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INTERIM REPORT ON THE HYDROLOGIC FEATURES OF THE GREEN SWAMP AREA IN CENTRAL FLORIDA

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Prepared by U. S. Geological Survey
in cooperation with
The Florida Geological Survey
and
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ABSTRACT

The Green Swamp area as used in this report is located near the center of the Florida Peninsula. It covers an area of almost 900 square miles of swampy flatlands and sandy ridges. The elevation of the land surface varies from about 200 feet above mean sea level in the eastern part to about 75 feet in the river valleys in the western part of the area.

About 720 square miles of the Green Swamp area is drained by the Withlacoochee River. Streams that drain into the St. Johns River, Hillsborough River, Kissimmee River, and Peace River basins also originate in or near the area.

The drainage divides of these basins are broken in several places by swamp channels and gaps in the surrounding ridges. Water may flow through these gaps from one basin to another, the direction often not definitely established but depending on the relative elevation of the water level in each basin. These interconnections have a significant influence on the surface drainage pattern of the area.

During the water year ending September 30, 1959, the rainfall over the Green Swamp area was about 72.5 inches.

This was 20 inches above normal. The runoff from the area during this period was 24.26 inches.

Drainage operations in recent years have not significantly changed the amount of annual runoff from the total area. However, the distribution of the drainage has been changed by canals that divert some of the flow from the upper Palatlakaha Creek into the Withlacoochee River.

The Floridan aquifer underlies all of the Green Swamp area. It is composed of porous marine limestones. The aquifer crops out in the western part of the area and occurs at depths of more than 200 feet below land surface in the eastern part. The Floridan aquifer is overlain by a nonartesian aquifer which consists primarily of sand and clay. The nonartesian aquifer is thin or absent in the western part of the area and ranges from 50 to 100 feet in thickness in the eastern part. The principal source of recharge of ground water in the nonartesian aquifer is local rainfall.

Piezometric levels in the Floridan aquifer occur at an elevation of about 130 feet above mean sea level in the southeastern part of the area. Recharge to the Floridan aquifer occurs along the eastern side of the area.

The maximum mineral content found in the surface water was 122 parts per million and the maximum in ground water was 350 parts per million. Generally water is considered to be usable if the mineral content is less than 400 to 500 parts per million. Surface water was highly colored but ground water was relatively clear.

INTRODUCTION

To satisfy the demands of a rapidly increasing population, many acres of land in Florida are converted each year to residential and industrial uses. Most of this land previously had been devoted to agricultural uses. Urbanization of these areas and the demand for increasing the food supply thus require that man search for new areas to develop for agricultural uses. This search, in many instances, has led to the development of marginal lands.

The most productive lands for many types of agriculture have been found in river flood plains and in swamp bottoms where for centuries deposits of fertile organic soil have been built up. The reclamation of these areas for agriculture has required extensive drainage developments. In many places, drainage canals and ditches have been constructed without any provision for water control and the inevitable result has been overdrainage.

The development of the Everglades of southern Florida about half a century ago was in the interest of reclamation and the drastic effects of overdrainage were not foreseen. The construction of drainage canals lowered the average water level several feet, not only in the Everglades but also in the coastal ridge. This lowering of the fresh water level resulted in salt water moving inland along the coastal area to pollute the ground water and to threaten the water supply of the heavily populated area along the lower east coast. As the organic soils of the Everglades dried up, they began to shrink and the land surface began to subside. The mucky soils in many areas caught fire and almost completely disappeared. These are some of the results of overdrainage of the Everglades. Present plans for redeveloping the Everglades include conservation areas and water-control structures, as well as more effective drainage canals.

Purpose and Scope

The Green Swamp area in central Florida is another area where man is developing agricultural land from marginal land. Though the area is by no means as extensive as that of the Everglades, the present efforts for its development are similar to the early efforts for developing the Everglades in that many miles of canals and ditches have been constructed to improve the drainage.

Lest the early mistakes of the Everglades be repeated, the Florida Department of Water Resources considered that an appraisal of the physical and hydrologic features of the area was needed to determine the broad effects of draining and developing the swamp.

The future water supplies in many localities may depend, in part, upon the management of the waters of this one area. The purpose of the investigation that preceded this report was to define the areal hydrology and its effect upon that of other areas and thus to facilitate better management.

A reconnaissance of the general hydrology of the Green Swamp area was made by the U.S. Geological Survey in cooperation with the Florida Geological Survey and the Florida Department of Water Resources. The investigation covered a 2-year period beginning July 1, 1958. During the first part of this period, water records were collected; the drainage characteristics of the area were determined by field reconnaissance; and many of the facts concerning the physical and geologic features and their influence on the hydrology were established. The report of this investigation was prepared during the latter part of the 2-year period.

Even prior to this investigation, the Green Swamp area was known to be the source of several large streams in central Florida. Also the area was believed to be an important recharge area for ground water in central Florida. Other than this general information, very little was known of the hydrology of the area.

The scope of this reconnaissance does not permit a comprehensive appraisal of the water resources of the area. However, the reconnaissance does provide information required by the State of Florida for determining its responsibility and policy in regard to the Green Swamp area and for formulating future plans for water management of the area.

Some of the features that have been determined are: the amount of rainfall on the area; the pattern of surface-water drainage; the amount and direction of surface-water runoff; the direction of ground-water movement; the interrelationship of rainfall, surface water, and ground water; the effects of improved drainage facilities; and the effects of the hydrologic environment on the chemical quality of water of the area.

A general appraisal of the hydrology of the Green Swamp area and its significance to central Florida has been made on the basis of the findings of this investigation. This reconnaissance will be the foundation for a more comprehensive investigation.

Previous Investigations

Only minor investigations of the water resources and geology of the Green Swamp area were made before the reconnaissance described in this report was started. A few long-term records of streamflow and ground-water levels had been collected in the vicinity, however, as part of the statewide data-collection programs.

Records of streamflow have been collected for several years at sites near the boundaries of the area. Table 1 lists the gaging stations that have long-term records and the points where surface-water data were collected for the present investigation. Locations of these points are shown in figure 7. The longest streamflow record listed is that for the Withlacoochee River at Trilby (station 39 in table 1) where continuous records have been collected since 1930. Streamflow records for the gaging stations listed in table 1 have been published annually in water-supply papers of the U. S. Geological Survey.

Ground-water levels in three wells near the area of investigation have been recorded and are published in the annual water-supply papers of the U. S. Geological Survey. They are as follows: well 810-136-1 (Polk 44), which taps the Floridan aquifer, is located about 1.5 miles northeast of Davenport, Polk County, and continuous records have been collected since 1946; well 810-136-1 (Polk 47), which taps the nonartesian aquifer, is also located about 1.5 miles northeast of Davenport, Polk County, and continuous records have been collected since 1948; and well 816-211-1 (Pasco 16), which taps the Floridan aquifer, is located about 1.5 miles north of Zephyrhills, Pasco County, and records have been collected since 1936.

Table 1. Surface-Water Data - Collection Points in the Green Swamp Area and Vicinity

Station No.	Location	Drainage area (square miles)	Type of data	Period of record
1	Lowery Lake near Haines City, Florida	-	Chemical analysis of 1 water sample	Nov. 13, 1959
2	Cypress swamp in sec. 3, T. 27 S., R. 26 E., near Haines City, Florida	-	Chemical analysis of 1 water sample	May 5, 1959
3	Cypress swamp in sec. 34, T. 25 S., R. 26 E., near Haines City, Florida	-	Chemical analysis of 1 water sample	May 5, 1959
4	Big Creek near Clermont, Florida	67	Occasional discharge measurement Daily record of stage and discharge Chemical analyses of 4 water samples	1945-47, 1952-56. July 1958 to date. Aug. 19, 1958; Mar. 17, 23; Nov. 19, 1959
5	Little Creek near Clermont, Florida	(a) 15	Occasional discharge measurement Discharge measurement at monthly interval Chemical analyses of 4 water samples	1945-47 1952-56. July 1958 to date. Aug. 19, 1958; Mar. 17, 23; Nov. 19, 1959
6	Lake Louisa near Clermont, Florida	-	Daily record of stage Chemical analysis of 1 water sample	March 1957 to date. Nov. 13, 1959
7	Lake Minnehaha at Clermont, Florida	-	Daily record of stage	June 1945 to date.
8	Palatlakaha Creek at Cherry Lake outlet near Groveland, Florida	160	Daily record of stage and discharge	March 1957 to date.
9	Palatlakaha Creek near Mascotte, Florida	180	Daily record of stage and discharge	May 1945 to March 1956.
10	Lake Apopka at Winter Garden, Florida	-	Monthly observation of stage Daily record of stage	December 1935 to August 1942. September 1942 to date.
11	Shingle Creek at airport near Kissimmee, Florida	86	Daily record of stage and discharge	October 1958 to date.
12	Cypress Creek near Vineland, Florida	31.0	Daily record of stage and discharge	August 1945 to date.

Table 1. (Continued)

Station No.	Location	Drainage area (square miles)	Type of data	Period of record
13	Reedy Creek near Loughman, Florida	[b]117	Daily record of stage and discharge	October 1939 to September 1959.
				Nov. 13, 1959.
14	Horse Creek near Davenport, Florida	-	Chemical analysis of 1 water sample	November 13, 1959.
15	Peace Creek drainage canal near Dundee, Florida	50	Daily record of stage and discharge	December 1946 to September 1959.
16	Crystal Lake at Lakeland, Florida	-	Chemical analysis of 1 water sample	November 9, 1959.
17	Withlacoochee-Hillsborough overflow near Richland, Florida	-	Daily record of stage and discharge	February 1930 to September 1931.
			Discharge measurement at monthly interval	July 1958 to date.
			Chemical analyses of 3 water samples	February 25, March 18, November 19, 1959.
18	Hillsborough River at State Highway 39 near Zephyrhills, Florida	-	Chemical analysis of 1 water sample	November 9, 1959.
19	Crystal Springs near Zephyrhills, Florida	-	Discharge measurement at bi-monthly interval	October 1934 to date.
			Chemical analyses of 2 water samples	November 9, 1959
20	Blackwater Creek near Knights, Florida	110	Daily record of stage and discharge	January 1951 to date.
21	Hillsborough River near Zephyrhills, Florida	220	Daily record of stage and discharge	November 1939 to date.
22	Cypress swamp in sec. 15, T. 25 S., R. 25 E., near Polk City, Florida	-	Chemical analysis of 1 water sample	May 4, 1959.
23	Withlacoochee River near Eva, Florida	[a]130	Daily record of stage and discharge	July 1958 to date.
			Chemical analyses of 6 water samples	August 19, Sept. 11, 1958; Feb. 27, Mar. 18, Mar. 24, Nov. 13, 1959.
24	Cypress swamp in sec. 4, T. 26 S., R. 25 E., near Polk City, Florida	-	Chemical analysis of 1 water sample	May 4, 1959.

Table 1. (Continued)

Station No.	Location	Drainage area (square miles)	Type of data	Period of record
25	Pony Creek near Berry, Florida	-	Specific conductance, 1 observation	Sept. 11, 1958.
26	Grass Creek near Rock Ridge, Florida	-	Chemical analysis of 1 water sample	June 10, 1959.
27	Little Lake Agnes near Polk City, Florida	-	Chemical analysis of 1 water sample	Nov. 9, 1959.
28	Withlacoochee River near Rock Ridge, Florida	-	Specific conductance, 1 observation Chemical analysis of 1 water sample	Sept. 11, 1958. Nov. 12, 1959.
29	Gator Creek at Foxtown, Florida	-	Specific conductance, 1 observation	Feb. 26, 1959.
30	Withlacoochee River at Larkin's Bridge near Richland, Florida	-	Chemical analysis of 1 water sample	Nov. 12, 1959.
31	Withlacoochee River near Dade City, Florida	410	Daily record of stage and discharge Discharge measurement at monthly interval Chemical analyses of 6 water samples	February 1930 to March 1933. July 1958 to date. August 18, Sept. 12, 1958; February 25, March 19, March 23, November 12, 1959.
32	Pasco Packing Company canal at Dade City, Florida	-	Discharge measurement at monthly or bi-monthly interval Chemical analyses of 2 water samples	February 1957 to date. Feb. 25, Nov. 12, 1959.
33	Withlacoochee River at Cummer-Cypress Co. Road near Lacoochee, Florida	-	Chemical analyses of 2 water samples	February 25, November 13, 1959.
34	Cypress swamp in sec. 30, T. 24 S., R. 25 E., near Cumpressco, Florida	-	Chemical analyses of 2 water samples	November 18, 1959.
35	Gator Hole Slough in sec. 34, T. 23 S., R. 23 E., near Slaughter, Florida	-	Chemical analysis of 1 water sample	February 26, 1959.

Table 1. (Continued)

Station No.		Drainage are (square miles)	Type of data	Period of record
36	Gator Hole Slough in sec. 25, T. 23 S., R. 22 E., near Slaughter, Florida	-	Chemical analysis of 1 water sample	February 26, 1959.
37	Tributary of Gator Hole Slough in sec. 19, T. 23 S., R. 22 E., near Lacoochee, Florida	-	Chemical analysis of 1 water sample	February 26, 1959.
38	Withlacoochee River at State Highway 575, near Lacoochee, Florida	-	Chemical analysis of 1 water sample	February 26, 1959.
39	Withlacoochee River at Trilby, Florida	620	Daily record of stage and discharge Chemical analyses of 3 water samples	August 1928 to February 1929. February 1930 to date. August 25, September 12, 1958; November 12, 1959.
40	Bay Lake near Bay Lake, Florida	-	Chemical analysis of 1 water sample	November 9, 1959.
41	Bay Root Slough in sec. 14, T. 23 S., R. 22 E., near Bay Lake, Florida	-	Chemical analysis of 1 water sample	February 26, 1959.
42	Little Withlacoochee River at North Loop Road near Slaughter, Florida	-	Chemical analyses of 2 water samples	February 26, 1959.
43	Little Withlacoochee River at Rerdell, Florida	160	Daily record of stage and discharge Chemical analyses of 4 water samples	July 1958 to date. August 18, September 12, 1958; March 19, November 12, 1959.
44	Withlacoochee River at Croom, Florida	880	Daily record of stage and discharge Chemical analysis of 1 water sample	November 1939 to date. November 13, 1959.

Note: The unclosed dates under period of record indicate that the station was in operation in December 1959.
(a) Drainage basins for Little Creek and Withlacoochee River are interconnected.
(b) Drainage basins for Reedy and Shingle Creeks are interconnected above gaging station.

General descriptions of the geology of the region have been given by Cooke (1945), Vernon (1951), White (1958), and Stewart (1959). Stringfield (1936) defined and described the principal aquifer of Florida.

Analyses of water from surface and ground sources in the vicinity of the area of investigation are given in reports by Collins and Howard (1928) and Black and Brown (1951).

Methods of Investigation

Most of the data for this investigation were collected during the 15-month period from July 1958 to September 1959. For a more complete and comprehensive investigation, the period of data ollection should be long enough to cover a wide range of hydrologic conditions. However, much can be learned from short-term records.

Surface-water characteristics of the area were determined by collecting stage, discharge, and chemical-quality data at gaging stations and miscellaneous sites; by making field and aerial reconnaissance of the area; and by studying maps and aerial photographs.

Discharge and stage records were collected at five major outlets from the Green Swamp area, at other sites within the area, and in other stream basins adjoining the area of investigation. At most of these stations, daily discharge records were collected. At other sites, stage, discharge, and chemical-quality data were collected at monthly or less frequent intervals. The conclusions about the runoff characteristics and the environmental factors that influence the quality of surface water in the area are based on the data collected at these stations and sites.

The physical features of the land surface of most of the accessible areas were inspected by automobile travel and on foot. Inspections were made of the landforms, the drainage development, the interconnections of drainage basins, the road fills and drainage structures, the type and density of vegetation, and the surface geology. These features of the land surface were studied to appraise their relation to the hydrology.

An aerial reconnaissance of the entire area from an altitude of about 1,000 feet enabled the investigators to observe many features in areas that are not easily accessible by land travel. Stereophotographs in color of many of the important features were made from the air to provide a closer examination of these features.

Recent aerial photographs of the entire area and advance copies of topographic maps for much of the area were used to define the drainage divides and to locate places where the basins are interconnected.

Information on the quality of surface water obtained during high, intermediate, and low flows indicates the general chemical characteristics and the extremes in mineral content during the period of study. Because of the limited scope of the investigation the data on quality of water were collected by reconnaissance of the area. Data were collected over the entire area generally within a period of 1 to 3 days. Most of the data-collection points were visited at least twice during the study. Information obtained in this manner was used to determine the quality of water prevalent in the area at a given time and also was used to considerable advantage in understanding the interrelationships between water above and below the land surface.

Test drilling was started in February 1959 to obtain information on the occurrence of artesian and nonartesian ground water in the Green Swamp area. Five test wells were drilled into the Floridan aquifer (principal artesian aquifer) and were equipped with water-level recording instruments to record the fluctuations of the piezometric surface. A shallow well was drilled into the nonartesian aquifer beside each of four of the deep wells. Water-level recorders were installed on these wells to record the fluctuation of the water table. Four of these installations were equipped with standard 8-inch rain gages and tipping-bucket attachments to record rainfall.

A second test-drilling program was started in July 1959 to provide additional geologic and hydrologic information. The five existing test wells were deepened and five new test wells were drilled into the Floridan aquifer.

The wells are numbered on the basis of a state-wide grid of 1-minute parallels of latitude and 1-minute meridians of longitude. A well number is a composite of three parts separated by hyphens. The first part of the number is composed of the last digit of the degree and two digits of the minute that identifies the latitude on the south side of the 1-minute quadrangle in which the well is located. The second part of the number is composed of the last digit of the degree and two digits of the minute that identifies the longitude on the east side of the same 1-minute quadrangle. The third part of the number indicates the order in which the wells were inventoried in that quadrangle.

Test-well data are shown in table 2.

The wells were drilled by a churn drill, and during the drilling a log was made and samples of rock cuttings were collected. The well logs show changes in lithology with depth, the occurrence of representative fossils in the various formations, relative hardness of the rocks, drilling speeds, and significant changes in water levels in the well. Identification of the geologic formations was made in the field and is considered to be tentative until verified by microscopic examinations of the well cuttings.

An inventory of selected wells was made to obtain information on the depth of the well, the amount of casing, and the depth to static water level. Nearly all of the inventoried wells penetrated the Floridan aquifer. The approximate elevations above mean sea level at most wells were determined by use of an altimeter. During the period October to December 1959, water-level measurements were made in wells to determine the elevation of the piezometric surface. These measurements were used to prepare a piezometric map (figure 22) which shows the direction and relative movement of water in the Floridan aquifer.

Samples of ground water were collected during the test drilling and analyzed to determine the chemical quality of the water in various formations. Water samples were collected periodically from the deep and the shallow observation wells to determine progressive changes in quality.

Table 2. Test Well Data in the Green Swamp Area

Well Number	Date drilled	Total depth below land surface (feet)	Casing		Open hole		Aquifer	Remarks
			Diameter (inches)	Depth below land surface (feet)	Diameter (inches)	Range in depth (feet)		
Lake County								
832-154-1	Feb. 1959	73	6	63	5½	63-73	Floridan	
	July 1959	160			2½	73-160	Floridan	Deepened for geologic control.
832-154-2	Feb. 1959	22	6	16	5½	16-22	Nonartesian	Gravel packed (limestone pebbles).
822-149-1	Feb. 1959	95	6	59	5½	59-95	Floridan	
	July 1959	192	6	100	5½	95-192	Floridan	Deepened for geologic control. Added casing.
822-149-2	Feb. 1959	23	6	18	5½	18-23	Nonartesian	Gravel packed (limestone pebbles).
Polk County								
815-157-2	July 1959	168	3	52	2½	110-168	Floridan	Existing U. S. G. S. well deepened for geologic control.
813-149-1	Feb. 1959	90	6	78	5½	78-90	Floridan	
	July 1959	217			5½	90-217	Floridan	Deepened for geologic control.
813-149-2	Feb. 1959	27	6	20	5½	20-27	Nonartesian	Gravel packed (limestone pebbles).
813-201-1	July 1959	255	3	40	2½	40-255	Floridan	
810-144-1	July 1959	249	6	101	5½	101-249	Floridan	
Pasco County								
816-206-1	July 1959	200	3	41	2½	41-200	Floridan	
Sumter County								
827-158-1	July 1959	175	3	99	2½	99-175	Floridan	
821-158-1	July 1959	53	3	53	2½	0	Floridan	Chert at 53 feet impenetrable. Well destroyed.
821-158-2	July 1959	49	3	49	2½	0	Floridan	Chert at 49 feet impenetrable. Bottom of casing blasted open for use as observation well.
821-202-3	Feb. 1959	29	6	20	5½	20-29	Floridan	
	July 1959	143			2½	29-143	Floridan	Deepened for geologic control.
821-202-4	Feb. 1959	12	6	5	5½	5-12	Floridan	Gravel packed (limestone pebbles).
Orange County								
822-138-1	Feb. 1959	114	6	103	5½	103-114	Floridan	
822-138-2	Feb. 1959	30	6	13	5½	13-30	Nonartesian	Gravel packed (limestone pebbles).

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The investigation was conducted and the report prepared by R. W. Pride, hydraulic engineer of the Branch of Surface Water and project leader; F. W. Meyer, geophysicist of the Branch of Ground Water; and R. N. Cherry, chemist of the Branch of Quality of Water.

The authors wish to express their appreciation for the cooperation of the many residents and public officials of the area for information given during the well inventory and reconnaissance of the area.

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The work on this project was done under the supervision of the Florida Water Resources Division Council comprised of A. O. Patterson, district engineer of the Branch of Surface Water M. I. Rorabaugh, district engineer of the Branch of Ground Water and J. W. Geurin, district chemist of the Branch of Quality of Water.

DESCRIPTION OF THE AREA

One of the most prominent topographic features in the central part of the Florida Peninsula is an extensive area of flatland and swamp at a relatively high elevation that is

called Green Swamp. Five major drainage systems originate in or near the Green Swamp area and flow in several directions to the sea. Figure 1 shows the location of the Green Swamp area and its relation to the headwaters of streams in the central part of the Florida Peninsula. The area is the headwaters of the Oklawaha River, which flows generally northward to become the largest tributary of the St. Johns River; the Kissimmee and Peace rivers that flow southward; the Hillsborough River that flows southwestward; and the Withlacoochee River that flows northwestward.

Green Swamp has many swamps and marshes, some of which are interconnected but many of which are separated by ridges, hills, and upland plains.

Location

The Green Swamp area is west of the center of central Florida on a high sandy ridge that forms the major axis of the peninsula. The boundaries of the area are not well established and may vary according to individual interpretation. The small drainage basin that is generally known as Green Swamp Run lies in the headwaters of the Big Creek watershed in southern Lake County and northeastern Polk County. However, the boundaries of the Green Swamp area, as designated for this investigation, have been extended to encompass a much larger area. The project area (fig. 1; 7) includes the southern parts of Lake and Sumter counties, the northern part of Polk County, and the eastern parts of Pasco and Hernando counties.

The eastern boundary of the Green Swamp area is U. S. Highway 27, from Clermont south-southeastward to Haines City. Mostly, this highway follows the top of a relatively high ridge that forms the divide for surface drainage between the Big Creek and Reedy Creek basins.

The southern and southwestern boundaries of the area are generally along the divides that separate drainage to the north into the Big Creek and Withlacoochee River basins from that drainage to the south into the Peace River and Hillsborough River basins. This boundary follows a meandering line from Haines City westward to Providence and then northwestward to Dade City.

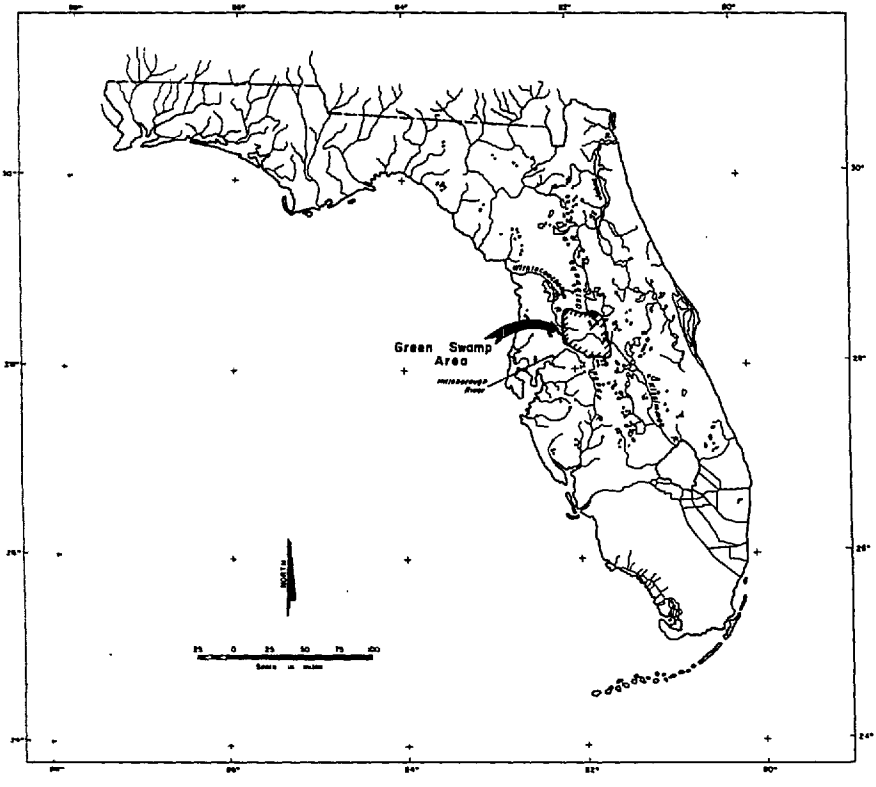


Figure 1. Map of Florida showing location of Green Swamp area.

The western boundary of the area is U. S. Highway 301 from Dade City to St. Catherine. The Withlacoochee and Little Withlacoochee rivers, which drain the greater part of the Green Swamp area, cross this boundary and converge into one channel about 3 miles to the west.

The northern boundary extends from St. Catherine eastward along the Little Withlacoochee River basin divide to State Highway 50 and along State Highway 50 eastward to Clermont.

The boundaries described enclose an area of 880 square miles.

Topography

The Green Swamp area is in the Central Highlands topographic region as defined by Cooke (1945, p. 8). The area is almost surrounded by high sandy ridges, forming a basin that is roughly quadrilateral in shape, breached on the north by the Palatlakaha Creek, Little Withlacoochee River, and Withlacoochee River channels and on the southwest by the diversionary channel from the Withlacoochee River to the Hillsborough River basin.

The area is bordered on the eastern side by the Lake Wales Ridge, on the southern side by the northern terminus of the Winter Haven and Lakeland ridges, and on the western side by the Brooksville Ridge (White, 1958, p. 9-11). These ridges form natural surface-water drainage divides.

Although designated the Green Swamp area, the entire area is not a continuous expanse of swamp but is a composite of many swamp, sloughs, and sinkholes that are distributed fairly uniformly within the area. Interspersed among the swamps are ridges, hills, and flatlands that are several feet higher than the surrounding marsh. Several large and many small lakes rim the area. These are most numerous in the southeastern and northeastern parts of the area.

The elevation of the land surface varies from about 200 feet above mean sea level in the eastern part to about 75

feet in the river valleys in the western part. The interior of the area is a broad flat marsh with only slight relief.

State Highway 33 crosses the area in a northerly direction from Polk City to Groveland. A few miles to the west, the Seaboard Air Line Railroad extends in a north-northwesterly direction through the interior of the area. This railroad divides the area into two approximately equal parts. The alignment of the uplands swamp in the eastern part differs from that of the western part.

A prominent topographic feature affecting the drainage of the eastern part of the area is the alternate pattern of low ridges and swales that extends in a generally N. 15° W. direction from the southern boundary to the Polk-Lake county line. The ridges parallel the major axis of the Florida Peninsula and their configuration suggests a shoreline of a former marine terrace, although the swales between the ridges could have been formed by stream erosion. Aerial photographs of the area between U. S. Highway 27 and the Seaboard Air Line Railroad show five of these long narrow ridges with intervening swales.

The uniform pattern of elongated ridges and swamps in the eastern area is broken by saddles in the ridges and cross connection of the swamps in many places. Some of these saddles may have been formed by partial dismemberment of the ridges due to the collapse of underground solution channels or by erosion. Many of the saddles have been lowered to the level of the swamps between the ridges and connect the adjacent drainage basins.

In the western part of the Green Swamp area there is little evidence of the elongated ridges, and the main land-surface features are large swamps, flatlands, and rolling hills. There are many small swamps in patches and strips, generally less than half a mile across, in the area. Most of these swamps support good growths of cypress trees while in the uplands pine and scrub oak trees grow abundantly. In the fringe areas pine and cypress growths intermingle in an irregular fashion. The largest continuous expanse of swampland lies within the valley of the Withlacoochee River

and is more than a mile wide at places. Exposures of limestone are found from Rock Ridge in Polk County, northwestward to Richloam in Hernando County.

Drainage

Because of the flat land and poorly developed stream channels, the surface drainage of the Green Swamp area is sluggish. Following heavy rainfall the water stands in large shallow sheets over much of the area, which delays the time of concentration in streams.

The water is removed from the land surface by the combined effect of four processes. Part is removed by evaporation from the increased surface area of water retained temporarily in storage on the land surface, and part is lost through transpiration by the cypress trees and other luxuriant vegetation. Another part of the water seeps downward into the sandy soil or percolates into the underlying porous limestone. The part of the water that remains on the land surface eventually collects in the stream channels and drains from the area. Of the four processes by which water is removed from the land surface, the only one that can be measured directly is the removal of water by streamflow. Streamflow measured at a gaging station is the surface flow from the basin above that point together with ground-water inflow to the stream.

Surface drainage from most of the Green Swamp area is generally toward the north and west. In contrast to this pattern, however, the headwaters of the Peace River basin originate along the southern limits of the area and flow is generally southward. Along the eastern boundary of the area drainage is toward the east and southeast into the headwaters of Reedy Creek, a tributary of the Kissimmee River. Other drainage from the Green Swamp area is toward the southwest into the Hillsborough River through a natural diversionary channel through the watershed boundary in eastern Pasco County.

Culture and Development

The Green Swamp area is sparsely populated except for the few small towns and communities on the ridges along the border and along State Highway 33. There are also a few ranch and farm homes in rather isolated locations scattered through the area.

Most of the land is owned in large tracts by private individuals or corporations. The only large area of public land in the area is the Withlacoochee State Forest, part of which is within the boundaries of the Green Swamp area in Sumter, Hernando, and Pasco counties.

The principal industry is agriculture. Much of the upland area has been cleared and planted in citrus groves. Other upland areas have been cleared, planted in pasture, and are used for cattle raising. Very little of the land is cultivated. Because of poor drainage the low swampland is unsuitable for agriculture. Drainage of the swamps has been attempted by the digging of ditches and canals connecting many of the isolated swamps and sinkholes to the natural stream systems. In spite of the many miles of these ditches, water still stands in the low pockets. Even in the cleared areas that are suitable for agricultural uses, no attempts have been made to reclaim the many small, round cypress swamps that dot the area.

Lumbering is an important industry in the western part of the area, particularly in the Withlacoochee River Swamp where there are extensive growths of cypress trees. The first access roads to penetrate the interior of the swamp were trails and tram roads built for cypress lumbering operations. Considerable lumber is produced also by pine flatwoods which are interspersed with the swamps and marshes. Other native vegetation of the area consists of saw palmetto, scrub oak, and occasional hammocks of cabbage palm trees.

The southern boundary of the Green Swamp area lies adjacent to extensive phosphate deposits in Polk County. Some phosphate is mined within the area but the amount is only a small percentage of that produced in southern Polk and western Hillsborough counties.

Deposits of sand, suitable for building uses, are found in many places on the eastern ridges, and the quarrying of this sand for the commercial market contributes to the local economy.

Climate

The Green Swamp area is located near the center of the Florida Peninsula a few miles nearer the Gulf of Mexico than the Atlantic Ocean. This geographical position, well south in the Temperate Zone, and the proximity to large bodies of subtropical water produce a warm subhumid climate.

Precipitation and temperature, the principal climatic elements that influence the hydrology of the Green Swamp area, are described separately.

Precipitation

The study of precipitation in central Florida can be restricted to rainfall only, because snow and hail are virtually unknown. Most of the records of rainfall collected in the Green Swamp area are published monthly by the U. S. Weather Bureau in "Climatological Data, Florida."

The normal or long-term average annual rainfall of the Green Swamp area is 52.6 inches. This normal is based on the unweighted mean of the annual rainfall record for 34 or more years at each of the following U. S. Weather Bureau stations: Brooksville Chinsegut Hill, Clermont 6 miles south, Isleworth, Kissimmee, Lake Alfred Experiment Station, Lakeland, and St. Leo (fig. 4). These precipitation stations are located uniformly around the boundary of the Green Swamp area except for the station 6 miles south of Clermont, which is the only one within the area. The unweighted mean of the rainfall values at these seven stations is assumed to represent the average rainfall on the project area. The rainfall records were checked for consistency by plotting the cumulative rainfall at each station against the mean cumulative rainfall for the seven stations. The

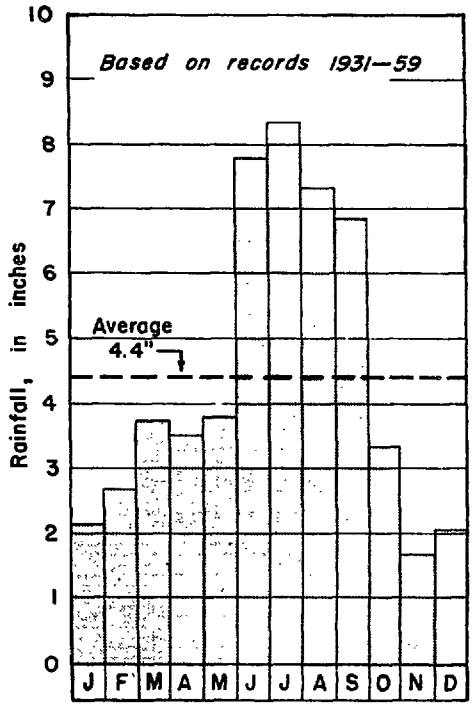
tests showed that the records are consistent and that there has been no change in catch because of moving of rain gages or other reason.

The average rainfall for the stations at Brooksville and St. Leo, both west of the area, is slightly higher than that for the other five stations which are located farther inland. The average rainfall at the seven stations ranges from a minimum of 49.9 inches at the Clermont station to a maximum of 56.6 inches at the Brooksville station. In view of the small deviation of these extreme values from the mean, the average figure of 52.6 inches of rainfall for the area of investigation appears to be reasonably accurate.

About 60 percent of the annual total rainfall occurs during the wet season from June through September. In the spring and early summer, thunderstorms of local high intensity and short duration sweep over the area. Showers occur almost daily, or perhaps several times a day, during June and July. Heavier and more prolonged rainfalls occur generally from August through September and are often intensified by tropical storms that occasionally reach hurricane proportions. On the other hand, there have been periods of a month or more with little or no rainfall. These periods of below average rainfall usually occur during the winter season from November to February. The average monthly rainfall of the Green Swamp area, based on long-term records of the seven U. S. Weather Bureau stations, is shown by bar graph in figure 2.

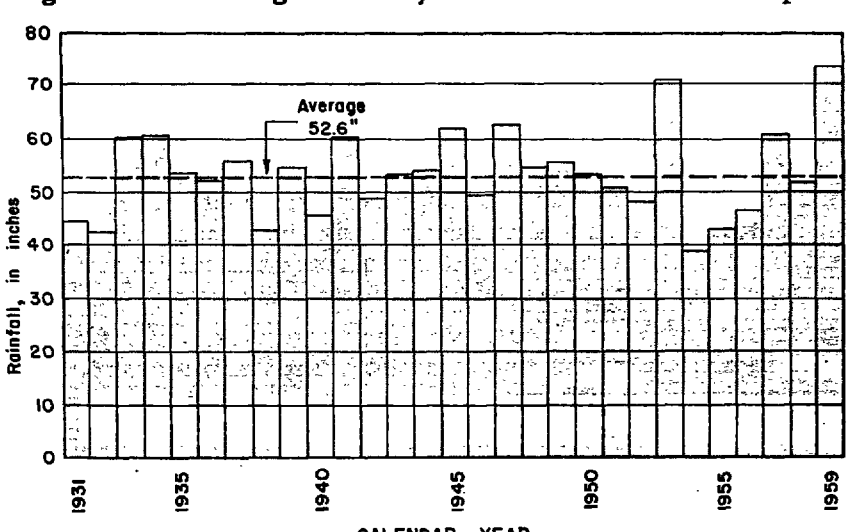
The amount of rainfall in the area varies yearly as well as seasonally. During wet years the annual rainfall averages about one and one-half times that of the dry years. The average annual rainfall of the seven representative stations during 1931-59 is shown by bar graph in figure 3.

During the period of this investigation, July 1958 to September 1959, daily records were collected at 11 additional rain gages (fig. 4), some of which were located in the interior of the project area. The denser network of rain gages closer to the project area gives a better indication of the amount of rainfall on the area during the period of investigation than would the seven stations used for determining the long-term average.



SOURCE: U.S. WEATHER BUREAU DATA FOR STATION AT BROOKSVILLE, CLERMONT, ISLEWORTH, KISSIMMEE, LAKE ALFRED, LAKELAND AND ST. LEO.

Figure 2. Average monthly rainfall of Green Swamp area.



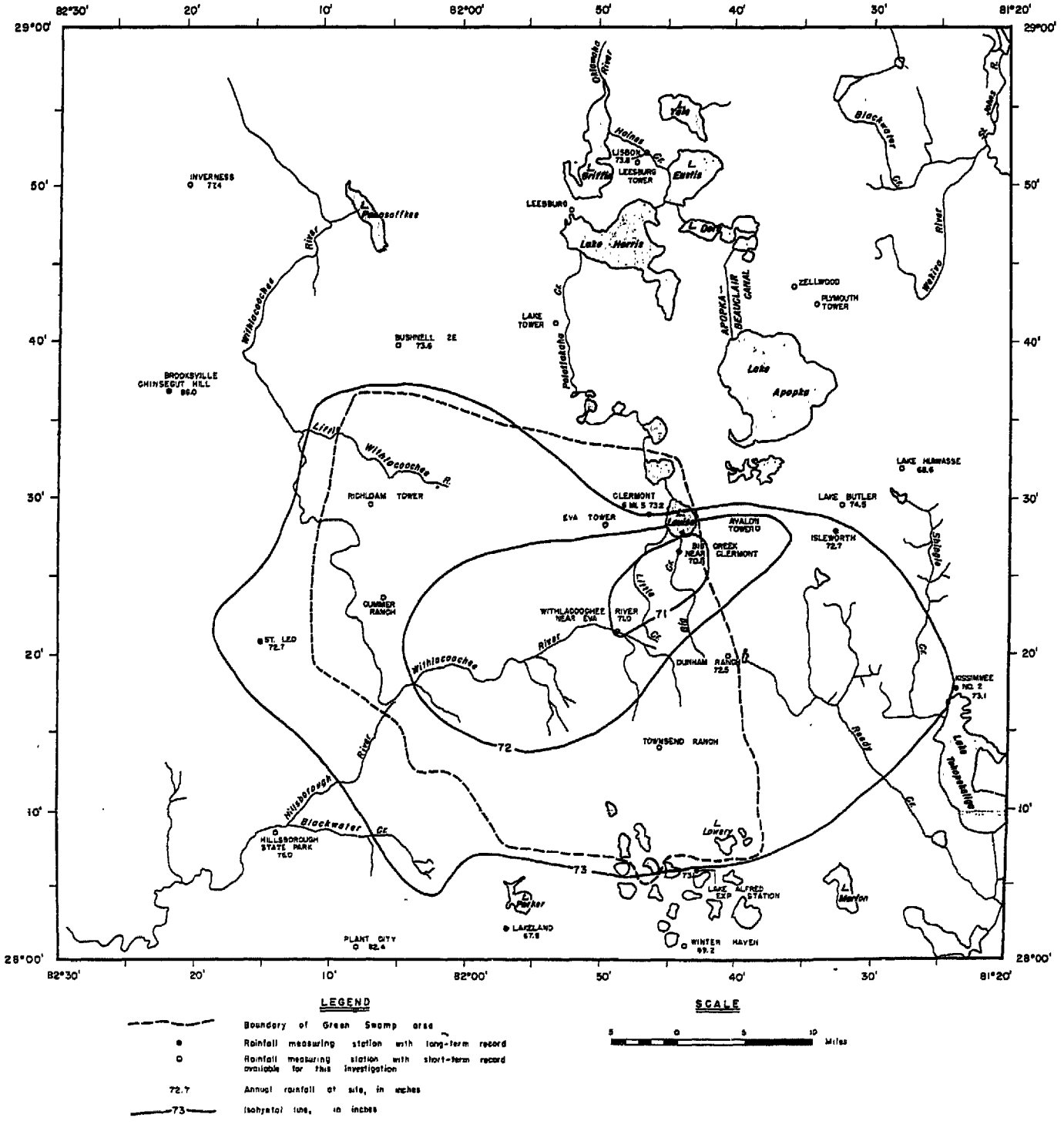
SOURCE: U.S. WEATHER BUREAU DATA FOR STATIONS AT BROOKSVILLE, CLERMONT, ISLEWORTH, KISSIMMEE, LAKE ALFRED, LAKELAND AND ST. LEO.

Figure 3. Average annual rainfall of Green Swamp area.

The total rainfall computed for the 1959 water year for each of the 18 rain gages in or near the area was used to prepare the isohyetal map shown in figure 4. The locations of the rain gages and the yearly total rainfall, in inches, at each of these gages are shown on the map. Lines of equal rainfall were drawn by interpolating between the measured rainfall at each station. Visual inspection of the isohyetal map in figure 4 indicates a total rainfall of the Green Swamp area of about 72.5 inches for the year, distributed fairly uniformly over the area. Thus during the 1959 water year the rainfall was 20 inches above normal.

The rainfall records used for the preparation of the isohyetal map were from standard 8-inch nonrecording gages or from tipping-bucket attachments to water-stage recorders at stream-gaging stations. Most of these rainfall records were collected by the U. S. Weather Bureau. However, at three sites within the area (Big Creek near Clermont, Withlacoochee River near Eva, and Dunham Ranch) rainfall records were collected by the U. S. Geological Survey as part of the basic data for this investigation. Standard 8-inch gages were used at these project stations so that the records are comparable with those collected at the official U. S. Weather Bureau stations.

Rainfall data obtained from graduated glass test-tube gages were collected at each of the Florida Forest Service fire towers and at the Cummer and Townsend ranches within the area. The cumulative yearly rainfall totals as determined from each of these gages were higher than those from the standard stations by amounts ranging from 20 to 28 inches. The difference is too great to be attributed to the vagaries of distribution as some of the tube gages are located only a few miles from standard stations. On the basis of this comparison and because the records from the test-tube gages are consistently higher than those from the official standard gages, they are assumed to be in error and the yearly amounts have been disregarded in drawing the isohyetal lines shown in figure 4.



LEGEND

Boundary of Green Swamp area

Rainfall measuring station with long-term record

Rainfall measuring station with short-term record available for this investigation

72.7 Annual rainfall at site, in inches

73 Isohyetal line, in inches

SCALE

5 0 5 10 Miles

Figure 4. Map of Green Swamp area showing isohyetals for 1959 water year and principal streams draining the area.

Temperature

A knowledge of temperature variations in central Florida is pertinent to a study of its water resources because of the dominant influence of temperature on rates of water losses by evaporation and transpiration.

Water loss from a drainage basin is the difference between the average rainfall over the basin and the runoff from the basin for a given period (Williams, 1940, p. 3). In humid regions, where generally there is sufficient water to satisfy the demands of vegetation, the mean annual water loss is principally a function of temperature (Langbein, 1949, p. 7). The relation between mean annual temperature and mean annual water loss under such conditions is shown in figure 5, which is taken from U. S. Geological Survey Circular 52. For the Green Swamp area where the mean annual temperature is 72°F., the annual water loss would be 48 inches according to this figure.

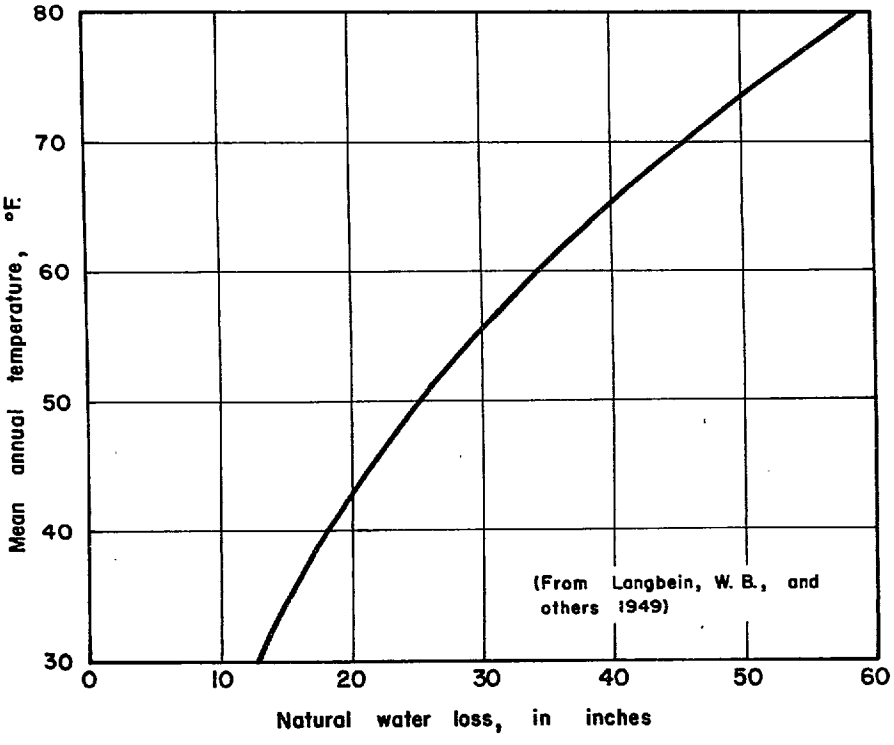


Figure 5. Relation of annual water loss in humid areas to temperature.

The mean monthly temperature in the Green Swamp area ranges from 61° F. for January to 82° F. for August. The lowest temperature recorded during the 66-year period of record at the Clermont station was 18° F. and the highest was 104°F. Daily temperatures recorded at the U. S. Weather Bureau stations show that all parts of the area are essentially at the same temperature, varying no more than 2 to 3° F.

Killing frost occurs infrequently in this area, and damage to vegetation, although severe from the standpoint of agriculture, seldom is great enough to affect the hydrologic factors pertinent to water supplies.

Geology[1]

The Green Swamp area is underlain by several hundred feet of marine sediments, composed primarily of limestone, that have been periodically exposed to erosion. The limestone is mantled with a varying thickness of clastic deposits, chiefly sand and clay, that were deposited in fluctuating shallow seas. No attempt has been made to separate formations within the clastic material because of lack of data.

Topographically, the surface of the area resembled a structural basin, or trough, opening to the north. However, test-drilling data show that the Green Swamp area overlies part of an eroded, faulted anticline. The oldest formations are exposed along the axis of the fold and eroded remnants of younger formations rim the flanks of the uplift, presenting a basin-like shape.

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[1] The classification and nomenclature of the rock units conform to the usage of the Florida Geological Survey and also, except for the Tampa formation, and the Ocala group and its subdivisions, with those of the U. S. Geological Survey which regards the Tampa as the Tampa limestone and the Ocala group as two formations, the Ocala limestone and the Inglis limestone.

The porous limestone formations underlying the Green Swamp area are a part of the principal artesian aquifer in the State. The principal artesian aquifer was first described by Stringfield (1936) and later named the Floridan aquifer by Parker (1955, p. 189). According to Parker, the Floridan aquifer includes those limestone formations ranging in age from the middle Eocene (Lake City limestone) through early Miocene (Tampa formation, and the permeable zones of the middle Miocene (Hawthorn formation) that are in hydraulic contact with the rest of the aquifer.

Test drilling in the Green Swamp area penetrated the following formations of the Floridan aquifer (from youngest to oldest); the Suwannee limestone of Oligocene age; the Ocala group which includes (from youngest to oldest) the Crystal River, Williston, and Inglis formations, and the Avon Park limestone of Eocene age.

The Floridan aquifer is overlain by a varying thickness of clastic deposits. Generally, these clastic sediments are thickest under the topographic highs. The upper part of the clastic deposits forms a distinct hydrologic unit, commonly referred to as the nonartesian (unconfined) aquifer. The basal portion of the clastic deposits is composed mostly of clay and is less permeable than both the overlying, saturated, clayey sands and the underlying Floridan aquifer. Where present, the clay retards the rate of water movement between the two aquifers.

The lithology was described and the formations were identified during the drilling of the test wells. Drilling logs of the test holes were supplemented by electric and gamma-ray logs of wells 828-154-2 and 825-151-1 (Lake County), driller's logs of wells 834-153-1 and 822-140-1 (Lake County), and a log by E. R. Applin (from Florida Geological Survey file of well 813-210-1 (Pasco County).

Formations

Generalized cross sections (fig. 6) were constructed between wells along line A-A' from southwest to northeast, along line B-B' from west to east, and along line C-C' from south to north across the area (see sketch map in fig. 6).

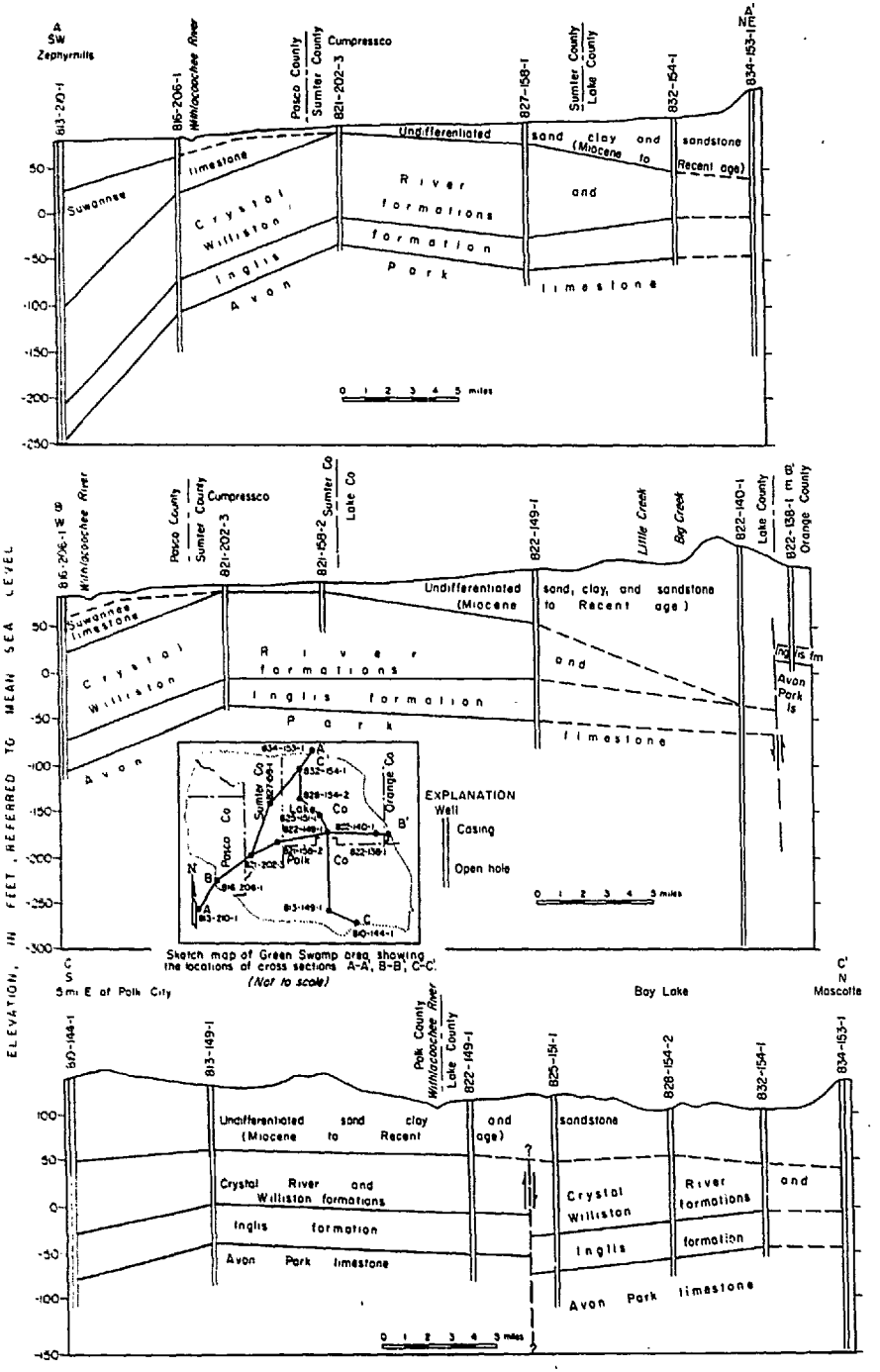

Figure 6. Generalized geologic cross sections across the Green Swamp area and their locations.

The contacts of the formations have been projected between widely separated wells. Additional wells would improve the definition of the features. Two fault zones have been inferred on the cross sections. They probably represent only a few of those that exist on the major structure (anticline) within the Green Swamp area.

The inferred regional dips on cross sections C-C' and B-B' show that faults probably occur between wells 822-149-1 and 825-151-1; and between wells 822-140-1 and 822-138-1. The fault between the latter two wells is located in the vicinity of the Kissimmee faulted flexure (Vernon, 1951, p. 56). The fault between the former two wells is highly interpretive but, considering the fracturing characteristics of limestone, it seems more probable that the beds are faulted rather than bent. The existence of many rectangular drainage features tends to indicate fracturing. Faulting here is further supported by the occurrence of fractures and faults in Citrus and Levy counties, a few miles northwest of the Green Swamp area.

Avon Park Limestone: The Avon Park limestone (Applin and Applin, 1944, p. 1686) of late middle Eocene age was the deepest formation penetrated by test wells. The formation is near the surface on an upthrown block in southwest Orange County and on the crest of the anticline in eastern Pasco County and in southern Lake and Sumter counties (see cross section B-B' in fig. 6). The formation is at considerable depth in the area and southwest of Green Swamp. The top of the formation was identified in the field by a distinct color change from tan to brown limestone and by abundant "cone-type" foraminifers. However, a more recent observation indicates that perhaps the top of the formation is 20 to 30 feet below the first "cone" zone at an unconformity probably at the occurrence of a coral reef.

The formation is characteristically a brown dolomitic, fossiliferous limestone. It is highly permeable and is the best source of water for most of the high-capacity wells in the area.

Ocala Group: The Ocala group (Puri, 1957) consists of limestone formations of late Eocene age which have been

separated on the basis of lithology and fossils. Test drilling indicated that local unconformities may occur within the group in the Green Swamp area, but the general stratigraphic sequence was recognized.

The subdivisions of the Ocala group are (in ascending order) the Inglis, Williston, and Crystal River formations. The Williston formation was not easily recognized by field examination of the well cuttings; therefore, it was included with the Crystal River formation on the geologic sections (fig. 6).

The Inglis formation is a hard, white to tan fossiliferous limestone containing small amounts of clay probably as fill. The texture of the formation is finer than that of the Crystal River and Williston formations because of dolomitization. The formation contains fragments of an Eocene echinoid, Periarchus lyelli. The formation is about 50 feet thick except on the fault block located on the east side of the Lake Wales ridge where it is thin (see section B-B' in fig. 6). There are some indications that the Inglis is thinner over the central part of the area (see section A-A' in fig. 6).

The Williston formation is a medium to hard, tan to cream limestone containing abundant fossils. The rock cuttings are slightly coarser than those from the Inglis formation but lack the large foraminifer Lepidocyclina ocalana that is characteristic of the Crystal River formation. The Williston ranges from 10 and 20 feet in thickness in some wells but is thin or absent in others.

The Crystal River formation consists primarily of a coquina of large foraminifers with some clay fill. The Crystal River contains local zones of chert where it is exposed or occurs near the surface in an area extending from Rock Ridge in northern Polk County, through Cumpressco at the southern end of Sumter County, to Slaughter in Pasco County. The formation is generally 50 to 100 feet thick but is absent near southwestern Orange County.

The Crystal River formation is overlain unconformably by the Suwannee limestone, Tampa formation, or undifferentiated young clastic deposits. The Crystal River contains

cavity fill, composed largely of the basal part of the overlying undifferentiated clastic deposits, in the area from State Highway 33 to U. S. Highway 27.

Suwannee Limestone: The Suwannee limestone of Oligocene age (Cooke, 1945, p. 86) is a white, dense, fossiliferous limestone that is present in the southern and western parts of the Green Swamp area and absent in the remainder. The Suwannee limestone crops out along the Withlacoochee River near the junction of Polk, Pasco, and Sumter counties. Southwestward in Pasco County the formation thickens rapidly. Apparently many of the springs along the upper Hillsborough River flow from exposures of Suwannee limestone or the overlying Tampa formation. The Suwannee limestone is unconformably overlain by either undifferentiated clastic deposits or the Tampa formation.

Tampa Formation: The Tampa formation of early Miocene age (Cooke, 1945, p. 111) is a white, sandy, fossiliferous limestone containing abundant mollusks that reportedly occur at or near the surface in southeastern Pasco County and along State Highway 50 in southern Sumter County. The Tampa formation was not recognized in any of the test holes drilled in the area. The Tampa formation is overlain unconformably by undifferentiated clastic deposits.

Hawthorn Formation: The Hawthorn formation (Cooke, 1945, p. 144) of middle Miocene age consists chiefly of interbedded sandy to silty, montmorillonitic clay and white to gray, sandy phosphatic limestone. About 35 feet of light green to gray clay with interbedded phosphatic sandstone was present in well 810-144-1 in Polk County. It did not occur in any of the other test holes. Where present, the Hawthorn formation generally retards the movement of water between the nonartesian and Floridan aquifers. The Hawthorn formation as used in this report is not differentiated from the other clastic deposits.

Undifferentiated Sand, Clay, and Sandstone: Undifferentiated clastic deposits, ranging from Miocene to Recent in age, cover the entire Green Swamp area except in those areas where the Crystal River formation, Suwannee limestone, or Tampa formation is exposed.

The clastic deposits consist primarily of quartz sand with varying amounts of clay, phosphate sand, and calcareous sandstone. The following general stratigraphic sequence was indicated (oldest to youngest): (1) dark gray to green to blue, phosphoritic clay; (2) light tan to gray to blue, montmorillonitic clay; (3) light green to gray clay and interbedded phosphatic sandstone (Hawthorn formation); (4) fine to coarse, quartz sand and varying amounts of white kaolinitic clay; and (5) fine quartz sand with varying amounts of organic detritus or clay.

The dark phosphoritic clay ranges from 10 to 25 feet in thickness. It was generally present in the area east and south of the limestone plain at Rock Ridge in Polk County. Similar clay containing more sand occurs as cavity fill within the Crystal River formation. The dark clay may be part of the Tampa formation of early Miocene age, or may represent the basal part of the Hawthorn formation of middle Miocene age. A dark blue clay was present below the Hawthorn formation in well 810-144-1 in Polk County. The clay retards movement of water between the nonartesian aquifer and the Floridan aquifer.

Clay, resembling the clays in the Hawthorn formation, occurs above the Suwannee limestone and Crystal River formations in the western part of the area but becomes progressively more sandy toward the eastern part. Its age and stratigraphic position is questionable, but the clay is a confining bed in the western part of the area.

Sand containing some variegated white to red to tan, kaolinitic clay underlies the entire Green Swamp area except where the Crystal River formation, Suwannee limestone, or Tampa formation is exposed. The deposit is about 100 feet thick under the ridges that rim the area and is thin or absent over the limestone plain in the vicinity of Rock Ridge. The sand has a higher permeability than that of the underlying clay and constitutes part of the nonartesian aquifer. The geologic age and origin of the sand deposits are questionable.

Surficial sand ranging from 0 to 10 feet in thickness overlies the clayey sand deposit and is the upper part of the nonartesian aquifer.

Structure

The hydrology, stratigraphy, and topography of the Green Swamp area are directly related to structure formed by the Ocala uplift and indirectly to the Peninsular Arch. The Peninsular Arch (Applin, 1951, p. 3), a buried anticlinal structure of Paleozoic sediments, trends generally north-northwestward and its crest is located east of the Green Swamp area. A flexure that probably developed on the western flank of the Peninsular Arch in the Tertiary limestones is called the "Ocala uplift." The Green Swamp area is located at the southern end of the Ocala uplift.

Vernon (1951, p. 54) dated the deformation of the Ocala uplift as post-Oligocene in age. However, the structure inferred in constructing the cross sections (fig. 6) suggests that uplift and faulting may have occurred over a longer period of time, possibly extending from late Eocene to Pleistocene. The occurrence of apparent local unconformities within the Eocene section, such as the unconformity between the Avon Park limestone and the Ocala group, and lithologic changes and unconformities within the Ocala group, might reflect concurrent uplift and deposition. The cross sections indicate a slight thinning of the Inglis over the limestone plain near Cumpressco in Sumter County. This change in thickness could be caused either by error in selecting the top or bottom of the formation or by thinning of the Inglis over the area during active uplift.

A general thinning of the Ocala group occurs northward and the Suwannee limestone was entirely absent. This suggests erosion or nondeposition over a structural high.

Faults complicate the definition of the geologic history. No conclusions have been reached as to the number or age of the faults that occur in the Green Swamp area. The faults shown on the cross sections have been inferred from a general interpretation of the structure. The linear topographic features and drainage patterns show that the area probably is highly fractured. The vertical displacement along the faults probably ranges from a few feet to about 100 feet.

Structure probably could affect the hydrology of the Green Swamp in the following ways:

(1) The joints or fault zones have been widened by solution, causing zones of high permeability within the Floridan aquifer. These zones appear as troughs in the piezometric surface of the Floridan aquifer.

(2) The displacement along the faults could position formations of different lithology (hence permeability) one against the other, breaking the hydraulic continuity.

(3) Faults cutting confining beds increase or decrease ground-water circulation between aquifers, depending upon the displacement.

HYDROLOGY

General

The endless circulation of water by evaporation, movement through the atmosphere, precipitation, and movement to the sea by surface and underground routes is known as the hydrologic cycle. Because of this natural circulation, water may be regarded as a transient but renewable resource. Although the amount of water involved in the hydrologic cycle remains about constant for the earth as a whole, the amount available at a particular place varies with precipitation.

The water supply of the earth, whether it is on the surface or below the ground, has its origin in precipitation. Of the precipitation that reaches the ground, a portion is returned to the atmosphere by evapotranspiration, a portion remains above ground and is stored temporarily in lakes, ponds, and swamps, or moves to the sea as streamflow, and a portion filters into the ground, some to replenish the soil moisture and some to enter the zone of saturation and

recharge the ground-water supply. Ground water moves laterally under the influence of gravity, toward areas of discharge such as wells, springs, streams, lakes, or the ocean. Much of the dry-weather flow of streams is derived from ground-water discharge.

Surface Water

Occurrence and Movement

The occurrence and availability of water on the land surface are determined largely by topography, climate, and geology. As there is no inflow of water from outside of the Green Swamp area, the only source of water is from rainfall. In the previous discussion of precipitation, it was stated that the average rainfall for the area is 52.6 inches. Much of this total rainfall is stored temporarily on the land surface in the many natural reservoirs such as swamps, lakes, and other topographic depressions. This temporary storage of water during wet seasons increases the area of water surface and, thus, increases the opportunity for evaporation. The retention of water on the land surface likewise increases the opportunity for percolation to recharge the aquifer. In addition, a considerable amount of water is transpired by the cypress trees and other aquatic plants which grow luxuriantly in the area. Thus, evaporation, transpiration, and percolation remove much of the water while it is stored temporarily on the land surface.

The topographic, climatic, and geologic influences that contribute to this loss of surface water also tend to reduce the magnitude of the flood peaks and to sustain the base flow of streams during dry periods.

Characteristics of Drainage Basins

The headwaters of five stream systems lie in the Green Swamp area. These streams, listed in order of the proportion of the area drained, are: Withlacoochee River, Little Withlacoochee River, Palatlakaha Creek, Hillsborough River,

and Reedy Creek. Palatlakaha Creek drains to the St. Johns River and Reedy Creek to the Kissimmee River.

Other streams that head near the boundaries of the Green Swamp area are: Davenport and Horse Creek in the Kissimmee River basin, Peace Creek drainage canal and Saddle Creek in the Peace River basin, Fox Branch in the Hillsborough River basin, and Jumper Creek and a major canal that head northwest of Mascotte in the Withlacoochee River basin.

The drainage system of the Green Swamp area and vicinity is shown on the map in figure 7. Of the total area of 880 square miles, 720 square miles are drained by the Withlacoochee River and its tributaries.

Withlacoochee River: The headwaters of the Withlacoochee River are a group of lakes and swamps in the north-central part of Polk County in the vicinity of the towns of Polk City and Lake Alfred. Lakes Van and Juliana, the uppermost of these headwater lakes, drain into Lake Mattie. Surface drainage from Lake Mattie spills through a wide shallow marsh along the northeastern shoreline and flows northward through a series of interconnected shallow swamps to the northern boundary of Polk County, where it enters Withlacoochee River, which at that point is poorly defined. Other headwater tributaries of the Withlacoochee River originate in the marshes between Lake Mattie and Lake Lowery and flow generally northward between the confining sand ridges.

These sand ridges form elongated north-south drainage basins in the eastern part of the Withlacoochee River basin, the upper Palatlakaha Creek basin, and in other areas of the central peninsula. The valleys between the ridges are not deeply incised by natural processes but their effectiveness as drainage channels has been improved by the many miles of canals and ditches that have been dug. Some parallel drainage basins are interconnected in several places by gaps or saddles through the ridges. Through these gaps water may flow from one stream valley into another. The amount and direction of flow depend on the relative elevation of water levels in the adjoining basins and the hydraulic conveyance characteristics of the connecting channels.

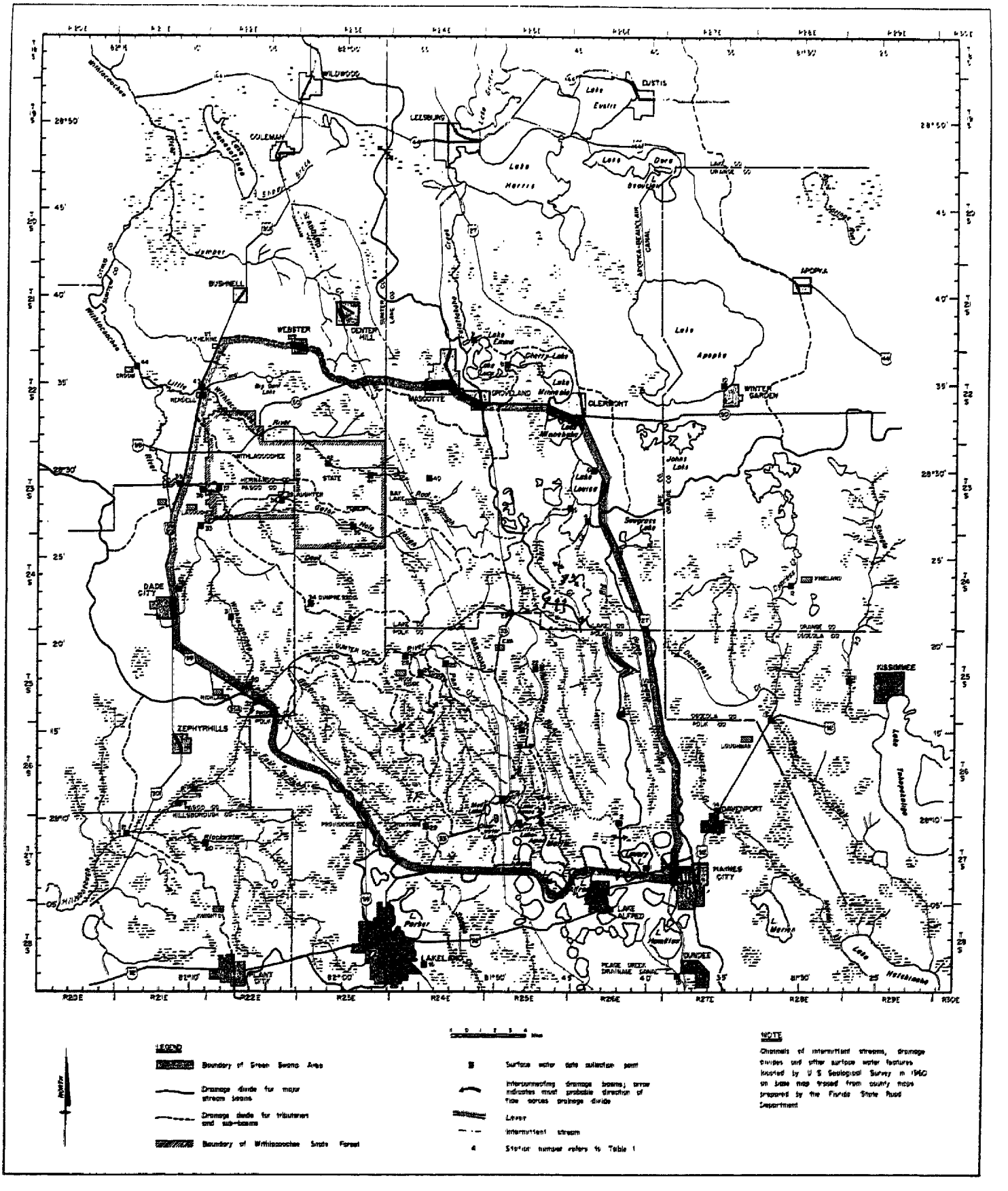

Figure 7. Surface-water drainage features in Green Swamp area of Central Florida.

West of the Seaboard Air Line Railroad the tributaries of the Withlacoochee River are not confined by the ridges that are prominent in the area east of the railroad. These tributaries have developed more generally fan-shaped basins than those in the eastern part. The Withlacoochee River follows a meandering course, generally in a southwesterly direction, to the point of diffluence to the Hillsborough River. Between the railroad and this point of diffluence, the main tributaries of the Withlacoochee head in the southern part of the area and flow in a northwesterly direction.

Many miles of canals and ditches have been dug within the basins of these tributaries in an effort to improve the effectiveness of the drainage system. These canals and ditches, for the most part, have been dug to follow the natural drainage courses through the shallow swamps. However, in some places, probably to provide firm footing for the excavation equipment and to avoid clearing through the dense growth of cypress trees, the ditches have been dug along the rim of the large swamps rather than through the interior. Also to provide better alignment in some places the ditches have been cut through ridges to connect the adjacent swamps. These shortcuts have bypassed the circuitous natural drainage routes through swamps and, in general, have straightened and shortened the entire course of the waterway.

The first of the larger tributaries west of the Seaboard Air Line Railroad is Pony Creek which heads just east of State Highway 33 near Polk City. This stream flows in a northwesterly direction to the Withlacoochee River.

Grass Creek is the next large tributary and empties into the Withlacoochee River about $1\frac{1}{2}$ miles downstream from Pony Creek. Grass Creek heads in a group of small lakes in the vicinity of Polk City. These lakes are Little Lake Agnes, Lake Agnes, Clearwater Lake, and Mud Lake. Little Lake Agnes is connected to Lake Agnes by a marsh. The outlet from Lake Agnes is a ditch leading from the northern end of the lake and connecting with the network of canals and ditches that carry the water through the swamp in a northwesterly direction. During high water Clearwater Lake has a surface outlet on its southern shore that connects

with Mud Lake. The outlet from Mud Lake is a ditch from the northeastern end of the lake, connecting with the main ditch from Lake Agnes about 1 mile downstream. Several other tributaries flow into Grass Creek as it crosses the swamp.

Gator Creek empties into the Withlacoochee River at the Polk-Pasco county line. This is the largest tributary upstream from the diffluence of the Withlacoochee River to the Hillsborough River. Gator Creek heads in several small swamps northeast of Lakeland and flows northwestward through a network of swamp channels and ditches. The total drainage area of the Gator Creek basin is 92 square miles.

From the point of diffluence to the Hillsborough River, the channel of the Withlacoochee River turns abruptly to the north in a wide sweeping curve and continues in a northwesterly direction to the western boundary of the Green Swamp area at U. S. Highway 301.

About 12 miles downstream from the point of diffluence, a major canal draining several lakes and swamps east of Dade City empties into the river from the west bank. This canal receives also the drainage from an area of hills and lakes west of Dade City and the effluent from citrus concentrate plants at Dade City. The water supply for the plants is obtained from wells.

One of the larger tributaries entering the Withlacoochee River from the east is formed by the confluence of Devil Creek and Gator Hole Slough. Devil Creek heads in a swamp about 2½ miles east of the abandoned lumbering camp of Cumpressco. The drainage divide between the headwaters of Devil Creek and the Withlacoochee River is a low ridge about 3 miles north of, and roughly paralleling, the river. At higher stages some water from the Withlacoochee River is diverted naturally into Devil Creek through a gap in the low ridge. This water is returned to the Withlacoochee River farther downstream. Unlike many of the other swamp channels in the Green Swamp area, there have been few, if any, improvements in the Devil Creek channel, and drainage in this basin is poor.

Gator Hole Slough heads just east of the Seaboard Air Line Railroad and flows generally westward through an unimproved swamp channel, entering the eastern boundary of the Withlacoochee State Forest about 3 miles west of the railroad. It continues within the boundaries of the State Forest to the confluence with Devil Creek which empties into the Withlacoochee River $2\frac{1}{2}$ miles farther west.

There are no other large tributaries of the Withlacoochee River between this point and the western boundary of the Green Swamp area, 4 miles downstream. The drainage area of Withlacoochee River at Trilby (station 39) at the western boundary is 620 square miles. All of this drainage basin is within the project area except for 60 square miles of lakes and hills west of U. S. Highway 301 and south of U. S. Highway 98 near Dade City.

Little Withlacoochee River: The Little Withlacoochee River is the largest tributary of the Withlacoochee River within the Green Swamp area. It heads near State Highway 33 in Lake County and flows in a westerly direction. Much of the basin east of the Seaboard Air Line Railroad consists of rolling hills, lakes, and swampy flatlands. In the western part of the basin the slopes are considerably flatter. The elevation of the land surface varies from about 125 feet near State Highway 33 to about 75 feet at the western boundary of the Green Swamp area.

Bay Root Slough is the headwater tributary of the Little Withlacoochee River. This slough collects the drainage from several lakes and swamps east of the Seaboard Air Line Railroad and flows northwestward to the Lake-Sumter county line where it enters the Withlacoochee State Forest. Downstream from the eastern boundary of the State Forest, Bay Root Slough forms the Little Withlacoochee River.

The river channel within the State Forest is wide and shallow and contains dense growths of cypress trees. The channel has been allowed to remain in its natural swampy condition to store as much water as possible, rather than to remove the water by improved drainage, as a precautionary measure against fire damages to the valuable cypress and pine trees in the State Forest.

The Little Withlacoochee River emerges from the State Forest reservation near the Sumter-Hernando county line, where it is joined on the north by a major canal. This canal drains a swampy area between the State Forest reservation and State Highway 50. The river continues through the swamp in a westerly direction to the crossing of State Highway 50 where it turns and flows in a northwesterly direction toward U. S. Highway 301. Another canal joins the river about a quarter of a mile upstream from U. S. Highway 301. This canal heads near Webster, flows southward about $1\frac{1}{2}$ miles, then turns westward to Big Gant Lake and then to the Little Withlacoochee River.

The Little Withlacoochee River continues westward from U. S. Highway 301 and empties into the Withlacoochee River 3 miles downstream. The total drainage area of Little Withlacoochee River at Rerdell (station 43) is approximately 160 square miles.

Palatlakaha Creek: Palatlakaha Creek drains a long narrow strip along the eastern part of the Green Swamp area. This creek forms the headwaters of the Oklawaha River which is the largest tributary of the St. Johns River.

From its headwaters to the point at which this drainage system empties into the St. Johns River, the many tributaries of the stream bear different names. To aid in understanding the relationship of these tributaries to the entire system, the flow diagram shown in figure 8 has been prepared.

Lowery Lake, the largest of a group of lakes located near Haines City, is the headwaters of Palatlakaha Creek. Most of the drainage from Lowery Lake is to the north into Green Swamp Run through a culvert in the old Haines City - Polk City road. At extremely high lake stages the road is inundated.

The Palatlakaha Creek basin is confined by sand ridges that extend from Lowery Lake northward almost to Lake Louisa. Between Lowery Lake and the Polk-Lake county line the drainage course is called Green Swamp Run. The stream channels in this water course are not deeply incised, and drainage occurs through wide shallow swamps.

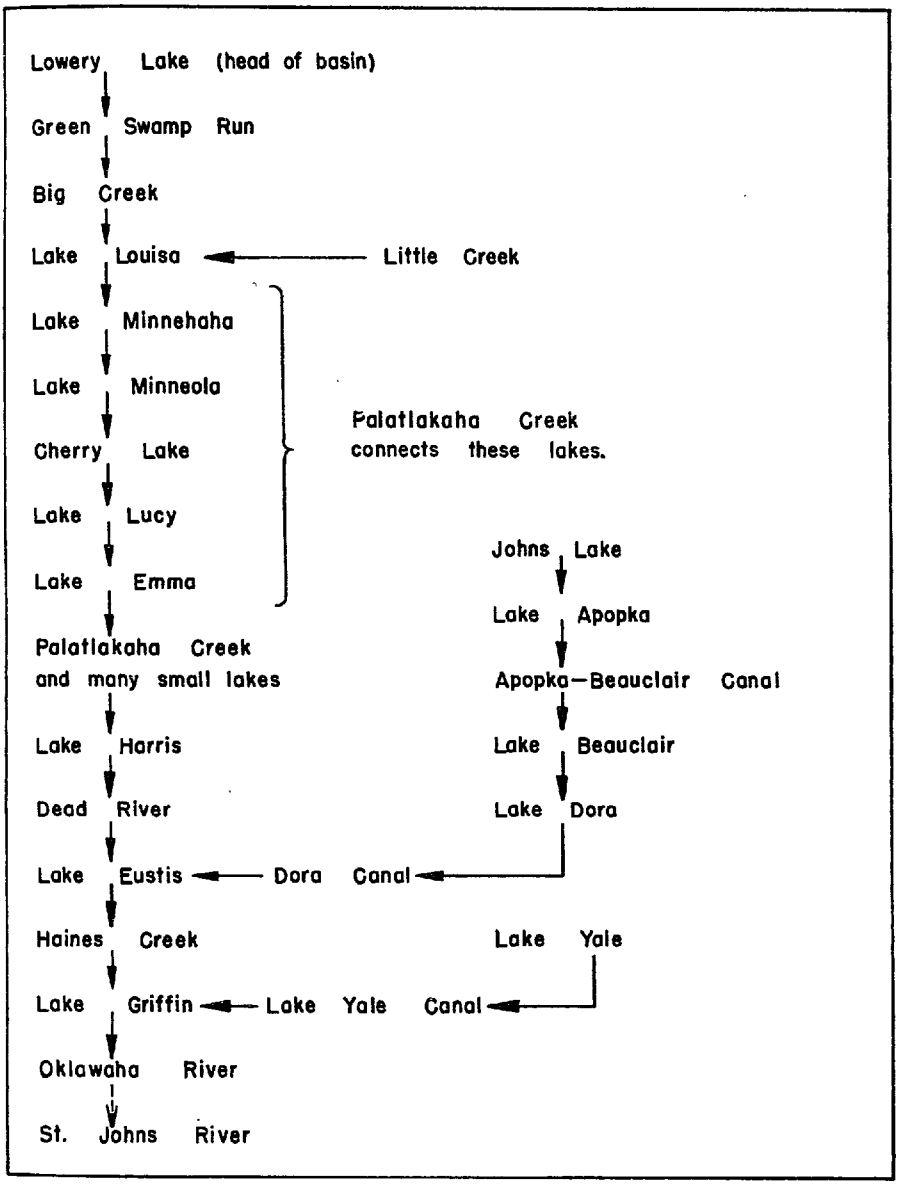

Figure 8. Flow diagram of the upper Oklawaha River.

Big Creek and Little Creek drain the basin between the Polk-Lake county line and Lake Louisa. Big Creek is a continuation of Green Swamp Run. The stream channels for both Big Creek and Little Creek have more definitely incised valleys and the flood plain swamps are not as wide as those for Green Swamp Run.

The Big Creek basin is confined along its eastern boundary by a high ridge. However, along the western boundary, the ridge is broken by swamps in several places and the Big Creek and Little Creek basins are interconnected. Big Creek, including Green Swamp Run, drains an area of about 70 square miles. The basin, from Haines City to Lake Louisa, is about 25 miles long and from 2 to 4 miles wide. The elongated shape of this basin, in addition to the flat slopes and the dense vegetation in the swamp channel, result in an inefficient drainage system.

Little Creek drains the area west of Big Creek and empties into Lake Louisa. The western boundary of the Little Creek basin is fairly well defined by low ridges. However, in a few places the ridges are broken by saddles. The exchange of surface drainage between Little Creek and Withlacoochee River through these saddles appears to be negligible.

The southern boundary of the Little Creek basin is not well defined. The probable boundary is along an old road that extended from State Highway 33 to U. S. Highway 27 about a mile or two north of the Lake-Polk county line. This old road is now impassable.

Much of the drainage from the area that was formerly drained by Little Creek has been diverted into the Withlacoochee River by interceptor canals. These canals are located near the Polk-Lake county line. However, some water from its former basin still drains into Little Creek through natural swamp channels that were not closed when the interceptor canals were dug.

The present (1960) drainage area for Little Creek, as outlined in figure 7, is about 15 square miles during dry

periods. During wet periods water flows into the basin through the openings in the road along the southern boundary of Lake County.

Lake Louisa is the uppermost of a chain of large lakes in the upper Palatlakaha Creek system. Lake Minnehaha, Lake Minneola, and Cherry Lake are next in order below Lake Louisa. These lakes are connected by the wide, deep channel of Palatlakaha Creek. In addition to draining these lakes, Palatlakaha Creek also drains an area of smaller lakes and upland marshes westward to State Highway 33. This area affords storage facilities for large quantities of water.

During the latter part of 1956 an earthen dam with two radial gates was built at the outlet of Cherry Lake to maintain the stages of the waterway and lakes upstream during prolonged periods of dry weather. The water surface from the upper pool at this dam to Lake Louisa is essentially level except during periods of high discharge. During the period of maximum discharge in 1959, the stage of Lake Louisa was about 0.7 foot higher than that of the upper pool at Cherry Lake outlet. The fall between Lake Louisa and Lake Minnehaha was about 0.3 foot during this period.

The channel below Cherry Lake has been improved by a canal leading into Lake Lucy and Lake Emma. Palatlakaha Creek follows a more definite channel with steeper gradient from Lake Emma to its mouth at Lake Harris. In this reach the fall is about 32 feet in about 12 miles.

Hillsborough River: One of the major drainage outlets from the area of investigation is a wide shallow swamp channel where part of the flood waters from the Withlacoochee River overflows into the Hillsborough River basin. This outlet is located in southeastern Pasco County. The outlet is about a mile wide and extends $3\frac{1}{2}$ miles southward from the Withlacoochee River to Fox Branch. The confluence of the outlet and Fox Branch forms the Hillsborough River.

White (1958, p. 19-24) presents considerable evidence to support an assumption that the Withlacoochee-Hillsborough overflow channel was formerly the main outlet of the upper

Withlacoochee River. The drainage pattern, as shown in figure 7, could certainly lead to this conclusion.

The valley of the Withlacoochee-Hillsborough overflow is crossed by the road fill and bridge of U. S. Highway 98. The channel at the highway crossing has been narrowed to about 200 feet in width.

The overflow channel is crossed also by State Highway 35A about 1 mile downstream from U. S. Highway 98. Two bridges cross the channel at State Highway 35A.

Reedy Creek: Reedy Creek is one of the headwater tributaries of the Kissimmee River. The drainage from 5 square miles of the Green Swamp area in southeastern Lake County flows eastward past U. S. Highway 27 into Sawgrass Lake and into marshes in the headwaters of Reedy Creek. The hydraulic conveyance of the waterway east of the highway has been improved by dredging, and the capacity of the channel is adequate for satisfactory drainage. The upstream channel west of the highway is unimproved.

Diversions and Interconnection of Basins

Although surface drainage from the Green Swamp area follows rather definite routes and although the drainage divides are generally determined by the topographic features, there are several places where the basins are interconnected and water is diverted from one basin to another. Many of these points of diversion have been mentioned under the foregoing discussion of the drainage basins. The hydrologic importance of these interconnections, which are integral parts of the drainage systems, is shown in the following discussion.

The arrows on the map in figure 7 locate and show the direction of flow through many of the saddles in the drainage divides. The interconnections that are shown on the map are the most important ones disclosed by the investigation, but they by no means include all such points in the small subbasins where there is no definite drainage divide.

One of the major diversionary channels is the Withlacoochee-Hillsborough overflow in southeastern Pasco County. This diversion was discussed in detail under the section describing the Hillsborough River basin. This overflow channel is at a higher elevation than the Withlacoochee River channel and receives no discharge when the Withlacoochee River is at low stages. However, at high stages more than a fourth of the flow from the Withlacoochee River is diverted through this channel into the Hillsborough River basin.

Another major area where the basins are interconnected is near the Polk-Lake county line in the eastern part of the Green Swamp area. The sand ridges in this area are dismembered by a transverse network of swamps that connect the Withlacoochee River and Little Creek basins. The alignment of the swamps and the relative widths of the flood plains shown on aerial photographs indicate that, in the former natural state, water carried to this area from the south was discharged by either of three different routes - Big Creek, Little Creek, or Withlacoochee River. The greater evidence indicates that most of the drainage from the southeastern area ran off via Big Creek and Little Creek.

In recent years, probably since 1950, extensive operations by the landowners have considerably altered the pattern of drainage in the eastern area. Many miles of canals, ditches, and drains have been dug; levees with resulting borrow ditches have been constructed; and road fills with drainage structures have been built. These physical changes, which were made for the development of the area, apparently changed the proportion of the water that drained by the three routes. Based entirely on the present pattern of drainage canals and without any factual data on the streamflow from the upper basins prior to the development of the area, it appears that the most significant change has been a decrease in the area drained by Little Creek and an increase in the area drained by the Withlacoochee River.

Major canals, extending in a northwesterly direction, near the Polk-Lake county line appear to have intercepted the greater part of the flow from an area of about 60 square miles that was formerly the headwaters of the Little Creek basin. This area is roughly 18 miles long and 3 to 4 miles

wide. It extends from the present southern divide of the Little Creek basin southward almost to the town of Lake Alfred. The greater part of the water from this area now drains to the Withlacoochee River. However, as discussed in preceding paragraphs, some flow still enters the Little Creek basin from its former upper basin. Then, too, before the interceptor canals were dug, some flow escaped from the Little Creek basin through the natural swamp channels into the Withlacoochee River. Because the drainage basins were unconfined before development, and still are unconfined even with the present drainage canals, the change in proportion of drainage between the two basins and the increased effectiveness of the system in draining the areas may be determined from streamflow records only for broad areas rather than for the local areas where the major changes have occurred. The runoff under present conditions, as compared with the runoff that occurred during the earlier years for which streamflow records are available, is discussed in a following section of this report.

A levee now fills a saddle in the drainage divide between Green Swamp Run and the Withlacoochee River in sec. 5, T. 25 S., R. 26 E., south from the Polk-Lake county line (fig. 7). Prior to the construction of the levee, drainage from Green Swamp Run divided into flow westward into the Little Creek basin (now the Withlacoochee River basin) and flow northward into Big Creek basin. The levee closed the major saddle between Big Creek basin and adjacent basins through which natural diversion occurred.

Lowery Lake and swamps in the upper Withlacoochee River basin are connected by a natural saddle in the confining ridge along the northwest shoreline of the lake. This saddle is 200 to 300 feet wide and is one of the points at which flow is diverted between the Palatlakaha Creek and Withlacoochee River basins. The two basins are interconnected at this point only at high stages. Water may flow through this saddle in either direction, depending on the distribution of rainfall and the relative water levels in the basins.

There are three interconnections between Big Creek and Little Creek. These openings, all in Lake County, are

small and their net exchange of water is probably negligible in comparison with the total flow from the basin.

Other places, shown on the map in figure 7, where basins are interconnected are: between the Withlacoochee River headwaters and Peace River headwaters, between Lake Mattie and Pony Creek, between Pony Creek and Grass Creek, and between the Withlacoochee River and Devil Creek. Many of these interconnections act as equalizing channels through which water may flow in either direction, depending on the relative water levels in connecting basins.

Runoff Characteristics

Seasonal Distribution: Streamflow records for Withlacoochee River at Trilby (station 39) are available for the periods August 1928 to February 1929, and February 1930 to December 1959. The drainage basin above this gaging station occupies two-thirds of the Green Swamp area. The records for this station are a good index for showing the variations of surface runoff from the entire area.

The yearly and seasonal runoff from the basin follow the same pattern as that for the corresponding rainfall. Figure 9 shows a bar graph of the annual discharge for Withlacoochee River at Trilby for each complete year of record, 1931-59. The relationship between rainfall and runoff is shown by comparing the runoff pattern in figure 9 with the rainfall pattern in figure 3. Rainfall and runoff records show that the year 1959 was the wettest of record. The total rainfall over the Green Swamp area for the 1959 calendar year was 73.6 inches. The average discharge at the Trilby station for that year was 1,152 cubic feet per second. Runoff in inches, adjusted for the flow diverted to the Hillsborough River, for that year was 29.2 inches.

The drought of 1954-56 was probably the most severe dry period of record, considering its 3-year duration and yearly deficiencies. Average rainfall over the area for 1954-56 was 38.5, 40.3, and 46.6 inches per year, respectively. The prolonged period of low rainfall resulted in low discharges at the Trilby station for each of the three years;

the lowest yearly mean discharge at the Trilby station, however, was 75.4 cubic feet per second for 1932, a year in which the annual rainfall amounted to 42.4 inches. Distribution and intensity of the rainfall and the effluent from citrus concentrate plants, derived from ground-water sources, probably helped account for the fact that annual discharges for 1954-56 were higher than those for 1932.

The average monthly flow for the Withlacoochee River at Trilby is shown by bar graphs in figure 10. These averages indicate that runoff from the basin is lowest for the months of November through June, with May being the month of lowest flows. The season of highest flows is the 4-month period, July through October. During these months, 58 percent of the average annual flow from the basin has occurred.

The variation of runoff, as shown in figure 10, is due to seasonal rainfall. The runoff and rainfall patterns are similar except that increases in discharge lag the increases in rainfall by 1 to 2 months. The seasonal distribution of rainfall is shown in figure 2. The time lag is an indication of the effects of natural storage capacity of the drainage basin.

At the beginning of the wet season in June and July, much of the water is temporarily stored in the swamps and the streamflow does not increase in the same proportion as the rainfall. After the surface and ground-water reservoirs are nearly filled there is less storage capacity in the area and runoff from subsequent heavy rains reaches the streams more quickly. September has been the month of highest runoff. Although the average rainfall decreases sharply in October, the runoff remains high as the result of water draining into the stream channels from storage.

The duration curve of daily flow for Withlacoochee River at Trilby for the 29-year period, 1931-59, is shown in figure 11. It indicates the percentage of time that a specified discharge was equaled or exceeded during the period of record. In a strict sense the flow-duration curve applies only to the period for which data were used to develop the curve. However, if the flow-duration curve represents a long-term period of flow of the stream, the curve may be

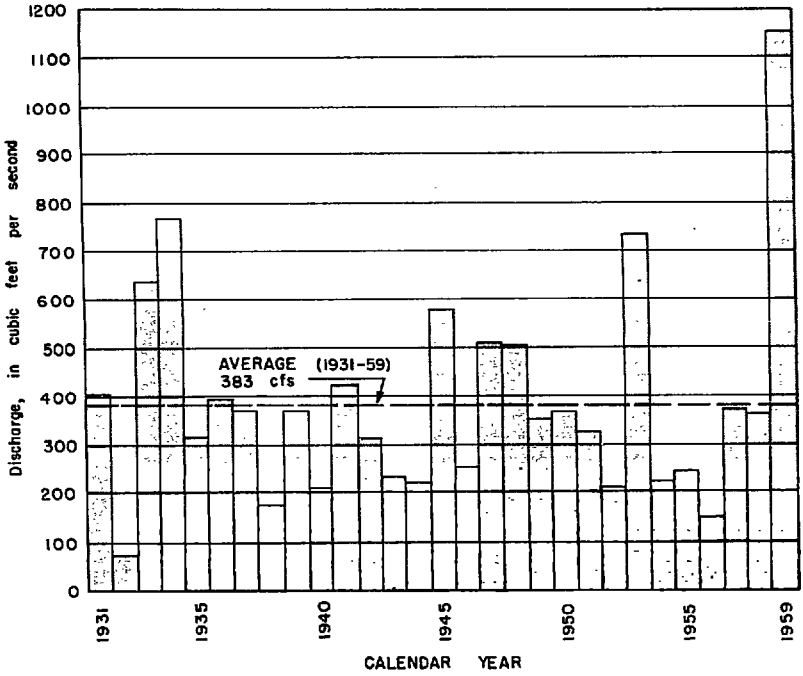

Figure 9. Annual discharge of Withlacoochee River at Trilby, Florida.

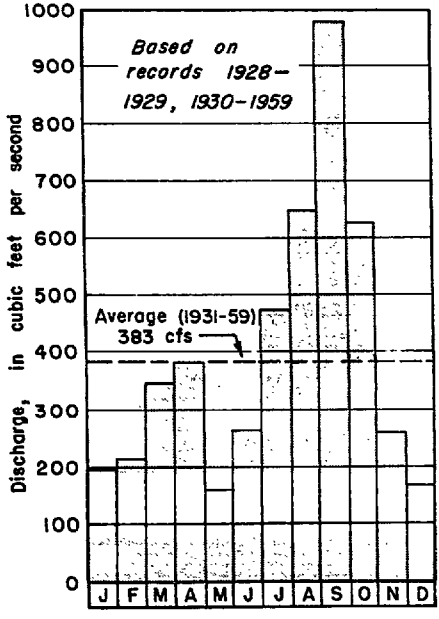

Figure 10. Average monthly discharge of Withlacoochee River at Trilby, Florida.

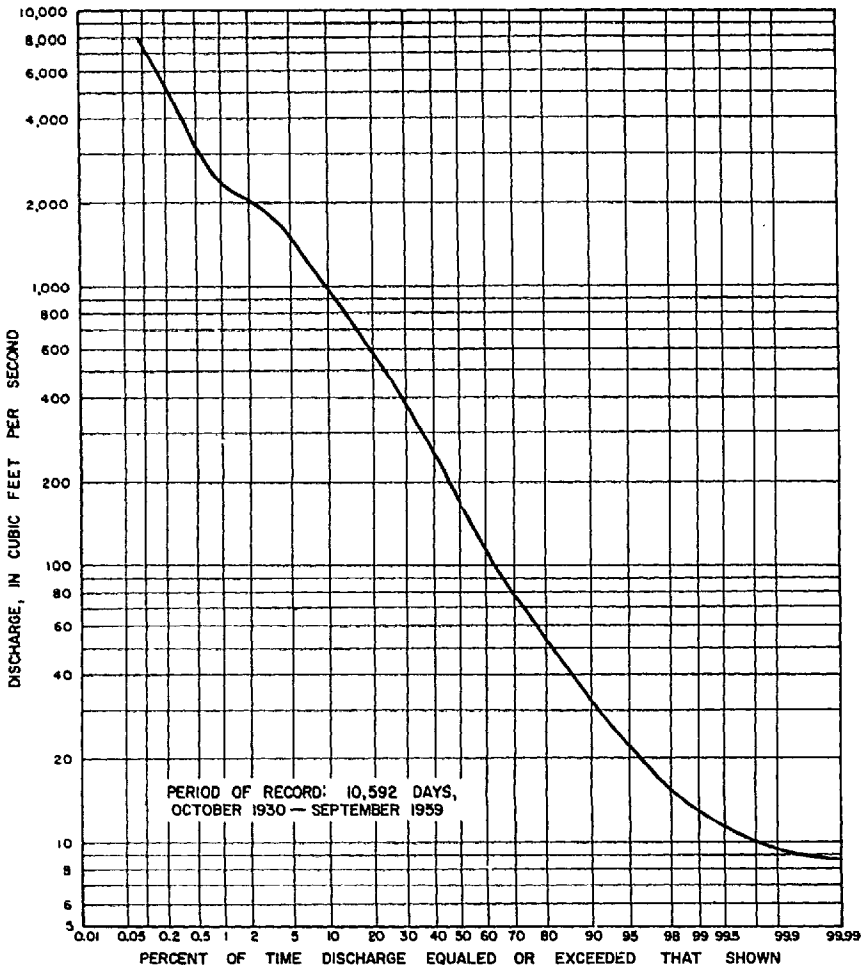

Figure 11. Flow-duration curve of Withlacoochee River at Trilby, Florida.

considered a probability curve and used to estimate the percent of time a specified discharge will be equaled or exceeded in the future. The use of flow-duration curves to indicate the future pattern of flow from a basin is valid only if the climatic conditions remain the same and amount and distribution of runoff from the basin is not significantly changed by man-made changes in drainage systems, storage capacities, land use, and diversions.

The flow duration curve for Withlacoochee River shown in figure 11 may be only an approximate representation of duration of future low flows because of the progressive increases in ground-water pumpage above the gaging station. Since about 1941 or 1942, the effluent from the citrus concentrate plants at Dade City has been draining into the Withlacoochee River above the Trilby gaging station. The water used by these plants is obtained from wells. The effluent, measured at station 32 during 1958-59, ranged from 5 cubic feet per second, when the plants were at minimum operation, to about 66 cubic feet per second at peak operation during the citrus packing season. This inflow to the river produces higher discharges at the gaging station during dry periods than would be derived from the natural yield of the basin.

Areal Distribution and Basin Runoff: The total runoff from 862 square miles, most of which is in the area of investigation, was measured by gaging stations at each of the five major outlets. Table 3 summarizes the mean discharges determined at each of these outlets for the water year beginning October 1, 1958, and ending September 30, 1959.

This table shows the distribution of the discharge from month to month as well as by streams draining from the area. During the 1959 water year, which was the wettest of record, the Withlacoochee River carried 62 percent of the total runoff. Little Withlacoochee River carried 20 percent, Bit Creek carried 6 percent, Little Creek carried 4 percent, and about 8 percent of the flow was discharged into the Hillsborough River. The proportional amounts of the runoff carried by each of these outlets vary with amount and distribution of rainfall because of the increasing rate of discharge diverted between the interconnected basins during

Table 3. Outflow from Green Swamp Area, Water Year 1958-59

Month	Mean discharge in cubic feet per second							
	Sta. No. 4 Big Creek near Clermont (drainage area, 67.0 sq. mi.)	Sta. No. 5 Little Creek near Clermont (drainage area, 15 sq. mi.)	Sta. No. 17 Withlacoochee-Hillsborough overflow near Richland	Sta. No. 39 Withlacoochee River at Trilby (Drainage area, 620 sq. mi.)	Sta. No. 43 Little Withlacoochee River at Rerdell (Drainage area, 160 sq. mi.)	Total of all outlets (Drainage area 862 sq. mi.)	Cubic feet per second per square mile	Runoff in inches
October 1958	20.7	* 2	0	55.1	12.5	90.3	0.105	0.12
November	33.2	* 10	0	98.9	35.4	177.5	.206	.23
December	11.8	* 9	*10	75.3	21.1	127.2	.148	.17
January 1959	62.9	* 43	*90	600	182	977.9	1.13	1.30
February	31.6	* 20	* 4	384	99.9	539.5	.626	.65
March	128	*107	*350	1,457	760	2,802	3.25	3.75
April	168	*115	*250	1,742	459	2,734	3.17	3.54
May	72.2	* 42	* 30	790	122	1,056.2	1.23	1.42
June	63.8	* 74	*220	915	178	1,450.8	1.68	1.87
July	205	*108	*270	1,921	488	2,992	3.47	4.00
August	152	* 93	*160	1,461	622	2,488	2.89	3.33
September	133	*117	*210	1,942	701	3,103	3.60	3.88
Water year	90.5	61.8	134	956	308	1,545	1.79	24.26
Percent of total	6	4	8	62	20	100		

* Estimated on basis of discharge measurements made at monthly intervals and records for other stations

high water. During prolonged periods of little or no rainfall the combined flows of Big Creek, Little Creek, and Withlacoochee-Hillsborough overflow are negligible.

Continuous records of stage and discharge for Big Creek near Clermont (station 4) are available from July 17, 1958, to September 30, 1959. Maximum discharge for this period was 283 cubic feet per second on July 12, 1959. The minimum discharge was 0.4 cubic foot per second on September 7, 1958. Since May 1945 occasional discharge measurements have been made at this gaging station. The maximum discharge measured was 428 cubic feet per second on September 23, 1947. No flow was observed on May 31, 1945.

The discharge of Little Creek was measured at a site (station 5) about half a mile upstream from Lake Louisa. Discharge measurements were made at monthly intervals during the period of the investigation. The maximum discharge measured was 210 cubic feet per second on March 23, 1959. The minimum discharge measured was 0.6 cubic foot per second on October 15, 1958. Since May 1945 occasional discharge measurements have been made on the same days that the flow of Big Creek was gaged. The maximum discharge measured during the earlier years was 359 cubic feet per second on September 23, 1947. No flow has been observed several times.

The 1959 water year mean monthly discharge figures for Little Creek, shown in table 3, were estimated on the basis of monthly discharge measurements and daily records for nearby stations. Little Creek carries only a small percentage of the total discharge from the area of investigation. Although the estimated figures of discharge for Little Creek may be subject to considerable error, the composite figures of runoff from the total area of investigation should be fairly reliable.

Daily records of discharge from the upper Withlacoochee River basin are available from July 22, 1958, to September 30, 1959. These records were collected at the crossing of State Highway 33 near Eva (station 23). The drainage area above this gaging station is approximately 130 square miles.

The maximum discharge at this station for the period of record was 836 cubic feet per second on March 21, 1959. No flow occurred October 3, 1958. For several days in August, September, and October 1958, the flow was less than 1 cubic foot per second. The mean annual discharge for the 1959 water year was 208 cubic feet per second.

During the period February 1930 to September 1931 daily discharge records of the Withlacoochee-Hillsborough overflow were collected. This gaging station was located at the crossing of State Highway 35A which is about 1 mile downstream from U. S. Highway 98. For the period July 1958 to September 1959 discharge measurements were made at monthly intervals at U. S. Highway 98 (station 17). The water stage was determined by measuring from a reference point on the bridge. A rating curve of stage versus discharge was plotted. The stage of each significant rise was determined from floodmarks on a crest-stage indicator and the corresponding discharge was computed from the rating curve.

The maximum discharge, that occurred during the period July 1958 to September 1959, was 870 cubic feet per second in March 1959. At low stages of the Withlacoochee River, no flow occurs in this overflow channel. Correlation of discharge in this overflow channel with those for the gaging station on Withlacoochee River at Trilby (station 39) indicates that little or no flow occurs in the overflow channel when the discharge at Trilby is less than 200 cubic feet per second, which is about 50 percent of the time according to the flow-duration curve for the Trilby station, shown in figure 11. During the period of the investigation, no flow occurred from July to the latter part of December 1958.

The monthly discharges, shown in table 3, for the Withlacoochee-Hillsborough overflow were estimated from discharge measurements, recorded peak stages, and daily records for nearby stations.

Many of the characteristics of streamflow for the Withlacoochee River at Trilby have been discussed in the preceding section relating to the seasonal distribution of flow.

The discharge at the Trilby gaging station does not represent the natural runoff from the Withlacoochee River basin because of the high-water flow diverted from the basin by the Withlacoochee-Hillsborough overflow channel and the effluent into the river from the citrus concentrate plants at Dade City. Above the stage at which the Withlacoochee River flows through the diversionary channel, the amount of discharge diverted into the Hillsborough River increases in direct proportion to the discharge of the Withlacoochee River. Studies of basin runoff for either the Withlacoochee or the Hillsborough rivers must be adjusted for the amount of discharge diverted from one basin to the other. Percentagewise, the plant effluent into the basin is small except when the discharge in the Withlacoochee River is extremely low and the plant is at peak operation.

The average discharge for the Withlacoochee River at Trilby for 29 years of record, 1931-59, is 383 cubic feet per second. The maximum discharge of record was 8,840 cubic feet per second on June 21, 1934. Flood-frequency studies by Pride (1958, p. 104) indicate that this flood was an event of rare occurrence. Historical data collected after the flood of 1934 showed that it was the highest flood peak in at least 75 years. The minimum discharge for the period of record at the Trilby station was 8.6 cubic feet per second June 9-17, 1945.

The average discharge for the Little Withlacoochee River at Rerdell (station 43) for the 1959 water year was 308 cubic feet per second. The maximum discharge that occurred during the period of the investigation was 1,940 cubic feet per second on March 22, 1959. The minimum for this period was 2.9 cubic feet per second on October 17, 18, 1958.

The runoff characteristics of Little Withlacoochee River basin and those for the Withlacoochee River basin follow the same general pattern but differ in some respects. The Little Withlacoochee River basin has a higher runoff. The runoff at the Rerdell gaging station was 1.92 cubic feet per second per square mile (26.1 inches) for the 1959 water year. The concurrent runoff at the Trilby station, adjusted for the flow diverted to the Hillsborough River basin, was 1.76 cubic

feet per second per square mile (23.9 inches). Also, comparison of discharge records for stations at Trilby and at Rerdell show that the flood peaks of the Little Withlacoochee River generally occur about a week before those of the Withlacoochee River.

Rainfall-Runoff Relation

Many attempts have been made to express in equational form a relation between precipitation and streamflow. An approximate relation for a particular drainage basin may be determined using yearly figures of precipitation and runoff from that basin, but this relation would not necessarily be correct for other drainage basins.

The three general factors that affect the relation between rainfall and runoff are: (1) climatic factors, the most important of which are rainfall and temperature; (2) drainage basin characteristics, which include size, shape, surface slope, the amount of water area, the character of the surface and subsurface geology, and the condition and type of vegetative cover; and (3) storage underground and in natural lakes, ponds, swamps, and artificial reservoirs.

Runoff measured at a gaging station is the total surface flow from the basin including ground water that has seeped into the stream above the station. When the flow is converted into runoff in inches over the drainage basin, it can be compared with the average precipitation over the basin which is measured also in inches. The ratio of rainfall to runoff is better defined when average values for long periods are used. Thus, by using yearly averages the effects of storage are minimized as part of the water that is temporarily stored on the surface and underground during the wet season is eventually removed as streamflow.

The amount of precipitation that fell the previous year is one of the factors that affect the relation between precipitation and runoff and cause points on a graph of annual precipitation plotted against annual runoff to scatter. Generally the scatter of the points can be reduced by plotting an effective precipitation (Searcy and Hardison, 1960) instead of the observed precipitation.

Use of an effective precipitation is one way of making allowance for the variable amount of water carried over from year to year as ground-water storage in the basin. The effective precipitation (P_e) commonly used is that proportion of the current year's precipitation (P_o) and the proportion of the preceding year's precipitation (P_1) that furnishes the current year's runoff, or

$$P_e = aP_o + bP_1.$$

The coefficients a and b can be determined by statistical correlation. The effective annual precipitation thus determined for the Withlacoochee River basin above Trilby and for the Palatlakaha Creek basin above Mascotte is

$$P_e = 0.3P_o + 0.7P_1.$$

Runoff is the residual of precipitation after all of nature's demands have been met. These demands taken collectively are called water loss. A simple definition for water loss is: Water loss equals precipitation minus runoff adjusted for change in storage and for seepage into and out of the basin. The basic concept is that water loss is equal to evapotranspiration, that is, water that returns to the atmosphere and thus is no longer available for use. However, as used in this report, the term applies to differences between measured inflow and outflow even where part of the difference may be seepage.

The equation for water loss is:

$$L = P_e - R - \Delta S - S_e$$

Where, L = water loss

P_e = effective precipitation

R = surface runoff

ΔS = increase in storage both surface and underground

S_e = net seepage out of the basin (seepage into basin equals negative out-seepage)

The annual water-loss curve for Withlacoochee River at Trilby is shown in figure 12. The $P_e = L$ line (dashed line) in figure 12 represents the theoretical limit of water loss which would occur if the loss equaled the precipitation and none ran off as streamflow. The average water-loss curve is shown by the solid line which was drawn to average the annual figures of effective precipitation and loss ($P_e - R$) for the basin. The departures of the yearly data from the average curve may be caused in part by storage and seepage changes and in part by differences in the way precipitation is distributed within the year. No adjustment is made for ΔS and S_e in the water loss equation for Withlacoochee River at Trilby and they thus add to the apparent evapotranspiration.

The effective annual precipitation of about 30 inches, indicated by the point where the downward extension of the curve coincides with the $P_e = L$ relation, is the probable yearly amount below which no runoff would occur. Under some conditions of intensity and distribution of precipitation, there could be runoff with less than the 30 inches of precipitation.

As shown by the curve in figure 12, the average water loss increases with the precipitation until it becomes a constant for higher values of precipitation. This is the maximum loss that would occur regardless of the amount of precipitation and is called the potential natural water loss for the basin. The potential natural water loss for the Withlacoochee River at Trilby is shown to be 45 inches. This figure compares favorably with the 48 inches of average water loss shown for 72° in figure 5.

Figure 13 shows the plotted yearly figures of rainfall and runoff for the Trilby station and an average curve. The average curve was determined by using the curve in figure 12 and plotting the departures of the potential water-loss curve from the limiting $P_e = L$ line.

The runoff from the upper Palatlakaha Creek basin has been measured since 1945. Streamflow records were collected near Mascotte (station 9) for the period 1945-56 and at Cherry Lake outlet near Groveland (station 8), about 6 miles upstream, for the period 1956-59. The drainage area

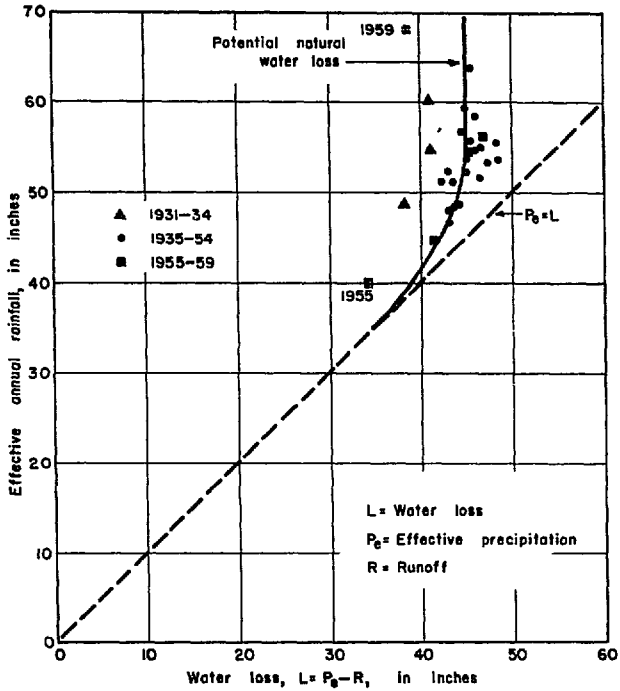

Figure 12. Relation of effective annual rainfall and annual water loss, Withlacoochee River at Trilby, Florida, 1931-59.

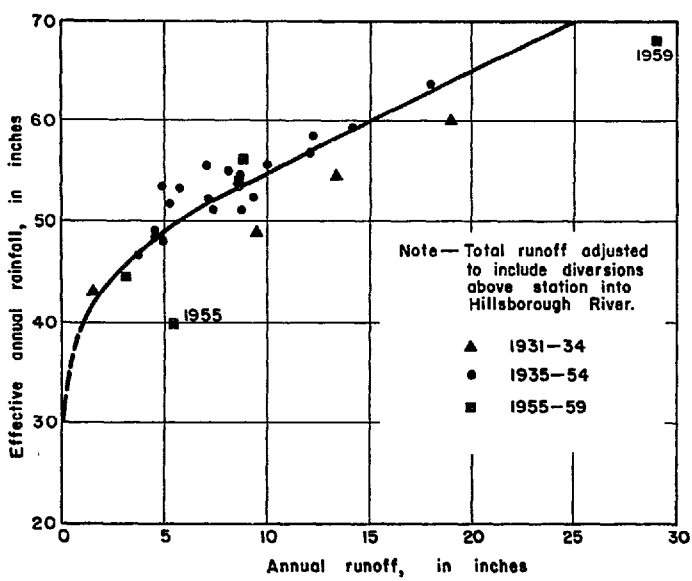

Figure 13. Relation of effective annual rainfall and annual runoff, Withlacoochee River at Trilby, Florida, 1931-59.

at the lower station is approximately 180 square miles and at the upper station, 160 square miles. Figures of runoff per square mile at the two stations are assumed to be equivalent for studying the characteristics of the upper basin.

The water-loss curve for the upper Palatlakaha Creek basin is shown in figure 14. Annual changes in storage in the many lakes and swamps above the gaging station were computed by measuring the water-surface area from maps and using the year-end changes in stage as recorded for Lake Minnehaha. No allowance was made for change in underground storage or for seepage into or out of the basin.

The water-loss curves shown in figures 13 and 14 indicate that for a year in which rainfall was 30 inches or less, the natural losses would equal the rainfall and no runoff would occur from either the Withlacoochee River or the Palatlakaha Creek basins, both draining from the Green Swamp area.

The potential natural water loss for the upper Palatlakaha Creek basin, as shown in figure 14, is 50 inches which also compares favorably with the 48 inches of annual water loss shown for 72° in figure 5.

The potential natural water loss in the Palatlakaha Creek basin appears to be 5 inches more than that for the Withlacoochee River basin. Increased evaporation losses from the open-water surface of the many lakes in the Palatlakaha Creek basin and ground-water movement out of the basin could account for this difference, but as explained in the next section, man-made changes may be a more logical explanation for part of the difference.

Figure 15 shows the relationship of the effective annual rainfall and runoff for the upper Palatlakaha Creek basin. The average curve was determined by using the curve in figure 14 and plotting the departures of the potential water-loss curve from the limiting $P_e = L$ line. The figures of annual runoff have been adjusted for changes in storage as explained in a preceding paragraph but not for diversions from the basin.

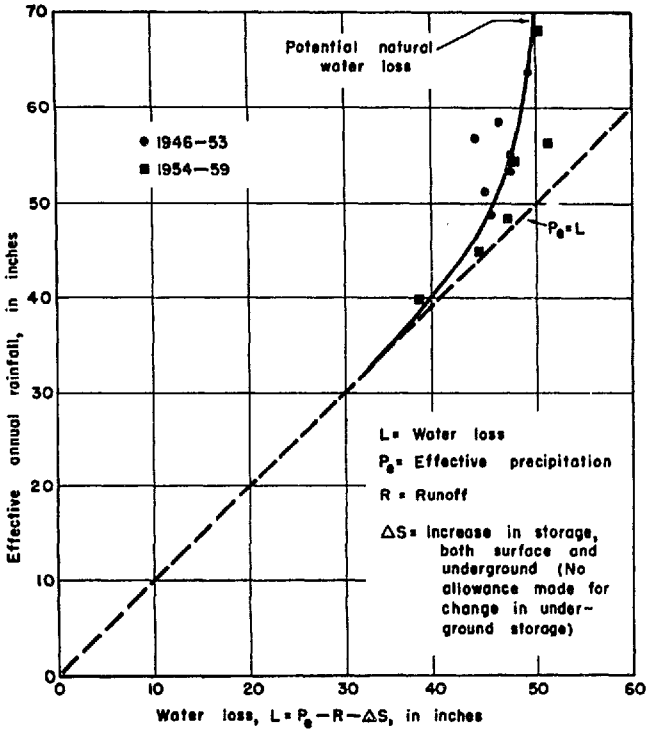

Figure 14. Relation of effective annual rainfall and annual water loss, Palatlakaha Creek above Mascotte, Florida, 1946-59.

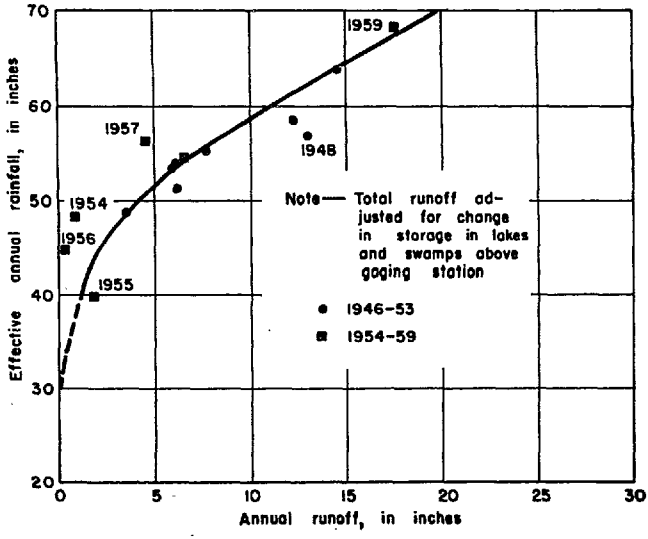

Figure 15. Relation of effective annual rainfall and annual runoff, Palatlakaha Creek above Mascotte, Florida, 1946-59.

The Effects of Man-Made Changes

Many of the physical changes that have been made on the land surface through man's efforts have already been described. The most extensive developments of the area have occurred in recent years, but the first changes in the hydrologic characteristics undoubtedly occurred several years ago when logging trails and tramroads were built and much of the native timber was cleared from the area. The early developments of the area cannot be evaluated as they predate the period of data collection, but they probably had only minor effects on the hydrology.

The present network of canals, ditches, roadfills, borrow canals, and dikes was constructed over a period of several years but the most extensive developments probably occurred after 1950. The canals and ditches were constructed to improve the effectiveness of the drainage system.

Some of the results of the improved drainage in small local areas are obvious from inspections of the area. Improved pasturelands now occupy areas where the water once stood for long periods in shallow sheets over flatlands. Citrus groves have been planted in many flatland areas because flood hazards have been reduced by improved drainage. The water levels in many small landlocked sinkholes, cypress swamps, and saucer-like depressions have been lowered by ditches connecting them with swamps at lower elevations. These are some of the obvious results of improved drainage in small areas but give no indication of overall changes in drainage from the general area.

Changes in the drainage characteristics of the area of investigation can be detected by comparing the hydrologic data for early years before drainage developments occurred with the data collected since the major developments have occurred. Since February 1930 continuous daily-discharge records have been collected for the Withlacoochee River at Trilby, the major drainage outlet of the area. Rainfall records at network stations in central Florida began at an earlier date than did the records of discharge. Some of the rainfall records extend back about half a century. Daily-discharge records have been collected since 1945 in the

upper Palatlakaha Creek basin. A longer record would be more useful for detecting changes or trends in the pattern of discharge from the upper Palatlakaha Creek basin, but the available records cover the period when most of the changes occurred and have been used in this study.

Double-mass curves of cumulative measured runoff and cumulative computed runoff have been plotted to provide a means of examining the records of streamflow from the area of investigation to detect changes that may have occurred (Searcy and Hardison, 1960). A double-mass curve is obtained by plotting cumulative totals of one variable against cumulative totals of a second variable for the same period of time. Any significant change in the relationship of these variables is identified by a break or change in slope of the straight line averaging the points. The variables used in preparing the curves shown in figure 16 are the values of cumulative computed runoff, taken from the precipitation-runoff relations in figures 13 and 15, and cumulative measured runoff at each of the two gaging stations.

The rainfall pattern is not affected by the progressive changes to the drainage system in the Green Swamp area. Likewise, it can be assumed that the theoretical or computed runoff has not changed as it is taken from an average curve for several years of record. Therefore, any change in slope in the double-mass curves of figure 16 would be caused by changes in actual or measured runoff.

Curve A in figure 16 is the double-mass curve for the Withlacoochee River basin above the Trilby gaging station. Straight lines are drawn to average several points that show definite overall trends. Changes in slope of these lines occur between 1934 and 1935 and between 1954 and 1955. The change in slope between 1934 and 1935 is an indication of a change in the runoff pattern but the authors have no knowledge of the cause of such a change. Between 1935 and 1954 the yearly values, in general, are averaged by a single straight line, thus indicating no significant change in runoff pattern from the basin between these dates. Minor deviations of the plotted yearly values of runoff are probably caused by variations of rainfall distribution and intensity during the year and are not indications of changes in the

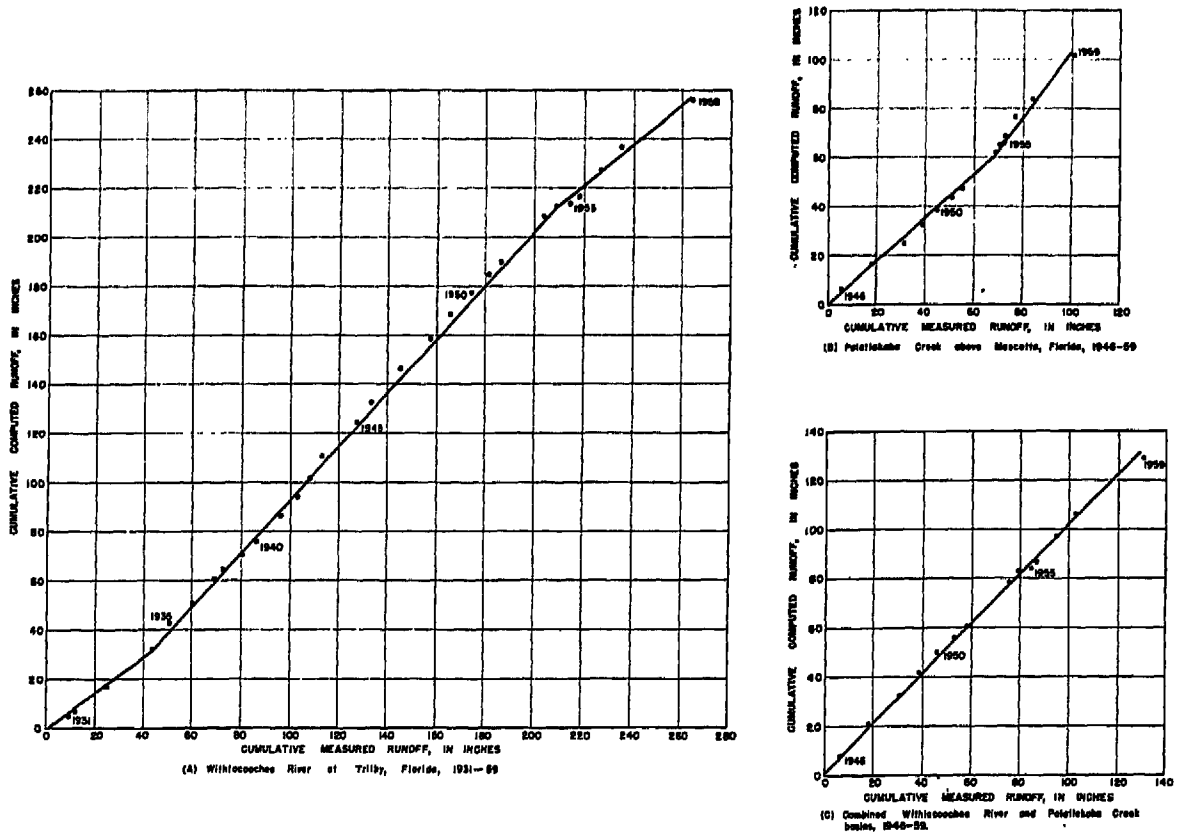

Figure 16. Double-mass curves of measured runoff versus computed runoff, Withlacoochee River and Palatlakaha Creek basins.

long-term trends. Yearly values of runoff for 1955-59 define an average line with a flatter slope than that for 1935-54. This change in slope indicates that a higher rate of runoff from the basin occurred during 1955-59 than that indicated from the same rainfall pattern of previous years.

Curve B in figure 16 is the double-mass curve for the upper Palatlakaha Creek basin. The figures of annual runoff were adjusted for storage changes as described in the previous discussion of the relation between rainfall and runoff. For the period 1945-53, curve B takes the general direction as shown by the straight line. However, after 1953, a definite break occurs in the slope of the average line of curve B indicating that less runoff occurred from the area. The decrease in runoff since 1953 as indicated by the difference in slope of the line averaged about 3 inches per year. Three possible explanations of the decreased runoff from the upper Palatlakaha Creek basin since 1953 could be: (1) increased seepage and evapotranspiration losses since the Cherry Lake control was constructed in 1956, (2) lowered ground-water levels during the dry years of 1954-56, which allowed more infiltration to the aquifers, and (3) the diversion of the headwaters of Little Creek into the Withlacoochee River. (Much of the drainage work in the area was started during the dry years of 1954-56.)

The minimum stage of the chain of lakes above Cherry Lake was stabilized by the construction of the control in 1956. The average increase in stage at this control is small, ranging from 2.5 feet at low flows to none at high flows. The water-surface area above the Cherry Lake control was increased also by a small amount. Seepage and evapotranspiration losses may have been slightly increased by the low-head pool but the amount is negligible, percentagewise. The increased runoff during 1959, an extremely wet year, partly compensated for the effect of the dry years of 1954-56. Additional years of record will be required to establish the slope of the curve that will average the effects of wet and dry years since 1953 and to evaluate further changes in diversions mentioned in (3) above.

Curve C in figure 16 has been plotted to show the cumulative runoff from the combined Withlacoochee River and Palatlakaha Creek basins. The average line defining curve C has the same slope for the entire period, 1945-59. This indicates that there has been no significant loss from the combined basins.

The only remaining explanation for the significant decrease in runoff from the Palatlakaha Creek basin is a decrease in the size of the drainage area. Such a change in the headwaters of Little Creek, a tributary to Palatlakaha Creek, has been previously discussed. This change has resulted in the diversion of part of the flow from the Little Creek basin into the Withlacoochee River basin. This also explains the increased runoff from the Withlacoochee River basin for 1955-56 as indicated by curve A in figure 16. However, the gain to this basin is not as obvious as the loss from the Palatlakaha Creek basin because of the difference in size of the drainage basins.

The effects of the diversions from the Palatlakaha Creek basin to the Withlacoochee River basin are not clearly indicated at present by the plotting of data for the precipitation-water loss relations (figs. 12, 14) and the precipitation-runoff relations (figs. 13, 15). The fact that such diversions have occurred is more apparent when the cumulative amounts are magnified by the double-mass curves in figure 16.

Chemical Characteristics of Surface Water

The chemical characteristics of a water depend on the environment through which it has passed. For instance, rain water usually has a very low mineral content as there is a very low concentration of minerals in the atmosphere. However, rain water does contain some dissolved gases such as carbon dioxide and oxygen. As the rain water contacts the ground some minerals are dissolved, depending mostly on the solubility of the minerals, the time of contact, and the acidity of the rain water.

Because of prolonged leaching, the minerals at the surface of the ground in most of the Green Swamp area are of low solubility; therefore, surface water is generally low in mineral content. The more soluble minerals are generally found below the surface of the ground. Also, water under the ground has a greater area of contact with these soluble minerals and the time of contact of the water with the soluble minerals is usually longer than water on the surface. Therefore, water that has been stored in the ground and returned to the surface usually contains a higher mineral content than that remaining on the surface.

Water has been typed according to the concentrations of the individual mineral constituents for convenience in the discussion that follows. For example, a chloride-type water is a water that contains more chloride in parts per million than any other mineral constituent. The concentration of chloride could be less than 10 parts per million and still be a chloride-type water. Mineral content that is less than 100 parts per million is generally considered to be low. A water that contains more than 100 units of color is considered to be highly colored.

The surface water of the Green Swamp area is low in mineral content. The content ranged from 18 to 122 parts per million. Generally water is considered to be usable if it contains less than 400 to 500 parts per million of mineral content. However, water that contains less than 400 to 500 parts per million may be suited for one industrial or municipal concern but may be completely unusable for another. The most undesirable characteristic of the surface water in the Green Swamp area would probably be its color. Most of the water is highly colored and color values as high as 600 were noted. None of the surface water was hard, that is, the water had a hardness of less than 120 parts per million.

The effects of environment are discussed by comparing the characteristics of water at various points in the river basins. The characteristics are determined for both high and low flows.

During the period of relatively high flow in November 1959, the water in the Withlacoochee River between Eva (station 23) and Dade City (station 31) was found to be chloride in type, low in mineral content, and highly colored. Between Dade City and Croom (station 44) the water changed to a carbonate type and mineral content increased from 30 to 56 parts per million (fig. 17). This increase was greater between Dade City and the bridge on Cummer Cypress Company road (station 33) than between other points along the river within the area of investigation. Part of this increase in mineral content could be due to industrial and municipal disposals into a drainage canal at Dade City. This canal empties into the Withlacoochee River between Dade City and station 33.

Between station 33 and Trilby (station 39), there was a slight decrease in mineral content. This decrease probably was caused by inflow water from Gator Hole Slough and Devil Creek. This water is low in mineral content.

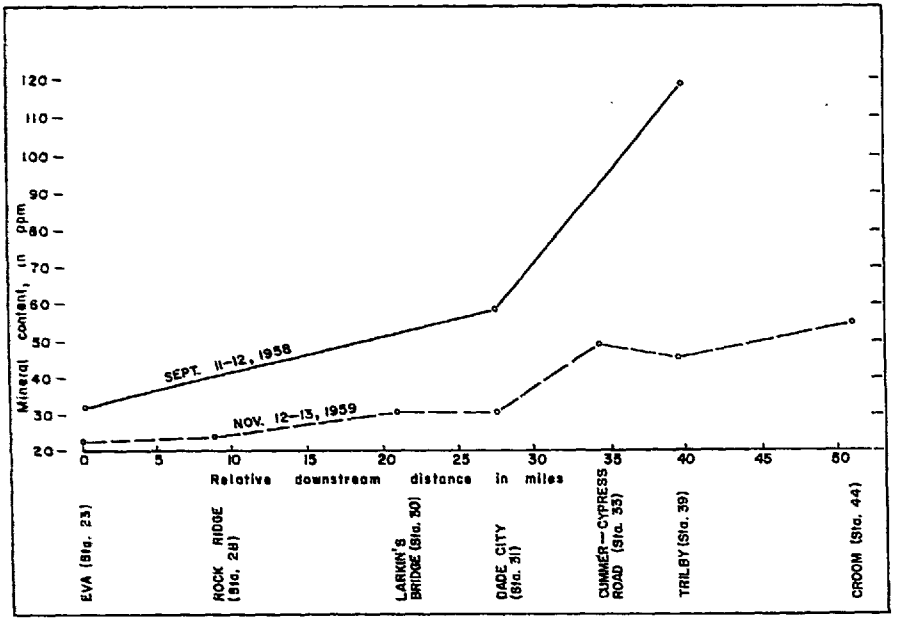

Figure 17. Mineral content in the Withlacoochee River.

Between Trilby and Croom (station 44) there is an indication of ground-water inflow to the river. The mineral content of the possible total inflows was estimated on the basis of data collected on November 12-13, 1959, from three stations:

Station	Discharge in cubic feet per second	Mineral content in parts per million
(39) Withlacoochee River at Trilby	950	46
(43) Little Withlacoochee River at Rerdell.....	120	46
(44) Withlacoochee River at Croom	1,230	56

By using the equation, $Q_1C_1 + Q_2C_2 + Q_3C_3 = Q_4C_4$ (Hem, 1959): where,

Q is the discharge in cubic feet per second
C is the mineral content in parts per million
Q_1C_1 is the instantaneous load at Trilby
Q_2C_2 is the instantaneous load at Rerdell
Q_3C_3 is the instantaneous load between the stations
Q_4C_4 is the instantaneous load at Croom

the instantaneous load, Q_3C_3, was computed. The increase in discharge (Q_3) was determined to be 160 cubic feet per second by subtracting the sum of discharges at Trilby and Rerdell from that at Croom. The mineral content (C_3) thus computed is about 120 parts per million. The mineral content in the principal aquifer in this area is usually greater than 250 parts per million. The computed mineral content indicates that the inflow between the stations was probably a composite of surface-water and ground-water inflows.

At the time of low flow in September 1958, the water in the Withlacoochee River near Eva was chloride in type, of low mineral content, and highly colored. Between Eva and Dade City, the water changed to a carbonate type and increased in mineral content from 32 to 59 parts per million. From Dade City to Trilby, the mineral content increased

and undoubtedly part of this increase was due to waste disposals into the canal at Dade City. In addition, some ground-water inflow probably occurs along this reach of the river, but the data are insufficient to advance any conclusions concerning the quantity and chemical quality.

The Little Withlacoochee River was investigated at various points in its headwaters and at Rerdell. The headwaters were chloride in type and of low mineral content, ranging from 30 to 86 parts per million. The color intensities ranged from 80 to 150 units. At Rerdell the water was carbonate in type for both high and low flows. This indicates ground-water inflow to the stream between the headwaters and Rerdell.

Samples were obtained at the Withlacoochee-Hillsborough overflow at U. S. Highway 98 (station 17) in February, March, and November 1959, and at Hillsborough River at State Highway 39 near Zephyrhills (station 19) in November 1959. These data indicate the possibility of ground-water inflows to the stream above these points. The water was carbonate in type, low in mineral content, and contained some color. The mineral content was 44 parts per million in Withlacoochee-Hillsborough overflow and was 48 parts per million in Hillsborough River at State Highway 39. This mineral content is higher than that along the upper reaches of the Withlacoochee River and most other areas within the Green Swamp. The mineral content in the upper Withlacoochee River was less than 30 parts per million.

The waters in Big Creek and Little Creek near Clermont (stations 4 and 5) were chloride in type, of low mineral content, and highly colored. These streams are similar in chemical characteristics and show little change in characteristics between high and low flows. In Big Creek, the mineral content from four samples ranged from 21 to 31 parts per million when discharge ranged from 5.9 to 279 cubic feet per second. Little Creek was sampled four times and the mineral content ranged from 18 to 23 parts per million and discharge ranged from 4.7 to 210 cubic feet per second. The color intensities in these streams ranged from 130 to 300 units.

Horse Creek near Davenport (station 14) and Reedy Creek near Loughman (station 13) were sampled once in November 1959 when most of the streams in the area were above base flows. Chemical analysis of the water sample from Horse Creek shows that the water was carbonate in type, of low mineral content (58 ppm), and colored (72 units). The mineral content was similar to those collected in the Hillsborough River above State Highway 39 (station 18). The water from Reedy Creek was chloride in type, of low mineral content (33 ppm), and colored (80 units).

Water samples were collected for analysis in September 1959 from Lake Louisa near Clermont (station 6) and in November 1959 from Bay Lake near Mascotte (station 40), Little Lake Agnes near Polk City (station 27), Crystal Lake at Lakeland (station 16), and Lowery Lake near Haines City (station 1). The mineral content in waters of these lakes was less than 70 parts per million. Based on these five analyses, there does not appear to be any significant differences in the mineral content in the waters of the lakes.

Ground Water

General

Ground water is the subsurface water in the zone of saturation - that zone in which all pore spaces are filled with water under atmospheric or greater pressure. Ground water can be divided into two classes related to the geology of an area: (1) ground water that occurs under nonartesian (unconfined) conditions, and (2) ground water that occurs under artesian (confined) conditions.

In an unconfined aquifer the upper surface of the zone of saturation is free to rise and fall. In a confined or semi-confined aquifer the deposits are completely saturated and the water is under sufficient pressure (greater than atmospheric) to rise above the top of the aquifer in wells that tap it. The level to which artesian water will rise in tightly cased wells that penetrate the artesian aquifer is called the piezometric surface.

Ground-water movement depends on the permeability of the aquifer and the hydraulic gradient. Generally, clays have low permeability or low water-transmitting capacity, and coarse gravels have high permeability.

Ground water may move through a confining bed when there is a difference between the head of the water across the bed. When the water table is higher than the piezometric surface of the confined water, the potential leakage is downward (recharge to the artesian aquifer). If the piezometric surface of the confined water is higher than the water table, the potential leakage is upward (discharge from the artesian aquifer). The rate of ground-water movement through the confining bed depends on (1) its vertical permeability and (2) the hydraulic gradient across it (the difference in head divided by the thickness of the bed).

The ground water of the Green Swamp has been divided into two general classes based on its occurrence: (1) nonartesian ground water, which occurs in the undifferentiated clastic deposits, and (2) artesian ground water, which occurs in the porous limestones of the Floridan aquifer (fig. 18).

Nonartesian Ground Water

Occurrence: In the Green Swamp area the nonartesian ground water occurs primarily in an unconfined aquifer composed of undifferentiated clastic deposits, mainly sand and clayey sand. The nonartesian aquifer ranges from 0 to more than 100 feet in thickness. The base of the aquifer is marked by either a dark silty clay which ranges from 0 to more than 50 feet in thickness, or a light green silty montmorillonitic clay which ranges from 0 to more than 30 feet in thickness. The major portion of the nonartesian aquifer consists of fine to coarse grained quartz sand with varying amounts of multi-colored kaolinitic clay. The nonartesian aquifer is thick in the eastern part of the area and thin or absent over the limestone plain (exposures of the Floridan aquifer) in the western part.

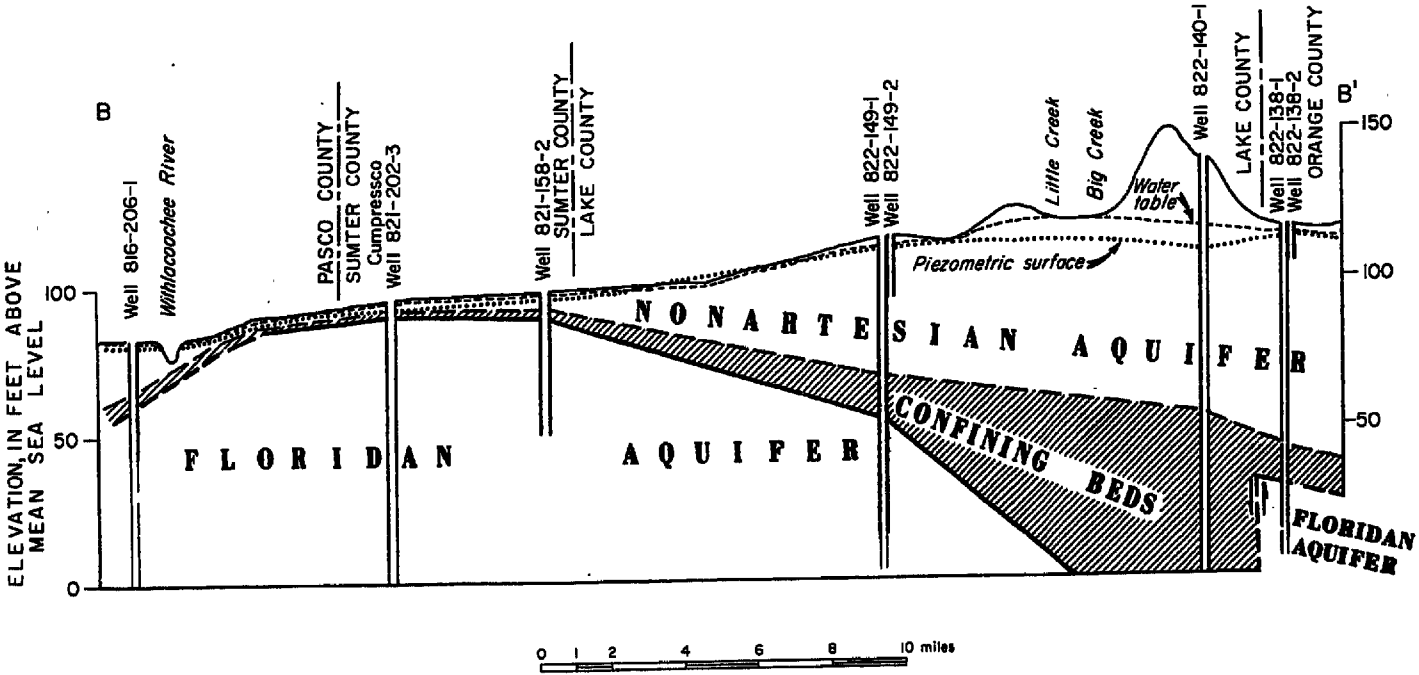

Figure 18. Generalized hydrologic cross section along line B-B', figure 6.

Data obtained during test drilling showed that the clay at the base of the nonartesian aquifer is of sufficiently low permeability to confine water in the Floridan aquifer (fig. 18). The dark clay in the eastern part of the area does not extend across to the western part of the area. A light green clay forms the confining bed in the western part but appears to interfinger with the clayey sands of the nonartesian aquifer to the east.

Fluctuations of the Water Table: The water table fluctuates with changes in ground-water storage in the same manner as the water surface of a reservoir or lake that rises when water is added (recharge) and falls when water is withdrawn (discharge). When the rates of recharge and discharge are equal, the water surface does not fluctuate but when they are unequal, the water surface rises or falls. Fluctuations of the water table were recorded in several shallow wells within the area but the records are of insufficient duration to study the correlation between the water table, surface-water flow, and artesian water levels. The only well in the area with a long-term record of water-table fluctuations is well 810-136-2 (Polk County 47). The well is located north of Davenport and east of the Green Swamp area (fig. 19) in an area where flowing artesian wells are found. The hydrograph of well 810-136-2 (fig. 20) shows that the water-table fluctuations ranged about 6 feet during the period 1948-59. Comparison of the hydrograph of well 810-136-2 (nonartesian) with that of well 810-136-1 which taps the Floridan aquifer shows that the water table fluctuated through about 1 foot greater range than the piezometric surface did. The general correlation between the two hydrographs seems to indicate that a relatively good hydraulic connection between the nonartesian aquifer and the Floridan (artesian) aquifer occurs nearby. Stringfield (1936, p. 148) noted the apparent lack of confining beds between the nonartesian and artesian aquifers in this area.

Water-table fluctuations were recorded in four wells in the Green Swamp area during 1959. They are: wells 832-154-2 and 822-149-2 in Lake County, well 822-138-2 in Orange County; and well 813-149-2 in Polk County (see fig. 19 for locations). The hydrographs of the water table at wells 813-149-2, 822-149-2, and 822-138-2 showed approximately the same range of fluctuation and the same

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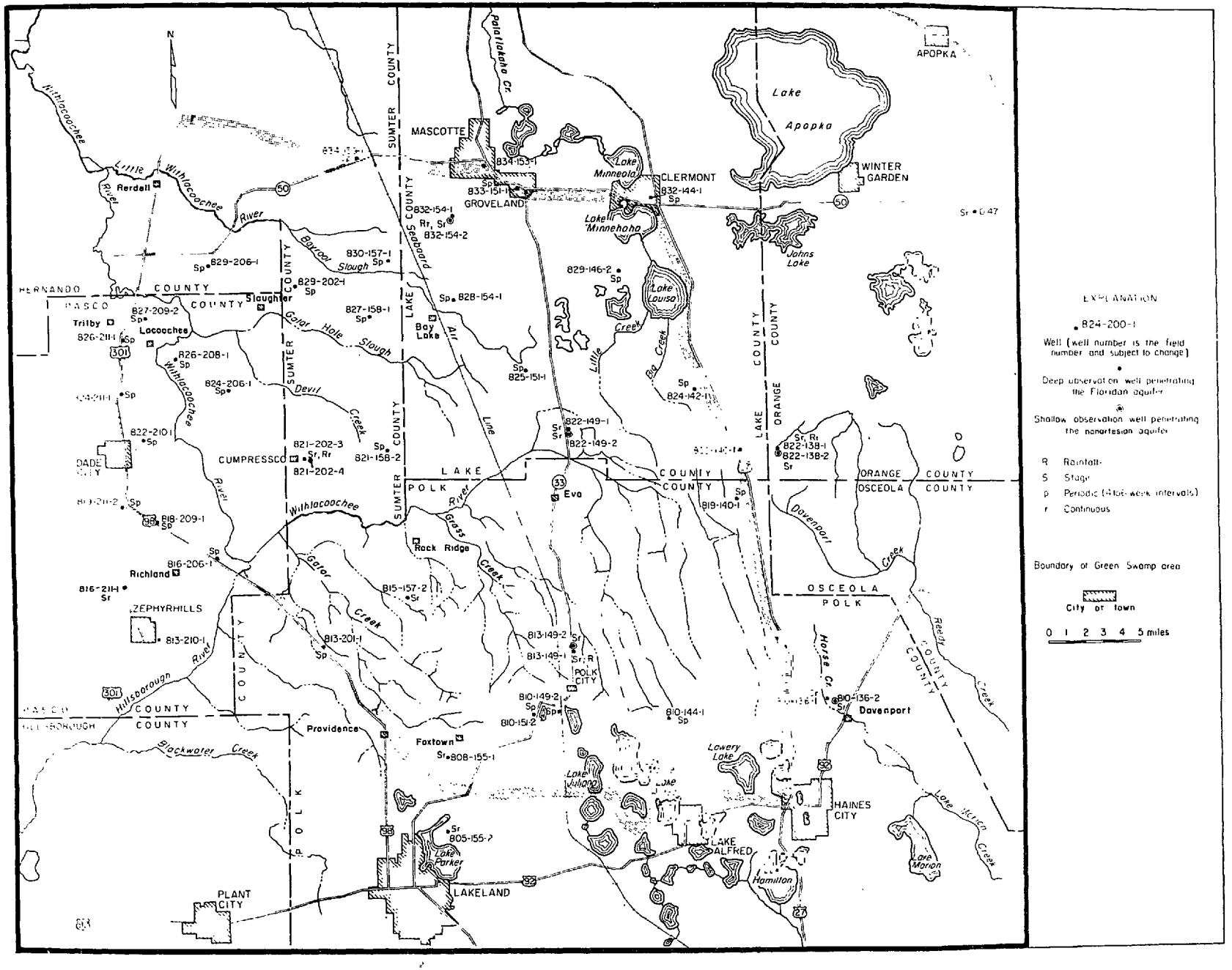

Figure 19. Map of Green Swamp area showing ground-water data-collection points.

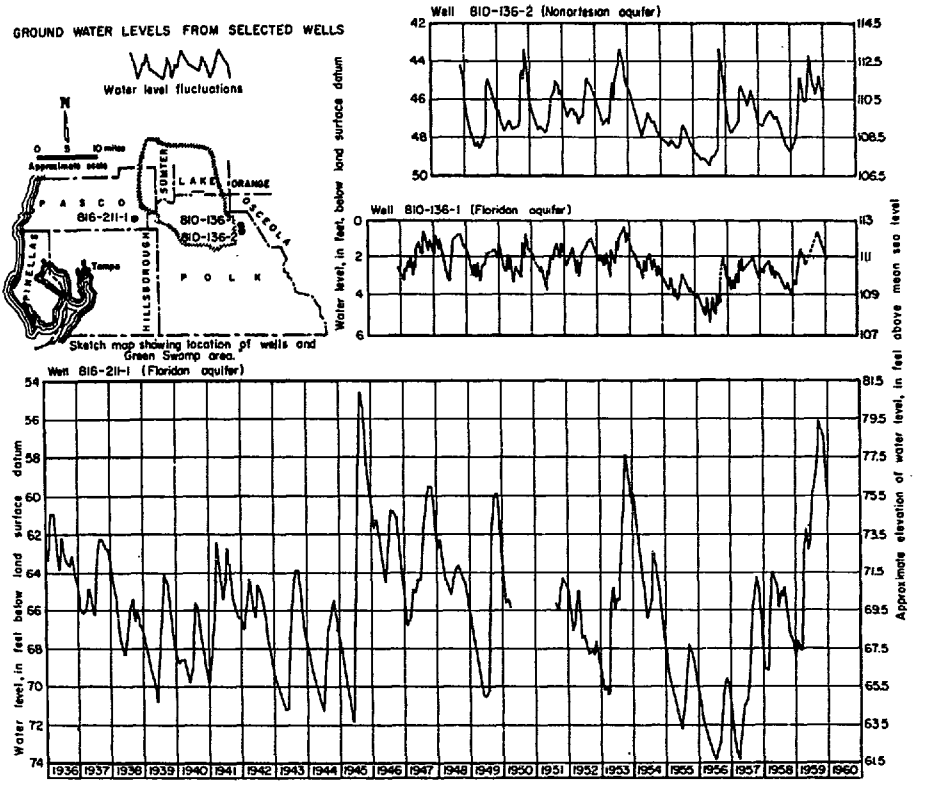

Figure 20. Hydrographs of long-term water-level records from wells near the Green Swamp area.

head relationship to the piezometric surface; therefore, the hydrograph of well 813-149-2 was chosen as representative of the other wells.

Figure 21 shows a comparison of recorded fluctuations of the water table and piezometric surface with recorded rainfall at wells 832-154-1 and 2 (Lake County), 821-202-3 (Sumter County, and 813-149-1 and 2 (Polk County). All hydrographs show rapid rises following heavy rains. The hydrograph of well 813-149-2 shows that the water table remained near the surface and that downward leakage to the Floridan aquifer was maintained during 1959. The hydrograph of well 832-154-2 (nonartesian) shows a slightly greater range in fluctuation of the water table than in well 813-149-2 (nonartesian). This probably is due either to pumping from a drainage canal near well 832-154-2 or the proximity of the well to an abrupt change in the land surface. The hydrographs of 832-154-2 and 832-154-1 (artesian) show that the water table fluctuates above and below the piezometric surface. However, the indicated direction of ground-water movement is predominantly from the artesian to the nonartesian aquifer. A conductivity recorder installed in well 832-154-1 showed a decrease in conductance in the water from the Floridan aquifer within 2 or 3 days following a rain. The conductance indicates the mineral concentration in water. Therefore, decreased conductance in this well implies dilution of ground water in the Floridan aquifer by flow from the nonartesian aquifer which normally contains less highly mineralized water. Apparently the zone that separates the two aquifers is sufficiently permeable to permit significant amounts of ground water to move between the aquifers.

Comparison of the water-level fluctuations in well 832-154-2 with those of well 821-202-3 shows that the range of fluctuation and rates of recession of the water table and piezometric surface of the Floridan aquifer are similar because the Floridan aquifer is exposed in the vicinity of well 821-202-3, and locally the aquifer is unconfined. The thin, saturated zone of the nonartesian aquifer that occurs locally above the unsaturated portion of the Floridan aquifer is called a "perched" aquifer.

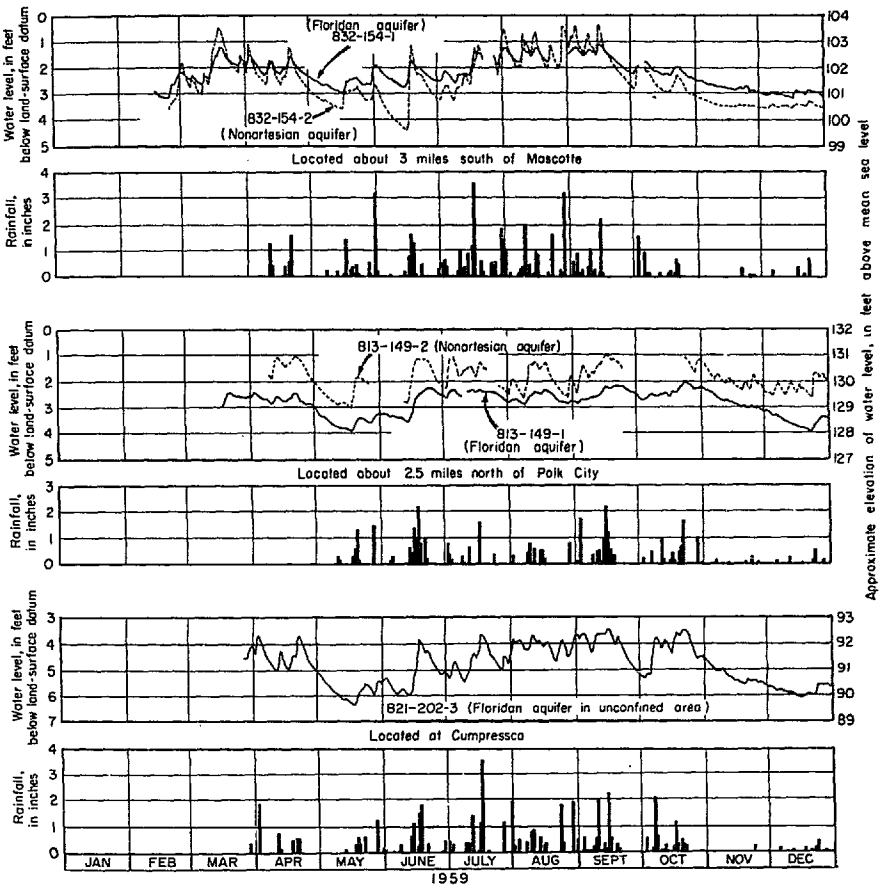

Figure 21. Hydrographs of water-level and rainfall records at wells in the Green Swamp area.

Recharge and Discharge: Ground water in the nonartesian aquifer within the Green Swamp area is replenished principally by local rainfall. It is discharged by: (1) flow into surface-water bodies, (2) evapotranspiration, (3) downward leakage into the Floridan aquifer, (4) subsurface discharge through the nonartesian aquifer, and (5) draft by a few wells.

In the eastern part of the Green Swamp area the nonartesian aquifer is thick and has a relatively large storage capacity, and the water table stands at high elevation. In the western part of the area the aquifer is thin or absent and accordingly has a small storage capacity.

Movement of nonartesian ground water within the aquifer is from areas of high head to areas of low head. Consequently, ground water moves from areas where the water table is high in the eastern and southern parts of the Green Swamp area to areas where the water table is low in the western part. Ground-water flow from the east tends to maintain a shallow water table in the west so that part of potential recharge from rainfall in the western part is rejected. The direction of ground-water movement indicates that the eastern part is a recharge area.

The topographically higher sand ridges in the eastern and southern parts of the area have a large ground-water storage capacity because of their thickness. However, most of the high sand ridges (such as the Lake Wales Ridge) do not store large quantities of ground water. The water table beneath the ridges was found to occur at approximately the same elevation as the regional water table on the eastern and western sides of the ridge. Therefore, as much as 100 to 200 feet of the deposits are unsaturated beneath these high sand ridges.

The water table ranges in elevation from about 100 to 130 feet above mean sea level in the eastern and southern parts of the area and from 75 to 100 feet above mean sea level in the western part. The slope of the water table conforms generally to the topography. Surface-water bodies in sandy areas generally indicate places where the land surface intersects the water table and ground-water divides

coincide generally with surface-water divides. See figure 7 for drainage divides. During dry periods some of the ground-water divides may shift position, or even disappear, because of changes in direction of ground-water movement.

Artesian Ground Water

Occurrence: The Floridan aquifer, the principal source of artesian ground water in Florida, underlies all of the Green Swamp area. The top of the aquifer is at land surface in the western part of the area and occurs at depths of more than 200 feet below land surface in the eastern part. The actual thickness of the aquifer is not known because the test wells have penetrated only 100 to 200 feet of the aquifer. However, a relatively impermeable zone of undetermined extent occurs in other wells at a depth of about 1,000 feet, perhaps forming the base of the aquifer. Thus, the thickness is probably on the order of 700 to 900 feet.

Fluctuations of the Piezometric Surface: Ground water in the Floridan aquifer in the Green Swamp area is replenished (recharged) principally by local rainfall that percolates downward from the surface of the ground through the nonartesian aquifer and by direct percolation into the exposed portions of the aquifer. Ground water in the artesian aquifer is discharged by (1) subsurface outflow to areas of lower piezometric head beyond the limits of the Green Swamp area, (2) seepage and spring flow into the surface-drainage systems, (3) leakage to the nonartesian aquifer, (4) evapotranspiration, and (5) pumping. The piezometric surface rises when the rate of recharge exceeds discharge and declines when that of recharge is less than discharge. The fluctuations of the piezometric surface were observed by continuous water-level recording instruments and by periodic water-level measurements in selected wells. No long-term records of fluctuations of the piezometric surface are available for wells within the Green Swamp area, but long-term records are available for nearby wells 810-136-1 (Polk County 44) and 816-211-1 (Pasco County 16). Hydrographs of the water level in these wells are presented in figure 20.

The two hydrographs indicate that the range of fluctuation of the piezometric surface was greater in western Pasco County than in northeastern Polk County during the period 1947-59. The piezometric surface at well 816-211-1 fluctuated from about 56 to 74 feet below land surface and at well 810-136-1 it fluctuated from about 0.5 to 5 feet below land surface. The large fluctuation in well 816-211-1 is caused by its proximity to local recharge and discharge areas near the Hillsborough and Withlacoochee rivers. Also, well 810-136-1 is located in an area which has a relatively different type geology from that of well 816-211-1 because the top of the aquifer is deeper. The hydrographs of well 810-136-1 and a nearby water-table (nonartesian) well 810-136-2 show that the piezometric surface is usually higher than the water table (fig. 20). Therefore, well 810-136-1 is in a potential artesian leakage area.

Short-term water-level records are available for wells 832-154-1 and 822-149-1, in Lake County; well 822-138-1, in Orange County; well 821-202-3, in Sumter County; and well 813-149-1, in Polk County (fig. 19). The water-level records of well 813-149-1 show the same general range of fluctuations of the piezometric surface as wells 822-149-1 and 822-138-1. The wells are located in areas where the water table is above the piezometric surface and the Floridan aquifer occurs at about the same depth. Therefore, the water level in well 813-149-1 is probably representative of artesian water levels in the eastern part of the Green Swamp area.

Hydrographs comparing the fluctuations of the piezometric surface of the confined water in wells 832-154-1, 821-202-3, and 813-149-1 with fluctuations of the water table and rainfall are presented in figure 21.

The fluctuations of the piezometric surface in the three wells showed the same general trend, in that rainfall caused a rise in water level and lack of rainfall caused a decline in water level. Differences in the range of fluctuation, rates of recession, and rate of response to recharge and discharge are apparent if the hydrographs are compared from east to west.

Well 813-149-1 is located on the piezometric high in the southeastern part of the Green Swamp area. The water-level rise caused by rainfall continues for about 2 days after the rain indicating slow seepage. The subsequent water-level recession occurs at a rate of about 1 foot in 30 days. The maximum range in fluctuation is about 2 feet; however, an increase in recession during December 1959, which is indicated by steepening of slope, was probably caused by increased pumping of ground water from the aquifer during the citrus season.

Well 832-154-1 is between the recharge areas in the eastern part and discharge areas in the western part of the Green Swamp area. The peaks caused by rainfall occur about 1 day after the rain. The peaks are sharper than those of well 813-149-1 and the subsequent recession occurs at a rate of about 1 foot in 20 to 30 days. However, the initial slope of recession is greater for well 832-154-1; this may be due partly to greater intensity of rainfall and partly to the proximity of the well to local recharge and discharge areas. The flow of ground water increases and decreases in the same manner as water flowing in a stream with steep gradients and a well defined channel. The range of fluctuation of the water level in well 832-154-1 is about 2 feet and it is about the same as the range in well 813-149-1. Another difference between the hydrographs of these two wells is that the water level in well 813-149-1 had a steeper recession curve than well 832-154-1 during December 1959. This is probably related to effects of local pumping.

Well 821-202-3 is located in the western part of the Green Swamp area. The water-level peaks caused by rainfall are steeper than those in the wells in the eastern part of the area and they occur about 1 to 2 days after the rainfall. The subsequent recession rate is about 1 foot in 10 to 15 days. On November 21, 1959, no rainfall was recorded at well 821-202-3 but the piezometric surface responded to rainfall in the same manner as the water level in wells 813-149-1 and 832-154-1. This indicates that there is probably good hydraulic continuity in the aquifer from east to west or the rise is associated with loading on the Floridan aquifer. The range of fluctuation of the piezometric surface

at well 821-202-3 is about 3 feet. The greater rate of recession and range of fluctuation at well 821-202-3 could be due to the combined effects of (1) nonartesian conditions in the Floridan aquifer while artesian conditions occur at the other two wells (discussed in nonartesian section), (2) direct entry of rainfall through exposed portions of the aquifer, and (3) the proximity of the well to surface-water drainage.

The fluctuations of the piezometric surface in well 813-149-1 and the water table in well 813-149-2 with rainfall show the same general trend, but the position of the water table is above the piezometric surface. This suggests that the wells tap two separate but interconnected aquifers. The direction of ground-water movement is from the nonartesian aquifer to the Floridan aquifer.

The fluctuation of the piezometric surface in well 832-154-1 and of the water table in well 832-154-2 with rainfall do not coincide, but show the same general trend. The hydrographs of the piezometric surface and the water table cross several times, and the rate of water-table recession is much greater than that of the piezometric surface. This indicates that the wells penetrate separate aquifers and the water level fluctuates in response to changing recharge and discharge conditions in each aquifer. The direction of ground-water movement between the aquifers changes, but the predominant direction is from the Floridan to the nonartesian aquifer. The greater rate of recession of the water table may be due partly to a nearby drainage ditch which is pumped intermittently.

Fluctuations of the water level in the nonartesian aquifer were not recorded near well 821-202-3, therefore no comparison can be made. The relatively thin section of nonartesian aquifer (sand and clay) in this area could store little water. The low permeability of the clay confining bed is probably one of the factors that causes increased surface runoff in the western part of the Green Swamp area.

Shape of the Piezometric Surface: The piezometric map (fig. 22) shows the shape of the piezometric surface of the Floridan aquifer in the Green Swamp and nearby areas.

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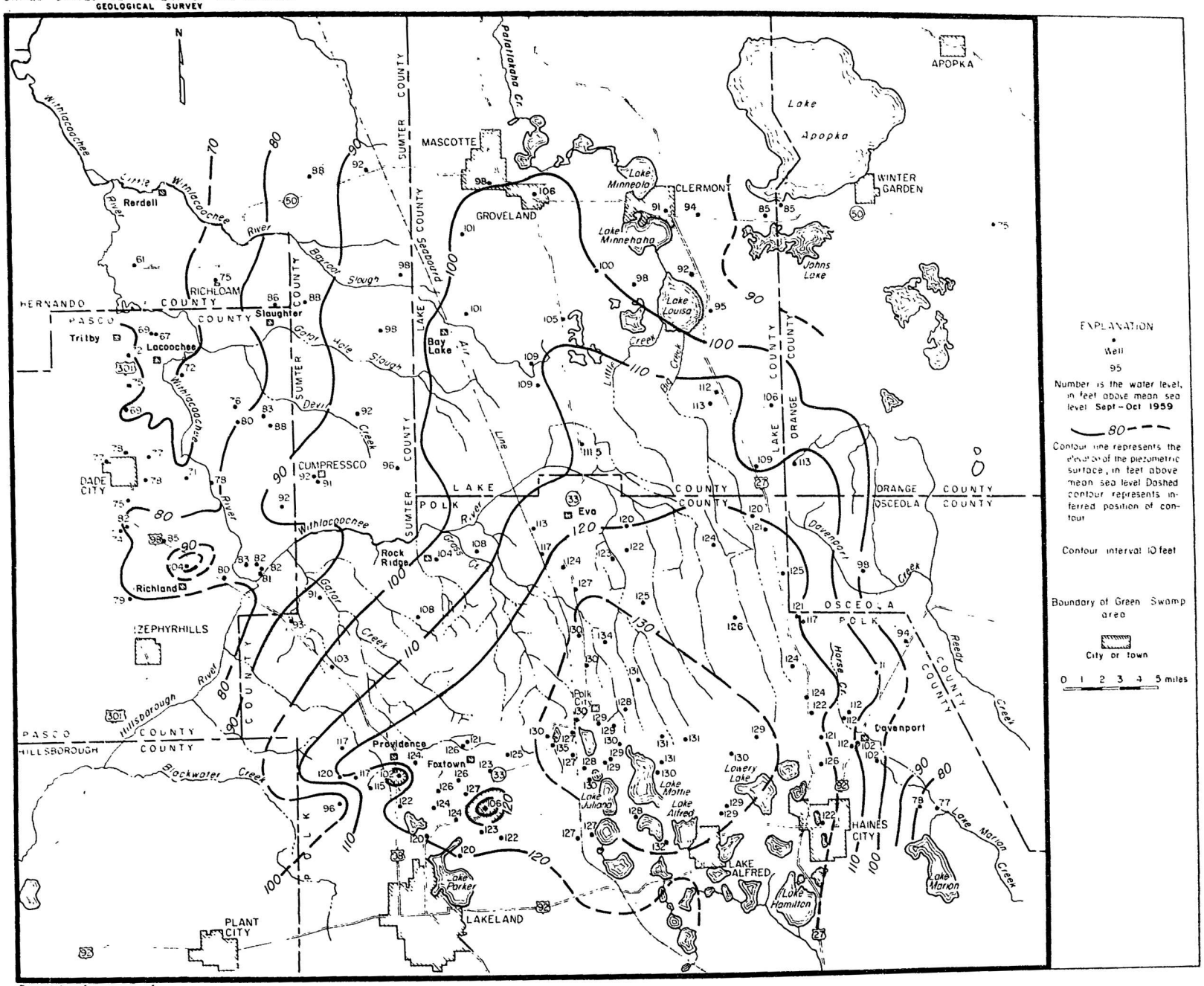
GEOLOGICAL SURVEY



Base taken from maps of Florida State Road Department

Figure 22. Map of Green Swamp area showing the shape of the piezometric surface of the Floridan aquifer.

The map was constructed from water-level measurements made, during the period September through October 1959, in selected wells that were cased into the aquifer. The water level in each well was referred to mean sea level datum and contour lines were drawn to connect points of equal piezometric head. The direction of ground-water movement in the aquifer is perpendicular to the contour line from areas of high head toward areas of lower heads. Piezometric highs (sometimes referred to as mounds) usually indicate principal areas of recharge to the aquifer. Piezometric lows (sometimes referred to as troughs) usually indicate areas of discharge from the aquifer. The distance between the contour lines indicates the hydraulic gradient of the piezometric surface. The hydraulic gradient may vary because of unequal amounts of recharge or discharge, changes in permeability of the aquifer, or changes in thickness of the aquifer.

Figure 18 shows an east to west hydrologic cross section through the central part of the Green Swamp area. On the eastern side, the top of the aquifer occurs between 100 to 200 feet in depth beneath a relatively thick, non-artesian aquifer. The thickness and type of material comprising the confining beds and the position of the piezometric surface of the confined water and water table indicate that a good hydraulic connection exists between the two aquifers.

The general direction of ground-water movement in the Floridan aquifer is outward in all directions from an elongated piezometric high that extends approximately from central Lake County to southern Polk County at least. The apex of the high (130-foot contour) occurs within the southeastern quarter of the Green Swamp area. The northern extent of the elongated mound lies within the eastern half of Green Swamp (fig. 22). The southern boundary of the Green Swamp area extends across the piezometric high.

The direction of ground-water movement in the Green Swamp is eastward to discharge areas in Orange, Osceola, and eastern Polk counties, westward to local discharge areas in the western half of the Green Swamp area, southward toward areas of lower piezometric head in west-central Polk County and northeastern Hillsborough County, and northward into southern Lake County.

The 130-foot contour line (fig. 22) encloses an area of high piezometric head in the Floridan aquifer. The mound near Polk City is in a moderately flat, poorly drained area. The land surface ranges in elevation from about 130 to 150 feet above mean sea level and there are numerous cypress swamps and lakes. The Floridan aquifer is overlain by about 100 feet of sand and clay of which the basal 10 to 50 feet is considered to act as a confining bed. Recharge to the Floridan aquifer within the high is believed to occur by downward percolation through the confining bed and also through the many cypress swamps and lakes which apparently mark sinkholes in the underlying limestone.

The hydraulic gradient, as indicated by the distance between contour lines, is greater toward the east than toward the west, thereby inferring a greater rate of ground-water movement eastward. If it is assumed that the permeability and thickness of the aquifer are uniform, then the discharge to the east would be two to three times greater than the discharge to the west.

The difference in hydraulic gradient could be caused by (1) a decrease in permeability in the aquifer eastward, (2) a decrease in the thickness of the aquifer eastward, (3) water-table conditions occurring within the Floridan aquifer in the western part of the area, (4) barrier effects of structure, (5) pumping to the east, or (6) by combinations of these conditions.

The piezometric map shows numerous small recharge mounds in the western part of the Green Swamp. These are probably caused by rainfall that occurred immediately prior to the period of water-level measurements and will dissipate after a short time. Local runoff and recharge causes large fluctuations of the piezometric surface in the western area.

Figure 22 indicates that there is considerable ground-water discharge from the Floridan aquifer into the Withlacoochee River downstream (north) from Dade City. The Floridan aquifer also discharges water into the Hillsborough River downstream from the diffluence of the Hillsborough and Withlacoochee rivers, and some ground water is discharged into the Withlacoochee River upstream from the

diffluence. There is also evidence that ground-water flow, as well as surface-water flow, is diverted from the Withlacoochee River through the Withlacoochee-Hillsborough overflow.

Pumping in the area north of Lakeland is indicated by cones of depression in the piezometric surface. There are trough-like lows developed on the piezometric surface near the Hillsborough River that probably indicate rapid movement of ground water to the discharge areas by means of solution-widened fracture zones. Discharge of ground water from the Floridan aquifer occurs by upward leakage to the Reedy Creek and Lake Marion Creek areas on the eastern flank of the Green Swamp. Some ground water from the northern part of Green Swamp area moves northward and is discharged into the Palatlakaha Creek basin.

Chemical Characteristics of Ground Water

Information concerning the quality of ground water was obtained by field observations and from the analyses of water samples collected from wells within the Green Swamp area.

The conclusions concerning the quality of water are based for the most part on the data collected during the reconnaissance of November 1959. During this reconnaissance all of the deep observation wells were sampled by pumping. All samples that contained suspended matter were filtered in the field. These data were supplemented by data collected during the period of investigation and during previous investigations.

The quality is discussed by comparing the water characteristics in the area of the piezometric high (southeastern area) with those for the remaining area.

In general, the mineral content of water in the Floridan aquifer along the southern boundary of the area was less than 150 parts per million and that for the remaining area was about 300 parts per million. Figure 22 indicates that water enters the ground and the Floridan aquifer in the

southeastern part of the area; that is, the ground water in this area is being replenished by surface water. This could account for lower mineral content. The water in the Floridan aquifer adjacent to the lakes was generally lower in mineral content than that more distant. This could indicate downward movement of the surface water from the lakes to the aquifer.

The mineral content in the nonartesian aquifer generally was higher than the mineral content in the water on the land surface and lower than the mineral content of the Floridan aquifer. This could have resulted from prolonged leaching of the shallow sediments, increase in contact time, and increase in area of contact of the water with soluble minerals under the ground. Generally the mineral content in the water in the nonartesian aquifer was less than 125 parts per million.

In the southeastern area, where the nonartesian aquifer overlies the Floridan aquifer, it contains beds of calcareous sandstone. This results in water of variable mineral content within this area; that is, two wells may be drilled to the same depth and within the same general area, yet the water in one well may have been in contact with a calcareous bed, or other soluble material, while the water in the other well may not have been. Also, two wells may penetrate similar formations and one of these could receive more water directly from surface sources than the other and their water characteristics would be dissimilar.

In the western area, the mineral content in the artesian aquifer is more uniform than in the southeastern area. The mineral content during the November reconnaissance ranged from 269 to 350 parts per million.

In the western area the Floridan aquifer occurs at or near the land surface. Water at shallow depths in this area is more highly mineralized than water at depths of several hundred feet in the southeastern area.

Previous investigations indicate that the sinkhole lakes in the Green Swamp, particularly in the southeastern area, may be contributing recharge to the Floridan aquifer (Stringfield, p. 148). A few samples collected from wells in this area

tend to bear this out. One sample collected from a well that was 200 feet deep had a mineral content of only 15 parts per million. This low mineral content is not much greater than that in rain water.

Low mineral content occurs in the waters of the non-artesian aquifers. This low content may not be a result of the rapid movement of water but possibly may be due to the absence of soluble material.

SIGNIFICANCE OF THE HYDROLOGY OF THE AREA

The findings of this reconnaissance may be summarized by appraising the hydrology of the area and by theorizing on some of the changes in the hydrology that could result from increased drainage or from water conservation in the area.

Much of the project area consists of rolling hills and flatlands at relatively high elevation. These areas are presently developed for agricultural uses. Marsh areas have limited or no agricultural use because of the high water table and poor surface drainage. Therefore, any plan of proposed water management should consider the use of the land of the area.

Information collected thus far indicates that the highest piezometric levels of the Floridan aquifer in central Florida occur in the southeastern part of the Green Swamp area. This is an area of high topography and consequently the origin of most streams that drain the area. Thus the southeastern area may be considered as the headwaters both for the drainage systems and for the principal ground-water aquifers in much of central Florida.

Because the hydrology of the area east of the Seaboard Air Line Railroad is somewhat different from that of the area west of the railroad, the important hydrologic features of the two areas are discussed separately in the following sections.

Eastern Part

Drainage systems east of the Seaboard Air Line Railroad are poorly defined and the surface drainage is inefficient. Most of the rainfall is disposed of by evapotranspiration and seepage into the ground. The remainder runs off as streamflow.

The annual potential natural water loss for the upper Palatlakaha Creek basin is 50 inches. Little or no runoff would occur from the basin when the annual rainfall is 30 inches or less, assuming normal intensity and distribution.

Ground-water recharge in the eastern part of the area is from the surface to the nonartesian aquifer to the Floridan aquifer. Both surface and ground water are low in mineral content. The predominant directions of movement of ground water in the Floridan aquifer are toward the north and the east. Ground-water gradients are steeper east of the piezometric high than those on the west, indicating that more ground water apparently moves eastward than westward.

The drainage systems have been improved by many miles of canals and ditches. These improvements have caused minor changes in the distribution of runoff by the diversion of water from the Palatlakaha Creek basin to the Withlacoochee River headwater tributaries which carry it to the western area. Breaks in slope of the double-mass curves in figure 16 indicate that significant diversions between the two basins started about 1954.

Western Part

West of the Seaboard Air Line Railroad, in the Green Swamp area, the drainage systems are better defined than those in the eastern part and drainage is somewhat more efficient. Many miles of canals and ditches have improved the drainage in local areas but have not significantly changed the total runoff from the western area.

The annual potential natural water loss for the Withlacoochee River basin above the Trilby gaging station is 45 inches. This is 5 inches less than that for the upper Palatlakaha Creek basin in the eastern part of the area. Evaporation losses from the open-water surface of the many lakes in the Palatlakaha Creek basin and ground-water movement into the Withlacoochee River basin could account for this apparent difference although part of the difference could be caused by seepage into or out of the basins.

The general direction of ground-water movement from the western area is toward the Withlacoochee and Hillsborough rivers. The ground water in the western part contains higher mineral content than that in the eastern part of the area.

Theoretical Effects of Increased Drainage of the Green Swamp Area

If the drainage of the Green Swamp area is increased by further development and improvement of the drainage systems, the following results could be expected:

1. Increase in runoff as a result of less opportunity for evaporation and transpiration.

2. Decrease in recharge of the Floridan aquifer.

3. Decline in elevation of the water table and the piezometric surface of the Floridan aquifer.

4. Flat hydraulic gradients and a decrease of ground-water outflow to areas of lower head.

5. Decline in the levels of lakes in or adjacent to the Green Swamp area.

6. Decrease in base flow of streams draining from the area.

7. Increase in flood peaks within the area and in the downstream reaches of streams draining from the area.

Theoretical Effects of Water Conservation in the Green Swamp Area

If conservation pools are created in the Green Swamp area, the following results could be expected:

1. Decrease in runoff as a result of greater opportunity for evaporation and transpiration.

2. Increase in the availability of water for recharge of ground-water storage.

3. Rises of the water table and the piezometric surface of the Floridan aquifer.

4. Steeper hydraulic gradients and increased ground-water outflow.

5. Increase in base flows of streams draining from the area.

6. Decrease in flood peaks within the area and in the downstream reaches of streams draining from the area by proper operation of water-control structures.

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GLOSSARY

Anticline. An upfold or arch of rock strata, dipping in opposite directions from an axis.

Aquifer. A formation, group of formations, or part of a formation that will yield water in usable amounts.

Artesian ground water. Water that is under pressure sufficient to cause it to rise above the top of the aquifer in which it occurs.

Base flow. The discharge entering stream channels from ground water.

Clastic. Pertaining to fragmental material derived from pre-existing rocks transported mechanically into its place of deposition, for example, sand and clay.

Color. The color of water is due only to materials in solution. Color is determined by comparison with standard colored discs that are calibrated in units according to the platinum cobalt scale.

Confining bed. A bed which, because of its position and its impermeability or low permeability relative to that of the aquifer, gives the water in the aquifer either an artesian or subnormal head.

Confluence. The meeting or junction of two or more streams.

Conformable. Beds or strata lying one upon the other in an unbroken and parallel order.

Discharge. Flowing or issuing out. Also used to designate the volume of water flowing past a cross section of a stream in a unit of time.

Double-mass curve. A plot of the cumulative values of one variable versus the cumulative values of another.

Drainage area. The size of a drainage basin usually expressed in square miles.

Drainage basin. An area enclosed by a topographic divide such that direct surface runoff from precipitation normally would drain by gravity into the river basin.

Drainage divide. The boundary line, along a topographic ridge, separating two adjacent drainage basins.

Drainage system. A surface stream or a body of impounded surface water, together with all surface streams and bodies of impounded surface water that are tributary to it.

Diffluence. Flowing apart. A term used to describe a stream which branches in a downstream direction.

Effective precipitation. A weighted average of current and antecedent precipitation that is "effective" in correlating with runoff.

Evaporation. The process by which water becomes vapor, including vaporization from free water surfaces and from land surfaces.

Evapotranspiration. Evaporation plus transpiration.

Fault. A fracture or fracture zone along which there has been displacement of the two sides relative to one another parallel to the fracture.

Flexure. Synonomous with anticline or fold.

Ground water. That part of the subsurface water that is in the zone of saturation.

Hydraulic conveyance. The water-carrying capacity of a stream channel.

Hydraulic gradient. As applied to an aquifer, it is the rate of change of pressure head per unit of distance of flow at a given point and in a given direction.

Hydrograph. A graph showing stage, flow, velocity, or other property of water with respect to time.

Isohyetal map. A map showing lines of equal precipitation.

Marine. Of or belonging to or caused by the sea.

Mineral content. A summation of the individual values, in parts per million, of the determined dissolved chemical constituent in the water.

Nonartesian ground water. Water in an aquifer that is unconfined.

Parts per million (ppm). A unit weight of a dissolved chemical constituent in a million unit weights of water.

Perched ground water. Ground water separated from an underlying body of ground water by unsaturated rock.

Percolation. The movement of water by gravity through the pores in a rock or soil, excluding the movement through large openings such as caverns.

Piezometric surface. The level to which water will rise in tightly cased wells that penetrate a given aquifer.

Potential natural water loss. The maximum water loss that could occur in a basin under actual conditions of moisture supply and native vegetation.

Recharge (of ground water). Intake. The processes by which water is absorbed and is added to the zone of saturation. Also used to designate the quantity of water that is added to the zone of saturation.

Retention. The part of storm rainfall which is intercepted, stored, or delayed, and thus fails to reach the concentration point by either surface or subsurface routes during the time period under consideration.

Runoff. That portion of the total surface outflow from a given drainage area that has its origin in precipitation on that area.

Runoff in inches. The depth to which an area would be covered if all the water draining from it in a given period

were uniformly distributed on its surfaces.

Seepage. The percolation of water through the soil.

Streamflow. The actual discharge in surface streams. It includes runoff modified by artificial causes.

Surface water. Water that occurs above the surface of the ground.

Time of concentration. The time required for the water to flow from the farthest point on the watershed to a gaging station or to another specified point.

Transpiration. The process by which water vapor escapes from a living plant and enters the atmosphere.

Unconformity. A surface of erosion or nondeposition that separates younger strata from older rocks.

Water loss. The difference between the average precipitation over a drainage basin and the runoff adjusted for changes in storage and for interbasin movement of ground water. The basic concept is that water loss is equal to evapotranspiration, that is, water that returns to the atmosphere and thus is no longer available for use. However, as used in this report the term applies to differences between measured inflow and outflow even where part of the difference may be seepage.

Water year. A 12-month period beginning October 1 and ending the following September 30. Designated by the calendar year in which it ends.

Zone of saturation. The zone in which the permeable rocks are saturated with water under pressure equal to or greater than atmospheric.