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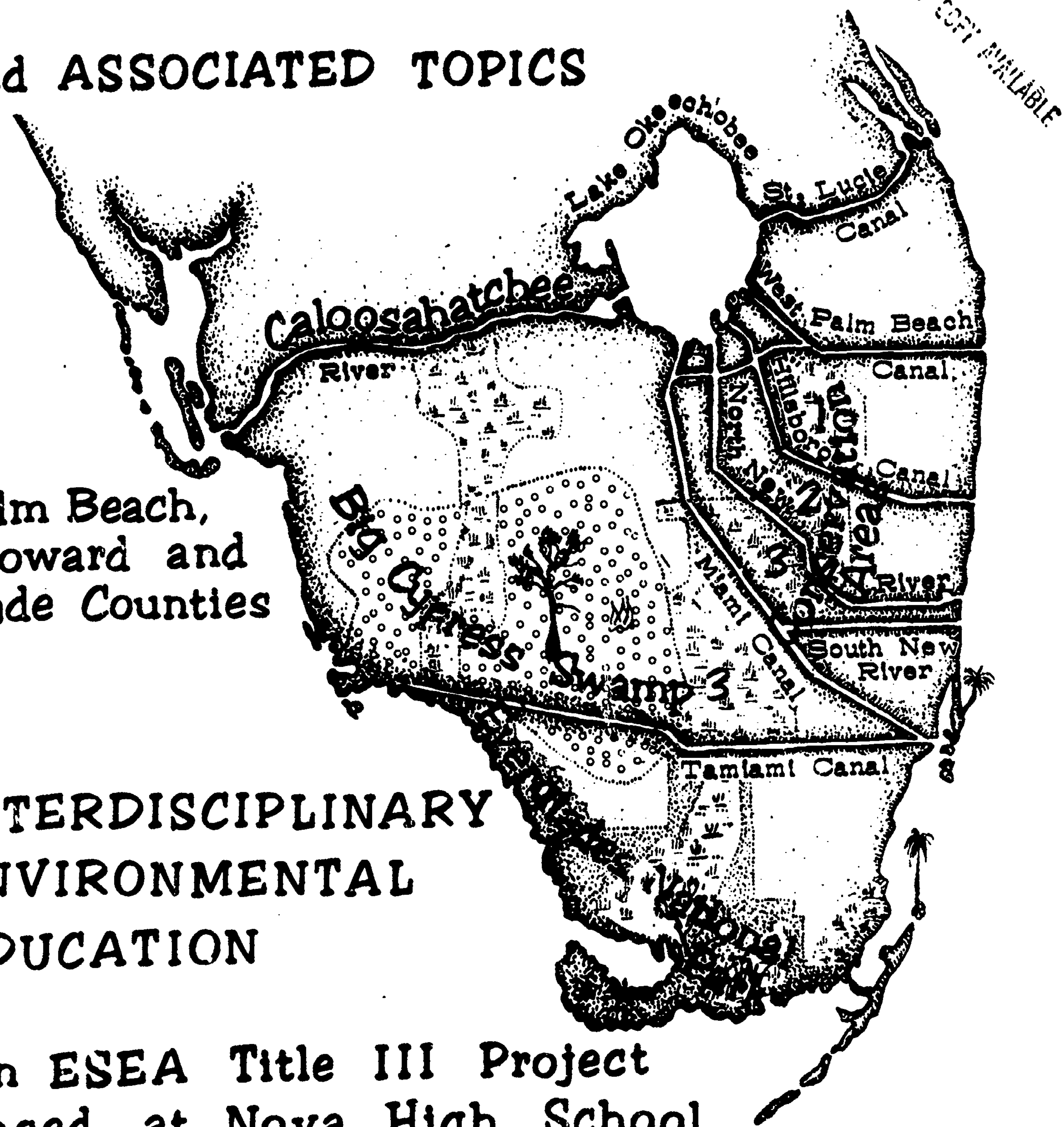
ABSTRACT

This booklet deals with the hydrology of southeastern Florida. It is designed to provide the citizen, teacher, or student with hydrological information, to promote an understanding of water resources, and to initiate conservation practices within Florida communities. The collection of articles within the booklet deal with Florida water resources and Florida water problems, but much of the information is applicable to other areas. Topics such as the hydrologic cycle, ground water aquifers, water resources and demands, water quality, the Everglades, and water-life are covered, accompanied by maps, diagrams, tables, and illustrations. The articles are written by various people--engineers, environmentalists, researchers--or are excerpts from publications or speeches and present different viewpoints on controversial issues. A brief historical overview of the hydrology of Florida, a glossary, and reference list are also included. (TK)

HYDROLOGY of Southeast Florida

and ASSOCIATED TOPICS



Palm Beach, Broward and Dade Counties

INTERDISCIPLINARY ENVIRONMENTAL EDUCATION

An ESEA Title III Project based at Nova High School BROWARD COUNTY, FLORIDA

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INTERDISCIPLINARY ENVIRONMENTAL EDUCATION PROJECT
An ESEA Title III Project
The School Board of Broward County, Florida

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FOREWARD

Anyone living in south Florida a century ago would have found hydrologic patterns quite different than they are today. Nature had been building one of the most delicately contrived ecosystems for more than 5000 years. An enormous grassland inundated with water, called the Everglades, was densely populated with all forms of life. This tremendously expansive land spread south from Lake Okeechobee to the peninsula's broad tip whose fringes grew thick mangrove forests and islands. A 50 mile swath of a barely visible river only inches deep flowed gently southward for more than 100 miles. Nature in her own way had made this particular stretch of land saucer-shaped so that water flowed gently towards the center from east and west. The land area slope of three inches a mile led the water gently southward to the sea.

Beneath this great land mass lay a very porous limestone that absorbed great quantities of water. Known as the Biscayne Aquifer, this underground storage area supplies all south Floridians with its water supply. Due to natural laws which will be discussed later, this underground reservoir held back the salt water of the oceans from intruding beneath Florida's land surface.

The natural conditions that existed at that time enhanced the growth of a diverse population of vegetation. The nutrient content of the water, established through its gentle course over miles of decaying undergrowth was made available to plants, and new luxurious growth emerged throughout the marsh and flood plains. Diverse forms of animal life also flourished as they fed upon the thriving vegetation readily available to them. Growth and death processes enriched bottom sediments creating valuable muck deposits upon which a host of aquatic organisms also thrived. It was a land so deluged with water during long periods of rainfall that it was able to survive periods of drought.

In the latter part of the nineteenth century man's attention was drawn to the favorable climatic conditions, good fishing, and an abundance of wildlife for his larder. Obviously he could not settle in this low watery terrain and instead began to settle on higher ground found along Florida's coast for it was less susceptible to the ravages of hurricanes and floods. Miami, Fort Lauderdale, and Palm Beach became small communities settled by these adventurous early settlers. Dissatisfied with conditions of the land for agricultural purposes, farmers began to move inland to take advantage of rich bottomlands. Ditches were gouged out of the land for drainage purposes and farmlands developed further inland.

And so it went until hurricane-spawned floods plundered the land. Dikes were built around the perimeter of Lake Okeechobee in order to stem the ravages created by reoccurring flood conditions. In 1926 and 1928, nature destroyed these efforts and reclaimed her land. Dikes were reconstructed only to be devastated again. Many settlers lost their lives drowning in high flood waters.

In 1948, Congress authorized measures to be taken in matters of flood control. The U.S. Army Corps of Engineers were given the responsibility of developing methods and procedures that would effectively deal with flood control.

In 1949, the State of Florida created the Central and Southern Florida Flood Control District (CSFFCD). Today the CSFFCD maintains more than 1400 miles of canals and drainage ditches built by the U.S. Army Corps of Engineers.

Today Florida has the distinction of being one of America's favorite vacation lands. It has added another distinction, for it is now considered "the" place to live. Testimony to this is the fact that Broward County alone has some 50,000 new residents each year. The "good life" has attracted families and individuals from a large cross-section of the United States and Canada. These new "settlers" are experiencing life styles that differ in many respects from that of towns and cities from which they emigrated.

The local mass media speaks of water problems that range from flood to drought--from abundant supply to critical shortage. Many of these new residents are unaccustomed to the problems related to our water resources. Questions by an inquisitive citizenry are numerous. Some ask, "Where does our water come from?" Others ask, "Who is responsible for managing our water supplies?" These simple inquiries must be answered if any headway is to be made in resolving the water problems that confront us today. So complex have issues become that individuals, through a lack of fundamental data, find it extremely difficult to evaluate the statements made by various citizen groups debating environmental issues.

The following pages are devoted to giving the people of Florida a better understanding of our water resources.

HOW CAN THIS BE ACCOMPLISHED?

The writer has drawn from the expertise of water engineers, professors, state agencies, and many other sources to compile in a hopefully meaningful way a text-like approach to the hydrology of Florida. It may be used by students, teachers, and the community at large. Reports issued by the Central and Southern Florida Flood Control District have been used extensively but not exclusively. The reader may find that viewpoints by other agencies on similar topics may contradict each other. This has been done intentionally so that individuals may hear two sides of controversial issues.

It is my privilege to acknowledge the following authors, agencies and publications who congenially granted permission to use their materials and viewpoints. They are: Arthur Marshall, Director of the Center for Urban Studies, Division of Applied Ecology University of Miami; John W. Woods, Chief, Fisheries Division, Florida Game and Fresh Water Fish Commission; In Depth Report authors of articles published by Central and Southern Florida Flood Control District: Robert L. Hamrick, Planning Engineer; William V. Storch, Chief Engineer; Jan Browning, Environmental Engineer; Z. C. Grant, Director, Department of Field Services; ENFO Newsletter published by Environmental Information Center of the Florida Conservation Foundation, Inc.

A special thanks to Dr. Kerry K. Steward, U.S. Department of Agriculture, for allowing me the use of the Department's research fields for photographing aquatic plant species.

If the information compiled herein leads to the initiation of additional conservation practices within our communities, then we will all have benefited.

SOUTH FLORIDA'S 'UNMANAGED' RESOURCE

By Robert L. Hamrick
Planning Engineer (FCD)

Hydrology, somewhat loosely defined, may be called the study of the natural occurrence of water in all its various forms and transformations in the hydrologic cycle (see Fig. 1).

Like most natural mechanisms, this one is basically driven by solar energy. The driving energy is absorbed in the evaporation of water into the air and raising it to form clouds. The water droplets suspended in cloud formations may be considered to be at the very top of the cycle. They have the basic energy impulse stored in them to carry them through to the point of evaporation again and are in a relatively pure state insofar as quality is concerned. In this state the water droplets may be easily transported and redistributed over the surface of the earth by wind movement.

From this point on in the cycle it may be generally said that everything is "downhill." The energy in the droplets is expended in falling to the earth as rain, and flowing over and through the earth. Their quality is degraded by materials picked up while falling through the air, and in flowing on the ground. The flow path of the rainfall is largely determined by gravity and physical obstructions.

In general, most people are not at all concerned with this natural mechanism and, in fact, do not even recognize its existence unless rainy weather interferes with their plans, or the system is generating too much or too little water resulting in either flood or drought.

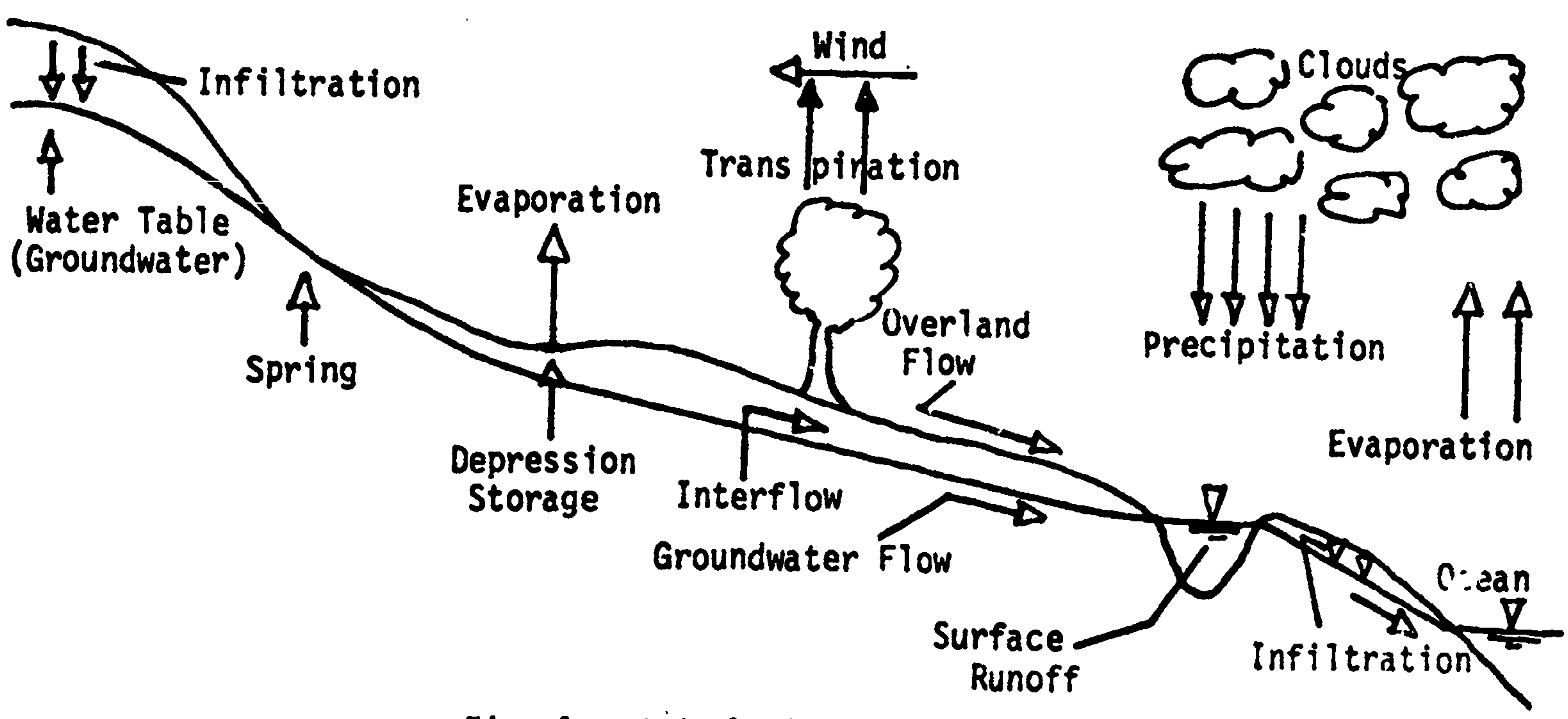


Fig. 1. Hydrologic Cycle

Some people still seem to believe that we have "underground rivers" available for water supply--a bountiful supply that wells up from an unlimited source. It is true that we are blessed with plentiful groundwater supplies in Florida, but they are not unlimited and their source is rainfall.

All the normal sources of water for man's use originates in rainfall, somewhere, sometime. (A little study of the hydrologic cycle in Figure 1 should make this clear).

Water may be transported for considerable distances from where it fell as rain, and it may be stored for long periods of time, but with very few exceptions it originates as rainfall.

Consequently, the measurement and study of rainfall is in truth the measurement and study of our potential water supply.

Although Lake Okeechobee provides a vast surface water storage area, as do, at times, the three Everglades Conservation Areas, South Florida's greatest urban water supply source lies underground.

The Floridan Aquifer system underlying most of southern Florida has recharge areas in the Orlando-Green Swamp area, as well as farther north. The Biscayne Aquifer is a water table system that is recharged over most of its surface area. The latter area extends no farther north than the southern portion of Conservation Area 1 (south Palm Beach County line), and no farther west than Conservation Area 3. (See Fig. 2)

In the context of South Florida, this means that usable groundwater must have originated as rainfall within approximately 200 miles of the point of use for the deep aquifer system, and usually within just a few miles for the water table systems.

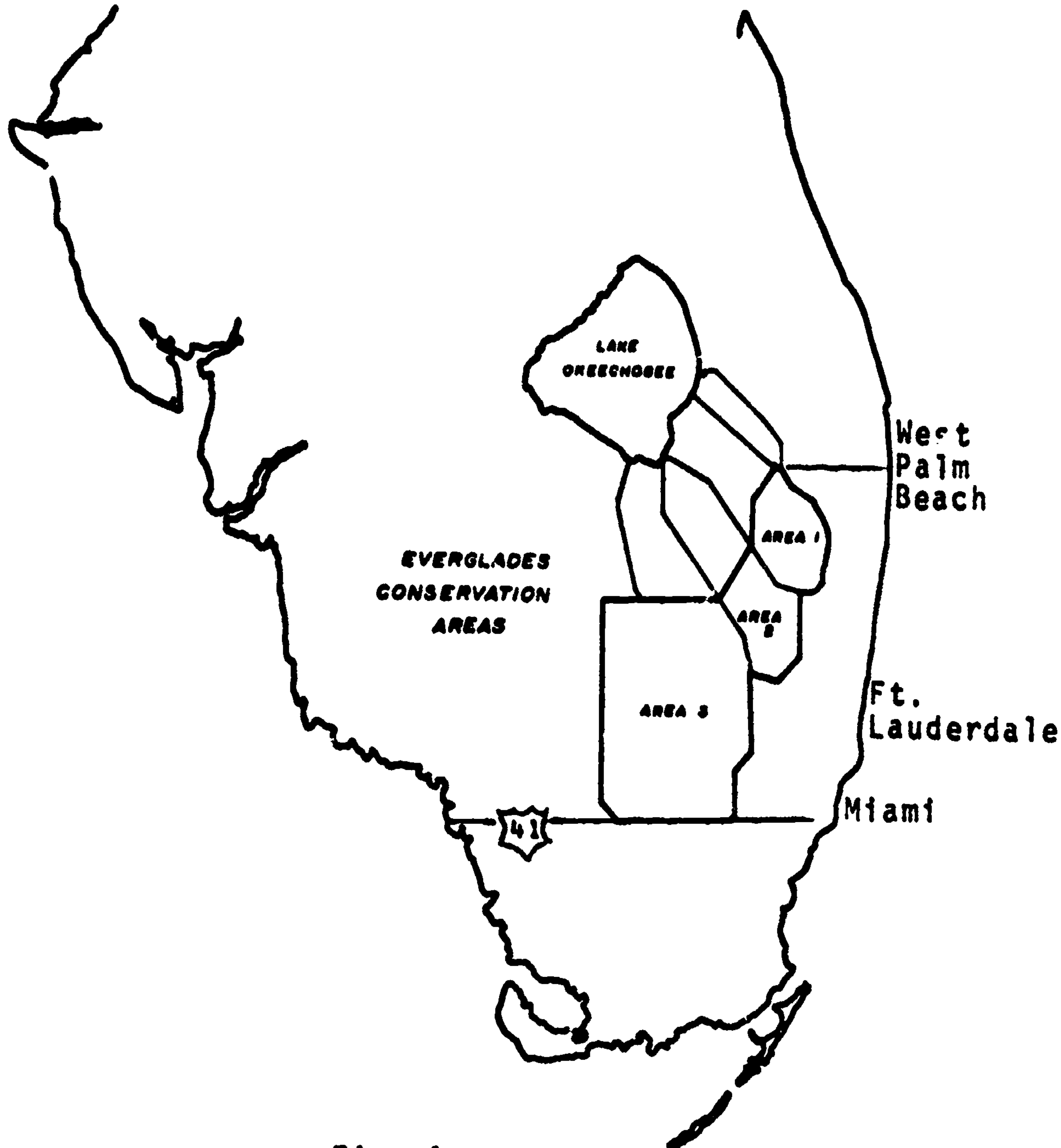


Fig. 2.

<u>Wet And Dry - More Or Less</u>

SOUTH FLORIDA IS A "TWO-SEASON REGION

The rainfall regime in South Florida is quite different from that farther North. Rather than the typical four season description of the Temperate Zone, South Florida climate may more accurately be described in the <u>wet and dry season</u> terminology of the tropics and sub-tropics. The "wet season" extends roughly from June through the middle of October, with the remainder of the year being "dry season."

Figure 3 shows the average monthly amounts for each month in the year for a typical station. It should be clearly understood, however, that there is no guarantee that there will not be major rainfall events during the "dry season," or that, on the other hand, there will not be extended dry periods during the "wet season." The wet season may actually begin earlier in the year than June or much later.

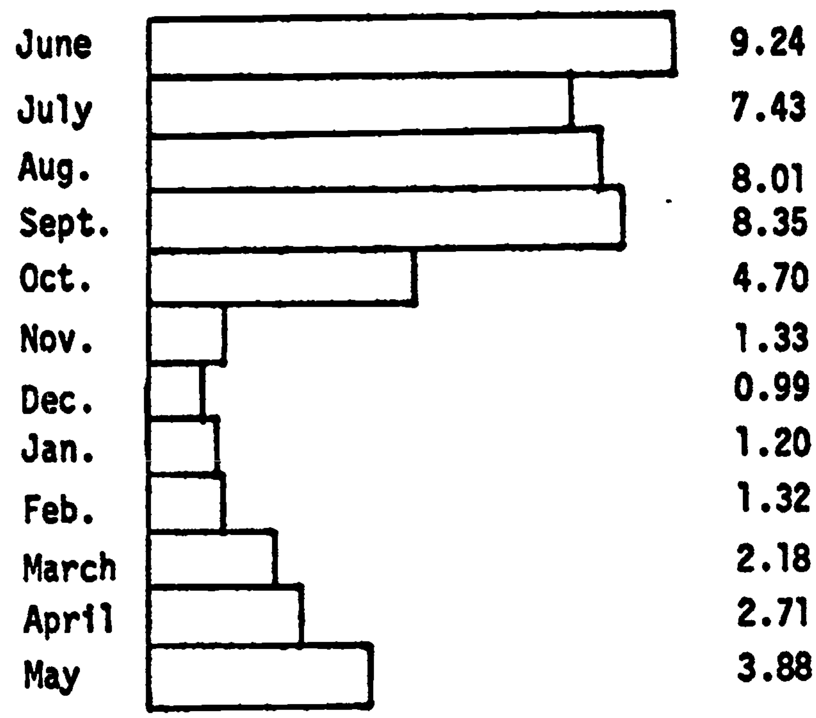


Figure 3. Normal Rainfalls

Dry season rainfall is typically derived from frontal activity as cold fronts sweep through from the West and North. The relatively warm, moist air is displaced upward by the heavier cold air and, as it rises, it becomes cooler and the moisture condenses to form clouds. As the droplets coalesce (grow together or merge) they begin to fall.

People often wonder why the raindrops that fall from the cumulus clouds of a cold front are so small or fine compared to the big drops that pelt down from the cumulus clouds of a summer thunderstorm. The answer is that drop sizes are directly related to the amount of turbulence and updraft.

The stronger updrafts and higher speeds in the violent, towering cumulus of the summer months keep the droplets bouncing up and down in the atmosphere longer, where they keep merging with others until the drops become big enough to resist the force in the updrafts and finally fall to the ground. In the less turbulent cumulus of the average cold front, this merging effect is reduced considerably. The droplets fall from the clouds sooner and therefore are much smaller.

It is often possible to see one of these frontal systems move in with a sharply defined cloud front stretching from horizon to horizon in a general west-east direction. As the front approaches the wind tends to pick up, switching clockwise from westerly to northerly quadrants. The temperature begins to drop and a light rain begins to fall as the cloud cover moves over. If the front is strong and moving rapidly, the weather may turn cool and clear shortly after. On the other hand, the front may stall in a locality, resulting in a few days of cloudy, drizzly, moderately cool weather.

Thunderstorm Center of U.S.

The typical wet season weather is dominated by the convective-type rainshower. This is the system that builds up many small clouds during the morning and early afternoon, followed by rain in the middle to late afternoon. The reason for the timing of these showers is not difficult to follow. As the ground heats up during the day, the air above it is warmed and begins to rise. The clouds tend to form over the warmer locations.

Florida has the highest rate of thundershower incidence in the United States. The highest concentration in the State is in the Tampa area. These showers are often quite small and rain over a path that may be several miles long and less than a mile wide. This gives rise to a great variation in the amount of rainfall over an area. With longer time spans these effects tend to average out. Given favorable conditions, these small storms can build into large systems of awesome power, that drench large areas and occasionally spawn hailstones as large as golf balls.

The other rainfall occurrences that contribute to the wet season are easterly waves, depressions, tropical disturbances and hurricanes. Not all tropical storms are terrifically wet, but even a "dry" hurricane will usually produce several inches of rain along its path.

The total annual rainfall is made up by a combination of wet season and dry season weather events. There is a great amount of variability, as may be expected. For instance, there are years when the contribution of tropical disturbances to the total rainfall is minimal, but in other years these events dominate the entire rainfall record. Total dry season rainfall is normally quite small in the total, but coming during the crop season, it can have a positive or negative effect far out of proportion to its actual input.

Over Surface Water Storage Areas

RAINFALL AMOUNTS LESS WHERE NEEDED MOST

The annual amount of rainfall normally expected varies considerably from place to place geographically. A look at the iso-hyetal map in Figure 4, which joins points of equal annual rainfall amounts, demonstrates variability. Some of this variation is due to specific reasons.

For instance, the coastal rainfalls are noticeably heavier than inland amounts, an effect of the mechanism of convective storms. The strong difference in air temperature between the land and water areas will result in cool moisture-laden air from over the ocean moving in to replace the rising hot air over the land. This gives rise to the well known "seabreeze effect." It supplies large amounts of moisture as it in turn is warmed and rises to form clouds. This effect naturally declines progressively moving inland.

The reason for the concentration of this increased rainfall effect along the southeast coast between Miami and Stuart is not so obvious. It is well known that metropolitan areas with their large heat releases, and increased dust loads to provide raindrop nuclei, cause an increase in rainfall in the immediate vicinity. Whether this is the total causative factor in this case or not is somewhat speculative. The rainfall on Lake Okeechobee itself is considerably less than the surrounding area, due to the fact that the relatively cool water area (in contrast to land surface) does not generate cloud formations.

In any case, these variations are quite important when you consider that rainfall is the ultimate source of supply for our entire fresh water system. The higher rainfall expectations tend to be along the coast where it is highly likely that the water will be run out to sea; and even if it were not, the urban nature of most of the coastal areas guarantees a fairly heavy pollution load. (See Fig. 4)

On the other hand, the lower expectations are found inland over the water storage and supply areas. The lowest of all rainfall expectations in South Florida are those over the Kissimmee Basin, Lake Okeechobee, the Everglades Conservation Areas and the southwest Gulf Coast; or in all but one of these areas exactly where there is the greatest need for rainfall to replenish surface water storage.

Numerically, these differences are considerable. If we compare the extreme cases of a return period of once in 100 years and once in two years rainfall expectancy* along the southeast coast, and near Lake Okeechobee, it will demonstrate the range of difference in expectancies over both time and space. Comparing the two-year amounts shows rainfall in the coastal area to be 20 percent more than the interior station. For the 100-year period the comparison is 30 percent more than the interior station.

ADAPTED FROM CORPS OF ENGINEERS DATA

FIGURE 4

RAINFALL DATA VITAL IN WATER MANAGEMENT

Rainfall data and the information derived from it are used for a variety of purposes in water management. Some uses require long term records for statistical validity. Other uses need recent history to determine trends; still other uses require up-to-the-minute information for decision making purposes.

*Note: Data taken from Corps of Engineers DPR, Part 6, Section 6, Plates 5 and 30.

Long term historical records are quite often analyzed to gain an insight into just what may be expected in terms of maximum rainfall events, minimum events, the most often occurring event, and the degree of variability. Statistical measures such as the mean, the standard deviation, etc., are also used in this manner. Another group is more directly predictive in nature; such as trend analysis, cyclical analysis, and spectral analysis.

The first group of expectancies tend to assume tha the past is an adequate representation of the future; while the second group is aimed at determining if there is some pattern that is predictive, or if there is some trend indicating that the future is departing from the past record.

Another use for long term records is in the development of rainfall-runoff relationships. Rainfall data used in conjunction with records of basin discharge and the physical properties of the basin have been used to derive a wide variety of relationships.

These relationships are oriented toward determining the volume of discharge and/or the rate of discharge from the basin. They may be quite simple or quite complex, depending upon the uses and the locality for which they were developed. The simpler ones usually require experience and good judgment to utilize successfully, because many variables are not accounted for and the user must make up the difference.

The more complex relationships require more skill to set up and adjust. They tend to be fairly stable so long as the physical conditions in the basin are stable. The most promising new tools for water management have developed out of the various hydrologic and hydraulic modelling techniques in recent years. But one does not deal with watershed models very long before it becomes evident that good, accurate rainfall information is the prime input to any basin model. It is an inescapable essential because rainfall is the ultimate source of supply.

ADEQUATE RAINFALL MEASUREMENTS BASIC NEED

Basic to obtaining data for meaningful analyses of rainfall records, of course, is the reasonable accurate measurement of the rainfall itself. This is not as easy as it may seem on the surface, as there are common problems with different types of raingages; and there is always the problem of obtaining truly representative measurements from the available number of raingages in any given area.

The standard can gage is probably the best known of all raingages. This is an eight-inch diameter device with a funnel to an internal container. It requires someone to manually measure each day's rainfall. The next step up in sophistication is a recording raingage of some type.

These are similar to the standard can in the outside opening and funnel, but instead of routing the water to a measuring tube, one type routes it instead to a bucket on a scale. A clock mechanism turns a chart under a pen, and the position of the pen is determined by the weight on the scale.

Another common type of recording gage is the tipping bucket. It routes the water into a small double bucket arranged on a pivot so that when one bucket is filling, the other is emptying. Each time the mechanism tilts, a counter is advanced and an event is recorded on the chart. Each tip of the bucket is supposed to represent either 0.1 or 0.01 inches of water, depending on the bucket size used.

There are many other types available, but they generally have a set of common problems. These problems are related to the various aspects of the sensitivity of the measurement to the pattern of air currents around the gage. The hills and valleys of the terrain for a considerable distance around can affect the catch. Buildings and vegetation can have profound effects if the location is not selected with care. However, one of the greatest problems is the varying effect of wind velocity on the catch. It has been estimated that a normal raingage may underestimate the rainfall by 70 percent in winds of 40 miles per hour. This effect may be minimized by attaching well-designed wind screens.

The other thing common to almost all of them is the fact that they measure rainfall at a single point. They tell you little or nothing about what is happening a few feet or a few miles away, other than what you are willing to infer. Here lies the problem.

If, for instance, the primary interest is major flood control works, a rather sparse network will suffice to provide data. This is based on the assumption that small events that pass between gages are of little or no concern for flood purposes. This is generally a valid premise because floods are usually touched off by very large weather systems, and they tend to be fairly homogeneous.

At the opposite end of the scale, it is important from the water management point of view to know just how much usable water is available in either ground or surface storage, or what deficiency you may have in every area. Then it becomes important to measure very carefully the total rainfall over the basin. Otherwise, there is no knowledge, or very limited knowledge, of the single greatest input contributing to the water balance of the basin.

Cost Is Factor In Sparse Distribution

'DENSITY' OF RAINGAGES LESS THAN DESIRED

Another way of looking at the validity of rainfall measurements is to look at how well the rainfall measurement sample represents the total population of possible measurements. In other words, a standard eight-inch diameter opening gives a catch area of approximately 0.35 square feet. In an acre area this is approximately one part in 125,000; for one square mile it is one part in 80 million.

In the United States, a representative raingage density is on the order of one in 250 to 350 square miles. The FCD has some areas with gages set at approximately one in 150 square miles. Based on the calculations above, the 250 to 350 square mile distribution gives a simple rate of one part in 19 to 27 trillion. Even the relatively dense FCD areas have a sample rate of one part in 12 trillion. These are extremely small samples to use in attempting to project the nature of the total rainfall over a watershed.

There are valid reasons why this sampling rate has not been improved. It is not because the responsible agencies have simply been dilatory in performing their duties. One set of reasons relate to some of the problems referred to earlier concerning the factors affecting the accuracy of readings at an individual gage. The measurement tool simply is not adequate. The other set of reasons have to do with the expense and logistics of deploying, servicing and maintaining large numbers of these gages.

For example, during the cloud seeding experiment in April and May of 1971, the FCD temporarily installed a network of 121 gages for the purpose of evaluating the effectiveness of the seeding.

The gage density of one in 36 square miles (one part in 2.85 trillion) was selected as the absolute minimum to give a fair representation of the rainfall distribution. To service and maintain this network, the FCD incurred a cost of about $128 per day for personnel alone. This does not include travel costs, or the cost of data handling in the office.

This amounts to approximately $1.00 per day per gage. If this cost was projected to cover the entire District with a network of this density, it would cost approximately $160,000 per year in personnel for service and maintenance. Again, this includes only a portion of the total cost, but it demonstrates very graphically why raingage networks remain relatively sparse.

Cost Again Is Big Factor

RADAR IS LIKELY SUBSTITUTE FOR RAINGAGES

There is a possible alternative to the usual raingage approach to measuring rainfall over large areas. The capability of measuring rainfall by means of radar has developed rapidly in recent years. Reasonable radar measurement of rainfall can be made out to a range of 80 to 100 miles. This permits a single installation to provide data from a large area. Furthermore, the data is available as the event occurs rather than a week to six weeks later.

The principal objection to radar raingages now is the high cost of operation. It requires the constant attention of highly skilled operators to produce valid data under the current state of development. Continuing development is expected to automate a major portion of the current manual operations and consequently make this an economically feasible alternative.

In Summation

The basic decision making factors in water management systems may be boiled down to approximately four categories; (1) Background knowledge of the probable rainfall excesses or shortages based on analysis of historical rainfall data; (2) Background information on water demand (also rainfall related); (3) Knowledge of the current state of the system; and (4) Runoff expected from current and imminent rainfall. These factors combined with the physical and socio-economic limitations of the system largely determine the course of action taken.

SOUTH FLORIDA'S GROUND WATER AQUIFER

By William V. Storch
Chief Engineer (FCD)

Municipal water supplies for most of the nation's major cities are drawn from surface water sources, but in Florida, where groundwater of good quality is available almost everywhere, the situation is reversed.

Almost every large Florida city taps the groundwater with well fields for its municipal water supply. In the southeast coastal region, for example, West Palm Beach is the only city south of the St. Lucie Canal (Stuart area) that obtains its water directly from a surface source.

The great subsurface water source on the lower east coast is the Biscayne Aquifer (1), a sprawling mass of water-bearing formations consisting of a variety of deposits. The accompanying map of this area (Figure 5) shows the locations of major well fields which draw from this aquifer.

In the southern portion of the area, the upper layer of the aquifer is the formation known as the Miami Oolite. North of this, the upper rock stratum is the Anastasia Formation. The approximate limits of these two formations are shown in Figure 5. The indicated boundaries are an over-simplification of some rather complex geology, however.

The major municipal water supply withdrawals from the southern portion of the aquifer amount to 504 million gallons per day (MGD). From the northern portion of the aquifer withdrawals total about 72-1/2 million gallons per day.

Together, these supply systems serve a population of nearly two million. Tables I and II present a breakdown of individual supply system capacities and the population served by each system.

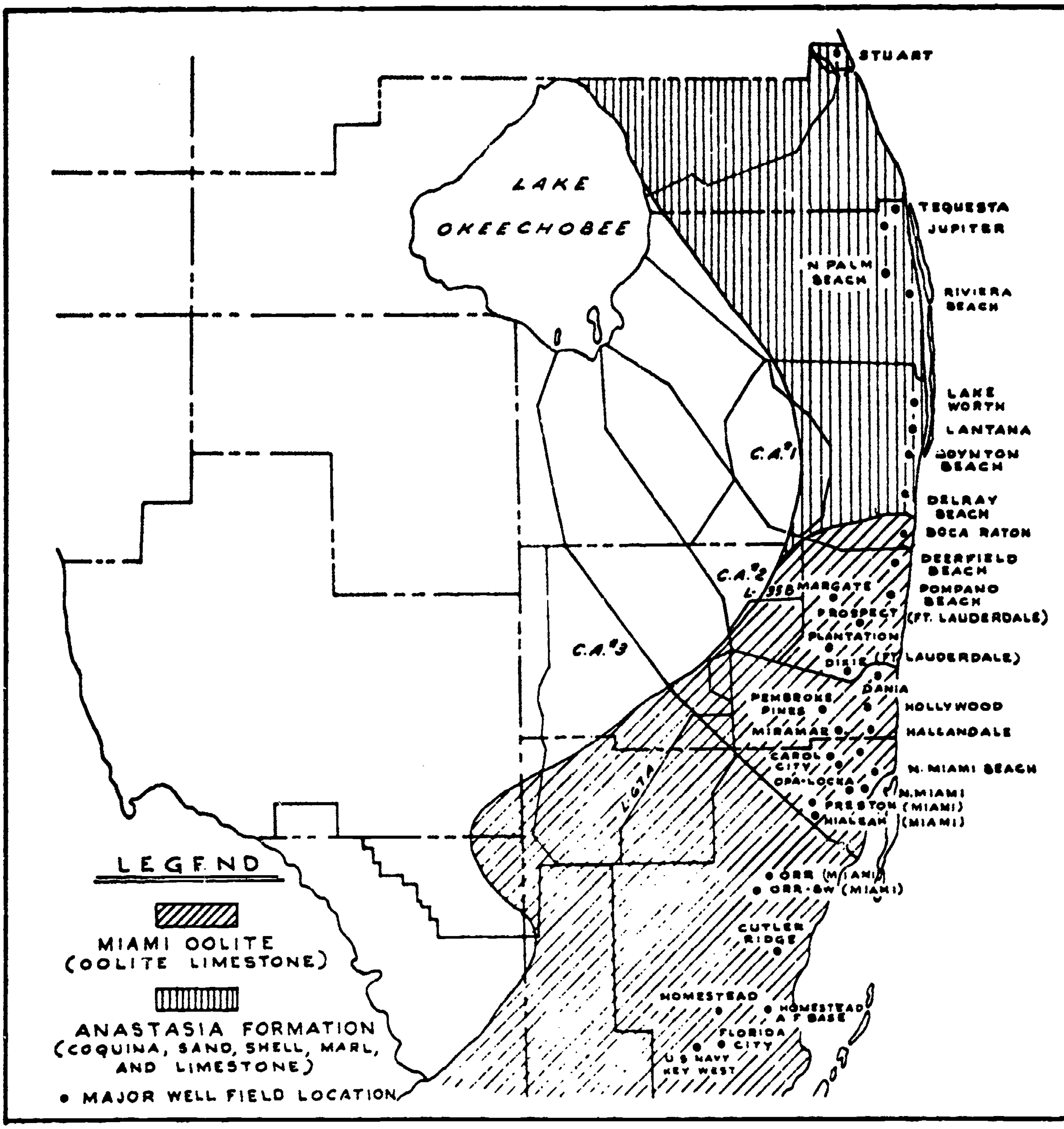


FIGURE 5. PARTIAL GEOLOGIC MAP OF SOUTHERN FLORIDA

The total withdrawal by the municipalities listed in the accompanying tables is 576.5 million gallons per day (MGD), or a flow rate of about 865 cubic feet per second (cfs). One MGD is the equivalent of a constant flow of water at the rate of about 1-1/2 cfs for one day. This total municipal use of groundwater (865 cfs) can be compared with an average annual flow rate of about 2100 cfs for the Kissimmee River near Lake Okeechobee, and about 1200 cfs for the St. Johns River near Cocoa.

The yearly withdrawal from the groundwater by major municipal systems is 210 billion gallons. This converts to a total volume of about 630,000 acre feet (AF). One MGD, is equal to a volume of water which would cover one acre to a depth of three feet--that is, 3 acre feet (AF). For comparison, these yearly municipal withdrawals are equivalent to 1.4 feet of water on Lake Okeechobee, which contains 450,000 AF for each foot of depth above elevation 14.5 feet.

TABLE I
(Southern Portion)

City	Capacity (MGD)	Population Served (est.)
Miami		
Preston	60.0	
Hialeah	60.0	
Orr-Southwest	100.0	915,000
North Miami Beach		
Sunny Isles	6.0	
Norwood	5.0	
Myrtle Grove	12.0	100,000
North Miami		
East Plant	3.0	
West Plant	7.0	55,000
Opa-Locka	2.5	14,000
Homestead	12.0	13,000
Carol City (private)	4.0	15,500
Key West	7.0	64,000
Florida City	1.5	5,000
Homestead AFB	2.5	5,000
Cutler Ridge, etc. (private)	4.0	12,000
Dania	3.0	8,500
Deerfield Beach	16.0	15,000
Fort Lauderdale		
Dixie	20.0	
Prospect	40.0	186,000
Hallandale	8.0	25,000
Miramar	6.0	23,000
Pembroke Pines	4.0	20,000
Pompano Beach	24.0	52,500

Table I (Cont'd.)

City	Capacity (MGD)	Population Served (est.)
Hollywood	20.0	100,000
Broward County (7 sites)	17.5	58,500
Other Municipal in Broward County	4.0	15,000
Plantation (private)	6.5	22,000
Margate (private)	1.5	13,000
Other private in	10.0	10,500
Boca Raton	37.0	35,000
	504.0	1,783,000

TABLE II
(Northern Portion)

City	Capacity (MGD)	Population Served (est.)
Delray Beach	16.5	20,000
Boynton Beach	12.0	19,000
Lantana	3.0	7,000
Lake Worth	16.0	26,000
Riviera Beach	14.0	23,000
Tequesta	1.5	3,000
Jupiter	1.0	3,000
North Palm Beach Utilities (private)	7.0	17,000
Stuart	1.5	8,000
	72.5	126,000

NOTE: Data in the above tables has been adapted from basic information furnished by the U. S. Geological Survey.

Another way to look at municipal water use from groundwater in eastern Martin, Palm Beach, Broward and Dade Counties is to compare it with the water which is potentially available. There are about 2,000 square miles, or 1,280,000 acres, in only that portion of the aquifer area shown on Figure 5 which lies east of the Everglades Conservation Areas and Everglades National Park. In Volume 1, Number 1, of In Depth Report it was indicated that this area was generally one of water surplus. Map Series No. 32 of the Florida Department of Natural Resources was referred to for this statement.

That document shows an average excess of rainfall over potential evapotranspiration of approximately 8 inches for the area. The average volume of water which is potentially available as runoff, at a minimum, is on the order of 850,000 AF (1,280,000 acres X 8 inches). This is certainly not indicative of South Florida turning into a desert.

There is a reasonable sufficiency of water for foreseeable municipal uses, provided the resource is properly managed. And proper management involves reduction of waste and retention of the surplus.

GEOLOGIC NATURE OF BISCAYNE AQUIFER DESCRIBED

In view of the heavy reliance on groundwater for municipal requirements along the lower east coast it would seem that water management would very nearly be synonymous with groundwater management. Although true in a sense, it is not quite as simple as this.

The Biscayne Aquifer is what geohydrologists call a "groundwater aquifer." Basically, this means that it is a shallow aquifer not under artesian pressure, and that the upper surface is at, or very near, ground surface and receives its recharge from local rainfall.

As a consequence there is a very intimate connection between water in its surface and sub-surface manifestations. It's like twin brothers; when you hit one, the other one hollers "ouch." So, in actuality, one can't do anything realistic in the way of water management without considering the totality of the area's water system.

Some important principles which are involved in the hydrology and management of a groundwater aquifer can be illustrated by taking a closer look at the Biscayne Aquifer and particularly the portion in Dade County. Since this aquifer is also connected with a salt water source, its study will also furnish a look at some other classic principles.

The Biscayne Aquifer is described by Parker in Water-Supply Paper 1255, of the U.S. Geological Survey, published in 1955 (1). This document is a good starting point for anyone desiring to develop an understanding of the hydrology, geology and geohydrology of South Florida. (Much of the same information on the Biscayne Aquifer is contained in Report of Investigations No. 17 of the Florida Geological Survey, dated 1958.)

Briefly, the Biscayne Aquifer consists of a number and variety of marine and freshwater sediments; sands, shells, marls, limestones, etc. The major formations which comprise the aquifer are the Fort Thompson, the Miami Oolite, and the Anastasia. The Biscayne Aquifer is not described by any single geologic formation, but rather by general similarities in the hydrology of several formations or portions of formations.

It is important to understand this difference. The Fort Thompson Formation is the water producing formation in Dade County. This geologic formation extends northward to Lake Okeechobee as the floor of the Everglades Basin. However, close to the Dade-Broward County line, the hydrologic character of the formation changes markedly.

Parker states: ". . . this part of the formation (in the Lake Okeechobee area) makes a very poor aquifer; its limestones are dense and hard, and the intercalated mud and fine sand layers have very low coefficients of permeability." (2) Therefore, the southern portion of this formation is, essentially, hydrologically independent of the northern portion. Groundwater levels in the northern part of the formation can be raised or lowered without affecting groundwater levels in Dade County.

The Biscayne Aquifer is wedge-shaped with a thickness of 100 feet, or slightly more, at the coast, feathering out inland. Although not in accord with Parker's designation, by more or less common usage the term "Biscayne Aquifer" generally applies to that area wherein the top stratum is the Miami Oolite, as shown on Figure 5. A very rough approximation of the location of the westerly edge of this portion of the aquifer are the interior levees in the Conservation Area; L-35B in Area 2 and L-37A, etc., in Area 3.

POROUS AQUIFER IS ALSO HOST TO SALT WATER

Because the Biscayne Aquifer is highly permeable, and is also connected with a salt water source (the ocean), it rather dramatically illustrates the intimate relationship between surface water and groundwater. Consideration of this relationship can best start with a look at the comparatively delicate balance between fresh and salt water.

Salt water is denser than fresh water. This is readily understandable since salt water contains much larger quantities of dissolved minerals. The relationship between the densities, or specific gravities, of the two liquids is such that it takes a column of fresh water 41 feet high to balance a 40 foot high column of salt water.

So in a very porous environment such as the Biscayne Aquifer, open to both fresh and salt water sources, if the fresh water stood one foot above sea level you would not expect to encounter salt water until you reached a depth of 40 feet below sea level. For every foot of fresh water above sea level, then, there would be 40 feet of fresh water below. Ideally, three feet of fresh water "head" would mean 120 feet of fresh groundwater.

At the shoreline, of course, since there is no fresh water head, the aquifer will be salty throughout its depth. But, under natural conditions, the elevation rises and consequently there is an increasing depth of fresh groundwater as one moves inland.

At some inland point the fresh water head is sufficient in terms of the thickness of the aquifer to maintain a fresh water condition throughout the aquifer's depth. If this progressive increase in depth of fresh groundwater can be visualized, it is then easy to see that the salt water forms a wedge which intrudes into the coastal portion of the aquifer. (See Figure 6)

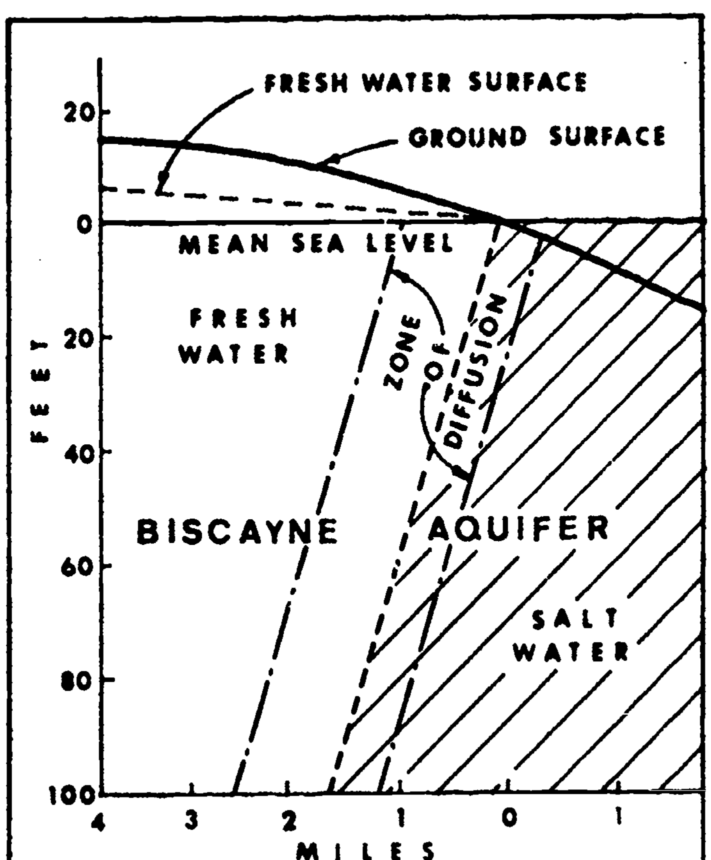


FIGURE 6
SALT WATER WEDGE & ZONE OF DIFFUSION

Under the natural order of things the location of this wedge of salt water can change temporarily. During prolonged droughts, fresh water heads would be reduced and the point of the wedge would move inland. But over the long term, the location of the wedge would be comparatively stable.

This density principle is known as the <u>Ghyben-Herzberg Theory</u>. In reality it means that the fresh water floats on top of the salt water much as an iceberg floats on the sea, with most of its bulk below the surface.

Avoiding Losses Through Canals

MANMADE BARRIERS RESIST SALT INTRUSION

With this principle fixed firmly in mind, it can readily be seen that salt water encroachment is not simply a matter of salt water moving up a natural tidal stream or a manmade tidal channel and being confined there. Such streams and channels lower the fresh water head in the adjacent aquifer. Thus they induce inland movement of the salt water wedge within the aquifer itself.

But natural streams are part of the natural system whereas manmade channels are not. The latter alter the equilibrium of the stable natural system. Such alterations work to reduce the volume of groundwater available for use.

First is the loss of some water received from rainfall now drained away which formerly would have gone into groundwater storage in inland areas. Second, and more grievous, is the displacement of fresh water as a result of salt water encroachment along the coast. The well-documented history of salt water encroachment in Dade County indicates the magnitude of this loss (3) (4). Such loss adversely affects municipal water supplies.

This loss can be avoided, however. By placing a barrier in the downstream reach of a tidal canal the necessary fresh water head can be maintained. What is the necessary head? Assuming an aquifer thickness of 100 feet, the Ghyben-Hertzberg Theory says a fresh water stage 2-1/2 feet above sea level on the upstream side of the barrier should keep the point of the salt wedge at the bottom of the aquifer in the vicinity of the barrier.

A program of salinity barrier construction in the major Dade County canals was initiated by Dade County after the severe drought of 1945. Initial work was accomplished under the direction of John C. Stephens and subsequently by

F. D. R. Park, the present Dade County Water Control Engineer. A salinity barrier ordinance was adopted by the county prohibiting construction of tidal canals inland of the "salt barrier line" unless a salt barrier is provided at, or seaward of, the line. Broward County now has a similar ordinance.

Salinity barrier construction was incorporated in the FCD plan and under that plan new barriers have been, or will be, provided in all the primary canals of Dade and Broward Counties.

Monitoring The Salt Water Line

'ISOCHLOR' INDICATES CONDITION OF AQUIFER

Returning to the salt water wedge concept, common sense indicates that there would not be an immediate and abrupt change along the inclined face of the wedge from sea water to fresh water. There is, in fact, a zone of diffusion or mixing. (See Figure 6)

This means there is a gradual transition from salt water to fresh water in the aquifer over some considerable horizontal distance. Ordinary sea water has a concentration of chloride salts on the order of 20,000 parts per million (ppm). Chlorides in normal fresh groundwater in this area run about 15 ppm. Therefore, along any horizontal plane within the aquifer there will be a gradual reduction in chloride concentrations as one moves inland.

Assuming the bottom of the aquifer to be roughly a horizontal plane, at some point on this plane a chloride concentration of 1000 ppm will be encountered. Moving inland from a number of starting points along the coast, an equivalent number of 1000 ppm points will be encountered at the bottom of the aquifer.

The line connecting all these points is the 1000 ppm isochlor; "iso" meaning the same or equal, and "chlor" being an abbreviation for chlorides. It is like a contour line, on a topographic map, which connects points of equal ground elevation.

The movement of the "salt water front" is recorded by periodically preparing maps on which the location of the 1000 ppm isochlor is plotted. This is the commonly used measure of salt water encroachment. (Figure 7 shows the extent of salt water encroachment at the end of 1970.)

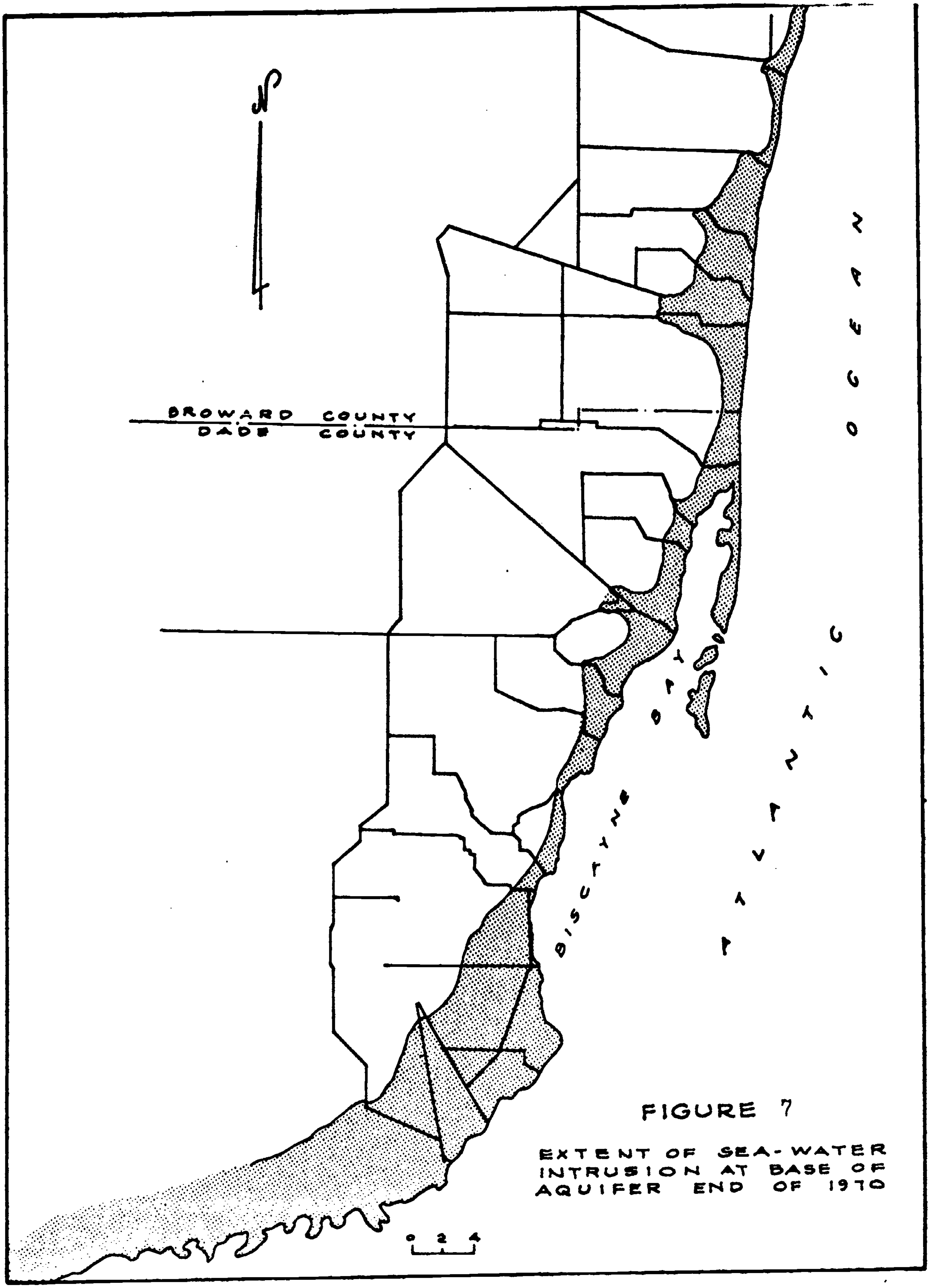


FIGURE 7

EXTENT OF SEA-WATER INTRUSION AT BASE OF AQUIFER END OF 1970

But 'Back-Up' Source Needed in Drought

CANALS REPLENISH MUNICIPAL WELL FIELDS

Groundwater and surface water interact in another way through the manmade canal system. When a groundwater well, such as a municipal supply well, is pumped, groundwater levels in the vicinity are lowered. They are lowered most at the location of the well itself.

Depths of lowering decrease with distance from the well. In effect, a "hole" is sucked out of the groundwater by the pumping well. The hole is roughly cone-shaped and is accordingly called a "cone of depression." The size and shape of the cone is dependent on such factors as the porous quality of the aquifer and pumping rates.

If such a supply well in the Biscayne Aquifer is located close to a fresh water canal the cone of depression will intersect the water surface of the canal. When this is done, and as long as a fairly stable level is maintained in the canal, the supply well will be drawing water from the canal. A stable canal level is generally maintained by moving water from higher groundwater table areas inland to the salinity barriers near the coast. This water movement is accomplished simply by gravity flow.

Therefore, by locating a supply well near such a canal a municipality is not only drawing on the groundwater in the immediate vicinity of the well but also on the groundwater in more or less remote inland areas. The economy of this for the municipality is quite evident. Rather than locating a well field inland with the consequential cost of distribution to coastal urban centers, it is far cheaper to make use of a canal which taps that inland source and which is there for flood control purposes anyhow. This results in many canals of the flood control system serving the additional purpose of water supply.

There are risks involved in locating supply wells close to the coast. If close to a source of salt water there is the possibility of inducing saline water flow into the cone of depression. Then there is the possibility, during severe droughts, of there being a general drastic lowering of groundwater levels. When this happens gravity flow from inland groundwater sources via the canal, in quantities sufficient to maintain a stable canal elevation adjacent to the wells, can no longer be accomplished. The latter risk is alleviated if the canal is connected with some other "back-up" source of water.

The Miami Canal in Dade County furnishes a good example of this sort of situation. The City of Miami's Miami Springs-Hialeah well field complex is located on both sides of the Miami Canal. Fred W. Meyer, of the U.S. Geological Survey, has suggested that as much as 75 percent of the water pumped at this location can come from infiltration from the Miami Canal.

During the 1970-71 drought it was found in mid-April that stable stages in the canal above the salinity barrier could no longer be maintained by groundwater recharge to the canal from inland areas. Therefore, surface water releases were made into the canal first from Conservation Pool 3B then from Pool 3A and eventually from Lake Okeechobee. For a period of 60 days, water in surface storage was used to maintain the necessary rates of canal infiltration into Miami's well field.

Slowing The 'Leaks" Reduces Waste

INTERIOR LEVEES RETARD SEEPAGE TO COAST

The high permeability (porous quality) and transmissibility of the Biscayne Aquifer results in a comparatively rapid movement of water through the aquifer both vertically and laterally. As with surface water, lateral groundwater movement is down-gradient--from points of higher elevation to points of lower elevation. Rates and volumes of groundwater flow increase with increasing differences in elevation, or head, between two points. Movement of groundwater in response to this head from one area to another is called "seepage."

As shown on Figure 5, the eastern perimeter levees of Conservation Areas 2 and 3 were constructed across the top surface of the southern portion of the Biscayne Aquifer. With higher surface water stages being held in the conservation areas, seepage into the area east of the levees was increased. Seepage rates as high as 40 cfs per foot of head per mile of levee were measured (5).

Although it is desirable to maintain a seepage flow eastward to hold up groundwater levels in that area, the amounts of seepage occurring were considered excessive. Much of this seepage occurred during wet periods, was picked up by the canal system, and was simply discharged to tidewater as surplus.

Accordingly, interior levees were constructed in Conservation Areas 2 and 3 as close to the outer limits of the aquifer as practicable. These levees reduce the head differential across the perimeter levees, thus reducing seepage to the east.

The net result has been to increase the effectiveness of the conservation areas as water retention areas while still maintaining an adequate groundwater gradient from west to east.

Six-Inch Rise From One Inch of Rain

SHALLOW AQUIFERS RECHARGED BY RAINFALL

Shallow aquifers receive their recharge from local rainfall over the aquifer itself. A common characteristic of shallow aquifers, then, is their responsiveness to local rainfall. Because the top strata of the aquifer is so close to the ground surface, and because of the high permeability of the aquifer formations, this is particularly the case with the Biscayne Aquifer. A rough rule of thumb is that an inch of rainfall will cause about a 6-inch rise in the groundwater table.

Lack of rainfall, with accompanying high rates of evapotranspiration, result naturally in severe lowering of groundwater levels in the Biscayne Aquifer (6). The canal system, with its ability to transfer inland groundwater to the coastal area, can play a useful role in such circumstances.

In north Dade County, the major canals are connected with surface water sources; the Everglades Conservation Areas and Lake Okeechobee. Adequate water levels for salinity control can be maintained by making water transfers from surface storage.

The situation in south Dade County is different. No connection with the reservoirs to the north exists. Presently, one of the major water management efforts is to provide such a connection and water delivery capability. This work is now in the planning stage. In addition to providing recharge for the aquifer in south Dade County, such a system will also be capable of delivering surface water flow to Taylor Slough in Everglades National Park, and to the Eastern Panhandle of the Park.

Billions of Gallons Remain in Aquifer

WATER SUPPLY PROBLEMS LOCALIZED IN DROUGHT

The example of the difference in groundwater elevations at Florida City between June 1945 and October 1947 represents a somewhat extreme occurrence. Although the normal annual fluctuation in the water table throughout the lower east coast area varies, a range of about 3-1/2 to 4 feet appears to represent a rough average for the general area.

This change in water table elevation reflects, of course, the annual change in groundwater storage. The volume of water stored between the spring low groundwater stage and the fall high stage is substantial. But here, as with surface water storage, losses take their toll; evapotranspiration, natural outseepage to the ocean through the aquifer, and seepage into the drainage system.

Although this annual storage increase is normally more than enough to meet municipal water supply requirements (even considering the natural "losses") municipal supply wells do not tap the entire "annual groundwater storage pool." The supply wells are concentrated and therefore draw water from only a portion of the groundwater pool. As pointed out earlier, the drainage canals can and do extend the area of the pool which can be tapped. During droughts, however, critical conditions can occur because:

(a) the annual storage pool contains less water,

(b) the area of the pool which can be tapped becomes more restricted due to general overall reduced water tables, and

(c) at the supply wells the point of the "cone of depression" extends deeper into the aquifer.

When this occurs the threat of salt water contamination arises.

In most years the area is self-sustaining in terms of water supply. The annual storage increase which results from rainfall is adequate. In drought periods the problem is essentially localized in character. It is a problem which is centered around the municipal supply wells and derives from their location close to the centers of demand along the coast and their concentrated nature. It must be remembered that even during droughts there are still many billions of gallons of fresh water in the aquifer which is up to 100 feet thick over an area of more than 2000 square miles.

<u>Adding To Extensive Studies</u>

ELECTRONIC MODEL SIMULATES AQUIFER FUNCTIONS

Through the course of the years the hydrology of the Biscayne Aquifer has been rather extensively studies. These investigations have been conducted by personnel of the U.S. Geological Survey. They have been financed 50 percent by the Federal Government and the remainder variously by Dade County, Broward County, the Cities of Miami and Fort Lauderdale, Everglades National Park and the Flood Control District.

The purpose of every one of these investigations is to gain a better understanding of the aquifer, with the objective of improving water management. Although there is a lot more to be learned, there is now a good body of knowledge and information available. There is no reason for anyone to be ill-informed on the Biscayne Aquifer.

Conventional analytical methods are available to the professional geohydrologist which, together with necessary field information, will permit reasonable answers to be given to specific questions concerning the hydrology of the Biscayne Aquifer.

Another type of tool is now being used to support and supplement these analytical methods. In the late 1960's the U.S. Geological Survey developed and tested a model of the Biscayne Aquifer. This work was funded by the U.S.G.S. and the Flood Control District, with support from Everglades National Park. At the local level, the development work was the responsibility of Charles Apel, of the U.S.G.S. The model itself, located at Phoenix, Arizona, is now functional.

It is what is called an "electrical analog" model. It makes use of the principle that the flow of electrical current and the flow of water is analogous. The model was developed using the data gathered over the years concerning the characteristics of the aquifer (permeability, transmissibility, etc.). Electrical components are used to simulate aquifer characteristics at a multitude of points, or "nodes."

When subjected to an electrical current representing, say, a specific rainfall event, the model will produce, at each node, information as to what groundwater levels will be in response to the event. Other features, such as water supply wells, canals, water level control structures, can be "plugged in" to the model.

The model was used to estimate the amount of supplementary water which would have to be brought into South Dade County to maintain groundwater elevations. Next year it will be used to evaluate the performance and effectiveness of inland water level control structures on Snake Creek, Biscayne and Little River Canals, which were proposed by the Governor's Conference on Water Management. Several additional tasks for the model have already been formulated.

With 'Rational" Land Use Plan

PRESERVATION OF THE RESOURCE VITAL NEED

Shallow groundwater is abundant in coastal Martin, Palm Beach, Broward and Dade Counties. The Biscayne Aquifer is an enormous reservoir of fresh water. In this area the average excess of rainfall over potential evapotranspiration is significantly greater than the current municipal requirement.

This means that the area is potentially self-sustaining without the necessity for "mining" its groundwater reserves on a long-term basis of diminishment. Beyond this there are in existence back-up surface water supplies to the west and northwest. And there are the means to deliver this back-up water to much, but not all, of the area.

In terms of the resource itself, and its potential for replenishment, the picture is good. But droughts will continue to occur, and supply wells located too close to salt water sources will be threatened with saline contamination. Ill-planned, intensive development of inland portions of the area will increase runoff and thereby reduce the present margin of rainfall which goes into temporary groundwater storage. Increasing demands and usage rates for domestic water will further reduce the present "living on current income," or self-sustaining, capabilities of the system.

Government, then must continue to pursue a program of preserving the resource and its replenishment capability. Among its tasks will be those of properly locating municipal well fields, reducing waste, providing effective carryover storage for drought periods, and developing a framework for rational use of the land in relation to the needs of the resource itself as well as those who use it. The future will very soon become the present.

FLORIDA IS ON A BUDGET TOO!

Capturing Runoff Could Be Key To Plenty

BUDGET REFLECTS STATE OF WATER RESOURCES, DEMANDS

By William V. Storch
Chief Engineer (FCD)

Anyone who is familiar with the record South Florida drought of 1971 would probably find it difficult to think of that extreme phenomenon of nature as a "budget problem."

But budgets exist in many forms, and may involve water as well as money or time. Just as the homeowner or Congressman must scrape the bottom of the barrel to pay the bills when funds run short, water management specialists must squeeze droplets from reserves when the rains fall short.

To the hydrologist or engineer, the "water budget" adds up to the primary procedure in evaluating a surface water or groundwater basin.

A water budget can be used variously for gaining a better understanding of the mechanics of a basin, for planning the water resource development of a basin, or for managing the water resource of a basin.

It is essentially an accounting procedure. Basically, the questions asked are:

Where does the water come from? Where does the water go?

It's like balancing a checking account. The accounting procedure is made possible by the fact that for any specified period of time input must equal outgo.

The hydrologist's problem is first, to identify the inputs and outputs and second, to establish the quantity of water from each source and the various demands on the whole water resource of the basin.

Taking a surface water system, for example, rainfall on the basin and surface water runoff which reaches the basin are the most obvious inputs. A less obvious input is ground water inflow.

On the outgo side there is water runoff or discharge, and consumptive use for domestic water supply and irrigation. Evaporation and evapotranspiration (water released to the atmosphere as part of the life process of vegetation) are large outflows and must be accounted for. So must surface water seepage into the ground water. Finally, there are changes that occur in water storage, which may be either plus or minus in the "input equals output" equation.

The major problem in developing a water budget is to establish input and output quantities. A good budget analysis requires large amounts of data, but the hydrologist has the analytical tools available to develop a reasonably good water budget from scattered data and short term records.

PRACTICAL APPLICATIONS OF A WATER BUDGET

Is a serious drought situation again confronting South Floridians?

Going into mid-December (1971), a rainfall deficiency continued to prevail over South Florida, and water levels in storage areas remained below desired scheduled levels and were inching downward.

However, water conditions generally were considered to be less critical than they were last year during the same period which was followed by severe drought.

Monthly reports on the status of South Florida's water resources from Lake Okeechobee southward have been disseminated to the public by the Central and Southern Florida Flood Control District since October, and will be continued through the dry season.

These reports include a budget of total stored surface water in Lake Okeechobee and the three Everglades Conservation Areas in the Palm Beach, Broward and Dade Counties. Two budgets are presented. One is for a condition of normal rainfall for the remainder of the dry season, and the other is for a condition of last year's rainfall for the same period.

The inputs include water presently in storage, rainfall on the reservoirs and runoff to the reservoirs from that rainfall. The outputs are the combined losses (evaporation, evapotranspiration and seepage) and the beneficial use demand (irrigation and municipal supply). Subtracting output from input gives either a surplus or a deficiency.

The December water budgets:

For normal rainfall, period Dec. 14, 1971 through May 31, 1972

Supply	
Storage on 12/14/71	2,041,000 Acre Feet
Direct rainfall on reservoirs	1,260,000 Acre Feet
Runoff to reservoirs	423,000 Acre Feet
	3,724,000 Acre Feet

Demand	
All demands and losses on the reservoirs	2,639,000 Acre Feet
Surplus: 3,724,000 – 2,639,000 =	1,085,000 Acre Feet

For below normal rainfall, period Dec. 14, '71 through May 31, '72

Supply	
Storage on 12/14/71	2,041,000 Acre Feet
Direct rainfall on reservoirs	644,000 Acre Feet
Runoff to reservoirs	312,000 Acre Feet
	2,997,000 Acre Feet

Demand	
All demands and losses on the reservoirs	2,639,000 Acre Feet
Surplus: 2,997,000 – 2.639,000 =	358,000 Acre Feet

EFFECTS OF WATER MANAGEMENT ERA IN SOUTH FLORIDA

A consequential effect of South Florida's modern era of water management on the disposition of water resources is reported by J. Hartwell, of the U.S. Geological Survey, in his September, 1970, report entitled "Some aspects of the Availability of Water from the Everglades to Everglades National Park, Florida."

The report, in essence, establishes a significant reduction in the discharge of fresh water to tidewater on the southeast coast of Florida, with a concurrent increase in the fresh water flow to the National Park.

A generalized water budget procedure was used by Hartwell to make the following comparisons:

In comparing the period 1940-1951 with the period 1952-1963, Hartwell found that the discharge to tidewater through the West Palm Beach, Hillsboro, North New River and Miami Canals was reduced by 5.8 million acre-feet during the latter 12-year period as compared to the first 12-year period. During those same comparative periods, flows to Everglades National Park through Shark Slough increased 2.7 million acre-feet.

Hartwell attributed part of the increase to the Park to greater rainfall amounts. But both the increase in southerly flow and decrease in flow from the Everglades to tidewater in part, stated Hartwell,". . . resulted from new control works of the Central and Southern Florida (Flood Control District) Project, which reduced flow to the sea through coastal canals."

ELUSIVE ELEMENTS OF THE WATER BUDGET

Evaporation and evapotranspiration are two of the factors which are the most difficult to quantify in preparing a water budget. If a hydrologist suddenly begins to talk to himself, the cause is probably the variables involved in the volumes of water lost through these two factors.

Total evaporation and evapotranspiration losses are dependent upon sunlight intensity, wind velocity, availability of water, temperature and the growth cycles of vegetation. Since these factors (and resultant losses) vary from day to day, short term water budgets are subject to inaccuracies from these sources.

These variabilities tend to iron out as the budget period lengthens, but there are still rather large yearly variations. Therefore, the hydrologist avoids use of "average annual" values unless nothing better is available.

Figure 1 shows the hydrologic cycle, which includes evaporation and transpiration.

The tremendous loss of stored surface water through evaporation is a primary factor in planning for additional reservoir areas in South Florida.

Evaporation increases proportionately with additional water surface area. Therefore, it is profitable to increase the holding capacity of existing reservoirs without increasing surface area rather than to create new reservoirs.

This simple fact of water management is readily understandable, yet it has become apparent that there is some misconception concerning increasing the holding capacity of Lake Okeechobee, where the evaporation loss is 55.70 inches per year. It has been said that it is pointless to increase the storage capability of the big Lake since any reasonable increase in Lake stage is just about equivalent to what would be lost to evaporation.

This is fallacious reasoning. All other factors being the same, water lost to evaporation is dependent completely upon surface area. Lake Okeechobee has the same surface area at 17.5 feet as it does at 15.5 feet, and thus the evaporation loss is the same.

The effect of having two more feet of water in the Lake is having two more feet of water to use--900,000 acre-feet of water we would not otherwise have. It is obvious why, for the sake of maximum storage efficiency, it is better to raise the level of the Lake rather than create new water storage areas with additional evaporation losses.

EVAPOTRANSPIRATION PROCESS NEVER CEASES

Evapotranspiration, the process by which water is evaporated from moist plant surfaces and transpired to the atmosphere as water vapor, is another loss factor that has to be reckoned with--especially in the heavily vegetated marshes of the three Everglades Conservation Areas.

A phenomenon which is generally not very well known, however, is that this process is at work even after water normally standing in the marsh disappears. Under these conditions ground water actually is lost to evapotranspiration.

Although the evapotranspiration rate decreases as water levels continue to recede below the ground surface, large losses still occur. This was reported by Steward and Mills following experiments at the Agricultural Research Service Station at Plantation. They found that with the ground water table three feet below ground level evapotranspiration from a sod field was 78 percent of the rate observed at one foot below ground level. (Transactions American Society of Agricultural Engineers, Vol. 10, No. 6, 1967.)

J. Hartwell, of the U.S. Geological Survey, has reported a dramatic example of this natural process at work on groundwater supplies in a 1963 paper entitled "Preliminary Evaluation of Hydrologic Situation in Everglades National Park, Florida."

Hartwell wrote that during the drought year of 1962, groundwater levels in the southeastern portion of the Park declined to an elevation of 1.5 feet below sea level by the end of May. He stated that the low groundwater level was the result of a prolonged deficiency in rainfall and a "high rate of evapotranspiration."

The evapotranspiration loss from the area of this depression, Hartwell noted, was 1,580 acre-feet per day. A similar condition occurred again in April, 1963, and Hartwell noted, "this decline can be attributed to evapotranspiration only."

It is obvious then, that in developing a water budget for a groundwater aquifer the hydrologist must take into account the evapotranspiration losses which will occur even when water levels are considerably below ground surface.

<u>How, Where To Store All That Water?</u>

IN WHICH THE HYDROLOGIST'S BUDGET RUNNETH OVER

An extremely important factor for the hydrologist in developing a water budget for a basin is surface water runoff; the quantity of water that leaves the basin.

This quantity of water is often called the "yield" of the basin and is expressed in "inches of water" or "acre-feet of water." It is the quantity that is left over after all natural and man-made processes have acted upon the water system of the basin.

If the hydrologists and engineers could capture all the runoff and find a means to store it all, the spectre of drought in South Florida would be routed. But, above-ground reservoirs gigantic enough to hold the bulk of the runoff which occurs in times of plenty are obviously impractical. given South Florida's topography. Basin water yields vary rather widely from year to year over most of the country, and South Florida is no exception. Here is a typical example:

In 1960, the total discharge of the Kissimmee River into Lake Okeechobee was 4,266,000 acre-feet. This was the maximum volume of discharge in over forty years of record keeping.

Three years later, however, the discharge was 397,200 acre-feet, the minimum on record. These discharges represent the total surface water runoff from the Kissimmee Basin, an area of some 3,000 square miles. Because of this sort of variability in annual basin yields, the use of average data is totally unacceptable for the purpose of designing reservoirs.

SOUTH FLORIDA'S WATER RESOURCES ARE ADEQUATE

Despite recurring drought problems in Florida, South Florida's water resources, on the average, are more than adequate, so indicated in the State Department of Natural Resources' Map Series 32, "The Difference Between Rainfall and Potential Evaporation in Florida." This document shows this to be particularly the case along the east coastal ridge and even in the Everglades Conservation Areas.

But water resource planning and management cannot be based on average values. The marked seasonal pattern of South Florida's annual rainfall, together with the larger cycles of wide variations in annual rainfall totals, ensure the continued occurrence of surplus and "waste" of water and periods of deficiency and drought. These latter periods will occur despite the fact that averages indicate this is an area of water surplus. A technique for "dampening" the effect of these extremes is the provision of carryover storage.

Clyde S. Conover, Florida District Chief of the U.S. Geological Survey has said, "if discharge to the ocean is held to a minimum, there will be on the average adequate water on the land for all foreseeable potential uses. The problem reduces, simply, to one of holding onto the water and accordingly reducing flow to the oceans." Again, it is a matter of providing some means for storing surplus runoff.

The topography of South Florida is such that there are no natural sites available (deep stream valleys, for example) where extensive carryover storage can be developed.

These same topographical constraints hold true for the remainder of South Florida. The Corps of Engineers, after investigating many alternatives, found in its Water Resources Report of 1967 that Lake Okeechobee was the only practicable site for the development of reasonable carryover surface water storage capability in the South Florida area.

WATER LEVEL FLUCTUATIONS IN EVERGLADES DESIRABLE

The hydrologist and engineer see carryover storage as being of primary importance in reducing "waste" and as a means for extending supplies to meet demands. A more transient or short-term type of storage--annual storage--is also important. Taking the conservation areas as an example, this type of storage is perhaps more important to the biological scientist than to the hydrologist or engineer.

Wide fluctuations of water levels in the Everglades were a natural occurrence and hence are also desirable under present more or less controlled conditions. These, however, are the larger cyclic fluctuations. Within these cycles it seems desirable to dampen the effects of the annual dry season or of a somewhat below normal rainy season. Placing water which may be surplus elsewhere into transient storage to maintain water elevations in the conservation areas is what might be termed provision of an annual storage capability.

The situation which existed along the lower east coast in early and mid-November of this year affords an example of how this type of capability might work to advantage. During this period there were several high intensity rainfall occurrences over coastal Palm Beach, Broward and Dade Counties. Eventually, the runoff from this rainfall became surplus, and to avoid flooding of urban areas coastal structures were opened and the surplus was discharged to tidewater.

This surplus was truly "waste"; a waste which was quite obvious to any observer. It created an anomalous situation wherein needed water was being discharged while the area's reservoirs to the west were water-deficient. This waste occurred because there is no present capability (pumping stations) to move such surplus water into transient storage in the conservation areas. In South Florida this method of moving coastal area water surpluses into transient, or annual, storage in the conservation areas is called "back-pumping." Back-pumping facilities in the Tamiami and West Palm Beach Canals and at two locations in Broward County have been authorized for construction by Congress.

Back-Pump, Store Undesirable Water?

WITHIN THE BUDGET ANOTHER BUDGET TO MONITOR NUTRIENTS

Back-pumping surplus runoff in order to more fully utilize South Florida's "adequate rainfall" at first may seem to be an ideal solution to the threat of water shortages. It probably would be exactly that except for comparatively recent concern about the overenrichment of bodies of water resulting from an excess of nutrients.

Valid concerns involving water quality considerations have led to questioning the desirability of providing either extended carryover storage capability in Lake Okeechobee or the means to more fully utilize annual storage capability in the conservation areas.

For this reason the water budget is a valuable tool in developing a budget for various chemical water quality parameters. The chemical elements of considerable recent interest and concern because of their involvement with the natural aging, or eutrophication process of water bodies, are the primary nutrients; nitrogen and phosphorus.

Since these chemical constituents are carried by water, a nutrient budget can be readily developed from a water budget. All that is necessary to know, in addition to water inputs and outputs, is the nutrient concentrations in the incoming and outgoing water.

The input for most, if not all lakes, is larger than the output, and the difference is expressed as the amount of nitrogen and phosphorus "trapped" in a body of water. This includes the nutrients absorbed on the bottom sediments as well as those nutrients which go to support both the desirable and undesirable plant and animal growth within the confines of the body.

In summation, the water budget, in effect, reflects the problems of water management in South Florida today. And at present it adds up to something of a dilemma.

The hydrologists and engineers, armed with a basic adequate water resource, indeed possess the technology to reduce runoff to tidewater and to back-pump this water inland for storage for current and later use. But, they are also faced with the possibility of back-pumping and storing water that has become overenriched with nutrients as it travels through the realm of man's daily activity. The question appears to be: Can we have our cake and eat it too? Can we hold on to our recurring water surpluses by storage and still maintain a good quality environment?

MAN'S EFFECT ON THE QUALITY OF OUR WATER

By Jan Browning
Environmental Engineer (FCD)

". . . the useful trouble of the rain"--Tennyson--

Water pollution, indeed, is a relative thing; so much so in this era that it is virtually impossible to find a single definition that applies to all manifestations of this rapidly proliferating environmental problem.

One definition that has been received with wide acceptance is found in the Glossary--Water and Wastewater Control Engineering (8), as follows:

"Pollution--a condition created by the presence of harmful or objectionable material in water."

This concise definition seems to make the problem of pollution easy to grasp--if it is harmful or objectionable, it's not good.

But it's not really that simple.

For example, we think that water which is of sufficiently good quality to drink is suitable for almost any purpose. There are, however, many industries that must extensively treat water of potable (drinkable) quality before it can be used in their processes. And water which meets the drinking water requirements that ensure minimal salt content may injure numerous crops when used on them for irrigation purposes. Water which may met minimum chloride standards for drinking water may actually cause leaf damage to citrus when used for overhead irrigation.

The examples of the relativity of pollution problems seem almost endless. The purest salt water entering a surface or ground water supply of fresh water may be a pollutant. On the other hand, the purest fresh water entering a body of salt water may be considered a pollutant, depending upon the circumstances. Present Florida water quality standards for waters from which shellfish may be harvested are much more strict than the standards for a source of drinkable water. This is because pollutants tend to become concentrated in shellfish, which are filtering and straining feeders. The necessity for the difference in standards, therefore, is obvious.

And so it is that, with pollution, the problem is one of degree; one which must be related to use requirements and long term effects on the system, of additions to a waterbody which were not there in essentially the same quantity before man came along. For a point of view, or standard of reference in this discussion, pollution will be regarded as any change in the quality of a given body of water, whether physical, chemical or biological, if that change is due to man's activity.

Simple Example of Complex Effects

POLLUTION BEGINS ALONG A FOOTPATH

Man's mere presence in a watershed can create pollution problems. A textbook example of this at the most basic, elementary level is a situation that may develop in almost any recreation area. The usual pattern of cause and effect develops as follows:

Foot traffic in recreation areas tends to follow certain routes. The constant repetition of compression of the earth by foot traffic will kill existing vegetation and compact the earth to the point where oxygen is prevented from penetrating to root systems for utilization by plants. Water falling on the surface cannot penetrate into the earth and runs rapidly off. If the terrain is such that the rapid runoff can continue along the bare path, erosion will soon begin to take place. The erosion will make the path uneven to walk on and, consequently, the users of the path will widen the path or seek other walkways. In either case, the problem is enlarged.

The eroded materials in the runoff from the paths can create a pollution problem in any body of water that receives the runoff. Silt-laden waters decrease light penetration to desirable plants, causing reductions in photosynthesis (the process of converting simple elements into complex plant tissue, using sunlight as a source of energy). The silt will settle out of the water and may completely cover desirable plants and animals. The suspended material can quite possibly clog the gills of fish, causing severe losses in their ability to remove oxygen from the surrounding waters, and can cause suffocation of the fish.

There are also the physical effects of discoloration of the waterbody as the sediment settles from the moving water.

From this illustration of the possible impacts of seemingly harmless recreational pursuits, it becomes apparent that the more diverse and larger scale activities of man wherever he is present are most assuredly going to cause extensive and severe water quality problems unless such activity is scrutinized continuously for detrimental effects.

MAN DEGRADES ENVIRONMENT IN SATISFYING NEEDS

Man has chosen for himself a life style which is centered around mechanized and multi-faceted methods of providing food, drink, shelter and alteration of those portions of his environment which he <u>thought</u> were objectionable to him. In order that the needs of the ever-increasing human population were to be taken care of, more specialized and concentrated activities took place. Farmers began growing fewer types of crops on each farm, but increased the sizes of the farms and changed farming methods to increase yield per acre.

The overwhelming demands for consumer goods put on industry caused tremendous growth. The industrial growth created great demands for manpower to staff the industries needed to satisfy the ever-increasing demands for manufactured products. Large population centers soon began appearing with people living closer together and covering larger areas than was ever believed possible. The effects of this development were foreseen by very few and heeded by virtually no one. Now we find ourselves in the position of being faced with a degraded environment, and a development pattern difficult to change in any major aspect.

<u>Because Discharge Factors are Known</u>

DOMESTIC AND INDUSTRIAL POLLUTION ARE THE EASIEST TO CONTROL

Much has been said and is now being done concerning the pollution of streams, lakes and other waterbodies by the direct discharge of domestic and industrial wastes. Across the country, these sources can be considered not only the biggest contributors, the most obvious sources, but the <u>easiest</u> to bring under control. These pollution sources have two features which make this statement possible.

First, these sources are in almost all instances point discharges. That is the discharge is made at one point or group of points through some type of confined pipe or channel. In addition, the discharge is planned for and part of the design of the facility and not some secondary effect which just takes place.

The second basis for the statement is that these discharges are relatively uniform in quality and quantity over time. They vary, but not dramatically as do some other types of pollution. From a practical point of view, these point discharges originate from easily identifiable sources and it is therefore much more convenient to fix the responsibility for the offending discharge and to take measures to eliminate the polluting effects of the discharge.

Domestic waste is in most instances being either adequately treated, or plants to provide the necessary treatment are in the planning-construction stage. No endorsement of particular disposal schemes is intended. We are, however, buying time with which to evaluate the proper direction future treatment methods should take. At the same time, no one should disagree that improvements are being made, no matter how overdue they may be.

Industry in South Florida is not of the type which has tremendous waste disposal problems. In fact, the study made in Dade County by the Environmental Protection Agency (9) stated: "Few industries discharge wastewater directly into streams or canals in Dade County." The EPA study found 89 industries which had significant wastewater discharge. Fifteen of these industries discharged into canals and 36 discharged to ground water, with the remaining wastewater sources being handled by sanitary sewers. So even the most industrialized area of South Florida has few sources of industrial wastewater. These sources are now being investigated and corrective measures taken.

<u>From Ag Lands, Urban 'Sprawls'</u>

QUALITY OF RUNOFF WATER CAUSES CONCERN

With the eventual elimination of poorly treated and disposed of domestic and industrial wastewater in sight, what is left as a source of significant pollution? What is left is the pollution which causes the most concern when considering the sources of water for the future in South Florida--pollution created by the growth of urban sprawls and intense agricultural development. Surface waters which are now considered excess and are available for future use are those waters which originate primarily as storm runoff from our urban and agricultural land areas. In creating places for man to shelter and feed himself, we have at the same time created situations which waste the water he needs to survive.

The excess water in urban areas is created by a combination of several factors connected with the manner in which we live. In an area where man has not altered the state of nature, rain which fell on the ground either infiltrated downward, ran off into nearby rivers and lakes or merely puddled in low depressions in the ground until lost by evapotranspiration to the atmosphere. Now enters man who dislikes living in surroundings which may be wet by rains, or where puddles collect to create mud and insect breeding areas, or makes it difficult for him to drive his two cars.

To provide relief from these problems he has built houses, roads, driveways, parking lots--all surfaces which do not allow water which falls as rain to be infiltrated into the ground. At this point we now have more water, which has collected faster due to smoother surfaces for the water to pass over. This then tends to create larger and deeper puddles on the remaining low spaces. This state of affairs is obviously not pleasing, so storm sewers are constructed to convey these excess waters to the nearest stream or canal. Most coastal canals discharge to the ocean and the excess water then truly goes to waste.

The methods by which these excess waters from the urban areas can be saved are known. The plans have been laid, and the method is called backpumping. For South Florida, the backpumping plans call for the excess storm water to be stored either in the Conservation Areas in Dade, Broward and Palm Beach Counties or in Lake Okeechobee. The water in these storage areas is now in relatively good condition. However, there is some question as to the quality of the excess storm waters and what effect storing this water in the Conservation Areas or Lake Okeechobee will have on these storage areas. Thus the quality of this excess storm water must be understood.

Forecast For South Florida

STORM RUNOFF NO LONGER 'SECONDARY' POLLUTION PROBLEM

There is not a very good understanding of the pollution potential of urban runoff. This is due primarily to the overshadowing impact on the waterbodies of the discharge of domestic and industrial wastewaters which were in some cases not treated at all, or were poorly treated. Today, however, due to the longstanding efforts of the old Florida State Board of Health and the newer Florida Department of Pollution Control, these older and more significant pollution sources are being cleared up, phased out, and new potential sources are being required to dispose of their wastes in such a manner that no pollution potential is created for Florida's surface waterbodies and ground water aquifers. Although it should not be concluded that the job is finished, it is, however, well underway.

We are now at the point where recognition is being given to the secondary pollution sources, those of urban and agricultural runoff from excess storm waters. There have been a few surveys and studies of the quality and quantities of actual and potential pollutants which are present in urban runoff (10, 11). Although there has apparently been little or no published work done on the water quality aspects of urban runoff in South Florida, work which has been done in other areas of the country can certainly be used to describe and predict the problems which will be faced in the near future here in South Florida.

The sources of the urban pollution which finds its way into storm runoff are many and varied. Street litter can be washed into storm sewers in bulk or in the form of material dissolved from the litter. Material will be washed from surrounding lands to the streets and gutters. The multitude of chemicals utilized by public operations or private citizens for control of pests, insects, weeds and rodents, or for fertilizers and soil conditioners will be washed from land and plant surfaces by rainfall and carried into the storm sewers.

Animal and bird droppings which fall on impervious surfaces such as streets, buildings and sidewalks will be washed off by the rain and flow into the storm sewers. Litter from lawns and gardens, which is produced in large quantities due to the long growing season in South Florida, is washed into waterways to decompose. Portions of household and commercial waste find their way into the streets and storm sewers due to the carelessness (not to mention deliberate intent) on the part of citizens and business. The fallout from air pollution, in addition, settles on surfaces to await the coming of the next rain which will wash it to the nearest available storm sewer or drainage channel.

Studies in Several Cities Show

ASTOUNDING POLLUTION LOADS IN URBAN RUNOFF

Reports from studies made in Seattle, Cincinnati, and other cities show quite astounding pollution loads in urban runoff (10). The Seattle study showed, for water samples taken from street gutters, turbidity levels 36 times higher than the maximums found in Lake Okeechobee. The runoff was six times more colored than Lake Okeechobee under maximum conditions of color in the water. The BOD (used to indicate the organic pollution level) was well into the range which is indicative of polluted water. Bacteria counts made in the runoff showed the numbers of bacteria present in the water to be 16 times greater than that which is allowable under Florida law for swimming.

Nutrients were found in great quantity in the runoff. The amounts of nitrogen present in the urban runoff was more than six times greater than that found in the worst tributaries to Lake Okeechobee. The phosphorus levels found were at least 10 times greater than that which is found in most phosphate-containing detergents. It should be remembered that these are usually maximum values taken where antecedent rainfall had been low.

Data from a similar study in Cincinnati was adjusted to allow comparison between the amounts of various materials found in the urban runoff with the amounts of these materials which could be found in the sanitary wastewater from the same area. The volume of the stormwater runoff was 160 percent of the sanitary wastewater discharge; BOD in the runoff was seven percent; phosphate five percent and total nitrogen 14 percent. It should be remembered that these numbers are based on raw untreated wastewater and not the effluent from a wastewater treatment plant.

If we were now to compare these same pollutants found in the urban runoff to those found in sanitary wastewater during a similar time period, we would find that the suspended solids in the urban runoff was 2,000 percent greater than in the sanitary wastewater; BOD, 110 percent greater; phosphate, 70 percent more; and total nitrogen, 200 percent higher. In addition, bacteria levels were found to be high enough that under Florida water quality standards, the water would be unfit for swimming. Table III lists some of the typical characteristics of urban runoff found throughout the United States.

<u>Severity of 'Shock Loads' Known</u>

POLLUTION FROM CITY STREETS PREDICTABLE

A thorough study done in Chicago (10) on sources of pollution found in urban runoff has furnished some basic information on the amounts of pollution to be found as determined by land use. Table IV illustrates the amounts of pollution found in the dirt and dust on various neighborhood streets. A series of computations based on the information obtained in Table IV and a knowledge of the particular urban area under consideration, will enable one to predict the actual pollution potential of the material found in just the dirt and dust commonly found in our streets.

Data needed in addition to the type found in Table IV includes the area of the streets involved, the percentage of the various housing or industrial classifications in the area, and the estimated number of persons per mile of street to be found in the study area. For a city the size of Miami, the figures approach a pollution potential of around one percent of the amount of raw sanitary sewage which the same number of people would generate. A smaller city, 5,000 to 10,000 people would increase the figure to around two percent of the raw sanitary sewage.

TABLE III

CHARACTERISTICS OF STORM WATER +

City	BOD mg/l	Total Solids mg/l	Suspended Solids mg/l	Coliform /100 mg	COD mg/l
1. East Bay Sanitary District (Chicago)	87	1401	613	1180	-
2. Cincinnati, Ohio	17	-	227	-	111
3. Los Angeles County	161	2909	-	-	-
4. Washington, D. C.	126	-	2,100	-	-
5. Seattle, Washington	10	-	-	1610	-
6. Detroit, Michigan	96-234	310-914	102-213	93000*	-

* Maximum found

\+ Table excerpted from: Water Pollution Aspects of Urban Runoff, U. S. Department of the Interior, Federal Water Pollution Control Administration, WP-20-15, January 1969.

TABLE IV

AMOUNT OF POLLUTANT BY TYPE OF LAND USE +

Item	Single Family	Multiple Family	Commercial
Water Souble (mg/l)	6.0	5.6	12.4
Volatile Water Soluble (mg/l)	3.8	3.4	6.9
BOD (mg/l)	5.0	3.6	7.7
COD (mg/l)	40	40	39
PO_4 (mg/l)	.05	.05	.07
N (mg/l)	.48	.61	.41
Total Plate Counts/g (x1000)	10,900	18,000	11,700
Confirmed Coliform/g (x1000)	1,300	2,700	1,700
Fecal enterocci/g	645	518	329

\+ Table excerpted from: Water Pollution Aspects of Urban Runoff, U. S. Department of the Interior, Federal Water Pollution Control Adminstration, WP-20-15, January 1969.

At first glance, these figures do not seem in the least significant. It is, however, important to consider the impact of the material in light of the manner and timing with which it is flushed from the streets and placed into the water environment.

If we were to assume that a two week period had elapsed since the last rain, and if the rain fell over a two hour period, then for the Miami example, the pollution potential of the dirt and dust in the streets would be 160 percent of the raw sanitary sewage generated by the population during the same two hour time period. The same scale-up applies to the smaller towns and cities.

This peak effect is a much more realistic way of looking at the pollution effects of urban runoff. The runoff does occur over a short time period and we are thus faced with an accumulation of dirt and debris impacting on the environment instantaneously and most definitely not spread over the period of accumulation. These peak or shock loads can cause severe pollution problems such as dissolved oxygen depletion due to the BOD present, turbidity and discoloration from the suspended solids, large amounts of the major nutrients deposited into the waterbody and as previously indicated, sufficient bacteria so as to cause the water to be unfit for body contact sports.

An additional complicating feature of urban runoff in South Florida is the fact that normal flow in our canals (or streams) is comprised almost entirely of excess storm water runoff. There is little or no minimum sustaining flow to provide transportation or dilution of the heavily polluted waters after they find their way into a canal. Now we are faced with the problem of what to do with this water. Do we waste a vital resource by discharge to tidal waters or do we backpump into storage for use in times when rainfall is below normal?

<u>Some Travel By Air</u>

VARIETY OF POLLUTANTS IN AG RUNOFF

The other water quality problem, or pollution source, to be considered in assessing man's effect on water quality is the nature of the effects agriculture has on runoff. Agriculture places heavy demands on water management, as can be expected. Too much water during the cultivation periods and the crop can neither be planted, grown nor harvested. Periods of deficient rainfall create a demand for water of adequate quality for use in crop irrigation.

The very size of the winter vegetable farming effort in the face of the difficulties in growing a successful crop, illustrates the demand and importance of these farms, not only to the South Florida area, but to a large portion of the country. However, despite (and because of) the importance of agriculture to the nation's and Florida's economy, attention must be given to its role in water pollution.

A publication of the U.S. Department of Agriculture (12) lists eight basic categories of materials from agriculture which may cause pollution problems. These are: chemical air pollutants, dusts, sediment, plant nutrients, inorganic salts and minerals, organic wastes, infectious agents and allergens, and agricultural chemicals.

Chemical air pollutants, while important, are not a problem with respect to water quality. Dusts, however, are another matter. Two illustrations will serve to point up their importance. Recall the view of a dry field being cultivated. Do you remember the cloud of dust following the equipment? This material is important to water pollution from several different aspects. The fertilizers which are applied to a crop in most instances are not entirely utilized by the plants. Certain portions of these plant nutrients will affix themselves to soil particles.

Pesticides and herbicides behave in a similar manner. The soil particles are carried into the atmosphere where they may settle back to the ground and be flushed into streams as storm runoff. They may form the center of a rain drop and fall to the ground, or they may simply be flushed from the air by rainfall. In this manner, a large amount of nutrients, pesticides and herbicides appear in rainwater. The high nutrient level in rainfall has been documented by Boyd F. Joyner of the U.S. Geological Survey in a study of Lake Okeechobee (13) as follows:

"Rainfall contributes significant amounts of nutrients to the Lake, and concentrations in rain are at times similar to concentrations in both the Lake and its major tributaries . . . The concentration of total phosphorus (as P) in rainfall averaged 0.04 mg/l, equivalent to the average concentration in Lake Okeechobee during 1969-70. . . The concentration of total nitrogen (as N) in rainfall averaged 0.73 mg/l, which was approximately 50 percent of the average concentration in the Lake during 1969-70."

The practice of burning sugarcane fields prior to harvesting, places large amounts of ash and hydrocarbons into the air which can then also get into the water system either through fallout and flushing by rainfall or from direct action by rainfall.

Soil particles with their trapped nutrients, pesticides and, as in the case of the organic soils around Lake Okeechobee, the soil itself, may easily be carried by excess storm water from the fields into the canal systems. This excess water, now carrying pollutants, must either be disposed of to tidewater as waste or saved by storage for future use.

And of course there is the great problem of pesticides and herbicides which are applied to crops and find their way into the water environment. Most of the pesticides are not water soluble so they are not carried nor found in any large amount in the water of a stream or lake. What does seem to happen is the droplets, in aerosol form, go into the atmosphere where they are spread far and wide, disperse to the surface of the land via rain and dustfall and become part of the bottom sediments of waterbodies. These pesticides can also be transmitted by erosion of sediments from fields on which they have been applied. The pesticides then become concentrated in living organisms through the feeding habits and retention characteristics of the various animals.

Plant nutrients can be dissolved from the soil and carried in solution via storm runoff to whatever receiving body is appropriate for that location. If the water is stored, the dissolved plant nutrients take on a very significant degree of importance. These nutrients would then be available to aid in the growth of algae and nuisance aquatic weeds. Inorganic salts and minerals are not much of a problem here in South Florida.

An Effect of Food Production

ANIMAL WASTES HAVE POLLUTION POTENTIAL

Animal wastes have become a pollution problem of considerable importance in some areas of South Florida. One of the consequences of man's moving to urban centers has been the necessity for farms to increase in size and efficiency. The dairy industry, for one, has been caught up by the expansion squeeze. In the past, each farmer had a few cows to furnish him milk and a small surplus he could sell. Now dairy herds are measured in the hundreds of head of cattle. Instead of a few cows scattered over several acres, we now find large numbers crowded into paved feed lots and milking barns. There is not much imagination required to realize that in estimating pollution potential, a 500 head dairy herd will produce a lot of waste.

This waste, or at least the portion which accumulates in the barns must be removed immediately for health reasons. The most expeditious and economical way is to wash the waste into gutters and let it flow to the nearest water course. Rainfall on feed lots would create a muddy quagmire in short order unless good drainage is provided. Where does the animal waste from the feed lots go? All too often into the nearest stream. It can truthfully be said that these materials make good fertilizers. However, with the economics of collecting and spreading this large bulk of material, it is usually cheaper to apply manufactured inorganic fertilizers.

Taylor Creek, one of the tributaries to Lake Okeechobee, has a large number of dairies in its watershed. Several studies have shown that the water in Taylor Creek has extremely high bacteria levels. The Lake Okeechobee study by Joyner shows that 23 percent of the phosphorus flow into Lake Okeechobee comes from Taylor Creek, even though the Creek contributes only four percent of the waterflow. Evaluation by the Florida Department of Pollution Control has tended to show that the dairies are the source of much of the pollution load to be found in Taylor Creek.

Action has been taken by the Department of Pollution Control to provide on-site disposal for the waste from the dairies in the watershed, with the full cooperation of dairymen in the area. Waste treatment lagoons and land spreading systems are in the planning-construction stage for almost all of the dairies. Approximately 35 percent of these treatment facilities have been completed and are in operation.

From a public health standpoint, there are several diseases which may be transmitted from animal to man or between animals by means of water borne infectious agents (bacteria and viruses). Here, again, the storm water runoff from livestock operations has a pollution potential, not only for man directly, but for other animals.

<u>Man Has To Have Water He Now Pollutes</u>

RUNOFF POLLUTION MUST BE CONTROLLED

The problems associated with excess water from storm runoff are now apparent. The next step is to try to alter the conditions which cause the poor quality of the urban and agricultural runoff. Obviously, better housekeeping by all of us in our cities and towns would eliminate much of the trash and debris which now finds its way into the waterbodies during rainstorms. Research to obtain more precise information on the needs for fertilizers by agricultural users, as well as the proper timing and application methods of these fertilizers is now being conducted. This information hopefully will allow better utilization of the applied fertilizers and thereby reduce the amounts found in storm runoff from the fields.

Some research is now being undertaken to evaluate methods for treating urban runoff. Most of the present treatment systems are oriented towards temporary storage, with subsequent treatment by existing domestic wastewater treatment plants. By making use of the unused capacity of these domestic plants during the low flow, early morning hours, portions of the runoff may conceivably be treated.

There are proposals to reduce outflow from agricultural hands by the use of private reservoirs. The reservoirs store the excess waters during rainy periods, eliminating the necessity for discharging to a canal, river or lake. The water in the small reservoir can then slowly seep into the ground, evaporate or may later be used to irrigate the very fields from which it has to be pumped. These private reservoirs are already in use in a few areas of South Florida.

There is a great need to accelerate efforts to cope with growing threats to our water resources, for man now finds himself "between a rock and a hard place."

In order to live, man has deemed it necessary to live in prescribed formality. He has chosen his habitat without much regard for the hazards of the natural features of geography or weather. Now he finds himself living where the water he needs to live, used to be stored as it fell to the ground. In order to produce the food for his table he has pre-empted still more of the land which was formerly seasonally flooded.

His increasing numbers create an ever-increasing demand for a water supply which his activities pollute. Now he must work towards finding the compromise between continued expansion and the natural environment which is essential to his survival.

RECYCLE-REUSE, INFALL-OUTFALL DECISIONS CONFRONT SCIENCE, PUBLIC

By Jan Browning
Environmental Engineer (FCD)

The public, in recent years, has been bombarded with an almost unending amount of data, projections, claims and denials regarding the extent of the pollution of this world's water bodies. There is disagreement among the experts in the environmentally oriented sciences as to the scope of the problem. The proper directions in which to move to apply whatever corrective measures are necessary have been widely debated.

There have been numerous claims that waste disposal to the oceans is creating situations which may spread disease and end the ability of the oceans to provide oxygen and food to the inhabitants of this earth. By the same token, these waste materials, when discharged into inland water bodies, commonly commence the process of cultural eutrophication, or the man-caused succession of lakes to marshes, bogs and woodlands.

Answers are desperately needed to the question of just what damage, if any, will be caused by the continuing and anticipated waste discharges made into the oceans. What levels of treatment will be required to prevent the possible damage which is being predicted? We also must establish the expected damage to the fresh water environment caused by various treatment levels of wastewater being released inland. So complex has the issue become that the individual citizen, through a lack of fundamental data, finds it extremely difficult to evaluate the statements made by various factions debating the recycle-reuse/outfall-infall question.

Terms Frequently Confused

'RECYCLE' AND 'REUSE' ARE NOT THE SAME

While recycling and reuse are considered to be similar and are sometimes used synonymously, they are two separate water conservation concepts. Recycling can most easily be viewed as the disposing of the treated wastewater in such a fashion that it returns to the hydrologic cycle suitable for any of several conventional uses. If the wastewater is treated and used for the same purpose as the previous use cycle, then it would be considered a reuse. An example of reuse would be a wastewater treatment plant outfall being connected to the drinking water treatment plant intake. That would be reuse of treated wastewater. Recycling would be the use of treated domestic sanitary wastewater for ground water recharge or irrigation.

When considering whether recycling or reuse of wastewater is the best course of action, several questions arise, the answers to which lead the observer in the direction of the correct choice between recycling and reuse.

1. What is the demand on this source of water?

2. What levels of treatment are necessary to enable the wastewater to be utilized in a beneficial manner?

3. What levels of treatment for the wastewater are necessary to prevent it from degrading the environment it is placed in?

4. How can the answers to questions 1 - 3 be combined to maximize the use of this water resource?

<u>But It's An 'Asset' In Drought</u>

WASTEWATER MUCH LESS THAN STORM RUNOFF

Considering warnings of a general water shortage in South Florida after 1976, how significant is the prospect of treated wastewater as a fresh water source? Let us consider the Gold Coast area of Palm Beach, Broward, and Dade Counties. In these three counties reside approximately 2,500,000 people who, on the average, will produce 250,000,000 gallons per day of wastewater or 280,000 acre-feet per year. If this total annual volume of wastewater were to be placed into Conservation Areas 1, 2, and 3 at one instant, the mass of water would cause a rise of a little less than four inches.

During periods of deficient rainfall or even drought conditions, the volume of water available from treated wastewater must be viewed as an asset. During the worst portion of the drought in early 1971, it took 200 cubic feet per second (the sewage generated by 1,300,000 people) of water to maintain the necessary water depth in the Miami Canal adjacent to the City of Miami well field. Therefore, a portion of the wastewater flow could be diverted to assist in maintaining vital ground water levels in the area of well fields endangered by salt water contamination. Due to losses from evapotranspiration and seepage, an 800 cubic-feet per second release was required at Lake Okeechobee to maintain the 200 cubic-feet per second at the exit from Conservation Area 3 into the Miami canal.

Another aspect of the problem of handling our water resources is the excess storm waters discharged to tidewater every year by canals dug during the last 70 years for drainage and flood control. As we mentioned before, if all the people in Dade, Broward, and Palm Beach counties were being provided sewer services, they would generate 280,000 acre-feet of wastewater per year. At the same time, during an <u>average</u> year, these major coastal drainage canals will discharge 2,535,000 acre-feet of water to the ocean. The wastewater amounts to approximately 11 percent of the amount of storm water runoff discharged to tidal waters as an unstorable resource.

<u>To Make Recycling, Reuse Worthwhile</u>

YEAR-TO-YEAR WASTEWATER CARRY-OVER NEEDED

As a portion of its continuing investigations into the interrelationship of the water resource within the Flood Control District, the U.S. Geological Survey constructed a model of the Biscayne Aquifer. One of the situations which was studied with this model was the amount of water required to prevent salt water encroachment into the Biscayne Aquifer during drought conditions. The study concerned itself with that portion of south Dade County lying east of Conservation Area 3 and Everglades National Park, and south of the Kendall area (C-2 or Snapper Creek Canal).

It was found by use of the model, that 1,320 cubic-feet per second of water would be required to maintain sufficient water height in the ground to supply domestic and agricultural needs and prevent salt water encroachment of the aquifer. It would require 8.5 million people to generate this amount of wastewater. For perspective, the 1970 census credited the entire State of Florida with having a population of 6,789,000. Thus the treated wastewater from the entire state would not be enough water to entirely prevent salt water encroachment in south Dade County alone during drought conditions.

The amounts of water required during drought conditions are much greater than the recycleable sources available. This does not mean that the treated wastewater has no value as a source of fresh water, only that it would be difficult to justify advanced wastewater treatment based on the value of the day-to-day volumes of water made available under this method of treatment.

If the treated wastewater is to be considered as much of a reuseable or recycleable resource, some method of storage must be developed which will allow the carryover of the treated wastewater from year to year until it is needed. Then it would conceivably be available in sufficient quantity so as to make the water truly valuable in respect to the cost of treatment.

More Than 2,000 Feet Down

'BOULDER ZONE' CONSIDERED FOR STORAGE OF WASTEWATER AND URBAN RUNOFF

One method of combined storage-treatment of domestic wastewater (and also excess urban runoff) that has been proposed is injection and storage underground in deep, unused geologic formations. This proposal is an exciting one and is now being investigated by several agencies and organizations.

The particular formation involved is popularly known as the "Boulder Zone." It occurs at varying depths below 2000 feet. There are several thick, dense, and impervious (to water) layers between the Boulder Zone and the potable or drinking water formation close to the surface. This fact is important in that it provides assurance that materials placed in the Boulder Zone would not return to the surface naturally.

The Boulder Zone is basically an extensive layer of limestone, which over a long geologic period of time, became riddled with large ir erconnected caverns or holes.

Subsequent investigations into this formation, have revealed there is a strong possibility that the Boulder Zone connects to the Florida Straits at a depth of around 2500 feet and lower. Observations of an existing disposal well in Dade County have shown water roughly the same salinity and temperature as sea water at that depth. In addition, pressure measurements recorded on the well showed a rise and fall the same as the ocean tides. The water in the Boulder Zone is under artesian pressure. That is, if a well were drilled and the pipe left open, water would flow like a spring.

Treatment Before Injection Mulled

TWO CONCEPTS FOR UNDERGROUND STORAGE

Two basic concepts have been proposed for underground storage. First is a combined treatment-storage concept. This entails the use of secondary treated wastewater plus tertiary filtering and injection down the well to the Boulder Zone. Injection of chlorine or ozone into the descending waste stream is anticipated. It is expected that the disinfectant will be extremely effective under the tremendous pressures created by a depth of water at greater than 2500 feet. It is anticipated that the survival of viruses and other pathogenic organisms will be very poor due to the hostile environment in the Boulder Zone.

Native water in the Boulder Zone is highly saline and is denser than treated wastewater. This will allow the formation of a "bubble" of fresh water in the Boulder Zone. If all the normal physical laws are upheld, the fresh water bubble should move very slowly to the southeast and the ocean because of the slope of the confining layers of the Boulder Zone.

The continued pumping of treated wastewater into the Boulder Zone over a period of years between droughts will make available a much larger supply of water with which to combat the effects of periodic water shortages. The simplest form of recycling this water would be to position the injection wells in the areas where the water would be of most value in minimizing the effects of drought. To tap the stored water, all that would have to be done is to open the well and let the water flow out under the natural artesian pressure.

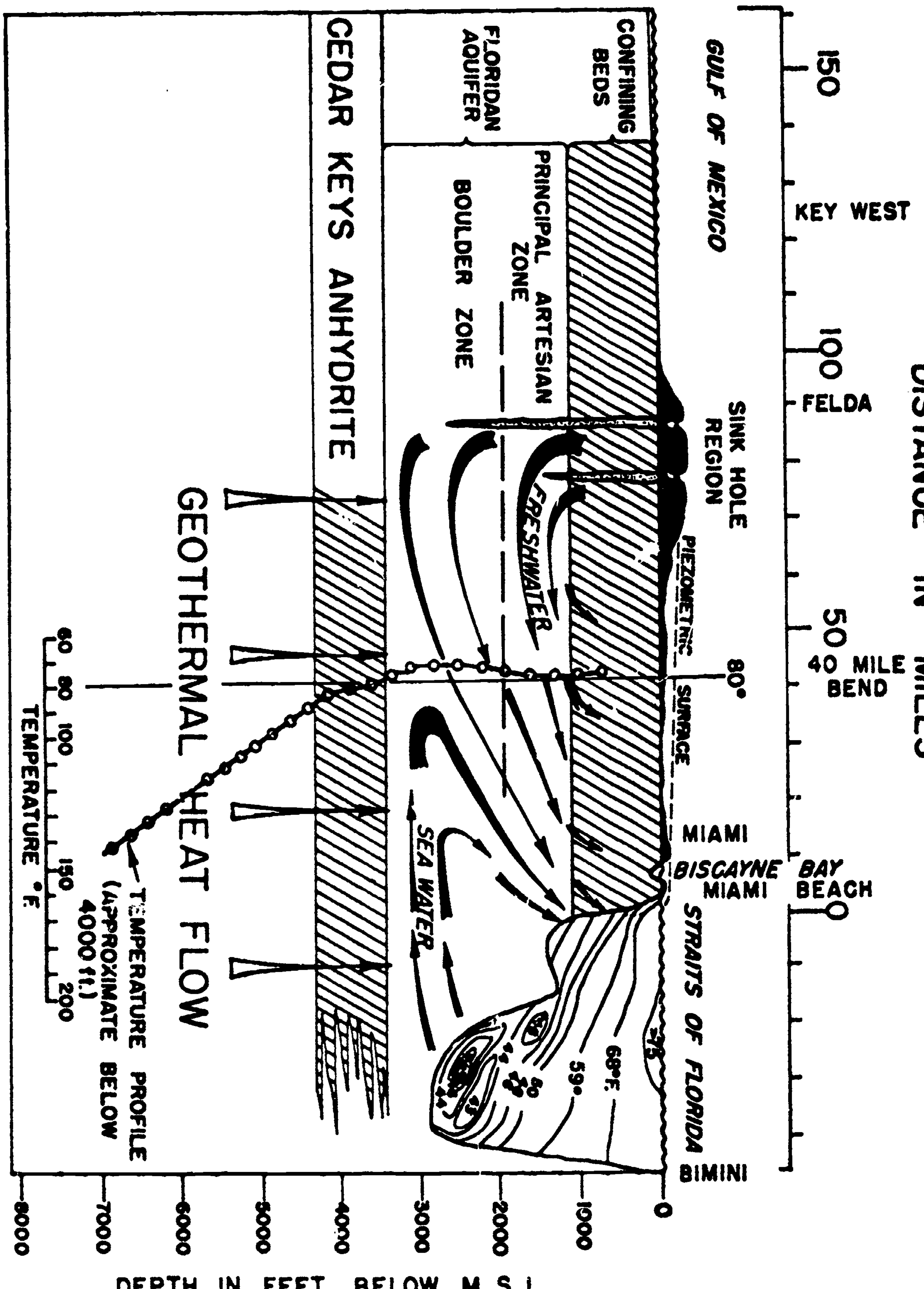
Urban runoff is an additional source of water which falls to the ground as rain, causes the ground water levels to rise to unwanted levels, and then must be drained by canals to the ocean. A possible solution to both the extremes of rainfall overabundance and drought would be to pump a portion of the excess into the Boulder Zone along with the wastewater. With a small amount of forethought, water of drinkable quality could be placed down the well. This water would dilute the matter present in the treated wastewater which secondary treatment and disinfection do not affect.

The storage method is attractive for the following two reasons:

1. It is estimated that as much as 95 percent of the water injected into the Boulder Zone is recoverable. This means that water can be stored for several years. Contrast this with surface storage where evapotranspiration losses all but eliminate the possibility of carry-over storage through the annual dry season.

2. As previously mentioned, the water can be recovered where it is needed and need not be transported long distances prior to beneficial usage and thereby suffer losses in transit.

There are some unanswered questions concerning this treatment-storage method. What will be the effect of the wastewater on the limestone of the Boulder Zone and vice versa? Is the projected slow rate of movement of the bubble through the Boulder Zone a fact or will more rapid travel occur, preventing the formation of a large useable water source? Is there a possible danger of formation of pockets of gases due to continued decomposition of organic materials in the injected waters? These and other questions must be investigated to bear out the feasibility of underground storage-disposal of excess water.



THIS GEOLOGIC PROFILE SHOWS THE TEMPERATURES MONITORED IN A TEST WELL DRIVEN THROUGH THE BOULDER ZONE IN DADE COUNTY. ORDINARILY, THE TEMPERATURE WOULD RISE PROGRESSIVELY WITH DEPTH, BUT WATER TEMPERATURES THROUGH THE SALINE BOULDER ZONE ARE SIMILAR TO OCEAN TEMPERATURES AT SIMILAR DEPTHS. BENEATH THE IMPERVIOUS FLOOR OF THE BOULDER ZONE TEMPERATURES RISE STEADILY.

Several Levels of Treatment Available

FILTRATION AND AERATION ARE THE TWO BASIC SECONDARY SEWAGE TREATMENT METHODS

There are commonly several levels of treatment of wastewater available, and the distinctions between them are not always apparent. Primary treatment may consist of any or a combination of the following steps: chlorination, grinding, sedimentation, skimming and sludge digestion. Chlorine, being an aggressive element, is utilized primarily as a disinfectant. The remaining steps in the primary treatment process physically separate out of the carrying water the large visible floating and settleable solids.

These materials are then either run through a grinder to reduce their size, or are placed in a separate tank where the organic material is stablized to prevent odor formation. In the process, a portion of the oxygen demanding material is removed from the effluent. A common method fo· disposal of ground-up solids in primary plants was to place them back into the waste stream for discharge. It is thus quite evident that primary treatment does not accomplish much and is quite deserving of its bad reputation.

Secondary treatment may use portions of the primary treatment system to prepare the waste for the secondary treatment processes. There are two basic secondary treatment methods, the trickling filter and several aeration methods. The trickling filter may in a simple form be a pile of rocks over which the wastewater is sprayed or "trickled."

In a short period of time, the outer surfaces of the rocks have grown on them a layer of microscopic organisms which are adapted to using the organic material in the wastewater as a food source. The organic material is removed from the wastewater as drops slide over the surfaces of the rocks. After one or more passes through the rock pile, the organic levels in the wastewater are reduced to a level characteristic of the waste and scavenger organism feeding on the waste.

They Feed On Objectionable Wastes

LIVING ORGANISMS IMPORTANT IN TREATMENT

The aeration processes, extended aeration and activated sludge, are also biological in nature. With these two methods of treatment, the wastewater is placed in tanks and supplied with air and stirred. Here, as in the case of the trickling filter, a group of organisms forms which is characteristic of the particular waste. These organisms live within the tank and are kept in constant contact with the organic food material in the wastewater by stirring.

Air is mixed with the wastewater to provide oxygen for the living organisms to breathe. After the wastewater has been in contact with the organisms for a period of time sufficient to enable them to utilize most of the organic material dissolved in the wastewater as food, the entire mixture is transferred into another tank. In this tank no aeration or stirring takes place, allowing the well-fed organisms to settle to the bottom of the tank and the secondarily treated wastewater to be drawn off the top of the tank.

The activated sludge process, together with some of its modifications, has been found to be more efficient than the extended aeration treatment but more difficult to control for good treatment. Consequently, for most small plants, extended aeration is the recommended treatment, with activated sludge being preferred for the larger treatment plants.

As part of the secondary treatment plant in Florida, a "polishing pond" is often provided for an extra bit of treatment prior to discharge. The foremost function of these ponds is to provide another form of plants, the algae, to utilize a portion of this remaining fraction of organic material as a food supply and further increase the degree of treatment provided by the plant. These ponds are usually large and shallow, deep enough to prevent emerged aquatic plants from growing, but shallow enough to permit sunlight and oxygen to penetrate the water to the bottom of the pond.

A properly designed and operated secondary treatment plant will provide the 90 percent BOD and suspended solids removal as required by Florida law.

Many Types of Tertiary Processes

EFFLUENT CAN END UP AS DISTILLED WATER

Tertiary or advanced wastewater treatment can be any number of processes from secondary on up to having distilled water as the end product. While each of the following wastewater advanced treatment processes are considered separately as to how they work in developing a design for a treatment plant, the engineer will evaluate the various options as to methods and order of treatment steps.

The simplest form of advanced wastewater treatment is filtration. Filtering the water removes a large portion of the solid particles which are too small to settle out of the liquid in a reasonable length of time. Filtration may be used after normal secondary treatment or as an accessory step following another treatment procedure such as phosphate removal. There are several types and combinations of filtering media which may be used, depending upon the nature of the material to be removed from the liquid.

After most treatment processes there are still some traces of organic materials which can cause taste, odors or other problems. Materials such as pesticides may find their way into the wastewater to be treated. Activated carbon has a unique capability to absorb organic materials. This ability is utilized by filtering the wastewater through beds of activated carbon for removal of most of the troublesome organic compounds. With the three treatment steps described so far--activated sludge, filtration and activated carbon absorption--it is possible to remove virtually all organic material from the wastewater.

Advanced Treatment Can Remove Nutrients

THE TOP CONTRIBUTORS TO EUTROPHICATION ARE CARBON, NITROGEN AND PHOSPHORUS

The three main creators of overenrichment and cultural eutrophication are carbon, nitrogen and phosphorus. Carbon for use in manufacturing plant tissue can be acquired from waste organic materials acted upon by certain classes of bacteria to produce carbon dioxide. With the removal of the organic material, the first of the three basic tissue building materials is eliminated.

The removal of phosphorus from wastewater is an advanced wastewater treatment concept very much under discussion today. Phosphate can be removed from solution in the wastewater by adding one of several chemicals. The most commonly used phosphate removal chemicals are alum, lime or iron salts.

The particular choice will depend upon other aspects of the chemical nature of a particular wastewater and the engineer's choice of treatment steps required to achieve the desired degree of treatment for a given wastewater. Alum or lime is used when the removal of phosphate is to take place during a phase of primary treatment and where the pH (tells whether the liquid is acidic or basic) and alkalinity increases created by lime additions cannot be tolerated. Lime would be used most often if the ammonia stripping nitrogen removal method is contemplated.

The removal of nitrogen is perhaps the most difficult process to carry out. There are three basic nitrogen removal processes currently accepted as being feasible for use in large scale operations.

The first of these methods is called ammonia stripping. This nitrogen removal method relies upon the careful operation of the preceding organics removal steps to insure that the major portion of the inorganic nitrogen exists in the form of the ammonium ion. Lime is then added to raise the pH of the solution and converts the ammonium ion to dissolved ammonia. The ammonia in the liquid is then removed in a forced draft cooling tower. This method is easily coupled with lime removal of phosphate as was previously discussed.

Another method of nitrogen removal is similar to activated sludge process. This method depends upon a certain class of bacteria which, when exposed to nitrogen in the form of nitrate in the absence of oxygen, will use the oxygen in the nitrate ion (NO_3) for respiration. This useage causes the nitrogen to be released as a gas to the atmosphere which is approximately 80 percent nitrogen.

Recently, synthetic resins have been developed which selectively absorb the ammonium ion. These resins show promise as a method of nitrogen removal for advanced wastewater treatment plants.

<u>A Few Developed From Desalination</u>

OTHER TREATMENT METHODS SHOW PROMISE

Some other methods for removal of dissolved minerals from treated wastewater are techniques originally developed for desalination of seawater. These methods include reverse osmosis, electrodialysis and ion exchange.

Physical-chemical treatment is a complete secondary treatment system which is non-biological in operation. Instead of a biological consumption of organics from the wastewater, water treatment techniques of coagulation, flocculation and sedimentation are utilized. This treatment method has the advantage of being an excellent preliminary step for phosphorus removal and ammonia stripping if lime is possible for use as the coagulant. The disadvantages of increased chemical costs and large sludge volumes must, however, be considered.

A concept that has been receiving a great deal of attention is that of land spreading of wastewater after it has received a certain amount of treatment. Most of these methods rely on the action of soil particles, soil bacteria and plants to filter out solids, remove or inactivate nutrients and render harmless pathogenic organisms by keeping them for long periods of time in a hostile environment. A common feature of land spreading disposal methods is a soil which is well drained and granular but which does not permit exceedingly rapid percolation.

There are two methods or aims of land spreading. The first is use of land spreading for the disposal of an already adequately treated wastewater effluent. If disposal alone is the use to which the spreading technique is put, then the only caution is that the rate of application of the wastewater does not cause excessive or unwanted water table problems. However, when treatment is to be provided as the main function of land spreading, the soil characteristics, location of the water table with respect to the ground surface, and the type of plants growing on the site become very important.

In South Florida, the limiting factor is the requirement of an unsaturated soil depth of 10 feet or more to provide for the time and length of travel exposure of the wastewater and soil. It would be exceedingly difficult to find the required acreages with adequate water tables which would render the site suitable for land spreading in South Florida. Thus the successful and widely publicized land spreading projects at Santee, California; Muskegon County, Michigan; and Pennsylvania State University, as well as many others, would not be very successful in South Florida.

Normal Disinfection Ineffective

TERTIARY PROCESSES WILL KILL VIRUSES

Viruses have been causing much concern to those involved in wastewater treatment and disposal. Viruses are very small and extremely difficult to detect or identify. Available evidence indicates that a single virus can cause infection in a susceptible host. Unless the virus is in the tissue of a specific host, it cannot multiply. In a water environment, then, their numbers could only decrease. The rate of decrease is important, as days to weeks may be necessary for an effective virus die off.

Normal disinfection procedures are not very effective against viruses. This is not because the viruses are so resistant to chlorine which is erroneously used, but due to the normal association of virus particles with any solid materials in the effluent. Viruses are usually found attached to, or absorbed in other materials. It is these other materials which create the disinfection problem in that they create a demand for the chlorine or other chemical disinfectant before it can act on the sheltered virus, thus neutralizing the effect of the disinfectant.

Treatment methods commonly used in the treatment of drinking water have been found to be very effective in removing and killing the viruses found in our water sources. If it is decided that the numbers of viruses surviving a secondary or some other wastewater treatment process are too high from a public health standpoint, then advanced wastewater treatment may be called for to provide the measure of protection deemed necessary.

TABLE V

AVERAGE DEGRADATION OF QUALITY RESULTING FROM ONE CYCLE OF USE

Component	Concentration Increase From Tap Water to Raw Wastewater (Milligrams per Liter)
Gross organics (COD)	300-500
Biodegradable organics (As biochemical oxygen demand - BOD)	250
Sodium	70
Potassium	10
Total Nitrogen	40
Calcium	15
Magnesium	7
Chloride	75
Sulfate	30
Silica	15
Total Phosphorus (As phosphates)	35
Hardness (As calcium carbonate)	70
Total dissolved solids	320

SOURCE: Leeds, Hill and Jewett, Inc.

Every discussion of advanced wastewater treatment must eventually consider what is in the wastewater, the various treatment methods available and finally, the costs of the various treatment methods. Table V illustr-tes the increases for common constituents found in wastewater after one cycle of use. After the decision has been made as to the desirable level of the various components found in wastewater, the proper methods of treatment must be chosen. There may easily be several treatment processes which can affect a given material found in wastewater. Table VI represents a brief rundown of the major pollutors found in wastewater and the effectiveness of the common treatment methods in removing them.

TABLE VI

TYPICAL CONSTITUENT REMOVALS BY VARIOUS WASTEWATER RECLAMATION PROCESSES

PERCENTAGE OF CONSTITUENT REMOVED BY RECLAMATION PROCESSES

CONSTITUENT	Primary (P)	Primary + Seconary (Activated Sludge-AS)	AS + Sand Filtration	AS + Coagulation and Sedimentation (CS)	AS + Activated Carbon (AC)	AS + CS + AC	AS + CS + AC Nitrogen Removal	AS + CS + Electro-dialysis (ED)	AS + CS + AC + ED
BOD	35	90	94	93	98	99	99	99	99
Suspended Solids	60	90	99	99	99	99	99	99	99
Total Phosphorus (as phosphates)	10	30	30	95	30	95	95	35	97
Total Nitrogen	20	50	50	50	55	55	90	70	75
TDS 1/	0	5	5	10	10	15	15	50	50

1/ Rate of removal for indicated processes will vary appreciably depending upon specific ions present, chemicals used for coagulation, and with design of electrodialysis unit.

SOURCE: Leeds, Hill and Jewett, Inc.

Consideration of Growth 'Advisable'

COST BIG FACTOR IN TREATMENT PLANNING

The proper choice of a treatment method cannot be made without data as to the projected costs of various treatment processes. Great care must be exercised in comparing costs for treatment by various processes as reflected in Table VII with charges levied by operators of treatment facilities. Most cost figures are based on the plant to be run at full capacity, while they are commonly built larger than initially required. This is done to provide excess capacity for future demands on the system. The result of this excess capacity is to increase the cost of the initial user who must carry the burden of the plant. This is, however, an advisable course of action to take.

Although costs for the treatment plant and its operation may vary according to specific needs from location to location, the costs involved in the wastewater collection system vary greatly. It is these costs which must be included in a realistic cost estimate that create a large share of the confusion when comparing wastewater collection and treatment charges between different areas. Widespread, flat areas such as are found in much of South Florida, require much more expensive pumps and force mains to transmit the wastewater to the treatment plant. Areas where there are more pronounced differences in ground elevation, usually provide more opportunities for flow of the wastewater by gravity and thereby eliminate the expensive pumping facilities.

Another factor which is often overlooked in the casual comparison of utility bills is that it is a common practice in many areas to support a portion of the costs of utilities, including wastewater treatment, from general taxation revenues. In this way, the utility bill understates the true cost of the service.

Table VII is a comparison of the relationship between the costs for construction and operation of various methods of water and wastewater treatment. The prices are given in dollars per household per month. These numbers are considered averages and should not be compared, except in a general manner, with a specific locale.

TABLE VII

TYPICAL 1972 COSTS OF VARIOUS WATER AND WASTEWATER TREATMENT PROCESSES

Process(es)	Water Cost - Dollars Per Household Per Month 1/					
	10 mgd Plant			50 mgd Plant		
	Capital 2/	O & M	Total	Capital 2/	O & M	Total
WATER TREATMENT						
Filtration (F)	0.317	0.293	0.610	0.207	0.196	0.354
Coagulation, Sedimentation and Filtration (C, S, & F)	0.659	0.500	1.159	0.390	0.268	0.659
C, S, & F plus Softening 3/	0.817	0.903	1.720	0.500	0.659	1.159
WASTE TREATMENT						
Primary including flotation	0.683	0.415	1.098	0.464	0.244	0.708
Secondary - trackling filter	0.927	0.415	1.342	0.610	0.244	0.854
Secondary - activated sludge (AS)	1.293	0.634	1.928	0.842	0.451	1.293
AS + Sand filtration (SF)	1.647	1.025	2.672	1.049	0.659	1.708
AS + activated carbon (AC)	1.757	1.196	2.952	1.122	0.830	1.952
AS + phosphate and nitrogen removal	2.306	1.391	3.697	1.513	1.049	2.562
AS + AC + demineralization 4/	2.318	2.578	4.892	1.586	1.928	3.514

1/ Assume 3.3 persons per unit and 100 gal/cap/day sewage discharge

2/ In calculating unit capital costs, the following assumptions were made:

Interest rate:	6.0%
Economic life:	40 years for Water Treatment Processes,
	25 years for Wastewater Treatment Processes

Treatment processes utilized at full design capacity during economic life.

3/ 200 mg/l hardness removal

4/ 500 mg/l TDS removal by electrodialysis process

SOURCE: Leeds, Hill and Jewett, Inc.

IN SUMMATION

The answer to the earlier question of what is the demand on the treated wastewater as a source of recycleable water seems to be "not much" unless some methods of long-term storage are devised. Examination of the relative volumes of water available between treated wastewater and excess storm water runoff makes it obvious that storage of a small percentage of the excess storm runoff will provide a much larger source of water than available from treated wastewater.

The biological sciences and public health disciplines must provide the standards of acceptable water quality for placing treated wastewater into either the fresh water or ocean environments. Once these criteria have been set, the engineer will be able to select the most suitable treatment method for the particular wastewater under consideration.

In South Florida, the question of infall or ocean outfall can be seen to hinge almost entirely upon one question: Does the discharge of secondary treated wastewater to the edge of the Gulfstream cause an actual, substantial measure of threat to the health of the ocean itself and/or man who depends on the ocean for so much?

If the answer is "no," then the ocean outfall will remove from the land areas those nutrients, bacteria and other objectionable materials which (it is almost universally agreed) harm the fresh water environment.

Should the need for a high degree of advanced wastewater treatment be shown, then the treated wastewater should be placed back into the fresh water environment. This should not be done primarily because of the quantity of water reclaimed for use but, since the water will not harm the fresh water environment after its advanced treatment, an infall would be much cheaper than an ocean outfall.

It therefore seems that the paramount consideration in planning infall-outfall or reuse-recycle programs will be the anticipated harm, if any, of discharge to the ocean of our treated wastewater.

*References: (14), (15), (16), (17), (18).

[illegible] AQUATIC WEED [illegible]

By [illegible]. C. Grant, Director
Department of Field Services

An estimated 10 to 11 million dollars are being spent yearly for the control of noxious aquatic weeds in Florida.

Despite this huge expenditure, the total infestation continues to grow, and experts see no end to steadily increasing costs unless new controls are found.

With public resistance to the use of chemicals increasing, research efforts are being doubled to discover effective biological controls and uses that will make it profitable to harvest species of noxious weeds.

Two of the newest exotic aquatic weeds to make an appearance in Florida, hydrilla and Eurasian watermilfoil, are spreading with amazing speed. Of all the noxious plants, hydrilla is considered the greatest threat to Florida waters. Watermilfoil, with its high tolerance to salt, threatens to infest even our coastal waters.

And while the battle is waged against the species that already infest our waters, there are warnings that new exotic undesirable aquatic plants may find their way into the United States at any time. There are no laws or regulations to keep them out.

The Undesirables Defined

FLORIDA'S NOXIOUS AQUATICS ARE EXOTICS

What is a noxious aquatic weed?

The dictionary defines the word noxious as meaning harmful or destructive. We can, therefore, say that a noxious aquatic plant is one which is harmful and destructive of the water environment in which it exists.

Certainly not all aquatic vegetation is harmful to the environment. In fact, quite the contrary; aquatic plants are a necessary part of the water environment, if there is to be fish and other aquatic life. Most of the aquatic plants which are found in Florida waters are not noxious. The aquatics which are classified most noxious have been without exception imported into Florida and placed in the water environment of the state.

Without natural enemies, these aquatics have proceeded to take over and replace the natural aquatic plants in the areas of infestation. They have impeded the flow of natural waterways and man-made waterways; have prevented or impeded navigational use of these waterways, and have adversely affected the fisheries and other wildlife benefits that should be derived for these waters. They have also contributed to the pollution of the canals, lakes, and streams of Florida.

HYACINTH INFESTATION

FOUR CLASSIFICATIONS OF AQUATIC PLANTS

There are four basic classifications for aquatic plants: (1) floating; (2) submersed; (3) emersed, and (4) aquatic and ditchbank grasses.

A floating aquatic is one which stays on the surface of the water and does not generally root itself or attach itself to the bottom or bank but is free to move about with the currents or the wind. Two common floating aquatics are hyacinths and water lettuce.

Submersed plants are those aquatics which generally root themselves to the bottom and stay entirely within the water area. They do not protrude or extend from the water. Some of the common submersed aquatics found in Florida are the hydrilla (Florida elodea), southern naiad, coontail, Eurasian watermilfoil, bladderwort, Cabomba, Vallisneria (better known as eelgrass), and Chara.

Emersed aquatics generally root to the bottom but will also grow above the water surfaces. Some common emersed aquatics of Florida are alligatorweed, spatterdock, cattail, pickerelweed, waterlily, arrowhead, and buttonbush.

Aquatic and ditchbank grasses are those aquatics which are similar to the emersed aquatics but grow in very shallow areas along the banks. They can also grow entirely out of the water environment, and on dry land as regular grasses would do. Examples of the common ditchbank grasses found in Florida are maidencane, torpedograss, paragrass, napier grass, sawgrass, giant cutgrass, and southern water grass.

Certainly, not all those aquatics mentioned above are to be considered noxious aquatic plants. Most of them, under normal circumstances, are not. It is recognized that any of these aquatics could, under some circumstances, be considered noxious because they interfere with intended use of water areas. This is not, however, generally the case.

There are just a few among those mentioned which must be carefully watched and controlled if they are to be prevented from destroying or seriously damaging the water environment or seriously impeding the capability of man to properly utilize his water resources. Those aquatics which have the greatest potential to seriously injure or damage the water environment or upset its natural ecological balance are:

Classification	Name
floating	water hyacinth
emersed	alligatorweed
submersed	hydrilla Eurasian watermilfoil

Will Even Persist On Dry Site

HYACINTH AN OLD ENEMY; ARRIVED IN 1884

Of those aquatics which would be classified as the most widely known is probably the water hy

The hyacinth was first botanically described in Brazil and is thought by some historians to have originated in Puerto Rico. It was introduced into the United States in 1884 and by prolific growth rapidly became a pest in Florida and throughout the other southeastern states by the turn of the century. It is reported that the water hyacinth is a serious water weed problem in most of the subtropical and tropical areas of the world today. The water hyacinth, if left uncontrolled, will seriously impede the flow of water in the waterways and block boat traffic.

The water hyacinth has green, shiny, polished-appearing leaves which are four to six inches across. The spongy leaf stalks are often inflated and arise from a central point. The leaf stalks or leaves may be up to four feet tall and may be partly submersed. The fine feathery roots are fibrous and branched.

The inflorescence is a spike bearing several to many flowers that are quite showy and may be white, blue, or violet with all shades between. The upper lobe of each flower is characterized by a yellow marking surrounded by a deep blue margin. The plants reproduce largely by vegetative means and are interconnected by stolons. However, the seed will germinate on floating mats of decaying vegetation or an organic bank or bottom.

WATER HYACINTH

The habitat of the water hyacinth [illegible] water. The plant can become established in very [illegible] soil and then persist in a relatively dry site for several months at a time.

Flourishes In Fertile Areas

ALLIGATORWEED IMPEDES WATER FLOW, BOATS

Alligatorweed probably grows in a wider range of water and soil conditions than any other plant. Equally profuse growth may be found when alligatorweed is completely free floating, loosely attached in forming a mat, rooted, or in a dry field. Alligatorweed responds rapidly to fertilization; it grows best in areas of sewage inflow, fertilized fields, and similar highly fertile areas. It grows primarily in fresh water, but will tolerate salt to 10 percent of sea strength in still water and 30 percent of sea strength in flowing water. This plant is found in the coastal states from Virginia to Texas, while a few infestations have been noted as far west as California.

The alligatorweed is believed to have been introduced into the United States in a ballast of ships from South America. The greatest problem of this plant in Florida is caused in streams and canals where dense floating mats may block boat traffic and interfere with the flow of water.

ALLIGATOR WEED

Alligatorweed grows as a mat of vegetation interwoven with stems that have become prostrate. The nodes generally have two buds, each of which may sprout to produce a shoot. Reproduction is by vegetative means from the axillary buds. The leaves are opposite, two to five inches long and lance-shaped with a distinct midrib. A very few hairs may be found on the leaf surface and margin. The stems are hollow. The flowers occur on long stalks in a solitary head up to 1/2 inch in diameter. From six to 20 white florets may be found on each flower. Roots may form at every node near the water or submersed in water or in moist soil. Upon reaching soil, the small aquatic roots enlarge, thicker, and in general take on the characteristics of other perennial terrestrial roots.

Causes Ecological Shift

HYDRILLA TERMED 'GREATEST THREAT'

Probably the greatest threat to the water environment of Florida and the plant with the greatest capability to upset the present ecological balance of the waters of this state lie in the submersed aquatic-hydrilla, known as Florida elodea.

Hydrilla is found in canals, ponds, and streams. It is strictly a submersed plant and cannot withstand extensive drying. In Florida, infestations of this plant are found in drainage and irrigation canals, fresh water ponds, lakes, and even in tidal streams.

This plant which can be found throughout most of the world, did not become established in the United States until 1959 when the first infestation was found in Dade County, Fla. Since that time it has spread all over the state and into the other southern states. Recent reports have confirmed the establishment of this plant in the Midwest.

Hydrilla's very prolific growth rate creates a progressive ecological shift in the canals and waterways from the native aquatic vegetation to hydrilla. It will effectively and completely block the flow in the waterways and prevent the utilization of these waterways for boating, fishing and water movement. Hydrilla has continued to spread in South Florida since it was first discovered, until, at this time, hydrilla now infests all of the canals of Dade, Broward, and Palm Beach Counties, and the three Everglades Conservation Areas.

Very recent discoveries of the infestation of this plant have been made in the canals of Hendry County, Collier County, five areas of Lake Okeechobee and those canals which flow into the lake from the northwest and the northeast shores. This plant has created problems in the lakes of central Florida around Orlando and Winter Park. There is reason to believe that these problems will spread to other fresh water lakes, rivers and canals in Florida.

Hydrilla is a submersed aquatic, rooted to the bottom and having long, branching stems. Lower leaves are opposite and small whereas the median and upper leaves are in whorls of three. Leaves are narrowly lance-shaped 3/8 inch to 3/4 inch long and about 1/8 inch wide with two edges and ending in a minute spine. There are flowers from near the stem apex. They are found at or near the water surface.

HYDRILLA

The entire flower is inconspicuous, measuring no more than 1/4 inch wide on thread-like stalk. Seed formation, if it occurs at all, is poor. Reproduction is both vegetative and by fruits. Broken shoots develop into new plants that attach themselves to hydrosoil by fine roots. Plants also produce subterranean shoots with swollen tips, densely clothed with fleshy, scale-like leaves. These in turn breed additional hydrilla plants. An additional propagated structure, the "turion," is also produced by hydrilla.

'No Apparent Deterrent'

WATERMILFOIL HAS MANY NOXIOUS EFFECTS

The other submersed aquatic that can be considered a serious threat to the water environment of Florida is Eurasian watermilfoil. Eurasian watermilfoil is a perennial submersed plant that spreads very rapidly both by vegetative reproduction and by seed. It is rooted in the bottom mud. Each node produces roots, especially when it touches the soil. Large clumps of vegetation can break loose and continue to grow even though they are not touching the soil.

Large infestations of this plant are found throughout the eastern United States with extensive stands reported in and near Chesapeake Bay, Tennessee Valley Authority Lakes, and the Chattahoochee, Homosassa, and St. Johns Rivers of Florida.

WATERMILFOIL

There is no apparent deterrent to the further spread of this Eurasian watermilfoil, which was first found in Florida in the mid 1960's.

Thick growth of this plant effects shellfish severely, prevents fishing, interferes with boat traffic and impedes the flow of water. This plant has a very high tolerance for salt water and can thrive in brackish estuarian areas. This makes this plant a serious threat to the waters of the Florida coast.

The leaves are in whorls and have 10 to 14 finely dissected segments on each side. The spike is emersed, above the water, and has no leaves. Eurasian watermilfoil grows in fresh water but will tolerate salt content up to 33 percent of sea strength. The plant is generally found in water from one foot to ten feet, depending on how much light is penetrating the water, and it overwinters well in relatively cool water.

Reduce Pollution Potential

ADVANCES SLIGHT IN CONTROL BY MACHINES

There are three basic methods of aquatic weed control in use today: mechanical, chemical and biological.

When aquatic plants first became a problem in the United States, the initial efforts to bring the plants under control were by use of machinery. The first efforts to construct machinery specifically for aquatic control were in 1899 when the Congress authorized the construction of two crusher boats; one for Florida and one for Louisiana, to be operated by the Corps of Engineers to combat the growing hyacinth threat. By 1902 these machines were abandoned because they were inadequate to cope with the problem.

A series of more effective and faster operating machines were developed between then and 1937, when handling capacity increased to a 135-ton diesel electric crusher boat. Machinery is being used today for aquatic weed control. It is more sophisticated and efficient but is still basically a refinement of the machinery developed during the early part of the century.

Mechanical removal has the advantages of removing the aquatic weed to greatly reduce any pollution from decay without having an adverse effect upon areas outside the work area. The disadvantages are the inefficiency of the degree of control, the possible spreading of the infestation and its high cost.

Unpopular But Effective

CHEMICAL CONTROL CURRENTLY INDISPENSABLE

Chemicals were used for the control of hyacinths as early as 1900. These early attempts to kill the plants by the application of chemicals were not very successful. According to an article by Julian Raynes, 23 different chemicals were tried on aquatics in tests run in 1906. These included Arsenit, copper sulfate, formaldehyde, kerosene emulsion, and whale-oil-soap solution.

Six of the 23 chemicals were found to be effective on aquatics but all were toxic to cattle and man. As a result, chemicals were not used extensively until the nineteen forties when 2,4-D was made available and found to be effective in killing water hyacinths. Since that time many new herbicides have been developed and put to use in aquatic weed control. Many of these herbicides are selective in which aquatics they will affect. This can be advantageous in minimizing the effects on the total water environment.

In recent years, much controversy has arisen over the effects of placing chemicals in the water and its effect upon the ecology and environment. There are those who believe that the use of herbicides for aquatic weed control should be discontinued because they are dangerous to man and his environment. While it is certainly true that some chemicals do fall in this category, it certainly is not true of all. Some of the herbicides which, when applied correctly in the proper amounts, are safe to mammals and fish are: Dalapon, Dichlobenil, Diquat, Fenac, 2,4-D and Silvex.

Herbicides are the most efficient, effective means of controlling aquatics available today. Without their use we would be unable to keep the waterways and lakes of Florida open for water movement.

There are certain disadvantages to their use, such as:

1. They can drift to nearby plants and cause damage.

2. Overdosage of chemicals can be toxic to fish and marine life.

3. If used in a heavily infested area, the decaying vegetation may have a detrimental effect on the water environment.

These disadvantages can be overcome by proper application as part of an adequate continuous maintenance program.

Search For Killers Goes On

BIOLOGICAL CONTROL SHOWS FUTURE PROMISE

The primary objective of biological control is to reduce the density of any aquatic by use of biological agents to the point that the plant is no longer a problem. There are many different biological agents: insects, fish, mammals, birds, parasites, diseases and plant competition to name some. To date there has been relatively little use made of this method of control because no known effective biological control agents are available for most aquatics.

More and more experimental work is being done to try to develop or find biological control agents. There is at present work being done with insects, fish and diseases to find effective control agents.

This method of control shows promise for use in the future. It would have the advantages of ease of application, low cost, no special equipment.

The disadvantages would be that the initial results would be slow in coming and may require the use of other methods in conjunction with it.

Tabulated in Table VIII are the methods now in general use in the State of Florida for control of the previously described noxious aquatic weeds.

Other Noxious Weeds Pose Threat

NEED FOR FEDERAL CONTROLS CITED

It must be again noted that none of these noxious aquatics are native to the United States but have been brought into the country and placed in the waters of this state where they have created serious weed control problems.

Had there been adequate Federal legislation controlling the importation and interstate transportation of exotic aquatic plants, it is possible that three of these species would not be here today: hyacinths, hydrilla and Eurasian watermilfoil.

The truth of the matter is that there is no Federal legislation preventing or regulating the importation or interstate transportation of aquatics. Efforts have been made to have this done and legislation was sponsored by the late Senator Spessard Holland. Unfortunately, it was never passed. This type of legislation is ver necessary if we are to prevent any future infestations o new exotic aquatic plants.

TABLE VIII

CURRENT AQUATIC WEED CONTROL METHODS

AQUATIC WEED	BIOLOGICAL	MECHANICAL	CHEMICAL
Hyacinth	None	(a) Dragline (b) Motor-driven cutting machine with conveyor to get harvested material to bank or shore	(a) * 2,4-D at a rate of 2-4 lbs. per acre (b) Diquat at a rate of 0.5 - 1 lb. per acre. All sprayed under high pressure directly on plant.
Alligatorweed	Flea Beatle Thrip	(a) Dragline (b) Same as (b) above.	(a) *Spray Silvex at a rate of 6-8 lbs. per acre directly on plant. Sprayed under high pressure.
Hydrilla	None	(a) *Drag plow to tear material loose from canal bottom and then remove it by dragline or loader. (b) Same as (b) above.	(a) *Use pelletized form of Endothall placed on bottom at a rate of 10 - 15 lbs. per acre. (b) Use formulation of diquat and copper at a rate of 4 lbs. Diquat plus 7 lbs. copper per acre.
Eurasian Watermilfoil	None	(a) Same as (a) above. (b) Same as (b) above.	(a) *Use pelletized form of 2,4-D placed on bottom at a 20 -30 lbs. per acre. (b) Use Diquat at rate of 0.5 pp mw.

* Most commonly used methods.

There are still hundreds of aquatic plants in the world which are not yet found in the United States but could create problems of control if introduced.

There are adequate, safe, and economical control methods available for hyacinth and alligatorweed control by the use of the herbicides as shown in Table VIII. If these chemicals were not available for this use, hyacinths and alligatorweed would again begin to seriously interfere with our use and utilization of our water resources.

Present mechanical methods cannot cope with the rapid growth and reproduction rates of these plants. Even if they could, the cost of mechanical removal of these aquatics would be prohibitive. The mechanical removal of these aquatics is at least 10 times as expensive as chemical treatment. It costs between $8 and $12 per acre to treat hyacinths with chemicals and $80 to $120 per acre to remove them mechanically.

Experimental Work Only Hope

TWO SPECIES SPREADING AT 'ALARMING RATE'

At the same time, the submersed aquatics, hydrilla and Eurasian watermilfoil (which are relatively new to the State), are spreading at an alarming rate throughout the state and threaten every fresh water course. With these aquatics the mechanical and chemical methods are both expensive, in excess of $100 per acre for chemicals and about two to four times that amount for mechanical control. Both methods have their own distinct disadvantages as outlined previously.

There are some well-meaning people who wish to see the use of chemicals for aquatic weed control banned in Florida. This action would be disastrous to the efforts of the agencies responsible for control. These agencies do not need their tools of aquatic control taken away, but instead need to have new and better tools developed.

Whether these new tools be mechanical, chemical or biological makes no difference to those responsible for aquatic weed control as long as they are a safer, more efficient and effective way of controlling the weed menace. The important thing is that much experimental work is necessary if we are to ever hope to bring submersed aquatics under control or have any hope of noxious aquatic weed eradication.

Experimentation is now being carried out with all three methods of control. The most activity, however, appears in biological and mechanical control methods. Some biological experimental efforts include:

(a) The use of insects for hyacinth control.

(b) Use of the White Amur fish for submersed aquatic weed control.

(c) The effect of virus, bacteria and fungi diseases on aquatics.

(d) Work to break down the plants' resistance to insect attack.

All of the above show promise but much work is necessary before any could be considered an operational tool.

Weaponry In A Market?

PROFITABLE USES OF NOXIOUS WEEDS SOUGHT

In the mechanical field, work is being carried on to find uses for the aquatics that are harvested from the water. Examples include use as feed for cattle, chickens or swine, and use in the manufacture of products such as paper. The intent of this work is to create a market for what now is a useless waste produce and, therefore, reduce the overall cost of mechanical control. Work is also being done to develop new machines for more efficient harvesting of aquatics.

The only experimental work being carried out with chemicals is to try to reduce the amount of chemical required to kill the plant by increasing the plant uptake of the chemical.

It is certainly hoped that the experimental work being carried out in all areas of aquatic weed control is successful, but it appears that it will be a long time before any additional methods of control are ready for large-scale operations in the field.

Until the experimental work now being carried out is fruitful in finding better and more effective and efficient ways of controlling aquatics, we can expect infestations to continue to spread and the cost of control to continue to rise.

*References: (19), (20), (21).

THE CULTURE AND CARE OF AQUATIC WEEDS

ENFO NEWSLETTER, 7/72
Environmental Information Center

Florida's 4,000 square miles of freshwater surface consists of 8,000 linear miles of waterways and 30,000 lakes, most of which are ideal for development into waterfront property. This does not include the innumerable swamps and water retention areas which, with a little extra expense and effort, can also be utilized as waterfront property through the technology of dredging canals and filling in the swamps.

Under natural conditions these waterways do not meet accepted landscaping standards. They are bordered by lush, tropical vegetation which is infested with myriads of native insects, birds and wildlife. The tangle of vegetation is usually so dense it blocks access to the waterway and its roots are immersed in gooey organic detritis trapped during stormwater runoff. In many cases, marsh grasses and weeds extend from shore out into the water, an unacceptable condition for a conventional bathing beach. However, these obstacles are easily overcome by standard land improvement methods.

The wild, native vegetation is cleared away and replaced with neat, well-manicured shrubs and lawns. Sand is trucked in to bury the objectionable marsh grasses and create a clean, artificial beach. Insecticides keep the bugs under control, herbicides hold down obnoxious native plant growths, and chemical fertilizers maintain the lawn and shrubs in a healthy condition. A dredged, bulkheaded channel provides a convenient, private boat dock. Storm drains and ditches insure that dirty runoff water from inland developments is bypassed directly into the water without contaminating the manicured landscape. Underground septic tanks and sewer lines dispose of human waste by getting it out of sight, letting it seep into the water.

The result is the conventional waterfront development which provides near perfect conditions for the propagation, culture and care of exotic aquatic weeds. The proliferation of this type of waterfront landscaping is a major cause of Florida's 4,000 square mile aquatic weed headache.

The automatic, maintenance-free natural system of nutrient recycling and fish production is replaced with a synthetic, cultivated environment which pours both natural and manmade pollutants into the water. Eventually elodea or some other exotic weed will be i troduced by boat traffic, or from someone's tropical fish collection, and noxious aquatic weeds thrive in polluted water.

A 4,000 Square Mile Weed Problem

Water weeds were no problem in Florida prior to the turn of the century. At that time the water in lakes, rivers and streams was clean and clear, and provided some of the world's finest freshwater fishing. Some lakes, such as Apopka, established national reputations for world record bass.

Since the early 1900's the spread of exotic aquatic weeds has been in almost direct proportion to Florida's population growth and accompanying pollution. Also, freshwater fishing has declined in almost direct proportion to the proliferation of the weeds.

A 1947 survey by the U.S. Army Corps of Engineers disclosed that hyacinths infested about 63,000 acres of Florida waters. In 1962, after a massive eradication program by spraying with 2,4-D which cost more than a million dollars a year, federal and state agencies are still spraying hyacinths with 2,4-D and the weed has spread into almost every waterway in the state.

The hyacinth is an exotic (imported) weed which escaped from a fish pond 78 years ago and has spread inexorably across Florida ever since. Accompanying the spread of hyacinths are submersed varieties of exotic aquatic weeds which are even more of a threat to fishing and recreation, and far more difficult to control. A few of the most notorious of these are alligatorweed, elodea (Hydrilla), southern naiad, and watermilfoil. Most of these can grow with or without roots anchored to the bottom and some exceed lengths of 18 to 20 feet. All of the weeds can be propagated and spread from particles and pieces floating in the water, and most of the submersed varieties can regenerate from root nodules buried in bottom sediments.

A certain amount of aquatic vegetation is beneficial and necessary to maintain the balance in a freshwater ecosystem. Growing vegetation removes nutrients (fertilizers in the form of phosphates, nitrates, other minerals and organic matter) and releases oxygen to the water in much the same manner as vegetation on land. However, an overabundance of nutrients stimulates an unnaturally lush growth of vegetation. This is especially true of exotic weeds which are controlled by few, if any, natural enemies and compete successfully in polluted water with desirable native plant species. As a result, massive infestations of hyacinths blanket water surfaces, and submersed weeds choke waterways from shore to shore and from bottom to the surface; blocking navigation, destroying fishing and water sports, restricting flow and wasting water through excessive evapotranspiration. In effect, explosive growths of aquatic weeds make Florida's waterways unusable, and useless.

Attempts to eradicate or control these weeds has presented Florida citizens with a multimillion dollar expense and created a bonanza for chemical herbicide manufacturers and salesmen.

The Chemical Control Cult

The Rivers and Harbors Act of 1899 authorized the U.S. Army Corps of Engineers to destroy or remove water hyacinth from navigable waters of five southern states, including Florida.

In 1958, Public Law 85-500 authorized "a comprehensive project to provide for control and progressive eradication of the water hyacinth, alligatorweed, and other obnoxious aquatic plant growths . . ." in the five southern states, and approved an expenditure of $1,350,000 each year for five years. The Corps of Engineers was charged with the responsibility, and the Florida Game and Fresh Water Fish Commission was designated as the state agency. Florida's participation cost its citizens 30% in matching funds.

In 1962, the estimated cost of the expanded project in Florida was $2,169,900. Currently the Florida Game and Fresh Water Fish Commission alone spends about $900,000 annually for aquatic weed control, and the annual total spent by all governmental bodies for operations and research on this problem in Florida is now several million dollars a year.

Currently, the Corps is responsible for control on the navigable, large waterways, and still finances research. The Florida Department of Natural Resources and the Florida Game and Fresh Water Fish Commission are responsible for control and for more research in areas of the state not covered by the Corps.

As these figures clearly show, attempts to "eradicate" aquatic weeds are completely ineffective and the spiraling costs of present control methods have no end in sight. Except for a few minor experiments with mechanical and biological measures in terms of funding and total effort, the aquatic weed control effort has depended upon the use of chemical herbicides. And abundant evidence is available that killing aquatic weeds with chemical poisons is creating more problems than it solves.

Many of the fish kills which occur regularly in some of Florida's waters are attributed to the effects from herbicides and decomposing vegetation. Weeds killed by chemicals sink to the bottom where they decompose, adding to the oxygen-demanding wastes accumulated in bottom sediments of polluted waters. In addition to their toxic properties, the chemicals are also oxygen-demanding materials.

SOME CHARACTERISTICS OF THE FOUR MAJOR EXOTIC WATERWEEDS ESTABLISHED IN FLORIDA

From: "An Appraisal of the Florida Cross State Barge Canal in relation to the dispersal of exotic vegetation," by William M. McLane, Ph.D. 1969

SPECIES	FLORIDA DISTRIBUTION	GROWTH FORM	GROWTH RATE	CHEMICAL CONTROL
Water Hyacinth (*Eichornia crassipes*)	Statewide in fresh water	Floating; reproduction primarily vegetative	20 adult plants will normally spread to 20 acres in 8 months	4 lbs. 2,4-D/acre, 3 times a year. ($35.40/year/acre for chemical and labor)
Florida Elodea (*Hydrilla verticillata*)	Peninsular Florida, mostly in fresh water	Rooted aquatic, with vertical root systems, + reproductive propagules + some flowering	Probably the fastest growing & most rapidly multiplying submersed aquatic seed plant in the world	1 ppm Diquat + 4 ppm copper sulfate/acre/foot, injected from a surface boat. (chemicals alone: $30.50/acre/foot)
Eurasian Milfoil (*Myriophyllum spicatum*)	Jackson & Citrus Counties in brackish & fresh waters	Rooted & floating clumps; vegetative reproduction & seeds	Up to 2 inches per day	2,4-D from surface or air. (chemical cost alone: $32/surface/acre)
Brazilian Waterweed (*Egeria densa*)	Upper Florida Peninsula in fresh water	Rooted aquatic, spreading vegetatively	Stem growth up to 1 inch per day	Diquat most economically practical control. (chemical control alone: $27.50/acre/foot)

Thus, killing weeds with herbicides eliminates the benefits of nutrient removal from growing vegetation and substitutes an additional load of oxygen-demanding material. The result is often a reduction of dissolved oxygen throughout the water column and the fish suffocate. The dead fish eventually sink to the bottom and their decaying carcasses add to the oxygen demand of bottom sediments. Regrowth of the weeds is so rapid that spraying must be repeated several times during a season and some badly polluted waters require as many as fifteen to twenty herbicide applications within the few months of hot summer weather.

Thus chemical weed control, combined with the heavy pollutional load in most Florida waterways, causes a rapid acceleration of eutrophication, chronic fish kills, production and accumulation of algae scums, offensive odors and eventual degeneration into septic conditions. Lake Apopka and some of our badly polluted freshwater canal systems are classic examples of the lethal effect of this combination on Florida's waterways.

Although many of the herbicides are lethal to fish and other aquatic life, Mr. Robert Blackburn and other experts of the U.S. Department of Agriculture claim that their use under controlled conditions does no permanent harm. However, under certain conditions, herbicides strong enough to kill the weeds will also kill fish. An example occurred with broadleaf watermilfoil in Port Charlotte canals, in which permission to use copper sulfate and 2,4-D amine in quantities and by methods recommended by Mr. Blackburn, was requested. It was admitted that the chemical concentrations recommended would predictably cause a fish kill, but it was claimed that lower concentrations would not satisfactorily control the watermilfoil said to extend from bank to bank and almost from top to bottom.

When the water contains excessive nutrients from pollution, the elimination of one type of aquatic weed often leads to reinfestation by another, more obnoxious species. A Central and Southern Florida Flood Control District pamphlet states, "In a sense, weeds fight back. Ecological shifting has already been noted. For example, in Southern Florida weed experts no sooner found methods to kill southern naiad when elodea moved in and took over."

Mr. C. W. Sheffield, Orange County Pollution Control Officer, states, "There are many toxic chemicals that will not only kill the plants, but other forms of life within or using the waters . . . .

"Copper sulfate has been and is very popular today when combined with other chemicals for the control of Phytoplankton and submerged aquatic weeds. This chemical is normally applied at rates not toxic to humans. It is very harmful to fish and fish food organisms at low concentration. (Copper at levels of 0.1 mg/L is toxic to fish, very synergistic with other metals.) Copper is precipitated on the fish gills and thereby causes it to suffocate . . . copper can precipitate . . . in the water as a copper carbonate compound and end up on the lake bottom. It is a very persistent metal in the silt and muds and can be recycled from these sediments . . . when the fish spawn the copper is toxic to the eggs, small fry or concentrates in bottom dwelling organisms."

STUDY OF RELATIVE TOXICITY OF VARIOUS COMPOUNDS TO BOTTOM ORGANISMS AT LAKE IVANHOE, ORLANDO, FLORIDA

Data from William Beck, Florida Department of Air and Water Pollution Control, Reported by C. W. Sheffield, 1970

1. Control - 0% reduction
2. 2,4-D - 14% reduction
3. Copper sulfate - 23% reduction
4. Hydrothol 191 - 50% reduction
5. Diquat - 86% reduction (moderate fish kills)
6. Acrolein - 91% reduction (large fish kill)

Sheffield also stated that in all cases where weeds were killed and dropped to the bottom, the organisms declined to leeches, worms and other nuisance species in lieu of a healthy, well-balanced biota.

Although the recommended applications of poisonous herbicides are concentrations considered non-toxic to humans, different government agencies and private property owners can spray public drinking water supplies at the same time and without each other's knowledge. Students of the University of South Florida, in a study sponsored by the National Science Foundation, discovered that as many as three different governmental agencies were spraying herbicides into the Hillsborough River, each not knowing of the other's actions. In addition, the students found discrepancies in the records of some of the agencies as to the amount of 2,4-D used in the river and surrounding lakes.

The permissable limit of 2,4-D in drinking water is 0.1 ppm, and analysis of the Tampa Water Treatment Plant revealed that concentrations of 2,4-D in the water were within permissable limits. However, Mr. Sheffield states that it is virtually impossible to accurately measure 2,4-D residues. It is not presently known if 2,4-D is concentrated in a recipient's body. And the Perrine Primate Laboratory of E.P.A. discovered that an equivalent dose of 6 ppm orally administered to monkeys caused a change in electroencephalogram readings. The animals are also showing birth difficulties; some offspring do not live more than four or five weeks.

The water in Port Charlotte canals is also used for drinking water where a combination of copper sulfate and 2,4-D amine was used to treat watermilfoil. The request for a permit contained calculations which indicated that the copper and amine would settle out and not reach the water treatment plant in quantities sufficient to be a hazard. However, copper has a cumulative effect, is subject to biological magnification, and is suspected of triggering ciguatera fish poisoning in some marine fishes according to Dr. Bruce Halstead of World Life Research.

In spite of such evidence that chemical control of aquatic weeds is an expensive, destructive and unending process, the preponderance of research funds and effort is still concentrated upon chemical control while other control methods receive unanimous verbal support, but insignificant funding. It has been impossible to obtain accurate, total up-to-date costs for the entire program of chemical control of aquatic weeds in Florida.

A letter from Lt. Colonel John L. Rudser, Corps of Engineers, Jacksonville District, to Congressman Paul G. Rogers, in 1968, states, "The Corps of Engineers does not question that hyacinth killed by our spray operations constitute pollution. We also agree that physical removal of hyacinth by mechanical means would be desirable from a pollution standpoint. On the other hand, mechanical equipment capable of coping with a problem of the size which faces us this year is simply not available."

Another letter from Colonel R. P. Tabb of the Corps in March 1968, discussing the congressionally authorized aquatic weed project stated ". . . research under the project is a federal responsibility." The same letter stated that of the $100,000 appropriated for research, $65,000 was for chemical control, $35,000 for biological control, nothing was set aside for research for mechanical control, and in 1972 the Corps can continue to state that equipment capable of coping with the problem is simply not available, as was stated in 1968.

The defense of chemical control of aquatic weeds receives support from some federal and state officials that borders on the fanaticism usually associated with the defense of DDT and other insecticides. The multi-million dollar market created for herbicides is a bonanza for many of the same chemical companies that manufacture pesticides, and most aquatic weed research is under the direction of the Agriculture Department, which stridently supports the continued use of insecticides such as DDT. It is unlikely that chemical companies would welcome control methods which threaten this bonanza and they are suspected of influencing the direction of aquatic weed research.

Weed-Eating Fish, Insects and Snails

The fact that exotic aquatic weeds have few if any natural enemies led to the belief that biological control promised a cure for all of our weed problems. According to proponents of this method, all that is needed is to find an insect, bug, virus, snail or fish that relishes these particular weeds and the problem would be solved.

According to the Institute of Food and Agricultural Science, University of Florida, the most successful research to date is with the flea beetle and the Marisa snail. Tests show that the flea beetle will eat nothing but alligatorweed and dies of starvation when the weed is eradicated. Hence, it is no threat to desirable plant species. The beetle was cultivated and released throughout Florida, and is credited with control and even eradication of alligatorweed in many areas. However, as the CSFFCD stated, when the alligatorweed disappeared, elodea moved in to take its place.

The Marisa snail shows a preference for submersed aquatics such as elodea, southern naiad, coontail, and pondweed as well as certain types of algae. However, the snails are not expected to be effective in other than small, confined bodies of water under conditions favorable to their increasing populations.

Some work has recently been initiated on disease organisms which attack aquatic weeds. However, researchers must be extremely cautious with such methods for fear of starting the spread of aquatic epidemics if the pathogens should develop an appetite for beneficial plants.

A recent surge of publicity centered around the white amur, a fish which has a superficial resemblance to our chub. The amur is promoted as a weed eater, grows at a rate of five pounds per year, reaches weights of 70 and 80 pounds, is a sportfish and is good eating. However, it was recently discovered that the white amur has an exceptionally short intestine and, as one prominent biologist put it, "We would have to put diapers on the fish to prevent reinfestation by fragments of undigested weeds."

A common fallacy of proponents of both chemical and biological weed control is that they tend to ignore the basic cause of our aquatic weed problem, which is water pollution. Any attempt to control aquatic weeds which does not also remove excess nutrients from the water is doomed to failure. Such methods only invite reinfestation by the same weeds, or an invasion by other species which may be even more objectionable. Also, when weeds are killed the water immediately undergoes a spectacular increase in turbidity. Until we discontinue the practice of using our waterways as open sewers for the disposal of industrial wastes, agricultural wastes, urban runoff and domestic sewage, aquatic weed control by chemicals, biology and drawdowns are an exercise in futility. Under present conditions, and as far as can be seen into the future, we can expect a bumper crop of aquatic weeds to invade our waters every summer. The time is long past due for responsible agencies to forget about eradication and control methods and approach the problem from the standpoint that aquatic weeds represent a useful crop, to be harvested and utilized in the same manner as other agricultural products.

Weed Harvesting -- A Solution To Pollution?

The University of Florida Institute of Food and Agricultural Sciences has been interested in using water hyacinth as a cattle feed for more than twenty years. All indications from their research show that both hyacinths and submersed aquatics concentrate nutrients sufficiently to make dried or pelleted weeds a suitable forage type feed.

In 1967, the Governor's Aquatic Research and Development Committee initiated a study of mechanical harvesters of aquatic weeds and the publicity triggered the development of numerous designs of weed harvesters by private individuals and corporations, some of which showed great promise. At this time the first trial feeding of hyacinths with cattle was tried by Lykes Brothers in cooperation with the Game and Fresh Water Fish Commission. The chopped hyacinths were sprayed with molasses and fed to cattle in open troughs. The trials were successful and Mr. Darrel McAteer of Lykes Brothers reported that the hyacinth compared favorably with a presently used product and should have a value of about $30.00 per ton.

In 1968, a conference in Orlando resulted in a cooperative experiment involving the Game and Fresh Water Fish Commission, University scientists and a number of private industries which produced dried, pelletized water weeds for use as a cattle feed. The materials produced were evaluated by a wide range of industries and laboratories which concluded that the material had a distinct value as a cattle food supplement but that additional research was needed. As a result, more than 38 individuals and companies expressed an interest in cooperating in the project. A spokesman for the I. S. Joseph Company stated, "Since we are exporters and processors of by-products, we know that there is a constant demand for animal feed stuffs the world over, especially in the countries where population has forced the farmer to feed his animals from the bag or feed truck instead of the pasture . . . the by-products that were common to animal feeding ten years ago, are now disappearing from the ingredient supply."

A number of studies have shown that aquatic weeds have a tremendous capacity for removing nutrients from water and have even been used successfully for advanced treatment of sewage, removing most of the nitrogen and phosphorus compounds which standard treatment methods do not eliminate.

C. W. Sheffield and the GFWFC used hyacinths in a lake restoration project. In six to eight weeks the nitrogen and phosphorus were eliminated and after fifteen months the hyacinths were sinking to the bottom because they were starving to death.

The use of harvested aquatic weeds to reduce muck soil subsidence in critical areas such as those south of Lake Okeechobee, was recommended to the Trustees of the Internal Improvement Fund in a Florida Conservation Foundation study last year. Combined with sewage wastes and other organic refuse applied to experimental sections of state-owned mucklands, this program could become a pilot project leading to solutions of problems of waste disposal, water pollution abatement and soil conservation. Although the idea appears to have appealed to most authorities, it has yet to be initiated.

The results of these experiments have shown that mechanical harvesting of aquatic weeds would be of great benefit in cleaning up Florida's polluted water and the additional costs of this process can be offset by marketing the weeds as cattle feed, fertilizer, mulch, paper board and other uses. And as more efficient methods are developed, mechanical harvesting may even prove profitable to private industry without government support.

The American ingenuity that developed mechanical harvesting of corn and celery in Florida's muck farms, cattle feed from citrus wastes, and which developed the technology to cause the water pollution which brought about these water problems, can certainly find an efficient method of harvesting aquatic weeds. As long as we continue to encourage land use that overenriches our water bodies and put off to another year any meaningful program of utilization of water weeds, it will be easier to justify economically the use of sprays; and Florida will continue to spend millions of dollars a year on herbicides which pollute our waters, kill our fish and destroy some of our most valuable recreation areas.

WATER WEED RESEARCH IN FLORIDA INCLUDES:

Corp of Engineers:

Biological control, including cooperative programs with U.S. Department of Agriculture.
Mechanical removal research, now finished but reported not promising.
(Other research at Vicksburg, Miss., includes Laser beam research.)

Department of Natural Resources, at the University of Florida:

Plant diseases, including viruses and bacteria.
Insects, including Agrentine Weevils.
Paper fiber from hyacinths.
Animal feed from hyacinths, for cattle and swine.
Soil amendments.

(The last three would require mechanical removal of weeds, and therefore nutrients from the water.)

FLORIDA'S FILTHY WATERS - SOCIAL AND ECONOMIC COSTS

ENFO NEWSLETTER, 11/72
Environmental Information Center

The State Department of Pollution Control's moratorium on additional hookups to substandard sewage treatment systems, effective October 1, 1972, has generated a raging controversy which has thoroughly confused the average citizen. Reactions to the DPC's action ranged from a building contractor who stated the moratorium will cause "An economic disaster surpassing that of the Great Depression of 1929," to a conservationist who termed it, "A courageous action, vital to protect the health and welfare of Florida's citizens and to preserve its environment."

The law requiring 90% treatment of sewage by January 1, 1973 was passed on January 17, 1969. Florida's cities and counties have had four years to comply with its provisions, yet sewage treatment throughout Florida is still hopelessly inadequate.

Bacteria Contamination

Sewage is a polite term for one of the deadliest concoctions known to man. The lethal qualities of this witches-brew are vividly described by John V. Betz, Ph.D., Associate Professor of Microbiology, University of South Florida. Dr. Betz says,

> "Domestic sewage is 99% water. The remaining fraction is just about anything that human beings wash down their drains or flush down their toilets. . . grime and soap from hands and dishes, feces and urea from human excrement. However, it is the fantastic biological and chemical potency of this small fraction which makes it absolutely imperative that it be thoroughly transformed in an adequate treatment process <u>before</u> it is returned to nature.
>
> "Human feces is two-thirds roughage or undigested food. The full remaining 33% by weight is bacteria: pure, compacted, live actively growing bacteria. The following is a short list of the pathogenic microorganisms in feces.
>
> "There are the small animals, parasitic worms, their eggs and larvae, and protozoans. These include various types of tapeworms, hookworms, agents of amoebic dysentery and tissue attacking amoebae.
>
> "There are the viruses of polio, hepatitis and the various viral enteritis such as winter vomiting disease.

"Of the bacteria, there is infrequently the vibrio of Asiatic cholera, and always the golden staphylococcus of boils, pus-like infections and septicemia. These two organisms thrive in warm, salty environments. Klebsiella causes a frothy pneumonia which is 90% fatal if untreated. Proteus causes kidney, bladder and urinary tract infections which are notoriously resistant to antibiotic therapy. Pseudomonas causes the same types of infections plus a mastoiditis in which a colorful blue-green pus is produced. The genus Salmonella which cause typhoid fever; Shigella, his cousin, which causes epidemics of bacterial dysentery.

"Clostridium botulinus is the cause of the most deadly type of food poisoning, botulism. Its toxin, botulin, is the most deadly poison known to man. Its lethal dose is measured not in milligrams or micrograms but in molecules. Appriximately 8 molecules per nerve cell in five percent of the nerve cells, or 20,000 molecules will kill a mouse.

"Last, but certainly not least, are the wound infection organisms: Clostridium tetani, the cause of tetanus or lockjaw; Clostridium perfringens, the cause of gas gangrene, and various streptococci which cause general blood poisoning.

"So virulent are these last three types of bacteria that they have been and are being employed in one of the most effective campaigns of biological warfare yet conceived. The Viet Cong smeared the points of thin sharpened bamboo stakes or nails with their own fresh feces, then placed these 'punji sticks,' as they are called, on the ground with the poisoned point up along trails as a booby trap. A man who steps on one receives an inoculum of fecal bacteria in a clean deep stab wound which quickly closes, trapping organisms in the tissue. Any man who receives such a wound will almost certainly develop tetanus, gangrene, or blood poisoning, or all three unless he quickly receives massive preventive antibiotic therapy; and that soldier is effectively neutralized. The U.S. Army was forced to develop a new, puncture proof combat boot to offset this very simple, very effective biological weapon.

"Please keep in mind that the active ingredient in the punji stick is not something exotic developed in a billion dollar biological warfare laboratory. It is something very simple, very common, very close to home. In many areas of Florida a person can be vividly and nostalgically reminded of the punji stick by cutting his foot on a dead oyster shell. The microbial slime on that razor sharp oyster shell did not come from a Viet Cong. It came from the friendly inadequate neighborhood sewage treatment plant down the canal, or from his neighbor's houseboat, and possibly from the man's own body. You can have the same experience at many public beaches, lakes and rivers in Florida.

"Besides their pathogenicity to man, the other pollution problems traceable to fecal bacteria are caused by their unmatched ability to grow and reproduce. During my doctoral research I once grew the gas gangrene organism under favorable conditions which allowed it to double in numbers every eight minutes.

"Using as nutrients the 67% by weight of undigested food with which we thoughtfully provide them as they leave us, the bacteria in sewage continue to increase in numbers.

"Like men, fish and all other animals and plants, most of the bacteria require dissolved oxygen from water for their growth However, because of their tiny size and simpler constitution, bacteria can use up oxygen at a fantastically fast rate . . . much faster than fish and other animals and much faster than a photosynthetic green plant can produce it. A few ounces of bacteria can use up within minutes the oxygen required to keep a hundred pound tarpon alive for an hour.

"When bacteria reach certain critical concentrations, they not only suffocate the fish and other animals, they use up all the oxygen the plants can produce faster than the plant can use its share. By killing not only the organisms which use the oxygen, but also the organisms which normally supply it, the bacteria extinguish the possibility of its normal replenishment. The carcasses of the dead plants and animals serve the bacteria as additional nutrients, they increase further, growing anaerobically when the oxygen is entirely gone, and at this point whatever original, natural ecosystem kept the water clean and healthy is gone almost beyond recall."
(Emphasis added)

Only small amounts of raw or inadequately treated sewage in Florida's warm waters are necessary for these deadly organisms to grow and multiply with frightening rapidity.

Dr. Betz states, "If the present worldwide endemic of cholera ever jumps the Atlantic, as some public health officials are warning that it may, the warm, salty, sewage-polluted estuaries of Florida will be ready-made environment for such cholera organisms."

Other Pollutants

In addition to human waste, domestic sewage receives massive amounts of organic solids from food processing industries such as sea food plants, citrus plants, slaughter houses, poultry processing, produce packaging, and grocery processing of all kinds. All of these flush their waste products down the drain, often producing a biochemical oxygen demand (BOD) from bacterial action 100 times more concentrated than domestic sewage. These effluents do not contain the concentration of lethal bacteria in human excrement, but when mixed in with the sewage, they provide a fantastic amount of food upon which the bacteria can feed and multiply.

Chemicals, Drugs and Toxic Metals

The mass of virulent bacteria is only a part of the lethal mixture of sewage. A cursory examination of any household will disclose a plethora of dangerous chemicals and drugs which are routinely disposed of by flushing down drains. Among these are powerful bathroom bowl cleaners, caustic sodas and acids used for unplugging stopped up drains; detergents, soaps, concentrated bleaches, floor cleaners, deodorants, sleeping pills, pesticides, medicines, and drugs of all types and prescriptions. All of these go into the sewage along with garbage, dishwater, and chemicals for treating, coloring and bleaching hair.

Domestic sewage is a prime source of toxic metals. A report published in the magazine "Environment" states that upwards of 40% to 50% of the mercury in the environment may be from sewage and a large proportion of this from home and medical use. Drugs, anti-bacterials, dental amalgams used to fill teeth, and broken thermometers are the main sources of home and medical mercury.

Mercury poisoning from contaminated fish caused an epidemic in several Japanese towns, resulting in deaths, crippling, mental disorders and birth defects among the population. Mercury contamination has all but eliminated swordfish from U.S. markets and has drastically affected the tuna industry.

A number of rivers and lakes in the U.S. have been closed to fishing due to mercury contamination. Other toxic metals such as cadmium, arsenic, zinc and lead are also causing serious water poisoning problems in Japan and Sweden, and these are flushed down Florida's drains along with the mercury and other pollutants.

Joining the chemicals, drugs, medicines, toxic metals and deadly bacteria that pour from our homes are the toxic substances from business establishments, such as service stations, garages, laundromats, car washes, newspapers, tire recapping, metal plating, printing companies and similar activities.

The average Floridian utilizes around 100 to 200 gallons of water a day, and discharges about 100 gallons a day of waste water in the form of sewage. Multiplied by a permanent population of over seven million visitors on any one day, this equals around 1.4 billion gallons of domestic sewage which must be disposed of every day. What we do with it, and how we treat it, may well determine the course of Florida's future.

Four years after the law requiring minimum treatment was passed, half of Florida's population is still on septic tanks and hundreds of private and publicly owned sewage facilities are still dumping raw or partially treated effluent into our waters.

Health Warnings

Palm Beach Post-Times, Sept. 13, 1970, quoted state health officials that sewage pollution has caused "about 80 percent of the shellfish in Florida to be declared unfit for human consumption."

Palm Beach Post-Times, Sept. 15, 1970, "In 1969 Florida had 1,149 cases of infectious hepatitis which required hospitalization. Health officials suspect that sewage in drinking water causes much of it."

Palm Beach Post-Times, Sept. 15, 1970. Forty-two North Florida youngsters became ill with dysentery bacillus due to septic tanks overflowing during heavy rains. A resident stated, "Raw sewage floats down the streets on rainy days and most of my neighbors can't even use their bathrooms." Palm Beach County Sanitarian, Carrol Shelor, says, "Sewage washes in the streets and garbage is piled up everywhere. Eventually the area will become a major health threat to Riviera Beach and West Palm Beach.

Palm Beach Post-Times, 1971. Fish caught in the Intracoastal Waterway near Boynton Beach contained pathogenic bacteria and viruses known to cause meningitis and hepatitis.

Miami Herald, Sept. 20, 1972. "Miami River Most Toxic in the United States. PCB's, a group of industrial compounds chemically similar to DDT, have been found in Florida waters at more than 200 times recommended levels, the U.S. Geological Survey reported Tuesday . . . . PCB contamination was also detected in dozens of other locations throughout South Florida."

Sun Sentinel, Dec. 9, 1971. "Hepatitis a Threat in Intracoastal Water . . . . Broward and Palm Beach County biologists and physicians are expressing alarm that children continue to frolic in the fecal matter infested water."

Tampa Tribune, Nov. 10, 1971. "Pollution Traced to Human Waste . . . . Not only is it dangerous to swim in thousands of acres of canal waters from Weeki Watchee to Punta Gorda, it could be deadly to walk on bottomlands. Gangrene causing microbes are flourishing in the muck and silt while fecal coliforms swim above."

Fish and Bird Kills

Miami Herald, Jan. 23, 1972. "Bacteria-Laden Outfalls to Blame for Bird Deaths." (Hundreds of seabirds; loons, herons, egrets, sandpipers, and others were dying along the Florida Atlantic coast from Jacksonville to Miami. The cause was blamed on an anaerobic intertoxin or "food poisoning" by Game and Fresh Water Fish Commission Chairman, C. A. Peacock.)

Orlando Sentinel, April 20, 1972. "Massive Duck Kill at Sky Lake to be Probed Today." (Bird kills have been reported from time to time at Lake Apopka, Lake Okeechobee and on other Florida lakes and canals. Game and Fresh Water Fish officials suspect botulism as the cause in most cases. Remember Dr. Betz stated that Clostridium botulinus is present in human feces and that its toxin, botulin, is the most deadly poison known to man.)

Palm Beach Post-Times, Aug. 13, 1972. Ducks are blamed for the pollution of Lake Eola in Orlando.

Tampa Tribune, Aug. 29, 1971. "Deadly Amoeba Thrives in Hillsborough and Pasco Lakes." In recent years five persons have died in agony from a newly recognized disease, amoebic meningoencephalitis, contracted from swimming in Central Florida lakes. The causative organism, Naegleria gruberi, has long been known to be present in almost all waters, but was not thought to produce disease. Many authorities feel that some unknown factor in polluted water causes virulent strains to develop suddenly, and strike, typically, young swimmers. It gets into the nose and eats its way up the nerves of smell, into and through the brain.

Pollution from sewage and industrial wastes cause massive fish kills in Florida's lakes, canals, rivers and estuaries almost every summer. Escambia Bay is world famous for its massive annual fish and oyster kills. The latest Pensacola kill, in September, 1972, was in Perdido Bay and attributed to a streptococcus bacterium. Also in September a massive, pollution-caused fish kill on Florida's lower Gulf Coast caused officials to order the City of Punta Gorda to stop all sewage dumping in the Peace River and closed a number of beaches in the Tampa Bay area to bathing.

South Florida cities along the Gold Coast dump 116 million gallons of virtually raw sewage into the ocean every day. The beaches in areas such as Miami Beach are often so contaminated they are unsafe for body contact (but are rarely, if ever, posted). Ocean game fish populations have been drastically reduced and a number of party boat skippers claim they must now travel 50 miles from Miami to find good fishing. Sailfish catches have dropped from an average of 4,000 fish before 1948 to a scant 900 fish since 1962. Even more alarming, sick fish with cancers, tumors, lesions, and fin and tail rot are showing up in Biscayne Bay. Sick fish have also been observed in the Florida Keys, Escambia Bay and Tampa Bay, and they are no doubt present in other grossly polluted waters.

Drinking Water Contamination

Some of the main flood control canals in South Florida have pure sewage excrement piled up within a few inches of the surface near sewer outfalls, and boats must be careful in these areas to avoid running aground on fecal matter and sludge. These canals are a prime source of fresh water for South Florida. They are directly connected to the Biscayne Aquifer and, during droughts, are used to recharge the aquifer by releasing water from Lake Okeechobee into the canals.

Who's In Charge?

Determination of whether or not water is fit to drink is under the supervision of the State Department of Health, not the Department of Pollution Control. Water from public utilities wells is tested once each month, for bacteria only, not metals, pesticides or other dissolved contaminents.

With thousands of drainage wells pouring tons of liquid garbage into our aquifer, it would be surprising if disease-causing bacteria are not also thriving on this bountiful source of nutrients. Chapter 403 of Florida Statutes gives responsibility for ground water quality to the Department of Pollution Control.

Septic Tanks

When properly installed under the right conditions, septic tanks provide an adequate method of sewage treatment. Bacteria in the tank digest the organic material and the effluent in drainage fields is recycled. In effect, the action of filtration, soil bacteria, and the utilization of nutrients as fertilizer by surface vegetation provide tertiary treatment. However, in many areas Florida's soil is so porous and the water table so shallow that effluents are not recycled before leeching into the aquifer or adjoining waterways.

Responsibility for septic tanks was recently transferred from the Department of Health to Pollution Control, along with some Health Department employees. Unfortunately, DPC has in turn handed jurisdiction over septic tanks down to counties, where more leniency can be expected than if still under a state department.

Primary and Secondary Treatment

These are the conventional methods used by the hodgepodge of small plants and individual "package plants" in attempts to comply with the January 1, 1973 deadline. The moratorium on new sewer hookups in some cases permits developers to proceed on a temporary basis through the use of "package" plants.

Biochemical oxygen demand (BOD) is a property of sewage which measures the amount of oxygen required to oxidize the organic material (phosphorus, nitrogen solids and microorganisms) contained in the sewage. Primary treatment consists of screening, grinding and settling which removes roughly 50% BOD and 50% of the microorganisms. Dr. Betz says that so much organic matter is left in primary effluent that chlorine is wasted because it reacts more with the residual organic matter than with the bacteria, and the nutrient supply permits the unaffected bacteria to grow and multiply after the material is released.

Secondary treatment can remove up to 90% of the BOD and up to 99% of the bacteria in sewage by encouraging the bacteria in sewage to digest the organic matter. The raw sewage is first given primary treatment. This effluent is then exposed to bacterial action in either a trickling filter or by activated sludge. Solids are usually further removed in settling basins or lagoons, then the effluent is treated with chlorine to kill remaining bacteria and discharged to receiving waters.

This is the minimum treatment required to meet requirements of Florida law.

Disposal

Sewage must not only be collected and treated, the effluent and sludge must be disposed of safely and the methods proposed for disposing of secondary treated effluent are the source of some of Florida's most violent conflicts and confrontations. Most of the present and planned sewage systems for coastal cities are designed to utilize ocean outfalls. Inland cities which utilize rivers or canals will also indirectly utilize the ocean through river discharge into estuaries.

The strongest argument for outfalls is that the tremendous volumes of ocean water offer almost unlimited dilution.

Deep Well Injection

Deep well injection as a sewage disposal method is an unknown risk. An initial experiment with two half-mile deep injection wells leaked sea water into Miami well fields and endangered the water supply for nearly a million persons.

Infalls

Infalls, the disposal of effluent from secondary treatment plants by pumping it into inland swamps and marshes, such as the Everglades, present frightening possibilities. These are the prime recharge areas for underground water supplies and ecologists shudder at the possible effects from a continuous, long-term inundation with effluent loaded with nitrates, phosphates, pesticides, toxic metals and other exotic contaminants. The contention that swamp and marsh vegetation could remove this quantity of synthetic pollutants from the effluent does not withstand close scientific examination. A Central and Southern Florida Flood Control District official has reported an accumulation rate of about 1 inch per year.

Land Spreading

A method of advanced treatment which has received a great deal of publicity and is being actively promoted by a number of Florida groups and agencies is land spreading, or spray irrigation. Proponents contend that the nutrients remaining in the effluent from secondary treated sewage are nitrogen, phosphorus and potash which are essentially the same as those contained in commercial fertilizer. The hypothesis is that irrigating the land with this effluent is no different from using liquid fertilizer and that crops, natural vegetation and soil bacteria will utilize the nutrients and purify the water. The blessings claimed for this method are: (1) inexpensive, (2) safe disposal of effluent, (3) a cheap source of fertilizer for crops, farms, pastureland and forests, and (4) recycling and conserving freshwater by returning it to underground and surface supplies.

What Price Clean Water?

A comparison of the costs of conventional treatment vs. water purification treatment in two sewerage systems, one in Lake Tahoe, California, which is now in operation, and one in Tampa, Florida, for which engineering and cost studies are well advanced, show that the cost for the tertiary phase of sewage treatment is about equal to the cost of the primary and secondary phases of sewage treatment. Extensive cost analyses at the Lake Tahoe plant showed a complete cost of 17¢ per 1,000 gallons for primary and secondary treatment, and a further cost of 21¢ per 1,000 gallons for the tertiary phase of treatment. The entire treatment process thus costs about 38¢ per 1,000 gallons. This small amount of money buys water that meets all U.S. Public Health Service requirements for drinkwater and is actually purer than some of the water consumed in Florida today. The effluent is pumped to Indian Creek Reservoir which has been certified as safe for body contact sports by both state and federal agencies, a population of rainbow trout thrive in the water, and the "sewage created lake" has received a grant as a recreation area. Water from the reservoir is used for irrigation downstream. In addition to pure water, this plant also reclaims and reuses or sells lime, carbon, and other products from the sewage sludge. Only a sterile ash is left for disposal. Nitrogen nutrients in the sewage, which many scientists claim is a greater hazard to human health than mercury or pesticides, is removed by a process called ammonia stripping.

The Tampa system is designed for a capacity of 50 million gallons per day and the total comparative costs are:

Secondary treatment--$114 million for complete system
Advanced treatment --$130 million for complete system

This will make a difference of only $16 million capital cost for clean water, which amounts to a minimum monthly household bill of $6.15 for conventional treatment compared with $8.38 for advanced treatment, a difference of only $2.23 per month. These monthly costs anticipate a federal grant for both systems. Without the grant for conventional treatment, the monthly charge would be exactly the same as for advanced treatment with the grant. The total cost of advanced waste treatment need not be more than $3 to $4 per family per month.

Nitrogen is removed from sewage in the Tampa plant by denitrification, a process more expensive and less reliable than the Lake Tahoe design, but which produces an end product of gaseous nitrogen which makes up 80% of our atmosphere, and is completely safe.

The cost of advanced treatment if designed competently, might be even less than the average homeowner is already paying for piece-meal treatment if the special reduced rates for large volume for industries is eliminated. Some Tampa taxpayers may receive a slight reduction, or no increases, in rates when advanced treatment is available, if all users are charged the same rate per gallon and preferential rates for large volume contributors are discontinued.

ECONOMIC IMPACT OF EVERGLADES MUCK FARMS

ENFO NEWSLETTER, 8/71
Environmental Information Center

The 700,000 acres of muck soils south of Lake Okeechobee are some of the richest agricultural areas in the world, producing the nation's largest share of winter vegetables. Present production brings an annual income of approximately $250 million, and represents a capital investment approaching $700 million. This tremendous capital investment and income will be dissipated as the soils subside.

Five thousand years were required for naturally building the deep peat and muck deposits of the Everglades. In only 60 years man has destroyed two-thirds of this soil and, by the year 2,000, just thirty years away, all of it will be gone. Studies of the area show that the soil is dissipating at the rate of one inch per year, primarily due to biochemical oxidation. Unless this rate of subsidence is checked, large scale farming in the area will be abandoned by the turn of the century, according to authorities.

Drainage History

Ironically, the destruction of peat and muck soils is caused by the same drainage system that made Everglades farming possible. Al-o, history discloses that the original purpose of the present extensive flood control system was to convert the Everglades to agriculture. As of 1948, 40 years of continuous state supported efforts to drain the Everglades for agriculture were unsuccessful. The cost of the canals was greater than undeveloped land warranted. Funds were exhausted and canal construction was discontinued.

In 1948, Congress authorized the Central and Southern Florida Flood Control Project and in 1949 the state created the Central and Southern Florida Flood Control District. Since then the major drainage and water management control program has been under the U.S. Army Corps of Engineers and the CSFFCD. The result has been a massive artificial manipulation of South Florida's water supply that is a design for disaster threatening the health and welfare of all living things in the area.

The destruction of Everglades peat and muck soils has played an important role in the environmental problems of south Florida.

Muck Soil Effect On Water Quantity

Widespread drainage has caused the destruction of most of the peat soils which once covered large areas of South Florida. Soil reduction is inevitable when organic soils are drained. When exposed to the air the organic matter is subject to shrinkage, compaction, wind erosion, loss of ground water buoyancy, burning and biochemical oxidation. The loss is rapid at first, then slows to a steady rate, primarily due to oxidation. Unused land that is drained dissipates as rapidly as land that is under cultivation. The rate of loss is more dependent upon groundwater levels than any other factor. The higher the water table, the slower the rate of soil depletion.

One of the most serious results from the loss of these organic soils is the effect upon salt water intrusion into the underground water supply. The Biscayne Aquifer is the only source of fresh water for Dade and Broward Counties and salt water intrusion into this critical water supply has been the chief threat to water resources of the Southeast coast of Florida since drainage of the Everglades was started. The early history of Miami's water supply has been that of moving well fields westward as they became contaminated by saltwater intrusion. The greatest penetration of sea water is along the flood control canals, and only the installation of adjustable barriers has obstructed this intrusion.

The loss of peat soil has lowered the surface elevation of the land and reduced the head of freshwater required to depress the saltwater. At one time peat soils covered more than two million acres of the Everglades at depths averaging five feet higher than present ground levels. In portions of Everglades National Park and along the coastal ridges, the peat has disappeared completely, leaving only bare rock and marl. The peat formerly acted as a sponge to absorb rainfall and store it above present ground levels. One inch of rainfall will normally raise surface waters only one inch above ground surface, but, one inch of rainfall will raise underground water levels about 7 inches, a ratio of 7 to 1 of increased pressure head. Thus, the sponge-like qualities of the peat soils, combined with this 7 to 1 ratio of water table rise to rainfall, exerted a powerful leverage in maintaining hydrostatic heads of freshwater to combat seawater encroachment. The fact that these former hydrologic conditions have been destroyed and can never again be restored has been overlooked by many engineers and most laymen.

Indiscriminate drainage has reduced the quantity of fresh water available and created a serious water shortage in all of South Florida. During the wet season an overabundance of water in the area brings flood control canals into play. Water from the 4,700 sq. mi. Kissimmee River Basin is flushed quickly through the Kissimmee Canal into Lake Okeechobee. Also, excess water flooding the 700,000 acres of muck farms is either pumped directly into Lake Okeechobee, or into Project Canals which drain in both directions, into Lake Okeechobee from the northern sector and into Conservation Areas from the southern sector. When Lake Okeechobee reaches a predetermined height, flood gates are opened and tremendous quantities of fresh water is wasted by flushing it directly to the sea.

During extended dry periods, the water shortage becomes critical and saltwater again threatens the coastal city well fields. During the recent drought the FCD released water from Lake Okeechobee to the Biscayne Aquifer via the canals, but, as the lake level dropped, the ability to supply water was reduced and supplies became critical.

In the dry season the muck farms depend upon Lake Okeechobee water for irrigation. Estimates place the need as an equivalent to one foot of depth over the area per year. As population expands and the demand for water increases, the competition for Lake Okeechobee water between the coastal cities, Everglades National Park and the agriculture area will become extremely critical. The Corps of Engineers and most scientists predict a serious water shortage in South Florida by 1976.

Project plans to solve this problem call for raising the level of Lake Okeechobee, impounding flood waters, and backpumping. However, the rate of evapotranspiration is so great that many experts question if this will be sufficient. Also, ecologists are concerned that the nutrients and contaminents in backpumped sewage and canal water will have a disastrous effect upon the South Florida ecosystems with possible contamination of the Biscayne Aquifer.

Muck Farm Effect Upon Water Quality

Water pumped from the muck farms either goes directly into Lake Okeechobee or into Project Canals, the northern half of which drain into the lake. In addition to flood and rainwater, the majority of the farmers in the area utilize a system of alternate flooding and drying as a method of pest and weed control. Certain insects are allowed to mature, then are drowned by flooding. Others are brought out of the dormant stage by flooding, matured by drying, then flooded to drown. Most of the farms are deliberately flooded for a period of about eight weeks out of the year.

Everglades organic soils require heavy fertilization and insecticide and herbicide control. Herbicides are used to control weeds in ditches, canals and on ditchbanks. Superphosphate is recommended by the Department of Agriculture as an additive to muck and insecticides are recommended throughout the growing season. Parathion and DDT are recommended on sweet corn even before the ground is planted.

Normal runoff water from muck farms is loaded with nutrients, but some experts claim that these soils have an affinity for fertilizers and pesticides which reduces leaching of these contaminents through bottom sediments to a minimum. If this is true, the possibility exists that the tremendous accumulation of pesticides and fertilizers applied and retained by muck soils over a period of many years may be released at an accelerated rate as the soils are depleted. If these contaminents have not reached equilibrium in the soils as they are applied, a tremendous concentration retained in bottom formations could be released in a short period of time.

Test reports show that pesticides are building up in bottom sediments of the Conservation Areas into which the muck farm water is drained. But of greatest concern is the effect of muck farm drainage on Lake Okeechobee, which is the key to water regulation in all of South Florida. Continued pollution of Lake Okeechobee could cause a major disaster.

A report by B. F. Joyner, Chief, Water Resources Division Lab., U.S.G.S., Ocala, states, "Fish kills have been reported in the Miami Canal and North New River Canal during reverse flows. . . . The fish kills were probably caused by depletion of oxygen by heavy oxygen consuming organic material that is pumped in from the agricultural area. The water pumped into Lake Okeechobee from the agricultural areas is probably the poorest quality entering the lake." (Emphasis added)

A report by Phillip Greeson, Water Resources Division, U.S.G.S., Albany, N. Y., states that the average concentration of Phytoplankton in Lake Okeechobee on July 16, 1970, was much higher than the previous year. Greeson also states, "An equally alarming situation in the lake is the change of dominant organisms."

Aphanizomenon holsaticum, the most notorious alga for causing lake eutrophication, was the most numerous alga at most collecting stations.

Greeson finally states, "The increased concentration of phytoplankton to bloom levels and the change in dominant organisms indicate a rapid acceleration of eutrophication in Lake Okeechobee. The lake, as shown by the characteristics of its phytoplankton, can now be doubtlessly classified as a eutrophic lake. (Emphasis added)

Lothian Ager, Florida Game and Fresh Water Fish Commission, Project Leader on the Lake Okeechobee-Kissimmee River Project, reports that the increased erosion of substrate from the agricultural area into canals is probably the most important factor in water quality in respect to the lake. Because of high oxygen demand of organic material, the water is characteristically low in dissolved oxygen. Periodically, heavy rains after a two or three week dry period create immense fish kills on the south end of the lake, as water is pumped into the lake.

A water quality study, conducted by the U.S.G.S. in cooperation with the CSFFCD, showed that bottom sediment samples of Lake Okeechobee contained appreciable concentrations of pesticides in the DDT series. These persistent pesticides enter the food chain by microinvertebrates that injest water and organic material in bottom sediments. The microinvertebrates become food for macroinvertebrates which in turn become food for fishes. These insecticides generally increase ten-fold through each step in the food web. In South Florida, the biological magnification of DDT and related compounds is greatest at the "top" end of the food web in organisms such as raptorial birds and in man.

Sample tests by the Game Commission show that all Lake Okeechobee fish contained some pesticides, and that in some the DDT concentrations were as high as 57 parts per million. The Department of Agriculture specifies 5 ppm as the maximum safe level for human consumption. It is important to note that it was very difficult to determine pesticide counts in fish in the agriculture canals because so few fish were present.

The long term deterioration of Lake Okeechobee water is shown by the fact that in 1948 the lake water was of excellent quality and used regularly for both domestic and irrigation purposes. In 1971, the City and County of Okeechobee were studying the feasibility of importing water from Lake Placid, 35 miles north, for domestic use because Okeechobee water is so poor at certain times of the year it is difficult to treat.

Recycling -- A Possible Solution

Nowhere in the extensive literature dealing with organic soil subsidence is there a reference to experiments with methods of control. In view of the tremendous economic value of the area, a program of recycling organic waste material into a compost to counteract subsidence of muck soils makes a lot of sense, both economically and environmentally. A few of the possibilities well worth considering in such a program are:

1. Aquatic Weeds - Explosive growths of aquatic weeds in Florida's waterways present serious problems to navigation, flood control and drainage. The weeds also are a threat to boating, fishing, swimming and other water sports recreation. Present met 's of aquatic weed control primarily utilize herbicides which celerate eutrophication and degradation of water quality.

An explosive growth of aquatic weeds is usually preceded by overenrichment of the water with nutrients. Chemicals, or other methods of control which do not remove the nutrients from the water, invite reinfestation or replacement of the weeds by other organisms which may be even more damaging to the water environment.

Mechanical harvesting of aquatic weeds, as a crop, would tend to remove nutrients from the water in the same manner that land vegetation removes nutrients from the soil. Machines have been developed to harvest the weeds, but their use costs more than can be justified exclusively for control, and disposal has presented a problem.

If aquatic weeds were harvested to produce a compost for use in counteracting the subsidence of muck soils, both the economic and the disposal problem might be reduced. A disadvantage is that aquatic weeds are 93% water and if used alone, are unlikely to provide enough bulk to counteract muck soil depletion. But, if used in conjunction with other materials, the benefits to agriculture alone would justify the expense.

2. Organic Solid Wastes - Thousands of tons of organic wastes, such as paper, garbage, vegetation, and other trash, present a disposal problem which is accelerated by increasing population and industrial growth. The same is true of other organic wastes such as sewage sludge from treatment plants and sediments from dredging lake, river and canal bottoms. Methods of disposal, other than burning, landfill and ocean dumping must be found.

All of these materials can be recycled and used in conjunction with aquatic weeds to form a soil building compost which may be effective in counteracting the subsidence of muck soils.

3. Economic Justification - If such a program only cut the rate of subsidence by half, the life of agricultural production would be extended 15 years. At an annual crop value of $250 million per year, this would be a saving of $3,750,000,000. If soil loss could be reversed, the capital investment of $700 million would be saved and the income would continue indefinitely.

At the same time, such a recycling program could provide tremendous economic benefits by cleaning up Florida's water and air. A considerable portion of our $5-1/2 billion tourist industry is dependent upon sports fishing and water sports recreation which is now in jeopardy because of weed choked and polluted waters. Cleaner waters from recycling aquatic weeds and organic wastes would also enhance waterfront real estate values and improve commercial fishing.

A potential danger from applying recycled compost to muck farms is the possibility of contaminating water supplies from runoff and drainage waters. A possible solution to this, and to pollution from backpumped sewage water, lies in the utilization of state-owned muck lands.

State Owned Muck Lands as a Settling Basin

The state of Florida owns approximately 82,500 acres of muck lands in the agricultural area south of Lake Okeechobee. Most of these are scattered throughout the area and many are leased to private agricultural interests. Both the used and unused land is dissipating due to subsidence. The scattered nature of the parcels make management in the best public interest virtually impossible.

An alternate to present leasing practices would be to consolidate state holdings into a single, large tract by an exchange of property with private owners. The deepest and most valuable mucksoils are near Lake Okeechobee where warm weather protects crops from freezing. This soil and colder weather make land near the conservation areas less desirable for agriculture. Private owners should be eager to trade less attractive land near conservation areas for state owned lands near the lake. A large tract of state land near the conservation areas could be utilized in several beneficial ways.

Due to the underlying impermeable rock, such an area would be ideal for use as a buffer zone and settling basin for muck farm water and backpumped water from coastal areas. The impermeable substrate prevents water in the agricultural area from exerting any appreciable effect upon recharging the aquifer. Thus, flooding the area would have little bearing upon south coast water supplies because the vegetation tends to fix and hold contaminents in organic bottom sediments.

A portion of such state consolidated land could be used for recycled organic wastes in an attempt to retard or reverse subsidence. Another section could be farmed, and the remainder used as a buffer zone for backpumped water. After one or more years, the various uses could be rotated if such a procedure proved desirable.

At any rate, it is strongly recommended that game management and/or recreation areas be enlarged and consolidated north of conservation areas which can be used to filter waters before they enter the conservation areas.

It is also strongly recommended that the U.S. Army Corps of Engineers Water Resources Development Project for Central and Southern Florida be required to eliminate the flow of untreated muck farm drainage water into Lake Okeechobee. As presently designed, project improvements do not present a solution to this problem. All muck farm drainage should be directed into a settling basin of consolidated, state-owned agricultural lands.

EUTROPHICATION, A NATURAL PROCESS COMPOUNDED BY MAN

By Jan Browning
Environmental Engineer

A eutrophic lake is not a dead lake. In fact, a eutrophic lake is more alive than those lakes which are considered to be in good condition. If this is indeed true, then why is eutrophication of lakes looked upon as a state of degeneration? Why is so much attention, time and money being spent to evaluate the condition of our water bodies, and to slow down or reverse the process of eutrophication?

A simple definition of eutrophication is "the process of enrichment with nutrients." Although this is a very neat description, the process itself is one of great complexity as illustrated by Figure 8. This figure shows the various interrelationships of the more common factors which can affect the eutrophication of a lake or other water body

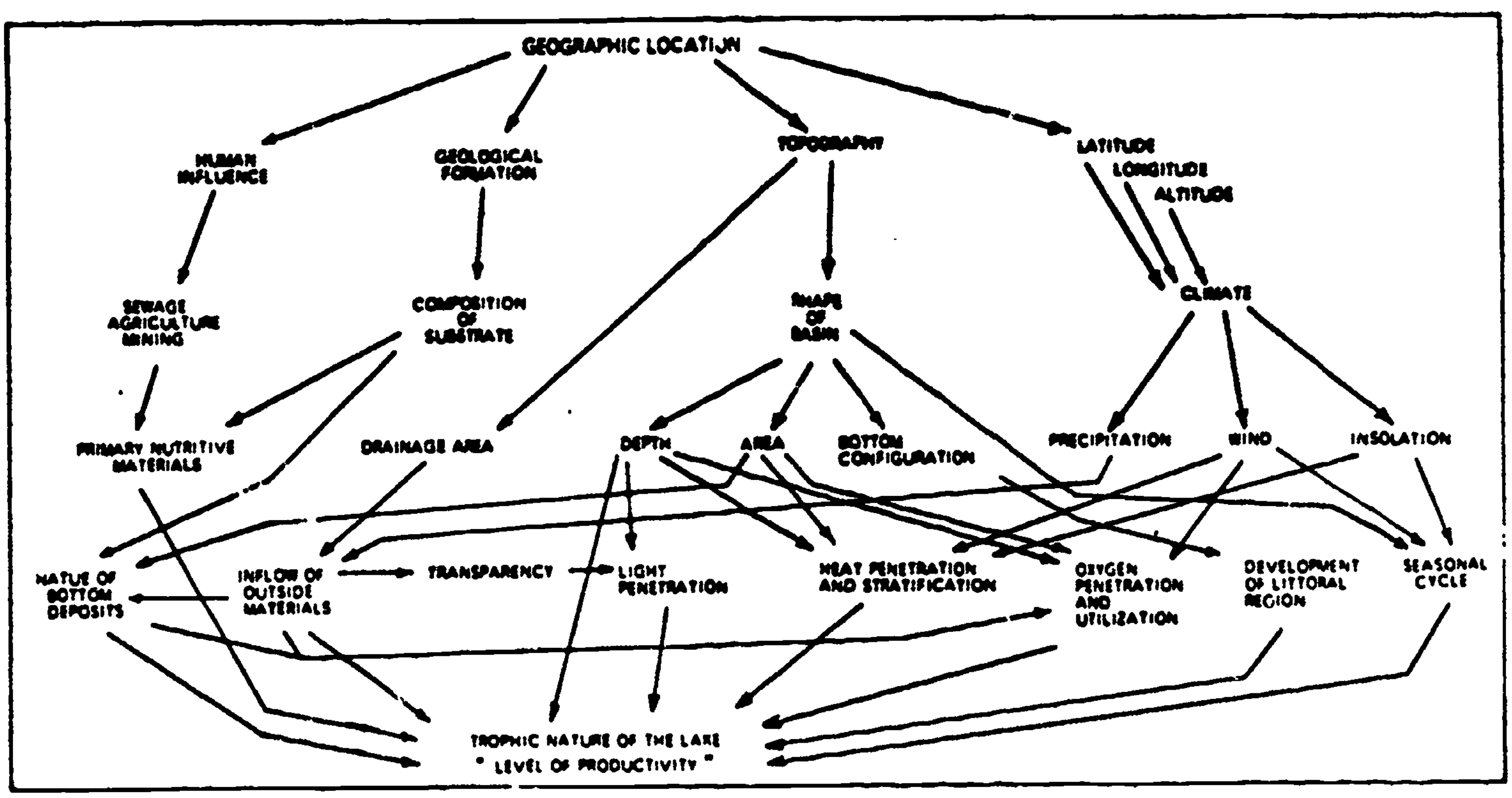


Figure 8. Complexity of interrelationships of selected factors affecting the eutrophication of lakes
(Courtesy of Water Resources Assoc. Bulletin)

The process of eutrophication is a natural one. From the moment of its inception, a new lake begins to age and to drift closer to becoming a eutrophic lake. Eutrophication is the natural process of aging as a lake progresses (ecological succession) from one life cycle to another, based on the rate of change in nutrient levels and biological productivity.

There are several stages in the natural life cycle of a lake. The youngest period has been characterized by low concentrations of nutrients for plants and little biological productivity. Lakes in this phase of their life cycle are referred to as oligotrophic, (from the Greek oligo meaning "few" and trophein meaning "to nourish"; thus oligotrophic means few nutrients). During the aging of a lake it becomes mesotrophic, (meso = intermediate) and further ages to a eutrophic condition (eu = well). The final stage of life before total loss of identity as a water body finds the lake becoming a pond, marsh or swamp.

Enrichment of the lake increases as the lake gets older. As a rule, a lake will capture a portion of the nutrients which comes into it, and will gradually increase the total amount of nutrients present. These nutrient materials may come from the surrounding drainage basin, rainfall or even groundwater inflow. This process of enrichment, together with deposition of sediments, is the main cause of the aging of lakes.

The Sudden Shift

THE CRITICAL POINT IN EUTROPHICATION

The vegetation of the lake system utilizes a portion of the nutrients in the water, decays and becomes a portion of the sediment deposit on the bottom of the lake. Other forms of life, such as fish and algae, also contribute to this process. Overextended periods of time, dependent upon the rate of nutrient inflow, the sediments increase on the bottom of the lake. The lake becomes more and more shallow, and smaller due to the invasion of shoreline vegetation. Then the lake becomes a pond, a marsh, and finally dry ground. The extinction of a lake, then, is a process of enrichment, productivity, decay and sedimentation.

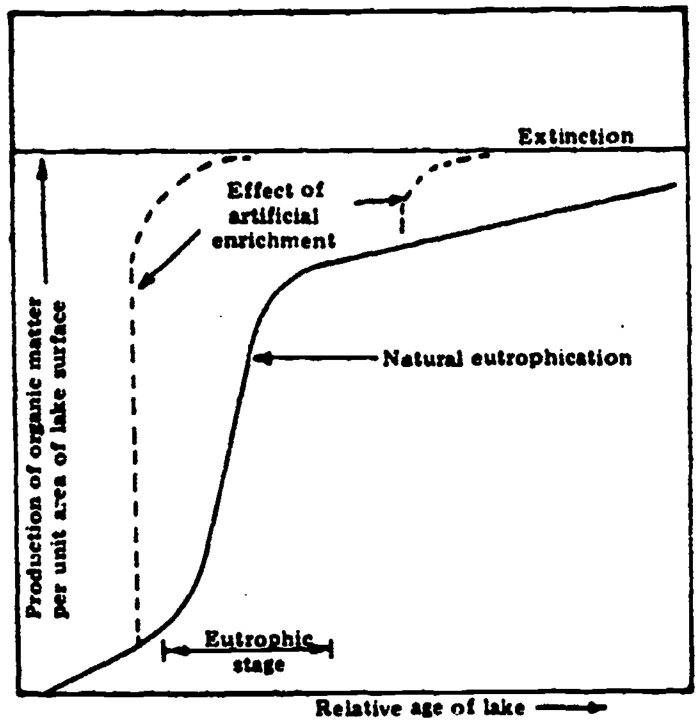


Figure 9. Hypothetical curve of eutrophication

An examination of Figure 9 will point out the relationship between biological productivity (for the production of organic matter) and the relative age of a lake. There are two features of the curve which are of major importance. First, it should be noted that during the initial aging phase of a lake there is a gradual increase of productivity. However, when the lake has gone through the oligotrophic and mesotrophic stages and enters the eutrophic phase, the rate of biological productivity shifts dramatically upward and gets much larger in a short period of time.

Secondly, the lake's almost immediate shift (on a lake lifetime basis) toward extinction due to artificial enrichment should be noted. What this means is that a lake may seem to be doing well and may not be changing very much, but if its age puts it close to the upturn point on the curve only a very small increase in enrichment can cause a sudden and significant shift in the trophic state of the lake.

Effects of Stratification

NUTRIENTS ARE RECYCLED IN SOME LAKES

Another important influence on the aging of lakes is the occurrence of stratification of the waters within the lake. When a lake stratifies, it separates into two or more layers which remain unmixed until some event forces a change. Heat differences between the water and air cause the thermal stratification of a lake.

Starting with a lake in which the water is the same temperature throughout, we can describe the establishment of thermal stratification. The wind blowing across the surface of a lake mixes or circulates the water to a depth which is primarily dependent upon the average wind velocity.

In the spring of the year, the air over the water becomes warmer than the water. The portion of the lake which is circulated by the wind is exposed to the air and becomes warmer. In this manner a zone or layer of warmer water is formed on top of the cooler uncirculated water. The warmer water is less dense than the cooler, weighs less for equal volumes and thus floats on top of the cooler water. The result is the creation of a zone of stagnant water on the bottom of the lake. The depth of this stagnant zone varies in each lake.

What happens next is that plants and animals which die in the lake, along with introduced organic material, settle to the bottom of the lake to decompose. The organisms which decompose this organic material breathe oxygen and take it from the water. However, this water is stagnant and therefore cannot get to the surface of the lake and to an exposure to air for a new supply of oxygen. The stagnant layer becomes devoid of oxygen. In the absence of oxygen, chemical conditions become favorable for the release of nutrients from the bottom sediments into the surrounding water.

When fall comes the air temperature falls and the top circulating layer of water begins to cool. Eventually the top layer becomes cooler and denser than the bottom stagnant layer. Since it is denser it will not float on the stagnant layer. As the surface layer sinks to the bottom of the lake, it forces the nutrient laden water to the surface. This internal recycling of nutrients can be very significant since it means that one load of nutrients can cause recurring problems year after year.

This phenomenon, called "overturning," does not occur in all lakes. Lake Okeechobee, for example, is very shallow, and all available information has failed to show the presence of any stratification. Apparently, the lake is shallow enough that the surface wind-mixed layer extends to the bottom of the lake.

Alga Blooms In Extreme Cases

NUTRIENTS RESULT IN HIGH PRODUCTIVITY

Having established the meaning of eutrophy -- "well nourished" -- the consequences of the abundance of nutrients becomes important. Under these conditions, biological productivity becomes high. Plants (especially algae) react strongly as they float in the water in direct contact with the nutrients. Algae becomes a primary producer of new organic matter upon which aquatic animal life depends. With algae being the base of the food chain, the basic problems of eutrophication can be evaluated in relation to the production of algae.

The form of algae which is of the most concern is the phytoplankton (plant wanderer). In oligotrophic lakes, these small plants usually are few in number of species present. At the opposite end of the scale, in a eutrophic lake, large numbers of a few species are present.

Phytoplankton are usually similar to all eutrophic lakes, but will vary quantitatively and qualitatively from one lake to another and will vary seasonally in any particular body of water. This is a result of the interaction of such factors as availability and types of specific nutrients, water temperature, light and geographic location.

Lakes that are eutrophic usually have algal forms called diatoms during the low water temperature period in the fall, winter and spring seasons; their numbers being greatest during the spring. In the late spring green alga become dominant; then begin to die out with the arrival of the blue-green alga which is typical of the summer months, when the highest temperatures and greatest light conditions exist. With favorable conditions, blue-green alga is capable of producing enormous population explosions called "algae blooms." An algal bloom is the tremendous increase in the total number of algal cells in a given unit of water.

Their number increases to such an extent that their presence renders difficult the use of a particular body of water for its intended purpose.

There have been numerous attempts to set a definite number of cells per unit in order to establish a definition for algal bloom. These attempts have failed, however, because this is a subjective decision, and not one easily defined, other than for a specific lake.

Minute Plant Life Vital But--

TOO MUCH ALGAE HAS ADVERSE EFFECTS

The presence of algae is not a bad thing. In fact, without some algae a lake would lose a great deal of its use to man. Algae or phytoplankton forms the base of the food chain in lakes and other water bodies. Thus a certain amount of algae is necessary to sustain a good sport or commercial fishery in a water body.

In some commercial fisheries (primarily in ponds used specifically for this purpose) commercial fertilizers are added to the ponds to induce an enriched condition. This enhances the growth of algae, and consequently provides an increase in food supplies for the various steps in the food chain, ultimately resulting in a larger fish population and a greater harvest from a given water body.

Unfortunately, however, the vast majority of the effects of eutrophication are not desirable. These special fish ponds which need increased nutrient levels are about the only case where higher nutrient levels are desirable. The higher nutrient levels found in eutrophic lakes cause conditions that create lowered esthetic values around the lake and for the lake itself.

For example, high nutrient levels cause increases in algal mats, and various types of vegetation and changes in fisheries, including fish kills. The enriched algae laden water can also cause problems for water treatment plants. The latter includes the clogging of filters, and bad tastes and odors in drinking water supplies, any or all of which would increase the costs of operation for these plants.

A 'Vicious Cycle' In Nature?

DYING PLANT LIFE TAKES VITAL OXYGEN

The production of organic matter (phytoplankton) is one of the major consequences of eutrophication. Since these algae are plants, they contain chlorophyll. Sunlight acting on the chlorophyll in the process of photosynthesis utilizes carbon dioxide to build new plant tissue, and gives off oxygen as a by-product. When the algal cell count is extremely high, as it is during a bloom, sufficient oxygen is produced to create high levels of dissolved oxygen (D.O.) in the water body.

The mass of algae is living plants. When these plants complete their life cycle, die and decompose, an additional demand is placed upon the D.O. available in the water. As the algae decomposes, it releases a portion of the plant nutrient materials which it utilized to build cell tissue back into the water where it becomes available for continued algal growth.

This cycle continues until some change in the environment causes a halt in the wild growth of the algae. This change could be an exhaustion of some essential nutrient (see Table IX), or merely a change in water temperature. The D.O. demands of the living and decaying algae can pull D.O. levels to near zero, causing fish kills and severe odor problems. The dead fish in turn add still more decaying organic matter to the lake and create even greater oxygen demands on the overtaxed D.O. supply.

Over a period of years, the remains of the excess amounts of organic matter formed from the stimulated plant growth tend to accumulate on the bottom of the lake in a loose deposit. This material makes it difficult for desirable rooted aquatic plants to grow as they either are uprooted very easily by waves or else can never become established in the first place. This loose organic layer also becomes an impediment to those gamefish that need a firm bottom upon which to deposit their eggs.

The decomposition of large amounts of organic material, under conditions of little or no dissolved oxygen, has as a by-product several gases which have both unpleasant odors and physical effects. In extreme cases, lead base house paints have been turned black by the gases given off from a eutrophic lake.

Certain members of the family of blue-green algae, typically present in bloom numbers in a eutrophic lake, give off toxic substances during phases of their life cycle. These toxins have not been a health problem for humans for one reason: they create such an unpleasant taste in the water that it would be difficult to force enough of the water into an individual to cause any problem. Livestock, however, have been known to die from consuming too much of this water.

Nitrogen and phosphorus are usually considered the two prime nutrients necessary for eutrophication to occur. Caution is necessary when discussing removing either of these nutrients in order to control excessive algal growth or eutrophication.

Table IX . . Elements Essential For The Growth And Reproduction Of Algae (1)

Element	Symbol	Minimum Requirements
(?) Aluminum	Al	Probably Trace Quantities
Boron	B	0.1mg/1
Calcium	Ca	20.0mg/1
Carbon	C	(Quantities Always Sufficient In Surrounding Medium)
Chlorine	Cl	Trace Quantities
Cobalt	C0	0.5mg/1
Copper	Cu	0.006mg/1
Hydrogen	H	(Quantities Always Sufficient In Surrounding Medium)
Iron	Fe	0.00065 - 6.0mg/1
Magnesium	Mg	Trace Quantities
Manganese	Mn	0.005mg/1
Molybdenum	Mo	Trace Quantities
Nitrogen	N	Trace Quantities - 5.3mg/1
Oxygen	O	(Quantities Always Sufficient In Surrounding Medium)
Phosphorus	P	0.002 - 0.09mg/1
Potassium	K	Trace Quantities
Silicon	Si	0.5 - 0.8mg/1
Sodium	Na	5.0mg/1
Sulphur	S	Less Than 5.0mg/1
Vanadium	V	Trace Quantities
Zinc	Zn	0.01 - 0.1mg/1

Controls Are Available

MAN CAUSES CULTURAL EUTROPHICATION

Although eutrophication is a natural process, man's activities have had great influence on the rate of the process. We call the increased rate due to man's activities "cultural eutrophication." The altering of lake and stream drainage basins, urban and agricultural storm runoff, deforestation and the discharge of municipal and industrial wastes have all contributed to the accelerated enrichment of our lakes and rivers.

Only those pollutants which contribute nutrients to the water add to the rate of cultural eutrophication. Other pollutants can indeed harm a water body, but they do not have an impact on the rate of nutrient enrichment.

There are several methods available for controlling the rate of eutrophication. These control measures are aimed at direct control, treatment of symptoms, and action directed at the fundamental causes of eutrophication. Land use controls such as zoning practices and proper farming techniques will serve to eliminate to a large degree the nutrients from these sources. Nutrient removal from domestic and industrial wastewater is possible by several methods:

- The diversion of nutrient-laden wastewater may offer help for a particular water body, but it may be at the expense of another.
- Weeds, algae and fish may be removed or harvested and thereby remove nutrients from the internal cycle of the system.
- It may be possible to introduce members of the food chain which feed on large amounts of the nuisance algae and thereby reduce their numbers.
- A smaller amount of light penetrating the water would reduce the source of energy for plants and thereby lessen their numbers and/or rate of reproduction.
- Additional water could be added to a particular water body to dilute the nutrients during critical conditions of algal growth.
- The elimination of layering in the waters of lakes would serve to hinder the internal nutrient cycling in lakes.
- Dredging of sediments could deepen a lake but at the same time remove nutrient-laden organic sediments.

Before control measures are undertaken, the consequence of the action should be carefully evaluated to make certain the cure is not harder on the patient than the illness.

Eugrophication, then, is a natural aging process for lakes as they progress towards dry ground. We have great impact on the rate of nutrient enrichment and eutrophication and man, if he wisely gauges his actions, can probably slow this natural process and in some cases provide a measure of temporary relief from the undesirable effects of eutrophication.

*References: (22), (23), (24).

A REVIEW OF WATER RESOURCE PROJECTS AND PROBLEMS IN CENTRAL AND SOUTH FLORIDA

An Address to the Governor and Cabinet of Florida
by Arthur R. Marshall - April 13, 1971

Governor Askew, members of the Cabinet, Ladies and Gentlemen. I have studied the growing problems of the Everglades Basin as a professional ecologist for the past 16 years. On the basis of those observations and my professional knowledge, I have no hesitancy in saying that we are now near the limits of resiliency of that great ecosystem. Should we continue on our past course of environmental insensitivity or indifference, we shall see a snowballing degeneration of major resources of the Everglades commence in this decade--within the term of this administration. We may have, for example, the unique experience of eliminating one or more wild species from the Florida scene--I say unique because I know of no other case where species extirpation has resulted from maltreatment of a National Park.

The Everglades is not just stressed--it is distressed--a condition brought about to a major degree by past works of the flood control project.

The lakes of the upper Kissimmee Basin are undergoing rapid overenrichment, owing to the combined stabilization of their levels by the flood control project and their ever-increasing nutrient loads. Lake Tahopakaliga is the most advanced--it is eutrophic and exhibits the conditions of massive algal blooms, surface scum and odors, deep ooze layers on its bottom and dominance of gizzard shad characteristic of such lakes.

Overenrichment proceeds apace down the Kissimmee to Lake Okeechobee, already involving Lakes Cypress, Hatchineha, Kissimmee, and Okeechobee itself.

The historic broad marshes of the lower Kissimmee Basin have been cut in half by drainage induced by the project channel in the lower 60 miles of the Kissimmee--with their loss, a great capacity to absorb fertilizing materials has been lost, and these are now readily transported to Lake Okeechobee, the heart of the water resource of South Florida. No other feature of the construction project offers more promise for catastrophe than the Kissimmee canal.

The marshes of Lake Okeechobee have also been vastly reduced, and if the plan to raise the lake to 21.5 feet mean sea level is realized, all of the marshes of Okeechobee will be destroyed. Recent analyses of algal content in Okeechobee waters clearly indicate approach of eutrophication. There is no question as to whether this will occur, it is a question of when. On the experience of Lake Tohopakaliga, we had better prepare for eutrophication of Lake Okeechobee within the next five to ten years.

South of Okeechobee, project features have provided means of discharging millions of acre-feet of fresh water to tidewater. Thus, in March of 1970, the sawgrass deer were again stressed by high water; the canals did their job, and that, coupled with a poor rainfall year, produced dust-drought conditions in the same area seven months later.

An environmental element of major proportions, the great evapotranspiration loss of glades water to the atmosphere, estimated to be about 80-90% of the annual rainfall volume, was largely disregarded in the design of the conservation areas. They function more as evaporating pans than as water reservoirs. This great atmospheric loss of water from Conservation Area #3 in particular means that if we shut the Tamiami Trail gates to the Park we will lose this water anyhow--a very few months later. Area 3 will not carry any significant volume of surface water over from one rainy season to the next.

The Everglades is too much shrunken by the project works--it is about one-half of its historic size. Now in time of flood the remnant pools must accommodate drainage from an inordinately large area; consequences are the instant floods which have several times put the deer in stress. When the rains let up, the E.T. loss takes its heavy toll, and the pools head for instant drought. These produce the yo-yo effect which keeps us all bouncing from high water problems of the deer to fires such as we have experienced.

A major historic component of the ecosystem of Everglades National Park was its long wet period. Rainfall on the Park was supplemented by long post-season flows from the north. Project works greatly curtailed the length of the wet season in the Park which has had a great deal to do with placing a number of its bird species in rare and endangered status.

Canals dug in the project have an assortment of detrimental effects. They discharge waters to tide which are subsequently needed. They overdrain the northern part of Area 3 after the rains let up. They transport nutrients, hyacinths and other troublesome plants over great distances. They carry organic oozes and hyacinths to tidewater, and dump them there, as in the St. Lucie Estuary and the south end of Lake Worth.

A loss of special nature is the rapid consumption of the muck resource south of Okeechobee. Tillage of this soil is expected to lead to its consumption within twenty-five years. Fire which occurred this year about six miles north of Pool 3 burned about one foot off the muck.

A difficult problem of water supply will soon confront south Florida users. The Corps has estimated that we can expect critical shortages in this decade. Project canals drain much to the sea and thus reduce the available supply. Project levees conversely, coupled with canals and pump stations, have opened great areas for intensive human use and thus increased the demand. The supply-demand curves will cross soon.

The hour for decisions essential to the survival of the Florida Everglades system is close upon us. No one could claim that project works are the sole agents of its stress, for there are also abundant residual pesticides, jetports sought, proposals to construct an Interstate Highway across the glades wetlands, private drainage canals, in troublesome exotic species--plant and animal--introduction of fertilizers into glades waters and others. Certainly, however, the magnitude of project effects is unequaled. I am particularly troubled that in this time of great fires across the Everglades, new project canals are now being built to drain still more water from the basin. These are C-109 and C-110 in South Dade County.

The Everglades has all the symptoms of environmental stress and approaching catastrophic decline which I have mentioned. It also has 15 rare and endangered species and an endangered National Park.

I have not been able to study the specific budget proposals considered for the C and SF project--but I have seen many project features built in the past with inadequate considerations of their environmental consequences. Almost all of them had consequential environmental effects. I therefore recommend to this Cabinet that no funds be sought for any segment of the project for which an adequate study of environmental consequences is lacking.

The environmental stresses now preying on the Everglades ecosystem require that we begin to <u>relieve</u> these stresses. We need a change of direction which this Cabinet can provide. Such a change can maintain the resources of the Everglades, and can provide the profits and jobs which we all know are necessary.

What Can Be Done

This Cabinet can ask the Congress to provide funds for the Corps to help in restoring the lakes of the Kissimmee, to help reflood and restore some of the lost marshes of the lower Kissimmee,* to reflood portions of the shrunken Everglades, to replant the reflooded portions with native grasses to convert waste nutrients to valuable muck, to locate all sources of nutrient input to the entire basin and to develop plans for their harmless or beneficial disposition (e.g. cow manure in large quantities which might be plowed into nutrient-deficient farm lands), to help in the restoration of coastal bays of South Florida--both those damaged by the project and others damaged by other encroachments, to develop means of reducing the yo-yo effect in the sawgrass Everglades, to restore as much as possible the ancient long wet period, to provide a flood plain study for the watershed of the Big Cypress portion of the Glades Basin and to establish the significance of that watershed in the growing water crisis, to reexamine its many miles of drainage canals and to eliminate those which are not needed.

I have long hoped that the Corps could become active in the construction of sewage treatment plants and sewage conveyance facilities. This element alone could dwarf the size of the budget you are now considering and be of immense importance to all the people and to all the governmental entities within this State.

Knowing that even the best sewage treatment facilities leave potentially valuable nitrates and phosphates in their effluents, I have felt that we require extensive experimental investigations of spray-irrigating those effluents on farm and woodlands--providing the agriculturist or the forester with those valuable nutrients while conserving our fresh waters through groundwater recharge.

Few agencies have the wherewithal to undertake this vital job. It occurred to me not long ago that the Department of Defense could do it. It has large blocks of land in Florida--stretching from Homestead Air Force Base to Eglin and beyond; it has sewage treatment facilities on all of these; it has all kinds of professional personnel--biologists, chemists, engineers, foresters and agronomists; a portion of its budget is allotted to environment; and it does need some good P. R.

*Authors Note: In an article taken from the Fort Lauderdale News, December 12, 1972, "Cabinet members, however, expressed doubts over the restoration plan after Flood Control officials told them (Cabinet) it would cost $88 million, much of it in buying back privately owned lands that would be reflooded."

I have presented this idea to a friend of mine who now has an appointment within a few weeks with the Secretary of the Army to discuss its possibilities. It would be possible for the Corps to take a major role--with other defense agencies--in this activity.

These are all purposes which this Cabinet can pursue, to help in the maintenance of the Everglades as well as most of the Florida environment. These are the kinds of changes of direction which are needed.

In closing I would like to refer specifically to the stressed condition of Everglades National Park--knowing well that it is not all of the Everglades. But there is a story here. The United States was the first nation in the history of the world to establish a system of National Parks. Must we be the first nation and State to destroy one?

REPAIRING THE FLORIDA EVERGLADES BASIN

By Arthur R. Marshall
June 11, 1971

For ninety years canals have been built to drain fresh water from the Kissimmee-Okeechobee-Everglades Basin. The network of canals now intercepts large volumes of water from its historic southerly flow diverting it to tide water via much shortened routes. Pre-drainage observations indicate rainy season water levels in the lower Everglades have been lowered five feet or more.

Loss of this fresh water has eliminated rainy season flooding over half or more of the historic flood plain of the basin. The surface flood period has been shortened by weeks in the higher portions of the remaining basin and by months in the lower sawgrass Everglades and Everglades National Park.

Extensive changes in plant and animal populations have resulted from this "drying." Ground water levels have been markedly lowered--especially in the dry seasons--in the interior of the basin and around its periphery inducing increased salt intrusions; salinity concentrations in tidal waters are either raised, as in upper Florida Bay, or lowered, sometimes suddenly and drastically, as in the St. Lucie Estuary and south Lake Worth. There is some concern that South Florida's weather may have been altered through drainage to a condition in which drought induces drought.

The muck sponge retains water during the wet season and slowly releases it in the dry season--and WE ARE LOSING THE MUCK. The mechanism of summer flooding and related growth of vegetation which produced the peat and muck beds of south Florida has essentially been destroyed. Exposure of the existing muckbeds to the atmosphere through drainage and tillage is eroding them rapidly. The reduction in surface flooding has shifted the muck "budget" from one of production and accumulation to one of consumption and rapid depletion. In the Okeechobee agricultural area, the thickness of the muck has been reduced 5 feet over 44 years. Its remaining life is about 25 years, barring extensive muck fires. In the northern area of the Park a layer of muck formerly about one foot thick has virtually been eliminated within the past twenty years, exposing great areas of sharply eroded pinnacle rock.

We have proceeded with drainage on the near sacrosanct belief that such works would do no harm, or the resultant harm would be offset by the benefits. There are increasing reasons to doubt this, including the threats to the Park, a lengthy list of rare and endangered species, the foreseeable end of the muck, the threats of salt intrusion and the growing competition for water. While water supply is decreased by drainage, urbanization and farming of the drained land increase the demand for water.

Despite the growing shortage of water and associated environmental problems, the Florida Department of Natural Resources, the Florida Cabinet and most of the Florida Congressional delegation are at the moment pressing Congress to provide more funds--the amount based chiefly on the premise that the Corps of Engineers should be allotted all the funds they can expend in a fiscal year.

Although the problems generated by drainage practices are environmental, ironically during the 90 year process, never have the hundreds of canal builders been required to prove that their works would not cause adverse environmental effects. Conversely, the few trained natural scientists who have been employed in the issues have always been expected to prove that more miles of canal would do harm--an unreasonable expectation in view of the environmental complexities and the speed and massiveness of construction. There are many examples of the inadequacies of this procedure.

In the 1950's, efforts of biologists and conservationists on behalf of the protection of the St. Lucie Estuary and the lower Kissimmee River were essentially rejected. The St. Lucie Estuary is now badly degraded and the Kissimmee ditch is an environmental catastrophe.

A threat of citizen injunction kept C-111 canal from being opened to the sea and forced the construction of a "plug," which is still unsatisfactory as it leaks in both directions. Furthermore, three more canals (C-109 and 110 which will drain into C-111, and C-108 to Card Sound) are now being dug nearby. These are in an area where ground water is now below sea level, salt has intruded in canals and agricultural wells must be lowered.

The public sees the Everglades water problem primarily as one of water quantity. It is also a problem of seasonality. We must aim to restore sheet flow over the land wherever possible over more months of each year. We have to think of the summer's water resupply as we do our paychecks. We must stretch the blessings both of the pay and of the water as closely as we can to the day when replenishment occurs. It is a problem of time duration rather than simply one of static storage. Static storage of water from one rainy season to the next is possible only in Lake Okeechobee and only in limited amounts there.

A problem of equal magnitude is water quality. Most of the lakes of the Kissimmee are overenriched. Lake Okeechobee i. rapidly becoming so. While this condition spreads south toward the Everglades, an equivalent pollution onslaught threatens the Glades from the east.

The coastal canals in Palm Beach, Broward and Dade Counties are grossly polluted. Pumping of about half of this water to the Glades has been authorized by Congress. We do need the water.

Resolution of this twin pollution threat to the Glades is at least as essential as resolution of the water quantity-seasonality problem. Because the problems are interrelated, so are our suggestions for "repair." The following list is a guide to the kinds of corrective steps we must now take. All of them require elaboration including a heavy infusion of ideas from environmental professions.

1. Restore the quality of the water in all the Kissimmee Lakes, as is now being attempted in Lake Tohopekaliga. This involves upgraded treatment or exclusion of all wastes, restoration of some semblance of natural water level fluctuations and intermittent drastic drawdowns to oxidize accumulated bottom ooze.

2. Reflood and restore some of the lost marshes of the channelized lower Kissimmee River.

3. Slow the rate of Kissimmee runoff into Okeechobee.

4. Upgrade treatment of or exclude all wastes entering Lake Okeechobee.

5. Raise Okeechobee to the authorized 15.5 - 17.5 foot schedule. The authorized four-foot rise to 17.5 - 21.5 if it could be accomplished, would destroy marshes in the northwest quadrant and release their bound-up nutrients into the lake waters (c.f. the demise of Lake Apopka, which was triggered by the uprooting of marsh vegetation by a hurricane).

6. Restudy the effect that the authorized diversion of water from Lake Okeechobee to the Martin County Canals would have on water supply to the Everglades including the Park and Palm Beach, Broward and Dade Counties, especially in DRY YEARS. This will require a critical decision as to which interests are to have priority. Had this plan been in operation this year, it would have been necessary to divert about 400-500,000 acre-feet of water for irrigation to the canals--an amount which would lower Okeechobee about one foot. This situation is a microcosm of the problems generated from overtaxing the water resource. If the diversion to Martin County Canals is accomplished, will it lead to more growth and more demand?

7. State acquisition of the Fahkahatchee Strand.

8. Federal acquisition of the Central drainage (subdrainage Area "C") of the Big Cypress Watershed. This is number one on the list of "Alternatives of Action" (in Report to Secretary of Interior, Big Cypress Watershed). There should be no drainage or interferences with sheet flow or other activities inconsistent with a National Recreation Area such as esthetic damages or risks of pollution. Remove the south half of Levee 28 and its canal, restoring natural flood flows between Conservation Area Three and the Big Cypress.

9. Reexamine the hydrologic and water quality effects of Alligator Alley and the Miami Canal. The additional hydrologic effects of the new Pump Station S-140 and authorized Levee L-100 should be considered. There may be more reason to remove Alligator Alley than there is to make it an Interstate Highway.

10. Raise the minimum ground water levels throughout the Glades, the Park and South Dade. Canals which have drained the lowest lands in South Dade--about five to ten percent of the area--have dropped ground water levels under all the rest, and increased the risk of salt intrusion. A series of weirs in the canals might help.

11. Acquire the 38,000-acre triangle in the natural headwaters of the Shark Basin east of the Park as proposed by the Department of the Interior and redesign all associated project works in the vicinity to restore flow in that deeper basin.

12. Stop the construction of Canals C-108, 109 and 110.

13. Fill in Canal C-111 from U.S. Highway 1 to Barnes Sound.

14. Reexamine all existing or proposed drainage canals with a view toward eliminating those which are not needed.

15. Institute all possible means for reducing the extremes of flood and drought throughout the system so as to reconstitute as much as possible the historic attenuated wet period.

16. Develop and implement plans to restore coastal bays that have been damaged--e.g., St. Lucie Estuary, Lake Worth and northern Biscayne Bay.

17. Request the Corps of Engineers to make a flood plain study of the watershed of the Big Cypress.

18. The problem of nutrients and other pollutants extends throughout the basin. The sources are sewage and industrial wastes, agriculture manures and certain crop residues, chemical fertilizers and pesticides. Some possible approaches are:

a Determine the beneficial and detrimental aspects of septic tanks in regard to water conservation, nutrients and eutrophication potential, other chemicals and public health.

b. Locate all sources of pollutant inputs into the basin and develop plans for their harmless or beneficial disposal.

c. Face the reality of the existence of nutrients in sewage and agricultural wastes and develop means for keeping them out of the lakes, the conservation areas and the Park. As a general frame of approach, they could be used:

(1) On uplands by direct application (manure and plant residues) or by spray-irrigation on and fertilization of lawns, gardens, pasture grasses, selected crops, or

(2) On reflooded glades lands for conversion via sawgrass or other native wetland plants into paper or peat into muck, or to grow ramie or rice, or

(3) In controlled and isolated upland ponds or nutrient interceptor canals to produce fish protein.

d. Seek the assistance of the Department of Defense in developing treated waste effluent recycling methods. DOD has large land tracts (Homestead Air Force Base and Avon Park Bombing Range), treatment plants and many professional people. The Corps of Engineers could construct sewage conveyance and treatment facilities if so directed by Congress.

e. Discontinue the use of persistent pesticides and replace them with environmentally acceptable alternates, chemical or biological.

19. Find an upland location for any new jetport.

20. Evaluate constraints that the environment places on developments--urban and agricultural--which depend upon the resources of the basin.

Demands on the Kissimmee-Okeechobee-Everglades basin are bound to increase. Even now the region requires large-scale rejuvenation, similar in magnitude to the renewals contemplated for stressed cities of the nation. One change in approach is that we must evaluate extreme conditions, such as those now occurring in respect to water, rather than relying on apparently benign averages, as we have done in the past.

South Florida is faced with accelerating impoverishment of its natural and human resources. The two are inseparable. Crowding, pollution and multiple corrosion of our habitat--both urban and Everglades--intensify the frustration, irrationality and apathy increasingly evident in our citizenry.

The stresses of overloading the south Florida environment reflect on the general populace. For this reason the principal criteria for adjudging and instituting solutions must be the public's interests.

We must change direction. Our exploitive and technological orientation must be redirected in favor of more considerate uses of natural systems. They have an efficiency of their own as well as finite limits which we can no longer disregard. We do not control nature. Our intrusions into natural systems merely bring into play other sets of natural laws--some favorable to man, some not.

The environmental problems of the Everglades are of such precipitous nature and so relevant to the broad public interest that no single agency of government has the perspective and authority to resolve them. If any is able to do so, that ability is not evident. Strong executive scrutiny, led by the Cabinet of Florida, is in order. An appointed board of appraisers, representing the public interest, should advise the Cabinet on these matters. The Cabinet should call a moratorium on all questionable construction until the effects of such construction are reviewed by the Board.

With such attitudes and approaches, we can maintain and restore much of the Everglades, our overall environment and our eroded psyche.

DEVELOPMENT OF PRIVATE WATERFRONT CANALS

ENFO NEWSLETTER, 2/72
Environmental Information Center

Many of the older canal systems in Florida are in such condition that property once considered an ecological delight has now become an environmental nightmare and economic liability.

Florida's fabulous fishing and water sports, which attracted tourists by the millions, have been bait used to lure prospective homebuyers into paying extra thousands of dollars for waterfront property. Oceanfront property and natural rivers by themselves could not possibly meet this constant and increasing demand, and so high, dry land and artificial waterways have been created by dredging wetlands previously considered worthless. The results have often been described as massive assaults on the environment.

Low-lying mangrove and salt grass swamps and marshes which were inexpensive and adjoined deeper waters have been the prime targets for such developments. In many parts of the state, partially-submerged land with maximum water depths of only a few feet normally extends miles into the sea. The loose surface sediments are easily excavated, and the dredged material provides the fill needed to raise lowlands above sea level. Thus, valuable property has been created by dredging up finger fills with narrow canals and boat channels excavated between the fingers.

Unfortunately, the canal waters of newly-created waterfront real estate may deteriorate into contaminated ditches unfit for fish, wildlife or man.

The Gold Coast, from Miami to about 30 miles north of Palm Beach, supports numerous examples of this type of development. Huge sections of the inland waterway there have been filled in and the natural shoreline has disappeared beneath a maze of dredged-up finger-fills. Tampa and Boca Ciega Bays are additional examples. Over 20% of Boca Ciega Bay has been filled and almost twice as much has been dredged out in order to obtain the fill material.

The result has been disastrous. It is now common knowledge that the estuaries are marine nurseries upon which between 70% and 80% of sport and commercial fish species depend for survival. Production of marine life in Boca Ciega Bay has declined 80% and game fish catches have dropped drastically.

Many party boat skippers claim that the Gold Coast, at one time one of America's most popular fishing rounds, is now almost a marine desert. Professional Miami fishermen say they must travel about 40 miles in either direction in order to find good fishing. Dr. Gilbert Voss, a University of Miami authority on sailfish, says that even this prolific species has practically disappeared from these waters.

Only in recent years has the value of natural wetlands been officially recognized and the state of Florida has curtailed dredging and filling of wetlands below the mean high water line by making it more difficult to obtain the required permits. One response of developers has been to move their excavations inland, creating massive networks of interconnected canal systems above the mean high water line, where there are no state regulations or controls. These systems are connected to public waterways by navigation channels. In some cases, the canals are excavated and property sold before application for a permit has been made to connect the canals to a public waterway. If such applications are denied, state officials are subjected to pressure from irate property buyers who demand access to a public waterway as promised by developers.

Massive canal systems are either underway or planned along coastal and inland waterways throughout the state. If the trend continues unabated, the entire state may be carved into labyrinthine canal systems. As a result, instead of remaining America's favorite water sports paradise, Florida may be converted into a national disaster area.

The Governor's Conference on Water Management in South Florida (1971) reported:

"Water quality is a far graver problem in the long run than is water quantity. The quality of the water in the South Florida water basin is deteriorating. This deterioration stems from the introduction into the basin of pesticides, herbicides, animal and industrial wastes, heavy metals, salt water, sewage and heated waters. Channelization has contributed substantially to the process of deterioration." (Emphasis added)

One of the recommendations of the report was:

"Consideration, after study, of filling in certain canals in the South Dade County area to improve ground water quality."

STAGNANT WATERWAYS

A widespread misconception is that only deadend canals are afflicted with poor water circulation and stagnant conditions. Among the remedies suggested are that culverts or interconnecting channels be required in order to eliminate dead ends and thus provide adequate circulation.

Investigation discloses that this assumption is largely a fallacy, and that eliminating deadend canals would by no means solve the problems of inadequate circulation and lack of flushing action.

1. Tidal Action and Gravity Flow

In coastal areas, the prime mechanism for water exchange is produced by tidal effects. In Florida, the tidal range varies from 1 foot to only about 3 feet, with slightly higher tides on the northern Atlantic Coast. This is not sufficient for good circulation, and much of the same water carried seaward on the ebb tide may be returned on the following flood tide. The distance of upland canals from the coastline further reduces any effect from tidal action, creating almost static or stagnant conditions.

Inland, freshwater canal systems which are not affected by tidal action derive circulation entirely from gravity flow due to differences in elevation, or seasonal differences due to rainfall. The low profile and flat nature of Florida's terrain precludes the possibility of good gravity circulation in most of the state. In some areas, the difference in elevation is at most only a few inches per mile. For this reason, even shallow freshwater canals are characterized by sluggish circulation and poor flushing action.

2. Excessive Depths

Often the primary purpose of canal excavation is to obtain the fill material needed to raise lowlands above the high water line or, in inland areas, above the flood plains or marshlands. These canals are almost invariably dredged to depths greater than are actually necessary for small boat navigation, which is around 5 or 6 feet. In some cases, canals are excavated to depths exceeding 30 feet, and some borrow pits or channels are deeper than 50 feet. Seldom has there been any checking after approved work is done, unless an obvious "overfill" has been created.

Most canals are far too deep to receive the light required for the production of desirable aquatic life and vegetation. Turbidity from dredging further reduces light penetration and bottom sediments become an anaerobic, unconsolidated muck which is usually dark, semi-fluid and sulfurous.

Even in the open water of bays and estuaries, the bottom water in deep-dredged channels is little affected by normal tidal action and currents. Only the surface waters are circulated and the protected, deeper "pockets" become stagnant sediment traps which accumulate all manner of dead and decaying organic matter.

A survey of canals in the Florida Keys disclosed that deep saltwater channels are often subject to temperature stratification. A warmer, upper layer usually has ample dissolved oxygen and supports a heavy plankton bloom. Lower layers are colder, devoid of plankton or other aquatic life, are anaerobic, and have an accumulation of decaying vegetation and detritus on the bottom. Stratification is apparently due entirely to depth, regardless of the proximity to open water or canal configuration.

Another common misconception regarding deep saltwater canals is that they offer a haven in which game fish thrive. This may be true in the early stages immediately after canal excavation. All known studies indicate that the accumulation of organic bottom sediments and low dissolved oxygen not only drastically reduce fish populations, but the contaminated conditions often lead to massive fish kills.

Also, it is commonly believed that the deep water of canals offers a warm water haven which protect fish, such as snook, from cold surface waters during winter months. It is true that snook take refuge in the warm water in these deep canals, but prolonged cold weather eventually reduces the temperature of bottom water and the fish die.

ACCELERATED EUTROPHICATION

The concentration of pollutants generated by a community is directly proportional to population density. Canals are receptacles for most of these pollutants and permit heavy population density in relation to shoreline length, greatly accelerating eutrophication. In addition to septic tanks, sewage effluent and live-aboard vessels, canals are heavily contaminated by urban stormwater runoff.

1. Urban Runoff

Studies show that stormwater runoff from residential areas is a major source of pollution, often containing concentrations of organic and toxic material comparable to that of raw, domestic sewage. In Florida waters, a concentration of coliform bacteria (an indicator of fecal contamination) which averages more than 1,000 per 100 milliliters, or which exceeds 2,400 per 100 ml on any one day, is classified as unsafe for body contact and unsuitable for fishing and water sports. A single stormwater sample yielded coliform bacteria concentrations of 3,800,000 per 100 ml. Storm water contains animal excrement, fertilizers, pesticides, garbage and trash; in addition to pollutants from automobiles, service stations, garages and junkyards, plus chemicals from auto washing, laundries and similar activities.

In the stagnant water of canals, the nutrient stabilization and water purification processes of natural waterways do not operate effectively and the pollutional load accumulates. The decaying organic matter depletes the water's dissolved oxygen and an anaerobic layer of muck and sludge builds up on the bottom. In some older canals, this sludge is more than 15 feet thick, and in others the water has been displaced, rendering the waterway useless.

2. Foul Odors

Decaying and fetid algae release hydrogen sulphide gas which smells like rotten eggs. This gas is corrosive and is lethal to marine life as it exerts a demand upon the water's dissolved oxygen supply. In some coastal areas, hydrogen sulphide from canals has turned white paint black on nearby homes, and boat owners must contend with expensive maintenance problems of corrosion and discoloration caused by the gas.

In older canals, fetid algal scums blanket the water surface, converting the waterways into an unsightly blemish and producing a stench that permeates waterfront homes.

Freshwater canals are plagued with explosive growths of noxious aquatic weeds which often spread to connecting lakes and rivers. The weeds are killed by powerful herbicides. The dead weeds sink to the bottom, adding to the accumulation of anaerobic, oxygen-demanding sludge. Repeated use of herbicides also adds to the oxygen-demanding contaminants in the water.

As surface water is depleted of oxygen, fish suffocate and their rotting carcasses add to the stench emanating from stagnant canals. Eventually, the dead fish sink to the bottom, adding their decaying carcasses to the accumulation of putrid, poisonous muck.

At this point, unless drastic and expensive remedial action is taken, the canal degenerates into septic conditions and becomes virtually an elongated community cesspool.

3. Fish Kills

Every known canal in both Dade and Broward counties is anaerobic at one time or another and fish kills are a common occurrence in many.

Recurrent fish kills in Palm Beach County canals are attributed to a combination of low dissolved oxygen and herbicides from aquatic weed spraying.

Fish kills occur so regularly in Port Charlotte canals that Game and Fresh Water Fish Commission personnel reportedly no longer bother to investigate them.

Additional fish kills are reported by field investigators throughout the state and the unanimous opinion of these and other experts is that a lack of dissolved oxygen due to accumulations of organic material is a chronic characteristic of practically all canals in Florida.

Canal fish kills can be set off by the turbulence of boat propellers and boat wakes, or by the stirring and mixing by wind action which bring contaminated, anaerobic bottom sediments to the surface, resulting in a drop of the water's dissolved oxygen.

EFFECTS ON HEALTH AND WELFARE

1. Coliform Bacteria

The human health hazard associated with water pollution in Florida is normally measured by the concentration of coliform bacteria present in the water. High densities of coliforms are an indication of fecal contamination, either human or animal, which can cause serious infections or diseases in man. Diseases may be contracted by ingesting small amounts of contaminated water while swimming or wading, or even from hands and food wet with polluted water. Also, contact with polluted water can cause skin infections and infections in open wounds and body openings.

Practically every canal in Broward County has coliform densities violating state standards, which prohibit counts in excess of 2,400 per 100 ml at any time for body contact. Many of the canals are well above danger levels of 5,000 to 10,000 per 100 ml, and the Plantation Canal has concentrations above 1,000,000 per 100 ml.

Dade County canals also have serious fecal contamination and health problems throughout the system. Blue-green algae are prevalent, an organism widely recognized as an indicator of extreme pollution and degradation. Skin rashes have been reported frequently. Botulism, Type C, is common in the canals and has been responsible for many bird kills. Sewage sludge adjacent to outfalls has built up to within a few inches of the surface in some canals. In these areas, a person aboard a boat who puts his hand in the water might come in contact with pure excrement. Some of the Dade canals have coliform counts ranging between 500,000 and 1,000,000 per 100 ml.

"This state must realize (and soon) that we cannot continue the creation of waterfront lots either through finger-fills of estuaries or canals into the uplands. If a developer buys land with five miles of waterfront, that should be the extent of his waterfront development. By filling of bays, we are destroying the estuary resources and by digging canals in the upland, we are creating septic canals." Nathaniel P. Reed, Assistant Secretary of the Interior, February 3, 1972, in a speech to Florida Audubon Society.

Few data are available on the extent of bacteriological contamination of other canals but the few samplings that have been taken indicate that high coliform densities are prevalent. Some finger canals bordering Lake Lowery had MPN coliforms as high as 35,000 per 100 ml. A number of canals bordering other lakes also had coliform densities which made them unsafe for body contact.

2. Gas Gangrene in Bottom Sediments

The Environmental Information Center sponsored a study by Dr. John Betz, a University of South Florida microbiologist, to analyze water samples taken from canals in the Tampa Bay area. Both surface water and bottom sediment samples were taken in canal systems ranging from Weeki Watchee south to Punta Gorda at 80 separate stations. Surface water received the routine test for coliform bacteria, and bottom sediments were analyzed in addition for Clostridium perfringens (also called C. welchii) which is the most common causative organism in gas gangrene. This organism is known to produce food poisoning more severe than Salmonella or Staphylococcus and is an excellent indicator, not only of fecal contamination, but also of anaerobic conditions because it can only thrive in the absence of oxygen, under conditions where normal animal life is impossible.

Although C. perfringens is naturally widely distributed in small numbers (as are coliforms), high concentrations are a definite indication of fecal contamination. Since C. perfringens is rarely found in salt water under natural conditions, Dr. Betz's analysis of Tampa's saltwater canals disclosed only the tip of the bacterial iceberg. His results showed:

70% of the canal systems had coliform counts above 2,400/100 ml.
56% had gas gangrene counts above 1,000/100 ml.
44% had high counts of both coliform and gas gangrene.
83% had either a high coliform or a high gangrene count.
One canal in Venice had a gangrene anaerobe count of 100,000/100 ml.

Betz says that these conditions represent a serious health hazard. People wading or swimming in these waters might get gangrene, tetanus, streptococcal or staphlococcal blood poisoning from open wounds, or they could get gastroenteritis from various bacterial toxins, such as Salmonella, Pseudomonas and others of a complex and little understood spectrum of virus diseases contracted from ingesting small amounts of contaminated water.

The condition of the canals which produced these results is typical of the older, box-cut canal systems in Florida, and it is reasonable to assume that studies of other canal systems would produce similar results.

EFFECTS ON RECEIVING WATERS

1. Underground Water Supplies

The seriously contaminated flood control channels and secondary canals of Dade, Broward and Palm Beach counties are a major source of South Florida's water supply. They are deep incisions into the Biscayne Aquifer, and there is a free exchange of water between the canals and the underground supply, the sole source of fresh water for all of South Florida. Detergents discovered in the water for all of Broward County wells were suspected of coming from septic tanks into the canals. Increasing amounts of arsenic detected in wells in 1962 and 1965 was suspected of originating from weed spraying with herbicides and/or from agricultural and industrial effluents released to canals.

"During the dry season inflow to the canals is from inland areas where groundwater levels are higher than canal levels, but in coastal areas controls are closed, canal levels are higher than groundwater levels and water generally flows from the canals into the aquifer. Thus the period when canals are the primary supplemental source of replenishment to groundwater supplies occurs when effluent wastes in the canals are most concentrated." (Emphasis added) From: Grantham, R.G. and C.B. Sherwood, "Chemical Quality of Waters of Broward County, Florida," U.S. Geological Survey, Report of Investigation No. 51, June 1968.

In view of the porous nature of Florida's soil and the high underground water table, it is reasonable to assume that highly-polluted water of canals in other areas also present a serious threat of aquifer contamination.

Saltwater intrusion caused by extensive drainage which lowers groundwater tables is widely attributed to coastal canal systems. Less understood but equally important is that canal systems which lower inland water tables can also cause saltwater intrusion in coastal areas which are many miles away. All streams, sinks, lakes, springs and aquifers are part of a much larger complex hydrologic system. Usually, anything that affects water levels in one component of the system will affect water levels in another component of the system.

An example is Crystal River which drains an area 80 square miles. Canal systems in the area are cut into the aquifer releasing large flows of aquifer water under artesian pressure. Developers capitalize on this by advertising "spring-fed canals." The flow lowers the water table and permits saltwater encroachment into wells closer to the coast.

There is little doubt that extensive canal systems lower the groundwater table and cause saltwater intrusion. Repeated warnings by the U.S. Geological Survey and private hydrologists stress that extensive canal construction will deplete underground water supplies.

2. Effects on Surface Waters

The accumulation of organic sludge and poisonous wastes in dredged channels and canals reduce or eliminate desirable aquatic life in both saltwater and freshwater areas. Studies of Escambia Bay show that the accumulated bottom sediments in dredged channels and canals contribute significantly to the massive fish kills which occur each year in Mulatto Bayou. The condition of these canals is described in a report by P. J. Doherty, Regional Engineer for the Department of Pollution Control in Pensacola. Mr. Doherty states:

"Several fish kills have occurred during 1970 and 1971 in the Escambia Shores canals. It was noticed upon investigating these kills that because of inadequate flushing, the dead fish remained trapped in the canal system. Unusually poor conditions were noted, such as the breeding of maggots and the bubbling of hydrogen sulfide gas from the sediments . . . . Six fish kills have been documented and investigated in the Escambia Shores Canal system during 1970 and 1971 . . . . The size of the fish kills ranged from 700,000 menhaden to 65,000,000 menhaden."

A number of scientists and pollution control officials are convinced that the conditions in Escambia Bay and adjoining canals may be a prelude to the ultimate fate of other Florida canal systems and receiving waters. In their opinion, situations exist in many other areas which will produce similar environmental and economic disasters if pollution becomes as severe as it has in Escambia Bay.

Symptoms of such disasters are already appearing. Anaerobic sediments flushed into Lake Okeechobee from Taylor Creek and muck farm canals by heavy rains caused massive fish kills. The damage to ecosystems in bays and estuaries from silt, sediments and pollutants carried into them by flood control channels during heavy rains is also well documented.

Stormwater runoff from torrential rains causes a stirring and mixing of anaerobic canal bottom sediments. This rain-caused circulation washes much of this contamination into receiving waters. However, the real danger is that, in some cases, a slug of contaminated sludge which has been accumulating for years may be flushed into receiving waters by torrential rains or tides. Such large quantities of toxic materials can cause widespread damage to the biota of receiving waters.

RECOMMENDATIONS

In view of the serious and permanent nature of the environmental degradation created by standard methods of canal construction and the lack of guidelines based upon comprehensive studies, the Environmental Information Center requested and received recommendations for remedial action from authorities who are familiar with the situation. The following are the measures most often mentioned:

1. An immediate moratorium on further canal construction until a detailed, comprehensive study can be made to determine if it is possible to avoid or correct the problems resulting from present methods of development. The study should establish guidelines and design criteria for future canal development.

2. In view of the health hazard presented by these waterways, it should be mandatory that all canals be examined periodically for coliform contamination, and that results of these counts be posted prominently at sampling sites. If the waterway is in violation of water quality standards, this should be clearly indicated and the public warned to avoid contact with those waters.

3. In view of the wide fluctuation in dissolved oxygen and coliform counts at specific sites, procedures for measuring these should be standardized and incorporated into the written standards. Analyses of bottom sediments should also be added to the criteria for water quality.

4. Geological studies must be performed to determine those existing canal systems which are affecting quantity and quality of aquifer waters.

5. A survey must be made of existing canal systems to determine the necessity of requiring the developer or property owners to fill in those which cannot be brought up to Class III water quality criteria.

FUTURE OF FRESH WATER FISHES IN FLORIDA

By John R. Woods, Chief
Fisheries Division

Florida has a nationally famous reputation for its high quality fresh water fishing. More than 193,000 non-resident fishing licenses were sold in addition to the 659,000 resident state licenses during the 1970-71 fiscal year. It is estimated that the fresh water fishermen contributed more than $295,500,000 to the total economy of Florida in 1970 by purchasing items relating to the pursuit of this sport. Fresh water fishing is a resource that has played an important role in making Florida the great state that it is today.

While sport fishing is not considered in the same category as production of food and fiber, it most certainly plays a major role in the making for a desirable environment with the increasing pressure of modern life, the chance to "get away from it all" simply for recreation is taking on added importance. The future demand for fresh water fishing and related recreation will greatly increase with the expected growth of the state.

The most important problem now facing Floridians in the battle for a quality environment and desirable fresh water sport fishery is pollution. Pollution is anything that alters our environment, making it less desirable to the well-being of man. When man's environment deteriorates, so does many of the creatures man considers as desirable (fresh water fish). Numerous examples of pollution and deterioration already stand out in Florida. Fortunately, we have such a tremendous wealth of fresh water lakes and streams that people were able to move to other lakes and streams when their favorite area became polluted and no longer desirable for fishing or other types of water recreation. The pace of pollution has increased at such an astounding rate in the past few years that the outlook for the future is quite dim as we are rapidly running out of new bodies of water to turn to when others are polluted.

Through geological aging, greatly accelerated by man's activity, many of Florida's lakes and streams are rapidly becoming highly eutrophic or overenriched. Unless there is a change in the values of Florida's fresh water lakes, this trend will increase. The eventual result will be septic conditions in most of the lakes and streams in Florida. The changes in the aquatic environment from pollution are irreversible without tremendous expenditures of money and manpower. Technology available at the present time can stop and reverse some aspect of eutrophication; however, most people are not ready to accept the hardships or costs involved in such an undertaking.

Some of the major causes of degradation of aquatic habitat and fresh water fishing in Florida are as follows:

1. Discharge of domestic agricultural and industrial wastes into rivers and lakes without proper treatment. The gross examples of improperly treated waste being dumped into bodies of water destroying aquatic habitat have been presented numerous times. They would include the Fenholloway River, St. Johns River from Palatka to Jacksonville, Peace River and Lake Apopka. Less publicized examples are even more numerous.

2. Stabilization and reduction of water levels in rivers and lakes which have historically fluctuated widely. Such fluctuation helps oxidize organic buildup and flush out some of the soluble nutrients present in the lakes. Stabilization enhances waterfront development but transforms the lake into a stagnant watershed nutrient trap which creates ideal conditions for rapid eutrophication. This not only destroys the aquatic environment for the desirable fresh water fishes, but renders the lake unsuitable for contact water sports and eventually reduces waterfront property values.

3. The increased runoff of pesticides and nutrients from the watershed. The natural marshes and flood plains which formerly acted as a "biological waste treatment complex" absorbing and utilizing excess watershed nutrients are rapidly being drained and channelized. Channelization provides an excellent conveyor of nutrients and pesticides to our fresh water lakes, streams and estuaries.

4. Unrestricted dredging and filling of lakes and streams for industrial and urban development of waterfront sites. In the last two years over 200 illegal dredge and fill operations have been reported to the Trustees of Internal Improvement Fund. Each of the operations destroyed vital littoral zone for nursery grounds required for desirable fresh water species.

5. Elimination of the full utilization of a natural resource by restricting the removal of commercially harvestable fishes. In most cases this would be beneficial and not detrimental to all interests concerned.

6. Uncontrolled killing of water hyacinths and other so-called noxious aquatic weeds. By allowing the dead plants to sink to the bottom, there is a rapid recirculation of nutrients into the water column, creation of anaerobic conditions and a significant buildup of bottom silt. Each time these plants are sprayed, it increases the opportunity for the nutrients to be utilized in a less desirable form such as algae blooms.

7. <u>Unauthorized importation and introduction of exotic fresh water fish species</u>. Many of the introduced species compete and can replace desirable native fresh water fishes. Introduction of exotic fishes for biological weed control without consideration of ecological damage to the native fresh water aquatic habitat.

The problems of lakes and streams of Florida have been briefly described with expected effects on aquatic life. They will continue to deteriorate the aquatic environment unless there is full implementation of available and future technology. In a recent report from the Game and Fresh Water Fish Commission in which predictions were made about a sport fishing in the St. Johns Valley in the year 2020, we indicated there would be only two places in the 18 county area where largemouth bass could be caught if present trends persist. The implementation of available and future technology can regenerate or at least retard the rapid destruction of desirable aquatic habitat.

Technology available at present which will sustain or enhance aquatic life is as follows:

1. All lakes in Florida should be allowed to fluctuate on a wide range to simulate natural conditions thereby stimulating game fish production. In many cases, the lakes may need to be severely drawn down to set back the eutrophication process.

2. More efficient nutrient removal and utilization of industrial, domestic and agricultural effluent, e.g., photosynthetic sewage treatment, spray irrigation sewage treatment.

3. Stringent zoning legislation should be enacted to protect all flood plains.

4. All dredging and filling, except for enhancement for the aquatic environment, should cease.

5. Stricter legislation should be enacted to reduce and control the pesticides and herbicides used in the environment.

6. To facilitate nutrient removal and full utilization of the resources, increased fresh water fishing harvest techniques of certain species should be employed.

7. Also, to facilitate nutrient removal, there should be a development of a mechanical aquatic weed harvester which can transform aquatic weeds to animal food supplements.

8. Investigate desirable natural and exotic fishes which exhibit superior short-term qualities and can live in an adverse aquatic environment.

9. Screen commercially harvestable native and exotic species which exhibit a dual purpose of removing nutrients and food production.

10. Applicable short-term management techniques may involve selected rotenone treatments and total renovation of the fish population in some regions.

11. Investigate various organisms, native and exotic, which are capable of biologically controlling problem aquatic plants.

Cultural practices which either contribute nutrient materials to the ecosystem or accelerate detrition by enduced recirculation of nutrients within the system, result in environmental changes which persist after the practices have been discontinued.

Those intent on grandiose projects to mechanically and chemically remodel our environment have too often found that while they are experts with structural steel, concrete, ditches, dams, chemical formulas and waterways, they are not trained in the application of ecological principles. The tragedy is in the fact that much of the aquatic and environmental destruction could have been avoided in the original planning.

By now you are probably asking yourself what all of this has to do with the future of fresh water fisheries in Florida. We say it has everything to do with it. We cannot continue to develop high quality sport fishing in waters that are becoming unfit for the survival of fishes. It is interesting to note that a society such as ours, where man can remove himself to a certain degree from the influences of nature, continues to ignore the fact that we are changing environment to such an extent that some of the lower animals cannot survive. If all this sounds a little dramatic and removed from your actual situation, don't you believe it! Nothing is more important in our existence than reversing exploitation and devastation of our environment. If it continues at the present pace, we won't have time to worry about whether the bass are biting in Lake Jackson or how big the specks are in Lake Okeechobee--we will be too busy trying to survive.

A "ROUGH CUT" MODEL OF A SOUTH FLORIDA WATER SUPPLY PLAN

By William V. Storch
Chief Engineer (FCD)

Water supply, with everything these words imply in relation to land use, population growth, agricultural expansion and maintenance of environmental quality, is a major issue in South Florida.

It is an issue of which the public cannot help but be aware as we again are experiencing a dry season with seriously deficient surface water supplies after having had to restrict water use for more than six weeks less than two years ago.

Recognizing the growing problem of water supply, the Florida Legislature responded with the Water Resources Act of 1972. The response of the Governing Board of the Central and Southern Florida Flood Control District in December, 1972, was its "reexamination of directions," in which the Board designated water supply planning and development in conjunction with land use planning a priority objective of the District.

Several of the earlier issues of In Depth Report dealt (in greater or lesser detail) with many of the significant factors related to water supply for South Florida. Some of these raised questions of environmental quality associated with the development of additional water supplies.

What was said in those earlier issues about the nature of South Florida's water source, and surface water storage, could be summarized as follows:

- South Florida's usable water originates as rainfall within no more than 200 miles of the point of eventual use. (Vol. 1, No. 4)

- There is a marked seasonality to South Florida's rainfall distribution, with wide variations within this general pattern. (Vol. 1, No. 4)

- There is a geographical pattern to the annual rainfall distribution, with the greatest rainfall occurring along the southeast coastal strip. (Vol. 1, No. 4)

- Basin water yields vary widely with both seasonal and annual rainfall variations. (Vol. 1, No. 1)

- For surface water reservoirs to be effective in terms of water supply, carry-over storage is required to dampen the effect of rainfall runoff variations. (Vol. 1, No. 1)

• Adding storage capacity to existing surface water reservoirs is more efficient than creating new reservoirs. (Vol. 1, No. 1)

In those earlier issues, the following major points were made concerning the great quantity of water untapped in South Florida:

• Annual surface water runoff to tidewater along the southeast coast is large, since this is an area of average annual water surplus. (Vol. 1, No. 3; Vol. 1, No. 6)

• If surface discharge to the ocean is held to a minimum, water adequate for foreseeable demands will be available. (Vol. 1, No. 1; Vol. 1, No. 3)

• Backpumping is a method for recovery of surplus storm runoff. (Vol. 1, No. 1)

• Deep underground storage is another method for capture and recovery of storm runoff. (Vol. 1, No. 6)

• Although small in quantity when compared with storm runoff, adequately treated wastewater has a potential for recovery and reuse. (Vol. 1, No. 6)

South Florida's vast subsurface aquifers were the subject of these factual comments:

• The prolific water table aquifers of the southeast coast are heavily used for municipal and industrial water supplies but, at present, are normally self-sustaining. (Vol. 1, No. 3)

• These aquifers, however, are subject to saline encroachment and during critical periods are dependent on more remote interior areas for stabilizing the salt front. (Vol. 1, No. 3)

• The volumes of water required to maintain aquifer integrity during critical periods are large and are an important water supply consideration. (Vol. 1, No. 6)

• The delivery of water from remote interior supply sources to the southeast coastal aquifers involves transmission inefficiencies. (Vol. 1, No. 6)

And the hard facts that must be considered in plans to backpump and capture rainfall runoff that is currently wasted were presented as follows:

- Urban and agricultural storm runoff are potential sources of pollution for receiving water bodies; estuaries, streams, marshes and lakes. (Vol. 1, No. 2)

- Placement of larger volumes of storm runoff into surface water storage reservoirs creates the potential for degradation of environmental quality. (Vol. 1, No. 2; Vol. 1, No. 8)

In this issue of In Depth Report an attempt will be made to assemble the above statements of fact in such manner as to create a rough, "first cut" approximation of a model for a water supply plan for South Florida. The types of investigations and studies which will be needed to test, modify, and refine such a model are indicated.

Lake Okeechobee is the "heart" of South Florida's water supply system. Major arteries are the primary canals connecting the Lake with the three Everglades Conservation Areas (1, 2 and 3).

Not Really a "New" Concern

WATER SUPPLY WAS A CONSIDERATION OF ORIGINAL FLOOD CONTROL PLAN

The original water resources program for central and southern Florida authorized by the Congress in 1948 was entitled, "Comprehensive Plan for Flood Control and Allied Purposes." Although the title emphasized flood control, and the impetus for authorization was the 1947 flood, water supply was not ignored. Two specific water supply and water conservation features included in the original authorization were raising the regulatory stages for Lake Okeechobee and creation of the three Everglades water conservation areas in Palm Beach, Broward and Dade Counties.

Recognition of the importance of water supply considerations was also evidenced in that early plan by the specific attention and emphasis given to control of salt water encroachment in the coastal areas. That plan authorized the replacement of existing "temporary" salinity barriers by more permanent type controls in all the major canals discharging to tidewater.

The 1948 plan considered the need to correct the past abuses of overdrainage. It recognized the region's potential for urban and agricultural expansion. Accordingly, it provided those measures believed necessary at that time to protect existing supplies and augment the total supply in the face of increasing demands on the region's water resource. The shortcoming of that plan from the standpoint of water supply was one of degree, not of kind. Future water supply needs were recognized, but were underestimated.

Nevertheless, the storage of surface water in Lake Okeechobee and the water conservation areas, and the protection of the shallow groundwater aquifers along the southeast coast are still, twenty-five years later, key elements in water supply planning for the region.

Attention Focuses on National Park

THE POTENTIAL FOR COMPETITION BETWEEN SOUTH FLORIDA WATER USERS

Immediately south of Lake Okeechobee are the deeper mucklands of the northern Everglades, now largely developed for agricultural purposes. Along the southeast coast are the sand and rock lands which support an incipient megalopolis, now containing a population of 2-1/2 million. Sandwiched between these is what remains of the Everglades floodway; the three water conservation areas. And, at the lower end of the floodway, is Everglades National Park.

The national park is uniquely water-dependent, as are the conservation areas. South Florida's agriculture involves the largest irrigated acreage east of the Mississippi. The "Gold Coast" population requires nearly 400 million gallons of water per day. All need water from the same source to supplement direct rainfall. The potential for direct competition for water, if not obvious now, certainly will be obvious in the future.

Attention was focused on the national park's water needs during the 1961-63 drought. A study of the water supply needs of South Florida, including Everglades National Park, was authorized by Congress in 1962 and 1963. The park's water requirements from the system to the north were defined in terms of recent historical hydrological observations. The issue of potential competition for supplemental water from the system was raised during the course of the study. The study, performed by the Corps of Engineers, resulted in a water supply plan for South Florida which was authorized for construction by the Congress in 1968.

The features of that water supply plan will be outlined subsequently herein. Pertinent at this point is the manner in which that plan addressed the questions of the park's water needs and the potential for competition for available water supplies.

And Priority Status In "Adversity"

CONGRESSIONAL ACT GIVES NATIONAL PARK MINIMUM ANNUAL WATER ALLOCATION

The plan authorized in 1968 accepted the National Park Service's figure of 315,000 acre feet as representing the minimum annual amount of supplemental water to be furnished the park from the system to the north. This total annual amount is to be delivered in accordance with a monthly schedule which ranges from a low of 2100 acre feet in April and May to a high of 81,000 acre feet in October.

The plan established these minimum deliveries as a specific objective of the project but stated that in times of water shortage the "adversity" was to be shared by the park with other water users. The plan contemplated making additional water supplies available in such quantity as to meet with a high degree of satisfaction of all projected demands to the year 2000. Thus, theoretically at least, the specter of competition for water between the park and other water users would be laid to rest until about the year 2000.

In some quarters at the national level there was dissatisfaction with the manner in which the twin questions of park water deliveries and potential competition had been addressed. Park water deliveries had been set forth as an objective rather than as a specific requirement, and a fixed procedure for "sharing the adversity," in view of potential competition for water, was not clearly defined.

These presumed deficiencies were rectified in the River Basin Monetary Authorization Act of 1970. In authorizing additional expenditures for the Central and Southern Florida Project, the act stated: "That as soon as possible . . . delivery of water from the central and southern Florida project to the Everglades National Park shall be not less than 315,000 acre feet annually . . . ." (underscoring supplied). In addition, the Senate Committee Report accompanying the act provided a formula for the park's "sharing of adversity" with only those other water uses which were in existence in 1970.

There is thus an additional dimension to South Florida's water supply picture. There is not only the requirement to meet the national park's minimum supplemental water needs. There is also the requirement to recognize the priority status of these needs with respect to water demands generated subsequent to 1970.

LAKE OKEECHOBEE IS THE HEART OF CORPS' WATER SUPPLY PLAN

The Corps of Engineers' water supply plan, authorized for construction in 1968, was the end product of several years of intensive study by a competent body of engineers, hydrologists, economists, agronomists and water supply experts. Both conventional and exotic means for augmenting water supplies were considered and examined. Many alternative surface water storage sites were considered and evaluated. During the course of the study several of the basic statements of fact listed in the introduction to this article were postulated, and their validity established.

The final plan is well documented and is a matter of public record. It will not be detailed here. Its basic features are those facilities needed to increase the water storage capability of Lake Okeechobee and those needed to recover storm runoff from the lower east coast by backpumping to the Everglades water conservation areas.

The first set of facilities provides the needed long-term carryover storage capability within the system. The second set provides a more effective shorter-term seasonal, or "transient" storage capability closer to the areas of increasing demand. These features in combination were found to be capable of meeting projected demands to about the year 2000. Performance studies indicated that demand would be met with a high level of satisfaction.

The dimension of the demand levels which the Corps of Engineers found could be met by this plan is indicated by the population and agricultural acreage projections which were used. The Corps projected a 1995 population in Palm Beach, Broward and Dade Counties of 4.8 million (nearly double the 1970 population). Developed agricultural lands within the study area were projected to contain 2.1 million acres by 1995, compared with 1.4 million acres in 1965.

The larger portion of the additional water made available by this plan derives from increasing the storage capability of Lake Okeechobee. In effect, the lake is the heart of this plan. To meet the water demands generated by the indicated projected levels of population and agricultural development it was found feasible to increase the lake's upper regulatory stage from the soon-to-be achieved 17.5 ft. level to 21.5 ft.

Obviously, under such a plan the lake will not reach a stage of 21.5 ft. every year any more than it reaches 15.5 ft. every year under the present schedule, nor will it reach 17.5 ft. annually under the 15.5 ft.-17.5 ft. schedule. However, by providing the capability to store water to higher levels, more water can be retained within the lake during years of high rainfall and runoff rather than releasing it to tidewater as would be the case with a lower regulation stage.

Figure 10 compares historical lake stages for the period 1947 through 1962 with stages which would have resulted had the 21.5 ft. schedule been in effect for the same period of time. The filling of the lake during the high runoff years of 1947 and 1948 will be noted. The carryover effect is illustrated in the period July 1953 through September 1956. Large water surpluses were generated in the 1953 and 1954 wet seasons, but 1955 and 1956 (through September) were extremely dry years. Under the 21.5 ft. regulation, portions of the 1953 and 1954 surpluses would have been carried over into the dry years with the result that entering the 1956 irrigation season the lake would have been 4 feet higher than it actually was.

As in the original plan, the 1968 plan considered raising Lake Okeechobee stages to be the key water supply feature. In developing the 1968 plan a much better assessment of projected water needs was made and, for the first time, the supplemental water needs of Everglades National Park were recognized as a demand to be supplied by the system.

The Two Sides of the Same Coin

WATER SUPPLY AND ENVIRONMENTAL QUALITY CONSIDERATIONS BROUGHT TOGETHER

In view of the degraded condition of Dade County's surface waters, in 1970 then-Governor Claude Kirk requested the institution of enforcement proceedings in Dade County. A Federal-State Enforcement Conference was held in October 1970 at Miami. Among the conclusions and recommendations adopted by the conferees was the following:

"A technical committee comprised of The Federal Water Quality Administration, the State of Florida, and the Dade County Pollution Officer shall be established to develop, in cooperation with other Federal, State and local agencies, a regional water quality management plan for the conservation and reuse of the waters of Dade County. This committee shall report to the conferees as to its progress and future plans by November 1, 1971."

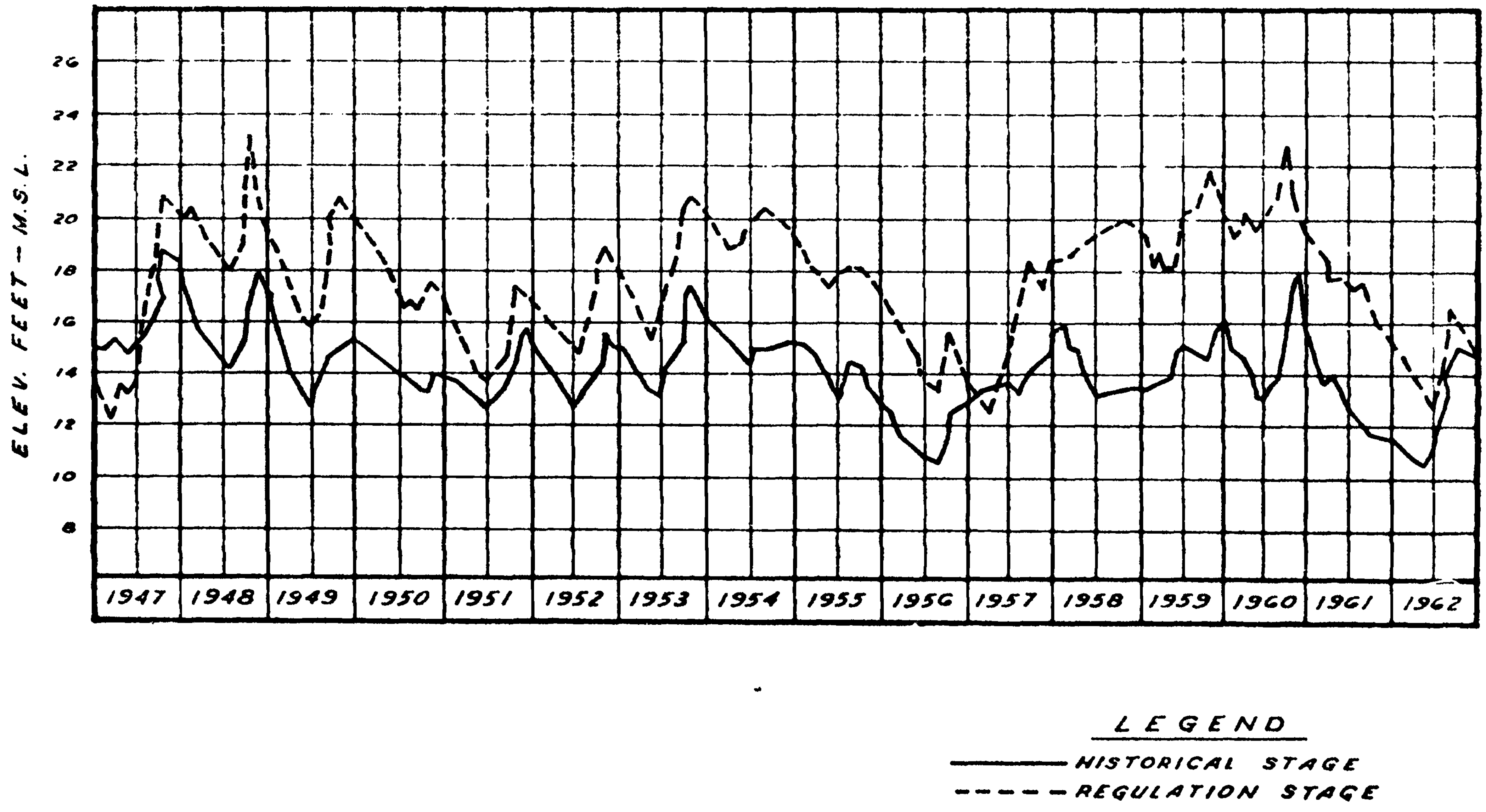


FIGURE 10
LAKE OKEECHOBEE STAGES WITH 19.5 FT. – 21.5 FT.
REGULATION SCHEDULE

The State's members on this committee were designated by Governor Kirk and these, together with the FWQA representative and the Dade County Pollution Control Officer, gathered together a group of recognized experts from various federal, state and local jurisdictions. This group was called "The Ad Hoc Technical Committee." By November 1971 this committee had completed and submitted to the Enforcement Conferees its report, entitled "A Plan of Study to Develop Alternative Decisions Required to Implement Wastewater Reuse and Storm Water Conservation in Southeast Florida."

The committee's view of the water supply question is summarized in the following quotation from the introductory section of its report:

"It is the consensus of the Committee that the most vulnerable points in the fresh water system of Southeast Florida under drought conditions are the intakes of the water treatment plants serving the public and the salinity control structures where fresh water is restrained from discharging into saline tidal waters.

"The Committee acknowledges severe drought damage suffered by agriculture and by the wildlife and vegetation of the Everglades and Everglades National Park but believes that drought is a natural occurrence for the Everglades and that these areas are self-restoring with the return of normal weather; whereas, salt water intrusion into fresh water zones underground or on the surface may cause irreparable damage.

"Further, the Committee believes that the reuse of wastewater in substantial amounts in times of drought to supplement present sources for urban water supplies and the storage and subsequent use of excess surface runoff for salinity barriers will also relieve demands on upstream storage areas.

"This plan of study, therefore, is designed to develop the requirements for reuse of treated wastewater and the storage and use of excess surface runoff at the most advantageous locations to serve as recharge for urban water supplies and (or) to maintain necessary groundwater stages to serve as salinity barriers."

The committee's viewpoint was particularly expressed in two of the conclusions presented in its report, as follows:

"Research is required to determine management practices and structural requirements to control the residual quality of treated wastewater and of surplus surface runoff, so as to prevent adverse impact on the environment."

"The study indicated by the preceding conclusions must be made in coordination with land and water use planning by the State of Florida for the purpose of determining supportable levels of economic development."

The report of the Ad Hoc Committee more closely defined the area of critical water supply concern. Perhaps more importantly, it emphasized the need in water supply planning for evaluating the environmental impact of alternatives and for considering water supply within a framework of land and water use. In these respects it suggests a water supply planning approach somewhat different than that used by the Corps of Engineers in developing its 1968 plan.

"More Is Not Necessarily Better"

A LESS TRADITIONAL APPROACH TO WATER SUPPLY PLANNING IS NEEDED

It is apparent that the traditional, conventional approach to water supply planning procedures, based on a limited set of values, should now be modified or even abandoned. The technology is still valid; but the philosophy which undergirds the application of that technology is changing. This change is probably still best expressed by the phrase which has become a present-day cliche: "More is not necessarily better."

Conventional planning for future needs has almost always started with a projection into the future of trends initiated in the past. Past population growth rates are extrapolated to future finite population levels at fixed time points. Past trends in per capita consumption of water are extended in similar manner. Future demands are fixed in this same general fashion for all types of water use. It is then left to technology to find the means whereby these demands can be satisfied. The procedure implies a general inability to exercise some degree of control over those factors which generated, for example, historical population growth and per capita water consumption trends.

Conventional planning procedures have usually based plan selection, performance being equal, on lowest tangible monetary cost and political feasibility (or expediency). Total cost, including cost in terms of environmental quality, was ignored. Even with the enactment of the National Environmental Policy Act the tendency to use the traditional approach still remains. One can still find instances of plan selection based on conventional cost considerations with the Environmental Impact Statement being written around the plan so selected.

Water supply planning for South Florida should be carried forward within a conceptual framework not necessarily fixed by the traditional procedures indicated above; a framework which:

1. Recognizes the existence of possible institutional means whereby historical trends in land use, population growth, water consumption, and hence water supply needs, can be modified without stopping economic growth; and

2. Provides that environmental impact assessment be an integral part of the process of evaluating and selecting alternative plan elements.

Within such a general framework, which will require further definition in the form of a rational analytical system, the approximate form of a water supply plan for South Florida can begin to be sketched in.

<u>Location of Storage Areas Important</u>

A "FIRST CUT" WATER SUPPLY PLAN EMERGES

Assuming that South Florida's economic growth will continue into the future at some as yet unspecified rate, we can also assume that this growth will generate additional demands on the region's water resources. These are valid assumptions. With these assumptions, but without reference to rate of growth which is not pertinent at this point, certain necessary features of a water supply plan for South Florida can be identified. These take into account the physical "facts of life" listed in the introductory section of this article.

A water supply plan for South Florida should:

1. Make maximum effective, safe use of the shallow water table aquifers and ensure adequate protection of local recharge.

2. Provide carryover storage capability at a point, or points, within the system and/or within the geographical limits of the region.

3. Provide storage as close to the areas of demand as possible.

Making maximum safe use of the water table aquifers involves several considerations. In many cases, municipal supply wells are located dangerously close to the salt front in the aquifer. At these locations withdrawals from the aquifer are already at, or beyond, the safe yield limit. Nevertheless, the reserve of water in the Biscayne Aquifer in particular, is enormous. Considering the total aquifer, its safe yield has not yet been reached.

Some of the considerations to be examined, therefore, are development of additional supply wells in interior areas, forward pumping of groundwater from interior areas into the canal system to maintain fresh water heads at the salinity controls, and installation of secondary controls in certain of the primary drainage canals.

In regard to carryover storage the question is not whether or not it is needed, but rather the amount which should reasonably be provided and where. Even if additional municipal supplies can be safely developed in the interior areas of northern Dade County and Broward County, as is quite likely, the existing supply wells closer to the coast must be protected.

At the very least, carryover storage within the system will be required for this purpose. Such storage cannot be provided in the conservation areas without high losses due to seepage and evapotranspiration, and without inducing probably undesirable changes in the Everglades environment.

Lake Okeechobee is still the prime candidate for provision of such storage capability, but it may also be possible to provide this capability by deep underground storage. If feasible, this would have the advantages of greater water storage efficiency (diffusion losses are likely to be less than evapotranspiration losses) and greater water transfer efficiency (by virtue of location of storage closer to the area of eventual use).

Recovery and storage of surplus runoff for later use is of vital importance to South Florida's water supply. Nearly as important, however, is the location of the storage areas with respect to the areas of demand, since the movement of water over comparatively long distances exposes the system to certain uncontrollable transmission losses.

Ideally, Lake Okeechobee should be counted on only to supply irrigation water to the agricultural lands adjacent to the lake and supplemental municipal water to northern Palm Beach County. The Park's minimum requirements should be supplied from the conservation areas. Finally, the lower east coast area should get its supplemental water from local storage (interior shallow groundwater reserve and deep underground storage), in combination, perhaps, with the Everglades conservation areas.

It may not be possible to achieve this postulated ideal situation. However, it appears quite possible that with backpumping such as contemplated at the West Palm Beach and Tamiami Canals the park's need can be met, leaving adequate surplus to meet a portion of the supplemental water needs of the lower east coast. Then if, for example, deep underground storage proves feasible, it is possible that large transfers of water from Lake Okeechobee may not be required except under extreme conditions.

A POSSIBLE PLAN, IN SUMMATION:

It appears at this point that a "first cut" model of a water supply plan for South Florida will include, in some combination, additional development of the shallow water table aquifers, backpumping from the lower east coast into the conservation areas, deep underground storage of storm runoff from the lower east coast, and storage in Lake Okeechobee (certainly to the 17.5 ft. stage now planned, possibly to some environmentally acceptable higher stage).

Types of Studies Needed Are Defined

MATCHING WATER WITH PEOPLE AND THE ENVIRONMENT

The refinement of a model such as that roughly described above will, among other things, require the quantification of its several elements. Some of the types of studies required are indicated:

1. Selection of a "design drought" condition. This will require a statistical analysis of return intervals for rainfall deficient periods of one, two and three years duration, and their degree of severity.

2. Determination of the safe yield of the shallow water table aquifers, related to the design drought condition or conditions. This would involve use, to the extent possible, of the analog model of the Biscayne Aquifer now in existence.

3. Deep underground storage research and development program involving a site adjacent to the Miami Canal in the vicinity of the Miami Springs-Hialeah well field. The program would involve determination of the carryover capability of the storage zone, recovery efficiency, water quality changes, and probable costs of injection and recovery. Figure 11 illustrates injection well construction through the various formations in the vicinity of the Miami Springs-Hialeah well field.

4. Determination of the performance of various backpumping options. This will involve long-term, short-interval routings of backpumped water to evaluate the time distribution of this water in terms of its availability for: (a) maintenance of the conservation area environment, (b) meeting Everglades National Park's minimum requirements, and (c) providing supplemental water to the lower east coast. Figure 12 is an example of this type of routing for the West Palm Beach Canal backpumping in relation to Conservation Area No. 1.

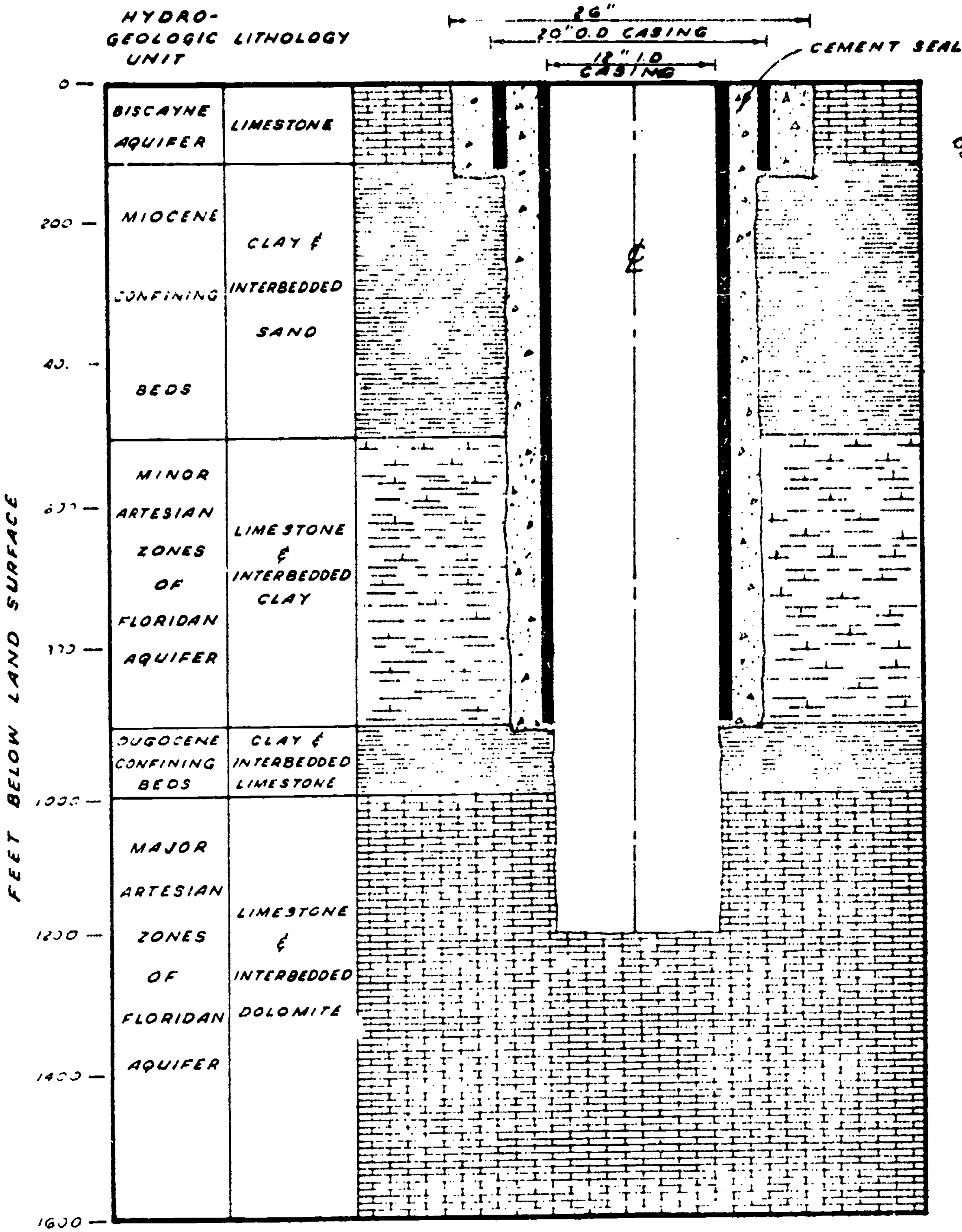


FIGURE 11

CONSTRUCTION OF TYPICAL INJECTION WELL IN VICINITY OF MIAMI SPRINGS–HIALEAH WELL FIELD (ADAPTED FROM U.S.G.S.)

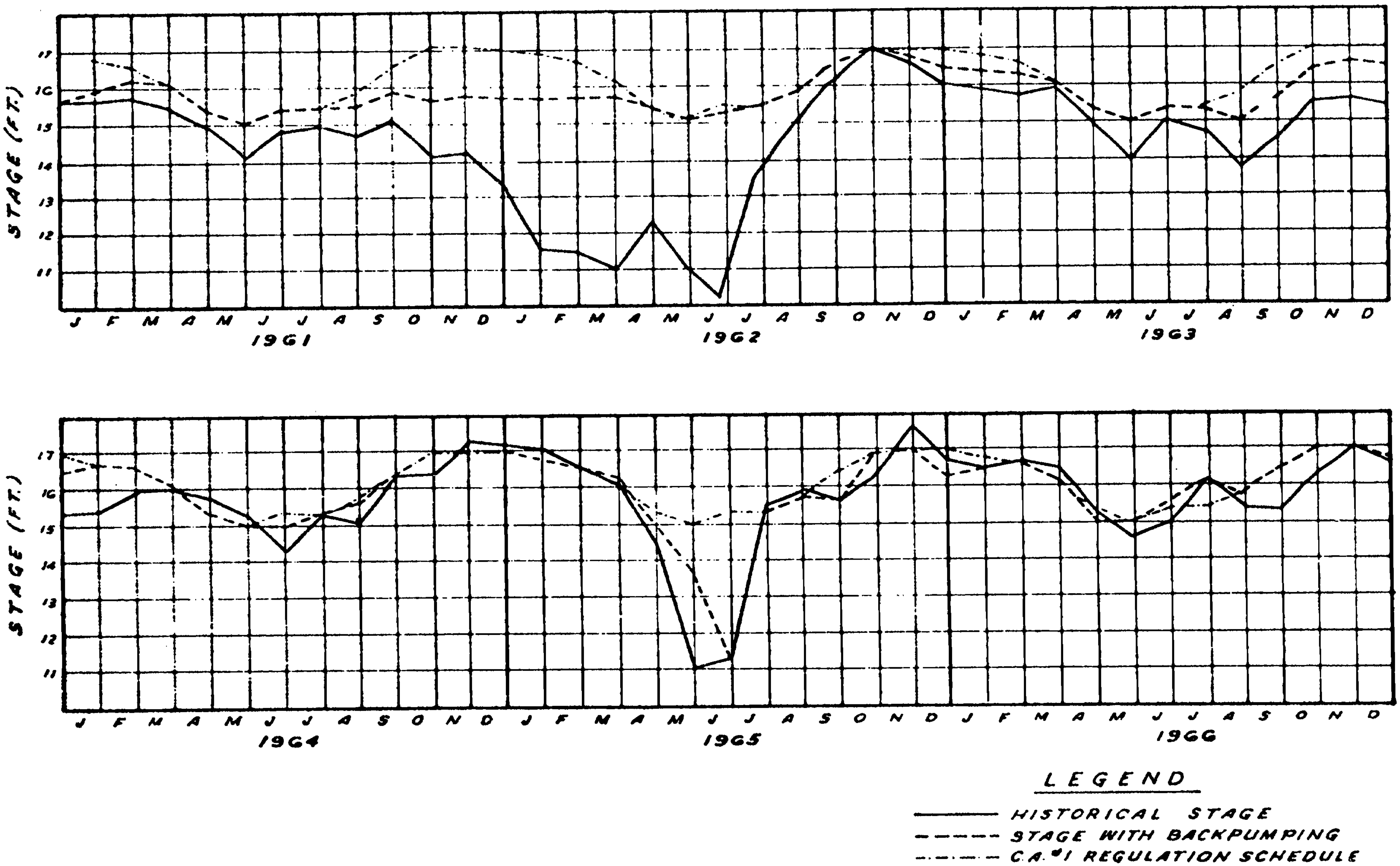


FIGURE 12

CONSERVATION AREA No. 1 STAGES WITH PROPOSED WEST PALM BEACH CANAL BACKPUMPING

5. Determination of quality of runoff water to be recovered and stored, and development of methods for controlling runoff water quality where necessary.

6. Water quality, biological and physical studies of Lake Okeechobee. This will involve procurement of additional data sufficient to develop a predictive model of the lake. If such a model can be developed and tested it would permit predictions to be made concerning changes in the lake environment under various water level regimes.

7. Determination of transmission efficiencies involved in the transfer of water from Lake Okeechobee to various points of use in Palm Beach, Broward and Dade Counties.

8. Refinement of an existing digital simulation model of Conservation Area No. 3, and application of this model to Areas 1 and 2. This model should permit certain environmental evaluations (from both quantity and quality standpoints) to be made of backpumping options.

9. Projection of changes, if any, in water use requirements in the agricultural areas south of Lake Okeechobee in relation to muck subsidence in that area and the resultant probable changing land use.

In somewhat general, perhaps oversimplified, terms it is expected that these, and other studies and determinations will indicate a water yield for a number of water supply options. In turn, the environmental impact of each option will have been evaluated. The water supply options could be assembled sequentially, in a variety of combinations, or in groups ordered sequentially.

Each water supply option would be associated with a certain population level, agricultural development level and population distribution. Theoretically, the end product would be an array of water supply options which would have associated with them a population and human activity level, an environmental quality evaluation, a cost and ability to pay estimate, and an implementation and/or management schedule.

An approach such as this, if soundly developed, would give the decision-makers a reasonable basis for matching people and activities with a water supply base and an environment of acceptable quality.

Time Is No Longer On Our Side

THE YEARS OF DECISION ARE AT HAND

The next three to five years will be the years of decision for South Florida in regard to water supply. Within this time frame an acceptable water supply and water use plan must be developed and its implementation started.

The concept of increasing the storage capability of Lake Okeechobee was incorporated in the original plan of 1948. It will be another two years before the raise to 17.5 ft. can be achieved. It will have taken 26 years to implement the key water supply feature of the original plan. Time is no longer on our side. It should be obvious that we cannot afford to take another 26 years to accomplish that which needs to be done in order to avert future severe shocks both to South Florida's economy and its environment.

A FEW FACTS & FIGURES
ABOUT THE FLOOD CONTROL DISTRICT

March 1973

Area of the District.. 15,200 square miles (This is more than three times the size of Connecticut.)

Number of Counties in the District............................ 18

	Year	Population	% of State's Population
Population of the District...............................	1950	803,887	29%
	1960	1,781,811	36%
	1970	2,852,930	43%
	1972	3,150,000	44%

1950 Assessed Valuations of all property within the FCD.. $1,193,233,000

1972 Assessed Valuation of all property within the FCD.. $22,367,495,790

Objectives of the Flood Control District:

1. Water supply (for all needs, including wildlife)
2. Salinity prevention
3. Flood protection
   (a) For areas with an acceptable land use plan
   (b) For areas where the Project is responsible for remedial flood protection works
4. Water conservation
5. Maintenance of desirable ground and surface water levels
6. Protection and enhancement of fish and wildlife
7. Preservation of important wilderness areas and their ecosystems
8. Public recreation
9. Navigation

Total Estimated Initial Cost of the Flood Control Project................ $581,000,000

(Federal and non-Federal) Note: The total includes the $76 million Water Resources Plan and the $15 million Martin County Plan authorized by Congress in August, 1968.

Federal Appropriations from 1948 to June 30, 1972 (Funds for construction and engineering)	$197,098,200
State Allocation through June 30, 1972 (This is principally "matching" money for construction.)	$ 67,914,204
FCD Net Income through June 30, 1972 (This money is used principally for acquisition of land and rights-of-way and for operation and maintenance of completed works.)	$ 99,293,264
Completion of Project to date	Approximately 50%
Year of Flood Control Project Authorization by Congress	1948
Year Flood Control District Created by Florida Legislature	1949
Latest Benefit-to-Cost Ratio	5.2 to 1 (That is, $5.20 in benefit coming back for every dollar spent to build the Project.)
Total number of FCD Employees	750
Total Miles of Canals and Levees now managed by the FCD	Over 1,400 miles
Total Miles of Canals and Levees when Project is completed	About 2,000 miles
Number of Spillways and Dams now operated by the FCD	More than 90
Number of Pumping Stations operated by the FCD	14
Capacity of Pumping Stations	Over 14 million gallons of water per minute

Major Works Completed and in Operation:

(1) Coastal Canals -- 32 canals extending a total of 410 miles, between Fort Pierce and the Keys, equipped with 44 water control structures. They serve metropolitan, urban, and developing areas. Cost: $37 million.

Major Works Completed and in Operation: (Continued) BEST C...

(2) East Coast Protective Levee -- Built in the 1950s, this levee extends more than 100 miles from a point southwest of Miami to Lake Okeechobee. It forms the eastern boundary of the three Everglades Conservation Areas. Excess water (from rainfall) is impounded behind this levee. Flooding of coastal cities is thus prevented.

(3) Three Conservation Areas -- Almost 50% of the original Everglades is preserved in a wilderness state in Palm Beach, Broward and Dade Counties. These water storage and wildlife areas cover 1,345 square miles. They are surrounded with levees, canals and water control structures. Excess water impounded here is diverted south to Everglades National Park. Conveyance channels crossing the interior of these Florida Glades augment water supplies to the Park in dry seasons. Cost of constructing conservation area works: $34 million.

(4) Everglades Agricultural Area -- South of Lake Okeechobee, an area of 700,000 acres is leveed and pumped. About 400,000 acres of the total is now in agricultural production. The rest will be developed in the future. The 20 levees and seven pumping stations serving this land cost $37 million.

(5) Lake Okeechobee -- A major levee (the Herbert Hoover Dike) has been constructed around the perimeter of the lake, a distance of 100 miles. This levee prevents a reoccurrance of hurricane driven wind tides, such as those that drowned 3,000 persons in 1926 and 1928. The levee also will make possible storage of two more feet of water in the big lake (the main source of water for South Florida). Cost: about $60 million.

(6) The Caloosahatchee River -- A 50-mile waterway project, between Lake Okeechobee and the Gulf of Mexico (at Fort Myers) has been completed. The River improvements serve a basin area of 1,200 square miles and also add discharge capacity for emergency releases from the Lake to tidewater when necessary. Cost of construction: $27 million.

(7) The Kissimmee River -- A 58-mile channel, between Lake Okeechobee and Lake Kissimmee, was finished by mid-1971. The widened and deepened river is equipped with six large dam and spillway structures, operated by the FCD. Each structure has a navigation lock 30 by 90 feet, designed to pass vessels of 5½ foot draft. The river improvements serve a drainage area of 758 square miles and provide an outlet for excess water from the Upper Kissimmee Valley. Impoundment areas upstream of each dam benefit fish and wildlife, and the FCD is planning to deepen and enlarge these impoundments. Cost of construction of the canal and structures: $[illegible]0 million.

(8) Upper Kissimmee River Basin -- To date 15 canals, equipped with eight water control structures, have been constructed, linking together 14 lakes in the Upper Kissimmee, in central Florida. The system, now about 3/4 finished, will serve an area of 1,633 square miles. Cost of construction to date: $3.4 million.

NOTE: The costs of land, easements, rights-of-way, and relocations are in addition to construction costs, above. These totalled $61,750,000 as of June 30, 1970.

Under Construction:

(1 Interceptor levees, canals and structures near the northeast shore of Lake Okeechobee, due for completion within a year.

(2) Pumping Station S-4 at Clewiston.

(3) S-163 (Wolf Creek Structure) on Levee 73.

(4) S-26 (Salinity Control Structure) in Miami Canal.

Deferred:

(1) The Upper St. Johns River Basin Project -- A $50 million system to provide water management for the 90-mile-long basin, inland from the Missile Coast, has been under construction three years, and could be completed in five more years, after environmental studies have been conducted. The FCD has acquired the majority of the 177,000 acres of reservoir and floodway land needed for this project. Construction expenditures to date -- for the Sebastian Canal (an emergency relief floodway between the St. Johns River and tidewater at Sebastian), and Levee 73 which will create the first of three large upland detention reservoirs -- have totalled $8.7 million.

(2) Canals in South Dade County, below Florida City -- This is part of a $20 million program to provide flood protection, water supply, and to benefit Everglades National Park.

Future Construction authorized by Congress:

(1) Improvements to West Palm Beach Canal (to cost about $20 million).

(2) Hendry County -- A project to levee and pump farming areas of 261 square miles southwest of Lake Okeechobee. Will cost $6.5 million.

(3) The remainder of t South Dade and Upper St. Johns River Projects (See Above).

(4) Shingle Creek and Boggy Creek Projects, south and southwest of Orlando. They will tie into the Kissimmee Basin Project to the south. Cost will be $6.3 million.

(5) Martin County -- A $15 million water control system for Martin County, which will also benefit St. Lucie County.

(6) A $76 million water resources project for southern Florida. This was authorized by Congress in late 1968. Bigger levees and additional structures around the perimeter of Lake Okeechobee will make possible storage of four more feet of fresh water in the Lake. The total project will also involve construction of pumping stations, to backpump east coastal canals, moving additional water westward into the Lake and Conservation Areas. Better water distribution facilities, from the Lake coming southward, will also be constructed.

Total Amount of Construction Contracts now underway throughout the FCD $10,500,000

Who pays for construction .... Federal & State Appropriations (Normally 80% federal and 20% state)

What is FCD Tax Money used for .... (a) Purchase of land and rights-of-way.
(b) Operation & maintenance of completed works.
(c) Administrative costs, salaries, wages.
(d) Public recreation (Expenditures limited to 1/50 of a mill per dollar of assessed property valuations in the FCD -- About $440,000 per year.)

FCD Tax Levy for 1972-73 in the 18 counties .... 52/100 of 1 mill per dollar of assessed valuation.

(The tax amounts to 52 cents per year for every $1,000 of non-exempt property value, according to county valuations.)

When will the Project be completed .... Depends on future appropriations

Area of Lake Okeechobee .... 730 square miles

Water Conservation Areas in Palm Beach, Broward, and Dade Counties .... Area 1 -- 221 square miles
Area 2 -- 210 square miles
Area 3 -- 914 square miles

Members of the FCD Governing Board who serve without pay:

(1) Robert L. Clark, Jr., Chairman, Fort Lauderdale
(2) C. A. (Mutt) Thomas, Vice Chairman, Lake Harbor
(3) Dr. John M. DeGrove, Boca Raton
(4) Arthur R. Marshall, Coral Gables
(5) R. Emmett McTigue, Fort Lauderdale
(6) Robert W. Padrick, Fort Pierce
(7) B. L. Pratt, Miami
(8) W. J. Scarborough, Lake Placid
(9) J. R. Spratt, La Belle

Executive Director, G. E. DAIL, JR.

State Appropriation for Fiscal Year 1971-72 .... $1,380,000

State Appropriation for Fiscal Year 1972-73 .... $3,385,400

Federal Appropriation for Fiscal Year 1971-72 .... $8,761,000

Federal Appropriation requested for Fiscal Year 1973 .... $8,750,000

Flood damages prevented - major storms January 1950 to June 1970	$194,258,000

ESTIMATED AVERAGE ANNUAL BENEFITS

Flood damage prevention	$ 36,691,000
Increased land use	$ 63,719,200
Recreation	$ 7,068,800
Water Supply (Agriculture)	$ 15,151,500
Urban Water Supply	$ 6,054,800
Fish, Wildlife & Navigation	$ 1,662,500
TOTAL ANNUAL BENEFITS	$130,347,800

CENTRAL AND SOUTHERN FLORIDA FLOOD CONTROL DISTRICT
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GLOSSARY

ACRE FOOT	A measure of water volume; the amount which covers an acre to a depth of one foot (about 325,000 gallons).
AQUIFER	Any portion of the earth's crustal layer which is capable of storing water and yielding water for use on the earth's surface. The water in such formations is called groundwater. The Biscayne Aquifer is a shallow "groundwater table" aquifer.
BISCAYNE AQUIFER	A porous limestone water-bearing formation underlying portions of Dade, Broward, and Palm Beach Counties.
BOD	Abbreviation for biochemical oxygen demand. The amount of oxygen necessary for the oxidative decomposition of a material present in the water by microorganisms.
CARRYOVER STORAGE	Reservoir storage capacity which will permit the retention of surface water surpluses for carryover to supply needs in subsequent periods of water deficiency.
COLIFORM GROUP BACTERIA	A group of bacteria predominantly inhabiting the intestines of man or animal.
CONFINING LAYERS	An impervious stratum or confining layer directly above or below one bearing water.
EVAPOTRANSPIRATION	Water withdrawn from soil by evaporation and/or plant transpiration.
HYDROLOGIC CYCLE	The circuit of water movement from the atmosphere to the earth and return to the atmosphere through various stages or processes, such as precipitation, percolation, and evapotranspiration.

ION	An atom or molecule that has lost or gained one or more electrons.
IRRIGATION DEMAND	Supplemental water applied to agricultural crops and lawns. A portion of this goes to supply the growth requirements of crops and grasses. The remainder returns to the system through percolation to groundwater and surface water return flow.
mg/1	Milligram per liter, a unit of the concentration of water or wastewater constituent. It is 0.001 gram of the constituent in 1000 ml of water. It has replaced the unit formerly used commonly parts per million, to which it is approximately equivalent, in reporting the results of water and wastewater analysis.
NUTRIENTS	Although many chemical constituents are required for plant growth, nitrogen and phosphorus are considered to be the primary nutrients. Both occur in inorganic and organic forms. The inorganic forms of nitrogen found in solution in water bodies are nitrates, nitrites and ammonia.
NUTRIENT BUDGET	An accounting of nutrient inputs and and outputs (usually nitrogen and phosphorus) for a water system.
PATHOGENIC ORGANISMS	Disease-causing bacteria.
pH	A measure of the hydrogen ion concentration (how acidic or basic).
PRIMARY TREATMENT	The first major treatment (sometimes the only) in a wastewater treatment plan, usually sedimentation.
SECONDARY TREATMENT	The treatment of wastewater by biological methods.

SURFACE WATER YIELD — The amount of surface water runoff from a watershed, or portion of a watershed, which leaves the basin. This is usually expressed in terms of "inches of runoff." This allows for ready comparison with rainfall, which is always expressed in inches. A very generalized figure for Southeast Florida is that average runoff approximates 20% of the average rainfall.

SUSPENDED SOLIDS — Solids that either float on the surface of, or are in suspension in, water, wastewater, or other liquids, and which are largely removable by laboratory filtering.

TERTIARY TREATMENT — Any treatment beyond secondary, commonly considered as advanced filtration or nutrient removal.

TRANSPIRATION — A vital natural element of the hydrologic cycle; the return of water to the atmosphere in the form of water vapor as a result of the growth process of vegetation.

VOLATILE SOLIDS — The quantity of solids in water, wastewater, or other liquids, lost on ignition of the dry solids at 600° C.

WASTEWATER — The spent water of a community. It may be a combination of the liquid and water-carried wastes from residences, commercial buildings, industrial plants and storm water that may be present.

WATER BUDGET — For any water system, an accounting over any fixed time span of where water comes from and where it goes.

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