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REPORT OF INVESTIGATION
OF THE ENVIRONMENTAL EFFECTS OF
PRIVATE WATERFRONT CANALS

By

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THE PRIVATE WATERFRONT CANAL REPORT
A RETROSPECTIVE VIEW

Every month, year after year, researchers are plagued with a deluge of government-funded reports of studies, surveys and investigations dealing with virtually every subject under the sun. The cost of these reports ranges from a few thousand dollars to millions of dollars each -- and their size and complexity range from a few pages to multi-volume epistles that could require months or years to understand.

The vast majority of these reports is buried in archives and are rarely seen or read other than by a few employees, scholars, and specialty researchers. A few make a temporary splash in the news media but are soon forgotten. But once in a while, a rare jewel with an impact that helps to influence the course of events is produced.

The enclosed Investigation on the Environmental Effects of Private Waterfront Canals is one of these jewels. It was prepared by the Environmental Information Center of the Florida Conservation Foundation at the request of Joel Kuperberg, then Director of Florida's Trustees of the Internal Improvement Fund, to be used as background information in determining state policy regarding the widespread practice of waterfront development of homesites situated around a network of canals excavated above the mean high water line.

The total cost of this investigation and report to the State of Florida was only $5,000. But its effectiveness can be guaged from the fact that a number of environmental engineering and consulting firms submitted proposals offering to make new studies to discredit this report, some of which were estimated to cost hundreds of thousands of dollars each.

Despite such efforts, the Environmental Information Center's report has withstood the test of time and is as valid today as it was when it was first released in February of 1972. It has been circulated widely across the nation and has helped to influence official policy, particularly in Florida and other coastal states.

At the time of this investigation no comprehensive studies had been made of the environmental impact of private waterfront canals and the only data that existed were fragmented and scattered bits and pieces developed by local and regional offices of Florida's state agencies.

The report is a compendium of these fragmented data which reveals that the networks of box-cut canals which were so popular as a profitable and easy method of providing thousands of people with high-priced "waterfront property" are not only disastrous to fish and wildlife, it also shows that they are a serious threat to the health and welfare of humans who inhabit homes adjacent to the canals, and to others who may wade or fish in them.

In anticipation of widespread attempts to discredit the information reported by other scientists and officials, the Environmental Information Center asked me if a sampling test could be conducted that would document how badly the canals are polluted, and in a manner that would be difficult to refute. I agreed, and a sampling test was made at 80 locations of 41 separate canal systems in Southwest Florida coastal areas.

In order to demonstrate, unequivocally, that there were organisms harmful to humans in these canals I chose to assay for an organism which is such a bad actor as to defy anyone to ridicule the results of our tests (if the proved positive). The logical choice was *Clostridium welchii*, alias *Clostridium perfringens*.

Like all organisms, some strains are harmless. But some strains of *C. perfringens* can cause: ulcerative lesions of the intestinal tract, food poisoning, the dissolution of red blood cells, various types of gastroenteritis, appendicitis, peritonitis, and gas-gangrene. It can only grow where oxygen is absent. So large numbers indicate a bottom slime where ordinary animal life is impossible. They originate in feces and can survive for long periods as highly resistant spores. Further, a method was available to detect and enumerate this organism in the presence of many other types of bacteria.

Of the 41 canal systems sampled, 70% had excessively high coliforms in their waters, 56% had high *C. perfringens* counts in sediments, and 83% had either high coliforms or high *C. perfringens.*

Our knowledge of the causes and the serious effects of water pollution has advanced tremendously since this report was written in 1972. A plethora of scientific studies have compiled a wealth of data which is reflected in comprehensive federal, state and local laws designed to clean up America's waters.

The enclosed report on the environmental impact of private waterfront canals, however, still stands alone as an example of the results that can be produced by a few dedicated, concerned citizens at very little cost to the taxpayers. It should also serve as an example to our bureaucratic agencies that the true value of a piece of work cannot always be measured by the high price tag (in taxpayers' dollars) placed on it.

John V. Betz, Ph.D.
Tampa, Florida
June, 1977

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INTRODUCTION AND PURPOSE OF SURVEY

Florida's subtropical climate and clear waters present diverse opportunities for outdoor recreation that attract millions of tourists and thousands of new residents every year. This influx of population has created a tremendous demand for waterfront property with convenient access to fishing, swimming and water sport areas. For many years, this demand has been satisfied by dredging and filling shallow bays and estuaries. Waterfront property is manufactured by finger-fills with deep, narrow canals dredged between the fingers, or by connecting such upland canal systems with natural waters.

Florida is uniquely vulnerable to this type of development. Unlike most states which have steep sloping beaches and rocky shorelines, Florida's terrain is flat. Most coastal areas are bordered by low-lying swamps and marshes which gradually blend into marine embayments, and it is often difficult to determine where the land stops and the sea begins. In many places, partially-submerged land, with water depths of only a few feet, extends miles into the sea. The loose surface sediments are easily excavated, and dredged material from canals and boat channels provides the fill needed to raise lowlands above sea level.

In recent years, the value of the estuaries and their surrounding marshlands as highly productive nursery and spawning grounds for marine life is becoming increasingly recognized. The destructive effects of dredging and filling of those submerged lands has been recognized as a serious threat to Florida's waters, its most valuable resource. (Consensus*) Steps were taken to control this method of development, and legislation, properly reflecting public concern, has curtailed dredging and

*"Consensus," as used in this report, reflects the opinions expressed by an overwhelming majority of the professional people interviewed for this investigation and whose names appear in the attached references.

filling of submerged lands which lie below the mean high water lines. Numerous laws, administrative actions, and court decisions offer confirmation that protection of submerged lands is in the public interest.

These restrictions have caused waterfront development to move inland with homesites situated around a network of canals excavated above the mean high water line.

At present, Florida has no restrictions governing dredging and filling on upland private properties. The only controls available to authorities are the permits required for dredging access channels which connect those upland canal systems to a navigable waterway, or which would utilize submerged lands or state-owned property.

Often the canal systems have been excavated and homesites sold before an application for dredging an access channel is received by the state. In these cases, responsible officials are caught in a dilemma. They must either grant what amounts to an after-the-fact permit or face the wrath of irate home buyers who have been promised waterfront property with access to a navigable waterway. (Consensus, field representatives in Department of Pollution Control and Game and Fresh Water Fish Commission)

Secretary of the Army, Stanley Resor, in a letter to the Governor of Florida (December 4, 1969) stated:

> "We are, of course, particularly concerned over the possibility that individual purchasers of home sites might be misled with respect to the character of the land in question or the date of anticipated dredging and filling activities. Developers should avoid making financial and other arrangements which assume the granting of major permit applications, since all such applications will, at the very least, be carefully reviewed at the Department of the Army level in Washington." (73)

Col. A. S. Fullerton, District Engineer of the Corps of Engineers, in a news release (July 20, 1970), was quoted:

> "Col. Fullerton also expressed concern about excavation on upland property which could later find its way into navigable waters. Fullerton said no one should assume that a Corps of Engineers' permit will be issued routinely, even though canal excavations are started on private upland property."

Projects involving massive canal systems are either underway or planned along coasts, streams and lakes throughout the state. These include inland waterways as well as along both coasts. If this trend continues unabated, Florida may eventually be blanketed by a labyrinth of artificial canal systems interconnected with publicly-owned waterways.

The purpose of this survey is to determine the impact of canal-type waterfront developments upon Florida's environment and the ways in which they affect the public interest. This survey was commissioned by the Trustees of the Internal Improvement Fund as background in determining new state policy.

SCOPE, METHODS AND TECHNIQUES

A review of existing literature revealed that a complete ecological study of private canal systems has never been made. The data available are primarily derived from water quality studies in conjunction with other projects and results are intermixed with numerous agency field reports.

In order to ensure that the scope of this investigation included private property canal systems over the entire state, and to ensure the greatest possible accuracy in our determinations, the above data were supplemented with an input of professional observations and opinions which were requested and received from the following sources: 1) federal, state, regional, county, and local pollution control field biologists and investigators; 2) Florida Game and Fresh Water Fish Commission biologists; 3) flood control and water management district hydrologists; 4) regional and local field agents for the federal Environmental Protection Agency, U.S. Geological Survey, Bureau of Sport Fisheries and Wildlife, and National Marine Fisheries Service; 5) state and county health department officials; 6) numerous private scientists specializing in particular areas; 7) scientists employed by major developers; and 8) private citizens and homeowners in canal-type developments.

The Environmental Information Center sponsored a special test for gas gangrene organisms in bottom sediments of canal systems in the Tampa Bay area which has been made an attachment (Appendix A).

The determinations presented in this report are a synthesis of information gathered from the foregoing wide variety of sources. Only those points which represent the consensus of professionals in this field, or which are supported by research data, are presented.

TYPES OF CANALS

Waterfront canals discussed in this investigation have been placed in two general categories: 1) finger-fill canals created by dredge and fill of submerged lands of bays, estuaries, lakes, or other wetlands; and 2) canals cut into upland property and connected to flood control channels, lakes, rivers, or other natural or artificial waterways.

A third category to which many of the same environmental characteristics apply includes drainage and flood control canals which carry runoff water from urban developments, agricultural areas and highways. However, this investigation is primarily concerned with private waterfront canal systems.

I. FINGER-FILL CANALS

The destructive effects of dredge and fill in bays and estuaries resulting in the elimination of highly productive marine nursery and spawning grounds is well documented and widely recognized. (Consensus) Florida's commercial and sport fishing industries and a large segment of its tourist industry are supported by food and sport fisheries which depend upon the estuaries for survival. (1,4,6)

In addition to the destruction of fish nursery and spawning grounds, the deep canals, channels, and borrow pits excavated into both saltwater and freshwater wetlands have other deleterious effects.

A. Effects on Fish and Fishing

A common fallacy regarding finger canals is that their depth provides a haven in which game fish thrive. This may occur in the very early stages after canal excavation. A typical pattern is that in the first few months of early spring, bottom animals and fish are abundant in newly-dug canals. However, with the advent of summer and hot weather, dissolved oxygen in lower waters drops to zero, or near zero. There is heavy mortality of benthic organisms and practically no fish are found. When cooler weather returns, benthic animals may recolonize newer canals and the fish move back in. But as dead and decaying organic materials gradually build up in the canal bottom, the number of marine creatures declines and eventually there is virtually no desirable biological production in the canal.

John L. Taylor and Carl Saloman in their studies of the effects of dredging in Boca Ciega Bay, stated:

> "...the sediments in undredged areas averaged 94 percent sand and shell whereas the sediments in dredged canals averaged 92 percent silt and clay."

The result is a paucity of sport and commercial species in these areas. (7)

Taylor and Saloman also found very little recolonization of benthic forms in ten year old box-cut canals and half as many species of fish in canals as in surrounding areas. They believe that the accumulation of organic material and low dissolved oxygen in these canals have a permanent adverse affect on fish and marine life.

A similar conclusion was reached by Dr. J. Kneeland McNulty after a study of the effects of abatement of domestic sewage pollution in Biscayne Bay in 1970. He found that in deeper, dredged portions where there is little current, the sediment is a soft, gray to black ooze of predominantly fine fractions. Comparisons of before and after pollution abatement showed drastic changes in macroinvertebrate populations. However, there was no evidence of improved commercial and sport fishing in dredged areas following abatement. McNulty interpreted this to mean that long-lasting detrimental effects resulted from pollution and dredging. (11) For instance, after abatement the soft sediments persisted, indicating the persistance of wastes once they have been allowed to accumulate.

Deep dredged canals and channels also contribute to massive fish kills in several different ways. A mass mortality of snook in Tampa and Boca Ciega Bays in 1966 was caused by a change in water temperature in deep dredged canals. The temperature of the deeper water stays warm into the winter months and fish take refuge from the cold water in these areas. Prolonged cold weather eventually lowers the bottom temperatures and the fish die. (7)

Taylor reports that kills of snook and other fish from this dredge-caused temperature change are a continuing problem, and the stench of rotting fish emanates from these areas until the fish sink to the bottom. The decaying fish add to the organic detritus accumulated in the bottom of finger canals.

The majority of Florida's fish kills are attributed to over-enrichment by pollutants which deplete the water's dissolved oxygen below fish survival levels. (Consensus) Fish kills due to oxygen depletion in canals are often caused by the leaching of decaying organic material and hydrogen sulfide from anaerobic bottom sediments. (14,15,16,19,20,27)

B. Adverse Effects of Excessive Depths

1. Stagnation and Anaerobic Conditions

With rare exceptions, deep excavations are little affected by normal tidal action and currents. The movement of water in Florida's shallow bays and estuaries flows across the surface of these steep-walled channels leaving the deeper water relatively undisturbed. The lack of water movement causes static conditions with virtually no flushing action to remove accumulated debris. Thus, box-cut dredged channels become sediment traps for dead and decaying organic material. These accumulated materials exert a tremendous oxygen demand upon overlying waters, dissolved oxygen is depleted and anaerobic (no oxygen) conditions prevail. (7,8,11,12,13,14,15,16,17,18, 19,20,65,77,78,79,80,83)

This characteristic has been observed in the open Gulf of Mexico as well as in bays, estuaries and canal systems. (11,12,13,14)

This is almost universally the characteristic condition of areas dredged to depths greater than the surrounding terrain. (7,8,11,12,13,14,15,16,17,18,19,65,77,79,80,83)

John W. Bellinger, a fishery biologist with the Bureau of Sport Fisheries and Wildlife in Vero Beach, stated:

> "Dredging (both hydraulic and dragline operations) has a variety of possible adverse effects, including removal of established marine sediments and associated biota, creation of water depths in which plant communities can no longer survive, creation of pockets which can trap organic materials and lead to conditions of low, even anaerobic, oxygen levels, and the always present dangers of siltation, increased water turbidity, and salt water intrusion." (5)

Taylor and Saloman also stated that canal bottoms in Boca Ciega Bay are far too deep to receive light required for the growth of sea grass. Turbidity from dredging limits biological production and resulting sediments are dark, semi-fluid and usually sulfurous. They are predominantly organic, consisting of accumulations of decomposing detritus. (7)

2. Temperature Stratification

In a study of a number of box-cut canals in the Florida Keys, Dr. James O'Hara, a University of South Carolina ecologist, found a distinct temperature stratification in all canals deeper than 15 feet. The warmer, upper layer usually had ample oxygen and supported a heavy plankton bloom. At depths of 10 to 12 feet, the water was sharply divided, with colder, clearer water extending from the stratified layer to the bottom. Algae were absent in the bottom water and no marine life was detected. Dissolved oxygen dropped sharply at the stratification zone with anaerobic conditions prevailing throughout the lower layer. Decaying vegetation and detritus was accumulated on the bottom and hydrogen sulfide gas was concentrated throughout the lower layer of water.

Stratification was apparently due almost entirely to depth, regardless of proximity to open water or canal configuration. (12)

Similar problems have been reported from other sections of the Gulf Coast, and it is reasonable to assume that additional investigations will disclose temperature stratification as a common characteristic of salt-water canals dredged to excessive depths. (19)

C. Odors

Additional problems usually encountered in deep-dredged finger canals throughout the state are foul odors emanating from hydrogen sulfide gas, decaying algae and other wastes which collect under anaerobic conditions. These odors are often quite pronounced at various times of the year and cause numerous complaints from waterfront property owners. (Consensus)

Taylor and Saloman observed windrows of the alga *Ulva lactuca* in bayfill access canals after residents reported objectionable odors in the central part of Boca Ciega Bay. These and other filamentous algae become fetid as they decompose. (7) Similar conditions are common in finger canals throughout the state. (Consensus)

Hydrogen sulfide, a poisonous, corrosive gas which smells like rotten eggs, emanates from decaying algal mats under anaerobic conditions. It is lethal to marine life, exerts a powerful oxygen demand upon overlying waters and has a corrosive effect upon metals, paint and other materials. It is present in practically all of Florida's salt water canals and is readily detected whenever bottom sediments are disturbed. (7,12,19,20,22,23)

Hydrogen sulfide emanating from canals has turned white paint black on nearby homes (7) and contributes to fish kills both by its poisonous effect upon marine life and by contributing to the reduction of oxygen in overlying waters. (14,16,19,24,25,26)

D. Effect on Receiving Waters

The accumulation of organic sludge and poisonous waste in deep dredged channels and canals presents a threat to marine life in large sections of bays and estuaries. (15,16,20,24,25) A 1970 study of Escambia Bay by the Federal Water Quality Administration (now incorporated into EPA) disclosed that a deep channel dredged for the construction of the I-10 bridge, and the canals of Escambia Shores, contribute significantly to the massive fish kills which occur regularly in Mulat-Mulatto Bayou. The report states, "The borrow area has become a settling basin for suspended organic material including algal organisms. The very high oxygen demand of this material has totally depleted DO (dissolved oxygen) and has turned this area into an anaerobic digester of organic wastes. During the ebbing current, this deoxygenated water and suspended and dissolved waste material is carried into Escambia Bay as previously discussed, and into the main section of Mulatto Bayou....The combination of waste input; poor circulation caused by alteration of the natural physical configuration; and dredging practices are the major causes of the fish kills occurring in Mulat-Mulatto Bayou." (16) *(Emphasis added)*

A report by P. J. Doherty, Regional Engineer for the Department of Pollution Control in Pensacola, describes the condition of the Escambia Shores canals. 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.
>
> "...Conclusions:
>
> "(1) Poor flushing action in deadend canals allows a buildup of organic material (including dead fish). This material requires oxygen for aerobic decomposition. Sufficient oxygen is not available to decompose large amount of organic material and anerobic decomposition occurs, causing the release of hydrogen sulfide gas.
>
> "(2) Anerobic conditions deplete the dissolved oxygen in the canals. Dissolved oxygen can usually be supplied by a combination of algae, sunlight and wind action during daylight hours in sufficient quantities to overcome the demand by the sediments, but the oxygen is not usually supplied after dark and it is rapidly depleted.

"(3) Fish go into the canals during daylight hours when sufficient dissolved oxygen is available in the water, but become trapped after dark when the oxygen is depleted. They can be killed by either the lack of dissolved oxygen or the increase of hydrogen sulfide gas which is no longer being oxidized.

"(4) The dead fish in the canals are not removed from the canals rapidly because of poor flushing. As they decay, they add to the organic matter in the sediments. Septic conditions occur because of the anerobic conditions and maggots have been seen breeding in abundance.

"(5) The poor quality water in the canals mixes with adjacent water, adding to their degradation.

"...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." (14)

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 bays and canal systems. In their opinion, situations exist in many other areas which can produce similar environmental and economic disasters if pollution becomes as severe as it has in Escambia Bay. (7,19,20,24)

II. UPLAND CANALS

Whereas the environmental problems presented by finger-fill canals primarily involve saltwater and marine ecosystems, upland canals may affect saltwater, freshwater or a combination of both environments. Many of these canal networks are located long distances from receiving waters with one or more box-cut navigation channels serving as the sole means of water circulation and exchange. In addition to their effect upon coastal areas and marine life, upland canals encounter problems with freshwater fish and fishing, underground water supplies, aquatic weeds and inland bodies of freshwater.

A. Effects on Fish and Fishing

The fallacy that canals provide a haven in which game fish thrive is also a common belief of upland canals. This misconception is partially due to the fact that most of these canals are excavated into dry land areas where fish could not exist prior to canal construction. Therefore, if any fish at all exist in such upland canals, it can be stated that fishing has been improved.

As with finger-fill canals, upland canals may provide good fishing during the early stages after canal construction. However, they are virtually a closed body of water which serve as nutrient traps which accumulate dead and decaying organic materials, with the same results as in finger-fill canals. In freshwater canals, this is accompanied by explosive growths of noxious aquatic weeds. Decaying vegetation accelerates eutrophication and reduces dissolved oxygen in the water below the point where desirable fish can survive. Thus, in typical upland canals, water quality deteriorates, dissolved oxygen is depleted, fish kills occur, and eventually few, if any, desirable species exist. (Consensus)

The rare exceptions are large canals adjacent to undeveloped swamps and marshes, such as in the conservation areas. (61) However, these waterways present an entirely different situation from canals in urban areas which are primarily designed to provide waterfront property. Such marshland canals are not the subject of this investigation.

1. Fish Kills

The importance of dissolved oxygen conditions in subsurface water is indicated by the massive fish kills in Escambia Shores canals which occur repeatedly during the summer. Measurements of DO taken from surface waters in these canals on bright, sunny days would be extremely misleading because photosynthesis provides an abundant supply of oxygen, and fish survive. At night and on overcast days, anaerobic bottom sediments and plant respiration deplete the oxygen in surface waters and the fish die. (14,20,23,25)

Very few complete DO studies have been made of Florida canals. Those studies which are available indicate that anaerobic bottom conditions prevail. Many have conditions similar to the canals in Escambia Shores but to a slightly lesser degree of severity. The regularity of summer fish kills in these and other canals where fish do exist is additional evidence that anaerobic conditions are characteristic of upland canals. (Consensus)

This is supported by a United States Geological Survey report on the water quality in Broward County, Florida, by Rodney G. Grantham and C. B. Sherwood (1968), which states:

> "When the dissolved oxygen becomes very low, there are often problems of odor, floating sludge, and killing of fish and aquatic life. It is generally established that 5 ppm dissolved oxygen is necessary to support fish life. In extreme cases when the dissolved oxygen is totally depleted, there is no self-purification of the water and a septic condition develops." (44) *(Emphasis added)*

A few examples for which data are available are:

Every known canal, both primary and secondary, in both Dade and Broward counties is anaerobic at one time or another, and fish kills are a regular occurrence in many. (28,29,30,31,32,75)

The Kissimmee Canal, C-38, which has an average depth of 25 to 30 feet, is anaerobic or near anaerobic below depths of approximately 10 feet and the lower two-thirds of depth will not support desirable species of fish. There is little flow due to impoundments and DO levels drop from roughly 3.0 to 3.5 ppm at 10 feet, to less than 1 ppm at the bottom. (35)

Recurrent fish kills in Palm Beach County upland canals, particularly in the vicinity of Palm Beach Gardens and the P.G.A. Golf Course, are an indication of anaerobic conditions. (36)

Dissolved oxygen profiles of Marco Island canals show anaerobic and near anaerobic conditons in lower layers of water. (53)

Fish kills occur so regularly in Port Charlotte canals that Game and Fresh Water Fish Commission personnel no longer bother to investigate them. (38,39)

Additional fish kills in canals are reported by field investigators throughout the state and the unanimous opinion of these and other experts is that a lack of adequate dissolved oxygen due to an accumulation of organic material is a chronic characteristic of canals in Florida. (Consensus)

This stagnant condition of canal water magnifies the adverse effects from pollution, accelerates eutrophication and leads to degeneration into septic conditions which can endanger the health of both animals and humans.

The fact that greater numbers of fish are not killed in private waterfront canals, and that some of the very old canals do not experience fish kills, is attributed to water of such poor quality that few fish are attracted to these areas. (Consensus)

2. <u>Dissolved Oxygen</u>

Per Bruun of the University of Florida Coastal Engineering Laboratory in "Bay-Fills and Bulkhead Lines," 1959, defines a "stagnant pocket" as a body of water having no adequate exchange with adjacent bodies of clean water. Bruun states that "dead-water" pockets have little or no free oxygen, often have an offensive odor, and collect all kinds of debris. He goes on to say that deeper pockets are more objectionable and generate more odor than shallow pockets.

Dr. Bruun was referring to finger-fill canals in estuaries; however, the universal lack of circulation which is characteristic of Florida's upland canals converts these waterways into elongated "stagnant pockets." The question of an adequate supply of free oxygen in these canals is a subject of some controversy between representatives of developers and public officials because of the wording of Florida's laws governing the specifications for water quality.

Chapter 17-3 of Florida's Administrative Code specified the criteria for DO for both Class II (shellfish harvesting) and Class III (recreation, fish and wildlife) water as follows:

> "(5) Dissolved Oxygen--shall not be artificially depressed below the values of four (4.0) ppm (unless background information available to the regulatory agency indicates prior existence under unpolluted conditions of lower values.) In such cases, lower limits may be utilized after approval by the regulatory authority." (47)

However, the law does not specify at what depth, or depths, or times, DO measurements shall be taken and some reports which conclude that adequate dissolved oxygen conditions exist are based upon samples taken only from surface waters under optimum conditions. Such measurements do not reflect the true quality of the water and can be extremely misleading.

In some states, where procedures have been set, the accepted approach is that DO measurements be taken 5 feet off the bottom in canals 10 feet or more in depth or, in canals less than 10 feet deep, taken from a depth halfway to the bottom. A more accurate test of water quality, especially in stratified waters, should show DO profiles at various depths from the surface to the bottom.

An example of dissolved oxygen variations at different depths is shown in a 1971 report on water quality in an environmental study of Punta Gorda Isles canals by Connell Associates, Inc. "The data collected on September 21 and 22 show a marked decrease in dissolved oxygen below 4 feet at each station." Dissolved oxygen test charts accompanying the report indicate anaerobic conditions at the bottom of most of the canal test sites, although adequate DO was shown at the surface in the majority of cases.

B. Effects of Excessive Depths

1. Stagnation and Anaerobic Conditions

The stagnation and anaerobic conditions common to finger-fill canals are primarily attributed to excessive depths and box-cut configuration of the excavations. These factors also contribute to the deterioration of water quality in upland canals. Often the primary objective of canal-type development is to obtain fill material for building up lowland properties. The need for material often leads to excavating canals to depths greater than is necessary for small boat navigation and similar uses. (Consensus) Also, in upland canals, the problems created by excessive depths are compounded by other factors.

2. Temperature Stratification

Temperature stratification is apparently a phenomenon primarily associated with saltwater canals of excessive depth and inadequate circulation. At present, no evidence is available of similar conditions existing in Florida's freshwater canals and anaerobic conditions prevailing in these waterways is due to other causes.

C. Odors

Many of the complaints received by public agencies from owners of property on upland canals are of foul odors emanating from those canals. The odors are usually associated with deteriorating water quality accompanied by decaying vegetation, accumulated detritus, floating algal scums and dead fish. Hydrogen sulfide gas and other odor-causing detritus accumulated on canal bottoms may be stirred and brought to the surface by the action of boat propellers or turbulence from wind conditions, releasing foul odors which spread to surrounding communities. (Consensus)

In numerous canal communities, offensive odors convert canalfront property into a detriment rather than an asset. (Consensus) The effect of such odors on property values has not been evaluated.

D. Stagnation from Inadequate Circulation

The problems of adequate circulation in upland canals which are some distance from receiving waters are more acute than those of finger-fill canals. In coastal areas, the prime mechanism for water exchange is produced by tidal effects. In Florida, the tidal range varies from a few inches to a maximum of only about 3 feet. This is not conducive to good flushing because 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 of tidal action, creating almost stagnant conditions. (17,19,24,28, 29,30,31,32,33,34,65,82) This is true not only of deadend canals; interconnected systems and flood control channels exhibit the same characteristics with a lesser degree of severity.

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 only a few inches per mile, and few regions provide elevation differences of more than a foot per mile. (U.S. Geological Survey) Thus, shallow, freshwater canals also have sluggish or static flow conditions.

That practically all of Florida's canals are plagued with inadequate circulation and flushing has been obtained from field investigators and biologists with the Department of Pollution Control and the Game and Fresh Water Fish Commission. The consensus of these, and other experts, is that few of Florida's private waterfront canal systems provide sufficient circulation to obtain adequate flushing. (Consensus)

Additional evidence, reported by agents in every region and almost every county in the state, is that the bottoms of canal systems in Florida have an accumulation of organic sediment and detritus. In older canals, this sludge is several feet thick, often filling the canal to within a few feet of the surface, sometimes completely displacing the water and rendering the waterway unusable. (Consensus)

A Dade County Department of Pollution Control investigation disclosed that in canals adjacent to outfalls, deposits of sewage sludge have accumulated to depths 10 to 12 feet thick, often within a few inches of the water surface. (30,31,32) (See Appendix B) Even the release of tremendous volumes of storm-water by the Central and Southern Florida Flood Control District (FCD) does not create sufficient current to displace this sludge, while these discharges create other deleterious environmental effects. At other times, the water in FCD channels is virtually static. (28,29,30,31,32,35) Objects placed in a tributary canal 500 yards from the New River require three complete tidal changes in order to move this short distance. (33) Water near the bottom experiences even less circulation from this combination of wind and tidal currents. (12,20)

Sewage sludge studies underway in Broward County canals were not completed at the time of this investigation, but Mr. R. T. Willcox, President of the New River Civic Association, states that a Harbor Patrol boat went aground on sewage sludge accumulated in the New River.

Some hydrologists and coastal engineers maintain that adequate circulation in certain types of canals in specific areas can be obtained by designs which follow detailed advance mathematical calculations. However, no such systems are known to exist in Florida and a characteristic which is virtually universal in present box-cut canals, both finger-fill and upland, is poor circulation and inadequate flushing. (Consensus)

E. Aquatic Weeds

The explosive growths of aquatic weeds which plague many of Florida's waterways are usually accompanied by overenrichment of the water by manmade sources of pollution. (Consensus) The growth of vegetation in water utilizes nutrients and releases oxygen in much the same manner as vegetation on land. An over-abundance of nutrients stimulates an unnaturally lush growth of vegetation. This is especially characteristic of exotic weeds which are controlled by few, if any, native forms of wildlife, and which compete successfully under these artificial conditions with desirable native plant species.

Because of the polluted condition characteristic of canals, these simplified systems are extremely vulnerable to heavy infestations of one or a few species of aquatic weeds. This is supported by reports from regulatory agency investigators and other experts which indicate that virtually all fresh water canals in Florida are subject to infestation by such heavy growths of weeds that use of the waterways for navigation, fishing, flood control, or other purposes is virtually impossible until the weeds are removed. (Consensus)

Studies of the Oklawaha River also indicate that some of Florida's natural rivers are more resistant to noxious aquatic weeds than artificial canals. Dr. David S. Anthony, a University of Florida biochemist, states:

> "The established communities of potentially noxious exotic aquatic weeds in the lower Oklawaha River are associated with artificial canals or impoundments. These canals have been excavated by individuals as access channels for upland property. The natural river system is resistant to invasion by objectionable exotic weeds. This is particularly true of submersed exotics which, to my knowledge, are not established in objectionable quantities in any portion of the natural river." (50)

Canals are suspected to be sources of noxious weed infestations which spread to adjacent waters. (39,46) Submersed aquatics which invaded the Butler chain of lakes were suspected of spreading from adjoining canals. Boat traffic is a major means by which the weeds are transported from one area to another. (46) Also, many lakes, such as Crooked Lake and Lake Tarpon, remain relatively free from weed problems while surrounding canals are heavily infested. (39)

The accepted method of aquatic weed control is by the use of herbicides in concentrations strong enough to kill the weeds. Although many of these chemicals are lethal to fish and other aquatic life, it is claimed that their use under controlled conditions by skilled experts does no permanent harm, according to Robert D. Blackburn, USDA. However, under certain conditions, herbicides strong enough to kill the weeds will also cause fish kills. The quantity of chemicals recommended for waterweed problems in Port Charlotte canals is an example.

A request directed to the Aquatic Plant Research and Control Coordinator of the Department of Natural Resources, stated that the canals were infested with broadleaf water-milfoil "from bank to bank and almost bottom to top." Permission was requested to use copper sulfate and 2,4-D amine in quantities and methods recommended by Mr. Blackburn. It was admitted that the concentrations of copper compounds recommended would cause a fish kill but it was claimed that lower concentrations would not satisfactorily control the watermilfoil. (52)

The water in Port Charlotte canals is used for domestic supplies but the request contained calculations indicating that the copper and amine in the herbicides would not reach the water treatment plant in quantities sufficient to be a hazard. (52)

Many of the fish kills which occur regularly in fresh water canal systems are attributed to the effects from herbicides and decomposing vegetation. (13,28,30,36,38,39,51,65) Weeds killed by chemicals sink to the bottom where they decompose, adding to the oxygen-demanding wastes accumulated in canal sediments. In addition to their toxic properties, the chemicals applied in weed control are also oxygen-demanding materials. Thus, chemical control of aquatic weeds eliminates the benefits of nutrient removal and oxygen production from growing vegetation and substitutes an additional load of oxygen-demanding material. The result is a reduction of dissolved oxygen throughout the water column and the fish suffocate. (Consensus)

Chemical weed control, when combined with the stagnant condition, low dissolved oxygen and heavy pollutional load characteristic of canals, causes a rapid acceleration of eutrophication, chronic fish kills, the accumulation of algal scums, offensive odors and eventual degeneration into septic conditions. (Consensus)

III. SOURCES OF POLLUTION - ALL CANALS

A. Urban Storm Water Runoff

Storm waters from residential communities are normally collected in street drains, storm sewers and drainage ditches and channeled into receiving waters. In private developments having canals, waterways replace some of the streets and serve as convenient receptacles for all manner of pollutants. These include insecticides, herbicides, fertilizers and animal excrement washed from lawns, gardens, parks and parkways; oil, grease and other materials derived from automobiles, service stations, garages and junk yards; chemical products from auto washing, laundries and similar activities; and garbage, refuse, and trash washed or thrown into the waterway. All of these pollutants accumulate in the canals to decompose eventually under anaerobic conditions. (Consensus)

Dr. Luna B. Leopold in Geological Survey Circular #554 (1968) states:

> "Of all land-use changes affecting the hydrology of an area, urbanization is by far the most forceful."

His studies show that in residential areas with homes on 6,000 square foot lots, runoff volume is 80 percent. In areas with lot sizes from 6,000 to 15,000 square feet, runoff decreases to 40 percent. Where lot sizes are 15,000 square feet or more, runoff is only 25 percent. (21)

That storm water runoff from residential areas is a major source of water pollution is often overlooked. Studies show that this water often contains concentrations of organic and toxic material comparable to that of raw domestic sewage. (40,41,42)

1. Nutrients

In an attempt to prevent aquatic vegetation from interfering with recreational use of Green Lake, located near a residential section of Seattle, Washington, investigators found that stormwater runoff in street gutters contained such high concentrations of pollutants they reportedly recommended discontinuance of most stormwater drainage into the lake, and the addition of 10,000 gallons per day of city water supply to the lake to prevent overenrichment. (40)

Field studies of a 27-acre residential and light commercial urban watershed in Cincinnati started in 1962, showed that stormwater was a "highly significant" pollutant. In the conclusion, the authors state:

> "Constituent loads...calculated both on an annual basis and on the basis of daily discharges during storms, and compared with sanitary sewage production at a 9-person acre...population density, indicated that the pounds (kg) of suspended solids discharged annually in the runoff equal 160 percent of those produced as sanitary sewage; COD, 33 percent; BOD, 7 percent; total hydrolyzable phosphate, 5 percent; and total nitrogen, 14 percent. During runoff, stormwater runoff constituent discharge rates, expressed as percentages of average raw sewage constituent production rates...at the same population density mentioned above, are: suspended solids, 2,400 percent; COD, 520 percent; BOD, 110 percent; total hydrolyzable phosphate, 70 percent; and total nitrogen, 200 percent." (40) *(Emphasis added)*

2. Bacterial Contamination

Florida statutes governing the bacteriological criteria for Class III waters state:

> "Coliform group not to exceed 1,000 per 100 as a monthly average, (either MPN or MF counts); nor to exceed this number in more than 20% of the samples examined during any month; nor exceed 2,400 per 100 ml (MPN or MF count) on any day. This criteria shall apply only to waters used for body contact activities." (47)

Coliform bacteria counts exceeded 460,000 per 100 ml in 10 percent of the samples of the Cincinnati study and were in excess of 2,900 per 100 ml in 90 percent of the samples. The presence of both fecal coliforms and fecal streptococci demonstrated microorganisms derived from warm-blooded animals, either animal or man. (40)

In another study, a single stormwater sample yielded Salmonella thompson (pathogenic to man):

Total coliforms of 3,800,000 per 100 ml

Fecal coliforms of 450,000 per 100 ml

Fecal streptococci of 370,000 per 100 ml

Tests showed that chlorination with free chlorine is no assurance that virtually all coliform and pathogens will be eliminated. Despite high chlorine treatment, "total coliforms experienced aftergrowth." (42)

The investigators stated that such concentrations of pollutants are not acceptable to natural bodies of water, such as free-flowing rivers and streams used for recreation or higher uses. In stagnant canal waters which do not have the benefit of normal aerobic stabilization, these pollutants accumulate and decompose under anaerobic conditions, and their effect is far more severe than in natural waterways. (Consensus)

B. Septic Tanks

More than half of Florida's canal-type developments utilize septic tanks for municipal sewage disposal. (Consensus) In many areas, soil conditions or population density reduce the efficiency of septic tanks to the point where untreated sewage is leached into the waterways, yet many counties still permit their installation in new developments. (Consensus)

A land-use planning study of the Florida Keys states that none of the soil in Monroe County is suitable for septic tanks. A high water table combined with extremely porous soil nullifies the filtering capacity and virtually raw sewage is leached into the waterways. Approximately 90 percent of the Keys utilize septic tanks, many of which drain into canals. (43)

The soil in recharge areas of the Biscayne Aquifer in South Florida is described by the U. S. Geological Survey as "about as porous as loose gravel" and the water table is so high that there is a free exchange between water in the canals and the aquifer. (44) Yet over 50 percent of Dade and Broward counties are on septic tanks and a federal-state pollution conference in December 1971, disclosed that Dade commissioners continue to permit septic tank installations in new developments. (45) Broward County is reported to have approximately 80,000 septic tanks, many of them serving canal-front homes and other buildings. The Stranahan High School, with 3,166 students, utilizes septic tanks for sewage disposal, as do the Broward Education Department building and the Police Department building, all of which are adjacent to the New River Canal or its tributaries. (33)

U. S. Geological Survey data showed that similar porous soil conditions exist in many areas of Florida, particularly along the coastal plains where underground water tables are usually very high. The consensus among experts contributing to this investigation is that a substantial proportion of the pollution reaching canal waters can be attributed to septic tank installation. (Consensus)

These opinions are substantiated by other studies. W. L. Mallmann and W. N. Mack (1961) reportedly showed that bacteria introduced into a permeable soil by a septic tank seepage field moved 10 feet in 2 days, 20 feet in 3 days, and appeared in a well 30 feet away after 10 days. (21)

Dr. Leopold states:

> "The observations indicate that, for soil cleansing to be effective, contaminated water must move through unsaturated soil at least 100 feet....It would seem prudent that no septic tank should be as close to a channel as about 300 feet, if protection of the stream water quality is to be achieved.
>
> "Even this minimum setback does not prevent the dissolved materials (nitrates, phosphates, chlorides) from enriching the stream water and thus potentially encouraging the proliferation of algae and otherwise creating a biotic imbalance." (21)

An additional hazard from septic tanks in areas with high underground water tables is the danger of overflow during periods of torrential rains. (43)

C. Sewage Treatment Plant Effluent

Canals provide a convenient disposal site for domestic sewage effluent, both treated and untreated, and are used widely for this purpose throughout Florida. (Consensus)

Due to a lack of adequate public sewage facilities provided by either counties or cities, the trend in many newly developed communities has been toward a proliferation of small privately-owned and operated treatment facilities and the so-called "package" plants. (45) These small systems, as well as larger municipal systems, tend to become overloaded as communities expand, with the result that inadequately treated effluent is often discharged into canal systems. (Consensus) The proper operation and maintenance of a sewage treatment system requires a trained technician which small, privately-owned plants rarely can afford to hire. The proliferation of these plants makes adequate supervision by enforcement agencies extremely difficult. (Consensus) Enforcement problems combined with a well-publicized lack of adequately trained treatment plant operators are additional factors contributing to the discharge of poorly-treated sewage into canals.

Chapter 17-3.04 of the Florida Administrative Code required that all discharges from municipal and privately-owned domestic waste plants receive 90% treatment (secondary) or better not later than January 1, 1973. This law does not prohibit the discharge of sewage effluent into any public body of water but gives discretionary power to the regulatory agency to impose more stringent standards of treatment where required in order to maintain water quality standards. (47)

The "schoolbook" solution to abatement is to start from the point of discharge and work back in order to determine the required degree of treatment. For some of Florida's receiving waters, this method would require 100% treatment. (45)

Secondary treatment removes most of the organic material and bacteria from domestic sewage but does not remove dissolved contaminents such as phosphates, nitrates and other chemicals. These are oxygen-demanding materials which, when discharged into canals which are already oxygen deficient, contribute significantly to the degradation of water quality. Tests show that bottom sediments in anaerobic finger canals contain many times more phosphates, nitrates and similar nutrients than surrounding bottom areas. (16,48)

The present trend by regulatory agencies in new developments is toward methods of containing sewage effluent rather than discharging into receiving waters. This is achieved by oxidation ponds (spray irrigation) and evaporation-percolation ponds in which a combination of ground percolation and evaporation removes all effluent, leaving virtually no discharge. However, this is not a set policy but is a discretionary judgment of the regulatory agencies based upon an evaluation of each individual situation. (45) Existing privately-owned domestic waste treatment plants will continue to discharge into canals until replaced by larger municipal facilities. (45,46,75)

It is reasonable to assume that under present policy and laws, additional small, privately-owned sewage treatment facilities will in some cases be authorized to discharge effluent into canal systems. It is also reasonable to expect continuing problems from overloaded and inadequately treated sewage due to a lack of trained operators and enforcement problems.

D. Boats and Houseboats

In addition to the usual pollution problems associated with boats, such as discharges of gasoline, oil, bilge water, garbage, refuse and similar materials, many of the larger canals are utilized by live-aboard vessels which present problems of sewage disposal. The usual practice for all boats is to discharge sewage and other wastes directly into the water. In coastal areas, live-aboard vessels are frequently docked in canals and used as residences, especially during the winter tourist season, and these contribute a significant quantity of pollutants to canal waters. (28,29,49)

E. <u>Canal Water Quality</u>

Dr. Landon T. Ross, Regional Biologist, Florida Department of Pollution Control, in a memorandum of July 1, 1971, said:

> "It has been hypothesized that up-land dead end canals will result in a future lowering of water quality because of 1) an increased amount of available nutrients because of an increased residential density in the immediate area, and 2) an increased rate of flow of nutrients into the body of water because of the destruction of natural shoreline "nutrient traps" (i.e., mangroves and other near-shore vegetation). Because of a low rate of water exchange in dead end canals, these nutrients may be expected to accumulate until, eventually, an uncontrolled amount of plant growth will occur. Such plant growth, in the form of algal blooms, will result in oxygen depletion and fish kills. Dead fish cause additional strain on the available oxygen levels of the system, as well as providing higher nutrient levels. Once this stage is reached, positive feedback is operative, and remedial measures seem to be either drastic or of little value.
>
> "The situation described above can be immediately recognized as being equivalent to natural aging or eutrophication in any body of water. The <u>rate</u> of eutrophication, however, seems to be much greater in dead end canals than in natural bodies of water. In a closed system, the rate of eutrophication can be more or less directly correlated with the ratio: nutrient input/water volume. If the body of water in question is surrounded by residential areas, nutrient input may be correlated with population density or with length of shoreline. Using the ratio shoreline length/water volume it may readily be seen why artificial canal systems are likely to have a rate of eutrophication several orders of magnitude higher than natural bodies of water." (77)

F. pH as an Indication of Water Quality

An example of the change in water quality in a single canal may be determined by pH data. Tests taken of canals by James W. Carr, Regional Biologist, Department of Pollution Control, Jacksonville, showed that dead end finger canals changed up to over 100-fold in hydrogen-ion concentration. Carr explained the significance of this change in pH:

> "Although a change in pH values of 0.162 appears insignificant, it is noteworthy to mention that even a small decrease or increase in pH values means a considerable rise or fall in hydrogen-ion concentration. For example, a rise or fall in pH value by 0.1 roughly means a 100% decrease or increase respectively in hydrogen-ion concentration. A change of one unit on the pH scale indicates a tenfold or 1000% change in hydrogen-ion concentration. The chemical reactions necessary for self purification by streams and the biochemical reactions of organisms only take place at a certain pH value or within a narrow pH range, depending upon the specific reaction. Discharging of artificial canal waters increases the "buffer loads" on these natural waters slowly degrading the water quality. Organisms must be able to survive as much as a hundredfold hydrogen-ion change within distances of five hundred feet.
>
> "Increased nutrient loading of the artificial canals by concentrating surface water run off and septic tank drainage combined with intense sunlight increasing photosynthesis can lead to alkaline conditions in a stream due to removal of carbon dioxide by green plants. When the dissolved oxygen concentration approaches 150% of saturation, fish develop maxillary diseases and dropsy. With the development of 'algae blooms' the dissolved oxygen is utilized by the respiratory energy cycles producing an increased carbon dioxide levels above normal. At high concentrations of carbon dioxide the ability of fish to extract oxygen from the water is impaired. The accumulative effects of rapid pH changes, increased carbon dioxide concentrations, and decreased dissolved oxygen concentrations, 3.0 ppm or below, produce the fish kills so common in these artificial canals." (66)

IV. EFFECTS ON PUBLIC HEALTH AND WELFARE

The human health hazards associated with water pollution in Florida are normally judged by the number of coliform bacteria present. High densities of coliforms are an indication of fecal contamination, either human or animal, which can cause serious infections or diseases in man. These diseases may be contracted by ingesting small amounts of polluted water while swimming or bathing; or from touching the mouth while hands are wet with contaminated water; or from ingesting food handled with wet hands. Infections may be caused from water in open wounds or body openings. Skin infections can also be acquired from contact with seriously polluted water.

Bacteria in fish are usually destroyed by cooking. However, infections can be incurred from handling or cleaning contaminated fish before they are cooked.

Florida Administrative Code 17-3.09 defines Class III waters as, "...waters to be used for recreational purposes, including such body contact activities as swimming and water skiing; and for the maintenance of a well-balanced fish and wildlife population." Most of Florida's inland waters, including artificial waterfront canal systems, are designated as Class III, and thus coliform bacteria counts that exceed 2,400 per 100 ml on any day are in violation of federally approved Florida Statutes as unsafe for body contact.

Class II waters (shellfish harvesting) under Florida Statutes have more stringent bacteriological criteria than Class III, and coastal canals affect the water quality of estuaries where shellfish are normally harvested.

The consensus of sources contacted in this investigation was that the heavy pollutional load, inadequate circulation, and generally poor water quality which are characteristic of box-cut labyrinthine canal systems lead almost inevitably to contamination from fecal bacteria.

Few reports are available of complete bacterial studies in artificial canal waters but existing data tend to verify that a large percentage of canals are unsafe for body contact because of fecal contamination.

A. South Florida Canals

Woodrow W. Smith, Broward County pollution control officer, states that practically every canal in the county will exceed state standards for coliform contamination and, therefore, are unsafe for body contact. (28,54) Data show extreme fluctuations in coliform densities in samples taken at the same location over a period of time. In the Sunrise Canal, samples taken in February 1969 showed coliform counts of only 45 per 100/ml. In June 1970, the same location had counts of 3,200 per 100 ml, and in January 1971, counts were 150,000 per 100/ml. Sample stations in location on other canals show a similar wide fluctuation, ranging from less than 100 per 100/ml to well above dangerous levels of 5,000 to 10,000 per 100/ml. (54)

Extensive data on Dade County canals show serious fecal contamination and health problems throughout the system and field inspectors state that secondary canals pose major problems in maintenace and pollution. (30,75)

Jim C. Eggert of Dade County Pollution Control stated:

> "Health problems can be expected in many of Dade's waterways. Our records show high MPN counts in many waterways. Several lakes have received much publicity because of eutrophication. With ideal conditions some of the blue-green algae can become toxic to animals. So far, there have been no records of human deaths. Reports of skin rash have been noted....Botulism, type C, is common in Dade County. Many birds have been killed by this toxin. Health problems occur with the occurrence of dead fish and animals in public waterways.... Fish taken from Dade's canals at times appear to be undesirable for eating. Proper cooking should eliminate any danger involved, although the taste may be somewhat unpleasant (muddy)." (30)

(The complete report of Mr. Eggert dated October 13, 1971 on the condition of Dade County canals is attached as Appendix C.)

The health hazards from the buildup of sewage sludge in Dade County canals is obvious. In addition to the coliform densities in these areas which range as high as 500,000 to 1,000,000 per 100/ml, many of these sludge piles are so close to the surface that submerged sewage could be touched by persons reaching from a boat. (31,32,55)

Additional health hazards are indicated in a report by C. Morrissey et al. of the Dade County Pollution Control on conditions in the Oleta River.

This report states that over 400,000 gallons of sludge have been deposited on the bottom of the river over a distance of 1/3 mile. Bacteria counts of 160,000 or more per 100 ml were found downstream from the outfall. The odor of sewage and hydrogen sulfide gas was pronounced. Fecal sludge deposits on bank and sewage pop-ups in water create a definite health hazard. (55)

That similar conditions exist in practically all of the South Florida canals is verified by a FWQA report "Pollution of the Waters of Dade County, Florida" (1970) (75) and by a U.S. Geological Survey report "Chemical Quality of Water of Broward County," (1968). Also, Frank Kleeman stated that the dredging of a canal system usually results in an ecological disaster because canals collect all of the pollutional loads imposed by concentrations of people. What starts out as a delightful asset turns out to be a detriment in that it ultimately turns into an open sewer. The lower oxygen levels cannot support many species of fish or other marine life, and so fish kills occur with resultant odors. Some canals have coliform counts ranging from half million to a million per 100 ml. (29)

B. Other Canals

Few data are readily available on the extent of bacteriological contamination of canals in other areas but the samplings that have been made indicate that fecal contamination is far more prevalent in canals than in natural open bodies of water. Data provided by the West Central Region of the Department of Pollution Control show that finger canals bordered by residences have considerably higher bacterial counts than adjacent lakes. (48) Some of the finger canals bordering Lake Lowery had MPN coliforms as high as 30,000 and 35,000 per 100/ml. A number of the canals bordering other lakes also had coliform counts which made them unsafe for body contact. The water of lakes bordered by these canals had very low coliform densities. (48)

Reports from field agents in the Southwest Region of the Department of Pollution Control state that many canals show "serious fecal coliform densities." This is supported by bacteriological data in canals of Punta Gorda Isles, Inc. which show a substantial number with MPN coliform counts above 2,400 per 100/ml. Densities of 2,400 per 100/ml on any day make such waters unfit for body contact by Florida statute. (48,56)

C. Bottom Sediments

In addition to the bacteriological criteria established for Class III waters, Florida Administrative Code 17-3.02 defines the minimum conditions for all waters as:

> "17-3.02 Minimum conditions of all waters; times and places.
> "The following minimum conditions are applicable to all waters, at all places and at all times. Within the territorial limits of this state all such waters shall be free from:
>
> "(1) Settleable Substances -- substances attributable to municipal, industrial, agricultural, or other discharges that will settle to form putrescent or otherwise objectionable sludge deposits.
>
> "(2) Floating Substances -- floating debris, oil, scum, and other floating materials attributable to municipal, industrial, agricultural, or other discharge in amounts sufficient to be unsightly or deleterious.
>
> "(3) Deleterious Substances -- materials attributable to municipal, industrial, agricultural or other discharges producing color, odor, or other conditions in such degree as to create a nuisance.
>
> "(4) Toxic Substances -- substances attributable to municipal, industrial, agricultural, or other discharges in concentrations or combinations which are toxic or harmful to humans, animal, plant, or aquatic life."

Accumulations of organic detritus and anaerobic conditions which are characteristic of box-cut labyrinthine canals present the probability that bottom sediments contain concentrations of toxic materials and pathogenic organisms which pose a hazard to human health. Bacteriological data were woefully lacking on these sediments and it was considered imperative that an effort be made to determine the potential of this hazard.

1. Study of *C. welchii* (Gas gangrene anaerobes and related forms)

In a separate study, the Environmental Information Center made arrangements with Dr. John Betz, a University of South Florida microbiologist, to analyze samples taken from canals in the Tampa Bay area.

The method used was that detailed by: Marshall, Robert S., J. Frank Steenbergen and L. S. McClung (1965), Rapid Technique for the Enumeration of *Clostridium perfringens*, Applied Microbiology 13 (4) : 559-563.

Since this is not a standard method and may not be familiar to all persons who review this report, it should be explained that the methods used in this test would give conservative results, and any overriding error would lead to a low estimate of the true bacterial number, not a high count. Also, the results reported were the lowest count justified by the data. Thus, a report of 1,000 gas gangrene anaerobes could be as high as 9,999--or even 99,000 if single cells were counted rather than clumps of cells.

The data using these conservative methods and counts show:

- 63% of all samples had coliform counts of 2,400 per 100/ml or greater
- 45% of all samples had gangrene anaerobe counts over 1,000 per 100/ml
- 32% of all samples had both a coliform count of over 2,400 per 100 ml and a gangrene anaerobe count of over 1,000 per 100 ml.

In several instances, a number of samples were taken from different locations in the same canal in order to compare conditions at inland "dead ends" of canals with location near the mouth.

When results are summarized on the basis of the number of separate and distinct bodies of water, a more meaningful evaluation of the degree of canal pollution appears. On the basis of 41 separate canals and canal systems, the results were:

- A coliform count of 2,400 or more in 70% (29 of 41)
- A gas gangrene count over 1,000 in 56% (23 of 41)
- High counts of both coliform and gangrene anaerobes in 44% (18 of 41)
- Either high coliform or a high gangrene anaerobe count in 83% (34 of 41)

2. Conclusions

The potential health hazard posed by the gross fecal pollution in bottom sediments shown in this test is obvious. Other bacteria present with the gangrene organism are often of equal virulence. Gangrene, tetanus, streptococcal or staphylococcal blood poisoning can be incurred from untreated cuts. Gastroenteritis (stomach and bowel upsets) can be caused by various bacterial toxins such as from *Salmonella* and *Shigella*. Ear and urinary tract infections can be caused by *Proteus*, *Pseudomonas* and others which are a complex and little understood spectrum of virus diseases. (57, Appendix C)

The condition of the canals which produced these results is typical of the older, box-cut canal systems throughout Florida, and it is reasonable to assume a similar study of other canals adjoining expensive and often prestigious property would produce similar results.

Data are not available on the incidence of infection and illness caused from contact with polluted canal waters. However, a logical assumption is that the unsightly appearance and offensive odor of these waterways prevent people from utilizing them for body contact activities. This is supported by reports from field investigators that in many canals the boat docks and landing facilities are unused and in disrepair. Also, a number of waterfront homes have eventually erected high walled fences to block the waters from view and to protect children and pets from straying into the water. (Consensus)

It is also reasonable to assume that the incidence of infections and diseases is increased from contact with contaminated water and data provided through a cooperative program with the medical profession would be useful.

V. EFFECT OF CANALS ON UNDERGROUND WATER SUPPLIES

The effects of canals upon groundwater supplies are well documented. The Governor's Conference on Water Management in South Florida (1971) reported:

> "There is a water crisis in South Florida today.... The quantity of water, though potentially adequate for today's demand, cannot now be managed effectively over wet/dry cycles to assure a minimum adequate water supply in extended drought periods."

The conference report went on to state:

> "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."

The conference also recommended that there should be no further draining of wetlands for any purpose. (63)

There is no question that private waterfront canal systems have had an effect on underground water supplies. The majority of these developments are located on flood plains adjacent to rivers and lakes or on coastal lowlands where the ground water tables are usually very shallow. (Consensus) Often the primary purpose of these excavations is to obtain inexpensive fill material to raise the land above flood levels and the canals become deep incisions into the shallow aquifer. (Consensus)

A United States Geological Survey report on the chemical quality of waters of Broward County, by Rodney G. Grantham and C. B. Sherwood (1968), indicates the extent to which canals affect ground water. They state that there is a free exchange of water between canals and the aquifer, and that the fresh water in both flood control canals and interconnected tributary canals is called a major natural resource.

> "During the dry season inflow to the canals is from inland areas where ground-water levels are higher than canal levels, but in coastal areas controls are closed, canal levels are higher than ground-water levels and water generally flows from the canals into the aquifer. Thus the period when canals are the primary supplemental source of replenishment to ground-water supplies occurs when effluent wastes in the canals are most concentrated." *(Emphasis added)*

> "Water having pH values below 7 are acidic, and water having pH values above 7 are alkaline....in unpolluted water, nitrate usually does not exceed 10 ppm....Where both chloride and nitrate concentrations are above normal for an area the possibility of contamination by human or animal wastes should be investigated....Most people can detect a salty taste in water when the chloride reaches 200-300 ppm. Water containing a sulfate concentration of about 250 ppm may have a laxative effect on some people."

Public water supplies in Florida are required to meet U. S. Public Health Service standards for drinking water. However, each public water supply system provides its own water analysis to the Health Department. (44)

Grantham and Sherwood reported that ABS (detergents) in the water of Broward County wells was suspected of coming from septic tanks into the canals. They also reported that increasing amounts of arsenic detected in drinking water wells in 1962 and 1965 was suspected of originating from weed spraying with herbicides and/or from agricultural or industrial effluents released to canals. High fluoride concentrations were found in the Pompano Canal, a high chloride content in the Hollywood canal, and pesticides in the Plantation and Snake Creek canals. (44)

The investigators stated:

> "The interchange between the aquifer and the canal system contributes to the contamination of the waters of Broward County. There has been, and will continue to be, problems of pollution and salt-water intrusion."

In view of the anaerobic conditions and generally poor water quality characteristic of the box-cut canals, it is reasonable to assume that similar problems will develop in all areas where these systems are cut into fresh water aquifers.

A. Saltwater Intrusion

Saltwater intrusion into coastal water supplies is caused by extensive drainage or pumping which lowers groundwater levels. By lowering the freshwater head, a saltwater wedge is permitted to move inland at depth in the aquifer. In Dade County, saltwater encroachment has been most extensive along canals. (64)

Less understood but equally important is that drainage programs which lower inland water tables can also cause saltwater intrusion in coastal areas which are many miles away. Cherry *et al.*, in General Hydrology of the Middle Gulf Area of Florida, states:

> "All streams, lakes, springs, sinks, and aquifers in the Middle Gulf area are part of a much larger complex hydrologic system....Generally, factors that affect water levels in one of the components of the system will affect water levels in another component to some degree..." (18)

Many of Florida's rivers and streams are fed largely by ground water. An example is Crystal River which receives an inflow of underground water from a drainage area of 80 square miles. Seeps in the many canals excavated into limestone bedrock contribute to the flow of Crystal River. Numerous drainage canals and boat channels constructed in and near the town of Homosassa Springs are also cut into the aquifer. Lakes Hancock and Neff, connected to the aquifer by sinks, have been greatly reduced in size and depth in the last few years. Neff Lake has become essentially a wet prairie. This is due to a lowering of aquifer water levels, either from overpumping or drainage by canals, or both. (18)

Cherry et al. (1970) stated:

> "It can be foreseen that, before many years have passed, the coastal communities will have outgrown their average annual local water crop and will have to look for other sources, or reuse the recycle (sic) existing supplies on a vast scale." (18)

B. Depletion of Water Supplies

The depletion of underground water supplies by extensive canal construction is stressed in repeated warnings by the United States Geological Survey and private hydrologists and geologists. J. S. Rosenshein, Subdistrict Chief, U.S.G.S., Tampa, Florida, stated,

> "In the Crystal River area the limestone aquifer lies close to the land surface and may be readily breached during construction of finger canals; thereby, releasing substantial quantities of water....seeps occur in many canals excavated into the limestone bedrock." (58)

A U. S. Geological Survey booklet, "Large Springs of Florida's Sun Coast (1970)," provides additional warnings. The interdependence of underground and surface sources is indicated by the fact that aquifer water levels fluctuate with the tide and that the flow of springs is affected by tidal fluctuations. (59)

Each foot of fresh water above sea level indicates 40 feet of fresh water below sea level. Whenever fresh water levels at the coast decline to or near sea level, sea water moves up coastal streams and into the aquifer. Any set of conditions, either natural or influenced by man, that markedly decreases the level of fresh water, decreases the freshwater discharge and permits sea water to move further inland. Extensive drainage canals may permit saltwater intrusion and cause springs to become more saline. (59)

There is no doubt that waterfront development canals are causing saltwater intrusion. (60,76) In Citrus County, developers are cutting canals into underground springs, then advertising "spring fed canals." The excavations relieve the pressure in the artesian aquifer, underground water levels are lowered, and salt water moves inland. (60,76)

A number of field investigators report observing an inflow of groundwater into dead-end canals.

VI. EFFECT ON RECEIVING WATERS

Few studies have been made and few data exist regarding the effect of upland private canals on adjacent natural bodies of water. Anaerobic bottom sediments from finger canals and borrow pits contribute significantly to the massive fish kills which occur in Escambia Bay each year. (16) Also, evidence exists that anaerobic sediments flushed into Lake Okeechobee from Taylor Creek and muck farm canals by heavy rains, cause massive fish kills. (61) 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. (3,19)

Siltation resulting from dredging of finger canals can affect extensive areas beyond the immediate area of operation, and has been a matter of concern for many years.

The consensus of persons interviewed for this investigation was that extensive private upland canal systems also cause similar environmental degradation in receiving waters, and for the same reasons attributed to major channels. It is believed that stormwater runoff from torrential rains into canal systems causes a stirring and mixing of anaerobic bottom sediments. Rain-caused circulation washes these into receiving waters in concentrations which are often sufficient to cause fish kills and other damage. In some cases, a "slug" of anaerobic sediments may be flushed into receiving waters by torrential rains or tides. Under these conditions, the large quantities of toxic material accumulated in canals over a period of years could be flushed into receiving waters adversely affecting the biota of an estuary. (Consensus)

VII. ECONOMIC IMPACT OF CANAL-TYPE DEVELOPMENTS

Housing developments located on waterfront canal systems have been often presented as local economic assets which convert unused land into taxable property, broaden the tax base and increase the value of surrounding property. Additional benefits often cited are that high value homes with convenient access to a navigable waterway attract affluent people to Florida, which is beneficial to business and creates more jobs.

The theory that "getting lands on the tax rolls" will lower taxes generally, or provide more and better community services, is apparently an illusion. If development were invariably beneficial, highly-developed areas such as Miami and Jacksonville would have lower taxes than less-developed communities. The present trend of population is a movement to rural areas to escape high city taxes and general urban degradation.

> "Never in history has the addition of property to the tax rolls reduced an individual's taxes. Always has the cost of serving, and the investment required, gone <u>up</u> as an area grew, <u>not</u> down." (John McQuigg, May 6, 1971) (1)

Other studies verify that urban growth is more often a tax liability than a benefit to existing communities.

> "Speaking of one region in the country, an official of the Department of Housing and Urban Development said, 'A rule of thumb seems to be that any house under $40,000 won't pay for itself.' An analysis of suburban land uses in Barrington, Ill. found that 'the more typical, lower-priced suburban tract development, with an average of perhaps four bedrooms per unit and an average sales price of $35,000, would result in an expected annual deficit of about $1,150 per dwelling unit.' Even $60,000 homes wouldn't pay their own way, the study concluded." ("Who Pays for What," by Darwin G. Stuart and Robert B. Teska, Urban Land, March 1971) (87)

Community services required by new developments usually include schooling, roads, water supply, sewage and waste collection and treatment, police protection, fire protection, parks, and so on, the cost of which usually far exceeds the revenue produced from new taxes.

Of these, schooling is one of the most expensive services to be provided. In Virginia, for example, a housing development on three-quarter acre lots contributed $572,765 in property taxes, but the county spent $736,000 to educate that development's children. (87)

A startling example of the effect of unplanned growth upon a city's economic welfare occurred in San Jose, California. Following a policy of annexation on the assumption that any new development would bring more taxpayers into the city and thus reduce the tax rate, the city increased from 17 square miles in 1950 to 137 square miles in 1970. This growth has caused the city's tax rate and cost of utilities to rise, and per capita bonded debt to double. (87)

These examples are primarily for single family residences. In Florida's densely-populated coastal areas, the demand for waterfront property is creating a trend toward high rise apartments and condominiums which multiply the requirements for services, with attendant increases in costs to taxpayers .

> "If 20 single family units are replaced with a multiple family apartment complex increasing population to 270 families on the same site, these families will generate a need for:
>
> 12 acres public land
> 3 acres service industry
> 4 acres retail stores

11 more classrooms
400 more cars
120,000 more gallons of water per day needed
100,000 more gallons effluent and wastes generated
2 more firemen + $8100 per year more equipment
12 more teachers + $75,000 per year to school budget
3 more policemen + $12,900 per year for facilities
1600 more library books
2 miles improved streets
in addition to:
$39,000 for health services per year
$4,160 for recreation per year
$69,650 for other services per year" (88)

Virtually all coastal states now recognize that waterfront property represents environmental and recreational values which are far more important to the public interest than the claimed benefits from developing such land for increased taxes. As a result, there is a definite trend for coastal states to impose stronger controls designed to reduce or eliminate this type of development. (87)

The long-term economic impact of waterfront canal developments must be judged on the basis of the best public interest. Evidence developed by this investigation shows that present methods of design and construction create environmental problems of such magnitude that many of these developments are a threat to the public welfare. If the intangible costs of environmental degradation are considered, these canals must realistically be considered as long-range economic liabilities rather than assets as originally claimed.

A. Values of Natural Areas

The chief victims of waterfront canal developments are the shallow bays, estuaries, marshes and other lowlands which are essential for the production of fish and other aquatic life.

In assessing the economic impact of such developments, the monetary, recreational and esthetic values of the self-sustaining natural areas they are replacing should be considered. Also, the maintenance costs for pollution control, aquatic weed control and similar costs due to environmental degradation are added charges borne by taxpayers.

McQuigg (1) has calculated the value of these natural lands at $22,210.80 per acre, based on biological productivity alone. He points out that Dr. C. P. Idyll, a marine biologist at the University of Miami, states that 90% of sport fish are estuary-dependent at some life stage. McQuigg calculates the total state income derived from sport fishing and shellfish activities as $2,056,675,525.00. Each waterfront canal development which replaces a portion of a bay, estuary, marsh or mangrove swamp with buildings, eliminates some of the fish and aquatic life and a portion of the income they produce.

Florida may be repeating the experience of other areas with networks of artificial canal systems. Venice, California, once touted as the Venice of America because of its extensive waterfront canal system, encountered financial difficulties from degradation of water quality in the canals. They became so rank from pollution that citizens, fearing an epidemic, demanded that they be filled in. But the cost was so great that the taxpayers of this small community could not afford the project.

When the community voted on annexation to the city of Los Angeles in the 1930's, a major stipulation was that if annexation were approved, Los Angeles would convert the polluted waterways into streets.

The problems from the canals in Venice, Italy, are well-publicized. Not only are the canals referred to as "open sewers," but pollution-accelerated erosion and subsidence are destroying historically invaluable canal-front buildings at an alarming rate.

B. Importance of Natural Features on Tourism

The importance of tourism is stated by Governor Reubin O'D. Askew, in "Florida Tourist Study 1970," an annual report issued by the Florida Department of Commerce.

> "Tourism is our state's biggest economic activity and one of the nation's largest industries of any kind. In terms of gross annual income, it channeled 3.6 billion dollars into the coffers of Florida government and private enterprise in the 1970 calendar year." (62)

Table 16 of this study, "Things Looked Forward To, 1970," not surprisingly shows that activities which demand water of highest quality are essential for supporting "our state's biggest economic activity." (See Appendix D)

A 1970 Florida Department of Natural Resources' report, from its Division of Recreation and Parks, indicated that more than 78% of Florida's resident population participated in outdoor recreational activities, and about one-half go swimming. The number of tourists who enjoyed outdoor recreation in Florida exceeded the resident population.

In ESCAROSA, a study of the Escambia and Santa Rosa County areas by the Florida Coastal Coordinating Council, the following statement appears:

"Out-of-state tourists participated in beach activities, salt-water swimming, and salt-water fishing as primary outdoor recreational activities."

Florida's major tourist features, such as parks, forests and outdoor recreational areas, natural scenery, camping, and participant sports all rely heavily on water contact recreation. Those parts of state and national parks which attract the largest concentrations of people are those containing water suitable for swimming, boating, fishing or nature observation. The U. S. Forest Service considers their past practice of developing campsites on springs, river banks, or other "tender areas" a mistake due to overuse that threatens natural values, and they are proposing to withdraw camping from such sites, leaving those areas for day-use only.

Florida's foremost industry, tourism, is heavily dependent upon water and water sports which require a purity at least equal to Class III standards. This investigation discloses that the water in canal-type developments characteristically does not meet these standards.

As a recreational area, Florida provides citizens not only with a delightful environment, but also a viable economy. As America's most popular playground, Florida is an asset to the entire nation. Unrestricted waterfront development can destroy Florida as a water sports recreational area and produce economic problems similar to those plaguing densely-populated northern states.

VIII. SUMMARY

The practice of developing waterfront property by excavating artificial canals causes serious environmental degradation which reaches beyond the boundaries of the immediately developed property and therefore affects the public interest.

The almost universal characteristic of these deep, narrow box-cut canals and dead-end configurations is sluggish circulation and a lack of flushing action, compounded by insufficient tidal exchange or a lack of adequate gravity flow due to flat terrain.

The lack of water exchange characteristic of these canals leads to an accumulation of oxygen-demanding and toxic sediments and organic wastes, causing low dissolved oxygen, objectionable odors, floating sludge, fish kills and anaerobic and septic conditions.

Eutrophication of limited-circulation canals is greatly accelerated by a heavy pollutional load due to the increased population density in relation to shoreline length. The sources of pollution include urban runoff, septic tanks, sewage effluent and live-aboard houseboats.

In freshwater canals, these adverse effects are compounded by heavy infestations of aquatic weeds, the application of herbicides and the addition of decaying vegetation to the accumulation of oxygen-demanding bottom sediments.

These conditions produce waterways with a paucity, or a complete absence, of desirable fish and aquatic life and which eventually become so contaminated they are unsafe for body contact. This investigation shows that the water in most of Florida's canals cannot meet federal and state water quality standards, and canal characteristics may make it impossible for these waterways ever to achieve these minimum legal standards.

Many of these canals are deep incisions into the aquifer and threaten underground water supplies either by lowering the water table through drainage, or by the flow of contaminated canal water into the aquifer.

The contaminated condition of labyrinthine canal systems presents a health hazard to both animals and humans, threatens the quality of receiving waters, and creates costly problems in maintenance for both individual property owners and public agencies.

The consensus of contributors to this investigation is that the present trend toward proliferation of canal-type developments, if continued unabated, will lead to an environmental disaster for Florida citizens.

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APPENDIX A

UNIVERSITY OF SOUTH FLORIDA
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TAMPA, FLORIDA 33620
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November 14, 1971

Mr. William M. Partington, Director
Environmental Information Center
935 Orange Avenue
Winter Park, Florida, 32789

Dear Mr. Partington:

This letter and the appended materials are my report to you on the survey of water quality in the canals and other man-made channels on the coast of west, central Florida which we performed at your request.

I. Sampling Procedure, Methods Used and Their Evaluation.

On Saturday, Oct. 16, 1971, approximately 30 volunteer samplers met with me at the University of South Florida. They included members of diving clubs, the Audubon Society, Suncoast Active Volunteers for Ecology (S.A.V.E.) students and/or faculty from U.S.F., St. Leo's College, Tampa U., and private citizens. The project was explained to them and each was given detailed instructions on how to obtain valid and useful samples, and twomsterile sample bottles for each sampling stations. In assigning sampling stations, I had the invaluable assistance of Mr. Roger Stewart, the Director of the Hillsborough County Pollution Control Commission, who knows the water quality problems of the Tampa Bay Area as few others do.

On the following Saturday, Oct. 23, 1971, the volunteers dispersed to their preassigned areas and collected samples as directed. The first sample was taken at 7:50 AM and the last at 12:50 PM. The last sample to be received at the university was processed before 6:00 PM. Thus the entire operation of sampling and processing was accomplished in about 10 hours.

Two samples were taken at each location: a.) A sample of the undisturbed water column, near the surface; b.) A sample of the "top of the bottom", i.e., a benthic sample of the sediments which had collected on the bottom of the waterway.

The surface water sample was subjected to a presumptive coliform analysis using the Multiple Fermentation Tube method which has been the standard for years. It was carried out as described in the American Public Health Association's "Standard Method's for the Examination of Water and Wastewater", 13 th edition, 1971, Part 400. The Most Probable Number (MPN) of coliform organisms per 100 ml was calculated using Table 407(2). For reasons of economy of materials, we performed the test in such a way that it would enumerate a maximum of 24,000 colifoms as an MPN/100 ml. Since this is 10 times the maximum limit for body contact, it was considred to be as high as necessary to have significance under state law. It is about 300 times higher than the maximum for waters from which shellfish may be harvested.

The benthic or sediment sample was subjected to a quantitaive bacteriological analysis for Clostridium perfringens, the most commonly encountered causative organism in gas gangrene. It is also known as C. welchii, is always found in high numbers in human fecal material and sewage, and is used in some European countries as an indicator organisms of sewage pollution much as we use coliform organisms in this country. Like some coliforms, it is present naturally in soils and sediments in small numbers, but its occurrence in larger numbers is invariably indicative of sewage or fecal pollution. It is very commonly encountered in sanitary bacteriology although many partially trained technicians do not seem to realize this. It grows well in the presumptive lactose broth coliform test and, like the coliforms, produces copious gas. Is is so common in the same situations as are coliforms, that in the fecal and confirmed tests for coliforms, special provisions must be made to inhibit its growth so that coliforms may be positively identified. In the BGBL broth used for the Confirmed Test and the EC broth used for the Fecal Test, Bile salts are added to the media to suppress C. perfringens growth. In the EMB plate method for the Confirmed Test, it is inhibited by incubation on an oxygen exposed surface- C. perfringens is a strict anaerobe. Since it produces resistant endospores, it can survive longer in nature. But when it is found in high numbers, it is an excellent indicator not only of sewage pollution but of highly anaerobic or reducing conditions: it can thrive only in the abscence of molecular oxygen, under conditions in which normal animal life is impossible.

The method used was that detailed by:

Marshall, Robert S., J.Frank Steenbergen and L.S.McClung, 1965. Rapid Technique for the Enumeration of Clostridium perfringens. Applied Microbiology 13 (4): 559 - 563.

This method was developed to detect C. perfringens in foods since McClung and others have shown that it produces a food poisoning more severe though somewhat less frequent than Salmonella or Staphylococcus. Themethod was specifically designed to eliminate interference in detecting C. perfringens by a number of organisms presnent in spoiled food which might also interfere with its isolation from marine sediments. These included several other mesophilic Clostridia, several sulfide-producing Salmonella and Proteus species, and two strains of fecal streptococci. Desulfovibrio species do not grow at the elevated incubation temperature used, and C. nigrificans grows too slowly, if at all, at the incubation temperature used.

The method uses a combination of physiological and cultural properties uniquely possessed by C. perfringens to identify and enumerate this organism.

1. Colonies must develop under obligately anaerobic conditions.

2. Colonies must be black, i.e., show hydrogen sulfide production.

3. Colonies must develop at 46°C (about 115°F or 16.4°F above body temperature- at this temperature the gas gangrene organism has a doubling time of about 12 minutes).

4. Colonies must develop in the presence of two potent antibiotics: polymyxin B sulfate at a concentration of 20 micrograms/ml and neomycin at a concentration of 50 micrograms/ml.

5. Colonies must be clearly visible within 24 hrs. incubation time.

Cell concentrations were calculated from the number of colonies which developed from a given diultion of sample. A number of colonies checked microscopically, at random, had cells with the general morphology, staining reactions and endospore position characteristic of C. perfringens. There is every indication that the method worked in an entirely satisfactory way.

Since this is not a "Standard Method" however, and since the results may be criticized by individuals responsible for the situations encountered, it is prudent to interpret and to report results in the most conservative manner consistent with substantial honesty. In this regard, it is essential to understand that the source of error which overrides all others with a method of this type leads to a low estimate of the true number, not a high count. Bacteria in water samples and especially in sediments exist in clumps or attached to detritus. Thus the colony count does not reflect single cells but clumps of cells. The true number of organisms might thus be approximated by multiplying the colony count obtained by a factor of, at least, ten. We have not done this, of course, in the absence of further experiments to determine the magnitude of the factor. Nor is their any need to in this assay. It is important to recognize clearly, however, that the counts given are quite trustworthy as rock-bottom minima.

We have also chosen to report our results as the lowest count justified b y the data, thus:

Calculated No. of C. perfringens per 100 ml.	Reported Lower Limit of Gangrene like anaerobes per 100 ml.
none	N.D. (none detected)
1 - 99	few
100 - 999	100
1000 - 9,999	1000
10,000 - 99,999	10,000
100,000 +	100,000

In summary, we have great confidence in both the qualitative and quantitative aspects of our results. We have detected C. perfringens specifically in the presence of many other potentially similar organisms and our statement of their concentrations is a significant though very conservative minimum defensible against any reasonable doubt.

House Bill No. 2127 (Chapter 67 - 1504) is "An Act creating and establishing the Hillsborough county pollution control commission" and authorizing that commission to establish "rules", i.e., standards and criteria for air and water quality. It is the pollution law with which I am most familiar, but has language which is very similar or identical to that of the State Air and Water Pollution Control Law, those of the 15 or so other counties which have local anti-pollution laws, and the rules which these agencies promulgate.

H.B. 2127, Sec. 3 "Definitions", (21) "Water Pollution" shall mean the introduction in any surface or underground water, or tidal salt water, of any organic or inorganic matter or deleterious substance in such quantities, proportions or accumulations which are injurious to human, plant, animal, fish and aquatic life, or property, or which unreasonably interferes with the comfortable enjoyment of life or property, or the conduct of business."

Section 14 of the same law specifically prohibits and declares unlawful any discharge causing or tending to cause water pollution as defined in Sec. 3.

Under H.B. 2127, the Hills. Co. Poll. Cont. Comm. has the right to establish "Rules" which may not be less stringent than similar state rules, and are usually identical with them. The following are from the "Rules of the Hillsborough County Pollution Control Commission".

Chapter 1 - 4.02. <u>Minimum Conditions of All Waters; Times and Places</u> "The following minimum conditions are applicable to all waters, at all places and at all times. Within the limits of this county all such waters shall be free from:

"1. <u>Settleable Substances</u> - substances attributable to municipal, industrial, agricultural, or other discharges that will settle to form putrescent or otherwise objectionable sludge deposits.

"3. <u>Deleterious Substances</u> - materials attributable to municipal, industrial, agricultural or other discharges producing color, odor, or other conditions in such degree as to create a nuisance.

(Sec. 12 defines a <u>nuisance</u>, in part, as "the commission of any acts, that cause or materially contribute to.... interfere(nce) with the health, repose, or safety of any considerable number of persons or the public, ... Any violation(of this)act which becoes detrimental to health or threatens danger to the safety of persons or property, ... or prevents the reasonable and comfortable use and enjoyment of property by any considerable number of the public."

"4. Toxic Substances - substances attributable to municipal, industrial, agricultural or other discharges in concentrations or combinations which are toxic or harmful to humans, animal, plant or aquatic life."

Chapter 1 - 4.08 gives the minimum bacteriological standards for Class III waters, for body contact, as not to exceed an MPN of 2400 coliforms on any day, nor exceed a monthly average of 1000 coliforms, nor exceed 1000 coliforms in more than 20% of the samples examined during any month.

The results of our tests should be interpreted in the context of these laws and rules.

II. Results

Water column samples were received from 80 different locations. These are numbered on the appended Table running roughly North to South, and will be referred to in the table and in this discussion by their "Map Number", the number showing their location on the C.G.S. Chart 1257 and the other maps accompanying this letter. On the Table of results, a Sample Number, assigned to the samples as they were received for processing, is also given with the Map No. Also included are a set of duplicate sampling cards which bear the Map No., the Sample No., the name, address and telephone of the volunteer sampler, and his description of the exact location of the sample place and time. Volunteers have agreed to guide us personally back to the sample location should any need for a check arise.

Benthic samples were received from all locations excpt #35, and were processed for all the others except # 14 and # 74.

Samples were gotten from as far north as the Weeki Wachee River in Hernando Co. to as far south as Punta Gorda in Charlotte Co. Most, 64 of 80, were collected in the Tampa Bay Area, as defined by CGS chart 1257, which includes the Anclote River in Tarpon Springs on the North to the Manatee River at Bradenton in the South, as well as the whole of Tampa Bay and its tributaries, Boca Ciega Bay, St. Joseph's Sound and the entire Gulf Coast of Pinellas County. Eight samples were taken north of these boundaries and seven to the south. We had hoped to have a much more extensive sampling of Sarasota Bay, but an unfortunate accident to the equipment of the professional divers who kindly volunteered to cover this area prevented that.

In summarizing the significance of our results, we chose to give special attention to those samples which gave a coliform count of 2400 per 100 ml or above, since this is a legal limit for body contact safety. In lieu of a legal standard, we choose to give special significance to a Gangrene anaerobe count of 1000 per 100 ml because, as explained above, these are very conservative estimates, the other bacteria present with the gangrene organism (but not counted) are often of equal virulence, and because this concentration would be quite sufficient to insure contact of the organism with the skin of a person's hands, feet etc., in these sediments, if the individual waded in or handled them without protection.

On a bright sunny Saturday in October, 1971, a person contacting the waters in canals or other man made channels up and down the suncoast of Florida would have found that:

In 63% of all samples, 50 of 80, the coliform count was 2400 or over.

In 45% of all samples, 35 of 77, the Gangrene anaerobe count was over 1000.

In almost 1/3 of all samples, 25 of 77 or 32%, <u>both</u> the coliform count was over 2400 <u>and</u> the Gangrene anaerobe count was over 1000.

In many localities, more than one sample was taken from a given canal system, or enclosed body of water to attempt to establish the pattern of distribution of impurities. A clear-cut example would be the counts at Apollo Beach, No.'s 69, 70 and 71 on the map. Near the mouth of the canals to the open bay, #69, the coliform count is low and there are no G.A.'s; at #70, halfway up the canals, the coliform count is higher and anaerobes are detectable if few. At the deadend of the canal system, # 71, the coliform count skyrockets to 9180 and the anaerobes pass 100.

In many places, then, samples of a given body of water were collected at points expected to be relatively clean to establish at other places in the same body of water or canal system. If we summarize results on the basis of the number of distinct bodies of water, i.e. canals, canal systems, channelized creeks, dredged and filled bayous, etc., a somewhat different picture emerges.

Our sampling covered 41 distinct bodies of water- 41 separate canal systems (e.g., Apollo Beach, Davis Islands, Baycrest, each count as 1), or impounded bayous (e.g., Coffee Pot Bayou, Smacks Bayou, count as 1 each) or separate creeks or channels (e.g., Allan's Creek, Stevenson's Creek, Sweetwater Creek and Bear Creek each count as 1).

A citizen or tourist wading, swimming, skiing in any one of these 41 spots along the Florida Suncoast from Weeki Wachee to Punta Gorda on a sunny Saturday in October 1971, might have encountered somewhere in each:

A coliform count of 2400 or more in 70% (29 of 41).

A gas ganrene count over 1000 in 56% (23 of 41).

Both a coliform count over 2400 and a gangrene anaerobe count over 1000 in 44% (18 of 41).

Either a coliform count over 2400 or a gangrene anaerobe count over 1000 in 83% (34 of 41).

There are then, sanitary water conditions which constitute gross violations of pollution control standards in 4 out of 5 situations along the suncoast of Florida which we sampled.

These results should not be cause for hysteria or panic. These conditions must have existed for some time, and yet people apparently do not frequently catch gas gangrene in this area of Florida.

This does not mean that these situations do not present a potential health hazard. If the people were to swim or wade in these waters, they might get gangrene, tetanus, streptococcal or staphylococcal blood poisoning from untreated cuts. They may get gastroenteritis, stomach or bowel upsets, from various bacterial toxins, from Salmonella and Shigella, ear and urinary tract infections from Proteus, Pseudomonas and others, a complex and little understood spectrum of virus diseases, from swimming in or ingesting small amounts of these waters. They may get almost any of these types of diseases from eating clams or oysters taken from these waters. Lastly, they may transfer many of these organisms to foods by hand contact where they may cause various types of food poinsoning, especially after cleaning or handling fish caught in these waters then transferring the microbes on the slime on the surface of the fish to other foods.

How much these situations contribute to various non-lethal, sometimes undiagnosed, but annoying, debilitating, expensive illnesses is not known. For the sake of argument, we may assume that these conditons do not, in reality, cause any increase in human illness, while also agreeing that, in theory, they could do all the things listed above.

A very apparent reason why more diseases are not attributed to contact with these waters is that the average American, when he encounters these places, is repelled by the sight and odor, and instinctively avoids contact with them. The people on Davis Islands or Baycrest Canals or those like them simply do not use their canals. In the older, more obvious situations of this type, people who built or bought expensive homes on the water do not wade, or ski, or swim, or take oysters from their canals. When the canals were new, residents built docks and diving boards. In five to ten years, these are in disrepair and fences are erected to stop children or pets from falling in. In 15 to 20 years, many build opaque wood fences in order to screen the canal from sight.

These situations are the result of three interacting causes:

First, the creation of canals, channels, and impoundments which cannot get proper tidal flushing.

Second, the destruction in this process of the natural biological water purification mechanisms- the clams, oysters, and worms on the natural bottoms and the effective water quality regulation complex which is a mangrove stand or *Spartina* marsh.

Third, the supply of organic and inorganic pollutants and of excessive intestinal organisms by the untreated or inadequate treatment of the sewage of the people who reside in these developments.

In my opinion, similar conditions would be found in most parts of Florida where canals exist which "appear polluted."

Sincerely yours,

John V. Betz

John V. Betz, Ph.D.
Associate Professor of Microbiology

APPENDIX B

MEMORANDUM

107.07-17A

TO Mr. Hans Schmitz, Chief
Planning and Evaluation

DATE October 13, 1971

SUBJECT Summary of Canals in Dade County

FROM Jim C. Eggert
Inspector I

Most Dade County canals and waterways have long been a problem with regards to pollution.

Special efforts should be given to the hundreds of miles of small branch canals. These waterways have a history of algae, overgrowth of weeds and trash problems. Odors and health problems are not uncommon.

The canal maintenance program should be revised. The State and County sometimes have conflicts concerning canal jurisdiction. Florida Flood Control maintains most of the main canal systems. The County maintains most secondary canals. Often the State will clear out a main waterway leaving small branch canals for the County. These canals are often dead end and become clogged with material from the main canal. The junk and aquatic growth presents a constant complaint from the public. Bank weed control as well as aquatic growth control is usually done by spraying with herbicides. The type herbicide is important but of more importance is how it is applied. Many miles of canals are sprayed regularly. Dead organic matter, causes water quality damage.

The primary function of canals and waterways in Dade is or was drainage of flood waters. We find many canal systems are developed coincidentally by highway construction. Run-off from roads and highways, entering our canals, cause poor water quality many miles downstream. Drainage canals are being used intentionally and unintentionally to transport waste away from residential, commercial, industrial and agricultural areas. With increased development, the quality of water in the canals will deteriorate.

Salt water intrusion also plays an important role in Dade's canals and waterways. The present system of salinity dams is barely holding its own. Construction of weirs in the canals would permit discharge of flood waters only. This would step levels up from lower elevations at the coast to high elevations in the interior. This is a State problem.

The depth of most canals is usually constant. With the exception of several natural waterways all canals are dug to a uniform depth. Several canal systems surveyed by our office showed an average of 10 to 12 feet. Many small canals are not as deep; some are much deeper. Several canals have heavy deposits of silt or sludge on the bottom. The flow rate in most canals is very low. Even during times of flood waters, little flushing action is noted. When flow decreases, we have less dilution of any pollutants reaching the canals. Pollutants such as silt and mud from construction activities, pesticides and herbicides from agricultural areas and private homes, and storm drain runoff (oil, silt, solid waste) all contribute to this problem.

Health problems can be expected in many of Dade's waterways. Our records show high MPN counts in many waterways. Several Lakes have received much publicity because of eutrophication. With ideal conditions some of the blue-green algae can become toxic to animals. So far, there have been no records of human deaths. Reports of skin rash have been noted. Swimming is not recommended in any Dade Waterway that is not tested regularly by the Health Dept.

Botulism, type C, is common in Dade County. Many birds have been killed by this toxin. Health problems occur with the occurrence of dead fish and animals in public waterways. Fish kills have reached a new peak this past month (Nov.) in South Florida. With the exceptions of one or two main canals most fish kills were associated with small or secondary canals.

Recreation, boating, swimming and fishing are an important part of South Florida life. Unfortunately, most of our canals offer little for water sports. Some waterways in the far south and western portions of Dade are exceptions. It is of interest to note many of our (rock pits) and lakes have remained in very good condition for many years.

Boat traffic in most Dade canals is limited to small portable-type boats. Only the Miami River has any regular movement of large boats. Salinity dams in all but the Oleta River prevent any boat traffic from the bay inland. Coral Gables waterway provides boat access inland to U.S. I. (Salt Water).

Fish taken from Dade's canals at times appear to be undesirable for eating. Proper cooking should eliminate any danger involved, although the taste may be somewhat unpleasant (muddy).

Some recommendations could be: filling in some of the smaller ditch type canals such as Coral Way, new canals should be regulated with regards to road, commercial, residential, industrial and agricultural runoff.

Existing spoil areas and banks of canals should be cleaned and planted to reduce erosion problems. Waste treatment facilities should not be permitted to enter any canal. Those effluents now entering canals should have advanced levels of treatment, including nutrient removal.

Many canals should be cleaned, including bottom materials, and maintained on a regular basis. Methods of sludge removal depend on conditions.

Canals and waterways with a history of problems are:

Fla. City Canal - MPN high
Military Canal - Fish kills, MPN high, low DO
C-103 - MPN high, fish kills
Goulds Canal - Overgrown aquatic conditions
S.W. 87 Ave. Canal - fish kills
Black Creek - fish kills
Bel Aire canals - silt, fish kills, algae, duck kills.
C-100 A - fish kills, duck kills
Snapper Creek - Fish kills, MPN high, low DO
Ludlam Canal - Fish kills, algae
Miller Canal - Fish kills, algae, duck kills
Bird Rd. canal - silt, low DO
Village Green Canal - algae, low DO
Central Canal - fish kills, algae,low DO, duck kills.
Coral Gables Canal - fish kills, algae, low DO
Coral Way Canal - overgrowth, trash
N.W. 117 Ave. Canal - fish kills
Comfort Canal - fish kills, low DO, algae
Wagner Creek, MPN high, fish kills, silt, etc.
FEC Canal - Fish kills

FEC Borrow Canal - Fish kills
58 St. Canal - Fish kill, overgrowth
Okeechobee (Miami) Canal - Fish kills, silt
Russian Colony Canal - Fish kills, silt
N.W. 138 St. Canal - fish kills, low DO
Gratigny Canal - Fish kills, low DO
Little River Canal - Fish kills, low D.O.
Biscayne Canal - Fish kills, low DO, duck kills
Carol City Canal - Fish kills, low DO,
Red Rd. CAnal - Fish kills, low DO
Snake Creek - fish kills, low DO
Oleta River - Fish kills, low DO

Many more canals can be included on this list, mostly those small, one or two blocks long.

JCE:lkr

GENERAL CONDITION OF DADE COUNTY CANALS

Most canals in Dade County are in very poor condition. A few canals in the southern end of the county are in good shape; clear, clean and free of any problems. These canals are in a very sparsely populated area and have been in existence only a few years.

A weed control (both aquatic and bank) program of spraying with herbicides is used by both the County and State. Plants which are sprayed and killed remain in the water, decaying and reducing its quality. Many miles of canals are sprayed at one time, sometimes with little regard to careful or acceptable methods.

Several surveys made by our office show a very delicate balance in dissolved Oxygen in most Dade Canals. If the D.O., usually quite low, has a slight drop the results are disastrous to aquatic life. We found when the D.O. is in a low range near the surface, it drops fast with depth and is usually zero at the bottom.

Many canals in Dade have a history of "unnatural" sludge on the bottom. This can be from sewage or industrial waste. A "natural" sludge is present in many canals, usually organic material settled on the bottom. Any disturbance of these sludge deposits cause a drastic change in water quality. Many fish kills have occurred after heavy rains stir up these bad canals, reducing oxygen.

Little or no flow contributes greatly to our problems in Dade. Canals fill with algae, duck week and tons of junk. Clean-out efforts must be stepped up during these "no flow" times.

Conditions have improved with bacteriological conditions in most canals, but other problems such as Oxygen and Phosphates have become worse in many canals.

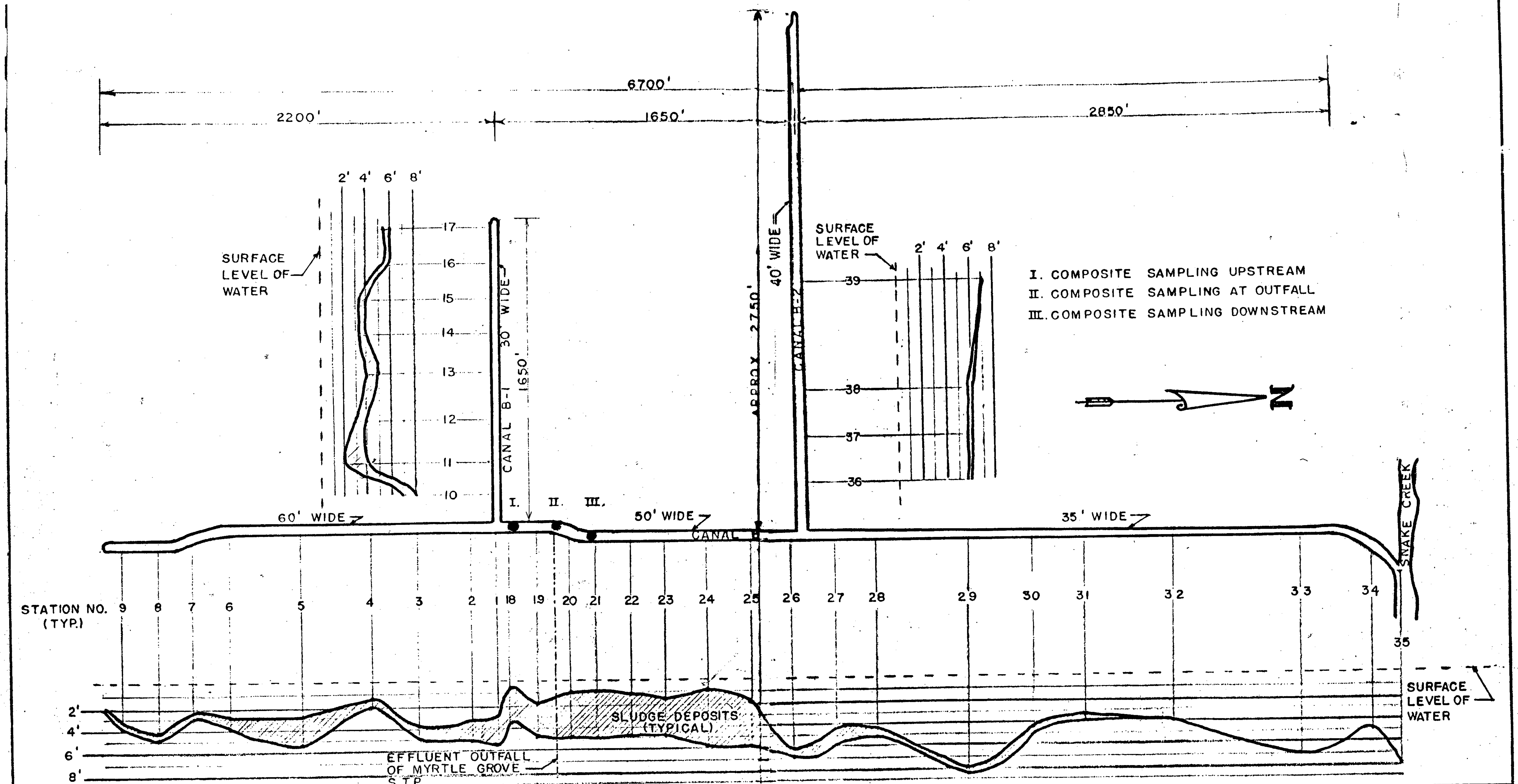
Submitted by,

Jim Eggert

Jim Eggert
Inspector I
Pollution Control

JE:lkr

APPENDIX C



CANAL-B SURVEY OF SLUDGE DEPOSITS ON CANAL BED

SCALE: 1" = 500'

DADE COUNTY POLLUTION C.	
EVALUATION & PLANNING	
DATE: 4/17/70	BY: B.J.

APPENDIX D

Things Looked Forward to And Enjoyed By Tourists

Florida's beaches, the vacation atmosphere, and water sports continued to rank highest in the anticipation of our tourists. Table 16 shows in detail what tourists expected to enjoy, while Table 17 indicates the responses of the outgoing tourists as to what they had enjoyed.

It is interesting to note that beaches and natural scenery were the only two specified items that were enjoyed more than had been anticipated.

Table 16 THINGS LOOKED FORWARD TO, 1970

Item	PERCENT Total	Visitor First	Visitor Repeat	Season Winter	Season Summer	Mode of Transportation Auto	Mode of Transportation Plane
Beaches	67	63	69	63	76	69	58
Atmosphere of Relaxation and Fun	58	51	53	59	56	57	63
Water Sports	52	47	46	45	61	51	53
Commercial Attractions	36	42	28	33	43	39	22
Parks, Forests and Outdoor Recreational Areas	31	41	25	32	31	34	20
Natural Scenery	29	36	24	29	29	30	25
Historical Places and/or Art Museums	25	33	19	24	29	28	15
Dancing and Night Life	18	18	15	17	18	15	30
Camping	15	17	13	16	13	17	5
Sports to Participate in	15	12	15	15	15	14	19
Sports to Watch	14	10	13	16	13	14	14
Cultural or Special Events	9	10	8	8	8	9	9
Other	11	9	10	11	9	10	17
TOTAL	380	389	328	368	401	387	350

Note: Multiple responses were permitted on this question.