LARGE SPRINGS OF FLORIDA'S "SUN COAST" CITRUS AND HERNANDO COUNTIES

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LARGE SPRINGS OF FLORIDA'S "SUN COAST" CITRUS AND HERNANDO COUNTIES

By

J. A. Mann and R. N. Cherry

INTRODUCTION

Florida has more first magnitude springs than any other state in the nation. A first magnitude spring has an average discharge (flow) of at least 100 cfs (cubic feet per second) or 64.6 mgd (million gallons per day). About 20 springs or spring complexes within Florida are in this category. Four of the large spring complexes are in Citrus and Hernando counties, along the west-central gulf coast of Florida. These four spring complexes provide almost the entire fresh-water flow of Crystal, Homosassa, Chassahowitzka, and Weekiwachee Rivers, figure 1. The combined flow of these rivers averages or exceeds one billion gallons per day, which equals 1,000 mgd, and could have supplied all of Florida's industrial and municipal water used in 1967.

The four large spring complexes are of utmost importance to the future development of the "Sun Coast" area because of their value to tourists (the largest industry of the area) and their esthetic and natural resource value.

GEOGRAPHIC SETTING OF THE SPRINGS

The four spring complexes near the head of the Crystal, Homosassa, Chassahowitzka, and Weekiwachee Rivers occur where the aquifer, in this case a water-bearing limestone, lies near the land surface or is exposed in the headwaters or channels of the rivers.

The lands along the springfed rivers abound in natural beauty. For several miles the rivers wind through lowlands containing lush tropical and semitropical growth, the habitat of numerous varieties of animals and birds. The aquatic plants and the associated invertebrate animals that thrive in the crystal-clear, warm (about 74°F year round) unpolluted waters attract thousands of fresh and salt-water fish, including bass, redfish, snook, tarpon, sheepshead, and spotted weak fish (locally called trout). Thus, the springs form giant natural fish bowls, figure 2, which are popular sites for sport fishing, skin diving, and other recreational activities.

The area around the large springs and to the east is sparsely populated. Most people live in the towns near the springs. Many retirees have moved to the area, attracted by the mild climate, natural beauty, and recreational opportunities.

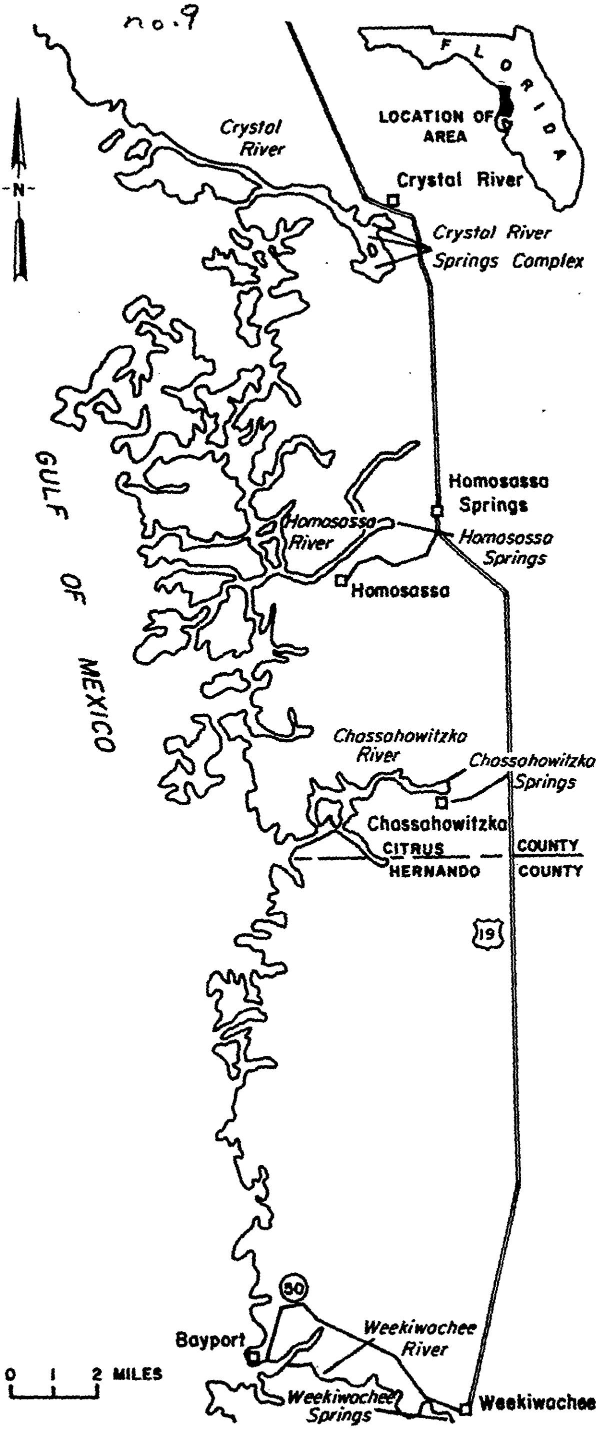


Figure 1. "Sun Coast" springs area of Florida.

Figure 2. Thousands of fish of many kinds gather at "Nature's Giant Fishbowl"–Homosassa Springs. The vertically striped fish are sheepshead, a favorite of fishermen.

The springs at Homosassa and Weekiwachee are tourist attractions of national and even international reknown, figures 3 and 4. Chassahowitzka Springs, however, remains in a nearly natural setting and is used mostly by local swimmers and fishermen. The area around Homosassa and Chassahowitzka springs is well known for its excellent hunting. The 35,000-acre Chassahowitzka National Wildlife Refuge offers seasonal hunting of wild turkeys, ducks, doves, squirrels, hogs, and deer.

The brackish conditions (semi-salty) caused by the discharge of good quality fresh water into sea water provide an ideal habitat for oysters and other mollusks. Shell mounds left by the early Indian inhabitants of the Crystal River area attest to the ready availability of this food supply. Commercial fishing and the seafood industry flourish on the excellent salt water fishing grounds nearby, figure 5. The abundance and variety of seafood from this area is well known throughout Florida and neighboring states. Crystal River was once mainly a fishing village; but in recent years as tourism has grown, the town has become a tourist recreational center and a retirement community.

Limerock is mined at several places, mostly south of Bayport and near Crystal River, figure 6. Much of the mining is done in conjunction with land development; limerock sold for use in road building partially pays the cost of land development.

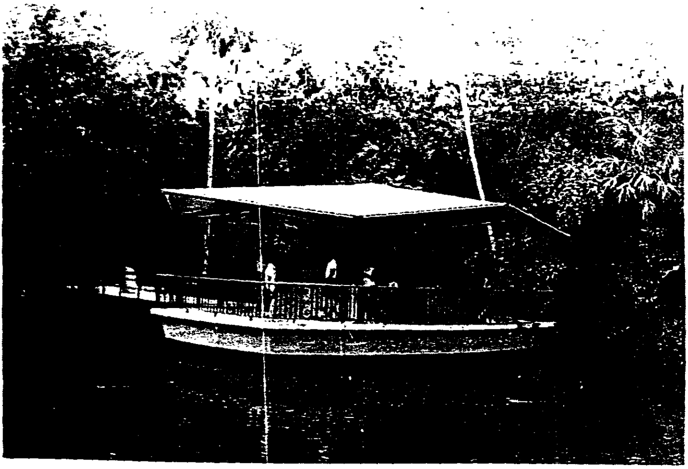


Figure 3. Homosassa Springs, "Nature's Giant Fishbowl"–underwater observatory at the main springs openings at Homosassa River.

Figure 4. Weekiwachee Springs–"The Springs of Live Mermaids"–underwater amphitheater and glass-bottom cruise boats at the main springs openings at Weekiwachee River.

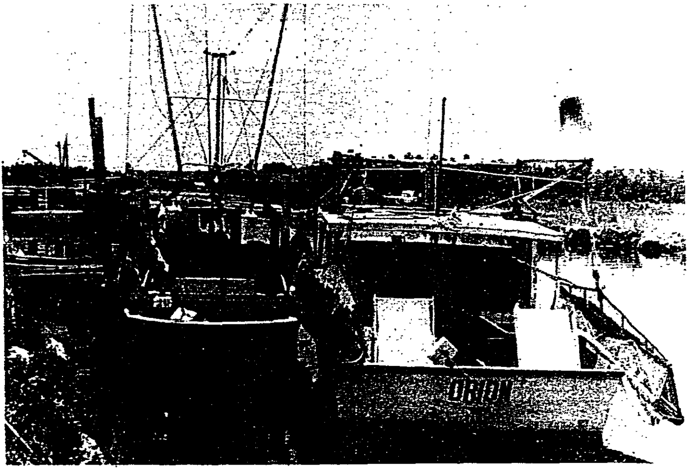


Figure 5. Commercial fishing and the seafood industry are important to "Sun Coast" area.

WHAT IS THE FLOW OF THE SPRINGS?

The flow of the springs varies seasonally--during or following a drought the discharge is much less than during or following an exceptionally wet period. Although response to seasonal variations in rainfall is apparent, the fluctuations of flow are slower than those of normal streams. Time is required for rainfall to infiltrate the soil and flow through the limestone aquifer (called the Floridan aquifer) to the spring vent where it is noticeable as an increase in discharge.

A comparison of flow from the four major spring complexes can be made from the data of table 1. Hydrologic conditions in the area during the period January 1964 to June 1966 were near average for the long-term records of flow for Homosassa and Weekiwachee Springs.

The flow from the spring complex at the head of Crystal River is apparently the largest in the area. Because the springs occur at various points in the headwaters of Crystal River, the flow from the individual springs could not be measured. The average flow represents that recorded at the gaging station about three miles downstream from the town of Crystal River (fig. 1) and includes most of the spring discharge to Crystal River. The monthly mean flow of Crystal River at this location is shown on figure 7. Maximum flow occurs during the dry season of the year and minimum flow during the wet season, whereas in most streams the maximum and minimum flow

TABLE 1. DISCHARGE OF MAJOR COASTAL SPRINGS IN CITRUS AND HERNANDO COUNTIES

Spring Complex	Measurement Period	Discharge in million gallons per day: Average	High	Low	Number of Measurements
Crystal River	[1] 1964-66	600	[2] 4,340	[2] -1,520	Continuous Record
Homosassa	1932-66	129	166	81	25
Homosassa	[1] 1964-66	145	166	110	12
Weekiwachee	1917-66	112	178	65	300
Weekiwachee	1964-66	114	178	110	18
Chassahowitzka	1964-66	90	127	21	18

[1] January 1964 to June 1966

[2] Daily mean (negative sign indicates upstream flow)

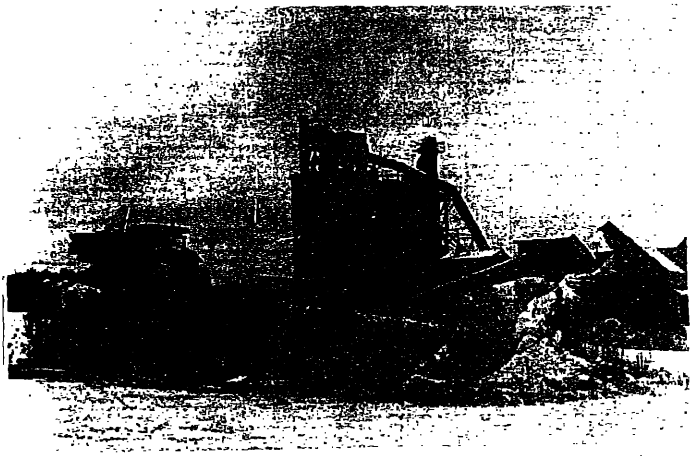


Figure 6. Limerock mining near Crystal River, Florida.

normally coincides with the wet and dry seasons. The anomalous timing of the flow of Crystal River is probably caused by seasonal tides. The highest seasonal tides occur during wet seasons, and impose a backwater condition which decreases the river's flow; lowest tides occur during dry seasons and allow water to flow out of storage, increasing the river s flow. The minimum and maximum net daily flow to the ocean at the gaging station on Crystal River occurred during Hurricane Dora, September, 1964. On September 10, the hurricane passed and wind tides carried sea water upstream, at an average rate for the day of 1,520 cfs. The maximum daily flow occurred the following day as the tides subsided and the wind-blown water flowed seaward at 4,340 cfs.

The flow of Homosassa Springs has been measured periodically since 1932. From 1932 through 1966 the flow averaged 129 mgd on the basis of 25 discharge measurements. The maximum measured flow occurred August 4, 1965, during median hydrologic conditions. The minimum measured flow, 81 mgd, occurred April 3, 1946 during a severe drought. The measured flows include the discharge of springs in the Southeast Fork of Homosassa Springs. The average flow of Homosassa River from January 1964 to June 1966 was about 250 mgd.

The flow of Weekiwachee Springs has been measured periodically since 1917. The average flow is 112 mgd, on the basis of 300 measurements from 1917 to 1966. The maximum measured flow occurred October 19, 1964, during median

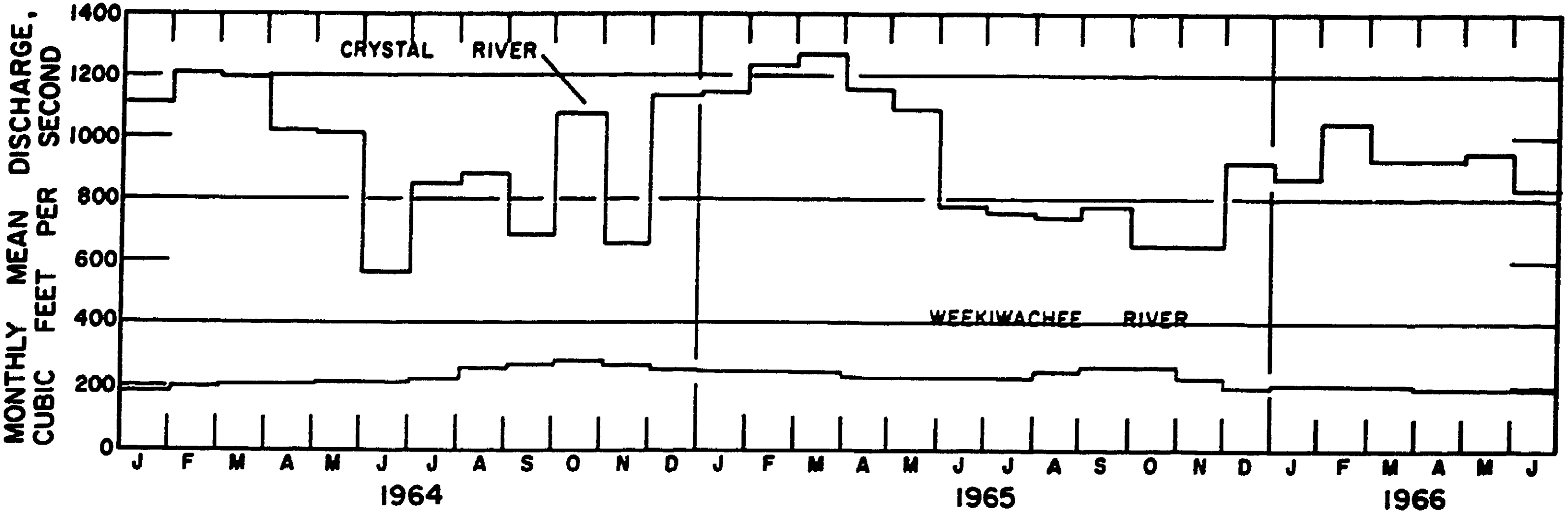


Figure 7. Monthly mean flow of Crystal River and Weekiwachee River, January 1964 - June 1966.

hydrologic conditions. The minimum measured flow, 65 mgd, occurred July 24, 1956, during a severe drought. The flow of Weekiwachee River is derived mainly from Weekiwachee Springs. However, the flow of Little Weekiwachee Springs and countless small springs in the channel along the entire length of the river also contribute to the river's flow. The flow of the river about 5 miles downstream from the main springs averaged about 170 mgd from January 1964 to June 1966.

The flow of Chassahowitzka Springs is measured together with the flow from several small springs in the headwaters and the springs in Crab Creek (a small tributary of Chassahowitzka River) at a point in Chassahowitzka River downstream from Crab Creek. The average combined flow for the January 1964-June 1966 period was 90 mgd. The maximum measured flow (127 mgd) occurred May 18, 1966 during median hydrologic conditions. The minimum measured flow (21 mgd) occurred July 8, 1964.

The flow of all the large springs, with the exception of Weekiwachee Springs, is affected by tidal fluctuations in the Gulf of Mexico. Weekiwachee Springs is unaffected because of the high discharge per unit of channel cross sectional area and the elevation of the springs which effectively blocks tidal movement upstream to the springs.

Variation in specific conductance and discharge caused by tidal flow, as measured at the gaging station on Crystal River, is shown in figure 8. Specific conductance measurement is a convenient and rapid way to determine the approximate amount of dissolved solids in water. The greater the specific conductance, the more dissolved solids (high mineral content). Commonly, the amount of dissolved solids(in milligrams per liter) is about 65 percent of the specific conductance (in micromhos). The mineral content of water in Crystal River is due mostly to sodium chloride from sea water; therefore, high conductance indicates high concentration of sodium chloride. The high values of conductance on September 10, 1964, resulted from wind blown tides caused by Hurricane Dora. The variation in mineral content of water from Homosassa and Chassahowitzka springs caused by salt water migrating upstream on flood tides are about the same as at Crystal River. However, the mineral content of water from Weekiwachee Springs maintains an almost constant value of about 150 mg/l (milligrams per liter), or conductance of about 230 micromhos.

The flows of Crystal River and Homosassa, Weekiwachee, and Chassahowitzka springs vary as shown by the correlation in figure 9. The maximum rate of water movement and total volume of water discharge by these spring-fed rivers is high

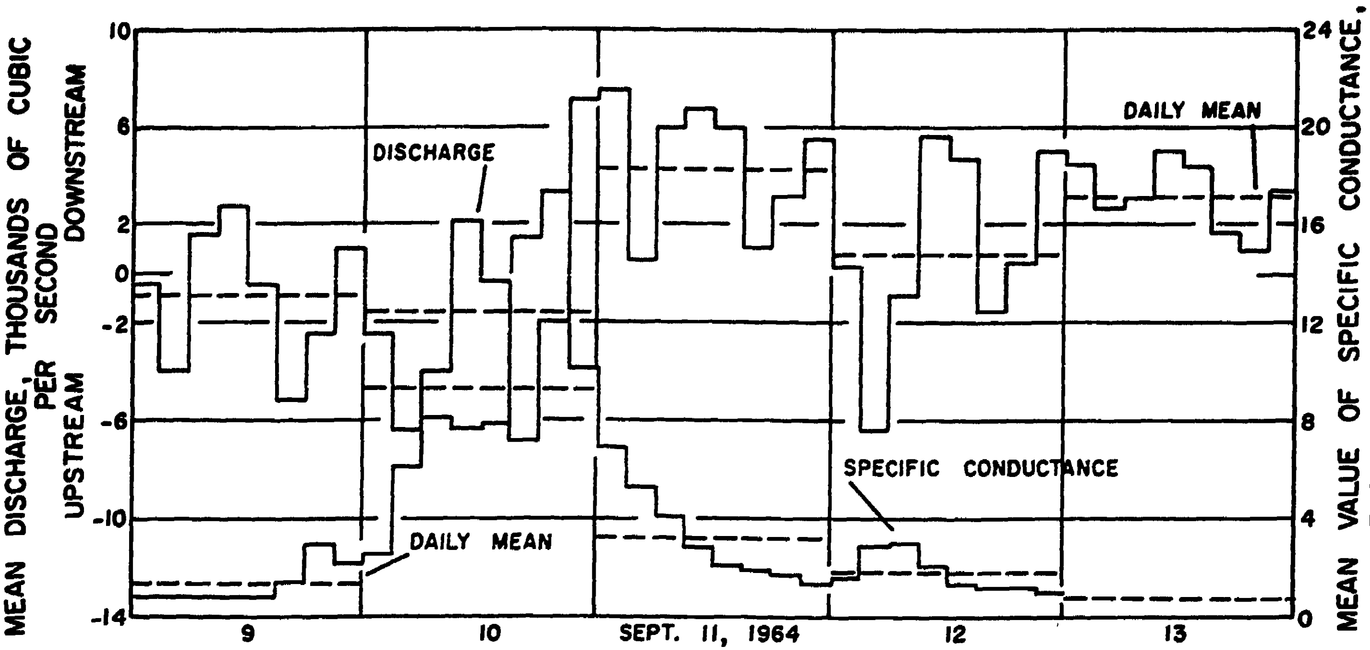


Figure 8. Variation in specific conductance and discharge for three-hour intervals at Crystal River near Crystal River, Florida, Septmeber 9-13. 1964.

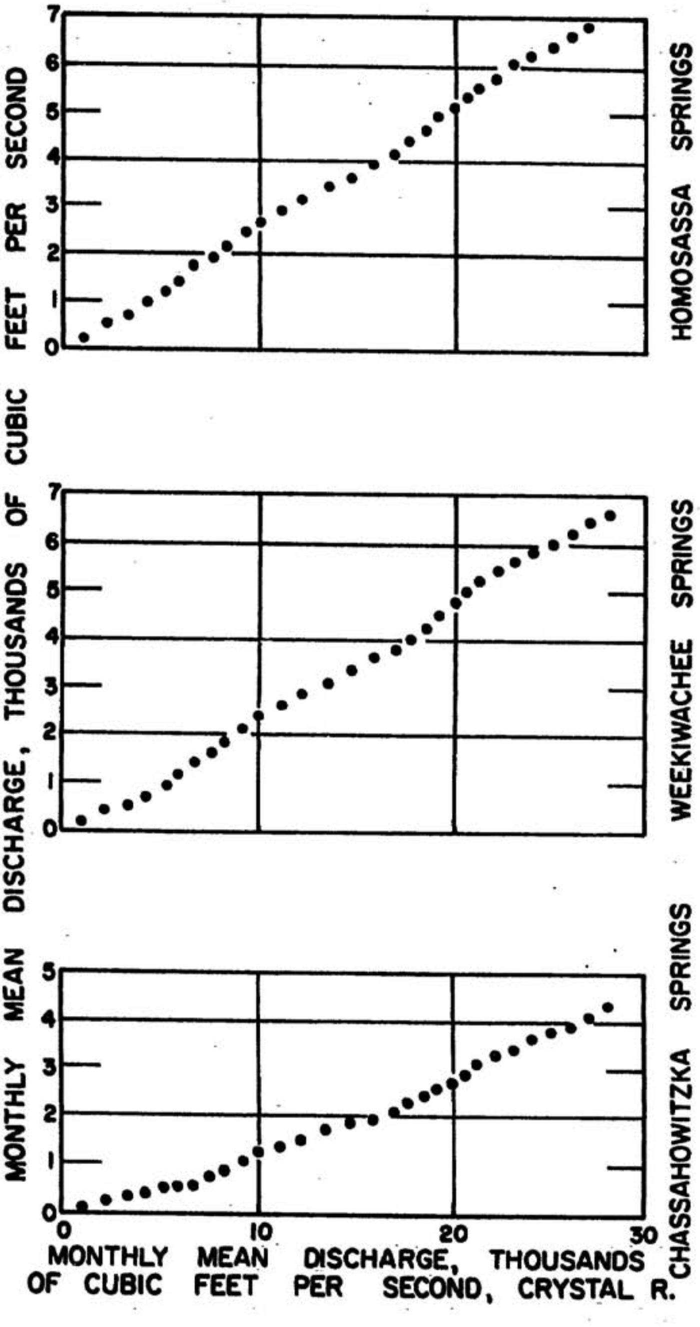


Figure 9. Correlation of discharge of Homosassa, Weekiwachee, and Chassahowitzka Springs with Crystal River.

during tidal cycles. At Crystal River during normal tidal cycles the maximum positive (downstream) and negative (upstream) flow is about 4,000 cfs. During Hurricane Dora in September, 1964, the maximum instantaneous negative flow was estimated to be more than 10,000 cfs--largely caused by wind-driven tides.

WHERE DOES THE WATER COME FROM?

The vast flow of the springs is derived from rain--about 55 inches annually--that falls on about 2,300 square miles east of the springs, figure 10. About 38 inches of the rain returns to the atmosphere annually by the evapotranspiration--evaporation from water, soil, and plant surfaces and by transpiration by vegetation.

Very little water (as streamflow) leaves the area immediately west of the western topographically defined drainage divide of the Withlacoochee River (fig. 10). This 570 square mile area is almost devoid of surface drainage. Surface runoff (runoff per square mile of topographic drainage area) from the Withlacoochee River is low in comparison to adjacent stream basins. Much of the rain that falls on the area enters the Floridan (limestone) aquifer either by percolation through the soil zone into the limestone or by drainage through sinkholes, moves generally westward toward the large coastal springs, and reappears as springflow and seepage into the coastal rivers.

The Floridan aquifer, which is composed of more than 1,000 feet of limestone and dolomite in the "Sun Coast" area, is one of the most productive aquifers in the United States and probably the world. The aquifer transmits water beneath the area to the springs near the coast and is the source of virtually all water used locally. Figure 11 shows the piezometric surface of the Floridan aquifer in the coastal springs area. The contour lines represent the height above mean sea level to which water would rise in tightly cased wells that penetrate this aquifer, and the arrows indicate the general direction of flow through the aquifer.

The top of the aquifer is about 60 to 80 feet below land surface in the central part of the state but is at or near land surface close to the coast. The gentle slope of the limestone aquifer, its high calcium carbonate content and natural porosity, the small amount of surface runoff, the dense vegetation and humid climate, and active circulation of ground water create an environment in this area of Florida that is most favorable for solution of the limestone. The results of limestone solution is cavity formation and the development of

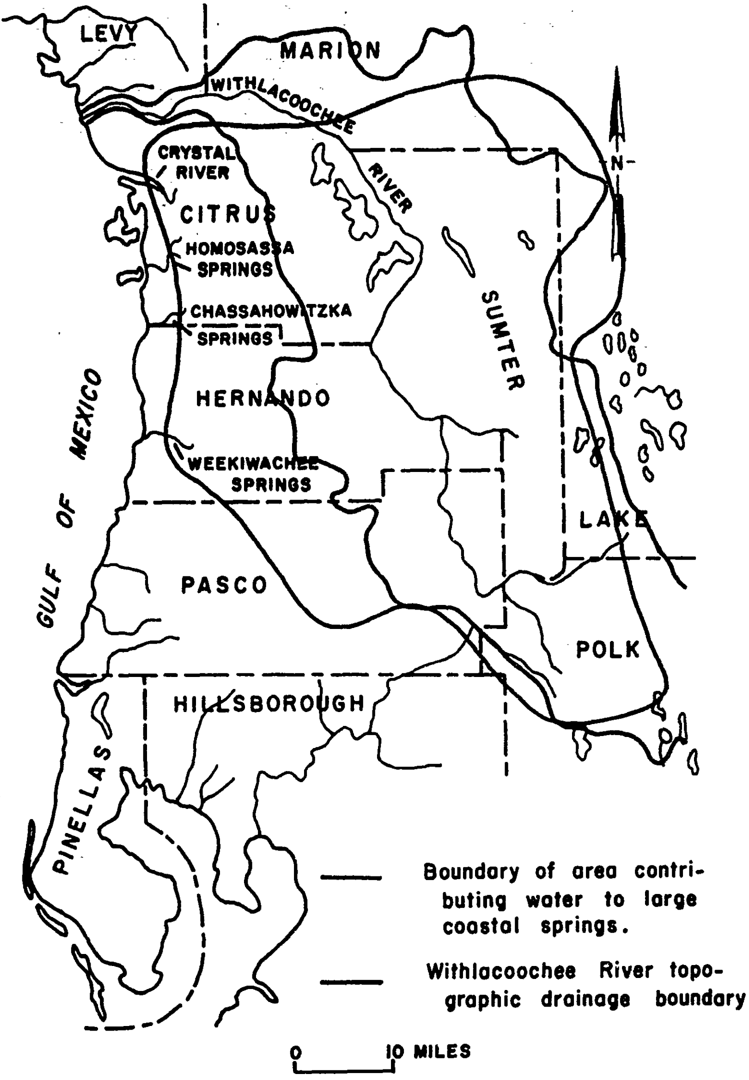


Figure 10. Water contributing area for large coastal springs and topographic drainage divide of the Withlacoochee River.

high permeability. The springs orifices are elongated vertical solution cavities that intersect an especially permeable part of the aquifer at depth. Such orifices provide avenues for water under pressure in the aquifer to escape from the aquifer thus creating the big springs.

WHY ARE SOME SPRINGS FRESH AND SOME SALTY?

Some springs in the coastal area discharge fresh water, some salty water, and some at times discharge fresh or at other times salty water. The mineral content of water from the main

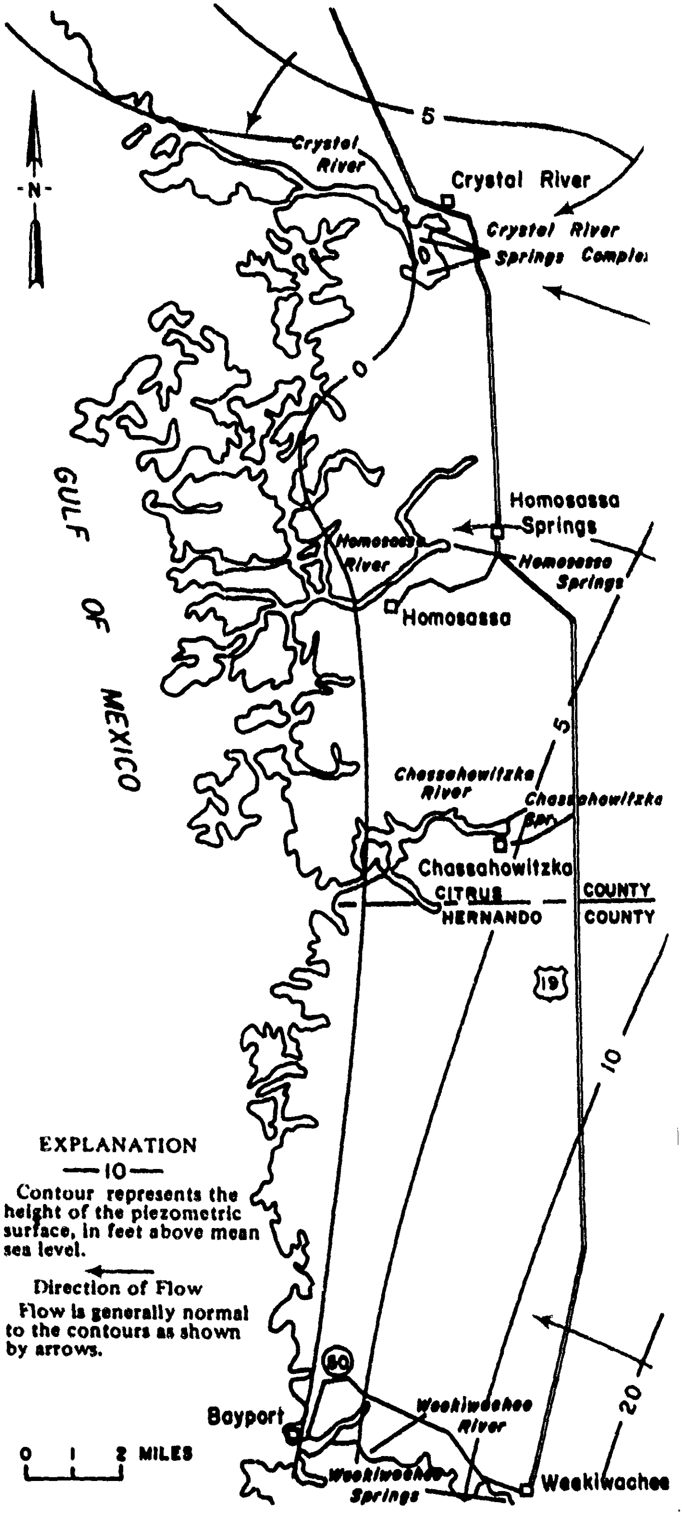
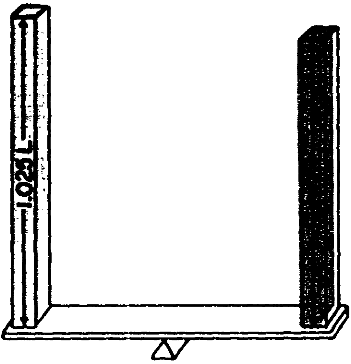


Figure 11. Piezometric surface of the Floridan aquifer, Sun Coast area, August-September 1965.

springs at the head of Crystal River varied from about 200 to 1,100 mg/l during the January 1964-June 1966 period, and mineral content of water from the main springs at the head of Chassahowitzka River varied from about 300 to 2,000 mg/l during the August 1964-June 1966 period. Sodium chloride, common table salt, was the principal dissolved mineral constituent in the more mineralized water. The reason for the variation in mineral content is complex and only partly understood; it is probably controlled by a fluctuation of the dynamic balance between the denser sea water and the level of the fresh water above sea level and the dynamics imparted by the diurnal tidal cycle. Because the density of sea water is greater than that of fresh water, a 41-foot column of fresh water is theoretically required to balance 40 feet of sea water, figure 12. Thus, in theory, in a coastal aquifer each foot of fresh water above sea level would indicate 40 feet of fresh water below sea level. In the coastal area, the balance between the two heads constantly changes: whenever fresh-water levels at the coast decline to or near sea level, sea water moves inland; if fresh-water levels are at or below sea level, salt water moves up coastal streams and into the aquifer.

The zone in the aquifer between fresh and salt water that exists because of this dynamic balance is known as the fresh-salt water interface. Because of changes in hydrostatic pressure in the aquifer, this interface can move both horizontally and vertically within an aquifer. The interface is normally not sharp but is a transitional zone of some thickness. In the Miami, Florida area where it has been extensively studied in great detail, Parker (1955, p. 620) reports that the zone is about 60 feet thick.

Figure 13 illustrates how movement of this interface could cause variation in quality of the water discharging from the springs. During periods of high fresh water levels in the aquifer (wet season) the fresh-salt-water interface is below the spring vent as shown in figure 13-A, and discharge from the spring is fresh. During low fresh water levels (dry season) the depth to the interface decreases--the interface zone may be located within the spring vent as shown in figure 13-B. Under this condition, discharge from the spring would be salty to some degree. The interface could remain relatively stationary for a year or more, could change seasonally as illustrated, or could change as a result of ground-water withdrawals in an area. Depending on the location of the fresh-salt-water interface, the quality of the spring flow could be changing seasonally or as physical changes are imposed on the aquifer system.

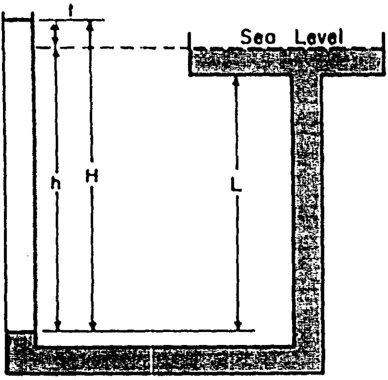


The basic principle is that of balanced weights.

1 cubic foot of sea water weighs 64.06 lbs.

1 cubic foot of fresh water weighs 62.5 lbs.

Thus salt water is $\frac{64.06}{62.5}$ or 1.025 times as heavy as fresh water and a column of salt water L feet in height will balance a column of fresh water (1.025) L feet in height.



Connect the salt and fresh water columns shown in A by a connecting tube and add a reservoir to the top of the salt water column. The result is shown above. Then as explained in A,

$$H = 1.025\ L$$

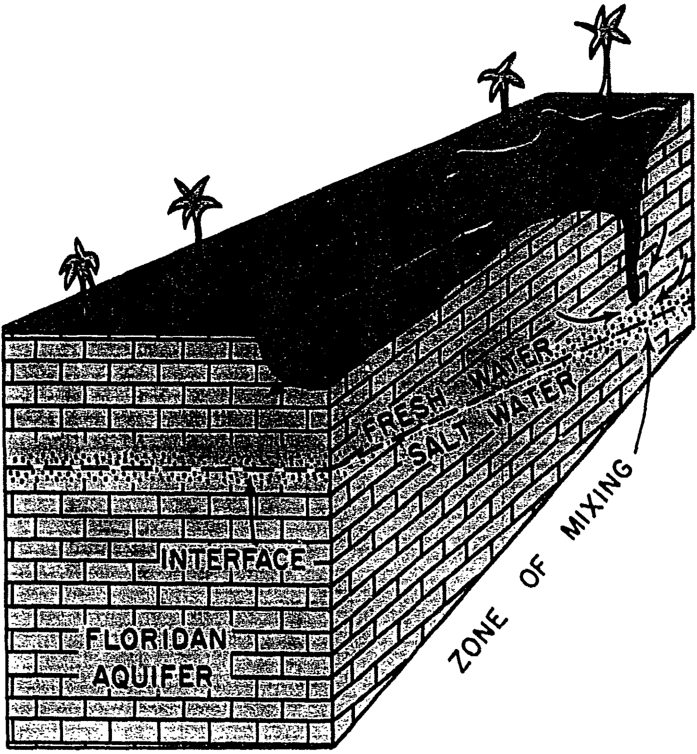
$$\text{or } h + t = 1.025\ L = 1.025\ h$$

$$h = \frac{t}{(1.025 - 1)} = \frac{t}{.025}$$

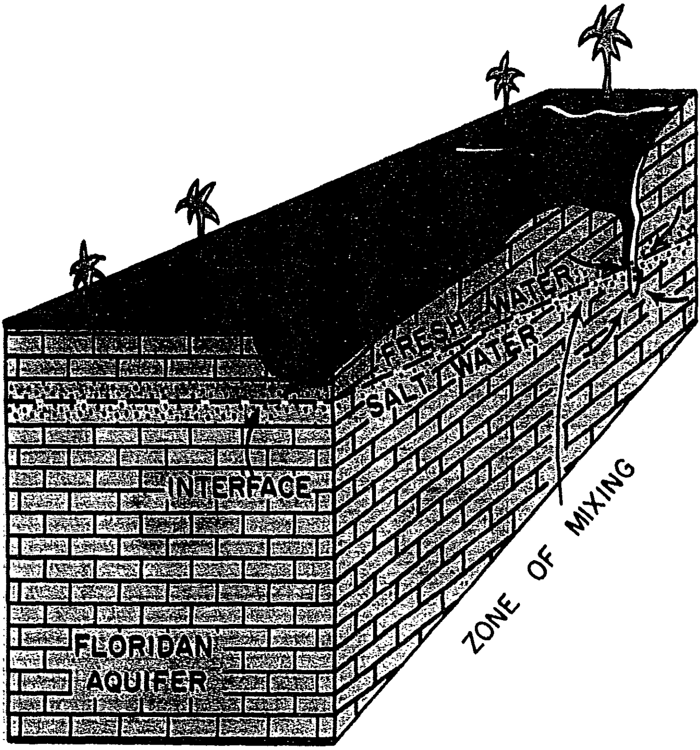
When t = 1, h = 40.

Hence for every foot of fresh water above sea level there are 40 feet of fresh water below sea level.

Figure 12. The hydrostatic relationship between salt and fresh water, known as the Ghyben-Herzberg Principle (Black, A.P., Brown, Eugene, and Pearce, J.M., 1953, "Salt water intrusion in Florida, 1953": Fla. State Board of Conservation water survey and research paper no. 9).



A. High fresh-water levels.



B. Low fresh-water levels.

Figure 13. Movement of fresh-salt water contact at a spring vent.

Records from an observation well in the Floridan aquifer near the headwaters of Crystal River show that the water level in the aquifer fluctuates with the tide. The water level remains generally about one-half to one foot above mean sea level, figure 14. The level of fresh water is sufficient to depress the salt water at this point about 20 to 40 feet below mean sea level. The rivers and springs tend to be fresher upstream from the gulf, where water levels in the aquifer are generally higher. Rivers and springs also tend to be fresher during the summer and early fall when water levels in the aquifer are highest. When the fresh-water level declines the salt water moves inland during high tide and may mix with the fresh water flowing upward toward the spring openings.

The Crystal, Homosassa and Chassahowitzka spring systems are much more subject to variations in chemical quality of water between extremes of fresh and salty than Weekiwachee Springs. During the 1964-66 study period, the measured range of dissolved solids in Crystal River was 300 to 15,000 mg/l; in Homosassa River was 550 to 9,100 mg/l; in Chassahowitzka River was 300 to 2,000 mg/l; and Weekiwachee Springs was 125 to 150 mg/l. The wider range in variation in chemical quality occurs because the water level at the former springs is about one foot above msl whereas the level at the main springs at Weekiwachee is about 10 to 12 feet above mean sea level.

Any set of conditions, either natural or influenced by man, that markedly decreases the level of the fresh water, decreases the fresh water discharge and permits sea water to move further inland. This can, in turn, cause increased salinity in water discharging from the low-lying springs. For example, excessive pumping from the fresh-water aquifer in the area adjacent to the springs or extensive drainage by canals, or deepening of natural river channels in and adjacent to springs may permit reduction in the level of the fresh water and allow more frequent discharge of salt water or saltier water from the springs, figure 15.

Various state, county, water-management districts, and citizen groups are aware of the fresh-salt water balance in the area of the springs. Suggestions and proposals are under study and data are being collected for realistic water-management programs to safeguard the unique spring system for use by future generations.

EXTENT OF KNOWLEDGE ON THE SPRINGS

Completed elements of hydrologic investigations in the area include: (1) extensive field reconnaissance to locate all springs and points of potential spring flow under changing hydrologic

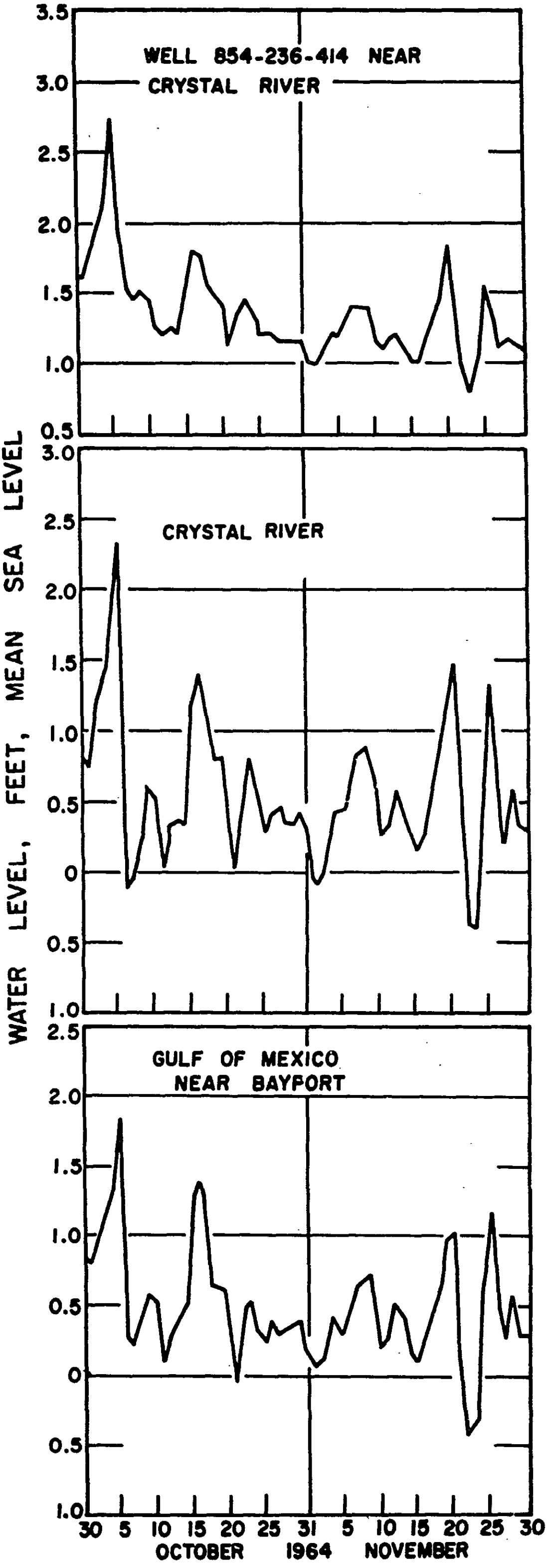
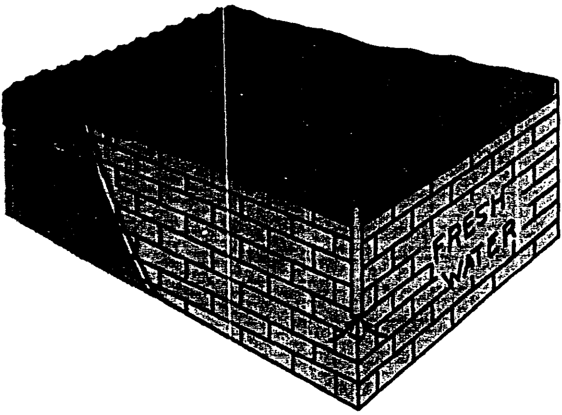
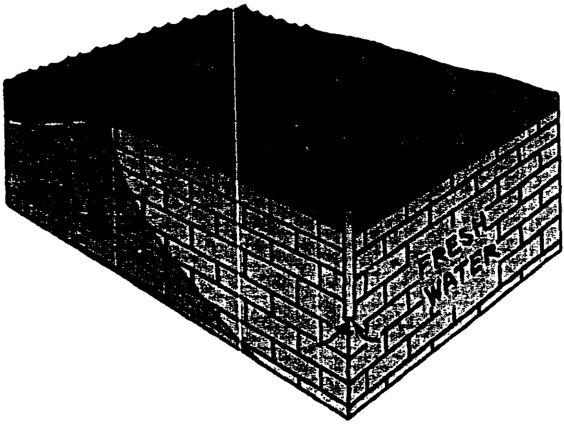


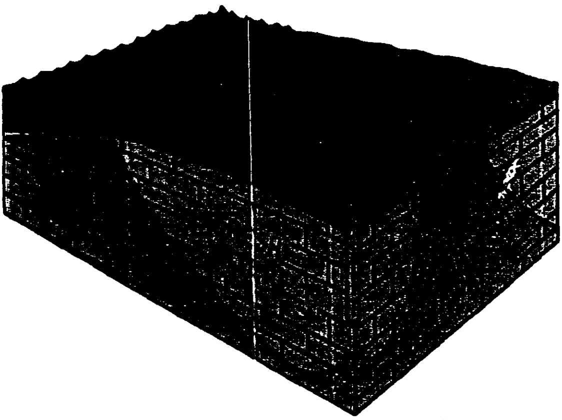
Figure 14. Comparison of water levels in the Floridan aquifer, Crystal River and the Gulf of Mexico.



Fresh-salt water balance in a coastal area under natural conditions altered slightly by ground-water withdrawal.



Inland migration of fresh-salt water interface as a result of construction of an uncontrolled tidal canal which allows increased discharge of fresh water from the aquifer and inland movement of salt water through the canal.



Fresh-salt water interface migrates farther inland as ground water withdrawals increase and canal is extended. Can cause saline contamination of a previously fresh supply.

Figure 15. Results of alerting the fresh-salt balance in the aquifer in a coastal area.

conditions(2) detailed analysis of the amount and variation of the salinity of water from wells in the Crystal River area; (3) determination of the elevation of the piezometric surface in the Floridan aquifer in the coastal area and approximate location of the line where the ground-water level equals sea level; (4) the continuous monitoring of the flow of Crystal River; and (5) an extensive program of recording the discharge, water level, and chemical quality of water from streams, lakes, springs, sinkholes, and wells (part of the investigation of the hydrology of the Middle Gulf area cooperatively planned and financed by the Southwest Florida Water Management District and the Bureau of Geology, Florida Department of Natural Resources, and the U.S. Geological Survey).

Continuing hydrologic investigations in the area include: (1) an expanded hydrologic-records program to determine discharge, water level and chemical quality of water from streams, lakes, springs, sinkholes, and wells, to monitor changes in the hydrologic system brought about by accelerated land development; (2) test drilling to determine the position of the fresh-salt water interface in the aquifer and to obtain basic geologic and other hydrologic data; and (3) studies to determine the minimum level of fresh water required in the area to prevent salt-water intrusion of the aquifer and saline contamination of water supplies such as those of the cities of Crystal River and Homosassa.

Additional hydrologic investigations needed in the area include: (1) more detailed definition of the fresh-salt water interface in the aquifer, the extent of its movement from year to year, and its relation to natural events and to developmental measures. Eventually key wells will be equipped with electronic instruments which will continuously measure the salinity and water level within the aquifer; and (2) definition of the areas of major local recharge. Although the recharge area for the springs includes a large area east of the springs, some of the water that emerges from the springs is probably recharged locally. Local recharge areas need to be defined so that the spring flow will not be endangered by improper use of the land.

The area surrounding the springs is attractive for land development. However, caution should be used in land development, so that damage to the springs, the hydrologic system feeding them, and the potable water supplies in the aquifer can be avoided or minimized.

WHERE CAN MORE INFORMATION BE OBTAINED?

Additional information on the hydrology and geology of Citrus and Hernando counties and of coastal areas in general is contained in the following reports:

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