INTRODUCTION

The Floridan aquifer is the principal source of freshwater in Duval County (fig. 1). Most water-supply wells penetrate only the upper 600 feet of the aquifer because highly mineralized water is found in the deeper zone. Earlier investigations have shown that within the upper 600 feet of the aquifer, the water quality varies considerably. In most areas the water contains very low concentrations of inorganic constituents whereas in other areas the concentrations are much higher.

In order to determine the areal distribution of the inorganic constituents in the upper part of the aquifer, water samples were collected from selected wells throughout Duval County and analyzed for common chemical constituents. This report presents the results of that study.

The study was done in cooperation with the City of Jacksonville, Department of Public Works, and the Department of Health and Bio-Environmental Services.

CONVERSION FACTORS

For readers who prefer to use metric (SI) units rather than inch-pound units, the conversion factors for the terms used in this report are listed below:

Multiply inch-pound unit	*By*	*To obtain metric units*
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)

CHEMICAL QUALITY MAPS

Between 1977 and 1980, water samples were collected from 211 wells that penetrate as much as 900 feet of the upper part of the Floridan aquifer. Eighty percent of the sampled wells penetrate less than 600 feet of the aquifer. Analyses of water from these wells were used to delineate the areal distribution of water quality. Data from wells penetrating more than 600 feet are also shown on the quality maps, but were not used in determining the water-quality patterns. The four maps in this report show: (1) dissolved solids concentration, (2) total and noncarbonate hardness concentrations, (3) chloride concentration, and (4) chemical types of water.

Dissolved Solids

All natural waters contain dissolved substances. Rainwater absorbs gases from the atmosphere; additional substances are then dissolved by biological and chemical processes as water percolates into the soil and moves through the subsurface. The amount of these dissolved substances in water is indicated by the dissolved solids concentration. The areal distribution of dissolved solids indicates the general chemical quality of water in the aquifer system. In Duval County, the dissolved solids are comprised mainly of calcium, magnesium, bicarbonate, and sulfate.

Figure 2 shows the dissolved solids concentration of water from the Floridan aquifer. Concentrations range from less than 200 mg/L in the extreme southwest part of the county (determined from studies in adjacent counties) to more than 500 mg/L in the southeast part.

Excessive dissolved solids are objectionable because of possible health effects, mineral tastes, corrosiveness, and the necessity for treatment of the public drinking water supply (U.S. Environmental Protection Agency, 1976). The National Secondary Drinking Water Regulations set a limit of 500 mg/L dissolved solids concentration where other less mineralized sources are available (U.S. Environmental Protection Agency, 1977). Recommended limits of dissolved solids for some industrial and agricultural uses are listed in table 1. Most analyses of water sampled were below recommended limits.

Hardness

Water hardness is caused by polyvalent cations, primarily calcium and magnesium. The calcuim and magnesium carbonates and sulfates are the most common natural sources of water hardness in Duval County.

Total hardness is defined as the sum of all polyvalent cations present in solution, each expressed as the equivalent quantity of calcium carbonate. Carbonate hardness is that portion of the total hardness chemically equivalent to the dissolved carbonate species. Carbonate hardness is numerically equal to alkalinity. Noncarbonate hardness is that amount of the total hardness in excess of the carbonate hardness. Thus, carbonate hardness plus noncarbonate hardness is equal to the total hardness.

The areal distribution of total hardness shows patterns and variations in the major cations (calcium and magnesium). The distribution of the major anions (bicarbonate, sulfate, and chloride) can be shown by differentiating between carbonate and noncarbonate hardness. For example, increases in bicarbonate relative to sulfate and chloride increase the carbonate portion of the total hardness. In the same way, increases in sulfate and chloride relative to bicarbonate increase the noncarbonate portion of the total hardness.

Figure 3 shows the total hardness and the noncarbonate hardness (as percent of total hardness) of water from the Floridan aquifer. The total hardness distribution is similar to the pattern of dissolved solids concentration. Total hardness in the southwest third of the county is less than 200 mg/L. The hardness in most other areas of the county ranges from 200 to 300 mg/L, but concentrations as high as 430 mg/L are found in the southeast part.

The noncarbonate contribution to the total hardness is less than 30 percent in the southwest part of the county, more than 40 percent in the extreme northern part, and from 40 to more than 60 percent in the southeast and central parts.

There have been many attempts to classify water according to its hardness. The classification used by the U.S. Geological Survey (Durfor and Becker, 1964) and that used by the U.S. Environmental Protection Agency (1976) are tabulated below:

Description	*Total hardness, mg/L $CaCO_3$*	
	USGS	*EPA*
Soft	0-60	0-75
Moderately hard	61-120	75-150
Hard	121-180	150-300
Very hard	>180	>300

Detrimental effects of hard water include excessive soap and detergent consumption, formation of scale deposits, yellowing of fabrics, and toughening of vegetables when cooked. Detrimental effects of soft water include increased corrosiveness and possible harmful effects on human health (Crawford and others, 1968; Masironi, 1969; National Academy of Sciences and National Academy of Engineering, 1972; and Fodor and others, 1973). Present information is insufficient to balance the desirability of setting a limit for hardness against the potential health risk of soft water. Therefore, a limit was not recommended in the National Primary or Secondary Drinking Water Regulaions (U.S. Environmental Protection Agency, 1977).

The relative amounts of carbonate to noncarbonate hardness is an important factor in industrial processes and in municipal water softening. In general, carbonate hardness causes fewer problems, and is easier and less expensive to remove than noncarbonate hardness (American Water Works Association, 1971). Recommended limits of total hardness for some industrial uses are listed in table 1.

Chloride

Chloride is present in all natural water. Most chloride in ground water comes from dissolution of minerals in the rocks, activities of man, and intrusion of seawater into the aquifer.

Chloride is generally unaffected by chemical processes that alter the concentration of other constituents, and its circulation in the hydrologic cycle is largely through physical processes. Thus, its areal distribution may provide information about hydrologic and geologic conditions in the aquifer. For example, areas of large variations in chloride concentration may indicate conditions such as: (1) variation in geologic structure, (2) variation in lithology, (3) pollution, or (4) saltwater intrusion.

Figure 4 shows the chloride concentration of water from the upper part of the Floridan aquifer. Concentrations are less than 10 mg/L in the southwest part of the county; 10 to 20 mg/L in the central and southeast parts; and 20 to 30 mg/L in the northern part. Areas of chloride that exceed 40 mg/L are located in east-central and coastal Duval County.

The National Secondary Drinking Water Regulations recommend a limit of 250 mg/L chloride concentration where sources of better quality are available (U.S. Environmental Protection Agency, 1977). This limit is based upon taste perception rather than upon ill effects to health (National Academy of Sciences and National Adademy of Engineering, 1972). Recommended limits of chloride for some industrial and agricultural uses are listed in table 1.

Chemical Types

The chemical type of water determined from a chemical analysis is a representation of the predominant ions in the sample. The delineation of types over a large area will, therefore, effectively group those waters of similar chemical composition.

In order to determine the water type from a chemical analysis, the predominant ions are first determined. The method is the same one used for plotting data on trilinear diagrams (Piper, 1944). The water type is then found by combining the predominant cation with the predominant anion.

The areal distribution of the predominant ions and the resulting water types are shown in figure 5. Calcium is the predominant cation in central and extreme southwest Duval County. A calcium-magnesium mixture predominates over the northern, south-central, and extreme southeastern parts. Sulfate is the dominant anion in the southeastern and central parts of the county, and bicarbonate in most other areas. A bicarbonate-sulfate mixture of anions is found in extreme northern Duval County, and along the interface between the bicarbonate and sulfate areas.

Chloride is not a dominant ion in the upper part of the aquifer. It comprises less than 10 percent of the anions in most of the wells sampled. Only 13 wells yield water that contains chloride of 20 percent of the anions or more. These sites are indicated in figure 5, and are all located either in east-central Duval County or along the coastal areas.

Different combinations of the predominant cations and anions result in six chemical types of water in the Floridan aquifer in Duval County. These six types of water are:

- Calcium bicarbonate
- Calcium bicarbonate-sulfate
- Calcium sulfate
- Calcium-magnesium bicarbonate
- Calcium-magnesium bicarbonate-sulfate
- Calcium-magnesium sulfate

Water in western and east-central Duval County is a calcium bicarbonate type. In the south-central part, the water is a calcium-magnesium bicarbonate type. Water in northern Duval County is calcium-magnesium bicarbonate and calcium-magnesium bicarbonate-sulfate types. Dominating the southeast and central parts of the county are calcium sulfate and calcium bicarbonate-sulfate type waters.

SUMMARY

This report describes the water quality in the upper 900 feet of the Floridan aquifer in Duval County. In general, the southwest part of the county has the lowest concentrations of dissolved solids, chloride, and total and noncarbonate hardness. The concentrations of these constituents increase toward the north and east. The southeast part of the county has the highest concentrations of dissolved solids and total and noncarbonate hardness. Areas of relatively high chloride concentration exist in east-central and coastal Duval County. Six different chemical types of water are found in the county. The most prominent is a southeast to northwest tongue of calcium sulfate and calcium bicarbonate-sulfate water that extends from southeastern Duval County into the central part of the county.

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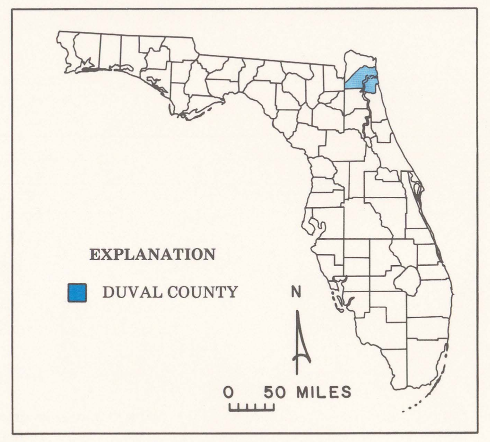

Figure 1.—Location of Duval County, Florida.

Table 1.—*Recommended limits of dissolved solids, total hardness, and chloride in water for selected industrial and agricultural uses*

[From McKee and Wolf, 1963]

Use	Dissolved solids, mg/L	Total hardness, mg/L as $CaCO_3$	Chloride mg/L
Brewing, general	500-1,500	200-300	60-100
Carbonated beverages	850	200-250	250
Dairy industry	—	180	30
Food equipment washing	850	10	250
Pulp and paper processing water			
Ground wood pulp	500	200	75
Soda and sulfate pulps	250	100	75
Kraft paper, bleached	300	100	200
Kraft paper, unbleached	500	200	200
Fine papers	200	100	—
Textile manufacture	—	0-50	100
Irrigation	700	—	100
Stock watering	2,500	—	1,500

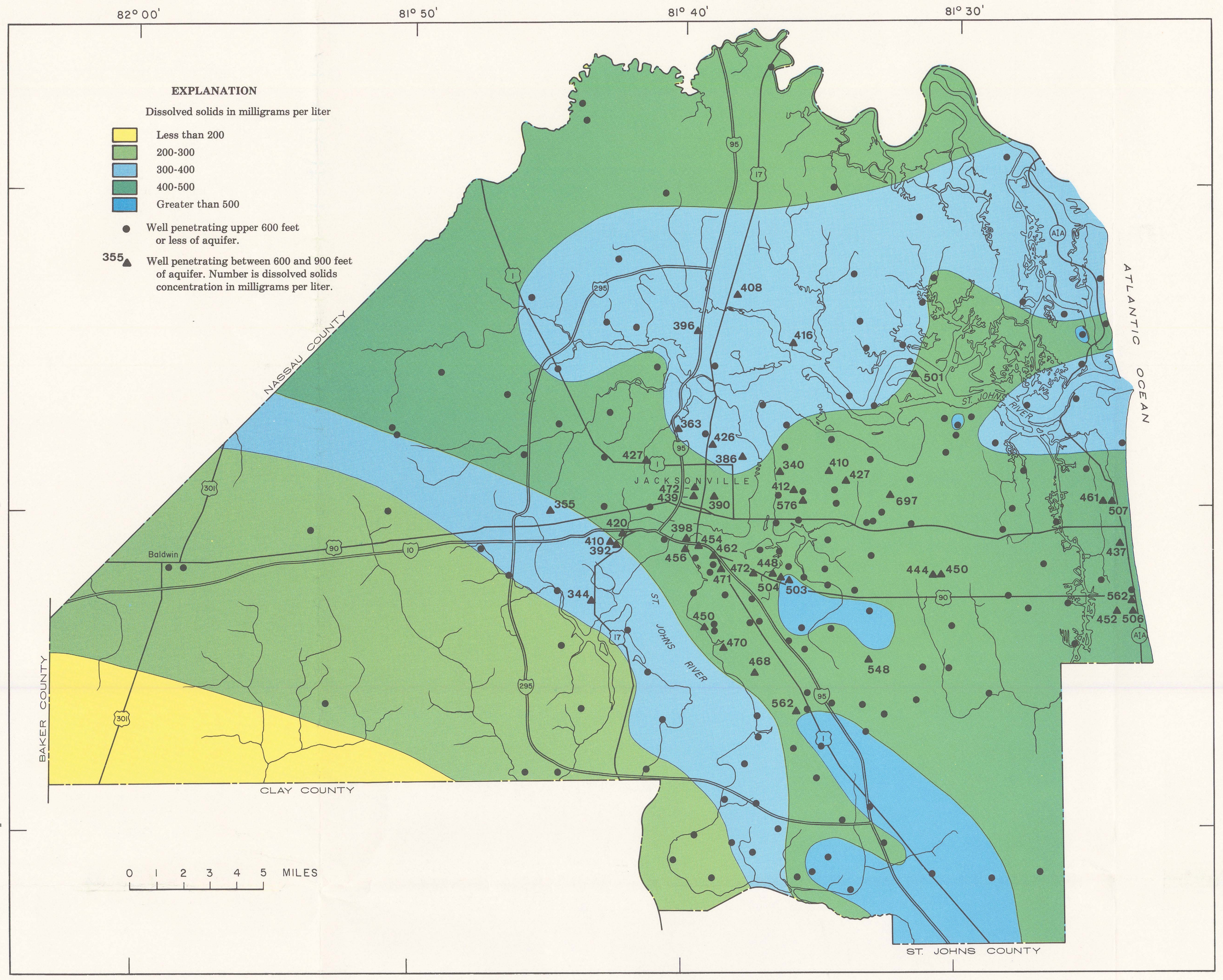

Figure 2.—Dissolved solids concentration.

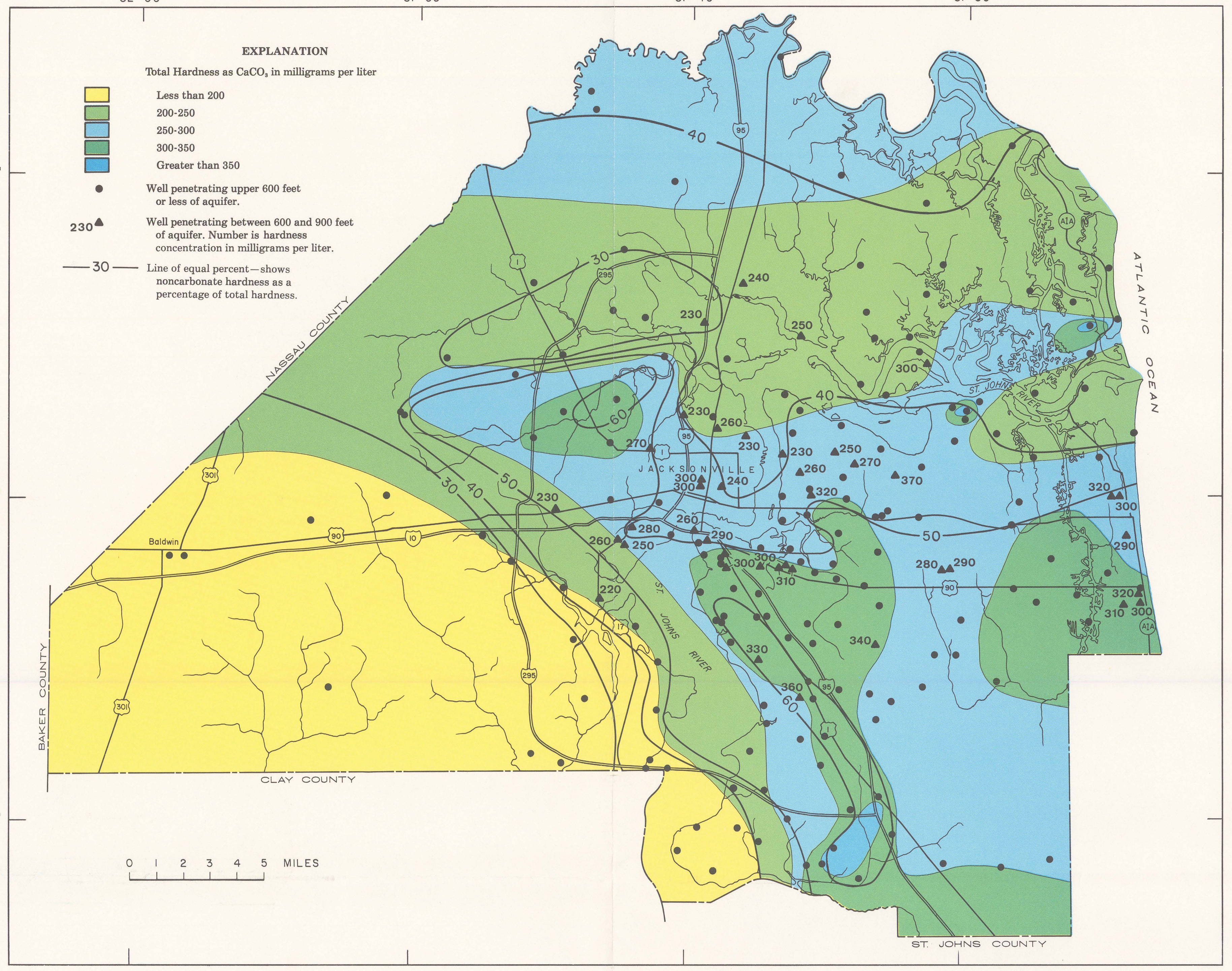

Figure 3.—Total and noncarbonate hardness concentrations.

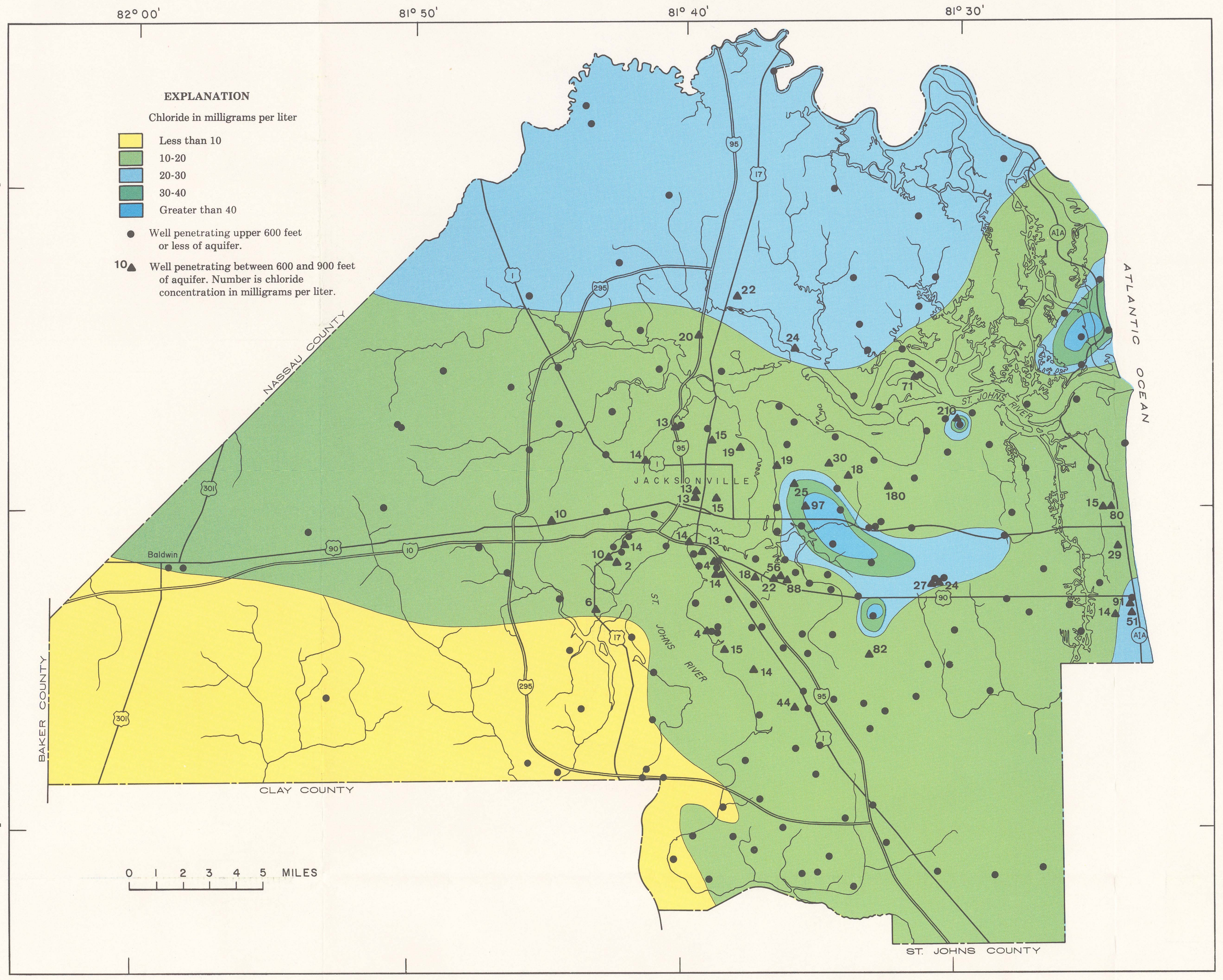

Figure 4.—Chloride concentration.

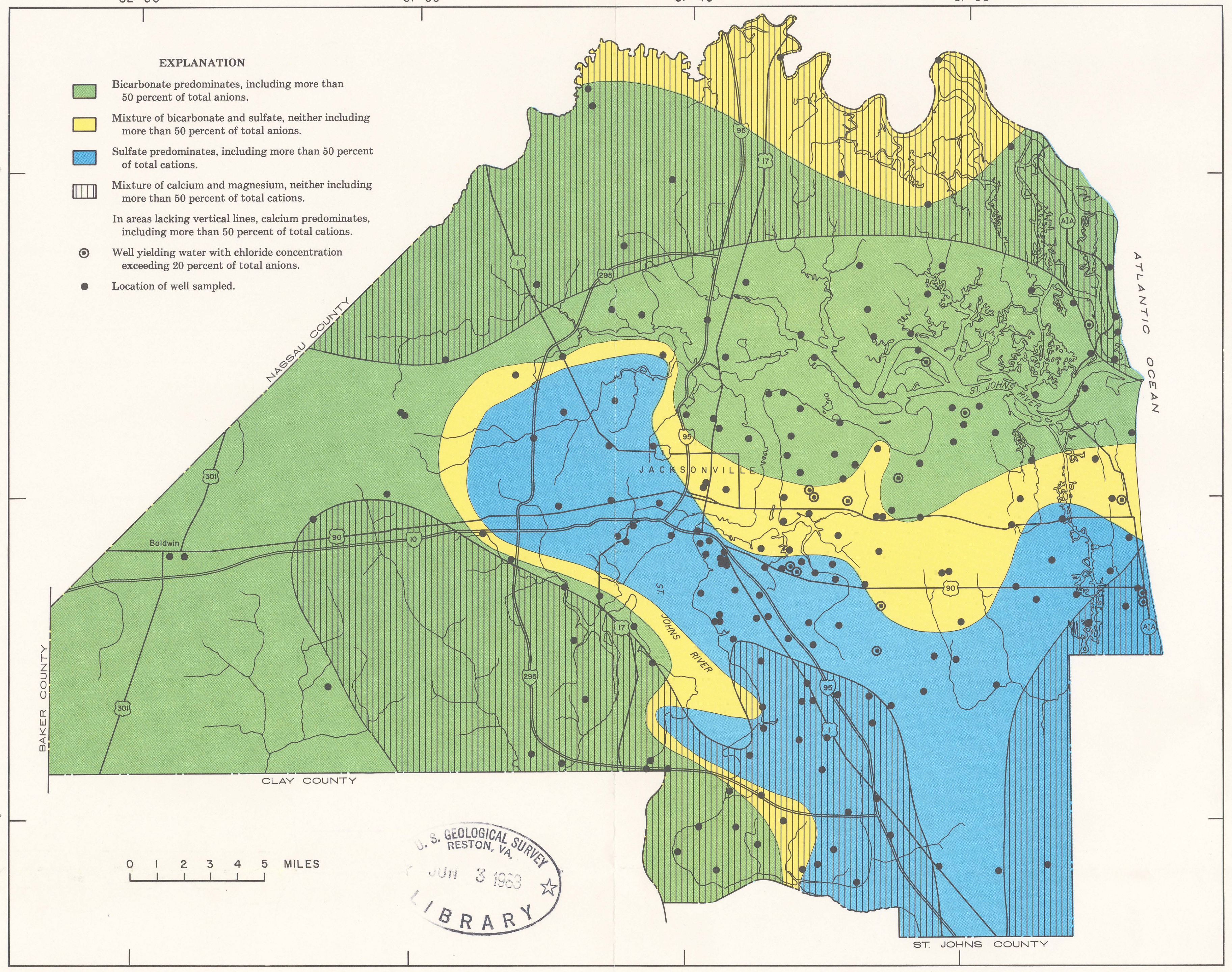

Figure 5.—Chemical types of water.

CHEMICAL QUALITY OF WATER IN THE UPPER PART OF THE FLORIDAN AQUIFER, DUVAL COUNTY, FLORIDA

By
Thomas H. Thompson

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