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BUREAU OF GEOLOGY
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Report of Investigations No. 57

EVALUATION OF THE QUANTITY AND QUALITY OF THE WATER RESOURCES OF VOLUSIA COUNTY, FLORIDA

By
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U.S. Geological Survey

Prepared by
UNITED STATES GEOLOGICAL SURVEY
in cooperation with the
FLORIDA DEPARTMENT OF NATURAL RESOURCES
DIVISION OF INTERIOR RESOURCES
BUREAU OF GEOLOGY
and the
BOARD OF COUNTY COMMISSSIONERS OF VOLUSIA COUNTY

TALLAHASSEE, FLORIDA
1971

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LETTER OF TRANSMITTAL

Bureau of Geology
Tallahassee
September 23, 1970

Honorable Reubin O'D. Askew, *Chairman*
Department of Natural Resources
Tallahassee, Florida

Dear Governor Askew:

The Bureau of Geology, Division of Interior Resources, Department of Natural Resources, is publishing as its Report of Investigations No. 57, an "Evaluation of the Quantity and Quality of the Water Resources of Volusia County, Florida." This report amplifies and refines some of the data already issued covering the water resources of Volusia County, which were published as Report of Investigations No. 21. The work in the report was accomplished as a cooperative program between the Department of Natural Resources, the U. S. Geological Survey and the Board of County Commissioners of Volusia County. Volusia County is almost totally dependent upon the water which falls upon the county and has a recharge area contained along the western portion and the central portions of the county. Excellent water is produced in the areal recharge and it is anticipated that this data will expand the existing knowledge of the water resources to permit the development of a great capacity for existing utilities and to offset and solve some of the problems now in the area.

Sincerely yours,

R. O. Vernon, *Chief*

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EVALUATION OF THE QUANTITY AND QUALITY OF THE WATER RESOURCES OF VOLUSIA COUNTY, FLORIDA

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ABSTRACT

Volusia County includes about 1,200 square miles along the central east coast of Florida. The population of the county increased by 60 thousand people between 1955 and 1965. Water use in 1967 averaged about 25.9 mgd (million gallons per day), of which the major use (15.8 mgd) was for public supply. In the 20-year interval, 1950 to 1970, the amount of water used for public supply, all of which is ground water, will have more than doubled. On the average, it is estimated that 300 mgd is available for man's use. Ninety-five percent of the water used in Volusia County comes from the Floridan aquifer.

The county receives most of its fresh water from rainfall, which averages 52 inches per year. The unconsolidated sand of the clastic aquifer absorbs much of the rainfall. Seepage from the clastic aquifer is to streams and to the underlying Floridan aquifer.

Recharge to the Floridan aquifer occurs throughout the county wherever the water table in the clastic aquifer is higher than the piezometric surface in the Floridan aquifer. No area is a principal recharge area, but parts of the ridges and the eastern part of the Talbot terrace appear to have the greatest recharge per unit area.

In the central part of the county the clastic aquifer is full and rejecting recharge through runoff and evapotranspiration. If the piezometric surface were lowered in this area by withdrawing water from the Floridan aquifer for use, this rejected recharge would be decreased by the capture of water. This would increase the amount of water available for use.

Of the few hundred lakes in the county, most occur along the DeLand ridge, where there are about 120 larger than 5 acres. Many of the ridge lakes, because of their size, purity, and small range in surface level fluctuation have excellent recreational potentials. Water in most lakes in the county has a low mineral content with mineralization ranging from slightly less than 25 to 150 mg/l (milligrams per liter).

Streamflow out of the county averages about 590 mgd. Flow into the Atlantic Ocean is about 225 mgd and the St. Johns River

receives about 365 mgd. The average streamflow is many times larger than the water use for the entire county, but is adequate as a water supply because of the variation in flow. During low-flow periods, streamflow averages less than 5 mgd. The mineralization of the water in the streams is relatively low with the exception of the St. Johns River and the estuarine sections of Tomoka River and Spruce Creek along the Atlantic coast. Under average flow conditions, the mineral content of the water is less than 200 mg/l, the pH about 6 and the color about 300 platinum-cobalt units.

The productive Floridan aquifer underlies the entire county. Movement of water in the aquifer is outward from the central part of the county, west, north and south to the St. Johns River and east toward the Atlantic Ocean. Water levels were slightly higher in 1966 than in 1955, but show no upward or downward trend except in heavily pumped areas. In one such area near Daytona Beach, water levels have declined more than 5 feet since 1955. Mineral content of water from the Floridan aquifer ranges from 100 to 400 mg/l except in the highly mineralized areas along the St. Johns River and the Atlantic coast.

Most high capacity wells in the county withdraw water from the Floridan aquifer for the public supply of areas near the Atlantic Ocean and the St. Johns River. The relatively shallow presence of saline water in these areas limits useful well depths to about 300 feet. Such wells, however, generally yield 1,000 to 1,500 gallons per minute. The depth to saline water in the undeveloped central part of the county is as much as 1,450 feet; thus development of deeper wells in that area should result in higher yields because of the greater available thickness of fresh water in the aquifer. Such development would also have the added desirable effect of capturing recharge water that is currently rejected and lost to the area by runoff and evapotranspiration.

The Floridan aquifer discharges water through large springs along the St. Johns valley. Blue Springs, the ninth largest spring in Florida, has an average flow of 105 mgd and Ponce de Leon Springs has an average flow of 20 mgd. This large volume of water however, is generally unsuitable for public supply. The chloride content of Blue Springs is always greater than the 250 mg/l limit suggested by the U. S. Health Service. During periods of high discharge, Ponce de Leon Springs also exceeds the suggested chloride limit.

INTRODUCTION

Volusia County, an area of 1,200 square miles, is located along the central east coast of Florida, figure 1. In 1965, it ranked fifteenth in rate of growth of the state's 67 counties. The population in 1965 was 157,900, an increase from 1955 of about 60 thousand (Florida Development Commission, 1965). The county's population is expected to continue to increase, causing a commensurate increase in water use. The greatest water use, at present, is along the coast where nearly 60 percent of the population resides.

PURPOSE AND SCOPE

In 1960, a report on the ground-water resources of Volusia County was published by the Florida Geological Survey (Wyrick, 1960). This report, based on an investigation made during the mid-1950's, provided a base for an understanding of the complex hydrologic system within the county but also raised a number of pertinent questions. To further consider these questions and expand the scope of the earlier study to include surface waters and attendant drainage problems, a 3-year investigation of the water resources of Volusia County was begun in August 1964 by the U. S. Geological Survey in cooperation with the Board of County Commissioners of Volusia County and the Bureau of Geology, Florida Department of Natural Resources.

This investigation was intended to: (1) Define the primary areas of recharge to the Floridan aquifer, including the rate and quantity of downward movement of water from the clastic aquifer to the Floridan aquifer and describe the hydrologic system in terms of the effects of physiography, hydrogeology, and rainfall on the occurrence, quantity and movement of water; and (2) evaluate the surface-water resources of the county with respect to quantity, quality, drainage characteristics and surface drainage feasibility. The accomplishment of the above should provide a more comprehensive scientific basis for optimum development of the county's water resources.

To accomplish these objectives, a series of test wells was drilled and hydrologic data from throughout the county were collected and analyzed. Figure 1 shows the locations where hydrologic data were collected on a periodic basis. Descriptions of the sites and types and periods of record are given in table 8 in the Appendix. Miscellaneous hydrologic data were collected at numerous other sites. During the investigation climatic conditions varied from extremely wet to

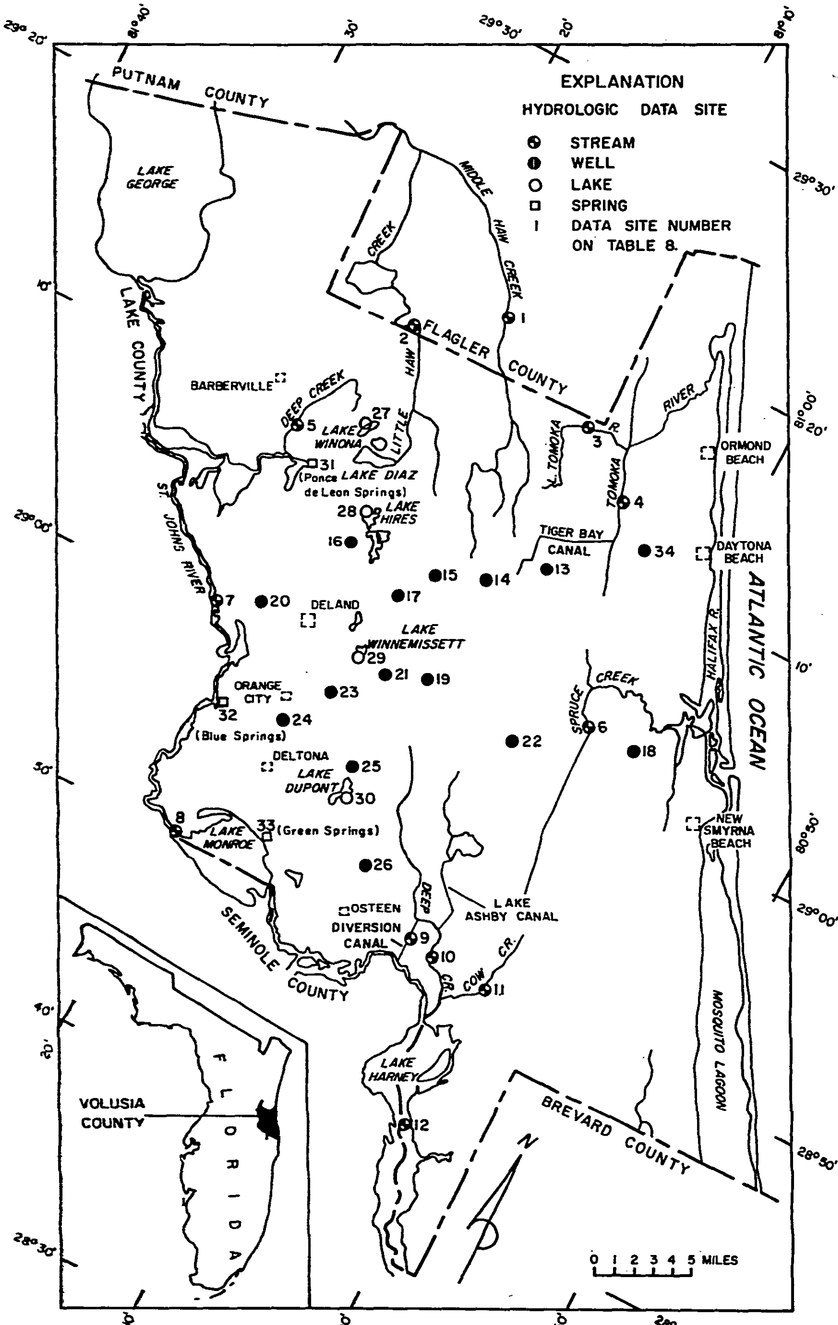

Figure 1. Map of Volusia County showing the location of hydrologic data-collection sites.

extremely dry which permitted observation of the hydrologic system under a wide range of conditions.

This report describes the hydrologic system with reference to the movement of ground water from the clastic aquifer to the Floridan aquifer. The two aquifer systems are described and the influence of geologic faulting on the quality of water in the Florida aquifer is discussed. Surface waters are discussed in terms of the quantity and quality of water in lakes and streams. Water-use trends are predicted for public supply, irrigation, industrial and rural uses. Only minimal information about the St. Johns River is included in this report as a more detailed description of the water resources of the St. Johns is given by L. J. Snell and Warren Anderson (1970).

A report, discussing surface drainage characteristics has recently been published as a result of this investigation (Knochenmus, 1968). Conjunctive use should be made of that report and the current report to provide the basis for optimum water resource development in Volusia County.

ACKNOWLEDGMENTS

Appreciation is extended to the many people of Volusia County who supplied information for the investigation. Thanks are due Thomas Well Drilling Company and Mr. Roger Brooks who supplied information about wells and quality of water and to the city officials who furnished information on municipal water use. Thanks are also extended to county officials, who cooperated in all aspects of the investigation.

HYDROLOGIC SYSTEM

The various environments on, above, or beneath the land surface through which water moves constitute a hydrologic system, and the circulation of water through these environments is known as the hydrologic cycle. The ultimate source of water used by man is rainfall, although water may move into any given political division, such as a county, from outside its boundaries through streams or by underground flow. In Volusia County most of the fresh water in the hydrologic system has originated as rainfall on the County.

PHYSIOGRAPHY

The topography of Volusia County has been described by Wyrick (1960). A generalized picture is of a succession of terraces

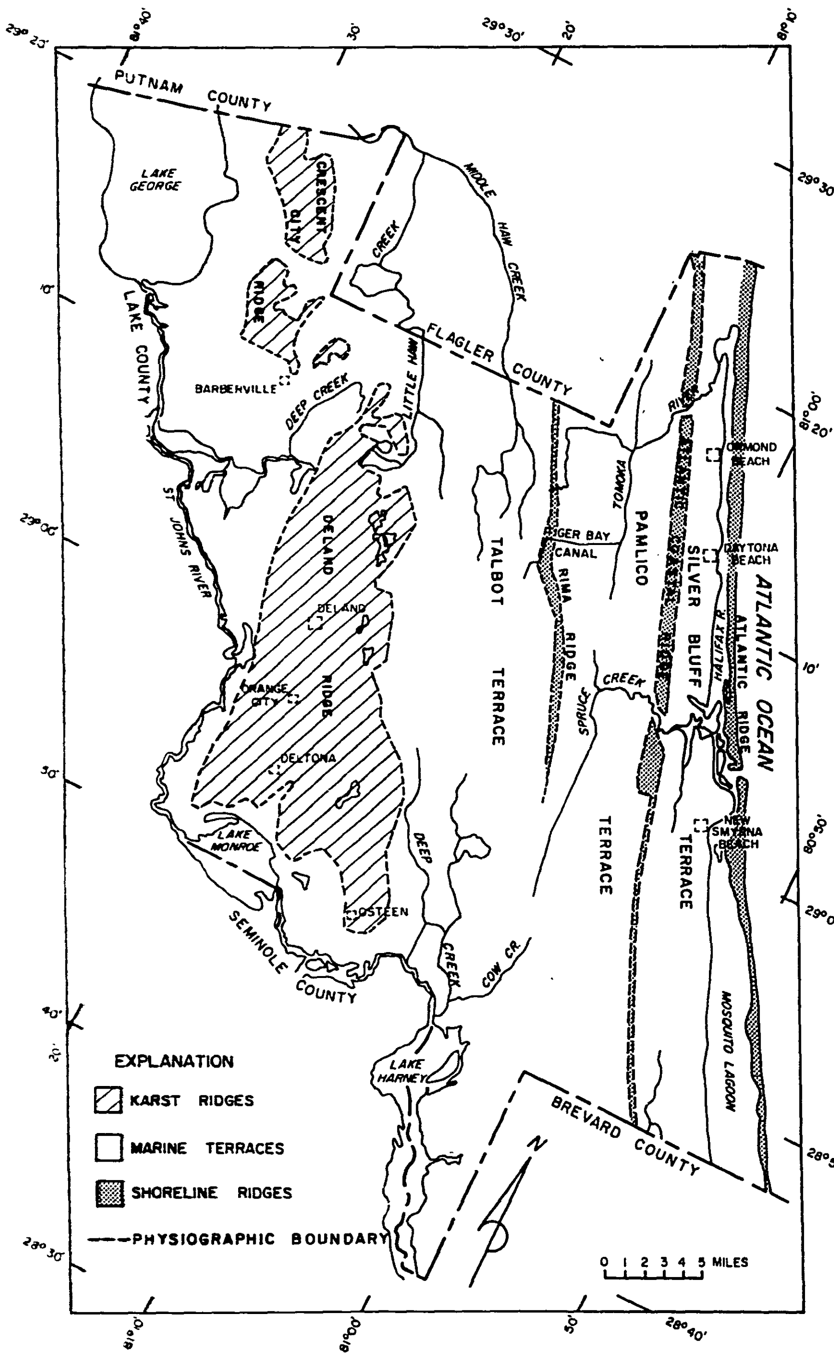

Figure 2. Physiographic features of Volusia County.

that begin at sea level and, progressing westward, rise steplike to an altitude of 100 feet at DeLand, and then drop sharply to almost sea level at the St. Johns River, figure 2.

A classification of the physiographic features into three divisions; karst ridges, marine terraces, and ancient and present shoreline ridges, was adapted from Puri and Vernon (1964).

Karst topography, as exemplified by the Crescent City and DeLand ridges, is characterized by high local relief, sinkhole lakes and ponds, dry depressions, and subsurface drainage. Near Deltona the land is over 110 feet in altitude, whereas nearby, southeast of Orange City, depressions dip to 10 feet above mean sea level. This results in relief of about 100 feet on the DeLand ridge. The county has about 120 lakes larger than five acres with 90 percent located within the karst ridges. On the DeLand ridge most of the lakes are along the eastern and southern edges whereas they occur over the entire extent of the Crescent City ridge.

More water is cycled through the ground-water system from the karst ridges, with their comparatively high relief and good subsurface drainage, than from areas where surface drainage is better developed. These ridges also act as reservoirs for the storage of surface and ground water until it recharges the Floridan aquifer or evaporates.

The marine terraces are poorly drained flat surfaces covered with forest vegetation and are commonly called "flat-woods". Three terraces are shown on figure 2; Silver Bluff terrace at 10 foot altitude, Pamlico terrace at 25 feet, and Talbot terrace at about 40 feet. Numerous swamps and cypress heads occupy shallow depressions which had their origin on the ancient sea floor. A topographic map of the county, figure 3, indicates a youthful surface, flat and poorly drained. Surface drainage on marine terraces is in the first stages of development. Knochenmus (1968) delineated the drainage basins, mapped the runoff distribution and indicated feasibility of drainage of the terraces in Volusia County.

Figure 3. Topographic map of Volusia County.
(In pocket)

Streams on the marine terraces generally flow north or south parallel to the coastline. The beach ridges parallel to the coast (fig. 2), which formed during the building of the terraces, prevent the streams from draining directly to the ocean. One stream system, by taking a longer route to the ocean, can drain an area that would have required many short streams. Many short streams flowing into the ocean might have allowed salt water to move inland in numerous places, whereas only Tomoka River and Spruce Creek now allow salt water to move inland.

The third physiographic division, the shoreline ridge, encompasses a low ridge on the seaward edge of each of the three marine terraces (fig. 2). Rima ridge is a low sand ridge rising 5 to 10 feet above the Talbot terrace; the Atlantic Coastal ridge rises 10 to 15 feet above the Pamlico terrace; and the present Atlantic ridge rises about 10 feet above the Silver Bluff terrace. Rima ridge and the Atlantic Coastal ridge are ancient shoreline ridges whose depositional history is similar to the deposition of the present Atlantic ridge.

The shoreline ridges act as reservoirs for the storage of ground water. The water table beneath the ridges is higher than beneath the adjacent terraces resulting in a more vigorous subsurface circulation and recharge into the limestone in the areas of the ridges.

HYDROGEOLOGY

The geologic materials of Volusia County comprise two major hydrogeologic units, the upper poorly consolidated clastic deposits and the underlying thick sequence of limestone and dolomite, commonly called the Floridan aquifer; both are shown in the fence diagram of figure 4. Wyrick (1960, p. 25) discussed the two major units in terms of the nonartesian and artesian aquifers.

Figure 4. Fence diagram of hydrogeologic sections in Volusia County. (In pocket)

The clastic deposits are made up of poorly consolidated sand, clay, and shell of Pleistocene to Miocene age. They occur as discontinuous, lenticular, and interfingering beds (fig. 4). The material in any given bed may grade from sand to clayey sand to clay, and the shell beds may have a matrix of sand, clay, or both. In general the surface material is fine sand which is underlain by clay lenses and then by shell beds which in turn overlie the limestone except in a few areas near the coast where clay lenses underlie the shell beds.

Under the eastern edge of the Talbot terrace, the sand appears to thicken, and particularly under the Rima ridge the clay is thin or missing (sites 13 and 22, fig. 4). In places the shell beds are as much as 50 feet thick and are comprised of large shells.

Permeability is a measure of the ability of a geologic material to transmit water in response to differences in hydraulic head, or gradient. The movement of ground water between the clastic deposits and the Floridan aquifer is controlled by the permeability of the clastic deposits and the head differential between the units. Because of the lenticularity and discontinuity of the clastic deposits, the rate of vertical movement of water ranges widely. On the basis of cuttings from a few wells it appears that the variation in vertical permeability is as great from site to site within the same physiographic division as between sites within different physiographic divisions. For example, low permeability beds occur at site 16 (fig. 4) on the north end of DeLand ridge and at site 19 on the Talbot terrace, whereas higher permeability beds were found at site 25 on the south end of DeLand ridge and site 14 on the Talbot terrace. Where a confining bed of relatively impermeable clay or sandy clay overlies the Floridan aquifer, the water in the Floridan aquifer is confined. Locally, in areas downgradient from a topographic high where there is an overlying confining bed, water in the shell bed and even in the sand occurs under confined conditions. Such areas occur along Highway 44, on the east side of DeLand ridge and on the west side of Rima ridge (sites 21 and 22, fig. 4).

The top of the Floridan aquifer dips eastward from its high under the DeLand ridge, toward the coast at about 3 feet per mile. Under the terraces the clastic deposits thicken from 65 feet on the eastern flank of the DeLand ridge to 100 feet at the coast. Under the DeLand ridge where the relief is much greater the clastic deposits are 50 to 100 feet thick.

Structually Volusia County is an uplifted fault block (fig. 4). Wyrick (1960, fig. 4) mapped a north-south trending fault west of DeLand and an east-west trending fault on the north edge of Lake Monroe. An extention of a north-south trending fault, mapped by Brown (1962, fig. 9) in Brevard County, cuts Volusia County 5 to 15 miles inland of the coast and completes the fault block.

Most of the water supplies in Volusia County are obtained from the limestone and dolomitic limestones of the Floridan aquifer, which in this area is composed of formations of middle and late Eocene age. A hard, dense, irregular layer of dolomitic limestone acts as a confining bed that divides the aquifer into an upper and lower part (fig. 4). This layer is at depths of 150 feet under the DeLand ridge and 250 feet near the coast. The Floridan aquifer is known to be greater than 600 feet thick in the eastern part of the county, based on data from a 700-foot test hole which did not fully penetrate the aquifer (hydrologic data site 18, fig. 1).

A schematic drawing of part of the hydrologic cycle for Volusia County showing the movement of water to and from the surface, on the surface, infiltrating the surface, and through the subsurface is shown by figure 5.

Figure 5. Block diagram of part of Volusia County showing the movement of water. (In pocket)

Water movement on and under each physiographic division follows a somewhat characteristic path. The terraces are characterized by surface runoff and vertical movement of ground water through the clastic deposits. The ridges are characterized by subsurface drainage and a vertical as well as horizontal component of movement of ground water through the clastic deposits. The water moves laterally through the Floridan aquifer under both the ridges and the terraces but with a component of downward movement near areas of recharge and a component upward movement near the discharge areas (fig. 5).

Under the terraces (fig. 5), the water table is near the surface with a relatively thin unsaturated zone available for storage of water during a rise of the water table. Rain quickly saturates the porous surface sand after which the water can no longer infiltrate and must run off or evaporate. The water which has infiltrated moves downward to the zone of saturation if not used by plants or retained as soil moisture. As the water moves vertically through the clastic deposits it may follow tortuous paths around discontinuous lenses of less permeable material, and continue in its downward movement into the Floridan aquifer. It then moves laterally toward the east where it discharges to the coastal well fields or to the ocean.

As rain falls on the ridges (fig. 5) it infiltrates the sand, and water which is not used by plants or to replenish soil moisture moves down to the water table. The water table generally follows the configuration of the land surface. After it reaches the water table, water moves generally parallel to the slope of the water table to ponds or lakes or to low-lying areas where some seeps to the surface to create the swampy conditions adjacent to the ridges. Ground water moves along the slope of the water table and also downward through the clastic deposits to recharge the Floridan aquifer. The movement of water in the Floridan aquifer under the DeLand ridge is westward toward the St. Johns River. Under the low sand ridges movement of water in the Floridan aquifer is eastward toward the coast.

RECHARGE TO FLORIDAN AQUIFER

A condition where water is confined in an aquifer by relatively impermeable layers is called artesian. The poorly consolidated sediments of the clastic deposits are not highly pervious and tend to retard the downward movement of water. Because water does leak down into the Floridan aquifer, however, it is described as a semi-confined artesian aquifer. At many locations there is no geologic evidence of a confining layer and from water level fluctuations it appears as though the Floridan aquifer is hydraulically connected to the overlying clastic deposits. Hydrographs of water levels in wells at hydrologic data sites 14, 23, and 25 are shown on figure 6. The configuration and water level response to rainfall is very similar for

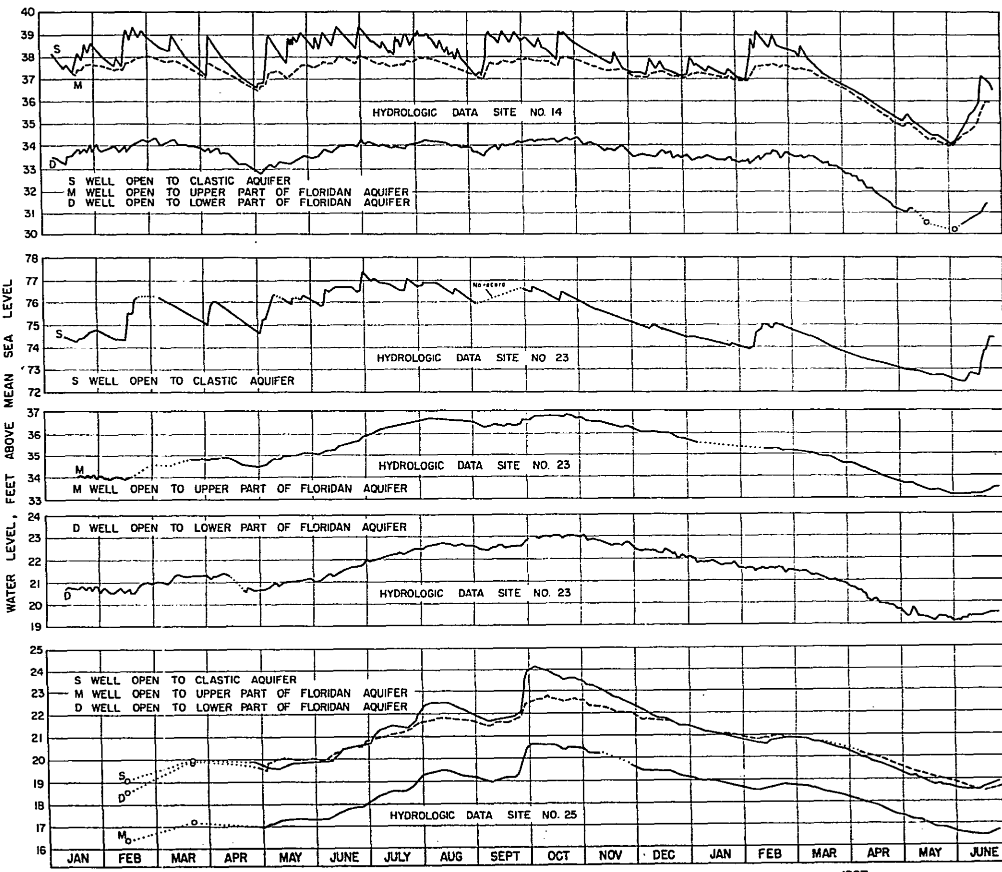

Figure 6. **Hydrographs of water levels in wells at hydrologic data sites 14, 23, and 25.**

the well in the clastic deposits and the well in the Floridan aquifer (data site 14) which indicates a good hydraulic connection between the two units. Hydrographs for wells at hydrologic data site 23 indicate a lesser degree of connection while at site 25 there appears to be a good connection, with water moving downward into the upper part of the Floridan aquifer. At site 25, water is also moving upward into the upper part of the Floridan aquifer from below and, therefore, water must be moving laterally through the upper part of the aquifer.

Water moves downward into the Floridan aquifer wherever the water table in the clastic deposits is higher than the piezometric surface. Piezometric surface, *as used in this report,* means the level to which water will rise in tightly cased wells that penetrate the Floridan aquifer. Ridges which rise above adjacent land are capable of supporting a higher water table and this increased head results in greater leakage from the clastic deposits to the Floridan aquifer, assuming equal permeabilities and thicknesses of material. Where the land surface is relatively low, the piezometric surface is near land surface, which results in less recharge and greater surface runoff. In stream valleys and at low altitude along the coast the wells which penetrate the Floridan aquifer will flow. In these areas, where the piezometric surface is above the land surface (see fig. 18, Wyrick, 1960), there is no recharge to the Floridan aquifer.

Earlier Wyrick (1960, p. 27 and fig. 14) had reached similar conclusions when he stated that recharge to the Floridan aquifer (artesian aquifer) occurs wherever the water table is higher than the piezometric surface. Wyrick (1960, p. 27 and fig. 13) also indicated that the principal area of recharge to the Floridan aquifer in Volusia County was within the closed 40-foot contour along the eastern edge of the DeLand ridge (Penholoway terrace) near DeLand. But the 40-foot contour of Wyrick's map also encloses the western part of the Talbot terrace, where the piezometric surface is presently at about the level of the water table and in many places rises above it. There are areas outside the 40-foot contour where the hydraulic gradient between the water table and piezometric surface is greater and the permeability is as great, and which are thus better recharge areas. No area in Volusia County can be considered the principal recharge area. Visher and Wetterhall (1967) state that in Florida most piezometric highs indicate areas of low permeability and low or rejected recharge. Similar results were reported by Schneider (1964) in his studies of the carbonate rock aquifer of central Israel. Schneider noted that piezometric ridges appeared to coincide with down-faulted blocks or structural basins, regarded as regions of lower permeability than adjacent regions having lower piezometric levels.

The data suggest that the piezometric high areas are not principal recharge areas in Volusia County.

Under present hydrologic conditions, the most productive recharge areas are the eastern part of the Talbot terrace and the ridges. There is a relatively good hydraulic connection between the clastic deposits and Floridan aquifer under most of the Talbot terrace, with a greater head between the two hydrogeologic units in the eastern part of the terrace than in the western part, resulting in a better recharge area in the former. The western part of the terrace has good recharge potential, provided a sufficient head differential were maintained, either by lowering the piezometric surface or by raising the water table.

The ridges are good recharge areas mainly because of their topographic relief. In general, the ridges have as good a hydraulic connection as the terraces, however, along the eastern edge of the DeLand ridge, in the area east of DeLand coinciding with the 40-foot piezometric contour, the clastic deposits have lower permeability. This area of lower permeability is reflected by the line of lakes whose water surfaces stand relatively high above the piezometric surface. The lake level at data site 29 (fig. 1) is as much as 18 feet above the piezometric surface. A greater head compensates for an otherwise lower recharge through the less permeable material. Lakes themselves are probably no better points of recharge than the surrounding lake basin. The lakes are shallow, 20 feet or less in depth, and their bottoms are not incised into the aquifer, therefore, it is the material between the lake bottom and the aquifer that controls the movement of water to the aquifer.

Areas of little or no runoff as shown on a runoff distribution map (Knochenmus, 1968) coincide generally with the areas of higher recharge. Areas where the piezometric surface is at or above the water table (discharge areas), exhibit the highest runoff.

RAINFALL

Local rainfall is the source of Volusia County's fresh-water. The average (normal) annual rainfall on Volusia County for the period 1931-60 was 52 inches, or about 3,000 mgd (million gallons per day), based on records collected by the U. S. Weather Bureau at Daytona Beach Airport and DeLand. Only a small part, about 10 percent, of this water is readily available for use by man. Average annual rainfall of the two stations during the period of record ranged from a maximum of 74 inches in 1953 to a minimum of 38 inches in 1954. This large annual variation in rainfall is shown on figure 7.

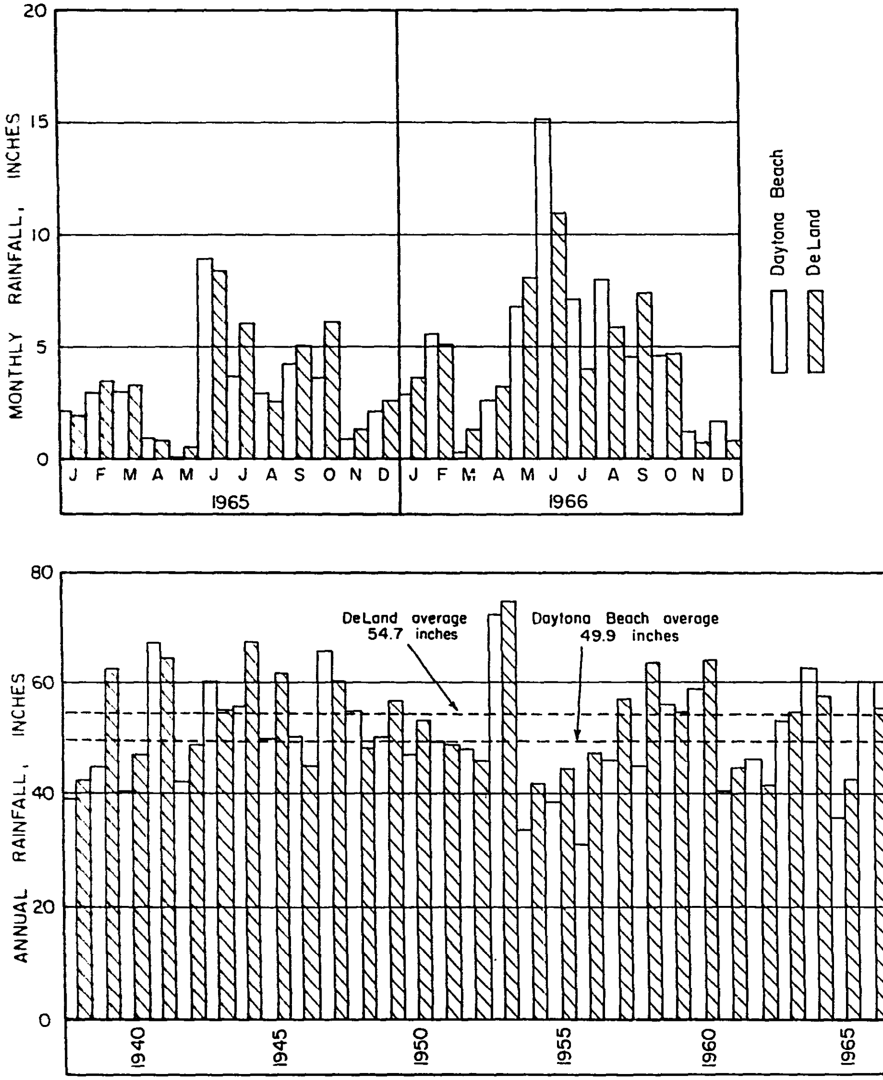

Figure 7. Monthly and annual rainfall at Daytona Beach Airport and DeLand.

The period of investigation included a year of dry conditions (1965) and a year of slightly wetter than normal conditions (1966). Although 1966 was an exception, the western part of the county generally receives more rain than the eastern part. For the long term record, the yearly average at DeLand is 4.8 inches more than at Daytona Beach Airport. In 1965, DeLand received 6.5 inches more rain than Daytona Beach Airport, but in 1966 DeLand received 5 inches less than Daytona Beach Airport. The five summer months (June-October) generally receive 65 percent of the annual rainfall.

The chemical quality of rain varies slightly with weather conditions and with industrial and agricultural activities. Generally, rain contains small amounts of dissolved mineral matter and atmospheric gases. The mineral matter is derived from windborne salts picked up from the open sea or from the land. If the salts are from the sea, the chemical character of the rain is somewhat similar to a diluted sea water with NaCl (sodium chloride) being the predominant constituent. In contrast, when the windborne salts originate from the land the chemical character of rain becomes that of a $CaHCO_3$-$CaSO_4$ (calcium bicarbonate-calcium sulfate) type water.

The amount of dissolved mineral matter in rain varies with the amount of rainfall. At the beginning of a storm the amount of windborne dust is relatively great and the rain washes this dust from the air resulting in higher concentrations of dissolved salts in the precipitation. As the storm continues, the dust is removed from the air and the remaining rainfall is lower in dissolved salts content.

The average dissolved mineral content of rainfall for Volusia County is probably no more than 25 mg/l (milligrams per liter). This value is deduced from the dissolved solids content of several small lakes which have small, closed drainage basins and whose source of water is rainfall and seepage from the relatively insoluble surficial deposits within the basin. Additionally the average dissolved mineral content of rainfall at Ocala, in inland central Florida, and at various sites along the west coast of central Florida is generally no more than 25 mg/l.

Rainfall is slightly acid because of the solution of atmospheric CO_2 (carbon dioxide) in water droplets, resulting in the formation of H_2CO_3 (carbonic acid). Also, industrial operations may add gases to the atmosphere which can produce acids when dissolved in water. The median pH value of the rainfall in Volusia County is about 6.

WATER RESOURCES

The quality and quantity of water in lakes, streams, and aquifers dictates the usefulness of the water from that particular source.

Water changes in chemical quality while moving through the several environments that constitute the hydrologic cycle. Many of these changes are significant and studies of them add to the understanding of the hydrologic system and permit a more comprehensive evaluation of the water resources. Therefore, a discussion of the chemical processes which affect water quality in Volusia County is included in the discussions of lakes, streams and aquifers which follow.

SURFACE WATER

LAKES

The numerous lakes of the County act as storage reservoirs for water. Most of the 120 lakes larger than 5 acres are located on the DeLand ridge where they occupy sink holes. The largest is Lake Diaz with a surface area of 700 acres.

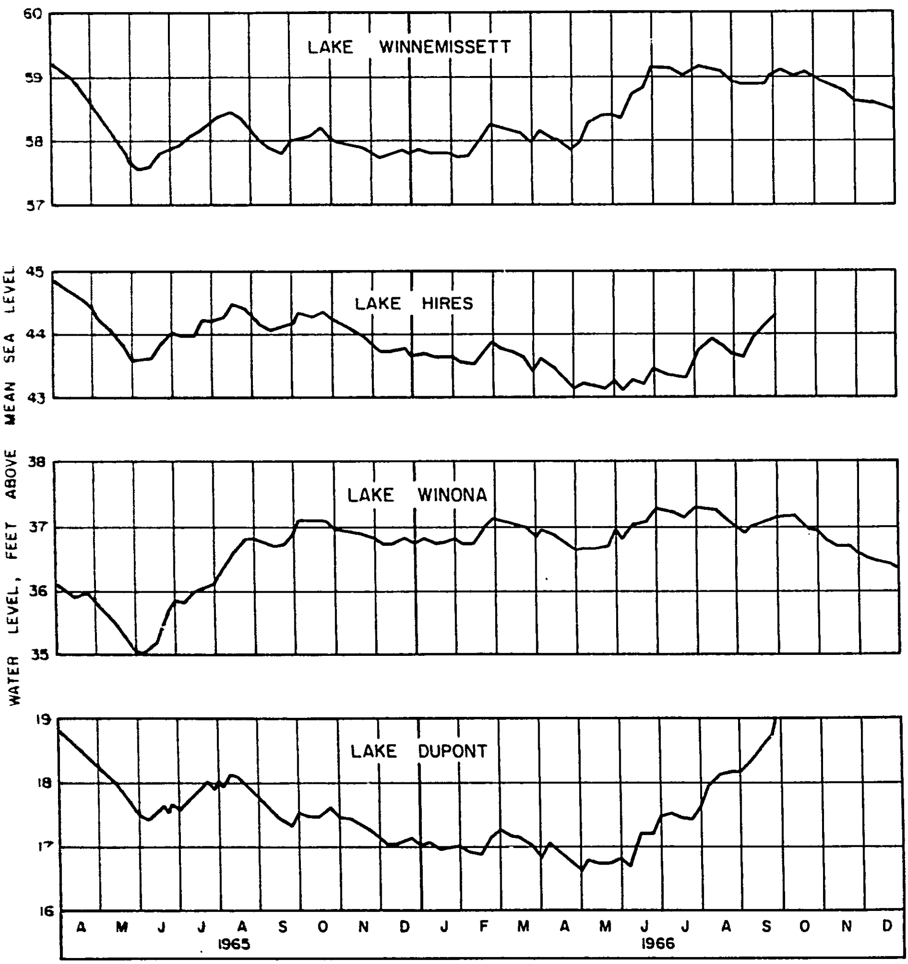

Figure 8. Hydrographs of daily stage for four lakes in Volusia County.

Because of their size, purity and small range in surface level fluctuation, a number of lakes on the DeLand ridge have excellent recreational potentials. At the present time, however, they are used mostly for irrigation water supplies. Most lakes are along the eastern edge of the ridge where the highest water table occurs. Hydrographs of four lakes are shown on figure 8. Lake Winona (site 27, fig. 1), at the north end of the DeLand ridge, had a water level fluctuation of 2.3 feet during the period of this investigation. The level of the lake is approximately 5 feet above the piezometric surface of the Floridan aquifer. Lake Hires (site 28, fig. 1), four miles to the south had a fluctuation during the period of 1.8 ft.; its surface is about 7 feet above the piezometric surface. Six miles farther south, Lake Winnemissett (site 29, fig. 1), one of the higher lakes on the ridge had a fluctuation of 1.7 feet and its surface is approximately 18 feet above the piezometric surface. At the south end of the ridge, Lake Dupont (site 30, fig. 1) had the greatest fluctuation of the four lakes (2.9 feet), and it is about at the level of the piezometric surface.

The lakes appear to be water table lakes and thus are related to the piezometric surface in the same manner as the water table is related to the piezometric surface. Lake Dupont has, as has the water table in that area (site 25, fig. 6), a better hydraulic connection to the Floridan aquifer than Lakes Winona, Hires and Winnemissett. The greater fluctuations of the water surfaces in Lake Winona and Dupont are probably due to greater fluctuations of the water table in the area surrounding the lakes, which in turn are related to the greater relief in the area.

Water in most lakes in the county has a low mineral content with mineralization ranging from slightly less than 25 mg/l to 150 mg/l. Many of the lakes are in closed drainage basins where urban and agricultural development are minimal. Lake water in this environment usually contains less than 50 mg/l total dissolved solids and is similar to the quality of rain water. In contrast, some lakes on the ridge area in large actively farmed drainage basins contain water with as much as 50 mg/l dissolved solids and of a different chemical character than other lakes in the county. Table 1 shows chemical analyses from Lake Dupont in a relatively undeveloped area and Lake Winnemissett located in an area of considerable agricultural activity (more than 50 percent of the basin is under cultivation). Lake Winnemissett contains about five times the amount of dissolved mineral matter as Lake Dupont. Pfischner (1968) has shown that the dissolved solids content of lakes in southwest Orange County, Florida, is generally related to the percentage of the lake basin covered by citrus groves.

Table 1. – Comparison of chemical analyses of Lake Winnemissett and Lake Dupont.

Chemical analyses, in milligrams per liter

Date of collection	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved Solids		Hardness as $CaCO_3$		Specific Conductance (micromhos at 25 °C)	pH	Color
												Residue at 180 °C	Calculated	Calcium-Magnesium	Non carbonate			
Lake Winnemissett near DeLand, Fla. (site 29, fig. 1)																		
5-11-65	0.0	0.00	18	6.3	10	7.5	8	61	20	0.0	0.9	–	128	71	64	230	6.4	5
Lake Dupont near Lake Helen, Fla. (site 30, fig. 1)																		
5-18-65	0.0	0.04	1.2	0.9	5.5	0.3	2	4.8	9.5	0.1	0.2	–	24	6	5	55	5.7	0

STREAMS

Important aspects in considering a stream as a potential water supply are the quantity, quality, and associated variations in flow and quality of its water, and the storage capabilities of the stream channel. The average rate of flow of the two largest streams wholly within the county, Deep Creek near Osteen (130 mgd) and Tomoka River (100 mgd), is more than the predicted water use for the entire county in 1980, but they are inadequate as a water supply because their minimum flows are so small. Less than 5 million gallons per day flows out of Volusia County in streams during dry periods.

From a water use viewpoint, storage facilities would be necessary to insure a dependable surface-water supply during minimum flow periods. Natural channel storage is small in the poorly defined channels but large capacity storage reservoirs could be constructed on the swampy flood plains of the streams. Such storage facilities could be an earthen-diked reservoir, shallow in depth with a relatively large surface area where evaporation would be at a maximum.

Water in the streams comes from direct runoff during rains, flow out of swamps and seepage from ground water. Ground-water seepage and swamp drainage supply base flow during the periods between rains. During dry spells, when swamps desiccate, base flow is supplied entirely by ground water. Most of the ground-water contribution to base flow comes from the poorly consolidated clastic deposits. Even in those areas of upward seepage from the Floridan aquifer, particularly in the western part of the county such as Deep Creek near Barberville and the other Deep Creek near Osteen, the chemical quality of the stream water indicates that very little seepage from the Floridan aquifer reaches the stream channels.

Water leaves the county in streams at an average rate of about 590 mgd. About 225 mgd flows into the Atlantic Ocean from Tomoka River, Spruce Creek and smaller streams. St. Johns River receives about 365 mgd from Deep Creek (Osteen), Middle Haw Creek, Little Haw Creek, and Deep Creek (Barberville). Streamflow data are given in table 2. The values of streamflow, except those for Spruce Creek, are estimated from continuous discharge records or from periodic discharge measurements. Based on the data in table 6, over 20 times more water flows out of the county than is presently used (see section on water use below) but the variation in flow limits streamflow as a reliable source of water supply.

The magnitude of flow of the major streams is shown on figure 9. The highest rate of flow (average 130 mgd) of streams draining the county is from Deep Creek basin (Osteen) – a runoff of 17 inches

Table 2. – Drainage areas, average flows, and low flows of subbasins in Volusia County.

Creek basin	Drainage area sq. mi.	Average flow mgd	Low flow mgd
Deep Creek (Osteen)	157	*130	0.4
Tomoka River	121	**100	.4
Spruce Creek	96	50	.3
Cow Creek	28	50	0
Middle Haw	41	30	0
Little Haw	61	30	0
Deep Creek (Barberville)	39	25	0
Little Tomoka	15	10	0
All Others	–	225	–

* Includes flow of Cow Creek

** Includes flow of Little Tomoka

per year. Flow in the St. Johns River at DeLand averages 2,100 mgd – far greater than that of any stream within the county.

Certain areas of the County, such as the DeLand, Crescent City, Rima, and Atlantic Coastal ridges, have poorly developed surface drainage systems. The runoff from these areas is from 0 to 6 inches per year (Knochenmus, 1968).

Profiles of the water surface of Volusia County streams show flat gradients in their upper reaches with steepening gradients downstream. Two profiles for Deep Creek (Osteen), one at high flow and the other at low flow, during 1966 are given in figure 10. The fluctuation of the water surface in the swampy headwaters was less than a foot while the level fluctuated 4½ feet near the mouth. Rain falling on the swampy headwaters causes the water surface to rise about the same as the depth of rainfall, whereas downstream the runoff is collected into a definite channel and the water surface may rise many times the depth of rainfall.

Stream flood plains in the county are largely flat swampy areas and become inundated almost every year. The poorly incised channels cannot transport the excess water during wet periods so that water ponds in the swamps and inundates much of the area. The floods on most streams were extremely high in 1964. The peak discharges of Spruce Creek and Middle Haw Creek during the floods of 1964 were determined from curves published by Barnes and

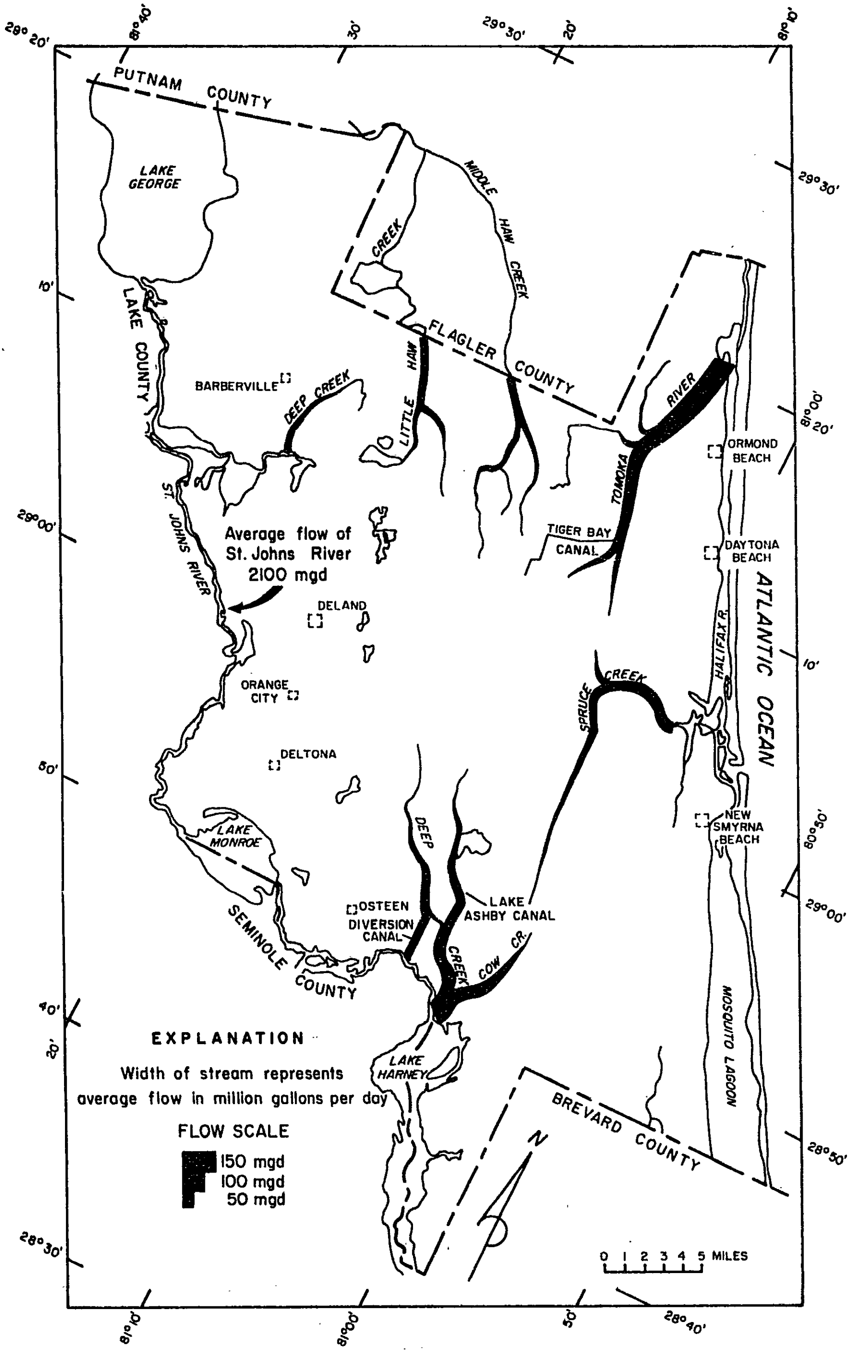

Figure 9. Flow chart of streams in Volusia County.

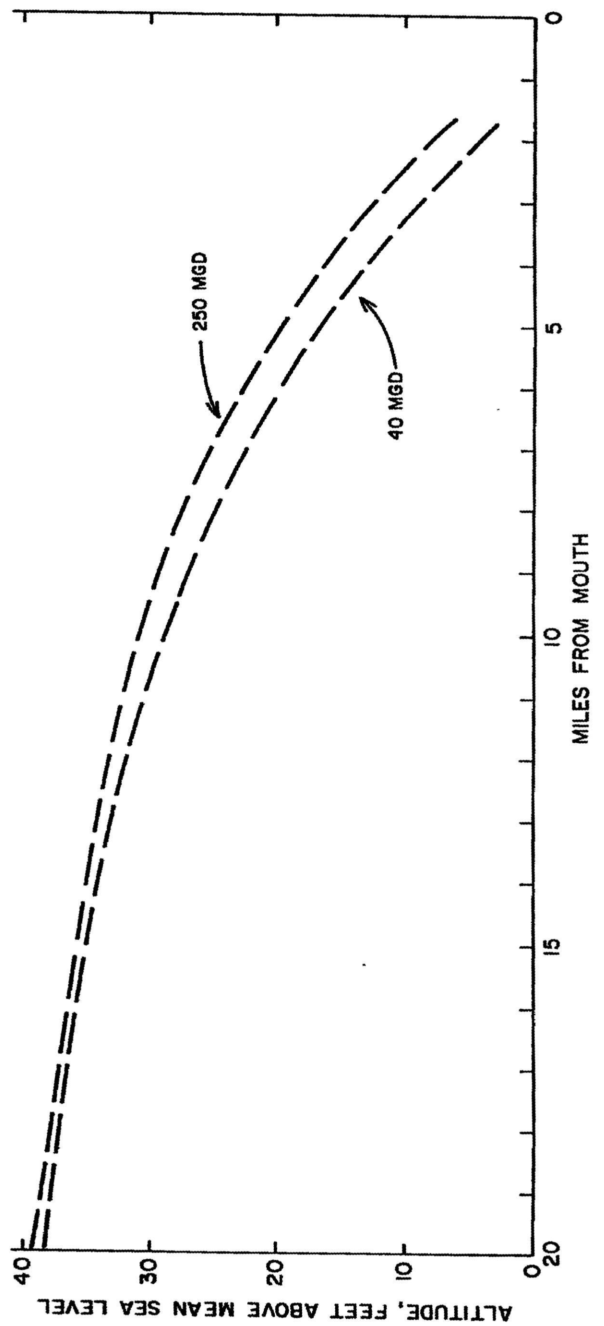

Figure 10. Water surface profiles of Deep Creek (Osteen) for high and low discharges.

Golden (1966) to be greater than 50-year floods, whereas the peak discharges of Tomoka and Deep Creek (Osteen) were greater than 20-year floods.

Runoff characteristics of different streams can be compared by analyzing their flow-duration curves, figure 11. Flow-duration curves show the percent of time during which specified discharges are equaled or exceeded. All the curves are similar in shape with the exception of the lower end of the curve for Spruce Creek. The slopes of all the curves are steep indicating little channel storage and ground-water contribution. The high-discharge end represents mostly overland flow (direct runoff) and the low-discharge end represents ground-water seepage. The low end of the Middle Haw curve is very steep, approaching the vertical, which indicates very little ground-water seepage. The Middle Haw Creek basin is flat with a very shallow stream channel; therefore, with a small lowering of the ground-water level, the water-table falls below the stream bed. With no ground-water seepage to sustain base flows, Middle Haw Creek decreases from medium flow to zero flow very rapidly. Streams with steeply sloped duration curves are characterized by maximum flows 100 times greater than median flow (50 percent line on duration curve). Median flows for Spruce Creek, Middle Haw Creek, Tomoka River and Deep Creek (Osteen) are 4.6, 18, 23, and 39 mgd respectively. About 15 percent of the time Middle Haw Creek has no flow whereas about 15 percent of the time Deep Creek has slightly more than 3 mgd flow.

The water in streams in Volusia County has widely differing chemical characteristics, depending on the source of the water. Some streams, especially during low flow, receive discharge from the Floridan aquifer by seepage and from flowing wells. In the lower reaches of streams near the coast the chemical quality of the water reflects mixing with highly saline ocean water.

The waters range from only slightly mineralized to ocean salinity, from colorless to highly colored, and from acidic to basic. Values of some of the more important water-quality constituents at surface-water data sites (fig. 1) are listed in table 3.

Most streams in Volusia County are supplied by direct rainfall, overland flow, and seepage from the clastic deposits. The quality of the water varies not only because the quality of the rainfall varies, but because most of the water has moved over or through the ground, dissolving mineral matter and transporting it to the streams.

Mineral matter derived from the breakdown or weathering of organic and inorganic materials, application of fertilizers, and

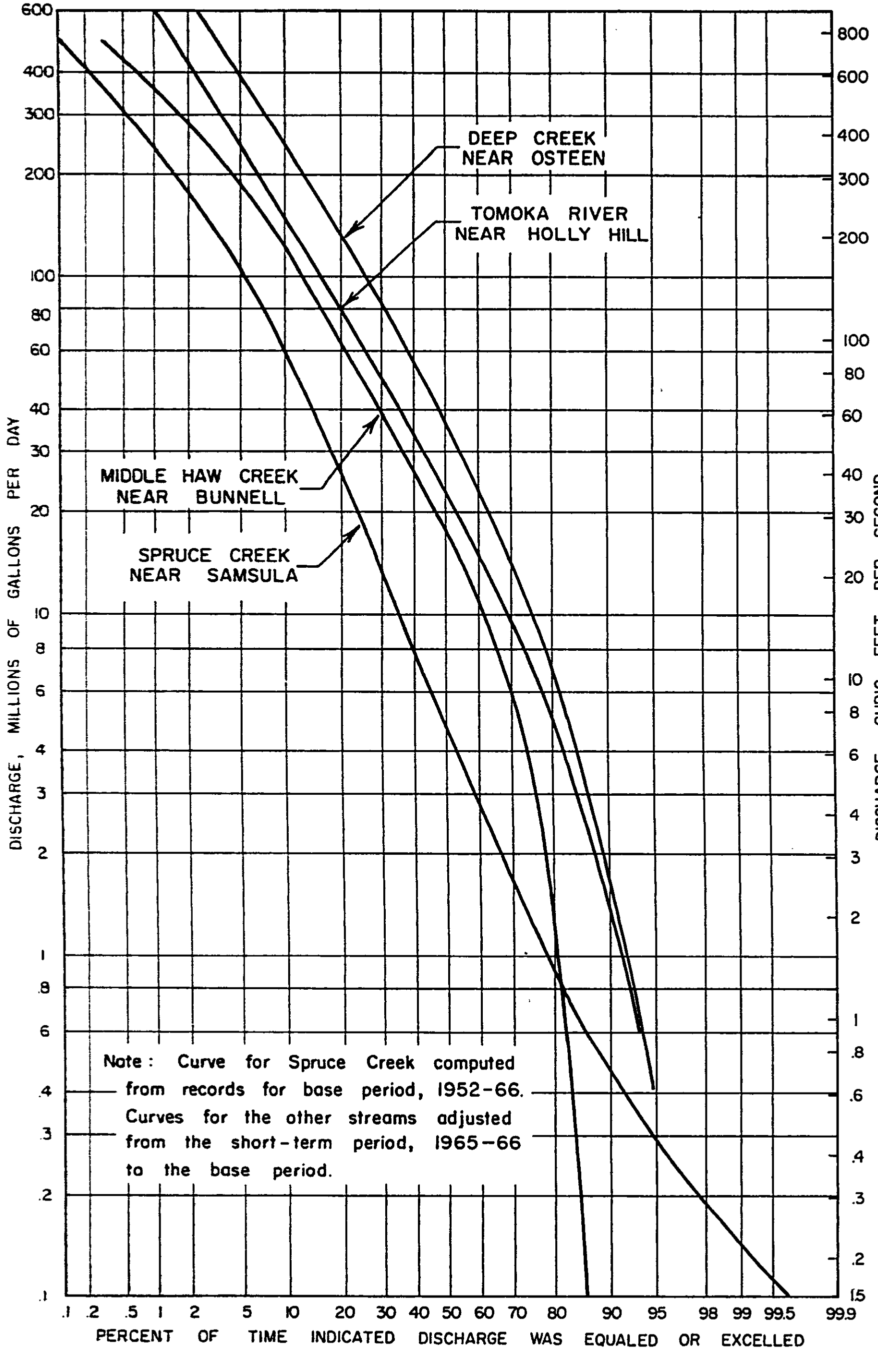

Figure 11. Flow duration curves for major streams in Volusia County.

Table 3. — Selected chemical characteristics of surface waters in Volusia County.

Station Name	Data Site, (fig. 1)	Color (units)		Dissolved Solids (mg/l)		Total Hardness (as mg/l $CaCO_3$)		Chloride (mg/l)		Sulfate (mg/l)		pH (units)	
		Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
Middle Haw Creek	1	360	180	35	22	12	6	21	8.0	4.0	0.0	5.4	4.4
Little Haw Creek	2	450	170	39	29	22	10	19	9.0	6.4	.0	6.2	5.1
Tomoka River	4	400	120	197	77	138	47	36	18	13	5.0	7.7	6.4
Deep Creek (Barberville)	5	800	30	790	43	307	18	305	12	9.2	.0	7.5	5.3
Spruce Creek	6	400	40	437	55	310	42	74	20	9.6	4.0	8.5	6.0
St. Johns River	7	270	30	1,090	120	313	44	505	52	153	11	7.5	6.6
Deep Creek (Osteen)	10	260	75	88	28	50	11	21	6.5	21	3.6	7.3	6.2
Lake Winnemissett	29	5	0	129	120	71	63	24	18	61	56	6.5	6.4
Lake Dupont	30	5	0	24	24	9	6	9.5	9.5	4.8	4.0	5.7	5.7

atmospheric fallout accumulates on the ground between periods of rainfall. The amount of accumulation depends partly on the length of the period between rainfalls. Thus, longer periods between rainfalls allow greater amounts of mineral matter to accumulate. Hence, the overland flow after periods of infrequent rainfall usually contains greater amounts of dissolved mineral matter than flow during periods of more frequent rain.

The amount of dissolved mineral matter in overland flow also depends upon the duration of the storm. Initially, storm runoff contains relatively large amounts of dissolved mineral matter because the rain "washes" the surface of the ground and removes much of the soluble mineral dusts. However, as the storm continues the amount of readily soluble mineral dust decreases so that the overland flow contains less dissolved mineral matter.

Variations in chemical quality for a stream whose source is direct rainfall, overland flow and seepage from the shallow ground water is exemplified by Deep Creek in southern Volusia County. Data collected on this stream at a station near Osteen exhibits the rainfall-discharge-mineral content relationship described. Figure 12 shows hydrographs of daily rainfall, discharge, specific conductance (a measure of the ability of water to conduct an electic current, which is a function of the amount and type of ions in the water and thus can be used to estimate the dissolved solids content of the water) and temperature of streamflow for Deep Creek. During prolonged rainy periods following long dry periods (start of the rainy season in June 1965), discharge increases in response to rainfall while specific conductance increases initially with increased discharge but decreases with continued rise in discharge. The hydrograph also shows that the specific conductance is generally lower during periods of frequent rainfall (July 5 to August 20) and higher during periods of drought (May 1-25).

The dissolved solids duration curve in figure 13 shows that although there is some variation in values for Deep Creek, the minimum and maximum values are relatively low. The minimum dissolved solids content observed during the 2-year period of record is 28 mg/l while the maximum content is only 135 mg/l. The flat curve suggests that most of the water comes from a single source and the chemical quality shows that the water comes from the clastic aquifer which is composed of slightly soluble materials. Very little seepage from the Floridan aquifer reaches the creek, as indicated by the relatively low dissolved solids content.

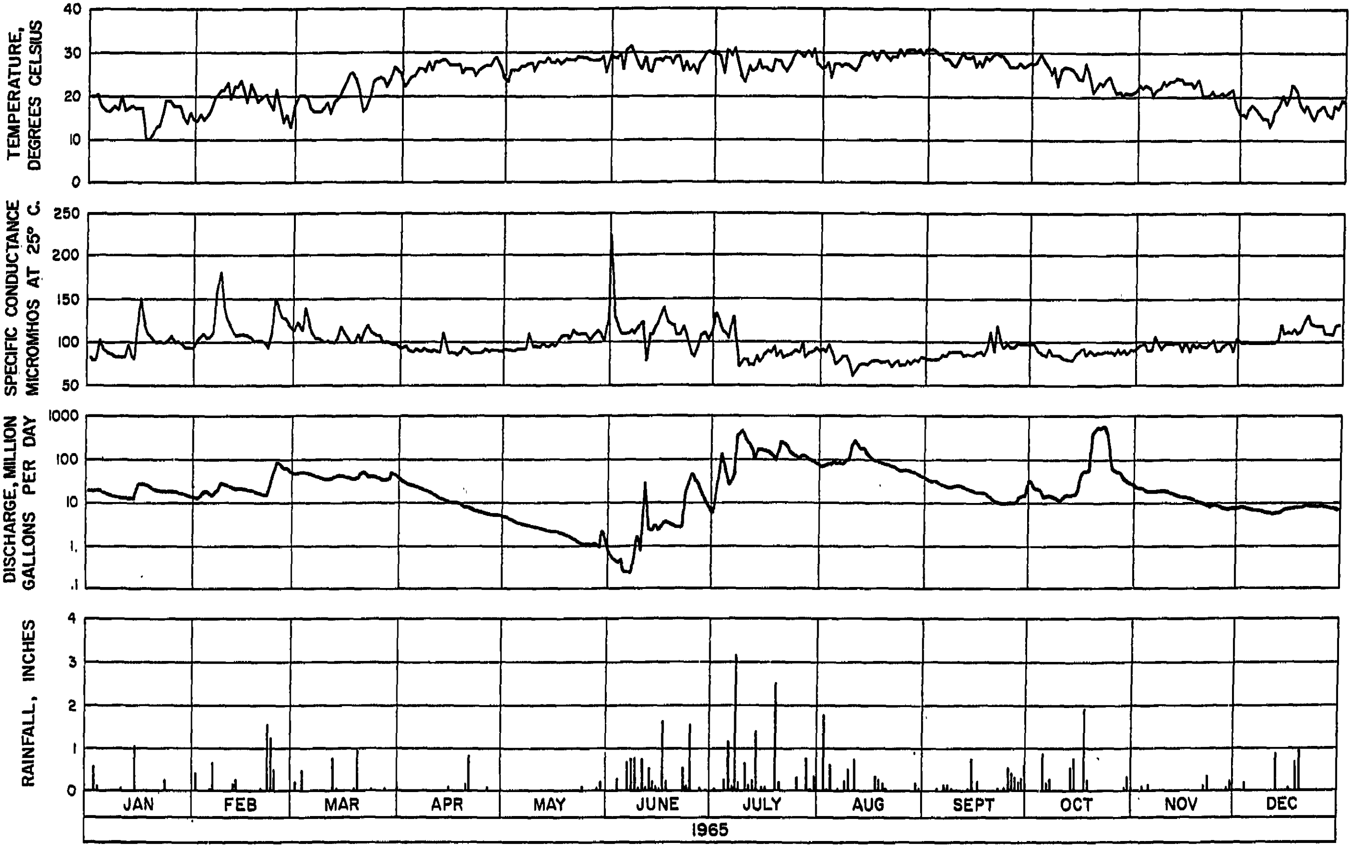

Figure 12. Hydrographs of temperature, specific conductance, streamflow, and rainfall for Deep Creek near Osteen, 1965.

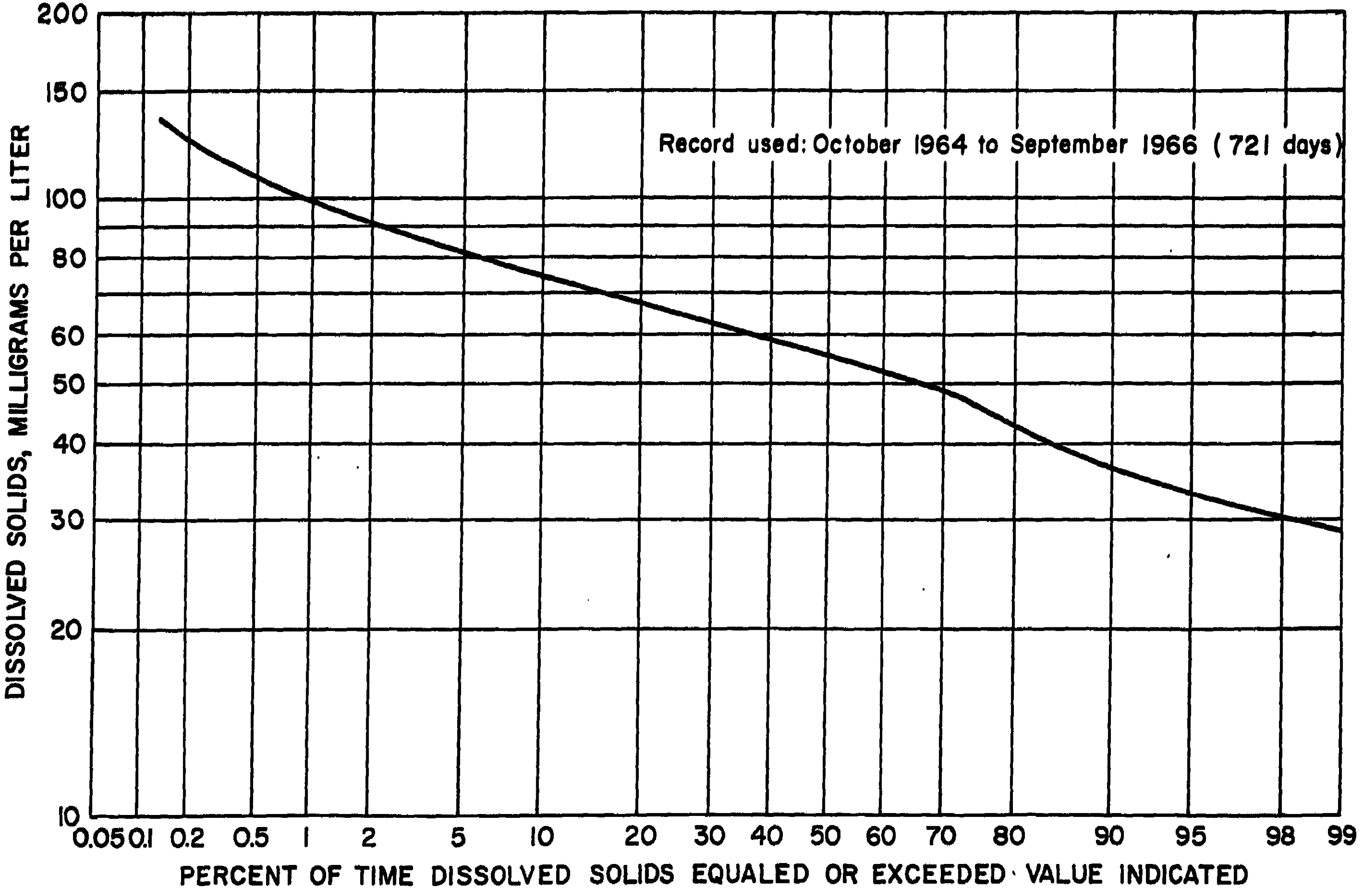

Figure 13. Dissolved solids duration curve for Deep Creek near Osteen.

Stream temperature is closely related to air temperature and subject to seasonal variation. Stream temperatures may rise or fall after precipitation depending upon the relative temperatures of the streams and of the precipitation; during the warm seasons stream temperatures usually decrease after a rainfall because of the cooling effect of the rain. This relationship is shown on figure 12. The average temperature for Deep Creek during this study was 23°C (73°F).

Color and acidity increase after rainfall because rain flushes highly colored and acidic organic materials from the surface. Color is highest during the warm seasons and lowest during the spring drought period. Three analyses of water from Deep Creek having low, medium, and high concentrations of dissolved solids are shown in milliequivalents per liter in figure 14. In an analysis expressed in milliequivalents per liter, unit concentrations of all ions are chemically equivalent. Figure 14 shows that the relative proportions of the constituents remain the same in each of the analyses and that the only major change in chemical quality is in the total amount of dissolved mineral matter.

The quality of the water in streams that intercept significant seepage from the Floridan aquifer reflects the influence of the limestone of that aquifer and, in some cases, the influence of saline water discharged from the deeper part of the aquifer. The St. Johns River apparently receives discharge from the part of the Floridan aquifer which contains salt water. This discharge results in high concentration of dissolved solids in the river except during periods of high flow. The average dissolved solids content for the St. Johns River near DeLand is about 700 mg/l and ranges from 120 mg/l to 1,090 mg/l. The water is highly colored and ranges from slightly acidic to slightly basic.

Middle Haw and Little Haw Creeks exhibit chemical characteristics similar to that of Deep Creek near Osteen. These streams are slightly mineralized, highly colored, and slightly acidic. During low flows Deep Creek near Barberville, and to some extent Spruce Creek, exhibit chemical characteristics similar to the St. Johns River. These streams are moderately mineralized, slightly colored, and range from slightly acidic to slightly basic.

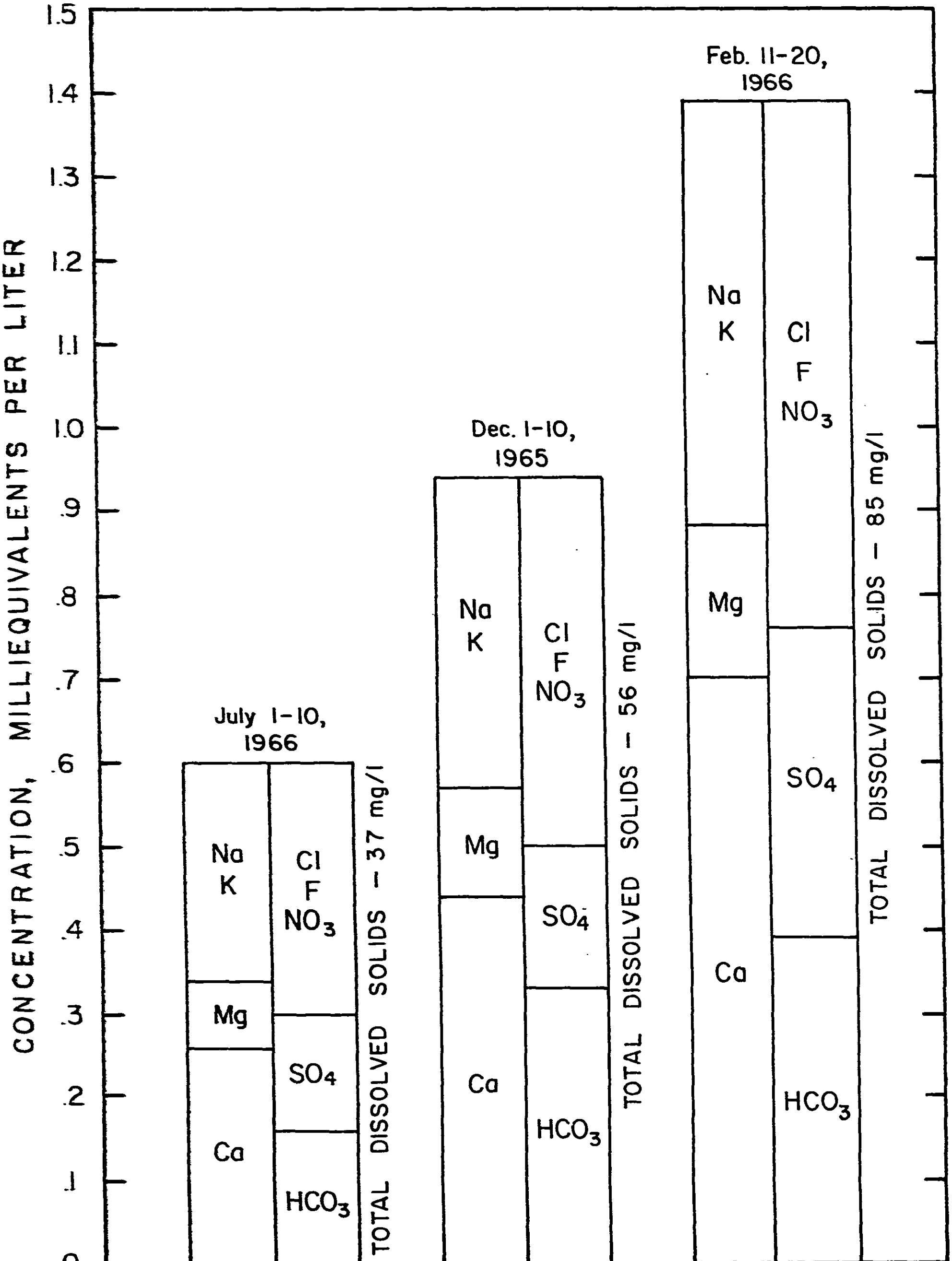

Figure 14. Chemical analyses of selected composites of samples from Deep Creek near Osteen showing relative proportions of major mineral constituents.

GROUND WATER

A description of the aquifers and their hydraulic characteristics has been presented by Wyrick (1960). During the present investigation of the aquifer systems emphasis was on the determination of the rate and quantity of vertical movement of water (recharge) from the clastic aquifer to the Floridan aquifer.

The hydrogeologic units as described previously are differentiated on the basis of their composition and their prime function in the hydrologic system. The poorly consolidated sediments of the clastic aquifer (Wyrick's nonartesian aquifer) functions primarily as a subsurface reservoir that stores water until some of it leaks into the Floridan aquifer (Wyrick's artesian aquifer).

The limestones and dolomites underlying the clastic aquifer constitute a much larger reservoir as the thickness of the Floridan aquifer is greater than 600 feet compared to about 75 feet for the clastic aquifer. The Floridan aquifer readily transmits water and is a major water supply source (Wyrick, 1960, p. 25).

CLASTIC AQUIFER

The clastic aquifer is composed of poorly consolidated sand, shell and clay. The clay in some areas functions as an aquitard (a less pervious formation) in separating the sand from the shell and in other areas in separating the clastics from the limestone (fig. 4). The sand is predominantly fine grained and has a porosity of about 35 percent. It has a coefficient of storage, based on the coefficient of storage of similar material, of about 0.25 or approximately equal to the specific yield. The shell beds, which have a sand matrix contain large quantities of water but they are seldom utilized for a water supply because sand free water can be obtained only if a well screen is employed. In the vicinity of Oak Hill where the Floridan aquifer water is not potable because it contains 400-2400 mg/l chloride, potable water is obtained from shell beds for domestic use.

The present (1969) use of water from the clastic aquifer is small compared to the amount of water it has in storage. From an average storage coefficient and saturated thickness, the aquifer is estimated to contain 3 x 10^{12} gallons of fresh water. To this large volume of water, it is estimated that an average of 400 million gallons are added daily from rainfall for subsequent recharge to the Floridan aquifer. The clastic aquifer will continue to function primarily as a storage reservoir for recharge to the Florida aquifer until techniques of well-screen installation and well development in fine sand and shell beds come into common usage locally.

Fluctuations of the water table in the clastic aquifer were recorded in several shallow wells. The hydrographs of three of these wells open in the sand show a maximum fluctuation of 5 to 5.5 feet (fig. 6). The water table responds to rainfall and the closer the water table is to the land surface the more responsive it is to rainfall. This is shown by the degree of unevenness of the clastic aquifer hydrographs in figure 6. At site 14, where the water table fluctuates between 1 and 6 feet below the land surface, the hydrograph is most uneven, whereas at site 25, where the water table is between 12 and 17 feet below the land surface, the hydrograph is the smoothest.

Water in the clastic aquifer is less mineralized than that in the Floridan aquifer (table 4) because of the lower solubility of the sand. The mineral content of water from shallow wells in the sand ranges from 25 to 50 mg/l and is higher in the shell beds due to the higher solubility of the shells. The principal dissolved mineral constituents in water from the clastic aquifer are sodium, chloride, calcium and bicarbonate.

FLORIDAN AQUIFER

The hydraulic characteristics of the Floridan (artesian) aquifer, as reported by Wyrick (1960) are coefficients of transmissibility[1] that range from 28,000 to 370,000 gallons per day per foot and a storage coefficient[2] of about 0.0007. Water level measurements made during the present investigation were used to construct a map showing the configuration of the aquifer's piezometric surface in November 1966, figure 15.The 1966 map is in general similar to the 1955 piezometric map (Wyrick, 1960, fig. 13) but there are some significant differences. The greatest difference is the portrayal on the 1966 map of a large piezometric low which is less than 10 feet above mean sea level and extends northeast from Blue Springs to DeLand. This piezometric low is a cone of depression that is caused in part by the discharge of Blue Springs. The cone of depression is elongate to the northeast of the spring. The elongation is caused by a preferred direction of permeability (fig. 15), probably a result of faulting. Additional asymmetry resulted when the natural cone coalesced with the cone of depression of DeLand's municipal wells.

[1] The rate of flow of water (in common U. S. Geological Survey units) in gallons per day, at prevailing temperature, through a vertical strip of aquifer one foot wide and having a height equal to the thickness of the aquifer, under a unit hydraulic gradient.

[2] The volume of water released from or taken into storage per unit volume of aquifer per unit change in head.

Table 4. – Comparison of ground water quality at various depths in Volusia County.

Chemical analyses in milligrams per liter

Hydrologic Data Site [1]	Well Number [2]	Depth of well (ft)	Date of collection	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved Solids		Hardness as $CaCO_3$		Specific Conductance (micromhos at 25 °C)	pH	Color
															Residue at 180 °C	Calculated	Calcium-Magnesium	Non carbonate			
16	290534N-0811750.3	19	4-21-66	1.3	0.03	6.2	1.3	6.2	0.0	24	0.0	11	0.0	0.1	-	28	21	2	88	6.7	5
16	290534N-0811750.1	114	4-21-66	13	.33	63	2.8	7.2	1.3	214	.0	10	.1	.0	-	202	169	0	370	7.6	5
16	290534N-0811750.2	260	4-21-66	12	.25	66	9.1	6.6	.4	242	.0	10	.0	.1	-	223	202	4	360	7.8	5
17	290432N-0811449.4	7	6-13-66	6.5	.39	6.1	1.9	6.8	.7	5	2.4	20	-	.2	-	48	23	19	76	5.2	140
17	290432N-0811449.1	84	4-18-66	13	2.08	78	1.9	9.1	.7	244	3.6	10	.1	.1	-	237	203	3	405	7.8	5
17	290432N-0811449.2	310	4-21-66	15	.90	75	5.6	14	1.6	266	4.4	17	.2	.0	-	264	210	0	480	7.9	15

1 Number refers to site location on figure 1.

2 Well number refers to latitude and longitude (290534N0811750.3 = lat. 29°05'34" north, long. 81°17'50", well no. 3).

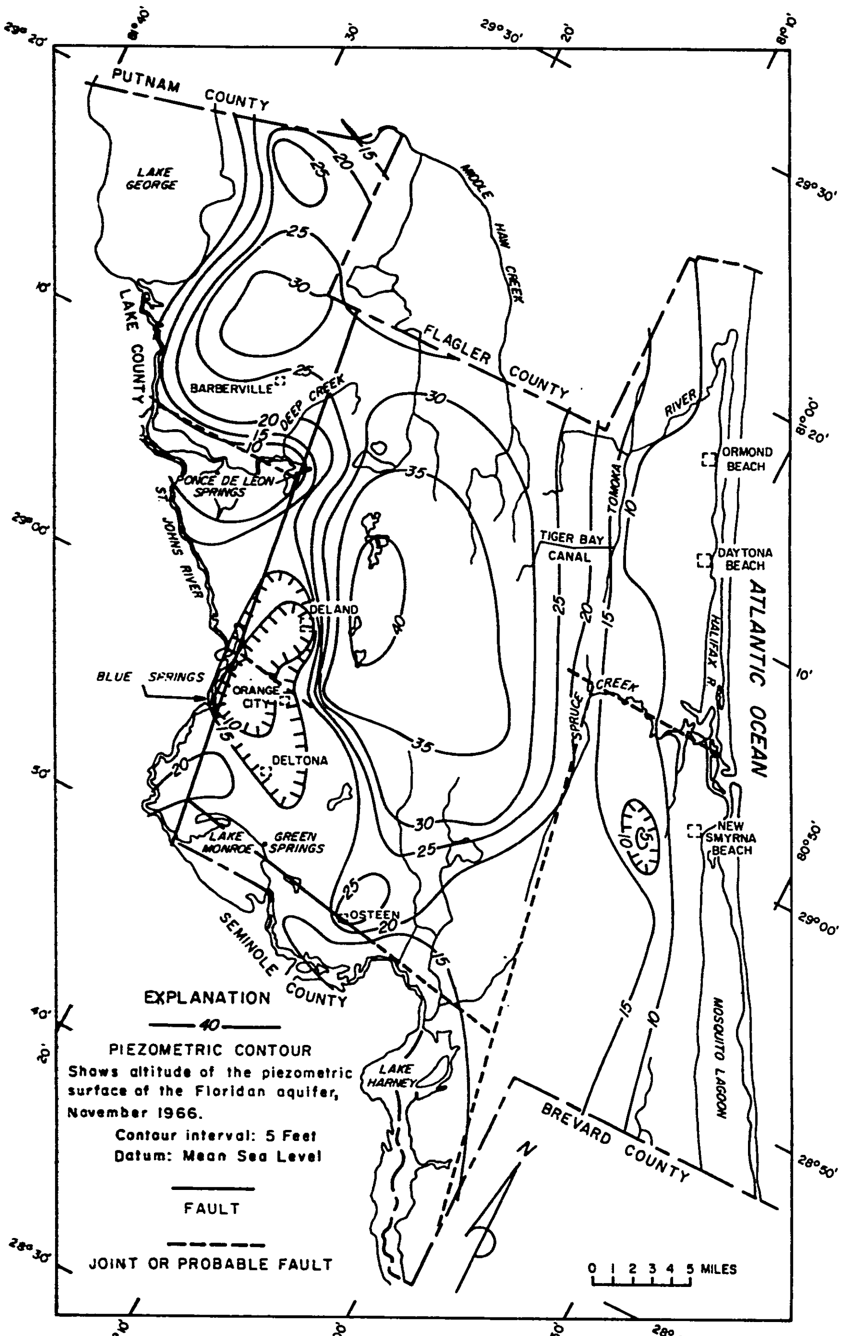

Figure 15. Volusia County showing contours on the piezometric surface of the Floridan aquifer.

Rainfall in Volusia County was slightly above normal in 1966. Thus water levels, except where influenced by increased pumpage, were a little higher in 1966 than they were in 1955, although the trend for the last 20 years shows a slight decline (1-2 feet) of water level, as represented by the hydrograph of the Barberville well in figure 16. Along the east coast, where pumpage is increasing, water levels have declined about 6 feet as shown by a 10-year hydrograph of a well near Daytona Beach well field (fig. 16).

The apparent reduction in the size of the area enclosed by the 40-foot contour between 1955 and 1966 and its slight shift to the west is a result of more data being available for the 1966 map. Another significant feature of the new map (fig. 15) is the piezometric low around the New Smyrna Beach well field. This low has probably developed since 1955 as a result of increased pumpage.

The volume of fresh water in the Floridan aquifer in Volusia County is estimated at 16 x 10^{12} gallons. Not all of this water is available for use and only 400 million gallons of the total in the aquifer are estimated to be exchanged daily under present hydrologic conditions.

Chemical data were collected at sites consisting of groups of three wells. Each group of wells tap the water table in the clastic aquifer, the upper part of the Floridan aquifer, and a lower part of the Floridan aquifer. Water levels at these selected sites were successively lower with increasing well depth, suggesting a downward movement of water. Table 4 gives water quality at various depths from near the surface to well within the limestone of the Floridan aquifer.

As water moves through the subsurface it undergoes changes in chemical quality. Rain water which enters the ground begins to dissolve mineral matter and gases from the soil. The amount of mineral matter dissolved depends on the chemical composition of the soil and on the chemical nature of the water. Gases dissolved from the soil include relatively large amounts of carbon dioxide, which in turn produces carbonic acid, an agent that greatly increases the ability of water to dissolve some types of minerals, particularly carbonate minerals.

The soil of the county consists primarily of quartz sand with lesser amounts of clay and shells. The sand and clay contribute small amounts of silica (SiO_2) to the water and bring about only minor changes in chemical quality; however, the shell beds add significant amounts of calcium and bicarbonate to the water. As the water moves down into the limestone, which underlies the clastic deposits,

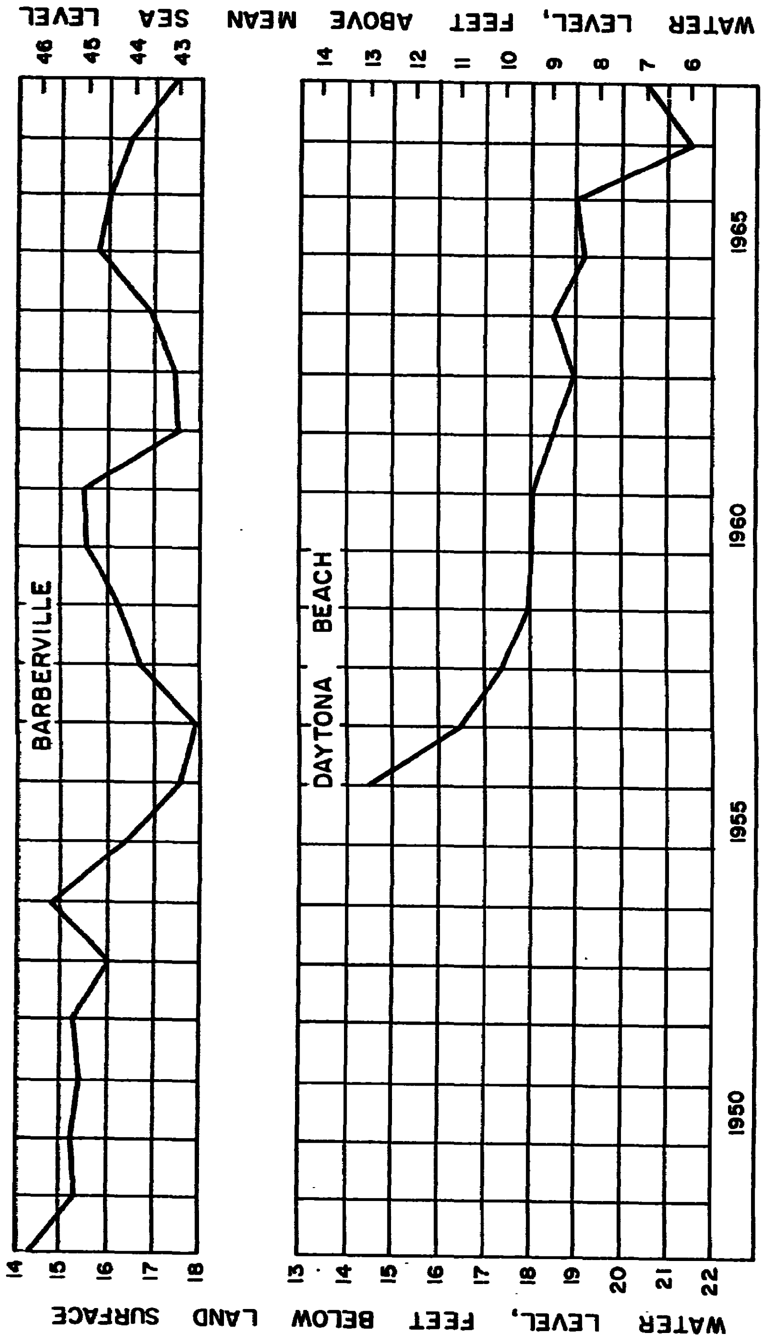

Figure 16. Hydrographs of long-term records of ground-water levels in the Floridan aquifer near Barberville and Daytona Beach.

still more calcium and bicarbonate are added to the water. By the process of solution the ground water becomes a calcium bicarbonate type water.

Increases in mineral content relate to direction of water flow, allowing greater opportunity for dissolution of the aquifer minerals in the down gradient direction. Chemical quality factors which reflect the solution process can be plotted areally and their distribution may be used to show relative direction of water movement in the aquifer.

Chloride content of ground water is an important quality factor in Volusia County. Rainwater, which is low in chloride, recharges the ground-water system and displaces the high chloride water that lies at depth in the aquifer. The zone of diffusion between the fresh and saline water moves up and down in relation to the head of fresh water above the zone. This movement causes variations in the quality of water withdrawn from wells that penetrate the zone of diffusion.

The chemical quality of water in the upper part of the Floridan aquifer is of particular importance because most of the water used in the county is withdrawn from this zone. Some of the more important factors that affect ground-water usability in Volusia County are total dissolved solids, total hardness, and chloride content.

The total dissolved solids content of water in the upper part of the Floridan aquifer is shown in figure 17. The dissolved solids values range from less than 100 mg/l to several thousand mg/l and represent water ranging from a calcium bicarbonate type to waters of a sodium chloride type. Water containing low dissolved solids is found in the central part of the county and is principally calcium bicarbonate type water. Here, the low dissolved solids values are probably due to recharge from the ridges and terraces in the central part of the county. Higher dissolved solids values occur along the St. Johns River and along the Atlantic coast, where principally sodium chloride type waters are discharged from the lower parts of the aquifer.

Total hardness of water from the upper part of the Floridan aquifer in Volusia County is shown in figure 18. The distribution of the total hardness values is similar to that of the dissolved solids. In the interior of the county this similarity occurs because the solution of limestone accounts for nearly all of the dissolved mineral matter in the water as well as for the property of hardness. The water discharged along the coast and the St. Johns River is higher in both hardness and sodium chloride and this accounts for the increased dissolved solids in these areas.

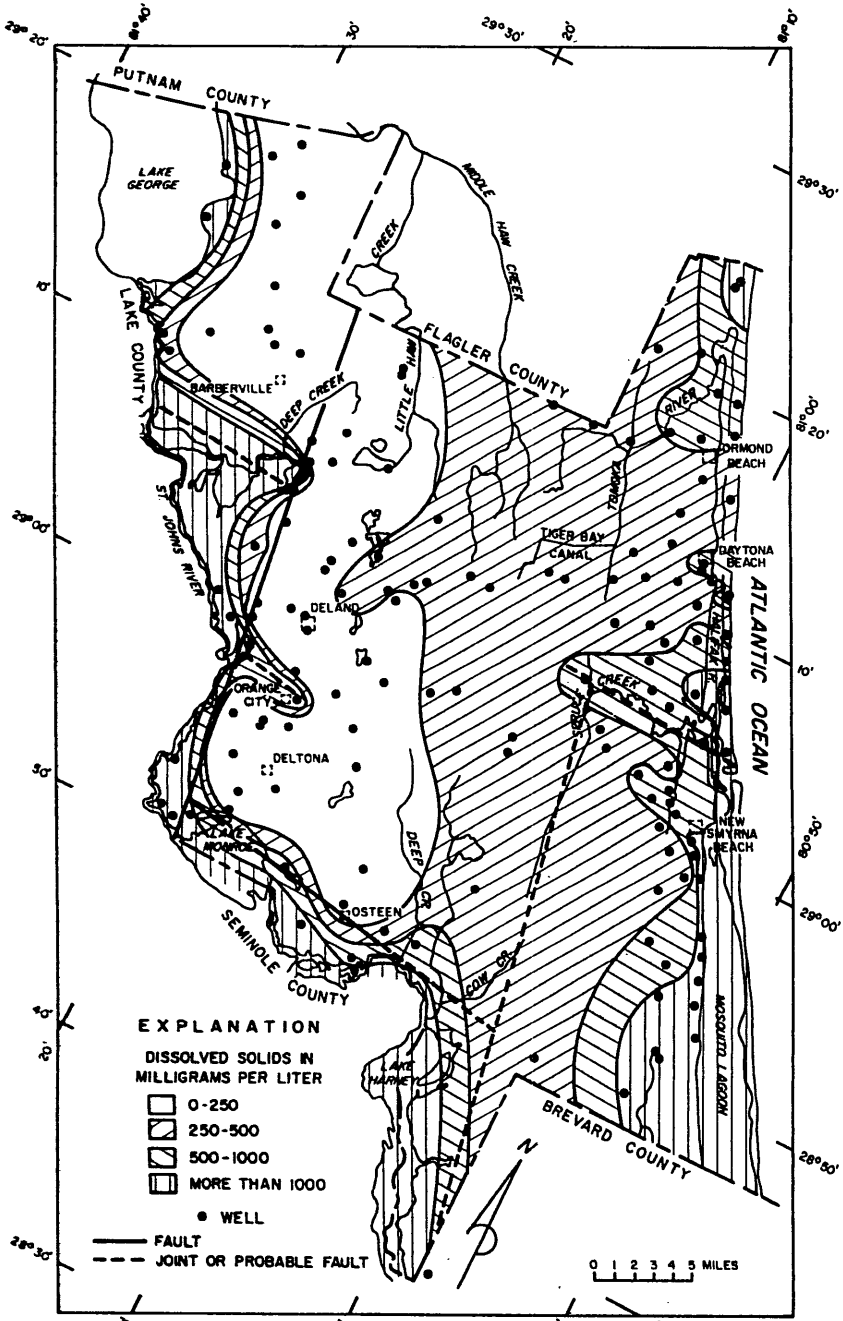

Figure 17. Total dissolved solids in ground water from upper part of Floridan aquifer in Volusia County.

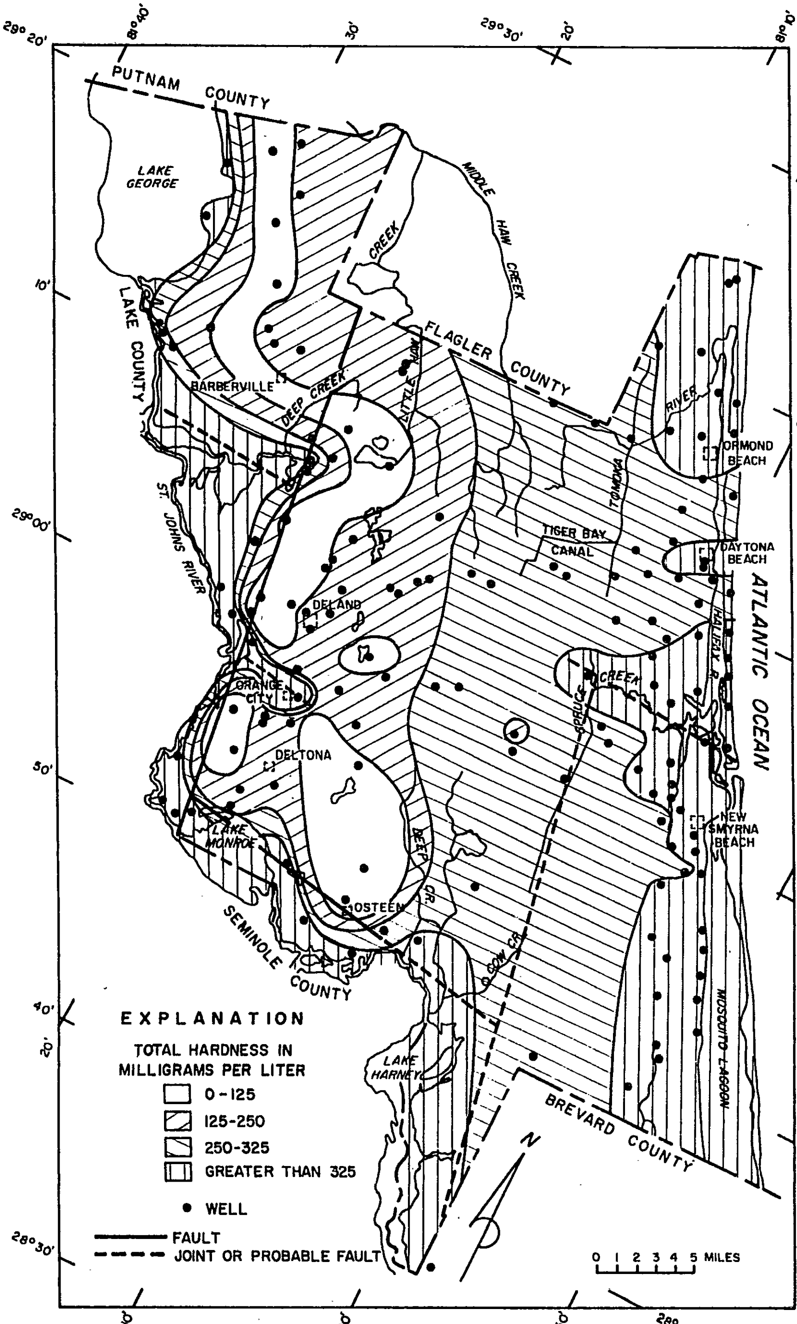

Figure 18. Total hardness of ground water trom upper part of Floridan aquifer in Volusia County.

Chloride content of water from the upper part of the Floridan aquifer in the county is shown in figure 19. Chloride in the county's ground water is derived from rainfall and from the saline water that is present at depth in the aquifer. In areas of recharge the chloride is derived from rainfall and concentrations are generally less than 25 mg/l. In areas of discharge, along the St. Johns River valley and the Atlantic coast, saline water permeates the entire thickness of the aquifer and chloride concentrations may reach several thousand milligrams per liter.

The dissolved solids, hardness, and chloride maps show similar east-west indentations of more highly mineralized water (figs. 17, 18, 19). The indentations, or reentrants are parallel to either faults or joint systems. Highly mineralized water from deep in the aquifer may move into the upper part of the aquifer along fault planes or joint systems. The reentrant at Ponce de Leon Springs is aligned with the reentrant at Spruce Creek along the east coast; both are probably situated along a fault. Another reentrant extends into the DeLand ridge between DeLand and Orange City.

Wyrick (1960) estimated the depth to saline water (greater than 1,000 mg/l of chloride) in the aquifer in the center of the county to be about 750 feet. From a deep well drilled in 1969, data were obtained which showed that the depth to saline water is 1450 feet. This apparent change in depth is a result of new data rather than an actual change in the depth to saline water. The saline-fresh water zone of diffusion can shift up and down though, as a result of changes in the hydraulic heads in the upper and lower parts of the aquifer. This movement produces changes in the ground-water quality for parts of the aquifer near this zone. For example, lowering the hydraulic head in the upper part of the aquifer could result in upward movement of water from the lower part of the aquifer. This movement may in turn result in increased salt content of wells located near the zone of diffusion. This process is generally called salt-water encroachment and is described in detail by Wyrick (1960, p. 41-48).

The chloride content of ground water in the upper part of the Floridan aquifer was measured during the mid 1950's and again in the mid 1960's. A comparison of these two periods shows that during the drought conditions of the mid 1950's, the chloride content of the ground water was higher than during the relatively wet conditions of the mid 1960's. The most probable source for the higher chlorides was from recharge water which contained a higher chloride content. The volume of soluble airborne chloride salts is

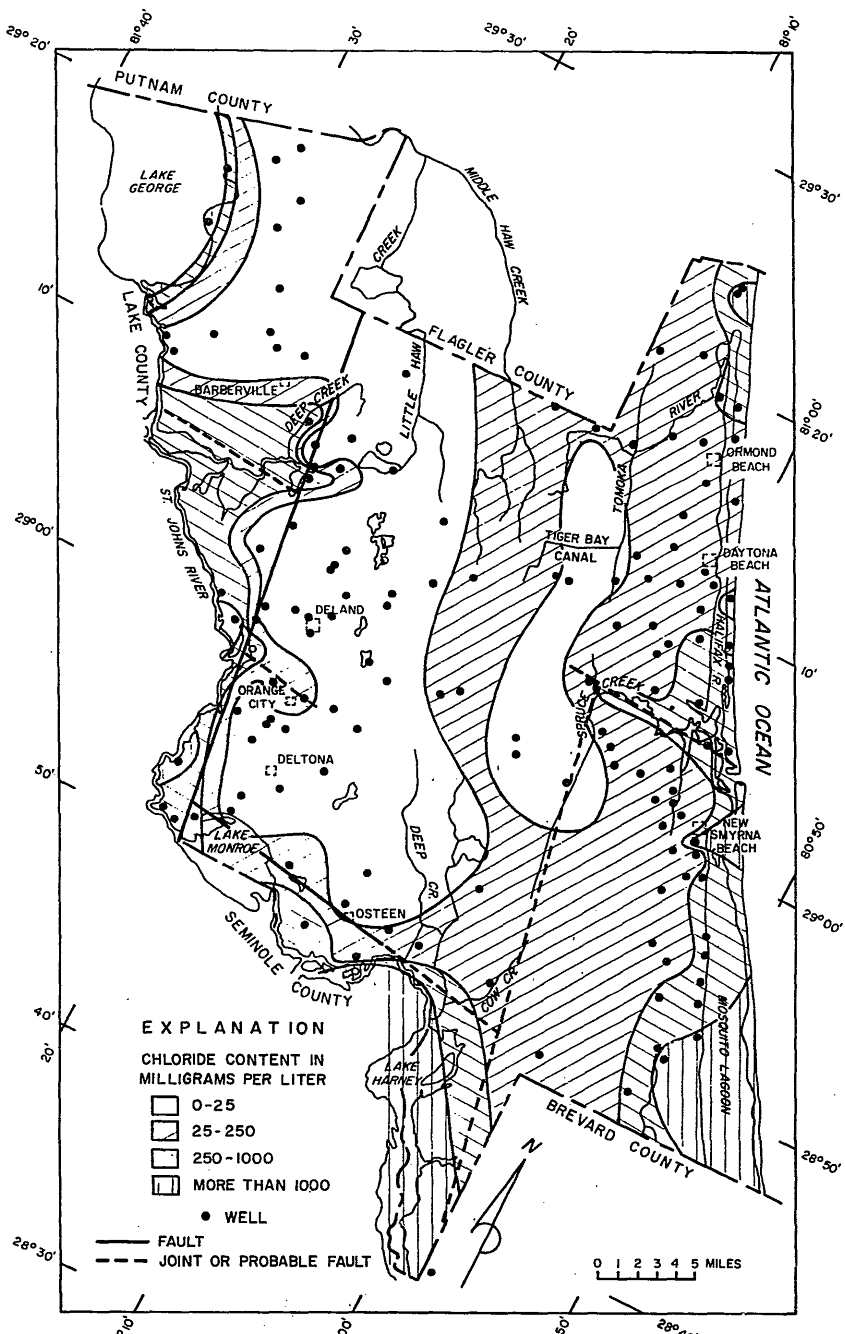

Figure 19. Chloride content of ground water from upper part of Floridan aquifer in Volusia County.

Table 5. – Chemical analyses of springs in Volusia County.

Chemical analyses in milligrams per liter

Date of collection	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved Solids		Hardness as $CaCO_3$		Specific Conductance (micromhos at 25 °C)	pH	Color	Discharge (CFS)
												Residue at 180 °C	Calculated	Calcium-Magnesium	Non carbonate				
Ponce de Leon Springs near DeLand, Fla. (site 31, fig. 1)																			
10-21-64	6.9	0.01	48	18	135	5.6	128	36	240	0.1	5.0	-	558	195	90	1,000	7.7	2	-
5- 8-67	7.0	.01	39	6.8	33	2.0	122	10	60	.2	2.6	242	221	126	26	415	7.7	0	29.5
Blue Springs near Orange City, Fla. (site 32, fig. 1)																			
5-26-66	8.8	0.00	70	36	301	10	149	78	550	0.1	0.6	-	1,130	322	200	2,120	7.2	0	156
5- 9-67	8.6	.00	57	26	215	7.7	160	52	388	.2	.8	876	835	250	119	1,520	7.6	0	155
Green Springs near Osteen, Fla. (site 33, fig. 1)																			
2-12-65	–	–	–	–	–	–	–	–	740	–	–	–	–	–	–	2,500	–	–	–

probably constant during wet and dry periods, but during wet periods the chloride concentration in precipitation and surface water is less due to the dilution effect.

SPRINGS

Springs along the flanks of the DeLand ridge discharge water which has infiltrated the ridge (fig. 15). Blue Springs, the ninth largest spring in Florida (U. S. Geological Survey, 1964, p. 508), is a first magnitude spring with an average flow of 105 mgd. Another large spring is Ponce de Leon Springs which has an average flow of 20 mgd. Both springs are on the western edge of the DeLand ridge. Green Springs, a relatively small spring, discharges water from the south end of DeLand ridge at an average flow of 0.5 mgd. The flow from just these three springs is almost 10 times the amount of water presently withdrawn for public supplies in the county, but high chlorides in their water (table 5) make it undesirable for public supply.

Ponce de Leon Springs exhibits an unusual relationship between the discharge and dissolved mineral content of its waters. The dissolved mineral content of most springs decreases with increasing discharge; but for Ponce de Leon Springs, the chloride content, which is a major mineral constituent, increases with increasing discharge, figure 20. The scatter of the points is probably due to the variable control on the head of the spring. The outlet structure (control), which forms the spring into a swimming pool, is manipulated frequently to adjust the water level. During periods of low water levels, when the chloride concentrations increase in the surface and ground waters, chloride concentration in Ponce de Leon Springs reach lows of 60 mg/l, which is well below the maximum limit of 250 mg/l recommended by the U. S. Public Health Service (1962).

The phenomenon of high discharge and high chloride concentration is not fully understood but one explanation is that during periods of greater recharge the increased fresh-water head causes the zone of diffusion to be suppressed under the DeLand ridge. As the zone of diffusion is suppressed, fresh water displaces the water with greater chlorides in the zone of diffusion, which is then discharged through the springs.

WATER AVAILABILITY AND USE

The availability of water in Volusia County depends on how and where water is removed from the hydrologic system. The

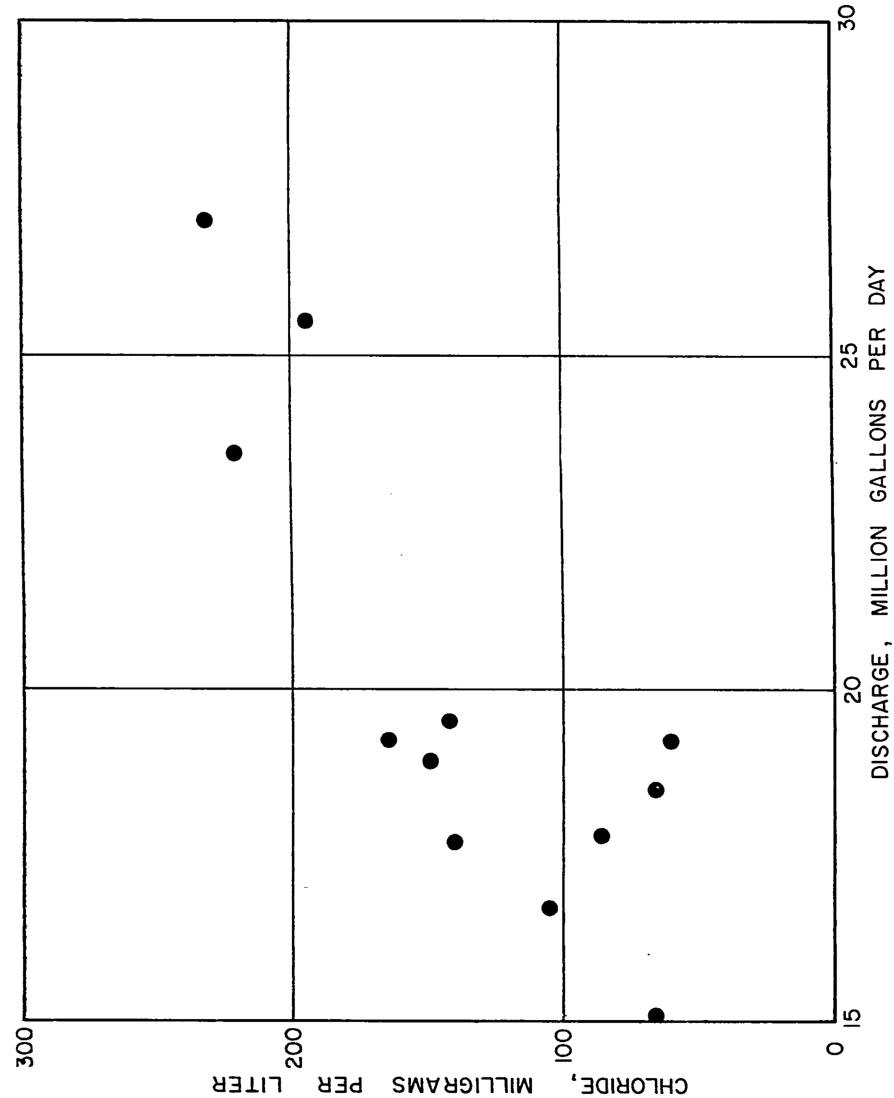

Figure 20. **Relation of chloride concentration to discharge at Ponce de Leon Springs.**

hydrogeologic conditions in the central part of the county are such that the aquifer is full and rejecting recharge. If the piezometric surface were lowered in this area by withdrawing water from the Floridan aquifer for use, recharge would increase from capture of water from evapotranspiration and runoff. The increase in recharge would increase the amount of water available.

In Volusia County the difference between precipitation and evapotranspiration depends on the hydrogeologic conditions and is in the form of runoff and/or ground-water discharge. If average conditions for the whole county are used, an estimate of this difference can be made. Average annual rainfall over the county is 52 inches (3,000 mgd) and average evapotranspiration is estimated at 35 inches (2,000 mgd) based on values used by other investigators for similar areas. Kohler and others (1959, pl. 2) estimated the average annual lake evaporation in this part of central Florida to be about 46 inches. Evapotranspiration from the Green Swamp area in central Florida was estimated by Pride and others (1966, table 18) to be about 37 inches. In Orange County, Lichtler and others (1968, p. 145) estimated that evapotranspiration is 70 percent (36 inches) of rainfall. In Volusia County the difference of 17 inches between precipitation and evapotranspiration is accounted for by surface runoff and ground-water drainage. The average annual surface runoff as determined in this investigation is 10 inches (590 mgd) which leaves 7 inches (410 mgd) as an estimation of ground-water discharge. The amount of water used presently from the ground-water system is about 26 mgd or just less than 0.5 inch of water over the entire county.

Most large production wells are used for public water supplies and as such are drilled relatively near the centers of population along the Atlantic Coast and St. Johns River. Because the depth to saline water is shallower in these areas than in the central part of the county, wells are generally not over 300 feet deep. These large diameter public supply wells (8-12 inch) will generally yield 1,000 to 1,500 gallons per minute. As well fields are developed nearer the central part of the county, well yields should increase somewhat due to the greater thickness of fresh-water-saturated aquifer there.

An estimate of the amount of readily available water throughout the whole county is 300 mgd. This 300 mgd (equal to 5 inches of water over the county) would be available from a slight decrease in evapotranspiration, a result of lowering the water table; a slight decrease in runoff, a result of greater infiltration; and a slight decrease in natural ground-water discharge, a result of a lower gradient on the piezometric surface. Under the hydrogeologic conditions in Volusia County, one way of increasing the amount of available water is to use it.

The major uses of water are for public supply, rural supply, irrigation, and industry. Water for recreation is also a major use but is not so considered herein. In this report water is considered used when it is removed from an aquifer or surface-water body.

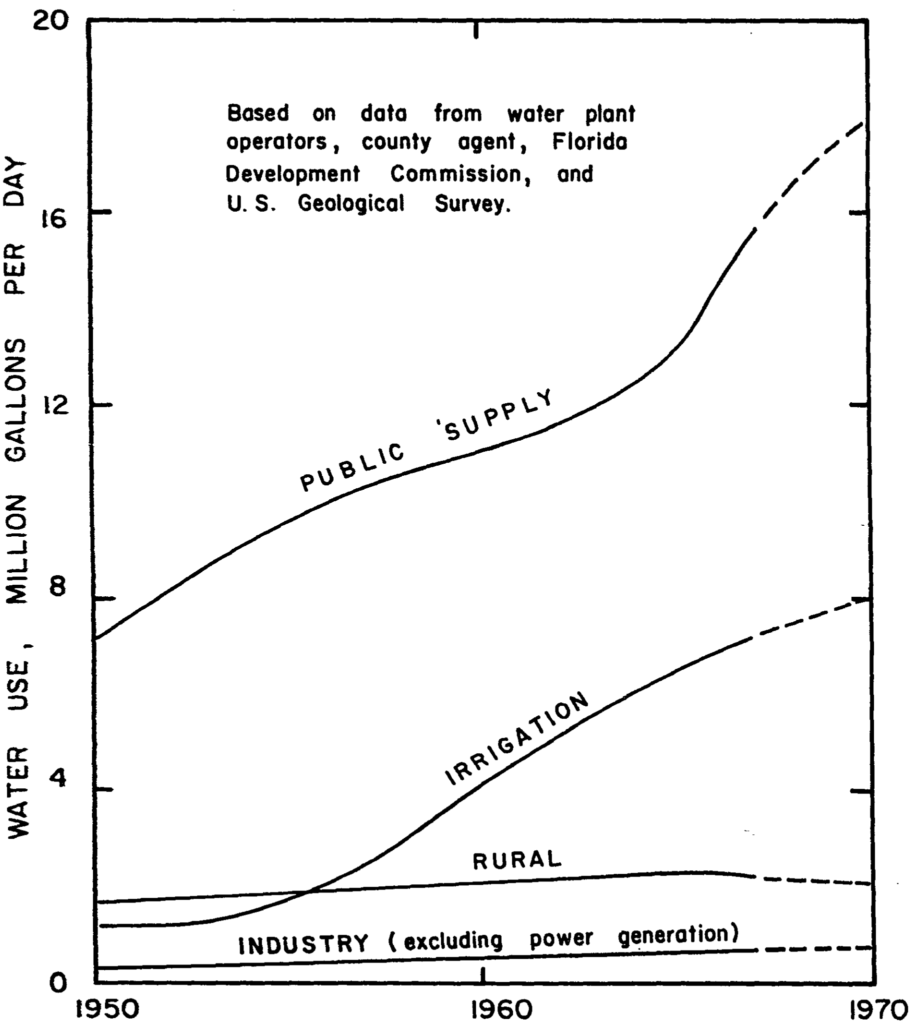

Figure 21. Graph of water use in Volusia County, 1950-1970.

Of the 25.9[1] mgd used in Volusia County in 1967, 15.8 mgd or 60 percent was used for public supply. Water use from 1950 to 1967 and extrapolated to 1970 is shown in figure 21. In the 20-year interval the amount of water used for public supply will more than double, the amount of water for irrigation will increase more than four times whereas water for rural and industrial uses will increase but slightly.

1 Does not include cooling water used in electrical generating.

Ninety-five percent of the water used in Volusia County comes from ground water and all but a fraction of a percent of this comes from the Floridan aquifer. In 1967, 24.5 mgd was withdrawn from the Floridan aquifer, all of which was recharged by rainfall on Volusia County. The amount of water used for cooling in generating electricity has not been included in the water use figures but is shown in table 5. It is withdrawn from the Atlantic Ocean and the St. Johns River to cool the generating plants and then returned to the same sources.

Water is not uniformly available throughout the county. More water is available in the central part of the county where the runoff is greatest and the fresh-water part of the aquifer is thickest. The water quality maps (figs. 17, 18, 19) show that fresh water is unavailable from the Floridan aquifer along the Atlantic Coast and St. Johns River.

Water data for the public supplies, rural supply, irrigation and industry are given in table 6. To diminish the possibility of salt-water encroachment from the ocean that is induced by increased pumpage, Daytona Beach, the largest water user in the county is constructing new well fields to the west of the city and abandoning well fields nearer the ocean. The location of the major well fields in the county are shown on figure 22. Chemical analyses of public water supplies are given in table 7.

SUMMARY

Most of the fresh water in Volusia County comes from the average yearly 52 inches of rain that falls on the county. The natural topography helps retain much of this water within the county. Karst and shoreline ridges with their high rates of infiltration allow little or no runoff. Although marine terraces have the highest runoff, their streams do not have deeply incised channels and the water table remains near the surface. Low sand ridges at the escarpment of each terrace prevent streams from flowing directly to the ocean.

The two major hydrogeologic units are the clastic aquifer and the underlying Floridan aquifer. The clastic aquifer is important as a reservoir in which local rainfall is stored until it moves downward to recharge the Floridan aquifer or is lost to evapotranspiration and streamflow. The clastic aquifer comprised of sand, clay and shell has a porosity of about 35 percent and a coefficient of storage of about 0.25. The infiltration capacity of the surficial sand is large, and it absorbs much of the rainfall except in areas where the water table is

Table 6. – Water use in Volusia County, PUBLIC SUPPLY

City	Population Served (1967)	Ownership	Source of Supply	Well Fields	Wells	Depth of wells (feet)	PUMPAGE MGD (million gallons per day) Annual variation (1967)	Yearly Average					
Breezewood Park[1]	250	Private	Floridan aquifer	1	1	300	0.01-.04	1967	0.02				
Daytona Beach	60,000	Municipal	Floridan aquifer	5	26	-	4.3-9.6	1933	1.4	1954	4.7	1963	6.0
								1950	3.5	1955	4.7	1964	5.7
								1951	3.7	1956	4.8	1965	6.3
								1952	4.1	1958	5.5	1966	6.0
								1953	4.0	1962	5.9	1967	7.0
DeBarry	650	Private	Floridan aquifer	1	1		.03-.1	1966	.05				
								1967	.06				
DeLand	18,800	Municipal	Floridan aquifer	4	6	300-350	1.2-4.2	1963	2.1				
								1964	2.0				
								1965	2.0				
								1966	1.8				
								1967	1.9				
DeLand	2,200	Private	Floridan aquifer	1	2	-	-	1967	.2				
Deltona	3,700	Private	Floridan aquifer	-	8	250	.2-4	1966	.6				
								1967	1.0				
Edgewater	3,700	Municipal	Floridan aquifer	1	2	-	.2-.4	1963	.15				
								1964	.20				
								1965	.20				
								1966	.23				
								1967	.30				
Holly Hill	11,500	Municipal	Floridan aquifer	1	5	225	15-1.2	1954	.46	1959	.47	1964	.64
								1955	.37	1960	.46	1965	.68
								1956	.45	1961	.52	1966	.69
								1957	.57	1962	.62	1967	.72
								1958	.51	1963	.72		
Lake Beresford Water Assoc.	360	Private	Floridan aquifer	1	2	200	.02-.04	1965	.02				
								1966	.02				
								1967	.03				

Orange City	3,250	Private	Floridan aquifer	1	3	-	.2-.4	1960 .19 1965 .15 1961 .23 1966 .23 1962 .25 1967 .23 1963 .21 1964 .17
Lake Helen	1,500	Municipal	Floridan aquifer	1	1	460	.04-.12	1963 .06 1964 .07 1967 .07
New Smyrna Beach	16,500	Municipal	Floridan aquifer	1	5	200	1.2-4.0	1963 1.5 1964 1.7 1965 1.7 1966 1.8 1967 2.0
Ormond Beach	24,000	Municipal	Floridan aquifer	2	10	200-220	1.4-2.8	1952 .64 1957 1.0 1965 1.5 1953 .68 1958 1.5 1966 1.5 1954 .72 1962 1.5 1967 1.7 1955 .83 1963 1.7 1956 .95 1964 1.5
Port Orange	6,000	Municipal	Floridan aquifer	2	5	-	.38-.85	1953 .15 1958 .27 1963 .37 1954 .19 1959 .29 1964 .41 1955 .21 1960 .29 1965 .47 1956 .21 1961 .31 1966 .50 1957 .23 1962 .32 1967 .60

RURAL SUPPLY [2]

Year	Population	WATER USE (MGD)	
		Ground Water	Surface Water
1956	30,000	1.8	0.2
1965	32,000	2.1	.2
1967	25,000	2.0	.2

IRRIGATION

Year	WATER USE (MGD)		ACRES			
	Ground Water	Surface Water	Citrus	Truck	Fern	Other
1965	5.5	1.1	1,500	500	1,400	300
1967	6.1	1.1	1,500	500	1,600	300

INDUSTRIAL

Year	GROUND WATER (MGD)		SURFACE WATER [3] (MGD)	
	Fresh	Saline	Fresh	Saline
1965	0.4	0.2	144	
1967	.5	.2	144	16

1 Unincorporated.

2 Includes all people using private domestic wells or obtaining water from small systems supplying less than 100 people.

3 Water used in electrical generating.

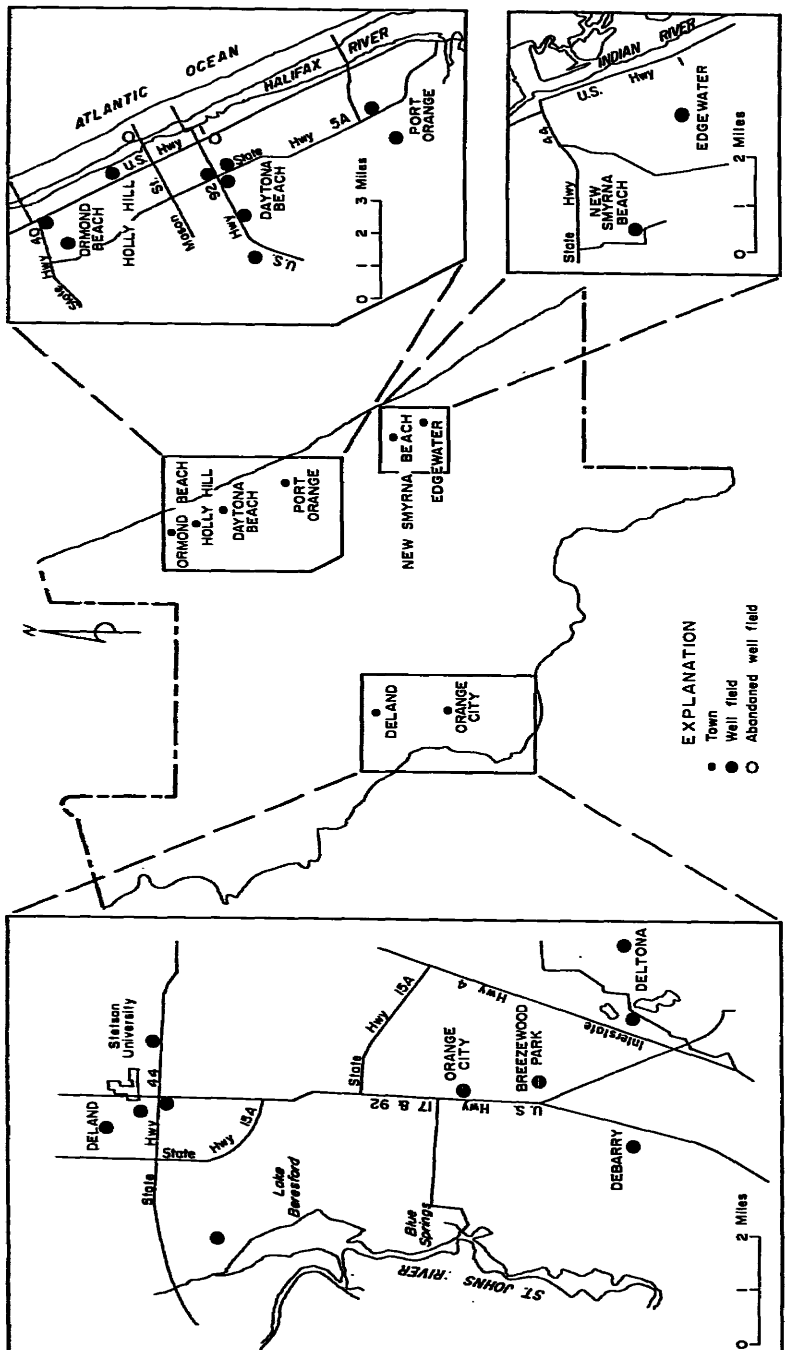

Figure 22. Map showing location of well fields.

at the surface. The shell beds contain a relatively large amount of water and in places along the coast are a source for domestic water supplies. Dissolved solids concentration of the water in the clastic aquifer is lowest in the sand beds and higher in the shell beds.

The Floridan aquifer, comprised of limestone and dolomitic limestone, underlies all of Volusia County. It is a semiconfined artesian aquifer and the principal source of water supply in the county. A hard, dense, dolomitic zone divides the aquifer into an upper and lower part. Geologic structure appears to be a major factor in the hydrogeologic system of the Floridan aquifer. Faults form a fault-block that encloses the piezometric high in the center of the county. Zones of highly mineralized water occur along fault planes or joint systems. Water levels in the upper part of the aquifer along the coast have declined about 5 feet since 1955. This is attributed to increased pumping for the rapidly growing east coast area. Other areas, where pumping has not greatly increased, exhibit stable levels. Water in the upper part of the Floridan aquifer is of good chemical quality in most of the interior of the county. It is principally calcium bicarbonate type water but there is also some sodium chloride type water in this area. Aquifer chlorides as low as 10 mg/l and hardness of 100 mg/l are found in the interior. However, highly saline water is found at depth in the aquifer and in the discharge areas along the coast and the St. Johns Valley.

Recharge to the Floridan aquifer occurs throughout much of Volusia County. Some recharge generally occurs wherever the water table is higher than the piezometric surface. However, areas of piezometric highs should not be considered principal recharge areas in Volusia County. Such a high occurs in the western part of the Talbot terrace where the piezometric surface is near or above the water table most of the time, a condition which prevents recharge to the Floridan aquifer. Areas where the water table is higher than the piezometric surface such as parts of the karst ridge and the eastern part of the Talbot terrace are areas of greater recharge.

Most of the lakes in Volusia County are on the DeLand ridge, where there are about 120 larger than 5 acres. These lakes, with a few exceptions, are generally shallow (less than 20 feet) and have a small seasonal fluctuation (less than 3 feet). Lakes which are surrounded by agricultural or residential land are more highly mineralized than lakes isolated from human activity.

Streamflow from the county averages about 590 mgd. This is over 20 times the daily water use, however, the minimum flow during the spring dry season is less than 5 mgd. Volusia County streams have very little channel storage and the potential of using streams for a water supply is slight due to their flow characteristics. Most of the streams are slightly mineralized, highly colored and slightly acid. The flow of the St. Johns River is about 80 times greater than the amount of water used daily in the county. However, the water is of poor chemical quality and generally unsuitable for most uses. At times, during low flow, some streams are affected by discharge from the Floridan aquifer and exhibit chemical quality similar to the ground water.

It is estimated that 300 mgd on an average throughout the county is readily available for use. This water could be obtained by lowering the piezometric surface through pumping in the central part of the county which would decrease evaporation, runoff, and natural ground-water discharge and increase infiltration.

Total water use in Volusia County in 1967 was 26 mgd, of which 95 percent was derived from the Floridan aquifer.

Table 7. – Chemical analyses of public water supplies.[1]

Chemical analyses, in milligrams per liter

City	Date	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved Solids	Total Hardness	pH
Daytona Beach	1957[2]	21	14	104	5	25[3]	-	353	0	32	-	-	315	280	-
	1965[2]	-	.2	101	9	-	-	276	-	46	-	-	-	286	7.2
DeLand	1923[4]	16	.07	39	6.8	7.5[3]	-	140	9.0	12	-	4.3	164	125	-
(Municipal)	1962[4]	8.2	.01	46	6.6	9.5	1.8	156	12	16	0.2	.0	177	142	8.0
DeLand (Private)	1965[4]	7.3	.00	39	6.0	6.7	.8	136	13	11	.2	.0	151	122	7.7
Deltona	1965[4]	-	.1	50	5	-	-	128	5	28	.5	-	238	146	7.4
Holly Hill	1952	-	-	94	18	33[3]	-	347	4	67	-	-	484	310	-
	1966	23	.02	101	12	-	-	356	5	74	.4	1	508	308	7.2
Lake Beresford	1965	10	.06	39	4	12	.9	110	15	24	.1	5	188	114	7.4
Water Assoc.	1967	-	.03	43	5	-	-	122	25	45	-	-	215	130	7.4
Orange City	1964	-	.3	68	8	-	-	217	10	-	-	-	242	206	7.0
Lake Helen	1950	-	0	58	4	-	-	195	0	10	.1	-	210	160	7.4
	1958	-	.02	59	6	-	-	180	3	13	.05	-	203	174	7.5
New Smyrna	1950	-	1.1	116	8	-	-	381	0	60	.2	-	465	324	7.4
Beach	1961	-	.15	31	6	-	-	331	10	79	.15	-	488	196	7.9
Ormond Beach	1958	.3	0	104	16	95	-	342	8	149	-	-	675	324	7.3
	1962[4]	19	.05	107	21	90	2.2	322	9.6	200	.3	.1	608	354	8.0

1 Untreated water.

2 Airport well field.

3 Includes potassium.

4 Analyses by U. S. Geological Survey.

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APPENDIX

The following table lists sites where hydrologic data on lakes, streams, aquifers and springs were collected. Data were collected at some sites prior to the investigation and constitute a long record of hydrologic information whereas other sites were established during the investigation. The location, type, frequency and period of record for each site are given in the table.

Table 8. — Hydrologic data-collection sites in Volusia County and vicinity.

Type of record: D, Discharge and stage; A, Standard chemical analysis; S, Stage; P, Partial chemical analysis.

Frequency of record: r, Continuous; p, Periodic; d, Daily (10) Total number of analyses.

STREAMS

Site No. on figure 1	Location	Type and frequency of record	Period of record
1	Middle Haw Creek at Relay station, near Bunnell	Dr A(10)	October 1964 to September 1966 1964-66
2	Little Haw Creek, at State Hwy. 11, near Bunnell	Dp A(12)	1964-66 1964-67
3	Little Tomoka River near Ormond Beach	Dp A(9)	1943, 1945-46, 1956, 1962-67 1964-66
4	Tomoka River near Holly Hill	Dr A(12)	October 1964 to September 1967 1964-67
5	Deep Creek near Barberville	Dp A(13)	1964-67 1964-67
6	Spruce Creek near Samsula	Dr A(11)	May 1951 to September 1967 1964-67
7	St. Johns River near DeLand	Dr A(47)	October 1933 to September 1967 1948-49, 1954, 1962, 1966-67
8	St. Johns River near Sanford	Sr, Dp A(13)	July 1941 to September 1967 1954, 1962, 1965-67
9	Deep Creek diversion canal near Osteen	Sd A(9)	October 1964 to September 1966 1964-66
10	Deep Creek near Osteen	Dr Pd A(69)	October 1964 to September 1966 1964-66
11	Cow Creek near Maytown	Dp A(8)	1964-66 1964-66
12	St. Johns River, above Lake Harney, near Geneva	Sr, Dp A(13)	July 1941 to September 1967 1957-58, 1962, 1966-67

WELLS

Site No. on figure 1	Location	Depth feet	Type and frequency of record	Period of record
13	290842N0810846.1[1]	100	Sp	1965-67
			A(1)	1966
14	290655N0811112.1	95	Sr	January 1966 to December 1967
			A(1)	1966
	290655N0811112.2	304	Sr	January 1966 to December 1967
			A(1)	1966
	290655N0811112.3	18	Sr.	January 1966 to December 1967
			A(1)	1966
15	290541N0811329.1	351	Sr	May 1955 to May 1965
			Sp	1965-67
16	290534N0811750.1	114	Sr	April 1966 to December 1967
			A(1)	1966
	290534N0811750.2	260	Sr	April 1966 to December 1967
			A(1)	1966
	290534N0811750.3	19	Sr	April 1966 to December 1967
			A(1)	1966
17	290432N0811449.1	84	Sr	January 1966 to August 1967
			A(1)	1966
	290432N0811449.2	310	Sr	January 1966 to August 1967
			A(1)	1966
	290432N0811449.3	47	Sr	January 1966 to August 1967
			A(1)	1966
	290432N0811449.4	7	A(1)	1966
18	290251N0810014.1	700	Sp	1965-67
			A(6)	1965-66
19	290142N0811059.1	91	Sp	1965-67
			A(1)	1966
20	290138N0812032.1	62	Sr	April 1966 to June 1967
			A(1)	1966
	290138N0812032.2	500	Sr	April 1966 to June 1967
			Sp	1967
			A(6)	1965-66
21	290106N0811321.1	92	Sr	January 1966 to December 1967
			A(1)	1966
	290106N0811321.2	340	Sr	January 1966 to December 1967
			A(1)	1966
	290106N0811321.3	47	Sr	January 1966 to December 1967
			A(1)	1966
22	290107N0810620.1	111	Sr	January 1966 to December 1967
			A(1)	1966
	290107N0810620.2	21	Sr	January 1966 to December 1967
			A(1)	1966
	290107N0810620.3	282	Sr	January 1966 to December 1967
			A(1)	1966
23	285904N0811526.1	222	Sr	January 1966 to December 1967
			A(1)	1966
	285904N0811526.2	22	Sr	January 1966 to December 1967
			A(1)	1966
	285904N0811526.3	325	Sr	January 1966 to December 1967
			A(1)	1966

1 Well number refers to latitude and longitude (290842N0810846.1 = lat. 29°08'42" north, long. 81°08'46", well no. 1.)

24	285655N0811656.1	171	Sr A(1)	January 1966 to August 1967 1966
	285655N0811656.2	32	Sr A(1)	January 1966 to August 1967 1966
	285655N0811656.3	70	Sr A(1)	January 1966 to August 1967 1966
25	285643N0811226.1	97	Sr A(1)	April 1966 to December 1967 1966
	285643N0811226.2	37	Sr A(1)	April 1966 to December 1967 1966
	285643N0811226.3	202	Sr A(1)	April 1966 to December 1967 1966
26	285221N0810950.1	222	Sr A(1)	April 1966 to June 1967 1966
	285221N0810950.2	92	Sr A(1)	April 1966 to June 1967 1966
34	291130N0810417.2	500	Sp Pp	1955-67 1955-67

LAKES

Site No. on figure 1	Location	Type and frequency of record	Period of Record
27	Lake Winona near DeLand	Sr A(3)	March 1965 to September 1967 1965-67
28	Lake Hires near DeLand	Sr A(2)	March 1965 to September 1966 1965-66
29	Lake Winnemissett near DeLand	Sr A(4)	March 1965 to September 1967 1965-67
30	Lake Dupont near Lake Helen	Sr A(2)	March 1965 to September 1966 1965-66

SPRINGS

31	Ponce de Leon Springs near DeLand	Dp A(4) P (8)	1929, 1932, 1946, 1956, 1960 1964-67 1923, 1946, 1964, 1967 1965-67
32	Blue Springs near Orange City	Dp A(3) P(10)	1932-67 1964-67
33	Green Springs near Osteen	Dp P(1)	1932, 1960, 1965, 1966

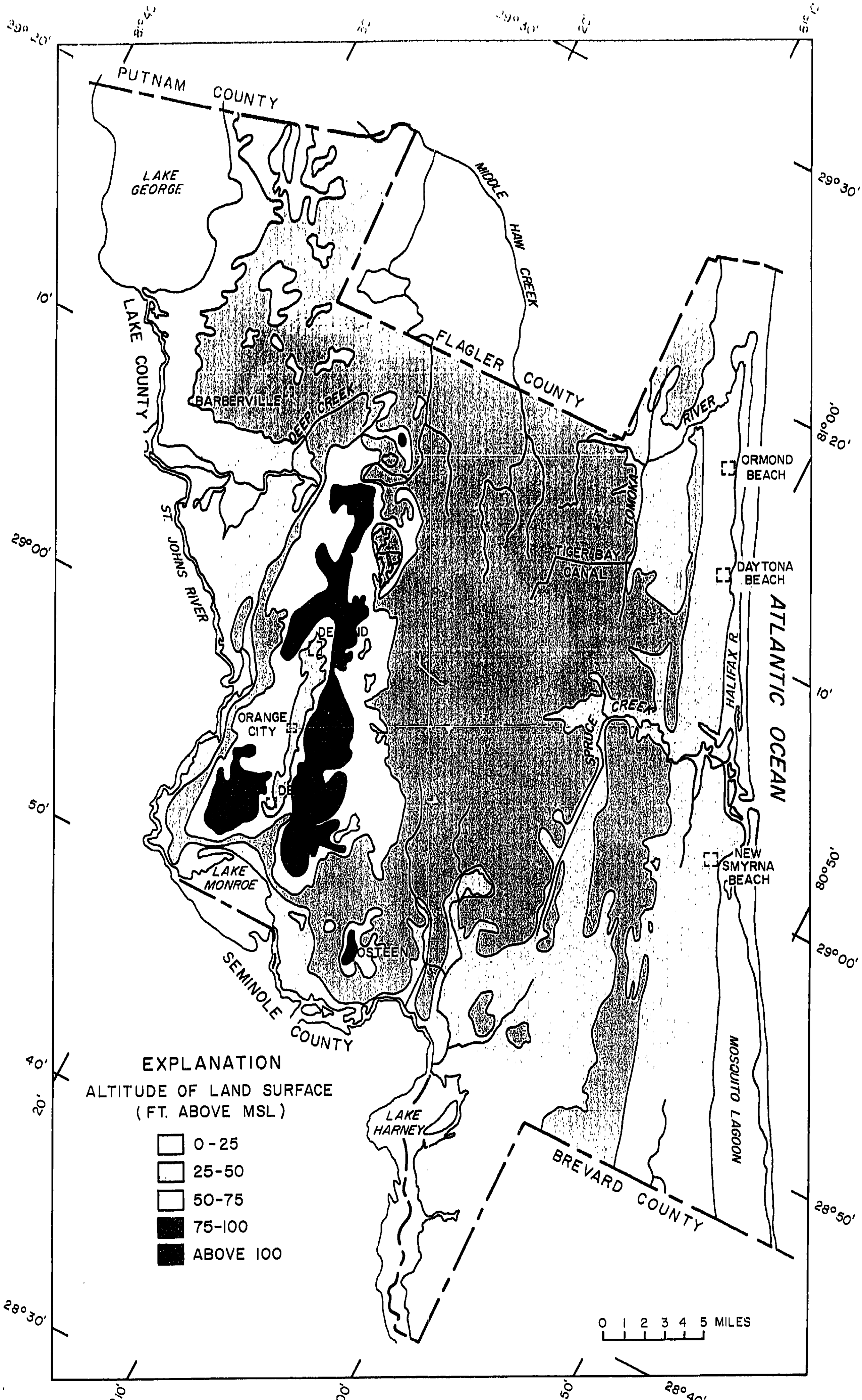

Figure 3. Topographic map of Volusia County.

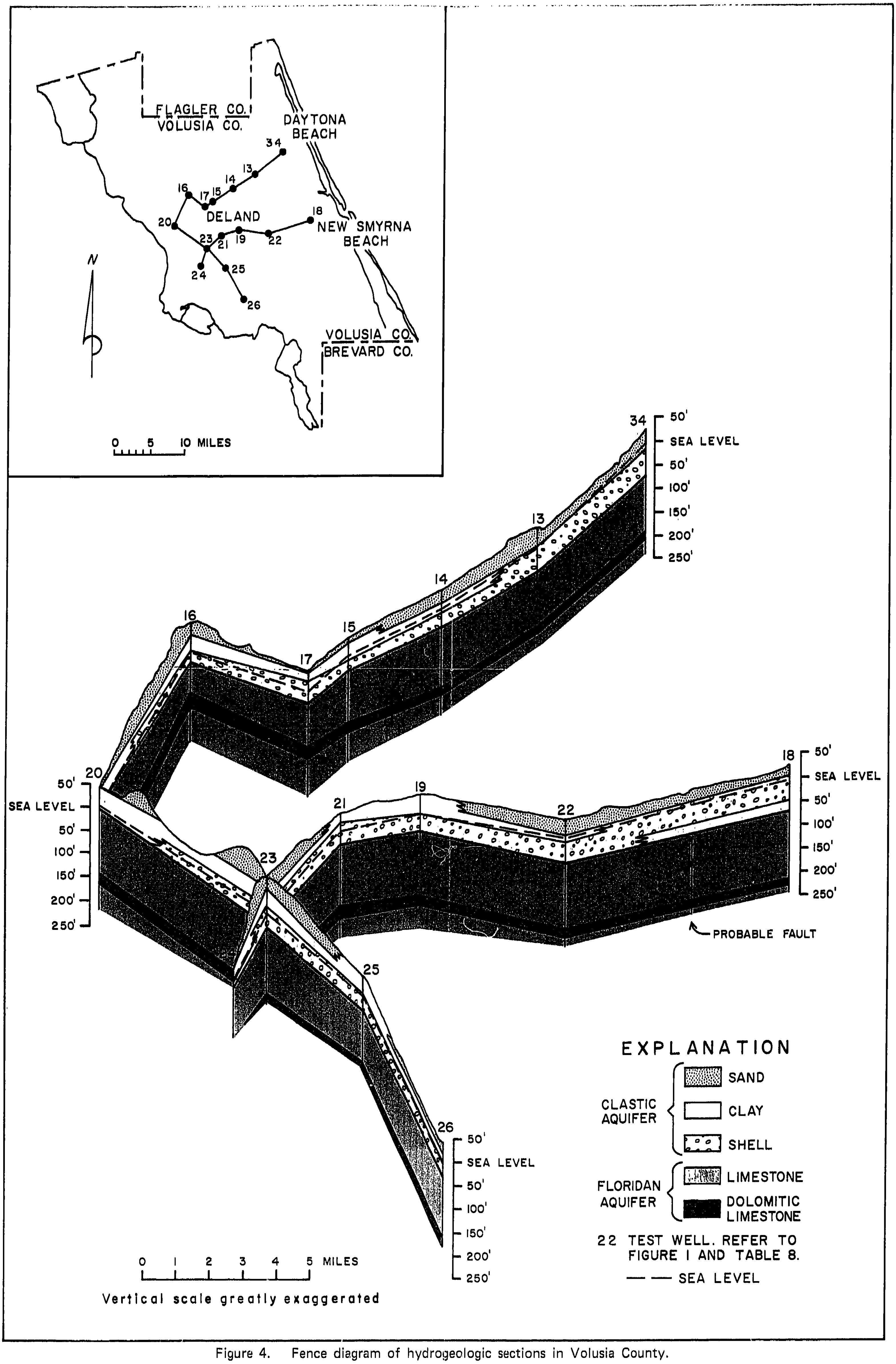

Figure 4. Fence diagram of hydrogeologic sections in Volusia County.

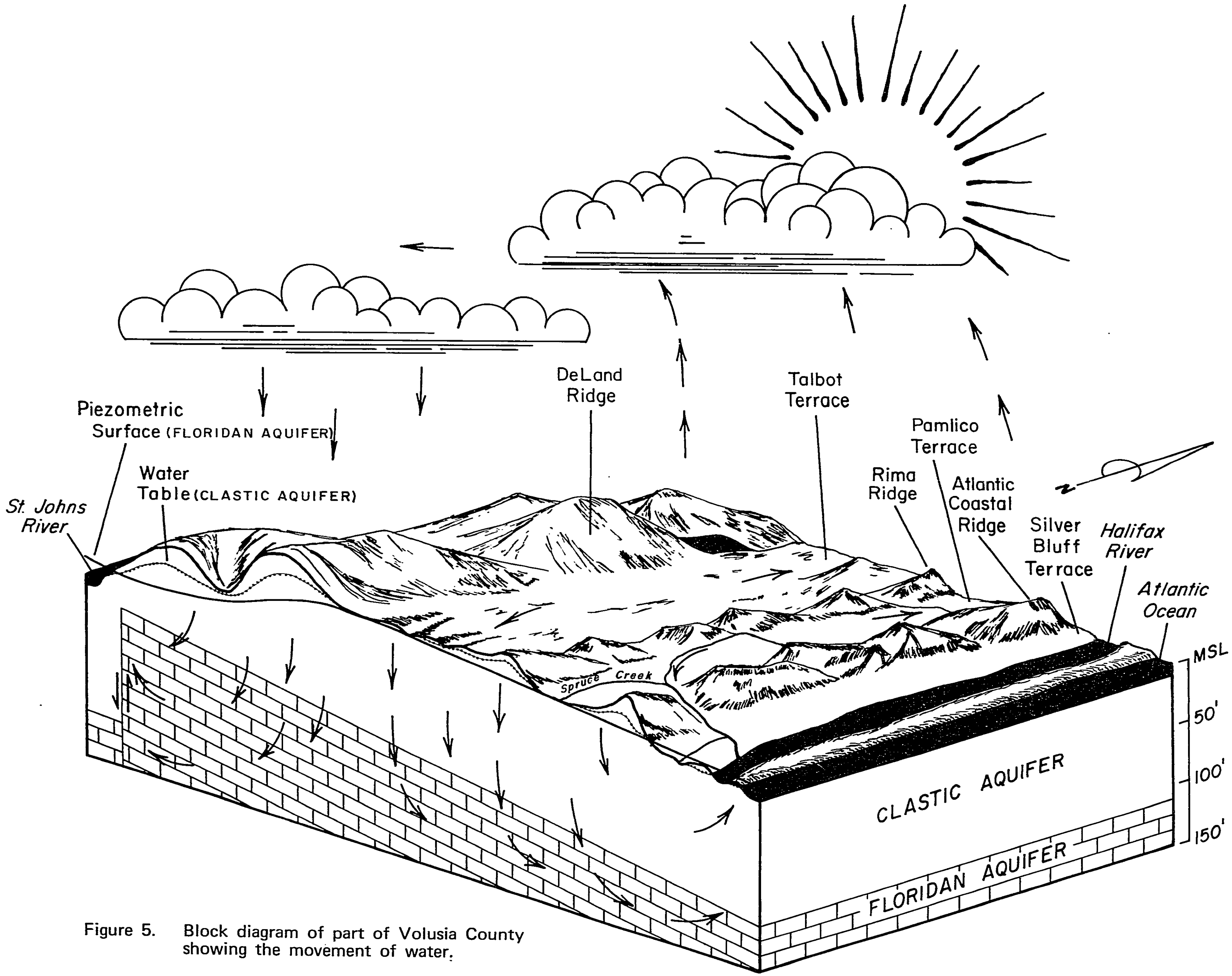

Figure 5. Block diagram of part of Volusia County showing the movement of water.