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INTERIM REPORT ON SALT-WATER ENCROACHMENT IN DADE COUNTY, FLORIDA

By

HOWARD KLEIN

PREPARED BY U. S. GEOLOGICAL SURVEY
IN COOPERATION WITH DADE COUNTY, THE CITIES OF MIAMI
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ILLUSTRATIONS

SALT-WATER ENCROACHMENT IN DADE COUNTY, FLORIDA

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Recently there has been much activity in reclaiming the low-lying coastal areas of Dade County for residential use, by the addition of fill. The fill is obtained by digging canals both normal to and parallel to Biscayne Bay. The canals serve the additional purpose of providing an access to the Bay for boats. A problem needing to be considered is the effect that these canals will have on the ground-water resources. It is expected that the canals will have little effect on ground water in parts of the county distant from the coast, but their effect in coastal areas is a matter of concern. In order to predict what may happen in the vicinity of these new canals if they are not equipped with adequate control structures, it is instructive to review what has happened in the vicinity of similar canals in the past.

The U. S. Geological Survey, in cooperation with Dade County, the cities of Miami and Miami Beach, the Central and Southern Florida Flood Control District, and the Florida Geological Survey has collected water-level and salinity data on wells and canals in Dade County since 1939. Some of the agencies named, and others, collected similar data before 1939. Analysis of all the data shows that sea water in the Atlantic Ocean and Biscayne Bay is the sole source of salt-water contamination in the Biscayne aquifer of the Dade County area.

According to the Ghyben-Herzberg principle, a head of fresh water one foot above mean sea level indicates that fresh water extends to a depth of about 40 feet below mean sea level. Present studies in the Miami area indicate that this principle is valid but is modified (greatly in certain areas) by field conditions, particularly the movement of ground water.

A report by Parker and others 1/ presents a fairly complete history of salt-water encroachment in the Miami area. Figure 1, adapted from figure 169 of that report, shows successive stages of salt-water encroachment in the Miami area from 1904 through 1953. The stippled areas in the figure represent the zones in which wells 80 to 100 feet deep would have tapped ground water having a chloride concentration of 1,000 ppm (parts per million) or more. Figure 2 shows the extent of salt-water encroachment in Dade County in 1951.

Uncontrolled or inadequately controlled tidal canals have been the chief cause of salt-water contamination in the Biscayne aquifer, the principal aquifer of southeastern Florida. Such canals cause salt-water encroachment in two ways:

1. They drain off fresh ground water, thereby reducing the fresh-water head that opposes the inland movement of salt water; and,

2. They provide a path for sea water to move readily inland during dry periods. A tongue of salty ground water extends several miles inland along each principal tidal canal.

A comparison of the maps in figure 1 shows that the greatest inland movement of salt water occurred between 1943 and 1946, as a result of the severe drought during 1944 and 1945. Much of the aquifer near the Miami, Little River, and Biscayne canals, and also a large part of the aquifer underlying Coral Gables, became contaminated. The map for 1950 indicates the effectiveness of temporary control structures in the several canals in retarding overdrainage of ground water from storage and in retarding inland movement of salt water in open canals. In the vicinities of Biscayne, Little River, and Miami canals, the salt-water front

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1/ Parker, G. G., Ferguson, G. E., Love, S. K., and others, 1955, Water resources of southeastern Florida: U.S. Geol. Survey Water-Supply Paper 1255.

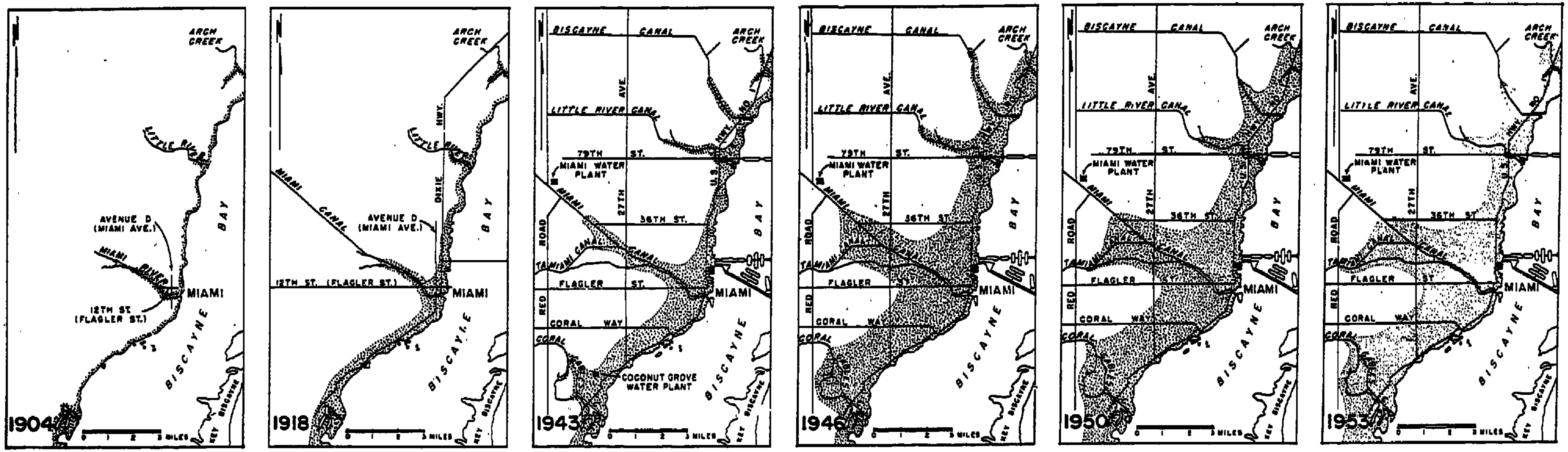

Figure 1. Maps showing progressive salt-water encroachment in the Miami area, 1904-53.

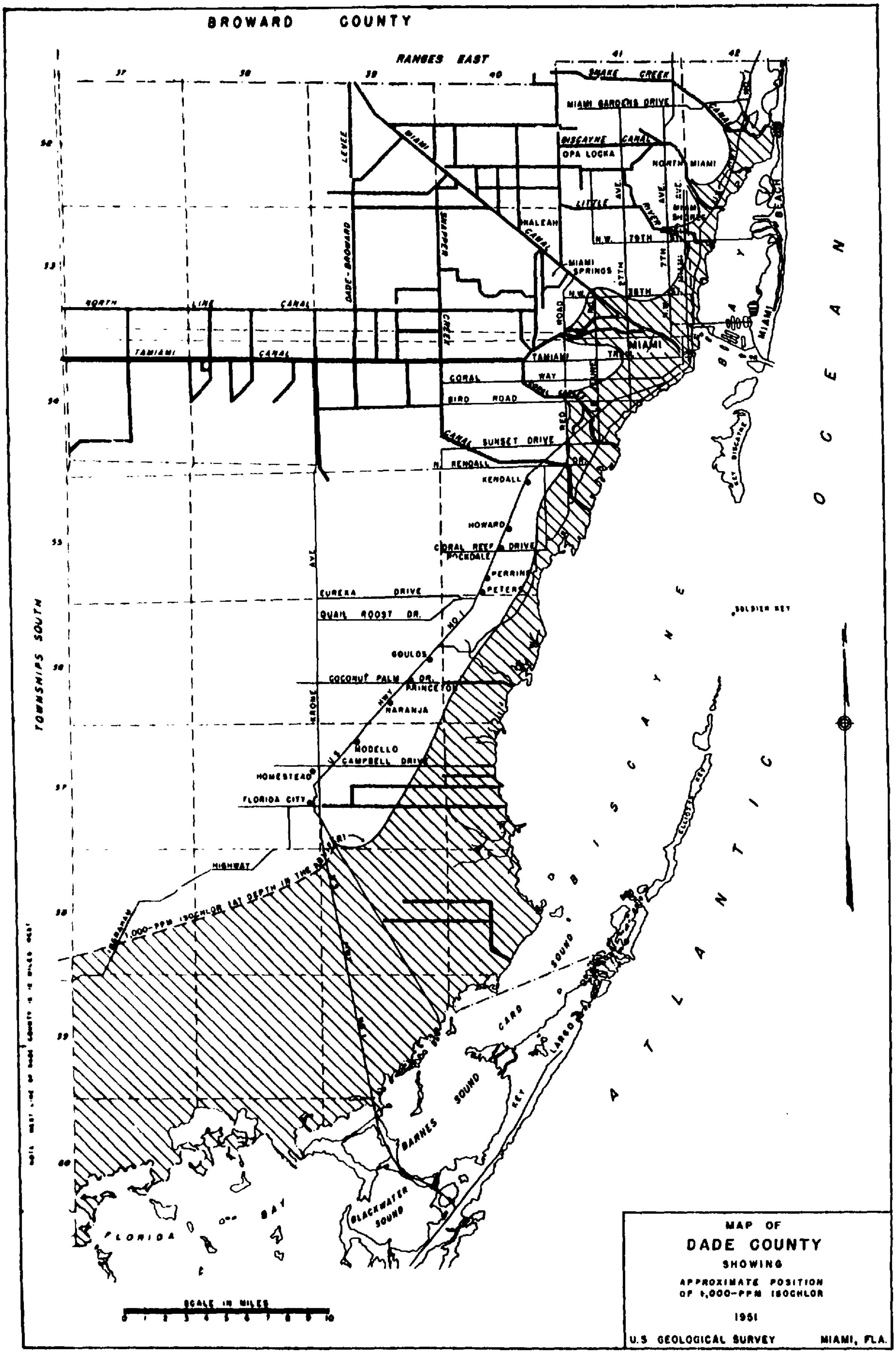

Figure 2. Map of Dade County showing approximate position of the 1,000-ppm isochlor.

retreated seaward approximately to the control structures, but along the Coral Gables and Tamiami canals it migrated farther inland, almost to Red Road. The continued encroachment in the vicinities of the Coral Gables and Tamiami canals can be attributed to the fact that the control structures were placed too far upstream to be effective in retarding the inland movement of salt water.

One of the most intensively studied areas in Dade County is the Silver Bluff area, where Garald G. Parker, during early years of the cooperative study, and Nevin D. Hoy and Francis A. Kohout, in recent years, have correlated the movements of salt water with ground-water levels. An opportunity to expand these studies came in August 1954 when the State Road Department began excavation of an open-trench storm sewer beneath 27th Avenue. This excavation, in reality, was an uncontrolled tidal drainage ditch, because the altitude of its bottom ranged from three feet below mean sea level at the Bay to sea level at a distance of about 9,000 feet from the outlet. On June 17, 1954, prior to the ditching operations, measurements of water levels were made in various wells in the Silver Bluff area and these were used to draw the water-level contours in figure 3. On November 29, 1955, something like a year after the completion of the ditching operations, the water levels in the wells were measured again, and these measurements were used to draw the water-level contours in figure 4. The most prominent change in the patterns shown by figures 3 and 4 is the realignment of the contours along 27th Avenue. This realignment indicates that ground water drains continuously into the storm sewer and thence to Biscayne Bay. Figure 4 shows that by November 1955 the effects of this drainage had extended over a considerable area on both sides of 27th Avenue and to a point north of 16th Street.

In addition to the water-level measurements, water samples from many wells in the Silver Bluff area were analyzed for chloride content. Figure 5 is a contour map of the surface below which the chloride content exceeded 1,000 ppm on July 20, 1953, prior to the excavation of the trench. This is to be compared with figure 6, a contour map of this surface on April 4, 1956. In the 1956 map the contours curve northward along 27th Avenue, indicating that

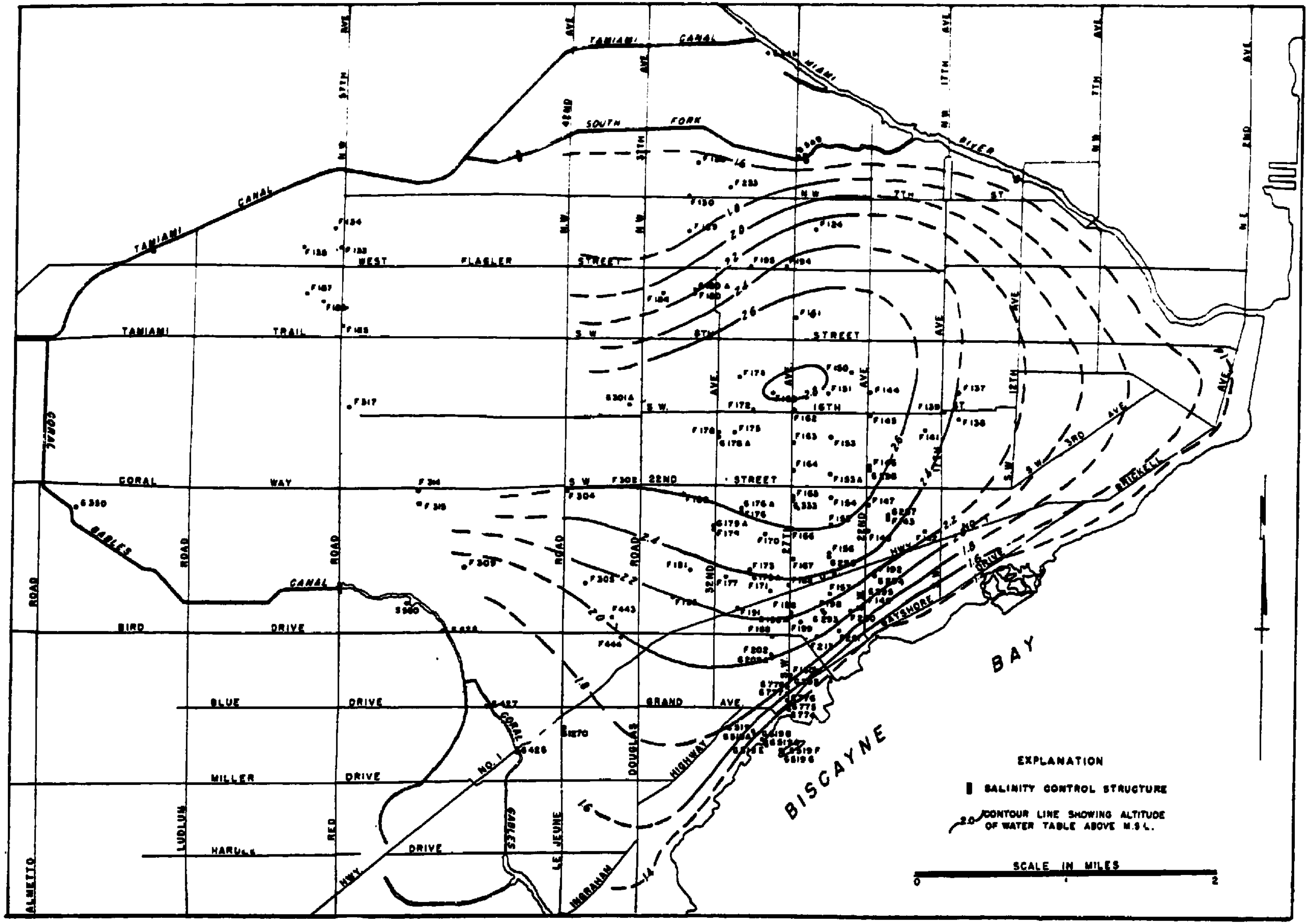

Figure 3. Contour map showing the altitude of the water table in the Silver Bluff area, June 17, 1954.

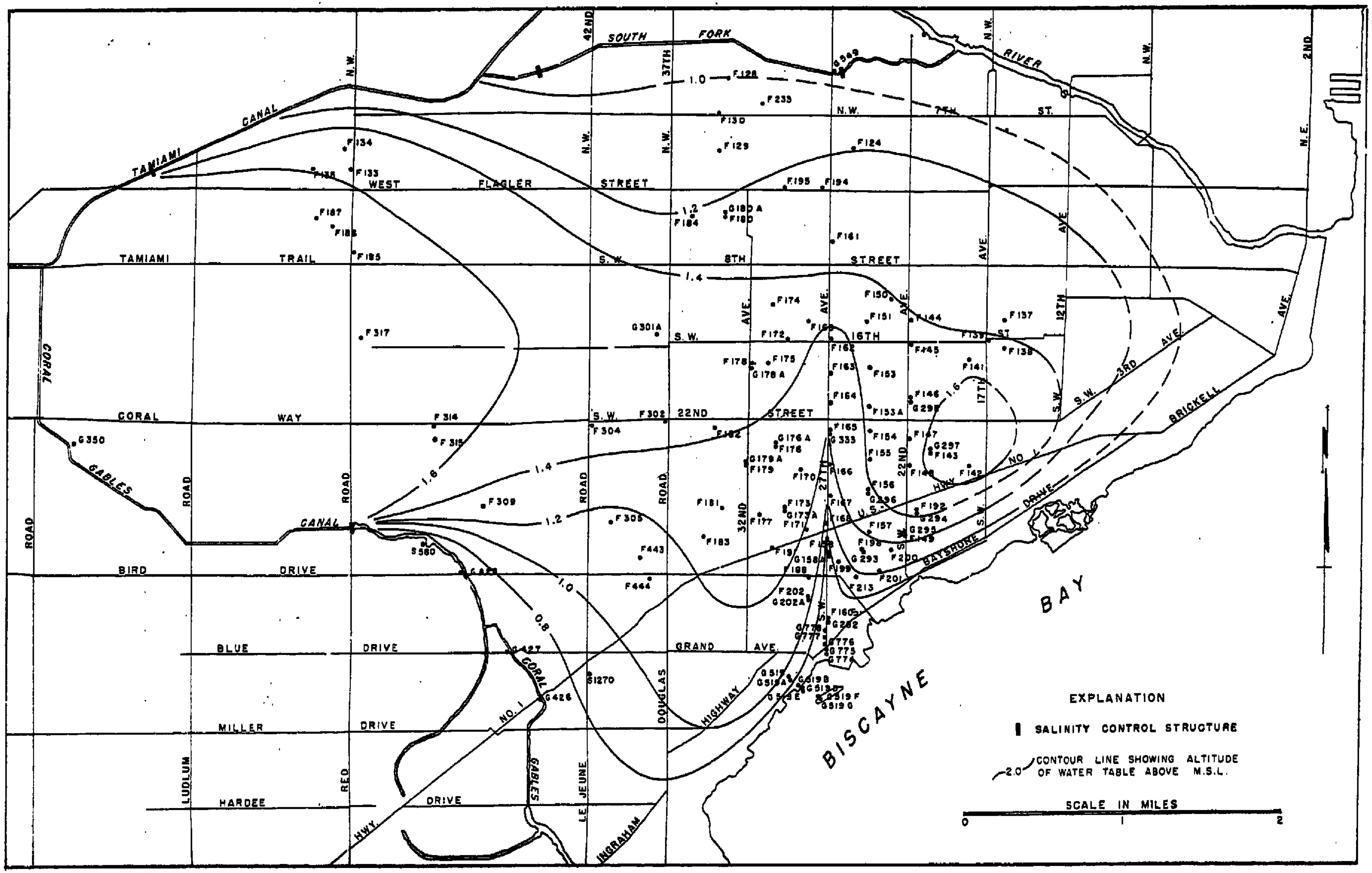

Figure 4. Contour map showing the altitude of the water table in the Silver Bluff area, November 29, 1955.

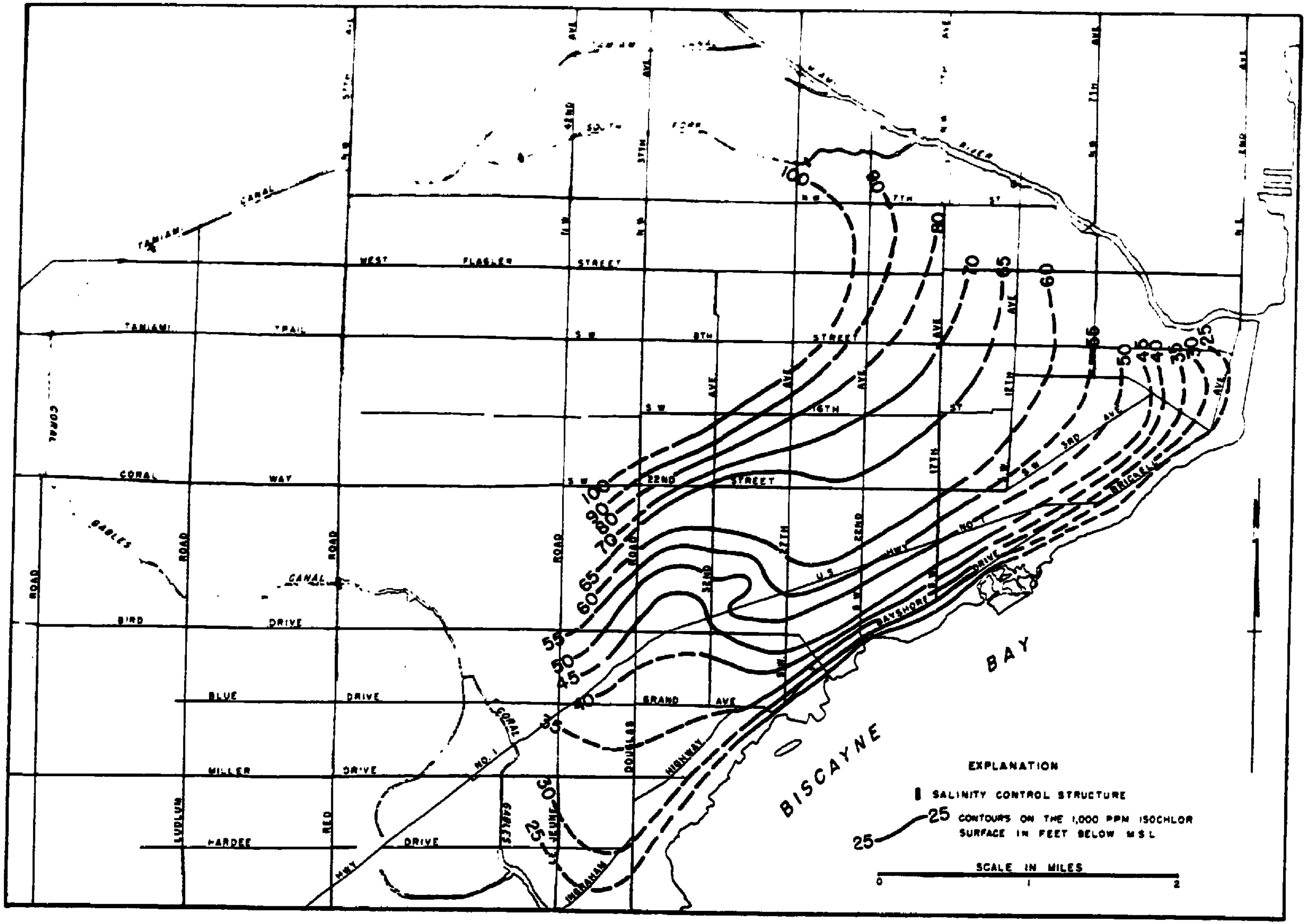

Figure 5. Contour map showing the depth of the 1,000-ppm isochlor surface in the Silver Bluff area, July 20, 1953.

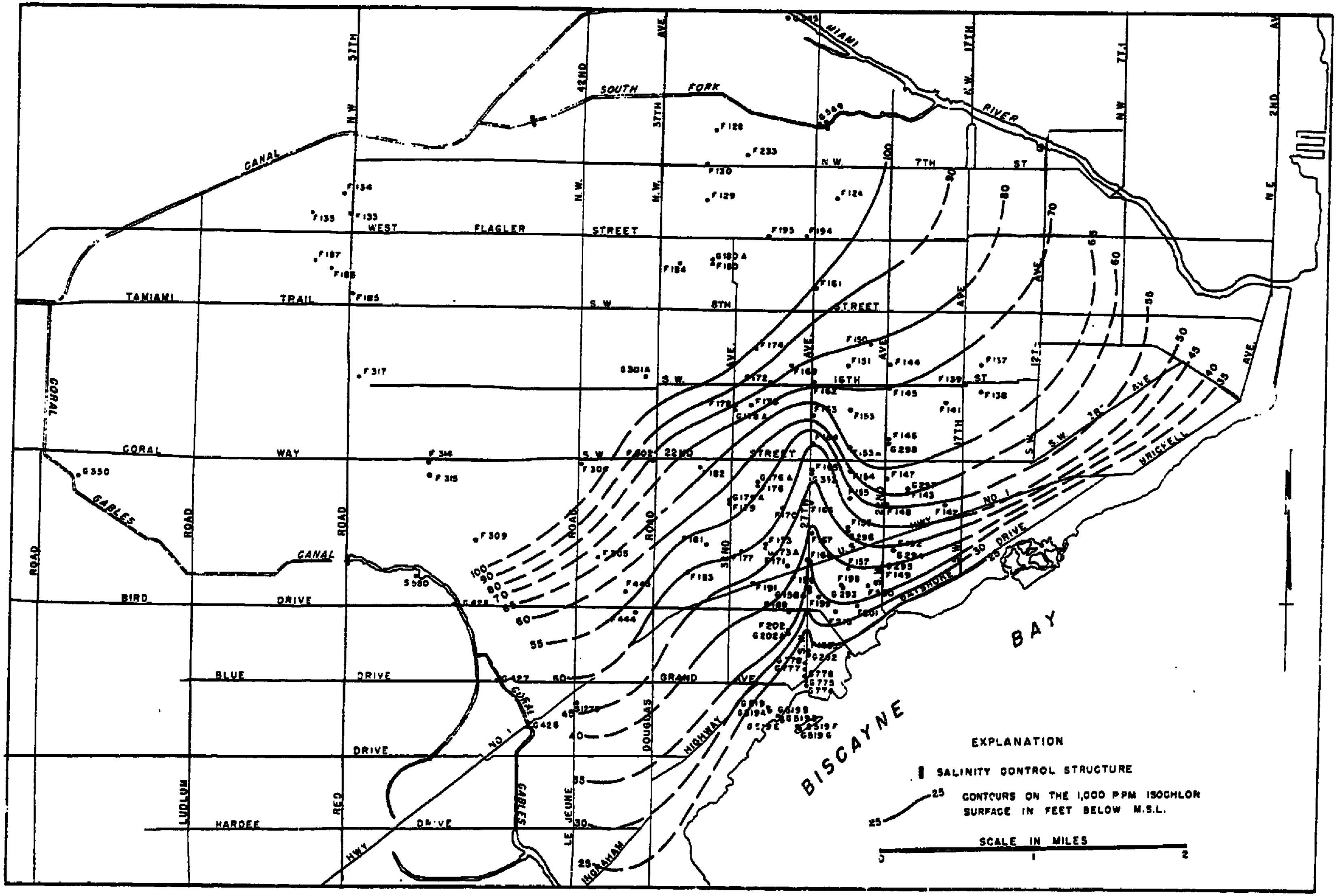

Figure 6. Contour map showing the depth of the 1,000-ppm isochlor surface in the Silver Bluff area, April 4, 1956.

the chloride content in the ground water in that area had increased as a result of the drainage of ground water. However, the encroachment had occurred only in a relatively narrow area parallel to the trench.

Figures 7 to 10 show the water level and the chloride content of the water in wells in the immediate vicinity of 27th Avenue. The graphs show that the chloride content decreases when the water level is high and increases when the water level is low. The increase in chloride content that began in December 1954 can be attributed chiefly to the lowering of the water table as a result of the drainage of ground water into the trench and out to the Bay.

As shown in figure 2, salt-water encroachment has occurred throughout coastal Dade County and farther inland along tidal canals. This does not mean, however, that fresh water is not available in these areas. Moderate quantities of fresh water can be obtained at shallow depths throughout the area affected by encroachment, except in areas immediately adjacent to the Bay or tidal canals and in low-lying coastal marshes that are periodically covered by tidal water.

Data on the salinity of water in wells in the coastal areas indicate that the interface between the fresh water and salt water moves fairly rapidly in response to changes in ground-water levels. Figure 11-A shows, in profile, the position that the interface would assume according to the Ghyben-Herzberg principle. It rises and moves inland whenever the water table is low, and falls and moves seaward when the water table is high. Also shown in figure 11-A are two supply wells, each of which will yield fresh water under the stated conditions.

Figure 11-B assumes the same conditions as those in figure 11-A, except that a network of uncontrolled tidal canals has been added. The position of the interface in the immediate area of the canals is shown to have shifted inland by a distance approximately equal to the maximum inland extension of the canals. As a result of this shift, well 1 would yield salty water at all times and well 2 would do so during low-water conditions.

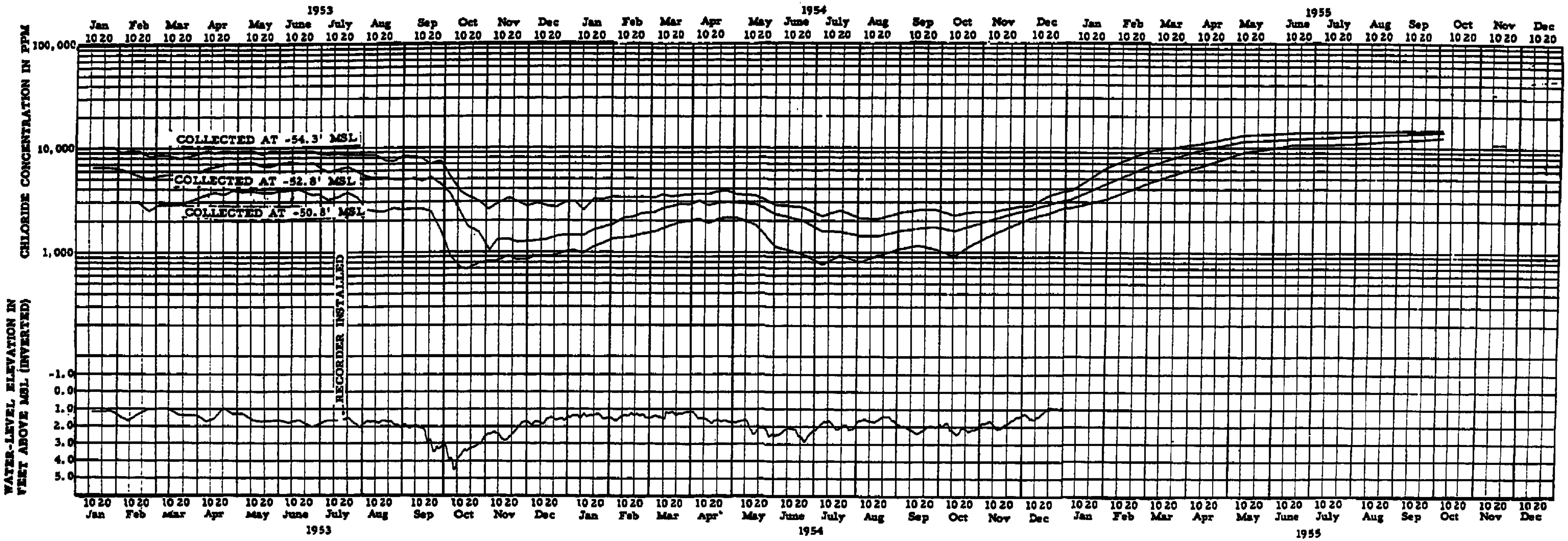

Figure 7. Graph showing fluctuations of chloride content in the open-hole part of well F-198, compared with water-level fluctuations.

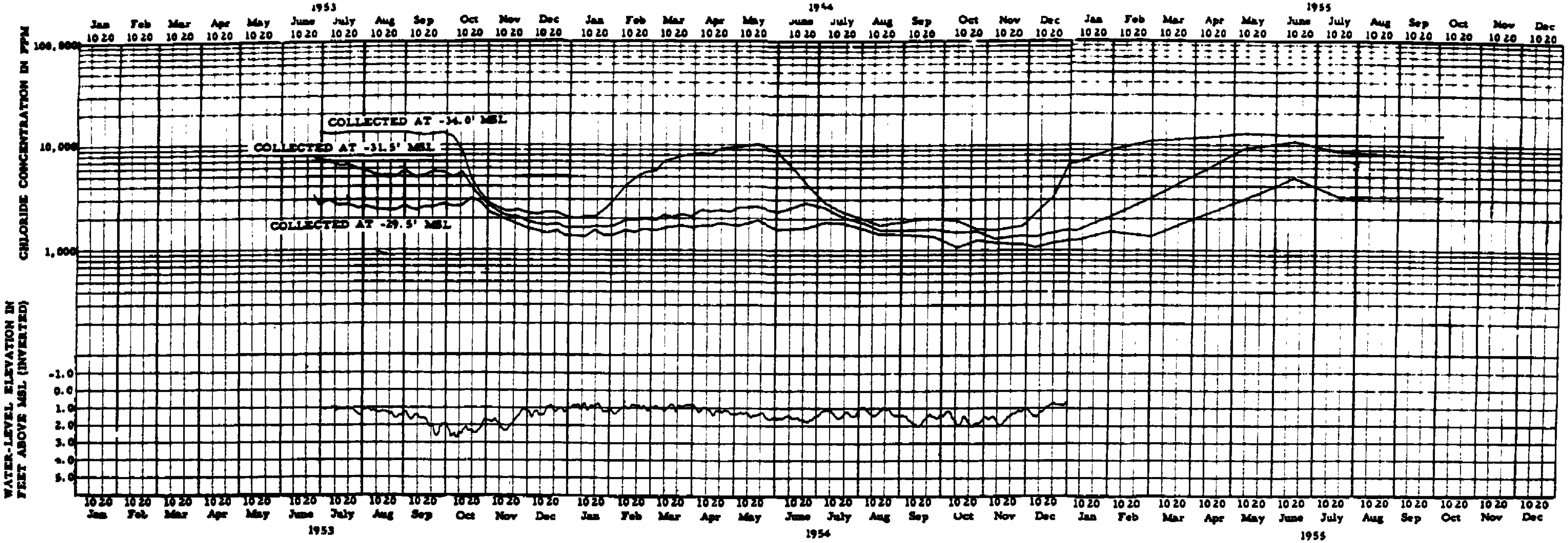

Figure 8. Graph showing fluctuations of chloride content in the open-hole part of well G-519A, compared with water-level fluctuations.

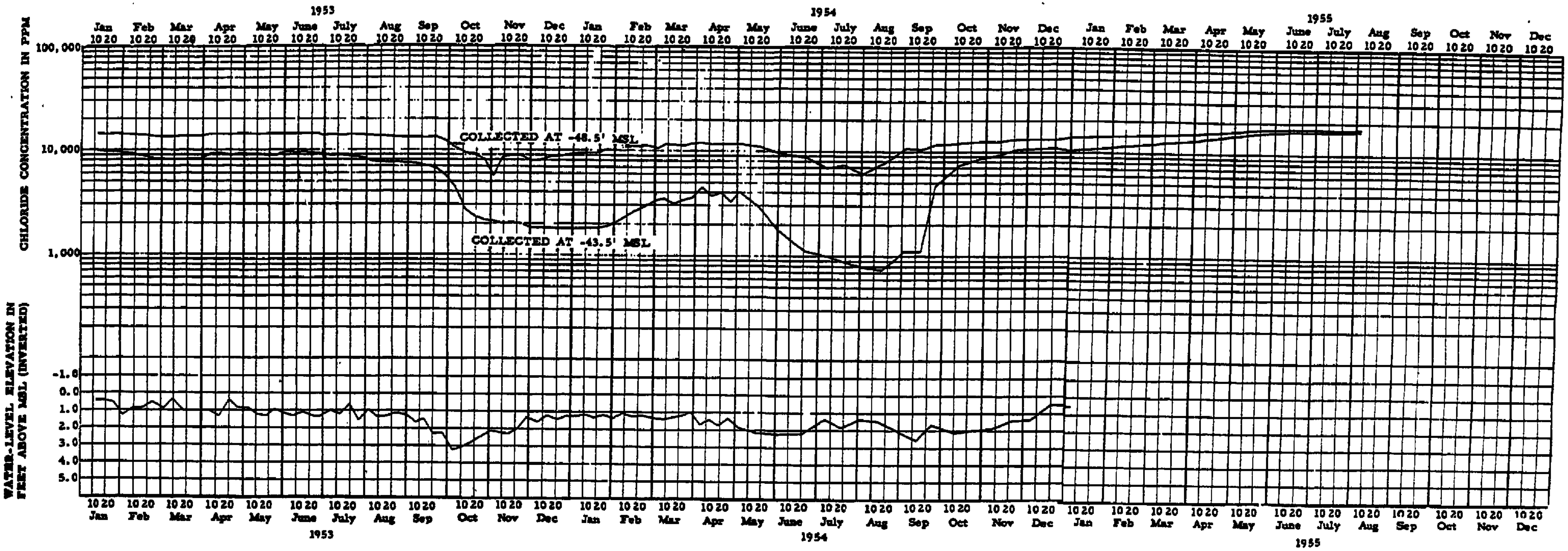

Figure 9. Graph showing fluctuations of chloride content in the open-hole part of well F-160, compared with water-level fluctuations.

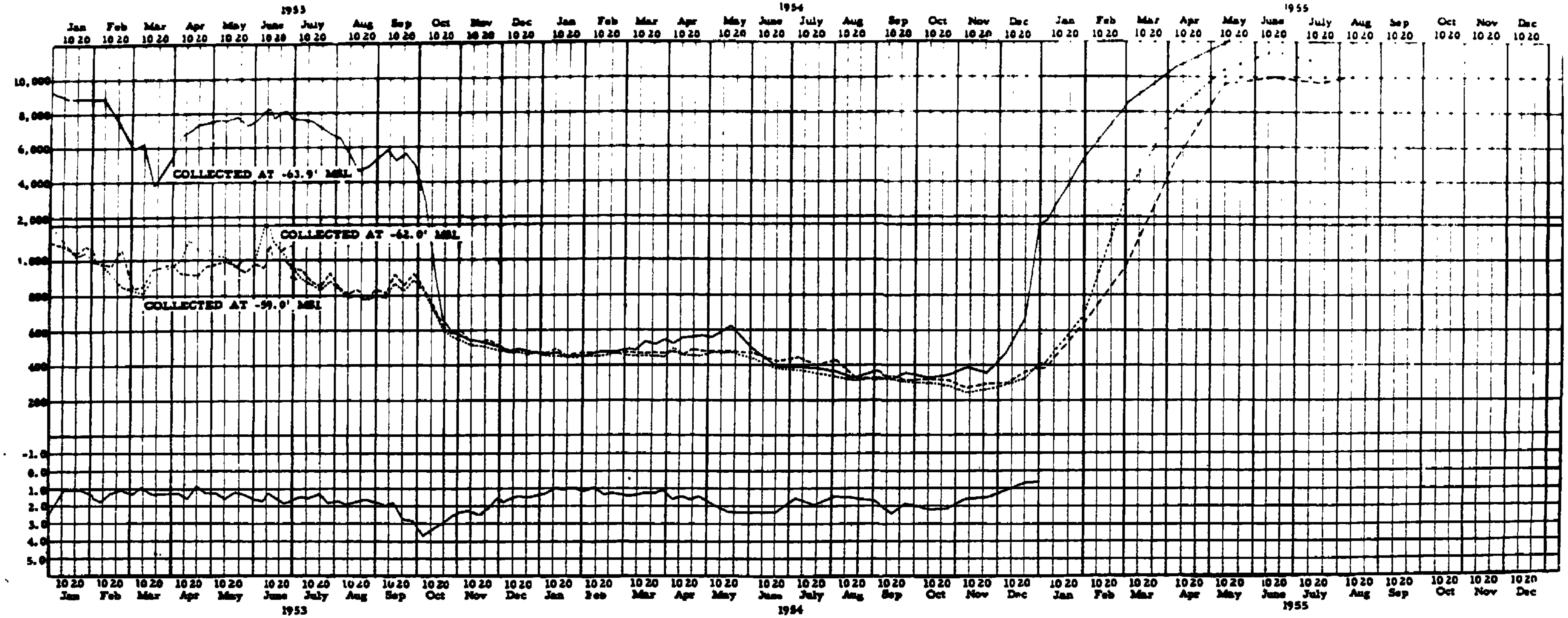

Figure 10. Graph showing fluctuations of chloride content in the open-hole part of well F-202, compared with water-level fluctuations.

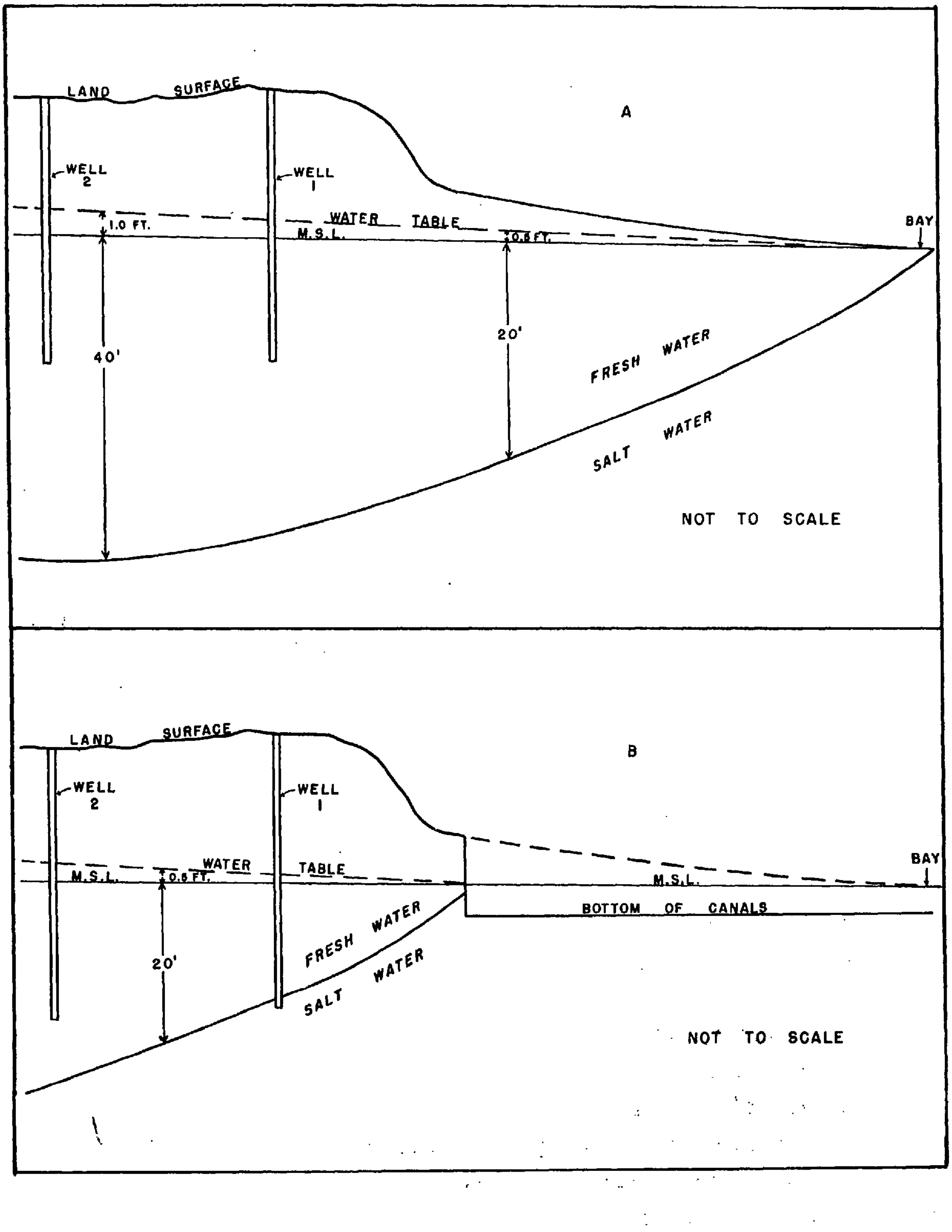

Figure 11. Diagrammatic cross section of coastal area, showing theoretical positions of the fresh-water salt-water interface.

Where a series of closely spaced, uncontrolled tidal canals has been excavated, the ultimate position of the interface would be nearly the same as if an arm of Biscayne Bay extended as far inland as the canals. A network of canals, all connected with the Bay, would cause salt water to move inland over a broad front. The intercanal areas might be underlain to shallow depth by fresh water, but during droughts some or all of the wells in these areas would yield salty water.

The sole source of fresh ground water in the Biscayne aquifer is the rainfall in the area. However, only a part of the water that falls as rain becomes ground water. Much of it runs off or is evaporated and transpired before it reaches the water table. Of that which reaches the water table some is also evaporated and transpired, and the rest flows into Biscayne Bay and the tidal canals or is pumped from wells. Obviously, if a series of uncontrolled tidal canals were dug to the bay, the rate of ground-water outflow would increase, and the water table would fall. A lowering of the water table along the coast will inevitably be accompanied by an advance of the salt-water interface.

Figure 2 indicates that there has been little encroachment in the vicinity of Cutler (south of Snapper Creek), near the center of a coastal reach that has not yet been dissected by canals. The reason that the salt water has not moved inland is probably that the water table is high locally (fig. 12). The nearest drainage canal (Snapper Creek) has little effect on ground-water levels in the Cutler area.

In summary, it is to be stressed that one of the chief causes of the encroachment of salt water in the underlying rocks in the Miami area is the system of uncontrolled or inadequately controlled tidal drainage canals. It has been shown that water-control structures, properly placed, have retarded encroachment and, in some places, have caused the salt water to retreat seaward. In some canals, however, the controls have been placed too far upstream to be effective in retarding or preventing encroachment. The effects of uncontrolled tidal canals between Biscayne Bay and the coastal ridge would be the same as if arms of the Bay extended to the ridge; the salty ground water would occur farther inland over a broad front.

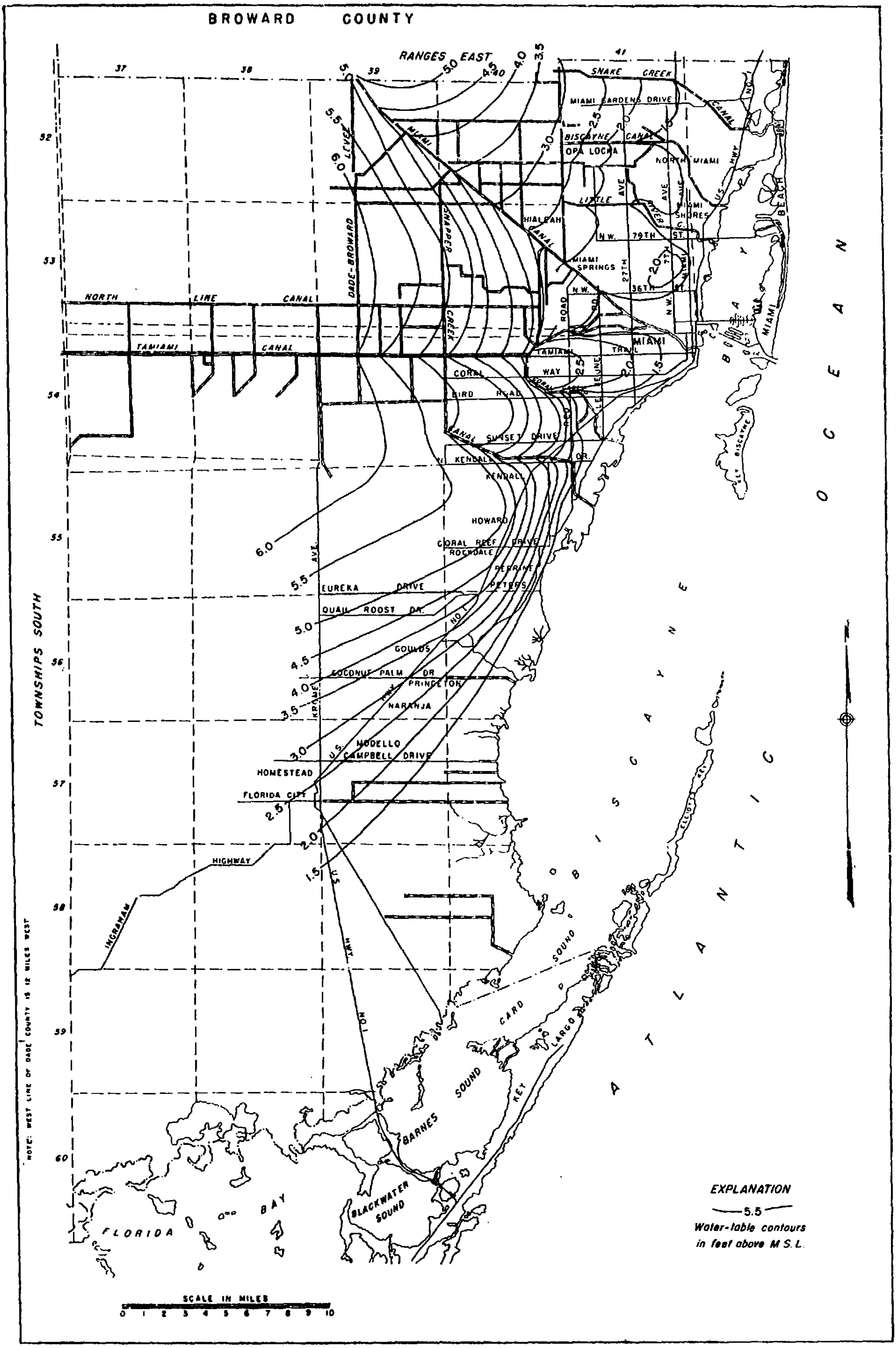

Figure 12. Contour map showing the average altitude of the water table in Dade County, 1940-50.