# HYDROGEOLOGY AND WATER QUALITY OF SIX LANDFILL SITES IN HILLSBOROUGH COUNTY, FLORIDA

By J. W. Stewart, A. D. Duerr, and Mario Fernandez, Jr.

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GEOLOGICAL SURVEY

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## ABBREVIATIONS AND CONVERSION FACTORS

Factors for converting inch-pound units to International System (SI) of Units and abbreviations of units

| Multiply | By | To obtain |
|---|---|---|
| inch (in) | 25.4 | millimeter (mm) |
| foot (ft) | 0.3048 | meter (m) |
| mile (mi) | 1.609 | kilometer (km) |
| square mile ($mi^2$) | 2.590 | square kilometer ($km^2$) |
| acre | 0.004047 | square kilometer ($km^2$) |
| gallon (gal) | 3.785<br>0.003785 | liter (L)<br>cubic meter ($m^3$) |
| gallon per minute (gal/min) | 0.00006309 | cubic meter per second ($m^3/s$) |
| pound (lb) | 453.6 | gram (g) |
| cubic foot per second ($ft^3/s$) | 0.028317 | cubic meter per second ($m^3/s$) |
| foot per day (ft/d) | 0.305 | meter per day (m/d) |
| foot squared per day ($ft^2/d$) | 0.09290 | meter squared per day ($m^2/d$) |
| micromho per centimeter at 25° Celsius (umho/cm at 25°C) | 1.000 | microsiemen per centimeter at 25° Celsius (uS/cm at 25° C) |

Temperature in degrees Fahrenheit (°F) can be converted to degrees Celsius (°C) as follows:

$$(°F-32)0.566 = °C$$

* * * * * * * * * * * * * *

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 mean sea level. NGVD of 1929 is referred to as sea level in the text of this report.

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# HYDROGEOLOGY AND WATER QUALITY OF SIX LANDFILL SITES IN HILLSBOROUGH COUNTY, FLORIDA

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## ABSTRACT

A hydrogeologic study of six landfills in Hillsborough County, Florida, showed that refuse was deposited in trenches constructed in the upper part (2 to 5 feet) of the surficial aquifer. Use of the trench method resulted in an increased rate of decomposition of refuse buried below the water table. Accelerated degradation of water in the surficial aquifer occurred because as much as 50 percent of the refuse was deposited in the saturated zone. Use of oxidation ponds to store water pumped from trenches that contained refuse, and refuse and debris that collected in perimeter ditches, also affected the quality of water in the surficial aquifer. The trench method of landfilling has restricted use in Hillsborough County and other areas of Florida where high water levels occur.

Continued monitoring of surface- and ground-water sites after a landfill is closed would help to assess the long-term movement of leachate from a landfill and its effect on water quality.

## INTRODUCTION

Rapid population growth during the past decade has resulted in a significant expansion and development of urbanized areas in Hillsborough County. This population growth, along with an increased standard of living and increased use of prepackaged-disposable commodities, has created a need for solid-waste disposal capacity within the county. Solid-waste disposal has become a major problem, not just in Hillsborough County, but nationwide. During the past two decades, the national expenditure for disposal of solid waste has been exceeded only by expenditures on education and highways (Bogue, 1970).

The most common practice of solid-waste disposal is the use of the landfill. While landfills are effective in removing and isolating solid wastes, they are a potential source of water pollution that may result in a significant reduction in usable water resources. This problem becomes magnified where the hydrogeologic environment is conducive to rapid interchange of surface and ground water, as occurs in much of Hillsborough County.

In 1969, the U.S. Geological Survey, in cooperation with Hillsborough County and the city of Tampa, began a study to determine the hydrogeology and water quality of two landfill sites in the county. In 1972, the program was expanded to include four additional landfill sites. This report describes the hydrogeology and water quality of the six sites and the effects of landfilling in Hillsborough County. The report is a contribution to the U.S. Geological Survey's data base regarding the quality of ground water in areas that are potentially impacted by waste disposal. Information acquired during the study, and the potential impact of waste disposal on water quality, may be applied to other areas in the State that use similar disposal methods.

## Purpose and Scope

The objectives of this investigation were to describe the hydrology and geology of six landfill sites and to determine, when possible, changes in water levels due to landfill operations, the direction and extent of leachate movement, and changes in water quality in the surficial aquifer and the Floridan aquifer. The scope of this report is to evaluate pertinent data and results from six landfill site studies that have been conducted in Hillsborough County since 1969.

## Description of Area

Hillsborough County is about midway down the west coast of Florida (fig. 1) and has a land area of 1,040 $mi^2$. Land-surface altitudes range from sea level along Tampa Bay to about 160 feet above sea level at the Hillsborough-Polk County line. The county has more than 200 lakes that have surface areas of 10 acres or more. Numerous swamps and marshes are scattered throughout the county. There are at least three sinkholes that are more than 200 feet deep and there are numerous shallow sinkholes that are probably hydrogeologically connected to the Floridan aquifer; internally drained areas are common in the central part of the county. Also, several large springs occur in the central part of the county; one serves as a supplemental water supply for the city of Tampa.

### Urban Development

Hillsborough County had a population of 646,960 in April 1980 (University of Florida, 1981), an increase of 32 percent during the previous decade. Most of the population is in the northwestern part of the county that includes the cities of Tampa and Temple Terrace. Tampa, the largest city, had a population of 271,523.

### Climate

Mean monthly temperatures in Hillsborough County range from 59°F to 82°F. Temperature extremes range from below freezing to about 100°F. The average annual precipitation is 51.5 inches. About 60 percent of the annual precipitation falls during June through early September. August is the wettest month and accounts for about 17 percent of the annual precipitation. November is the driest month with about 4 percent of the annual precipitation. Several hurricanes of varying intensities have affected the county during the past 25 years.

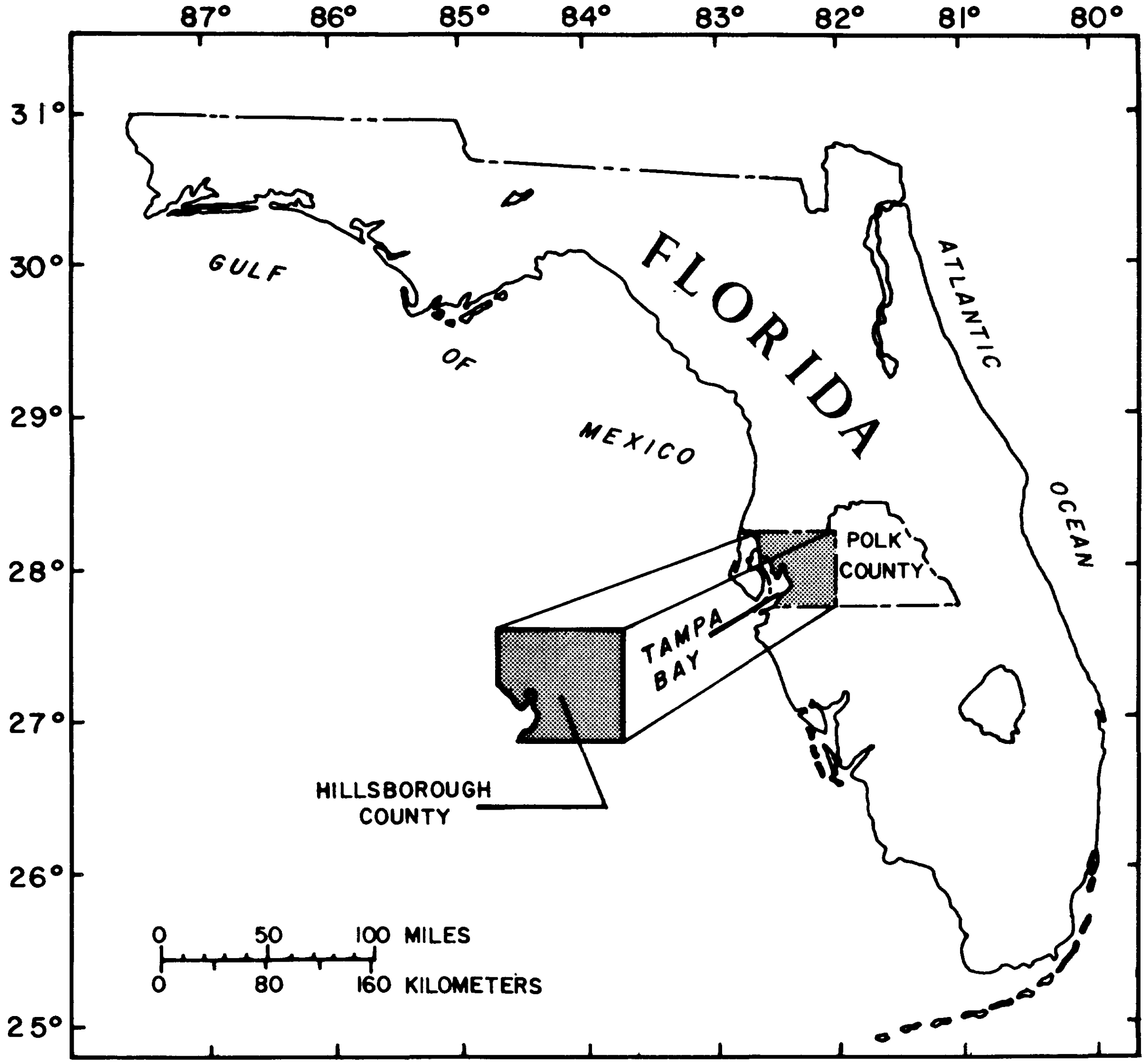



Figure 1.--Location of Hillsborough County.

## Acknowledgments

This report was prepared as part of the cooperative program of water-resources investigations with Hillsborough County and the city of Tampa. The cooperation of Pickens Talley, former Director of Utilities, Hillsborough County; J. D. Gorman, Director, Hillsborough County Mosquito Control and Operations Chief for county landfills from 1969 to 1972; and Robert Becker, former Director, Sanitation and Landfill Department, is gratefully acknowledged.

Special thanks are due to Dale Twachtman, former Administrator, Water Resources and Public Works, city of Tampa, for his cooperation and support of the study from 1969 to 1972. The cooperation of numerous other people is gratefully acknowledged, especially that of J. H. Dobbins, former Executive Director, Hillsborough County, and Rudy Rodriguez, former Hillsborough County Commissioner.

## Previous Investigations

A report describing the geology and hydrology of Hillsborough County was prepared by Menke and others (1961). Stewart and others (1971) mapped the potentiometric surface of the Floridan aquifer for May 1969 in an area that included Hillsborough County. Semiannual maps of the potentiometric surface that include the study area have been prepared by the U.S. Geological Survey since 1971.

Factors that affect utilization of land for landfills in the northern half of Hillsborough County were described by Stewart and Hanan (1970). Hydrologic and geologic factors to be considered for solid-waste disposal in west-central Florida were discussed by Stewart and Duerr (1973). A compilation of water-quality data for four landfills in Hillsborough County for the period January 1974 to October 1977 was prepared by Fernandez and Hallbourg (1979). Hydrogeologic data for the Eureka Springs landfill, 1969-73, was prepared by Duerr and Stewart (1980), and a similar report for the Rocky Creek Landfill was prepared by Duerr and Stewart (1981).

# GEOLOGY

The geology of Hillsborough County was described by Menke and others (1961). The county is underlain by several hundred feet of limestone and dolomite that comprise the following Tertiary formations in ascending order: Lake City Limestone, Avon Park Limestone, Ocala Limestone, Suwannee Limestone, Tampa Limestone, and Hawthorn Formation. These formations compose the Floridan aquifer, the principal source of water in Hillsborough County as well as most of west-central Florida.

Overlying the limestone is a layer of undifferentiated surficial deposits that consist of sand, silt, sandy clay, and clay. The deposits range in thickness from a few feet near the coastal area to about 80 feet in the eastern part of the county. The average thickness of the surficial deposits is about 40 feet.

## GROUND WATER

Ground water in Hillsborough County occurs in unconfined conditions in the surficial deposits and in confined or under artesian pressure in the Floridan aquifer. Artesian conditions occur where water in an aquifer is confined by less permeable material under hydrostatic pressure greater than atmospheric.

### Surficial Aquifer

Water in the surficial aquifer is derived from rainfall, and water levels fluctuate about 1 to 3 feet with individual rainstorms, depending on the amount of rain. The annual range in water-level fluctuations is about 2 to 5 feet. Depth to the water in the surficial aquifer ranges from land surface to about 20 feet, depending on the area and the season of the year. A map showing the generalized thickness of the surficial deposits and altitude of the water in the surficial aquifer in the northern part of Hillsborough County in 1967 was prepared by Stewart and Hanan (1970). Wolansky and others (1979) showed the generalized thickness of the surficial deposits for the Southwest Florida Water Management District, which includes Hillsborough County.

### Floridan Aquifer

The Floridan aquifer is the principal artesian aquifer in Hillsborough County, as well as in most of west-central Florida. Water in the aquifer is replenished chiefly by infiltration of rainfall in areas of recharge in Hillsborough and adjoining counties (Stewart, 1980).

Maps of the Southwest Florida Water Management District, which includes Hillsborough County, show the generalized configuration of the top of the Floridan aquifer (Buono and Rutledge, 1978) and the bottom of the Floridan aquifer (Wolansky and others, 1979). In Hillsborough County, the thickness of the aquifer ranges from 1,000 to 1,300 feet (Wolansky and Garbade, 1980).

## SOLID WASTE

### Types and Quantities

Hillsborough County landfills received residential and commercial wastes that consisted of mixed garbage, rubbish, construction and demolition wastes, municipal solid wastes, and industrial solid wastes. In February 1976, an average of 690 tons of solid waste was disposed of daily at four landfills. At the end of 1980, only one of the six landfills included in this report was in operation. The landfill received an estimated 200 tons of solid waste daily. All other solid waste was deposited in a new landfill in the central part of the county.

## Methods of Disposal

A properly designed landfill includes methods and practices that eliminate or minimize (1) infiltration of rainfall into refuse, (2) flooding, (3) saturation by ground water, and (4) direct or indirect access of leachate into aquifers through sinkholes, borrow pits, streams, and lakes.

Two methods of land disposal of solid waste were used by Hillsborough County--the trench method (Sorg and Hickman, 1970) and the Florida high-rise method (Florida Division of Health, 1972).

Trench method.--With this method, trenches are excavated in the surficial deposits and solid wastes are placed in the trenches and compacted and covered daily with a 6-inch layer of earth material to form cells. Completed trenches are covered with a minimum of 2 feet of compacted earth material. Cover material for daily and final covers is obtained from the spoil of the trench. The landfill trenches average 8 feet in depth, 125 feet in width, and 400 feet in length. The volume of an average trench is about 400,000 $ft^3$. The trenches are divided into five to seven cells separated by undisturbed earth dikes.

Florida high-rise method.--This method is used because of the shallow depth of the water table and because of the limited availability of land suitable for landfill operations. The method usually consists of constructing a mound of refuse 20 to 30 feet above the surrounding terrain. The method requires that cover material be well compacted at each lift to permit drainage of leachate. The particular method used in Hillsborough County consists of constructing a landfill on top of one or more filled and covered trenches to form a "high-rise" of solid waste as much as 30 feet above land surface.

# DATA-COLLECTION STUDY METHODS

## Hydrogeologic Information

Geologic information collected at the landfill sites included cuttings and cores from test wells and core samples of material from the sides and bottoms of selected landfill trenches. Drillers' logs also were obtained of privately owned wells in the vicinity of the landfills.

Test wells were constructed within and adjacent to the landfills to: (1) determine the thickness of surficial deposits; (2) define confining layers and permeable zones in the surficial aquifer; (3) determine depth to top of the Floridan aquifer; and (4) determine the rate and direction of movement of ground water in the surficial aquifer.

Test wells were drilled using a 6-inch diameter hollow-stem auger. The wells were cased with a 2-inch schedule 40-PVC (polyvinylchloride) plastic pipe and finished with a 2- to 4-foot section of 100-mesh plastic screen. In areas where material was relatively impermeable, as in clayey sand, it was necessary to pack coarse sand and gravel around the screen to insure that the well would yield water. The test wells were developed by pumping and surging.

Split-spoon samples of surficial materials were collected at various depths from selected wells during drilling. Quantitative analyses of the samples included particle-size distribution, hydraulic conductivity, specific yield, specific retention, and porosity. Cation exchange capacity determinations were made for samples from two test wells. Sediment samples were collected during construction from the bottoms and sides of selected trenches to determine horizontal and vertical conductivity. All analyses were made by the U.S. Geological Survey, Denver, Colo.

At most sites, multidepth wells (cluster wells) were installed in the surficial aquifer to monitor water levels and to collect water samples. Where surficial deposits were a minimum of 40 feet thick, clusters of three wells were installed at different depths to monitor permeable zones. Test wells constructed in the Floridan aquifer were cased to the top of the limestone and were completed as open-hole wells.

Samples of material from the bottoms and sides of selected trenches at two landfill sites were collected to determine hydrologic properties, types of material in the trenches, and to prepare geologic sections.

## Water-Level Data

Water levels in wells in the surficial and Floridan aquifers were measured at intervals of 1 to 3 months during the first year of landfill operations, and semiannually thereafter, in May at the end of the dry season and in September at the end of the wet season. Data were used to prepare water-table and potentiometric-surface maps that show the head relation between the surficial and Floridan aquifers and the general direction of ground-water movement.

## Water-Quality Data

Water-quality samples were collected monthly during the first year of operation at the Rocky Creek and Eureka Springs landfills. Subsequently, the sampling was periodical. Specific conductance, temperature, and pH were determined in the field. Concentrations of sodium, potassium, calcium, magnesium, chloride, trace metals, biochemical oxygen demand, coliform species, and nitrogen and phosphorus species were determined in the laboratory.

The wells were sampled using a centrifugal or peristaltic pump. The intake hose was attached to a 3/4-inch PVC pipe installed in each well. The purpose of the pipe was to minimize cross-contamination of water samples by eliminating the need for a suction hose inside the well casing. The lower end of the 3/4-inch pipe was capped to prevent bottom sediments from entering the pipe during pumping. Water was obtained through a 2-foot perforated section located 0.5 foot above the bottom of the well. Each test well was pumped sufficiently to insure that a representative water sample was collected.

## Leachate

Leachate is a malodorous liquid that results from water that has been in contact with or has flowed through refuse and has removed dissolved and suspended materials from the refuse. Leachate has a high concentration of dissolved constituents (iron, chloride, potassium, sodium, and calcium) and is high in hardness and biochemical and chemical oxygen demand. Generally, the color ranges from light gray to black, depending upon age.

Water is essential for the generation of leachate. If water does not enter refuse, leachate is not generated, except possibly a small quantity that may result from moisture contained within the refuse.

In the subtropical climate of west-central Florida, rainfall exceeds evapotranspiration throughout most of the year. This results in water being available to replenish soil mositure and to recharge the surficial and Floridan aquifers. Under these conditions, leachate is generated at landfills.

Six water-quality parameters were selected for use in illustrating trends in ground-water and surface-water quality that are caused by landfill operations. The parameters, representative of the physical and chemical and organic and inorganic character, are: specific conductance, chloride, total organic nitrogen, ammonia nitrogen, potassium, and biochemical oxygen demand.

# SOLID-WASTE DISPOSAL SITES

Hydrologic and geologic information were collected for the following landfill sites: (1) Rocky Creek, (2) Eureka Springs, (3) Gunn Highway, (4) Turkey Creek, (5) Gibsonton, and (6) Ruskin (fig. 2). The Gunn Highway landfill was completed in 1960 and was included in this report for background information; all other landfills were in operation during all or parts of the study period. The landfill sites were completed and closed by April 1981.

## Rocky Creek Landfill

### Location, Construction, and Operation

The Rocky Creek landfill (also referred to as the Northwest landfill) is in northwest Hillsborough County, about 8 miles northwest of Tampa (fig. 2). The site consists of 206.6 acres, of which about 80 acres were used for refuse disposal, and about 2 acres were used for the disposal of septic-tank effluent. The area is in one of the most rapidly developing sections of west-central Florida. Several privately owned wells 3-1/4 miles southeast of the landfill supply a small subdivision. Three public-supply well fields are in the area, about 1 mile south of the landfill, 3-1/2 miles north of the landfill, and 5-1/2 miles northeast of the landfill. Rocky Creek is at the northern and western boundaries of the landfill site, and Wilsky Boulevard and Linebaugh Avenue are near the eastern and southern boundaries (fig. 3).

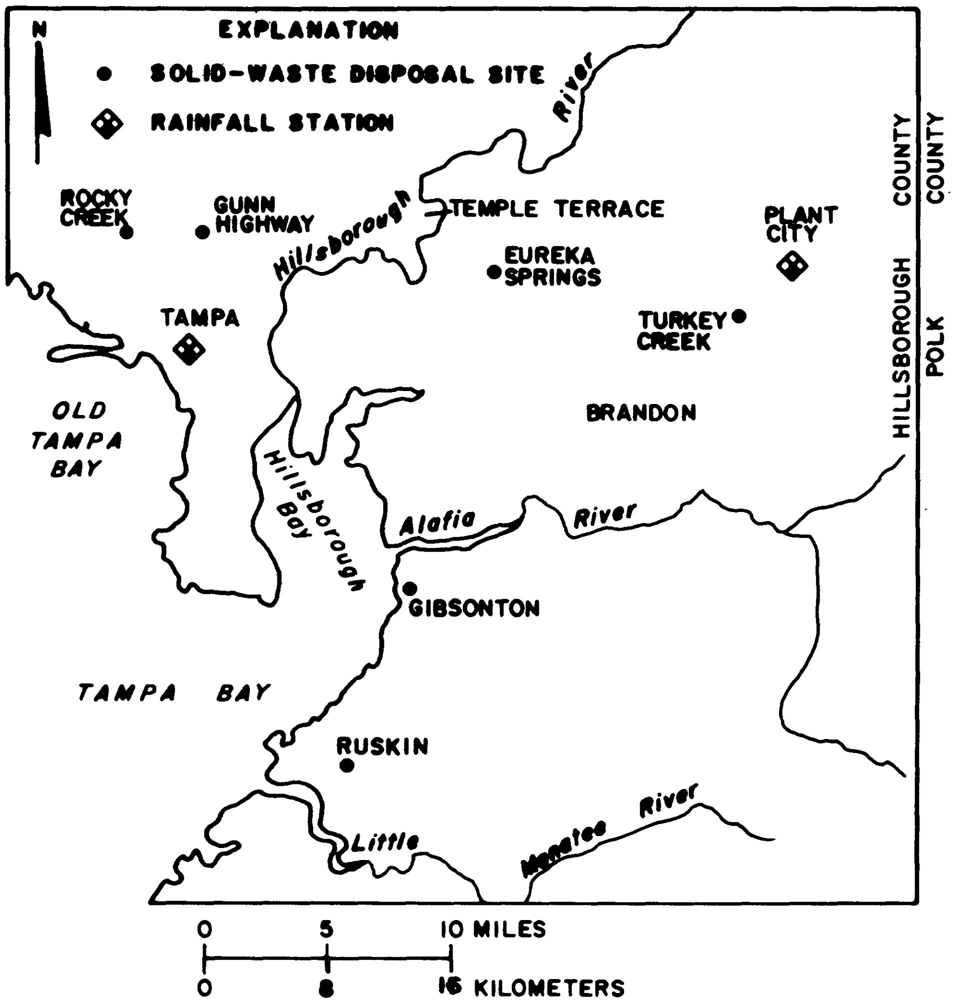



Figure 2.--Locations of landfill sites and rainfall stations.

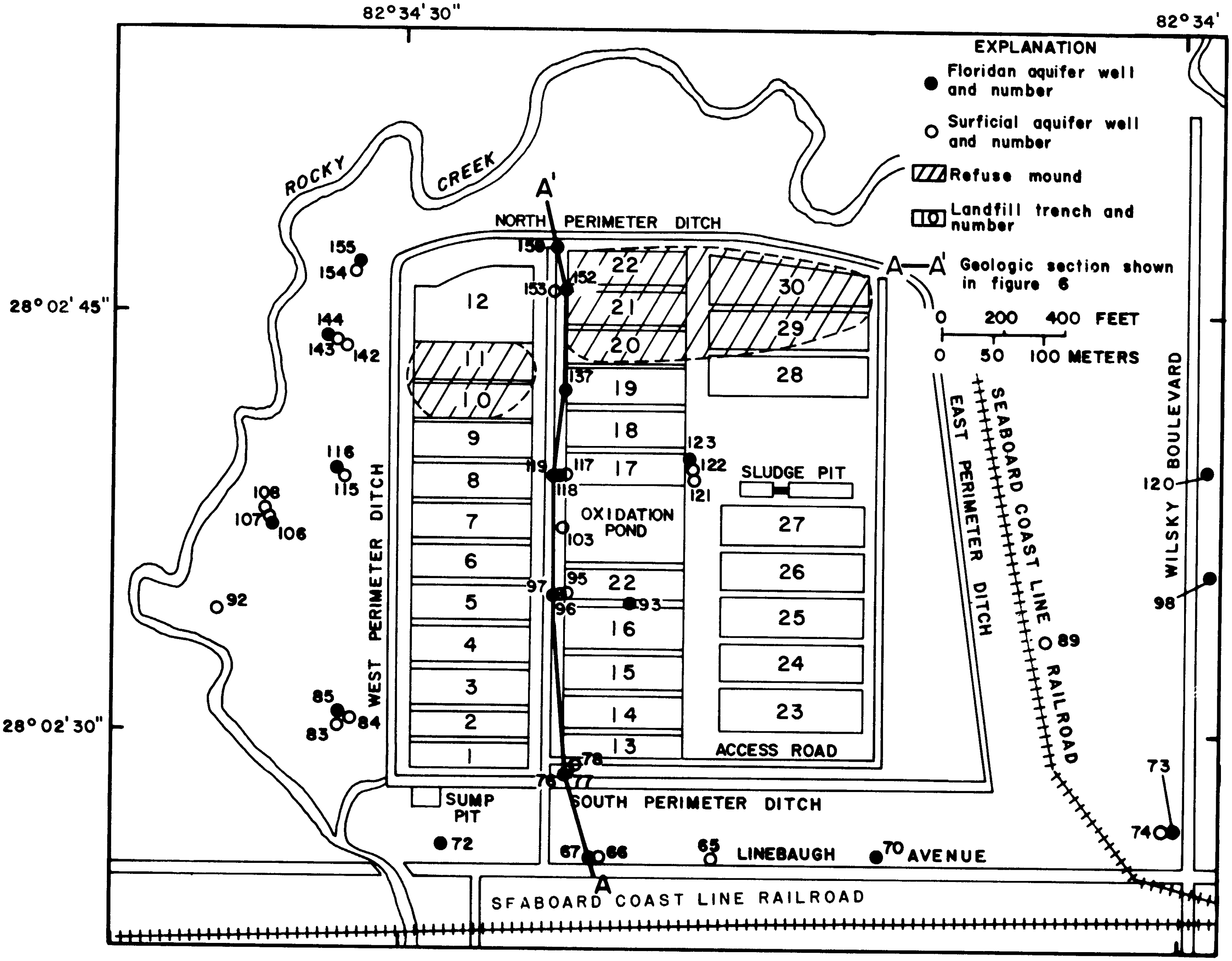



Figure 3.--Locations of trenches, monitor wells, and section A-A', Rocky Creek landfill.

The trench method of landfilling was used during the early development of the Rocky Creek landfill site. The trenches were 7 to 10 feet deep, 75 to 120 feet wide, and 360 to 400 feet long. The average depth of trenches was 8 feet, and they penetrated 2 to 4 feet of the upper part of the surficial aquifer. Land-surface altitudes at trench sites were 20 to 22 feet above sea level; trench bottoms were 12 to 14 feet above sea level. Filled trenches were completed by adding 2 to 3 feet of solid waste above land surface and capping them with 2 feet of excavated material. The landfill was enclosed by a perimeter ditch that was 8 to 10 feet deep, 10 feet wide at the top, and 4 feet wide at the bottom. The perimeter ditch was constructed to dewater the landfill and to regulate water levels in the site. Water in the perimeter ditch flowed into a sump pit near the southwest corner of the landfill. Periodically, water was pumped from the pit into a small channel that was connected to Rocky Creek. An unlined oxidation pond was constructed in the center of the landfill to provide storage for water and leachate that were pumped from active trenches during dewatering operations. The pond was 400 feet long, 166 feet wide, and 8 feet deep and had side slopes of 1:1. Its volume was 496,000 $ft^3$ or 3.7 Mgal. Most of the water pumped into the pond infiltrated the surficial aquifer because of the high hydraulic conductivity of the surficial deposits.

In 1972-73, high-rise refuse mounds were constructed on filled trenches in the northwestern and northeastern parts of the site. The maximum heights of the mounds were about 20 feet above land surface when construction ceased.

The Rocky Creek landfill began operations on February 2, 1970, when trench 1 was opened to receive refuse (fig. 3). Trenches 1 through 12 were the first to be filled, followed by trenches 13 through 22 and 23 through 30. Refuse mounds were initially constructed on filled trenches 10, 11, 20, 21, 22, 29, and 30. However, by the end of 1980, most of the trenches were filled and had been covered by a high-rise refuse mound.

## Physical Setting

The area of the Rocky Creek landfill is well drained at an average land-surface altitude of 25 feet above sea level. The soil is classified largely as Blanton and Rutledge fine sand (U.S. Department of Agriculture, 1958). Rocky Creek is a small meandering stream about 15 miles long that flows adjacent to and drains the landfill site. The creek has its headwaters in a lake complex and several swamps northeast of the landfill and discharges into Old Tampa Bay. The drainage area is about 35 $mi^2$, and the average discharge is about 40 $ft^3/s$.

The surficial deposits in the Rocky Creek landfill area consist of fine to coarse sand, silt, sandy clay, and clay. The deposits are 40 to 50 feet thick at the western boundary and as much as 90 feet thick at the eastern boundary (fig. 4). The top of the Floridan aquifer generally ranges from about 25 to 40 feet below sea level within 1 mile of the landfill to about 10 feet above sea level 5 miles north and east of the landfill (fig. 5).

Beneath the landfill, the top of the Floridan aquifer ranges from about 10 to 60 feet below sea level (fig. 6). Clay layers, 3 to 32 feet thick, confine the Floridan aquifer. A lithologic log of materials penetrated in a well near the northern edge of the landfill is shown in table 1.

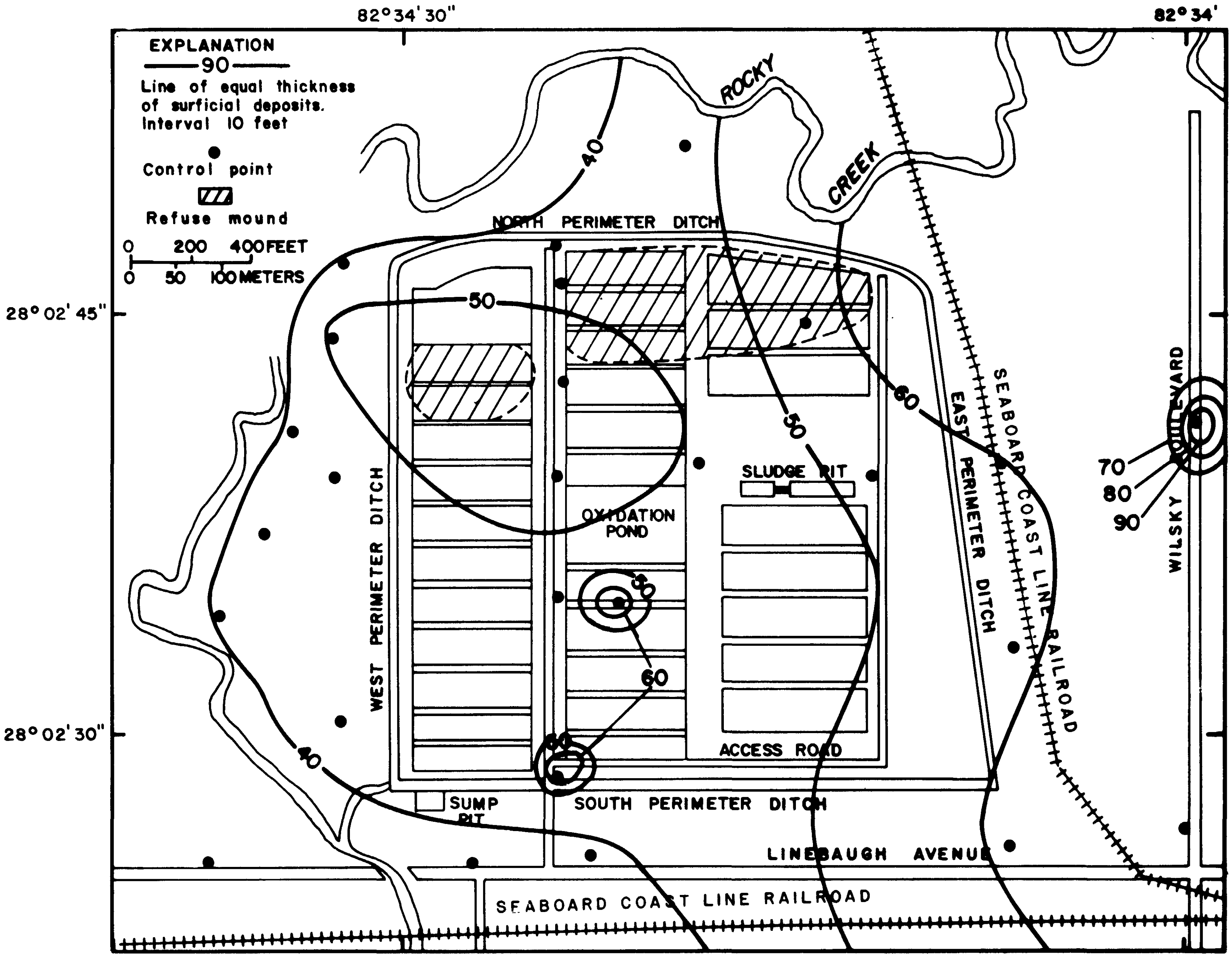



Figure 4.--Thickness of surficial deposits, Rocky Creek landfill.

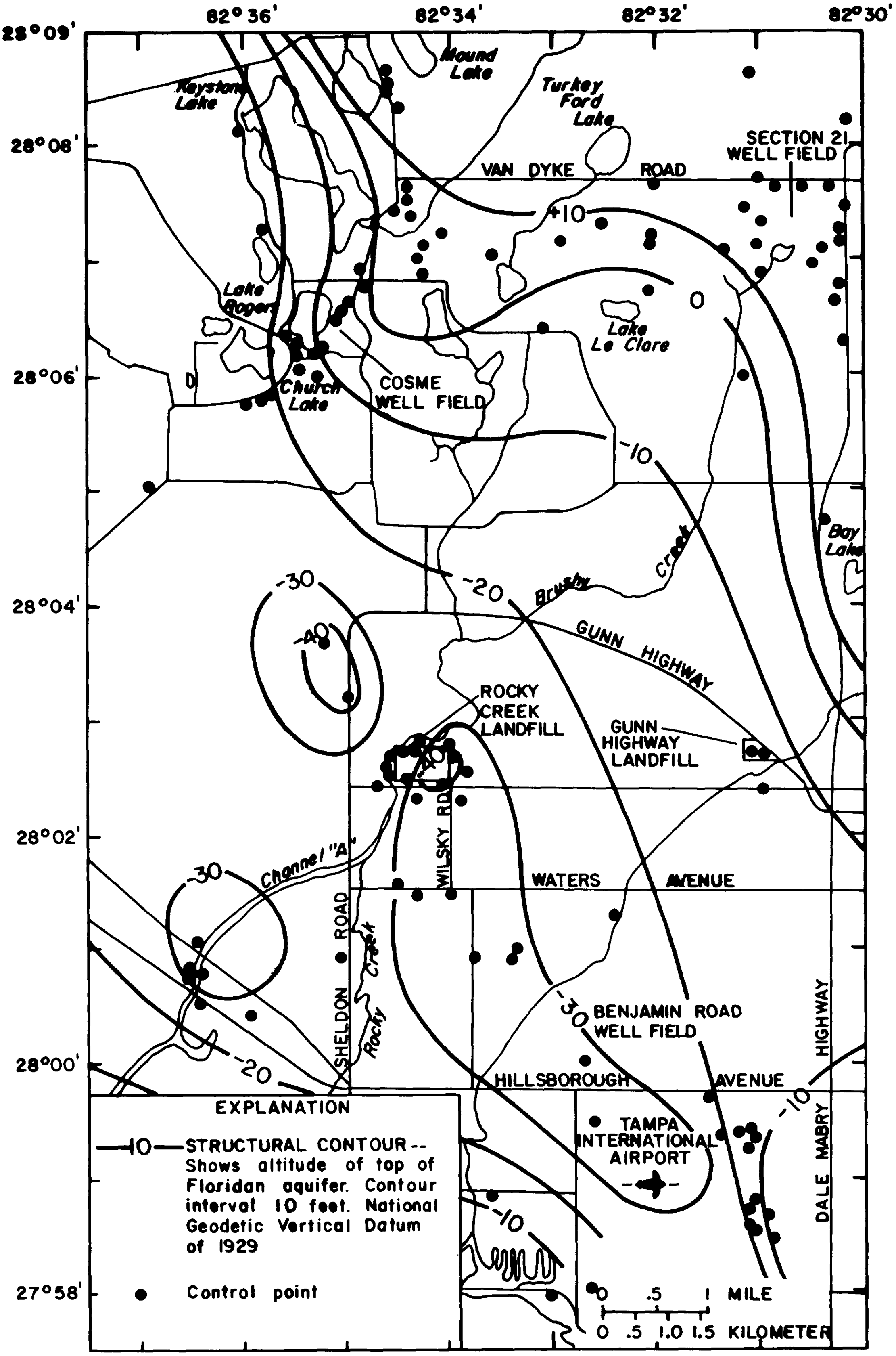



Figure 5.--Configuration of the top of the Floridan aquifer, northwest Hillsborough County.

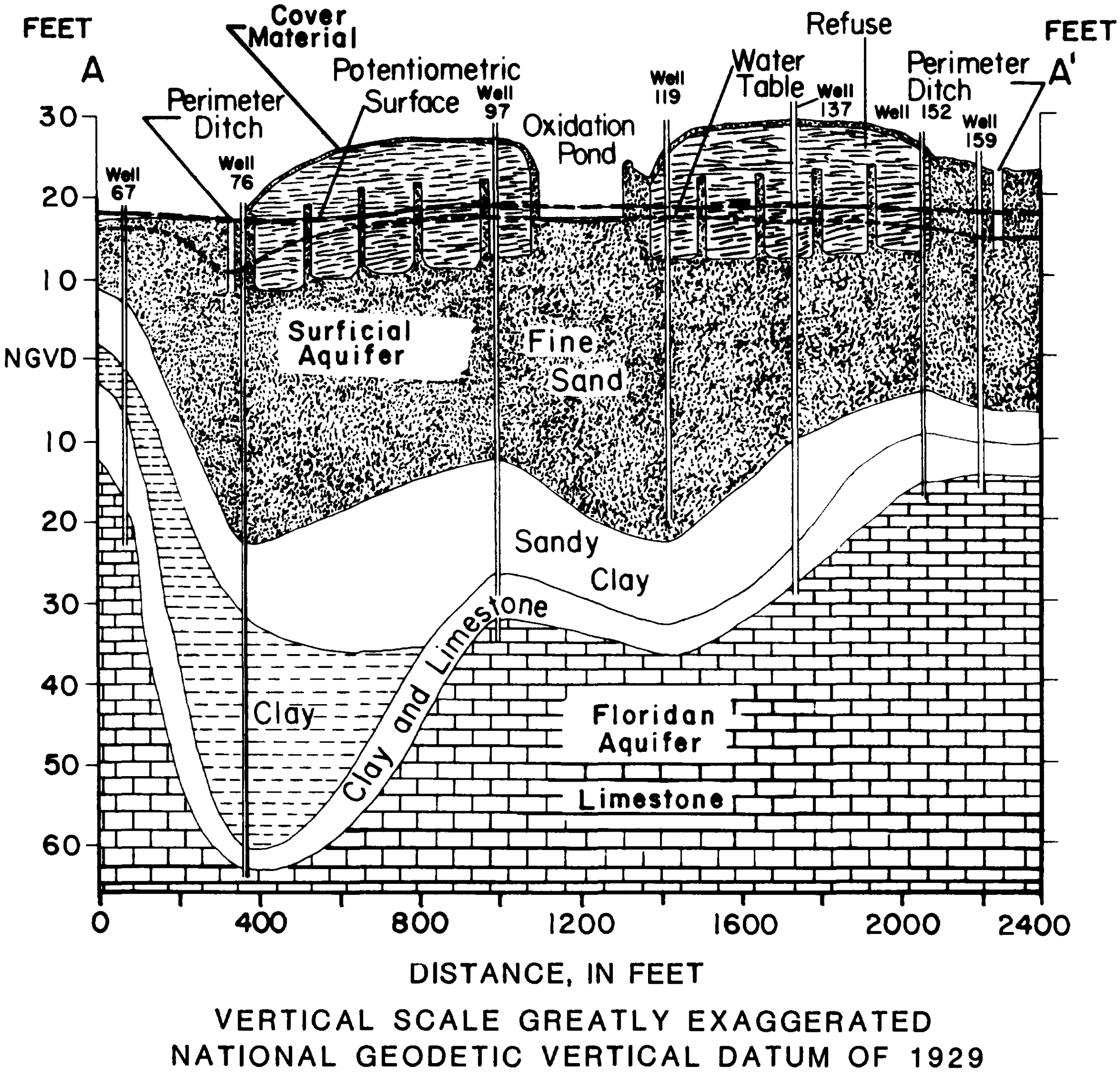



Figure 6.--Geologic section, Rocky Creek landfill. (Location of section is shown on figure 3.)

Table 1.--Lithologic log of well 152, Rocky Creek landfill

| Lithologic description | Thickness (feet) | Depth (feet) |
|---|---|---|
| Sand, light-gray, fine | 2.0 | 2.0 |
| Sand, pinkish-gray, fine | 3.5 | 5.5 |
| Sand, brownish-gray, fine, silty | 5.0 | 10.5 |
| Sand, pinkish-gray, fine | 8.5 | 19.0 |
| Sand, yellowish-brown, fine, with silt and clay | 6.5 | 25.5 |
| Clay, olive-gray, plastic, with some fine sand | 8.5 | 34.0 |
| Limestone, yellowish-gray, clayey | 6.5 | 40.5 |

Two 4-inch diameter and ninety 2-inch diameter test wells were constructed at the landfill site and adjacent areas. An additional 11 test wells were constructed in filled trenches.

Laboratory analyses of surficial sediments collected at the landfill site are listed in table 2. The vertical hydraulic conductivity of material other than clay collected from test wells ranged from $8.2 \times 10^{-4}$ to 10.8 ft/d at depths of 10 to 80 feet. The specific yield of the samples ranged from 7.2 to 39.9 percent and averaged 30 percent; the specific gravity averaged 2.65. The vertical hydraulic conductivity of a single clay sample collected at a depth of 28 feet was $1.4 \times 10^{-5}$ ft/d.

Eleven horizontal sediment samples were collected from the sides and four vertical sediment samples were collected from the bottoms of three trenches in the central part of the landfill. One vertical sample was collected from compacted cover material of a trench filled with solid waste. The hydraulic conductivity of the horizontal samples at depths of 2 to 10 feet below land surface ranged from $4.2 \times 10^{-1}$ to 24.9 ft/d. The highest hydraulic conductivities were obtained at depths of 3 to 6 feet below land surface. One vertical sample collected from a depth of 6.9 to 7.4 feet had a hydraulic conductivity of 12.4 ft/d. Three other vertical samples had hydraulic conductivities of $1.8 \times 10^{-1}$ to 4.2 ft/d at depths of 6.5 to 8.5 feet. The vertical hydraulic conductivity of the compacted cover material was 10.8 ft/d. Native materials in the central part of the site were predominantly fine to coarse sand (fig. 7).

## Infiltration Tests

Infiltration is the downward flow of water into soils or sediments. Infiltration rates were determined for several completed trenches and undisturbed sites using 10-inch and 24-inch double-ring infiltrometers. The infiltrometers were driven into native soil and trench cover to a depth of 6 inches, and a constant water level of 4 inches was maintained in both infiltrometer rings to insure representative testing of the cover material.

Table 2.--Laboratory analyses of surficial sediments, Rocky Creek landfill

[$g/cm^3$ -- grams per cubic centimeter; me/100 g -- milliequivalents per 100 grams; H -- horizontal hydraulic conductivity, all other conductivities are vertical; a -- cover material on trench 2]

| Sample site | Depth (feet) | Type of material | Specific gravity ($g/cm^3$) | Specific retention (percent) | Specific yield (percent) | Total porosity (percent) | Hydraulic conductivity (ft/d) | Cation exchange capacity (me/100 g) |
|---|---|---|---|---|---|---|---|---|
| Well 106 | 10.0-10.5 | Medium sand | 2.67 | 3.0 | 36.3 | 39.3 | - | - |
| | 15.0-15.5 | Medium to fine sand | - | - | - | - | 3.6 | - |
| | 25.0-25.5 | Medium to fine sand | - | - | - | - | 10.8 | - |
| | 30.0-30.5 | Fine sand | 2.67 | 5.4 | 36.9 | 42.3 | - | - |
| | 35.0-35.5 | Fine sand | - | - | - | - | $3.6x10^{-4}$ | - |
| | 39.5-40.0 | Fine sand | - | - | - | - | $1.4x10^{-1}$ | - |
| | 50.0-50.5 | Clay and limestone | 2.72 | 30.6 | 10.8 | 41.4 | $2.8x10^{-3}$ | - |
| Well 93 | 10.0-10.5 | Medium sand | 2.66 | 4.9 | 34.6 | 39.5 | - | - |
| | 20.0-20.5 | Fine to medium sand | - | - | - | - | $1.1x10^{-1}$ | - |
| | 30.0-30.5 | Fine sand | 2.66 | 5.8 | 33.7 | 39.5 | - | - |
| | 34.0-34.5 | Clay and silt | - | - | - | - | $1.5x10^{-3}$ | - |
| | 40.0-40.5 | Fine sand | - | - | - | - | $2.4x10^{-1}$ | - |
| | 45.0-45.5 | Medium to fine sand | 2.60 | 6.6 | 36.7 | 43.3 | $3.9x10^{-2}$ | - |
| | 50.0-50.5 | Fine sand | 2.61 | 6.6 | 36.7 | 43.3 | - | - |
| | 55.0-55.5 | Fine to medium sand | 2.65 | 6.9 | 39.9 | 46.8 | $1.3x10^{-2}$ | - |
| | 65.0-65.5 | Fine sand | - | - | - | - | $6.5x10^{-4}$ | - |
| | 70.0-70.5 | Medium sand | 2.65 | 21.7 | 20.6 | 42.3 | $1.9x10^{-2}$ | - |
| Well 76 | 9.5-10.0 | Medium sand | 2.67 | 5.4 | 31.7 | 37.1 | 3.6 | - |
| | 19.5-20.0 | Very fine sand | - | - | - | - | $9.8x10^{-1}$ | - |
| | 30.0-30.5 | Very fine sand | 2.66 | 5.5 | 35.5 | 41.0 | - | - |
| | 40.0-40.5 | Very fine sand | - | - | - | - | 1.3 | - |
| | 49.5-50.0 | Very fine sand | 2.68 | 40.6 | 7.2 | 47.8 | $5.9x10^{-4}$ | - |
| | 60.0-60.5 | Very fine sand | - | - | - | - | $8.2x10^{-4}$ | - |
| | 69.7-70.1 | Medium to fine sand | - | - | - | - | $2.2x10^{-1}$ | - |
| | 79.5-80.0 | Limestone | - | - | - | - | $2.7x10^{-3}$ | - |
| Well 88 | 28.0-28.5 | Clay | - | - | - | - | $1.4x10^{-5}$ | 31 |

Table 2.--Laboratory analyses of surficial sediments, Rocky Creek landfill--Continued

| Sample site | Depth (feet) | Type of material | Specific gravity ($g/cm^3$) | Specific retention (percent) | Specific yield (percent) | Total porosity (percent) | Hydraulic conductivity (ft/d) | Cation exchange capacity (me/100 g) |
|---|---|---|---|---|---|---|---|---|
| Well 70 | 38.0-38.5 | Sandy clay | - | - | - | - | $2.3 \times 10^{-2}$ | 7.6 |
| Trench 2 | 6.5-7.0 | Sand, very fine | - | - | - | - | $1.8 \times 10^{-1}$ | - |
| | 6.9-7.4 | Sand | 2.57 | 3.0 | 33.2 | 36.2 | 12.4 | - |
| | 5.6 | Sand | - | - | - | - | 24.9 H | - |
| | 7.5 | Sand, very fine | - | - | - | - | 4.2 H | - |
| | 8.0-8.5 | | - | - | - | - | 2.1 | - |
| Trench 2[a/] | 0-0.5 | Sand | - | - | - | - | 10.8 | - |
| Trench 9 | 3.0 | | 2.66 | 2.5 | 39.6 | 42.1 | 24.6 H | - |
| | 5.0 | | 2.65 | 3.6 | 38.7 | 42.3 | 22.9 H | - |
| | 8.0-8.5 | | 2.64 | 7.0 | 31.2 | 38.2 | $3.3 \times 10^{-1}$ | - |
| | 8.4 | | 2.64 | 5.7 | 36.7 | 42.4 | 9.8 H | - |
| | 10.0 | | 2.65 | 6.9 | 30.5 | 37.4 | $6.5 \times 10^{-1}$ H | - |
| Trench 27 | 2.0 | | - | - | - | 40.6 | 13.4 H | - |
| | 4.0 | | - | - | - | 39.3 | 13.1 H | - |
| | 5.0 | | - | - | - | 37.0 | 6.5 H | - |
| | 7.0 | | - | - | - | 37.5 | 3.9 H | - |
| | 8.0 | | - | - | - | 40.3 | 6.5 H | - |
| | 9.0 | | - | - | - | 37.8 | $4.2 \times 10^{-1}$ H | - |

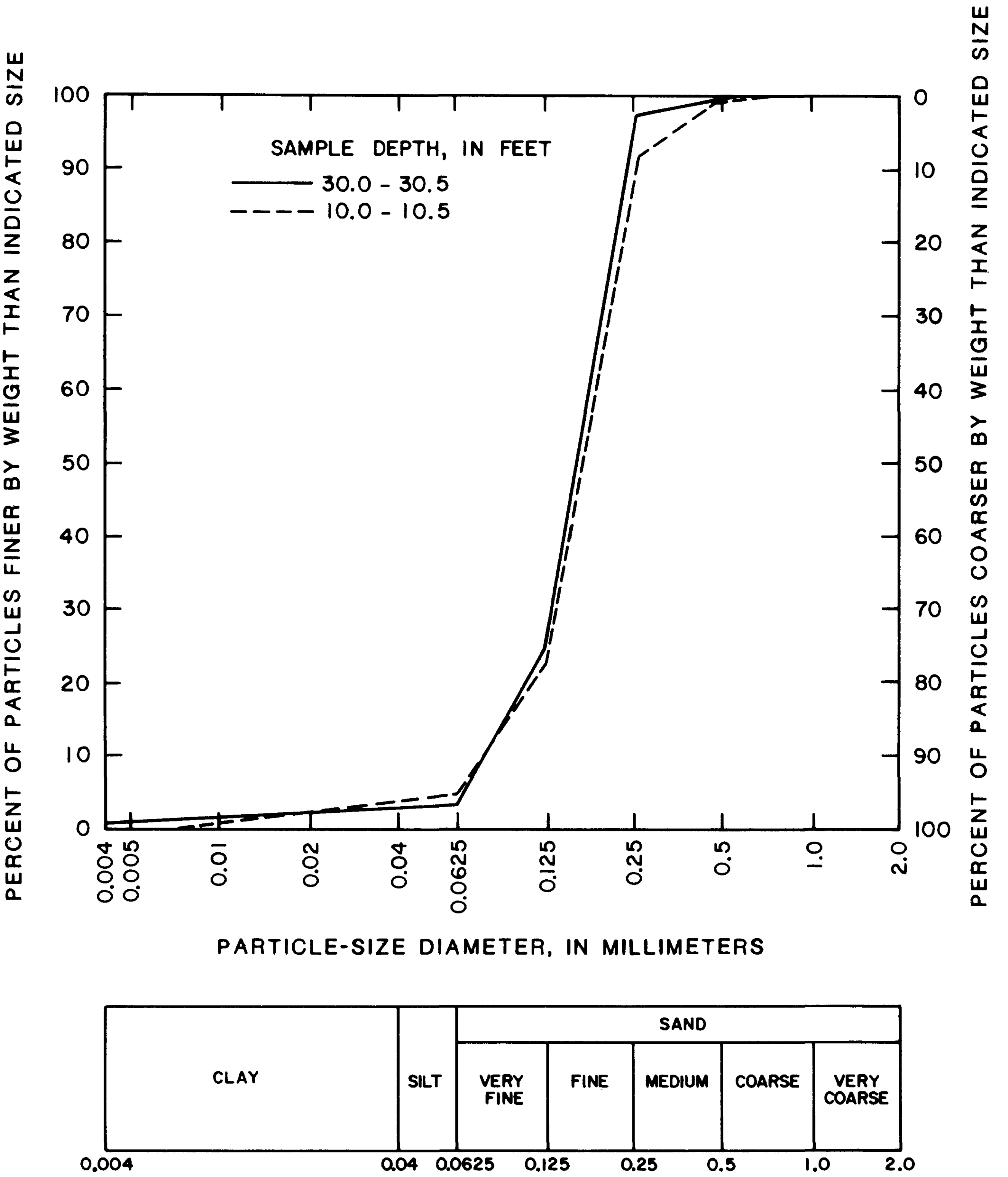



Figure 7.--Particle-size distribution for materials from well 93, Rocky Creek landfill.

The purpose of the tests was to determine the effectiveness of trench covers in limiting or retarding the infiltration of water into the underlying solid waste. The trench cover was a 1-foot-thick layer of permeable fine sand, and the undisturbed native soil was a fine sand, high in organic silt.

The infiltration tests were made during a hot, slightly windy period when the soil was relatively dry. The infiltration rates of native soil averaged about 7.5 inches per hour and rates for the compacted cover material averaged about 0.3 inch per hour.

## Water Levels

During the dry period, the oxidation pond had isolated pockets of water. Generally, the pond contained less than half a foot of water during the rainy season. Most of the water pumped from the trenches into the pond infiltrated into the surficial aquifer.

Water-level maps were prepared to show regional and local water levels in the surficial aquifer and the potentiometric surface of the Floridan aquifer for selected periods from May 1969 to May 1980. The maps show changes in water levels that have occurred over a period of several years and indicate the general direction of ground-water movement.

On January 22, 1970, about 10 days before the landfill became operational, the potentiometric surface of the Floridan aquifer within the site was 18 feet above sea level. The water level of the surficial aquifer ranged from 14 to 18 feet above sea level (fig. 8). West of the landfill, water levels in the surficial aquifer ranged from 6 to 12 feet above sea level. Water levels in the Floridan aquifer and the surficial aquifer were relatively high owing to more than 3 inches of rain that occurred in January. The potentiometric surface of the Floridan aquifer ranged from about 1 foot below the water level in the oxidation pond to about 12 feet above the level in the surficial aquifer adjacent to Rocky Creek.

On May 12, 1971, 15-1/2 months after the landfill opened, the 12 trenches in the western half of the landfill had been filled with solid waste. Water levels in the surficial aquifer were 2 to 4 feet lower than those of January 1970. The 14-foot water-level contour encircled the oxidation pond, which was dry.

After 2-1/2 years of operation (September 1972), the water level in the surficial aquifer at the oxidation pond was 16 feet above sea level, 2 feet less than after the wet period of October 1971. Construction of a high-rise section on two trenches in the northwestern part of the landfill had minimal effect on water levels.

On May 11, 1973, 3-1/4 years after landfilling began, water levels in the surficial aquifer within the landfill were 12 to 16 feet above sea level (fig. 9). Water levels over most of the site were about 16 feet above sea level and a slight increase in water levels from those of May 1971 occurred east of the site.

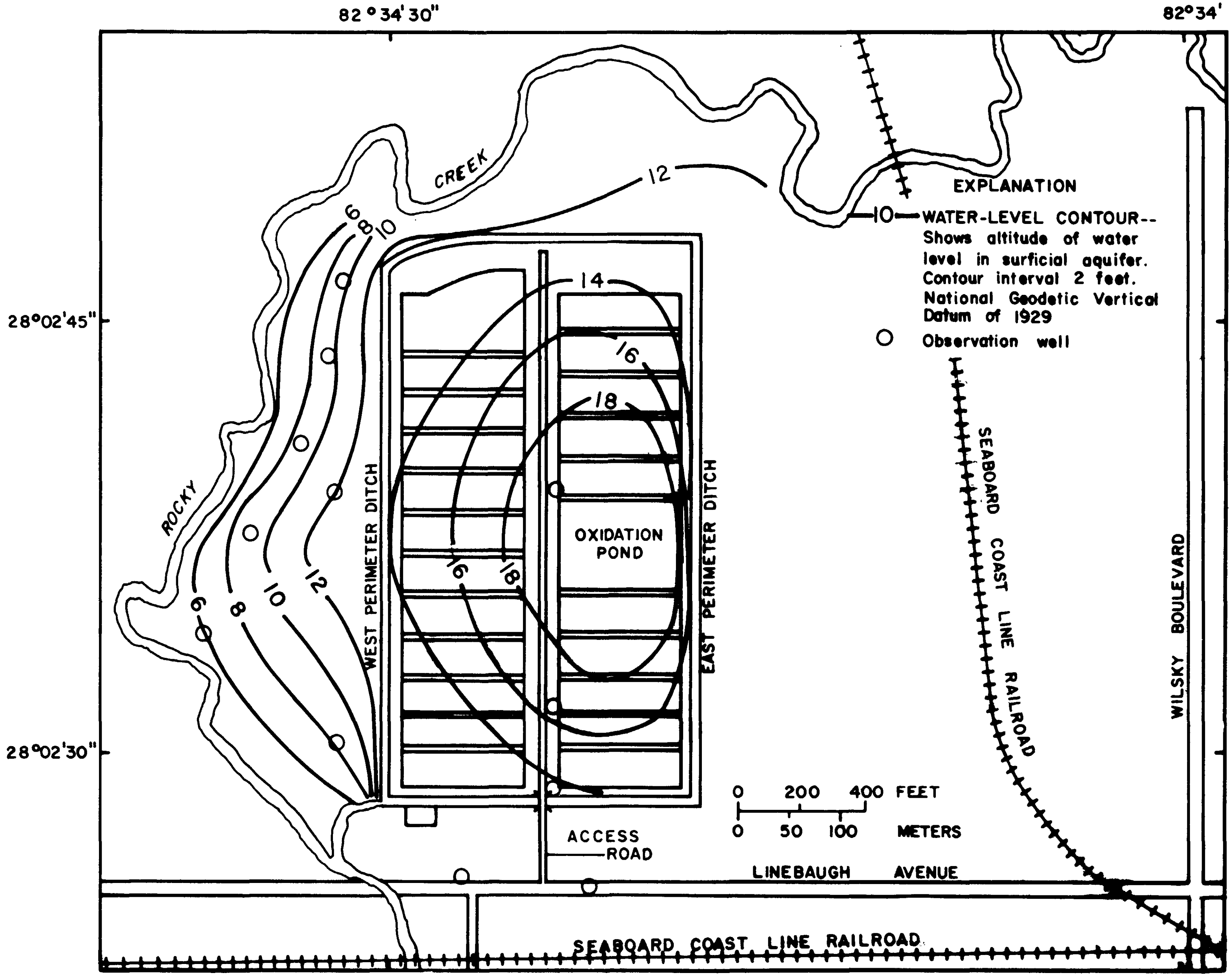



Figure 8.--Configuration of the water level in the surficial aquifer, January 22, 1970, Rocky Creek landfill.

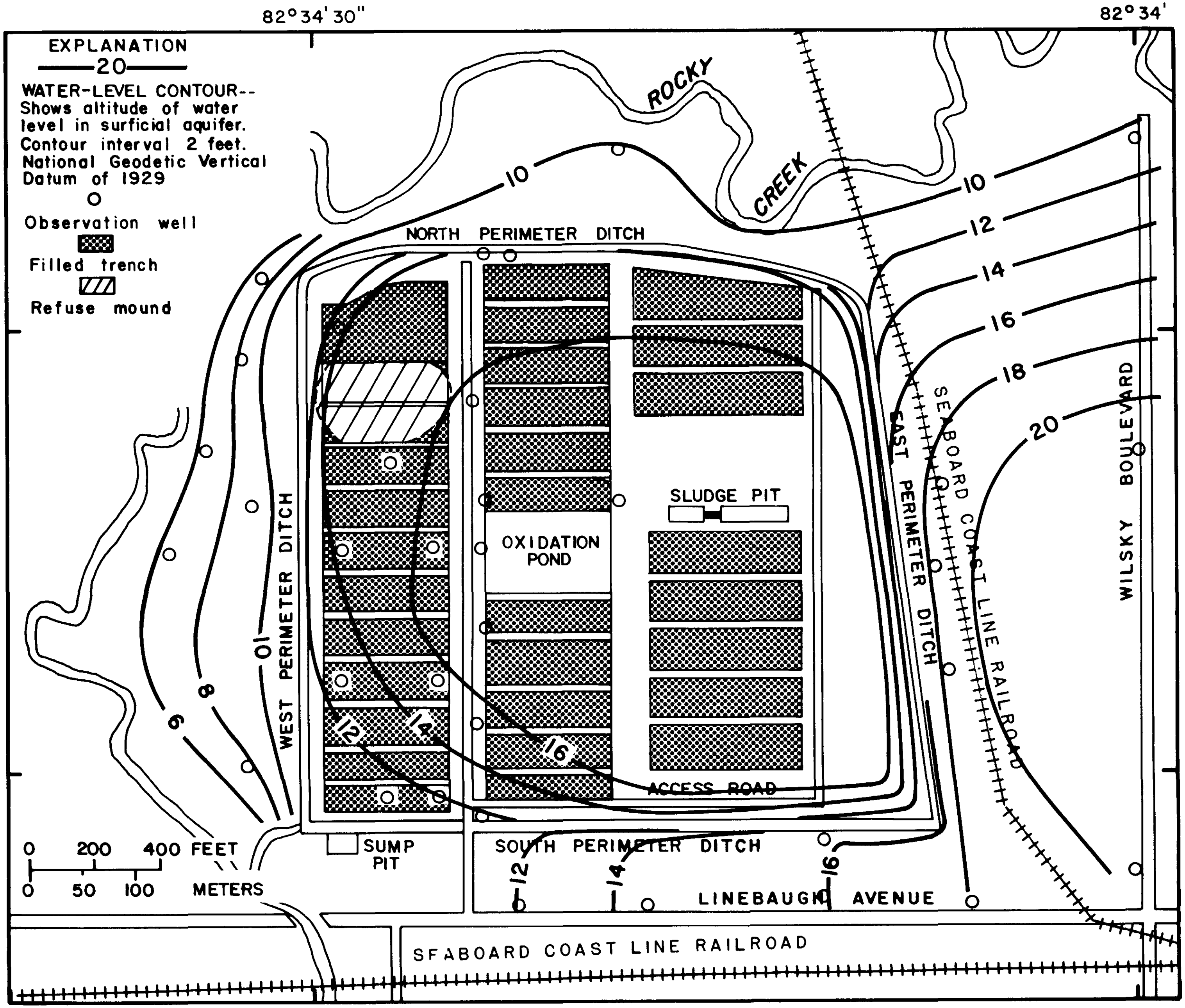



Figure 9.--Configuration of the water level in the surficial aquifer, May 11, 1973, Rocky Creek landfill.

On October 3, 1973, after 3-2/3 years of operation, water levels in the surficial aquifer within the landfill were 14 to 16 feet above sea level (fig. 10), about the same as in September 1972. The most noticeable change in water levels was that the 16-foot contour included most of the area within the perimeter canal. This was due largely to nearly 9 inches of rainfall in September and partly to construction of a second high-rise in the northern part of the landfill.

Head differences between water levels in the surficial aquifer and the potentiometric surface of the Floridan aquifer for May and September 1973 indicated little change between the dry and wet seasons (fig. 11). The most noticeable difference was a slight increase in the size of the areas showing zero to 4 feet of head difference (potentiometric surface above water table). A maximum head difference of 10 feet occurred west of the landfill near Rocky Creek. The head difference between the two aquifers did not show any appreciable change from 1970 to 1980.

In October 1974, after more than 4-1/2 years of operation, water levels at the landfill were 2 to 6 feet higher than in October 1973, even though rainfall in September and October 1974 was about 6 inches less than for the preceding year. Water levels were as much as 18 feet above sea level, the highest levels recorded since January 1970. The highest water levels were south of the high-rise sections in the northern part of the landfill (fig. 3). The high-rise sections were 25 to 45 feet above previous land-surface altitudes in the northern and eastern parts of the landfill and from 5 to 35 feet above land surface in the southern and western parts. Saturation of solid waste in filled trenches and in the high-rise sections following heavy rains probably was a contributing factor to the buildup of water levels. After saturation of the solid waste, lateral movement of water into the undisturbed surficial deposits was inadequate to drain the large volume of water entering the trenches. The net effect was a buildup of water levels.

On May 15, 1975, water levels were 12 to 16 feet above sea level within the area enclosed by the perimeter ditch (fig. 12). The 16-foot water-level contour enclosed the oxidation pond and parts of two filled trenches; the 12-foot contour intersected the southwest corner of the landfill. Water levels around the periphery of the landfill were 1 to 2 feet lower than in October 1973 (fig. 10). After May 1975, all network observation wells within the landfill site were destroyed.

The May 1980 map shows water levels for most of the periphery of the landfill, but not within the landfill (fig. 13). The potentiometric surface along the east side of Rocky Creek was 6 to 10 feet higher than the water level in the surficial aquifer. This head in the surficial aquifer was about the same as that observed in January 1970 and May and October 1973 (figs. 8 and 10).

A regional water-table and potentiometric-surface map for May 1980 is shown on figure 14. Generally, the potentiometric surface was slightly lower in May 1980 than in May 1969 prior to landfill operation.

Water levels in the surficial aquifer within the perimeter ditch increased from 1 to 3 feet during 1970-80. West of the perimeter ditch near Rocky Creek, water levels in 1980 were about 2 feet higher than in 1970, and south of the

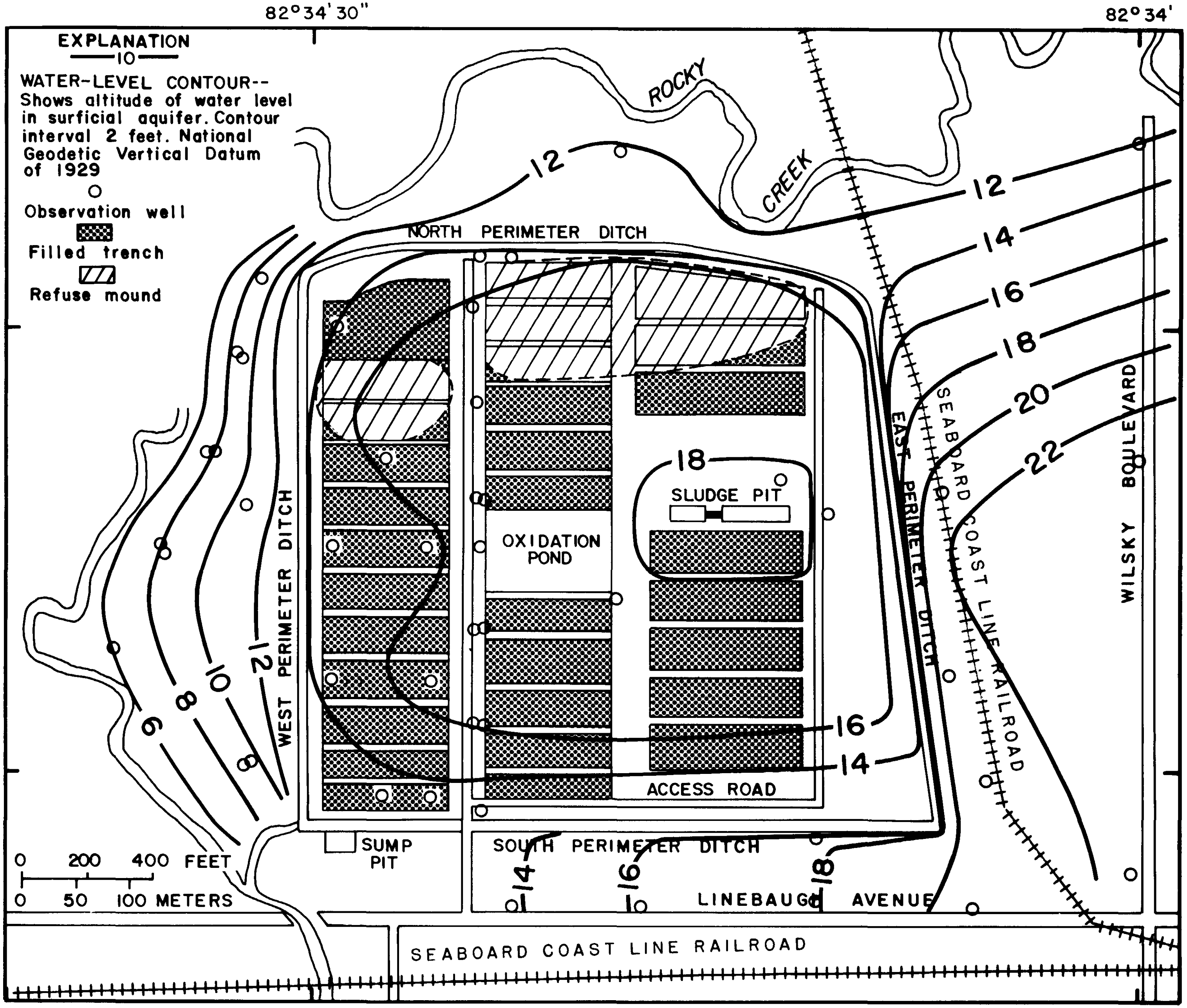



Figure 10.--Configuration of the water level in the surficial aquifer, October 3, 1973, Rocky Creek landfill.

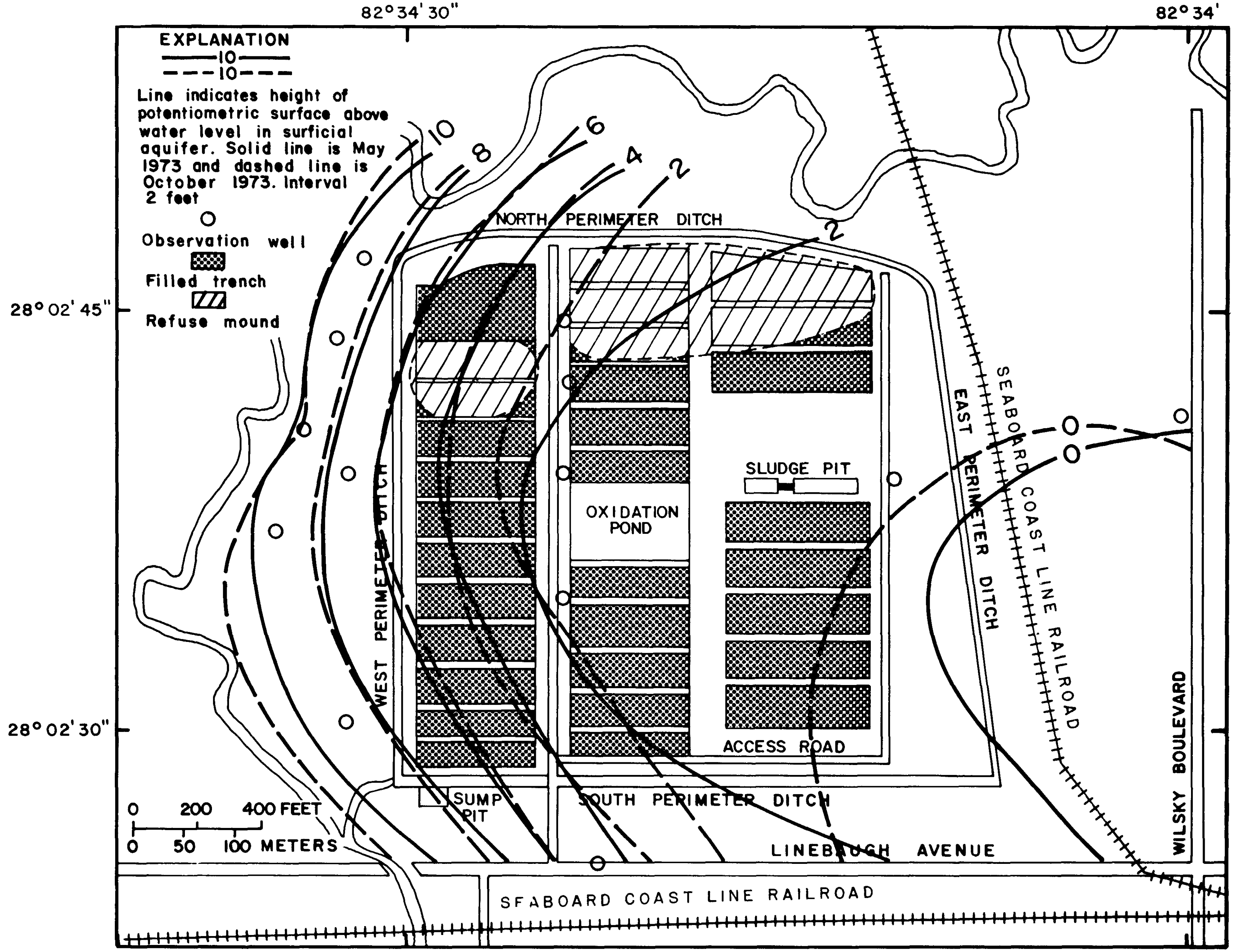



Figure 11.--Difference in head between the water level in the surficial aquifer and the potentiometric surface of the Floridan aquifer, May 11 and October 3, 1973, Rocky Creek landfill.

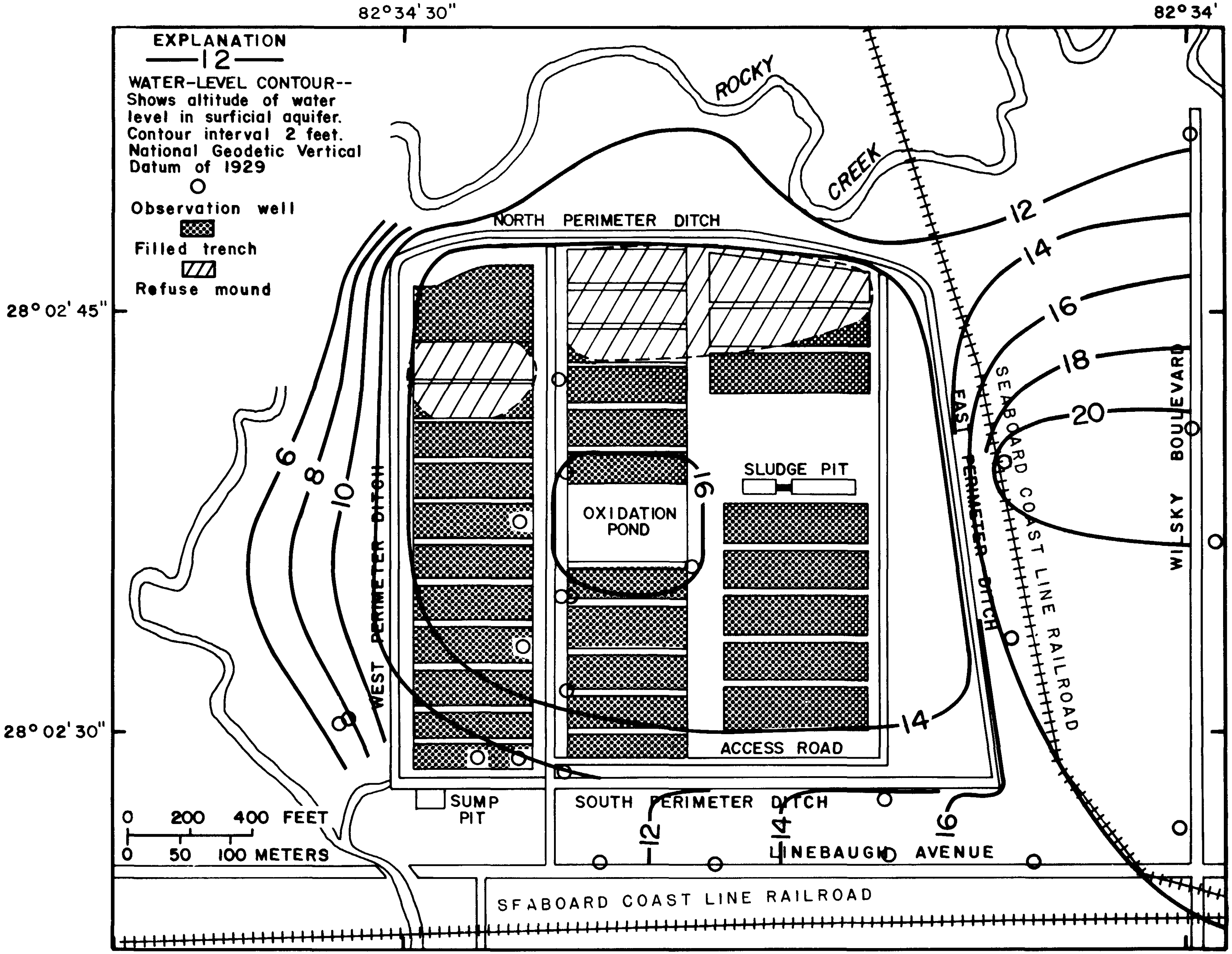



Figure 12.--Configuration of the water level in the surficial aquifer, May 15, 1975, Rocky Creek landfill.

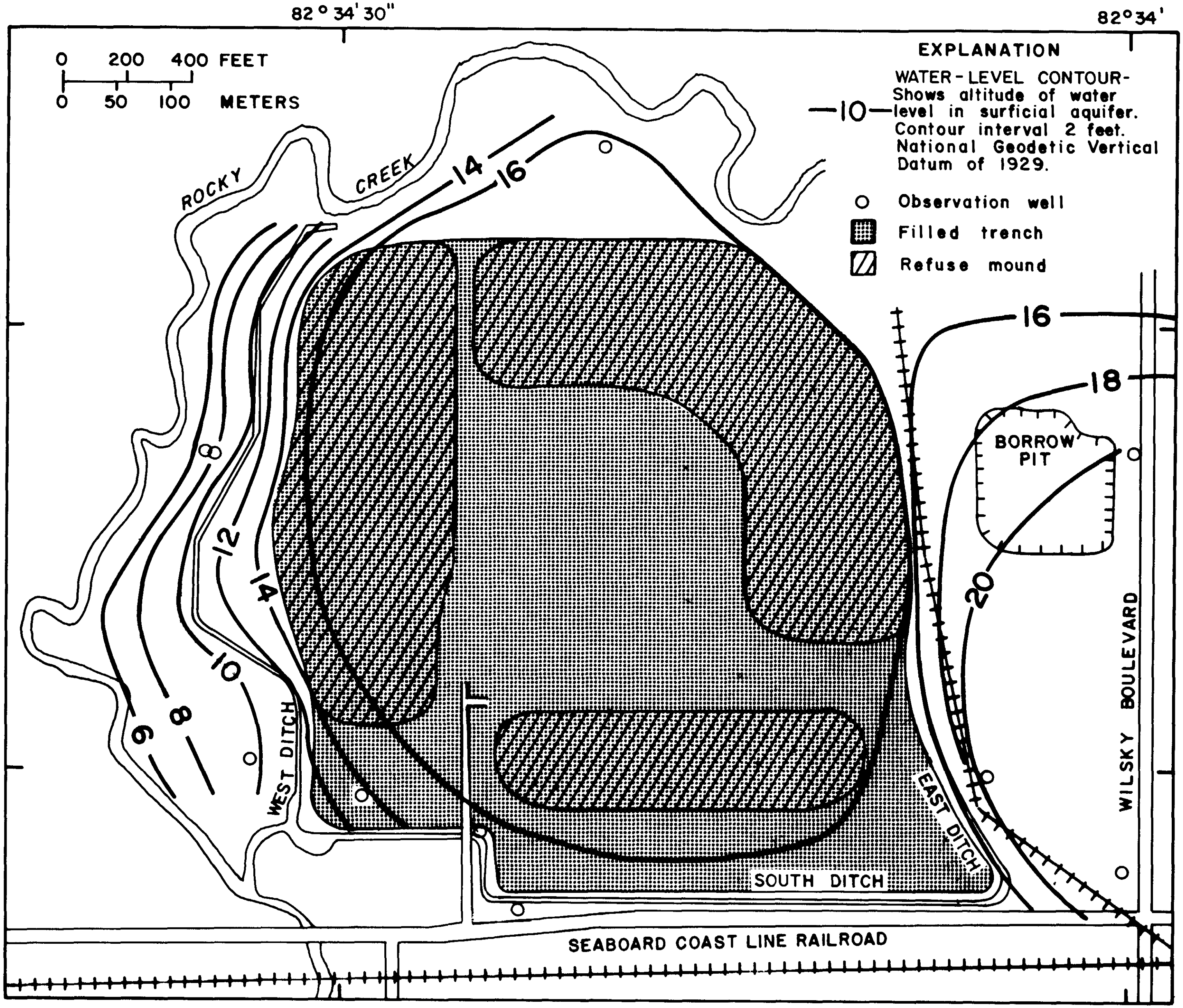



Figure 13.--Configuration of the water level in the surficial aquifer, May 22, 1980, Rocky Creek landfill.

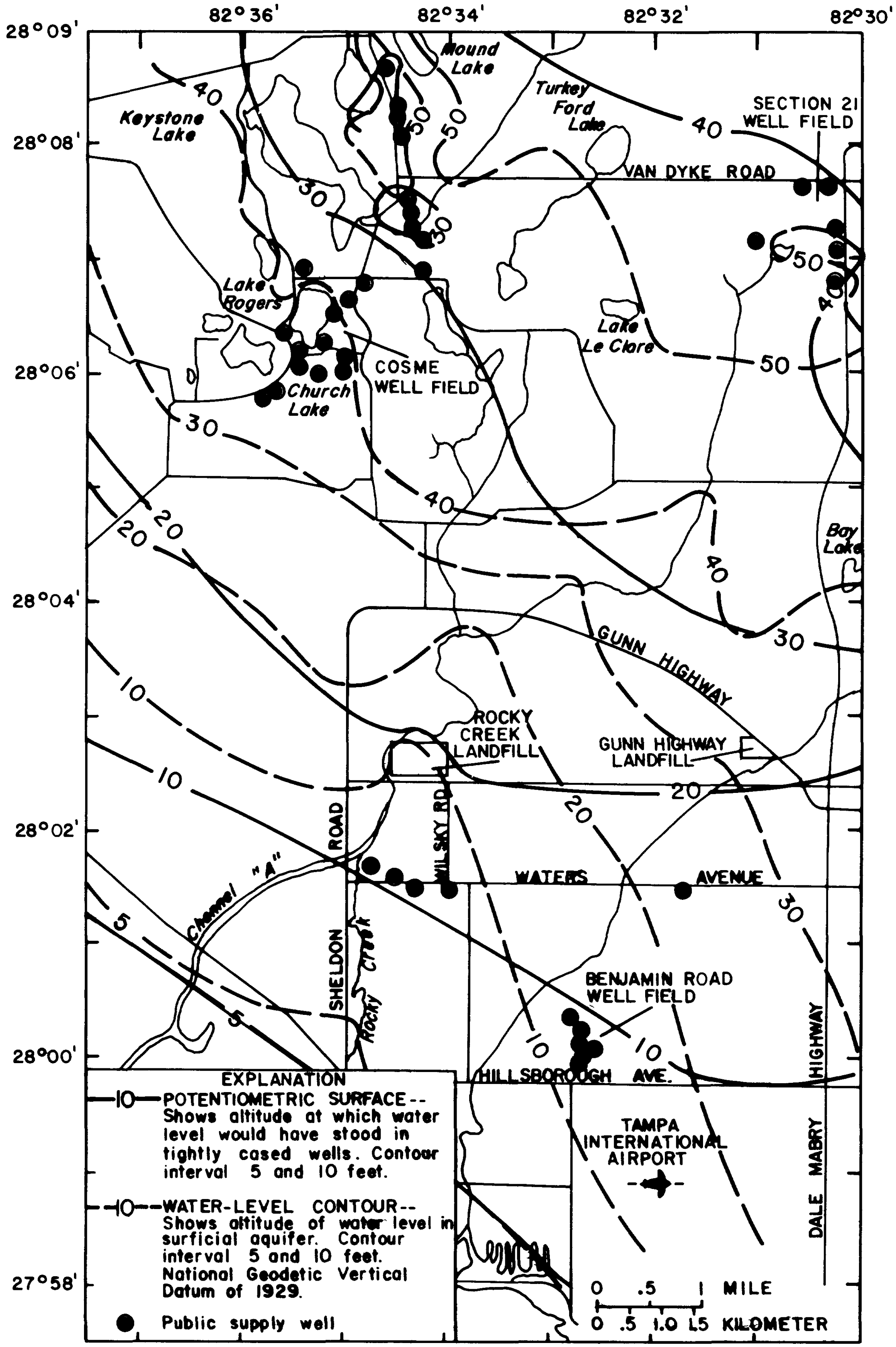



Figure 14.--Configuration of the water level in the surficial aquifer and the potentiometric surface of the Floridan aquifer, May 1980, northwest Hillsborough County (modified from Yobbi and others, 1980).

landfill near Linebaugh Avenue, water levels were as much as 6 feet higher than in 1970. In 1980, rainfall in the area was 40.6 inches, a deficiency of 8.78 inches. However, high water levels at the landfill in 1980 were due to above average rainfall in 1979 (66.9 inches), capacity of the high-rise refuse mounds to absorb large quantities of rainfall, and changes in drainage patterns at the landfill.

During 1970-80, the potentiometric surface of the Floridan aquifer west of the landfill ranged from 6 to 10 feet above water levels in the surficial aquifer. The potentiometric surface east of the landfill ranged from 1 to 2 feet below water levels in the surficial aquifer. No noticeable regional impact on water levels was observed.

## Ground-Water Movement

Ground water flows from areas of high hydraulic head to areas of low hydraulic head, along paths generally normal to contours of equal head in an isotropic aquifer. The velocity of flow is controlled by hydraulic conductivity, effective porosity, and hydraulic gradient. In a surficial aquifer, the hydraulic gradient is the slope of the water table, and in an artesian aquifer, the gradient is determined by the slope of the potentiometric surface. In general, water flows slowly where the gradients are gentle and fast where gradients are steep, assuming that hydraulic conductivity remains essentially constant.

The velocity of ground-water movement in the surficial aquifer was calculated using the following form of Darcy's equation:

$$V = KI/n_e \tag{1}$$

where:
- $V$ = horizontal velocity, in feet per day;
- $K$ = horizontal hydraulic conductivity, in feet per day;
- $I$ = hydraulic gradient, in feet per foot; and
- $n_e$ = effective porosity, dimensionless.

On the basis of laboratory tests of cored material and particle-size analyses of samples collected from test holes, and similar data obtained in the Tampa area by Sinclair (1971; 1977), the horizontal hydraulic conductivity of the surficial aquifer was estimated to be 13 ft/d.

On January 22, 1970, shortly before the site became operational, the hydraulic gradient on the west side of the landfill (between the west perimeter ditch and Rocky Creek) ranged from 0.013 to 0.030 ft/ft and averaged 0.021 ft/ft. The gradient was determined by dividing the change in head by the distance, in feet, between the 6- and 12-foot contours (fig. 8). The effective porosity of the material was 0.30, as determined from samples collected from auger holes. When the values are substituted in equation 1, the velocity of ground-water movement is computed to be 0.9 ft/d. At this rate, it would take about 350 to 750 days for ground water to move from the west perimeter ditch to Rocky Creek. Based on the gradient in the northwestern part of the landfill (0.03 ft/ft), the ground-water velocity would be about 1.3 ft/d. At this rate, it would require 200 to 500 days for ground water to move from the perimeter ditch to Rocky Creek.

Ground-water gradients west of the landfill did not change appreciably during the period of study. The steepest gradients (0.03 to 0.047 ft/ft) occurred in the northwestern part of the landfill; the flattest gradients (0.008 to 0.018 ft/ft) occurred west of the landfill. Based on maximum gradients of 0.018 and 0.047 ft/ft, the velocity ranged from 0.8 to 2 feet per day. The earliest estimated time of arrival of leachate at Rocky Creek would occur in about 150 days near the northwest corner of the site where the gradient was steepest. The arrival of leachate at Rocky Creek west of the site would occur in about 560 days because of the flat gradients there.

Water levels in the surficial aquifer at trench sites were 14 to 18 feet above sea level during a wet period shortly before the landfill became operational. The highest water levels after operation began, 16 to 18 feet above sea level, generally occurred in October; the lowest, 12 to 14 feet above sea level, occurred in May. At an altitude of 18 feet above sea level, about 4 feet of solid waste was saturated in the surficial aquifer; a condition conducive to generation of leachate.

Vertical movement of water from the surficial aquifer to the Floridan aquifer will not occur within the landfill site provided that the potentiometric surface remains higher than the water table. The potentiometric surface was 1 to 10 feet higher than the water table throughout most of the site during the period of study, 1970-80. The greatest head difference was in the western part of the landfill near Rocky Creek, and the smallest difference was in the eastern part near the east perimeter ditch.

Two relict sinkholes occur in the eastern part of the landfill. Test wells drilled in the sinkholes bottomed in sand and sandy clay well below the top of limestone, indicating that the sinkholes were indirectly connected to the Floridan aquifer. If the potentiometric surface declines below the water level in the area, leachate may move horizontally along the top of relatively impermeable materials until it intersects a sinkhole. Under this condition, leachate will then move rapidly through the more permeable material in the sinkhole into the Floridan aquifer.

East of the landfill, the potentiometric surface was 1 to 2 feet lower than the water table, and water in the surficial aquifer could move into the Floridan aquifer. Confining layers of sandy clay and clay underlying the eastern part of the area will retard movement of water between aquifers. The rate of vertical movement is governed by the vertical hydraulic conductivity of the confining layers. The vertical hydraulic conductivity of the least permeable material averaged about $5 \times 10^{-4}$ ft/d (table 2). The saturated thickness of the surficial aquifer averaged 40 feet, the effective porosity averaged 0.3, and the head difference between the surficial and Floridan aquifers was 2 feet.

The vertical movement of water from the surficial aquifer east of the landfill through the confining layers was determined using the following modified form of Darcy's equation:

$$V = K_v h/mn_e \tag{2}$$

where: $V$ = vertical velocity, in feet per day;
$K_v$ = average coefficient of vertical hydraulic conductivity of confining layer, in feet per day;
$h$ = head difference between the surficial and Floridan aquifers, in feet;
$m$ = thickness of confining bed, in feet; and
$n_e$ = average coefficient of effective porosity of confining layer, dimensionless.

Substituting values into equation 2 gives the following result:

$$V = \frac{(5\text{x}10^{-4}\text{ft/d})\ (2\text{ ft})}{(40\text{ ft})\ (0.3)}$$

$$V = 8.3\text{x}10^{-5}\text{ ft/d}$$

The rate of vertical movement of water is relatively low because it is based on the assumption that the head difference between aquifers is small.

The quantity of water moving through the surficial aquifer into Rocky Creek was computed using the equation:

$$Q = TIL \tag{3}$$

where: $Q$ = discharge, in gallons per day;
$T$ = transmissivity, in square feet per day;
$I$ = hydraulic gradient, in feet per foot; and
$L$ = length of section through which water moves normal to the direction of flow, in feet.

The transmissivity of the surficial aquifer is estimated to average 300 $ft^2/d$, based on the results of an aquifer test conducted in northwest Hillsborough County (Sinclair, 1977). The results of laboratory analyses of core samples for vertical hydraulic conductivity and particle size indicate that the material at the Rocky Creek site is similar to that in the northwestern part of the county.

The quantity of ground water in the surficial aquifer moving out of the landfill toward Rocky Creek was computed for different hydrologic conditions during the period 1970-80. These conditions included a period prior to landfilling to establish base conditions and during wet and dry seasons.

On January 22, 1970, the average hydraulic gradient west of the landfill (fig. 8) was 0.021 ft/ft, and the average length of section through which water flowed was 2,000 feet. If a transmissivity of 300 $ft^2/d$ is assumed, the quantity of water flowing through the section would be computed to be about 95,000 gal/d.

On May 12, 1971, the quantity of water moving toward Rocky Creek west of the landfill was also about 95,000 gal/d. On October 29, 1971, 21 months after opening of the landfill, the gradient averaged 0.024 ft/ft, and the flow to Rocky Creek was about 110,000 gal/d. At the maximum average gradient (0.03 ft/ft), ground-water flow was about 135,000 gal/d in October 1974. The increased flow is probably related to rainfall and to construction of the high-rise sections in the northern part of the landfill (fig. 9).

The quantity of ground water discharged from the landfill is significant because water acts as a medium of transportation for leachate as well as a diluter of leachate. Increased ground-water discharge is due primarily to increased ground-water gradients during buildup of water levels. The direction of ground-water movement usually changes slightly during periods of high water levels.

## Water Quality

This section presents a detailed description of water-quality data from selected surface-water and ground-water sites at the Rocky Creek landfill. A summary of the results is presented at the end of this section.

Surficial aquifer well 74 and Floridan aquifer well 98 were selected to obtain background water-quality data for comparison with data from wells drilled into similar materials in and near the landfill (fig. 3). Well 74, an 18-foot deep well, is southeast of the landfill and well 98, a 65-foot deep well, is east of the landfill.

Sampling of water from well 74 began in July 1972. Specific conductance and chloride concentrations in the well and annual rainfall in the area for 1969-80 are shown on figure 15. The first sample had a specific conductance of 347 umho (micromho) and a chloride concentration of 14 mg/L (milligrams per liter). The specific conductance was about 400 umho in April 1973, after which it declined to generally less than 200 umho. Chloride concentrations fluctuated between 10 and 16 mg/L. The decrease in specific conductance and changes in chloride concentration probably reflect the effects of rainfall.

The specific conductance of water samples collected from well 98 averaged about 390 umho; the chloride concentration averaged 9 mg/L (fig. 16). The values are within the range expected for water in the Floridan aquifer in northwest Hillsborough County.

A statistical summary for specific conductance and chloride concentrations of water from surficial aquifer well 74 and Floridan aquifer well 98 is as follows:

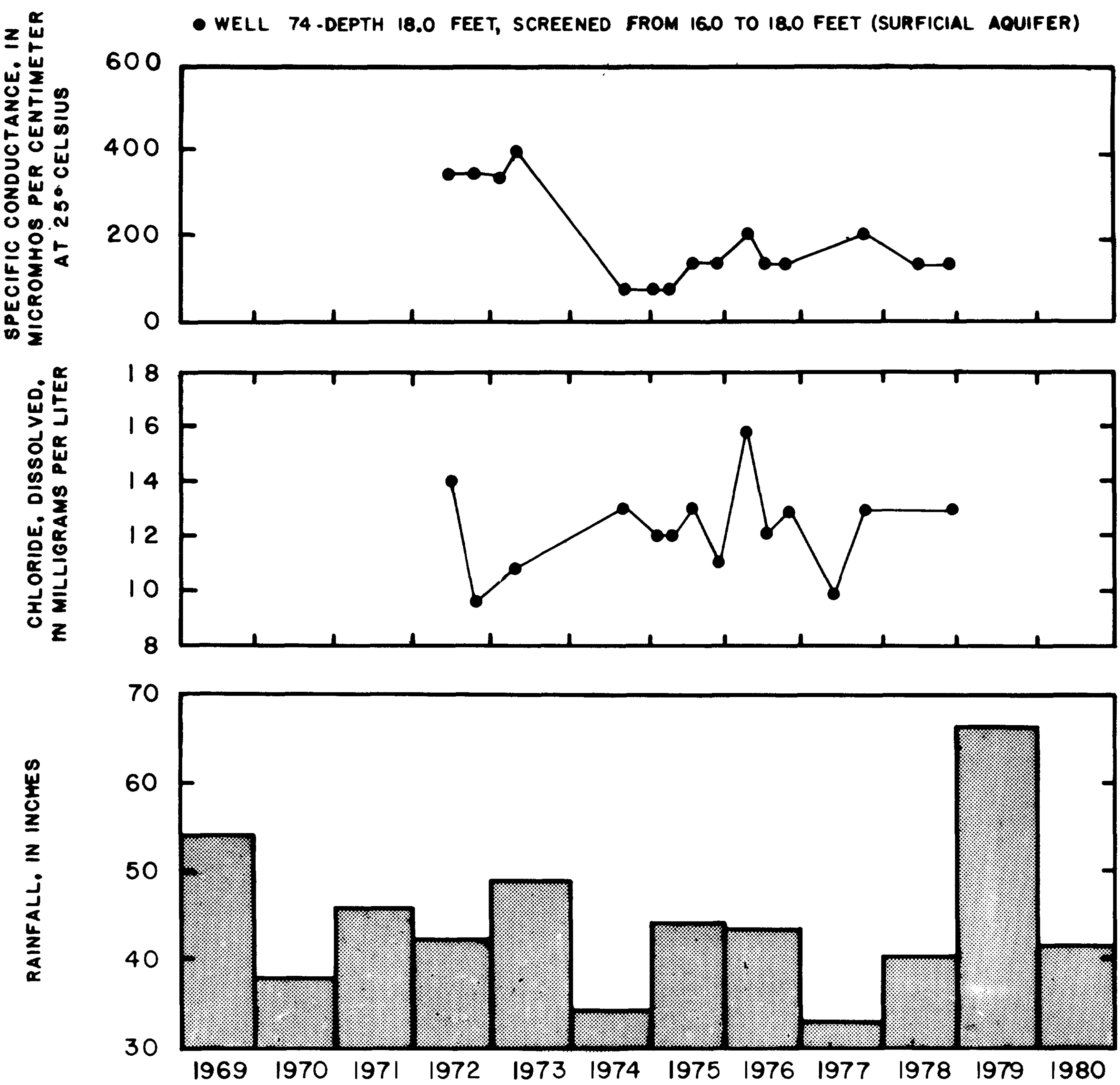



Figure 15.--Specific conductance and chloride concentration of water from surficial aquifer well 74, Rocky Creek landfill, and rainfall at Tampa.

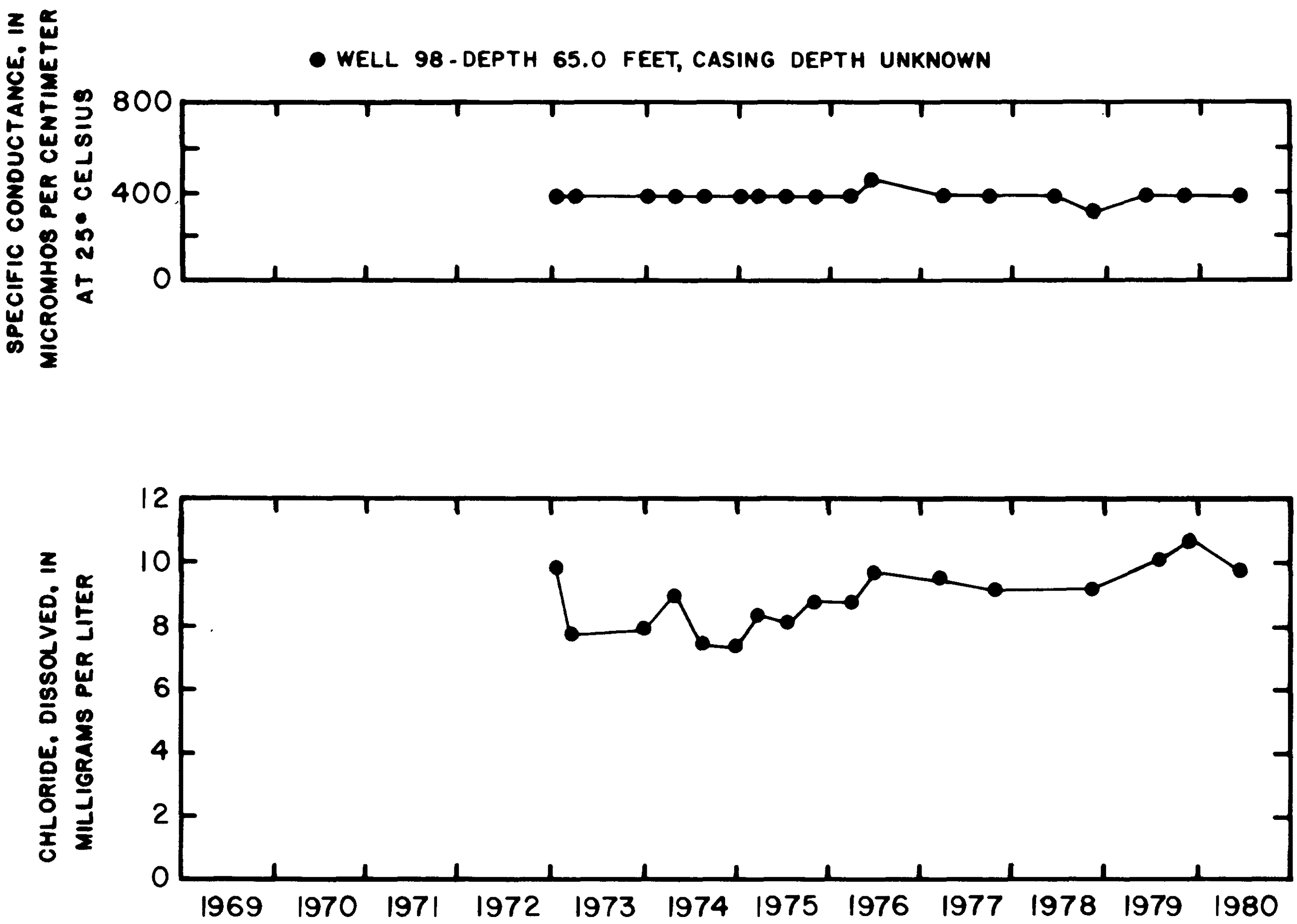



Figure 16.--Specific conductance and chloride concentration of water from Floridan aquifer well 98, Rocky Creek landfill.

| Well number | Parameter | Mean | Standard deviation | Range | Standard error of the mean | Number of samples |
|---|---|---|---|---|---|---|
| 74[a] | Specific conductance (umho/cm) | 131 | ±34 | 88-181 | ±11 | 11 |
| | Chloride (mg/L) | 12 | ±1.5 | 10-16 | ±0.5 | 11 |
| 98 | Specific conductance (umho/cm) | 390 | ±20 | 365-450 | ±5 | 18 |
| | Chloride (mg/L) | 9.2 | ±0.9 | 7.9-11 | ±0.2 | 17 |

[a]Represents data after 1973 when water from well 74 appears to have stabilized.

A cluster of three wells (83, 84, and 85, fig. 3) were drilled to different depths near the southwest corner of the landfill. The well cluster was about 250 feet northwest of trench 1 where the disposal of solid waste began in February 1970. The first indication of a water-quality change in the surficial aquifer wells was almost 4 years after the disposal of solid waste began. Water samples from surficial aquifer wells 83 and 84 showed an increasing trend in specific conductance from about 100 to more than 500 umho during the period 1974-80 (fig. 17). Well 83 was drilled to a depth of 13.9 feet and screened from 11.9 to 13.9 feet; well 84 was drilled to a depth of 24 feet and screened from 22 to 24 feet. Chloride concentrations in water from well 83 did not increase for the period of record. However, chloride concentrations in well 84 increased from less than 10 mg/L in the latter part of 1973 to 120 mg/L in 1976. The well was constructed in a permeable sandy zone 20 to 24 feet below land surface, as determined from core samples collected during drilling. Well 85 (depth 50.0 feet, cased to 50 feet) did not show any changes in specific conductance or chloride concentrations.

Paired wells 115 and 116 were 200 feet west of the west perimeter ditch (fig. 3). Water samples taken at a depth of 13.5 feet from surficial aquifer well 115 increased in specific conductance from 200 umho in 1970 to 500 umho in the latter part of 1971. Chloride concentrations of the samples also showed a small increasing trend during the same period. Water samples from Floridan aquifer well 116 (depth 43.5 feet) did not show any noticeable changes in specific conductance or chloride concentrations.

Paired wells 143 (surficial aquifer) and 144 (Floridan aquifer) were about 400 feet north of wells 115 and 116 (fig. 3). There were only slight increases in specific conductance; however, chloride concentrations from July 1973 to February 1974 increased from 7 to 38 mg/L in well 143 (fig. 18). Data for well 143 indicate a change in water quality in the surficial aquifer at a depth of 18 to 20 feet below land surface about 2 years after disposal of solid waste in trenches east of the well. The general direction of movement of water in the surficial aquifer at the well is westward toward Rocky Creek. For this reason, it is unlikely that trenches south of trench 10 would have had any effect on leachate movement toward well 143.

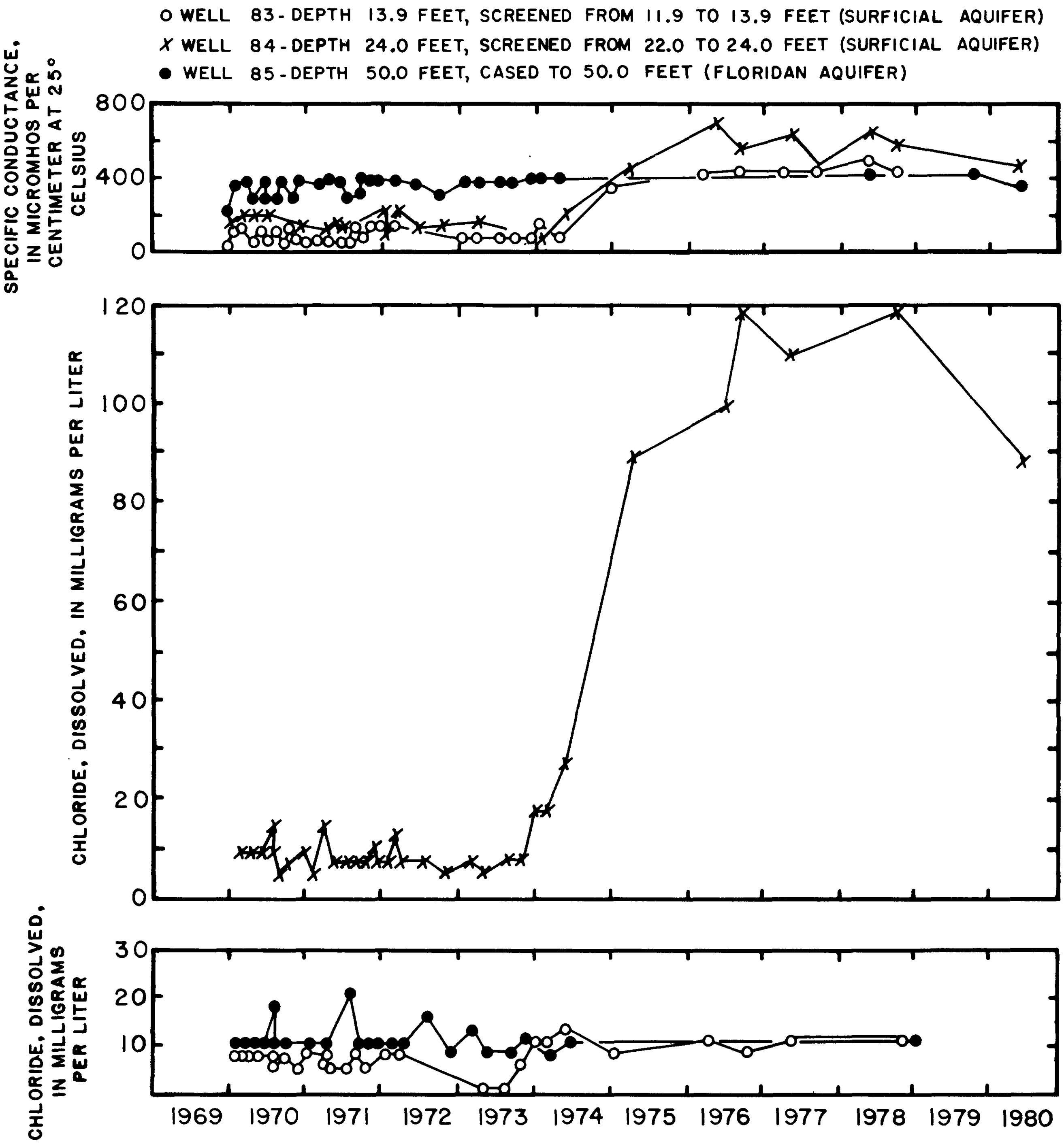



Figure 17.--Specific conductance and chloride concentration of water from wells 83, 84, and 85, Rocky Creek landfill.

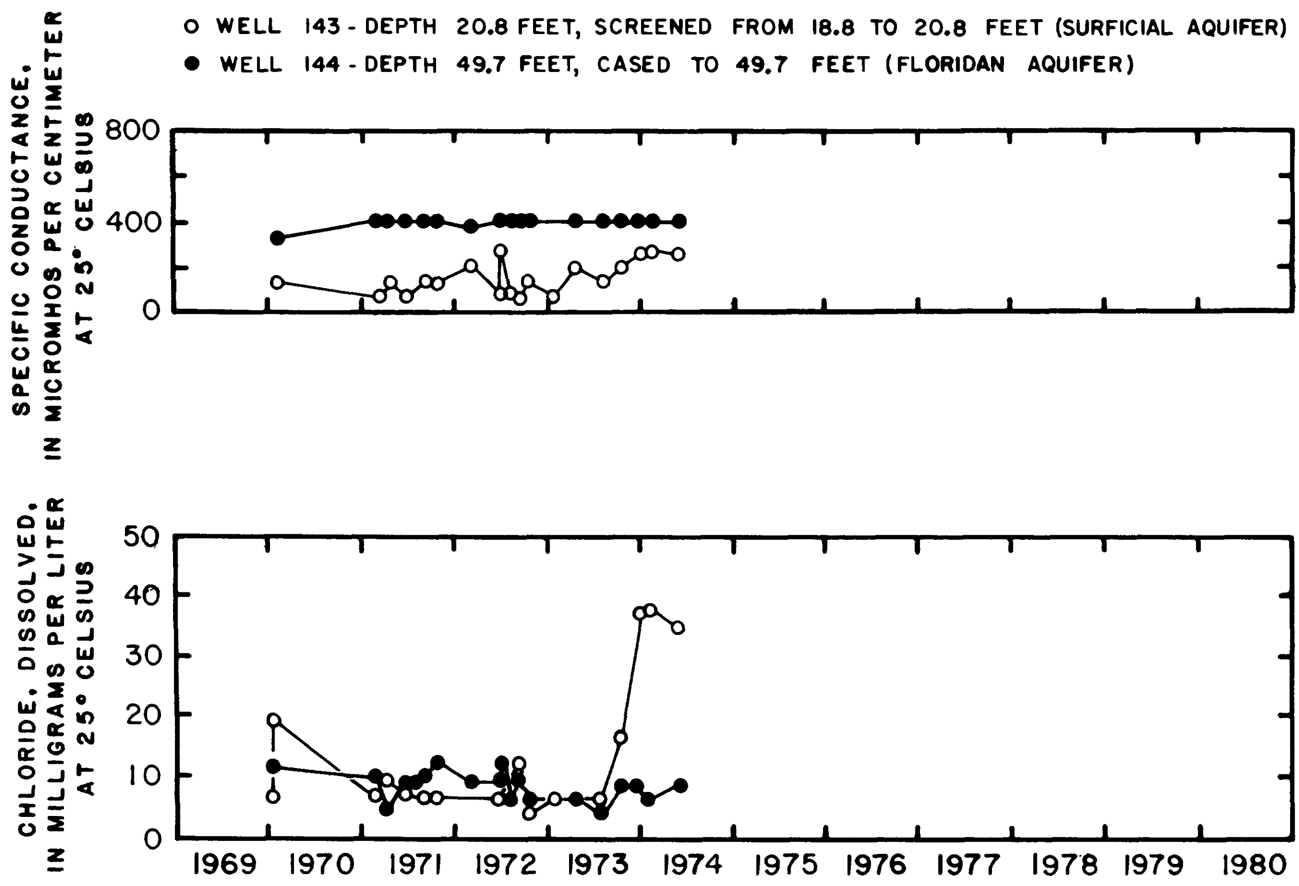



Figure 18.--Specific conductance and chloride concentration of water from wells 143 and 144, Rocky Creek landfill.

At well 144, a 50-foot Floridan aquifer well, the specific conductanc water remained relatively unchanged at 400 umho for the period of record. conductance is within the background range of Floridan aquifer water in the

Paired wells 152 and 153 were near the north end of the landfill access road, about 160 feet south of the north perimeter ditch (fig. 3). Water samples from surficial aquifer well 153 (depth 14.4 feet) showed an increase in specific conductance from 45 umho in early 1970 to more than 900 umho in mid-1974. The large increase in specific conductance in the well was probably due to migration of leachate from nearby filled trenches and a nearby high-rise refuse mound. Chloride concentrations in water from the well also showed an increasing trend during the same period. For Floridan aquifer well 152 (depth 38.6 feet), specific conductance of the water increased from 200 to 400 umho in late 1970 and remained generally unchanged at this level to mid-1974. The initially low specific conductance was probably due to water from the surficial aquifer entering the Floridan aquifer during drilling. The well was destroyed in 1974.

A cluster of three wells (117, 118, and 119) was drilled near the northwest corner of the oxidation pond (fig. 3). Water samples from surficial aquifer wells 117 and 118 indicated slight changes in specific conductance from 1970 to early 1972 (fig. 19). Additional data were not available for well 117, but chloride concentrations increased in well 118, at a depth of 22 to 24 feet, from 10 mg/L in 1974 to 160 mg/L in 1977.

Water samples from Floridan aquifer well 119 showed an increase in specific conductance from 250 umho in early 1970 to 400 umho in early 1971. The specific conductance mostly remained at about 400 umho from 1971 to mid-1974 and about 450 umho from early 1975 through 1977. Chloride concentrations in water in the shallow and deep wells were about 10 mg/L. Increases in specific conductance of water in the surficial aquifer were attributed to movement of leachate from nearby filled trenches and the oxidation pond. The altitude of the ground-water mound at the oxidation pond ranged from 12 to 18 feet above sea level during 1970-75.

A cluster of three wells (76, 77, and 78) was installed south of the landfill on the east side of the access road and north of the perimeter ditch (fig. 3). Water samples from surficial aquifer well 77 (depth 9.3 feet) showed an increase from 100 to 350 umho in 1970. Specific conductance increased further to 350 umho between late 1970 and late 1971. Chloride concentrations fluctuated between 8 and 15 mg/L during 1970-72. Based on the increased specific conductance in well 77, it appears that leachate was moving at a depth of 7 to 9 feet below land surface.

Water samples from surficial aquifer well 78 (depth 24.4 feet) showed that specific conductance remained fairly steady at 360 umho during 1970-73. Chloride concentrations fluctuated between 7 and 16 mg/L during the period. These concentrations are within the limits of background levels in the area.

Specific conductance of water samples from Floridan aquifer well 76 (depth 80 feet) ranged from 475 to 500 umho during the first half of 1970, but decreased to 400 umho from mid-1970 to mid-1973. Thereafter, specific conductance fluctuated between 375 and 450 umho. Although specific conductance was slightly greater than background levels, departure from background levels was probably due to natural variations. Chloride concentrations declined from 30 mg/L in early 1970 to 10 mg/L in early 1972. During the remaining period (1972-74), the concentrations were about 10 mg/L.

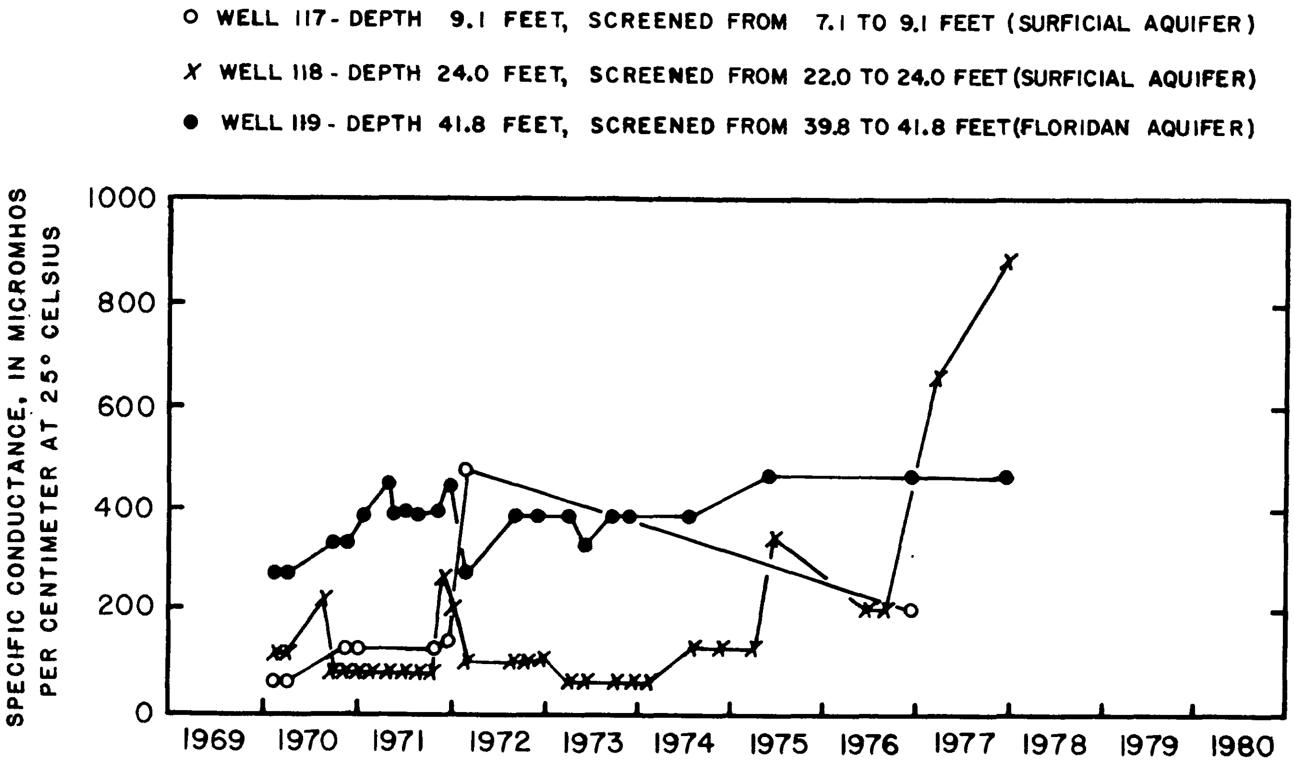



Figure 19.--Specific conductance of water from wells 117, 118, and 119, Rocky Creek landfill.

Two surficial aquifer wells (65 and 66) and Floridan aquifer well 67 were constructed south of the landfill (fig. 3). Surficial aquifer well 65 was about 200 feet south of the south perimeter ditch and 25 feet north of Linebaugh Avenue. Water samples collected from the well showed an increase in specific conductance from 135 umho during most of 1970-75 to 390 umho in 1976-77. Chloride concentrations showed a slight increasing trend (2 to 30 mg/L) during the same periods.

Paired wells 66 and 67 were about 400 feet west of well 65 and about 150 feet east of the landfill entrance. Water samples from surficial aquifer well 66 showed a slight increasing trend in specific conductance from April 1970 (50 umho) to mid-April 1977 (400 umho, fig. 20). The specific conductance increased sharply to nearly 2,200 umho by the end of April 1977, but declined to 1,300 umho in September 1977. A maximum specific conductance of 2,500 umho occurred in November 1978, after which time conductance gradually decreased to about 700 umho by November 1980. Chloride concentrations remained fairly steady at 20 mg/L from January 1970 to April 1977; from April 1977 to October 1979, concentrations increased to 100 mg/L. The specific conductance of water from Floridan aquifer well 67 remained fairly steady at 380 umho during 1970-77. Chloride concentrations ranged from 7 to 17 mg/L. Well 67 was destroyed sometime after October 1977. Based on changes in specific conductance and chloride concentrations, it appears that two periods of leachate movement occurred in the surficial aquifer.

The large changes in specific conductance and chloride concentrations in surficial aquifer wells south of the landfill probably were due to movement of leachate from the south perimeter ditch. Water from the surficial aquifer was in the bottom of the ditch during parts of each year. Water quality in the ditch was affected by leachate from nearby trenches and by wind-blown debris that collected in the ditch. As water flowed toward the sump pit, leachate moved into the surficial aquifer.

Water samples from well 72, a 47-foot deep flowing Floridan aquifer well southwest of the landfill, had an average specific conductance of 380 umho and a chloride concentration of 9 mg/L during the period 1970-74. The specific conductance and chloride concentration were within background levels.

Water-quality data for selected surface-water and ground-water sites are shown in tables 3 and 4. These include surficial aquifer and Floridan aquifer wells and sampling sites at Rocky Creek, oxidation pond, perimeter ditch, and sump pit.

## High-Rise Refuse Mound

Four surficial aquifer and four Floridan aquifer wells within 100 to 300 feet of the high-rise refuse mound were sampled for colifcrm bacteria and nutrients from June 1972 to October 1973. The sampling was to determine the contribution of the refuse mound to the occurrence, concentration, and movement of coliform bacteria and nutrients in the surficial aquifer and the upper part of the Floridan aquifer.

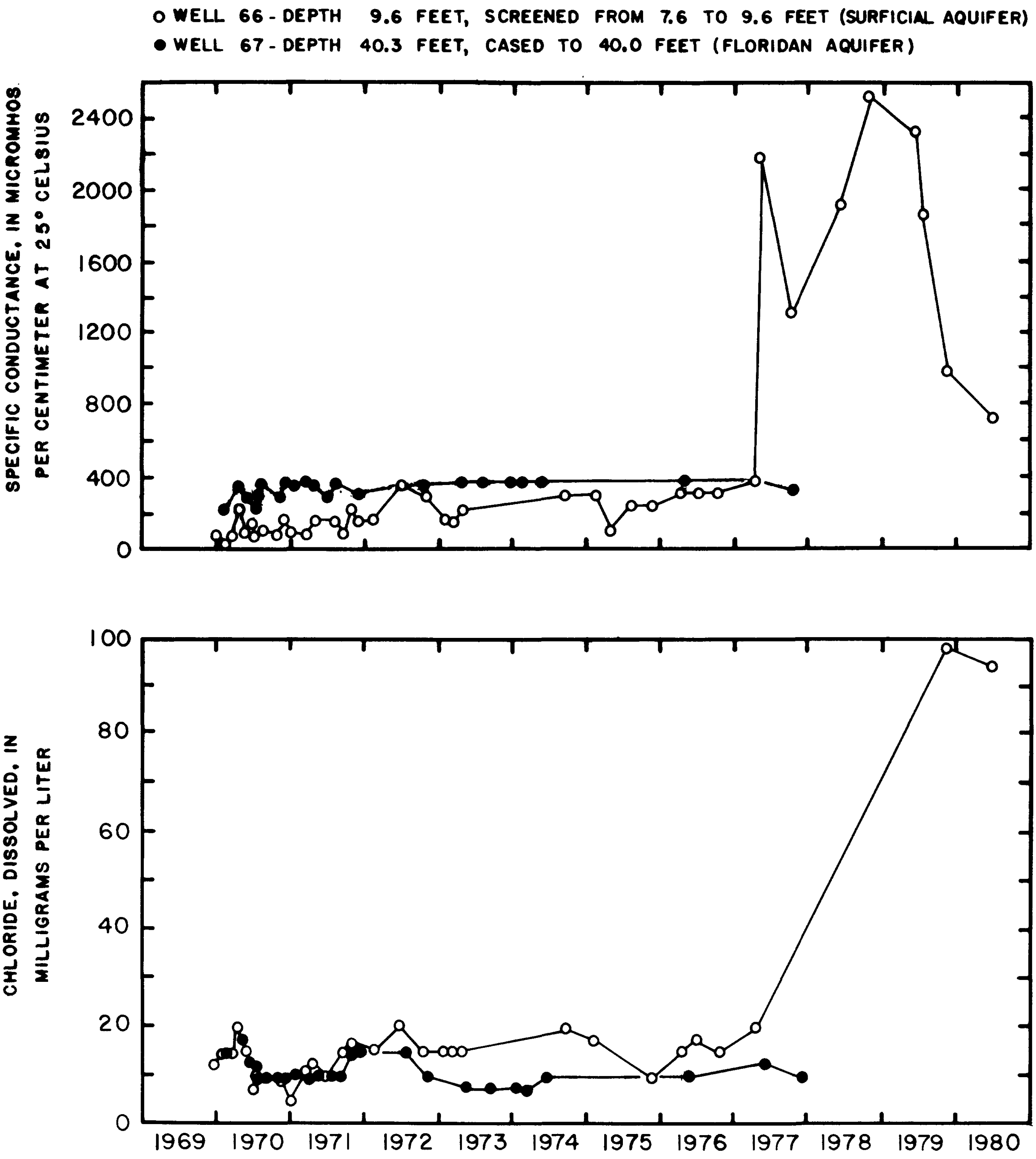



Figure 20.--Specific conductance and chloride concentration of water from wells 66 and 67, Rocky Creek landfill.

Table 3.--Water-quality data for selected ground-water sites, Rocky Creek landfill

[Concentrations are in milligrams per liter except as noted. Chloride, calcium, magnesium, sodium, potassium, hardness, sulfate, fluoride, and silica concentrations are dissolved]

| Well number | Depth (feet) | Aquifer | Date of sample | Temperature (°C) | Specific conductance (umho/cm) | Chloride (Cl) | pH | Alkalinity (as $CaCO_3$) | Calcium (Ca) |
|---|---|---|---|---|---|---|---|---|---|
| 115 | 13.5 | Surficial | 2-04-70 | -- | 278 | 5 | 7.0 | 136 | 49 |
| | | | 3-16-72 | -- | 250 | 7 | --- | --- | 110 |
| 116 | 43.5 | Floridan | 2-04-70 | 21.0 | 378 | 9 | 7.9 | 189 | 68 |
| | | | 3-16-72 | -- | 360 | 12 | --- | --- | 190 |
| 83 | 13.9 | Surficial | 2-04-70 | 19.5 | 135 | 7 | 6.8 | 52 | 11 |
| | | | 12-20-73 | -- | 63 | 9 | --- | --- | 8 |
| | | | 1-28-75 | -- | 337 | 8 | 7.6 | --- | 62 |
| | | | 5-17-77 | -- | 395 | 9 | 6.9 | --- | 71 |
| 85 | 50.5 | Floridan | 2-04-70 | 20.0 | 385 | 10 | 7.3 | 187 | 70 |
| | | | 10-15-73 | -- | 376 | 10 | --- | --- | 69 |
| | | | 5-14-74 | -- | 370 | 9 | --- | --- | 70 |

| Well number | Date of sample | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Dissolved solids | Hardness (as $CaCO_3$) | Sulfate ($SO_4$) | Fluoride (F) | Silica ($SiO_2$) |
|---|---|---|---|---|---|---|---|---|---|
| 115 | 2-04-70 | 1.0 | 2.8 | 0.6 | 163 | 127 | 8 | 0.1 | 2.0 |
| | 3-16-72 | 4.6 | 0 | .8 | --- | 290 | - | --- | --- |
| 116 | 2-04-70 | 3.9 | 6.0 | 1.0 | 226 | 186 | 0 | .2 | 14 |
| | 3-16-72 | 14.0 | 1.0 | .7 | --- | --- | - | --- | --- |
| 83 | 2-04-70 | 1.0 | 2.7 | 2.3 | 86 | 32 | 4 | .1 | 3.8 |
| | 12-20-73 | .9 | 6.3 | 2.2 | --- | 23 | - | --- | --- |
| | 1-28-75 | 4.1 | 6.0 | .7 | --- | 170 | - | --- | --- |
| | 5-17-77 | 4.1 | 6.3 | .9 | --- | 190 | - | --- | --- |
| 85 | 2-04-70 | 4.2 | 6.8 | 1.5 | --- | 126 | 0 | .2 | 15 |
| | 10-15-73 | 3.9 | 6.3 | .7 | --- | 190 | - | --- | --- |
| | 5-14-74 | 4.2 | 7.1 | 1.0 | --- | 190 | - | --- | --- |

Table 4.--Water-quality data for selected surface-water sites, Rocky Creek landfill

[Concentrations are in milligrams per liter except as noted. Chloride, calcium, magnesium, sodium, hardness, and oxygen concentrations are dissolved]

| Site number | Site description | Date of sample | Temperature (°C) | Specific conductance (umho/cm) | Chloride (Cl) | pH |
|---|---|---|---|---|---|---|
| SW-1 | Rocky Creek at railroad bridge | 10-27-70 | 22.0 | 180 | 13 | 6.3 |
| | | 11-22-71 | -- | 129 | 13 | --- |
| | | 12-20-73 | -- | 185 | 22 | --- |
| | | 10-14-77 | 23.0 | 130 | 18 | 4.2 |
| | | 10-18-79 | 25.5 | 102 | 10 | 6.5 |
| SW-2 | Sump pit | 10-27-70 | 22.5 | 240 | 16 | 6.4 |
| | | 11-22-71 | 17.5 | 220 | 21 | --- |
| | | 4-27-73 | -- | 420 | 36 | --- |
| SW-5 | Oxidation pond | 10-26-70 | 28.5 | 77 | 10 | 7.9 |
| | | 11-22-71 | -- | 625 | 45 | --- |
| | | 12-19-73 | -- | 126 | 20 | --- |
| SW-6 | South perimeter ditch | 10-26-70 | 29.5 | 54 | 8 | 6.0 |
| | | 7-28-71 | 27.0 | 51 | 8 | 5.4 |
| | | 4-27-73 | -- | 166 | 25 | --- |

| Site number | Date of sample | Alkalinity (as $CaCO_3$) | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Hardness (as $CaCO_3$) | Oxygen (O) |
|---|---|---|---|---|---|---|---|---|
| SW-1 | 10-27-70 | 68 | -- | --- | --- | --- | 71 | --- |
| | 11-22-71 | -- | 12 | 1.5 | 6.5 | 1.3 | 36 | --- |
| | 12-20-73 | -- | 21 | 3.9 | 12.0 | 7.8 | 69 | --- |
| | 10-14-77 | 23 | 13 | 2.5 | 9.3 | 3.4 | 43 | 2.1 |
| | 10-18-79 | 36 | 9 | 1.8 | 6.3 | 3.6 | 30 | 4.2 |
| SW-2 | 10-27-70 | 95 | -- | --- | --- | --- | 101 | --- |
| | 11-22-71 | -- | 23 | 4.5 | 12 | 1.6 | 76 | --- |
| | 4-27-73 | -- | 46 | 4.4 | 18 | 5.8 | 130 | --- |
| SW-5 | 10-26-70 | 10 | -- | --- | --- | --- | 21 | --- |
| | 11-22-71 | -- | 58 | 8.6 | 43 | 28 | 180 | --- |
| | 12-19-73 | -- | 16 | 1.7 | 8.9 | 19 | 47 | --- |
| SW-6 | 10-26-70 | 10 | -- | --- | --- | --- | 14 | --- |
| | 7-28-71 | 8 | -- | --- | --- | --- | 21 | 4.2 |
| | 4-27-73 | -- | 12 | 2 | 14 | 1.5 | 38 | --- |

Water collected from selected surficial aquifer wells (18 to 22 feet deep) had a greater number of colonies per 100 milliliters (col/100 mL) of fecal coliform and fecal streptococci bacteria than water from the Floridan aquifer wells (39 to 50 feet deep). The surficial aquifer had fecal coliform bacteria counts that ranged from zero to 6,000 col/100 mL and fecal streptococci bacteria counts from zero to 2,100. The Floridan aquifer had fecal coliform bacteria counts that ranged from zero to 1,700 and fecal streptococci bacteria counts from zero to 1,100 col/100 mL. There were occasional high counts of fecal coliform and fecal streptococci bacteria in several surficial aquifer wells, but there were no observed trends or patterns for bacteria in the area of the high-rise refuse mound.

The high coliform bacteria counts in water from the wells probably indicate surface leakage around well casings. The wells were not grouted and heavy vehicular traffic near the wells may have disturbed the material around the well casings.

Concurrently with collection of samples for bacteria analyses, samples were collected for determination of the following nutrients: organic nitrogen (N), ammonia nitrogen (N), nitrate nitrogen (N), nitrite nitrogen (N), orthophosphate (P), and total phosphorus (P). Concentrations of organic nitrogen (N) in samples collected from the surficial aquifer ranged from zero to 2.8 mg/L for filtered and 0.7 to 1.9 mg/L for unfiltered samples. Concentrations for samples from Floridan aquifer wells were 0.01 to 0.71 mg/L for filtered and 0.08 to 0.63 mg/L for unfiltered samples.

Concentrations of ammonia nitrogen (N) ranged from zero to 1.3 mg/L for filtered samples from the surficial aquifer. Concentrations of nitrate nitrogen (N) and nitrite nitrogen (N) were at or near detection limits for filtered samples from surficial and Floridan aquifer wells. Concentrations of orthophosphate (P) ranged from zero to 0.06 mg/L for filtered samples collected from surficial aquifer wells. Concentrations of total phosphorous (P) ranged from 0.01 to 0.06 mg/L for filtered and 0.02 to 0.26 for unfiltered samples. Concentrations of biochemical oxygen demand (BOD) ranged from 0.4 to 1.9 mg/L.

## Septic-Tank Sludge

Disposal of septic-tank sludge northeast of the oxidation pond began in May 1973 and continued until July 1975. The sludge was discharged into two unlined ponds that were excavated to depths of 8 to 10 feet in the surficial deposits. A 12-inch corrugated pipe about 2 feet below land surface connected the two ponds.

Six surficial aquifer wells and six Floridan aquifer wells were sampled periodically to monitor the effects of the sludge on the quality of water in the aquifers. A single high fecal coliform bacteria count (3,500 col/100 mL) was obtained in a 22-foot-deep surficial aquifer well 200 feet southeast of the sludge ponds. Coliform bacteria were not observed in other surficial and Floridan aquifer wells sampled near the ponds.

Organic nitrogen in water samples collected from Floridan aquifer wells ranged from 0.06 to 0.68 mg/L, filtered, and 0.04 to 1.8 mg/L, unfiltered. These concentrations were less than those obtained for the surficial aquifer wells (0.13

to 0.96 mg/L, filtered, and 0.37 to 1.9 mg/L, unfiltered). Concentrations of ammonia nitrogen (N), filtered, from the surficial aquifer ranged from 0.14 to 0.69 mg/L, and unfiltered samples ranged from 0.28 to 0.44 mg/L. Concentrations of nitrate nitrogen (N) and nitrite nitrogen (N) were at or near detection limits for filtered and unfiltered samples. Concentrations of orthophosphates (P) for filtered and unfiltered samples from surficial aquifer wells ranged from zero to 0.74 and zero to 0.02 mg/L, respectively. Concentrations of total phosphorus (P) for filtered surficial aquifer samples ranged from zero to 0.23, and unfiltered samples ranged from 0.02 to 0.78 mg/L. Concentrations for water from Floridan aquifer wells were zero to 0.01, filtered, and 0.02 to 0.04 mg/L, unfiltered.

## Summary


The general direction of movement of water in the Floridan aquifer is southwest toward Old Tampa Bay. The direction of movement of water in the surficial aquifer is west and north toward Rocky Creek and south toward Linebaugh Avenue.

Water samples from most surficial aquifer wells along the west side of the landfill, between Rocky Creek and the west perimeter ditch, showed slight to moderate increases in specific conductance and chloride concentrations from mid-1972 to late 1973, about 1-1/2 years after landfill operations began. Water samples from surficial aquifer wells near the southwest corner of the landfill increased in specific conductance and chloride concentrations beginning in early 1974. The specific conductance increased from about 200 to 600 umho, and chloride concentrations increased from 10 to 60 mg/L. No noticeable changes in water quality were observed for wells 40 to 50 feet deep.

Water samples from most shallow and deep surficial aquifer wells within the landfill west of the oxidation pond showed increases in specific conductance and chloride concentration during 1970-71. During the period of study, specific conductance increased from 45 to 900 umho, and chloride concentrations increased from 10 to 60 mg/L. Surficial aquifer wells within the landfill showed changes in water quality because of deposition of refuse in trenches that intercepted the water table and the proximity of the wells to the trenches.

Water samples collected from surficial aquifer wells near the oxidation pond and west of the sludge pit increased in specific conductance from 110 to 420 umho. Chloride concentrations remained unchanged at 6 to 12 mg/L. The 29- and 48-foot deep wells did not show any appreciable changes in specific conductance or chloride concentrations.

Water samples from surficial aquifer wells south of the landfill showed an increasing trend in specific conductance and chloride concentrations beginning in 1970 and continuing into 1977. A large increase in specific conductance (400 to 2,000 umho) occurred at the end of April 1977; a maximum specific conductance of 2,500 umho occurred in November 1978. Changes in water quality in the wells apparently were due to movement of leachate from the south perimeter ditch into the surficial aquifer. No changes in water quality were observed in wells 40 feet deep or greater south of the landfill.

## Eureka Springs Landfill

### Location, Construction, and Operation

The Eureka Springs landfill is in north-central Hillsborough County, about 10 miles northeast of Tampa and 6 miles northwest of Brandon (fig. 2). A major highway in the area is U.S. Highway 301 (fig. 21). A paved access road connects the landfill with U.S. Highway 301.

Several tropical fish farms are located along Eureka Springs Road about half a mile south of the landfill. The farms consist of one or more parallel rows of rectangular ponds. The ponds average 4 to 6 feet in depth, 15 feet in width, and 45 feet in length. Water levels and water temperature in the ponds are controlled by flowing artesian wells in the Floridan aquifer.

The trench method of landfilling was used at the site. The trenches ranged from 7 to 10 feet in depth, 70 to 125 feet in width, and 400 to 425 feet in length. The landfill (fig. 22) was enclosed by a perimeter ditch similar to the one constructed at the Rocky Creek landfill. Water in the ditch drained into a sump pit in the north perimeter ditch. Periodically, water was pumped from the pit into the north landfill canal. An unlined oxidation pond was also constructed to provide storage for water and leachate during dewatering operations. The pond was about 400 feet long, 165 feet wide, and had side slopes of 1:1.

For this report, landfill operations at the Eureka Springs site are designated west and east landfills. The west landfill includes the western part of the landfill and is referred to as Eureka Springs west landfill (fig. 21). The site included 68 acres operated from October 1969 to November 1973. The eastern part of the landfill is referred to as Eureka Springs east landfill and consists of 60 acres operated from November 1973 to May 1976. The two landfills are separated by an access road to the east landfill.

Eureka Springs west landfill became operational on October 1, 1969, when trench 18 (fig. 22) received trees, shrubs, grass cuttings, and construction and demolition wastes. Trench 14 began receiving domestic and industrial solid wastes at the end of October 1969. Except for temporary changes in operating procedures, trenches were filled with solid waste, moving eastward from trench 14 to trench 29 and westward from trench 30 to trench 42. Trenches 12, 13, 34, 41, and 43 and the oxidation pond were the last to be filled.

### Physical Setting

The landfill site is in a flat, swampy area that has average land-surface altitudes of 20 feet above sea level. The area contains numerous flowing wells, cypress swamps, ponds, springs, and drainage canals. The area is drained by a network of canals that discharge into Sixmile Creek (fig. 21). Much of the discharge of Sixmile Creek during the dry season comes from springs near the landfill. Sixmile Creek was deepened and widened in 1978 as part of the Tampa Bypass Canal project and was incorporated into the canal system. The purpose of the bypass canal is to provide flood protection to the cities of Tampa and Temple Terrace.

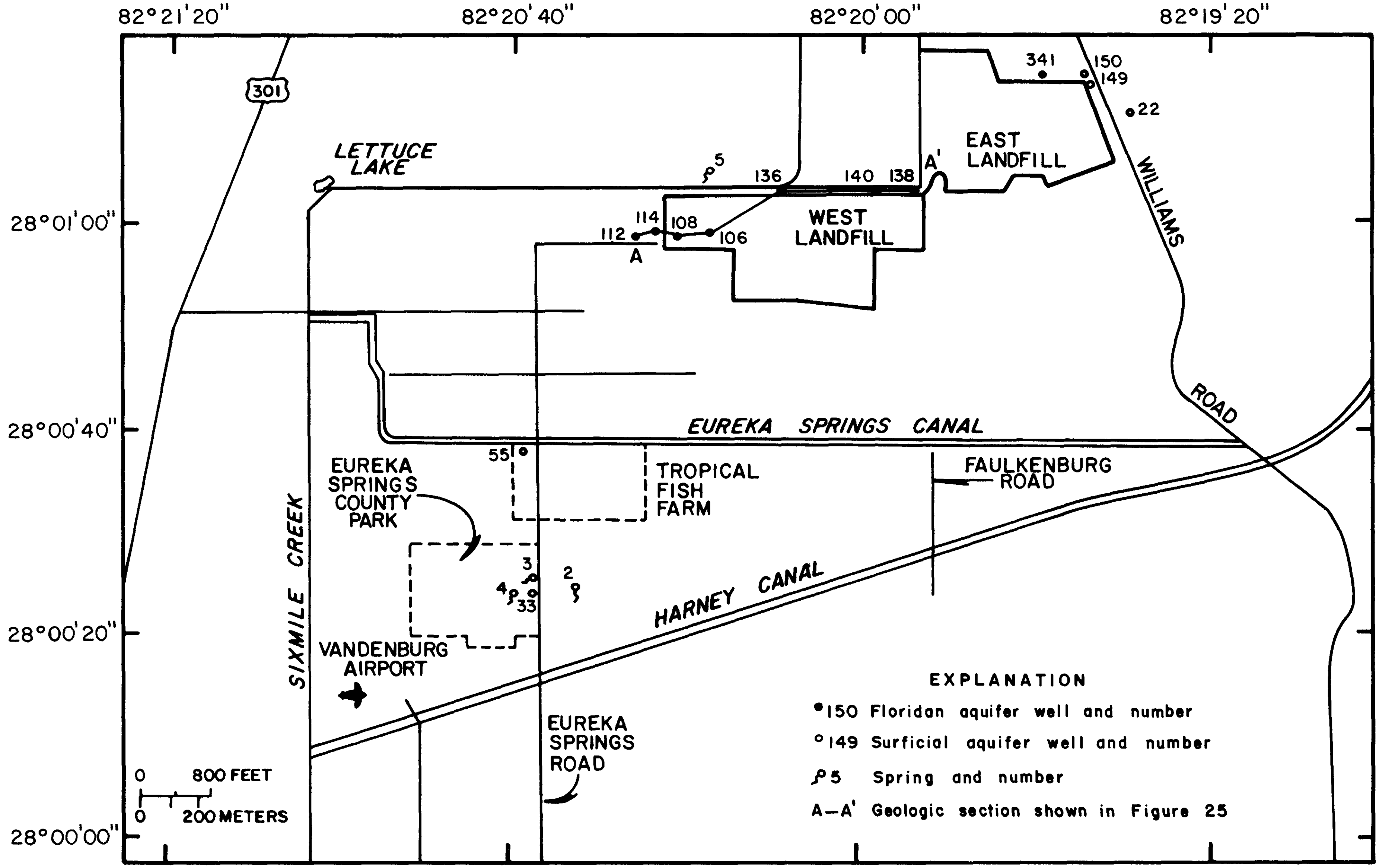
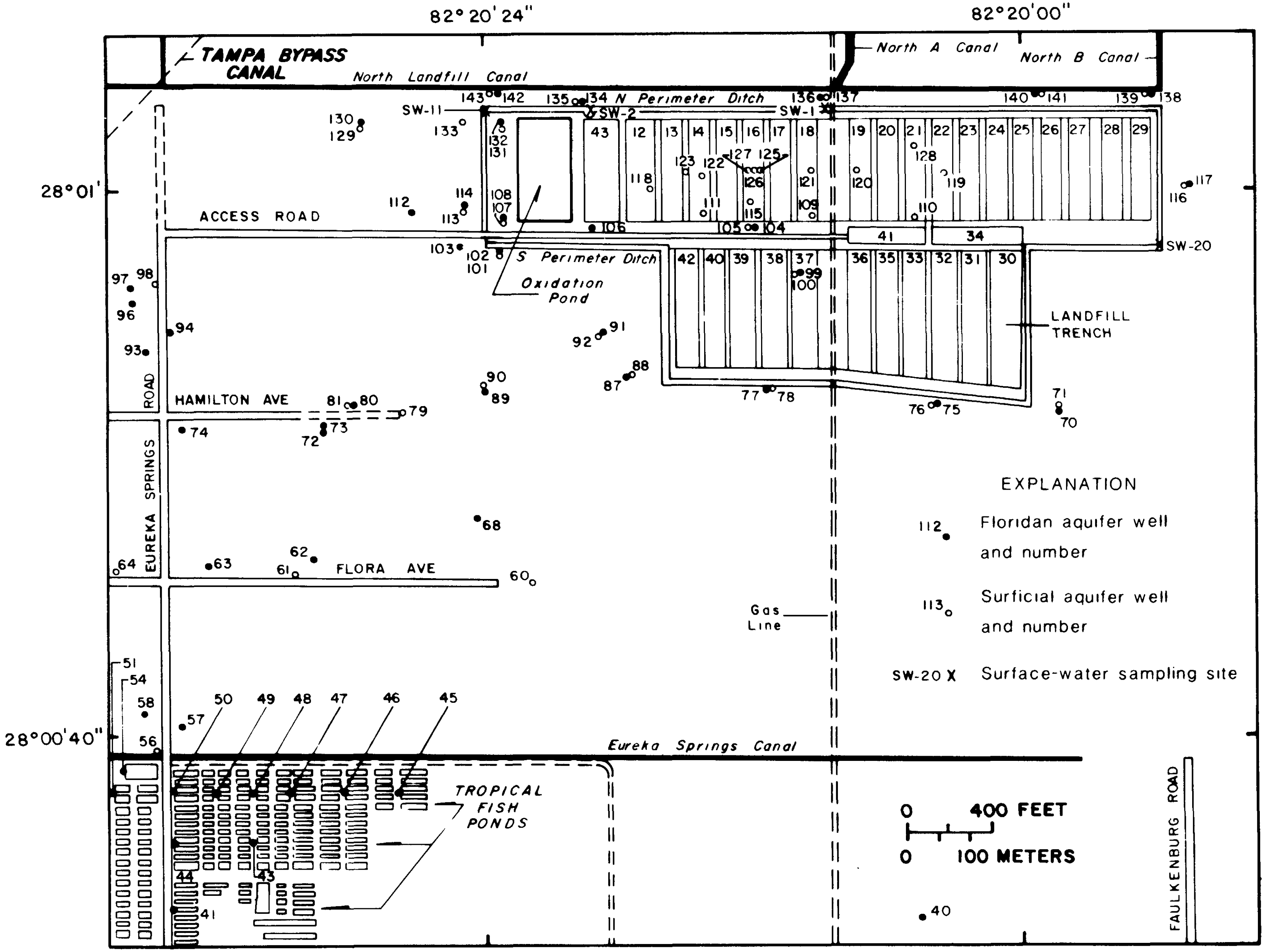



Figure 21.--Locations of monitor wells, springs, and section A-A', Eureka Springs east and west landfills.



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

Figure 22.--Locations of landfill trenches and wells, Eureka Springs west landfill.

The landfill area is overlain by surficial deposits that consist of sand, silt, sandy clay, and clay in the west landfill; the soil is classified predominantly as a Felda fine sand and Delray fine sand. In the east landfill, the soil is mostly Terra Ceia peaty muck (U.S. Department of Agriculture, 1958). The deposits are less than 25 feet thick along the western side of the landfill and are as much as 45 feet thick in the eastern part (fig. 23). The top of the Floridan aquifer areally ranges in altitude from about 10 feet below sea level near the landfill to about 30 feet above sea level 2 to 3 miles southeast of the landfill (fig. 24). The top of the Floridan aquifer beneath the Eureka Springs west landfill ranges from 7 to 33 feet below sea level (fig. 25).

Clay layers 10 to 32 feet thick underlie the surficial deposits beneath the landfill. The clays form a confining layer overlying the Floridan aquifer and retard movement of water between the surficial and Floridan aquifers. A lithologic log of materials penetrated in a 48-foot well near the eastern boundary of the west landfill is shown in table 5.

Table 5.--Lithologic log of well 138, Eureka Springs west landfill

| Lithologic description | Thickness (feet) | Depth (feet) |
|---|---|---|
| Sand, brownish-gray, fine | 10 | 10 |
| Clay, white, with streaks of green, plastic, sandy | 8 | 18 |
| Clay, bluish-green, plastic | 7 | 25 |
| Clay, bluish-green, friable | 11 | 36 |
| Clay and limestone | 11 | 47 |
| Limestone | 1 | 48 |

During the study period, two 6-inch diameter PVC test wells and sixty 2-inch diameter PVC test wells were drilled in the Eureka Springs site and adjacent areas (fig. 22). Most test wells in the west landfill that were completed in the upper part of the limestone flowed at land surface when first drilled. Recording gages were installed on the 6-inch diameter wells to obtain records of water levels. An additional 11 test wells were drilled in selected trenches that were filled with solid waste and completed with a cover of clayey sand. Most test wells were drilled in the west landfill because it was the original study site.

Split-spoon samples of surficial materials were collected at various depths from selected wells during drilling. Quantitative analyses of the samples included: particle-size distribution, hydraulic conductivity, specific yield, specific retention, and porosity. Cation exchange capacity determinations were made for 17 samples collected from five test wells. Undisturbed sediment samples were collected from the sides and bottoms of selected trenches to determine the horizontal and vertical hydraulic conductivity, specific gravity, and total porosity. The results for selected test wells and trenches are shown in table 6.

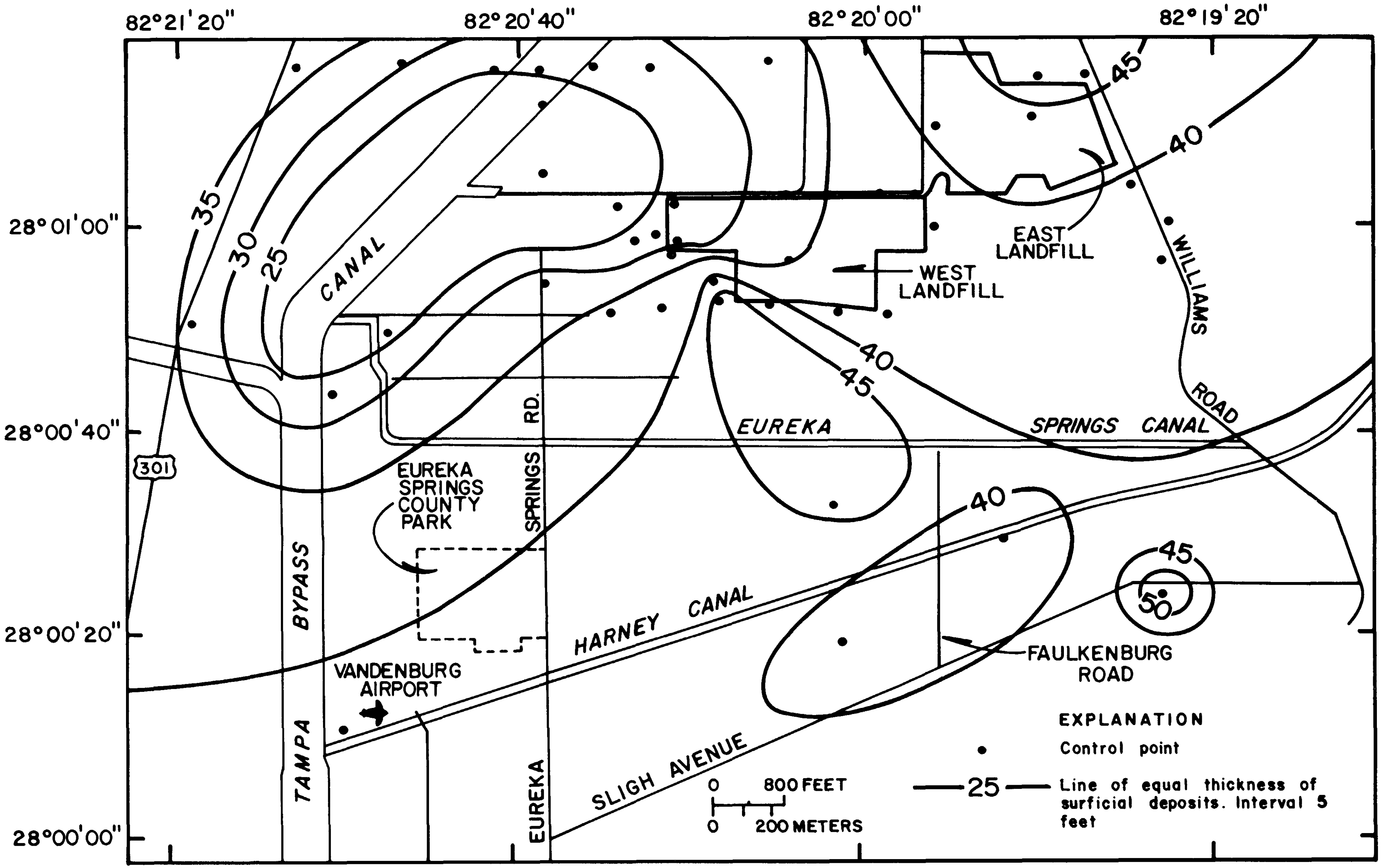



Figure 23.--Thickness of surficial deposits, Eureka Springs east and west landfills.

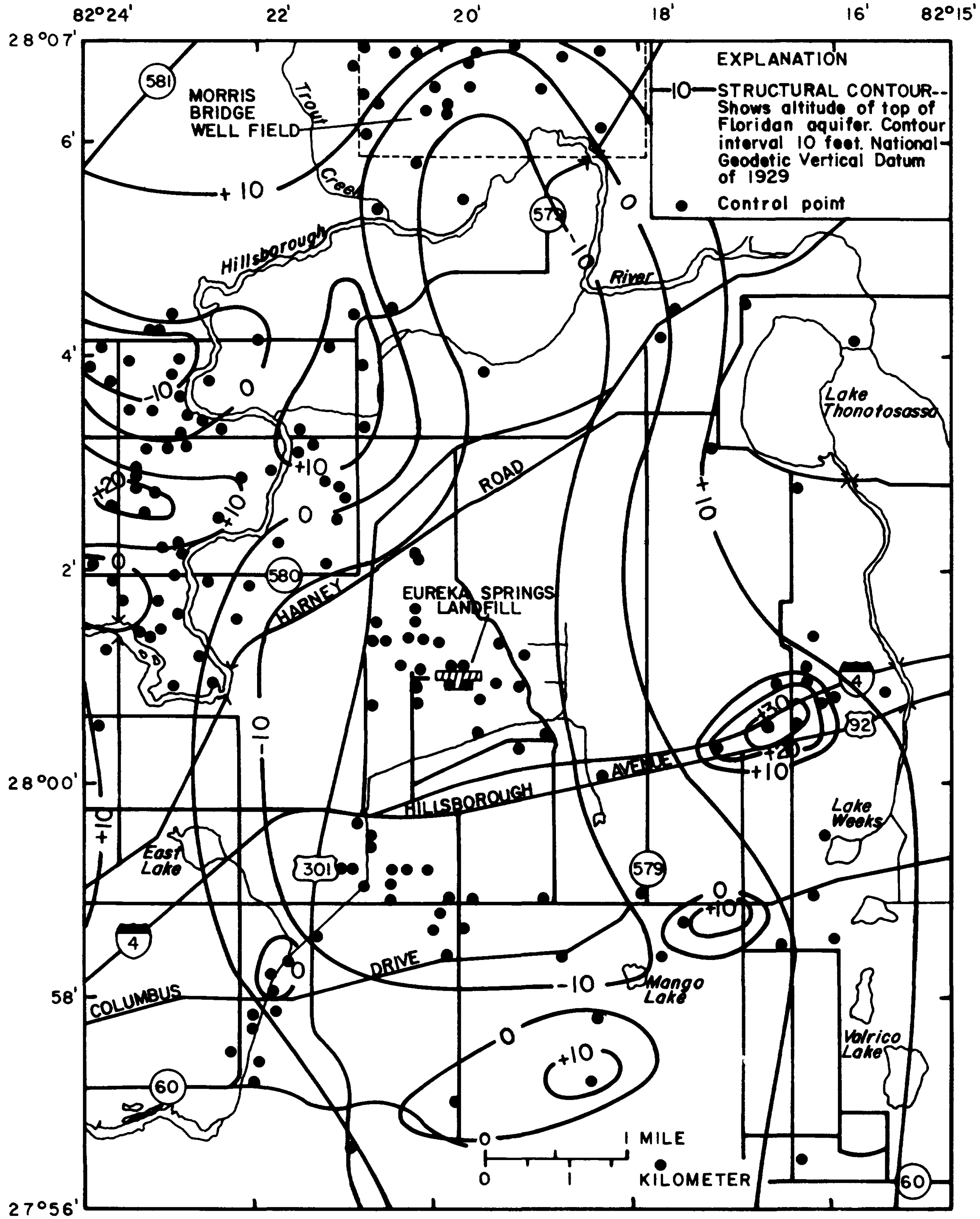



Figure 24.--Configuration of the top of the Floridan aquifer, north-central Hillsborough County.

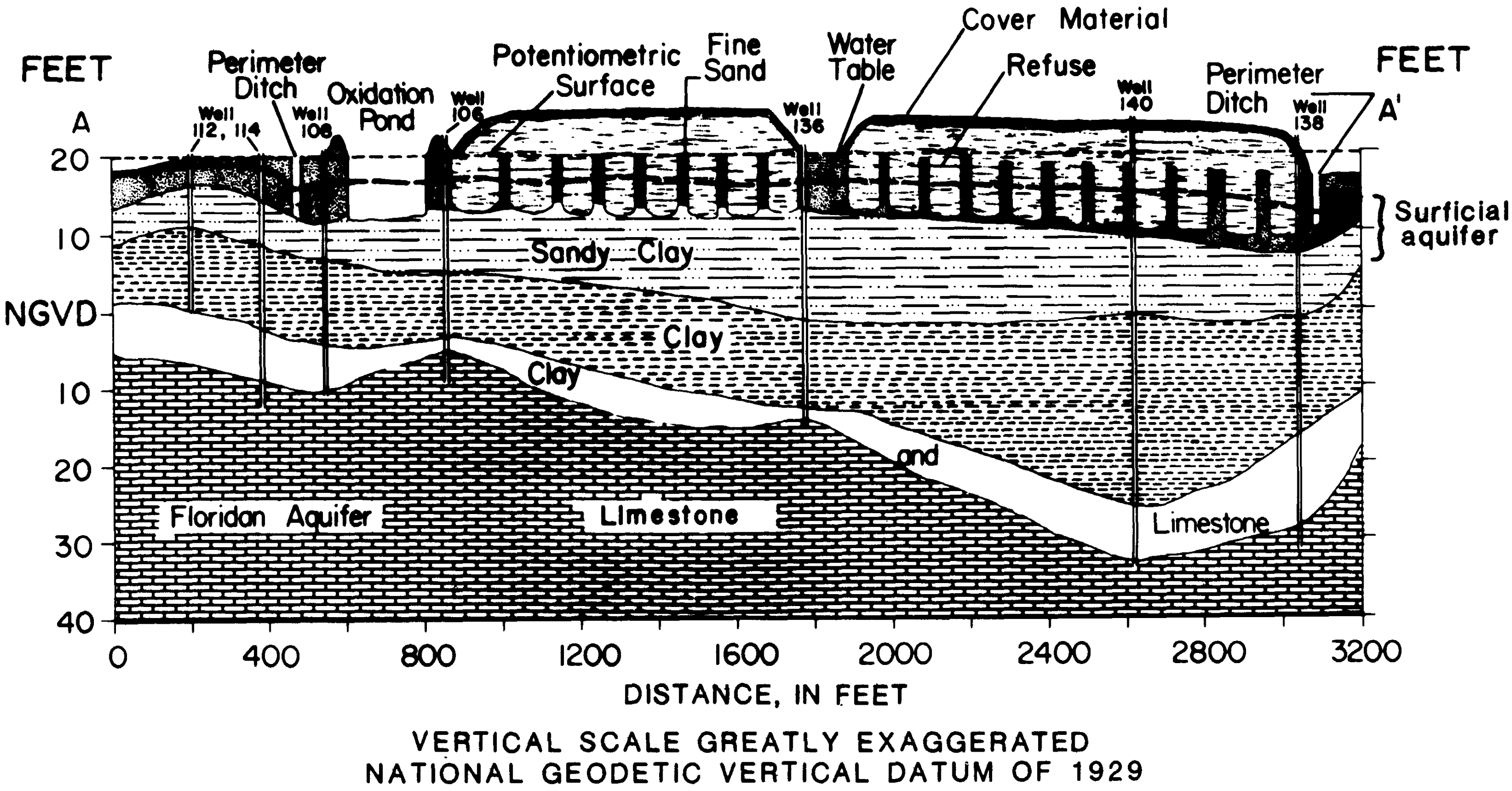



Figure 25.--Geologic section, Eureka Springs west landfill.
(Location of section is shown on figure 21.)

Table 6.--Laboratory analyses of surficial sediments, Eureka Springs east and west landfills

[$g/cm^3$ -- grams per cubic centimeter; me/100 g -- milliequivalents per 100 grams; a -- cover material on trench 16; H -- horizontal conductivity, all other conductivities are vertical]

| Sample site | Depth (feet) | Type of material | Specific gravity ($g/cm^3$) | Specific retention (percent) | Specific yield (percent) | Total porosity (percent) | Hydraulic conductivity (ft/d) | Cation exchange capacity (me/100 g) |
|---|---|---|---|---|---|---|---|---|
| Well 97 | 13.0-13.5 | Clay | 2.62 | -- | -- | -- | $1.1x10^{-5}$ | 27 |
| | 18.0-18.5 | Clay | 2.59 | -- | -- | -- | $2.0x10^{-6}$ | 28 |
| Well 52 | 9.0-9.5 | Clay and shells | -- | 20.5 | 31.6 | 52.1 | $1.3x10^{-1}$ | -- |
| | 10.0-10.5 | Clay and shells | -- | 25.5 | 35.6 | 61.1 | $2.7x10^{-3}$ | -- |
| | 14.5-15.0 | Clay and shells | -- | 28.0 | 29.0 | 57.0 | $9.5x10^{-3}$ | -- |
| | 24.5-25.0 | Medium stiff clay | -- | 34.0 | 2.2 | 36.6 | $5.2x10^{-3}$ | -- |
| | 25.0-25.5 | Medium stiff clay | -- | 22.7 | 27.5 | 50.2 | $2.6x10^{-4}$ | -- |
| | 30.0-30.5 | Limestone | -- | 28.2 | 8.0 | 36.2 | $1.3x10^{-4}$ | -- |
| Well 112 | 13.0-13.5 | Clay | 2.64 | -- | -- | -- | $3.3x10^{-5}$ | 25 |
| | 18.0-18.5 | Clay | 2.56 | -- | -- | -- | $3.2x10^{-5}$ | 19 |
| Well 79 | 17.0-17.5 | Clay | 2.60 | -- | -- | -- | $2.5x10^{-4}$ | 19 |
| Well 99 | 4.0-4.5 | Very fine sand | 2.70 | 10.6 | 35.3 | 45.9 | -- | -- |
| | 9.0-9.5 | Silty, clayey sand | 2.84 | 5.4 | 41.8 | 47.2 | $5.9x10^{-1}$ | -- |
| | 14.0-14.5 | Clay | -- | -- | -- | -- | $1.3x10^{-3}$ | -- |
| | 19.0-19.5 | Stiff clay | -- | -- | -- | -- | $5.9x10^{-4}$ | -- |
| | 24.0-24.5 | Stiff clay | -- | -- | -- | -- | $5.6x10^{-4}$ | -- |
| | 29.0-29.5 | Loose clay | -- | -- | -- | -- | $1.0x10^{-2}$ | -- |
| | 29.5-30.0 | Clay and limestone | -- | -- | -- | -- | $3.0x10^{-2}$ | -- |
| | 34.5-35.0 | Soft limestone | -- | -- | -- | -- | $2.2x10^{-2}$ | -- |
| Well 141 | 11.0-11.5 | | 2.67 | 21.1 | 11.1 | 32.2 | -- | -- |
| | 16.0-16.5 | Clay | 2.62 | 29.1 | 11.3 | 40.4 | -- | -- |
| | 21.0-21.5 | Clay | 2.65 | 42.3 | 0.7 | 43.0 | $3.8x10^{-4}$ | -- |
| | 26.0-26.5 | Fine sand | 2.64 | 30.7 | 11.3 | 42.0 | $1.8x10^{-4}$ | -- |
| | 36.0-36.5 | Sand | 2.64 | 30.6 | 23.4 | 54.0 | $1.2x10^{-3}$ | -- |

Table 6.--Laboratory analyses of surficial sediments, Eureka Springs east and west landfills--Continued

| Sample site | Depth (feet) | Type of material | Specific gravity ($g/cm^3$) | Specific retention (percent) | Specific yield (percent) | Total porosity (percent) | Hydraulic conductivity (ft/d) | Cation exchange capacity (me/100 g) |
|---|---|---|---|---|---|---|---|---|
| Well 341 | 13.0-13.5 | Clay | 2.56 | -- | -- | -- | $8.5x10^{-5}$ | -- |
| | 18.0-18.5 | Clay | 2.63 | -- | -- | -- | $4.3x10^{-5}$ | 27 |
| | 23.0-23.5 | Clay | 2.58 | -- | -- | -- | $4.9x10^{-5}$ | 32 |
| | 28.0-28.5 | Silty clay | 2.65 | -- | -- | -- | $4.6x10^{-4}$ | 6.7 |
| | 33.0-33.5 | Silty clay | 2.67 | -- | -- | -- | $3.3x10^{-5}$ | 8.6 |
| | 38.0-38.5 | Clay | 2.64 | -- | -- | -- | $6.2x10^{-6}$ | 30 |
| | 43.0-43.5 | Clay | 2.68 | -- | -- | -- | $2.5x10^{-4}$ | -- |
| | 48.0-48.5 | Silty clay | 2.70 | -- | -- | -- | $9.8x10^{-3}$ | -- |
| Well 146 | 16.0-16.5 | Clay | 2.61 | -- | -- | -- | $8.5x10^{-4}$ | 27 |
| | 21.0-21.5 | Silty clay | 2.66 | -- | -- | -- | $2.5x10^{-2}$ | 10 |
| Trench 14 | 6.6 | Clayey sand | -- | -- | -- | -- | $1.8x10^{-1}$ H | -- |
| | 7.5 | Clayey sand | -- | -- | -- | -- | $4.6x10^{-4}$ H | -- |
| | 7.4-7.9 | Clayey sand | -- | -- | -- | -- | $1.4x10^{-3}$ | -- |
| | 7.9-8.4 | Clayey sand | -- | -- | -- | -- | $3.3x10^{-3}$ | -- |
| | 8.0-8.5 | Fine sand | -- | -- | -- | -- | $8.2x10^{-3}$ | -- |
| | 10.3-10.8 | Clayey sand | -- | -- | -- | -- | $3.3x10^{-4}$ | -- |
| | 12.5-13.0 | Fine sand | -- | -- | -- | -- | $1.0x10^{-2}$ | -- |
| Trench 16 | 0-0.5 | Sand, clay, silt | -- | -- | -- | -- | $1.3x10^{-3}$ a | -- |
| Trench 21 | 1.0 | Sand | -- | -- | -- | -- | $1.8x10^{-1}$ H | -- |
| | 3.3 | Sand | -- | -- | -- | -- | $9.2x10^{-1}$ H | -- |
| | 4.8 | Sand | 2.67 | 8.7 | 30.3 | 39.0 | $7.9x10^{-1}$ H | -- |
| | 6.0 | Sand | 2.66 | 10.1 | 28.2 | 38.3 | $3.9x10^{-2}$ H | -- |
| | 6.0-6.5 | Sand | 2.68 | 9.1 | 29.0 | 38.1 | $7.9x10^{-2}$ | -- |
| | 7.0-7.5 | Sand | -- | -- | -- | -- | $4.9x10^{-2}$ | -- |

The vertical hydraulic conductivity of sands and silts collected from test wells at depths of 4 to 35 feet ranged from $1.8 \times 10^{-4}$ to $5.9 \times 10^{-1}$ ft/d. Most material below 9 feet had a hydraulic conductivity of $3.3 \times 10^{-4}$ to $3.3 \times 10^{-5}$ ft/d. The hydraulic conductivity of the confining bed (clay) at depths of 13 to 18 feet ranged from $7.8 \times 10^{-6}$ to $2.4 \times 10^{-3}$ ft/d. The specific yield of samples at depths of 4 to 12 feet averaged about 31 percent, and the porosity averaged about 48 percent.

The clay and silt content of samples from most wells increased with depth. Particle-size distribution graphs for wells 141 and 341 are shown on figures 26 and 27.

## Infiltration Tests

Tests of undisturbed soils and trench cover material at the Eureka Springs west landfill indicated low values of infiltration rates for the soils and cover material. The infiltration tests were made during a period when the soil was slightly to moderately wet. The trench cover was a 2-foot-thick layer of permeable fine sand mixed with less permeable clay. The undisturbed soil was a fine sand, high in organic silt, underlain by sandy, nearly plastic clay. Infiltration rates of natural soil ranged from 0.5 to 1.0 inch per hour; rates for compacted cover material ranged from 0.05 to 0.1 inch per hour. The lower infiltration rates for the cover material were due to greater amounts of silt and clay in the cover than in native materials and compaction of the cover material on the trenches.

## Water Levels

The oxidation pond was constructed in the surficial aquifer, and water levels in the pond generally reflected water levels in nearby wells. However, during pumping into the pond or following periods of heavy rains, water levels in the pond were 1 to 3 feet higher than water levels in the surficial aquifer.

Trench depths at the west landfill averaged 8 feet and were 4 to 6 feet into the upper part of the surficial aquifer. Water levels at trench sites were 14 to 16 feet above sea level during a wet period shortly before the landfill became operational. After the landfill became operational, the highest observed water levels, 14 to 21 feet above sea level, generally were in September and October; the lowest, 13 to 17 feet above sea level, were in May. At an elevation of 21 feet above sea level, about 9 feet of solid waste (1 foot above original land surface) in trenches was saturated by the surficial aquifer.

Land-surface elevations at the east landfill ranged from 17 to 25 feet above sea level in the western part of the site, 24 to 29 feet in the central part, and 21 to 31 feet along the eastern boundary near Williams Road (fig. 21). Landfill trenches were 8 to 10 feet deep in the western part of the site and about 8 feet deep in the remainder of the site. Water levels in the western part of the site were 16 feet above sea level in May and September 1980, which indicates 7 to 9 feet of solid waste in the trenches was saturated by the surficial aquifer. Water levels in the eastern part were 25 feet above sea level in May 1980, the highest levels observed during the study period. At this level, about 3 to 4 feet of solid waste in trenches was saturated.

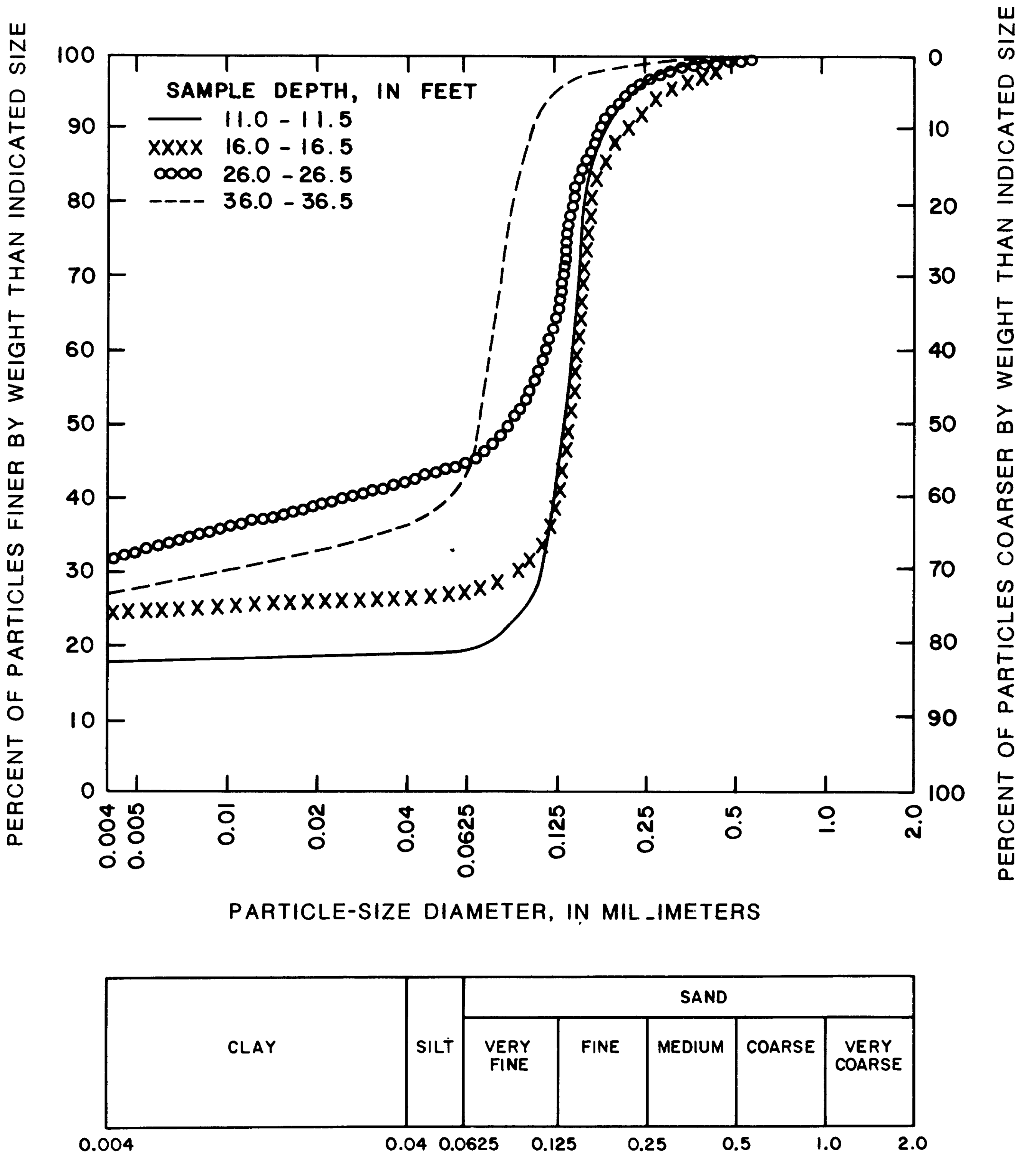
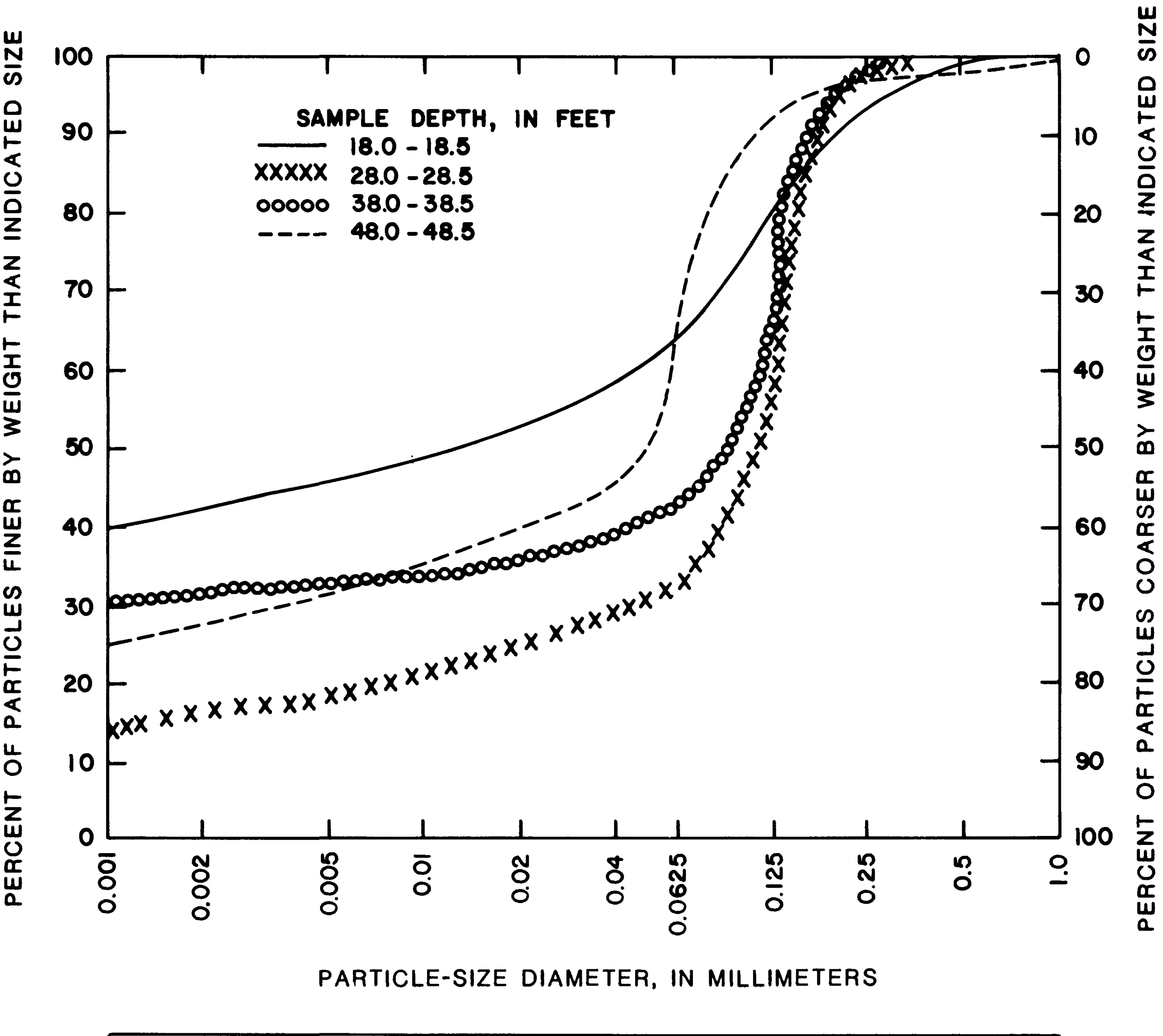



Figure 26.--Particle-size distribution for materials from well 141, Eureka Springs west landfill.



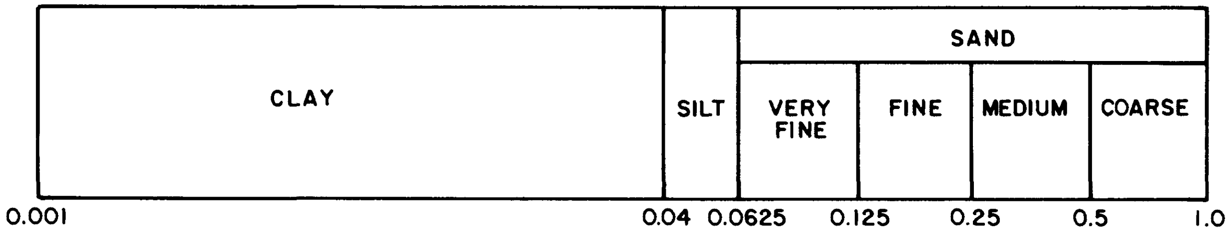




Figure 27.--Particle-size distribution for materials from well 341, Eureka Springs east landfill.

A regional map of the potentiometric surface of the Floridan aquifer for May 1969 indicates that the surface is 20 feet above sea level at the landfill site (fig. 28). Ground-water movement is generally southwest. The Temple Terrace well field is about 2 to 2-1/2 miles northwest of the landfill site and Tampa's Morris Bridge well field is about 4 miles north of the site. Both are upgradient of the general direction of ground-water flow from the Eureka Springs landfill.

Water levels in the surficial aquifer ranged from 17 to 20 feet above sea level southwest of the west landfill and about 15 to 17 feet above sea level within the site (fig. 29). Water levels averaged about 25 feet above sea level 1 mile east of the site.

The high water level southwest of the landfill represents a low, perennially wet area that is probably caused by upward leakage of water from the Floridan aquifer. High water levels existed in the area before the landfill became operational. The general direction of ground-water movement at the site was southwest toward Eureka Springs, north toward the north landfill canal, and southeast toward the Eureka Springs Canal.

By November 11, 1970, 13-1/2 months after landfilling began, trenches 14 through 21 (except trench 15, which was in use) had been filled with solid waste and capped with 2-foot earth covers. Rainfall in November was less than an inch, and water levels south and southwest of the landfill (fig. 30) were about the same as observed in May 1970, an unusually wet period.

By the end of the second year of operation (October 26, 1971), trenches 12 through 24 had been filled, covered, and compacted. Trench 25 was in use and was partially filled with solid waste. Rainfall in October was in excess of 4 inches; rainfall for May through September ranged from 5.38 to 8.98 inches. The configuration of the water table was about the same as in November 1970, but the groundwater mound south-southwest of the landfill was slightly higher (fig. 31). The highest water level was 18 feet above sea level, compared with 17 feet in November 1970. Water levels within the landfill were also about a foot higher than the previous year.

Four years after the west landfill opened (October 1973), the area enclosed by the 18-foot contour showed a slight increase. As filling of trenches progressed, the water-table mound continued to expand and shift northeastward. On May 14, 1975, about 5-1/2 years after landfill operations began, water levels in the surficial aquifer at the site were 15 to 18 feet above sea level (fig. 32). In May 1980, water levels in the surficial aquifer were 16 to 21 feet above sea level (fig. 33), an increase of about 3 feet since May 1975 and the highest for the period of record.

Water-level data at the west landfill during May 1980 indicated a buildup of water levels in the surficial aquifer and a potentiometric surface lower than water levels in the surficial aquifer. Water levels in the Floridan aquifer and the surficial aquifer for the period 1970-80 for two test wells are shown on figure 34. The wells are within 5 feet of each other and are about 200 feet southwest of the oxidation pond. The potentiometric surface was higher than the water level in the surficial aquifer from 1970 through 1975; however, during most of 1976-80, the potentiometric surface was 1 to 4 feet lower than the water table. The buildup of water levels in the surficial aquifer was due to an increase in annual precipitation from 1978 through 1980. Infiltration into the trenches exceeded outflow, thereby causing a rise in water levels.

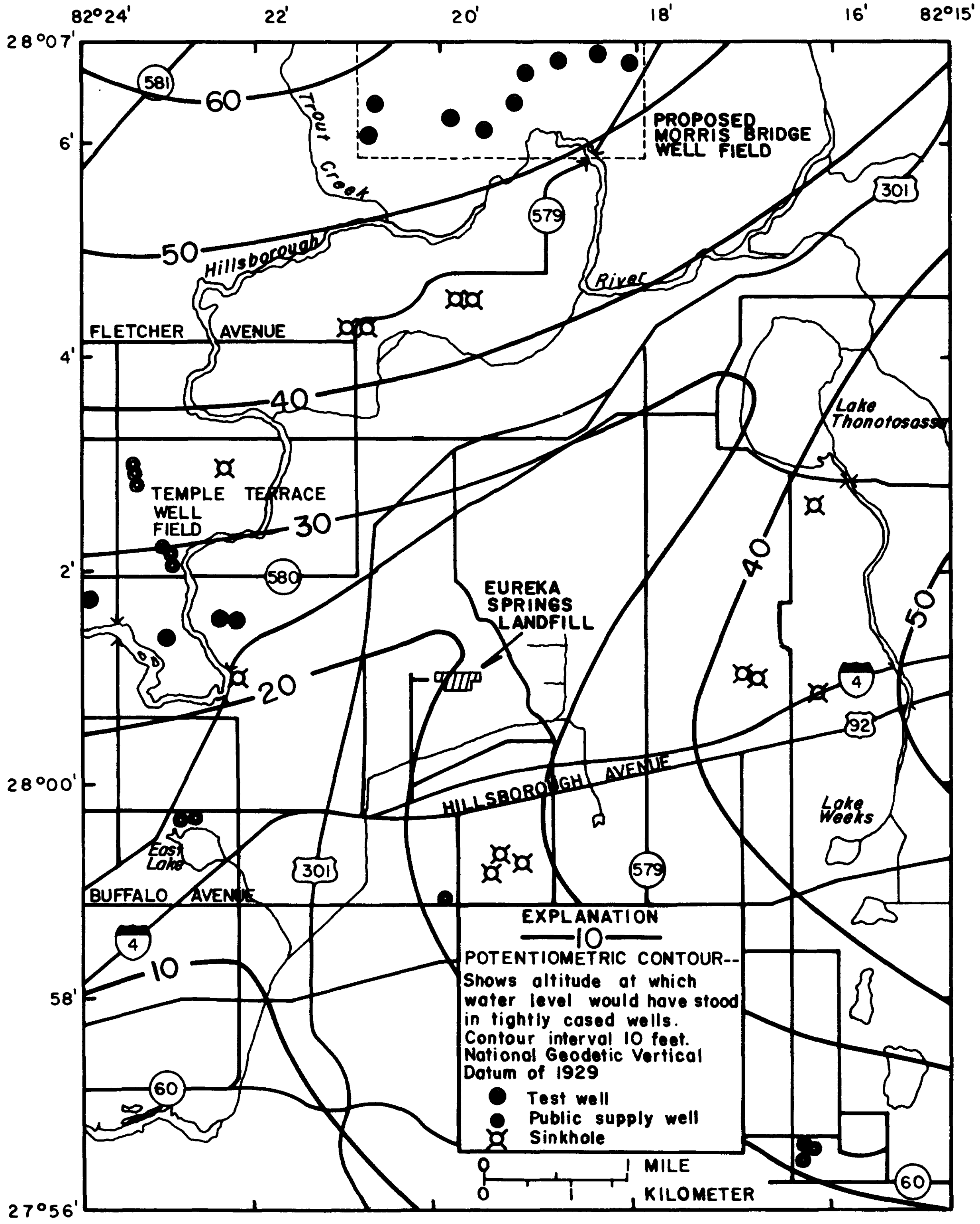



Figure 28.--Potentiometric surface of the Floridan aquifer, May 1969, north-central Hillsborough County (modified from Stewart and others, 1971).

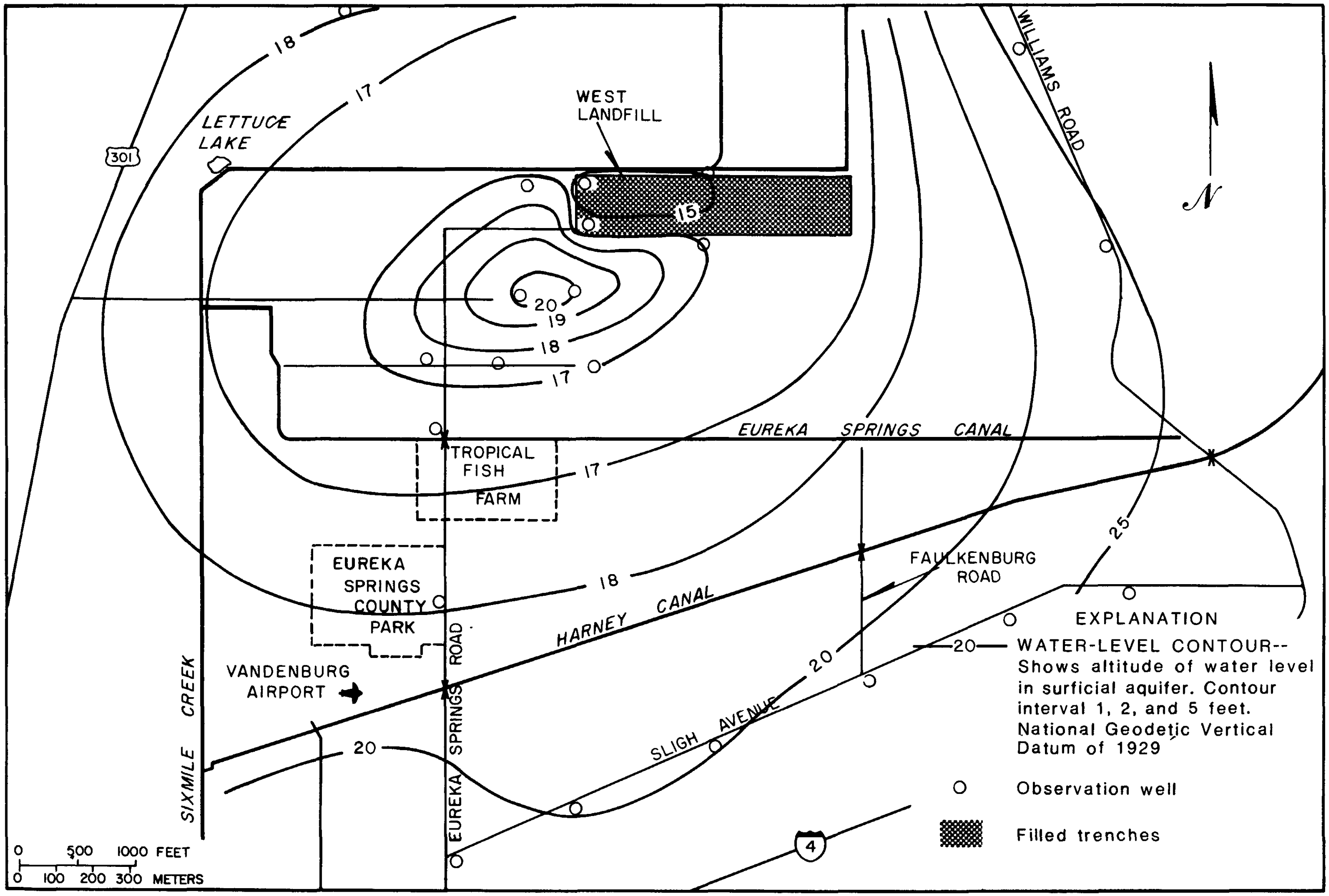



Figure 29.--Configuration of the water level in the surficial aquifer, August 27, 1969, Eureka Springs west landfill.

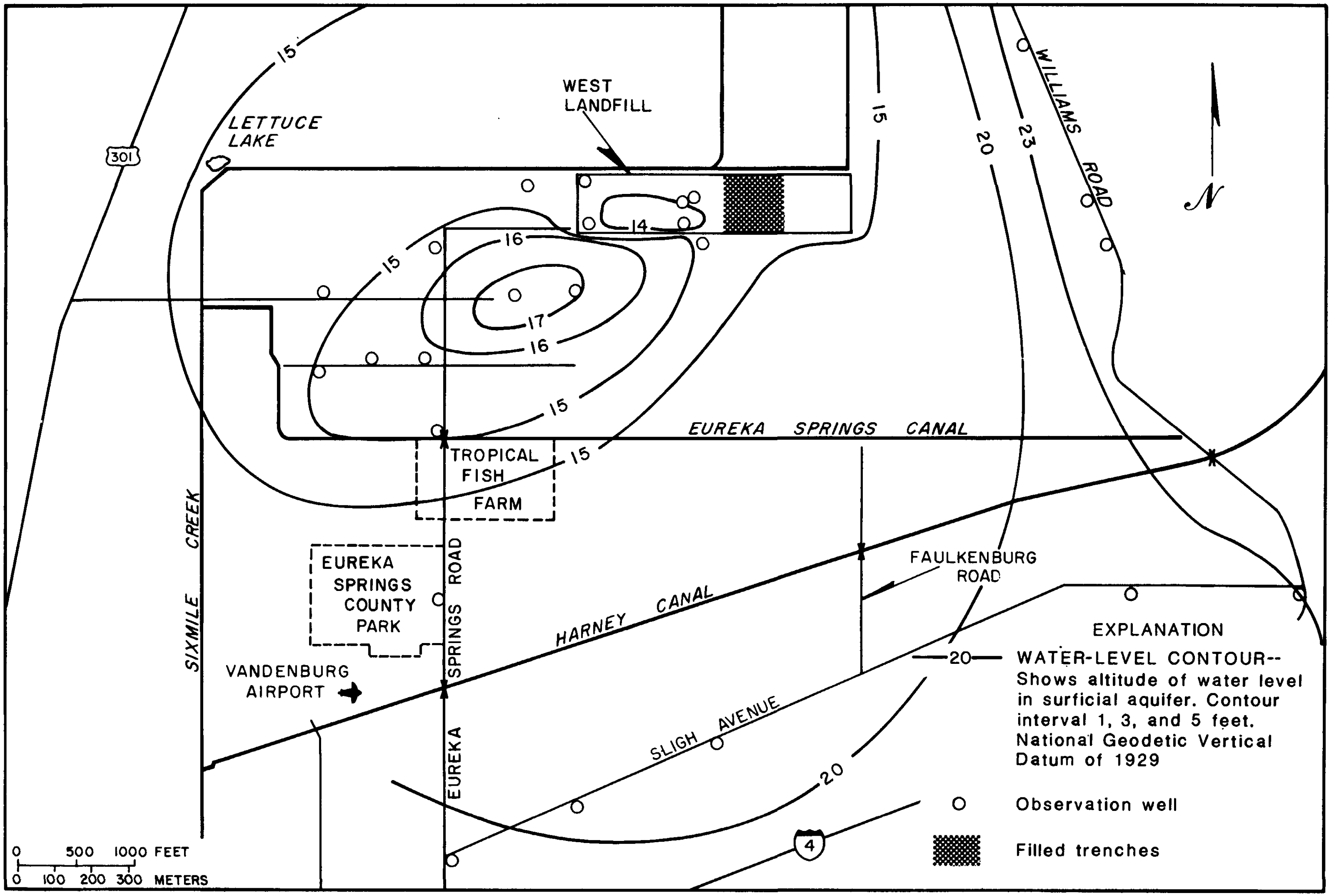



Figure 30.--Configuration of the water level in the surficial aquifer, November 11, 1970, Eureka Springs west landfill.

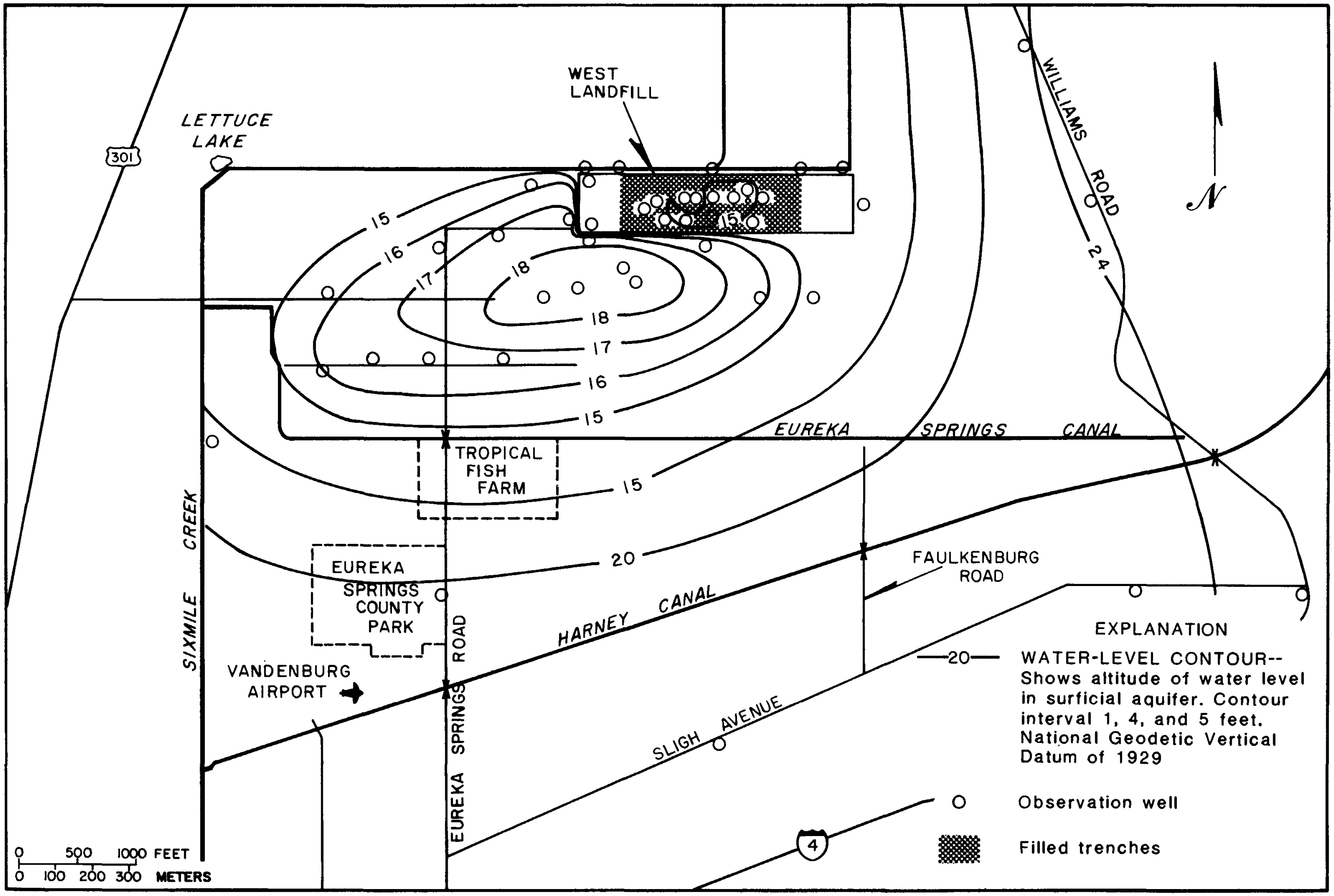



Figure 31.--Configuration of the water level in the surficial aquifer, October 26, 1971, Eureka Springs west landfill.

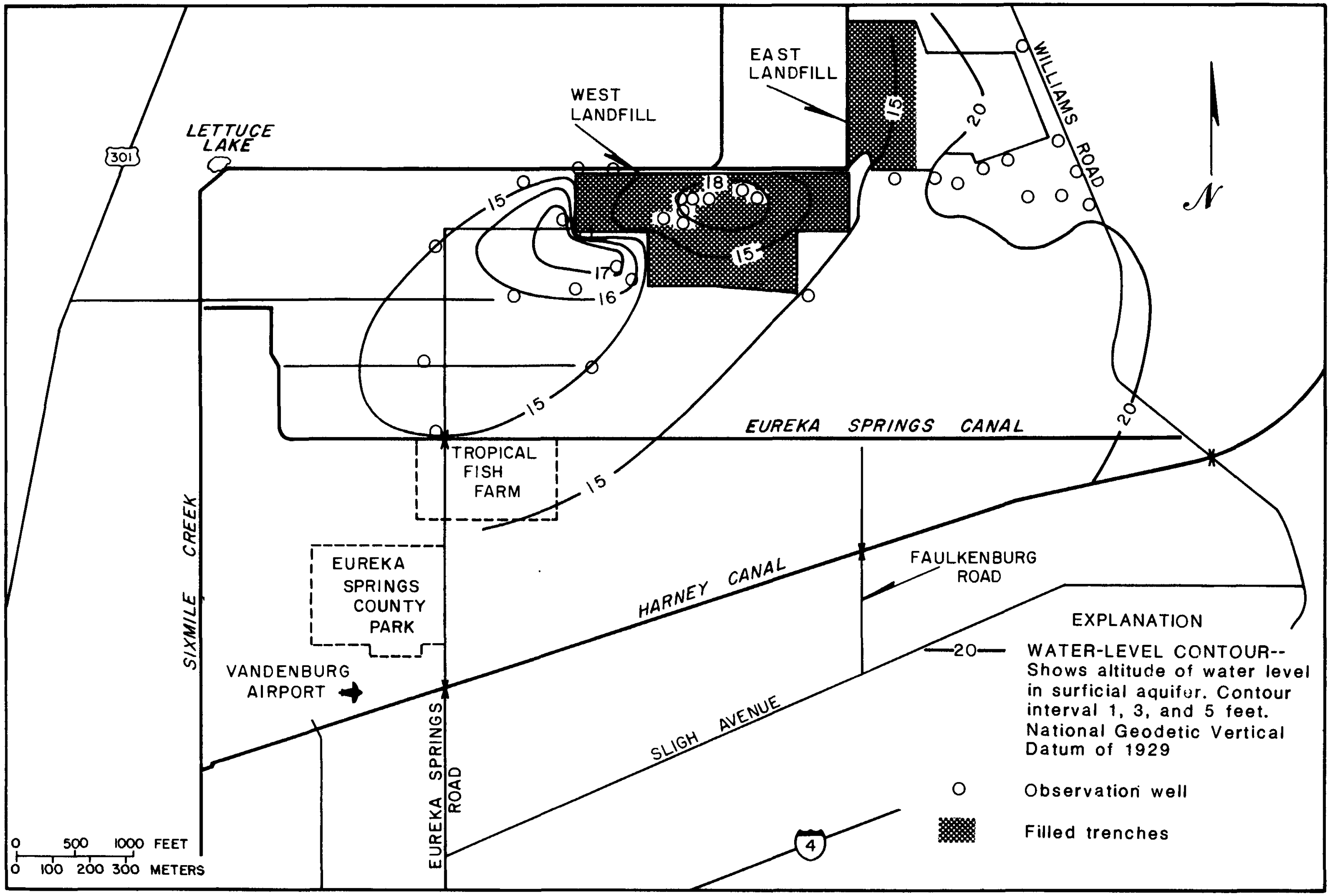



Figure 32.--Configuration of the water level in the surficial aquifer, May 14, 1975, Eureka Springs east and west landfills.

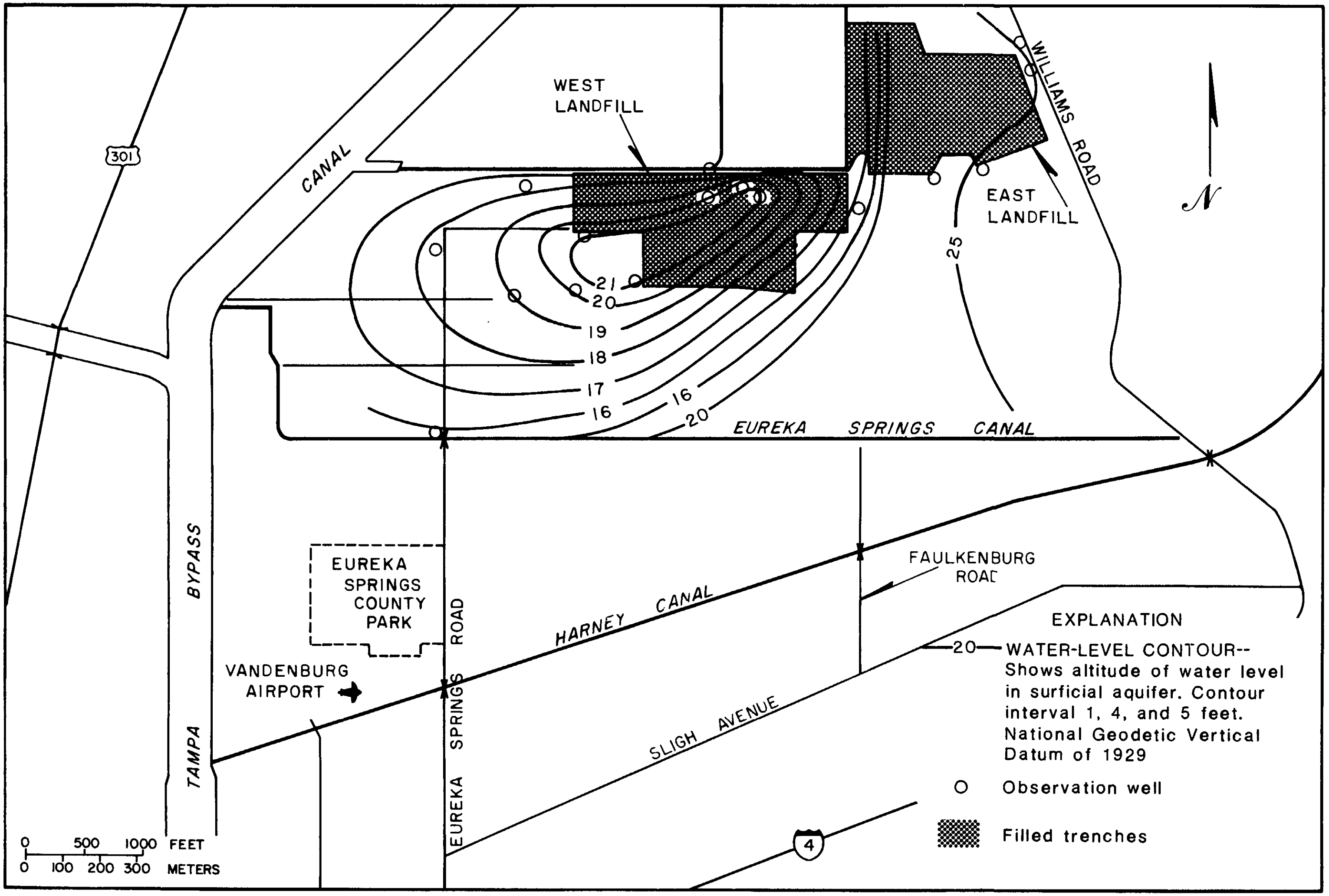



Figure 33.--Configuration of the water level in the surficial aquifer, May 23, 1980, Eureka Springs east and west landfills.

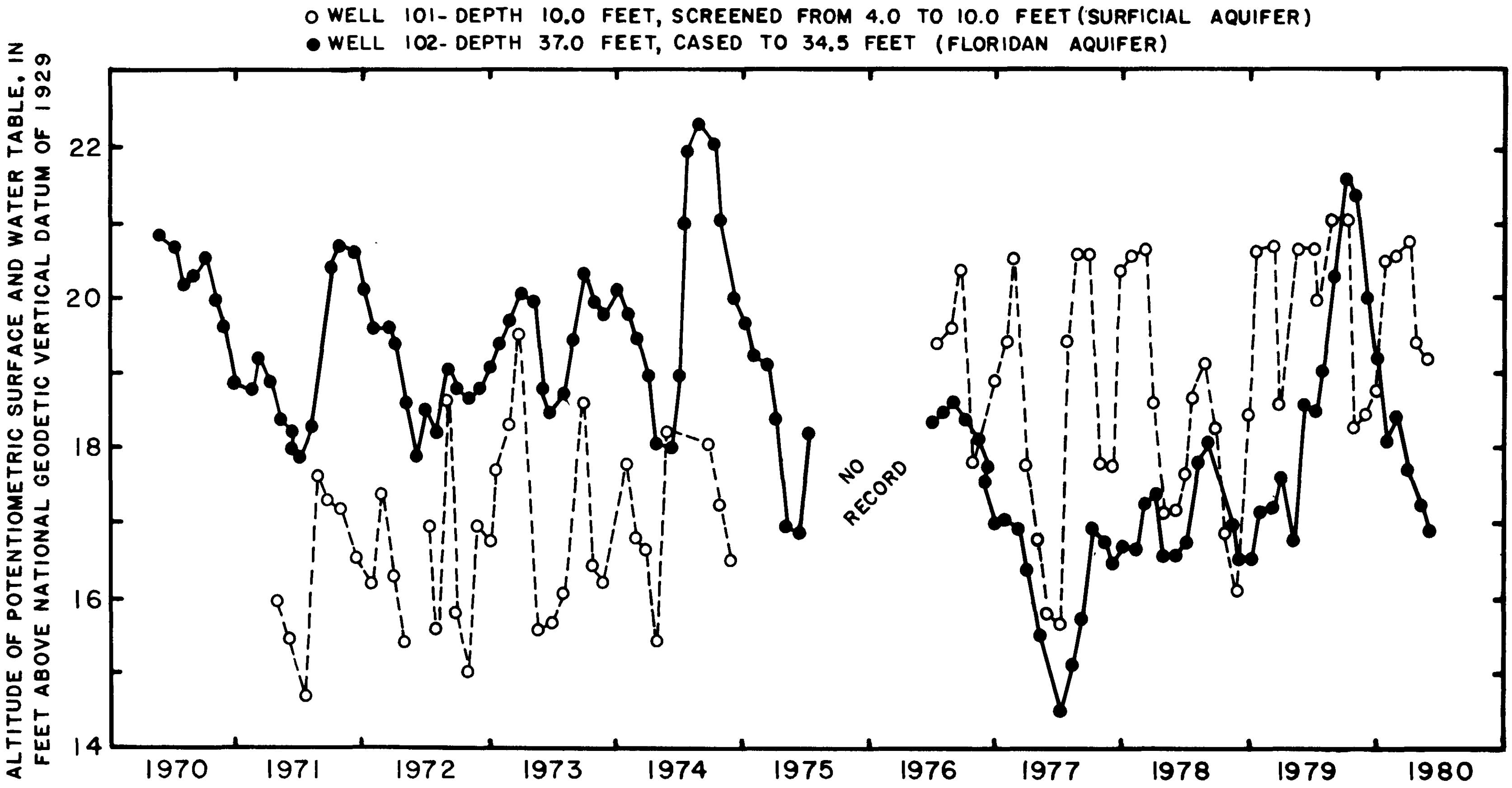



Figure 34.--Water levels in the surficial and Floridan aquifers, 1970-80, Eureka Springs west landfill.

The decline in the potentiometric surface was attributed largely to breaching of the confining layer of the limestone aquifer during construction of the Tampa Bypass Canal. Removal of the confining layer increased discharge from the Floridan aquifer, resulting in a decline in the potentiometric surface. Dewatering of the Floridan aquifer in 1980 during construction of the Tampa Bypass Canal about 1 mile north of the landfill also affected water levels in the Eureka Springs area.

On September 29, 1980, water levels in the surficial aquifer were about 2 feet lower than in May 1980. The potentiometric surface in September 1980 was essentially the same as in May 1980.

## Ground-Water Movement

The rate and direction of movement of water in the surficial aquifer was affected by canals in and near the landfill and by the ground-water mound southwest of the site. Normally, ground-water movement was toward the north landfill canal and the Eureka Springs Canal (fig. 29). Ground-water movement to the west and southwest was altered by the ground-water mound southwest of the oxidation pond. During periods of heavy rains, water levels in the landfill rose higher than water levels outside the landfill, and ground water moved temporarily to the west and southwest. The reversal in gradient occurred when water levels in filled trenches increased more rapidly than water levels in the surrounding area. During these periods, leachate moved west and southwest in the surficial aquifer.

Based on laboratory analyses of core samples from the sides of landfill trenches and the yield of wells constructed in the surficial aquifer, horizontal hydraulic conductivity was estimated to be about 10 ft/d. The effective porosity of the sand beds in the surficial deposits averaged 29 percent. During the study period, hydraulic gradients at the site ranged from 0.0002 to 0.01 ft/ft. Applying the same procedure used for the Rocky Creek landfill, the rate of ground-water movement on May 23, 1980 (fig. 33), was about 0.34 ft/d north of the landfill; 0.08 and 0.14 ft/d south and southwest, respectively; and 0.2 ft/d southeast of the landfill. Based on the rate of ground-water movement to the north, the estimated time of arrival of leachate at the north landfill canal is less than a year.

During the period 1970-75, water levels in the surficial aquifer were about 1 to 3 feet lower than the potentiometric surface, and water flowed from the Floridan aquifer to the surficial aquifer. From 1976 to 1980, the potentiometric surface was 1 to 4 feet lower than the water table, and vertical movement of water was from the surficial aquifer to the Floridan aquifer. The interchange of water during this period could affect the quality of water in the Floridan aquifer.

A confining clay layer, 8 to 28 feet thick, underlies the west landfill (fig. 25). The vertical hydraulic conductivity of the clay ranged from $7.8 \times 10^{-6}$ to $1.3 \times 10^{-3}$ ft/d. The saturated thickness of the surficial aquifer averaged 15 feet; the effective porosity of the clay averaged 11 percent; and a maximum head difference of 4 feet occurred between the water level in the surficial aquifer and the potentiometric surface of the Floridan aquifer. Vertical movement of water, computed for the minimum and maximum ranges in vertical hydraulic conductivity, ranged from $2 \times 10^{-5}$ to $3 \times 10^{-3}$ ft/d.

## Springs

Periodic sampling and discharge measurements were made for five springs in the area (fig. 21 and table 7). Discharge for the largest spring, Lettuce Lake, ranged from 6.86 to 12.5 $ft^3/s$ for the period 1969-73. The spring discharges into the north landfill canal that flows into the Tampa Bypass Canal. Discharge for tributary spring 5, the second largest spring, ranged from 0.95 to 1.89 $ft^3/s$. The spring flows into the north landfill canal. The combined discharge of tributary springs 2, 3, and 4 ranged from zero to 3.72 $ft^3/s$.

Table 7.--Discharge of selected springs, Eureka Springs landfill

[All units in cubic feet per second]

| Spring | Date of measurement | | | | |
|---|---|---|---|---|---|
| | 4-28-69 | 9-17-69 | 3-25-70 | 11-12-70 | 5-21-71 |
| Lettuce Lake | 12.5[a] | 23.5[b] | 21.6[b] | 12.1[a] | 6.86[a] |
| Tributary Spring 2 | .81 | .22 | .49 | 0 | 0 |
| Tributary Spring 3 | .46 | .14 | .55 | .12 | 0 |
| Tributary Spring 4 | 2.11 | 2.60 | 2.68 | 1.86 | 0 |
| Tributary Spring 5 | 1.70 | 1.72 | 1.80 | 1.43 | .95 |

| Spring | Date of measurement | | | | |
|---|---|---|---|---|---|
| | 10-13-71 | 6-1-72 | 10-20-72 | 5-18-73 | 5-6-76 |
| Lettuce Lake | 10.2[a] | 7.6[a] | 9.4[a] | 9.58[a] | Flowing |
| Tributary Spring 2 | .62 | 0 | 0 | .02 | 0 |
| Tributary Spring 3 | .30 | 0 | .006 | .12 | 0 |
| Tributary Spring 4 | 1.51 | 0 | .63 | 1.25 | 0 |
| Tributary Spring 5 | 1.89 | .98 | 1.11 | 1.48 | Flowing |

[a]Discharge measured at spring.

[b]Includes flow of Sixmile Creek. Discharge measured at culvert, 1,200 feet south of spring.

## Water Quality

Several surficial aquifer and Floridan aquifer wells were monitored to observe changes in water quality from October 1969 to September 1980. Water samples from selected surficial aquifer wells in and adjacent to the landfill prior to its operation had specific conductances that ranged from 465 to 1,300 umho and chloride concentrations of about 50 mg/L, well above background levels. High values of specific conductance and chloride concentrations are probably related to the use of the land for pasturing.

Surficial aquifer well 98 and Floridan aquifer well 96 (fig. 22) were selected to establish background water-quality conditions at the landfill. Well 98 was about 1,000 feet west of the landfill, and well 96 was about 100 feet southwest of well 98. Specific conductance and chloride concentrations in wells 96 and 98 and annual rainfall in the area for 1969-80 are shown on figure 35. Water from well 98 showed a slight increasing trend in specific conductance, from 400 to 500 umho from 1969 to mid-1976. Chloride concentrations ranged from about 15 mg/L in 1971 to 45 mg/L in early 1973. During 1973-76, chloride concentrations decreased to 20 mg/L. Water from well 96 had an average specific conductance of about 400 umho; chloride concentrations averaged about 10 mg/L.

A statistical summary for specific conductance and chloride concentrations of water from surficial aquifer well 98 and Floridan aquifer well 96 is as follows:

| Well number | Parameter | Mean | Standard deviation | Range | Standard error of the mean | Number of samples |
|---|---|---|---|---|---|---|
| 98 | Specific conductance (umho) | 450 | ±89 | 270-580 | ±20 | 20 |
| | Chloride (mg/L) | 25 | ±8.4 | 15-36 | ±1.9 | 20 |
| 96 | Specific conductance (umho) | 382 | ±34 | 356-500 | ±9 | 15 |
| | Chloride (mg/L) | 10 | ±4.8 | 7-25 | ±1.3 | 15 |

West landfill

Water samples collected from surficial aquifer well 137, north of the landfill (fig. 22), indicated a declining trend in specific conductance and chloride concentrations from 1969 to 1974 (fig. 36). Specific conductance decreased from 1,400 umho in 1969 to about 400 to 700 umho in 1974. Chloride concentrations decreased from about 90 mg/L in 1969 to about 20 mg/L in 1974. Samples from Floridan aquifer well 136 did not show any appreciable changes in specific conductance or chloride concentrations during the same period. Data indicate that the quality of water in the surficial aquifer may be influenced by the north landfill canal and the north perimeter ditch.

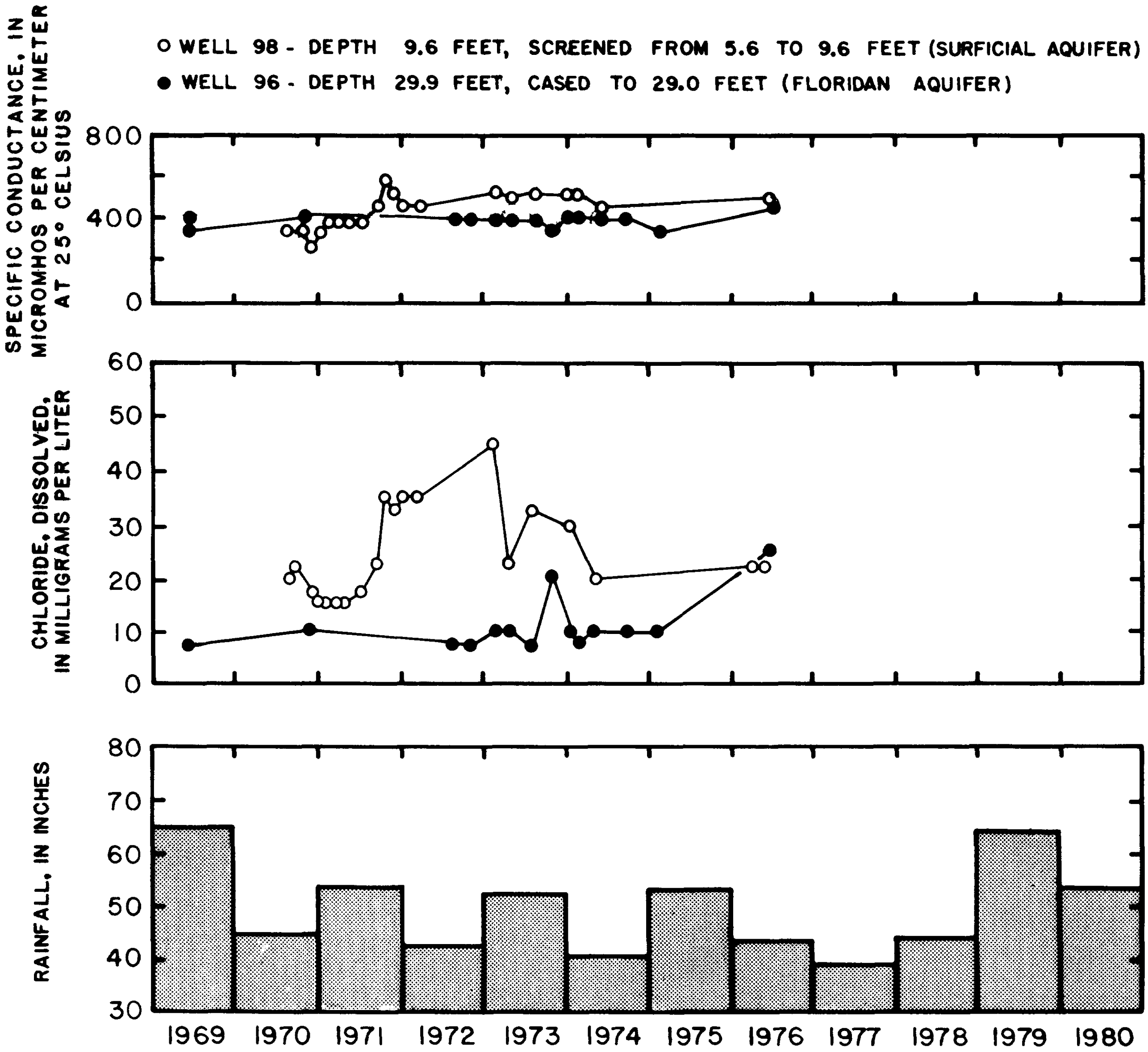



Figure 35.--Specific conductance and chloride concentration of water from wells 96 and 98, Eureka Springs west landfill, and rainfall at Plant City.

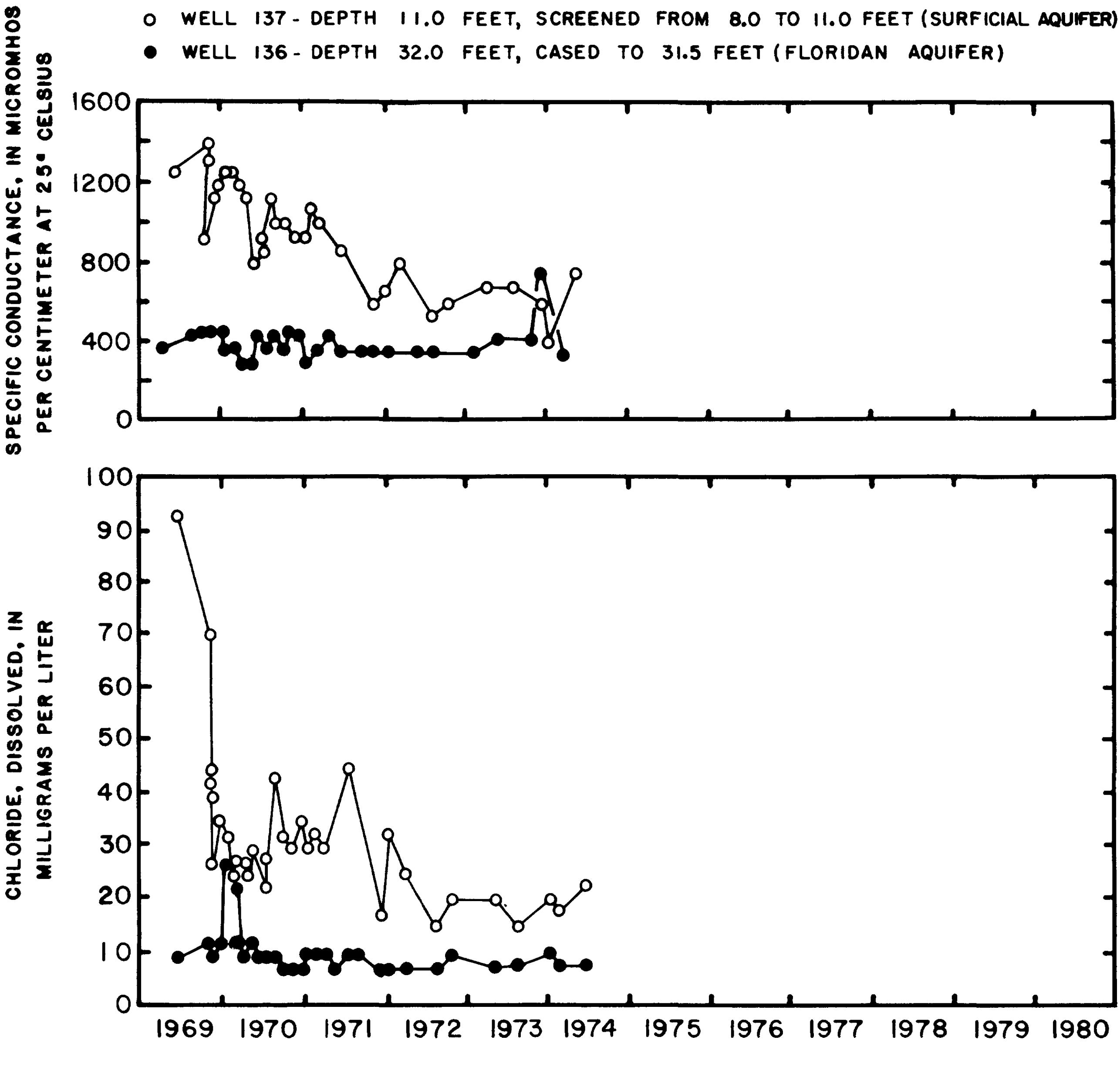



Figure 36.--Specific conductance and chloride concentration of water from wells 136 and 137, Eureka Springs west landfill.

Surficial aquifer well 131 is on the west side of the landfill between the oxidation pond and the west perimeter ditch (fig. 22). Specific conductance increased from about 400 to 1,200 umho from late 1969 to early 1970. During the same period, chloride concentrations increased from 25 to about 45 mg/L. During 1970-74, specific conductance and chloride concentrations declined. Floridan aquifer well 132 did not show any appreciable changes in specific conductance and chloride concentrations during the same period. Wells 131 and 132 were destroyed in 1974 during construction of trench 44. Data indicate that leachate may have moved west through the surficial aquifer during the early stages of landfill operation.

Paired wells 99 and 100 were about 200 feet south of the access road (fig. 22). The wells were destroyed in late 1972 during construction of trench 37. Water samples from surficial aquifer well 100 indicated an increase in specific conductance from 800 to 1,600 umho from mid-1969 to early 1970, after which conductance decreased to about 800 umho. Chloride concentrations decreased from about 70 to 55 mg/L in 1969 and early 1970, followed by a sharp decline to about 10 mg/L by mid-1970. By mid-1971, chloride concentrations had increased to 90 mg/L, but then declined to 30 mg/L. Chloride concentrations appeared to level off at about 50 mg/L in 1972. Floridan aquifer well 99 did not show appreciable changes in specific conductance and chloride concentrations during the period of record.

Paired wells 89 and 90 were about 700 feet southwest of the oxidation pond (fig. 22). Water from shallow well 90 had a specific conductance of 350 to 1,100 umho during the period of record 1969-74 (fig. 37). Chloride concentrations declined from 65 mg/L in 1969 to 15 mg/L in 1974. The decline in chloride concentrations was probably due to reduced use of the land for pasture and dilution by natural recharge. Water from Floridan aquifer well 89 had slight changes in specific conductance and chloride concentrations in 1971, but showed very little change before and after 1971.

Well 81 was located about 1,000 feet southwest of the west landfill (fig. 22). Specific conductance of water from the well averaged about 500 umho during the period 1969-76. In July 1976, specific conductance increased to 800 umho. Chloride concentrations of water from the well declined from 80 mg/L in 1969 to 40 mg/L in 1974-75. In 1976, chloride concentrations increased from 45 to 60 mg/L. The specific conductance of water from Floridan aquifer well 80 did not show any appreciable changes during the same period, and chloride concentrations averaged about 10 mg/L.

Well 55, a Floridan aquifer well at a fish hatchery, was 1,000 feet southwest of well 62 (fig. 21). Water samples from well 55 had a specific conductance of 400 umho. Chloride concentrations were about 10 mg/L during 1969-80. Specific conductance and chloride concentrations were within background levels.

Well 71 was a surficial aquifer well at the southeast corner of the west landfill (fig. 22). Data are available for the well from 1971 to mid-1974. Specific conductance increased from 300 to 600 umho during 1971, then decreased to about 200 umho by 1974. Chloride concentrations above background levels at the end of 1971 indicated movement of leachate to the well site.

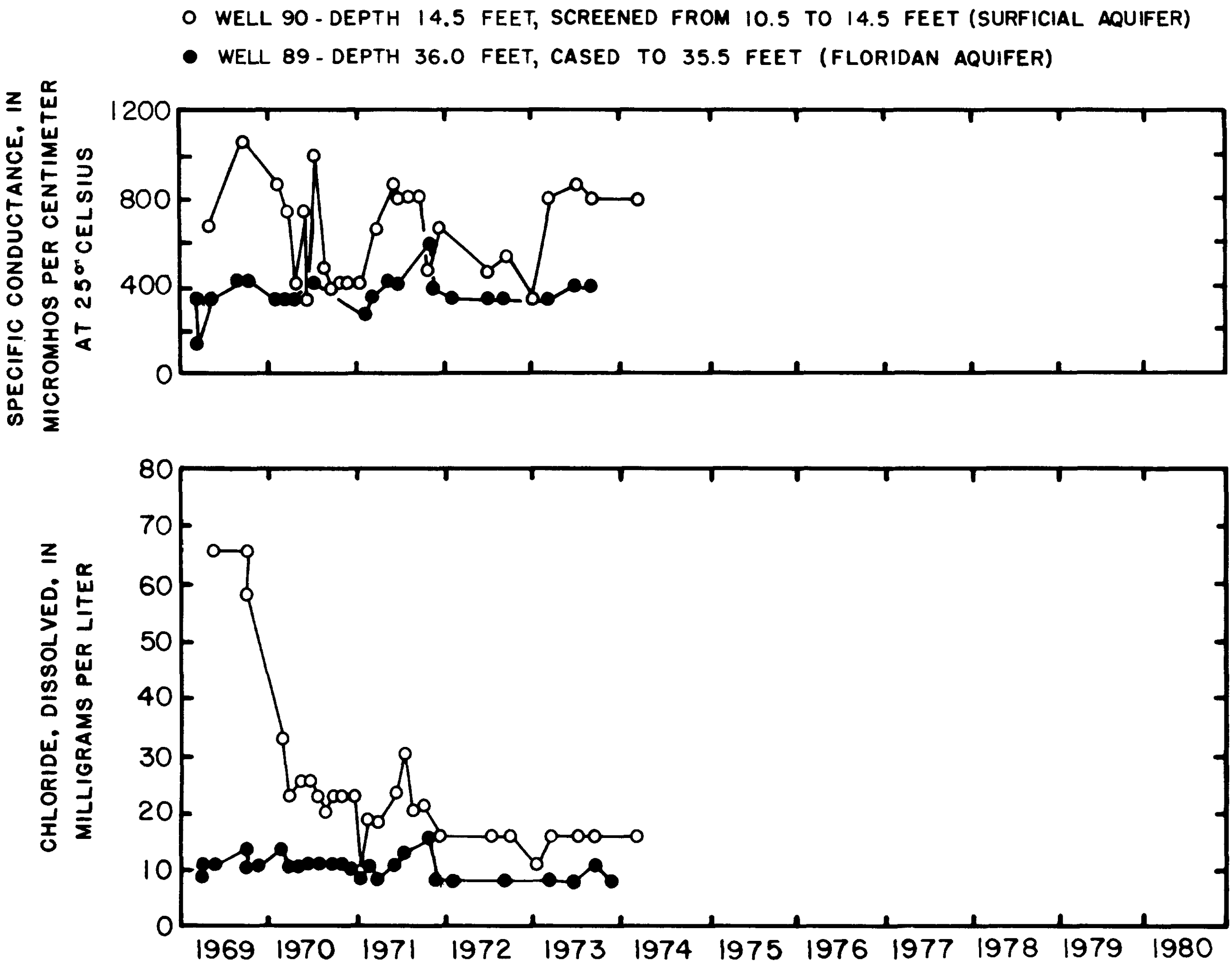



Figure 37.--Specific conductance and chloride concentration of water from wells 89 and 90, Eureka Springs west landfill.

Wells 126 and 127 were drilled in trench 16 to depths of 20 and 23 feet, respectively (fig. 22). The wells were drilled to determine the effectiveness of the confining bed in preventing or retarding leachate movement into the underlying limestone. The material penetrated in the wells consisted of a 2-foot cover of fine sand and clay, 10 feet of refuse, 3 feet of sand and refuse, and 5 to 8 feet of green, bluish-green clay. The yield of the wells was very minimal.

The top of the screen in well 126 was 3 feet below a sand and refuse mixture, and in well 127, the top of the screen was 6 feet below the sand and refuse. Both wells had changes in specific conductance and chloride concentrations at about the same time and magnitude, which indicate the well casings were not effectively sealed off from the sand and refuse section.

Specific conductance of samples from wells 126 and 127 increased from about 200 to 800 umho shortly after sampling began in early 1970 (fig. 38). Specific conductance of water from both wells followed the same general pattern. In 1974, the specific conductance of water from well 126 was 1,000 umho; in well 127, it was 800 umho. Changes in chloride concentrations coincided with changes in specific conductance and ranged from about 10 to 75 mg/L. Specific conductance and chloride concentrations for wells 126 and 127 indicated vertical downward movement of leachate in the surficial aquifer beneath the trench.

### East landfill

Surficial aquifer well 149 and Floridan aquifer well 150 were about 200 feet northeast of the east landfill (fig. 21). Sampling of water from the wells began in 1974, just prior to the start of operations at the landfill. Specific conductance and chloride concentrations of water from well 149 showed a wide range of fluctuations (fig. 39). Specific conductance ranged from about 400 to 2,400 umho and chloride concentrations ranged from 40 to 110 mg/L. Water from well 150 did not show any appreciable change in specific conductance and chloride concentrations during the period. The large changes in specific conductance and chloride concentrations of water from well 149 indicated leachate movement at a depth of 5 to 9 feet. Former use of the land as pasture contributed to degradation of water quality in the surficial aquifer, but the effects were less than that caused by leachate from the landfill.

Floridan aquifer well 22 was about 400 feet southeast of well 149 and 100 feet east of Williams Road (fig. 21). The well was reported to be 90 feet deep and cased to about 55 feet. Specific conductance and chloride concentrations of water from the well did not show any appreciable changes during the period 1974-80.

Water-quality data for selected ground-water and surface-water sites are shown in tables 8 and 9. These data are for the surficial and Floridan aquifer wells and sampling sites at the oxidation pond, perimeter ditches, and a spring.

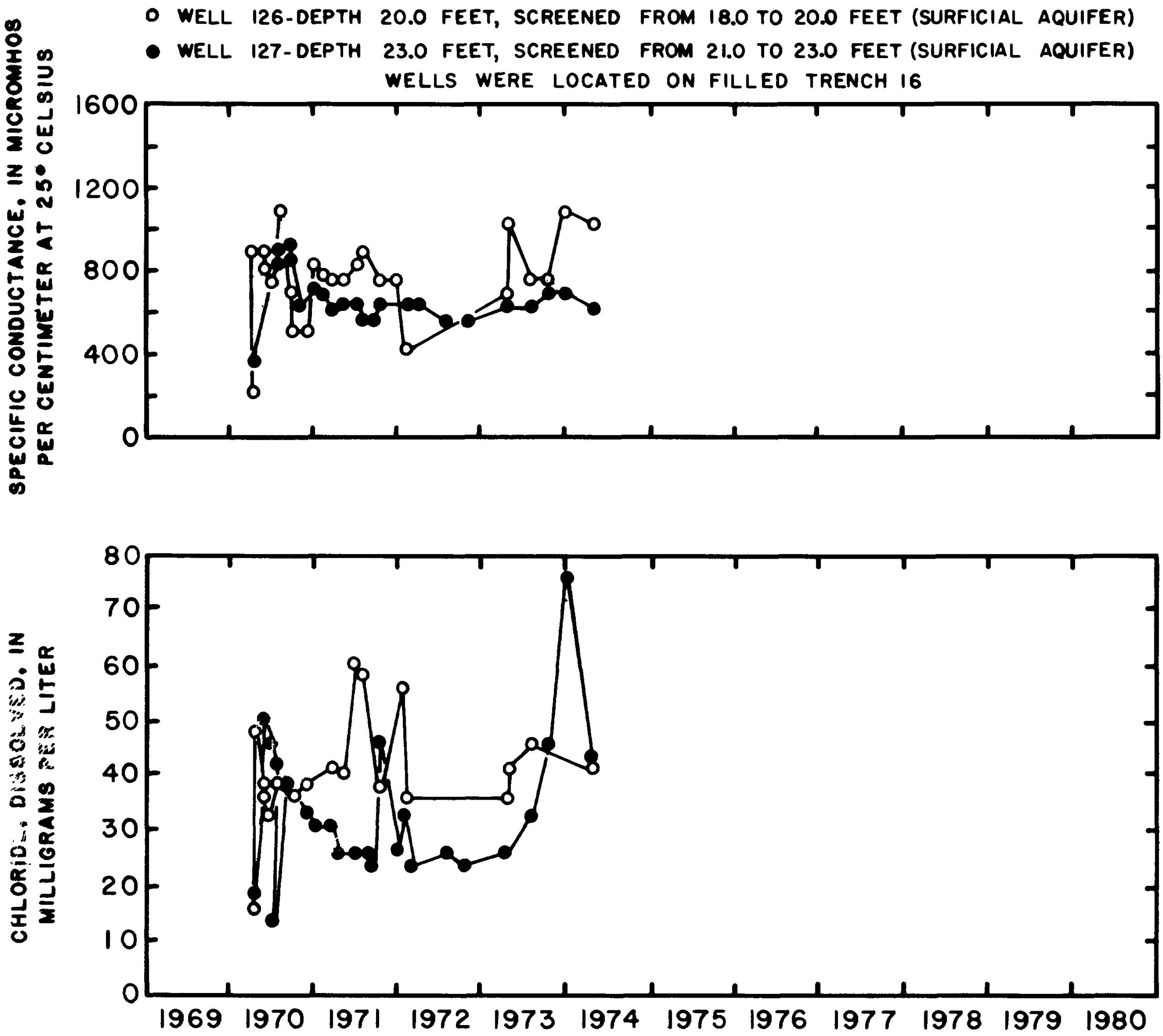



Figure 38.--Specific conductance and chloride concentration of water from wells 126 and 127, Eureka Springs west landfill.

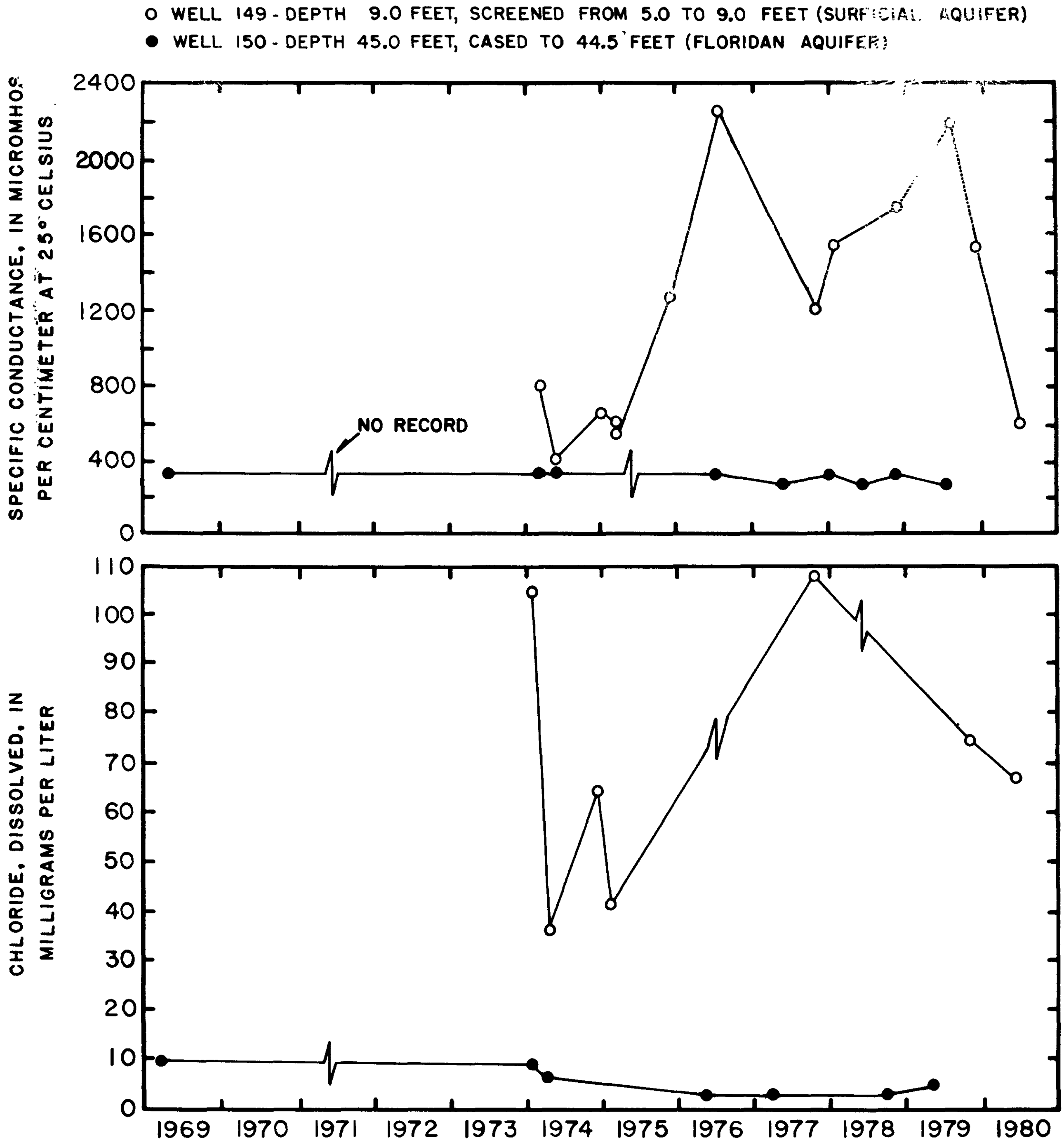



Figure 39.--Specific conductance and chloride concentration of water from wells 149 and 150, Eureka Springs east landfill.

Table 8.--Water-quality data for selected ground-water sites, Eureka Springs landfill

[Concentrations are in milligrams per liter except as noted. Chloride, calcium, magnesium, sodium, potassium, hardness, sulfate, fluoride, and silica concentrations are dissolved]

| Well number | Depth (feet) | Aquifer | Date of sample | Temperature (°C) | Specific conductance (umho/cm) | Chloride (Cl) | pH | Alkalinity (as $CaCO_3$) | Calcium (Ca) |
|---|---|---|---|---|---|---|---|---|---|
| 80 | 37.0 | Floridan | 1-29-73 | -- | 360 | 13 | 7.7 | --- | 61 |
| | | | 5-31-77 | -- | 420 | 58 | 6.3 | --- | 95 |
| 81 | 13.9 | Surficial | 1-29-73 | -- | 550 | 55 | 7.4 | --- | 92 |
| | | | 12-03-75 | -- | 460 | 40 | 7.7 | --- | 60 |
| 96 | 29.2 | Floridan | 10-15-70 | 21.7 | 371 | 10 | 8.3 | 139 | 64 |
| | | | 4-18-73 | -- | 370 | 9 | 7.7 | 134 | 69 |
| | | | 1-23-75 | -- | 356 | 9 | 7.7 | --- | 63 |
| 98 | 9.6 | Surficial | 11-23-71 | -- | 530 | 32 | --- | --- | 88 |
| | | | 4-18-73 | -- | 530 | 23 | --- | --- | 81 |
| | | | 4-07-76 | -- | --- | 23 | --- | --- | 80 |

| Well number | Date of sample | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Dissolved solids | Hardness (as $CaCO_3$) | Sulfate ($SO_4$) | Fluoride (F) | Silica ($SiO_2$) |
|---|---|---|---|---|---|---|---|---|---|
| 80 | 1-29-73 | 6.4 | 5.3 | 0.8 | --- | 180 | -- | --- | -- |
| | 5-31-77 | 20 | 13 | .3 | --- | 320 | -- | --- | -- |
| 81 | 1-29-73 | 15 | 9.2 | .4 | --- | 240 | -- | --- | -- |
| | 12-03-75 | 12 | 9.4 | 1.5 | --- | 200 | -- | --- | -- |
| 96 | 10-15-70 | 6.5 | 5.2 | .2 | 228 | 187 | 44 | 0.3 | 12 |
| | 4-18-73 | 3.9 | 5.4 | .5 | 243 | 190 | 46 | .4 | 12 |
| | 1-23-75 | 6.4 | 5.6 | .4 | --- | 180 | -- | --- | -- |
| 98 | 11-23-71 | 9.7 | 6.0 | .4 | --- | 260 | -- | --- | -- |
| | 4-18-73 | 12 | 5.2 | .5 | --- | 250 | -- | --- | -- |
| | 4-07-76 | 12 | 10 | .5 | --- | 250 | -- | --- | -- |

Table 9.--Water-quality data for selected surface-water sites, Eureka Springs landfill

[Concentrations are in milligrams per liter except as noted. Chloride, calcium, magnesium, sodium, potassium, hardness, and oxygen concentrations are dissolved]

| Site number | Site description | Date of sample | Temperature (°C) | Specific conductance (umho/cm) | Chloride (Cl) | pH |
|---|---|---|---|---|---|---|
| SW-1 | North perimeter ditch | 5-27-70 | 37.5 | 1,310 | 112 | 8.3 |
| | | 4-27-71 | 28.5 | 690 | 40 | --- |
| | | 3-14-72 | -- | 950 | 39 | --- |
| | | 7-20-72 | -- | 560 | 15 | --- |
| SW-3 | Oxidation pond | 8-06-70 | 31.0 | 501 | 29 | 8.4 |
| | | 11-23-71 | 20.0 | 530 | 32 | --- |
| | | 7-20-72 | -- | 484 | 32 | --- |
| | | 12-18-73 | -- | 535 | 25 | --- |
| SW-5 | South perimeter ditch | 5-27-70 | 29.0 | 1,860 | 84 | 8.1 |
| | | 11-23-71 | -- | 1,520 | 47 | --- |
| | | 7-19-72 | -- | 1,010 | 39 | --- |
| | | 4-18-73 | -- | 970 | 44 | --- |
| SW-6 | Tributary Spring 5 | 6-25-70 | 23.5 | 300 | 7 | 8.1 |
| | | 11-23-71 | -- | 340 | 8 | --- |
| | | 7-20-72 | -- | 351 | 6 | --- |
| | | 12-18-73 | -- | 366 | 8 | --- |

| Site number | Date of sample | Alkalinity (as $CaCO_3$) | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Hardness (as $CaCO_3$) | Oxygen (O) |
|---|---|---|---|---|---|---|---|---|
| SW-1 | 5-27-70 | 169 | --- | -- | -- | --- | 800 | --- |
| | 4-27-71 | --- | --- | -- | -- | --- | 340 | 7.3 |
| | 3-14-72 | --- | 160 | 19 | 21 | 0.6 | 490 | --- |
| | 7-20-72 | --- | 110 | 10 | 11 | 1.3 | 320 | --- |
| SW-3 | 8-06-70 | 106 | --- | -- | -- | --- | 171 | 7.3 |
| | 11-23-71 | --- | 57 | 14 | 25 | 7.5 | 200 | --- |
| | 7-20-72 | --- | 48 | 13 | 24 | 5.2 | 170 | --- |
| | 12-18-73 | --- | 76 | 18 | 18 | 6.4 | 260 | --- |
| SW-5 | 5-27-70 | 188 | --- | -- | -- | --- | 332 | --- |
| | 11-23-71 | --- | 280 | 17 | 24 | 0 | 770 | --- |
| | 7-19-72 | --- | 190 | 17 | 21 | --- | 540 | --- |
| | 4-18-73 | --- | 150 | 21 | 31 | 1.0 | 460 | --- |
| SW-6 | 6-25-70 | 174 | --- | -- | -- | --- | 161 | --- |
| | 11-23-71 | --- | 57 | 4.4 | 4.5 | 0 | 160 | --- |
| | 7-20-72 | --- | 57 | 6.0 | 4.5 | .3 | 170 | --- |
| | 12-18-73 | --- | 70 | 7.0 | 5.5 | 1.0 | 200 | --- |

### Summary

The Eureka Springs landfill is in the northwest corner of a dairy pasture. Water samples collected from surficial and Floridan aquifer wells before the landfill became operational had specific conductances of 375 to 1,300 umho and chloride concentrations of 50 mg/L or more. These values generally are above background levels for wells outside the area and appear to be related to the use of the land as a pasture.

Because of high water levels in the surficial aquifer in the Eureka Springs landfill, trenches were dewatered in order to compact the refuse and to provide a daily cover of sand and clay. Water pumped from trenches was discharged into an oxidation pond constructed in the surficial aquifer. A perimeter ditch at the landfill also intersected the water table in the surficial aquifer. The movement of leachate from the oxidation pond and perimeter ditch probably hastened changes in water quality in surficial aquifer wells north and west of the landfill.

Samples collected from surficial aquifer wells 1,200 to 2,000 feet west and southwest of the west landfill showed changes in specific conductance and chloride concentrations. Most surficial aquifer wells that had changes in water quality were located southwest of the landfill, the general direction of ground-water movement from the landfill. The greatest changes in water quality occurred in wells near perimeter ditches or canals downgradient from filled trenches. Surficial aquifer wells located at these sites had high values of specific conductance and chloride concentrations; however, Floridan aquifer wells at the sites did not show any appreciable change in water quality.

Infiltration rates for the Eureka Springs site were 7 to 15 times smaller than those for the Rocky Creek site due to differences in the types and composition of materials. The materials at the Eureka Springs site contained more silt and clay and less fine to medium sand than the material at the Rocky Creek site. The vertical hydraulic conductivity of compacted cover material on a Eureka Springs trench was $4 \times 10^{-4}$ ft/d, and at a Rocky Creek trench, it was 10.8 ft/d.

## Gunn Highway Landfill

### Location and Operation

The Gunn Highway landfill is about 3 miles east of the Rocky Creek landfill and about 3 miles northwest of the northern limits of the city of Tampa (fig. 2). The landfill included 14 acres of pasture on the southwest side of Gunn Highway and is about 400 feet north of Sweetwater Creek (fig. 40). The landfill was operated by Hillsborough County from about 1960 to 1962 (Gorman, Dan, Director, Hillsborough County Mosquito Control, oral commun., 1970). The site was completed and closed to landfilling about mid-1962, or about 8 years before this study began. This landfill was included in the study to obtain information on changes in water quality over a period of years at a "closed" landfill. Factors that favored selection of the landfill for observation were (1) the trench method of landfilling was used and (2) the undisturbed condition of the site following its closing in 1962.

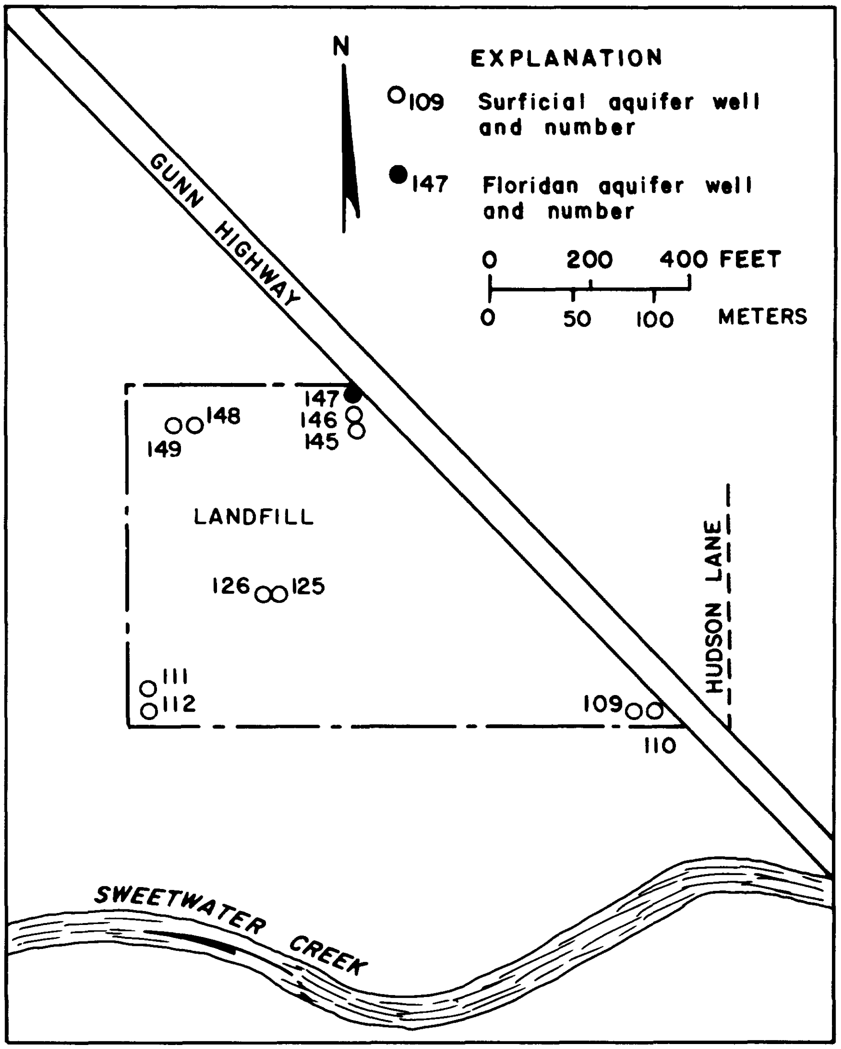



Figure 40.--Locations of wells, Gunn Highway landfill.

## Physical Setting

The landfill is on a flat, slightly sloping area that averages about 35 feet above sea level. The soil is classified predominantly as Leon fine sand that is somewhat poorly drained (U.S. Department of Agriculture, 1958). The area is drained by Sweetwater Creek, which has a drainage area of 14.3 $mi^2$ and originates in a lake area several miles northeast of the landfill. The creek discharges into Old Tampa Bay.

The area is overlain by surficial deposits that consist of sand, shell fragments, sandy clay, and clay. The deposits are generally about 35 to 40 feet thick, but are as much as 50 feet thick in the northeastern part of the landfill site. A lithologic log of materials penetrated in a well in the northwestern part of the landfill is shown in table 10. The top of the Floridan aquifer at the landfill is about 10 feet below sea level.

Table 10.--Lithologic log of well 149, Gunn Highway landfill

| Lithologic description | Thickness (feet) | Depth (feet) |
|---|---|---|
| Sand, gray, fine | 5.0 | 5.0 |
| Clay, dark yellowish-brown, plastic, with some fine sand | 5.5 | 10.5 |
| Sand, white, very fine, with limonite streaks | 15.0 | 25.5 |
| Sand, light-gray, fine, sugary | 5.0 | 30.5 |
| Sand, gray, fine, clayey, with limestone | 4.5 | 35.0 |
| Clay and limestone, light-gray, with some sand | 5.5 | 40.5 |

Eleven 2-inch diameter PVC test wells (fig. 40) that range in depth from 11 to 46 feet were constructed at the landfill site. The wells were completed with 4-foot sections of plastic screen in the lower part of the hole.

Split-spoon samples of surficial materials were collected from well 125 near the west-central part of the landfill at depths ranging from 5 to 30 feet below land surface. Laboratory analyses of the samples included: particle-size distribution, vertical hydraulic conductivity, specific yield, specific retention, and porosity. The results of the tests are shown in table 11.

The vertical hydraulic conductivity of material was 6.7 and 8.0 ft/d for two samples in sand and ranged from $4.0\times10^{-4}$ to $5.4\times10^{-4}$ ft/d for three samples collected in clay. The most permeable zones were at depths of 5 and 20 feet below land surface; the least permeable zones were at depths of 10, 15, and 30 feet.

Table 11.--Laboratory analyses of surficial sediments, well 125, Gunn Highway landfill

| Depth (feet) | Type of material | Specific retention (percent) | Specific yield (percent) | Total porosity (percent) | Vertical hydraulic conductivity (ft/d) |
|---|---|---|---|---|---|
| 5.0-5.5 | Fine sand | 4.0 | 39.8 | 43.8 | 80 |
| 10.0-10.5 | Clay | 30.9 | 8.3 | 39.2 | $5.4\times10^{-4}$ |
| 15.0-15.5 | Clay | 22.3 | 10.5 | 32.8 | $5.4\times10^{-4}$ |
| 20.0-20.5 | Fine sand | 8.2 | 32.9 | 41.1 | 6.7 |
| 30.0-30.5 | Clay; limestone at bottom | 27.5 | 26.5 | 54.0 | $4.0\times10^{-4}$ |

## Water Levels

The potentiometric surface of the Floridan aquifer at the landfill was about 28 feet above sea level in May 1969 when the wells were drilled and 20 feet above sea level in May 1980 (fig. 14). Water levels in the surficial aquifer were about 25 feet above sea level in February 1969 when the wells were drilled and about 30 feet above sea level in May 1980.

The general direction of movement of water in the surficial aquifer is south-southwest toward Sweetwater Creek; ground-water movement in the Floridan aquifer is generally to the southwest. Horizontal movement of ground water was determined for the surficial aquifer following the same procedure used for Rocky Creek. Based on an average effective porosity of 33 percent, an estimated vertical hydraulic conductivity of 7 ft/d, and a hydraulic gradient of 0.001 ft/ft, the maximum rate of movement was computed to be about 0.02 ft/d. However, the highly transmissive sand beds are probably localized and are not necessarily representative of the regional flow system.

## Water Quality

Water samples were collected periodically from June 1970 through October 1973. Sampling was discontinued until June 1980, when five wells were resampled. Water-quality data for selected ground-water sites that were sampled between July 1970 and June 1972 are listed in table 12.

Specific conductance and chloride and potassium concentrations for water samples from wells at the landfill are shown on figures 41 and 42. Background water-quality data for the surficial aquifer were not established because of the long-term use (more than 30 years) of the land as a pasture.

A cluster of three wells, drilled in the northeast corner of the landfill (fig. 40), consisted of one Floridan aquifer well (147) and two surficial aquifer wells (145 and 146) drilled to different depths. The wells were drilled

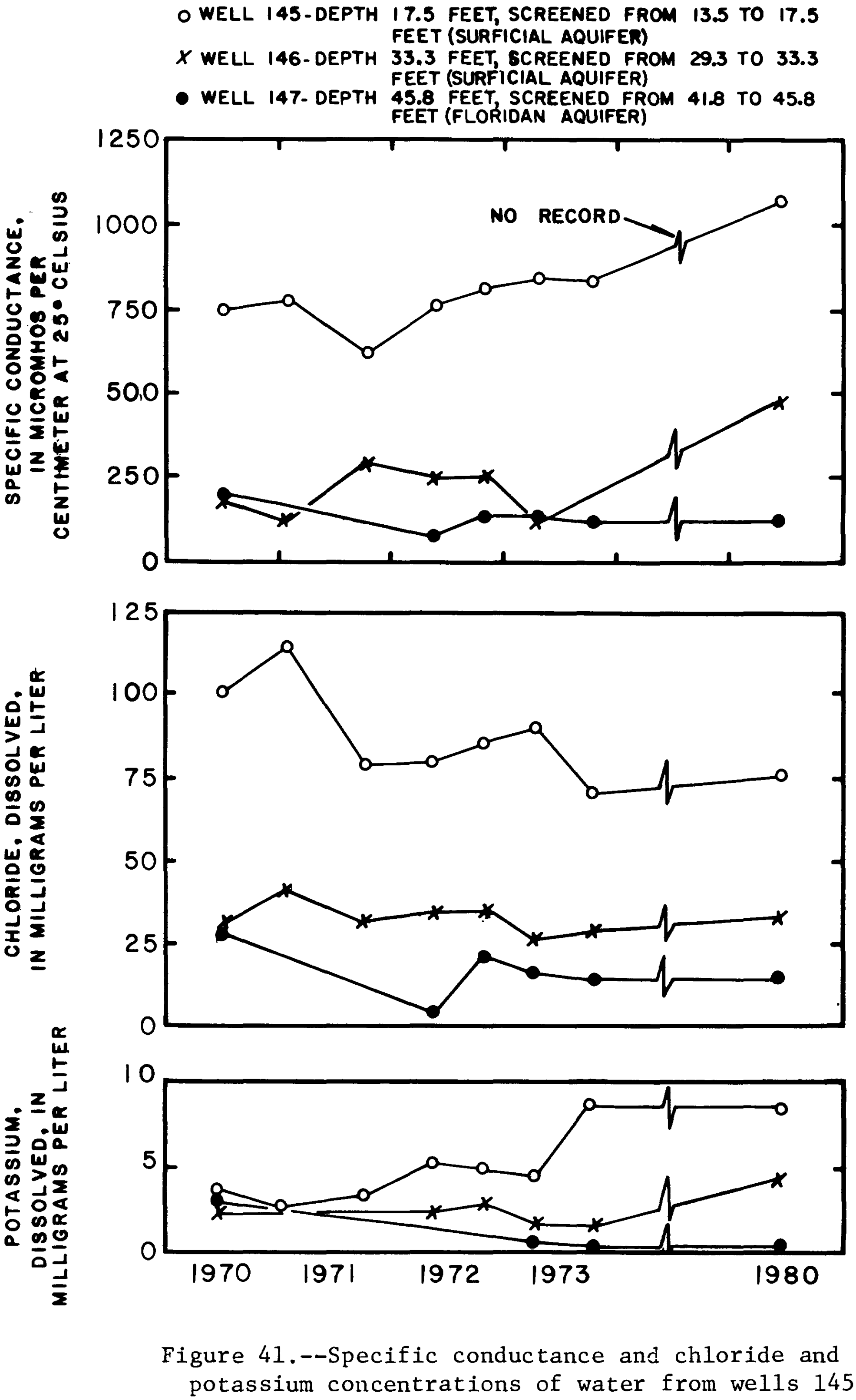



Figure 41.--Specific conductance and chloride and potassium concentrations of water from wells 145, 146, and 147, Gunn Highway landfill.

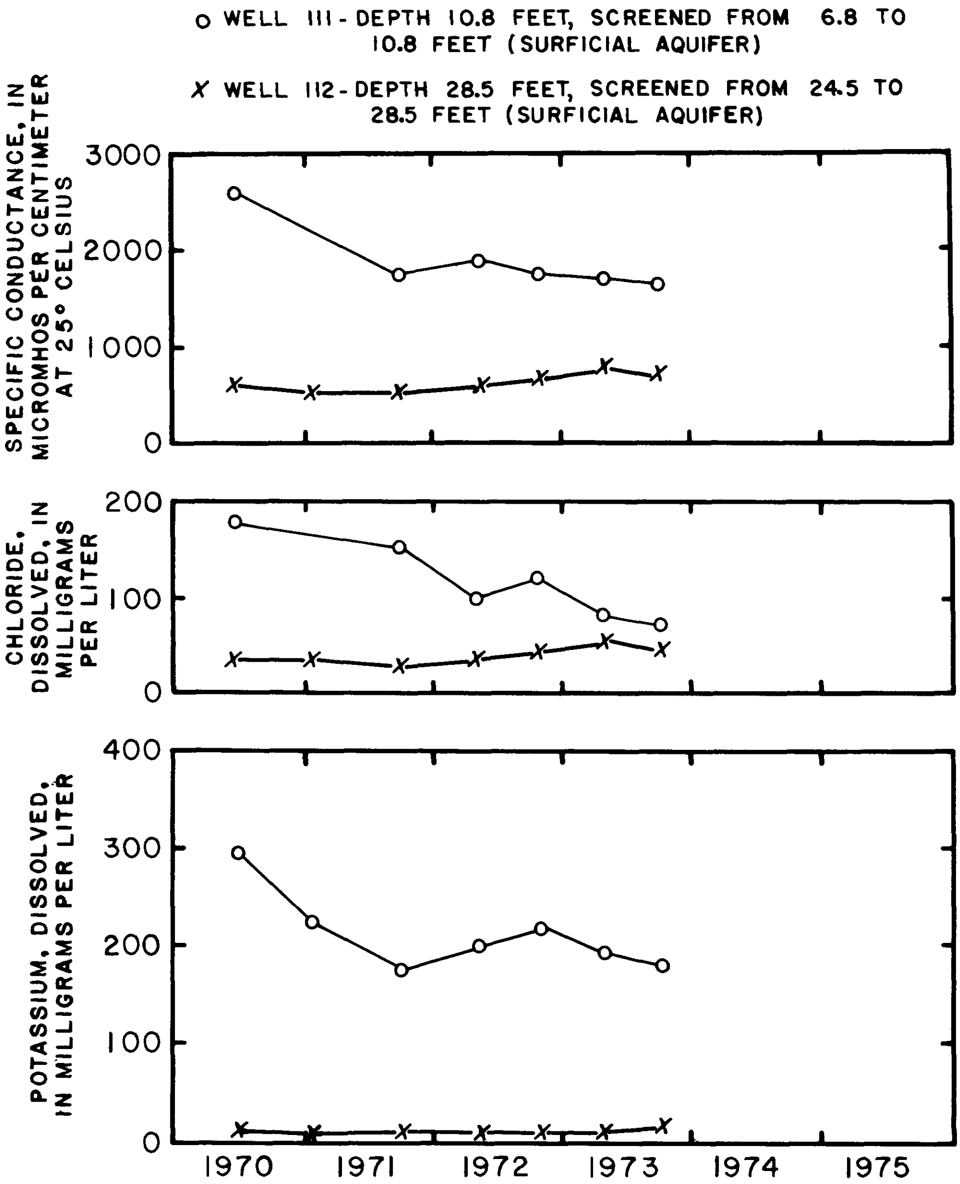



Figure 42.--Specific conductance and chloride and potassium concentrations of water from wells 111 and 112, Gunn Highway landfill.

Table 12.--Water-quality data for selected ground-water sites, Gunn Highway landfill

[Concentrations are in milligrams per liter except as noted. Chloride, calcium, magnesium, sodium, potassium, hardness, sulfate, fluoride, and silica concentrations are dissolved]

| Well number | Depth (feet) | Aquifer | Date of sample | Temperature (°C) | Specific conductance (umho/cm) | Chloride (Cl) | pH | Alkalinity (as $CaCO_3$) | Calcium (Ca) |
|---|---|---|---|---|---|---|---|---|---|
| 145 | 17.5 | Surficial | 7-02-70 | 24.5 | 765 | 100 | 7.0 | -- | 24 |
| | | | 1-29-71 | 19.0 | 800 | 114 | 7.5 | -- | 27 |
| | | | 5-18-72 | -- | 770 | 81 | --- | -- | 29 |
| 146 | 33.3 | Surficial | 7-01-70 | 24.0 | 198 | 32 | 6.5 | -- | 4.9 |
| | | | 1-29-71 | 22.0 | 230 | 40 | 6.4 | -- | 4.9 |
| | | | 5-18-72 | -- | 230 | 34 | --- | -- | 5.9 |
| 147 | 45.8 | Floridan | 7-01-70 | 24.0 | 210 | 27 | 6.9 | -- | 6.8 |
| | | | 6-21-72 | -- | 68 | 2 | --- | -- | 2.0 |

| Well number | Date of sample | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Dissolved solids | Hardness (as $CaCO_3$) | Sulfate ($SO_4$) | Fluoride (F) | Silica ($SiO_2$) |
|---|---|---|---|---|---|---|---|---|---|
| 145 | 7-02-70 | 12 | 70 | 3.6 | 560 | 169 | 0 | 0.1 | 15 |
| | 1-29-71 | 20 | 84 | 2.8 | 414 | 150 | 2.8 | .2 | 18 |
| | 5-18-72 | 10 | 50 | 5.0 | --- | 110 | 1.2 | --- | -- |
| 146 | 7-01-70 | 3.1 | 18 | 2.2 | 137 | 26 | -- | 0 | 7.2 |
| | 1-29-71 | 2.7 | 16 | 2.4 | 135 | 39 | -- | 0 | 7.7 |
| | 5-18-72 | 2.9 | 20 | 1.9 | --- | 27 | 10.0 | --- | -- |
| 147 | 7-01-70 | 2.0 | 8 | 3.0 | 157 | --- | 4.4 | 0 | 3.8 |
| | 6-21-72 | 2.6 | 2 | 7.8 | --- | --- | -- | --- | -- |

near the edge of a filled landfill trench and probably were at the trailing edge of a leachate plume. Water from well 145, the shallowest surficial aquifer well (depth 17.5 feet), had a specific conductance of about 750 umho during 1970-73; in 1980, specific conductance increased to 1,100 umho (fig. 41). Samples from Floridan aquifer well 147 (depth 45.8 feet) had a specific conductance of about 100 umho.

Chloride concentrations of water from well 145 decreased from 115 to 75 mg/L for the period of record. The chloride concentrations of water from wells 146 and 147 fluctuated between 5 and 40 mg/L. Potassium concentrations of water in well 145 increased from 3 mg/L in 1971 to 8 mg/L in October 1973. Potassium concentrations of water in the surficial aquifer outside the landfill area ranged from less than 1 to about 2 mg/L. Data are not available for the well after 1973 except for a single sample collected in June 1980 that showed a potassium concentration of 3 mg/L, the same as observed in 1971. Surficial aquifer well 146 and Floridan aquifer well 147 did not show any changes in potassium concentrations from May 1970 to October 1973. However, a sample collected from well 146 in June 1980 indicated a slight increase in potassium, and a sample collected from well 147 indicated a slight decrease in potassium.

Wells 111 and 112 were drilled as surficial aquifer wells in the southwest corner of the landfill (fig. 40). The wells were downgradient of wells on the east side of the landfill. Specific conductance of water from well 111 declined from 2,600 to 1,700 umho between 1970 and 1973 (fig. 42). Specific conductance of water from well 112 generally remained at about 600 umho.

Chloride concentrations of water from well 111 declined from 180 mg/L in July 1970 to 70 mg/L in October 1973. Chloride concentrations of water from well 112 were less than 40 mg/L from 1970 to early 1972, but showed a slight increasing trend during 1973.

Potassium concentrations in well 111 ranged from 290 mg/L in June 1970 to 180 mg/L in October 1973. Potassium concentrations in water from well 112 ranged from 0.7 to 10 mg/L; the highest concentrations occurred in October 1973.

Shallow wells 109 and 110 are in the southeast corner of the site (fig. 40). In July 1970, when sampling began, specific conductance of water from well 109 and well 110 was 300 umho. During the remainder of 1970-73, specific conductance of water from well 110 ranged from 550 to 900 umho, and water from well 109 ranged from 370 to 390 umho. Chloride concentrations in water from well 110 ranged from 25 to 45 mg/L, and for well 109, the range was from about 10 to 25 mg/L. The potassium concentrations of water from well 110 ranged from 10 to 20 mg/L; for well 109, the range was 0.5 to 3 mg/L.

Wells 148 and 149 were constructed as surficial aquifer wells in the northwest corner of the landfill (fig. 40). The wells were completed at depths of 13.7 and 26.5 feet, respectively. Surface runoff from a dairy into a topographic depression probably affected ground-water quality in the area.

Water from well 148, the shallowest well, showed a decrease in specific conductance from about 4,500 umho in July 1970 to 4,000 umho in October 1973. During the period February 1971 to May 1972, chloride concentrations decreased from 500 to 320 mg/L, and from May 1972 to October 1973, chloride concentrations increased to 430 mg/L. The specific conductance of water from well 149 decreased from about 1,000 to 500 umho during the period of record. Chloride concentrations of samples from the well were consistently less than 90 mg/L during 1970-73.

Water from well 148 showed unusually high concentrations of potassium, 180 to 290 mg/L, similar to concentrations in well 111. The high potassium concentrations in water from both wells probably were due to fertilizer or other material high in potassium. The potassium concentrations of water from well 149 ranged from 0.4 to 1.2 mg/L.

Degradation of the quality of water in the surficial aquifer by landfilling could not be assessed because the site had been used as a pasture for more than 30 years, which probably contributed to some changes in water quality.

## Summary

The Gunn Highway landfill was located in a corner of a pasture, and ground-water quality probably was affected by use of the land as a cattle pasture. Sampling at the site began 8 years after the site was closed, and prelandfill water-quality data were not available for analysis.

The most significant fact about the Gunn Highway landfill was the high concentrations of chemical constituents that occurred in water from the surficial aquifer nearly 20 years after the landfill was closed. The high concentrations illustrate the slow rate of leachate movement in the surficial aquifer and the long-term potential hazard of the landfill.

The highest values of specific conductance and chloride and potassium concentrations were determined for samples collected from wells 11 to 28 feet deep on the west side of the landfill. Specific conductance ranged from about 600 to 4,500 umho; chloride concentrations ranged from 30 to 500 mg/L; and potassium concentrations ranged from 175 to 290 mg/L. Most ground water in the surficial aquifer moves along highly permeable zones that occur at depths of 5 and 20 feet below land surface. Well screens in surficial aquifer wells were placed at or slightly below landfill trench bottoms and at depths of 15 to 18 feet below the trench bottoms.

Wells on the west side of the landfill were downgradient of wells drilled near Gunn Highway, and water quality at the wells was affected by movement of leachate. Water from wells in the southeast corner of the landfill showed the least effect from leachate migration because they are upgradient of the landfill.

Degradation of water in the surficial aquifer occurred largely as a result of leachate from the landfill and partly because the site had been used as a pasture for more than 30 years.

## Turkey Creek Landfill

### Location and Operation

The Turkey Creek landfill is in central Hillsborough County about 2 miles southwest of Plant City and 15 miles east of Tampa (fig. 2). The landfill was constructed in 1969 and is on the east side of Turkey Creek Road about 0.8 mile south of State Highway 574 (fig. 43). The site is about 600 to 800 feet east of a Plant City landfill that was closed in 1969. The study included sampling of test wells at both sites. The Turkey Creek landfill was operated by the county from 1969 to 1971. In 1971, responsibility for landfill operation was transferred to Plant City. Sampling at the site was discontinued shortly after Plant City began operating the landfill.

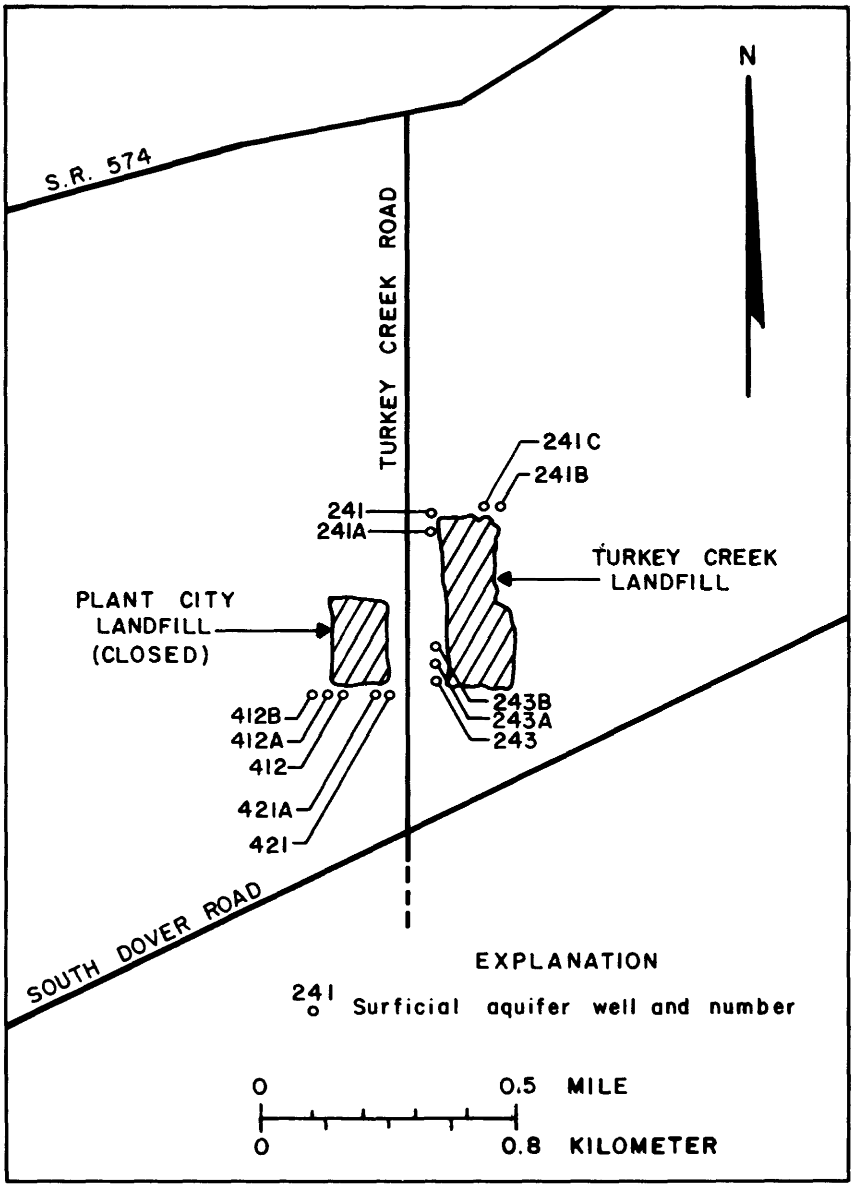



Figure 43.--Locations of wells, Turkey Creek landfill.

## Physical Setting

The landfill is in a predominantly swampy area underlain by thick layers of unconsolidated sand and clay. Land surface is about 140 feet above sea level. The southern part of the site is in a low, swampy area. The soil is poorly drained, dark-colored sands (Ona-Scranton) and well-drained, deep sands (Blanton-Lakeland-Eustis) (U.S. Department of Agriculture, 1958). The area is drained by a tributary of Turkey Creek that originates in a swamp at the landfill. Turkey Creek flows into the Alafia River about 7 miles south of the landfill.

The landfill site is overlain by surficial deposits of sand, silt, sandy clay, and clay that range in thickness from 100 to 120 feet. The top of the Floridan aquifer probably averages about 110 feet below land surface. A lithologic log of materials penetrated in well 243, a 100-foot-deep test well at the southwest corner of the site, is shown in table 13.

Table 13.--Lithologic log of well 243, Turkey Creek landfill

| Lithologic description | Thickness (feet) | Depth (feet) |
|---|---|---|
| Sand, light-gray, fine to medium, with some peat | 3.5 | 3.5 |
| Sand, brown, fine to medium | 3.5 | 7.0 |
| Sand, brownish-black, fine to medium | 8.5 | 15.5 |
| Sand, brown, medium, with some silt and clay | 9.5 | 25.0 |
| Sand, dusky yellow, fine to medium | 4.0 | 29.0 |
| Clay, yellowish-gray, friable, with much phosphate and some sand | 6.5 | 35.5 |
| Sand, light gray, fine to medium, with some clay | 4.5 | 40.0 |
| Clay, greenish-gray, plastic, with some sand and phosphate | 10.0 | 50.0 |
| Clay, dark greenish-gray, friable, with some sand and phosphate | 20.0 | 70.0 |
| Clay, greenish-gray, plastic, with thin lenses of sand | 15.0 | 85.0 |
| Clay, greenish-gray, plastic, with thin lenses of sand and some limestone fragments | 15.0 | 100.0 |

During the study period, twelve 2-inch diameter PVC test wells were drilled at the landfill. The wells ranged in depth from 13 to 100 feet and were completed in the surficial aquifer with 4-foot sand points in the lower part of the wells.

Ten split-spoon samples of surficial materials were collected at about 5-foot depth intervals from well 243. Quantitative analyses of the samples are shown in table 14. The vertical hydraulic conductivity of samples collected at depths of 5 to 25.5 feet ranged from $1.3 \times 10^{-1}$ to 16 ft/d; and for samples collected at depths

Table 14.--Laboratory analyses of surficial sediments, well 243, Turkey Creek landfill

| Depth (feet) | Type of material | Specific retention (percent) | Specific yield (percent) | Total porosity (percent) | Vertical hydraulic conductivity (ft/d) |
|---|---|---|---|---|---|
| 5.0-5.5 | Sand and clay | 5.9 | 30.3 | 36.2 | 5.4 |
| 9.5-10.0 | Sand and clay | 7.1 | 29.1 | 36.2 | $1.3x10^{-1}$ |
| 15.0-15.5 | Fine sand and clay | 9.0 | 30.6 | 39.6 | $5.4x10^{-1}$ |
| 19.5-20.0 | Medium sand | 4.6 | 35.0 | 39.6 | 16.0 |
| 25.0-25.5 | Medium sand | 4.0 | 36.4 | 40.4 | 13.4 |
| 29.5-30.0 | Stiff clay | 38.4 | 13.7 | 52.1 | $9.4x10^{-5}$ |
| 35.0-35.5 | Loose clay | 31.1 | 16.8 | 47.9 | $2.7x10^{-4}$ |
| 40.0-40.5 | Loose clay, sandy | 15.5 | 26.0 | 41.5 | $1.3x10^{-1}$ |
| 44.5-45.0 | Stiff clay | 52.4 | 2.3 | 54.7 | $1.3x10^{-4}$ |
| 49.5-50.0 | Stiff clay | 35.0 | 21.2 | 56.2 | $1.3x10^{-4}$ |

of 29.5 to 50 feet, vertical hydraulic conductivity ranged from $9.4x10^{-5}$ to $1.3x10^{-1}$ ft/d. Clay and silt constituted about 4 percent of the sample collected at a depth of 25.0 to 25.5 feet and about 51 percent of the sample collected at a depth of 29.5 to 30.0 feet. The sample collected at 44.5 to 45.0 feet had the highest silt and clay content--15.5 and 60.7 percent, respectively. Particle-size distribution graphs for three samples are shown on figure 44.

## Water Levels

The potentiometric surface of the Floridan aquifer at the landfill was about 65 feet above sea level in May 1969 (Stewart and others, 1971) and in May 1980 (Yobbi, Woodham, and Schiner, 1980). Water levels in the surficial aquifer ranged from about 120 to 140 feet above sea level in February 1969 when the test wells were drilled. The general direction of ground-water flow in the Floridan aquifer is southwest, and in the surficial aquifer, flow is south.

## Water Quality

Water samples were collected from 11 wells at the landfill for determination of specific conductance, chloride, sodium, potassium, calcium, and magnesium. Water-quality data for selected ground-water sites are shown in table 15.

Surficial aquifer wells 241 and 241A (fig. 43) were selected to establish background water-quality conditions at the landfill site. The wells were about 150 feet east of Turkey Creek Road at the northwest corner of the landfill. Water from the wells showed little change in specific conductance and chloride and potassium concentrations for the period 1971-73 (fig. 45).

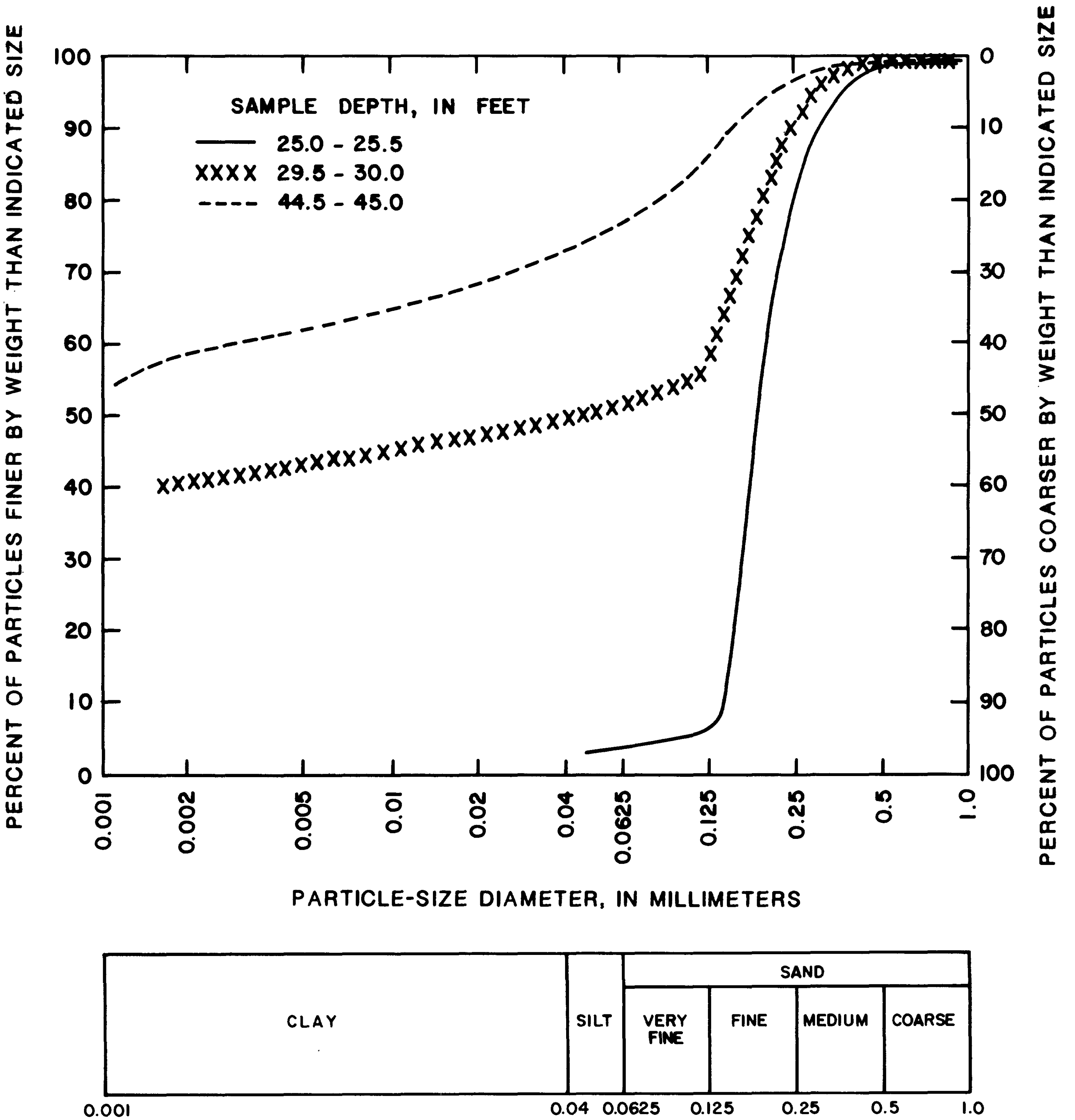



Figure 44.--Particle-size distribution for materials from well 243, Turkey Creek landfill.

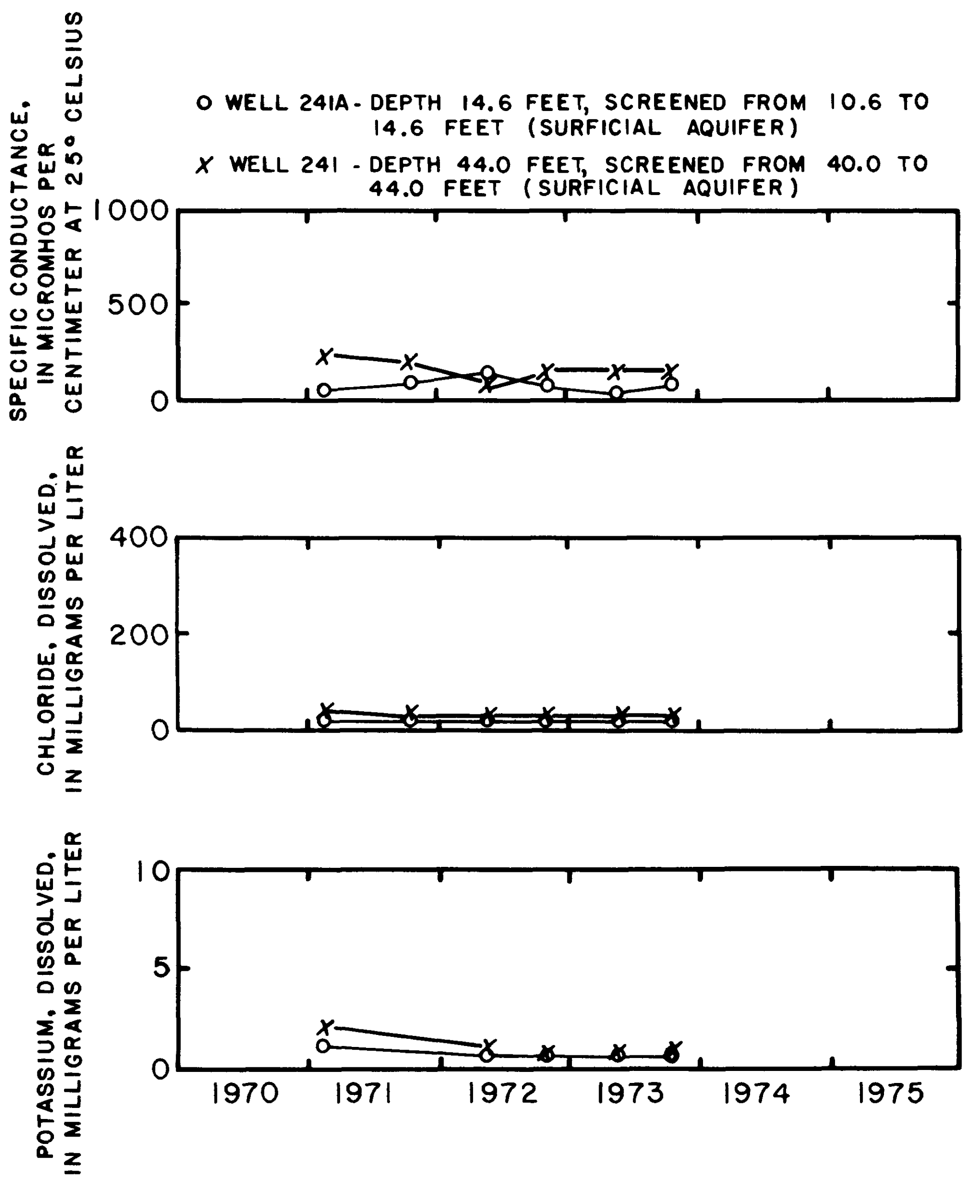



Figure 45.--Specific conductance and chloride and potassium concentrations of water from wells 241 and 241A, Turkey Creek landfill.

Table 15.--Water-quality data for selected ground-water sites, Turkey Creek landfill

[Concentrations are in milligrams per liter except as noted. Chloride, calcium, magnesium, sodium, potassium, hardness, sulfate, fluoride, and silica concentrations are dissolved]

| Well number | Depth (feet) | Aquifer | Date of sample | Temperature (°C) | Specific conductance (umho/cm) | Chloride (Cl) | pH | Alkalinity (as $CaCO_3$) | Calcium (Ca) |
|---|---|---|---|---|---|---|---|---|---|
| 243A | 50.0 | Surficial | 2-02-71 | 23.0 | 119 | 4 | 6.9 | -- | 9.4 |
| | | | 5-04-73 | -- | 170 | 5 | --- | -- | 9.0 |
| 243B | 18.8 | Surficial | 2-02-71 | 22.0 | 73 | 4 | 6.4 | -- | .6 |
| | | | 5-17-72 | -- | 320 | 45 | --- | -- | 3.8 |

| Well number | Date of sample | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Dissolved solids | Hardness (as $CaCO_3$) | Sulfate ($SO_4$) | Fluoride (F) | Silica ($SiO_2$) |
|---|---|---|---|---|---|---|---|---|---|
| 243A | 2-02-71 | 4.8 | 3.2 | 1.8 | 85 | 48 | 4 | 1.0 | 17 |
| | 5-04-73 | 4.5 | 4.4 | 4.2 | -- | -- | - | --- | -- |
| 243B | 2-02-71 | .3 | 1.8 | 1.2 | 49 | -- | 0 | .2 | 3.6 |
| | 5-17-72 | 8.6 | 15.0 | 2.2 | -- | 45 | - | --- | -- |

A statistical summary for specific conductance and chloride concentrations of water from well 241A and 241 is as follows:

| Well number | Parameter | Mean | Standard deviation | Range | Standard error of the mean | Number of samples |
|---|---|---|---|---|---|---|
| 241A | Specific conductance (umho/cm) | 70 | 14 | 50-147 | 6 | 5 |
| | Chloride (mg/L) | 4.1 | 1.0 | 3.2-5.8 | 0.4 | 6 |
| 241 | Specific conductance (umho/cm) | 170 | 47 | 3.5-248 | 21 | 6 |
| | Chloride (mg/L) | 9.4 | 6.1 | 3.6-20 | 2.7 | 6 |

Wells 241B and 241C were about 700 feet east of wells 241 and 241A at the northeast corner of the landfill. The specific conductance of water from well 241B increased from about 500 umho in February 1971 to about 2,500 umho in October 1972 (fig. 46). Chloride concentrations followed a similar trend, increasing from about 100 mg/L in February 1971 to about 725 mg/L in October 1972. During the same period, specific conductance for the shallower well, 241C, increased from about 350 to about 1,650 umho. Chloride concentrations in water from well 241C increased from about 100 to 500 mg/L. Potassium concentrations were less than 2 mg/L in well 241B, except for one high value of 6.5 mg/L in February 1971. Potassium concentrations in well 241C were less than 3 mg/L. The wells were destroyed sometime after October 1972. It appears that leachate moved rapidly to wells 241B and 241C. The sharp increase in specific conductance and chloride concentrations indicated rapid horizontal and vertical migration of leachate.

Wells 243A and 243B, both in the surficial aquifer, were about 150 feet east of Turkey Creek Road near the southwest corner of the landfill (fig. 43). Specific conductance of water from well 243B showed a general increase from about 60 umho in August 1970 to 470 umho in October 1973 (fig. 47). Chloride concentrations increased from about 10 to 100 mg/L during the same period. Potassium concentrations increased steadily from 0.9 to 6.4 mg/L. The quality of water from well 243A was more consistent. Specific conductance fluctuated between 100 and 170 umho, and chloride concentrations ranged from about 2 to 4 mg/L.

Well 243 was 100 feet deep and screened from 96 to 100 feet in the surficial aquifer. Water from the well was sampled in February 1971. Specific conductance was 292 umho, chloride concentration was 11 mg/L, and potassium concentration was 1.9 mg/L.

Water-quality data for the wells indicate that horizontal movement of leachate probably was through highly permeable sands at depths of about 15 to 30 feet below land surface. The response of shallow and deep wells to changes in water quality at about the same time indicates a high vertical hydraulic conductivity of the surficial aquifer.

Wells 412A and 412B, both in the surficial aquifer at depths of 28.9 and 14.4 feet, respectively, were near the southwest corner of the old Plant City landfill (fig. 43). Water quality in the shallower well, 412B, had specific conductances of greater than 2,000 umho during late 1970 and early 1971, followed by a decline to about 400 umho in October 1973. Chloride concentrations declined steadily from about 100 mg/L in August 1970 to about 10 mg/L in October 1973. During 1970-72, potassium concentrations were high, 50 to 90 mg/L, but declined to 8 mg/L by October 1973.

Water from well 412A (depth 29 feet), about 15 feet deeper than well 412B, had an increase in specific conductance from about 100 to about 400 umho during 1972. This temporary increase in specific conductance probably was due to vertical movement of leachate from the landfill. The increase occurred simultaneously with a decrease in specific conductance in shallow well 412B, which indicates vertical migration of leachate. Chloride concentrations in water from well 412A paralleled the specific conductance and ranged from 4 to 55 mg/L during the period of record. The highest concentration, 55 mg/L, was recorded in 1972. Potassium concentrations ranged from 0.2 to 1.5 mg/L.

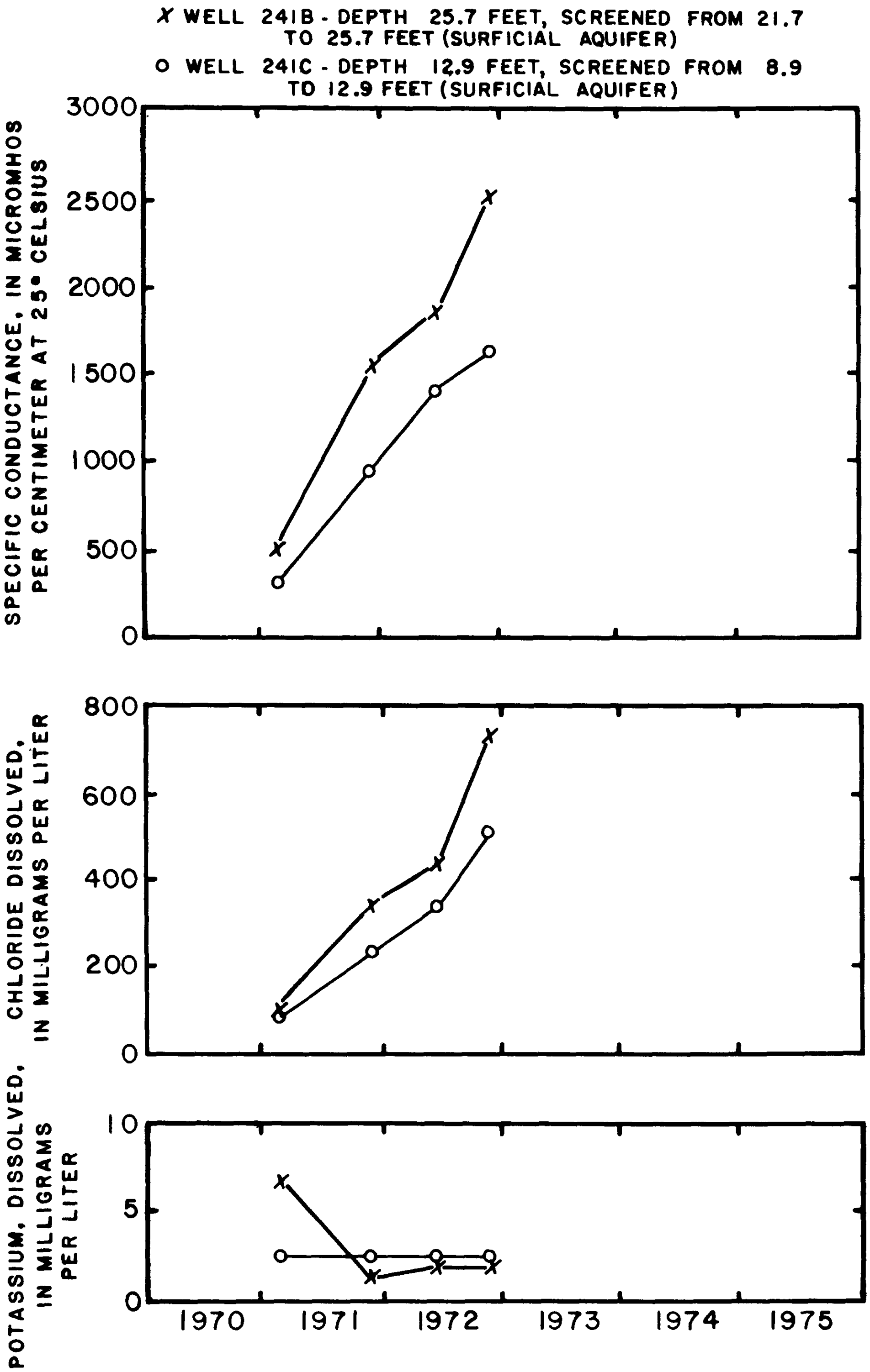



Figure 46.--Specific conductance and chloride and potassium concentrations of water from wells 241B and 241C, Turkey Creek landfill.

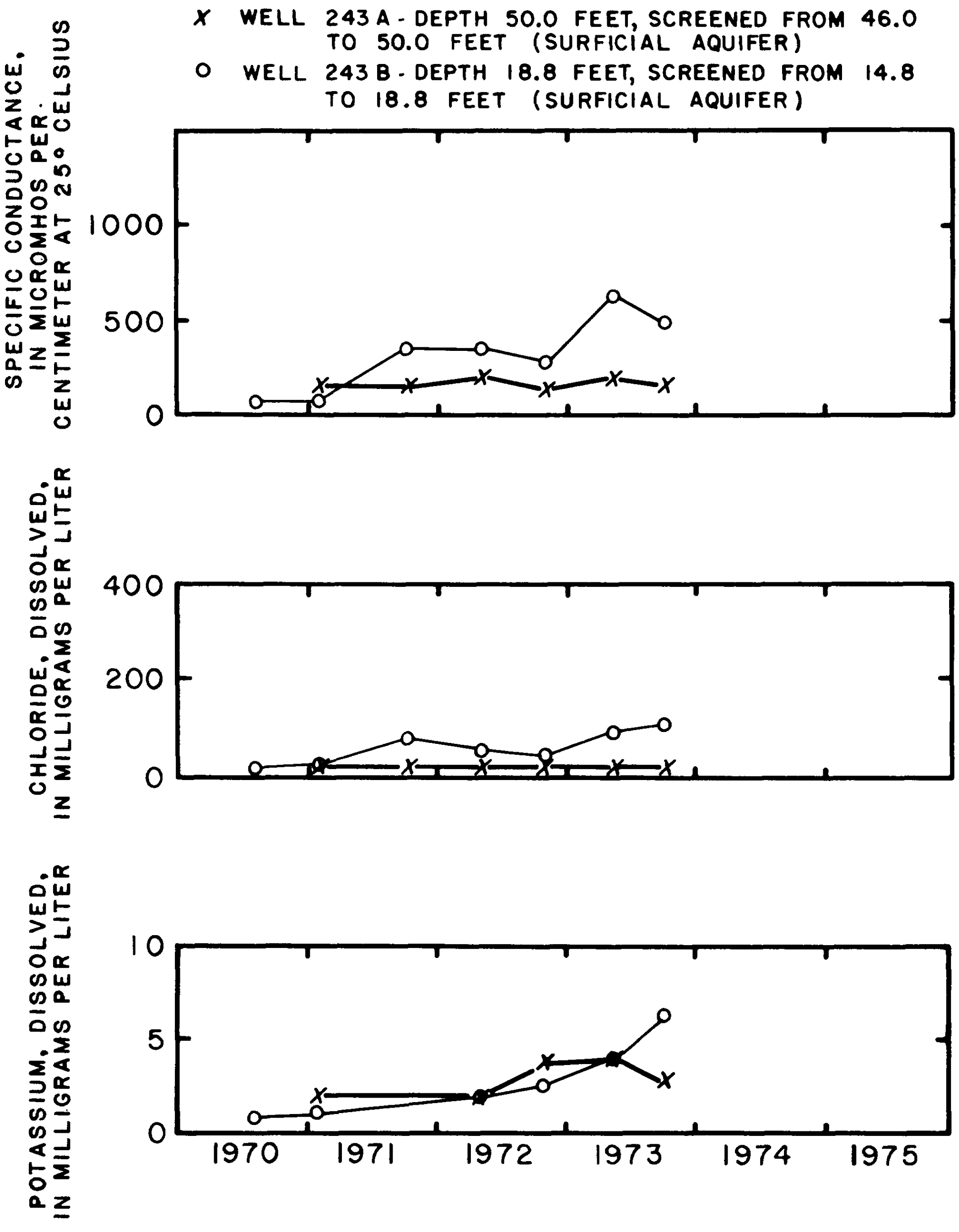



Figure 47.--Specific conductance and chloride and potassium concentrations of water from wells 243A and 243B, Turkey Creek landfill.

Well 412, the deepest of the three wells, was 62.8 feet deep and screened from 58.8 to 62.8 feet in the surficial aquifer. Water from the well did not show any evidence of leachate contamination. Specific conductance ranged from 152 to 200 umho, chloride concentrations ranged from 7 to 13 mg/L, and potassium concentrations ranged from 1.2 to 2.3 mg/L.

### Summary

Water of poor quality was observed in the surficial aquifer northwest of the Turkey Creek landfill, but degradation of water quality was not observed in the aquifer northeast of the landfill. Water from wells southwest of the landfill showed gradual increases in specific conductance and chloride and potassium concentrations during 1970-73. Water in the surficial aquifer southwest of the old Plant City landfill showed high concentrations of potassium from late 1970 through 1972. Specific conductance declined from more than 2,100 to less than 1,000 umho during this period.

Changes in water quality in shallow and deep surficial aquifer wells indicate a high vertical hydraulic conductivity of the surficial aquifer. Most horizontal movement of leachate occurred in a permeable sand zone about 15 feet below land surface.

## Gibsonton Landfill

### Location and Operation

The 50-acre Gibsonton landfill is in southwest Hillsborough County about 6 miles south of the city of Tampa (fig. 2). The landfill is about a quarter of a mile west of U.S. Highway 41 and about 1.5 miles south of the Alafia River. North, west, and south of the landfill there are tidal mangrove marshes, and on the east, there are several small houses (fig. 48). Two canals connect the landfill site with Hillsborough Bay. The landfill was constructed and operated by Hillsborough County from 1959 to 1976. The trench method of landfilling was used.

### Physical Setting

The Gibsonton landfill was constructed in a flat, coastal, sandy area with land-surface altitudes of less than 5 feet above sea level. The soil is predominantly Ruskin fine sand and tidal marsh unclassified soils (U.S. Department of Agriculture, 1958). The area drains north, west, and south into tidal marshes.

The site is overlain by surficial deposits 15 to 20 feet thick that consist of sand and shell fragments. Underlying these surficial deposits is the Hawthorn Formation consisting of sandy, calcareous, phosphoritic clay interbedded with layers of sandy, phosphoritic limestone. The Hawthorn Formation is about 30 to 40 feet thick and is the principal confining bed for the underlying Floridan aquifer. A lithologic log of materials penetrated in a 42-foot well on the north side of the landfill is shown in table 16.

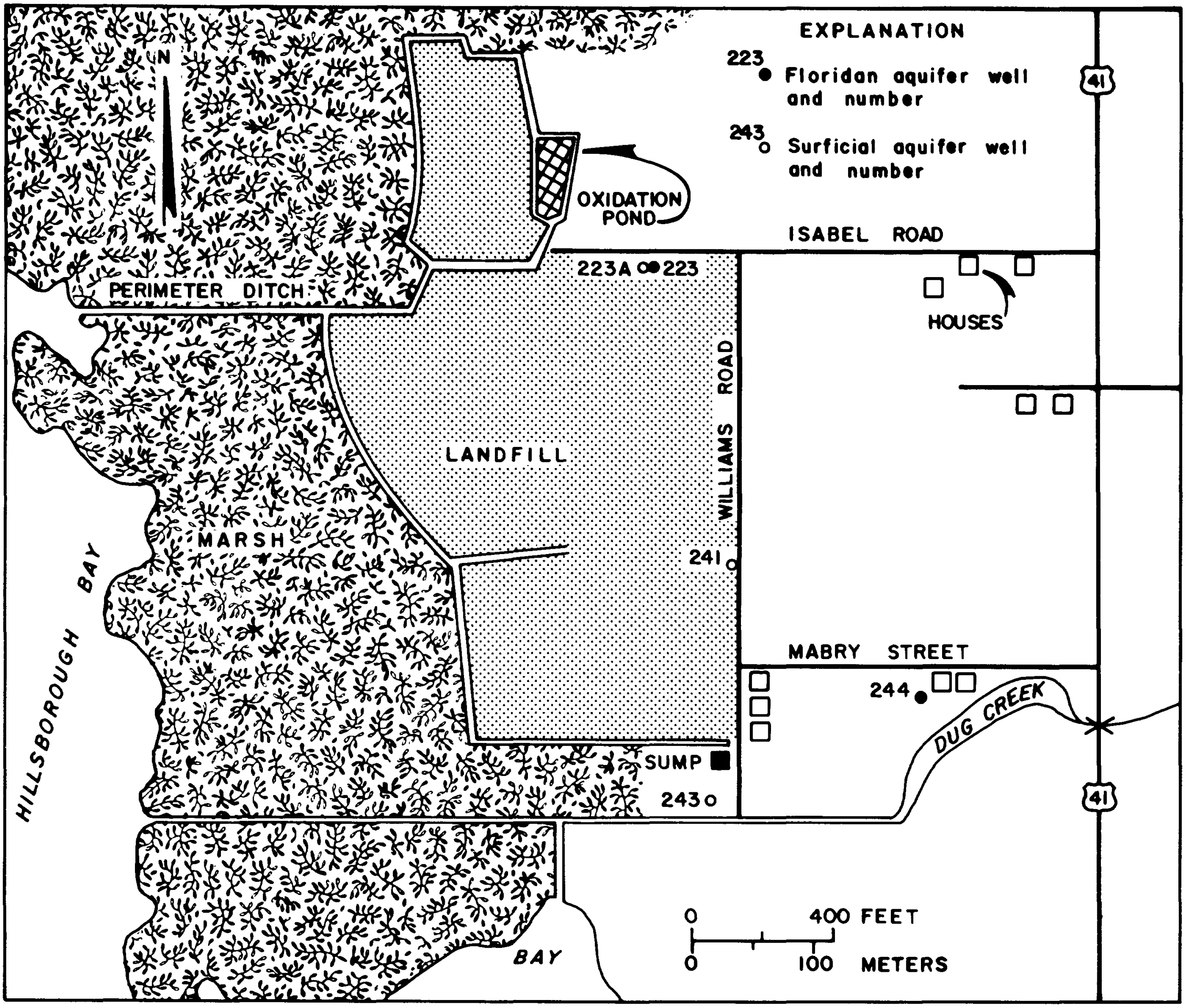



Figure 48.--Locations of wells, Gibsonton landfill.

Table 16.--Lithologic log of well 223, Gibsonton landfill

| Lithologic description | Thickness (feet) | Depth (feet) |
|---|---|---|
| Sand, fine | 5 | 5 |
| Sand, fine, with shell fragments | 7 | 12 |
| Sand, medium to fine, with shell fragments | 5 | 17 |
| Sand, clayey | 5 | 22 |
| Clay, sandy, with some limestone chips | 10 | 32 |
| Clay, limey, with limestone chips | 10 | 42 |

During the study period, four 2-inch diameter test wells were constructed at the Gibsonton landfill and adjacent area. The wells ranged in depth from 10 to 42 feet, were cased with 2-inch PVC pipe, and were finished with 5-foot sections of 2-inch PVC slotted screens.

## Water Levels

The potentiometric surface at the Gibsonton landfill was at sea level in May 1975 (Mills and Laughlin, 1976) and about 5 feet below sea level in May 1980 (Yobbi, Woodham, and Schiner, 1980). Water levels in the surficial aquifer ranged from about 2 feet below sea level to about 1 foot above sea level in January 1974 when the test wells were drilled. In May 1980, water levels in the surficial aquifer were about 3 feet above sea level. The general direction of ground-water flow in the Floridan aquifer and the surficial aquifer is west toward Hillsborough Bay.

## Water Quality

Water samples were collected periodically from five wells at the Gibsonton landfill during the period 1974-77. Determinations were made for specific conductance, chloride, sodium, potassium, calcium, and magnesium. The landfill is in an area that contains water of poor quality in the surficial aquifer (high in chloride and potassium). Water-quality data for selected ground-water sites are listed in table 17.

Background water-quality levels were not established for the landfill because the site is in an area where water in the surficial aquifer is affected by saltwater from nearby Hillsborough Bay. The quality of water in the Floridan aquifer has also been altered by saltwater intrusion (Duerr, 1975).

Table 17.--Water-quality data for selected ground-water sites, Gibsonton landfill

[Concentrations are in milligrams per liter except as noted. Chloride, calcium, magnesium, sodium, potassium, hardness, sulfate, fluoride, and silica concentrations are dissolved]

| Well number | Depth (feet) | Aquifer | Date of sample | Temperature (°C) | Specific conductance (umho/cm) | Chloride (Cl) | pH | Alkalinity (as $CaCO_3$) | Calcium (Ca) |
|---|---|---|---|---|---|---|---|---|---|
| 223A | 17.0 | Surficial | 4-29-74 | -- | 3,010 | 540 | --- | -- | 270 |
| | | | 3-30-76 | -- | 3,050 | 560 | --- | -- | 350 |
| 244 | 135.0 | Floridan | 4-29-74 | -- | 8,520 | 2,400 | --- | -- | 460 |
| | | | 6-01-77 | -- | 9,000 | 2,600 | 7.2 | -- | 480 |

| Well number | Date of sample | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Dissolved solids | Hardness (as $CaCO_3$) | Sulfate ($SO_4$) | Fluoride (F) | Silica ($SiO_2$) |
|---|---|---|---|---|---|---|---|---|---|
| 223A | 4-29-74 | 110 | 260 | 9.3 | -- | 1,100 | -- | -- | -- |
| | 3-30-76 | 100 | 270 | 7.8 | -- | 1,000 | -- | -- | -- |
| 244 | 4-29-74 | 250 | 1,000 | 25 | -- | 2,200 | -- | -- | -- |
| | 6-01-77 | 240 | 1,200 | 24 | -- | 2,200 | -- | -- | -- |

The quality of water in the surficial aquifer is illustrated by graphs of specific conductance and chloride and potassium concentrations of water from well 223A (fig. 49). The well is located near the northeast corner of the landfill. Specific conductance ranged from 2,900 to 3,800 umho; chloride concentrations ranged from 520 to 650 mg/L; and potassium concentrations ranged from 7.8 to 12 mg/L.

Well 241, 16 feet deep in the surficial aquifer, was constructed 15 feet west of Williams Road near the east side of the landfill. Water from the well had specific conductance as high as 34,000 umho and a chloride concentration of 13,000 mg/L. Potassium concentrations were as high as 220 mg/L. The poor quality water is attributed largely to a tidal saltwater marsh that bordered three sides of the landfill.

Graphs showing specific conductance and chloride and potassium concentrations of water collected from well 244, 500 feet east of Williams Road, are shown on figure 50. The well was completed as a Floridan aquifer well at a depth of 135 feet, cased to 92 feet. The specific conductance of water from the well ranged from 7,000 to 9,000 umho during the period of record 1974-77. Chloride concentrations ranged from 1,800 to 2,600 mg/L, and potassium concentrations ranged from 16 to 25 mg/L. The quality of water in the aquifer probably is affected by nearby Dug Creek (fig. 48), a small tidal stream that discharges into Hillsborough Bay.

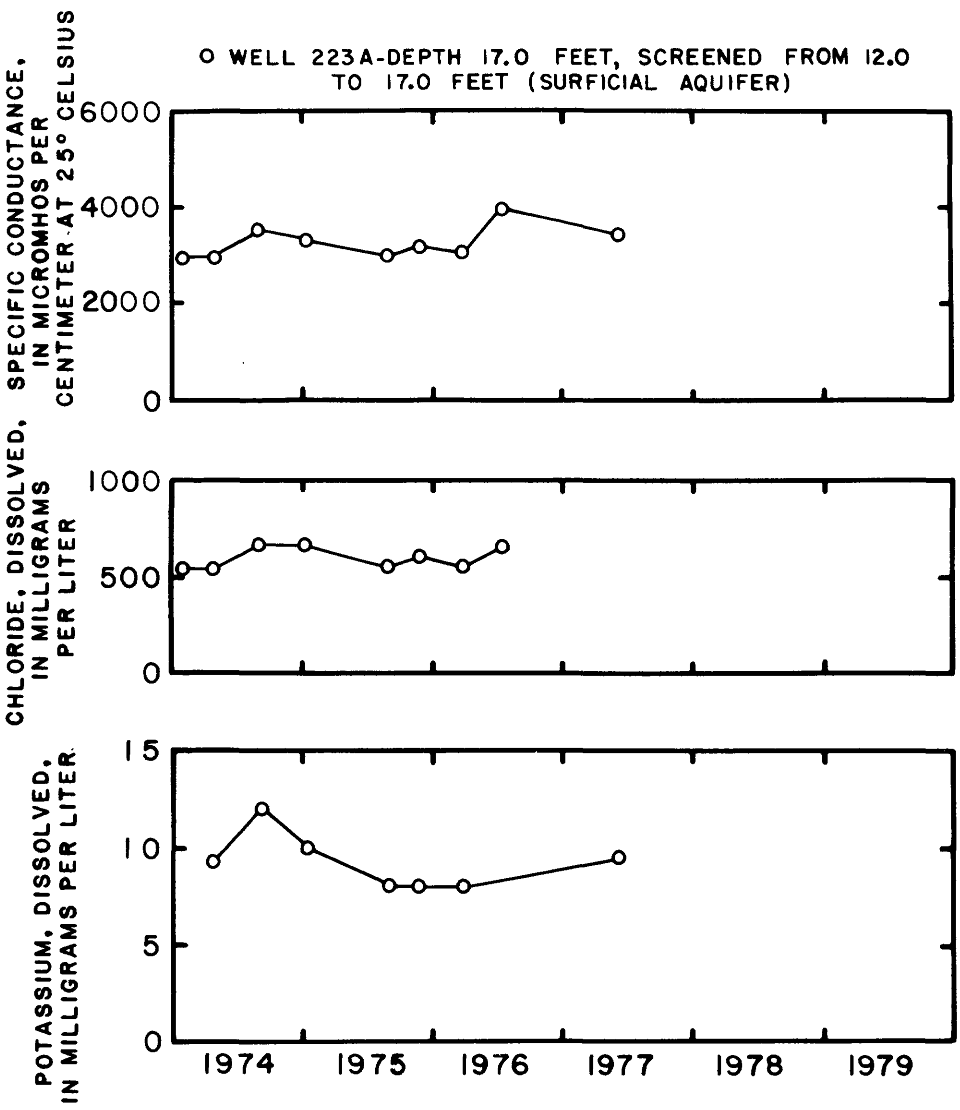



Figure 49.--Specific conductance and chloride and potassium concentrations of water from well 223A, Gibsonton landfill.

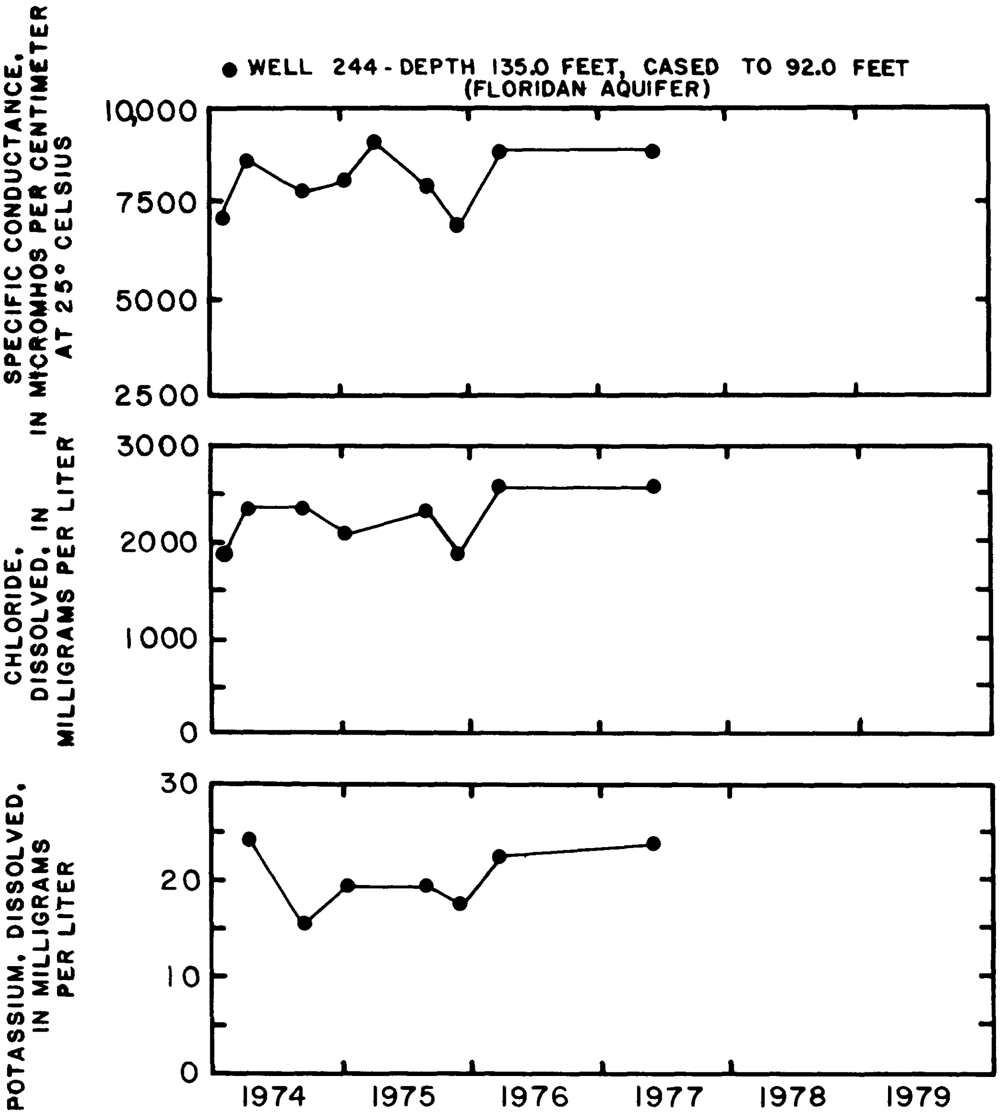



Figure 50.--Specific conductance and chloride and potassium concentrations of water from well 244, Gibsonton landfill.

### Summary

The effects of leachate on ground-water quality in the surficial and Floridan aquifers were not determined because background water-quality data were not available, and degradation of water in the aquifers had occurred prior to landfill operations. The landfill was located in a tidal marsh on the east side of Hillsborough Bay. The poor quality water in the aquifers was due largely to movement of saltwater from the bay and marsh into the aquifers.

## Ruskin Landfill

### Location and Operation

The Ruskin landfill includes about 25 acres in southwest Hillsborough County about 12 miles south of Tampa (fig. 2). The landfill is about 0.2 mile east of U.S. Highway 41 in a predominantly agricultural area that is rapidly becoming urbanized (fig. 51). The landfill was constructed and operated by Hillsborough County from 1967 to 1978. The trench method of landfilling was used at the site.

### Physical Setting

The Ruskin landfill is in a flat, sandy area that has average land-surface altitudes of about 8 feet above sea level. The soil is classified predominantly Ruskin fine sand and Bradenton fine sand (U.S. Department of Agriculture, 1958). The area drains southeast and southwest into several small channelized tributaries and canals that drain into the Little Manatee River.

The Ruskin site is overlain by surficial deposits 15 to 20 feet thick that consist of sand and shell fragments. Underlying these deposits is the Hawthorn Formation that consists of sandy, calcareous, phosphoritic clay interbedded with layers of sandy, phosphoritic limestone. The Hawthorn Formation is about 100 feet thick; it is the confining bed for the underlying Floridan aquifer. A lithologic log of materials penetrated in a 47-foot well on the north side of the landfill is shown in table 18.

Table 18.--Lithologic log of well 112, Ruskin landfill

| Lithologic description | Thickness (feet) | Depth (feet) |
|---|---|---|
| Sand, fine, with shell fragments | 5 | 5 |
| Sand, coarse to fine, with shell fragments | 10 | 15 |
| Clay, sandy, cohesive, fairly impermeable | 3 | 18 |
| Clay, limey, with layers of limestone, hard lenses 22-25 feet and 32-33 feet | 22 | 40 |
| Limestone | 7 | 47 |

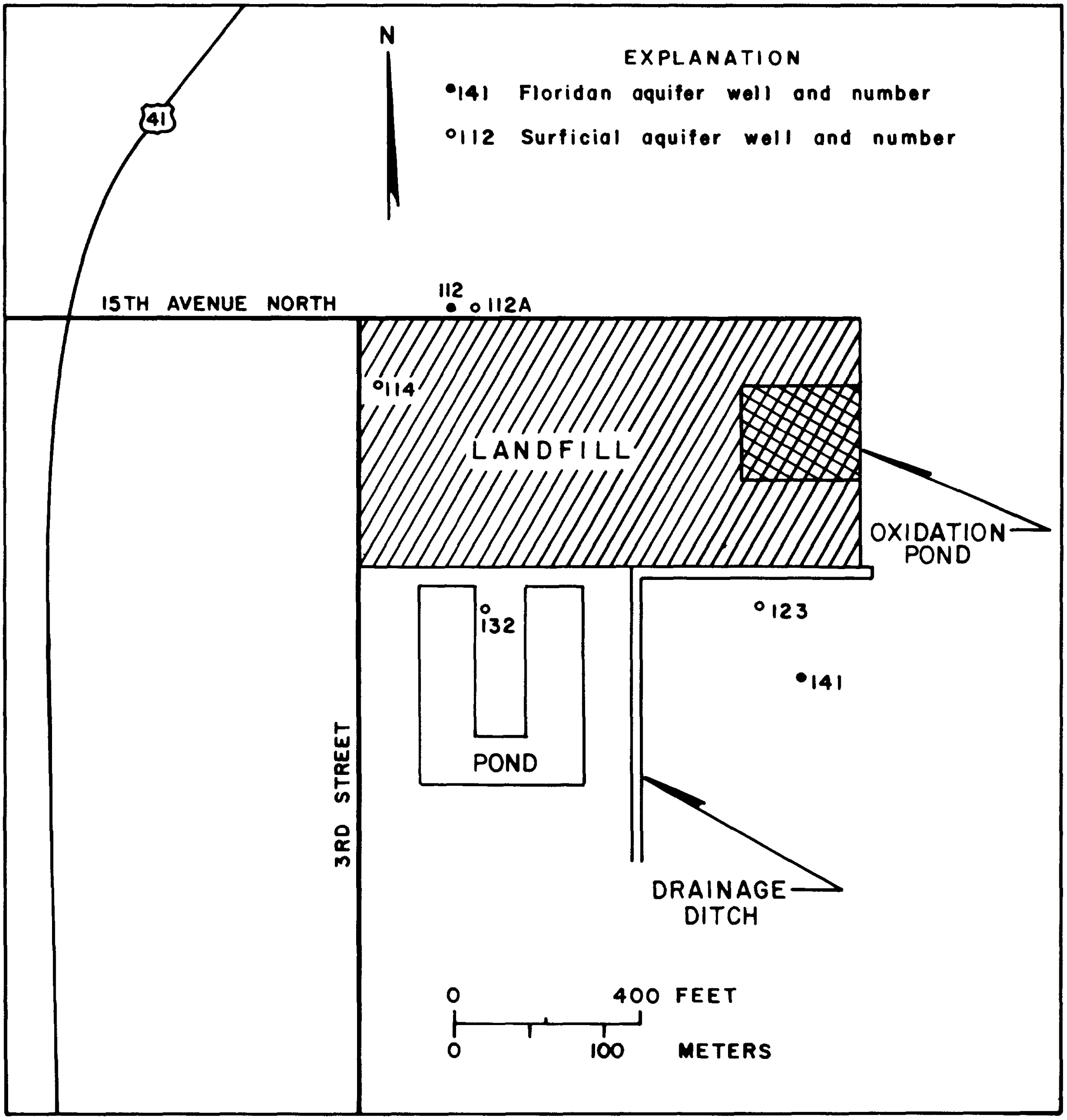



Figure 51.--Locations of wells, Ruskin landfill.

During the study period, five 2-inch diameter PVC test wells were constructed at the Ruskin landfill and adjacent area. The wells ranged in depth from 12 to 47 feet and were finished with 5-foot sections of 2-inch PVC slotted screens.

## Water Levels

The potentiometric surface at the Ruskin landfill was at sea level in May 1975 (Mills and Laughlin, 1976) and about 5 feet above sea level in May 1980 (Yobbi, Woodham, and Schiner, 1980). Water levels in the shallow sand aquifer were about 3 feet above sea level in February 1974 when the test wells were drilled. The general direction of ground-water flow in the Floridan aquifer is west toward Tampa Bay; flow in the surficial aquifer is west-southwest toward Tampa Bay.

## Water Quality

Water samples were collected for determination of specific conductance, chloride, sodium, potassium, calcium, and magnesium during the period 1974-77. Because the landfill had been in operation since 1967, baseline data were not available for the site. Water-quality data for selected ground-water sites are shown in table 19.

Water-quality data for wells 123 (surficial aquifer) and 141 (Floridan aquifer), 100 and 200 feet south of the east side of the landfill, respectively, are shown on figure 52. The specific conductance of water from well 123 averaged about 1,200 umho, but had a temporary high of more than 5,000 umho in March 1976. The increase was probably due to contamination through the well casing at land surface. Chloride concentrations fluctuated between 60 and 210 mg/L and averaged about 120 mg/L; potassium concentrations averaged 1.0 mg/L.

The depth of the well and casing of privately owned domestic well 141 were unknown, but the owner reported that the well was constructed in the Floridan aquifer. Specific conductance and chloride and potassium concentrations were fairly constant during the period 1974-77. Specific conductance averaged about 750 umho, chloride concentrations averaged about 20 mg/L, and potassium concentrations averaged about 2 mg/L. These values were similar to those reported by Duerr (1975) for wells that tap the Floridan aquifer in the Ruskin area.

Surficial aquifer well 132 (12 feet deep) was constructed about 75 feet south of the landfill near a tropical fish pond. Minimal changes in the quality of the water were noted during the period of record. Specific conductance averaged about 750 umho. Chloride concentrations averaged about 25 mg/L, and potassium concentrations averaged about 0.6 mg/L.

Surficial aquifer well 112A (depth 13 feet, screened from 8 to 13 feet) was constructed about 75 feet north of the landfill. Water samples were collected in February and April 1974. Specific conductance averaged about 850 umho, chloride concentrations averaged about 30 mg/L, and potassium concentrations averaged about 0.5 mg/L. Shallow aquifer well 114 (depth 12 feet, screened from 7 to 12 feet) was constructed 75 feet east of Third Street and was sampled twice in 1974 before being destroyed by trench excavations. Water quality was similar to that of water from well 112A.

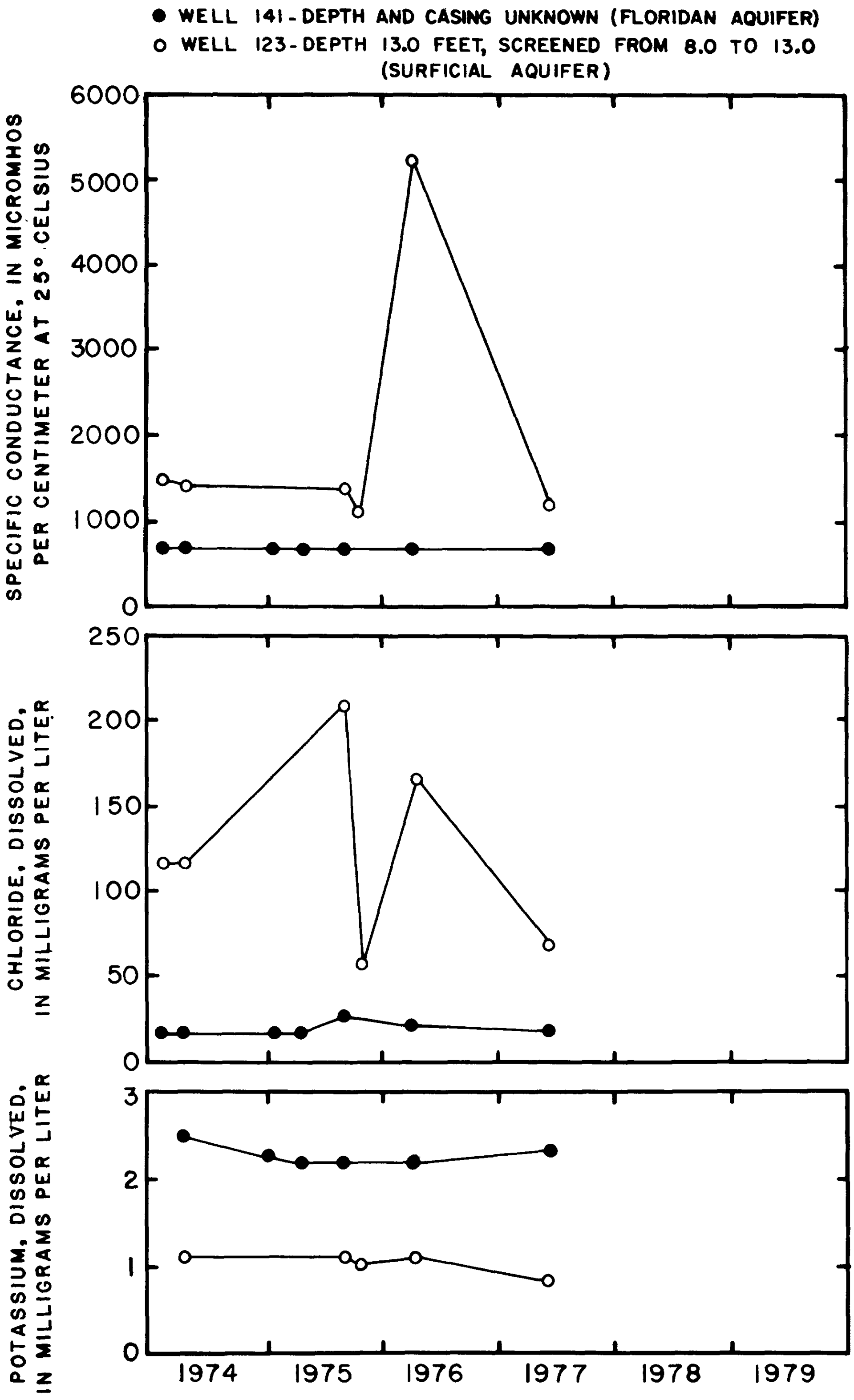



Figure 52.--Specific conductance and chloride and potassium concentrations of water from wells 123 and 141, Ruskin landfill.

Table 19.--Water-quality data for selected ground-water sites, Ruskin landfill

[Concentrations are in milligrams per liter except as noted. Chloride, calcium, magnesium, sodium, potassium, hardness, sulfate, fluoride, and silica concentrations are dissolved]

| Well number | Depth (feet) | Aquifer | Date of sample | Temperature (°C) | Specific conductance (umho/cm) | Chloride (Cl) | pH | Alkalinity (as $CaCO_3$) | Calcium (Ca) |
|---|---|---|---|---|---|---|---|---|---|
| 123 | 13.0 | Surficial | 4-29-74 | -- | 1,450 | 120 | --- | -- | 200 |
| | | | 6-01-77 | -- | 1,180 | 70 | 7.4 | -- | 270 |
| 141 | Unknown | Floridan | 4-29-74 | -- | 753 | 21 | --- | -- | 90 |
| | | | 6-01-77 | -- | 780 | 20 | 7.8 | -- | 97 |

| Well number | Date of sample | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Dissolved solids | Hardness (as $CaCO_3$) | Sulfate ($SO_4$) | Fluoride (F) | Silica ($SiO_2$) |
|---|---|---|---|---|---|---|---|---|---|
| 123 | 4-29-74 | 27 | 110 | 1.1 | -- | 610 | -- | -- | -- |
| | 6-01-77 | 27 | 120 | .9 | -- | 790 | -- | -- | -- |
| 141 | 4-29-74 | 43 | 16 | 2.5 | -- | 400 | -- | -- | -- |
| | 6-01-77 | 43 | 15 | 2.3 | -- | 420 | -- | -- | -- |

## Summary

The Ruskin landfill was operated by Hillsborough County from 1967 to 1978. Sampling of test wells at the site began in 1974 and continued through 1977. Background water-quality data were not available, but a study of the area in 1978 showed that water in the Floridan aquifer near the landfill was similar to that found along the coastal area near Ruskin. Samples collected from one Floridan aquifer well at the landfill did not indicate any changes in the quality of water during the sampling period.

The specific conductance of samples from three surficial aquifer wells averaged about 800 umho, and chloride concentrations averaged 30 mg/L. Samples from surficial aquifer well 123 south of the landfill had an average specific conductance of 1,200 umho and a chloride concentration of 120 mg/L. The water in this well probably was affected by movement of leachate from a ditch south of the filled trenches and oxidation pond.

## SUMMARY AND CONCLUSIONS

Field studies were made of five active and one inactive landfill sites in Hillsborough County during the period October 1969 to October 1980. A summary of the results is as follows:

1. A buildup of water levels in the surficial aquifer of 1 to 3 feet occurred in the landfills shortly after trenches were filled with solid waste.

2. Deposition of solid waste in areas of high water levels using the trench method of landfilling accelerated degradation of water quality in the surficial aquifer and possibly the Floridan aquifer at some sites.

3. Oxidation ponds were a principal cause of degradation of water in the surficial aquifer.

4. Perimeter ditches were a contributing factor that caused water-quality changes in the surficial aquifer.

5. High-rise refuse mounds, such as the one constructed at the Rocky Creek landfill, are potential sources of large quantities of leachate that can move directly into the surficial aquifer or can emerge at the surface through seeps and drains.

6. The potential for degradation of water in the surficial aquifer by leachate may increase after a landfill is closed because pumping and dewatering operations and maintenance are discontinued. This condition occurred at the Gunn Highway landfill where high concentrations of chemical constituents were found in the surficial aquifer nearly 20 years after the landfill was closed.

7. The trench method of landfilling in Hillsborough County has restricted use because a high water level occurs throughout most of the county. At the six sites studied, trenches were excavated to depths of 7 to 10 feet and averaged 8 feet below land surface. These depths placed the lower part of most trenches below the water level in the surficial aquifer. As a result, as much as 50 percent of the refuse deposited in trenches was placed directly into the saturated zone of the aquifer. In addition, the upper part of most trenches was within the range of seasonal water-level fluctuations in the area.

8. A monitoring network of surface-water and ground-water sites established after a landfill is closed would help to assess the long-term movement of leachate from a landfill and the effects of leachate on water quality. This phase of the operation is an integral part of initial landfill planning because it may be several years before any significant quantity of leachate moves out of a site.

9. The effects of landfill operations near the coastal area of southwest Hillsborough County were not evaluated because of insufficient hydrologic and geologic data. The landfills were in operation 4 to 7 years before the studies were initiated, and base conditions at the sites were unknown. In addition, saltwater contamination of the surficial aquifer and the upper part of the Floridan aquifer in these areas had occurred many years prior to the landfill operations.

A properly designed landfill includes methods and practices that eliminate or minimize (1) infiltration of rainfall into refuse, (2) flooding, (3) saturation by ground water, and (4) direct or indirect movement of leachate into aquifers through sinkholes, borrow pits, streams, and lakes.

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# GLOSSARY

This glossary presents simplified definitions of technical terms used in this report. For additional terms relating to the subjects see Langbein and Iseri (1960); U.S. Department of Health, Education, and Welfare (1970a; 1970b); Brunner and Keller (1972); and Lohman (1972).

Ammonia nitrogen: The ammonia nitrogen species is a major constituent in leachate. Old leachate has high levels of ammonia nitrogen because of degradation of organic nitrogen. Ammonia nitrogen decreases with age of leachate if nitrification occurs (U.S. Environmental Protection Agency, 1975).

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

Artesian: Ground water that is under sufficient hydrostatic pressure to rise above the zone of saturation. Synonymous with confined.

Biochemical oxygen demand: Biochemical oxygen demand (BOD) is a measure of the biochemically oxidizable matter in leachate and is expressed as the oxygen equivalent of oxidizable organic matter (U.S. Environmental Protection Agency, 1975).

Cell: The volume of compacted solid waste enclosed by natural soil or cover material in a sanitary landfill.

Cell thickness: Perpendicular distance between cover material placed over the last working faces of two successive cells in a sanitary landfill.

Chloride: The chloride ion is a major constituent in most landfill leachate and is considered to be a tracer because it tends to persist in solution and to move in the same manner as the water in which it is dissolved.

Cluster: The location of three or more wells of different depths within about 5 feet of each other; usually referred to as a well cluster.

Confined aquifer: An aquifer containing confined ground water.

Confined ground water: Water in an aquifer under pressure significantly greater than atmospheric. The aquifer's upper limit is the bottom of a bed of distinctly lower hydraulic conductivity than the material in which the confined water occurs.

Construction and demolition wastes: Waste building materials resulting from building, remodeling, repairing, or demolishing of buildings or other structures.

Head: The elevation relative to some datum, generally sea level, of the upper surface of water that occurs in a well that penetrates an aquifer, also called static head.

Hydraulic conductivity: The property or capacity of a porous rock, sediment, or soil for transmitting a fluid.

Hydraulic gradient: Change of hydraulic head per unit distance.

Isotropic: A condition in which aquifer properties are the same in all directions.

Leachate: A liquid emanating from a land disposal cell that contains dissolved, suspended, or microbial contaminants from the solid waste.

Lift: A layer of cells covering a designated area of a sanitary landfill.

Mixed garbage: Material consisting mainly of animal and vegetal waste, together with small bits of paper or packaging.

Porosity, effective: Refers to amount of interconnected pore space available for fluid transmission. It is expressed as a percentage of the total volume occupied by the interconnected interstices.

Potassium: The potassium ion belongs to a group of extended indicators that are commonly used by researchers and regulatory agencies (U.S. Environmental Protection Agency, 1975). Owing to its inertness, it is considered to be a tracer where clay content in the surficial deposits is low.

Refuse: Putrescible and nonputrescible solid wastes, except body wastes, and includes garbage, rubbish, incinerator ash and residue, street cleanings, and industrial wastes.

Rubbish: Nonbulky domestic and commercial solid waste exclusive of garbage.

Sanitary landfill: A well planned, carefully designed, and properly located operation that is based on engineering methods and techniques, applied knowledge of hydrology and geology, and operated in a manner that protects and maintains the quality of our environment.

Solid waste: Synonymous with refuse.

Specific conductance: Specific conductance is a measure of the ability of a water to conduct an electrical current and can be used to estimate the concentration of total dissolved mineral solids in the water.

Storage coefficient: Volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head.

Sump pit: Excavated pit in the bottom of a perimeter ditch used to collect and temporarily store water from the ditch.

Total organic nitrogen: Total organic nitrogen is a major constituent in leachate and is a precursor of ammonia nitrogen. Organic nitrogen breaks down to ammonia by bacterial action in the buried refuse.

Transmissivity: Rate at which water is transmitted through a unit width of the aquifer under a unit hydraulic gradient.

Unconfined aquifer: An aquifer in which the upper surface of the saturated zone, the water table, is at atmospheric pressure and is free to rise and fall.

Unconfined ground water: Water that is in an aquifer and that has a free water table.

Water table: The upper surface of the zone of saturation.

Well cluster: See cluster.

Zone of saturation: A subsurface zone in which all the interstices are filled with water under pressure greater than that of the atmosphere.