

**INTRODUCTION**

In the first and second decades of this century, primary drainage canals were constructed in Broward County, Florida (fig. 1). The canals drained large areas of wetlands, causing declines in ground-water levels. In subsequent years, rapid urbanization, construction of canals for recreation and flood control, and the pumpage of well fields for water supply near the shoreline increased the rate of decline of the ground-water levels. The consequent gradual inland migration of oceanic saltwater into freshwater-bearing parts of the Biscayne aquifer threatens the water quality of public-supply wells along the east coast of Florida. In response to this concern, the U.S. Geological Survey, in cooperation with the South Florida Water Management District, began a study in 1992 to delineate the areal extent of saltwater intrusion in the Biscayne aquifer in eastern Broward County. Results of this study provide hydrologic information for future water-resources planning in Broward County.

**Purpose and Scope**

This report delineates and describes the inferred areal extent of saltwater intrusion in the Biscayne aquifer in eastern Broward County in 1990. The extent of saltwater intrusion is defined as the approximate landward limit of ground water with a chloride concentration of 1,000 milligrams per liter. Chloride concentrations in water samples collected from 63 saltwater monitoring wells in 1980 and 1990 were compared to determine if a westward movement of saltwater occurred during the 10-year period. The study area was limited to coastal Broward County east of Florida's Turnpike.

Data from the current U.S. Geological Survey saltwater monitoring network were compiled for wells completed in the Biscayne aquifer. Although these wells were sampled from 1 to 12 times during each year, water samples collected near the end of the dry season (November-April) were used to delineate the extent of saltwater intrusion.

**Methodology**

Generally, wells with 10 years of chloride data were selected for this study. These monitoring wells are mostly distributed near major well fields as a "warning system" for public-supply wells. Generally, the wells are point monitors with water samples collected from a 1- to 10-foot open-hole section beneath the casing. The water samples were collected using low yield pumps (not exceeding 5 gallons per minute) and taken to the laboratory in the U.S. Geological Survey Miami office where a silver nitrate/potassium chromate titration was performed to determine the chloride concentration (Fishman and Friedman, 1989). The data were plotted on U.S. Geological Survey 1:24,000 quadrangle maps, which then were reduced to 1:100,000 scale. A line representing 1,000 milligrams per liter of chloride concentration for 1990 was drawn. Klein and Hull (1978) present a similar chloride concentration line for 1975. A graph showing trends in chloride concentration as a function of time was prepared. Chloride concentrations from well G-1237 in southern Fort Lauderdale, G-1435 in Hollywood, and G-2055 in Pompano Beach were used for this time-trend analysis.

**HYDROGEOLOGY**

Broward County is underlain by a surficial aquifer system that contains two main aquifers, the Biscayne aquifer and the gray limestone aquifer (fig. 2). The Biscayne aquifer, the sole source of drinking water within the study area, is nonhomogeneous and contains several geologic units. These units, in descending order, are: Pomlico sand, Miami Limestone, Key Largo Limestone, Anastasia Formation, Fort Thompson Formation, and the Tamiami Formation. All of these units are of Pleistocene age, except for the Tamiami Formation of Pliocene age. Detailed geologic descriptions of these units are given by Parker and others (1955) and Fish (1988). The hydraulic characteristics vary considerably and are described by Fish (1988).

**DELINEATION OF SALTWATER INTRUSION**

Chloride concentrations in water from 63 selected saltwater monitoring wells (fig. 1 and table 1) were used to delineate the areal extent of saltwater intrusion in eastern Broward County. The 1990 landward extent of ground water with a chloride concentration of at

least 1,000 milligrams per liter is shown in figure 3. Available data for 1980 and 1990 for each of the monitoring wells are also shown in figure 3. The areal extent of saltwater intrusion is inferred over much of eastern Broward County because almost all of the monitoring wells are clustered near the well fields.

Before development, freshwater was in hydrodynamic balance with saltwater in the Biscayne aquifer, and the landward extent of saltwater was probably no more than 1 mile from naturally occurring brackish surface-water bodies (Parker and others, 1955, fig. 169). Saltwater has subsequently intruded laterally into the aquifer in response to lower ground-water levels resulting from the construction of drainage canals and the withdrawal of water from well fields. Saltwater also enters uncontrolled coastal reaches of canals, moves inland with tides, and infiltrates into the adjacent aquifer through the bottom and sides of the canals. This type of saltwater intrusion is limited to the immediate vicinity of the canal system and is not considered to be part of the regional saltwater intrusion process, which depends on the difference between ground-water levels in the aquifer and sea level at the coastline.

A comparison of 1980 and 1990 chloride concentration data (fig. 3) indicates that the landward movement of the saltwater-freshwater interface continued through this time period. Increased chloride concentrations in water from monitoring wells east (seaward) of the well fields (fig. 4) also provide evidence of the landward movement of saltwater in the aquifer. Wells G-1435 and G-2055 (fig. 4) are seaward of the Hallandale and Pompano Beach Well Fields, respectively. Chloride concentrations indicate a continual increase, except for minor seasonal variations after the leading edge of the intruding saltwater reaches the monitoring wells.

The chloride concentrations in water from monitoring well G-1237, located approximately midway between the Dixie and Hollywood Well Fields (fig. 1), began increasing in 1974. The rate of increase slowed in 1980, with chloride concentrations in subsequent water samples ranging from 1,300 to 1,400 milligrams per liter in 1983-88. The reason for the stabilization of chloride concentrations in the vicinity of G-1237 has not been determined. Possible explanations include the establishment of a regional equilibrium between the saltwater-freshwater contact or an increase in ground-water levels. Neither of these explanations, however, has been investigated.

**SUMMARY**

Chloride concentrations in water samples from 63 saltwater monitoring wells in eastern Broward County were used to delineate the areal extent of 1,000 milligrams per liter of chloride concentration in water from the Biscayne aquifer. The 1990 landward extent of saltwater intrusion and data for 1980 and 1990 for each monitoring well are presented.

The results of the study indicate that chloride concentrations in ground water east of major well fields have increased and that the saltwater-freshwater interface has moved landward from 1980 to 1990. Historical data from three monitoring wells (G-1237, G-1435, and G-2055) were analyzed to determine trends in chloride concentration as a function of time. Water samples from well G-1435 east of the Hallandale Well Field and well G-2055 east of the Pompano Beach Well Field indicate that the chloride concentrations have increased steadily; whereas data from well G-1237, located between the Dixie and Hollywood Well Fields, indicate that chloride concentrations have stabilized in the vicinity of this well.

**REFERENCES CITED**

- Fish, J.E., 1988, Hydrogeology, aquifer characteristics, and ground-water flow of the surficial aquifer system, Broward County, Florida. U.S. Geological Survey Water-Resources Investigations Report 87-4034, 92 p.
- Fishman, J.J., and Friedman, L.C., eds., 1989, Methods for the determination of inorganic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water Resources Investigations, book 5, chap. A1, 545 p.
- Klein, Howard, and Hall, J.E., 1978, Biscayne aquifer, southeast Florida. U.S. Geological Survey Water-Resources Investigations Report 78-107, 52 p.
- Parker, G.G., Ferguson, G.E., Lowe, S.K., and others, 1955, Water resources of southeastern Florida, with special reference to the geology and ground water of the Miami area. U.S. Geological Survey Water-Supply Paper 1255, 965 p.

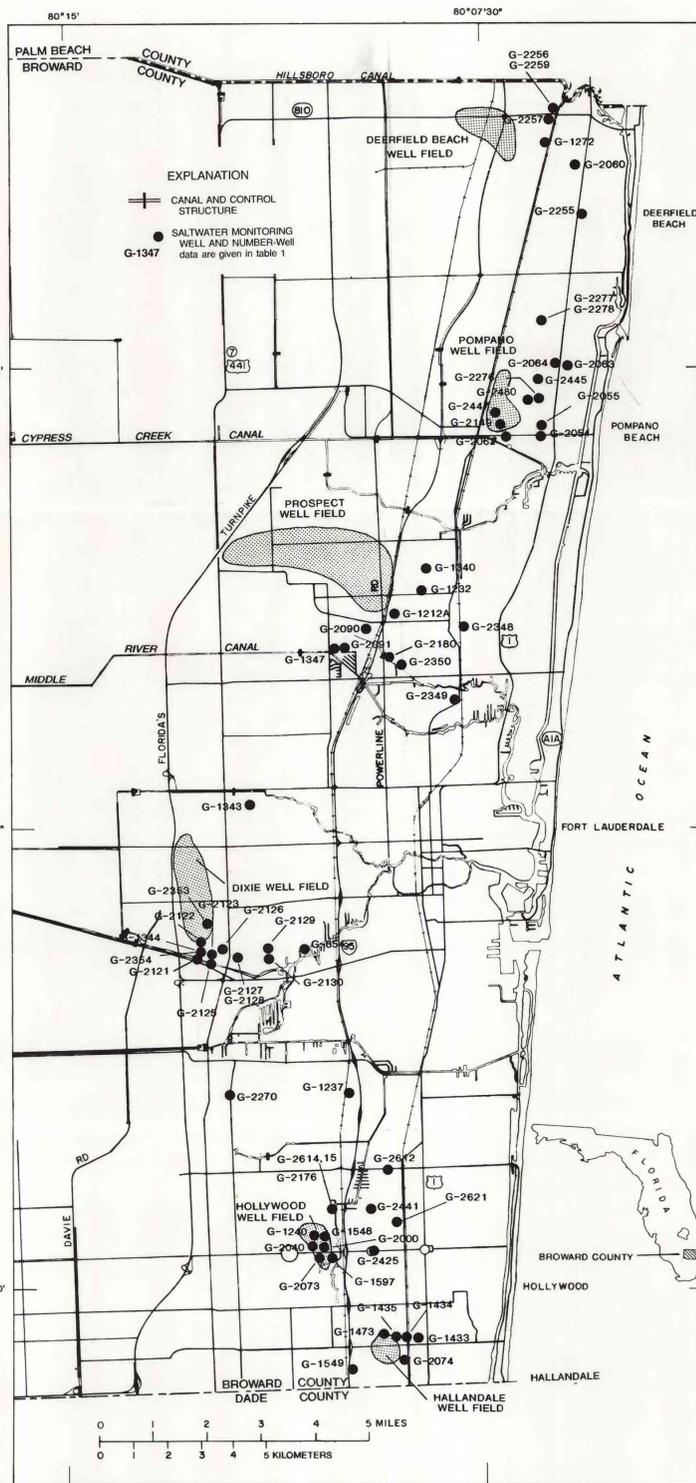


Figure 1. Location of selected saltwater monitoring wells in the Biscayne aquifer and major well fields in eastern Broward County.

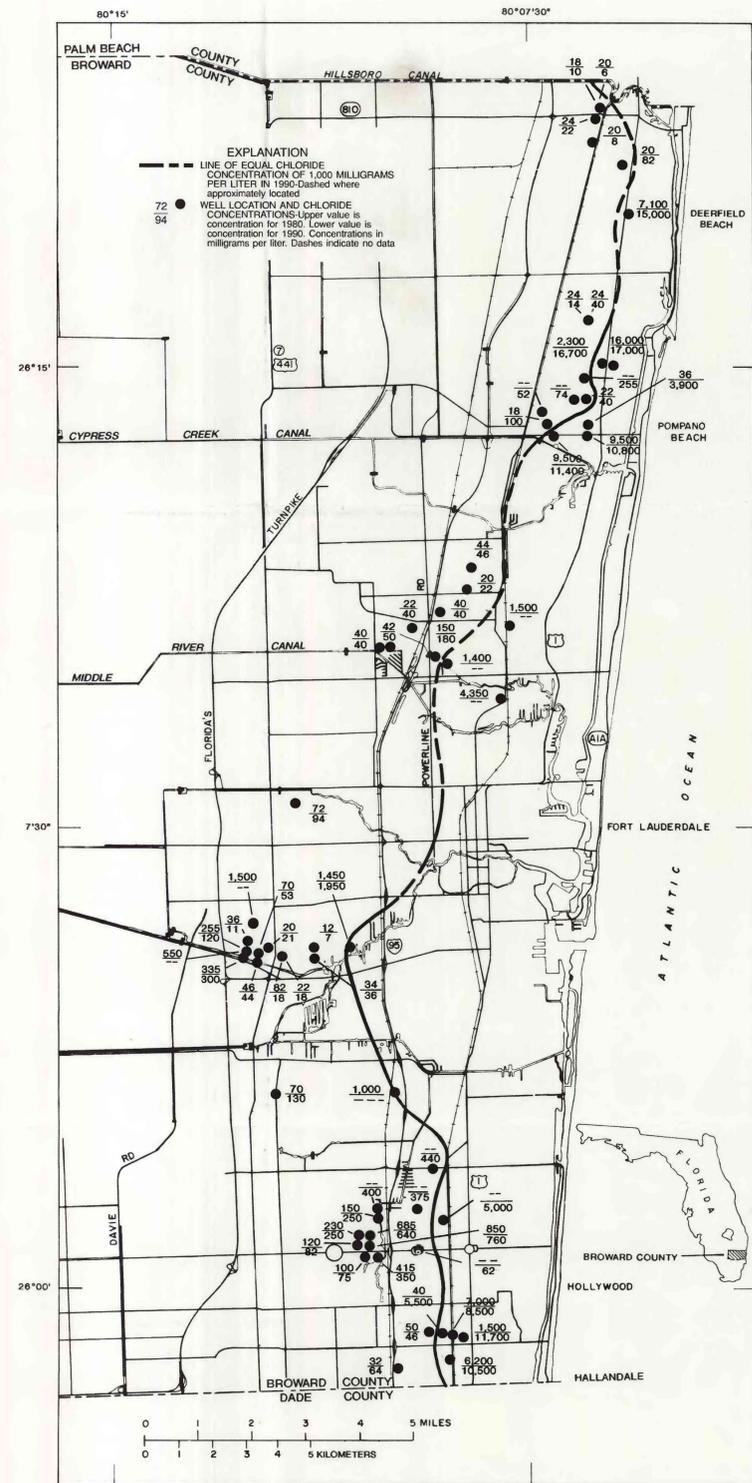


Figure 3. Chloride concentrations in water from monitoring wells in the Biscayne aquifer sampled in 1980 and 1990 and approximate extent of 1,000 milligrams per liter of chloride concentration in 1990.

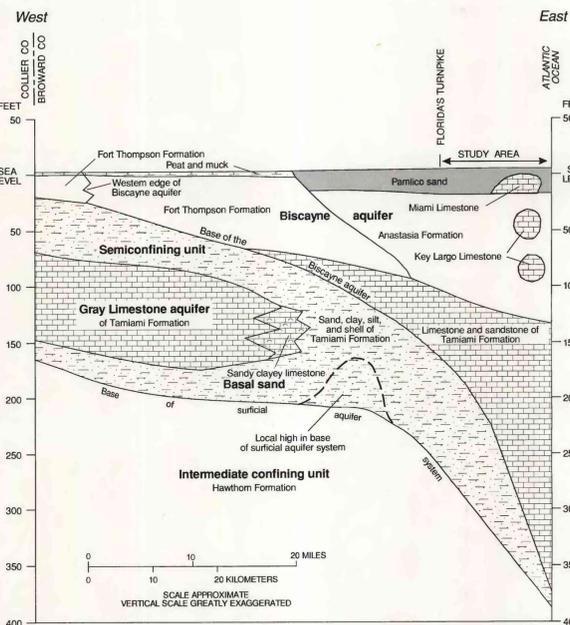


Figure 2. Geologic formations, aquifers, and confining units of the surficial aquifer system in central Broward County (modified from Fish, 1988).

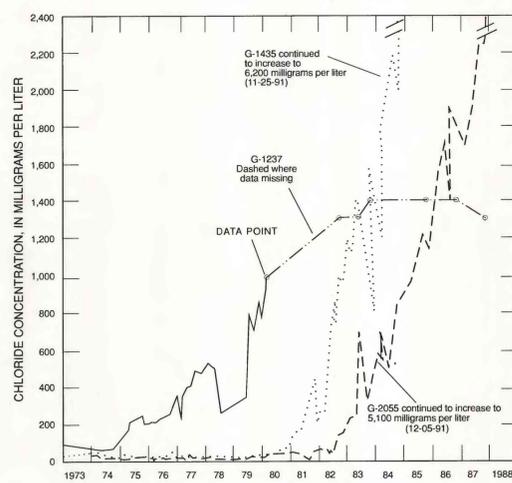


Figure 4. Chloride concentrations in water from monitoring wells G-1237, G-1435, and G-2055, 1973-88.

Table 1. Data from selected saltwater monitoring wells in the Biscayne aquifer, eastern Broward County

Local well number	Latitude (degrees)	Longitude (degrees)	Well depth (feet below land surface)	Year data collection began	Local well number	Latitude (degrees)	Longitude (degrees)	Well depth (feet below land surface)	Year data collection began
G-854	260555	0801043	206	1959	G-2123	260528	0801223	182	1974
G-1124	261100	0800904	84	1962	G-2125	260521	0801234	58	1974
G-1232	261122	0806834	205	1964	G-2126	260533	0801210	169	1976
G-1237	260312	0806955	200	1964	G-2127	260529	0801158	190	1975
G-1240	260054	0801033	200	1964	G-2128	260529	0801158	61	1975
G-1272	261834	0800619	196	1965	G-2129	260534	0801221	180	1975
G-1340	261143	0801829	217	1968	G-2130	260530	0801221	60	1975
G-1343	260793	0801139	210	1968	G-2149	261403	0800708	137	1974
G-1344	260527	0801238	182	1968	G-2176	260111	0801014	171	1974
G-1347	261026	0801007	200	1968	G-2180	261018	0800911	106	1974
G-1433	255916	0800845	190	1969	G-2255	261726	0800541	203	1976
G-1434	255916	0800853	192	1969	G-2256	26914	0800608	110	1976
G-1435	255916	0800904	204	1969	G-2257	261996	0800611	94	1976
G-1473	255918	0800918	132	1969	G-2259	261914	0800608	26	1976
G-1548	260053	0801023	187	1971	G-2270	260311	0801204	184	1976
G-1549	255845	0800953	184	1971	G-2276	261427	0800627	200	1978
G-1597	260055	0801015	163	1971	G-2277	261544	0800624	131	1978
G-2000	260085	0801022	192	1971	G-2278	261544	0800624	203	1978
G-2040	260045	0801034	177	1972	G-2348	261047	0800750	122	1980
G-2054	261351	0800625	142	1972	G-2349	260935	0800801	136	1980
G-2055	261359	0800623	180	1972	G-2350	261011	0800858	171	1980
G-2060	261814	0800546	211	1974	G-2353	260538	0801227	237	1980
G-2062	261354	0800702	139	1973	G-2354	260529	0801238	231	1980
G-2063	261500	0800554	82	1973	G-2425	260401	0800931	203	1986
G-2064	261501	0800907	201	1973	G-2441	260120	0800934	181	1986
G-2073	260035	0801026	190	1973	G-2445	261446	0800628	132	1987
G-2074	255854	0800856	168	1973	G-2447	261413	0800714	135	1987
G-2090	261045	0800935	101	1974	G-2480	261427	0800609	102	1988
G-2091	261026	0801023	124	1974	G-2612	260155	0800620	273	1988
G-2121	260525	0801239	185	1974	G-2614	260120	0801015	50	1988
G-2122	260533	0801237	135	1974	G-2615	260120	0801015	175	1988
					G-2621	260106	0800904	300	1988

**DELINEATION OF SALTWATER INTRUSION IN THE BISCAYNE AQUIFER, EASTERN BROWARD COUNTY, FLORIDA, 1990**

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