IMPACTS OF THE TAMPA BYPASS CANAL SYSTEM ON THE AREAL HYDROLOGY, HILLSBOROUGH COUNTY, FLORIDA

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ABBREVIATIONS AND CONVERSION FACTORS

Factors for converting inch-pound units to International System of Units (SI) and abbreviations of units

Multiply	By	To obtain
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
acre	0.4047	hectare (ha)
square foot (ft^2)	0.09294	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallon (gal)	0.003785	cubic meter (m^3)
gallon per minute (gal/min)	0.00006309	cubic meter per second (m^3/s)
micromho per centimeter at 25° Celsius (umho/cm at 25°C)	1.000	microsiemens per centimeter at 25° Celsius (uS/cm at 25°C)

Temperature in degrees Fahrenheit (°F) can be converted to degrees Celsius (°C) as follows:

$$°F = 1.8°C + 32$$

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ABSTRACT

The Tampa Bypass Canal system was constructed in north-central Hillsborough County to divert water from the Hillsborough River to alleviate flooding in Tampa and Temple Terrace. Construction started in 1966 and ended in 1981. Excavation of the canal system resulted in cutting into the confining bed that separates the Upper Floridan aquifer from the overlying surficial aquifer and in several places breached the Upper Floridan aquifer.

Records of discharge from the canal area indicate that base-flow discharge for the period 1975 to 1978 was about one-and-a-half times the discharge prior to construction. After 1978, the base-flow discharge was about twice that of the preconstruction period.

Discharges for Baker and Flint Creeks, the inlet and outlet streams of Lake Thonotosassa, which is near the canal area, have not been affected by construction of the canal system. Lower levels of the potentiometric surface caused by excavation of the canal system, however, resulted in reductions in the discharge from springs. Records for Sixmile Creek Spring and Lettuce Lake Spring show reductions in discharge of 55 and 35 percent or more, respectively.

Water levels of the Upper Floridan aquifer adjacent to the tidal reach of the canal system (downstream from structure S-160) have not been affected by canal construction. Water levels in the canal upstream of structure S-160 are higher than preconstruction levels due to impoundment of water. An increase in levels of up to 4 feet is indicated.

Water levels of the Upper Floridan aquifer upstream of structures S-162 and S-159 and in the Cow House Creek area are generally 2 to 4 feet lower as a result of construction.

Water levels in wells near structure S-161 on the Harney Canal closely follow levels of the Hillsborough River, indicating a good hydraulic connection between the river and the Upper Floridan aquifer. In the lower reaches of the Harney Canal, water levels of the Upper Floridan aquifer have been lowered about 2 to 4 feet due to construction.

Water levels for two surficial aquifer wells and adjacent Upper Floridan aquifer wells, near structure S-162 and Sixmile Creek Spring, show the potentiometric surface to be generally higher than the water table prior to about mid-1975. Subsequently, the potentiometric surface has been generally lower than the water table.

For most surface-water sites, little or no change in water quality was noted. Downstream from structure S-160 there were some reductions in nutrient concentrations. Similarly, upstream of structures S-160 and S-162, small reductions in nutrient concentrations were noted. Upstream of structure S-159, increases in specific conductance, hardness, and potassium were noted.

Water-quality data for Cow House Creek and Harney Canal show little change with time but show some seasonal change as a function of discharge. Water-quality data for Baker and Flint Creeks fluctuate widely, due to seasonal changes in discharge, runoff from agricultural areas and undeveloped marshlands, and municipal and industrial effluent discharges. Construction of the planned canal C-132 in the Baker and Flint Creeks area was dropped from the bypass canal plans. Thus, there was little potential for change in that area.

Water-quality data from the Upper Floridan aquifer wells near the mouth of the Palm River showed a decline in specific conductance (700 to 200 micromhos) and in concentrations of chloride (90 to 60 milligrams per liter). Further upstream in the Palm River area, increases in specific conductance (1,200 to 1,500 micromhos) and chlorides (200 to 350 milligrams per liter) were noted.

Chloride concentrations in water from Upper Floridan aquifer well 10 near structure S-160 showed a gradual increase from 1971 to about 1979, as did the specific conductance. Chloride concentrations increased from about 60 to 90 milligrams per liter, and specific conductance increased from about 650 to 750 micromhos. Chemical-quality data for water from other wells show minor or temporary changes in the concentrations of some constituents.

INTRODUCTION

The Tampa Bypass Canal system was constructed in north-central Hillsborough County, Fla. (fig. 1), to divert water from the Hillsborough River to McKay Bay. The diversion is to alleviate flooding in Tampa and Temple Terrace (fig. 2) and is accomplished by two canals: (1) the Tampa Bypass Canal, C-135, that extends southward from the Lower Hillsborough Flood Detention Area (LHFDA) to McKay Bay; and (2) the Harney Canal, C-136, that extends eastward from the Hillsborough River near Temple Terrace to the Tampa Bypass Canal (fig. 2). Construction of the canals began in July 1966 at the mouth of Palm River. The canal system became operational in mid-1981.

In January 1972, the U.S. Geological Survey, in cooperation with the U.S. Army Corps of Engineers and the Southwest Florida Water Management District, began an investigation to assess possible hydrologic impacts that might be caused by construction and operation of the canal system. A report, entitled "Hydrologic Effects of the Tampa Bypass Canal System" (Motz, 1975), was published as a result of that investigation. The report indicated that excavation of the canals would cut into the confining bed that separates the Upper Floridan aquifer from the overlying surficial aquifer and, in several places, would breach the Upper Floridan aquifer. Because the potentiometric surface of the Upper Floridan aquifer is higher than the planned operational stages of the canal system, water would flow from the Upper Floridan aquifer into the canals. A decline in the potentiometric surface of the Upper Floridan aquifer would be produced by water flowing from the aquifer into the canals. This decline would increase the head difference between the water table and the potentiometric surface and increase downward leakage from the surficial aquifer into the Upper Floridan aquifer. Motz (1975) pointed out that a decline in the potentiometric surface could

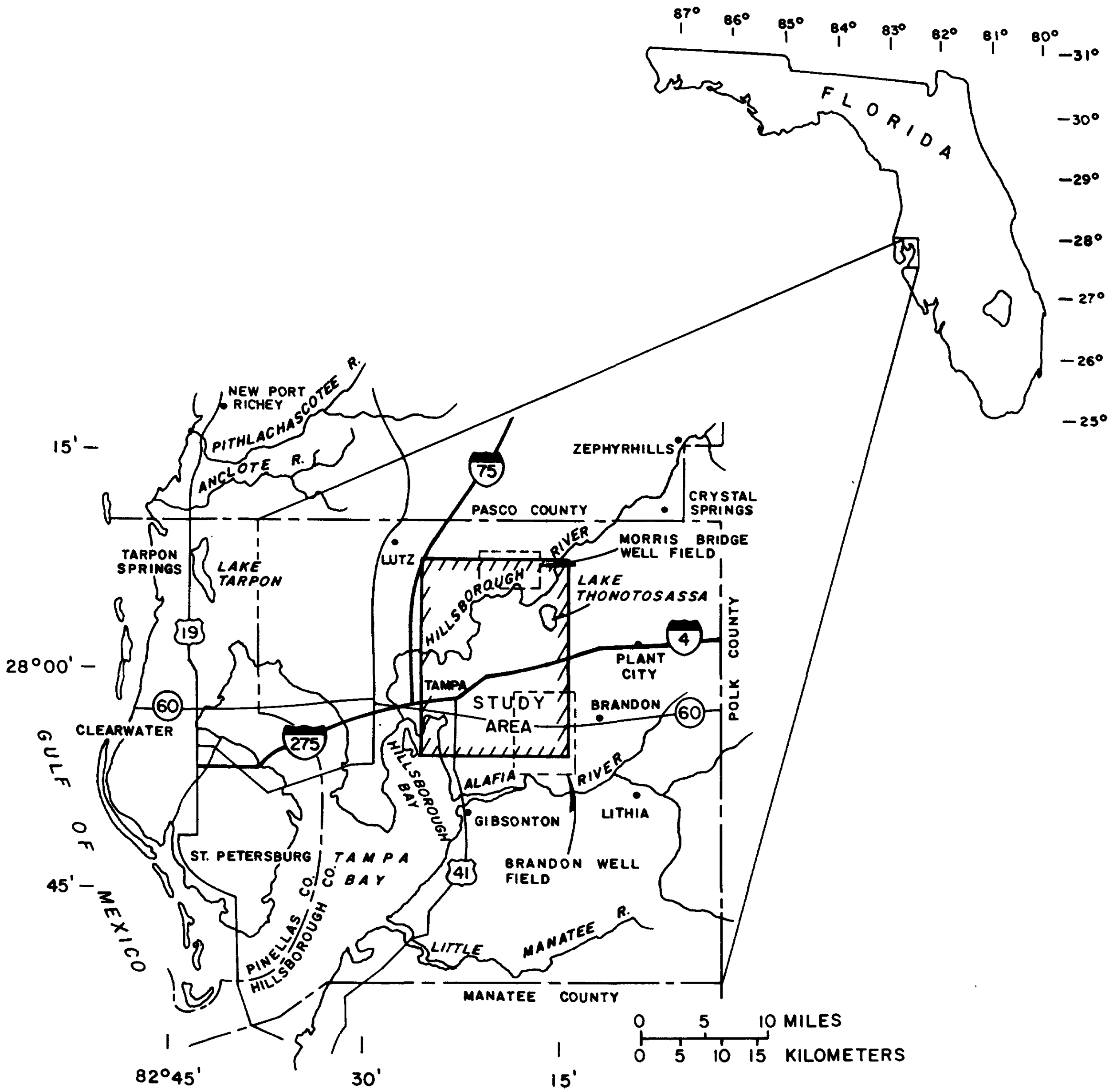


Figure 1.--Location of study area.

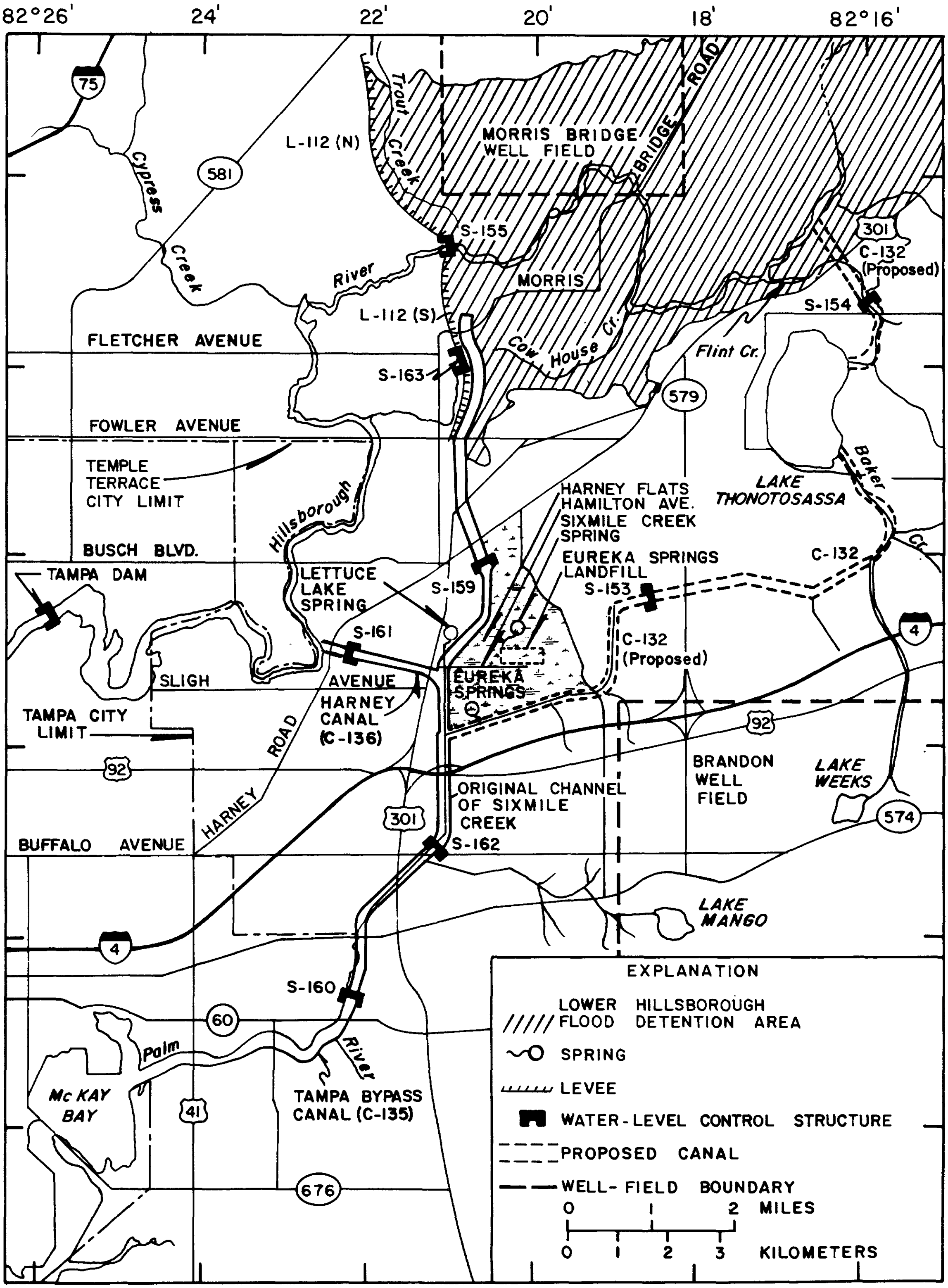


Figure 2.--Configuration of the Tampa Bypass Canal system.

result in: (1) reduction of discharge from springs; (2) lowering of the water table; (3) drying of swamps; (4) movement of saltwater into the Upper Floridan aquifer; and (5) change in concentrations of chemical constituents in ground water in areas adjacent to the canal.

Since 1973, the U.S. Geological Survey has maintained a data-collection network in the canal area to monitor: (1) levels of the potentiometric surface in the Upper Floridan aquifer; (2) quality and quantity of water in the canal system, nearby streams, and springs; and (3) quality of water in the Upper Floridan aquifer. The network was designed to provide data for defining any impacts due to construction of the canal system on the areal hydrology.

Purpose and Scope

The purpose of this study is to determine the impacts of construction of the Tampa Bypass Canal system on the occurrence, circulation, and chemical properties of surface water and ground water along the canals. Hydrologic and water-quality data from the canal area are examined and evaluations made that will facilitate planning for efficient conservation of freshwater resources and protection of the environment.

The study area is approximately 150 mi^2 in size and is centered about 2 miles southeast of the city of Temple Terrace and about 4 miles east of the city of Tampa (fig. 2). This study examines the nature and extent of changes in water chemistry of the surface water and ground water in the vicinity of the canals. The study also evaluates changes in rates of flow of surface water and changes in the potentiometric surface of the Upper Floridan aquifer and the water table of the surficial aquifer.

Previous Investigations

Since 1961, the U.S. Army Corps of Engineers has prepared several internal reports and unpublished memoranda on many aspects of the Tampa Bypass Canal system, including geology and hydrology. Cooke (1945), Carr and Alverson (1959), and Puri and Vernon (1964) described the geology of the area in their reports. Aspects of the physiography and geomorphology of Florida, including the area near Tampa, were described by MacNeil (1949) and White (1958). Maps of the potentiometric surface of the Floridan aquifer system and hydrologic studies of Florida, including the Tampa area, were prepared by Stringfield (1936; 1964; 1966). Menke and others (1961) studied the water resources of the Tampa area, and in 1965, Shattles reported on the water quality of the area. In 1971, Stewart and others prepared a potentiometric surface map of the Upper Floridan aquifer that included the Tampa area. A recent report was prepared by Stewart and others (1983) on hydrogeologic data for the Eureka Springs landfill and adjacent area.

Reports that deal directly with the canal system include the report by Motz (1975) who studied the hydrologic effects of the canal system. A report on hydrologic data for the Tampa Bypass Canal system was prepared by Causseaux and Rollins (1979). Geraghty and Miller, Inc. (1982), evaluated the canal system for its potential as a water-supply source.

DESCRIPTION OF AREA

Physical Setting

The Tampa Bypass Canal system is in an area that is experiencing urbanization as development spreads from Tampa, Temple Terrace, and adjacent areas in Hillsborough County. Major existing residential areas occur mainly to the south of Interstate Highway 4 (fig. 2). Most new residential and industrial development is occurring north of Harney Road. Some industrial activities occur in the lower reaches of the canal system, and tropical fish are raised near the canal north of Interstate Highway 4. Areas that have not been developed are largely in citrus groves interspersed with some swampy lowlands. Interstate Highway 75, currently (1984) under construction, is just to the west of the bypass canal north of structure S-159 (fig. 2), intersects the bypass canal near structure S-159, and parallels the canal about 2 miles to the east, south of structure S-159. With completion of the highway, development in the area may increase.

The Eureka Springs landfill is within one-half mile of the canal system (fig. 2). The 128-acre landfill became operational on October 1, 1969 (Stewart and others, 1983). The landfill area is drained by a network of canals that connect to the Tampa Bypass Canal. The landfill initially received trees, shrubs, grass cuttings, and construction and demolition wastes. Subsequently, it received domestic and industrial solid waste. Use of the site as a landfill was discontinued in 1976. Water samples from the surficial aquifer at the landfill showed relatively high levels of specific conductance (465 to 1,300 umhos) and chloride (50 mg/L), well above background levels (Stewart and others, 1983). Water samples from the Upper Floridan aquifer did not show any significant change in quality due to the landfill. Some leachate could reach, and may have reached, the bypass canal system by way of the network of drainage canals from the landfill.

Topography and Drainage

The Tampa Bypass Canal is in the sandy, poorly drained Coastal Lowlands, one of five topographic divisions of Florida (Cooke, 1945; Puri and Vernon, 1964). A plain that occurs in areas adjacent to the canal slopes gently upward from the lower end of the canal system at McKay Bay to the Harney Flats just north of Interstate Highway 4. The plain is a former bay bottom that was once part of an estuary that was larger than the present Hillsborough Bay (MacNeil, 1949). Away from the canal, the land surface is more undulating or hilly, except near the Hillsborough River, which has a broad, swampy flood plain.

Land-surface altitudes in the plain area range from sea level at McKay Bay to about 20 feet at the scarp that rims the plain area. Between the canal and Lake Thonotosassa, land-surface altitudes exceed 100 feet in several places and reach a maximum of about 140 feet. Surface drainage from Lake Thonotosassa is north to the Hillsborough River. West of the lake, drainage is to the west by way of Cow House Creek to the Hillsborough River, or to the southwest by way of the original Sixmile Creek and Palm River water courses to McKay Bay.

Climate

The climate of the area is subtropical and is characterized by warm, humid summers and mild winters. Some rainfall normally occurs each month of the year, but there is a distinct rainy season that extends from June through September and a low-rainfall season that extends from October through May. About 60 percent of the annual rainfall occurs during the rainy season. Winter rainfall is generally light because Florida is normally the southern limit of winter frontal systems, the causative factors in winter rainfall. Summer rainfall is derived principally from convection storms that usually occur in the afternoon or early evening. Spatially, summer rainfall is highly variable. Areas only a few miles apart often receive widely differing amounts of rain.

The long-term average annual rainfall, based on records at Tampa for 1941 to 1970, is 49.4 inches. The mean monthly distribution of rainfall is shown in figure 3. The average annual temperature is 72.2°F, and the range in average monthly temperatures is from 60.4°F in January to 82.2°F in August.

The annual rainfall since 1960 for the weather station at Tampa is shown in figure 4. For most years since construction of the canal system began (1966), rainfall has been less than the 1941 to 1970 average. Rainfall during 1979 was

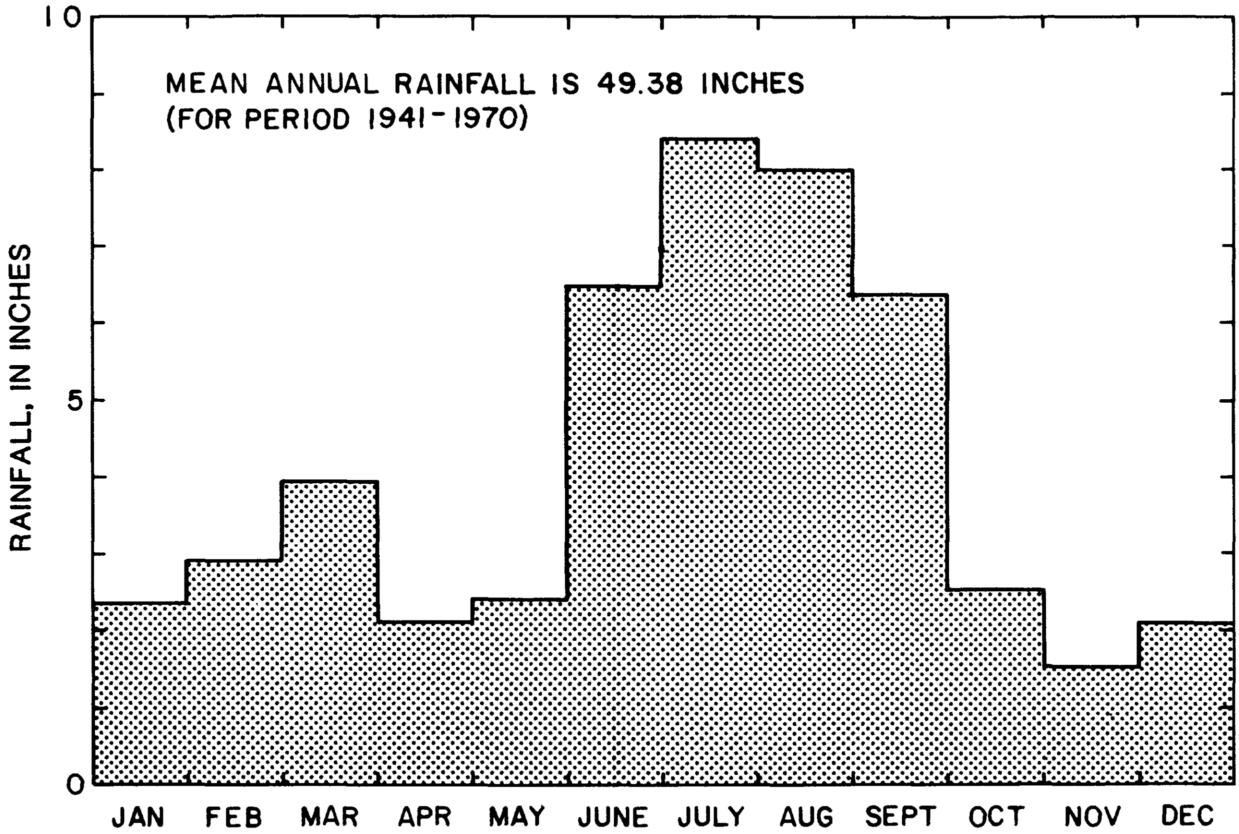


Figure 3.--Mean monthly rainfall at Tampa.

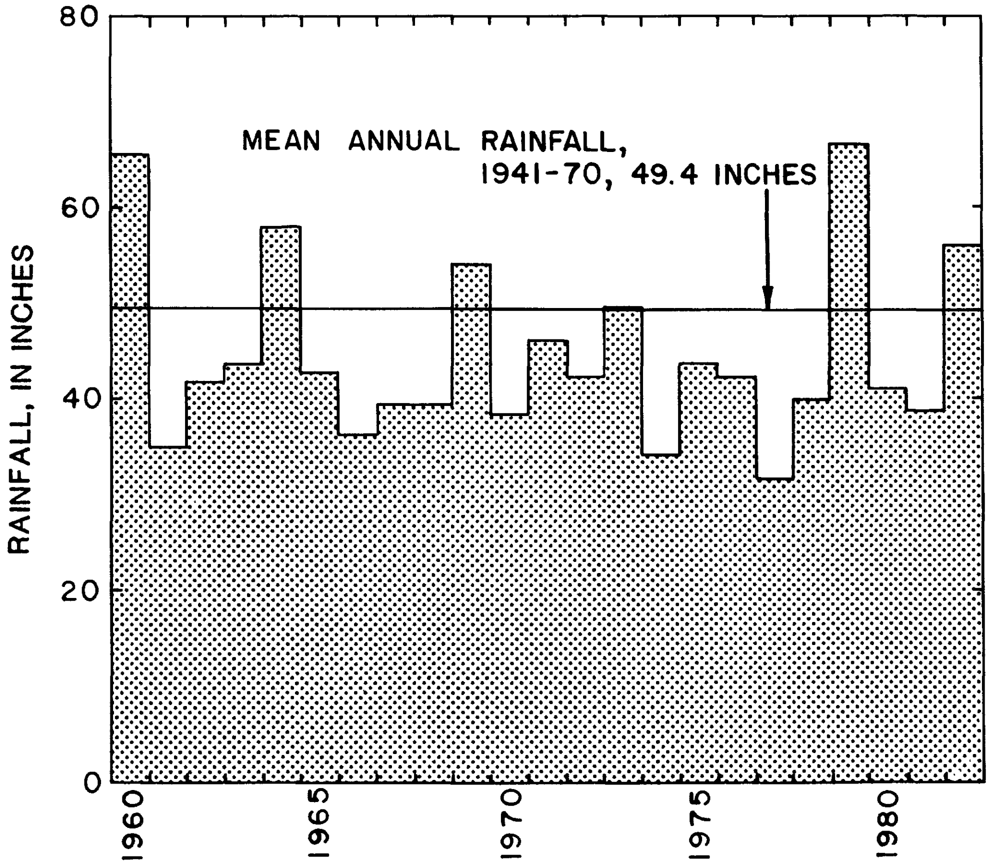


Figure 4.--Annual rainfall at Tampa, 1960-82.

unusually high and caused some flooding in the Tampa area. Although the rainfall record shown does not indicate an unusually dry condition from mid-1980 to mid-1981 (rainfall generally less than 40 inches), most of west-central Florida experienced drought-like conditions during the period. By mid-1981, ground-water levels were at or lower than record lows, and low-flow discharges of streams were in amounts that would be expected as infrequently as once in 20 years or more.

HYDROLOGIC SETTING

Geology

A generalized geologic column of the bypass canal area is shown in figure 5. Near land surface, the rock units are mostly undifferentiated deposits that contain varied amounts of sand, silt, clay, and shells. These deposits average about 35 feet in thickness, but in places, the thickness may be as much as 60 feet (Geraghty and Miller, Inc., 1982). Along the canal system, the deposits average about 25 feet in thickness (fig. 6). In most places, beds of clay occur at the base of the unconsolidated deposits. The beds have an average thickness of about 10 feet and form a semipermeable confining layer over limestone and

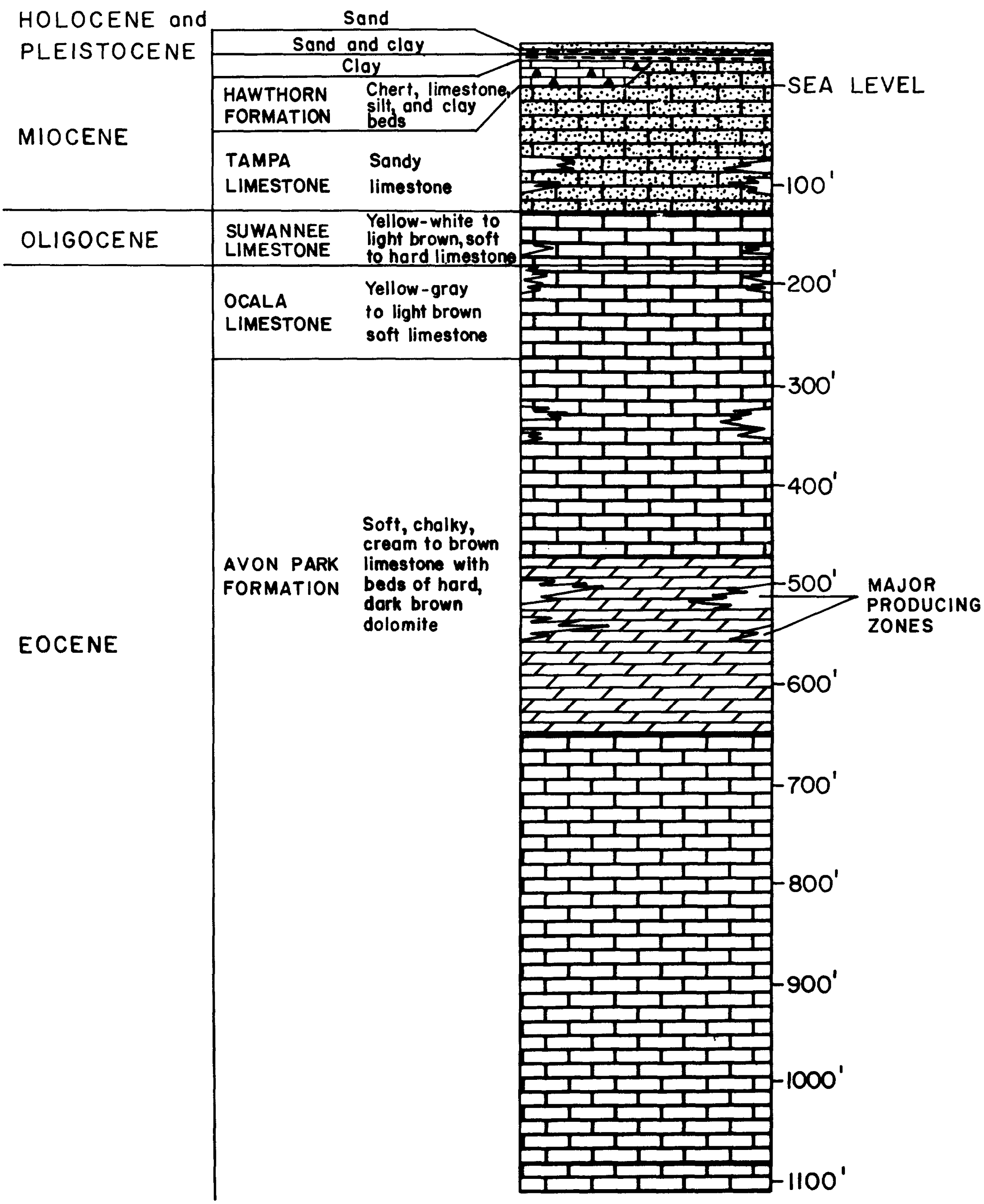


Figure 5.--Generalized geologic column of the Tampa Bypass Canal area (modified from Ryder and others, 1980).

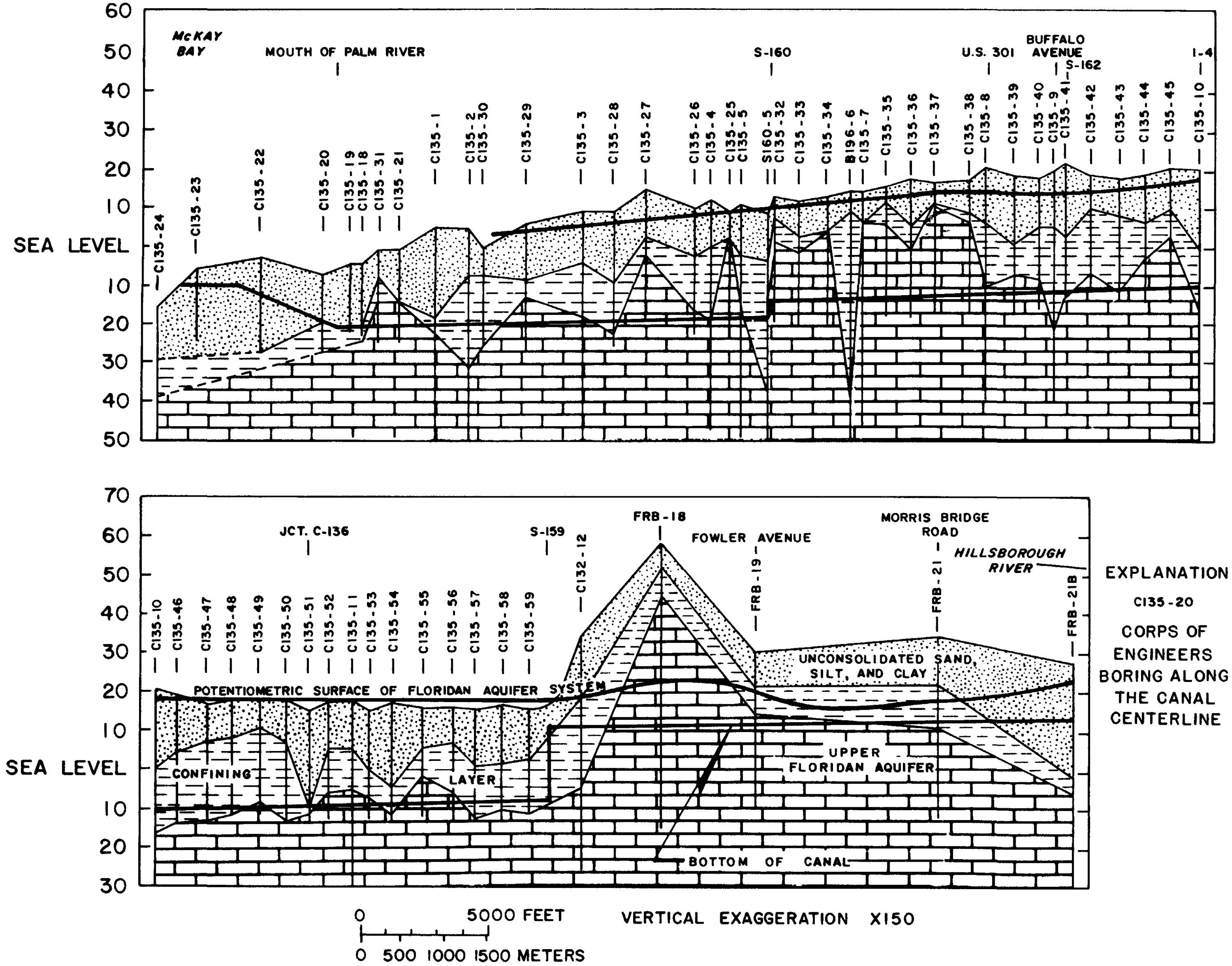


Figure 6.--Hydrogeologic section along the Tampa Bypass Canal (from Motz, 1975).

dolomite formations. The erosional or depositional edge of the Hawthorn Formation occurs in the vicinity of the canal system, and the formation tends to pinch out or is relatively thin or patchy. In this area, the formation consists largely of clay and can be considered to be part of the unconsolidated deposits. The formation thickens to the south.

The limestone and dolomite formations beneath the unconsolidated deposits are several hundred feet in thickness. These formations, in descending order, are the Tampa, Suwannee, and Ocala Limestones and the Avon Park Formation.

The Tampa Limestone is a white, gray, and tan, hard, dense, sandy limestone (Peek, 1959). The limestone has a large number of fractures and solution channels and is an important source of water. The underlying Suwannee Limestone consists mainly of soft to hard, granular, fossiliferous limestone that varies in color from yellow-white to light brown. In some places, it contains beds of crystalline, partly silicified dolomite (Peek, 1959). The Suwannee Limestone is the source for most domestic water wells in the area.

The Ocala Limestone is a somewhat granular, coquinoid, chalky limestone that contains echinoids, mollusks, and other loosely cemented fossils in a fine, chalky, granular matrix. The limestone varies from yellow-gray to light brown. This zone is not very productive and yields small amounts of water to wells that are completed in it.

The Avon Park Formation is the deepest producing zone of the Upper Floridan aquifer. The limestone is a soft, chalky, granular limestone that contains foraminifers and other fossils. Highly fractured dolomitic zones in the formation are important sources of water. These zones yield most of the water that is pumped from the Morris Bridge well field in the northern part of the study area. However, few wells penetrate the formation in most of the canal area because the water is highly mineralized (Peek, 1959).

Surface-Water Hydrology

Surface waters in the canal area consist of the Hillsborough River and numerous small streams, drainage canals, lakes, and springs. The Hillsborough River has a drainage area of about 400 mi^2 at structure S-155 (north-central part of study area) and 650 mi^2 at the Tampa Dam. The river is the major source of public water supply for the city of Tampa. Smaller streams include Baker and Flint Creeks, the inlet and outlet streams of Lake Thonotosassa, respectively; Cow House Creek; Sixmile Creek; and Palm River.

Cow House Creek currently (1984) flows along its original course across the Tampa Bypass Canal and to the Hillsborough River. The flow is through structure S-163 that controls the discharge through levee L-112(S) (fig. 2). If the upper control at structure S-159 is open, some discharge from Cow House Creek could flow through the bypass canal to McKay Bay rather than to the Hillsborough River. The normal course, however, is to the Hillsborough River as the upper structure at S-159 is usually closed. During floods, Cow House Creek would provide about 50 percent of the conveyance for discharge released to the bypass canal system. The bypass canal was alined with Palm River and Sixmile Creek and those former streams are now part of the canal system.

The principal springs are Eureka Springs, Sixmile Creek Spring, and Lettuce Lake Spring, but there are also many other small springs in the area. Formerly, all these springs discharged to Sixmile Creek. As a consequence, Sixmile Creek had a unit runoff (discharge divided by drainage area) that was approximately twice that of either the Hillsborough River at Zephyrhills or the Alafia River at Lithia (Menke and others, 1961). Also, Sixmile Creek had one of the highest base flows of all streams in west-central Florida. The Eureka Springs area has been altered by ditches in the past and was developed into a recreation and education center in 1982. As part of that development, the springs were again altered slightly and canals dug to confine, direct, and control discharge from them. Currently (1984), however, the springs flow unregulated and discharge is directly to the canal system.

Lakes in the area include Lake Mango, Lake Weeks, and Lake Thonotosassa. Lake Thonotosassa and its inlet and outlet were planned initially to be part of the bypass canal system through proposed canal C-132 (fig. 2). The canal was dropped from the plans as construction of the bypass canal system progressed. Lake-stage data have been collected on Lake Thonotosassa continuously since 1965; records are also available for 1956 to 1958. Levels of the lake are controlled by a structure at its outlet. Stage data are not available for the other lakes.

Ground-Water Hydrology

The rock units form a hydrologic system that consists of a surficial aquifer, a confining bed, and the artesian Upper Floridan aquifer of the Floridan aquifer system. The saturated parts of the unconsolidated deposits constitute the surficial aquifer, and the thick sequence of carbonate rocks collectively form the Upper Floridan aquifer.

Recharge to the surficial aquifer and Upper Floridan aquifer is primarily from rainfall. Rainfall recharges the surficial aquifer directly as the rain percolates through the unconsolidated deposits to the water table. Recharge to the Upper Floridan aquifer is derived mostly from leakage from the surficial aquifer through the confining beds (Motz, 1975). In places where sinkholes occur, recharge from the surficial aquifer is directly to the Upper Floridan aquifer.

Water levels in the surficial aquifer and Upper Floridan aquifer respond to rainfall and fluctuate seasonally. During the annual dry season, water levels decline and generally reach their lowest levels in May or June. Summer rains reverse the downward trend and result in normal seasonal highs in water levels during September or October.

Water levels in the surficial aquifer and Upper Floridan aquifer for May and September 1981 are shown in figures 7 and 8, respectively. The levels are for a period of below average rainfall, but typify the configuration of the May and September water levels.

Water levels in the surficial aquifer are generally higher than those in the Upper Floridan aquifer and are more varied areally. The levels are a subdued expression of local topography and consequently vary over short distances. Directions of ground-water movement in the surficial aquifer are areally to the south and southwest, but vary locally where the aquifer discharges to lakes and streams.

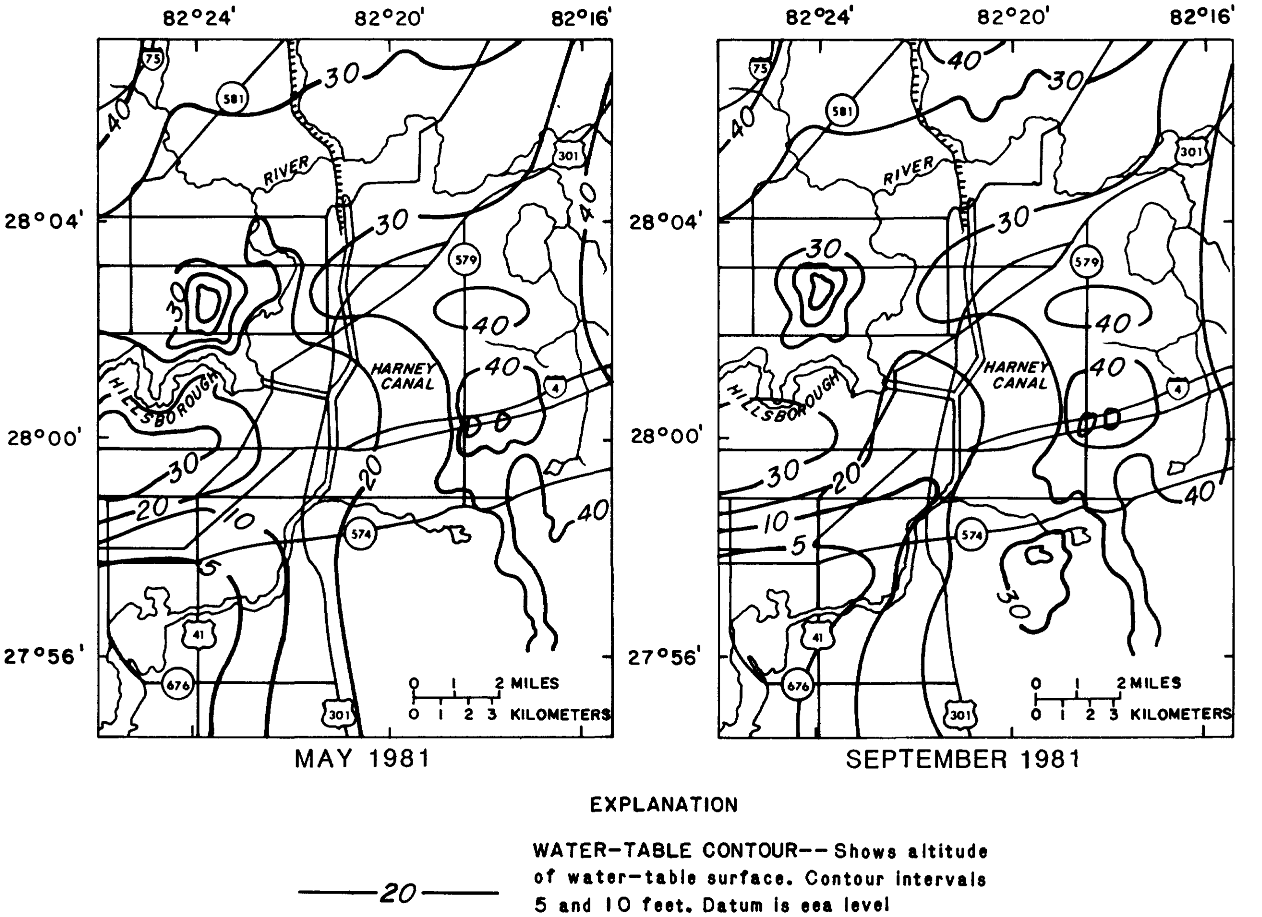


Figure 7.--Water table of the surficial aquifer, May and September 1981 (from Yobbi and Woodham, 1981; Yobbi and Barr, 1982).

Water in the Upper Floridan aquifer also flows in a south and southwesterly direction. Water levels in the southwestern part of the study area are affected by large ground-water withdrawals at Gibsonton, about 5 miles south of the study area (fig. 1). A cone of depression caused by the withdrawals lowers the potentiometric surface to sea level or below sea level in areas south of McKay Bay. The cone of depression is indicated by the circular 0-, 5-, and 10-foot contour lines in figure 8.

The Floridan aquifer system is the principal water-supply source for most of Florida; the Upper Floridan aquifer is of primary importance in the Tampa Bay area where it is used for public water supplies in Tampa and Hillsborough County. Parts of the Morris Bridge and Brandon well fields are within the study area (fig. 2) and also obtain water from the Upper Floridan aquifer for public supply. Numerous nearby well fields also use the aquifer for water supply, although pumping from them does not affect water levels significantly in the study area (Hutchinson, 1984).

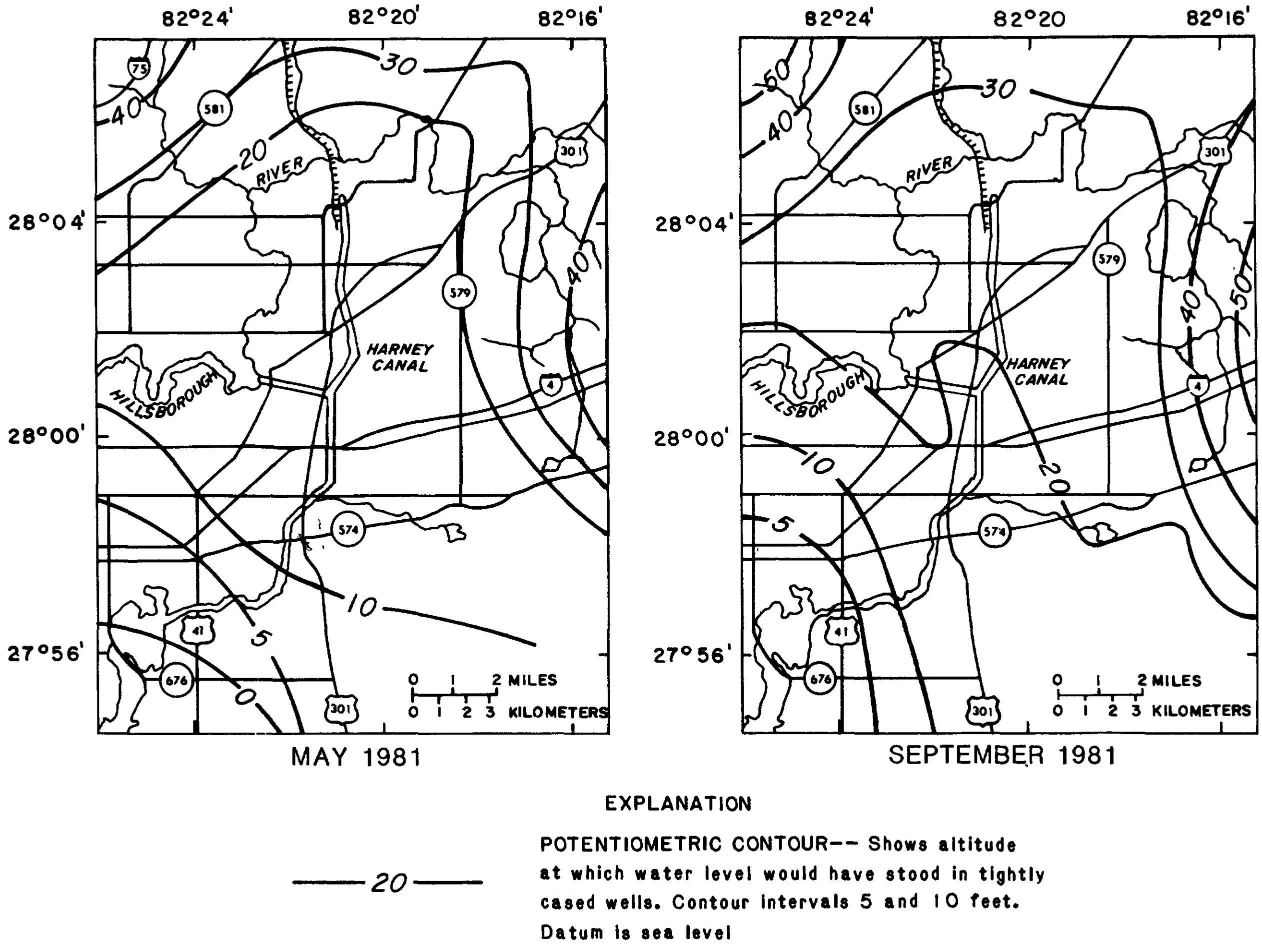


Figure 8.--Potentiometric surface of the Upper Floridan aquifer, May and September 1981 (from Yobbi and others, 1981; Yobbi and Schiner, 1982).

Ground-Water Withdrawals

There are almost 300 wells within the study area for which consumptive-use permits for ground-water withdrawals have been issued by the Southwest Florida Water Management District (D. Wiley, Southwest Florida Water Management District, written commun., 1984). The permits allow for an average annual withdrawal of about 35 Mgal/d. Of this amount, almost 6 Mgal/d is for industrial and irrigation use and about 29 Mgal/d is for public supply use. These are permitted amounts; generally, actual water use is somewhat less than that permitted. Withdrawals at the Morris Bridge and Brandon well fields (fig. 1) account for nearly 80 percent of the public supply use. Withdrawals from these fields have a greater impact on the potentiometric surface than withdrawals for the other water uses.

The Morris Bridge well field has 20 water-supply wells that are distributed throughout the 6-mi^2 well-field area. Most of the well field is within the boundaries of the study area (fig. 1). Production from the well field began in 1978 when, on an annual basis, ground-water withdrawals averaged 7.6 Mgal/d (D. Wiley, Southwest Florida Water Management District, written commun., 1984). In 1979, withdrawals averaged 13.5 Mgal/d, and since that time, withdrawals have averaged between 12.7 and 18.2 Mgal/d. The maximum withdrawal rate was in 1981.

The Brandon well field includes an area of about 32-mi^2, about one-fourth of which is within the study area (fig. 1). Although the Brandon well field is classified as a well field, it is probably more a grouping of wells rather than a designed well field. There are currently (1984) 25 wells within the field. Early records on ground-water withdrawals from within the well field are for individual wells. The records indicate a gradual increase in pumpage with time. Records for 1982 and 1983 show average withdrawal rates of 7.3 and 7.5 Mgal/d, respectively.

The Morris Bridge and Brandon well fields were investigated to determine whether withdrawals from those fields result in cones of depression that would impact the Tampa Bypass Canal area. Ryder and others (1980) and Hutchinson (1984) developed digital ground-water flow models that simulate the impacts of withdrawals at the Morris Bridge well field. Ryder's work described drawdowns for the design withdrawal rate of 40 Mgal/d, and Hutchinson described drawdowns for a withdrawal rate of 18 Mgal/d, slightly more than current (1984) actual use rates.

The model-simulated drawdowns at the Morris Bridge well field for withdrawals averaging 18 Mgal/d are shown in figure 9. As shown, the 1-foot drawdown contour extends into the canal area to about structure S-159. If the simulated drawdowns are accurate, some of the lowering of water levels in the northern part of the canal area can be attributed to well-field pumping. Impacts from the well field would probably not be noticed until about 1979 when pumping rates began to approach the 18 Mgal/d rate, as simulated.

A large regional model developed by Ryder (1982) was used to evaluate drawdowns caused by the Brandon well field. The model covers all of west-central Florida, and thus, the grid size (4 miles by 4 miles) is relatively large. The model, however, could provide indications of the impacts of withdrawals. As such, withdrawals totaling 7.5 Mgal/d, the current (1984) withdrawal rate, were entered into grid model nodes appropriate to the Brandon well field. The maximum simulated drawdowns were about one-half foot in areas near the well field. In areas to the west and north, drawdowns were generally less than 0.3 foot. Thus, although some drawdowns were indicated by model simulation, the amounts are relatively small.

CANAL SYSTEM

The Tampa Bypass Canal system consists of two canals, a series of control structures, areas that drain to the canals, and a flood detention area (fig. 10). The flood detention area consists of a levee, a floodway, and the detention area.

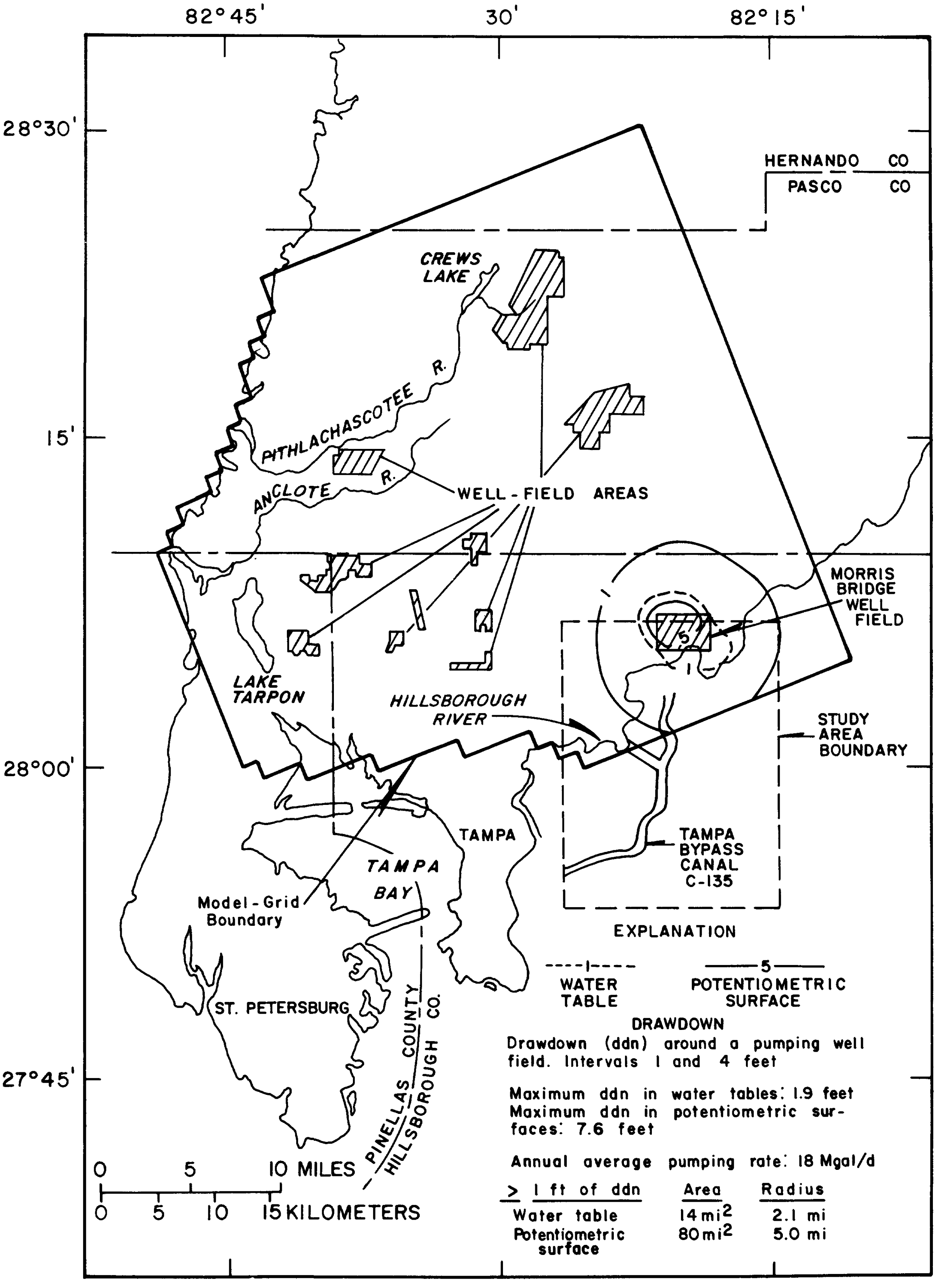


Figure 9.--Model-simulated drawdown at the Morris Bridge well field (modified from Hutchinson, 1984).

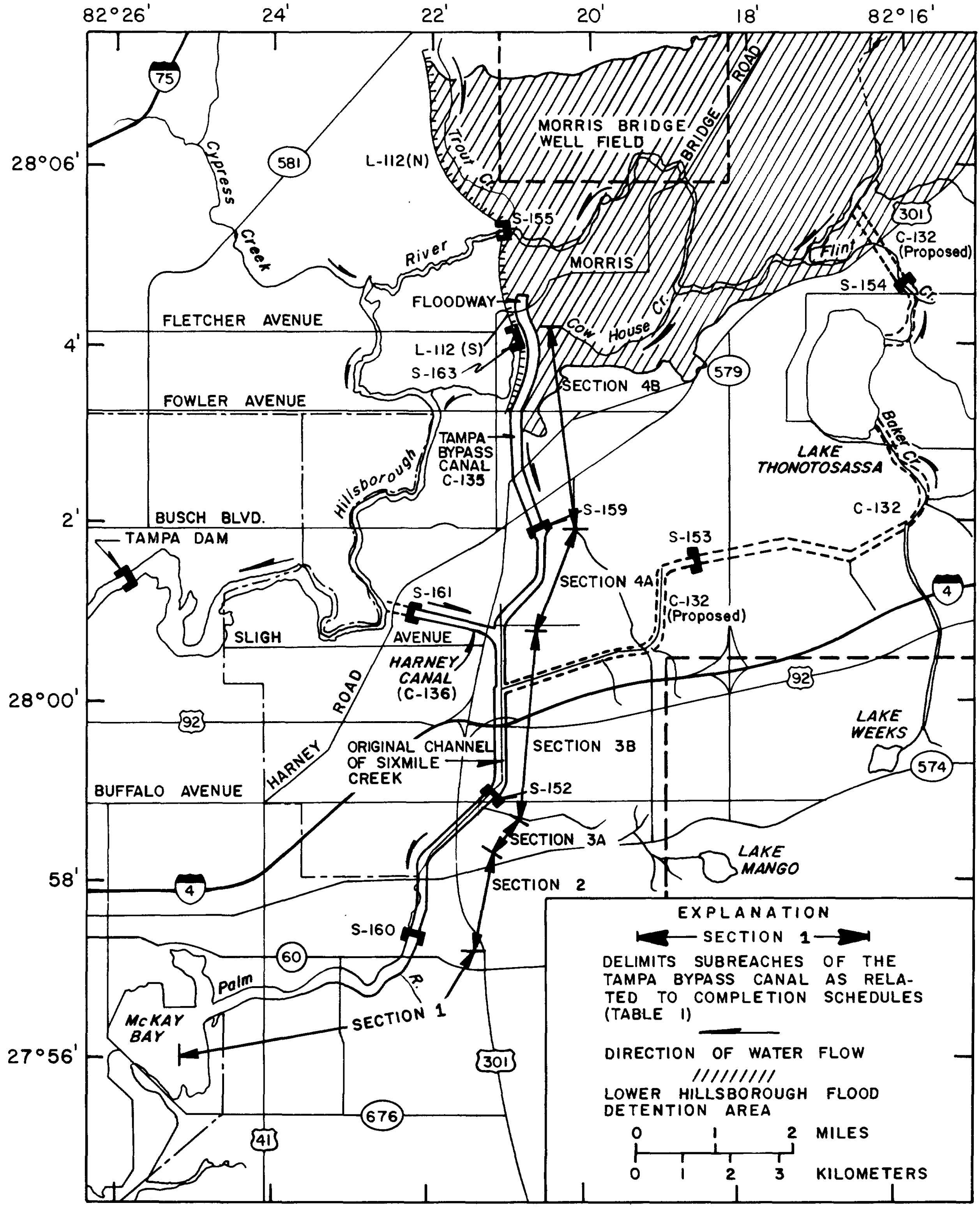


Figure 10.--Tampa Bypass Canal system.

The Tampa Bypass Canal (C-135) extends from McKay Bay to Cow House Creek, a distance of about 14 miles. The system is designed to convey a discharge of 12,000 ft^3/s from the Lower Hillsborough Flood Detention Area (LHFDA), 4,000 ft^3/s from the Hillsborough River by way of Harney Canal (C-136), and the standard project flood runoff (about 9,000 ft^3/s) from the 33-mi^2 area adjacent to canal C-135 (U.S. Army Corps of Engineers, 1983).

Descriptions of principal elements of the canal and flood-detention area are as follows:

Section 1:--This section extends from McKay Bay to structure S-160 (fig. 10). The section was divided into three parts during construction as shown on the completion schedule (table 1). The canal width of section 1 is about 400 feet. The water surface is tidal and the canal depths range from 18.5 to 21 feet.

Structure S-160:--This structure is a gated Ogee spillway. It is designed to control water levels in sections 2 and 3A and to prevent saltwater intrusion into the canal. The structure is normally closed and an optimum water level of 10.0 feet above sea level is maintained. Discharge through the structure is controlled by use of vertical lift gates and slide gates. Discharge records have been collected at the structure since 1974. Additional details on the structure are provided in tables 1 and 2.

Sections 2 and 3A:--These sections (separated by U.S. Highway 301) extend from structure S-160 to structure S-162 (fig. 10). The canal width is about 300 feet. Water levels in the sections are held at about 10.0 feet above sea level (fig. 11). Bottom elevations are about 10 to 14 feet below sea level.

Structure S-162:--This structure is a gated Ogee spillway. It is normally closed, and optimum water levels between 12 and 15 feet above sea level upstream of the structure are maintained (fig. 12). The spillway controls water levels upstream to reduce lowering of ground-water levels and discharge from the Upper Floridan aquifer into the canal.

Sections 3B and 4A:--These sections extend from structure S-162 to canal C-136 and from canal C-136 to structure S-159, respectively (fig. 10). Bottom widths of section 3B range from 210 to 365 feet; those of section 4A range from 240 to 290 feet. Water levels in the sections are maintained at 12 to 15 feet above sea level (fig. 12), except during floods. Bottom elevations in section 3B are about 5 feet below sea level; in section 4A, they are about 4 feet below sea level.

Structure S-159:--This structure is a composite of three spillways, an upstream gated Ogee spillway and two downstream ungated Ogee spillways. These structures were needed to spread the differential head to avoid foundation problems. The gate on the uppermost structure has remained closed since constructed and water in the canal above it (section 4B) is ponded. Details on the structures are provided in table 2.

Section 4B:--This uppermost section extends from structure S-159 to Cow House Creek. Water levels are held at about 24 feet above sea level. Bottom widths in the section are about 200 feet.

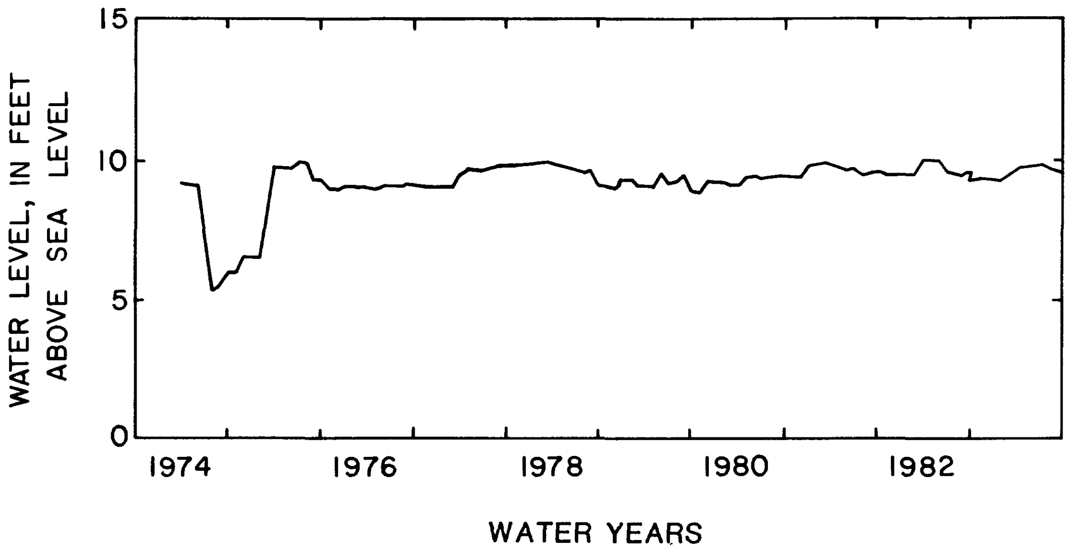


Figure 11.--Month-end water levels upstream from structure S-160, 1974-83.

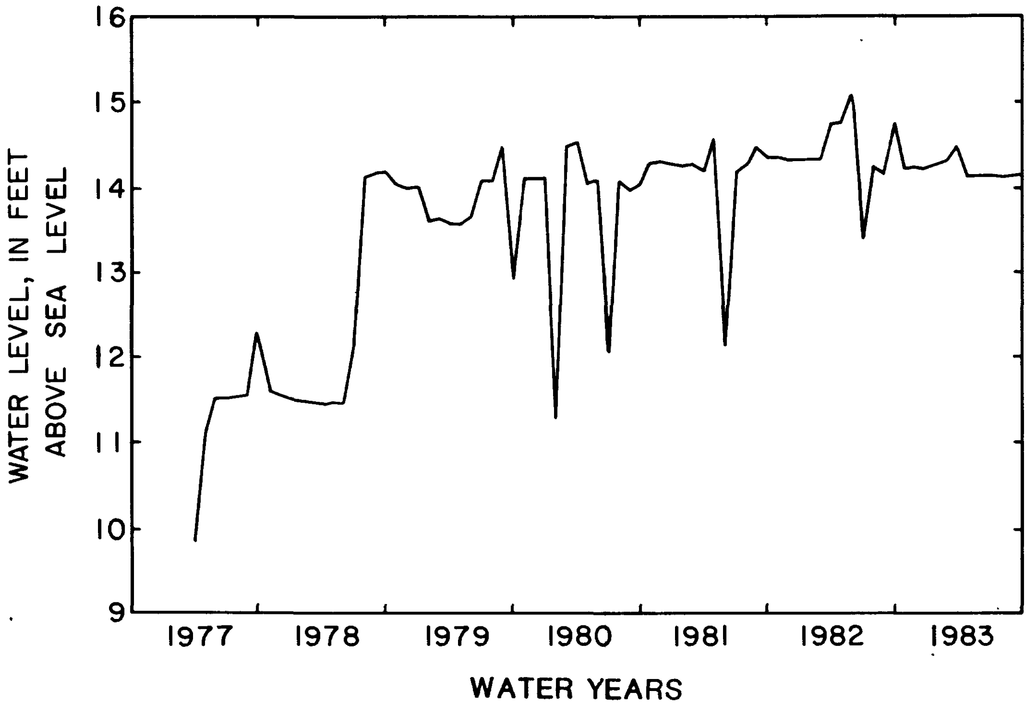


Figure 12.--Month-end water levels upstream from structure S-162, 1977-83.

Table 1.--Tampa Bypass Canal system completion schedule

Description	Contract award date		Completion date	
	Month	Year	Month	Year
Section 1A	5	1966	8	1967
Section 1B	4	1968	7	1972
Section 1C	11	1970	12	1973
Structure S-160	5	1967	1	1969
Section 2	11	1970	12	1973
Section 3A	11	1972	2	1975
Structure S-162	4	1975	3	1977
Section 3B	2	1975	6	1977
Section 4A	3	1976	1	1979
Structure S-159, middle and lower	3	1979	8	1981
Structure S-159, upper	6	1979	11	1982
Section 4B	1	1977	12	1982
Structure S-163	4	1978	11	1982
Floodway	4	1978	11	1982
Levee L-112	4	1978	11	1982
Structure S-155	4	1978	11	1982
Harney Canal C-136	6	1975	4	1977
Structure S-161	6	1975	11	1977

Structure S-163:--This structure is a gated culvert. It is used to pass discharge of Cow House Creek through levee L-112(S) to the Hillsborough River. Water levels above and below the structure are dependent on the levels of the Hillsborough River, which backs water up into Cow House Creek except during periods of low flow in the Hillsborough River. The water levels at the structure are also dependent on the water levels in section 4B. In the LHFDA above L-112(S), Cow House Creek and the Hillsborough River are hydraulically connected at stages greater than 26.0 feet above sea level.

Floodway:--The floodway is a 200-foot wide, shallow channel that was excavated to an elevation of 26 feet above sea level. The floodway becomes active when the Hillsborough River stages exceed 26 feet and water is allowed to flow into the canal system. The floodway provides conveyance for about 50 percent of the water diverted from the Hillsborough River to C-135 (U.S. Army Corps of Engineers, 1983). The other 50 percent reaches canal C-135 by way of Cow House Creek.

Levee L-112:--Levee L-112 is comprised of levee L-112(N) (north of structure S-155) and levee L-112(S) (south of structure S-155). The levee is designed to retain floodwater within the LHFDA. The south levee is 2.8 miles in length and the north levee is 3.5 miles long. The elevation of the top of the levee is 48 feet above sea level.

Table 2.--Summary of hydraulic design data on the canal structures

[All elevations in feet above or below sea level]

Structure S-160, Ogee spillway	
Crest elevation	-0.7
Vertical lift gates (number)	6
(size, feet)	28.0 x 11.7
Design discharge (ft^3/s)	26,700
Optimum headwater elevation	10.0
Optimum tailwater elevation	Tidal
Structure S-162, Ogee spillway	
Crest elevation	4.2
Vertical lift gates (number)	7
(size, feet)	28.0 x 11.8
Design discharge (ft^3/s)	23,500
Optimum headwater elevation	12.0 to 15.0
Optimum tailwater elevation	10.0
Structure S-159, Ogee spillway, lower (ungated)	
Crest elevation	13.6
Design discharge (ft^3/s)	12,000
Optimum headwater elevation	13.6 to 15.0
Optimum tailwater elevation	12.0 to 15.0
Structure S-159, middle (ungated)	
Ogee crest elevation	20.4
Design discharge (ft^3/s)	12,000
Optimum headwater elevation	20.4
Optimum tailwater elevation	13.6 to 15.0
Structure S-159, Ogee spillway, upper	
Crest elevation	24.3
Vertical lift gates (number)	3
(size, feet)	29 x 12.7
Design discharge (ft^3/s)	12,000
Optimum headwater elevation (controlled by S-163)	24.3
Optimum tailwater elevation	20.4
Structure S-163 (gated culvert)	
Corrugated metal pipe culvert	84-inch
Invert elevation	17.0
Design discharge (ft^3/s)	200
Design headwater elevation	26.2
Design tailwater elevation	25.0

Table 2.--Summary of hydraulic design data on the canal structures--Continued

Structure S-155, Ogee spillway

Crest elevation	15.2
Vertical lift gates (number)	2
(size, feet)	30.0 x 21.4
Design discharge (ft^3/s)	8,000

Structure S-161, Ogee spillway

Crest elevation	11.3
Vertical lift gates (number)	2
(size, feet)	18.0 x 11.7
Design discharge (ft^3/s)	4,000
Optimum headwater elevation	19.5 to 22.0
Optimum tailwater elevation	12.0 to 15.0

Structure S-155:--This structure is on the Hillsborough River in alinement with levee L-112. The structure is used to control discharge in the Hillsborough River. The structure remains fully open except during floods when it will be used to control bypass of water to the floodway and down canal C-135 to eliminate flood damages in the lower reaches of the Hillsborough River.

Lower Hillsborough Flood Detention Area:--The 26-mi^2 area is designated a flood detention area, but it seldom contains water above that stored naturally in the area. During flooding, the Hillsborough River is controlled at structure S-155 so that the flood water is either diverted to canal C-135 or goes into temporary storage in the LHFDA.

Harney Canal (C-136):--This canal is about 9,000 feet long and extends from the Hillsborough River to the Tampa Bypass Canal (C-135). The canal has a capacity of 4,000 ft^3/s. Its bottom width is 70 feet downstream from structure S-161 and 45 feet upstream from structure S-161.

Structure S-161:--This structure is a gated Ogee spillway. It regulates the diversion of floodwater from the Hillsborough River to the Harney Canal. The structure is normally closed, and the optimum water level upstream from the structure is between 19.5 and 22.0 feet above sea level. Water levels downstream from the structure are controlled by structure S-162 on canal C-135 at elevations between 12 and 15 feet above sea level (fig. 12).

HYDROLOGIC MONITORING PROGRAM

The hydrologic data-collection program was initiated in 1973. The data-collection network consisted of surface-water and ground-water sites where data on streamflow, water levels, and water quality were obtained. For each well that was drilled, lithologic logs were obtained to define the characteristics of the aquifer materials. Data from the network and data collected in the area under other cooperative programs were used to monitor impacts of canal construction on the hydrology of the area.

A summary of surface-water data-collection sites and periods of record are given in table 3. Their locations are shown in figure 13. Data consisted of continuous gaging of streamflow and water levels, miscellaneous discharge measurements, and sampling of water and bed materials for chemical-quality analyses. The types of data collected at each site varied appreciably and the periods of data collection also varied. Water-quality analyses consisted of field parameters, major constituents, nutrients, phytoplankton, benthic invertebrates, and trace metals. Analyses of bottom samples consisted of pesticides, nitrogen and phosphorus species, inorganic constituents, trace metals, and selected miscellaneous parameters, such as chemical oxygen demand, total organic carbon, and volatile dissolved solids.

A summary of ground-water data-collection sites, well depths, and periods of record are given in table 4, and locations of the sites are shown in figure 14. At most sites, data consisted of water-level measurements and sampling for chemical-quality analyses. Wells 10, 12, 19, and 36 had recorders for continuous collection of water-level data generally throughout their periods of record. Wells 27, 28, 30, 47, 48, and 52 initially were measured periodically, but were converted to recorder stations during their periods of record. All other sites were measured periodically, from weekly to semiannually to incidental measurements. Sampling for water-quality analyses also varied from weekly to semiannually.

IMPACT OF CANAL CONSTRUCTION ON STREAMFLOW

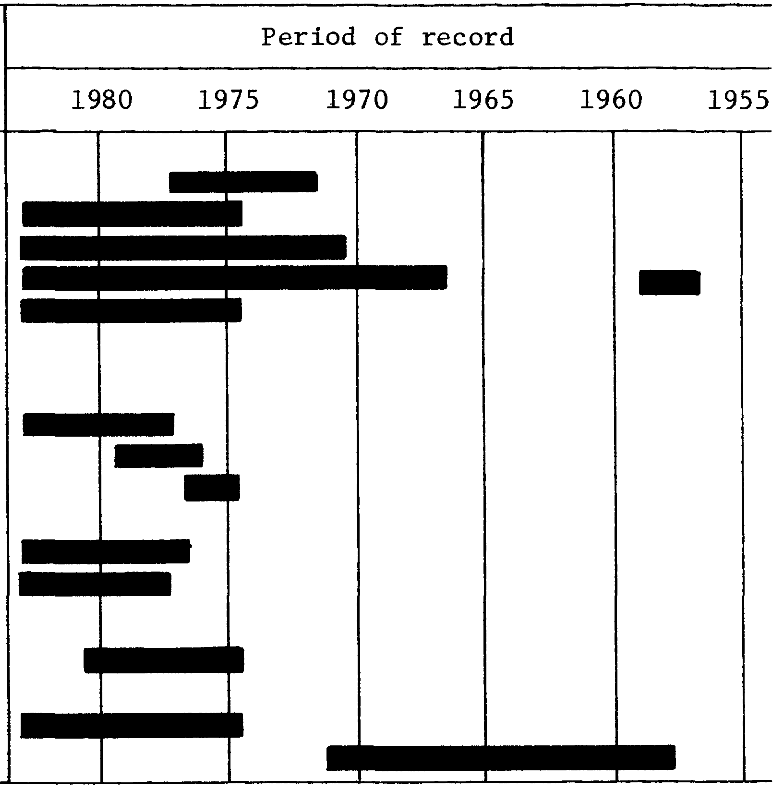
Sixmile Creek and the Canal at Structure S-160

Streamflow data for the Tampa Bypass Canal area were collected on Sixmile Creek at Tampa (at State Road 574) prior to canal construction and have been collected at structure S-160 since 1974 (map number 2S, table 3 and fig. 13). Although the gaging station on Sixmile Creek was more than one-half mile upstream from the present location of structure S-160, records collected at the two sites are considered to be equivalent. There are no tributary streams between the two locations, and the intervening drainage area is small--less than 1 mi^2. Data for the two stations, therefore, were used to determine impacts of canal construction on discharge from the area.

To determine whether there has been any change in discharge, streamflow records for Sixmile Creek at State Road 574 and from the canal system at structure S-160 were related to concurrent records for nearby streams. One method used was a double-mass analysis of mean annual discharges. In this analysis, the accumulated mean annual discharges of two stations are plotted against each other. A change in slope in the relation would infer a change in discharge in one of the stations. The analysis used discharges for Sixmile Creek for water years (October through September) 1957 to 1974 and discharges at structure S-160 for water years after 1975. Records are not available for water years 1970 and 1971. Discharge at structure S-160 during water years 1979, 1980, and 1982 was affected by diversion of floodwater from the Hillsborough River into the canal system. The affected discharges were adjusted by subtracting the amount of discharge diverted to the canal prior to using the record in the analysis. Also, in 1981, water was pumped from the canal system to the Hillsborough River during a water-supply pumping test. The mean annual discharge for 1981 was adjusted by adding the amount diverted from the canal system to the annual discharge.

Table 3.--Summary of surface-water data-collection sites and periods of record

Map No. (fig. 13)	Station No.	Station name
1S	02301780	Sixmile Creek near Tampa
2S	02301802	Tampa Bypass Canal at S-160
3S	02303271	Baker Creek near Thonotosassa
4S	02303300	Flint Creek near Thonotosassa
5S	275647082240601	Palm River at U.S. Highway 41 near Tampa
6S	275857082211200	Tampa Bypass Canal at S-162
7S	280014082203600	C-132 at Eureka Springs Road
8S	280101082222301	Harney Pond near Temple Terrace
9S	280105082221501	Harney Canal below S-161
10S	280158082203700	Tampa Bypass Canal below S-159
11S	280412082204400	Cow House Creek near Temple Terrace
12S	280516082205001	Hillsborough River above S-155
13S	02301800	Sixmile Creek at Tampa



Note.--Data collection consisted of continuous measurement of streamflow, periodic measurement of discharge, and periodic water-quality sampling. Collection of each type of data may not have been throughout the period of record indicated; however, some type of data was collected.

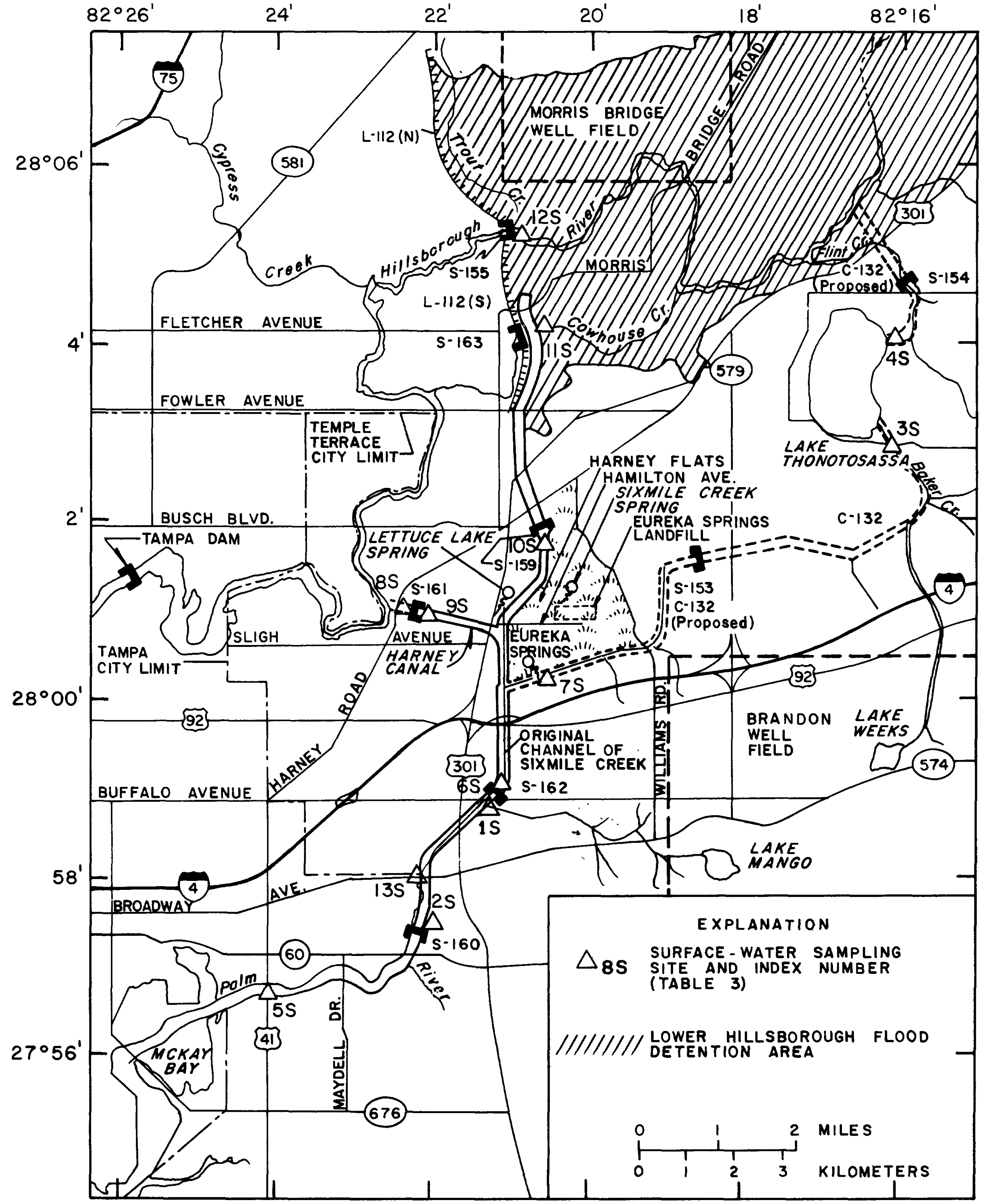


Figure 13.--Locations of surface-water data-collection sites.

Table 4.--Summary of ground-water data-collection sites and periods of record

Map No. (fig. 14)	Station No.	Station name	Well depth (feet)
1	275615082230601	Palm River well 14 at Tampa	165
2	275629082234001	Palm River well 5 at Tampa	100
3	275634082244101	Palm River well 2 at Tampa	70
4	275642082224201	Palm River well 18 at Tampa	72
5	275615082230601	USCE well TBC-15 at Tampa	72
6	275701082230301	USCE well TBC-11 at Tampa	30
7	275701082230302	USCE well TBC-12 at Tampa	10
8	275701082230303	USCE well TBC-13 at Tampa	60
9	275701082230304	USCE well TBC-16 at Tampa	202
10	275724082221001	Structure S-160 well near Tampa	240
11	275725082221101	USCE well TBC-17 at Tampa	420
12	275728082222801	Tampa Bypass deep well 624 at Tampa	136
13	275814082214001	Tampa Bypass deep well 621 near Tampa	63
14	275843082222201	Tampa Bypass deep well 618 near Tampa	69
15	275846082210401	USCE test well 3S-SMC (617) near Tampa	80
16	275856082210301	USCE test well 2S-SMC near Tampa	86
17	275858082215201	USCE well TBC-14 near Tampa	100
18	275906082203901	USCE test well 3E-SMC (616) near Tampa	90
19	275906082204901	USCE test well 2E-SMC (615) near Tampa	90
20	275906082205601	USCE test well 1E-SMC near Tampa	79

Period of record

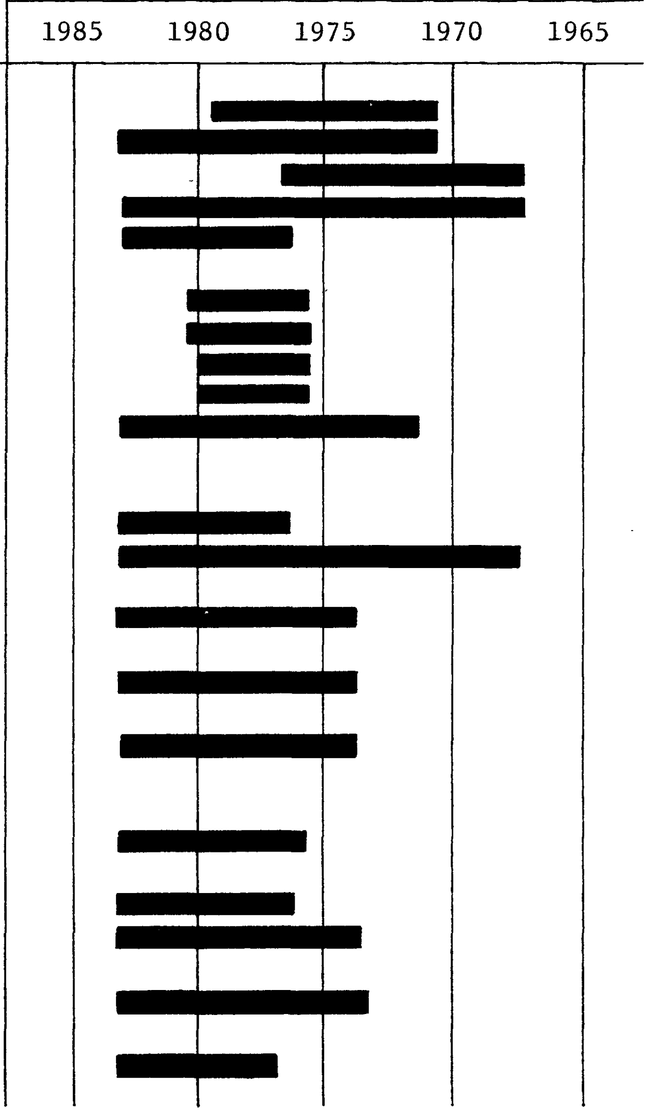


Table 4.--Summary of ground-water data-collection sites and periods of record--Continued

Map No. (fig. 14)	Station No.	Station name	Well depth (feet)
21	275906082205901	USCE test well P-SMC near Tampa	306
22	275906082211001	USCE test well 2W-SMC near Tampa	95
23	275906082212001	USCE test well 3W-SMC near Tampa	121
24	275910082213601	U.S. Highway 301 Fairground deep well near Tampa	---
25	275913082220601	SWFWMD well WMDD near Tampa	88
26	280012082204901	USCE well TBC-05 near Temple Terrace	100
27	280022082205401	SWFWMD well at Vandenburg Airport near Temple Terrace	42
28	280022082210501	SWFWMD well west of Vandenburg Airport near Temple Terrace	37
29	280030082190801	Tampa Bypass deep well 610 near Temple Terrace	170
30	280033082200501	Tampa Bypass deep well 609 near Temple Terrace	310
31	280035082181001	Tampa Bypass deep well 611 near Temple Terrace	200
32	280038082204201	EVRGLDS AQTC NRSRY well ES-55 (608) near Temple Terrace	53
33	280044082212601	USCE well TBC-07 near Temple Terrace	100
34	280055082203801	USCE test well 3S-ES (607) near Temple Terrace	89
35	280055082222701	USCE well TBC-09 at Temple Terrace	110

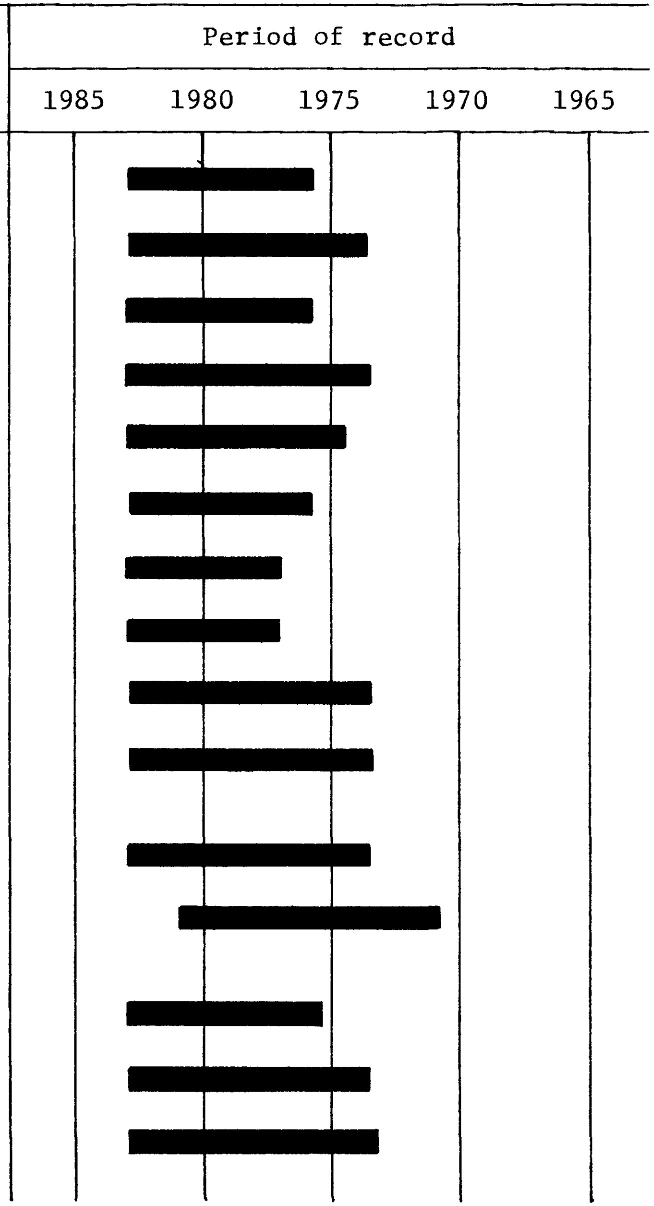


Table 4.--Summary of ground-water data-collection sites and periods of record--Continued

Map No. (fig. 14)	Station No.	Station name	Well depth (feet)
36	280058082202201	Eureka Springs landfill deep well near Temple Terrace	37
37	280103082210901	USCE well TBC-06 near Temple Terrace	100
38	280105082222801	USCE well TBC-08 at Temple Terrace	100
39	280116082201501	USCE test well 3E-ES (607) near Temple Terrace	84
40	280116082202601	USCE test well 2E-ES (631) near Temple Terrace	91
41	280116082205301	USCE test well 2W-ES near Temple Terrace	87
42	280116082210101	USCE test well 3W-ES near Temple Terrace	87
43	280122082214701	Sunnybrook Diary well 604 near Temple Terrace	58
44	280142082195901	Tampa Bypass Forbes well near Temple Terrace	---
45	280142082210901	Tampa Bypass deep well 603 near Temple Terrace	---
46	280144082212201	USCE well TBC-10 near Temple Terrace	56
47	280148082203801	USCE well TBC-04 near Temple Terrace	110
48	280203082202301	USCE well TBC-03 near Temple Terrace	100
49	280212082211101	Blanco deep well 601 near Temple Terrace	350
50	280229082200201	Tampa Bypass deep well 600 near Temple Terrace	---

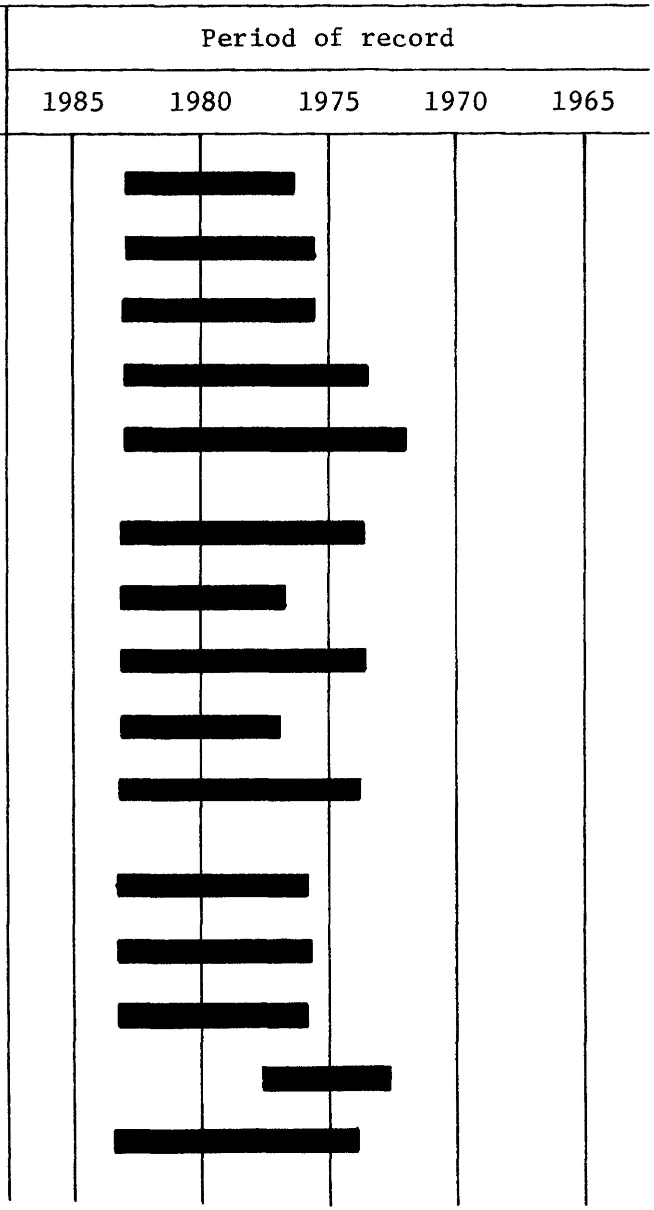
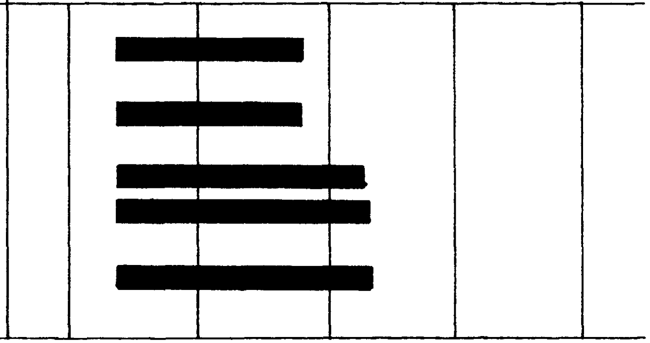


Table 4.--Summary of ground-water data-collection sites and periods of record--Continued

Map No. (fig. 14)	Station No.	Station name	Well depth (feet)	Period of record (1985, 1980, 1975, 1970, 1965)
51	280230082205601	USCE well TBC-02 near Temple Terrace	100	
52	280243082203701	USCE well TBC-01 near Temple Terrace	110	
53	280352082210201	Gates Trailer Park well	120	
54	280414082195201	Tampa Bypass deep well 520 near Temple Terrace	---	
55	280642082195801	Morris Bridge deep well near Brandon	260	



Note.--Data collection consisted of continuous or periodic measurement of water levels and periodic sampling for water-quality analysis. Collection of each type of data may not have been throughout the period of record indicated; however, some type of data was collected. All wells are completed in the upper Floridan aquifer.

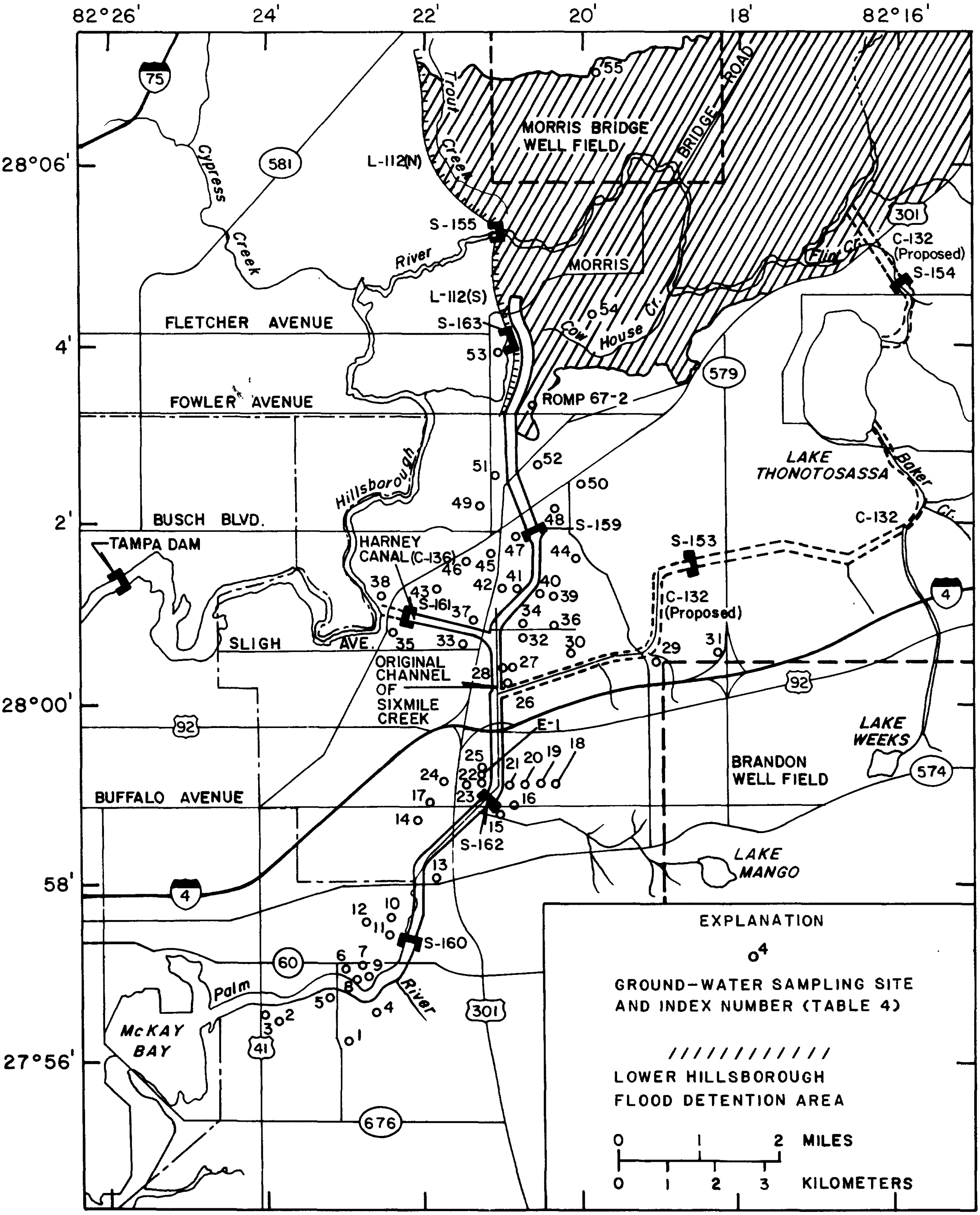


Figure 14.--Locations of ground-water data-collection sites.

In the analysis, mean annual discharges for Sixmile Creek and at structure S-160 were accumulated and related graphically with accumulated mean annual discharges for the Alafia River at Lithia (fig. 15), a gaging station about 12 miles southeast of the canal system (fig. 1). The analysis shows a distinct change in the discharge relation between the 1957 to 1974 and 1975 to 1982 periods. This change indicates an increase in discharge from the canal system. Straight dashed lines have been drawn in figure 15 to indicate the gross change in the discharge relation. Data after about 1975, however, seem to show a curvilinear relation whereby discharge from the canal system is gradually increasing in time relative to the Alafia River. This is most likely what had happened as discharge from the canal system increased gradually throughout the period of construction. It is expected, now that construction is completed, that the straight-line relation will prevail as equilibrium conditions are again reached. A similar analysis of data for Sixmile Creek and the canal system at structure S-160 was made with discharge data for the Hillsborough River near Zephyrhills (fig. 16), about 15 miles northeast of the canal system (fig. 1). This analysis also shows a change in the relation for the two periods of record and the discharge from the canal system gradually increasing relative to that of the Hillsborough River.

Discharges for water years 1959 and 1960, based on the long-term record for the Hillsborough River and Alafia River gages, were unusually high--more than twice their long-term averages. The relations in figures 15 and 16 indicate that the discharge of the two rivers is increasing more during years of high flow than is the discharge for Sixmile Creek or the canal system. This is not unexpected because much of the discharge in the canal system is from springflow (Eureka Springs, Lettuce Lake Spring, and others) and ground-water seepage and, as such, is more uniform from year-to-year. Because of probable different runoff characteristics during wet and dry seasons between the two rivers and the canal system, an analysis was also made for discharges that were essentially unaffected by storms. For this analysis, discharge and rainfall records were inspected and mean monthly discharges were listed for all months that had little or no contributions to runoff from rainfall. The data were, therefore, essentially streamflows that are largely derived from ground-water sources. Of the record available from 1957 to 1982, data for about 120 months were included in the analysis.

The double-mass analysis of base-flow data for Sixmile Creek and at structure S-160 and the Alafia River is shown in figure 17. Again, the plot shows a continuing gradual change in the relation after 1975 and a more distinctive break in the relation in 1978. The data indicate an increase in the base-flow discharge from the canal system over that of Sixmile Creek when compared to the Alafia River. The relation also indicates that base-flow discharge continued to increase as construction of the canal progressed. This would indicate an increase in discharge from ground-water sources, primarily the Upper Floridan aquifer, to the canal system. Some of the increase in discharge may be attributed to some additional contributing drainage area in the upper reaches of the canal system. Unless structure S-159 is left closed, small areas that once drained to the Hillsborough River would drain to the canal and be reflected in the record at structure S-160. The relation in figure 17 indicates that base flow during the 1975 to 1978 period is about 50 percent more than the earlier record. For the period after 1978, the indicated increase in base flow is more than twice that of the pre-1975 base flow.

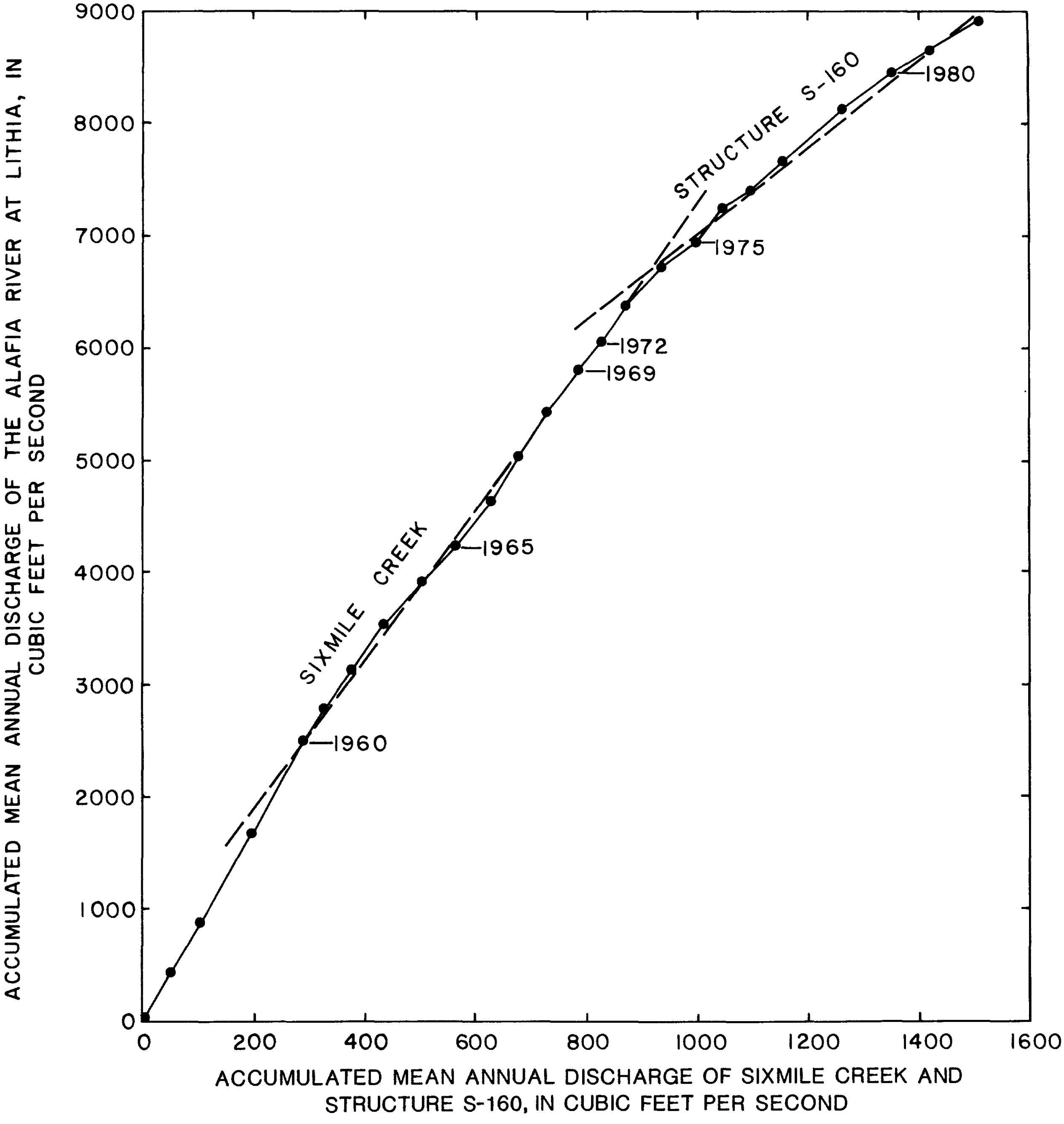


Figure 15.--Double-mass curve of mean annual discharges for Sixmile Creek and at structure S-160 and the Alafia River at Lithia.

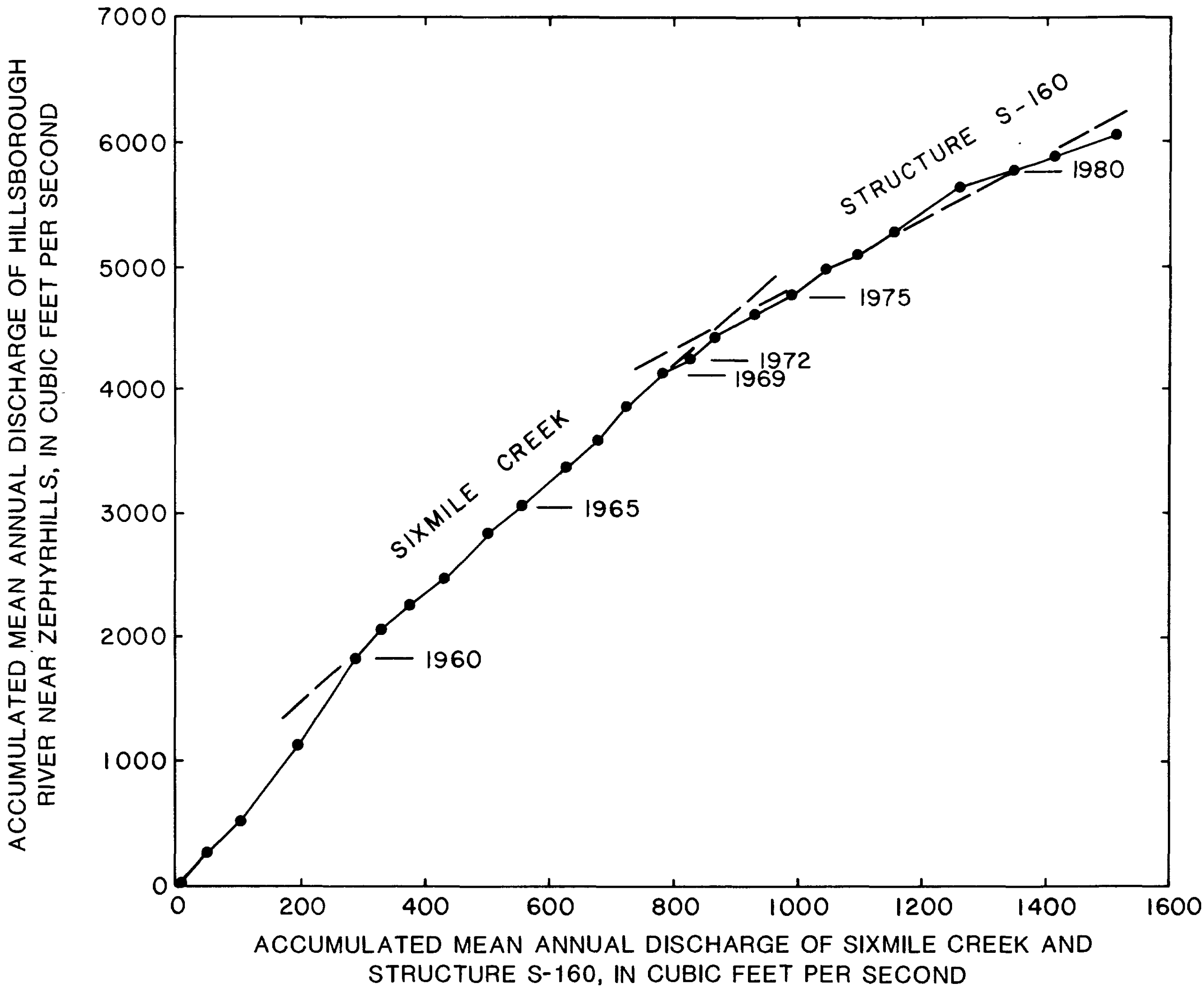


Figure 16.--Double-mass curve of mean annual discharges for Sixmile Creek and at structure S-160 and the Hillsborough River near Zephyrhills.

Baker Creek and Flint Creek

The initial design of the Tampa Bypass Canal system included canal C-132 at Lake Thonotosassa (fig. 2). Canal C-132 was to run from Lake Thonotosassa to the main bypass canal and from the lake to the Hillsborough River. Water could have flowed in either direction from the lake. Although canal C-132 was dropped from the final plans as construction progressed, some data collection continued in the lake area. Streamflow and water-quality data were collected on Baker Creek, the inlet to Lake Thonotosassa, and on Flint Creek, the outlet from the lake (fig. 13). Streamflow records for the two sites (Baker Creek near Thonotosassa and Flint Creek near Thonotosassa) were analyzed to determine

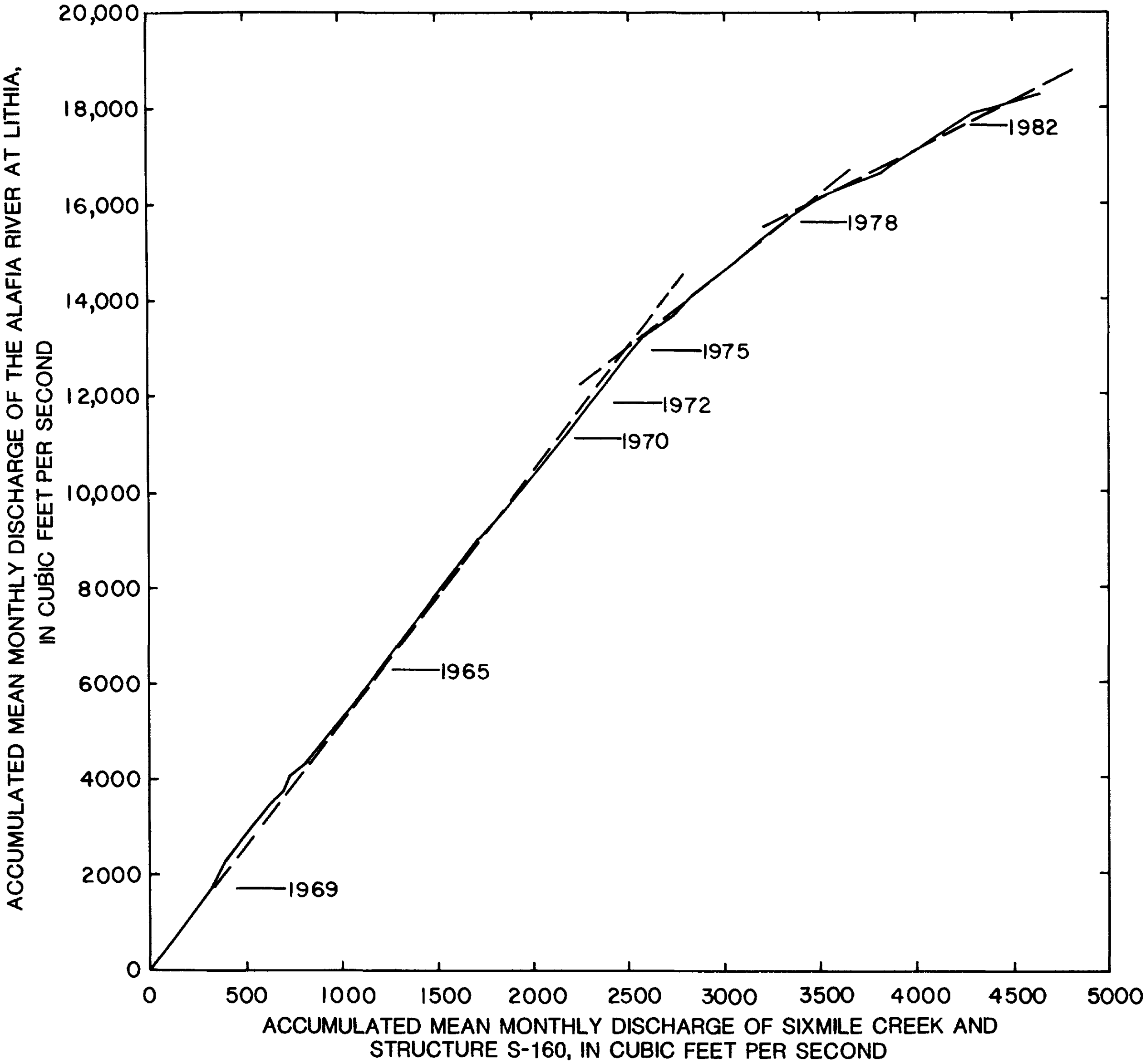


Figure 17.--Double-mass curve of selected mean monthly discharges for Sixmile Creek and at structure S-160 and the Alafia River at Lithia.

whether any changes in runoff characteristics that might be attributed to construction of canal C-135 could be determined. The record for Baker Creek consisted of 53 discharge measurements made between 1970 and 1977. Additionally, three measurements were made in 1980. There are no data available on the stream prior to construction of the canal system.

Discharge measurements on Baker Creek were correlated with mean daily discharges for nearby gaging stations on the Hillsborough River, Flint Creek, and Blackwater Creek about 12 miles northeast of Lake Thonotosassa. Correlations with these stations showed a relatively wide scatter in the data. Correlation coefficients were generally about 0.8. The large scatter may be attributed to natural variations in runoff between river basins. However, Baker Creek is affected by municipal-industrial effluent discharge into its headwaters (Reichenbaugh and Hunn, 1972). Variations in effluent discharge may be reflected in the scatter of data. No distinctive patterns or trends were evident from any of the analyses. Although results from the correlations are not conclusive, any changes in runoff characteristics of Baker Creek due to construction of the canal system are remote.

Continuous records of streamflow are available for Flint Creek for water years 1957 and 1958 and since 1971. These data were also correlated with data for nearby gaging stations to determine whether any changes in runoff patterns had occurred. Records for Flint Creek are affected by manipulation of stoplogs, pipes, and gates on a control structure at the outlet of Lake Thonotosassa. Changes at the structure are made periodically to control levels of the lake. These changes affect natural runoff patterns and make analysis of the data difficult. Generally, daily and monthly runoff values are too highly affected by regulation to be used in most analyses. Annual runoff, however, except in accounting for the effects of evaporation losses from the lake surface, could be analyzed. As such, the mean annual discharges for Flint Creek were correlated with data for the Hillsborough River near Zephryhills (fig. 18). As shown, runoff for Flint Creek after 1974, except perhaps for 1980 and 1981, is somewhat less than for the earlier years. Data points for 1975 to 1979 plot to the right, indicating that the discharge of Flint Creek is less than might be expected based on data for the Hillsborough River. That these differences can be attributed to construction of the canal system, however, is not logical. The scatter in data more likely reflects normal variations in runoff from year-to-year between basins.

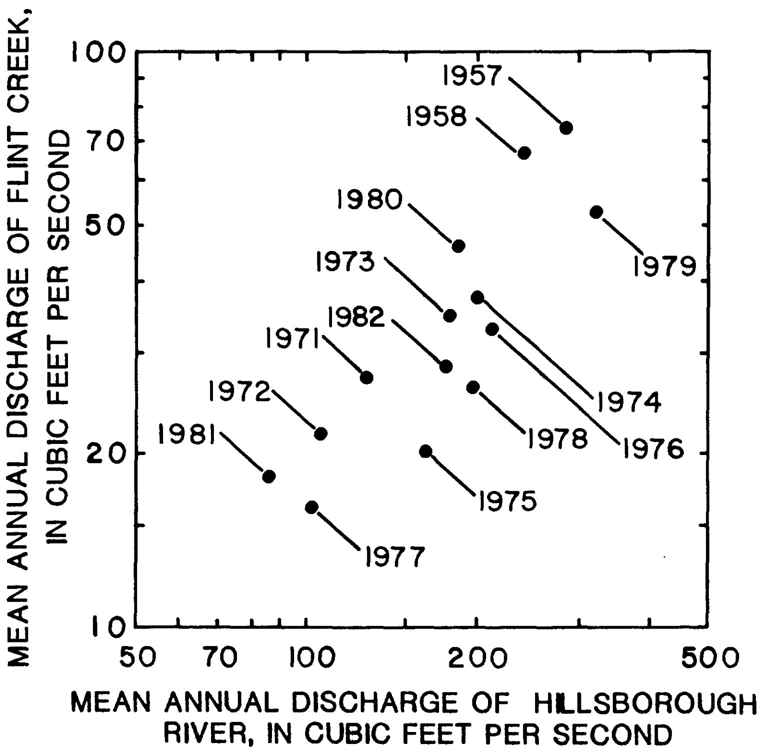


Figure 18.--Relation between mean annual discharges for the Hillsborough River near Zephyrhills and Flint Creek near Thonotosassa.

Springs

The major springs in the Tampa Bypass Canal area are Eureka Springs, Lettuce Lake Spring, and Sixmile Creek Spring (fig. 2). As mentioned previously, Eureka Springs has been affected by ditches that were dug to confine and control its flow. Lettuce Lake Spring has been altered by canal construction and water levels in the canal above structure S-162 now usually submerge the spring. Discharge measurements have been made at each of the springs, but the frequency of measurement has been sporadic (table 5). The only springs that were measured before and after construction and that have adequate data for analysis are Lettuce Lake Spring and Sixmile Creek Spring. Discharge measurements at these sites were compared with hydrologic data for nearby sites to determine whether the canal system has had any impact on their flow.

Discharge data for the springs were correlated with concurrent discharge data for nearby streams, but the results were inconclusive. Because of the greater uniformity of discharge from springs as compared to that of streams, any impact of canal construction on spring discharge could not be ascertained from such an analysis.

Concurrent discharge data for springs outside the canal area were also investigated to evaluate changes in spring discharge in the canal area. The only unregulated spring with concurrent data was Crystal Springs near Zephyrhills about 15 miles northeast of the canal system (fig. 1). A comparison of data for Crystal Springs and springs in the canal area indicated a probable reduction in discharge of the canal area springs. The amount of concurrent data, however, was small, and the degree of correlation was such that the impacts of construction could not be determined conclusively.

Because correlations could not be utilized with adjacent surface waters, discharge data for the springs were evaluated in relation to ground-water levels. It was recognized that if the canal had lowered levels in the Upper Floridan aquifer, the primary source of water for the springs, discharge of the springs would be reduced. This potential change could be determined by relating spring discharge to water levels in nearby wells--wells that are outside the zone of influence of the canal system and that are not affected by withdrawals for water supply or other use.

Records of ground-water levels for all nearby wells were inspected; however, most wells either did not have record prior to about 1973 or were affected by pumping. Adequate record, however, was available for the DeBuel Road deep well near Lutz. The well is about 10 miles northwest of the canal area (fig. 1), and its water levels are representative of those in the canal area. For example, correlation of concurrent data for the DeBuel Road deep well and wells in the canal area had coefficients of correlation of about 0.85. Water levels measured at the well could, therefore, be used to determine changes in the canal area.

The relation between water levels in the DeBuel Road deep well and the discharge of Sixmile Creek Spring and Lettuce Lake Spring are shown in figures 19 and 20, respectively. The relations show that discharges from both springs after about 1976 are less than what might be expected based on water levels for the DeBuel Road deep well. For example, consider Sixmile Creek Spring (fig. 19).

Table 5.--Discharge measurements of Eureka Springs, Lettuce Lake Spring, and Sixmile Creek Spring

Date	Eureka Springs (ft^3/s)	Lettuce Lake Spring (ft^3/s)	Sixmile Creek Spring (ft^3/s)
5-01-46	3.91	--	--
5-01-56	1.02	--	--
11-19-58	5.0	--	--
11-02-60	6.82	--	--
4-28-69	3.38	12.5	1.70
9-17-69	--	--	1.72
10-15-69	2.96	21.8	--
3-25-70	3.72	19.8	1.80
11-12-70	2.08	12.1	1.43
5-21-71	0	6.86	.96
10-13-71	2.72	10.2	1.89
6-01-72	0	7.60	.98
10-20-72	.64	9.40	1.11
5-18-73	1.57	9.58	1.48
6-18-76	0	--	1.39
7-06-76	0	--	2.35
10-14-76	.004	--	--
10-22-76	0	9.75	1.45
11-23-76	0	7.32	1.09
11-30-76	--	7.75	.99
12-08-76	--	7.47	.78
12-21-76	--	7.20	.65
1-26-77	--	8.0	.76
3-11-77	--	7.0	.78
4-15-77	--	6.1	.08
2-28-78	--	7.5	--
7-17-79	0.11	8.3	.50
1-06-81	--	1.9	0

At a water level of 55 feet, discharge prior to about mid-1976 would be about 1.7 ft^3/s. After mid-1976, the discharge would be 0.75 ft^3/s or less. A curve or relation is not drawn for the post mid-1976 data because the relation changed over time as construction progressed (note for example, the zero or near zero discharges in 1977 and 1981). Considering Lettuce Lake Spring (fig. 20), at a water level of 55 feet, the apparent decrease in discharge would be from about 12.5 ft^3/s to about 7.5 ft^3/s. These are approximate changes and are weighed heavily on data for 1976 and 1977 when most of the discharge measurements were made. The measurements made in 1981 indicate that the reduction in discharge may be even greater. Again, a curve for the post mid-1976 data is not shown in figure 20 because the relation appeared to change with time.

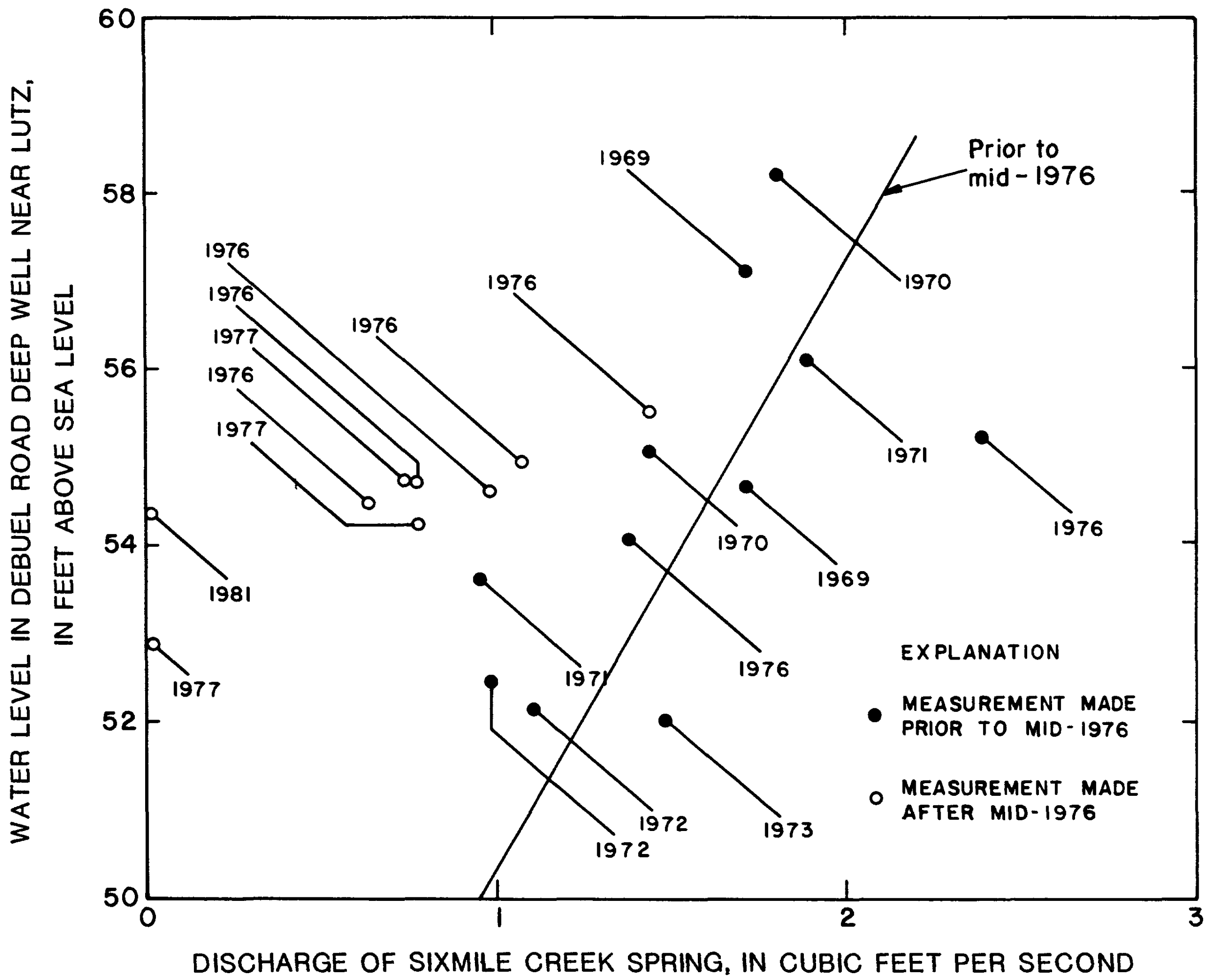


Figure 19.--Relation between discharge of Sixmile Creek Spring and water levels in the DeBuel Road deep well near Lutz.

That there should be a reduction in discharge from the springs is not unexpected. Water levels of the Upper Floridan aquifer in the springs area have been lowered somewhat as a result of canal construction, as discussed in the subsequent section. With a reduction in water levels, the discharge from the springs would also be reduced. Water that formerly discharged through the springs is now discharged as increased baseflow to the canal system.

The relations shown in figures 19 and 20 are similar to those defined from data for other nearby wells. Because the record for the DeBuel Road deep well is long enough so that concurrent data are available for most of the measurements, it was used here as an example to show the impact of canal construction on discharge from springs.

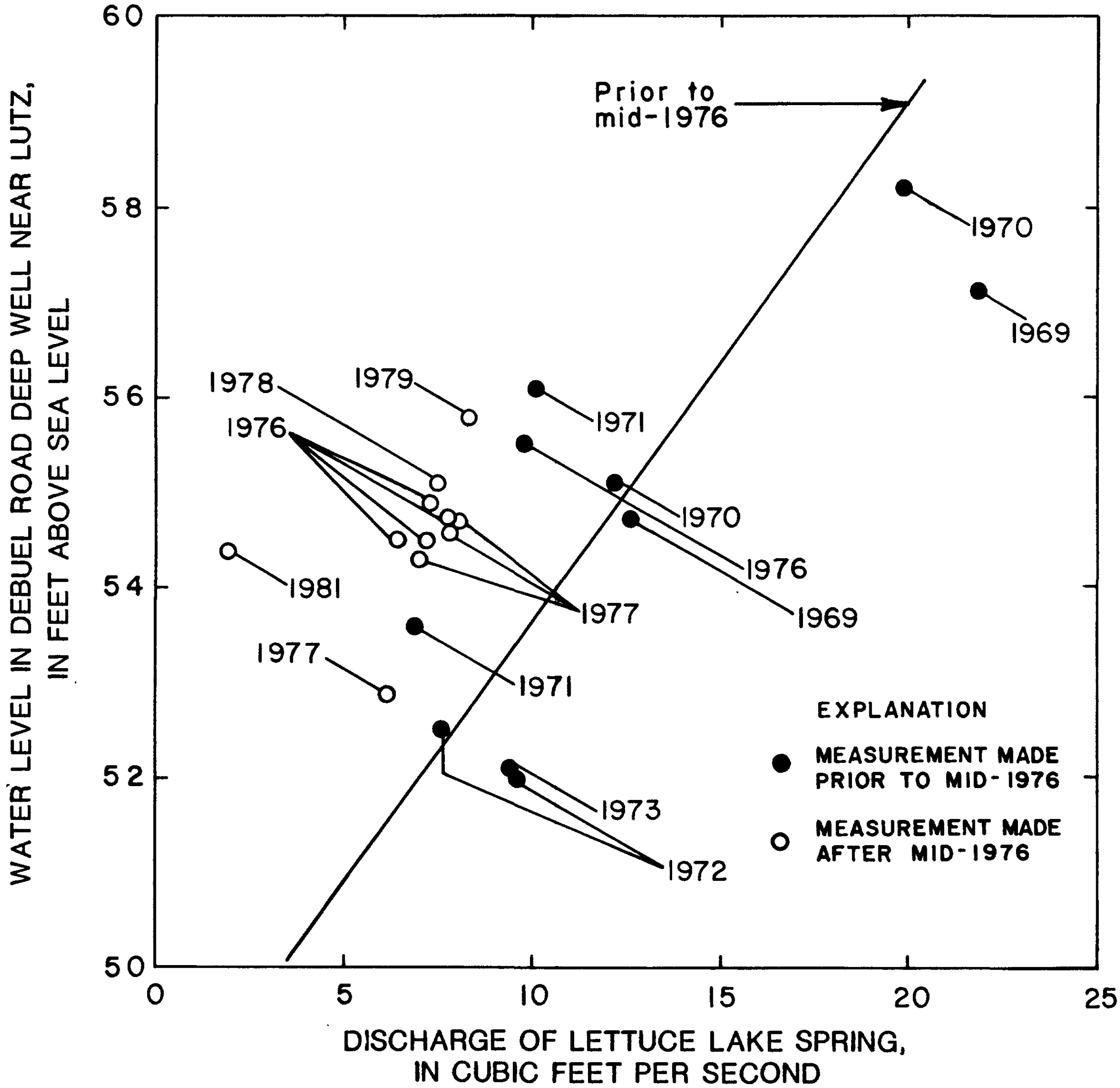


Figure 20.--Relation between discharge of Lettuce Lake Spring and water levels in the DeBuel Road deep well near Lutz.

IMPACT OF CANAL CONSTRUCTION ON GROUND-WATER LEVELS

Water-level data for selected wells in the area of the canal system were analyzed to determine whether canal construction had any impact on ground-water levels. Because few data are available for many wells prior to about 1976, wells that were selected for analysis were those that had sufficient length of record and that provided areal coverage.

To determine whether changes in water levels due to canal construction had occurred, levels for each respective period of record were correlated with concurrent data for nearby wells that were not affected by canal construction. The primary unaffected well used for correlation was the DeBuel Road deep well near

Lutz (fig. 1). Continuous water-level data have been collected at the well since 1965, and its levels have minimal effect from ground-water withdrawals for water supply or other uses. Water levels for wells in the canal area were also correlated with water levels in the Turner well near Brandon, about 10 miles southeast of the canal area (fig. 1). Correlations with data for the Turner well confirmed the correlations made with water levels in the DeBuel Road deep well. Therefore, for purposes of discussion here, references are generally to correlations with data for the DeBuel Road deep well.

To illustrate the method of analyses used, the correlation for water levels in well 26 (fig. 14) and the DeBuel Road deep well is shown in figure 21. Water-level data are collected continuously at the DeBuel Road deep well and monthly water-level measurements are made in well 26. The plot of concurrent data indicates that there are two major relations between the two stations. One relation is evident for water levels prior to about mid-1976, and a second relation is apparent for subsequent data. The change in the relations corresponds to canal construction activities near well 26 and indicates that water levels in well 26 are 2 to 4 feet lower than they would have been had construction not occurred. Scatter among the data can be attributed to changes in the relation over time as canal construction progressed, to changes in water level in the canal, and to natural variations. Correlations between water levels in most other wells in the canal area and the DeBuel Road deep well showed a similar degree of scatter. However, where changes in water levels in wells in the canal area had occurred, distinctive changes in the relations between water levels in those wells and in the DeBuel Road deep well also occurred. The following discussion defines the changes in water levels along the canal system.

McKay Bay to Structure S-160

Very little water-level data have been collected from wells along the canal system downstream from structure S-160. Most monitor wells in this area were used for water-quality sampling, and at some sites, ground-water levels could not be measured. Where water-level data are available, the periods of record usually are not long enough to define any impacts of canal construction. At most sites, data collection started in 1976 (table 4), well after canal construction in the area had been completed (1973, table 1). Because of the absence of adequate preconstruction water-level data, definition of any impacts cannot be made precisely.

Excavation of the canal downstream of structure S-160 breached the Upper Floridan aquifer in several places (fig. 6). Where the Upper Floridan aquifer was not breached, much of the confining layer between the Upper Floridan aquifer and surficial aquifer was removed. These excavations could have facilitated upward movement of water from the Upper Floridan aquifer into the canal system and thereby lowered the potentiometric surface of the Upper Floridan aquifer. Data, however, are not available to determine whether any lowering of the surface actually occurred. Additionally, if lowering did occur, it would be difficult to quantify because of the impact on water levels caused by ground-water withdrawals for industrial supply south of the canal area. The withdrawals cause a large cone of depression that extends to the canal area (fig. 8). The cone is reflected in the circular 0-, 5-, and 10-foot contours. Thus, if upward movement of water from the Upper Floridan aquifer increased because of construction of the canal, the increase could have been reduced due to lowering

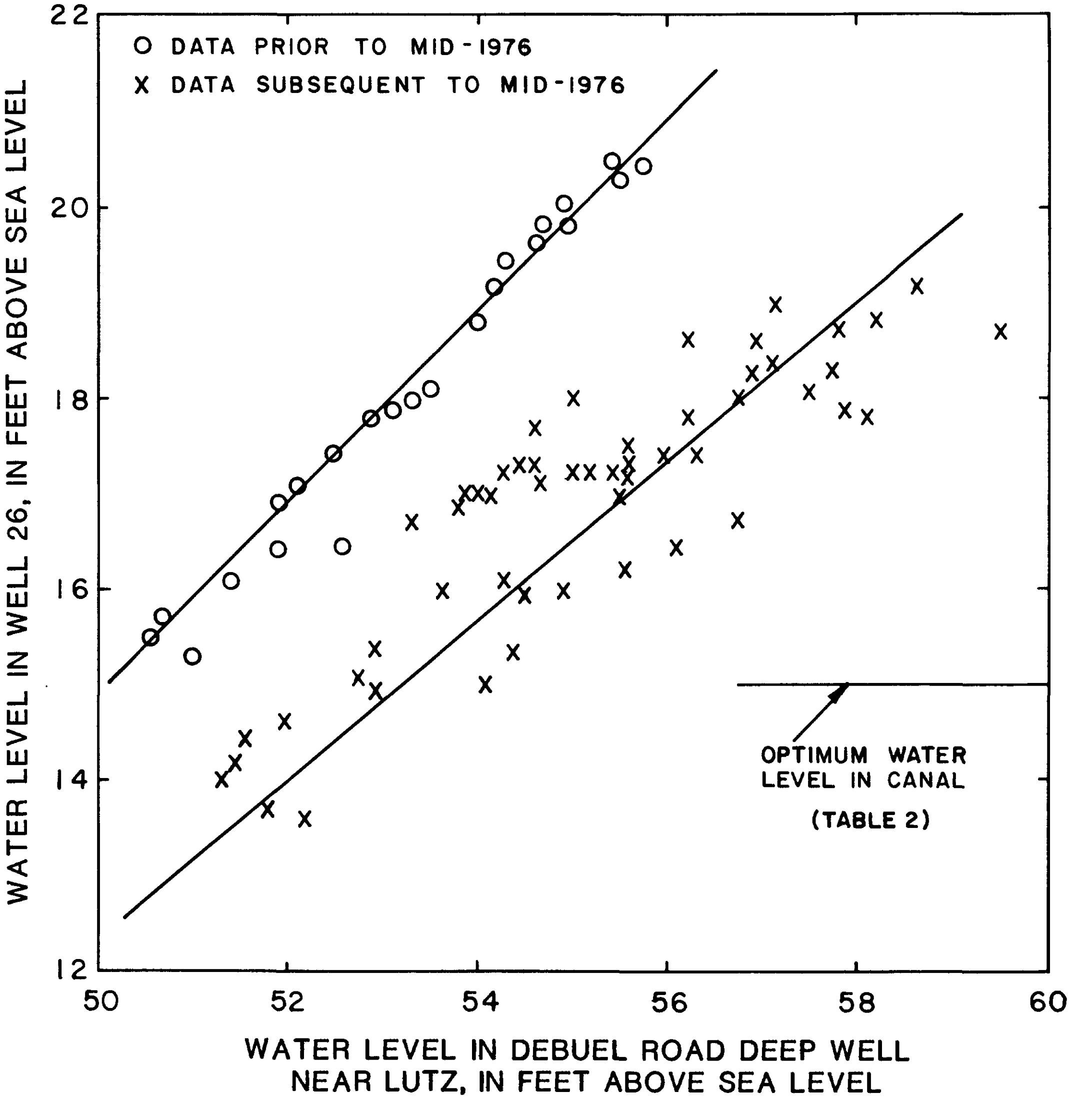


Figure 21.--Relation between water levels in the DeBuel Road deep well near Lutz and well 26.

of the potentiometric surface caused by the withdrawals. It is expected that any changes in ground-water levels downstream of structure S-160 are minimal because of the flat water-level gradient, shallow depths to water, and the proximity of this area to McKay Bay.

Structure S-160 to Structure S-162

Structure S-160 was completed in January 1969, and the canal sections immediately upstream from it were completed by 1973 (table 1). As with the downstream reach, very little water-level data were collected in the reach from structure S-160 to structure S-162 during this period. Data collection at most wells began in late 1973 (table 4). The only well that has water-level data available throughout the construction period is well 12 (fig. 14).

Correlation of water-level data in well 12 and the DeBuel Road deep well indicates a gradual increase in water levels with time (fig. 22). At least three different relations are evident from the record. Relations in figure 22 were defined by a least squares fit of the data collected prior to January 1968, for data from January 1968 to mid-1976, and for data after mid-1976. A hydrograph plot of water levels in well 12 also illustrates an increase in levels with time (fig. 23) that cannot be attributed to changes in annual rainfall. As shown in figure 4, except for above average rainfall in 1979 and 1982, rainfall had been at or below average. The increases in water levels in well 12 are related to construction and higher water levels due to impoundment of water in the canal upstream from structure S-160 (fig. 11). A total increase in the potentiometric surface of the Upper Floridan aquifer in the vicinity of well 12 of about 4 feet is indicated by the data (fig. 22).

Although data for well 10 (fig. 14) are for a shorter period than for well 12, its record also indicates an increase in water levels during the 1971 to 1983 period of about 2 feet. This is about the same magnitude of increase experienced in well 12 during that period. Based on data for these two wells, it is probable that the potentiometric surface near structure S-160 increased about 4 feet as a result of canal construction.

Data on ground-water levels upstream from structure S-160, but downstream of structure S-162, are available from about 1973 (table 4). Data for well 13 that had the longest period of record were evaluated. An increase in water levels early in 1973 is indicated by the record; however, because of the paucity of data, the analysis is not conclusive. Because water levels in the canal in this reach are higher than preconstruction levels due to impoundment of water upstream from structure S-160, some increase in ground-water levels would be expected. The increase would be largest near the most downstream part of this reach, near structure S-160.

Structure S-162 to Structure S-159

Impacts of canal construction on ground-water levels between structures S-162 and S-159 were evaluated using data for wells 19, 22, 24, 26, 29, 32, and 45 (fig. 14). Collection of water-level data at each of the sites began in 1973 except for well 26 where data collection began in 1975 and well 32 where data collection began in 1971 (table 4). Because construction in this reach was not completed until about 1977, the records were of sufficient length to define impacts of the construction on the potentiometric surface.

The impact of construction on water levels in well 26 was discussed previously by way of example (fig. 21). The total apparent lowering of the potentiometric surface in well 26 is about 2 to 4 feet. Water-level data for wells 19, 22, 24, 29, and 32 also indicate a lowering of the potentiometric surface. The indicated changes range from about 2 to 4 feet. The lowering was generally greater near structure S-159 than near structure S-162. In all cases, the apparent lowering in the potentiometric surface occurred over a relatively short

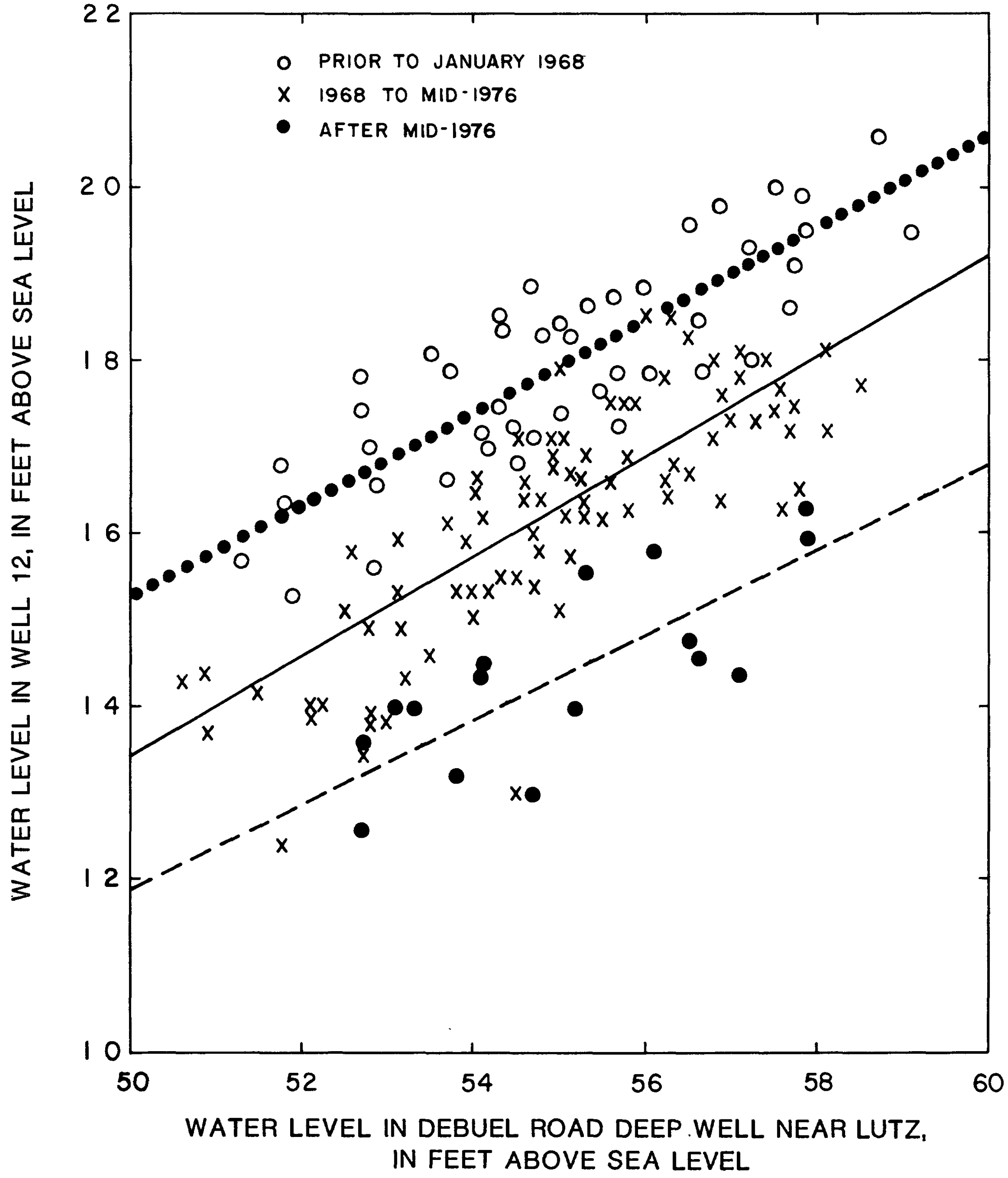


Figure 22.--Relation between water levels in the DeBuel Road deep well near Lutz and well 12.

period in early-1976, as shown by the hydrograph of water levels in well 22 (fig. 24). The initial lowering is largely due to dewatering done to facilitate construction. Figure 24 indicates that there has been some recovery in levels since the lower levels in 1976. This recovery is probably related to cessation of dewatering and increase in water levels in the canal upstream from structure S-162 (fig. 12).

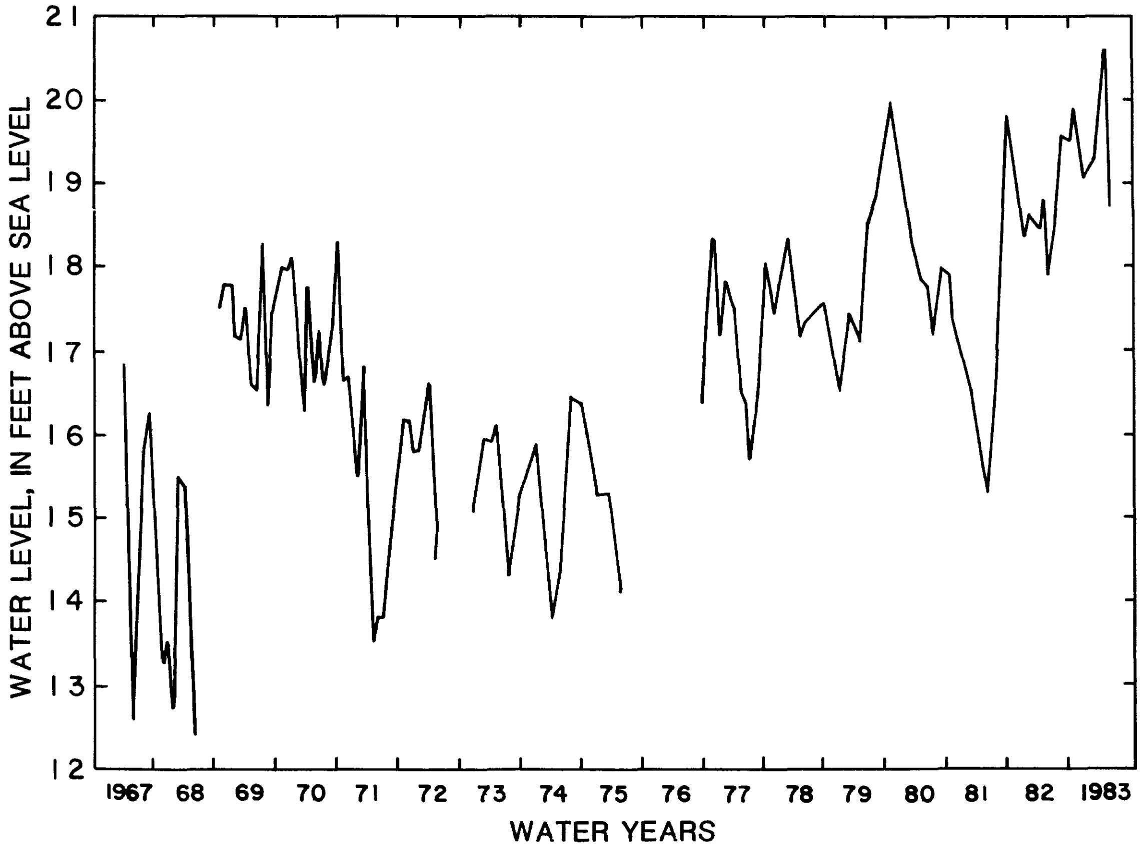


Figure 23.--Month-end water levels in well 12, 1967-83.

Data on water levels in well 45 near structure S-159 indicate a series of water-level declines over time (fig. 25). Correlations of water levels prior to December 1977 for the DeBuel Road deep well and well 45 are indefinite and show a wide scatter among data points. Some patterns, or periods of stable relations, can be noted, but data are inadequate for definition of a relation. The wide scatter in data points may be attributed to instability of water levels and changing conditions caused by construction and channelization and by pumping for irrigation.

A fairly well defined relation is evident for water-level data collected at the DeBuel Road deep well and well 45 from December 1977 to February 1980. A second relation is also indicated for subsequent data, although there is a wider scatter in data points. The data indicate that a total lowering in the potentiometric surface of 6 or more feet may have occurred. Some of the apparent lowering may be attributed to pumping at the Morris Bridge well field. As shown in figure 9, the model-simulated cone of depression caused by pumping extends to about structure S-159. The indicated drawdown is about 1 foot. As such, some of the lowering in water levels after 1978 may be due to pumping rather than construction of the canal.

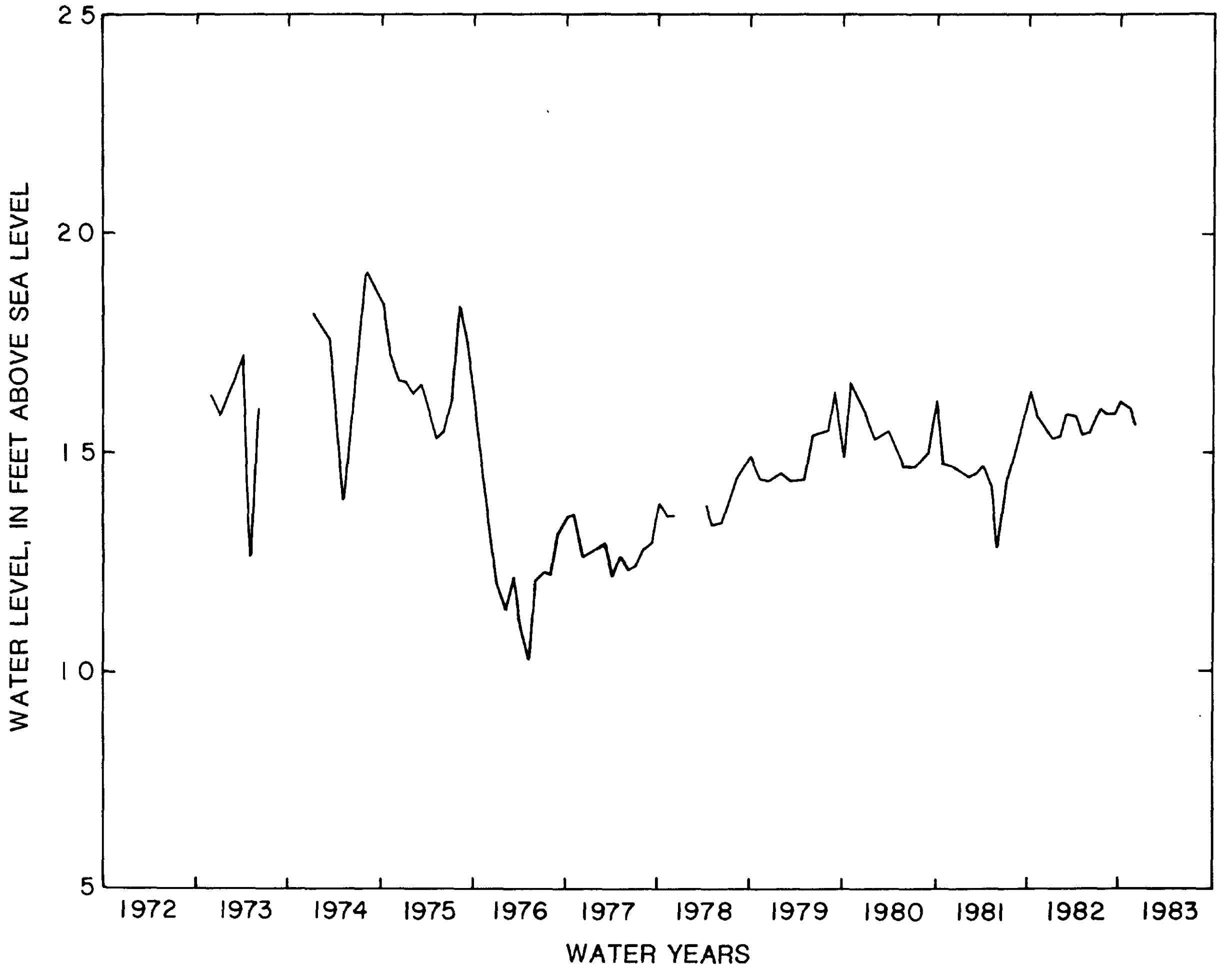


Figure 24.--Month-end water levels in well 22, 1972-83.

Upstream of Structure S-159

Impacts of canal construction upstream of structure S-159 were evaluated by analysis of data for wells 51, 52, 53, and 54 (fig. 14). At each site, the amount of data available prior to mid-1976 was small--only 5 to 10 water-level measurements had been made. Although the amount of early data is sparse, a lowering of water levels in each well is indicated. As with the more downstream reaches of the canal, water levels declined about 2 to 4 feet. At wells 51, 52, and 53, the change in levels occurred in mid-1976. At well 54 that is further from the canal, however, the lowering of levels did not occur until after about September 1977. As for well 45, some of the lowering may be due to pumping at the Morris Bridge well field.

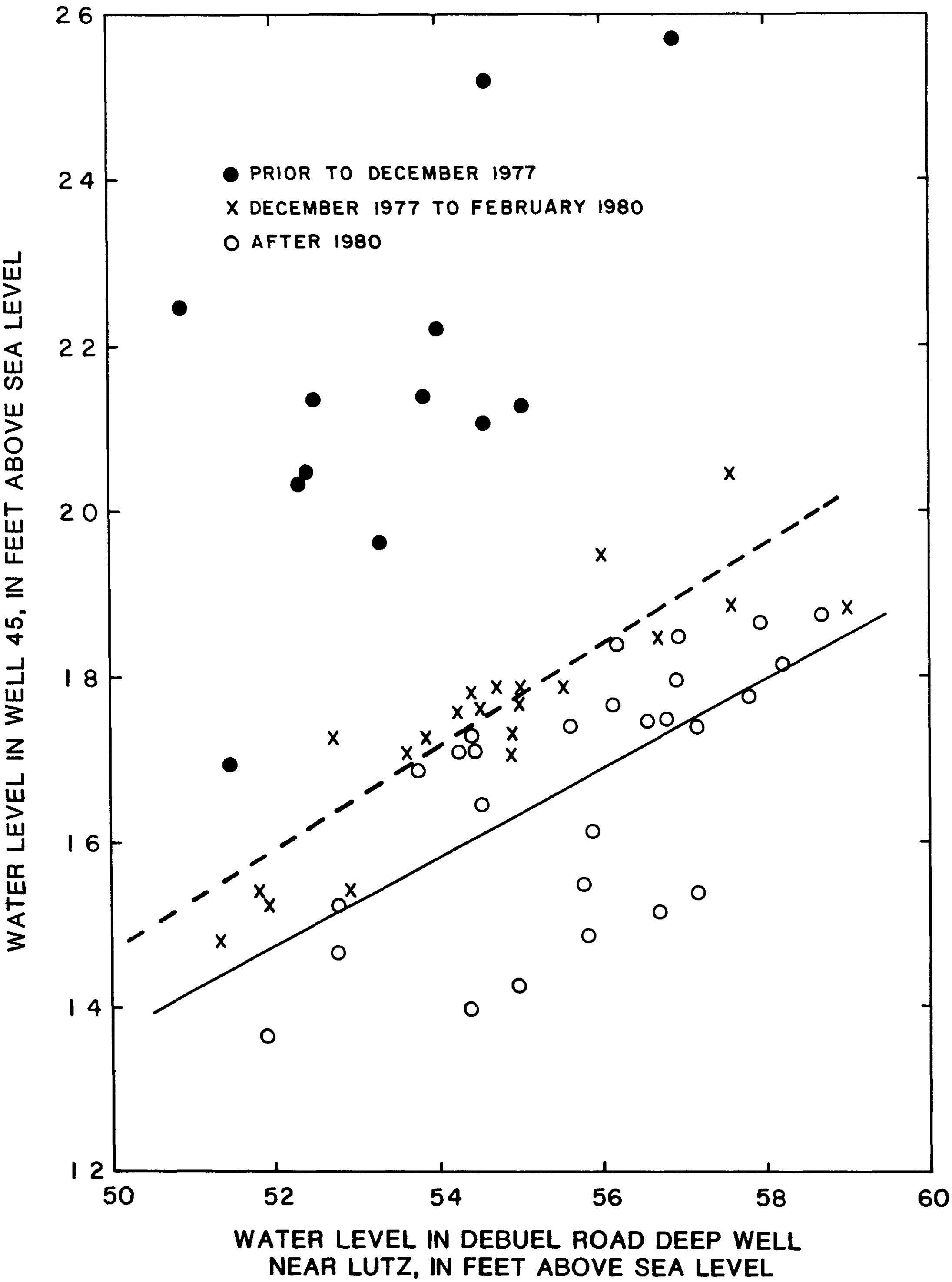


Figure 25.--Relation between water levels in the DeBuel Road deep well near Lutz and well 45.

Water-level data in the canal upstream of structure S-159 have been collected since August 1982. A hydrograph of water levels for the 1983 water year are shown with concurrent water-level hydrographs for wells 51, 52, and 53 in figure 26. Also plotted are levels for the Southwest Florida Water Management District's Regional Observation and Monitor Program well (ROMP 67-2). This well is near well 53. The wells have depths of from 100 to 141 feet and are about equidistant from the canal. In general, water levels in the canal were higher than those in the observation wells. At times, however, water levels in the more northern wells (wells 53 and ROMP 67-2) were higher than water levels in the canal. Water levels in the observation wells closely track the water levels in the canal. The magnitude of water-level change for the canal and the wells are similar, and the peak levels and low levels occur on mainly the same day. This indicates a good hydraulic connection between water in the canal and in the Upper Floridan aquifer. Because water levels in the canal are generally higher than ground-water levels, the canal recharges the aquifer, except at times in areas near structure S-163. Water levels in the canal, however, are lower than preconstruction water levels of the surficial aquifer (fig. 7).

Harney Canal C-136

Water levels in the Harney Canal area were evaluated using primarily water-level data for well 35. Records on the well began in May 1975. Completion of the canal and structure S-161 was in November 1977 (table 1). Thus, the record encompasses the preconstruction and postconstruction periods.

Water levels for well 35 were related to levels for the DeBuel Road deep well. The correlation indicates a possible lowering of the levels, but the scatter in data makes the assessment inconclusive. Because of the proximity of well 35 to the Hillsborough River, data for the well were related to water levels in the river to determine whether there is a correlation between the river and the Upper Floridan aquifer. The plot (fig. 27) shows a strong comparison between water levels in the river and the well. Water levels in the river are regulated by the Tampa Dam and maximum levels are at about 22 feet above sea level. Except for minor differences, mostly at higher stages, the levels in the river and the well are the same, indicating that water levels in well 35 are influenced by water levels in the river. Because of this relation, the impacts of canal construction in the upper end of the Harney Canal, near structure S-161, cannot be fully assessed. Construction of the canal, however, did breach the Upper Floridan aquifer in the vicinity of structure S-161 (Motz, 1975). This should enhance the hydraulic connection between the river and the Upper Floridan aquifer and may be a causative factor in the similarity in water levels seen in figure 27.

The interconnection between the Hillsborough River and Harney Canal was also documented by Geraghty and Miller, Inc. (1982), during pumping tests run in the canal system to evaluate the potential of the canal and Upper Floridan aquifer for water supply. In the test, water was pumped from the canal near structure S-161 to the Hillsborough River, and drawdown in the canal and adjacent wells was monitored. From analysis of the data, approximately 500,000 gal/d were recirculated between the river and canal during the test period. This amounted to about 2 percent of the water pumped during the test and further indicates that there is a hydraulic connection between the river and the Upper Floridan aquifer. This connection is also confirmed when comparing water-level data for well 38 and water levels of the Hillsborough River.

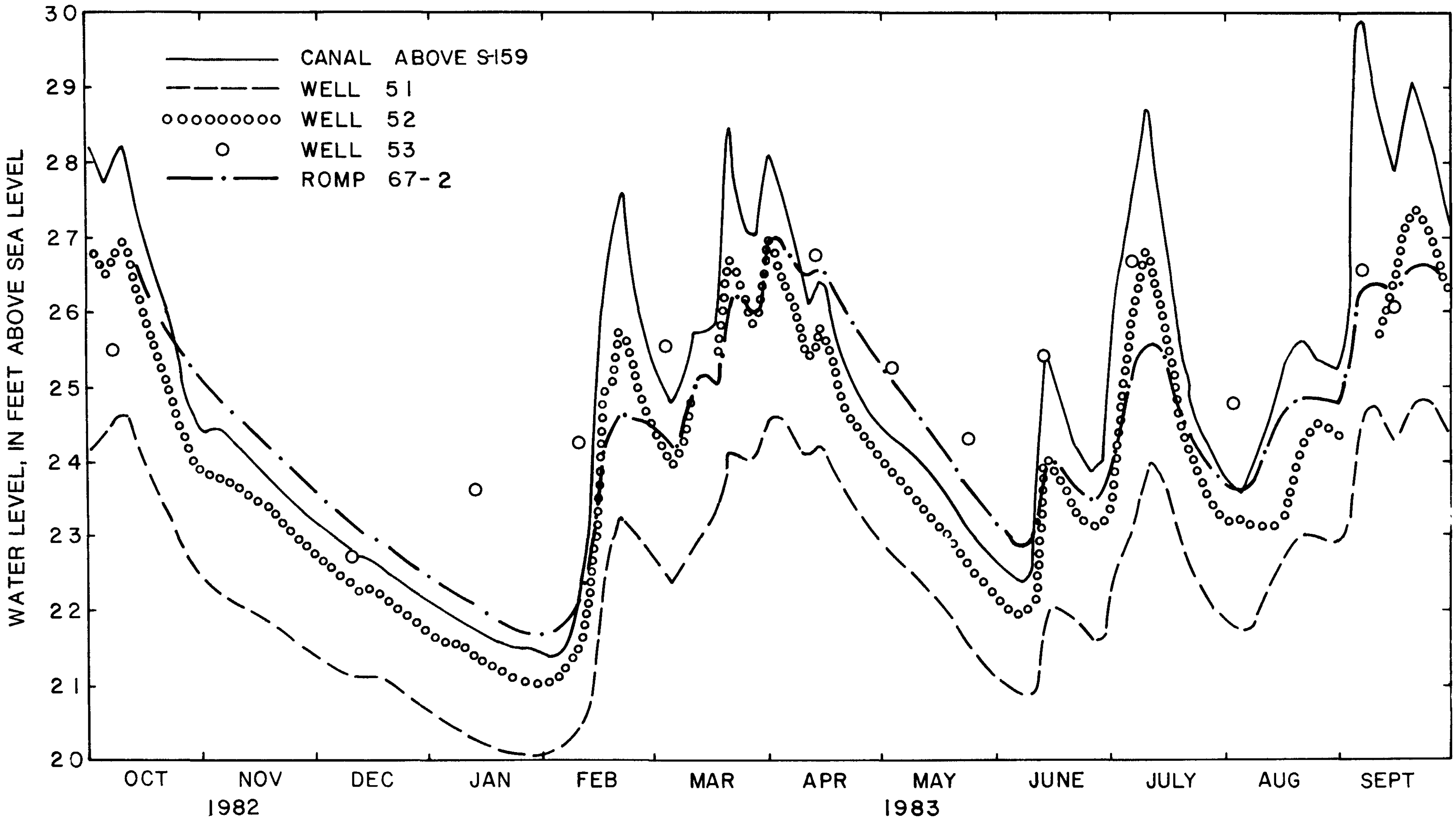


Figure 26.--Water levels in canal C-136 upstream from structure S-159 and in wells 51, 52, 53, and ROMP 67-2.

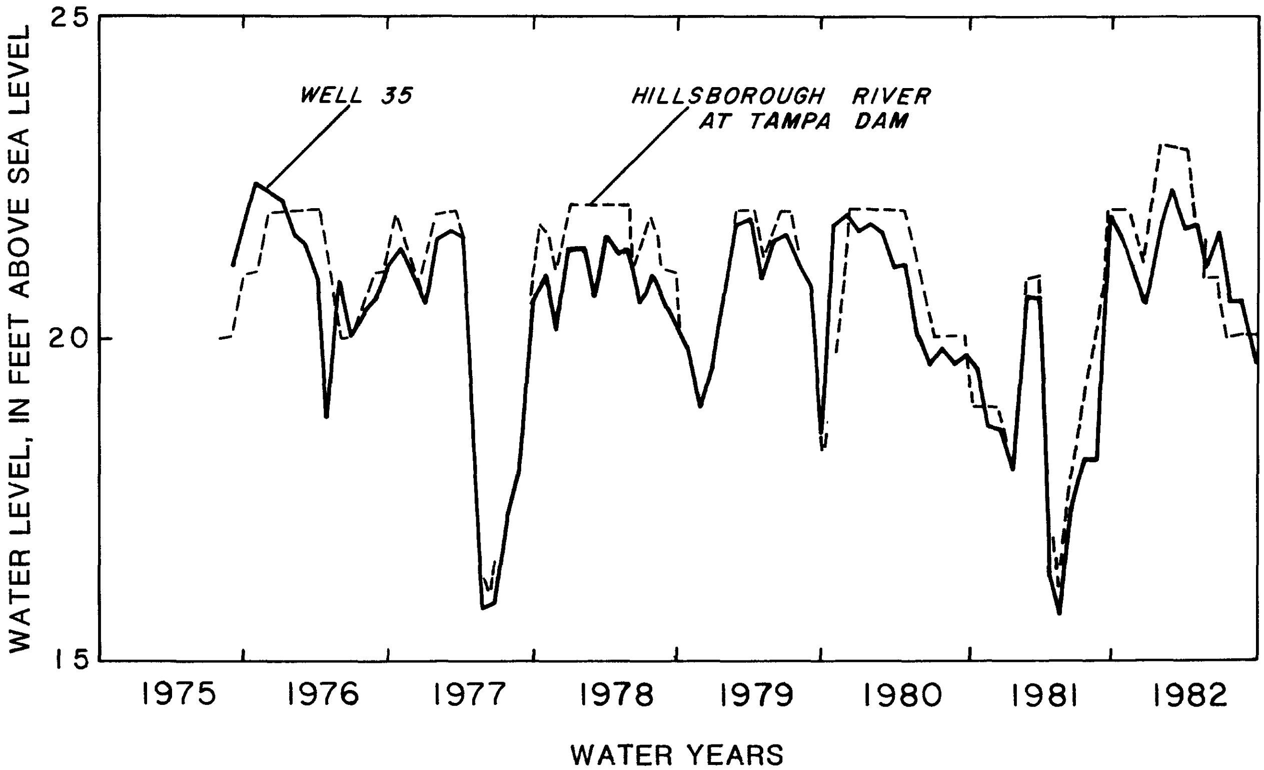


Figure 27.--Month-end water levels for the Hillsborough River and well 35, 1975-82.

Records of water levels for most wells in the lower reaches of canal C-136 began in about 1976 (table 4). Generally, the records prior to canal construction are too short to fully evaluate the impact of canal construction. Water-level data for well 33 (fig. 28) indicate that a lowering in water levels of about 3 feet may have occurred during 1976. This change corresponds to that for wells adjacent to the Tampa Bypass Canal (C-135) in this area. It is probable that water levels were lowered about 3 feet during 1976, but any changes prior to that time cannot be ascertained.

The overall impact of the canal system on the potentiometric surface of the Upper Floridan aquifer is illustrated in figure 29. The more noticeable impact is along the canal between structures S-160 and S-159. Lower water levels, particularly upstream from structure S-162, are reflected in the V-shaped contours pointing up the canal system. As shown in figure 14, most monitor wells are relatively near the canals and impacts noted reflect changes primarily adjacent to the canals. Although data are more sparse away from the canals, a general lowering of the potentiometric surface throughout the canal area is not evident from the contours.

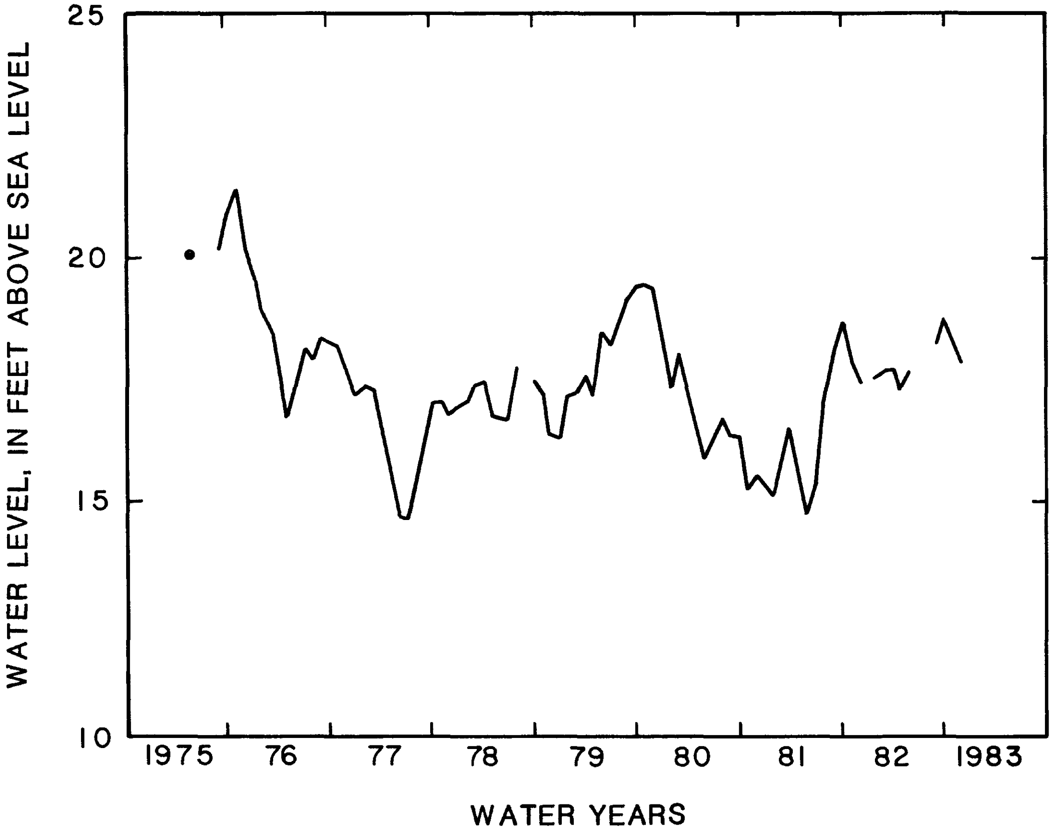


Figure 28.--Month-end water levels in well 33, 1975-83.

Surficial Aquifer

Very little data on water levels in the surficial aquifer have been collected in the canal area. Some data were collected as parts of other project activities, but the periods of data collection are generally of too short duration to define impacts due to canal construction. Sufficient long-term data on the water table, however, are available for the Southwest Florida Water Management District shallow well E-1 near Tampa. The well is adjacent to well 22 (fig. 14). Hydrographs of water levels in wells E-1 and 22 are shown in figure 30. As expected, the water table of the surficial aquifer responds more readily to rainfall and its levels fluctuate more than the potentiometric surface of the Upper Floridan aquifer. These fluctuations cause some differences, but in general, until about 1975, the potentiometric surface was generally higher than the water table of the surficial aquifer. Subsequently, the water table was higher than the potentiometric surface. Analyses of data for well 22, as discussed previously, indicate that, after mid-1975, the potentiometric surface declined about 4 feet. This amount of decline is enough to cause the reversal in relative water levels, as shown in figure 30.

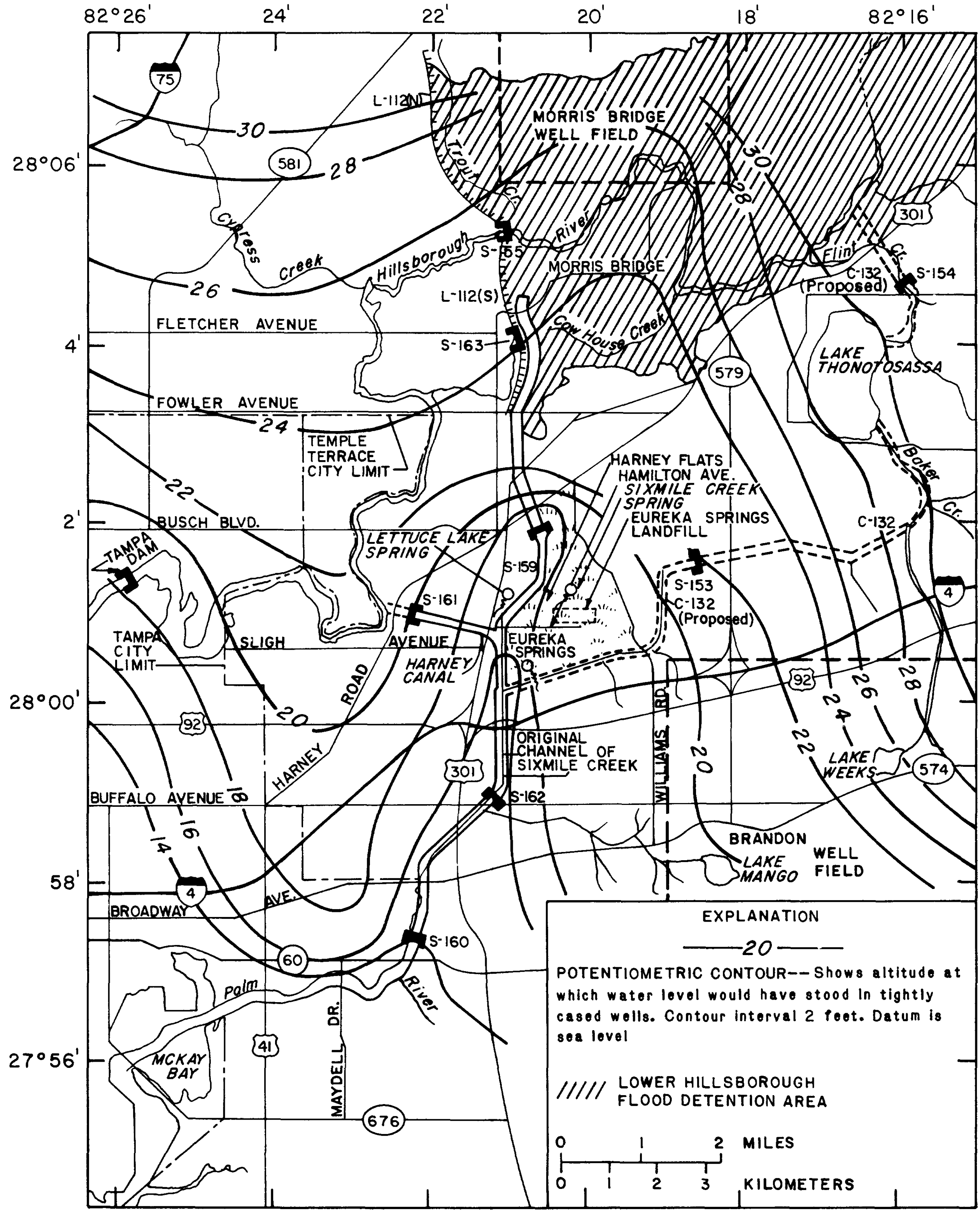


Figure 29.--Potentiometric surface of the Upper Floridan aquifer, May 1983 (from Barr and Schiner, 1983).

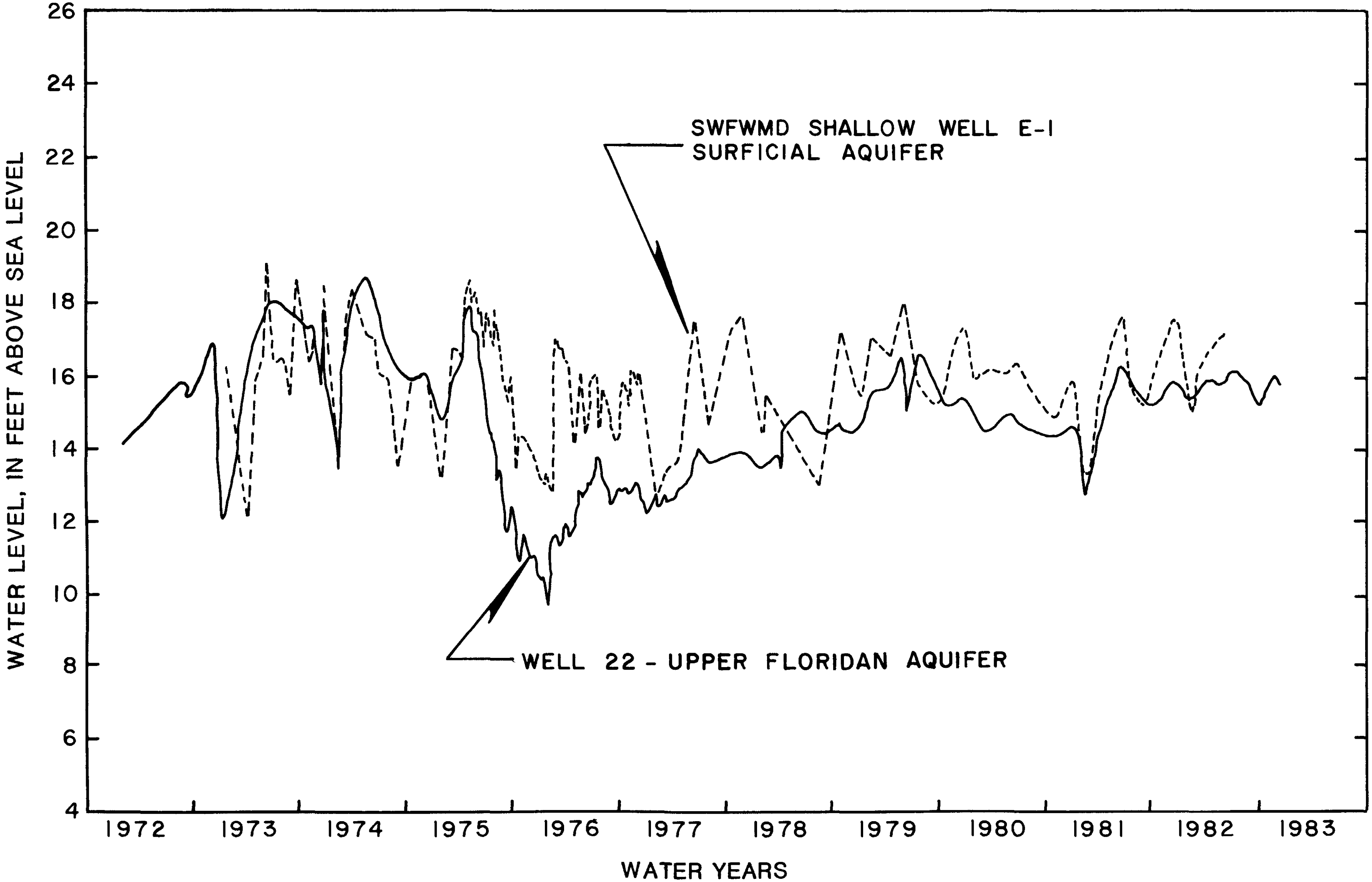


Figure 30.--Monthly water levels in the Southwest Florida Water Management District shallow well E-1 and well 22.

Prior to mid-1975, water from the Upper Floridan aquifer generally flowed upward to the surficial aquifer and acted as a source of recharge to the surficial aquifer. Since mid-1975, the opposite occurs and water from the surficial aquifer recharges the Upper Floridan aquifer. The amount of recharge is related to the hydraulic properties of the confining bed and the head difference between the water table and the potentiometric surface. Definition of the amount of recharge to or from the surficial aquifer is beyond the scope of this project; however, it is significant to note that the relative water levels of the two aquifers have changed. The change permits downward movement of water from the surficial aquifer, and thus, the water table could be lowered, especially during extended dry periods due to vertical drainage into the underlying Upper Floridan aquifer.

To determine whether the water table may have been lowered due to canal construction, water-level data for the Southwest Florida Water Management District shallow well E-1 were related to water-level data for another shallow aquifer well near Lutz. The correlation shows a wide scatter in data, but a change in the relation occurred after mid-1975. A lowering of the water table of about 2 feet is indicated.

Water-level data on the shallow aquifer were also collected in a well adjacent to well 36 as part of a study of the Eureka Springs landfill (Stewart and others, 1983). Analysis of water levels in those two wells shows the same response as water levels in the wells shown in figure 30. Data at the landfill were missing for part of the 1975 to 1976 period, but the record prior to that period shows the potentiometric surface to be higher than the water table of the surficial aquifer. After 1976, the opposite is true, with the water table being higher. Some of the change may be attributed to canal construction, but the landfill could also have affected the levels, particularly in the shallow aquifer. Drainage ditches at the landfill prior to 1976 may have lowered the water table. Subsequent to 1976 and after operation of the landfill ceased, water-level data indicate that some water-table mounding occurred at the site. Thus, some of the higher levels in the surficial aquifer after 1976 may be due to the mounding caused by the landfill.

Water-level data on the surficial aquifer elsewhere are lacking or consist of periodic water-level measurements obtained during times of water-quality sampling. The amount of data is too small for meaningful analysis.

Throughout most of the study area, the water table of the surficial aquifer is higher than the potentiometric surface of the Upper Floridan aquifer (figs. 7 and 8). In areas where the potentiometric surface has been lowered because of canal construction, leakage from the surficial aquifer to the Upper Floridan aquifer would increase because of greater head differences. The increased leakage would result in lower levels of the water table. In areas where the potentiometric surface was higher than the water table, but was lowered sufficiently by construction of the canal to be lower than the water table, such as at wells 22 and 36, the water table would be impacted and be lowered.

WATER QUALITY

The quality of surface water and ground water in the canal area is generally good and suitable for most uses. Tables 6 and 7 provide water-quality data for a few selected parameters for selected surface-water and ground-water sites.

Table 6.--Water-quality data for selected surface-water sites

[Number of analyses is indicated in parentheses; values are for mean, maximum, and minimum]

Site (fig. 13)	Specific conductance (umho/cm)	Chloride, Cl (mg/L)	Sulfate, SO_4 (mg/L)	Iron, Fe (ug/L)	Total phosphorus as P (mg/L)	Total ammonia nitrogen as N (mg/L)	Total nitrate nitrogen as N (mg/L)
2S	(55)	(16)	(16)	(5)	(35)	(35)	(35)
	462	34	70	44	0.30	0.15	0.09
	858	150	100	110	1.30	1.40	.59
	190	10	18	10	.06	.02	.00
4S	(105)	(29)	(29)	(22)	(84)	(84)	(84)
	286	20	22	44	.73	.08	.04
	480	30	38	180	3.90	.97	1.90
	149	10	7.8	10	.19	.00	.00
5S	(27)	(14)	(14)	(5)	(23)	(22)	(22)
	27,600	10,800	1,500	50	1.07	.25	.08
	39,000	14,000	2,100	100	1.90	.72	.57
	3,300	4,400	630	20	.54	.01	.00
6S	(15)	(8)	(8)	(4)	(11)	(11)	(11)
	439	18	63	88	.28	.07	.08
	582	29	97	310	.44	.18	.47
	194	11	17	10	.07	.01	.00
9S	(23)	(14)	(14)	(5)	(18)	(17)	(17)
	399	16	61	48	.23	.05	.07
	500	26	97	130	.43	.14	.99
	190	11	17	10	.08	.01	.00
10S	(16)	(11)	(11)	(3)	(15)	(15)	(15)
	362	12	64	43	.13	.09	.02
	480	15	92	110	.34	.48	.04
	260	8	24	10	.05	.01	.00
11S	(19)	(12)	(12)	(6)	(17)	(13)	(13)
	293	10	31	170	.53	.14	.08
	403	14	56	380	1.80	.94	.62
	120	4	9	40	.05	.02	.00
12S	(25)	(16)	(16)	(6)	(23)	(23)	(23)
	332	13	25	117	.33	.32	.49
	538	28	57	480	.98	4.60	4.50
	112	7	9	10	.03	.01	.00

Table 7.--Water-quality data for selected ground-water sites

[Number of analyses is indicated in parentheses; values are for mean, maximum, and minimum]

Site (fig. 14)	Specific conductance (umho/cm)	Chloride, Cl (mg/L)	Sulfate, SO_4 (mg/L)	Iron, Fe (ug/L)
2	(35)	(36)	(7)	(2)
	643	72	9.2	1,550
	75	150	22	1,800
	464	42	.6	1,300
10	(121)	(123)	(9)	(3)
	691	79	83	87
	840	130	91	90
	366	49	78	80
26	(9)	(10)	(8)	(3)
	369	9.5	49	197
	390	10	53	260
	328	8.5	45	140
35	(13)	(10)	(8)	(3)
	385	21	45	93
	568	22	51	120
	322	19	33	60
51	(4)	(5)	(10)	---
	300	5.4	44	---
	352	6.2	52	---
	228	4.3	21	---
53	(13)	(14)	(8)	(4)
	437	12	45	37
	465	13	51	70
	300	8.1	33	10

The sites listed were chosen to provide areal coverage and the parameters were selected as indicators of overall water quality. The sites were also selected so that data could be compared between adjacent or nearby surface-water and ground-water sites. Locations of the sites are shown in figures 13 and 14. Nutrient data are provided for the surface-water sites. Data are also provided for Flint Creek (site 4S), although data on ground-water quality near the site are not available. Results of all water-quality analyses made in the canal area are available in annually published reports by the U.S. Geological Survey on "Water Resources Data for Florida, Southwest Florida."

Although differences in concentrations of specific constituents can be noted between tables 6 and 7, the differences are generally small. The only significant difference occurs in the area downstream from structure S-160 as reflected by data for surface-water site 5S (fig. 13) and well 2 (fig. 14). Values of the parameters for the surface-water site are high and reflect the quality of water in Tampa Bay (seawater). Elsewhere, the quality of surface water and ground water is similar and any interchange of water between surface- and ground-water sources caused by canal construction would not result in large changes in water quality. A summary of changes in water quality noted in the canal area follows.

Impact of Canal Construction on Surface-Water Quality

Water-quality sampling was done at 12 surface-water sites in the canal area (table 3). At most sites, sampling began in 1974. Sampling has continued through 1983 at eight of the sites shown in table 3.

Downstream from structure S-160, water-quality data were obtained at U.S. Highway 41 (site 5S, fig. 13). This reach of canal is tidal, and water quality is affected by saline water from McKay Bay flowing into and out of the reach. Concentrations of chlorides were generally from 10,000 to 14,000 mg/L, and specific conductance was about 30,000 umhos. Because of the saline water flowing into the reach, cause and effect relations due to canal construction are difficult to determine.

Concentrations of ammonia nitrogen, organic nitrogen, total nitrogen, biochemical oxygen demand, fluoride, and phosphorus at site 5S were generally lower after about 1979 than for the earlier years. The lower concentrations may indicate the effects of dilution due to increased freshwater discharge from the canal system. However, changes in operation of the Eureka Springs landfill, agricultural runoff, and improved quality of Tampa Bay water (Hillsborough County Environmental Protection Commission, 1981) may also be significant factors. Additionally, the first "flush" due to bypass of flood water from the Hillsborough River occurred in 1979. This release of large volumes of freshwater may have altered water-quality characteristics temporarily, but it is unlikely to have affected the long-term changes observed since 1979.

Except that increased discharge from the canal system may affect water quality, any impacts due to canal construction downstream of structure S-160 are indefinite. Construction in this reach of canal was completed by 1973 (table 1). This was prior to initiation of water-quality sampling. Thus, impacts on water quality cannot be fully ascertained.

From structure S-160 to structure S-162, and based on data for site 2S, figure 13, only minor changes in water quality with time are indicated by the record that began in 1974. Some small reductions in biochemical oxygen demand (4.0 to 2.0 mg/L) and silica (12.0 to 7.0 mg/L) are indicated. These reductions may reflect dilution due to increased discharge from the canal system, changes in agricultural runoff, changes in operation of the Eureka Springs landfill, or other causes. Changes in concentrations of other constituents were not evident.

The reach of canal from structure S-160 to structure S-162, and perhaps areas beyond this reach, was estaurine prior to canal construction. Structure S-160, as described earlier, forms a salinity barrier to prevent saltwater intrusion from McKay Bay. The quality of water above the canal has thus been changed from saline to fresh. Lack of preconstruction quality data, however, prohibits quantification of this change.

Data were collected at sites 1S and 6S at structure S-162 (fig. 13) during the periods 1974 to 1976 and 1977 to 1981, respectively. The records are too short for meaningful analysis. The record at site 1S, however, shows a significant decrease in phosphorus (0.75 to 0.20 mg/L), nitrogen (1.7 to 0.5 mg/L), and biochemical oxygen demand (6.0 to 1.0 mg/L) similar to that at sites 2S and 5S. At site 6S, relatively high concentrations of phosphorus (0.2 to 0.4 mg/L) were noted. The analyses and changes in concentrations at sites 1S and 6S confirm those for the more downstream sites.

Water samples were collected from 1976 to 1979 from a small tributary (site 7S, fig. 13) that was to be part of the proposed canal C-132. The short record indicates that concentrations of many constituents fluctuate with discharge. Concentrations of phosphorus (1.6 mg/L) were relatively high at times, similar to those for the more downstream sampling sites. The high concentrations are probably related to farming, citrus growing, and landfill operations. No impacts due to construction of canal C-136 are evident from the short period of record.

Water-quality sampling at structure S-159 (site 10S, fig. 13) began in 1977 and primarily reflects the quality of water from the upper reaches of the canal system. The data show a general increase in specific conductance (300 to 400 umhos) and in concentrations of hardness (150 to 200 mg/L), biochemical oxygen demand (2.0 to 4.0 mg/L), chloride (8.0 to 15.0 mg/L), magnesium (4.0 to 7.5 mg/L), sulfate (40 to 90 mg/L), and potassium (0.6 to 1.7 mg/L). Concentrations of the various constituents approach those of ground water, but vary in response to runoff events.

Water-quality data have been collected on Cow House Creek (site 11S, fig. 13) and at structure S-155 (site 12S, fig. 13) since 1974. Data at both sites indicate that concentrations of the various constituents are related to discharge. Concentrations fluctuate between high and low discharges and from flushing caused by runoff events. Any impacts on water quality due to construction are not indicated by the record.

Water-quality data on the Harney Canal were collected upstream and downstream of structure S-161, prior to its completion, at sites 3S and 9S, respectively (fig. 13). Sampling upstream of S-161 for nutrient concentrations was done only for the years 1974 to 1976. Analyses of the few samples taken show relatively high levels of phosphorus, ammonia nitrogen, and organic nitrogen. However, whether they can be attributed to canal construction is uncertain. Analyses of other constituents do not indicate any impacts due to construction; however, the length of record is short.

Water-quality data at site 9S are available for the period 1976 to 1983. Concentrations of most constituents have remained fairly constant throughout the period of record. Some temporary changes are noted when water was diverted from the Hillsborough River through the canal. However, no trends or changes are evident.

Water-quality data for Baker and Flint Creeks (sites 3S and 4S, fig. 13) are available for the periods 1970 to 1979 and 1956 to 1983, respectively. The data indicate large fluctuations in the concentrations of most constituents. The fluctuations are related to variations in discharge, but are also affected by effluent discharge. Reichenbaugh and Hunn (1972) pointed out that "water quality has been affected by runoff from agricultural lands, undeveloped marshlands, and municipal-industrial effluents from Plant City and vicinity" in the headwaters of Baker Creek. Although a treatment plant was built in 1970 to reduce nutrient loading of the stream, some impacts on water quality may still occur. Data on Baker Creek continued to show high levels of phosphorus throughout its period of record. Impacts on water quality of Baker and Flint Creeks due to canal construction are remote.

Impact of Canal Construction on Ground-Water Quality

Water-quality samples have been collected from most of the wells listed in table 4. In many cases, the length of record is too short for evaluation of impacts of canal construction, but could be used in conjunction with data for wells that were sampled over longer periods. Sampling generally began about 1973. The frequency of sampling ranged from monthly to only one sample. Sampling has continued through 1983 at 14 sites.

Analyses of water samples from well 2 (depth 100 feet) near the mouth of the Palm River showed a slight decline in specific conductance (700 to 600 umhos) and in the concentrations of chlorides (90 to 60 mg/L) during the period 1967 to 1981 except for a temporary reversal in 1980 and early 1981. Changes for other parameters were not evident or the sampling was too infrequent for definition of changes in water quality. Declines in specific conductance and chloride might be due to increased flow of fresh ground water due to excavation of the canal, or water-level drawdown caused by nearby industrial pumping. In any event, the declines are small.

At well 4 (depth 72 feet), further upstream in the Palm River area, specific conductance and chloride concentrations have shown a gradual increase since 1971. Average specific conductance has increased from about 1,200 to 1,500 umhos and average chloride concentrations have increased from about 200 to 350 mg/L (fig. 31). Some increase in concentrations of those parameters is also indicated by the data for wells 6 and 8. However, samples from those wells cover only the years 1976 to 1979 and the number of samples is small. The data indicate that some saltwater intrusion or upconing may be occurring or that saline water in the estuarine reach of the canal system is entering the aquifer. At site 5S, for example, chloride concentrations in the canal exceed 10,000 mg/L (table 6). Drawdown caused by nearby industry could cause the more saline water in the canal to move into the Upper Floridan aquifer.

Water samples for analysis of chloride concentrations were collected monthly from 1971 to 1983 at well 10 upstream of structure S-160. The data show a gradual increase in chloride concentrations from 1971 to about 1977 (fig. 32). Subsequently, the concentrations have remained fairly steady or the rate of increase much slower. By 1983, the chloride concentrations were about 40 mg/L higher than the 1971 concentrations. Specific conductance data also show an increase during the same period and a leveling off after about 1977 or 1978. Specific conductance was about 650 umhos in 1971 and increased to about 750 umhos by 1979 and remained at about that level thereafter. Concentrations of other constituents do not show any similar increases or trends.

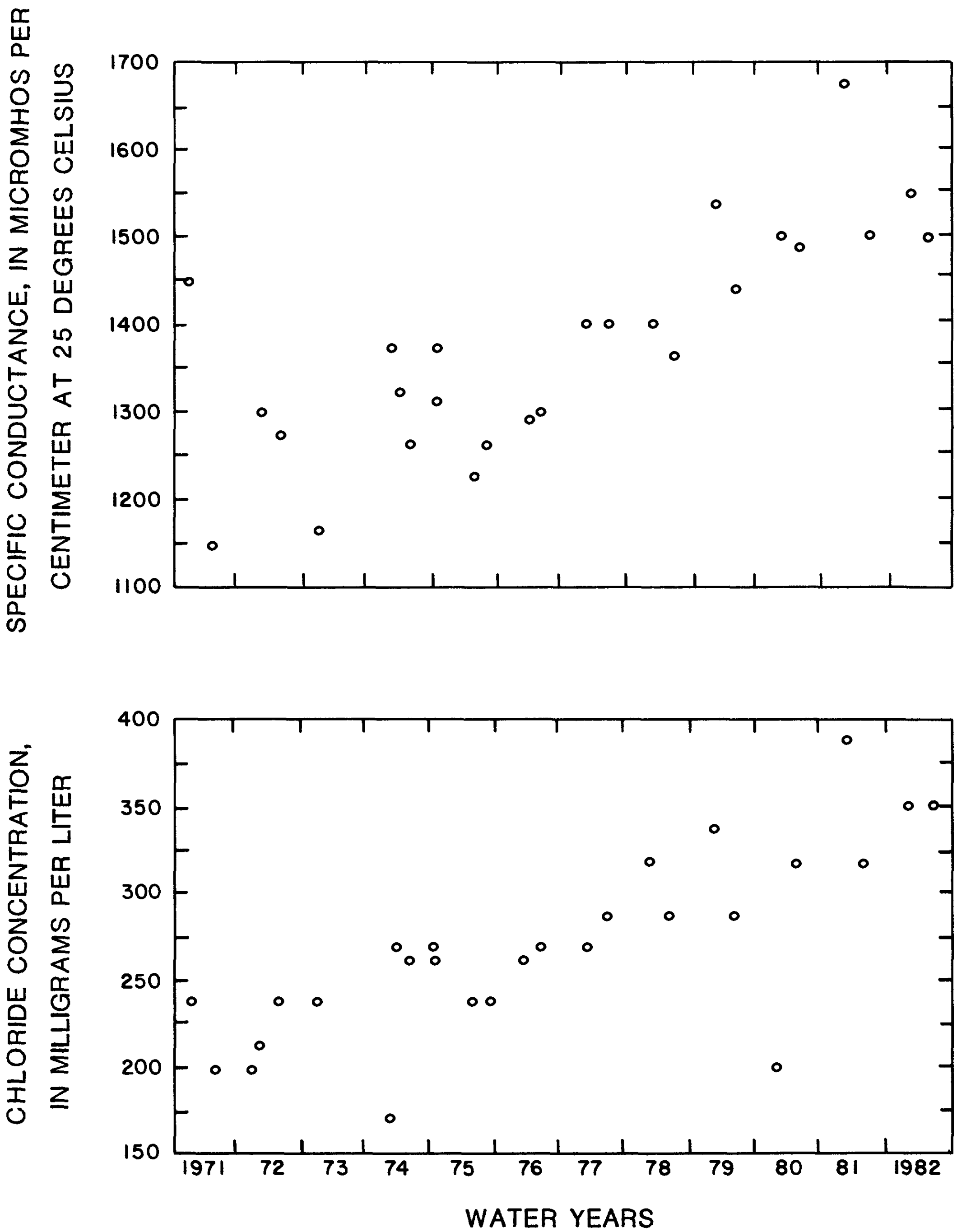


Figure 31.--Specific conductance and concentrations of chlorides in water from well 4, 1971-83.

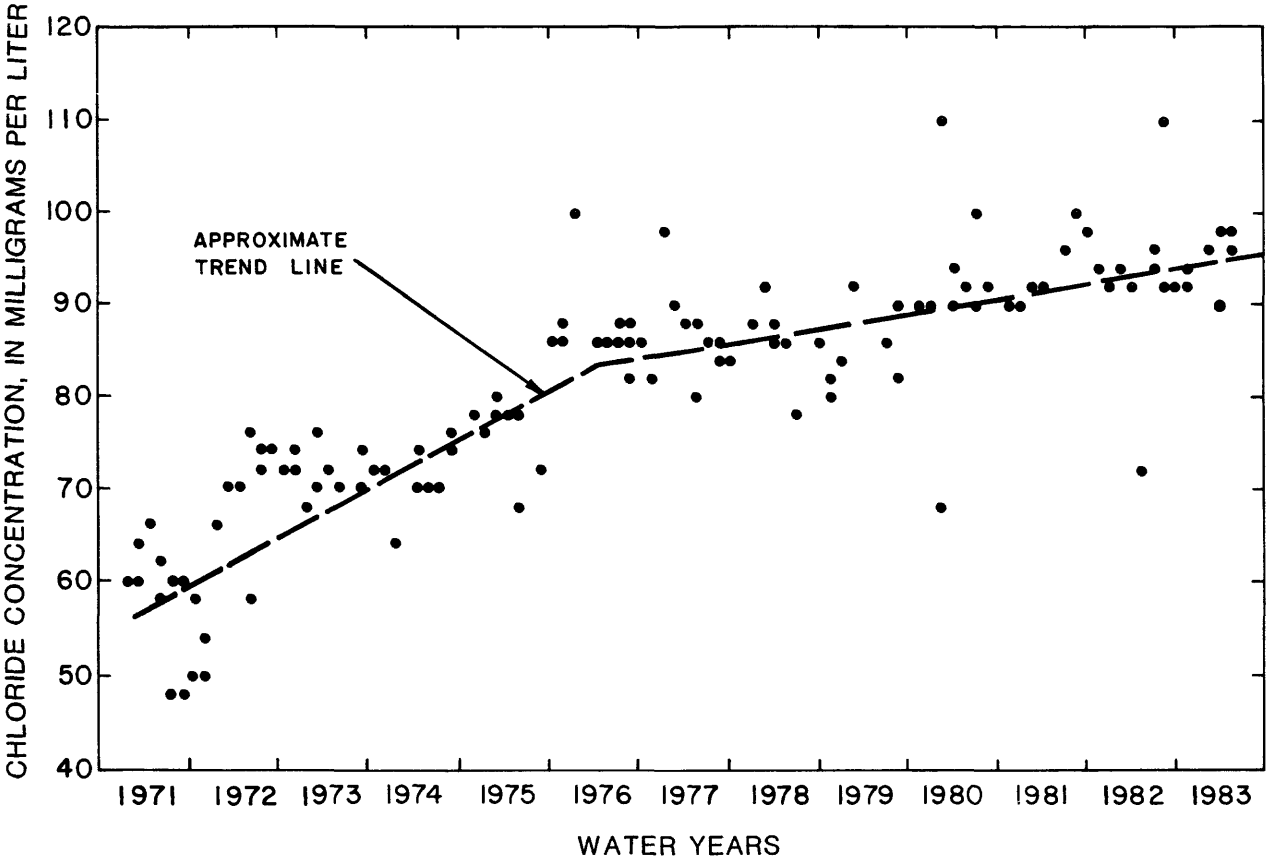


Figure 32.--Chloride concentrations in water from well 10, 1971-83.

Water-quality data for wells 16, 17, 26, 29, 32, 35, 37, 39, and 41 between structures S-160 and S-159 do not show any significant changes in the concentrations of most constituents. Concentrations of strontium in water from wells 16, 17, and 29 were lower after 1977 than for previous years. Concentrations of strontium in water from well 16 decreased from about 200 to 150 ug/L, and in water from well 17, the decrease was from about 690 to 640 ug/L. Concentrations of strontium in water from well 29 dropped from about 800 to 100 ug/L. No significant changes were noted for any of the other constituents analyzed.

At well 37, some increases were noted in the concentrations of dissolved solids, chloride, sulfate, and manganese; however, the number of samples was small, and the period of record (1976-80) was too short to evaluate trends. Specific conductance prior to mid-1979 was about 400 umhos. In 1980, conductance was about 550 umhos. Water from well 39 shows reduced concentrations of sulfate, manganese, hardness, and strontium during 1978 and 1979; however, concentrations returned to previous levels subsequently. The lower concentrations may be related to natural causes. Major rains in 1978 and 1979 may have been a factor in reducing the concentrations.

Water from well 41 shows a reduction in dissolved solids (260 to 240 mg/L) between 1972 and 1982 and in specific conductance (390 to 350 umhos). Water from well 51 showed a reduction in specific conductance (340 to 260 umhos) between 1977 and 1983. In both cases, the number of samples are few.

Upstream of structure S-159, water-quality data for ground-water sites are relatively sparse as data collection did not begin until 1977. Analyses of water samples from wells 51, 52, 53, and 55 were evaluated. Little or no change or trends were noted for the constituents analyzed. Where changes did occur, they were generally temporary and concentrations returned to previous levels.

Although data for wells 51, 52, 53, and 55 do not show any lasting water-quality changes, there has been at least one indicated change in the quality of water in a private well tapping the Upper Floridan aquifer in the area. Analyses of water from the well, near well 52, showed great similarities with that of canal water upstream of structure S-159 (Southwest Florida Water Management District, written commun., 1982). Specific conductance and hardness were almost identical in water from the well and the canal; phosphate, nitrate, and organic carbon concentrations were higher than normal for ground water; color was fairly high; and organic carbon and coliform concentrations in the canal and well were similar. Because of these similarities, it was concluded that a connection could exist between the well and the canal, and because of head differences, water could flow from the canal to the well (Southwest Florida Water Management District, written commun., 1982).

Interchange of water between the canal and the Upper Floridan aquifer is possible because of the higher water levels in the canal upstream of structure S-159. Water levels in the canal have been held at an elevation of from 21 to 29 feet above sea level. These levels are generally higher than water levels in the Upper Floridan aquifer in this area (fig. 26). Thus, downward leakage could occur from the canal to the aquifer. However, other causes, such as the higher levels of the water table (fig. 7) and septic tank effluent, may also have been a cause of the occurrence of coliform in the water in the well.

SUMMARY AND CONCLUSIONS

The Tampa Bypass Canal system was constructed in central Hillsborough County to divert water from the Hillsborough River and thereby alleviate flooding in Tampa and Temple Terrace. Excavation of the canal cut into the confining bed that separates the Floridan aquifer system from the overlying surficial aquifer. In several places, the excavation breached the Upper Floridan aquifer. To determine whether the excavation would impact on the areal hydrology, a monitoring program was established to obtain data on water levels, discharge from streams and springs, and the quality of surface and ground water.

Drainage from the canal area prior to construction was primarily by Sixmile Creek and Palm River. Records of discharge for Sixmile Creek prior to construction and at structure S-160 subsequently were evaluated to define changes in flow from the canal area. The analyses indicate that base-flow discharge from the area for the period 1975 to 1978 was about one-and-a-half times more than for the preconstruction period. After 1978, the discharge was more than twice that of the preconstruction period. Most of the increase in discharge is from ground-water sources, primarily the Upper Floridan aquifer.

Discharge for Baker and Flint Creeks, the inlet and outlet streams to Lake Thonotosassa, probably has not been affected by canal construction. Comparisons of the discharge of the streams with other nearby streams show some variations in discharge. However, these variations probably reflect normal year-to-year variations in runoff or changes in effluent discharge from upstream sources rather than changes due to canal construction.

Lower levels of the potentiometric surface caused reductions in the discharge from springs in the area. Records for Sixmile Creek Spring and Lettuce Lake Spring show reductions of 55 and 35 percent or more, respectively.

Water levels of the Upper Floridan aquifer adjacent to the tidal reach of the canal system (downstream from structure S-160) do not seem to have been affected by canal construction. Excavation breached the Upper Floridan aquifer and the breach could facilitate upward movement of water from the aquifer. However, low ground-water levels in this coastal area and drawdowns caused by withdrawals for nearby industrial use may reduce any potential for upward movement of water into the canal. Although the lengths of records for wells in this area are too short for definitive analysis, the likelihood of the canal impacting water levels is minimal.

Postconstruction water levels in the canal upstream of structure S-160 are higher than preconstruction levels due to impoundment of water upstream from the structure. The higher water levels in the canal cause an increase in downward leakage and consequent higher water levels in the Upper Floridan aquifer than preconstruction levels. An increase in levels of up to 4 feet is indicated.

Water levels of the Upper Floridan aquifer upstream of structure S-162 and in the Cow House Creek area are generally 2 to 4 feet lower as a result of construction. Near structure S-159, the total lowering may be 6 feet or more. Upstream of structure S-159, the indicated lowering of the potentiometric surface is about 2 to 4 feet.

Water levels in wells near structure S-161 follow closely the levels of the Hillsborough River, indicating a good hydraulic connection between the river and the Upper Floridan aquifer. Because of this, impacts of canal construction on ground-water levels near structure S-161 are indefinite. In the lower reaches of canal C-136, water levels of the Upper Floridan aquifer have been lowered about 2 to 4 feet due to construction. This lowering in levels is similar to the amount of lowering of levels near the main canal, C-135, in this area.

Data on the surficial aquifer are available for only two sites, one of which may have been affected by landfill operations. Water levels for both wells, however, show that the potentiometric surface of the Upper Floridan aquifer was higher than the water table of the surficial aquifer prior to about mid-1975, whereas the opposite occurred subsequent to that time.

For most of the surface-water sites that were monitored, little or no change in water quality was noted. Some changes, however, may have resulted from increased runoff from the canal area, changes in rural and urban runoff, or discharge from a landfill area.

Downstream from structure S-160, some reductions in the concentrations of ammonia nitrogen, organic nitrogen, total nitrogen, biochemical oxygen demand, fluoride, and phosphorus are indicated. These changes may be due in part to increased freshwater flow from the canal area.

Upstream of structures S-160 and S-162, small reductions were noted in biochemical oxygen demand, silica, phosphorus, and nitrogen similar to the more downstream reach. Upstream of structure S-159, increases in specific conductance, hardness, biochemical oxygen demand, chloride, magnesium, sulfate, and potassium were noted. These changes may reflect increases in ground-water discharge from that area.

Water-quality data for Cow House Creek and Harney Canal show little change with time. Concentrations of most constituents fluctuate in response to runoff and diversions of water from the Hillsborough River to the canal system.

Concentrations for many water-quality parameters for Baker and Flint Creeks fluctuate widely. The changes are due to changes in discharge, runoff from agricultural areas and undeveloped marshlands, and municipal and industrial effluent discharge.

Analyses of water from well 2 near the mouth of the Palm River show a slight decline in specific conductance (700 to 600 umhos) and in the concentrations of chloride (90 to 60 mg/L). Water from well 4, however, showed an increase in specific conductance (1,200 to 1,500 umhos) and chloride concentrations (200 to 350 mg/L).

Chloride concentrations in water from Upper Floridan aquifer well 10 showed a gradual increase from 1971 to about 1979 as did the specific conductance. Water-quality data for other wells show minor or temporary changes in the concentrations of some constituents. In most cases, however, the number of samples analyzed and length of record were too short to evaluate trends or to define impact of canal construction.

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