HYDROGEOLOGY AND LEACHATE MOVEMENT NEAR TWO CHEMICAL-WASTE SITES IN OSWEGO COUNTY, NEW YORK

By Henry R. Anderson and Todd S. Miller

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CONVERSION FACTORS AND ABBREVIATIONS

Factors for converting the inch-pound units used in this report to International System of units (SI) are shown below.

Multiply Inch-Pound Unit	By	To Obtain SI Unit
foot (ft)	0.3048	meter (m)
yard (yd)	0.914	meter (m)
mile (mi)	1.609	kilometer (km)
acre	0.004	square kilometer (km2)
square mile (mi2)	2.590	square kilometer (km2)
gallon per minute (gal/min)	0.0038	cubic meter per minute (m3/min)
million gallons per day (Mgal/d)	3785.	cubic meter per day (m3/d)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
gallon per day (gal/d)	0.0038	cubic meter per day (m3/d)
foot per day (ft/d)	0.3048	meter per day (m/d)
foot squared per day (ft2/d)	0.0929	meter squared per day (m2/d)
degrees Fahrenheit (°F)	1.8°C + 32	degree Celsius (°C)

Other Abbreviations

micrograms per liter ()g/L)	milligram per liter (mg/L)

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Abstract

Forty-five observation wells and test holes were installed at two chemical-waste-disposal sites in Oswego County to evaluate the hydrogeologic conditions and the rate and direction of leachate migration.

At the site near Oswego, ground water moves northward at an average velocity of 0.4 feet per day (ft/d) through unconsolidated glacial deposits 10 to 40 ft thick and discharges into White Creek and Wine Creek, which border the site and discharge to Lake Ontario. Leaking barrels of chemical wastes have contaminated the ground water within the site, as evidenced by detection of nine "priority pollutant" organic compounds and elevated levels of specific conductance, chloride, and some trace metals (arsenic, lead, and mercury) at wells inside the site but not at wells upgradient or beyond the streams.

At the site near Fulton, a sanitary landfill in which 8,000 barrels of chemical wastes were buried, ground water in the sand and in the sand and gravel aquifer that borders the landfill to the south and east moves southward and eastward at an average velocity of 2.8 ft/d and discharges to Bell Creek (which discharges to the Oswego River) or moves southward beneath the creek. Leachate is migrating to the east, southeast, and southwest of the landfill, as evidenced by elevated values of specific conductance, temperature, and several trace metals in water at wells in these areas.

INTRODUCTION

Large quantities of toxic chemicals were buried or temporarily stored at nine or more sites within Oswego County during 1968-77. The largest known amount of stored chemical waste is at a 46-acre waste-incinerator facility at the eastern edge of the City of Oswego, 1/2 mi south of Lake Ontario (fig. 1). The site began operation in 1969 and, during the next 9 years, incinerated monthly about 1 Mgal of liquid chemical acids, bases, nonchlorinated organic solvents, and organic solids (Scrudato and others, 1980).

In 1974, a chemical spill at the site caused chemicals to overflow from a storage lagoon, flood the site, and flow 1/2 mile north to Lake Ontario. This event, combined with earlier violations of local, State, and Federal regulations, resulted in condemnation of the site. In August 1977, the owners abandoned the facility. Approximately 11,000 fifty-five gallons drums of chemical waste remain stockpiled at the site.

The waste-incinerator facility was equipped to handle liquid waste only. In 1974, approximately 8,000 fifty-five-gallon barrels containing solid waste were transported from the Oswego site and buried at a 70-acre county sanitary landfill near the City of Fulton, 10 miles southwest of the main site (fig. 1). Another 9,000 barrels of chemical waste are at seven other locations in the county.

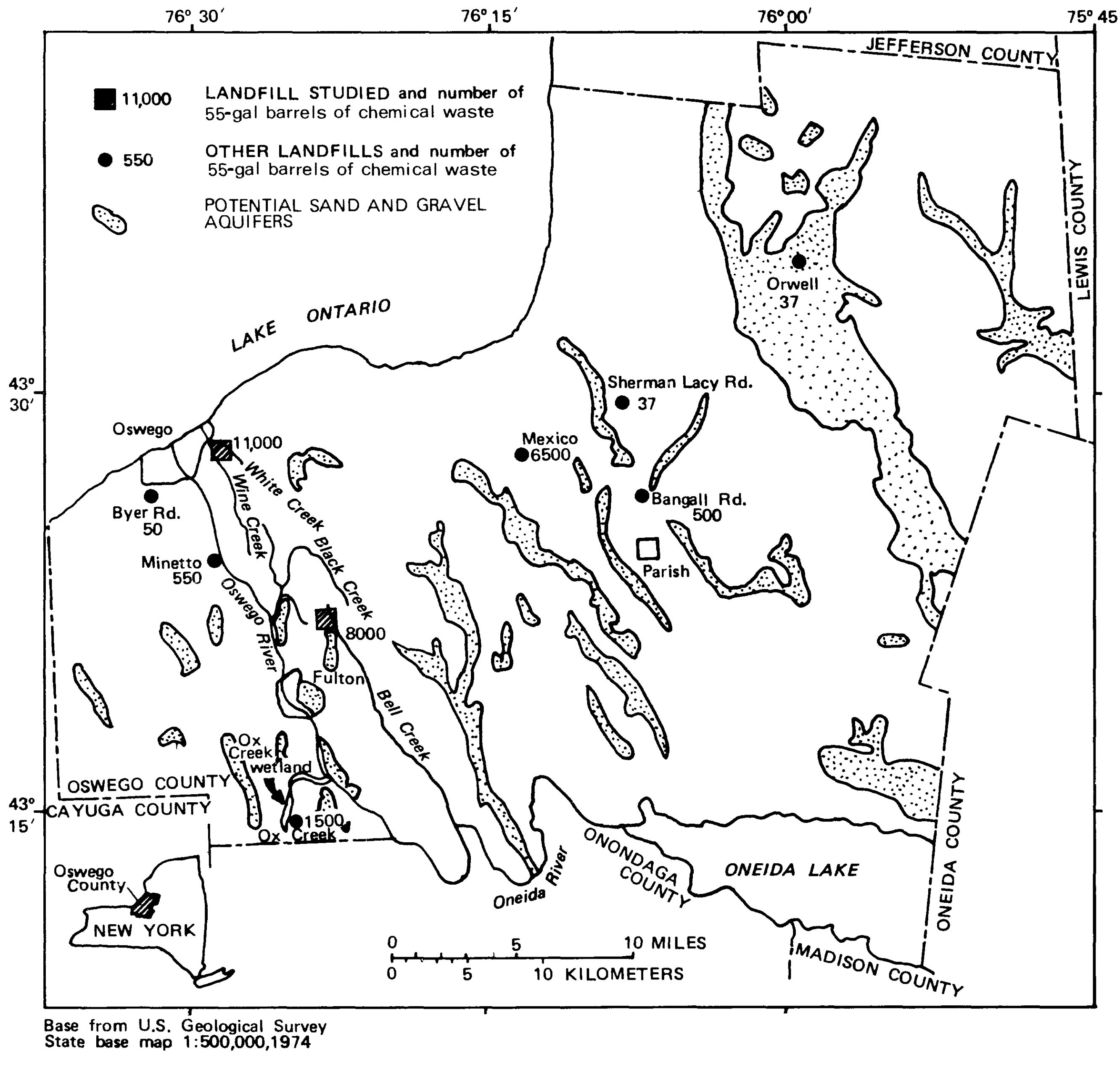

Figure 1.--Location of chemical-waste-disposal sites in relation to sand and gravel deposits in Oswego County. (Modified from Miller, 1982.)

The 28,000 barrels of chemical waste at the nine sites in the county present a threat to the county's water resources and also pose a potential health hazard. Approximately 70 percent of the county's population obtains drinking water from ground-water resources, and the remaining 30 percent from Lake Ontario, to which all water in the county flows.

The U.S. Geological Survey, in cooperation with Oswego County and the State University Research Center at Oswego (SURCO), studied hydrologic conditions and leachate movement at the two disposal sites during 1979-1981.

Purpose and Scope

This report evaluates the potential for contaminant migration from the 19,000 barrels of chemical waste at the two largest chemical-waste-disposal sites in the county. It also presents tables of chemical analyses and a series of maps illustrating the extent of leachate migration from the sites. Maps and cross sections showing geology, temperature, and specific conductance of ground water, and the water-table altitude at the two sites, are included for reference. Suggestions for further sampling at the two sites also are given.

Previous Work

Miller (1980, 1981) mapped and described the surficial geology of this part of Oswego County and indicated the location of the county's major permeable deposits. Scrudato and others (1980) presented a historical review of the waste sites and compiled an inventory of the number of barrels and types of chemical wastes.

Methods

The U.S. Geological Survey mapped the major aquifers, documented the direction and estimated rate of ground-water movement, and measured specific conductance and temperture of ground water. SURCO sampled the ground water and described its chemical character.

A total of 45 test holes and wells were installed, 21 at the waste-incinerator facility near Oswego and 24 at the landfill near Fulton, to obtain hydrogeologic and water-quality information needed to compile maps showing direction of ground-water flow and the extent of leachate migration. At least one well was installed upgradient of each site to evaluate background water quality. Well screens were installed in the most permeable unit encountered during drilling (usually sand, gravel, or artifical fill) because these deposits would be the ready avenues of contaminant migration. If a permeable unit was thick or occurred as several interbedded layers, a set of nested wells was installed at differing depths to detect the vertical extent of contamination.

The basal confining unit at both sites is a till consisting of a very fine sandy, clayey silt matrix with embedded pebbles and cobbles. Wells had a 1-1/4-inch or 2-inch inside diameter and ranged from 5 to 80 ft deep. At most drill sites, a steel well was installed for sampling organic and inorganic compounds, but at some, a polyvinylchloride well was installed for sampling inorganic compounds.

Ground-water samples were collected at 14 wells (7 at each site) and sent to the U.S. Geological Survey laboratory in Atlanta, Ga., for analysis. Five samples from each site were analyzed for 28 of the 129 "priority pollutants" (Keith and Telliard, 1979) of the U.S. Environmental Protection Agency, and two other samples from both sites were analyzed for several trace metals and two for halogens. Sampling locations were chosen to provide data on ground water both upgradient and downgradient of the waste sites. Specific conductance and temperature were measured quarterly to document seasonal variations and to serve as indicators of leachate migration.

Before sample collection, at least three volumes of water in the well casing were removed to ensure that the water sampled was from the aquifer and not water that had been standing in the casing. A peristalic pump with Tygon[1] tubing was used to pump the wells and collect the samples.

Acknowledgments

The project was done with the assistance of of Dr. Ronald Scrudato of the State University Research Center (SURCO) at Oswego, N.Y. SURCO was instrumental in planning and organizing the project and assisted in obtaining equipment and collecting and analyzing water samples.

REGIONAL HYDROGEOLOGY

Bedrock

Bedrock in Oswego County is almost entirely covered by glacial deposits but is exposed locally in some stream channels and quarries. Distribution of the major units in Oswego County is depicted in figure 2. The area studied is underlain by sedimentary-rock units of Ordovician and Silurian age. The Oswego Sandstone crops out beneath the waste-incinerator facility site near Oswego; the Queenston Formation and Medina Sandstone Group crops out beneath the landfill near Fulton (fig. 2).

Bedrock typically yields larger quantities of ground water than till, clay, or silt, but lesser quantities than sand and gravel. Although the intergranular pore spaces are mostly filled with cement, fracturing increases effective porosity to approximately 5 percent. Where water is confined under artesian pressure, water levels in wells tapping bedrock may rise above the land surface. The median yield of drilled wells tapping the local sandstone is 10 gal/min and ranges locally from 0.5 to 125 gal/min (Kantrowitz, 1970).

On a regional basis, ground water in the bedrock flows northward, against southward dip of the beds, and discharges into Lake Ontario (Kantrowitz, 1970). In recharge areas south of Lake Ontario, ground water flows downward, dissolving salts from deeper marine deposits, and becomes mixed with entrapped brackish water and brine. Thus, ground water below 100 ft in depth in Oswego County generally is brackish.

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1 Use of brand names is for indentification only and does not imply endorsement by the U.S. Geological Survey.

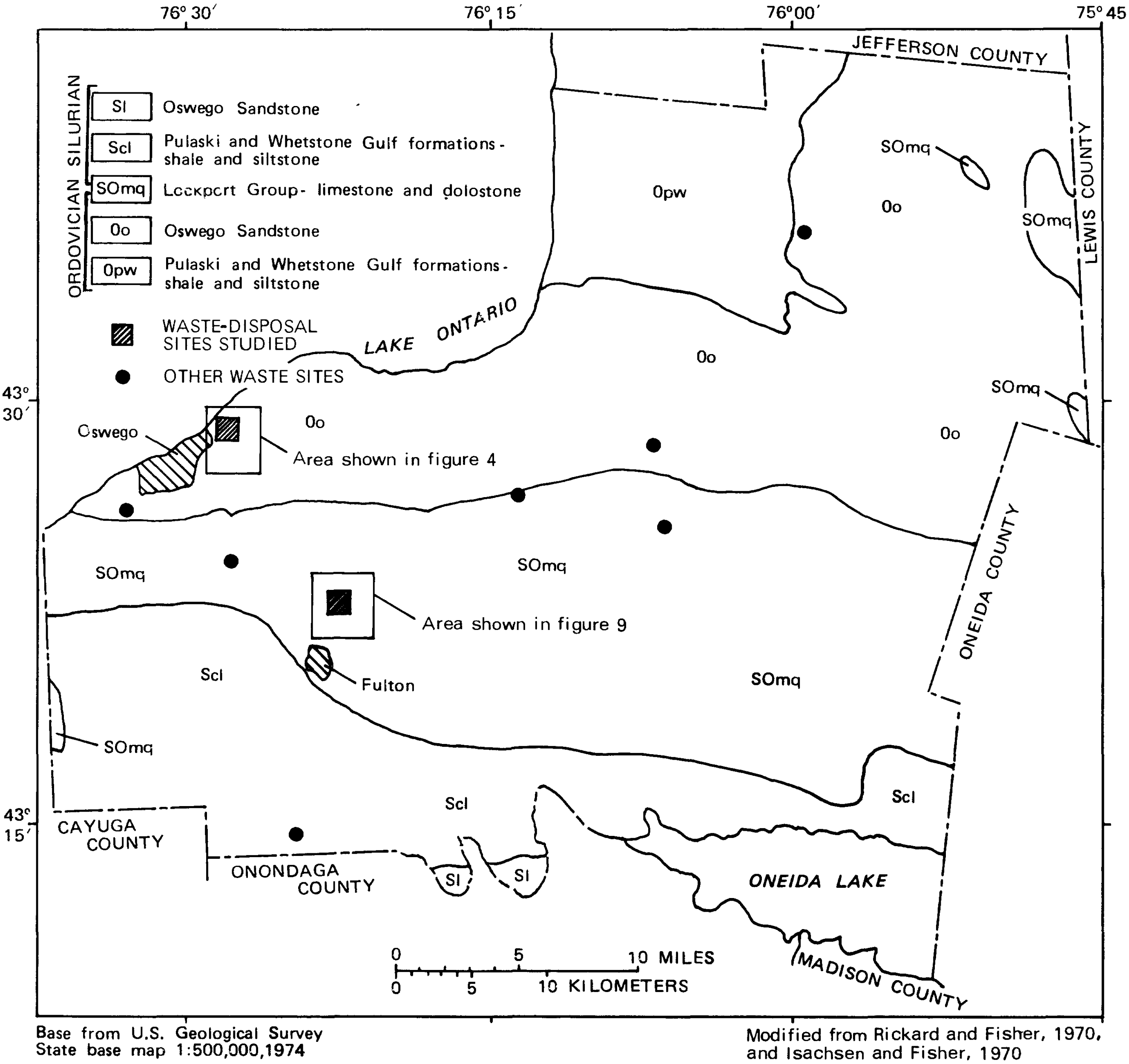


Figure 2.--Bedrock geology of Oswego County. (Modified from Isachsen and Fisher, 1970.)

Unconsolidated Deposits

The unconsolidated materials overlying bedrock in Oswego County consist of glacial and swamp deposits. The two chemical-waste sites studied are within a drumlin field that covers much of north-central New York. The lower flanks of drumlins and the interdrumlin areas are overlain with relatively impermeable lake deposits consisting of fine sand, silt, and clay. Sporadic patches of ablation till and sand and gravel, deposited as kames or by glacial-lake wave action, are present throughout the drumlin field. Some of these sand and gravel deposits are potential ground-water sources. The distribution of surficial unconsolidated deposits is shown in figure 3; the location of the chemical-waste sites in relation to sand and gravel deposits is depicted in figure 1.

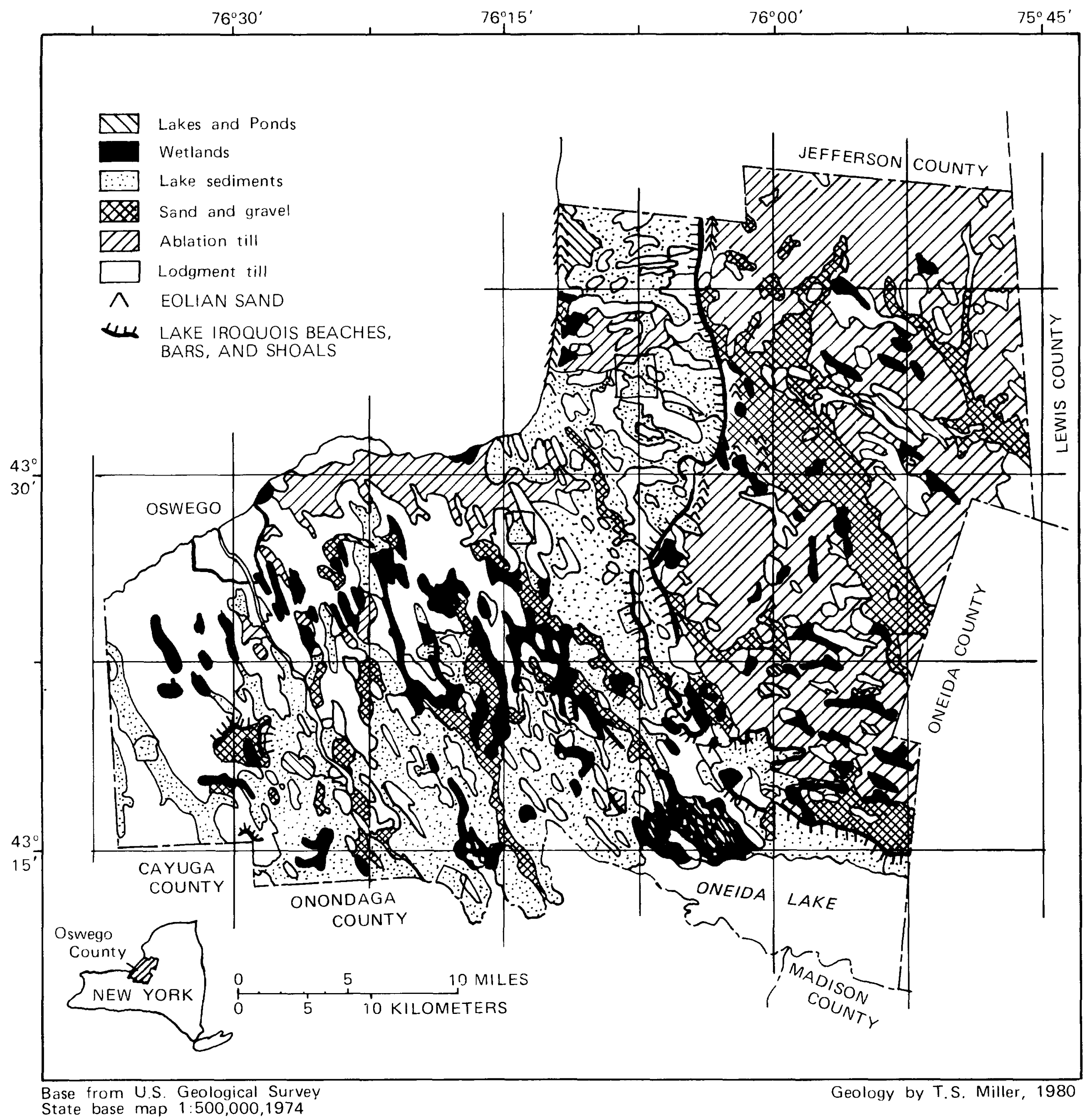


Figure 3.--Surficial geology of Oswego County. (Modified from Miller, 1982.)

Lodgment Till

Lodgment till is a poorly sorted, dense, clay to boulder material compacted upon the bedrock surface by glaciers. In the vicinity of the chemical-waste sites studied, lodgment till forms elliptical, streamlined hills called drumlins that are aligned parallel to the direction of glacier movement and range in thickness from 5 ft to more than 150 ft. Lodgment till in some areas is covered by more permeable deposits, including ablation till or sand and gravel. The lower flanks of drumlins and interdrumlin areas are commonly covered with lake or swamp deposits.

Lodgment till is relatively impermeable and is therefore a poor aquifer; however, it yields sufficient water for domestic and small-farm use through large-diameter dug wells.

Ablation Till

Ablation till was deposited by stagnant melting glaciers as loosely unconsolidated clay, silt, and large boulders. It forms irregular knobby hills that parallel former glacier margins and typically overlies lodgment till or bedrock. Ablation till is coarser, less consolidated, and slightly more permeable than lodgment till but less permeable than sand or gravel.

Lake Deposits

Lake sediments consisting of relatively impermeable very fine sand, silt, and clay were deposited in an ice-impounded lake (Lake Iroquois) that inundated most of western and central Oswego County. Most deposits are less than 50 ft thick and occur mostly along the lower flanks of drumlins, within interdrumlin areas, and offshore from former beaches. Lake deposits of well-sorted fine sand have moderate aquifer potential.

Sand and Gravel

Stratified sand and gravel deposits are the most productive aquifers in Oswego County. They were deposited by glacial meltwater in fast-moving streams and by wave action that formed beaches of glacial lakes. Most sand and gravel deposits overlie lodgment till, but in the interdrumlin areas they may be buried beneath lake deposits. Sand and gravel deposits in central and western Oswego County typically cover less than 1 mi^2 and are less than 80 ft thick.

Sand and gravel is highly permeable and porous. Where deposits are at land surface, the ground water may be unconfined, but where the deposits are buried beneath lacustrine silt and clay, the ground water may be confined and under artesian pressure. Porosity ranges from 25 to 50 percent. Well yields from these deposits are controlled by the size of the recharge area and the recharge rate. Yields are greatest where the aquifers are hydraulically connected to surface-water sources, where pumping induces recharge from the stream or lake. In Oswego County, yields to wells from such deposits may provide 100 to 1,000 gal/min.

GROUND-WATER CONDITIONS AND LEACHATE MOVEMENT AT SITE NEAR OSWEGO

This waste-incinerator-facility site is a 46-acre area on the northeastern edge of the city of Oswego at the confluence of White Creek with Wine Creek, the latter of which flows 1/2 mi north to Lake Ontario (fig. 1). Approximately 11,000 barrels of chemical wastes were abandoned at the site in 1977. A list of chemicals received by the facility for disposal is given in table 1. Although the disposal facility was designed to receive liquid waste only; another 8,000 barrels of reportedly solid waste were received and then sent from this site to the landfill near Fulton for disposal in 1974.

Table 1.--Chemical compounds received at chemical-waste site near Oswego, 1969-77

[Data from Scrudato and others, 1980.]

Elements	Organic compounds
Lead	Methylene chloride (dichloromethane)
Arsenic	Benzene
Cadmium	Toluene
Bromine	o-Xylene (dimethylbenzene)
Sulfur	Chloroform
Aluminum	Ethanol
Chlorine	MEK (2-butanone)
Chromium	DMF (dimethylfuran)
Copper	Methanol
Iodine	Butanol
Iron	Xylenol (1,2-dimethyl-3-hydroxybenzene)
Mercury	Glycerine (propanetriol)
Nickel	Methylchloroform
Silicon	DMA (dimethylaniline)
	Acetaldehyde
	Pyridine
Inorganic compounds	PCB's (polychlorinated biphenyls)
	Chlorinated pesticides
Sodium hydroxide	Acrylonitrile (vinyl cyanide)
Ammonium chloride	Bromoform
	Styrene
	Phenol
	Formaldehyde (from methanol)
	Nitrobenzene
	Chloronitrobenzene
	2-thiourea (H_2NCSNH_2)
	Oleic acid (cis-9-octadecanoic acid)
	Allyl alcohol (2-propen-1-ol)
	Butyl carbitol (diethyleneglycol monobutyl ether)

Hydrogeology and Ground-Water Conditions

The site lies on fill that is underlain by 2 to 14 ft of glacial-lake deposits consisting of silt and clay on the west side, and sand and silt on the east, as shown on the surficial geologic map in figure 4. Ablation and

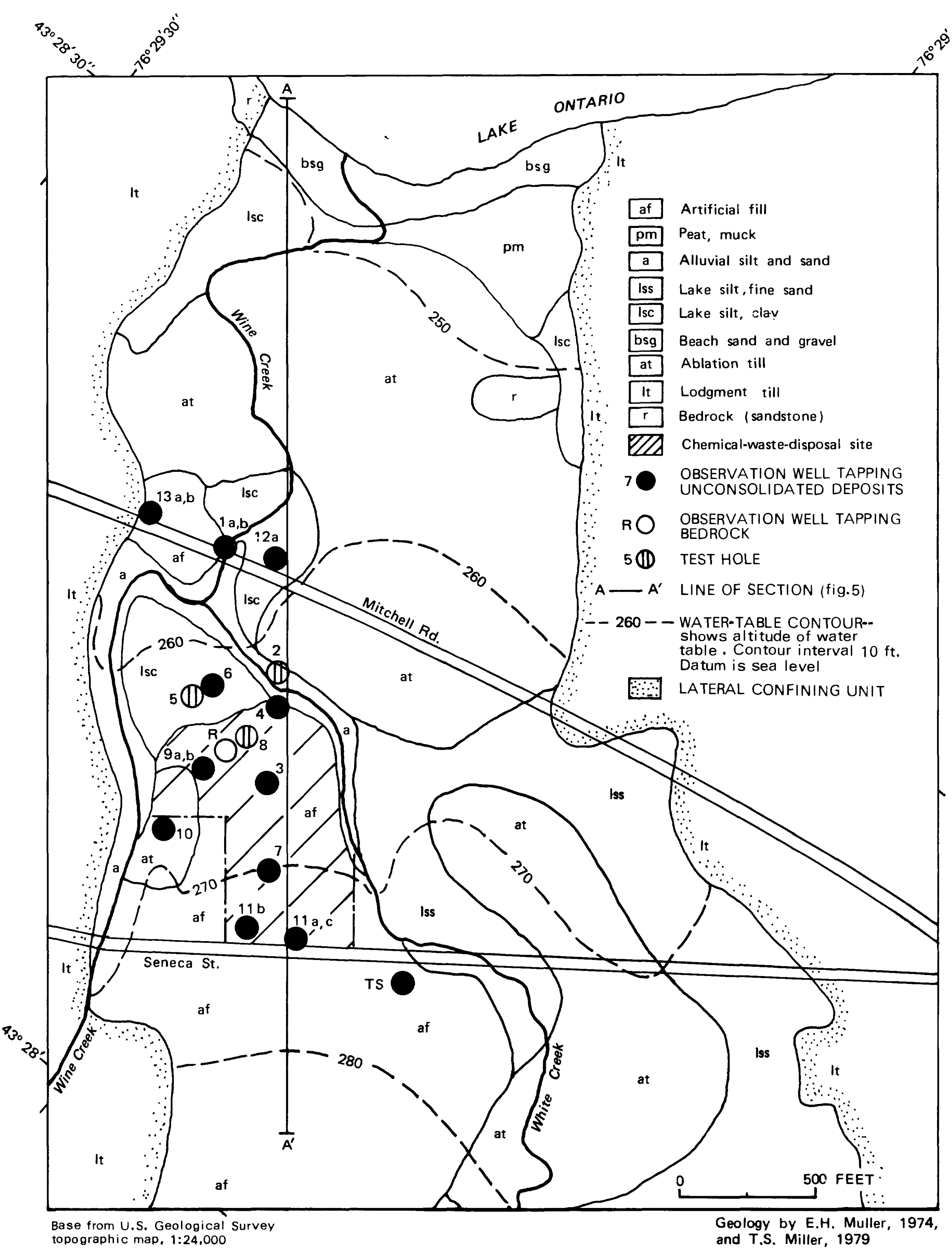


Figure 4.--Surficial geology, location of observation wells and test holes and 1980 water-table contours in vicinity of chemical-waste-disposal site near Oswego. (Location is shown in fig. 2.)

lodgment tills underlie the lake deposits to depths as great as 40 ft. Bedrock underlies the till, which at places reaches depths of 40 ft but in most places reaches only 20 to 25 ft, as indicated in the geologic section in figure 5. The glacial deposits at the site, whether lake silt, clay, fine sand, ablation till, or lodgment till, are relatively impermeable.

One well was installed southeast of the site to measure water levels and obtain water samples upgradient from the site (well TS, fig 4). Three pairs of wells (1a, 1b; 12a, 12b; 13a, 13b in fig. 4) were installed downgradient from the site and on the opposite side of the two streams to detect contamination extending beyond the streams. Eleven wells (3, 4, 6, 7, 9a, 9b, 10, 11a, 11b, 11c, R) were installed in the waste-storage area to measure water levels, define stratigraphy, and identify the extent of contaminant migration. Water levels were measured in all wells quarterly to obtain data for a water-table map (fig. 4) and plot the direction in which ground water moves. Records of wells and test holes are in table 8 (at end of report).

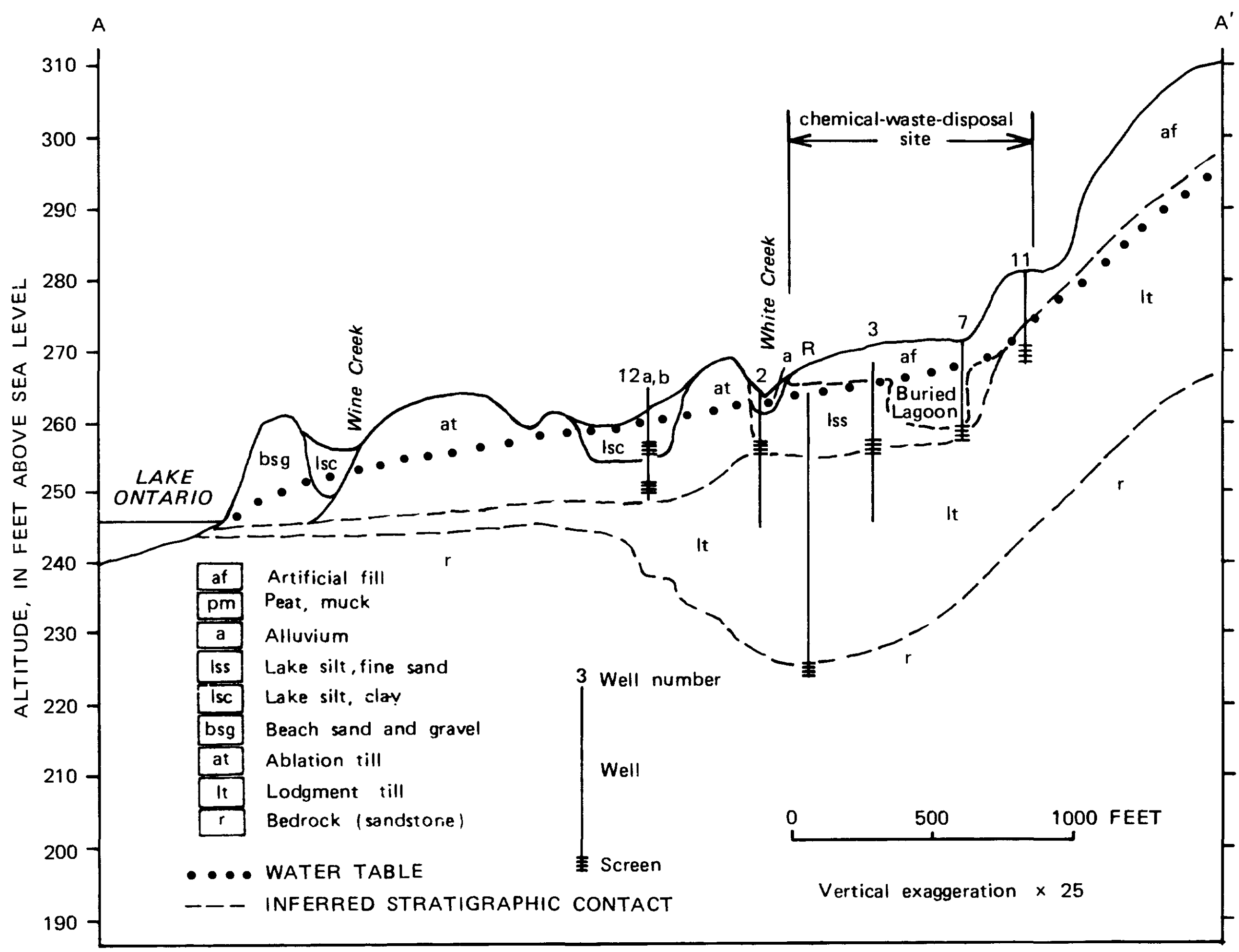


Figure 5.--Geologic section A-A' through vicinity of chemical-waste-disposal site near Oswego. (Location of section is shown in fig. 4.)

Water levels in wells indicate that ground water moves northward toward Lake Ontario (fig. 4). Water in the shallow ground-water system discharges directly to White Creek and Wine Creek; water in the deeper zones, particularly the upper fractured zone of the bedrock, may flow beneath Wine Creek and ultimately seeps into Lake Ontario.

Permeability

Brief pumping tests at four wells tapping till and bedrock indicate a relatively low permeability ranging from 0.06 to 7.5 ft/d. The permeability values and calculated rates of ground-water flow through the various units are given in table 2. Values are based on a water-table gradient of 0.013 ft/ft, determined from measured water levels and, for till, an estimated porosity of 0.30, which is typical of till (Freeze and Cherry, 1979). All flow rates are less than 1 ft/d. The highest rate (0.32 ft/d) is in the upper bedrock zone. At this flow rate, ground water would take approximately 21 years to migrate the 2,500 ft from the site to Lake Ontario.

Table 2.--Results of permeability tests at chemical waste-disposal site near Oswego
[Well locations are shown in fig. 4.]

Well no.	Geologic unit	Type of test	Transmissivity (ft^2/d)	Permeability (ft/d)	Calculated ground-water flow rate (ft/d)
11a	Lodgment till	Slug removal	0.164	0.1	0.004
13a	Till and sandstone	Slug injection	10.0	5.0	.22
12b	Ablation till	Slug removal	13.0	4.3	.19
R	Sandstone bedrock	Theis recovery[1]	15.2	7.5	.32

[1] Described in Lohman, 1979.

Specific Conductance of Ground Water

Specific conductance of water is roughly proportional to the concentration of dissolved salts in the water. Leachates normally contain higher concentrations of salts than native ground water; therefore, increased specific conductance may indicate presence of leachate. Specific conductance was measured in the field from samples collected at 15 wells (1a, 1b, 3, 7, 9a, 10, 11a, 11b, 11c, 12a, 12b, 13a, 13b, TS, R) quarterly throughout 1980 to discern whether leachate from the site had entered shallow and deep ground water. Lines of equal specific conductance at the site are shown in figure 6.

Specific conductance of ground water in unconsolidated deposits within the site ranged from 1,000 to 5,000 μmho/cm, whereas conductance at wells downgradient (north) ranged from 500 to 2,200 μmho/cm.

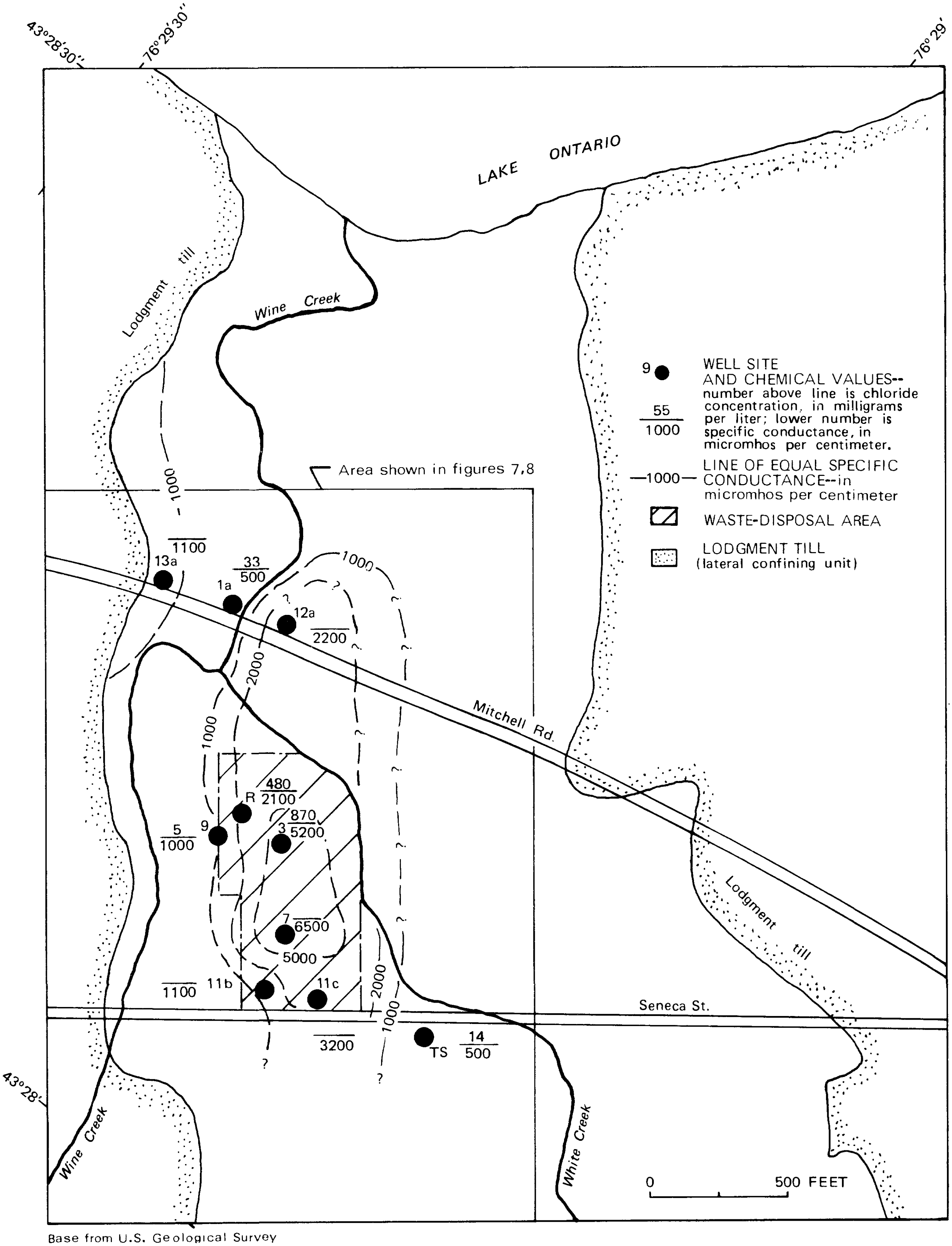


Figure 6.--Specific conductance of ground water in vicinity of chemical-waste-disposal site near Oswego, August 1980. (Location is shown in fig. 2.)

Chemical Quality

In August 1980, SURCO collected ground-water samples from seven wells (six in unconsolidated deposits and one in bedrock). Two samples--one from well TS and one from well 12a--were analyzed for chloride, bromide, arsenic, lead, mercury, and zinc. Samples from the other five wells (1a, 3, 7, 9a, and R) were analyzed for the same constituents and for 28 volatile organic compounds on the Environmental Protection Agency list of 129 "priority pollutants" (tables 3 and 4).

Table 3.--Concentrations of selected halogens and trace metals in water from observation wells at the chemical-waste facility near Oswego.

[Analyses by U.S. Geological Survey, Atlanta, Ga. Numbers in parentheses indicate maximum recommended concentration for drinking water (U.S. Public Health Service, 1962). Underlined values exceed Federal drinking-water standards. Dashes indicate no standard exists. Well locations are shown in fig. 8.]

Well no.	Type of casing[1]	Screen depth below land surface (ft)	Halogens (mg/L) total		Trace metals (µg/L) total		
			Chloride (250)	Bromide (--)	Arsenic (50)	Lead (50)	Mercury (2)
Offsite wells							
TS	S	6	14	0.1	3	160	0.6
Onsite wells							
7	S	14	6,500	0.9	24	3,800	4.5
3	S	13	870	6.3	24	52	15
9a	S	16	51	0.6	3	8	0.1
R	S	41	480	1.1	20	5	0.2
12a	P	8	--	0.3	6	92	0.2
1a	S	10	33	0.6	17	64	2.3

1 S, steel; P, PVC.

Halogens.--High chloride concentration is a common indicator of leachate in areas of landfills and chemical-waste sites. Bromide was analyzed to discern whether the chloride was from the chemical waste or from upward-moving brackish water discharging from bedrock. (Bromide in natural waters is associated with brine and evaporite deposits and, like chlorides, is concentrated in sea water.) Brines generally contain more than 100 mg/L bromide; sea water contains 65 mg/L (Hem, 1970). Uncontaminated ground water generally contains only trace amounts.

Bromide concentrations in shallow ground-water samples from the site contained from 0.1 to 6.3 mg/L, with a median of 0.6 mg/L (table 3). The higher concentration of 6.3 mg/L within the site at well 3 probably reflects contamination from the chemical wastes, and not brine from bedrock, because the bromide concentration at the bedrock well (R) was only 1.1 mg/L.

Chloride concentrations in ground water in glacial deposits in Oswego County are typically less than 100 mg/L. Within the chemical-waste site near Oswego, however, chloride concentrations ranged from 14 to 6,500 mg/L (fig. 6). High concentrations within the site (6,500, 870, and 480 mg/L at wells 7, 3, and R, respectively (table 3 and fig. 6), suggest contamination. Concentrations at wells TS and 1a, above and below the site, were 14 and 33 mg/L, respectively (fig. 6).

Trace Metals.--Seven ground-water samples from test wells within and outside the site were analyzed for arsenic, lead, and mercury. Results are depicted in figure 7 and are given in table 3 along with the U.S. Public Health Service drinking-water standards.

Lead concentration exceeded the 50-μg/L limit both inside and outside the site in five of the seven wells sampled; these were well TS (upgradient from the site but downgradient from an old landfill), wells 7 and 3 (inside the site), and wells 12a and 1a (downgradient from the site). Mercury exceeded the 2-μg/L limit in well 3 (inside the site) and in well 1a (downgradient). Arsenic was below the 50-μg/L limit at all seven wells.

Whether the relatively high concentrations of trace metals in some of the wells are derived entirely from this site is uncertain. For example, the high lead concentrations downgradient from the site in wells 1a and 12a may be due to auto emissions along Mitchell Road (fig. 7), overflow from the site's waste lagoon in 1974, or fly-ash fill material (which commonly contains heavy metals) under Mitchell Road. Well 1a is screened in fly ash that was used as road fill. The highest concentrations of trace metals were detected at wells within the confines of White and Wine Creeks and are probably derived from leaking barrels. Some trace metals may be contributed from the old landfill south of Seneca Street (fig. 4).

Organic Compounds.--According to site records, more than 30 organic chemicals were handled at the disposal facility during 1968-77 (Scrudato and others, 1980). Ten of these have been classified among U.S. Environmental Protection Agency's "priority pollutants" (Keith and Telliard, 1979) for which the U.S. Geological Survey performed analyses. Samples from four test wells within the site (table 4) contained nine of the 10 "priority pollutants"; these included benzene, chloroform, polychlorinated biphenyls (PCB's), phenol, 1,2 trans-dichloroethylene, methylene chloride, toluene, 1,1,1 trichloroethane, and trichloroethylene. (The concentrations at several wells are shown in fig. 8.) In addition, some alcohols and carboxylic acids were detected in the four wells within the site. A list of the 18 "priority pollutants" analyzed for but not detected is given in table 5. No organic compounds were detected in well 1a on the other side of the streams.

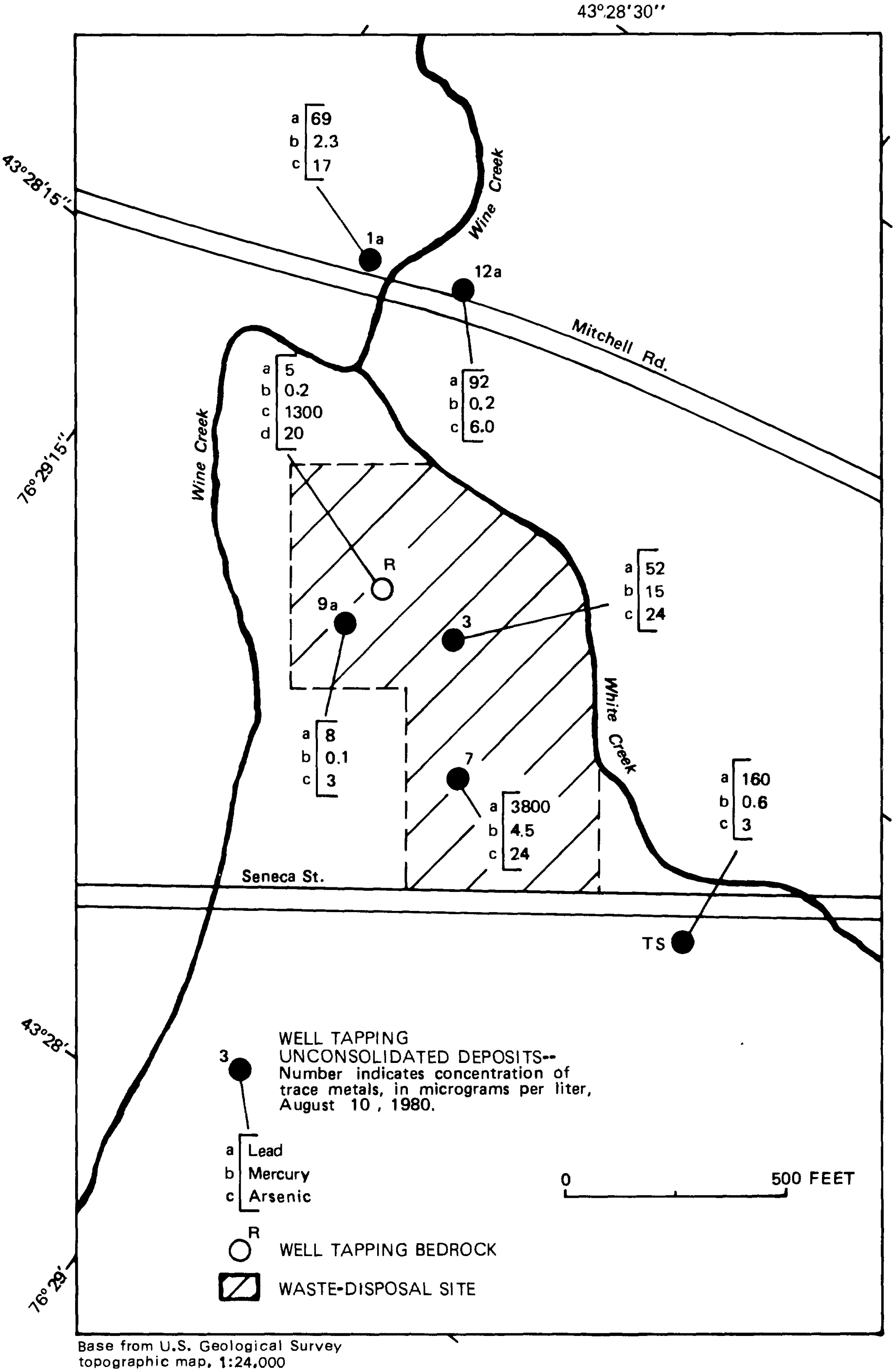


Figure 7.--Concentration of lead, mercury, and arsenic in ground water in vicinity of chemical-waste-disposal site near Oswego, August 1980. (Analyses by U.S. Geological Survey, Atlanta, Ga.; additional data are given in table 3. Location is shown in fig. 6.)

Table 4.--Chemical analyses for selected organic compounds in ground water from vicinity of chemical waste-disposal site near Oswego, N.Y., August 1980

[Analyses by U.S. Geological Survey, Atlanta, Ga. Concentrations are in total micrograms per liter (μg/L). Dashes indicate compound not tested for. <, less than. Well locations are shown in fig. 4.]

Well no.[1]	Screen depth below land surface (ft)	Benzene	Chloroform	Methylene chloride	PCB	Phenol	Toluene	1,2-trans-dichloroethylene	1,1,1-Trichloroethane	Trichloroethylene	Remarks
1a	10	<3.0	<3.0	<3.0	<0.1	--	<3.0	<3.0	<3.0	<3.0	--
3	13	<3.0	2,240	265,000	0.1	--	37,200	<3.0	6,850	13,200	Also contains numerous alcohols and several carboxylic acids.
7	14	<3.0	<3.0	5,000	<0.1	7	<3.0	<3.0	<3.0	160	Also some alcohols and carboxylic acids.
9a	16	<3.0	<3.0	<3.0	<0.1	2	400	<3.0	<3.0	--	Sample is one third alcohol and carboxylic acids by volume. Extremely reactive. Requires macroanalyis.
R	41	150	360	34,000	<0.1	8,250	<3.0	1,500	880	500	Contains several alcohols and carboxylic acids.

[1] All well casings are steel.

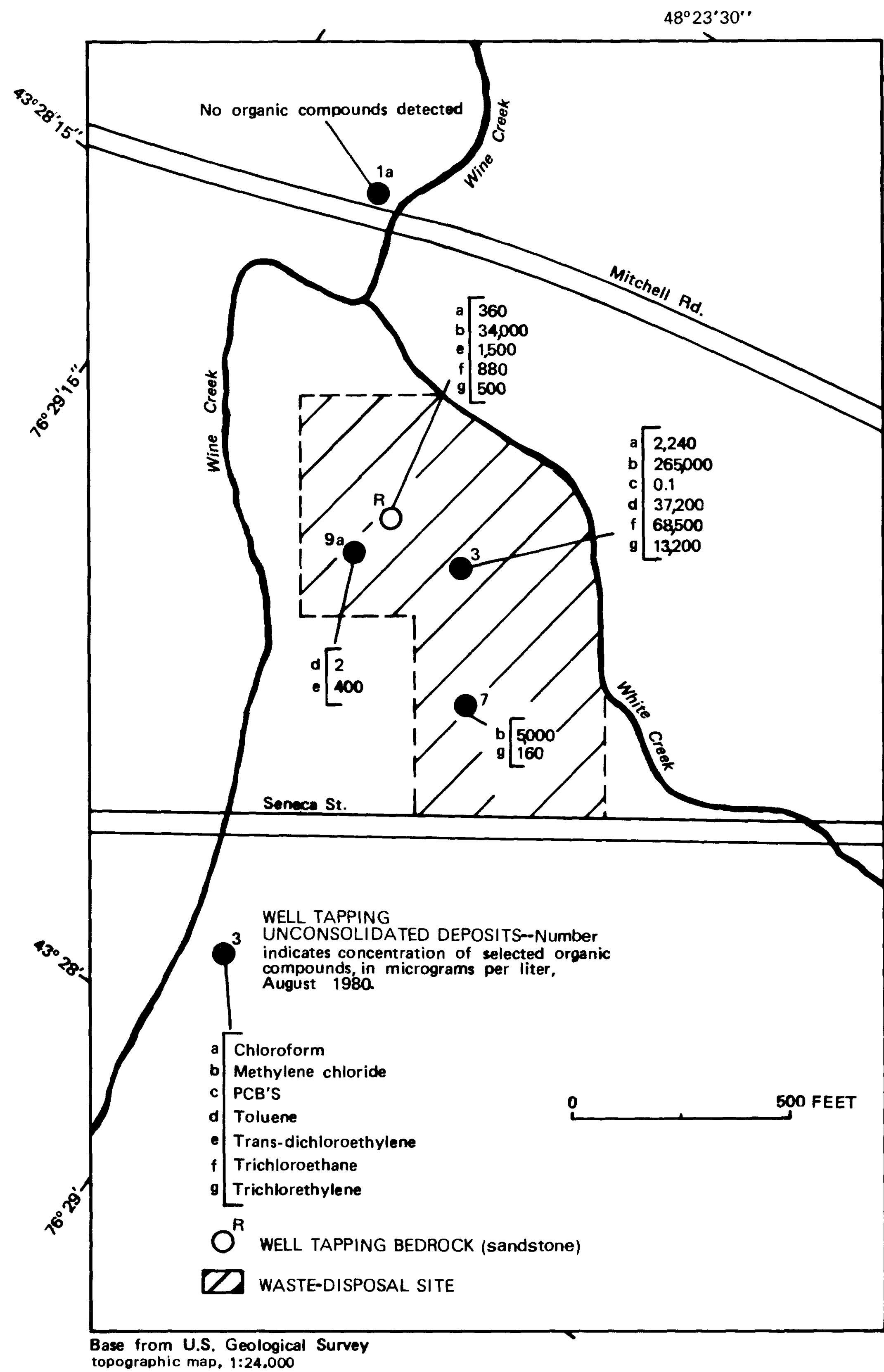


Figure 8.--Concentration of selected organic compounds in ground water in vicinity of chemical-waste-disposal site near Oswego, August 1980. (Analyses by U.S. Geological Survey, Atlanta, Ga.; additional data are given in table 4. Location is shown in fig. 6.)

Table 5.--Volatile organic "priority pollutants" tested for but not detected in ground-water samples from vicinity of chemical-waste-disposal site near Oswego, N.Y.

[Analyses by U.S. Geological Survey, Atlanta, Ga.]

Bromoform	Trichlorofluoroethane
Carbon tetrachloride	Vinyl chloride
Chlorobenzene	1,1-Dichloroethane
Chlorodibromomethane	1,1-Dichloroethylene
Chloroethane	1,2-Dichloroethane
Chlorodibromomethane	1,2-Dichloropropane
Ethylbenzene	1,3-Dichloropropane
Methylbromide	1,1,2,2-Tetrachloroethane
Tetrachloroethylene	2-Chloroethylvinyl ether

Movement of Leachate

Water levels indicate that ground water within the site moves northward toward White Creek and Wine Creek (fig. 4). The four wells inside the site contained organic and some inorganic contaminants, including well R, which taps bedrock, but the well downgradient and on the opposite side of White Creek (well 1a) did not contain organics (table 4). A conservative soluble contaminant would take about 3 years to move 500 ft to reach well 1a; insoluble and reactive contaminants may take longer. This estimate is made from the following formula, based on a median hydraulic conductivity of 4.32 ft/d, obtained from the permeability tests:

$$\text{velocity (ft/d)} = \frac{\text{hydraulic conductivity (ft/d)} \times \text{water-table gradient(ft/ft)}}{\text{porosity (dimensionless)}}$$

$$= \frac{4.32 \times 13/1000}{0.30}$$

$$v = 0.19 \text{ ft/d}$$

Thus, time needed for a soluble contaminant to reach Mitchell Road would be

$$\frac{500 \text{ ft}}{0.19} = 2{,}632 \text{ days, or } 7.2 \text{ years.}$$

The northward flow of ground water and the absence of organic compounds in well 1a (located north of White Creek and Wine Creek) suggest that leachate in the unconsolidated deposits discharges into White Creek and Wine Creek. Although the leachate would be diluted by streamflow, future analysis of stream samples should indicate whether leachate is entering these creeks.

The well tapping bedrock within the site (well R) was found to contain organic chemical contamination (table 4). More sampling of bedrock wells would be needed to determine whether contaminants have seeped into the bedrock flow system, were introduced during drilling, or are derived from the landfill upgradient (south of the site).

Results of the chemical analyses indicate that contamination within the site is derived from chemicals leaking from barrels and from spills of a former lagoon. Ground water moving from the abandoned landfill several hundred feet south of the site (fig. 4) may also be contributing some contaminants to the site. Ground water in the upper layer of unconsolidated deposits discharges to Wine Creek and White Creek and from there to Lake Ontario. Water from a well tapping the upper bedrock was found to contain several organic compounds, but otherwise, little data are available to indicate the depth to which contaminants have migrated.

GROUND-WATER CONDITIONS AND LEACHATE MOVEMENT AT LANDFILL NEAR FULTON

The second largest chemical-waste site in Oswego County is a sanitary landfill that occupies about 70 acres about 2 miles northeast of Fulton (fig. 1). The chemical-disposal facility near Oswego was designed to handle only liquid waste; therefore, in 1974, approximately 8,000 barrels of reportedly solid chemical wastes were sent to the landfill near Fulton for disposal. The barrels were reportedly buried at a depth of 20 ft.

Hydrogeology and Ground-Water Conditions

This landfill is on top of a north-south-trending drumlin that is covered by a veneer of sand and gravel. The drumlin forms a drainage divide between two watersheds, one that drains southeast to Bell Creek, the other northwest to Black Creek (fig. 9). Both creeks flow into the Oswego River, which in turn flows northwestward about 7 mi to Lake Ontario (fig. 1). The landfill is adjacent to and upgradient from a sand and gravel aquifer on the south and east (fig. 10). Most of the landfill is in the catchment area of Bell Creek.

The eastern part of the landfill is excavated in permeable sand and gravel deposits 10 to 50 ft thick that flank the east side of the drumlin. Only the lower part of the sand and gravel is saturated, however, as indicated in sections A-A' and B-B' (fig. 11). The central and western parts of the landfill are excavated into the top of the drumlin, which is composed of lodgment till. The 10-ft-thick layer of sand and gravel that covered the central and western part of the landfill was removed and mixed with till for use as cover material. The saturated sand and gravel adjacent to the landfill is less than 10 ft thick but increases southward to a thickness of about 20 ft (section C-C', fig, 11).

Water levels in observation wells indicate that the direction of ground-water flow in the sand and gravel (fig. 9) is controlled by the relatively impermeable till of the drumlin surface that forms the base of the sand and gravel aquifer. Precipitation that infiltrates the landfill generates

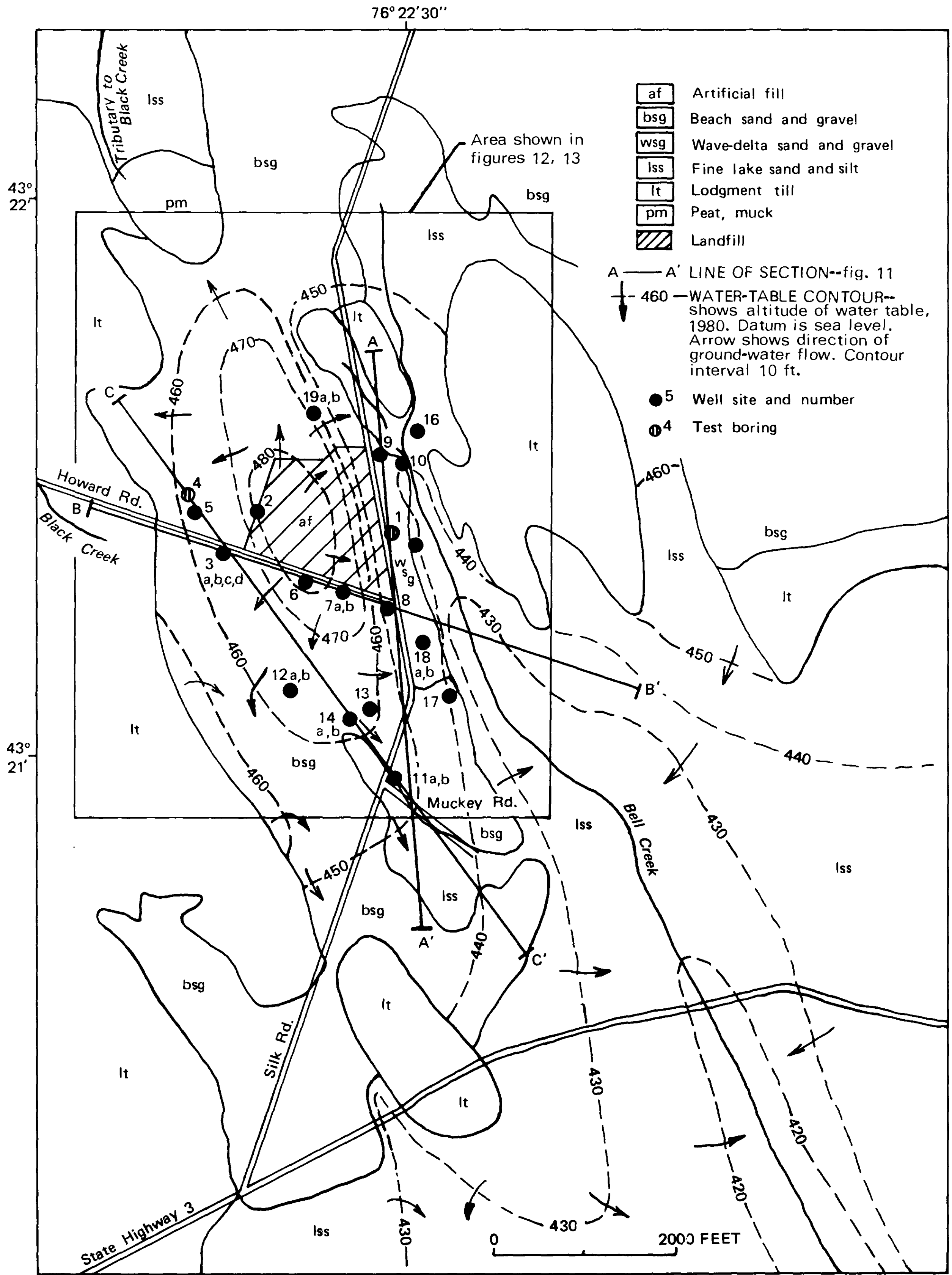


Figure 9.--Surficial geology, location of observation wells and test holes, and water-table contours in vicinity of landfill near Fulton 1980. (Location is shown in fig. 2.)

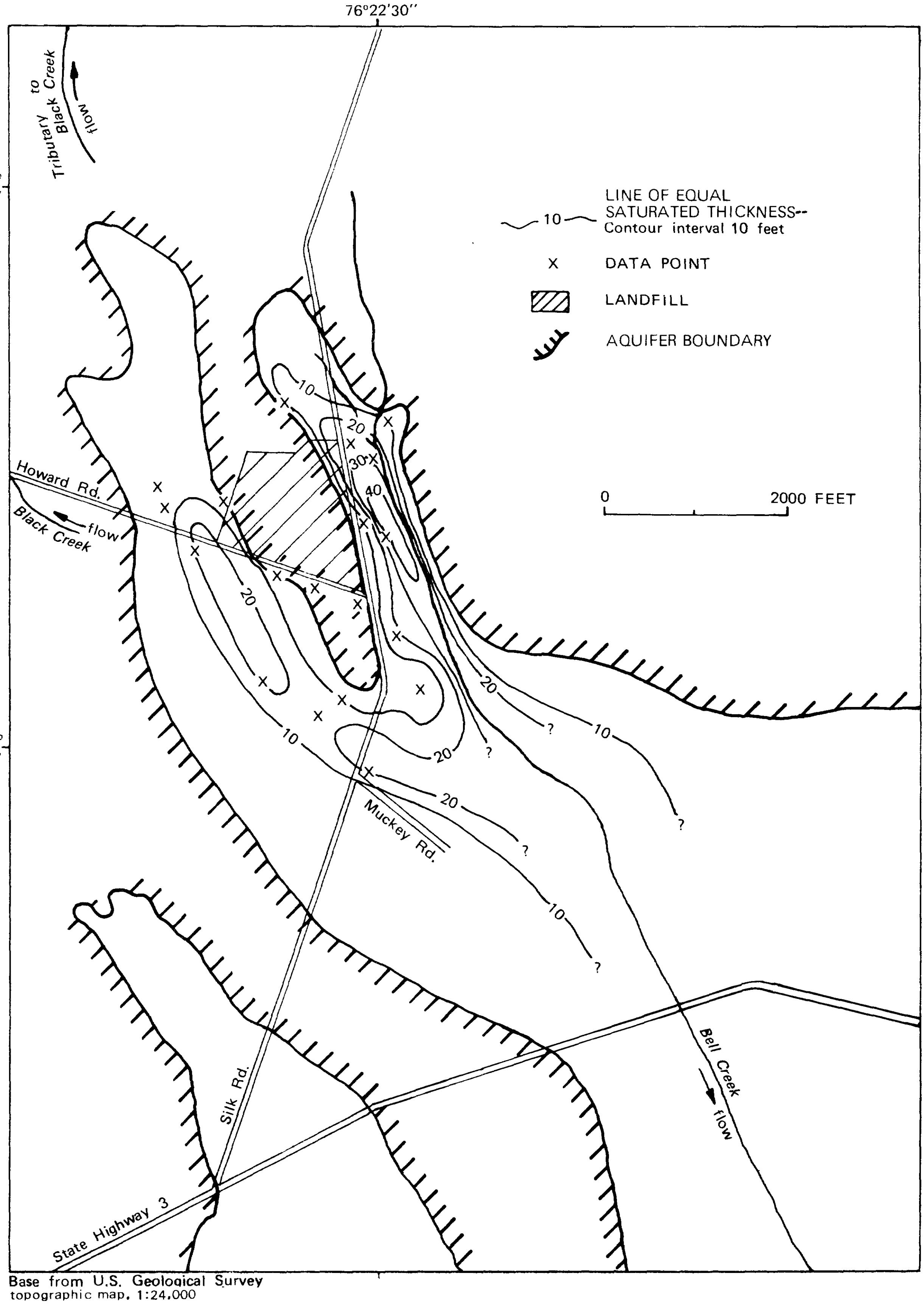


Figure 10.--Saturated thickness of sand and of sand and gravel aquifer in vicinity of landfill near Fulton. (Location is shown in fig. 2.)

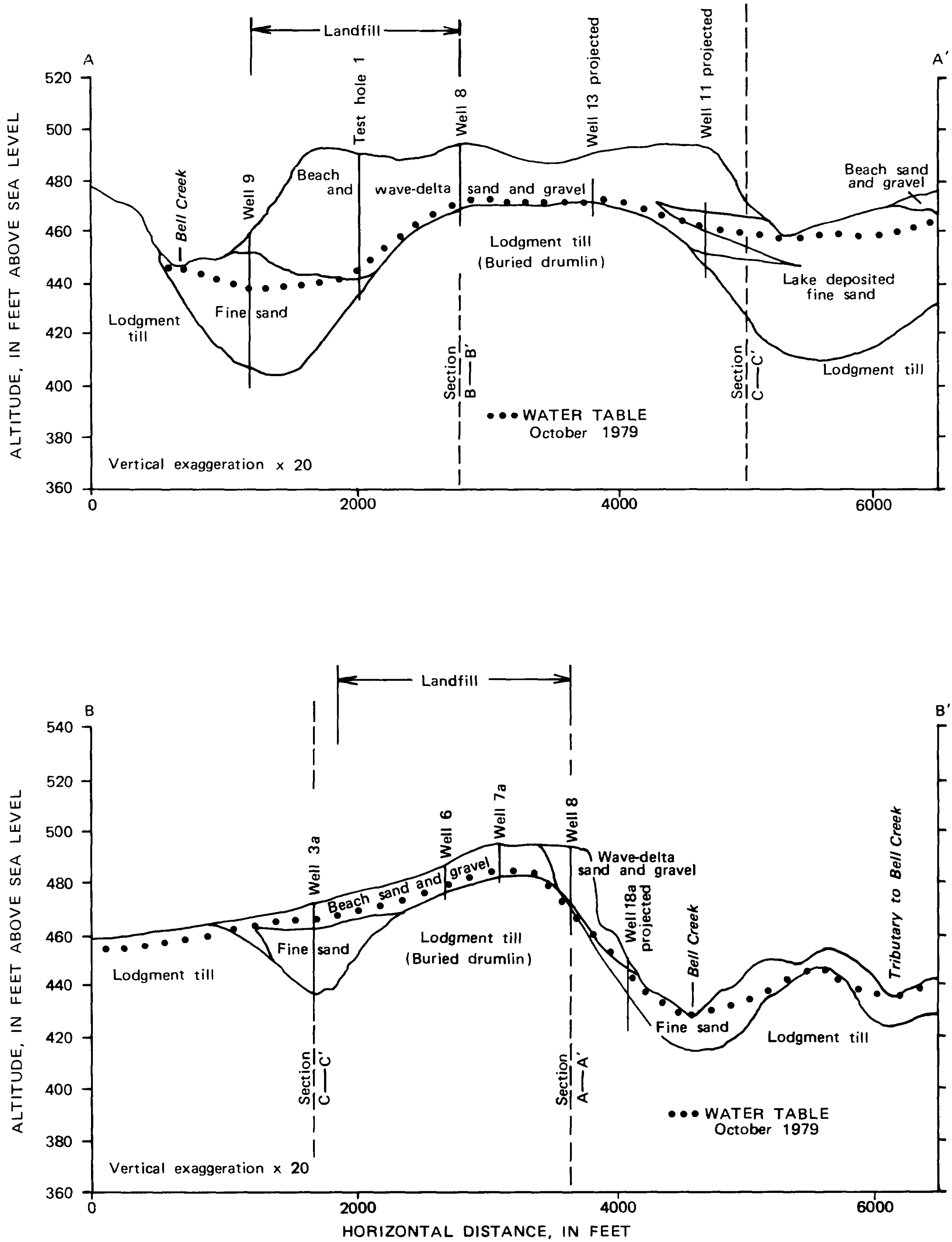


Figure 11.--Geologic section A-A' along Silk Road and B-B' along Howard Road in vicinity of landfill near Fulton. (Locations are shown in fig. 9.)

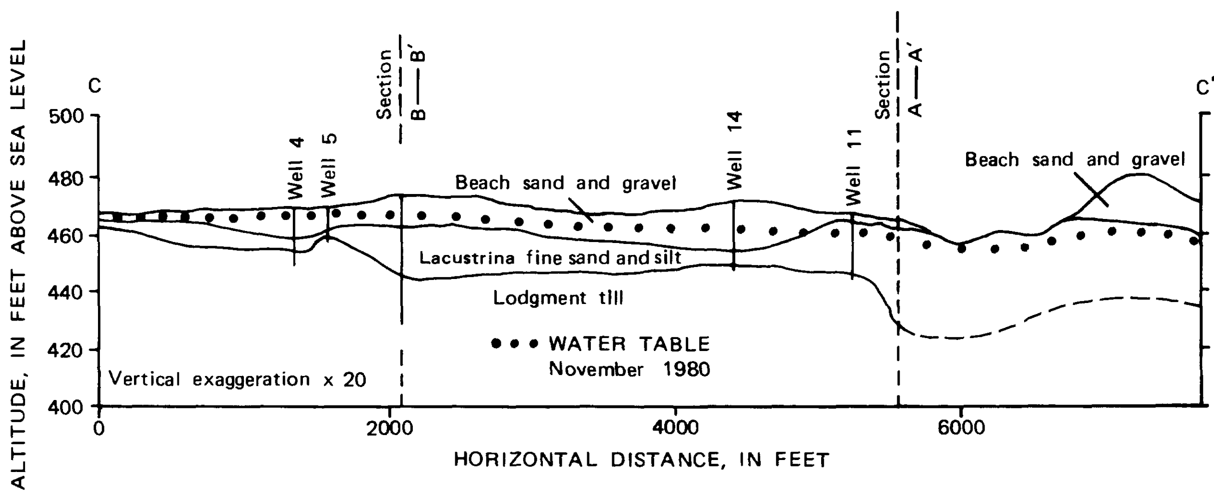


Figure 11 (continued).--Geologic section C'C' south of landfill near Fulton. (Location of section is shown in fig. 9.)

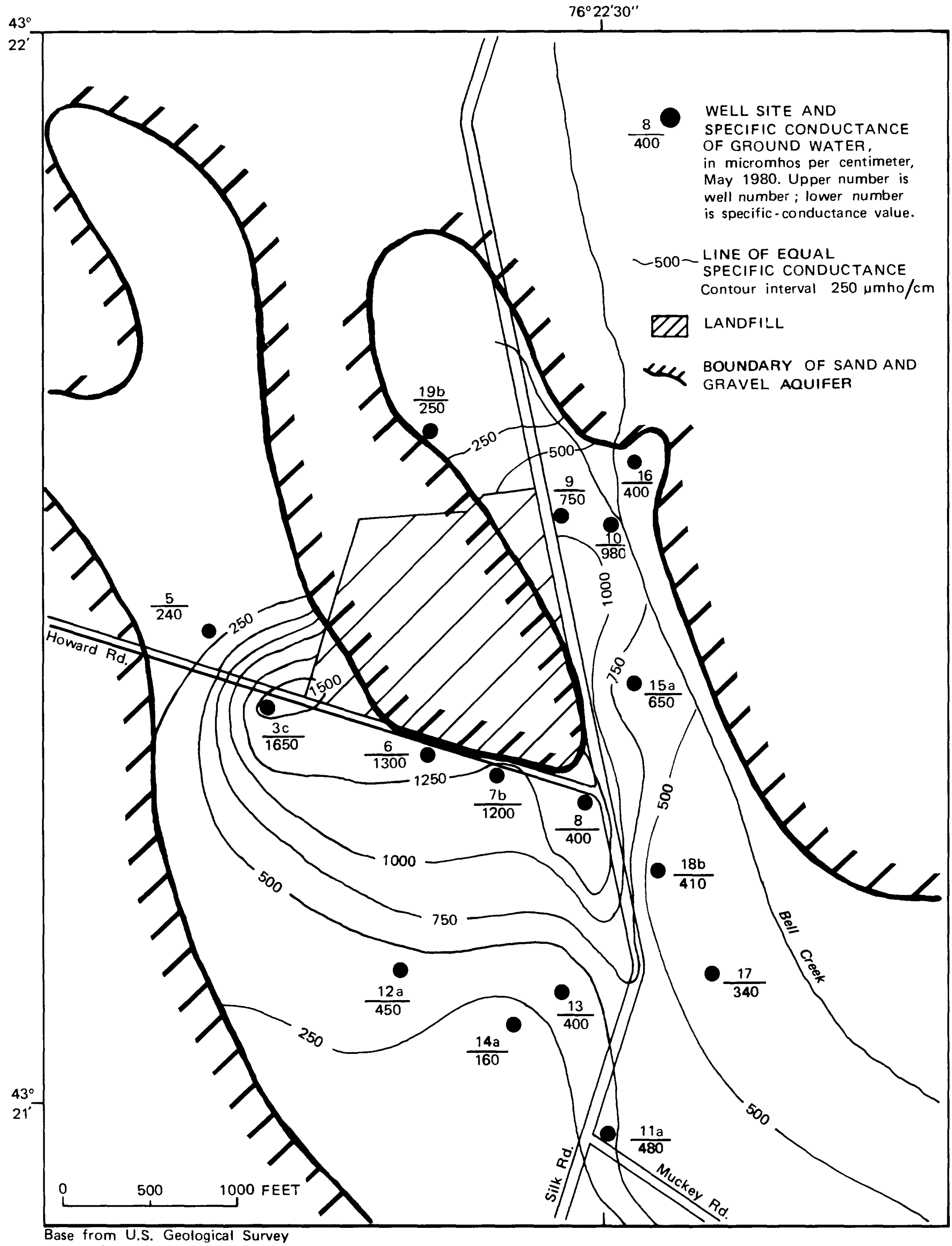
leachate, which then moves radially away from the top of the drumlin and discharges partly to surface seeps along the edges of the landfill and partly as underflow down the buried flanks of the drumlin and into the sand and gravel aquifer, from which it either discharges eastward into Bell Creek or flows southwest into a tributary of the Bell Creek drainage system (fig. 9). It may also move downvalley (southward) as underflow beneath Bell Creek, and some may move northwestward through thin beach sand and gravel, but data on this area are scant. Some leachate generated within the landfill may infiltrate into the relatively impermeable till, but again, little information about the ground-water flow system in the drumlins is available. Records of wells and test holes are in table 9 (at end of report).

Permeability

The sand and gravel aquifer at this landfill (fig. 10) generally is more permeable than the deposits underlying the site near Oswego. A pumping test at well 14b (fig. 9), screened at 15 to 17 ft in fine to coarse sand, indicated a transmissivity of 400 ft2/s and a permeability of 67 ft/d. The saturated thickness of the aquifer is about 6 ft. A recovery test on well 3c, screened from 33 to 35 ft in very fine lacustrine sand, indicated a transmissivity of 1.5 ft2/s. Permeability is estimated to be 0.2 ft/d.

Specific conductance

Maps showing the specific conductance of ground water during May 1980 and February 1981 are given in figures 12A and 12B. Specific conductance of



Base from U.S. Geological Survey topographic map, 1:24,000

Figure 12A.--Specific conductance of ground water in vicinity of landfill near Fulton, May 1980. (Location is shown in fig. 9.)

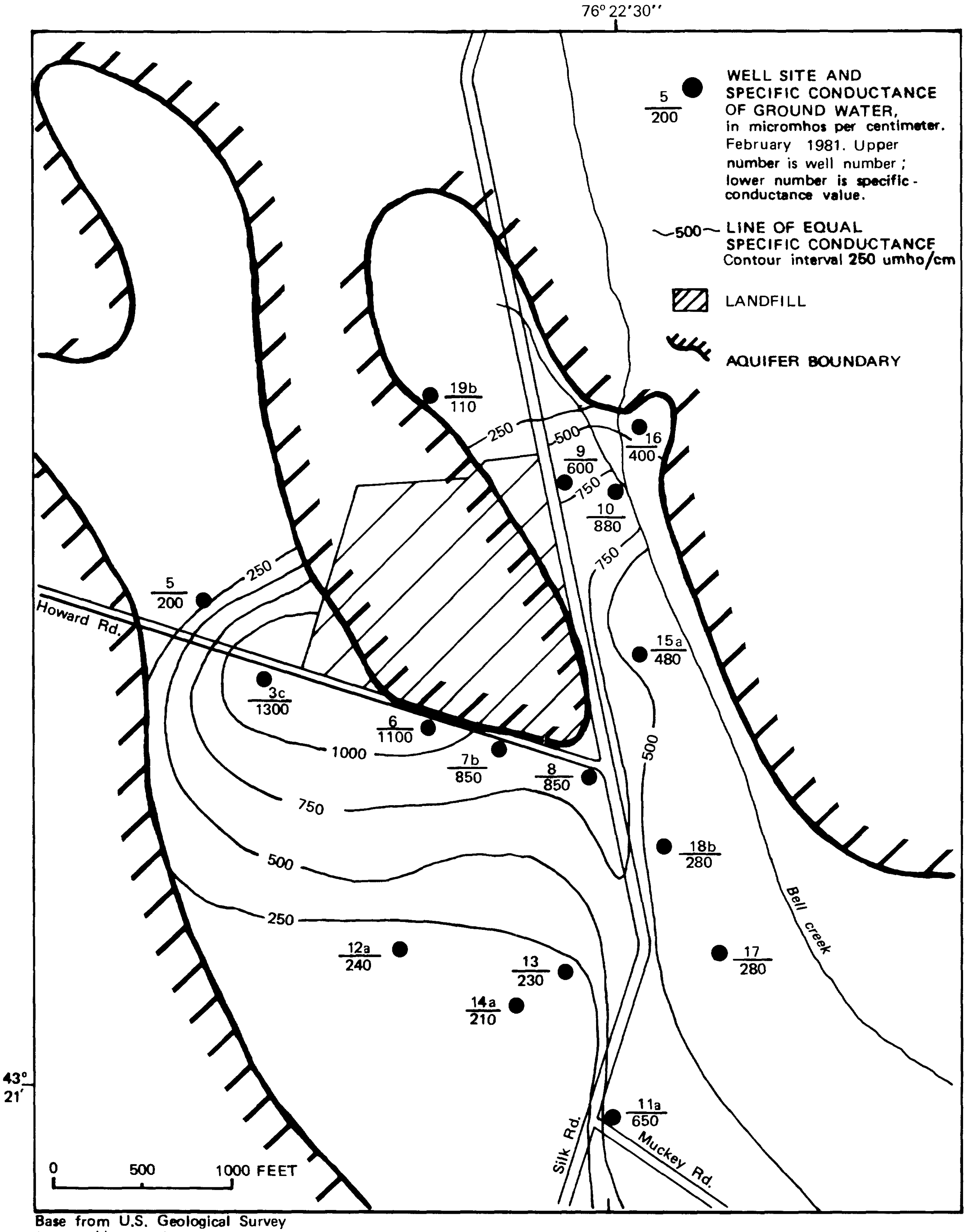


Figure 12B.--Specific conductance of ground water in vicinity of landfill near Fulton, February 1981. (Location is shown in fig. 9.)

ground water at wells furthest from the landfill and least likely affected by it was less than 250 µmho/cm. The specific conductance of water in wells along the south boundary of the landfill, along Howard Road (wells 3a, 3b, 3c, 3d, 6, 7, and 8 in fig. 12), ranged from 850 to 1,650 µmho, which indicates movement of leachate-enriched water southward from the landfill. Wells 9, 8, 10, 15a, and 15b, along the east margin of the landfill, ranged from 480 to 1,400 µmho/cm, indicating some leachate movement eastward toward Bell Creek. Wells west and north of the landfill (wells 5 and 19b, respectively) had low specific-conductance values, which indicates little or no leachate movement to those areas.

All specific-conductance values were higher in spring than winter, presumably because the water table was receiving little or no recharge in May 1980, which allowed the leachate to become more concentrated. February 1981 was a period of relatively high recharge from rainfall and an early snowmelt, which would have diluted the leachate and resulted in lower conductance values.

Road salting may contribute to the conductance plume along Silk Road, southeast of the landfill (figs. 12A and 12B), but the values elsewhere do not reflect the road patterns.

Outside the landfill area, precipitation that infiltrates land surface forms a layer of fresh water over the leachate plume. Leachate-rich water is slightly denser and therefore sinks to lower saturated zones. For example, wells 3c and 3d, southwest of the landfill (fig. 9), revealed a vertical zoning within a leachate front in which denser leachate with a higher dissolved-solids concentration has moved below the lighter ambient ground water. Water in the deeper well (3c, depth 34.5 ft) had a specific conductance of 1,300 µmho/cm on May 22, 1980, whereas water in the shallow well (3d, depth 10 ft) had a specific conductance of 500 µmho/cm.

Temperature

Temperatures of leachate-enriched ground water are higher than those of ambient water as a result of the heat generated by decomposition of organic matter. This is evidenced by the tendency of vegetation at landfills to stay green longer and snow to melt faster than elsewhere. The distribution of ground-water temperature at the site on May 22, 1980, November 2, 1980, and February 26, 1981 is shown in figure 13. During May 22, 1980, relatively high temperatures were recorded at well 9 (east of landfill), well 8 (southeast of landfill), and well 3c (southwest of landfill). (See fig. 13A.) Ground-water temperatures in February 1981 (fig. 13C) show the same pattern, except that all temperatures were lower. In November 1980 (fig. 13B), ground-water temperatures within and southeast of the landfill exceeded 15.0°C, whereas ground water from distant wells ranged from 10.5° to 12.0°C. The temperature contours in figure 13 suggest that some of the leachate is moving eastward, southeastward, and southwestward from the landfill.

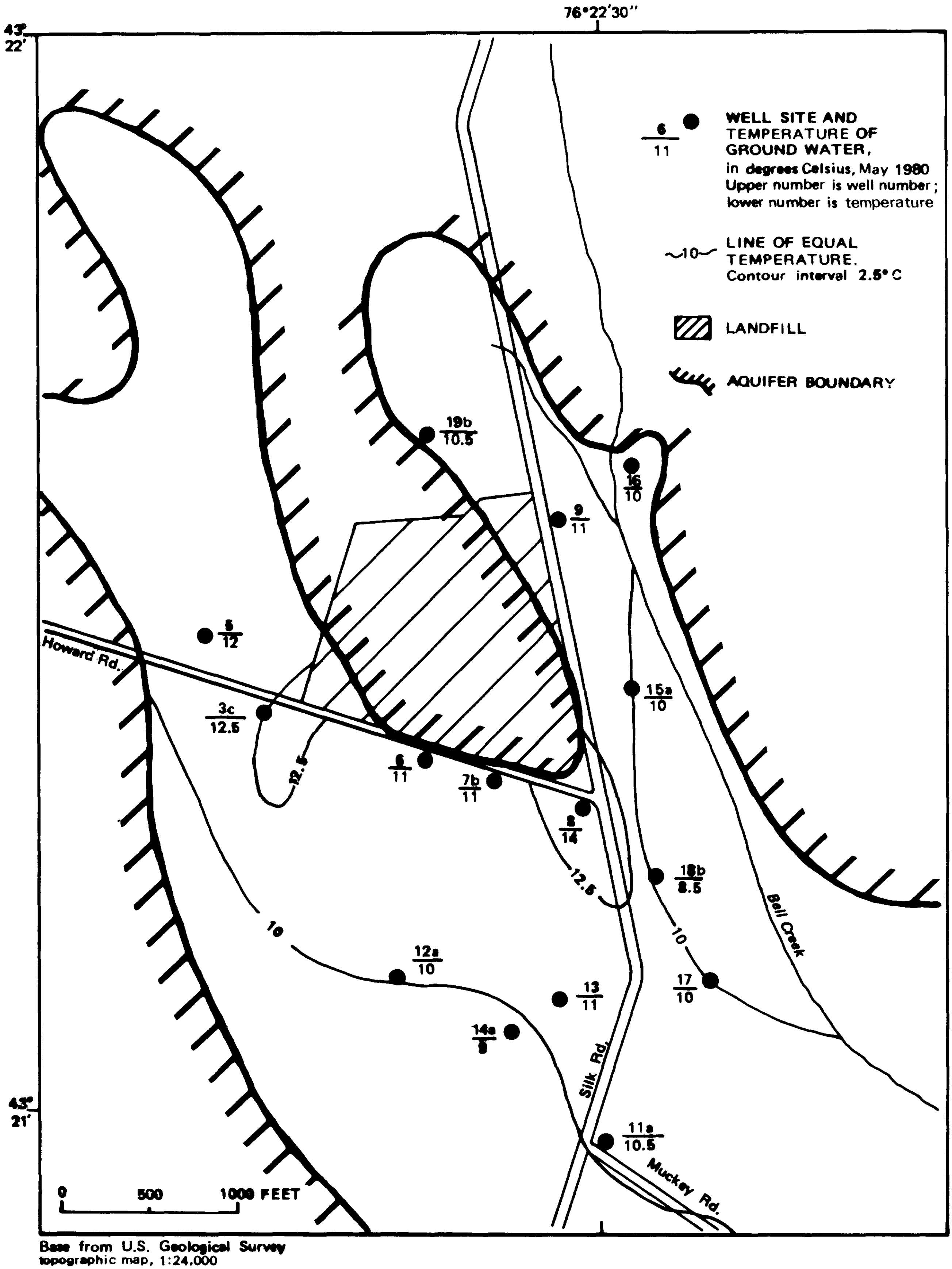
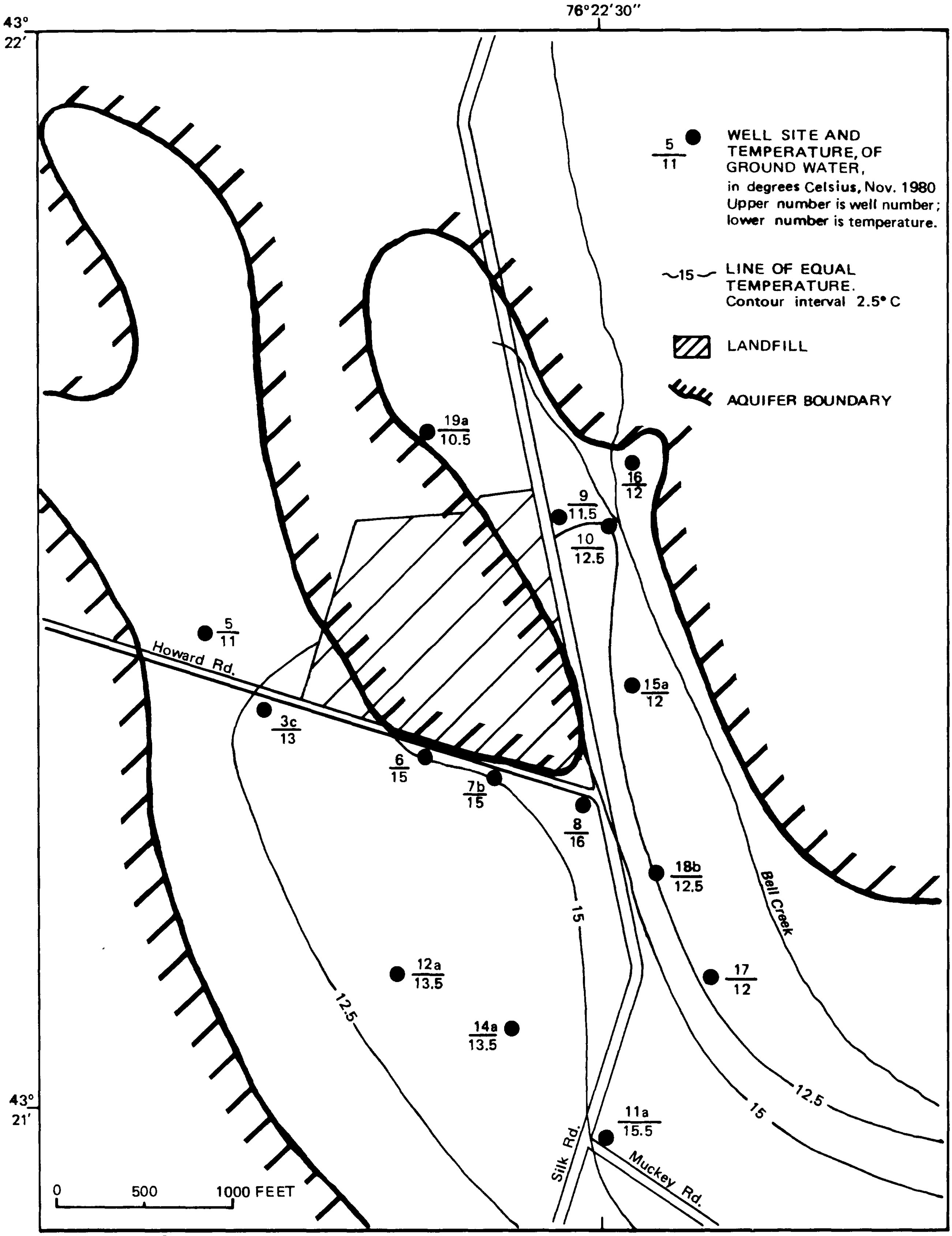


Figure 13A.--Temperature of ground water in vicinity of landfill near Fulton, May 1980. (Location is shown in fig. 9.)



Base from U.S. Geological Survey topographic map, 1:24,000

Figure 13B.--Temperature of ground water in vicinity of landfill near Fulton, November 1980. (Location is shown in fig. 9.)

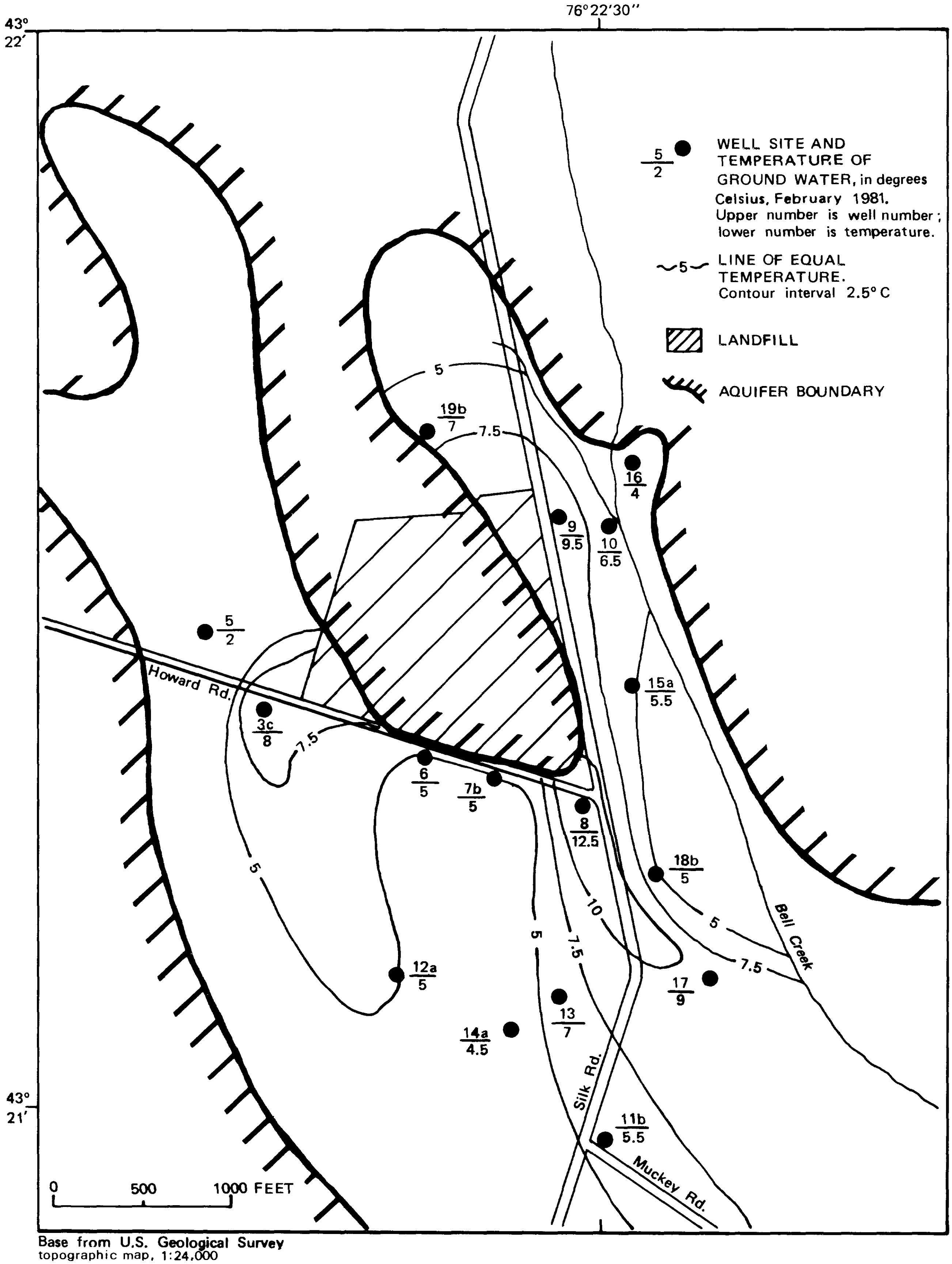


Figure 13C.--Temperature of ground water in vicinity of landfill near Fulton, February 1981. (Location is shown in fig. 9.)

Chemical Quality

Water samples were collected from seven wells (fig. 9), one within the site (well L) and six outside it (wells 3a, 10, 11a, 11b, 14b, and 15a) and analyzed for arsenic, lead, mercury, bromide, and chloride (table 6). Additional samples were collected from five of these wells, including the one within the site, and analyzed for selected organic compounds (table 7).

Halogens.--Chloride and bromide concentrations were generally low outside the site, but inside the site the chloride concentration was 1,500 mg/L and that of bromide was 1.3 mg/L.

Trace Metals.--Results of the trace-element analyses are given in table 6. Arsenic concentrations exceeded the U.S. Public Health Service standard of 50 µg/L at well 10, which is in the path of eastward ground-water flow to Bell Creek (fig. 9). Lead concentrations exceeded the 50-µg/L limit in the well inside the landfill and in wells 3a and 10, south and east of the landfill, respectively. Mercury concentrations were less than the 2 µg/L standard in all wells sampled.

In general, the analyses indicate little movement of heavy metals or of halogens outside the landfill, although lead and arsenic did exceed USPHS standards in two wells downgradient.

Table 6.--Concentrations of trace metals and halogens in ground water in vicinity of landfill near Fulton

[Analyses by U.S. Geological Survey, Atlanta, Ga. Underlined values exceed U.S. Public Health Service standards, and numbers in parentheses indicate maximum recommended concentration. Well locations are shown in fig 9. NA, not analyzed.]

			Trace metals (µg/L)				Halogens (mg/L)	
Well no.	Type of casing[1]	Screen depth below land surface (ft)	Arsenic (50)	Lead (50)	Mercury (2)	Zinc (5,000)	Bromide ([2])	Chloride (250)
Leachate well (onsite)								
	P	10[3]	39	500	0.3	7,100	1.3	1,500
Offsite wells								
3a	S	34	3	80	.3	NA	.9	120
10	S	12	61	180	.3	NA	.5	49
11a	P	18	4	11	.2	20	.1	85
11b	S	18	4	12	.2	NA	.3	81
14b	S	17	3	14	.1	NA	0	.8
15a	P	20	5	13	.1	90	0	26

[1] S, steel; P, PVC.
[2] No standard given.
[3] Estimated value.

Organic Compounds.--Samples from five wells were sampled and analyzed for 28 of the 129 "priority pollutants" (table 7). Water from well L (fig. 9) inside the landfill contained toluene, trichloroethylene, methylene chloride, and PCB's in concentrations of 660, 120, 30,000, and 1.4 μg/L, respectively. The other samples contained zero or only traces or undetectable concentrations of organic compounds, except for 250 μg/L of toluene at well 3a, at the southwest corner of the landfill.

Table 7.--Concentrations of selected "priority" organic compounds in ground water in vicinity of landfill near Fulton

[Analyses by U.S. Geological Survey, Atlanda, Ga. Concentrations are in micrograms per liter; <, less than. Locations are shown in fig. 10.]

Well no.	Type of casing[1]	Screen depth below land surface (ft)	Toluene	1,2 trans-Dichloroethylene	Trichloroethylene	Methylene chloride	PCB	Remarks
Leachate well (onsite)								
L	P	10	660	<3.0	120	30,000	1.4	Contains many carboxylic acids.
Offsite wells								
3a	S	34	250	7	3	<3.0	<0.1	Also contains several carboxylic acids.
10	S	12	<3.0	<3.0	<3.0	<3.0	<0.1	Contains large amount of molecular sulfur.
14b	S	17	2	<3.0	<3.0	<3.0	<0.1	Also contains several alcohols.
11b	S	18	2	<3.0	<3.0	<3.0	<0.1	Also contains several alcohols.

[1] S = steel, P = PVC

Movement of Leachate

The volume of leachate migrating from the landfill near Fulton each year may be substantial because of high permeability of sediments in hydraulic contact with the landfill along its southwestern, southern, and eastern boundaries. Because recharge is variable throughout the year, leachate is generated as periodic pulses. Leachate-rich water sinks to the bottom of the aquifer and moves downgradient, forming a leachate front or plume, the shape of which is determined by the aquifer's permeability. Where permeablity is uniform, the leachate front forms as an arc, broadening away from the site;

but where the permeability is higher, the leachate extends forward as a narrow plume. The amount and concentration of leachate is a function of the area and saturated thickness of the refuse, whereas the distance leachate moves from the landfill is a function of time and ground-water velocity (Kimmel and Braids, 1980).

A soluble conservative compound would take a minimum of 28 months to travel 2,400 ft from the landfill southward to the intersection of Muckey and Silk Roads (fig. 12A), as calculated from an estimated hydraulic conductivity of 67 ft/d for the fine to pebbly coarse sand that forms the aquifer, a porosity of 30 percent, and a water-table gradient of 0.0125. (Insoluble and reactive contaminants could take appreciably longer.) From the formula for velocity (v):

$$v = \frac{\text{hydraulic conductivity (ft/d)} \times \text{gradient (ft/ft)}}{\text{porosity (dimensionless)}}$$

$$= \frac{67 \times 0.0125}{0.30} = 2.8 \text{ ft/d}$$

the velocity of ground-water movement is 2.8 ft/d or 1,022 ft/yr.

SUMMARY AND CONCLUSIONS

Forty-five test holes and observation wells were installed at two major chemical-waste disposal sites in Oswego County--an abandoned chemical-waste-disposal facility near Oswego and a landfill northeast of Fulton--to evaluate ground-water conditions and the direction and extent of contamination emanating from the sites.

Site Near Oswego

This site contains 11,000 fifty-five-gallon barrels of chemical waste and occupies a north-south-trending interdrumlin swale. The barrels are on top of relatively impermeable unconsolidated glacial sediments less than 40 ft thick.

Fine-grained glacial-lake sediments overlie ablation and lodgment tills, which in turn overlie bedrock. The unconsolidated sediments have hydraulic conductivity values ranging from 0.06 to 4.3 ft/d. Horizontal hydraulic conductivity of the upper part of the fractured bedrock is 7.5 ft/d. Horizontal ground-water velocities range from 0.01 ft/d in the till to 0.75 ft/d in the bedrock. Ground water in the shallow unconsolidated deposits discharges to White Creek and Wine Creek. Deeper regional flow in bedrock is northward toward Lake Ontario, 0.5 mi to the north.

Leachate moves approximately 0.4 ft/d toward White Creek and Wine Creek, which join at the north end of the site and flow into Lake Ontario. Specific conductance of ground water within the site was as high as 5,000 µmho/cm but was less than 1,000 μmho/cm outside the site. Lead concentrations in five of seven wells sampled exceeded the U.S. Public Health Service standard of 50 μg/L. Lead concentrations at wells installed in unconsolidated deposits within the site ranged from 64 μg/L to 3,800 μg/L. Mercury concentrations exceeded the U.S. Public Health Service standard of 2 μg/L in three of the seven samples, including one downgradient of the site. Arsenic concentrations were below the 50-μg/L standard at all seven wells sampled.

Nine of the 28 organic compounds tested for and designated by the U.S. Environmental Protection Agency as "priority pollutants" were found in water from four wells within the site. These included benzene, chloroform, polychlorinated biphenyls (PCB's), phenol, trans-dichloroethylene, methylene chloride, toluene, trichlorethane, and trichloroethylene. The well downgradient from the site and across White Creek and Wine Creek contained none of the organic compounds.

More sampling would be needed between this site and the abandoned landfill several hundred feet upgradient (south) to determine what contaminants, if any, are coming from the latter. Leachate movement in fractured bedrock could be monitored if several test wells were installed in the 0.5-mi strip between the site and Lake Ontario.

Landfill Near Fulton

This landfill contains about 8,000 fifty-five-gallon barrels of solid chemical waste. The landfill is on top of a drumlin, covered by a veneer of sand and gravel, that forms a drainage divide separating two watersheds--one that drains south toward Bell Creek, the other west-northwest toward Black Creek. Both creeks are tributary to the Oswego River. The landfill is mostly in the catchment area of Bell Creek.

The eastern part of the landfill is excavated in permeable sand and gravel deposits 10 to 50 ft thick on the eastern side of the drumlin. The direction of ground-water flow through the sand and gravel is primarily east and southeast to Bell Creek. The direction of movement is controlled by the underlying surface of relatively impermeable lodgment till.

The western and central part of the landfill is excavated into the lodgment till that forms the drumlin. The overlying deposits of sand and gravel (10 ft or less) were removed before landfilling began and were used with till as cover material. South of and adjacent to the landfill, the saturated sand and gravel is less than 10 ft thick but increases southward to 20 ft thick. Ground-water temperatures and specific-conductance patterns indicate that leachate plumes are moving southwest, southeast, and east away from the landfill.

Analyses of trace metals in water at seven wells sampled indicate that arsenic exceeds the U.S. Public Health Service standard of 50 μg/L at a well 100 yards east of the landfill. Lead exceeded the 50 μg/L limit at the well inside the landfill, at a well south of the site, and at a well east of the site. Mercury concentrations were less than the limit of 2 μg/L at all seven wells sampled.

Analyses for organic compounds in water from the well inside the landfill indicated significant concentrations of toluene (660 µg/L), trichloroethylene (120 µg/L), and methylene chloride (30,000 µg/L). Another well 100 yards southwest of the landfill contained toluene (250 µg/L). The other three wells sampled contained insignificant amounts of the "priority pollutants" for which samples were analyzed.

Specific-conductance and temperature measurements of ground water indicate leachate to be migrating from the landfill to the southwest, southeast, and east. At well 3a, at the southwest corner of the landfill, lead exceeded the U.S. Public Health Service standard, and toluene was detected.

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Table 8.--Records of selected wells and test holes at the chemical-waste site near Oswego, N.Y.

Well number	Latitude ° ' "	Longitude ° ' "	Sequence number	Date drilled	Well depth (ft)	Type of casing[1]	Casing diameter (in.)	Screened interval (ft)	Aquifer type[2]	Depth to bedrock (ft)	Altitude of land surface (ft)	Water level: Depth below land surface (ft)	Water level: Date	Remarks
1a	43 28 18	76 29 11	.01	1979	9.5	S	2	7-9.5	af	11	260	2.5	10-16-79	Artificial fill consists of fly ash.
1b	43 28 18	76 29 11	.02	1979	9.5	P	2	7-9.5	af	11	260	2.4	10-16-79	
2	43 28 14	76 29 07		1979	12	--	--	--	--	17	268	4.5	9- 5-79	Test hole
3	43 28 12	76 29 01		1979	13	S	2	10.5-13	s	--	273	1.8	10-15-79	
4	43 28 13	76 29 01		1979	5	S	1.25	3.5-5	af	--	270	1.3	10-15-79	
5	43 28 12	76 29 06		1979	4.5	--	--	--	--	--	268	--	--	Test hole
6	43 28 13	76 29 05		1979	5	S	1.25	3.5-5	s	--	268	2.0	10-15-79	
7	43 28 09	76 28 58		1979	14	S	1.25	12-14	af	--	278	9.5	10-15-79	
8	43 28 13	76 29 02		1979	19	--	--	--	--	--	273	--	--	Test hole
9a	43 28 12	76 29 05	.01	1979	16	S	2	13.5-16	s&g	--	275	.9	10-15-79	
9b	43 28 12	76 29 05	.02	1979	16.5	P	2	14-16.5	s&g	--	275	.9	10-15-79	
10	43 28 08	76 29 06		1979	13	S	2	10-13	till	--	280	4.6	10-15-79	
11a	43 28 08	76 28 57	.01	1980	10	S	2	7.5-10	till	--	282	6.3	8-22-80	
11b	43 28 07	76 28 58		1980	12.5	S	2	10-12.5	till	--	282	6.3	8-22-80	
11c	43 28 08	76 28 57	.02	1980	9	P	2	7-9	s&clay	--	282	5.3	8-23-80	
12a	43 28 18	76 29 07	.01	1980	8	P	2	6-8	silt	--	268	4.5	8-12-80	
12b	43 28 18	76 29 07	.02	1980	14	S	2	11-14	till	--	268	4.0	8-12-80	
13a	43 28 17	76 29 13	.01	1980	9.5	S	2	7.5-9.5	till	--	262	8.5	8-13-80	
13b	43 28 17	76 29 13	.02	1980	13	S	1.5	10-13	gravel&till	--	262	8.9	8-13-80	
R	43 28 12	76 29 03		1980	41	S	2	39-41	sandstone	38	263	6.4	8-15-80	
TS	43 28 08	76 28 51		1979	6	S	2	3.5-6	af	--	285	2.2	10-15-79	

[1] S, steel; P, PVC; dashes indicate no data.
[2] af, artificial fill; s, sand, s&g, sand and gravel.

Table 9.--Records of selected wells and test holes at the landfill near Fulton, N.Y.

Well number	Latitude ° ' "	Longitude ° ' "	Sequence number	Date drilled	Well depth (ft)	Type of casing[1]	Casing diameter (in.)	Screened interval (ft)	Aquifer type[2]	Altitude to surface (ft)	Water level: Depth below of land surface (ft)	Water level: Date	Remarks
1	43 21 30	76 22 33		1979	58	--	--	--	--	490	47	9-12-79	Test hole
2	43 21 27	76 22 53		1979	20	S	2	11.5-14	till	485	7.8	10-15-79	
3a	43 21 22	76 22 57	.01	1979	34	S	2	31.5-34	s	474	6.1	10-15-79	
3b	43 21 22	76 22 57	.02	1979	10	S	2	7.5-10	s&g	474	6.0	10-15-79	
3c	43 21 22	76 22 57	.03	1979	34.5	P	2	33-34.5	s	474	6.0	10-15-79	
3d	43 21 22	76 22 57	.04	1979	10	P	2	8-10	s&g	474	6.1	10-15-79	
4	43 21 28	76 23 04		1979	19	--	--	--	--	468	12	10- 4-79	
5	43 21 27	76 23 02		1979	8.5	S	2	6-8.5	till	470	1.3	10-15-79	
6	43 21 20	76 22 45		1979	10	S	2	7.5-10	s&g	490	8.6	10-15-79	
7a	43 21 29	76 22 40	.01	1979	10	S	2	8.5-10	s&g	493	10.2	10-15-79	
7b	43 21 19	76 22 40	.02	1979	10	P	2	8.5-10	s&g	493	9.5	10-15-79	
8	43 21 18	76 22 33		1979	28	S	2	25-28	s&g	494	23.8	10-15-79	
9	43 21 32	76 22 34		1979	36.5	S	2	34-36.5	s	460	22.1	10-15-79	
10	43 21 32	76 22 33		--	30	S	6	--	s&g	450	11.0	7-30-80	
11a	43 20 57	76 22 32	.01	1980	18	P	2	14-18	s&g	468	7.9	5-22-80	
11b	43 20 57	76 22 32	.02	1980	18	S	2	16-18	s&g	468	7.5	5-22-80	
12a	43 21 08	76 22 51	.01	1980	17	P	2	13-17	s	474	7.3	5-22-80	
12b	43 21 08	76 22 51	.02	1980	18	S	2	16-18	s	474	7.0	5-22-80	
13	43 21 07	76 22 38		1980	12	P	2	12	till	480	10.0	5-22-80	Destroyed 11-1-81
14a	43 21 06	76 22 40	.01	1980	17	P	2	15-17	s	470	10.3	5-22-80	
14b	43 21 06	76 22 40	.02	1980	17	S	2	15-17	s	470	10.3	5-22-80	
15a	43 21 26	76 22 31	.01	1980	20	P	2	16-20	s&g	455	8.4	7-30-80	
15b	43 21 26	76 22 31	.02	1980	23	S	2	21-23	s&g	455	8.5	7-30-80	
16	43 21 36	76 22 48		1980	18	P	2	16-18	s	463	9.9	7-30-80	
17	43 21 06	76 22 25		1980	31	P	2	29-31	s	470	13.6	7-30-80	
18a	43 21 13	76 22 28	.01	1980	22	S	2	20-22	s	463	13.8	7-30-80	
18b	43 21 13	76 22 28	.02	1980	21.5	P	2	19.5-21.5	s	463	13.8	7-30-80	
19a	43 21 38	76 22 45	.01	1980	33	S	2	31-33	s	490	22.9	6-27-80	
19b	43 21 38	76 22 45	.02	1980	32	P	2	30-32	s	490	24.3	7-30-80	

[1] S, steel, P, PVC; dashes indicate no data.
[2] s, sand; s&g, sand and gravel.