indicates an area with steeply dipping topography and a well-developed fracture network. Ground-water flow in this zone also is primarily through fractures. Highly weathered and fractured dolomite, identified from outcrops and lithologic logs for wells near Woodland Creek and the West Ravine, supports this conclusion.

Stratigraphic descriptions of cores (Environmental Resources Management, 1990, appendix C; Michael Sargent, Illinois State Geological Survey, written commun., 1993) and analysis of lithologic and geophysical logs (figs. 7–14) indicate that the Guttenberg Formation typically is about 5 ft thick beneath zone 1 and the transitional areas between zones 1 and 2 (fig. 21). This analysis also indicates that the Guttenberg Formation was largely or completely eroded during the Ordovician System beneath zone 3, parts of zone 2 (MW18 and MW21 well clusters, wells B6R, DF21, MW41, and possibly well B4), and zone 4 (DF22 well cluster, well DF17, and perhaps well DF15). Erosion of the Guttenberg Formation may have increased the formation and development of secondary permeability features in the Galena-Platteville aquifer making the aquifer more permeable where the Guttenberg Formation was eroded. Where the Guttenberg Formation is present, extensive development of secondary permeability features appears to have been retarded. It appears, therefore, that the water-table altitude in zones 1–4 and the permeability distribution in the Galena-Platteville aquifer is affected by the presence or absence of the Guttenberg Formation.

The configuration of the potentiometric surface at the base of the Galena-Platteville aquifer is similar to the water-table configuration (fig. 19). The overall direction of ground-water flow is toward the Rock River with components of flow toward topographic lows at Woodland Creek and the West Ravine.

Comparison of water levels between the water table and the middle or the base of the Galena-Platteville aquifer indicates the potential for downward ground-water flow in this aquifer in most of the study area. The water-table altitude is about 45 ft higher than head values in the middle of the aquifer and about 60 ft higher than head values at the bottom of the aquifer in zone 1 (compare data from the B5/AW5I/AW5D, DF5S/DF5D, and AW1S/AW1D well clusters in table 1). The water-table altitude is less than 5 ft higher than head values at the base of the aquifer in much of zone 2 and less than 17 ft higher in the transitional areas (compare data from the MW8/9, MW15/16, DF14S/DF14D, and PC3B/DF6 well clusters in table 1). The water-table altitude ranges from less than 1 to more than 10 ft higher than the head at the base of the Galena-Platteville aquifer in much of zone 4 (compare data from the DF1S/DF1D, AW4S/AW4D, and PC1B/DF8 well clusters in table 1). The head at depth in the aquifer is less than 1 ft higher than the water-table altitude at the DF2S/DF2D and DF22S/DF22D well clusters indicating horizontal or slight upward flow.

A more detailed analysis of the vertical variations in head within the Galena-Platteville aquifer was obtained from discrete test intervals isolated with a packer assembly (fig. 4). Test intervals sampled most or all of the saturated thickness of the aquifer at boreholes DF5D, DF12, DF13, DF17, SPW, AW1S, and PZ1 (table 4). Head values did not equilibrate during testing in boreholes DF2D, DF4D, DF6, and DF14D because of slow recovery rates due to low horizontal hydraulic conductivity of the aquifer at these boreholes. Therefore these boreholes were not use.

Head values obtained from the test intervals indicate the potential for downward flow within the Galena-Platteville aquifer at boreholes DF5D, DF12, DF13, SPW, AW1S, and PZ1, and the potential for upward flow near borehole DF17. Differences in head values between the top and bottom of the aquifer typically exceeded 23 ft for those boreholes in zone 1 (DF5D, SPW, AW1S, and PZ1), except for borehole SPW (table 4). Differences in head values between the top and bottom of the aquifer are less than 2.5 ft for those boreholes in zone 2 (DF17) and transition areas

Table 4. Water-level altitudes above, within, and below test intervals isolated with a packer assembly under approximately hydrostatic conditions, Byron Superfund site

[The test interval includes the shallowest or deepest part of the aquifer]

Water-level altitude: NA, not applicable; NT, measurement not taken;
NE, water level had not reached equilibrium at the time of measurement; >, greater than

Borehole name	Test interval	Depth of test interval (feet below measurement point)	Water-level altitude (feet above sea level)		
			Above test interval	In test interval	Below test interval
AW1S	A	67.9 – 82.7	803.93	767.63	NA
AW1S	B	29.8 – 48.9	NA	804.12	NT
DF5D	A	154.0 – 170.0	756.32	754.41	NA
DF5D	B	144.0 – 154.0	756.28	756.12	755.14
DF5D	C	134.0 – 144.0	756.31	756.17	756.14
DF5D	D	124.0 – 134.0	756.35	NT	756.20
DF5D	E	114.0 – 124.0	756.22	756.19	756.05
DF5D	F	91.0 – 114.0	NA	756.24	756.20
DF5D	G	104.0 – 114.0	767.92	756.02	756.02
DF5D	H	68.0 – 100.0	NA	776.02	755.79
DF5D	I	66.5 – [1]75.0	NA	777.42	765.07
DF12	A	133.0 – 94.0	759.87	759.87	NA
DF12	B	94.0 – 104.0	759.87	759.82	NT
DF12	C	84.0 – 94.0	>760.30	759.91	NT
DF12	D	80.0 – 84.0	NA	759.85	NT
DF13	A	143.7 – 158.8	764.02	763.95	NA
DF13	B	133.6 – 143.7	NE	NE	NE
DF13	C	123.3 – 133.3	763.58	763.54	763.52
DF13	D	113.3 – 123.3	763.67	763.64	763.61
DF13	E	103.3 – 113.3	NT	763.60	763.54
DF13	F	93.3 – 103.3	NE	NE	NE
DF13	G	73.3 – 92.4	NA	764.80	764.50
DF17	A	105.0 – 121.8	736.78	738.73	NA
DF17	B	95.0 – 105.0	736.87	NT	738.74
DF17	C	83.2 – 95.0	NA	736.79	NT
PZ1	A	151.0 – 167.0	753.85	754.00	NA
PZ1	B	141.0 – 151.0	753.91	753.81	754.23
PZ1	C	134.0 – 144.0	753.93	753.83	754.41
PZ1	D	124.0 – 134.0	754.31	753.86	753.80
PZ1	E	114.0 – 124.0	754.39	754.05	754.05
PZ1	F	104.0 – 114.0	759.58	755.03	755.03
PZ1	G	94.0 – 104.0	758.64	755.09	755.14
PZ1	H	84.0 – 94.0	791.54	758.84	>755.51
SPW	A	134.4 – 149.8	NT	NT	NT
SPW	B	124.4 – 134.4	754.13	754.05	NA
SPW	C	114.4 – 124.4	753.68	753.58	NT
SPW	D	104.4 – 114.4	753.58	753.56	NT
SPW	E	94.4 – 104.4	NT	NT	NT
SPW	F	82.9 – 94.4	NA	753.56	NT

[1]Approximately.

(DF13), and less than 1 ft at borehole DF12 in zone 3. These results are consistent with the head data obtained from the monitoring wells.

Data from the test intervals in the boreholes and monitoring wells in zone 1 indicate that the differences in water level between the water table and the base of the Galena-Platteville aquifer in zone 1 were appreciably higher than in zones 2, 3, or 4 (table 3). If flow in this area is constant, application of Darcy's law indicates that the vertical hydraulic conductivity of the Galena-Platteville aquifer in zone 1 is lower than in zones 2, 3, and 4. This is consistent with the analysis of the water-table configuration, which indicated that the fractures in zone 1 are less permeable, less interconnected, and fewer in number than the fractures and solution openings in zones 2, 3, and 4.

Water levels measured in the wells and open boreholes with the packer assembly indicate that levels are affected by the vertical distribution of head and horizontal hydraulic conductivity in the aquifer along the open interval of the well or borehole (Sokol, 1963, p. 1079). This is especially apparent in zone 1.

The effect of vertical variations of head in the aquifer on the head measured in the well or borehole was demonstrated during testing with the packer assembly in borehole AW1S (table 4). This borehole is open to the aquifer from 7 to 83 ft below land surface (table 1). The head in this borehole was 780.99 ft above sea level before insertion of the packer assembly. When test interval A (from 67.9 to 82.7 ft) was isolated, purged, and allowed to recover for about 13 hours, the head within the test interval fell to 767.63 ft above sea level while the head above the test interval rose to 803.93 ft above sea level. This indicates that the head value in the open borehole was affected by the vertical distribution of head in the aquifer along the open interval of the borehole. The actual water-table altitude in the vicinity of borehole AW1S is greater than the value obtained from the open borehole and noted in table 1 and figure 18. Similar to borehole AW1S, wells MW3, AW2, and MW1 have open intervals that penetrate a large part of the saturated thickness of the aquifer in zone 1 (table 1). The head value measured in these wells also may be as much as 20 ft lower than the actual water-table altitude. This also is supported by television camera logging in boreholes AW1S, AW2, and PZ1, which indicates the aquifer is saturated above the water level in the well.

The effect of vertical variations in horizontal hydraulic conductivity on head values in open boreholes was demonstrated during testing with the packer assembly in borehole DF5D (fig. 7, table 4). Lithologic and geophysical logs indicate that the aquifer permeability at that part of the borehole from 727 to 740 ft above sea level (approximate depth from 105 to 118 ft) is higher than the aquifer permeability in the remainder of the borehole. The head above the test interval was about 756.3 ft above sea level when the test intervals below the permeable part of the borehole were isolated (test intervals A–D) (table 4). This is similar to the head within the test interval when the permeable section of the borehole was isolated (test intervals E–G). The head value above (interval G) or within (intervals H and I) the test intervals increased to over 777 ft above sea level when that part of the aquifer above the permeable section of the borehole was isolated. Similar trends were observed in borehole PZ1 (table 4). This indicates that the head value in a borehole (or well) is affected by the head at the most permeable part of the aquifer to which the borehole (or well) is open.

Flowmeter Logging

In addition to using water-level data to characterize flow directions and the distribution of permeability in the Galena-Platteville aquifer, the flow direction and aquifer permeability was characterized using flowmeter logs (figs. 8–14) (Frederick Paillet, U.S. Geological Survey, written commun., 1991, 1993). Flowmeter logs indicate ground-water flow is directed downward in boreholes DF4D, DF5D, DF12, DF13, PZ1, and B6R and upward in borehole DF17 under conditions of natural flow. This is consistent with flow directions indicated by water-level measurements collected with the packer assembly in these boreholes (table 4). Comparison of acoustic-televiewer logs to the intervals of measurable change in flow identified from the flowmeter logs indicates that most of the flow in the aquifer is through fractures, vugs, and solution openings in the dolomite (figs. 8–14). This is typical of flow in a fractured-carbonate aquifer.

Flowmeter logging in borehole DF4D, under conditions of natural flow, indicates inflow of water draining down the borehole to the top of the water column at 67 ft and inflow along subhorizontal bedding-plane fractures from about 70 to 80 ft (fig. 8). Outflow was through bedding-plane fractures, inclined fractures, and vugs from about 80 to 102 ft. About 0.20 gal/min of outflow was measured through bedding-plane fractures from 131 ft to the bottom of the borehole. No flow into or out of the borehole was measured from 105 to 131 ft. Flowmeter logging during pumping of the borehole indicated the same flow intervals.

Inflow of ground water draining down the borehole wall to the top of the water column at 82 ft, and possibly, inflow from one or more bedding-plane fractures between 82 and 85 ft, was detected in borehole DF5D (fig. 9). Inflow from above the top of the water column, which also was detected at borehole PZ1, indicates that the aquifer is saturated above the water level in the borehole. This is consistent with the analysis of the water-level data collected with the packer assembly. Outflow through a number of fractures and vugs was detected from 105 to 115 ft. No flow was detected below 115 ft.

Inflow through vugs and fractures from approximately 92 to 105 ft was identified in borehole DF12, under conditions of natural flow (fig. 10). Although the cavity at the bottom of the borehole prevented measurements from being taken, it is probable that there was outflow through the fractures and solution openings between 110 ft and the bottom of the borehole. No flow was detected from the numerous fractures above 90 ft and from 105 to 110 ft. Flowmeter logging during pumping in borehole DF12 identified the same flow intervals.

Flowmeter logging in borehole DF13, under natural conditions, indicated little or no flow in the borehole (fig. 11). This lack of flow can probably be attributed to the small differences in head over the length of the borehole (table 4). Flowmeter logging during pumping identified measurable flow along bedding-plane fractures at 80 and 105–107 ft as well as through a vuggy weathered zone at about 92 ft. A small amount of flow (about 0.25 gal/min) through the dolomite matrix was indicated from about 137 ft to the bottom of the borehole.

Flowmeter logging in borehole DF17, under conditions of natural flow, indicated inflow from solution openings below 110 ft and outflow through a bedding-plane fracture at about 90 ft (fig. 12). No change in flow was detected from 81 to 89 ft and 91 to 110 ft.

Flowmeter logging in borehole PZ1, under conditions of natural flow, indicated water seeping into the borehole and draining down to the static water level in the borehole. Outflow was through a vuggy, fractured part of the aquifer at about 130 ft (fig. 14). No other changes in flow were detected.

No vertical flow was identified in borehole SPW (fig. 13). This is consistent with the results of dilution logging conducted in the borehole (Pedlar, 1991), but it does not agree with head values collected with the packer assembly (table 4), which indicate the potential for downward flow. These results indicate that hydrologic conditions in April 1991, when the flowmeter and borehole-dilution logging were conducted, were different than in September 1991, when the water-level measurements were taken. It also is possible that measurement error resulted in incorrect calculations of head values during packer testing, indicating that vertical flow was possible when it was not. The vertical fracture intercepted by borehole SPW should provide good vertical hydraulic connection within the aquifer in this area, which would result in small or no vertical changes in head over the length of the borehole and in a lack of vertical flow within the borehole.

Flowmeter logs from boreholes DF4D, DF5D, DF12, DF13, and DF17 indicate measurable changes in the rate of flow in the Galena-Platteville aquifer from 730 to 760 ft above sea level (fig. 22). This interval is primarily within the Grand Detour Formation of the Platteville Group (figs. 8–12), which indicates that this formation is more permeable than the other formations within the Galena-Platteville aquifer. The changes in the amount of flow also indicate a network of interconnected fractures from 730 to 760 ft above sea level in the vicinity of boreholes DF4D, DF5D, and DF13. The extent of this fracture network is uncertain.

Aquifer Tests

Analysis of aquifer tests, conducted by previous investigators, indicate that ground-water flow in the Galena-Platteville aquifer is complex. Horizontal hydraulic conductivities, calculated by previous investigators, from slug tests in monitoring wells open to the Galena-Platteville aquifer ranged from 7.0×10^{-1} to 6.4×10^{1} ft/d (Camp Dresser & McKee, Inc., 1989, p. 3:20; Olson, 1988, p. 62; Warzyn, 1988, p. 2). The wide range of values indicates the aquifer is heterogeneous. Constant-discharge aquifer tests conducted during previous studies indicate that the aquifer is anisotropic, and the direction of anisotropy is affected by the orientation of the inclined fractures near the pumped well (Kay and others, 1989, p. 31–41). The calculated transmissivity of the aquifer at the salvage yard was at a maximum of 670 ft^2/d directed N. 60 W. from the pumped borehole (SPW). The transmissivity

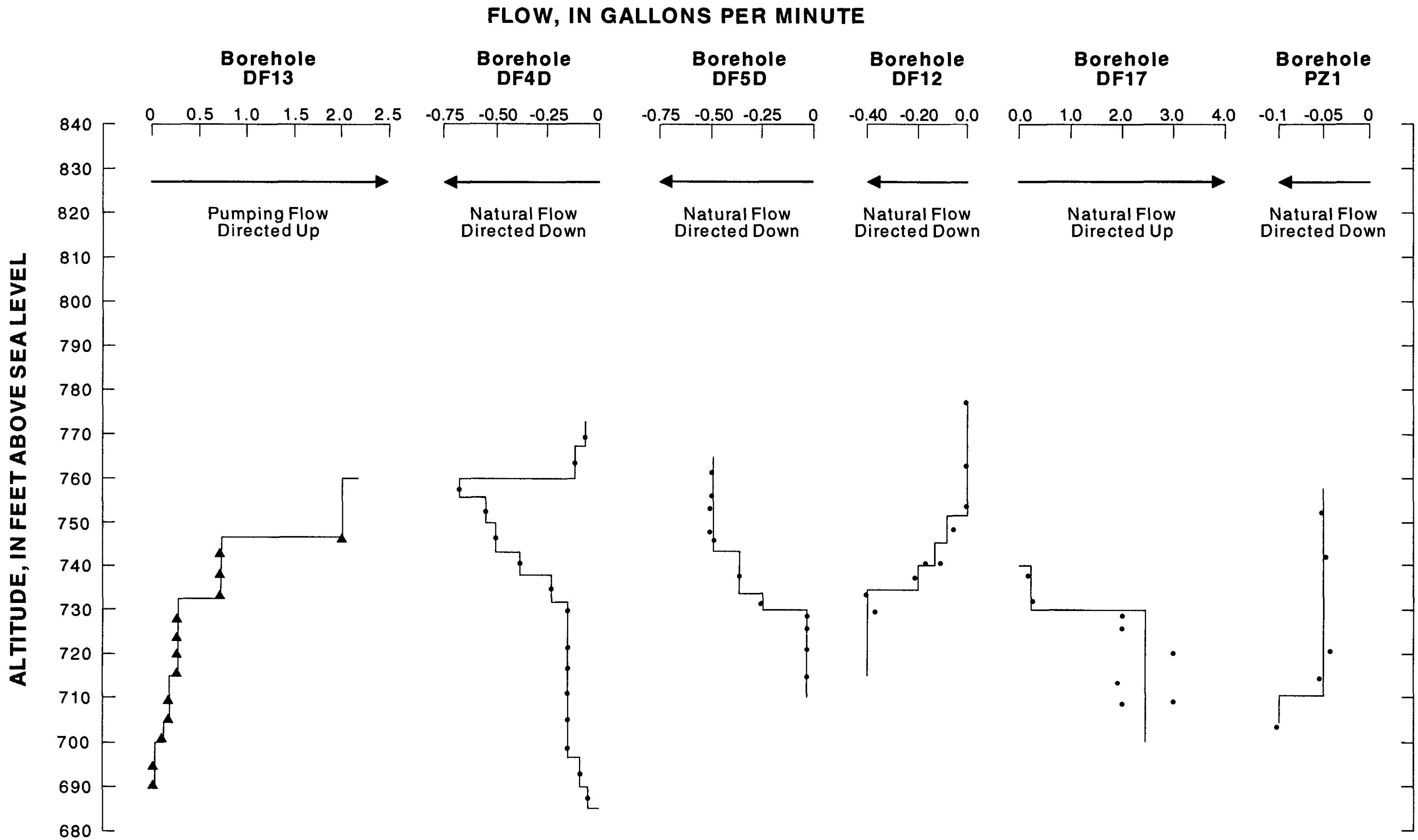


Figure 22. Flowmeter logs from selected boreholes, Byron Superfund site.

of the aquifer was calculated to be 490 ft^2/d perpendicular to the N. 60 W. direction.

The slug tests and constant-discharge aquifer tests conducted during this study expanded on the work of previous investigators. This additional testing has substantially improved the understanding of the hydrology of the Galena-Platteville aquifer.

Slug Tests

Slug tests were conducted in test intervals isolated with the packer assembly at boreholes DF2D, DF4D, DF5D, DF6, DF12, DF13, DF14D, SPW, PZ1, and AW1S. All but two of these boreholes (DF2D and DF12) are located in zone 1 of the Galena-Platteville aquifer or transitional areas near zone 1 (fig. 21). The results of this testing are not necessarily representative of conditions in the Galena-Platteville aquifer throughout the study area.

Slug tests in the test intervals were done to determine the vertical distribution of horizontal hydraulic conductivity in the Galena-Platteville aquifer. This information was used to identify laterally, extensive zones of high or low horizontal hydraulic conductivity in the aquifer and to determine the median horizontal hydraulic conductivity of the formations that compose the aquifer. Slug tests also were conducted to identify areas of hydraulic interest in the borehole. This information was used to guide the placement of the well screen, when the monitoring well was installed in the borehole, ensuring that the monitoring well provided as much useful information as possible.

Slug tests were conducted in 55 finished monitoring wells open to the Galena-Platteville aquifer throughout the study area. These slug tests were conducted to determine the spatial distribution of horizontal hydraulic conductivity in the aquifer and to identify the horizontal hydraulic conductivity of the formations that compose the aquifer.

Borehole Test Intervals

Horizontal hydraulic conductivities, determined from slug tests in the test intervals in the boreholes, ranged from 3.4×10^{-3} ft/d in test interval A of borehole DF14D to 1.1×10^{4} ft/d in test interval B of borehole DF12 (table 5). This range of seven orders of magnitude indicates the aquifer is heterogeneous. The frequency distribution of horizontal hydraulic conductivities from these test intervals indicates an approximately even distribution around a maximum value of 10^{-1} ft/d (fig. 23), which indicates that the horizontal hydraulic conductivity of most of the Galena-Platteville aquifer beneath the area tested is from 1.0×10^{-2} to 9.9×10^{0} ft/d. There also were two values in the 10^3 to 10^4 ft/d range.

Comparison of horizontal hydraulic conductivities to elevation (table 5) indicates an interval of elevated conductivity from 719 to 744 ft above sea level in boreholes DF5D (test intervals E and G), DF4D (test intervals D and E), and DF13 (test intervals E and F). The horizontal hydraulic conductivity above 735 ft above sea level at borehole DF6 (test interval F) is slightly higher than in the remainder of the borehole. The horizontal hydraulic conductivity below 743 ft above sea level at borehole DF12 (intervals A and B) is substantially higher than above this elevation. An interval of high horizontal hydraulic conductivity was detected from 724 to 744 ft above sea level at borehole PZ1 (test intervals F and G), but the lateral extent of this interval is not known. The horizontal hydraulic conductivity of the Galena-Platteville aquifer near the salvage yard and DFP is higher (from 719 to 744 ft above sea level) than in other altitudes. This interval usually corresponds to the Grand Detour Formation (figs. 8–11 and 14) indicating that stratigraphy affects the horizontal hydraulic conductivity of the Galena-Platteville aquifer.

Horizontal hydraulic conductivities calculated for test intervals A, E, F, and G in borehole DF14D are less that 3.0×10^{-1} ft/d. Water levels recovered too slowly for slug tests to be conducted in intervals B, C, D, and H, which indicates a horizontal hydraulic conductivity of less than 1.0×10^{-3} ft/d in these intervals. A small circular depression in the land surface at borehole DF14D and the high amount of clay returned from the boring during drilling indicate a sinkhole that has been completely infilled with clays is located in this area. The uniformly low horizontal hydraulic conductivity of the aquifer in this area is considered a localized feature.

The high horizontal hydraulic conductivity, calculated at all of the test intervals in borehole DF12, indicates permeable fractures and solution openings over the entire thickness of the Galena-Platteville aquifer near this borehole (fig. 10). However, the fractures and solution openings at test intervals A and B are substantially more permeable than those at test interval C, which are substantially more permeable than those at test interval D. This interpretation is consistent with interpretations made from analysis of

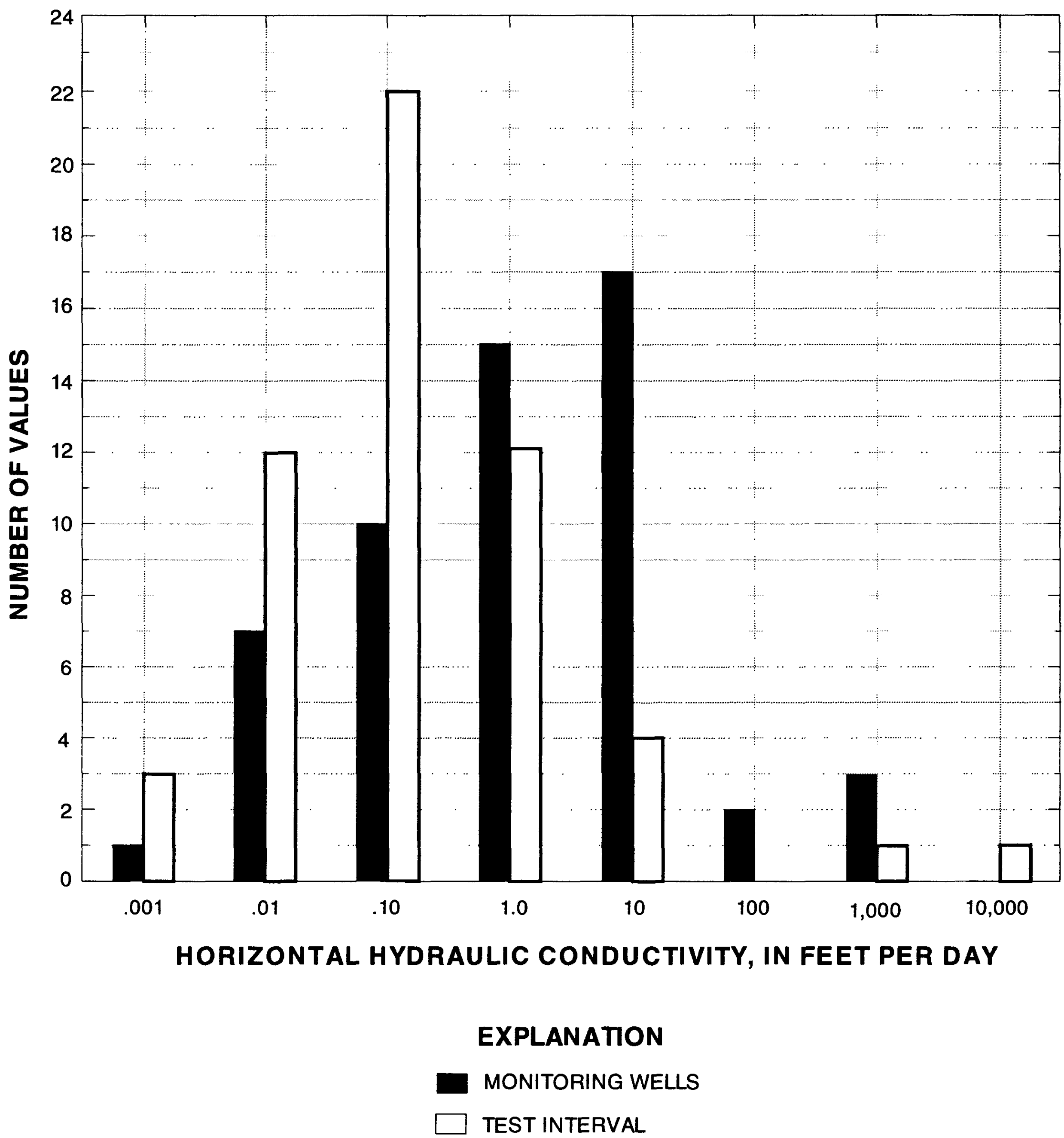


Figure 23. Distribution of horizontal hydraulic conductivity within the Galena-Platteville aquifer determined from monitoring wells and from test intervals in selected boreholes, Byron Superfund site.

Table 5. Results of slug testing in test intervals isolated with a packer assembly, Byron Superfund site

Aquifer zone: Shown in figure 21; T, transitional area between zones

Stratigraphic units tested: P, Pecatonica Formation; M, Mifflin Formation; GD, Grand Detour Formation; N, Nachusa Formation; QM, Quimbys Mill Formation; G, Galena Group

Borehole name	Test interval	Aquifer zone	Stratigraphic units tested	Measuring point altitude (feet above sea level)	Depth of test interval (feet below measuring point)	Horizontal hydraulic conductivity (feet per day)
AW1S	A	1	N	833.96	67.9– 82.7	4.5×10^{-3}
AW1S	B	1	G	833.96	29.8– 48.9	3.8×10^{-2}
DF2D	A	4	P	796.80	96.0–113.0	9.9×10^{-1}
DF2D	B	4	M/P	796.80	86.0– 96.0	1.2×10^{0}
DF2D	C	4	GD	796.80	66.0– 81.0	1.3×10^{0}
DF4D	A	1	P	834.06	135.0–150.0	8.4×10^{-1}
DF4D	B	1	P	834.06	124.6–134.6	4.8×10^{-1}
DF4D	C	1	M	834.06	114.2–124.2	1.2×10^{-1}
DF4D	D	1	GD	834.06	103.8–113.8	1.7×10^{0}
DF4D	E	1	GD	834.06	93.4–103.4	6.5×10^{0}
DF4D	F	1	GD	834.06	83.0– 93.0	3.1×10^{-1}
DF4D	G	1	N/GD	834.06	71.8– 83.0	3.7×10^{-1}
DF5D	A	1	P	844.97	154.0–170.0	6.9×10^{-3}
DF5D	B	1	P	844.97	144.0–154.0	5.6×10^{-2}
DF5D	C	1	M/P	844.97	134.0–144.0	2.9×10^{-2}
DF5D	D	1	GD/M	844.97	124.0–134.0	6.7×10^{-2}
DF5D	E	1	GD	844.97	114.0–124.0	1.8×10^{1}
DF5D	F	1	GD	844.97	91.0–114.0	3.2×10^{0}
DF5D	G	1	GD	844.97	104.0–114.0	9.3×10^{0}
DF5D	H	1	QM/N/GD	844.97	68.0–100.0	5.3×10^{-2}
DF6	A	T	P	828.08	136.0–151.0	6.3×10^{-2}
DF6	B	T	P	828.08	126.0–136.0	2.2×10^{-1}
DF6	C	T	M	828.08	116.0–126.0	1.3×10^{-1}
DF6	D	T	M	828.08	106.0–116.0	2.4×10^{-2}
DF6	E	T	GD	828.08	96.0–106.0	5.2×10^{-2}
DF6	F	T	GD	828.08	75.0– 93.0	7.1×10^{-1}
DF12	A	3	GD/M/P	834.82	133.0– 94.0	3.6×10^{3}
DF12	B	3	GD	834.82	94.0–104.0	1.1×10^{4}
DF12	C	3	GD	834.82	84.0– 94.0	8.9×10^{1}
DF12	D	3	GD	834.82	80.0– 84.0	4.9×10^{0}
DF13	A	T	P	836.61	143.7–158.8	4.6×10^{-1}
DF13	B	T	P	836.61	133.6–143.7	4.6×10^{-1}
DF13	C	T	M/P	836.61	123.3–133.3	2.1×10^{-1}
DF13	D	T	GD/M	836.61	113.3–123.3	1.9×10^{-1}
DF13	E	T	GD	836.61	103.3–113.3	2.9×10^{0}
DF13	F	T	GD	836.61	93.3–103.3	1.6×10^{1}
DF13	G	T	N/GD	836.61	[1]73.3– 93.3	4.8×10^{-1}
DF14D	A	T	P	[1]845.00	154.8–169.6	3.4×10^{-3}
DF14D	E	T	GD	[1]845.00	114.0–124.0	1.5×10^{-1}
DF14D	F	T	GD	[1]845.00	104.0–114.0	1.5×10^{-1}
DF14D	G	T	GD	[1]845.00	94.0–104.0	2.9×10^{-1}
PZ1	A	1	P	838.51	151.0–167.0	2.5×10^{-2}
PZ1	B	1	P	838.51	141.0–151.0	1.5×10^{-1}
PZ1	C	1	M/P	838.51	134.0–144.0	3.5×10^{-1}
PZ1	D	1	M	838.51	124.0–134.0	1.0×10^{1}
PZ1	E	1	M/GD	838.51	114.0–124.0	2.7×10^{-1}
PZ1	F	1	GD	838.51	104.0–114.0	9.7×10^{-1}
PZ1	G	1	GD	838.51	94.0–104.0	9.1×10^{-1}
PZ1	H	1	GD/N	838.51	84.0– 94.0	2.8×10^{-2}
SPW	A	1	P	836.43	134.4–149.8	2.0×10^{-2}

Table 5. Results of slug testing in test intervals isolated with a packer assembly, Byron Superfund site—Continued

Borehole name	Test interval	Aquifer zone	Stratigraphic units tested	Measuring point altitude (feet above sea level)	Depth of test interval (feet below measuring point)	Horizontal hydraulic conductivity (feet per day)
SPW	B	1	M	836.43	124.4–134.4	6.6×10^{0}
SPW	C	1	GD/M	836.43	114.4–124.4	1.0×10^{0}
SPW	D	1	GD	836.43	104.4–114.4	4.4×10^{-2}
SPW	E	1	GD	836.43	94.4–104.4	3.3×10^{0}
SPW	F	1	N/GD	836.43	82.9– 94.4	1.5×10^{0}

[1]Approximately.

the geophysical logs and the water-table configuration in zone 3.

Horizontal hydraulic conductivities in borehole SPW are in the 10^{-2} ft/d to 10^{0} ft/d range. The higher values are from test intervals that intercepted the vertical fracture in this borehole (fig. 13). The lower values are from test intervals not open to the fracture.

The areas of elevated horizontal hydraulic conductivity identified from analysis of the slug tests in the boreholes could only be partially correlated with intervals of elevated permeability identified by the flowmeter logging (figs. 8–14). The correlation was more consistent between intervals of low permeability identified from analysis of slug tests and flowmeter logs.

Analysis of slug tests and flowmeter logs indicates the aquifer open to borehole DF4D has high permeability (horizontal hydraulic conductivity greater than 1.5×10^{0} ft/d) from 93 to 103 ft, moderate permeability (horizontal hydraulic conductivity from 7.0×10^{-1} to 1.5×10^{0} ft/d) from 135 ft to the bottom of the borehole, and low permeability (horizontal hydraulic conductivity less than 7.0×10^{-1} ft/d) from 83 to 93 ft (fig. 8). Flowmeter logs indicated a change in flow of almost 0.75 gal/min above 83 ft, which indicates a permeable interval, whereas analysis of slug tests indicates low permeability above 83 ft. Slug tests indicate that the permeability from 103 to 113 ft is high. No change in flow in this interval was detected by flowmeter logging, which indicates low permeability.

Analysis of the slug tests and flowmeter logs indicates the permeability of the aquifer at borehole DF5D is low from 85 to 104 ft, high from 104 to 124 ft, and low from 124 ft to the bottom of the borehole (fig. 9). Flowmeter logs indicate inflow and high permeability from 80 to 85 ft, whereas analysis of the slug tests indicates low permeability at this depth. These differences are attributed to the flowmeter log measuring inflow of water draining down the borehole walls to the static water level, not inflow from a permeable fracture.

Although the saturated thickness of borehole DF12 was about 12 ft less during the slug testing, both slug tests and flowmeter logs indicate that the permeability in the borehole was high and increasing with depth from about 95 to 105 ft, and very high but with an interval of lower permeability from 105 to the bottom of the borehole (fig. 10). The inability to lower the flowmeter or packer assembly below 110 ft reduces the ability to make interpretations from this borehole. Slug tests indicate high permeability above 90 ft, whereas no change in flow was detected by flowmeter logging, which indicates low permeability. This discrepancy can probably be attributed to the fact that though greater than 1.5 ft/d, the horizontal hydraulic conductivity of the aquifer above 90 ft is more than an order of magnitude less than the interval below 90 ft.

Analysis of the flowmeter logs and slug tests indicates that the permeability in borehole DF13 is high around 106 ft and low below about 110 ft (fig. 11). Flowmeter logs indicate high permeability from 80 to 92 ft, whereas slug tests indicate low permeability.

Much of the discrepancy between intervals of high and low permeability identified by the slug testing and flowmeter logging can probably be attributed to differences in the length of the interval tested with each method. Flowmeter measurements generally were collected in the boreholes at intervals of 5 ft or less, whereas slug tests were done at intervals of 10 ft or more.

Most of the intervals where flowmeter logs indicated high permeability and slug tests indicated low permeability, especially from 68 to 100 ft in borehole DF5D and from 73 to 93 ft in borehole DF13, involved slug tests on aquifer intervals of 20 ft or more. Because the technique utilized for the slug-test analysis assumes that the tested part of the aquifer is homogeneous, the response of the thick low-permeability intervals (the dolomite matrix) are combined with the response of the thin high-permeability intervals (vugs, fractures) resulting in low-permeability estimates for the interval as a whole. Flowmeter measurements allow for the characterization of permeability at numerous discrete points within the aquifer, which permits the assembly of a more detailed permeability profile than is possible utilizing a 10-ft packer assembly.

The absence of head variation over the length of the borehole may have resulted in an absence of vertical flow within some of the boreholes, or some parts of a borehole, and may explain some of the discrepancies in the permeability profiles. This may be the case where flowmeter logging indicated low permeability and slug testing indicated high permeability. For example, flowmeter measurements, under conditions of natural flow, indicate no flow and low permeability in boreholes DF13 and SPW; whereas, slug tests indicate permeable intervals in both boreholes.

Monitoring Wells

Horizontal hydraulic conductivities calculated from slug tests in monitoring wells open to the Galena-Platteville aquifer range from 8.1×10^{-3} ft/d at well DF2S to 8.5×10^{3} ft/d at well DF24 (table 2). The frequency distribution of horizontal hydraulic conductivities from the monitoring wells increases consistently between 10^{-3} and 10^{1} ft/d (fig. 23). Over half of the values are from 1.0×10^{0} to 9.9×10^{1} ft/d. This indicates that most of the Galena-Platteville aquifer has a horizontal hydraulic conductivity in excess of 1.0×10^{0} ft/d in the study area.

Horizontal hydraulic conductivities calculated from analysis of slug tests in the monitoring wells generally are higher than the values calculated from the test intervals in the boreholes (fig. 23). This indicates that the monitoring wells are open to more permeable parts of the aquifer than the boreholes that were tested with the packer assembly. The horizontal hydraulic conductivity in zone 1 of the Galena-Platteville aquifer, where most of the boreholes tested with the packer assembly are located, is lower than in zones 2–4, where most of the monitoring wells are located.

Horizontal hydraulic conductivities calculated from analysis of slug tests in monitoring wells DF2D, DF4D, DF5D, DF6, DF12, and DF13 were similar to the values calculated from the test intervals that correspond to the open interval of the monitoring wells installed in these boreholes (compare the horizontal hydraulic conductivity from test interval A in boreholes DF2D, DF4D, and DF12; test interval F in borehole DF5D; test intervals C and D in borehole DF6; and test interval E in borehole DF13 with the horizontal hydraulic conductivities from their respective monitoring wells) (tables 2 and 5). This indicates that the discrepancy in the horizontal-hydraulic-conductivity trends is not related to the testing method.

The geometric mean of the horizontal hydraulic conductivities determined from slug-test analysis in monitoring wells and test intervals was calculated for the four zones of the Galena-Platteville aquifer identified from the water-table map (fig. 21, tables 2 and 5). The results of slug tests in monitoring wells installed in boreholes tested with the packer assembly are not included in the analysis. The mean horizontal hydraulic conductivity in zones 1, 2, 3, and 4 was 3.1×10^{-1}, 5.2×10^{0}, 2.4×10^{2}, and 8.0×10^{0} ft/d, respectively (table 3). The median horizontal hydraulic conductivity of the upper part of the aquifer in zone 1 (1.1×10^{-1} ft/d) is lower than that of the middle and lower parts of the aquifer in zone 1 (4.8×10^{-1} ft/d). These results are consistent with the results of the analysis of the lithologic and geophysical logs, and the water-table configuration.

Horizontal hydraulic conductivities calculated from slug tests in the monitoring wells and the test intervals of the open boreholes were compared to the stratigraphic unit to which the well or test interval was open (fig. 24). Except for well DF12, the results of slug tests from monitoring wells installed in boreholes tested with the packer assembly are not included in figure 24. Test interval A of borehole DF12 was not included in this analysis because of its long interval. If the well or test interval was open to more than one geologic unit (table 2 and 5), then the calculated horizontal hydraulic conductivity was assumed to be representative of each of the geologic units unless lithologic or geophysical data indicated a preponderance of flow through one unit. The geometric means of the horizontal hydraulic conductivities for the Galena Group was about 1.2×10^{-1} ft/d. The geometric mean of the Pecatonica, Nachusa, and Quimbys Mill Formations is from 2.3 to 6.2×10^{-1} ft/d. The geometric mean of the Mifflin and Grand Detour Formations are 1.3 and 2.7×10^{0} ft/d, respectively. If the values for wells DF12 and MW16 northwest of the salvage yard are excluded,

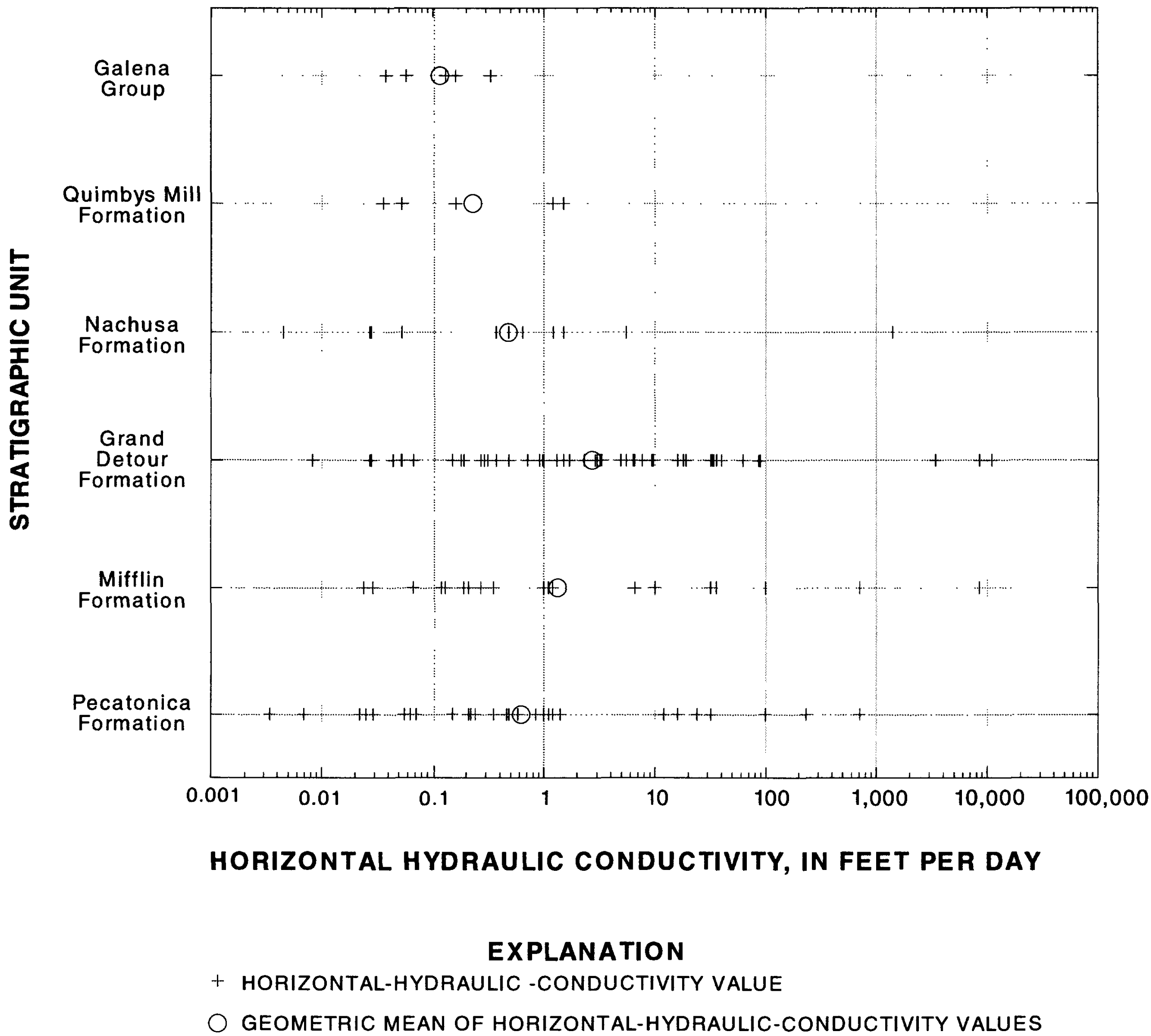


Figure 24. Distribution of horizontal hydraulic conductivity within the stratigraphic units that compose the Galena-Platteville aquifer, Byron Superfund site.

the mean horizontal hydraulic conductivity of the Mifflin Formation is calculated to be 7.1×10^{-1} ft/d. This indicates that the permeability of the Mifflin Formation is not appreciably higher than that of the Pecatonica, Nachusa, and Quimbys Mill Formations in most of the study area. The higher mean horizontal hydraulic conductivity in the Grand Detour Formation is consistent with the results of the flowmeter logging and the observation of outcrops at the Benesh Quarry.

Constant-Discharge Tests

Constant-discharge aquifer tests were conducted in borehole DF4D and attempted in borehole DF12 to determine the horizontal hydraulic conductivity, transmissivity, and specific yield of the Galena-Platteville aquifer, and to identify the presence and direction of anisotropy in the aquifer.

Borehole DF4D Aquifer Test

The constant-discharge aquifer test was conducted in and near borehole DF4D from January 31 to February 5, 1992 (fig. 25). Borehole DF4D is 6 in. in diameter and open to the entire thickness of the Galena-Platteville aquifer. Monitoring wells DF4DS and DF4DD were installed in borehole DF4D after the aquifer test was completed. The aquifer test was conducted in four phases.

Water levels were monitored during all phases of the aquifer test with pressure transducers rated at 0–5 and 0–10 lb/in^2 in the observation and background wells. These transducers can accurately detect water-level changes of 0.01 ft. Water levels in borehole DF4D were monitored with a 0–30 lb/in^2 transducer, which is capable of accurately detecting water-level fluctuations of about 0.10 ft. The accuracy of the transducer data was checked periodically with electric-tape measurements. The electric-tape measurements typically were within 0.03 ft of the transducer readings.

The first phase of the aquifer test consisted of a production test during which borehole DF4D was pumped at variable rates while the water-level response in the borehole was monitored. Water-level data obtained during the production test indicated that the borehole could sustain a discharge rate of 8.0 gal/min.

The second phase of the aquifer test consisted of water-level monitoring in the observation wells (PC3B, DF6, DF4S, DF5S, DF5D, DF13, DF14D, PC2B, MW36, MW37, and B6R) and the background wells (B5, AW5I, AW5D, and DF15) (fig. 25) for 4 days prior to the start of pumping. This is the background water-level monitoring phase of the test. Background water-level monitoring was done to determine the magnitude and cause of water-level variations in the absence of pumping so more accurate values of drawdown (water-level changes due to pumping) could be determined. Wells PC3B, DF5S, PC2B, B6R, B5, and DF15 are open to the water table at the top of the Galena-Platteville aquifer. Wells DF4S, DF5D, DF13, and AW5I are open to the middle of the aquifer. Wells DF6 and DF14D are open to the upper part of the base of the aquifer. Wells MW36 and AW5D are open to the lower part of the base of the aquifer. Well MW37 is open to the St. Peter aquifer.

The third phase of the aquifer test (pumping phase) consisted of pumping water from borehole DF4D at a constant rate of 7.25 gal/min (1,447.2 ft^3/d) for 400 minutes while monitoring water levels in the observation and background wells. A flowmeter was connected to the discharge line to verify that the discharge rate was constant. The pumping rate was checked periodically by timing how long it took to fill a 5-gal bucket with water from the discharge line. The water was discharged to natural drainage approximately 1,000 ft downgradient from borehole DF4D. The pumping phase of the test was terminated after 400 minutes when borehole DF4D was dewatered.

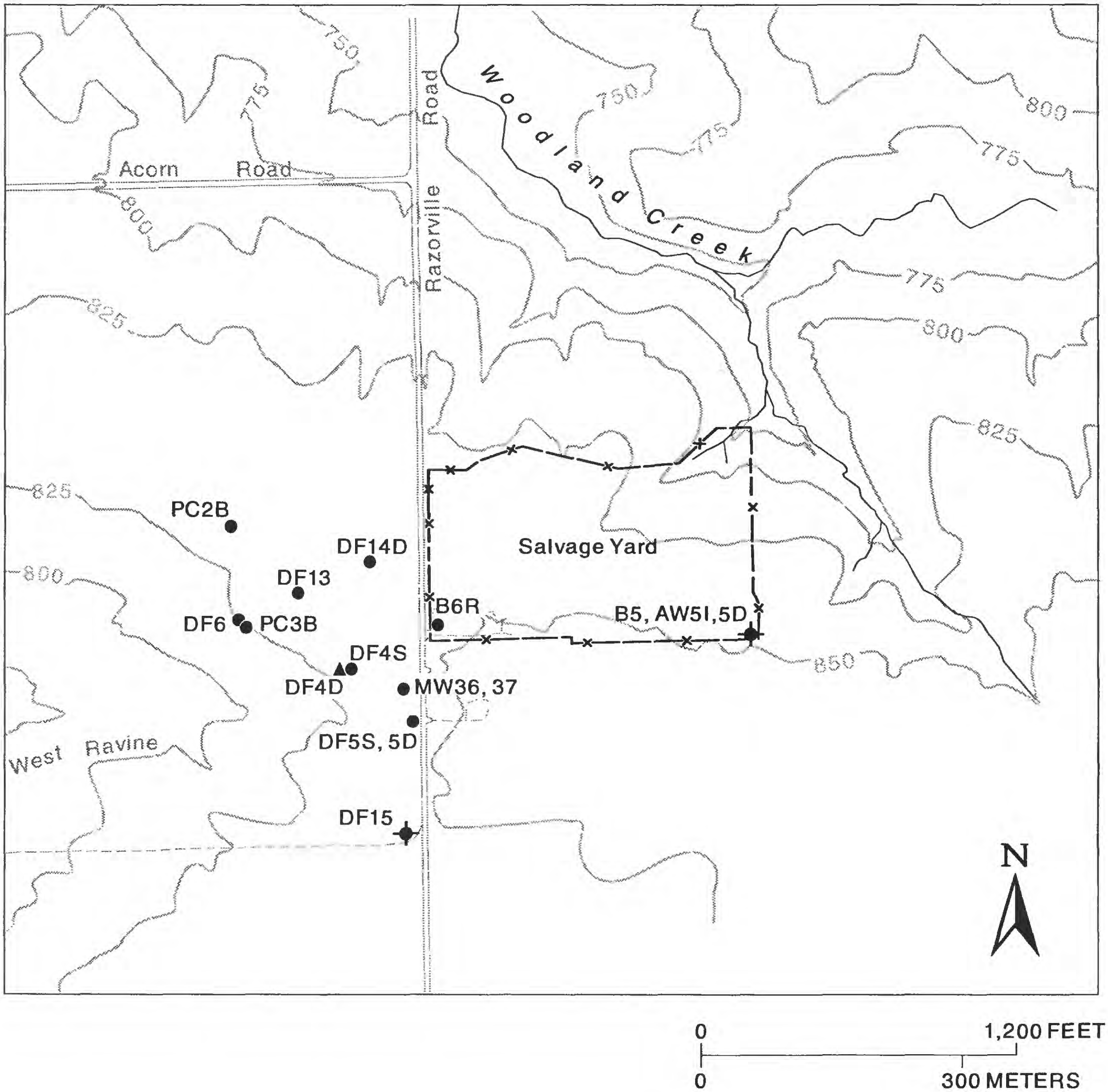
The fourth phase of the aquifer test (recovery phase) consisted of monitoring water levels in borehole DF4D, the observation wells, and the background wells for approximately 400 minutes after the termination of pumping. Time and water-level data for the recovery phase did not show good agreement with the data from the pumping phase and were not analyzed.

After the raw time and water-level data from the pumping phase were collected, corrections for the effects of changes in barometric pressure, background water-level fluctuations, partial penetration of the observation wells, and dewatering of borehole DF4D on the water-level data were considered so an accurate value for drawdown could be determined. Where corrections could not be quantitatively applied, qualitative effects on water levels were considered.

Barometric-pressure readings were collected at the site and compared with ground-water levels to determine the effect of barometric-pressure fluctuations on water-level changes in the wells. It was determined that the changes in barometric pressure during the aquifer test were too small to appreciably affect the calculated drawdown. No corrections for barometric-pressure changes were applied to the drawdown data.

Water-level data from the background wells and four of the observation wells indicated no appreciable changes during the background water-level monitoring and pumping phases of the test. As a result, no corrections for background fluctuations in water level were required.

Drawdown data corrections necessitated by the effects of partially penetrating observation wells could not be applied because of the heterogeneous and anisotropic nature of the aquifer. It may be assumed, however, that transmissivity calculated from analysis of time-drawdown data from the partially penetrating observation wells (wells that are not open to the entire thickness of the aquifer) will be different than if the wells had been fully penetrating. Drawdown measured in a partially penetrating well is usually representative of conditions only at the screened interval of the well and, therefore, may not accurately represent the total hydraulic stress imparted to the entire aquifer by pumping in borehole DF4D. This particularly applies to fractured-rock aquifers where the open intervals of the observation wells may not penetrate water-bearing zones that contribute a substantial amount of water to the pumped borehole.



EXPLANATION

—750— TOPOGRAPHIC CONTOUR--Shows elevation of land surface, in feet. Contour interval 25 feet. Datum is sea level

▲ DF4D PUMPED WELL LOCATION AND NAME

● DF5D OBSERVATION WELL LOCATION AND NAME

✦ DF15 BACKGROUND WELL LOCATION AND NAME

Figure 25. Location of pumped, observation, and background wells, borehole DF4D aquifer test, Byron Superfund site, January 31–February 5, 1992.

Dewatering at borehole DF4D and the resulting effects on well-loss computations prevented quantitative analysis of the data from the borehole. No attempt was made to determine the transmissivity of the aquifer from these data.

After revising the raw data, it was determined that drawdown in observation wells DF4S, DF5D, DF6, DF13, PC3B, and MW36 were in response to pumping in borehole DF4D (figs. 26, 27, and 28a). No drawdown was detected in observation wells DF5S, DF14D, B6R, MW37, and PC2B.

Analyses of slug tests and flowmeter logs in borehole DF4D indicate that water will flow to borehole DF4D primarily through a permeable interval from about 730 to 760 ft above sea level (about 75 to 105 ft below land surface). This interval corresponds to the upper part of the Grand Detour Formation. Because the majority of flow is through this interval, it can be assumed that observation wells in good hydraulic connection with this interval will have the largest drawdown, whereas observation wells in poor hydraulic connection will have the smallest drawdown. Wells DF5D and DF13, open to the Grand Detour Formation, are in good hydraulic connection with the permeable interval in borehole DF4D. This indicates that the permeable part of the Galena-Platteville aquifer corresponding to the upper part of the Grand Detour Formation is continuous between wells DF5D and DF13, a distance of over 600 ft. This is consistent with the analysis of the flowmeter logs and slug tests. Wells DF6, PC3B, and MW36 also appear to be in good hydraulic connection with the permeable interval. Wells DF5S, B6R, DF14D, MW37, and PC2B are either too far from the borehole to be affected by pumping or are not in good hydraulic connection with the permeable interval around borehole DF4D.

The importance of discrete permeable intervals on flow within the aquifer is indicated by plotting the drawdown in the aquifer (figs. 28a and 28b). Where two observation wells are at approximately equal distances from the pumped borehole, drawdown in the well open to the middle or lower parts of the aquifer (DF5D and DF6) exceed drawdown in those wells open to the water table (DF5S and PC3B) (fig. 28b).

The absence of drawdown in well DF5S indicates poor hydraulic connection (low vertical hydraulic conductivity) between the upper and middle parts of the Galena-Platteville aquifer in this area. The drawdown data indicate greater hydraulic connection (higher vertical hydraulic conductivity) between the upper and lower parts of the aquifer near the DF6/PC3B well cluster. This is consistent with the analysis of the vertical differences in water level with depth in the aquifer, which indicated low vertical hydraulic conductivity in zone 1 and higher vertical hydraulic conductivity in the transition areas and zones 2, 3, and 4. The absence of drawdown in well MW37 indicates poor hydraulic connection between the Galena-Platteville and St. Peter aquifers in this area.

Hydraulic connection within the Galena-Platteville aquifer is dependent on direction as well as depth. A plot of the maximum amount of drawdown measured in the observation wells, 400 minutes into the test, has a roughly elliptical shape (fig. 28a). The major axis of the drawdown ellipse is oriented approximately east-west, approximately parallel to the West Ravine (fig. 2) and the inclined-fracture orientation identified from the acoustic-televiewer logs in boreholes DF4D and DF5D. This indicates that east-west oriented inclined fractures intercept the permeable interval in the Grand Detour Formation and are conduits for flow to borehole DF4D. The extent of fractures in the upper part of the aquifer near well MW36 is not known because of an absence of wells at this depth. The absence of drawdown at well DF5S, however, indicates that vertical fracturing is minimal in the upper part of the aquifer near well DF5S.

Time-drawdown plots prepared on a log-log scale (figs. 26 and 27) were compared to type curves of the Boulton (1963) delayed-yield model. Transmissivity (T) and specific yield (Se) were calculated from the data at a match point common to the field data curve and the type curve. No curve match could be made for the data from wells DF4S and PC3B.

Transmissivities calculated from the aquifer at wells along the direction of maximum drawdown (MW36 and DF6) were an order of magnitude lower than transmissivities calculated for the aquifer at wells not along the direction of maximum drawdown (DF5D and DF13) (fig. 28 and table 6). This is contrary to the theory of flow in anisotropic aquifers, which indicates that the wells closest to the direction

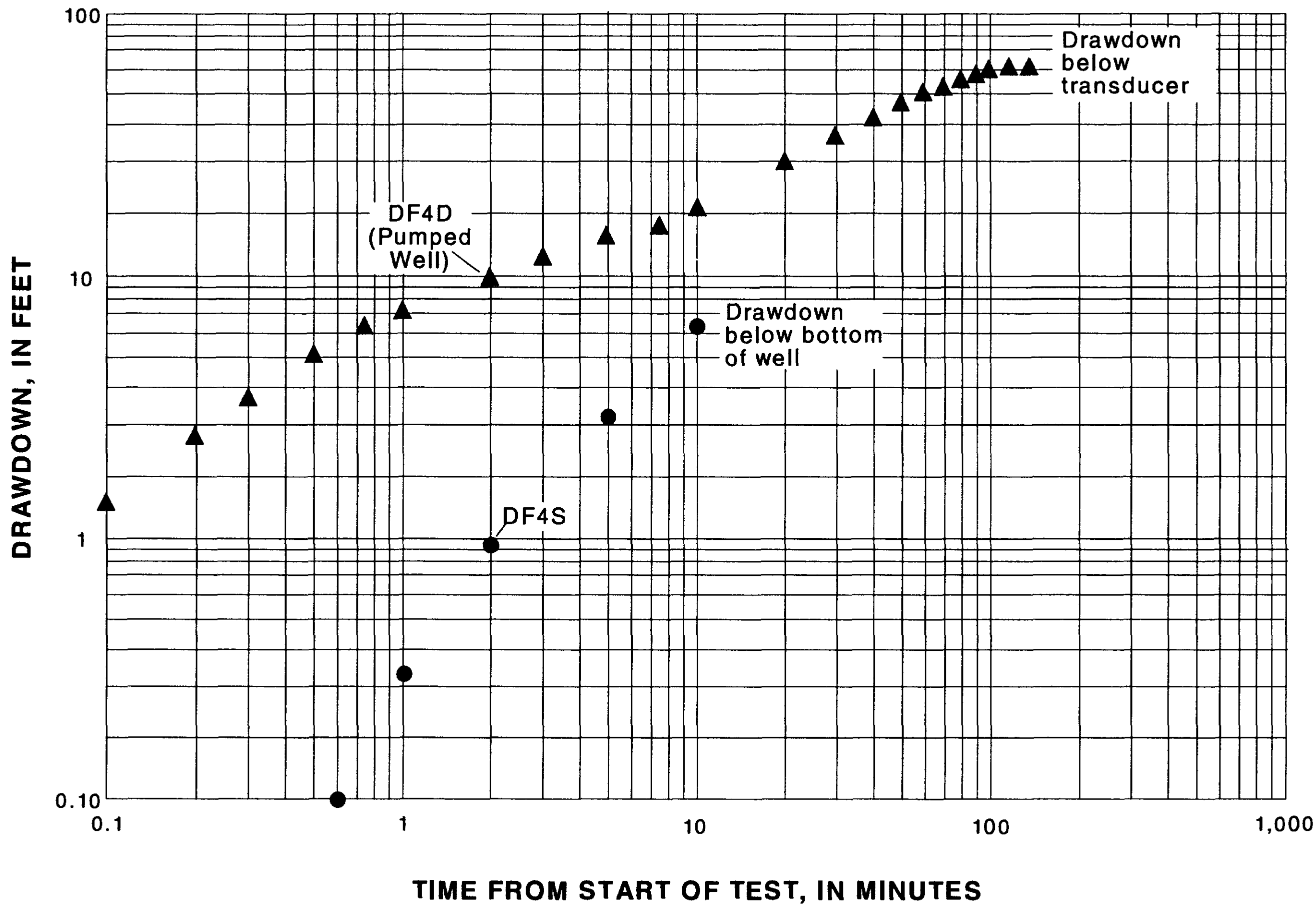


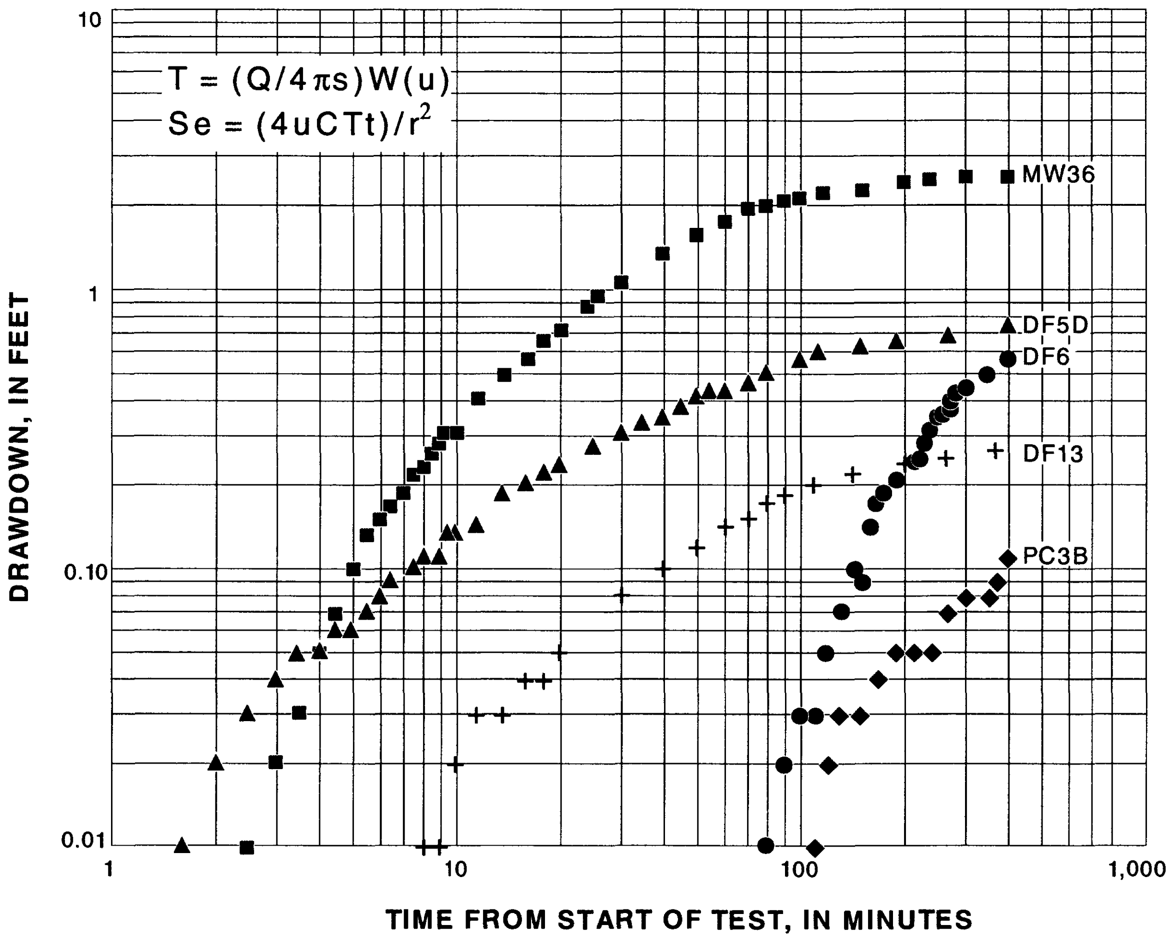
Figure 26. Time and drawdown for observation well DF4S and the pumped well during the pumping phase of the borehole DF4D aquifer test, Byron Superfund site, February 2, 1992.

of maximum drawdown should be oriented nearest the direction of maximum transmissivity in the aquifer, whereas the wells closest to the direction of minimum drawdown should be oriented nearest the direction of minimum transmissivity (Papadopulos, 1965, p. 69). Therefore, values in table 6 are probably not accurate estimates of transmissivity or specific yield.

Attempts to calculate a transmissivity tensor from the aquifer-test data resulted in negative transmissivities, a physical impossibility, which indicates directional diffusivity (transmissivity divided by specific yield) is not elliptical in shape. Therefore, the drawdown ellipse shown in figure 28a is probably not the actual distribution of drawdown in the aquifer during the test.

Table 6. Estimated horizontal hydraulic conductivity, transmissivity, and storage coefficient from data collected at observation wells during the aquifer test in borehole DF4D, Byron Superfund site, winter 1992

Well name	Horizontal hydraulic conductivity (feet per day)	Transmissivity (feet squared per day)	Storage coefficient (dimensionless)
DF5D	6.7×10^{0}	6.98×10^{2}	7.04×10^{-3}
DF6	8.1×10^{-1}	8.86×10^{1}	3.10×10^{-4}
DF13	9.7×10^{0}	8.35×10^{2}	2.49×10^{-5}
MW36	6.7×10^{-1}	9.00×10^{1}	5.28×10^{-5}



CURVE MATCH DATA FOR THE BOULTON (1963) TYPE CURVE MATCH

Q = 1447.2 cubic feet per day

MW36 t = 8.8 minutes, s = 1.28 feet, W(u) = 1.0, Se = 1.0, r/B = 0.4, r = 204 feet

DF5D t = 3.4 minutes, s = 0.165 feet, W(u) = 1.0, Se = 1.0, r/B = 0.1, r = 306 feet

DF6 t = 230 minutes, s = 1.30 feet, W(u) = 1.0, Se = 1.0, r/B = 0, r = 426 feet

DF13 t = 13 minutes, s = 0.138 feet, W(u) = 1.0, Se = 1.0, r/B = 0.4, r = 305 feet

PC3B Field data and type curves did not match, r = 204 feet

EXPLANATION OF SYMBOLS

T = Transmissivity, in feet squared per day

Q = Discharge, in cubic feet per day

s = Drawdown, in feet

W(u) = Well function of u

Se = Early time apparent specific yield

u = A value defined by $r^2Se/4T$

C = Conversion factor, 1,440 minutes per day

t = Time, in minutes, since the start of pumping

r = Radial distance from the pumped well, in feet

Figure 27. Curve-match data for observation wells MW36, DF5D, DF6, DF13, and PC3B during the pumping phase of the borehole DF4D aquifer test, Byron Superfund site, February 2, 1992.

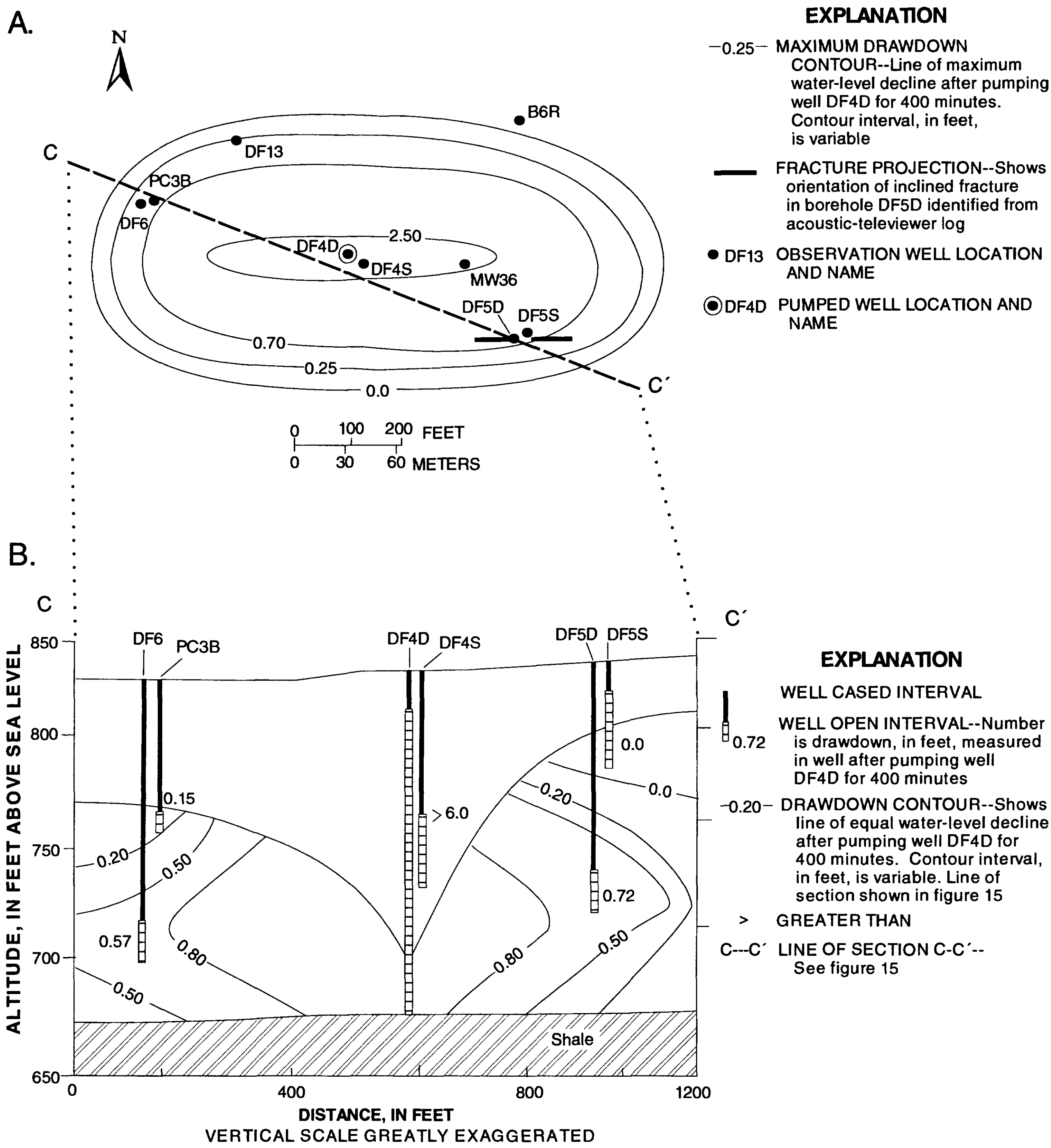


Figure 28. Distribution of drawdown in the Galena-Platteville aquifer after pumping borehole DF4D for 400 minutes, borehole DF4D aquifer test, Byron Superfund site, February 2, 1992: A) maximum drawdown in the aquifer; B) drawdown in the aquifer along line of section C—C′ (modified from Paillet and others, 1993, fig. 9).

A negative transmissivity tensor typically is caused by heterogeneities in the aquifer (Allen Shapiro, U.S. Geological Survey, written commun., 1992). Therefore, the results of the aquifer test indicate that the aquifer is both heterogeneous and anisotropic in the area where drawdown was induced. This is consistent with an analysis of the water-table configuration. Comparison of the areas where drawdown was observed (figs. 25 and 28a) with the location of the aquifer zones (fig. 21) indicates that borehole DF4D was drawing water from zone 1 of the aquifer, transitional areas between zones 1 and 2, and possibly zone 4. As noted previously, differences in the vertical and horizontal hydraulic conductivities are present between each zone and between the zones and the transitional areas. Therefore, any part of the Galena-Platteville aquifer composed of two or more zones, or a zone and a transitional area, may be heterogeneous.

Borehole DF12 Aquifer Test

Borehole DF12 was pumped at about 13, 33, and 71 gal/min on three different occasions during the spring of 1991 to develop the borehole and determine a suitable discharge rate for a constant-discharge aquifer test. After pumping at 71 gal/min for 112 minutes, no more than 0.14 ft of drawdown was induced in borehole DF12 and no clearly identified drawdown was measured in wells PW3, DF10, or MW39 (the nearest observation wells) (fig. 2). It was determined from these data that appreciable drawdown could not be induced in borehole DF12 and the surrounding observation wells unless a discharge rate of at least 200 gal/min was obtained. Because of the difficulties associated with the treatment and disposal of the pumped water, and obtaining a pump that could produce 200 gal/min and fit inside a 6-in. hole, the long-term constant-discharge aquifer test planned for borehole DF12 was not conducted.

The transmissivity of the Galena-Platteville aquifer at borehole DF12 was estimated at a minimum of 1.30×10^5 ft^2/d based on the specific-capacity data obtained during the 71 gal/min test. The high transmissivity at borehole DF12 indicates an extensive network of secondary permeability features in this area. This interpretation is consistent with the conclusions made from analysis of the water-table configuration, slug testing, and geophysical logging.

The Galena-Platteville aquifer is underlain by the Harmony Hill Shale semiconfining unit. The results of a constant-discharge aquifer test indicate that the Harmony Hill Shale semiconfining unit has a leakance of 4.65×10^{-3} ft/ft at the salvage yard (Kay and others, 1989, p. 47) and restricts flow between the overlying Galena-Platteville and underlying St. Peter aquifers.

St. Peter Aquifer

The St. Peter aquifer is composed of the basal part of the Glenwood Formation, where it is sandstone, and the St. Peter Sandstone. The St. Peter aquifer is under semiconfined conditions in the study area except near the Rock River, where the Harmony Hill Shale semiconfining unit and the Galena-Platteville aquifer have eroded and the St. Peter aquifer is in direct hydraulic connection with the unconsolidated aquifer (fig. 16).

Water Levels

Ground-water flow in the St. Peter aquifer in the study area is from the area near well MW2 northwest to the Rock River (fig. 20). This is similar to the flow direction at the water table and at the base of the Galena-Platteville aquifer. Components of ground-water flow in the St. Peter aquifer toward Woodland Creek and the West Ravine are assumed but cannot be verified with the current well configuration.

The water levels in the wells open to the base of the Galena-Platteville aquifer are approximately 70 ft higher than the water levels in the wells open to the St. Peter aquifer in the upland areas beneath the salvage yard and the DFP (compare water-level altitudes at wells MW39 and MW42 in table 1). This indicates the potential for downward vertical flow from the Galena-Platteville aquifer to the St. Peter aquifer. Away from the salvage yard, at wells MS1 and MS2, the head at the base of the Galena-Platteville aquifer is approximately 16 ft higher than at the top of the St. Peter aquifer (figs. 19, 20, and table 1).

Aquifer Tests

A constant-discharge aquifer test conducted at the salvage yard, at well DPW in 1987 (fig. 2), indicates the St. Peter aquifer has a storativity of about 1.20×10^{-3}, a transmissivity of about 1.5×10^3 ft^2/d, and a horizontal hydraulic conductivity of about 3.5×10^0 ft/d (Kay and others, 1989, p. 47). Analysis of the constant-discharge aquifer test indicated that the aquifer is isotropic.

Horizontal hydraulic conductivities obtained from slug tests, conducted by previous investigators, in six monitoring wells open to the upper part of the St. Peter aquifer range from 2.0 to 8.7×10^0 ft/d (Camp Dresser & McKee, Inc., 1989, p. 3:20; Olson, 1988, p. 62; Warzyn, 1988, p. 2; Avery, 1994, p. 8). In five of these wells, horizontal hydraulic conductivities were from 2.0 to 5.7×10^0 ft/d. Horizontal hydraulic conductivities calculated from slug tests in three wells open to the St. Peter aquifer during this study ranged from 2.8 to 5.8×10^0 ft/d (table 2). Horizontal hydraulic conductivities obtained from slug tests conducted during the current and previous investigations in wells MW2 and MW37 show good agreement. The narrow range of horizontal hydraulic conductivities indicates that the St. Peter aquifer is homogeneous, at least in the upper part. The good agreement between the horizontal hydraulic conductivities obtained from slug-test analysis and the constant-discharge aquifer test indicates that the hydraulic conductivity of the St. Peter aquifer is not scale dependent, also indicating that the aquifer is homogeneous.

GROUND-WATER QUALITY

Ground-water samples were collected from test intervals in boreholes DF2D, DF4D, DF5D, DF6, DF12, DF13, DF14D, DF17, SPW, and AW1S, and from 65 finished monitoring wells. The boreholes and the monitoring wells are located primarily on the salvage yard and the DFP. Samples were collected from 5 monitoring wells open to the unconsolidated aquifer, 5 wells open to the St. Peter aquifer, and 55 wells open to the Galena-Platteville aquifer. Wells DF4D and DF12 were open boreholes when sampled during sampling period 1. Monitoring wells DF4DS and DF4DD were installed in borehole DF4D and monitoring well DF12 was installed in borehole DF12 before sampling period 2. Samples from the test intervals and monitoring wells were analyzed primarily for VOC's and cyanide.

Borehole Test Intervals

Water-quality sampling from the test intervals was done to obtain a preliminary understanding of the type, concentration, and vertical distribution of VOC's in the Galena-Platteville aquifer. This information was utilized to help define the mechanisms by which contaminants are migrating within the aquifer. Information on the vertical distribution of VOC's also was used to guide the placement of the well screen when the monitoring well was installed in the borehole. These data ensured that the monitoring well provided as much useful information as possible.

The results of the water-quality sampling in the test intervals indicated that the highest concentrations of VOC's were detected at boreholes AW1S and SPW (fig. 2 and table 7). The VOC's detected at these boreholes were primarily toluene and xylene isomers with lower concentrations of chlorinated ethenes (trichloroethene, 1,1- or 1,2-dichloroethene, and vinyl chloride).

The concentration of VOC's in water from boreholes SPW (fig. 13), AW1S, and DF2D generally decreased with depth. Low concentrations of chlorinated ethenes and ethanes were detected at borehole DF2D (table 7). Boreholes SPW, AW1S, and DF2D are in or near known disposal areas (fig. 3).

Concentrations of VOC's greater than 100 μg/L were detected below 94 ft in borehole DF12 (fig. 10). These high concentrations indicate that VOC's, primarily trichloroethene (TCE), are migrating at a depth with ground-water flow from the salvage yard toward the Rock River.

High concentrations of toluene were detected in the samples from borehole DF14D. No toluene was detected in monitoring wells DF14S and DF14D during two subsequent sampling periods. Monitoring well DF14D was installed in borehole DF14D at a depth where over 80 μg/L of toluene was detected in the test intervals (tables 1 and 7). The discrepancy between the results of sampling in the monitoring wells and the test intervals indicates that the toluene detected in samples from the test intervals is not representative of in place water quality in the vicinity of well DF14D.

No single VOC was detected at a concentration greater than 20 μg/L in samples collected from the test intervals in boreholes DF2D, DF4D, DF5D, DF6, and DF17 (table 7). The VOC's detected in the test intervals at boreholes DF2D, DF4D, DF5D, and DF6 were primarily 1,1,1-trichloroethane (TCA) and its degradation products. Some TCE also was detected. The VOC's detected in the test intervals at borehole DF17 were chloroform and cis-1,2-dichloroethene (c1,2DCE). No c1,2DCE was detected in a sample collected from borehole DF17 before insertion of the packer assembly (a grab sample taken during well development) or from the monitoring well completed in borehole DF17 after sampling with the packer

Table 7. Results of water-quality sampling in test intervals isolated with a packer assembly, Byron Superfund site
[µg/L, micrograms per liter]

Test interval: dup., duplicate sample

Volatile organic compound detected: TCA, 1,1,1-trichloroethane; TCE, trichloroethene; TOL, toluene; DCE, total dichloroethene; DCA, total dichloroethane; EB, ethylbenzene; XY, total xylenes; 4M2P, 4methyl-2pentane; CS2, carbon disulfide; CF, chloroform; VC, vinyl chloride; BEN, benzene; CN, cyanide; PCE, tetrachloroethene; PCA, carbon tetrachloride; 2BUT, 2butanone; 2HEX, 2hexanone

Volatile organic compound concentration: J, estimated concentration below detection limit; D, sample diluted; E, concentration estimated; B, constituent detected in blank sample, result not included in figure 9

Borehole name	Test interval	Measuring point altitude (feet above sea level)	Depth of test interval (feet below measuring point)	Volatile organic compound (detected/concentration) (µg/L)
AW1S	A	833.96	67.9–82.7	VC/65D, DCE/84D, TCE/49D, BEN/0.6J, TOL/73/D, EB/1, XY/2, PCE/16, CN/224
AW1S	B	833.96	29.8–48.9	VC/90D, DCE/155D, TCE/84D, BEN/1, TOL/58D, EB/6, XY/11, 2BUT/18J, 2HEX/17, PCE/8, CN/112
AW1S	B	833.96	29.8–48.9	VC/75D, DCE/145D, TCE/76D, BEN/1, TOL/60D, EB/5, XY/11, 2BUT/19J, 2HEX/17, PCE/8, CN/120
DF2D	A	[1]797	97.0–113.0	None
DF2D	AA	[1]797	97.0–107.0	None
DF2D	B	[1]797	87.0– 97.0	TCA/4.5
DF2D	C	[1]797	87.0– 66.0	TCA/4.3, TCE/4.2
DF4D	A	[1]834	130.0–140.0	TCA/5.9
DF4D	AB	[1]834	124.0–134.0	TCA/1
DF4D	AB dup.	[1]834	124.0–134.0	None
DF4D	B	[1]834	120.0–130.0	TCA/3.8
DF4D	C	[1]834	110.0–120.0	TCA/4.0
DF4D	D	[1]834	100.0–110.0	TCA/8.7
DF4D	E	[1]834	90.0–100.0	TCA/5.9
DF4D	F	[1]834	73.0–91.0	TCA/9.0
DF4D	G	[1]834	130.0–150.0	TCA/6.5
DF5D	A	844.97	154.0–170.0	None
DF5D	B	844.97	144.0–154.0	TCE/2B, TCA/1J
DF5D	C	844.97	134.0–144.0	TOL/1JB
DF5D	D	844.97	124.0–134.0	TOL/1JB
DF5D	E	844.97	114.0–124.0	TOL/1JB, TCE/1JB, TCA/1
DF5D	F	844.97	91.0–114.0	TCA/1, TCE/1JB
DF5D	G	844.97	104.0–114.0	TCA/1, TCE/1JB
DF5D	H	844.97	71.0–100.0	TOL/1JB, TCE/1JB
DF5D	I	844.97	68.0-75.0	TOL/1JB, TCE/1JB
DF6	A	828.08	136.0–151.0	TOL/0.7J, 4M2P/0.9
DF6	B	828.08	126.0–136.0	TCA/6, DCE/0.9, DCA/4
DF6	C	828.08	116.0–26.0	DCE/2.29, DCA/12.06, TCA/19.68, EB/2.32, XY/4.76
DF6	D	828.08	106.0–116.0	Sample incorrectly analyzed
DF6	E	828.08	96.0–106.0	DCE/2.21, DCA/11.48, TCA/18.54, TOL/0.39, 4M2P/0.9
DF6	F	828.08	75.0–93.0	DCA/11.04, TCA/16.67
DF12	A	834.82	94.0–133.0	TCE/150, DCE/3, TCA/5.8, PCE/3, TOL/11
DF12	B	834.82	94.0–104.0	TCE/120, DCE/3, TCA/4.9
DF12	C	834.82	84.0–94.0	TCE/87, TCA/3.3, TOL/3
DF12	D	834.82	72.0–84.0	TCE/6.1, TOL/6.7

Table 7. Results of water-quality sampling in test intervals isolated with a packer assembly, Byron Superfund site—Continued

Borehole name	Test interval	Measuring point altitude (feet above sea level)	Depth of test interval (feet below measuring point)	Volatile organic compound (detected/concentration) (µg/L)
DF13	A	836.61	144.0–159.0	None
DF13	B	836.61	134.0–144.0	None
DF13	C	836.61	123.0–133.0	None
DF13	D	836.61	113.0–123.0	None
DF13	E	836.61	103.0–113.0	TCA/15, DCA/4.1
DF13	F	836.61	93.0–103.0	None
DF13	G	836.61	77.0–93.0	TOL/3.3
DF14D	A	[1]845	158.0–172.0	TOL/13
DF14D	B	[1]845	144.0–154.0	TOL/93
DF14D	C	[1]845	134.0–144.0	TOL/90
DF14D	D	[1]845	124.0–134.0	None
DF14D	E	[1]845	114.0–124.0	None
DF14D	F	[1]845	104.0–114.0	TOL/16
DF14D	G	[1]845	94.0–104.0	TOL/24
DF14D	H	[1]845	85.0–94.0	TOL/13
DF17	A	[1]823	105.0–121.0	DCE/12, CF/2
DF17	B	[1]823	95.0–105.0	DCE/6, CF/2
DF17	C	[1]823	85.0–95.0	DCE/10, CF/2
SPW	A	836.43	134.4–149.8	VC/53D, TCE/3, DCE10, DCA/0.6, BEN/1, TOL/141D, EB/19DJ, XY/33DJ, CN/15
SPW	A	836.43	134.4–149.8	VC/70D, DCE/12D, DCA/0.5J, TCE/2, BEN/1, EB/20D, XY/49D, PCE/5DJ, PCA/6DJ, CN/15
SPW	B	836.43	124.4–134.4	VC/68D, DCE/22D, DCA/2.8J, TCE/7, BEN/3, TOL/173D, EB/8DJ, XY/13DJ, CN/17
SPW	C	836.43	114.4–124.4	VC/69D, DCE/15, DCA/1.4, TCE/1, BEN/3, TOL/220DJ, EB/22D, XY/11DJ, PCA/5DJ, CN/23
SPW	D	836.43	104.4–114.4	VC/68D, DCE/16D, DCA/1.4J, TCE/5, BEN/2, TOL70D, EB/15D, XY/10DJ, CN/28
SPW	E	836.43	94.4–104.4	VC/65D, DCE/43D, DCA/2.6J, TCE/1, BEN/4, TOL/1100DJ, EB/48D, XY/66D, PCA/7D, CN/28
SPW	F	836.43	82.9–94.4	VC/96D, DCE/53D, DCA/2.8, TCE/0.8J, BEN/5, TOL/1300DE, EB/75D, XY/102D, CN/27

[1]Approximately.

assembly. It is possible that the c1,2DCE detected from samples collected from the test intervals is not representative of water quality in the aquifer near well DF17.

Comparison of horizontal hydraulic conductivity and flowmeter data to water-quality data from the test intervals indicates a potential correlation between intervals of high horizontal hydraulic conductivity and high concentrations of VOC's in water from boreholes DF5D, DF12, and DF13 (figs. 9–11). A correlation also may be present at borehole DF4D (fig. 8). All of these boreholes are outside the limits of known disposal areas. This indicates that in boreholes where the horizontal hydraulic conductivity of one or more intervals is high and the permeability contrasts in the aquifer are large, VOC's tend to migrate through the most permeable intervals. This indicates that advection (migration with ground-water flow) is an important mechanism for contaminant transport in the Galena-Platteville aquifer, and VOC's will tend to preferentially migrate through the most permeable parts of the aquifer.

Slightly higher concentrations of total VOC's were detected in test intervals A and C of borehole DF17 than in test interval B (fig. 12). Borehole DF17 also is outside the limits of known disposal areas. Changes in flow were measured at the depths corresponding to test intervals A and C during flowmeter logging, indicating that the aquifer is permeable at these depths. The data indicate a correlation between aquifer permeability and ground-water quality at borehole DF17. However, the uncertain accuracy of the water-quality data and the lack of slug-test data at this borehole makes this correlation uncertain.

Although the test intervals with high horizontal hydraulic conductivities tend to have higher concentrations of total VOC's than the test intervals with low horizontal hydraulic conductivities, no clear correlation is indicated between horizontal hydraulic conductivity and concentrations of VOC's in water samples from borehole SPW (fig. 13). However, this borehole is in a disposal area and was open for 6 years before the samples were collected. It is possible that the sampling results were partially affected by highly contaminated shallow water that diffused or migrated down the borehole and is not completely representative of conditions in the aquifer, at the test intervals.

The lack of reliable water-quality data combined with a lack of large differences in horizontal hydraulic conductivity at borehole DF6 (tables 5 and 7) make interpretation of these data difficult. The highest concentrations of VOC's at borehole DF6 were detected in the test intervals in the middle of the aquifer and have no apparent correlation with horizontal hydraulic conductivity.

Monitoring Wells

Chlorinated aliphatic hydrocarbons (primarily chlorinated ethenes and ethanes) and the monocyclic aromatic hydrocarbons (primarily benzene, toluene, ethylbenzene, and xylenes) (figs. 29–32, at end of report, and table 8) were the VOC's detected most frequently and at the highest concentration in samples collected from the monitoring wells. Cyanide also was detected (fig. 33, at end of report). Chlorinated aliphatic hydrocarbons were detected in samples from wells open to the unconsolidated, Galena-Platteville, and St. Peter aquifers. Monocyclic aromatic hydrocarbons and cyanide were detected only in samples from wells open to the Galena-Platteville aquifer.

Chlorinated Aliphatic Hydrocarbons

Chlorinated aliphatic hydrocarbons, particularly TCE and TCA, were detected in the largest number of wells sampled for this study. The concentrations of these compounds remained fairly constant during both water-quality sampling periods, and generally are comparable to the concentrations detected during previous studies (Camp Dresser & McKee, Inc., 1989, appendix C; Environmental Resources Management, 1990, p. 4:8–4:13).

Samples were collected during this study from five wells open to the unconsolidated aquifer (MW12S, MW12I, DF7S, DF7D, and DF9S). Less than 4 µg/L of TCE or TCA was detected at wells DF7D and DF9S (figs. 29 and 30). No VOC's were detected in wells MW12S, MW12I, or DF7S. Although there is no indication of extensive contamination in the unconsolidated aquifer in the part of the study area shown in figures 29 and 30, VOC's have been detected from some of the RR series of wells, which are open to the unconsolidated aquifer near the Rock River (Avery, 1994, tables 2–4).

TCE and TCA were detected in the upper part of the St. Peter aquifer at well MW20R in the northwestern part of the DFP (fig. 2). No VOC's were detected in the St. Peter aquifer at wells MW2, MW21, MW37, and PC1C during this study. TCE and (or) TCA were

Table 8. Results of water-quality sampling from monitoring wells, sampling periods 1 and 2, Byron Superfund site

[Modified from U.S. Environmental Protection Agency, 1990, tables 5–6; µg/L, micrograms per liter; --, not applicable]

Well name: dup., duplicate sample; (B), sample collected January 1992; (C), sample collected April 1992

Compound detected: ACE, acetone; TOL, toluene; 4M2P, 4methyl-2pentane; 2BUT, 2butanone; XY, total xylenes; VC, vinyl chloride; BEN, benzene; DCA, total dichloroethane; TCA, 1,1,1-trichloroethane; EB, ethylbenzene; NS, not sampled; DCE, total dichloroethene; TCE, trichloroethene; CF, chloroform; ND, no detections; PCE, tetrachloroethene; CDS, carbon disulfide; CTC, carbon tetrachloride

Compound concentration: E, concentration estimated because of sample dilution; D, sample diluted; J, estimated concentration below detection limit; B, compound detected in blank sample

Well name	Compound (detected/concentration): Sampling period 1 (May 1991) (µg/L)	Compound (detected/concentration): Sampling period 2 (November 1991 to April 1992) (µg/L)
AW2	TCE/39, CTC/28, TCA/5J, PCE/3J	TCE/42, CTC/23, TCA/5J, PCE/3J
AW5D	NS	ND
AW6	TOL/130, XY/110, EB/28, PCE/7J	NS
AW6 (dup.)	TOL/130, XY/120, EB/31, PCE/7J	NS
B3	TCE/420, 2BUT/170, VC/130, DCE/37, PCE/30	DCE/356, TCE/320, PCE/17
B4	NS	VC/90, DCE/67, TCE/57, DCA/17, TCA/1J
B6	TCE/360, DCE/12J, DCA/11J, PCE/6J	NS
B6R(B)	NS	TCE/410D
B6R (dup.)(B)	NS	TCE/400D
DF1S	ACE/61000ED, TOL/46000ED, 4M2P/9900E, 2BUT/5700E, XY/2400E EB/520, VC/120, BEN/53, DCA/20, TCA/1J	ACE/25000E, 2BUT/3300E, XY/1500E, TOL/910E, EB/590E, VC/42, BEN/34, DCA/10
DF1S (dup.)	NS	TOL/27000D, ACE/13000D, XY/1700DJ, 4M2P/8600D, 2BUT/2000DJ
DF1D	DCA/33, TCA/12, DCE/12, TCE/6, TOL/2J	DCA/26, TCE/3J
DF1D (dup.)	DCA/35, TCA/15, DCE/11, TCE/6, TOL/1J	NS
DF2D	TCA/4J, PCE/3J, TCE/1J	ND
DF2S	TCA/23, DCA/22, DCE/7J, CF/4J, TCE/3J	ND
DF3	DCA/21, TCA/6	DCA/24, TCA/4J
DF4D	CDS/3J, TCA/2J	NS
DF4DD(C)	NS	TCA/24, VC/14, DCA/2J, DCE/1J
DF4DD (dup.)(C)	NS	TCA/15, DCE/3J
DF4DS(C)	NS	ND
DF4S	TCA/1J	TCA/15, DCA/10, DCE/1.2J, VC/1, TCE/0.6J
DF4S(C)	--	DCA/4J, TCA/3J, DCE/2J
DF5D	TCA/2J, DCA/1J	TCA/0.6J
DF5S	ACE/4J	ND
DF6	TOL/640, XY/120, TCA/52, DCA/22, EB/21	DCA/11 TCA/6J TOL/5J EB/2J
DF7D	TCE/3J	ND
DF7S	ND	NS
DF8	TCA/9, DCA/9, TCE/7	DCA/19, TCA/13, TCE/4, CF/2, DCE/0.9J, PCE/0.5J
DF9D	ND	TCA/0.9J
DF9D (dup.)	NS	TCA/0.6J
DF9S	CF/1J, TCA/1J	CF/2, TCA/2,TCE/0.9J, DCA/0.7J
DF10	ACE/4J	0.7J
DF10(C)	--	TCA/10, PCE/3
DF11	TCE/2J	TCE/2, PCE/0.8J
DF12	TCE/150, TCA/5J, PCE/2J	TCE/220, TCA/7, CF/4J, DCE/3, PCE/2, DCA/1, CTC/1
DF13	TCA/17, DCA/5J, TCE/2J	TCA/16, DCA/7, TCE/2, DCE/1
DF13 (dup.)	TCA/18, DCA/5J, TCE/2J	NS
DF14D	ND	DCA/0.7J
DF14S	ACE/11, XY/3J, PCE/1J, BEN/1J, TOL/1J	NS
DF15	ND	CF/15, TCA/2

Table 8. Results of water-quality sampling from monitoring wells, sampling periods 1 and 2, Byron Superfund site—Continued

Well name	Compound (detected/concentration) Sampling period 1 (May 1991) (µg/L)	Sampling period 2 (November 1991 to April 1992) (µg/L)
DF15(C)		CF/5J, ACE/5J
DF17	CF/10, TCA/3J	CF/12, TCA/3, ACE/3J
DF17 (dup.)	NS	CF/11, TCA/3
DF17(B)	--	CF/11, TCA/2
DF18	4M2P/66, DCA/36, ACE/20, VC/19, TCA/14, PCE/12	DCA/19, PCE/12, TCA/8J, DCE/7, XY/4J, TCE/3J, TOL/2J
DF19	PCE/28, DCA/9, TCA/8, DCE/6J, XY/5J, TCE/4J	PCE/16, DCA/10, TCA/6J, CF/4J, CTC/2J, BEN/2J, TOL/2J EB/2J
DF20	NS	ND
DF21	NS	TCE/6, TCA/4, ACE/3J, DCE/2, DCA/0.6J
DF22DD(B)	NS	CF/9, TCA/2
DF22SD(B)	NS	CF/6, TCA/2
DF23(B)	NS	CF/4, TCA/3, DCA/1, TCE/0.9J, DCE/0.7J
DF24	NS	TCA/2, TCE/0.7J
GW42	TCE/150, TCA/6, PCE/2J	TCE/160, DCE/7J, TCA/6J, PCE/2J
MW1	ND	ND
MW2	ND	NS
MW3	CDS/2J	NS
MW8	TCE/110, PCE/15, DCE/15, TCA/7, DCA/3J	NS
MW9	TCE/140, DCE/31, PCE/25, TCA/24, CDS/3J	NS
MW12I	NS	ND
MW12S	NS	ND
MW15	TCE/260, DCE/7J, PCE/5J	TCE/200 TCA/8J DCE/5J MC/4J PCE/3J
MW15 (dup.)	NS	TCE/180, TCA/5J
MW16	TCE/250, DCE.10J, PCE/5J	TCE/180, TCA/7J, DCE/6J, PCE/2J
MW16(B)	--	TCE/160, TCA/7, DCE/5, PCE/3, DCA/1
MW20R	TCE/110, DCE/11J, TCA/7J	NS
MW21	ND	NS
MW30(B)	TOL/6, 4M2P/3J	ND
MW31	TOL/0.9J	ND
MW36	TCE/10	TCE/6, DCA/1
MW36 (dup.)	TCE/11, TCA/1J	NS
MW37	ND	NS
MW37 (dup.)	ND	NS
MW41	TCE/180, TCA/6J, PCE/3J	TCE/180, TCA/7J, DCE/7J, PCE/3J
MW42	TCE/11, TCA/6J, PCE/3J	NS
PC1B	TCA/7, TCE/7, DCA/6	TCA/8, DCE/4.5, TCE/4, ACE/3J, PCE/0.9J
PC1B (dup.)	TCA/7, TCE/7, DCA/6	NS
PC2B	ND	ND
PC3B	XY/770, TOL/290, TCA/281, EB/260, DCA/79, BEN/12J	TCA/15, DCA/8J, EB/2J
PC4B	CF/5, TCA/2J	CF/7, TCA/2, DCA/0.7J
PC4B (dup.)	NS	CF/6, TCA/2, DCA/0.7J
PC5B	TCE/10, TCA/7, DCA/3J, PCE/2J	DCA/11, TCE/7J, TCA/5J
PC5B (dup.)	NS	DCA/11, TCE/6J, TCA/5J
PC5B(B)	--	TCE/9, DCE/7, TCA/5, PCE/2
PC5B (dup.)(B)	NS	TCE/8, DCE/7, TCA/5, PCE/2
PC6B	TCE/3J	TCE/1 TOL/0.5J
PW3	TCE/130, TCA/4J, ACE/4J, DCE/3J, PCE/3J	TCE/130, TCA/5J, PCE/2J

detected in wells MS2, MW18, MW39, and PC1C open to the St. Peter aquifer during previous investigations (Environmental Resources Management, 1990, appendix C; Avery, 1994, p. 11).

The concentration and distribution of chlorinated aliphatic hydrocarbons in the Galena-Platteville aquifer varies across the site. The highest concentrations of TCE were detected in samples from wells open to the Galena-Platteville aquifer beneath the salvage yard and the northeastern part of the DFP (fig. 29). TCE is either absent or at concentrations less than 12 μg/L in the Galena-Platteville aquifer beneath the southern half of the DFP. TCA was detected in samples from most of the wells beneath the southern half of the DFP (fig. 30). TCA typically is absent or at concentrations less than 10 μg/L beneath the salvage yard and the northern half of the DFP.

Analysis of TCE to TCA ratios from all of the samples indicates that the concentrations of TCE exceeded the concentrations of TCA, usually by a factor of 10, beneath the salvage yard and the northern part of the DFP, except for well DF10 (fig. 31). TCE was either not detected or typically was detected at a lower concentration than TCA beneath the southern part of the DFP. The dividing line between the areas where TCE or TCA is the compound detected at the highest concentration approximately corresponds to the location of the ground-water ridge south of the salvage yard (fig. 18).

TCE and TCA have similar physical and chemical properties (Montgomery and Welkom, 1990) indicating that their migration in ground water will be similar. If biodegradation does not appreciably affect the relative concentrations of TCE and TCA in the ground water of the study area, the observed variations in the concentrations of these compounds can be attributed to differences in their amount and concentration in the source material. This indicates that there are at least two sources of VOC's in the study area.

Other chlorinated ethenes and ethanes including vinyl chloride, 1,1-dichloroethene (1,1-DCE), 1,2-dichloroethene (1,2-DCE), 1,1-dichloroethane (1,1-DCA), PCE, and 1,2-dichloroethane (1,2-DCA), were detected in the Galena-Platteville aquifer. Low concentrations (11 μg/L) of DCE were detected at well MW20R in the St. Peter aquifer.

Many of the chlorinated ethene and ethane compounds can be related as degradation products. PCE can degrade to TCE, which can degrade to 1,2-DCE and 1,1-DCE, and both can degrade to vinyl chloride. Carbon tetrachloride can degrade to TCA, which can degrade to 1,1-DCE, which can degrade to vinyl chloride or 1,1-DCA, which can degrade to chloroethane (Vogel and others, 1987, p. 726; Norris, 1993, p. 154). Vinyl chloride and chloroethane can degrade to carbon dioxide and water. Degradation products in ground water indicate both chlorinated ethenes and ethanes are being degraded in the study area, decreasing the total amount of these compounds. This assumes that pure product was disposed in the source areas.

The presence of vinyl chloride and intermediate degradation products such as DCE and DCA in samples collected from wells near the salvage yard (wells SPW, AW1S, B4, B3) and the West Disposal Area (wells DF1S, DF18) (tables 7 and 8) coupled with the low dissolved-oxygen content and oxidation-reduction potential in these areas (U.S. Environmental Protection Agency, 1994, p. 5:26), indicates that TCE is being degraded to vinyl chloride in the less oxidized water beneath these areas. The absence of vinyl chloride in wells away from the salvage yard and the West Disposal Area coupled with the higher dissolved-oxygen content and higher oxidation-reduction potential in the water away from these areas, indicate that vinyl chloride is being degraded in the more highly oxidized water away from the disposal areas.

Monocyclic Aromatic Hydrocarbons

Monocyclic aromatic hydrocarbons, particularly ethylbenzene, toluene, and xylenes, were detected at concentrations greater than 500 μg/L in samples from wells AW6, DF1S, PC3B, and DF6 (fig. 32). These wells are open to the Galena-Platteville aquifer. Well AW6 is at the salvage yard; well DF1S is near the West Disposal Area; and wells PC3B and DF6 are near the possible Central Disposal Area (fig. 3). Samples collected from wells at the salvage yard and the West Disposal Area have consistently contained high concentrations of ethylbenzene, toluene, and total xylenes. Samples collected from wells PC3B and DF6 contained high concentrations of monocyclic hydrocarbons only during the May 1991 sampling period (table 8). Samples collected from wells PC3B and DF6 during prior sampling periods (Camp Dresser & McKee, Inc., 1989, Appendix C; Environmental Resources Management, 1990, p. 4:8–4:13) and during the second sampling period of this study contained considerably lower concentrations of total VOC's and monocyclic aromatic hydrocarbons.

Though detected at very high concentrations, the extent of the monocyclic aromatic hydrocarbons in the study area is limited to the immediate vicinity of the salvage yard, the West Disposal Area, and the possible Central Disposal Area. Vinyl chloride also was detected in many of the wells where monocyclic aromatic hydrocarbons were detected at the salvage yard (AW1S and SPW) and the West Disposal Area (DF1S) (tables 7 and 8). Ground water in the areas where monocyclic aromatic hydrocarbons were detected at high concentrations tends to have low oxidation-reduction potential and dissolved-oxygen content (U.S. Environmental Protection Agency, 1994, p. 5–26). The areas of low oxidation-reduction potential are surrounded by areas of high oxidation-reduction potential where monocyclic aromatic hydrocarbons (and vinyl chloride) were not detected. Monocyclic aromatic hydrocarbons (and vinyl chloride) are readily biodegraded in aerobic environments, resulting in the consumption of oxygen (Rittman and others, 1992, p. 29). Monocyclic aromatic hydrocarbons probably were degraded beneath the disposal areas subsequent to their disposal. Eventually, enough oxygen was consumed in biodegradation to create an anaerobic environment in parts of the salvage yard, the West Disposal area, and the possible Central Disposal area. The absence of oxygen in water limits degradation of the monocyclic aromatic compounds and vinyl chloride, allowing these compounds to persist in these areas, but does allow for degradation of those compounds preferentially degraded under anaerobic conditions. As oxidized water is recharged to the aquifer downgradient from these areas, the oxidation-reduction potential and dissolved-oxygen content of the water increases. These aerobic conditions allow biodegradation of the aromatic compounds and vinyl chloride to be completed.

Cyanide

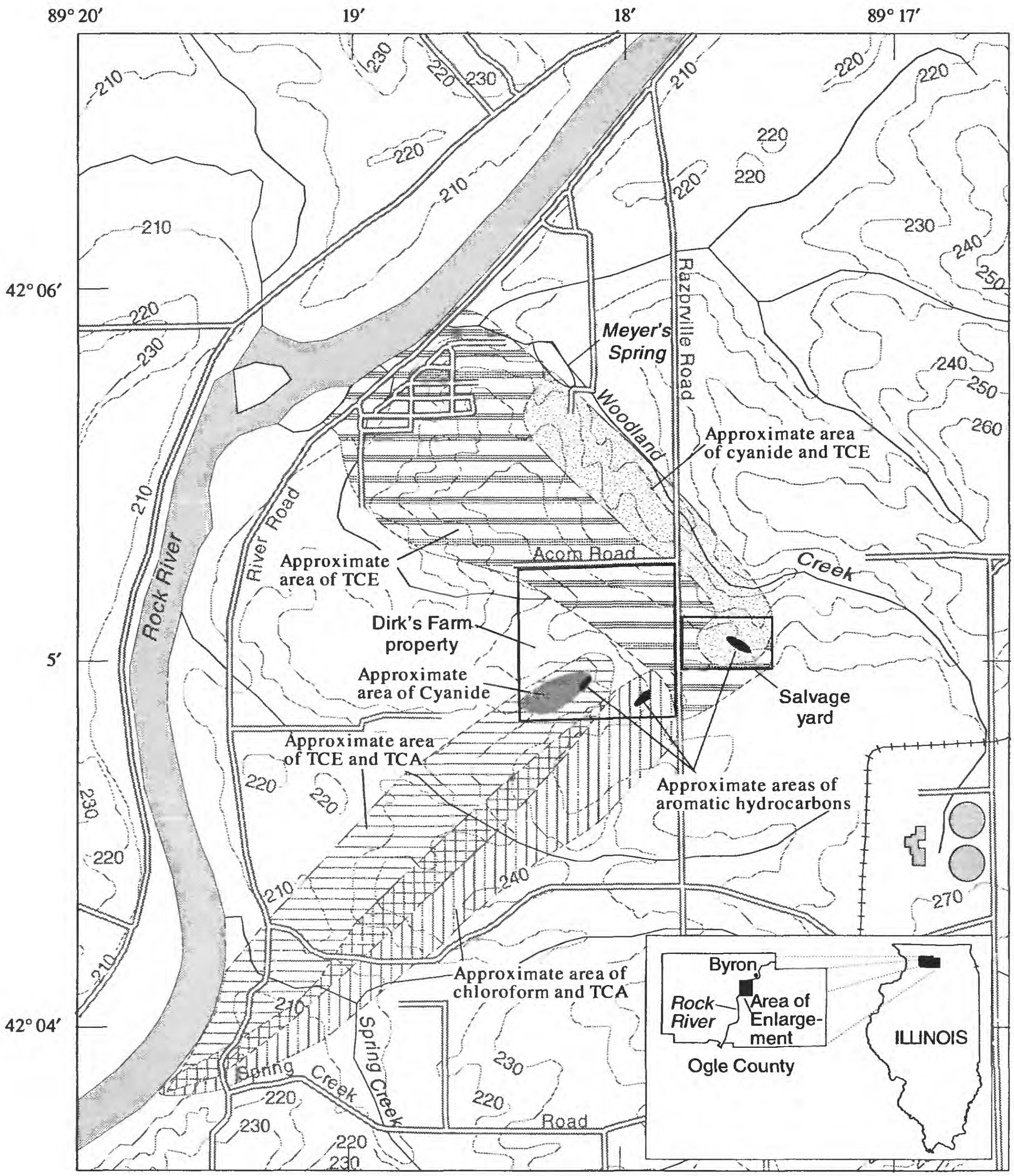
Cyanide was detected in ground-water samples from four wells at the salvage yard (B3, B6R, AW2, and AW6) and from five wells near the West Disposal Area (DF1S, DF2S, DF2D, DF18, DF19) (fig. 33). Cyanide also was detected in samples from wells hydraulically downgradient from the West Disposal Area (PC1B, PC5B, and DF8) along the northern half of the West Ravine. All these wells are open to the Galena-Platteville aquifer. Cyanide also was detected in samples from wells along Woodland Creek and at Meyer's Spring during previous investigations (Camp Dresser & McKee, Inc., 1989, p. 3:15).

Distribution of Contaminants in Ground Water

Analysis of the geologic, hydrologic, and water-quality data from this and previous studies indicates widespread contamination in the study area (U.S. Environmental Protection Agency, 1994, fig. 9:2). The pathways of contaminant migration typically are along the direction of ground-water flow.

Cyanide, TCE, and aromatic hydrocarbons are the primary contaminants in ground water beneath the salvage yard (fig. 34). The distribution of TCE between the salvage yard and the Rock River, defined by the northern area of TCE, indicates that TCE migrates with ground-water flow from the Galena-Platteville aquifer at the salvage yard to the St. Peter aquifer; then migrates to the unconsolidated aquifer before discharging to the Rock River (Avery, 1994, p. 17). Some preferential flow and contaminant transport may be occurring through the Grand Detour Formation near the salvage yard and the northeastern part of the DFP, and through the Grand Detour and Mifflin Formations near borehole DF12. The USEPA has concluded that TCE derived from the North Disposal Area also is migrating toward the Rock River (U.S. Environmental Protection Agency, 1994, p. 9:16).

The distribution of cyanide and TCE in the northern half of the study area indicates a component of flow from the eastern part of the salvage yard to Meyer's Spring through the permeable parts of the Galena-Platteville and unconsolidated aquifers near Woodland Creek (Ecology and Environment, Inc., 1976, p. 55; Camp Dresser & McKee Inc., 1989, figs. 4–18). Migration of aromatic hydrocarbons and vinyl chloride from the salvage yard probably has been prevented by the biodegradation of these compounds. The extent of TCE and cyanide contamination in the northern part of the study area approximately corresponds to flow boundaries defined by the ground-water ridge south of the salvage yard (fig. 18), the no-flow boundary at Woodland Creek, and the regional discharge area at the Rock River. A long time period may be required for contaminants to migrate out of the areas of low permeability in the Galena-Platteville aquifer beneath the salvage yard, under conditions of natural flow.



Base from U.S. Geological Survey
1:100,000 Digital Line Graphs
Albers Equal-Area Conic Projection
Standard parallels 33° and 45°, central meridian -89°

0 0.5 1 MILE
0 0.5 1 KILOMETER

EXPLANATION

220	TOPOGRAPHIC CONTOUR--Shows elevation of land surface, in meters. Contour interval 10 meters. Datum is sea level
TCA	TRICHLOROETHANE
TCE	TRICHLOROETHENE

Figure 34. Type and extent of ground-water contamination, Byron Superfund site (from U.S. Environmental Protection Agency, 1994, fig. 9:2).

Aromatic hydrocarbons and TCA are the primary VOC's detected in ground water near the possible Central Disposal Area in the southeastern quarter of the DFP (fig. 34). TCE was detected in samples from only one well (DF4S) in this area at a concentration of less than 1 µg/L. Chloroform and TCA were detected beneath the southeastern edge of the DFP near the South and East Disposal Areas. The distribution of TCA and chloroform beneath the southeastern part of the DFP indicates that ground-water flow and contaminant migration are to the southwest through the Galena-Platteville aquifer. There may be some preferential flow through the Grand Detour Formation in part of this area. Migration of aromatic hydrocarbons near the possible Central Disposal Area appears to have been prevented by biodegradation. The northern boundary of chloroform and (or) TCA detections is approximately defined by the ground-water ridge south of the salvage yard (fig. 16). The southern extent of these contaminants is not well defined.

Cyanide, TCE, TCA, and aromatic hydrocarbons are in the Galena-Platteville aquifer beneath the southwestern part of the DFP near the West Disposal Area (fig. 34). The distribution of TCE, TCA, and, to a lesser extent, cyanide in this area indicates ground-water flow and contaminant migration in this area is to the southwest through the permeable dolomite near the West Ravine. As was the case at the salvage yard and the possible Central Disposal Area, biodegradation appears to have prevented the formation of a large aromatic hydrocarbon plume, and perhaps created a smaller vinyl chloride plume beneath the southwestern part of the DFP. The northern boundary of this contamination appears to correspond to the West Disposal Area. The southern extent of contamination in this area is not well defined.

SUMMARY AND CONCLUSIONS

The U.S. Geological Survey, in cooperation with the U.S. Environmental Protection Agency, conducted a study of the hydrogeology and contaminant distribution at the Byron Superfund site near Byron, Ill., from August 1990 to March 1994. The study was designed to define the geologic and hydrologic properties that affect ground-water flow, and to determine the type and extent of ground-water contamination in the study area.

The bedrock geology in the study area consists of the St. Peter Sandstone, Glenwood Formation, and the Platteville and Galena Groups of Ordovician age. The St. Peter Sandstone is a coarse-to-medium grained quartz arenite. The Glenwood Formation is a heterogeneous unit of sandstone, dolomite, and shale, which overlies the St. Peter Sandstone. The Platteville and Galena Groups overlie the Glenwood Formation and are composed of fractured, partly cherty, partly argillaceous dolomite. The Platteville and Galena Groups are the geologic units of primary interest to this study.

Analyses of geophysical logs indicate the presence of numerous fractures and solution openings in the Platteville and Galena Groups. The orientation of the inclined fractures in any part of the study area typically is parallel to the orientation of the fracture traces in that part of the study area. Geophysical logs also indicate that the bedrock stratigraphy can be correlated throughout the study area and that the presence or absence of the Guttenberg Formation may affect the concentration of fractures and solution openings in the dolomite.

Quaternary deposits unconformably overlie the bedrock throughout the study area. Alluvial sand and gravel deposits are located in the valley of the Rock River and along the lower reaches of Woodland Creek, the Northwest Ravine, and the West Ravine. Windblown sand and silt deposits (loess), underlain by outwash sand and gravel deposits, generally are present along the upper reaches of Woodland Creek, the Northwest Ravine, and the West Ravine. Loess and till compose the surficial deposits in the upland and interstream areas.

A bedrock ridge trending southeast to northwest is present between Woodland Creek and the West Ravine and is reflected by a prominent topographic ridge. The bedrock ridge is composed of dolomites of the Platteville and Galena Groups. Near the Rock River, the Platteville and Galena Groups and the Glenwood Formation have been eroded, and the bedrock is composed of the St. Peter Sandstone.

The geologic units in this area can be divided into four hydrologic units—the unconsolidated aquifer, the Galena-Platteville aquifer, the Harmony Hill Shale semiconfining unit, and the St. Peter aquifer. The unconsolidated aquifer is unconfined. The Galena-Platteville aquifer is a heterogeneous, anisotropic, unconfined, double-porosity aquifer. The St. Peter aquifer is homogeneous, isotropic, and semiconfined, except near the Rock River where the semiconfining unit has been eroded and the St. Peter aquifer is in direct hydraulic connection with the overlying unconsolidated aquifer.

The water-table configuration generally mirrors topography. The overall direction of ground-water flow is toward the Rock River with components of flow toward topographic lows at Woodland Creek and the West Ravine. The configuration of the potentiometric surface at the base of the Galena-Platteville aquifer is similar to the water-table configuration. Ground-water flow in the St. Peter aquifer also is toward the Rock River. Water levels indicate the potential for downward flow from the water table to the base of the Galena-Platteville aquifer into the St. Peter aquifer in most of the study area away from the Rock River. Head values indicate the potential for ground water to recharge the Rock River.

The Galena-Platteville aquifer underlying the salvage yard and the Dirk's Farm property can be divided into four zones primarily based on the water-table altitude. Hydraulic characteristics among zones vary and appear to be affected by lithologic and structural controls on the permeability distribution in the aquifer.

Zone 1 underlies much of the central and southeastern parts of the salvage yard and the southeastern part of the Dirk's Farm property. The water-table altitude in zone 1 typically is higher than 770 ft above sea level. Changes in water level with depth in zone 1 can exceed 50 ft and the mean horizontal hydraulic conductivity of the zone is 3.1×10^{-1} ft/d.

Zone 2 is defined by the flat part of the water table beneath the western part of the salvage yard and the northern part of the Dirk's Farm property. The water-table altitude in zone 2 typically is from 745 to 770 ft above sea level. Changes in head with depth in zone 2 are less than 5 ft and the mean horizontal hydraulic conductivity of the zone is 5.2×10^{0} ft/d.

Zone 3 is encompassed by zone 2 and is in the area northwest of the salvage yard. The water-table altitude does not vary appreciably across the zone. Changes in head with well depth in zone 3 appear to be about 1 ft and the mean horizontal hydraulic conductivity of the zone is $2.4 \text{ X } 10^{2}$ ft/d.

Zone 4 is in the topographically low areas near Woodland Creek and the West Ravine. The water-table altitude in zone 4 typically is less than 750 ft above sea level near Woodland Creek and less than 730 ft above sea level near the West Ravine. Changes in head with well depth in zone 4 are less than 11 ft. The mean horizontal hydraulic conductivity of this zone is 8.0×10^{0} ft/d.

The horizontal hydraulic conductivities calculated from slug-test data were correlated with stratigraphy. The geometric mean of the horizontal hydraulic conductivities for the Galena Group is about 1.2×10^{-1} ft/d. The mean value for the Pecatonica, Nachusa, and Quimbys Mill Formations of the Platteville Group is from 2.3 to 6.2×10^{-1} ft/d. The mean values for the Mifflin and Grand Detour Formations of the Platteville Group are 1.3 and 2.7×10^{0} ft/d, respectively.

In the winter of 1992, a constant-discharge aquifer test was conducted in borehole DF4D. The distribution of drawdown in the observation wells indicates that water flows to the borehole from east-west oriented vertical and inclined fractures, which intercept the Grand Detour Formation. A transmissivity of 1.30×10^{5} ft^2/d was calculated from specific-capacity tests conducted at borehole DF12.

Comparison of the horizontal-hydraulic-conductivity data to water-quality data from the test intervals isolated with a packer assembly indicates a correlation between zones of high horizontal hydraulic conductivity and high concentrations of volatile organic compounds in boreholes DF5D, DF13, and DF12. A correlation also may be present at boreholes DF4D and DF17. No clear correlation between horizontal hydraulic conductivity and high concentrations of volatile organic compounds was identified in boreholes SPW, AW1S, DF2D, and DF6.

Cyanide, trichloroethene, and aromatic hydrocarbons were detected in ground water beneath the salvage yard. Trichloroethene migrates with ground-water flow from the salvage yard northwest to the Rock River. Cyanide and trichloroethene also are present along Woodland Creek between the salvage yard and Meyer's Spring. The extent of these compounds in ground water approximately corresponds to ground-water-flow boundaries.

Aromatic hydrocarbons, trichloroethane, and chloroform were detected in ground water beneath the southeastern quarter of the Dirk's Farm property. The trichloroethane and chloroform in this part of the study area appear to be migrating to the southwest.

Cyanide, trichloroethene, trichloroethane, and aromatic hydrocarbons were detected in ground water beneath the West Disposal Area. Cyanide, trichloroethene, and trichloroethane are migrating with ground-water flow to the southwest of the West Disposal Area.

Aromatic hydrocarbons beneath the salvage yard and the southern part of the Dirk's Farm property appear to be biodegrading and have been detected in only small areas.

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GLOSSARY

Anisotropy. The condition of having different properties in different directions.

Aquifer. A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

Argillaceous. Composed of clay minerals.

Borehole. Area of rock evacuated by the drilling process in which a well has not yet been installed.

Contaminant. An undesirable substance not normally present or an unusually high concentration of a naturally occurring substance.

Darcy's law. An empirical law, which states that the velocity of flow through a porous medium is directly proportional to the hydraulic gradient assuming flow is laminar and inertia can be neglected.

Dip. The angle a plane makes with a horizontal plane, measured perpendicular to the strike.

Fault. A fracture in rock along which there has been an observable amount of displacement.

Formation. Aggregation of related strata distinguishable from beds above and below, and of mappable extent.

Fracture. Breakage in the rock not related to the crystalline structure of the minerals, which compose the rock, often having a preferred orientation.

Fracture trace. Surficial expression of a fracture.

Group. Two or more superadjacent formations having prominent features in common.

Head. The height above a standard datum of the surface of a column of water that can be supported by the static pressure at a given point.

Heterogeneity. A characteristic of a medium in which material properties vary from point to point.

Hydraulic Conductivity. A proportionality constant relating hydraulic gradient to specific discharge, which for an isotropic medium and homogeneous fluid equals the volume of water at the prevailing kinematic viscosity that will move in unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow.

Hydraulic gradient. The change in static head per unit of distance in a given direction.

Leakance. The rate of flow across a unit (horizontal) area of a semipervious layer into (or out of) an aquifer under one unit of head difference across this layer.

Lithologic log. Description of the geologic deposits encountered during drilling.

Matrix. The solid framework of a porous system.

Member. Units of lesser rank in a heterogeneous formation, which are lithologically distinct.

Permeability. A measure of the relative ease with which a porous medium can transmit a fluid under a potential gradient and is a property of the medium alone.

Porosity. The ratio, usually expressed as a percentage, of the total volume voids of a given porous medium to the total volume of the porous medium.

Potentiometric surface. An imaginary surface representing the static head of ground water and defined by the level to which water will rise in a tightly cased well.

Semiconfining unit. A confining unit that retards but does not prevent the flow of water to or from an adjacent aquifer. It does not readily yield water to wells or springs but may serve as a storage unit for ground water.

Solution opening. A large cavity in a rock formed by chemical dissolution.

Storage coefficient. The volume of water an aquifer releases from storage per unit surface area of the aquifer per unit change in head.

Strike. The direction in which a horizontal line can be drawn on a plane. The strike can be used to describe the general direction of a structure.

Transmissivity. The rate at which water of the prevailing kinematic viscosity is transmitted through the unit width of the aquifer under a unit hydraulic gradient. It is equal to an integration of the hydraulic conductivities across the saturated part of the aquifer perpendicular to the flow paths.

Vug. A cavity in a rock.

Water table. The upper surface of the zone of saturation on which the water pressure equals the atmospheric pressure.

Well. A bored, drilled, or driven shaft of a dug hole, whose depth is greater than the largest surface dimension.

Well loss. Water-level decline in a well caused by turbulent flow between the well and the aquifer.

FIGURES 9–21

FIGURES 29–33

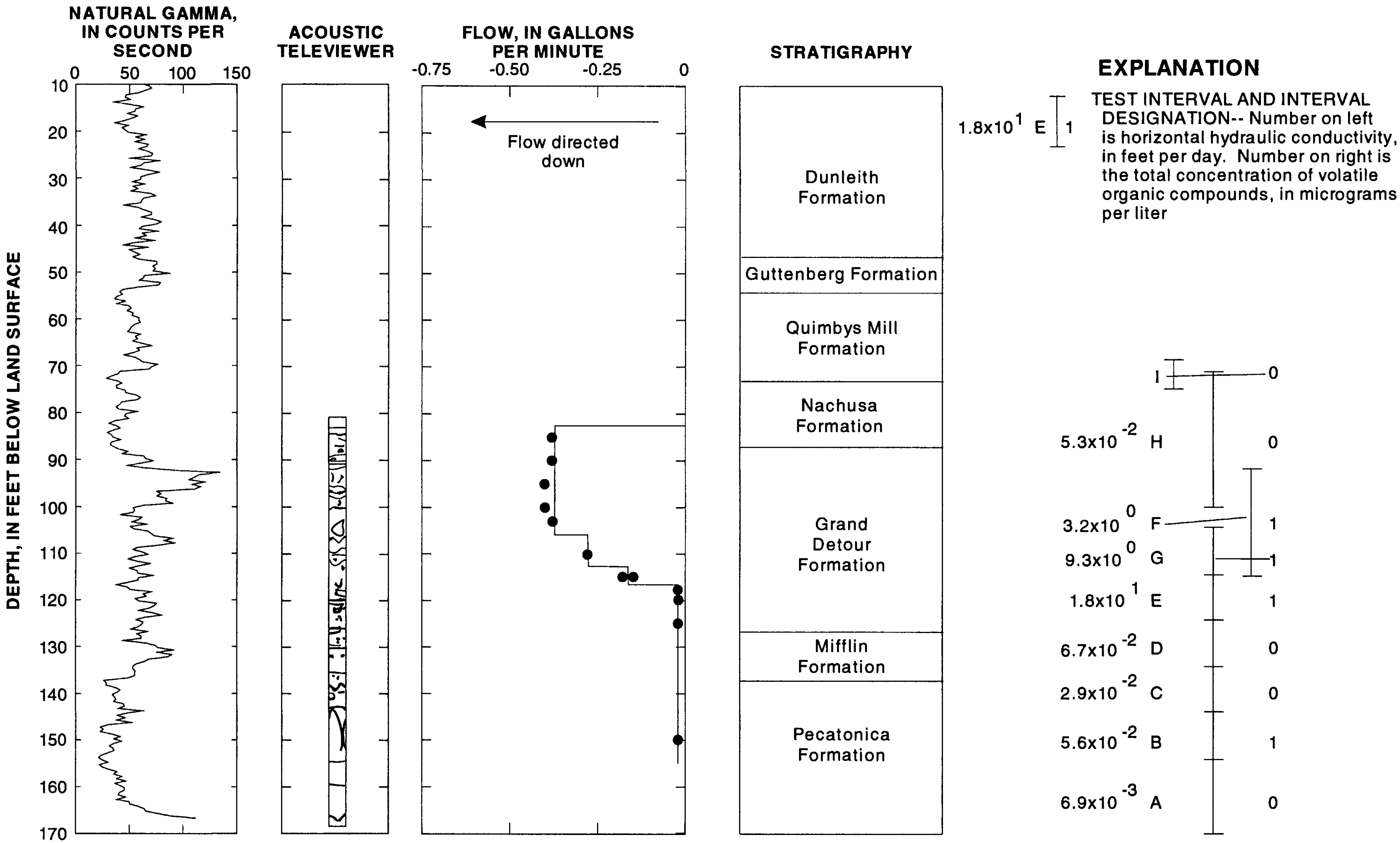


Figure 9. Natural-gamma, acoustic-televiewer, and flowmeter logs; stratigraphy; horizontal hydraulic conductivities; and total concentration of volatile organic compounds in the test intervals isolated with a packer assembly for borehole DF5D, Byron Superfund site.

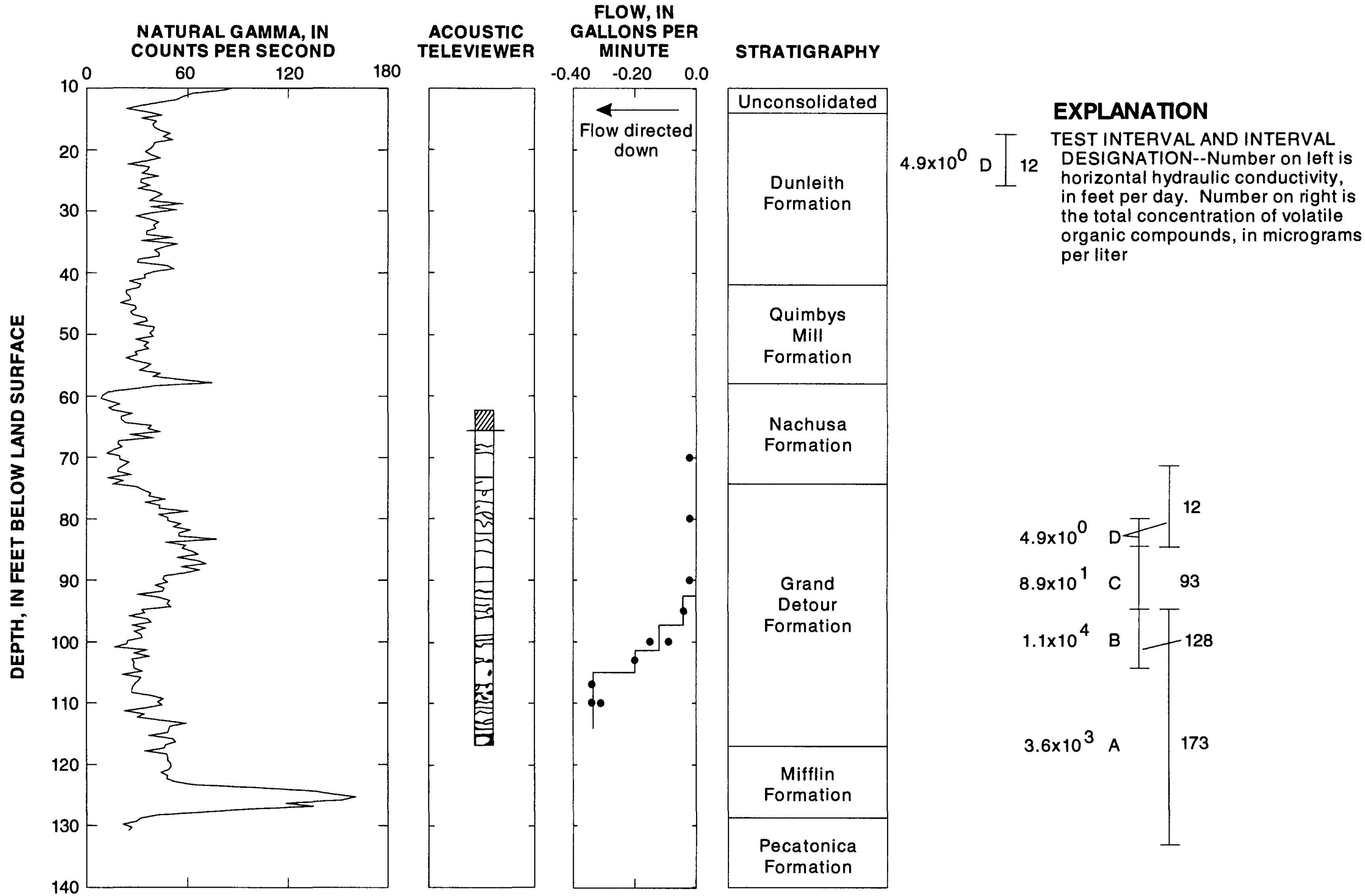


Figure 10. Natural-gamma, acoustic-televiewer, and flowmeter logs; stratigraphy; horizontal hydraulic conductivities; and total concentration of volatile organic compounds in the test intervals isolated with a packer assembly for borehole DF12, Byron Superfund site.

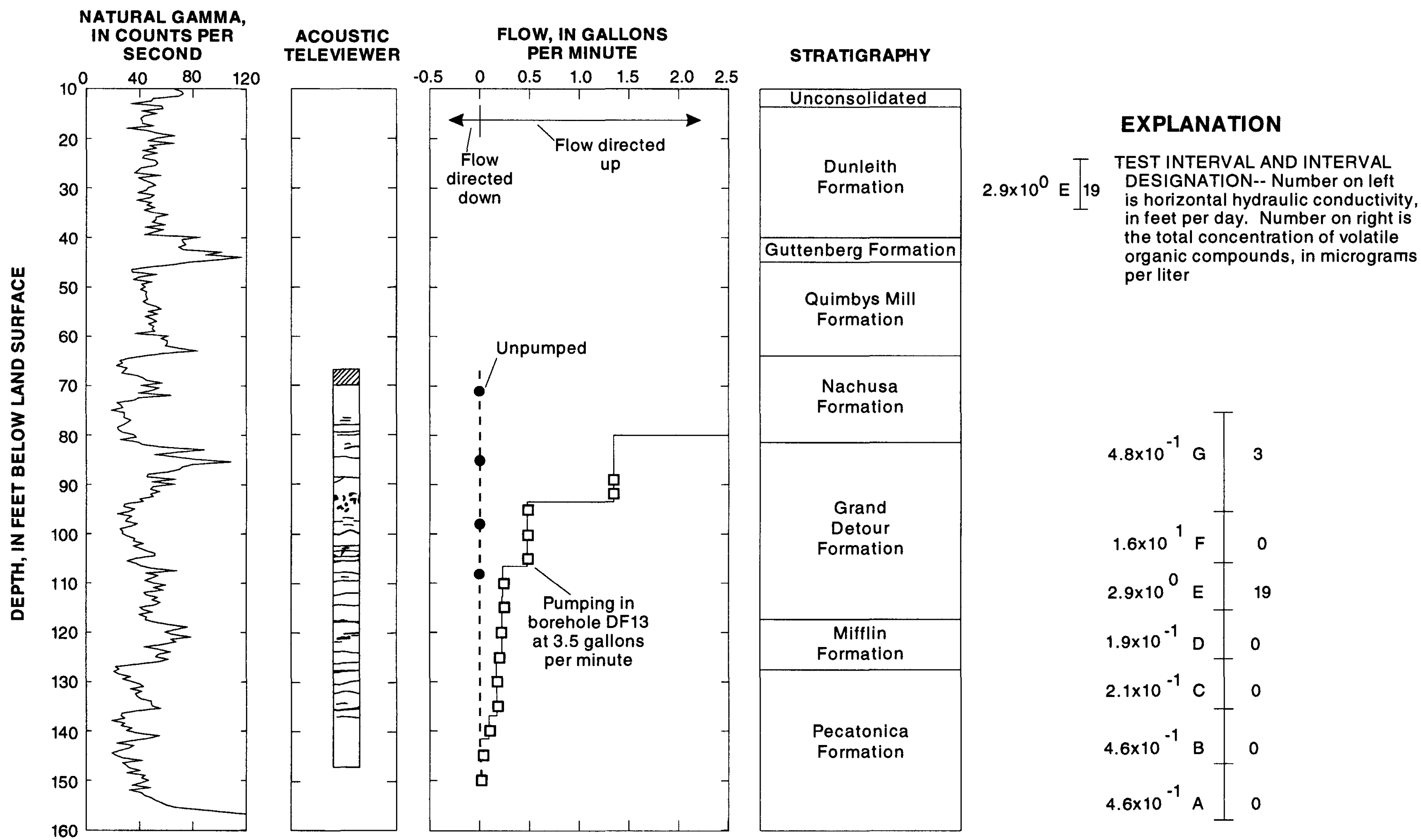


Figure 11. Natural-gamma, acoustic-televiewer, and flowmeter logs; stratigraphy; horizontal hydraulic conductivities; and total concentration of volatile organic compounds in the test intervals isolated with a packer assembly for borehole DF13, Byron Superfund site.

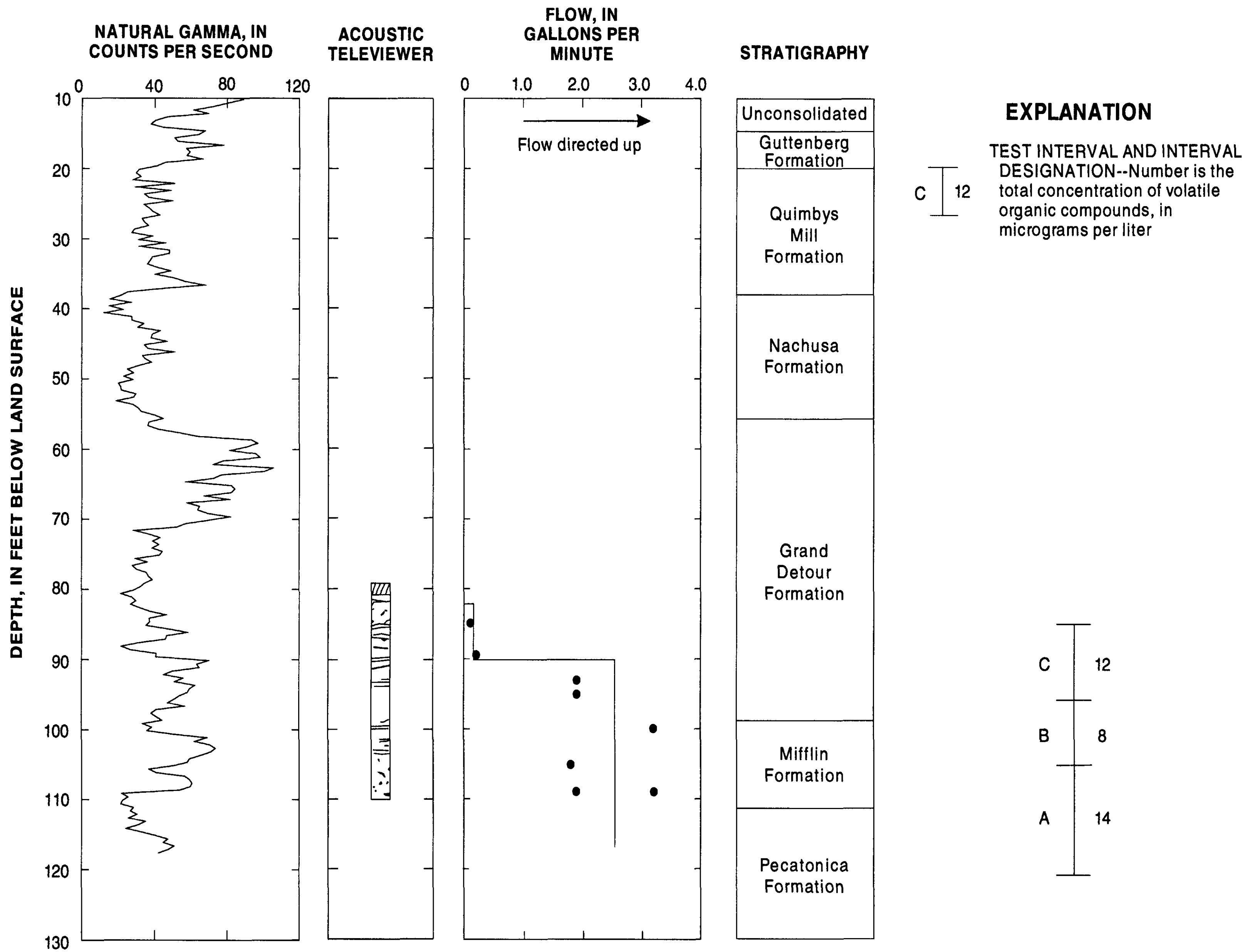


Figure 12. Natural-gamma, acoustic-televiewer, and flowmeter logs; stratigraphy; and total concentration of volatile organic compounds in the test intervals isolated with a packer assembly for borehole DF17, Byron Superfund site.

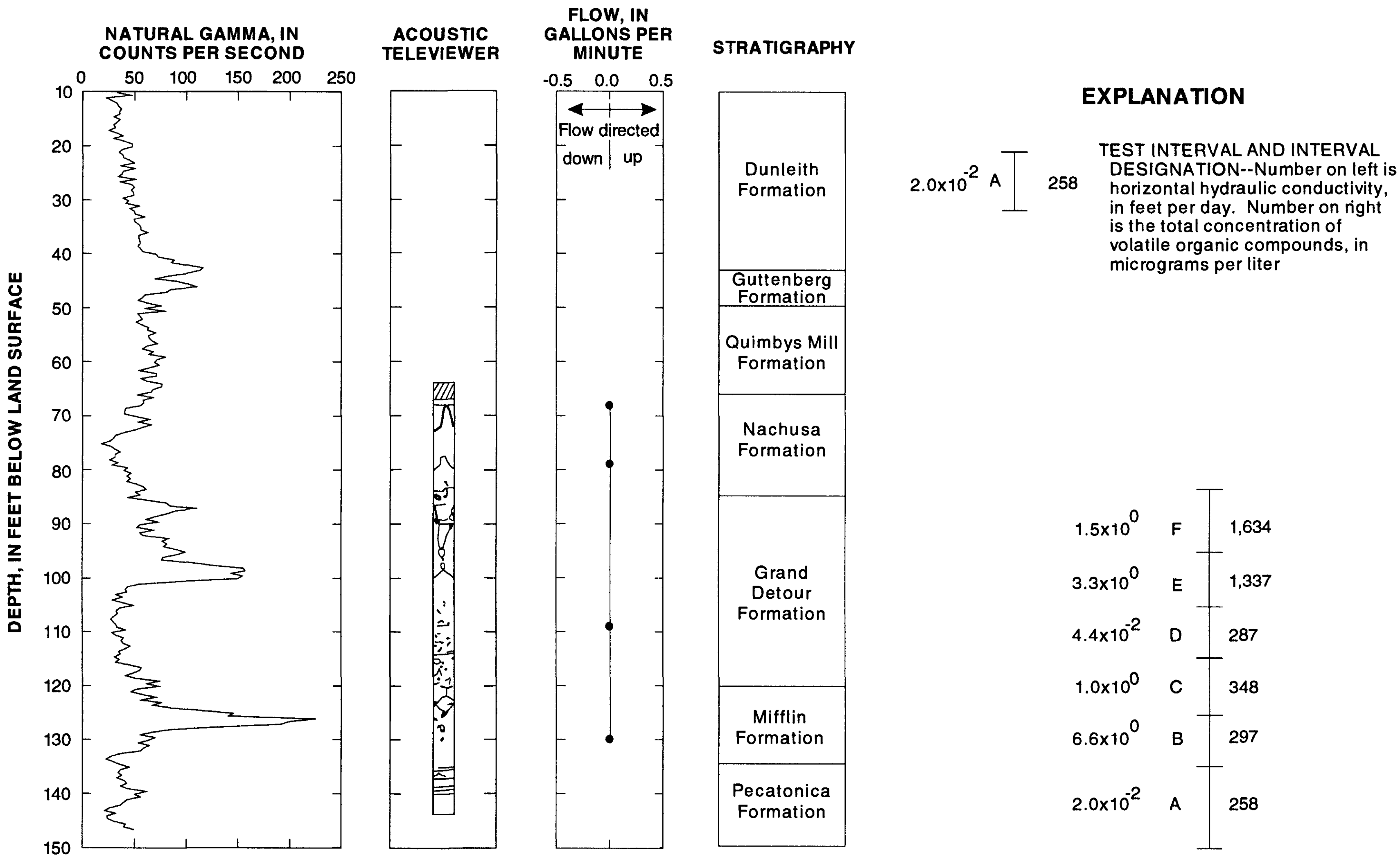


Figure 13. Natural-gamma, acoustic-televiewer, and flowmeter logs; stratigraphy; horizontal hydraulic conductivities; and total concentration of volatile organic compounds in the test intervals isolated with a packer assembly for borehole SPW, Byron Superfund site.

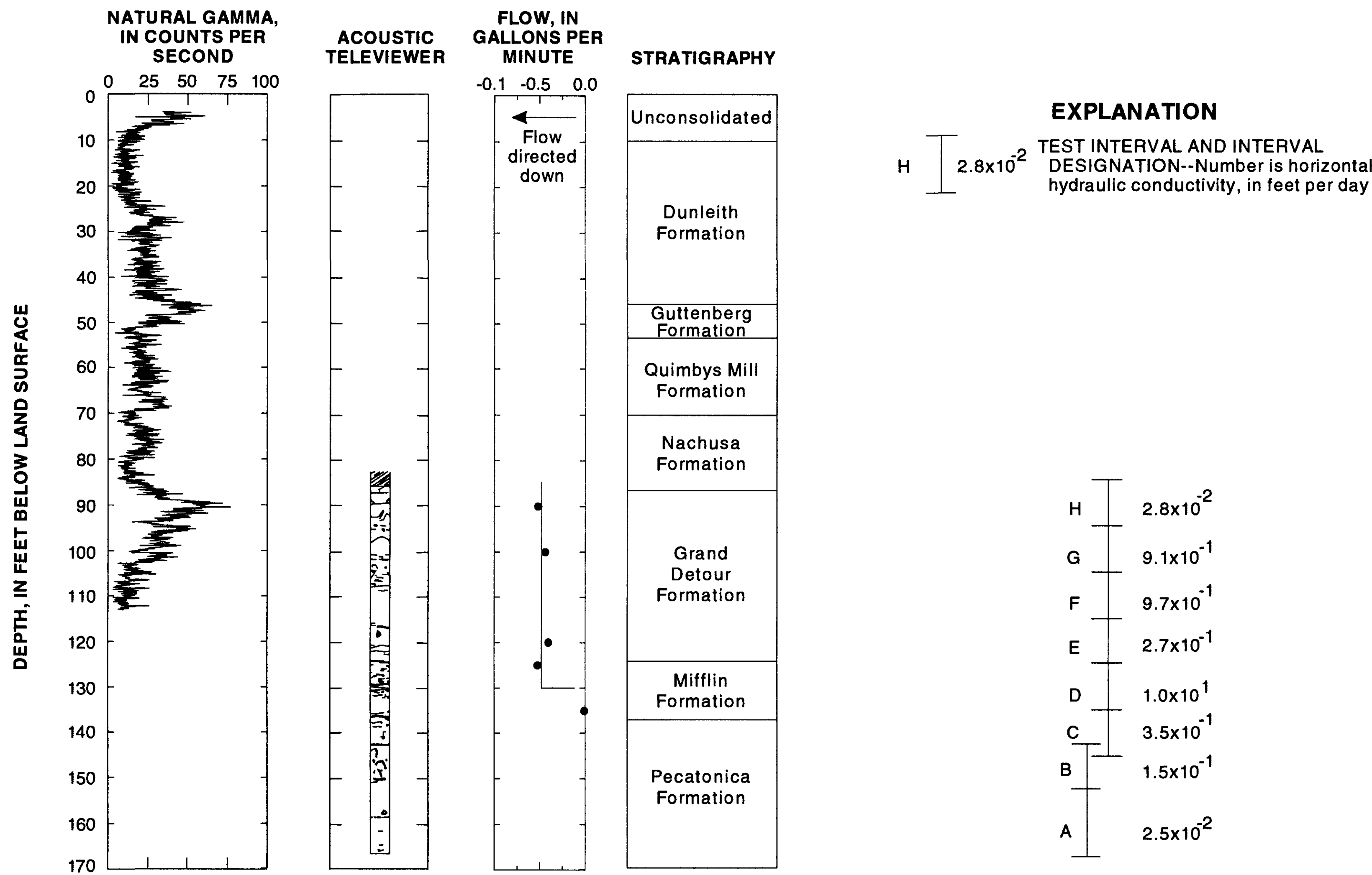


Figure 14. Natural-gamma, acoustic-televiewer, and flowmeter logs; stratigraphy; and horizontal hydraulic conductivities in the test intervals isolated with a packer assembly for borehole PZ1, Byron Superfund site.

EXPLANATION

—— 750 —— TOPOGRAPHIC CONTOUR--Shows elevation of land surface, in feet. Contour interval 25 feet. Datum is sea level

A · · · – A′ LINE OF GEOLOGIC SECTION--Sections shown on figures 16, 17, and 28

B ············ B′

C ———— C′

• MS1,2 MONITORING WELL LOCATION AND NAME

0 2,000 FEET

0 500 METERS

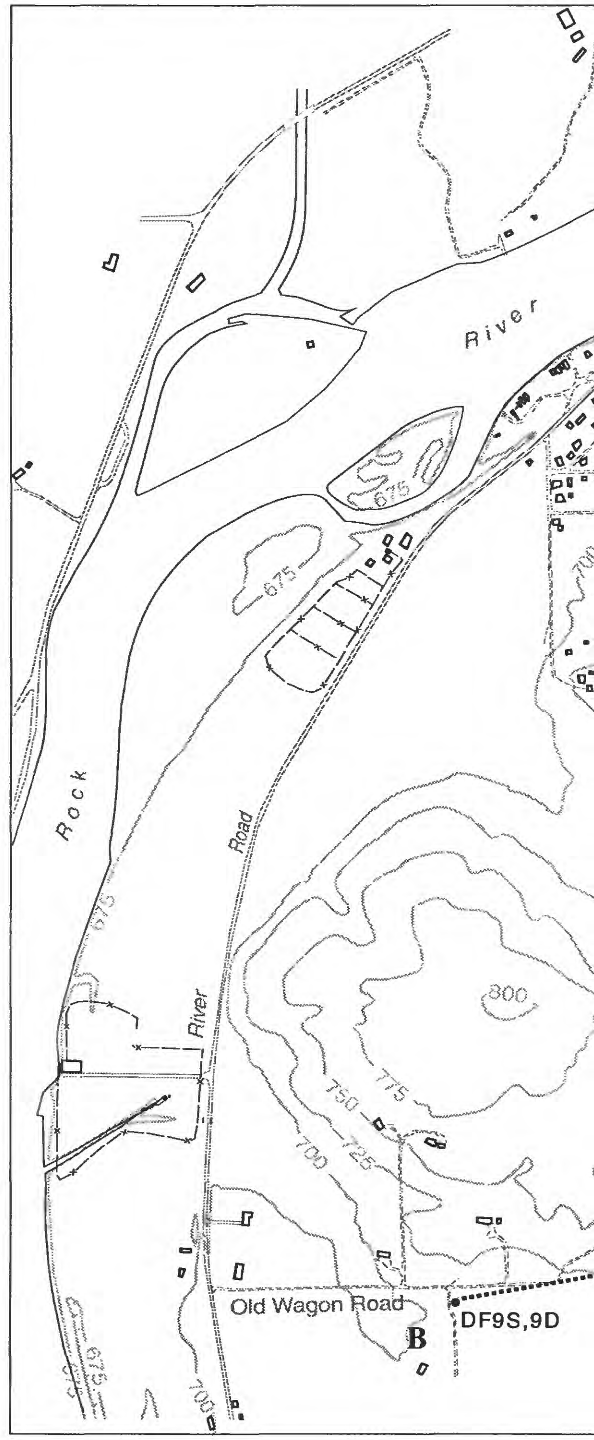


Figure 15. Lines of geologic section, Byron Superfund site.

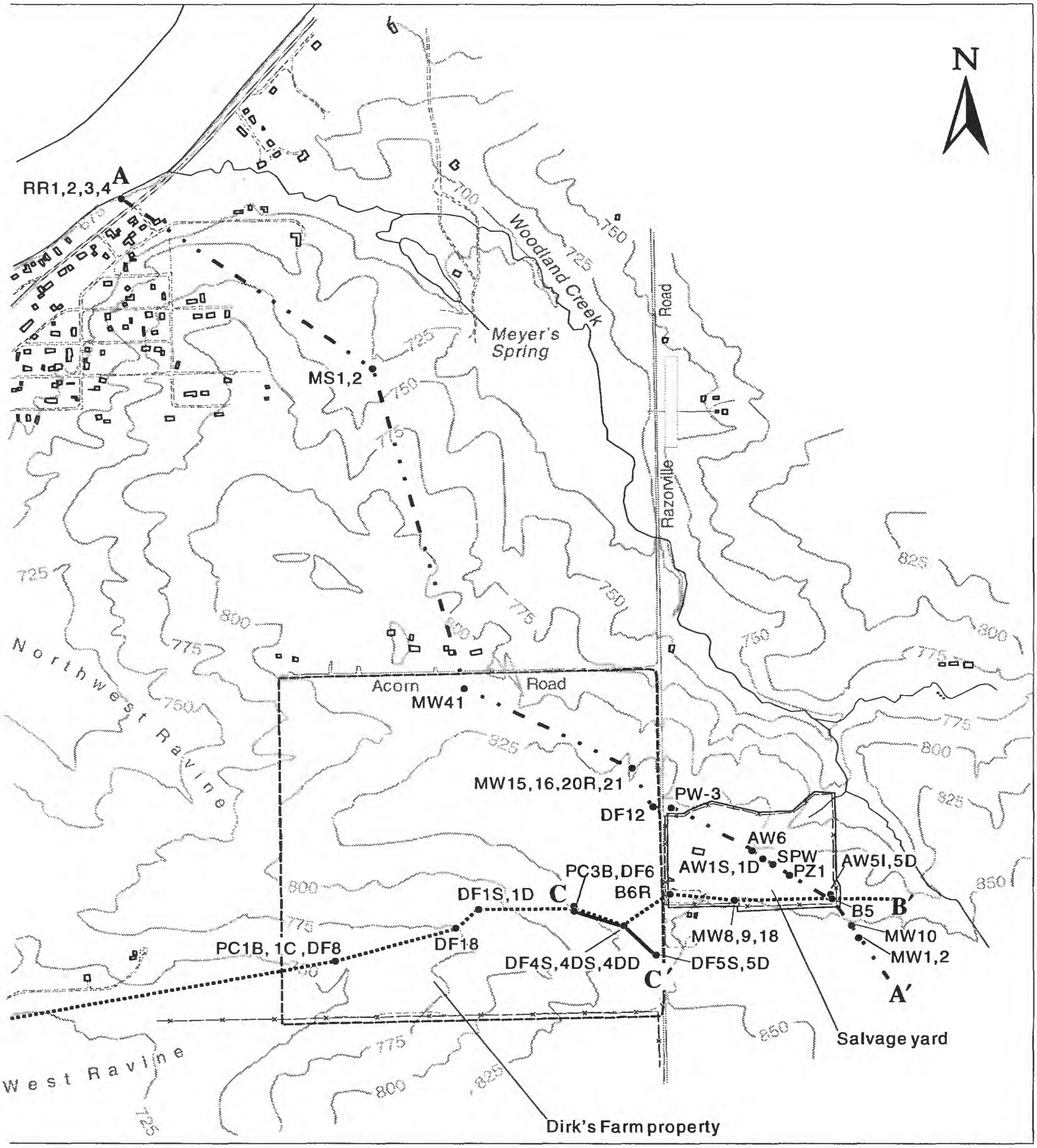


Figure 15. Continued.

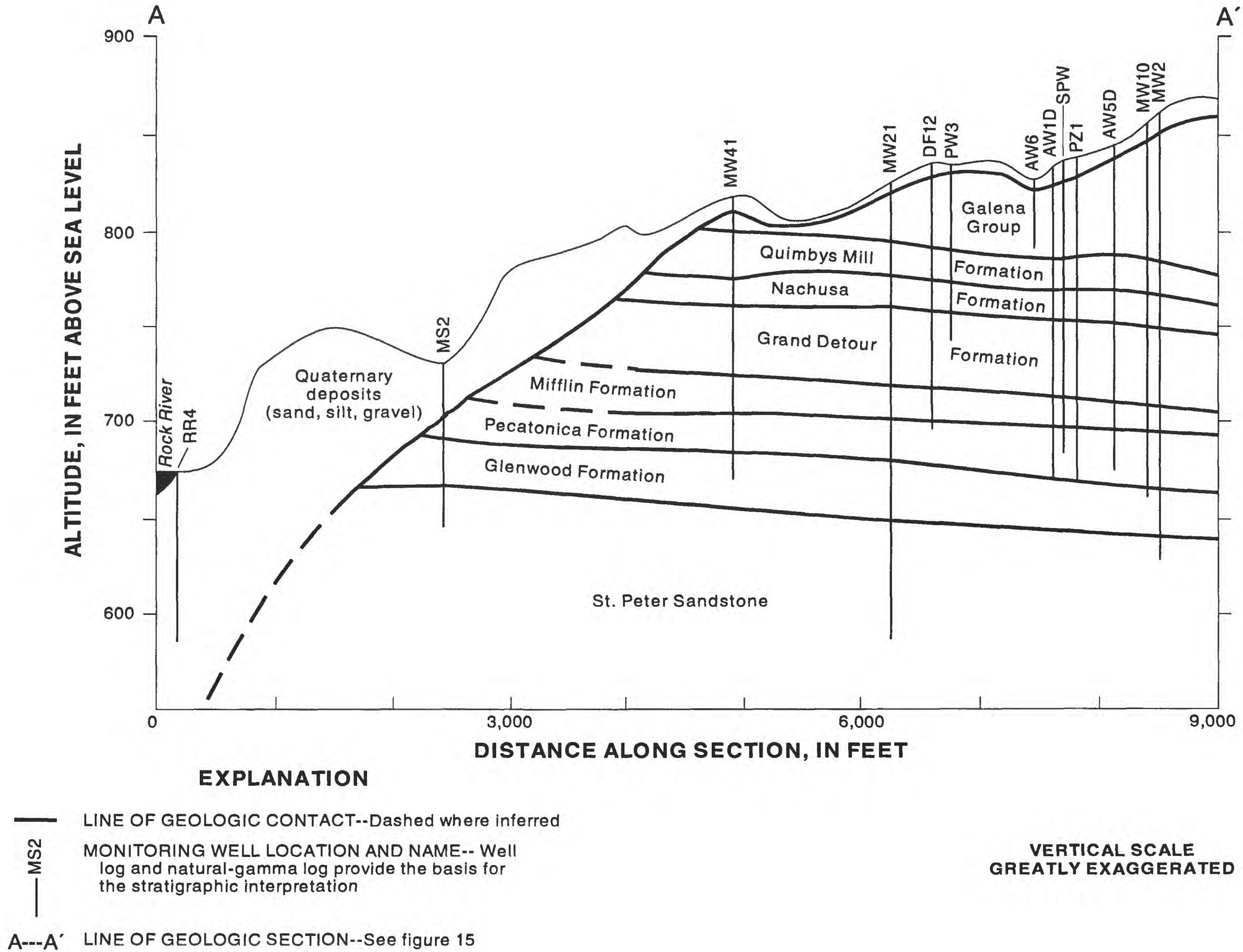
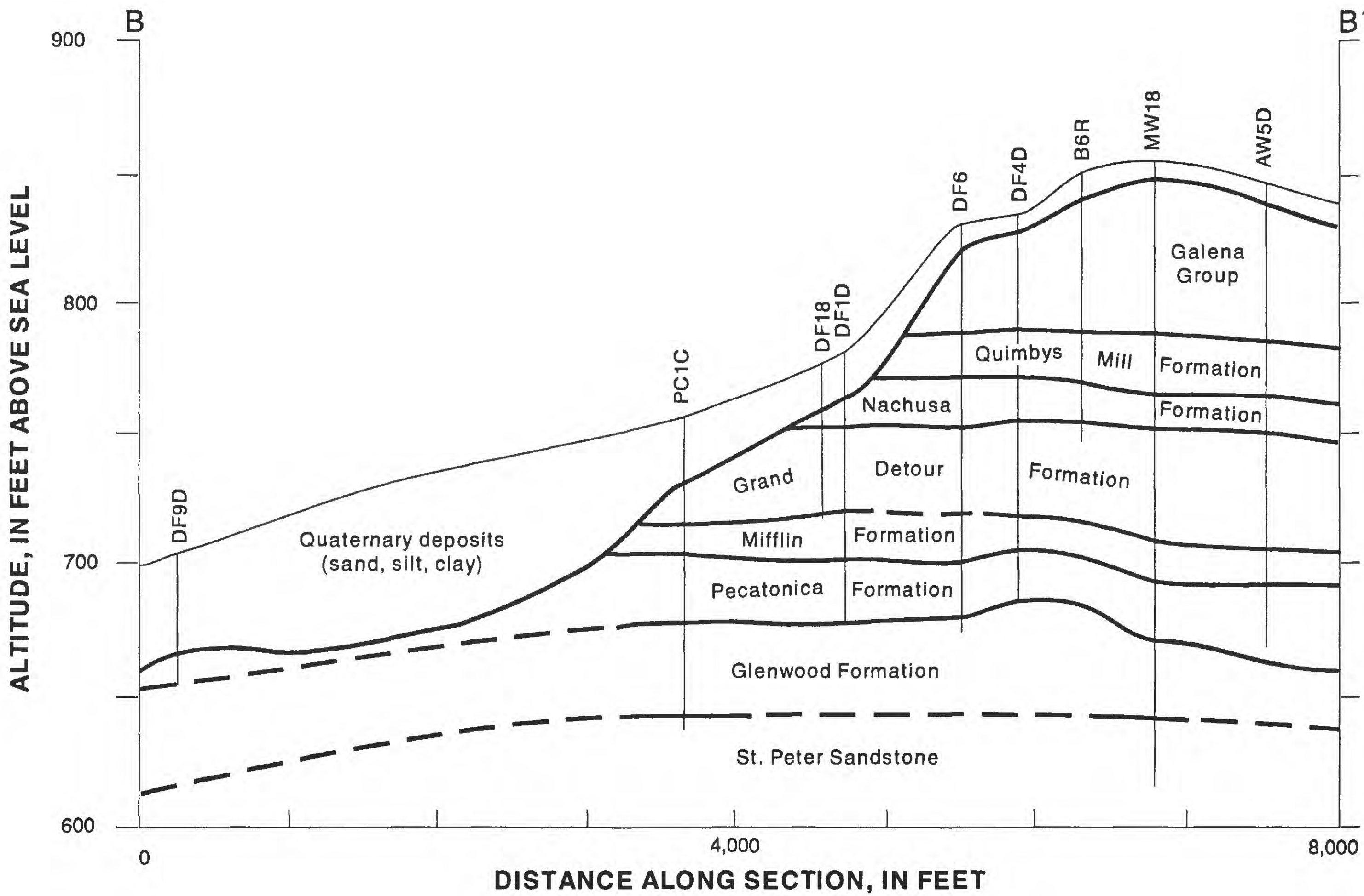


Figure 16. Geologic section A—A', Byron Superfund site.



EXPLANATION

— LINE OF GEOLOGIC CONTACT-- Dashed where inferred

—DF6 MONITORING WELL LOCATION AND NAME--Well log and natural-gamma log provide the basis for the stratigraphic interpretation

B---B′ LINE OF GEOLOGIC SECTION--See figure 15

VERTICAL SCALE GREATLY EXAGGERATED

Figure 17. Geologic section B—B', Byron Superfund site.

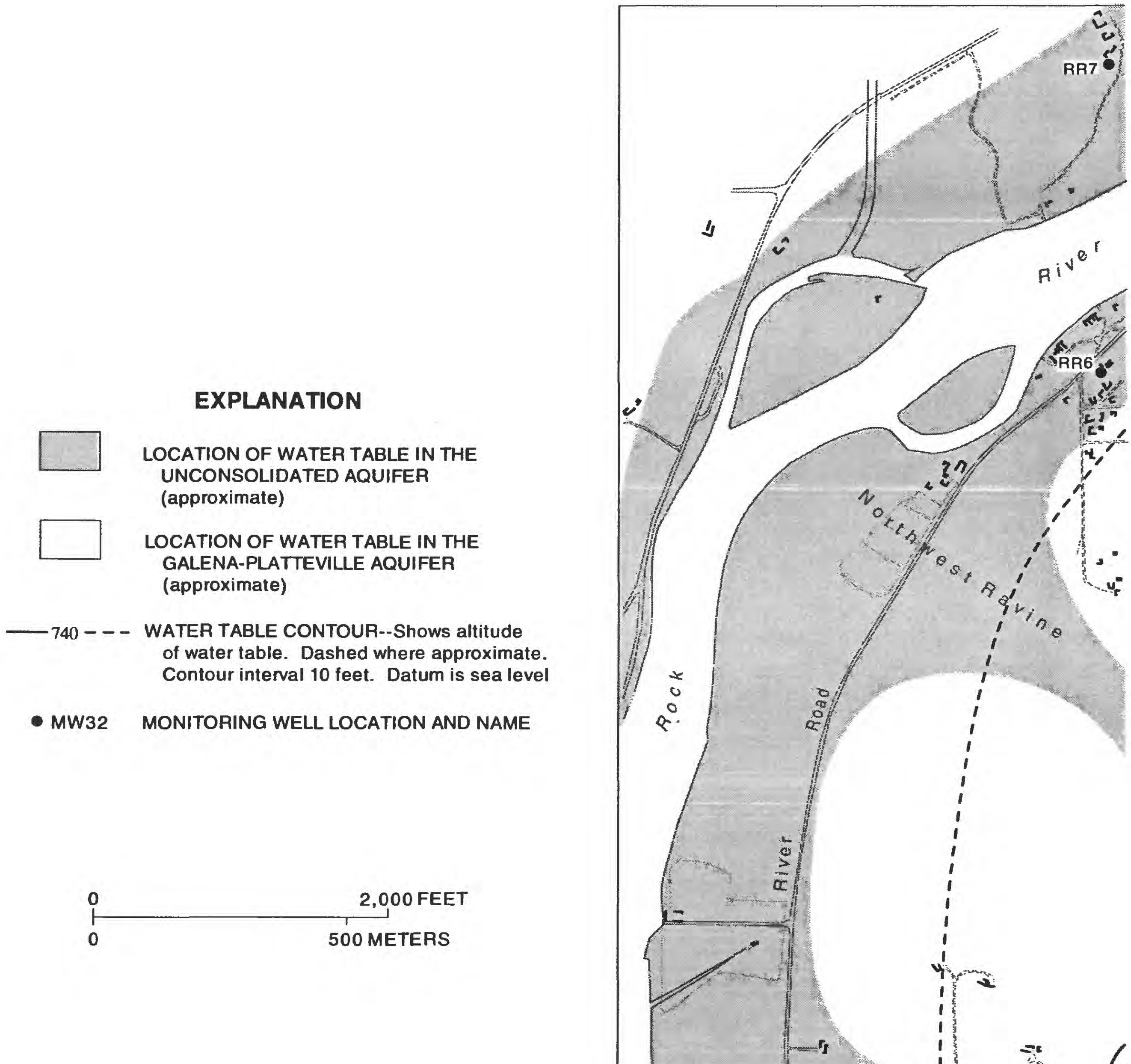


Figure 18. Water-table altitude, Byron Superfund site, January 27, 1992 (modified from U.S. Environmental Protection Agency, 1994, appendix L).

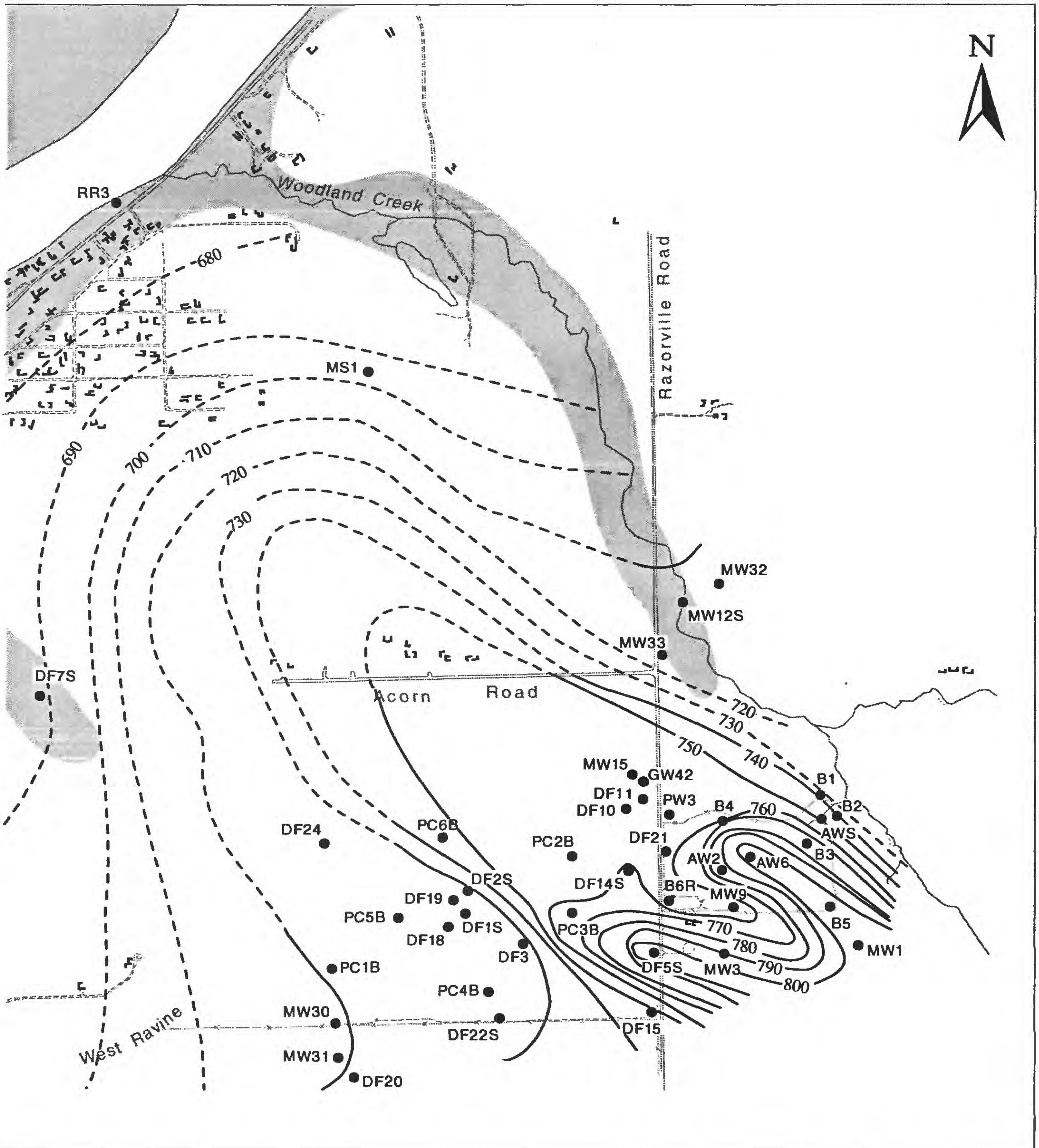


Figure 18. Continued.

EXPLANATION

—750 - - - WATER-LEVEL CONTOUR--Shows altitude at which water level would have stood in tightly cased wells. Dashed where approximate. Contour interval 10 feet. Datum is sea level

• DF9D MONITORING WELL LOCATION AND NAME

0 — 2,000 FEET

0 — 500 METERS

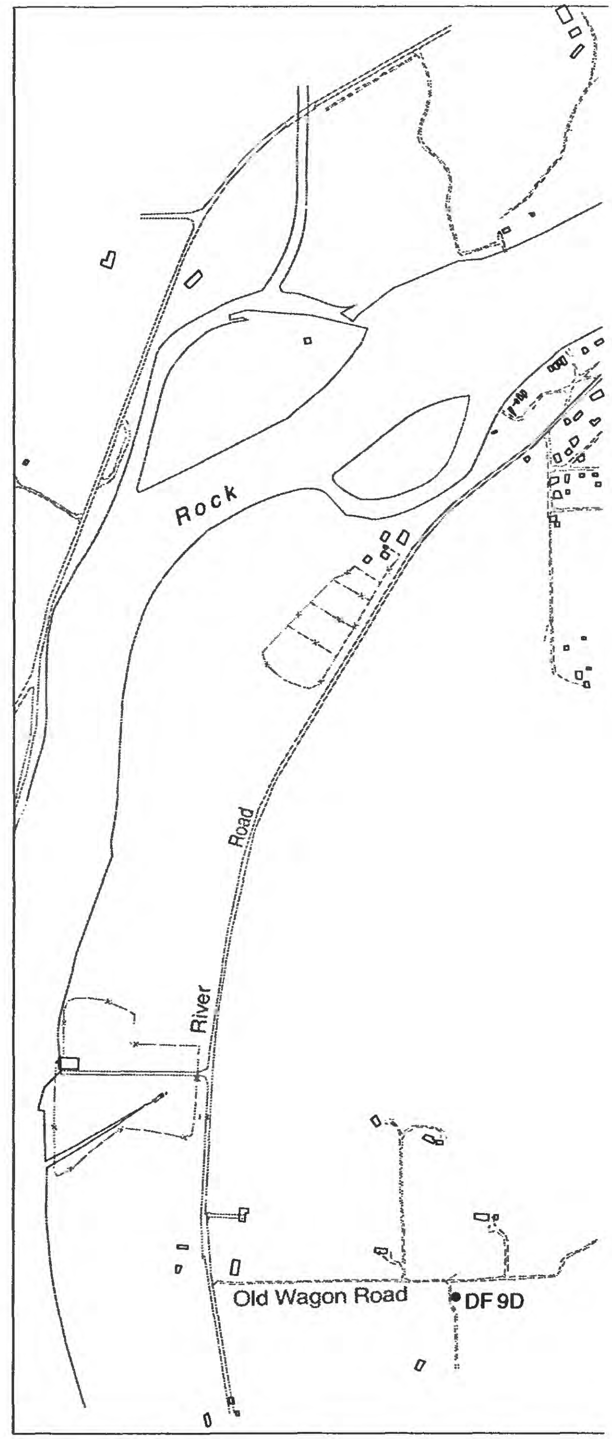


Figure 19. Water-level altitude in wells open to the base of the Galena-Platteville aquifer, Byron Superfund site, January 27, 1992 (modified from U.S. Environmental Protection Agency, 1994, appendix L).

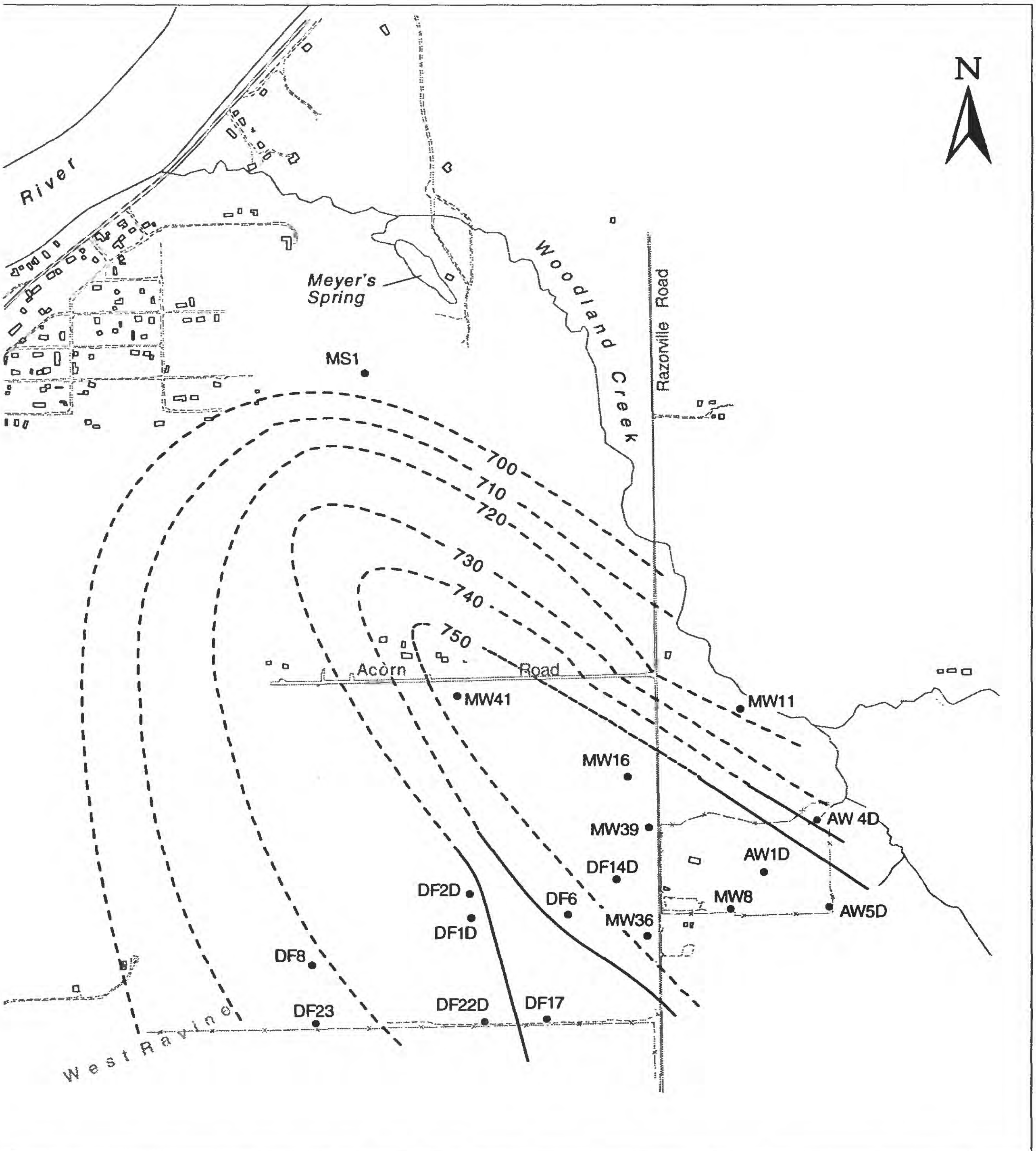
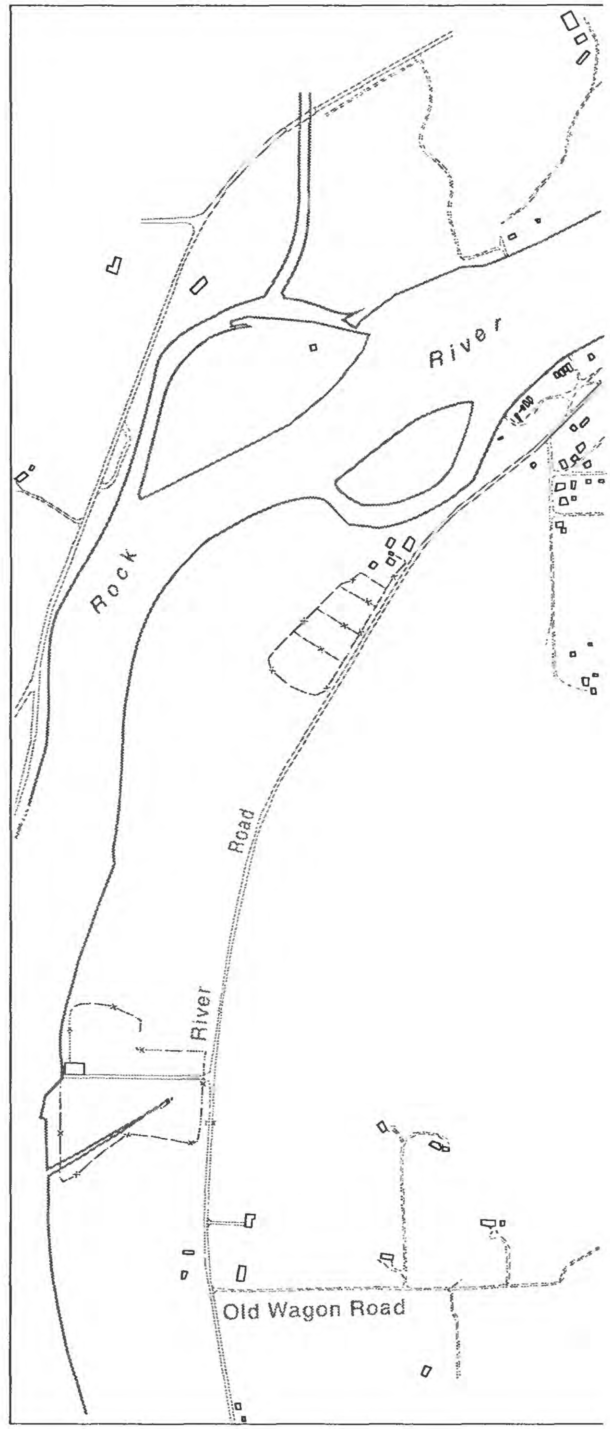


Figure 19. Continued.



EXPLANATION

——683 – – – WATER-LEVEL CONTOUR--Shows altitude at which water level would have stood in tightly cased wells Dashed where approximate. Contour interval 1 foot. Datum is sea level

● MS2 MONITORING WELL LOCATION AND NAME

0 2,000 FEET
0 500 METERS

Figure 20. Water-level altitude in wells open to the top of the St. Peter aquifer, Byron Superfund site, January 27, 1992 (from U.S. Environmental Protection Agency, 1994, appendix L).

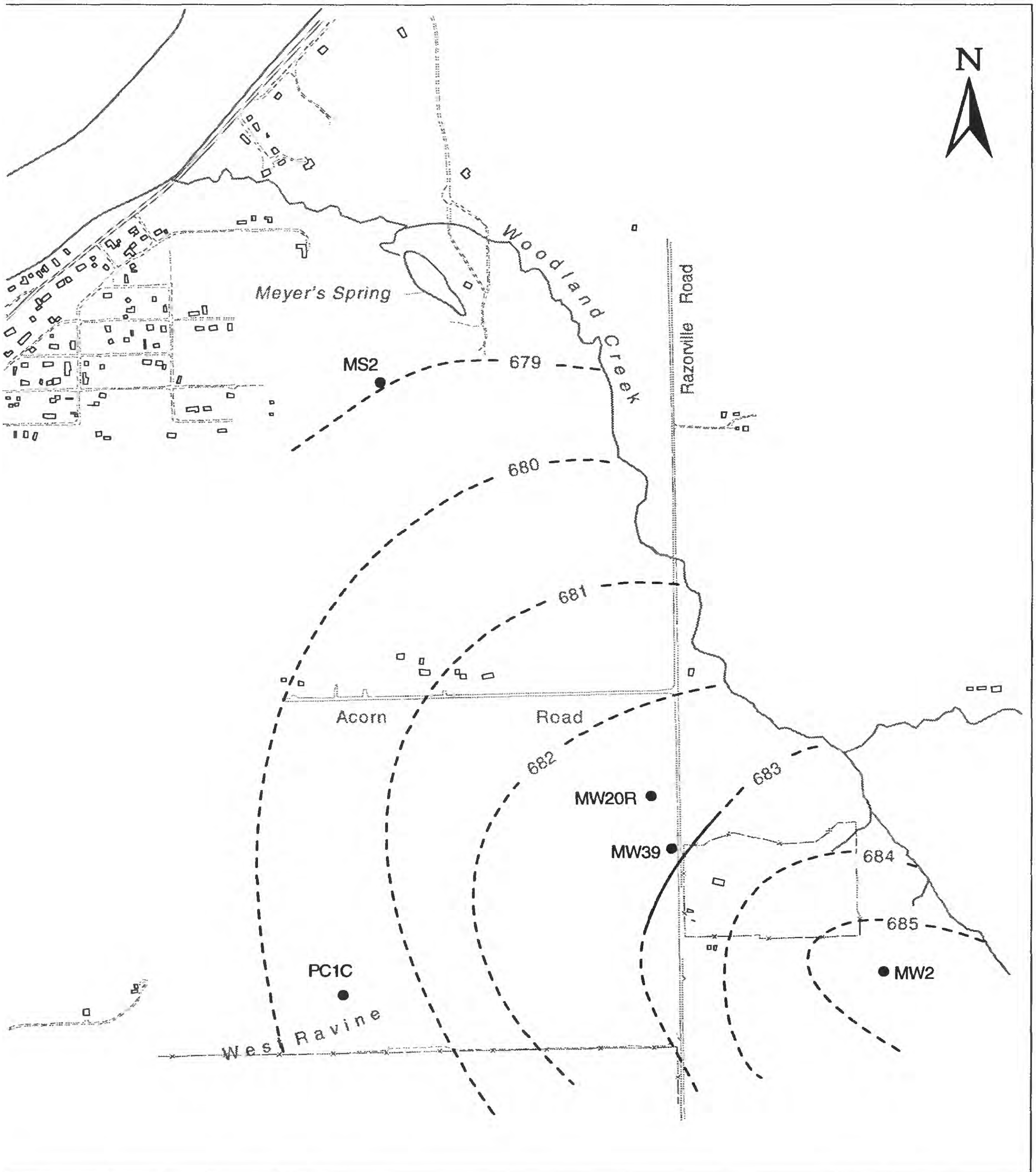


Figure 20. Continued.

EXPLANATION

GALENA-PLATTEVILLE AQUIFER ZONES (Not defined in unpatterned areas)

- Zone 1
- Zone 2
- Zone 3
- Zone 4
- Transitional area between zones

740 — — WATER-TABLE CONTOUR--Shows altitude of water table. Dashed where approximate. Contour interval 10 feet. Datum is sea level

● MONITORING WELL LOCATION

0 — 2,000 FEET

0 — 500 METERS

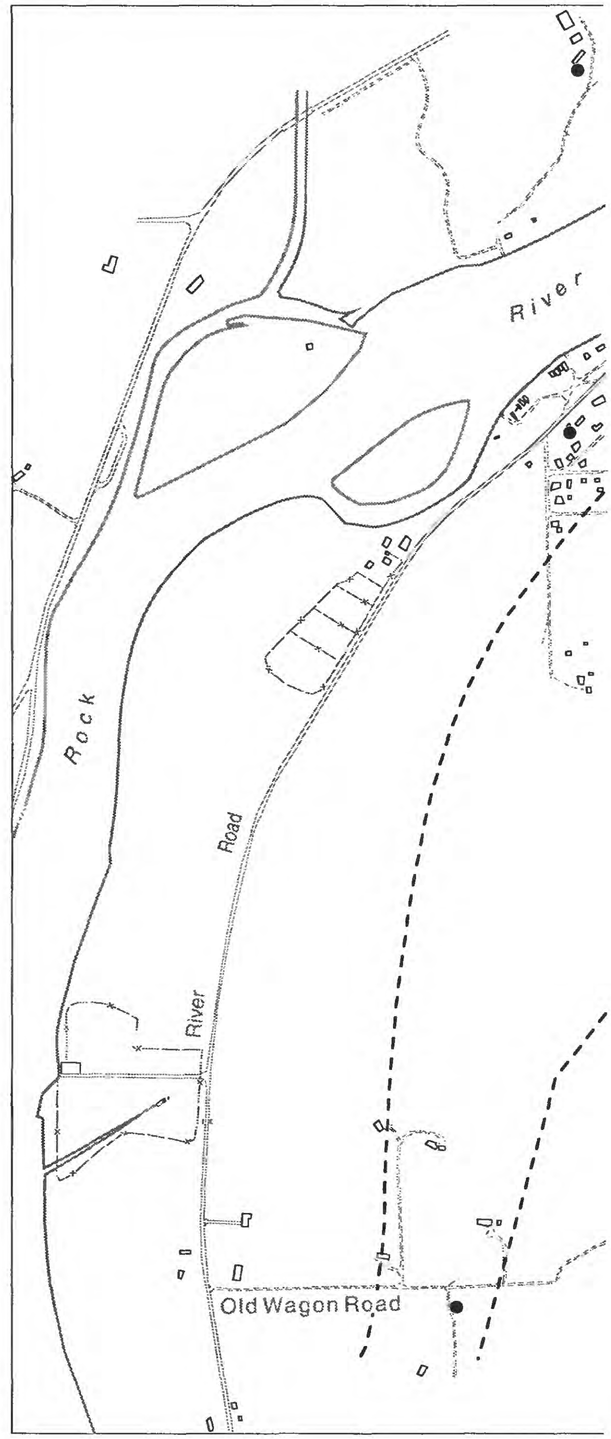


Figure 21. Zones in the Galena-Platteville aquifer, Byron Superfund site, January 27, 1992.

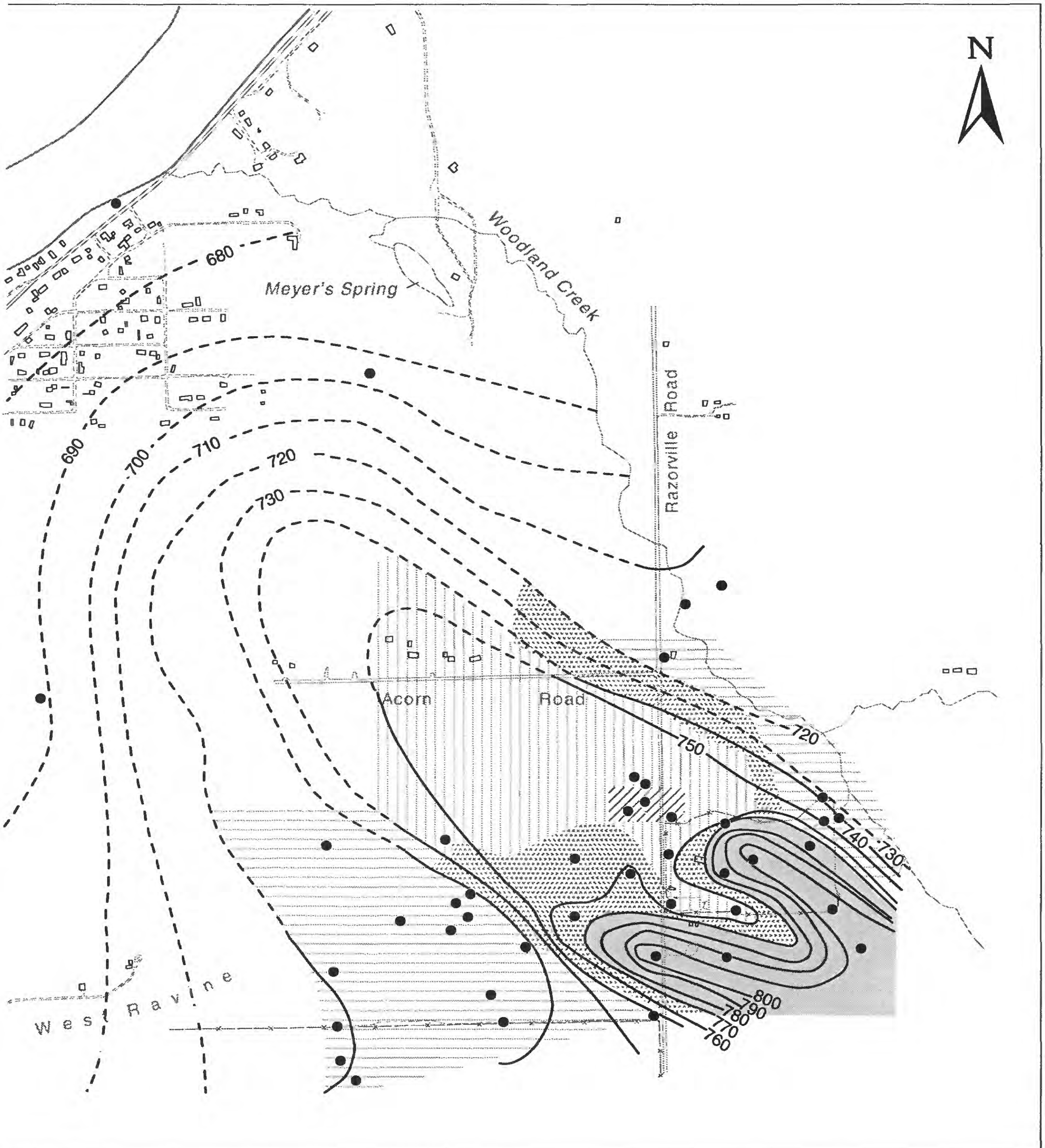
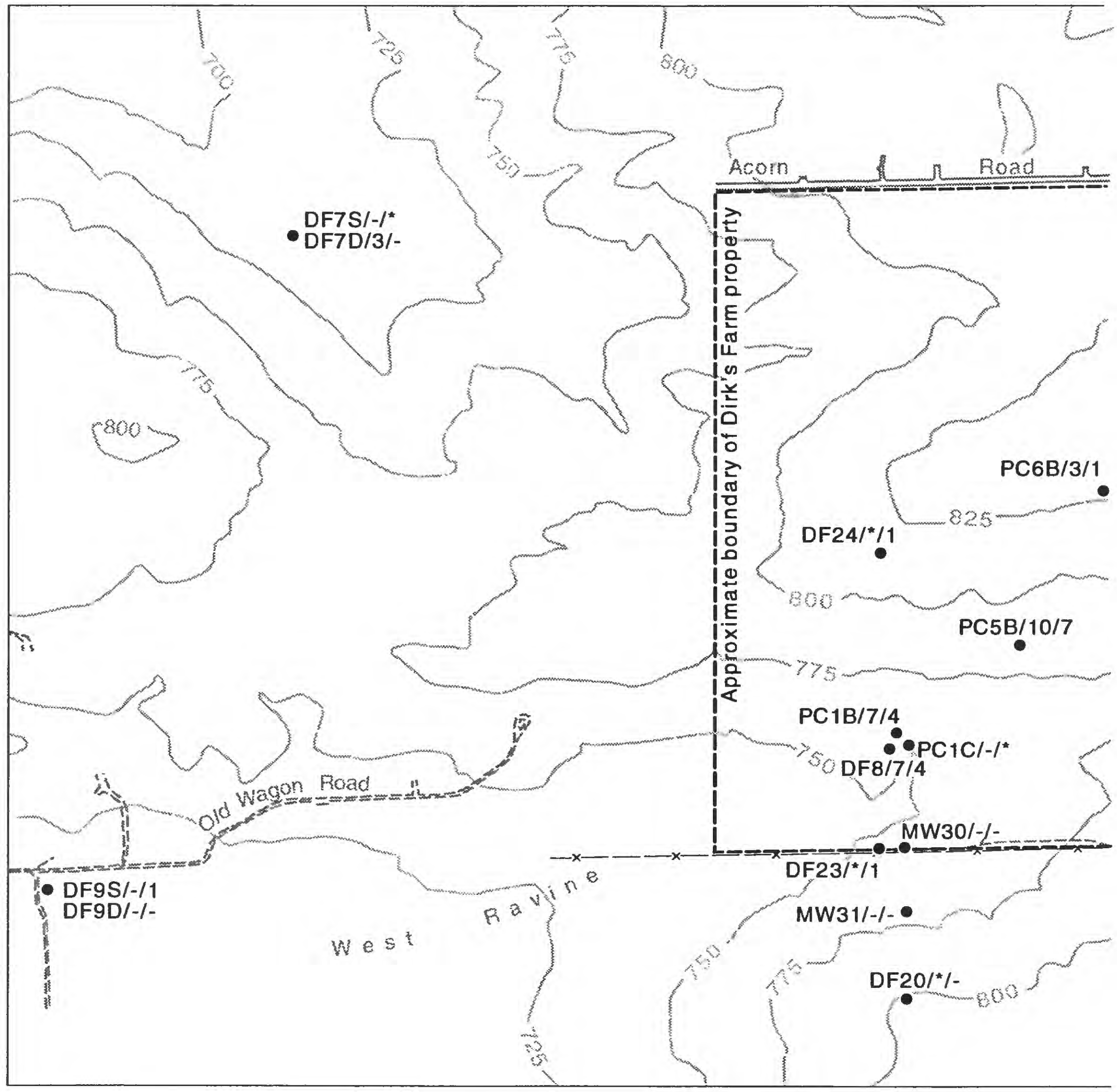


Figure 21. Continued.



EXPLANATION

—800—	TOPOGRAPHIC CONTOUR-- Shows elevation of land surface, in feet. Contour interval 25 feet. Datum is sea level
B3/420/320 ●	MONITORING WELL LOCATION AND NAME--First number is concentration of trichloroethene detected during the first sampling period (May 1991). Second number is maximum concentration of trichloroethene detected during the second sampling period (from November 1991 to April 1992). - indicates trichloroethene not detected. * indicates no sample taken. Concentrations are in micrograms per liter

Figure 29. Concentration of trichloroethene (TCE) in ground water, Byron Superfund site, May 1991 and November 1991–April 1992.

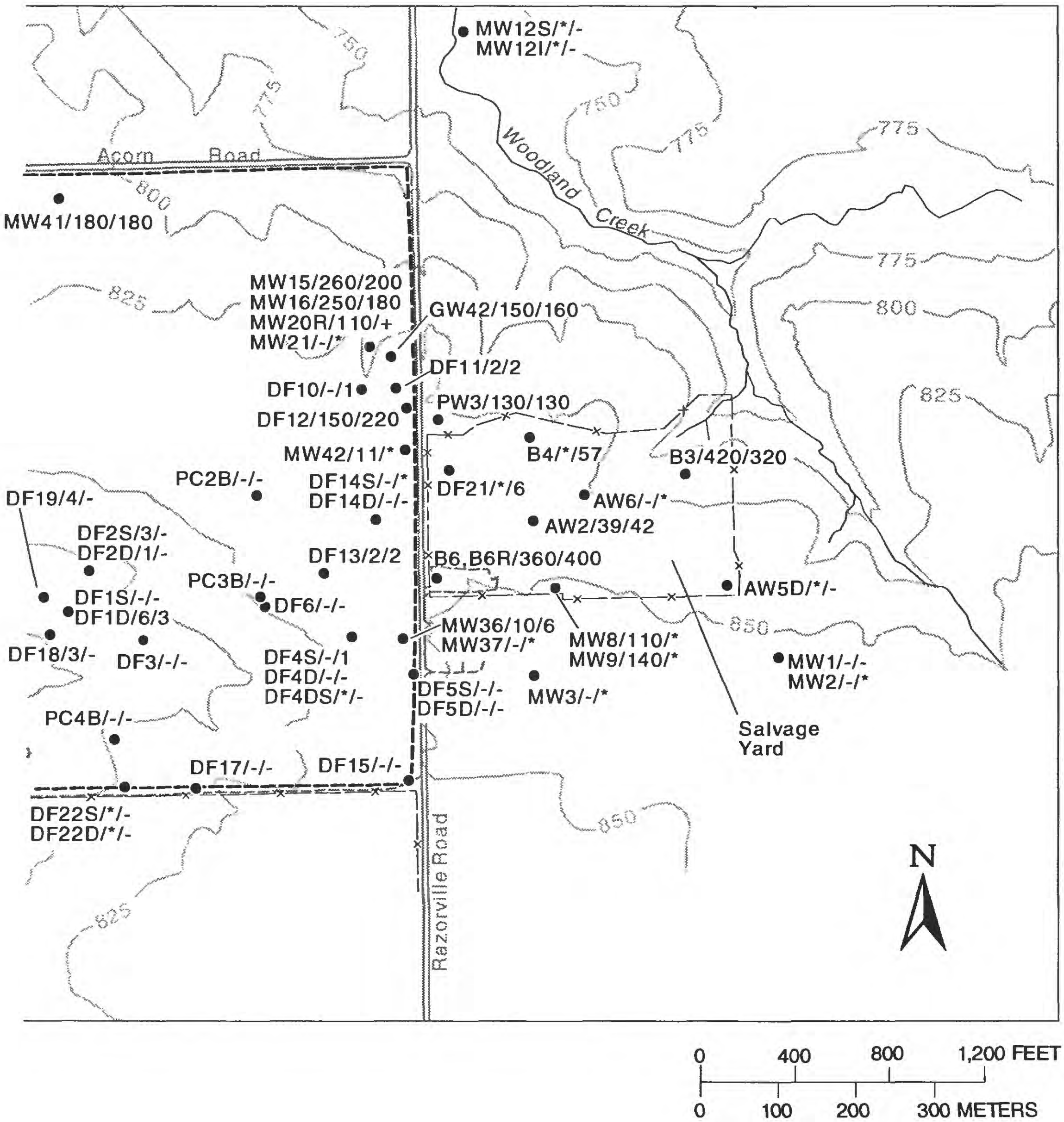
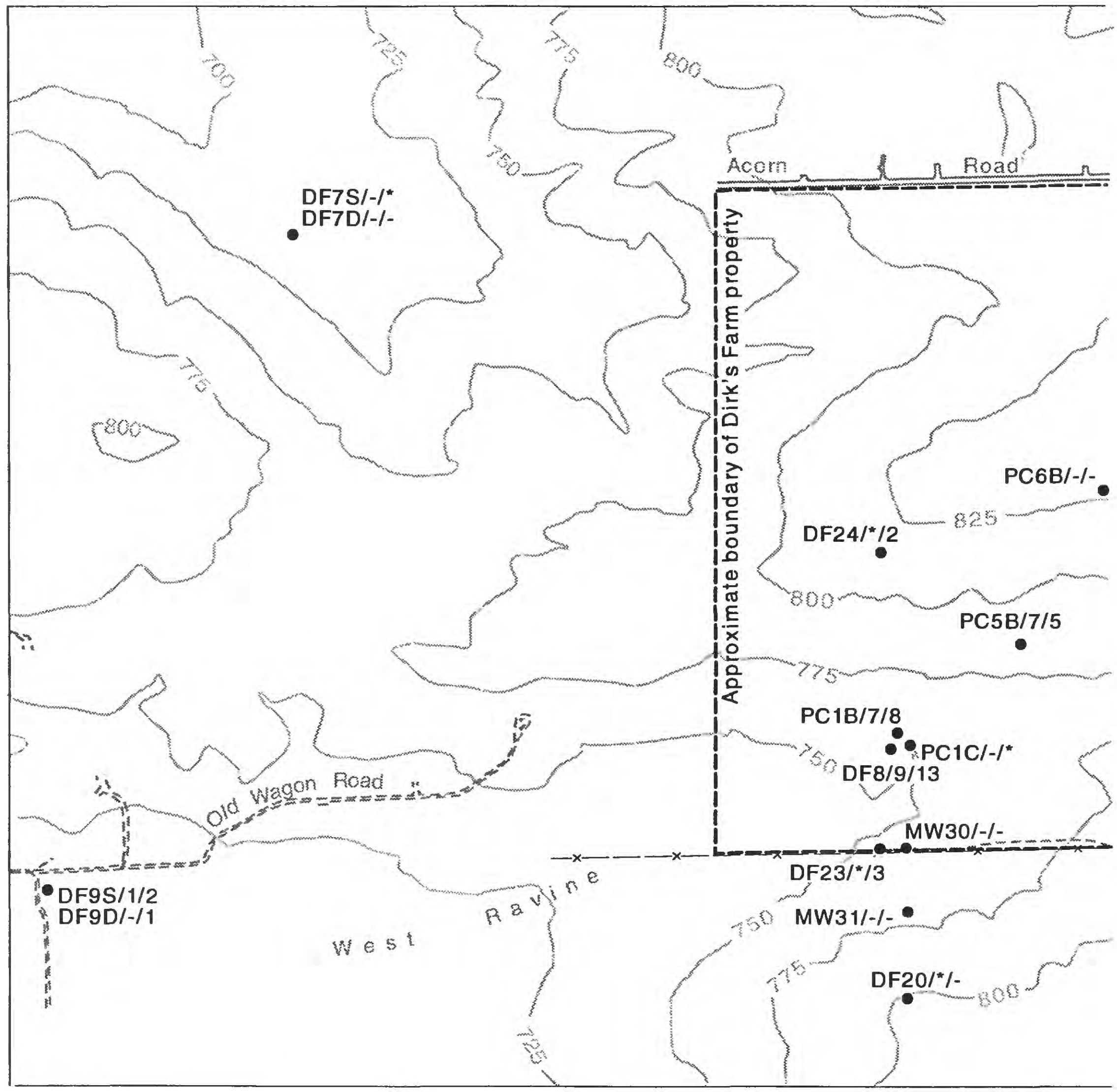


Figure 29. Continued.



EXPLANATION

—800—	TOPOGRAPHIC CONTOUR-- Shows elevation of land surface, in feet. Contour interval 25 feet. Datum is sea level
●DF8/9/13	MONITORING WELL LOCATION AND NAME--First number is concentration of trichloroethane detected during the first sampling period (May 1991). Second number is concentration of trichloroethane detected during the second sampling period (from November 1991 to April 1992). - indicates trichloroethane not detected. * indicates no sample taken. Concentrations are in micrograms per liter

Figure 30. Concentration of trichloroethane (TCA) in ground water, Byron Superfund site, May 1991 and November 1991–April 1992.

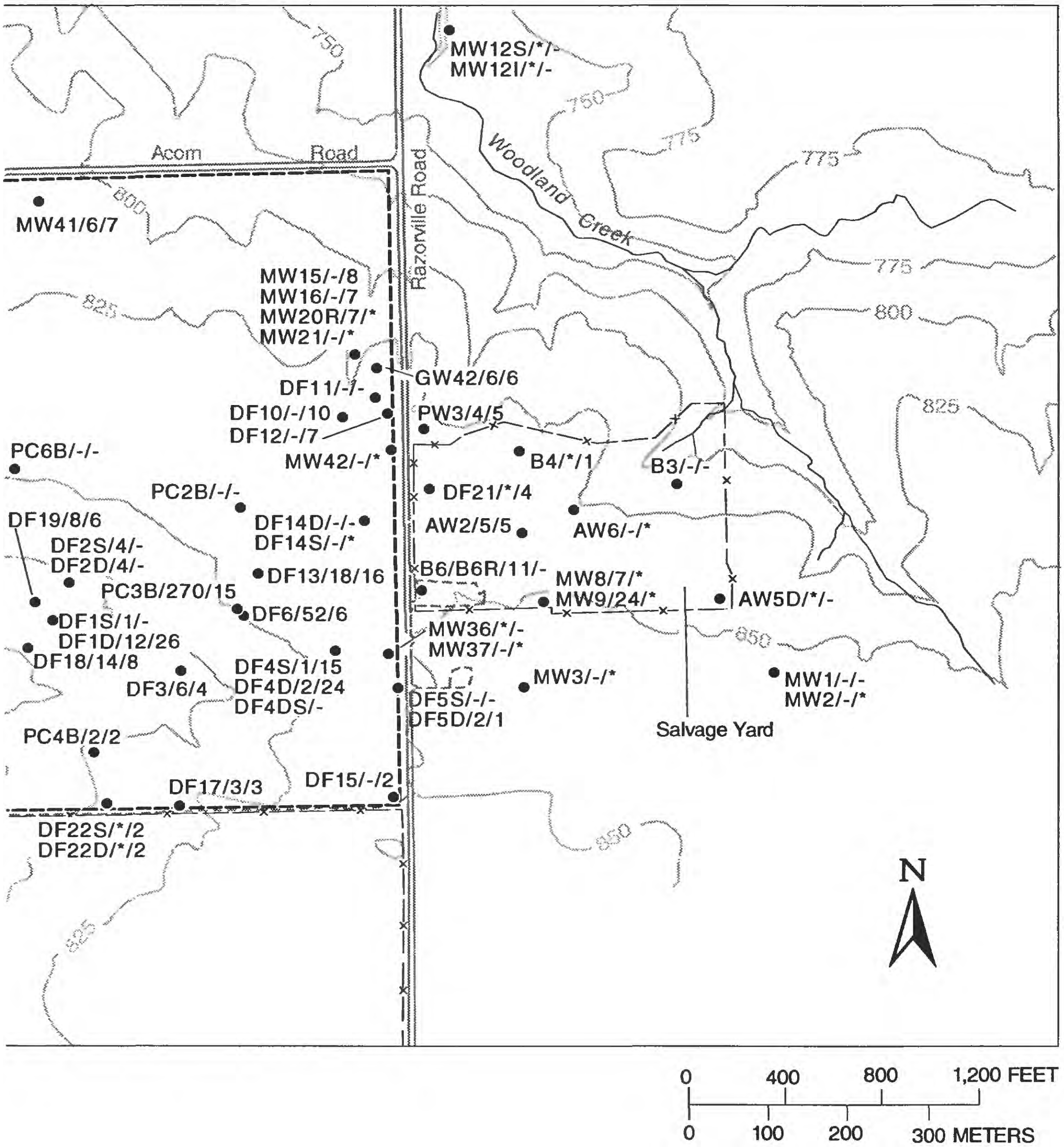
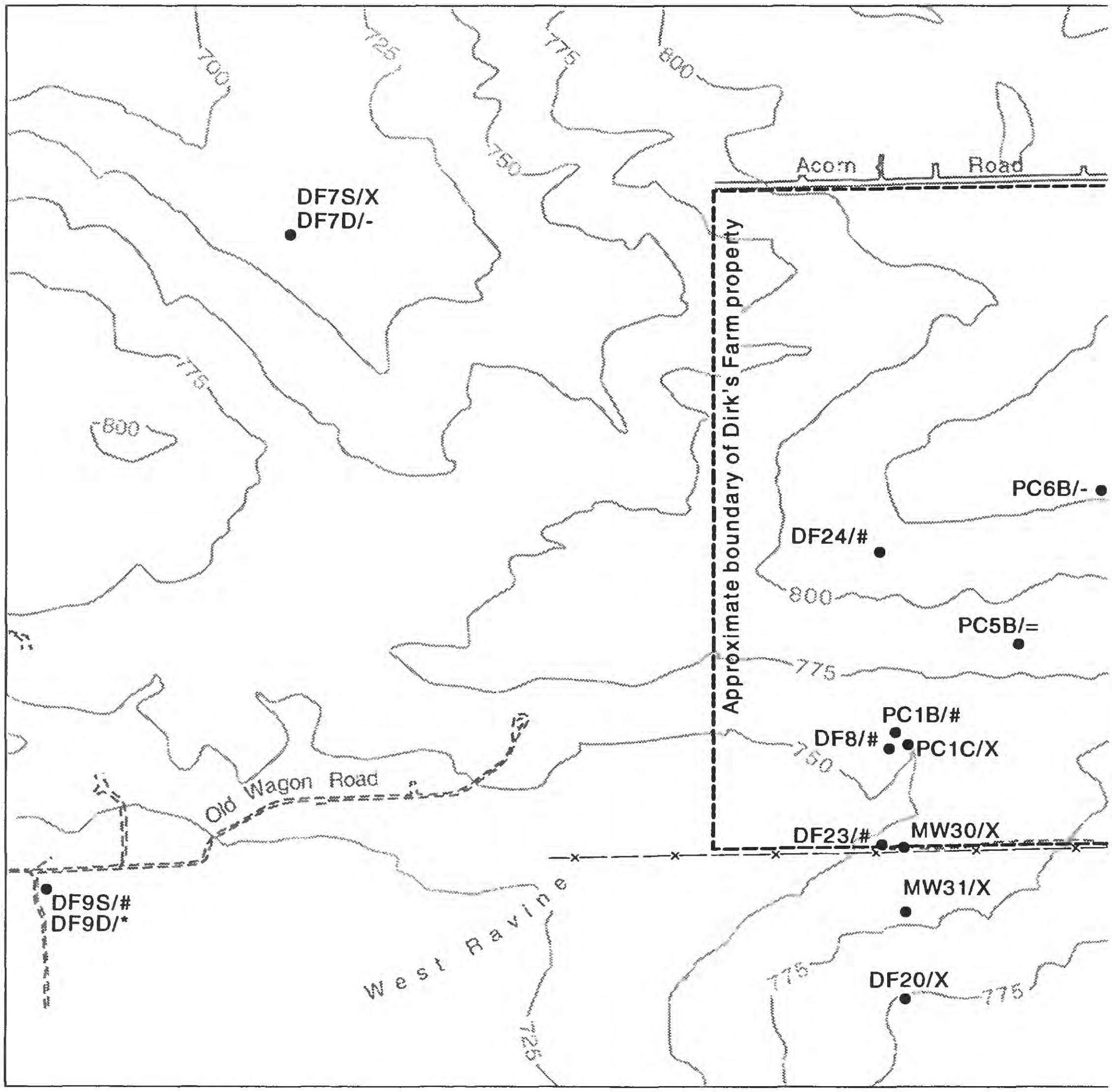


Figure 30. Continued.



EXPLANATION

800 — TOPOGRAPHIC CONTOUR-- Shows elevation of land surface, in feet. Contour interval 25 feet. Datum is sea level

● DF8/= — MONITORING WELL LOCATION AND NAME--Symbol denotes ratio of average concentration of trichloroethene to trichloroethane detected during the first (May 1991) and second (from November 1991 to April 1992) sampling periods. X indicates trichloroethene and trichloroethane not detected. - indicates trichloroethane not detected. * indicates trichloroethene not detected. # indicates trichloroethene to trichloroethane ratio less than 1. = indicates trichloroethene to trichloroethane ratio from 1 to 10. + indicates trichloroethene to trichloroethane ratio greater than 10

Figure 31. Ratio of the average trichloroethene (TCE) to trichloroethane (TCA) concentrations in ground water, Byron Superfund site, May 1991 and November 1991–April 1992.

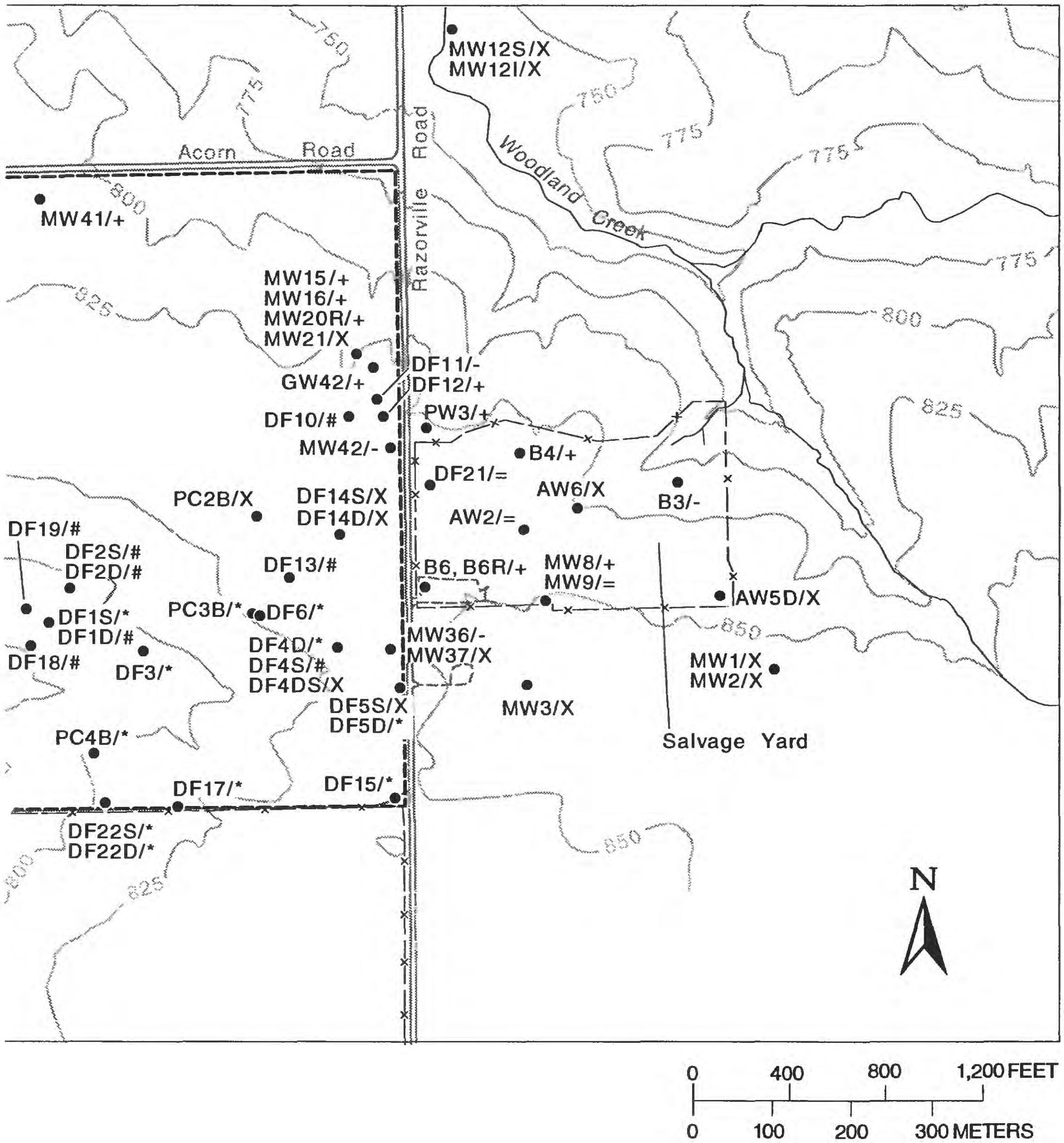
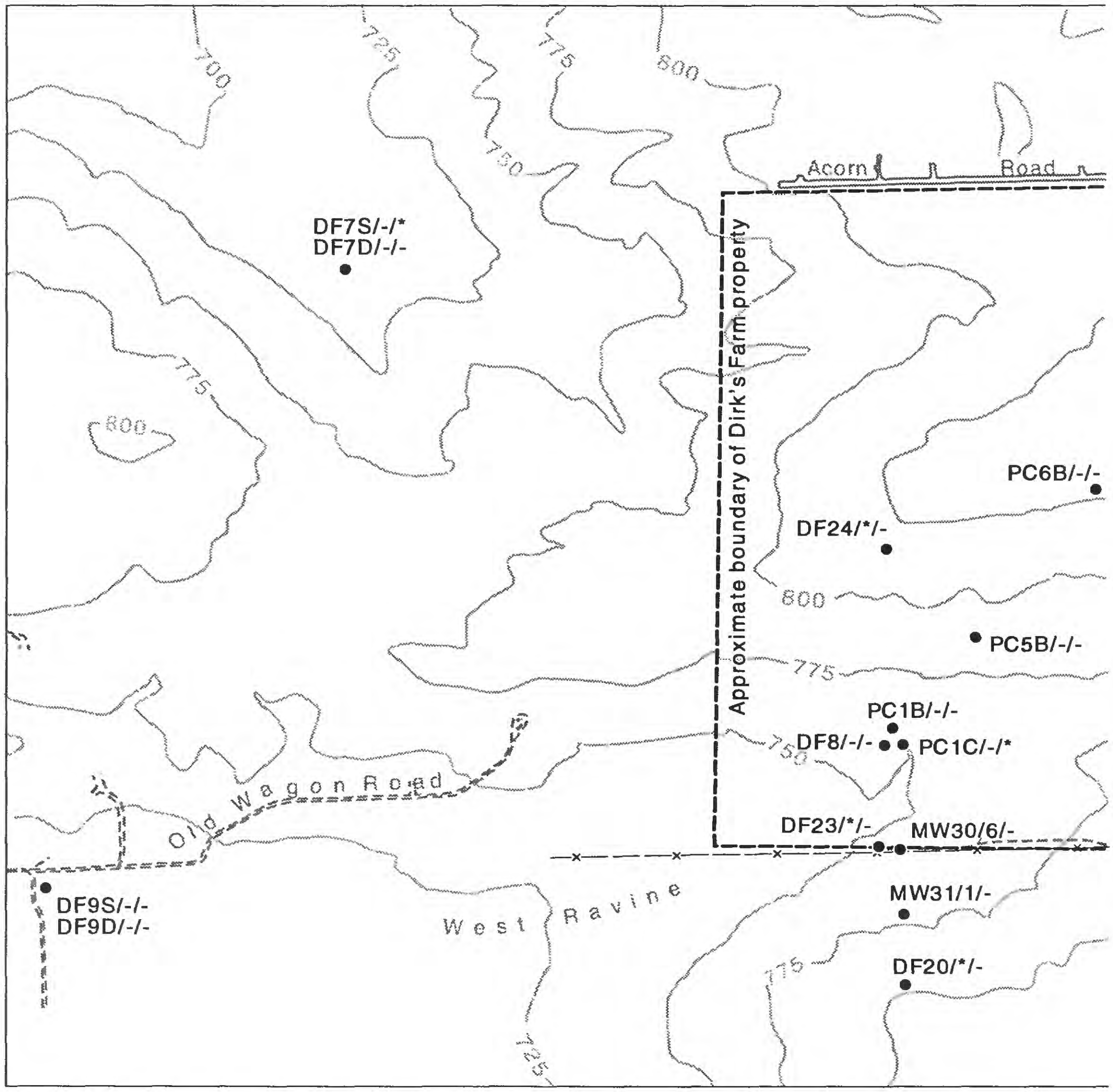


Figure 31. Continued.



EXPLANATION

800 TOPOGRAPHIC CONTOUR--Shows elevation of land surface, in feet. Contour interval 25 feet. Datum is sea level

DF6/781/7 MONITORING WELL LOCATION AND NAME--First number is concentration of benzene, ethylbenzene, toluene, and xylene detected during the first sampling period (May 1991). Second number is concentration of benzene, ethylbenzene, toluene, and xylene detected during the second sampling period (from November 1991 to April 1992). - indicates benzene, ethylbenzene, toluene, and xylene not detected. Detection limit is 10 micrograms per liter. * indicates no sample taken. Concentrations are in micrograms per liter

Figure 32. Total concentration of benzene, ethylbenzene, toluene, and xylene in ground water, Byron Superfund site, May 1991 and November 1991–April 1992.

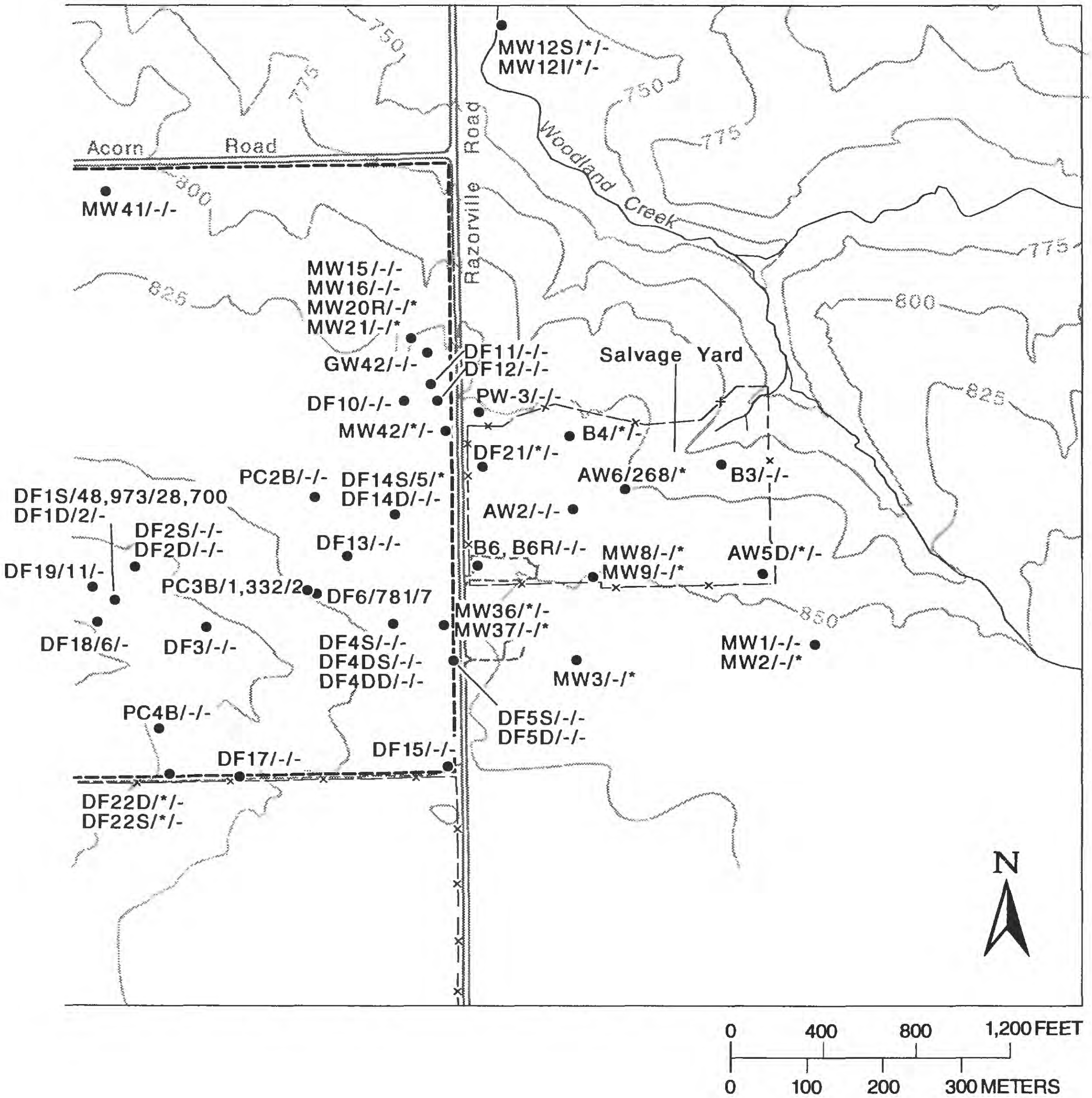
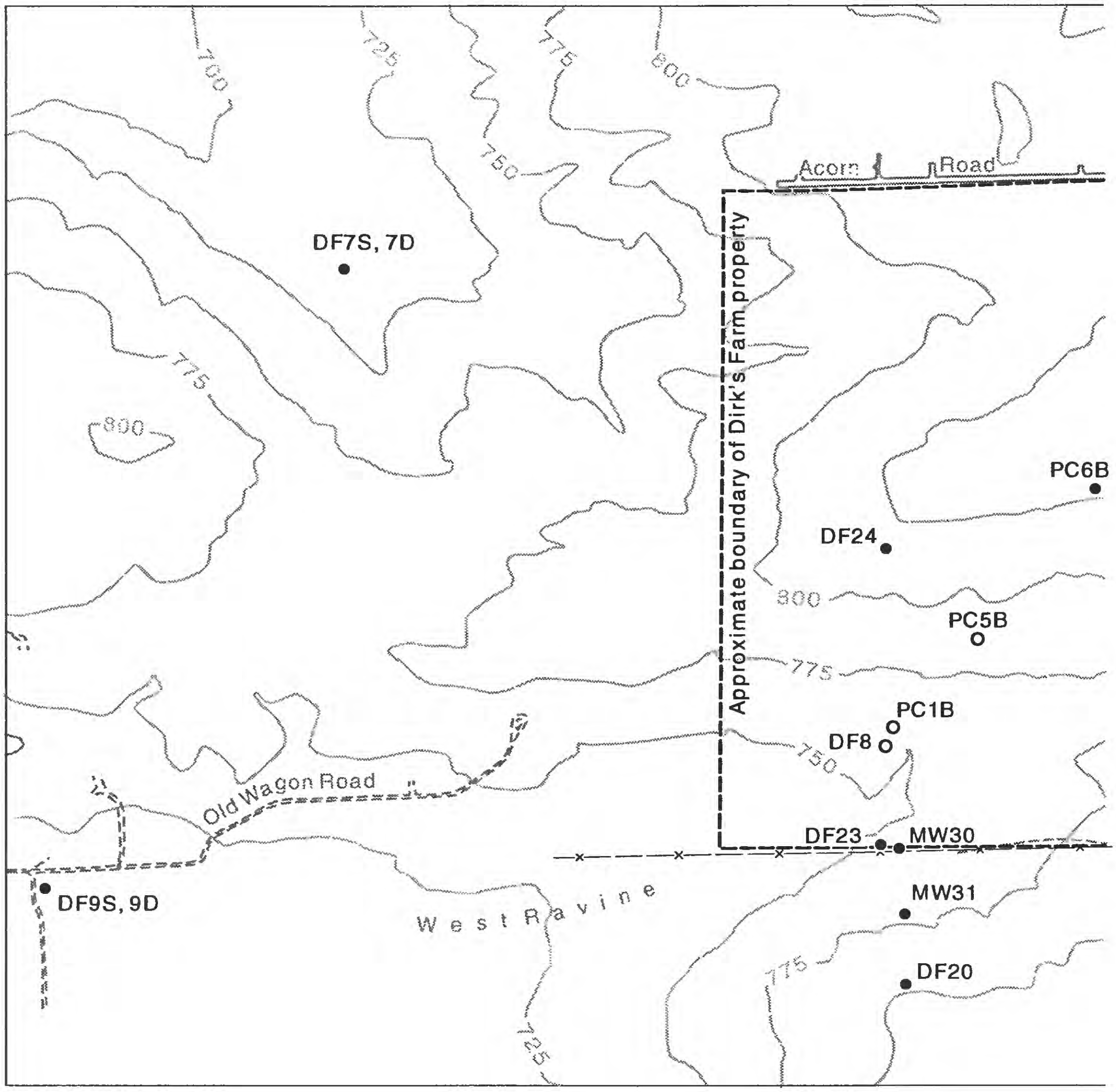


Figure 32. Continued.



EXPLANATION

800	TOPOGRAPHIC CONTOUR--Shows elevation of land surface, in feet. Contour interval 25 feet. Datum is sea level
B3	MONITORING WELL NAME
●	CYANIDE NOT DETECTED--Detection limit is 10 micrograms per liter
o	CYANIDE CONCENTRATION ABOVE DETECTION LIMIT OF 10 MICROGRAMS PER LITER, BUT BELOW 100 MICROGRAMS PER LITER
▲	CYANIDE CONCENTRATION ABOVE 100 MICROGRAMS PER LITER

Figure 33. Average concentration of cyanide in ground water, Byron Superfund site, May 1991 and November 1991–April 1992.

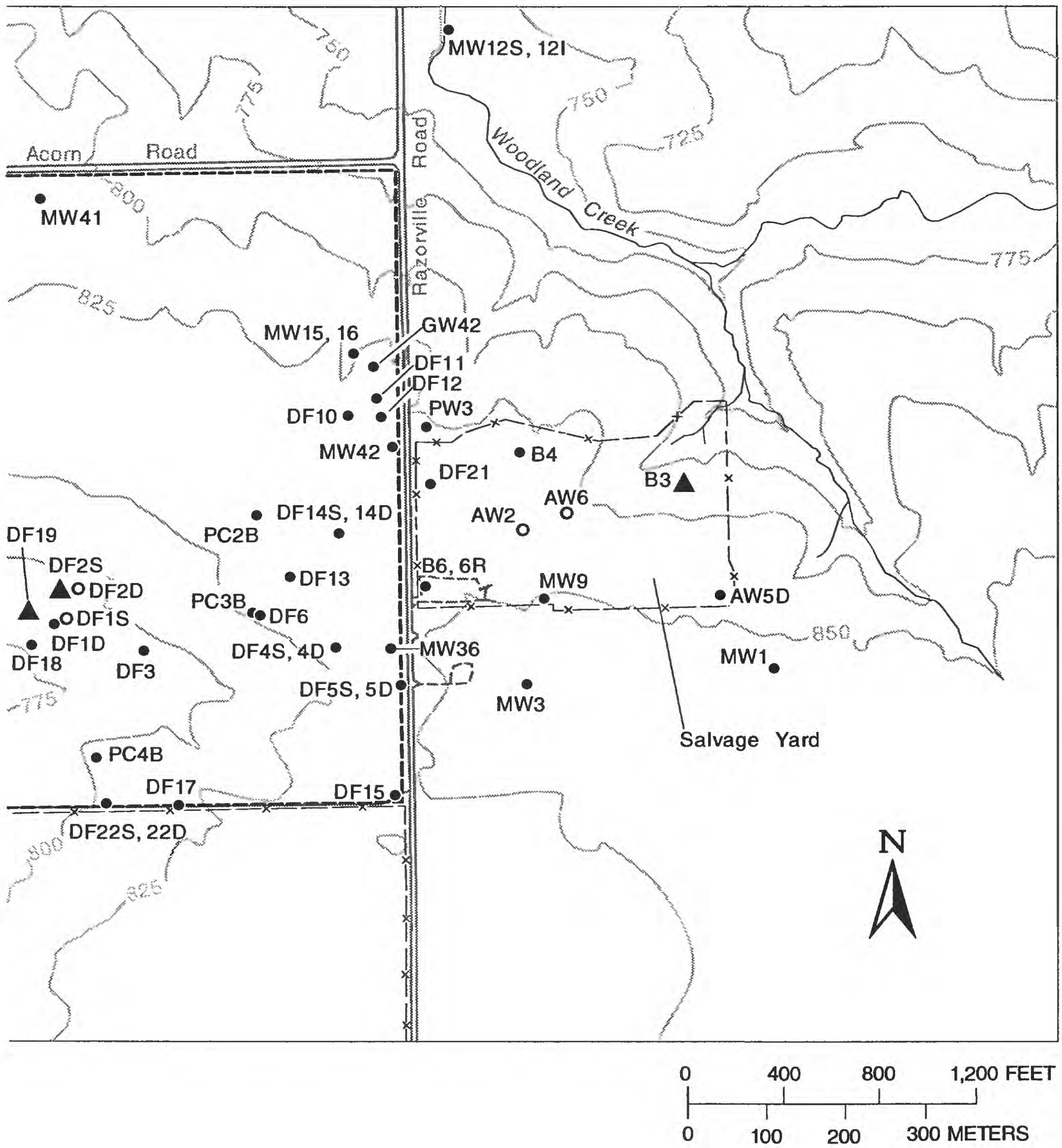


Figure 33. Continued.