STATE OF FLORIDA
DEPARTMENT OF NATURAL RESOURCES
Randolph Hodges, *Executive Director*

DIVISION OF INTERIOR RESOURCES
Robert O. Vernon, *Director*

BUREAU OF GEOLOGY
Charles W. Hendry, Jr., *Chief*

Report of Investigation No. 66

SALINITY STUDIES IN EAST GLADES AGRICULTURAL AREA SOUTHEASTERN DADE COUNTY, FLORIDA

By
J. E. Hull and F. W. Meyer

Prepared by the
U.S. GEOLOGICAL SURVEY
in cooperation with
CENTRAL AND SOUTHERN FLORIDA FLOOD CONTROL DISTRICT
and the
BUREAU OF GEOLOGY
FLORIDA DEPARTMENT OF NATURAL RESOURCES

Tallahassee, Florida

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Bureau of Geology
Tallahassee
September 24, 1973

Honorable Reubin O'D. Askew, *Chairman*
Department of Natural Resources
Tallahassee, Florida

Dear Governor Askew:

The Department of Natural Resources, Bureau of Geology, is publishing as its Report of Investigation No. 66 the report entitled, "Salinity Studies in East Glades Agricultural Area, Southeastern Dade County, Florida, " by J. E. Hull and F. W. Meyer, of the U. S. Geological Survey.

The nearly frost-free climate and rich, marly soils are ideal for raising winter vegetables for northern markets. However, farming of some fields is periodically prevented by salt accumulation in the soil. This report is the result of the investigation to determine the cause of the saline soils. The results indicate there will be no improvement in saline soil problems unless land use changes significantly, permitting maintenance of higher water levels along the coast to halt the inland movement of sea water.

Respectfully yours,

Charles W. Hendry, Jr., *Chief*
Bureau of Geology

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SALINITY STUDIES IN EAST GLADES AGRICULTURAL AREA, SOUTHEASTERN DADE COUNTY, FLORIDA

By
J. E. Hull and F. W. Meyer

ABSTRACT

Saline soils in the East Glades Agricultural Area are caused chiefly by brackish ground water moving upward from the water table during dry periods. Brackish ground water is caused by infiltration of salt water from nearby coast-normal canals and by inland movement of salt water through the deep parts of the Biscayne aquifer during droughts. The soils most prone to salt accumulation generally occur within the area affected by sea-water intrusion. The outlook for the East Glades is for no improvement in saline soil problems unless land use changes significantly, permitting maintenance of higher water levels along the coast to halt the inland movement of sea water.

INTRODUCTION

The East Glades Agricultural Area, located east of Homestead in southeastern Dade County (fig. 1), is part of the nation's "winter breadbasket." The nearly frost-free climate and rich marly soil are ideal for raising winter vegetables for northern markets. Studies by the U. S. Geological Survey and the U. S. Department of Agriculture indicate that part of the East Glades is underlain by salty ground water, and that farming of some fields is periodically prevented by salt accumulations in the soil. Local agriculturalists believe that the saline soil problem might be related to operations of salinity controls at the mouths of major canals that cross the area.

In July 1970, the C&SFFCD (Central and Southern Florida Flood Control District) which is the agency responsible for regional water management, requested the U. S. Geological Survey to conduct an investigation to determine the cause of the saline soils.

PURPOSE AND SCOPE

The purposes of this investigation were to determine the source of salts in the soil and the process by which the salts accumulate. Data collected by Dr. J. D. Dalton of the Dade County Agricultural Extension Office indicates that repeated crop failures occur in the area east of Homestead due to saline soils.

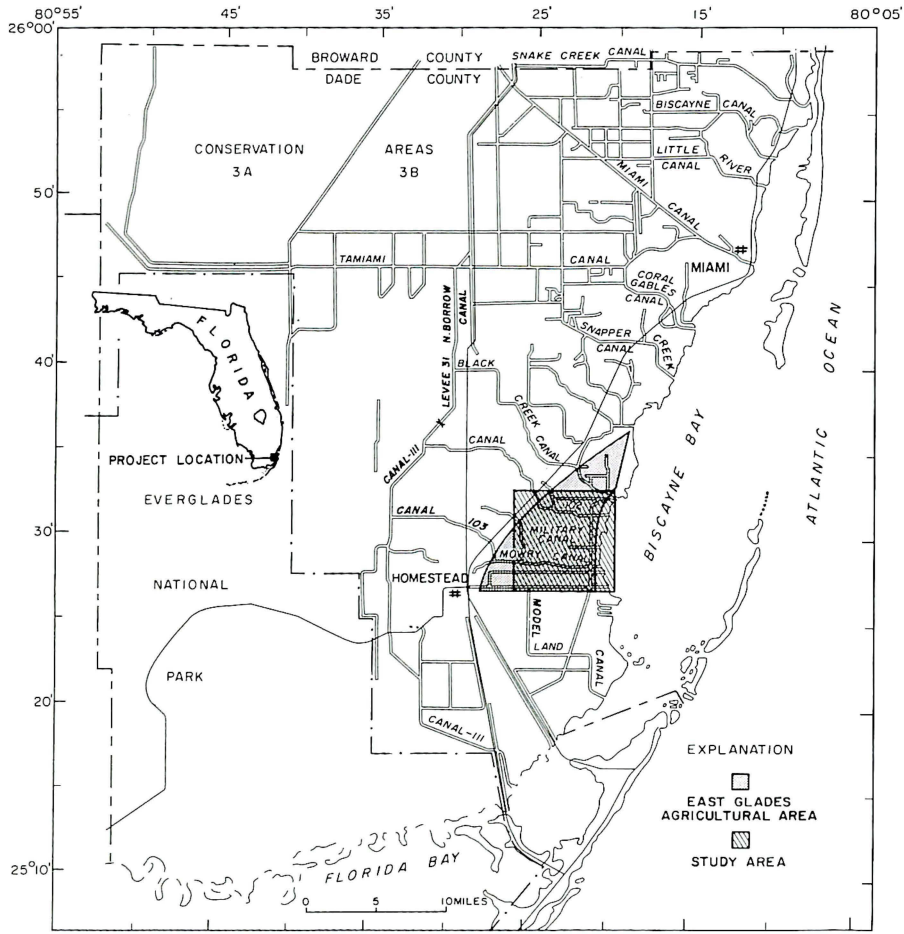


Figure 1. Dade County showing locations of East Glades Agricultural Area and study area.

After discussions with Dr. Dalton and U. S. Department of Agriculture personnel, it was decided that the investigation be centered in a 20-square mile area near the Homestead Air Force Base and that two affected areas (sites A and B on fig. 2) would be studied intensively. Site A, a 20-acre plot known locally as the East Glades Experiment Station, is about 1 mile southeast of the base; and site B, an 80-acre plot known locally as the Peterson Farm, is 0.25 mile northeast of the base.

Observation wells and piezometers were drilled to depths ranging from 1 to about 60 feet, in order to periodically collect data concerning water-levels and

salinities at different depths in the soil and in the underlying Biscayne aquifer. Water-level and salinity data were also collected in nearby canals and ditches.

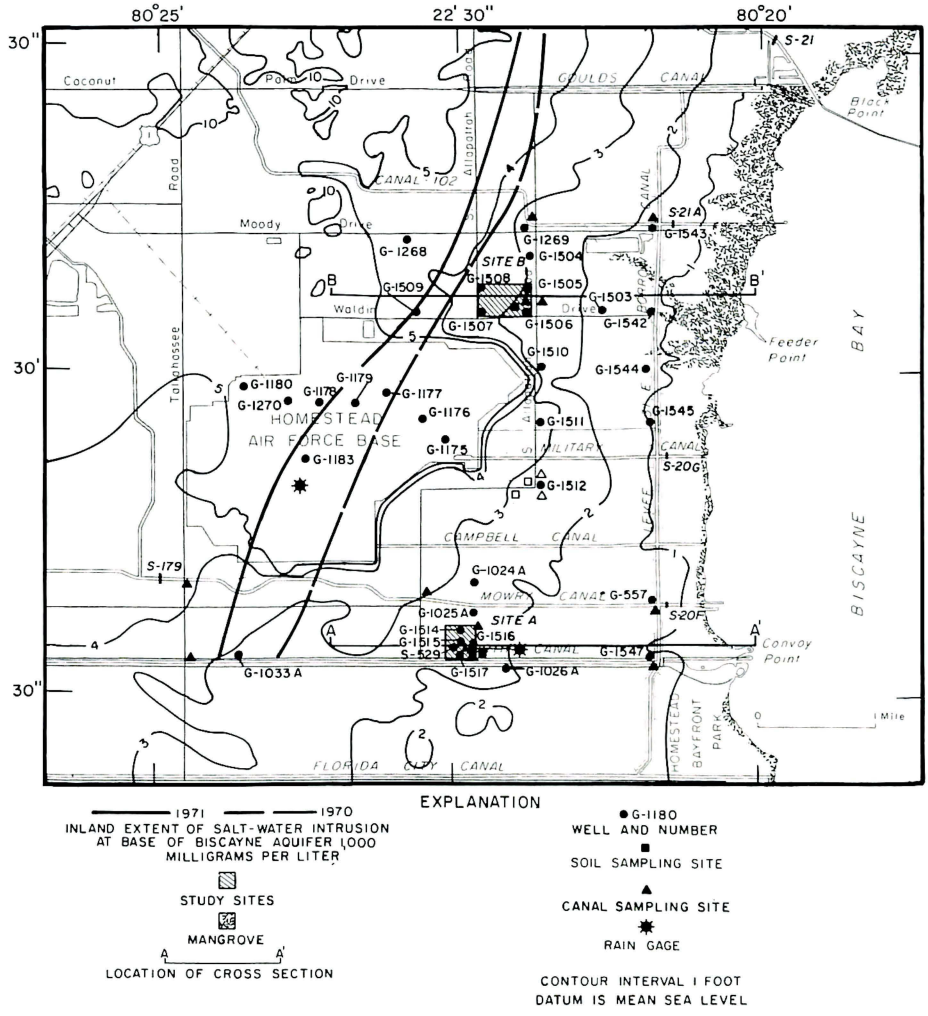


Figure 2. **Study area showing locations of special study sites, data-collection points, topography, and the positions of the 1970 and 1971 salt fronts.**

PREVIOUS STUDIES

During the drought years 1943-45, the U. S. Geological Survey investigated extensive salt contamination in canals east of Homestead. Parker, Ferguson, Love and others (1955, p. 679-682) reported salt contamination of crop land due to intrusion of sea water from nearby east-west canals. In 1945, they found that sea water had moved inland in both controlled and uncontrolled canals. Chloride concentration (which is commonly used as an indicator of sea-water intrusion) in some canals was higher than in normal sea water. Because of high evapotranspiration rates in the agricultural area, they concluded that the salty canal water seeped laterally from the canals into the porous limestone and contaminated the underlying ground water in nearby fields. They also presented a map of eastern Dade County showing the inland extent of sea-water intrusion in 1946 (1955, fig. 200). Since then the U. S. Geological Survey has mapped the approximate position of the salt front for 1951 (Klein, 1957, fig. 2), 1961 (Kohout, 1964, fig. 1), 1968 (Hull, 1970, fig. 35), 1969 (Hull, 1971, fig. 39), and 1970 (Hull, 1972, fig. 38).

The sea-water intrusion maps cited above indicate that the east half of the East Glades Agricultural Area is underlain by ground water whose chloride content is more than 1,000 mg/l (milligrams per liter) at depths ranging from a few feet near the coast to about 70 feet about 3 miles inland.

During 1967-69, E. H. Stewart and R. R. Alberts, of the U. S. Agricultural Research Service, studied the occurrence of saline soils at the East Glades Experiment Station (site A) in cooperation with the University of Florida Tropical Experiment Station and the Florida Agricultural Extension Service. Data concerning grain-size of soils, hydraulic conductivity, soil depth, ground-water levels, rainfall, leaching tests, and the distribution of chloride in the soil, were presented in the 1967-69 annual reports by the Plantation Field Laboratory, Fort Lauderdale, Florida. Data concerning the effects of crop density and water-table depth on evapotranspiration rates were reported by E. H. Stewart and W. C. Mills (1967).

ACKNOWLEDGMENTS

This report was prepared by the U. S. Geological Survey as part of the cooperative water resources program with the Central and Southern Florida Flood Control District.

The authors thank the following people for providing data and assistance during the investigation: Mr. William V. Storch, Chief Engineer of the Central and Southern Florida Flood Control District; Dr. J. D. Dalton of the Florida

Agricultural Extension Service; Messrs. E. H. Stewart and R. R. Alberts of the U. S. Agricultural Research Service; and Dr. P. G. Orth of the Florida Agricultural Experiment Station.

HYDROLOGIC SETTING

CLIMATE

The climate of the East Glades Agricultural Area is humid sub-tropical. The average annual temperature at the Homestead Experiment Station 3 miles north of Homestead is 73.7°F; and the average annual rainfall is 64.69 inches. Rainfall is usually greatest during June through November and least from December through May.

During the investigation (July 1970 - June 1971) the average temperature was 73.3°F., a departure of 0.4°F. below normal. The coldest months, January and February, averaged about 66°F. with 1 day below freezing (fig. 3). The total rainfall was 32.95 inches, a departure of 31.74 inches below normal. Rainfall was greatest from July through October 1970 and May through June 1971, and least from November 1970 through April 1971. Because the investigation was conducted during one of the most severe droughts in south Florida's history, the soil salinities probably were above normal.

TOPOGRAPHY AND DRAINAGE

Land surface slopes gently southeastward from the Homestead Air Force Base toward the shore of Biscayne Bay (fig.2). The elevation of the land along Tallahassee Road, on the west side of the area is generally less than 5 feet above msl (mean sea level of 1929), except for the area within Homestead Air Force Base which is partly filled. East of the base, the land is generally less than 3 feet above msl. The actual shoreline of Biscayne Bay probably lies slightly west of a band of mangrove trees shown on figure 2. The crest of Levee 31E, which was constructed in 1966 to prevent tidal flooding, is about 8 feet above msl. Because of the low elevation and marly soil, the East Glades is subject to flooding during the wet periods. Tidal flooding occurs infrequently when hurricane driven tides top the levee. For example, a hurricane flood tide at the Homestead Bay Front Park tide gage (see location on figure 2) on September 8, 1965 reached a height of 9.82 feet above msl.

Drainage canals and ditches were excavated through a bed of marl, ranging from about 1 to 6 feet in thickness, into the permeable Miami Oolite, the upper unit of the Biscayne aquifer. Water levels in the ditches and canals compare closely with nearby ground-water levels.

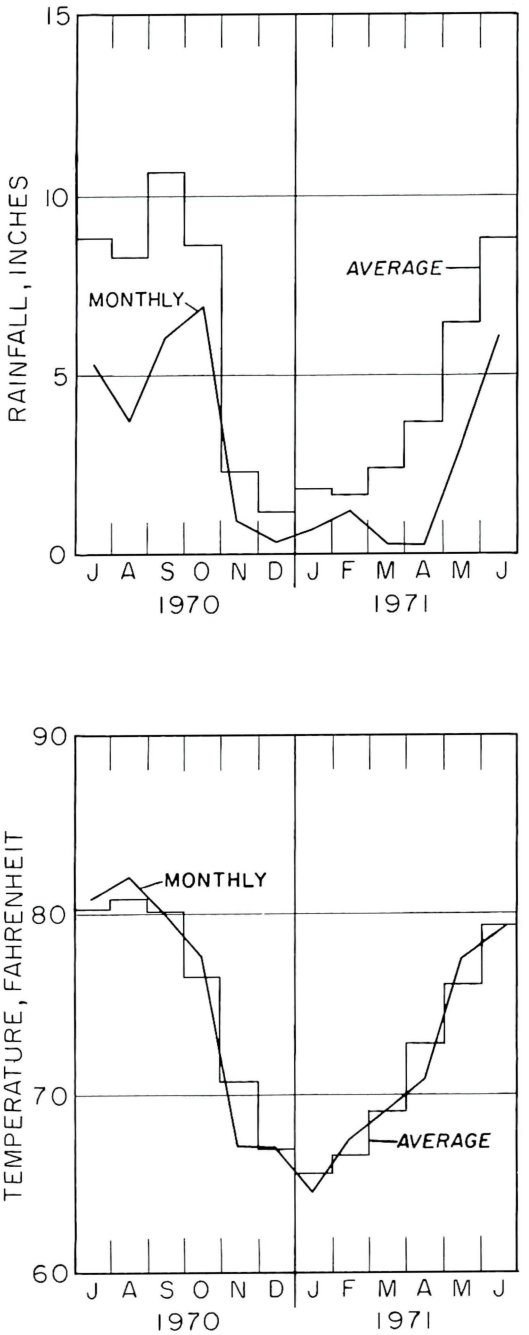


Figure 3. Monthly rainfall and temperature, July 1970 - June 1971.

Most of the area shown in figure 2 is drained by Canal 102, Military Canal, and Canal 103. Canal 102 connects the inland drainage system, which consists of Canal 111 and Levee 31N Borrow Canal with the coast (fig. 1) and water levels are controlled by strategically placed gated structures designed to hold increasingly higher water levels inland from the coast. Locally, the Levee 31E Borrow Canal receives drainage from the ditched area northeast of the base between Military Canal and Canal 102, and empties into Canal 102 just upstream of salinity control structure S-21A.

Military Canal drains only the Homestead Air Force Base, and water levels there are controlled by salinity control structure S-20G. The Levee 31E Borrow Canal is separated from Military Canal by earthen plugs.

Canal 103 (Mowry Canal) drains the area south and east of the base. The canal also connects the inland drainage system (Canal 111) with the coast, and water levels there are controlled by strategically placed gated structures designed to hold higher water levels inland from the coast. Locally, the Levee 31E Borrow Canal receives drainage from Florida City Canal, North Canal, and the ditched area southeast of the base and empties it into Canal 103 just upstream of salinity control structure S-20F.

Before Canals 102 and 103 were constructed by the C&SFFCD in the mid 1960's, water levels in the East Glades area were controlled by high-capacity low-lift pumps above dams in Florida City Canal, North Canal, Military Canal, Mowry Canal, and Goulds Canal.

Salinity controls S-21A and S-20F near the bay in Canals 102 and 103 (fig. 2) are operated by the C&SFFCD to provide drainage for the agricultural area and to abate sea-water intrusion. The operational range of the controls varies with the growing season. Usually the controls are set low (average 1.2 feet above msl) from November 15 to January 15 (the beginning of the winter growing season); and the controls are set high (average 2.0 feet above msl) during the remainder of the year. Unfortunately, certain crops, such as potatoes, require low water levels from November through April, which nearly corresponds to the annual dry season, November through May, when fresh-water levels should be held high. As a result the control settings are frequently changed during January - April in an attempt to accommodate the needs of a particular crop and to conserve fresh water at the same time. This procedure often results in insufficient fresh-water head above the controls to prevent sea-water intrusion during the latter part of the dry season.

At this point it is important to distinguish between msl (mean sea level) and present day sea, or bay level. Mean sea level is a datum based on mean sea

level of 1929 and it is used for determining relative elevations for surveys. Since 1929, mean sea level has risen at a rate of about 0.01 foot per year so that present day mean sea level averages about 0.3 foot above msl (Schneider, 1969, p. 13).

GROUND WATER

The Biscayne aquifer (Parker, 1955, and Schroeder and others, 1958) is the sole source of fresh ground water in the East Glades Agricultural Area. The aquifer, or ground-water reservoir, is composed chiefly of highly permeable limestone and locally underlies a thin bed of marl to a depth of about 60 feet below msl. The ground water is obtained from local rainfall and from rainfall on topographically higher areas to the west. The water table rises chiefly in response to infiltrating rainfall and declines in response to evapotranspiration and seepage losses.

Ground water moves generally southeastward (down gradient) across the East Glades Agricultural Area, as shown by the configuration of the water table contours in figure 4. The average position of the water table during 1959-71 ranged from about 2.8 feet above msl along the west side of the area to about a foot above msl on the east side.

The average yearly highest water level during 1959-71 was about 5.5 feet above msl along the west side of the area and about 3 feet above msl along the east side; and the average yearly lowest water level was about 1 foot above msl along the west side and slightly below msl along the east side.

Generally the water table is less than 3 feet below land surface. The capacity to store additional ground water in the East Glades is therefore relatively small and heavy rains often cause the water table to rise above land surface inundating the area. Rapid drainage of the area is achieved, however, by a network of ditches and canals which discharge into Biscayne Bay.

Because of the shallow water table the evapotranspiration loss is high. The water table, in the southeast part of the East Glades, as shown by the hydrograph for well G-1183 (fig. 5) often declines below bay level during the dry season due to high evapotranspiration and to inadequate recharge from rainfall and the canals. During April and May 1971, water levels in the south half of the East Glades area declined below bay level and an extensive water-level depression developed in the area south of Canal 102. The contour pattern in the study area for April 14-15 (fig. 6), shows that fresh water was moving south toward the center of the depression, and that salt water was moving westward toward the center from Biscayne Bay. Within the large water-level depression are three smaller depressions, which indicate locally higher ground-water loss; and a ground-water mound which indicates recharge.

The water-level depressions near sites A and B (as shown by the minus 0.3-foot contours) are a result of evapotranspiration; and the cone of depression within Homestead Air Force Base, as shown by the minus 0.1-foot contour, is a result of well-field pumpage. The ground water mound about Military Canal is a result of infiltration of effluent from the base sewage treatment plant.

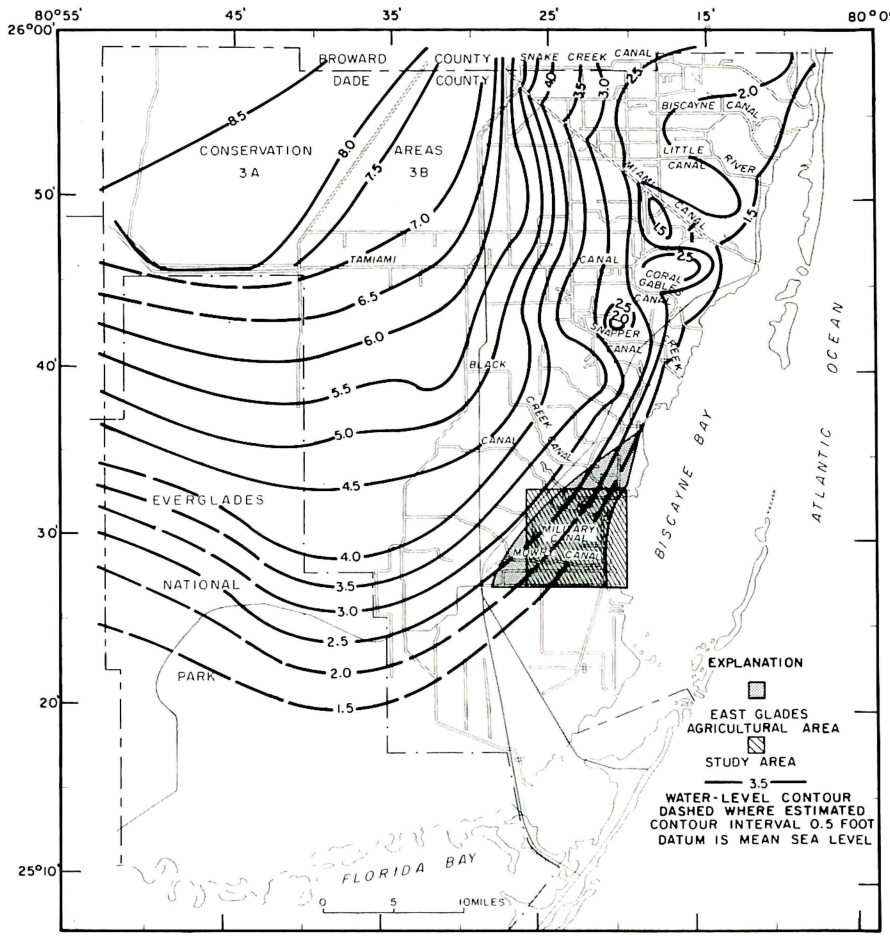


Figure 4. Dade County showing contours on the average water table, 1959-71.

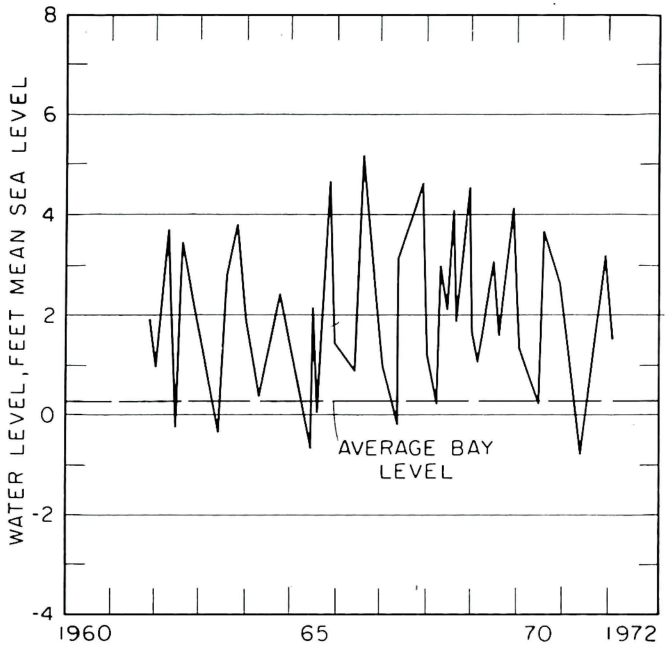


Figure 5. Hydrograph for well G-1183 at Homestead Air Force Base, 1961-72.

SEA-WATER INTRUSION

The salinity of water in the East Glades Agricultural Area varies seasonally. During the wet season, water levels are usually higher in the interior and fresh water moves generally eastward through the canals and aquifer to flush salts toward Biscayne Bay. During the dry season, water levels in the interior are usually low and fresh-water flow to the coast is generally insufficient to sustain coastal water levels high enough to prevent inland movement of sea water into both the canals and aquifer.

Sea-water intrusion is commonly detected by high chloride concentration in the water. Chloride concentrations in fresh ground water or surface water are generally less than 20 mg/l. The concentration of chloride in water in Biscayne Bay averages about 20,000 mg/l.

During the 1943-45 drought, sea water had moved inland through controlled and uncontrolled coastal canals almost to Homestead and, in some cases, the chloride content in water in the canals exceeded that in normal sea water by 30 percent (Parker, 1955, p. 679-682, fig. 188). Analyses of water from test wells about 3 miles southeast of Homestead indicated in 1941 that ground water at depts of 70 feet contained more than 20 mg/l of chloride.

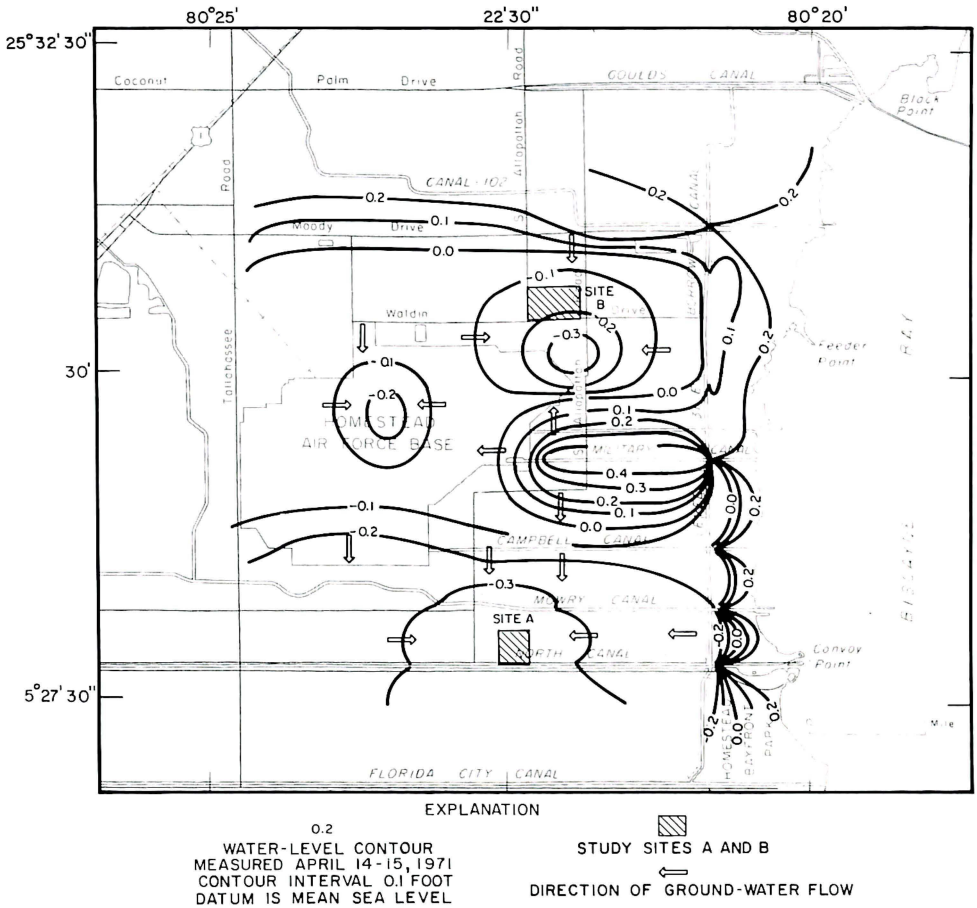


Figure 6. Water-table map of study area, April 14-15, 1971.

In December 1946, G. G. Parker, R. H. Brown, D. B. Bogart, and S. K. Love, of the U. S. Geological Survey, mapped the approximate inland extent of the 1,000 mg/l chloride line (salt front) at the base of the Biscayne aquifer in eastern Dade County (p. 709). From 1946 to 1971 the salt front moved only slightly farther inland beneath the East Glades area (fig. 7). The greatest inland movement occurred south of Canal 102 in the vicinity of Homestead Air Force Base in 1971 as a result of drought conditions and wellfield pumpage. Data are insufficient to determine the position of the salt front prior to development and drainage, but the low altitude of the area and close proximity to the bay suggest that the salt front was inland from the coastline before any of the area was drained.

Variations in chloride content in water from well S-529 at site A during 1945-72 (fig. 8) indicate the advance and retreat of the salt front. Inland movement is indicated by increasing chloride content and bayward movement by decreasing chloride content. Inland movement was caused chiefly by the droughts of 1943-45, 1956-57, and 1970-71 and by tidal inundation from severe hurricanes in 1946 and 1965. Bayward movement was caused chiefly by heavy rains and associated high water levels during 1947-48, 1958-60, and 1968-69.

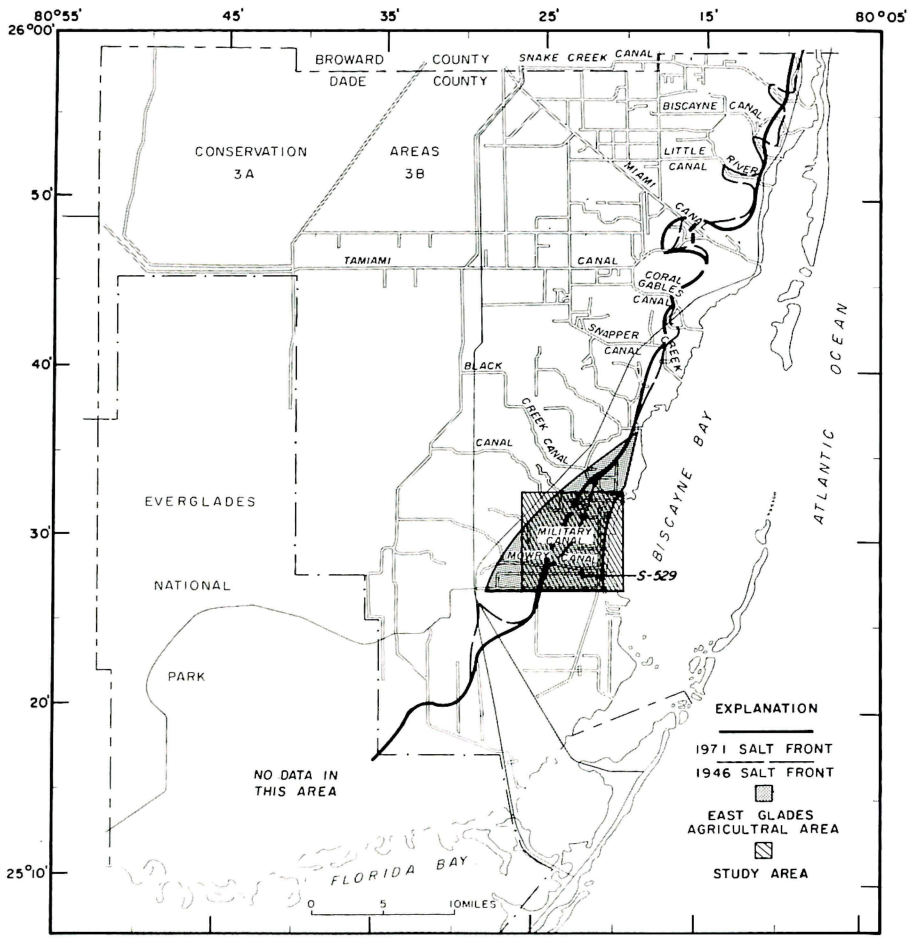


Figure 7. Dade County showing the approximate position of the 1,000 milligrams per liter chloride line at the base of the Biscayne aquifer, 1946 and 1971.

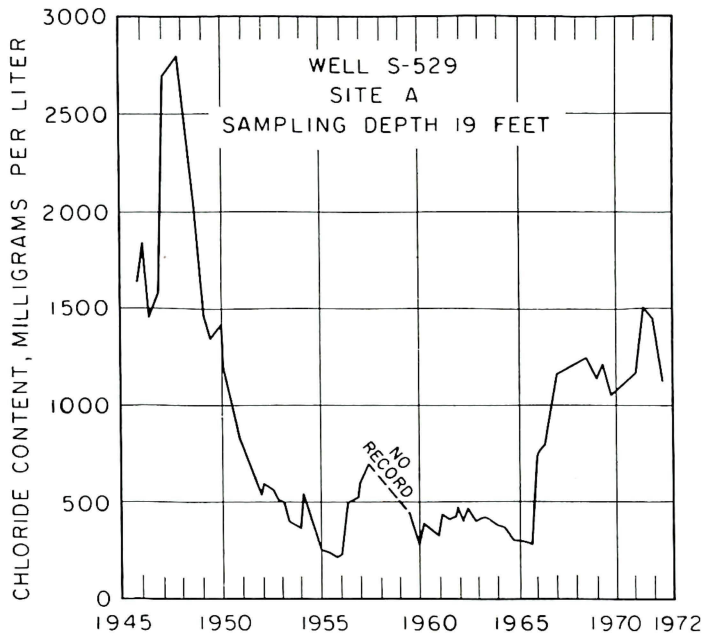


Figure 8. Chloride content in water from well S-529 at site A, 1945 - 72.

During 1965-67, Levee 31E was constructed to protect the East Glades area from hurricane tides; and water-control facilities were constructed to improve drainage. Prior to construction of these works the chloride concentration in water from well S-529 decreased at a relatively rapid rate following heavy rains. Only slight reductions in chloride content have occurred under similar conditions since completion in 1967. The apparent reduction in flushing capability is believed by the authors to be related to the reduction in peak water levels which formerly provided the necessary fresh-water head to move the salt front toward Biscayne Bay.

Studies by Klein (1957) and Kohout (1964) in canals north of East Glades suggest that water levels upstream from salinity controls should be maintained at least 2 feet higher than present sea level, or about 2.3 feet above msl, in order to prevent sea-water intrusion. However use of this criterion would cause inundation of a large part of the area of investigation.

LAND USE

The East Glades Agricultural Area is farmed extensively. Principal crops are tomatoes, potatoes, snap beans, pole beans, squash, cabbage, peppers, celery,

and corn. Malanga and yucca were recently introduced to the area due to their popularity with the growing Latin population. During early stages of development before 1940 most of the area east of U. S. Highway 1 was cropped except for the mangrove and tidal marsh areas along the coast. During recent years, the Homestead Air Force Base and urban development have encroached upon the area from the west and cropland along the coast has been abandoned due to poor drainage, salt-water contamination, and saline soil conditions. The current (1971) distribution of agricultural land east of U. S. Highway 1 is shown on the land use map (fig. 9).

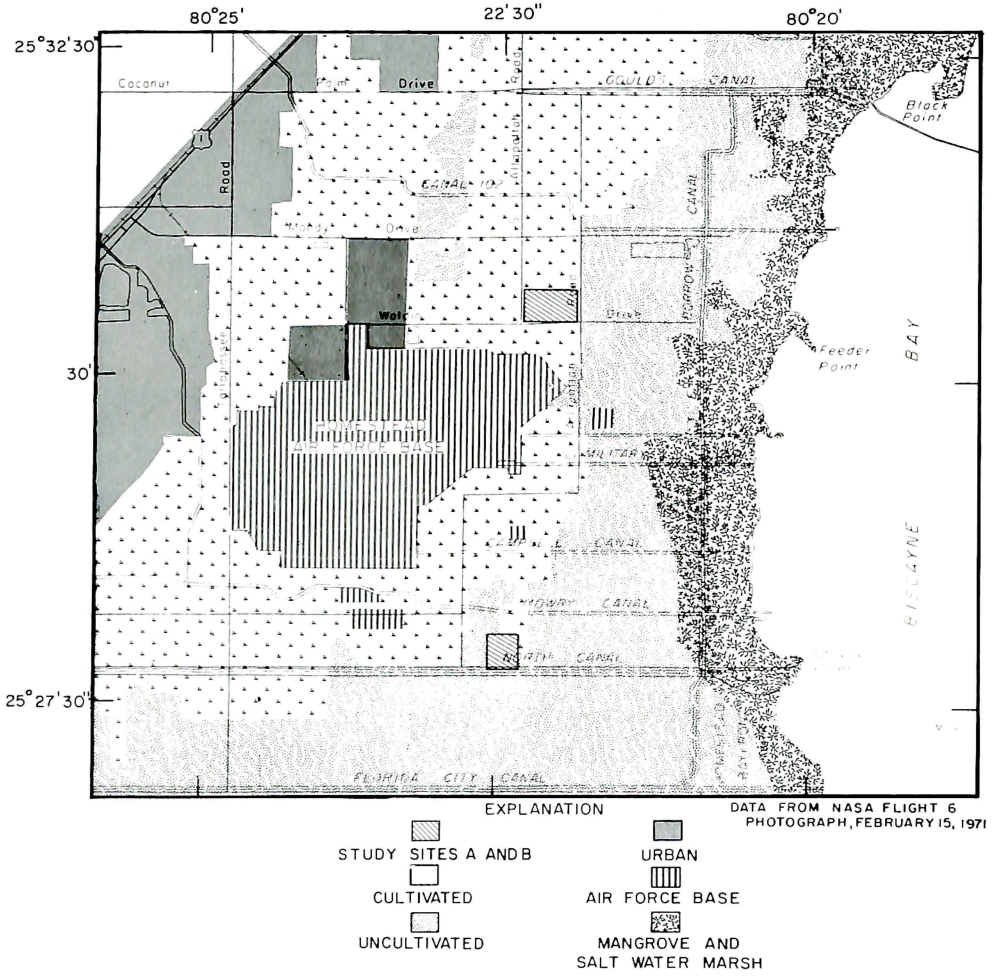


Figure 9. Land use in southeastern Dade County, February 1971.

SOILS

The dominant soil in the East Glades agricultural area is the Perrine marl (Leighty and others, 1958). It is composed chiefly of unconsolidated finely divided calcareous sediments that are mainly of fresh-water origin. The marl contains slightly more silt than clay. The hydraulic (saturated) conductivity of the soil is very low and the water retentivity is high. Capillary conductivity of the soil is high; therefore upward movement of water from the water table occurs during dry periods. The porosity of the soil is about 50 percent.

Generally the Perrine marl has a silty loam texture and varies in thickness from a few inches on the limestone ridge near U. S. Highway 1 and Homestead Air Force Base to about 6 feet along the coast. The soil is alkaline and low in organic matter, nitrogen, available phosphorus, and potassium. The lack of mineral nutrients necessitates frequent fertilize applications. The marl occurs chiefly in flat areas only a few feet above sea level and frequently becomes waterlogged during the rainy season unless drained. During the dry season, the soils often become either too friable and (or) too salty for plant growth. Therefore, drainage irrigation, and heavy fertilized applications are required in order to farm this soil.

The soils map of the study area (fig. 10) shows that the Perrine marl feathers out against the limestone ridge (designated as Rockdale soils) in the vicinity of the Homestead Air Force Base. The marl deposit is thickest in a band parallel to the coastline.

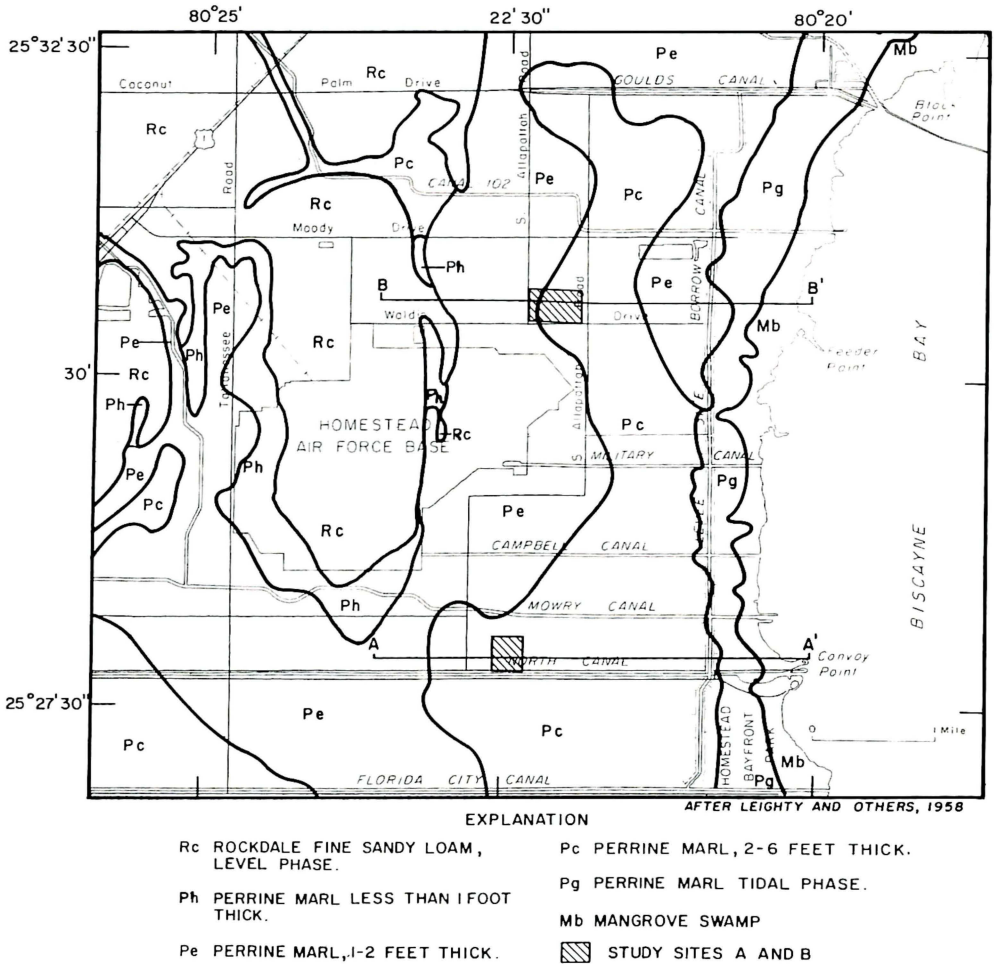
EAST GLADES SALINITY STUDIES

SITE A - EAST GLADES EXPERIMENT STATION

DESCRIPTION

Site A, locally referred to as the East Glades Experiment Station, is east of Homestead and about 2.2 miles west of Biscayne Bay on the west side of SW 112 Avenue extended between SW 328 Street (North Canal Drive) and SW 324 Street extended (see location on figs. 2 and 11). The site is about 20 acres and it is used extensively as an experimental farm by personnel of the Florida Agricultural Experiment Station in Homestead.

Land surface at site A ranges in altitude from 1.4 to 2.6 feet; most of it is above 2.0 feet. The surface is pockmarked by numerous small depressions which are only a few tenths of a foot lower than the surrounding land. Some of the depressions appear to be surface expressions of similar features on the



AFTER LEIGHTY AND OTHERS, 1958

EXPLANATION

Rc ROCKDALE FINE SANDY LOAM, LEVEL PHASE.

Ph PERRINE MARL LESS THAN 1 FOOT THICK.

Pe PERRINE MARL, 1-2 FEET THICK.

Pc PERRINE MARL, 2-6 FEET THICK.

Pg PERRINE MARL TIDAL PHASE.

Mb MANGROVE SWAMP

STUDY SITES A AND B

Figure 10. Soils map of study area.

underlying limestone surface, thereby suggesting relatively recent sinkhole development.

The Perrine marl underlies the site to a maximum depth of 3 feet. The average thickness of the marl is about 2.5 feet and the marl feathers out to the west against the limestone ridge near Homestead Air Base. Ditches on the north and east side of the site convey excess water northward about one-quarter mile to Canal 103 (Mowry Canal). Fields to the east have been abandoned for farming due to salinity and drainage problems. Salt accumulation in the soil has been a long-term problem at site A.

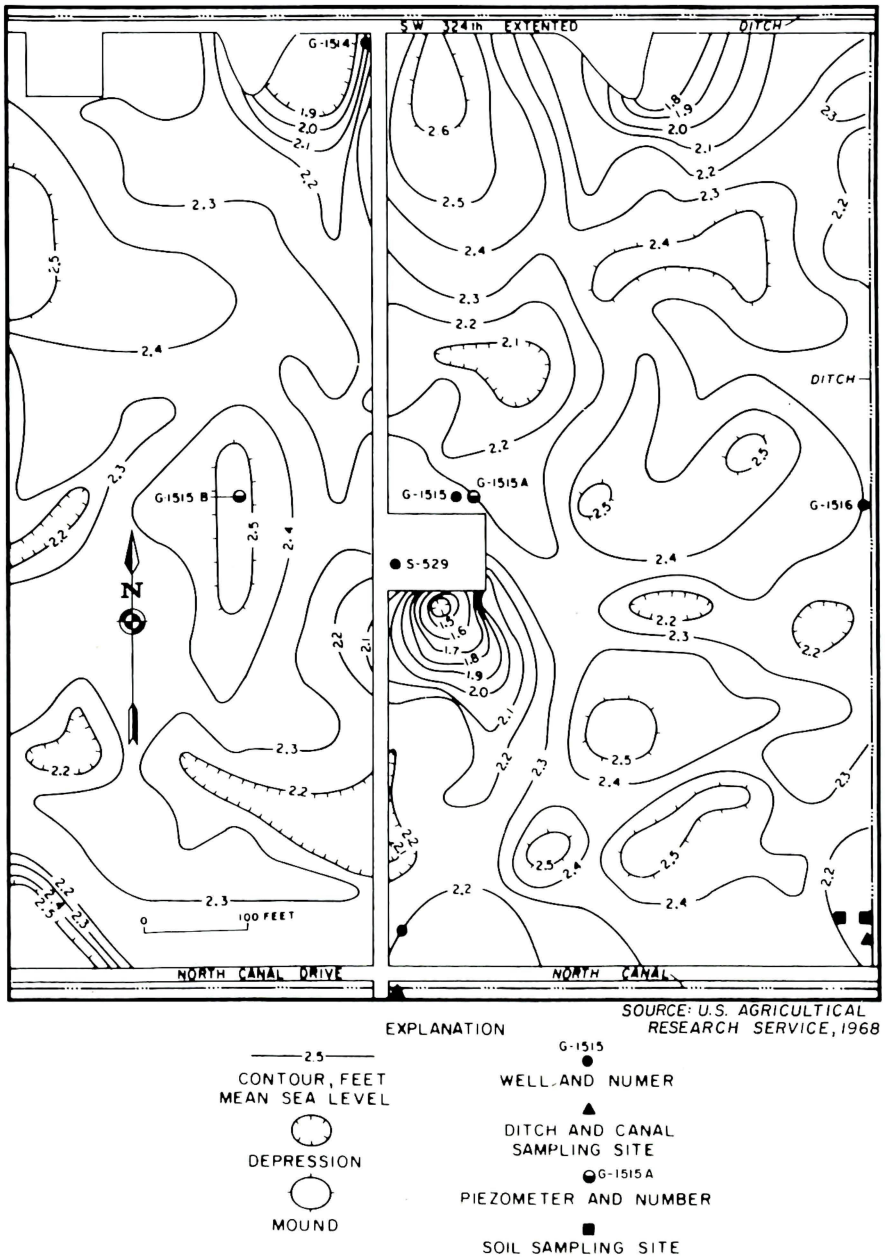


Figure 11. Site A showing locations of data collection points and topography.

Table 1. Records of wells at site A.

Well Number: Lettered numbers are for piezometers.

Water Level: Measured on April 15, 1971.

Chloride: Sample collected at bottom of well on April 15, 1971.

Well Number	Depth (feet, msl)	Casing (feet, msl)	Casing Diameter (inches)	Elevation Land Surface (feet, msl)	Water Level (feet msl)	Chloride (mg/l)	Remarks
G-1514	-58.28	- 2.72	6	2.72	-0.36	11,800	Continuous water-level record
G-1515	-57.45	- 2.54	6	2.46	-0.35	11,400	Continuous water-level record
G-1515A	+ 0.34	+ 0.34	9	2.46	Dry	Dry	Continuous water-level record
G-1515B	- 1.11	- 0.61	2	2.50	-0.38	910	
G-1515C	-12.82	-12.32	2	2.50	-0.40	1,225	
G-1515D	-17.14	-16.64	2	2.50	-0.37	1,400	
G-1515E	- 8.59	- 8.09	2	2.50	-0.37	920	
G-1515F	-22.28	-21.78	2	2.50	-0.38	1,550	
G-1515G	-11.38	-10.88	2	2.50	-0.38	1,125	
G-1516	-55.00	- 2.62	6	2.38	-0.39	11,900	Continuous water-level record
G-1517	-56.05	+ 1.05	6	3.05	-0.35	11,000	

Descriptions of wells and piezometers at site A are presented in table 1. Data on water levels, soil salinity, and water salinity were collected at the points shown on figure 8. Most of the data were collected during January through June 1971. Rainfall data at the site were obtained from Dr. P. G. Orth of the Florida Agricultural Experiment Station. Soil salinity data were obtained from Dr. J. D. Dalton of the Dade County Agricultural Extension Office. Supplementary water-level and salinity data were collected at selected points in the vicinity of site A as shown on figure 2. Results of intensive studies of saline soils at the site by E. H. Stewart and R. P. Albert during 1967-69 were used to help determine cause-and-effect relationships.

WATER LEVELS AND WATER MOVEMENT

The water table at site A normally is about 0.8 foot below land surface, or about 1.5 feet above msl. The water table rises when recharge by infiltrating rainfall and canal water exceed losses by drainage and evapotranspiration. During the wet season it frequently rises above land surface; and during the dry season it often declines below bay level. The water table at site A is closely related to the water levels in Canal 103 and other nearby canals because the hydraulic connection between the Biscayne aquifer and the canals is good.

Semidiurnal water-table fluctuations resembling tidal fluctuations are frequently observed during wet periods. These fluctuations are caused by the reduction in flow when the automatic tide gates in salinity control S-20F in Canal 103 close in response to high tides in Biscayne Bay, thereby producing a pulse effect. Evapotranspiration during daylight hours causes a diurnal fluctuation in the water table during dry periods.

A comparison of the water level in Canal 103 upstream from the salinity control structure S-20F with the water level in Biscayne Bay at Homestead Bayfront Park (fig. 12) indicates that the automatic gate control was set to hold upstream water levels at about 1.8 feet above msl during July through October 1970. During late October the setting was lowered about one-half foot and upstream water levels held at about 1.3 feet above msl until January 1971 when the water level in the canal began to decline more rapidly. By February 6 the water level fell to 0.7 foot above msl but rose sharply to 1.3 feet above msl by February 14 due to local heavy rainfall. As a result of the rain, the automatic gates in S-20F opened and part of the timely rainfall was discharged to the bay. During March through mid-May the water level in Canal 103 declined due chiefly to evapotranspiration losses in the surrounding area. By mid-March the water level declined below bay level and the normal bayward hydraulic gradient was reversed. As a result bay water began to seep inland around S-20F to contaminate parts of Canal 103, the Levee 31E Borrow Canal, North Canal, and

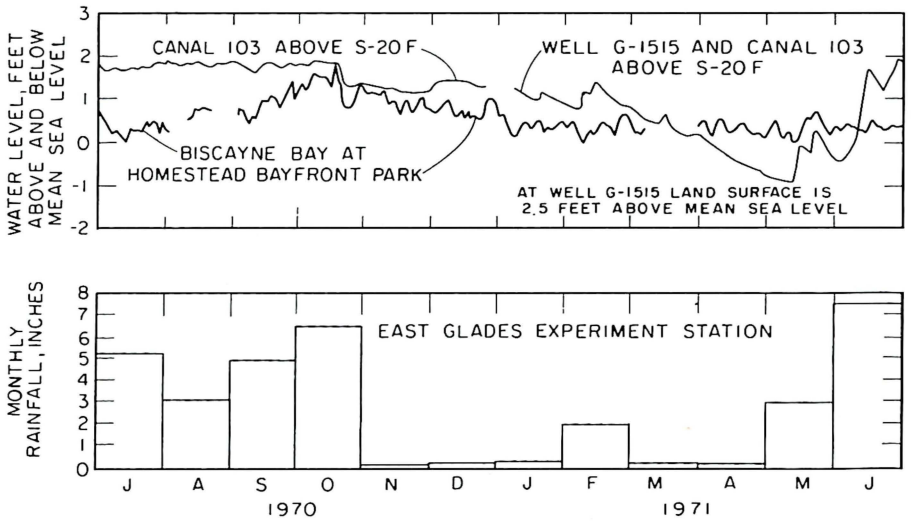


Figure 12. Water levels in Canal 103 in Biscayne Bay, and in well G-1515; and local rainfall; July 1970 - June 1971.

Florida City Canal. By May 11 the water level had declined to 0.95 foot below msl (or about 1.2 feet below bay level) and parts of the canals were highly contaminated by salt water. Heavy rains in late May and in June caused water levels to rise to 1.8 feet above msl at the end of June thus ending the 1971 drought.

Early in March the water table, as shown by the water level in well G-1515 on figure 12, began to decline below the bottom of the marl in a small area at the west side of site A and by May 11 the water table declined below the marl. The hydraulic continuity between the water table and the marl was reduced and capillary flow from the water table to the surface probably decreased.

The water-table map for April 14-15, 1971 (fig. 6) shows that site A was within a shallow depression (as shown by the minus 0.3-foot contour), the center of which was slightly west and south of site A. Ground-water movement, though slight, was chiefly westward beneath site A from Biscayne Bay. The principal direction of regional ground-water movement was, however, upward to the surface as a result of evapotranspiration.

Evapotranspiration is high because the ground altitude is low and the water table is near land surface, and the Perrine marl and the water table are

usually in contact, thereby providing excellent capillary flow to the surface.

In order to more clearly describe the flow pattern at site A a cross section (fig. 13) was constructed along line A-A' located on figure 2. The data for April 15, 1971 were selected to show the position of the water table and the distribution of chloride. The general direction of water movement is shown by arrows, and the number of arrows represent the relative amounts of flow.

Flow upward through unsaturated soil is generally greatest where the water table is nearest to land surface, provided all other things are equal. On this basis, flow would be slightly greater on the east side of site A than on the west side. Because the salt content in ground water is also greater on the east side, a higher salt accumulation would be expected there.

The decline in water levels at site A during February - May was caused chiefly by evapotranspiration. The water table at site A declined at an average rate of 0.029 foot per day during April 1971, according to the hydrograph for well G-1515 on figure 12. The approximate evapotranspiration from aquifer storage was computed by using the equation:

$$ET_S = R\,P$$

where ET_S is the average daily evapotranspiration loss, in feet per day, from ground water storage.

R is the rate of water-level decline, 0.029 foot per day.

P is the aquifer porosity, 0.25.

By substitution,

$$ET_S = 0.029 \text{ foot per day} \times 0.25$$
$$= 0.0072 \text{ foot per day, or about 2,400 gallons per day per acre.}$$

In addition to the storage depletion estimated above, total evapotranspiration would include return of precipitation and transfer of incoming ground water to the air. Rainfall in April 1971 was very small and may be neglected. Based on approximate water table gradients in figure 6 and a transmissivity of 400,000 feet squared per day, a crude estimate of transfer of ground-water inflow to the air in April 1971 amounted to 0.006 foot per day, or about 2,000 gallons per day per acre. The net ET is therefore about 0.013 foot

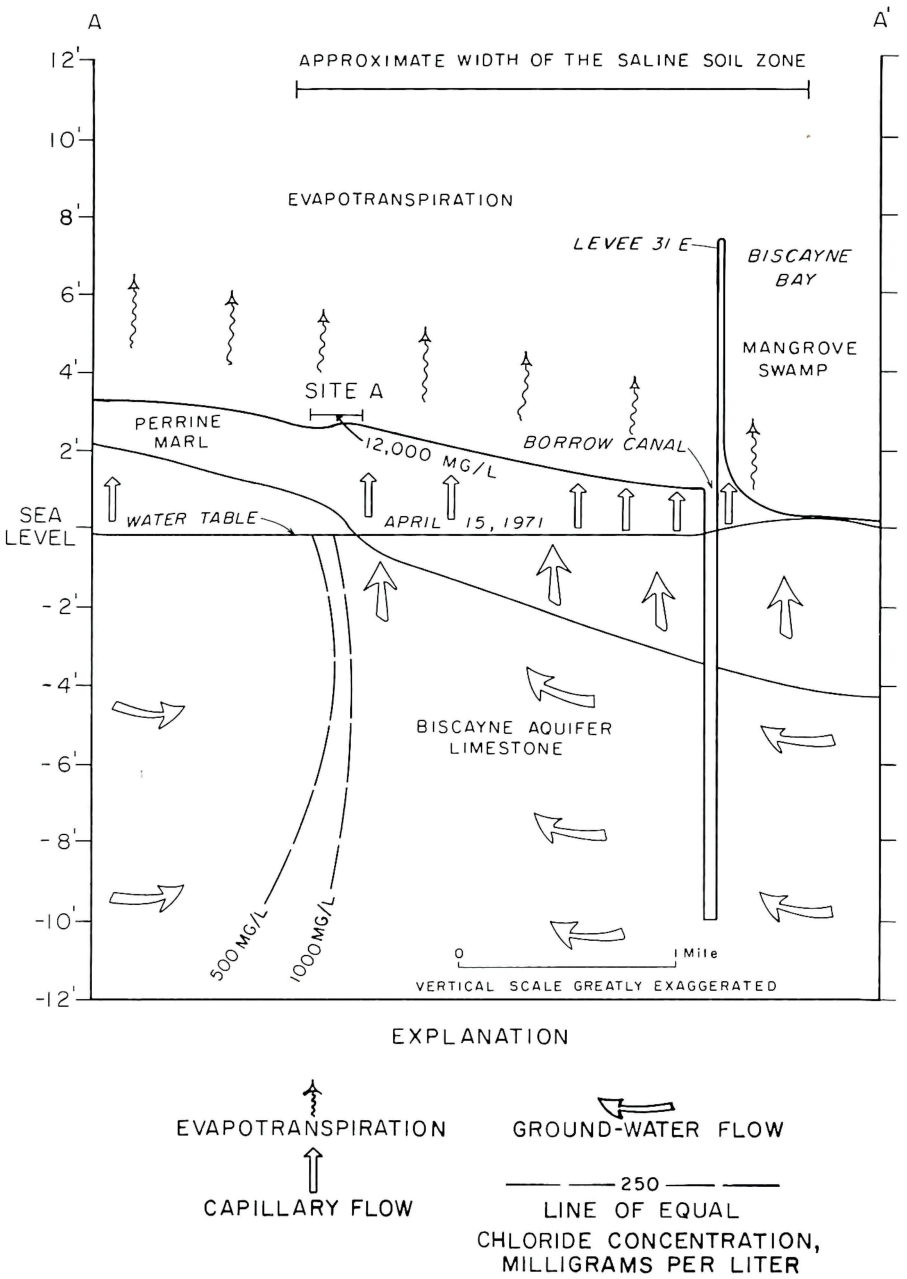


Figure 13. Generalized cross section A-A' through site A showing water movement and chloride content.

per day, or about 4.7 inches per month. This estimated value does not include the small amount of rainfall in April and effects of salt content on hydraulic gradients, thus the estimated value is lower than the true value. But the value compares well with estimates of 4 inches for April, based on average evapotranspiration from fully sodded, fine sand, evapotranspirometers in which the water table was about 3 feet below the surface (Steward and Mills, 1967).

DISTRIBUTION AND SOURCE OF SALTS

At site A, chloride concentrations were highest in the top two inches of soil and in the ground water at the base of the Biscayne aquifer (fig. 14). In the extracts from soil samples obtained from the southeast corner of the site, chloride concentrations ranged from about 200 mg/l in October 1970 to 15,000 mg/l in May 1971. Soil samples obtained at the east edge of the field (outside) within a tree line during August 1970 through February 1971, contained about the same amount of chloride as that inside the field; however, samples obtained there during March through May 1971 contained only minor amounts of salt compared to the samples taken from inside the field. A comparison of the chloride concentrations in the soil with the concentration in water from Canal

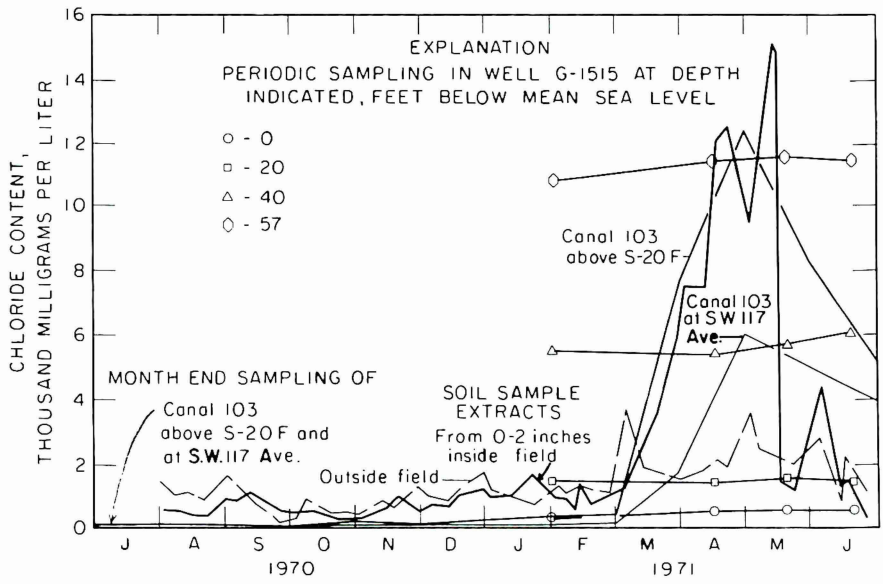


Figure 14. Chloride content in soils at site A, in Canal 103 at SW 117 Avenue and above S-20F, July 1970 - June 1971; and chloride content in water from selected depths in well G-1515, January-June 1971.

103 suggests that during March through May the soil salt was related to the increase in salt content in the canal water. Rains during late May and June 1971 effectively leached most of the salt from the soils at both locations and flushed salt water from Canal 103.

The effect of the 1971 drought was more subtle in the aquifer than in the canals and soils, because salt concentrations there increased less spectacularly as shown by the concentration in water at selected depths from well G-1515 (fig. 14). The chloride content in water from well G-1515 near the center of the site increased only a few hundred milligrams per liter at all levels.

A comparison of the vertical distribution of chloride in water from wells G-1514 through G-1517 on April 15, 1971 (fig. 15) shows that chloride content

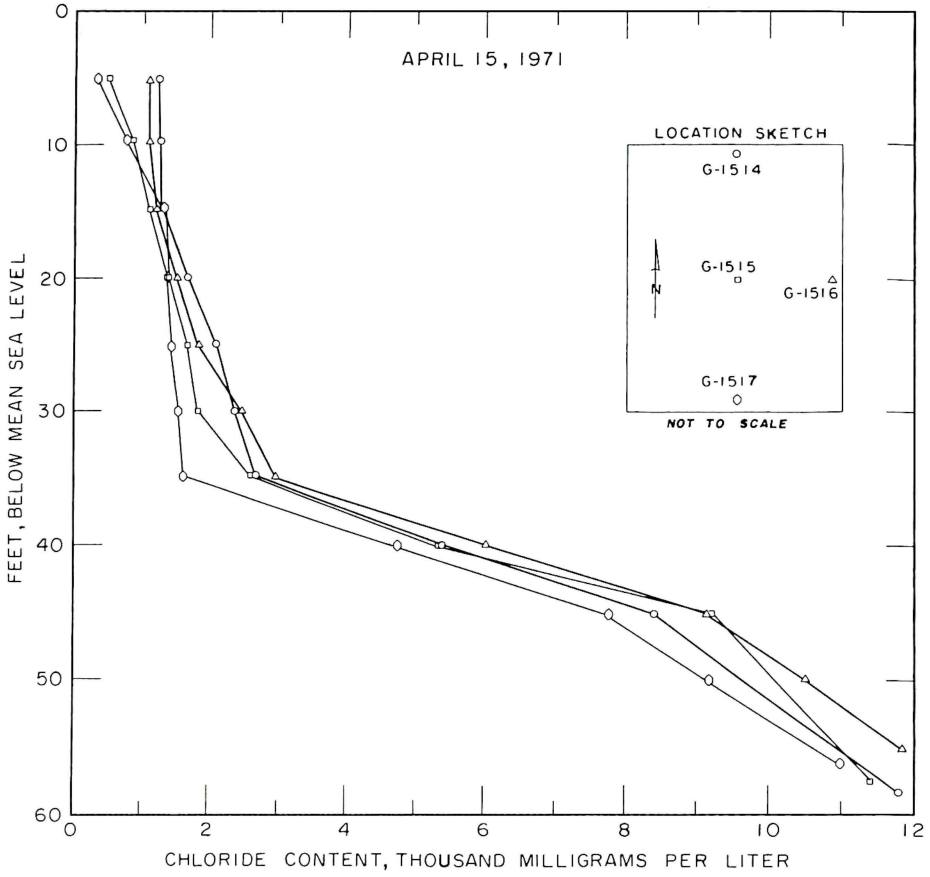


Figure 15. Chloride content in ground water in wells G-1514 through G-1517 at selected depths, April 15, 1971.

in ground water at 5 feet below msl was higher in wells G-1514 and G-1516 than in wells G-1515 and G-1517, thereby suggesting that the source of salt-water intrusion was located northeast of site A; or in the vicinity of Canal 103.

Data collected on April 15, 1971 were selected to show the dry season chloride (salinity) distribution at site A. The chloride content in the soil extract (inside field) was 12,000 mg/l. The chloride content of water in the unsaturated soil zone was not determined because samples of soil water were not obtained there. Water in nearby ditches contained 1,200 mg/l chloride. Chloride content in ground water at mean sea level ranged from 400 mg/l in wells G-1515 and G-1517 to 1,100 mg/l in wells G-1514 and G-1516; chloride content in these four wells at elevation -10 feet msl was about 1,100 mg/l, and below elevation -40 feet msl was more than 5,000 mg/l. Chloride content of the water at the bottom of North Canal adjacent to site A was 3,800 mg/l; in water at the bottom of Canal 103 at SW 117 Avenue was 2,800 mg/l, and upstream from the control S-20F it was 12,400 mg/l.

The amount of salt (as NaCl) carried to the surface daily by capillarity and osmosis was computed to be about 64 pounds per acre, based on an evapotranspiration rate of 0.013 foot per day and a sodium chloride content of 1,800 mg/l (1,100 mg/l chloride).

Thus the distribution of chloride in water at site A suggests that the saline soil was formed chiefly by evapotranspiration of brackish ground water that moved upward from the water table by capillarity and osmosis to the surface.

SITE B - PETERSON FARM

DESCRIPTION

Site B, an 80-acre plot locally referred to as the "Peterson Farm" is northeast of Homestead Air Force Base and about 1.8 miles from Biscayne Bay, on the north side of SW 280th Street between SW 107th and 112th Avenues (see location on figs. 2 and 16). Land surface there ranges in altitude from about 2.5 and 3.5 feet above msl and averages about 3 feet (fig. 16). The site is completely underlain by Perrine marl to a depth of about 2 feet. The Perrine marl feathers out to the west against the limestone ridge in the vicinity of Homestead Air Force Base. Soil in the southeast corner of the site, the area of lowest altitude, has periodically become too saline for farming. Adjacent fields are cropped except those to the east which have been abandoned due to salinity and drainage problems. Ditches on the north and south sides of the site convey excess water eastward about 1 mile into the Levee 31E Borrow Canal. A ditch on the west side of SW 112 Avenue conveys excess water northward about 1 mile to Canal 102.

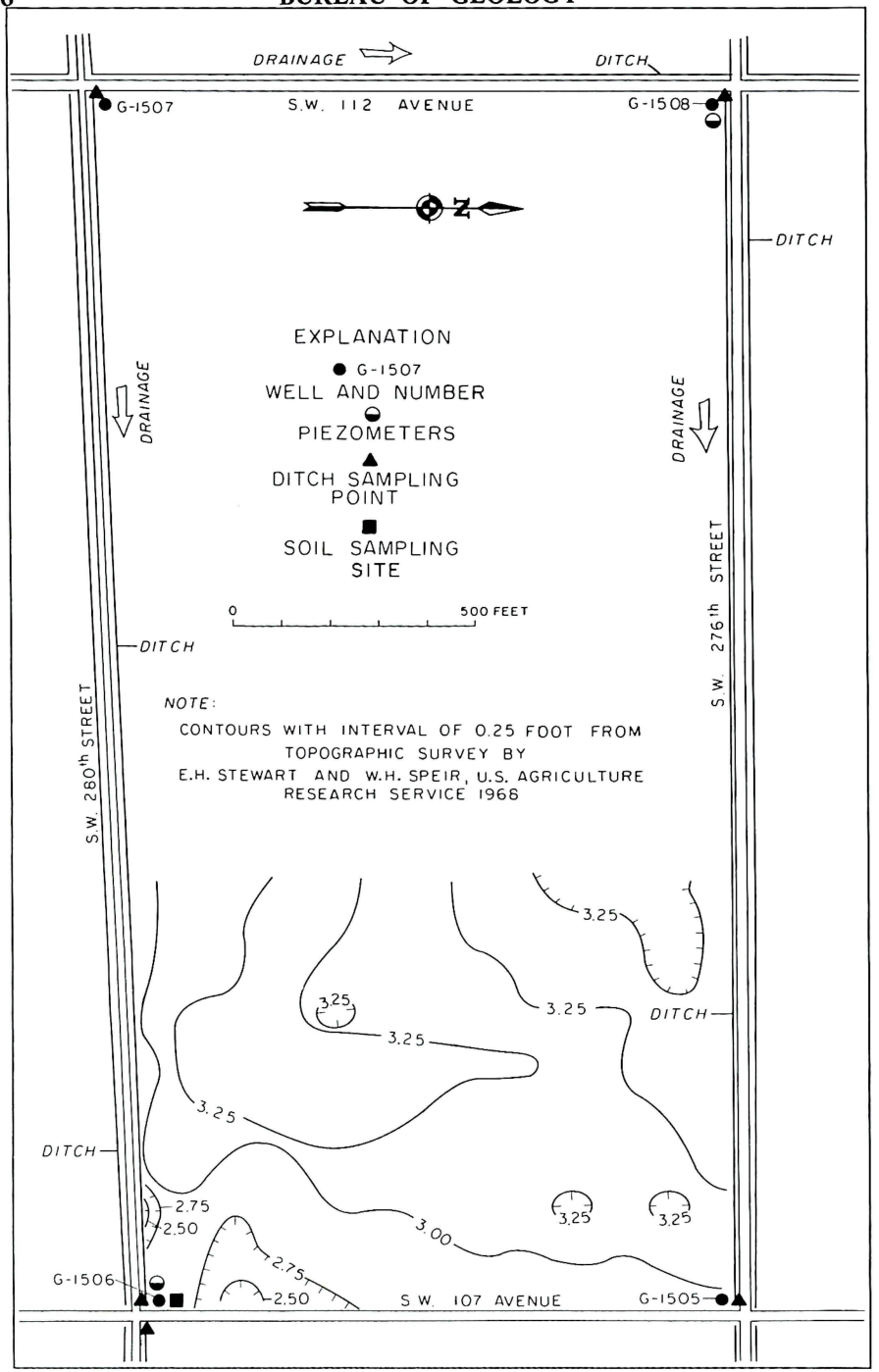


Figure 16. Site B showing locations of data-collection points and topography.

Table 2. Records of wells at site B.

Well Number: Lettered well numbers are for piezometers.

Water Level: Measured on April 14, 1971.

Chloride: Sample collected at bottom of well on April 14, 1971, in milligrams per liter (mg/l).

Well Number	Depth (feet, msl)	Casing (feet, msl)	Casing Diameter (inches)	Elevation Land Surface (feet, msl)	Water Level (feet msl)	Chloride (mg/l)	
G 1505	-41.28	+ 0.42	6	2.42	-0.13	3200	
G 1506	-28.20	- 2.50	6	2.50	-0.20	1350	Continuous water-level record
G 1506A	- 1.08	- 0.58	2	2.50	-0.21	1/	
G 1506B	- 7.56	- 7.06	2	2.50	-0.21	660	
G 1506C	-19.50	-19.00	2	2.50	0.00	104	Plugged
G 1506D	-12.45	-11.95	2	2.50	-0.20	620	
G 1506E	- 2.91	- 2.41	2	2.50	-0.21	360	
G 1506F	-12.68	-12.18	2	2.50	-0.16	114	Partially plugged
G 1507	-47.12	+ 1.28	6	3.28	-0.16	3700	
G 1508	-43.20	- 2.28	6	2.72	-0.15	1840	Continuous water-level record
G 1508A	-26.77	-26.27	2	2.72	-0.12	475	
G 1508B	-11.48	-10.98	2	2.72	-0.14	285	
G 1508C	-17.22	-16.72	2	2.72	-0.14	370	
G 1508D	- 0.50	0.00	2	2.72	-0.15	1/	
G 1508E	- 3.78	- 3.28	2	2.72	-0.15	265	
G 1508F	- 7.15	- 6.65	2	2.72	-0.15	270	

1/ Insufficient water for analysis

Descriptions of wells and piezometers at site B are presented in table 2. Data on water levels, soil salinity, and water salinity were collected during January through June 1971 at the points shown on figures 2 and 16. Rainfall data were obtained from Homestead Air Force Base. Soil salinity data were obtained from Dr. J. D. Dalton of the Dade County Agricultural Extension Office.

WATER LEVELS AND WATER MOVEMENT

The water table at site B normally is about 1 foot below land surface, or slightly less than 2 feet above msl. The water table rises when recharge by infiltrating rainfall and canal waters exceed losses by drainage and evapotranspiration, and falls when losses exceed replenishment. During the wet season the water table frequently rises above land surface; and during the dry season it often declines below bay level. The water table at site B is closely related to the water levels in nearby ditches and canals. Semidiurnal fluctuations of the water table resembling tidal fluctuations are produced by the opening and closing of automatic tide gates in salinity control S-21A at the mouth of Canal 102 in response to the tides in Biscayne Bay during wet periods. Diurnal fluctuations of the water table during daylight hours are produced chiefly by evapotranspiration during dry periods.

A comparison of the water level in Canal 102 upstream from the salinity control S-21A with the water level in Biscayne Bay at Homestead Bayfront Park (fig. 17) indicates that during June through November 1970 the automatic gate control was set to hold upstream water levels at a stage of about 2 feet above msl. During December 1970 the gate setting was lowered and the canal's water level began to decline. During April and May the water level above S-21A declined below the bay level thereby reversing the normal bayward gradient. As a result, bay water seeped inland around the control and contaminated parts of Canal 102 and the Levee 31E Borrow Canal. By May 11 the upstream water level had declined to 0.11 foot below msl, or about 0.5 foot below bay level. Heavy rains in late May and June caused the upstream water level to rise to 2 feet above msl by the end of June 1971.

At site B the water table, as shown by the water level in well G-1506 on figure 17, was generally below the water level in Canal 102 during January through June 1971, except following heavy rains when the water table peaked higher. The relationship indicates that usually there is a hydraulic gradient from Canal 102 toward site B and that seepage from Canal 102 sustains water levels there. Comparisons of the two water levels during the recession from March 1 through May 11 shows that the water level in well G-1506 declined at a slightly faster rate, thereby suggesting that evapotranspiration at site B exceeded the recharge from the canal.

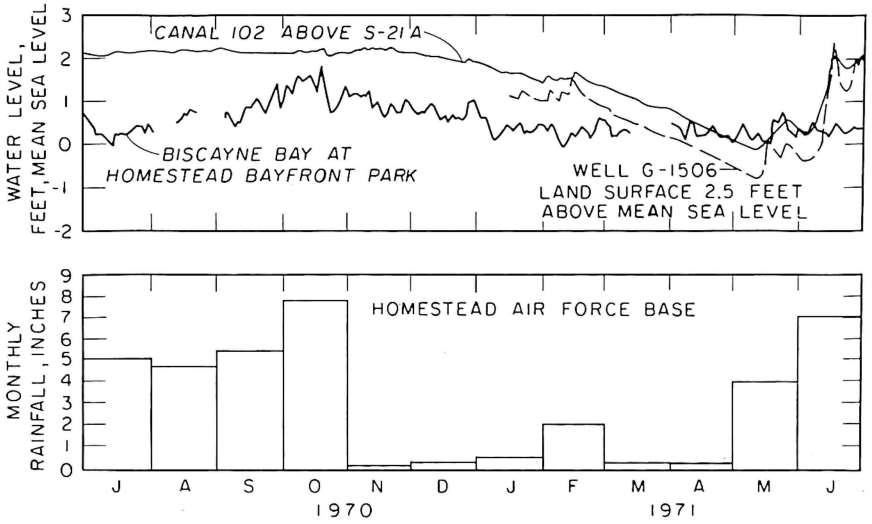


Figure 17. Water levels in Canal 102 above S-21A, in Biscayne Bay, and in well G-1506; and local rainfall, July 1970 - June 1971.

In January the water table was about 0.3 foot below the marl at the west side of site B, and by early March it had declined below the marl on the east side. In mid-March the water table had declined below the bay level, and by May 11 it was 0.8 foot below msl, or about 1 foot below bay level.

During January through June 1971, water levels in wells G-1507, and G-1508 (Hydrographs not shown) were only slightly higher than that in well G-1506 the record for which is shown on figure 17. The hydraulic gradients between wells and the water-table map for April 14-15, 1971 (fig. 6) indicate that some ground-water moved southward beneath site B toward the center of the depression, as indicated by the closed minus 0.3-foot contour south of site B. The principal direction of ground-water movement was, however, upward to the surface as a result of evapotranspiration. The depression at site B was a result of inadequate recharge and a high rate of evapotranspiration.

Ground-water flowed toward the center of the depression south of site B chiefly from Military Canal, Canal 102, and Biscayne Bay. Flow of fresh ground water toward the center was greatest from Military Canal because the aquifer was being recharged by effluent from the Base sewage treatment plant. Flow of fresh ground water from the west (inland) was least. The contours east of site B indicate inland movement of salt water from Biscayne Bay.

Water levels in the shallow piezometers at site B during January through May 1971, were a few hundredths of a foot lower than water levels in the deep piezometers; therefore some ground water moved upward from the lower part of the aquifer to replace losses in the upper part.

In order to more fully describe water movement at site B a cross section (fig. 18) was constructed along line B-B' located on figure 2. The data for April 14, 1971 were selected to show the position of the water table and distribution of chloride. The arrows indicate the general direction of water movement and the number of arrows suggest the relative amounts of flow.

Capillary flow through unsaturated soil is generally greatest where the water table is nearest to land surface, provided all other things are equal. On this basis, upward flow would be slightly greater on the east side of site B than on the west side. Because salt content in the ground water is greater on the east side a higher salt accumulation would be expected there.

The decline in water levels at site B during April 1971 was chiefly caused by evapotranspiration. An approximation of the magnitude of evapotranspiration was made by assuming that evapotranspiration was equivalent to the loss in ground-water storage.

The water table at site B declined at an average rate of 0.022 foot per day during April 1971, according to the graph of the water level in well G-1506 on figure 17. The approximate evapotranspiration from aquifer storage (ET_S) was computed by using the equation as described earlier in the section dealing with site A.

By substitution in the equation $ET_S = R P$

ET_S = 0.022 foot per day x 0.25
= 0.0055 foot per day, or 1,800 gallons per day per acre.

In addition to the storage depletion estimated above, the transfer of incoming ground water to the air was estimated to be 0.011 foot per day, based on approximate water table gradients in figure 6 and a transmissivity of 400,000 feet squared per day. The net ET is therefore about 0.016 foot per day, or about 5.8 inches per month. This estimated value does not include the small amount of rainfall in April, thus the estimated value is lower than the true value. But the value compares well with estimates of 4 inches based on studies by E. H. Steward and W. C. Mills (1967).

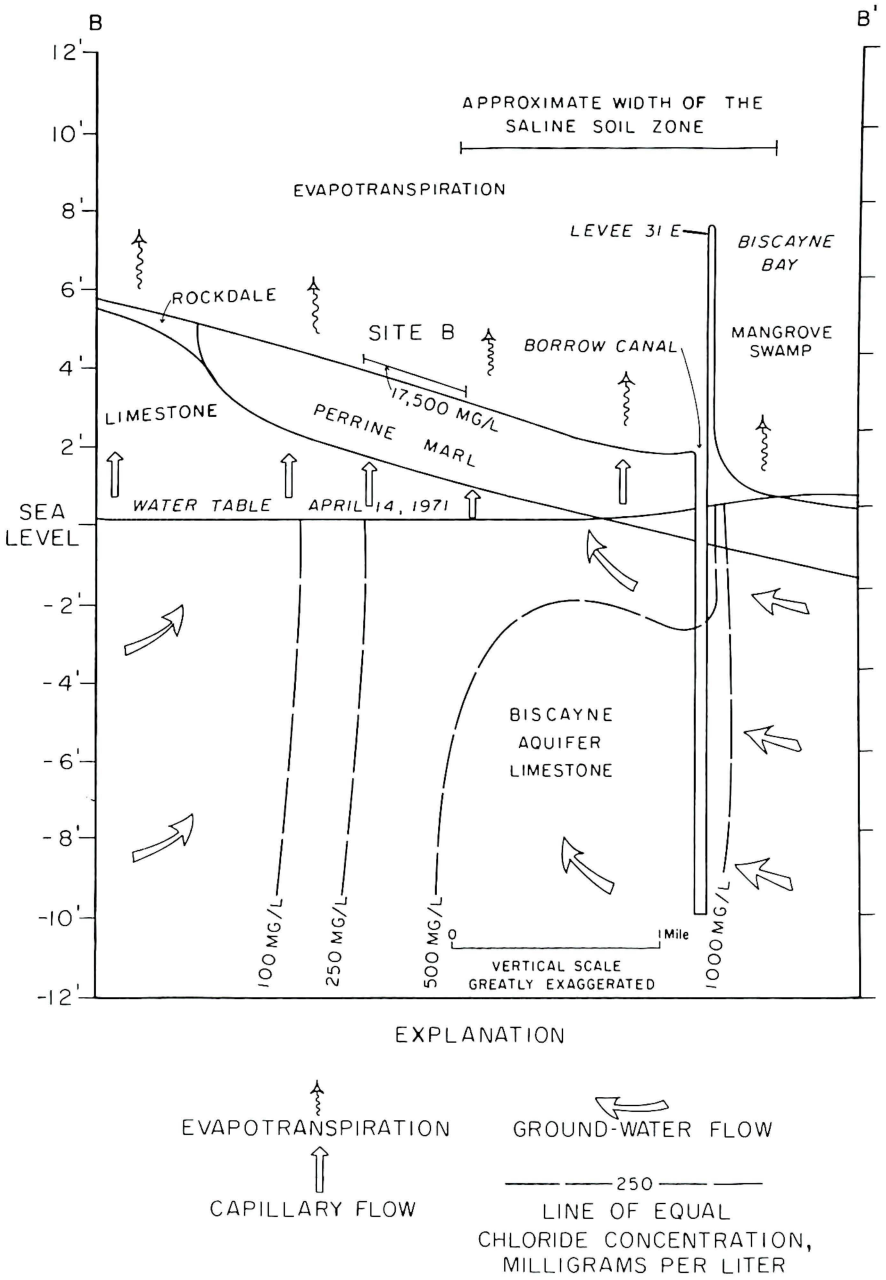


Figure 18. Generalized cross section B-B' through site B showing water movement and chloride content.

DISTRIBUTION AND SOURCE OF SALTS

At site B the concentrations of chloride were highest in the top two inches of soil and in the ground water at the base of the aquifer. Extracts from samples of soil near well G-1506 in the southeast corner of the site (see location on fig. 16) contained chloride in concentrations ranging from 1,000 mg/l in October 1970 to 17,500 mg/l in April 1971 (fig. 19). Concentrations in the soil decreased during the wet season and increased during the dry season. Significant reductions in chloride occurred during the dry season, however, as a result of leaching following heavy rains in February and March.

The concentration of chloride in ground water generally increased with increasing depth in the aquifer and with decreasing distance from Biscayne Bay. For example, in April 1971 the chloride content in water from well G-1506 was about 600 mg/l at 5 feet below msl and 1,400 mg/l at 28 feet below msl. A water sample from the lower part of the aquifer probably would have contained more than 5,000 mg/l chloride.

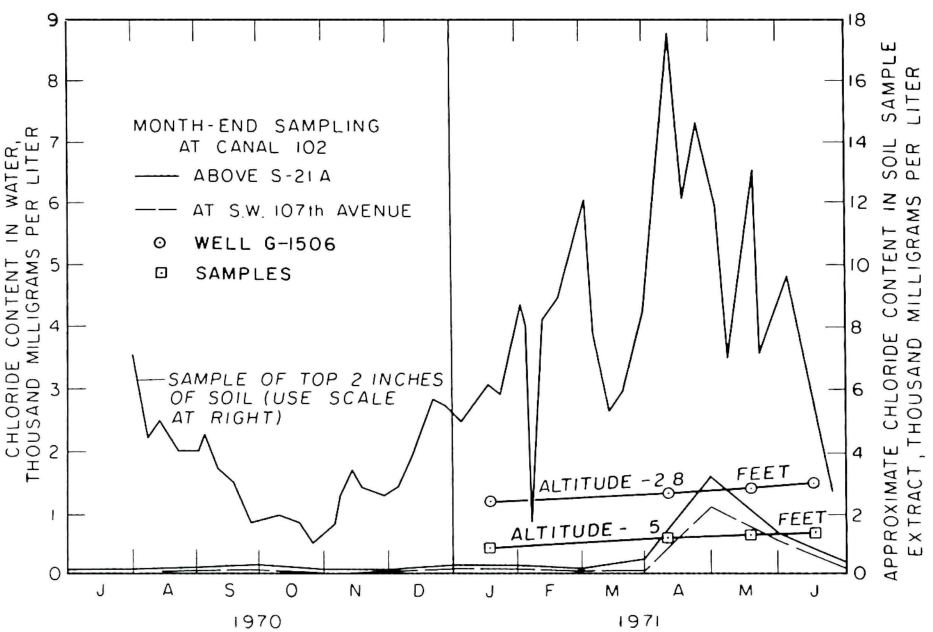


Figure 19. Chloride content in soil at site B, in Canal 102 at SW 107th Avenue and above S-21A, July 1970 - June 1971: and chloride content in well G-1506 at selected depths, January - June 1971.

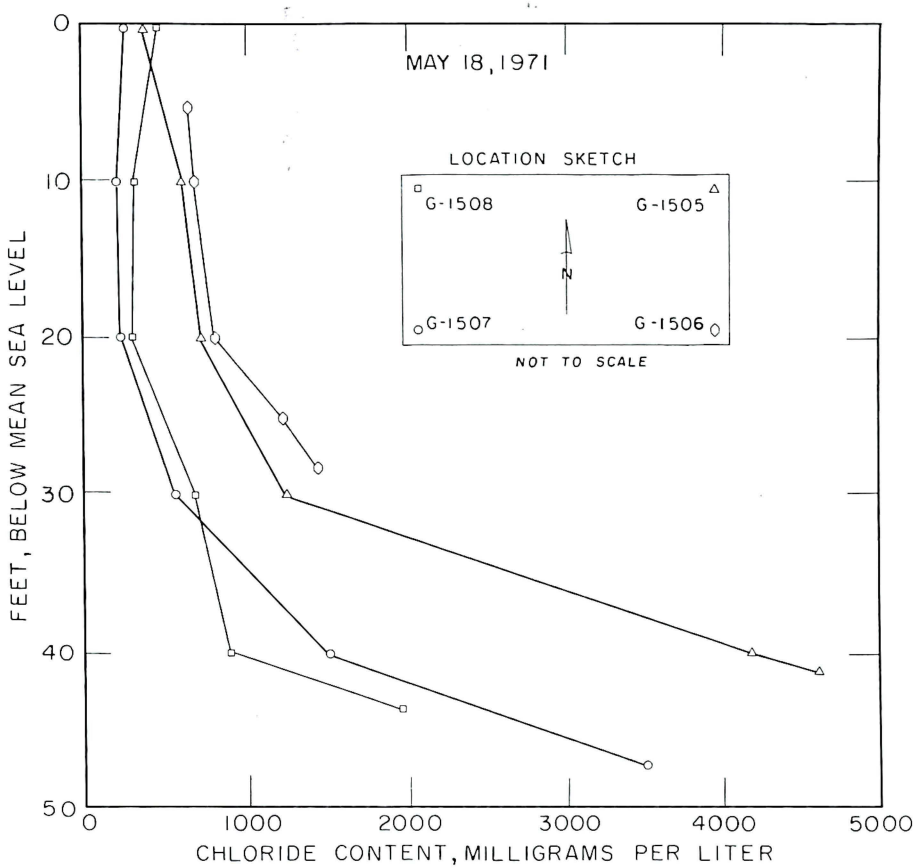


Figure 20. Chloride content in ground water in wells G-1505 through G-1508 at selected depths, May 18, 1971.

Chloride content was generally higher in water at equivalent depth in wells G-1505 and G-1506 on the east side of site B than in wells G-1507 and G-1508 on the west side (fig. 20). The concentrations at depths below 40 feet at site B greatly exceed 1,000 mg/l, therefore the 1,000 mg/l chloride line at the base of the aquifer lies considerably west of site B.

Data collected on April 14, 1971 were selected to show the dry season chloride (salinity) distribution at site B. The chloride content in the extract from the soil in the southeast corner of the site was about 17,000 mg/l. The chloride content in soil at the west side was not determined; however, it was assumed to be low based on the excellent condition of crops there. The chloride content in the unsaturated zone was unknown because samples of soil water were not

obtained. Most of the nearby ditches were either dry or ponded and chloride content of the water there was about the same as the chloride content of the ground water. Chloride contained in ground water at altitude -5 feet msl ranged from about 300 mg/l in wells G-1507 and G-1508 on the west side of site B to about 600 mg/l in wells G-1505 and G-1506 on the east side. Chloride content of the water in the bottom of canal 102 (at approximately altitude -10 feet msl) ranged from 750 mg/l upstream from the control S-21A to 600 mg/l at SW 107 Avenue; and chloride content 1 foot below the canal's water surface at the same locations was 350 mg/l and 120 mg/1. In the southeast corner, the amount of salt (as NaCl) carried to the surface daily by capillarity and osmosis was computed to be about 43 pounds per acre, based on an evapotranspiration rate of 0.016 foot per day and a sodium chloride content of 990 mg/l (600 mg/l chloride).

SEA-WATER INTRUSION AND SALINE SOILS

The sea-water intrusion and saline soil problems are interrelated because the saline soils cannot exist without a source of relatively salty ground water. Salty ground water is chiefly caused by inland movement of bay water during dry periods; however, infrequent inundation by hurricane tides also contribute to sea-water intrusion.

Data collected by the U. S. Geological Survey and the U. S. Department of Agriculture since the early 1940's indicate that both are long-term problems. Data collected during this investigation at sites A and B support previous findings and conclusions. The movement of ground water and the distribution of chloride content (salt) at both sites indicate that the soil salinity is caused by evapotranspiration of relatively brackish ground water that moves upward from the water table by capillarity and osmosis during dry periods.

The supporting data for this report were collected during an unusual drought; however water-level conditions in the East Glades have reached almost the same proportions on several occasions since the early 1940's. Records of water levels prior to drainage in the 1940's are lacking; however, water levels have declined below sea level on several occasions in undrained low-lying areas near the East Glades and in Everglades National Park, south of the East Glades area. Figure 7 shows that the salt front is inland about 5 miles from Florida Bay in the eastern part of Everglades National Park. Because of the close similarity between the two areas, it is apparent that in East Glades the present (1971) position of the salt front probably is only slightly farther inland from its natural position. Thus saline soils are for the most part a natural occurrence in the East Glades except when sea-water intrusion can be traced to man-made causes, such as, salt-water seepage from a canal or increased inland movement due to lowered water levels (this could be related to pumpage or to increased drainage).

At site A the chloride content in the ground water near the water table appears to be caused chiefly by infiltrating salt water from nearby canals; and at site B it appears to be caused by upward movement of salty ground water from deeper parts of the aquifer.

Comparison of the chloride content in extracts from the upper 2 inches of soil at sites A (fig. 14) and B (fig. 19) shows a wide variation in peak concentration and in rates of buildup and leaching. Peak concentration was higher at site B than at site A. There is no simple explanation for these variations; but according to the chloride concentrations in the ground water and the position of the water table with respect to the bottom of the soil (Perrine Marl) and to the land surface, the reverse of the situation would be expected. Therefore one can only speculate on the cause of the variations in soil salinity at the two sites.

Stewart and Albert (1968) found that salt concentrations varied widely in soils at site A. They found very little correlation between the depth to the water table and soil salinity. The data collected at sites A and B for this investigation suggests that partially shading at site A would cause variations in the local soil salinity by reducing evapotranspiration and that differences in permeability, ground cover, and rainfall would also account for variations in concentration. Therefore the variations in soil salinity at sites A and B could be caused by local conditions, but in each case only a slightly brackish ground-water source was needed to produce unfavorable salt buildup in the soil.

Infiltration of salt water from coastal canals during extended dry periods helps to sustain high chloride concentrations in the ground water. Infiltration of salt water from canals is chiefly man made and movement of salty ground water inland through deep parts of the aquifer are both natural and man made. Both types of intrusion are related to the inability to hold fresh water levels high during drought. Based on existing data it is not possible to clearly separate the parts of intercanal areas affected by natural intrusion from parts affected by man. Apparently a large part of the coastal part of the East Glades was underlain by salt water prior to drainage; however, recent intrusion is indicated since the late 1960's as a result of increased water use and reduction of peak water levels.

Studies by the U. S. Geological Survey indicate that water levels along the eastern and southern sides of East Glades Agricultural Area often decline below bay level during dry periods thereby causing a reversal in the normal bayward hydraulic gradient. As a result salt water moves inland through the aquifer and up the canals. The inland advance of the salt front during the dry season is usually reversed by seaward moving fresh water during the wet season; however, the advance during a drought, such as that in 1971, would require an event of

opposite but equal magnitude to return the salt front to the original position. Current land use in the area does not permit widespread flooding, therefore the chances of returning the salt front to the pre-drought position without raising water levels is remote.

The long-term solution to the saline soil problem would be to prevent further intrusion from coastal canals by holding water levels higher there during dry periods. The fact that the winter growing season generally corresponds with the annual dry season poses a special problem to the Central and Southern Florida Flood Control District because the respective water-level needs are conflicting. Agriculturalists in East Glades require that water levels in coastal canals be held sufficiently low to farm low-lying fields while water managers require that coastal water levels be held sufficiently high to prevent sea-water intrusion.

Keeping water levels low during the dry season is a short-term benefit to agriculture because the practice often leads to increased sea-water intrusion which is a long-term detriment to agriculture. Thus the outlook for the East Glades Agricultural Area is for no improvement in sea-water intrusion and saline soil problems unless there are significant changes in land use that will permit the maintenance of higher water levels upstream from the coastal salinity control structures.

ALTERNATIVES

Current land use and farming practices in the East Glades are in conflict with the need to maintain water levels upstream from coastal controls high enough to prevent sea-water intrusion. The Perrine marl is of major agricultural and economic importance and the need to utilize this valuable resource to the fullest will become more apparent as the need for future food supply and "green areas" increase. The solution to the problems of sea-water intrusion and saline soils presents a challenge to those responsible for land and water management. The data collected thus far indicates that the problems are related and that the solution will require changes in land use as water levels are raised to optimum levels to halt sea-water intrusion and to reclaim lands already affected by sea-water intrusion.

One method of changing the land use would be to mound the marl deposit in low-lying fields so that water levels can be raised. Another method would involve the complete removal of the marl deposit from all low-lying lands along the coast and the distribution of the deposit on higher areas to the west. The denuded fields could be filled with crushed limestone for urban development and the raised fields could be used for agriculture and parks. Both methods

would permit holding higher water levels above the coastal controls and continued use of the marl for agriculture.

SUMMARY

Saline soils in the East Glades Agricultural Area are caused chiefly by evapotranspiration of brackish ground water during dry periods. Salt concentration in soils are highest where the underlying ground water contains high concentrations of salt and the flow upward from the water table is greatest. Salt content in the ground water is caused by sea-water intrusion (infiltration of salt water from nearby canals and by inland movement of salt water through the aquifer, both occurring during dry periods). Upward flow from the water table is greater through the Perrine marl than through the limestone of the Biscayne aquifer because the soil moisture content and capillary conductivity of the Perrine marl is higher. Upward flow is also greater in areas where the water table occurs nearest land surface.

Salt concentrations in soils can vary considerably within short distances depending upon the local variations in the above mentioned conditions; however, the area most prone to development of soil salinity generallly coincides with the zone affected by sea-water intrusion along the coast. The zone of intrusion is caused by man-made and natural factors.

The problems of sea-water intrusion and saline soils are partly related to the need to control water levels sufficiently low in the coastal reaches of canals that cross the area so that low-lying fields can be farmed. The need to maintain low water levels during the winter growing season conflicts with the need to maintain high water levels for prevention of sea-water intrusion during the same period; however, to date the needs of agriculture have had priority. Therefore, the outlook for the East Glades is for no improvement in sea-water intrusion and saline soil problems unless there are significant changes in land use which will permit maintenance of higher water levels upstream from the salintiy controls in the major coastal canals.

REFERENCES

Galliher, C. F. and Hull, J. E.
1969 *Hydrologic conditions during 1967 in Dade County, Florida:* U. S. Geol. Survey open-file report.

Hull, J. E. and Galliher, C. F.
1968 *Hydrologic conditions during 1966 in Dade County, Florida:* U. S. Geol. Survey open-file report.

1970 *Hydrologic conditions during 1968 in Dade County, Florida:* U. S. Geol. survey open-file report.

1971 *Hydrologic conditions during 1969 in Dade County, Florida:* U. S. Geol. survey open-file report.

1972 *Hydrologic conditions during 1970 Dade County, Florida:* U. S. Geol. survey open-file report.

Israelson, O. W., and Hansen, V. E.
1962 *Irrigation principles and practices:* John Wiley and Sons, Inc., New York, New York.

Klein, Howard
1957 *Salt-water encroachment in Dade County, Florida:* Florida Geol. Survey Inf. Cir 9.

Kohout, F.A., and Leach, S. D.
1964 *Salt-water movement caused by control-dam operation in Snake Creek Canal, Miami, Florida:* Florida Geol. Survey Rept. Inv. 24, part 4.

Leighty, R. G., Henderson, J. R. and others
1958 *Soil Survey (Detailed-Reconnaissance) of Dade County, Florida:* U. S. Dept. of Agriculture, Soil Survey Series 1947, No. 4.

Parker, G. G., Ferguson, G. E., and Love, S. K.
1955 *Water resources of southeastern Florida, with special reference to the geology and ground water of the Miami Area:* U. S. Geol. Survey Water Supply Paper 1255, 935 p.

Richards, L. A., and others
1954 *Diagnosis and improvement of saline and alkali soils:* U. S. Dept. of Agriculture, Handbook No. 60.

Schneider, J. J.
1969 *Tidal relations in the south Biscayne Bay area Dade County, Florida:* U. S. Geol. Survey open-file report.

Schroeder, M. C., Klein, Howard and Hoy, N. D.
1958 *Biscayne aquifer of Dade and Broward Counties, Florida:* Florida Geol. Survey Rept. Inv. 17.

Stewart, E. H., Albert, R. R., and others
1967 *Salinity status and water relationships of marl soils in southern Florida:* U. S. Dept. of Agriculture, Agricultural Research Service, Everglades Project Annual Report.

1968 *Salinity status and water relationships of marl soils in southern Florida:* U. S. Dept. of Agriculture, Agricultural Research Service, Everglades Project Annual Report.

Stewart, E. H., Albert, R. R., and others
1969 *Salinity status and water relationships of marl soils in southern Florida: U. S.* Dept. of Agriculture, Agricultural Research Service, Everglades Project Annual Report.

Stewart, E. H., and Mills, W. C.
1967 *Effect of depth to water table and plant density on evapotranspiration rate in southern Florida:* Am. Soc. Agr. Engineers Trans. Vol. 10, no. 6, pp. 746-747.

U. S. Weather Bureau
1970 *Climatological Data, Florida:* v. 74, No. 13.

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