INTRODUCTION

The Floridan aquifer is one of the principal sources of water supply in St. Johns County, Florida (fig. 1). It is composed of a series of permeable water-bearing limestones and dolomites that range in altitude from 100 feet below the National Geodetic Vertical Datum of 1929 (mean sea level) in the southwest part of the county to more than 300 feet below the datum in the northeast. Throughout the county, water in the aquifer is confined and, in much of the county, wells that tap the aquifer will flow at land surface. In some parts of the county, wells tapping the aquifer flow naturally at rates as great as 1,500 gallons per minute.

Variations in water quality occur both areally and with depth in the aquifer. In the northern part of the county, the upper part of the aquifer yields water suitable for domestic use. Most wells in this area penetrate less than 300 feet of the aquifer. Below this depth the aquifer contains water with high chloride concentrations. In much of the coastal region and southern part of the county, water in the upper part of the Floridan aquifer is not suitable for domestic or public supply. In these areas, potable water is usually obtained from wells drilled into the surficial aquifer at depths of 100 feet or less below land surface. These wells yield much less water than wells tapping the upper part of the Floridan aquifer.

Water supplies available from the surficial aquifer are probably adequate to meet short-term increases in demand, but future urbanization and an expanding tourist industry in the coastal region will require additional sources of potable water. In the future, it may be necessary to utilize a mixture of water from the Floridan aquifer and water from the surficial aquifer to insure adequate water supplies for the area. A knowledge of the quality of water available from the Floridan aquifer in St. Johns County can aid in evaluating the potential of the aquifer as a source of supply.

The purpose of this report is to show the distribution of chloride concentration and total hardness concentration in water obtained from the upper 300 feet of the Floridan aquifer in St. Johns County. The maps showing chloride and total hardness concentrations were constructed from data collected by the U.S. Geological Survey and the St. Johns River Water Management District from 1976 to 1979 and reflect the highest values observed during that period. A brief description of the hydrogeology of the county is also presented.

This investigation was part of a cooperative water-resource program between St. Johns County and the U.S. Geological Survey. The assistance provided by the St. Johns County Commission and members of their staff is greatly appreciated. Particular acknowledgment is expressed to J. L. Harrington, St. Johns County Administrator, and to Allen Nease, Planning Director, St. Johns County. The authors also wish to express appreciation to the St. Johns River Water Management District, especially James Frazee, hydrologist, for furnishing valuable data.

HYDROGEOLOGY

A detailed discussion of the hydrogeology of St. Johns County can be found in Bermes and others (1963). A summary of their description is given in table 1.

Surficial deposits (Holocene to Pliocene) comprise the surficial aquifer in St. Johns County. They consist primarily of interbedded lenses of sand, shell, and clay, and yield moderate amounts of water (up to 40 gal/min from 2-inch wells). In general, water in the surficial aquifer is unconfined but semiconfined conditions occur in some areas.

The Hawthorn Formation (Miocene) consists of phosphatic sandy clay and marl interbedded with lenses of phosphorite pebbles, phosphatic sand, and phosphatic sandy limestone. The sand and limestone lenses of this formation yield small to moderate amounts of water (up to 40 gal/min from 2-inch wells) under artesian pressure. The clays and marls of the Hawthorn Formation separate the surficial aquifer from the deeper Floridan aquifer and confine the water in the Floridan aquifer under artesian pressure.

The Ocala, Avon Park, Lake City, and Oldsmar Limestones of Eocene age compose the Floridan aquifer. The Ocala Limestone, a sequence of chalky and granular limestones, yields large quantities of water under artesian pressure. It is the principal source of ground water in most of northeast Florida. The Avon Park and Lake City Limestones consist of alternating beds of permeable water-bearing limestone and dolomite separated by beds of relatively impermeable limestone and dolomite. This report treats the upper 300 feet of the Floridan aquifer—the Ocala Limestone and the upper part of the Avon Park Limestone.

POTENTIOMETRIC SURFACE

The potentiometric surface of an aquifer is an imaginary surface to which water will rise in tightly cased wells penetrating the aquifer. It shows, in a general way, the distribution of pressure head in the aquifer. In figure 2, the potentiometric surface of the Floridan aquifer is depicted by a series of contour lines connecting points of equal water-level altitude above the NGVD of 1929. Water in the aquifer tends to move perpendicular to the contour lines from higher water levels toward lower water levels.

Fluctuations in the potentiometric surface of the Floridan aquifer are caused principally by rainfall in the aquifer recharge areas and pumping of water for agricultural use. In general, the highest water levels occur from June to September during periods of high rainfall and the lowest water levels occur from March to May during periods of low rainfall. Seasonal fluctuations in St. Johns County are usually less than 4 feet. Fluctuations are greater in parts of the county influenced by heavy pumping of the aquifer for agricultural irrigation, particularly during the dry season. Water-level fluctuations of as much as 16 feet have occurred in wells near Hastings (Frazee and McClaugherty, 1980, p. 37).

The potentiometric surface map was constructed from data collected in May 1979 when water levels were expected to be at or near their lowest for the year. The most conspicuous features on the map are two large depressions depicted in the northern part of the county. The depression along the St. Johns River in northwest St. Johns County is the result of natural upward leakage from the aquifer. Green Cove Springs, to the west of this area approximately 2 miles from the county line, and perhaps other undetected springs that discharge under the St. Johns River, are related to this depression (Bentley, 1977, p. 27). The depression in northeast St. Johns County, a rapidly developing area, is the result of heavy pumpage for golf-course irrigation.

Two additional areas of discharge are indicated by the slope of the potentiometric surface in the southern half of the county. The slope toward the southeast coast is the result of submarine discharge of a large spring 2.5 miles east of Crescent Beach (Stringfield, 1966, p. 170). Smaller, undetected springs and seeps may also discharge in this area. The slope in the southwest part of the county is influenced by heavy pumpage for agricultural irrigation. During periods of greatest pumpage, a cone of depression forms in this area (Munch and others, 1979, p. 42).

CHLORIDE

Chloride is a common constituent of natural waters. Naturally occurring concentrations of chloride range from about 0.1 mg/L (milligrams per liter) in arctic snow to as much as 150,000 mg/L in some brines (Davis and DeWiest, 1966, p. 110). Seawater has a chloride concentration of about 19,000 mg/L. Relatively low concentrations occur in most shallow ground waters in inland areas.

The sources of chloride in ground water include the solution of minerals in rocks of the aquifers and confining beds, mixing with connate water (water trapped in the rocks during their formation), intrusion of seawater, and pollution. Small amounts are also contributed by rainfall and surface materials. Near the coast, rainwater generally contains between 3 and 6 mg/L of chloride (Davis and DeWiest, 1966, p. 110).

The chloride concentrations of water from the upper 300 feet of the Floridan aquifer in St. Johns County range from less than 10 mg/L in the northwest part of the county to more than 1,000 mg/L in the southeast coastal area and extreme southwest (fig. 3). In the northern part of the county, water from the upper 300 feet of the Floridan aquifer has a chloride concentration of less than 50 mg/L and potable water containing less than 250 mg/L chloride may possibly extend to 1,250 feet below land surface (Klein, 1971). In much of the southern part of the county, however, water in the aquifer is not potable.

In the southeast part of the county, saline water probably entered the aquifer during a high stand of the sea during the Pleistocene Epoch and has not been flushed from the aquifer by freshwater (Stringfield, 1966, p. 170). The discharge of the submarine spring 2.5 miles east of Crescent Beach may induce the continuous upward migration of saline water from deep zones within the aquifer (Bermes and others, 1963, p. 88). In the southwest part of the county, Munch and others (1979, p. 76) reported that the high chloride concentrations were the result of upward movement of deeper, more saline water. Agricultural irrigation has required heavy pumpage, which has reduced the artesian pressure in the upper zones of the aquifer and induced this upward movement.

The National Secondary Drinking Water Regulations recommend that the chloride concentration of public water supplies not exceed 250 mg/L if sources of lower concentration are available. This standard is based upon taste considerations and not health hazards (National Academy of Sciences and National Academy of Engineering, 1974). Table 2 gives recommended limits of chloride concentration in water used for some industrial and agricultural purposes.

TOTAL HARDNESS

Water hardness is due to the presence of polyvalent cations in solution. Calcium and magnesium predominate and cause hardness in most water. Other cations, such as iron and strontium, also contribute to hardness when they are present but they usually occur in insignificant quantities. The total hardness is defined as the sum of all constituents which produce hardness expressed as an equivalent concentration of calcium carbonate ($CaCO_3$). Hardness in ground water is usually the result of the dissolution of $CaCO_3$ (calcite) in limestone and $CaSO_4$ (gypsum).

Many diverse scales have been created to classify "hard" and "soft" waters. The classifications used by the U.S. Geological Survey (Durfor and Becker, 1964) and the U.S. Environmental Protection Agency (1976) are given below:

Description	*Total hardness as $CaCO_3$ (in milligrams per liter)*	
	USGS	*EPA*
Soft	0–60	0–75
Moderately hard	60–120	75–150
Hard	120–180	150–300
Very hard	Greater than 180	Greater than 300

Detrimental effects of hard water include excessive soap consumption, the formation of scum and curds, yellowing of fabrics, toughening of vegetables cooked in hard water, and the formation of scale in boilers, hot water heaters, and cooking utensils. Soft water exhibits increased corrosiveness, and its use as drinking water may present hazards to human health (National Academy of Sciences and National Academy of Engineering, 1974). Present information is inadequate to balance the desirability of softer water for many domestic uses against the possible health hazards; therefore, no limits were recommended in the National Primary or Secondary Drinking Water Regulations (U.S. Environmental Protection Agency, 1977). Recommended limits of total hardness concentration in water used for some industrial purposes are given in table 2.

The total hardness of water from the upper 300 feet of the Floridan aquifer in St. Johns County ranges from 110 mg/L in the northwest part of the county to 1,700 mg/L in the southeast coastal area (fig. 4). The general distribution of total hardness is similar to the chloride distribution suggesting that, in much of the county, the high total hardness concentrations are due to the presence of saline water in the aquifer. An exception occurs in the western part of the county along the St. Johns River. The northern part of this area generally corresponds to a depression in the potentiometric surface resulting from natural discharge (see fig. 2). The high total hardness concentrations could be associated with structural features such as faults and joints which could allow very hard water from deeper zones containing gypsum to move upward (Fairchild, 1977, p. 48) or may indicate the presence of gypsum beds in the upper part of the aquifer (Bermes and others, 1963, p. 83).

VARIATIONS IN WATER QUALITY

Seasonal variations in the chloride and total hardness concentrations are not shown by the maps but do occur in St. Johns County. In general, concentrations of most chemical constituents show an inverse relationship to seasonal fluctuations in the potentiometric surface. The higher water levels from June to September usually correspond to lower concentrations and the lower water levels from March to May usually correspond to higher concentrations (Bermes and others, 1963, p. 88). In most of the county, these variations are small, but large variations have been observed in the coastal area south of St. Augustine and in the farming areas in the southwest part of the county. The large seasonal variations in concentrations in the southwest are related to the heavy pumpage in this area during the dry season (Munch and others, 1979, p. 43). Wells for which data were collected in 1979 are shown in figures 3 and 4 and listed with their concentrations in table 3.

SUMMARY AND CONCLUSIONS

In much of St. Johns County, high concentrations of chloride and total hardness in the upper part of the Floridan aquifer indicate the presence of saline water. Along the southeast coast, saline water probably entered the aquifer during a high stand of the sea during Pleistocene time and has not been flushed from the aquifer by freshwater. The reduction in artesian pressure in this area resulting from natural discharge may induce the continual upward migration of saline water from deeper zones. In the southwest part of the county, heavy pumping of the upper part of the Floridan aquifer for agricultural irrigation has caused saline water to move upward. Total hardness distribution is similar to chloride distribution and may indicate the presence of saline water, but high hardness concentrations along the St. Johns River do not appear to be caused by the presence of saline water. These concentrations could be structurally controlled or may indicate the presence of gypsum evaporite beds. In much of the northern half of the county, the upper 300 feet of the Floridan aquifer yields water suitable for domestic and some industrial uses.

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CONVERSION FACTORS

For the use of those readers who prefer to use metric units rather than inch-pound units, the following conversion table is provided.

Multiply inch-pound unit	*By*	*To obtain metric unit*
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
gallon per minute (gal/min)	0.06309	liter per second (L/s)

National Geodetic Vertical Datum of 1929 (NGVD of 1929).—A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level. The datum was derived from the average sea level during many years at 26 tide stations along the Atlantic, Gulf of Mexico, and Pacific Coasts.

Table 1.—Generalized hydrogeology of St. Johns County

Geologic age		Stratigraphic unit	Thickness (ft)	Hydrogeologic unit
Period	Epoch			
Quaternary	Holocene to Pliocene	Surficial deposits	20–120	Surficial aquifer
Tertiary	Miocene	Hawthorn Formation	50–115	Confining unit
	Late Eocene	Ocala Limestone	120–200	Floridan aquifer
	Middle Eocene	Avon Park Limestone	170–225	
		Lake City Limestone	230	
	Early Eocene	Oldsmar Limestone	700	

Table 2.—Recommended limits of chloride and total hardness concentrations in water for selected industrial and agricultural uses

[Modified from McKee and Wolf, 1963. Constituents shown in milligrams per liter]

Use	Total hardness as $CaCO_3$	Chloride
Brewing, general	200–300	60–100
Carbonated beverages	200–250	250
Dairy industry	180	30
Food-equipment washing	10	250
Pulp and paper processing:		
Groundwood pulp	200	75
Soda and sulfate pulps	100	75
Kraft paper, bleached	100	200
Kraft paper, unbleached	200	200
Fine papers	100	—
Textile manufacture	0–50	100
Irrigation	—	100
Stock watering	—	1,500

Table 3.—Chloride and total hardness concentrations in water from wells penetrating the upper 300 feet of the Floridan aquifer in St. Johns County, May and September 1979

[Constituents shown in milligrams per liter]

Well No.	Chloride concentration May	Chloride concentration Sept.	Total hardness concentration as $CaCO_3$ May	Total hardness concentration as $CaCO_3$ Sept.
1	20	20	300	280
2	20	20	370	360
3	90	95	340	310
4	30	30	730	670
5	250	270	420	480
6	130	130	530	500
7	130	120	1,100	980
8	910	960	750	460
9	1,700	850	1,100	770
10	3,300	3,300	1,700	1,700

Figure 1.—Location of St. Johns County

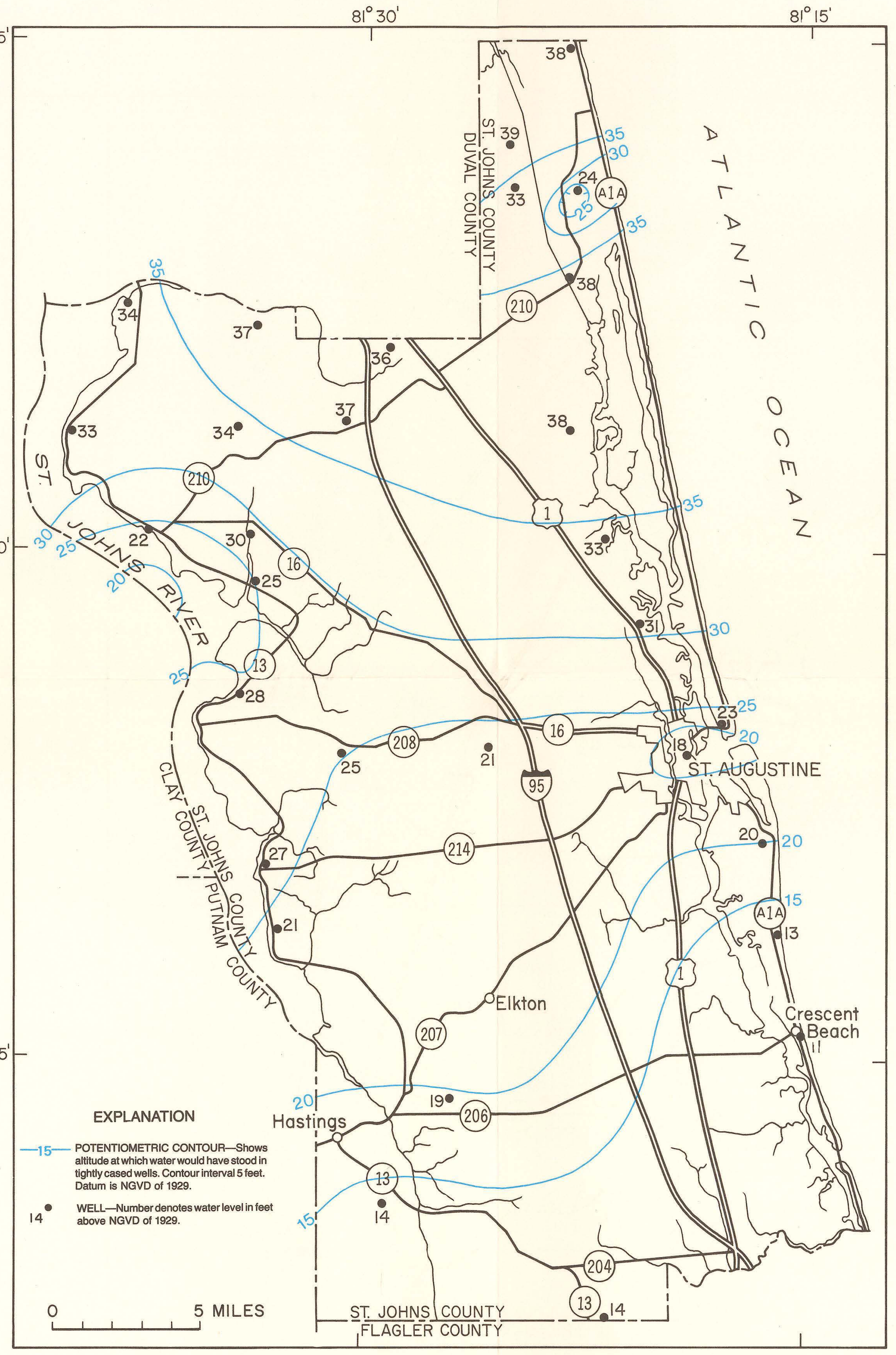

Figure 2.—Potentiometric surface of the Floridan aquifer, May 1979 (modified from Laughlin and others, 1980).

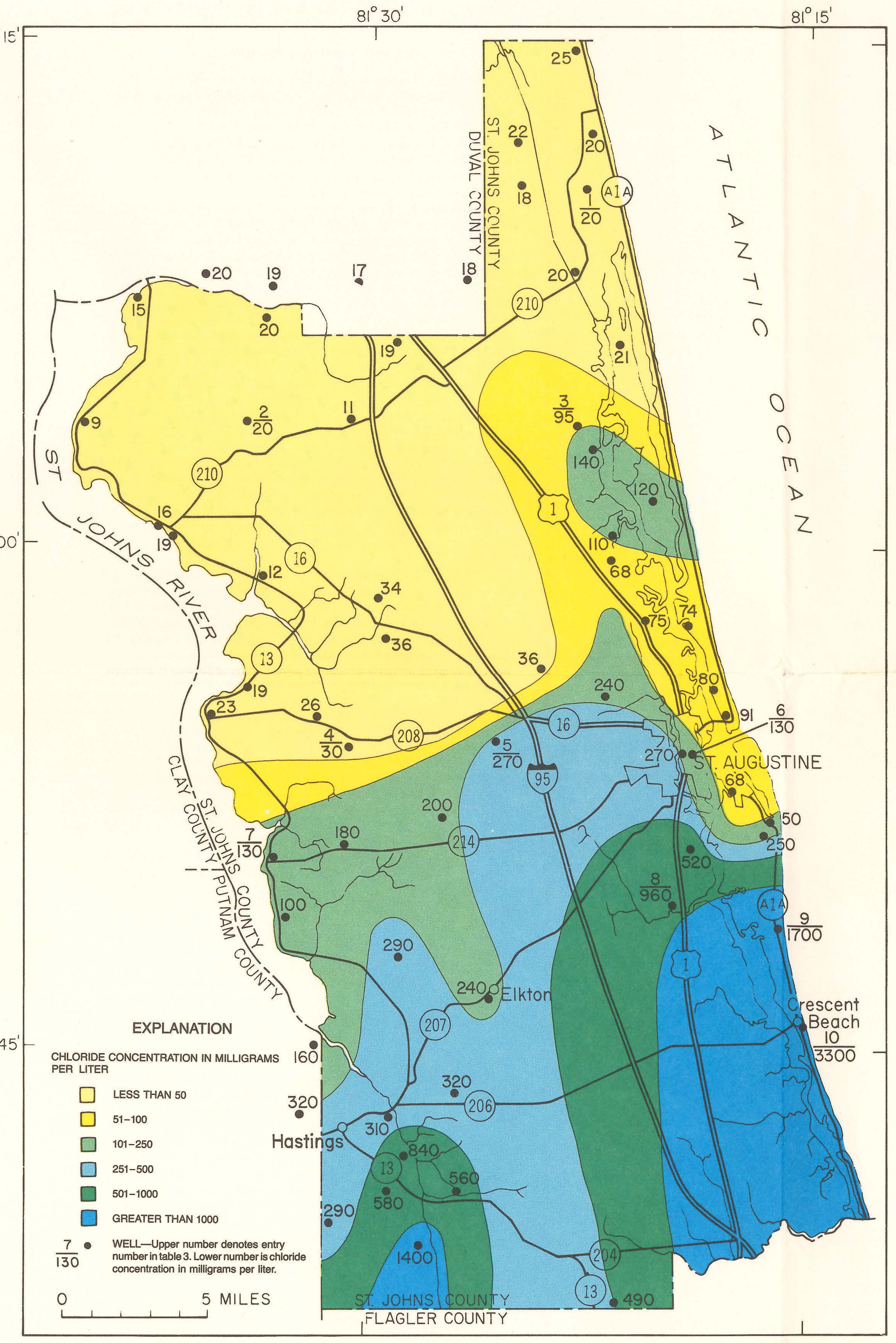

Figure 3.—Chloride concentration of water from the upper 300 feet of the Floridan aquifer.

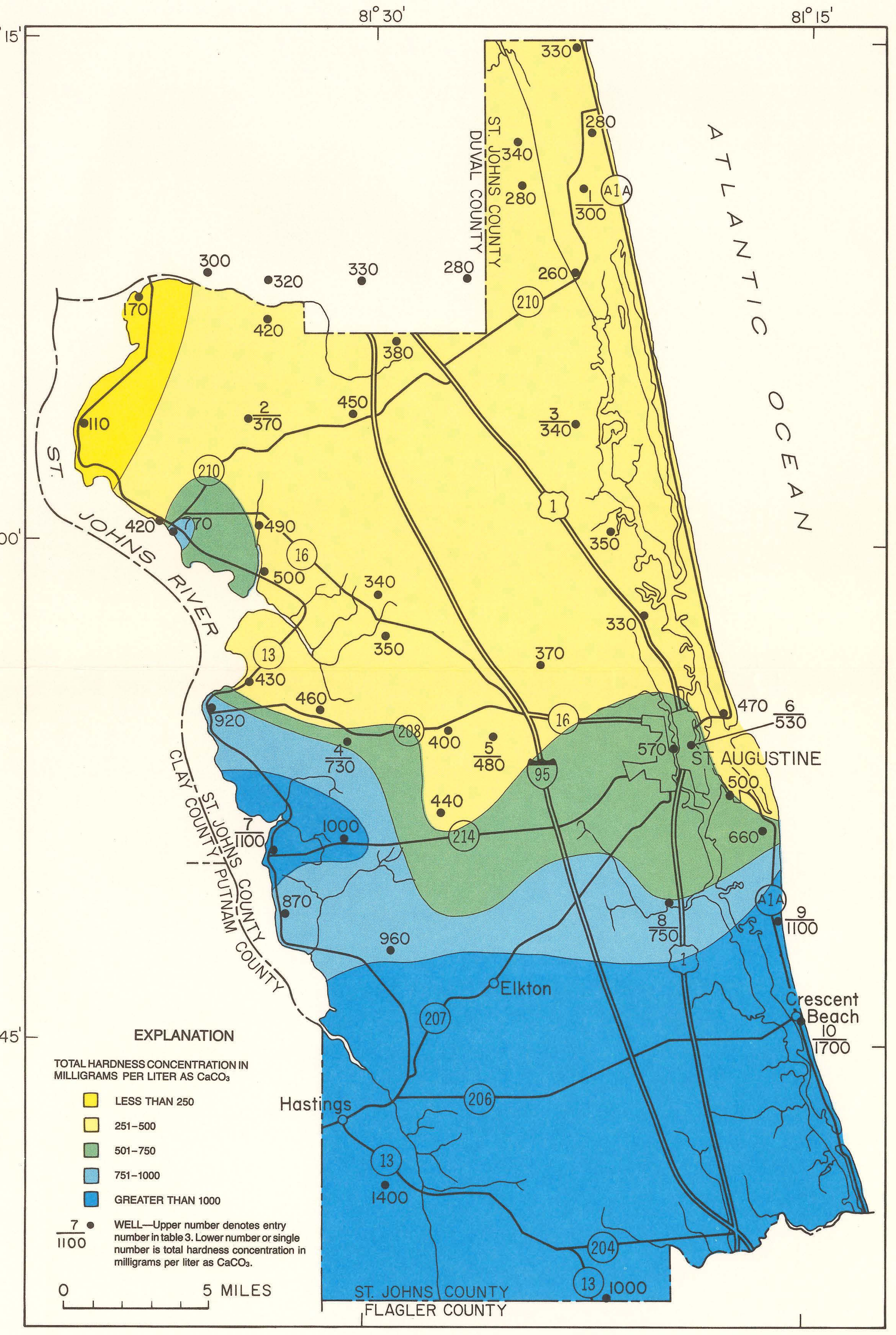

Figure 4.—Total hardness concentration of water from the upper 300 feet of the Floridan aquifer.

CHLORIDE AND TOTAL HARDNESS CONCENTRATIONS OF WATER FROM THE UPPER PART OF THE FLORIDAN AQUIFER IN ST. JOHNS COUNTY, FLORIDA

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