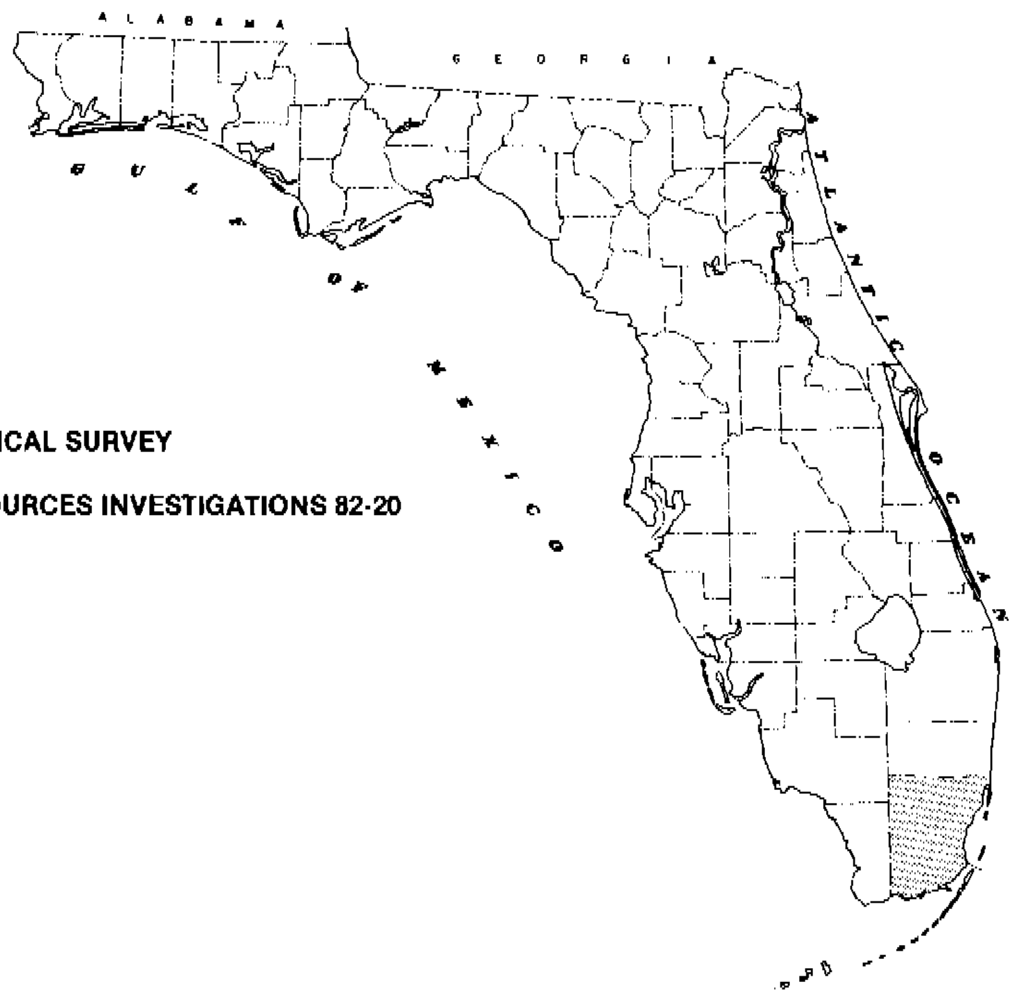
AREAL EXTENT OF A PLUME OF MINERALIZED WATER FROM A FLOWING ARTESIAN WELL IN DADE COUNTY, FLORIDA



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WATER-RESOURCES INVESTIGATIONS 82-20

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By Bradley G. Waller

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 82-20

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Multiply	By	To obtain
	Length	
inch (in)	25.40	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
acre	0.4047	hectare (ha)
	Flow	
gallon per minute (gal/min)	0.06309	liter per second (L/s)
	6.309×10^{-5}	cubic meter per second (m^3/s)
	Electromagnetic conversions	
1,000 millimhos per meter (conductance)	=	ohm-meter or ohm-meter x 3.28 = ohm feet (resistivity)
conductance in millimhos per meter x 10	=	conductance in micromhos per centimeter

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National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "mean sea level." NGVD of 1929 is referred to as sea level in this report.

AREAL EXTENT OF A PLUME OF MINERALIZED WATER FROM

A FLOWING ARTESIAN WELL IN DADE COUNTY, FLORIDA

By Bradley G. Waller

ABSTRACT

A flowing artesian well tapping the Floridan aquifer at Chekika Hammock State Park, Dade County, Florida, has been contaminating the overlying Biscayne aquifer with saline water since 1944. The contaminating plume extends approximately 7 miles downstream and southeast of the well and ranges in width from 1 to 2 miles. The area of contamination is approximately 12 square miles. The primary contaminating chemical constituents are chloride, sodium, and sulfate ions.

INTRODUCTION

Chekika Hammock State Park, operated by the Florida Department of Natural Resources, occupies 640 acres (1 mi^2) in the central part of a virtually undeveloped wetland area in southwest Dade County, Florida (fig. 1). A flowing artesian well within the park is maintained as an attraction for visitors and campers (fig. 2). The well (S-524) is known locally as the Grossman well.

Chemical analyses of water samples in September 1978 by the U.S. Geological Survey from shallow wells 10 to 50 feet deep southeast of the Grossman well disclosed that a more highly mineralized water than expected was in these wells. The U.S. Geological Survey, in cooperation with the Metropolitan Dade County Planning Department, further investigated to determine the extent of the mineralization. The area of investigation (fig. 1) was determined from known points where mineralized water was detected and from the knowledge of the areal ground-water flow (Schneider and Waller, 1980).

The Grossman well taps the upper part of the Floridan aquifer, which yields saline water in southern Florida and is under artesian condition. The Floridan aquifer is separated from the nonartesian Biscayne aquifer by approximately 700 feet of confining sand and clay of low permeability, which Parker and others (1955) called the Floridan aquiclude.

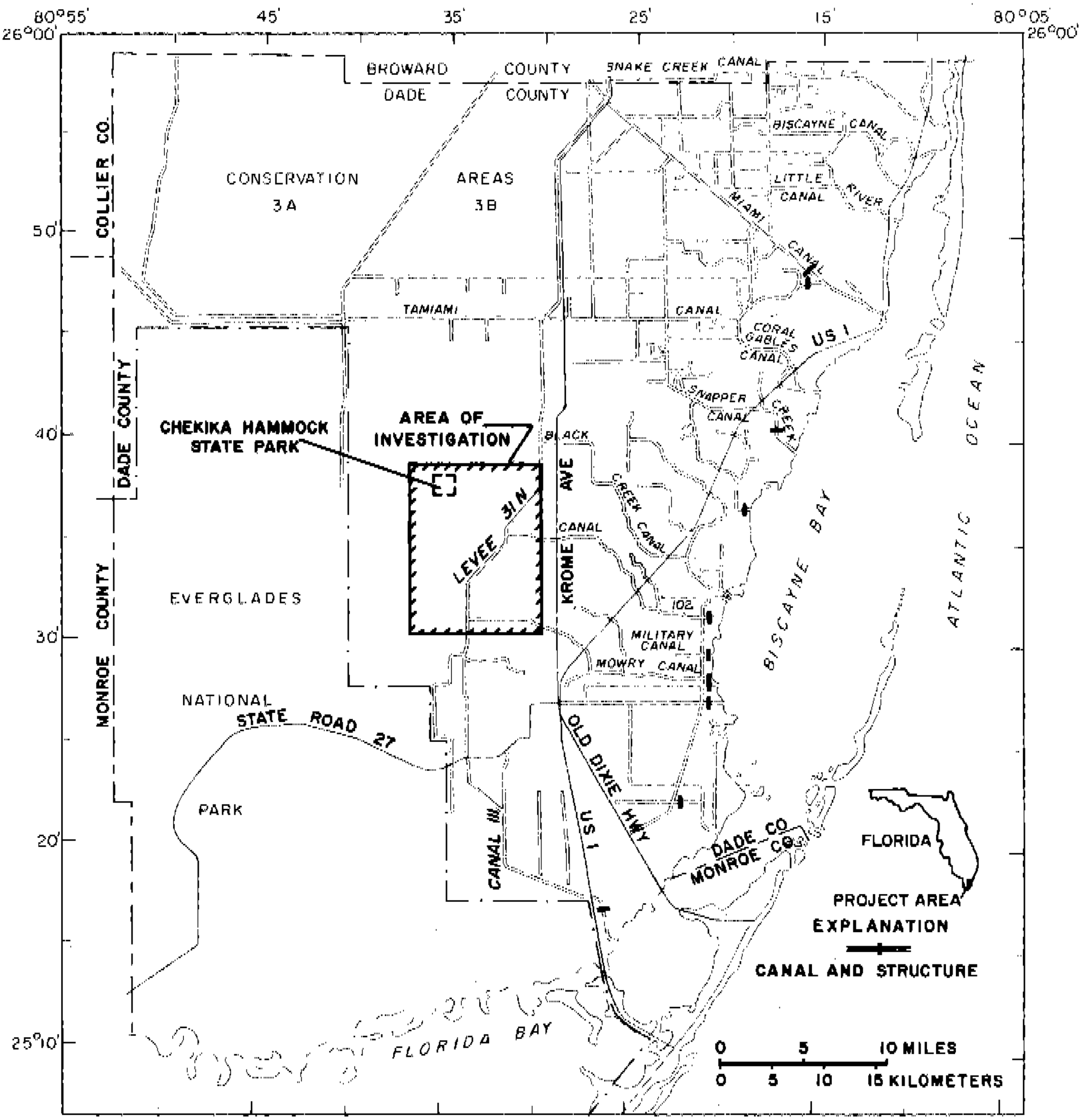

Figure 1.—Location of Chekika Hammock State Park and the area of investigation in Dade County, Florida.

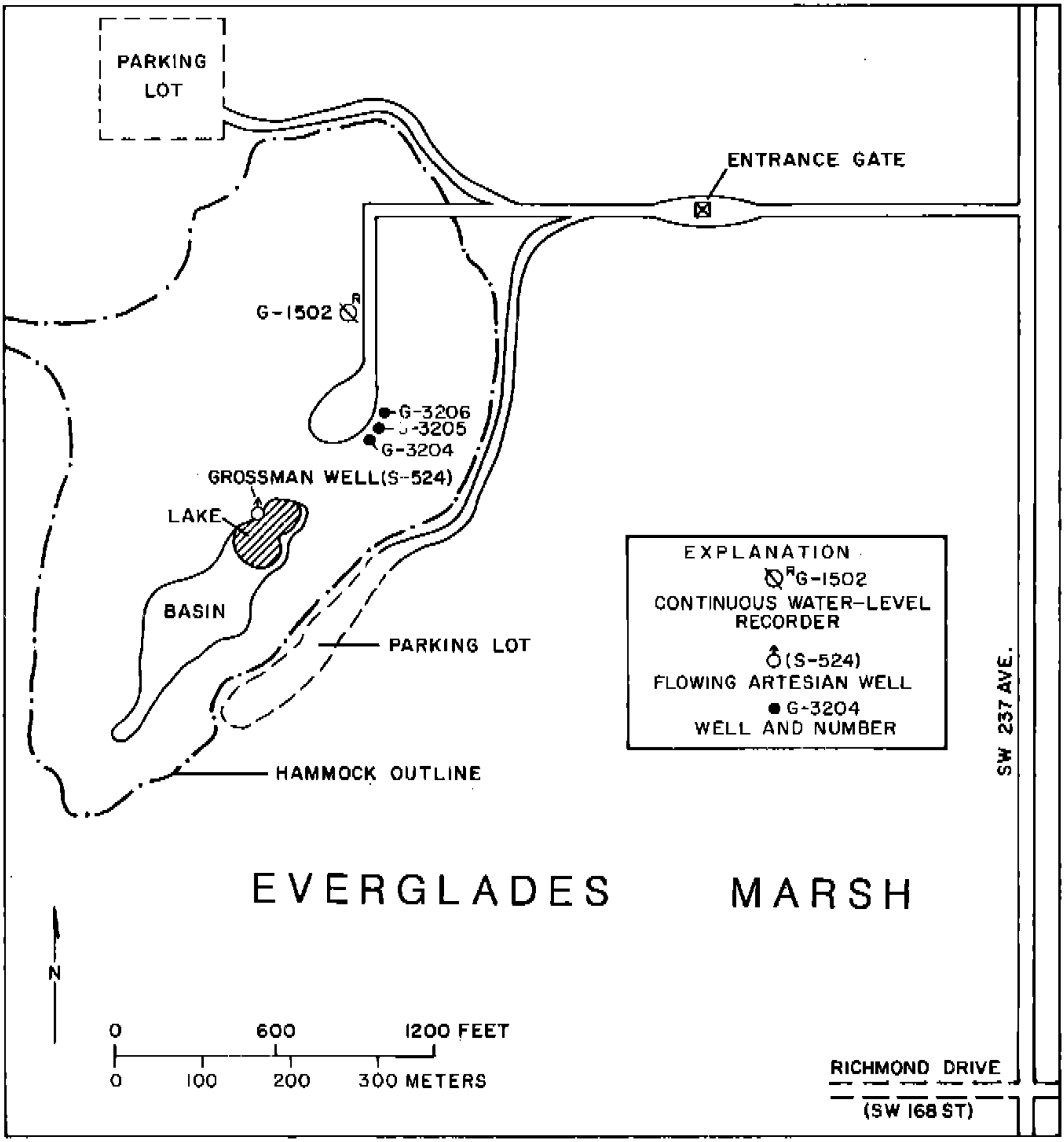

Figure 2.--Location of the Grossman well, the lake, and the basin in Chekika Hammock State Park.

Purpose and Scope

The purpose of this investigation was to delineate the areal extent of a plume caused by mineralized water emanating from the Grossman well into the Biscayne aquifer. The delineation was made from hydrogeologic information, conductance measurements, and chemical analyses of ground-water and surface-water samples.

In March 1979, conductance determined by electromagnetic (EM) technique was made on surface points adjacent to and downgradient of the Grossman well. The ground-water gradient and flow direction were determined by water-table contour maps prepared by Schneider and Waller (1980). Water from wells tapping the Biscayne aquifer and from canals (fig. 3) in the area of investigation was sampled concurrently and analyzed for specific conductance and chloride concentration. Information on the geology of the Biscayne aquifer near the Grossman well was obtained from rock cores and lithologic logs kept by the U.S. Geological Survey office in Miami.

History of the Grossman Well

The Grossman well (S-524) was drilled in 1944 to a depth of 1,248 feet by the Miami Shipbuilding Company and was initially cased with 12-inch iron pipe to a depth of 440 feet. In 1958 an 8-inch plastic liner was placed in the upper 80 feet and cemented in place to reduce leakage through the corroded iron pipe. The artesian pressure ranges between 40 and 45 feet above sea level or about 30 feet above land surface (Healy, 1975). The well has been flowing continuously since it was drilled.

No previous investigation determining the effects of saline water from the Grossman well on the Biscayne aquifer has been made. Parker and others (1955) briefly mentioned the Grossman well and its flow rate. Meyer (1971) described the characteristics of the well in a discussion of alternative uses of saline artesian water in south Florida. Healy (1975) used the artesian level of this well in mapping the potentiometric surface of the Floridan aquifer in the south Florida area. Beaven and Meyer (1978) included the Grossman well in a well inventory of the Floridan aquifer in south Florida and listed pertinent information including chemical analyses. Geophysical logs of the Grossman well were obtained in 1969 by the Florida Bureau of Geology and in 1974 by the U.S. Geological Survey.

Historic data concerning the flow rates and quality of water from the Grossman well are sparse. The data listed in table 1 are from Beaven and Meyer (1978), and from recently analyzed water samples. The initial flow rate at land surface in 1944 was 2,300 gal/min but had decreased to about 1,000 gal/min in 1968. Chloride concentration of the artesian water increased from 970 mg/L (milligrams per liter) in 1944 (Meyer, 1971) to 1,300 mg/L in 1963 (table 1) and was essentially the same in 1979.

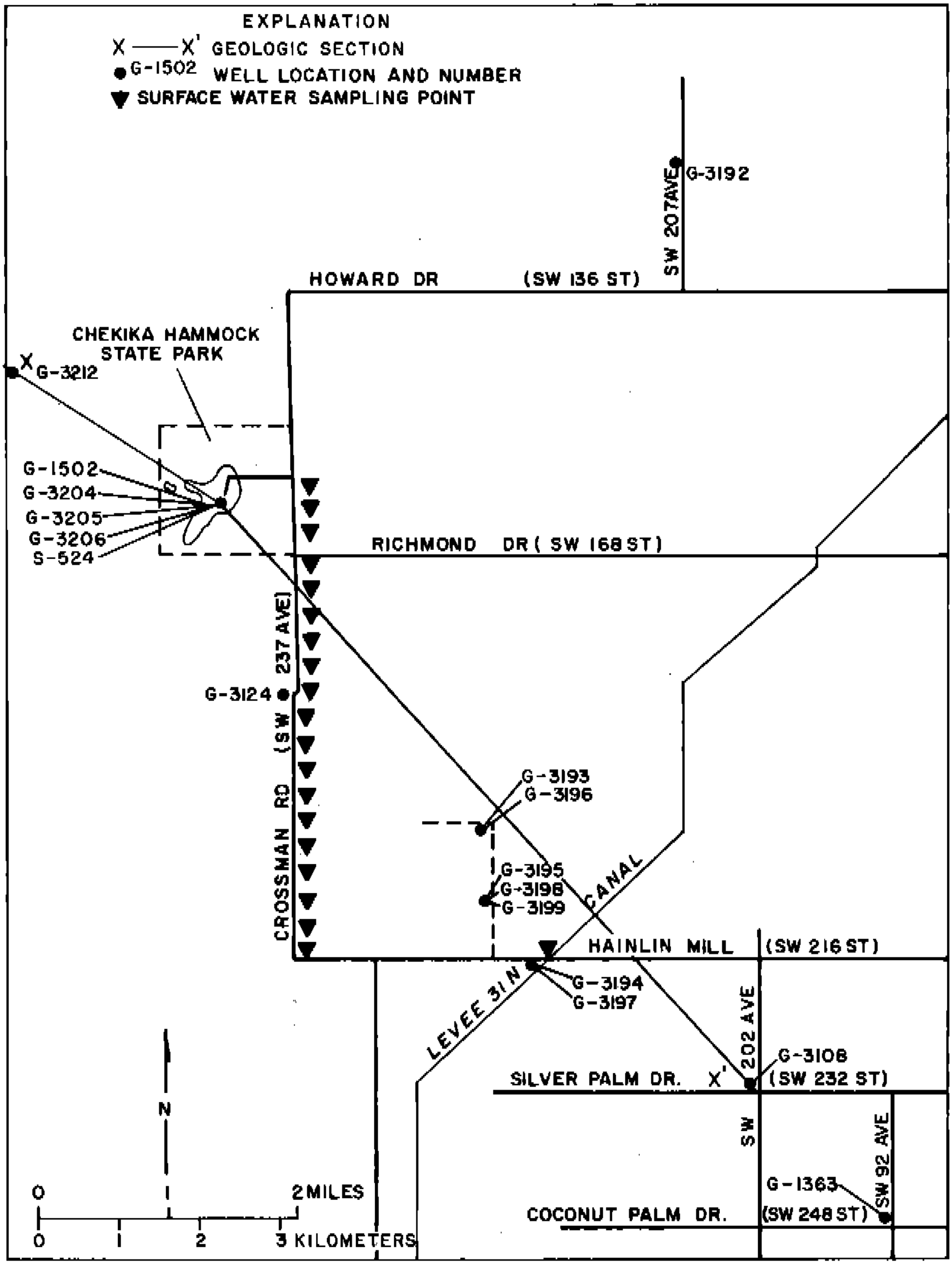

Figure 3.--Location of ground-water and surface-water sampling stations and geologic section X-X'.

Table 1.--Concentrations of major ions, dissolved solids, and hardness at the Grossman well (S-524)

[Constituents shown in milligrams per liter, except for specific conductance which is in micromhos per centimeter at 25°C]

Depth (feet)	Date of collection	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Chloride (Cl)	Sulfate (SO_4)	Fluoride (F)	Bicarbonate (HCO_3)	Specific conductance	Residue at 180°C (dissolved solids)	Sum of constituents (dissolved solids)	Calcium, magnesium (hardness [$CaCO_3$])	Noncarbonate (hardness [$CaCO_3$])	Silica (SiO_2)
1,248	1/06/14/63	80	100	980	38	1,300	490	2.0	270	4,300	3,360	3,110	250	390	15
	1/04/29/64	73	110	780	39	1,200	480	2.5	270	4,780	3,000	2,860	220	430	15
	1/10/18/73	75	100	820	40	1,200	430	2.2	270	4,450	—	--	220	430	16
	1/09/17/75	73	97	810	39	1,200	420	1.8	260	--	2,950	2,790	210	380	16
	10/27/78	71	100	820	40	1,200	480	1.9	260	5,080	2,980	2,860	210	380	16
	03/14/79					1,300				4,800					

1/ Data from Beaven and Meyer (1978).

The well is used for recreation within the park. The water from the well flows freely over a manmade rock cascade and into a large, clay-lined lake which overflows into a shallow basin and enters the surrounding Everglades marsh (fig. 2). The lake was constructed primarily for swimming. The lake level is artificially maintained at 9.1 feet above sea level (NGVD of 1929) or about 3 to 6 feet above the surrounding water table in the Biscayne aquifer, as indicated by water-level records from well G-1502 within the park (fig. 2).

Acknowledgments

The author would like to thank Vida S. Piera of the Metropolitan Dade County Department of Environmental Resources Management for collecting water samples for chemical analysis, and the owners of Silver Palm Groves, Inc., for allowing the U.S. Geological Survey to install and sample wells on their property.

DATA COLLECTION AND METHODS OF ANALYSIS

Geologic information was collected by core drilling the Biscayne aquifer near Chekika Hammock State Park by the U.S. Geological Survey. A northwest-southeast generalized geologic section through the park indicates that the Biscayne aquifer, southeast (downgradient) of the Grossman well, ranges in thickness from about 43 feet at the Grossman well to about 70 feet, 7 miles southeast of the well (fig. 4). The Miami Oolite and Fort Thompson Formation of Pleistocene age comprise the Biscayne aquifer, but locally the aquifer may include water-bearing sand, shell, and clay (Parker and others, 1955) in the upper part of the Pliocene Tamiami Formation. The soil cover is a thin layer of marl and peat.

Conductivity measurements were made at 125 stations within the area of investigation (fig. 5). These measurements were made at the beginning of the investigation to delineate the areal extent of the mineralized plume. The selection of observation wells to be sampled was facilitated by this delineation. These wells were sampled for chloride concentration and specific conductance to aid in determining the accuracy of the conductivity measurements. The conductivity measurement was produced by an electromagnetic technique that induces a current into the ground, therefore, the conductivity, in millimhos per meter, are composite values of both the geologic materials and the mineralization of the ground water. The conductivity measurements and a technical report were provided by Technos, Inc., a geophysical consulting firm in Miami under contract to the U.S. Geological Survey.

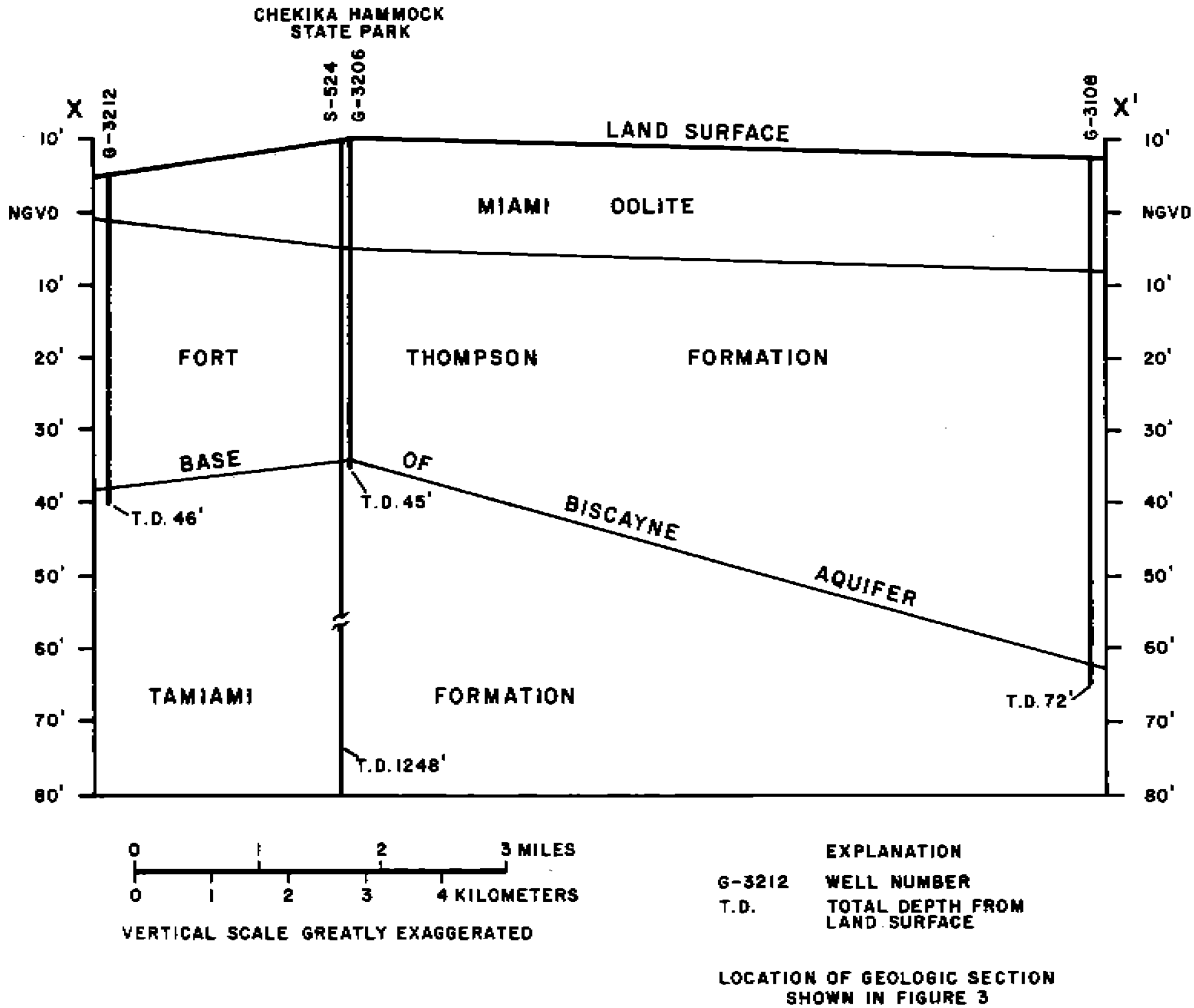

Figure 4.—Geologic section X-X' of the Biscayne aquifer.

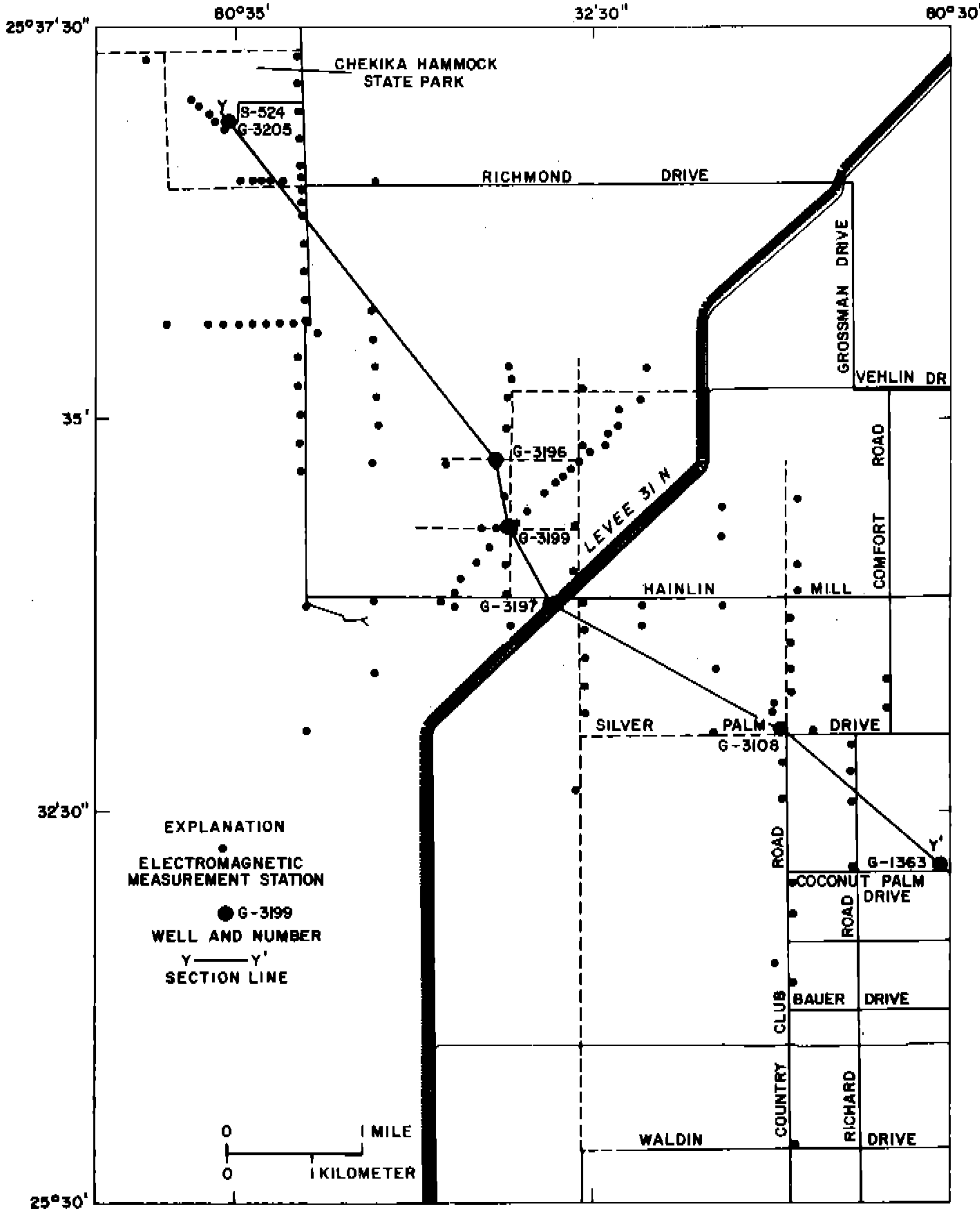

Figure 5.--Location of EM measurement stations, cross section Y-Y', and selected water-quality monitoring wells.

Conductivity measurements were distributed over approximately 20 mi^2 but were concentrated over the anticipated location of the plume. Measuring stations were generally located off compacted surfaces to minimize possible interferences with measurements. An electromagnetic measurement was taken at each sampling station to provide data on the shallow (0 to 25 feet) zone. Several measurements were made remote from the plume area to provide background conductivity values (see fig. 5 for location of EM sampling stations).

The plume of mineralized water was clearly detectable, because the specific conductance of water from the Grossman well (4,800 umhos/cm [micromhos per centimeter]) was approximately an order of magnitude greater than that of uncontaminated ground water in the Biscayne aquifer (well G-3192, 480 to 500 umhos/cm [table 2]). The composition of the Biscayne aquifer sedimentary rock in the area of investigation is relatively uniform (Howard Klein, U.S. Geological Survey, oral commun., 1979). Thus, any change in conductivity can be primarily interpreted to be caused by the variation in the degree of mineralization of the ground water.

Specific conductance measurements and determination of chloride concentrations from surface-water and ground-water samples (fig. 3) were made concurrently with the conductivity measurements on March 14, 1979. Surface water was collected at 20 canal stations. Ground water was collected by pumping each well until the water stored in the casing was cleared and a representative water based on physical characteristics was produced.

EXTENT OF THE MINERALIZED PLUME

Conductivity measurements ranging from approximately 7 to 23 millimhos per meter indicate that the plume of mineralized water extends about 7 miles southeast from the Grossman well (fig. 6). The width of the plume ranges from 1 to 2 miles. The terminus of the plume is near Country Club Road (S.W. 202nd Avenue) and Silver Palm Drive (S.W. 232nd Street). At the terminus, conductivity measurements decrease due to dilution and dispersion of the mineralized, artesian water in the freshwater of the Biscayne (water table) aquifer.

The shape of the plume is influenced by the regional southeast ground-water movement for south Dade County, but the pattern of the contours suggests appreciable dispersion to the south, because of the seasonal variation from southeast to south in ground-water movement (Schneider and Waller, 1980). The Levee 31N Canal, which penetrates the upper 15 feet of the aquifer, appears to have virtually no effect on the shape of the plume (fig. 6). The outer line of equal conductance in figure 6 represents 8 millimhos per meter of conductivity, which is slightly above background values of 6.7 to 7.9 millimhos per meter.

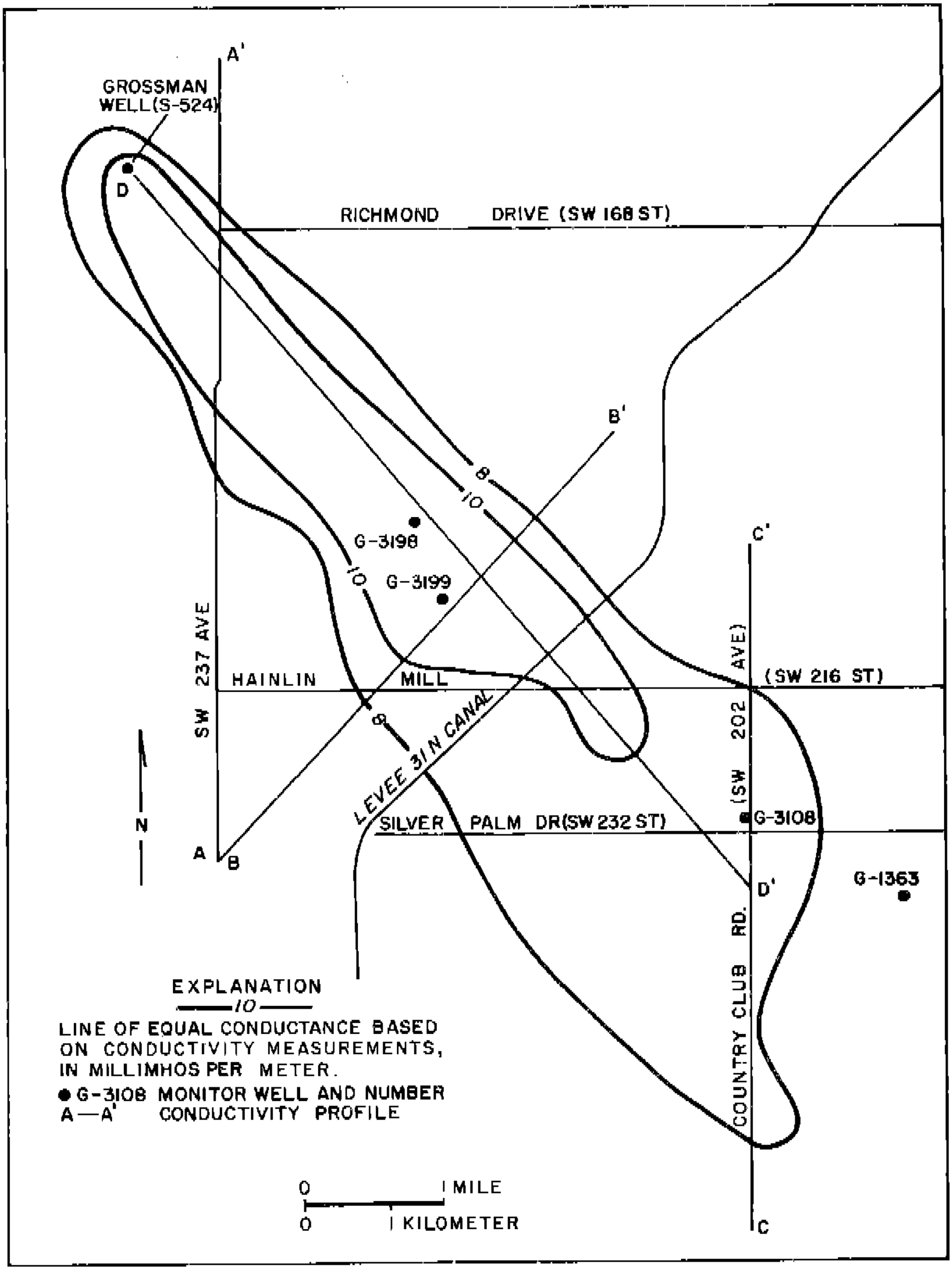

Figure 6.--Conductivity (EM) contours in the shallow (0 to 25 feet) part of the aquifer.

Table 2.--Concentrations of major ions, dissolved solids, and hardness at six wells tapping the Biscayne aquifer in the vicinity of the Grossman well

[Constituents shown in milligrams per liter, except for specific conductance which is in micromhos per centimeter at 25°C]

Well No.	Depth (feet)	Date of collection	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Strontium (Sr)	Chloride (Cl)	Sulfate (SO_4)	Fluoride (F)	Bicarbonate (HCO_3)	Specific conductance	Residue at 180°C (dissolved solids)	Sum of constituents (dissolved solids)	Calcium, magnesium (hardness [$CaCO_3$])	Noncarbonate (hardness [$CaCO_3$])	Silica (SiO_2)
G-3192 (back-ground)	41	09/06/78	87	4.4	12	0.4	0.6	21	14.0	0.4	259	480	302	270	240	24	5.0
		04/18/79	85	4.3	12	.4	.6	19	16	.2	300	500	303	290	230	0	5.0
G-3204	13	09/12/78	86	3.7	42	1.6	.7	53	16	.3	306	550	385	360	230	0	5.1
		04/19/79	82	4.4	19	.5	.6	31	4.8	.2	304	520	313	298	220	0	5.3
G-3205	44	09/12/78	110	63	660	24	2.6	970	390	.6	270	3,750	2,430	2,360	540	320	10
		04/19/79	80	7.1	36	1.6	.7	54	17	.3	304	620	373	352	230	0	5.6
G-3199	48	09/07/78	100	7.4	120	2.4	.3	190	85	.6	268	1,160	678	640	280	60	4.0
		04/18/79	95	7.1	120	2.4	.7	190	80	.1	296	1,130	650	645	270	24	4.1
G-3198	21	09/07/78	120	8.1	130	2.9	.8	190	98	.1	270	1,150	694	687	330	110	3.8
		04/18/79	96	7.8	120	3.7	.7	180	84	.1	296	1,160	651	642	270	30	3.8
G-3108	71	01/23/76	100	3.0	14	16	.8	41	52	.2	240	650	358	349	260	63	3.7
		02/20/76	100	3.5	14	8.0	.8	43	46	.2	245	655	354	340	270	69	3.8
		08/24/76	100	3.8	17	6.0	.8	52	38	.2	252	680	374	347	270	60	4.1

A conductivity profile along the axis of the plume, shown as D-D' in figure 7, shows the gradual downgradient decrease in conductivity from 23 to 7.2 millimhos per meter. Approximately 7 miles downgradient from the Grossman well the conductivity approaches background levels. Conductivity profiles transverse to the axis of the plume are shown in figure 8 (see fig. 6 for location of profile). The profile near the Grossman well (A-A') shows the largest range in conductivity. The edge of the plume is well defined in this area. The profile near the middle of the plume (B-B') shows a sharp definition of the edge of the plume, but the peak conductance near the axis is reduced. The profile at the southwest end of the plume (C-C') shows that the end of the plume is diffuse and ill defined, and the peak conductance near the axis is approaching background levels.

Specific conductance of surface water along the southern part of the Grossman Road Canal (a borrow pit adjacent to S.W. 237th Avenue), plotted with the conductivity profile along A-A' in figure 8, indicates the general relation between specific conductance and EM conductivity. The specific conductance of the canal water represents the general ground-water quality in the shallow (0 to 10 feet) part of the aquifer along line A-A'. The northern part of the canal is uncontaminated. Increased mineralization in the canal water occurs 0.8 mile south of the park entrance (fig. 2).

Specific conductance measurements and chloride concentrations (fig. 9) of ground water and surface water show the same general pattern as the conductivity determined by the EM technique. The specific conductance at the Grossman well was 4,800 umhos, and the chloride concentration was 1,300 mg/L (table 1). The specific conductance and chloride concentrations decreased in a southeasterly direction observed at the following wells on March 14, 1979 (see fig. 3 for location of wells):

Well No.	Depth (feet)	Specific conductance (umhos)	Chloride concentration (mg/L)	Distance from Grossman well (miles)
G-3192	41	500	21	(Background)
G-3205	44	3700	970	0.09
G-3124	10	880	126	1.57
G-3199	48	1120	200	3.57
G-3108	55	720	80	6.00
G-1363	33	560	24	7.45

Although the conductivity measurements, specific conductance, and chloride concentrations are utilized to indicate the extent of the plume, a more extensive chemical analyses of ground water at selected sites (table 2) are presented to quantify the degree and type of contamination. From the analyses, the same pattern of

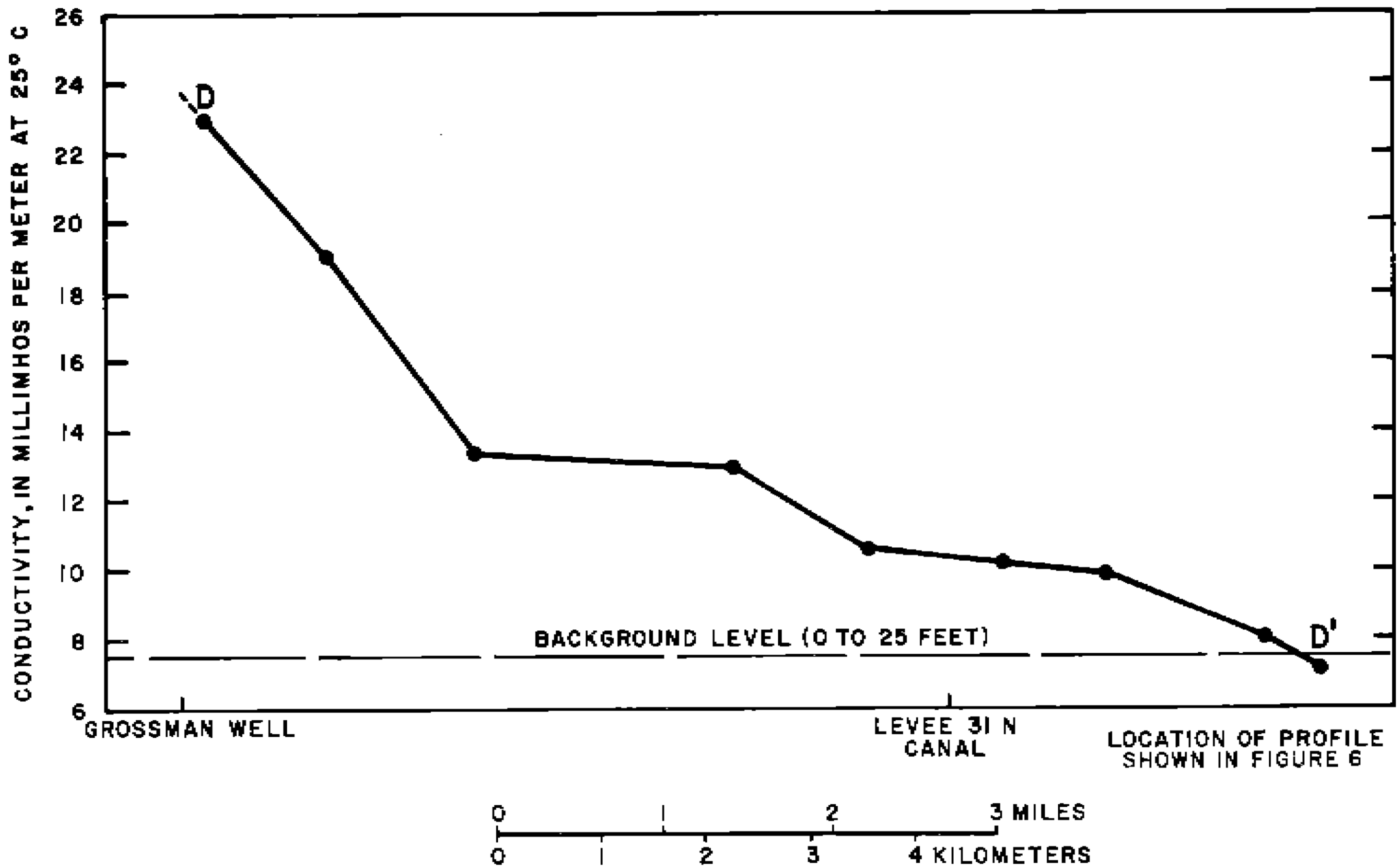

Figure 7.--Conductivity (EM) profiles of the mineralized plume at 0 to 25 feet along profile D-D'.

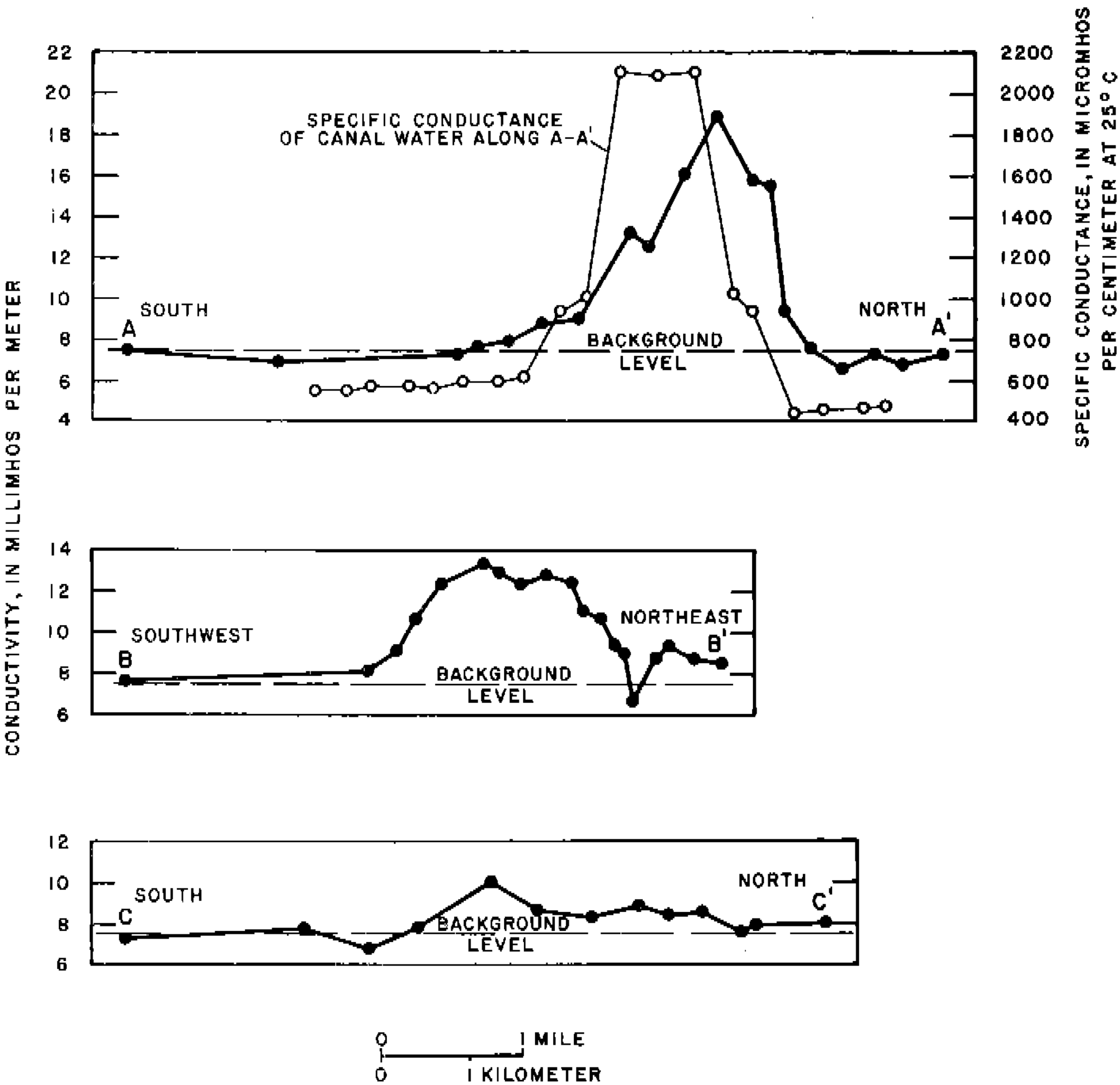

Figure 8.--Conductivity (EM) profiles transverse to the axis of the mineralized plume in the shallow (0 to 25 feet) part of the aquifer.

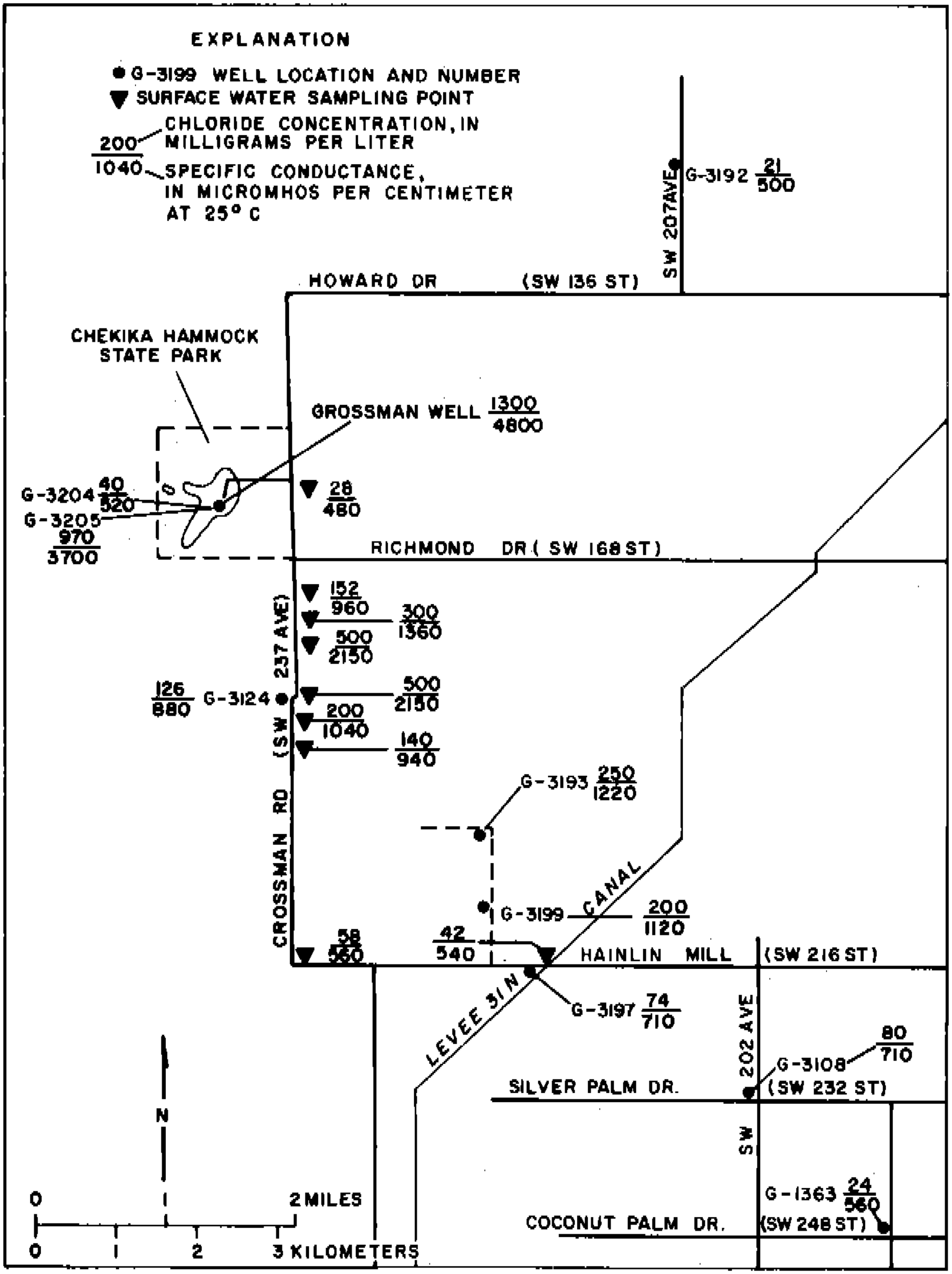

Figure 9.—Specific conductance measurements and chloride concentrations at ground- and surface-water stations in the vicinity of the Grossman well, March 14, 1979.

downgradient decrease in concentration is evident for all the major ions. Near the southeast edge of the plume (G-3108), the ions are still higher than the background ion concentrations (G-3192 and G-1363, northwest and southeast of the plume, respectively). The principal ions causing the increase in mineralization of the ground water are sodium, chloride, and sulfate, although other major ions also show increased concentrations over background values.

Stiff diagrams (Stiff, 1951) at selected wells near the axis of the plume are shown to better illustrate the changing ionic composition of water flowing away from the Grossman well (fig. 10). Background ionic composition at G-3192 is of the calcium bicarbonate type. The water within the plume is a mixed type being dominated by calcium bicarbonate, sulfate, and sodium chloride.

The water from the wells nearest the Grossman well (G-3204 and G-3205) show the most marked seasonal change in water composition (table 2). In the dry season (April 19, 1979) sample collection, when the ground water movement is in a southerly direction, the wells appear uncontaminated by the saline water, whereas in the wet season (September 12, 1978) sample collection,when movement is in a southeasterly direction, the wells definitely are affected by saline water from the Grossman well.

The vertical distribution of saline water within the plume at a set of wells about 3.5 miles downgradient from the Grossman well is uniform. The following specific conductance measurements were made at the set of wells near the center of the plume (see fig. 3 for well locations).

[Specific conductance in micromhos per centimeter at 25°C]

Date	G-3195 (depth 12 feet)	G-3198 (depth 19 feet)	G-3199 (depth 48 feet)
09/78	1,140	1,150	1,160
10/78	1,100	1,100	1,120
11/78	1,040	980	1,080
12/78	1,200	1,220	1,240
01/79	1,120	1,160	1,170
02/79	1,120	1,120	1,140
03/79	1,120	1,120	1,120
04/79	1,150	1,160	1,130
05/79	1,080	1,090	1,110
06/79	1,100	1,100	1,120
Average	1,117	1,120	1,139

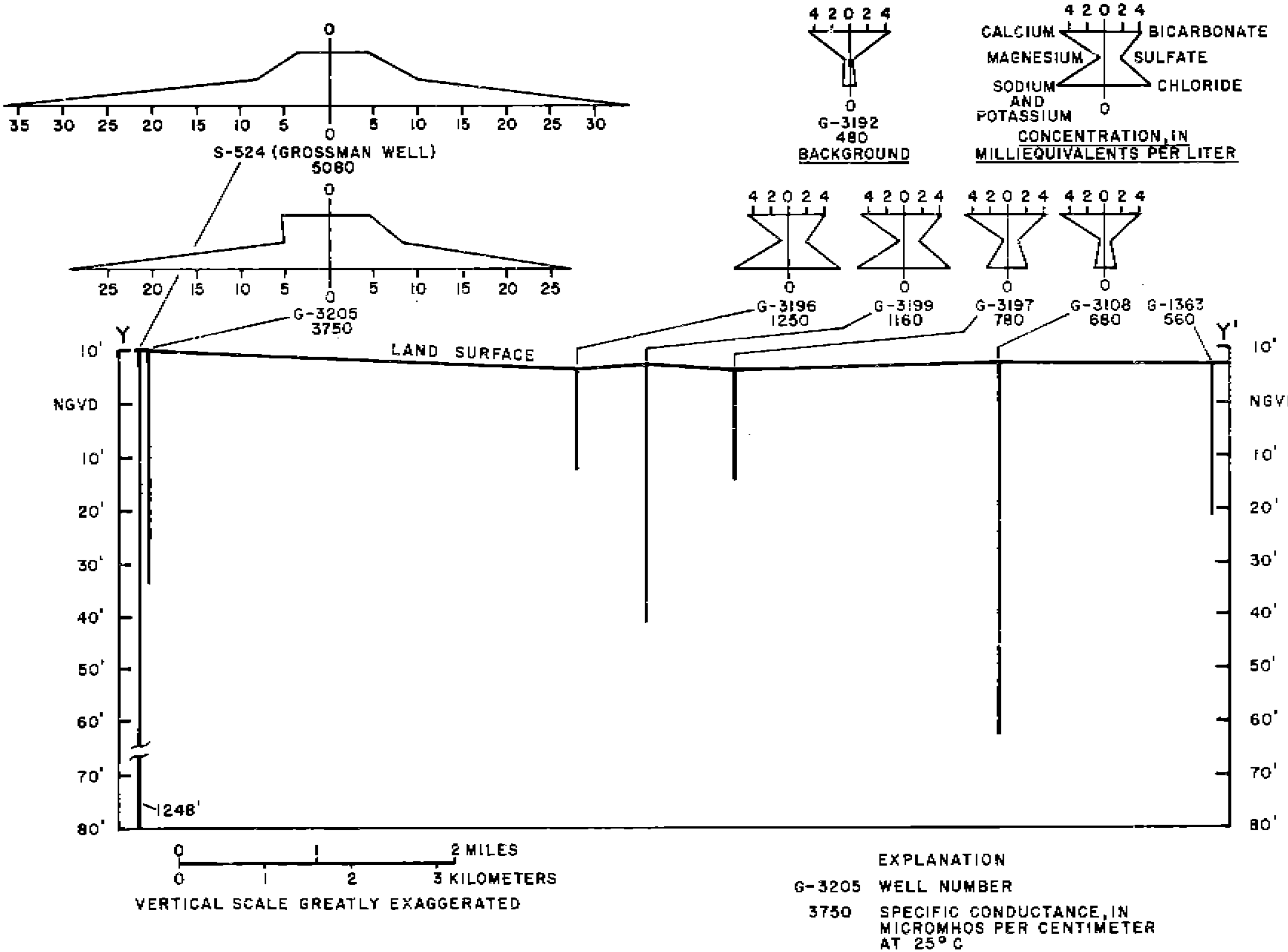

Figure 10.--Cross-section Y-Y' showing Stiff diagrams (ionic composition) at selected wells.

There appears to be some seasonal variation in mineralization, and the degree of mineralization increases slightly with depth as indicated by average specific conductance values.

The relation between EM measurements, specific conductance, and chloride concentration was determined by using data from the following sampling sites.

Well No.	EM measurement (millimhos per meter)	Specific conductance (umhos/cm)	Chloride concentration (mg/L)
G-3124	9.0	880	126
G-3196	12.7	1,220	250
G-3199	13.3	1,120	200
G-3197	9.0	710	76
G-3108	8.0	720	80
G-1363	7.5	560	24

There is a strong correlation between specific conductance and chloride concentration as evidenced by the correlation coefficent (r) of 0.99. There is also a good correlation between EM values and chloride concentration (r = .94). From these data, it appears that EM readings or chloride concentrations can be used to refine the delineation of the plume in this area.

SUMMARY

A study made in 1979 shows that a plume of mineralized artesian water emanating from the Grossman well (S-524) in Chekika Hammock State Park is contaminating approximately 12 square miles of the Biscayne aquifer in southwestern Dade County, Florida. The axis of the plume is approximately 7 miles long and extends southeasterly. The width of the plume varies between 1 and 2 miles.

The principal ions causing the increased mineralization are chloride, sulfate, and sodium, although all the major ions show an increased concentration over background conditions. Chloride concentrations at the Grossman well are 1,300 milligrams per liter. Chloride concentrations decrease 4 miles downgradient (southeast) to 200 milligrams per liter at G-3199 and at 7 miles downgradient to background concentrations of 24 milligrams per liter at G-1363.

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