

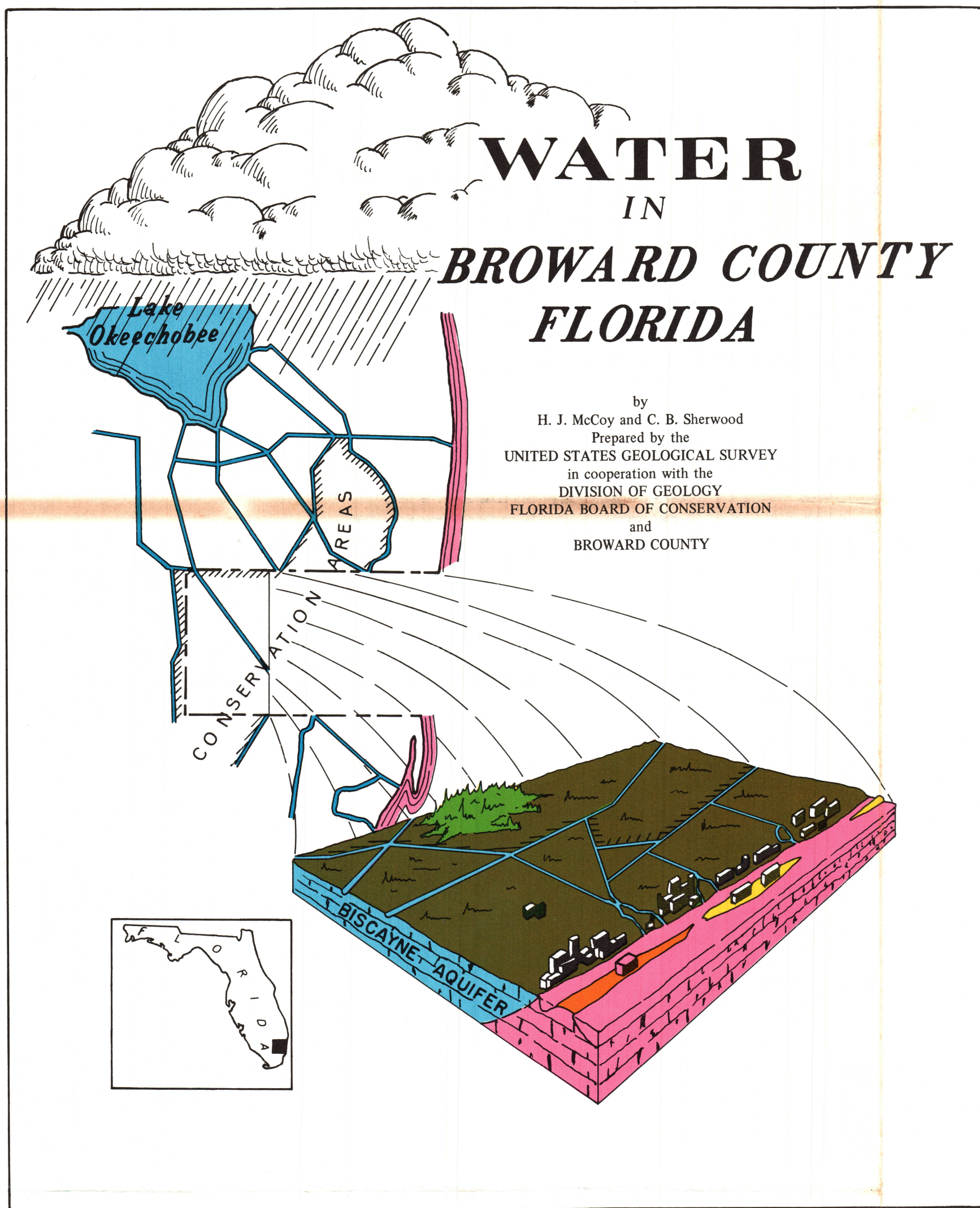


Figure 1.- Broward County receives an abundant supply of fresh water from an annual rainfall of about 60 inches and water brought into the county by canals of the Central and Southern Florida Flood Control District. The Biscayne aquifer readily stores and transmits this water. Salt-water intrusion is shown by the pink shaded area.

INTRODUCTION

The purpose of this report is to present a general picture of the water resources of Broward County, the regional and local water management facilities designed to alleviate present and future water problems, and the methods used for obtaining large municipal water supplies. Selected data are shown to aid in understanding the hydrologic system and the natural and man-made factors that affect the quantity, quality, and movement of water within the system.

This is one of a series of reports resulting from a comprehensive study of the water resources of the county begun in 1961 by the U.S. Geological Survey in cooperation with Broward County, to provide information needed for the management and protection of water supplies.

Broward County receives an abundant 60 inches of rainfall during most years, and it is undisturbed by water-bearing materials (an aquifer) which can store and transmit water readily. It also has an extensive network of controlled canals which are connected to inland water-conservation areas (fig. 1).

The availability of an adequate supply of fresh water has been an essential factor in Broward County attaining its rank as the 5th largest in population and 10th fastest growing county in Florida (Bureau of Devel. Comm., 1965). Industry and agriculture also have expanded as a result of the availability of an abundant water supply.

WATER PROBLEMS

Although the water picture is encouraging, the explosive urbanization of this low-lying coastal area has been accompanied by a number of natural and man-made water problems. Natural problems of flood and drought are caused by extreme variations in rainfall that may range from as much as 20 inches per day during hurricanes in the rainy seasons to little or none during the dry seasons. Man-made problems include: 1) Sea-water intrusion that resulted from overdrainage of the area; 2) obtaining adequate municipal water supplies for the mushrooming population; and 3) disposing of increasing quantities of man-made wastes.

During the floods of 1947 and 1948 caused by excessive rainfall during hurricanes, several sections of downtown Ft. Lauderdale were under 2 to 3 feet of water and large inland residential areas were flooded for several days. In contrast, the fires of 1962 in the western part of the county occurred after a prolonged drought when water levels declined below surface level and became so dry that fires started as if by spontaneous combustion.

The threat of sea-water intrusion into municipal well fields has been a historic problem. As large amounts of fresh water were removed by drainage for urbanization, regional fresh-water levels declined and sea water advanced up the canals and inland through the aquifer during dry periods. In recent years, municipal well fields in Dania and Ft. Lauderdale have experienced some degree of sea-water contamination. This insidious invasion of salt water is an ever-present danger to the fresh-water supply of coastal well fields.

The need to expand municipal water supplies is a natural consequence of a rapidly increasing population. Also, per capita consumption of fresh water has increased with increased population. In 1955, the City of Ft. Lauderdale supplied about 15 mgd (million gallons per day) for a population of about 86,000, or 175 gal (gallons per day) per person. In 1965, the average pumpage was 28.5 mgd for a population of 139,000 or 205 gal per person. The peak water needs occur during the dry winter and spring when water levels are lowest but when tourist and irrigation uses are high. The daily water needs for Broward County in 1965 for municipal supplies are predicted to be as high as 500 mgd.

Waste disposal is rapidly becoming a major problem in Broward County. Most of the water used by man is discharged as effluent into the Biscayne aquifer through septic tanks or directly into canals, streams, and the ocean. The more water man uses, the greater the problem of effluent treatment and disposal becomes. The method and degree of treatment and the locations of disposal sites will have a significant effect on the quality and the quantity of future water supplies.

HYDROLOGIC SYSTEM

GENERAL DESCRIPTION

Most municipal, domestic, irrigation, and industrial supplies in Broward County are obtained from the Biscayne aquifer (fig. 2). The aquifer extends from the surface to depths of more than 200 feet near the coast and thins out near the surface 25 to 40 miles westward in the

Everglades. The aquifer contains beds of pure or sandy limestone separated by beds or lenses of sand. Any of the limestone beds of adequate thickness are capable of yielding large amounts of water to wells. Wells that tap the thick limestone in the deep part of the aquifer near the coast commonly yield more than a thousand gallons per minute.

Broward County lies within the Central and Southern Florida Flood Control District (CSFCD). The CSFCD accomplishes its function of flood control and water conservation by means of a network of levees, canals with control structures, and pumping stations to regulate water levels and flow in the canals.

During flood periods, the gated structures (fig. 3) near the coast are opened and ground water moves to the canals and is discharged to the ocean thereby lowering water levels. Pumping station S-13 on the South New River Canal assists gravity flow to the ocean during wet periods but station S-9 (fig. 4), farther inland, pumps flood waters westward into the conservation area. During droughts the gated structures near the coast are closed and pumping station S-9 pumps fresh water eastward from the conservation area through the canals. As a result, the levels of the canals near the coast are generally higher than the adjacent ground water, and the aquifer is replenished from the canals.

CHEMICAL QUALITY OF WATER

The quality of the water in the integrated flow system is generally good. Water from the aquifer is typically a hard, calcium-bicarbonate type suitable for most uses with simple treatment. Surface water is of good but variable quality—soft and highly colored by drainage from inland swampy areas during high-water periods, but increasingly mineralized by ground-water inflow during low-water periods. Effluent from some sewage and industrial plants in the county is discharged directly into controlled canals. Irrigation water containing fertilizers and pesticides also drains into the canals from inland farm areas. Analyses of water samples from canals indicate that pollutants at present (1967) do not constitute a health hazard. However, increases in the amounts of these pollutants caused by future increases in population and farm activity will necessitate detailed monitoring of the quality of the water in the canals and aquifer to protect the water resources of the county.

RECHARGE, DISCHARGE AND WATER MANAGEMENT

The amount of water potentially available for withdrawal in Broward County is determined by the recharge to and the discharge from the hydrologic system. Infiltration of rainfall through surface materials and seepage from controlled canals are the means of recharge to the Biscayne aquifer in Broward County. Discharge from the aquifer is by evapotranspiration, by ground-water flow to canals and the ocean, and by pumping from wells. Discharge through the canals and evapotranspiration are greatest during and after periods of heavy rainfall, when water levels are high, whereas discharge by pumping is greatest in the dry periods, at the peak of the tourist season. In general, the discharge by evapotranspiration and canal flow greatly exceeds the discharge by pumping from wells.

Because canals are closely controlled to minimize losses, and because they extend far inland to areas where ground-water levels are relatively high throughout the year, water levels adequate to provide recharge to the aquifer near the coast can be maintained. Broward County's annual rainfall averaged about 60 inches for the 1954-65 period, ranging from 35 to more than 75 inches. Although most of the rainfall occurs in the summer and fall (see fig. 5) coinciding with the hurricane season, it usually is unevenly distributed. This is clearly demonstrated by records of October 14-15, 1965 when 25 inches of rainfall was recorded at the coastal yacht harbor in Fort Lauderdale, and less than 5 inches was recorded at an agriculture station eight miles inland.

If rainfall during the wet season is deficient, water levels during the following dry season will be correspondingly low. For example, the rainfall for the 12 months prior to June 1962 was 36 inches, but the rainfall for the 12 months prior to November 1965 was 81 inches. Countywide water levels at the end of these two periods represented the low and high levels respectively since 1948.

Fluctuations of the water level reflect the effects of recharge to and discharge from the aquifer. These fluctuations are recorded by water-level measurements in a countywide network of canal stations and observation wells. Some of the stations and wells are equipped with continuously recording instruments and provide detailed records. Records from some of these stations and wells for the years 1962 and 1965 are shown in the hydrographs in figures 6 and 7.

Hydrographs show fluctuations of the water level with respect to

time. They indicate both instantaneous reactions and long-term trends. Water-level contour maps are three-dimensional representations of the water surface for a specific time and indicate the amount of water stored in the aquifer. A comparison of hydrographs and contour maps representing low-water level periods and high-water level periods aids in the determination of the effects man and nature have on the hydrologic system.

The thirteen graphs shown in figures 5, 6, and 7 indicate the hydrologic conditions in Broward County during 1962 (red) and 1965 (blue). Discharge of the Hillsboro Canal and stage and discharge of the North New River and Snake Creek Canals for 1962 and 1965 are shown on figure 6. Seven of the hydrographs (fig. 7) show water levels in wells. These graphs are identified by the well number and the location of the well as shown by number on figures 8 and 9. The combined pumpage for the two Fort Lauderdale well fields and rainfall at Fort Lauderdale for 1962 and 1965 is shown on figure 5.

The graphs show the effects on the water level caused by seasonal variations in rainfall and the effects of man's control and use. They reflect the characteristic low levels of the long winter dry season and the high levels of the wet season, June through October. The graph of pumpage (fig. 5) indicates that the time of greatest water needs corresponds with period of lowest levels because peak needs for the tourist influx and irrigation occur during the dry season.

At the beginning of 1962 the effects of extended drought are shown in the hydrographs by the relatively low water levels and canal flow. The rains of the summer and early fall of 1962 raised the water levels appreciably and canal discharge increased correspondingly. Figure 8 represents the low-of-record water levels that occurred (May 22-23, 1962) at the end of a prolonged drought. This was a period of large ground-water withdrawal. All coastal canal structures were closed to conserve as much fresh water as possible for recharge to the aquifer. The contours show that pumping from the major municipal well fields had created large water-level depressions. In the Prospect Well Field, the water level had declined to two feet below mud (mean sea level) and in the Dixie and Pompano Beach well fields they had declined to 10 ft. The contours also indicate that the control structures in the Middle River and North New River Canals are too far inland to provide adequate water for recharge to effectively minimize well-field depressions, and protection against salt-water intrusion from the tidal reaches of those canals.

Water conditions during the first half of 1965 were similar to those of 1962 in most parts of the county. Several of the hydrographs show that water levels during May and June of 1965 were lower than they were during the period of the area-wide low-water conditions of 1962. However, most of these graphs represent relatively local area where water levels were lowered by heavy well pumping, as shown by uncontrolled reaches of canals, whereas the water level contour maps were prepared from measurements made in more than a hundred wells throughout the county and represent regional conditions. Also, pumping and the resultant water-level drawdowns had increased appreciably in all major well-field areas during the interval between 1962 and 1965.

Figure 9 shows the configuration of the water surface on November 1, 1965, a time of extremely high levels. This extreme condition resulted after 42 inches of rain had fallen during October (see fig. 5). Compared to the low-water map, water levels in figure 9 are as much as 10 feet higher in the northeastern part of the county and about five feet higher in the remainder of the county. All coastal controls in canals were prepared from measurements made in more than a hundred wells throughout the county and represent regional conditions. Also, pumping and the resultant water-level drawdowns had increased appreciably in all major well-field areas during the interval between 1962 and 1965.

Figure 5 shows the configuration of the water surface on November 1, 1965, a time of extremely high levels. This extreme condition resulted after 42 inches of rain had fallen during October (see fig. 5). Compared to the low-water map, water levels in figure 9 are as much as 10 feet higher in the northeastern part of the county and about five feet higher in the remainder of the county. All coastal controls in canals were prepared from measurements made in more than a hundred wells throughout the county and represent regional conditions. Also, pumping and the resultant water-level drawdowns had increased appreciably in all major well-field areas during the interval between 1962 and 1965.

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SEA-WATER INTRUSION

The pink shaded area in figure 1 represents the maximum inland extent of sea-water intrusion at the bottom of the Biscayne aquifer in Broward County in 1964. The salt-water body in the aquifer is wedge shaped (fig. 1), thickest at the coast and thinning inland to an edge where it underlies fresh ground water at depths of 160 to 200 feet. Greatest inland penetration of sea water is in the vicinity of tidal canals.

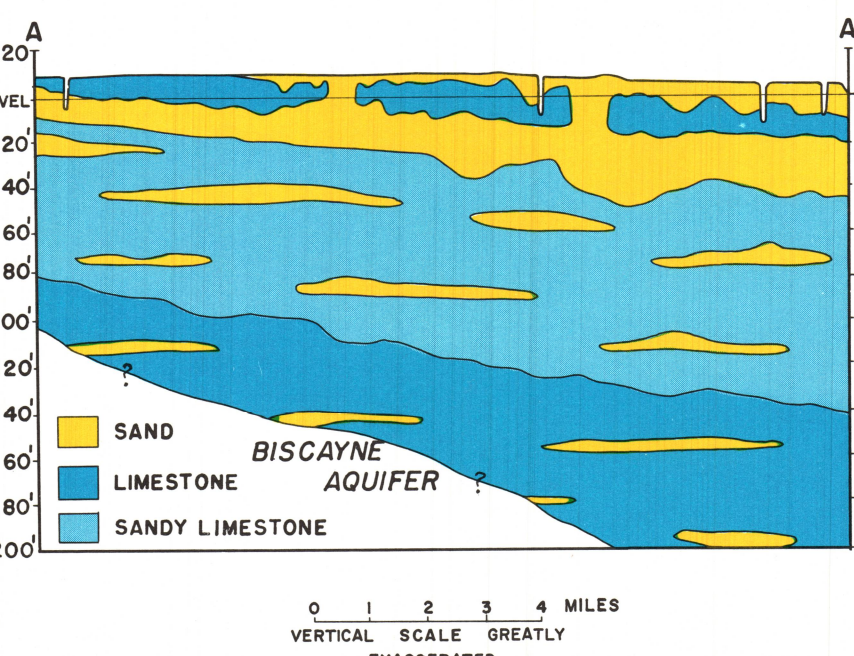


Figure 2.- Broward County is underlain by more than 200 feet of permeable water-bearing materials called the Biscayne aquifer. The aquifer contains beds of pure or sandy limestone separated by beds or lenses of sand. Any of the limestone beds of adequate thickness are capable of yielding large amounts of water to wells. Wells that tap the thick limestone in the deep part of the aquifer near the coast commonly yield more than a thousand gallons per minute. (Section is along line A-A' in figure 8).

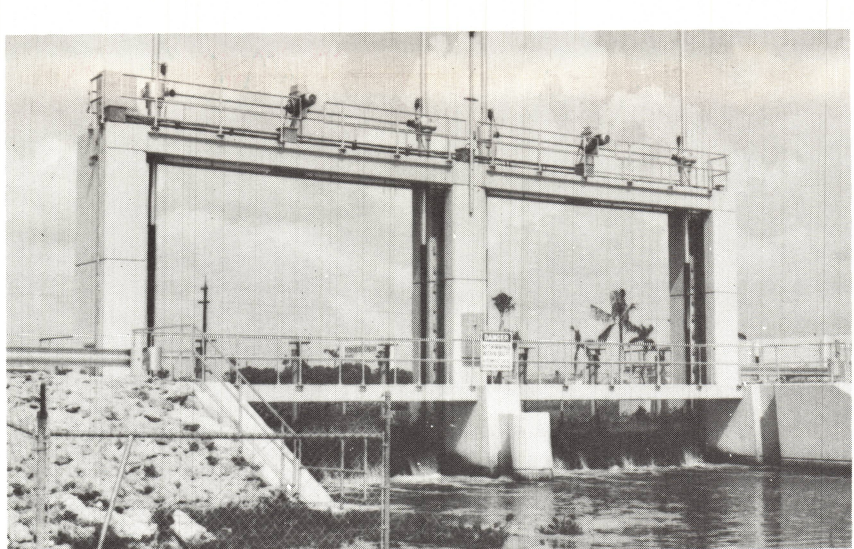


Figure 3.- Salinity control structure S-37A on Cypress Creek Canal (C-14) near Pompano Beach helps to prevent the intrusion of salt water into the Fort Lauderdale Prospect well field. When heavy rainfall occurs the gates are opened to prevent flooding in the inland areas. During dry periods the gates are closed to conserve fresh water. View is looking upstream toward the coast.

Figure 4.- Pumping station No. 9 is located on the South New River Canal (C-13) at the eastern edge of the conservation area. The principal function of this pumping station is to remove storm flows at the rate of as much as 1.3 million gallons per minute from the drainage area and discharge them into the conservation area for storage and future use in dry periods. View is looking west (upstream). (From CSFCD brochure).

OUTLOOK

Water control and management practices are being constantly improved on both regional and local levels. Recent legislation gives the Broward County Water Resources Department and the Water Resources Advisory Board the power to control man-made changes in the flow system, subject to approval of the Board of County Commissioners.

Hydrologic information indicates that the network of canals and hydraulically-connected aquifer form an integrated flow system which provides the physical basis for management of the area's water resources. Thus, the source of supply and the area's basic facilities for efficient water management are available, and the methods for development of maximum municipal supplies are clearly indicated. The application of comprehensive water-management policies and careful planning of changes within the flow system based on continuing hydrologic studies seemingly cannot provide solutions to Broward County's growing water problems, such as floods, drought, sea-water intrusion, and pollution, but also assume ample long-term municipal supplies.

Further information and data on the water resources of Broward County are included in the following reports:

1. *Water Resources of Southeastern Florida*: 1955. U.S. Geological Survey, Water Supply Paper 1255.
2. *Biscayne Aquifer of Dade and Broward Counties, Florida*: 1958. Florida Geological Survey Report of Investigations No. 17.
3. *Ground-water Resources of the Oakland Park area of eastern Broward County, Florida*: 1959. Florida Geological Survey Report of Investigations No. 20.
4. *Hydrology of the Biscayne Aquifer in the Pompano Beach area, Broward County, Florida*: 1964. Florida Geological Survey, Report of Investigations No. 36.
5. *Control of sea-water intrusion in Broward County, Florida*: 1965. Florida Geological Survey Leaflet No. 5.
6. *Chemical Quality of Waters of Broward County, Florida*: 1968. Florida Geological Survey Report of Investigations No. 51.
7. *Records of water levels, streamflow, and water quality are published annually in "Water Resources Data for Florida"* prepared by the U.S. Geological Survey in cooperation with the State of Florida and other agencies.

For current information contact the U.S. Geological Survey, 51 S.W. First Avenue, Miami, Florida or Broward County Water Control, Broward County Courthouse, Fort Lauderdale, Florida.

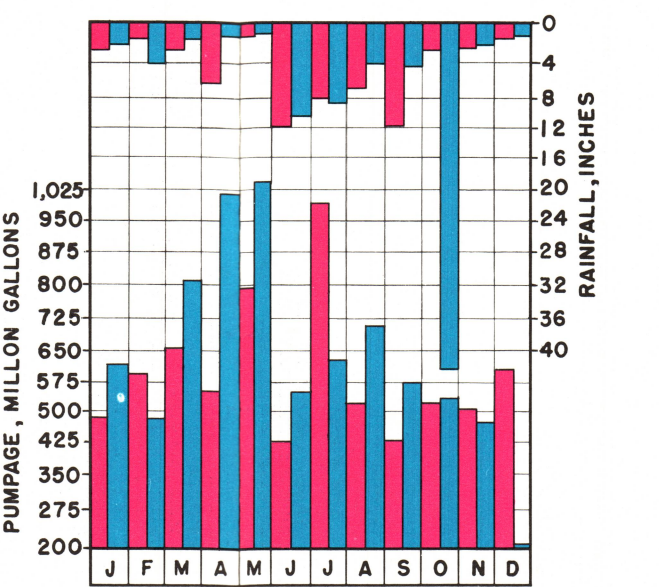


Figure 5.- Total monthly pumpage of the Fort Lauderdale Dixie and Prospect well fields and monthly rainfall at Fort Lauderdale for 1962 (red) and 1965 (blue).

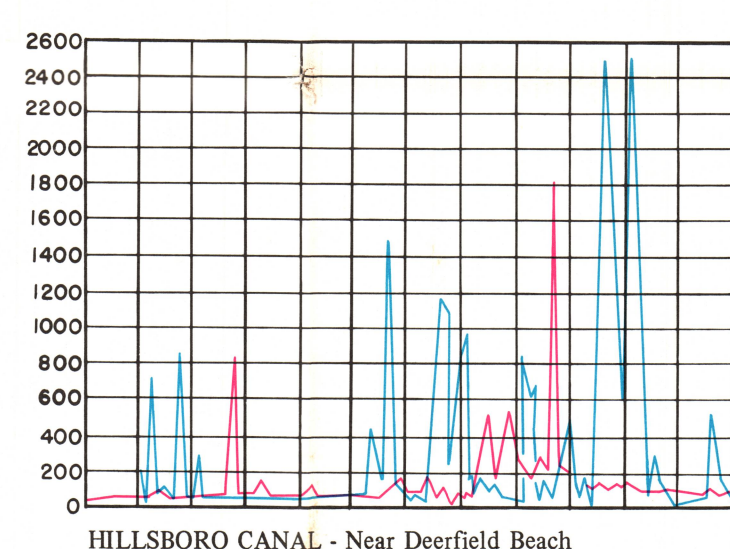


Figure 6.- Stage and discharge hydrographs of selected canals. Location of the measurement sites are shown on figures 8 and 9. 1962 record is shown by the red line and 1965 record is shown by the blue line.

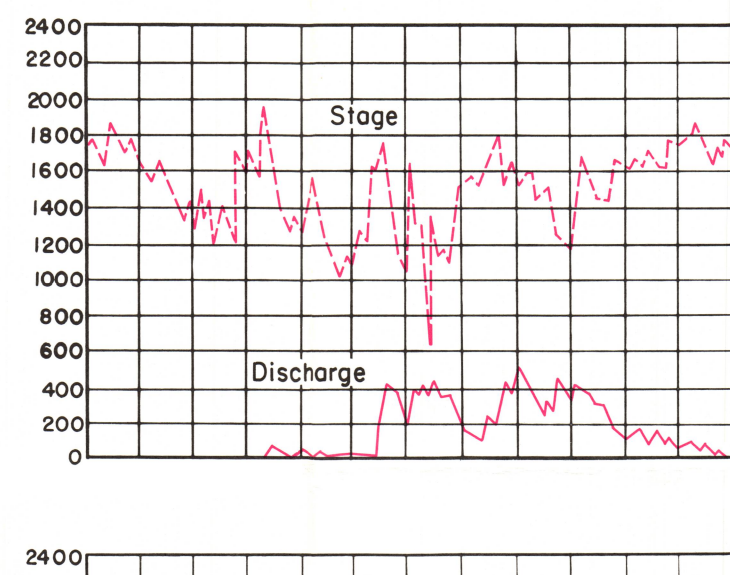


Figure 7.- Hydrographs of selected wells equipped with continuous water-level recording instruments. The 1962 record is shown by the red line and the 1965 record by the blue line. Location of wells are shown by their number on figures 8 and 9. Arrows indicate dates of record low and high water level conditions shown on figures 5 and 9.

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Figure 10.- Stage and discharge hydrographs of selected canals. Location of the measurement sites are shown on figures 8 and 9. 1962 record is shown by the red line and 1965 record is shown by the blue line.

Figure 11.- Stage and discharge hydrographs of selected canals. Location of the measurement sites are shown on figures 8 and 9. 1962 record is shown by the red line and 1965 record is shown by the blue line.

Figure 12.- Stage and discharge hydrographs of selected canals. Location of the measurement sites are shown on figures 8 and 9. 1962 record is shown by the red line and 1965 record is shown by the blue line.

Figure 13.- Stage and discharge hydrographs of selected canals. Location of the measurement sites are shown on figures 8 and 9. 1962 record is shown by the red line and 1965 record is shown by the blue line.

Figure 14.- Stage and discharge hydrographs of selected canals. Location of the measurement sites are shown on figures 8 and 9. 1962 record is shown by the red line and 1965 record is shown by the blue line.

Figure 15.- Stage and discharge hydrographs of selected canals. Location of the measurement sites are shown on figures 8 and 9. 1962 record is shown by the red line and 1965 record is shown by the blue line.

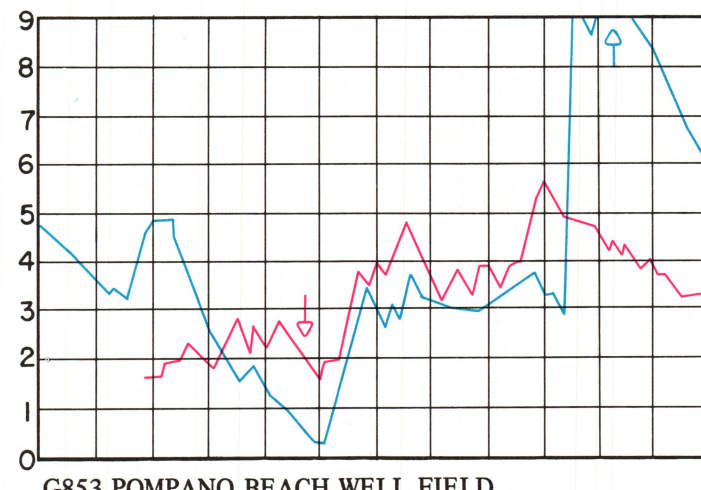


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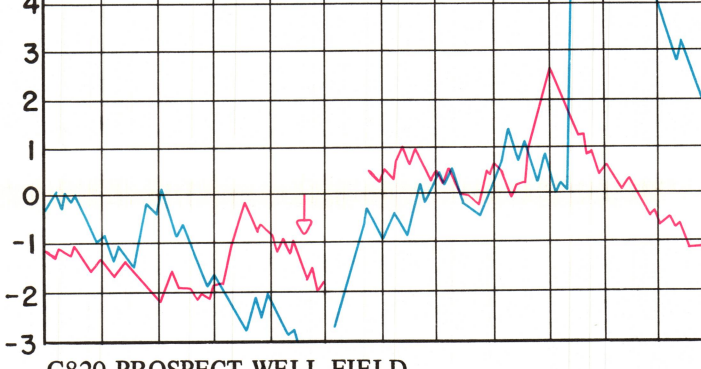


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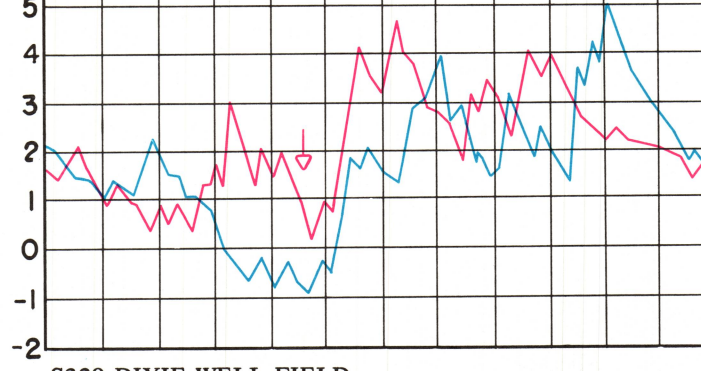


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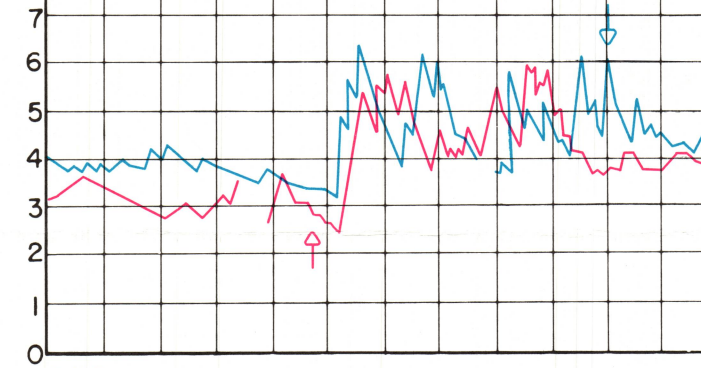


Figure 11.- Stage and discharge hydrographs of selected canals. Location of the measurement sites are shown on figures 8 and 9. 1962 record is shown by the red line and 1965 record is shown by the blue line.

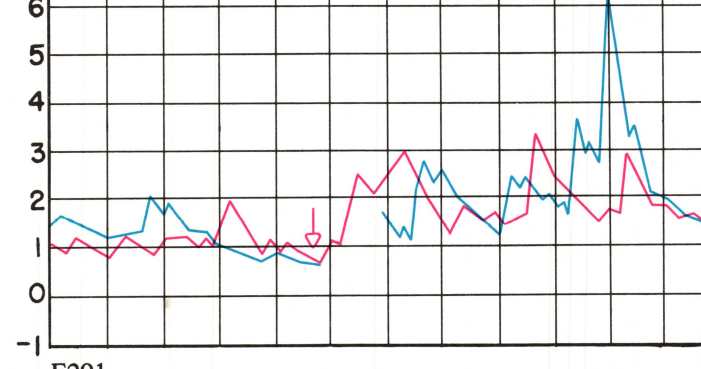


Figure 12.- Stage and discharge hydrographs of selected canals. Location of the measurement sites are shown on figures 8 and 9. 1962 record is shown by the red line and 1965 record is shown by the blue line.

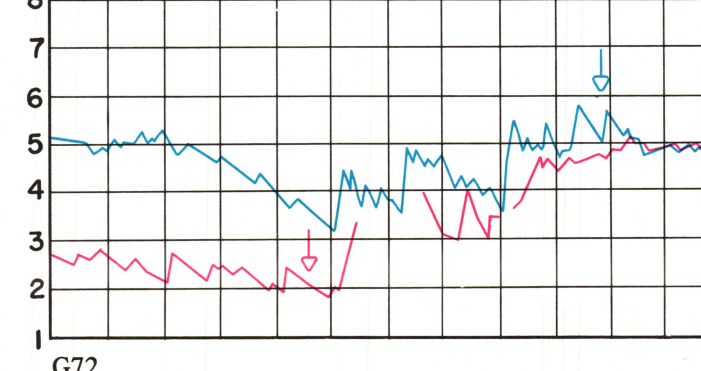


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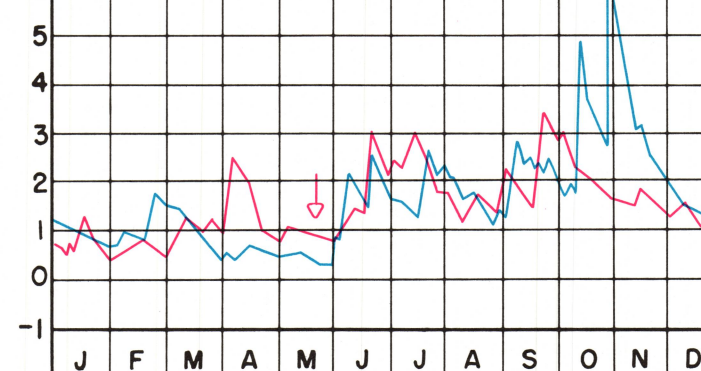


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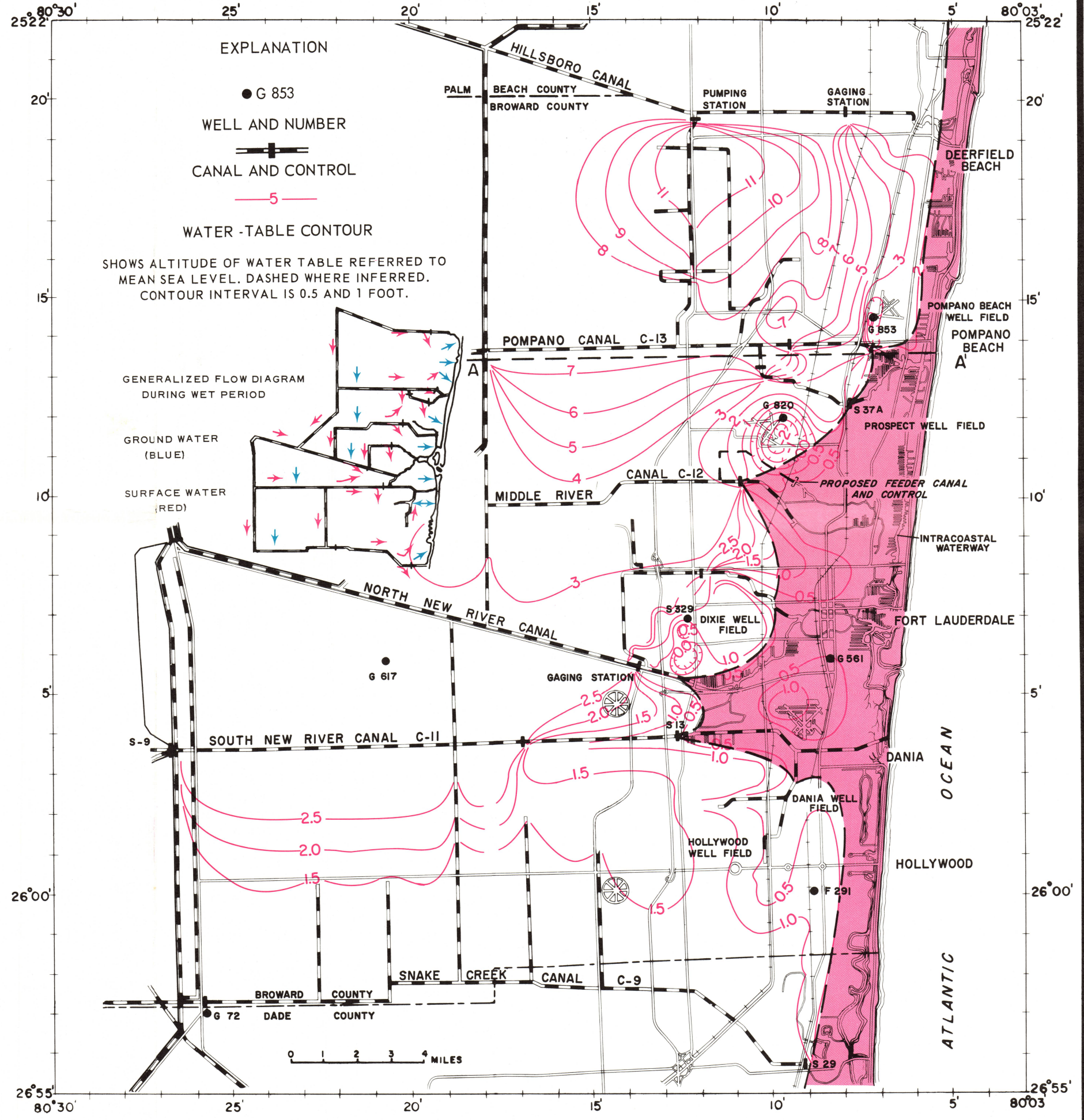


Figure 8.- LOW-WATER CONDITIONS -- Contours on the record low water table of May 22-23, 1962 are shown by the red lines. Sea-water intrusion in Broward County in 1964 is shown by pink shading. The salty water in the aquifer is wedge shaped (fig. 1), thickest at the coast and thinning inland where it underlies fresh ground water at depths of 160 to 200 feet. Greatest inland penetration is in the vicinity of tidal canals.

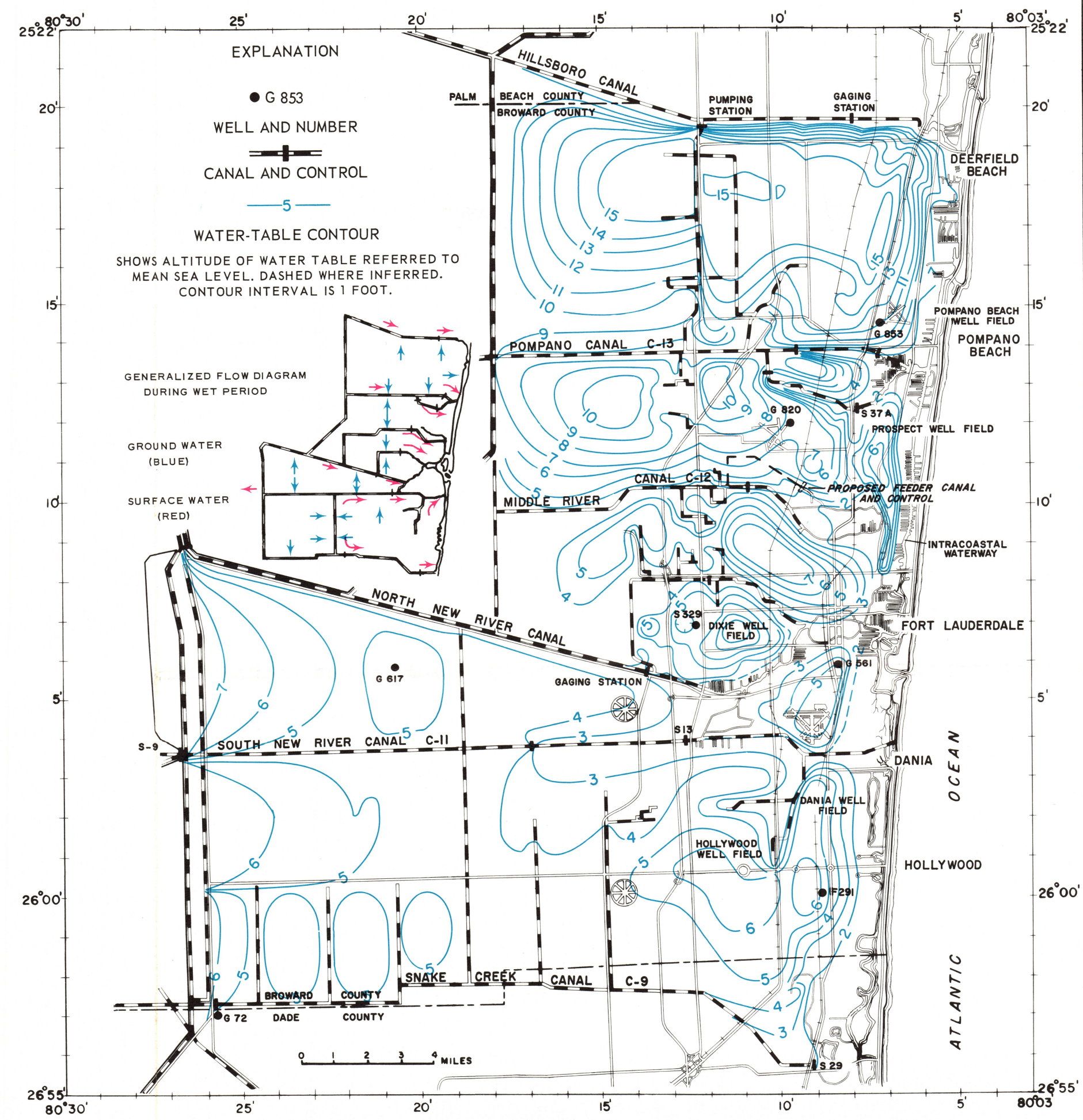


Figure 9.- HIGH-WATER CONDITIONS -- Contours on the record high water table on November 1, 1965 are shown by blue lines.