Ground-Water Quality and Trends at Two Industrial Wastewater-Injection Sites in Northwestern Florida, 1975-91

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CONTENTS

FIGURES

TABLES

CONVERSION FACTORS, VERTICAL DATUM, ABBREVIATED WATER-QUALITY UNITS, AND ACRONYMS

Multiply	By	To obtain
inch (in.)	2.54	centimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
feet per mile (ft/mi)	0.1894	meter per kilometer
gallon	3.785	liter
gallon per minute (gal/min)	3.785	liter per minute
pound per square inch (lb/in^2)	6.897	kilopascal

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

˚C = (˚F-32)/1.8

Sea level: In this report, “sea level” refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Abbreviated Water-Quality Units and Acronyms

µS/cm at 25 ˚C = microsiemens per centimeter at 25 ˚C
mg/L = milligrams per liter
PVC = Polyvinyl chloride
USGS = U.S. Geological Survey
WATSTORE = Water Data Storage and Retrieval System

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Abstract

Approximately 25 billion gallons of industrial wastewater was injected into the Lower Floridan aquifer at a nylon-manufacturing plant north of Pensacola, Florida, from July 1963 to April 1991 and approximately 4.4 billion gallons of industrial wastewater was injected at an acrylic fiber-manufacturing plant southwest of Milton, Florida, from 1975 to January 1991. Water from four monitoring wells completed in the Floridan aquifer system at each of these plants has been sampled by the U.S. Geological Survey since December 1969 north of Pensacola, and since May 1975 southwest of Milton. The purpose of the sampling was to monitor the effects of this injection on ground-water quality and to assess the occurrence of seepage of injected wastewater to the overyling Upper Floridan aquifer. Large differences in hydraulic heads between the Upper and Lower Floridan aquifers, the lack of a potentiometric surface mound in the Upper Floridan aquifer corresponding to the mound in the Lower Floridan aquifer, the great thickness of the Bucatunna Formation separating these aquifers, and the water-quality data indicate that there is no hydraulic connection between these two aquifers at these plants, and thus no upward leakage of injected wastewater.

None of the selected water-quality characteristics (pH, specific conductance, and concentrations of total ammonia plus organic nitrogen, calcium, sodium, and chloride) had significant trends (from 1975 to 1991) in water from the north well, completed in the Lower Floridan aquifer 1.9 miles northwest of the injection wells at the plant north of Pensacola, indicating that water in this aquifer has probably not been affected by injected wastewater at this well. Significant trends in specific conductance and the concentrations of total ammonia plus organic nitrogen, calcium, and magnesium in water from the south monitor well, located 1.5 miles south of the injection wells at this plant, indicate mixing with wastewater in the Lower Floridan aquifer at this well. In water from shallow wells 1 and 2, completed in the Upper Floridan aquifer at this plant, pH was the only water-quality characteristic with a significant positive trend. Negative trends of concentrations of magnesium in water from shallow well 1 and of chloride in water from shallow well 2 in seasonal samples from April to October are of small magnitude and are probably not related to upwelling of wastewater from the Lower Floridan aquifer.

At the plant southwest of Milton, trend testing indicated a positive trend for calcium in water from the north well, located 1.5 miles north of the injection well. The low magnitude of this trend (less than 1 percent of the median value per year) and the lack of significant trends in the other indicator characteristics in water from this well indicate that the quality of water in the Lower Floridan aquifer at this well has probably not been affected by injected wastewater. Water from the standby injection well, located 1,600 feet from the injection well at this plant, and from the deep test well, located 1,025 feet from the injection well, had a significant positive trend in the concentration of total thiocyanate (analyzed at site 2 only) and significant negative trends in specific conductance and concentrations of magnesium, sodium, potassium, and chloride. These trends indicate that wastewater has affected

the quality of water in the Lower Floridan aquifer at this well. Analyses of water from the shallow well, completed in the Upper Floridan aquifer at the plant southwest of Milton, showed significant positive trends in pH and the concentration of calcium, and a significant negative trend in the concentration of total ammonia plus organic nitrogen. The low magnitudes of the these trends and the fact that injected wastewater at this plant has lower pH values and a higher concentration of total ammonia plus organic nitrogen than water in this aquifer indicate that these trends are probably unrelated to upward seepage of wastewater from the Lower Floridan aquifer.

INTRODUCTION

Two plants manufacturing synthetic-fibers in northwestern Florida are permitted by the State to inject industrial-process wastewater into the confined Lower Floridan aquifer of the Floridan aquifer system, which contains nonpotable water in this area. From July 1963 to April 1991, a nylon manufacturing plant located 13 miles (mi) north of Pensacola, Fla., in Escambia County (fig. 1, site 1) injected about 25 billion gallons of acidic wastewater at rates ranging from 500 to 2,500 gallons per minute (gal/min) at an average pressure of 150 pounds per square inch ($lb/in.^2$) into this aquifer. From 1975 to January 1991, an acrylic-fiber manufacturing plant located 5 mi southwest of Milton, Fla., in Santa Rosa County (fig. 1, site 2) injected about 4.4 billion gallons of treated and filtered wastewater into the Lower Floridan aquifer at rates ranging from 400 to 700 gal/min at an average pressure of 80 lb/in^2.

To address concerns about possible contamination of drinking water supplies from the injection of industrial wastewater into the Lower Floridan aquifer in northwestern Florida, the U.S. Geological Survey (USGS), in cooperation with the Florida Department of Environmental Protection, has conducted periodic water-quality monitoring of the Floridan aquifer system since December 1969 at site 1 and since May 1975 at site 2. Water-quality data obtained from sampling of monitoring wells at these sites are stored in the Water Data Storage and Retrieval System (WATSTORE) data base maintained by the USGS.

Purpose and Scope

This report describes ground-water quality and trends in ground-water quality in water samples collected from eight monitoring wells completed in the Floridan aquifer system from September 1977 to April 1991 at site 1 and from May 1975 to April 1991 at site 2. To evaluate mixing and migration of wastewater injected into the aquifer system, the quality of wastewater and ground water in this system is compared with trends of selected indicator water-quality characteristics in water samples collected at these two sites. Data on historical rates and volumes of wastewater injection, hydrogeologic sections, well construction, and potentiometric-surface elevations are also included in this report.

Previous Studies

Barraclough (1966, 1967) presented preliminary information on the hydrogeology and wastewater-injection activities of site 1, and general hydrogeologic information on Escambia and Santa Rosa Counties. Goolsby (1971) discussed geochemical aspects of wastewater injection at site 1. Construction of monitoring wells at site 1 was discussed by Foster and Goolsby (1972). Movement of wastewater injected into the Lower Floridan aquifer was discussed by Goolsby (1972). Pascale (1975, 1976) and Pascale and Martin (1978) presented hydrologic and water-quality data from monitoring wells at both sites. Ehrlich and others (1979) discussed hydraulic characteristics of the Lower Floridan aquifer and the effects of denitrification on the concentrations of nitrate and organic carbon in wastewater as it migrates through this aquifer at site 2. Hull and Martin (1982) presented information on hydrogeology, well construction, and injection histories of both sites. Subsurface wastewater injection in Florida and its general effects were reported by Hickey and Vecchioli (1986).

Merritt (1984) used data from digital simulation of the wastewater-injection rates of 1984 at both sites to estimate that 4,400 years would be required for wastewater to migrate to the upgradient areas where potable water is withdrawn from the Lower Floridan aquifer. Ward and others (1992) used computer simulations to determine that, given an aquifer thickness of 100 ft, a 95-percent concentration of wastewater would migrate up to 1 mi from the injection wells in the Lower Floridan aquifer at site 1 by the year 2033.

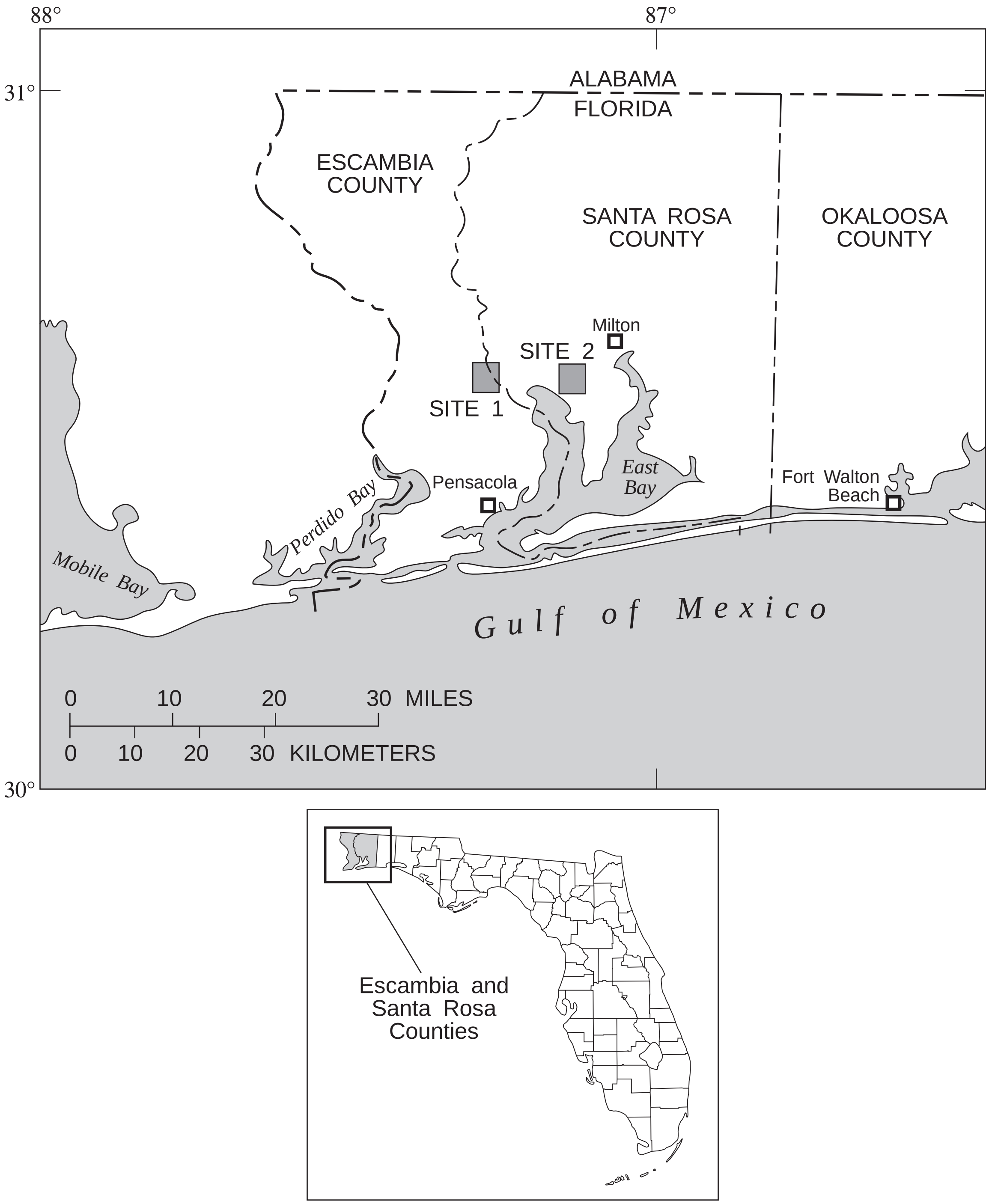

Figure 1. Location of wastewater-injection sites.

DESCRIPTION OF WASTEWATER-INJECTION SITES

Descriptions of hydrogeologic setting, locations, and construction of injection and monitoring wells, wastewater-injection practices, and ground-water flow at two industrial wastewater-injection sites in northwestern Florida are included in the following sections.

Hydrogeologic Setting

Sites 1 and 2 are underlain by approximately 2,000 ft of aquifers and confining beds that dip toward the southwest (fig. 2). The three principal aquifers in this region are the sand-and-gravel aquifer and the Upper and Lower Floridan aquifers of the Floridan aquifer system. The sand-and-gravel aquifer, the uppermost aquifer in the region, consists of approximately 450 ft of quartz sands and lenses of clay and gravel of Holocene to Pliocene age at these sites (Musgrove and others, 1965). The sand-and-gravel aquifer supplies 100 percent of withdrawals in Escambia County and about 90 percent of withdrawals in Santa Rosa County (Marella, 1992). To the north of the injection sites, the sand-and-gravel aquifer is directly underlain by the Upper Floridan aquifer (fig. 2). At these sites, the sand-and-gravel aquifer is underlain by about 450 ft of Pensacola clay of Miocene-age (fig. 2) that serves as a confining layer to the Upper Floridan aquifer. The Upper Floridan aquifer at both sites consists of approximately 100 ft of the Tampa Limestone of Miocene age overlying approximately 100 ft of the Chickasawhay Formation of late Oligocene age (Musgrove and others, 1965, p. 16). The Upper Floridan aquifer is underlain by approximately 200 ft of clays of the Bucatunna Formation, which confines the Lower Floridan aquifer at both sites. The Lower Floridan aquifer beneath the sites consists of about 300 ft of chalky, shaley limestone of Eocene age which unconformably overlies less permeable shales and clays of Eocene age (Musgrove and others, 1965, p. 17).

Injection and Monitoring Wells

The wastewater-injection system at site 1 consisted of three wells (A, B, and C) in 1991. The monitoring well network at site 1 consisted of the north and south wells, completed in the Lower Floridan aquifer; and shallow wells 1 and 2, completed in the Upper Floridan aquifer (table 1, fig. 3). To protect against corrosion, the bottom 20 ft of casing of all injection-zone wells is stainless steel, as is the inner injection tube of each injection well (Hull and Martin, 1982, p. 3). In August 1977, stainless-steel sampling tubes were added to the monitoring wells at site 1 to decrease the volume of water purged from these wells prior to sampling.

The wastewater-injection system at site 2 consisted of the primary and standby injection wells in 1991. The standby injection well has never been used for wastewater injection, but has been used for water-quality monitoring of the Lower Floridan aquifer. The deep-test and north wells are also completed in the Lower Floridan aquifer at this site (table 2, fig. 4). The shallow well taps the Upper Floridan aquifer at site 2. The injection wells at this site are constructed in a similar manner to those at site 1. Stainless steel-tipped polyvinyl chloride (PVC) sampling tubes were installed in the summer of 1975 in the deep-test and north wells (Hull and Martin, 1982, p. 6). The potentiometric heads of the Lower Floridan aquifer at this site and at site 1 are above land surface, so the wells completed in this aquifer are flowing artesian wells. Because the water level is below the land surface in the Upper Floridan aquifer at this site, a submersible pump attached to a 3/4-in. PVC pipe extending 1,100 ft below land surface is used for withdrawing water samples from the shallow well at site 2 (Hull and Martin, 1982, p. 6).

Potentiometric-surface altitudes measured in the monitoring wells completed in the Lower Floridan aquifer at sites 1 and 2 had similar patterns of pressure heads, increasing up to 25 ft after the onset of wastewater injection, peaking in the late 1970's and subsequently leveling off (figs. 5, 6). Water levels in the Upper Floridan aquifer have not had similar fluctuations, indicating a lack of hydraulic connection between the two aquifers. There has been a gradual drawdown of water levels in the Upper Floridan aquifer since 1970 due to withdrawals at Fort Walton Beach, Fla.

Wastewater Injection

Wastewater injection rates at site 1 have varied markedly since injection started in 1963. From December 1963 to June 1972, wastewater-injection rates at site 1 were increased by a factor of 5, from about 500 gal/min to 2,500 gal/min (fig. 7). Wastewater-injection rates at this site remained at about 2,500 gal/min, with a brief decrease in 1975, until 1979, when wastewater injection decreased to approximately 1,300 gal/min. Wastewater injection remained at this rate through 1991 (fig. 7). The cumulative volume of wastewater injection at site 1 from 1963 to 1991 was about 24 billion gallons (fig. 7).

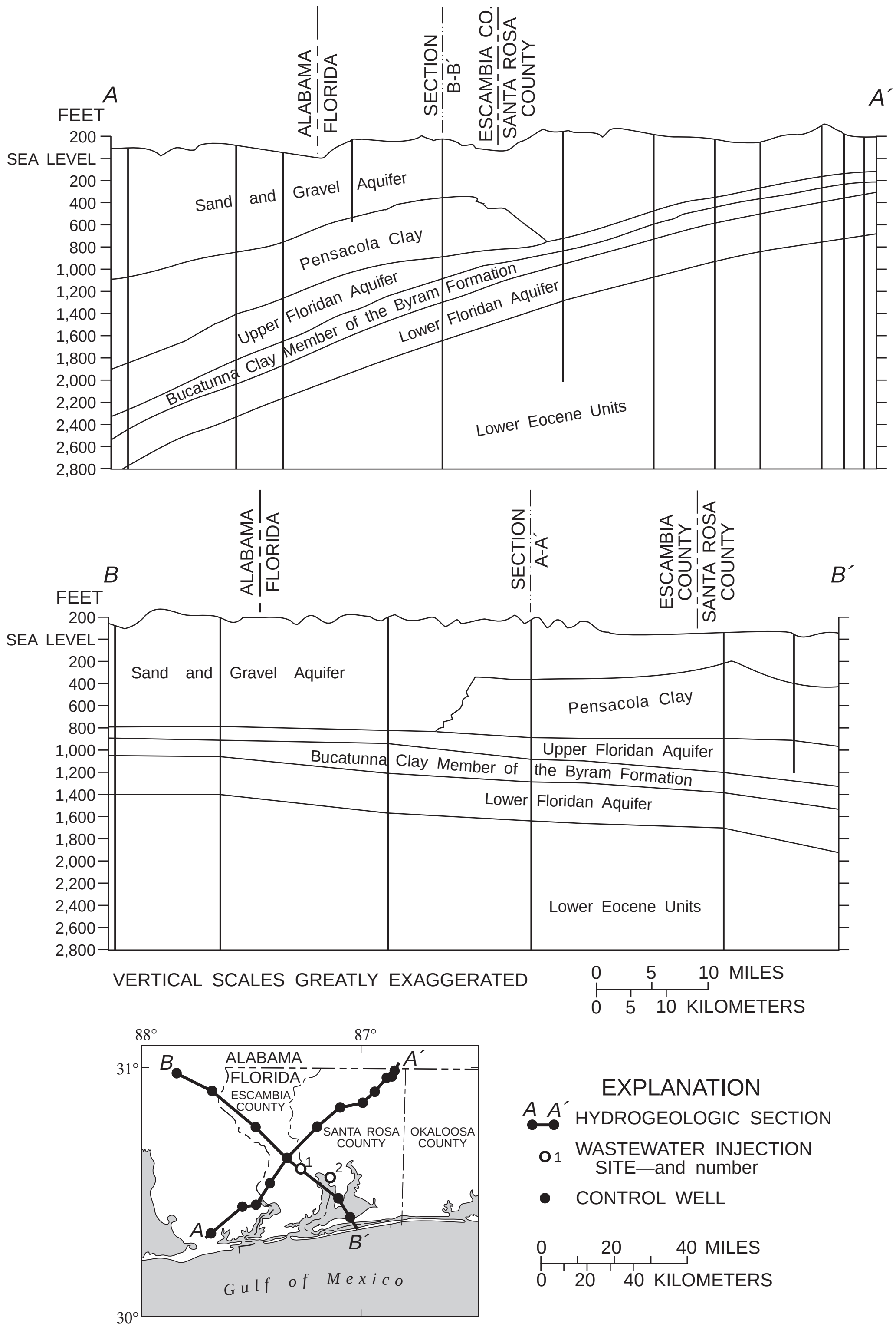

Figure 2. Hydrogeologic sections parallel to the regional strike and dip, northwestern Florida.

Table 1. Description of wells at wastewater-injection site 1 north of Pensacola, Fla.

[ft, feet; in., inches. Modified from Hull and Martin, 1982]

Well name	Station number	Well completion date	Depth of well below land surface (ft)	Casing (ft)	Injection or sampling tube (ft)
Injection well A	303537087145601	March 1963	1,808	24-in. steel, 0-86 18-in. steel, 0-982 12-in. steel, 872-1,370 12-in. stainless steel, 1,370-1,390	6-in. stainless steel, 0-1,396
Injection well B	303528087150601	August 1964	1,654	16-in. steel, 0-110 10-in. steel, 0-1,395 10-in. stainless steel, 1,395-1,415	6-in. stainless steel, 0-1,417
Injection well C	303537087144501	February 1982	1,664	30-in.steel, 0-106 18-in. steel, 0-1,190 10 3/4-in. steel, 0-1,314 10 3/4-in. stainless steel, 1,314-1,340	6-in. stainless steel, 0-1,391
North	303657087154301	February 1969	1,523	16-in. steel, 0-100 8-in. steel, 0-1,320 8-in. stainless steel, 1,320-1,340	
		August 1977			3/4-in. stainless steel, 0-1,360
South	303417087141701	December 1969	1,596	16-in. steel, 0-100 8-in. steel, 0-1,410 8-in. stainless steel, 1,410-1,430	
		September 1977			3/4-in. stainless steel, 0-1,120
Shallow 1	303538087145501	August 1963	1,140	16-in. steel, 0-100 8-in. steel, 0-972	
		August 1977			3/4-in. stainless steel, 0-1,120
Shallow 2	303541087144402	December 1981	1,138	10-in. steel, 0-1,088	3/4-in. stainless steel, 0-1,133

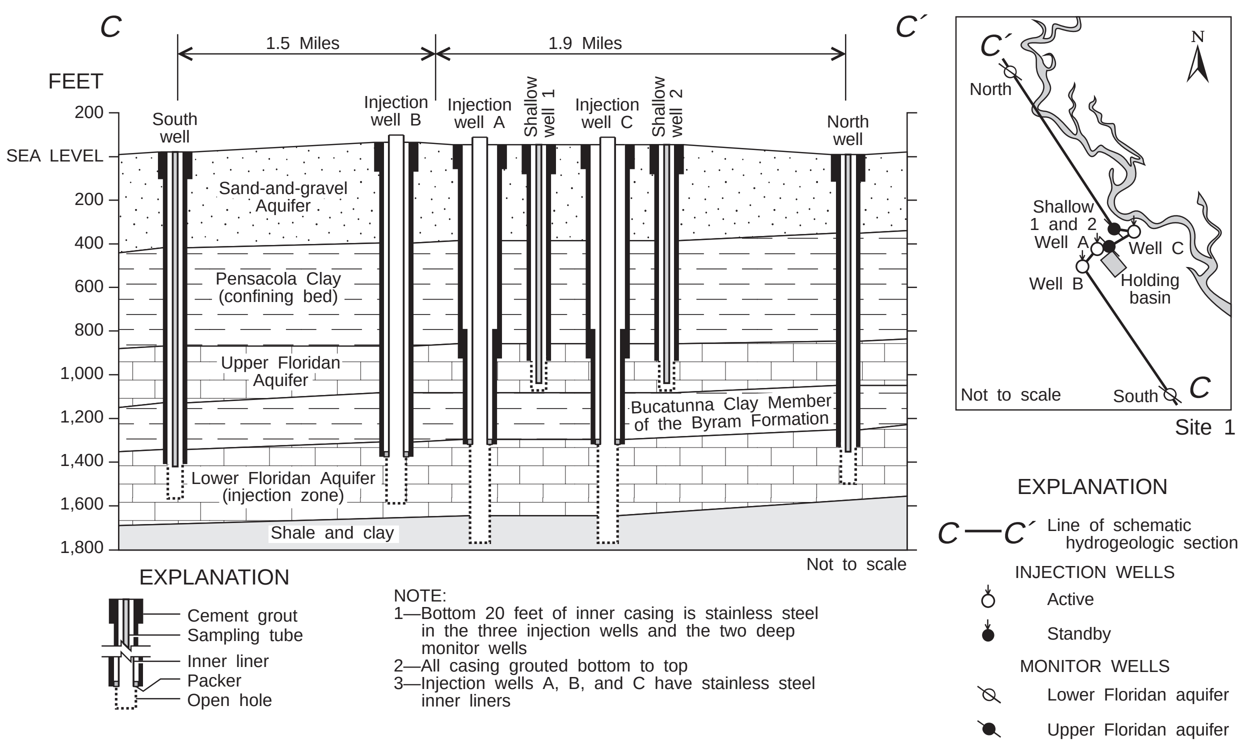

Figure 3. Schematic and hydrogeologic section at wastewater-injection site 1 north of Pensacola, Fla. (modified from Hull and Martin, 1982).

Table 2. Description of wells at wastewater-injection site 2 southwest of Milton, Fla.

[ft, feet; in., inches. Modified from Hull and Martin, 1982]

Well name	Station number	Well completion date	Depth of well below land surface (ft)	Casing (ft)	Injection or sampling tube (ft)
Primary injection well	303130087063801	November 1974	1,526	24-in. steel, 0-100 16-in. steel, 0-870 12-in. steel, 0-1,300 12-in. stainless steel, 1,318-1,338	8-in. stainless steel, 0-1,320
Standby injection	303357087063801	December 1974	1,508	24-in. steel, 0-100 16-in. steel, 0-863 12-in. steel, 0-1,300 12-in.stainless steel, 1,300-1,320	8-in. stainless steel, 0-1,320
Deep test	303537087144501	December 1971	1,546	18-in.steel, 0-100 12-in. steel, 0-881 6-in. steel, 0-1,444 6-in. stainless steel, 1,444-1,464	
		August 1975		3/4-in. PVC, 0-1,300	1/2-in. stainless steel, 1,300-1,320
North	303541087054801	December 1974 June 1975	1,492	6-in. steel, 0-100 3/4-in. PVC, 0-1,300	
Shallow	303413087063802	November 1974	1,492	6-in. steel, 0-1,096 1/2-in. steel, 0-160	3/4-in. PVC, 160-1,100

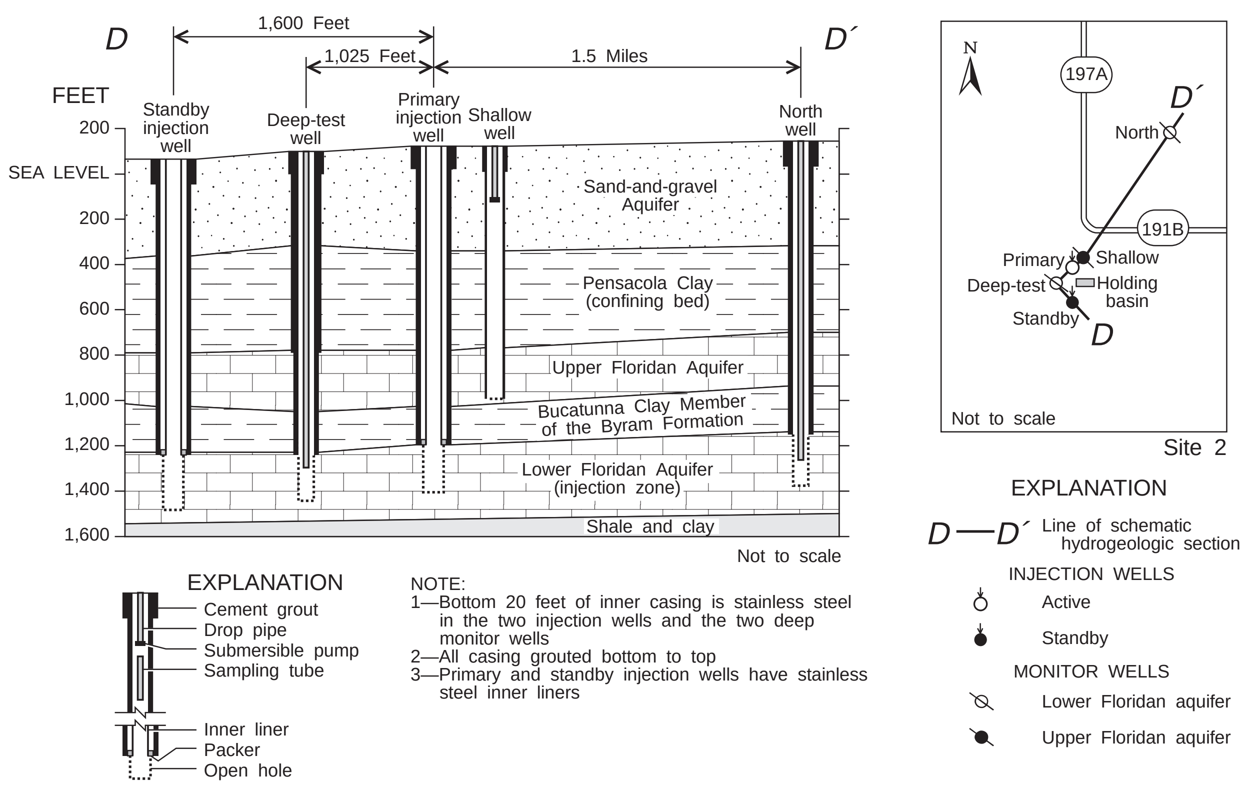

Figure 4. Schematic and hydrogeologic section at wastewater-injection site 2 southwest of Milton, Fla. (modified from Hull and Martin, 1982).

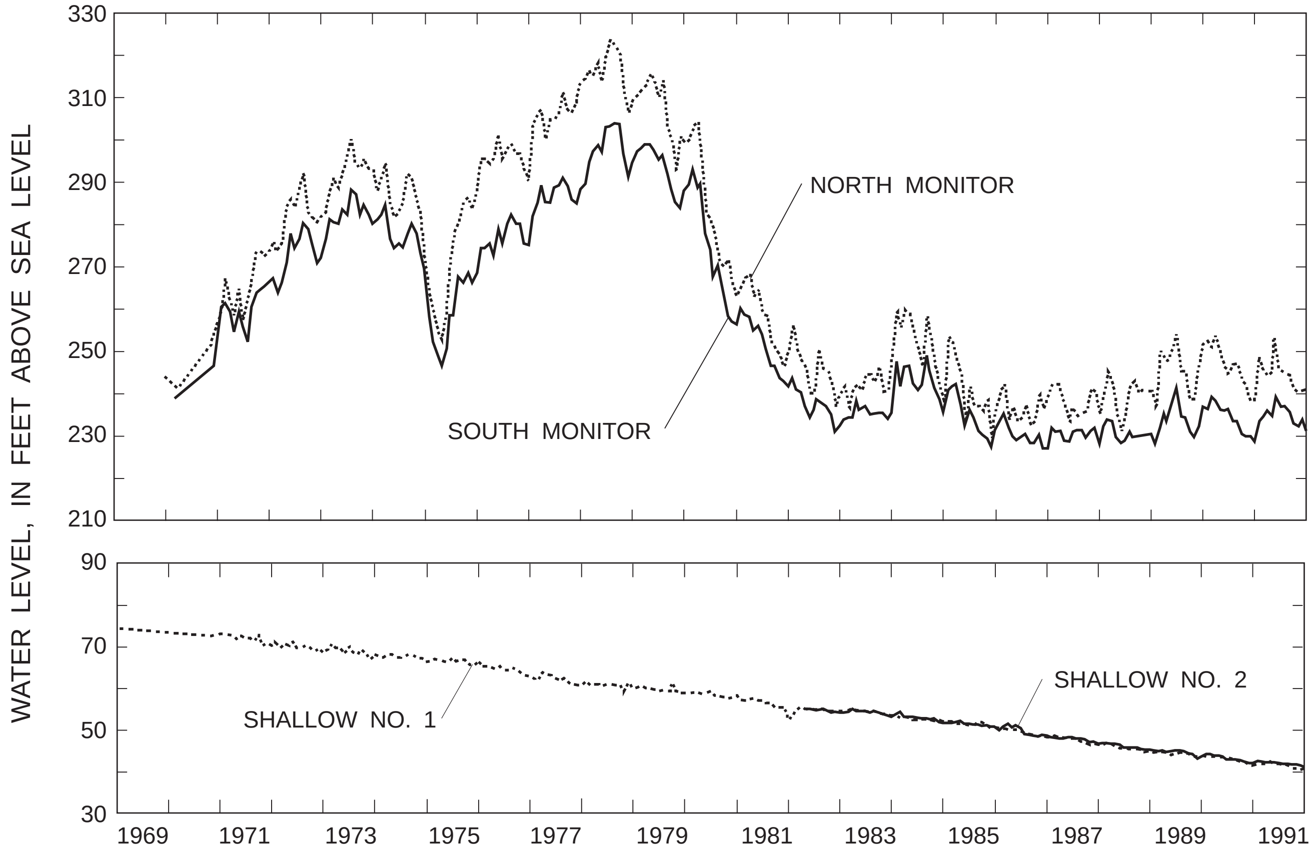

Figure 5. Water levels in monitoring wells at wastewater-injection site 1 north of Pensacola, Fla., 1969-91.

Wastewater-injection rates were more constant at site 2 than at site 1, averaging approximately 600 gal/min from 1975 to 1983 (fig. 8). From January 1983 to October 1989, wastewater-injection rates decreased to approximately 500 gal/min (fig. 8). Wastewater-injection rates increased to an average of 650 gal/min from October 1989 through April 1991 (fig. 8). The cumulative volume of injected wastewater at site 2 from 1975 to 1991 was approximately 4.4 billion gallons. The quality of industrial wastewater injected at both sites is discussed later in this report.

Ground-Water Flow

Prior to the onset of wastewater injection, the potentiometric gradient of water in the Lower Floridan aquifer in the western Florida Panhandle was about 2.5 feet per mile (ft/mi) toward the southeast (Merritt, 1984, p. 22). Computer simulation of the wastewater injection in this aquifer indicates the presence of an oval-shaped mound in the potentiometric surface which is centered around the injection wells at sites 1 and 2 (fig. 9). The simulated potentiometric contours indicate that water in the Lower Floridan aquifer flows radially away from sites 1 and 2 (fig. 9). Water in the Upper Floridan aquifer flows toward the southeast at both sites (fig. 9). The lack of a potentiometric-surface mound centered around these sites in the Upper Floridan aquifer, the substantially higher heads in the Lower Floridan aquifer, and the great thickness of the Bucatunna Formation separating these aquifers indicate that there is no hydraulic connection between these aquifers at these sites.

GROUND-WATER QUALITY AND TRENDS

Water-quality sampling has been conducted at site 1 by the USGS since December 1969. This sampling program, designed to monitor the effect of wastewater injection on the Floridan aquifer system, consists of periodic field samplings that included measurement of temperature, pH, specific conductance, and total alkalinity of water from monitoring wells. Less frequent, comprehensive sampling included analyses for the following water-quality characteristics (dissolved unless specified as total): color, total ammonia and organic nitrogen, nitrite, and nitrate nitrogen; total phosphate, total phosphorus, total organic carbon, cyanide, calcium, magnesium, sodium, potassium, chloride, sulfate, fluoride, silica, barium, boron, chromium, cobalt, copper, iron, nickel, strontium, zinc, total cyanide (1982 to 1991), total thiocyanate (1986 to 1991), and solids (residue on evaporation). The frequencies of field and comprehensive samplings at this site have varied since 1969. From 1969 to 1970, comprehensive samplings were conducted quarterly. From January 1971 to December 1976, comprehensive samplings were conducted monthly. Comprehensive sampling was conducted at 6-week intervals from January 1977 to December 1981. In 1982, comprehensive samplings were conducted bimonthly. From January 1983 to April 1991, field measurements were made quarterly, and comprehensive samplings were conducted semiannually at site 1.

Water-quality sampling has been conducted at site 2 by the USGS since May 1975. From May 1975 to December 1977, this program consisted of limited sampling for the following water-quality characteristics: temperature, pH, specific conductance and concentrations of total alkalinity, total ammonia plus organic nitrogen, nitrite, nitrate, total phosphate, total phosphorus, calcium, magnesium, chloride, sulfate, and fluoride. During this period, limited samplings were conducted monthly and comprehensive sampling, identical to those conducted at site 1, were conducted semiannually at site 2. During 1978, limited samplings were conducted every 6 weeks and comprehensive samplings were conducted quarterly. The concentration of total thiocyanate in water from monitoring wells at this site has been analyzed since November 1978. From January 1979 to December 1982, limited samplings were conducted bimonthly, and comprehensive samplings were conducted semiannually at site 2.

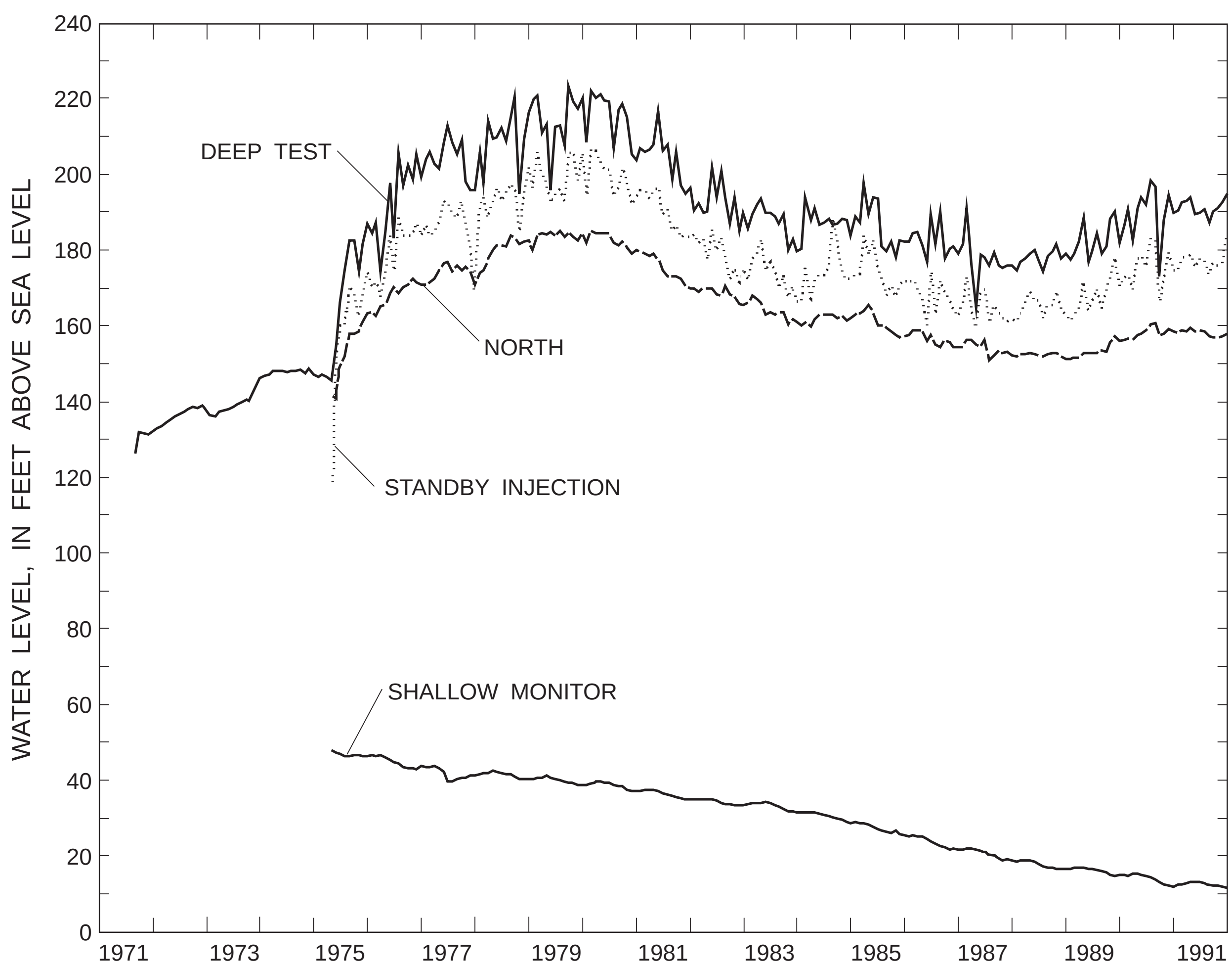

Figure 6. Water levels in monitoring wells at wastewater-injection site 2 southwest of Milton, Fla., 1971-91.

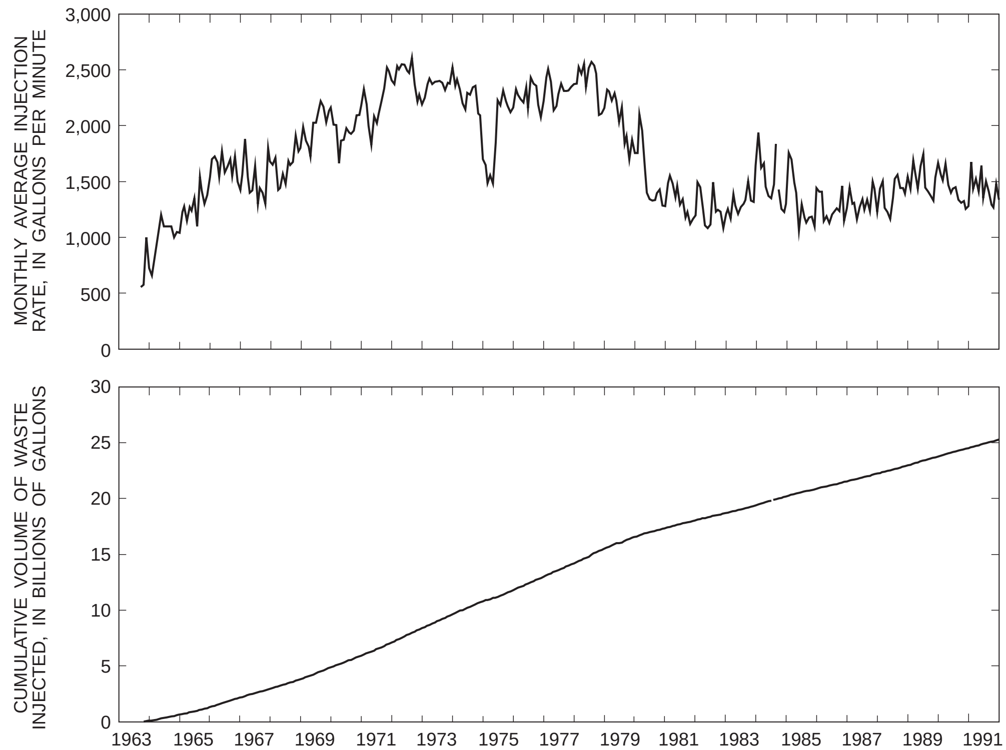

Figure 7. Monthly average injection rate and cumulative volume of wastewater injected at wastewater-injection site 1 north of Pensacola, Fla., 1963-91.

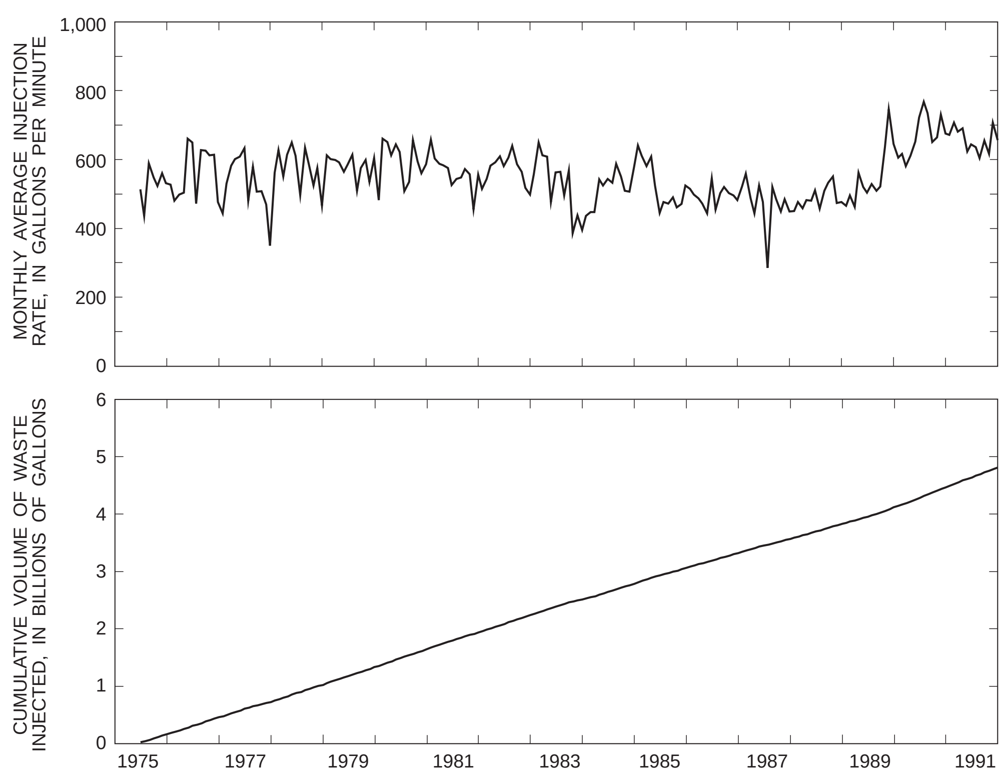

Figure 8. Monthly average injection rate and cumulative volume of wastewater injected at wastewater-injection site 2 southwest of Milton, Fla., 1975-91.

From January 1983 to December 1986, field measurement of temperature, pH, specific conductance, and the concentration of total alkalinity were conducted quarterly at site 2, whereas comprehensive samplings were conducted semiannually. From January 1987 to April 1991, field measurement was conducted quarterly and comprehensive samplings were conducted annually at site 2. At both sites, counts of bacteria, including sulfate reducers, denitrifiers, aerobes, and anaerobes; and concentrations of the gases carbon dioxide, methane, nitrogen, and oxygen in water from the monitoring wells were determined annually.

Changes in purging times and sampled intervals, a consequence of the installation of sampling tubes in the monitoring wells at site 1 and of procedural changes at site 2, caused changes in the values of water-quality characteristics in samples collected at both sites. In September 1977, sampling tubes were installed in the north, south, and shallow 1 wells at site 1. These tubes reduced the amount of water purged from these wells prior to sampling, and changed the depths from which water was sampled. Because these changes biased trend analysis of water-quality data from these wells at this site, water-quality trends were only analyzed for samples collected from September 1977 to 1991 for this report. At site 2, well-purging practices have been constant for all monitoring wells except for the shallow well. From 1975 to June 1979, purging times for this well ranged from less than 1 hour to 7 hours. From July 1979 to April 1991, the purging time for the shallow well averaged about 20 hours (Hull and Martin, 1982, table 18). Because of this change in purging practices, only water-quality data collected from this well from July 1979 to 1991 are presented in this report.

Because analytical methods have changed for many of the analyzed water-quality constituents since sampling began at these sites and because many of these constituents had substantial numbers of analyses below detection limits, water-quality statistics and water-quality trends are only presented for the following water-quality characteristics designated as indicator characteristics in this report: pH, specific conductance, and concentrations of total ammonia plus organic nitrogen, calcium, sodium, chloride, and total thiocyanate (site 2 only). These indicator characteristics typically have detectable values in water from the wells on both sites and the analytical methods for these characteristics have remained unchanged during the sampling periods.

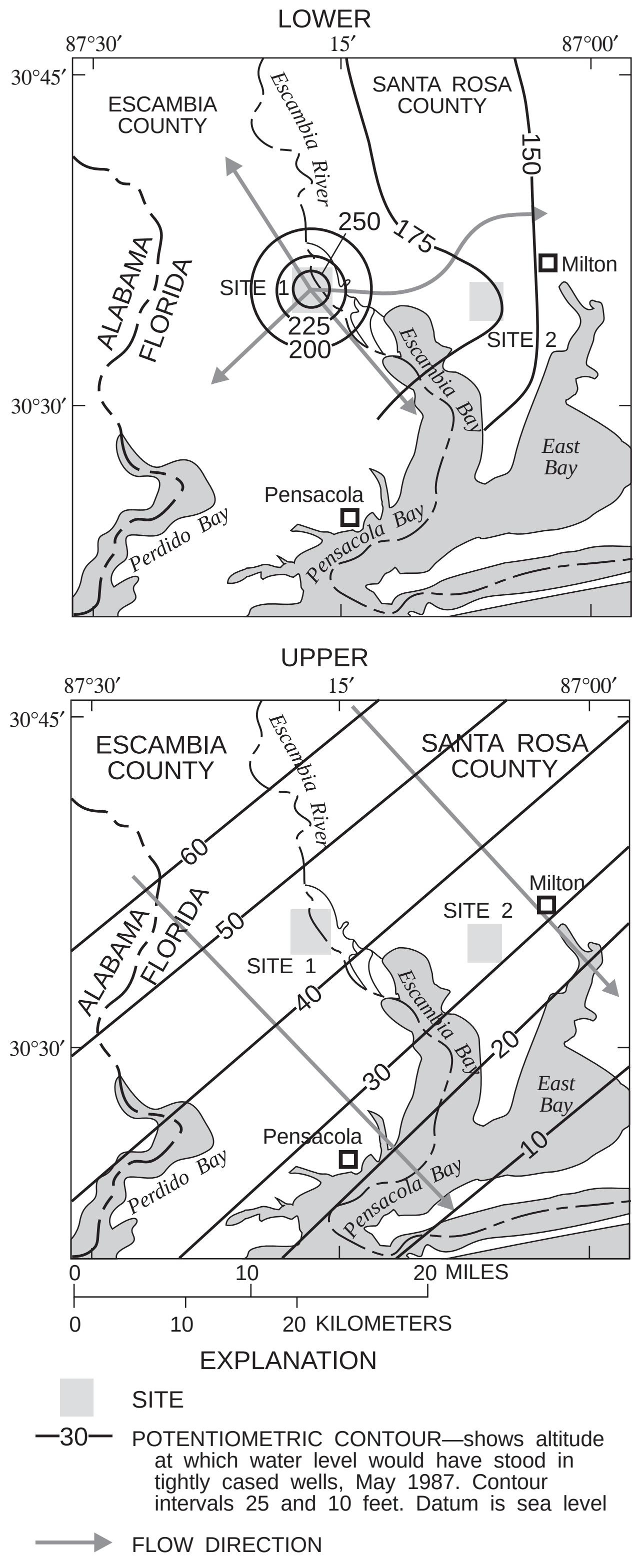

Figure 9. Potentiometric surface and direction of flow in the Lower Floridan aquifer (1987) and the Upper Floridan aquifer (1991) in the vicinity of wastewater-injection sites 1 and 2 (modified from Meadows, 1991; and Ward and others, 1992).

Trend Analysis

Trends in water-quality characteristics were determined by the nonparametric Kendall trend test (Hirsch and others, 1982). For this report, the Kendall tau test statistic (τ_k) is derived from the following equation:

$$\tau_k = (P-Q)/(n(n-1)/2), \qquad (1)$$

where
P is the number of data pairs that increase,
Q is the number of data pairs that decrease, and
n is the total number of data pairs (Daniel, 1978, p. 307).

Kendall tau values range from -1 to +1, negative tau values indicating downward trends and positive tau values indicating upward trends. Data without trends have tau values near 0. For each test, a p-value representing the confidence level is determined. In this report, a significant trend is assumed if a p-value is equal to or less than 0.05. Estimates of the rate of change (trend slope) for the period of record (expressed as a percentage change relative to the median value of the characteristic per year) is also computed for each of the indicator water-quality characteristics for this report.

For analysis of trends in water-quality data from site 1, the data were segregated into two seasonal data sets because wells at this site were continually purged from November to March (to avoid valve freezing during the winter). This seasonal change in well-purging caused variation in some values of the indicator water-quality characteristics, compared to samples collected from April to October. At site 2, purging practices were not varied seasonally, so the water-quality data are not seasonally segregated for trend analysis.

Injection Site 1 North of Pensacola

The quality of wastewater and water at site 1, and trends in the values of water-quality characteristics in samples collected from September 1977 to April 1991 from monitoring wells completed in the Floridan aquifer system at site 1 are discussed in the following three sections. Site 1 is not as well suited to long-term trend analysis as site 2 because of numerous changes in the quality of wastewater and because of changes in well construction at site 1.

Injected Wastewater

Wastewater samples from site 1 were collected periodically from December 12, 1966 to January 11, 1980, by USGS personnel from a tap 200 ft south of injection well A on the pipeline from the holding pond to that well (Hull and Martin, 1982, p. 22). Wastewater was periodically analyzed by staff of the manufacturing plant for pH and concentrations of total ammonia plus organic nitrogen and chloride (table 3). The wastewater injected by the plant is acidic, with a median pH of 3.1, and has relatively high median specific conductance (8,300 μS/cm) and elevated median concentrations of total ammonia plus organic nitrogen (870 mg/L) and sodium (810 mg/L). According to Batz (1964), major constituents in wastewater injected at this site include organic monobasic and dibasic acids, nitric acid, ammonia, hexamethylenediamine, sodium hydroxide, sodium carbonate, alcohols, and ketones. Before 1963, wastewater at site 1 was untreated prior to injection (Hull and Martin, 1982, p. 11). Since 1963, wastewater injected by the plant has been periodically neutralized. Since 1968, wastewater from various process-wastewater streams has been mixed in a holding pond from which it is injected into the Lower Floridan aquifer.

Table 3. Summary of the indicator water-quality characteristics in wastewater-injection at site 1 north of Pensacola, Fla.

[pH in standard units; specific conductance in microsiemens per centimeter at 25 degrees Celsius; all other constituents in milligrams per liter]

Characteristics	Number of samples	Median	Minimum	Maximum
pH[1]	314	3.1	1.3	6.6
Specific conductance[2]	4	8,300	4,800	8,600
Total ammonia plus organic nitrogen[3]	20	870	545	1,850
Calcium[2]	25	4.5	3.0	8.2
Magnesium[2]	25	5.9	1.0	7.4
Sodium[2]	5	810	400	950
Potassium[2]	5	1.9	1.4	7.0
Chloride[4]	6	8.0	3.0	227

[1]From daily values from the manufacturer for the 15th of each month, May 1964-April 1991.
[2]From periodic analyses by the U.S. Geological Survey, December 1966-January 1980.
[3]From quarterly analyses by the manufacturer, March 1986-April 1991.

Lower Floridan Aquifer

Sodium, potassium, and chloride are the principal dissolved constituents in water from the north well, located 1.9 mi northwest of the injection wells at site 1 (table 4). The following indicator water-quality characteristics have higher median values in water from this well than in the wastewater injected at site 1: specific conductance, pH, calcium, magnesium, sodium, potassium, chloride (tables 3, 4). Total ammonia plus organic nitrogen is the only indicator constituent with a lower median concentration in water from the north well than in wastewater injected at this site (tables 3, 4).

Trend analysis of the indicator water-quality characteristics in water from the north well indicated that none of these characteristics had statistically significant trends (p-values less than 0.05) (table 5). A graph of chloride concentrations in water from this well (fig. 10) illustrates a lack of trend in the quality of water from this well. If wastewater reached this well, chloride concentrations in water from this well would probably decrease, due to dilution by wastewater, which has a lower median chloride concentration than water sampled from this well.

Sodium, potassium, and chloride are the principal dissolved constituents in water sampled from the south well, completed in the Lower Floridan aquifer 1.5 mi south-southeast of the injection wells at site 1 (table 4). Water sampled from this well has higher median values of specific conductance, pH and higher median concentrations of calcium, magnesium, sodium, potassium, and chloride, and a lower median concentration of total ammonia plus organic nitrogen than wastewater injected at site 1 (tables 3, 4). Trend analysis implies significant positive trends in the following indicator water-quality characteristics in water sampled from the south well from September 1977 to April 1991: specific conductance, total ammonia plus organic nitrogen, calcium, magnesium, and chloride (summer only) (table 5). Total ammonia plus organic nitrogen, the concentration of which increased at a rate of 6 percent of its median value per year, occurs in higher concentrations in wastewater than in water from this well, so the increasing trend in concentrations of this constituent may indicate mixing with wastewater at this well. The cause of the slight positive trends in specific conductance and in concentrations of calcium and magnesium, which occur in lower values in wastewater than in water from this well, might be due to dissolution of dolomitic limestone in the Lower Floridan aquifer by the acidic wastewater. The positive trend in chloride (fig. 11) in water from this well, which is slight, is unlikely to be caused by mixing with lower-chloride wastewater at this well, but may represent natural variations in the aquifer.

Table 4. Summary of the indicator water-quality characteristics in water from the Lower Floridan aquifer at wastewater-injection site 1 north of Pensacola, Fla.

[pH in standard units; specific conductance in microsiemens per centimeter at 25 degrees Celsius; all other constituents in milligrams per liter. First value in column applies to April-October samples, followed by value shown in parentheses for November-March samples]

Well (period of (record)	Characteristics	Number of samples	Median	Minimum	Maximum
North	pH	43 (28)	7.4 (7.4)	7.3 (7.3)	7.6 (7.6)
(September 1977-April 1991)	Specific conductance	42 (28)	16,900 (17,900)	15,300 (13,800)	26,400 (22,200)
	Total ammonia plus organic nitrogen	30 (20)	7.5 (7.8)	6.3 (6.9)	14 (10)
	Calcium	31 (22)	100 (140)	84 (91)	250 (180)
	Magnesium	32 (21)	95 (120)	81 (85)	210 (160)
	Sodium	15 (12)	3,600 (4,500)	3,400 (3,600)	5,700 (4,700)
	Potassium	15 (12)	61 (74)	43 (55)	100 (100)
	Chloride	31 (22)	6,000 (6,800)	5,600 (5,400)	10,000 (8,700)
South	pH	43 (28)	7.2 (7.2)	7.2 (7.0)	7.4 (7.4)
(September 1977-April 1991)	Specific conductance	43 (28)	20,000 (20,600)	18,300 (16,800)	22,000 (22,400)
	Total ammonia plus organic nitrogen	28 (20)	15 (14)	9.4 (10)	28 (37)
	Calcium	32 (21)	110 (140)	80 (76)	150 (160)
	Magnesium	32 (21)	130 (140)	92 (100)	160 (160)
	Sodium	16 (12)	4,400 (4,600)	4,100 (4,400)	4,600 (4,900)
	Potassium	16 (12)	84 (86)	69 (71)	95 (110)
	Chloride	30 (22)	7,200 (7,600)	5,900 (6,000)	8,000 (8,600)

Table 5. Kendall tau values, p-values, and trend slopes of the indicator water-quality characteristics in water from the monitoring wells at wastewater-injection site 1 north of Pensacola, Fla.

[Two-sided p-values adjusted for serial correlation. Trend slope expressed in percent of median per year. First value in column applies to April-October samples, followed by value shown in parentheses for November-March samples]

Well (period of (record)	Characteristics	Number of samples	Kendall tau value	p-value	Trend slope
North	pH	15 (14)	0.1 (0.3)	0.6 (0.09)	0 (0.1)
(September 1977-April 1991)	Specific conductance	15 (14)	-0.3 (0.3)	0.1 (0.2)	0.2 (0.9)
	Total ammonia plus organic nitrogen	14 (10)	-0.05 (0.2)	0.4 (0.5)	-0.4 (2)
	Calcium	14 (11)	0.3 (0.3)	0.3 (0.2)	0.1 (3)
	Magnesium	14 (11)	-0.2 (0.2)	0.4 (0.4)	-0.2 (2)
	Sodium	14 (10)	0.04 (0.5)	0.9 (0.5)	0 (0.2)
	Potassium	14 (10)	0.03 (0.04)	0.9 (0.9)	0.2 (0.6)
	Chloride	14 (11)	-0.1 (0.2)	0.5 (0.3)	-0.1 (2)
South	pH	15 (14)	-0.3 (-0.02)	0.9 (1)	0 (0)
(September 1977-April 1991)	Specific conductance	15 (14)	0.6 (0.6)	0.003 (0.007)	0.5 (1)
	Total ammonia plus organic nitrogen	14 (11)	0.6 (0.8)	0.003 (0.001)	6 (6)
	Calcium	14 (12)	0.5 (0.5)	0.02 (0.03)	2 (3)
	Magnesium	14 (12)	0.5 (0.5)	0.006 (0.02)	0.8 (2)
	Sodium	14 (11)	0.3 (0.2)	0.2 (0.4)	0.2 (20)
	Potassium	14 (11)	0.3 (0.4)	0.1 (0.08)	1 (2)
	Chloride	13 (12)	0.7 (0.3)	0.001 (0.2)	0.8 (2)
Shallow 1	pH	15 (14)	0.6 (0.6)	0.004 (0.002)	0.3 (0.3)
(September 1977-April 1991)	Specific conductance	15 (14)	-0.2 (0.3)	0.4 (0.2)	-0.06 (0.1)
	Total ammonia plus organic nitrogen	14 (12)	0.02 (-0.1)	1.0 (0.6)	0 (-0.6)
	Calcium	14 (12)	-0.09 (0.4)	0.7 (0.1)	0 (0.9)
	Magnesium	14 (12)	-0.4 (-0.06)	0.04 (0.8)	-1 (0)
	Sodium	14 (11)	-0.06 (-0.22)	0.8 (0.4)	0 (-0.3)
	Potassium	14 (11)	0.2 (0.1)	0.3 (0.6)	0.9 (0.6)
	Chloride	14 (12)	0.3 (-0.08)	0.1 (0.8)	0.6 (-1)
Shallow 2	pH	9 (10)	0.6 (0.7)	0.02 (0.004)	0.4 (0.6)
(March 1982-April 1991)	Specific conductance	9 (10)	-0.03 (0.1)	1.0 (0.6)	-0.02 (0.04)
	Total ammonia plus organic nitrogen	9 (10)	-0.4 (-0.1)	0.2 (0.8)	-2 (0)
	Calcium	9 (8)	0.06 (0.04)	0.9 (1)	0.4 (0)
	Magnesium	9 (8)	-0.3 (-0.3)	0.4 (0.3)	-1 (-0.9)
	Sodium	8 (8)	0.4 (-0.1)	0.2 (0.8)	0.4 (-0.6)
	Potassium	9 (8)	0.4 (0.5)	0.1 (0.2)	3 (2)
	Chloride	8 (8)	-0.2 (0.1)	0.03 (0.8)	-0.5 (0)

Upper Floridan Aquifer

Because the wells completed in the Upper Floridan aquifer at site 1 are extremely close to the injection wells (fig. 3), leakage from the Lower Floridan aquifer would cause the quality of water from these monitoring wells to become similar to that of wastewater after the onset of wastewater injection. Sodium, potassium, and chloride are the principal dissolved constituents in water from shallow 1 and 2 wells at site 1. Median values of pH, potassium, and chloride are higher in water from these wells than in wastewater; whereas specific conductance, total ammonia plus organic nitrogen, calcium, magnesium, and sodium have lower median values in water from these wells than in the wastewater at this site (tables 3, 6).

Trend analysis demonstrated that pH was the only indicator water-quality characteristic with a significant positive trend in water from shallow wells 1 and 2 at this site from September 1977 to April 1991. The trend in pH values was less than 1 percent of the median value per year and is probably not related to upward seepage of wastewater from the Lower Floridan aquifer. Trend analysis indicates a slight decreasing trend in the concentration of magnesium in water samples collected during the summer seasons (April-October) from shallow well 1 and in the concentration of chloride in water sampled during summers from shallow well 2 (figs. 12, 13). These slight, seasonal negative trends are also unlikely to be related to upward seepage of wastewater into this aquifer.

Injection Site 2 Southwest of Milton

This section presents information about the quality of wastewater and ground water and trends in ground-water quality in samples collected from monitoring wells at site 2. Site 2 is better suited than site 1 for examining water-quality trends because well-purging practices at site 2 have been more consistent than at site 1,

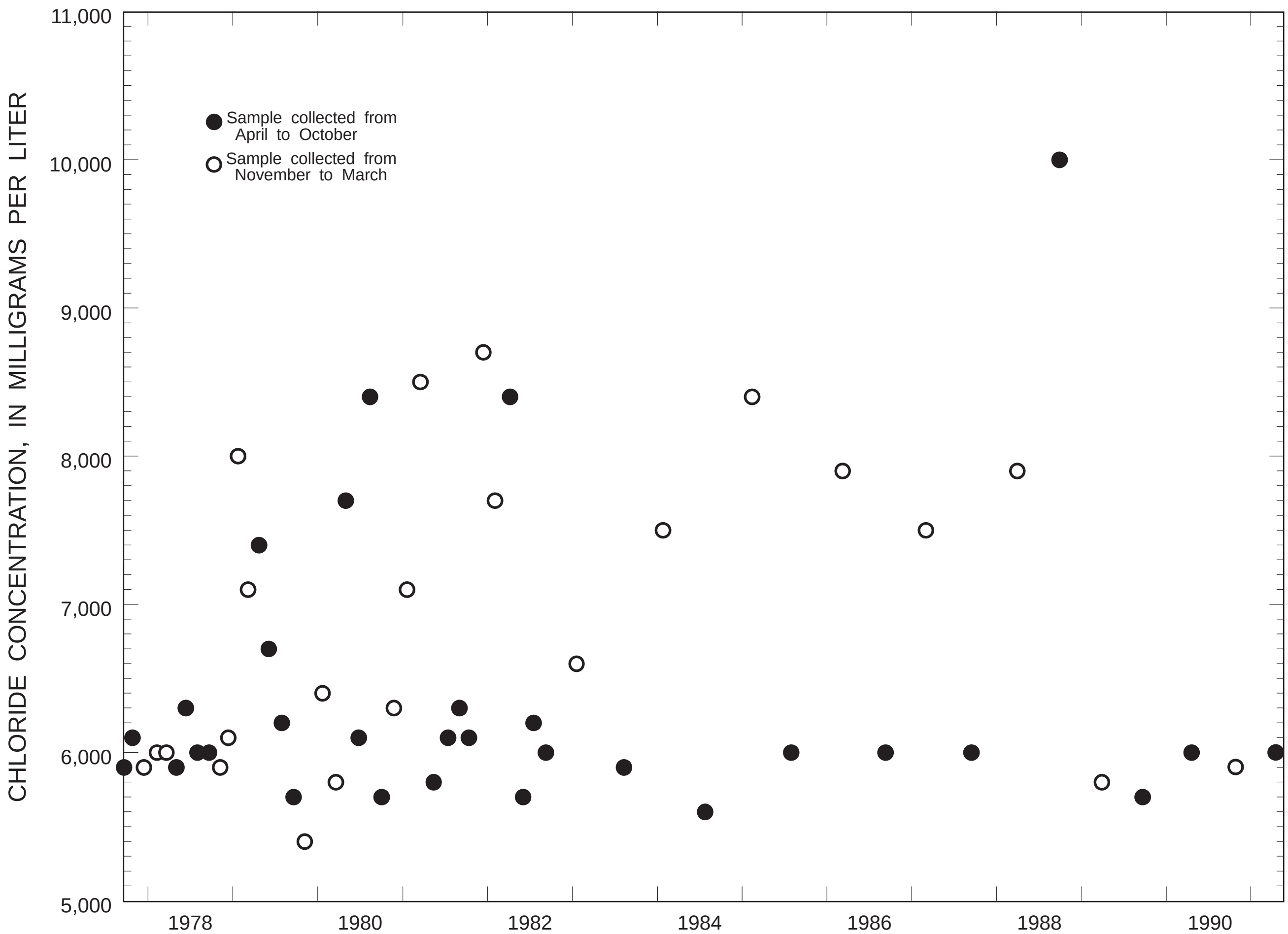

Figure 10. Chloride concentration in water from the north well at wastewater-injection site 1 north of Pensacola, Fla., September 1977-April 1991.

the quality and rate of injection of wastewater have been relatively constant, and there have been no changes in well construction at this site between 1975 and 1991.

Injected Wastewater

Wastewater samples from site 2 were collected from July 16, 1975, to June 24, 1980, by USGS personnel from a tap on the north side of the primary injection wellhead (Hull and Martin, 1982, p. 23). Personnel from the manufacturing plant also periodically analyzed wastewater for total concentrations of ammonia plus organic nitrogen and thiocyanate (table 7). The wastewater injected at site 2 is slightly acidic, with a median pH of 5.8, and has an elevated median value of specific conductance (6,000 µS/cm) and elevated median concentrations of total ammonia plus organic nitrogen (200 mg/L), sodium (1,400 mg/L), and total thiocyanate (160 mg/L). According to Hull and Martin (1982), the major components of the treated wastewater at site 2 include sodium nitrate, sodium sulfate, sodium thiocyanate, and organic compounds such as acrylonitrile.

Part of the wastewater from this plant is temporarily stored in a pond, where solids settle before the liquid is injected. The remainder of the wastewater from this plant is aerated and neutralized with sodium hydroxide (Hull and Martin, 1982, p. 3). A polymer compound is added to the wastewater to flocculate suspended solids and the wastewater is subsequently clarified by filtration through sand and coal filters to which hydrogen peroxide is added to inhibit bacterial filter-caking (Hull and Martin, 1982, p. 3, table 20).

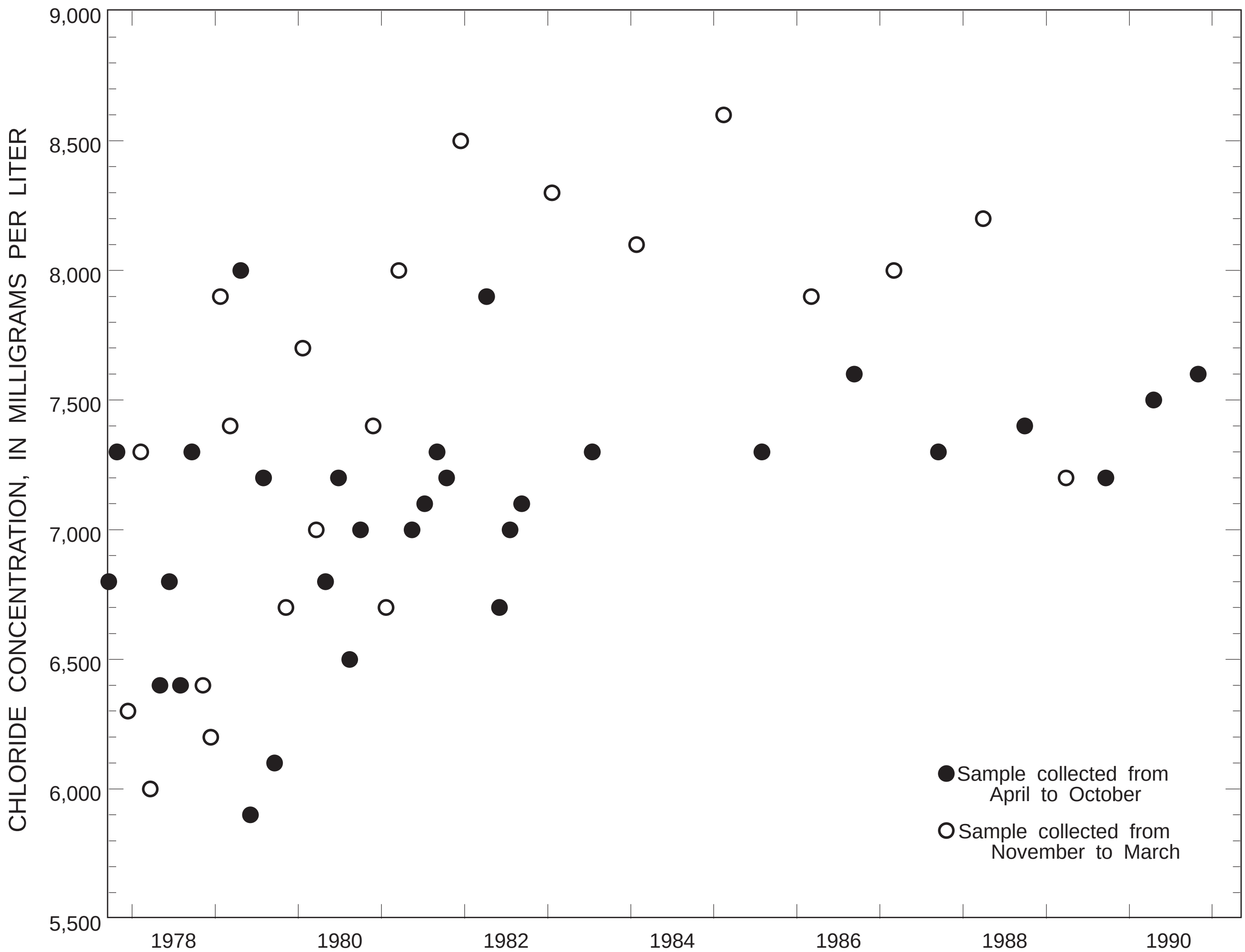

Figure 11. Chloride concentration in water from the south well at wastewater-injection site 1 north of Pensacola, Fla., September 1977-October 1990.

Lower Floridan Aquifer

Sodium and chloride are the primary dissolved constituents in water from the north monitor well, located 1.5 mi north of the injection well at site 2 (table 8). Water-quality characteristics with higher median values in water from this well than in wastewater at this site include: specific conductance, pH, calcium, magnesium, potassium, and chloride (tables 7, 8). Sodium occurs in equal median concentrations (1,400 mg/L) in water from this well and in wastewater injected at this site. Total ammonia plus organic nitrogen and total thiocyanate are the only indicator constituents with lower median values in water from the north well than in wastewater. Trend analysis indicated a significant positive trend for calcium in water from the north well (table 9). Because calcium has a lower median concentration in wastewater than in water from this well (tables 7, 8), increasing concentrations of this constituent are probably not due to mixing with wastewater. Dissolved chloride concentrations in water from this well had no significant trend (fig. 14).

Sodium, potassium, and chloride are the primary dissolved constituents in water from the standby injection well (table 8). Water sampled from this well, which is located 1,600 ft from the primary injection well, has a higher median specific conductance (15,000 μS/cm) and higher median concentrations of sodium (3,000 mg/L) and chloride (4,900 mg/L) than in water sampled from the north well (table 8). The median value of pH, and the median concentrations of calcium, magnesium, and potassium were higher in water from the standby injection well than in wastewater at site 2. In contrast, total ammonia plus organic nitrogen and total

Table 6. Summary of the indicator water-quality characteristics in water from the Upper Floridan aquifer at wastewater-injection site 1 north of Pensacola, Fla.

[pH in standard units; specific conductance in microsiemens per centimeter at 25 degrees Celsius; all other constituents in milligrams per liter. First value in column applies to April-October samples, followed by value shown in parentheses for November-March samples]

Well (period of record)	Characteristics	Number of samples	Median	Minimum	Maximum
Shallow 1	pH	42 (29)	8.6 (8.6)	8.3 (8.4)	8.8 (8.8)
(September 1977-April 1991)	Specific conductance	42 (29)	1,970 (1,970)	1,750 (1,850)	2,020 (2,000)
	Total ammonia plus organic nitrogen	31 (20)	1.5 (1.5)	1.0 (1.0)	2.0 (1.9)
	Calcium	31 (22)	2.0 (2.0)	1.0 (1.3)	2.4 (2.6)
	Magnesium	31 (22)	1.1 (1.1)	.80 (.95)	1.3 (2.5)
	Sodium	15 (13)	440 (430)	410 (400)	460 (540)
	Potassium	15 (13)	5.7 (5.7)	4.7 (4.9)	7.2 (7.1)
	Chloride	31 (23)	310 (320)	270 (300)	390 (380)
Shallow 2	pH	20 (15)	8.8 (8.9)	8.7 (8.5)	9.0 (9.0)
(March 1982-April 1991)	Specific conductance	21 (14)	2,060 (2,040)	1,990 (2,000)	2,120 (2,090)
	Total ammonia plus organic nitrogen	9 (9)	1.5 (1.4)	1.2 (1.1)	1.6 (1.6)
	Calcium	10 (9)	1.8 (1.7)	1.5 (1.6)	4.0 (2.0)
	Magnesium	10 (9)	.88 (.85)	.80 (.80)	2.7 (1.0)
	Sodium	9 (9)	440 (440)	410 (420)	460 (490)
	Potassium	10 (9)	6.1 (6.1)	4.9 (5.1)	7.0 (7.4)
	Chloride	8 (9)	400 (390)	350 (350)	400 (480)

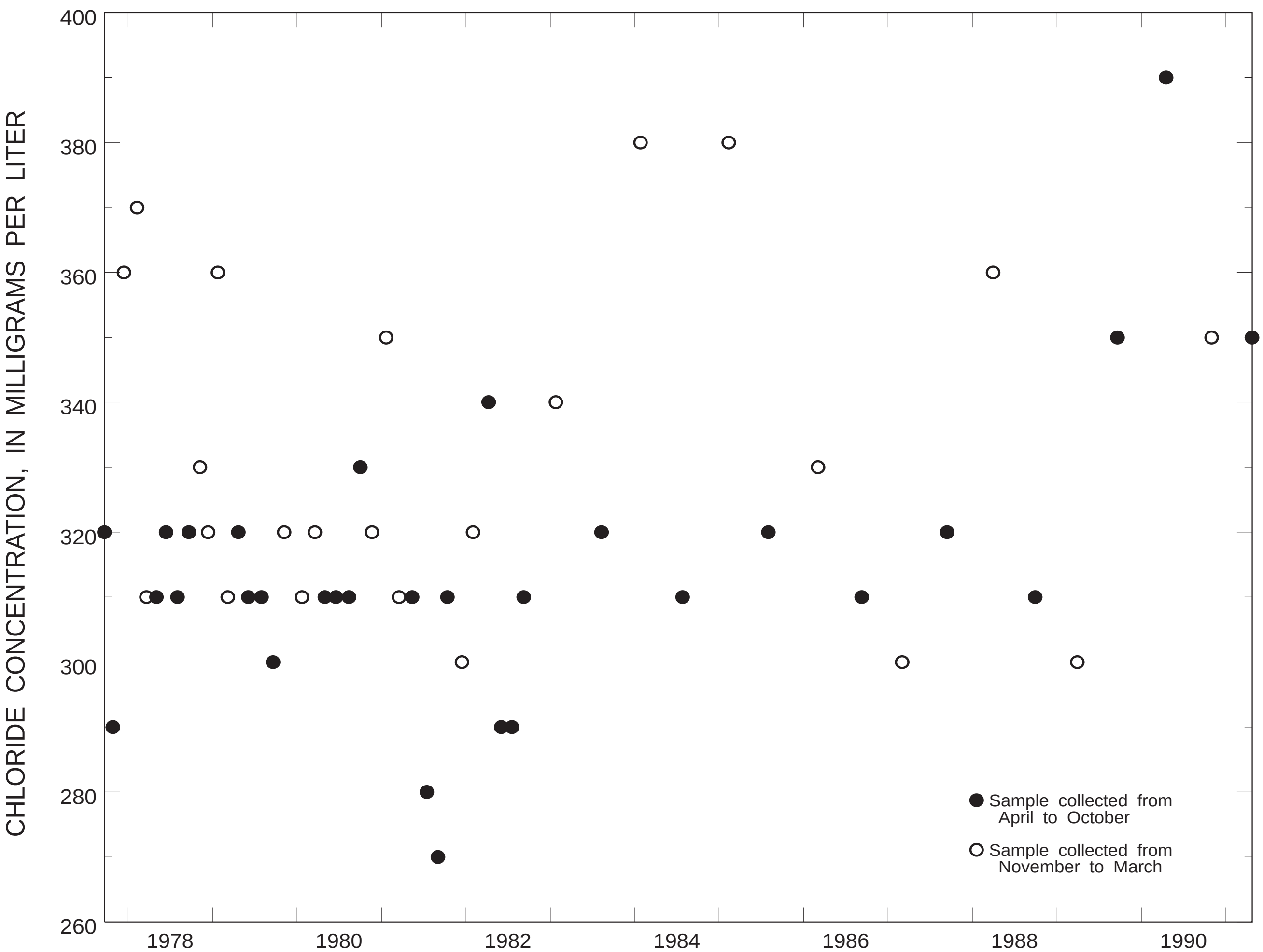

Figure 12. Chloride concentration in water from the shallow 1 well at wastewater-injection site 1 north of Pensacola, Fla., September 1977-April 1991.

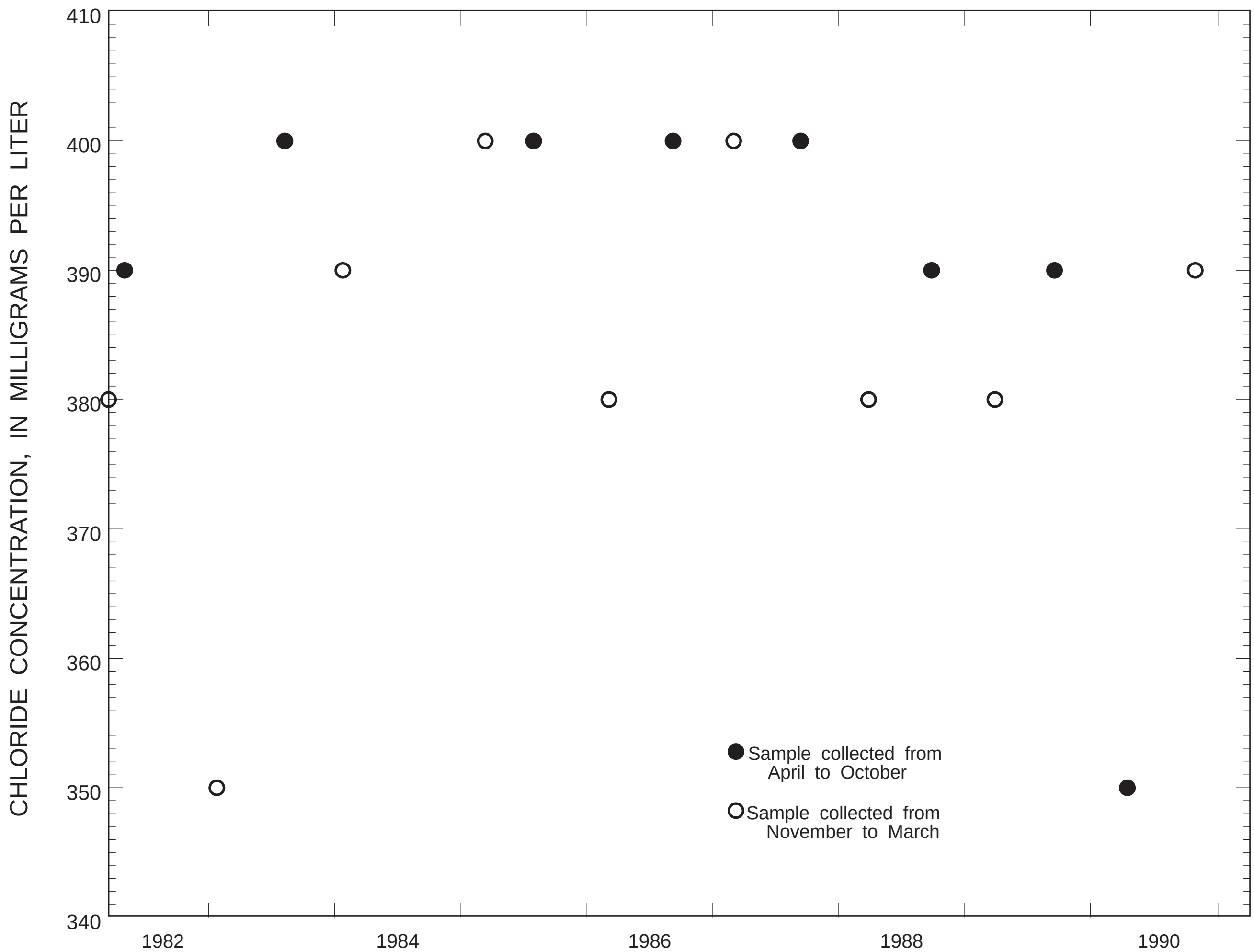

Figure 13. Chloride concentration in water from the shallow 2 well at wastewater-injection site 1 north of Pensacola, Fla., March 1982-November 1990.

thiocyanate have lower median concentrations (30 and 44 mg/L, respectively) in water from this well than in wastewater (tables 7, 8).

Trend analysis indicates significant positive trends in the concentrations of total ammonia plus organic nitrogen and total thiocyanate in water sampled from the standby injection well (table 9). Because these constituents also have higher median concentrations in wastewater than in water from this well (tables 7, 8), positive trends in the concentrations of these constituents indicate that wastewater is mixing with ground water in the Lower Floridan aquifer at this well. Significant decreasing trends were indicated for specific conductance and concentrations of calcium, magnesium, sodium, potassium, and chloride (fig. 15), all of which have lower median values in wastewater than in water from this well (table 9), also indicating that wastewater is mixing with ground water in the Lower Floridan aquifer at this well.

Water from the deep test well, located closest (1,025 ft) to the injection well of the three monitoring wells completed in the Lower Floridan aquifer at site 2, has higher median values of specific conductance, and pH and higher concentrations of calcium, magnesium, potassium, and chloride than wastewater at this site (tables 7, 8). Similar to the north well, water from this well has a median sodium concentration (1,400 mg/L) equal to that of wastewater injected at this site. Total ammonia plus organic nitrogen and total thiocyanate have lower median concentrations (120 and 130 mg/L, respectively) in water from the deep test well than in wastewater injected at this site (tables 7, 8).

Table 7. Summary of the indicator water-quality characteristics in wastewater injected at wastewater-injection site 2 southwest of Milton, Fla.

[pH in standard units; specific conductance in microsiemens per centimeter at 25 degrees Celsius;, all other constituents in milligrams per liter]

Characteristics	Number of samples	Median	Minimum	Maximum
pH[1]	12	5.8	4.5	6.8
Specific conductance[1]	12	6,000	4,600	6,600
Total ammonia plus organic nitrogen[2]	17	200	120	290
Calcium[1]	11	1.3	0.9	13
Magnesium[1]	10	1.3	0.3	2.1
Sodium[1]	10	1,400	1,000	1,600
Potassium[1]	10	0.9	0.4	1.5
Chloride[1]	10	160	98	260
Total thiocyanate[2]	17	160	34	390

[1]From U.S. Geological Survey analyses, July 1975-July 1981.

[2]From annual mean values provided by the manufacturer, 1975-91.

Trend analysis of the water-quality indicator characteristics in water from the deep test well indicates significant upward trends in pH and the concentration of thiocyanate (table 9). The median concentration of total thiocyanate is higher in wastewater injected at this site than in water from this well, so the increasing trend in the concentration of total thiocyanate indicates mixing with wastewater at this well. The positive trend in pH in water from this well appears to contradict the occurrence of wastewater mixing in the Lower Floridan aquifer at this well because wastewater is more acidic than water sampled from this well. The relatively high pH value in water from this well (7.5-8.9) could be due to hydroxyl (OH^-) ions released by denitrification of the nitrogen-rich wastewater, as reported by Ehrlich and others (1979). Trend analysis indicated

Table 8. Summary of the indicator water-quality characteristics in water from the Lower Floridan aquifer at wastewater-injection site 2 southwest of Milton, Fla.,

[pH in standard units; specific conductance in microsiemens per centimeter at 25 degrees Celsius; all other constituents in milligrams per liter; <, less than. First value in column applies to April-October samples, followed by value shown in parentheses for November-March samples]

Well (period of record)	Characteristics	Number of samples	Median	Minimum	Maximum
North	pH	100	7.7	7.5	8.5
(May 1975-April 1991)	Specific conductance	100	6,600	5,800	11,000
	Total ammonia plus organic nitrogen	74	3.0	2.5	5.5
	Calcium	79	24	19	80
	Magnesium	79	22	17	54
	Sodium	33	1,400	1,200	2,000
	Potassium	33	25	5.9	41
	Chloride	79	1,900	1,700	3,200
	Total thiocyanate	40	<0.1	<0.1	<0.1
Standby injection	pH	97	7.6	7.2	7.8
(June 1975-April 1991)	Specific conductance	97	15,000	11,800	23,500
	Total ammonia plus organic nitrogen	73	30	6.2	79
	Calcium	76	120	79	230
	Magnesium	76	100	84	190
	Sodium	31	3,000	2,700	4,500
	Potassium	30	58	41	100
	Chloride	75	4,900	3,800	8,300
	Total thiocyanate	39	44	13	47
Deep test	pH	98	8.0	7.5	8.9
(August 1975-April 1991)	Specific conductance	97	6,600	4,600	10,000
	Total ammonia plus organic nitrogen	78	120	4.0	220
	Calcium	76	18	10	65
	Magnesium	76	26	11	41
	Sodium	33	1,400	940	2,100
	Potassium	32	20	3.8	48
	Chloride	75	670	160	3,300

significant negative trends in specific conductance and concentrations of calcium, magnesium, sodium, potassium, and chloride in water from this well (fig. 16). Because these characteristics have lower median values in wastewater than in water from this well, these significant negative trends (table 9), also indicate mixing with wastewater in the Lower Floridan aquifer at this well.

Upper Floridan Aquifer

Sodium and chloride are the principal dissolved constituents in water sampled from the shallow well (table 10), the only well completed in the Upper Floridan aquifer at site 2. Because changes in purging procedures caused changes in the values of water-quality characteristics in water from this well, the concentrations and trends in water-quality characteristics were only analyzed for samples collected from July 1979 to April 1991. Potassium and pH have higher median values in water from this shallow well than in wastewater injected at site 2 (tables 7, 10). The median concentration of calcium is equal in water from this well and in wastewater at site 2 (1.3 mg/L) . The median value of specific conductance and the median concentrations of total ammonia plus organic nitrogen, magnesium, sodium, chloride, and total thiocyanate were lower in water from this well than in wastewater injected at this site (tables 7, 10).

Trend analysis indicates significant positive trends in pH and calcium concentrations (τ_k= 0.5 and 0.6, respectively) in water from the shallow well at site 2. The trend slopes of pH and calcium are very small (0.2

Table 9. Kendall tau coefficients, p-values, and trend slopes of the indicator water-quality characteristics in water from monitoring wells at wastewater-injection site 2 southwest of Milton, Fla.,

[Kendall tau values, two-sided p-values (adjusted for serial correlation), and trend slopes (as a percent of medians per year);<, less than)]

Well (period of record)	Characteristics	Kendall tau value	p-value	Trend slope
North	pH	0.2	0.4	0
(May 1975-April 1991)	Specific conductance	0.07	0.7	0
	Total ammonia plus organic nitrogen	-0.2	0.2	-0.5
	Calcium	0.5	0.005	0.9
	Magnesium	-0.2	0.4	-0.4
	Sodium	-0.3	0.2	-0.5
	Potassium	0	1.0	0
	Chloride	0.1	0.5	0
	Total thiocyanate	0	1.0	0
Standby injection	pH	-0.2	0.2	0
(June 1975-April 1991)	Specific conductance	-0.5	0.008	-1.0
	Total ammonia plus organic nitrogen	0.6	0.003	6.0
	Calcium	-0.5	0.005	-2.0
	Magnesium	-0.6	0.002	-2.0
	Sodium	-0.5	0.008	-1.0
	Potassium	-0.5	0.01	-1.0
	Chloride	-0.5	0.005	-2.0
	Total thiocyanate	0.5	0.03	5.0
Deep test	pH	0.7	<0.001	0.9
(August 1975-April 1991)	Specific conductance	-0.7	<0.001	-4.0
	Total ammonia plus organic nitrogen	0.3	0.09	4.0
	Calcium	-0.4	0.02	-5.0
	Magnesium	-0.6	0.002	-7.0
	Sodium	-0.7	<0.001	-4.0
	Potassium	-0.7	<0.001	-20.0
	Chloride	-0.7	<0.001	-10.0
	Total thiocyanate	0.8	<0.001	10.0
Shallow	pH	0.5	0.02	0.2
(July 1979-April 1991)	Specific conductance	-0.09	0.7	0
	Total ammonia plus organic nitrogen	-0.5	0.02	-2.0
	Calcium	0.6	0.009	2.0
	Magnesium	-0.03	0.9	0
	Sodium	0.07	0.8	0
	Potassium	0.4	0.07	2.0
	Chloride	-0.4	0.08	-0.6
	Total thiocyanate	0	1.0	0

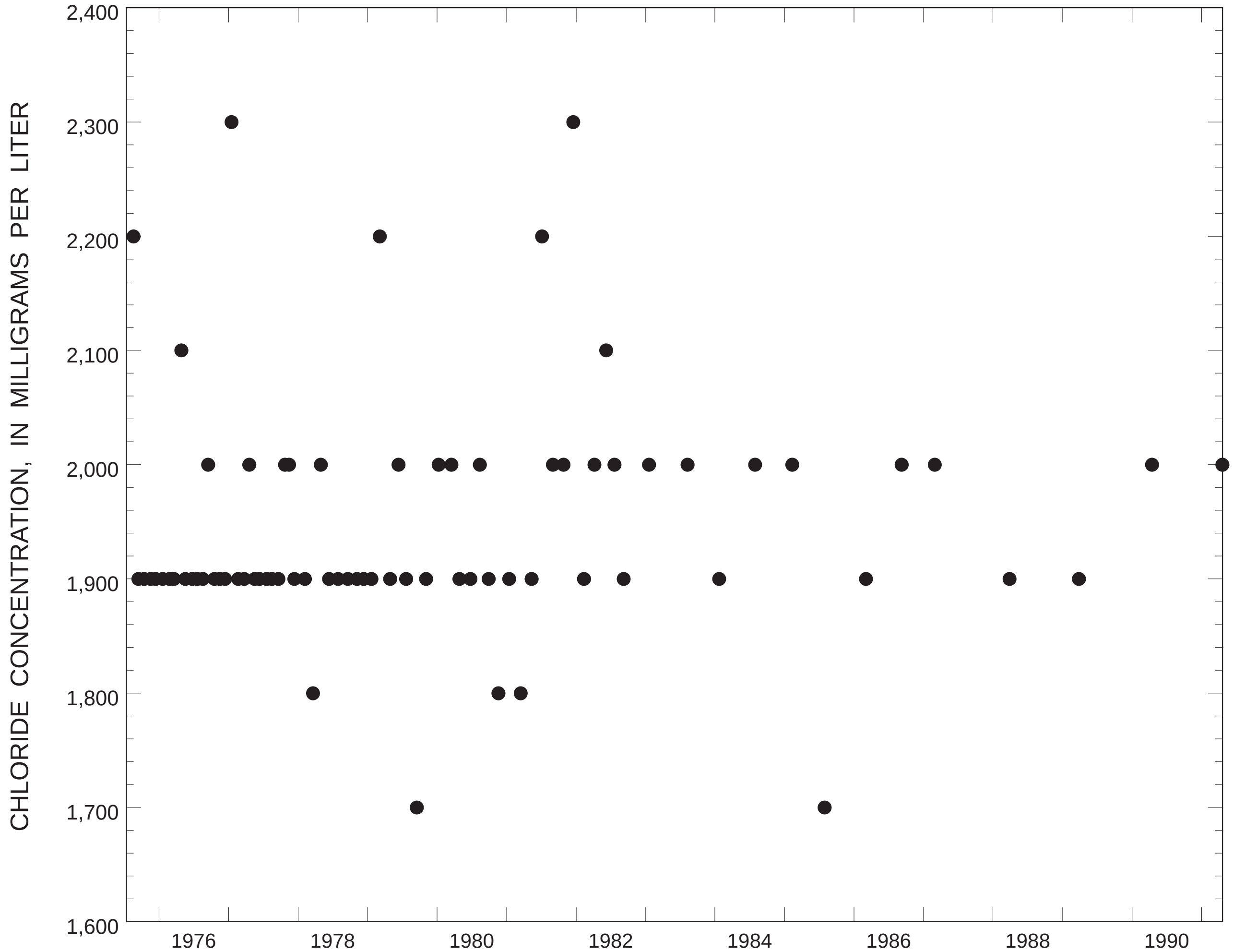

Figure 14. Chloride concentration in water from the north well at wastewater-injection site 2 southwest of Milton, Fla., July 1975-April 1991.

and 2 percent of their median values, respectively) and are unlikely to be due to upwelling of wastewater from the Lower Floridan aquifer. Trend analysis indicates a significant negative trend in concentrations of total ammonia plus organic nitrogen (τ_k = -0.5) in water sampled from this well (table 9), indicating that upward seepage of nitrogen-rich wastewater from the Lower Floridan aquifer is not occurring in the Upper Floridan aquifer at this well. Dissolved chloride concentrations in water from this well (fig. 17) had no trend.

SUMMARY

Approximately 25 billion gallons of industrial wastewater was injected into the Lower Floridan aquifer at a nylon-manufacturing plant north of Pensacola, Fla. (site 1) from July 1963 to April 1991, and about 4.4 billion gallons of industrial wastewater were injected at an acrylic fiber-manufacturing plant southwest of Milton, Fla. (site 2) from 1975 to January 1991. Water from four monitoring wells completed in the Floridan aquifer system at each site were sampled by the U.S. Geological Survey for numerous water-quality characteristics since December 1969 at site 1, and since May 1975 at site 2. This report describes the water-quality data and trends in water-quality data collected at these sites from May 1975 to April 1991 and assesses migration of injected industrial wastewater in the Lower Floridan aquifer and the occurrence of upward seepage of injected wastewater to the overlying Upper Floridan aquifer through analysis of hydrology, water quality, and trends in water quality.

Hydrologic evidence, including the large differences in hydraulic heads between the Upper and Lower Floridan aquifers, the lack of a potentiometric surface mound in the Upper Floridan aquifer corresponding to that in the Lower Floridan aquifer, and the great thickness of the Bucatunna Clay separating these aquifers, indicates that there is no hydraulic connection between these two aquifers at sites 1 or 2, and that upward leakage of industrial wastewater to overlying aquifers is unlikely at this site. Trend analysis of selected indicator water-quality characteristics was used in the report to evaluate the migration of injected industrial wastewater at these sites.

Trend analysis indicates no significant trend in selected indicator water-quality characteristics (pH, specific conductance, and concentrations of total ammonia plus organic nitrogen, total thiocyanate (site 2 only), calcium, magnesium, sodium, potassium, and chloride) in water sampled from the north well, completed in the Lower Floridan aquifer 1.9 miles northwest of the injection wells at site 1. This lack of trend indicates that ground water in the Lower Floridan aquifer has probably not been affected by injected wastewater at this well. Significant trends in values of specific conductance, and in concentrations of total ammonia plus organic nitrogen, calcium, and magnesium in water sampled from the south monitor well, located 1.5 mi south of the injection wells at site 1, indicate that ground water in the Lower Floridan aquifer at this well may be mixed with wastewater. The significant upward trend in the concentration of total ammonia plus organic nitrogen in water from this well and the magnitude of the trend (6 percent of its median value per year) suggest that the nitrogen-rich wastewater has affected the quality of water sampled from this well.

In water sampled from shallow wells 1 and 2, completed in the Upper Floridan aquifer at site 1, pH was the only indicator water-quality characteristic with a significant positive trend. However, the trend in pH is

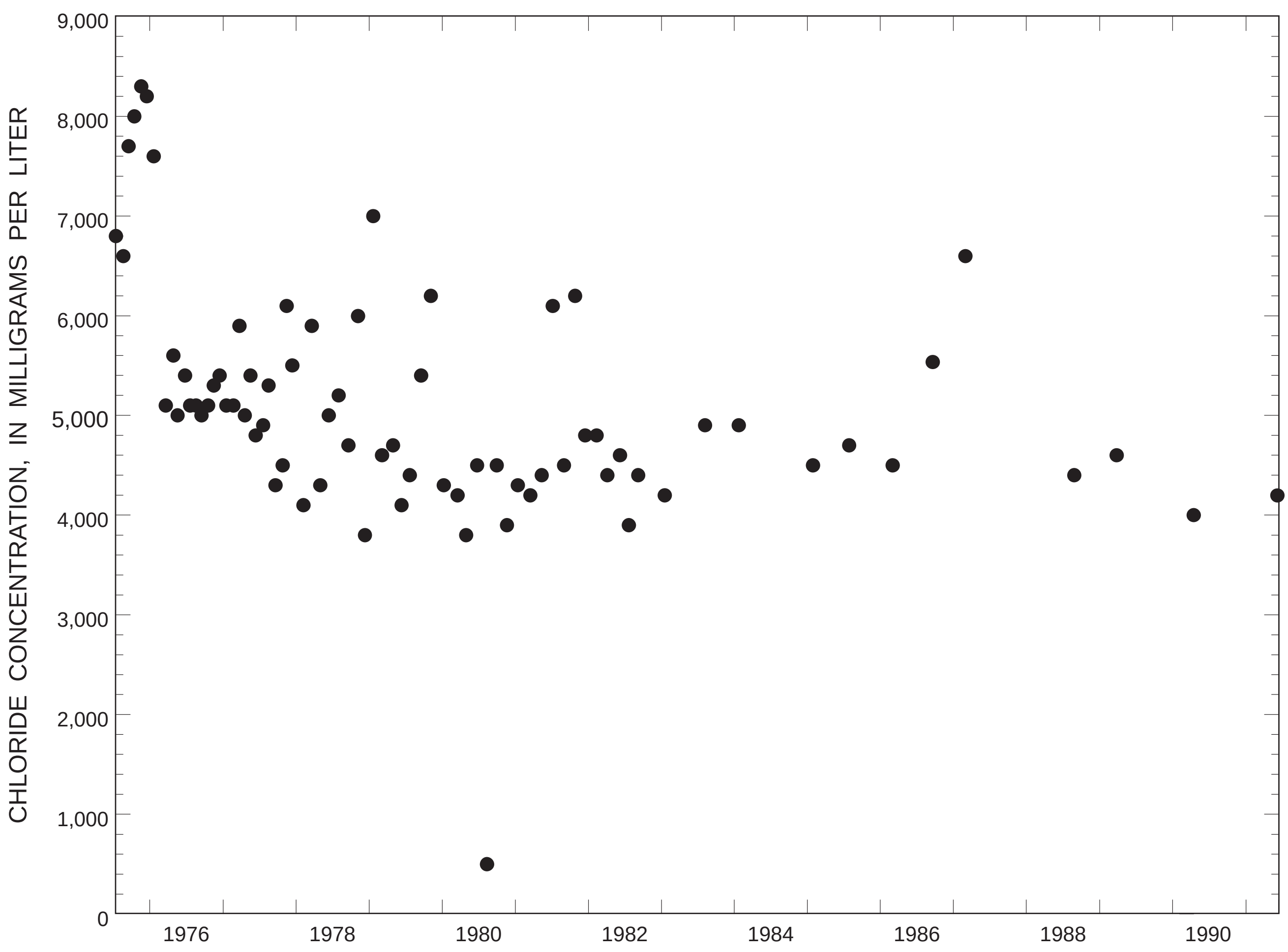

Figure 15. Chloride concentration in water from the standby injection well at site 2 southwest of Milton, Fla., July 1975-April 1991.

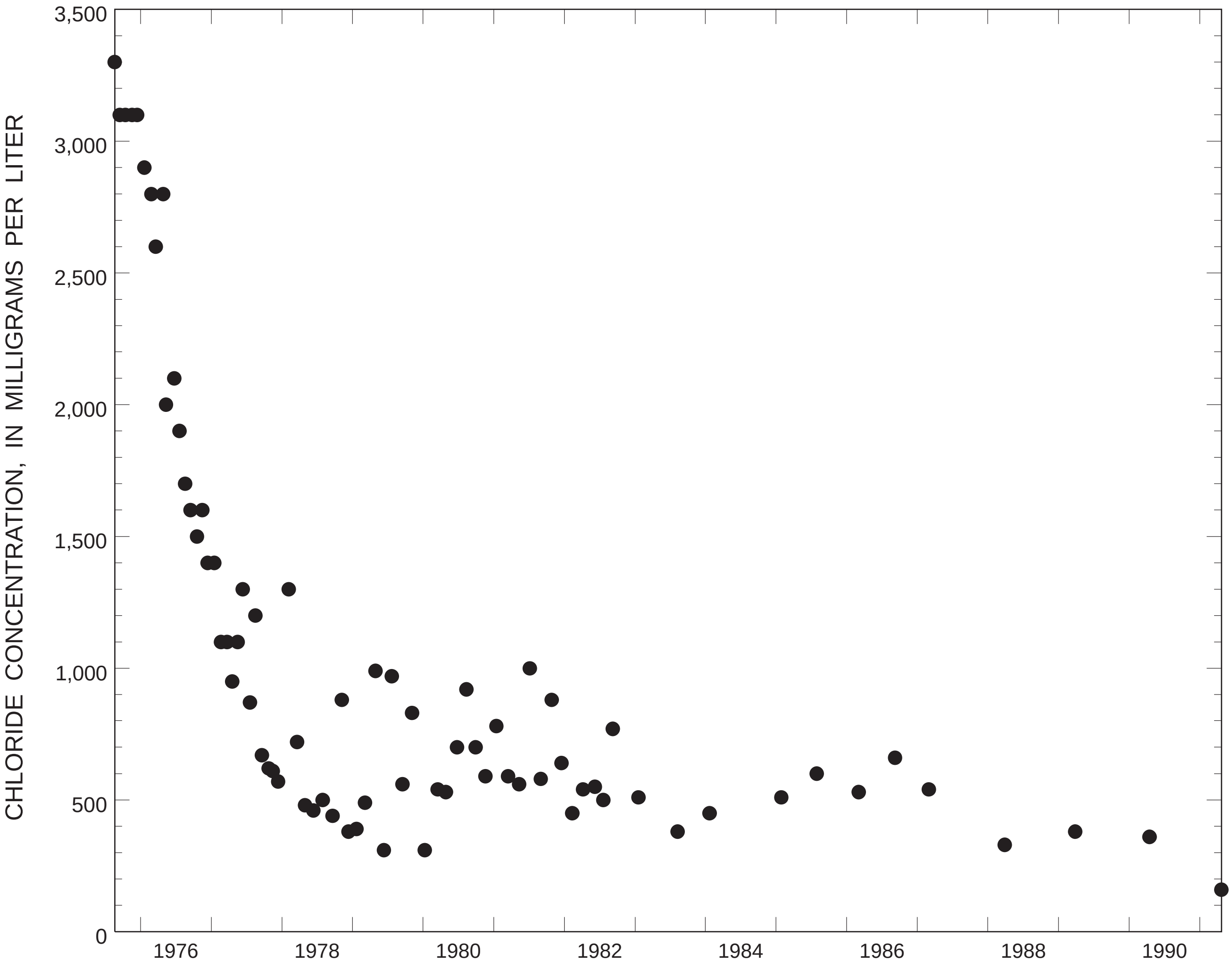

Figure 16. Chloride concentration in water from the deep test well at site 2 southwest of Milton, Fla., August 1975-April 1991.

small and probably unrelated to upwelling of acidic wastewater from the Lower Floridan aquifer. Trend analysis also indicates a significant negative trend in concentrations of magnesium in water from shallow well 1 and in concentrations of chloride in water from shallow well 2 (in samples collected from April to October from both wells). The small magnitude of these trends (-1 percent and -0.5 percent of the median values of these constituents, respectively) and the seasonality of these trends imply that they are probably unrelated to upward seepage of wastewater from the Lower Floridan aquifer.

At injection site 2, trend analysis indicated a significant positive trend only in calcium concentrations in water from the north well, located 1.5 miles north of the injection well. The low magnitude of this trend (less than 1 percent of the median value per year) and the lack of significant trends in the other indicator characteristics analyzed in water from this well indicate that the quality of water in the Lower Floridan aquifer at this well has probably not been affected by wastewater injection at this site. Trend analysis indicated significant positive trends in pH and in total concentrations of ammonia plus organic nitrogen and thiocyanate and significant negative trends in specific conductance, and in concentrations of magnesium, sodium, potassium, and chloride in water sampled from the standby injection well, located 1,600 ft from the injection well at site 2. Because total ammonia plus organic nitrogen and thiocyanate occur in higher median concentrations in wastewater than in water from this well, the significant positive trends in these constituents indicate that wastewater is affecting water quality in the Lower Floridan aquifer at this well. The negative trends in the other constituents, which occur in lower concentrations in injected wastewater at this site, also suggest that wastewater has mixed with ground water at this well. Significant positive trends in the concentration of total thiocyanate and pH and

Table 10. Summary of the indicator water-quality characteristics in water from the Upper Floridan aquifer at wastewater-injection site 2 southwest of Milton, Fla.,

[pH in standard units; specific conductance in microsiemens per centimeter at 25 degrees Celsius; all other constituents in milligrams per liter; <, less than

Well (period of record)	Characteristics	Number of samples	Median	Minimum	Maximum
Shallow	pH	49	8.8	8.4	9.0
(July 1979-April 1991)	Specific conductance	49	1,300	1,300	1,400
	Total ammonia plus organic nitrogen	25	1.3	1.0	1.8
	Calcium	28	1.3	1.0	1.4
	Magnesium	28	0.60	0.20	0.80
	Sodium	17	320	290	360
	Potassium	17	4.9	4.0	6.1
	Chloride	28	84	73	110
	Total thiocyanate	28	<0.1	<0.01	<0.1

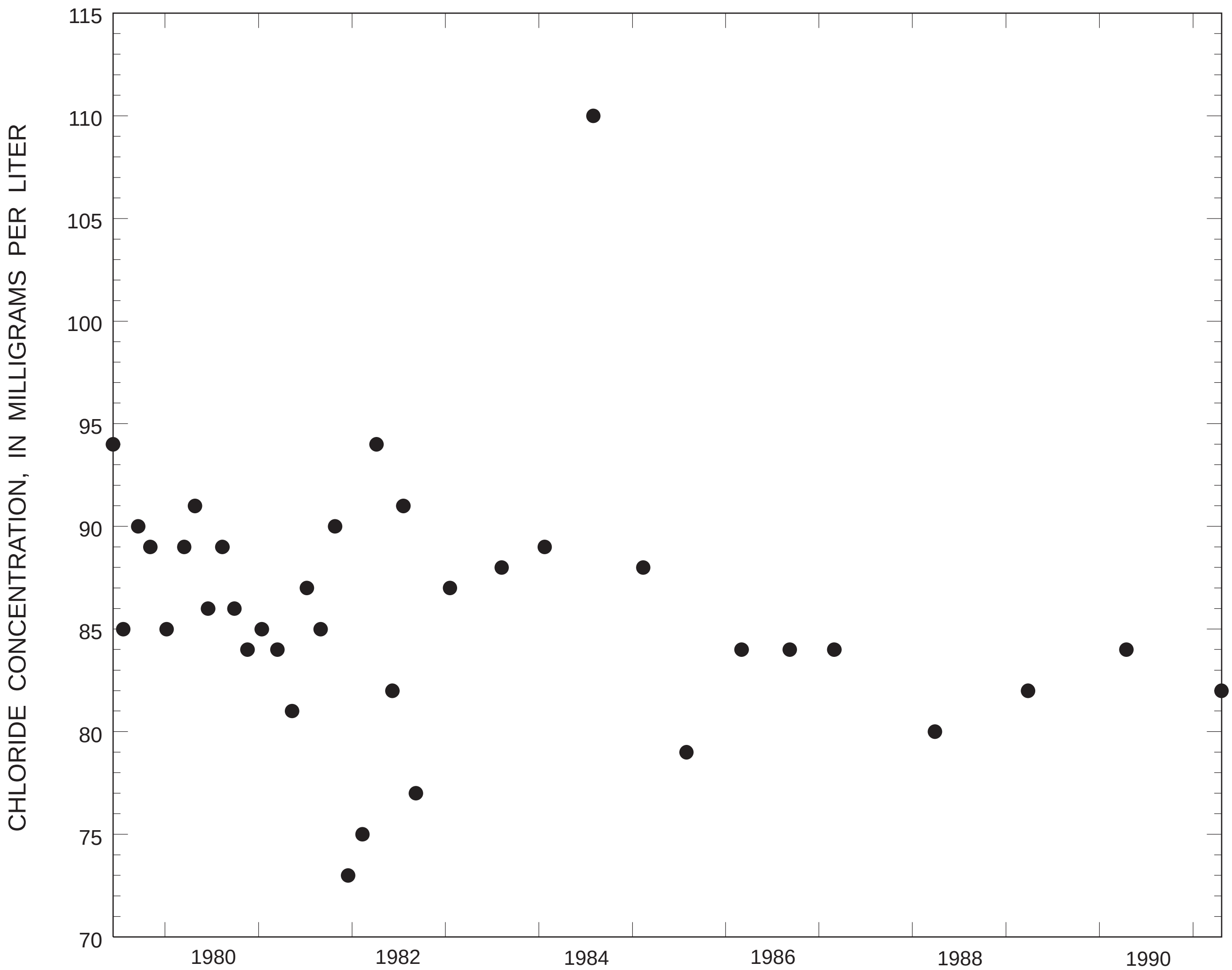

Figure 17. Chloride concentration in water from the shallow monitoring well at site 2 southwest of Milton, Fla., June 1979-April 1991.

significant negative trends in specific conductance, concentrations of calcium, magnesium, sodium, potassium, and chloride occurred in water from the deep test well, located 1,025 ft from the injection well at site 2. These trends indicate mixing with wastewater in the Lower Floridan aquifer at this well. The lack of a significant positive trend in concentration of total ammonia plus organic nitrogen and the positive trend in pH in water from this well may be due to denitrification of the nitrogen-rich wastewater in the Lower Floridan aquifer.

Trend analysis indicated significant positive trends in pH and in the concentration of calcium, and a significant negative trend in the concentration of total ammonia plus organic nitrogen in water from the shallow well, completed in the Upper Floridan aquifer at site 2. The low magnitudes of the trends in pH and in the concentration of calcium in water from this well (0.2 and 2 percent of their median values per year) indicate that upward seepage of wastewater from the Lower Floridan aquifer is not occurring at this well. The negative trend in the concentration of total ammonia plus organic nitrogen in water sampled from this well also indicates that nitrogen-rich wastewater has not seeped upward into the Upper Floridan aquifer at this well.

Trends of the selected indicator water-quality constituents generally implied that ground-water quality in the Lower Floridan aquifer was affected by injected wastewater in water from wells located within 1/2 mi of the injection wells at these sites and in wells completed in this aquifer at greater distances south, the regional downgradient direction. Trend analysis indicated that the quality of water from wells completed in the Upper Floridan aquifer at these sites has not been affected by the injected wastewater.

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