WATER QUALITY AT AND ADJACENT TO THE SOUTH DADE COUNTY SOLID-WASTE DISPOSAL FACILITY, FLORIDA

By Donald J. McKenzie

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ABBREVIATIONS AND CONVERSION FACTORS

Factors for converting inch-pound units to International System (SI) of metric units and abbreviation of units

Multiply	By	To obtain
inch (in)	25.4	millimeter (mm)
square foot (ft^2)	0.0929	square meter (m^2)
foot (ft)	3.048×10^{-1}	meter (m)
mile (mi)	1.609	kilometer (km)
acre	0.4047	hectare (ha)
gallon (gal)	3.785	liter (L)
gallon (gal)	3.785×10^{-3}	cubic meter (m^3)
million gallons (Mgal)	3,785	cubic meters (m^3)
gallon per minute (gal/min)	0.06309	liter per second (L/s)

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. The datum was derived from the average sea level during many years at 26 tide stations along the Atlantic and Pacific Oceans and the Gulf of Mexico. NGVD of 1929 is referred to as sea level in this report.

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ABSTRACT

A water-quality reconnaissance was conducted at the south Dade County solid-waste landfill near Goulds, Fla., from December 1977 through August 1978. The landfill is located directly on the unconfined Biscayne aquifer, which in the study area, is affected by saltwater intrusion. Water samples collected from six monitor well sites at two depths and four surface-water sites were analyzed to determine the chemical, physical, and biological conditions of the ground water and surface water of the study area. Results indicated that water quality beneath the landfill was highly variable with location and depth. Leachate was generally more evident in the shallow wells and during the dry season sampling, but was greatly diluted and dispersed in the deep wells and during the wet season. High concentrations of contaminants were generated primarily in areas of the landfill with the most recent waste deposits. Chloride (limited to the shallow wells and the dry season), alkalinity, ammonia, iron, manganese, lead, phosphorus, and organic nitrogen indicate leachate contamination of the aquifer. Water-quality characteristics of the surface waters indicated only slight leachate contamination.

INTRODUCTION

Dade County, on the southeastern tip of the Florida peninsula, is underlain by the Biscayne aquifer, a highly transmissive body of limestone, sandstone, and sand that yields large quantities of high-quality ground water for municipal supply and agricultural use. This wedge-shaped aquifer narrows as it extends westward into Collier and through Monroe Counties and northward through Broward and into Palm Beach Counties. Its importance is heightened by the fact that it is the sole source of potable water for over 3 million people, of which 90 percent reside in the Miami metropolitan area in northeast Dade County.

For several decades, Dade County water-resource planners and managers have been actively engaged in protecting this vital water resource from degradation. Since the 1930's, for example, a primary focus of water agencies has been identifying and impeding saltwater intrusion into the aquifer. As a result of these efforts, many management practices are now utilized that greatly minimize the impact of saltwater contamination of the Biscayne aquifer. More recently, however, water-resource agencies have become increasingly concerned regarding the potential for ground-water degradation caused by the ever increasing point source or diffuse sources of contamination. Many of these potential sources of contamination are the result of various waste-disposal practices. One such source, for example, is the landfill which is a common method for the disposal of solid wastes.

Landfills are a well documented source of point-source contamination caused by the biochemical decomposition (decay) of solid waste and subsequent leachate commingling with local water resources. However, to assess the magnitude of adverse impacts, site specific data are usually necessary. This is because the severity of contamination depends upon the amount, type, and age of refuse, its degree of compaction, the amount of water in contact with it, and the temperature. The principal waste materials that most contribute to leachate quality are biodegradable organic matter, soluble inorganic materials, and soluble metal complexes. Water availability generally determines the rate of decomposition and whether the process is predominantly aerobic or anaerobic. Aerobic decay produces stable end products, such as carbon dioxide, nitrate, sulfate, water, and relatively inert residue. Anaerobic decay of organic material produces carbon dioxide, methane, ammonia, hydrogen gas, alcohols, and organic acids and other partially oxidized organic species (Salle, 1954, p. 376). Metals, such as iron and manganese, also may be concentrated in the leachate in such a reducing environment (Apgar and Langmuir, 1971, p. 77).

This report is part of a three-site assessment of water-quality conditions in areas of solid-waste disposal in Dade County. It is primarily intended to furnish county water planners and managers with specific water-quality information regarding the quality of landfill leachate, along with generalized observations on the quality impact on contiguous water resources due to leachate encroachment. The results are also intended as a general data contribution to the U.S. Geological Survey's activities in the areas of water-quality impacts of surface-waste disposal and ground-water quality. The first assessment was conducted at the Northwest 58th Street disposal facility in central Dade County (Mattraw and others, 1978), and the second assessment was conducted at the north Dade County solid-waste disposal facility (McKenzie, 1982).

Purpose and Scope

From 1977 to 1978, the U.S. Geological Survey, in cooperation with the Dade County Department of Public Works, conducted a water-quality reconnaissance of the south Dade County solid-waste disposal facility (landfill) near Goulds, Fla. The general purpose of this reconnaissance was to describe water-quality conditions of the landfill and nearby area, and to assess generally the water-quality impact of solid-waste leachate migration from the landfill into contiguous ground- and surface-water resources. The scope of this study primarily included: the construction of monitor wells of variable depth upgradient from and within the landfill, coring of an upgradient well for geohydrologic analysis, the establishment of stream-sampling sites, and the periodic collection and analysis of ground-and surface-water samples for selected water-quality characteristics.

Specific objectives of the reconnaissance were: (1) determine and describe general water-quality conditions of surface and ground water upgradient from and within the landfill; (2) generally describe selected water-quality impacts (variations) possibly resulting from the downgradient movement of leachate from the landfill; (3) compare selected water-quality characteristics of the landfill area with the National Primary and Secondary Drinking Water Regulations; and (4) based on the 1977-78 reconnaissance, outline a general data-collection program for the monitoring of the landfill area to assess future quality of water impacts caused by leachate migration from the landfill.

Acknowledgments

For assistance in the design of the reconnaissance, the author is indebted to William M. Powell, Director, and Joseph M. Brown of the Dade County Department of Public Works. Much appreciated technical assistance was provided by Sidney Leopold and Anthony Sobrino of the Department. The author expresses special appreciation to Peter Thomas of the Department's Civil Engineering Division for cooperation and technical aid.

DESCRIPTION OF AREA

The south Dade County disposal facility is located in eastern Dade County about 20 miles southwest of Miami, 11 miles northeast of Homestead, and 0.5 mile west of Biscayne Bay (fig. 1). The nearest towns or populated areas are Goulds (2 miles to the west) and Cutler Ridge (2 miles to the north). Although a few domestic wells are located nearby, the closest public water supply is 4 miles to the southwest of the landfill at Homestead Air Force Base.

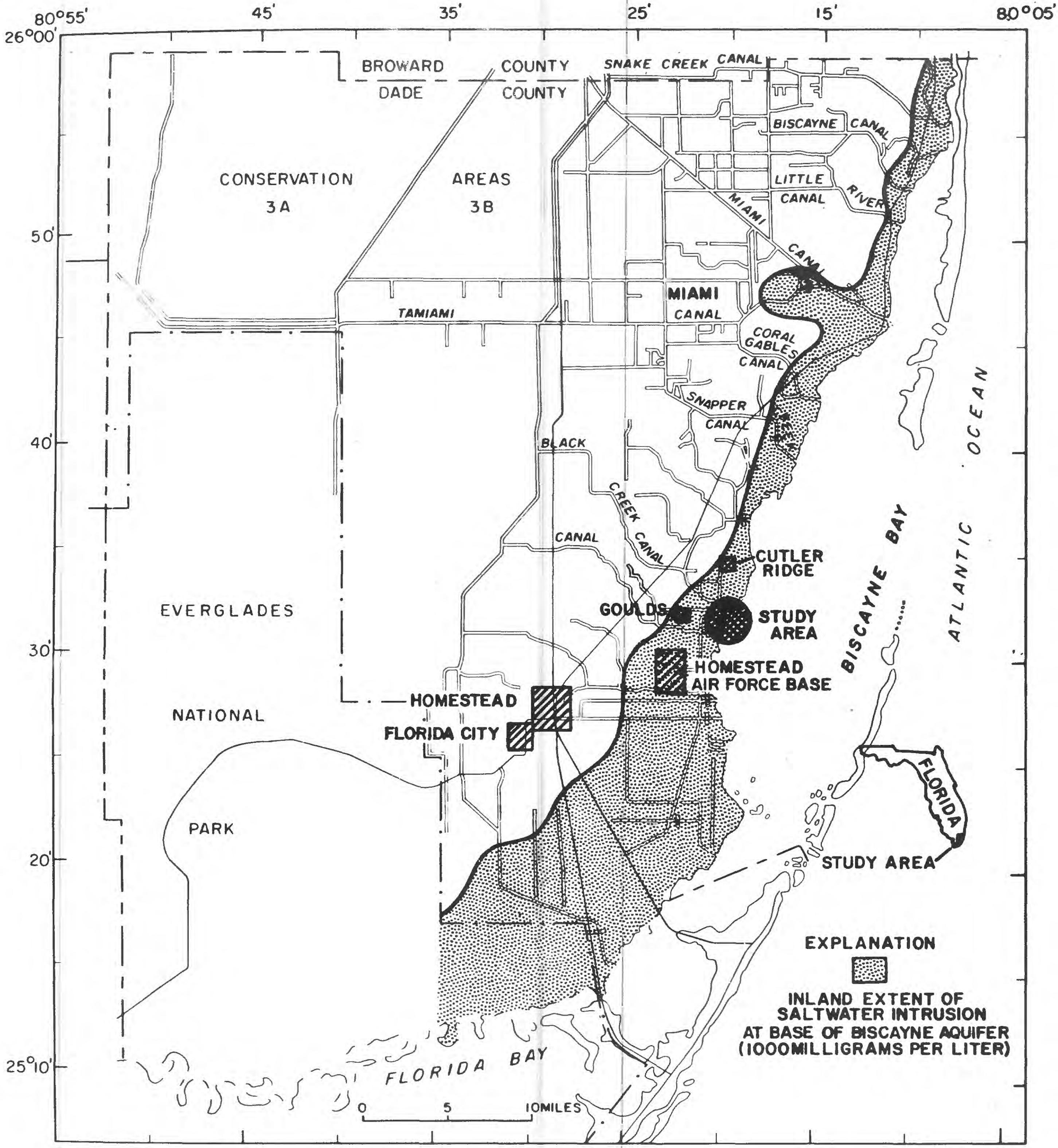


Figure 1.--Study site in south Dade County, Florida, and the inland extent of saltwater intrusion at the base of the Biscayne aquifer (modified from Hull and Meyer, 1973, p. 12).

Land use in the region primarily consists of agriculture to the west and southwest. Urban development is encroaching on the region from the northwest. Between the landfill and Biscayne Bay is a mangrove marsh.

The study area encompassed roughly 2,000 acres including the completed, active, and proposed landfill sections and the monitoring locations (fig. 2). The total landfill (completed, active, and proposed sections) occupies just under 600 acres; the completed section of the landfill occupies about 270 acres or roughly the southern half of the total landfill area. A monitoring site (site 1) to determine the native (background) quality of the ground water was located 0.7 mile north of the completed section of the landfill. A monitoring site (site 2) to determine upgradient migration of the landfill leachate was located 0.5 mile west of the completed section of the landfill. Monitoring sites to determine the quality of ground water beneath the landfill (sites 3-6) and quality of the surface water (sites 7-10) were located within and on the boundaries of the completed section of the landfill. (Site 7 was located with site 2.)

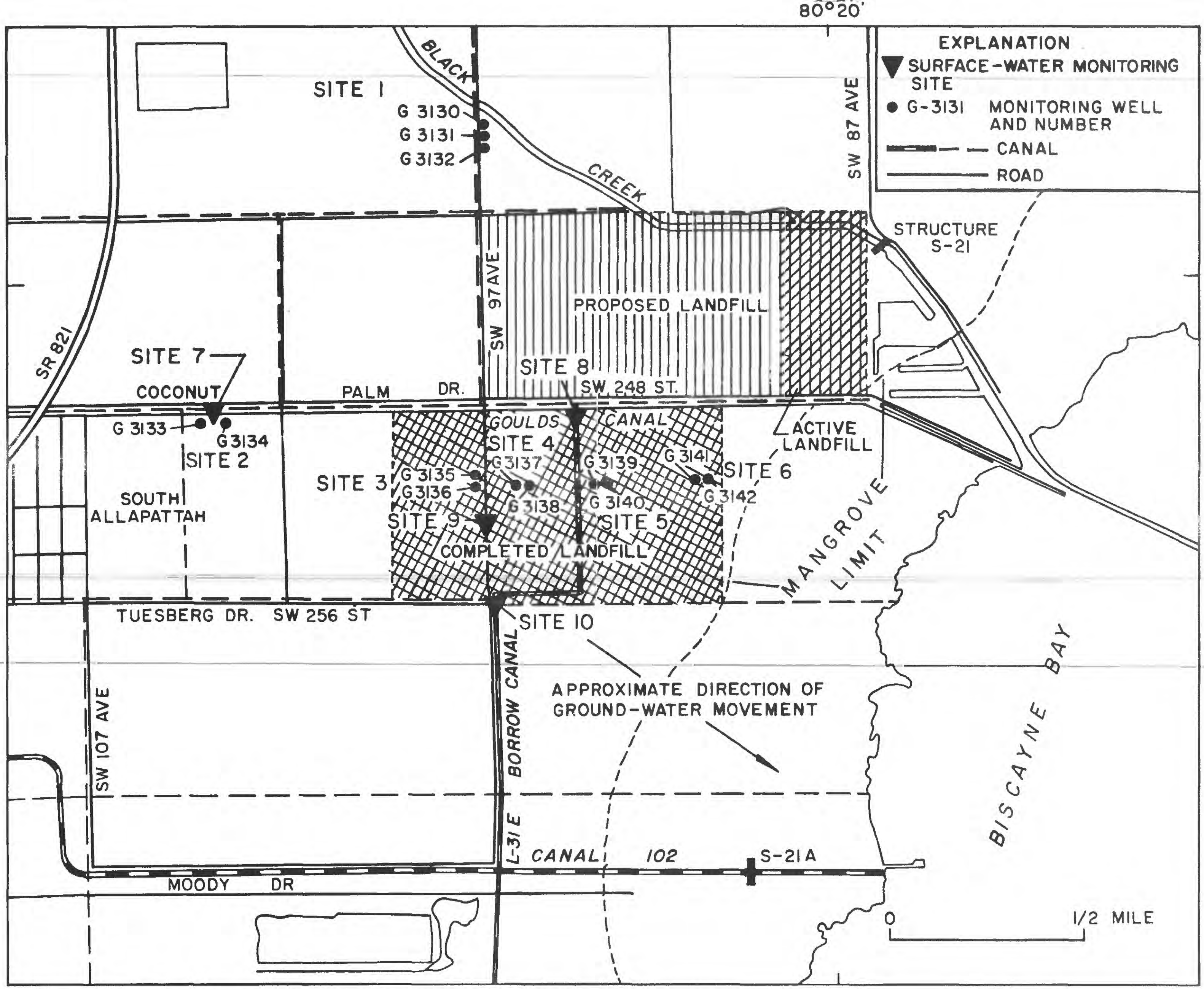
The area in and around the landfill is crisscrossed by primary and lesser canals, and drainage ditches. The completed section of the landfill is bounded on the north by the Goulds Canal and on the south by a lesser canal.

The natural land surface is nearly flat and slopes gently southeastward toward the bay. Elevation at the western edge of the landfill is about 3 feet above sea level. Because of the low elevation and marly soil, the surface is saturated for long periods. Tide flooding, caused by hurricane-driven tides, occurred in 1946 and 1965.

The climate is humid subtropical with an average annual temperature of about 70°F and an average annual rainfall of about 65 inches. Rainfall is greatest during May through October and least from November through April (Hull, 1978, p. 6).

Geology of the Study Area

The Biscayne aquifer is wedge-shaped, ranging in thickness from about 70 to 160 feet along the eastern coast and thinning to about 10 feet along the western edge of Dade County. The base of the aquifer is estimated to be about 70 to 80 feet below the natural land surface in the landfill area (Schroeder and others, 1958, fig. 2). The aquifer consists of sand and permeable sandy limestone, and calcareous sandstone. Parker and others (1955, p. 160-167) determined that much of the limestone contains closely spaced cavities formed by solution, and indicated further that the Biscayne aquifer is one of the most permeable aquifers investigated by the U.S. Geological Survey. The transmissivity of the aquifer in the Homestead area is about 2.0×10^6 ft^2/d (Pitt and others, 1975, p. 14 and 40).



BASE FROM U.S. GEOLOGICAL SURVEY 1:24,000 QUADRANGLES

Figure 2.--Location of south Dade County landfill area and U.S. Geological Survey ground-water quality monitor wells and surface-water quality monitoring sites.

Test-well G-3132 was drilled and cored at site 1 (fig. 2) to provide geohydrological information. Two-inch diameter steel pipe was used to case the well. The lithologic log and description of the well core are shown in figure 3.

Hydrologic Aspects

Ground water moves generally southeast (downgradient) in south coastal Dade County (fig. 4). Water levels in the aquifer are affected by tide and also respond somewhat to the automatic opening and closing of the gates in control-structure S-21A in Canal 102 and S-21 in Black Creek Canal (fig. 2). The water table under the landfill area is normally 1 to 3 feet below the natural land surface.

During dry periods, water levels are raised or lowered in the canals to accommodate the cultivation of crops west of the landfill. Because the changes in the canal levels are intermittent, the effects are normally of short duration and do not alter the overall ground-water flow to the southeast.

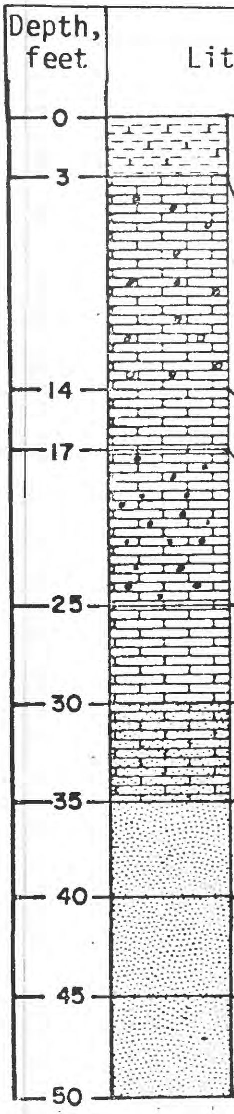
The Biscayne aquifer is subject to saltwater intrusion (fig. 1). Chloride concentration in the landfill area is at least 1,000 milligrams per liter (mg/L) at the base of the aquifer.

Landfill History

The south Dade County landfill has been in operation since about 1952. The first waste deposits were made in the eastern extremity of the site, and as the desired height was reached, the operation moved westward. In 1978, the completed section of the landfill was closed, and operations were begun adjacent to Black Creek Canal, indicated as the active landfill in figure 2.

The exact manner of disposal operations during the early years was not recorded. Waste was probably placed directly on the undisturbed land surface without soil-filling to raise the land surface above high ground-water levels or flood levels. In some cases, excavation may have occurred below the water table. Waste material was eventually covered to allow access over the fill, although the specific types of cover materials that are now required in landfill operations were not applied. Prior to 1960, garden trash was burned in open fires to reduce volume, and the residue was used as fill.

In recent years, the fill-and-cover method was used. At the end of each day, the accumulated deposits were covered by a layer of soil about 1 foot thick to alleviate offensive odors and animal disease carriers. The fill is about 6-8 feet thick in the area east of S.W. 97th Avenue and about 15 feet thick to the west in the area of the most recent deposits.



Lithology	Description
Marl	Alkaline, low in organic matter, nitrogen, phosphorus, and potassium. Low hydraulic conductivity, becomes waterlogged during rainy season. Sources: Hull and Meyer, 1973, p. 15; Leighty and Henderson, 1958.
Limestone, oolitic	Slighty chalky, solution riddled, interconnected, high vertical but lower horizontal conductivity. Source: Parker and others, 1955, p.66.
Limestone	Very hard.
Limestone	Solution riddled, interconnected, filled with sand, highly permeable.
Limestone	Dense.
Limestone	Hard, sandy.
Sandstone	Soft, yielded 25-30 gal/min during half-hour tests from 2-inch well G-3132.
Sand and Sandstone	
Sand	

Figure 3.--Lithologic section and description of well G-3132 at site 1.

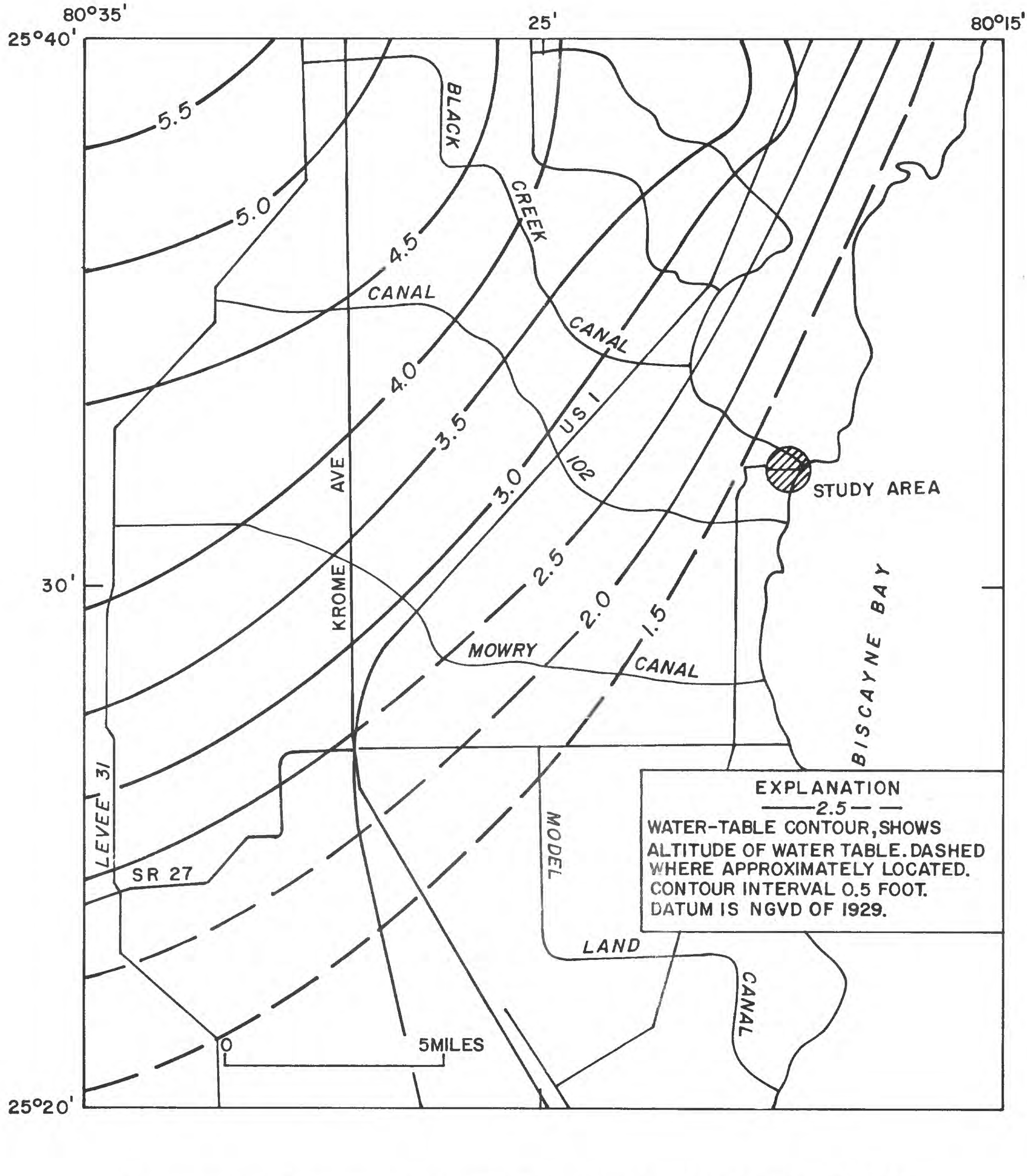


Figure 4.--Contours of the average ground-water level, 1960-75. (modified from Hull, 1978, p. 10).

The amount of waste deposited in the south Dade County landfill has increased substantially since 1960 (table 1). For example, the total waste deposited in 1974-75 was almost 5 times greater than that deposited in 1960-61. Prohibition of open-pit burning in 1960 was mostly responsible for the greater volume of waste deposited each year since then.

Refuse at the disposal facility consists of trash and garbage from private, municipal, and county sources. The composition and primary sources of the waste are shown in table 2. Sludge from the Virginia Key sewage-treatment plant, the largest in southeast Florida, has been disposed of at the landfill for several years, but there are no records to determine the amount or placement of disposal.

METHODS AND PROCEDURES

Monitoring Network

Pairs of observation wells were established at six sites upgradient from and within the completed section of the landfill (fig. 2). At each site, one well penetrated the upper few feet of the Biscayne aquifer, and the other penetrated 6-17 feet (generally about 10 feet) deeper. A third well was cored at site 1 to a depth of 45 feet to provide detailed geohydrologic and lithologic information. All wells are in about equally permeable zones and have the bottom 1 foot, or less, of depth uncased and open to the aquifer.

The wells at site 1, 0.7 mile north of the completed landfill, provided information on the background water quality of the aquifer. The wells at site 2, 0.5 mile west of the completed landfill, also provided background water quality and an indication of whether or not leachate had migrated upgradient from the landfill.

The wells at sites 3-6, established in an easterly direction across the completed landfill, provided water-quality data for that part of the aquifer that was being contaminated by landfill leachate. Site 6, at the eastern edge of the completed landfill, could not be located farther east (downgradient) because of the marshy conditions.

Because a probable hydraulic connection exists between the aquifer and the canals, surface-water sampling sites were established on the primary canals and a shallow drainage ditch. Site 7 was established on Goulds Canal adjacent to ground-water site 2, site 8 on Goulds Canal on the north side of the completed landfill, site 9 on the drainage ditch within the completed landfill, and site 10 on the L-31E Borrow Canal on the south side of the completed landfill. The canal depths are 9 to 12 feet below sea level and cut into the Biscayne aquifer. The drainage ditch cuts about 3 feet below the natural ground level and is just downgradient from the most recent waste deposits.

Table 1.--Waste loads in tons at the south Dade County solid-waste disposal facility, 1960-75

[Data from Dade County Department of Public Works]

Calendar year	Garbage	Trash	Total
1960-61	28,260	2,613	30,873
61-62	15,849	3,802	19,651
62-63	17,357	5,599	22,956
63-64	18,601	1/9,911	28,512
64-65	19,542	1,916	21,458
65-66	21,889	4,794	26,683
66-67	33,187	6,284	39,471
67-68	35,359	6,525	41,884
68-69	38,833	16,724	55,557
69-70	50,195	10,567	60,762
70-71	58,560	9,242	67,802
71-72	48,525	38,616	87,141
72-73	53,091	53,597	106,688
73-74	80,929	58,029	138,958
74-75	93,963	52,303	146,266
Total:			
15 years	614,140	280,522	894,662

1/ Additional trash due to damage from a hurricane.

Table 2.--Composition of solid wastes at the south Dade County solid-waste disposal facility

[Data from Dade County Department of Public Works]

Category	Composition		Sources
Garbage	Wastes from the preparation, cooking, and serving of food; market refuse, waste from the handling, storage, and sale of produce and meats.		Households, institutions and commercial concerns such as hotels, stores, restaurants, markets.
Trash	Bulky wastes	Large auto parts, tires; stoves, refrigerators, other large appliances; furniture, large crates.	Streets, sidewalks, alleys, vacant lots.
	Parkway and street refuse	Street sweeping, dirt; leaves; catch basin dirt; contents of litter receptacles; trees, branches, palm fronds, and stumps.	

Sampling and Analytical Methods

The U.S. Geological Survey National Water-Quality Laboratory--Atlanta, in Doraville, Ga., provided the analyses for major ions, metals, pesticides, oil and grease, phenols, and detergents. Also, the laboratory made determinations for turbidity, color, specific conductance, dissolved and suspended solids, and pH. The U.S. Geological Survey District Service Unit in Ocala, Fla., made determinations for nutrients (the common species of nitrogen and phosphorus), organic and inorganic carbon, and chemical oxygen demand (COD). The U.S. Geological Survey office in Miami made determinations for 5-day biochemical oxygen demand (BOD) and for indicator bacteria. Field determinations were made for temperature, alkalinity, specific conductivity, and pH. The analytical techniques used for most of the determinations are described by Brown and others (1970).

Ground-water samples were obtained by pumping the well long enough to obtain a sample of water representative of the zone at the base of the well. Bottle samplers were used to obtain integrated samples of the surface water. Analytical data for the water samples can be retrieved from WATSTORE (U.S. Geological Survey) and STORET (U.S. Environmental Protection Agency) using the U.S. Geological Survey identification numbers in table 3.

Frequency of Sample Collection

The monitoring sites were sampled initially in December 1977 (dry season) to determine: (1) the presence of toxic contaminants; and (2) whether any particular parameters should be emphasized or excluded during subsequent samplings. The sites were then sampled again in the dry season in April 1978, and in August 1978 during the wet season (fig. 5).

WATER QUALITY OF THE STUDY AREA

Quality of the Native Ground Water

Samples of water were collected from the site 1 monitor wells (G-3130 and G-3131) and were analyzed to determine the quality of the native ground water in the study area. Water-quality data from five water-supply wells in central and south Dade County (Irwin and Healy, 1978, p. 144-146; Hull, 1978, p. 87-113) were composited (table 4) so that comparison could be made between the native ground water in the study area (site 1) and the regional and historical water quality of the Biscayne aquifer. Comparison shows similar ranges of most of the characteristics with the notable exceptions of chloride and specific conductance. Concentrations of these two characteristics were substantially higher at the site 1 wells than at the water-supply wells. These comparisons would tend to indicate the site 1 wells were affected by saltwater intrusion.

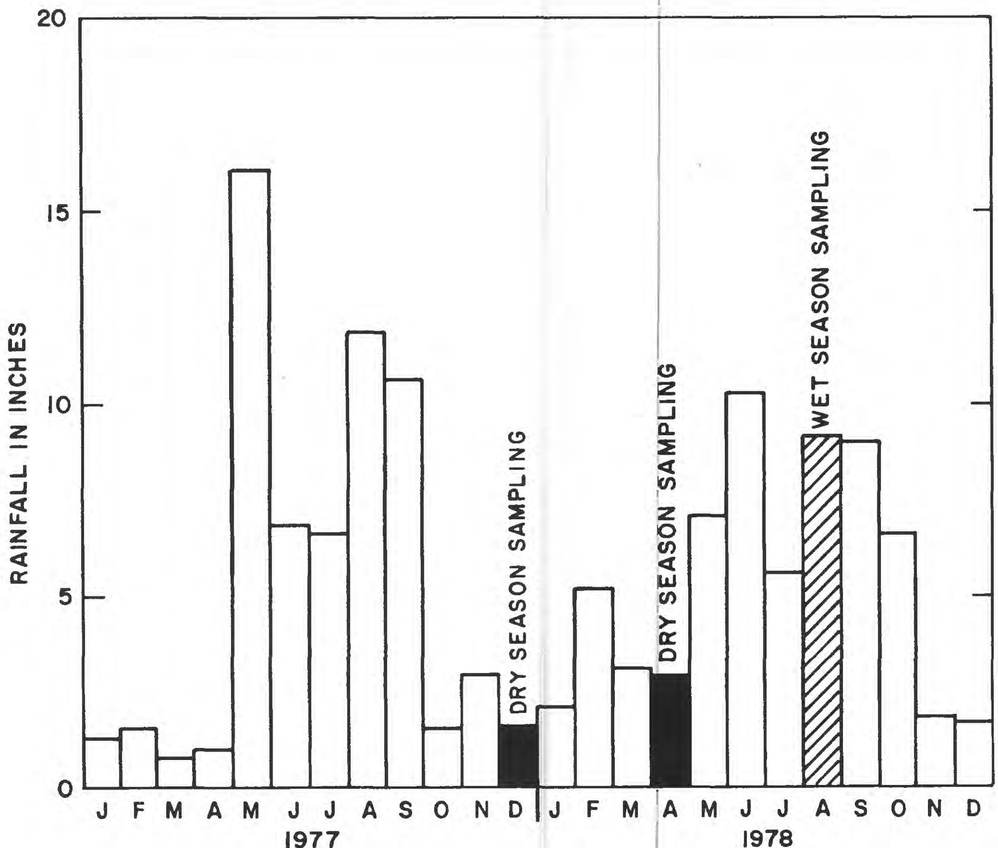


Figure 5.--Water quality sampling periods and monthly rainfall totals at the Homestead University of Florida Agricultural Research Station.

Table 3.--Ground-water and surface-water sampling sites, identification numbers, and well depths at the south Dade County solid-waste disposal facility

[See figure 2 for location of sites]

Ground-water site No.	Local well No.	USGS Identification well No.1/	Depth below landfill surface, in feet
		Background water quality	
1	G-3130	253249080205201	14.5
	G-3131	253249080205202	31.5
	G-3132	253249080205203	45.0
		Upgradient wells	
2	G-3133	253212080210801	10.6
	G-3134	253212080210802	19.7
		Wells within disposal site	
3	G-3135	253203080205301	15.3
	G-3136	253203080205302	26.2
4	G-3137	253203080204701	25.0
	G-3138	253203080204702	31.0
5	G-3139	253203080203501	28.5
	G-3140	253203080203502	38.6
6	G-3141	253203080202102	10.9
	G-3142	253203080202101	21.1

Surface water site No.	Canal name and location	Identification number
7	Goulds Canal west of 97th Avenue	253213080210800
8	L31E Borrow Canal at Coconut Palm	253212080203800
9	97th Avenue Seepage Ditch	253157080225200
10	L31E Borrow Canal at 256th Street	253145080205000

1/ Data can be retrieved from WATSTORE (U.S. Geological Survey) or STORET (U.S. Environmental Protection Agency), by using USGS identification numbers.

Table 4.--Summary of general ranges of selected water-quality characteristics of ground water from five water-supply wells in central and south Dade County[1]/

[Analyses by U.S. Geological Survey]

Characteristics	Concentrations
Major inorganics and related physical characteristics	**Concentrations in milligrams per liter**
Alkalinity (as $CaCO_3$)	226 - 243
Bicarbonate	276 - 296
Calcium	90 - 94
Chloride	25 - 82
Dissolved solids (residue at 180°C)	325 - 444
Fluoride	.2 - .3
Magnesium	.8 - 36
pH (standard units)	7.3 - 7.4
Potassium	2.3 - 3.4
Silica	6.8 - 11
Sodium	17 - 47
Specific conductance (umhos/cm at 25°C)	570 - 760
Sulfate	14 - 50
Trace elements	**Concentrations in micrograms per liter**
Arsenic	.0 - 2.0
Barium	.0 - .0
Cadmium	.0 - 4.0
Chromium	10 - 20
Lead	4 - 21
Mercury	.0 - .1
Selenium	.0 - .0
Silver	.0 - 7.0
Nutrients	**Concentrations in milligrams per liter**
Ammonia, total as N	.05 - 1.20
Nitrate, total as N	.00 - .07
Nitrite, total as N	.0 - .0

1/ U.S. Navy well No. 7 at Florida City.
Preston water-treatment plant at Hialeah.
Hialeah water-treatment plant at Hialeah.
Homestead Air Force Base water-treatment plant.
Orr water-treatment plant at Miami.

The wells at site 2 were sampled and analyzed to determine if leachate from the landfill had migrated upgradient. The results in table 5 show that the water quality of the site 2 wells is substantially similar to the water quality of the site 1 wells. Thus, there is no indication of upgradient movement of the landfill leachate, and the quality of water at site 2 is also representative of the quality of the native ground water.

Quality of Ground Water at the Landfill

Table 5 presents a summary of ranges of chemical, physical, and biological characteristics from monitor wells upgradient from (sites 1 and 2) and within (sites 3-6) the completed section of the landfill.

Ranges of characteristics from the upgradient wells are representative of the quality of the native ground water. Ranges of characteristics from the wells within the completed landfill reflect varying degrees of leachate contamination. Well G-3135, the shallow well at site 3, is located directly beneath recent waste deposits. It is distinguished from the other landfill wells because its ranges of characteristics indicate greater leachate contamination than do the ranges of characteristics from the other landfill wells in areas of older waste deposition.

The table indicates that many characteristics (such as chloride, alkalinity, ammonia, COD, and total coliform) were significantly more concentrated in well water from the landfill than from upgradient wells. Discussions of selected water-quality characteristics that appear to have significant concentration differences among the well sites or are of special significance are presented individually in the following sections.

Chloride

Chloride is a common constituent of solid-waste leachate. In Zanoni's (1971, p. 102) review of the literature concerning solid-waste disposal research studies, most authors reported that the chloride concentration in the leachate, directly below a landfill, was extremely high. In those studies, chloride was useful as an indicator of leachate concentration and as a tracer of the leachate plume. Chloride ions are conservative tracers and are retained in solution through most of the processes which separate other ions (Hem, 1970, p. 172). Kaufman and Orlab (1956, p. 559) found that chloride ions moved through most soils tested with less retardation or loss than other tracers.

Table 5.--Summary of analytical ranges of selected chemical, physical, and biological characteristics of water samples from ground-water sites 1-6, December 1977 and April and August 1978

[Analyses by U.S. Geological Survey]

Characteristics	Wells upgradient from landfill 3130-31 (Site 1)	Wells upgradient from landfill 3133-34 (Site 2)	Wells within landfill 1/3135 (Site 3)	Wells within landfill 3136-42 (Sites 3-6)
Major inorganic and related physical characteristics	Concentrations in milligrams per liter			
Alkalinity (as $CaCO_3$)	230 - 230	170 - 230	1,380 - 2,990	290 - 950
Bicarbonate	276 - 284	210 - 280	1,680 - 3,650	350 - 1,160
Calcium	100 - 100	93 - 130	220 - 300	74 - 130
Chloride	190 - 320	120 - 450	120 - 840	120 - 380
Dissolved solids (residue at 180°C)	629 - 846	535 - 1,210	1,940 - 4,410	623 - 1,230
Fluoride	.1 - .1	.1 - .2	.0 - .2	.1 - .3
Magnesium	12 - 19	10 - 26	49 - 130	15 - 40
pH (standard units)	7.3 - 7.3	7.1 - 7.4	6.7 - 7.8	6.7 - 7.7
Potassium	7.4 - 9.3	6.2 - 16	190 - 760	34 - 120
Silica	5.4 - 5.6	3.9 - 4.6	26 - 47	5.3 - 17
Sodium	110 - 180	54 - 220	190 - 560	95 - 260
Specific conductance (umhos/cm at 25°C)	1,140 - 1,550	810 - 1,900	870 - 7,500	1,320 - 2,400
Sulfate	58 - 64	65 - 99	18 - 37	13 - 83
Trace elements	Concentrations in micrograms per liter			
Aluminum	60 - 70	0 - 50	30 - 90	0 - 140
Arsenic	1 - 1	1 - 2	2/2	1 - 2
Barium	100 - 100	0 - 0	200 - 300	0 - 0
Cadmium	1 - 3	0 - 2	0 - 1	0 - 7
Chromium	10 - 10	10 - 20	60 - 70	10 - 20
Copper	0 - 11	1 - 5	3 - 29	0 - 16
Iron	740 - 2,900	1,500 - 5,000	21,000 -30,000	740 -26,000
Lead	11 - 16	0 - 21	1 - 36	0 - 52
Manganese	10 - 20	10 - 20	500 - 800	10 - 170
Mercury	.5 - .5	.5 - .5	.5 - .5	.5 - .5
Selenium	0 - 0	0 - 0		0 - 0
Silver	1 - 1	0 - 0	0 - 0	0 - 0
Strontium	1,100 - 1,100	1,100 - 1,500	2,500 - 3,600	1,100 - 1,500
Zinc	10 - 40	10 - 30	170 - 670	0 - 60

1/ Shallow well directly beneath recent waste deposits.
2/ One analysis only.

Table 5.--Summary of analytical ranges of selected chemical, physical, and biological characteristics of water samples from ground-water sites 1-6, December 1977 and April and August 1978--Continued

[Analyses by U.S. Geological Survey]

Characteristics	Wells upgradient from landfill: 3130-31 (Site 1)	Wells upgradient from landfill: 3133-34 (Site 2)	Wells within landfill: 1/3135 (Site 3)	Wells within landfill: 3136-42 (Sites 3-6)
Selected nutrients and related characteristics		Concentrations in milligrams per liter		
Ammonia, total as N-----	0.83 - 1.00	0.14 - 0.19	82 - 280	5.1 - 110
Nitrate, total as N-----	.00 - .01	0 - 0	0 - 0	0 - .01
Nitrite, total as N-----	0 - 0	0 - 0	.02 - .05	0 - .07
Organic nitrogen, total as N------------	.37 - .72	.01 - .28	14 - 44	.57 - 8.4
Phosphorus, total as P--	.08 - .09	.00 - .01	1.4 - 3.2	.01 - .23
Carbon, total organic---	7 - 7	0 - 13	145 - 550	.0 - 81
Carbon, total inorganic-	---	64 - 64	2/360	80 - 240
BOD, 5 day--------------	---	.2 - .8	.8 - 9	.7 - 9
COD (high level)--------	44 - 74	20 - 80	310 - 1,500	52 - 240
Carbon dioxide----------	18 - 23	13 - 36	62 - 536	21 - 370
Miscellaneous chemical characteristics		Concentrations in milligrams per liter		
Cyanide-----------------	0 - 0	0 - 0	2/.030	.000 - .020
Detergents (MBAS)-------	.10 - .10	.0 - .0	.10 - .90	.10 - .70
Oil and grease----------	.0 - 5.0	.0 - 1.0	1 - 9	0 - 2
Phenols-----------------	.002 - .004	0 - .100	.009 - .036	.000 - .039
Bacteria		Colonies per 100 milliliters		
Coliform, total---------	---	5 - 70	210 - 33,000	1 - 1,300
Coliform, fecal---------	---	1 - 32	140 - 16,000	1 - 80
Streptococci, fecal-----	---	2 - 112	160 - 290	1 - 1,500

1/ Shallow well directly beneath recent waste deposits.
2/ One analysis only.

In this study, high chloride concentrations were a condition of the native ground water due to saltwater intrusion. In table 6, the upgradient wells (sites 1 and 2) show increasing chloride concentration with depth, a distribution characteristic of saltwater intrusion. By contrast, dry-season chloride concentrations for wells within the landfill (sites 3-6) decreased, generally, with depth from a highest concentration of 840 mg/L directly beneath the recent waste deposits (G-3135) to lower concentrations approaching those of the native ground water. This type of distribution suggests that a chloride-rich leachate at shallow depths occurs during the dry season. During the wet season, although greater quantities of leachate are generated, it is subject to much more dilution and dispersion; thus, chloride concentrations contributed by leachate are masked by the native ground-water conditions. The conclusion is that chloride is of limited value as an indicator of leachate contamination because of the high native concentrations.

Alkalinity

In most natural water, the alkalinity (as $CaCO_3$) is produced by dissolved carbonate and bicarbonate ions and anions or molecular species of weak acids which are not fully dissociated above a pH of 4.5 (Hem, 1970, p. 152). The most common of the weak acids in natural water is carbonic acid, formed when carbon dioxide is dissolved. Limestone reacts with the acid, and calcium and bicarbonate are released:

$$CO_2 + H_2O \longrightarrow H_2CO_3$$

$$CaCO_3 + H_2CO_3 \longrightarrow Ca^{++} + 2HCO_3$$

The carbon dioxide released within the soil is mostly due to organic material decay. Thus, the alkalinity greater than background levels is an indirect measure of organic decomposition. From the wells within the landfill, alkalinity ranged from 290 to 2,990 mg/L, and bicarbonate from 350 to 3,650 mg/L (table 5). Such concentrations indicate organic decomposition. Where the concentrations of calcium, magnesium, and silica are greater than background, they are probably products of aquifer material dissolution by the weak carbonic acid and the acid leachate.

The alkalinity data for the study area are presented graphically in figure 6. The alkalinity range at site 1 was about the same as at site 2. Thus, the site 2 data in figure 6 represent the native ground-water conditions.

In the dry season, the water from well G-3135 in the area of recent waste deposition reached a maximum alkalinity of 2,990 mg/L. Most of the other wells in the completed landfill maintained an average alkalinity near 500 mg/L, about twice the native concentrations.

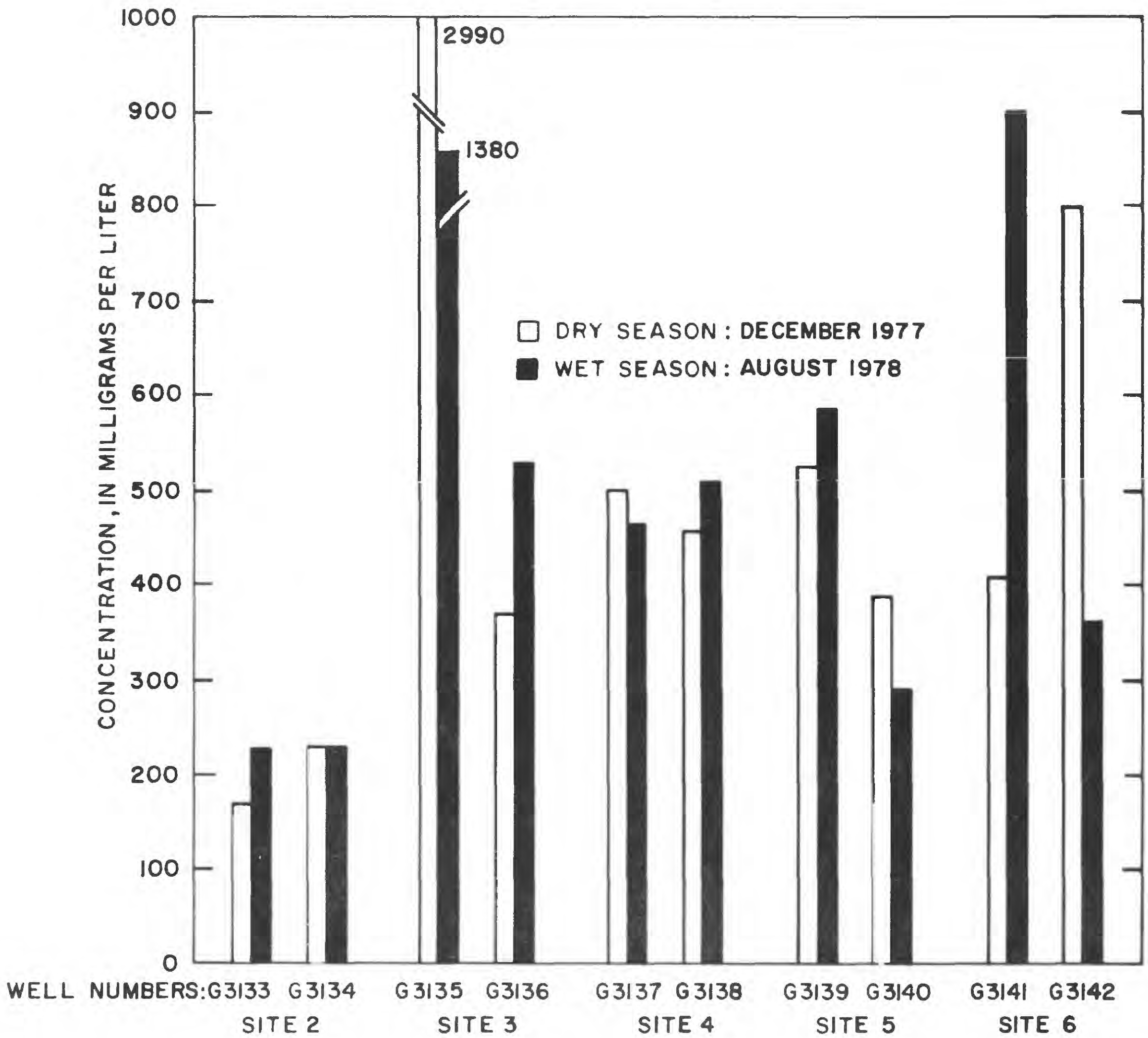


Figure 6.--Alkalinity (as $CaCO_3$) concentrations in ground water at the south Dade County solid-waste disposal facility.

Table 6.--Chloride concentrations in well waters of the study area by depth and season

[Analyses by U.S. Geological Survey]

Site No.	Well No.	Approximate depth below natural land surface (feet)	Chloride concentration (mg/L) Dry season April 1978	Chloride concentration (mg/L) Wet season August 1978
1	G-3130	12	190	(1)
	3131	29	320	(1)
2	3133	9	120	(1)
	3134	20	320	(1)
3	3135	3	840	120
	3136	15	240	360
4	3137	17	320	310
	3138	22	370	320
5	3139	11	300	240
	3140	23	240	160
6	3141	6	380	160
	3142	15	150	280

1/ Not measured.

Nitrogen and Phosphorus

Organic matter can be decomposed by nearly all species of anaerobic and aerobic bacteria to amino acids and ammonia (Salle, 1954, p. 376). In the anaerobic environment of the landfill, organic matter decomposes to ammonia and carbon dioxide. Without the availability of oxygen, there is little or no opportunity for the ammonia to become oxidized to nitrite (NO_2) and nitrate (NO_3). The high concentrations for ammonia versus low concentrations of nitrite and nitrate from wells within the landfill (table 5) indicate these conditions.

Ammonia concentrations at all wells within the landfill were substantially greater than those from the upgradient wells (table 5). The greatest concentrations occurred in the shallow well (G-3135) directly beneath the most recent waste deposits during the dry season (fig. 7). This reflects the active decomposition of organic matter. The wet-season concentrations were less than a third of those of the dry season at well G-3135 because of dilution and dispersion of the leachate, but were still among the greatest concentrations of ammonia at all wells. Only concentrations at the site 6 wells approached those at the G-3135 well. At site 6, high ammonia concentrations occurred in the shallow well (G-3141) during the wet season and in the deeper well (G-3142) during the dry season. These wells probably receive ammonia from the upgradient parts of the landfill and from decay of plant material in the marshy area almost directly above the site 6 wells. In studies of the movement of ammonia in a shallow, sandy aquifer with low exchange capacities and low organic matter content, Daniels and others (1975) noted that ammonia was a good tracer for ground-water flow. Little ammonia was fixed, and it moved freely with the ground-water flow with very little lateral dispersion.

Concentrations of organic nitrogen in the native ground water ranged from 0.01 to 0.72 mg/L at the upgradient sites 1 and 2 (table 5). Within the area of recent waste deposits at site 3, concentrations reached 44 mg/L. In the wells at other sites in the landfill, organic nitrogen averaged about 1.5 mg/L in the dry season and 2.6 mg/L in the wet season.

Total phosphorus is generally quite low in native ground water (table 5). The highest range of concentration was from well G-3135, the shallow well directly beneath the recent waste deposits. Phosphorus was generally insignificant elsewhere.

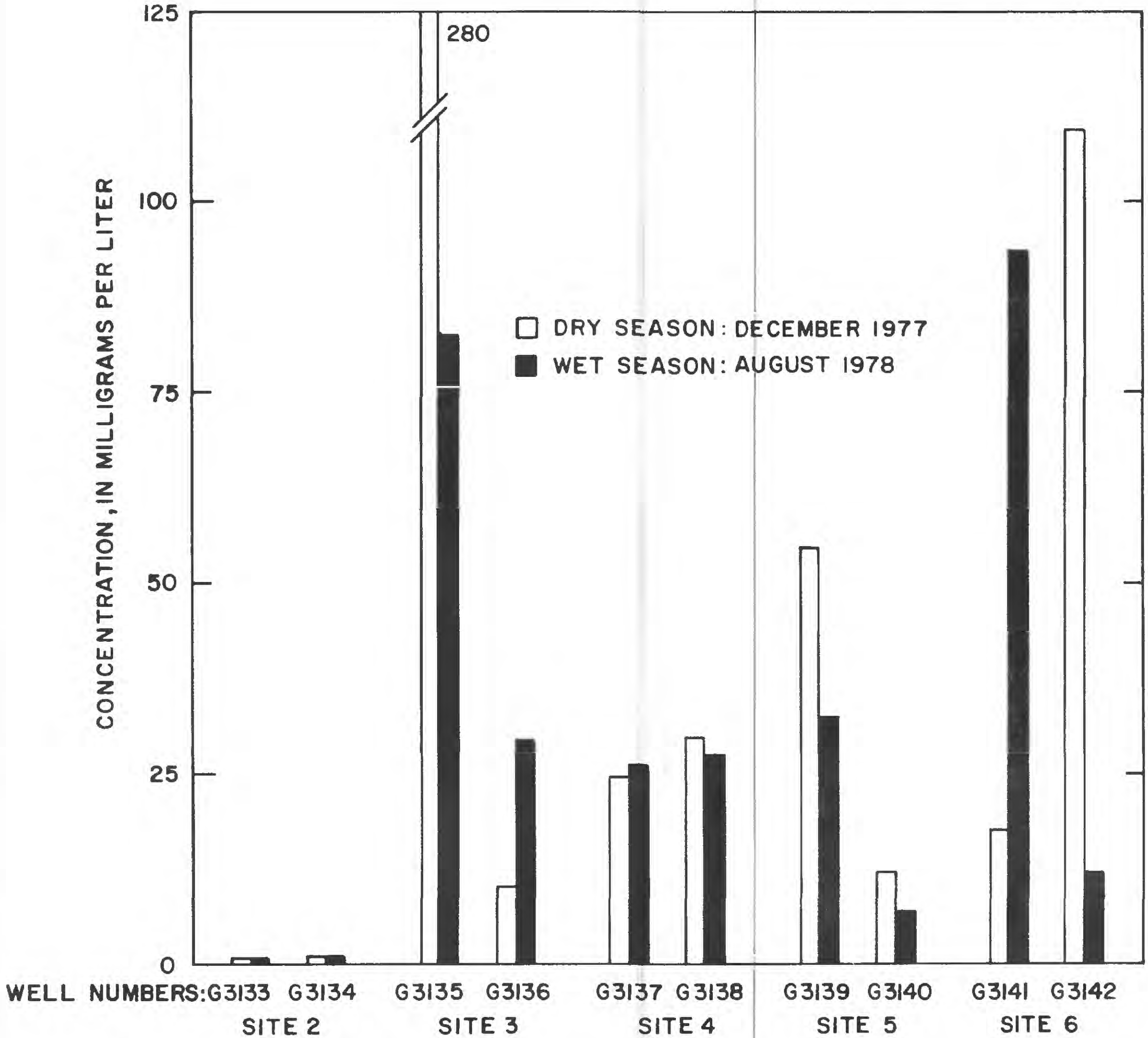


Figure 7.--Total ammonia nitrogen concentrations in ground water.

Total Organic Carbon

From table 5, the greatest concentration of total organic carbon, 550 mg/L, came from well G-3135 (site 3), directly beneath the area of recent waste deposits. At the other well sites within the landfill, concentrations ranged from 0 to 81 mg/L. Native concentrations ranged from 0 to 13 mg/L at sites 1 and 2. In addition, though not presented in the table, organic concentrations for wells within the landfill were greater in the dry season than in the wet season. The indication, then, is that total organic carbon is a component of leachate and a key indicator of organic materials.

Chemical Oxygen Demand

The distribution of the chemical oxygen demand (COD) in water from the monitor wells is shown in figure 8. COD is a general index of the levels of oxidizable materials (usually organic) in a water sample.

Concentrations of COD for the shallow well directly beneath the recent waste deposits (G-3135) far exceeded the concentrations for any other well.

Trace Elements

In wells beneath the landfill, concentrations of aluminum, arsenic, cadmium, chromium, copper, iron, lead, strontium, manganese, and zinc were greater than the native concentrations (table 5). For most of the characteristics, the highest concentrations were found in the shallow well beneath the recent waste deposits (G-3135).

Iron is naturally high in the Biscayne aquifer with concentrations of a few hundred micrograms per liter (ug/L) to 3,000 or 4,000 ug/L or more (Parker and others, 1955, p. 731). Native iron concentrations in the study area were as high as 5,000 ug/L. Iron concentrations in the landfill wells reached a maximum of 30,000 ug/L. Some of the iron detected at each of the wells may be attributed to the steel well casing; however, the magnitude of the difference between the upgradient wells at sites 1 and 2 and the landfill wells demonstrates the capacity of waste deposits to generate an iron-rich leachate.

Lead concentrations in wells beneath the landfill were slightly higher than native concentrations (table 5). Only in wells G-3137 (52 ug/L) and G-3140 (51 ug/L) did concentrations reach levels of concern.

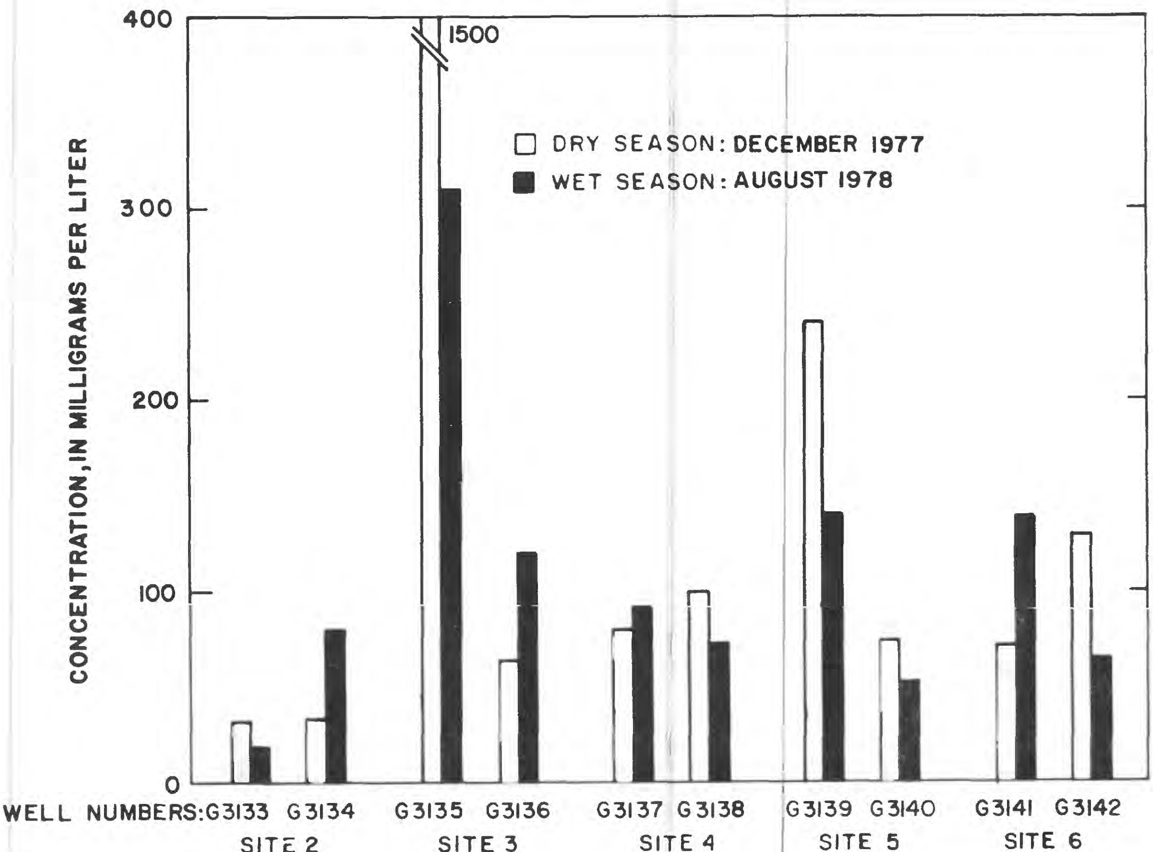


Figure 8.--Chemical oxygen demand concentrations in ground water.

Native concentrations of manganese are normally quite low (10 to 20 ug/L), but in the landfill wells, maximum concentrations reached 800 ug/L.

Concentrations of aluminum, arsenic, cadmium, chromium, copper, strontium, and zinc were slightly greater to over ten times greater in the landfill wells than native concentrations in the upgradient wells.

Pesticides and Industrial Compounds

All wells were sampled and analyzed for the following pesticides and industrial compounds (0.00 ug/L determination level):

Aldrin	Lindane	Chlordane
DDD	DDT	Dieldrin
Endrin	Ethion	Toxaphene
Heptachlor	Heptachlor epoxide	PCB
Malathion	Parathion	Diazinon
Methyl parathion	2,4-D	2,4,5-T
Trithion	Methyl trithion	Silvex
DDE	Endosulfan	

Concentrations for all, except silvex and methyl parathion, were 0.00 ug/L. Methyl parathion was 0.11 ug/L, and silvex was 0.18 ug/L at site 3. Silvex also had concentrations of 0.15 ug/L and 0.42 ug/L at site 2.

Microbiology

Three indicators of biological contamination are total coliform, fecal coliform, and fecal streptococci. Total coliform include a wide variety of bacteria; fecal coliform are derived only from the intestinal tract of warm-blooded animals, and fecal streptococci are prevalent in certain types of vertebrates. The fecal bacteria serve only as indicators of the possible presence of fecally-associated microbial pathogens. The major source of coliform bacteria at the solid-waste disposal site is septic-tank sludge. Other sources include the large number of scavenger birds and other animals.

It is recommended in Water-Quality Criteria, 1972 (National Academy of Sciences and National Academy of Engineering, 1974), that total coliform and fecal coliform in untreated surface-water sources not exceed 20,000 colonies/100 mL and 2,000 colonies/100 mL, respectively. Quality Criteria for Water, 1976 (U.S. Environmental Protection Agency, 1976), requires statistical analyses of time-quality relationships and applies to recreational waters. Hence, the more general 1972 requirements were used for the microbiological analyses for this investigation. Concentrations of most of the coliform bacteria in the landfill wells were low. Only in water from well G-3135, in the area of recent waste disposal, was the concentration significant. The maximum count of total coliform (33,000 colonies/100 mL) and fecal coliform (16,000 colonies/100 mL) was found in the dry-season samples.

Quality of Surface Water

Eight analyses of water from Black Creek Canal from May 1970 to June 1973 were used to establish the native surface-water quality for the study area (table 7). The high concentrations of sodium, chloride, and sulfate reflect the saltwater contamination from the Biscayne Bay. Locks downstream from the canal sampling sites prevented greater saltwater intrusion. Generally, other major-ion concentrations are within the ranges of analyses of surface water for southeast Florida (Parker and others, 1955, p. 768-770).

A summary of water-quality data collected at surface-water monitor sites 7-10 is presented in table 7. Site 9, the shallow drainage ditch near the area of most waste deposits, accounts for most of the maximum concentrations.

Of the major ions, only potassium and possibly calcium concentrations appear to be increased by leachate. The excess iron is likely a leachate product; surface waters in southeast Florida commonly contain much less than 1 mg/L of iron (Parker and others, 1955; Hull, 1975 and 1978). Aluminum is also probably a leachate product. Organic nitrogen and ammonia are both slightly greater than the background levels but are commonly found at these concentrations in Dade County canals (Hull, 1975).

Analyses were made during the initial sampling for the same pesticides analyzed in the well waters. Concentrations for all pesticides, except silvex, were below detection limits. The herbicide was found at 0.08 ug/L at site 9.

In the canals, the coliform concentrations were difficult to associate with leachate. The largest numbers were in Goulds Canal at site 7. The maximum count of total coliform was 4,400 colonies/100 mL, and fecal streptococci was 2,400 colonies/100 mL.

WATER QUALITY OF THE LANDFILL AREA AND NATIONAL DRINKING WATER REGULATIONS

As a general index of water-quality conditions in the study area, maximum levels of selected quality characteristics determined during the 1977-78 reconnaissance were compared with the national maximum contaminant levels (MCL) established for public drinking water. The MCL used for the comparison are those established by the National Interim Primary Drinking Water Regulations and National Secondary Drinking Water Regulations (U.S. Environmental Protection Agency, 1980, 1977, respectively). The primary regulations control contaminants in drinking water relating to public health. The secondary regulations control contaminants in drinking water that primarily affect the esthetic qualitites relating to the public acceptance of drinking water. The MCL are generally the same as those adopted by the State of Florida, Rules of the Department of Environmental Regulation, chap. 17-22, Water Supplies, amended, January 13, 1981.

Table 7.--Summary of analytical ranges of selected chemical, physical, and biological characteristics of water samples from surface-water sites 7-10, December 1977 and April and August 1978, and Black Creek

[Analyses by U.S. Geological Survey]

Characteristics	Black Creek	Sites 7-10
Major inorganics and related physical characteristics	Concentrations in milligrams per liter	
Alkalinity (as $CaCO_3$)	187 - 204	140 - 230
Bicarbonate	100 - 249	170 - 280
Calcium	72 - 85	73 - 120
Chloride	26 - 120	24 - 140
Dissolved solids (residue at 180°C)	281 - 486	290 - 594
Fluoride	0 - .3	.1 - .1
Magnesium	3.1 - 9.6	3.1 - 8.5
pH (standard units)	7.1 - 8.3	6.8 - 8.2
Potassium	1.4 - 4.4	5.3 - 18
Silica	3.0 - 4.9	.4 - 4.4
Sodium	16 - 80	13 - 75
Specific conductance (umhos/cm at 25°C)	477 - 820	460 - 915
Sulfate	21 - 37	40 - 59
Trace elements	Concentrations in micrograms per liter	
Aluminum	---	0 - 780
Arsenic	0 - 10	1 - 3
Barium	---	0 - 100
Cadmium	0 - 0	0 - 2
Chromium	0 - 0	10 - 20
Copper	0 - 10	1 - 5
Iron	0 - 400	20 - 1,000
Lead	0 - 10	0 - 32
Manganese	0 - 10	0 - 30
Mercury	0 - 0	.5 - .5
Selenium	---	0 - 0
Silver	---	0 - 0
Strontium	760 - 1,200	890 - 1,300
Zinc	10 - 60	0 - 50

Table 7.--Summary of analytical ranges of selected chemical, physical, and biological characteristics of water samples from surface-water sites 7-10, December 1977 and April and August 1978, and Black Creek--Continued

[Analyses by U.S. Geological Survey]

Characteristics	Black Creek	Sites 7-10
Selected nutrients and related characteristics	Concentrations in milligrams per liter	
Ammonia, total as N	0.08 - 1.0	0.01 - 1.8
Nitrate, total as N	.00 - .080	.16 - 2.30
Nitrite, total as N	.00 - .10	.01 - .13
Organic nitrogen, total as N	.08 - .85	.07 - .93
Phosphorus, total as P	.00 - 1.22	.01 - .10
Carbon, total organic	---	1 - 41
Carbon, total inorganic	---	33 - 55
BOD, 5 day	1.1 - 5.7	.7 - 4.0
COD (high level)	---	1 - 37
Carbon dioxide	---	1.7 - 67
Miscellaneous chemical characteristics		Concentrations in milligrams per liter
Cyanide	---	0 - 0
Detergents (MBAS)	---	.0 - .10
Oil and grease	---	0 - 2
Phenols	---	0 - .014
Bacteria	Colonies per 100 milliliters	
Coliform, total	---	34 - 4,400
Coliform, fecal	---	3 - 1,270
Streptococci, fecal	---	3 - 2,400

The general comparison given in table 8 is presented only as a relative index to water-quality conditions. That is, the National Primary and Secondary Drinking Water Regulations specifically pertain to water distributed as a community (public) water supply; water which is designated for other uses is not necessarily required to meet the MCL given in table 8. The ground water in the study area is not usable for public water supply. Saltwater intrusion has elevated chloride and dissolved-solids concentrations well above the MCL set by the regulations.

Of the trace elements, iron, manganese, lead, and chromium exceeded the levels of the regulations. Iron and manganese far exceeded the regulatory levels; but iron concentrations are naturally high in southern Florida, and the levels set for the regulations were set for prevention of objectionable taste and staining, not for toxicological reasons. Within the landfill wells, lead just exceeded the primary MCL, and in the canals, the maximum lead concentration was well below the 50 ug/L MCL and in line with other surface-water data for central and southern Florida (Goolsby and others, 1976). Chromium levels set by the primary regulations were only exceeded in the shallow well directly beneath the most recent waste deposits, indicating that chromium was not migrating through the aquifer. All other wells had chromium concentrations at background levels.

FUTURE WATER-QUALITY MONITORING

Continuation of seasonal monitoring of ground water and surface water would furnish data to determine when highly concentrated leachate is no longer generated. Appraisals can be accomplished by monitoring well G-3135 in the area of recent waste disposal and wells G-3139, G-3141, and G-3142, which had the most significant signs of leachate contamination. To determine background water-quality information, an uncontaminated well would have to be monitored.

The constituents to be monitored may be based on the following considerations: (1) likelihood of the constituent to appear, as indicated by previous analyses; and (2) possibility of the appearance of constituents that are so hazardous as to merit surveillance. The investigation determined that the following constituents are key indicators to leachate characteristics and hazardous substances near the landfill.

Key indicators of organic decomposition:

Ammonia	Carbon dioxide (calculation based on field determinations for pH and alkalinity)
organic nitrogen	

Key indicators of the presence of organic materials:

Total organic carbon
Chemical oxygen demand
Phosphorus

Table 8.--Comparison of maximum levels of selected quality characteristics of water from monitor sites 1-10 at the south Dade County solid-waste disposal facility with established maximum contaminant levels for drinking water

Characteristics	Primary maximum contaminant level 1/	Secondary maximum contaminant level 2/	Maximum native ground water concentration (sites 1-2)	Maximum landfill ground water concentration (sites 3-6)	Maximum surface water concentration (sites 7-10)
		Concentrations in milligrams per liter			
Chloride	—	250	450	840	140
Sulfate	—	250	99	83	59
Nitrate, total as N	10	—	.01	.01	2.30
Detergents (MBAS)	—	.5	.10	.90	.10
pH (standard units)	—	6.5-8.5	7.1-7.4	6.7-7.8	6.8-8.2
Dissolved solids	—	500	1,210	4,410	594
		Concentrations in micrograms per liter			
Arsenic	50	—	2	2	3
Barium	1,000	—	100	300	100
Cadmium	10	—	3	7	2
Chromium	50	—	20	70	20
Copper	—	1,000	11	29	5
Iron	—	300	5,000	30,000	1,000
Lead	50	—	21	52	32
Manganese	—	50	20	800	30
Mercury	2	—	.5	.5	.5
Selenium	10	—	.0	.0	.0
Silver	50	—	1	.0	.0
Zinc	—	5,000	40	670	50

1/ U.S. Environmental Protection Agency, 1980.
2/ U.S. Environmental Protection Agency, 1977.

Key indicators of leachate presence, concentration:

Chloride (as limited by the high native concentrations)
Ammonia
Alkalinity

Key indicator of industrial contamination:

Phenols

Hazardous materials:

Pesticides
Mercury
Lead

When long-term data are available, statistical analyses can be made for seasonal changes in the various wells and with reference to depths.

Oil and grease were found in both ground water and canals. They are not decomposed in an anaerobic environment and are very resistant to dilution (Zobell, 1969). The substances are unnatural in water and cause taste, odor, appearance problems, and can be a health hazard. It is recommended that public water sources be essentially free from these materials (U.S. Environmental Protection Agency, 1976).

Phenolic compounds are hydroxy derivatives of benzene. Some sources of phenol contamination are pesticides, plastics, petroleum, and organic wastes. Phenols beneath the landfill averaged 0.021 mg/L in the dry season and decreased to about 0.005 mg/L in the wet season. Phenol concentration was almost the same in the upgradient area. This could be due to fertilizer applications on the adjacent agricultural fields. Phenols were present in the background water in amounts of 0.002 to 0.004 mg/L. Phenols in the canal waters averaged 0.013 mg/L in the dry season. In the wet season, only water from site 7 contained phenols, 0.003 mg/L. Most water-treatment processes cannot efficiently remove phenolic compounds, and when the wastewater is chlorinated, chlorophenols are formed, producing odors. Quality Criteria for Water, 1976 (U.S. Environmental Protection Agency, 1976), recommended that phenols not exceed 0.001 mg/L for public water supplies.

SUMMARY

A water-quality sampling reconnaissance of the south Dade County solid-waste disposal facility near Goulds, Fla., was conducted in cooperation with the Dade County Department of Public Works from December 1977 through August 1978. The purpose of this reconnaissance was to measure and describe the chemical, physical, and biological conditions of the surface and ground water within and nearby the landfill, and to assess, in a general way, the effects of the leachate generated by solid-waste decomposition on the native water quality. The general scope of the reconnaissance included collection and analysis of periodic surface- and ground-water samples from ten monitor sites located upgradient from and within the landfill.

Results of the reconnaissance indicated that water quality beneath the landfill was highly variable with location and depth and depended upon the age of the waste materials and amount of rainfall (dry season versus wet season). High concentrations of many chemical, physical, and biological characteristics were present beneath the area of recent waste deposition. These high concentrations undoubtedly were due to active solid-waste decomposition and subsequent leachate production.

Concentrations of leachate characteristics were generally more evident at shallow depths and during the dry season. At greater depths certain characteristics, such as chloride and dissolved solids, were masked by high background levels resulting from saltwater intrusion. This condition causes the native ground water to be unsuitable as a potable water supply. During the wet season, greater quantities of leachate are produced, but the leachate is also greatly diluted and dispersed. Thus, chloride is restricted as an indicator of leachate presence to shallow depths and dry-season conditions.

Alkalinity and ammonia are good indicators of leachate presence and migration, and anaerobic decomposition. Concentrations were highest beneath the area of recent waste deposits; ammonia moves freely with ground-water flow, and these characteristics are not influenced by saltwater intrusion.

Phosphorus and organic nitrogen are good indicators of organic materials and organic decomposition. Concentrations were highest beneath the area of recent waste deposits where active decomposition was occurring. Concentrations were much lower beneath areas of the landfill containing older waste deposits.

Numerous trace elements were found in high concentrations beneath the landfill, especially beneath the most recent waste deposits. In two wells, lead exceeded the maximum contaminant levels set by the Federal drinking water regulations. Both iron and manganese greatly exceeded the regulations (iron is naturally high in southern Florida). No mercury was found in concentrations above background levels, but is of concern because of its toxicity.

High phenol concentrations found in surface and ground water can probably be attributed as much to agricultural fertilization practices to the west of the landfill as to leachate contamination.

Concentrations of water-quality characteristics in the surface waters nearby and within the landfill were generally low, only slightly above background levels. Highest concentrations were found in the drainage ditch within the landfill, near the recent waste deposits. The characteristics of note included potassium, calcium, iron, aluminum, and oil and grease.

Pesticides were insignificant, both in surface and ground water, but should be monitored regularly because of their dangers to animal and human health.

Continuation of seasonal monitoring of ground water and surface water would furnish data to determine when highly concentrated leachate production has ceased. Long-term data would allow for statistical analysis of concentration variations with depth and season. The characteristics already identified should be monitored because of their value as a key indicator of contamination or because of their hazardous nature.

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