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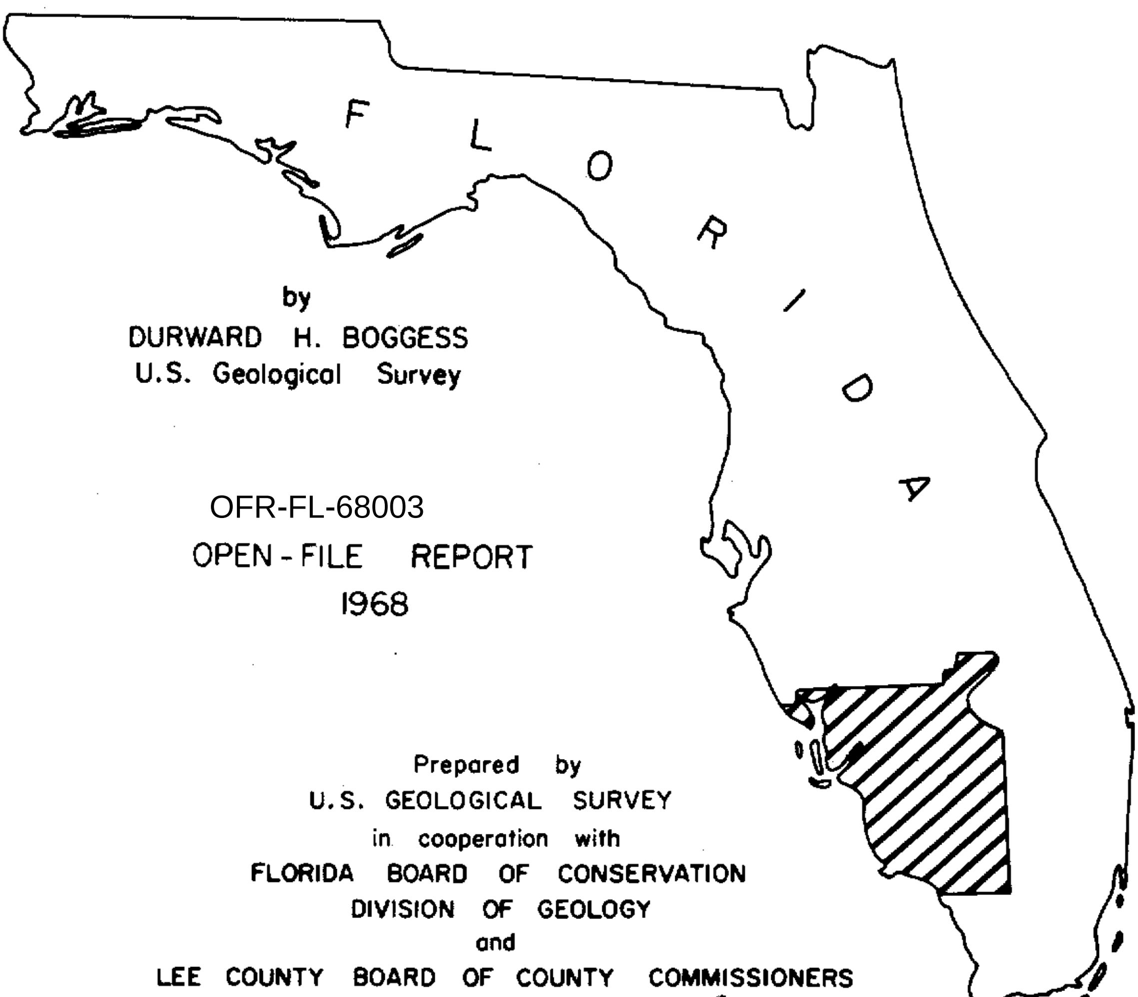
WATER-SUPPLY PROBLEMS in SOUTHWEST FLORIDA



by
DURWARD H. BOGGESS
U.S. Geological Survey

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OPEN-FILE REPORT
1968

Prepared by
U.S. GEOLOGICAL SURVEY
in cooperation with
FLORIDA BOARD OF CONSERVATION
DIVISION OF GEOLOGY
and
LEE COUNTY BOARD OF COUNTY COMMISSIONERS

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WATER-SUPPLY PROBLEMS IN SOUTHWEST FLORIDA

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INTRODUCTION

The rapid urbanization of many parts of southwest Florida has created numerous water-supply problems for both public and private water systems. The increased water demands by the expanding population, the increased water requirements for commercial and agricultural purposes, and the development of extensive drainage networks for the disposal of excess water have added to the magnitude and complexity of these problems.

This discussion is generally restricted to the water-supply problems that affect large segments of the urban and potential urban areas. Southwest Florida, as referred to herein, includes the five counties -- Charlotte, Collier, Glades, Hendry, and Lee -- adjacent to the lower west coast of Florida as shown in figure 1. Four of the counties -- Charlotte, Collier, Hendry, and Lee -- are among the 15 counties in Florida with the most rapid population increase for period 1960-64, as shown in Table 1 (Florida Development Commission, 1965)[1]. In the past 15 years, the population of this 5-county area has increased by more than 300 percent. The more densely populated areas are along the coastal margins and tidal waterways.

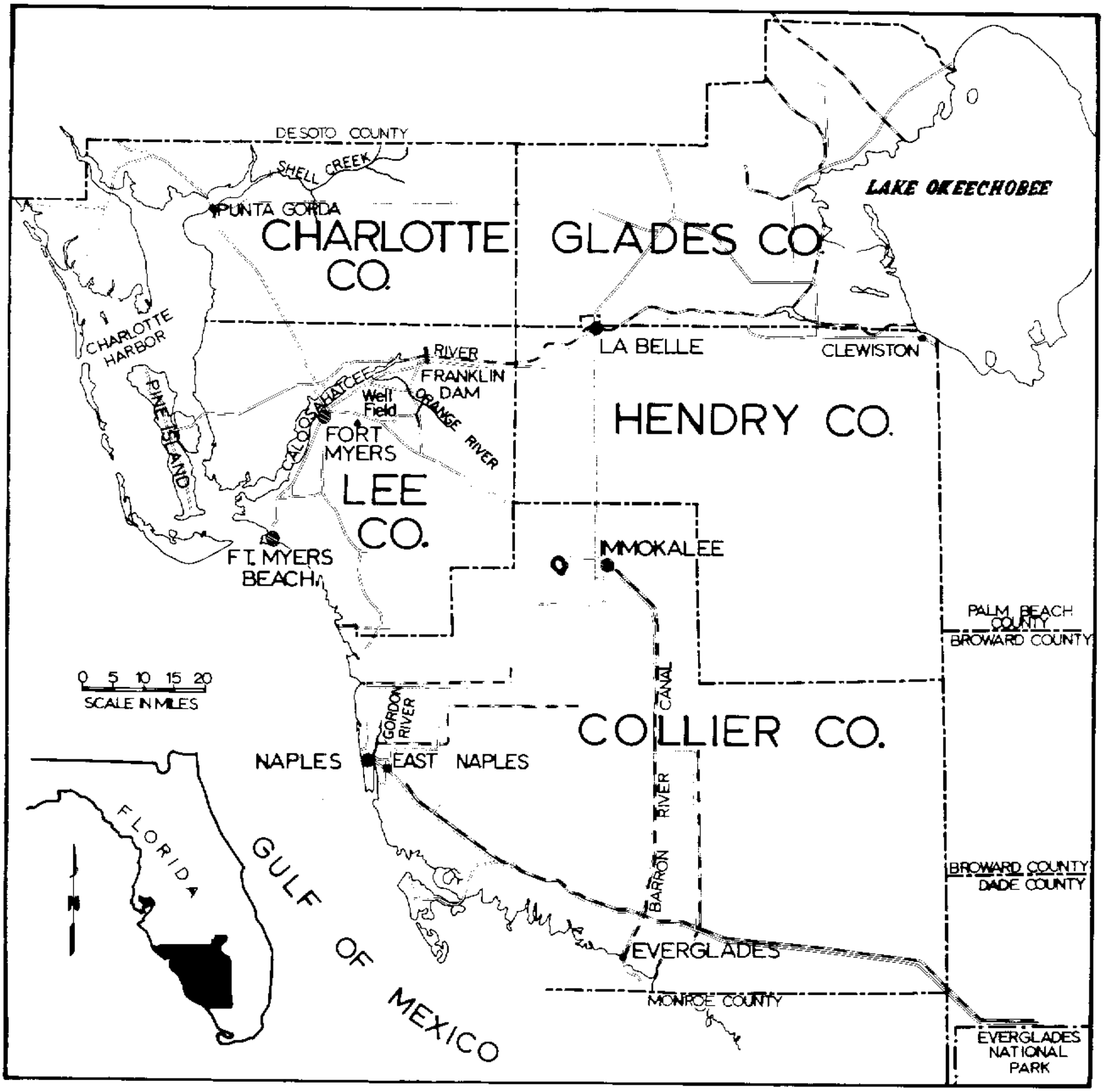

Figure 1.--Location of area described in this report.

TABLE 1

Fifteen Counties in Florida with the most rapid population increase

1960 - 1964

Rank	County	County Seat	Percent Increase in Population
1	Brevard	Titusville	53.9
2	Charlotte	Punta Gorda	52.4
3	Collier	East Naples	43.7
4	Hendry	La Belle	35.8
5	Okeechobee	Okeechobee	34.4
6	Martin	Stuart	32.5
7	Lee	Ft. Myers	25.3
8	Indian River	Vero Beach	23.3
9	Seminole	Sanford	22.2
10	Broward	Ft. Lauderdale	21.7
11	Citrus	Inverness	21.5
12	Sarasota	Sarasota	20.7
13	Okaloosa	Crestview	20.4
14	Palm Beach	West Palm Beach	20.2
15	Volusia	DeLand	19.6

Water-supply problems in southwest Florida are largely related to the quality, or deterioration in the quality of the water, rather than to the quantity of water available. When we consider that the abundant supply of water visible at the surface is only a fraction of the quantity stored in the ground-water reservoir beneath the surface, we are likely to conclude that the quantity of water available is more than adequate to meet present and future needs. However, because of certain natural factors, combined with those related to man's use, the supply of water of good quality is limited.

In southwest Florida most of the water of good quality occurs at the surface in lakes, ponds, streams and canals, and beneath the surface as ground water in the nonartesian and shallow artesian aquifers. At greater depths, the Floridan aquifer, a major source of supply in the northern and central parts of the state, contains water of poor quality. Water from this deep source is highly mineralized and the most objectionable constituent is chloride which varies over a wide range of concentration, but probably averages about 1,000 ppm (parts per million). Many of the water-supply problems in southwest Florida are similar to those encountered in other areas. However, the presence of salt water along the coast and in the tidal waterways, plus the high chlorides in the Floridan aquifer make the problem of salt-water intrusion of much greater significance in this area than in other parts of the state.

SURFACE-WATER PROBLEMS

The increased use of streams for water supply has focused considerable attention on the existing or potential problems associated with the development of this source of supply. Evidences of this increased use include the recently completed facility on Shell Creek in Charlotte County to supply water to the City of Punta Gorda, the system recently installed at Ft. Myers which will pump water from the Caloosahatchee River for use in artificially recharging the existing well field, and the proposed Lee County water system which will also derive water from the Caloosahatchee River for public supply purposes.

The principal problems affecting the use of streams or other surface-water sources are the variations in both the quantity and quality of water available. One of the most significant factors affecting quantity and quality is the unequal distribution of rainfall; about 75 percent of the annual total falls during May through October. This results in a relatively large seasonal variation in runoff. The rainfall-runoff relation for one of the streams in the area, the Orange River in Lee County, is shown in figure 2. As noted from figure 2, an unusually large storage would be required to make this stream a dependable source of supply. Kenner and Brown (1956)[2] indicated that flow from the Orange River was less than 3 cfs (cubic feet per second) for periods as long as 6½ months. Similar characteristics have been noted for other streams in the area, although somewhat larger quantities of water may be available during low-flow periods. Available streamflow records in southwest Florida generally are inadequate to define accurately the low-flow characteristics of most of the streams, particularly with reference to the effects that increased drainage and changing land-use practices have on the hydrology.

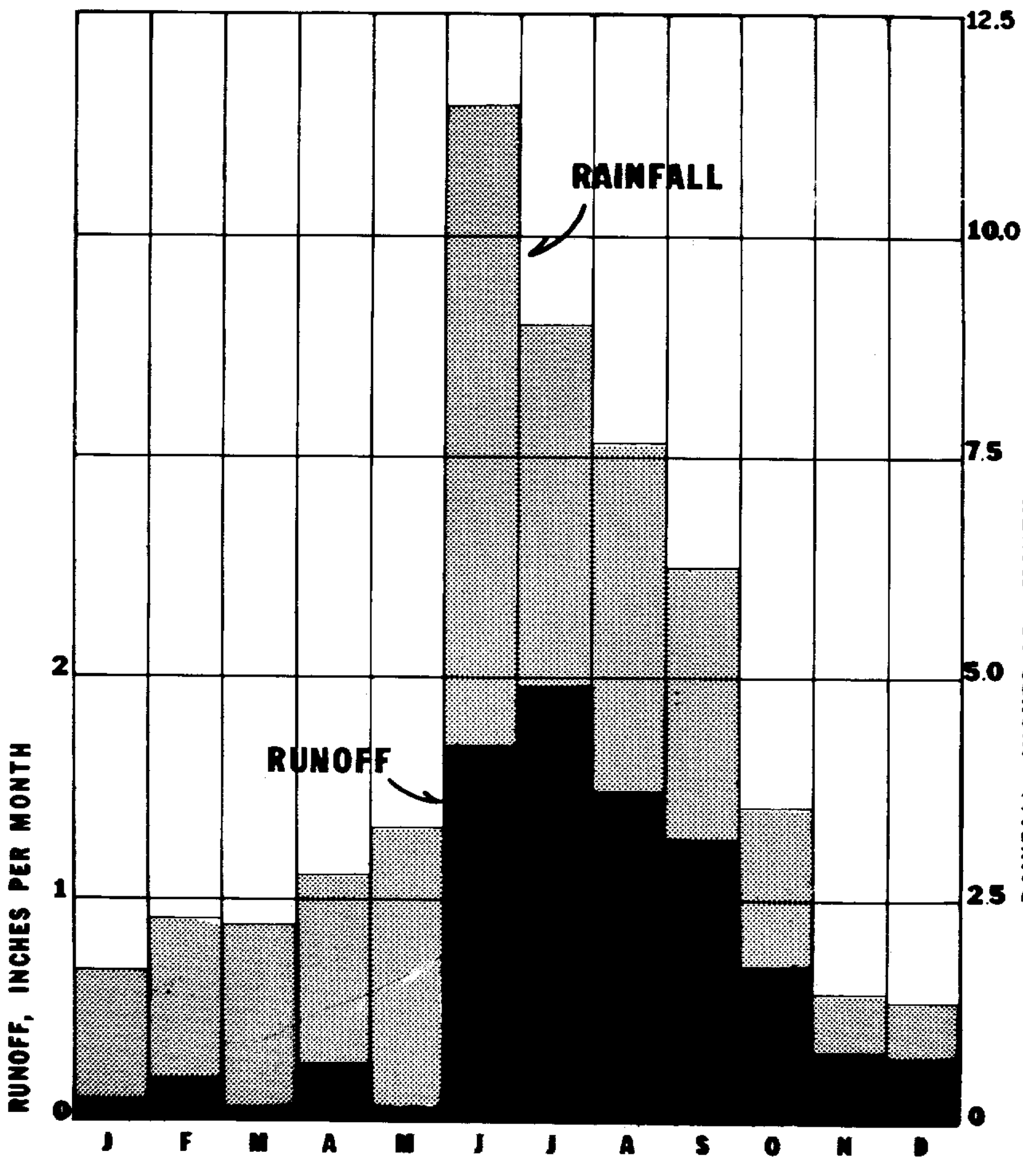

Figure 2.--Comparison of average monthly runoff of the Orange River, near Ft. Myers, and average monthly rainfall at Ft. Myers, for the period 1936-1946.

Variations in the quality of surface water, resulting from the unequal distribution of rainfall, are due primarily to the relative percentages of water derived from direct surface runoff compared to that from ground-water discharge. During rainy seasons, surface runoff is the dominant source of streamflow, whereas during dry seasons, the percentage contribution from more highly mineralized ground-water sources increases. This relation is shown by the analyses in table 2 and 3 (Water quality records in Florida and Georgia, 1964)[3]. The selection of streams outside the area was necessary because comparable data are not yet available for unregulated streams in this part of southwest Florida. Although the analyses shown may not be representative, they serve to illustrate the relationship between discharge and water quality. As noted from the tables, as the streamflow decreases, the chemical concentrations increase for all elements except iron. The range in concentrations between low and high discharge periods is generally greater for the smaller basin.

Many other factors may have an adverse effect on the development of surface-water sources. Prolonged droughts intensify problems of quantity and quality. Surface-water supplies are especially vulnerable to contamination from many sources, including fertilizers, pesticides, and other chemicals used in agriculture, commercial and industrial wastes, raw or improperly treated sewage, and salt water from surface or underground sources.

As the development of surface-water sources increases, so must our advance knowledge of the capabilities and limitations of this source increase. Because of the extended periods of time required to measure and evaluate these sources, comprehensive programs of measurements and observations should be started early.

TABLE 2

Chemical Analyses, Phillipi Creek near Sarasota

Constituent	Low Flow 5.9 cfs June 1964	High Flow 344 cfs Sept. 1964
Silica	17 ppm	6.3 ppm
Iron	.01	.05
Calcium	118	34
Magnesium	49	7.5
Sodium	26	7.6
Potassium	3.9	2.9
Bicarbonate	190	54
Sulfate	324	68
Chloride	45	11
Fluoride	1.0	0.4
Nitrate	0.4	0.0
Dissolved solids (calculated)	680	165
Hardness as $CaCO_3$		
Calcium-magnesium	494	116
Non-carbonate	338	72
Specific conductance	949 micromhos	270 micromhos
pH	7.6	7.0

Area of drainage basin: 24 square miles

Time-weighted average discharge: 36 cfs (cubic feet per second)

TABLE 3

Chemical Analyses, Peace River at Arcadia

Constituent	Low Flow 189 cfs June 1964	High Flow 3,880 cfs Sept. 1964
Silica	11 ppm	7.2 ppm
Iron	0.00	0.39
Calcium	36	12
Magnesium	12	3.9
Sodium	16	8.5
Potassium	1.9	1.2
Bicarbonate	83	27
Sulfate	64	13
Chloride	16	11
Fluoride	1.9	.7
Nitrate	.7	.0
Phosphate	7.3	3.0
Dissolved solids (calculated)	208	74
Hardness as $CaCO_3$		
Calcium-magnesium	140	46
Non-carbonate	72	24
Specific conductance	342 micromhos	112 micromhos
pH	7.2	7.3

Area of drainage basin: 1,370 square miles

Time-weighted average discharge: 973 cfs

GROUND-WATER PROBLEMS

Historically, ground water has been the principal source of water supply in southwest Florida. Although this source is considered to be adequate for present and future needs, only limited quantities of water of naturally good quality are available. As a general rule the degree of mineralization of ground water increases with depth, the water of best quality occurring in the nonartesian and shallow artesian aquifers. The deeper zones of the Floridan aquifer contain abundant supplies of water unsuitable for many purposes. Although used to limited extent as a source of domestic supply, the Floridan aquifer is used primarily for irrigation.

Water-supply problems associated with the development of shallow ground-water sources are similar in some respects to development of surface-water sources. The seasonal distribution of rainfall causes relatively large variations in the quantity of water in storage. The measurement of water levels in observation wells provides an indication of the changes in ground-water storage. Under natural conditions, ground-water levels rise during the period of highest rainfall, although this coincides with the period of maximum water losses to evapotranspiration and surface runoff. Conversely, water levels decline during the period of lowest rainfall, even though evapotranspiration and runoff are lowest during this time.

The changes in water levels caused by pumping are superimposed on the natural changes. The combined effects of these factors are shown in figure 3. It is noted that the periods of maximum pumpage frequently coincide with periods of minimum rainfall. The resultant lowering of water levels, although entirely normal, is of great concern at Ft. Myers because the shallow aquifer from which the water is obtained is relatively thin, averaging only about 30 feet thick, and of limited areal extent.

Pumpage records for the period 1941-1961 show that water use at Ft. Myers increased by more than 400 percent for a population increase of about 300 percent. This, and other related factors have led to the artificial recharge project presently under construction. Water will be pumped from the Caloosahatchee River, at a point about 1 mile upstream from the Franklin Dam, (fig. 1) to the Ft. Myers well field, a distance of about 12 miles. The recharge water will be used to maintain high water levels by spreading in a series of shallow ditches and depressions in the well field area. The rate of downward infiltration is expected to be sufficient to stabilize water levels in the vicinity thereby increasing the total capacity of the well field during periods of peak demand. A related factor in this project is the probable improvement in the quality of water yielded during low water level periods.

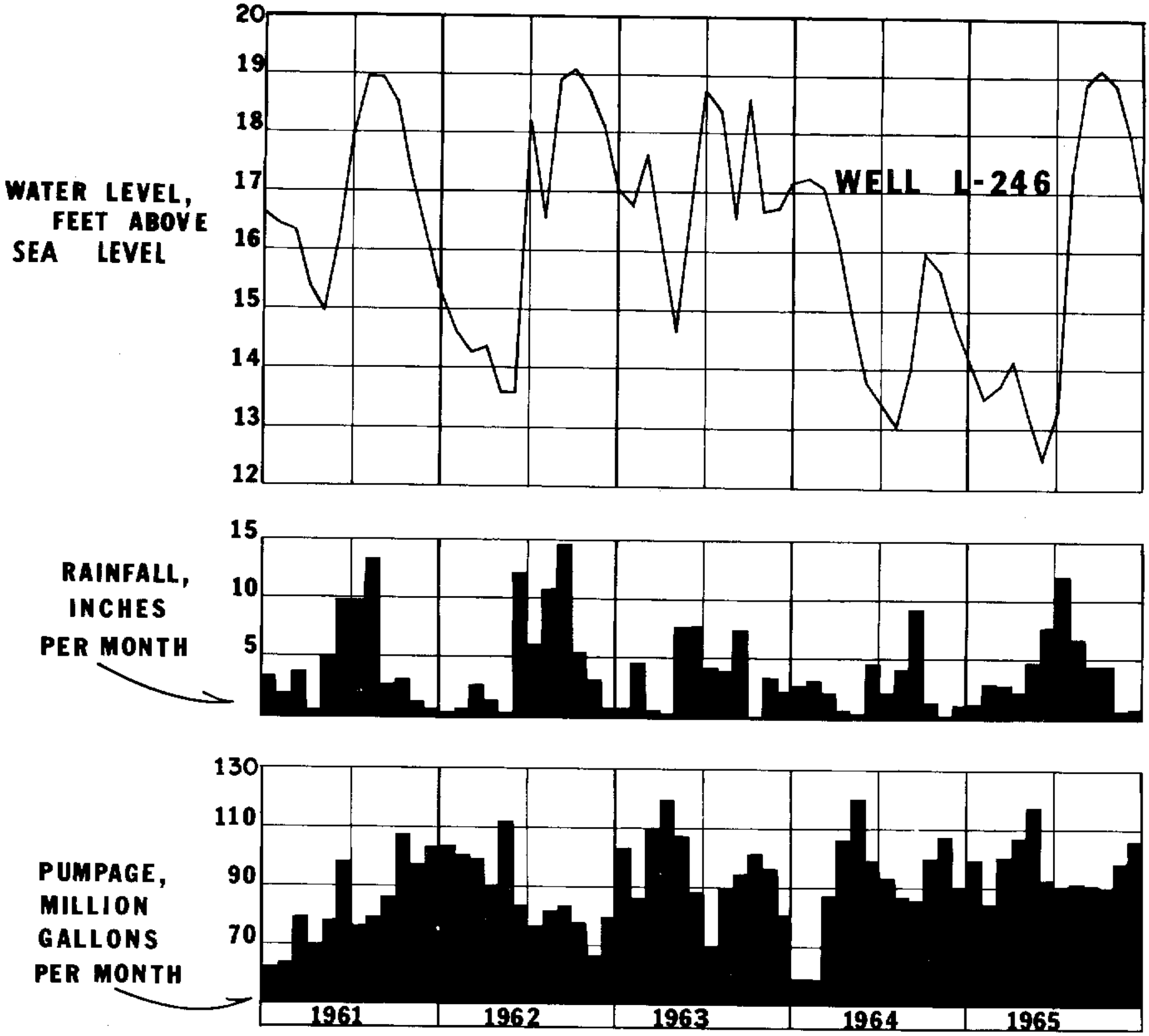

Figure 3.--Graph showing the combined effects of rainfall and pumping on water levels in the Ft. Myers well field, 1961-1965.

Lowering of ground-water levels in coastal areas or inland areas near salt-water bodies has caused serious problems of salt-water intrusion, in some cases forcing the abandonment of well fields. Salt water from the Caloosahatchee River was identified as the source of increasing chlorides in the well field formerly used at Ft. Myers. At Naples, intrusion of salt water from the Gulf of Mexico and the Gordon River led to the abandonment of the old well field in the southern part of the city (McCoy, 1962)[4]. Salt-water intrusion has been reported in the shallow artesian aquifer at Ft. Myers Beach.

The mechanics of sea-water intrusion into coastal aquifers have been extensively treated in the literature, so that it would serve little purpose to review them here. The lessons of the past in this, and in many other areas, should serve as ample warning of the limitations on development of water supplies in coastal areas. It should be noted that the practice of constructing tidal canals and drainage ditches without provision for salinity control devices, is introducing the problem of sea-water intrusion into many inland areas. The construction of uncontrolled tidal canals causes sea-water intrusion in two ways: it lowers ground-water levels as a result of increased drainage; and it provides open channels to convey salt water to inland areas during dry periods. As shown in figure 4A, wells pumping water from the aquifer adjacent to a tidal canal will be contaminated. In contrast, a controlled canal as shown in figure 4B can provide a perennial source of fresh water replenishment to prevent salt-water intrusion and provide a more dependable source of supply.

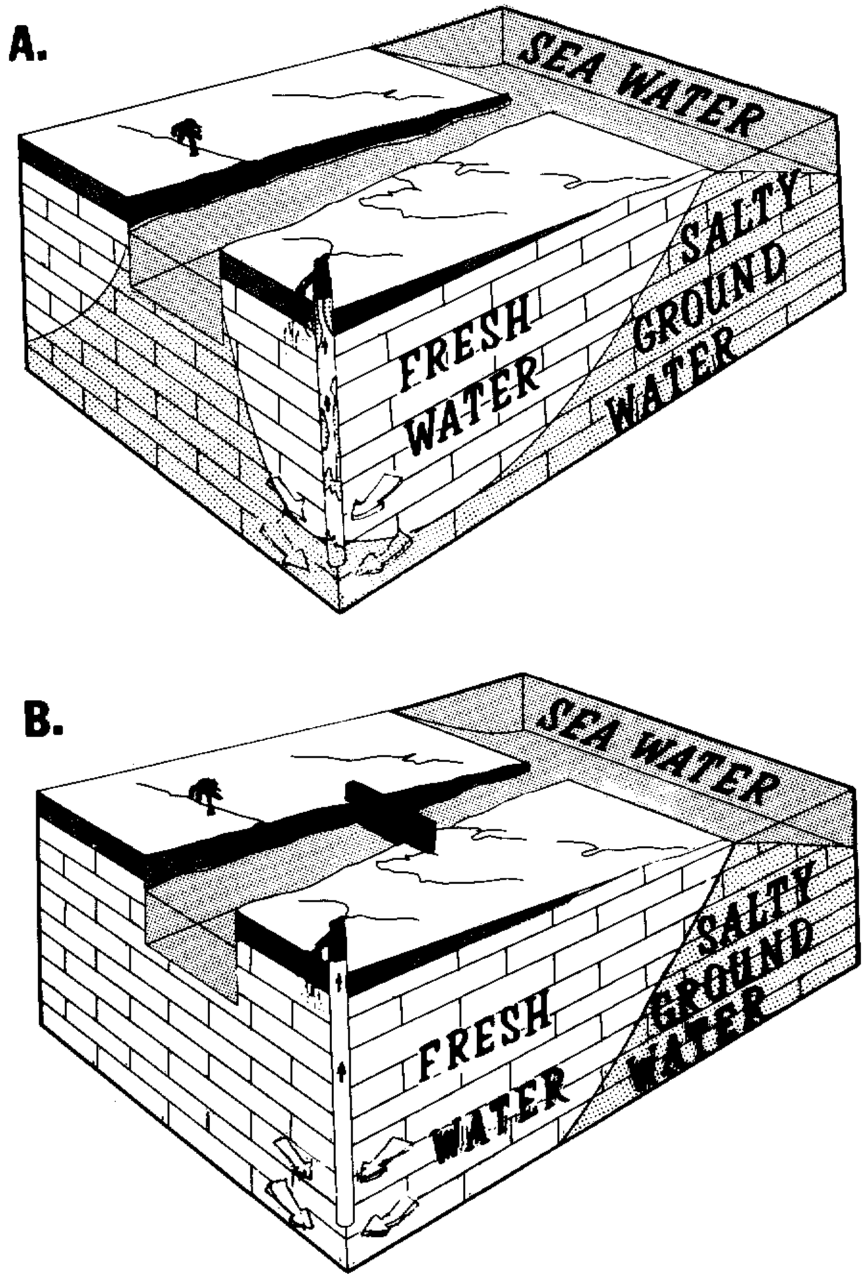

Figure 4.--A, Schematic diagram showing sea-water contamination caused by construction of an uncontrolled canal. B, Schematic diagram showing the effect of a control dam in limiting the inland movement of sea water. (Adapted from Sherwood and Grantham, 1966)[5]

A problem of particular concern in many parts of southwest Florida is salt-water contamination from deep underground sources caused by upward leakage through defective or improperly cased wells (figure 5). The Floridan aquifer contains water under pressure heads ranging from about 20 feet above mean sea level along the coastal margin to more than 50 feet above mean sea level in the interior. Wells drilled to this aquifer will flow at the surface throughout most of the area. As previously indicated, the chloride content of this water probably averages about 1,000 ppm, although values ranging from less than 100 to more than 4,000 ppm have been obtained. As shown in figure 5, water in the Floridan aquifer is under higher pressure than that in the secondary artesian aquifer or the unconfined aquifer. Therefore, if a deep artesian well is inadequately cased or the casing is broken or corroded at shallow depths, the salty water under high pressure is free to leak out of the well bore into the fresh water-bearing aquifers.

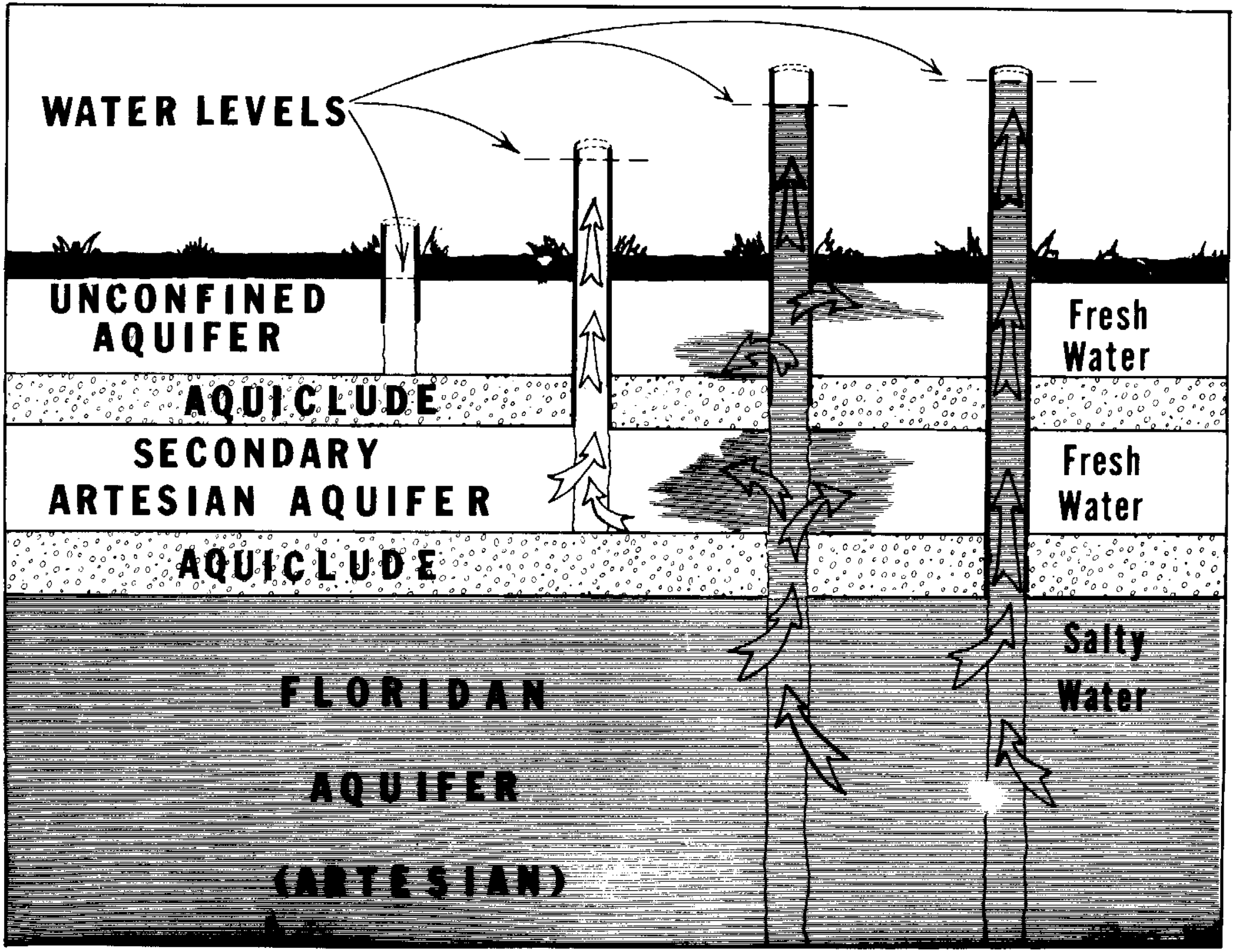

Figure 5.--Schematic diagram illustrating the problem of upward leakage through detective or improperly cased wells.

Evidence of salt-water contamination from the Floridan aquifer and the overall magnitude of the problem in southwest Florida is not well known. Klein and others (1964)[6] concluded that upward leakage through the deep wells and through the corroded water-distribution system were the probable sources of contamination of the shallow aquifer at LaBelle in Hendry County. Figure 6 shows the distribution of chloride in the shallow aquifer in the LaBelle area. In Lee County, engineers designing the new water system for Pine Island noted an immediate reduction in chlorides in the shallow artesian aquifer after sealing off the lower part of the well that had been constructed to the Floridan aquifer (Bennett, Bishop, and Passalacqua, 1965)[7]. Evidence accumulated during water sampling and well inventory programs in Lee County suggests that upward leakage of poor quality water from the Floridan aquifer may be a problem of major importance in the county. The magnitude of this problem in Lee County may best be described by considering some of the factors involved including: 1) the constant high artesian pressure in the aquifer, 2) the high-chloride content of the water, 3) the large number (2,000-3,000) of irrigation wells drilled to the aquifer, and 4) the possibility that the majority of these wells are not fully cased to the Floridan aquifer.

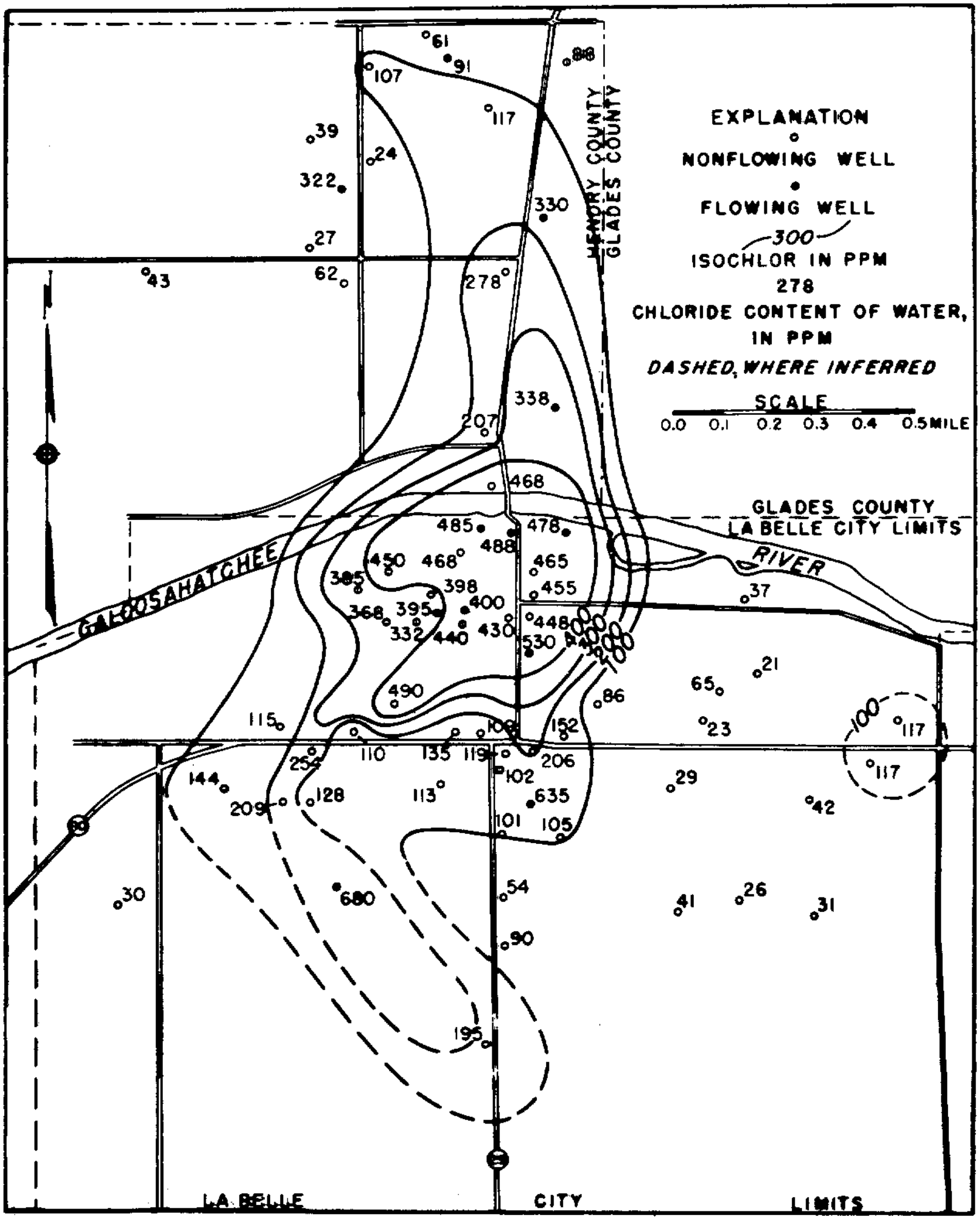

Figure 6.--Map showing the extent of salt-water intrusion in the shallow aquifer at LaBelle, 1952-1953. (Adapted from Klein, Schroeder and Lichtler, 1964)[6]

If all deep wells in the area were allowed to discharge freely at the surface, the flow probably would be in the order of magnitude of hundreds of millions of gallons per day. However, because most wells are effectively controlled by valves at the surface, much of the discharge from the Floridan aquifer occurs as upward leakage into shallower aquifers. The quantity of water thus introduced and the extent of contamination would vary in accordance with several factors. Under certain conditions, a single deep well may become the focal point of contamination for a large surrounding area. Where a large number of wells exist, contamination would be more widespread, probably affecting major areas served by shallow aquifers. The lowering of water levels resulting from increased use of the shallow aquifers may cause a progressive deterioration in the quality of the potable water, unless corrective action is taken to eliminate or reduce the sources of contamination. More detailed studies are needed to provide information for the immediate or long-term solution to this problem.

Another problem related to contamination from the Floridan aquifer, is water used for irrigation. Most of the water used for crop irrigation is applied during the winter growing season, coinciding with the period of low ground-water levels and reduced streamflow. Because of the abundance of free-flowing water available from the Floridan aquifer, irrigation water frequently is applied in excess of that required for plant growth. Some of this water percolates downward to the water table, causing an increase in chloride concentrations in the unconfined aquifer. Some of the water flows along surface drainageways to points remote from the irrigated lands, thus becoming a source of salt-water contamination in areas where the shallow aquifers are used extensively. Subsequent flushing by precipitation during the rainy season probably dilutes or removes most of the contaminants so that a progressive increase in chloride content may not occur. However, the residual salts remaining after incomplete flushing may tend to curtail crop production in some areas.

The increased water requirements of the rapidly expanding population, and the demand for water of better quality already has overtaxed the public water supply facilities, which were adequate until a few years ago. The increased demand has resulted in conflict between water users in some areas, creating a problem which may be of significant proportions in future years. In addition, newly constructed drainageways are reducing the quantity of water in storage in shallow aquifers and increasing the potential sources of contamination from chemical and biological wastes.

Effective management of the available water resources, based on increased knowledge of their occurrence, movement and quality, will be required to minimize the problems related to increased development. Further, the increased hydrologic knowledge needs to be obtained on a regional basis rather than on a local basis. Studies of flood control, water control, and management in heavily-developed southeastern Florida have shown that large inland areas can be utilized for urban or agricultural purposes without seriously depleting the regional water resources. However, this type of management requires carefully-planned drainage systems and the proper location and operation of salinity-control structures.

CONCLUSIONS

From the preceding discussions, it is obvious that most of the water-supply problems in southwest Florida are related to man's attempts to modify and control his environment without adequate knowledge of the effects of such activities. Sea-water intrusion or water-supply shortages, are conditions forceably brought to our attention because they require immediate corrective action. Other conditions, such as a gradual increase in chloride content of water or a general lowering of water levels, may pass unnoticed over long periods of time -- ultimately to pose serious problems and limit further use of the water resource.

Most of southwest Florida has not yet reached a stage of development where irreversible damage has occurred to water-supply sources. The problems of sea-water intrusion are presently being avoided by the establishment of permanent well fields in inland areas. A program of plugging and capping of deep artesian wells is relieving the problem of salt-water contamination of streams or shallow aquifers caused by upward leakage, or by open discharge from these wells. The establishment of a salinity line, such as that in Collier County, will forestall many of the problems related to sea-water intrusion through inland drainage or navigation canals, and provide a means of controlling fresh-water discharge. The trend toward increased use of surface-water supplies and the exploration for more dependable ground-water sources are further evidence of our quest for solutions to water-supply problems.

However, much remains to be done, for it appears that the magnitude and complexity of the problems are increasing at a rate greater than the means of resolving them. Compared to other parts of the state, the potable water supplies in southwest Florida are greatly limited. To prevent further deterioration and depletion of resources, and to improve and increase the total quantity available, more effective management and control is required. Detailed studies are needed in some areas with special problems to ascertain the facts and provide the best means of solution. Broad-area studies of the geologic/hydrologic relationships are needed to provide the knowledge essential to the orderly development of the water resources of the region. The program of measurements of streamflow, of water quality, and of groundwater levels should be expanded to provide information well in advance of development, and continued to provide a means of evaluating the effects of development.

Based on the total water concept, a long-range plan of water-resources development in the area should be formulated. Additional regulations and control probably will be required to avoid many of the problems associated with increased development, and to resolve some of the problems which exist at the present time.

REFERENCES

1. Florida Development Commission, Population of Florida, Research Bull. no. 16, (1965), p. 3.

2. Kenner, W. E., and Brown, Eugene, Surface water resources and quality of waters in Lee County, Florida, Fla. Geol. Survey, Inf. Circ. no. 7, (1956), p. 8.

3. U.S. Dept. of the Interior, Geological Survey, Water quality records in Florida and Georgia, (1964), pp. 47-48, 53-55.

4. McCoy, H. J., Ground-water resources of Collier County, Florida, Fla. Geol. Survey, Rept. Inv. no. 31, (1962), p. 33.

5. Sherwood, C. B., and Grantham, R. G., Water control vs. sea water intrusion, Broward County, Florida, Fla. Geol. Survey, Leaflet No. 5, (1966).

6. Klein, Howard, Schroeder, M. C., and Lichtler, W. F., Geology and ground-water resources of Glades and Hendry Counties, Florida, Fla. Geol. Survey, Rept. Inv. no. 37, (1964), p. 78.

7. Bennett, Bishop, and Passalacqua, Inc., Final report test well program, mimeographed report (1965), p. 11.