INTRODUCTION

The Floridan aquifer system is the principal source of water supply in northeastern Florida. Increasing demands for water from the Floridan aquifer system in Duval County (fig. 1) have resulted in a need to evaluate changes in water levels and chloride concentrations. Rapid population growth in Duval County is creating an increasing demand for freshwater. In 1960, the population of Duval County was about 455,000 (Brown and others, 1986), and in 2000 it was estimated to be about 779,000. As population continues to increase, additional water supplies will be needed. Increases in pumpage to meet these demands will lower the potentiometric surface and increase the potential for the upward movement of saline water from deeper zones of the aquifer system (Spechler, 1994; and Phelps and Spechler, 1997). The increased demand for water from the Floridan aquifer system requires that this valuable resource be adequately managed. Information on the trends in the potentiometric surface and chloride concentrations in the Floridan aquifer system is necessary for proper planning and management.

This map report, prepared in cooperation with the City of Jacksonville, depicts the altitude of the potentiometric surface of the Upper Floridan aquifer in Duval County, and shows trends in the potentiometric surface and in chloride concentrations in the Floridan aquifer system at selected locations. The information presented in this report includes: (1) graphs showing water use for Duval and adjacent counties from 1965 to 1999; (2) maps showing the altitude of the potentiometric surface of the Upper Floridan aquifer in Duval County for January-February 1960, September 1998, and May 1999; (3) a map showing changes in the potentiometric surface of the Upper Floridan aquifer from January-February 1960 to May 1999; (4) hydrographs showing long-term water levels of selected wells in Duval County; and (5) graphs showing chloride concentrations in water at selected wells in Duval County.

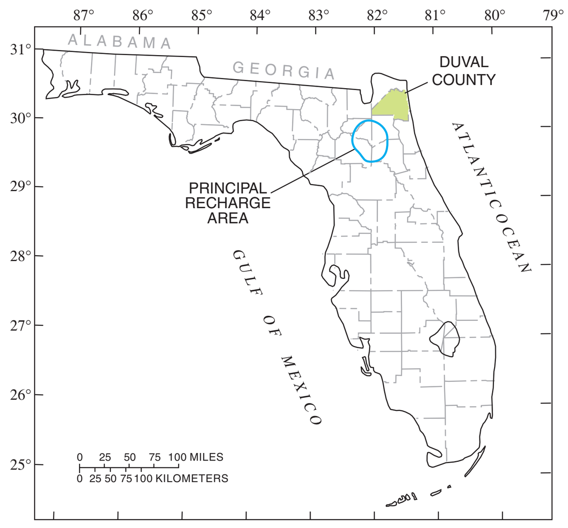

Figure 1. Location of Duval County, Florida.

Water Use

Ground-water withdrawals from the Floridan aquifer system in northeastern Florida accounted for about 90 percent of the total freshwater use in 1999. Water-use data have been collected by the U.S. Geological Survey and the St. Johns River Water Management District since 1965. In 1965, total ground-water withdrawals in Duval and surrounding counties (St. Johns, Clay, and Nassau) (fig. 2) was about 191 million gallons per day (Mgal/d), of which 127 Mgal/d was from Duval County (Marella, 1995). In 1999, withdrawals increased to about 272 Mgal/d, of which 152 Mgal/d was from Duval County. Of the total water used in Duval County in 1999, 74 percent was for public supply, 11 percent for commercial-industrial self-supplied, 9 percent for domestic self-supplied, 3 percent for thermoelectric power generation, 2 percent for recreational, and 1 percent for agricultural irrigation (R.L. Marella, U.S. Geological Survey, written commun., 2002).

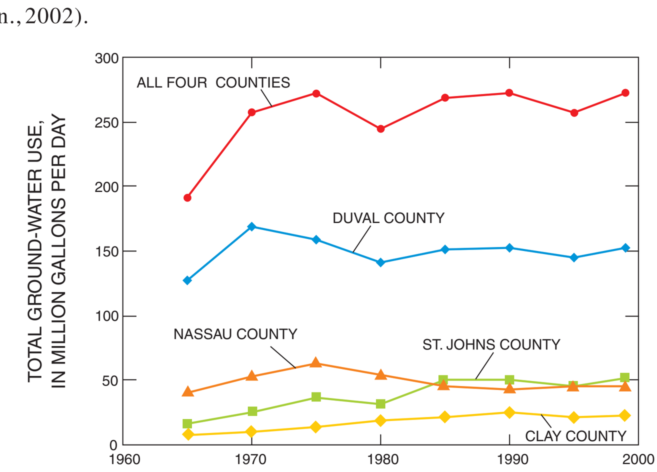

Figure 2. Total ground-water use in Duval County and adjacent counties, Florida, 1965-1999 (from Marella, 1995, 1999; and R.L. Marella, U.S. Geological Survey, written commun., 2000).

HYDROGEOLOGY

The principal water-bearing units in the study area are the surficial and the Floridan aquifer systems (fig. 3). The two aquifers are separated by the intermediate confining unit, which contains beds of lower permeability sediments that confine the water in the Floridan aquifer system. In Duval County, the Floridan aquifer system is divided into the Upper Floridan aquifer and the Lower Floridan aquifer, which are separated by a zone of lower permeability. Two major water-bearing zones exist within the Lower Floridan aquifer: the upper zone of the Lower Floridan aquifer and the Fernandina permeable zone. These zones are separated by a less permeable unit that restricts the vertical movement of water.

The Floridan aquifer system underlies all of Florida and parts of Alabama, Georgia, and South Carolina. It is composed chiefly of limestone and dolomite, and includes the following stratigraphic units in descending order: the Ocala Limestone, the Avon Park Formation, the Oldsmar Formation, and the upper part of the Cedar Keys Formation (fig. 3). The top of the Floridan aquifer system is defined by the top of the Ocala Limestone, and its altitude ranges from about 250 feet (ft) below sea level near Jacksonville Naval Air Station to about 600 ft below sea level in parts of central Duval County (Spechler, 1994). The surface of the Upper Floridan is a paleokarstic plain exhibiting erosional and collapse features that developed before the deposition of the overlying Hawthorn Group. Marine seismic reflection profiles show that the Continental Shelf off the coast of northeastern Florida is underlain by solution-deformed limestone of Late Cretaceous to Eocene age (Meisburger and Field, 1976; Popenoe and others, 1984; Kindinger and others, 2000). Dissolution and collapse features are scattered throughout the area. Seismic reflection investigations along the St. Johns River in northeastern Florida by Snyder and others (1989) and Spechler (1994, 1996) also revealed the presence of buried collapse and other karstic features that originated in the rocks of the Floridan aquifer system. Using land-based seismic reflection, such features also were discovered in Duval and St. Johns County (Odum and others, 1997). Two collapse features that penetrate the seafloor off the coast of St. Johns County were studied by Spechler and Wilson (1997) and Swarzenski and others (2001). Collapse features can create conduits of relatively high vertical hydraulic conductivity, providing a hydraulic connection between freshwater and deeper, more saline zones within the aquifer system.

Series	Stratigraphic unit	General lithology	Hydrogeologic unit	Hydrogeologic properties
Holocene to Upper Miocene	Undifferentiated surficial deposits	Discontinuous sand, clay, shell beds, and limestone	Surficial aquifer system	Sand, shell, limestone, and coquina deposits provide local water supplies.
Miocene	Hawthorn Group	Interbedded phosphatic sand, clay, limestone, and dolomite	Intermediate confining unit	Sand, shell, and carbonate deposits provide limited local water supplies. Low permeability clays serve as the principle confining beds for the Floridan aquifer system below.
Eocene	Ocala Limestone	Massive fossiliferous chalky to granular marine limestone	Floridan aquifer system: Upper Floridan aquifer	Principal source of ground water. High permeability overall. Water from some wells show increasing salinity.
	Avon Park Formation	Alternating beds of massive granular and chalky limestone, and dense dolomite	Floridan aquifer system: Middle semiconfining unit	Low permeability limestone and dolomite.
			Floridan aquifer system: Lower Floridan aquifer: Upper zone	Principal source of ground water. Water from some wells show increasing salinity.
	Oldsmar Formation		Floridan aquifer system: Lower Floridan aquifer: Semiconfining unit	Low permeability limestone and dolomite.
			Floridan aquifer system: Lower Floridan aquifer: Fernandina permeable zone	High permeability; salinity increases with depth.
Paleocene	Cedar Keys Formation	Uppermost appearance of evaporites; dense limestones	Sub-Floridan confining unit	Low permability; contains highly saline water.

Figure 3. General geology and hydrogeology of Duval County, Florida (modified from Spechler, 1994).

Ground-Water Flow System and Water Levels in the Floridan Aquifer System

The principal recharge area of the Upper Floridan aquifer in northeastern Florida is southwest of Duval County (fig. 1). Within this recharge area, water enters the Upper Floridan by downward leakage from the surficial aquifer system through breaches in the intermediate confining unit caused by sinkholes or where the confining unit is thin or missing, and by lateral inflow. Water is discharged from the Upper Floridan aquifer by pumpage, by diffuse upward leakage of water to the surficial aquifer system where the potentiometric surface of the Upper Floridan aquifer is above the water table, by lateral outflow, and by free-flowing wells.

General areas of recharge and discharge and the direction of ground-water movement can be determined from potentiometric surface maps. The potentiometric surface is an imaginary surface to which water from an artesian aquifer will rise in tightly cased wells that penetrate the aquifer. Ground water in the Floridan aquifer system moves from areas of high potential head to areas of low potential head, generally along flow lines perpendicular to the lines of equal head. The generalized configuration of the potentiometric surface of the Upper Floridan aquifer in Duval County for January-February 1960 (Leve, 1961) is shown in figure 4. The January-February 1960 potentiometric surface map was one of the first such maps constructed for Duval County. It represents conditions somewhere between the seasonal high and seasonal low water levels. The potentiometric surface ranged from more than 60 ft above sea level in extreme southwestern Duval County to about 30 ft above sea level in the depression in the south-central part of the county. The depression in the potentiometric surface is believed to be caused primarily by withdrawals from public-supply and industrial wells, and possibly by the natural discharge of water from the Upper Floridan aquifer into the St. Johns River combined with aquifer transmissivity variations (Phelps, 1994).

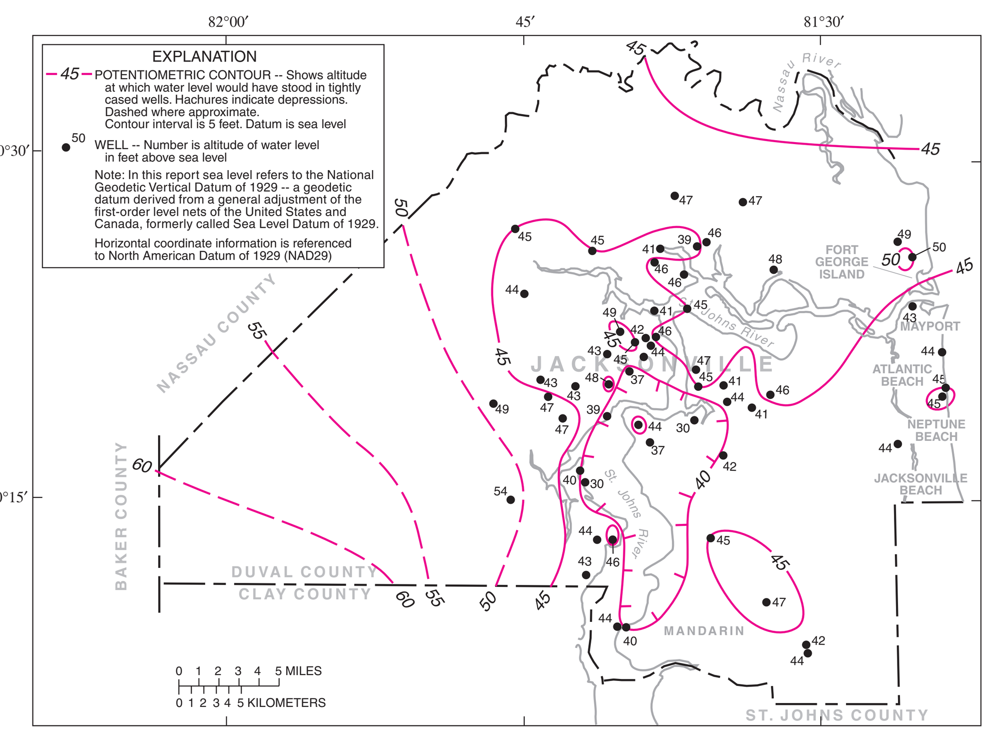

Figure 4. Potentiometric surface of the Upper Floridan aquifer, January-February 1960 (modified from Leve, 1961).

Potentiometric surface maps of the Upper Floridan aquifer for September 1998 and May 1999 for Duval County are shown in figures 5 and 6, respectively. Potentiometric surface maps for 2000 or 2001 were not included in this report, because water levels for those years were at or near record lows due to drought conditions, which were affecting much of the State, and, therefore, would not be representative of "normal" May and September water levels. The September 1998 potentiometric surface (fig. 5) represents conditions near the end of the wet season, when withdrawals from the aquifer are near minimum and water levels generally are near their highest. The potentiometric surface ranges from about 54 ft above sea level in the extreme southwestern part of the county to 23 ft above sea level within the depression in the south-central part of the county (Bradner, 1999). The May 1999 potentiometric surface represents conditions near the end of the dry season (fig. 6), when withdrawals from the aquifer are near maximum and water levels generally are near their annual low. The potentiometric surface ranged from about 53 ft to about 17 ft above sea level (Bradner and Knowles, 1999). Water levels in May 1999 averaged about 1 to 7 ft lower than in September 1998.

A comparison of the January-February 1960 potentiometric surface (Leve, 1961) with that of May 1999 (Bradner, 1999) shows that heads in most of the county have declined from 5 to 26 ft since 1960 (fig. 7). The degree of decline in the potentiometric surface varies depending on the location within Duval County. The smallest declines (less than 10 ft) were in the northwestern and extreme western part of the county, away from areas of large ground-water withdrawals. Declines ranging from 10 to 20 ft occured primarily in the northern half of Duval County. The greatest decline (greater than 20 ft) occurred mostly in southeastern and south-central Duval County, and is due primarily to increased withdrawals of water for public supply.

The potentiometric surface of the Upper Floridan aquifer is constantly fluctuating, mainly in response to ground-water withdrawals and seasonal variations in rainfall. This can be illustrated by long-term seasonal and year-to-year fluctuations of water levels measured in six wells (fig. 8) open to the Floridan aquifer system in Duval County (fig. 9). A comparison of hydrographs and analysis of water-level data collected for the biannual potentiometric surface maps shows that the September water levels generally range from 2 to 5 ft higher than May water levels. During periods of deficient rainfall, however, declines between September and May locally can be greater in heavily pumped areas.

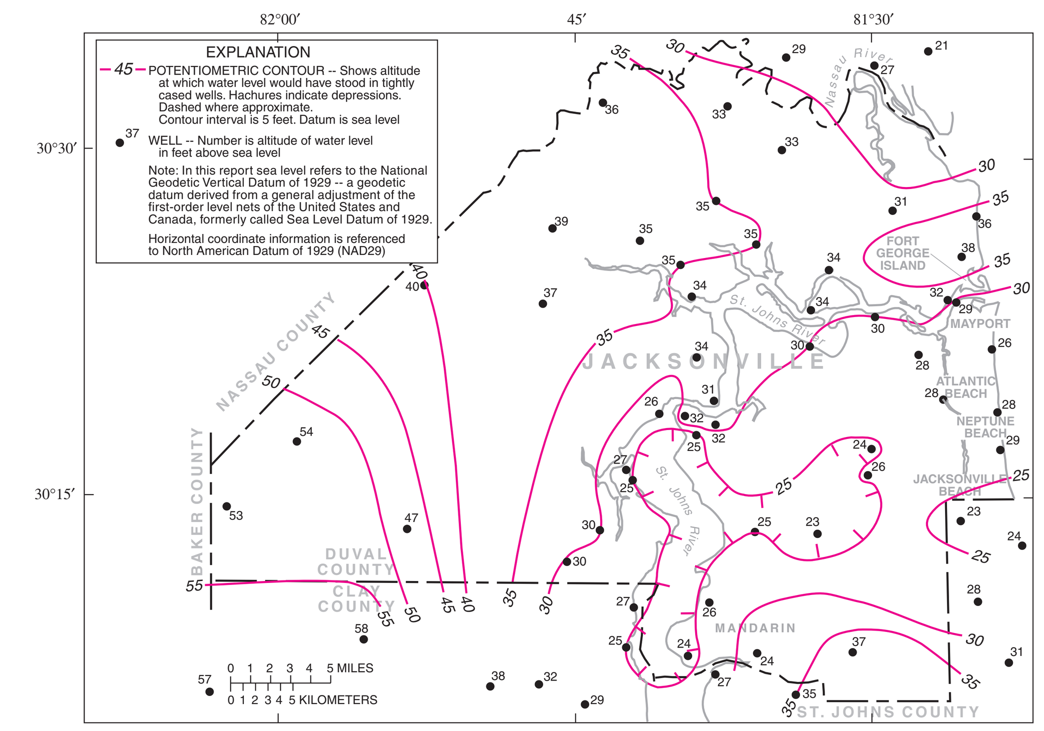

Figure 5. Potentiometric surface of the Upper Floridan aquifer, September 1998 (from Bradner, 1999).

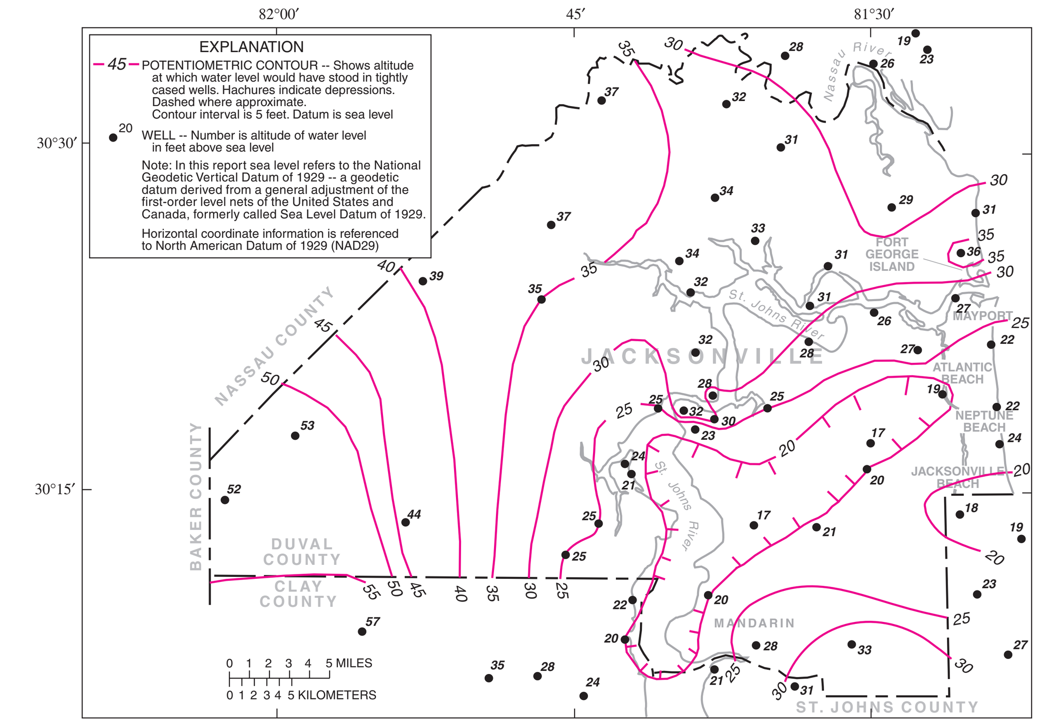

Figure 6. Potentiometric surface of the Upper Floridan aquifer, May 1999 (modified from Bradner and Knowles, 1999).

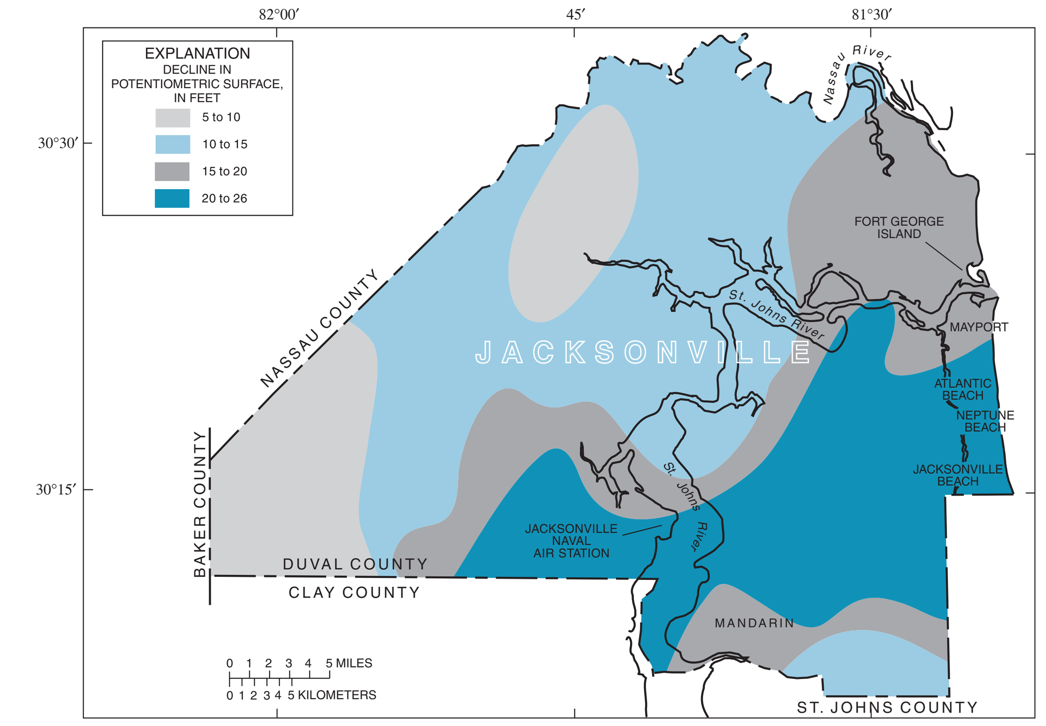

Figure 7. Approximate decline in potentiometric surface of the Upper Floridan aquifer from January-February 1960 to May 1999.

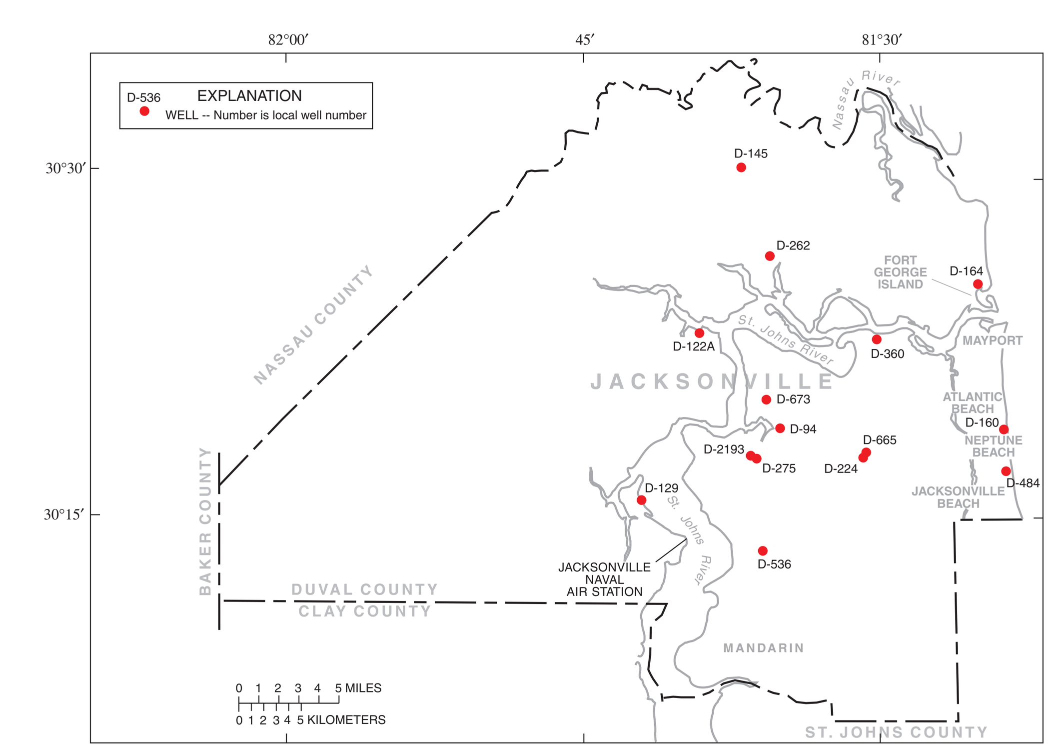

Figure 8. Selected wells with long-term water-level or chloride concentration data.

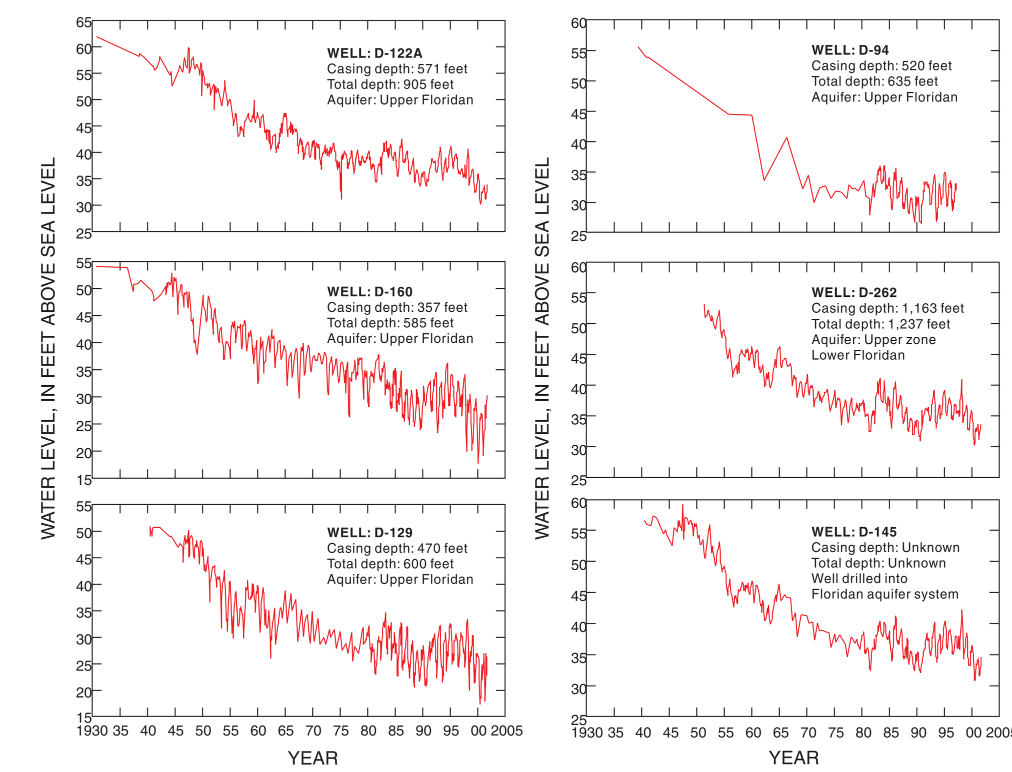

Figure 9. Water levels in selected wells tapping the Floridan aquifer system (well location shown in figure 8).

Long-term hydrographs of Floridan aquifer system monitoring wells indicate a downward trend of water levels in many wells in Duval County. Water levels measured in six monitoring wells (fig. 9) show declines of about 25-30 ft from the 1940's to 2001. Although some of the water-level declines may be a result of long-term below-average rainfall, much of the declines can be attributed to increased pumpage. The hydrographs show that for much of the record, declines were observed whether there was a surplus or deficiency in rainfall (fig. 10). For example, moderate declines were observed during periods when there was a net cumulative deficiency in rainfall (1929 to 1943, 1951 to 1962, 1974 to 1990, and 1999 to 2001). However, declines also were observed during periods of surplus rainfall (1944 to 1950 and 1963 to 1973), indicating that increased ground-water development tended to offset the effects of greater than normal rainfall. An exception, however, was from 1991 to 1998, when a net surplus of about 60 inches of rainfall produced a rise in water levels at some well locations. Although declines in water levels in the monitoring wells have occurred during the entire period of record, the rate of decline appears to have moderated since the late 1970's and early 1980's. The moderation in water-level declines seems to be related to the stabilization of water use in Duval and surrounding counties, which began in the early 1970's.

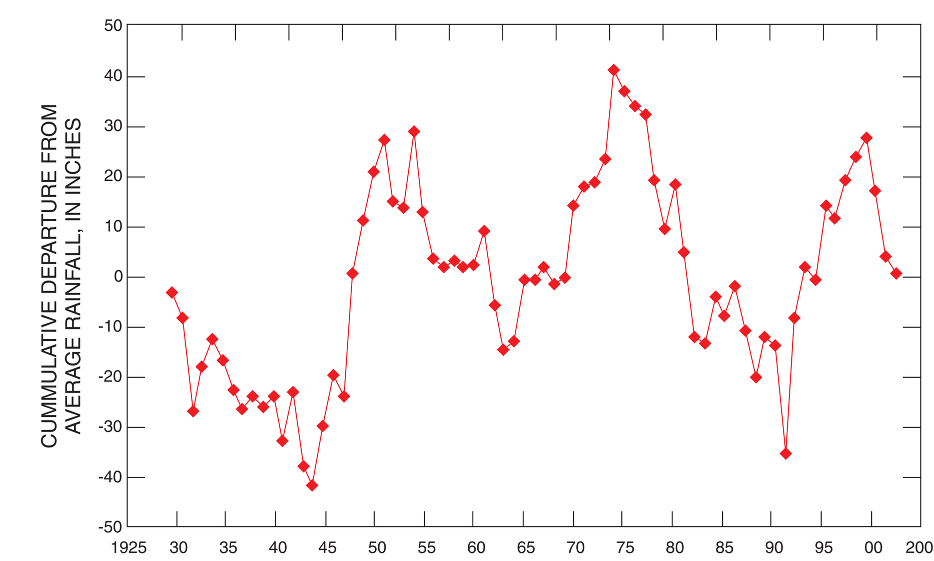

Figure 10. Cummulative departure from average rainfall at Jacksonville, Florida, 1929-2001.

LONG-TERM CHLORIDE CONCENTRATION TRENDS

The potentiometric surface of the Floridan aquifer system in Duval County has gradually declined primarily as a result of increased pumping. Associated with this decline in the potentiometric surface has been an increased potential for movement of saline water into the freshwater zones of the Floridan aquifer system. Gradual but continual increases in chloride concentrations in water from the aquifer system have been observed in a number of wells in Duval County. The potential for saltwater intrusion is expected to increase as population growth places greater demands on the ground-water resources of northeastern Florida.

Chloride concentrations in the Upper Floridan aquifer generally are relatively low throughout most of Duval County. The lowest concentrations occur in the southwestern part of the county, where concentrations are less than 15 milligrams per liter (mg/L). Chloride concentrations increase slightly toward the east, where concentrations typically do not exceed 30 mg/L (Spechler, 1994). Water samples collected during the drilling of monitoring wells in northeastern Florida show that, in general, water becomes more mineralized with depth; water in the Lower Floridan aquifer is more mineralized than water in the Upper Floridan aquifer, especially in the eastern part of the county. Chloride concentrations in water from the Fernandina permeable zone (deepest part of the Lower Floridan aquifer) can exceed 16,800 mg/L (Brown and others, 1986).

Although wells open to the Floridan aquifer system generally yield large quantities of good quality water, elevated chloride concentrations have been observed in more than 70 wells tapping the Upper Floridan and the upper zone of the Lower Floridan aquifers. Chloride concentrations exceeding 30 mg/L have been observed in some wells along the coast and up to 14 miles inland. Investigations by Spechler (1994) and Phelps and Spechler (1997) show that in a number of wells (all in eastern Duval County), chloride concentrations have increased with time. Chloride concentration trends in water from eight monitoring wells are shown in figure 11. In the western part of the county, where water in the lower part of the Floridan aquifer system probably is fresh, increased chloride concentrations in water samples from wells have not been observed. In some wells in the eastern part of the county, increases in chloride concentrations either have not been observed or are increasing at a slow rate. In a number of wells, however, chloride concentrations have increased at a steady rate. At present (2002), chloride concentrations in samples from only a few wells exceed the 250-mg/L recommended limit for drinking water; however, continued declines in water levels increase the risk of further water-quality degradation. A graph showing water-level and chloride data collected at well D-164 (1930-2000) is shown in figure 12. Long-term data indicate that an inverse relation between water levels and chloride concentrations exists. As water levels have declined (about 24 ft in 70 years), chloride concentrations have increased from 63 to 360 mg/L.

The mechanism of saline water intrusion into the Upper Floridan aquifer, described in detail in Spechler (1994) and Phelps and Spechler (1997), most likely is not lateral intrusion of seawater from the ocean or simple regional upconing of saline water from deeper zones in the aquifer. Instead, the upward movement of saline water most likely occurs along solution-enlarged joints or fractures and collapse features, combined with horizontal movement in fractures or solutionally enhanced flow zones. Such features include paleokarst features of both relatively small, local extent and larger, regional extent. The presence of both vertical and horizontal fractures or joints and solution collapse features developed along the planes of those fractures or joints also strongly influence the movement of saline water.

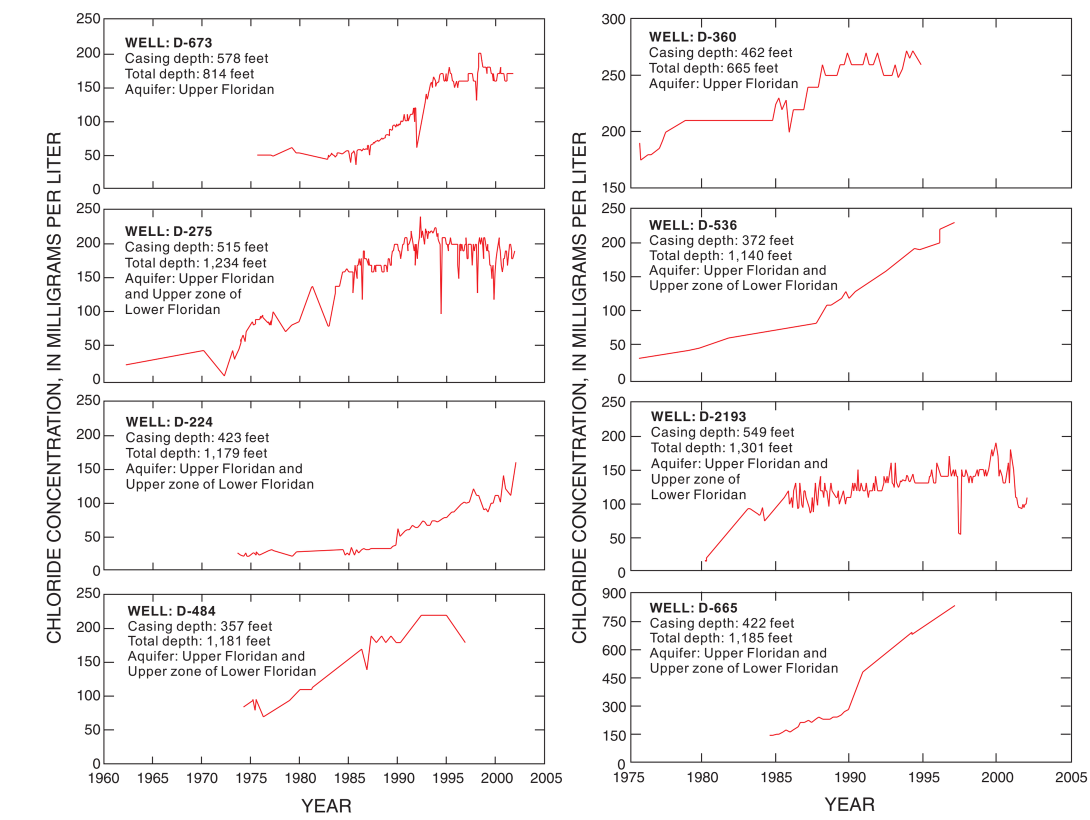

Figure 11. Chloride concentrations in water from selected wells tapping the Floridan aquifer system (well location shown in figure 8).

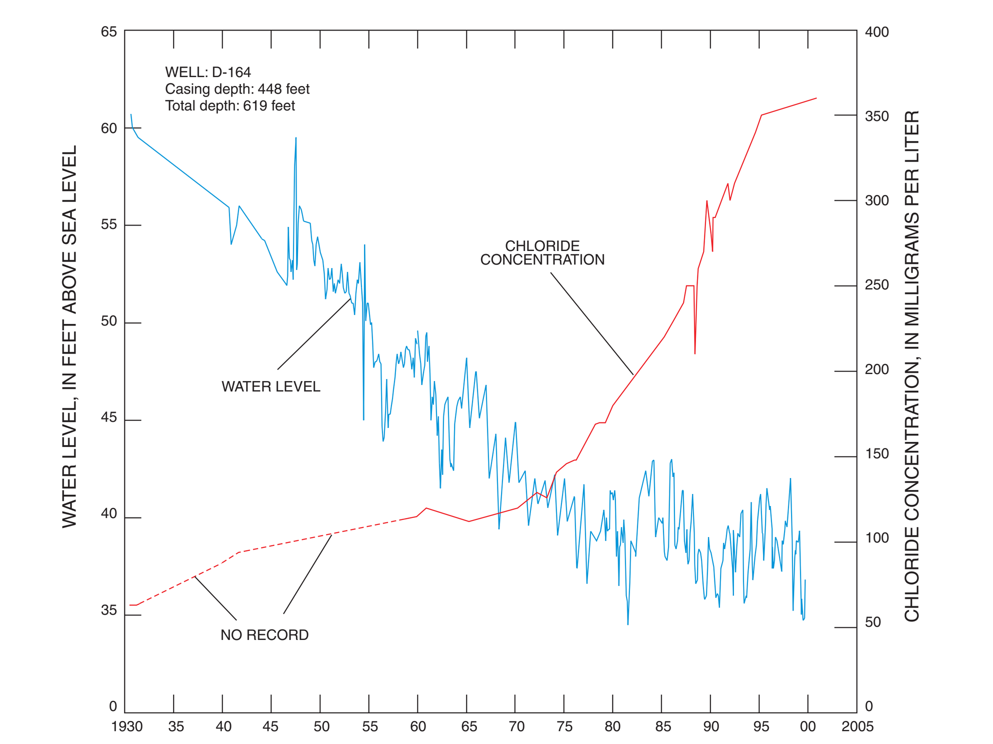

Figure 12. Water levels and chloride concentrations in water in well D-164, Fort George Island, 1930-2000.

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VARIATIONS IN WATER LEVELS AND CHLORIDE CONCENTRATIONS IN THE FLORIDAN AQUIFER SYSTEM IN DUVAL COUNTY, FLORIDA

By
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2002