Geohydrology of the Upper Part of the Galena-Platteville Aquifer Underlying a Waste-Disposal Site Near Wempletown, Illinois

By Steven M. Robinson and Douglas J. Yeskis

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U.S. GEOLOGICAL SURVEY
Thomas J. Casadevall, Acting Director

For additional information write to:

District Chief
U.S. Geological Survey
221 N. Broadway
Urbana, IL 61801

Copies of this report can be purchased from:

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
inch	2.54	centimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
acre	4,047	square meter
foot per day (ft/d)	0.3048	meter per day
pound per square inch (psi)	6,895	Pascal (Pa)

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 the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

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By Steven M. Robinson[1] *and* Douglas J. Yeskis[2]

Abstract

The uppermost bedrock of the Galena-Platteville aquifer underlying a waste-disposal site near Wempletown, Illinois, is composed of dolomite of the St. James, Beecher, Eagle Point, and Fairplay Members of the Dunleith Formation of the Galena Group. Chert beds in these formations have a higher porosity than the dolomite.

Ground-water flow is from a drum-storage area to the west and northwest toward low points west and northwest of the drum-storage area and the topographic low at the intermittent stream south of the landfill area. The direction of ground-water flow at the landfill area is affected by seasonal changes in precipitation.

Calculated horizontal ground-water velocities ranged from 3.5×10^{-2} to 8.8×10^{-2} feet per day; the lowest value was in the vicinity of the landfill area. Horizontal hydraulic-conductivity values calculated from single-well aquifer tests ranged from 1.0×10^{-2} to 1.0×10^{0} feet per day with an average of 4.0×10^{-1} feet per day.

INTRODUCTION

A series of investigations of a waste-disposal site near Wempletown, Ill., was performed from 1987 to 1994 by the U.S. Geological Survey (USGS) in cooperation with the U.S. Environmental Protection Agency (USEPA). The objective of the investigations was to determine the geohydrologic properties of the upper part of the Galena-Platteville aquifer underlying the site. This information was required to (1) guide possible future geohydrologic investigations in the area, and (2) characterize the rate and direction of shallow ground-water flow in the area.

Wempletown is located in central Winnebago County in north-central Illinois, about 4 mi northwest of the city of Rockford (fig. 1). The land surface at the approximately 110-acre farm site, where the waste-disposal areas are located, generally slopes to the northwest. The farm site is bounded by Telegraph Road on the north, Eddie Road on the west, and a network of monitoring wells on the south and east. The farm site contains two disposal areas: an above-ground drum-storage area and a landfill in an abandoned stone quarry. The landfill and drum-storage areas together cover about 3 acres. The farm site is underlain by saturated dolomite of the Galena and Platteville Groups, which will hereinafter be referred to as the Galena-Platteville aquifer.

Purpose and Scope

This report describes the results of a series of investigations designed to determine the geohydrology of the upper part of the Galena-Platteville aquifer underlying a waste-disposal site near Wempletown, Ill. The report presents the results and interpretations of water-level data, single-well aquifer testing, rock-core analysis, and geophysical logging collected during the investigations.

Three water-level surveys (1990, 1992, and 1993), two geophysical surveys (1987 and 1990), and two slug-test surveys (1988 and 1990) were made

[1]U.S. Geological Survey, DeKalb, Illinois.

[2]U.S. Environmental Protection Agency, Region 5, Chicago, Illinois.

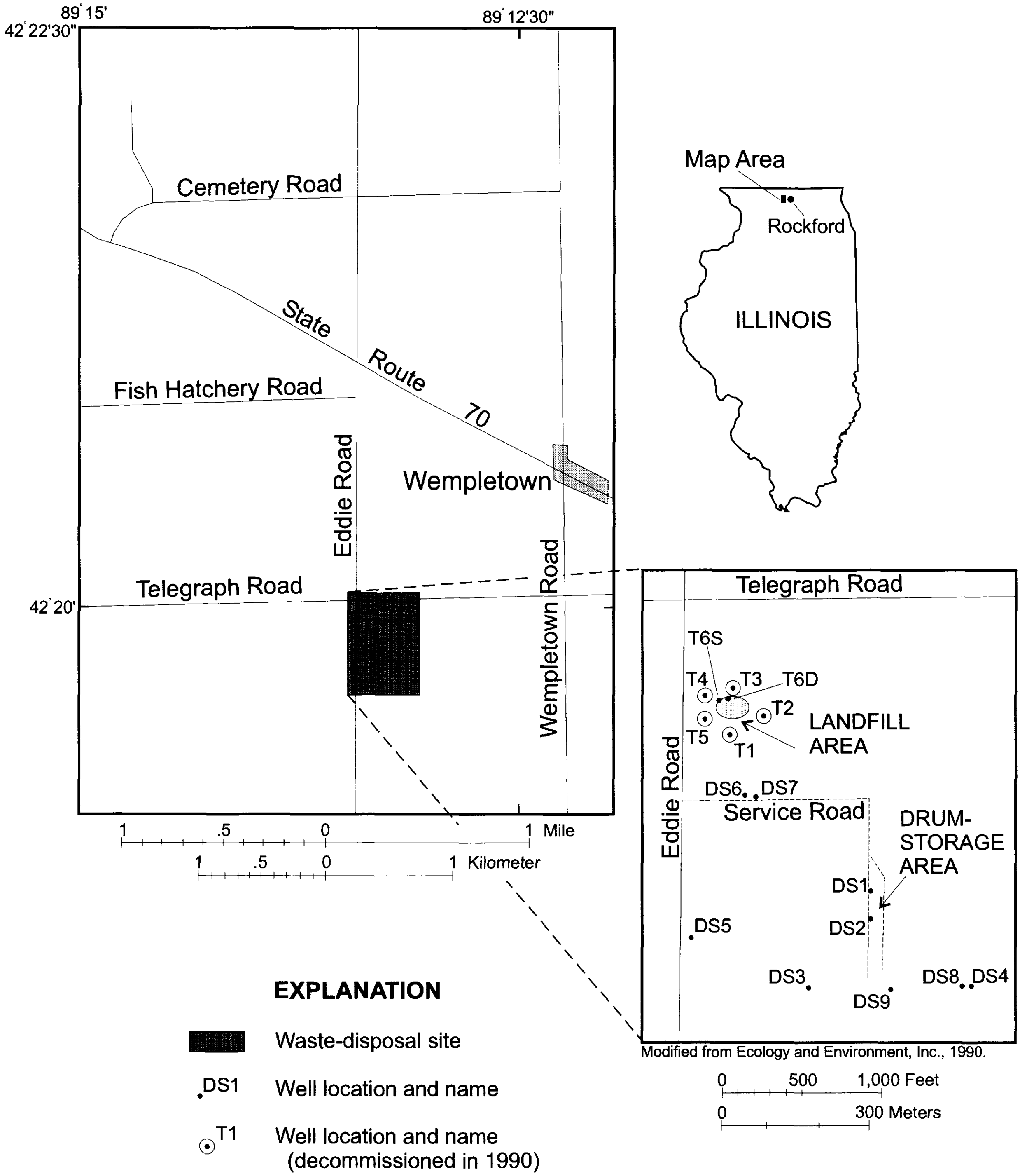


Figure 1. Location of waste-disposal site and monitoring wells near Wempletown, Illinois.

by the USEPA but not previously published. Water-level measurements and single-well aquifer tests were made at the site by the USGS in December 1994. The porosity values were determined by the USGS, and the lithology of the cores was described by the Illinois State Geological Survey (ISGS).

Site History

Wastes were accepted for disposal at the site from the early 1960's to 1972 (Ecology and Environment, Inc., 1986). Drums containing unidentified wastes either were landfilled in the abandoned quan stored above ground in the drum-storage area; n ner area was licensed for disposal activities (Ecology and Environment, Inc., 1990). Between 1968 and 1975, inspections by the Illinois Environmental Protection Agency (IEPA) noted that as many as 500 drums were present at the drum-storage area at one time and that many drums had leaked (Ecology and Environment, Inc., 1990). The drums in the drum-storage area were removed and the landfill was covered with soil in 1975. No other remediation work has been performed at the site.

Previous Work

The USEPA and IEPA conducted several investigations between 1968 and 1975. Nearby residential wells and the contents of drums in the drum-storage area were sampled for a limited number of constituents. Results of the sampling indicated concentrations of phenols in one well (Ecology and Environment, Inc., 1990).

In 1985, Ecology and Environment, Inc., installed five monitoring wells (T1–T5, fig. 1) around the landfill area, collected ground-water-level measurements, performed a surface-resistivity survey, and sampled ground water. Ground-water-level data collected as part of this investigation indicated a northwestern direction of flow around the landfill area, with a more northerly component during periods of low water levels. The resistivity survey detected a number of high and low resistivity anomalies, which would indicate the presence of unsaturated caverns/fractures (high resistivity) or saturated caverns/fractures (low resistivity). Four of the five monitoring wells were installed in areas with suspected karst features, and a small fracture was noted in only one well (Ecology and Environment, Inc., 1986). Analysis of water samples from the five monitoring wells indicated quantifiable concentrations of contaminants. The sample from well T1 contained 24 parts per billion (ppb) of 2,4-dimethylphenol, and the sample from well T5 contained 5 ppb of trans-1,2-dichloroethene. Water from both wells contained additional unquantifiable phenolic compounds (Ecology and Environment, Inc., 1990).

A followup geohydrologic investigation by Ecology and Environment, Inc. (1990) included installation of 11 additional monitoring wells (DS1–DS9, T6S, and T6D, fig. 1), ground-water-level measurements, soil sampling, and ground-water-quality sampling. The investigation indicated that, in general, the ground-water flow mirrors surface topography and that the major component of ground-water flow is to the west-northwest with seasonal variations and possible local variations because of fractures. The soil around the landfill area was found to be contaminated with phenolic compounds, chlorinated solvents, and heavy metals. Soil samples from the drum-storage area were contaminated with chlorinated solvents, polyaromatic hydrocarbons, xylenes, and heavy metals. Soil samples from the major surface-drainage pathways did not indicate the migration of contaminants by overland flow (Ecology and Environment, Inc., 1990). Ground-water-quality samples were collected in December 1987 and April 1988.

Samples collected in December 1987 indicated the presence of numerous phenolic compounds and other organic compounds in water from wells T1 and T5. Soil samples from the drum-storage area contained contaminants similar to those detected in well T1, which would indicate that the contaminants in water at well T1 are derived from the drum-storage area by movement through the ground-water system or by disposal in the landfill area of wastes from the drum-storage area (Ecology and Environment, Inc., 1990). Water-quality samples collected in April 1988 showed no contamination in well T1, but water samples from well T5 still contained detectable concentrations of phenolic compounds.

All of the following unpublished information was collected by the USEPA. Electromagnetic (EM), magnetometer, and seismic-refraction surveys were made in July 1987 to determine the presence of buried materials in the drum-storage area and to help define the bedrock beneath the site. Both EM and magnetometer surveys indicated the possibility of buried metallic items. A seismic-refraction survey in the vicinity of monitoring well DS3 indicated that the depth to bedrock was 30 ft below land surface. Installation of monitoring well DS3 confirmed that the depth to bedrock was 29 ft below land surface.

Single-well aquifer tests were done in wells DS6 and DS7 in March 1988. Single-well aquifer tests were done in wells T2, T3, T4, and T5 in January 1990; natural gamma, three-arm caliper, spontaneous potential (SP), and resistivity logs also were run in these wells at this time. Well T1 was accidentally destroyed during farming operations prior to 1990. The USEPA removed wells T2, T3, T4, and T5 in 1990.

In April 1990, ground-water levels were measured and single-well aquifer tests were done in wells DS1, DS2, DS5, and DS9. Ground-water levels were measured and ground-water-quality samples were collected in November 1992. An additional ground-water-level survey was completed in March 1993.

Study Methods

In 1994, 11 wells were present at the site. Wells DS1, DS2, DS4, DS5, DS6, DS9, and T6S were cased through the unconsolidated sediments and were uncased and unscreened in the bedrock at depths ranging from 28.5 ft to 43.5 ft below land surface (table 1). Wells DS3, DS7, DS8, and T6D were cased and screened in the bedrock at depths ranging from 44.0 ft to 72.0 ft. None of the 11 wells drilled at the site penetrate the entire thickness of the Galena-Platteville aquifer (fig. 2).

Water levels were measured with an electric tape calibrated to 0.01 ft. Rising- and falling-head, single-well aquifer tests were performed by the insertion and removal of a 5-ft-long, weighted, PVC cylinder (outside diameter = 1.375 inches). During the slug tests, water-level data were collected with a pressure transducer calibrated between 0 and 10 psi and a data logger set to record on a logarithmic time sequence.

Horizontal hydraulic-conductivity values (K) for the single-well aquifer tests were calculated using the method of Bouwer-Rice (Bouwer and Rice, 1976) in the slug-test solution category of the AQTESOLV (version 1.1) software package (Geraghty and Miller Modeling Group, 1991). For calculation of horizontal hydraulic conductivity in AQTESOLV, six variables—radius of the well casing (r_c), radius of the borehole (r_w), length of the well screen (L), saturated thickness of the aquifer (b), height of static water column in the borehole (H), and water-level elevation in feet above sea level (W_l)—were determined (table 2).

For wells DS1, DS2, DS4, DS5, DS6, DS9, and T6S, the radius of the well casing (r_c) was set equal to the radius of the borehole (r_w). The length of the well screen (L) was set equal to the saturated open interval in the uncased borehole. For wells DS3, DS7, DS8, and T6D, r_c was set equal to the radius of the well casing and L was set equal to the saturated length of the well screen.

A drillers log for a residential well, 3/4 mi to the southeast of the study area, indicates that the elevation of the base of the Galena-Platteville aquifer is 624 ft above sea level. If it is assumed that the elevation of the base of the aquifer is constant across the area, the saturated thickness of the aquifer can be determined by subtracting the water-surface elevation from the elevation of the bottom of the Galena-Platteville aquifer.

The water level (W_l) and height of static water column in the borehole (H) were calculated from data collected during the water-level surveys. All ground-water elevations were referenced to the arbitrary datum established by Ecology and Environment, Inc. (1986) and then converted to elevations above sea level for calculation of horizontal hydraulic conductivity. Measuring-point elevations for the wells, in feet above sea level, were determined from the Winnebago, Ill., quadrangle 7.5-minute topographic map. An error as large as ±5 ft may result in data referenced to sea level because of the uncertainty in determining the elevation of the wells from the topographic map.

Core samples of the bedrock from wells DS8 and T6D were inspected and the stratigraphic formation was identified by the Illinois State Geological Survey (Sargent and Lasemi, 1992). Porosity values were determined by weighing a saturated section of rock core and then drying and weighing the core again. From this procedure, the volume of voids was determined and the porosity calculated by dividing the void volume by the total volume of the saturated sample (Mills and others, in press). Vug and pore areas on the surface of the core were estimated and the initial porosity value was adjusted.

A Mount Sopriss Model II borehole-logging instrument with three-arm caliper, natural gamma, and spontaneous potential (SP) tools was used to collect the borehole-geophysical data. A three-arm-caliper log was run in wells T2–T5, SP logs were run in wells T2, T4, and T5, and a natural gamma log was run in well T5. The saturated interval was 5.5 ft for well T2, 8.0 ft for well T4, and 12.5 ft for well T5. The low water level at the time the SP logs were made limited the usefulness of the SP logs because of the short profile obtained.

Table 1. Monitoring well and water-level data at a waste-disposal site near Wempletown, Illinois

[a, dry well; --, no data available (wells decommissioned in 1990)]

Monitoring well data					Water-level elevations (feet above arbitrary datum[1])			
Well name	Total depth (feet below land surface)	Open interval (feet below land surface)	Land-surface elevation (feet above arbitrary datum)	Elevation of bottom of well (feet above arbitrary datum)	April 5, 1990	November 9–10, 1992	March 5, 1993	December 9, 1994
DS1	43.0	18.0–43.0	127	84.0	93.22	107.25	109.25	108.68
DS2	43.5	18.0–43.5	134	90.5	99.69	113.15	115.49	114.09
DS3	44.0	33.0–44.0	130	86.0	a	98.53	101.82	98.10
DS4	38.5	9.0–38.5	129.5	91.0	102.75	114.32	117.39	114.88
DS5	43.5	20.0–43.5	108	64.5	71.64	81.83	84.77	82.06
DS6	43.5	12.0–43.5	99	55.5	69.09	89.66	85.21	82.63
DS7	72.0	61.0–72.0	99	27.0	66.55	77.17	81.50	77.78
DS8	70.0	58.0–69.0	129.5	60.5	96.43	106.92	109.50	107.58
DS9	28.5	11.0–28.5	130.5	102.0	106.24	114.90	117.42	115.33
T6S	28.5	2.0–28.5	93	64.5	75.17	81.12	84.96	82.29
T6D	58.5	47.5–58.5	93	34.5	68.49	79.19	83.33	79.48
T2	30.0	13.2–30.0	--	--	--	--	--	--
T3	31.0	8.8–31.0	--	--	--	--	--	--
T4	32.5	12.8–32.5	--	--	--	--	--	--
T5	30.0	13.1–30.0	--	--	--	--	--	--

[1]Datum established in 1985 by Ecology and Environment, Inc.

SYSTEM	GROUP	FORMATION	SELECTED MEMBER	LITHOLOGY	HYDROLOGIC UNIT
QUATERNARY				Silt and clay, sand and gravel	Unconsolidated aquifer
ORDOVICIAN	GALENA	Dubuque		Dolomite	Galena-Platteville aquifer
		Wise Lake			
		Dunleith	Five members not listed		
			Fairplay		
			Eagle Point		
			Beecher		
			St. James		
			Buckhorn		
		Guttenberg			
		Spechts Ferry			
	PLATTEVILLE	Quimbys Mill			
		Nachusa			
		Grand Detour			
		Mifflin			
		Pecatonica			
	ANCELL	Glenwood		Dolomitic shale, sandstone	St. Peter aquifer
		St. Peter		Sandstone	

Modified from Willman and others, 1975.

Figure 2. Generalized geohydrologic column showing stratigraphy, lithology, and hydrologic units underlying a waste-disposal site near Wempletown, Illinois.

Acknowledgments

The authors thank James Ursic, Geologist, U.S. Environmental Protection Agency, Region 5, for his active support and participation during this investigation.

GEOHYDROLOGY

The geology and hydrology of Winnebago County have been described by several investigators (Hackett, 1960; Willman and others, 1975; Willman and Kolata, 1978; Berg and others, 1984). Their work, in combination with geologic and hydrologic data compiled during this investigation, form the basis for the discussion of the geology and hydrology.

The geologic description of the site is compiled from previous reports and analysis of lithologic and geophysical logs compiled during this investigation. The stratigraphic nomenclature used in this report is that of the Illinois State Geological Survey (Willman and others, 1975, p. 61–80, and 218–230).

Table 2. Data for calculation of horizontal hydraulic conductivity and results for the Galena-Platteville aquifer underlying a waste-disposal site near Wempletown, Illinois

[Data were collected by the U.S. Environmental Protection Agency for March 1988, January and April 1990. Data were collected by the U.S. Geological Survey during December 1994; fh, falling-head single-well aquifer test; rh, rising-head single-well aquifer test]

Well name (fig. 1)	Type of aquifer test	Date (month/year)	Casing radius (feet)	Borehole radius (feet)	Elevation of bottom of well (feet above sea level)	Thickness of saturated aquifer[1] (feet)	Length of well screen (feet)	Height of static water column (feet)	Water-level elevation (feet above sea level)	Horizontal hydraulic conductivity (times 10^{-1} feet per day)
DS1	rh	04/90	0.167	0.167	843	223.22	[2]4.11	4.11	847	1.0
	rh	12/94	.167	.167	843	238.69	[2]19.58	19.58	862	10.0
DS2	rh	04/90	.167	.167	847	229.69	[2]6.56	6.56	854	6.0
	rh	12/94	.167	.167	847	244.09	[2]20.96	20.96	868	5.0
DS3	rh	12/94	.083	.167	840	228.10	10.00	12.10	852	4.0
DS4	rh	12/94	.167	.167	846	244.88	[2]22.54	22.54	869	7.0
DS5	rh	04/90	.167	.167	819	201.64	[2]6.58	6.58	826	5.0
	rh	12/94	.167	.167	819	212.06	[2]17.00	17.00	836	5.0
DS6	rh	03/88	.167	.167	816	212.38	[2]20.13	20.13	836	5.0
	rh	12/94	.167	.167	816	212.63	[2]20.38	20.38	837	4.0
DS7	fh	03/88	.083	.167	781	212.38	10.00	55.38	836	3.0
	rh	03/88	.083	.167	781	212.38	10.00	55.38	836	3.0
	fh	12/94	.083	.167	781	212.63	10.00	55.63	837	3.0
	rh	12/94	.083	.167	781	212.63	10.00	55.63	837	3.0
DS8	fh	12/94	.083	.167	815	244.88	10.00	53.94	869	5.0
	rh	12/94	.083	.167	815	244.88	10.00	53.94	869	5.0
	rh	12/94	.083	.167	815	244.88	10.00	53.94	869	5.0
DS9	rh	04/90	.167	.167	856	236.24	[2]4.11	4.11	860	3.0
	rh	12/94	.167	.167	856	245.33	[2]13.20	13.20	869	10.0
T6S	rh	01/90	.167	.167	820	205.17	[2]9.67	9.67	829	1.0
T6D	rh	01/90	.083	.167	789	205.17	10.00	33.27	822	4.0
T4	rh	01/90	.167	.167	815	198.09	[2]7.45	7.45	822	.10
T5	rh	01/90	.167	.167	815	203.36	[2]12.72	12.72	827	1.0

[1]Aquifer saturated thickness based on data from nearby residential well.

[2]Open borehole; no well screen present. Length of well screen set to height of water column for analysis.

Geology

The geologic deposit of concern in this investigation is the upper bedrock units of the Galena-Platteville aquifer. The upper bedrock units were identified as the St. James, Beecher, Eagle Point, and Fairplay Members of the Dunleith Formation of the Galena Group (Sargent and Lasemi, 1992).

The following description of geologic formations and their thickness is solely derived from Sargent and Lasemi (1992). The Dunleith Formation is a porous, vuggy, medium crystalline dolomite, grading to a coarser medium crystalline dolomite in leached-out areas. The bedding is described as wavy and shaley with styolitic partings.

The dolomite at well DS8 is heavily leached throughout the core except for an interval from 20 to 26 ft below land surface that is not as heavily leached. The dolomite is porous and vuggy. A 2-inch-thick, white, chalky, very porous chert is the basis for determining the top of the Eagle Point Member. The Eagle Point Member contains numerous 1- to 2-inch-thick, white, chalky, chert beds throughout the interval (fig. 3). The chert bed at 26.1 ft below land surface is fossiliferous. Horizontal fracture zones were noted in the rock core in the middle Beecher, the upper and middle Eagle Point, and the lower Fairplay Members; vertical fractures were noted in the Eagle Point Member. Numerous zones of healed vertical fractures in the St. James, Beecher, and lower Eagle Point Members were noted (fig. 3). There is an oxidized hardground (defined as a zone of early diagenetic cementation in limestones by Leeder, 1982, p. 109) in the St. James at 56.8 ft below land surface and a series of hardgrounds in the Eagle Point at 39.0, 39.5, 40.5 to 41.7 ft below land surface.

The dolomite at well T6D is about 80 percent leached out except for the lower 4 ft, which is less leached. Some vuggy porosity is associated with the leached areas. The two chert beds in the Eagle Point Member are approximately 2 inches thick, mostly white, porous, and chalky (fig. 3). The upper chert bed contains small-pebble-size, light brownish-gray chert. The lower chert bed contains many fossil molds and some dolomitic clasts. Horizontal fracture zones were noted in the rock core in the lower Eagle Point. Vertical fractures were noted in the lower Eagle Point and in the upper and middle Fairplay Members. A series of hardgrounds is present in the Beecher at 38.8 to 44.4 ft below land surface, and a series of nearly planar hardgrounds is in the Fairplay from 22.4 to 24.9 ft.

The upper series of hardgrounds at well T6D has no equivalent at well DS8 (fig. 3). The lower series of hardgrounds at well T6D is similar to the hardgrounds series noted in the Eagle Point at well DS8. This series of hardgrounds is probably equivalent to the persistent corrosion surfaces noted in the Beecher by Willman and Kolata (1978). The hardground series is placed in the Eagle Point Member at well DS8 because of the chert that is present. The hardground at well T6D is placed in the Beecher Member because of the lack of chert and the purity of the dolomite (Sargent and Lasemi, 1992).

The three-arm caliper logs indicate the bedrock in the vicinity of wells T2 and T5 is not as fractured as the bedrock in the vicinity of wells T3 and T4 (fig. 4). There is some correlation with known fracture locations described in the rock core from well T6D and the suspected fracture zones shown in the three-arm caliper logs of wells T3 and T4 (figs. 3–4). There is a slight indication in the natural gamma and SP logs at well T5 that the top of the Eagle Point Member is at 25 ft below land surface. The SP logs at well T2 and T4 and the single-point resistivity log at well T4 also may indicate the interface between the top of the Eagle Point and the bottom of the Fairplay Member (fig. 5).

The St. James Member is described only at well DS8 and is 17.6 ft thick but may be thicker because the core description ends in the member (figs. 6–7). The total thickness of the Beecher Member is 6.1 ft at well DS8 and 8.2 ft at well T6D. The total thickness of the Beecher at well T6D may be greater because the core ends in the member. Thickness of the Eagle Point Member ranges from 27.8 ft at well DS8 to 5.4 ft at well T6D. The Fairplay Member varies in thickness from 10.2 ft at well DS8 to 30.8 ft at well T6D (figs. 6–7). Thickness of the Eagle Point and St. James Members at well DS8 and the Fairplay Member at well T6D are greater than the normal ranges suggested by Willman and Kolata (1978).

The total thickness of the Dunleith Formation at the site is unknown. The Dunleith Formation in northern Illinois ranges in thickness from 120 to 135 ft (Willman and Kolata, 1978). Total thickness of the Galena and Platteville Groups at the site is unknown.

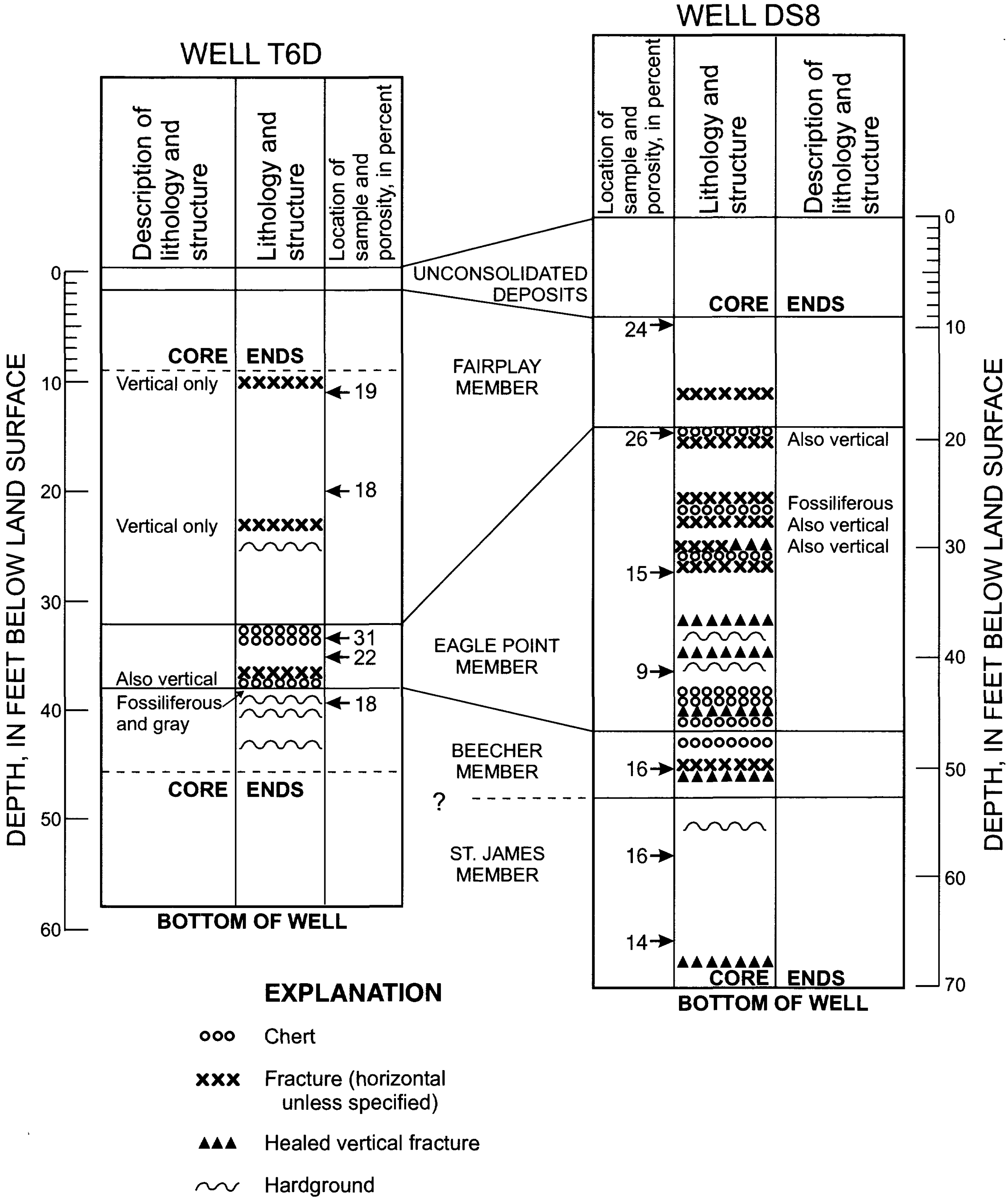


Figure 3. Location of fractures, chert beds, and corresponding porosity in cores from wells T6D and DS8 at a waste-disposal site near Wempletown, Illinois.

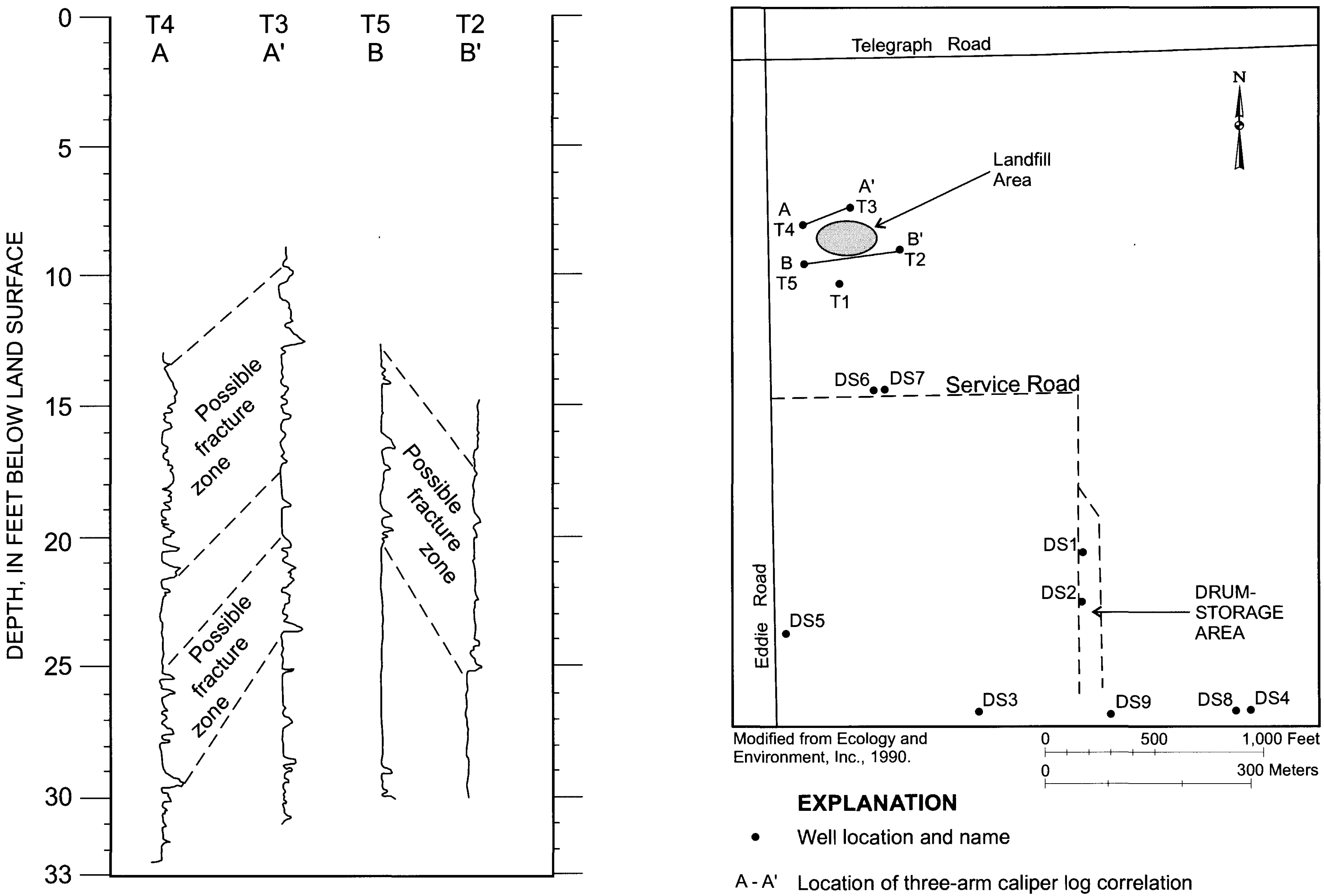
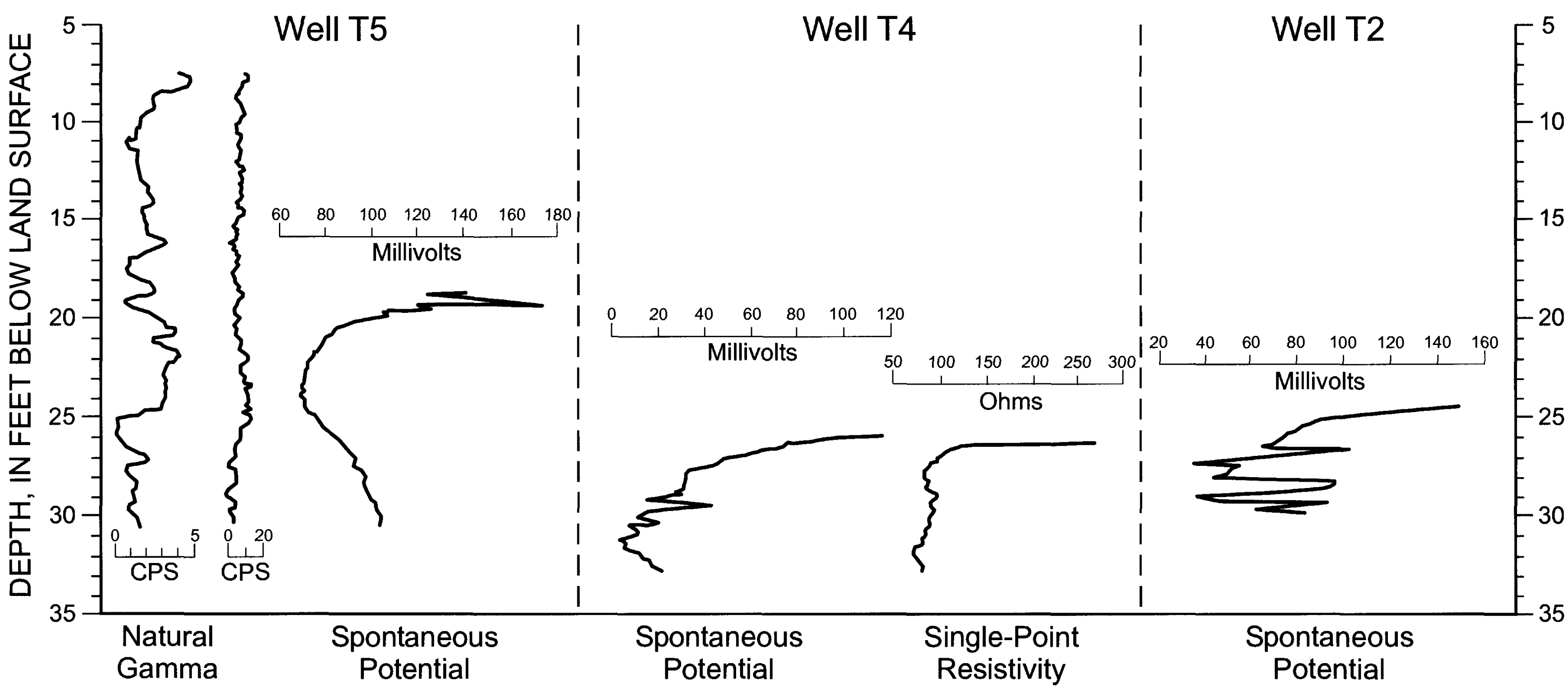


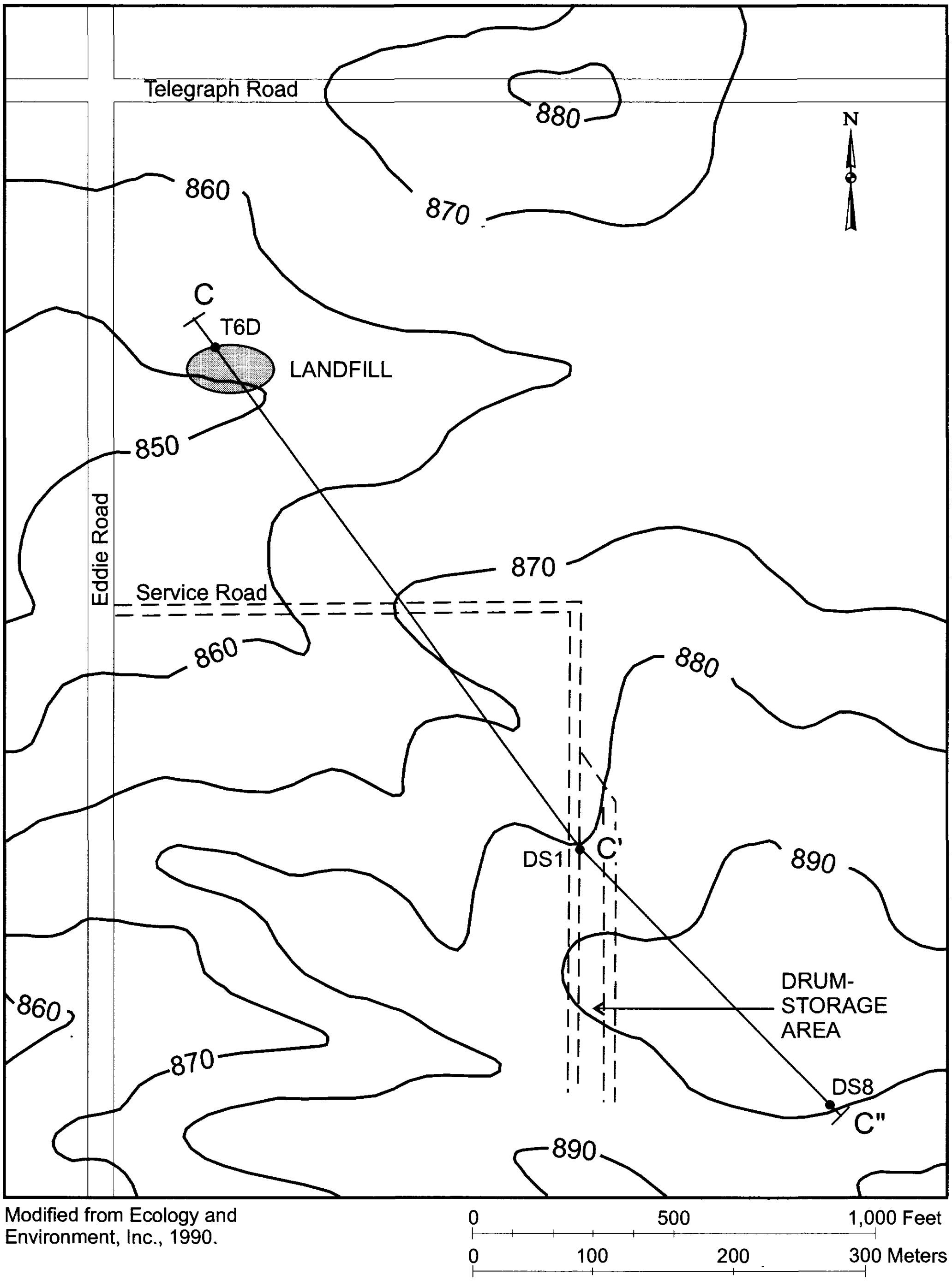
Figure 4. Three-arm caliper logs, correlation of possible fracture zones for wells T2, T3, T4, and T5, and location of transects at a waste-disposal site near Wempletown, Illinois.



EXPLANATION

CPS equals Counts Per Second

Figure 5. Geophysical logs for wells T2, T4, and T5 at a waste-disposal site near Wempletown, Illinois, January 1990.



EXPLANATION

—— 850 —— TOPOGRAPHIC CONTOUR -- Shows elevation of land surface in feet Contour interval is 10 feet. Datum is sea level

C-C'-C" Trace of cross section (see fig. 7)

Figure 6. Location of stratigraphic cross section and site topography at a waste-disposal site near Wempletown, Illinois.

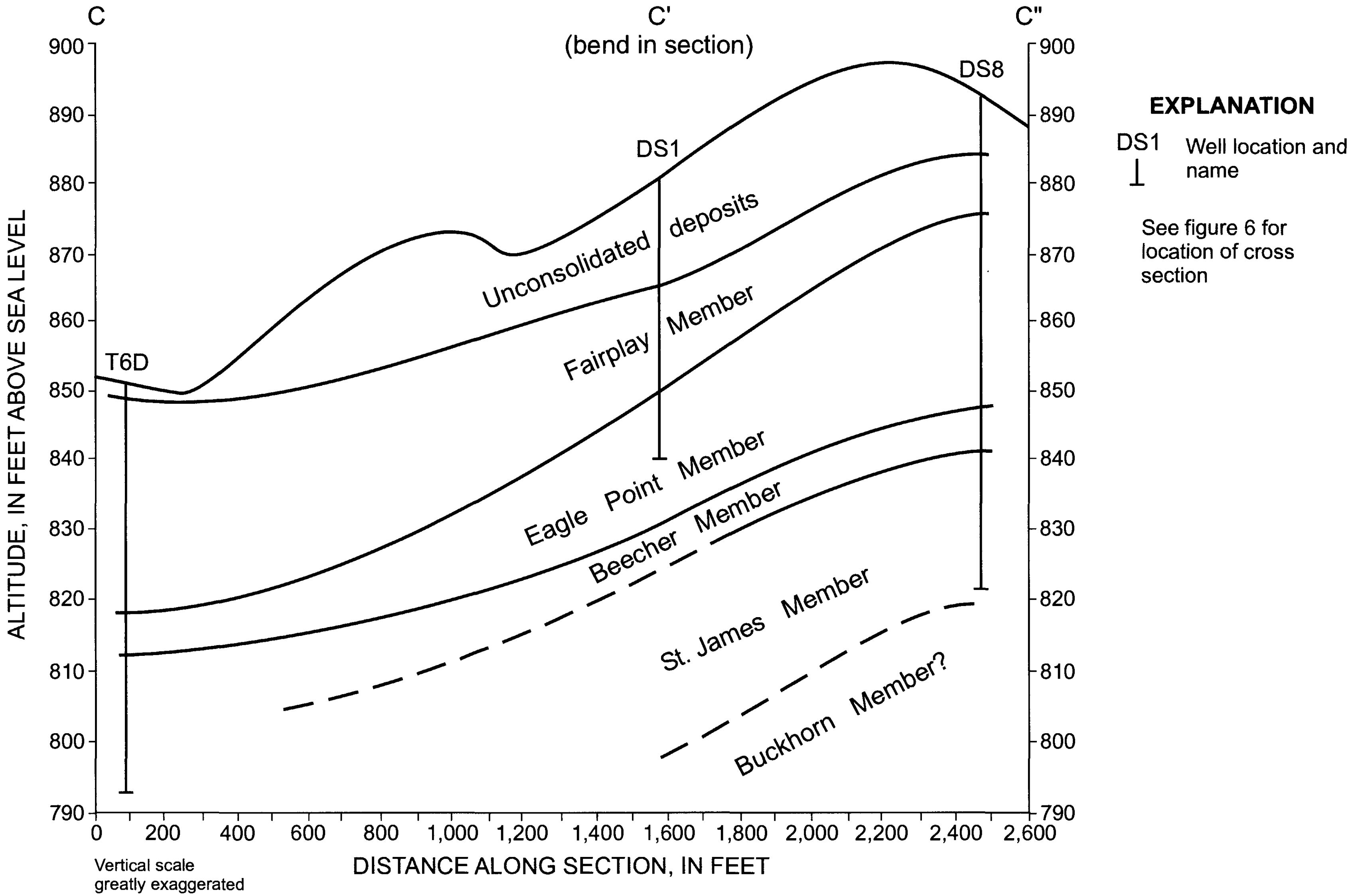


Figure 7. Stratigraphic cross section of the waste-disposal site near Wempletown, Illinois.

Descriptions of formations encountered during the installation of a residential well 3/4 mi southeast of the site indicate a thickness of 313 ft for the Galena and Platteville Groups. The thickness of the Platteville Group is 137 ft in Rockford, Ill. (fig. 1 in Willman and Kolata, 1978). The combined thickness of the Galena and Platteville Groups in Winnebago County can be 350 ft or more (Berg, Kempton, and Stecyk, 1984).

Hydrology

The water table at the disposal site is within the dolomite deposits of the Dunleith Formation, and ground-water flow through the upper bedrock is primarily through fractures, vugs, joints, and solution openings. Ground water flows in several directions beneath the site (figs. 8–11). Overall, the water-table configuration mirrors the surface topography (Ecology and Environment, Inc., 1990). Ground-water flow is from a ground-water divide near the drum-storage area toward low points west and northwest of the drum-storage area and the topographic low at the intermittent stream south of the landfill area (figs. 8–11). North of the intermittent stream, ground-water flow is typically west-southwest, although the direction of ground-water flow around the landfill is affected by seasonal changes in precipitation and also can be to the north and south (Ecology and Environment, Inc., 1990).

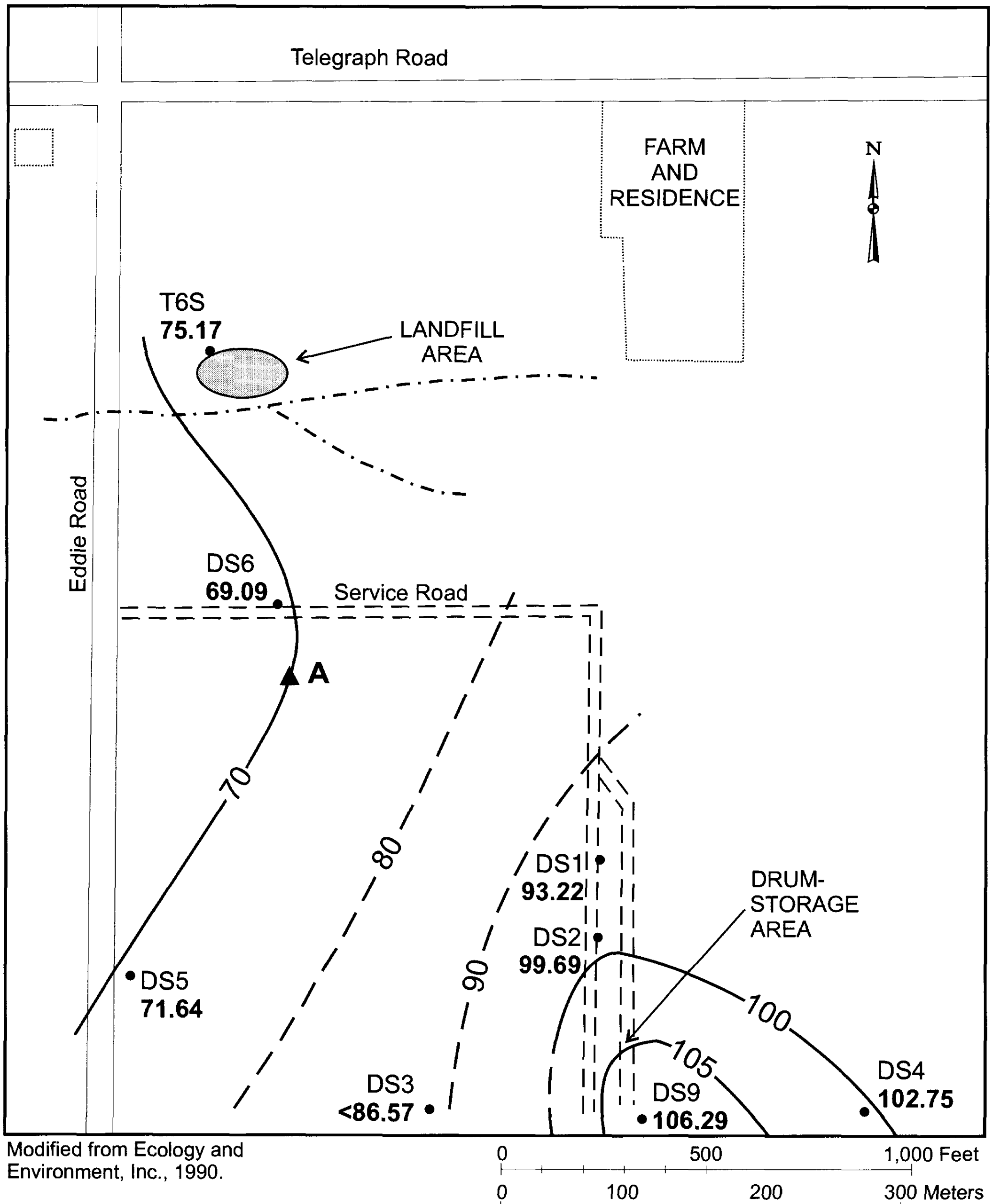
Water levels were measured at the site four times after the completion of the investigation by Ecology and Environment, Inc. (1990) (table 1). Water levels were collected by the USEPA in April 1990, November 1992, and March 1993, and by the USGS in December 1994. A pond was constructed near the residence on the site between the USEPA visits on April 1990 and November 1992.

The water-table configuration prior to construction of the pond indicates northwesterly flow away from the drum-storage area and southwesterly flow away from the landfill area (fig. 8). The water-table configuration after the construction of the pond (figs. 9–11) indicates a flow pattern similar to the water-table configuration before the construction of the pond with the exception of water levels measured in November 1992 (fig. 9). These levels indicate that the 80-ft contour line is approximately parallel to Eddie Road (fig. 9) at well DS6, contrary to the other measurement periods (figs. 10–11). For these other periods, a slight bend to the east was contoured in the vicinity of well DS6.

The north/south contour line shown in the water-table configuration, in the vicinity of well DS6 during November 1992, is probably a result of an incorrect reading of the water level for well DS6 (fig. 12). Comparison of water-level elevations from March 1993 and December 1994 with water elevations from November 1992 indicate that water levels were 2 to 3 ft higher in 1993 than in 1992 and 1 to 1.5 ft higher in 1994, except for well DS6. Water levels at well DS6 were 4.5 ft lower in 1993 compared to 1992 and 7 ft lower in 1994 (fig. 12).

Single-well aquifer tests were performed by the USEPA on wells DS6 and DS7 in 1988, and on wells DS1, DS2, DS5, DS9, T6S, T6D, T4, and T5 in 1990 (table 2). Horizontal hydraulic-conductivity values for 1988 and 1990 ranged from 1.0×10^{-2} to 6.0×10^{-1} ft/d with a mean of 3.0×10^{-1} ft/d. Single-well aquifer tests were performed by the USGS on wells DS1 through DS9 in 1994. Horizontal hydraulic-conductivity values calculated from tests performed in 1994 ranged from 3.0×10^{-1} to 1.0×10^{0} ft/d with a mean of 5.5×10^{-1} ft/d. Water levels in 1988 and 1990 were 7.1 to 15.5 ft lower than water levels in 1994.

Horizontal hydraulic-conductivity values in the landfill area of the site are the smallest determined at the entire site. This could be because of the lack of fractures, indicated by analysis of the three-arm caliper logs, or as a result of the low water levels in 1990. Comparison of horizontal hydraulic-conductivity values from 1990 to 1994 show that the aquifer open to wells DS2, DS5, and DS6 had similar hydraulic conductivity even with water-level increases of 14.4, 10.4, and 13.5 ft, respectively. This indicates that either the horizontal hydraulic conductivity of the upper part of the saturated interval of wells DS2, DS5, and DS6 is similar to the lower part of the saturated interval of the well or that the lower part of the saturated interval of the well is where most of the flow takes place. An order of magnitude increase and a threefold increase in horizontal hydraulic-conductivity values from 1990 to 1994 were measured in wells DS1 and DS9, respectively. Ground-water levels in wells DS1 and DS9 increased 15.4 ft and 9.1 ft, respectively, from 1990 to 1994. The increase in horizontal hydraulic conductivity of the aquifer at these wells may be because of the saturation of fractures that are not saturated at the lower water-surface elevation. Horizontal hydraulic conductivity for the Galena-Platteville aquifer at the wells on the site are within an order of magnitude, so the aquifer can be considered homogeneous.



Modified from Ecology and Environment, Inc., 1990.

EXPLANATION

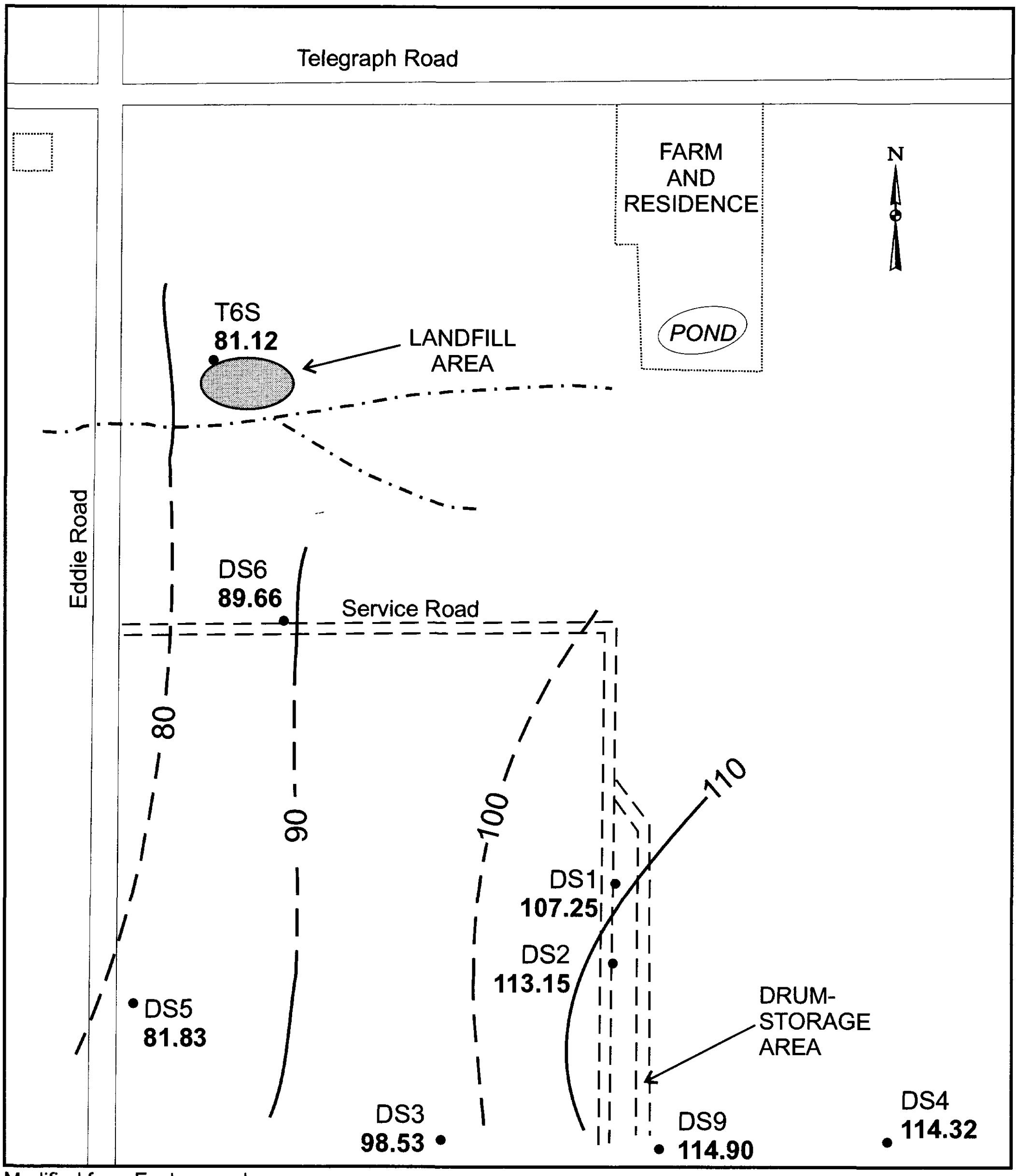
—80— WATER-TABLE CONTOUR -- Shows line of equal water level below datum. Dashed where approximate. Contour interval, in feet, is variable. Datum is arbitrary

–·–·–· Intermittent stream

• DS5 **71.64** Well location and name. Altitude of water level in well, in feet above arbitrary datum established by Ecology and Environment, Inc., 1986

▲A Ground-water transect endpoint and designation

Figure 8. Water-table configuration in and near a waste-disposal site near Wempletown, Illinois, April 5, 1990.



Modified from Ecology and Environment, Inc., 1990.

EXPLANATION

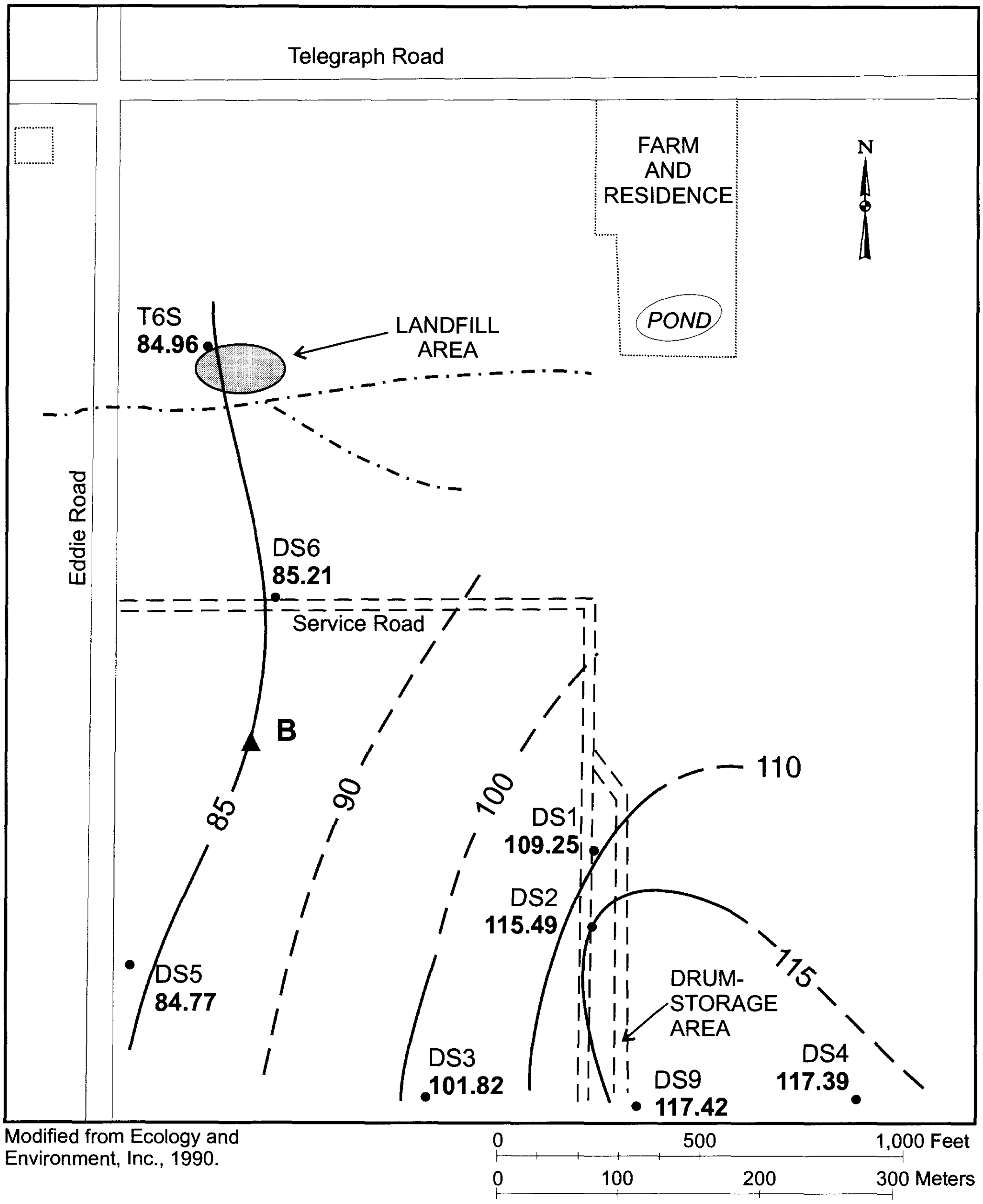
—80— WATER-TABLE CONTOUR -- Shows line of equal water level below datum. Dashed where approximate. Contour interval, in feet, is variable. Datum is arbitrary

-·-·-·- Intermittent stream

• DS5 Well location and name

81.83 Altitude of water level in well, in feet above arbitrary datum established by Ecology and Environment, Inc., 1986

Figure 9. Water-table configuration in and near a waste-disposal site near Wempletown, Illinois, November 9–10, 1992.



Modified from Ecology and Environment, Inc., 1990.

EXPLANATION

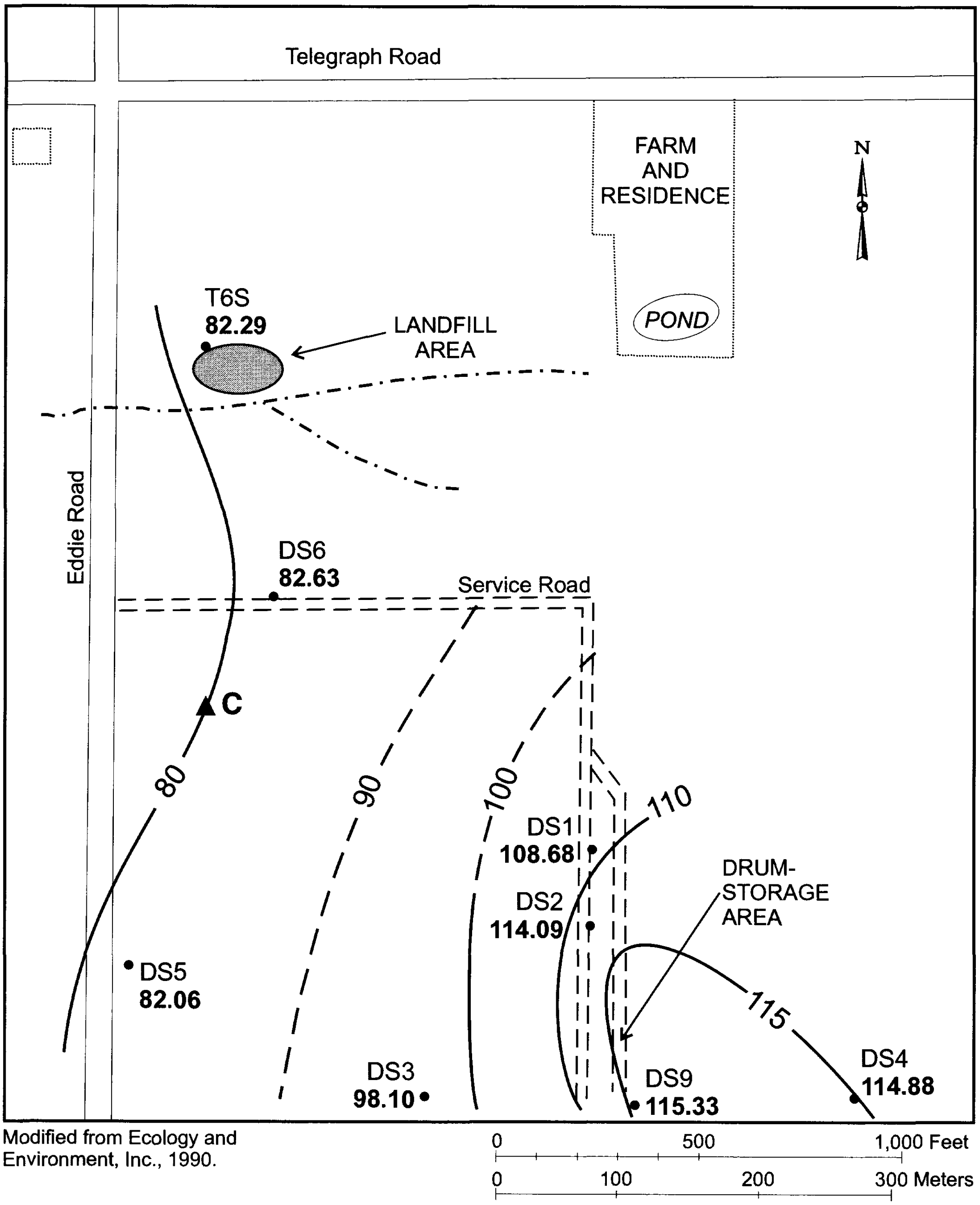
—80— WATER-TABLE CONTOUR -- Shows line of equal water level below datum. Dashed where approximate. Contour interval, in feet, is variable. Datum is arbitrary

-·-·-·- Intermittent stream

• DS5 Well location and name
84.77 Altitude of water level in well, in feet above arbitrary datum established by Ecology and Environment, Inc., 1986

▲ B Ground-water transect endpoint and designation

Figure 10. Water-table configuration in and near a waste-disposal site near Wempletown, Illinois, March 5, 1993.



Modified from Ecology and Environment, Inc., 1990.

EXPLANATION

—80— WATER-TABLE CONTOUR -- Shows line of equal water level below datum. Dashed where approximate. Contour interval, in feet, is variable. Datum is arbitrary

–·–·–· Intermittent stream

• DS5 **82.06** Well location and name. Altitude of water level in well, in feet above arbitrary datum established by Ecology and Environment, Inc., 1986

▲ **C** Ground-water transect endpoint and designation

Figure 11. Water-table configuration in and near a waste-disposal site near Wempletown, Illinois, December 19, 1994.

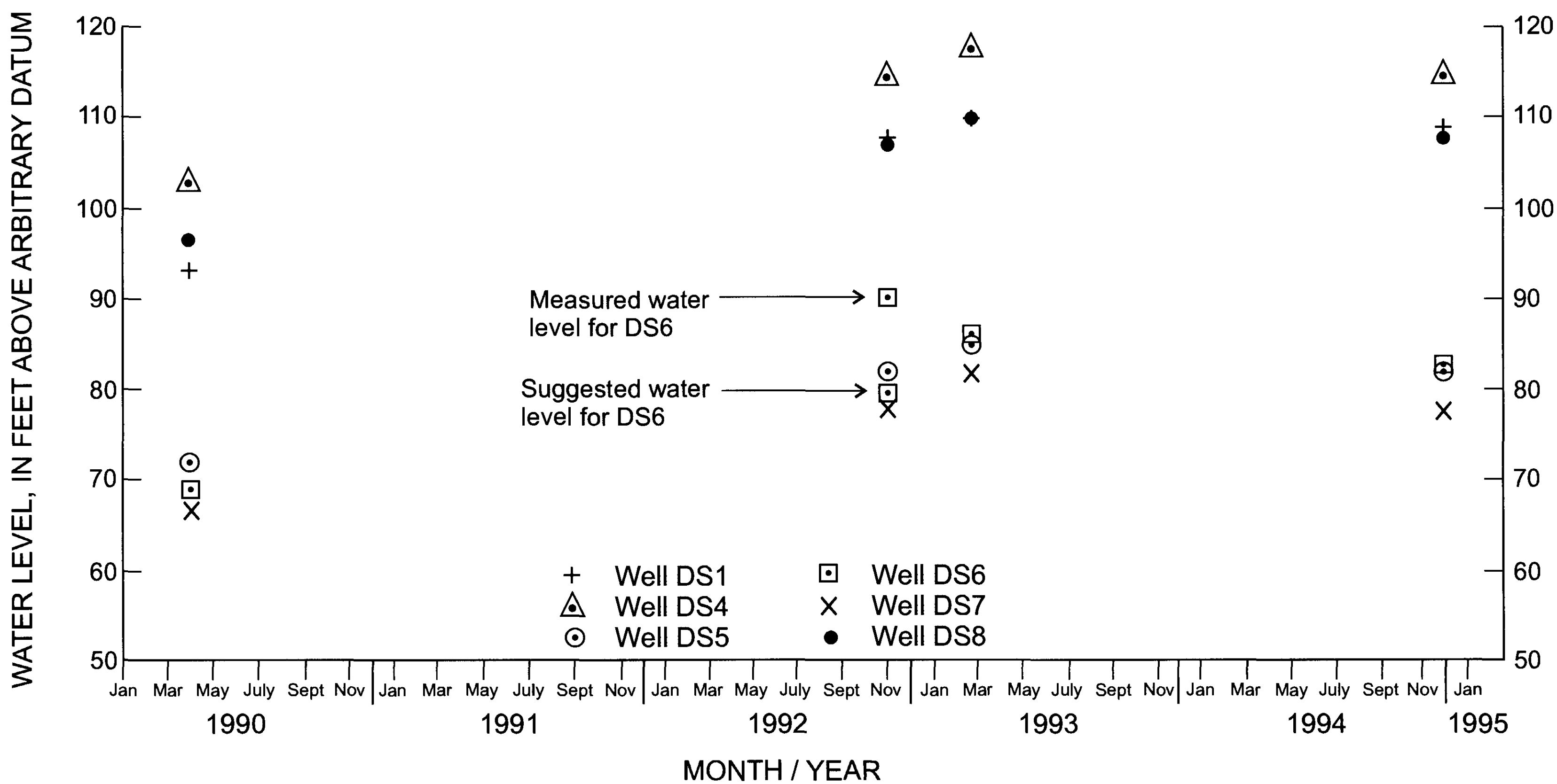


Figure 12. Change in water levels in selected wells at a waste-disposal site near Wempletown, Illinois.

The porosity values for core samples from wells DS8 and T6D range from 9 to 31 percent with the mean value of 19 percent (table 3). The mean porosities of core samples from wells DS8 and T6D are 17 and 22 percent, respectively. The interval between 33.8 and 34.0 ft in well T6D is composed entirely of chert and has the highest porosity (31 percent). The mean porosity value at well T6D, with the chert bed excluded, is 19 percent. The interval from 19.4 to 19.7 ft in well DS8 is partly composed of chert and has a porosity of 26 percent. It appears that the upper part of the Eagle Point Member at both wells and the lower part of the Fairplay Member at well DS8 have slightly higher porosities than the mean core porosity value. The porosity values of core samples from wells DS8 and T6D are within a common range, 0–20 percent, for a dolomite/limestone (Freeze and Cherry, 1979, p. 37).

Table 3. Stratigraphic information and porosity at selected intervals for core samples from wells DS8 and T6D at a waste-disposal site near Wempletown, Illinois

Well name	Interval (feet below land surface)	Group	Formation	Member	Porosity (percent)
DS8	10.5–10.8	Galena	Dunleith	Fairplay	24
	19.4–19.7	Galena	Dunleith	Eagle Point	26
	32.3–32.7	Galena	Dunleith	Eagle Point	15
	41.3–41.6	Galena	Dunleith	Eagle Point	9
	50.0–50.4	Galena	Dunleith	Beecher	16
	58.1–58.4	Galena	Dunleith	St. James	16
	66.0–66.3	Galena	Dunleith	St. James	14
T6D	11.1–11.4	Galena	Dunleith	Fairplay	19
	20.2–20.4	Galena	Dunleith	Fairplay	18
	33.8–34.0	Galena	Dunleith	Eagle Point	31
	35.4–35.8	Galena	Dunleith	Eagle Point	22
	39.7–40.0	Galena	Dunleith	Beecher	18

The water-level differences at the three well nests, DS4/DS8, DS6/DS7, and T6S/T6D, indicate the potential for downward movement of water through the upper bedrock aquifer. Vertical hydraulic gradients were calculated at well nests DS4/DS8, DS6/DS7, and T6S/T6D during April 1990, November 1992, March 1993, and December 1994 (table 4), using the equation

$$\text{vertical hydraulic gradient} = (dh/dl), \qquad (1)$$

where

dh = head of shallow well; head of deep well;

dl = depth to middle of deep well screen; depth to middle of saturated shallow well screen.

Vertical hydraulic gradients for well nest DS4/DS8 are fairly consistent over time. The average vertical gradient from 1990 to 1994 (0.194) for well nest DS4/DS8 was near the 0.216 average obtained by Ecology and Environment, Inc., in 1987 and 1988 (Ecology and Environment, Inc., 1990). Vertical hydraulic gradients for well nest T6S/T6D from 1990 to 1994 were larger during periods of lower water levels; the largest gradient (0.220) occurred in 1990.

Vertical hydraulic gradients at well nest DS6/DS7 show no clear trend over time (table 4). The vertical hydraulic gradient in November 1992 at well nest DS6/DS7 was not calculated because of the anomalous water-level measurement in well DS6. The vertical hydraulic gradient for well nest DS4/DS8, on average, was twice the gradients calculated for well nests DS6/DS7 and T6S/T6D. The difference in gradient between well nest DS4/DS8 and the other two well nests could result from its location on the upland area of the site, near the ground-water divide, or its location in a more highly fractured zone, or both (Ecology and Environment, Inc., 1990).

Horizontal ground-water velocity was calculated using the equation

$$V = (K/n) \times (dh/dl), \qquad (2)$$

where

K = horizontal hydraulic conductivity, in feet per day;

n = effective porosity, in percent;

dh = change in altitude of water level between data points along the flow path, in feet;

dl = distance between data points along the flow path, in feet.

Water-level data from table 1, horizontal hydraulic conductivities from table 2, porosity data from table 3, and horizontal distances measured off the water-table maps in figures 8–11 were used to calculate horizontal velocities using equation 2. Velocity values for March 25, 1988, were obtained from a table of calculated horizontal gradients in Ecology and Environment, Inc. (1990).

Calculated horizontal ground-water velocities ranged from 3.5×10^{-2} to 8.8×10^{-2} ft/d (table 5). The lowest value 3.5×10^{-2} ft/d was located in the vicinity of the landfill. The porosity values used in the calculation of values shown in table 5 are total measured porosities and not effective porosity values, which probably would be lower. As a result, the true horizontal ground-water velocities probably are higher than calculated values. Fractures and bedding features, which have not been seen in the available wells, would result in an underestimation of the horizontal velocities. Fractures, bedding-plane surfaces, and karstic features were noted in nearby quarries and through geophysical investigations (Ecology and Environment, Inc., 1986; Ecology and Environment, Inc., 1990).

Table 4. Vertical hydraulic gradients at a waste-disposal site near Wempletown, Illinois

[a, anomalous water level; data for 1987 and 1988 from Ecology and Environment, Inc., 1990]

Well nest	Vertical hydraulic gradients (foot/foot)								
	Nov. 1987	Dec. 1987	Mar. 1988	Mar. 1988	Apr. 1988	Apr. 1990	Nov. 1992	Mar. 1993	Dec. 1994
DS4/DS8	0.224	0.006	0.221	0.222	0.206	0.195	0.194	0.199	0.190
DS6/DS7	0	.038	.053	.083	.094	.084	a	.098	.131
T6S/T6D	.072	.065	.071	.062	.068	.220	.058	.046	.083

Table 5. Horizontal ground-water gradients and resulting velocities, for selected well pairs, at a waste-disposal site near Wempletown, Illinois

[Horizontal hydraulic gradient values for 03/25/88 from Ecology and Environment, Inc., 1990]

Transect (see figs. 8–11)	Date	Horizontal hydraulic gradient (foot per foot)	Porosity (percent)	Horizontal hydraulic conductivity (feet per day)	Horizontal ground-water velocity (feet per day)
DS9/DS3	03/25/88	3.2×10^{-2}	20	4.0×10^{-1}	6.4×10^{-2}
DS9/DS3	04/05/90	3.6×10^{-2}	20	4.0×10^{-1}	7.2×10^{-2}
DS9/DS3	11/09–10/92	3.1×10^{-2}	20	4.0×10^{-1}	6.2×10^{-2}
DS9/DS3	03/05/93	2.8×10^{-2}	20	4.0×10^{-1}	5.6×10^{-2}
DS9/DS3	12/19/94	3.4×10^{-2}	20	4.0×10^{-1}	6.8×10^{-2}
DS2/DS5	03/25/88	2.7×10^{-2}	16	5.0×10^{-1}	8.4×10^{-2}
DS3/DS5	04/05/90	1.8×10^{-2}	12	5.0×10^{-1}	7.5×10^{-2}
DS3/DS5	11/09–10/92	1.1×10^{-2}	12	5.0×10^{-1}	4.6×10^{-2}
DS3/DS5	03/05/93	2.1×10^{-2}	12	5.0×10^{-1}	8.8×10^{-2}
DS3/DS5	12/19/94	2.1×10^{-2}	12	5.0×10^{-1}	8.8×10^{-2}
DS1/A[1]	04/05/90	2.7×10^{-2}	18	4.5×10^{-1}	6.8×10^{-2}
DS1/B[2]	03/05/93	2.8×10^{-2}	18	4.5×10^{-1}	7.0×10^{-2}
DS1/C[3]	12/19/94	2.9×10^{-2}	18	4.5×10^{-1}	7.2×10^{-2}
T2/T6S	03/25/88	0.8×10^{-2}	23	1.0×10^{-1}	3.5×10^{-2}

[1]70-ft water-table level contour.
[2]85-ft water-table level contour.
[3]80-ft water-table level contour.

SUMMARY AND CONCLUSIONS

A geohydrologic investigation of the upper part of the Galena-Platteville aquifer at a waste-disposal site near Wempletown, Ill., was completed in December 1994 by the U.S. Geological Survey in cooperation with the U.S. Environmental Protection Agency. The investigation was conducted utilizing geophysical and lithologic logs, single-well aquifer-tests, and water-level data from previous investigations, as well as single-well aquifer test and water-level data collected as part of the present investigation.

The stratigraphy of the upper part of the Galena-Platteville aquifer was identified as the St. James, Beecher, Eagle Point, and Fairplay Members of the Dunleith Formation of the Galena Group. There is some correlation between known fracture locations in the rock core from well T6D and the three-arm-caliper logs in wells T3 and T4. Indications are present from the natural gamma log and spontaneous resistivity log at well T4 that the interface between the top of the Eagle Point and the bottom of the Fairplay is 25 ft below land surface. Natural gamma logs of the remaining monitoring wells on the site would allow for a more thorough understanding of the stratigraphy of the uppermost part of the Galena-Platteville aquifer.

Ground-water-level measurements indicate a generalized flow pattern to the north and west, from the drum-storage area. Porosity data indicate that the chert beds in the Eagle Point Member have a higher porosity than the dolomite.

Horizontal hydraulic conductivities of the Galena-Platteville aquifer underlying the site ranged from 1.0×10^{-2} to 1.0×10^{0} ft/d with a mean of 4.0×10^{-1} ft/d; the lowest values were in the vicinity of the landfill. Horizontal hydraulic conductivities for the Galena-Platteville aquifer at the wells on the site are within an order of magnitude. Calculated horizontal ground-water velocities ranged from 3.5×10^{-2} to 8.8×10^{-2} ft/d. The lowest value (3.5×10^{-2} ft/d) was calculated at a well in the vicinity of the landfill.

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