STATE OF FLORIDA
DEPARTMENT OF NATURAL RESOURCES
Randolph Hodges, *Executive Director*

DIVISION OF INTERIOR RESOURCES
Robert O. Vernon, *Director*

BUREAU OF GEOLOGY
Charles W. Hendry, Jr., *Chief*

Report of Investigations No. 67

APPRAISAL OF THE WATER RESOURCES OF EASTERN PALM BEACH COUNTY, FLORIDA

By
Larry F. Land, Harry G. Rodis and James J. Schneider

Prepared by the
UNITED STATES GEOLOGICAL SURVEY
in cooperation with
PALM BEACH COUNTY BOARD OF COMMISSIONERS
CITY OF BOCA RATON
CENTRAL AND SOUTHERN FLORIDA FLOOD CONTROL DISTRICT
and the
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LETTER OF TRANSMITTAL

Bureau of Geology
Tallahassee
October 18, 1973

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

Dear Governor Askew:

The Bureau of Geology of the Division of Interior Resources is publishing as its Report of Investigation No. 67 a report prepared by Larry F. Land, Harry G. Rodis and James J. Schneider of the U. S. Geological Survey entitled "Appraisal of the Water Resources of Eastern Palm Beach County, Florida".

We are pleased to have participated in this investigation with the U. S. Geological Survey.

It is hoped this report will furnish necessary data to water-management agencies needed to plan for protection and orderly development of water resources. Information is provided in several areas, including (1) location, amount and quality of water, (2) quantity and trends of water use, (3) relation of water use, land drainage, water levels and hydrologic conditions. The area of investigation primarily includes the eastern 8-10 miles of Palm Beach County, approximately 400 square miles.

Respectfully yours,

Charles W. Hendry, Jr., Chief
Bureau of Geology

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September 18, 1973
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APPRAISAL OF THE WATER RESOURCES OF EASTERN PALM BEACH COUNTY, FLORIDA

by
Larry F. Land, Harry G. Rodis, and James J. Schneider

ABSTRACT

Rapid population growth in the eastern coastal areas of Palm Beach County places increasing demands on the water resources of the area and locally has created critical problems. The water resources of the agricultural and undeveloped areas of the county remain largely unexplored and are not covered in this report.

Palm Beach County covers approximately 2,230 square miles and is the largest county east of the Mississippi River. Except for the narrow coastal ridge the land surface is flat and averages 20 feet above mean sea level. The county is drained mostly by a network of canals which are used mainly to control flooding, but also to distribute and store water and to deliver waters to irrigated areas.

Ground water from the shallow aquifer, a hydrologic unit comprised of the Biscayne, Pamlico and Anastasia Formations, underlies the entire area and is the principal source of water for most uses. The top of the Floridan aquifer, a limestone under high artesian pressure, underlies the area at depths ranging from 800 to 1,000 feet below land surface but the water is too brackish or salty for most uses.

Specific capacities of municipal wells range from about 10 to more than 350 gallons per minute per foot of drawdown. Municipal pumping averaged about 75 million gallons per day during 1970. West Palm Beach is the only community which uses surface water for municipal supply.

The differences between average annual rainfall and potential evaporation in eastern Palm Beach County is 8 to 14 inches per year. The annual rainy season extends from May to October when the eastern part of the county receives more than 40 inches of annual rainfall. Despite the periodic surpluses, several municipal well fields are beset with problems of salt-water intrusion caused by increasing pumpage during droughts.

Total dissolved solids of the fresh water in the shallow aquifer system ranges from 200 to 300 mg/1 (milligram per liter) in the coastal ridge to more than 500 mg 1 in the western areas.

In the surface water system, the water containing the least amount of dissolved solids, generally less than 200 mg/1, occurs in Canal 18 and Canal M immediately downstream from the Loxahatchee Slough. The inorganic nitrogen concentrations of this water is less than 0.15 mg 1. The most seriously contaminated water is in Canal 17 where the coliform bacteria count often exceeds 50,000 per colonies per 100 ml (milliliters) and inorganic nitrogen concentration usually exceeds 2 mg 1. The dissolved-solid content of the surface water is less than that of ground water.

Water in the shallow aquifer is slightly contaminated at shallow depths in the immediate vicinity of the Cross State Solid Waste Disposal Area. The contaminants probably stay near the water table and are filtered out by the sand.

INTRODUCTION

Population growth is rapid in the entire southeast coast of Florida. In Palm Beach County (fig. 1) the population increased from slightly less than 250,000 in 1960, to more than 333,000 in 1970, a growth of more than 50 percent. The population growth is applying increasing pressure on many natural resources including fresh water. To assure that the fresh-water supply will remain adequate, much hydrologic information is needed for water management and land-use decisions. The Palm Beach County Board of Commissioners in January 1970 entered into a cooperative agreement with the U.S. Geological Survey for a county-wide water-resource investigation. At a later date the commissioners requested special emphasis be placed on the eastern (urban-suburban) section where water-supply problems are numerous, and some critical.

One of the most pressing problems is the existing and potential pollution of the hundreds of miles of canals that dissect eastern Palm Beach County, and that cross agricultural as well as urban areas. Pollution in the canals is being increased by runoff that carries nutrients from the farms and ranches and by discharge of waste water from sewage plants. The County Health Department states that many of the canals and lakes, including Lake Worth are so contaminated they are unfit for recreation.

PURPOSE AND SCOPE

The purpose of this report is to furnish to water-management agencies much of the information needed to plan for the protection and orderly development of water resources. Information is

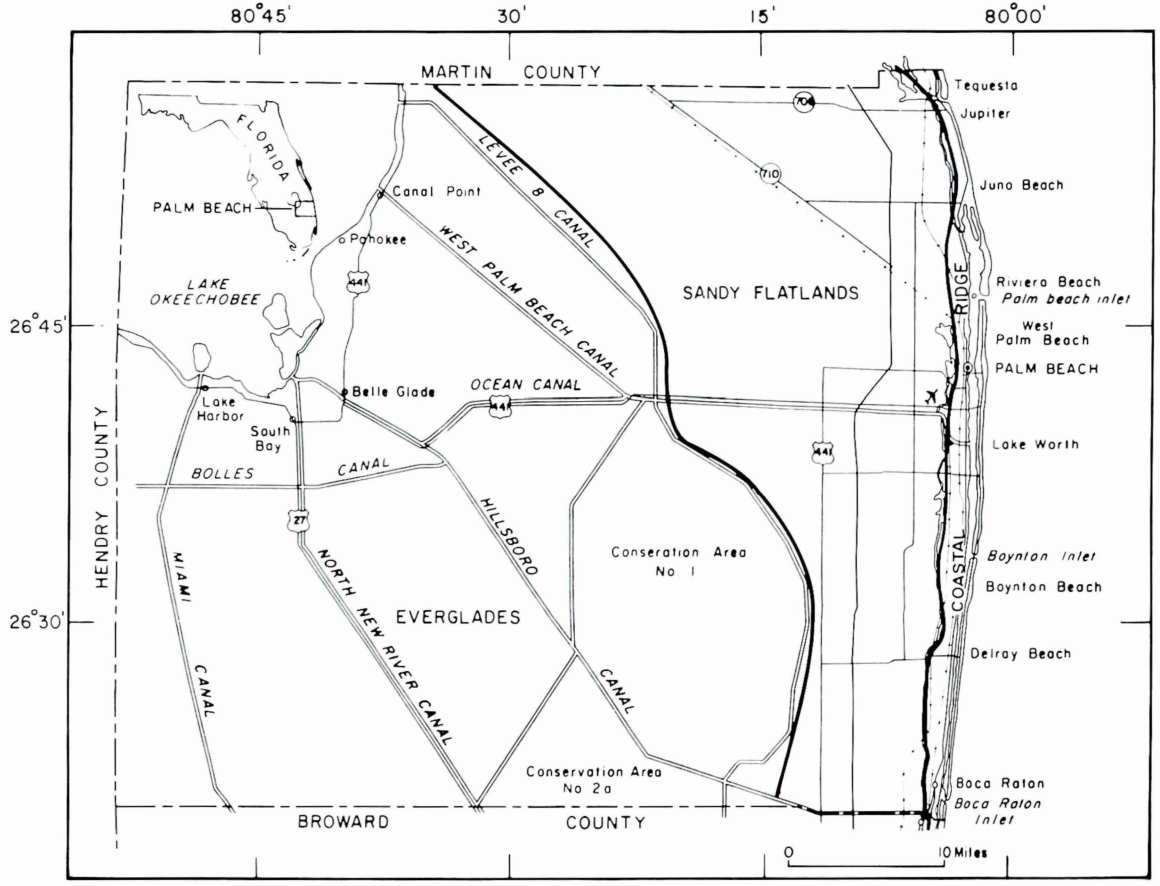


Figure 1. Physiographic subdivisions of Palm Beach County.

provided on (1) location, amount, and quality of water in the shallow aquifer system, (2) occurrence and extent of sea-water intrusion into the shallow aquifer, (3) quantity and trends of water use, (4) fluctuations of water-level and quality of water in lakes and canals, and (5) relation of water use, land drainage, water levels, and hydrologic conditions. The area of investigation primarily includes the eastern 8-10 miles of county, approximately 400 square miles.

ACKNOWLEDGMENTS

Appreciation is expressed to the many municipal water managers, well drillers and consulting engineers who provided data on wells. Special acknowledgment is made of the several Palm Beach County and Central and Southern Florida Flood Control District officials who were responsible for getting this study underway.

DATA COLLECTED

The first two steps of the investigation were a search of the literature for information on the geology and hydrology of the county and surrounding area and establishment of a network of surface-water and ground-water gaging stations to supplement the existing network. The surface-water stations were located on selected canals and lakes to monitor the fluctuations of water-level and canal flow (fig. 2). Some of these canal stations immediately inland from the Intracoastal Waterway are operated by other government agencies. The ground-water gaging stations, established on wells to monitor water-level fluctuations, are shown in figure 3.

Water samples were collected from selected canals, lakes, and wells for chemical analysis. The sampling sites are also shown in figures 2 and 3. From numerous surface-water sites, water samples were also collected and analyzed for pesticides, coliform bacteria, and nutrients. On three occasions four to six samples were collected at regular intervals during a 24-hour period and analyzed for specific conductance, nutrients, dissolved oxygen, and alkalinity.

The investigation also included drilling exploratory wells near the coast to monitor the extent of salt-water intrusion. Information collected during the drilling process was used to determine the geology of the area and the mineral content of the water within the aquifer.

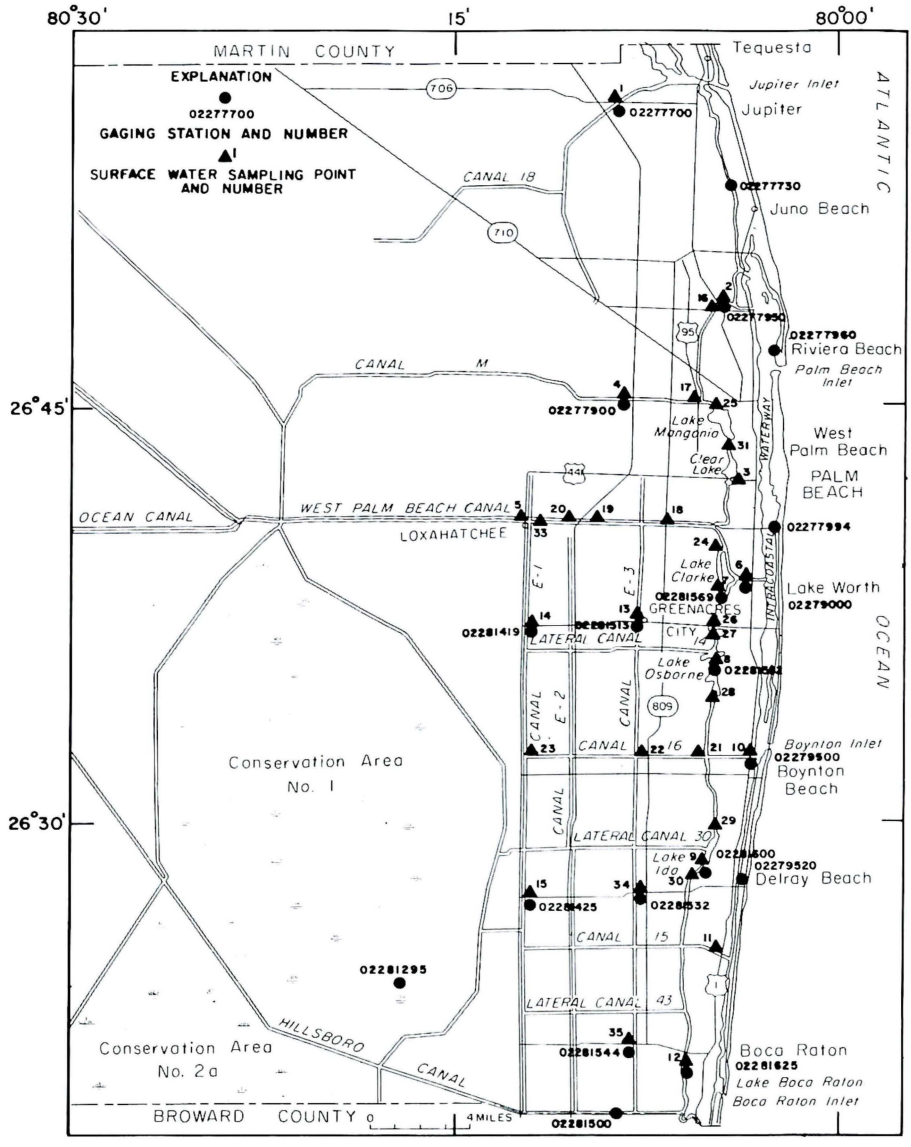


Figure 2. Surface-water data-collection sites in eastern Palm Beach County.

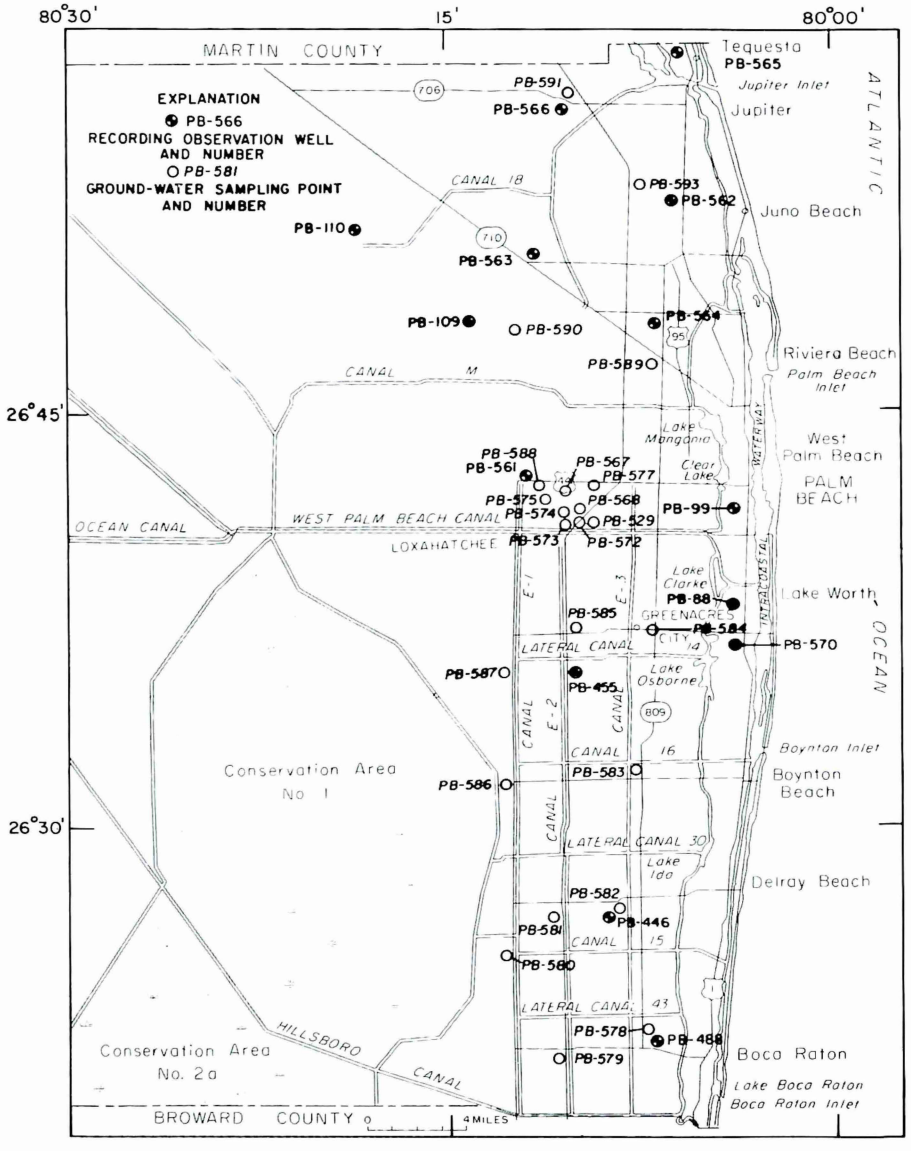


Figure 3. Ground-water data-collection sites in eastern Palm Beach County.

STATION IDENTIFICATION SYSTEM

Gaging stations on wells are numbered by determining the location of the well by latitude and longitude and combining these numbers, omitting the degree, minute, and second symbols. The latitude number is listed first, then the hemisphere designation ("N" for northern hemisphere), and then the longitude number. The PB (Palm Beach) number is for local identification.

For surface-water gaging stations within a given drainage basin, the smallest, eight-digit, station identification number is assigned to the farthest upstream station. Successively larger numbers are assigned to stations in sequence downstream.

GEOLOGIC SETTING

SOUTH FLORIDA

Peninsular Florida is the narrow, uppermost part of a much wider projection from the continental mass of North America. It has been called the Florida Plateau. It is a core of metamorphic and igneous rocks similar to those underlying the Piedmont region of eastern United States. The core is covered with marine sediments that range in thickness from about 4,000 feet in north-central Florida to more than 15,000 feet in south Florida.

The Tertiary and Quaternary rocks, formed from the marine sediments of Tertiary and Quaternary age are shaped into a broad, elongate dome, or anticline, that trends southeast. The Ocala Limestone (upper Eocene) slopes southward about 5 feet per mile and its top is about 1,200 feet below sea level in northeastern Monroe County. Formations of Oligocene and Miocene age flank the uplift and slope in all directions from the crest and thicken seaward. In Palm Beach County the lower Miocene formations dip to the east at about 3 feet per mile and to the south at about 5 feet per mile (Parker and others, 1955).

PALM BEACH COUNTY

For the purposes of this report the geologic formations in Palm Beach County are grouped into three hydrologic units; upper, middle, and lower. The upper unit is a shallow nonartesian aquifer; the lower unit is the deep artesian Floridan aquifer and the middle unit is a confining bed separating the two aquifers.

In Palm Beach County the shallow aquifer consists of the Pamlico Sand, Anastasia Formation, Miami Oolite, and Fort Thompson Formation, of Pleistocene age, and the Caloosahatchee

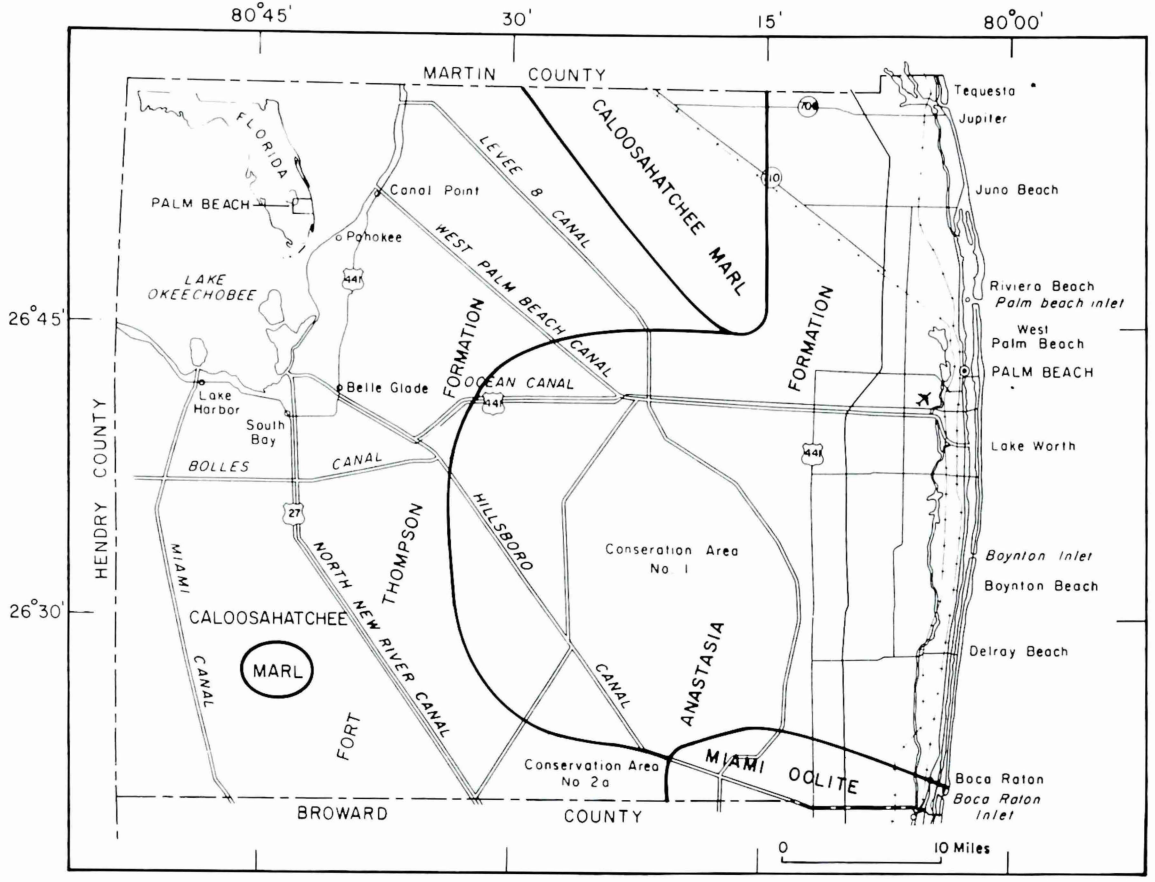


Figure 4. Geologic map of Palm Beach County, (pre-Pamlico, after Vernon and Puri, 1964).

Marl of Pliocene age (Schroeder and others, 1954, fig. 4, 5). Recent test drilling indicates that the Miami Oolite occurs in the extreme southeastern part of the county.

The artesian aquifer consists of the Hawthorn Formation (lower part) the Tampa Limestone of Miocene age, the Suwanee

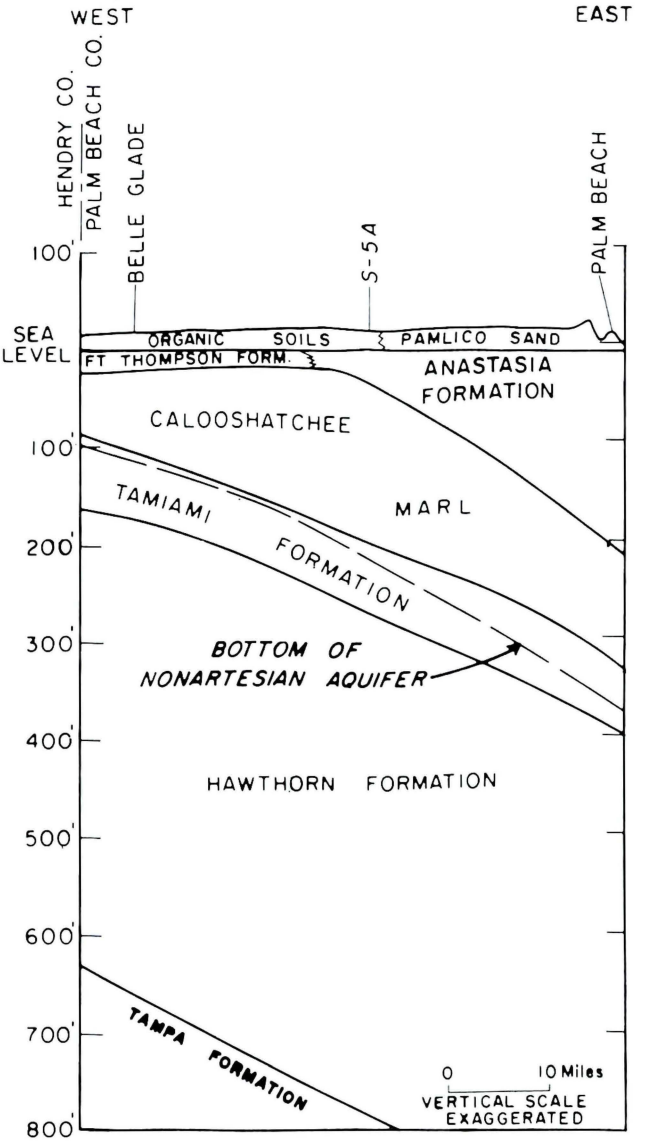


Figure 5. Generalized geologic cross-section through central Palm Beach County.

extends inland 2 to 3 miles from the ocean. The Everglades occupies much of the west and southwest two-thirds of the county. The sandy flatlands lie between the coastal ridge and the Everglades. The elevation of coastal ridge ranges from 25 to 40 feet msl (mean sea level) and extends as much as 30 feet above the adjacent sandy flatlands. The sandy flatlands range in natural elevation from 10 to 15 feet msl adjacent to the coastal ridge. The highest elevation in sandy flatlands area is about 25 feet msl at the northern boundary of the county and there the area slopes to the east and south. Elevations are least immediately west of the coastal ridge and at the Broward County line. The Everglades is virtually flat and ranges only from 16 feet in the north to 14 feet msl at the Broward County boundary.

RAINFALL AND EVAPOTRANSPIRATION

Rainfall in the east section of Palm Beach County averages about 60 in per yr (inches per year). On the average, in 1 out of 3 years, the average annual rainfall will either exceed 75 inches or will be less than 47 inches. Slightly more than 70 percent of the rain normally falls during May through October, the wet season. The climate is semitropical and the average temperature is about 75° F.

The combination of evaporation and transpiration — evapotranspiration — from land surface with vegetative cover under optimum moisture conditions (field capacity) equals the evaporation from lakes. In Palm Beach County this is about 50 in per yr (Kohler, Nordenson, and Baker, 1959). However, the actual evapotranspiration rate is somewhat lower because the moisture conditions are less than optimum during periods of low rainfall.

Water surplus — the difference between average annual rainfall and potential evaporation — varies considerably across Palm Beach County. The surplus is 4 in per yr at South Bay, 8 in per yr at Belle Glade, 14 in per yr at Loxahatchee — beyond the area of investigation — to 12 in per yr at West Palm Beach (Visher and Hughes, 1969). In eastern Palm Beach County the lowest surplus is 8 in per yr in the Jupiter area and highest is 13 in per yr at Canal E-1 and West Palm Beach Canal. The greatest surplus water within Florida, except for the west part of the panhandle of Florida, occurs at the town of Loxahatchee.

The water surplus, as defined above, is the minimum quantity of water available for outflow. For South Florida, the outflow probably does not exceed the difference between rainfall and potential evaporation by more than 3 inches. The surplus fluctuates considerably in quantity from year to year because rainfall fluctuates and potential evaporation remains stable.

HYDROLOGIC SETTING

SURFACE-WATER SYSTEM

Because of the very flat terrain, low elevations, and high rainfall (55 to 63 inches annually), much of the land surface was under water in the Everglades and sandy flatlands before an extensive network of canals was dredged. Control structures, back pumps, and storage facilities were built to help control seawater intrusion and to maintain reasonably stable and acceptable water levels. The selected range of water levels must satisfy a compromise between irrigation, drainage, control of sea-water intrusion, and conservation needs.

The major surface-water flow systems before land development were the Allapattah Marsh, the Hungryland Slough, the Loxahatchee Slough and the Hillsboro Lakes March (fig. 6). The only outflow to the ocean in Palm Beach County was through the Loxahatchee River (beyond the area of figure 6) and a small part of Hillsboro Lakes Marsh in the southeast. All the other surface flow moved to the south. These flow patterns were altered extensively after the canals and levees were built.

The major reasons for constructing a canal and storage system were to prevent flood damage, to control ground-water levels, to distribute water for irrigation, and to store water. The major components of the surface-water system in Palm Beach County (fig. 7) include Lake Okeechobee, Conservation Area 1, Miami Canal, North New River Canal, Hillsboro Canal, and the West Palm Beach Canal. One of the most important control complexes is at the S-5 structures located at the junction of West Palm Beach Canal, Levee 8, Ocean Canal, and Conservation Area 1. Figure 7 illustrates the layout of the surface-water system in 1972. Only the major canals are shown.

The largest unit water-control system in Palm Beach County is owned and operated by the Lake Worth Drainage District extending approximately between Canals E-1 and E-4 about 225 sq. miles (see fig. 7). The primary objective of the District is to maintain previously prescribed water-levels to protect crops and to conserve water. The Central and Southern Florida Flood Control District (CSFFCD) controls most of the other major canal systems.

Each of the main canals flowing to the ocean has a control structure near the coast. Some have gates with automatic controls to release flood waters rapidly.

Water-management plans in many areas, particularly in the lakes area in the extreme eastern part of the county, call for

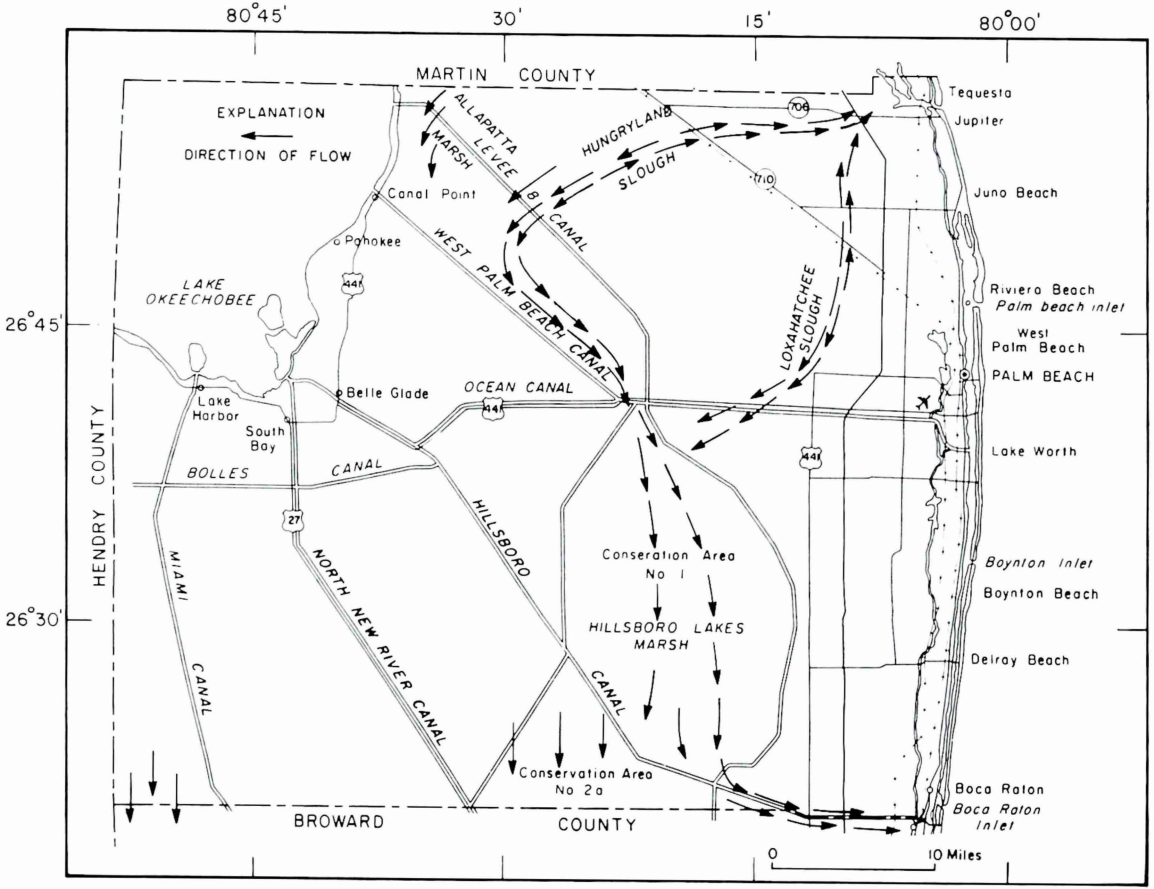


Figure 6. Direction of surficial flow before canals and levees were constructed.

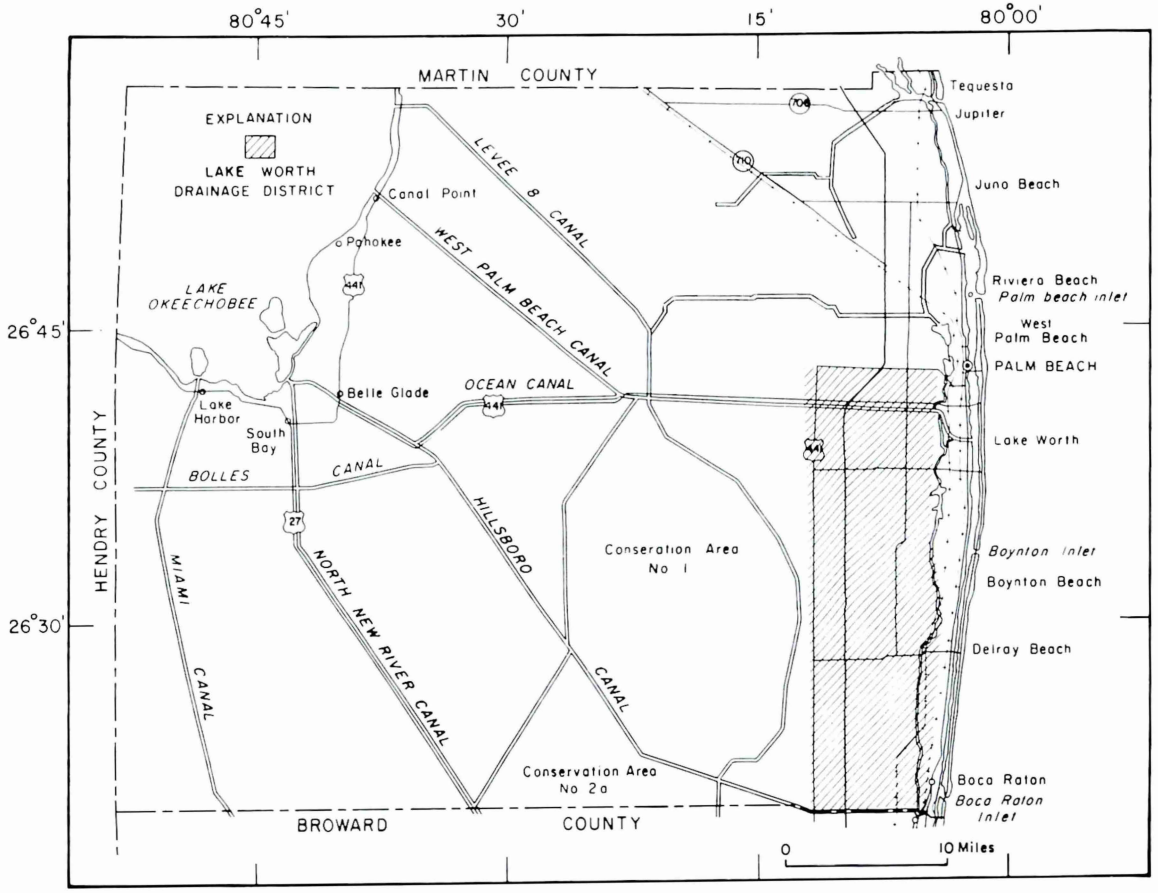


Figure 7. Layout of current (1972) surface-water system.

maintaining high water levels during dry periods and low water levels when rainfall is high. This practice is the opposite of what occurs in nature; however, this scheme can be implemented by control operation.

WATER-LEVEL FLUCTUATIONS

The water-levels in the canals and lakes are influenced mainly by (1) rainfall, (2) evapotranspiration, and (3) water-management practices. Water-management practices, the most important of the three, involve the many control structure operations by the Central and Southern Florida Flood Control District, the Lake Worth Drainage District, and other water-management agencies.

Included in this report are hydrographs and duration curves showing fluctuations in water level and flow of several canals and lakes in east Palm Beach County. Daily mean discharge hydrographs are given in figures 8 and 9 for Canal M at S.R. 809 near Mangonia Park and El Rio Canal at Boca Raton, respectively. The discharge hydrograph of Canal M shows a higher base or sustained flow and broader peaks before March 1971. This indicates rather stable and high water-level conditions in the

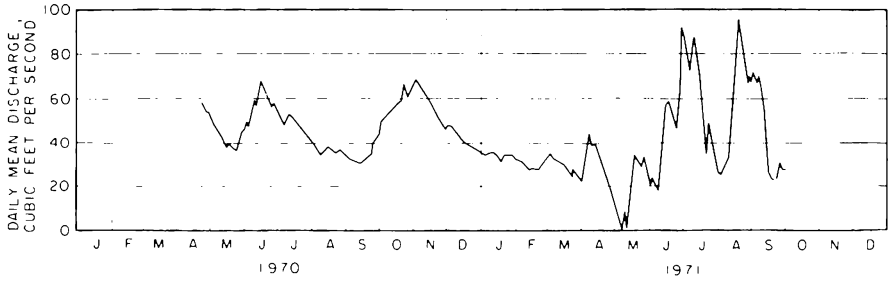


Figure 8. Discharge hydrograph for Canal M near Mangonia Park.

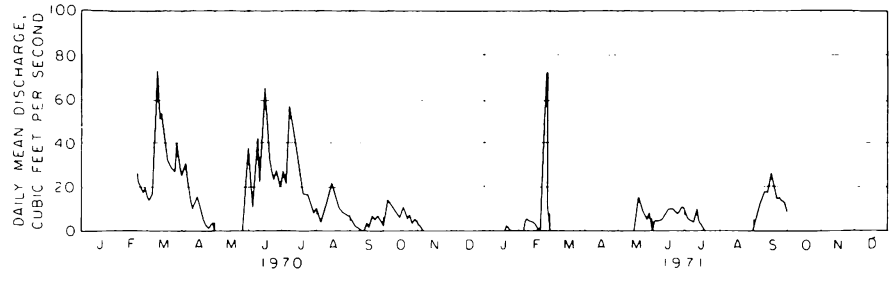


Figure 9. Discharge hydrograph for El Rio Canal at Boca Raton.

Loxahatchee Slough area. The effects of the most intense part of the 1970-71 drought, in terms of monthly rainfall, occurred during the first part of May 1971 and is clearly illustrated by the sharp decline in discharge. Rainfall increased sharply, although still deficient in comparison to long-term averages, to produce the rises shown in the summer of 1971. The water levels were still not high enough to produce flows comparable to those of 1970. Flows may have been altered by diversion of water to or from Levee 8. The total flow past this station for the period shown in figure 8 was 45,200 ac-ft (acre-feet).

The flow hydrograph for the El Rio Canal reflects most of the same overall rainfall conditions evident at the Canal M station. However, the quantity of flow in May - July 1970 was greater in the El Rio Canal than in Canal M. The sharper peaks show the effect of storm rainfall on the rather small, although undefined, watershed. The volume of water in the El Rio Canal that passed the Boca Raton station for the period shown in figure 9, Feb. 1970-Sept. 1971, was 10,900 ac-ft.

Hydrographs are given in figures 10-13 for Canal E-1, near Greenacres City and Delray Beach, and Canal E-3 at Greenacres City and Boca Raton. These and other hydrographs indicate that the fluctuations of water-levels in the Lake Worth Drainage District (fig. 7) are small. Changes, although minor, respond closely to gate operations and rainfall intensity. Water-levels in the canals are not affected by seasonal rainfall trends because of diversions from Conservation Area 1 and control operation.

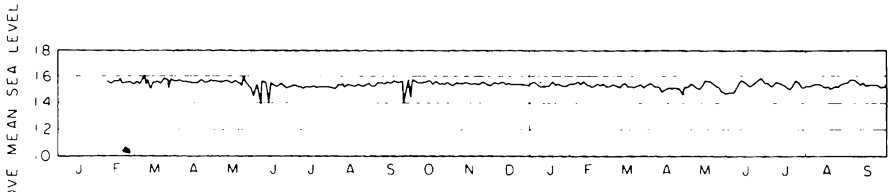


Figure 10. Stage hydrograph for Canal E-1 near Greenacres City.

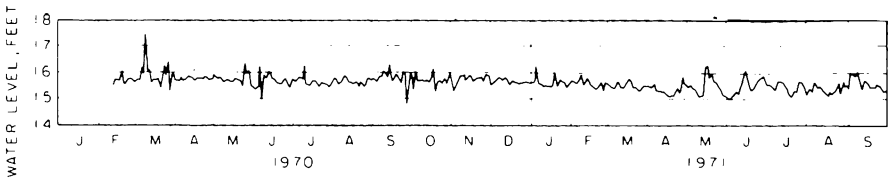


Figure 11. Stage hydrograph for Canal E-1 near Delray Beach.

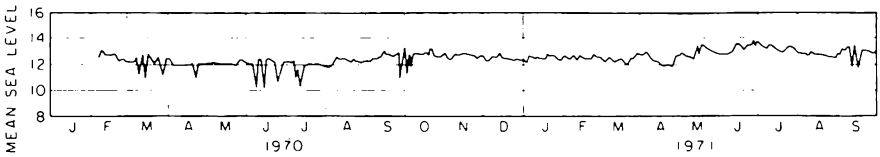


Figure 12. Stage hydrograph for Canal E-3 at Greenacres City.

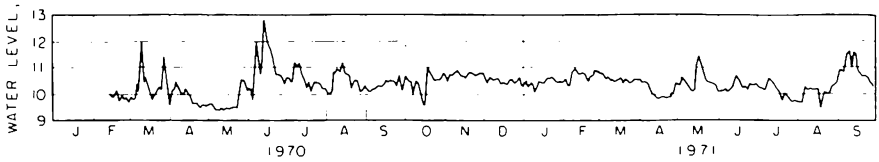


Figure 13. Stage hydrograph for Canal E-3 at Boca Raton.

About 80 percent of the time from November 1939 to September 1971, flow in the West Palm Beach Canal at West Palm Beach ranged from 200 to 1,700 cfs (cubic feet per second). About 80 percent of the time in 1970 the flow ranged from 300 to 1,400 cfs and at no time in 1971 did the flow exceed about 1,100 cfs. Flow duration curves in figure 14 show these relationships. The curves reflect the rainfall patterns and general water-level conditions in an east-west band through the county. Flow durations may also change with time due to changes in water-management practices.

The stage of Lake Ida ranged from 7.6 to 8.6 feet above sea level

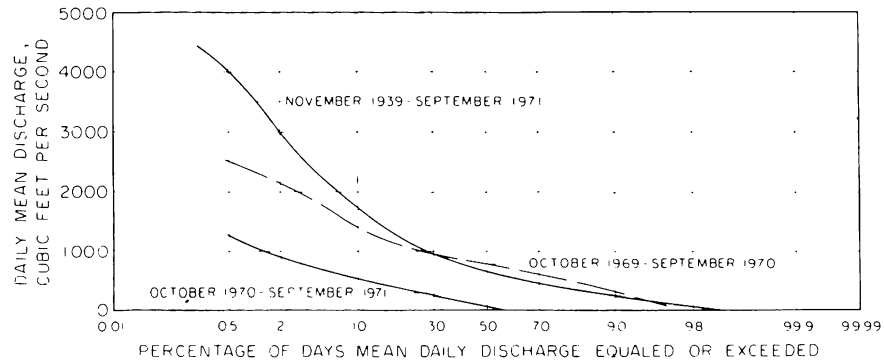


Figure 14. Flow-duration curves for West Palm Beach Canal at West Palm Beach.

about 80 percent of the time. (fig. 15). The stage of Lake Clark ranged more widely, from 7.0 to 8.9 feet 80 percent of the time (fig. 16). The operation of control structures below these lakes are the principle cause of the water-level fluctuations and the differences in the ranges.

TIDAL PATTERNS ALONG THE INTRACOASTAL WATERWAY

The Intracoastal Waterway in Palm Beach County is separated from the ocean by a series of offshore islands from the Broward County line to 4 miles north of Riviera Beach. North to the Jupiter inlet, the waterway has been dredged about one mile inland. Inlets provide tidal interchange between the waterway and the ocean. Tidal interchange is through Jupiter, Palm Beach, Boynton, and Boca Raton Inlets in Palm Beach County, and the Hillsboro Inlet in Broward County. The inlets in Palm Beach County are shown in figure 2.

Gaging stations record the tide level at four locations (fig. 2) along the Intracoastal Waterway. All gages are referenced to mean sea level, 1929 datum. Records from the Primary Tide Gage at Miami Beach were used for correlation.

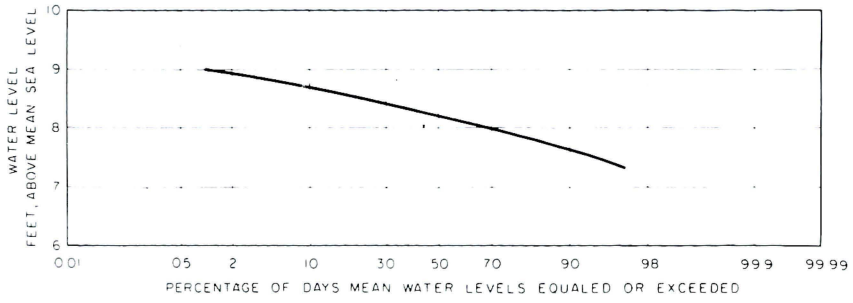


Figure 15. Stage-duration curve for Lake Ida.

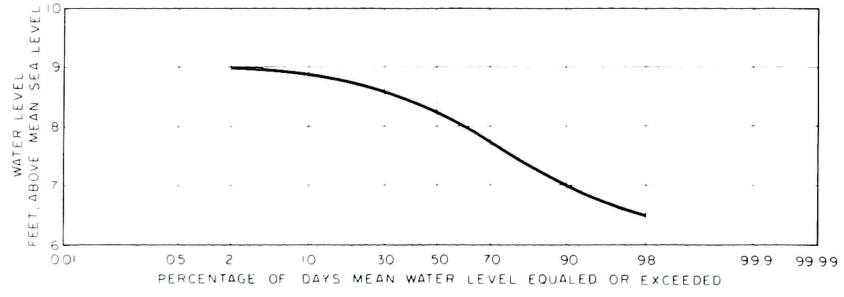


Figure 16. Stage-duration curve for Lake Clark.

In the Intracoastal Waterway the range between the average high and average low tides is approximately 2.7 ft or from -1.2 to 1.5 feet msl. Tidal peaks and troughs occasionally vary over 1 foot from their averages. The greatest tidal fluctuations in the waterway occur at the inlets. Dampening and lagging effects reduce the tides away from the inlets. The dampening effects on low tides is greater than on high tides because of a decrease in the waterway's conveyance.

The effects of strong easterly winds on the tide patterns at three stations along the waterway and Miami Beach are illustrated in figure 17. The winds began on December 22, were strongest (40 mph) on December 23, and diminished on December 24 and 25. As expected, the tides fluctuated with the wind. The tides on December 23 were approximately 0.8 foot above normal.

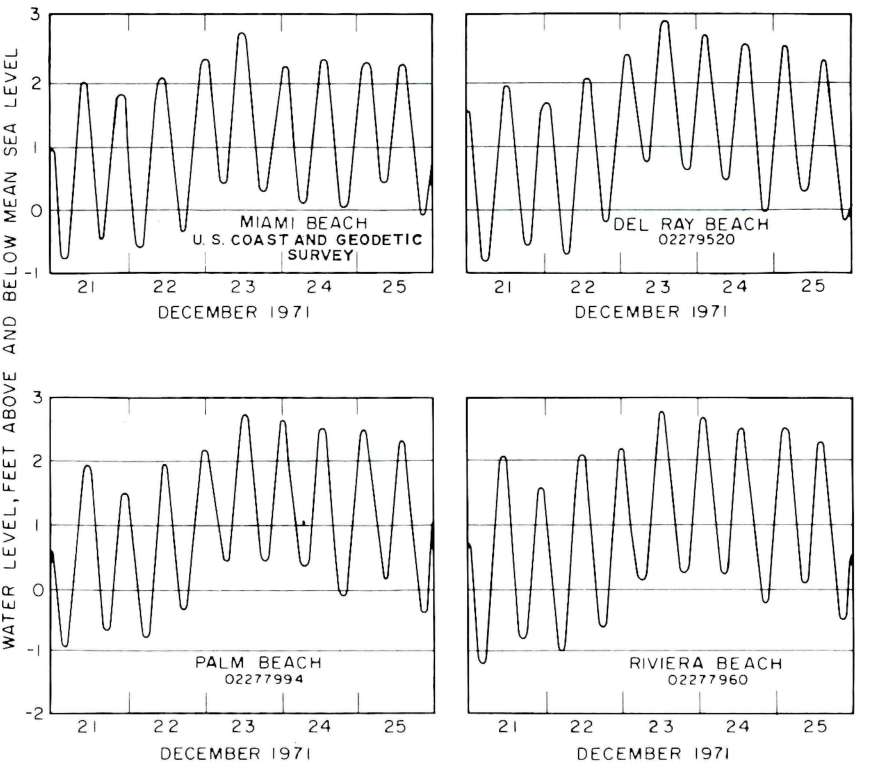


Figure 17. Hydrographs showing effects of strong easterly winds of December 22-25, 1971 on tidal patterns.

GROUND-WATER SYSTEMS

NONARTESIAN AQUIFER

Throughout Palm Beach County the shallow geologic formations make up an unconfined aquifer that contains fresh water. This aquifer is estimated to be at least 250 feet thick at the coast and to taper to less than 100 feet in places near the western part of the county. Actual thickness of the shallow aquifer is yet to be determined. The nonartesian aquifer extends downward to the top of the confining bed which covers the Floridan aquifer.

In eastern Palm Beach County the shallow aquifer is composed of the Pamlico Sand at the surface, the Anastasia Formation, and the Caloosahatchee Marl and a very small amount of Miami Oolite. These formations contain beds of sand, shell, limestone, sandstone, and marl. The strata vary in thickness and permeability. Permeable sections are generally thin and, in places, are isolated lenses or stringers. Much of the limestone has been solution-riddled and later filled with sand.

According to McCoy and Hardee (1970, p. 7) the Boca Raton area is underlain by the northernmost extension of the Biscayne aquifer of southeast Florida. Although the aquifer in this area is of relatively low permeability compared to the same aquifer in Broward and Dade County, it is several times more permeable than the shallow aquifer in most of Palm Beach County.

RECHARGE AND DISCHARGE

The principal source of recharge to the shallow aquifer is local rainfall. In the coastal area the shallow aquifer is replenished by seepage principally from the Equalizing Canal E-4, Clear Lake, C-17, lower reach of C-18, and the West Palm Beach Canal during the dry seasons when control structures in the primary canals are closed. Ground-water discharge is major during the rainy season when control structures are open; then the water moves to the nearest stream or canal and then to the ocean. A large quantity of ground water is withdrawn by evapotranspiration. Pumping from wells represents only a minor discharge from the system.

WATER-LEVEL FLUCTUATIONS

Fluctuations of the water-table reflect changes in the volume of water in storage in the aquifer. Major fluctuations are caused by a large net gain or loss of water by recharge or by discharge from the

aquifer. Atmospheric pressure changes cause minor fluctuations. Tides also cause minor fluctuations near the coast.

Because water-level fluctuations are directly related to rainfall, fluctuations can be expected to coincide with the seasonal rainfall pattern. Long-term water-level records of water levels at recording observation wells, PB 99 in West Palm Beach and PB 109 9 miles west of Lake Park are given in figures 18 and 19. These water-level records indicate the annual cyclic fluctuations and extremes. Both wells show no particular trends other than those resulting from climatic changes. PB 99 represents conditions in a well drained urban setting and PB 109 represents conditions in an undeveloped area where the only major loss is evapotranspiration.

An extreme drought from October 1970 to May 1971 severely

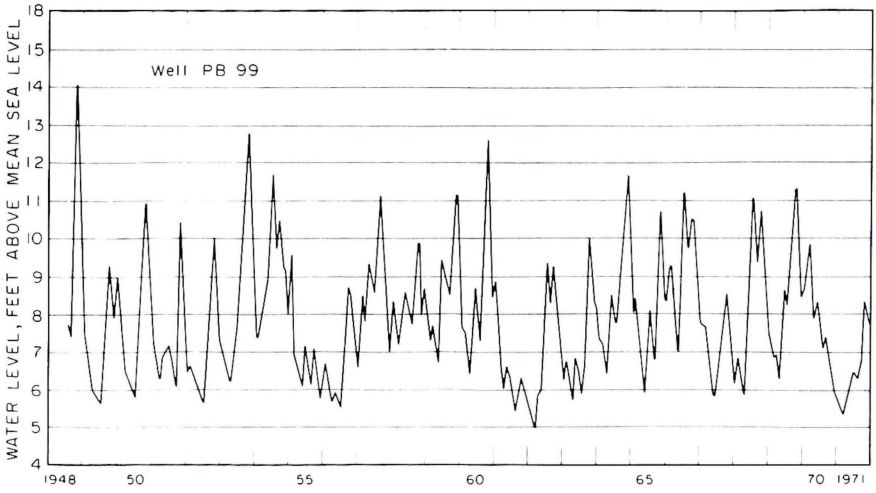


Figure 18. Hydrograph of well PB 99 in eastern Palm Beach County.

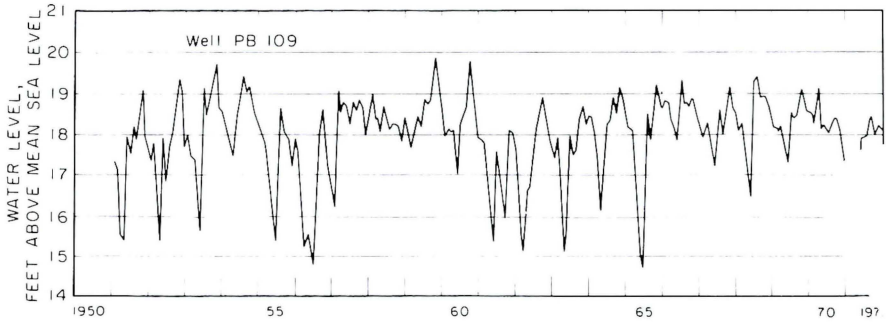


Figure 19. Hydrograph of well PB 109 in northeastern Palm Beach County.

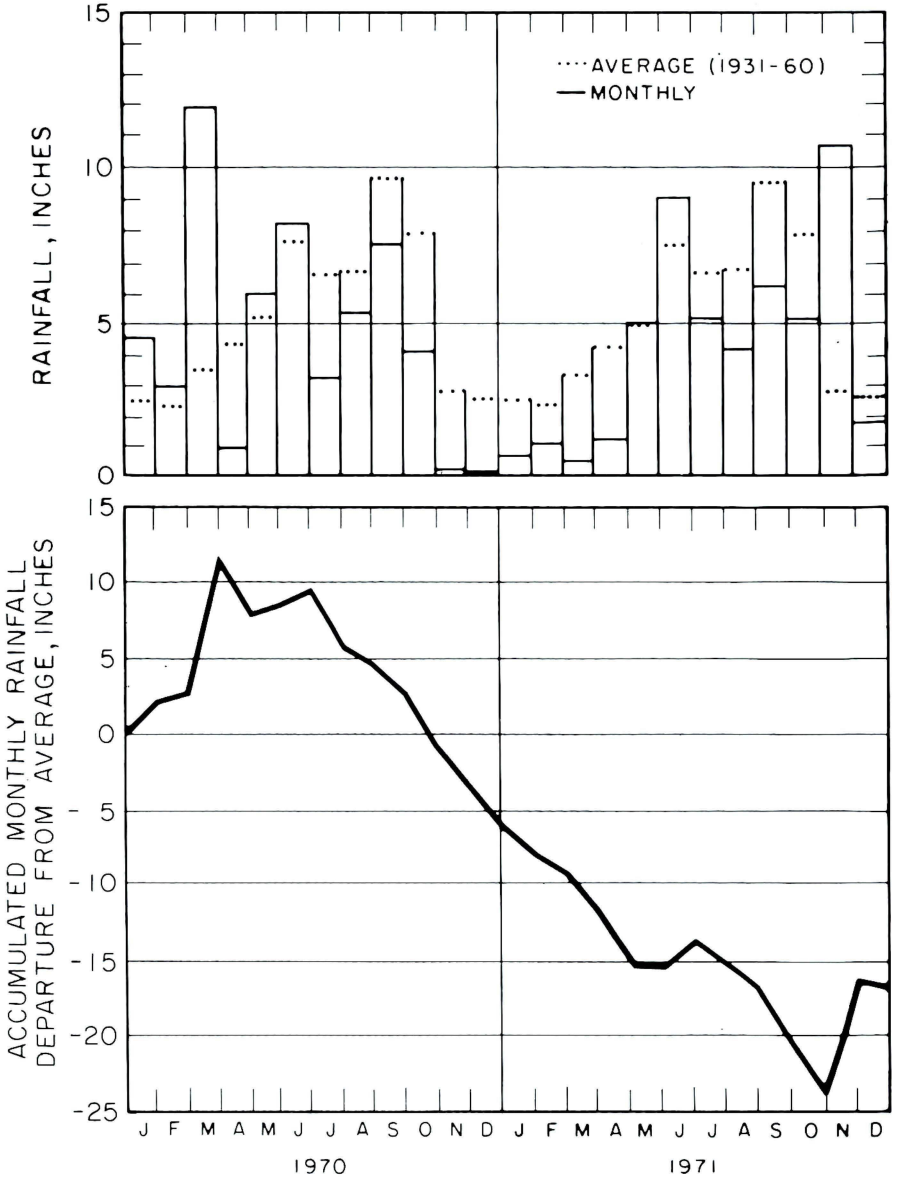


Figure 20. Monthly rainfall and accumulated monthly departures from average for 1970 and 1971 at Palm Beach International Airport.

affected Palm Beach County as well as elsewhere in south Florida. Levels were at record lows in three observation wells — about 2 feet lower than the low levels of an average dry season. The accumulated rainfall departure from the 30-year average at Palm Beach International Airport was deficient 15 inches from January

1970 through April 1971. The total deficiency was about 25 inches, starting from a 10-inch excess in May 1970. Much of the excess rainfall in the early part of 1970 was lost to increased evapotranspiration and outflow. The major effect of the drought ended in May 1971 although the rainfall deficiencies generally continued to increase until November. The drought virtually ended in May because the total monthly rainfall averages increased from less than 1 inch for the previous 4 months to over 5 inches for May - November. A graph of the accumulated departure of rainfall from average is given in figure 20.

During the 1970-71 drought ground-water levels had declined as much as 5 feet in the Canal 18 area in the northeast part of the county and about 2 feet in an area between Equalizing Canals E-1 and E-3. The aquifer in this area was supplemented with water by the Lake Worth Drainage District's pumping from Conservation Area 1, Hillsborough Canal, West Palm Beach Canal and Equalizing Canal E-4. The configuration of the water table on October 1, 1970, during a normal wet season, is shown in figure 21. The effects of the drought on ground-water levels is shown by the water-table configuration on April 30, 1971 (fig. 22), only a short time before the drought ended in mid-May.

HYDRAULIC PROPERTIES

The shallow aquifer is the source of fresh ground-water in the county. Most of the high-capacity supply wells in the coastal area tap the aquifer at depths from 100 to 200 feet. Wherever possible the wells are terminated in rock and finished by open-hole. Numerous high-capacity wells are screened and gravel packed. Expected yield of an 8-inch diameter well in the Boca Raton area is more than 1,000 gpm (gallons per minute). Wells in Delray Beach are expected to yield about 600 gpm. Wells farther north probably yield 500 gpm or less and most require a longer length of screen than those elsewhere. Wells in the interior part of the county generally yield less than wells in the coastal part.

The permeability of the shallow aquifer decreases northward and westward because of the increasing content of fine sand and marly material. Data from aquifer tests in a few municipal well fields were used to determine its transmissivity and specific yield. Transmissivity is a measure of the rate water will move through a unit width of aquifer under a unit hydraulic gradient; specific yield is the ratio of the volume of water that will drain from a unit volume of saturated aquifer. The specific capacity of a well, which is the discharge per foot of drawdown (gpm ft), is often used as an

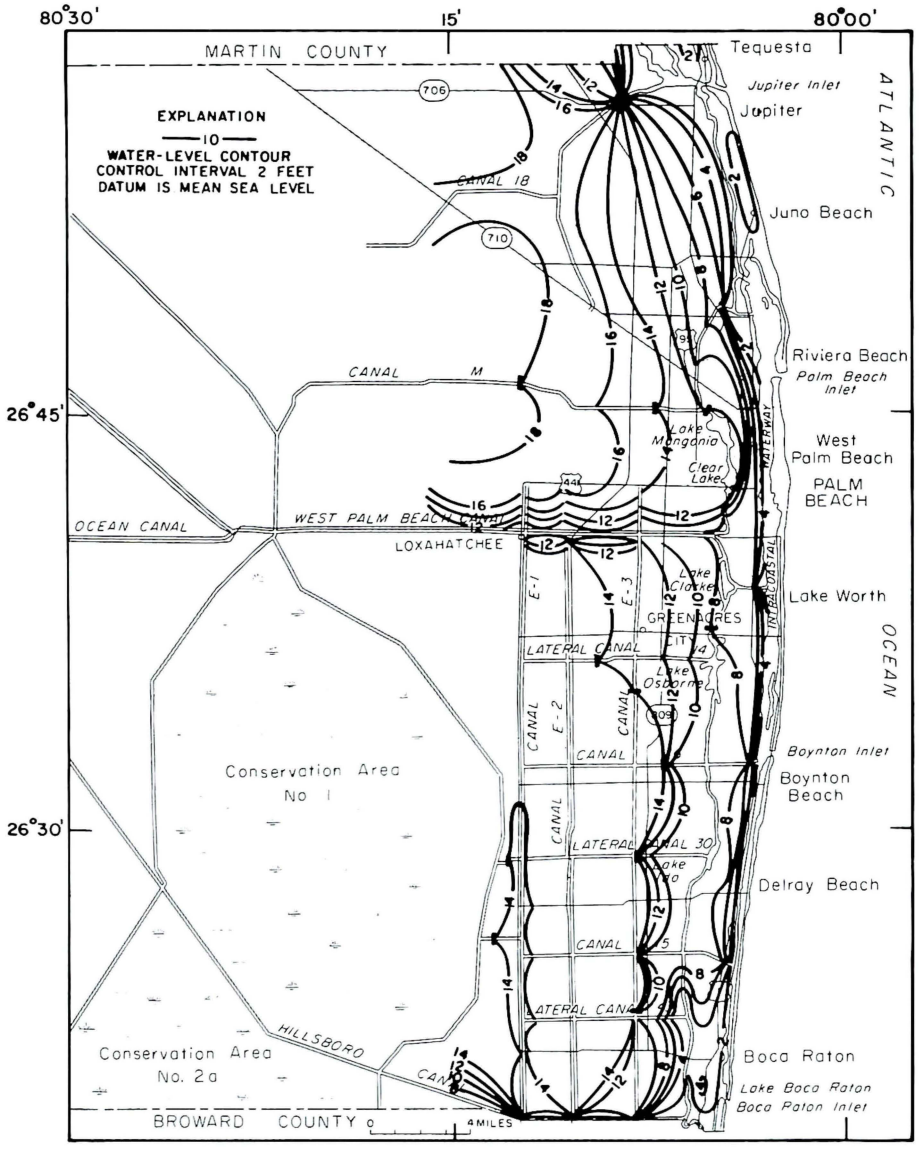


Figure 21. Water table contour map of eastern Palm Beach County on October 1, 1970, end of wet season.

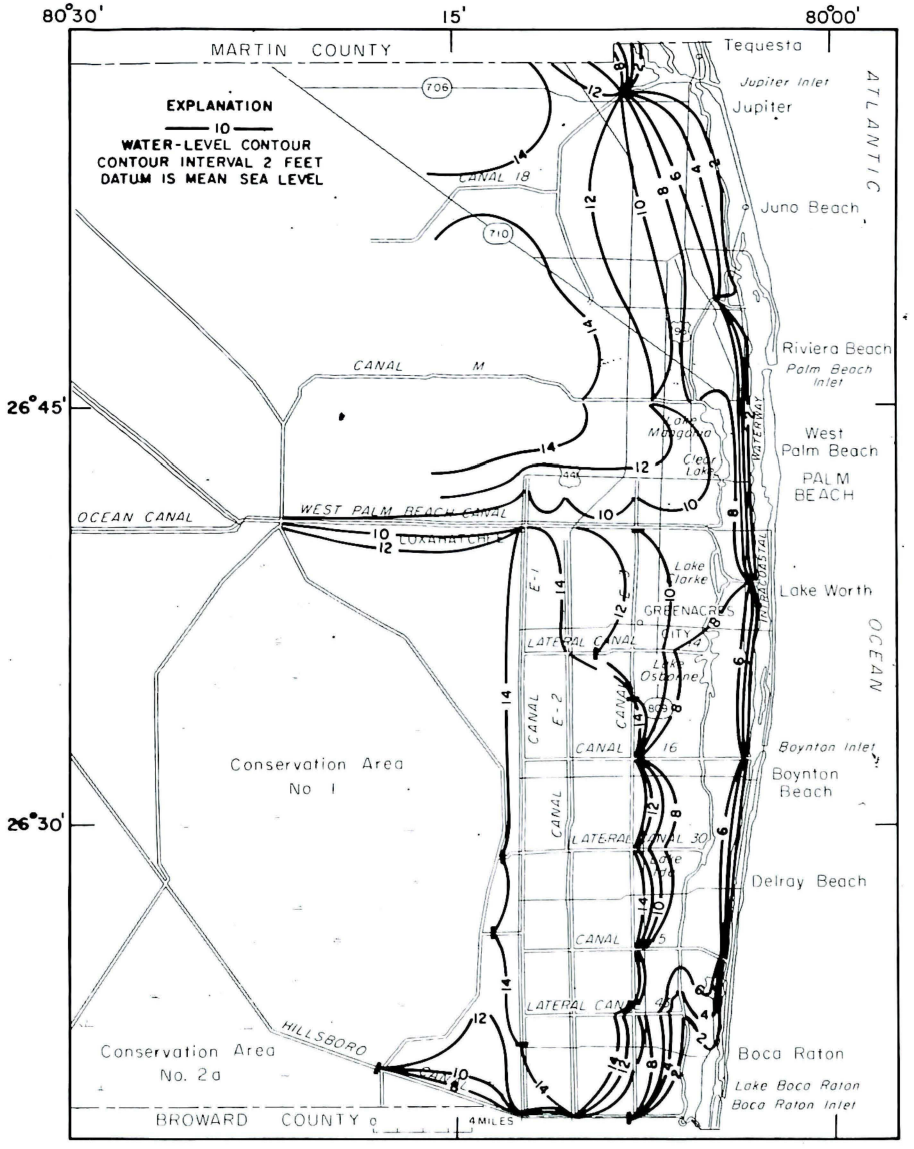


Figure 22. Water table contour map of eastern Palm Beach County on April 30, 1971, end of dry season.

indication of the transmissivity of the aquifer (Bentall, 1963, p 331-336).

The highest transmissivity in the eastern part of the county is in the Boca Raton area. A test there (McCoy and Hardee, 1970, p. 25) indicates a transmissivity of 380,000 gpd/ft (gallons per day per foot), a specific capacity 1_/ of 377 gpm/ft, and a storage coefficient of 0.04. An aquifer test in the Delray Beach area indicates a transmissivity of 140,000 gpd/ft, a specific capacity of 60 gpm/ft, and a storage coefficient of 0.36. At West Palm Beach an aquifer test indicates the transmissivity to be less than 10,000 gpd/ft and the specific capacity 10 gpm/ft. However, other tests in the Delray Beach to West Palm Beach area indicate the specific capacity generally ranges from 40 to 60 gpm/ft which corresponds to a transmissivity of 100,000 to 140,000 gpd/ft. From Riviera Beach to Tequesta the specific capacity generally ranged from 5 to 20 gpm/ft, or a transmissivity of 10,000 to 50,000 gpd/ft. A test using a 48-foot well at the Pratt-Whitney Aircraft Research and Development Center on State Road 710 showed a specific capacity of 72 gpm/ft and indicates the aquifer has a transmissivity in excess of 100,000 gpd/ft and a storage coefficient of 0.0013. A 146-foot well at the same location had a specific capacity of only 4 gpm/ft.

Generally, the ability of the aquifer to yield water to pumping wells increases from north to south in the coastal area; however, many local conditions will cause large changes in permeability with depth and location.

SEA-WATER INTRUSION

Because water levels throughout most of the coastal area are high, salt-water intrusion is not yet critical. Water-levels in the Tequesta, Jupiter and Juno Beach areas are low and there, intrusion has become critical.

To prevent salty water from advancing inland and contaminating the ground water in municipal well fields, the ground-water levels must remain higher than mean sea level. The head of fresh water above mean sea level necessary to suppress salt-water is given in the Ghyben-Herzberg relation. For normal densities of fresh water and sea water, 1 foot of fresh-water head is required to suppress the sea water 40 feet below sea level. For example, to keep the sea water at a depth of 200 feet in the vicinity

1 Specific capacity is the yield of a well per foot of drawdown for a specific period of time.

of the coast line, a minimum of a 5-foot head (above msl) must be maintained. The rate at which salt water will move horizontally is dependent on the aquifer's hydraulic properties: thickness as well as the water-table elevation and gradients. The wells that are the deepest and nearest the coast are the first to be affected because of the shape of the salt-water wedge. The most important and controllable factor in controlling sea-water intrusion is the elevation of the water-table in the vicinity of the coast. These levels are principally influenced by well-field pumping, ground-water outflow, rainfall, evapotranspiration, and drainage canals.

Northeast Palm Beach County

Decline in ground-water levels caused by increased pumping and prolonged drought permitted sea water to advance into the aquifer in the vicinity of the Loxahatchee River. Reduced flows in

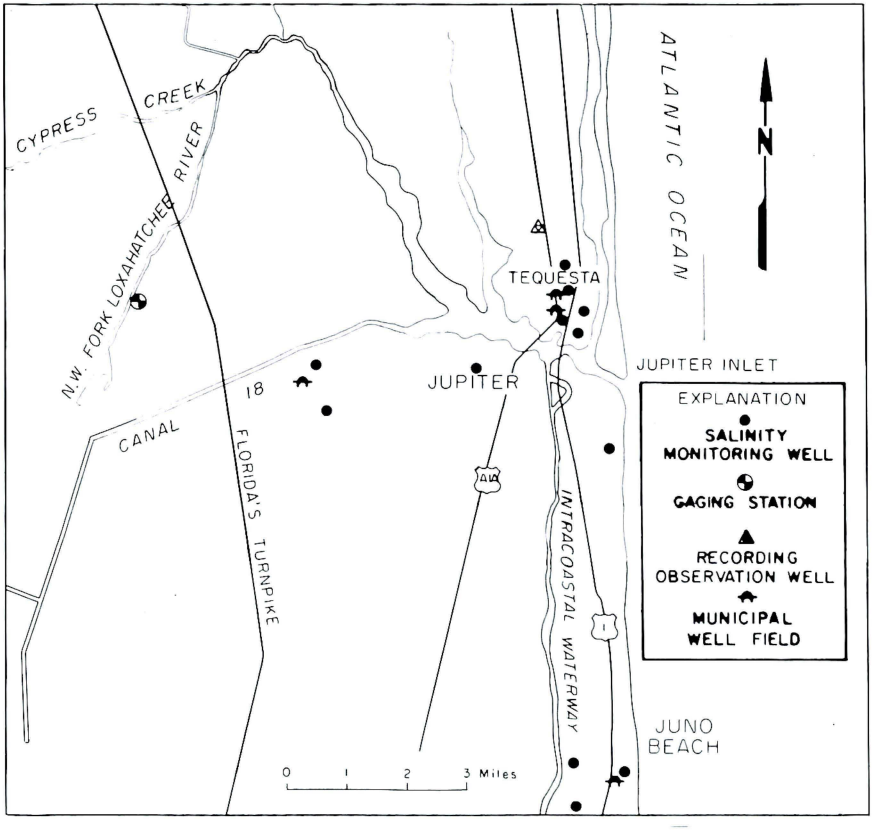


Figure 23. Location of well fields and salinity-monitoring wells in northeast Palm Beach County.

Loxahatchee River, due mainly to Canal 18 diversion from the Loxahatchee Slough into the Southwest Fork (fig. 23) and irrigation operations, have permitted sea water to advance up the river. In the past, high flows effectively kept sea water in the vicinity of the river's mouth. Sea water now extends several miles upstream.

During the drought of 1970-71 and the dry season of 1971-72, it was necessary to discontinue pumping at several wells in the Tequesta and Juno Beach well fields because of increasing salt content in the water. Before this time, the chloride content of the water from the wells averaged less than 50 mg/1. However, when chloride increased to more than 250 mg/1 in some wells, pumping was discontinued.

Sea-water intrusion caused the old Jupiter municipal well field to be abandoned several years ago. Use of many wells near the Loxahatchee River estuary, Intracoastal Waterway, and the ocean has also been discontinued.

To monitor sea-water intrusion several salinity monitoring wells were drilled between the source of sea water and the well fields (fig. 23). The depth and location of these wells and the changes in the chloride content of water from them provide the necessary information needed to predict the movement of the sea water.

Southeast Palm Beach County

Sea-water intrusion in the vicinity of the Boca Raton well field has been monitored since 1963 by the U.S. Geological Survey. The well field is located between the El Rio Canal and the ocean. The sources of sea-water intrusion are the ocean, the Intracoastal Waterway, and the uncontrolled tidal reach of the El Rio Canal. The primary canals — Hillsboro, El Rio, and Canal E-3 — have control structures that normally prevent salt water from moving up the canals. However, salt water did move upstream above the weir structure on the El Rio Canal during high tides in 1970.

When rainfall is about normal, sufficient flow over the control causes the chloride content to be approximately the same on the upstream as on the downstream side. Several times between October 1970 and April 1971, high tides topped the weir, which caused salt water to become trapped in the bottom of the controlled reach of the canal.

During the prolonged drought of 1970-71, pumping in the Boca Raton well field diverted the trapped salty water from the canal into the aquifer and toward the pumping wells; this resulted in temporarily curtailed use of several wells. Subsequent freshening of the aquifer occurred after the rainy season of 1971 began.

Pumping in the Boca Raton well field has caused the water table to form a trough configuration centered through the producing wells. The water table west of the wells is maintained rather stable throughout the year because the El Rio Canal recharges the aquifer. To the east a ground water ridge is centered between the Intracoastal Waterway and the well field. The ridge is saddle shaped near the well field. The configuration of the water table is shown by water-level contours in figure 24 for May 12, 1972.

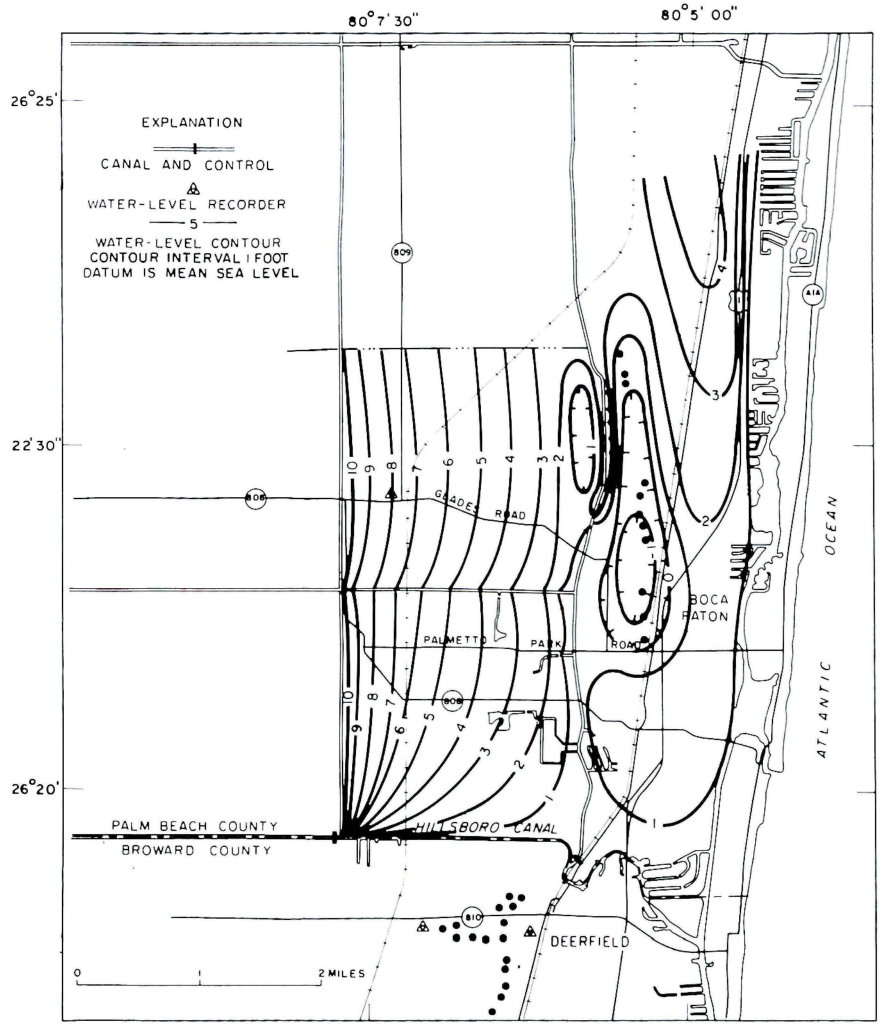


Figure 24. Water table contours in Boca Raton area for May 12, 1972.

FLORIDAN AQUIFER

The Floridan aquifer underlies all of Florida and parts of adjoining states. In Palm Beach County its top is about 800 feet below land surface along the southeast shore of Lake Okeechobee and about 1,000 feet in the Boca Raton area. It is composed primarily of permeable limestone that dips eastward and southward. The aquifer is separated from the shallow aquifer by several hundred feet of impermeable clay and silt. The water flows southeastward across Palm Beach County and is the aquifer recharged in central Florida. The water level in wells penetrating the aquifer is between 40 and 55 feet above mean sea level (Healy, 1970). Wells penetrating the Floridan aquifer will flow under artesian pressure (Vernon, 1969).

In Palm Beach County the water from Floridan aquifer has been used mainly for cooling purposes. It is too highly mineralized for almost any other use. Data obtained by Schroeder and others (1954) and Shampine (1965) showed the chloride content to be greater than 1,000 mg/1 in most of the county and the dissolved solids to be in excess of 3,000 mg/1. The water also is sufficiently corrosive to prevent its general use as a source for industrial cooling. Chemical analyses of water samples collected from artesian wells near Lake Okeechobee are given in table 2.

The main emphasis for present and future use of the aquifer is for waste-water disposal or storage of surplus fresh water. An industrial waste-disposal well drilled near Belle Glade to a depth of 1,705 feet has been in operation since 1965. A few sewage-disposal wells are in operation in Dade County. These wells are about 3,000 feet deep. Also, the upper part of the Floridan aquifer is a large source of brackish water (Meyer, 1971).

WATER QUALITY

SHALLOW AQUIFER

The quality of the ground-water in the shallow aquifer of Palm Beach County is highly variable; but often can be related to the permeability of the aquifer. Usually when permeability is high the quality of water is good. The reason is that the quantity of water moving through the aquifer is great enough to flush out any mineralized water that may be present.

As mentioned previously, by far the greatest source of the fresh water in the shallow aquifer is rainfall. The rainfall enters the saturated zone by infiltration through the soil zone or beds and

Table 2.—Chemical analyses of water from selected wells in central and western Palm Beach County.
(Results in milligrams per liter except as noted)

Test Well	Date of Collection	Depth (feet)	Specific conductance in Micromhos at 25 C ($\times 10^6$)	Dissolved Solids	Temperature (C)	Color (Hazen units)	pH	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na) + Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (N)	Total Hardness as $CaCO_3$
263320NO804240	6-5-42	16	1,130	698	24.0	360		0.15	172	55	7.6	576	144	35	0.05	655
(GS 2)	8	30	1,500	828	24.0				149	69	80	770	36	115	.05	656
	9	50	1,890	1,040	24.0				197	78	107	924	12	195		812
263910NO804515	6-11-42	19	1,860	1,350	24.0	220		.05	292	88	31	538	628	45	.02	1,090
(GS 3)	11	35	1,970	1,300	24.0				190	102	127	684	406	133	.00	894
	11	50	1,660	942	25.0				102	68	168	686	101	165	.00	534
263345NO803110	6-19-42	14	1,030	548	23.0	280		.10	100	34	69	480	17	91	.02	390
(GS 6)	24	55	1,200	637	23.0	280		.80	88	44	106	563	4.1	117	.02	400
264045NO802340	6-25-42	50	6,150	3,600	24.0				80	71	1,220	1,100	304	1,380		492
(GS 7)																
264055NO801220	6-29-42	5	398											7.0		
(GS 8)	30	35	1,500		24.0				143	17	175	473	13	258		427
	30	44	1,630	869	24.0									288		
	30	51	1,320		24.0									218		
262235NO802215	8-4-42	14	596	340	24.0	220		.05	89	13	27	322	11	41	.02	276
(GS 11)	5	50	11,900	7,210	24.0	.70		.10	218	166	2,300	836	716	3,400		1,230
262440NO801720	8-13-42	30	950	496	24.0	60			160	9.4	22	470	9.9	63	.02	439
(GS 12)	14	50	776	387	25.0	40		.03	121	6.6	23	390	9.5	35	.02	330
265440NO803620	8-13-43	23	3,380	2,210	24.0	380	7.1	.09	188	192	378	1,470	400	325	.34	1,260
(GS 24)	13	30	4,790	3,090	23.0	380	7.1	.00	157	200	758	1,640	326	840		1,210
	14	43	6,420	4,030	23.0	310	7.2	.04	232	95	1,220	1,780	254	1,350		970
	16	60	3,150	1,910		55	7.2	.08	154	123	404	1,050	270	445		890

Table 2.—Chemical analyses of water from selected wells in central and western Palm Beach County.
(Results in milligrams per liter except as noted)

Test Well	Date of Collection	Depth (feet)	Specific conductance in Micromhos at 25 C ($Kx10^6$)	Dissolved Solids	Temperature (C)	Color (Hazen units)	pH	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na) + Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (N)	Total Hardness as $CaCO_3$
264830NO803900		27	2,460	1,530	24.0	320	6.9	.13	210	124	197	1,120	231	215		1,030
(GS 25)		45	3,060	4,390	24.0	250	7.0	.20	204	103	1,360	1,160	267	1,890		932
		59	4,540											780		
265300NO804405	8-20-43	14	4,420	2,870	24.0	450	6.7	0.20	414	199	343	1,050	639	760		1,850
(GS 26)	20	30	4,300		24.0									830		
	21	42	4,540	2,780	24.0	240	6.9	.04	176	180	646	1,310	221	910		1,180
	23	78	4,870	2,960		95	7.1	.06	184	152	685	640	667	960		1,080
	23	92	4,730				7.0					852		910		
264210NO805000	8-25-43	12	697		25.0		7.1					358		33		
(GS 27)	25	29	583	305		23	7.4	.04	64	22	25	292	10	36	0.90	250
	25	39	1,610	922		33	7.5	.04	88	44	209	564	84	215	.87	400
	25	50	1,410				7.4					460		198		
	25	56	5,610	3,500		25	7.1	.02	165	98	1,010	882	605	1,180		815
Artesian Well																
264200NO803900	9-18-65	1320	—	1,820	—	—	7.6	1.4	—	—	—	—	415	690		600
	12-11-65	1705	—	4,875	—	—	7.4	.10	—	—	—	—	750	2,210		1,120

banks of canals and lakes. As rainfall infiltrates the surface and moves through the geologic materials it dissolves minerals and undergoes other chemical changes. For example, the water filtering through organic muck usually has color and iron added to it, whereas water flowing through limestone acquires bicarbonate, calcium, magnesium, and other constituents. Sand may also act as a filter to trap sediments or undissolved material.

Ground water of best quality in Palm Beach County is along the coastal ridge and of poorest quality is in the Everglades. The sandy flatlands contain water of transitional quality. A list of the most common parameters in the U.S. Public Health Service Drinking Water Standards (1962) and their recommended limits are given below:

Substance or Property	Concentration (mg/1, except as noted)
Arsenic (As)	0.01
Chloride (Cl)	250
Color	15 Hazen units
Iron (Fe)	0.3
Nitrate (NO_3)	45
Sulfate (SO_3)	250
Dissolved solids	500
Fluoride (F)	1.0
Phenols	0.001
Zinc (Zn)	5.0
Copper (Cu)	1.0
Manganese (Mn)	0.05

The practical limits of some chemical constituents and properties are based mainly on esthetic considerations. The levels of hardness, as classified by the U.S. Geological Survey, are as follows:

Hardness as $CaCO_3$ (mg/1)	Characteristics
0-60	soft
61-120	moderately hard
121-180	hard
over 180	very hard

EAST PALM BEACH COUNTY

The dissolved solids and hardness in water from the shallow aquifer tend to increase westward. Figure 25 shows dissolved

solids, total hardness, and color content in water from selected wells that tap the shallow aquifer in east Palm Beach County. Additional analyses are given in table 3 for water from some of the wells plotted on figure 3. The analyses shown on figure 25 are for water from wells 75 to 125 feet deep.

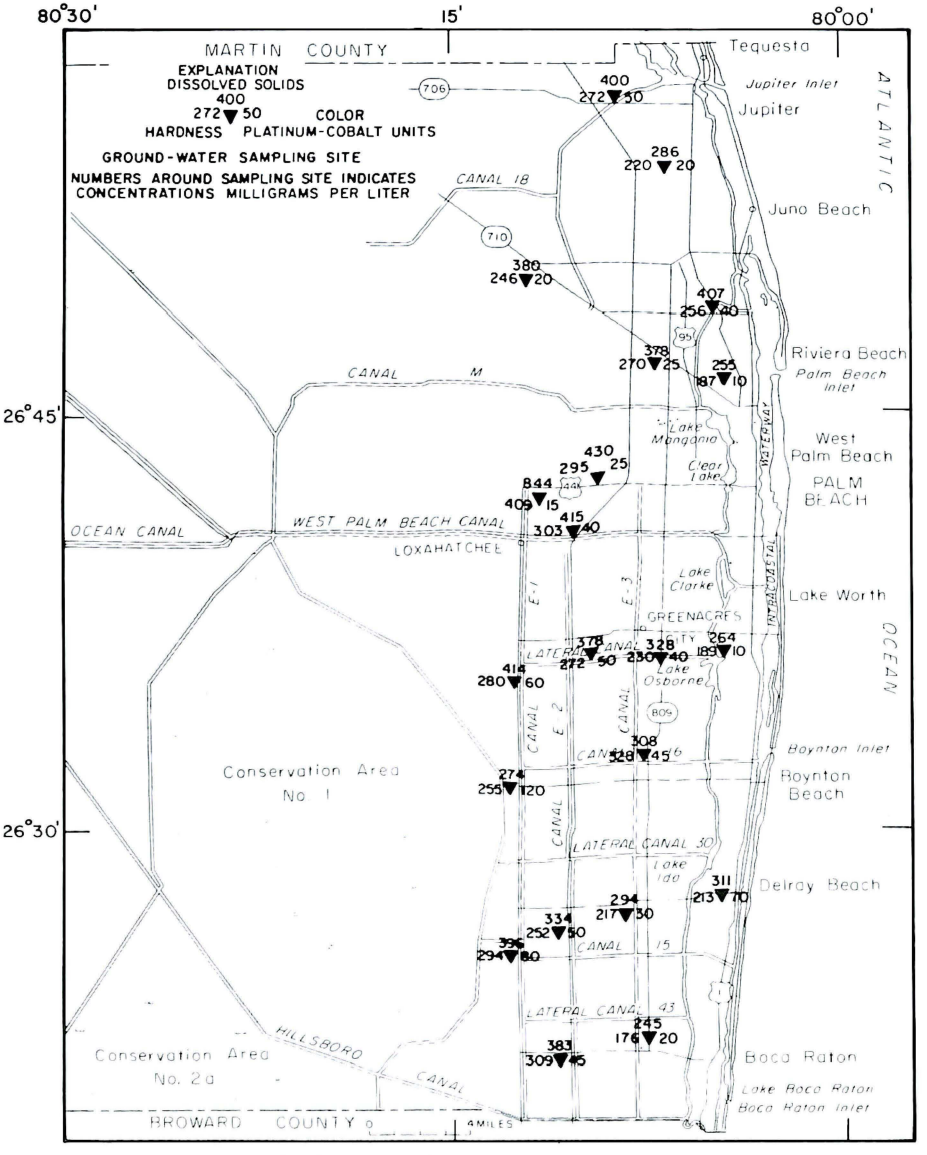


Figure 25. Areal distribution of selected constituents in and properties of ground water.

Table 3.—Chemical analyses of water from selected wells in east Palm Beach County.

(Results in milligrams per liter except as noted)

Station or Site number	Date of Collection	Specific conductance in micromhos at 25 C ($Kx10^6$)	pH	Temperature (C)	Color (cobalt-platinum units)	Turbidity (Jackson turbidity units)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Strontium (Sr)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Phosphorus as PO_4		Alkalinity as $CaCO_3$	Hardness (Ca, Mg)	Non-carbonate hardness	Dissolved solids		Nitrate (N)	Depth (ft)
																			Ortho	Total				Residue at 180 C	Calculated		
264054NO800957 PB 572	12-3-70	704	7.7	22.0	30	15				104	4.6	2.2	33	1.6	344	2.8	56	0.4	0.00		282	281	0	398	389	0.0009	100
264055NO801012 PB 573	12-3-70	712	7.5	25.0	40	14				112	5.0	2.4	35	1.6	356	4.0	58	.4	.05		292	303	11	415	408	.01	137
264104NO801020 PB 574	12-3-70	920	7.7	25.0	30	14				118	6.4	2.6	63	3.6	364	8.0	115	.4	.00		299	324	26	519	510	.01	200
264124NO801029 PB 575	12-3-70	1,130	7.7	24.0	30	14				134	7.0	3.2	84	2.4	396	12	160	.5	3.6		325	367	43	635	628	.49	75
261432NO800959 PB 576	12-3-70	920	7.6	25.0	20	14				120	5.8	2.8	61	2.2	380	.8	110	.3	.05		312	327	15	522	504	.009	56
264225NO800931 PB 577	12-3-70	686	8.4	25.0	25	15				104	8.0	2.0	30	12	323	23	50	.4	.6		271	295	24	430	410		124
262222NO800729 PB 578	12-17-70	421	8.2	24.0	20	12				68	1.5	.24	15	.8	208	4.0	28	.3	.05		171	176	6	245	232	.009	125
262148NO801021 PB 579	12-15-70	691	7.7	23.0	45	13				118	3.0	1.3	20	1.2	368	.8	36	.9	.02		302	309	7	383	375	.006	106
262455NO801250 PB 580	12-16-70	691	7.8	23.0	80	12				112	3.0	1.5	25	1.6	340	8.4	54	0.4	0.05		279	294	15	396	385	0.009	105
262600NO801114 PB 581	12-16-70	594	8.0	24.0	50	14				96	2.6	1.1	22	1.6	300	.8	39	.4	.00		246	252	7	334	326	.70	105
262720NO800753 PB 582	12-16-70	518	7.7	24.0	30	12				81	3.3	1.1	22	.6	256	.8	38	.4	.2		210	217	7	294	286	.009	100
263218NO800724 PB 583	12-16-70	540	8.1	24.0	45	13				86	2.8	1.3	17	1.0	282	8.0	30	.4	.05		231	228	0	308	299	.006	100
263631NO800653 PB 584	12-17-70	583	7.8	24.5	40	13				86	3.4	1.4	27	1.0	276	.8	45	.3	.05		226	230	4	328	314	.009	111

Table 3.—Chemical analyses of water from selected wells in east Palm Beach County. (Continued)

Station or Site number	Date of Collection	Specific conductance in micrombos at 25 C ($Kx10^6$)	pH	Temperature (C)	Color (cobalt-platinum units)	Turbidity (Jackson turbidity units)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Strontium (Sr)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Phosphorus as PO_4		Alkalinity as $CaCO_3$	Hardness (Ca, Mg)	Non-carbonate hardness	Dissolved solids		Nitrate (N)	Depth (ft)
																			Ortho	Total				Residue at 180 C	Calculated		
263701NO800951 PB 585	12-17-70	691	7.8	25.0	50	12			102	3.8	1.5	30	1.4	324	.8	54	.4	.02		266	272	6	378	366	.009	95
263131NO801222 PB 586	12-29-70	648	8.2	17.0	120	12			96	3.4	1.4	30	1.8	303	.8	52	.4	.05		249	255	7	374	347	.009	96
263530NO801223 PB 587	12-29-70	702	8.4	18.0	60	7.9			108	2.2	1.2	44	2.6	333	27	42	.4	.00		286	280	0	414	407	2.8	45
264227NO801143 PB 588	12-29-70	1,560	8.2	24.0	15	17			140	14	1.5	160	5.2	428	26	260	.3	0.00		350	409	58	844	835	0.003	66
264653NO800653 PB 589	12-29-70	686	8.6	20.0	25	11			104	4.2	1.5	26	1.0	302	0	44	.3	1.0		274	279	5	378	362	.003	94
264830NO801153 PB 590	12-30-70	612	8.3	24.0	20	16			92	3.8	.31	35	.8	268	8	66	.3	.7		226	246	20	380	354	.03	76
265609NO800942 PB 591	12-30-70	642	8.6	24.0	50	11			104	2.8	.54	28	.4	322	0	31	.4	.3		294	272	0	400	356	.003	43
265300NO800707 PB 593	12-30-70	497	8.2	24.5	20	9.3			84	2.2	.66	16	.7	268	.8	26	.3	.6		220	220	0	286	275	.03	70
262742NO800431 PB 601	7-26-71	585	6.4	26.5	70	6.3			81	2.3	.90	22	3.2	268	37	8.0	.2	.9		220	213	0	311	297	.000	109
263636NO800357 PB 602	5-23-71	423	6.5		10	5.8			72	2.1	.55	12	2.2	206	30	24	.1	.2		169	189	20	264	250	.000	125
264848NO800501 PB 603	5-26-71	670	6.5		40	13			92	5.9	1.4	42	1.0	310	8.5	66	.3	.9		254	256	2	407	387	.000	107
264659NO800401 PB 604	5-26-71	425	6.4		10	11			72	1.6	1.0	11	.4	252	2.8	18	.2	.09		207	255	0	255	242	.000	220

Figure 26 shows dissolved solids content in water from successively greater depths in east Palm Beach County. Analyses of water from four depth ranges (50-foot intervals) are used to illustrate quality changes with depth. The analyses used to develop these lines of equal concentration include not only the analyses made by the Geological Survey but also those made by private laboratories, and by local and State agencies. Most evident is the uniformity of water quality in a southerly direction and the increase in mineral content westward. The lines of equal concentration tend to be displaced eastward with increasing depth in the aquifer which means the mineral content generally increases with depth. However, the 300 mg/1 concentration line is in about the same position for both 101-150-and 151-200-foot depth ranges. The maps are generalized and do not take into account the near coastal area affected by sea-water contamination.

The graphs of specific conductance versus depth in figure 27 indicate changes in dissolved-solids content of the water with depth. The top of the wedge has a zone of diffusion between the salt and fresh water; therefore, the transition is not abrupt. At depths

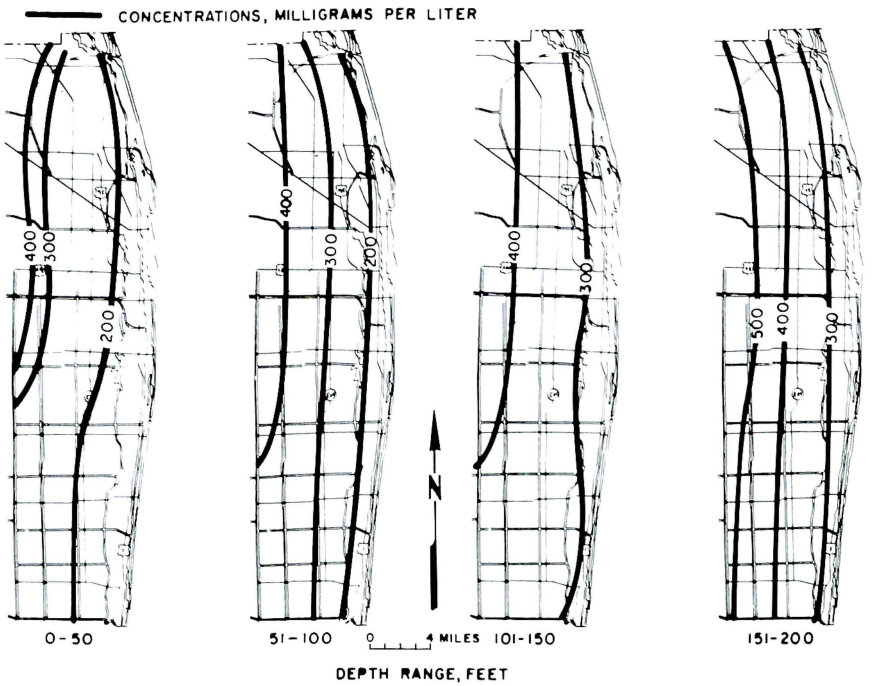


Figure 26. Dissolved solid concentrations in ground-water at various depths in east Palm Beach County.

above the transition zone the quality fluctuates slightly, and improves in some zones, with depth. The approximate top of the zone of diffusion is indicated by dashed lines on the graphs.

CENTRAL AND WEST PALM BEACH COUNTY

Considerable test drilling and water analysis was done in the early 1940's to locate a potable ground-water supply in the Everglades area of Palm Beach County. The sample analyses have been published (Parker and others, 1955) and some of them are again listed in table 2; well locations are shown on figure 28.

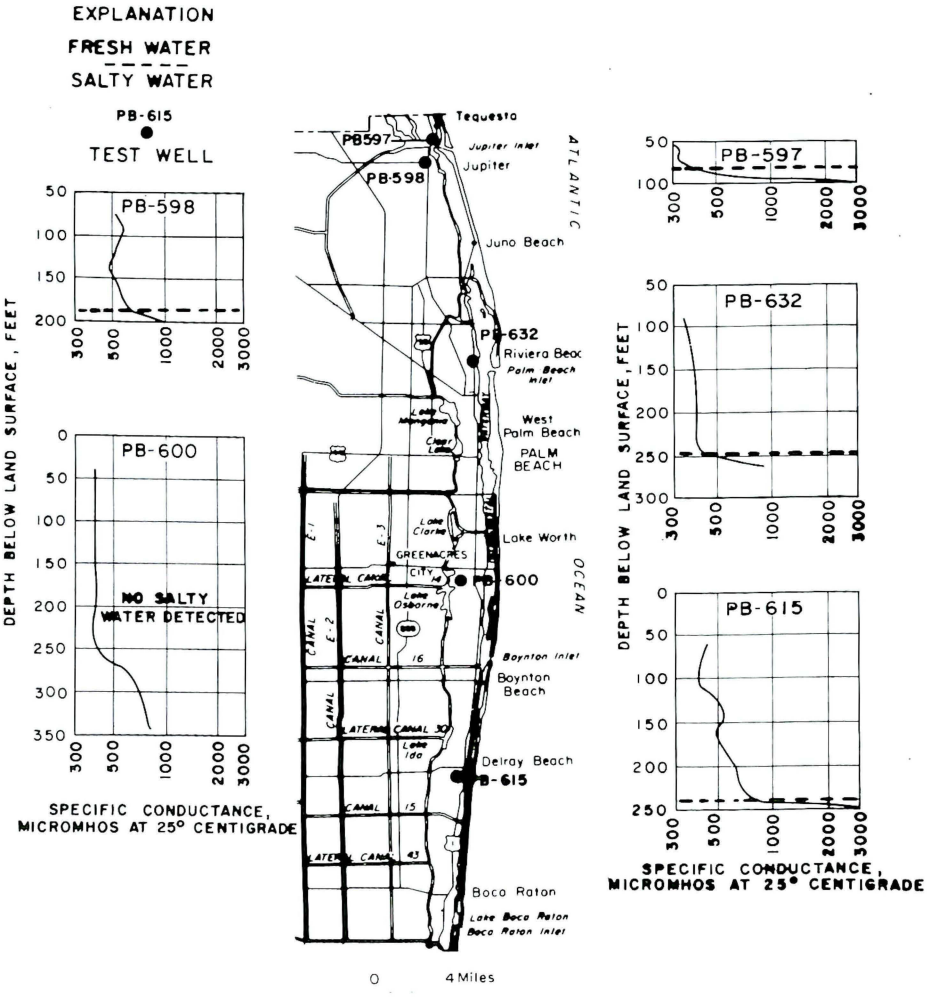


Figure 27. Areal distribution of changes in specific conductance of water with depth for selected test wells in east Palm Beach County.

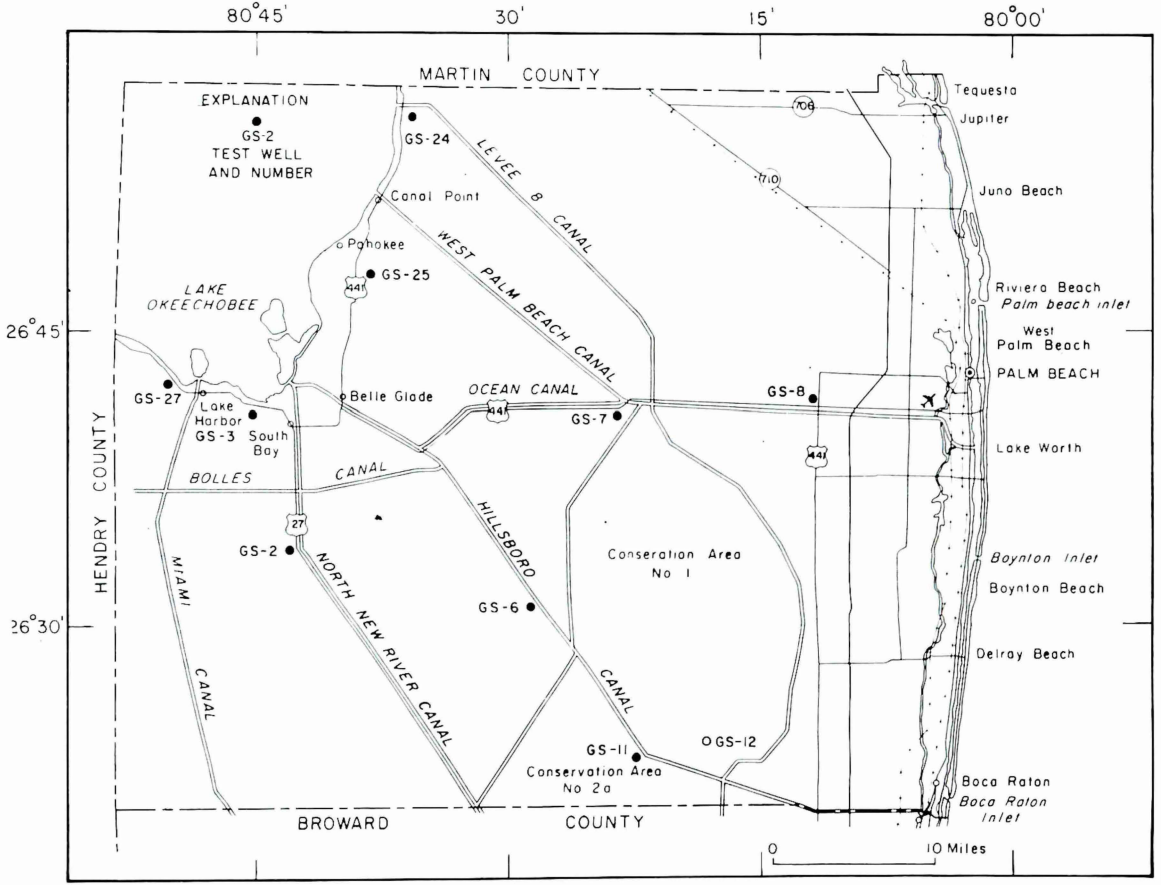


Figure 28. Location of selected test wells in central and western Palm Beach County.

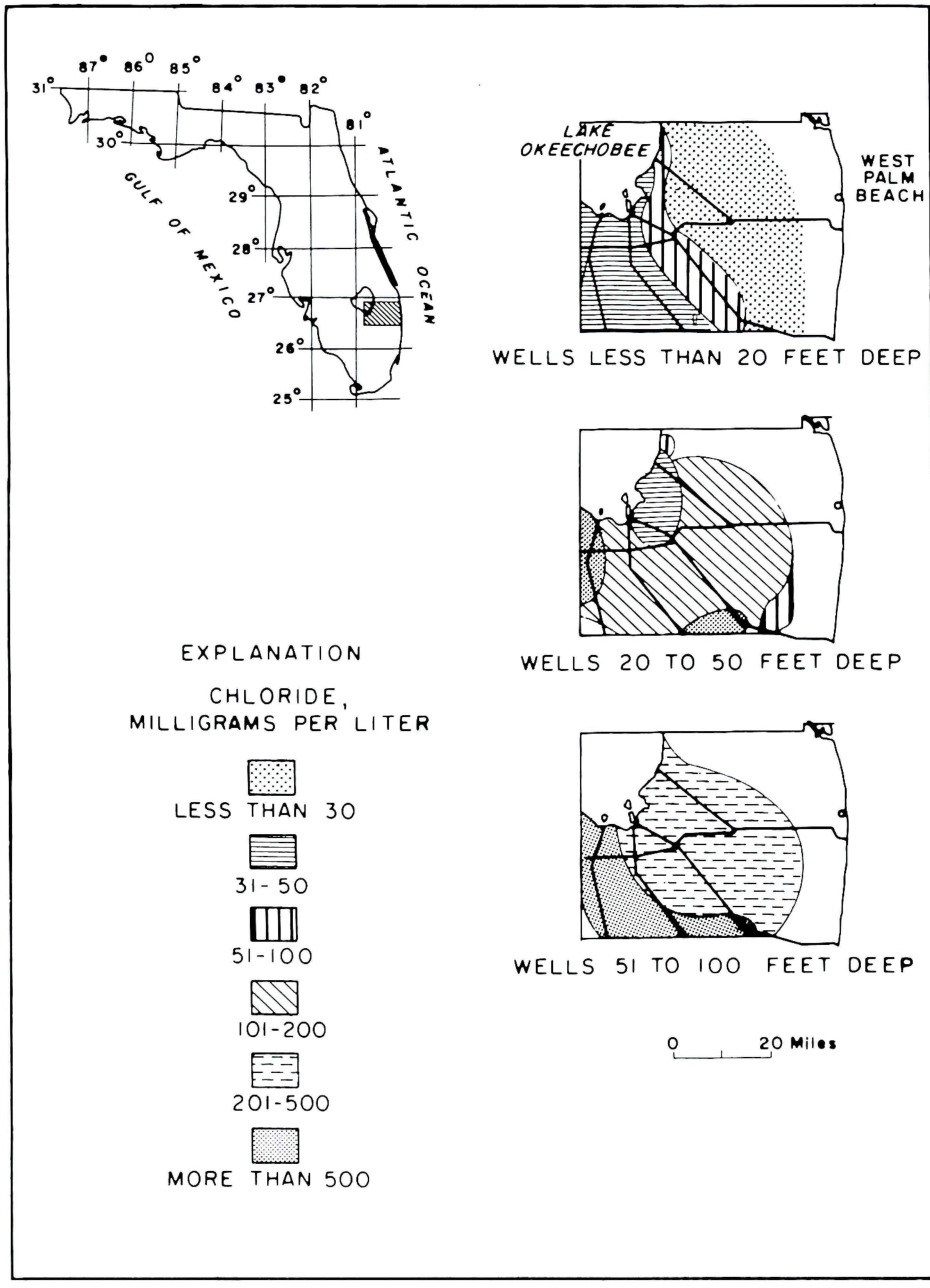


Figure 29. Chloride concentrations in ground water at various depths in the Everglades.

To illustrate the areal distribution of the ground-water's chloride content, lines of equal concentrations for three depth ranges are shown in figure 29 (Parker and others, 1955, p. 818-822). The water at depth is mineralized while at shallow depths it is fresh, or at least its dissolved solids content is less than that of the mineralized water. Water in the deeper ranges may be residual sea water, that has not been flushed from the ground-water system. Poor flushing action is caused by very low hydraulic gradients and strata of low permeability.

SURFACE WATER

The mineral content of water in the canals varies with discharge and water levels. When the discharge or water levels are high much of the water is surface runoff from inland areas. It is highly colored but contains only a small amount of dissolved solids. When the discharge or water levels are low much of the canal water is derived from ground-water inflow and the dissolved solids content increases. The specific conductance, an indication of dissolved solids, is listed on figure 30 for four suites of samples, March 1970 - September 1971. As expected the highest conductance almost always occurred in March 1971, during the 1970-71 drought. The lowest value most often occurred in March 1970 because rainfall was abnormally high at this time. Another reason for variation in dissolved solid content is the changes in flow patterns because by changes in operation of numerous pump stations and control structures. The water quality is relatively unchanged in large lakes, marshes, and conservation areas.

The dissolved solids content is lower in surface water than it is in water in the shallow aquifer, particularly, bicarbonate, silica, calcium, and hardness. However, the color and the bacterial content are usually lower in the ground water. For tidal sections of canals (below salt-water barriers) sea-water dominates and the water is high in chloride and dissolved solids. Chemical analyses of water from selected canals and lakes in east Palm Beach County are listed in table 4. Locations of the sampling sites are shown in figure 2.

The concentration of nutrients normally was higher in September, corresponding with the wet season, and lower in March, the dry season. This can usually be attributed to runoff carrying nutrients absorbed from fertilizers being used in the agricultural area. The concentrations were lowest in canals immediately downstream from the Loxahatchee Slough and highest in Canal 17 where sewage is present. The concentrations of

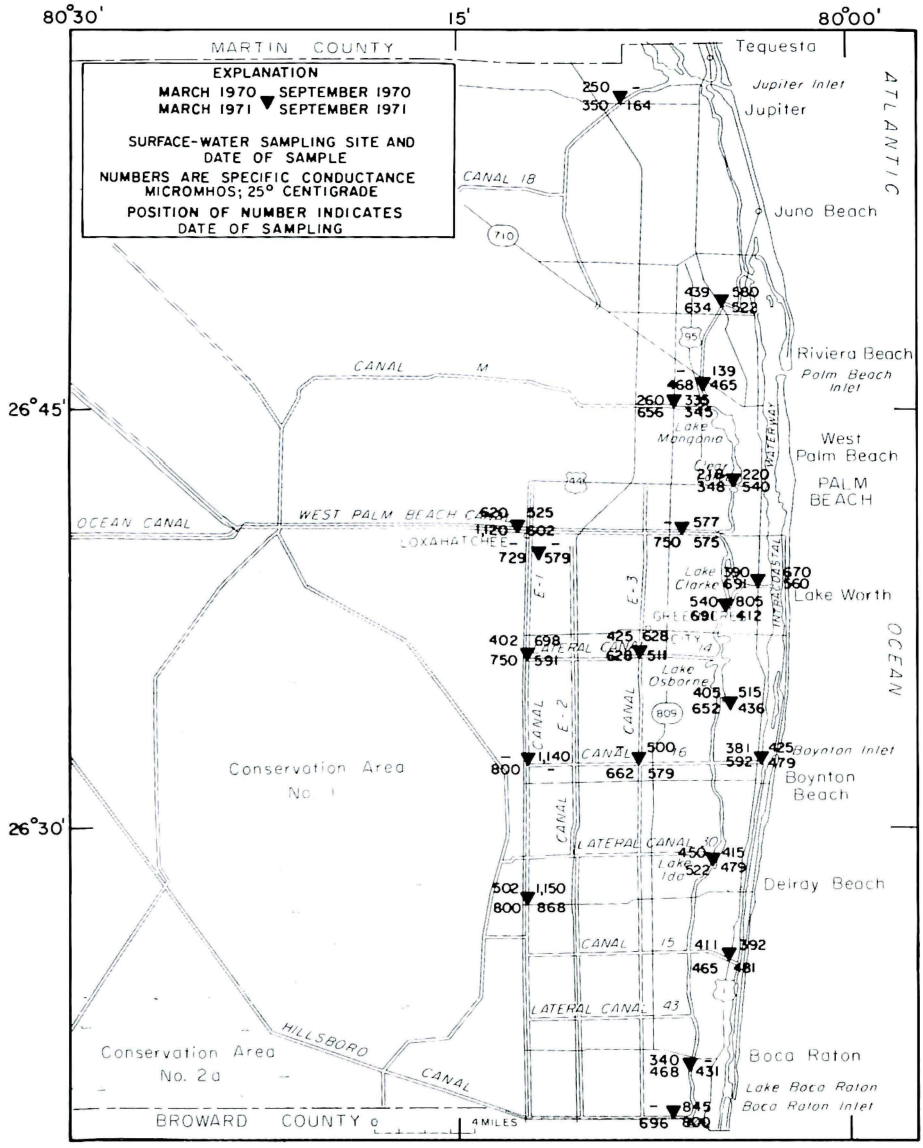


Figure 30. Areal distribution of specific conductance of waters from selected lakes and canals from March 1970 to September 1971.

Table 4.—Chemical analyses of water samples from selected canals and lakes in east Palm Beach County
(Results in milligrams per liter except as noted)

Station	Site	Date of Collection	Specific conductance in Micromhos at 25 C ($Kx10^6$)	pH	Temperature (°C)	Color (Hazen units)	Turbidity JTU	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Strontium (Sr)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (N)	Ortho Phosphate (P)	Total Phosphate (P)	Alkalinity as $CaCO_3$
02277700	1	3-18-70	250	7.0	21.0	50	4.3	1.6	0.12	0.01	33	2.4	0.20	14	1.0	96	10	24	0.2	0.02		0.009	
02277950	2	3-17-70	439	7.2		50	67	5.8	.12	.01	64	3.2	.82	22	1.4	187	15	37	.2	18	0.23	.25	153
	3	3-17-70	218	7.0	19.0	20	90	.7	.06	.00	22	3.5	.30	17	1.6	68	15	25	.1	14		.033	56
02277900	4	3-17-70	240	7.0	20.0	30	2.2	.9	.04	.01	25	3.8	.23	18	1.7	80	9.2	29	.2	.00	.003	.009	66
		5-1-70	170	7.6	27.0	25	38	.4			17	2.2	.15	12	1.4	56	2.8	19	.1	.00	.009	.016	46
	5	3-18-70	620	7.3		100	23	8.4	.20	.01	60	9.1	.52	48	2.5	188	42	75	.3	9.2	.036	.046	154
		8-11-70	517	8.1	29.0	80	28	7.9	.35	.02	68	5.7	.42	31	2.8	198	31	51	.3	.00	.046	.059	162
02279000	6	3-17-70	390	7.1		100	19	4.8	.19	.01	55	3.8	.43	21	2.1	145	21	36	.3	.5	.12	.14	119
		5-1-70	485	8.8	28.5	60	28	8.4			61	6.8		33	2.2	160	30	50	.3	.2	.079	.082	151
02281569	7	3-17-70	540	7.3	19.0	70	16	3.5	.13	.00	61	7.3	.76	37	3.2	171	38	56	.3	.6	.23	.28	140
		5-1-70	525	7.8	29.0	50	17	7.4			61	7.0		36	2.4	178	31	54	.3	.1	.13	.14	146
02281582	8	3-16-70	405	7.2	21.0	60	18	2.4	.06	.02	57	4.8	.57	18	7.5	143	31	30	.3	4.1	.52	.55	117
		5-1-70	540	7.8	28.5	50	16	4.9			65	7.0		38	3.1	192	31	55	.3	.00	.18	.19	157
02281600	9	3-16-70	450	7.2	20.0	80	36	3.4	.07	.00	51	6.7	.53	26	11	121	37	42	.4	4.4	.85	.91	99
		5-1-70	395	7.2	29.5	60	32	2.4			60	3.2		18	3.4	160	21	28	.2	.00	.11	.13	131
02279500	10	3-16-70	381	7.1	20.0	90	27	3.6	.13	.01	51	4.3	.50	19	6.3	132	27	29	.3	1.6	.59	.59	108
	11	3-16-70	411	7.2	20.5	70	26	4.2	.13	.01	53	5.3	.52	21	7.7	136	30	34	.3	3.2	.59	.59	112
02281625	12	3-16-70	340	7.0	18.0	100	9.3	7.3	.26	.00	54	2.8	.38	14	1.1	148	16	24	.3	.2	.13	.13	121
		5-1-70	396	8.5	25.0	60	14	6.5			70	2.5	.48	16	.4	182	7.2	28	.2	.00	.030	.030	171
02281513	13	3-18-70	425	7.1		60		5.9	.14	.01	68	3.8		15	3.1	187	21	27	.3	.5	.27	.29	153
		5-1-70	480	7.4	27.0	60	20	3.9			70	4.9		27	3.3	200	22	40	.3	.05	.16	.18	164
02281419	14	3-18-70	402	7.0	19.0	60		4.2	.17	.02	64	3.2		16	2.5	181	13	27	.4	.2	.27	.27	148
		5-1-70	550	8.6	27.0	40	15	5.3			61	8.5	.62	44	2.5	170	34	66	.3	.00	.023	.040	153

Table 4.—Chemical analyses of water samples from selected canals and lakes in east Palm Beach County
(Results in milligrams per liter except as noted)

Station	Site	Date of Collection	Specific conductance in Micromhos at 25°C ($Kx10^6$)	pH	Temperature (°C)	Color (Hazen units)	Turbidity JTU	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Strontium (Sr)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (N)	Ortho Phosphate (P)	Total Phosphate (P)	Alkalinity as $CaCO_3$
02281425	15	3-16-70	502	7.0	21.0	100		5.7	0.11	0.02	67	6.3		28	11	189	26	49	0.6	0.6	1.2	1.2	155
		5-1-70	720	7.3	27.0	120	17	14			54	13		77	3.7	207	19	111	.7	.00	.11	.11	170
	16	8-11-70	525	8.1	28.0	50	42	9.1	.23	.01	68	4.6	0.68	33	2.2	188	18	54	.4	3.2	.82	.82	154
	17	8-11-70	388	8.0	28.0	40	62	6.7	.22	.01	60	3.1	.50	19	1.6	166	14	31	.2	.2	.000	.11	136
	18	8-11-70	506	8.0	28.0	70	35	8.0	.28	.03	69	5.4	.49	29	2.8	196	30	46	.4	.3	.009	.10	161
	19	8-11-70	516	8.1	28.0	70	30	7.9	.30	.02	69	5.4	.45	30	2.8	199	31	48	.4	.00	.046	.059	163
	20	8-11-70	505	8.6	29.0	80	33	8.0	.32	.02	69	5.6	.42	31	2.8	178	32	50	.3	.5	.10	.12	159
	21	8-12-70	391	8.0	29.0	60	11	4.0	.13	.01	57	3.4	.47	18	3.6	173	16	28	.3	.09	.18	.23	142
	22	8-12-70	440	7.9	30.0	60	18	5.0	.17	.03	59	4.9	.57	22	7.6	173	26	35	.3	.02	.52	.59	142
	23	8-12-70	987	8.3	29.0	160	10	16	.22	.03	70	19	1.5	109	5.5	265	49	154	.7	.07	.18	.20	224
02281532	34	5-1-70	395	8.1	26.0	50	13	1.2			55	3.5	.74	19	2.8	170	18	28	.3	.00	.11	.14	139
02281544	35	5-1-70	285	7.9	25.0	50	13	4.0			31	2.6	.25	19	2.9	82	19	28	.2	.05	.62	.62	67
02281295		4-28-70	74	6.3	30.0	55	23	19	.07	.00	40	1.0	.03	7.8	.4	12	0	14	.0	.05	.013	.013	10
		8-6-70	101	7.5	31.0	50	4.9	2.0	.38	.09	7.1	1.4	.09	9.4	.1	21	2	15	.2	.00	.000	.007	17

Table 4.—Chemical analyses of water samples from selected canals and lakes in east Palm Beach County. (Continued)

Station	Site	Date of Collection	Hardness as $CaCO_3$		Dissolved Solids		Aluminum (Al)	Zinc (Zn)	Lead (Pb)	Copper (Cu)	Chromium (Cr)	Arsenic (As)	Bromide (Br)	Iodide (I)	Boron (B)	MBAS	Tannin and Lignin	Ammonium (N)	N-Organic	Nitrite (N)	Phenols	Oil and Grease
			Calcium Magnesium	Non Carbonate	Residue at 180 C	Calculated																
02277700	1	3-18-70	93	14	157	134	0.20	0.02	0.00	0.01		0.00			0.07		1.3	0.05	0.52	0.003		
02277950	2	3-17-70	174	20	274	243	.30	.03	.02	.00	.00		0.08	0.00	.09	0.05	1.5	1.0	.59	.036		
	3	3-17-70	70	15	135	119	.40	.03	.00	.00	.00	.00	1.8	.00	.05	.02	.6	.09	.49	.003		
02277900	4	3-17-70	79	13	146	127	.10	.03	.00	.01	.00	.00	1.1	.00	.09	.00	1.0	.09	.57	.003		
		5-1-70	52	6.0	103	83												.05	.32	.003		
	5	3-18-70	208	54	400	351	.50	.02	.00	.00	.00	.00	.08	.00	.09	.02	2.8	.37	1.0	.054		
		5-1-70	194	32	321	296	.02	.05	.01	.00	.00	.01								.003		
02279000	6	3-17-70	153	34	257	218	.50	.04	.00	.01	.00	.00	2.2	.00	.09	.02	2.0	.22	.54	.000		
		5-1-70	180	29	325	284												.05	.03	.036		
02281569	7	3-17-70	183	43	336	319	.30	.03	.02	.01	.00	.00	.80	.00	.10	.04	1.5	.15	1.20	.030		
		5-1-70	181	36	335	289												.06	.85	.030		
	8	3-16-70	162	45	260	241	.20	.02	.02	.01	.00	.00	.96	.00	.09	.02	1.4	.11	.88	.1		
		5-1-70	191	34	339	300												.05	.10	.003		
02281600	9	3-16-70	155	56	295	260	.40	.02	.02	.01	.00	.00	2.2	.00	.05	.04	1.6	.85	1.1	.2		
		5-1-70	163	32	256	215												.09	1.3	.006		
02279500	10	3-16-70	145	37	248	215	.30	.03	.00	.01	.00	.00	.48	.00	.04	.02	1.8	.54	1.1	.1		
	11	3-16-70	155	43	275	239	.40	.03	.00	.01	.01	.00	2.5	.00	.05	.05	1.5	.03	1.1	.2		
02281625	12	3-16-70	147	26	223	195	.40	.02	.02	.01	.00	.00	2.6	.00	.08	.03	2.2	.05	.74	.1		
		5-1-70	186	15	274	233												.06	.43	.012		
02281513	13	3-18-70	185	32	270	239		.02	.01	.00	.00					.06				.1		
		5-1-70	195	31	303	272												.05	.69	.006		

Table 4.—Chemical analyses of water samples from selected canals and lakes in east Palm Beach County. (Continued)

Station	Site	Date of Collection	Hardness as $CaCO_3$		Dissolved Solids		Aluminum (Al)	Zinc (Zn)	Lead (Pb)	Copper (Cu)	Chromium (Cr)	Arsenic (As)	Bromide (Br)	Iodide (I)	Boron (B)	MBAS	Tannin and Lignin	Ammonium (N)	N-Organic	Nitrite (N)	Phenols	Oil and Grease
			Calcium Magnesium	Non Carbonate	Residue at 180 C	Calculated																
02281425	14	3-18-70	173	24	256	221		.02	.01	.01	.00					.03				.015		
		5-1-70	188	35	325	314												.07	.78	.015		
02281425	15	3-16-70	193	38	341	293		0.03	0.00	0.00	0.00					0.06			0.61			
		5-1-70	188	18	475	395												0.36	1.6	0.033		
	16	8-11-70	190	36	308	300	0.06	.05	.01	.00	.00	0.00								.003		
	17	8-11-70	163	27	239	219	.02	.12	.01	.00	.00	.00								.000		
	18	8-11-70	195	34	311	290	.08	.09	.00	.01	.00	.01								.003		
	19	8-11-70	195	32	319	293	.12	.03	.00	.00	.01	.02								.003		
	20	8-11-70	196	36	323	298	.02	.04	.01	.00	.00	.00								.000		
	21	8-11-70	157	15	235	217	.11	.07	.01	.00	.00	.00						.24	.33	.033		
	22	8-11-70	168	26	275	247	.06	.12	.00	.00	.00	.01						.50	.27	.015		
	23	8-12-70	254	37	614	560	.04	.04	.01	.01	.00	.02						.10	1.4	.036		
02281532	34	5-1-70	153	13	244	213												.07	.78	.015		
02281544	35	5-1-70	89	22	181	149												.26	.79	.030		
02281295		4-28-70	14	4	68	35		.00	.00	.01	.00	.00						.23	.70	.009		
		8-6-70	24	7	77	45		.18	.00	.03	.01	00						.05	.73	.003		

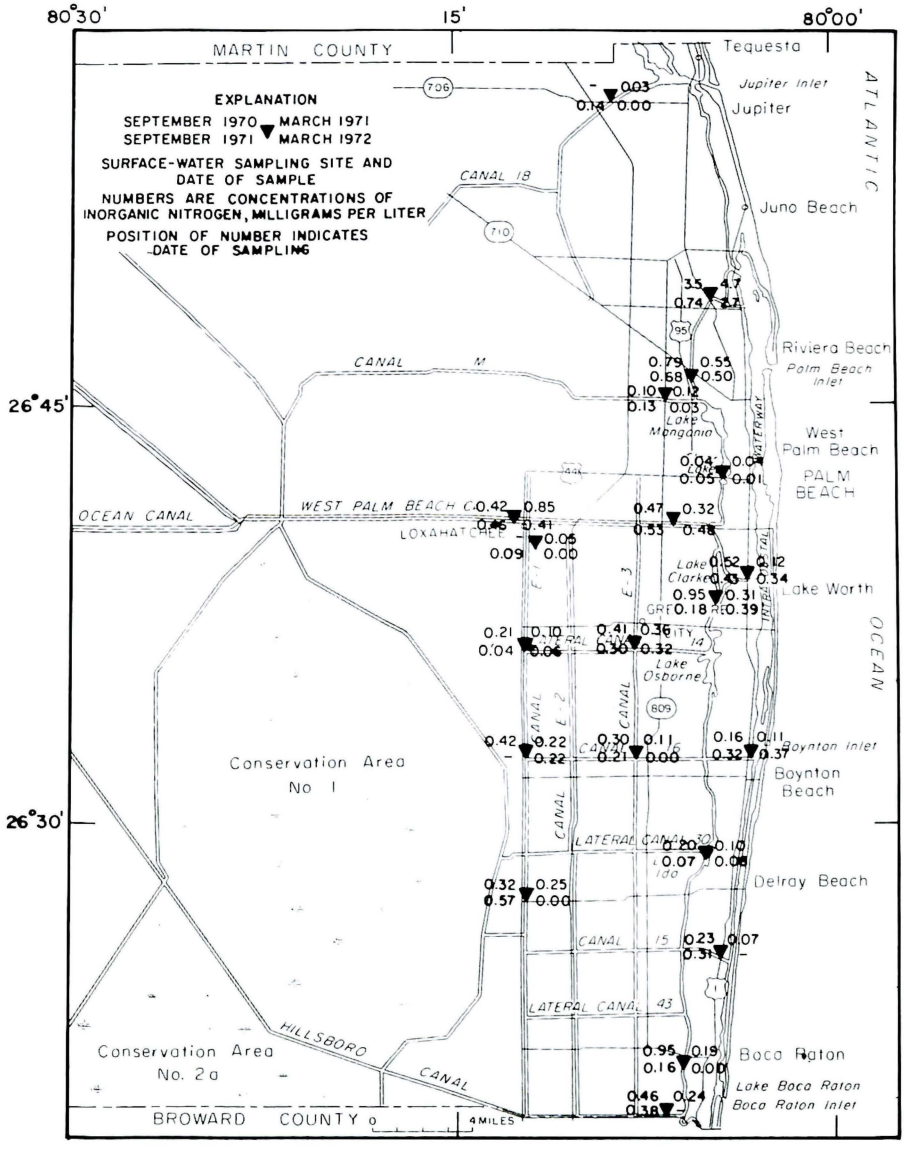


Figure 31. Areal distribution of inorganic nitrogen in waters from selected lakes and canals from September 1970 to March 1972.

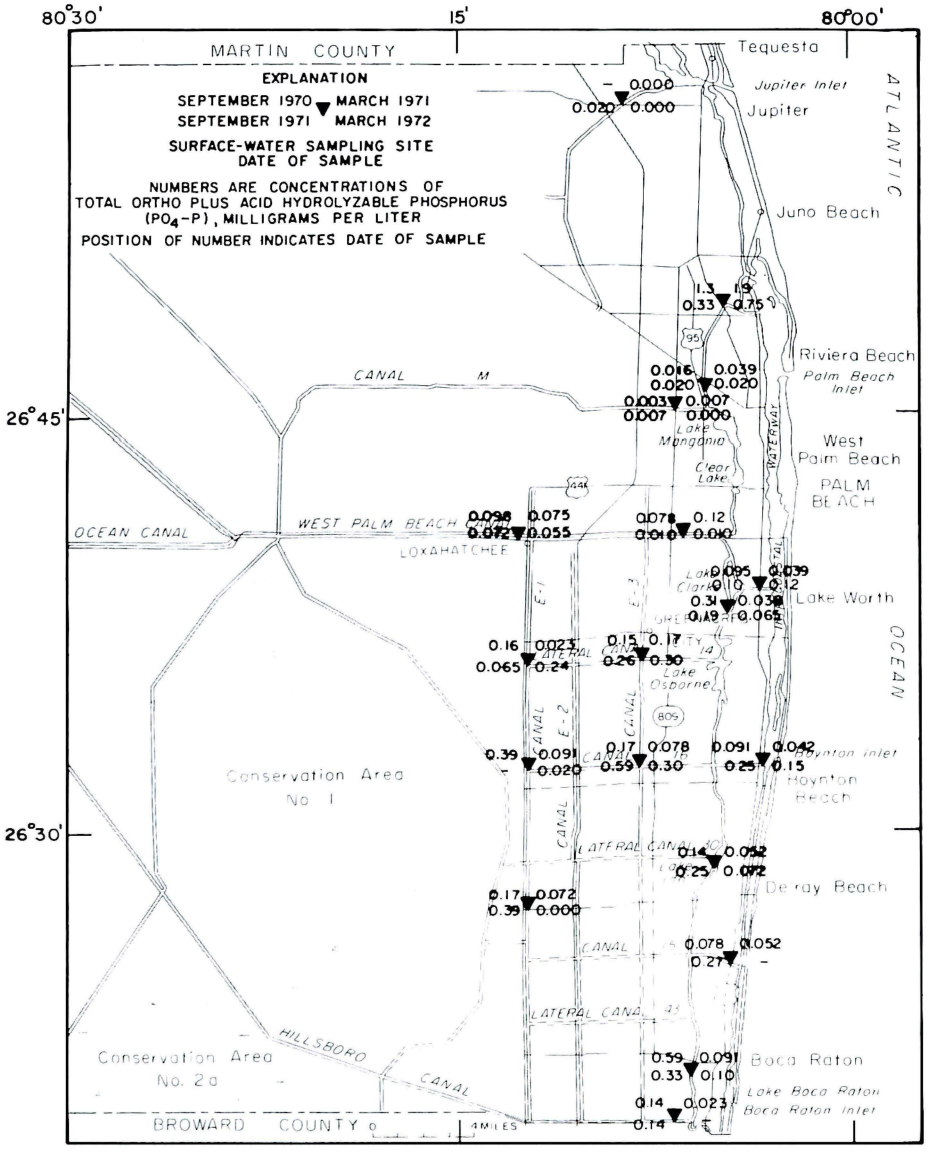


Figure 32. Areal distribution of phosphorus in waters from selected lakes and canals from September 1970 to March 1972.

nitrogen are shown in figure 31 and of phosphorus, in figure 32. The concentrations of inorganic nitrogen and phosphorus in four sets of samples that were collected at 6-month intervals September 1970 and March 1972 represent an average value from analysis of four to six samples collected during a 24-hour period. The sample collected in March 1972 is from a single sample. The inorganic nitrogen in figure 31 is the total of the individual concentrations of ammonia, nitrite and nitrate.

To illustrate the daily fluctuations of inorganic nitrogen and phosphorus concentrations, results from the analyses of samples from selected sites are shown graphically in figures 33 and 34. No diurnal pattern is noted.

The major nutrients (phosphorus, ammonia, nitrite, and nitrate) are significant in that they are essential to plant growth. An abundance will stimulate plant growth provided other essential elements are present. In many areas plant growth in the canals has been so profuse that the canals have become eyesores, nearly useless for recreation, and require frequent and costly maintenance.

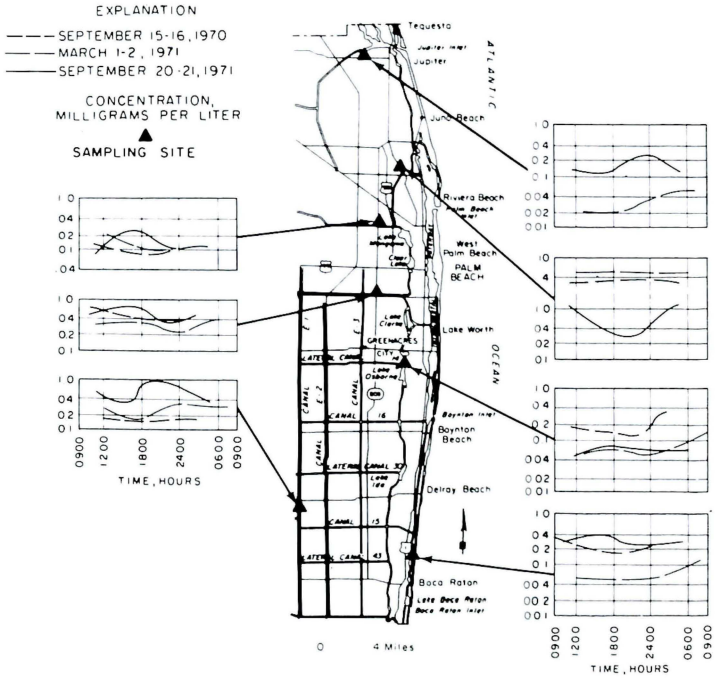


Figure 33. Inorganic nitrogen fluctuations for three 24-hour periods in 1970 and 1971 for selected canals and lakes.

The daily fluctuations of dissolved oxygen concentrations are given in figure 35. The determinations were made at the same time the nutrient samples were collected, that is, September 1970, March and September 1971 plus samples collected in August 1970. The patterns generally show that dissolved oxygen is highest during late afternoon and lowest about sunrise. This pattern is attributed to the respiration cycle of aquatic plants. In water from nearly every site, dissolved oxygen was highest in March 1971. The water was slightly cooler than when sampled at other times; therefore, the concentration at the point of saturation was about 10 percent higher.

Coliform bacteria, indicators of pollution, correspond to the patterns of nutrient concentrations, that is, they are highest in Canal 17 and lowest in canals immediately downstream from the Loxahatchee Slough (figs. 36 and 37). The high concentrations in Canal 17 are caused mainly by sewage. The low concentrations are a reflection of the relatively uninhabited slough area.

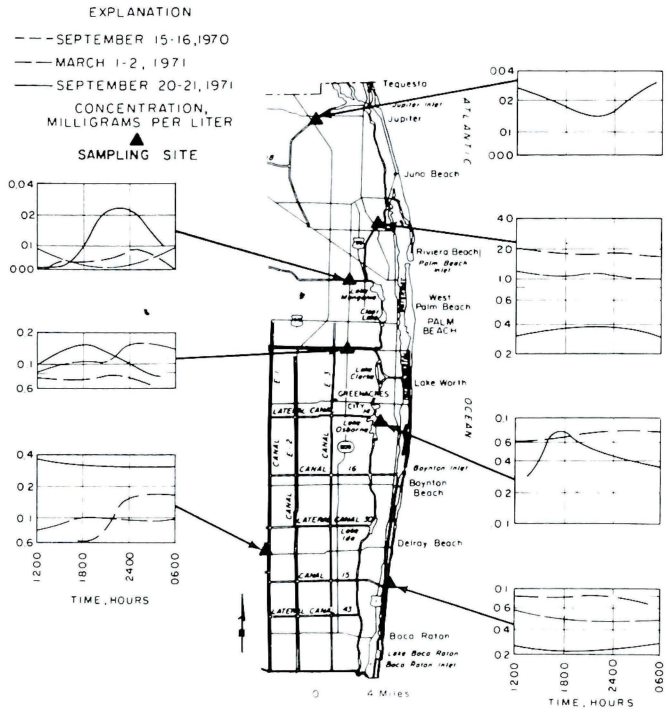


Figure 34. Total ortho plus acid hydrolyzable phosphorus (PO4-P) fluctuations for three 24-hour periods in 1970 and 1971 for selected canals and lakes.

The highest concentrations of any pesticide in surface-water samples collected at several sites in eastern Palm Beach County was 1.9 μg/1 (micrograms per liter) for the herbicide Silvex. This was found in Canal 17, immediately above the salinity barrier. The total pesticide concentration in water from the other sites was, or very near, 0.00 μg/1. The absence of pesticides in surface water is attributed to their insolubility. Not being very soluble in water, they tend to settle and accumulate in the sediments. Analyses of sediment samples from the Loxahatchee River revealed pesticide concentrations ranging from 2 to 141 μg/kg (microgram per kilogram).

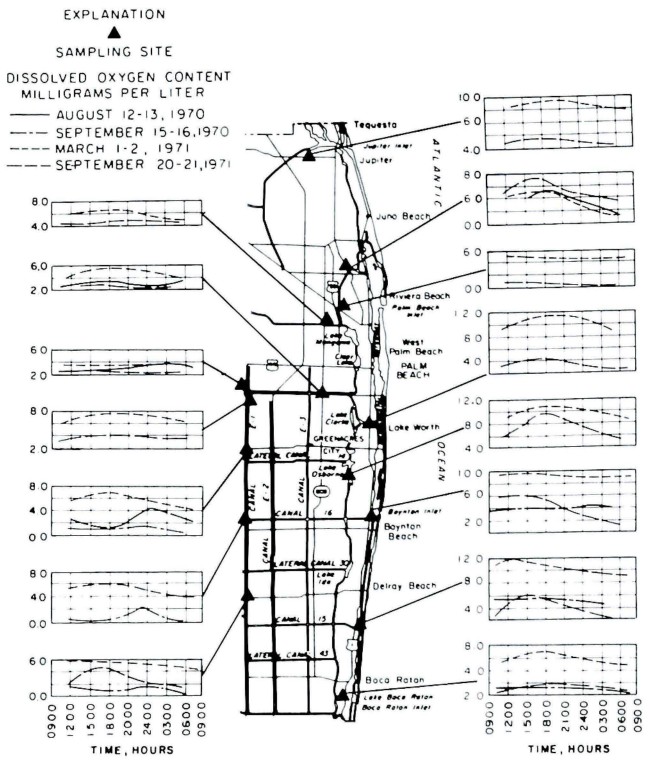


Figure 35. Dissolved oxygen fluctuations of water for four 24-hour periods in 1970 and 1971 at selected canals and lakes.

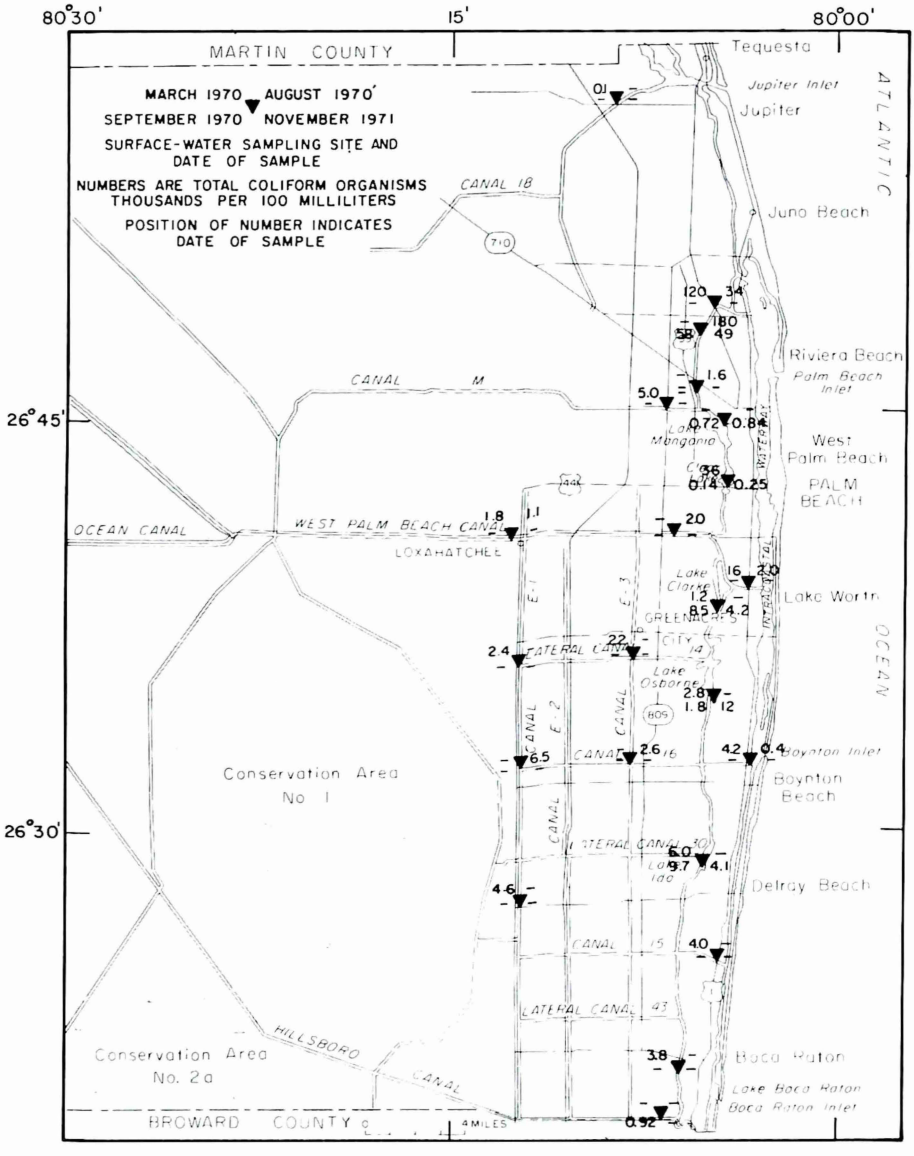


Figure 36. Areal distribution of concentrations of total coliform organisms in waters of selected lakes and canals for four samplings in 1970 and 1971.

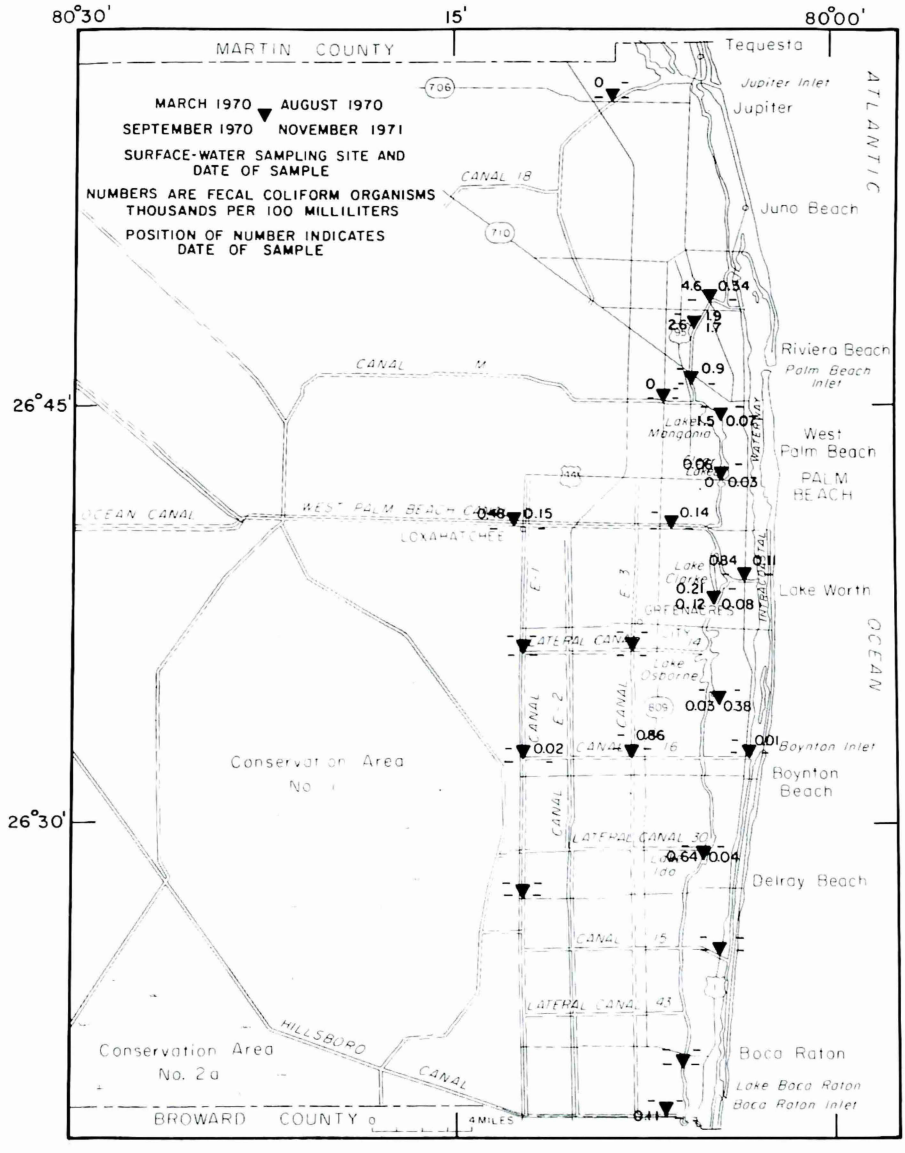


Figure 37. Areal distribution of concentrations of fecal coliform organisms in waters of selected lakes and canals for four samplings in 1970 and 1971.

For water from selected sampling sites shown in figure 2 the organic carbon concentrations ranged from 13 to 48 mg/1 and inorganic carbon ranged from 31 to 46 mg/1. Recently, dissolved carbon has been used as an indicator of pollution. The extremes of concentrations mentioned above can be considered near normal for this area.

WATER USE

During 1970 on the average, almost 500 million gallons of fresh water was withdrawn from lakes, canals, and wells each day for agriculture, public supply, industry, and private supplies. Electric power generation used approximately 564 mgd (million gallons per day) of sea water for cooling purposes.

AGRICULTURE

The largest demand for water in the county is for irrigation. In 1970 the demand was estimated at 460,000 acre-feet, or an average of 410 mgd. Of this amount, 268 mgd is considered lost by evapotranspiration. About 431,000 acres were irrigated during 1970. The crop acreage distribution is as follows: sugar cane, 183,000 acres; pasture, 127,000 acres; truck crops, 101,000 acres; and citrus 20,000 acres. Most of these acreages were irrigated by pumping from canals or wells into controlled ditches which serve to raise the water level to the plant roots or to spread water on the surface between crop rows. Specialized growers, such as flower farmers, use spray irrigation.

PUBLIC WATER SUPPLY

Palm Beach County had a permanent population of 345,000 in 1970 and an additional average transient population for that year of 42,000. The Palm Beach County Area Planning Board lists 210 municipal and private water systems. These systems pumped on the average about 75 mgd during 1970.

Ten of the major municipally owned and one private water utility pumped, on the average, 55 mgd during 1970 to supply a population of 247,000 and the associated commercial and industrial users. Of the 11 major suppliers listed in table 5, West Palm Beach, Belle Glade and Pahokee use surface water. The other cities and public supplies obtain water from the shallow aquifer.

CITY OF WEST PALM BEACH

In 1970 the West Palm Beach water system, the largest in the county, pumped 17 mgd on the average to serve a population of 66,000. The system has a capacity of 36 mgd, ground storage of 14 million gallons, and an elevated storage of 5 million gallons. Pumpage from 1950 to 1971 (fig. 38). Pumpage increased slightly from 1967 to 1971 (fig. 39). The relation between pumpage and rainfall is direct. The demand for water increases during dry periods and decreases during wet periods. This is because the demand for water to irrigate lawns and shrubs is larger during dry periods.

The immediate source of water for the West Palm Beach system is Clear Lake. Clear Lake connects to Lake Mangonia, which is replenished by flow from Canal M. Canal M drains an extensive water catchment area west of Military Trail. Canal M is tied to the Levee 8 Canal and during extreme drought water from Lake Okeechobee can be moved through the canals to supply water to the treatment plant.

CITY OF BOCA RATON

The second largest municipal water system and the largest using ground-water is at Boca Raton. This system serves one of the fastest growing populations in the county. During 1970 pumpage from the city's wells was 10.8 mgd to supply a population of 36,000. Monthly pumpage and rainfall for 1967-71 are shown in figure 40

Table 5.—Major Public Water Supplies in Palm Beach County

Supplier	Number of wells	Rated Capacity mgd	Population served 1970	Pumpage mgd 1970	Pumpage mgd 1971	Sewage mgd 1970	Sewage mgd 1971
City of Belle Glade	1	6.0	18,500	2.71	3.02	0.98	1.10
City of Boca Raton	25	37.0	35,000	10.81	11.01	2.17	2.20
City of Boynton Beach	10	12.0	19,000	3.59	4.40	1.50	1.60
City of Delray Beach	20	16.4	20,000	5.40	5.18	2.30	2.50
City of Lake Worth	11	16.0	26,000	4.30	5.30	2.67	3.36[3] 1.32[4]
Town of Lantana	4	3.0	7,000	1.34	1.36	0.72	[a]1.0
North Palm Beach Util. Inc.	16	7.0	16,900	3.78	4.13	1.80	2.37
Town of Pahokee	1	1.9	10,000	0.63	0.64	0.55	0.70
City of Palm Beach Gardens	5	4.0	6,000	1.62	1.95	0.75	[a]0.8
City of Riviera Beach	18	14.0	23,000	3.66	4.59	1.80	2.00
City of West Palm Beach	1	36.0	66,000	17.01[2]	18.01[2]	12.00	11.80

Notes: Population served includes seasonal residents, tourists, and migrants.
1 Surface water supply.
a estimated
2 Includes Palm Beach
3 Includes sewage from Lantana, Atlantis, Palm Beach Junior College, and Palm Springs
4 Lake Worth only

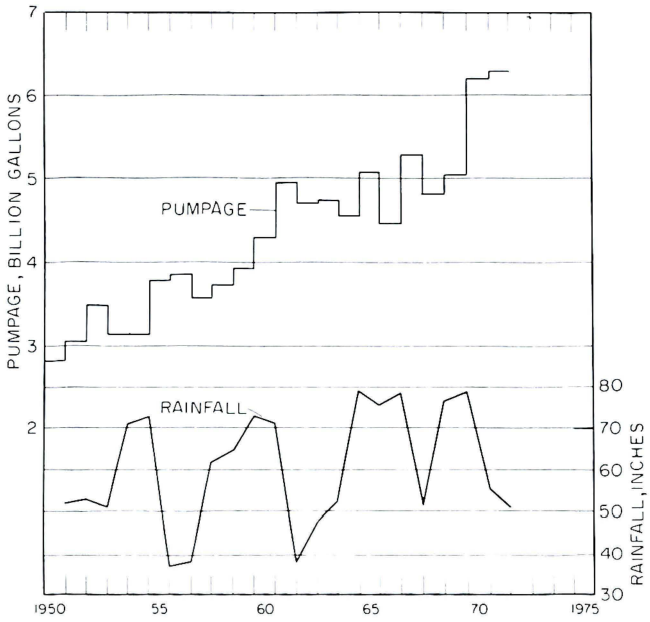


Figure 38. Yearly municipal pumpage and rainfall at West Palm Beach.

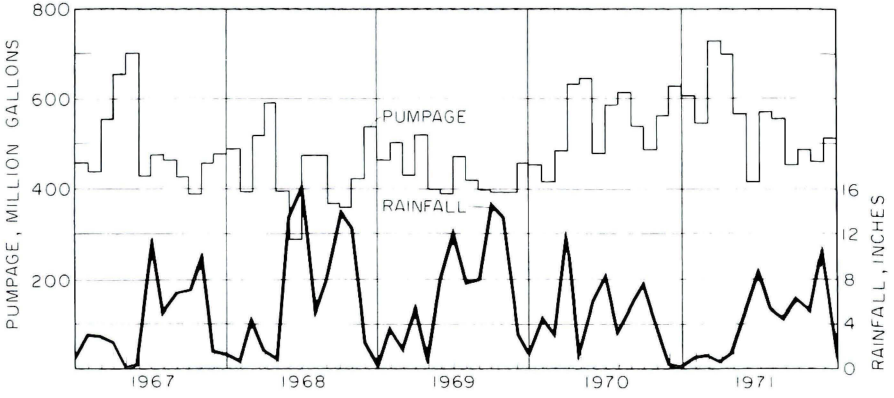


Figure 39. Monthly municipal pumpage and rainfall at West Palm Beach, 1967-71.

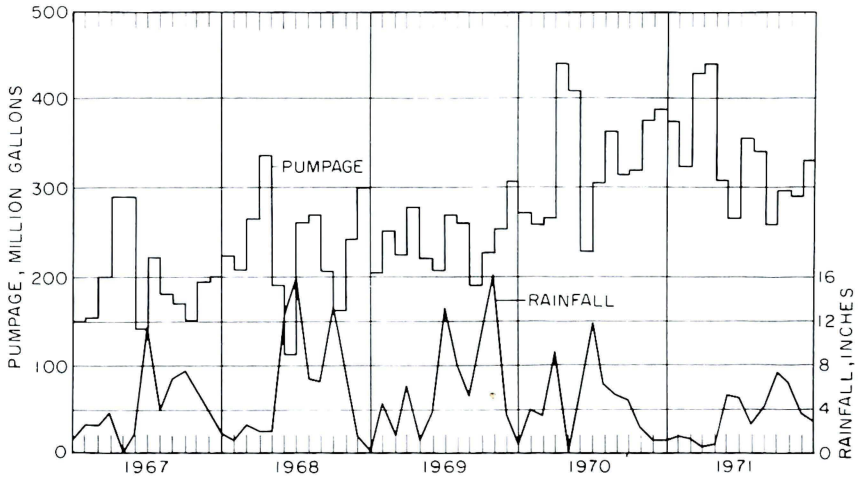


Figure 40. Monthly municipal pumpage and rainfall at Boca Raton, 1967-71.

which indicates more than a 50 percent increase in water withdrawals during the 5-year period. The large increase in demand for water during dry periods is evident.

The water plant is supplied by 25 wells adjacent to the El Rio Canal. The system has a capacity of 37 mgd. An additional water-treatment plant with a rated capacity of 25 mgd, and a sewage treatment plant are scheduled for completion during 1973. More wells are being drilled 1.5 miles west of the present well field along Canal E-3 to supply the new plant.

WASTE WATER

On the average the amount of waste water collected by the eleven suppliers listed in table 5 was 27.2 mgd in 1970. Of this amount, 24 mgd was discharged into the ocean or estuaries. The remainder was discharged into fresh-water canals.

Four cities in Palm Beach County discharge sewage to the oceans through outfall systems. They are for the cities of Boca Raton, Delray Beach, Lake Worth and Palm Beach. The discharges for each of the four sites range from 2.2 to 3.5 mgd and have a total average discharge of 11.7 mgd (1970). They discharge into 90 feet of water from conduits extending slightly over 1 mile into the ocean. The sewage is chlorinated only, with the exception of sewage discharged by Boca Raton. These wastes are given primary treatment.

INDUSTRIAL USE

The industrial use of fresh water in Palm Beach County in 1970 averaged about 45 mgd. Public supplies provided 16 mgd, and self-supplied industry pumped another 29 mgd. About 564 mgd of saline water was used in the generation of electric power.

EFFECTS OF SOLID WASTES LANDFILL ON GROUND WATER

Effect of operation of the Cross-State dump, west of West Palm Beach, on the ground-water's quality has been minimal in the 75-200-foot zone tapped by most producing wells in the vicinity. However, the water at very shallow depth and beneath and immediately adjacent to the dump is somewhat adversely affected. The water contaminated by the dump is expected to stay near the top of the saturated zone and move toward the perimeter canals. Also, sandy materials will act as a filter to remove some of the contaminants as the ground-water flows away from the dump.

OTHER U.S. GEOLOGICAL SURVEY STUDIES IN PALM BEACH COUNTY

The U.S. Geological Survey has undertaken or is monitoring several water-resources studies in Palm Beach County that are funded outside the County cooperative program. The programs are briefly described below.

In cooperation with the CSFFCD (Central and Southern Florida Flood Control District) and the Florida Department of Natural Resources, the Geological Survey is investigating the hydrology and water quality of the Loxahatchee River. Data being collected are continuous stage and discharge of the river near State Road 706, and periodic water-quality determinations including such parameters as pesticides, nutrients, dissolved oxygen, and salinity.

The Geological Survey is also cooperating with the Florida State Department of Transportation to determine the probable magnitude and frequency of floods on a small urban watershed in the city of Delray Beach. In the 50-acre area being investigated, streamflow and rainfall measurement stations have been constructed, and data are collected on a continuous basis.

The chemical, physical and biologic properties of the water in Lake Okeechobee were investigated by the U.S. Geological Survey in cooperation with the CSFFCD (Joyner, B.F., 1971). Of the 17

sampling points on the lake, seven were in Palm Beach County. The data obtained and evaluated during the investigation suggest that the lake is in early eutrophic condition — not significantly different from other water bodies in southern Florida. For the current investigation the water-quality data for Lake Okeechobee provide a base for determining water quality in its effluent canals.

Deep-well disposal of waste waters at Belle Glade is being monitored by the Geological Survey in cooperation with other governmental and private interests. The disposal well and a monitoring well are approximately 1,700 feet deep. Industrial waste (essentially 1 percent acetic acid) is being injected into the lower part of the Floridan aquifer (Garcia-Bengochea and Vernon, 1969). The water's chloride content is more than 2,000 mg/l at this depth.

SUMMARY

Palm Beach County, in southeast Florida, is characterized by flat and low-lying terrain and receives about 60 inches per year rainfall. The flat topography and high rainfall naturally cause drainage problems. An elaborate network of canals and control structures control water-levels in the eastern part of the county. Fresh ground-water is obtained entirely from the shallow, nonartesian aquifer. The shallow aquifer is about 250 feet thick near the coast and thins westward. The Floridan aquifer system contains brackish to saline water under sufficient head to cause the water level to raise 40-55 feet above mean sea level. The top of this artesian aquifer is about 900 feet below land surface. Although the shallow aquifer contains a large volume of fresh water, the amount of regulatable storage capacity is only a very small fraction of the total value. Water-levels must be maintained sufficiently low to prevent flooding. In newly developed areas, water-levels should be kept as high as possible to maintain maximum ground water storage. Hydraulic connection between the surface-water and ground-water system causes water-levels in the two systems to fluctuate similarly.

Surface waters typically have low concentrations of dissolved solids, 200-350 mg/l, but have high color, normally 50-80 units, and coliform bacteria contamination. The ground-water quality varies with location and depth, but progressively deteriorates westward from the coast. High chloride, color, odor, iron, and hardness are the problem parameters. Neither the ground-water nor the surface-water is contaminated significantly by pesticides or by

nutrients. In 1971 problems of sea-water encroachment were acute in Tequesta, Juno Beach and Boca Raton well fields. As water withdrawals from coastal well fields continue to increase, sea-water encroachment into the shallow aquifer will continue to cause problems.

Ground-water at shallow depths under a relatively small area adjacent to the solid-waste disposal dump west of West Palm Beach has been contaminated. Domestic wells in the area have not been affected.

The greatest use of fresh water is for irrigation, slightly over 410 mgd. Industrial and domestic users withdraw about 90 mgd.

In order to avoid creating hydrologic problems such as in Tequesta and Boca Raton, future municipal well field expansion should be preceded by a program of test drilling and aquifer evaluation. Adequate quantities of water for future expansion are available.

EXPLANATION OF TERMS

Artesian — water level in an artesian well stands above the top of the artesian water body it taps.

Aquifer — a formation, group of formations, or part of a formation that contains sufficient saturated, permeable material to yield significant quantities of water to wells and springs.

Duration curve — a cumulative frequency curve that shows the percentage of time that specified magnitudes are equaled or exceeded.

Ghyben-Herzberg relation — $$z = \frac{P_f}{P_s - P_f} h_f$$

where z = depth to salt-water wedge from sea-level datum.
h_f = head of fresh water above sea-level datum.
P_f = density of fresh water.
P_s = density of salt water.

Hydraulic gradient — the change in static head per unit distance in a given direction.

Hydrograph — a graph of stage or discharge against time.

Nonartesian — or "shallow" — under pressure not greater than atmospheric.

Permeability — the measure of the relative ease with which a porous medium can transmit a liquid under a potential gradient.

Salt-water wedge — the wedge shape of salty water extending inland from the coast with the leading edge at the base of the aquifer.

Sea-water intrusion — sea water entering or penetrating inland aquifers.

Specific capacity — is the yield of a well per foot of drawdown for a specific period of time.

Specific yield — the ratio of the volume of water which the rock or soil, after being saturated, will yield by gravity to the volume of the rock or soil.

Transmissivity — the rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient.

Water table — the surface in an unconfined water body at which the pressure is atmospheric. It is defined by the levels at which water stands in wells that penetrate the water body just far enough to hold standing water.

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FLORIDA DEPARTMENT OF NATURAL RESOURCES
BUREAU OF GEOLOGY

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LETTER OF TRANSMITTAL



Bureau of Geology
Tallahassee
October 18, 1973

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

Dear Governor Askew:

The Bureau of Geology of the Division of Interior Resources is publishing as its Report of Investigation No. 67 a report prepared by Larry F. Land, Harry G. Rodis and James J. Schneider of the U. S. Geological Survey entitled "Appraisal of the Water Resources of Eastern Palm Beach County, Florida".

We are pleased to have participated in this investigation with the U. S. Geological Survey.

It is hoped this report will furnish necessary data to water-management agencies needed to plan for protection and orderly development of water resources. Information is provided in several areas, including (1) location, amount and quality of water, (2) quantity and trends of water use, (3) relation of water use, land drainage, water levels and hydrologic conditions. The area of investigation primarily includes the eastern 8-10 miles of Palm Beach County, approximately 400 square miles.

Respectfully yours,

Charles W. Hendry, Jr., Chief
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