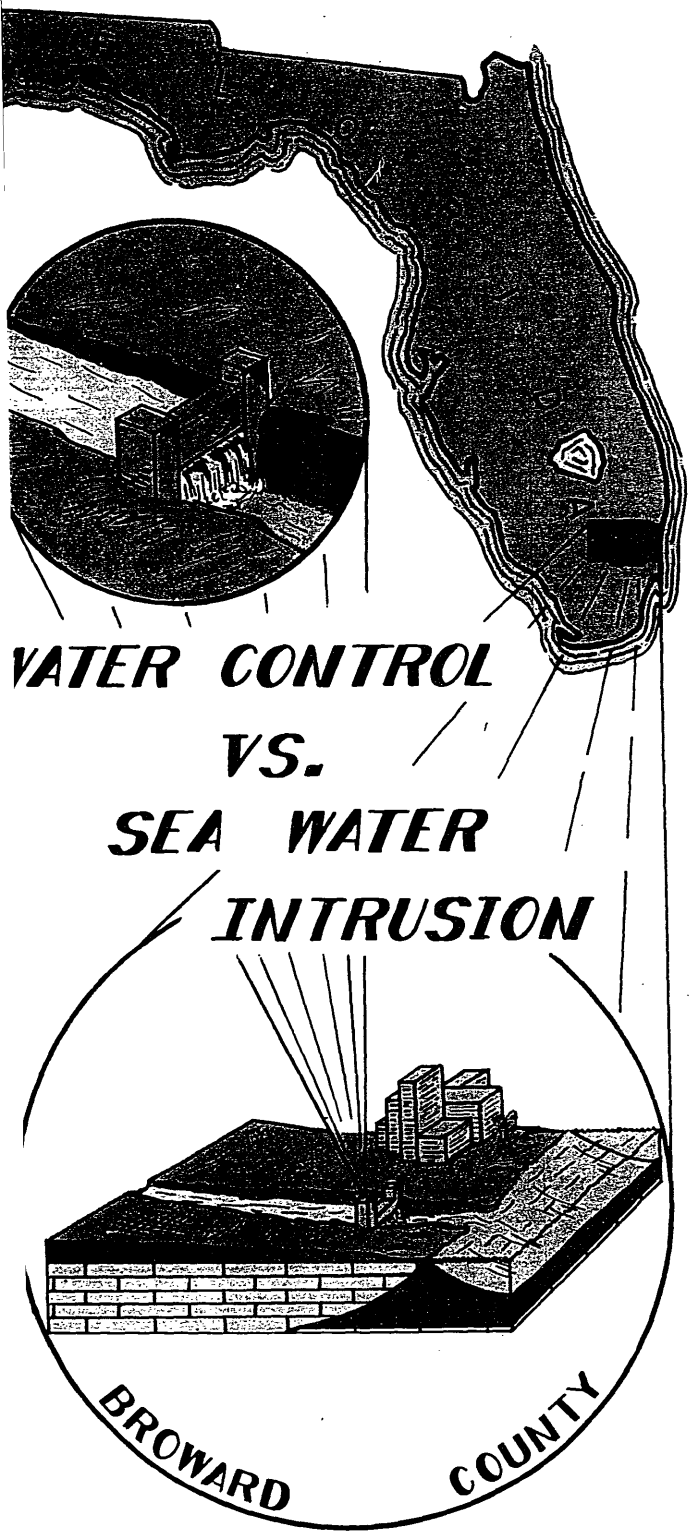

LEAFLET NO. 5

STATE OF FLORIDA
STATE BOARD OF CONSERVATION
DIVISION OF GEOLOGY

FLORIDA GEOLOGICAL SURVEY
Robert O. Vernon, *Director*

SECOND EDITION

LEAFLET NO. 5

WATER CONTROL VS. SEA-WATER INTRUSION, BROWARD COUNTY, FLORIDA

By
C. B. Sherwood and R. G. Grantham

Prepared by the
UNITED STATES GEOLOGICAL SURVEY
in cooperation with
BROWARD COUNTY
and the
FLORIDA GEOLOGICAL SURVEY

TALLAHASSEE

1966

PREFACE

Residents in coastal areas are aware of the perpetual battle between man and the sea. Reports of beach erosion, destruction of property, damage to ships, and loss of cargos are of common knowledge. However, one battle between man and the sea is a silent struggle that receives little publicity because it is invisible and not spectacular. This invisible struggle is waged to protect fresh-water supplies in coastal areas from inroads by the sea.

This leaflet tells in general terms how the problem of sea-water intrusion in the aquifer in Broward County came about, what has been done to control the intrusion, and what must be done to conserve the fresh water and keep the ocean where it belongs.

Although the leaflet deals specifically with conditions in Broward County, the principles described are valid in any coastal area having a similar hydrology. For this reason, this leaflet is of interest to people living in other coastal areas of Florida.

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WATER CONTROL VS. SEA-WATER INTRUSION, BROWARD COUNTY, FLORIDA

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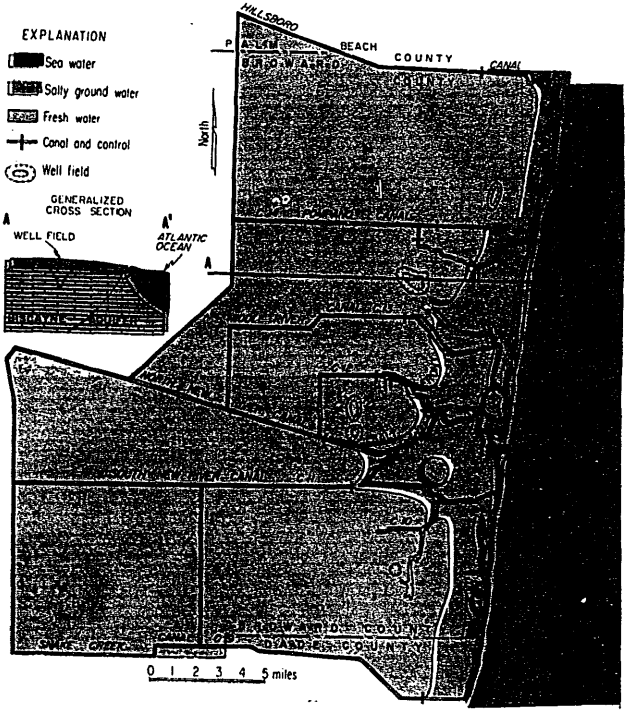
Broward County abounds in water--both fresh and salt. With careful management, the supply of fresh water is adequate for the present and future needs of the area. The wealth of salt water is a major asset--good for shipping and recreation, such as swimming, boating, and fishing. However, the ever present problem is keeping salt water in its place. In fact, the primary threat to the invaluable fresh-water resources of the county is intrusion of sea water into coastal streams and into subsurface water-bearing materials. Sea-water intrusion is a silent menace. It can spread without raising alarm; it can contaminate domestic wells and destroy city water supplies; and it can kill crops and render soils unusable for agriculture. *It not only can, but has.* However, studies indicate that with proper detection and control measures, sea-water intrusion can be halted, and with time the sea water can be flushed out.

Broward County is underlain by the Biscayne aquifer, a highly productive water-bearing system of limestone, sandstone, and sand that extends from land surface to depths of as much as 200 feet near the coast. The aquifer yields copious supplies of fresh water to municipal well fields in the area, but the porous nature of the materials exposed to the sea make it also especially vulnerable to sea-water intrusion.

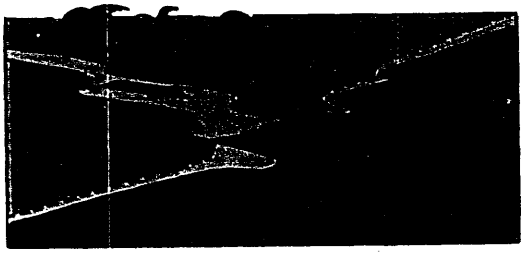
The inland extent of sea-water and salty-water intrusion in Broward County in 1964 is shown by red and pink shading on the map and cross section below. Salty water as distinguished from sea water is a mixture of fresh and sea water. The salty water body in the aquifer is wedge-shaped, being thickest at the coast, and thinning inland to an edge where it underlies the fresh ground water at depths from 160 to 200 feet below the land surface.

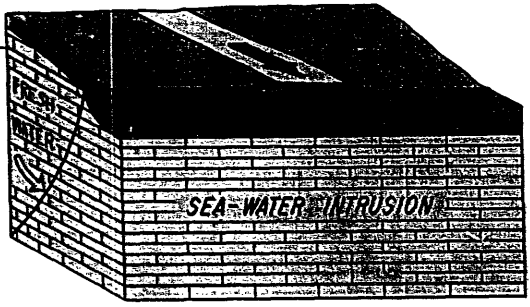


Sea-water intrusion in Broward County in 1964 is shown by pink shading. The salty water in the aquifer is wedge shaped (see cross section), thickest at the coast and thinning inland where it underlies fresh ground water at depths of 160 to 200 feet. Greatest inland penetration is in the vicinity of tidal canals.

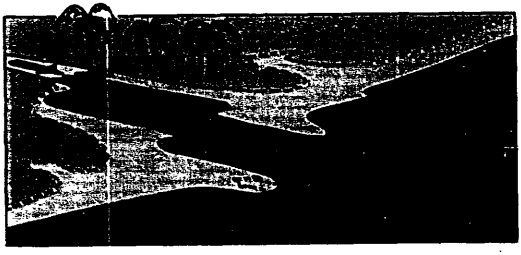
Because sea water contains large amounts of dissolved salts, it is slightly heavier than fresh water. A 41-foot column of fresh water is required to balance 40 feet of sea water. Thus, sea water moves inland unless fresh-water levels are appreciably higher than sea level. In coastal streams and in porous subsurface materials, there is a constant balancing between the two. If fresh-water levels are high, sea water is held near the coast. If fresh-water levels are low, sea water moves up the tidal streams and inland in the aquifer beneath the fresh ground water. Theoretically, in a coastal aquifer, each foot of fresh water above sea level would indicate 40 feet of fresh water below sea level.

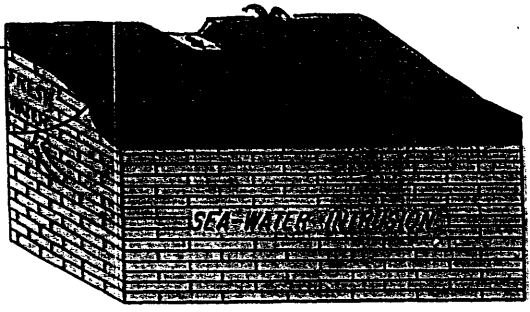
HIGH FRESH-WATER LEVELS





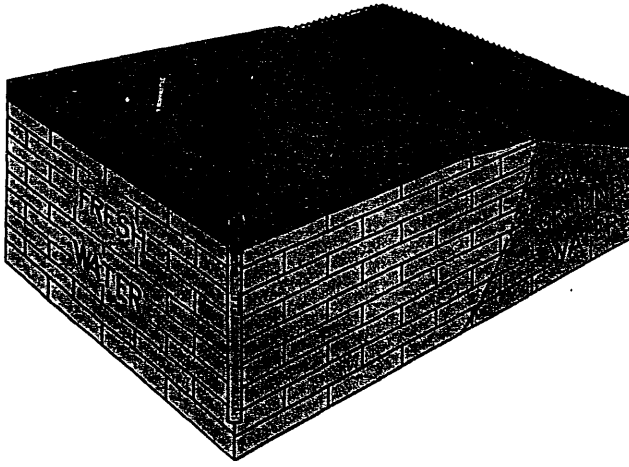
LOW FRESH-WATER LEVELS



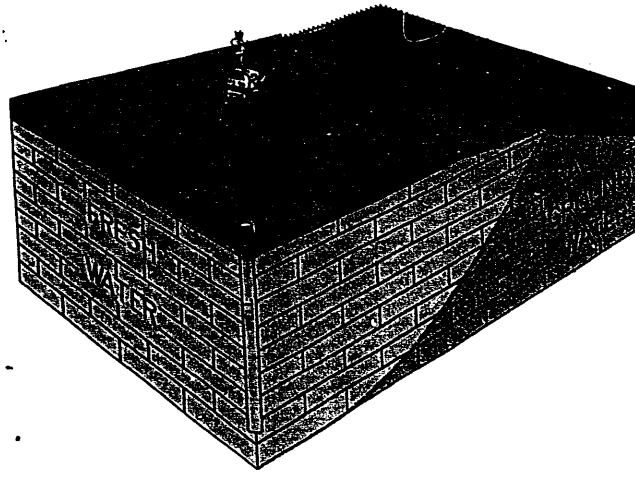


Because sea water is heavier than fresh water i tends to move inland unless balanced by highe fresh-water levels. When fresh water is abundant stream flow and water levels are high and the sea water is held near the coast. During drought, wher stream flow and fresh water levels are low, salt water moves up tidal streams and inland beneatl the fresh ground water.

Prior to drainage improvements in Broward County the existing streams were shallow and relatively ineffective as drainage channels. Therefore, fresh-water levels were high and little or no salt water intruded. In fact, old-time residents reported flowing wells in salt-water bays and inlets. Later, as deep, effective drainage canals were cut far inland to reduce flooding of farms and urban areas, coastal water levels were lowered greatly and salt-water intrusion began almost unnoticed. In addition, the rapid

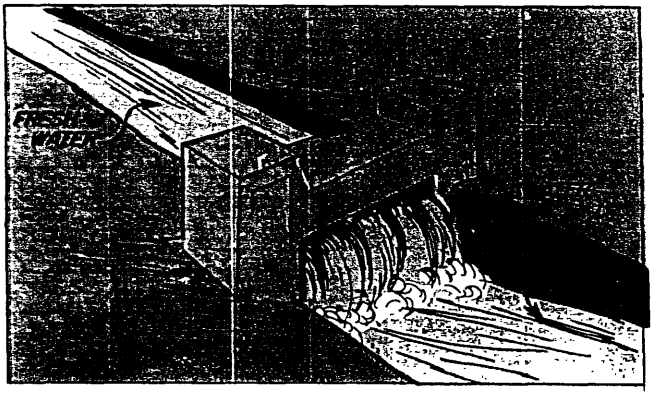


Sea water and fresh water in coastal area before construction of canals.



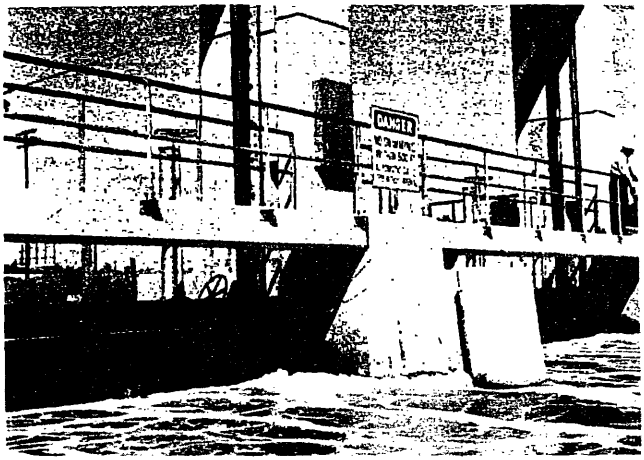
The construction of uncontrolled tidal canals causes sea-water intrusion in two ways: it lowers fresh-water levels, and it provides open channels to convey sea water inland. The salt front in the aquifer shifts inland adjacent to the new canal.

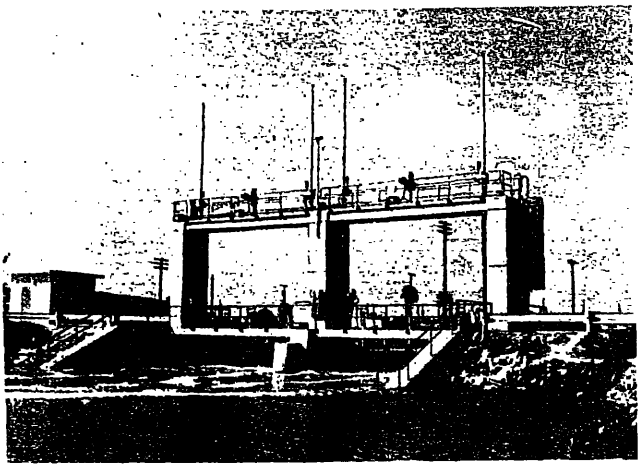
urbanization of the area brought an increased demand for drainage and for coastal canals to create attractive waterfront property. The desirable aspects of these developments were clearly apparent; the undesirable aspect--salt intrusion--was difficult to detect until domestic, industrial or irrigation supplies began to be contaminated. Uncontrolled tidal canals influenced the position of salt-fresh water contact in two ways--they lower fresh ground-water levels, thus reducing the opposition to inland movement of salt water and they provide a channel for sea water to move inland. The inland penetration of the salt front in the New River area of Fort Lauderdale was caused chiefly by extensive construction of canals. Fortunately, this type of intrusion can be corrected if a salinity control structure is built near the coast to raise the level of fresh water and to prevent the upstream movement of salt water. Salinity



Salinity control structures serve to hold sea water out, prevent excessive drainage of fresh water, and hold fresh-water levels high near the coast.

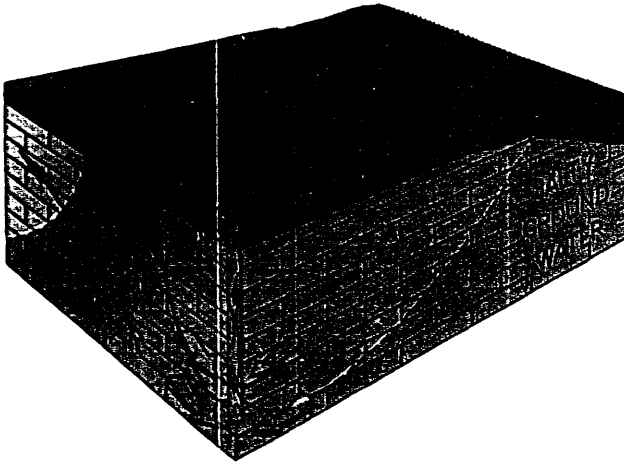
control structures have been constructed in coastal reaches of all primary canals of the Central and Southern Florida Flood Control Project to combat sea-water intrusion and to control water levels on an area-wide basis. In the older canals the controls were located as far seaward as the existing land use and marine interests permitted--in the newer canals they are placed very close to the coast.





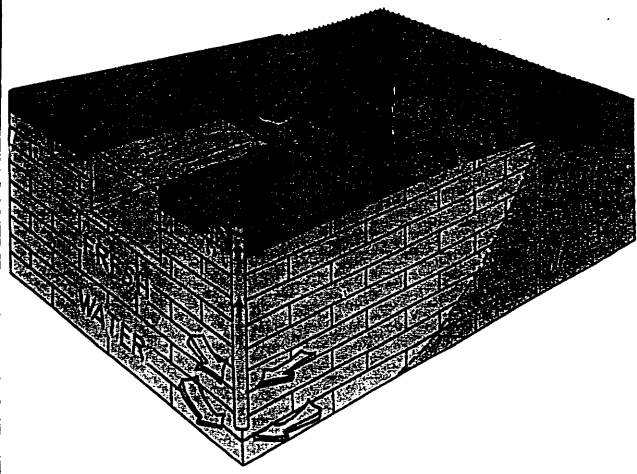
Salinity control structure S-37A on Cypress Creek Canal (C-14) near Pompano Beach helps to prevent the intrusion of sea water into the Fort Lauderdale Prospect well field. When heavy rainfall occurs the gates are opened to prevent flooding in the inland areas. During dry periods the gates are closed to conserve fresh water.

In Broward County the inland movement of the salt front is accelerated by the lowering of fresh-water levels near the coast as a result of large withdrawals of ground water. When established, the municipal well fields generally were located an appreciable distance inland. However, the westward expansion of urbanization necessitated drainage of larger areas by canals which in many instances passed within the area where ground-water levels were being



An uncontrolled canal that extends into an area of heavy pumpage can convey salt water inland to contaminate fresh water supplies.

lowered by well fields. In an area of heavy pumpage the ground-water flow is toward the well field, thus the combined effects of the canal and the pumpage can induce salt water to move into the well field. In contrast, a controlled canal can provide a perennial source of fresh water to replenish the well field and to prevent salt intrusion by bringing in additional fresh water from outside the area. Water-control structures as correction measures are presently being constructed in some critical areas where municipal supplies are threatened.

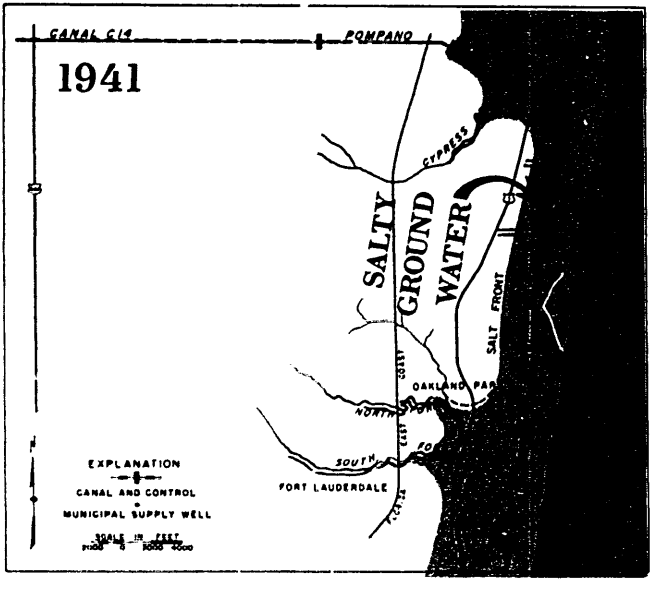


In contrast a controlled canal can provide a perennial source of fresh water to prevent salt-water intrusion and to replenish the well field by bringing in fresh water from outside the area.

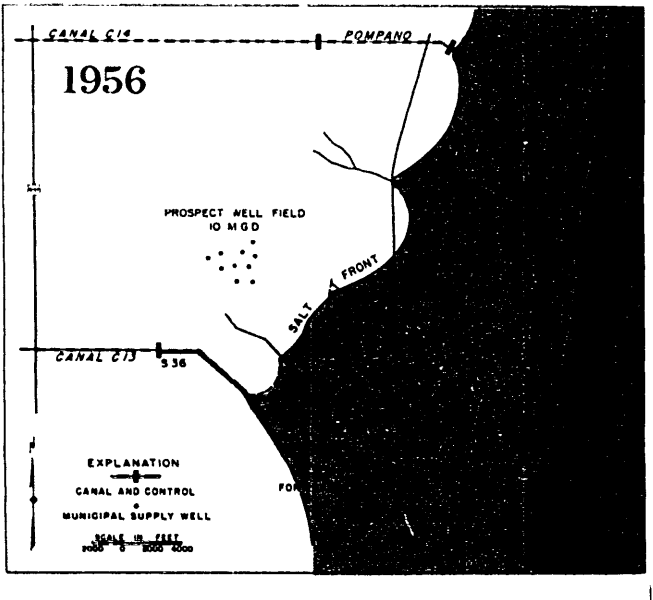
The map sequence below shows successive adjustments to the salt front pattern, which have occurred since 1941 in response to canal construction, large scale pumping, and salinity control works in the Middle River Prospect well field area, near Fort Lauderdale.

In the early 1940's pumpage of ground water was negligible and existing streams were shallow and drained very little water; consequently, fresh-water levels were high and salt-water intrusion was confined to areas adjacent to natural tidal channels. By the mid 1950's the primary canals had been constructed, the Prospect well field had been established, and excavation of an extensive secondary canal system by land developers was underway. Coastal water levels were being lowered and a very significant inland adjustment of the salt-front pattern resulted.

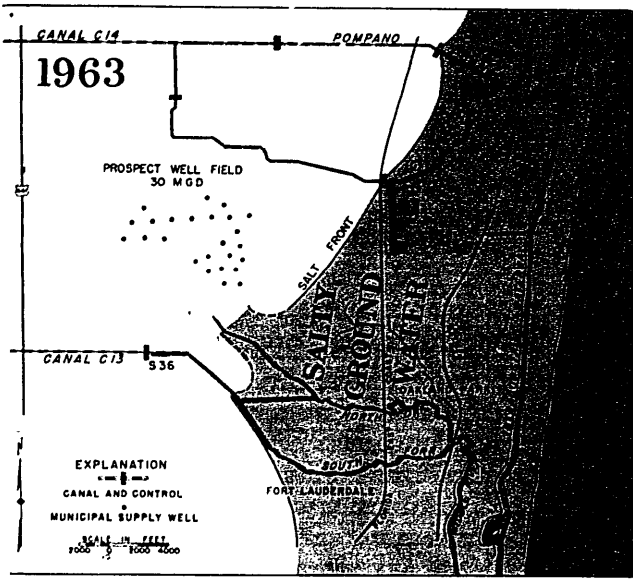
In 1963 the effects of the construction of the canal and control which integrated Cypress Creek into the flood control system are shown. Although pumpage had increased threefold, ground-water levels remained high and the salt front was essentially stabilized in the area north of the well field. In contrast, south of the



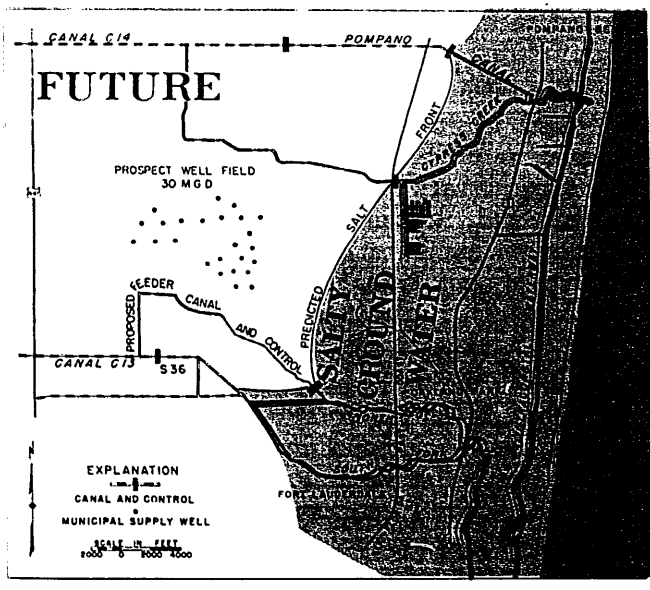
In 1941, prior to canal construction, fresh-water levels were high and sea-water intrusion was confined to areas adjacent to natural tidal channels.



By 1956 the primary canals had been constructed, the Prospect well field had been established, and the excavation of an extensive system of secondary drainage canals was underway. Coastal water levels had been lowered excessively and the salt front had moved appreciably inland.



he canal and control which connected Cypress reek into the flood-control system tended to stalize the salt front in that area despite a threeold increase in pumpage. In contrast, the uncorolled reach of the North Fork of the Middle River ermitted the salt front to move inland into the well field.



Predicted effects of a proposed fresh-water feeder canal and salinity control designed to halt sea-water intrusion and furnish fresh-water replenishment to the Prospect well field.

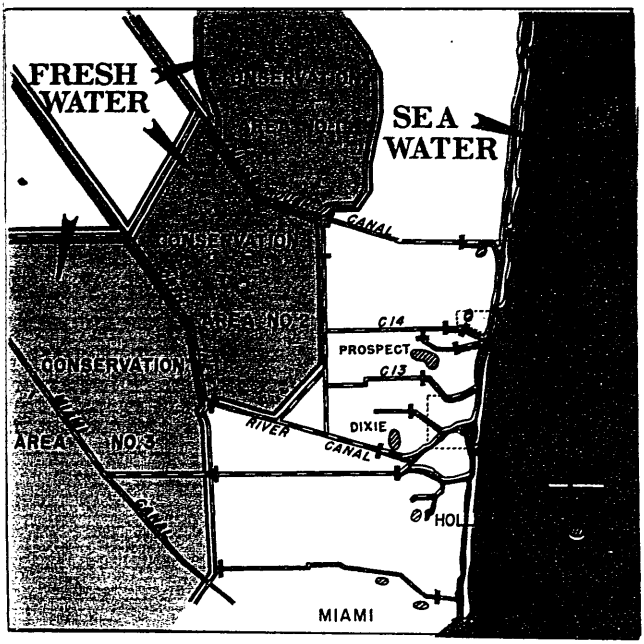
well field the salt front adjacent to the tidal portion of the North Fork of the Middle River moved steadily inland into the well field. The feeder canal shown in the fourth map has been proposed to provide higher fresh-water levels for the control of salt intrusion and for recharge to the well-field area.

Although the salinity-control structures in major canals have retarded intrusion in some areas, the rapidly increasing urbanization and water use create an urgent need for legislation to provide salinity control area wide. During 1963, the increased threat to ground-water supplies, accentuated by the contamination of a major well field, resulted in legislation to prevent the construction of additional salt-water canals and to require salinity control structures where needed in existing canals.

Expansion of the secondary drainage system and increased water use to keep pace with continued rapid development of coastal Broward County will lower water levels and will increase the danger of salt intrusion in the future. By the year 2000 water use for municipal supplies alone is predicted to exceed one-half billion gallons per day or more than ten times the present use. Hydrologic studies indicate that these water needs can be met by preventing the construction of new avenues for salt intrusion and by making the maximum use of the regional water-management system (see below).

The primary water-control system of the Central and Southern Florida Flood Control District is designed to alleviate the effects of both flood and drought. This is accomplished by draining a part of the flood waters to the sea and storing a part in conservation areas for release during droughts. This system, supplemented by a controlled secondary drainage network and by proper water-management can provide the solution to Broward County's salt-intrusion problem and can assure the county of a long-term water supply.

The hydrologic data which made possible the long-term delineation and monitoring of the salt front were collected in cooperation with the City of Fort Lauderdale. The collection of additional data in northern Broward County was



The Central and Southern Florida Flood Control Project is designed to alleviate the effects of both flood and drought on a regional basis. This is accomplished by draining a part of flood waters to the sea and storing the remainder in conservation areas for releases during droughts. This system, when supplemented by a network of controlled secondary drainage canals, can provide control of sea-water intrusion and assure a long-term water supply for Broward County.

begun in 1960 in cooperation with the City of Pompano Beach and in 1963 with the City of Deerfield Beach.

The cooperative investigation of the water resources of Broward County by the U.S. Geological Survey includes several salinity and hydrologic studies designed to aid in detecting and countering salt intrusion. Among these are: (1) a continuing program of water level and salinity data for observation wells and sampling points on canals to monitor the movement of salt in the aquifer and canals; (2) a test drilling program to determine the extent of intrusion in the aquifer; (3) electrical analog model studies to determine the effects of proposed changes in the canal system and increase in pumpage; and

(4) hydrologic studies to determine the water levels required at salinity controls in canals and the amount of fresh water flow required in canals to stop salt intrusion.

The results of these cooperative studies will be published by the Florida Geological Survey and the U.S. Geological Survey. Reports and data are currently available from the U. S. Geological Survey, 51 S.W. First Avenue, Miami, Florida. Further information on the mechanics of salt intrusion in the southeastern coastal area of Florida may be found in the references listed below.

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