

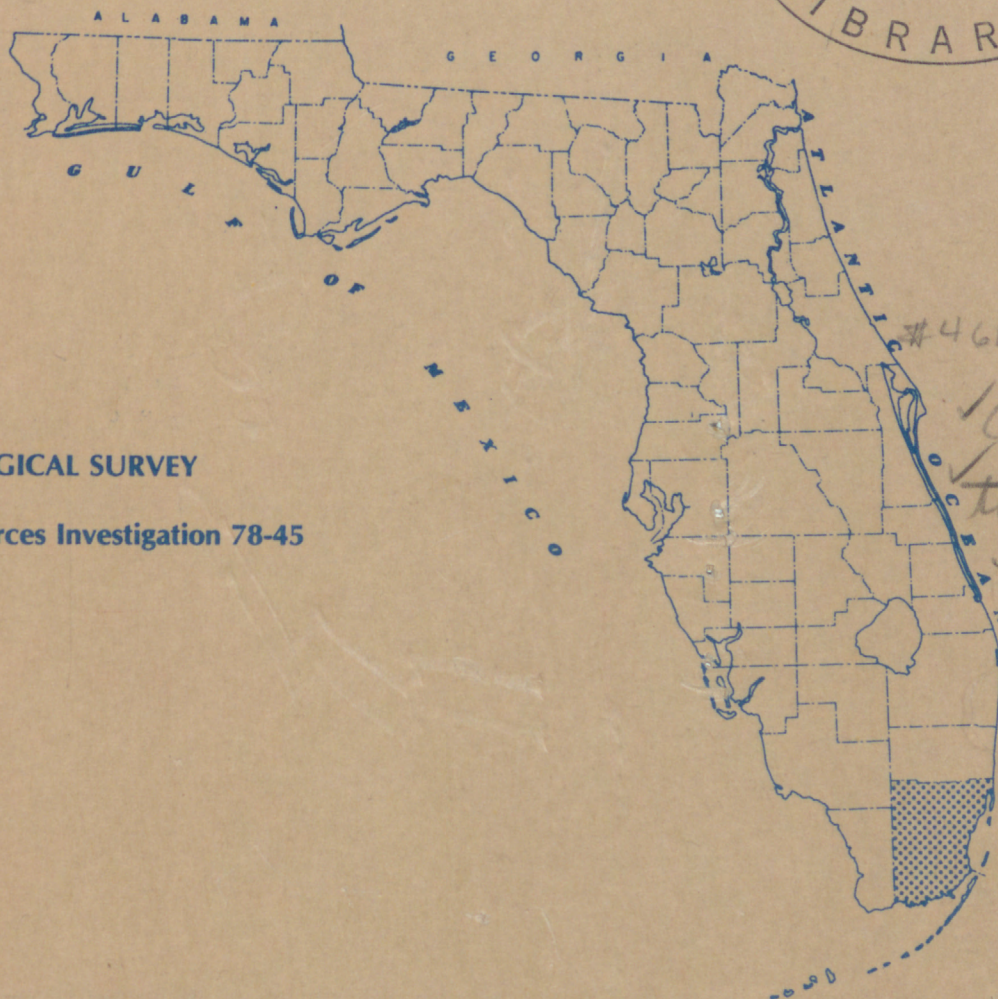
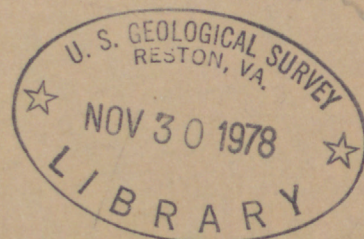
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no. 78-45

GROUND-WATER QUALITY NEAR THE NORTHWEST 58th STREET SOLID-WASTE DISPOSAL FACILITY, DADE COUNTY, FLORIDA

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U.S. GEOLOGICAL SURVEY

Water-Resources Investigation 78-45

Prepared in cooperation with
DADE COUNTY PUBLIC WORKS DEPARTMENT



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DADE COUNTY PUBLIC WORKS DEPARTMENT

April 1978

UNITED STATES DEPARTMENT OF THE INTERIOR

CECIL D. ANDRUS, Secretary

GEOLOGICAL SURVEY

H. William Menard, Director

For additional information write to:

U.S. Geological Survey
325 John Knox Road
Suite F-240
Tallahassee, Florida 32303

CONTENTS

	Page
Abstract.	1
Introduction.	1
Purpose and scope.	3
History of operations.	5
Description of disposal area.	5
General features	5
Geologic aspects	9
Hydrologic aspects	11
Water-level fluctuations.	11
Aquifer characteristics and ground-water flow	11
Water quality	21
Sampling locations and methods	21
Occurrence and movement of leachate.	25
Major ions	25
Chloride.	25
Sodium.	34
Other major ions.	34
Physical parameters.	40
Specific conductance.	40
Dissolved solids.	40
Turbidity	40
Color	45
Organic constituents	45
Nitrogen.	45
Total phosphorus.	47
Chemical oxygen demand.	47
Trace metals	47
Pesticides	51
Bacteria	56
Summary	60
Selected references	60

ILLUSTRATIONS

Figure	Page
1.--Map showing the location of the disposal area, the municipal well-field area, and drainage canals	2
2.--Map showing locations of the disposal area and well sites.	4
3.--Map showing soils in the vicinity of the disposal area	8
4.--Generalized geologic section in the vicinity of the disposal area.	10

ILLUSTRATIONS (Continued)

Figure	Page
5.--Hydrograph of well G-1165 and rainfall for August 1973 - July 1975.	12
6.--Map showing average water levels in part of north Dade County, 1960-73.	13
7.--Water-level profiles in the vicinity of the disposal area, October 8, 1974 and May 6, 1975	14
8.--Water-table altitude of the Hialeah-Miami Springs well field area, October 8, 1974	16
9.--Profile showing lines of equal potential in vicinity of disposal area, October 1973	17
10.--Profile showing lines of equal potential in vicinity of disposal area, January 1974	18
11.--Diagram delineating the flow section in Biscayne aquifer beneath disposal area	20
12.--Apparatus for collecting water samples from small diameter wells.	24
13.--Profile showing average excess chloride concentration, in percent, in ground water at and near the disposal area.	29
14.--Graphs showing chloride concentration of water from shallow wells at and near the disposal area	31
15.--Graphs showing chloride concentrations of water from sites 4, 5, and 6	33
16.--Graph showing sodium-chloride regression plot for water samples from shallow wells at and near the disposal area.	35
17.--Profile showing average excess sodium concentration, in percent, in ground water at and near the disposal area.	36
18.--Profile showing average leachate-related specific conductance, in percent, in ground water at and near the disposal area.	41
19.--Profile showing lines of equal specific conductance, April 1974.	42

ILLUSTRATIONS (Continued)

Figure	Page
20.--Profile showing lines of equal specific conductance, October 1974.	43
21.--Profile showing average excess dissolved solids residue, in percent, in ground water at and near the disposal area.	44
22.--Profile showing average excess ammonia, in percent, in ground water at and near the disposal area	46
23.--Profile showing average excess chemical oxygen demand, in percent, in ground water at and near the disposal area.	48
24.--Graphs showing average and range of total lead concentrations in 35 observation wells at and near the disposal area.	52
25.--Graphs showing average and range of total manganese concentrations in 35 observation wells at and near the disposal area	53
26.--Graph showing total coliform bacteria at and near the disposal area	57
27.--Graph showing fecal coliform bacteria at and near the disposal area	58
28.--Graph showing fecal streptococci bacteria at and near the disposal area	59

TABLES

Table	Page
1.--Waste loads during 1960-75.	6
2.--Composition of solid wastes at the Northwest 58th Street facility	7
3.--Designation and sampling period of wells.	22
4.--Chemical analyses of water from wells G-218 and G-224, 1941-1942	23
5.--Numbers of water samples collected, average concentrations and ranges in concentration of the parameters analyzed, and the analytical techniques used.	26

TABLES (Continued)

Table	Page
6.--Ground-water quality standards for Dade County.	32
7.--Average concentrations of major water-quality constituents from ground-water samples collected at and near the disposal area.	37
8.--Drinking water standards for metals and maximum observed concentrations	49
9.--Maximum observed metal concentrations in ground-water samples from wells at and near the disposal area.	50
10.--Concentrations of synthetic organic compounds in ground-water samples from wells at and near the disposal area.	54

GROUND-WATER QUALITY NEAR THE NORTHWEST 58TH STREET
SOLID-WASTE DISPOSAL FACILITY, DADE COUNTY, FLORIDA

By

Harold C. Mattraw, John E. Hull, and Howard Klein

ABSTRACT

The Northwest 58th Street solid-waste disposal facility, 3 miles (4.8 kilometers) west of a major Dade County municipal water-supply well field, overlays the Biscayne aquifer, a permeable, solution-riddled limestone which transmits leachates eastward at a calculated rate of 2.9 feet per day (0.9 meter per day). The disposal facility has operated since 1952. A multi-depth ground-water sampling program between August 1973 and July 1975 identified the leachate characteristics and the conservative components which most readily have migrated downgradient.

A discrete, identifiable leachate plume has been recognized under and downgradient from the waste disposal facility. Production of leachate from the disposal area depends on seasonal rainfall patterns. This causes some variability in concentration strength and location of the observed plume. Concentrations of sodium, chloride, ammonia, and dissolved solids decreased with depth beneath the disposal area and downgradient in response to an advective and convective dispersion. Downgradient, leachates were also diluted by the infiltration of rainfall into the aquifer. At a distance of about one-half mile (0.8 kilometer) downgradient, the rate of contribution of leachate from the source to the leading edge of the plume was about equal to the rate of loss of leachate from the leading edge of the plume by diffusion and dilution during the period covered by the nine samplings. Heavy metals, pesticides, and most other water-quality constituents are filtered, adsorbed by aquifer materials, or are precipitated near the disposal area.

INTRODUCTION

Since February 1952, Metropolitan Dade County, Florida, has operated a solid-waste disposal facility on 1 mi² (2.6 km²) of land bordering Northwest 58th Street on the south, west of the city of Hialeah (fig. 1). In recent years personnel of the Department of Environmental Resource Management and the Department of Public Works of Dade County have become increasingly aware of and concerned about the potential ground-water pollution posed by the chemical leachates from the facility, because of its low elevation and frequent flooding, and because the facility is 3 mi (4.8 km) upgradient of the largest municipal well field of the Miami-Dade Water and Sewer Authority (fig. 1). Further potential problems were posed when an auxiliary well field was established in an area less than 2 mi (3.2 km) from the east side of the solid-waste disposal area.

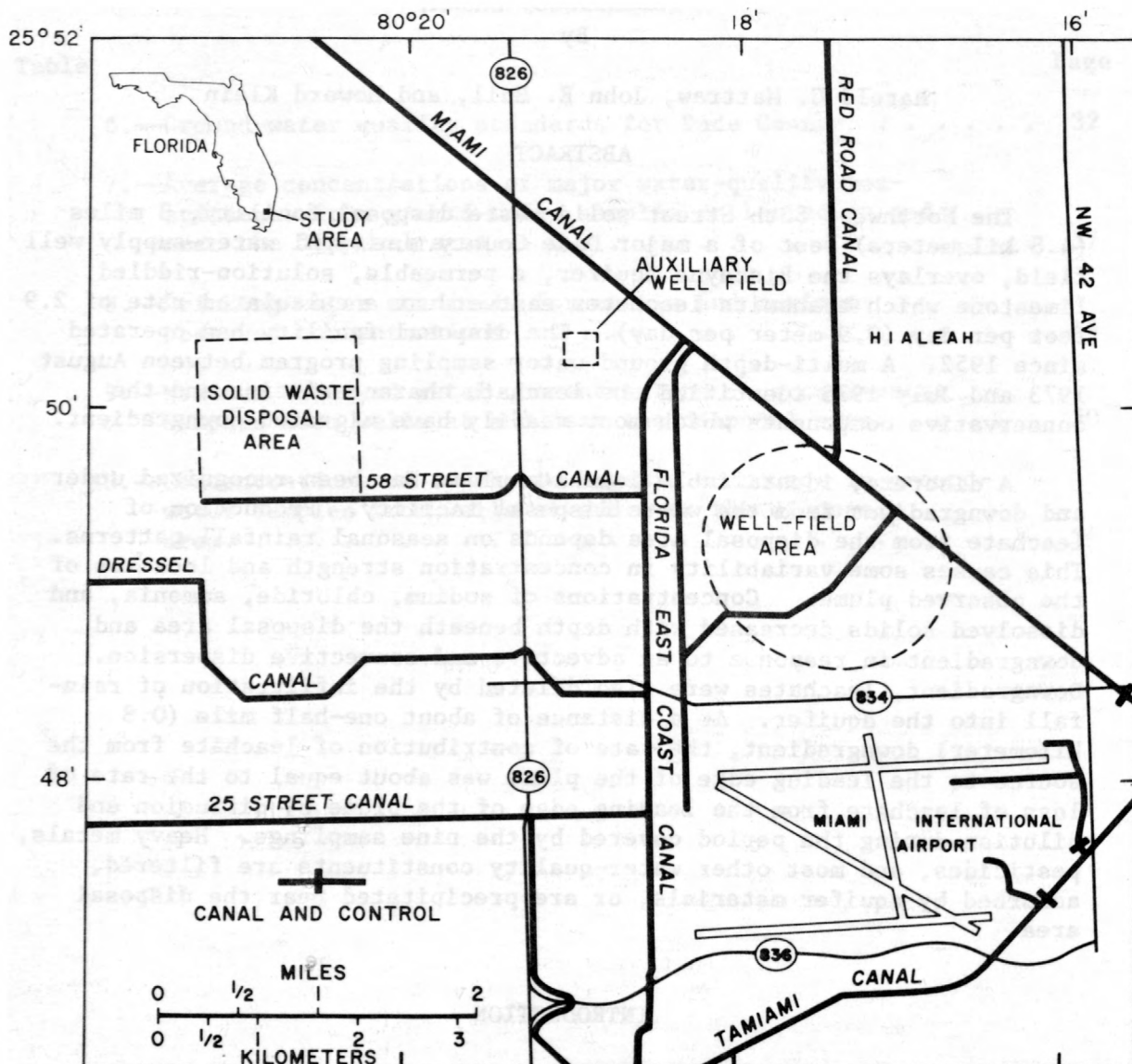


Figure 1.--Location of the disposal area, the municipal well-field area, and drainage canals.

In 1973 the U.S. Geological Survey, in cooperation with the Dade County Public Works Department, began an investigation of the ground-water quality in the vicinity of the disposal area to determine the characteristics of and the direction and extent of migration of leachate from the solid-waste disposal site. Results from this investigation may be useful in estimating the effects of solid-waste disposal operations in other areas of the county, and in locating and operating future facilities.

For those who prefer metric units to U.S. customary units, the conversion factors for the terms used in this report are listed below:

<u>Multiply U.S. customary unit</u>	<u>By</u>	<u>To obtain metric unit</u>
inches (in)	25.4	millimeters (mm)
feet (ft)	0.3048	meters (m)
miles (mi)	1.609	kilometers (km)
acres	.4047	hectares (ha)
square miles (mi ²)	2.590	square kilometers (km ²)
cubic feet (ft ³)	.02832	cubic meters (m ³)
gallons (gal)	3.785	liters (L)
tons (short)	.9072	metric tons (t)
transmissivity (ft ² /d)	.0929	transmissivity (m ² /d)
million gallons per day (Mgal/d)	.04381	cubic meters per second (m ³ /s)

Purpose and Scope

This investigation was designed to determine the chemical composition of leachate, to delineate the direction and extent of its movement from the solid-waste disposal area, and to study the effects of the leachate on water quality.

Six test sites were initially established in the vicinity of the disposal area (fig. 2), each containing five wells ranging in depth from 10 to 60 ft (3 to 18 m). Site 7, in the vicinity of the auxiliary well field, was established later to better define the extent of the eastward migration of the leachates. The sites were alined hydraulically down-gradient from west to east to measure changes from natural conditions (nonpolluted) at site 1, to polluted conditions in the vicinity of the waste-disposal area, and to the east where dilution occurs. Site 3 is near the active (1976) disposal, while site 4 is located in an inactive section of the waste disposal area. The analyses of water from the multiple-depth wells were used to determine the distribution of contaminants both laterally and vertically in the aquifer. Water samples were collected over 24 months in order to span two rainy and two dry seasons.

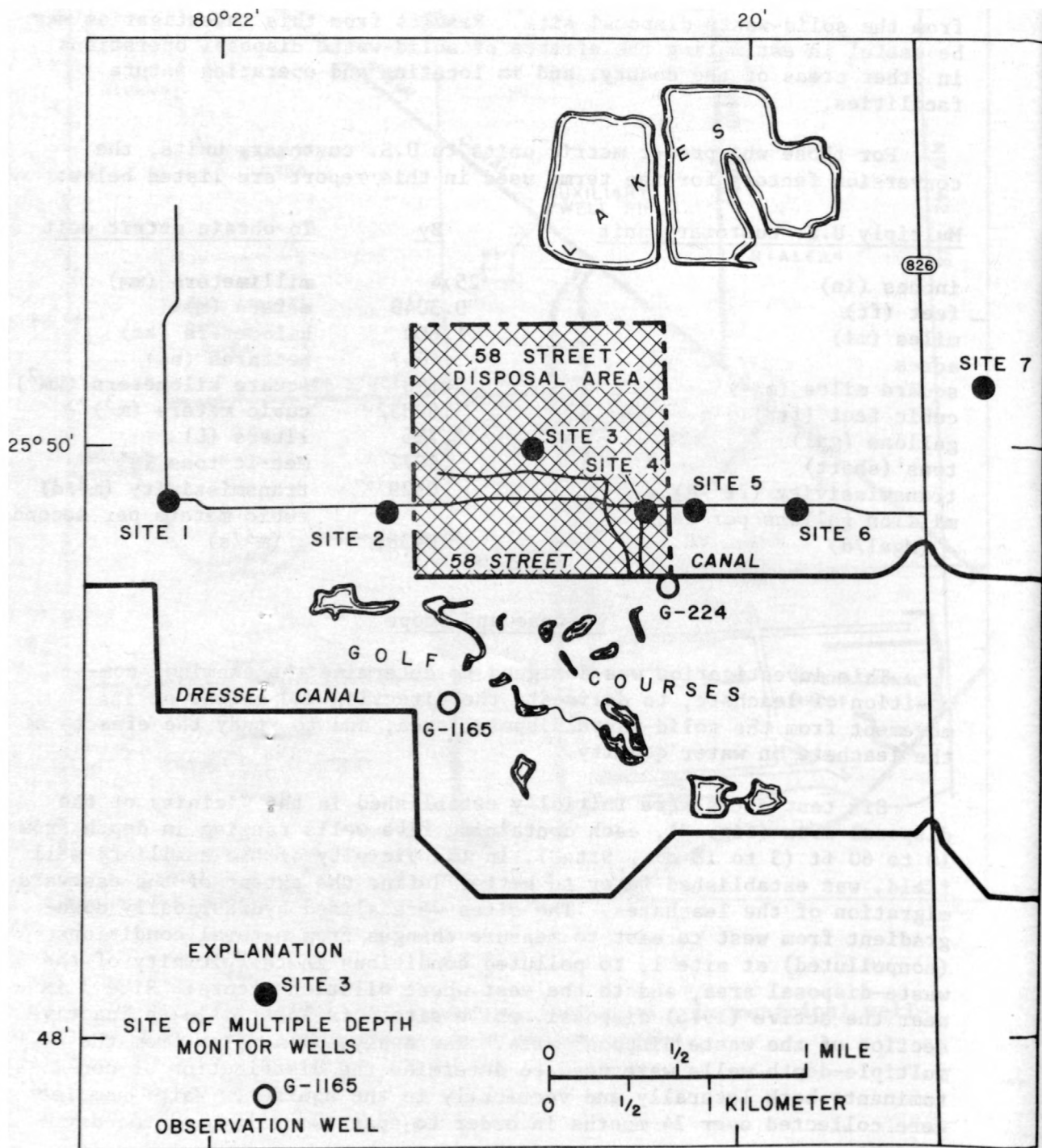


Figure 2.--Locations of the disposal area and well sites.

History of Operations

The 58th Street disposal facility has been in operation since 1952. Originally, waste was placed into shallow trenches dug below the water table; therefore, some refuse was deposited in the saturated zone of the aquifer. The waste material was eventually covered to allow access over the fill, although specific types of cover materials as required in landfill operations were not applied. Garden trash was burned in open fires to reduce volume, and the residue was used as fill.

Since 1960, when a ban was placed on open burning, refuse bulk has accumulated at almost three times the 1960-61 rate of 132,724 tons (120,407 metric tons). The tonnages of waste loads during 1960-75 are shown in table 1. A large tire and oil fire in 1966 resulted in an effort to prohibit open burning and to maintain cover material on old filled disposal areas.

By 1975 about 450 acres (182 ha) had been used as a depository, leaving little land as a source of cover material for future operations and for the phasing-out period. Refuse at the disposal facility consisted of 65 percent garbage and 35 percent trash from private, municipal and county sources. The composition and primary sources of solid waste within the two categories are shown in table 2. Frequent fires, sparse use of cover material and limited compaction have contributed to leachate formation.

DESCRIPTION OF DISPOSAL AREA

General Features

The 1 mi² (2.6 km²) area of the waste-disposal operation is near the western outskirts of the city of Hialeah and along the east edge of the Everglades. The land surface in the vicinity is flat, at an altitude of 5 ft (1.5 m) above sea level. Drainage is poor; the land is inundated intermittently during the rainy season, June-October, and swampy conditions persist for several weeks each year. Inundation is caused by rising water table rather than by runoff. The land immediately south of the disposal area has been developed into a country club containing several golf courses (fig. 2). To the north an extensive mining operation removes limestone from depths to 60 ft (18 m), leaving large lakes. Soils within the disposal area and vicinity cover an eroded limestone surface, and range in thickness from 2 to 24 in (50 to 600 mm). They are composed mainly of poorly drained fine sand, marl, and peat (fig. 3). In its natural state the disposal area was covered by peat, 6 to 18 in (150 to 460 mm) thick.

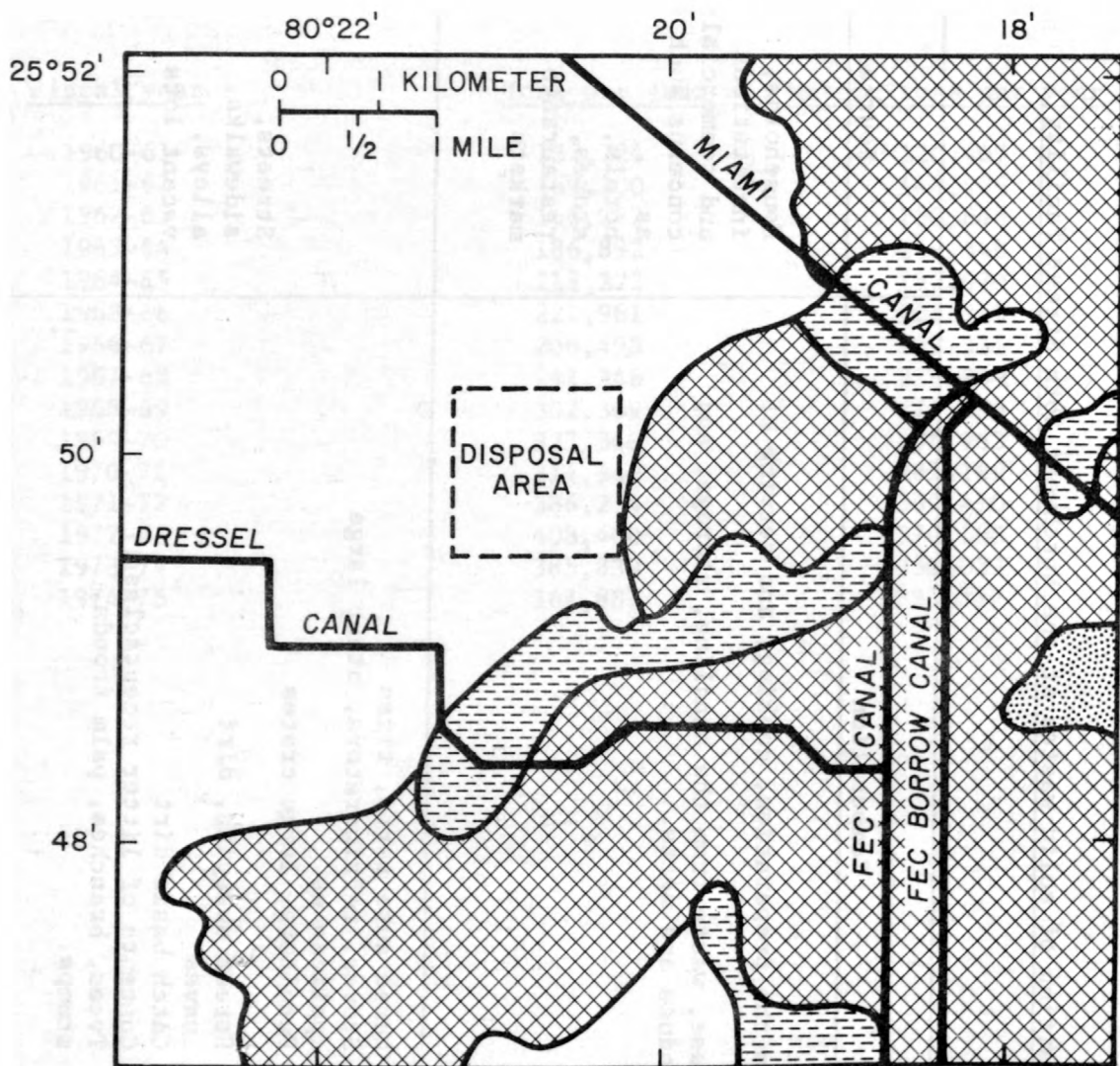
Annual rainfall at the Miami International Airport, 4 mi (6.4 km) southeast of the disposal site ranges from less than 40 in (1,020 mm) to more than 80 in (2,040 mm) and averages about 60 in (1,520 mm). As much as 80 percent falls during the rainy season. Major drainage of the area

Table 1.--Waste loads during 1960-75


<u>Fiscal year</u>	<u>Tons per year</u>	<u>Metric tons per year</u>
1960-61	132,724	120,407
1961-62	159,200	144,426
1962-63	166,277	150,846
1963-64	186,892	169,548
1964-65	218,222	197,970
1965-66	221,961	201,363
1966-67	206,498	187,335
1967-68	241,346	218,949
1968-69	302,309	274,255
1969-70	327,340	296,963
1970-71	314,340	285,169
1971-72	386,254	350,410
1972-73	408,400	370,500
1973-74	385,839	350,033
1974-75	367,887	333,747

Table 2.--Composition of solid wastes at the Northwest 58th Street facility.

Category	Composition		Sources
65 Percent Garbage	<p>Wastes from the preparation, cooking, and serving of food.</p> <p>Market refuse, waste from the handling, storage, and sale of produce and meats.</p>		<p>Households, institutions and commercial concerns such as hotels, stores, restaurants, markets</p>
35 percent Trash	<p>Bulky Wastes</p> <p>Parkway and Street Refuse</p>	<p>Large auto parts, tires</p> <p>Stoves, refrigerators, other large appliances</p> <p>Furniture, large crates</p> <p>Street sweeping, dirt</p> <p>Leaves</p> <p>Catch basin dirt</p> <p>Contents of litter receptacles</p> <p>Trees, branches, palm fronds, stumps.</p>	<p>Streets, sidewalks, alleys, vacant lots</p>




SAND, WELL
DRAINED; 2-4 INCHES


MARL, VERY POORLY
DRAINED; 2-6 INCHES


SAND, POORLY
DRAINED; 6-10 INCHES

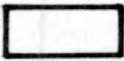

PEAT, VERY POORLY
DRAINED; 6-18 INCHES

Figure 3.--Soils in the vicinity of the disposal area.

is by the Miami Canal and, to a lesser extent, by the Tamiami Canal (fig. 1). Their combined flow empties into Biscayne Bay, 9 mi to the southeast. Secondary drainage is by the 58th Street canal, the Dressel Canal, and the 25 Street canal. The usual direction of flow of these canals is east to the Florida East Coast Canal. The Florida East Coast Canal flows north to the Miami Canal or south to the Tamiami Canal, as dictated by the water levels maintained in the Miami and Tamiami Canals.

A major influence on the hydrology of the area is the large municipal well field, north of the Miami International Airport (fig. 1), operated by the Miami-Dade Water and Sewer Authority, the prime water supplier in Dade County. Withdrawal from the wells was about 125 Mgal/d ($5.48 \text{ m}^3/\text{s}$) in 1975. An auxiliary well field is being established by the Water and Sewer Authority in the area between State Road 826 and the north end of the Florida East Coast Canal (fig. 1). Its capacity will be about 40 Mgal/d ($1.75 \text{ m}^3/\text{s}$). Auxiliary wells will be pumped during dry seasons when saltwater intrusion poses a threat to municipal wells in the southern part of the main well field, near the airport.

Geologic Aspects

Dade County is underlain by the Biscayne aquifer, a wedge-shaped body of limestone, sandstone, and sand that yields water for all municipalities in the area (Schroeder and others, 1958). Beneath the waste disposal area and the immediately surrounding area the bottom of the aquifer ranges in depth from 70 to 90 ft (21 to 27 m) below land surface. The top of the aquifer is the eroded limestone surface underlying the marl and peat soils.

Geologic data obtained from exploratory core borings at sites 1-7 are shown in figure 4. The uppermost unit is the Miami Oolite of Pleistocene Age, a relatively soft sandy limestone containing small solution openings which permit rapid infiltration of rainfall. The bottom part of the formation is a highly permeable cavity-riddled limestone composed of bryozoans. Most of the cavities are usually filled with sand or silt. A layer of fine-to-medium grained sand ranging in thickness from 7 to 15 ft (2.1 to 4.5 m) separates the bryozoan zone from limestone of the Pleistocene Fort Thompson Formation, which forms the lower part of the aquifer. The Fort Thompson Formation is composed of alternating thin layers of hard, dense limestone, and thick layers of solution-riddled limestone whose openings are larger than those of the bryozoan zone, imparting overall high permeability. Solution openings in the Fort Thompson Formation generally do not contain sand. A layer of nodular sandstone and sand of high permeability forms the bottom part of the aquifer. All wells of high capacity, ranging from 1,000 to 7,000 gal/min, bottom in the permeable sandstone and the limestone of the Fort Thompson Formation.

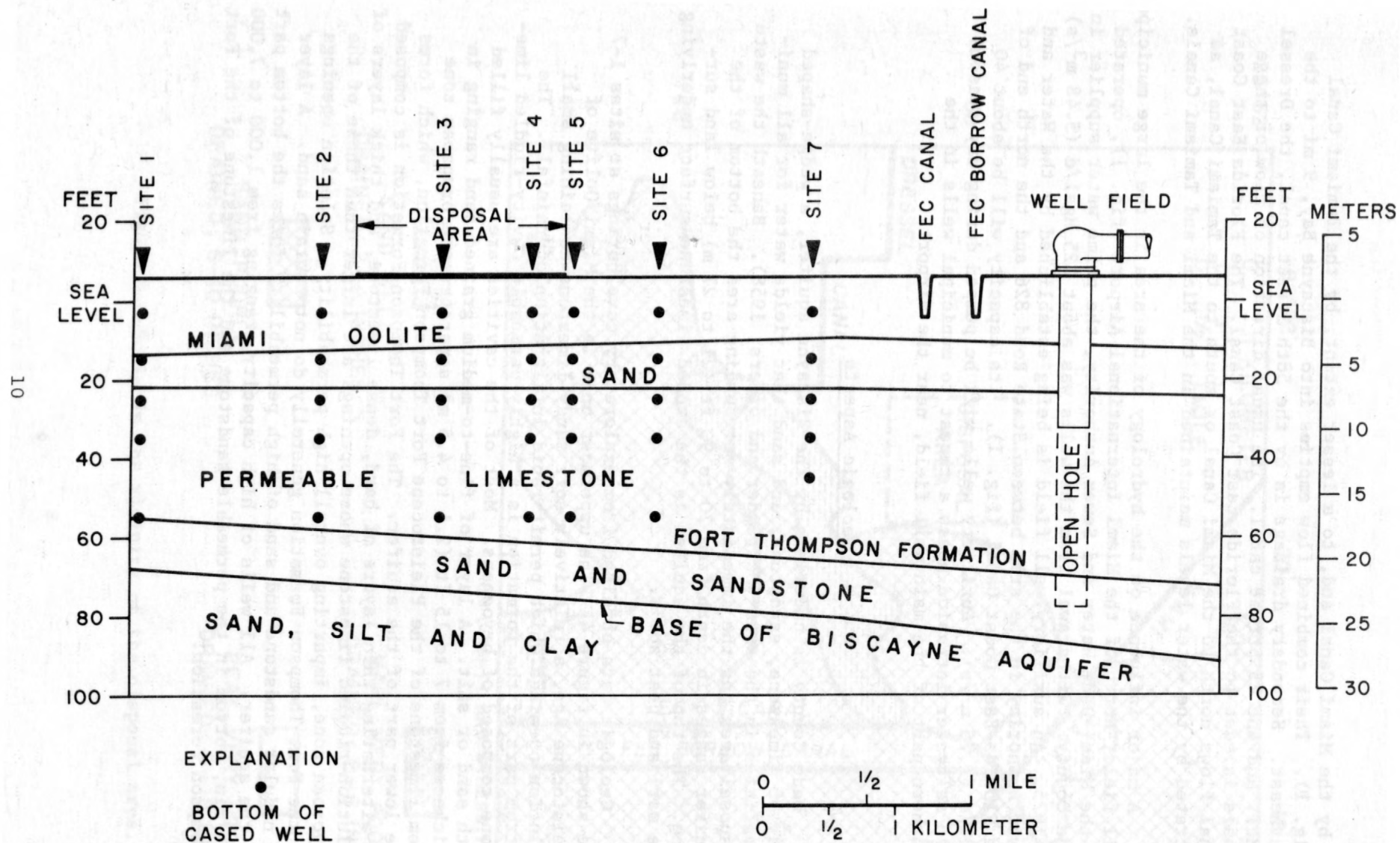


Figure 4.--Generalized geologic section in the vicinity of the disposal area.

The Biscayne aquifer is underlain by fine sand, silt, and clay to a depth of about 700 ft (210 m). This thick section of relatively impermeable material retards downward movement of water from the Biscayne aquifer as well as upward movement of mineralized artesian water from the deep Floridan aquifer.

Hydrologic Aspects

Water-level Fluctuations

The Biscayne aquifer is recharged by local rainfall, primarily during the rainy season. Therefore ground-water levels are highest during the rainy season and lowest near the end of the dry season, as shown by the hydrograph of well G-1165 (location in fig. 2) in figure 5.

The average ground-water level at the waste-disposal site is 3 ft (0.9 m) above sea level or 2 ft (0.6 m) below the natural land surface. The water table slopes upward to the west to 7 ft (2.1 m) above sea level in Conservation Area 3B, where water is impounded during the rainy season and part of the dry season, and slopes downward toward the Miami Canal and the municipal well field (fig. 6). The water-level profiles in figure 7 show the shallow depth of ground-water levels beneath the waste-disposal area, and the influence that the heavy pumping in the well field has on water levels. The decline in water levels in the area west of the well field between October 8, 1974 and May 6, 1975 ranged from 1 ft to 1.5 ft (0.3 to 0.45 m). For the days that each profile was prepared, the water level in the Florida East Coast (FEC) Canal and the FEC borrow canal was higher than the ground-water level, indicating that water was moving from the canals into the ground-water system. The borrow canal is fed at the north end by flow from the Miami Canal. The FEC Canal is fed primarily by the Miami Canal, but also at times by northward flow from the Tamiami Canal and eastward flow from the 58 Street canal, the Dressel Canal and the 25 Street canal (fig. 1).

Aquifer Characteristics and Ground-water Flow

Ground-water flow in north Dade County east of Levee 30 Canal is eastward along lines perpendicular to the water-level contours shown in figure 6. The two major influences on the direction and rate of flow are drainage by the Miami Canal and the pumping from the municipal wells near the Miami Canal. During the rainy season the 36th Street control structure in the Miami Canal near the well field (fig. 6) is opened repeatedly to release surplus water from inland parts of the canal drainage basin, thereby minimizing flooding in low areas. Thus, when the canal is draining, the ground water in the vicinity of the waste-disposal area that moves into the canal is ultimately discharged through the control structure. Eastward flow of ground water is also induced by the continuous pumping at the municipal well field where the withdrawal

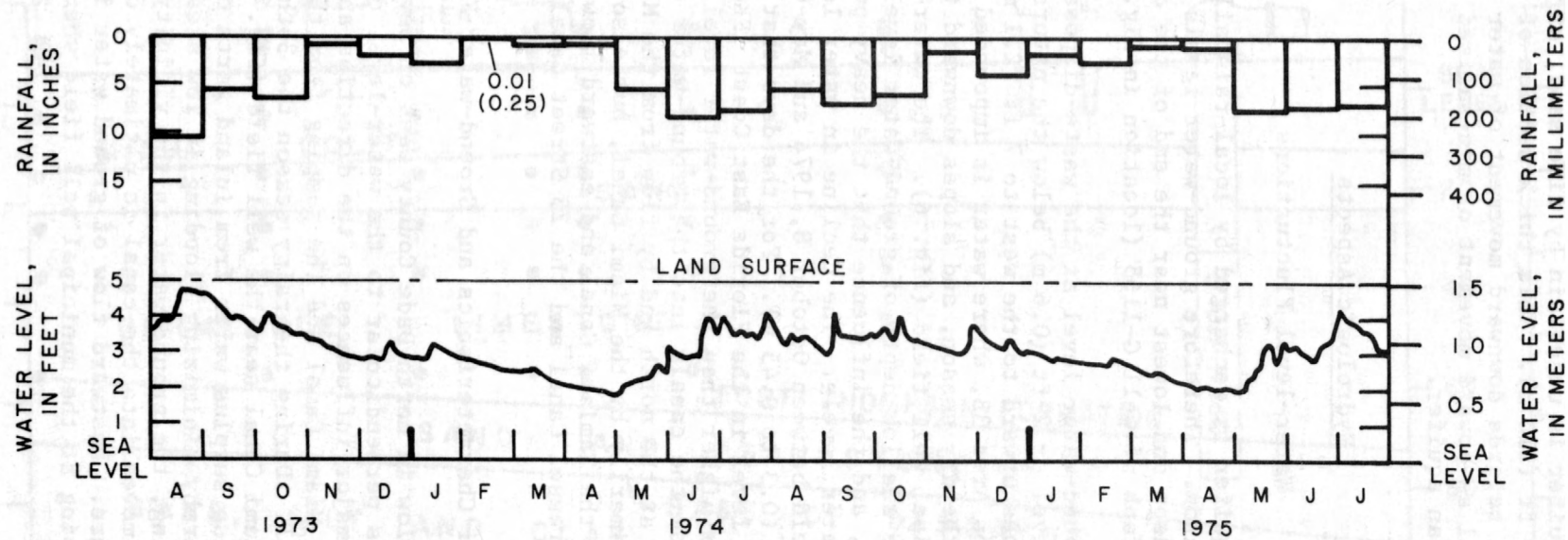


Figure 5.--Well G-1165 and rainfall for August 1973 - July 1975.

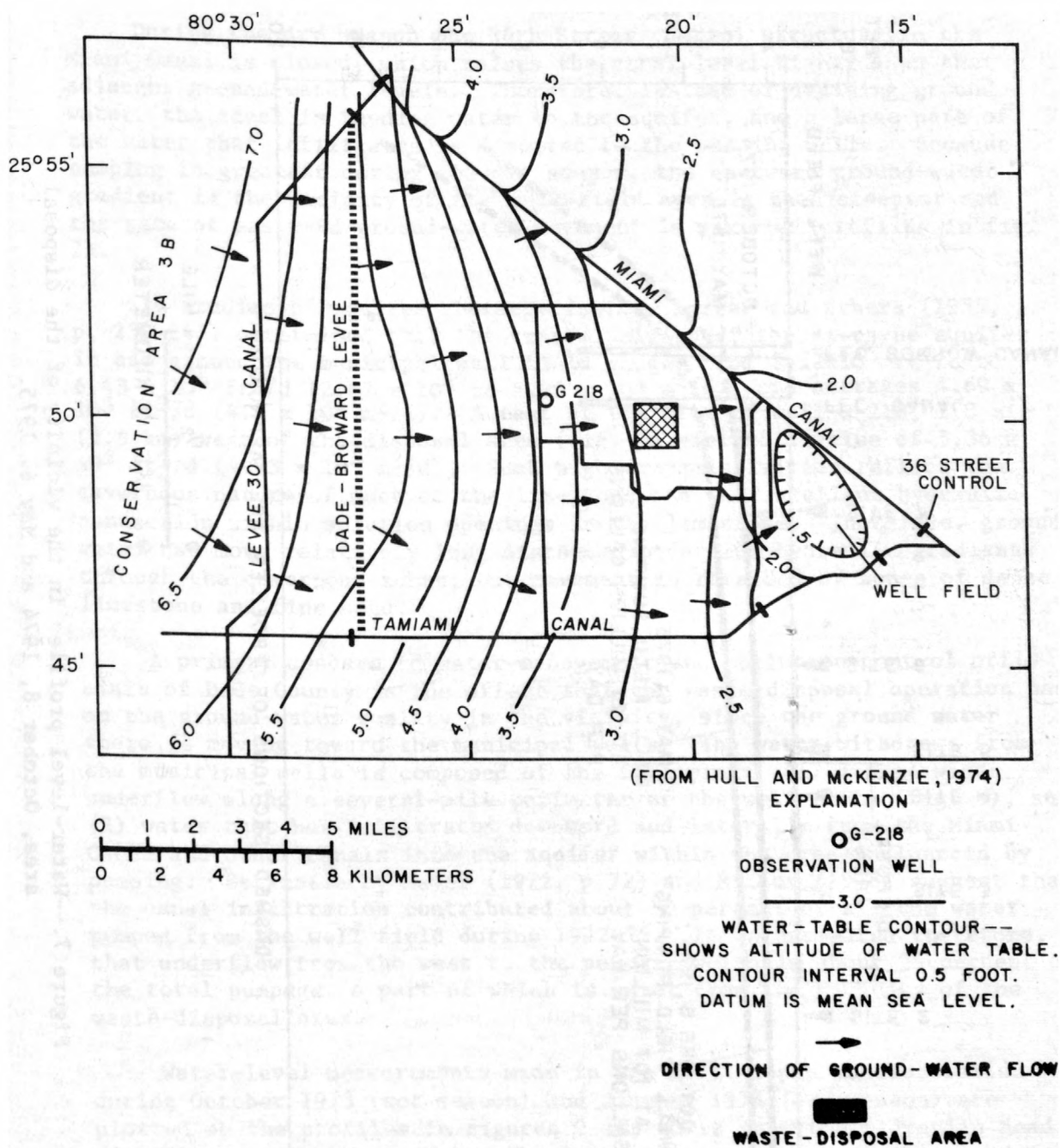


Figure 6.--Average water levels in part of north Dade County, 1960-1973.

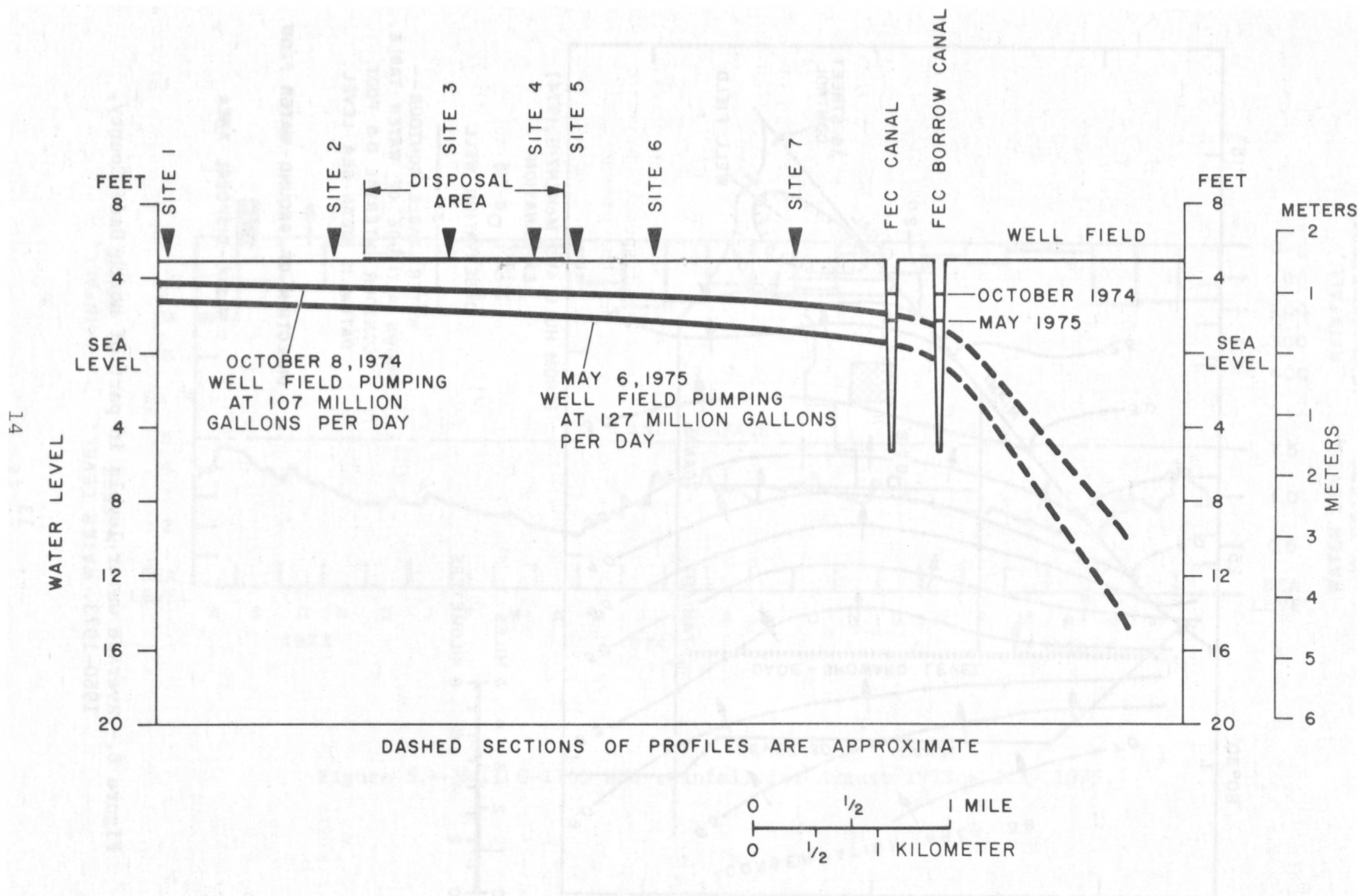


Figure 7.--Water-level profiles in the vicinity of the disposal area, October 8, 1974 and May 6, 1975.

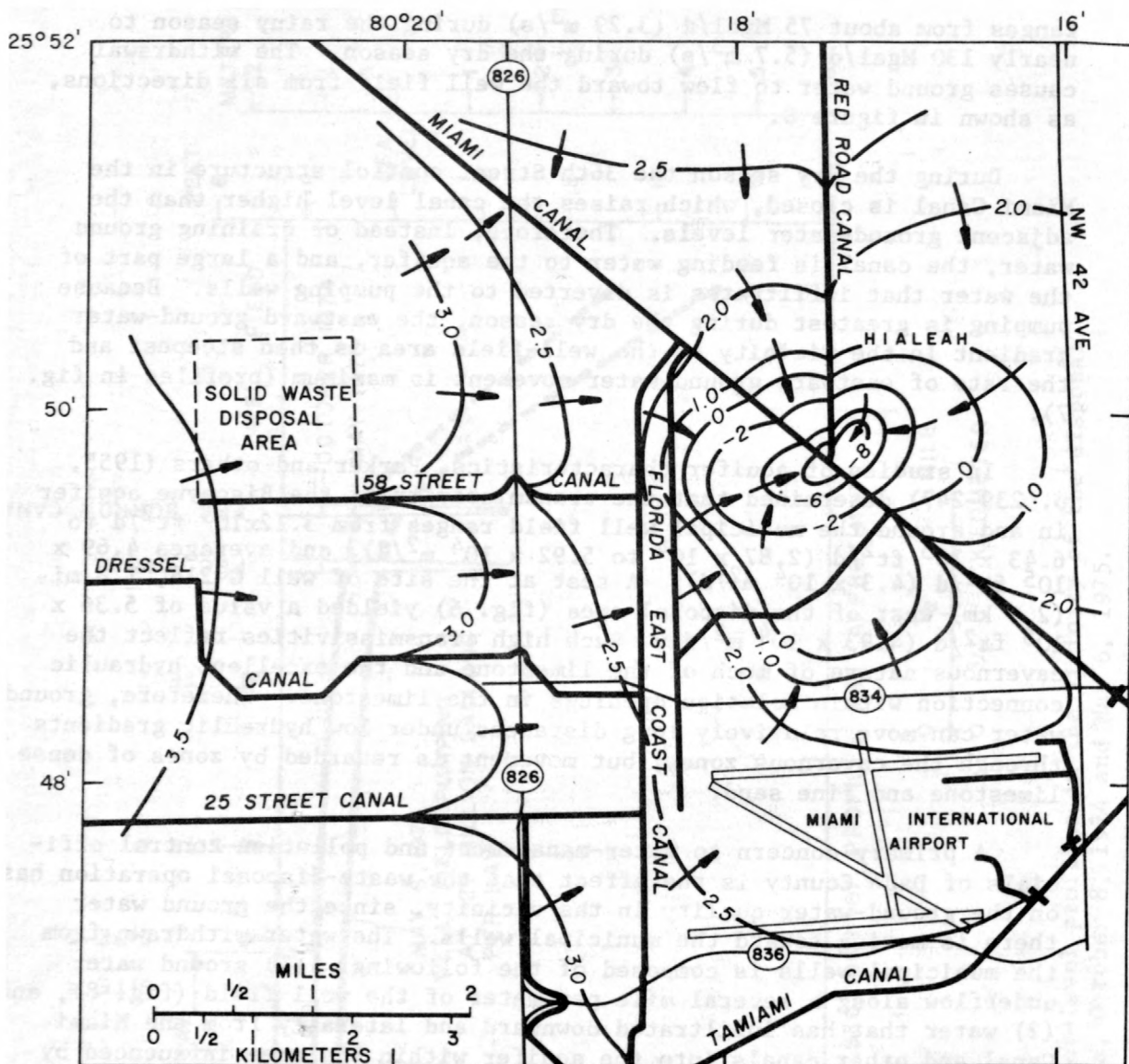
ranges from about 75 Mgal/d ($3.29 \text{ m}^3/\text{s}$) during the rainy season to nearly 130 Mgal/d ($5.7 \text{ m}^3/\text{s}$) during the dry season. The withdrawal causes ground water to flow toward the well field from all directions, as shown in figure 8.

During the dry season the 36th Street control structure in the Miami Canal is closed, which raises the canal level higher than the adjacent ground-water levels. Therefore, instead of draining ground water, the canal is feeding water to the aquifer, and a large part of the water that infiltrates is diverted to the pumping wells. Because pumping is greatest during the dry season, the eastward ground-water gradient in the vicinity of the well-field area is then steepest and the rate of eastward ground-water movement is maximum (profiles in fig. 7).

In studies of aquifer characteristics, Parker and others (1955, p. 239-247) determined that the transmissivity of the Biscayne aquifer in and around the municipal well field ranges from $3.12 \times 10^5 \text{ ft}^2/\text{d}$ to $6.43 \times 10^5 \text{ ft}^2/\text{d}$ (2.87×10^4 to $5.92 \times 10^4 \text{ m}^2/\text{d}$), and averages $4.69 \times 10^5 \text{ ft}^2/\text{d}$ ($4.3 \times 10^4 \text{ m}^2/\text{d}$). A test at the site of well G-218, 1.8 mi (2.9 km) west of the disposal area (fig. 6) yielded a value of $5.36 \times 10^5 \text{ ft}^2/\text{d}$ ($4.93 \times 10^4 \text{ m}^2/\text{d}$). Such high transmissivities reflect the cavernous nature of much of the limestone and the excellent hydraulic connection within solution openings in the limestone. Therefore, ground water can move relatively long distances under low hydraulic gradients through the cavernous zones; but movement is retarded by zones of dense limestone and fine sand.

A primary concern to water-management and pollution-control officials of Dade County is the effect that the waste-disposal operation has on the ground-water quality in the vicinity, since the ground water there is moving toward the municipal wells. The water withdrawn from the municipal wells is composed of the following: (1) ground water underflow along a several-mile perimeter of the well field (fig. 8), and (2) water that has infiltrated downward and laterally from the Miami Canal and other canals into the aquifer within the area influenced by pumping. Estimates by Meyer (1972, p 72) and Miller (1978) suggest that the canal infiltration contributed about 50 percent of all the water pumped from the well field during 1972-75. It is estimated therefore, that underflow from the west to the pumping wells is about 25 percent of the total pumpage, a part of which is water from the vicinity of the waste-disposal area.

Water-level measurements made in the multi-depth monitor wells during October 1973 (wet season) and January 1974 (dry season) are plotted on the profiles in figures 9 and 10 to show the hydraulic head distribution in the aquifer. The lateral hydraulic gradient ranged from 0.00012 ft/ft in October 1973 to 0.000052 ft/ft in January 1974. The vertical equipotential lines show that ground-water flow was horizontal and eastward.



EXPLANATION

— 2.5 —

WATER-TABLE CONTOUR --
SHOWS ALTITUDE OF WATER TABLE.
CONTOUR INTERVAL 0.5, 1.0, AND 2.0 FEET
DATUM IS MEAN SEA LEVEL.



GROUND-WATER FLOW



CANAL AND CONTROL

Figure 8.--Water-table altitude of the Hialeah-Miami Springs well-field area, October 8, 1974.

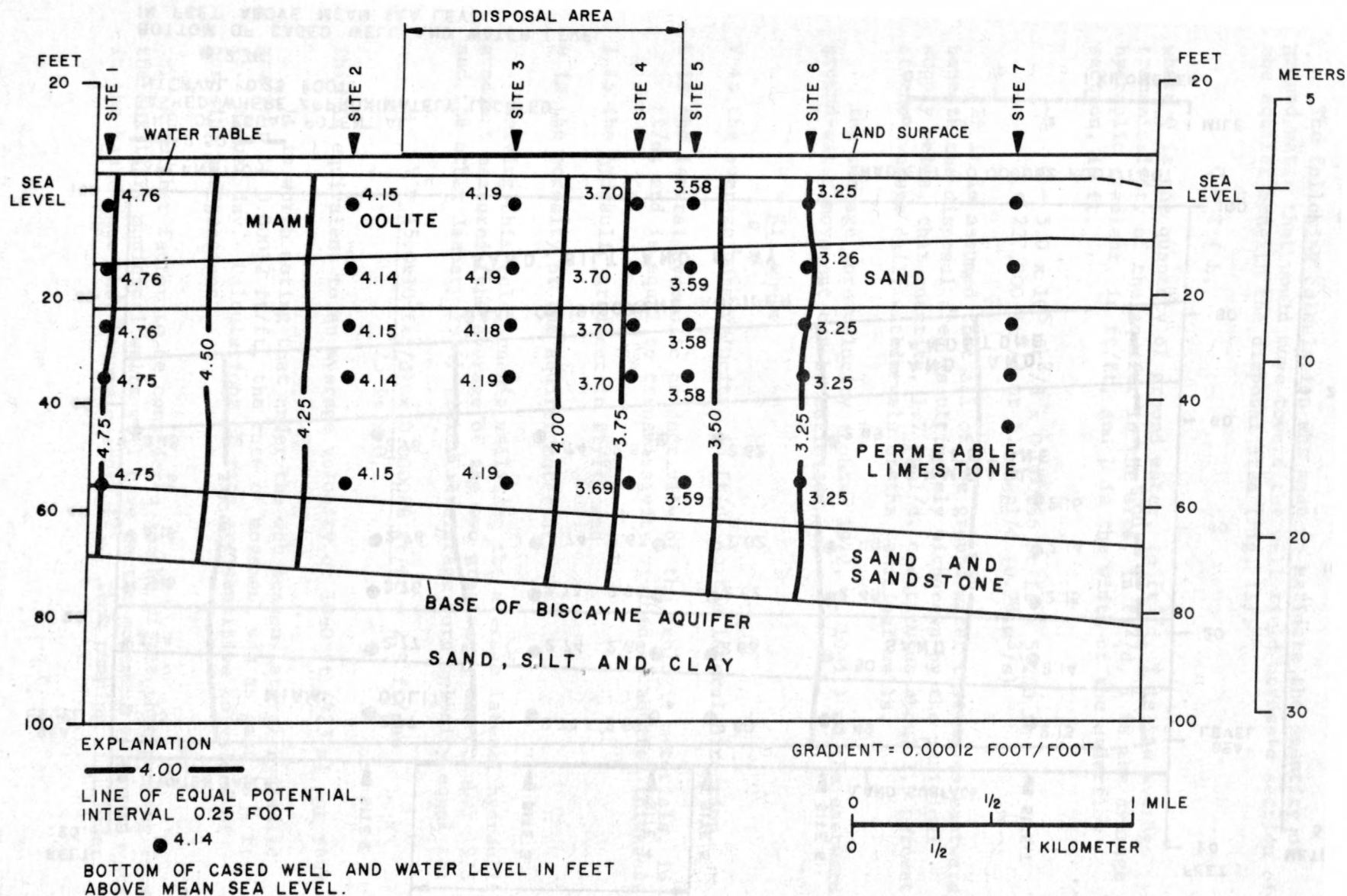


Figure 9.--Lines of equal potential in vicinity of disposal area, October 1973.

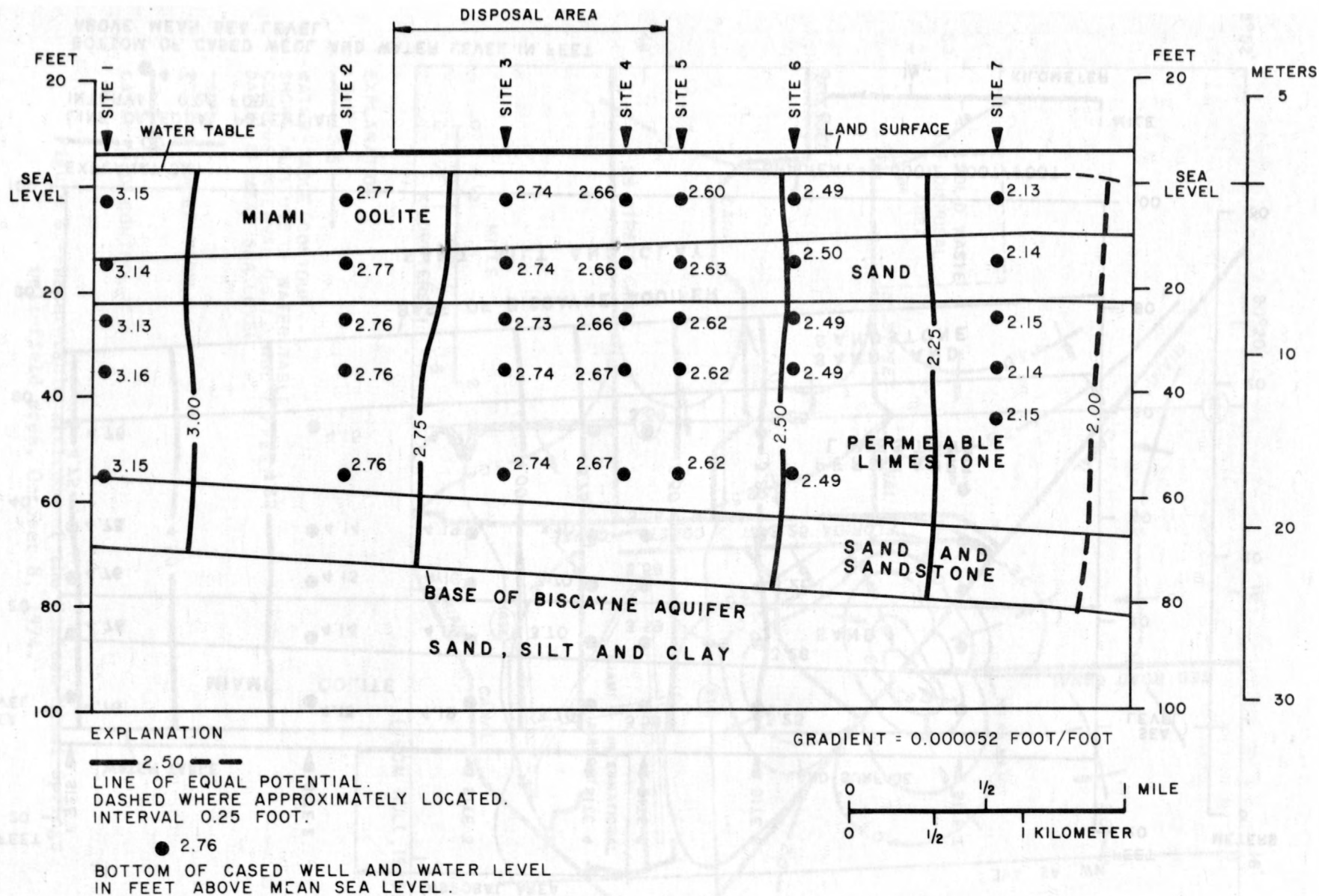


Figure 10.--Lines of equal potential in vicinity of disposal

The following calculation was made to estimate the quantity of ground water that would move toward the well field across a section of the aquifer beneath the disposal area (fig. 11):

$$Q = T I L,$$

where Q is the quantity of ground water, in ft³/d, T is the average transmissivity of the aquifer in the area, in ft²/d, I is the average hydraulic gradient, in ft/ft, and L is the width of the underflow section, in ft.

$$Q = 5.0 \times 10^5 \text{ ft}^2/\text{d} \times 0.000086 \text{ ft/ft} \times 5,280 \text{ ft}$$

$$Q = 227,000 \text{ ft}^3/\text{d} \text{ or } 1.7 \text{ Mgal/d (0.74 m}^3/\text{s)}$$

If it is assumed that all of the ground water that moves eastward beneath the disposal area is ultimately withdrawn by the municipal supply wells, that quantity, 1.7 Mgal/d, constitutes about 1.5 percent of the average daily withdrawals of the municipal wells.

The average pore velocity (Lohman 1972, p. 10-11) of the eastward ground-water movement can be estimated by:

$$V = \frac{KI}{\theta} \text{ where}$$

V is the average pore velocity, in ft/d, in the lateral direction.

K is the lateral hydraulic conductivity of the geologic materials, in ft/d; and is equal to transmissivity divided by aquifer thickness.

I is the hydraulic gradient in ft/ft, and

θ is the porosity of the aquifer material.

Solving this relationship utilizing the average lateral hydraulic gradient measured (the average of the two gradients, one October 1973 and the other January 1974) yields an average pore velocity equal to:

$$V = \frac{(5.0 \times 10^5 \text{ ft}^2/\text{d}) \times 0.000086 \text{ ft/ft}}{75 \text{ ft} \times 0.2} = 2.9 \text{ ft/day}$$

This is equivalent to an average velocity or 1060 ft (323 m) per year.

It is worth noting that under the wet season lateral hydraulic gradient of 0.00012 ft/ft, the rate of movement was as fast as 4 ft (1.2 m) per day. Calculations of rate are sensitive to values of porosity and gradient.

A further factor to be considered is the effect that pumping from the auxiliary municipal wells will have on the movement of ground water in the basin once they become operational. That pumping will lower

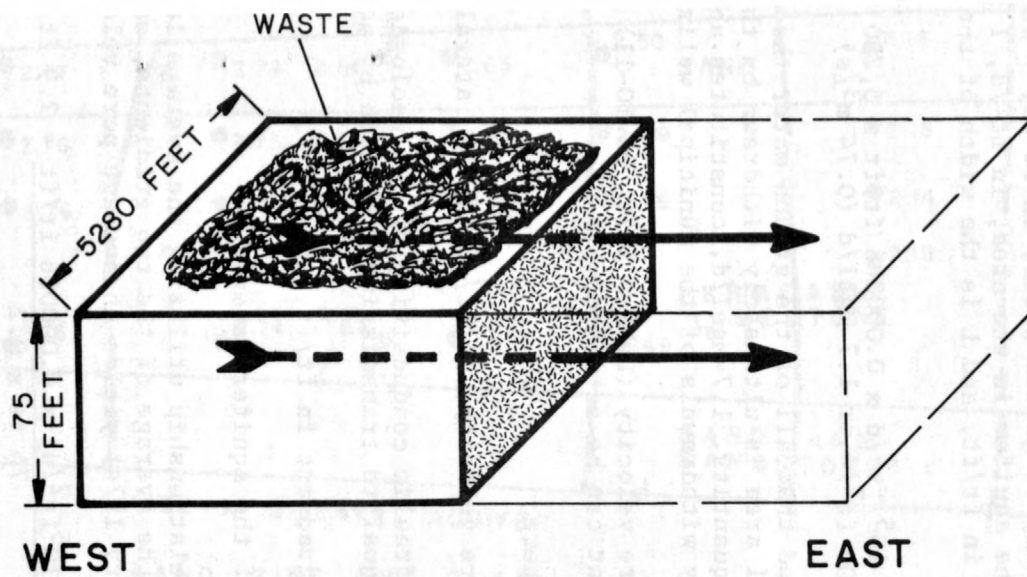


Figure 11.--Delineation of the flow section in Biscayne aquifer beneath disposal area.

water levels northwest of the existing area of pumping and thereby divert to the northeast some of the ground water that normally would flow east. Because the area of the auxiliary wells is relatively close to the waste-disposal area, the movement of water beneath the disposal area would be diverted northeast at an accelerated rate due to an increase in gradient in that direction.

WATER QUALITY

Sampling Locations and Methods

Observation wells were installed at the seven locations shown in figure 2. Sites 1 and 2 are upgradient of the disposal area and wells there tapped uncontaminated ground water. Sites 3 and 4 are within the disposal area and sites 5, 6, and 7 are downgradient of this contaminant source. Water from wells at these locations showed various degrees of contamination.

Individual wells at the 7 sites are identified in this report by the site number and the well depth (table 3). For example, well 1-10 is the 10-foot (3 m) deep well at site 1. Well 3-10 is site 3, 10 ft (3 m) below natural land surface. The actual depth of well 3-10 however, is 20 ft (6 m) since 10 ft (3 m) of waste-fill material overlies natural land surface.

A well is also identified by a 15-digit station identification based on its latitude, longitude, and sequence number. Well 1-10 is:

2 5 4 9 4 8

0 8 0 2 2 1 3

03

Latitude

Longitude

Sequence number

Retrieval of analytical results is possible from both Watstore (U.S. Geological Survey) and Storet (Environmental Protection Agency) using the station identification number. The local well numbers, station identification, site location, and well depths are shown in table 3.

Analyses of ground water obtained in 1941 and 1942 from observation wells G-218 (fig. 6) and G-224 (fig. 2) are given in table 4. These analyses represent the ground-water quality in the area before the establishment of the waste-disposal facility. Well G-224 was at the southeast corner of what is now (1976) the waste-disposal area.

Water samples were obtained quarterly during 1973-75 from the multi-depth monitoring wells by use of a vacuum pump as shown in figure 12. Sterile PVC (polyvinyl chloride) tubing is lowered down the well into the water. The upper end of the tubing is attached to a 5-gal (19-L) glass container. Water flows into the glass jar under the induced vacuum. Twice the volume of water standing in the well casing is with-

Table 3.--Designation and sampling period of wells.

Site No.	Depth below natural land surface in feet	Well number (Dade County)	Station I.D.	Date of first sampling	Date of last sampling	Number of samples
1	10	G-3027	254948080221303	73-08-16	75-07-08	9
	20	G-3025	254948080221301	73-05-23	75-07-08	10
	30	G-3028	254948080221304	73-08-16	75-07-08	9
	40	G-3029	254948080221305	73-08-16	75-07-08	9
	60	G-3026	254948080221302	73-05-23	75-07-08	10
2	10	G-3030	254948080212301	73-08-14	75-07-08	9
	20	G-3031	254948080212302	73-08-14	75-07-08	9
	30	G-3032	254948080212303	73-08-14	75-07-08	9
	40	G-3033	254948080212304	73-08-14	75-07-08	9
	60	G-3034	254948080212305	73-08-14	75-07-08	9
3	10	G-3035	255000080204701	73-08-15	75-07-09	9
	20	G-3036	255000080204702	73-08-15	75-07-09	9
	30	G-3037	255000080204703	73-08-16	75-07-09	9
	40	G-3038	255000080204704	73-08-16	75-07-09	9
	60	G-3039	255000080204705	73-08-16	75-07-09	9
4	10	G-3040	254950080202501	73-08-15	75-07-09	9
	20	G-3041	254950080202502	73-08-15	75-07-09	9
	30	G-3042	254950080202503	73-08-15	75-07-09	9
	40	G-3043	254950080202504	73-08-15	75-07-09	9
	60	G-3044	254950080202505	73-08-15	75-07-09	9
5	10	G-3045	254950080201201	73-08-14	75-07-10	9
	20	G-3046	254950080201202	73-08-14	75-07-10	9
	30	G-3047	254950080201203	73-08-14	75-07-10	9
	40	G-3048	254950080201204	73-08-14	75-07-10	9
	60	G-3049	254950080201205	73-08-14	75-07-10	9
6	10	G-3050	254950080195001	73-08-13	75-07-10	9
	20	G-3051	254950080195002	73-08-13	75-07-10	9
	30	G-3052	254950080195003	73-08-13	75-07-10	9
	40	G-3053	254950080195004	73-08-13	75-07-10	9
	60	G-3054	254950080195005	73-08-13	75-07-10	9
7	10	G-3056	255013080190701	74-01-14	75-07-11	7
	20	G-3057	255013080190702	74-01-14	75-07-11	7
	30	G-3058	255013080190703	74-01-14	75-07-11	7
	40	G-3059	255013080190704	74-01-14	75-07-11	7
	50	F-491*	255013080190705	74-01-14	75-07-11	7

* Fire well

Depth of natural land surface is 10 feet below top of fill at site 3.

Table 4.--Chemical analyses of water from wells G-218 and G-224,
1941-1942 (from Parker and others, 1955).

	Well G-218	Well G-224
Depth, ft	64	37
Temperature, degrees F	74	74
Color	70	70
Conductance, mmho	527	566
Calcium, mg/L	93	102
Magnesium, mg/L	6.8	9.6
Sodium and potassium, mg/L	11	3.7
Bicarbonate, mg/L	312	300
Sulfate, mg/L	2.5	28
Chloride, mg/L	18	19
Nitrate, mg/L	.0	.0
Total dissolved solids, mg/L	285	310
Hardness, mg/L	260	294

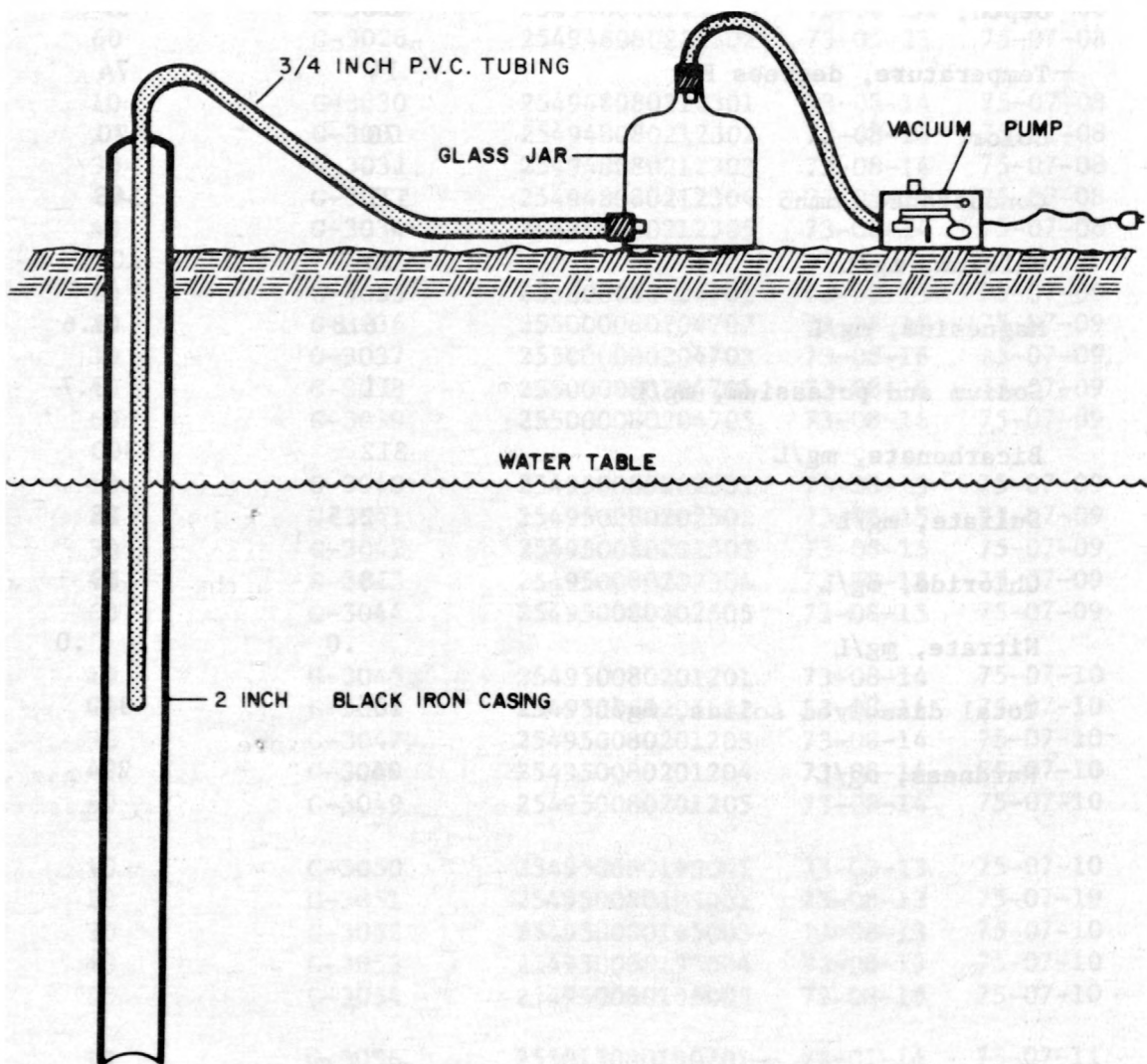


Figure 12.--Apparatus for collecting water samples from small diameter wells.

drawn and discarded before a sample is kept for analyses. After the sample is collected, the end of the tubing is crimped and pulled from the well. Samples for bacteria analysis are drained into a sterile bottle directly from the tubing.

During storage or shipment, most water samples change somewhat in chemical and physical character. To avoid introduction of errors into the analysis from this source, analyses of some constituents and properties were run in the field. Where it was not feasible to run the analysis in the field for time-sensitive parameters, the samples were shipped without delay by bus in refrigerated containers to the Geological Survey Laboratory in Ocala, Florida. Samples for major dissolved ions, trace metals, and organic substances were mailed to the Survey Laboratory in Atlanta, Georgia, for analysis. The numbers of samples collected, the average concentrations and ranges in concentration of the parameters analyzed, and the methods of performing the analyses are listed in table 5.

Occurrence and Movement of Leachate

The leachate from deposits of solid waste is generally harmful or toxic because it contains substances that have been dissolved (or are in suspension) from the waste materials. Its content of dissolved or suspended materials and their concentration will depend upon the composition of the waste deposits and the rate of movement and the quantity of the water that infiltrates the waste. Leachate below the 58th Street disposal site results from water or rainfall infiltrating the waste deposits, and by contact of the waste deposits with the zone of saturation in the Biscayne aquifer.

Information from test borings within the disposal area, and reported information from operating personnel indicate that the peat soil within parts of the disposal area was removed before operations began. Refuse was placed directly on the eroded limestone surface of the aquifer, at elevations ranging from 3.5 to 4.0 ft (1 to 1.2 m) above sea level, thereby increasing the opportunity for refuse to be submerged by ground water for extended periods of the rainy season, and for leachate to be generated during these periods.

Major Ions

Chloride

Chloride is a common constituent in ground water throughout south Florida. In undisturbed sections of the Biscayne aquifer, remote from the influences of coastal saltwater intrusion, chloride concentration ranges from 5 to 35 mg/L. Chloride concentrations at sites 1 and 2, west and upgradient of the disposal area, ranged from 20 to 35 mg/L. The average value for the 9 samples of water from each of the 10 wells

Table 5.--Number of water samples collected, average concentrations and ranges in concentration of the parameters analyzed, and the analytical techniques used.

Parameter	Analytical Techniques	Lab	Number of Samples	Average	Units	Range
Well Depth	Tape	F	35		Feet	10 - 70
Temperature	Thermometer	F	321	25.9	Degrees C	23 - 34
Turbidity	Turbidimeter	A	304	23.7	JTU	0 - 380
pH	pH meter	F	334	7.3*	pH Units	6.8 - 8.2
Specific Conductance	Wheatstone Bridge	F	334	728	mmho	125 - 2340
Dissolved Solids Residue	Evaporation 180°C	A	304	412	mg/L	172 - 982
Carbon Dioxide	Calculated		308	37.1	mg/L	2.4 - 149
Alkalinity	Calculated		308	323	mg/L	177 - 1210
Bicarbonate	Titration	F	308	395	mg/L	216 - 1480
Carbonate	Titration	F	308	0.989	mg/L	0 - 304
Total Hardness	Calculated		305	294	mg/L	170 - 1100
Non Carbonate Hardness	Calculated		304	6.2	mg/L	0 - 72
Calcium	Atomic Absorption	A	304	105.5	mg/L	58.9 - 340
Magnesium	Atomic Absorption	A	305	7.33	mg/L	2 - 63.9
Dissolved Strontium	Atomic Absorption	A	303	815	ug/L	0.9 - 2100
Dissolved Sodium	Atomic Absorption	A	305	26.9	mg/L	0.5 - 150
Dissolved Potassium	Atomic Absorption	A	305	8.07	mg/L	0.3 - 100
Dissolved Lithium	Atomic Absorption	A	196	1.64	ug/L	0 - 32.9
Chloride	Mercurimetric	MA	305	42.4	mg/L	4.6 - 200
Sulfate	Spectrophotometric	A	305	2.9	mg/L	0 - 47
Fluoride	Colorimetric	A	305	0.311	mg/L	0 - 1.7
Silica	Colorimetric	A	305	8.04	mg/L	3.7 - 25
Total Manganese	Atomic Absorption	A	199	49.4	ug/L	0 - 630
Total Iron	Atomic Absorption	A	305	4304	ug/l	0 - 49,000
Color	Color Comparator	A	305	115	Pt-Co Std.	20 - 500
Ortho Phosphate	Auto Analyzer	O	302	0.021	mg/L	0 - 0.399
Total Phosphorus	Digestion, Auto Analyzer	O	303	0.044	mg/L	0 - 0.999
Total Nitrogen	Calculated Sum		299	11.38	mg/L	0.39 - 109
Organic Nitrogen	Digestion, Auto Analyzer	O	304	1.58	mg/L	0 - 36.9
Ammonium	Auto Analyzer	O	304	9.65	mg/L	0.02 - 103
Nitrite	Auto Analyzer	O	303	0.008	mg/L	0 - 0.099

Table 5.--Number of water samples collected, average concentrations and ranges in concentration of the parameter analyzed, and the analytical techniques used (Cont'd).

<u>Parameter</u>	<u>Analytical Techniques</u>	<u>Lab</u>	<u>Number of Samples</u>	<u>Average</u>	<u>Units</u>	<u>Range</u>
Nitrate	Auto Analyzer	O	303	0.006	mg/L	0 - 0.899
Total Organic Carbon	Carbon Analyzer	O	301	21.7	mg/L	5.0 - 150
BOD	5-day incubation	MO	267	0.83	mg/L	0 - 7
COD	Titrametric	O	204	62.0	mg/L	4 - 200
Oil and Grease	Extraction, Gravimetric	A	157	6.5	mg/L	0 - 32
Detergents	Spectrophotometer	A	162	.20	mg/L	0 - 2.2
Total Coliforms	Filtration, 24 hr. incubation	M	298	1730	colonies/100 mL	0 - 100,000
Fecal Coliforms	Filtration, 24 hr. incubation	M	304	.7	colonies/100 mL	0 - 44
Fecal Streptococci	Filtration, 48 hr. incubation	M	303	4.6	colonies/100 mL	0 - 140

* Median pH value

A Atlanta laboratory

M Miami laboratory

O Ocala laboratory

in sites 1 and 2 was 26 mg/L. This value is considered the background or uncontaminated chloride concentration for the ground water in this interior part of Dade County. Chloride in the ground water beneath the disposal area, and east of it, is a combination of the chloride from the leachate and the background chloride. The difference in concentration between the observed and the background values gives a picture of the leachate concentration and also of the decrease in concentration as the chloride moves vertically and laterally.

As ground water moves downgradient (east) the leachate--and the added chloride ions from leachate--move with the natural ground-water flow. Since the process of leachate mixing occurs both laterally and vertically, a three-dimensional plume is formed. This can be visualized, in plan view, as tear-shaped and moving away from the source.

To facilitate the description of the various processes it is helpful to calculate the chloride in excess of background concentrations in terms of percentage of chloride from the leachate as sampled in the monitor wells. The concentration of the leachate is taken as the greatest average concentration obtained from any one of the monitor wells. The computation is:

$$\frac{\text{Chloride concentration of sample} - \text{Background chloride} \times 100}{\text{Chloride concentrations of Leachate} - \text{Background chloride}} = \text{Percentage of chloride from leachate}$$

The values in figure 13 are the average percentage of chloride contributed by leachate in the ground water at the four well sites in and downgradient of the disposal area. The chloride concentration of the leachates is arbitrarily taken as the maximum average chloride concentration in the 10-ft monitor well, in this case well 3-10. Chloride concentration is relatively constant 20 ft (6-m) or more below land surface, except near an active source of contamination. Thus, the use of an average leachate chloride does not bias the indication of how high the chloride concentration is or how far chloride has migrated. As shown in figure 13, there is a definite indication that leachate containing chloride in excess of background concentration is detectable more than one-half mile (0.8 km) downgradient from the disposal source.

The low percentage of chloride leachate (20 percent) in the 10-ft (3-m) well at site 4 (fig. 13) probably is due to the inactivity along the east section of the disposal area for approximately 15 years. As the nearly 60 inches (1,500 mm) of rainfall annually infiltrates the waste materials, the readily soluble components are carried to the saturated zone and then flow downgradient. The percentage of leachate sodium also was low at the 10-ft (3-m) depth at site 4. Other leachate components do not show this behavior, presumably due to their lower solubility in water.

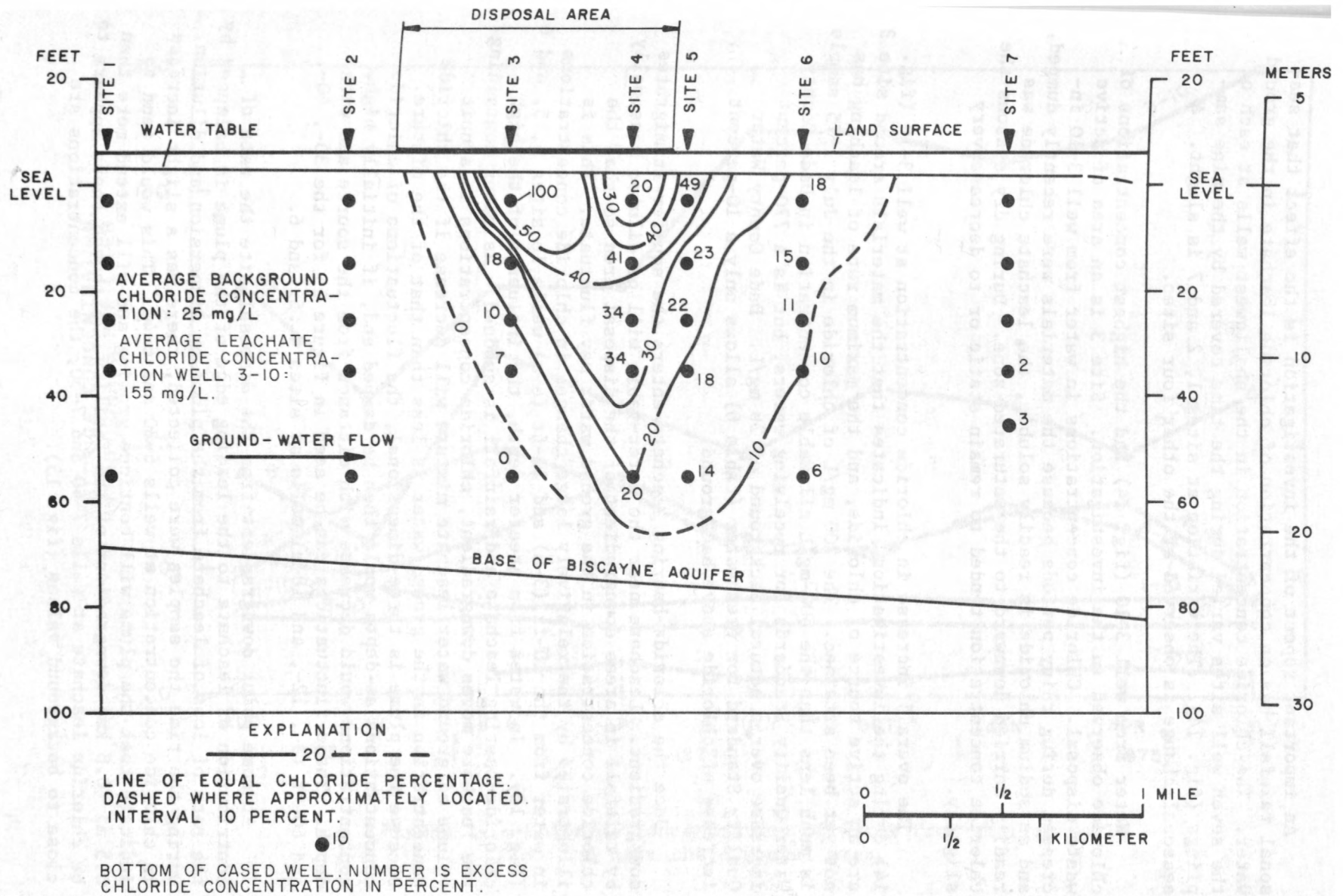


Figure 13.--Average excess chloride concentration, in percent, in ground water at and near the disposal area.

An important aspect of the investigation is the effect that seasonal rainfall has on concentration of chloride leachate in the ground water. The chloride concentration in the shallowest wells at each of the seven well sites varied during the time covered by the nine samplings (fig. 14). The variation at sites 1, 2 and 7 is slight. A seasonal change is observed at the other four sites.

Water from well 3-10 (fig. 14) had the highest concentrations of chloride observed in the investigation. Site 3 is an area of active waste disposal. Chloride concentrations in water from well 3-10 increased during rainy periods because the materials were recently dumped, and as sodium chloride is readily soluble, the leachate chloride was readily carried downward to the saturated zone. During dry seasons the chloride concentration tended to remain static or to decrease very slightly.

The overall increase in chloride concentration at well 3-10 (fig. 14) during the investigation, indicates that the materials around site 3 are an active source of chloride, and the maximum rate of leaching has not yet been attained. The 200 mg/L of chloride in the July 1975 sample is much less than the 500-mg/L allowable concentration in Dade County Water Quality Standards for receiving waters, but is a 770-percent increase over a natural background of 26 mg/L. Dade County Water Quality Standard for freshwater (table 6) allows only a 10-percent increase of chloride above background.

Once the chloride-bearing leachate enters the aquifer it migrates downgradient. Leachate near the water-table will be diluted seasonally by rainfall in areas downgradient of the disposal area so that the chloride concentration in the ground water may fluctuate. This is illustrated by the relatively large changes in chloride concentrations in water from the 10-ft (3-m) and 20-ft (6-m) wells in sites 4, 5, and 6 (fig. 15). In water from greater depth, the influence of the high chloride-bearing leachate and rainfall is subdued. As water containing the leachate moves downgradient, chloride concentrations in a unit volume of ground water/leachate mixture will decrease if the chloride concentration in the ground water is less than that of the mixture. Because the plume is three-dimensional, the fluctuations of chloride concentrations at depth would then be damped and, if initially high, concentrations would decrease with distance from the source and with depth. These fluctuations can be seen in figure 15 for the 30-, 40-, and 60-ft (9-, 12-, and 18-m) wells at sites 4, 5, and 6.

At some point downgradient from the disposal site the rate of contribution of leachate to the leading edge of the plume is balanced by the rate of loss of leachate from the plume by dispersion and dilution. During the time the samples were collected, there was a slight increase in chloride concentration at wells 6-30 and 6-40. This would tend to indicate that the plume will continue growing and will extend more than 0.5 mi (0.8 km) downgradient of the facility. Although there appears to be chloride leachate at wells 7-40 and 7-50, the concentrations are close to background values (fig. 13).

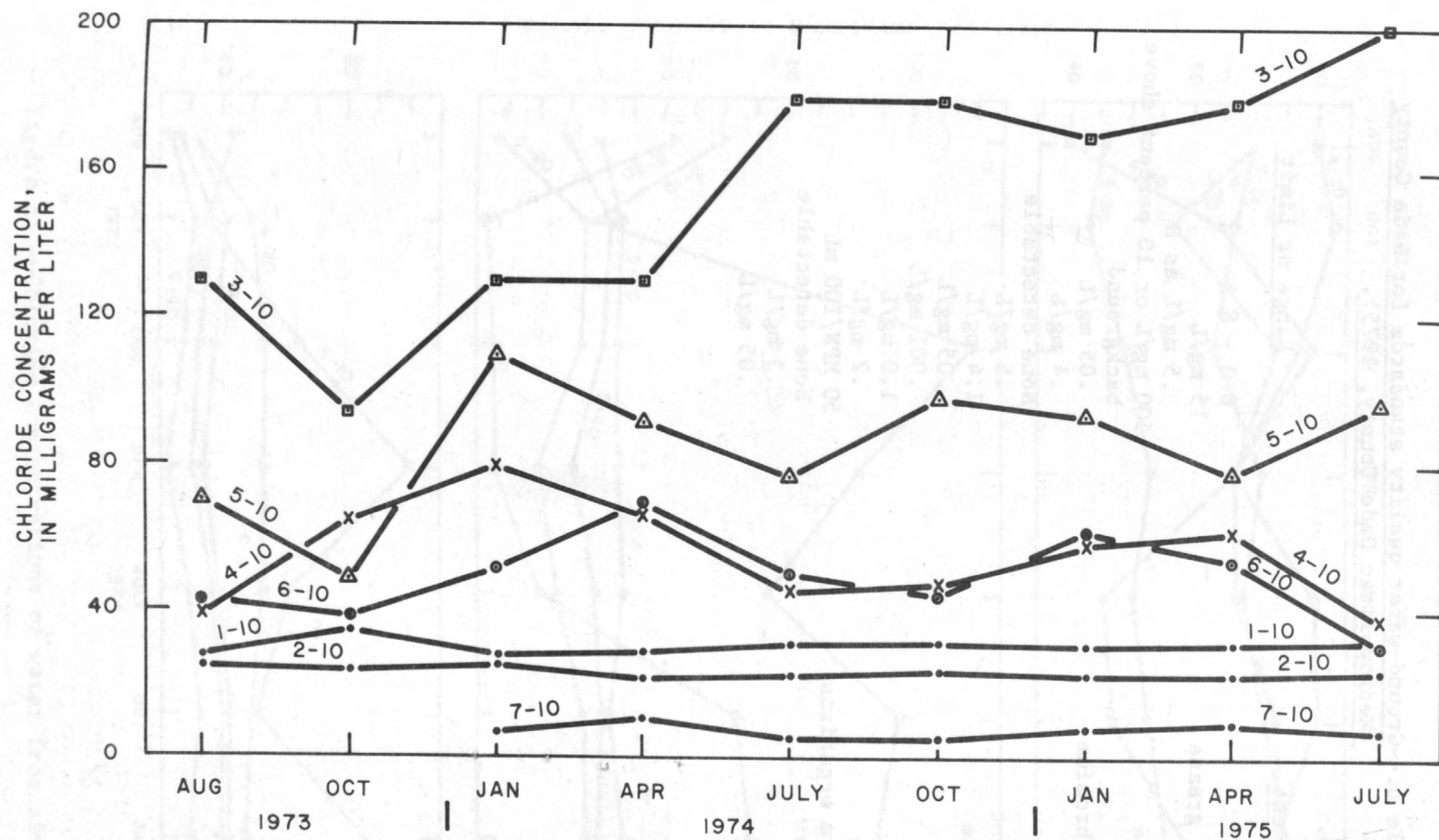


Figure 14.--Chloride concentration of water from shallow wells at and near the disposal area.

Table 6.--Ground-water quality standards for Dade County
(Metropolitan Dade County, 1975).

<u>Constituent</u>	<u>Range or Limit</u>
pH	6.0 - 8.5
Oil and grease	15 mg/L
Ammonia	.5 mg/L as N
Chloride	500 mg/L or 10 percent above background
Total chromium	.05 mg/L
Copper	.4 mg/L
Cyanide	None detectable
Detergent	.5 mg/L
Fluoride	1.4 mg/L
Lead	.05 mg/L
Phenol	.001 mg/L
Zinc	1.0 mg/L
Sulfide	.2 mg/L
Coliform organisms	50 MPN/100 mL
Mercury	None detectable
Iron	.3 mg/L
Arsenic	.05 mg/L

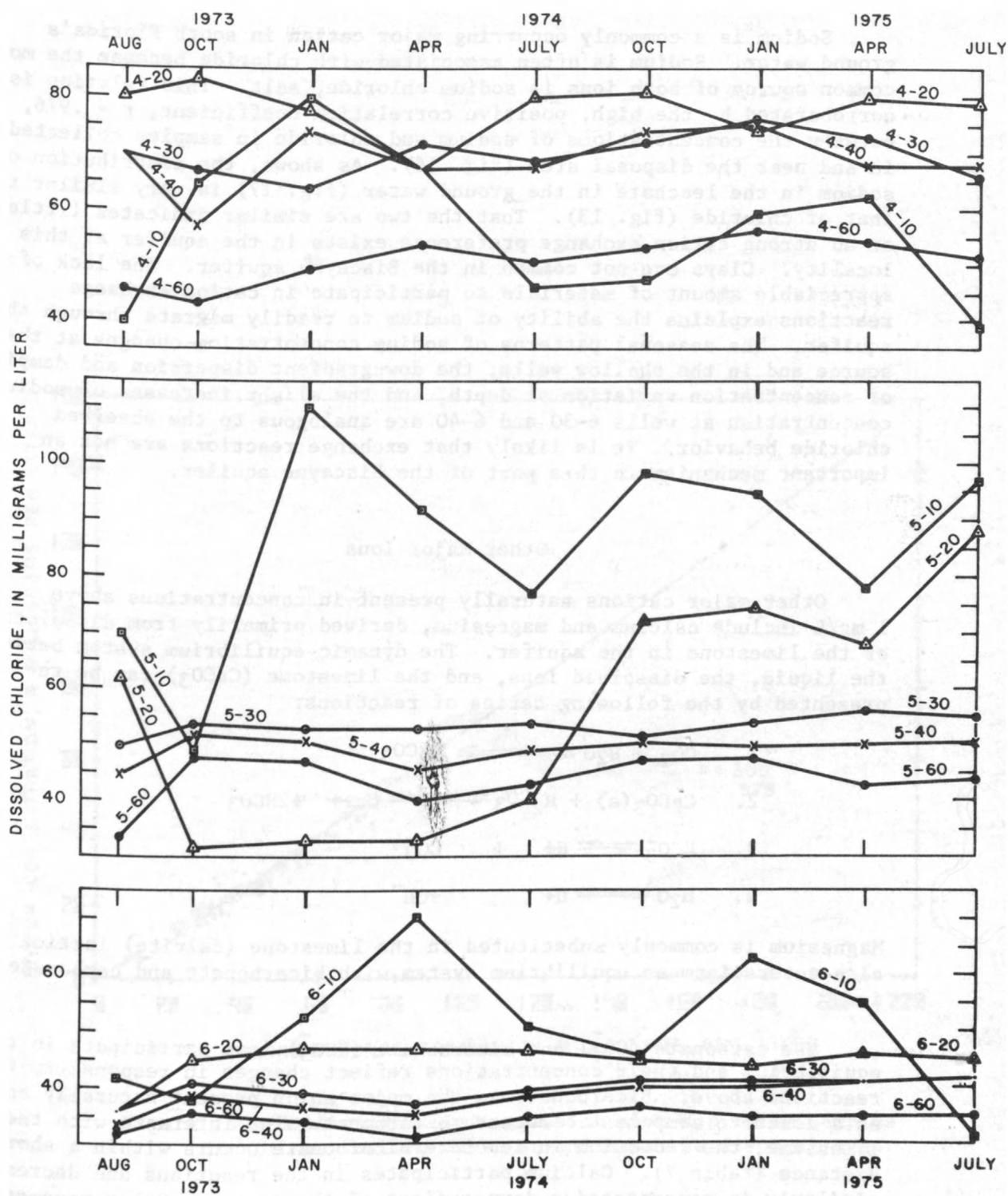


Figure 15.--Chloride concentrations of water from sites 4, 5, and 6.

Sodium

Sodium is a commonly occurring major cation in south Florida's ground water. Sodium is often associated with chloride because the most common source of both ions is sodium chloride, salt. This relation is corroborated by the high, positive correlation coefficient, $r = .976$, between the concentrations of sodium and chloride in samples collected in and near the disposal area (fig. 16). As shown, the distribution of sodium in the leachate in the ground water (fig. 17) is very similar to that of chloride (fig. 13). That the two are similar indicates little or no strong cation exchange preference exists in the aquifer at this locality. Clays are not common in the Biscayne aquifer. The lack of an appreciable amount of materials to participate in cation exchange reactions explains the ability of sodium to readily migrate through the aquifer. The seasonal patterns of sodium concentration changes at the source and in the shallow wells, the downgradient dispersion and damping of concentration variation at depth, and the slight increases of sodium concentration at wells 6-30 and 6-40 are analogous to the observed chloride behavior. It is likely that exchange reactions are not an important mechanism in this part of the Biscayne aquifer.

Other Major Ions

Other major cations naturally present in concentrations above 1 mg/L include calcium and magnesium, derived primarily from dissolution of the limestone in the aquifer. The dynamic equilibrium system between the liquid, the dissolved ions, and the limestone (CaCO_3) can be represented by the following series of reactions:

1. $\text{CO}_2 + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{CO}_3$
2. $\text{CaCO}_3(\text{s}) + \text{H}_2\text{CO}_3 \rightleftharpoons \text{Ca}^{++} + 2\text{HCO}_3^-$
3. $\text{HCO}_3^- \rightleftharpoons \text{H}^+ + \text{CO}_3^{--}$
4. $\text{H}_2\text{O} \rightleftharpoons \text{H}^+ + \text{OH}^-$

Magnesium is commonly substituted in the limestone (calcite) lattice and also enters into an equilibrium system with bicarbonate and carbonate ions.

The carbonate (CO_3^{--}) and bicarbonate (HCO_3^-) ions participate in the equilibrium and their concentrations reflect changes in response to the reactions above. Bicarbonate is the major anion present naturally and as a leachate component. Because bicarbonate also interacts with the limestone, the reduction in leachate bicarbonate occurs within a short distance (table 7). Calcium participates in the reactions and decreases similarly in concentration downgradient of the source. Other parameters which participate in the reactions or are directly affected by the foregoing reactions include pH, carbonate, inorganic carbon, total alkalinity, dissolved solids, total hardness, and strontium.

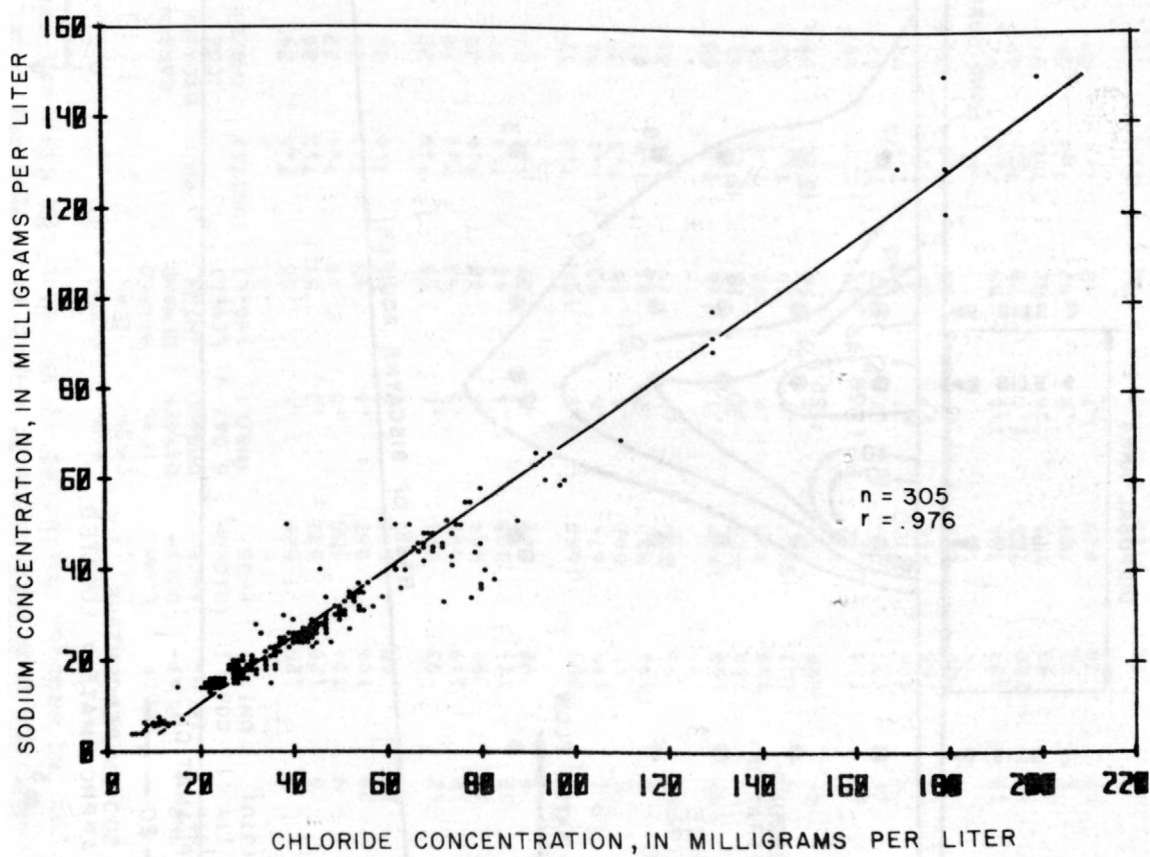


Figure 16.--Sodium-chloride regression plot for water samples from shallow wells at and near the disposal area.

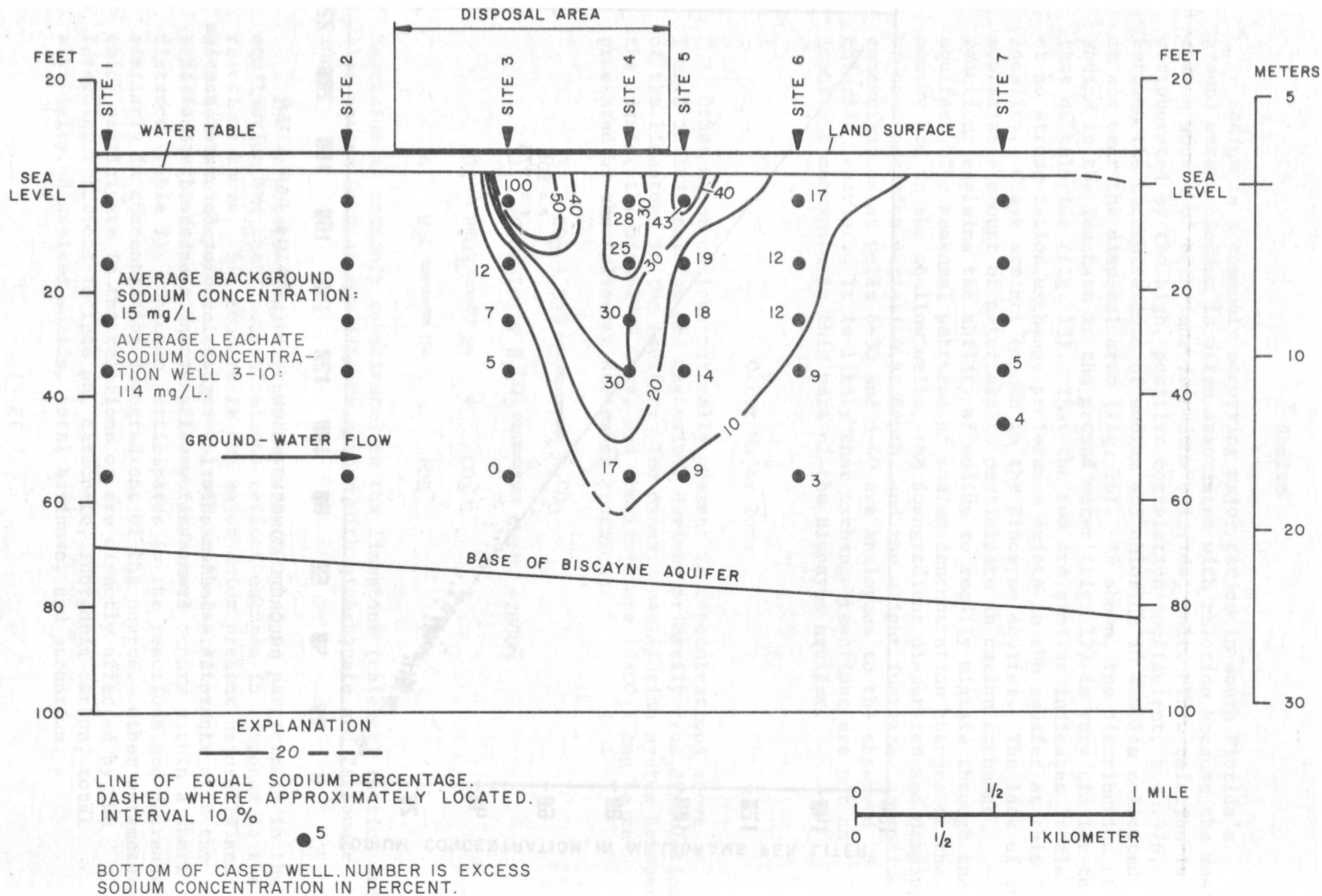


Figure 17.—Average excess sodium concentration, in percent.

Table 7.--Average concentrations of major water-quality constituents from ground-water samples collected at and near the disposal area.

WELL NUMBER	TEMPER- ATURE (DEG C)	TUR- BID- ITY (JTU)	COLOR (PLAT- INUM- CORALT UNITS)	SPE- CIFIC CON- DUCT- ANCE (MICRO- MHOS)	BIO- CHEM- ICAL OXYGEN DEMAND 5 DAY (MG/L)	CHEM- ICAL OXYGEN DEMAND (HIGH LEVEL) (MG/L)	PH (UNITS)	CARBON DIOXIDE (CO2) (MG/L)	ALKA- LINITY AS CACO3 (MG/L)	BICAR- BONATE (HCO3) (MG/L)	CAR- BONATE (CO3) (MG/L)	OIL AND GREASE (MG/L)
1-10	25.1	6	129	528	.5	56	7.4	24	250	305	0	5
1-20	24.8	18	120	531	.3	51	7.3	26	244	298	0	5
1-30	24.8	9	100	556	.5	49	7.4	22	256	312	0	5
1-40	24.6	29	106	562	.6	45	7.3	25	260	317	0	6
1-60	24.4	14	69	586	.4	45	7.4	22	257	315	0	8
2-10	24.9	12	93	501	.5	58	7.4	22	237	289	0	6
2-20	24.9	18	119	495	.5	53	7.3	22	237	289	0	6
2-30	24.9	10	93	504	.6	52	7.4	20	237	289	0	5
2-40	24.9	20	111	509	.4	48	7.4	21	237	289	0	8
2-60	24.8	9	92	529	.5	39	7.4	23	251	305	0	11
3-10	28.0	6	259	1648	2.9	154	7.2	92	650	793	0	7
3-20	26.7	41	149	674	.6	63	7.1	42	313	381	0	5
3-30	26.6	5	95	602	.6	60	7.3	30	270	330	0	5
3-40	26.3	8	134	570	.7	61	7.4	27	265	323	0	7
3-60	25.8	7	93	505	.6	49	7.4	21	240	293	0	6
4-10	30.2	157	103	1892	2.7	116	7.3	95	976	1191	0	8
4-20	29.0	73	164	905	.4	75	7.1	61	357	443	0	5
4-30	28.3	23	153	913	.8	80	7.2	55	384	468	0	3
4-40	27.2	5	107	917	.8	74	7.2	52	372	455	0	3
4-60	27.1	24	188	764	.9	58	7.2	39	326	397	0	4
5-10	25.3	11	128	1144	1.0	102	7.2	59	412	548	0	8
5-20	25.6	44	123	825	.7	82	7.2	42	358	437	0	7
5-30	25.9	5	100	775	.7	67	7.2	46	332	405	0	6
5-40	26.0	15	163	748	.7	57	7.1	47	311	379	0	8
5-60	26.0	33	136	687	.6	59	7.3	33	303	370	0	6
6-10	25.6	13	177	796	1.0	69	7.3	41	347	424	0	7
6-20	25.6	45	120	765	1.5	73	7.2	42	355	432	0	7
6-30	25.4	5	93	745	.6	62	7.3	37	342	418	0	6
6-40	25.4	5	91	727	.8	62	7.3	35	328	400	0	12
6-60	25.3	52	70	629	.7	42	7.4	24	287	350	0	10
7-10	25.7	8	76	425	.9	16	7.4	18	207	253	0	2
7-20	25.8	19	29	488	1.0	25	7.3	23	245	299	0	1
7-30	25.7	20	37	443	1.3	29	7.4	16	220	269	0	11
7-40	25.5	6	68	611	.9	55	7.2	35	290	354	0	1
7-50	25.6	37	57	603	1.2	48	7.3	29	280	341	0	3

Table 7.--Average concentrations of major water-quality constituents from ground-water samples collected at and near the disposal area (Continued).

WELL NUMBER	TOTAL NITRO- GEN (N) (MG/L)	TOTAL ORGANIC NITRO- GEN (N) (MG/L)	TOTAL AMMONIA NITRO- GEN (N) (MG/L)	TOTAL NITRITE (N) (MG/L)	TOTAL NITRATE (N) (MG/L)	TOTAL PHOS- PHORUS (P) (MG/L)	TOTAL IN- ORGANIC CARBON (C) (MG/L)	HARD- NESS (CA, MG) (MG/L)	NON- CAR- BONATE HARD- NESS (MG/L)	DIS- SOLVED CAL- CIUM (CA) (MG/L)	DIS- SOLVED MAG- NE- SIUM (MG) (MG/L)	DIS- SOLVED STRON- TIUM (SR) (UG/L)
1-10	2.1	1.2	.86	.00	.00	.01	--	260	10	95	5.7	749
1-20	2.0	1.0	1.0	.00	.00	.01	62	249	8	89	6.0	744
1-30	2.1	1.0	1.1	.00	.00	.01	--	269	11	96	6.2	789
1-40	2.0	.85	1.2	.00	.00	.01	--	267	9	95	6.6	819
1-60	2.0	.77	1.2	.00	.00	.01	66	274	21	98	6.9	853
2-10	1.8	1.1	.76	.00	.00	.01	--	246	11	89	4.9	697
2-20	1.8	1.1	.71	.00	.00	.02	--	242	7	88	5.2	709
2-30	1.9	1.1	.72	.00	.00	.01	--	250	14	91	5.2	750
2-40	1.8	1.0	.75	.01	.00	.01	--	247	11	90	5.4	754
2-60	1.7	.80	.93	.00	.00	.01	--	257	7	91	6.5	817
3-10	67	7.6	59	.01	.00	.15	--	357	0	115	16	876
3-20	4.4	1.1	3.2	.00	.00	.12	--	292	2	105	6.5	745
3-30	3.8	1.1	2.6	.00	.00	.01	--	277	9	101	6.2	789
3-40	3.3	1.1	1.9	.00	.00	.01	--	271	9	98	6.0	685
3-60	1.8	.90	.93	.00	.00	.01	--	249	8	89	5.9	716
4-10	75	10	64	.02	.15	.25	--	730	0	267	13	1291
4-20	10	1.4	9.1	.00	.00	.03	--	340	9	124	7.6	1092
4-30	17	1.1	16	.00	.00	.02	--	321	0	115	8.1	873
4-40	18	.94	17	.00	.00	.02	--	303	0	107	8.2	888
4-60	11	2.0	9.4	.00	.00	.02	--	304	0	109	7.6	859
5-10	32	2.5	29	.00	.00	.10	--	359	8	124	11	902
5-20	22	1.3	21	.00	.00	.02	--	253	0	89	7.2	626
5-30	12	1.7	11	.00	.00	.02	--	301	0	107	7.9	757
5-40	9.3	.89	8.4	.00	.00	.02	--	296	1	105	7.6	838
5-60	7.7	1.0	6.7	.00	.00	.14	--	292	3	104	7.4	842
6-10	11	1.0	10	.00	.00	.14	--	321	1	117	13	856
6-20	11	1.1	10	.01	.00	.04	--	303	0	111	6.3	827
6-30	15	.81	14	.00	.00	.01	--	280	0	101	6.9	932
6-40	15	1.2	14	.00	.00	.01	--	278	0	98	7.6	927
6-60	2.0	.89	1.1	.00	.00	.02	--	296	9	103	9.2	1207
7-10	.55	.44	.09	.00	.00	.01	--	216	8	82	2.2	410
7-20	.76	.40	.35	.00	.00	.02	--	250	8	93	3.9	673
7-30	.84	.43	.40	.00	.00	.03	--	233	12	85	4.3	534
7-40	2.6	.96	1.7	.00	.00	.01	--	293	7	106	6.3	782
7-50	2.3	.90	1.6	.00	.00	.01	--	286	8	103	6.3	790

Table 7.--Average concentrations of major water-quality constituents from ground-water samples collected at and near the disposal area (Continued).

WELL NUMBER	DIS- SOLVED SODIUM (NA) (MG/L)	DIS- SOLVED PO- TAS- SIUM (K) (MG/L)	TOTAL LITHIUM (LI) (UG/L)	DIS- SOLVED CHLO- RIDE (CL) (MG/L)	DIS- SOLVED SULFATE (SO4) (MG/L)	DIS- SOLVED FLUO- RIDE (F) (MG/L)	TOTAL ALUM- INUM (AL) (UG/L)	DIS- SOLVED SILICA (SI02) (MG/L)	TOTAL BORON (B) (UG/L)	PHENOLS (UG/L)	METHY- LENE BLUE ACTIVE SUB- STANCE (MG/L)	DIS- SOLVED SOLIDS (RESI- DUE AT 180 C) (MG/L)
1-10	18	.4	1	30	2.8	.3	20	5.6	54	29	.09	362
1-20	16	.5	1	25	2.0	.3	20	6.6	46	23	.05	323
1-30	17	.5	3	28	1.5	.3	64	6.9	65	28	.05	355
1-40	17	.5	1	29	1.5	.3	20	7.1	43	37	.13	349
1-60	17	.7	1	29	1.2	.3	21	7.4	39	31	.16	355
2-10	14	.5	0	23	1.8	.3	51	6.0	43	13	.26	331
2-20	14	.4	0	22	2.2	.3	1240	6.5	46	14	.18	327
2-30	14	.4	0	23	1.9	.4	48	6.3	44	19	.23	321
2-40	14	.4	5	22	1.8	.2	45	6.4	40	7	.03	320
2-60	14	.5	1	21	1.4	.2	28	7.8	37	8	.03	318
3-10	114	68	2	155	5.0	.5	43	9.7	304	11	.93	838
3-20	27	2.2	0	49	1.7	.2	117	7.4	76	24	.13	434
3-30	22	1.2	1	38	2.3	.3	26	7.1	73	21	.16	380
3-40	20	1.1	0	34	2.1	.2	21	7.0	61	6	.10	365
3-60	14	.5	0	23	1.7	.2	25	7.6	45	2	.19	323
4-10	43	24	7	54	12	.2	758	21	780	5	.78	760
4-20	40	5.9	8	78	5.0	.3	148	9.2	148	2	.17	543
4-30	45	12	1	69	2.1	.3	21	8.6	177	2	.09	527
4-40	45	15	1	69	2.2	.3	30	8.6	189	3	.16	505
4-60	32	8.2	1	51	2.0	.2	15	8.7	150	2	.30	458
5-10	55	28	0	85	4.8	.4	35	10	337	1	.48	587
5-20	34	21	3	55	3.2	.3	327	7.6	230	29	.09	414
5-30	33	11	1	53	6.1	.3	29	8.6	159	22	.08	435
5-40	29	7.2	0	49	1.9	.2	16	8.4	136	39	.15	404
5-60	24	5.0	0	43	2.5	.3	225	8.3	101	9	.03	392
6-10	32	11	0	49	4.4	.3	33	7.0	168	28	.28	455
6-20	27	11	4	44	1.8	.3	767	7.0	201	17	.31	455
6-30	27	14	0	39	1.5	.3	28	8.4	151	13	.42	403
6-40	24	13	0	38	1.4	.3	21	8.5	130	2	.19	392
6-60	18	.6	3	33	.7	.1	23	10	51	11	.24	376
7-10	5.3	1.7	0	7.9	6.2	.1	45	4.4	55	1	.08	241
7-20	6.1	1.1	2	11	5.4	.1	420	5.8	70	5	.04	285
7-30	6.2	.5	0	11	3.8	.2	183	6.5	35	16	.01	254
7-40	20	.9	0	28	1.9	.2	32	8.1	218	19	.12	359
7-50	19	.9	0	28	1.9	.2	7	7.4	203	51	.06	352

Physical Parameters

Specific Conductance

In general, specific conductance--a measure of the ability of water to conduct an electric current--is a useful parameter in estimating dissolved solids concentration in water. The usefulness of specific conductance to indicate the gross magnitude and general areas that have been affected by leachates is reduced somewhat because in the disposal area a large part of specific conductance in excess of the natural background (fig. 18) is due to calcium and bicarbonate. These react with the aquifer and show sharp reduction in concentration so that farther downgradient, the excess specific conductance is probably related to sodium and chloride in the leachate which probably are not reacting with the aquifer materials. Because specific conductance reflects these and other ions in major concentrations it is not ideal for describing the migration or quantitative changes in leachates from the solid waste disposal area.

Figures 19 and 20 show the specific conductance at the end of the dry season in April 1974 and at the end of the wet season in October 1974. The patterns of the equal conductance lines are similar for both profiles, but a prime difference is the increase in conductance during the wet season, particularly at shallow depth beneath and immediately downgradient from the disposal area. The patterns also indicate that leachate in the permeable limestone section is migrating downgradient, probably influenced by pumping in the Hialeah-Miami Springs well field.

Dissolved Solids

The weight of material dissolved in a known volume of filtered water at 180°C is obtained by evaporating the water to dryness and weighing the solid residue. "Dissolved solids residue" is a commonly used measure of material in solution when knowledge of the exact nature of the chemical species in solution is not required.

All of the ground water in the vicinity of the disposal area contains more than 300 mg/L of dissolved solids. The contribution from the wastes is shown in figure 21, where the upgradient (or background) dissolved solids residue of 336 mg/L is subtracted from the observed concentrations. The general pattern of excess dissolved solids is similar to the pattern of specific conductance (fig. 18), as might be expected since specific conductance is a measure of dissolved solids.

Turbidity

Turbidity is a measure of the light scattered by suspended matter in water. The turbidity of the water samples from well 4-10 is high because of particulate material from the decomposed waste. In general,

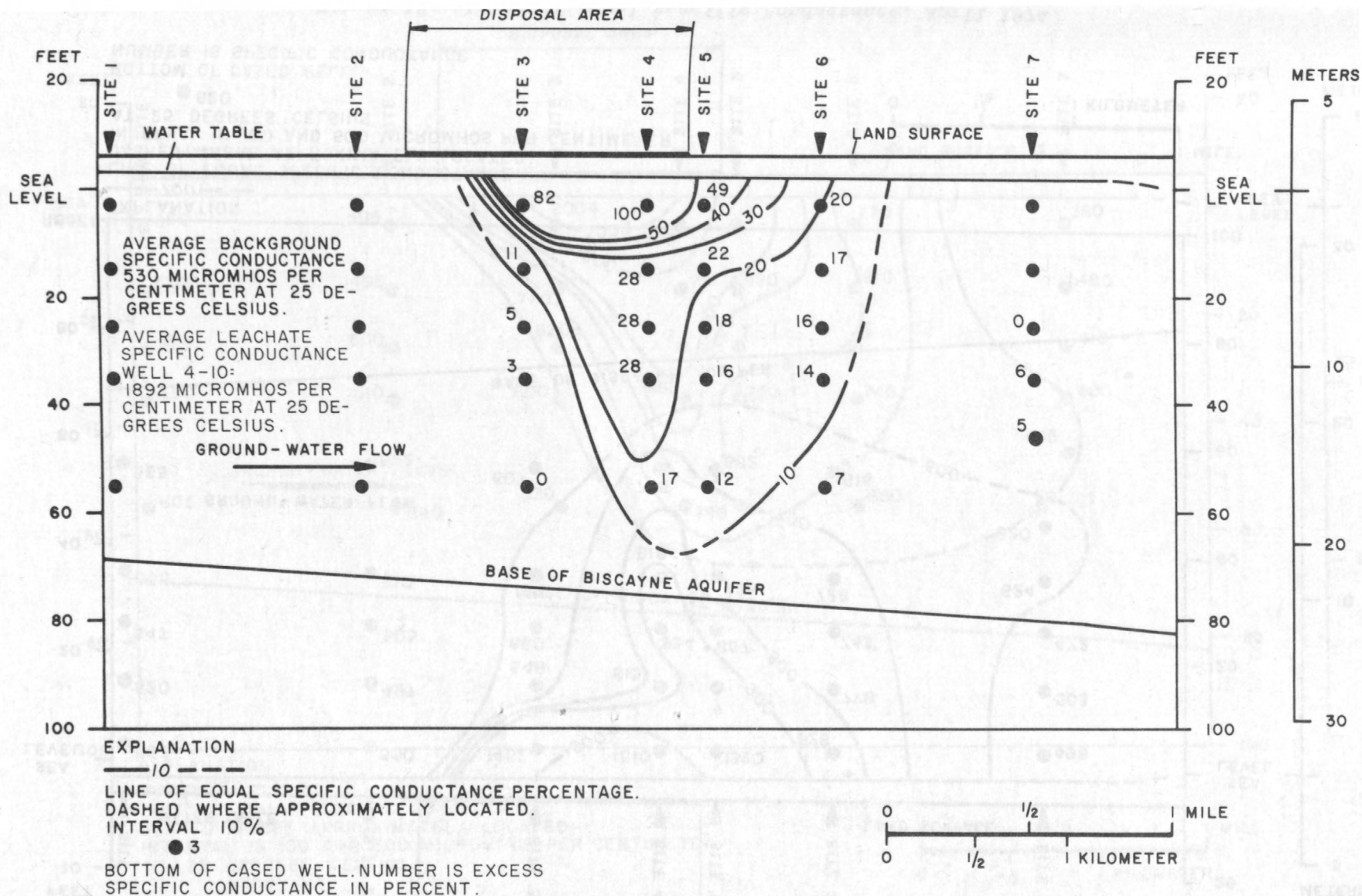


Figure 18.--Average leachate-related specific conductance, in percent, in ground water at and near the disposal area.

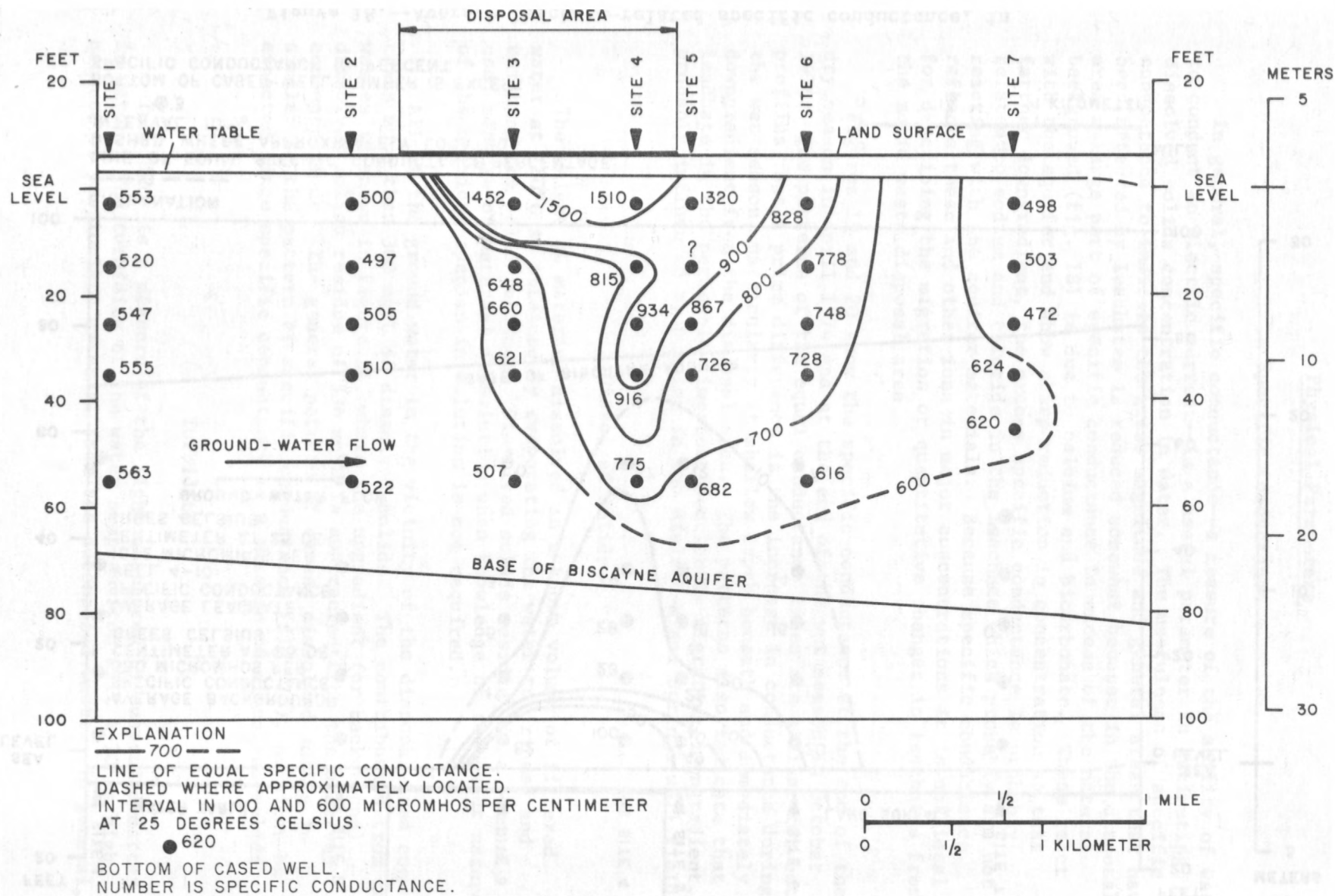


Figure 19.--Lines of equal specific conductance, April 1974.

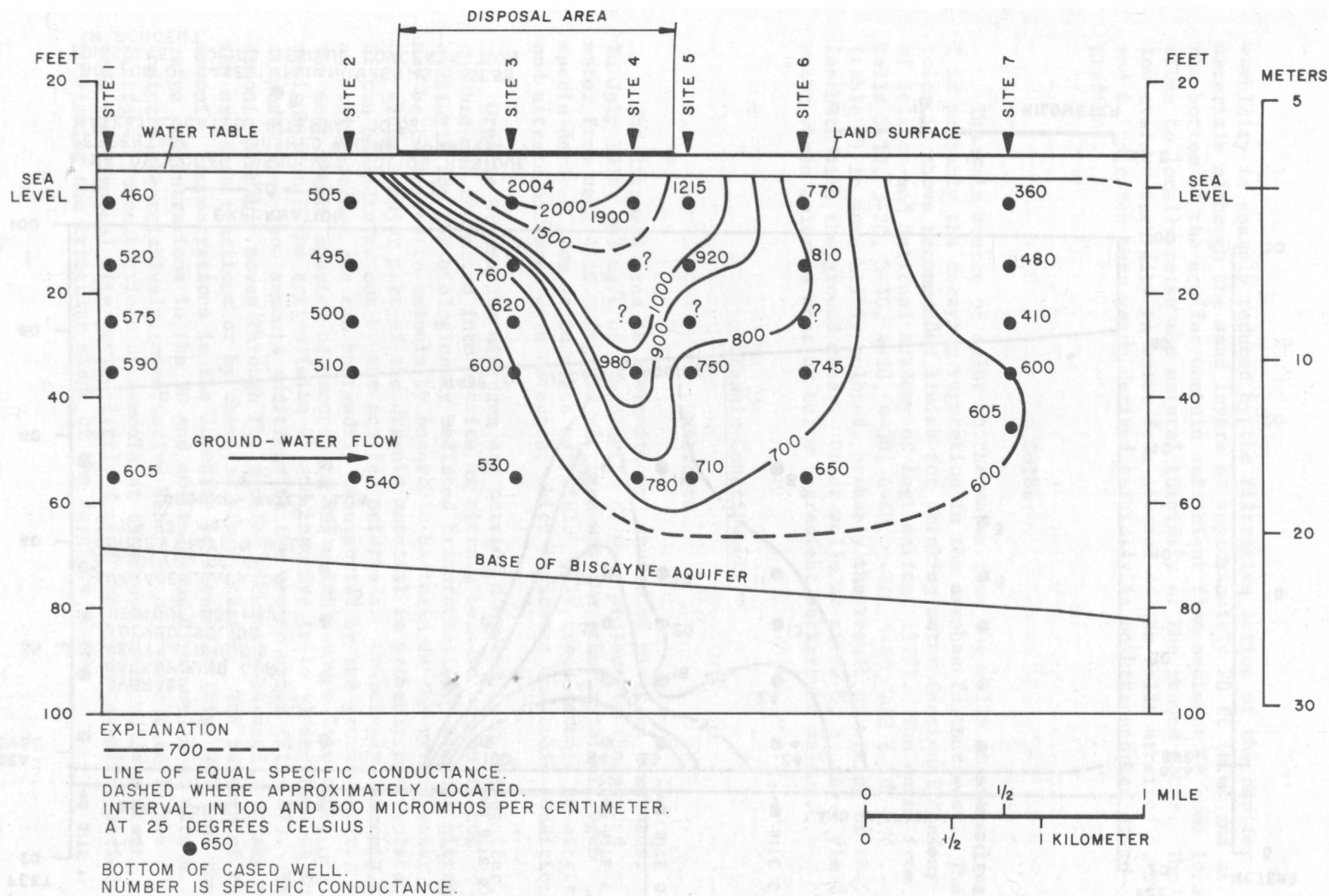


Figure 20.--Lines of equal specific conductance, October 1974.

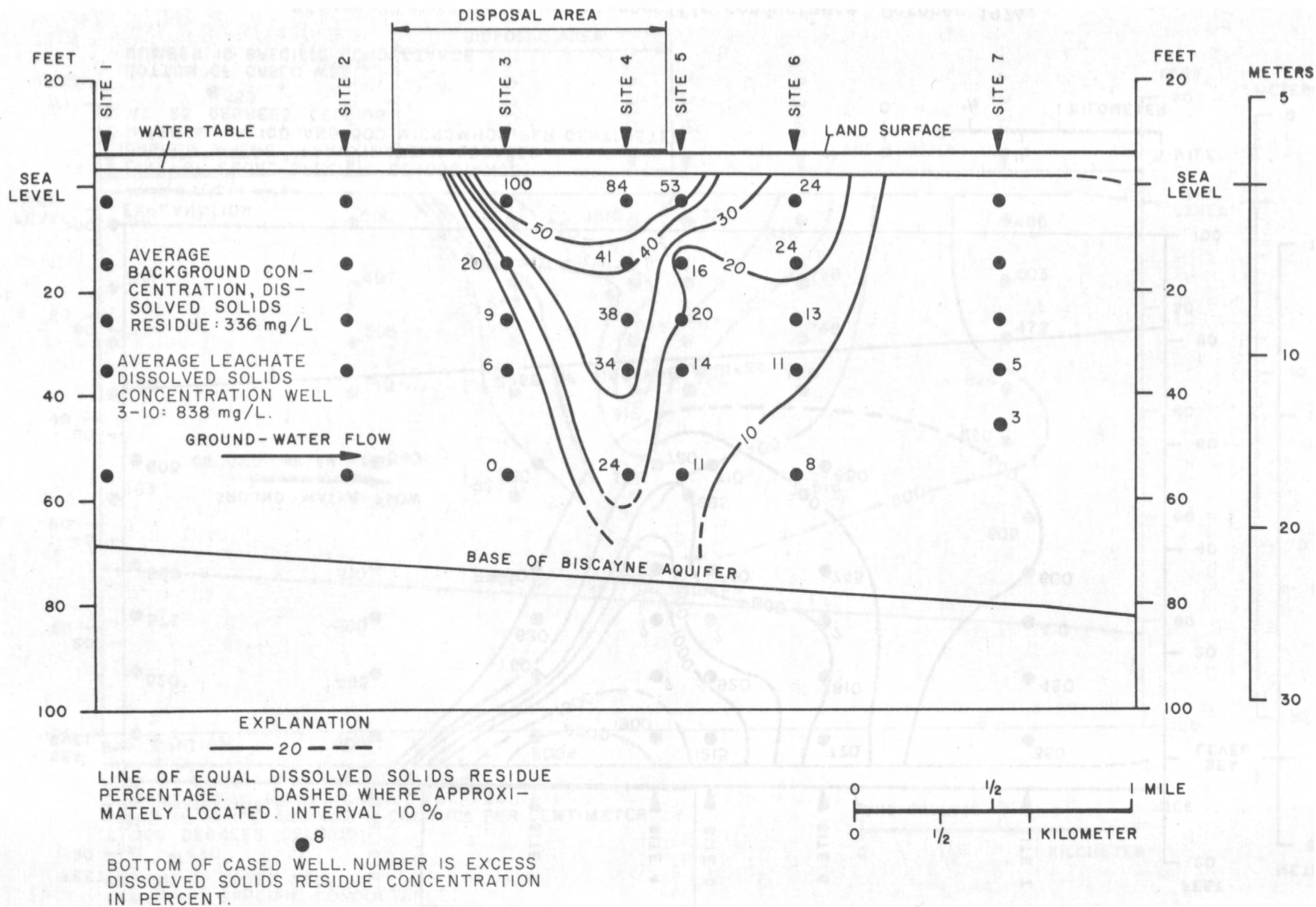


Figure 21.--Average excess dissolved solids residue, in percent,

turbidity is sharply reduced by the filtrative action of the aquifer materials although the sand layers at approximately 20 ft (6 m) and at the bottom of the aquifer contain sufficient fine sediment in some locations to locally raise the natural turbidity of the ground water. The low average turbidity in water from several of the wells at sites 4, 5, and 6 indicates that waste derived turbidity is not transported down-gradient.

Color

The main source of color in the water from the wells at sites 1 and 2 is probably the decaying vegetation in the marshes farther west. The color is above recommended limits for drinking water (National Academy of Science and National Academy of Engineering, 1973). The water from wells 3-10, 3-20, 3-40, 4-20, 4-30, 4-60, 5-40, 5-60, and 6-10 (table 7) is more highly colored, probably the result of mixing of the leachate with the ground water. Other wells at sites 5, 6, and 7 yield water whose color is near or below upgradient background values.

Organic Constituents

Nitrogen

The disposal area is a significant source of nitrogen compounds. In July 1974, 103 mg/L of ammonia (as N) were present in the ground water from well 4-10. Organic nitrogen was the other major nitrogen specie derived from solid waste material. Only trace amounts of nitrite and nitrate nitrogen were detected, which indicates anaerobic conditions.

Organic or ammonia nitrogen are carried downward into the aquifer, and are not converted into nitrite or nitrate because oxygen is not available for the biologically mediated transformation. Organic nitrogen may be converted to ammonia by anaerobic bacteria in the ground water or, since a major part of the organic material is probably particulate, it can be filtered out by the aquifer materials. Conversely, ammonia is an ionic species and can be readily transported by the ground water. The most common species of ammonia is NH_4^+ which behaves like other cations. Both the active (site 3) and inactive (site 4) sections of the disposal area show ammonia additions to the ground water (fig. 22). The ammonia probably moves through the aquifer without substantial uptake by the exchange reactions or by chemical precipitation. The pattern of the ammonia concentrations in the leachate is irregular (fig. 22), but the large concentrations in the 30 and 40-ft (9-and 12-m) wells at site 6 indicate the relatively conservative behavior of this cation in the aquifer. Concentrations of ammonia at those and other wells distant from the disposal site varied little during the 2-year sampling period, confirming the irregular shape of the leachate plume.

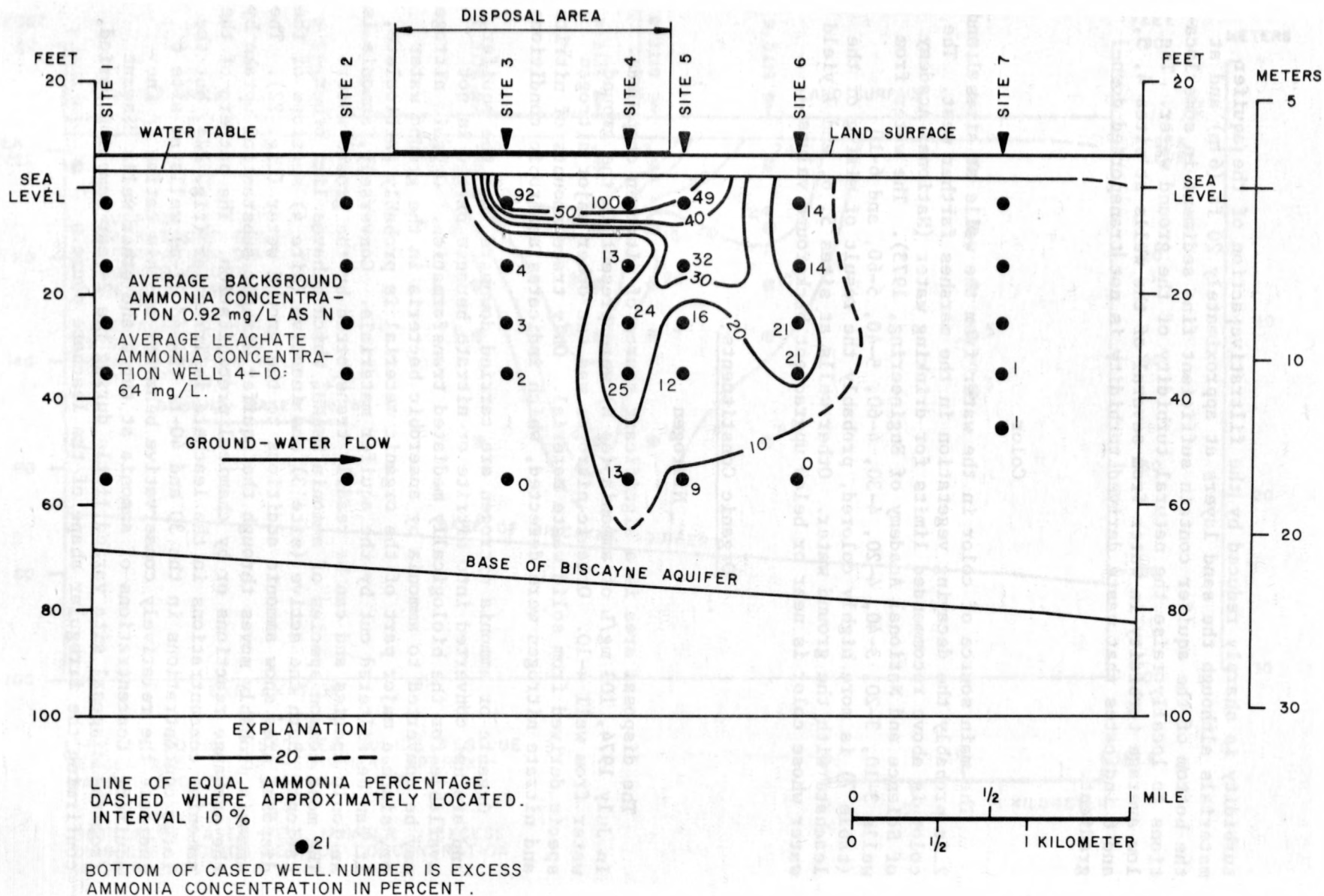


Figure 22.--Average excess ammonia, in percent, in ground water

Total Phosphorus

Total phosphorus includes dissolved orthophosphate plus any organically bound phosphorus. Concentrations of total phosphorus even at the shallow wells in the disposal area do not exceed 1 mg/L. Phosphorus is susceptible to complexation and precipitation with both calcium and iron. Little phosphorus, apparently, ever reaches the ground water. The biologically induced breakdown of organic compounds which contain phosphorus probably occurs in the unsaturated zone. The small amount of phosphorus that does reach the ground water probably precipitates very rapidly as calcium phosphate $\text{Ca}_5(\text{PO}_4)_3\text{OH}$.

Chemical Oxygen Demand

Chemical oxygen demand (COD) is a measure of organic and other oxidizable materials in water. The natural COD of ground water in the Biscayne aquifer decreases from north to south in Dade County (Pitt and others, 1975). In the remote interior parts of the county COD is high, due in part to naturally high levels of organic compounds from decaying marsh vegetation. The average COD for sites 1 and 2 is about 50 mg/L. The large excess COD in water from the 10-ft (3-m) wells at sites 3 and 4 (fig. 23) results from the leaching of waste-fill material. The general downgradient movement of leachate COD has an irregular distribution that is similar to that of ammonia (fig. 22). The downgradient reduction of COD can be accounted for by general dilution and dispersion. Despite the irregular distribution pattern, COD does not appear to be reduced by any chemical or physical mechanisms other than dispersion.

Trace Metals

The 14 elements listed in table 8 are commonly referred to as trace metals. Several are extremely toxic if consumed in large quantities. The recommended limits for drinking water (National Academy of Science - National Academy of Engineering, 1973) are listed in table 8 along with the applicable Dade County ground-water standards. The maximum observed concentrations (table 9) for cadmium, iron, lead, manganese, and zinc exceed the National Academy of Science and National Academy of Engineering (1973) recommended drinking water standards.

Cadmium is extremely low in or absent from most water samples. Approximately six samples per well were collected for trace metal analyses during the 2-year investigation. The detections of 14 ug/L of cadmium at well 7-40 and 13 ug/L cadmium at well 6-20 were the only detections of concentrations greater than the 10 ug/L recommended limit. Other cadmium samples from wells 7-40 and 6-20 are 3 ug/L or less. Maximum cadmium values from shallow wells indicate that little or no cadmium is derived from waste materials.

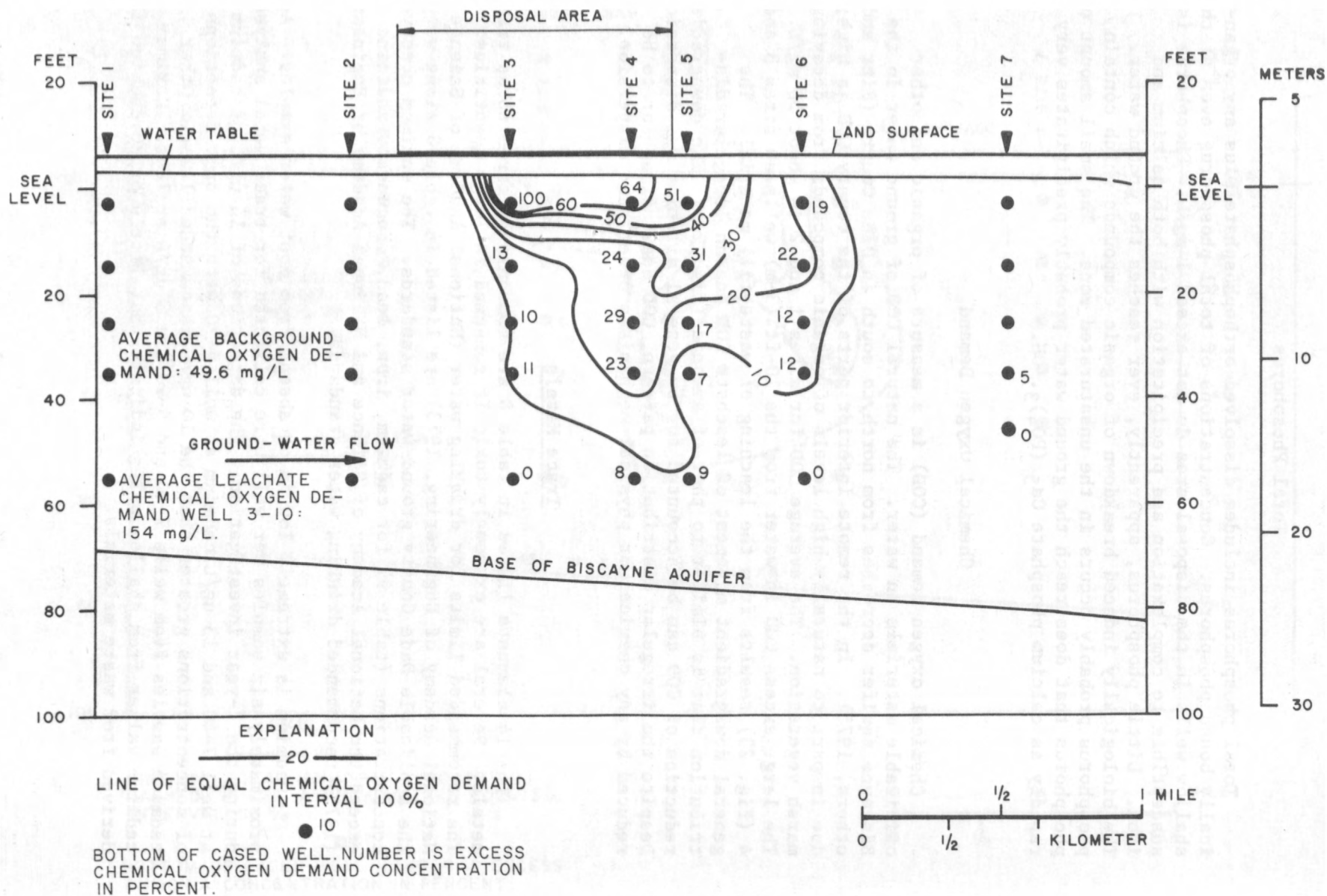


Figure 23.--Average excess chemical oxygen demand, in percent,
in ground water at and near the disposal area.

Table 8.--Drinking water standards for metals and maximum observed concentrations.

	<u>Recommended Limits of NAS-NAE¹ ug/L</u>	<u>Dade County² Standards</u>	<u>Maximum Observed Concentration (in ug/L)</u>	<u>Well Number</u>
Arsenic	100	50	30	2-40
Cadmium	10		14	7-40
Chromium	50	50	35	4-10
Cobalt	Not Discussed		15	4-20
Copper	1,100	400	61	4-10
Iron	300	300	47,000	4-10
Lead	50	50	110	4-10
Manganese	50		630	4-10
Mercury	2	None Detectable	1.7	7-10
Molybdenum	Not Discussed		5	1-60, 2-40
Nickel	Not Discussed		48	4-60
Selenium	10		0	
Silver	None Recommended		5	3-20, 6-60
Zinc	5,000	1,000	19,000	4-20

1 Drinking water recommended limits, National Academy of Sciences and National Academy of Engineering, 1973.

2 Metropolitan Dade County, 1975.

Table 9.--Maximum observed metal concentrations in ground-water samples from wells at and near the disposal area.

WELL NUMBER	TOTAL ARSENIC (AS) (UG/L)	TOTAL CAD- MIUM (CD) (UG/L)	TOTAL CHRO- MIUM (CR) (UG/L)	TOTAL COBALT (CO) (UG/L)	TOTAL COPPER (CU) (UG/L)	TOTAL IRON (FE) (UG/L)	TOTAL LEAD (PB) (UG/L)	TOTAL MAN- GANESE (MN) (UG/L)	TOTAL MERCURY (HG) (UG/L)	TOTAL MOLYB- DENUM (MO) (UG/L)	TOTAL NICKEL (NI) (UG/L)	TOTAL SELE- NIUM (SE) (UG/L)	TOTAL SILVER (AG) (UG/L)	TOTAL ZINC (ZN) (UG/L)
1-10	7	3	20	1	7	6000	35	67	.1	4	20	0	1	100
1-20	27	3	20	2	11	8000	33	40	.3	2	16	0	2	40
1-30	20	3	20	4	10	4700	34	50	.2	3	24	0	1	60
1-40	31	3	20	10	7	9800	58	330	.1	2	13	0	1	50
1-60	26	3	20	5	10	5500	36	50	.1	5	17	0	1	80
2-10	9	3	10	3	3	2700	35	50	.2	2	15	0	1	200
2-20	7	6	18	3	10	6800	38	50	.3	3	11	0	1	160
2-30	8	3	15	3	20	4100	35	40	.3	3	20	0	1	100
2-40	30	3	14	3	10	7200	27	67	.2	5	10	0	1	100
2-60	12	3	20	3	20	5800	25	50	.2	3	13	0	1	30
3-10	17	5	30	5	21	3100	33	70	.2	3	12	0	3	220
3-20	18	6	25	3	4	7900	33	130	.2	1	25	0	5	8500
3-30	23	1	20	3	9	2000	22	100	.3	4	27	0	4	170
3-40	20	1	10	5	4	4300	18	130	.4	3	28	0	4	60
3-60	9	1	10	3	10	4500	12	100	.3	3	29	0	0	60
4-10	10	1	35	4	61	49000	110	630	.9	2	29	0	4	550
4-20	8	8	55	15	10	25000	71	150	1.0	3	31	0	1	28000
4-30	11	1	31	5	10	6300	38	130	.8	3	33	0	3	160
4-40	10	4	14	4	10	1900	35	40	.2	2	15	0	2	250
4-60	5	3	20	5	17	12000	20	83	.7	5	48	0	2	150
5-10	3	4	18	5	5	8900	20	67	.2	3	11	0	3	130
5-20	7	5	15	10	6	9900	39	40	.2	3	15	0	4	15000
5-30	8	4	10	5	6	2300	27	33	.1	3	13	0	0	120
5-40	12	5	15	13	10	8700	35	50	.2	5	15	0	3	220
5-60	14	6	28	4	8	6700	44	50	.2	5	11	0	4	450
6-10	56	3	20	4	7	13000	31	83	.4	3	11	0	4	220
6-20	6	13	20	4	10	5600	46	50	.4	3	20	0	2	15000
6-30	9	3	10	10	10	2600	36	47	.9	3	29	0	3	150
6-40	15	3	20	5	10	2200	25	35	.3	5	33	0	0	90
6-60	2	3	10	3	7	9300	36	63	.3	3	30	0	5	150
7-10	17	5	10	10	6	2800	9	63	1.7	1	30	0	0	60
7-20	15	6	10	4	6	4900	16	63	.3	1	17	0	0	6500
7-30	16	6	10	10	3	6500	16	50	.5	2	14	0	0	4200
7-40	3	14	10	5	6	3200	16	50	.3	4	19	0	0	90
7-50	16	5	10	6	4	15000	13	400	.1	3	17	0	1	70

Although iron is naturally high (more than 1,000 ug/L) in the water of the Biscayne aquifer it is particularly high in ground water in this part of the County. The average total iron concentration for every well sampled is in excess of the county ground-water standards. Although some of the iron detected at each of the sites may be related to the black-iron pipe used for well casings, the 49,000 ug/L of iron in a sample from well 4-10 is clearly related to the iron leached from the disposal site by infiltrating water.

Lead is a readily complexed heavy metal that forms a variety of oxides, carbonates, and sulfides which are virtually insoluble. The 110 ug/L at well 4-10 is probably related to refuse materials. Two other samples at well 4-10 contained more than 50 ug/L. The average concentration of total lead at well 4-10 was 42 ug/L for the nine samples. The range in lead concentrations for the 35 observation wells (fig. 24) indicates the relatively common but generally low occurrence of lead in the ground water. Although one sample from well 1-40, upgradient of the facility, had a lead concentration exceeding the National Academy of Science - National Academy of Engineering (1973) recommended levels, the general low concentration of lead in ground water in the vicinity of the disposal site indicates that the lead originating at the site has not traveled far.

Manganese concentrations shown in table 8 are total values. Manganese readily oxidizes to black hydrated manganese oxides. The exact proportion of soluble manganese is not known but this form is the most objectionable to taste, and stains clothes and plumbing fixtures. The concentrations of total manganese in the observation wells commonly exceed the National Academy of Science - National Academy of Engineering (1973) recommended limits. The largest concentrations of total manganese (630 ug/L) occur at well 4-10 (fig. 25). Wells at sites 5 and 6 contain total manganese concentrations similar to the upgradient sites 1 and 2.

Average zinc concentrations at 20 ft (6 m) depth are as much as 100 times larger than those in shallower or deeper wells at sites 3, 4, 5, and 6. Wells 7-20 and 7-30 also show abnormally high concentrations of zinc. The sand horizon shown at 20 ft (6 m) in figure 4 necessitated finishing the observation wells with sand screen. The bronze filter screen has a lead-soldered seam. The solder contains several percent of zinc. The two wells 7-20, 7-30 have also been finished with screens. High concentrations of zinc in water from wells equipped with bronze screens, elsewhere in Dade County, have been reported by Pitt and others (1975, p. 73).

Pesticides

Four general classes of synthetic organic compounds are listed in table 10: chlorinated hydrocarbon insecticides, phosphorothioate insecticides, chlorophenoxy acid herbicides, and industrial compounds. Most of these compounds are only slightly soluble in water and readily sorb to organic matter, soils, and aquifer materials.

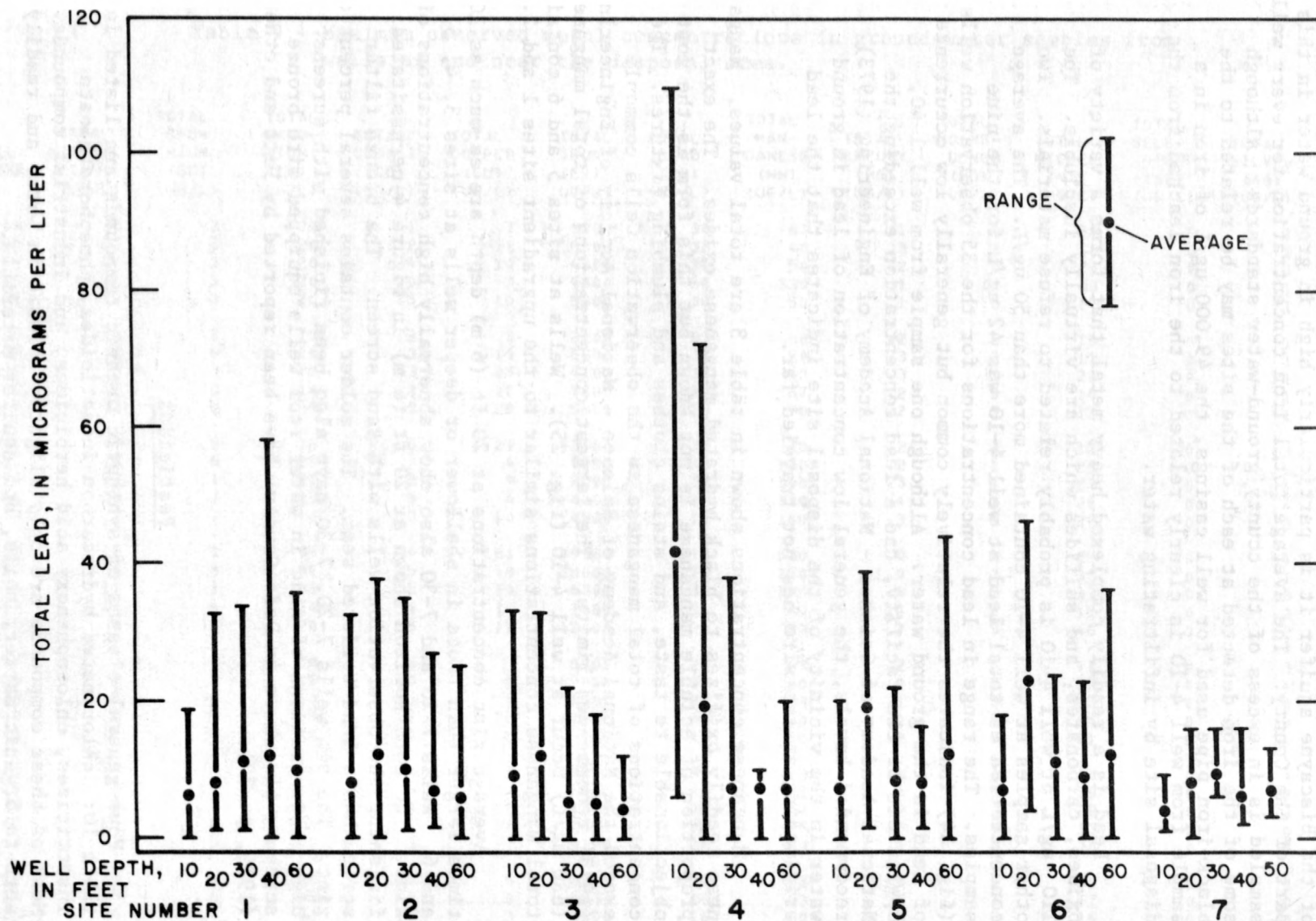


Figure 24.--Average and range of total lead concentrations in 35 observation wells at and near the disposal area.

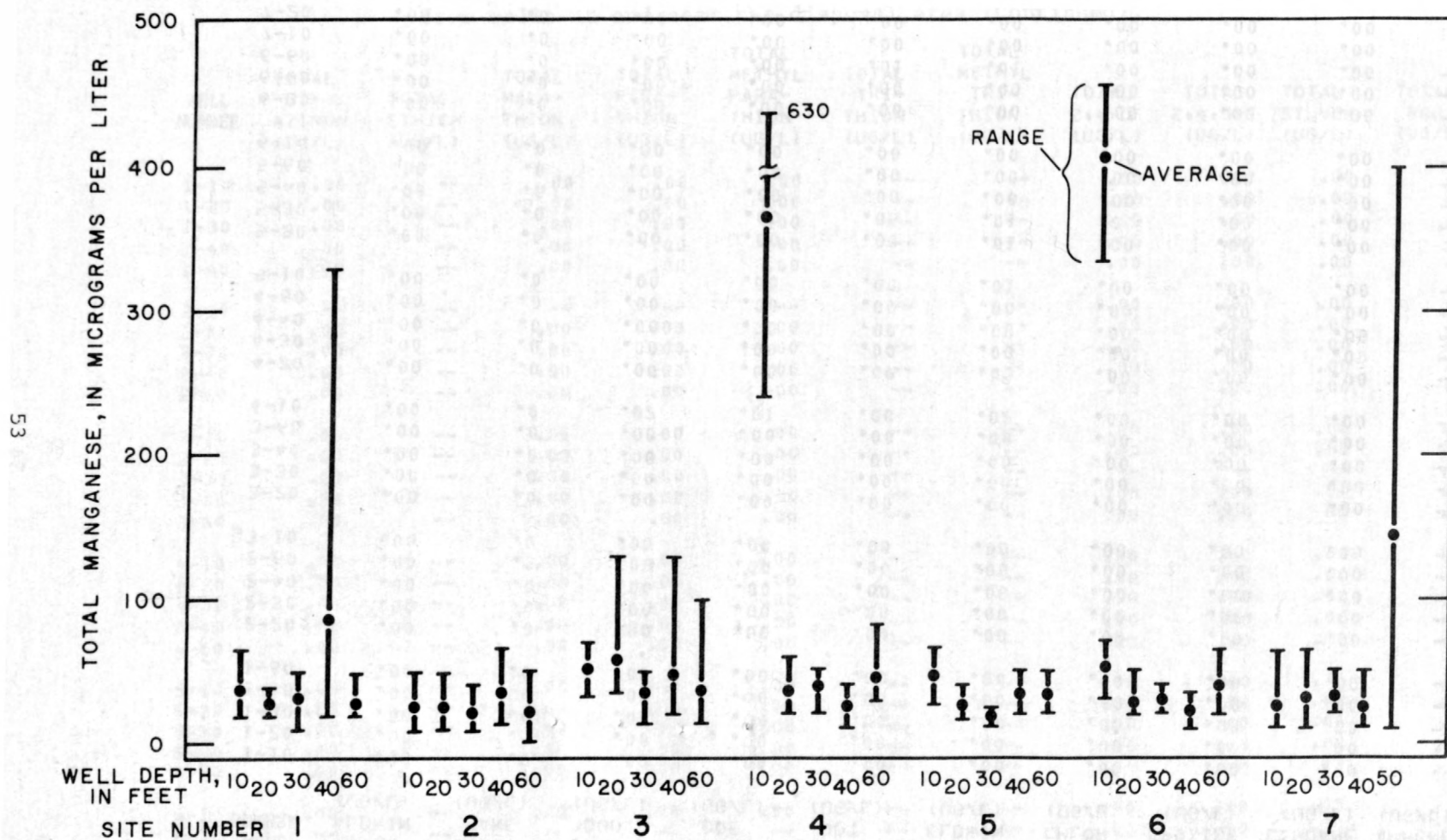


Figure 25.--Average and range of total manganese concentrations in 35 observation wells at and near the disposal area.

Table 10.--Concentrations of synthetic organic compounds in ground-water samples from wells at and near the disposal area.

WELL NUMBER	TOTAL ALDRIN (UG/L)	TOTAL CHLOR- DANE (UG/L)	TOTAL DDD (UG/L)	TOTAL DDE (UG/L)	TOTAL DDT (UG/L)	TOTAL DI- ELDRIN (UG/L)	TOTAL HEPTA- CHLOR (UG/L)	TOTAL HEPTA- CHLOR EPOXIDE (UG/L)	TOTAL LINDANE (UG/L)	TOTAL TOX- APHENE (UG/L)
1-10	.00	.0	.00	.00	.00	.00	.00	.00	.00	--
1-20	.00	.0	.00	.00	.00	.00	.00	.00	.00	--
1-30	.00	.0	.00	.00	.00	.00	.00	.00	.00	--
1-40	.00	.0	.00	.00	.00	.00	.00	.00	.00	--
1-60	.00	.0	.00	.00	.00	.00	.00	.00	.00	--
2-20	.00	.0	.00	.00	.00	.00	.00	.00	.00	--
2-30	.00	.0	.00	.00	.00	.00	.00	.00	.00	--
2-40	.00	.0	.00	.00	.00	.00	.00	.00	.00	--
2-60	.00	.0	.00	.00	.00	.00	.00	.00	.00	--
3-10	.00	.0	.00	.00	.00	.00	.00	.00	.00	--
3-20	.00	.0	.00	.00	.00	.00	.00	.00	.00	--
3-30	.00	.0	.00	.00	.00	.00	.00	.00	.00	--
3-40	.00	.0	.00	.00	.00	.00	.00	.00	.00	--
3-60	.00	.0	.00	.00	.00	.00	.00	.00	.00	--
4-10	.00	.0	.02	.01	.00	.02	.00	.00	.00	--
4-20	.00	.0	.00	.00	.00	.00	.00	.00	.00	--
4-30	.00	.0	.00	.00	.00	.00	.00	.00	.00	--
4-40	.00	.0	.00	.00	.00	.00	.00	.00	.00	--
4-60	.00	.0	.00	.00	.00	.00	.00	.00	.00	--
5-10	.00	.0	.00	.00	.00	.01	.00	.00	.00	--
5-20	.00	.0	.00	.00	.00	.01	.00	.00	.00	--
5-30	.00	.0	.00	.00	.05	.01	.00	.00	.00	--
5-40	.00	.0	.00	.00	.00	.00	.00	.00	.00	--
5-60	.00	.0	.00	.00	.00	.00	.00	.00	.00	--
6-10	.00	.0	.00	.00	.00	.00	.00	.00	.00	--
6-30	.00	.0	.00	.00	.00	.00	.00	.00	.00	--
6-40	.00	.0	.00	.00	.00	.00	.00	.00	.00	--
6-60	.00	.0	.00	.00	.01	.01	.00	.00	.00	--
7-10	.00	.0	.00	.00	.00	.00	.00	.00	.00	0
7-20	.00	.0	.00	.00	.00	.00	.00	.00	.00	0
7-30	.00	.0	.00	.00	.00	.00	.00	.00	.00	0
7-40	.00	.0	.00	.00	.00	.00	.00	.00	.00	0
7-50	.00	.0	.00	.00	.00	.00	.00	.00	.00	0

Table 10.--Concentrations of synthetic organic compounds in ground-water samples from wells at and near the disposal area (Continued).

WELL NUMBER	TOTAL DI- AZINON (UG/L)	TOTAL ETHION (UG/L)	TOTAL MALA- THION (UG/L)	TOTAL PARA- THION (UG/L)	TOTAL METHYL PARA- THION (UG/L)	TOTAL TRI- THION (UG/L)	TOTAL METHYL TRI- THION (UG/L)	TOTAL 2,4-D (UG/L)	TOTAL 2,4,5-T (UG/L)	TOTAL SILVEX (UG/L)	TOTAL PCB (UG/L)
1-10	.00	--	.00	.00	.00	--	--	.00	.00	.00	.0
1-20	.00	--	.00	.00	.00	--	--	.00	.00	.00	.0
1-30	.00	--	.00	.00	.00	--	--	.00	.00	.00	.0
1-40	.00	--	.00	.00	.00	--	--	.00	.00	.00	.0
1-60	.00	--	.00	.00	.00	--	--	.00	.00	.00	.0
2-10	--	--	--	--	--	--	--	.00	.00	.00	--
2-20	.00	--	.00	.00	.00	--	--	.00	.00	.00	.0
2-30	.00	--	.00	.00	.00	--	--	.00	.00	.00	.0
2-40	.00	--	.00	.00	.00	--	--	.00	.00	.00	.0
2-60	.00	--	.00	.00	.00	--	--	.00	.00	.00	.0
3-10	.00	--	.00	.00	.00	--	--	.00	.00	.00	.0
3-20	.00	--	.00	.00	.00	--	--	.00	.00	.00	.0
3-30	.00	--	.00	.00	.00	--	--	--	--	--	.0
3-40	.00	--	.00	.00	.00	--	--	.00	.00	.00	.0
3-60	.00	--	.00	.00	.00	--	--	.00	.00	.00	.0
4-10	.03	--	.00	.00	.00	--	--	.00	.00	.00	.0
4-20	.00	--	.00	.00	.00	--	--	.00	.00	.00	.0
4-30	.00	--	.00	.00	.00	--	--	.00	.00	.00	.0
4-40	.00	--	.00	.00	.00	--	--	.00	.00	.00	.0
4-60	.00	--	.00	.00	.00	--	--	.00	.00	.00	.0
5-10	.00	--	.00	.00	.00	--	--	.00	.00	.00	.0
5-20	.00	--	.00	.00	.00	--	--	.00	.00	.00	.0
5-30	.00	--	.00	.00	.00	--	--	.00	.00	.00	.0
5-40	.00	--	.00	.00	.00	--	--	.00	.00	.00	.0
5-60	.00	--	.00	.00	.00	--	--	--	--	--	.0
6-10	.00	--	.00	.00	.00	--	--	.00	.00	.00	.0
6-20	--	--	--	--	--	--	--	.00	.00	.00	--
6-30	.00	--	.00	.00	.00	--	--	.00	.00	.00	.0
6-40	.00	--	.00	.00	.00	--	--	--	--	--	.0
6-60	.00	--	.00	.00	.00	--	--	.00	.00	.00	.0
7-10	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
7-20	.00	.00	.00	.00	.00	.00	.00	.02	.00	.00	.0
7-30	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
7-40	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0
7-50	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.0

Chlorinated hydrocarbon insecticides are persistent compounds used for particular applications in the past decade. Four of these insecticides, DDD, DDE, DDT, and dieldrin were detected in ground water. Well 4-10 had the DDT residues, DDD and DDE, as well as dieldrin (table 10). DDT was found in only two samples, wells 5-30 and 6-60. Dieldrin was present in water from wells 4-10, 5-10, 5-20, 5-30, and 6-60. Dieldrin's principal use is the eradication of domestic termites and this substance is commonly found in surface-water samples and sediments in urban areas (Matraw, 1975). The concentrations of DDT, its degradation products DDD and DDE, and dieldrin are all 0.05 ug/L or less.

The phosphorothioate insecticides are generally more toxic but less persistent than the chlorinated hydrocarbon insecticides. The analytical technique for their detection is similar to that of Zweig and Devine (1969). Only diazinon was detected in a ground-water sample. A concentration of 0.3 ug/L was measured in a sample from well 4-10.

Chlorophenoxy acid herbicides are commonly used in surface waters of south Florida for the control of aquatic weed growth. The herbicide 2,4-D, because of its widespread use and generally less absorbent behavior, is more commonly found in ground-water samples than any other pesticide. Surprisingly 2,4-D was present (0.02 ug/L) in only one sample, well 7-20, and its occurrence is not related to waste disposal activities (table 10). No polychlorinated biphenyls (PCB's) were detected.

Bacteria

Three indicators of biological contamination are total coliform, fecal coliform, and fecal streptococci. Total coliform includes a wide variety of bacteria from soils, waste leachate and other sources including septic-tank sludge which is dumped along the main roads throughout the disposal area. Fecal coliform bacteria are derived solely from warm blooded animals, especially cattle, dogs and cats. Fecal streptococci are proportionally higher in other vertebrates. In addition to septic-tank sludge, another source of fecal streptococci is the large population of scavenging birds which feed on the garbage.

Special precautions were used to obtain uncontaminated ground-water samples during the investigation. The soil filters many of the bacteria from the percolating leachate. The apparent rapid die-off rate of bacteria reaching the ground water is indicated by the low occurrence of bacteria (figs. 26, 27, and 28). In general the highest observed concentrations and frequency of occurrence of total coliform and fecal streptococci bacteria were in the shallow wells. The virtual absence of fecal coliform bacteria (fig. 27) from well water at depths of 20 ft (6 m) and greater indicate that fecal coliform bacteria are filtered and do not multiply or survive in the ground water. Therefore, bacteria within the disposal area are not being transported downgradient in the ground water.

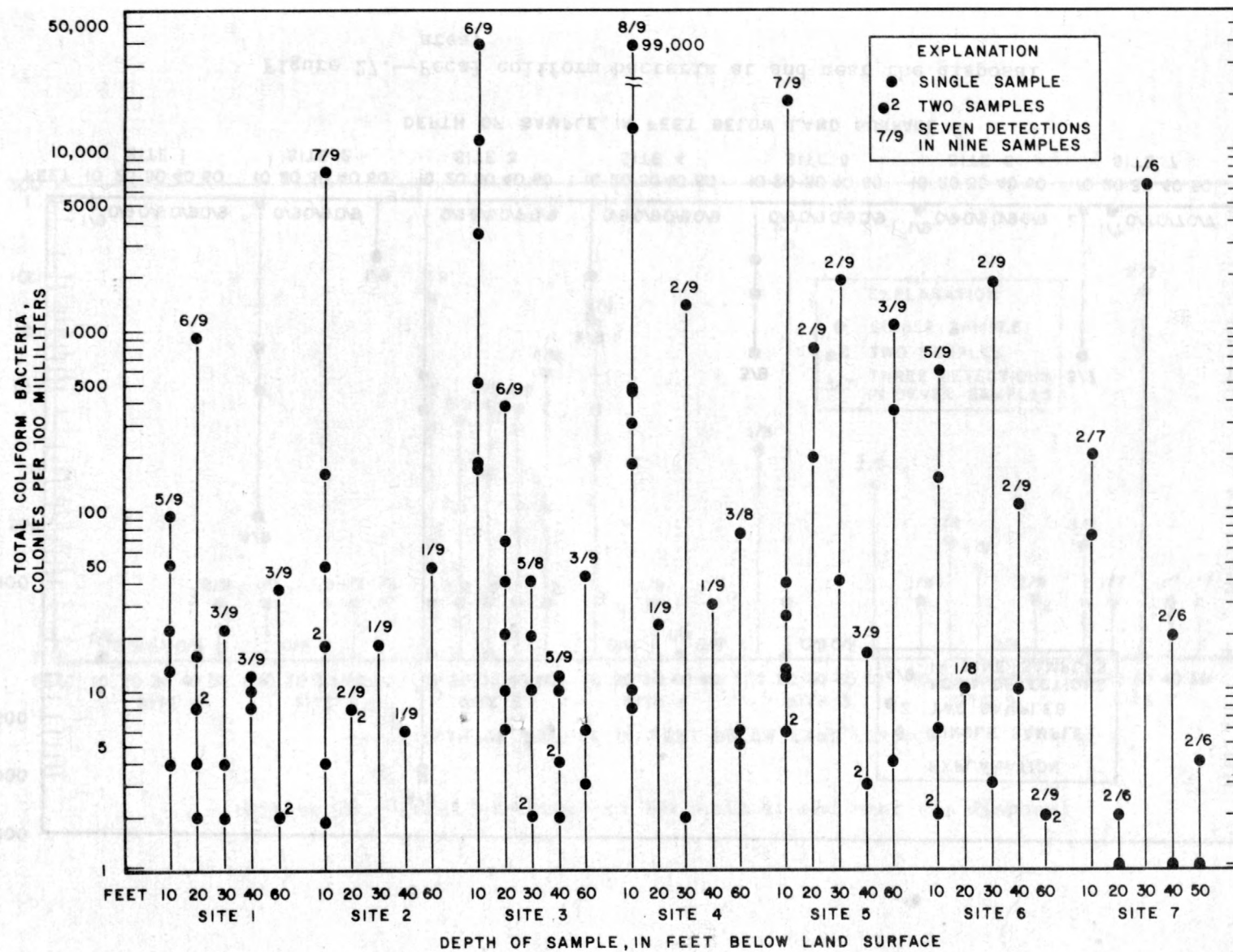


Figure 26.--Total coliform bacteria at and near the disposal area.

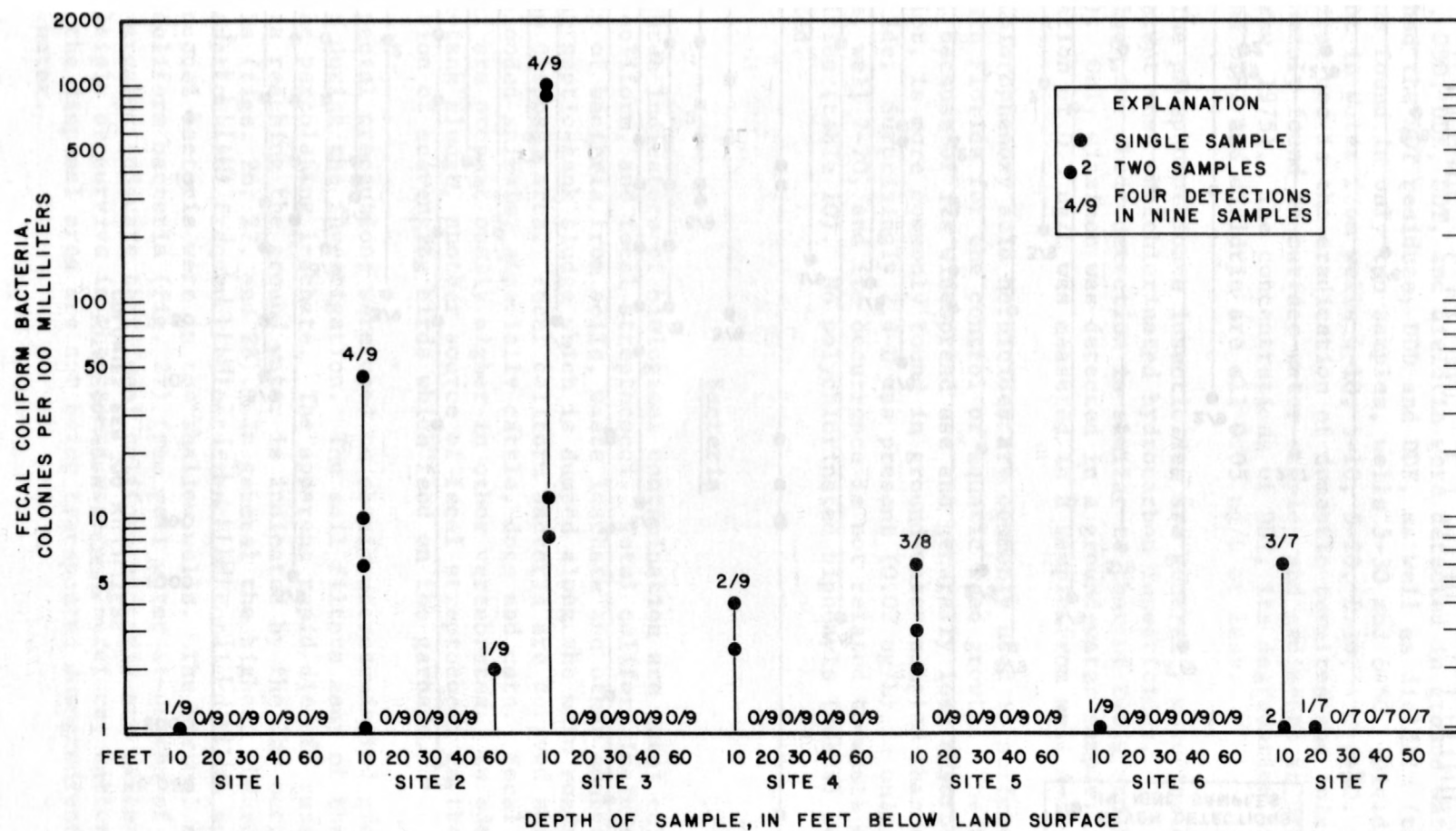


Figure 27.--Fecal coliform bacteria at and near the disposal area.

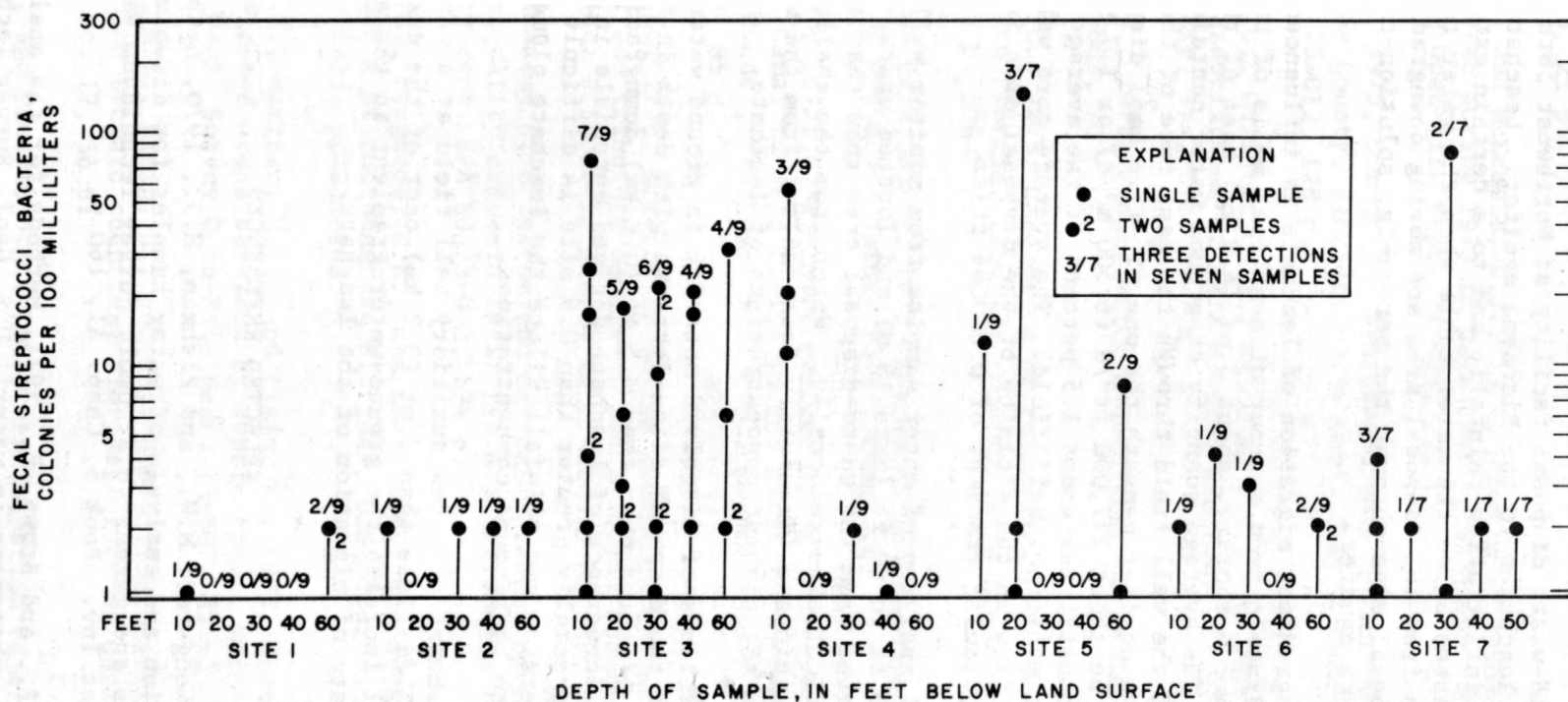


Figure 28.--Fecal streptococci bacteria at and near the disposal area.

SUMMARY

The solid-waste disposal facility at Northwest 58th Street is contributing leachates to the Biscayne aquifer. Leachates are formed primarily by infiltrating rainfall, and to a certain extent, by immersion of wastes below the water table when the water table is high. The leachates from the disposal area are moving downgradient, eastward, from the disposal area through the permeable, solution-riddled limestone of the Biscayne aquifer.

The downgradient migration of leachate is influenced by the continuous withdrawals from a group of municipal wells of the Miami-Dade Water and Sewer Authority, about 3 mi (4.8 km) east of the waste disposal area. The average quantity of ground water containing leachate moving toward the well field through the east face of the underflow section of the aquifer beneath the one mi² (1.6 km²) disposal area was estimated to be about 227,000 ft³/d (6,500 m³/d) or 1.7 Mgal/d 0.74 m³/s. This constitutes about 1.5 percent of the average daily withdrawal of the municipal well field. The average pore velocity of ground-water flow in the vicinity of the disposal area is 2.9 ft/d under an average hydraulic gradient of 0.000086 ft/ft.

Chemical analyses of water samples from monitor wells ranging in depth from 10 ft to 60 ft (3 to 18 m) and located upgradient, within, and downgradient from the waste-disposal area show that the concentration of leachate fluctuates seasonally. Water from the shallowest (10 ft or 3-m) wells within and immediately downgradient from the waste-disposal area contains the highest concentrations of leachate.

Concentrations of dissolved material in ground water--material that originates at the disposal site--decrease with depth in the aquifer. Leachate has migrated more than 0.5 mi (0.8 km) downgradient from the source. The occurrence of leachate-derived materials in ground water at distances appreciably greater than 0.5 mile is difficult to determine because dispersion and rainfall dilute the leachate plume to concentrations close to background concentrations.

Establishment of a new auxiliary well field at a capacity of 40 Mgal/d (151 ML/d) less than 2 mi (3.2 km) east of the disposal facility probably will increase the ground-water gradient in the area and increase the rate of migration of the leachate.

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