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GROUND WATER IN FLORIDA

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AND

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TALLAHASSEE, FLORIDA

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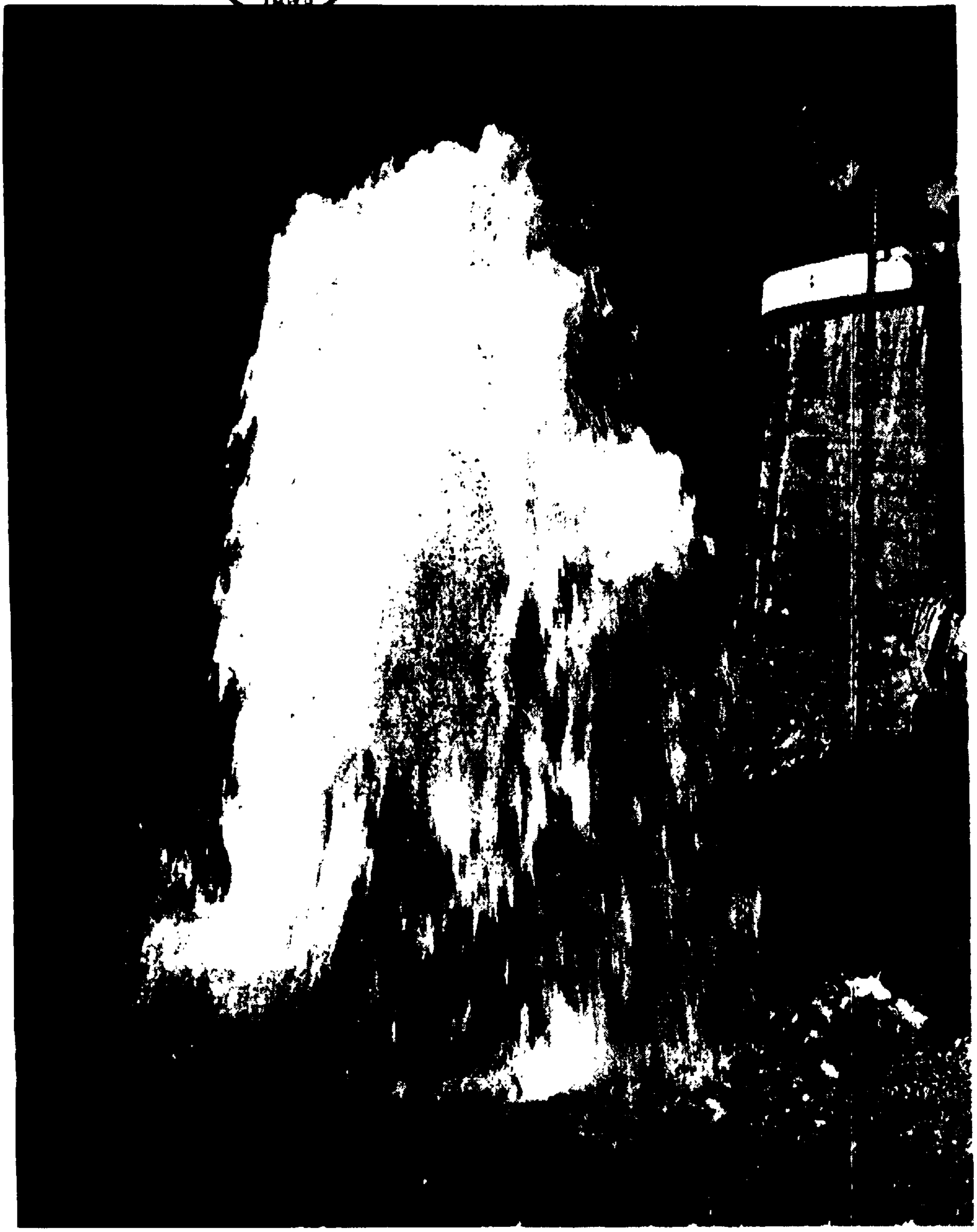


Well Flowing 6,500 Gallons Per Minute
Near Yukon, Duval County, Fla.

C O N T E N T S

I L L U S T R A T I O N S

GROUND WATER IN FLORIDA

By: H. H. Cooper, Jr., and V. T. Stringfield

INTRODUCTION

Ground water in Florida is the principal source of supply for industrial, municipal, agricultural, and domestic uses. During the last half century large developments of ground water have been made, and new developments are currently being added. However, although problems of supply, some of them critical, have arisen in certain areas, vast quantities of ground water are yet available for development over a major part of the State. It is quite conceivable that the availability of large developed water resources in Florida, in contrast with the shortages of supply in many other parts of the country, may play a dominant role in the agricultural and industrial growth of the State.

Early recognition of the potential economic importance of Florida's ground-water resources is indicated by the fact that the first report of the Florida Geological Survey (1), published in 1908, was a report on the ground water of central Florida. In the following years, several other contributions (2, 3, 4, 5) to the ground-water literature were made by the Florida Geological Survey and the U. S. Geological Survey. By 1930, problems of development and conservation of the ground-water resources pointed to the need for a continuing, systematic program of investigations, and, accordingly, the State and Federal Geological Surveys began at that time the cooperative investigations that are now in progress.

OCCURRENCE OF GROUND WATER

The ground water in Florida may be divided into two classes: (1) that generally known as the artesian water, which occurs in the extensive limestone aquifer of Eocene, Oligocene, and Miocene age that underlies almost all of Florida, the coastal area of Georgia, and the southernmost parts of South Carolina and Alabama; and (2) that occurring in several younger aquifers of relatively small areal extent, which consist chiefly of limestone, coquina, sand, and gravel in formations that range in age from Miocene to Recent.

The extensive artesian limestone aquifer is the principal source of water, except in Escambia and Santa Rosa Counties, where it is absent, and in that area in which the artesian water is too salty for most uses (fig. 1). The area in which the artesian water is generally salty includes a band about 20 miles wide along the east coast from St. Augustine south and practically all that part of Florida south of Lake Okeechobee. At a few places within this area, however, the artesian water is sufficiently fresh to be suitable for municipal use.

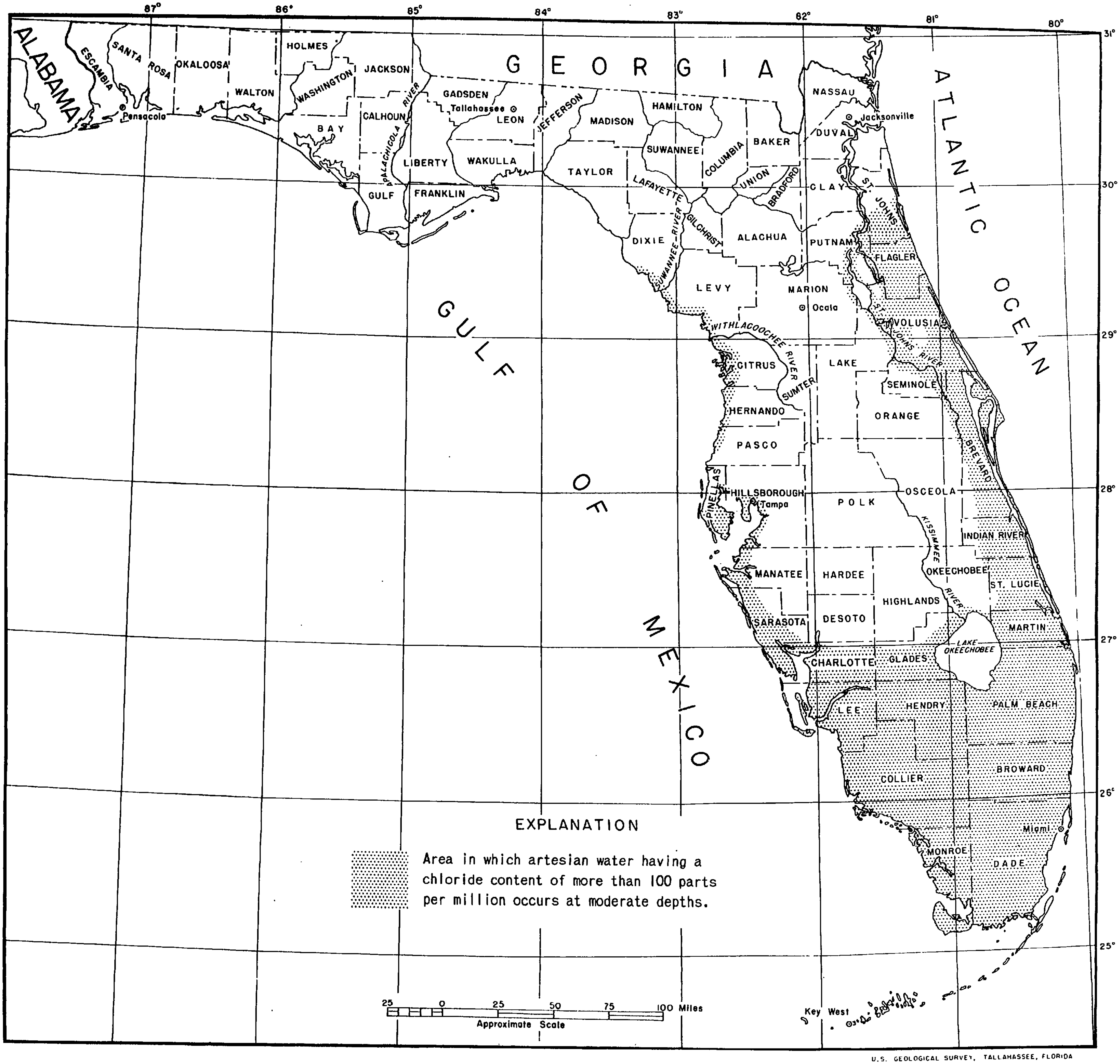


Figure 1. Map of Florida showing areas in which artesian water having a chloride content of more than 100 parts per million occurs at moderate depth.

Among the public supplies derived from the artesian water within this area are those of Daytona Beach, DeLand, and Everglades City.

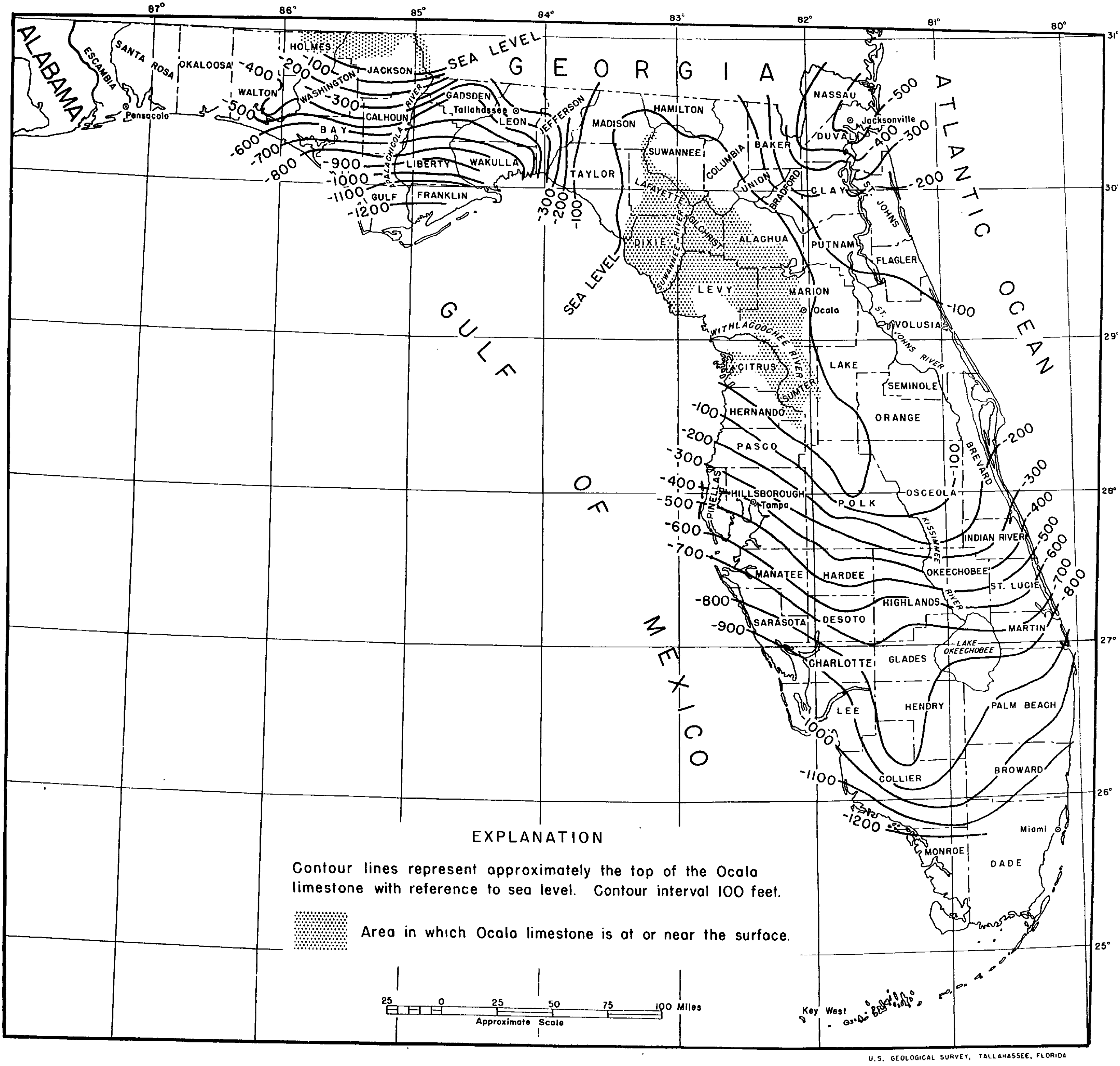
The artesian aquifer consists of the Ocala limestone and some of the underlying limestones of Eocene age, and, in some parts of the State, of overlying limestones of Oligocene and Miocene age. The geologic structure of the formations that comprise the aquifer is indicated in a general way by the top of the Ocala limestone. The Ocala is at or near the land surface in an area centered around Levy County, in the northwestern part of the peninsula, and in the northern parts of Holmes and Jackson Counties in western Florida. (fig. 2). It dips southward to more than 1,200 feet below sea level in southern and western Florida.

The artesian aquifer is the source of most of the large springs, such as Silver Springs, whose discharge, according to measurements by the U. S. Geological Survey, has ranged from 419 to 756 million gallons a day. In part of Seminole County alone, the aquifer yields water to more than 1,000 flowing wells used for irrigation. The natural flow of some of the individual wells that penetrate the aquifer is large. One well drilled at Jacksonville in 1942 yielded a flow of 6,500 gallons a minute, or about 9.5 million gallons a day. Some of the pumped wells yield slightly more water; one well in Polk County is reported to have yielded 7,500 gallons a minute -- about 10.5 million gallons a day -- with a drawdown of only 9 feet. Wells that produce such large quantities of water are generally those which penetrate solution channels in the limestone. Drillers report that in most parts of the State caverns are penetrated by some of the wells that end in limestone. Some of the caverns in the central part of the State are reported to have a height of as much as 20 feet.

The younger formations that overlie the artesian aquifer are the principal source of water in southern Florida and along the east coast from St. Augustine south, where the artesian water is generally salty (fig. 1), and in Escambia and Santa Rosa Counties, where the artesian aquifer is absent. In comparison with the artesian aquifer, most of these shallow formations have relatively small capacities to yield water to wells. Among them, however, is the Tamiami formation of Pliocene age, one of the most productive aquifers in the world, and the source of supply for Miami and other cities in Dade County. Ground water in the sand and gravel formations is generally much softer than that in the artesian aquifer. Water from a sand about 200 feet deep at Pensacola, for example, has only 41 parts per million of dissolved solids and a hardness of only 12 parts per million. The artesian water is relatively free from iron, but some of the shallow ground water has as much as several parts per million.

SOURCE AND MOVEMENT OF GROUND WATER

Most of the shallow aquifers of the State have relatively small areas of extent and are recharged more or less locally, but the artesian aquifer underlies almost all of Florida and extends into three other States. Much of the water that enters the artesian aquifer in



U.S. GEOLOGICAL SURVEY, TALLAHASSEE, FLORIDA

FIGURE 2. Structure contour map of Florida showing the top of the Ocala limestone. (After David B. Ericson)

an area of recharge travels more than 50 miles before it escapes through wells or springs. General recognition of the fact that the artesian water travels over long distances may be partly responsible for the false notion that the artesian water of Florida is derived from very remote places, such as the Appalachian Mountains, the Great Lakes, or the Rocky Mountains. The fact is, of course, that most of the ground water in the Florida peninsula is derived from rain that falls within the State, although the ground water in northern and western Florida is derived partly from local rainfall and partly from recharge in southern Georgia and Alabama.

Much of our information on the source and movement of water in the artesian aquifer is revealed through a map of the piezometric surface, which represents by contour lines the approximate height to which the artesian water will rise in wells with reference to sea level. Such a map is compiled by measuring the depth to water -- or, in areas of artesian flow, the pressure head -- with reference to selected measuring points in many wells throughout the State, and by establishing the altitudes of the measuring points by instrumental leveling. The control points so obtained are used in plotting the contour lines that represent the piezometric surface. Generally, recharge of the artesian system occurs where the piezometric surface is high, and discharge occurs where it is low. A map prepared (6, 7, 8) as a part of the cooperative ground-water investigations of the Florida Geological Survey and the U. S. Geological Survey represents the piezometric surface of the artesian water throughout most of Florida and the coastal area of Georgia (fig. 3). This map probably represents the piezometric surface over a larger area than any other yet prepared, and it is notable in that it indicates generally the areas of recharge and discharge and the direction of movement of the artesian water over hundreds of miles. Furthermore, it has revealed areas of recharge that were not recognized before its preparation. Among these is the large area of recharge centered around Polk County, from which most of the artesian water in central and southern Florida is derived.

Over roughly a third of the State, the piezometric surface is higher than the land surface, and wells will flow (fig. 4). However over a large part of the area of artesian flow the artesian water is relatively highly mineralized.

CONSUMPTION OF GROUND WATER

At the turn of the century the development of the artesian aquifer in Florida had barely begun. The history of the development indicates that the first successful artesian well in Florida was drilled at St. Augustine during the period 1880 to 1882. Shortly afterward, the first of the artesian wells for the Jacksonville municipal supply was drilled.

The average daily consumption of ground water in Florida today is estimated to be about 500 million gallons, of which about 20 percent is consumed by supplies used for irrigation. The consump-

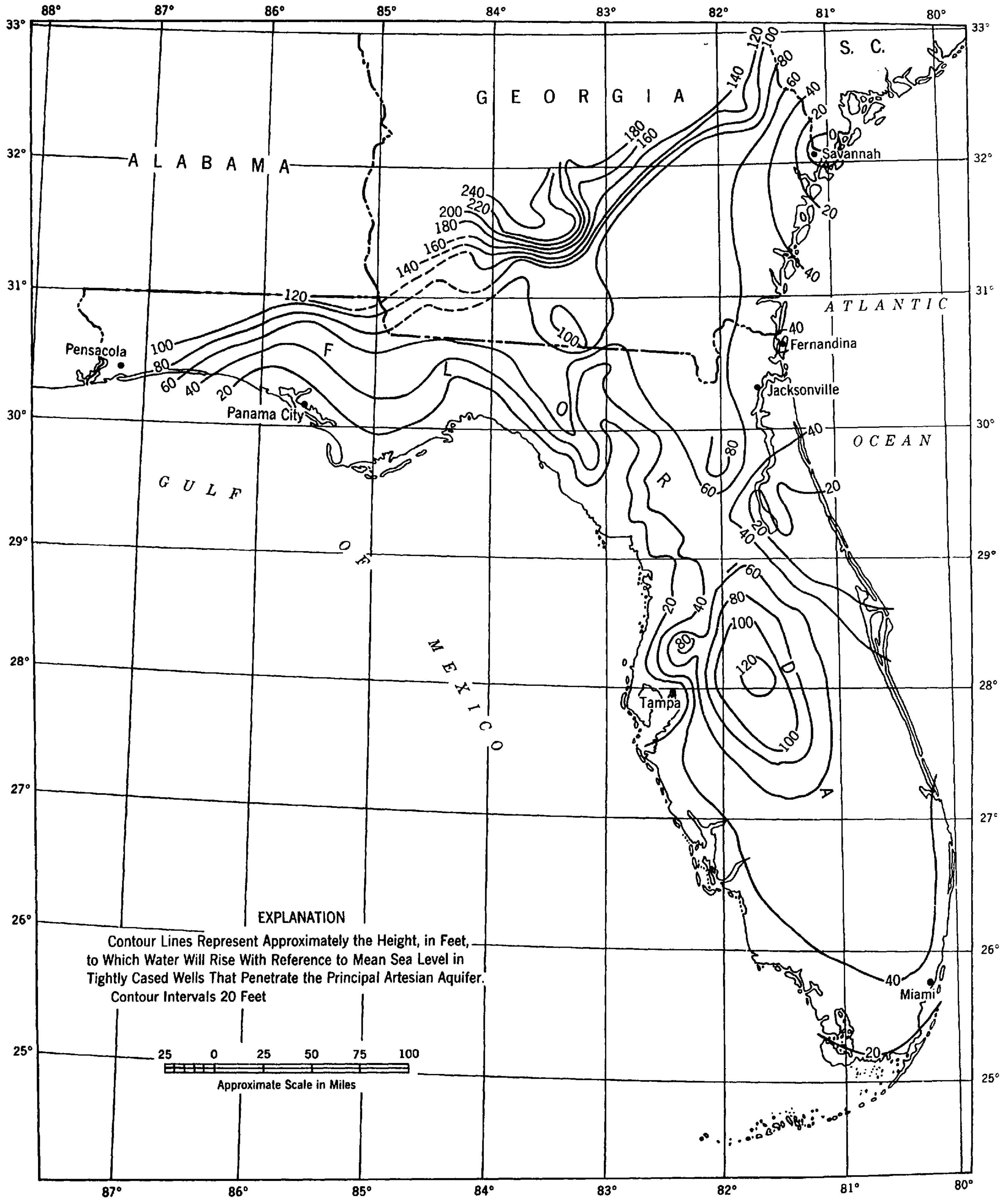


FIGURE 3. Map showing the piezometric surface in Florida and southeastern Georgia.

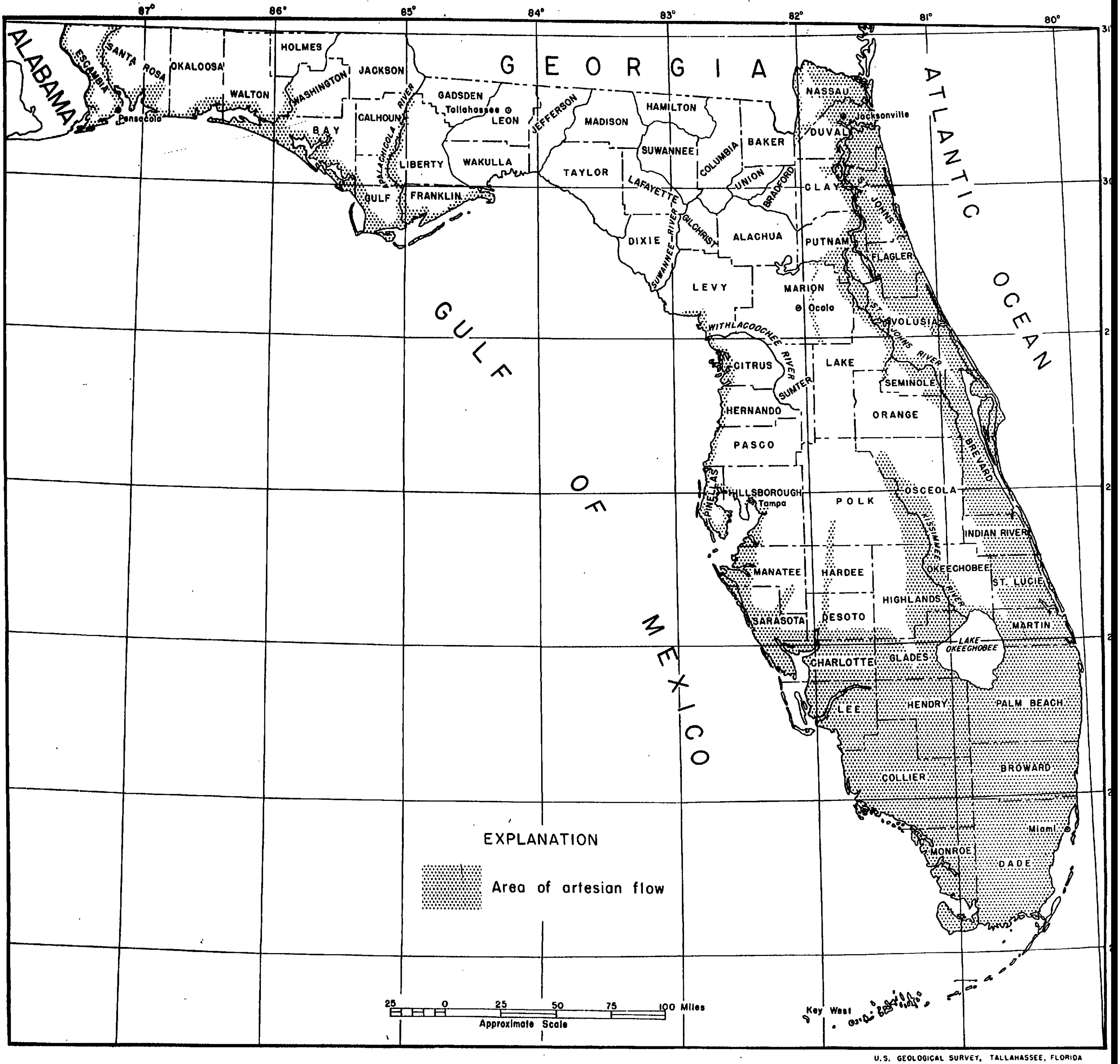


FIGURE 4. Map showing areas of artesian flow.

tion by the four principal types of supplies is as follows:

	(Gallons) a day
Public supplies serving 100 or more people	160,000,000
Industrial supplies	200,000,000
Agricultural supplies	100,000,000
Domestic supplies	40,000,000
Total	500,000,000

According to the U. S. Bureau of the Census, 4,631 flowing wells and 1,686 pumped wells were being used for irrigation in 1940. Many additional wells have, of course, been drilled during the 10 years since this census was made.

According to data compiled by the Florida State Board of Health, of about 357 public water supplies in Florida that serve 100 or more people, about 325 obtain their water entirely from wells. The public supplies serve a total population of 1,980,000, of which 79 percent is served by supplies obtained exclusively from wells, and an additional 6 percent is served by supplies that are obtained partly from surface sources and partly from ground water. Practically all the nonpublic domestic supplies in Florida are obtained from wells.

The consumption of 500 million gallons of water a day is, of course, a heavy draft on the ground-water resources, but this draft should not be a cause for concern in regard to the State as a whole when it is realized that the ground-water reservoirs are naturally discharging many hundreds of millions of gallons of water a day, much of which can be salvaged and used whenever it is needed. The tremendous discharges of Florida's large limestone springs, which rank among the largest in the world, forcibly demonstrate the large capacity of the ground-water reservoirs. The average flow of Silver Springs alone is equal to the estimated total consumption of ground water in the State.

PROBLEMS OF DEVELOPMENT AND CONSERVATION

However plentiful the undeveloped supply of ground water in the State as a whole may be, one cannot escape the fact that in some areas in Florida the demand for ground water is approaching the capacity of the aquifers to yield water perennially. The lack of an adequate quantity of water of suitable quality has become especially acute in a few coastal areas where overdevelopment or artificial drainage has permitted sea water to enter the aquifers and ruin some of the well supplies. The availability of water in those areas in which the ground water is salty from natural causes is likewise a critical problem (fig. 1). The problem of salt-water encroachment should not be confused with the problem of development where ground water is salty as a result of natural processes that occurred long before man's time. The first is a problem of avoiding the overdevelopment or the overdrainage that would permit the encroachment of sea water; the other is a problem of finding supplies of fresh water in areas where the water was naturally salty before the first wells were drilled.

It is well known that salt-water encroachment occurs as the result of a disturbance of a previously established balance between ground water and sea water (9). Prior to any artificial disturbance, ground water and sea water, occurring under conditions that have remained essentially unchanged for a long period of time, perhaps for many centuries, have assumed a state of dynamic balance. The occurrence of the two, under this balance, is determined by such factors as the relative densities of the two waters, the height of the water table (or piezometric surface) with reference to sea level, and the character and structure of the geologic formations. The balance between ground water and sea water is generally explained through an analogy with a hollow U-tube containing two liquids of different densities, the lighter liquid representing fresh water and the heavier, sea water. In such a tube the lighter liquid will stand higher than the heavier liquid, and the interface between the two will occur at a certain depth below the surface of the lighter liquid, this depth being determined by the relative densities and the difference in levels of the two liquids.

The density of sea water differs slightly from one place to another but is generally considered to be about 1,025. The density of fresh ground water is, for practical purposes, 1.000. Thus, the ratio of the two densities is 1.025:1.000, or 41:40. It is evident, therefore, that if fresh water and sea water were placed in a U-tube in such a way that they did not mix with one another, a column of the fresh water 41 units in height would balance a column of salt water 40 units in height. With respect to ground water in some coastal areas this relationship may be stated in another way: for each foot that the water table (or piezometric surface) stands above sea level there will be an additional 40 feet of fresh water below sea level. Thus we have the familiar criterion, commonly referred to as the Ghyben-Herzberg principle, by which, under proper conditions, one may judge the depth to salt water in a coastal area. In many areas, probably most, the relationship is applicable only if it is modified to allow for vitiating conditions. These conditions might include: (1) the presence of one or more strata of impervious material within or contiguous to the water-bearing formations, which would act to confine the two bodies of water; (2) the occurrence of a wide zone of diffusion between the fresh water and the salt water, caused by the agitation of tides and fluctuations of the water table; (3) a transient condition, possibly of many years duration, in which the original balance has been destroyed and a new balance is being established.

In Florida, the problem of salt-water encroachment is most pronounced in Dade and Pinellas Counties. The encroachment in Dade County has occurred principally as the result of artificial drainage to reclaim land for agriculture, pasture, and urban development (10). As a result many wells that once yielded fresh water will yield only brackish or salty water. Much of the encroachment came from a movement of sea water up the mouths of the drainage canals during droughts. The problem in the Dade County area has been improved considerably since the County undertook to control the levels of the canals several years ago.

The encroachment of salt water in Pinellas County has been caused by the withdrawal of ground water for irrigation and municipal supply (11). Over most of the southern part of the county and in some areas along the west coast wells are now yielding water having a chloride content of from 100 parts per million to several thousand parts per million. It appears probable that further migration of salt water in Pinellas County can be prevented only by limiting the withdrawal of ground water, although artificial recharge of the aquifer with water from surface streams might alleviate the problem to some extent.

Other places in the State at which salt-water encroachment has occurred include Fort Myers, Fort Pierce, Tampa, Daytona Beach, Panama City, and Pensacola (12). The encroachment at Tampa forced the abandonment of the old municipal supply wells about 25 years ago, and since that time Tampa has obtained its water supply from the Hillsborough River. However, the geologic and hydrologic conditions indicate that an adequate supply of ground water for Tampa could be obtained at a safe distance from Tampa Bay.

At many places along the east coast from St. Augustine south, and in southern Florida, where the artesian water is naturally salty, shallow aquifers that will yield water of good quality have been found, as in Dade County and at Fort Myers, Fort Pierce, and Titusville. At a few places, however, adequate supplies of fresh ground water have not yet been found, as at Cocoa, on the east coast. Apparently the fact that the artesian water is salty in some areas has not greatly limited its use for irrigation. Hundreds of flowing wells that yield water too salty for municipal and most industrial uses are being used for irrigation along the east and west coasts. Many yield water having a chloride content of more than 1,000 parts per million.

In the central part of the Florida peninsula from Lake Okeechobee north, and in northern and western Florida, large quantities of fresh ground water are available for future development. In these regions, where problems of salt water contamination are not likely to develop, the available supply within any given area probably will be limited only by the extent to which the water levels in wells may be lowered by pumping before economical pumping limits are exceeded. A lowering of water levels will, of course, inevitably accompany the withdrawal of water from an aquifer, the amount of lowering being more or less in proportion to the withdrawal. Thus, in a given area, as the withdrawal is increased water levels will be lowered further until eventually no further lowering is feasible. So far, this condition is being approached in only a few local areas, as at Fernandina, where the withdrawal of 30 million gallons a day by an industry has lowered the artesian head over a wide area (13). The withdrawal at Fernandina has caused the artesian head to decline 8 feet at Yulee, which is about 8 miles from the heavily pumped wells. Even so, it appears that additional quantities of water may be developed in the vicinity of Fernandina provided that new wells are dispersed over a sufficiently broad area.

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