LATERAL MOVEMENT OF CONTAMINATED GROUND WATER FROM MERRILL FIELD LANDFILL, ANCHORAGE, ALASKA

by Jilann O. Brunett

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CONVERSION FACTORS AND ABBREVIATIONS

For readers who may prefer to use metric (International System) units rather than inch-pound units, the conversion factors for the terms used in this report are listed below:

Multiply inch-pound unit	By	To obtain metric unit
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
acre	0.4047	hectare
gallon per minute (gal/min)	0.06308	liter per second (L/s)
degree Fahrenheit (°F)	°C = 5/9 x (°F-32)	degree Celsius (°C)

Other abbreviations in this report are:

mg/L, milligrams per liter

μg/L, micrograms per liter

mS/m, millisiemens per meter

ALTITUDE DATUM

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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ABSTRACT

A sanitary landfill used in Anchorage, Alaska, since the 1940's was closed in 1987. Leachate from the landfill does not appear to be contaminating a small creek flowing through a conduit in the landfill, but leachate is being transported by ground water into a wetlands to the south. An electromagnetic survey of the unconfined aquifer and subsequent sampling from wells indicate that minor amounts of contaminants have reached much of the wetlands as far as Chester Creek, about 2,200 feet to the south. However, concentrations of these contaminants in the ground water are generally less than U.S. Environmental Protection Agency standards for drinking water except within the landfill itself.

INTRODUCTION

The Merrill Field solid-waste landfill (fig. 1) was used for refuse disposal since the 1940's. When the site was closed in 1987, approximately 200 acres had been covered with soil and refuse to an average thickness of about 30 ft. Some of the refuse has been buried below the water table, thereby creating an environment in which the refuse is continuously leached.

Nelson (1982) analyzed vertical movement of ground water and determined that minor amounts of pollutants may reach the upper confined aquifer after many tens of years, but that water of the composition of leachate may not reach the upper confined aquifer for more than three centuries. However, his study did not address lateral migration of contaminants in the shallow unconfined aquifer.

The purpose of this study was to determine the extent of contamination of the shallow unconfined aquifer downgradient from the landfill. Ground water under the landfill was thought to move in the direction of the topographic gradient, toward Chester Creek. The wetlands between the landfill and Chester Creek therefore became the primary focus of this investigation.

The U.S. Geological Survey did this study in cooperation with the Municipality of Anchorage. The Municipality drilled the test wells and provided information on subsurface materials in the study area, as well as information on the history of the landfill.

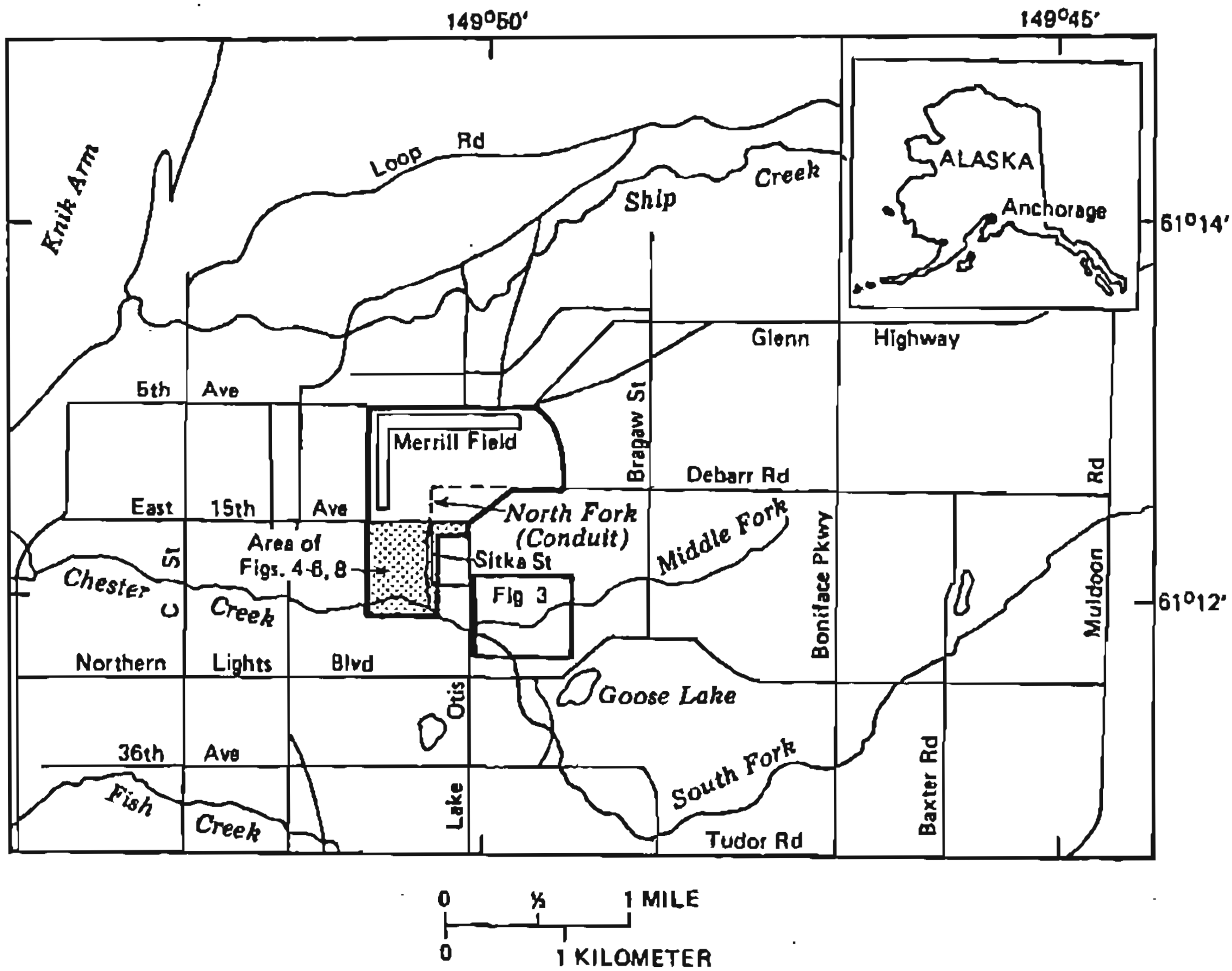

Figure 1.–Location of Merrill Field landfill in Anchorage.

PHYSICAL SETTING

In the 1940's Merrill Field Airport was on the outskirts of Anchorage. To the east and south of the airport was a high bluff overlooking the North Fork Chester Creek valley. This valley was from 1,300 to 2,600 ft wide in most places, and was wet and marshy.

The study area is underlain by a complex sequence of stratified glacial, fluvial, and lacustrine sediments, which Nelson (1982) generalized into seven units (fig. 2). The uppermost unit is an unconfined aquifer that consists of silty sand and gravel. In the wetlands the unconfined aquifer is generally less than 30 ft thick and is underlain by a poorly permeable silty clay that inhibits the vertical movement of water.

Unit	LITHOLOGY	Aquifer	Confining layer
I	Sand and gravel, clean to silty; lowest 15 feet saturated	•	
II	Silty clay		•
III	Gravelly sand and silt; contains thin low-yield aquifers		•
IV	Sand and gravel; yields 50 to 400 gallons per minute	•	
V	Gravelly sand and silt; contains few low-yield aquifers		•
VI	Sand and gravel; yields 500 to 2,000 gallons per minute	•	
VII	Clay		•

Figure 2.--Generalized stratigraphic column (Nelson, 1982).

LANDFILL HISTORY

The Merrill Field landfill was started by pushing accumulated refuse off the bluff near the east end of the Merrill Field Airport runway. In the early 1970's, the North Fork Chester Creek was diverted into a corrugated metal conduit through the middle of the landfill (fig. 1). The conduit, which is still in use, leaves the landfill just west of Sitka Street. From the outlet of the conduit, North Fork Chester Creek flows straight south in an open ditch to its junction with Chester Creek. Also in the early 1970's a leachate collection system (subdrain) was installed in the landfill at the top of a confining clay layer to intercept the leachate and discharge it into the sanitary sewer system. The subdrain routes the leachate to a lift station about 200 ft east of the intersection of East 15th Avenue and Sitka Street, from which it is pumped into a concrete sanitary sewer line and eventually reaches the Point Woronzof Wastewater Treatment Facility. The landfill was closed in 1987. The surface will be seal coated to create more parking for small airplanes at Merrill Field Airport.

ELECTROMAGNETIC SURVEY

Electromagnetic (EM), or induction, techniques that measure ground conductivities can locate ground-water pollution from a landfill because salts that have been dissolved from the refuse give the ground water a higher capacity than uncontaminated ground water to conduct electricity (Evans, 1982; Kelly, 1976). Many investigations have been done using EM surveys to delineate contaminated plumes (Barlow and Ryan, 1985; Grady and Haeni, 1984; Greenhouse and Slaine, 1983; Mack and Maus, 1986).

The Geonics[1] EM34-3 used for this study consists of transmitter and receiver coils that are held coplanar (in the same plane) (Grantham and others, 1987). When the coils are held vertically, the instrument measures the ratio of the primary to secondary magnetic field generated by the horizontal dipole and, when held horizontally, the instrument measures the ratio of the primary to secondary magnetic field generated by the vertical dipole. The EM34-3 is calibrated to be a direct-reading, linear terrain-conductivity meter (McNeill, 1980a). The earth conductivity is measured in millisiemens per meter (mS/m).

Six data points are obtained at each sampling point by taking readings at both the vertical and horizontal coplanar orientations at three coil spacings (the distance between the transmitting coil and the receiving coil): 10-m, 20-m, and 40-m. The exploration depth is dependent on the coil spacing and the operating frequency of the instrument (table 1).

Table 1.--*Approximate exploration depths for EM34-3 at various intercoil spacings (McNeill 1980a)*

Intercoil spacing (meters)	Approximate exploration depth (meters)	
	Horizontal dipoles	Vertical dipoles
10	7.5	15
20	15	30
40	30	60

For the direct surface electromagnetic reading to be a measure of the electrical conductance of ground water, the thickness of the unsaturated zone and subsurface lithology must be generally uniform, and no cultural sources of interference, such as power lines, pipelines, scrap metal storage, traffic, and metal fences should be present. Within the wetlands of the study area the unsaturated zone is 0 to 6.5 ft thick, and minor lithologic differences were thought to be of little electromagnetic significance. However, potential sources of interference that could cause anomalies or scatter in the data are present. A power line and major roadway along the north side of the wetlands, sewer lines and condominiums on the east side, and homes and utility corridors along the west side appear to have affected the readings in the peripheral part of the study area. A power line through the middle of the wetlands had a minor local effect on the earth conductivity readings. To minimize interference from these cultural features, the sampling grid was oriented perpendicular to them, and to avoid any radio-frequency interference, readings were suspended when aircraft passed overhead.

1 Use of trade names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

ELECTROMAGNETIC SURVEY RESULTS

The EM surveys were made in the winter of 1986 when the surface water in the wetlands was frozen. Although the weather was cold and occasionally snowy, collecting the data under such conditions proved more efficient than trying to use the coils while standing in water. Each EM measurement station was located midway between the transmitting and receiving coil, and six data readings were taken at each of the 444 stations.

An EM survey was done along Chester Creek upstream from any influence of Merrill Field landfill to determine the "background" readings (those in areas of no contamination) for glacial materials such as those in the study area. The 10-m coil spacing was used for this survey. The results of this survey indicate that background values are less than 4 mS/m (fig. 3). The one reading that exceeds 4 mS/m is close to Chester Creek and may be influenced by particles in the creek.

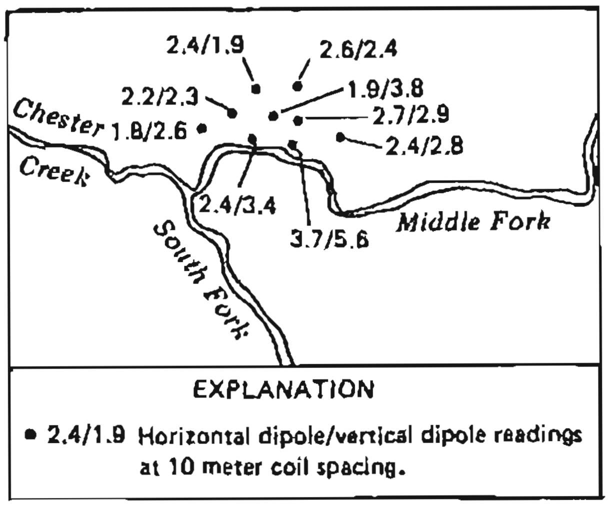

Figure 3.--Background values, apparent earth conductivity, in millisiemens per meter. (See figure 1 for location.)

A 100-foot sampling grid was surveyed throughout the northern part of the wetlands. When the EM measurements indicated ground conductivities substantially above background, the grid was extended to Chester Creek. All measuring points were surveyed to an approximate horizontal accuracy of 2 ft.

Data from the 10-m coil spacing surveys of shallow soils show a relatively high conductivity zone beginning near the intersection of East 15th Avenue and Sitka Street, crossing the wetlands toward the southwest, joining the original North Fork Chester Creek channel along the western side of the wetlands, and approximately following this channel to Chester Creek (fig. 4). This pattern indicates that a concentrated plume of contaminants is present near the corner of Sitka Street and East 15th Avenue. The data in figure 4 also indicate that smaller amounts of contaminants have reached most of the wetlands. The 20-m coil spacing data also show high readings in the area of Sitka Street and East 15th Avenue (fig. 5). However, many of these readings are only slightly above the background values. At the 40-m coil spacing, elevated readings of the horizontal dipole persist near the intersection of Sitka Street and East 15th Avenue. Readings are slightly elevated along the two roadways, but most readings are at background level (fig. 6). The progressive decrease in

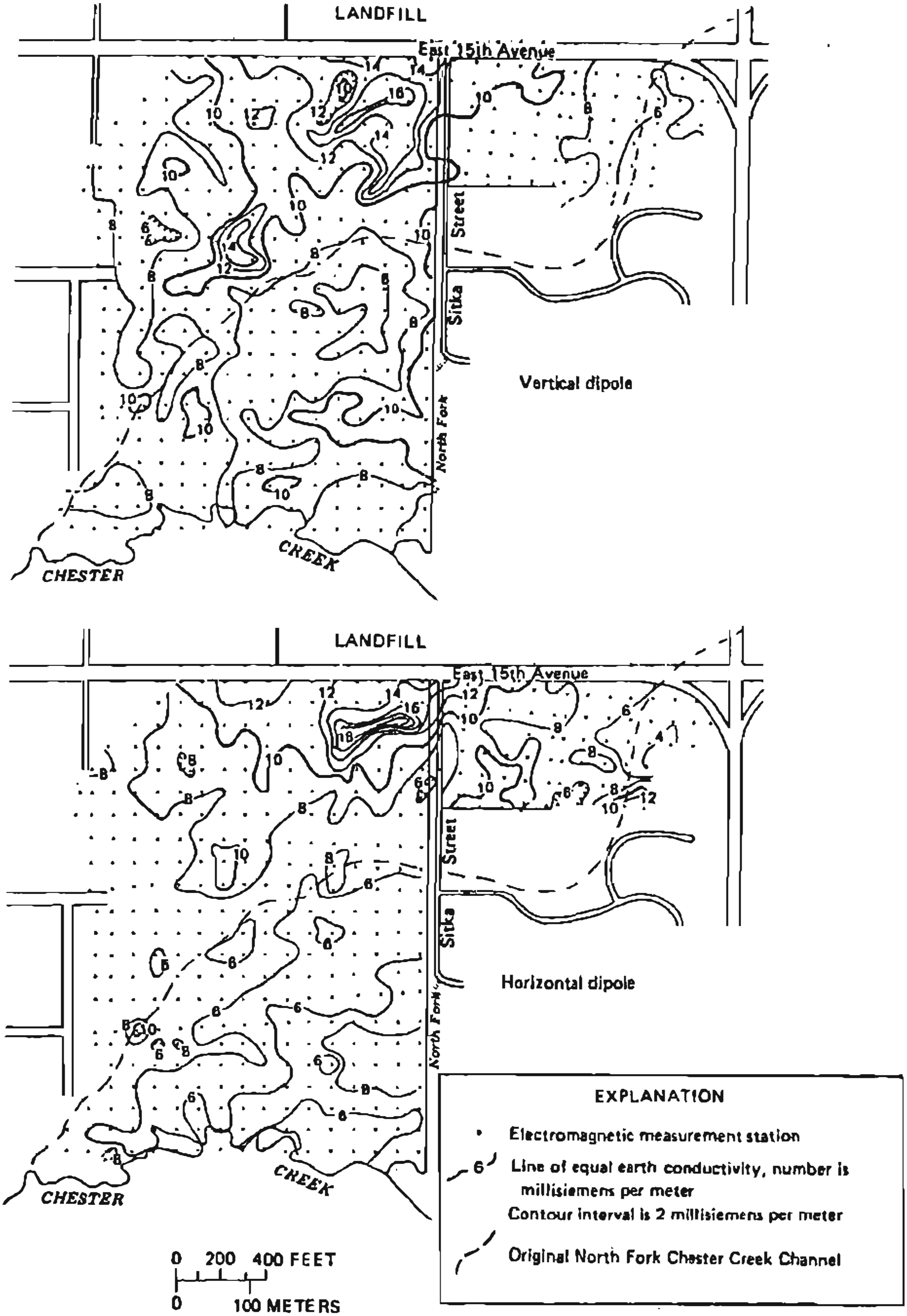

Figure 4.--Apparent earth conductivity, 10-meter coil spacing. (See figure 1 for location.)

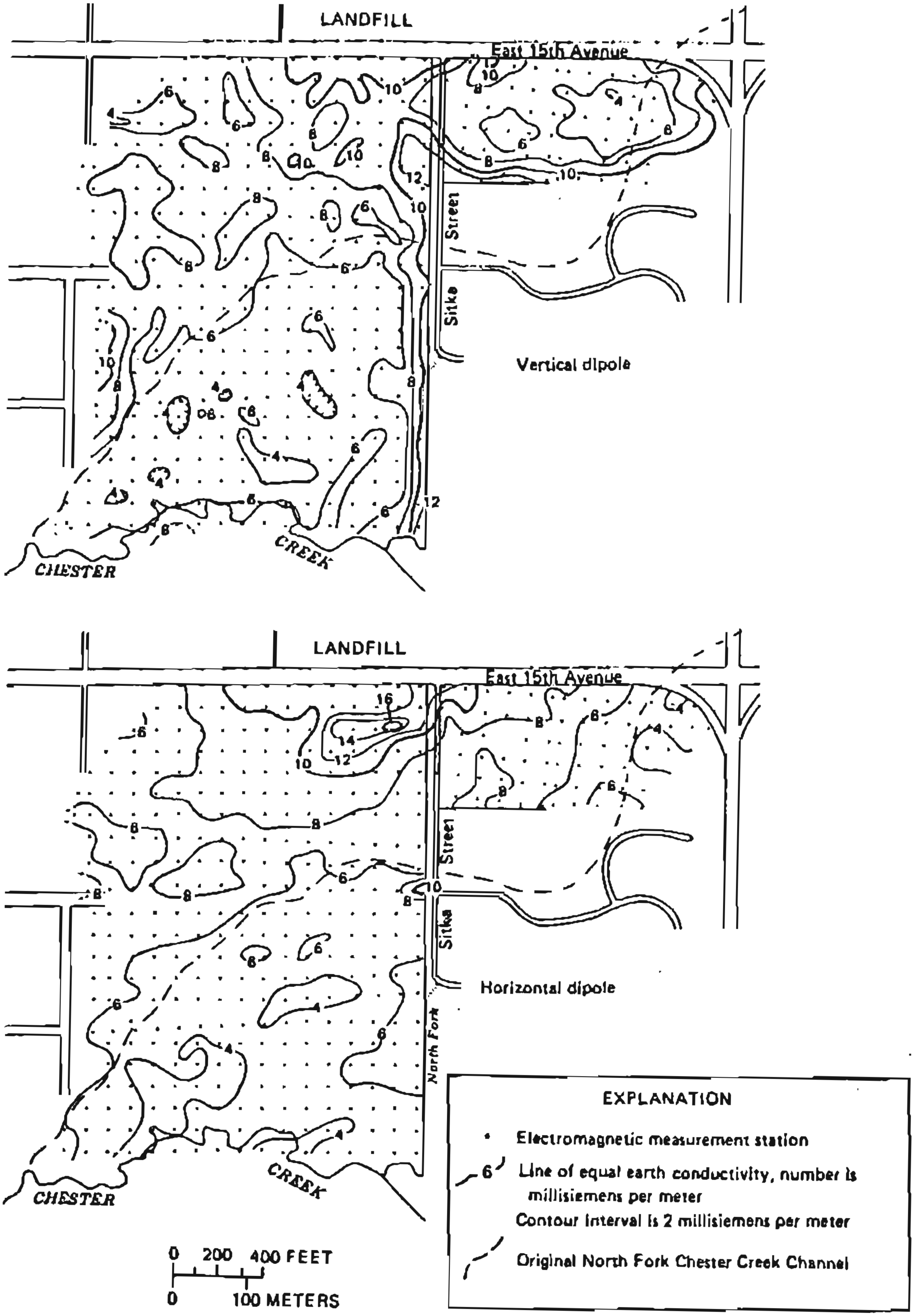

Figure 5.--Apparent earth conductivity, 20-meter coil spacing. (See figure 1 for location.)

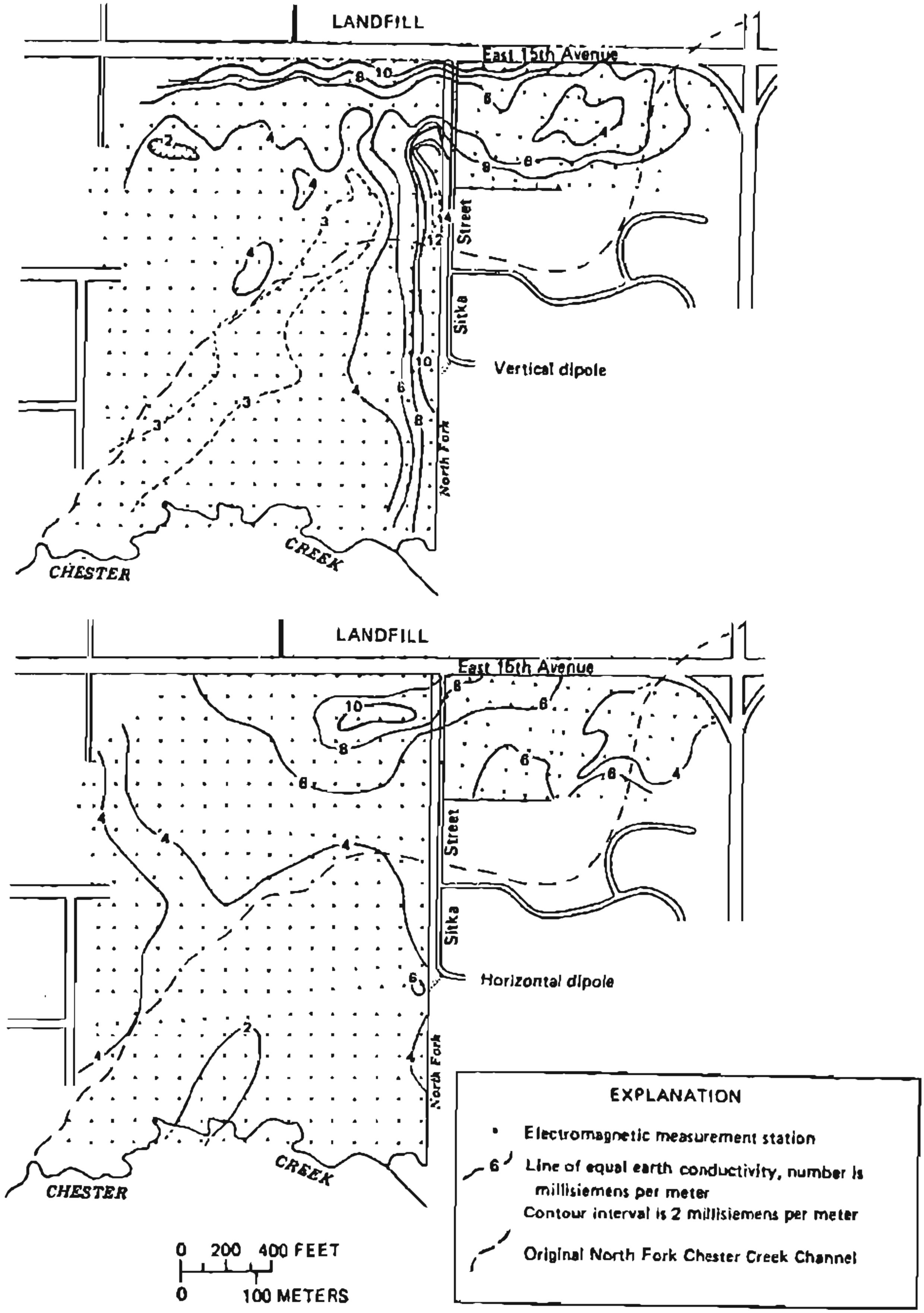

Figure 6.--Apparent earth conductivity, 40-meter coil spacing.
(See figure 1 for location.)

measured EM conductivities with increasing exploration depth (greater coil spacing) indicates that the concentration of contaminants decreases with depth. Thus the contamination is present primarily in the shallow unconsolidated silty sand and gravel.

OBSERVATION WELLS

Water-level (table 2) and water-quality data from 20 observation wells (fig. 7) were analyzed in this study . Wells 1 to 5 and 8 to 12 were drilled either for other studies or to obtain preliminary data for this study prior to the electromagnetic survey. Observation wells 13 to 22 were drilled after the electromagnetic survey was completed and were generally sited where the survey indicated high conductivity values, i.e. where contamination was suspected (fig. 8). The survey proved valuable for selecting well sites to locate this plume. A generalized geologic section of the landfill (fig. 7) supports the assumptions made in the **Electromagnetic Survey** section, that the thickness of the unsaturated zone and the subsurface lithology are uniform.

WATER-QUALITY RESULTS

The specific conductance of ground water determined by analysis of samples from the observation wells correlated well with earth conductivity values obtained in the electromagnetic survey at the 10-m coil spacing (fig. 9). Readings at the 10-m spacing represent apparent earth conductivity of approximately the upper 50 ft of subsurface materials.

Water-quality samples were collected and analyzed for all the priority pollutants, according to U.S. Environmental Protection Agency (EPA) (1987a) standards. In November and December 1985, samples were collected from observation wells 1 to 5 and 8 to 12; in August and September 1986, samples were collected from all wells. Table 3 shows chemical species that were detected and in which wells they were detected. Table 4 contains a listing of chemical species that were not detected in any of the samples, and table 5 lists wells in which concentrations exceeded drinking water standards (Alaska Dept. of Environmental Conservation, 1979; U.S. EPA 1977, 1987b). A complete listing of annlyses is available on request from the U.S. Geological Survey.

Wells 3 and 12 in 1985, and wells 3, 11, and 12 in 1986 had water that contained high concentrations of organic (extractable and purgeable) compounds, trace metals, and common ions. Wells 3 and 12 were completed within the landfill material, so the higher concentrations were expected. In well 11, which was completed at a depth below the landfill material, contamination was not evident in 1985, but by 1986 the leachate apparently had migrated downward, possibly around the casing.

Wells 1, 2, and 4 are 90 ft deep or deeper and are not affected by the leachate. This substantiates previous estimates (Nelson, 1982) that deep migration of pollutants will not be rapid.

No discernable patterns in concentrations of organic compounds and trace metals were evident in any of the other samples. However, a general decrease in specific conductance and chloride concentration is evident as distance from the landfill increases (fig. 10). The incidence of detectable organic contaminants also generally decreases toward Chester Creek (fig. 10). These trends may be due in part to sorption of pollutants on clays and silts common in the aquifer. As ground water

Table 2.--*Observation well information*

Well No. (fig. 7)	Date drilled	Well depth (feet below land surface)	Well completion		Water level (Measured Sept. 5, 1986)	
			Type	Screened interval (feet)	Depth (feet below land surface)	Altitude (feet above sea level)
1	6/ 6/74	115	Open end	--	40.5	81.15
2	6/10/74	90	Open end	--	40.0	81.15
3	6/11/74	39	Screened	13-19	28.3	92.79
4	8/17/76	91	Open end	--	5.34	80.26
5	8/28/76	35	Screened	32-35	5.48	80.56
8	10/ 3/85	20	Screened	9-19	3.78	107.25
9	10/ 3/85	25	Screened	15-25	3.70	71.80
10	10/ 9/85	45	Screened	25-45	7.58	89.18
11	10/ 1/85	70	Screened	50-70	38.38	90.79
12	10/ 2/85	50	Screened	29-49	30.03	91.47
13	9/ 2/86	20	Screened	10-20	6.78	79.95
14	9/ 2/86	20	Screened	10-20	6.38	78.74
15	9/ 3/86	15	Screened	5-15	.63	77.94
16	9/ 3/86	20	Screened	10-20	.65	76.47
17	9/ 3/86	20	Screened	5-15	.64	76.28
18	9/ 4/86	15	Screened	5-15	.62	73.96
19	9/ 4/86	15	Screened	5-15	- .06	72.10
20	9/ 4/86	20	Screened	5-15	.56	70.66
21	8/28/86	21	Screened	11-21	.03	69.68
22	8/28/86	20	Screened	10-20	.21	71.84

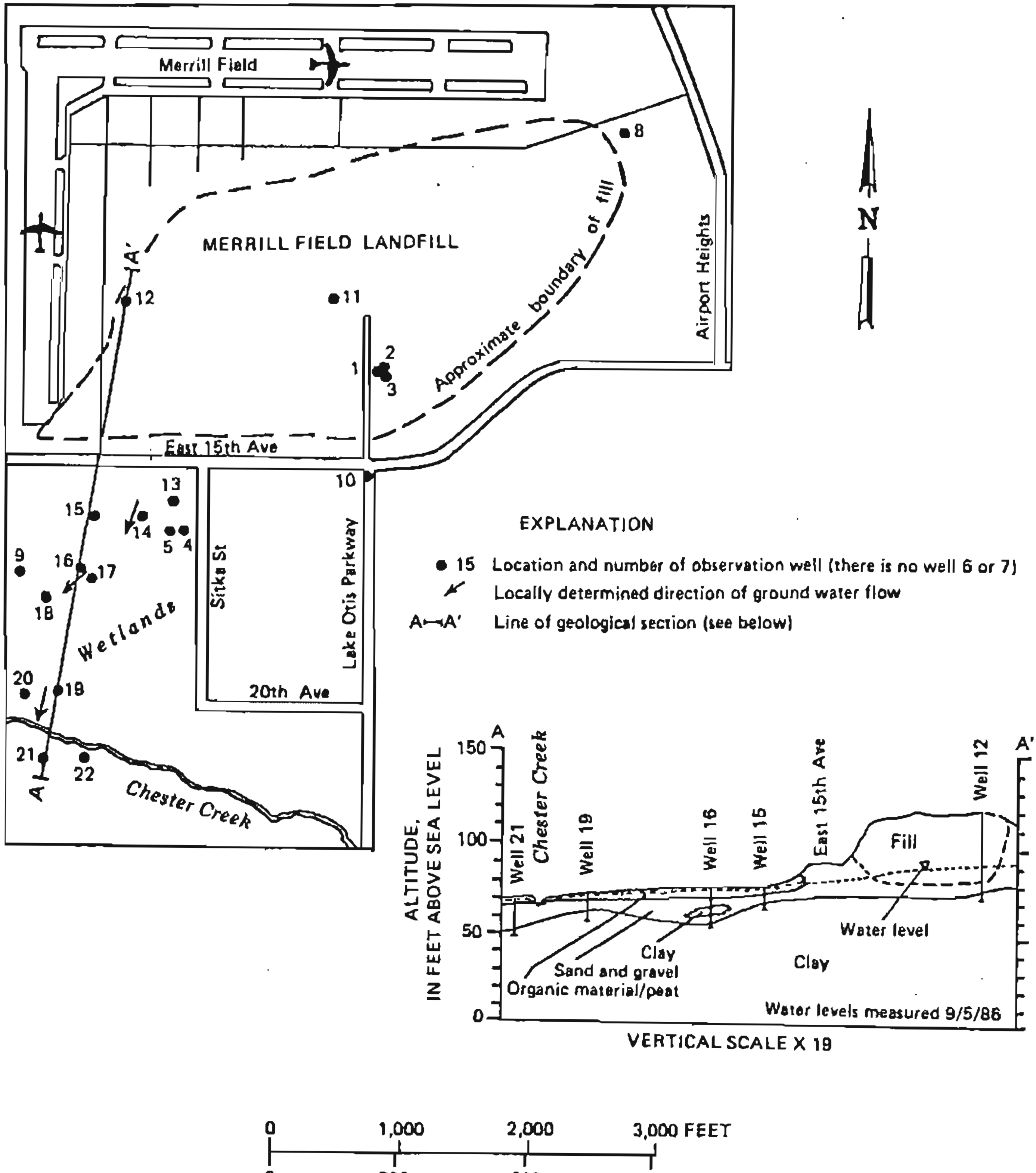

Figure 7.--Locations of observation wells, and geologic section through wetlands and the landfill. (See figure 1 for location.)

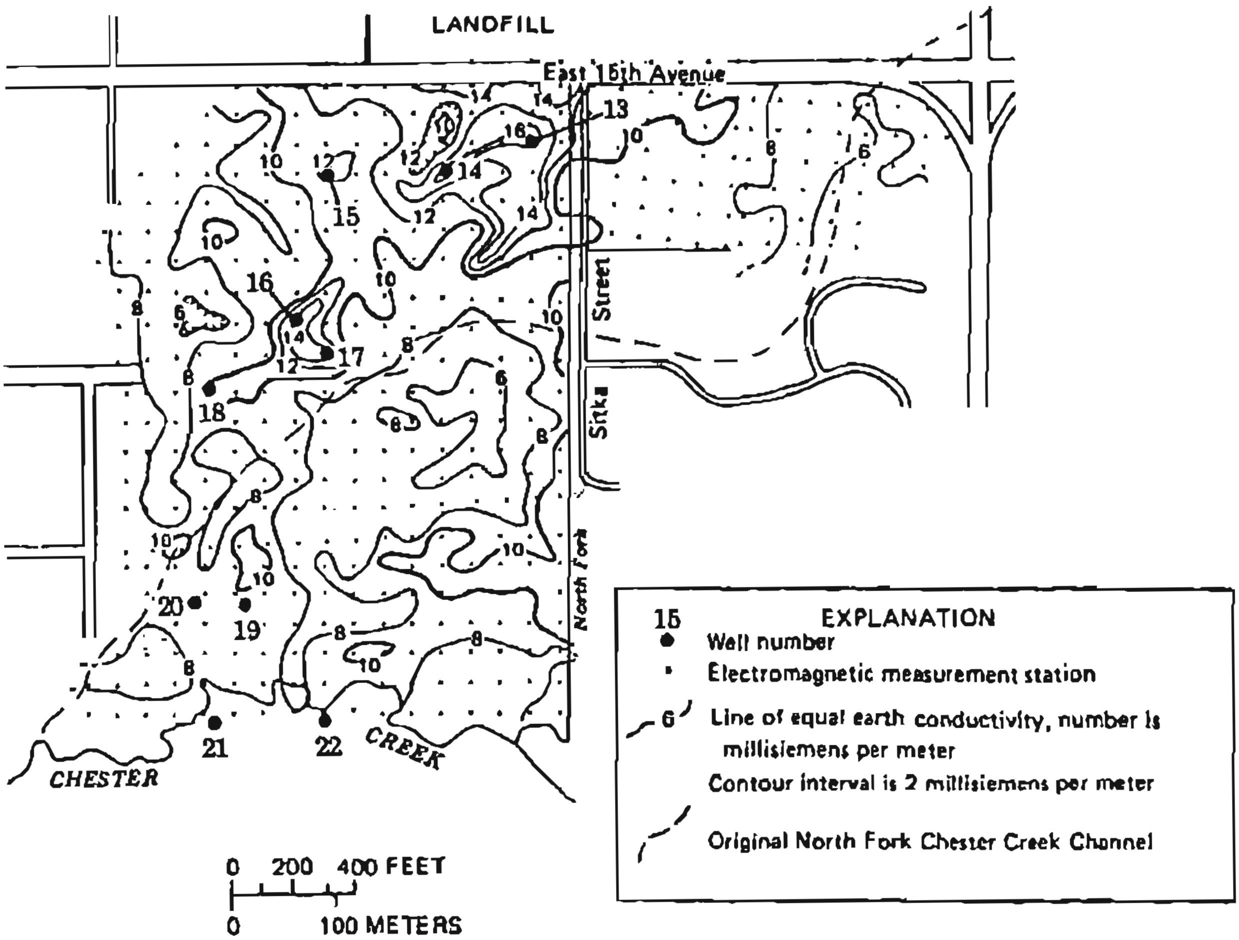

Figure 8.--Location of wells 13-22 sited in areas of high conductivity. (See figure 1 for location.)

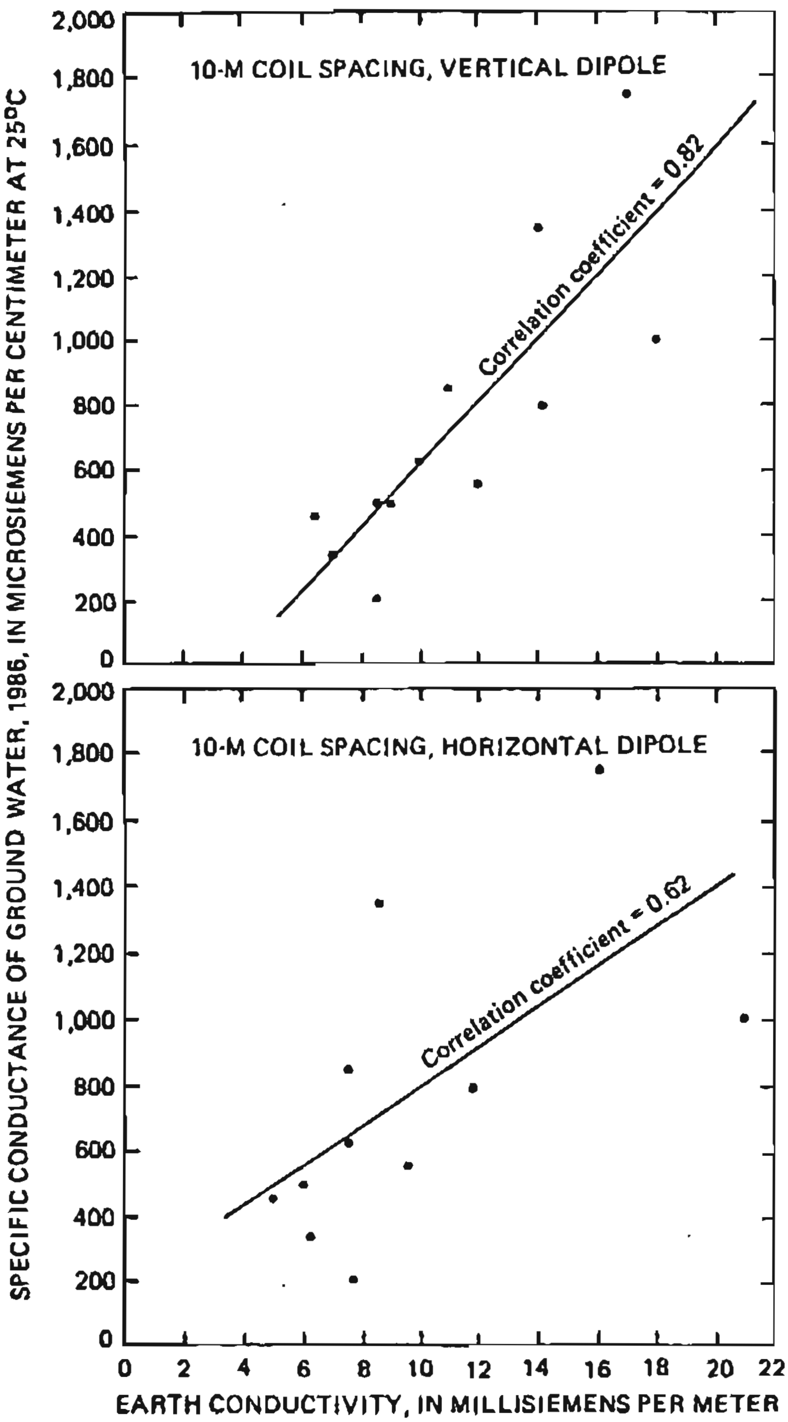

Figure 9.–Relation between earth conductivity and specific conductance of ground water.

Table 3.--*Chemicals detected in ground-water samples*

[Values not in data base; µg/L, microgram per liter]

Constituent	Wells in which found	Maximum concentration (µg/L)
Benzene	2*,3,11,12,13,15,21,22	20
bis (2-Ethylhexyl) phthalate	2,11	65
Carbon tetrachloride	4	0.2
Chloroethane	2*,3,11,12,14	33
Chloroform	4,12,13,14,21	0.6
Chloromethane	12	20
Dichlorodifluoromethane	4,5,9,11,12,14,15,16,17	90
Diethyl phthalate	3	42
Ethylbenzene	3,12	4.8
Freon	12	8.2
Methyl chloride	11,12,14,16,17,18	17
Methylene-chloride	1*,2,3,4,5*,9*,10*,11,12	320
Tetrachloroethylene	12	6.9
Toluene	3,4,5,12,14	560
Trichloroethylene	3,4,12	8.0
Trichlorofluoromethane	4,12	4.5
Vinyl chloride	2,3,5,11,12,14	53
Xylenes	3,12	41
1,1-Dichloroethane	5,12	140
1,1,1-Trichloroethane	12,16	26
1,2-Dichloroethane	3,11,12	1.5
1,2-Dichloropropane	3	0.5
1,2-trans-Dichloroethylene	3,12	8.8
2,4-Dimethylphenol	3	6
Antimony, total	1,2,3,4,5,8,9,10,11,12,15,17,22	14
Arsenic, total	All	130
Cadmium, total	11,19	1
Chromium, total	All	350
Copper, total	All	1,100
Iron, total	All	500,000
Lead, total	1,2,3,4,8,9,10,11,12,17,18,22	300
Manganese, total	All	84,000
Mercury, total	1,8,9,10,11,12,14,15,17,19,20	1.1
Nickel, total	All	1,000
Silver, total	10	1
Zinc, total	All, except 20	3,500

*Trace occurrences based on laboratory rerun

Table 4.--*Chemicals analyzed but not detected in any samples*

BASE/NEUTRAL EXTRACTABLE COMPOUNDS	PURGEABLE ORGANIC COMPOUNDS (Volatile Compounds)
Acenaphthene	Bromoform
Acenaphthylene	Chlorobenzene
Anthracene	Chlorodibromomethane
Benzo(a)anthracene 1,2-benzoanthracene	cis-1,3-Dichloropropene
Benzo (a) pyrene	Dichlorobromomethane
Benzo (b) fluoranthene	Methyl-bromide
Benzo(g,h,i)perylene 1,1,2-benzoperylene	Styrene
Benzo (k) fluoranthene	trans-1,3-Dichloropropene
bis (2-Chloroethoxy) methane	1,1-Dichloroethylene
bis 2-Chloroethyl ether	1,1,2-Chloroethane
bis (2-Chloroisopropyl) ether	1,1,2-Trichloroethane
Chrysene	1,1,2,2-Tetrachloroethane
Di-n-butyl phthalate	1,2-Dibromoethylene
Di-n-octylphthalate,	1,2-Di-chlorobenzene
Dimethyl phthalate	1,3-Di-chlorobenzene
Fluoranthene	1,3-Dichloropropene
Fluorene	1,4-Di-chlorobenzene
Hexachlorobenzene	2-Chloroethylvinylether
Hexachlorobutadiene	
Hexachlorocyclopentadiene	**ACID-EXTRACTABLE COMPOUNDS**
Hexachloroethane	
Indeno (1,2,3-cd) pyrene	Parachlorometa cresol (also known as chloro-methylphenol)
Isophorone	Pentachlorophenol
n-Nitrosodimethylamine	Phenol
n-Nitrosodi-n-propylamine	2-Chlorophenol
n-Nitrosodiphenylamine	2-Nitrophenol
Naphthalene	2,4-Dichlorophenol
Nitrobenzene	2,4-Dinitrophenol
Phenanthrene	2,4,6-Trichlorophenol
Pyrene	4-Nitrophenol
1,2-Dichlorobenzene	4,6-Dinitro-orthocresol (also known as Dinitromethylphenol)
1,2,4-Trichlorobenzene	
1,2,5,6-Dibenzanthracene	**TRACE METALS**
1,3-Dichlorobenzene	
1,4-Dichlorobenzene	Beryllium, total
2-Chloronaphthalene	Cyanide, total
2,3,7,8-Tetrachlorodibenzo-p-dioxin	Selenium, total
2,4-Dinitrotoluene	Thallium, total
2,6-Dinitrotoluene,	
4-Bromophenyl phenyl ether	
4-Chlorophenyl phenyl ether	

Table 5.--*Wells in which concentrations exceeded drinking-water standards*

[μg/L, microgram per liter]

Constituent	Wells in which found	Drinking-water standard maximum concentration limit (μg/L)
Benzene	3,12	5.0
Trichloroethylene	12	5.0
Vinyl chloride	3,11,12,14	1.0
Arsenic, total	1,2,5	50
Chromium, total	8,9	50
Iron, total	All, except 1,4,21	3,000
Lead, total	3,10,11,22	50
Manganese, total	All	50
Nickel, total	8,9,10,11,12,15,17,18,22	13.4
Zinc, total	10,11,12	320

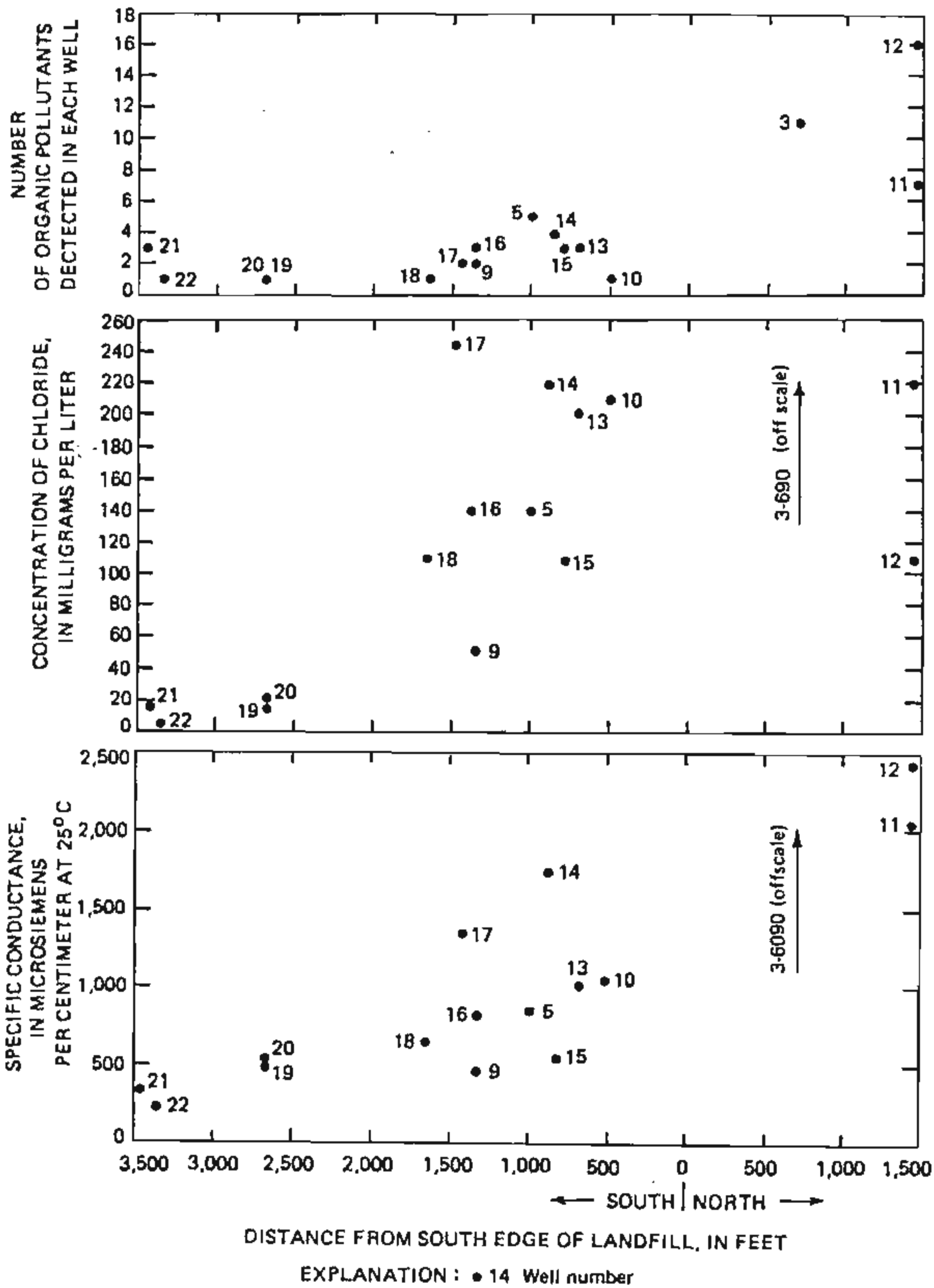

Figure 10.--Changes in specific conductance, concentration of chloride, and number of organic pollutants detected in each well with increasing distance from the landfill.

continues to carry leachate through the aquifer and sorption sites on the clays become saturated, the concentrations of ions in ground water may increase.

During these initial two rounds of sampling, the wells were pumped long enough to void at least three casing volumes of water prior to taking the actual sample. Monitoring specific conductance throughout the pumping period to ensure that it stabilized served as a check that the water being sampled was representative of the aquifer. To make sure that the volatile organic compounds were not being lost by this technique, wells 13 to 22 were sampled twice in June 1987, once prior to pumping and then again after pumping. In most cases the concentrations of the volatiles were higher after pumping. In the few cases where the reverse was true, the differences in concentrations were so slight that they could have been attributable to normal analytical error.

North Fork Chester Creek does not appear to undergo significant contamination during its transit through the conduit buried in the landfill, but limited evidence suggests that a small amount of leachate may be entering the creek through leaks in the conduit. Trace amounts of six organic compounds, only one of which is present in the creek above the landfill, were detected in samples from the conduit outlet (table 6). The concentrations of iron and manganese, both of which are present in high concentrations in leachate, also increase substantially as the creek flows through the landfill. However, concentrations of sodium and chloride, which are highly concentrated in leachate, do not increase substantially. In fact, in the samples collected in August 1986, the concentrations of both sodium and chloride were lower downstream from the landfill.

Table 6.--*Selected chemical constituents of North Fork Chester Creek above and below the landfill*

[ND, not detected; T, trace; µg/L, microgram per liter; mg/L, milligram per liter. Complete analyses are available on request from the U.S. Geological Survey.]

Constituent	December 2, 1985		August 27, 1986	
	Above	Below	Above	Below
Dichlorodifluoromethane (µg/L)	ND	ND	0.4	0.5
Tetrachloroethylene (µg/L)	ND	T	ND	.2
Toluene (µg/L)	ND	5.0	ND	ND
Trichloroethylene (µg/L)	ND	ND	ND	.2
Vinyl Chloride (µg/L)	ND	ND	ND	.2
1,1-Dichloroethane (µg/L)	ND	ND	ND	.2
Chloride, dissolved (mg/L)	41	45	25	19
Iron, dissolved (µg/L)	370	5,800	160	1,300
Manganese, dissolved (µg/L)	46	240	41	170
Sodium, dissolved (mg/L)	11	15	8.9	8.3

CONCLUSIONS

1. Ground water in the wetlands south of Merrill Field landfill is flowing toward the southwest, transporting contaminants toward Chester Creek, but the concentrations of these contaminants in the ground water are generally below the EPA standards for drinking water.

2. Both the electromagnetic survey of shallow subsurface geologic materials and analyses of ground-water samples indicate that the contaminants are concentrated in the upper 50 ft of the surface. The correlation between specific conductance of ground water and earth conductivity permits use of such surveys to estimate the extent of migration of landfill contaminants. The survey indicates that small amounts of pollutants probably have reached most of the wetlands and a slightly more concentrated plume of contaminants is present near the corner of Sitka Street and East 15th Avenue.

3. The electromagnetic survey is a valuable tool for designing a drilling program to sample points where the contamination was greatest. The location of the most concentrated plume of contaminants would not have been apparent and probably would have been missed without the EM survey data.

4. In the wetlands, the unconfined aquifer is generally less than 30 ft thick and is underlain by a poorly permeable silty clay that inhibits the vertical migration of water. Therefore, any contamination from Merrill Field landfill will be expected to move laterally through the unconfined aquifer toward Chester Creek.

5. Analyses for volatile organic compounds generally indicated higher concentrations when the wells were pumped before sampling than when samples were collected without pumping.

6. The water of North Fork Chester Creek is not significantly affected by its transit through the enclosed conduit in the landfill, but minor amounts of leachate may be entering the creek.

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