MANAGEMENT REPORT

Some Hydrographic Aspects of the Estuarine Area from Northeastern Florida Bay to Barnes Sound, especially in re Restoring Historical Water Connections

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SUMMARY AND RECOMMENDATIONS

Human activity in the study area over the past ‘70 years resulted in three principal kinds of hydrographic change. 1. Upland drainage into the estuary was diverted or impounded (Florida East Coast Railroad, Canal 111). 2. Channel connections and overland water exchange by wind tides between Barnes Sound and water bodies west of present U.S. Route 1 were blocked (FEC Railroad, U.S. Route 1). 3. Massive inland intrusion of salt water occurred in uncontrolled canals and borrow ditches (FEC Railroad, local canals). It seems an appropriate management goal for Everglades National Park to seek correction of those changes that have affected the Park and restoration original hydrographic conditions in the area.

Salt-water intrusion affected mainly the part of the area lying east of U.S. Route 1 and its impact has been effectively cancelled by placing plugs or controls near the seaward ends of the canals. Recommended actions under items 1 and 2 are outlined below and illustrated in Figure 1.[1]

Impounded Drainage -Canal 111 affects about 44 percent of the upland drainage area of Long Sound-Joe Bay and (despite -inverts intended to provide drainage) much of the water draining from this area appears to be impounded by the north spoil bank of C-111. The extent of and how to correct it need priority study, because eliminating the blockage of flow from this section should moderate adverse effects of hyper salinity in eastern Florida Bay A review of the status of the wedge of and between the south bank of C-111 and the Park boundary and of administrative means to assure unimpeded sheet flow to Florida Bay across this corridor should be included in such a study.

We also wish to emphasize in passing- that Park administration needs to keep closely informed of future developments that may affect the coastal. Wetlands along the mainland shore of Barnes Sound and Card Sound, These wetland areas are critical feeding grounds for

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Fig. 1. Summary of recommended actions [Figure not available at the moment]

many water bird populations that nest in and near eastern Florida Bay (including Wood Storks and Roseate Spoonbills) and they also support a Crocodile population. Thus, development that threatens significant encroachment is necessarily of the gravest concern to the Park.

Blocked Water Connections - The FEC Railroad-U.S. Route 1 embankment blocked movement of water across its alignment, both via natural channels and across areas of low mangrove swamp between C-111 and Key Largo by wind, but serious deficiencies of the data base header estimates of the effects of this long standing barrier. Data at hand indicate that water bodies on either side are now about equally prone to hyper salinity in drought years and that, at Manatee Creek, Long Sound is consistently fresher than Barnes Sound-Manatee Bay in years of heavy to moderate rainfall. Culverts now being placed at Manatee Creek and Jewfish Creek should be monitored to record the effects of the restored channel connections upon water exchange across the line of U.S. Route 1.

Head differences generated by winds can cause water to move overhead at points where adjacent lagoons are separated by narrow belts of mangrove. The significance of former water exchange in the study area by this route is unknown.

There is little doubt that the U .S. Route 1 embankment impedes movement of aquatic animals. Both Crocodiles and Manatees are much less frequently seen in the area than was once the case. Crocodiles are known to have been killed by traffic in attempting to cross U.S. Route 1.

Considering the above our recommendations are as follows: 1. All historical channel connections in the area should be restored both in the interest of reconstituting the original system and to afford safe passage for aquatic animals. Besides the programmed culvert connections at Manatee Creek and the north branch of Jewfish Creek, we suggest that restoring connections north of Manatee Creek between the back ponds of Long Sound and those of Manatee Bay should receive special attention and that one or several connections are also needed across Lake Surprise (Figure 1). 2. Because disturbance and injury by boats may be an important factor in the movement of both Manatees and Crocodiles, we recommend that any re-established connections should not be made available to small boat traffic. 3. Possible overland passages ("Crocodile crawlways") in the Cross Keys area (Figure 1) should be studied. Without any notion of engineering or cost feasibility, we visualize these as pilling-supported sections of road 10 to 15 yard long at locations where the water bodies are separated by narrow mangrove belts. Hopefully, they might be suitable for study of wind-generated water exchange as well as for Crocodile crossings. 4. Obvious need exists for a much improved hydrographic database to support proposals for mitigating changes that may become possible when U.S. Route 1 is 4-laned across the study area. To that end we suggest: Park water quality and biological sampling should be extended to include at least the Barnes Sound-Manatee Bay system; Biological sampling should be expanded and tightened to include more stations (Figure 1) and more frequent (at least biweekly) sampling with provision for immediate study of the effects of notable weather events such as heavy local rain and persistent strong winds. Characteristics of water exchange through the restored Manatee Creek connection should be closely monitored (see pp. for preliminary observations in the Spring of 1977); and, special studies should be made of wind movement of water across the Boggy Key-Shell Key section between Black water Sound and northeastern Florida Bay, and of the effects in Backwater Sound of water exchange via the Marvin D. Adams Waterway.

BACKGROUND

Beginning with the extension of the Florida East Coast Railroad in 1905-1907 construction of transportation corridors and canals in the area between Florida City and Key Largo substantially changed the original hydrographic. Upland drainage into the coastal lagoons was altered by diversion and impoundment, and movement of water (and aquatic animals) within the lagoon system was impeded by barriers across several natural waterways. Some of the affected area is in Everglades National Park and more extensive adverse impacts, such as a suspected trend toward increasingly frequent hyper salinity in parts of Florida Bay, are thought to have resulted. Within the past year, the Florida Dept. of Transportation's (DOT) plans for reconstruction of U.S. Route 1 bordering the Park presented an opportunity to restore some of the historical water connections blocked by the present highway.

Park files indicate concurrent planning by DOT for 4-laning U.S. Route 1 from F1orida City to Key Largo and for minor modifications of the existing road. It isn't entirely clear whether these were regarded as alternative or incremental actions to relieve current traffic problems. The principal item in the files concerning 4-laning is a letter (27 May 1976, W.J. Keating, Project Engineer, DOT, to Jack Stark, Superintendent, Everglades) transmitting a set of aerial photos of the preliminary proposal and stating that a draft Environmental Impact Statement might be available by July 1976. The files record no further official contacts about 4-laning and the draft EIS is apparently still to be circulated. A news clipping (Miami News, 28 October 1976) quotes "a DOT spokesman" to the effect that plans 4-lane the road had been referred "until the 1980s". Later clippings (Homestead News-Leader, 25 and 26 November 1976) indicated that south Florida legislators were pressing DOT for 4-laning at an earlier date and the matter is evidently still unresolved. The 4-laning of I7.S. Route 1 is important here, because any large-scale effort to restore original water connections is considered impractical until there is a major reconstruction of the road over the reach from Canal 111 to Key Largo.

The proposed minor alterations are installing left turn lanes at Jewfish Creek (Corps of Engineers Permit Application No. 76 L-0496, 26 May 1976) and at, Manatee Creek (CE Permit Application No. 76 K-0982, 24 Sept. 1976) and widening the road surface and shoulders from Florida City to Key Largo (CE Permit Application No. 76 L-0767, 8 October 1976). The record of agency interactions and Park actions with regard to these proposals isn't altogether clear from the files, but the essential chronology was approximately as follows. By letter of 19 August 1976 (Fish and Wildlife Service, Vero Beach, to CE District Engineer, Jacksonville) FWS recommended denial of the permit application for Jewfish Creek unless a culvert was placed in the blocked north channel of the creek. It isn't clear whether the Park concurred in this recommendation, but a letter of 22 October 1976 (Acting Supt., Everglades, to W.J. Scheb, Fla. Dept. of Environmental Regulation) commenting on both permit applications includes the following:

> "The original construction of State Road No. 5 [= U.S. Route 1] blocked the natural circulation of water between northeastern Florida Bay and Barnes Sound creating a hyper saline condition in Florida Bay which resulted in significant reduction n fish and wildlife resources. ... This seems an appropriate time to provide a number of openings through the highway between C-111 and Jewfish Creek."

In a meeting of most of the concerned agencies at the DOT office, Tallahassee, November 1976, DOT agreed to place culverts at Jewfish Creek and Manatee

Creek and the Park evidently concurred in this resolution of the matter by mailgram of 19 November 1976 (J.M. Good, Supt., Everglades, to Doug Jones, Fla. DER). A letter of 16 December 1976 (T.H. Kalayci, District Design Engineer, DOT, to C. McClain, Asst. Supt., Everglades) transmitted plans and specifications for two 60" culverts at Manatee Creek and one 60" culvert at the north channel of Jewfish Creek. On the basis of this information, FWS withdrew its objection to grunting the permit applications (L3 December 1976, J.D. Carroll, Jr., to Kalayci). Concurrence by the Park was transmitted by telephone (F.A. Nix, pers. comm.).

Thus, the situation appears to be that the restoration of old water connections that was possible during minor highway modification had been agreed upon before we were assigned the job of preparing this report. Any thoughts of additional restoration must await a decision on 4-laning the highway, which p-presumably will occur sometime during the next decade depending upon the play of political forces on the issue. Meanwhile, the restored culvert connections give us an opportunity to study water movement and its effects on salinity.

In as much as this report is somewhat after the fact, we have elected to treat all the information we could find on the hydrography of the area, past and present, rather than limiting comment to the question of connections across U.S. Route 1. In this way, we hope at least to provide a firm point of departure for the next Everglades NP biologist or hydrologist who may have this matter to consider.

MAN'S IMPACT UPON LOCAL HYDROGRAPHY

Possible correction of man-made changes in the movement of water in the study area is the essence of the present discussion. Accordingly, we've undertaken to determine the history and hydrographically significant characteristics of the major construction that has affected the area. These works and their impact are treated briefly below.

FLORIDA EAST COAST RAILROAD - We are greatly indebted to E. R. Fredrick (Engineer, Bridges and Buildings, FEC, St. Augustine) for information about this, earliest notable human intrusion in the area. FEC has deposited the plans and other records concerning construction and operation of the "Over.3CaLs Railroad" in the Flagler Museum, Palm Beach, and original documentation of virtually any detail about the railroad is available there. Work on the 1'EC extension to Key West began from Homestead in 1905 and the roadbed of the Florida City-Key Largo section is thought to have been completed early in 1907. The roadbed was built of crushed rock at least some of which was probably obtained from borrow ditches dug along either side. Mr. Fredrick stated that the marl and peat overburden almost surely was removed and the roadbed built up from a limestone base, but that he had no documentary confirmation available on that point. The east side borrow ditch was continuous "rid cut to tidewater at Manatee Bay; the west borrow ditch was discontinuous acid Lire reach connecting to Long Sound did not extend far inland. Because the drainage was considered to be "flat", no culverts, trestles or bridges were placed in the roadbed south of

Florida City, the first opening in the embankment being a 50-yard bridge across the main branch of Jewfish Creek.

The PEC embankment effectively blocked movement of water across the railroad alignment.

In the coastal marsh south of Florida City, the embankment cut off about 38 percent of the original upland drainage into Barnes Sound (Figure 2)[2], presumably diverting this flow toward Long Sound. In the estuarine section, roughly from present Canal-111 to Key Largo the embankment blocked former major channel connections at Manatee Creek and the north Branch of Jewfish Creek and other smaller connections and prevented possible movement of water over Cross Keys by wind tides. In addition, the borrow ditch connecting to Manatee Bay allowed unimpeded inland penetration of salt water. This accounts for the fact that dense stands of small red mangrove (Rhizophora mangle) now extend 2 to 3 miles farther north on the east side of U. S. Route 1 than on the west side. The vegetation difference on the two sides of the road is discussed in detail by Egler (1952) and it is already evident in aerial photographs of the 1940 series.

Finally, we note Egler's (1952) comment that an FEC engineer told him that one reason for locating a switchyard on Cross Keys at Little Black water Sound was because water fresh enough to use in locomotive boilers could be obtained there dependably. This statement is hard to reconcile with present conditions and with other observations suggesting that northeastern Florida Bay was sometimes hyper saline as early as the 1880s (Pierce, 1962), but it should be carefully investigated in original FEC source materials.

U.S. ROUTE 1 - Shortly after the 1915 "Labor Day" hurricane heavily damaged the railroad in the Florida Keys, FEC sold the roadbed and rights of way to the Florida Department of Transportation. State Road No. 5 (= U. S. Route 1) was built along the same alignment by adding to the width of the existing roadbed without any important changes as regards openings in the embankment or connections of the borrow ditches, the section from Florida the Keys being completed in 1938 (pers. comm., W. McAllister, DOT).

[2] Figure 2. Original upland drainage areas [not available at the moment]

LOCAL CANALS - Canals east of Florida City that discharge into Barnes Sound, Card Sound and southern Biscayne Bay (Figure 3[3]; including the borrow canal on the west side of Card Sound Road, not indicated in Fig. 3) affected the hydrography by speeding and concentrating runoff of fresh water into the estuaries and, formerly, by permitting major inland incursions of salt eater during times of drought. These canals were dug for drainage and agricultural water control and probably were operational by the early 1930s, although their exact history is somewhat vague (pers. comm., J. Dalton, Dade County Agriculture Extension Service). All these canals are now blocked near their seaward ends by earth plugs or by automated salt control structures triggered by water level differences across the structures, but originally all opened directly to salt water. Massive saline intrusions occurred in the canals when the head of fresh water was diminished with salinity readings as high as 47 ppt (26,000 ppm chlorinity[4]) recorded just east of Florida City at the north end of the card Sound Road borrow canal in June July, 1945 (Parker 1955). Such elevated salinity suggests that water at the canal outlet in Barnes Sound must also have strongly hyper salinity at the time. Salt intrusion and residual salt contamination of ground water forced abandonment in the mid-1940s of extensive farming areas on either side of Card Sound Road that are evident in the 1940 air photos.

CANAL-111 - C-111 (Figure 4) was built in three phases in 1964-67 for the stated purpose of conveying floodwaters to the coast (Corps of Engineers, 1963). Table 1 gives basic specifications of the canal and of Control Structure 18C which is located where the canal crosses the projected Dade County salt control line. S-18C is an automatic structure that opens when headwater elevation reaches 2.4' and closes when headwater elevation drops to 1.6'. The north and east spoil banks of C-111 are continuous except for small openings at 11 inlet structures. The south spoil bank from just south of s-180 to U. S. Route 1 has 100' openings at natural ground elevation for each 400' of spoil bank and these allow water to flow from the canal south toward Florida Bay when the canal stage is high enough. When upstream works are completed, C-111 will be the conveyance channel for the 18,000 acre-feet of water ticketed for the so-called "eastern panhandle" of the Park as part of the Park's minimum water allotment.

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[3] Figure 3. Local drainage canals, Florida City Area [not available at the moment]
[4] Calculated from the formula, ppt Salinity =- .03 + (1.805 X ppt Chlorinity).

C-111 precipitated a major environmental controversy when it became clear that the canal was to be built with an open connection to salt water at Manatee Bay.

TABLE 1. Some Specifications of Canal 111 and Structure 18C.

(Data from Corps of Engineers, 1963.)

CANAL 111 SOUTH DADE COUNTY, ENTIRE CANAL	
Drainage area (sq. miles)	34.1
Removal rate (pct. S.P.F.)	40
Length (miles)	19.4
CANAL 11.1, SECTION 1	
Length (miles)	9.1
Bottom width (ft.)	10
Bottom elevation (ft., m.s.l.)	12.0
Design water-surface elevation (ft.)	2.1 to 0.1
Canal side slopes	1 on 1
Excavation (cu. yds.)	2,480, 000
CONTROL STRUCTURE 18C	
Type - gated spill way with trapezoidal weir	
Design discharge (c.f.s)	2,100
Control gates:	
Number	2
Size - width by height (ft.)	22..0 x 11.0
Crest elevation (ft., m.s.l	-7.0
Design headwater elevation (ft., m.s.l.	2.6
Apron elevation (ft., m.s.l)	8.0
Slide gates:	
Type	Hand operated
Number	6
e- width by height (ft)	6.0 x 1.5
Bottom elevation(ft., m.s.l)	1.0

Studies outlining the potentially disastrous; hydrological and ecological effects on the Park of salt intrusion via C-111 (Klein, 1965, Tabb, et al., 1967) led to the present situation in which a manually operated gated culvert structure (S-197) east of U. S. Route 1 separates the fresh and salt reaches of C-111. Monitoring by the U. S. Geological Survey (Meyer and Hull, 1968) has indicated that S-197 is an effective salt control, as peak salinity recorded in the upstream reach hasn't exceeded 5 ppt. There are no strict regulatory criteria for the opening of S-197, in fact the structure has been opened only once or twice in the decade that it has been in place (pers. comm., f. Nix) and the fresh water input to Barnes Sound via C-111 has been minimal.

C-111 affects about 44 percent of the upland drainage area tributary to the Long Sound-Joe Bay estuary immediately to the south (Figure 5). Nine inlet structures containing a total of 11 culvert pipes each 72" in diameter were installed to provide for drainage through the north spoil bank of the canal. It appears, however, that these structures are largely effective because of water conveyance to the upstream ends of the culverts. Much of the drainage from the area within the big bend of C-111 appears to be impounded behind the north spoil bank. Effects of impoundment became particularly evident in September, 1965, when hurricane Betsy crossed the area with a storm tide that approached 10' asl m (Corps of Engineers, 1965). Although it isn't, clear whether the present inlet structures were in place at that time, l.c. salt water impoundment behind the north spoil bank of C-111 evaporated there resulting in a very extensive salt kill of marsh and tree island vegetation (Alexander in Tabb et al., 1967) still not repaired by plant succession. South of C-111 where water was able to drain off there was little salt kill.

<u>CANALS 109 AND 110</u> - This canal system inside the big bend of C-111 presumably was intended to facilitate drainage and, ultimately, development of lands along the canals. Construction of C-110 began in 1970, but the project ran into resistance from conservation groups and came to an uncertain halt in 1971 after C-110 and the part of C-109 south of the salt control line had been completed (Figure 4).[5] The future of these canals doubtless depends upon eventual decisions as to the fate of privately owned wild wetlands of extreme southeastern Dade County. C-109 and C-110 are designed for gravity drainage into C-111 but have remained unexcavated at the C-111 end. While the canals have had no effect to this point, they are potentially a factor in the unresolved problems of the upland drainage area of northeast Florida Bay.

<u>MARVIN D. ADAMS WATERWAY</u> - This canal (also called the Cross Key Cut or Key Iargo Waterway), built to provide boat passage across Key Largo, connects Largo Sound on the Atlantic side with the southeast corner of Black water Sound (Figure 1). The canal is 100' wide and the center section through the upland of Key Largo (essentially a long, narrow quarry) dug in 1959 by a private individual in exchange for the rock (used for building stone) is 32' to deep except for 12' depth across the right-of-way of U. S. Route 1. The lowland

[5] Figure 4. Canals 111, 110 and 109 [not available at the moment]

portions at either end are shallower and were dug somewhat later, so that the connection apparently wasn't completed until around 1964. The hydrographic effects of the waterway are little known, but tidal currents in the canal are said to be strong enough at times to be hazardous to boaters. The strength of the tide pulse into Black water Sound via the waterway and the timing of these tides in relation to the weak periodic tide that reaches Black water Sound from the north through Jewfish Creek evidently haven't been investigated. Lee (1969) recorded periodic tides north to Long Sound in these connected lagoons, but didn't discuss the source of the tide pulse. Normal tide in Black water Sound is an inch or two ranging up to one foot on spring and equinoctial tides (pers. comm., H. Gilbert, Gilbert's Marine, Jewfish Creek). How much water movement to and from Black water Sound occurs via the waterway is unknown, but salinity data suggest the waterway's area of influence is small. Black water Sound was consistently hyper saline for many months in 1974% (Schmidt, unpubl. data) and no dilution by tide flow through the waterway was evident. Local observers assert that the sea trout fishery in Black Water Sound began to decline as soon as the waterway was opened .

Summary - Table 2 summarizes the salient hydrographic effects of road and canal construction in the study area.

Table 2. Major Hydrographic Impacts of Construction in Study Area

Construction	Effective Date	Effects
FEC Railroad fill	1907	Blocked water movement, closing all natural channels N of Jewfish Creek and cutting off 38% of Barnes Sound drainage area. Salt intrusion via E borrow ditch.
U.S. Route 1	1938	Same. Railroad fill raised and widened.
Local Canals	Early 1930s	Extensive salt intrusion E and SE of Florida City
Canal 111	mid-1965	Cut off 4410 of upland drainage area of Long Sound-Joe Bay.
M.D. Adams Waterway	1964	Uncertain. Opened Blackwater Sound to ocean tide

HYDROGRAPHY OF THE STUDY AREA

Here we consider as briefly as possible the aspects of hydrography that seem most relevant to restoration of the original patterns of water movement across the line of U. S. Route 1. We have undertaken to review all the hydrographic data we could locate for the water bodies in question with particular attention to salinity data. Although we found a considerable body of information not previously reviewed in this connection, virtually all of the information is both recent and short-term. The hydrographic database remains inadequate at almost every point. Long-term, comparative records of water level and salinity in adjacent water bodies are simply not available, so far as we can, determine. Such deficiencies become critical in any attempt to evaluate system characterized both by great year-to-year variation related to rainfall and by significant water movement related to relatively infrequent weather events, such as persistent strong winds from a given quarter. Thus, predicting the effects of restored water connections is at this point largely a matter of guesswork. Perhaps our strongest recommendation is that studies planned to remedy present information gaps should be started at once. Only in this way will the Park be in position to advance reasonable, data-supported suggestions for design changes come the time when 4-laning of U. S. Route 1 across the study area is again an active topic.

PERIODIC TTDE - Within the study area, northeastern Florida Bay is essentially tideless and Barnes Sound is subject to a tidal pulse that moves southward from the ocean connections to southern Biscayne Bay via Card Sound. Tides in the geographically intermediate lagoons - Long Sound, Little Blackwater Sound and Blackwater Sound - are insignificant in amplitude ranging from an inch or two to about one foot, but probably complex in character, because Black water Sound has two tide connections at Jewfish Creek and at the M. D. Adams Waterway across Key Largo. Data given by Schneider 1969) suggest that the two tide pulses probably are almost completely out of phase. Taking tides at Government Cut, Miami Beach, as the base, tide in Barnes Sound at Card Sound Road lags 5 hr 20 min on high tide and 5 hr 30 min on low tide, while at Garden Cove on the ocean side of Key Largo just outside Largo Sound the lags are 20 min on high tides and 40 min on low tides.

The influence of the tide run from Biscayne Bay into Barnes Sound is progressively diminished because the numerous shoals retard water transport. Preceding south in this system, each successive basin shows a sharp decrease in tide amplitude and a sharp increase in tide lag. Thus, mean tidal range in Barnes Sound is 0.43 feet at Card Sound Road and 0.47 feet at C-111, Manatee Bay, less than one quarter of the mean tide range in southern Biscayne Bay (Schneider, 1969). Tides in the area are semi-diurnal, but Barnes Sound tides lag Government Cut by 52 to 6 hours (Lee, 1975; Schneider, 1969).

As might be expected from the low amplitude and extreme lag, water exchange in Barnes Sound as a result of periodic tide alone is almost negligible (Lee, 1975). Restoring historic water connections will open Long Sound to tides from Manatee Bay, but, considering the small tide range in Barnes Sound, it seems unlikely that an appreciable increase in water exchange due to periodic tide will occur.

WIND TIDE - Extensive studies of flushing rates and processes in Card Sound and Biscayne Bay (Lee, 1975; Lee and Rooth, 1976) show that wind forcing is the dominant mode of water exchange. Conclusions reached for Card Sound should apply to the similar shallow lagoons in the study area to the south, the principal difference being these water bodies are more enclosed and lack direct access to the ocean. The rate of water exchange thus seems likely to be considerably slower under comparable conditions than that calculated for Card Sound. Table 3, a 25-year record of average prevailing wind direction and speed at Homestead Air Force Base, and Figure 6[6], an array of typical monthly wind roses for Miami, summarize winds in the area.

TABLE 3. Average Prevailing Wind Conditions, Homestead AFB, 1943-671

	From Direction	Speed (Kts)	Peak Gust (Kts) (1943-1967)
Jan	N	7	53
Feb	E	8	39
Mar	E	8	48
Apr	E	9	41

[6] Figure 6. Monthly wind direction, frequency and strength at Miami, 1957. Values = average wind velocity times number of days wind blew from a given direction. From U. S. Weather Bureau, Climatological Summary, Florida, 1957. [no available at the moment]

May	E	8	50
Jun	E	6	49
Jul	ESE	5	36
Aug	E	5	44
Sep	E	6	120
Oct	E	7	46
Nov	E	7	36
Dec	N	7	39

[1]Data from National Climate Center, Asheville, N.C.

Lee and Rooth determined that steady wind of moderate speed from one direction, such as the prevailing east and southeast winds of southern Florida, moved water to the downwind side of lagoons, but were unimportant as a flushing mechanism. They concluded that significant water exchange occurred only during relatively infrequent weather events that involved winds stronger than usual persisting from a given direction for several days. The typical incident of this kind is passage of a winter cola front. The amount of water exchange with a cold front was directly related to wind velocity and was greatest in the case of winds aligned with the major axis of the lagoon. They estimated that 10 percent of the volume of Card Sound was exchanged in cold fronts of average intensity (5 m/sec wind velocity, = 11mph), such as occur about once a week in December through April. In the more intense cold fronts whit winds >10 m/sec that occur at intervals of 1 to Sound may be exchanged during the passage of the front.

No calculations of wind-generated water exchange are available for Barnes Sound or for other water bodies of the study area, but it seems certain that, with former natural connections closed, the rate is substantially slower than for Card Sound. Calculations of mean water renewal rate based on salinity data (lee, 1975) yielded an estimate of 3.4 month for Barnes Sound as Compared to 1.3 month for Card Sound. The principal water exchange in lagoons of the study area probably is associated with specific incidents of persistent high study area probably is associate with specifics incidents of persistent high winds of several days duration. The exchange rate probably is slow with mean winter residence times of the order of 3 to 4 months and little exchange at other times of year except with tropical storms. Slow water exchange and residence time predisposes these water bodies to hyper salinity whenever rainfall is reduced. North and northeast winds in late fall-early winter (Figure 6), are likely to be most effective for water exchange in Barnes Sound, and northwest to north winds probably are most effective in other water bodies of the area.

[N.B. Lee and Rooth slid not consider the possible effects of former connections on the western (downwind) side upon water exchange generated in the Barnes Sound system by ordinary prevailing winds. Spring, 1977, observations at the restored Manatee Creek connection indicated a substantial east to west movement of water between Manatee Bay and Long Sound under the influence of persistent easterly winds]

Tropical storms are virtually the only wind events in summer-early fall that are sufficiently intense to force large-scale water exchange. From records of storm tracks for the period 1871-1963 (Cry, 1965) we estimate that 47 tropical cyclonic disturbances, about one every 2 years, passed close enough to affect the study area. We found no detailed comment on tropical storm effects on water exchange, but the more severe storms doubtless result in complete (and abrupt) renewal of water. Hurricane Betsy in September 1965, for example, generated a storm tide of about 10' in the study area (Corps of Engineers, 1965). In the 1871-1963 -record (Cry, 1965), similar events (direct hits or very near misses by storms with winds 74 mph) occurred 19 times, or about 1 per 5 years. Less intense or more distant tropical storms, such as Abby of J1.111e, 1968 (Schneider, 1969), commonly produce several days of sharply increased tide range. Their effect on water exchange may be roughly comparable to that of a strong winter cold front.

We found no definite information on the hydrographic effects of overland wind movement of water between basins at points where adjacent water bodies are separated by narrow belts of mangrove. Such water exchange is usual in the case of more intense tropical storms and is known to occur at least occasionally with persistent strong winds at other seasons. Nothing seems to have been recorded about the frequency of these episodes or the volume of water moved. In the study area, water exchange by this means might occur (or, in the case of Cross Keys, might once have occurred) across Shell Key, Boggy Key and Cross Keys. Low beaches and eroding bluff-like marl banks along a considerable extent of the shoreline of these areas (Figure 7)[7] must tend to impede overland water movement, but, in all instances, such movement may be possible across stretches of low mangrove shore. Provisionally, it seems unlikely that overland water exchange is a significant hydrographic factor, but need exists for observations during weather events that might induce overland water movement.

SEASONAL SEA LEVEL CHANGE - A seasonal sea level rise of up to 0.7' in the Gulf of Mexico (Marmer, 1954) reaches its peak during the onset of the rainy season. In northeast Florida Bay, elevated sea level through the summer tends to limit dilution of the Bay by freshwater runoff to an area immediately adjacent to the mainland. The abrupt drop in sea level during October along with seasonal changes in wind speed and direction permits freshwater runoff from the mainland establishes lowered salinity throughout the Bay system during years of moderate to heavy rainfall.

TABLE 4. Mean and Extreme Rainfall, 1952 through 1976. (Average of homestead Exp. Eta., Royal palm R.s and Tavernier.)

	Minimum	Year	Mean ANNUAL	Maximum	Year
	35.02	1971	55.27	78.65	1969
			MONTHLY		
J	0.21	1960	1.78	7.45	1958
F	0.10	1974	1.98	4.26	1957
M	0.01	1956	1.78	5.84	1958
A	0.06	1970	2.27	6.79	1960
M	1.03	1962	6.08	17.78	1968
J	2.78	1952	9.86	21.27	1969
J	2.80	1961	6.21	9.65	1958
A	2.99	1966	6.61	12.19	1973
S	2.87	1961	8.19	18.19	1960
O	2.79	1974	7.14	14.01	1969
N	0.25	1970	1.93	5.95	1959
D	0.09	1968	1.44	5.13	1958

[7] Figure 7. Shoreline characteristics related to overland movement of water between adjacent basins. [no available at the moment]

RAINFALL - In the enclosed and semi-enclosed lagoons of the study area water quality characteristics depend strongly upon the seasonal and year-to-year variations in the amount of fresh water that enters the system. Salinity measurements, in particular, are practically impossible to interpret without reference to the probable input of fresh water in the months that proceeded sampling. The record of rainfall over the coastal lagoons and their tributary upland drainage areas is the best available estimator of fresh water supply to the system.

To obtain a manageable and representative single datum for rainfall we averaged monthly records from Climatological Data for Homestead Experiment Station, Dade Co. (25^0 35' N, 80^0 30' W), Royal Palm Ranger Station, Everglades National Park (25^0 23' N, 80^0 36' W), and Tavernier, Key Largo, Monroe Co. (25^0 N, 80^0 31' W) for the period 1952-1976. The 25-year reference period includes the dates of the available salinity measurements and provides a span sufficient to reflect the longer-period rainfall cycles that are believed to occur in southern Florida (Thomas, 1970). Table 4 shows minimum, mean and maximum values for annual (calendar year) and monthly rainfall. In this record, June and September are the months of Heaviest rainfall; December, March and January average dryest; and, on average, 80 percent of annual rainfall occurs in the months of May through October. Table 5 ranks the 25 years of the period according to the amount of annual rainfall. In this record, very dry years, rainfa11<40", tended to recur at intervals of about 5 years 1961, (1965), (1970), 1971, 1974) and very wet years, rainfall>70", were clustered several together at intervals of about a decade (1958, 1959, 196o; 1968, 1969).

TABLE 5. Ranking of Calendar Years, Dryest to Wettest, 1952-1976

Year	Rainfall	Year	Rainfall	Year	Rainfall
1. 1971	35.02	9. 1975	50.73	17. 1953	60.66
2. 1956	35.69	10. 1963	50.96	18. 1954	60.71
3. 1974	39.01	11. 1973	51.87	19. 1966	60.74
4. 1961	39.43	12. 1962	53.30	20. 1976	64.55
5. 1970	42.01	13. 1957	54.15	21. 1958	70.00
6. 1965	43.92	14. 1967	55.52	22. 1960	71.26
7. 1955	46.81	15. 1972	57.69	23. 1959	75.67
8. 1952	48.92	16.1964	58.61	24. 1968	76.06
				25. 1969	78.65

SALINITY - In this section we consider the available salinity records for the three coastal lagoon systems presently of concern, namely, 1. - Barnes Sound-Manatee Bay; 2. - Long Sound, Little Blackwater Sound and Blackwater Sound; and, 3. - the extreme northeastern embayment of Florida Bay, roughly the water area east of a line from Snipe Point to Porjoe Key. As already mentioned, these water bodies have somewhat different hydrographic characteristics although tenuous connections exist between them via various passes and creeks. The point of present interest is the likely effect of restoring the more extensive connections that formerly existed between areas 1. and 2. The effect on salinity is a key concern, because it has been thought that restoring historical water connections might tend to ameliorate the chronic hyper salinity of northeastern Florida Bay. We have not addressed the question of possible trends of change in the salinity pattern of eastern Florida Bay. Ai, analysis of the historical salinity data for this area is in progress (Schmidt, in prep.).

The salinity records discussed here were obtained by various techniques and apparatus including hydrometers, Beckman salinometers, A/0 Goldberg field refractometers, and a Bissett-Berman continuously recording flow-through thermosalinograph (Lee, 1975). We have assumed that any differences in precision inherent in the several methods are insignificant for present purposes. To facilitate comparison salinity values have been rounded to the nearest part per thousand, normal sea water salinity in this area being 36-37 ppt. We have referred to readings between 37 ppt and 40 ppt as slightly hyper saline and to those >40 ppt as strongly hyper saline.

Barnes Sound - Probably because Barnes Sound has been only peripherally involved in south Florida's estuarine environmental controversies, it has received little systematic study. The available salinity data (Table 6) all are relatively recent and, excepting one group of samples (Lee, 1975), they represent incidental measurements. From the sparse record available it appears that salinity in Barnes Sound follows rainfall closely. The area may be more dilute than sea water well into the dry season after fairly wet years (1966, 1976) and slightly to strongly hyper saline for extended periods following very dry years (1974). By good fortune, monthly salinity measurements are also available from Marker 41, extreme southern

Blackwater Sound (Table 7; Schmidt, unpubl. data), covering the 1974-75 hyper saline episodes. These data show that Blackwater Sound tended to be more hyper saline than the highest reading in Barnes Sound by 2 to 3 ppt. Lower salinity readings its Barnes Sound in October, 1974, through February, 1975, probably reflect the water exchange resulting from winter cold fronts. The same slight decrease during the winter months is evident from Blackwater Sound data. None of the isohaline maps of Barnes Sound (Lee, 1975) exhibits a belt of sharply reduced salinity along the west (mainland) shore such as occurs in southern Biscayne Bay where canals discharge fresh water into the bay (Figure 8)[8], but the configuration of isohalines frequently shows a weak west of east gradient of increasing salinity which doubtless reflects upland drainage into Manatee Bay.

[8] Figure 8. Salinity contours (southern Biscayne Bay to Barnes Sound), 28-29 October 1974 [not available at the moment]

TABLE 6. Salinity Measurements, Barnes Sound Area.

Date	Location	Salinity $^{0}/_{00}$)	Source
Feb.-Mar. 1967	Manatee Creek, E side of U. S. Rt. 1	28	Tabb et al., 1967
18-19 May 1974	All of Barnes Sound	41-42	Lee, 1975
12-13 Aug.1974		40-46	
10-11 Sept. 1974		43-46	
28-29 Oct. l974		37-41	
21-22 Dec. 1974		32-39	
22-23 Jan. 1975		37-39	
27-28 Feb. 1975		38-40	
1-2 Apr.1975		41-44	
28-30 Apr. 1975		42-46	
3-5 June 1975		43-47	
7 Jan. 1977	Manatee Creek, E side	33	Coleman, unpubl. data
	Cross Keys, N side	33-34	
	Manatee Creek, E side	33	Coleman
	Cross Keys , N side	33	Patty,unpubli Patty unpubl. data unpubl. data
	Open Water, Manatee Bay	31	
	Open Water, Barnes Sound	31-32	
Feb. through May, 1977 (5 readings)	Open water, Manatee Bay	29-37	
	Open Water, Barnes Sound	33-35	
6 June 1977	Manatee Creek, E side	16	Patty & Wideman, unpubl. data
10 June 1977		9	
17 June 1977		22	
24 June 1977		21	

<u>Long Sound, Little Blackwater Sound, Blackwater Sound</u> - These water bodies comprise the estuarine frontage of Everglades National Park on U. S. Route 1. Blackwater Sound connects to Barnes Sound via Jewfish Creek and to Florida Bay via the Boggies and also via Dusenbury Creek, Tarpon Basin and Grouper Creek to Buttonwood Sound; Long Sound connects to Florida Bay via Shell Creek and historically connected to the Barnes Sound-Manatee Bay system via Manatee Creek and several smaller creeks; Little Blackwater Sound connects to Long Sound via Long Sound Pass and to Blackwater Sound via Blackwater Pass but has no channel connections, present or historical to either Barnes Sound or Florida Bay. Table 7 shows the available salinity data.Very few measure had been obtained from Long Sound prior to our work in 1977, and most of the: more extensive record for Blackwater and Little Blackwater reflects conc9itions during an extended hyper saline episode coincident with low rainfall.

TABLE 7. Salinity Data for Long Sound (L), Little Blackwater Sound (LB), and Blackwater Sound (B) at Marker 41 (Nend Dusenbury Creek). Source: 1967 (Tabb et al., 1967); 1973-76 (Schmidt, unpubl. data); 1977 (Coleman and Patty, unpubl. data)

Months	1967	1973	1974	1975		1976		1977		
	L	B	B	LB	B	LB	B	L	LB	B
J			35	42		40	41	15-27	26-30	30-35*
F	21-25		36	43		40	40	25-28	30	30-32
M			33	46			40	32-34	34	34-35
A			42	46			43			
M		40	45	49		42	45	26-38	26-38	30-38
J			44	48			35	4-23	26-38	36-38
J			48	50		11				
A			47	43			35			
S		36	46	42			20 36-42**			
O		31	43	27	43					
N		34	40	33	39					
D		35				35	38			

* Six stations

**At marker 37, S

Fresh water drainage enters this system through Long Sound and the scanty record suggests that a gradient of increasing salinity generally exists from Long Sound to Little Blackwater and Blackwater. All three of these come at least slightly hyper saline in extended periods of reduced input of fresh water. Readings for Little Blackwater Sound on 30 May 1976 (42 ppt) and 8 July 1976 (11 ppt) illustrate how abruptly salinity may change with heavy rainfall (16.99", 1 May through 30 June). An additional complication in these lagoons is pro¯v-'d,--d by a weak tidal pulse (originating in Barnes Sound, or possibly in Largo Sound via the M.D. Adams Waterway) that runs from Blackwater Sound up into Long Sound with salinity differences of 2-3 ppt between ebb and flood tides (Figure 9)[9].

Northeastern Florida Bay - Northeastern Florida Bay has a more extensive database of salinity measurements (Table 8) than is available for other parts of the study area. The records of three hyper saline episodes - in 1957, 1965, and 1974-76 - are of particular interest. Peak readings around 50 ppt ti4ere obtained on each occasion. The hyper saline periods of 1957 and 1965, however, were followed by high rainfall years, in 1958 and 1966, and reduced salinities. In contrast, the low rainfall year of 1974 (third dryest of 25-year record) was followed by below average rainfall in 1975 and the early months of 1976, resulting in an extended period of hypersalinity.

TABLE 8. Salinity records, Extreme Northeastern Florida Bay[1]

Months	1953	1957	1958	1965	1966	1973	1974	1975	1976	1977
J					30_{-35}		33	44	42	29_{-35}
F			32_{-36}		30_{-36}		35	44	43	35
M							33	47	45	
A							44	48	45	41
M					.35		45	43	47	35_{-38}
J				40_{-45}			47	50	28	21_{-34}
J				47_{-50}	<20		50	48	39	
A		40_{-50}	.30				50	41	29	
S				40_{-45}		35	49	47		
O	.30					30	46	42		
N				.35		34	40	40		
D						37	44	40		

1 Sources: 1953 (Ginsburg, 1956); 1957-58 (McCallum and Stockman, 1964); 1965-66 (Tabb, unpubl. data); 1973-76 (Schmidt, unpubl. data); 1977 (Coleman and Patty, unpubl. data)

Summary - It seems obvious that records from a salinity sampling net that i.s much tighter in both space and time than that now available are required before there can be any detailed

[9] Figure 9. Salinity and surface currents on ebb (A) and flood (B) tides, Little Blackwater Sound vicinity, February-March, 1966 (from Lee, 1969) [Figure not available at the moment]

understanding of the processes and rates of salinity change in the study area. A close inverse relationship evidently exists between salinity in these water bodies and rainfall over the area, and effects of tidal mixing appear to be slight, even in Barnes Sound. Beyond these points, no general conclusions are possible from the data. Accurate prediction of the effects on salinity likely to result from restoration of historical water connections to Barnes Sound requires knowledge of salinity gradients across a wide range of rainfall conditions. For this, the present database of simultaneous readings across the various barriers and constricted connections in the study area is altogether inadequate. The recorded salinity ranges in water bodies of the study area (Table 9) and the salinity gradients evident in measurements taken at about the same time across barriers and constrictions (Table 10, Figure 10) suggest that Long Sound is regularly fresher than the other water bodies in the study area and that a fairly steep salinity gradient exists from Long Sound to Barnes Sound at Manatee Creek in years of heavy to moderate rainfall. Thus, in the conditions measured to date, restoring the historical Manatee Creek connection would tend to dilute Barnes Sound, rather than the reverse as sometimes suggested. Long Sound becomes hyper saline during extended droughts and the salinity gradient may be reversed under such crate, however, that Barnes Sound itself is prone episodes of greatly reduced rainfall. Given the small east to west salinity gradient likely to exist in even the most extreme drought conditions and the relative. The data indicate hypersalinity during episodes of greatly reduced rainfall. Given the small east to west salinity gradient likely to exist in even the most extreme drought conditions relatively inefficient connections at Manatee Creek and Shell Creek, it seems doubtful that introduction of Barnes Sound water into Long Sound is likely to relieve hyper saline conditions in northeastern Florida Bay.

Improving the partially blocked connection between Barnes Sound and Blackwater Sound at Jewfish Creek seems likely to have only minor effects upon salinity in Blackwater Sound. The few data available suggest that the salinity difference between Blackwater Sound and southern Barnes Sound is usually slight. Significant dilution of northeastern Florida Bay from Blackwater Sound is unlikely, because both water bodies tend to exhibit equally intense hypersalinity with reduced rainfall.

Table 9. Known Salinity range in Water Bodies of the Study Area

Water Body	No. of Salinity Measurements	Range (‰)
Barnes Sound -Manatee Bay	18	9 - 47
Long Sound	10	4 - 38
Little Blackwater Sound	22	11 - 42
Blackwater Sound	47	26 - 50
NE Florida Bay	53	<20 - 50

Table 10. Salinity Gradients between points. (From measurements made on or near the same day

Salinity Gradient (lower to higher) From – To	Date(s)	No. of Data points	Salinity Difference ‰
Barnes Sound, Nor NW- Barnes Snd., Sou SE	Oct.-Dec., 74; Feb-Apr.,'75	5	2,3,4,4,7
Barnes Snd., W- Barnes Snd.., E	Aug & Sep.,'74 Jan. & June,75'	4	2, 3, 4, 6
Barnes Snd., S- Barnes Snd.., N	May '74	1	1
Barnes Snd., Jewfish Cr. –BWS 41	Mar. '74-June'75;Mar.-June'77	10	1 to 4
Blackwater Snd., 41-BWS, 37	Sept. '76	1	7
BWS, 37-BWS, 41	Jan., 77	1	1
BWS, 41-Buttonwood Snd.; 54	May, '73;June, Aug, Sept. '76 Jan. – Mar., '77	7	4, 7, 7, 4, 2, 2, 2
BWS, 44 NE Fla, Bay Boggies	Dec. '73-Aug., '76; Jan.., '77	26	1(3); 1 to 5 (21); 5
NE Fla. Bay, Boggies-BWS, 41	Sept., '73 – Sep., '76	14	1(4); 1 to 5(7); 5
Bays N of Long Sound-Long Sound	Feb. – Mar., '67; Jan.,'77	2	7, 13
Manatee Creek, W – Manatee Creek, E	Feb. – Mar., '67; Jan.,'77 (2)	6	7,8,11,5,5, 1
Long Sound, E – Long Sound, W	Feb., - Mar., '67 Jan.-June, '77	5	5,12,3,1,19
Long Sound, W – Long Sound, E	May – June, '77	4	6, 2 ,8
Shell Creek, N – Shell Creek S	Jan. – June, '77	7	2,9,10,10,10,4,15
Long Sound Pass N-Long Sound Pass, S	Feb. – Mar '66; Jan. – June, '77	10	2, 2, 4, 3, 10, 10, 11
Black Water Pass N- BW Pass, S	Feb. – Mar., '66; Jan. – June, '77	7	2,2,2, 1, 13, 13, 60

Preliminary Observations, Manatee Creek Culverts - The two 60" culverts at Manatee Creek were in place and open to flow of water after early March 1977. In view of the delay in final drafting of this report, it seems appropriate to summarize initial observations of water movement via the restored connection. Available data include a number of casual notes on the direction and strength of flow at Manatee Creek and series of salinity samples taken on eight dates from late April to late June. Though the record is incomplete it permits preliminary comment on the characteristics of water exchange and its apparent effects on salinity under various weather conditions over a time span encompassing the end of the dry season and the first weeks of the rainy season.

Flow Characteristics - The direction and strength of flow at Manatee Creek appears to be determined primarily by wind force and direction, and, in the absence of effective easterly or westerly winds, flow characteristics are governed by the weak pulse of periodic tide that enters the Barnes Sound system from the north. Observations in March and in May-June showed that east to west and west to east flows were about equally com on, but that strong winds tended to establish a persistent flow in the downwind direction, apparently canceling the effect of the periodic tide. When wind forcing was not a factor and tidal effects predominated, flow commonly was less than full-bore of the culverts and probably little net movement of water occurred.

Excepting a few instances in the last week of the month, all observations at Manatee Creek in April, 1977, recorded east to west flow usually at full capacity of the culverts. This flow regime apparently was determined by a period of east to northeast winds (mostly 10 to 15 knots) that persisted through most of April. Although no measurements of flow are available, salinity data indicated that under these conditions there was a substantial net transport of water from the Barnes Sound system into Long Sound and possibly into northeastern Florida Bay

Effects on Salinity. Because we lack salinity data for most of April, belief that the strong east to west flow through the Manatee Creek culverts in April may have had some influence in northeastern Florida Bay must rest upon interpretation of salinity measurements made in the northeastern Bay on 28 April and throughout the relevant area on 5 May. On 28 April, northeastern Florida Bay was strongly hyper saline (41-45 ppt, 12 data points), but the pattern of the salinity measurements showed two unusual features. First, salinity readings in connecting waters along the southern mainland (Taylor River, Little Madeira Bay, Mud Creek Bay) were slightly higher (43-45 ppt, x = 44.6 ppt, 6 data points) than those in adjacent open waters of Florida Bay (41-44 ppt, = 42.7 ppt, 6 data points). Second, a weak east to west gradient of increasing salinity existed at the open water Bay stations from 41 ppt off Snipe Point to 43.3 ppt (range 42-44 ppt) at, three stations off Madeira Beach and Black Betsy Keys. The differences admittedly are slight, but we can find no other series of salinity measurements for the area that duplicates this pattern. It appears that the pattern could have resulted from transport of water of about seawater salinity from Barnes Sound to northeastern Florida Bay via Manatee Creek, Long Sound and Shell Creek. And, notably the salinities that suggest such an occurrence coincided with weather conditions that may have been sufficient to bring about the necessary water exchange.

A week later, on 5 May, a general decrease in salinity had occurred and mainland connecting waters averaged slightly less saline than the open waters of northeastern Florida Bay, doubtless reflecting the start of the rains. The east to west gradient of increasing salinity was still evident in the open Bay, however, with average readings of 37.5 ppt (2 data points) in the area from Snipe Point to the Boggies and 39.8 ppt (range 38-41) at 12 stations farther west to Black Betsy Keys. On 19 May and 27 May, the gradient had disappeared and stations in the extreme northeastern Bay average slightly more saline than those farther west. By early June, continued heavy rains had established a typical summer salinity pattern with a belt of reduced salinity along the entire mainland shore of the northeastern Bay.

Salinity measurements taken in Long Sound and Manatee Bay during May and June, 1977, indicated that the zone of influence of the Manatee Creek-connection was limited at that time to relatively small areas near the culverts. As anticipated, water exchange through the culverts tended to increase salinity in the eastern end of Long Sound and to dilute the adjacent areas on Manatee Bay.

Thus, it appears that the effects of water exchange via Manatee Creek are likely to be relatively local except during episodes of persistent strong winds from either east or west.

Periods of persistent easterly winds in spring are rather frequent, and, when they occur, they may force sufficient transfer of water to ameliorate slightly the chronic late dry season hypersalinity of northeastern Florida Bay.

Obviously, conclusions expressed above are highly provisional. We can only re-emphasize the need for much more precise and sustained study of water exchange of Manatee Creek and its effects.

MOVEMENT OF ANIMALS

The FEC Railroad-U. S. Route 1 embankment is an impassable barrier to the movement of aquatic animals across its alignment at any point north of the main channel of Jewfish Creek. Heavy traffic on the highway makes it also a considerable hazard and impediment to movement of amphibious and terrestrial animals. Of particular concern in this connection are the Manatee and the Crocodile, both endangered species. At present U. S. Route 1 appears to some degree to separate the southern Florida populations of these species into two semi-isolated segments.

Park wildlife records and the comments of local observers indicate the Manatees were seen much more frequently around Jewfish Creek and elsewhere in the study area 10 to 20 years ago than they are today. The names, Manatee Greek and Manatee Bay, also suggest that the species was once conspicuous in the area. Recent aerial surveys (pers. comm. D. K. Odell) however, have, recorded only an occasional Manatee in the area south of Sound Card. The most likely explanations of decreased use of the area by Manatees are disturbance and mortality resulting from greatly increased boat traffic at Jewfish Creek and in the area at large, and habitat deterioration, such as a decline in the standing crop of the aquatic plants Manatees feed on, due to increasingly saline conditions. Available information allows no choice between these possibilities but both may well have been important. Restoring historical water connections in a manner that does not make these passages available to boat traffic would at least facilitate potential movement of Manatees through the area.

Crocodiles still occur sparingly in all water bodies of the area on both sites of U. S. Route 1 but the record again suggests that they have become decidedly less common since the 1950s. In this case, man-caused mortality, including individuals killed by being hit by cars, has undoubtedly had considerable impact on a population that numbers no more than a few hundred adults. Ogden (in press) logged 11 known instances of man-caused mortality or Crocodiles in the period 1971-75 of which 4 (possibly 5) were traffic casualties. One known and one possible traffic kill occurred on U. S. Route 1 at Lake Surprise. Inasmuch as this record of recent mortality is almost surely incomplete, it seems obvious that provision of safe highway crossings could be a factor of some importance in the survival of the Crocodile population.

Odell (pers. comm.) indicated that Manatees might be expected to use submerged culverts of adequate size (60" diameter or larger) in moving between water bodies provided that the approach depth at the culvert ends was sufficient. Ogden (in litt.) stated that, although big Crocodiles doubtless cross highways where they choose, foraging individuals seemed to follow lines of least resistance and, where possible, avoided areas of heavy human activity. As their movements are often along the course of deep water channels, he felt there was little doubt that Crocodiles in the area would find and use culverts under U. S. Route 1. Ogden suggested that, in addition to the Manatee Creek and North Jewfish Creek connections, culvert passages north of Manatee Creek and near the east end of the fill across Lake Surprise would be especially desirable.

REPORT HISTORY AND AUTHORSHIP

Robertson was assigned the job of preparing this management report on 17 December 1976 and work of assembling the initial draft occupied about 5 weeks in January and February, 1977. The report may be considered the completion report of the East Florida Bay project. Coleman supervised the collection of field data for the report and researched and drafted part of the discussion of hydrography. Schmidt provided most of the recent salinity data from 1973-76 records of the Florida Bay Fish Ecology and Water Quality project, helped prepare the discussion of salinity, and reviewed the report. Hermance supplied information on the construction that impacted upland drainage in the area and reviewed the report. Rose calculated the original and altered drainage areas tributary to various water bodies in the estuary. Patty assisted in collection of field data, helped assemble data on construction, and saw the report through final revisions and typing. Robertson organized the effort and composed and typed several drafts.

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