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Robert O. Vernon, Director

REPORT OF INVESTIGATIONS NO. 25

WATER RESOURCES OF HILLSBOROUGH COUNTY, FLORIDA

By
C. G. Menke, E. W. Meredith, and W. S. Wetterhall

U. S. Geological Survey

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CITY OF TAMPA

TALLAHASSEE, FLORIDA
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LETTER OF TRANSMITTAL



Florida Geological Survey
Tallahassee

July 6, 1961

Honorable Farris Bryant, *Chairman*
State Board of Conservation
Tallahassee, Florida

Dear Governor Bryant:

The principal responsibility for preparing water resource data in Florida rests with the Florida Geological Survey. To the extent that the development of these data merges with the interests of the Nation, the U. S. Geological Survey likewise has responsibilities in Florida. The Florida Geological Survey was given funds to undertake a study in Hillsborough County and this department has merged its interests with those of the County Commissioners of Hillsborough County, of the city of Tampa, and of the U. S. Geological Survey, and we are pleased to publish, as Report of Investigations No. 25, a comprehensive study of the water resources of Hillsborough County, which was prepared by C. G. Menke, E. W. Meredith, and W. S. Wetterhall, of the U. S. Geological Survey.

The details on the water resources have been combined with general knowledge on the geology and hydrology developed by the Florida Geological Survey over a period of years and will be helpful in the future development of the culture of this county.

Respectfully yours,
Robert O. Vernon, *Director*

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PREFACE

This report was prepared by the U. S. Geological Survey, Water Resources Division, under the direction of J. W. Geurin, district chemist, Branch of Quality of Water; A. O. Patterson, district engineer, Branch of Surface Water, and M. I. Rorabaugh, district engineer, Branch of Ground Water. Preparation costs were borne by the U. S. Geological Survey, the Florida Geological Survey, Hillsborough County, and the city of Tampa. The cost of publication was borne by the Florida Geological Survey. Funds for the collection of data were supplied by the U. S. Geological Survey, the Florida Geological Survey, the Florida State Road Department, Trustees of the Internal Improvement Fund, Hillsborough County, and the city of Tampa.

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WATER RESOURCES OF HILLSBOROUGH COUNTY, FLORIDA

By
C. G. Menke, E. W. Meredith, and W. S. Wetterhall
U. S. Geological Survey

ABSTRACT

Hillsborough County is near the west coast of central Florida and is comprised of 1,040 square miles of land. The population was about 400,000 in 1960.

This report is an evaluation of the basic hydrology of the county and of some of the major factors that affect the available fresh water supply.

An average of 1,400 mgd (million gallons per day) of fresh water is potentially available in the county—1,000 mgd of surface water and 400 mgd of ground water. This is enough to supply 1,250,000 people using 1,100 gpd (gallons per day) per capita, if all the flood waters could be stored for use.

The fresh water supply is comprised of about 2,500 mgd of rainfall on the county, of 300 mgd surface-water inflow, and of 100 mgd ground-water inflow to the county. About 1,500 mgd is returned to the atmosphere by evapotranspiration.

Three rivers, the Hillsborough, Alafia, and Little Manatee rivers, have an average combined flow of 508 mgd and drain about 70 percent of the county. The average flow of the Hillsborough River is 173 mgd, of which about 23 mgd is used by the city of Tampa for its municipal supply. The average flow of the Alafia River is 220 mgd and of the Little Manatee River is 115 mgd. The observed minimum flow of the Hillsborough River was 31 mgd, of the Alafia River was 4.3 mgd, and of the Little Manatee River was 0.8 mgd. The flow of the Alafia River is used to dispose of industrial wastes, and the flow of the Little Manatee River is wasted to the sea.

Water may be obtained from three aquifers. The nonartesian aquifer, composed of surface sands, yields up to 200 gpm (gallons per minute) per well. The shallow artesian aquifer, composed of limestone and sand beds in the Hawthorn formation of Miocene age, yields up to 500 gpm, and the principle artesian aquifer, composed of limestones of Tertiary age lying below the Hawthorn formation, yields up to several thousands gpm per well.

The coefficient of transmissibility of the principal artesian aquifer ranges from about 75,000 to 220,000 gallons per day per foot, and the coefficient of storage from 0.00005 to 0.002 gallons per square foot per foot. The coefficient of leakance, in gallons per day per square foot under a unit gradient divided by the thickness in feet of the confining beds above and below the aquifer, is 0.002 at the site of the Tampa well field 6 miles west of Plant City.

Most of the 67 mgd of ground water used in the county is derived from the principal artesian aquifer. Movement in the aquifer is primarily through the zones of high permeability that are associated with joints and faults. Locally, these zones behave as aquifers when they are pumped or recharged at high rates. The aquifer is recharged through sinkholes and through the sands and clays that overlie it, and large amounts of water are discharged from the aquifer to streams in the northern half of the county and to the bay.

The water level in the nonartesian aquifer is generally within a few feet of the land surface. Water levels in the shallow artesian aquifer are erratic areally. The piezometric surface of the principal artesian aquifer is higher than 100 feet in the northeastern part of the county and generally slopes toward Tampa Bay. Troughs in the piezometric surface extend inland, indicating that water is discharged from the aquifer into the Hillsborough and Alafia rivers.

Dissolved materials of surface waters was generally less than 250 ppm (parts per million) in the county. Notable exceptions are the Alafia River, with an average dissolved-materials concentration of 292 ppm and a maximum of 658 ppm, and Sulphur Springs with an average of 500 ppm and a maximum of more than 1,000 ppm. Most of the streams have dissolved materials of less than 100 ppm but contain colored organic materials leached from vegetation.

Water in shallow aquifers appears to have less than 100 ppm dissolved materials in most of the county and may contain organic color in quantities ordinarily less than those found in streams. Ground water found between depths of 100 and 200 feet generally had less than 500 ppm of dissolved materials except in the coastal areas.

Where the piezometric surface is more than 30 feet above sea level, ground-water supplies containing less than 500 ppm of dissolved materials may be obtained at a depth below sea level not exceeding 40 times the elevation of the piezometric surface above sea level. Where the elevation of the piezometric surface is less

than 30 feet, the concentration of dissolved materials varies erratically with both depth and location from about 170 to more than 11,000 ppm. In the Ruskin area, the concentration and character of dissolved materials changes with the lowering of water levels.

Variations of rainfall, streamflow, ground-water levels, and concentrations of dissolved material are given in the report.

INTRODUCTION

PURPOSE AND SCOPE

The purpose of this report is to provide basic information necessary for optimum development of the water resources of Hillsborough County and to aid in the solution of some local water problems.

Quantitative and qualitative aspects of both surface and ground water are presented in this report. Surface-water interpretations are based on stage, discharge, and quality data collected in ten stream basins in the county. Rates of runoff per unit area were used in estimating flow into the county and into Tampa Bay. Miscellaneous measurements of stage, discharge, and quality of water in several lakes, springs, and minor streams supplement the more intensive data collected at regular gaging sites. Ground-water information was derived from studies of the geologic formations, well construction, water level, and pumping-test data.

The several aquifers and the geologic formations comprising them are described. The water-bearing and water-yielding properties and the chemical quality of the water from each aquifer are noted. The fluctuations of water levels in wells are shown, as is the configuration of the piezometric surface. Hydraulic properties of the aquifers as determined by analysis of pumping-test data are given, and a profile of the cone of drawdown near a pumping well at the proposed site of Tampa's well field is shown and discussed.

Most of the ground-water and quality-of-water information is restricted to the period 1956 through 1958 and consequently does not reflect the wide range of hydrologic conditions known to have existed in the county.

Both surface-water and ground-water information was used to estimate a water budget for the county.

ACKNOWLEDGMENTS

The collection of data for this report was substantially aided by the many citizens and firms who furnished data or services and who allowed the authors access to wells, streams, and lakes. A special debt of gratitude is acknowledged to the following well drillers who contributed data from their files and from their intimate knowledge of the area: Ben Lovelace and Company, May Artesian Well Drilling Company, F. A. May and Sons, Morrill Well and Pump Company, and Mr. Phillip Morrill, retired driller.

Mr. Lyle Dickman furnished data from which use of water for truck crops was computed.

PREVIOUS AND PRESENT STUDIES

The first documented study of water in Hillsborough County was made by Matson and Sanford and published in 1913. The

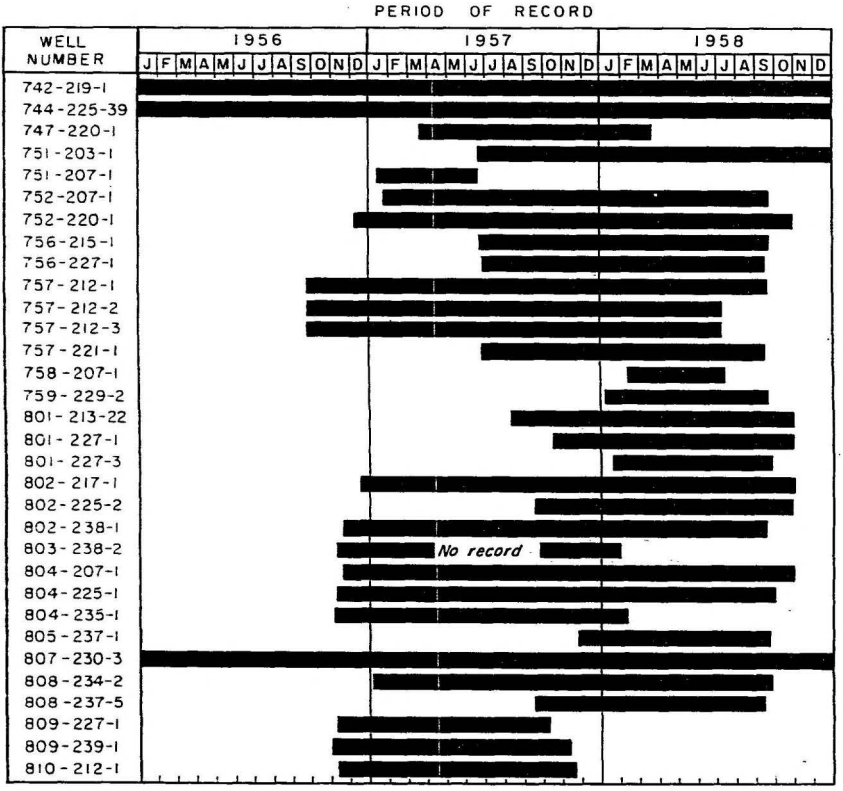


Figure 1. Periods of record for observation wells, 1956-58.

report gives information on the source, quality, and development of ground water, along with lithologic logs and tables of wells and springs.

A continuing observation well program, to observe ground-water levels throughout the State, was begun in 1930 and included one well in Hillsborough County. The water levels in this well and in two additional wells that were in operation at the beginning of this project are shown in figure 45. The periods of record for observation wells are shown in figure 1.

Between 1933 and 1938 streamflow measurement stations were established on the Alafia, Hillsborough, and Little Manatee rivers. By 1958, 17 gaging stations were in operation in the county (fig. 2).

The Florida State Board of Health conducted an intensive chemical and biological study of the Peace and Alafia rivers and reported the results of the study, along with recommendations, in two volumes and several supplements (Florida State Board of Health, 1955).

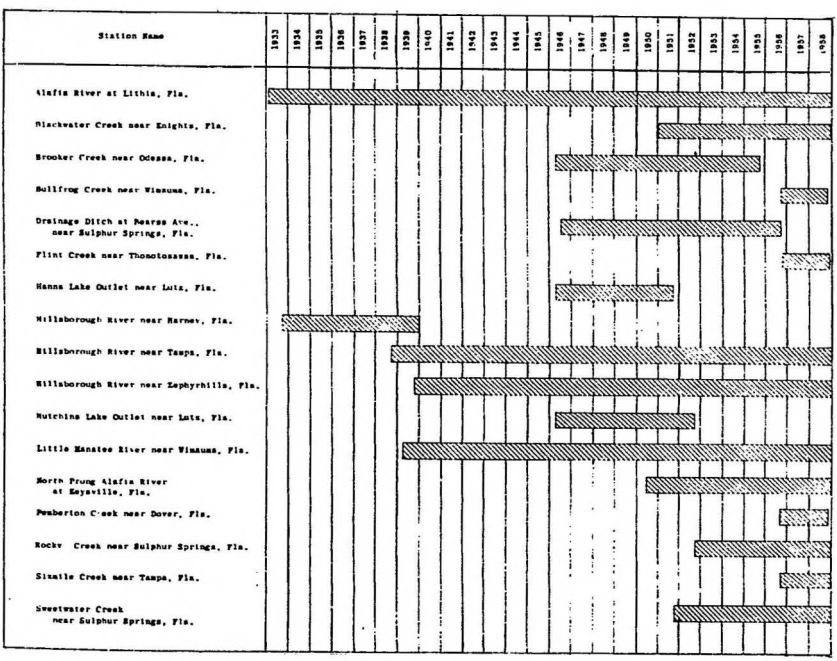


Figure 2. Periods of record at streamflow gaging stations.

Lake stage observations of 11 lakes were started in 1946 (fig. 3.)

Peek (1959) has described the geology and ground water of the Ruskin area in southwestern Hillsborough County.

The present study was begun about mid-1956. This report presents the results of concurrent countywide studies of the following:

(1) Streamflow
(2) Springflow
(3) Lake stage
(4) Geology
(5) Ground water
(6) Chemical quality of streams, lakes, and water in underground formations

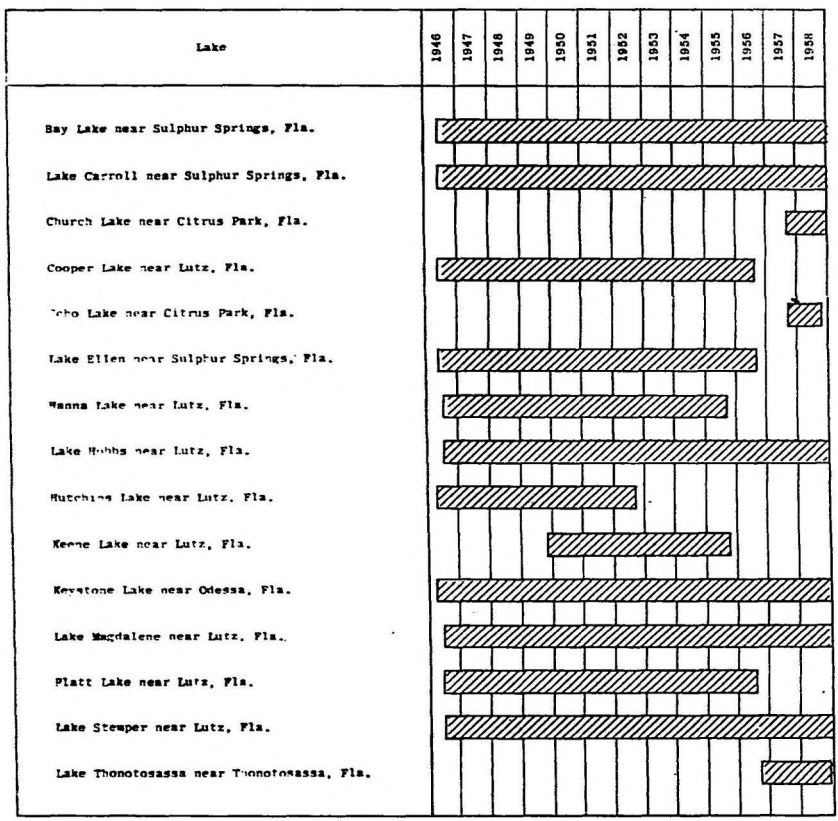


Figure 3. Periods of record at lake stage stations.

SOURCES OF ADDITIONAL INFORMATION

U. S. Geological Survey and U. S. Weather Bureau publications may be purchased from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. *Publications of the Geological Survey, May 1958,* lists all publications of the U. S. Geological Survey through May 1958. A revised edition is printed every 5 years and these are supplemented each year. It includes a list of Water-Supply Papers published as a numbered series.

U. S. Geological Survey Water-Supply Papers containing data related to streams and wells in Hillsborough County are listed below:

Year	Number	Year	Number
1913	319	1945	1032
1928	596G	1946	1052, 1072
1933	742	1947	1082, 1097
1934	757	1948	1112, 1127
1935	782	1949	1142, 1157
1936	773C, 802	1950	1172, 1166
1937	822	1951	1192, 1204
1938	852	1952	1222, 1234
1939	872	1953	1266, 1274
1940	892	1954	1322, 1334
1941	922	1955	1384, 1405
1942	952	1956	1434, 1450
1943	972	1957	1504, 1520
1944	1002	1958	1554, 1571

The Water-Supply Papers through No. 1032 are out of print but are available through certain public and college libraries.

A list of publications of the Florida Geological Survey may be obtained from the Florida Geological Survey. Reference files of these publications have been placed in more than 200 high school, college, university, public, state and federal agency libraries in Florida. Many early reports are out of print and are available only through the reference libraries.

District offices of the U. S. Geological Survey are sources of most current unpublished basic data. Locations and addresses of district offices in Florida are as follows:

Branch of Surface Water
Mr. A. O. Patterson, District Engineer
244 Federal Bldg. Ocala, Florida

Branch of Quality of Water
Mr. K. A. MacKichen, District Engineer
244 Federal Bldg., Ocala, Florida

Branch of Ground Water
Mr. M. I. Rorabaugh, District Engineer
P. O. Box 110, Tallahassee, Florida

State governmental offices are likewise a source of more current unpublished information. Mailing addresses:

Florida Geological Survey
Dr. Robert O. Vernon, Director
P. O. Box 631
Tallahassee, Florida

Florida Department of Water Resources
Mr. John W. Wakefield, Director
The Capitol
Tallahassee, Florida

Florida State Board of Health
Mr. David B. Lee, Director Bureau of Sanitary Engineering
P. O. Box 210
Jacksonville 1, Florida

Topographic map coverage of Hillsborough County is shown in the appendix. Copies of topographic maps may be purchased from the Map Information Office, U. S. Geological Survey, Washington 25, D. C. When ordering, include the title of the topographic sheet desired, along with latitude and longitude of the lower right-hand corner.

METHODS OF INVESTIGATION

The selection of sites at which measurements were made or samples were taken was based primarily on the following factors: (1) existing data, (2) accessibility of the site (for periodic measurements or sampling), and (3) simplicity of establishing relationships between stage, streamflow, and quality.

Records of stage were obtained either by continuous water-level recorders or by measuring directly with a tape or staff gage. Both surface-water and ground-water elevations are referenced to mean sea level, datum of 1929. Streamflow was determined by current meter measurements.

Water samples were collected and analyzed by standard methods as detailed in "Methods of Collection and Analysis of Water Samples," (Rainwater and Thatcher, 1960). Streams were sampled where measured, if practical. Ground-water samples were collected preferably from wells for which depth, depth of casing, well log, and elevations of the well and of the water were known. The results of the analysis of these samples were used to estimate water quality at other locations.

Dissolved materials, mineral content, and organic materials, as used in this report, are defined as follows: The term *dissolved materials* is the residue on evaporation at 180° C. The concentration of dissolved materials includes both organic materials and

mineral content whenever both types of substances are present. *Mineral content* is the concentration of dissolved inorganic earth materials. The term *organic materials* is an estimate of the concentration of dissolved organic materials. The concentration is calculated by substracting the amount of mineral content from the amount of dissolved materials. The organic materials are leached from vegetation and characteristically color natural waters. Whenever organic materials are essentially absent, the dissolved materials and mineral content become synonymous.

Data used in the evaluation of ground-water resources were obtained by direct observation, from the records and memory of well drillers and owners, and from the files of both the Florida Geological Survey and the U. S. Geological Survey.

Wells were inventoried in the county to determine the location, depth of well, depth and diameter of casing, owner, year drilled, and other miscellaneous physical information. The elevation of the water surface in the wells was determined with maximum error of 2 feet. These data were used in mapping the piezometric surface of the county.

Pump tests were made to determine water-transmitting and water storing capacities of the principal artesian aquifer and leakage of the confining beds.

A current meter was used to determine internal velocity of water in wells to permit comparison of the permeabilities of the water-yielding zones of the aquifer.

A drawdown test and the tracing of the progress of dye through the aquifer were helpful in understanding the hydrology.

Well cuttings were examined to determine the elevation of formational tops, referred to mean sea level. The geologic sections were prepared from these data.

DESCRIPTION OF AREA

Hillsborough County is located in the western part of peninsular Florida about midway down the west coast (fig. 4). The northern boundary of the county is located near latitude 28°10′ north, the eastern boundary near longitude 82°4′ west. It is bordered on the western side by Pinellas County, on the northern side by Pasco County, on the eastern side by Polk County, and on the southern side by Manatee County.

The county is square except for indentations in the southwestern part made by Tampa Bay. The bay gives the county an extensive protected coastline and makes excellent seaport facilities possible.

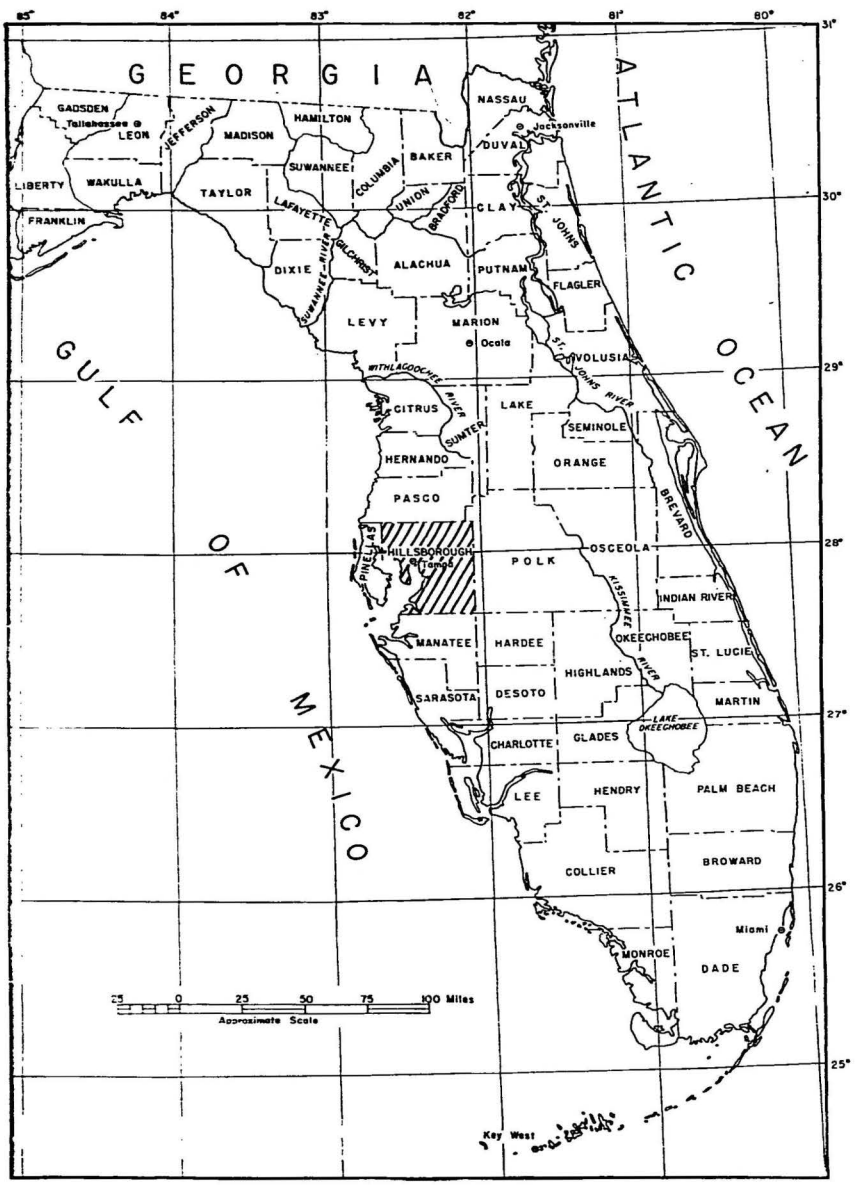


Figure 4. Location of Hillsborough County, Florida.

The land area is 1,040 square miles and ranges in elevation from sea level at the bay to more than 160 feet above sea level at the Hillsborough-Polk county line southeast of Keysville. There are many lakes in the northwestern part of the county.

There are three main surface drainage basins in the county: the Hillsborough, Alafia, and Little Manatee river systems. The three main rivers rise near the eastern boundary line of the county and drain toward the bay area.

Numerous springs occur in the northern half of the county.

Hillsborough County is one of the major metropolitan areas in Florida and the economy is based on manufacturing, agriculture, recreational activities, and allied trades (Bureau of the Census, 1956). The county occupies less than 2 percent of the land in the State, yet in 1954 it had about 10 percent of the manufacturing businesses in the State. During 1954 these businesses employed nearly 19,000 people and paid more than $57 million in wages. In 1958 about 98,000 acres of land was used for agricultural purposes, 38,000 for citrus farming, 25,000 for vegetable farming, and 35,000 for pasture (oral communication: Mr. Jean Beam, Hillsborough County Agricultural Agent).

In 1954 the retail sales in the county totaled more than $320 million. More than 15,000 people employed in this business received nearly $33 million in wages. About 8,000 people employed in wholesale trade received more than $28 million in wages. Businesses providing services employed about 5,000 people who received more than $12 million in wages.

During the decade 1940-50, Hillsborough County registered a growth in population of 38.7 percent for a total population of 249,894 in 1950. In the succeeding decade, the county registered a population growth of 59 percent for a population of 397,788 in 1960. This gave the county a population density of 380 people per square mile. More than 75 percent of these people live in urban areas. The greatest concentration of the people is in the city of Tampa.

Mean monthly temperatures range from about 60° F. to 82° F. Temperature extremes range from below freezing to about 100 degrees. From 310 to 365 days per year free of killing frost can be expected in the county.

The area has been affected by 29 hurricanes of varying intensities since 1900 (Corps of Engineers, 1956). The important hydrologic effect of these tropical disturbances is the very heavy rainfall associated with the storms.

HYDROLOGY OF HILLSBOROUGH COUNTY

In the hydrologic cycle, water that falls on the earth evaporates, runs off the land to the sea, and infiltrates the ground. The water entering the ground emerges on the surface in lakes, streams, springs, and the sea or is returned to the atmosphere by evapotranspiration. The quantity of water following any of these paths is dependent mainly on the weather, topography, and geology.

Water dissolves some of those materials with which it is in contact. The amount of minerals that may be dissolved in the water depends mainly on the rate of solution, the time of contact, and the solubility of the materials contacted. Solubility limits the amount of any materials in solution regardless of time of contact or rate of solution. Ultimately the mineralized water finds its way to the sea. Long continued addition of minerals in this manner has given rise to the highly mineralized water that we know as sea water.

The divisions of surface water and ground water have been used for the presentation of the bulk of the material that makes up this report.

RAINFALL

The average annual rainfall in Hillsborough County is 50.24 inches. This is equivalent to about 2½ bgd (billion gallons per day). Only a part of this water is available for use.

Rainfall varies with time, but averages based upon 30 or more years of record remain nearly the same. Mean, maximum, and minimum monthly rainfall is shown in figure 5, to illustrate the variation.

EVAPOTRANSPIRATION

The amount of evaporation and transpiration from the land and water surfaces of Hillsborough County has been estimated to be 1½ bgd. This is equivalent to a sheet of water 30 inches thick over the area of Hillsborough County each year. The figure of 1½ bdg is derived by difference between inflow plus precipitation and outflow plus water use.

About 50 inches of water per year evaporates from lakes in Hillsborough County. Records of evaporation have been collected since 1952 from a Class A pan located at Bay Lake. An average of about 61 inches of water evaporates from the pan per year. In

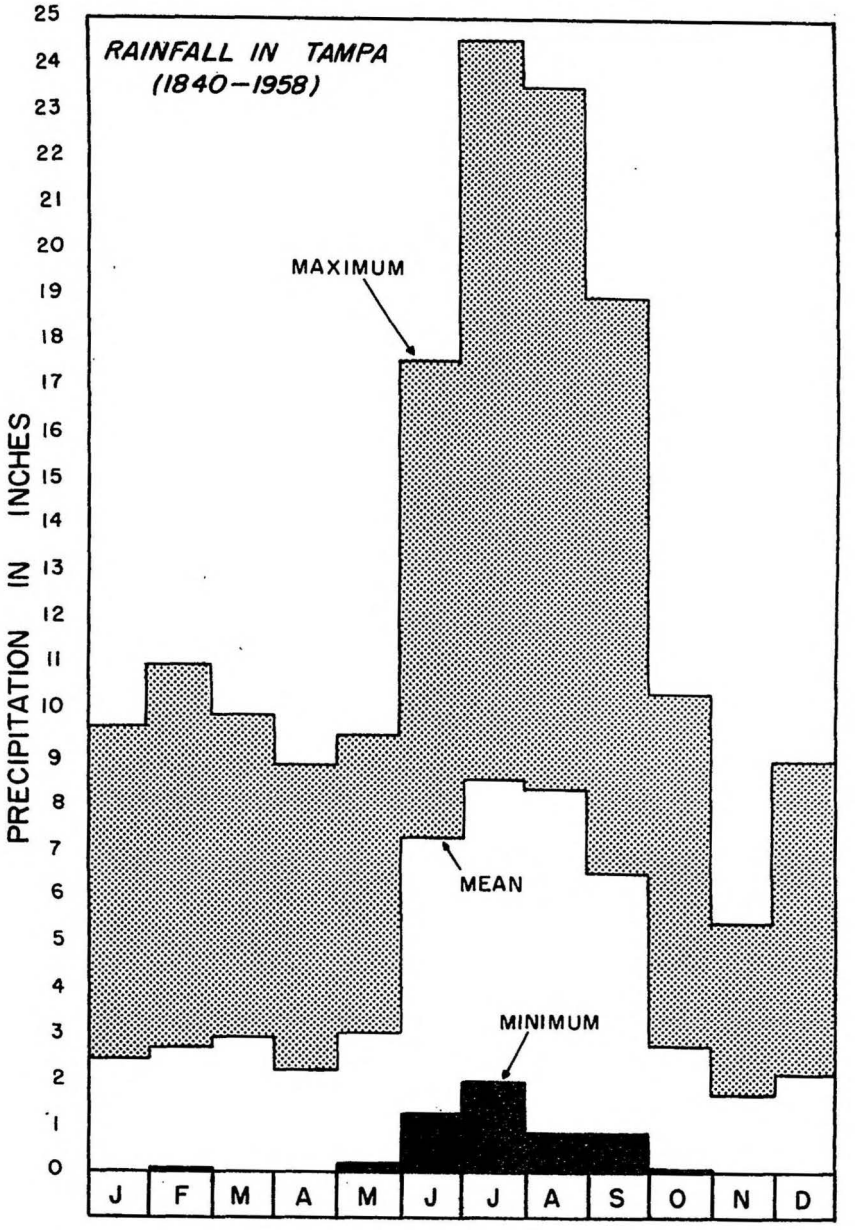


Figure 5. Mean, maximum, and minimum monthly rainfall at Tampa, Florida, 1840-1958.

December, an average of 2.8 inches evaporates. The average rate increases to 7.5 inches in May and gradually decreases to 5.2 inches in September.

Evaporation from the shallow pan is generally greater than that from a lake. Monthly coefficients have been computed from records collected from 1940-56 at Lake Okeechobee, Florida (table 1). They range from 0.69 for February to 0.91 for July and August. The computed evaporation from lakes in Hillsborough County is shown in table 1.

SURFACE FLOW

The streams in Hillsborough County generally flow towards Tampa Bay. In the northwestern part, Rocky Creek and Sweetwater Creek flow southward and empty into Old Tampa Bay. In the northeastern part, the Hillsborough River and Palm River flow southwestward and into Hillsborough Bay. In the southern half of the county, the Alafia River and the Little Manatee River flow westward and into Tampa Bay. Old Tampa Bay and Hillsborough Bay flow southward into Tampa Bay which, in turn,

TABLE 1. Monthly Mean Evaporation from Lakes in Hillsborough County

Month	Evaporation (inches)		
	Class A Pan[1]	Pan Coefficient[2]	Lakes
January	3.17	0.77	2.44
February	3.73	.69	2.57
March	5.23	.73	3.82
April	6.35	.84	5.33
May	7.53	.82	6.17
June	7.10	.85	6.04
July	6.18	.91	5.62
August	5.66	.91	5.15
September	5.24	.85	4.45
October	4.45	.76	3.38
November	3.44	.71	2.44
December	2.77	.83	2.30
Total			49.71

[1]Monthly mean of record for 1952-58 from U. S. Weather Bureau evaporation station at Bay Lake near Sulphur Springs, Florida.

[2]Computed evaporation data for Lake Okeechobee, Florida, Kohler, M. A., 1954.)

empties into the Gulf of Mexico. The average streamflow into the bays is slightly more than a billion gallons a day. About 6 percent flows into Old Tampa Bay, 77 percent flows into Hillsborough Bay, and 17 percent flows directly into Tampa Bay. Hillsborough County is the source of about two-thirds of this water. The remaining one-third comes from parts of Hernando, Lake, Sumter, Pinellas, Pasco, Polk, and Manatee counties.

Runoff is generally high in the southern part of the county, moderate in the northeastern part, and low in the northwestern part. Yearly mean values range from 12 inches in the northwest to 17 inches in the south. An exception is the Palm River basin. Although this basin is in the central part of the county, its runoff is high (24 inches). The yearly average runoff for the county is 15.6 inches.

UNDERGROUND FLOW

Generally, the piezometric surface in Hillsborough County slopes towards Tampa Bay, indicating the general direction of underground flow. In the northwestern part of the county, groundwater flow is southward to Old Tampa Bay; in the northeastern part, the flow is southwestward to Hillsborough Bay; and in the southern half it is westward to Tampa Bay.

About 100 mgd flows through the ground into Hillsborough County. This value was derived using the formula $Q=TIL$, where Q is the ground-water flow in gallons per day, T is the transmissibility rate in gallons per day per foot, I is the piezometric slope in feet per foot, and L is the length in feet of the contour crossed. The values used in the computation were 2.7×10^5 gpd per foot for the transmissibility rate, 9×10^{-4} for the average piezometric slope, and 3.85×10^5 feet for the length of contour at the county line.

Springs in Hillsborough County discharge water in quantities about equal to the ground-water flow into the county. Sulphur, Eureka, Buckhorn, and Lithia springs discharge 77 mgd, and other known springs discharge about 20 mgd.

Water probably seeps into the ground at a rate of more than 450 million gallons a day. About 50 mgd of this water emerges in the bays adjoining Hillsborough County. Another 67 mgd is pumped from the ground for industrial, farm, public and private water supplies. The remainder emerges in streams of the county and flows to the bays. The figure of 450 mgd excludes the ground water returned to the atmosphere by transpiration.

GEOLOGY

Hillsborough County is underlain by sedimentary rocks ranging in thickness from about 8,000 feet in the northeast to about 13,000 feet in the southwest (Applin, 1951). These sediments, which rest on crystalline rocks, consist of sandstone, anhydrite, and dolomite of Mesozoic age overlain by limestone, dolomite, clay, and sand of Cenozoic age.

Only the upper 1,000 feet of the Cenozoic section is used as a source of water in the county. Only two water wells over 1,000 feet deep were inventoried during the investigation.

The depth of a well is controlled by economy and by depth to salt water. For economical reasons, a well is finished at the shallowest depth at which a given yield at a given drawdown is obtainable. The depth of a well, for most purposes, must also be limited by the depth to salt water. In the northeastern part of the county, the depth to salt water is probably more than 4,000 feet below the surface. The maximum depth of a fresh-water well in that area would be about 4,000 feet. At this depth the entire Cenozoic section would have been penetrated.

Table 2 summarizes the geologic formations and their properties from the bottom of the Oldsmar limestone of Eocene age to the recently deposited sands and clays at the surface. This section is believed to include all of the formations that are economically exploitable as a source of water in the county.

The rocks of Cenozoic age in the county were laid down in essentially horizontal position. During deposition of sediments, the land was tilted downward to the southwest. This resulted in thickening of the beds in that direction. The forces resulting from differential compaction, along with regional forces associated with the Ocala uplift and the peninsular arch, warped the beds downward to the southwest. The stresses were relieved by faulting. The present attitude of the beds is the result of these structural changes. The available data indicate the existence of many faults, some with about 200 feet of vertical displacement. Additional data are necessary to place and limit these faults.

Because the beds thicken and dip to the southwest, wells of similar bottom elevation will penetrate older formations in the northeast than in the southwest. Most of the deep wells in the southwestern part of the county produce water principally from the Tampa and Suwannee limestones, whereas those in the central-east and northeast parts of the county commonly produce from the Avon Park limestone.

TABLE 2. Summary of Geologic Formations from Bottom of Oldsmar Limestone to the Ground Surface

Series	Formation	Thickness	Character of material	Water supply	Aquifer	Water level
Pleistocene and Recent Pliocene	Undifferentiated	0-150	Sand, clay, and marl.	Sand yields up to 200 gpm in some areas and generally 5 to 10 gpm to driven wells less than 40 feet deep. Clay and marl do not yield usable quantities of water to wells.	Water table aquifer	Water level generally less than 10 feet. Water table follows topography in a subdued manner.
Miocene	Hawthorn formation	0-250	Clay, sand, and limestone. Limestone, near bottom of formation, is white to gray, soft, sandy, and porous.	Limestone member yields up to 200 gpm.	Shallow artesian aquifer	Piezometric surface not defined. Water level is generally higher than that of nearby wells in principal artesian aquifer.
Miocene	Tampa limestone	80-400	White, cream, and gray, hard to soft, sandy limestone. Many molds of pelecypods and gastropods.	Yields up to 1,000 gpm. Supplies most domestic and commercial wells in county.	Principal artesian	Piezometric surface shown in figures 48 and 49.
Oligocene	Suwannee limestone		White, yellow, and light brown, soft to hard, dense, fine-grained limestone with chert lenses to 25 feet thick.			
Eocene, Ocala group[1]	Crystal River formation (Puri, 1957) Williston formation (Puri, 1957) Inglis limestone	90-300	Yellow-gray and brown soft, almost pure limestone. Mostly foraminiferal coquinas in pasty limestone matrix.	Rarely used for water supply because of low transmissibility.		
Eocene	Avon Park limestone	200+	Soft, chalky, cream to brown limestone containing beds of foraminiferal coquina and zones of brown to dark brown, hard, crystalline dolomitic limestone. Locally contains some gypsum.	Principal source of supply for wells yielding more than 500 gpm. Yield exceeds 5,000 gpm in some wells.		
Eocene	Lake City limestone	500				
Eocene	Oldsmar limestone	900	Fragmental dolomitic limestone with lenses of chert, thin shale beds, and some gypsum.	Not used for water supplies but is potential source of fresh water in north-central and northeastern part of county.		
Paleocene	Cedar Keys limestone	Not known	Not known	Not used. Potential use not known.		

[1]The Ocala group used here accords to the terminology of the Florida Geological Survey.

Geologic cross sections through Hillsborough County are shown in figure 6.

WATER PROBLEMS

Hillsborough County is now in a period of accelerated population and economic growth. Large quantities of water will be needed for municipal and industrial uses.

The need for land also is increasing with the growing population. Areas having poor drainage and the flood plain of streams are being used to fill the need. As more people occupy and use this type of land, pressure will be placed upon governmental agencies to have drainage and flood-control works performed.

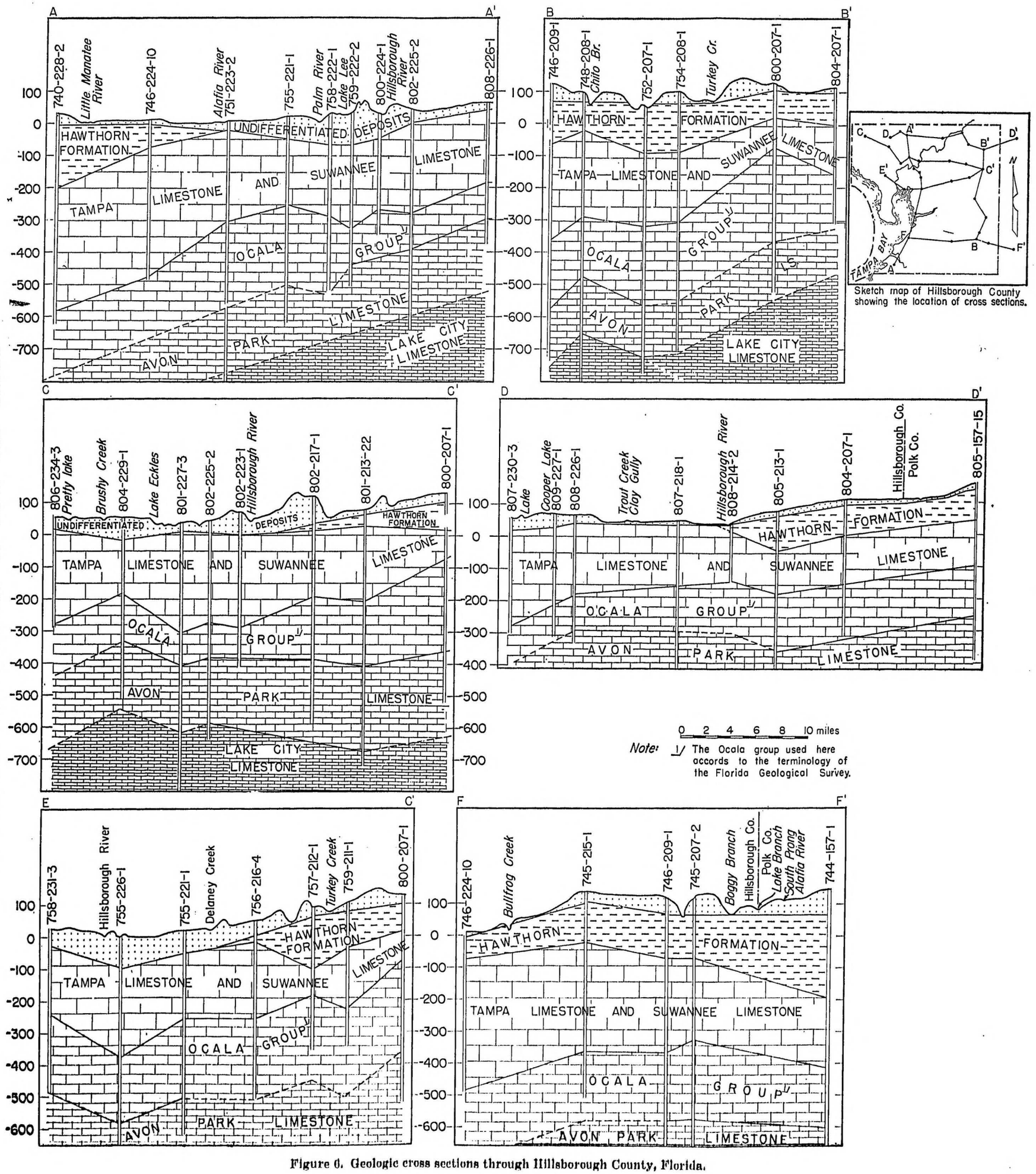
The per capita use of water in the county is estimated to equal the national average of 1,100 gallons per day. In 1955, the per capita use of water in Florida was 900 gallons per day. The county has many industries which make its per capita use greater than the average for the State.

It will be necessary to reclaim and re-use water or to import water when the population of Hillsborough County exceeds the number of persons that may be supported by the available water. An average of about 1,400 mgd is potentially available. This is enough water to supply 1,250,000 persons if all of the flood waters could be stored for use. At present 400 mgd of this water enters the county from adjoining counties.

Surface-water problems in Hillsborough County are caused by the distribution of water. Three relative conditions occur—low water, medium water, and floods. When flood conditions exist, the problem becomes one of eliminating excess water that might cause damage and inconvenience. During medium and low water periods, the problems may become one of finding suitable water sufficient to satisfy the needs.

The flooding of the community of Bloomingdale Acres in March 1959 illustrates the problems encountered when flood plains are used for residential purposes. Bloomingdale Acres was built on the north bank of the Alafia River during 1957 and 1958. In March 1959, the stage in the river rose to 26.9 feet above the mean sea level and a large portion of Bloomingdale Acres was flooded. In the past, similar stages have recurred every 4 to 5 years.

The question of whether a piece of property is subject to flooding may be determined from lake and stream stage data and topographic maps.



Sketch map of Hillsborough County showing the location of cross sections.

Figure 6. Geologic cross sections through Hillsborough County, Florida.

Ground-water problems are related to distribution and occurrence with respect to quality. Desired quality limits the quantity of water available for a given use. The elevation of the piezometric surface and the geology of the area are the principal factors controlling the quality of ground water.

Salt content is the major quality problem in the county. There are two potential sources of salt water, (1) Tampa Bay and (2) connate waters. Sea water can enter the aquifer when the water level in the aquifer is lowered sufficiently. This condition exists near Gibsonton. Heavy industrial pumping in that area has lowered the piezometric surface to below sea level in the vicinity of the channel cut in the bay. This condition also exists along the shore of the bay west of the Interbay peninsula where the piezometric surface is near sea level because of natural discharge.

Zonation in an aquifer allows a salty zone to exist in the upper part of the aquifer near a surface source of salt water at the same time that lower zones contain fresh water.

In the remainder of the county, as well as in some of the tidal areas, salt water in wells is derived from a body of salty connate water that has not been flushed from the aquifer since the area emerged from the sea. This water underlies the entire county at depth. In general, the salt water interface occurs at a depth below sea level of 40 times the elevation of the piezometric surface above sea level. The 40-to-1 relationship is based on specific gravities of 1 for fresh water and 1.025 for salt water and assumes a sharp interface in a static system. Actually the fluctuation of the piezometric surface, movement of ground water, ocean tides, and circulation of the salt water in convection-like currents, cause the interface to be gradational between fresh and salt water, with a thickness of more than 100 feet in places.

Salt content generally will increase with depth, but the increase is not uniform. In some areas, the bulk of the aquifer may contain salty water, but certain zones through which large amounts of water are moving may be relatively fresh. In other areas, the bulk of the aquifer may contain fresh water, but a cavity may contain very salty water. Areas near one of the many faults that may act as conduits for the upward movement of the connate water are potentially salty. Thus, with the development of the ground-water resource and the resultant lowering of the piezometric surface, the contaminated areas will become more numerous, and the existing areas of contamination will become more pronounced.

Prevention of problems from this source may require recharge

of the aquifer by surface water to raise the piezometric surface in the affected areas.

Future development of ground-water supplies for municipal or other large users will be controlled by the elevation of the piezometric surface and by geological conditions that affect quality of water.

The decline of water levels caused by extensive development of ground-water supplies may make the placing of well fields unfeasible in the area where the elevation of the piezometric surface is less than 50 feet above sea level.

The flanks of the piezometric highs centered in Pasco and Polk counties present nearly ideal sites for development of future water supplies. The area of the reentrant (indicated by upstream bending of the contour lines) in the piezometric surface that follows the Hillsborough River from near Tampa to the northeastern part of the county is not favorable for location of well fields. Any pumpage from wells in that area would only deplete the surface-water supply presently used by the city of Tampa as a source of water and would cause rapid contamination of the river and wells by salt water.

The Industrial Park area in northeast Tampa is unsuitable for large-scale ground-water development because of existing quality of water problems. Increased pumping would further contaminate the aquifer with the salty water that locally makes ground water in the area unsuitable for most purposes.

When a well is allowed to flow, it diminishes the usable volume of water that may be withdrawn from the aquifer. At present, wells flowing to waste are important only in the vicinity of Ruskin, where quality of water is directly related to local heavy withdrawal, and in the vicinity of Tampa, where salt water already has spoiled the water in part of the aquifer as a source of fresh water.

Development of the ground-water resource to its full potential will necessitate control of waste flow from wells and may warrant the plugging of springs where feasible.

SURFACE WATER

Eighty-four percent of the water drained from the 1,040 square miles of land surface in Hillsborough County is carried by 10 streams. The remainder is drained from the land adjacent to Tampa Bay by numerous small streams, canals, ditches, and sewers. Some characteristics are discussed for the following stream basins:

Anclote River basin
Brooker Creek basin
Rocky Creek basin
Sweetwater Creek basin
Hillsborough River basin
Palm River basin
Alafia River basin
Bullfrog Creek basin
Little Manatee River basin
Peace River basin

A map showing the area in Hillsborough County drained by the streams of these 10 basins is shown in figure 7.

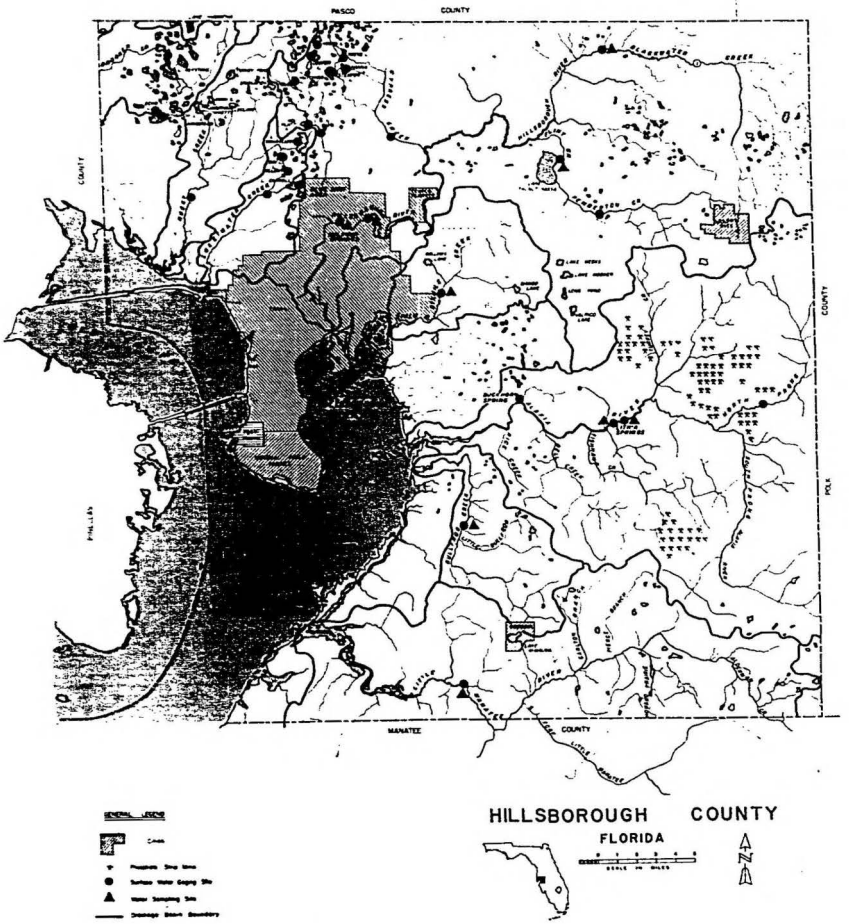


Figure 7. Surface-water features, location of gaging stations, and water sampling sites.

USE

The majority of surface water uses in Hillsborough County are nonconsumptive. Most of this water is used in some way for recreational purposes. Some is used for cooling, washing, shipping, etc. Water flowing in Pemberton Creek and in the Alafia River is used to dilute and carry waste materials.

No estimate is made of the quantity of surface water consumed in the county. The amount of water pumped for irrigation of citrus groves and truck crops is not known.. The known uses include 3 mgd for industrial processes and 23 mgd for municipal supply.

ANCLOTE RIVER BASIN

ANCLOTE RIVER

The Anclote River drains 113 square miles of land in Pinellas, Pasco, and Hillsborough counties. However, only about 3 square miles of the land is in Hillsborough County, along the northern boundary and is 40 to 60 feet above mean sea level. Water draining from this area moves northwestward to the Anclote River through Pasco and Pinellas counties. Osceola Lake, Lake Artillery, and Lake Hiawatha lie in the Hillsborough County portion of the river basin. Lake Hiawatha is the largest of these lakes. It has a surface area of 100 acres, of which 80 percent is in Hillsborough County and the remainder in Pasco County.

BROOKER CREEK BASIN

BROOKER CREEK

Brooker Creek drains approximately 42 square miles of land in Hillsborough, Pasco, and Pinellas counties, of which 28 square miles is in northwestern Hillsborough County. The remainder (14 square miles) is in Pasco and Pinellas counties. The creek heads in the marshy area 2 miles east of the town of Lake Fern and 4 miles southeast of Odessa. It flows generally in a south-southwestward direction to Keystone Lake, then northward to Island Ford Lake, and then southwestward toward Lake Tarpon in Pinellas County, crossing the county line half a mile south of State Highway 582. The land is about 60 feet above sea level in the northeastern part of the basin and 20 feet above sea level at the county line. There are numerous lakes in the upper part of the basin. The land in this area is used mainly for growing citrus.

The average discharge (1946-55) of the creek at the outlet of Keystone Lake was 4.8 mgd (0.48 mgd per sq. mi.). The highest recorded daily flow of 116 mgd occurred in August 1949. Several times during the period of record, there was no flow in the creek. In 1949, there was no flow for 159 consecutive days, and, in 1951, there was no flow for 94 consecutive days.

During the 8-year period, 1950-58, the flow of Brooker Creek 2 miles upstream from Lake Tarpon averaged 14.5 mgd (0.48 mgd per sq. mi.), the same rate of runoff per unit area as at the outlet of Keystone Lake.

KEYSTONE LAKE

Keystone Lake, with a surface area of 580 acres at a stage of 41 feet above mean sea level, is the largest of the two dozen named lakes and numerous unnamed lakes within the area drained by Brooker Creek. It is an integral part of the Brooker Creek channel. During the period, April 1946 to December 1959, the maximum and minimum stages of the lake were 43.20 (August 1949) and 38.60 feet (June 1949), respectively, in relation to mean sea level. Stages in this lake closely follow the seasonal rainfall pattern. The annual variation in stage on the lake is less than 5 feet. A stoplog dam was constructed at the lake outlet in October 1955.

CHURCH AND ECHO LAKES

Church and Echo lakes, located 2 miles northwest of Citrus Park, have a surface area of 70 and 25 acres, respectively, when the stage is 33 feet above mean sea level. The stage did not drop below the bottom of the channel connecting the two lakes during the period of this investigation. Therefore, the two lakes react as one.

Church and Echo lakes are reported by local residents to be used as a source of water for the irrigation of surrounding groves. It would take a pump with a capacity of 360 gpm, running continuously at full capacity for a period of 30 days, to lower the stage of these lakes half a foot.

During the 2 years of the stage investigation, Church and Echo lakes have ranged from 33.92 to 37.28 feet above mean sea level (fig. 8). When the stage is more than 35 feet above mean sea level, Church, Echo, Thorpe, and Williams lakes become interconnected. This complex of lakes was formerly called Lake Sullivan.

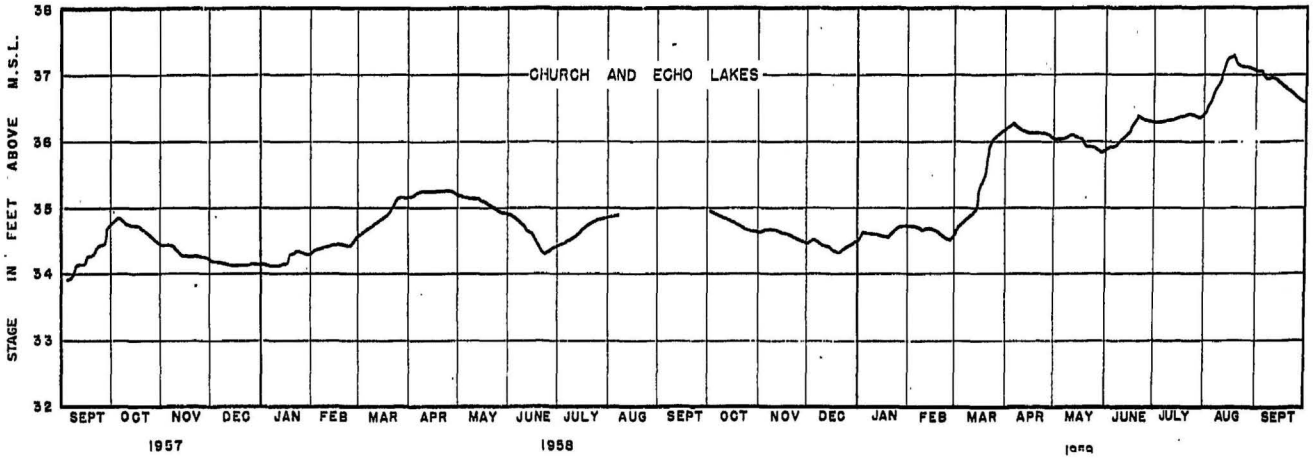


Figure 8. Stage of Church and Echo lakes, 1957-59.

ROCKY CREEK BASIN

ROCKY CREEK

Rocky Creek drains 42 square miles of land in Hillsborough County and 3 square miles in Pasco County. The creek proper begins at Turkey Ford Lake and flows southwestward through Rock Lake, Lake Josephine, Pretty Lake, and Lake Armistead, then southward into Old Tampa Bay. Land elevations are as high as 60 feet in the upper part of the creek basin and at sea level near the mouth. There are numerous lakes in the northern two-thirds of the basin but very few in the southern part.

The lake area in the northeastern part of the basin contributes water to Rocky Creek through ill-defined channels leading to Turkey Ford Lake. The only measurement of flow from this area was made at Vernon Road on September 27, 1947. The flow at the bridge crossing was 40.0 cfs (cubic feet per second). On this same day the mean daily flow of Brooker Creek at the outlet of Keystone Lake was 60.0 cfs, 8 times the 9-year average flow for 1946-55.

In 1953, a timber dam was constructed on Rocky Creek about a 100 feet upstream from the east-west tracks of the Seaboard Air Line Railroad, 4 miles above the mouth. Stage below the dam fluctuates with the tides of Old Tampa Bay, and, when flow is sufficient to just submerge the control, tidal fluctuations are discernible as far as 5 miles above the creek's mouth.

During the 5-year period, 1953-57, the average flow of Rocky Creek at the control was 20 mgd (0.57 mgd per sq. mi.). Flows ranged from a minimum of 0.3 mgd (May and June 1955) to a maximum of 450 mgd (September 1953). The flow fell below 1.5 mgd in 1953, 1955, 1956, and 1957. The longest period, 96 consecutive days, was in 1955.

The estimated average flow of Rocky Creek at the mouth is 24 mgd.

The concentration of material dissolved in Rocky Creek on January 29, 1959, was estimated to be about 50 ppm. About 30 ppm of this total was mineral content and the remaining 20 ppm was organic material. These estimates are based upon measurements of specific conductance and a color intensity of 110 platinum-cobalt scale units.

BUSHY CREEK

Bushy Creek, the largest tributary to Rocky Creek, drains 11 square miles of land west of Sulphur Springs. The creek begins at

Starvation Lake and flows southwestward, joining Rocky Creek a quarter of a mile south of Gunn Highway. Its largest tributary heads in Lake Le Clare and flows southward joining Brushy Creek about 1½ miles above its confluence with Rocky Creek.

The concentration of material dissolved in Brushy Creek on January 29, 1959, was estimated to be 70 ppm. About 35 ppm of this total was mineral content and the remaining 35 ppm was organic material. These estimates are based on measurements of specific conductance and a color intensity of 130 platinum-cobalt scale units.

SWEETWATER CREEK BASIN

SWEETWATER CREEK

Sweetwater Creek drains 25 square miles of land in Hillsborough County. It begins at Lake Magdalene, flows westward to Bay Lake, then southward to Lake Ellen, and finally, south-southwestward to Tampa Bay. Stoplog dams are used to regulate flow into and out of these lakes. The land drained by the creek ranges in elevation from 55 feet at the northern divide to sea level at the mouth. This creek basin is now becoming urbanized, especially around the lakes, with citrus groves and farms being replaced by housing developments.

During the 7-year period, 1952-58, the average discharge of Sweetwater Creek was 3.0 mgd at the Gunn Highway. This is equivalent to only 0.47 mgd per square mile of area drained. Other local watersheds having little surface storage yield about 0.6 mgd per square mile. The low yield from Sweetwater Creek watershed above the Gunn Highway is attributed to the detention of water in the lakes, which results in an increase in the evaporation and seepage losses. There was no flow in Sweetwater Creek many times during the period 1951-58. During the 18-month period November 1955 to April 1957, the maximum flow was 1.5 mgd and the average flow was less than 0.1 mgd.

The estimated average flow of Sweetwater Creek at its mouth is 14 mgd.

During periods of high water, the Hillsborough River basin is interconnected with the Sweetwater Creek basin between Platt Lake and Lake Magdalene.

One of the larger tributaries to Sweetwater Creek heads in White Trout Lake, flows southwestward and joins the creek 1.2 miles north of Hillsborough Avenue (State Highway 580) and 2.3 miles east of Dale Mabry Highway (State Highway 597). It

drains about 4 square miles of land lying west of Tampa and has an estimated average flow of 3 mgd.

On January 29, 1959, the concentration of dissolved material in the South Branch of Sweetwater Creek was estimated to be 110 ppm and in Sweetwater Creek just below South Branch it was estimated to be 80 ppm. About 55 ppm and 45 ppm, respectively, of this was mineral content, and the remainder was organic material. These estimates are based on measurements of specific conductance and respective color intensities of 220 and 110 platinum-cobalt scale units.

LAKE MAGDALENE

Lake Magdalene, the largest lake in the Sweetwater Creek basin, has a surface area of 230 acres when the stage is 47 feet above mean sea level. During the past 12 years, 1947-58, the stage has fluctuated between 44.5 and 50.8 feet above mean sea level. Ninety percent of the time the stage was greater than 46.4 feet; 50 percent of the time it was greater than 48.6; and 10 percent of the time it was greater than 49.5 feet.

Stage-duration curves for Lake Magdalene, Bay Lake, Lake Ellen, and Carroll Lake are shown in figure 9. The curves for Lake Magdalene, Bay Lake, and Lake Ellen are plotted on the same grid with Hobbs Lake, Cooper Lake, and Platt Lake. All of these lakes are part of the same drainage course during periods when some of the flow of the drainage ditch of the Hillsborough River basin is diverted into the Sweetwater Creek basin.

BAY LAKE

Bay Lake, 3.5 miles northwest of Sulphur Springs and 4.4 miles east of Citrus Park, has a surface area of 38 acres when the stage is 45 feet above mean sea level. During the past 12 years, 1947-58, the stage fluctuated between 43.0 and 46.7 feet. Ninety percent of the time the stage was greater than 43.9 feet; 50 percent of the time it was greater than 45.1 feet; and 10 percent of the time it was greater than 45.6 feet (fig. 9).

LAKE ELLEN

Lake Ellen, located 3.8 miles northwest of Sulphur Springs, has a surface area of 50 acres when the stage is 39 feet above mean sea level. During the 10-year period, September 1946 to August 1956, the stage fluctuated between 37.6 feet and 41.8 feet. Ninety

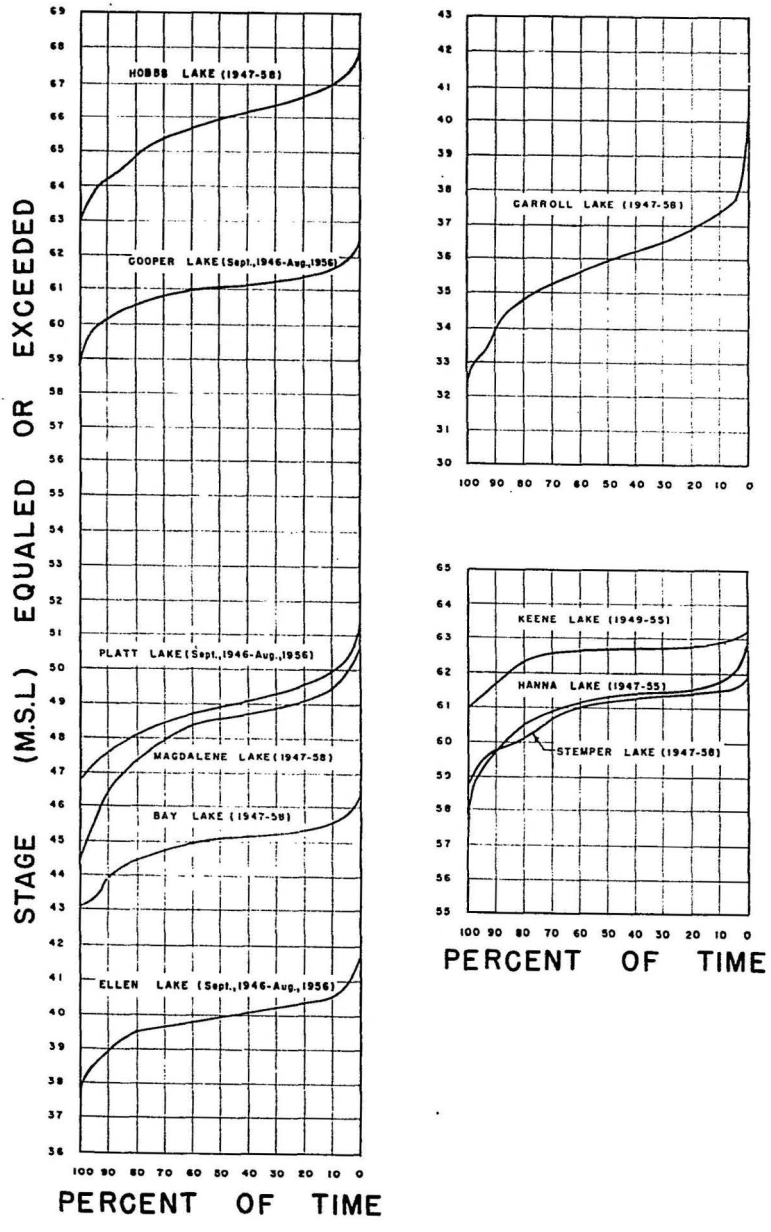


Figure 9. Stage-duration curves of some lakes in Hillsborough County.

percent of the time the stage was greater than 38.9 feet; 50 percent of the time it was greater than 39.9 feet; and 10 percent of the time it was greater than 40.6 feet (fig. 9).

CARROLL LAKE

Carroll Lake, located 2.8 miles northwest of Sulphur Springs in the Sweetwater Creek drainage basin, covers 186 acres when the stage is 34 feet above mean sea level. During periods of high stage, water from the lake flows southwestward through a swampy area and into Sweetwater Creek above Gunn Highway. Lake stages fluctuated between 32.2 feet and 40.1 feet above mean sea level during the past 13 years (1947-58). Ninety percent of the time the stage was greater than 33.9 feet; 50 percent of the time it was greater than 35.9 feet; and 10 percent of the time it was greater than 37.4 feet (fig. 9).

HILLSBOROUGH RIVER BASIN

HILLSBOROUGH RIVER

The Hillsborough River drains 690 square miles of land in Hernando, Pasco, Polk, and Hillsborough counties. During periods of high water, the Withlacoochee River, which drains parts of Lake and Sumter counties, overflows into the Hillsborough River basin near Richland. The river rises in the Green Swamp area of central peninsular Florida and flows southwestward to Hillsborough Bay at Tampa.

About 320 square miles of land in Hillsborough County is drained by the Hillsborough River. Land elevations range from sea level at the mouth of the river to more than 140 feet at a point east of Plant City. There are many lakes and springs in the basin. The greatest concentration of lakes is along the western basin divide, north of Tampa, and the largest lake, Lake Thonotosassa, is located between Plant City and Temple Terrace. Citrus groves, cattle ranches, and truck farms are located in the rural parts of the river basin. Plant City, Temple Terrace, and part of Tampa are in the basin.

The flow of the Hillsborough River is gaged at Hillsborough River State Park where the river drains approximately 220 square miles. During the 19-year period, 1940-58, the average discharge of the river there was 173 mgd (0.79 mgd per sq. mi.). The lowest flow recorded during this period was 31 mgd (June 1945). Flow in the river is sustained by the discharge of Crystal Springs, which

empties into the Hillsborough River in Pasco County just above the Hillsborough-Pasco county line. About 90 percent of the time the flow is 71 cfs or 46 mgd or more; 50 percent of the time it is 120 cfs or 78 mgd or more; and 10 percent of the time it is 600 cfs or 388 mgd or more (fig. 10). Usually the monthly flow is highest in late summer or early fall, and the lowest in the fall or spring seasons.

The total dissolved materials in the river water at Hillsborough River State Park averaged (time weighted) about 150 ppm from September 1956 to August 1958 and ranged from 50 to 218 ppm. The total dissolved materials generally ranged from 52 to 90 percent calcium-plus-magnesium as calcium carbonate, 1 to 31 percent colored organic matter, and 4 to 17 percent sulfate. The remaining dissolved materials were smaller amounts of various other minerals. Mineral content for the 1957 water year ranged from 56 to 201 ppm, as indicated by figure 11.

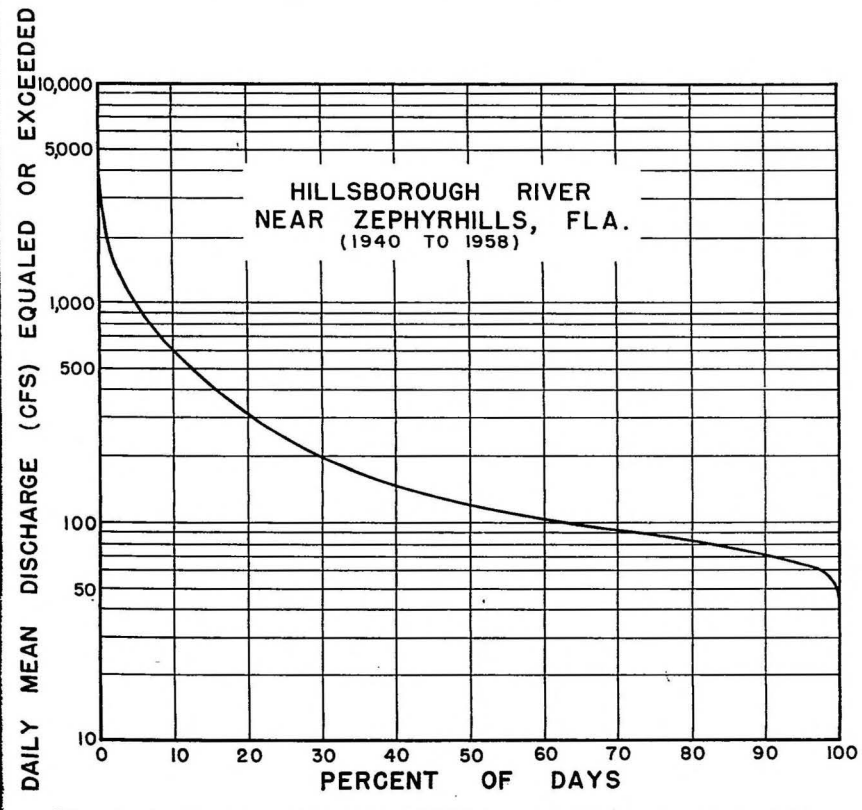


Figure 10. Flow-duration curve of Hillsborough River near Zephyrhills.

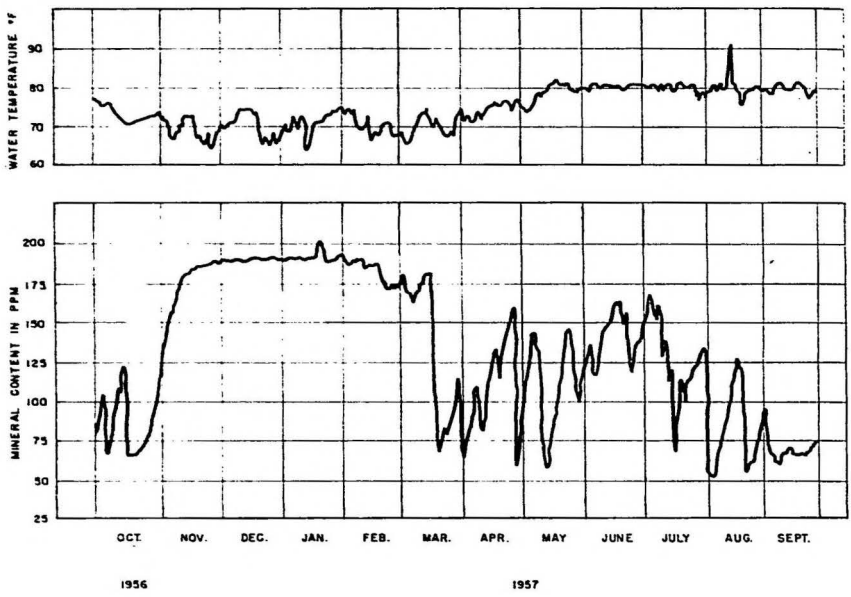


Figure 11. Mineral content and water temperature in Hillsborough River at Hillsborough River State Park.

About half the time, the mineral content was 127 ppm or less during the period September 1956 to September 1957. This value is based upon specific conductance. Figure 12 shows the percent of days the specific conductance was equal to or less than a given value for the period of record stated above.

Figure 12, in combination with the formula given below, can be used to estimate the mineral content of the Hillsborough River near Tampa for any desired percentage of time:

Mineral content in ppm=(0.59) x (specific conductance). The factor, 0.59, is the average of the ratios of mineral content to specific conductance for composite samples during the period September 1956 to August 1958.

Dissolved solids and water temperatures of the Hillsborough River vary with the seasons. Water temperatures ranged from 63° F. in January to 90° F. during August the period 1956 to August 1958. The effect of rainfall upon streamflow is usually accompanied by changes in both the amount and character of dissolved materials. Changes in the values for color, for instance, are shown in figure 13.

For the period September 1956 to October 1957 the streamflow

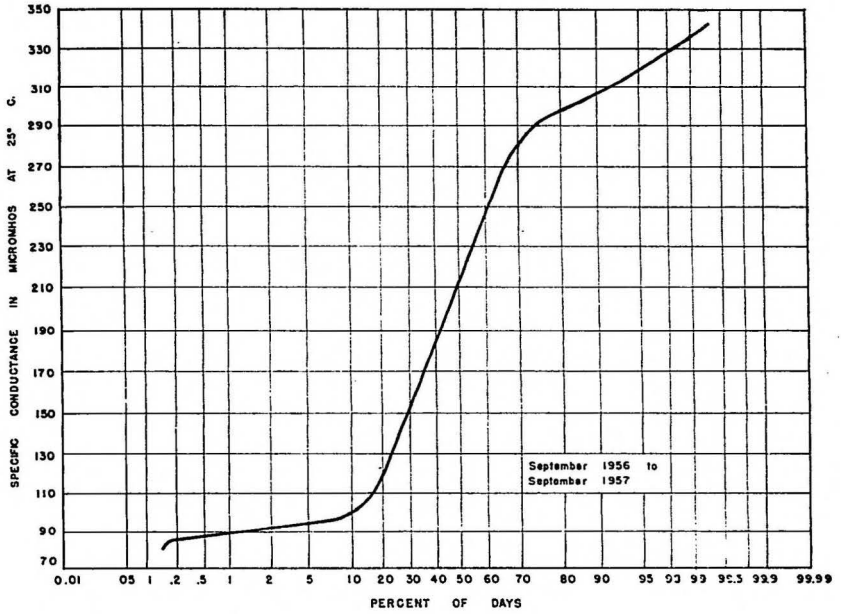


Figure 12. Percent of days specific conductance was equal to or less than a given value, Hillsborough River at Hillsborough River State Park.

tended to increase in direct proportion to rainfall, whereas calcium plus alkalinity as carbonate was nearly always present in amounts greater than most of the other dissolved materials. A trend of the chemical character of dissolved materials is indicated in figure 14. Figure 15 shows a similar trend for the period from October 1957 to October 1958.

The average concentration of dissolved materials (150 ppm) appears when streamflow is about 129 mgd, or about 200 cfs (fig. 16). The figure also shows the range of dissolved materials for the period in relation to flow.

During the 6-year period, 1934-39, the average flow of the Hillsborough River at Fowler Avenue was 350 mgd. It ranged between 30 and 7,600 mgd. At this point, the river drains about 525 square miles of land.

During the 20-year period 1939-58, the average flow of the Hillsborough River above the Tampa waterworks dam was 380 mgd (0.58 mgd per sq. mi.). The discharge over the dam has never fallen below 31 mgd. This low rate occurred on June 11-17, 1945. In 1957 the average amount of water withdrawn from the river by the Tampa water department was 23 mgd. Even during

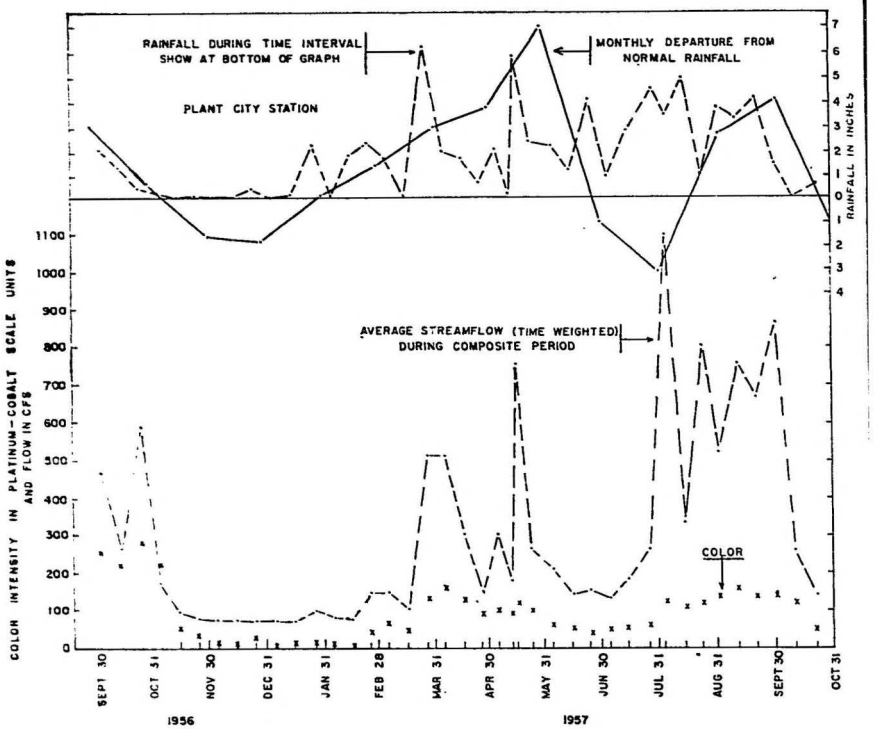


Figure 13. Color in relation to rainfall and flow of the Hillsborough River at Hillsborough River State Park (September 1956 to October 1957).

the 1945 period of extreme low flow, the water spilled over the dam (wasted to the sea) amount to 135 percent of the 1957 average withdrawal. The greatest flow, 3,800 mgd, was observed at the 40th Street bridge on September 7, 1933, prior to the failure of the Tampa power dam.

During the flood of September 1933, the Hillsborough River crested at 26.3 feet above mean sea level at the 40th Street bridge and at 15.2 feet at Nebraska Avenue. Flow of the magnitude that caused this extreme in stage recurs at a frequency of about once every 80 years. The frequency given is based on composite frequency curves.

At the mouth the average flow of the Hillsborough River probably exceeds 450 mgd.

The chemical character of dissolved materials in Hillsborough River water at the Tampa waterworks dam is shown in figures 17 and 18.

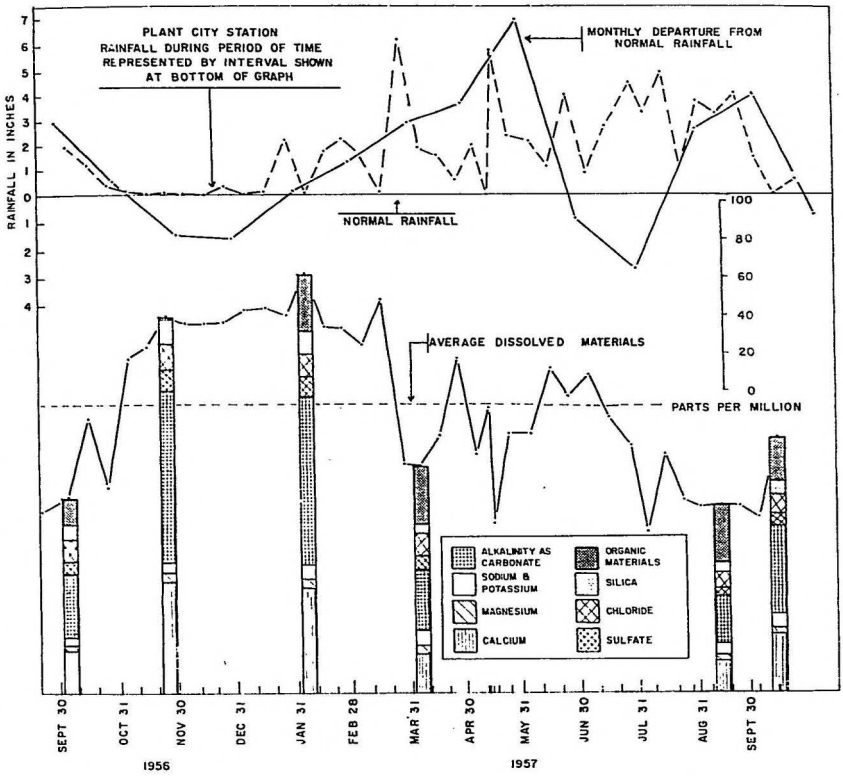


Figure 14. Chemical character of dissolved materials carried by Hillsborough River water at Hillsborough River State Park (September 1956 to October 1957).

During the period of the record from October 1956 to February 1957 and June to July 1957, rainfall on the county as indicated by the Plant City station was below normal. Most of the remaining record, September 1956, March to May 1957, and August to September 1957, was during a period of above normal rainfall. The time period used is not representative of a complete range in rainfall but is considered representative of the range of departure from normal rainfall.

Color intensity of the Hillsborough River water exceeds the maximum amount recommended for municipal supplies most of the time and requires treatment for its removal. This is most commonly accomplished by adding alum to the water, which causes the color to "floc" or separate from the solution in solid form. It then can be allowed to settle out, or it can be filtered. The amount

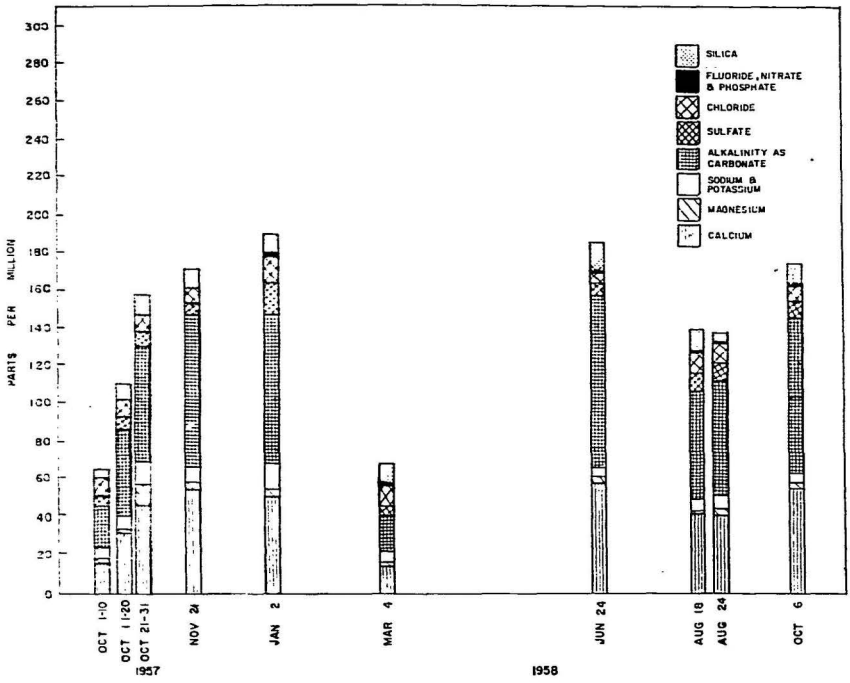


Figure 15. Chemical character of dissolved materials carried by Hillsborough River water at Hillsborough River State Park (October 1957 to October 1958).

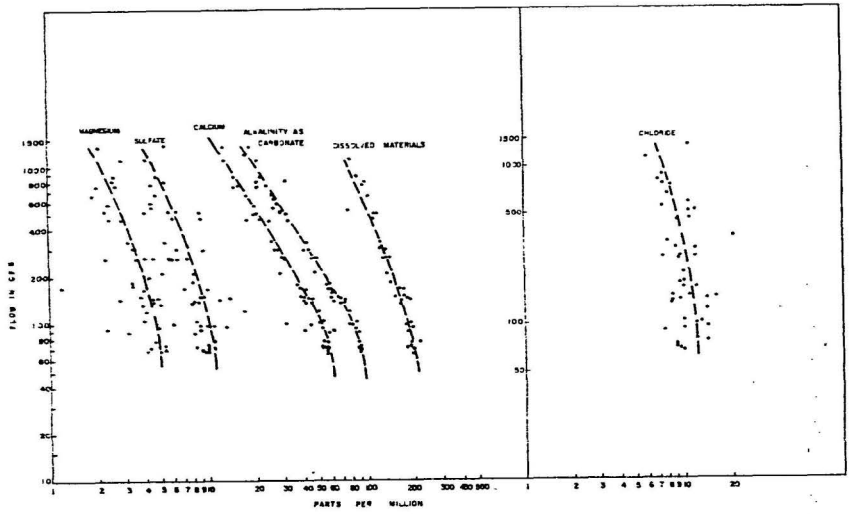


Figure 16. Dissolved materials in relation to flow, Hillsborough River at Hillsborough River State Park (September 1956 to September 1957).

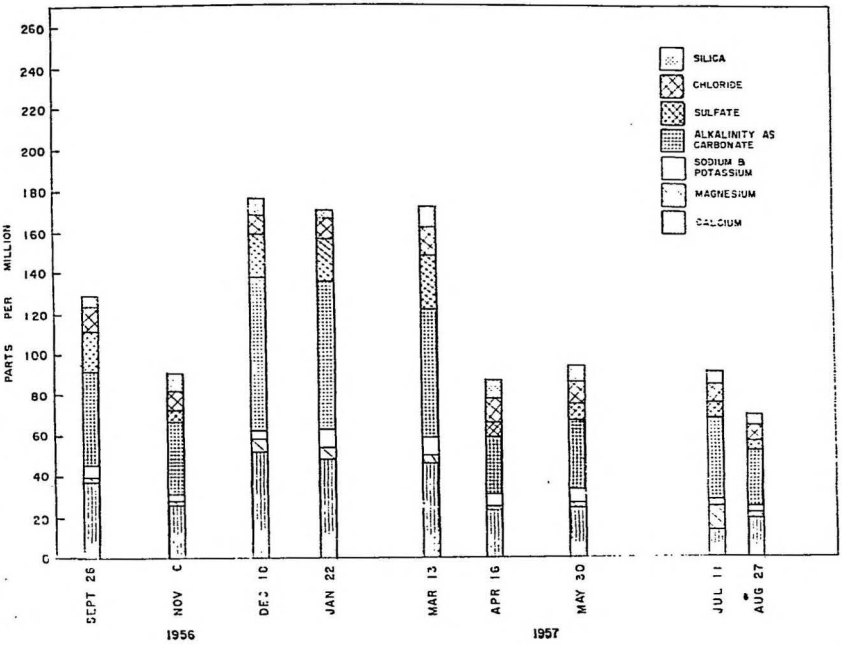


Figure 17. Chemical character of dissolved materials of Hillsborough River at Tampa (September 1956 to August 1957).

of iron present in the river is very likely greater than that shown by analysis, because iron precipitates out of solution during storage of samples. Iron is removed by aeration and is removed usually during the process of removing color. No other concentration of dissolved material was observed to exceed the maximum amount recommended by the U. S. Public Health Service.

Biological suitability, which is determined by the State Board of Health, is not included as a part of this report.

Water from the Hillsborough River apparently would be suitable for agricultural purposes. The objections noted above for municipal supplies do not affect the suitability of the water for agricultural purposes. Boron content is unknown.

Industrial uses vary widely, and water quality requirements vary almost as widely. Generally, the lesser the amount of dissolved matter in water, the more suitable the water is for industrial uses. The main exceptions to this rule are uses in which the water is not actually used in the process; for example, as cooling water in which practically the only considerations are temperature, corrosive properties, and quantity of water available

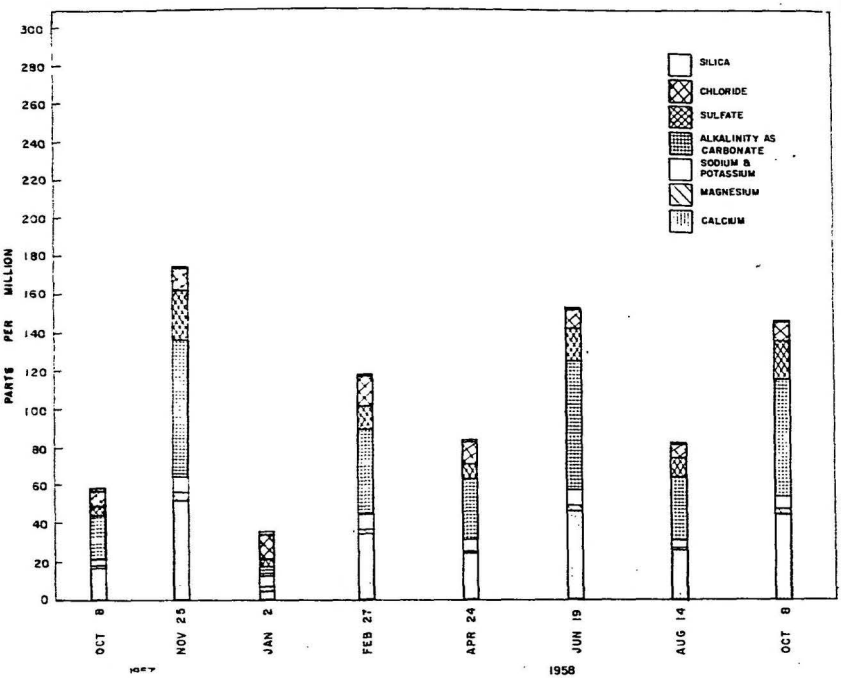


Figure 18. Chemical character of dissolved materials of Hillsborough River at Tampa (October 1957 to October 1958).

to meet the industrial needs. Water supplies that contain the lower dissolved solids concentrations are attractive to industries from an economic standpoint.

BLACKWATER CREEK

Blackwater Creek, one of the major tributaries of the Hillsborough River, flows into the river about a mile above the Hillsborough River State Park. During the 7-year period, 1952-58, the runoff from the 120 square miles of land in the Blackwater Creek watershed averaged 63 mgd (0.52 mgd per sq. mi.). The minimum flow was 0.45 mgd in May 1952. At the same time about 3 mgd was being withdrawn from the creek for irrigation purposes. On only three occasions has flow dropped below 1.5 mgd; the longest of these lasted 6 days.

FLINT CREEK

Flint Creek drains 71 square miles of land in Hillsborough County. The creek proper begins at Lake Thonotosassa and flows

eastward for half a mile, then northward for a mile, and then westward for 1½ miles to the river. During the 2-year period, October 1956 to December 1958, the average flow of Flint Creek at the outlet of Lake Thonotosassa was 42 mgd (0.70 mgd per sq. mi.). Zero flow was recorded during 18 days in June 1958. At the mouth the average flow of Flint Creek probably exceeds 50 mgd.

The average mineral content of the stream was about 74 ppm, estimated from the discharge-mineral content relationship shown in figure 19. The observed mineral content ranged from 46 to 92 ppm, and color intensity from 55 to 90 platinum-cobalt scale

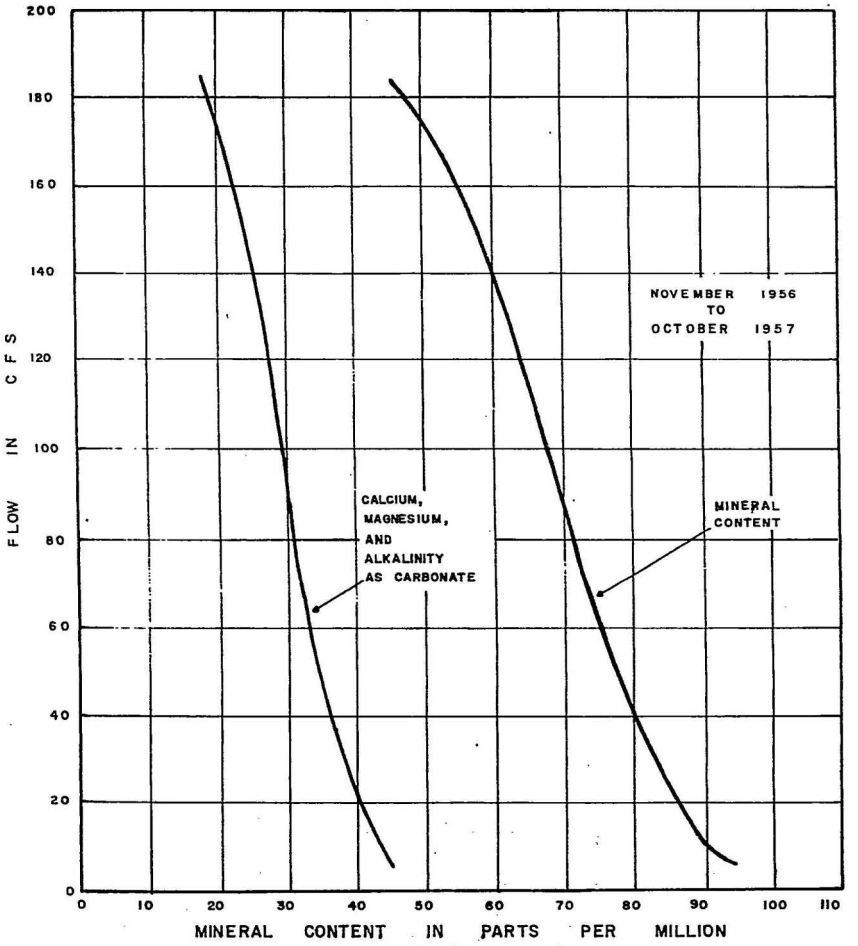


Figure 19. Mineral content in relation to flow, Flint Creek near Thonotosassa.

units. Calcium plus magnesium carbonate ranged from 34 to 45 percent of the mineral content.

The estimates are based on four chemical analysis of creek water during November, December 1956, and May, October 1957, and on streamflow measurements ranging from 3.9 to 119 mgd or 6.0 to 184 cfs.

LAKE THONTOSASSA

Lake Thonotosassa, with a surface area of about 830 acres, is the largest lake in Hillsborough County. Stages of the lake were recorded during the same period (1956-58) that data were collected on Pemberton and Flint creeks. During this period the elevation ranged from 34.85 feet to 36.52 feet above mean sea level, less than 2 feet (fig. 20). The range in stage would have been in the order of 6 feet for the same period had not the timber dam at the lake outlet been in place. This dam helps maintain a relatively constant stage during periods of low inflow, yet it has very little effect on stage when high inflow and high outflow exist.

During the period of no flow for Flint Creek in June 1958, the flow of Pemberton Creek ranged from 1.2 to 5.0 mgd. The record of this period indicates that the combined seepage and evaporation losses from Lake Thonotosassa exceeded 4 mgd. Considering the flow contributed to the lake by Baker Creek, it does not seem unreasonable to surmise that the losses often exceed 6 mgd.

BAKER CREEK

Baker Creek is the largest tributary to Lake Thonotosassa. It heads in the Lake Weeks and Lake Hooker area, 12 miles east of Tampa, and flows northward through improved channels to Lake Thonotosassa.

PEMBERTON CREEK

Pemberton Creek drains water from the land lying east of Plant City. From the headwaters, it flows westward to Baker Creek. The confluence is about a mile above the mouth of Baker Creek. During the 2-year period, September 1956 to December 1958, the flow of Pemberton Creek was studied at a point 1.8 miles above its mouth. Here the creek drains approximately 24 square miles of land, and the average flow was 17 mgd (0.71 mgd per sq. mi.), The minimum flow was 0.8 mgd (October 1958). The outflow of the Plant City sewage plant contributes substantially to the flow of the creek during periods of prolonged drought.

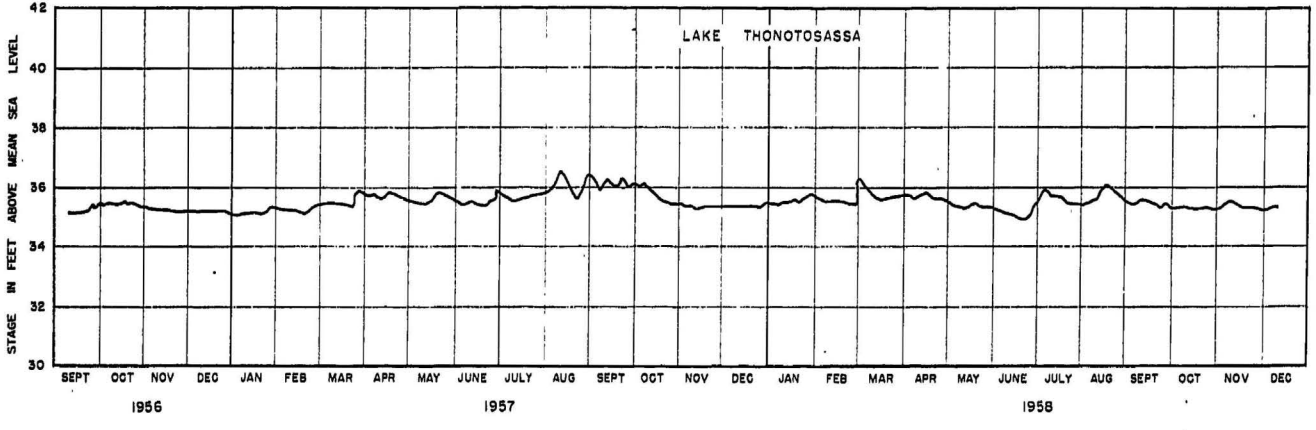


Figure 20. Stage of Lake Thonotosassa.

CYPRESS CREEK

Cypress Creek is another of the major tributaries of the Hillsborough River. It rises in Big Cypress Swamp, 12 miles north of Tampa. It then flows south-southeastward and joins the Hillsborough River about 2 miles north of Temple Terrace. During the period May 1956 to March 1959, the flow of Cypress Creek was measured periodically at the Skipper Avenue bridge, 5 miles north-northeast of Sulphur Springs. No flow existed when visits to the creek were made between May 1956 and March 1957, November and December 1957, and in June 1958. A large quantity of the rainwater falling on the land drained through Cypress Creek goes into storage in the lakes and swamps of the watershed. Some of the water enters the ground and probably emerges again in the spring lying in the lower part of the Hillsborough River basin, or in one of the bays near Tampa.

KEENE LAKE

Keene Lake, with a surface area of about 30 acres, lies west of Cypress Creek near Lutz. During the 7-year period, 1949-55, the stage of the lake ranged between 60.90 feet (June 1955) and 63.30 feet above mean sea level (September and October 1953). Ninety percent of the time the stage was 61.6 feet or more; 50 percent of the time it was 62.7 feet or more; and 10 per cent of the time it was 62.9 feet or more (fig. 9). The range in stage of the lake is minimized by the concrete control in the outlet channel at Sunset Lane. Water discharged from the lake flows southward to Hanna Lake.

HANNA LAKE

Hanna Lake lies west of Cypress Creek near Lutz. It has a surface area of about 30 acres. During the 9-year period, 1947-55, the stage of the lake ranged between 57.72 feet (June 1949) and 62.90 feet above mean sea level (August 1953). Ninety percent of the time the stage was 59.7 feet or more; 50 percent of the time it was 61.4 feet or more; and 10 percent of the time it was 61.7 feet or more (fig. 9). Water discharged from the lake flows south-southeastward to Cypress Creek.

During the period, May 1946 to September 1951 the average discharge was 1.7 mgd. Frequently, no water was discharged from the lake. The maximum discharge was 30 mgd in September 1947. Some water from the lake is diverted westward to Lake Stemper.

LAKE STEMPER

Lake Stemper lies west of Cypress Creek near Lutz. It has a surface area of about 130 acres. During the 12 years, 1947-58, the stage of the lake ranged between 58.68 feet (July 1949) and 61.96 feet above mean sea level (September 1953). Ninety percent of the time the stage was 59.8 feet or more; 50 percent of the time it was 61.2 feet or more; and 10 percent of the time it was 61.5 feet or more (fig. 9). Water discharged from the lake flows southeastward to Cypress Creek.

SULPHUR SPRINGS

Sulphur Springs flows from a circular pool about 50 feet in diameter over a control structure into an L-shaped run about 500 feet long and into the Hillsborough River about 1½ miles below the Tampa waterworks dam. During the period 1917-59, measurements of discharge from the springs were made at irregular intervals. The discharge ranged from 8.34 to 71.1 mgd, and the average of all the measurements is 37 mgd. About one-third of this water entered the ground in the Blue Sink area.

The time-weighted average concentration of the dissolved materials in Sulphur Springs water was 660 ppm from September 1956 to October 1958. This average concentration was calculated from 25 measurements taken at about 6-week intervals during the period of record and includes measurements made during the period of stage regulation. The mineral content ranged from 196 to 1,100 ppm.

The average and range in concentration includes concentrations observed when the pool level was lowered for the test described later in the Ground Water section. Excluding measurements made during the period of stage regulation, the average concentration of dissolved materials was about 540 ppm and the range in concentration was about 196 to 634 ppm. Concentration of organic materials usually was low; therefore, mineral content and concentration of dissolved materials were nearly equal.

The concentration of dissolved materials fluctuates with the stage and discharge of the springs. This is indicated by figures 21 and 22. The wide range in concentration observed, and the even greater range that is indicated as being possible, suggests hydraulic connection with aquifers lying at depths greater than any aquifers that have been penetrated so far by wells in this area.

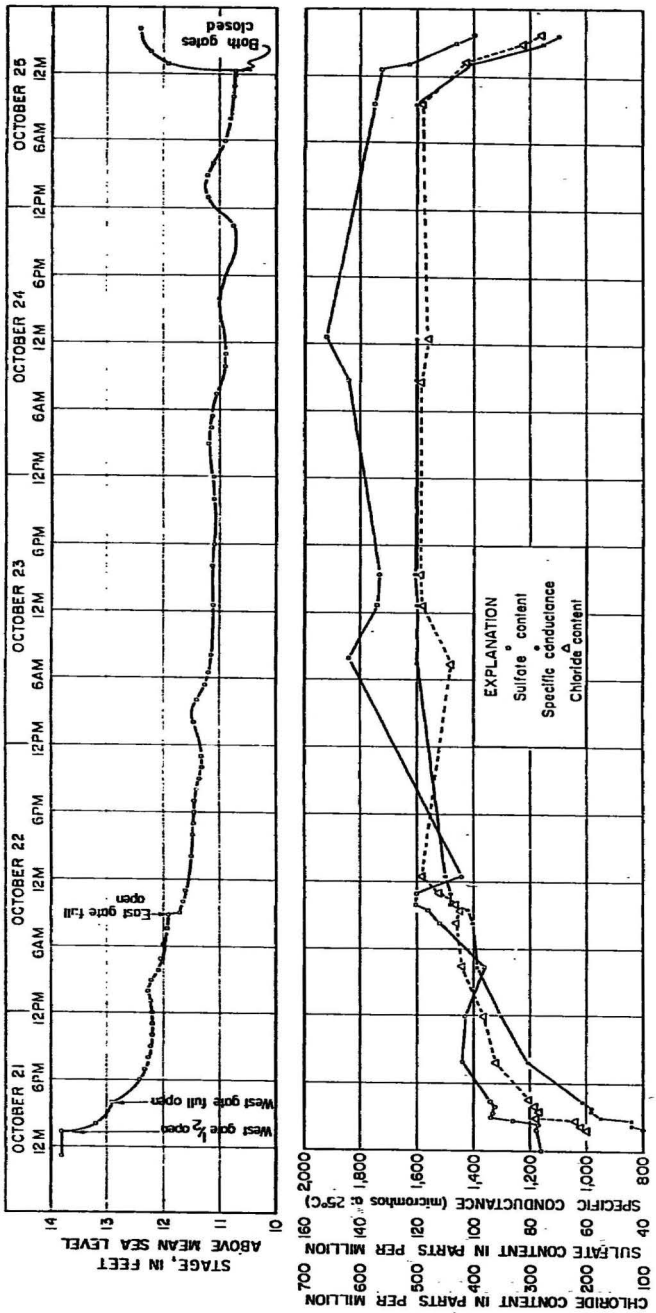


Figure 21. Relationship of chloride, sulfate and specific conductance to stage in Sulphur Springs (800-227-B).

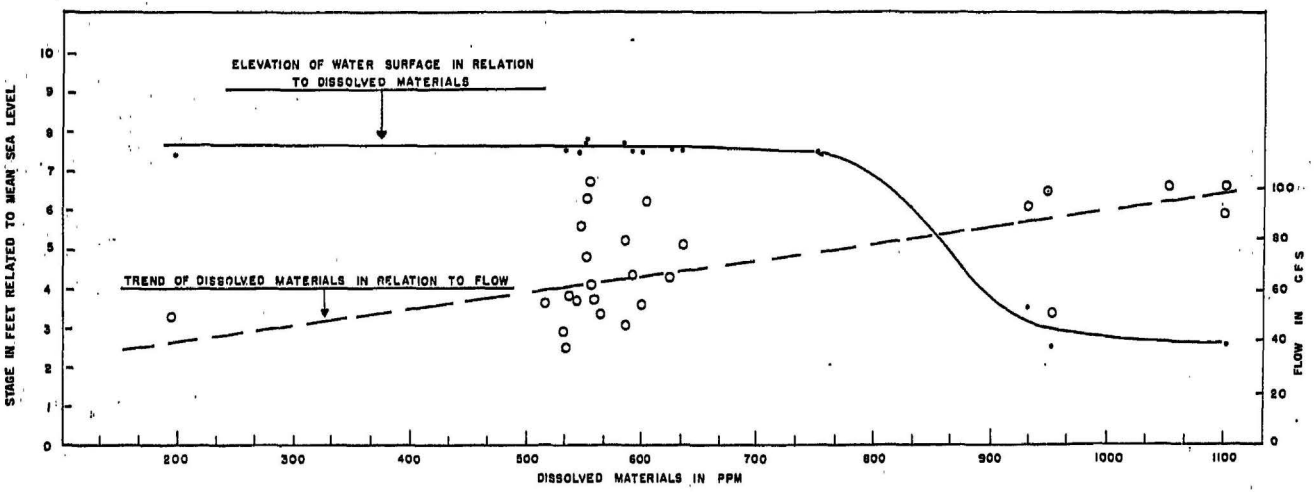


Figure 22. Dissolved materials of Sulphur Springs in relation to flow and to stage.

The particular significance of this interpretation is with respect to consideration of Sulphur Springs for use as a water supply. If natural conditions are allowed to prevail, the water quality of Sulphur Springs probably would fluctuate near the range observed. If the stage of the spring is lowered to increase the yield from Sulphur Springs, water quality can be expected to deteriorate rapidly, and it is likely that the springs would yield water of unsuitable quality.

BLUE SINK

The Blue Sink area drains approximately 26 square miles of land in Hillsborough and Pasco counties. It is located in the northern section of the city of Tampa west of Florida Avenue and south of Fowler Avenue. The sink area is perforated with sinkholes and has no surface drainage. Large quantities of surface water flow into the sinks from a drainage ditch carrying water from land lying north of Sulphur Springs. The average flow into these sinks probably exceeds 9 mgd.

DRAINAGE DITCH

A drainage ditch carries water from an area of many lakes situated north of Sulphur Springs to the Blue Sink area. During the period, July 1946 to September 1956, the discharge of the drainage ditch at Bearss Avenue was 4.4 mgd (0.37 mgd per sq. mi.). The longest of the many periods of no flow lasted 7 months—March to September 1956. In 1947, the discharge was as high as 69 mgd.

LAKE HOBBS

Lake Hobbs, which is located about half a mile northwest of Lutz, has a surface area of approximately 65 acres. During the 12-year period, 1947-58, the stage of the lake ranged between 63.36 feet (May 1956) and 68.10 feet above mean sea level (September 1953). Ninety percent of the time the stage was 64.2 feet or more; 50 percent of the time it was 65.9 feet or more; and 10 percent of the time it was 67.0 or more above mean sea level (fig. 9). Water discharged from the lake flows southward through a ditch to Cooper Lake.

COOPER LAKE

Cooper Lake is half a mile south of Lake Hobbs. It has a surface area of about 85 acres. During the 10-year period, September 1946 to August 1956, the stage of the lake ranged between

58.78 feet (June 1949) and 62.54 feet above mean sea level (September 1947). Ninety percent of the time the stage was 60.1 feet or more; 50 percent of the time it was 61.1 feet or more; and 10 percent of the time it was 61.7 feet or more above mean sea level (fig. 9). Water discharged from the lake flows southward through several lakes into Hutchins Lake.

HUTCHINS LAKE

Hutchins Lake lies 2 miles southwest of Lutz. It has a surface area of about 20 acres. During the period, April 1946 to September 1952, the range in stage was greater than 2.7 feet. The average discharge from the lake was 0.97 mgd (0.36 mgd per sq. mi.). There was no discharge from the lake many times during the period. The maximum discharge was 18 mgd in August 1947.

PLATT LAKE

Platt Lake is about 5 miles north of Sulphur Springs. It has a surface area of about 65 acres when the stage is 49 feet above mean sea level. Water from the lake flows through ditches to the Blue Sink area. During the 10-year period, September 1946 to August 1956, the stage of the lake ranged between 46.92 feet (June 1949) and 51.38 feet above mean sea level (September 1950). Ninty percent of the time it was 47.6 feet or more; 50 percent of the time it was 48.9 feet or more; and 10 percent of the time it was 50 feet or more above mean sea level (fig 9).

PALM RIVER BASIN

PALM RIVER

Palm River drains 40 square miles of land in Hillsborough County. It flows southwestward and empties into McKay Bay at Tampa. The river proper is a continuation of Sixmile Creek and is only about 2 miles in length. Land elevation in the basin ranges from 135 feet on Kennedy Hill, northeast of Tampa, to sea level at the river's mouth. Due south of Temple Terrace, there is a valley in the ridge dividing the Hillsborough and Palm River basins, through which water flowed into the Palm River basin during the 1933 flood. Stage of the river fluctuates with the tide in McKay Bay. The average net flow at the river's mouth probably exceeds 45 mgd.

SIXMILE CREEK

Sixmile Creek, the largest tributary to Palm River, rises in a low flat prairie and flows 7 miles in a southerly direction to join Palm River. In the upper reaches, the channel has been improved. During periods of heavy rainfall, the creek overflows its banks and inundates the prairie. In the upper portion of the basin the gradient of the channel is 2.9 feet per mile (0.05 percent). Below U. S. Highway 92, the gradient increases sharply to 8.8 feet per mile (0.17 percent) (fig. 23).

Much of the dry-season flow of Sixmile Creek comes from springs in the upper reaches.

A study of the flow characteristics of Sixmile Creek was started in 1956. During the 3 years of study, flow of the creek at the State Highway 574 crossing (Broadway Avenue) did not fall below 9 mgd.

Two tributaries join Sixmile Creek above State Highway 574 and give the stream pattern a fan-like appearance. The westernmost tributary drains an area of fairly flat, swampy land north of Orient Park. It rises at Bellows Lake and flows southeastward to join Sixmile Creek between Buffalo Avenue and State Highway 574. The channel is shallow and has an average slope of 16 feet per mile (0.3 percent). The easternmost tributary drains an area

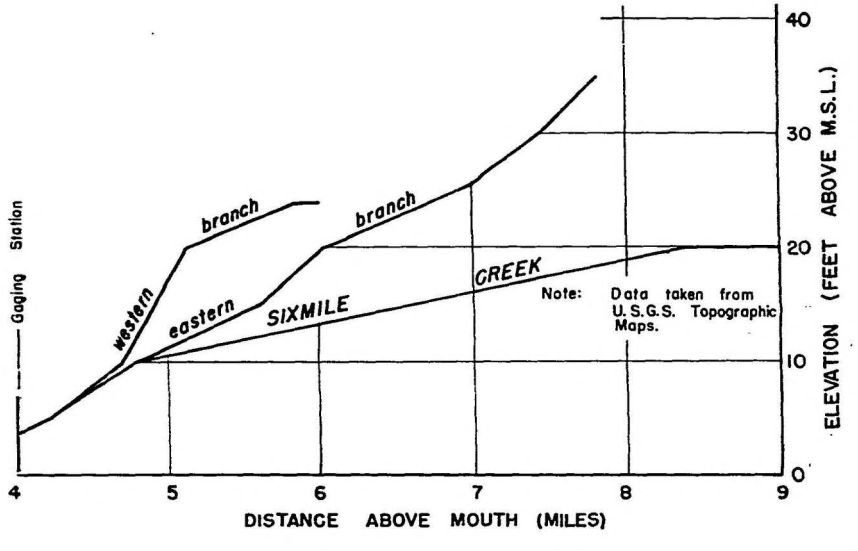


Figure 23. Profiles of streams in the Palm River basin.

of pasture and grove land. It heads in the boggy areas around Mango Lake and flows westward to enter Sixmile Creek about one-tenth of a mile below the Buffalo Avenue crossing. The channel is shallow. It has a gradient of 8.1 feet per mile (0.15 percent).

On April 25, 1958, the flow of tributaries to Sixmile Creek was measured to determine how much each contributed to the base flow of Sixmile Creek. Also, the quantity of ground-water pickup between measuring sites was determined. Six measurements of flow were made above the regular gaging station on Sixmile Creek and one was made at the station. These measurements are listed as follows:

Stream	*Tributary to:*	*Location of Measuring Site*	*Discharge (cfs)*
(Western branch)	Sixmile Creek	½ mile west of U. S. Hwy. 301 at Buffalo Ave.	2.0
Sixmile Creek	Palm River	At the U. S. Hwy. 92 bridge	40.1
——	Sixmile Creek	At U. S. Hwy. 301, ½ mile south of U. S. Hwy. 92	0
(Eastern branch)	Sixmile Creek	At Faulkenburg Rd., ½ mile north of State Hwy. 574	1.9
——	(Eastern branch)	At Buffalo Ave., 2 miles west of Mango	0.1
——	(Eastern branch)	At State Hwy. 574, ½ mile east of U. S. Hwy. 301	0.1
Sixmile Creek	Palm River	At State Hwy. 574 (Broadway)	51.0

Sixmile Creek above U. S. Highway 92 contributes most of the water (79 percent) found in the creek at State Highway 574 during periods of base flow. The western tributary to Sixmile Creek carries 4 percent at Buffalo Avenue and the eastern branch contributes another 4 percent at Faulkenburg Road. There is six miles of stream channel between the three measuring points mentioned above and the gaging station at State Highway 574. A total of 6.8 cfs of flow was picked up by this reach of channel for an average ground-water inflow of 0.7 mgd per mile of channel.

The dissolved materials in Sixmile Creek averaged (time weighted) 228 ppm and ranged from 112 to 342 ppm from September 1956 to September 1958. Figures are based on 17 water samples taken at about 6-week intervals during the period of measurement. Calcium plus magnesium carbonate ranged from 47 to 64 percent of the mineral content; sulfate was about 22 to 35 percent. Color intensity ranged from 5 to 180 platinum-cobalt scale units.

The relation of dissolved materials to flow of the stream is shown in figure 24.

Changes in streamflow usually are accompanied by changes in both the amount and character of dissolved materials. Changes in the amount and character of dissolved materials are indicated in figures 25 and 26.

Springs: There are many springs in the headwaters of Sixmile Creek. Only the springs known as Eureka Springs have been measured. These springs are located 0.7 mile north of U. S. Highway 92 and 0.8 mile east of U. S. Highway 301. The flow was 2.5 mgd on May 1, 1946, and 0.7 mgd on May 1, 1956.

The mineral content of Eureka Springs water was 213 ppm, as shown by combined samples taken on May 1, 1956, and on July 31, 1958. There was no significant difference in the mineral content

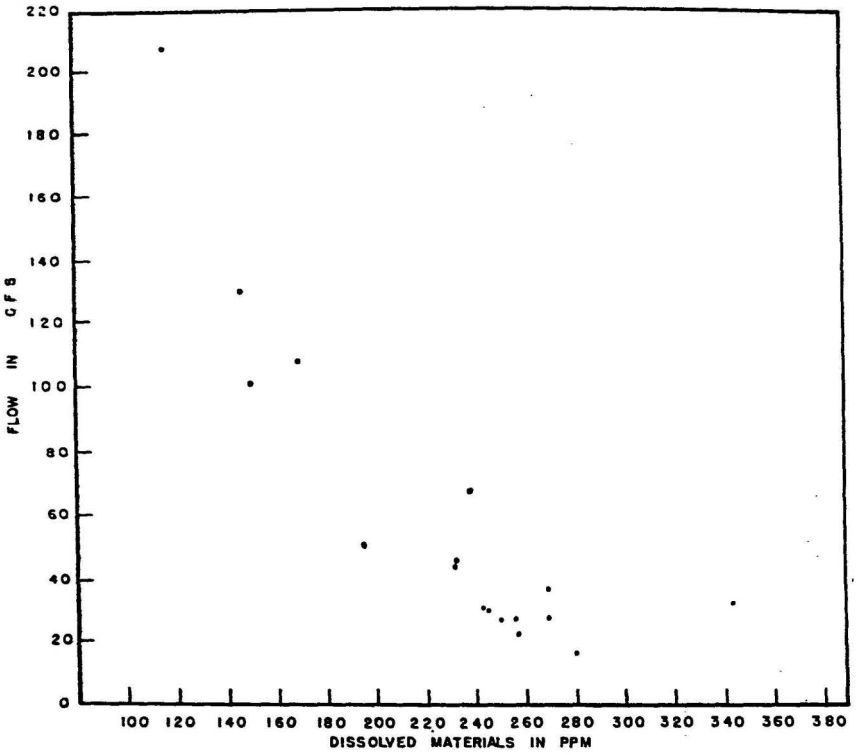


Figure 24. Dissolved materials in relation to flow, Sixmile Creek at Tampa (September 1956 to September 1958).

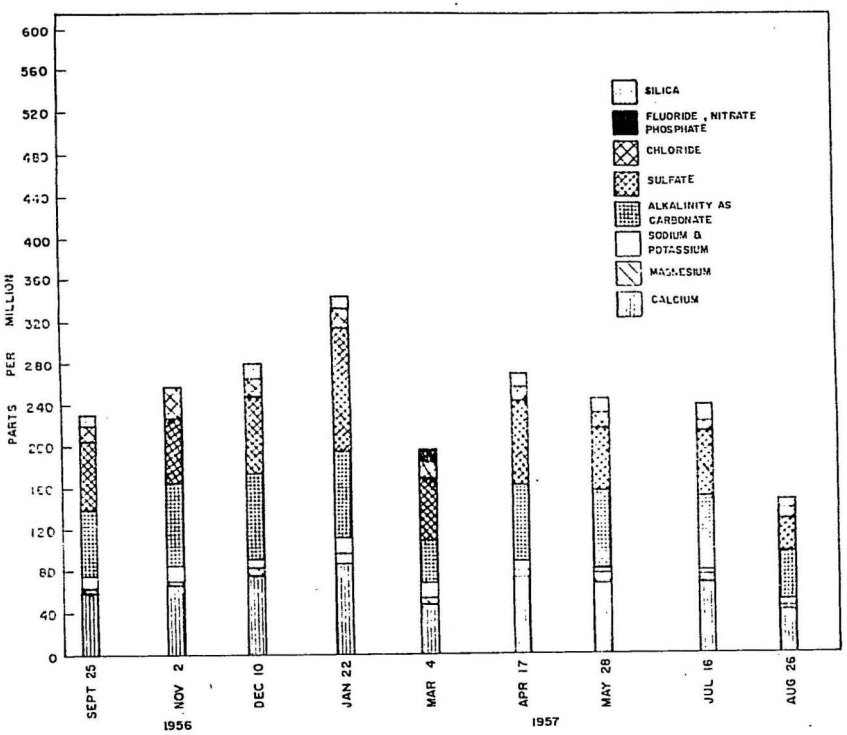


Figure 25. Chemical character of dissolved materials carried by Sixmile Creek at Tampa (September 1956 to August 1957).

on these 2 days. Calcium plus magnesium carbonate was about 68 percent and sulfate was about 20 percent of the mineral content.

Color intensity was 20 on May 1, 1956, and 4 on July 31, 1958 (platinum-cobalt scale units).

ALAFIA RIVER BASIN

ALAFIA RIVER

The Alafia River drains 410 square miles of land in Polk and Hillsborough counties. Two hundred and forty-five square miles of this land is in Hillsborough County. The river begins at the confluence of the North and South Prongs, about 4 miles east of the town of Lithia, flows westward, and empties into Tampa Bay near Riverview (fig. 7). Land elevations in the basin range from sea level near the mouth to 250 feet above mean sea level in the

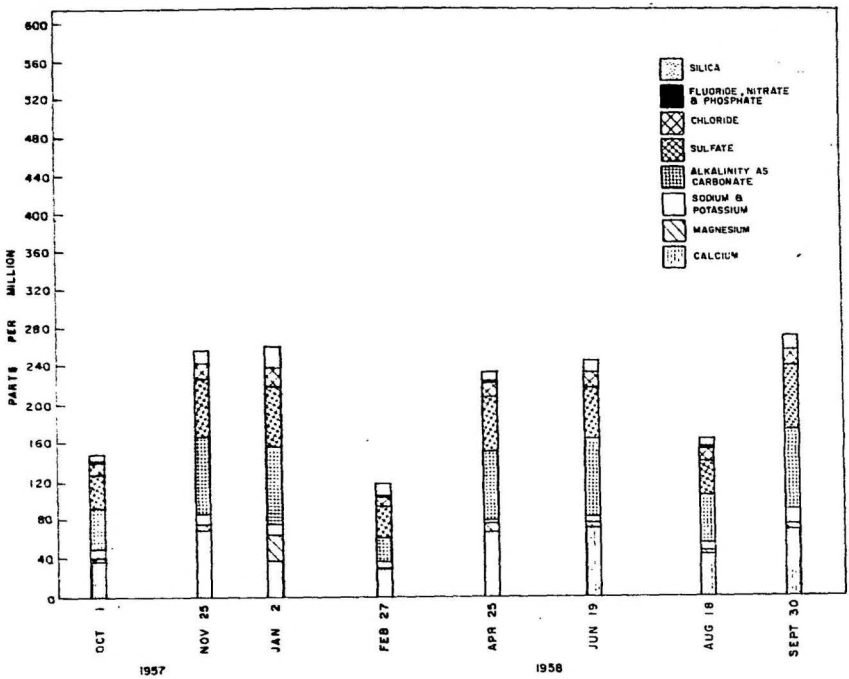


Figure 26. Chemical character of dissolved materials carried by Sixmile Creek at Tampa (October 1957 to September 1958).

eastern part. There are few natural lakes in the basin; however, open-pit phosphate mining operations have created many artificial ones. Soils in the basin are sandy, and the land is used principally for raising cattle and citrus. The population density is low.

Throughout most of its length the Alafia River flows through a shallow, wooded valley and in a well defined channel. Several large tributaries, many small ones, and many springs flow into it. The lower reach of the river rises and falls with tides in Tampa Bay and, when the flow of the river is low, tidal fluctuations are discernible as far as 10 miles upstream from the mouth. Channel gradients are shown in figure 27.

At Lithia, the average flow of the Alafia River is about 220 mgd. The maximum flow was about 12 bgd on September 7, 1933, and the minimum was about 4½ mgd on June 6, 1945. Fifty percent of the time the flow is 160 cfs or 103 mgd or more (fig. 28). Usually, the average monthly flow is highest in September and lowest in May.

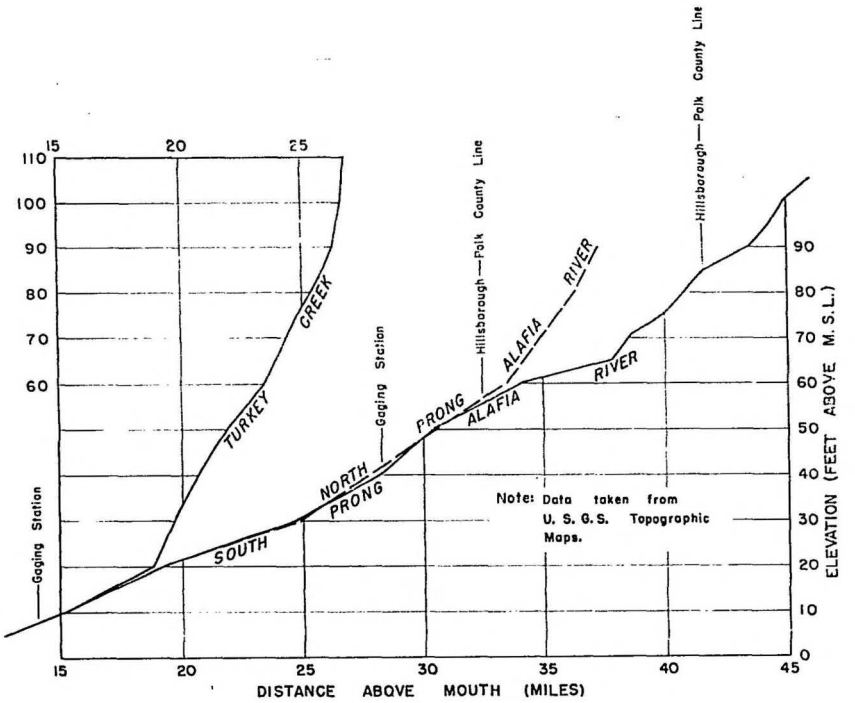


Figure 27. Profiles of streams in the Alafia River basin.

On September 7, 1933, the stage of the Alafia River at Lithia was 35.5 feet above mean sea level. Flow of the magnitude that caused this extreme in stage recurs at a frequency of about once every 80 years. The frequency given is based on composite frequency curves.

At the mouth, the average flow of the Alafia River probably exceeds 300 mgd.

The average concentration of dissolved materials (time weighted) in the Alafia River at Lithia was 292 ppm from October 1957 to September 1958. Dissolved materials ranged from 116 to 658 ppm during the same period. Dissolved materials were about 87 to 100 percent mineral content. Constituents reach high concentrations and vary considerably; for instance, sulfate concentration ranged from 33 to 222 ppm; phosphate, from 9 to 170 ppm; calcium, from 18 to 117 ppm; and silica, from 15 to 77 ppm; alkalinity as carbonate was essentially absent. Color intensity ranged from about 15 to 150 (platinum-cobalt scale units).

Industrial waste materials discharged into the stream mask

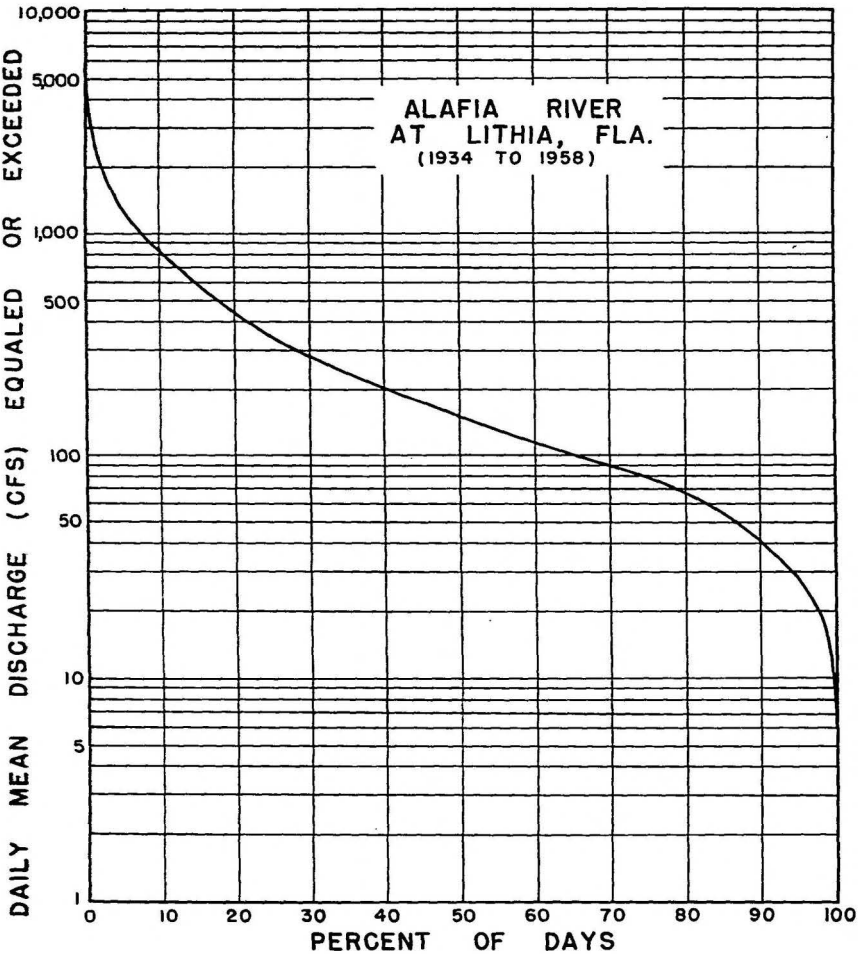


Figure 28. Flow-duration curve of Alafia River at Lithia.

the presence of naturally occurring concentrations of dissolved materials. The preceding estimates of dissolved materials in Alafia River water near Lithia are not representative of upstream locations on the Alafia River or its tributaries.

High but variable concentrations of wastes at different locations upstream from Lithia were indicated by specific conductance, by color intensity, and by fluoride content of water samples taken from the Alafia River near Lithia; the South Prong Alafia River 2.5 miles east of Pinecrest; the Alafia River 2.5 miles southeast of Bloomingdale; the North Prong Alafia River 0.5 mile north of

Keysville; and Fishhawk Creek 1 mile east of Boyette. These samples were collected during the period January 27-29, 1959. (See separate data report.)

Mineral content of the Alafia River at Lithia for the period October 1957 to September 1958 is indicated in figure 29. About 50 percent of the time the specific conductance was equal to or less than 340 micromhos. The mineral content, in parts per million, was about 77 percent of the specific conductance in micromhos; therefore, half the time the mineral content from October 1957 to September 1958 was equal to or less than 262 ppm. Figure 30 shows the percent of days that the specific conductance was equal to or less than a given value for the 1-year period ending September 1958.

Figure 30 can be used to estimate the mineral content for any desired percentage of time during the period of record according to the following relationship:



Figure 29. Mineral content and water temperature in Alafia River at Lithia (October 1957 to September 1958).

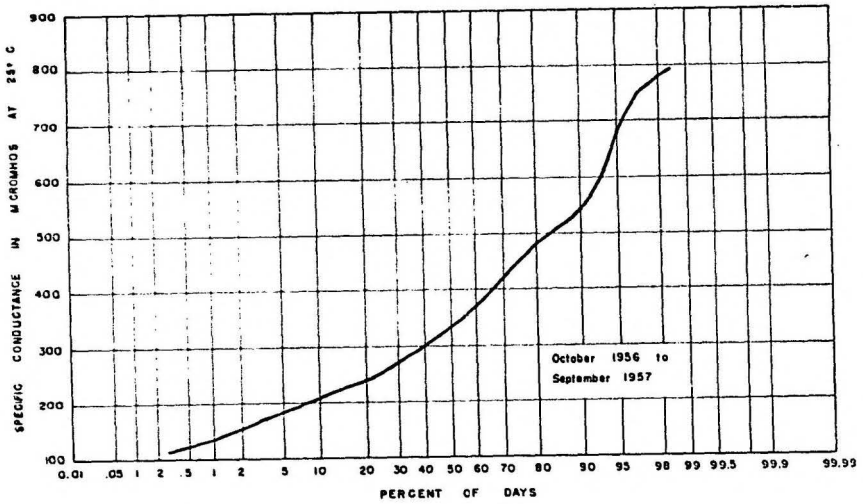


Figure 30. Percent of days specific conductance was equal to or less than a given value, Alafia River at Lithia.

Mineral content in ppm = (0.77) x (specific conductance). The factor, 0.77, is the average of the ratios of mineral content to specific conductance for composite samples during the period of record.

Figures 31, 32, 33, and 34 show the percent of days that sulfate, phosphate, fluoride, and pH values, respectively, were equal to or less than a given value.

The chemical character of the dissolved materials is shown in figures 35 and 36. The water temperatures in the stream varied from 45°F. in February to 85°F. in June (fig. 29).

According to U. S. Public Health standards, the water quality of the Alafia River was unsuitable for municipal uses during the period October 1, 1957 to September 30, 1958. Color intensity exceeded that desired most of the time. Fluoride concentrations exceeded the recommended maximum all the time, with concentrations in the stream reaching 17 ppm. Phosphate concentrations were observed up to 170 ppm. Fluoride, phosphate, and other materials enter the stream at various locations as industrial waste products. Water from the Alafia River would be difficult to treat economically for municipal use.

Biological suitability for use as municipal supplies is not included as a part of this report.

Regular use of Alafia River water for stock watering would

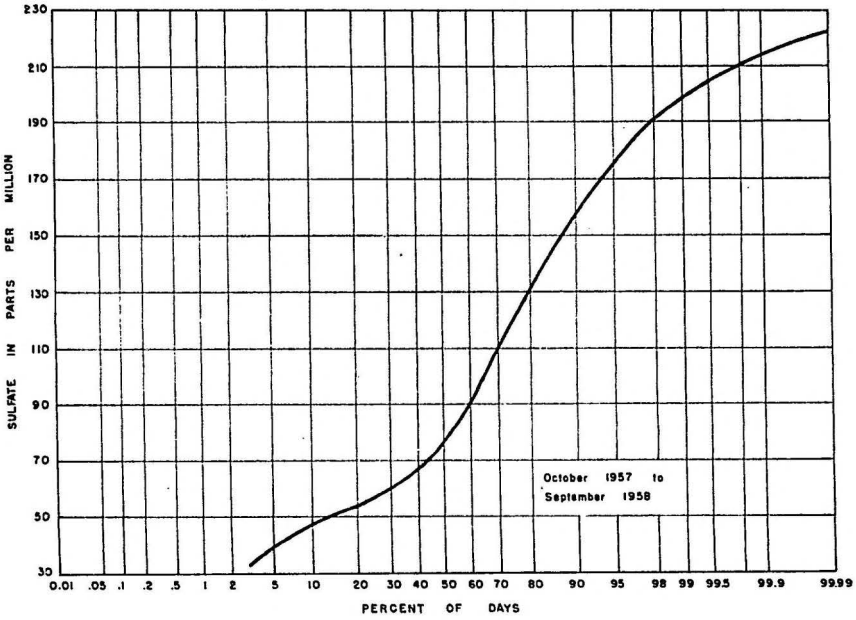


Figure 31. Percent of days sulfate concentration was equal to or less than a given value, Alafia River at Lithia.

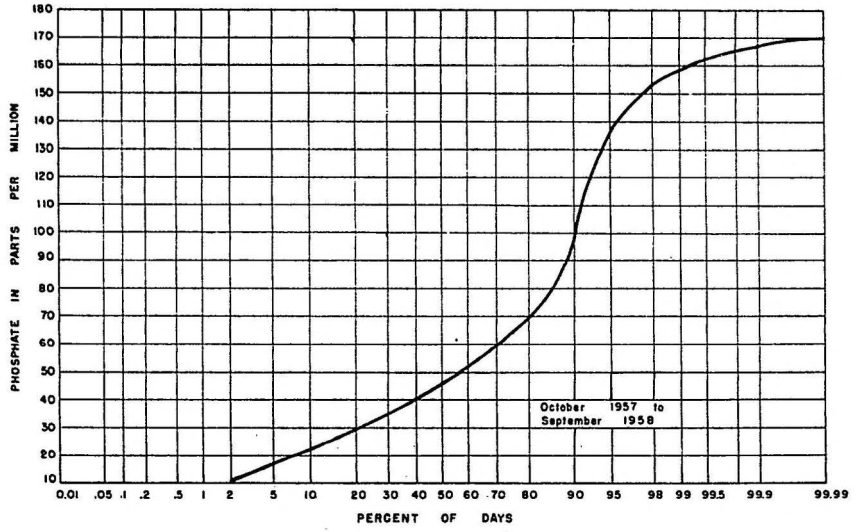


Figure 32. Percent of days phosphate concentration was equal to or less than a given value, Alafia River at Lithia.

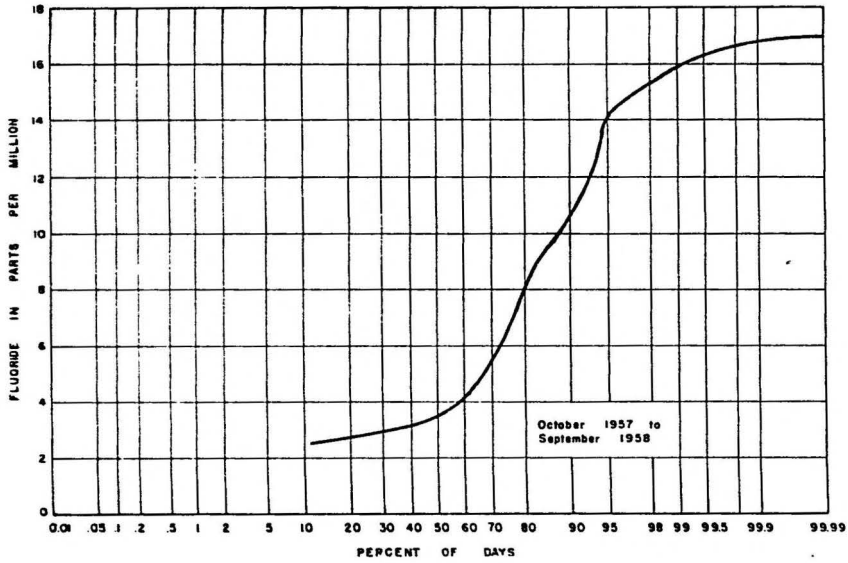


Figure 33. Percent of days fluoride concentration was equal to or less than a given value, Alafia River at Lithia.

result in mottled teeth and other pathological changes in the animals because of the fluoride content (California State Water Pollution Control Board, 1952, p. 256). Continued use would result in increasing economic loss to livestock producers along the river.

Extensive use of Alafia River waters for irrigation could result

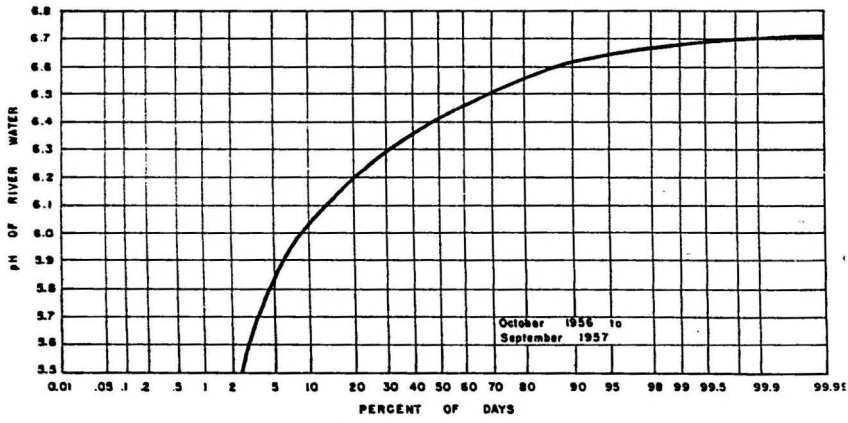


Figure 34. Percent of days pH was equal to or less than a given value, Alafia River at Lithia.

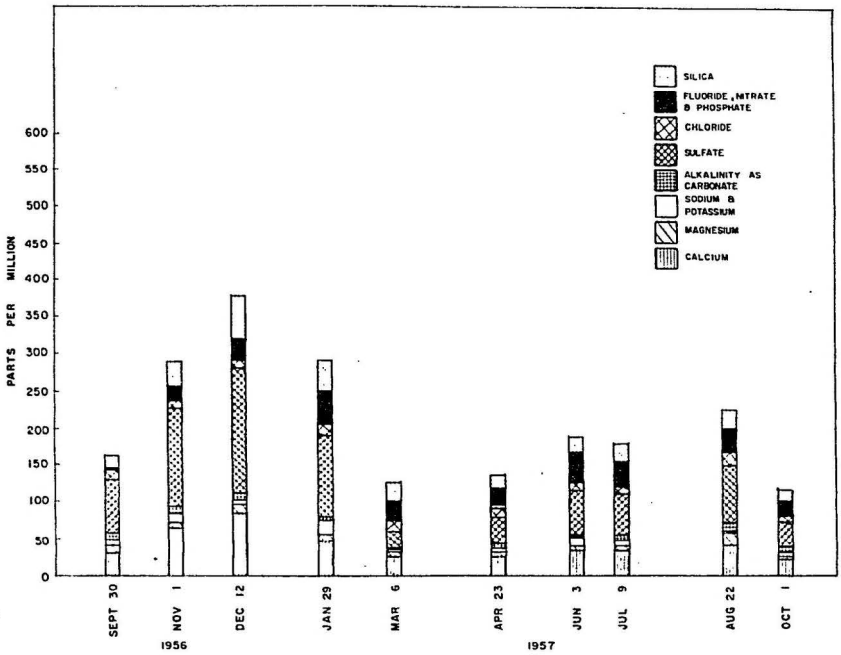


Figure 35. Chemical character of dissolved materials carried by the Alafia River at Lithia (September 1956 to October 1957).

in contamination of ground-water supplies hydraulically connected downgradient from the irrigated land. Shallow ground water is used for domestic supplies within the basin and would be vulnerable to contamination by fluoride and phosphate.

The Alafia River water was the least suitable of all river water in Hillsborough County for most uses because of the range in concentration of the dissolved materials.

NORTH PRONG ALAFIA RIVER

The North Prong Alafia River drains about 175 square miles of land southeast of Plant City. Fifty square miles of the basin area is in Hillsborough County, and the remainder lies in Polk County. Stream channels in the area run mostly through wide marshy or swampy areas and are not well defined. There are several springs in the basin.

The average flow of the North Prong is about 110 mgd.

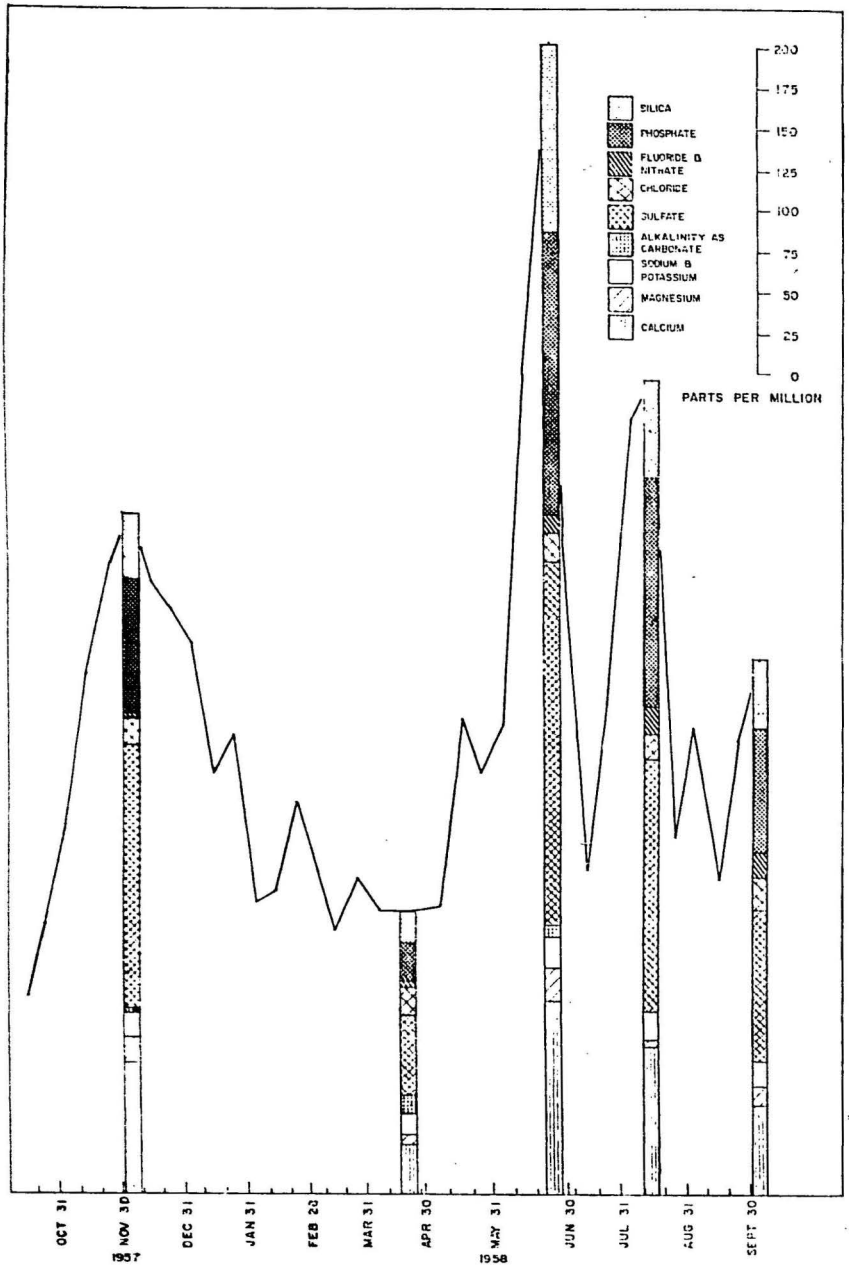


Figure 36. Chemical character of dissolved materials carried by the Alafia River at Lithia (October 1957 to September 1958).

SOUTH PRONG ALAFIA RIVER

The South Prong Alafia River drains about 120 square miles of land, 70 square miles of which is in Hillsborough County. The South Prong begins near Hookers Prairie (Polk County), flows westward for 20 miles, northward for 14 miles, and joins the North Prong. Average flow at the junction is probably 100 mgd.

TURKEY CREEK

Turkey Creek drains 40 square miles of land in the area southeast of Plant City. It flows into the Alafia River 2 miles upstream from Lithia Springs. There are numerous phosphate pits in the basin. Average flow is about 25 mgd.

FISHHAWK CREEK

Fishhawk Creek drains avout 30 square miles of land lying south of Lithia Springs. It flows northward and into the Alafia River 2 miles south of the town of Riverview. Average flow is about 20 mgd.

OTHER STREAMS

Bell Creek drains 15 square miles lying south of the Alafia River. It flows northward and enters the Alafia River about 5 miles downstream from Lithia Springs and 9 miles upstream from the mouth. Its average flow is about 7 mgd. Rice Creek, draining an area of about 5 square miles south of the river, flows in 5 miles upstream from the mouth. Average flow is probably more than 2 mgd.

Numerous lesser tributaries flow into the Alafia River throughout its course. The combined area that they drain is approximately 25 square miles and on the average they contribute about 20 mgd to the river.

LITHIA SPRINGS

Two springs, located on the south bank of the Alafia River about 19 miles upstream from the mouth and about 2 miles downstream from Turkey Creek, are known collectively as Lithia Springs. One of the springs forms a pool about 50 feet across. It is connected to the river by a run about 200 feet long. The other spring forms a pool 100 feet across. It is connected to the river

by a run about 600 feet long. The average combined flow of the springs probably exceeds 30 mgd. The flow of the springs was measured 17 times between 1934 and 1938. The highest combined flow measured was 46.7 mgd; the lowest, 25.9 mgd.

On the basis of five samples collected from Lithia Springs during the period from November 1957 to June 1958, the dissolved materials averaged about 268 ppm. The dissolved materials in the water from each spring opening are similar in both quantity and chemical character. Nearly 100 percent of the dissolved materials is mineral content. Calcium plus magnesium plus alkalinity as carbonate was about 51 percent, and sulfate was about 30 percent of the mineral matter. Color intensity was low, being in the range from zero to five platinum-cobalt scale units. These quantities compare very favorably with the dissolved materials and the chemical character of Lithia Springs on July 19, 1923, and again on April 30, 1946.

BUCKHORN SPRING

Buckhorn Spring flows into Buckhorn Creek which in turn flows into the Alafia River about 8 miles above the mouth. The spring is 3 miles northeast of Riverview and half a mile north of the Alafia River. It forms a pool about 30 feet across and empties directly into Buckhorn Creek. Its average flow is approximately 8 mgd. The U. S. Phosphoric Products Company pumps from the spring to supply a plant at Gibsonton.

Mineral content on April 26, 1956, was 310 ppm. Calcium plus magnesium plus alkalinity as carbonate was 44 percent, and sulfate was 22 percent of the mineral content. Color intensity was 20 platinum-cobalt scale units.

BULLFROG CREEK BASIN

BULLFROG CREEK

Bullfrog Creek drains 40 square miles of land in southern Hillsborough County. Headwaters of the creek are just north of Wimauma. From there the flow is westward, then northward, then westward and into Hillsborough Bay about a mile south of the Alafia River. The stream drains an area of sandy land dotted with ponds and sinkholes. The largest tributary is Little Bullfrog Creek. Land elevations in the basin range from sea level at the bay to 140 feet above sea level on ridges in the upper reaches.

Bullfrog Creek has a fairly well defined channel. The channel gradient is fairly steep (13 feet per mile) in the upper part and is moderate in the central part (5 feet per mile). In the lower part the gradient is nearly flat (1 foot per mile). Channel gradients are shown in figure 37.

The average flow of the creek at Big Bend Road (drainage area: 29 sq. mi.) is about 18 mgd. However, wide variations in flow occur. From October 1956 to October 1958, the highest flow was 1.4 bgd. Several times during the 2-year period the flow ceased. During June 1957, there was zero flow for 12 consecutive days. More than 20 percent of the time the flow was less than 1 mgd.

At the mouth of Bullfrog Creek, water flows in and out because of fluctuations in the level of the bay; however, the net flow is into the bay. The average net flow at this point probably exceeds 30 mgd.

The dissolved materials in Bullfrog Creek near Wimauma averaged 36 ppm and ranged from about 25 to 49 ppm, from September 1956 to September 1958. The values are based on 16 water samples taken at about 6-week intervals during the period. Color intensity ranged from about 65 to 200 platinum-cobalt scale units and was often a large percentage of the dissolved materials.

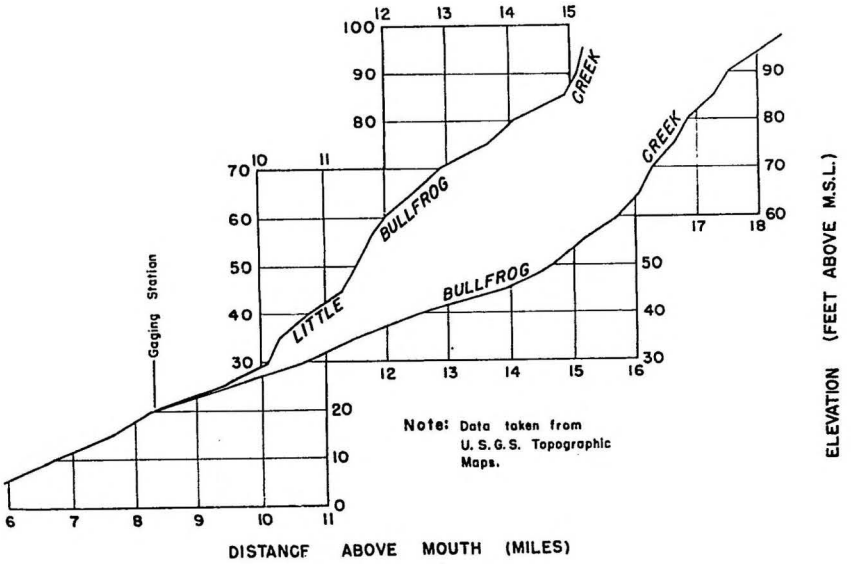


Figure 37. Profiles of streams in the Bullfrog Creek basin.

The remainder of the dissolved materials was mineral content with chloride, sodium, bicarbonate, silica, calcium, and sulfate in small amounts; chloride was present in greatest quantity most of the time, followed closely by most of the other minerals.

Large changes in streamflow are accompanied by irregular changes of small magnitude in the dissolved materials. The water contacts only the insoluble sand deposits, which overlie the impermeable Hawthorn formation and does not contact soluble materials. The wide range in color indicates contact with vegetable matter on the surface or at shallow depths.

LITTLE BULLFROG CREEK

Little Bullfrog Creek, which drains about 9 square miles of land south of Riverview, flows into Bullfrog Creek a mile south of Big Bend Road. It has a well defined channel with a gradient of about 11 feet per mile. At the mouth, the estimated average flow is 7 mgd.

LITTLE MANATEE RIVER BASIN

LITTLE MANATEE RIVER

The Little Manatee River, about 40 miles long, heads in a swampy area east of Fort Lonesome, in southeastern Hillsborough County, flows westward, and empties into Tampa Bay near the town of Ruskin. The stream drains 150 square miles of land in southern Hillsborough County and 75 square miles of land in northern Manatee County. At its source the channel is about 100 feet above sea level and has a fairly steep gradient, particularly in its upper reaches. (fig. 38). In general, the channel is well defined and has steep, sandy banks. Tributaries to the Little Manatee River enter from both sides at fairly regular intervals. In the lower reach of the river the stage rises and falls with the tide in Tampa Bay and when flow is low, tidal fluctuations are discernible as much as 15 miles upstream from the mouth.

Lake Wimauma is the largest of the several lakes in the river basin. It has a surface area of about 130 acres.

For the 19-year period from 1940 to 1958, the average discharge of the Little Manatee River at U. S. Highway 301 was 115 mgd. Flow ranged from a minimum of 0.8 mgd in June 1945 to a maximum of 6,110 mgd in June 1945. About 90 percent of the time the flow was 12 cfs or 8 mgd or more. Fifty percent of the time flow was 48 cfs or 31 mgd or more, and 10 percent of the time it was

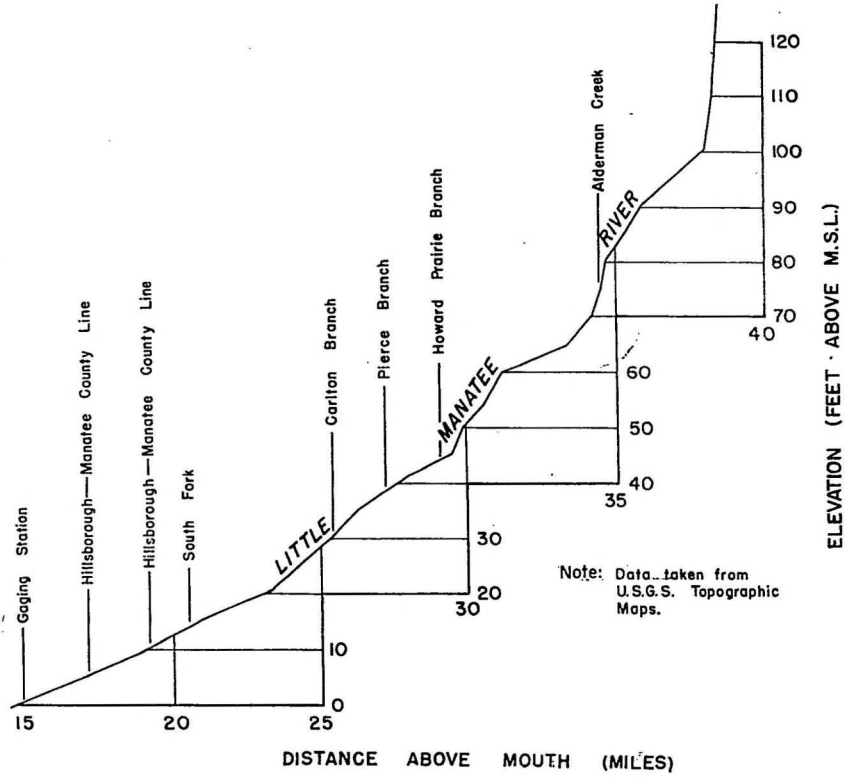


Figure 38. Profiles of streams in the Little Manatee River basin.

480 cfs or 310 mgd or more (fig. 39). Usually the average monthly flow is lowest in the spring and highest in the summer.

The dissolved materials carried by the Little Manatee River averaged 57 ppm (time-weighted) from October 1956 to September 1957 and ranged from 36 to 88 ppm. These materials were about 1 to 49 percent organic materials. The remainder of the dissolved material was mineral content with sodium chloride, bicarbonate, silica, calcium, and sulfate in small amounts, each predominating at different times. Mineral content for the same period ranged from 30 to 55 ppm as indicated by figure 40.

About 50 percent of the time, the specific conductance was equal to or less than 63 micromhos. The mineral content was about 62 percent of the specific conductance; therefore, half the time the mineral content from October 1956 to September 1957 was equal

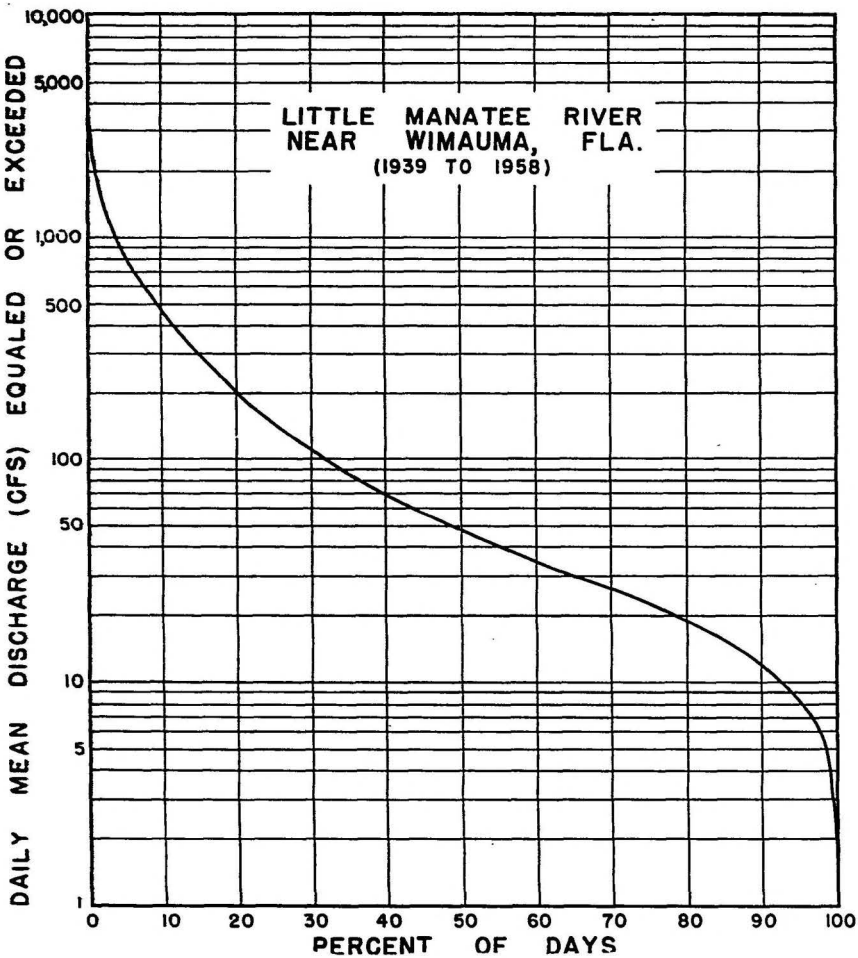


Figure 39. Flow-duration curve of Little Manatee River near Wimauma.

to or less than 40 ppm. Figure 41 shows the percent of days the specific conductance was equal to or less than a given value for the period stated.

Figure 41 can be used to estimate the mineral content for any desired percentage of days according to the following relationship:

Mineral content in ppm= (0.62) x (specific conductance). The factor, 0.62, is the average of the ratios of mineral content to specific conductance for composite samples collected during the period of record.

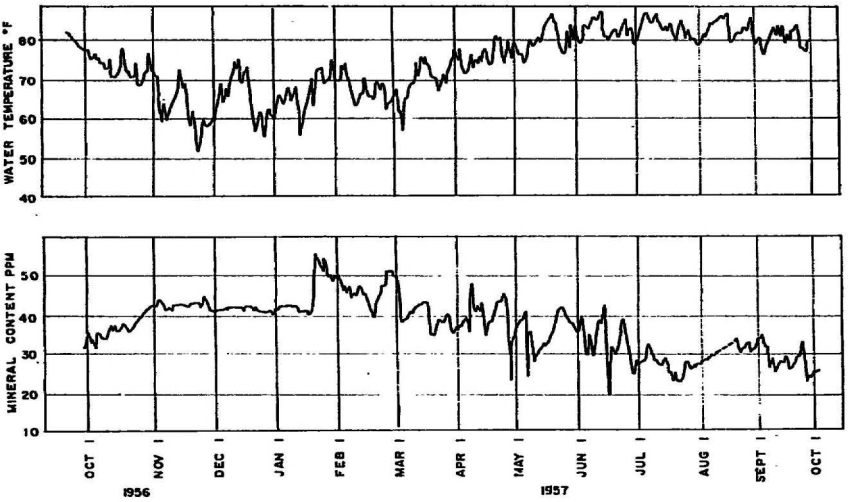


Figure 40. Mineral content and water temperature in Little Manatee River near Wimauma (October 1956 to September 1957).

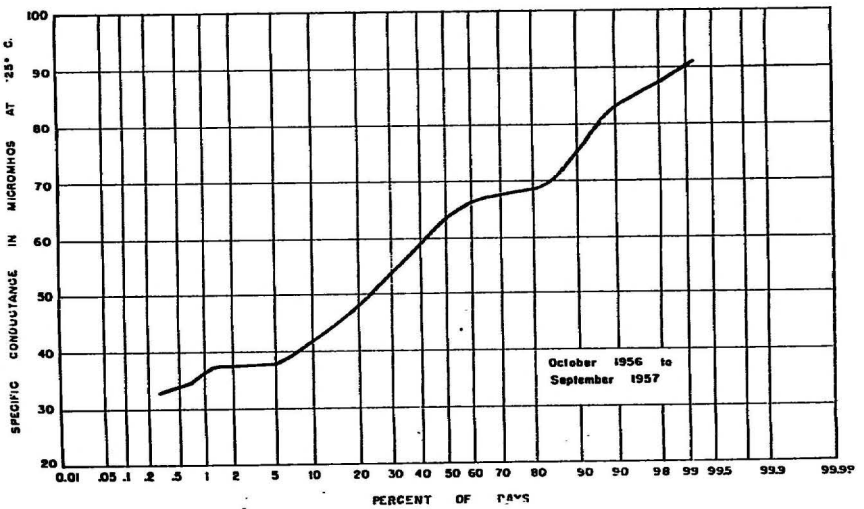


Figure 41. Percent of days specific conductance was equal to or less than a given value, Little Manatee River near Wimauma.

The color intensity during the low rainfall period from November 1956 to January 1957 was stable at about 75 units. During the early part of the rainy season, February to April, much of the soluble organic material was leached from the vegetation and the color intensity increased (fig. 42). Greater flow during the latter part of the rainy season resulted in less color intensity.

The effect of rainfall upon streamflow is usually accompanied by changes in both the amount and character of dissolved materials. Chemical character of dissolved materials is exhibited in figures 43 and 44.

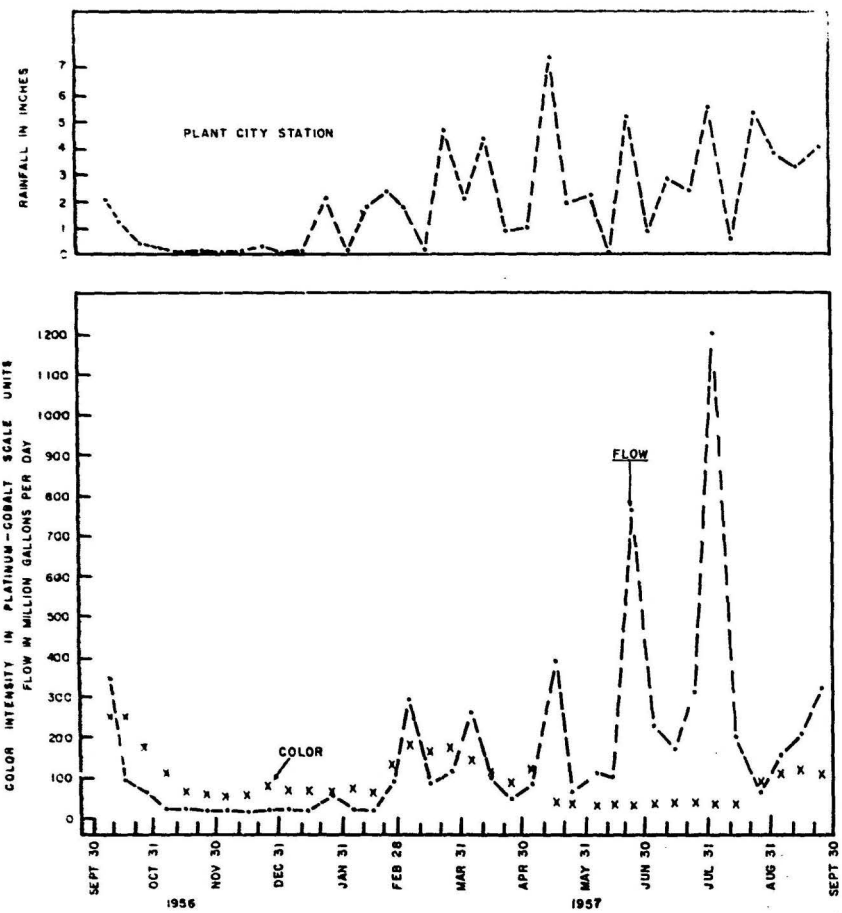


Figure 42. Color in relation to rainfall and flow of Little Manatee River near Wimauma (October 1956 to September 1957).

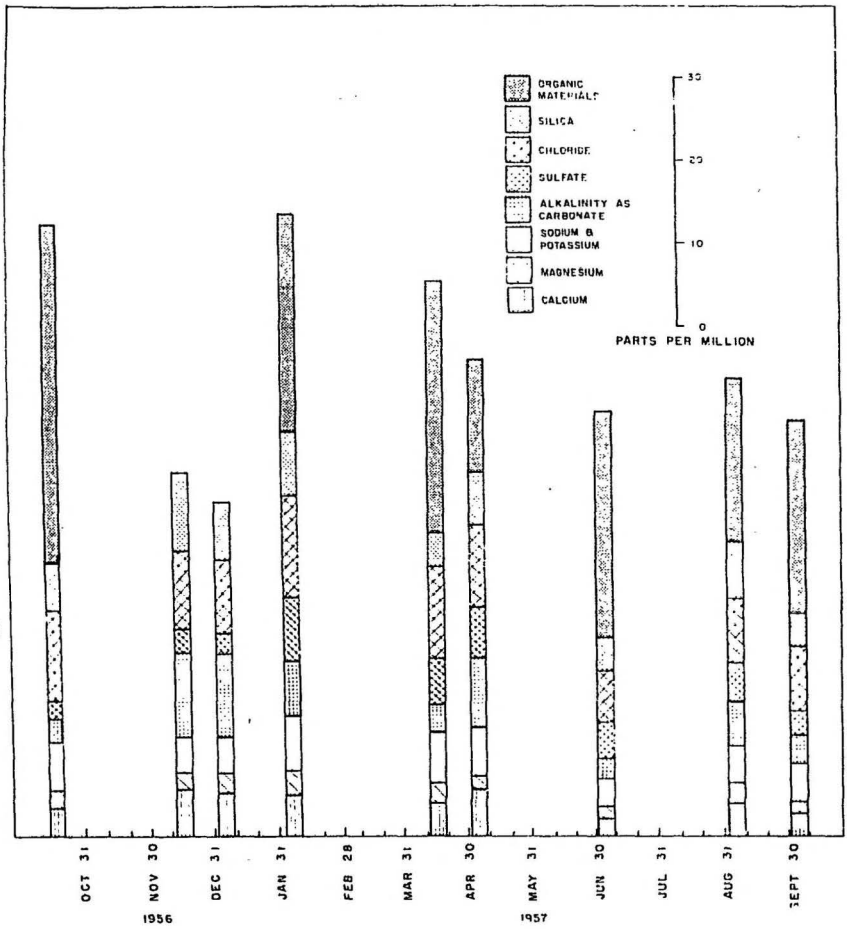


Figure 43. Chemical character of dissolved materials carried by the Little Manatee River near Wimauma (October 1956 to September 1957).

Water temperatures in the stream varied from 51° F. in November to 87° F. in June and July.

During the period October through December 1957, a relatively sharp increase in mineral content, from 24 to 181 ppm, occurred. Simultaneously color intensity decreased from 140 to 27 (platinum-cobalt scale units) and calcium plus magnesium plus alkalinity as carbonate increased from about 6 to 132 ppm. The sulfate increased from 2 to 20 ppm. These changes resulted from a combination of below-normal rainfall and heavy pumping of ground water for irrigation in the headwaters of the basin. Part of the water used

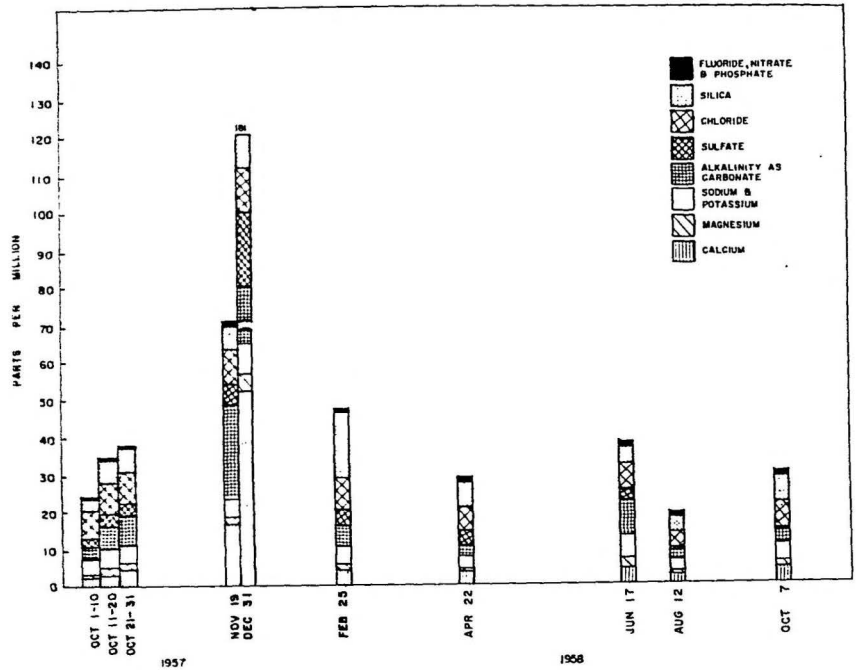


Figure 44. Chemical character of dissolved materials carried by the Little Manatee River near Wimauma (October 1957 to October 1958).

for irrigation infiltrates the soil and probably reaches the water table. It moves through the sand deposits and discharges into the streams of the basin.

The chemical character and concentration of dissolved materials in Little Manatee River may be explained largely by the interaction of rainfall upon the surface sand deposits. The sand deposits rest upon the relatively impermeable Hawthorn formation. The rain quickly permeates the sand. Downward and upward movement through the underlying Hawthorn formation is much slower. Therefore, rainwater tends to move over the ground or downgradient within the sands. The sands are only slightly soluble, and the length of time in contact is relatively short, thus limiting the mineral content. The range in color intensity indicates contact with vegetable matter on the ground surface or at shallow depths.

The Little Manatee River water is suitable for municipal use with respect to dissolved materials except for color intensity. Most of the time, color intensity exceeds the recommended amount. Iron

concentrations probably are greater than those indicated. Bacteriological suitability is not included as a part of this report.

Water from the Little Manatee River apparently is suitable for agricultural uses; this assumption is qualified to the extent that the boron content of the water is not known.

Little Manatee River water is more suitable for industrial uses than that from other major streams in the county. The dissolved material concentrations in this stream are relatively low compared to the other major streams in the county, except for color.

At the mouth, the average flow of the Little Manatee River probably exceeds 180 mgd.

The Little Manatee River above its confluence with Howard Prairie Branch drains 35 square miles of land of the eastern part of the river basin. About 31 square miles of this land is in Hillsborough County, and the remaining 4 square miles is in Manatee County. Alderman Creek brings water collected from Manatee County into Hillsborough County. This creek joins the Little Manatee River 34 miles above the mouth. The average flow of the river above Howard Prairie Branch is probably 30 mgd.

HOWARD PRAIRIE BRANCH

Howard Prairie Branch drains an area of about 13 square miles in Hillsborough County and 5 square miles in Manatee County. Water collected in Manatee County is channeled northward into Hillsborough County. Three lakes form part of the Howard Prairie Branch channel. The largest and easternmost lake is about 60 acres in area at a stage of 73 feet above mean sea level. At its confluence with the Little Manatee River, 29 miles upstream from Tampa Bay, Howard Prairie Branch contributed an average of 14 mgd to the river.

PIERCE BRANCH

Pierce Branch drains 10 square miles of land in Hillsborough County. This stream flows southward and enters the Little Manatee River at a point about 27 miles above the mouth. The average flow of Pierce Branch is probably 8 mgd.

CARLTON BRANCH

Carlton Branch drains 10 square miles of land in Hillsborough County. This stream, like Pierce Branch, flows southward. It enters the Little Manatee River about 26 miles above the river's mouth. The average flow of Carlton Branch is about 8 mgd.

SOUTH FORK LITTLE MANATEE RIVER

The largest tributary to the Little Manatee River is South Fork Little Manatee River. It drains approximately 40 square miles of land in Manatee and 1 square mile in Hillsborough County. The stream flows northwestward into Hillsborough County, flowing at an average rate of 30 mgd. The South Fork Little Manatee River flows into the Little Manatee River about 21 miles above the river's mouth and 2 miles above the point where the Little Manatee River flows across the Hillsborough-Manatee county line into Manatee County.

OTHER STREAMS

Numerous other streams drain the remaining 110 square miles of land not covered in the discussion of tributaries to the Little Manatee River. These streams contribute on the average about 90 mgd to the river or about one-half the flow at the mouth.

PEACE RIVER BASIN

The Peace River drains about 4 square miles of land in the southeastern corner of Hillsborough County. The river flows southward to Charlotte Harbor and the Gulf of Mexico. The area in Hillsborough County contributing water to the Peace River is mainly swampland that lies 130 to 145 feet above the sea.

GROUND WATER

Part of the rain that falls on the earth moves downward through the ground to the zone of saturation to become ground water. The ground water then moves laterally along the hydraulic gradient to discharge points such as springs, wells, or the sea. The materials through which the water moves in usable quantities is known as an *aquifer*. Where water in the aquifer is at atmospheric pressure and is free to rise, the water occurs under nonartesian conditions and the water surface is referred to as the *water table*. Where relatively impermeable beds restrict the vertical movement of water in a completely saturated aquifer, the water occurs under artesian conditions, and the surface described by the elevations to which water will rise in wells tapping the aquifer is referred to as the piezometric surface. Artesian conditions exist when the water is under greater than atmospheric pressure or when the water

will rise above the top of the aquifer where tapped. Where the piezometric surface is lower than the water table, the water may move downward from the monartesian aquifer into the artesian aquifer. Where the water table is lower than the piezometic surface, water may move upward from the artesian aquifer into the nonartesian aquifer or to flowing wells and springs. Ground water in Hillsborough County occurs under both artesian and nonartesian conditions.

WATER-TABLE AQUIFER

The undifferentiated surface sands and clays generally contain water under water-table conditions in Hillsborough County, but artesian conditions may occur locally. The water in the aquifer is derived from local rainfall, and the water table is only a few feet below the ground surface.

Wells deriving water from the sand are constructed by driving a screened well point into the saturated zone or, on the high "prairies," by sinking a pipe to the top of a layer of hardpan and chiselling a hole through the handpan into the underlying sand. The well is then pumped until the water is clear. Drive-point wells are generally less than 20 feet deep and yield about 5 gpm.

The wells developed below the hardpan are usually from 8 to 16 feet deep and may yield more than 200 gpm where the hardpan is sufficiently thick and strong to allow development of large cavities under it.

Generally water is not available in desirable quality or quantity from the water-table aquifer, and it is not a very important source of supply in the county.

SHALLOW ARTESIAN AQUIFER

Wells developed in the sand and limestone beds of the Hawthorn formation in the southern half of the county yield up to about 500 gpm of water of relatively poor quality. The advantages of developing wells in this aquifer are that shallower wells and less expensive pumps are required if only small to moderate yields of water are needed. The saving effected could offset the advantage of having better quality water from the deeper aquifers. The aquifer in the Hawthorn formation, though important in Polk County, is of minor importance throughout the small area of Hillsborough County in which it occurs.

PRINCIPAL ARTESIAN AQUIFER

The principal artesian aquifer includes the units described by Stringfield (1936, p. 124-128) and the Floridian aquifer of Parker (1955, p. 188-189). Parker (op. cit.) includes the Lake City limestone, Tampa limestone and, where hydrologically connected, the Hawthorn formation in the Floridan aquifer.

The physical limits of the aquifer should be set at hydrologic boundaries. In Hillsborough County, there is no evidence of a hydrologic boundary at the base of the Lake City limestone. In addition, rotary drilling in the county has resulted in loss of mud circulation throughout the older Tertiary formations (i.e., Oldsmar and Cedar Keys limestones) and possibly the upper part of the Lawson limestone of Cretaceous age. Loss of circulation indicates the presence of cavities that, in all probability, are the result of solution by ground water. Therefore, the entire Tertiary system from the base of the Hawthorn formation to the top of the Gulf series (as used by the Florida Geological Survey) of Cretaceous age is included in the principal artesian aquifer of this report. The general occurrence of cavities in the Eocene rocks and the inferred presence of similar cavities in the Oldsmar and Cedar Keys limestones indicate ground-water movement to at least that depth.

Limestone, more or less dolomitized, is the dominant lithologic component of the aquifer. Zones of high permeability are distributed erratically through the aquifer. These zones have not been traced over great distances. It is known from examination of caves in other areas that most horizontal water courses in limestone end in vertical openings that intersect other horizontal cavities at different levels. Similar conditions are assumed to be responsible for the hydrologic continuity observed in the principal artesian aquifer in Hillsborough County.

The hydraulic systems just described are limited in vertical extent by layers of rocks of low permeability. The rocks of the upper part of the Ocala group tend to restrict this system. The Tampa and Suwannee limestones, which are a hydrologic unit, comprise the aquifer above the Ocala. The few available data indicate that the formations underlying the Ocala group to the greatest depth commonly penetrated by water wells tend to form another gross hydrologic unit. The two systems are connected hydraulically by solution openings along structural planes that probably are faults. The vertical permeability of these openings is sufficient to allow approximate equilibrium to obtain between

the two systems when the time of interchange of water is great and the amount of water interchanged is small. Where either system is stressed by a local discharge through a large spring or well, the vertical movement of water is relatively small and the two systems behave as separate aquifers. Thus, throughout most of the county the total limestone section is essentially a hydrologic unit, but wherever either system is stressed by large volumes of discharge the Tampa and Suwannee limestones act as an aquifer, separate from the limestones below the Ocala group.

Several thousand gallons per minute can be pumped from any of the several zones in the aquifer. The specific capacity of the well depends on the size and continuity of the cavities penetrated by the well.

Sulphur Springs (801-227-B) flows an average of about 37 mgd. Based on chemical analyses of water from the spring as compared with water from well 801-227-3, about 90 percent of the water, or 33 mgd, is of good chemical quality derived from the Tampa and Suwannee limestones. The remaining 4 mgd consists of highly mineralized water from below the Ocala group. The proportions of minerals in the spring water are different from those in sea water, indicating that the concentration and chemical character of the water do not reflect salt-water intrusion from Tampa Bay. Instead, the water probably is diluted connate water. The connate water is derived from older rocks that have not been flushed by fresh water as have the more recent rocks near the surface. Concentrations of chloride of more than 69,000 ppm (Black and Brown, 1953) are known to occur in the older rocks in Florida. These rocks are rich in gypsum and anhydrite from which sulfate could be dissolved, giving rise to the type of water occurring in well 801-227-3.

The movement of water in the Tampa and Suwannee limestones was traced by introducing 8 pounds of sodium fluorescein into a sinkhole about 1,000 feet northwest of Blue Sink. During the test, the dye followed a sharply angular and narrow course corresponding to the trends of regional structures. The dye moved one-half mile southwest, then 1½ miles southeast from Blue Sink (803-227-A), then southwestward to 801-226-A, and to Sulphur Springs. A number of randomly located points in the area were monitored but did not show any dye. Though the test was not made under ideal conditions, the results seem to be quite clearly indicative of structural control of ground-water movement in the area. The inferred upward movement of connate water along fault planes and the observed path of the dye are interpreted as evidence that

some of the fault zones have a higher vertical permeability than the nonfractured rocks.

Water movement in limestones of the principal artesian aquifer is essentially restricted to solution zones that have developed along joints, faults, and bedding planes. The more permeable fractures are the avenues of movement of greater quantities of water than the less permeable smaller fractures. As the solution-enlarged fractures coalesced and extended to a point of discharge such as a spring, the pressure in the larger cavities was reduced and water moved from smaller fractures into the solution-enlarged cavities. This process resulted in virtual conduits through which water moved at relatively high velocities. As the velocity of the water in the conduit increased, the water reacted less with the limestone in the recharge area and thus was capable of dissolving more limestone closer to the discharge area and further enlarging the existing conduits. Eventually this destructive process led to overstressing and collapse of the limestone skeleton. After the supporting limestone had collapsed in a large enough area, the weak clays and sands fell into the cavity and resulted in the formation of a depression in the land surface called a sinkhole. The water, blocked by a plug of overburden, began development of a cavity system to bypass the plug. Relaxation of lateral stress in the vicinity of the original sinkhole resulted in redistribution of stress in the area and probably aided the expansion of joints and, consequently, the re-routing of water through the area. The process above, repeated many times over the years, produced the many sinkholes present today.

Thus, the existence of sinkholes in an area is indicative of a substantially cavernous condition and infers high permeability of the limestone. Where the sinkholes occur in a line or have coalesced to form a linear depression, the directional trends of the joint systems or faults which control the solution activity can be established. In Hillsborough County, these trends are at compass bearings of about N. 40 E., N. 40 W., N. 13 E., and N. 70 E.

Sulphur Springs derives the greater part of its water from the Suwannee and Tampa limestones. The apparent decline of water level in the Suwannee and in the Tampa is about 15 feet at the spring. Water level in the Avon Park limestone is lowered about 5 feet by discharge from the spring. Distribution of springs and linearity of surface features in the area suggest the existence of a fault along the course of the Hillsborough River and another trending northwest through the area. It is probable that the bulk of the water from the Avon Park and lower limestones is moving

along the fracture zone of a fault. This indicates that the Ocala group is acting as a confining bed in a localized area about the spring. The Suwannee and Tampa limestones should be considered as a separate aquifer in this area.

A similar condition probably exists to the north and northeast of Boiling Spring (755-204-A). Several instances of higher water levels with depth, lowering of water levels in one well following drilling of another well nearby, and water levels that are inconsistent with regional trends were reported in that area. The reports were fairly consistent and are believed to be qualitatively correct. The hydrology of the area adjacent to Boiling Spring is complicated by the presence of a fairly well developed aquifer in the Hawthorn formation and will require further study to determine the exact conditions.

The confining beds overlying the principal artesian aquifer are composed of clays of the Hawthorn formation and other undifferentiated formations. The thickness of the confining beds ranges from a few feet in the north-central part of the county to about 300 feet in the southeastern part. Numerous sand-filled sinkholes breach the confining beds in the northern half of the county. These sinkholes act as recharge wells and probably contribute a major part of the recharge to the aquifer in this area. Sinkholes become progressively fewer toward the discharge areas and, except for some quite ancient, obscure, and completely filled sinkholes, have not been found in discharge areas. Though some water moves into Hillsborough County from Pasco and Polk counties, the greater part of the water in the aquifer is introduced either by percolation through the confining beds or through sinkholes that may or may not be sand filled. Natural discharge is through springs either on the land surface or in rivers and lakes or Tampa Bay. Water discharges westward into the Gulf of Mexico from a small area in the northwestern part of the county.

The quantity of water that may be obtained from wells in this area is practically limited only by the desired quality of the water. Throughout the county, yield is generally controlled by size and depth of wells. However, salt water occurs at depth and quality of water becomes an important consideration in deciding how deep a well should be drilled. Consequently, the usable part of the aquifer may be only a small part of the total aquifer. The effective bottom elevation of the usable part of the aquifer is at a depth below sea level of about 40 times the elevation of the piezometric surface above sea level. The highest measured point on the piezometric surface in the county is about 100 feet above

mean sea level in a well about 3 miles northeast of Plant City (803-204-1). Assuming an effective head of 85 feet, a maximum bottom elevation of 3,400 feet below sea level is computed for wells that will yield fresh water under those conditions. As the piezometric surface approaches sea level, the thickness of the usable part of the acquifer approaches zero and fresh water cannot be obtained.

RECHARGE TO UNDERGROUND FORMATIONS

Recharge of the water-table aquifer occurs whenever rain falls on the land surface. The water-table aquifer in Hillsborough County consists of sand of about 30 percent perosity. The water table rises approximately 3 inches for each inch of rainfall that reaches it. The water table generally is only a few feet below land surface even in dry periods, and areas that are not well drained are likely to become saturated and to have water standing on the surface after a heavy rain. The fluctuation in water levels, though rapid, is only a few feet in magnitude.

Recharge of the artesian aquifers is more complex. It occurs both by percolation through the so-called confining beds and by surface water and discharge from other aquifers entering through exposures of the aquifer in sinkholes. The water will flow into and through all sediments. The rate of flow is determined in part by the porosity and the hydraulic gradient. Observed water-level fluctuations in the principal aquifer (fig. 45) are quite rapid and of large magnitude, indicating that part of the recharge enters the aquifers in a short time at a high rate. The most probable places where high rates of recharge occur are the numerous sinkholes and points where the aquifer is near the surface. The latter places are not sufficiently numerous to be of areal importance. Thus, sinkholes are the apparent avenue of rapid recharge of the aquifer. An example of this type of recharge may be seen in the system of sinkholes between Linebaugh and Fowler avenues west of Florida Avenue in Tampa. The introduction of large quantities of water into the aquifer from a drainage ditch through these sinkholes causes an almost immediate and large rise in water level, in a well near Nebraska Avenue at Temple Terrace Highway (801-227-1). This well is hydraulically connected with cavities in the Tampa and Suwannee limestones. See figure 46b.

Interpretation of the hydrographs of the group of three wells (757-212-1, 2, 3) supports this hypothesis. The water level in Well 2, reflecting water-table conditions, rises several feet in response

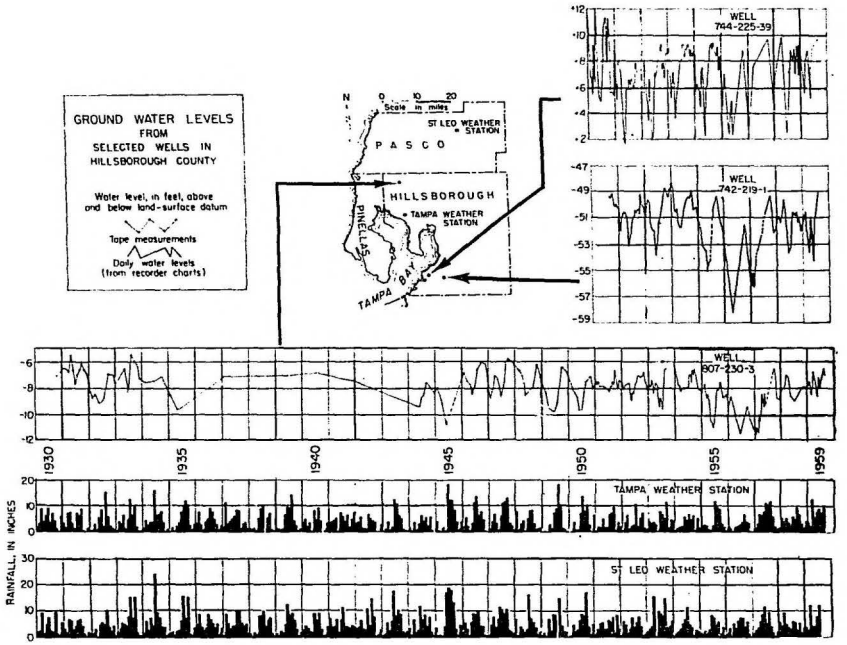


Figure 45. Water levels in selected wells and the precipitation at Tampa and St. Leo weather stations.

to a heavy rain. The water level in Well 1, in the principal aquifer, rises proportionally as and almost simultaneously with the level in Well 2. The water in Well 3, reflecting the level in the shallow artesian aquifer, rises with a lag of several days and in a subdued manner. This is interpreted as being indicative of recharge of the principal artesian aquifer by water that has not passed through a permeable phase of the discontinuous shallow artesian aquifer. The best explanation of this involves the presence of a vertical solution opening through which the water could move into the principal artesian aquifer from the nonartesian aquifer.

DISCHARGE FROM UNDERGROUND FORMATIONS

When an aquifer is saturated, the long-term volume of discharge must equal the long-term volume of recharge. Variations in the volume of water in storage are important only for short periods of time and do not change the long-term recharge-discharge relationships appreciably.

Ground water is discharged through both springs and wells

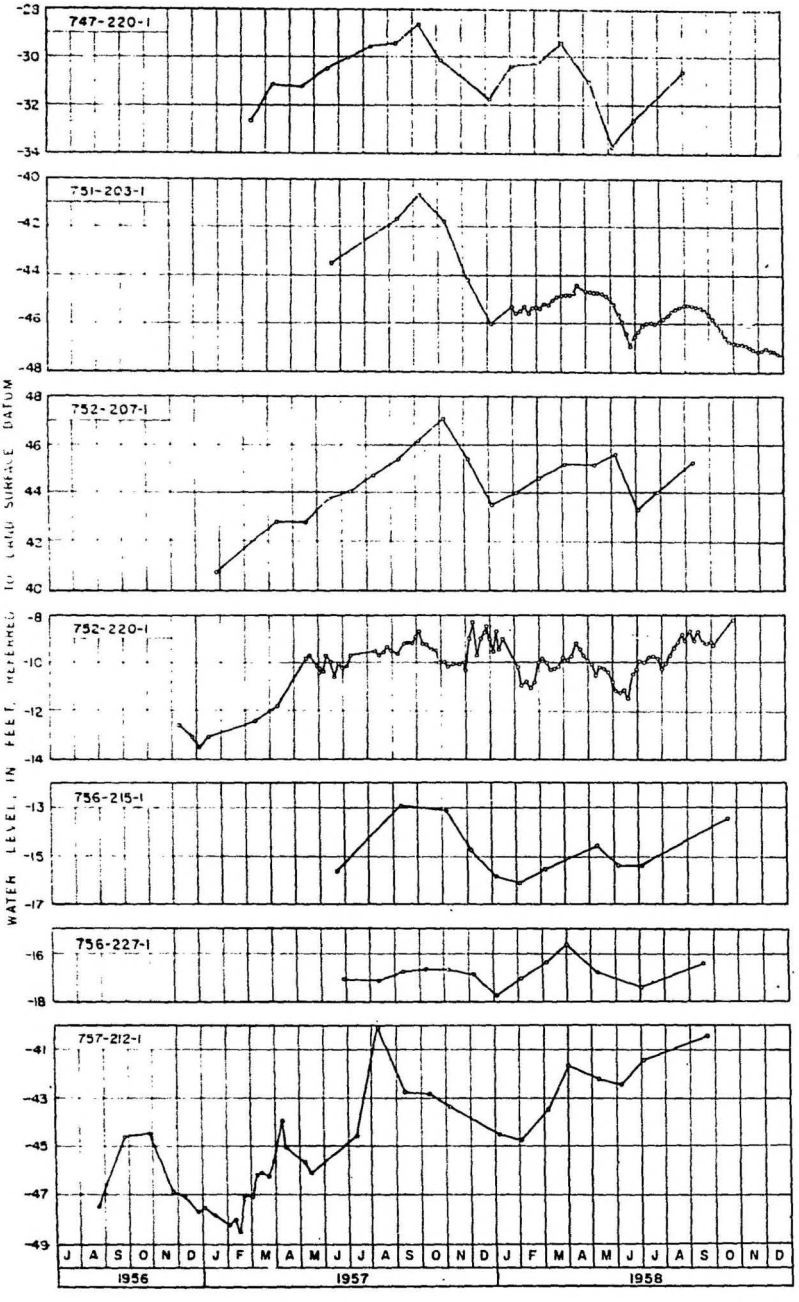


Figure 46a. Water levels in selected wells.

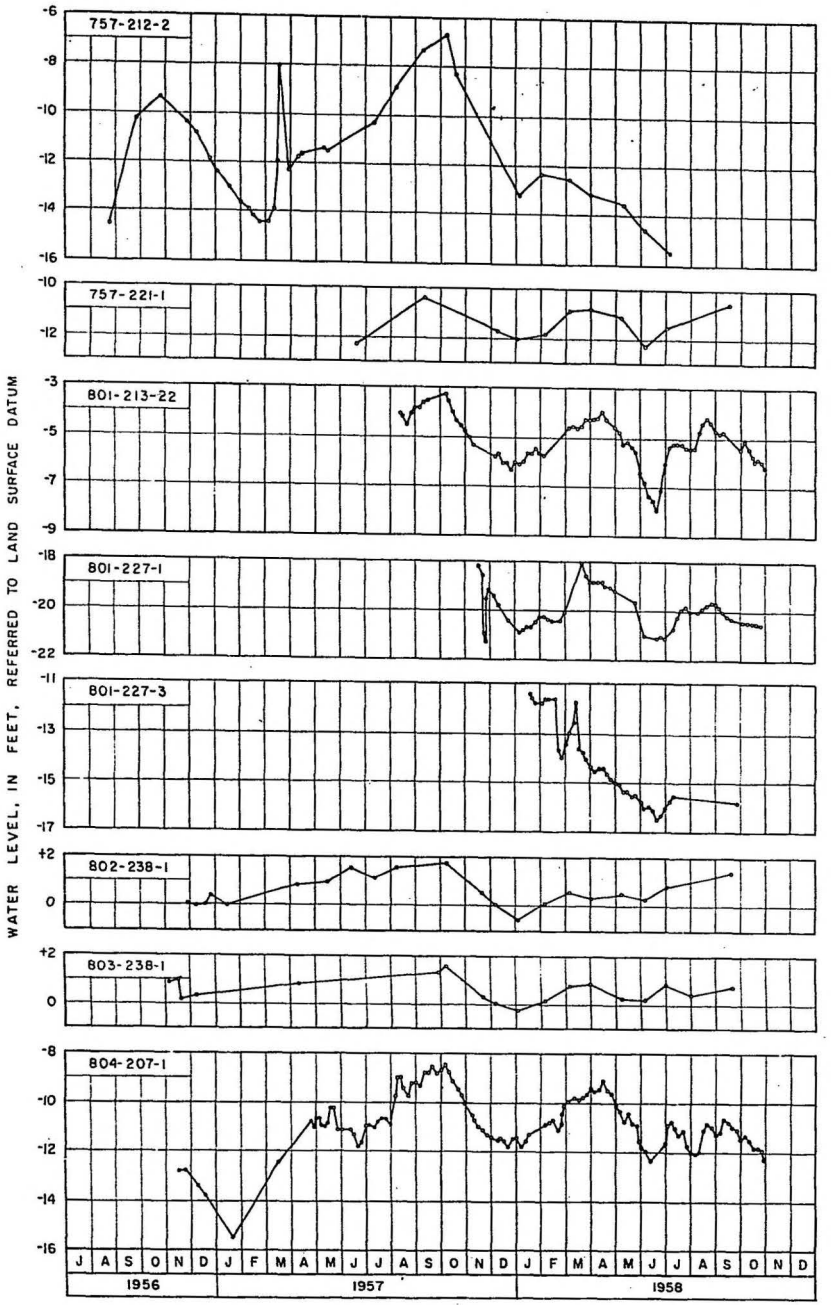


Figure 46b. Water levels in selected wells.

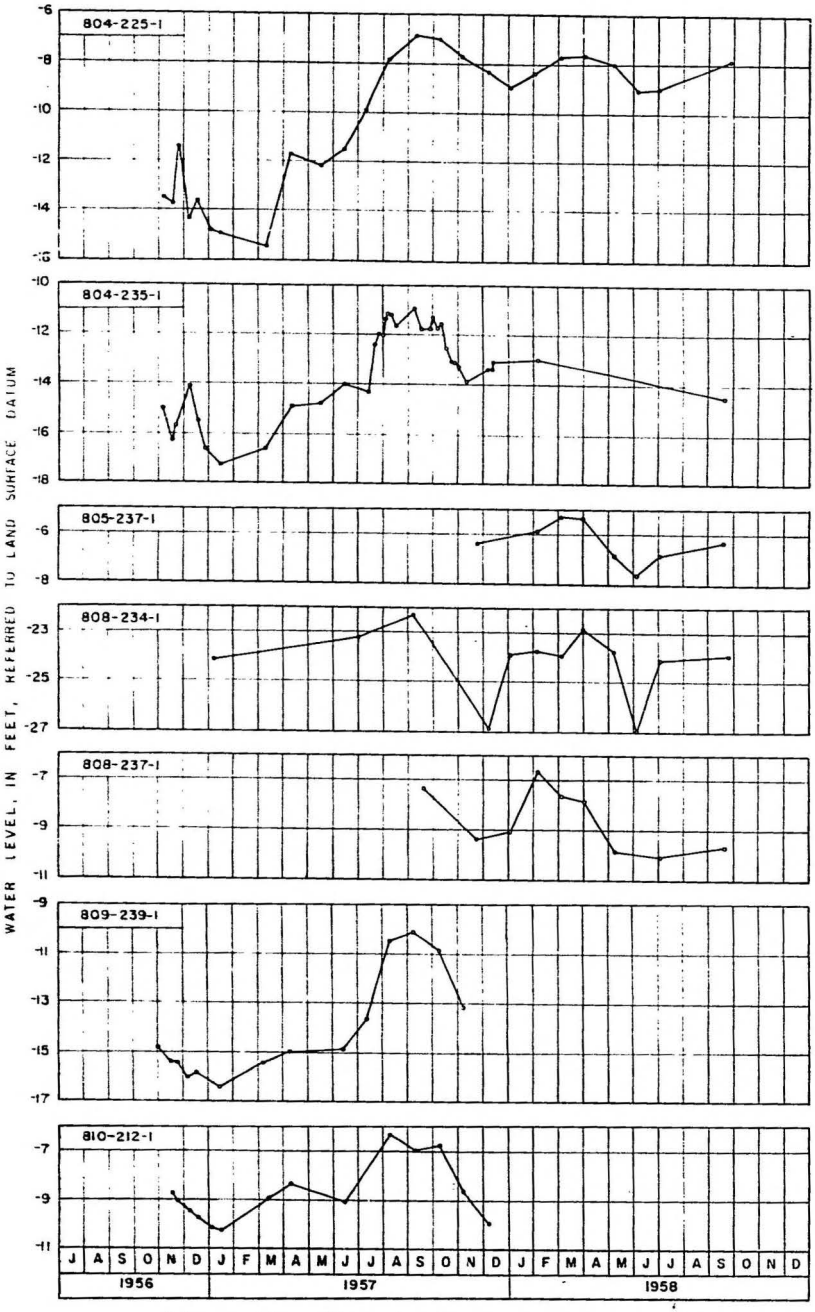


Figure 46c. Water levels in selected wells.

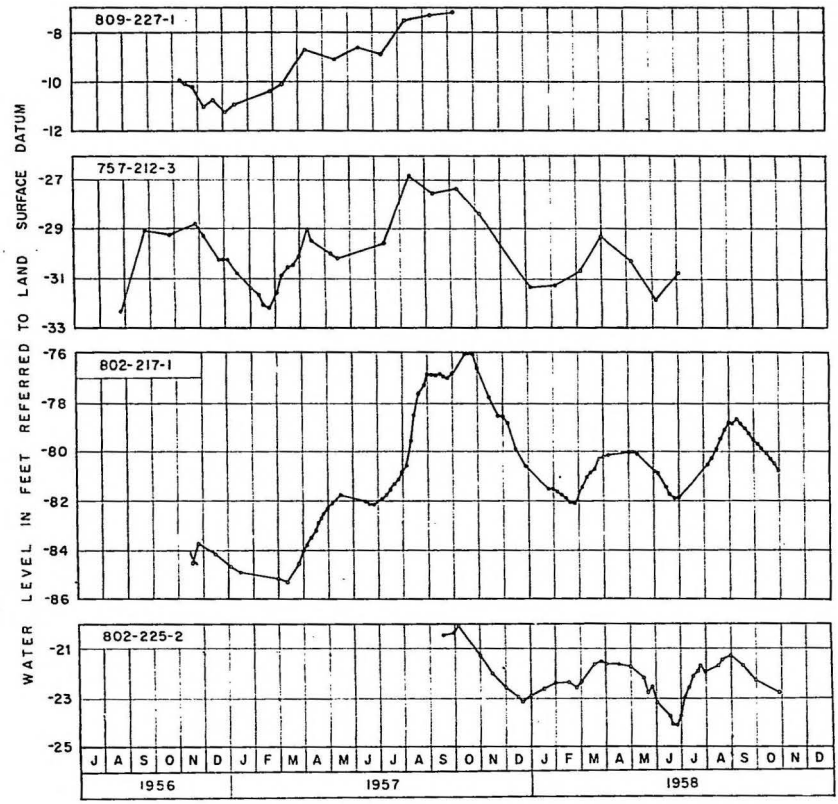


Figure 46d. Water levels in selected wells.

though, in general, more water is discharged through springs. Data were collected from several hundred springs and wells during this investigation. Information for most of the large and a few of the smaller springs is listed in table 3. The locations of these springs as well as many smaller springs for which no information was collected are shown in figure 47.

Spring flow varies with head in the aquifer and decreases when water levels decline. Low rainfall during the winter, use of irrigation wells from November through May, and increased use of water during the tourist season from January through April cause water levels to decline. Therefore, spring flow is decreased during the dry season.

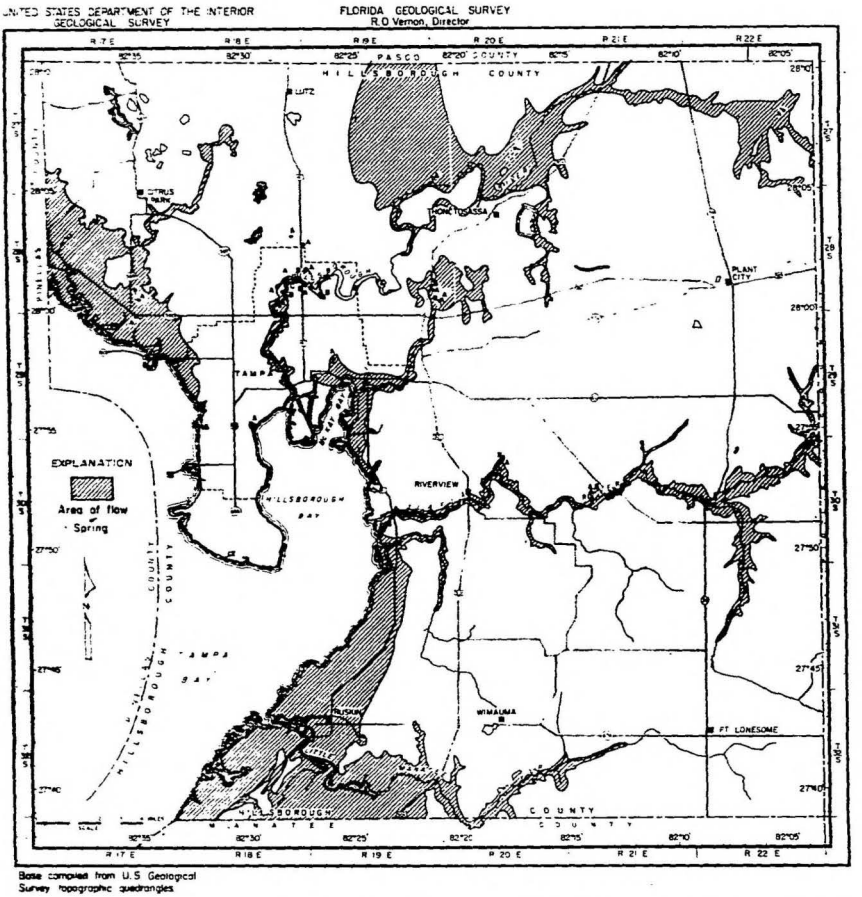


Figure 47. Locations of springs and areas in which water levels in the principal artesian aquifer were above land surface in September and October 1958.

WATER LEVEL

The amount of water in the ground at any time depends on the balance between recharge and discharge, on the transmissibility of the aquifer, and on the ability of the aquifer to expand and contract in response to changes in pressure. The water level is an indication of the amount of water in an aquifer, and changes in the amount of water in storage are reflected in changes of water levels in wells that penetrate the aquifer. A rise in water level indicates an increase in water pressure, which causes expansion of the aquifer and compression of the water and an increase in the

TABLE 3. Information on Selected Springs in Hillsborough County

Spring name	Spring number	Owner	Location	Estimated discharge (gpm)	Approximate elevation (ft.)	Use	Remarks
Lithia	751-213-A	County of Hillsborough	SW¼ SE¼ sec. 17, T. 30 S., R. 21 E.	20,000		Recreation	
Little Lithia	751-213-B	do.	SW¼ SE¼ sec. 17, T. 30 S., R. 21 E.	2,000		do.	
Messer	752-217-A	----------	SW¼ SW¼ sec. 14, T. 30 S., R. 20 E.	500		None	
Buckhorn	753-218-A	U. S. Phosphoric Products Corp.	SE¼ NE¼ sec. 9, T. 30 S., R. 20 E.	5,000		Industrial	
Boiling	755-204-A	----------	SW¼ NW¼ sec. 25, T. 29 S., R. 22 E.	2,000		None	
Palma Ceia	755-229-A	City of Tampa	NE¼ NE¼ sec. 34, T. 29 S., R. 18 E.	50		None	A complex of 6 openings.
Craft Mineral	757-222-A	Mrs. H. E. Herrington	SW¼ SW¼ sec. 13, T. 29 S., R. 19 E.	150		None	Water formerly bottled and sold.
Deshong	757-222-B	do.	SW¼ SW¼ sec. 13, T. 29 S., R. 19 E.	20		None	Formerly supplied slaughter house.
Oak	757-225-A	Oak Park Drive-in Theatre	NE¼ NW¼ sec. 17, T. 29 S., R. 19 E.	100		None	Spring is buried, discharge via conduit.
Magbee	757-227-A	City of Tampa	SE¼ NW¼ sec. 13, T. 29 S., R. 18 E.	300		None	High color, formerly public supply for Tampa.
Eureka	800-220-A	----------	SE¼ NW¼ sec. 31, T. 28 S., R. 20 E.	2,000		None	
Do.	800-220-B	----------	SE¼ NW¼ sec. 31, T. 28 S., R. 20 E.	200		None	200 ft. SW of 800-220-A.
----	800-221-A	----------	SE ¼ NW¼ sec. 30, T. 28S., R. 20 E.	1,000		None	
----	800-221-B	----------	SE¼ NW¼ sec. 30, T. 28 S., R. 20 E.	1,000		None	0. 15 mi. N. of 800-221-A Spring is in bottom of ditch.
	800-226-A	City of Tampa	NE¼ SW¼ sec. 30, T. 28 S., R. 19 E.	15	5	None	
----	800-226-B	Mrs. H. L. McGlammery	SW¼ SE¼ sec. 30, T. 28 S., R. 19 E.	100	25	None	
Lowry	800-227-A	City of Tampa	NW¼ SW¼ sec. 25, T. 28 S., R. 19 E.	30	7	None	Very strong H_2S odor, sulfur deposits on curb.
North Park	800-227-B	----------	NW¼ NW¼ sec. 36, T. 28 S., R. 18 E.	50	5	None	
Jackson	800-234-A	----------	SE¼ NW¼ sec. 35, T. 28 S., R. 17 E.	5	5	None	Formerly supplied laundry.
10th Street Sink	801-226-A	Mrs. Cecil Fink	SW¼ SW¼ sec. 19, T. 28 S., R. 19 E.	0	13	None	Dike prevents flow except at high stage.
----	801-226-B	City of Tampa	NW¼ SW¼ sec. 30, T. 28 S., R. 19 E.	15	5	None	
Purity	801-227-A	Purity Springs Water Co.	NE¼ NW¼ sec. 25, T. 28 S., R. 18 E.	500	7	Public supply	
Sulphur	801-227-B	City of Tampa	SE¼ NE¼ sec. 25, T. 28 S., R. 18 E.	60,000	7	Recreation	
Richardson	801-227-C	Hedrick Estate	SW¼ NE¼ sec. 25, T. 28 S., R. 18 E.	210	5	Public supply	
Trinity	802-226-A	----------	SW¼ SW¼ sec. 18, T. 28 S., R. 19 E.	-------	------		Spring flowed from orifice into pool—then out orifice on other side of pool; ceased flow 7-10-58 following earthquake.
Blue Sink	802-227-A	----------	SE¼ NW¼ sec. 13, T. 28 S., R. 18 E.	-------	------		Spring flows from orifice into pool —then out orifice on other side of pool.
----	804-218-A	----------	SE¼ NW¼ sec. 4, T. 28 S., R. 20 E.	20	30±5		
----	805-219-A	William Fink	SE¼ SE¼ sec. 29, T. 27 S., R. 20 E.	300	30±5	None	Spring is 150 feet. NW of sec. corner.
	808-205-A	----------	SE¼ NE¼ sec. 15, T. 27 S., R. 22 E.	-------	------		On south bank of Blackwater Creek, 50 ft. west of canal.

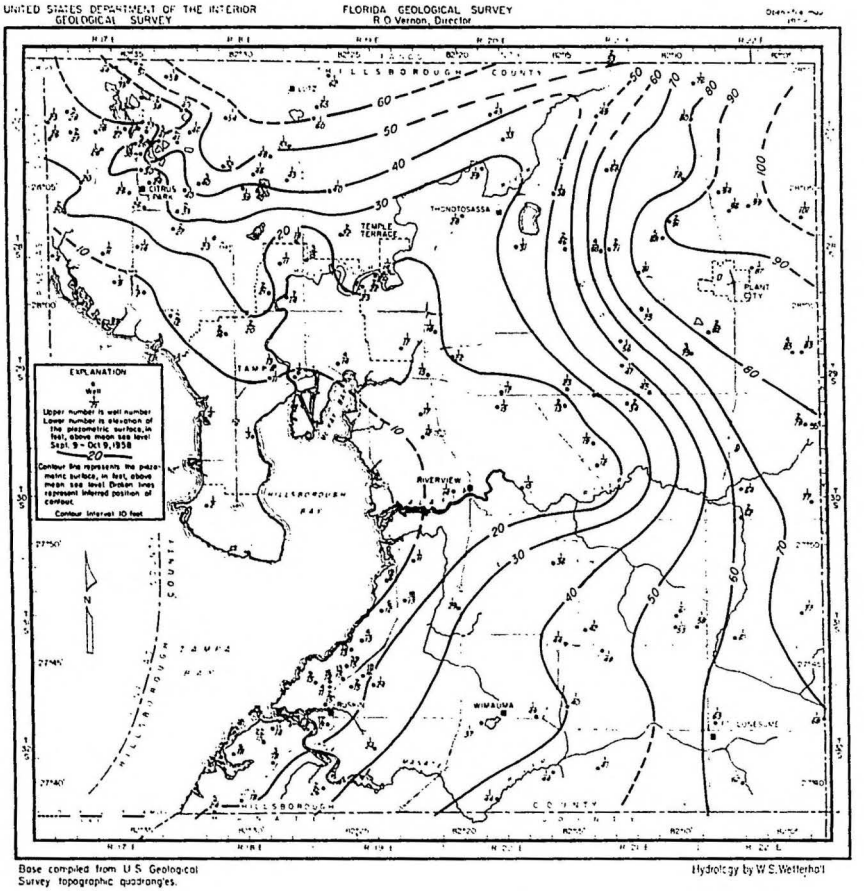


Figure 48. Piezometric surface in the principal artesian aquifer (September-October 1958).

amount of water in storage. Conversely, when the water level declines the aquifer contracts and the water expands, thus decreasing the amount of water in storage.

The configuration of the piezometric surface in Hillsborough County during September and October 1958 is shown in figure 48 by contour lines. This surface represents the water levels that may be expected in wells tapping the principal artesian aquifer throughout the county. The hydraulic gradient and direction of movement of water also may be determined from the map. Water always moves down the hydraulic gradient or normal to a contour line from any point.

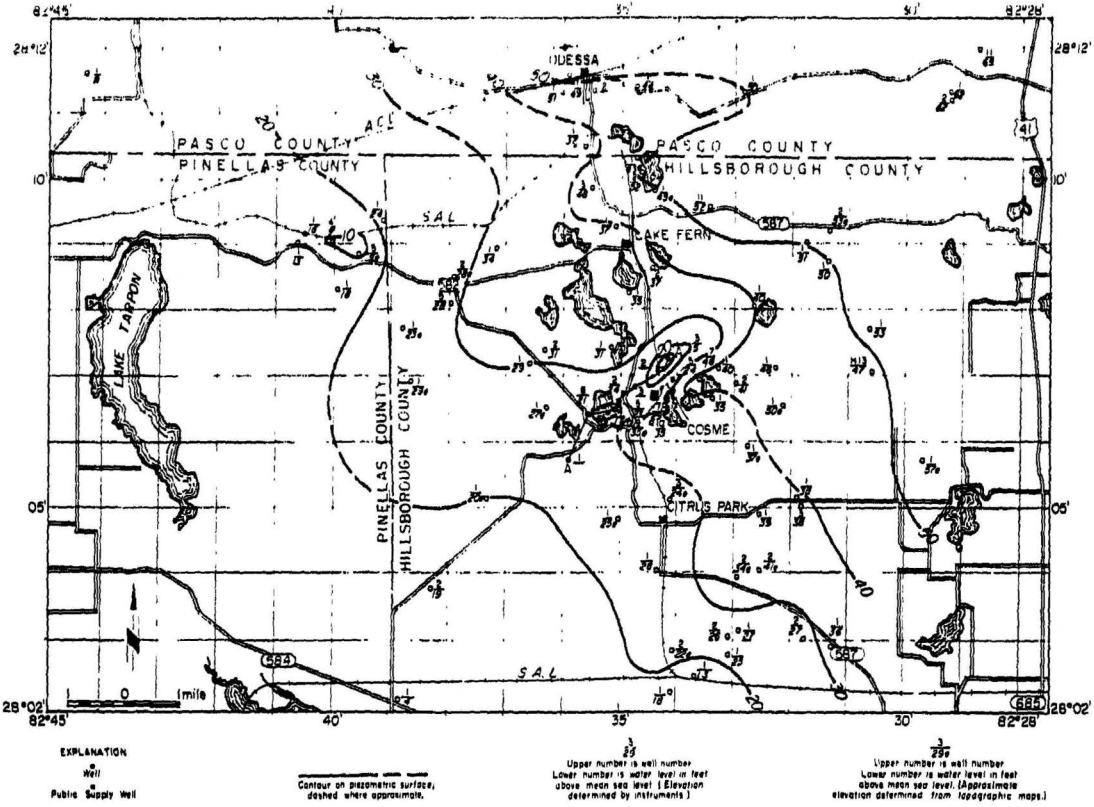


Figure 49. Piezometric surface in northwestern Hillsborough County (November 21-23, 1957).

The degree of uniformity of spacing of the contours is an indication of the uniformity of the geology and of recharge and discharge. Closer spacing of the contours or piezometric highs indicates low transmissibility, local recharge, or both. Conversely, wide spacing and re-entrants or lows in the surface indicate high transmissibility, local discharge, or both. The shape of the piezometric surface changes with rates of recharge and discharge.

The piezometric surface shown in figure 49 is based on measurements made during September and October of 1958. Normally, annual highwater levels occur inthese months. In 1958, however, water levels were very high during the winter months, reflecting unusually high rainfall, and were somewhat lower in the fall.

The piezometric surface generally slopes toward Tampa Bay from two piezometric highs, one in Polk County, and the other in Pasco County. Between the two highs is a re-entrant that generally follows the Hillsborough River. This re-entrant tends to become less pronounced down the gradient and probably is caused by discharge from the many springs in the river valley where the aquifer is near or at the surface. If underground drainage were largely responsible for the feature, the contours would be more distorted in the lower reaches of the drainage area than in the upper reaches.

A similar feature in the vicinity of the Alafia River also reflects the low pressure in the aquifer resulting from discharge by springs. On the flank of the re-entrant along the Hillsborough River is a cone of depression surrounding Sulphur Springs and many nearby springs. The contours shown depict the water level in the Avon Park limestone in the immediate vicinity of Sulphur Springs. Water levels in wells in the Tampa and Suwannee limestones are considerably more depressed in the area than those in wells in the Avon Park limestone because of higher discharge through the extensive cavity system that has been developed in the upper formations and of the retarding effect of the less permeable limestones of the Ocala group.

The shape of the piezometric surface in the northwestern part of the county is shown in detail in the vicinity of the St. Petersburg well field (fig. 49). The sharp re-entrant in the piezometric surface near the well field may reflect drawdown caused by withdrawal of water from the area but that drawdown may be superimposed on a re-entrant in the surface similar to the somewhat less pronounced re-entrant to the southwest. The piezometric ridge between these two re-entrants may be the result of recharge from the lakes, but its continuity into the discharge area to the

southeast indicates that it probably is controlled by a major pre-Mesozoic fault shown by Vernon (1951, fig. 11). Recharge probably is a factor in the determination of the shape of the surface. The existence of an impermeable zone along the fault may be responsible for the steep gradient on the south side of the pumping field. Additional data are necessary for a more definite resolution.

USE

Ground-water pumpage in Hillsborough County is estimated to average 67 million gallons a day. More water is used during the winter than during the summer because of the increase in irrigation in the usually dry winter and because of the influx of tourists and the consequent increase in domestic and commercial use. Public water systems for part of Tampa, for St. Petersburg in Pinellas County, for Plant City, Temple Terrace, and numerous subdivisions near Tampa derive their supplies from wells. More than 99 percent of the water pumped is used for domestic, commercial, and public building supply. About 0.3 mgd is pumped from wells at former Drew Field to supplement the surface-water supply of the city of Tampa. Purity Springs Water Company pumped 1.0 mgd, Hendrick Estates (commercial) pumped 0.02 mgd, and Florence Villa subdivision pumped 0.05 mgd. Figures from the city of Tampa indicated the presence of 1,500 to 1,600 wells in the city. The figures included 149 commercial wells and 1 industrial well. Individual wells supply an estimated 4 mgd to rural residents who are not furnished water by the public water systems.

Industrial cooling and processing water uses are estimated to be 24 mgd. Cooling water is frequently salty in the area of industrial development near Tampa Bay. The total pumpage from wells in this area was estimated to be 60 percent fresh water and 40 percent salty bay and connate water, based on chemical quality. The bay water enters the aquifer through exposures in the channel cuts in the bay. It flows toward the wells where the water level is lower than sea level.

Irrigation of truck crops and citrus groves by ground water probably exceeds 15 mgd. The exact pumpage and flow from irrigation wells is almost impossible to determine directly. The above figure is based on use of 1.4 million gallons of water per acre per year for truck crops and an average of 100,000 gallons per acre per year for the estimated 10 percent of the citrus groves that are irrigated with ground water in the county.

DRAINAGE WELLS

Drainage wells offer a low cost means of controlling flooding in ponded areas where conditions are favorable for their use. The principal problems involved are effectiveness, pollution of water in the aquifer, and possible property damage from high water levels. To be effective, the well must remove water from an area at such a rate that the storage capacity of the pond will not be exceeded during the heaviest, most prolonged rain that is expected for the area. The required capacity of drainage wells is inversely related to pond storage. Rate of runoff into a pond is usually quite large as compared with the capacity of most wells; therefore, several wells may be required to drain even a small area.

The drainage capacity of a well is about equal to the specific capacity of the well. The specific capacity is the rate at which water can be pumped from a well with a given drawdown. A well that yields 100 gpm per foot of drawdown will yield about 300 gpm with 3 feet of drawdown and will accept 300 gpm of drainage water with a rise in water level of about 3 feet. The stage of the pond or lake and the piezometric surface fluctuate approximately simultaneously, but the pond level fluctuates more quickly and with greater magnitude. This relatively high piezometric surface may not prevent satisfactory use of drainage wells to remove excess pond water if the specific capacity of the well is large. The water level in the pond must be above the piezometric surface in order for water to flow into the well.

Surface waters may contain bacteria and organic and inorganic materials that are undesirable or dangerous in drinking water. If this water is permitted to enter the aquifer through a drainage well, it may move very quickly to a well that is being used as a source of drinking water. Knowledge of the detailed hydrology of the area is necessary for evaluation of the effect of such drainage on other supplies. However, because the expense of such studies may be prohibitive, a general rule-of-thumb procedure is commonly used. If the well is cased to a salt-water bearing zone, the risk of pollution is slight. Such procedure is not generally practical because the top of the salt-water zone may be at a depth of several thousand feet in the eastern part of the county. If water of a given quality is drained into a zone of the aquifer that is not used for purposes that are affected by that quality, then the drainage water may be harmless. In areas where salt water is at shallow depths, such recharge may be desirable in that it will eventually push the fresh-salt contact to greater depth.

In some areas, as near Sulphur Springs, an artificially induced rise in water levels that are already high may result in considerable damage to some properties. In the natural condition, Sulphur Springs drew down the water levels in the surrounding area so that several former spring basins no longer flowed. When the water level in the spring was raised by construction of a concrete wall, several of these former springs resumed flow. They were diverted to the river through drains, or they were filled or diked to prevent flow. Several of these former springs, both evident and buried under fill, might flow if substantial drainage is disposed of through wells in the area.

WELL EXPLORATION STUDIES

The results of surveys of velocity, temperature, and chemical quality in three wells are shown in figure 50.

The velocity of the water, concentrations of chloride and sulfate, and the specific conductance are shown for various depths in well 802-225-2. The well is in the industrial park about 3 miles northeast of Sulphur Springs. When the well is pumped at 200 gpm, the principal producing zones appear to be a cavity at about 660 feet and a permeable zone from 440 to 540 feet.

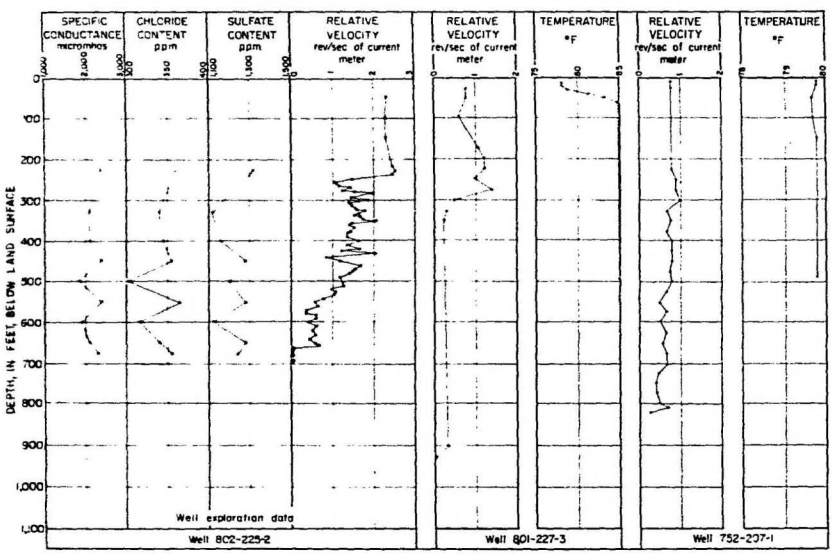


Figure 50. Well exploration data.

Velocity and temperature of water are shown for various depths in well 801-227-3, about 1 mile north of Sulphur Springs.

Essentially all of the water pumped (about 150 gpm) came from a cavity at the bottom of the well. The temperature of this water was about 85° F. The normal temperature of ground water in the upper zones of the aquifer is about 75° F.

Waters in the principal producing zones, as well as the several minor producing zones, vary in both concentrations and proportions of dissolved materials. Some of the zones contain very highly mineralized water. Thus the zone immediately below the casing yields but a small percentage of the water pumped but the concentration of sulfate increases by 1,000 ppm in that zone. The lower temperature in the upper 65 feet probably is caused by the flow of cooler water around the casing in the upper zones.

Well 752-207-1, about 1 mile southwest of Keysville, derived most of its flow from a cavity at the bottom of the well. The temperature remained almost constant with depth.

QUANTITATIVE STUDIES

The ability of an aquifer to transmit and store water is expressed in terms of coefficients that are derived from pump test data.

The coefficient of transmissibility (T) is defined by Theis (1938, p. 894) as the number of gallons of water at the prevailing water temperature that will move in 1 day through a vertical strip of the aquifer 1 foot wide normal to a unit hydraulic gradient. The coefficient of storage (S) is the volume of water released or taken into storage per unit surface area of the aquifer per unit change in head normal to the aquifer surface.

In the conventional units of the U. S. Geological Survey, T is in gallons per day per foot and S is in gallons per square foot per foot.

An index of the leakage between aquifers is the coefficient of leakance (P'/m'). It is expressed in units of gallons per day per square foot, under a unit gradient divided by the thickness of the confining bed or beds, in feet.

Theis (Wenzel, 1942) developed a method of determining T and S from time-drawdown data in observation wells in the vicinity of a pumped well. Theis assumed that the confining beds are impermeable. In natural systems, this condition does not obtain, and the Theis equation permits only an approximation of the true values, depending on the amount of leakage through the confining

beds. Hantush (1956) developed a solution introducing corrections for this leakance—an equation which allows the coefficient of leakance to be determined as well as the coefficients of transmissibility and storage. The method of determining coefficients from the Hantush equation is similar to that described by Theis (Wenzel, 1942). The field data consist of measurements of quantity of water pumped, distance between pumped well and observation well, and water levels in all wells with times of measurements. The data are reduced to logarithmic graphs with time (t) in days since pumping began divided by the square of the distance (r) from pumped well to observation well (t/r^2) as the abscissa, and drawdown (s) in feet as the ordinate. Each water-level measurement is made at an approximate time so that the points on the graph allow construction of a smooth curve. The resulting curve is then compared with a family of leaky aquifer type curves developed by H. H. Cooper, Jr., of the U. S. Geological Survey. This family of curves is based upon the equation for nonsteady flow in an infinite leaky aquifer developed by Hantush and Jacob (1955, p. 95-100) and described by Hantush (1956, p. 702-714). The values of a chosen match point, when substituted in the proper equation, give values for the three coefficients, T, S, and P'm'.

Pumping tests in three areas in Hillsborough County have been conducted by the U. S. Geological Survey to determine these coefficients.

In 1942, test pumping at Hookers Point in Tampa was conducted as part of a study to determine the feasibility of construction of "wet" ship construction basins to about 17 feet below mean low water. Only one of the many wells penetrated the Tampa limestone. Data from this well yielded a T of 75,000. Data from wells penetrating only a thin bed of limestone at about 32 feet below mean sea level indicated values for T ranging from 7,000 to 16,000 and values for S ranging from 0.00014 to 0.00077. The erratic results reflect the extremely variable nature of the formations tested.

In 1955 a test was made about half a mile east of Sun City. The flowing well (740-227-6) and the observation well (740-227-7) used for this test penetrate essentially the entire thickness of the Tampa and Suwannee limestones. The values for T and S, as determined by Peek (1959, p. 54) are 114,600 and 0.0006, respectively.

In 1957, the city of Tampa initiated the testing of a potential well field site 6 miles west of Plant City. The tests were conducted jointly by the U. S. Geological Survey and the consultants for

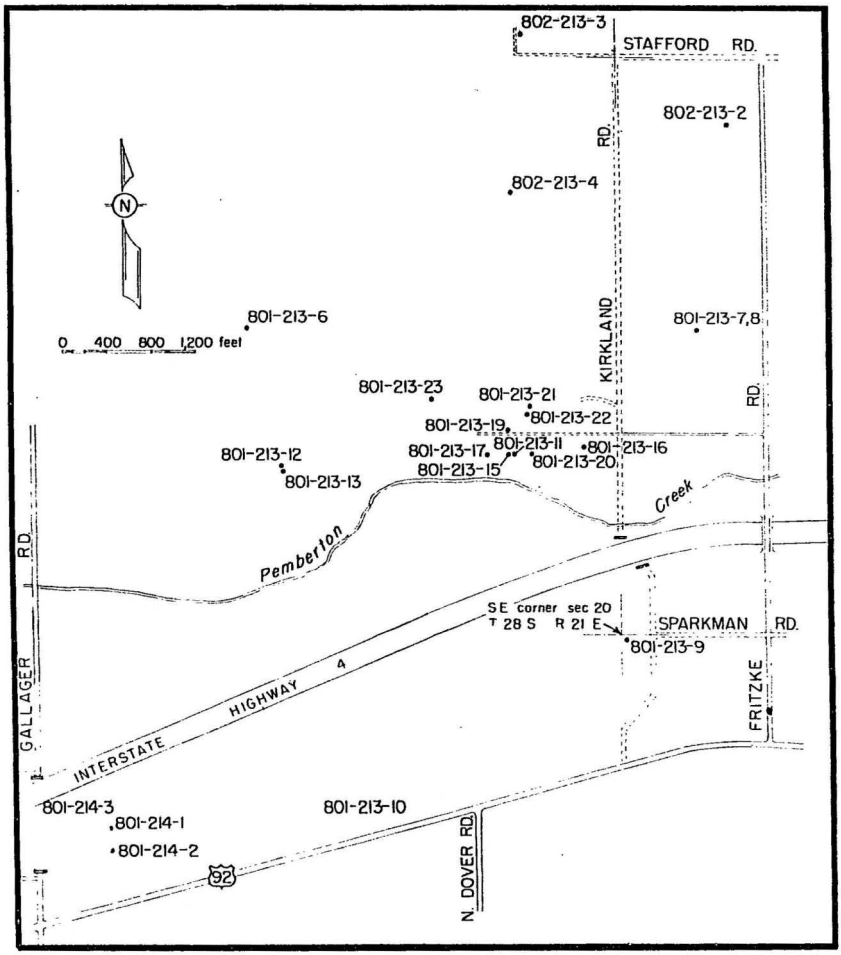


Figure 51. Tampa well-field site.

the city of Tampa, Robert and Company, Associates, of Atlanta, Georgia. The plan of the test site (fig. 51) shows the location of the 10 wells used in the tests and a number of selected off-site wells. The well construction data and test data are shown in table 4. Several of the wells were deepened after each test to allow testing of deeper zones of the aquifer.

The following table shows the elevation above sea level of the tops of formations penetrated by test wells:

Wells 801-213-11 and 15, only 25 feet apart, penetrated the top

TABLE 5. Elevation Above Sea Level of Formational Tops Penetrated by Test Wells

Well	Elevation of top of			
	Tampa limestone	Suwannee limestone	Ocala group	Avon Park limestone
801-213-11	+12	— 11	—296	
802-213-4	+17	— 85	—321	—418
-13	— 6	— 76	.....	.....
-15	+20	— 20	—183	.....
-16	+22	— 31	.....	.....
-19	none	— 12	—152	.....
-20	+ 9	— 31	—218	.....
-21	— 3	—115	.....	.....
-22	+25	— 35	—211	—412
-23	+12	.....	.....	.....

of the Ocala group at -321 and -183 feet, respectively, a difference of 138 feet. Well 801-213-23 bottomed in the Tampa limestone at -186 feet and 801-213-17 had not entered rock at -240 feet. The sand in this well (801-213-17) probably fills a vertical solution opening. Aerial photographs, in color, of the well field show a number of circular areas similar to that surrounding 801-213-17 within the limits of the test site. It is believed that these areas should be avoided in future drilling for water.

The geologic anomalies indicated in table 5 are the result of collapse following weakening of the rock in places by solution of limestone. The occurrence of solution features in such abundance may well be associated with faulting. The top of the Avon Park limestone is about the same elevation in the two wells on the site that penetrate it but more data are necessary if faulting is to be defined in the area.

Data from four of the six pumping tests were analyzed to obtain values for T, S, and P′/m′. Maximum, minimum, and "best fit" values were computed for each of the coefficients. These were used to obtain adjusted values.

For the first test, well 801-213-15 was pumped at 811 gpm for 400 minutes. Data from observation wells 801-213-11, -15, -19, and -20 were analyzed. Best values for the coefficients were determined to be T=35,000, S=0.00005, and P′/m′.=0.03. The section tested was from the top of the limestone to a depth of about 250 feet. Well 801-213-11 was 560 feet deep

TABLE 4. Well Construction and Test Data, Tampa Well-Field Site

USGS No.	802-213-4		801-213-13		801-213-11		801-213-16		801-213-20		801-213-19		801-213-23		801-213-21		801-213-15		801-213-22	
Tampa No.	1		2		3		4		5		6		7		8		A		B	
Test	Depth	Csg.[1]	Depth	Csg.	Depth	Csg.	Depth	Csg.	Depth	Csg.	Depth	Csg.	Depth	Csg.	Depth	Csg.	Depth	Csg.	Depth	Csg.
1	210	78	269	64	560	74	250	50	250	39	125	78	—	—	—	—	227	67.6	—	—
2	210	78	269	64	560	74	250	50	400	39	225	78	—	—	—	—	413	67.6	—	—
3	450	208	345	64	560	74	250	50	400	39	400	78	256	78	256	92	413	67.6	420	72
4	450	208	345	64	560	74	250	50	400	39	400	78	256	78	256	92	413	67.6	420	72
5	450	208	379	64	750	74	250	50	400	39	400	78	256	78	256	92	413	67.6	800	72
6	450	208	379	64	750	74	250	50	400	39	400	78	256	78	256	92	413	67.6	800	72

	Pumped well	Test No.	Time (1957 Start	Time (1957 End	Duration of test (mins.)	q-[2] (gpm)
USGS No.	801-213-15					
Tampa No.	A	1	9:00 a.m. 4-3	3:40 p.m. 4-3	400	811
	801-213-15					
	A	2	9:00 a.m. 4-12	6:00 p.m. 4-12	540	2,200
	801-213-22					
	B	3	10:03 a.m. 5-6	6:01 p.m. 5-7	1,920	1,520
	801-213-22					
	B	4	8:01 a.m. 5-10	8:08 a.m. 5-11	1,440	1,400
	801-213-15					
	A					2,820
	801-213-22					
	B	5	3:15 p.m. 7-22	3:20 p.m. 7-23	1,440	1,500
	801-213-22					
	B	6	1:10 p.m. 7-26	4:10 p.m. 7-30	7380	3,800

[1]Csg—Depth of casing
[2]q—Pumping rate

but the water level did not differ materially from the other wells in response to pumping. An excellent hydraulic connection between 801-213-11 and 801-213-15 was noted during drilling.

After the first test, wells 801-213-15, -19, and -20 were deepened. Test 2 consisted of pumping 801-213-15 for 540 minutes at 2,200 gpm. Data from wells 801-213-11, -19, and -20 were analyzed. The values for the coefficients were found to be T=100,000, S=0.003, and P′/m′=0.02. The section tested was from the top of limestone to a depth of about 410 feet.

After the second test, wells 801-213-21, -22, and -23 were drilled and 801-213-13 and -19 were deepened. Well 802-213-4 was deepened and subcased to 208 feet.

For test 3, well 801-213-22 was pumped for 1,920 minutes at 1,520 gpm. Data from observation wells 801-213-11, -19, 20, -23, and 802-213-4 were analyzed. Best values of the coefficients were T=50,000, S=0.0007, and P′/m′ =0.001. The section tested was essentially the same as for the second test. Two short tests were then run, but the data were not analyzed.

Wells 801-213-11, -13, and -22 were then deepened and the last test was run, with 801-213-22 pumping 3,800 gpm for 7,380 minutes. Data from wells 801-213-11, -15, -16, -19, -20, -21, and -23 were analyzed. Best values of the coefficients were determined to be T=220,000, S=0.002, and P′/m′ was 0.002. The section tested was from the top of limestone to a depth of about 800 feet. Continuous rain throughout most of the test did not appear to affect the data.

Adjusted values of the coefficients for each test are summarized in table 6.

The order of magnitude of the values of T in table 6 increases with depth as does the specific capacity of the wells. This indicates that the aquifer is layered. The principal water-bearing zones are separated by zones of lower permeability. The coefficient of

TABLE 6. Adjusted Values of T, S, and P′/m′ for Pumping Test at the Site of the City of Tampa Well Field.

Test	T	S	P′/m′	Pumped well	Depth (ft.)	Open hole (ft.)
1	35,000	.00005	0.03	801-213-15	227	159
2	100,000	.0003	.02	801-213-15	413	345
3	50,000	.0007	.001	801-213-22	420	348
6	220,000	.002	.002	801-213-22	800	728

leakance (P'/m') computed for the test in which the pumped and observed wells were deep is much lower than that for the test using relatively shallow wells. This indicates that a smaller percentage of the pumped water was derived from leakage in the deeper test. It is possible that the coefficient of leakance reflects leakage into the upper part of the section with resultant distortion of the observed rate of decline of water levels in the wells that penetrate the entire section. If a well were cased to about 350 feet, lessening direct lowering of head in the upper zones of the aquifer, the area immediately adjacent to the well field might not be dewatered as much as if the wells were cased only to the first substantial rock.

Figure 52 is a semilog plot of the profile of the cone of drawdown around a pumped well at the site of the city of Tampa well field. Scale units are given for a pumping rate of 1,000 gpm. The value of "S" for any pumping rate is computed by multiplying the value for "S" (drawdown in feet) at 1,000 gpm by the ratio of the new pumping rate to 1,000 gpm. The shape of the cone of drawdown will remain constant for a given rate of pumping after equilibrium has obtained, but will be shifted horizontally to a

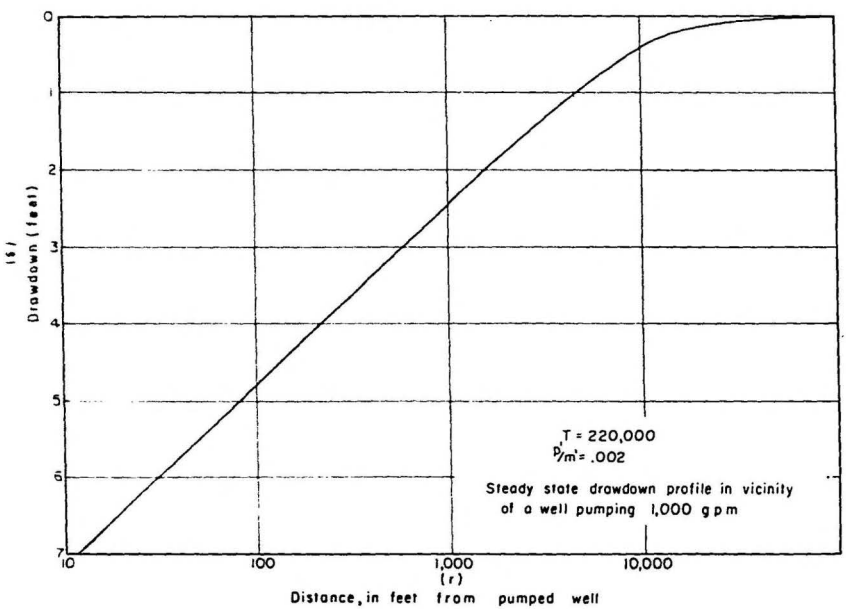


Figure 52. Drawdown in vicinity of a well after pumping 60 days or more at 1,000 gpm.

distance from the pumped well such that the drawdown will be proportional to the pumpage rate as the drawndown on the curve is to 1,000 gpm. If the sands and clays above the aquifer are dewatered, the water level will decline, following the type curve computed by Theis. The transmissibility will remain essentially constant but the storage coefficient will approximate 0.2.

The drawdown was greater than calculated in the early part of each test. This indicates that water is not being released from storage immediately when water levels are lowered. The large amount of sand in the limestone formations yields water slowly in comparison to the cavities in the limestone through which the water is transmitted to the well. Because the storage coefficient is larger and transmissibility smaller for the cavity fill than for the limestone, the cavity fill will yield water at a slower rate and for a longer time than the cavity proper. This slow yielding of water may distort the observed data to such an extent that only a long period of testing will allow accurate determination of the aquifer constants.

QUALITY

With the exception of the Ruskin area, certain areas in and near Tampa, and coastal areas, the water in underground formations generally contains less than 500 ppm dissolved materials. The dissolved materials in water from shallow zones of the aquifer generally range from 50 to 500 ppm with a nonuniform tendency toward increasing concentrations of dissolved materials with increasing depth. This is partially indicated by analysis of water from test well 801-213-15 near Plant City. (See separate data report.)

The average dissolved materials in most ground waters in Hillsborough County, calculated from 78 samples analyzed, was about 240 ppm. Water has been obtained from a depth of 1,489 feet 3 miles east of Wimauma that contained less dissolved materials than this average.

Dissolved materials in ground water indicate that the Gyben-Herzberg principle is reasonably applicable and may be used in the development of ground water in areas having artesian pressures great enough to cause water to rise in wells to an elevation of 30 feet, or more, above sea level. As the maximum safe depth, as computed from the Gyben-Herzberg principle, is approached, there is increasing danger that the water will contain higher concentrations of dissolved materials. Greater rates of pumping will result

in higher concentrations of dissolved materials. It is expected that the concentrations of dissolved materials will increase sharply at about the calculated safe depth.

The dissolved materials in water in the underground formations, with the exception of the above mentioned areas, are mainly calcium, magnesium, and bicarbonate. Together, these constituents average about 76 percent of the dissolved materials but may be as much as 98 percent. Small amounts of sulfate, chloride, and sodium are present.

In the Ruskin area during wet periods, when the area is not irrigated, concentration of the dissolved materials is about 500 ppm. Concentrations of sulfate and alkalinity as carbonate are about equal. During dry periods when the area is extensively irrigated, the concentrations of dissolved materials in the water increase to 1,840 ppm or more. During this same period, the chemical character of the dissolved materials changes with increased pumping. The concentrations of sulfate and calcium (and magnesium by a lesser amount) increase and the alkalinity as carbonate decreases by a nearly proportionate amount. The materials average about 43 percent sulfate and may be as much as 50 percent. Because of the increase in calcium and sulfate, the noncarbonate hardness often nearly equals the carbonate hardness at higher concentrations of dissolved materials. In the Ruskin area during periods of heavier pumping for irrigation, sulfate concentration has been as high as 821 ppm; at the same time chloride and sodium content has increased less rapidly to 270 and 105 ppm, respectively. These are only the maximum concentrations observed and do not necessarily represent maximum concentrations that could occur.

The concentrations and chemical character of the dissolved materials in the water vary widely in certain areas in the vicinity of Tampa and near the coast (except in the Ruskin area). Therefore average would be meaningless. The concentrations of dissolved materials vary nonuniformly with location and depth. Concentrations ranged from about 170 ppm to about 11,000 ppm, and the depths of wells ranged from about 145 to more than 2,000 feet. The higher concentrations of dissolved materials range from 14 to 50 percent chloride, 6 to 30 percent calcium plus magnesium plus alkalinity (as carbonate), 6 to 26 percent sodium, and 6 to 47 percent sulfate.

Seasonal variations in water levels cause the concentrations of dissolved materials to fluctuate in zones of aquifers that are affected by salt-water intrusion. The position of the fresh-salt

water interface is dependent on the elevation of the piezometric surface, and rise and fall of water levels cause a rise and fall of the interface between fresh water and salt water. Large fiuctuations in water level cause the zone of diffusion at the interface to be wide. Water from wells penetrating the upper part of the zone of diffusion may have only slightly higher concentrations on initial development but would increase in concentration rapidly during heavy pumping. Drilling of wells to depths that approach the interface should be avoided.

Except for some locations in the vicinity of Tampa and the coast, including the Ruskin area that is already heavily pumped, most ground waters would be suitable for municipal use. Sodium, chloride, and sulfate probably will exceed the maximum concentration recommended by the U. S. Public Health Service after heavy pumping of these areas. The upward movement of water containing highly concentrated dissolved materials probably will be indicated by more rapidly increasing concentrations of calcium and sulfate than of the other dissolved materials. Further pumping probably will result in increasing concentrations of sodium and chloride. If the concentrations of dissolved materials are observed periodically, the optimum development of the water resource may be attained and acceptable quality of water maintained. The availability of water having the desired quality is one of the first considerations for industrial use. Supplies containing low concentrations of dissolved materials cannot be developed in the vicinity of Tampa, along the coast, or in the Ruskin area.

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APPENDIX

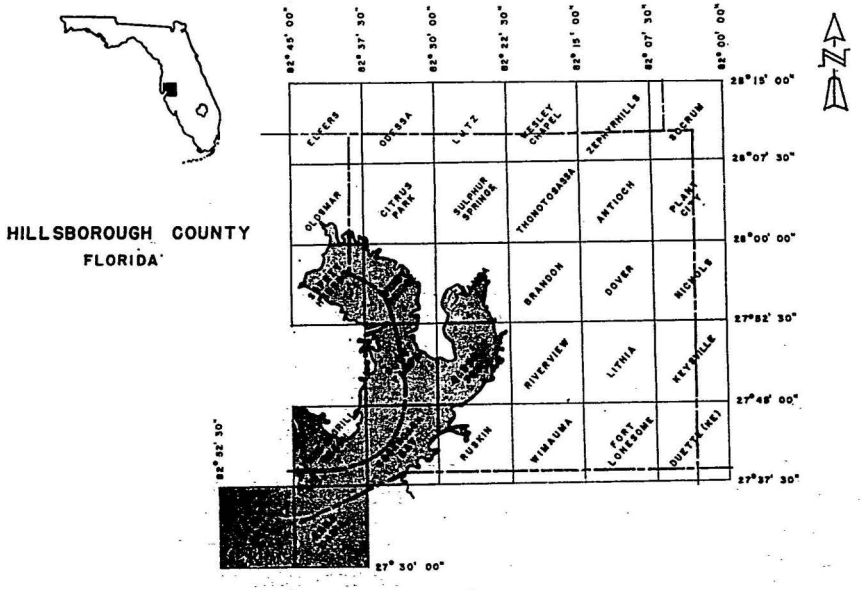
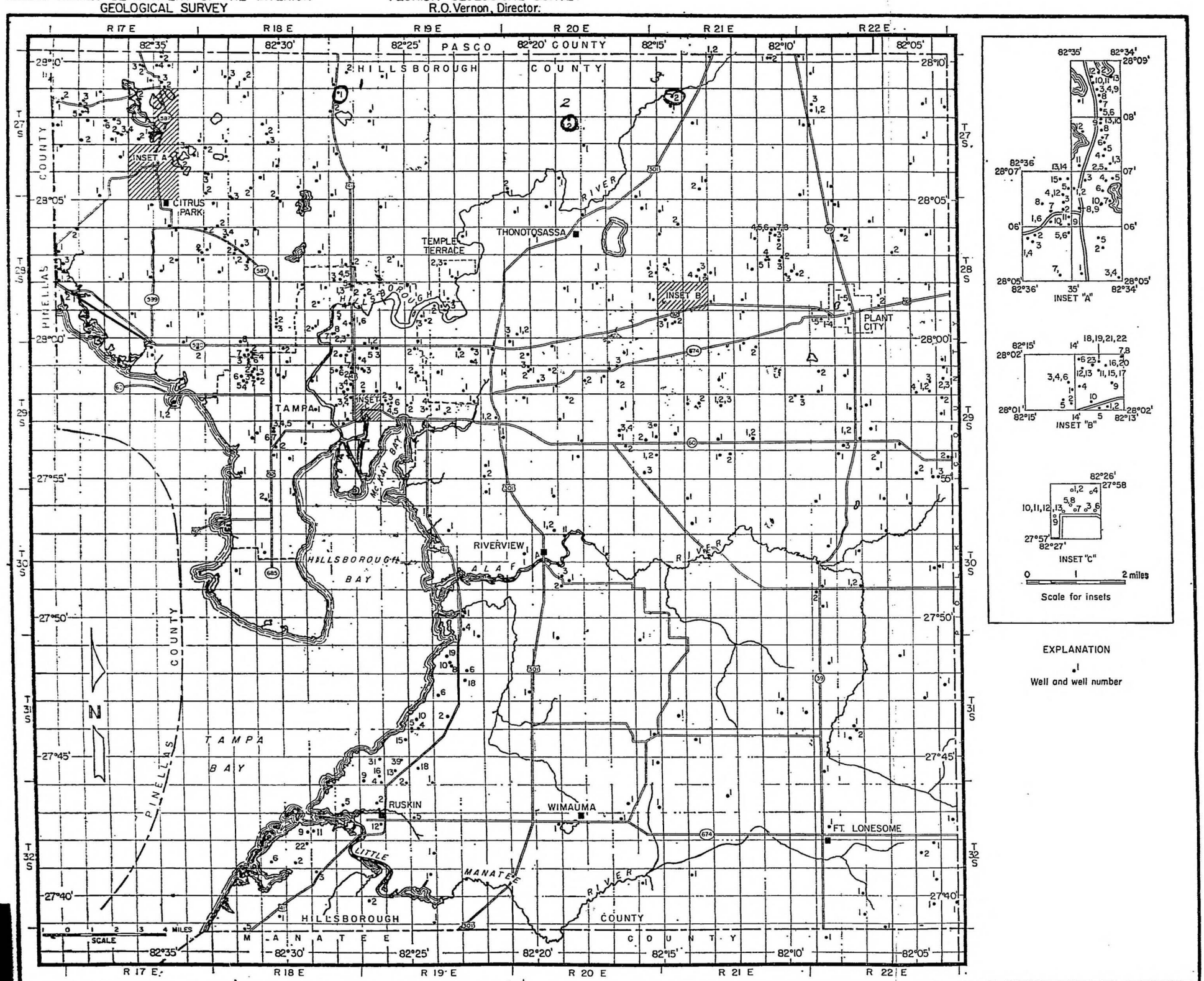


Figure 53. Topographic map coverage of Hillsborough County.

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

FLORIDA GEOLOGICAL SURVEY
R.O. Vernon, Director



EXPLANATION

•1
Well and well number

Base compiled from U.S. Geological Survey topographic quadrangles.

Well inventory by W. S. Wetterhall

Figure 54. Location of inventoried wells.

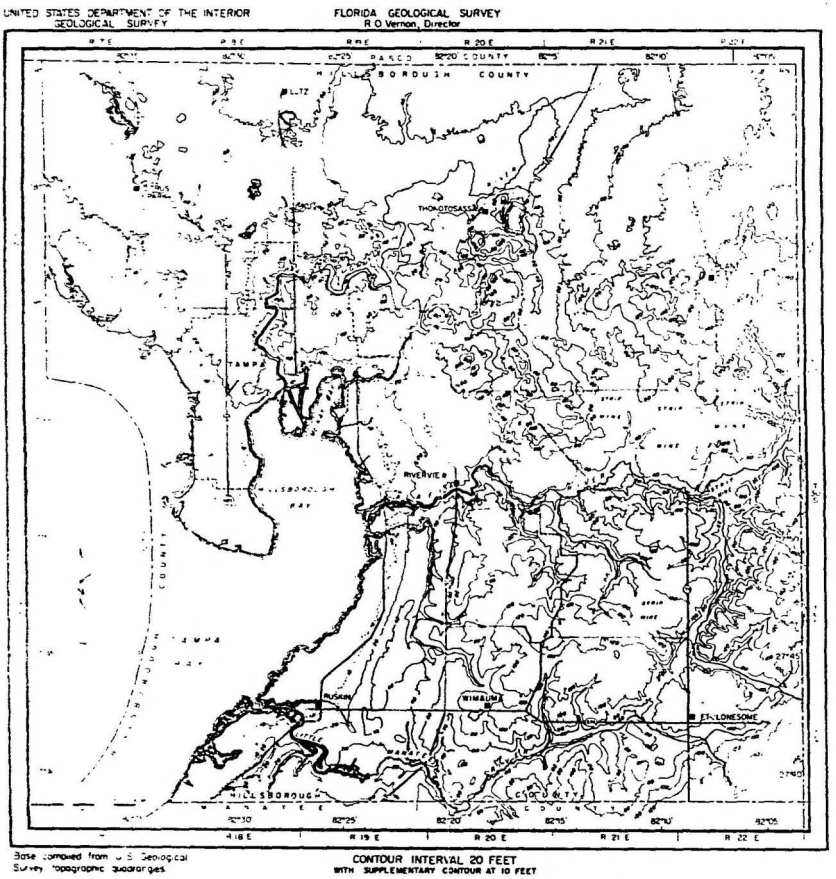


Figure 55. Topography of Hillsborough County.

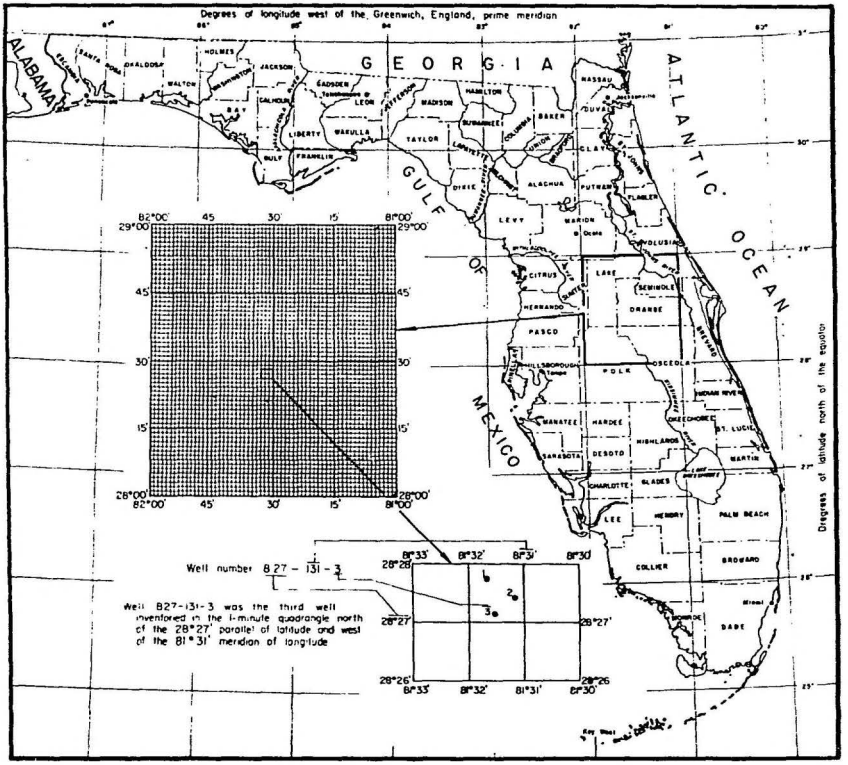


Figure 56. Explanation of well numbering system.