REPORT TO CORPS OF ENGINEERS BY DR. GUNTER,
DATED OCTOBER 15, 1960 ENTITLED:
BIOLOGICAL INVESTIGATIONS OF ST. LUCIE
ESTUARY IN CONNECTION WITH LAKE OKEECHOBEE
DISCHARGES THROUGH ST. LUCIE CANAL

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IN CONNECTION WITH
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A Report to the District Engineer,
Jacksonville District, Corps of Engineers,
By
Dr. Gordon Gunter, Biological Consultant,
Gulf Coast Research Laboratory,
Ocean Springs, Mississippi

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BIOLOGICAL INVESTIGATIONS OF ST. LUCIE ESTUARY
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A. INTRODUCTION

1. Study authorization.--A survey of the turbidity, salinity, and sediment effects of St. Lucie Canal discharge into St. Lucie Estuary was authorized by the Chief of Engineers on May 9, 1955. Expansion of that program to include the work of the present biological investigation was authorized by the Chief of Engineers on June 12, 1956.

2. Scope and purpose of this report is to: (a) Review the history of St. Lucie Canal and analyze the problems concerned with discharges of fresh water into St. Lucie Estuary; (b) present biological data from a 2-year investigation of estuarine conditions, January 1957 to January 1959; (c) determine the biological effects of operation of St. Lucie Lock and Dam with reference to important indicator species and evaluate the wide range of claimed damages relative thereto; and (d) determine operational procedures, practicable within the specific operational requirements of the project, which would either be beneficial or of the least damage to estuarine fishes and fishing conditions.

3. References.--Reference is made to the following reports and specific design memorandums of the Jacksonville District, Corps of Engineers, pertaining to the Central and Southern Florida Project. A separate bibliography of biological references is given at the end of this report.

a. The project document--Comprehensive Report on Central and Southern Florida for Flood Control and Other Purposes, dated December 19, 1947, printed as House Document No. 643, 80th Congress, 2d session.

b. Part I (basic report)--Agricultural and conservation areas (with preliminary information on Lake Okeechobee and principal outlets), dated July 10, 1951.

c. Part IV, Supplement 2, Section 5--Design memorandum, Lake-regulating facilities, dated January 12, 1954.

d. Part IV, Supplement 4--Design memorandum, Effects of fresh-water discharges through St. Lucie Canal, dated October 27, 1954.

4. Acknowledgment.--Mr. Gordon Hall, formerly Biologist for the Jacksonville District and the South Atlantic Division, Corps of Engineers, assisted in the collection and analysis of field data and preparation of this report. Mr. Chester Adams, boat operator, Clewiston Area Office, and Messrs. Robert Highsmith and Paul Berry, Survey Branch, Jacksonville District, ably assisted in the field collections.

B. BASIC CONSIDERATIONS

5. Purpose and history of St. Lucie Canal.--St. Lucie Canal was built originally by the Everglades Drainage District to provide an improved outlet to tidewater for control of floodwaters in Lake Okeechobee. Construction along the shortest and cheapest route to tidewater was begun in 1916 and practically completed in 1924. At that time the canal, with a capacity of 5,000 cubic feet a second with Lake Okeechobee at elevation 15.6 feet*, was controlled by two dams, one near the lake and the other near the lower end. Serious shoaling of eroded material and reduction of channel capacity occurred as a result of storms in 1924, 1926, and 1928. The deposited material was excavated by the Drainage District in 1927 and 1928 but channel capacity was again reduced during the storm of 1930. In 1930, the United States Government accepted control of Lake Okeechobee as an authorized project, and since that date the canal has been maintained and operated by the Corps of Engineers. Construction of fixed spillways at 16 inflow points along the banks of St. Lucie Canal (plate 1) was initiated

*Unless otherwise stated, all stages and elevations throughout this report refer to mean sea level datum.

in 1933 in order to prevent sediment from entering the canal. In 1937, the waterway was improved to provide a navigable channel 6 feet deep. The River and Harbor Act of 1937 authorized replacement of obsolete structures at the two locks with a new lock and spillway at the site of the lower dam. The main spillway was completed in 1944, except for tainter gates which were installed in 1950. The canal was enlarged in 1949 to provide a navigable depth of 8 feet and a discharge capacity of about 9,000 cubic feet a second with the lake stage at 15.6 feet.

6. Location and description.--a. St. Lucie Canal leaves Lake Okeechobee at Port Mayaca and extends northeast about 25.6 miles to the South Fork of St. Lucie River, 7 miles south of the confluence of the North and South Forks of that river at Stuart. St. Lucie Lock and Dam are located about 1.9 miles from the lower end of the canal, or about 23.7 miles from the entrance at Lake Okeechobee (plate 1). The local watershed of the canal between the lake and the lock and dam, 79 percent of which is on the north side, covers 185 square miles. The area is imperfectly drained, with flat slopes, many swamps, and small lakes, and is often wet. Elevations range from 45 feet along the northerly divide to 20 to 25 feet along the canal. The soil is mostly fine sands and the native vegetation principally wild grasses, sawgrass, and scattered pine and palmetto growth. St. Lucie Canal is a part of the cross-State Okeechobee Waterway that extends from the Atlantic Ocean near Stuart to the Gulf of Mexico southwest of Fort Myers. It is one of the two primary outlets used in regulating Lake Okeechobee levels under the Central and Southern Florida Flood Control Project (plate 2).

b. St. Lucie Estuary.--(1) General location.--St. Lucie Estuary is located in the tidewater area at the junction of the North and South Forks of St. Lucie River near Stuart, in Martin County, Fla. (plate 3). The main river empties into the Atlantic Ocean through St. Lucie Inlet, about 8 miles from where the two forks join. The outer portion of the estuary is separated from the Atlantic Ocean by two long strips of land between which flows the Indian River. The latter, except for the 8-foot dredged Intracoastal Waterway, is a shallow lagoon that also discharges into St. Lucie Inlet.

(2) St. Lucie Inlet was opened by citizens in the vicinity in 1892. It was originally 30 feet wide and 5 feet deep, but by 1898 it had widened to 1,700 feet with available depths at low water of 6 to 7 feet. Prior to opening of the inlet, St. Lucie River flowed into Indian River. Tidal currents in the estuary were low, and the water in lower St. Lucie River probably was much fresher than it is now.

(3) Description and physical characteristics.--St. Lucie Estuary consists of three main sections. Pertinent reference points and depth information are shown on plate 3. The outer and largest portion of the estuary extends from Sewall Point near the mouth of Indian River to Roosevelt Bridge (US 1) at Stuart. Two points of land there naturally

constrict the river opening to separate the outer from the inner estuary. The North Fork and South Fork arms comprise the inner estuary. The North Fork Estuary extends from the junction at Stuart to the mouth of the North Fork River near Kitching Cove. It receives runoff from a drainage area of 450 square miles in St. Lucie and Martin Counties via the North Fork of St. Lucie River, numerous agricultural drainage canals, and Bessey Creek. The South Fork of the estuary extends from United States Highway 1 bridge to the mouth of St. Lucie River above the Palm City bridge. The total surface area, volume of water, and miles of shoreline at mean low water in each of three sections of the estuary are given in table 1.

TABLE 1

Total surface area, volume of water, and shoreline miles at mean low water in the three main sections of St. Lucie Estuary

Area	Surface area (acres)	Volume of water (acre-ft.)	Shoreline (miles)
South Fork Head of estuary to U.S. Hwy. 1 bridge	960	4,720	9.20
North Fork Kitching Cove to U.S. Hwy. 1 bridge	1,840	16,740	12.05
Main estuary U.S. Hwy. 1 bridge to Sewall Point	2,730	19,690	14.25
Total	5,530	41,150	35.50

During nondischarge years and low flow periods, tidal waters extend up the South Fork to St. Lucie Lock and several miles up North Fork River. The mean range of tide is 2.6 feet at St. Lucie Inlet and 1.3 feet at Stuart. Normal salinities range from 5.0 to 20.0 parts per thousand throughout the inner estuary and from 20.0 to 35.0 parts per thousand in the outer estuary. However, normal rain and runoff into either of the forks, or rain on the estuary itself, are likely to make the surface waters of the estuary temporarily fresh to below Stuart.

7. Discharges into St. Lucie Estuary.--a. Through St. Lucie Canal.--Reliable estimates of St. Lucie Canal discharge are available since April 1931 when the United States Geological Survey began operations in the canal. For the purposes of this report, estimated volumes of monthly flows from Lake Okeechobee since 1945 are given in table 2. Lake Okeechobee stages for the last day of the month during the same period are given in table 3. The total annual discharges of St. Lucie Canal at St. Lucie Lock and Dam, which include runoff in some years from the local drainage area, are depicted on plate 4 for the period 1945-58.

TABLE 2

"Revised from "Monthly Discharges 1945-58""

St. Lucie Canal

Estimated volumes of monthly discharges

Year	Monthly discharge (1,000 acre-ft.)												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1945	13	10	16	17	18	24	15	16	91	343	258	15	836
1946	31	15	130	87	11	18	8	8	10	109	16	21	464
1947	22	3	116	224	90	106	290	320	310	402	410	394	2,687
1948	350	316	290	232	38	24	10	14	90	356	352	336	2,408
1949	140	4	2	1	1	1	1	32	384	324	-	-	890
1950	-	-	-	-	-	-	-	-	-	-	-	-	-
1951	-	-	-	-	-	-	-	-	-	397	130	-	527
1952	-	-	-	-	-	-	-	-	-	184	267	-	451
1953	-	-	-	-	-	-	-	351	463	578	499	514	2,405
1954	206	-	-	-	63	310	387	357	107	39	-	-	1,469
1955	-	-	-	-	-	-	-	-	-	-	-	3	3
1956	-	-	-	-	-	-	-	-	-	-	-	-	-
1957	-	-	-	-	46	90	-	85	385	253	-	-	859
1958	204	335	234	367	330	129	148	99	26	-	-	-	1,872

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7. <u>Discharges into St. Lucie Estuary</u>.--a. <u>Through St. Lucie Canal</u>.--Reliable estimates of St. Lucie Canal discharge are available since April 1931 when the United States Geological Survey began operations in the canal. For the purposes of this report, estimated volumes of monthly flows from Lake Okeechobee since 1945 are given in table 2. Lake Okeechobee stages for the last day of the month during the same period are given in table 3. The total annual discharges of St. Lucie Canal at St. Lucie Lock and Dam, which include runoff in some years from the local drainage area, are depicted on plate 4 for the period 1945-58.

TABLE 2

St. Lucie Canal

Monthly discharges, 1945-58

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Year	Monthly discharge (1,000 acre-ft.)												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1945	13	10	16	17	18	24	15	16	91	343	258	15	836
1946	31	15	130	87	11	18	8	8	10	109	16	21	464
1947	22	3	116	224	90	106	290	320	310	402	410	394	2,687
1948	350	316	290	232	38	24	10	14	90	356	352	336	2,408
1949	140	4	2	1	1	1	1	32	384	324	-	-	890
1950	-	-	-	-	-	-	-	-	-	-	-	-	-
1951	-	-	-	-	-	-	-	-	-	397	130	-	527
1952	-	-	-	-	-	-	-	-	-	184	267	-	451
1953	-	-	-	-	-	-	-	351	463	578	499	514	2,405
1954	206	-	-	-	63	310	387	357	107	39	-	-	1,469
1955	-	-	-	-	-	-	-	-	-	-	-	3	3
1956	-	-	-	-	-	-	-	-	-	-	-	-	-
1957	-	-	-	-	46	90	-	85	385	253	-	-	859
1958	204	335	234	367	330	129	148	99	26	-	-	-	1,872

VOID
SEE REVISED SHEET

TABLE 3

Lake Okeechobee stages for last day of month

1945-58

Year	Stage (ft.)												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly average
1945	13.2	13.0	12.9	12.1	11.6	11.7	12.6	13.2	15.5	15.8	15.4	15.5	13.5
1946	15.4	15.3	15.0	14.1	14.1	14.2	14.4	14.6	15.0	14.7	15.0	15.0	14.7
1947	14.8	14.8	15.3	14.8	14.5	15.2	15.7	15.9	17.9	18.7	18.4	17.4	16.1
1948	16.9	15.9	14.6	13.6	13.4	13.0	13.2	13.8	16.2	17.6	16.8	15.6	15.0
1949	14.7	14.1	13.5	13.1	12.6	13.1	13.6	14.6	14.8	14.7	14.8	15.2	14.1
1950	15.0	14.7	14.4	13.9	13.5	13.1	13.0	13.0	12.9	13.8	13.8	13.8	13.7
1951	13.6	13.5	13.1	13.1	12.9	12.8	13.2	13.7	13.9	15.6	15.1	15.0	13.8
1952	14.8	15.0	14.5	13.6	13.1	12.9	13.1	13.6	14.1	15.8	15.3	15.2	14.3
1953	15.2	14.9	14.2	13.7	12.9	13.3	13.9	14.2	16.0	17.6	17.0	16.1	14.9
1954	15.3	14.9	14.5	14.1	13.5	14.0	14.1	13.5	14.2	14.4	14.4	14.4	14.3
1955	14.4	14.3	13.8	13.5	12.9	13.5	13.5	13.5	13.6	13.3	13.0	12.8	13.5
1956	12.6	12.4	11.8	11.3	10.9	10.5	10.4	10.3	10.8	12.7	12.6	12.6	11.6
1957	12.9	12.9	13.2	13.4	13.6	13.3	13.5	13.9	14.9	14.7	14.8	15.5	13.9
1958	16.1	15.2	15.2	14.6	13.5	13.1	13.2	13.3	13.6	13.7	13.5	13.8	14.1
Period-of-record average since 1912	14.8	14.6	14.4	14.0	13.7	13.9	14.1	14.4	15.0	15.3	15.1	14.9	14.5

Although the capacity of St. Lucie Canal was almost doubled by the enlargement in 1949, caving banks and bottom filling since then have reduced the channel efficiency. The latest available rating curve gives maximum regulatory discharges from the lake through St. Lucie Canal for various lake stages as follows:

Lake stage (ft.)	Regulatory discharge (c.f.s.)
13.5	5,500
15.0	6,600
15.5	6,950
16.5	7,800
17.5	8,800
18.0	9,300

Between 1945 and 1957, the years of prolonged heavy discharge from the lake were 1947-48 and 1953-54.

b. From other areas.--Discharge measurements over a period of record for the North Fork of St. Lucie River and other areas draining into St. Lucie Estuary are not available. However, the total annual runoff from the North and South Forks, exclusive of Lake Okeechobee releases, was estimated from rainfall. The estimated total annual discharges into St. Lucie Estuary from all sources, except rainfall on the estuary, during the period 1945-58 are shown on plate 5. The estimated total amount of runoff from the separate local areas for that period is shown on plate 6. A comparison of plates 4, 5, and 6 shows the influence that the North Fork can have on fresh-water conditions in the estuary. During years when no lake waters are being released through St. Lucie Canal--such as 1950, 1955, and 1956--the North Fork contributes most of the total discharge, and its effects are evident. In other years, the effects of discharge from the North Fork area are often masked by the greater discharge from St. Lucie Canal. Instantaneous peak flood flows into the estuary from the North Fork River alone have been estimated to be as high as 5,000 cubic feet a second and the total peak flows from all runoff into the North Fork may reach 9,000 cubic feet a second under existing conditions.

C. DISCUSSION OF THE PROBLEM

8. Effects of fresh-water discharge.--a. Local contentions.--Local interests in the Stuart area, primarily through the Stuart News and spokesmen for the St. Lucie-Indian Rivers Restoration League, have contended for many years that the release of turbid, fresh waters through St. Lucie Canal has caused serious damages to fishing, boating, and esthetic attractions in St. Lucie Estuary. In turn, the tourist industry, on which the economy of that community is said to depend, is alleged to suffer in years when winter discharges are made. Specific complaints of damage are many and varied, the principal ones being that when the turbid fresh-water discharge replaces the water of the estuary:

(1) The small fish, and sometimes larger ones, are killed.

(2) The marine game and sport fishes leave the area.

(3) Sport fishes disperse throughout the estuary so that they are not easily caught.

(4) Sport fishes won't take bait or lures when the water is turbid.

(5) Marine organisms such as clams, snails, and oysters, unable to leave the area, are killed by the fresh water.

(6) Deposits of silt and ooze blanket the bottom, smothering bottom animals and destroying aquatic habitats.

(7) Commercial fishing, inside and outside the estuary, is damaged.

(8) Crabs and shrimp are driven from the area.

(9) The effects on fish, organisms, and their habitats endure long after the discharge stops.

(10) Sailfishing off the coast has been seriously affected.

(11) Shoal areas are formed in the river mouths and near the inlet, and boat navigation is affected.

(12) Real estate values around the estuary suffer.

(13) Tourists won't come to or stop in Stuart during discharge periods and the business economy suffers.

b. Previous studies.--(1) General.--News items and editorials condemning the St. Lucie Canal discharge have been appearing regularly in the Stuart newspaper for a number of years. In 1953, the local people formed the St. Lucie-Indian Rivers Restoration League, the primary objectives of which are discontinuance of lake releases through St. Lucie Canal and restoration of St. Lucie River to its former condition. The District Engineer has received protests from the League following practically all discharge periods. However, most of the allegations concerning the effects of the discharge on fish and fishing in the estuary have no factual basis. Prior to 1957, no comprehensive biological investigations had been conducted in those waters. Furthermore, other matters not directly concerned with present canal operations, such as removal of shoals, widening and deepening of the inlet, and real estate development, are of concern to local interests and often linked and confused with the fishing picture in the estuary.

(2) University of Miami reports.--In June 1953, the Jacksonville District contracted with the University of Miami Marine Laboratory for a preliminary survey of the effects of releasing water from Lake Okeechobee on marine life in the St. Lucie and Caloosahatchee Estuaries. University personnel collected field data on salinities and turbidities in relation to discharge and anecdotal evidence from local citizens and analyzed fish-catch statistics already available. No biological samples were taken. Three reports (see bibliography)--submitted in January, March, and June 1954--contained the following conclusions with regard to the effects of fresh-water releases into St. Lucie Estuary:

(a) Temperature, dissolved oxygen, and pH were not sufficiently affected to be of importance.

(b) The severe and rapid changes in salinity occurring as a result of lake releases were sufficient to cause temporary exodus from the area of fishes preferring a more saline habitat, and it could cause the death of forms unable to migrate.

(c) There was no indication of any serious reduction in commercial-fishing activity.

(d) Sports-fishing business is believed to be seriously harmed, although no damage may be done to the fish stocks themselves.

(e) Sediments are being deposited and retransported in the estuary during and following lake releases. In relation to both sports and commercial fishing, the effects of the sediment deposition are of a more permanent nature than the effects due to salinity changes, and control of the sediments was considered the most important problem involved in the water releases. The effects of the sediment cannot be fully appraised without a detailed investigation.

(f) Salinity changes and sediment deposition were sufficient to cause substantial damage to the area ecology and fisheries.

(g) Since continued releases of fresh water into the estuary to control Lake Okeechobee were necessary, the only possible means of alleviating the ill effects was to reduce the rate of flow and increase its duration. The reports recommended careful study of canal operations in that respect and detailed ecological investigations of the estuary in relation to sediment and salinity changes resulting from canal discharge.

9. The sediment problem.--a. Available sediment data.--In 1953 and 1954, the Jacksonville District conducted a study to determine the extent of the sedimentation problem in St. Lucie Estuary resulting from discharges through St. Lucie Canal. Analysis of the problem was based on data from previously available hydrographic surveys of St. Lucie Canal, River, and Estuary dating back to 1883 and other data as follows:

(1) A series of suspended-sediment samples taken between Port Mayaca and St. Lucie Inlet when full-capacity releases of the canal were being made.

(2) Secchi disk observations of turbidity at a number of locations between the lake and St. Lucie Inlet.

(3) Chemical and mineral analysis of samples of water flowing through St. Lucie Canal, as well as the amount of material in the water that would be flocculated upon mixing with sea water.

(4) Examination of the soils above the waterline along the banks of St. Lucie Canal and in the spillway outlet channels between Lake Okeechobee and St. Lucie Dam during full discharge conditions. Results of that study were presented in Part IV, Supplement 4 (reference 4d). The sedimentation problem in the estuary resulting from St. Lucie Canal discharges, as indicated in Part IV, Supplement 4, and other sources, is summarized below.

b. St. Lucie Canal.--Lake Okeechobee water released through St. Lucie Canal carries fine sand, shell fragments, and organic material into St. Lucie Estuary. The very fine organic material (clay or muck) usually suspended in the lake water gives it a dark, turbid appearance. When releases are being made, the turbid fresh water replaces portions of the salt water in the estuary. Although most of the organic material is carried into the ocean, some is deposited in places in the bay area where velocities are very low or in the mixing zone of fresh and salt water, which causes the material to flocculate. Even though the major portion of the organic material carried from Lake Okeechobee by the releases is not deposited in the estuary, it is objectionable to the people in the area because the water appears dirty and turbid. In addition, some desirable sport fishes may leave the estuary when turbid water is released. Under high flow conditions, there is rather uniform turbidity between Lake Okeechobee and Stuart. When canal discharge is discontinued, turbid conditions in the estuary clear rapidly unless there is heavy runoff from other sources. The principal source of sand material carried by St. Lucie Canal is from bank caving in stretches of the canal between the dam and the lake. Only a minor amount of sediment enters the canal now at the fixed spillways because of the retarding action of the structures and thick cover of vegetation upstream. Increased agricultural development and erosion of farm drainage ditches are contributing to the sedimentation problem. The heavier sands picked up along the canal are deposited in the estuary as soon as the velocity slows. The principal shoaling area is in the South Fork in the vicinity of Palm City (plate 3) where the stream velocities are suddenly reduced by the wider bay area. Hydrographic surveys indicated the Palm City shoal contained 1,183,000 cubic yards more material in 1954 than in 1932. Channel dredging is required at intervals to restore navigable depths in that vicinity following prolonged periods of discharge. Between 1937 and 1954, hydrographic surveys indicated material was eroded from St. Lucie Estuary downstream from United States Highway 1 bridge at Stuart, showing that the majority of the sediment from St. Lucie Canal is not carried farther than the Palm City area.

c. Other sources.--Other streams and agricultural canals in St. Lucie and Martin Counties contribute to the sediment problem in St. Lucie Estuary. The North Fork Estuary receives sand from agricultural areas and some organic materials from swamps in St. Lucie County. Turbid waters from the North Fork area are in evidence far down the main estuary during runoff periods when St. Lucie Canal is not discharging. Secondary drainage canals in St. Lucie County are largely uncontrolled, as is the primary canal (Rim Ditch) leading into the North Fork of St. Lucie River. Under such conditions, sediment materials have been carried unimpeded to the mouth of the river where large sandbars and shoals have formed. Boat navigation from the estuary to the North Fork River has been affected by those shoals. The shoals are being removed in the construction of Canals 23A and 24 now in progress. Shoal areas are also found in the mouth of Bessey Creek (C-23), emptying into the North Fork, and numerous shifting sandbars and shoals are located in the mouth of the main estuary near the inlet. The latter are believed by some local fishermen to be the result of St. Lucie Canal discharge. However, there is indication that little of the heavier sand material from St. Lucie Canal is carried that far down the estuary. Since those lower shoals are constantly shifting, it is more reasonable to consider that they are the result of storm-tide action on adjacent beaches and relocation of existing shoals through normal tidal action. Finally, sewage from a large portion of the local population is discharged into the estuary without treatment and no doubt adds to the sediment problem.

10. Need for further detailed studies.--A wide range of ill effects and damage claims has been applied to the turbidity and salinity changes occurring in St. Lucie Estuary during periods of discharge through St. Lucie Canal. However, no factual evidence or biological data were available to indicate the kind and extent of damages to support such claims. There are many varied reasons and factors, not necessarily connected with project operations, why fishing may be better or worse at one time than another or why people do or don't go fishing at certain times. Actual surveys of the estuary's fishes and animals under various discharge conditions had not been conducted by any agency. Sedimentation studies indicated that St. Lucie Canal carried and deposited sands in the shoal area at the head of the estuary and that releases of turbid Lake Okeechobee waters spread throughout the estuary and into the ocean. The immediate or permanent effects of that turbid water on estuarine fishes and animals and their environments were not known. The fresh-water discharge was believed to cause some fishes that desire more saline conditions to leave the area, but its effects on the majority of fishes and animals that usually live there and the normal seasonal movements in and out of the estuary were not understood. Evidence from studies elsewhere indicated that many marine fishes and organisms could live in very low salinities (Gunter, 1945) and that the nutritive materials brought into brackish estuaries with fresh-water discharge were beneficial to the production and growth of estuarine life. Furthermore, the contribution of runoff from the North Fork to the physical and biological conditions in St. Lucie Estuary was unknown. Before practical recommendations for regulation of discharge operations could be advanced, it was first necessary to determine (1) the biological and physical conditions existing in the estuary in all seasons without Lake Okeechobee releases; and (2) the temporary and longer lasting effects on each of those conditions of various rates of discharge from the lake, in the form of either damages or benefits.

With such data available from detailed studies, the possibilities within the requirements of the project of permanently changing or seasonally varying present operations to provide the most desirable or the least damaging conditions for fishes and fishing in the estuary could be considered.

D. PRESENT INVESTIGATIONS

11. Other agencies.--a. United States Fish and Wildlife Service.--Under the provisions of the Coordination Act (P.L. 732, 79th Cong., 1946), the Jacksonville District has made funds available to the Fish and Wildlife Service for studies in the St. Lucie Estuary area as follows:

(1) Central and Southern Florida Project--St. Lucie County Canals (Canals 23, 23A, 24, and 25).--The Service was requested to study the effects on fish and wildlife of the proposed improvement of those drainage canals to accelerate surface runoff of floodwaters into the North Fork Estuary and Fort Pierce Harbor. The field investigation was conducted during Fiscal Year 1957 (July 1956 to July 1957), the last year of a very dry period. An interim letter report was submitted in January 1957, and a second interim report was submitted April 22, 1959. The latter was a final report on all phases except the effects of discharge into the North Fork on the fishes and conditions of the main estuary. Annual damages resulting from the increased frequency of higher discharges into the North Fork, and based on future fisherman-use of that area with and without the project, were estimated to be $46,000. Copies of the summary letter of the Regional Director transmitting that report and the comments of the District Engineer thereon are presented in appendix A.

(2) Central and Southern Florida Project--Lake Okeechobee regulation.--A 1-year comprehensive biological study of St. Lucie Estuary--with specific reference to the effects on estuarine fishes and animals and fishing, both sport and commercial--of Lake Okeechobee releases through St. Lucie Canal was conducted during Fiscal Year 1958. The reporting date was originally scheduled for December 31, 1958, but at the request of the Service was delayed until March 1, 1959. A report on that investigation has not yet been received.

b. Florida State Board of Conservation, which is concerned with the administration and conservation of marine fishes and animals, was requested by the Central and Southern Florida Flood Control District to investigate the effects of all project discharges into St. Lucie Estuary. A preliminary report containing numerous conclusions as to expected damages, but no basic biological data, was submitted to the Flood Control District in October 1957.

12. Corps of Engineers.--a. Supervision of study by marine consultant.--In view of the complexity of the problem associated with the regulation of

project discharges and the inadequacy of information on comparable biological conditions, it was considered desirable by the Corps to enlist the services of a professional consultant in the biological field to work with the district biologist in the investgation. As a marine biologist with thirty years' experience with Gulf and South Atlantic coastal fisheries, and Director of the Gulf Coast Research Laboratory at Ocean Springs, Mississippi, I was employed in that capacity.

b. General plan of investigation.--The concept of the investigation was focused on the specific operational requirements of the project with sampling directed to identification of the important indicator species and what happened to them under various conditions related to the project. The foundation of the study was to be a comparison of the fishes, shellfishes, other aquatic organisms, and the physical conditions found at selected stations throughout the estuary in all seasons and under varying conditions of freshwater discharge from St. Lucie Canal. Since sport and commercial fish catches were to be included in studies of the Fish and Wildlife Service, emphasis in the district investigation was to be placed on the small food and bait fishes and animals and the young of sport and commercial fishes. Those groups are normal seasonal inhabitants of estuaries. Being more easily sampled than adult forms, they would furnish generally reliable indications of the temporary and permanent effects of physical changes in the estuarine environment, its inhabitants, and overall production. In addition, data on daily fishing pressure and fish catches below St. Lucie Lock and Dam were recorded to determine the effects of varying releases on that fishery.

c. Collection of basic data.--(1) Sampling gear and methods.--Trawl samples were collected with a 20-foot otter trawl of 1-inch stretch mesh in the main trawl section and 1/2-inch stretch mesh in the bag. All trawl hauls were of 15-minute duration in water at least 7 feet deep. (See fig. 1.) Seine samples were collected primarily with a 50-foot, 1/2-inch-mesh beach seine, the middle 25 feet of which was backed with bobbinet material. Occasional supplemental seine drags were taken with a 20-foot, 1/4-inch-mesh minnow seine. Top and bottom water temperatures and water samples for salinity determination were taken along with each trawl and seine sample. Salinities in parts per thousand were determined from direct-reading salinity hydrometers with correction for temperature differences. In certain instances where the salinities in the water samples were too low for accurate determination with the hydrometers (Sept. 1957, Jan. 1957, and May 1958), total chlorinities were determined by titration by Dr. Robert Miller, Chemist, of Fort Pierce, Fla. Those values were later converted to total salinities. Light penetration or gross turbidity was measured in inches with a standard 12-inch weighted Secchi disk. All fishes and organisms collected in each trawl or seine haul were counted and measured according to species. Specimens whose identity could not be readily determined were preserved for later study at the Gulf Coast Research Laboratory.

(2) Location and description of sampling stations.--The approximate locations of the various trawl (TS) and seine (SS) stations are shown on plate 7; detailed station descriptions are given below.

Biological sampling, St. Lucie Estuary, 24 Feb. 1958. Fresh-water discharge at St. Lucie Lock 4,800 c.f.s.; salinity in estuary less than 1 p.p.t.; turbidity (light penetration) less than 1 foot. Upper: Emptying trawl after 15-minute drag at station TS6. Lower: Portion of above trawl sample of fish and crabs at station TS6.

FIGURE 1

(a) Trawl stations.--Seven trawl stations were selected--four in the inner estuary, near the head and mouth of both the South and North Fork sections, and three in the outer estuary. The outermost trawl station was located in the area farthest upstream from the inlet where some bottom salinity could be expected to be maintained by daily tidal action, even during the period of greatest fresh-water discharge from St. Lucie Canal. Furthermore, that station was above the mouth of Indian River, a separate water system that also discharges into St. Lucie Inlet. The seven trawl stations are described as follows:

TS1--In channel above (south) Palm City bridge in the South Fork of St. Lucie River; depth, 9-11.5 feet; bottom--sand and muck; sand shoals on each side of channel.

TS2--At the Y at mouth of South and North Forks between channel marker 24 and Highway 1 bridge; depth, 8.5-12 feet; bottom--muck and sand.

TS3--Near head of North Fork of St. Lucie Estuary; depth, 7-10 feet; bottom--muck, sand, and detritus.

TS4--Off the mouth of Bessey Creek in the North Fork of St. Lucie Estuary; depth, 9 feet; bottom--sand and muck.

TS5--In channel north of Stuart and east of Highway 1 bridge, between beacons 22 and 23; depth, 8 feet; mud bottom with many dead *Mulinia* shells.

TS6--In main estuary east of Stuart, at bend where river turns south near marker 21; depth, 9 feet; bottom--sand, mud, and detritus.

TS7--Off Port Sewall in outer estuary between markers 14 and 15; depth, 10.5 feet; bottom--muck, trash, and vegetation.

(b) Seine stations.--It was desired to have a complementary seine station on the shore adjacent to each trawl station. However, because of the rim of mangrove trees, especially in the North Fork, and other vegetation growing down into the water, suitable sites for beaching seines were scarce in the inner estuary (See fig. 2.) In the outer estuary, residences were prevalent along the shorelines, and beaches were plentiful (fig. 2). A total of six seine stations--three each in the inner and outer estuaries--was selected. Only trawl station No. 4 in the North Fork did not have a complementary adjacent seine station. From 1 to 3 seine drags, enough to get a representative sample of fish, were made if possible at each station during each sampling period. On two occasions,

Biological sampling with 50-foot beach seine, St. Lucie Estuary, February 1958. Upper: Seine station 3 in North Fork. Lower: Seine station 2 in outer estuary

FIGURE 2

November 1957 and October 1958, exceptionally high waves and wind tides eliminated beaching sites and prevented sampling of some seine stations. The six seine stations are described as follows:

SS1--Beach along Sewall Point on east shore of estuary; sand bottom with mangroves at edge of water; new station (SS1A; see below) used after first sample.

SS1A--Beach on west side of estuary near marker 14; sand, shells, and debris; residential area with palm trees and flowering shrubs, several boat docks.

SS2--Beach on north shore of estuary opposite Stuart and east of Highway 1; sand bottom with some rocks.

SS3--Small beach near head of North Fork Estuary on west shore; soft bottom with plants and debris; mangrove trees.

SS4--Around shoals in South Fork above (south) Palm City bridge; hard-packed bottom, somewhat slick with algae and mud film; many dead Rangia shells.

SS5--Beach in South Fork near Y on west shore opposite Stuart around point SW. of marker 25; sand bottom.

SS6--Beach at point in outer estuary NE. of Stuart where river turns south; SW. of marker 21 and TS6; sand bottom.

(3) Extent of sampling during period of investigation.--Sampling in the estuary was begun January 28-29, 1957, and continued periodically during various discharge conditions for the next 2 years. A total of 10 samples was taken during the 2-year period--5 in 1957 (Jan., May, June, Sept., and Nov.), 4 in 1958 (Jan., Feb., May, and Oct.), and the final one in January 1959. During five of the sampling periods (Jan., May, and Nov. 1957; Oct 1958; and Jan. 1959) there was no discharge from St. Lucie Canal. The discharge of lake water on the other occasions was as follows:

Discharge (c.f.s.)	Date
2,200	June 1957
6,600	Sept. 1957
7,380	Jan. 1958
4,000	Feb. 1958
5,200	May 1958

Fish samples in January of three different years, on about the same dates (27-28), permitted comparative observations during a nondischarge period after 3 years of no discharge (1957); during a period of heavy discharge (1958); and during a nondischarge period, after a year of almost continuous fresh-water releases during most of the spawning and growing period. The total number of trawl and seine hauls taken in the three main sections of the estuary during each sampling period is given in table 4.

TABLE 4

The number of hauls with different gear in South Fork, North Fork, and outer St. Lucie Estuary for each collection period

Item	Collection period and number of hauls										
	1957					1958				1959	Total
	Jan.	May	June	Sept.	Nov.	Jan.	Feb.	May	Oct.	Jan.	
Trawl											
Inner estuary											
South Fork--	2	2	2	2	2	2	2	2	2	2	20
North Fork--	2	2	1	2	2	2	2	2	2	2	19
Subtotal---	4	4	3	4	4	4	4	4	4	4	39
Outer estuary-	3	3	2	3	3	3	3	3	3	3	29
Total------	7	7	5	7	7	7	7	7	7	7	68
Beach seine (50 ft.)											
Inner estuary											
South Fork--	5	4	5	4	1	2	3	2	0	2	28
North Fork--	3	2	0	3	2	3	1	1	1	0	16
Subtotal---	8	6	5	7	3	5	4	3	1	2	44
Outer estuary-	6	6	3	6	5	3	4	7	4	3	47
Total------	14	12	8	13	8	8	8	10	5	5	91
Minnow seine (20 ft.)											
Inner estuary											
South Fork--	-	-	2	-	-	-	-	-	0	0	2
North Fork--	-	-	0	-	-	-	-	-	2	2	4
Subtotal---	-	-	2	-	-	-	-	-	2	2	6
Outer estuary-	-	-	6	-	-	-	-	-	0	0	6
Total------	-	-	8	-	-	-	-	-	2	2	12
Grand total-----	21	19	21	20	15	15	15	17	14	14	171

E. PHYSICAL CONDITIONS DURING STUDY PERIOD

13. Fresh-water discharge into St. Lucie Estuary.--a. From Lake Okeechobee.--Lake Okeechobee stages on the last day of the month for 1957 and 1958 are given in table 3. The lake-regulation schedule in use at that time (plate 8) operated the lake levels seasonally between 12.5 and 15.5 feet. Under that schedule, discharges were required through St. Lucie Canal whenever the lake elevation was in Zone A. It was also necessary that the lake level be lowered to 13.0 feet by June 30, prior to the hurricane season. The average daily rates of discharge through St. Lucie Lock and Dam during 1957 and 1958 are given in tables 5 and 6 and graphically depicted on plate 9. The opening of the gates to release a small rate of flow on May 15, 1957, was the first regulatory discharge from Lake Okeechobee in 3 years. Compared to other years, 1957--except for a 2-month period during the peak of the rainy season--was a year of relatively low discharge. Peak flows for 5 weeks in September and October 1957 averaged about 7,000 cubic feet a second. The total discharge for 1957 was 859,200 acre-feet spread over 103 days. In contrast, 1958 was a year of heavy discharge, with a total of 1,873,660 acre-feet released on 229 days. Exceptional off-season rains and high lake stages in January 1958 required high discharges (over 6,500 c.f.s.) until mid-February. Moderate releases of about 3,500 cubic feet a second were made during most of March, but higher releases (6,500-4,500 cubic feet a second) were required from April until mid-June to bring the lake down to a safe prehurricane-season level. Discharge was cut off during the last 2 weeks of June but was continued thereafter at moderate to low rates until September 9. No lake releases were made between then and the end of the sampling, January 27, 1959.

b. From other areas.--Average daily rates of flow and total monthly discharge data are not available for the natural local watersheds of the North and South Forks. However, comparison of the total annual volumes estimated from rainfall (plates 5 and 6) gives an indication of the contribution of runoff from those areas to the total discharge into the estuary. In 1957, the total annual runoff from the North Fork was 380,000 acre-feet, or 28 percent of that which was discharged into the estuary that year. Lake Okeechobee releases accounted for the remainder. In 1958, there was higher discharge from the lake and a smaller percentage of local runoff. The effects of the local runoff were evidenced on May 16, 1957, when heavy rains and runoff into the North Fork caused much of the inner estuary to be of very low salinity before any lake water was released through the South Fork. With no lake releases being made in January 1959, the entire inner estuary was nearly fresh on the surface and the outer estuary waters were of relatively low salinity, as a result of recent heavy rains on the local watersheds.

TABLE 5

St. Lucie Canal at

St. Lucie Lock and Dam

Discharges, 1957

(Regulatory releases from Lake Okeechobee)

Date	Average daily discharge (c.f.s.)						
	May	June	July	Aug.	Sept.	Oct.	
1		2,200			5,100	6,830	
2		2,210			5,110	6,920	
3		2,210			5,090	7,400	
4		2,210			5,100	7,260	
5		2,210			5,480	7,080	
6		2,210			6,020	6,920	
7		2,210			5,010	6,840	
8		2,200			7,000	6,830	
9		2,220			6,750	7,050	
10		2,220			7,030	7,070	
11		2,210			6,780	6,980	
12		2,190			6,690	6,900	
13		2,190			6,630	6,820	
14		2,190			6,640	6,950	
15		2,180			6,870	6,990	
16	*	2,170		570	6,990	6,410	
17	330	2,170		1,690	6,920	5,800	
18	660	2,160*		2,240	6,890	3,610	
19	660	2,170		2,150	6,840	2,350	
20	910	2,170		2,240	6,870	2,330	
21	1,140	1,090		2,250	6,790	1,310	
22	1,140			2,260	6,720		
23	1,130			2,270	6,680*		
24	1,470			2,270	6,670		
25	2,220			2,280	6,630		
26	2,230			2,270	6,580		
27	2,230			2,620	6,590		
28	2,220			4,000	6,570		
29	2,210			4,320	6,600		
30	2,210			4,290	6,820		
31	2,210			4,820			
Total:							Total--1957
Day-second-feet	22,970	44,990		42,540	192,460	126,650	429,610
Acre-feet	45,940	89,980		85,080	389,920	253,300	859,220
Days	15	21		16	30	21	
Accumulative total	15	36		52	82	103	

NOTE: *Biological sampling day.

TABLE 6

St. Lucie Canal at

St. Lucie Lock and Dam

Discharges, 1958

(Regulatory releases from Lake Okeechobee)

Date	Average daily discharge (c.f.s.)								
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	-	7,190	3,450	5,830	5,750	4,820	-	2,510	1,580
2	-	7,200	3,460	6,360	5,700	4,820	850	2,500	1,580
3	-	7,100	3,470	6,370	5,680	4,780	2,530	2,500	1,580
4	-	6,970	3,440	6,380	5,700	4,700	2,540	2,190	1,580
5	-	6,850	3,410	6,360	5,700	4,700	2,530	1,570	1,590
6	-	6,810	3,420	6,360	5,820	4,720	2,520	1,570	1,590
7	-	6,850	3,440	6,350	5,940	4,710	2,510	1,560	1,600
8	-	6,940	3,440	6,240	5,750	4,650	2,500	1,560	1,600
9	630	6,770	3,440	6,100	5,570	4,600	2,500	1,560	1,060
10	1,870	6,720	3,450	6,050	5,490	4,560	2,490	1,570	
11	2,790	6,710	3,420	6,400	5,590	4,420	2,500	1,570	
12	3,070	6,700	3,420	6,470	5,710	3,370	2,510	1,580	
13	3,090	6,790	3,470	6,300	5,600	2,820	2,510	1,580	
14	3,090	6,620	3,490	6,080	5,420	2,470	2,520	1,560	
15	3,090	6,690	3,470	5,810	5,330	2,500	2,520	1,580	
16	3,130	6,780	3,450	6,070	5,350	1,670	2,530	1,580	
17	3,110	6,620	3,440	5,840	5,290		2,530	1,590	
18	3,090	6,540	3,450	5,920	5,230		2,530	1,590	
19	3,060	6,280	3,470	6,150	5,230*		2,530	1,210	
20	3,540	5,960	3,480	6,100	5,090*		2,540	840	
21	4,200	5,420	3,520	6,080	4,940		2,530	840	
22	4,230	4,815	3,470	6,100	4,900		2,530	840	
23	4,200	4,440	3,420	6,160	4,860		2,530	1,350	
24	5,060	3,930*	3,430	6,100	4,910		2,530	1,600	
25	7,220	3,460*	3,815	6,060	5,000		2,520	1,600	
26	7,450	3,470	4,890	6,010	4,990		2,510	1,610	

(Continued)

TABLE 6--Continued

Date	Average daily discharge (c.f.s.)									
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	
27	7,380*	3,500	5,110	5,930	4,910		2,500	1,610		
28	7,250*	3,480	5,150	5,880	4,900		2,490	1,600		
29	7,200		5,070	5,860	4,960		2,500	1,590		
30	7,200		5,030	5,830	4,900		2,500	1,590		
31	7,100		5,210		4,830		2,500	1,580		
Total:										Total--1958
Day-second-feet	102,050	167,605	117,095	183,550	165,040	64,310	73,830	49,580	13,760	936,820
Acre-feet	204,100	335,210	234,190	367,100	330,080	128,620	147,660	99,160	27,520	1,873,640
Days	23	28	31	30	31	16	30	31	9	
Accumulative total	23	51	82	112	143	159	189	220	229	

NOTE: *Biological sampling day.

14. Salinity conditions.--The range and average of surface and bottom salinities in the South Fork, North Fork, and outer estuary for each sampling period are summarized in table 7. Surface and bottom readings at individual stations will be given with the basic collection data in an addendum to this report. Plates 10 through 19 show a schematic presentation of general salinity conditions throughout the estuary during each sampling period, based on individual station readings and tide stages. Rates of fresh-water discharge from St. Lucie Canal are also shown. During periods of no lake discharge or local runoff, the salinity concentration generally increased steadily from the upper to the lower portions of the estuary. With lake discharge, salinities at all stations were low down to the salt-water front where there was a sharp increase, especially on the bottom. Salinities conditions varied with the rate of fresh-water inflow and the tidal condition. The salinity front was known to move up and down the estuary for a considerable distance with changes in tide. However, since the individual stations were sampled along with the fish samples at different times of the day and tide, those data were not adequate to show the daily variations in the position of the salt front. With lake discharges as low as 2,200 cubic feet a second, the entire inner estuary was nearly fresh. The same was true with local runoff from the North Fork. On all occasions of lake discharge, there was still bottom salinity at the outermost station of the estuary(TS7), which is considerable distance upstream from the inlet. The lowest bottom reading at that station was 4.5 parts per thousand when 7,380 cubic feet a second was being released through St. Lucie Canal. On other occasions of high discharges (above 4,000 c.f.s.), the bottom salinity at station 7 was much higher--for example:

Discharge (c.f.s.)	Bottom salinity (p.p.t.)
6,680	23.0
5,200	25.5
4,000	29.4

Under normal conditions, the range of salinity from surface to bottom at the same point would often vary 5.0 to 10.0 parts per thousand in the inner estuary, probably as a result of local rainfall and light surface runoff. In the outer estuary, the difference in top and bottom salinities was on occasion more than 10.0 parts per thousand because of the interaction of fresh-water runoff with certain tidal stages. Salinities in the inner estuary ranged from near 0 top and bottom with either lake discharge or local runoff to 5.0-20.0 parts per thousand under normal conditions. A greater range of salinities was found in the outer estuary, from near fresh to full sea strength, with various discharge conditions, but the bottom salinities were less affected by fresh-water runoff than the inner stations because the salt front remained in that area. The range of normal salinities in the outer estuary was generally from 15.0 to 30.0 parts per thousand at the upper stations and from 25.0 to 35.0 parts per thousand at the lower ones.

Date	Lak disch (c.f	Outer estuary			
		Surface		Bottom	
		mber of amples	Range and average	Number of samples	Range and average
1957					
Jan. 28-29		5	20.0-32.8 (25.6)	2	29.2-36.0 (32.6)
May 16		5	10.7-21.5 (17.7)	3	19.9-32.4 (25.1)
June 18	2,1	4	0.8-4.0 (2.2)	2	1.2-22.8 (12.0)
Sept. 23	6,6	6	0.17-8.5 (2.8)	3	0.20-23.0 (8.5)
Nov. 13		5	17.1-30.5 (25.0)	3	16.2-31.3 (24.9)
1958					
Jan. 27-28	7,3	6	0.23-1.54 (0.63)	3	0.22-4.50 (1.69)
Feb. 24-25	4,0	6	< 1.0-4.9 (1.7)	3	< 1.0-29.4 (12.3)
May 19-20	5,2	6	0.15-1.42 (0.57)	3	0.15-25.5 (8.7)
Oct. 27-28		6	14.0-27.4 (18.9)	3	26.3-31.5 (28.0)
1959					
Jan. 27		6	6.3-25.9 (12.3)	3	22.2-33.8 (26.7)

15. Turbidities.--The Secchi disk readings taken at various stations during each sampling period will be given with the individual station data in an addendum to this design memorandum. They are summarized here in table 8. The turbidity readings as measured during the investigation substantiated the conclusion of previous studies that the turbidity in the estuary varied with the lake discharge and local runoff. On most occasions, the turbidity increased directly with higher rates of lake discharge. However, it was less in September 1957 with 6,680 cubic feet a second discharge than in May of that year when no releases were being made and in June 1957 when only 2,160 cubic feet a second was being released. High winds and wave action in both Lake Okeechobee and the estuary, which keep sediment materials stirred up, are considered responsible for high turbidities at certain times. Turbid waters from Lake Okeechobee did not appear to penetrate too far into the North Fork, since on several discharge occasions when the waters in the South Fork and main estuary were clear to a depth of less than 1 foot, turbidity readings were 1.5 to 3 feet higher in the North Fork of the estuary. The highest turbidities were observed in January 1958. With maximum discharge of 7,380 cubic feet a second at that time, turbidities in the outer South Fork and estuary were 6 to 10 inches. Normal turbidities in the inner estuary appear to be 30 to 40 inches and in the outer estuary 36 to 60 inches. A fathometer survey conducted in October 1957 for the purpose of determining changes in depths of bottom sediments in the estuary since 1954 gave inconclusive results in that respect, although there was no evidence of appreciable deposition in the area. Slight deposition of materials in some sections apparently resulted from erosion of other reaches nearby. The mineral content of a composite water sample from St. Lucie Canal (Sept. 11, Oct. 3, and Oct. 15, 1957) at St. Lucie Lock and Dam is listed in table 9. It shows that the total nitrogen content of the water coming into St. Lucie Estuary through St. Lucie Canal was 0.8 part per million. In other analyses of St. Lucie waters by the United States Geological Survey, the nitrate content (NO_3) through the years has varied from a trace to 2.0 parts per million. On the basis of 0.8 part per million, there were 987 tons of nitrogen nutrients discharged into the estuary in 1957 and 2,040 tons in 1958 by way of St. Lucie Canal.

TABLE 8

Range and average turbidity readings
in the South Fork, North Fork, and outer estuary
for each sampling period

Month	Lake discharge (c.f.s.)	Turbidity reading (inches)		
		South Fork	North Fork	Outer estuary
1957				
Jan.	0	36	54	60
May	0	24	24	24
June	2,160	12-15(13.5)	24	22-30(27)
Sept.	6,680	28	29	26-27(26.5)
Nov.	0	No readings because of loss of disk		
1958				
Jan.	7,380	6-12(8)	22-31(25)	9-12(10)
Feb.	4,000	11-12(11)	50	12
May	5,200	16-21(18)	14-24(21)	12-14(14)
Oct.	0	34-38(36)	42-48(45)	36-48(41)
1959				
Jan.	0	28-31(30)	36	36-40(38)

TABLE 9

Mineral content of composite water sample from St. Lucie Canal at St. Lucie Lock and Dam (Sept. 11, Oct. 3, and Oct. 15, 1957)

Item	Parts per million
pH	8.1
Dissolved solids	194
Calcium as Ca	32
Magnesium as Mg	8
Sodium and potassium as Na	16
Iron as Fe (soluble)	0
Silica as SiO_2	5
Sulfates as SO_4	20
Chlorides as Cl	30
Nitrogen as N	0.8
Phosphorus	0
Alkalinity (methyl orange) as $CaCO_3$	85
(phenolphthalein) as $CaCO_3$	0
Total hardness as $CaCO_3$	113
Carbonate hardness as $CaCO_3$	85
Noncarbonate hardness as $CaCO_3$	28
Free carbon dioxide as CO_2	0

16. Temperatures.--a. Water.--The range and average of the surface and bottom water temperatures measured at each sampling station are summarized for all stations for each period in table 10. Individual station records will be given with the basic collection data in an addendum to this report.

TABLE 10

Number of readings, range, and average surface and bottom water temperatures for all stations during each collection period
(Readings in degrees Fahrenheit)

Date	Surface			Bottom			Grand average
	Number of readings	Range	Average	Number of readings	Range	Average	
1957							
Jan. 27	12	73.6-76.8	74.8	7	72.0-76.1	74.4	74.6
May 16	12	79.9-87.3	83.1	7	78.3-80.1	79.5	81.7
June 18	7	82.6-86.5	85.0	5	82.6-84.7	83.5	84.3
Sept. 23	12	82.6-87.6	85.0	6	73.2-82.6	76.8	82.2
Nov. 13	10	70.9-71.8	71.2	7	70.5-71.8	71.5	71.3
1958							
Jan. 28	9	59.0-63.9	61.7	5	59.9-62.2	61.2	61.5
Feb. 24	13	58.0-70.0	62.5	7	58.0-66.0	60.4	61.7
May 19	13	76.0-80.0	78.2	7	76.0-81.0	77.8	78.0
Oct. 27	11	72.0-78.0	75.3	7	74.0-78.0	75.7	75.5
1959							
Jan. 27	13	68.0-74.0	70.9	7	66.0-72.0	68.0	69.9

In 1957, the average water temperatures in the estuary samples varied from a low of 70.5° in November to a high of 87.6° in September. In comparison, 1958 was much colder, with lows of 59° and 58° in January and February respectively. The surface and bottom water temperatures averaged 13° colder in January and 5° colder in May 1958 than in 1957. Surface waters generally averaged a few tenths to 3 degrees warmer than the bottom waters, except in October and November when the reverse condition occurred. The year 1959 was milder than 1958 but not as mild as 1957.

b. Air.--The average daily maximum and minimum air temperatures at Stuart, for the three winter periods of this investigation (Nov. through Feb. 1956-57, 1957-58, and 1958-59), were extracted from Climatological Data for Florida and are summarized in table 11. The winter of 1956-57 was a mild season, with no freezing days during the 4-month period. Only five times--3 in November and 2 in December--did the temperature reach 40° or below.

The lowest January temperature was 42° on one day, and once in February it went down to 44°. The average maximum and minimum daily temperatures between October and March were about 78° and 58° respectively. In contrast, the winter of 1957-58 after November was an exceptionally cold year for all of Florida. Freezing temperatures were recorded at Stuart on 6 days--once in December, twice in January, and three times in February. Temperatures below 40° were recorded 16 times during the December-February period, 9 of which were in February. Maximum temperatures averaged 10° and 12° colder in January and February 1958 than in 1957; minimum temperatures averaged 6° and 16° colder, respectively. That exceptionally cold winter resulted in heavy losses of tourist business throughout central and southern Florida. The winter of 1958-59 was again a comparatively mild period, and, in November and February, was warmer on the average than the 1956-1957 season. In contrast to the previous year, the minimum daily February temperature averaged 20° warmer in 1959 than in 1958.

TABLE 11

Range and average of maximum and minimum daily air temperatures at Stuart, November through February 1956-57, 1957-58, and 1958-59

Month	Daily air temperature (degrees Fahrenheit)			
	Maximum		Minimum	
	Range	Average	Range	Average
Nov. 1956	69.0-84.0	77.5	34.0-73.0	58.0
Dec. 1956	62.0-87.0	77.1	36.0-70.0	56.6
Jan. 1957	69.0-83.0	77.6	42.0-68.0	56.2
Feb. 1957	73.0-85.0	79.0	44.0-71.0	61.2
Nov. 1957	72.0-87.0	80.6	51.0-72.0	65.1
Dec. 1957	56.0-82.0	74.1	29.0-71.0	55.9
Jan. 1958	50.0-78.0	67.6	30.0-64.0	50.0
Feb. 1958	53.0-85.0	66.9	30.0-68.0	45.1
Nov. 1958	74.0-90.0	83.6	56.0-74.0	67.7
Dec. 1958	65.0-83.0	74.7	41.0-71.0	57.2
Jan. 1959	59.0-85.0	72.5	33.0-69.0	54.1
Feb. 1959	72.0-88.0	81.1	58.0-72.0	64.9

17. Summary of physical conditions in the estuary during the study period.--The period of the investigation was one of contrasting physical conditions. The winter and spring collections in 1957 were made when there had been no fresh-water discharge from Lake Okeechobee for 3 years. Salinities were high and temperatures mild. There was a heavy discharge period that fall, but none from mid-October to January. In 1958, except for brief periods, discharges were moderate to heavy throughout the winter and spring and low to moderate throughout the summer until early September. The inner waters were fresh and turbid and the outer waters of low salinity in accordance with the discharge. The winter of 1957-58 was abnormally cold, with several freezes. There was no discharge, and salinities and temperatures were high from September 1958 until the end of the study in January 1959. Salinities during the period ranged from zero to 20.5 in the inner estuary and from zero to 36.0 parts per thousand in the outer estuary, Water temperatures ranged from 59.0° to 87.6° and turbidities from 6 inches to 5 feet. Low salinities in the estuary, as a result of local runoff from the North Fork watershed, were experienced on several occasions when no lake water was being released. Fish samples were collected on five occasions when there were no lake discharges and five when the rate of release ranged from 2,160 to 7,380 cubic feet a second.

F. RESULTS OF BIOLOGICAL SAMPLING

18. The fish catch.--Table 12 indicates that 83 species of fishes were taken during this investigation. Seventeen were fresh-water species; the remainder were marine. The separation is made on the basis of spawning locality--that is, in fresh or salt water. Table 13 lists the most abundant fishes taken in this study. Six species made up almost 90 percent of the total catch, and addition of 7 more species brings that total to over 95 percent. The remaining 70 species made up less than 5 percent of the total catch. Of the 13 most abundant species, only 2--the black crappie and the white catfish--were fresh-water species and they made up about 1.5 percent of the numbers taken. The remaining fishes were all marine, although all but one are capable of undergoing wide salinity changes--that is, are euryhaline. Therefore, they are largely characteristic of shallow shores and inshore waters. Furthermore, such fishes have a characteristically similar life history. They spawn in high or higher salinity waters and move back into lower salinity waters to grow up. Thus, most estuaries, such as the St. Lucie, are characterized biologically as nursery grounds. Total length data are not presented here, but it may be categorically stated that the majority of fishes caught were the young. Table 14 indicates that almost precisely two-thirds of the hauls were made with the minnow seines next to shore. Furthermore, this table shows that the numbers of fishes taken in the seine hauls were about four times as numerous per haul as those taken in the trawl catches. Table 15 indicates that the seine catch preponderance--which totaled almost seven times more than trawl catches--was caused by the catch of four species--mullet, menhaden, silversides, and anchovy. These were predominantly larval and juvenile fishes which reside in shallow waters and only the bay anchovy was taken in any numbers in the trawls.

Further examination of the data (table 16) indicates that the vast preponderance of young shore fishes, chiefly mullet and menhaden, were caught in January, February, and May 1958, when the spillway gates were open. In the midwinters of 1957 and 1959, the preponderance of seine-caught fishes over trawl catches was considerably less when the gates were closed. If the catch data from the 50-foot seine hauls were expanded to cover the entire 35-mile shoreline of the estuary, a rough approximation of the number of fish per mile of shoreline would have been 822,000 in January 1958, during the heavy discharges, as compared to 5,400 per mile in January 1957 after a long period of no lake discharge. Similar gross comparisons could be made for other periods during the 2 years of sampling. Table 17 lists the less numerous fishes in arbitrary divisions of abundance. They are more or less self-explanatory. Table 18 gives the frequency at which various fishes were taken with different gear. This does not correspond except in a general way with total abundance. For instance, the sea catfish, sand perch, and whiff were taken in a considerable number of hauls but in relatively small numbers. Table 12 lists the numbers of fishes taken in the three divisions of the estuary. In general, the South Fork was no saltier than the North Fork. However, the South Fork salinity varied with the opening of the gates and the North Fork salinity was often low from natural drainage. This probably accounts for the larger number of marine fishes taken in the South Fork, although the numbers of species of both fresh- and salt-water fishes were much the same in both areas. The higher salinity of the outer estuary is reflected in the small number of fresh-water fishes and the abundance of marine species. This information is summarized in table 19. An inspection of table 16 reveals that the variations in numbers of the marine fishes is largely a reflection of the numbers of menhaden, mullet, anchovy, and tidewater silversides. The latter two were most abundant in the outer estuary. The menhaden was most abundant in the two inside forks and the little mullet was least abundant in the North Fork, being about equally present in the South Fork and outside estuary. The other most abundant fish, the croaker, did not vary much with opening or closing of the gates--that is, fresh-water drainage. The common mojarra became less abundant. Table 16 also indicates that 19 salt-water species, including the most abundant ones, and 10 fresh-water fishes were most abundant when the water was fresher. That increase included overwhelming numbers of mullet, menhaden, and silversides. A few fishes--the pompano, puffers, mojarras, and a few other saliniphilous species--became less abundant when the water was fresher. The commercial fishery catch, treated in a later chapter, shows similarly that there was increase or decrease of certain species when the locks were open, but there was no decline of salt-water commercial species as a whole. In essence, the area under consideration is an environment for estuarine or euryhaline fishes. When the salinity is lowered, many of them flourish in greater numbers than ever and a few high-salinity forms leave the area. However, the region certainly does not become barren, and in one sense it becomes more productive as indicated by the large crop of young fishes. The menhaden, mullet, and silversides are forage fishes and a greater production of these will lead to an increase of game fishes elsewhere, possibly in the outer estuary at a later date. Mackerel and pompano and some other high-salinity fishes leave when the salinity drops, but the statement that the gate openings result in barren waters and a death of small fishes is completely spurious. Summaries of these data are given in tables 5, 6, 19, 20, 21, and 22. In this respect, observations are somewhat subjective because of the lack of comparative figures which would be derived from theoretically controlled flows, but at least there is nothing in these observations contradictory to the idea that an opening or flow up to 3,500 cubic feet a second from St. Lucie Lock and Dam is beneficial to the general life of the estuary, and it is believed that a continuous flow of about 2,500 cubic feet a second would be an optimum. Much higher flows (up to 7,400 cubic feet a second) were not found to be damaging to estuarine life, and, in fact, the greatest production and survival of young fishes was found to occur in the spring of 1958 during the period of continued high fresh-water discharges from Lake Okeechobee (plate 20). The tons of nutrient material brought in with the fresh water are undoubtedly partly responsible for the higher production, since this same phenomenon has been observed and measured in other areas (Viosca, 1938; Gunter, 1953).

TABLE 12

Total number of each species of fish caught in the South Fork, North Fork, and outer estuary

Species	Number of fishes caught		
	South Fork	North Fork	Outer estuary
Stingaree (Dasyatis sabina)	4	2	1
Spotted gar (Lepisosteus platyrhincus)	-	1	-
Tenpounder (Elops saurus)	1	-	2
Menhaden (Brevoortia smithi)	1,388	1,386	974
Threadfin shad (Dorosoma petenense)	41	15	25
Gizzard shad (Dorosoma cepedianum)	-	-	4
Sardine (Harengula pensacolae)	-	-	55
Striped anchovy (Anchoa hepsetus)	-	-	22
Bay anchovy (Anchoa mitchilli)	465	177	824
Lizardfish (Synodus foetens)	1	-	15
Sea catfish (Galeichthys felis)	111	22	260
Gafftopsail catfish (Bagre marina)	6	-	-
Channel catfish (Ictalurus punctatus)	29	1	4
White catfish (Ictalurus catus)	124	22	17
Brown bullhead (Ictalurus nebulosus)	-	3	2
Golden shiner (Notemigonus crysoleucas)	-	-	1
Red minnow (Notropis maculatus)	11	-	4
Needlefishes (Strongylura spp.)	-	6	15
Redfin killifish (Lucania goodei)	4	1	-
Marsh killifish (Fundulus confluentus)	-	1	-
Seminole killifish (Fundulus seminolis)	-	2	-
Sheepshead killifish (Cyprinodon variegatus)	-	-	1
Flagfish (Jordanella floridae)	7	-	-

(Continued)

TABLE 12--Continued

Species	Number of fishes caught		
	South Fork	North Fork	Outer estuary
Mosquitofish (Gambusia affinis)	3	14	2
Least killifish (Heterandria formosa)	6	57	1
Seahorse (Hippocampus hudsonius)	-	-	1
Scovell's pipefish (Syngnathus scovelli)		-	16
Pipefishes (Syngnathus floridae) (" louisianae)	1	-	7
Redear sunfish (Lepomis microlophus)	1	-	-
Bluegill (Lepomis macrochirus)	14	2	22
Dollar sunfish (Lepomis marginatus)	1	-	1
Bluespotted sunfish (Enneacanthus gloriosus)	1	1	2
Black crappie (Pomoxis nigromaculatus)	-	184	1
Round pompano (Trachinotus falcatus)	27	-	116
Common pompano (Trachinotus carolinus)	-		15
Jacks (Caranx hippos) (" latus)	14	-	16
Bumper (Chloroscombrus chrysurus)	-	-	3
Moonfish (Vomer setapinnis)	-	-	1
Lookdown (Selene vomer)	-	1	5
Leatherjacket (Oligoplites saurus)	2	-	21
Snook (Centropomus undecimalis)	13	4	2
Mangrove snapper (Lutjanus griseus)	3	-	2
Spot snapper (Lutjanus synagris)	2	-	9
Pigfish (Orthopristis chrysopterus)	-	-	2
Sand perch (Diapterus olisthostomus)	33	17	48
Mojarra (Eucinostomus gula)	125	361	490
Yellow tail (Bairdiella chrysura)	76	9	12
Spotted weakfish (Cynoscion nebulosus)	-	1	-
White trout (Cynoscion regalis)	48	16	66
Spot (Leiostomus xanthurus)	22	23	138
King whiting (Menticirrhus americanus)	-	1	12
Croaker (Micropogon undulatus)	824	355	794
Black drum (Pogonias cromis)	6	1	17
Red drum (Sciaenops ocellata)	35	51	41
Star drum (Stellifer lanceolatus)	-	-	4
Sheepshead (Archosargus probatocephalus)	-	5	-
Pinfish (Lagodon rhomboides)	3	32	12
Spadefish (Chaetodipterus faber)	1	-	20
Sergeant major (Abudefduf saxatilis)	-	-	1
Cutlass fish (Trichiurus lepturus)	-	-	1
Mapo (Bathygobius soporator)	-	-	1
Darter goby (Gobionellus boleosoma)	8	3	40
Ocean goby (Gobionellus gracillimus)	1	1	8
Sharptail goby (Gobionellus hastatus)	-	1	6

(Continued)

TABLE 12--Continued

Species	Number of fishes caught		
	South Fork	North Fork	Outer estuary
Naked goby (Gobiosoma bosci)---------------	1	-	-
Violet goby (Gobioides broussonneti)-------	1	1	4
Barracuda (Sphyraena barracuda)------------	-	-	1
Silver mullet (Mugil curema)---------------	12	2	-
Striped mullet (Mugil cephalus)------------	5,570	1,774	5,047
Rough silverside (Membras martinica)-------	9	1	-
Tidewater silverside (Menidia beryllina)---	486	179	1,041
Scorpionfish (Scorpaena grandicornis)------	-	-	1
Sea robin (Prionotus tribulus)-------------	1	-	3
Gulf whiff (Citharichthys macrops)---------	-	-	1
Spotfin whiff (Citharichthys spilopterus)--	18	30	44
Fringed flounder (Etropus crossotus)-------	-	-	8
Sole (Achirus lineatus)--------------------	-	9	-
Hogchoker (Trinectes maculatus)------------	20	10	39
Tonguefish (Symphurus plagiusa)------------	6	4	11
Northern puffer (Sphoeroides maculatus)----	-	-	2
Florida puffer (Sphoeroides nephelus)------	-	-	1
Marbled puffer (Sphoeroides testudineus)---	-	1	19
Spiny boxfish (Chilomycterus schoepfi)-----	-	-	3
Total:			
Fishes------------------------------	9,586	4,790	10,407
Species-----------------------------	48	45	70
Number of samples------------------	50	39	89
Average number of fishes per sample	191.7	122.8	126.8

NOTE: 1 dead eel (Anguilla rostrata) was caught in the November 1957 trawl catch in the South Fork and several dead tarpon (Megalops atlanticus) were observed floating and caught in trawl hauls in all three reaches in February 1958.

TABLE 13

Total numbers of fishes caught and percentage of total catch for all species with more than 100 specimens--St. Lucie Estuary

Scientific name	Common name	Total number caught	Percentage of total catch
Mugil cephalus	Striped mullet	12,391	50.0
Brevoortia smithi	Menhaden	3,748	15.1
Micropogon undulatus	Croaker	1,973	8.0
Menidia beryllina	Silversides	1,706	6.9
Anchoa mitchilli	Bay anchovy	1,466	5.9
Eucinostomus gula	Mojarra	976	3.9
	Subtotal	22,260	89.8
Galeichthys felis	Sea catfish	393	1.6
Pomoxis nigromaculatus	Black crappie	185	0.8
Leiostomus xanthurus	Spot	183	0.7
Ictalurus catus	White catfish	163	0.7
Trachinotus falcatus	Round pompano	143	0.6
Cynoscion regalis	White trout (weakfish)	130	0.5
Sciaenops ocellata	Red drum (redfish)	127	0.5
	Subtotal	23,584	95.2
	70 others	1,199	4.8
	Total	24,783	100.0

TABLE 14

Average catch per haul of fishes taken in trawls and seines in each collection in St. Lucie Estuary

Date	Number of hauls and average catch		
	Seines	Trawls	Total
Jan. 1957	14 65.3	7 58.6	21 63.0
May 1957	12 77.2	7 46.0	19 65.7
June 1957	16 15.4	5 94.0	21 34.1
Sept. 1957	13 47.6	7 47.6	20 47.6
Nov. 1957	8 8.5	7 28.7	15 17.9
Total number of hauls, 1957	63	33	96
Average catch	44.0	52.6	47.0
Jan. 1958	8 774.0	7 32.8	15 428.1
Feb. 1958	8 893.1	7 64.1	15 506.3
May 1958	10 372.1	7 80.8	17 252.2
Oct. 1958	7 46.7	7 33.6	14 40.1
Total number of hauls, 1958	33	28	61
Average catch	526.8	52.8	309.2
Jan. 1959	7 184.8	7 16.3	14 100.6
Grand total number of hauls	103	68	171
Grand average catch	208.3	49.0	144.9

TABLE 15

Order of abundance of most numerous fishes taken in seines and trawls in St. Lucie Estuary

Seine catches		Trawl catches	
Species	Number of fishes caught	Species	Number of fishes caught
Striped mullet	12,387	Croaker	1,471
Menhaden	3,745	Sea catfish	381
Tidewater silversides	1,706	Bay anchovy	262
Bay anchovy	1,204	Black crappie	183
Mojarra	832	White catfish	161
Croaker	502	Mojarra	144
Spot	158	White trout	128
Round pompano	143	Yellowtail	97
Red drum	127	Spotfin whiff	81
Least killifish	64	Sand perch	78
Sardine	55	Hogchoker	69
Threadfin shad	47	Threadfin shad	34
Darter goby	46	Channel catfish	33
Pinfish	46	Spot	25
Total	21,062	Total	3,147

NOTE: The above catches of 23 species represent 97.5 percent of the total of all fishes collected.

Species of fish	Gates close Jan. 28 1957	Gates closed c. 27-28, 58 (2)	Gates closed Jan. 27, 1959	Total
Dasyatis sabina----------------------	1	-	-	8
Lepisosteus platyrhincus-------------	-	-	-	1
Elops saurus------------------------	-	-	-	3
Brevoortia tyrannus-----------------	83	-	-	1,452
Brevoortia smithi-------------------	-	-	-	2,296
Dorosoma petenense------------------	-	-	-	81
Dorosoma cepedianum-----------------	-	-	-	4
Harengula pensacolae----------------	-	1	-	55
Anchoa hepsetus---------------------	-	1	7	24
Anchoa mitchilli--------------------	318	16	8	1,471
Synodus foetens---------------------	3	9	4	16
Galeichthys felis-------------------	7	19	4	393
Bagre marina------------------------	-	1	-	6
Ictalurus punctatus-----------------	-	-	-	34
Ictalurus catus---------------------	-	-	-	163
Ictalurus nebulosus-----------------	-	-	1	5
Notemigonus crysoleucas-------------	-	-	-	1
Notropis maculatus------------------	-	-	-	15
Strongylura spp.--------------------	-	6	1	21
Lucania goodei----------------------	-	-	4	5
Fundulus confluentus----------------	-	-	-	1
Fundulus seminolis------------------	-	-	1	2
Cyprinodon variegatus---------------	-	-	-	1
Jordanella floridae-----------------	-	-	2	7
Gambusia affinis--------------------	-	-	-	19
Heterandria formosa-----------------	-	-	-	64
Hippocampus hudsonius---------------	1	-	-	1
Syngnathus scovelli-----------------	2	-	4	18
Syngnathus louisianae---------------	1	1	3	6
Lepomis microlophus-----------------	-	-	-	1
Lepomis macrochirus-----------------	-	-	-	38
Lepomis marginatus------------------	-	-	-	2
Enneacanthus gloriosus--------------	-	1	-	4
Pomoxis nigromaculatus--------------	-	-	-	185
Trachinotus falcatus----------------	-	50	6	143
Trachinotus carolinus---------------	-	-	-	15
Caranx spp.-------------------------	-	4	-	30
Chloroscombrus chrysurus------------	-	2	1	3
Vomer setapinnis--------------------	1	-	-	1
Selene vomer------------------------	-	4	-	6
Oligoplites saurus------------------	-	9	1	23
Centropomus undecimalis-------------	-	2	1	19
Lutjanus griseus--------------------	-	-	-	7
Lutjanus synagris-------------------	-	9	-	9
Orthopristis chrysopterus-----------	-	-	-	2
Diapterus olisthostomus-------------	-	22	-	79
Eucinostomus argenteus--------------	21	30	200	560
Eucinostomus gula-------------------	19	238	165	443
Bairdiella chrysura-----------------	10	16	-	97
Cynoscion nebulosus-----------------	-	-	-	1
Cynoscion regalis-------------------	12	39	-	131
Leiostomus xanthurus----------------	-	1	1	183

Species of fish	Gates closed Jan. 28, 1957	Gates closed [illegible]t. 27-28, [illegible]958 (2)	Gates closed Jan. 27, 1959	Total
Menticirrhus americanus	[illegible]	2	-	13
Micropogon undulatus	19[illegible]	21	424	1,965
Pogonias cromis	[illegible]	1	-	24
Sciaenops ocellata	11[illegible]	3	2	127
Stellifer lanceolatus	-	-	-	4
Archosargus probatocephalus	-	-	-	5
Lagodon rhomboides	[illegible]	-	1	47
Chaetodipterus faber	-	18	1	21
Abudefduf saxatilis	[illegible]	-	-	1
Trichiurus lepturus	-	-	-	1
Bathygobius soporator	-	-	-	1
Gobionellus boleosoma	-	-	2	51
Gobionellus gracillimus	[illegible]	-	3	10
Gobionellus hastatus	-	-	-	7
Gobiosoma bosci	-	-	-	1
Gobioides broussonneti	-	-	-	6
Sphyraena barracuda	-	-	-	1
Mugil curema	-	-	-	14
Mugil cephalus	48[illegible]	9	530	12,391
Membras martinica	1[illegible]	-	-	10
Menidia beryllina	-	21	11	1,706
Scorpaena grandicornis	-	-	-	1
Prionotus tribulus	[illegible]	-	2	4
Citharichthys macrops	-	-	-	1
Citharichthys spilopterus	1[illegible]	1	7	92
Etropus crossotus	[illegible]	-	2	8
Achirus lineatus	-	-	-	9
Trinectes maculatus	[illegible]	4	3	69
Symphurus plagiusa	[illegible]	7	2	21
Sphoeroides maculatus	-	-	-	2
Sphoeroides nephelus	-	1	-	1
Sphoeroides testudineus	[illegible]	-	4	20
Chilomycterus schoepfi	[illegible]	-	-	3
Total	1,32[illegible]	569	1,408	24,792
Species	(29[illegible]	33)	(32)	-

NOTES: (1) Extremely poor seining conditions [illegible]
(2) Two seine stations (4 and 5) not [illegible]

In addition to the above, 1 dead [illegible]egalops atlanticus) were observed floating and caught in t[illegible]

TABLE 17

List of fishes caught in St. Lucie Estuary by all methods for all species with less than 100 specimens in the total catch

1 specimen

Florida spotted gar (Lepisosteus platyrhincus)
Golden shiner (Notemigonus crysoleucas)
Marsh killifish (Fundulus confluentus)
Sheepshead killifish (Cyprinodon variegatus)
Seahorse (Hippocampus hudsonius)
Redear sunfish (Lepomis microlophus)
Moonfish (Vomer setapinnis)
Spotted trout (Cynoscion nebulosus)
Sergeant major (Abudefduf saxatilis)
Cutlass fish (Trichiurus lepturus)
Mapo (Bathygobius soporator)
Naked goby (Gobiosoma bosci)
Barracuda (Sphyraena barracuda)
Scorpionfish (Scorpaena grandicornis)
Gulf whiff (Citharichthys macrops)
Florida puffer (Sphoeroides nephelus)

2 to 4 specimens

Tenpounder (Elops saurus)
Gizzard shad (Dorosoma cepedianuum)
Seminole killifish (Fundulus seminolis)
Dollar sunfish (Lepomis marginatus)
Bluespotted sunfish (Enneacanthus gloriosus)
Bumper (Chloroscombrus chrysurus)
Pigfish (Orthopristis chrysopterus)
Star drum (Stellifer lanceolatus)
Sea robin (Prionotus tribulus)
Northern puffer (Sphoeroides maculatus)
Spiny boxfish (Chilomycterus schoepfi)

5 to 10 specimens

Stingaree (Dasyatis sabina)
Brown bullhead (Ictalurus nebulosus)
Gafftopsail catfish (Bagre marina)
Redfin killifish (Lucania goodei)
Flagfish (Jordanella floridae)
Pipefishes (Syngnathus spp.-louisianae
-floridae)
Lookdown (Selene vomer)

(Continued)

TABLE 17--Continued

5 to 10 specimens--Continued

Mangrove snapper (Lutianus griseus)
Sheepshead (Archosargus probatocephalus)
Ocean goby (Gobionellus gracillimus)
Sharptail goby (Gobionellus hastatus)
Violet goby (Gobioides broussonneti)
Rough silversides (Membras martinica)
Sole (Achirus lineatus)
Fringed flounder (Etropus crossotus)

11 to 25 specimens

Striped anchovy (Anchoa hepsetus)
Lizardfish (Synodus foetens)
Red minnow (Notropis maculatus)
Needlefishes (Strongylura spp.-marina)
-notata)
Mosquitofish (Gambusia affinis)
Scovell's pipefish (Syngnathus scovelli)
Common pompano (Trachinotus carolinus)
Leatherjacket (Oligoplites saurus)
Snook (Centropomus undecimalis)
Spot snapper (Lutjanus synagris)
King whiting (Menticirrhus americanus)
Black drum (Pogonias cromis)
Spadefish (Chaetodipterus faber)
Silver mullet (Mugil curema)
Tonguefish (Symphurus plagiusa)
Marbled puffer (Sphoeroides testudineus)

26 to 50 specimens

Channel catfish (Ictalurus punctatus)
Bluegill (Lepomis macrochirus)
Jacks (Caranx spp.-latus)
-hippos)
Pinfish (Lagodon rhomboides)

50 to 100 specimens

Threadfin shad (Dorosoma petenense)
Sardine (Harengula pensacolae)
Least killifish (Heterandria formosa)
Sand perch (Diapterus olithostomus)
Silver perch--yellowtail (Bairdiella chrysura)
Darter goby (Gobionellus boleosoma)
Spotfin whiff (Citharichthys spilopterus)
Hogchoker (Trinectes maculatus)

TABLE 18

Frequency of occurrence of fishes in the trawl and seine collections for those species appearing in above 5 percent of the total station collections

Item	Trawls	Seines	All stations
Number of station collections	68	53	121
Species	Frequency (percent)		
Croaker (Micropogon undulatus)	81	17	53
Striped mullet (Mugil cephalus)	13	66	39
Bay anchovy (Anchoa mitchilli)	24	55	37
Mojarra (Eucinostomus gula)	18	55	34
Sea catfish (Galeichthys felis)	50	8	31
Tidewater silversides (Menidia beryllina)	0	66	29
Sand perch (Diapterus olithostomus)	28	23	26
Spotfin whiff (Citharichthys spilopterus)	34	13	25
Hogchoker (Trinectes maculatus)	41	0	23
Spot (Leiostomus xanthurus)	12	30	23
White trout (Cynoscion regalis)	35	2	21
Threadfin shad (Dorosoma petenense)	19	13	17
Snook (Centropomus undecimalis)	16	9	13
Menhaden (Brevoortia smithi)	4	30	13
Marbled puffer (Sphoeroides testudineus)	12	15	13
Darter goby (Gobionellus boleosoma)	7	17	12
White catfish (Ictalurus catus)	19	2	12
Yellowtail (Bairdiella chrysura)	19	0	11
Pipefishes (Syngnathus spp.)	0	25	11
Tonguefish (Symphurus plagiusa)	15	6	11
Bluegill (Lepomis macrochirus)	4	17	10
Red drum (Sciaenops ocellata)	0	23	10
Black drum (Pogonias cromis)	16	0	9
Pinfish (Lagodon rhomboides)	2	19	9
Jacks (Caranx spp.)	3	15	8
Channel catfish (Ictalurus punctatus)	13	2	8
Whiting (Menticirrhus americanus)	10	4	7
Round pompano (Trachinotus falcatus)	0	17	7
Needlefishes (Strongylura spp.)	0	17	7
Ocean goby (Gobiosoma gracillimus)	13	0	7
Leatherjacket (Oligoplites saurus)	0	15	7
Lizardfish (Synodus foetens)	2	11	6
Tenpounder (Elops saurus)	6	6	6
Mosquitofish (Gambusia affinis)	0	13	6
Red minnow (Notropis maculatus)	0	11	5
Striped anchovy (Anchoa hepsetus)	0	11	5
Stingaree (Dasyatis sabina)	7	2	5

TABLE 19

Salinity average of seine stations and bottom samples at trawl stations, together with numbers of species and numbers of individuals of marine and fresh-water fishes in each portion of the estuary

	South Fork	North Fork	Outer estuary
Average salinity (p.p.t.)-----------	6.0	6.3	14.1
Salinity range (p.p.t.)-------------	0.14-20.5	0.14-20.2	0.15-36.0
Number of fresh-water species-------	12	13	13
Number of fresh-water fishes--------	242	304	86
Number of marine species------------	35	32	57
Number of marine fishes-------------	9,344	4,486	10,321

TABLE 20

Summary of salinities (in p.p.t.) and numbers of fishes and invertebrate animals caught in St. Lucie Estuary

Item	1957					1958				1959
	Jan. 28-29	May 16	June 18	Sept.23	Nov. 13	Jan. 27-28	Feb. 24-25	May 19-20	Oct. 27-28	Jan.27
Lake discharge (c.f.s.)	0	0	2,160	6,680	0	7,380	4,000	5,200	0	0
Salinity range (1)	14.0-36.0	3.7-32.4	0.5-22.8	0.16-22.8	5.2-31.3	0.14-4.5	$<$1.0-29.4	0.14-25.5	7.8-31.5	$<$1.0-33.8
Salinity average (1)	21.5	14.1	3.4	2.7	17.8	0.67	3.6	2.2	19.6	14.5
Number of hauls	21	19	21	20	15	15	15	17	14	14
Fishes										
Fresh-water species (2)	0	4	3	6	0	14	8	8	1	4
Marine species (2)	28	32	26	21	25	26	25	29	31	28
Fresh-water specimens	0	68	8	87	0	53	307	100	1	8
Marine specimens	1,324	1,180	709	865	269	6,369	7,287	4,187	561	1,400
Invertebrates										
Fresh-water species	1	1	2	2	1	1	1	2	0	1
Marine species	14	8	7	6	9	3	7	5	13	8
Fresh-water specimens	1	3	2	6	1	16	17	21	0	8
Marine specimens	188	361	119	17	60	24	54	233	640	96

NOTES: (1) Based on all seine station samples and bottom samples from trawl stations.
(2) Based on spawning habitat.

TABLE 21

Salinity ranges per thousand at which the most abundant fishes in all collections were taken--St. Lucie Estuary

Item	Salinity range per thousand									Total
	< 0.5	0.5-1.9	2.0-4.9	5.0-9.9	10.0-14.9	15.0-19.9	20.0-24.9	25.0-29.9	30.0	
Species										
Mullet	(1) 10,732	679	262	224	45	68	1	380	-	12,391
Menhaden	(1) 3,578	62	25	-	31	7	45	-	-	3,748
Croaker	(1) 1,039	12	146	100	226	256	98	95	1	1,973
Silversides	(1) 1,412	207	40	10	20	2	10	5	-	1,706
Anchovy	(1) 543	119	13	301	94	101	287	8	-	1,466
Mojarra	80	7	315	82	74	41	12	(1) 361	4	976
Sea catfish	(1) 168	1	18	78	55	17	38	18	-	393
Black crappie	(1) 184	-	1	-	-	-	-	-	-	185
Spot	45	(1) 75	46	7	3	6	1	-	-	183
White cat	(1) 163	-	-	-	-	-	-	-	-	163
Round pompano	-	8	-	36	19	21	(1) 42	17	-	143
White trout	(1) 51	-	6	-	12	10	40	11	-	130
Red drum	2	1	3	-	(1) 49	36	16	20	-	127
Sand perch	(1) 33	8	7	22	7	-	15	6	-	98
Yellowtail	(1) 51	-	-	3	13	4	9	17	-	97
Whiff	(1) 44	2	2	-	4	9	16	15	-	92
Threadfin shad	(1) 75	3	2	1	-	-	-	-	-	81
Hogchoker	(1) 29	2	12	2	3	3	5	13	-	69
Total taken in salinity range	18,229	1,186	898	866	655	581	635	966	5	(2) 24,021
Percentage of total	75.9	4.9	3.7	3.6	2.7	2.4	2.6	4.0	0.1	100.0
No. of collections	50	3	6	10	13	11	13	10	5	121

NOTES: (1) Peak catch.
(2) 97 percent of all fish taken.

TABLE 22

Less abundant fishes taken in St. Lucie Estuary in certain salinity ranges
(Salinity readings in parts per thousand)

Above 30.0 only

Hippocampus hudsonius (sea horse)
Scorpaena grandicornis (scorpionfish)
Citharichthys macrops (gulf whiff)

Above 25.0 only

Chilomycterus schoepfi (boxfish)
Vomer setapinnis (moonfish)
Sphoeroides nephelus (Florida puffer)
Abudefduf saxatilis (sergeant major)

Above 20.0 only

Chloroscombrus chrysurus (bumper)
Sphoeroides maculatus (N. puffer)
Orthopristis chrysopterus (pigfish)
Harengula pensacolae (sardine)
Etropus crossotus (fringed flounder)

Above 15.0 only

Selene vomer (lookdown)

Above 10.0 only

Synodus foetens (lizardfish)
Menticirrhus americanus (whiting)
Membras martinica (rough silversides)
Gobiosoma bosci (naked goby)
Chaetodipterus faber (spadefish)

Above 5.0 only

Prionotus tribulus (sea robin)
Syngnathus spp. (pipefishes)
Trachinotus carolinus (pompano)

Below 0.5 only

Dorosoma cepedianum (G. shad)
Notropis maculatus (red minnow)
Lepomis microlophus (redear sunfish)
Lepomis marginatus (dollar sunfish)
Cyprinodon variegatus (sheepshead killifish)
Jordanella floridae (flagfish)
Lepisosteus platyrhinchus (spotted gar)

Below 2.0 only

Lepomis macrochirus (bluegill)
Notemigonus crysoleucas (golden shiner)
Ictalurus punctatus (channel cat)

(Continued)

TABLE 22--Continued

Below 5.0 only

Lucania goodei (redfin killifish)
Fundulus confluentus (marsh killifish)
Gambusia affinis (mosquitofish)
Cynoscion nebulosus (spotted trout)
Sphyraena barracuda (barracuda)
Heterandria formosa (least killifish)
Bathygobius soporator (mapo)
Fundulus seminolis (Seminole killifish)
Trichiurus lepturus (cutlass fish)

Below 10.0 only

Ictalurus nebulosus (speckled bullhead)
Elops saurus (tenpounder)
Enneacanthus gloriosus (bluespotted sawfish)
Mugil curema (silver mullet)

Scattered throughout range from 0.5 to 30.0

Syngnathus scovelli (Scovell's pipefish)
Sphoeroides testudineus (marbled puffer)
Pogonias cromis (black drum)
Gobionellus gracillimus (ocean goby)
Symphurus plagiusa (tonguefish)
Lagodon rhomboides (pinfish)
Strongylura spp. (needlefishes)
Bagre marina (gafftopsail catfish)
Caranx spp. (jacks)
Oligoplites saurus (leatherjacket)
Centropomus undecimalis (snook)
Lutianus griseus (gray snapper)
Anchoa hepsetus (striped anchovy)
Lutjanus synagris (spot snapper)
Achirus lineatus (sole)
Archosargus probatocephalus (sheepshead)
Gobionellus boleosoma (darter goby)
Gobionellus hastatus (sharptail goby)
Gobioides broussoneti (violet goby)
Stellifer lanceolatus (star drum)
Dasyatis sabina (stingaree)

19. Invertebrate catch.--Table 23, which lists the invertebrate animals caught, is in considerable contrast to table 13, which is the comparable one for fishes, in that no great predominance of a few numerous species is demonstrated. However, the jelly-like ctenophores could not be counted, and it was noted that the trawl hauls sometimes consisted virtually of a mass of jelly with the remaining less numerous organisms interspersed. If there was any predominant invertebrate it was the ctenophore, *Mnemiopsis*. The remaining most abundant invertebrates were two commercial shrimp, *Penaeus aztecus* and *P. duorarum*; two swimming crabs, *Callinectes*; a jellyfish; a small clam; and a small marine snail. Only one of the invertebrates, the river shrimp, *Macrobrachium*, was clearly a fresh-water species. The three *Palaemonetes* shrimp noted are difficult to define. At least two of them seem to be estuarine or marine. Several of the invertebrates, such as the squid, chiton, stone shrimp, and sea hare, were taken only in fairly high salinities and only a few times. This is indicated in table 24. Table 25 lists the numbers of organisms which were caught only a few times. Table 26 indicates the salinity distributions of the most abundant invertebrates. The invertebrate fauna in the estuary can be divided into several categories. The fresh-water component (*Macrobrachium*, possibly *Palaemonetes*, and the fresh-water snail) was quite few in numbers. The same thing can be said of the squid, sea hare, and chiton, which came into the outer estuary only when salinties were quite high. A third group--such as *Rangia*, *Mulinia*, and the ctenophores--is indigenous. The latter seems to be most abundant at moderately high salinities, and rangia clams are more abundant at low salinities. A fourth group raises in the estuaries similar to the fishes noted above. This includes three penaeid shrimp and the two swimming crabs. It was noted that the brown shrimp was found in lower salinities than the pink shrimp and in general the blue crab was in lower salinities than the ornate crab. One of those two crabs (blue crab) and the three penaeid shrimp are the only commercial invertebrates. The white shrimp, brown shrimp, and blue crab were common at quite low salinities and are known to raise in such areas (Gunter, 1950). The brown shrimp were most abundant seasonally in May, in both 1957 and 1958. Pink shrimp were found only in October 1958 and January 1959, after the gates were closed. The catch of blue crabs did not vary greatly at any time, and the white shrimp were not abundant at any time. In brief, the opening and closing of the St. Lucie spillway gates might cause a lowering in abundance of the pink shrimp, and possibly the brown shrimp, but it has no effect on the blue crab, the only other indigenous species present in any numbers. Oysters, where they are present, can tolerate a wide range of salinities and sediment conditions, and are most abundant where there is a continuous supply of fresh-water drainage. The St. Lucie Estuary has never been an important producer of commercial shellfish.

TABLE 23

Most abundant animals caught in each of the three main areas of St. Lucie Estuary

Species	Number of each species caught			
	South Fork	North Fork	Outer estuary	Total
Mnemiopsis mccradyi (ctenophore)---	Numerous	Few	Numerous	Numerous
Penaeus aztecus (brown shrimp)-----	248	76	167	491
Penaeus duorarum (pink shrimp)-----	156	35	33	224
Aurellia aurita (jellyfish)--------	51	Few	166	217
Callinectes sapidus (blue crab)----	72	33	81	186
Mulinia lateralis (clam)-----------	-	-	127	127
Callinectes ornatus (ornate crab)--	28	3	85	116
Nassarius vibex (common nassa)-----	-	1	113	114
Rangia cuneata (rangia clam)-------	5	76	6	87
Palaemonetes spp. (grass shrimp)---	17	15	16	48
Clibinarius vitatta (hermit crab)--	1	1	27	29
Macrobrachium acanthurus (river shrimp)--------------------------	11	10	5	26
Penaeus setiferus (white shrimp)---	16	-	1	17
Congeria leucophaeta (false mussel)-	Few	Several	Several	-
Aplysia willcoxi (sea hare-inkfish)------------------------	-	-	9	9

TABLE 24

Average salinity and range at which invertebrate animals were collected in St. Lucie Estuary

Species	Salinity (p.p.t.)	
	Average	Range
Pagurus floridanus (hermit crab)	36.0	36.0
Pagurites hummi (hermit crab)	36.0	36.0
Calliactes tricolor (sea anemone)	36.0	36.0
Arca sp. (ark shell)	36.0	36.0
Canthurus multangulus	33.8	33.8
Ophiothrix oerstedi (serpent star)	33.8	33.8
Chaetopleura apiculata (chiton)	33.8	33.8
Astropecten articulatus (starfish)	33.8	33.8
Aplysia willcoxi (sea hare-inkfish)	33.0	29.2-36.0
Sicyonia typica (stone shrimp)	29.2	29.2
Lolliguncula brevis (squid)	28.0	27.2-29.2
Mulinia lateralis (clam)	25.2	20.0-29.2
Solen viridis (razor clam)	22.9	22.9
Polynices duplicata (mooneye)	22.8	22.8
Crepidula plana	22.8	22.8
Mnemiopsis mccradyi (comb jelly)	21.2	13.8-31.5
Congeria leucophaeta (false mussel)	20.2	20.2-20.3
Aurellia aurita (moon jelly)	20.2	7.8-32.4
Penaeus duorarum (pink shrimp)	19.9	13.8-27.4
Callinectes ornatus (ornate crab)	18.9	0.34-36.0
Cancroid crab	18.8	7.8-36.0
Palaemonetes vulgaris (grass shrimp)	16.5	3.7-29.2
Molgula manhattensis (onion tunicate)	15.1	10.0-20.2
Penaeus setiferus (white shrimp)	14.0	0.7-21.0
Penaeus aztecus (brown shrimp)	13.4	0.22-29.2
Clibinarius vitatta (hermit crab)	12.9	2.34-36.0
Rangia cuneata (rangia clam)	9.7	0.15-26.3
Callinectes sapidus (blue crab)	9.4	0.15-29.4
Neritina reclivata (olive nerite)	7.8	7.8
Palaemonetes paludosus (grass shrimp)	2.6	< 1.0-4.9
Macrobrachium acanthurus (river shrimp)	1.8	0.15-14.8
Peppermint shrimp	< 1.0	< 1.0
Fresh-water snail	< 1.0	< 1.0
Neritina Virginea (Virginia nerite)	< 1.0	< 1.0
Sesarma cinereum (land crab)	0.8	0.8
Palaemonetes pugio (grass shrimp)	0.19	0.16-0.22

TABLE 25

Number of invertebrate animals with less than five specimens in total collections in St. Lucie Estuary

Four specimens

Molgula manhattensis (onion tunicate)
Cancroid crab

Three specimens

Astropecten articulatus (starfish)
Lolliguncula brevis (squid)

Two specimens

Neritina virginea (Virginia nerite)
Arca sp. (ark shell)
Crepidula plana
Peppermint shrimp
Chaetopleura apiculata (chiton)
Polynices duplicata (mooneye)

One specimen

Neritina reclivata (olive nerite)
Pagurus floridanus (hermit crab)
Pagurites hummi (hermit crab)
Solen viridis (razorclam)
Sicyonia typica (stone shrimp)
Sesarma cinereum (land crab)
Canthurus multangulus
Clathodrillia ostrearum
Ophiothrix oerstedi (serpent star)
Calliactis tricolor (sea anemone)
Fresh-water snail

TABLE 26

Salinity range and average at which most numerous invertebrate animals were taken in St. Lucie Estuary

Salinity range (p.p.t.): <0.5, 0.5-2.0, 2.1-4.0, 4.1-6.0, 6.1-8.0, 8.1-10.0, 10.1-12.0, 12.1-14.0, 14.1-16.0, 16.1-18.0, 18.1-20.0, 20.1-22.0, 22.1-24.0, 24.1-26.0, 26.1-28.0, 28.1-30.0, 30.1-32.0, 32.1-34.0, 34.1-36.0

Species	Salinity range (p.p.t.)	Average*
Callinectes ornatus	0.34-36.0	18.9
Callinectes sapidus	0.15-29.4	9.4
Clibinarius vitatta	2.34-36.0	12.9
Penaeus aztecus	0.22-29.2	13.4
Palaemonetes vulgaris	3.7-29.2	16.5
Rangia cuneata	0.15-26.3	9.7
Cancroid crab	7.8-36.0	18.8
Aurellia aurita	7.8-32.4	20.2
Penaeus setiferus	0.7-21.0	14.8
Molgula manhattensis	10.0-20.2	15.1
Macrobrachium acanthurus	0.15-14.8	1.8
Mnemiopsis mccradyi	13.8-31.5	21.2
Penaeus duorarum	13.8-27.4	19.9
Mulinia lateralis	20.0-29.2	25.2
Aplysia willcoxi	29.2-36.0	33.0
Lolliguncula brevis	27.2-29.2	28.0
Palaemonetes paludosus	<1.0-4.9	2.6

NOTE: *X indicates average salinity point on the range line.

G. OTHER FISHERY ASPECTS

20. Commercial fishing aspects in St. Lucie Estuary will be covered in more detail by the United States Fish and Wildlife Service in its forthcoming report. However, Service personnel furnished data on the nightly trammel net catches of one commercial fisherman in the South Fork and main estuary during one week in December 1956 and from January to June 1958. Those data, with discharge information added, are given in tables 27 and 28. During the 1958 period, there were 27 nightly catches in areas where the salinity was probably near zero and 10 catches where it was probably between 5.0 and 15.0 parts per thousand. From those data, there is little to indicate that fresh-water discharges are damaging to the commercial fishery. On individual nights, the total catch was often as good or better with than without discharge. With high flows, the average nightly catch of mullet, sheepshead, and snook was greater; with low or zero discharges, there were somewhat better average catches of croaker, trout, and menhaden and much better catches of gafftopsail catfish, tripletail, and jacks. The nightly catch of mojarra was about the same irrespective of discharge and salinity conditions. The commercial netting operations in 1956 occurred when there had been no regulatory lake discharge for 18 months. At that time, nightly mullet catches were about the same magnitude as in 1958, but snook catches were higher. The latter was a commercial species then, but not in 1958. Catches of other fishes were low or zero. Many other factors not connected with the lake discharge, including weather, prevailing market price for various species, number of fishermen, attraction of fishermen to other areas and other fishes, and seasonal abundance of fish affect the commercial fish catch in any one area. The University of Miami Marine Laboratory studies in 1954 covered commercial catch statistics in relation to fresh-water releases from St. Lucie Canal. The Laboratory's studies of fish landings in Martin County and in adjacent counties, as well as along the entire east coast, did not support the idea that there were adverse effects of the fresh water on commercial fish catches in Martin County, since landings rose or fell in all areas alike. The present investigation did not indicate any damage or significant adverse effect of fresh-water release on the commercial fishes of St. Lucie Estuary. In fact, in the long run, fresh-water flows during the spawning and early growing season are probably beneficial by virtue of increased production and survival of both young commercial species--such as croaker, mullet, trout, mojarra, and menhaden--and small food fishes.

TABLE 27

Trammel net catches of one commercial fisherman
in South Fork and main St. Lucie Estuary

(Data furnished by U. S. Fish and Wildlife Service)

Date	Location	Lake discharge (c.f.s.)	FISH									
			Mullet	Snook	Croaker	Mojarra	Trout	Sheepshead	Menhaden	Catfish	Tripletail	Jacks
11-30-56	Palm City--------------	0	237	50	3	-	-	-	-	-	-	-
12-1-56	do.----------------	0	10	541	-	-	-	-	-	-	-	-
12-2-56	do.----------------	0	17	214	-	-	-	-	-	-	-	-
12-3-56	do.----------------	0	-	81	-	-	-	-	-	-	-	-
12-4-56	do.----------------	0	-	162	-	12	-	-	-	-	-	-
12-5-56	do.----------------	0	17	170	-	-	-	-	-	-	-	-
12-6-56	do.----------------	0	-	72	-	-	6	-	-	-	-	-
1-25-58	Above Stuart bridge-----	7,450	132	-	10	33	24	121	-	-	-	-
1-27-58	do.-----------	7,380	130	-	-	-	15	-	-	-	-	-
1-28-58	do.-----------	7,250	84	-	11	44	-	114	-	-	-	-
2-21-58	Below Stuart bridge-----	5,420	-	-	14	-	-	-	30	-	-	-
2-24-58	do.-----------	3,930	65	-	-	-	-	45	-	-	-	-
2-25-58	do.-----------	3,460	20	-	60	-	-	-	-	-	-	-
3-7-58	Marker No. 19-----------	3,440	-	-	22	40	32	-	-	-	-	-
3-11-58	do.---------------	3,420	-	-	16	44	-	-	-	37	59	-
3-12-58	do.---------------	3,420	-	-	-	18	-	-	-	40	-	-
3-14-58	do.---------------	3,490	-	-	52	30	-	-	-	-	-	-
3-15-58	do.---------------	3,470	-	-	4	-	12	-	-	25	42	-
3-17-58	do.---------------	3,440	-	-	-	15	-	-	40	28	-	30
3-18-58	do.---------------	3,450	-	-	4	20	5	-	-	17	-	-
3-19-58	do.---------------	3,470	-	-	-	15	5	-	-	-	-	-
3-29-58	Palm City bridge--------	5,070	-	-	-	25	-	-	-	-	-	-
4-1-58	do.-------------	5,830	40	-	30	10	-	-	-	-	-	-
4-5-58	do.-------------	6,360	57	25	-	22	-	-	-	-	-	-
4-8-58	S.F. barges------------	6,240	2	35	-	-	-	-	-	1	-	-
4-8-58	Palm City bridge--------	6,240	2	6	1	-	-	-	-	-	-	-
4-8-58	Powell's Dock----------	6,240	1	-	2	3	-	-	-	1	-	-
4-15-58	Above Stuart bridge-----	5,810	80	-	-	17	-	20	-	-	-	-
4-20-58	do.-------------	6,100	72	-	-	40	-	-	-	15	-	-
4-23-58	do.-------------	6,160	58	-	-	50	-	-	-	-	-	-
5-7-58	do.-------------	5,940	235	-	-	23	-	-	-	-	-	-
5-17-58	do.-------------	5,290	24	-	-	-	-	-	-	-	-	-
5-18-58	do.-------------	5,230	23	-	-	7	-	-	-	-	-	-
5-21-58	do.-------------	4,940	42	-	3	45	-	-	-	10	-	-
5-22-58	do.-------------	4,900	21	-	-	-	-	-	-	-	-	-
5-26-58	do.-------------	4,990	152	-	5	50	-	-	-	-	-	-
5-28-58	do.-------------	4,900	65	-	-	15	-	-	-	-	-	-
5-29-58	do.-------------	4,960	15	-	-	18	-	-	-	-	-	-
6-14-58	do.-------------	2,470	15	-	-	15	-	-	-	-	-	-
6-16-58	do.-------------	1,670	175	-	-	59	-	-	-	-	-	-
6-18-58	do.-------------	0	26	-	-	34	2	-	-	-	-	-
6-27-58	S.F. barges-----------	0	-	1	1	-	-	-	-	1	-	-
6-27-58	Palm City bridge-------	0	-	3	7	6	1	2	-	-	-	-
6-27-58	Marker No. 27----------	0	-	-	15	13	-	-	1	-	-	-

TABLE 28

Commercial trammel net operation

January-June 1958

(Data furnished by U.S. Fish and Wildlife Service)

Fish	Fish catch			
	Salinity zero (1)		Salinity 5 or over (p.p.t.) (2)	
	Total	Catch/night	Total	Catch/night
Mullet	1,536	57	0	0
Croaker	137	5	120	12
Mojarra	510	19	201	20
Trout	41	2	55	6
Sheepshead	300	11	2	-
Menhaden	30	1	41	4
Catfish, gafftopsail	28	1	147	15
Tripletail	0	0	101	10
Jacks	0	0	30	3
Snook (3)	67	3	3	-
Total	2,649	-	700	-

NOTES: (1) 27 nights' fishing effort.
(2) 10 nights' fishing effort.
(3) Not sold.

Dated receipts furnished by cooperating commercial fishermen. Location noted by fishermen. Salinity estimated from graphs of known discharge rates.

21. Cold kill of fishes, January-February 1958.--As was stated and shown with the temperature data given earlier in this report, the winter of 1957-58 was one of the coldest of record for central and southern Florida. In connection with the several periods of freezing temperature that occurred in January and February, fish kills of considerable proportions also occurred throughout this State and other coastal sections of the southeast United States. During the February 24-25, 1958, sample, large numbers of dead fish were observed floating in the estuary and lying along the shorelines. These were predominantly ladyfish or tenpounder (*Elops saurus*) and sand perch (*Diapterus olisthostomus*), with some snook, tarpon, and mullet. (See fig. 3.) Many specimens which had been dead for some time were dragged up with the trawl. The great majority of the dead fish were adults, with some of the tarpon measuring up to 5 feet. Although the local newspapers blamed the St. Lucie Canal fresh-water discharge for the fish kills, there was considerable evidence to indicate that the cold weather was really the cause, as follows:

Ladyfish and sand perch killed by the cold in North Fork, St. Lucie Estuary, February 1958

Dead tarpon found floating in North Fork St. Lucie Estuary after cold kill, February 1958

FIGURE 3

a. The kill occurred in all parts of the estuary, including far up the North Fork, which area was unaffected by discharge from St. Lucie Canal:

b. Fish kills were reported about the same time for other parts of Florida (Tampa Bay and Biscayne Bay) and for coastal areas in Georgia and South Carolina and to the west in Mississippi and Texas. The Jacksonville District made inquiries of State and Federal fish and wildlife agencies and university laboratories to verify such reports. Those replies contain pertinent data on fish kills during that period and are included in appendix A.

c. Just prior to the observed kills in St. Lucie Estuary, the Stuart News reported the lowest weekly average temperature of record.

d. The fact that primarily large fish were killed is a known phenomenon associated with temperature kills (Brongersna-Sanders, 1957; Gunter, 1947), although the only explanation for this condition is that when the temperature is falling the metabolic rate apparently drops faster for larger animals than it does for smaller ones.

e. The fishes killed in St. Lucie Estuary were principally those with tropical distribution. Such species are more susceptible to decreasing temperature changes and generally leave the colder inner waters during the winter for the deeper, warmer waters of the ocean. However, quick drops in temperature will trap many of them in the inner bays before they are able to leave.

f. It is significant that the largest number of fish taken in any of the 10 samples over the 2-year period were collected in the February 1958 sample. If the fish kill had resulted from anything but the cold temperatures, such as fresh-water discharge or pollution, it would have been more widespread and less selective of adult, tropical species.

g. Data from the cold kill also furnished evidence that the fresh-water discharge does not drive out or destroy all the large game fishes. If it had done so during the previous month of continuous high discharge, then there would have been no large tarpon, snook, and ladyfish remaining in the estuary to be killed by the cold. In addition to the many small live fish that were taken, edible-size croaker and drum, which are more tolerant of cold waters, were abundant in the outer estuary. (See fig. 4.)

22. Sailfish and offshore sport fishery.--Both the inshore and offshore sport fishery aspects will be covered in greater detail in the United States Fish and Wildlife Service's report. However, the following items in that regard are included for consideration here. The University of Miami study concluded the offshore charter boat fishery was not significantly affected by the fresh-water release, although it was considered

Sample of live fish (croaker, spot, sand perch, pig-
fish, puffers, gobies) and crabs collected with trawl
at TS7, St. Lucie Estuary, during February 1958 when
large numbers of tropical forms were killed through-
out the estuary by low temperatures

FIGURE 4

that if the discharges were high enough some boats might have to travel farther to make their catch. In connection with sailfishing, inquiry was made of the University of Miami Marine Laboratory, which is conducting extensive investigations on the life history of sailfishes, whether or not there had been a general decline in sailfishing--particularly off the Stuart area--in the last 10 years. Charter boat captains had reported that to be so in a nationally publicized news item in December 1958 and had further indicated that fresh-water discharges from St. Lucie Canal were probably responsible for the decline in numbers. Copies of the District Engineer's inquiry and the Marine Laboratory's reply are presented in appendix A. In summary, University scientists stated there was no evidence of any decline in numbers of sailfishes along the Florida coast and that discharge of fresh water into estuaries has no bearing whatsoever on the sailfish life cycle. Sailfish concentrations off the Stuart area are well offshore (some 12 miles) and would not be affected by discharge of fresh water from St. Lucie Inlet. Further evidence in that connection was furnished in the editor's report on the fifth annual light tackle sailfish tournament of the Stuart Sailfish Club, which appeared in Southern Outdoors, March 1959. During the latest 3-day tournament off Stuart, 77 competing entrants took 166 sailfish, 161 of which were released. Furthermore, since the release program was begun by the West Palm Beach Fishing Club in 1950, over 9,000 sailfish have been successfully released. Such catch records would not indicate there had been any general decline in sailfish numbers in the last 10 years, or that discharge from St. Lucie Canal is in any way adversely affecting the sailfish fishery, which is an important part of the Stuart economy.

23. St. Lucie Lock and Dam fishery.--a. General.--St. Lucie Lock and Dam provides a congregation point on the lower St. Lucie Canal for a variety of marine and fresh-water fishes, and the area has supported a small local fishery ever since its construction. Prior to 1956, the lock area was visited more by sightseers and picnickers than by fishermen, but in the last 3 years the number of fishermen has greatly exceeded all other types of visitors (table 29). Construction of additional bank-fishing facilities below the dam in 1958 resulted in an increase in fishermen visits above that expected in the normal annual upward trend. Experienced fishermen in the Stuart area have long known that one of the best places and times to catch snook was below St. Lucie Dam when small to medium amounts of fresh water were being discharged. Also, mullet, catfish, sunfishes, crappie, and other species were known to be more abundant in certain seasons and conditions than others. Daily records of fishing activity in the lock area during the past 2 years have shown those conditions to be true. The first opportunity to check fishing pressure and fish catch with the release of fresh water was in May and June 1957.

TABLE 29

Total annual recreational visitors
St. Lucie Lock and Dam, 1955-58

Year	Number of visitors		
	Sightseeing and picnicking	Fishing	Total
1955-----	5,200	1,800	7,000
1956-----	2,937	7,676	10,613
1957-----	2,332	9,218	11,550
1958-----	3,610	15,774	19,384

b. Summary of fishing pressure and catch, 1957.--Prior to May 1957, a record of the number of visitors to St. Lucie Lock was kept, but this was not generally separated according to fishing and other activities. Nor was there an account of the number of pounds of fish caught daily, monthly, or annually. When it became evident in late spring that releases of fresh water would be required through St. Lucie Canal to bring Lake Okeechobee down to a safe operating level, the lock operators were requested to furnish a record of the number of fishermen and fish caught daily.

(1) May-June 1957 activity.--The record was begun on May 1 and continued through June 30. Discharge of fresh water was begun on May 16 and continued through June 21. During most of that period, the rate of discharge was about 2,200 cubic feet a second. An increase and decrease in fishing activity and fish catch--primarily snook--occurred simultaneously with the opening and closing of the gates (see plate 21). During the early part of May when the gates were closed, the number of fishermen ranged from 10 to 25 daily and their catch from 15 to 30 pounds. During the 5-week discharge period, except for the peak use on Memorial Day, May 30, the number of fishermen ranged from 55 to 70 daily and their total catch from 100 to 140 pounds. During the last 10 days of June when the gates were again closed, both the use and catch fell off to near predischarge conditions.

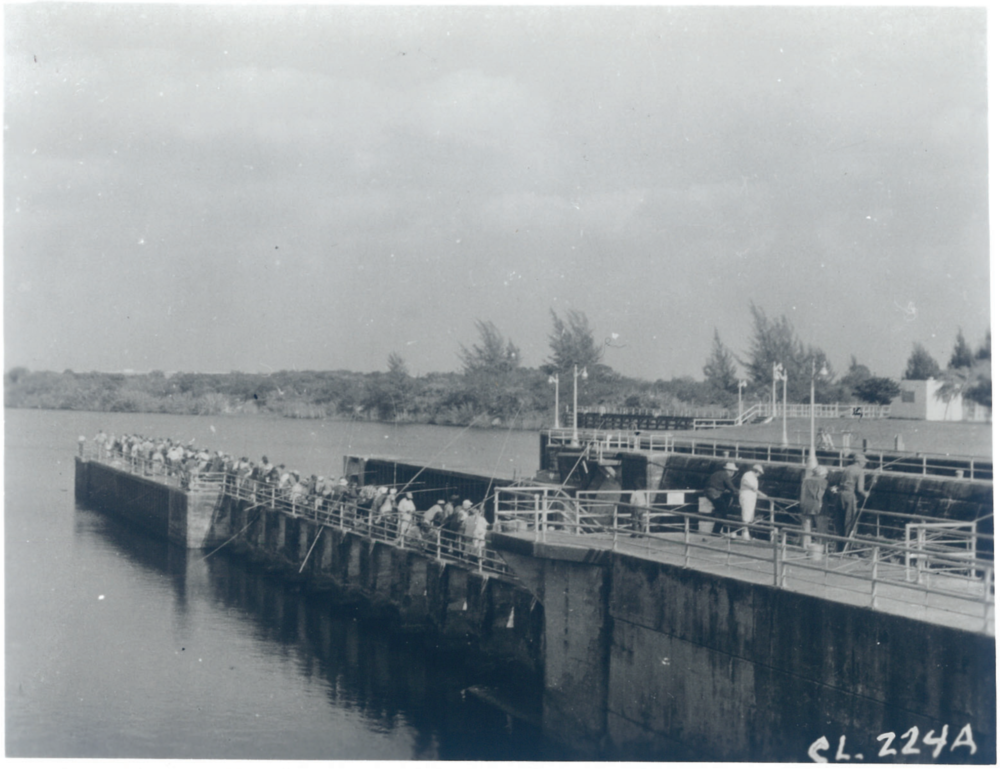
(2) August-October 1957 activity.--Records were also kept of the fishing activity during the fall discharge period from August 16 to October 21. During the first 10 days, when the rate of discharge was about 2,600 cubic feet a second, fishing activity was high, with counts of 100 fishermen recorded on several days. After September 1, the discharge rate was over 5,000 cubic feet a second daily and averaged nearly 7,000 cubic feet a second during the last 5 weeks. The number of fishermen daily was lower during the period of high discharge--usually below 50--although there

were good individual catches of large snook. In 1957, fishing pressure and fish catch at St. Lucie Lock totaled 9,218 fishermen and 14,994 pounds of fish respectively. The daily records of numbers of fishermen and pounds of fish caught in 1957 and 1958 will be presented in an addendum to this report.

c. Summary of fishing activity, 1958.--Beginning January 1, 1958, daily records of fishing activity in the lock area were kept, irrespective of discharge condition. The daily record of fishermen and the average rate of discharge every fifth day are graphically portrayed on plate 22. Monthly summaries of the fishermen-use and catch records are given in table 30 and illustrated on plate 23. In 1958, over 15,700 persons fished below the dam from the banks or retaining walls, and they caught a record total of 46,775 pounds of fish. Those figures do not include the 1,303 boat fishermen observed in the area, whose catches were not recorded. Unlike the bank fishermen who must enter and exit through the lock area, boat fishermen can come and go from downstream with no opportunity to check their catch. The 1958 totals amounted to nearly twice as many fishermen and over three times the amount of fish caught in 1957. Part of this increase, at least, resulted from the completion, in May 1958, of safety railings and the opening to fishermen of the previously closed section of the south wing wall extending below the dam. This opened several hundred more feet of fishing space directly over the moving water (see figures 5 and 6) where fish congregate during discharge periods. Sundays and holidays were the biggest days for fishermen at the lock. It was not unusual for over 100 fishermen to be present on a Sunday. Once in February, twice in March, five times in July (during the height of snook fishing), and once in both September and October, 150 fishermen were counted. The highest number for any one day in the year was 225 on July 27. Fishing success based on the pounds of fish caught per fishermen-day averaged about 3 pounds a day per fisherman over the entire year. On a monthly basis, fishing success ranged from about 1.7 pounds per fisherman-day in December to over 5.6 pounds in September during the big mullet run. The highest individual week was the last week of September when an average of over 8.0 pounds of fish per fisherman-day was recorded.

Fishermen on the retaining wall below St. Lucie Lock and Dam. Spillway gates closed; discharge through small turbine, 200-300 c.f.s. Upper: View looking downstream toward Stuart on Oct. 5, 1958. Lower: View toward north bank on Sept. 30, 1958, with picnic and additional fishing areas in background.

FIGURE 5



129 fishermen on retaining wall below St. Lucie Lock and Dam, Jan. 15, 1959. Spillway gates closed.

Snook fishing along north bank below St. Lucie Lock and Dam, April 7, 1959. Spillway discharge 1,600 c.f.s.

FIGURE 6

TABLE 30

Summary of monthly fishing activity at St. Lucie Lock and Dam, 1958

Month	Total visitors	No. of bank fishermen	Fish (lb.)	No. of boats fishing	No. of boat fishermen	Range of discharge (c.f.s.)	Average discharge (c.f.s.)*
January--------	1,204	836	2,292	18	36	0-7,450	(23) 4,440
February-------	1,619	1,315	4,009	18	36	3,460-7,200	(28) 5,990
March----------	2,355	2,101	5,283	59	118	3,410-5,150	(31) 3,780
April----------	1,578	1,392	3,908	61	125	5,810-6,470	(30) 6,120
May------------	1,186	1,048	2,788	48	94	4,830-5,940	(31) 5,320
June-----------	1,012	902	1,853	41	82	0-4,820	(16) 4,020
July-----------	3,432	2,563	5,360	146	492	0-2,530	(30) 2,460
August---------	1,250	989	2,232	49	96	840-2,500	(31) 1,600
September------	1,378	1,113	6,287	17	33	0-1,600	(9) 1,530
October--------	2,516	2,137	9,652	26	51	0	0
November-------	1,021	753	2,090	35	70	0	0
December-------	824	625	1,022	35	70	0	0
Totals----	19,375	15,774	46,776	553	1,303	-	-

NOTE: *No. of discharge days in parentheses.

d. Fishing activity versus discharge.--The fishery data collected in 1958 further substantiated the brief 1957 observations that fisherman-use and fish catch were greater during periods of low and medium discharges than at other times. Examination of plates 22 and 23 shows three peaks of activity during the year--in March, July, and September-October. The average rate of discharge during the first two periods approximated 3,500 and 2,500 cubic feet a second, respectively, and the gates were closed during the fall period. The March activity was primarily for snook, sunfish, catfish, and a run of crappie, which stayed in the area about 2 weeks. The highest activity of the year with respect to fisherman-use was in July, with snook the dominant fish caught. The largest numbers of fish were caught in September and October when mullet in tremendous numbers moved into the area below the dam. As a result of 200-300 cubic feet a second discharge from the small power generator, the mullet congregated in the pool alongside the retaining wall and directly below the fishing walkway, where up to 1,000 pounds were caught on some days on dough bait, bread, and worms. In general, more fishermen were present, and catches, especially of snook, were greater when 2,000 to 3,500 cubic feet a second was being discharged than with higher or lower rates of release. However, there was good fishing at other times, also, as evidenced by the catches shown in figures 7 and 8. Some excellent catches of large snook were made in the spring of 1958, when, because of heavy rains and high lake levels, it was necessary to release water for a long period at rates of 4,000 to 6,000 cubic feet a second. Snook (and snook fishermen) are less likely to be found in the area when the discharge rate is over 6,000 cubic feet a second and when the gates are closed than during intermediate rates of discharge.

e. Seasonal activity.--Snook are taken by fishermen below the dam at any time from early spring until cold weather in the fall, usually through September, but appear to be more abundant in the area in late spring and summer months when some fresh water is discharging. Peak catches have been made in two years in June and July with low to medium flows. The snook are apparently attracted by the fresh-water currents and by the large numbers of mullet and other food fishes that congregate in the low flowing pools below the dam. Mullet are found there at all seasons of the year, but are especially abundant during the early fall before spawning and on their return run from the ocean to Lake Okeechobee during early spring. In November and December each year, Lake Okeechobee mullet move downstream through St. Lucie Lock (which is often operated solely to move them through; reference Hall, 1956) and they do not linger long below the dam. However, on their return movements, they stay in the pool below the dam for a considerable period. In January 1959, there were 7 days on which more than 1,000 pounds of mullet were caught by cane-pole fishermen on the retaining wall. In years when there is considerable fresh-water discharge, sunfish and catfish, as well as snook and mullet, are abundant. If there is fresh water in early spring, large numbers of crappie will appear for a brief period. These fresh-water fishes are not as abundant in years when the gates are closed and tidal waters reach that far upstream. However, at such times their place is taken by such brackish and marine forms as sheepshead, mangrove snapper, jack, sand perch, flounder, and occasionally jewfish.

April 28, 1958
Spillway discharge 5880 c.f.s.
6 snook - 3 to 18-1/2 pounds

April 30, 1958
Spillway discharge 5830 c.f.s.
2 snook - 7 and 8 pounds

June 2, 1958
Spillway discharge 4815 c.f.s.
3 snook - total 32 pounds

June 14, 1958
Spillway discharge 2470 c.f.s.
Snook and sand perch

FISHING ACTIVITY 1958 BELOW ST. LUCIE LOCK AND DAM

FIGURE 7

f. Summary of fishing activity at lock.--A sizable fishery for snook, mullet, and various other species has developed below St. Lucie Lock and Dam in recent years. Use of that area by both local and non-resident fishermen is increasing each year. Installation of safety rails on the retaining wall over the discharge area in 1958, making it possible to fish over the flowing-water areas where the fish congregate, was partially responsible for a large increase in fisherman-use this year. Based on studies of fisherman-use and fishing success at the lock in 1957 and 1958, there is evidence of a direct benefit to fishing below the dam, especially for snook, by small to medium releases of fresh water. Higher discharges, above 3,500 cubic feet a second, or no discharge, particularly in late spring and early summer months when snook are most abundant, appear to result in poorer fishing. High winter discharges apparently have less effect on fishing at the lock because of the large numbers of mullet, sunfishes, catfishes, and crappie which use the area at that time. Furthermore, the winter fresh-water releases appear to promote greater production and survival of fall and winter spawning food and bait fishes downstream in the estuary. In past years, the St. Lucie Lock and Dam area was often used as a substitute fishing place when fishing was not good in other local areas. In 1957, a year when there were two separate discharge periods of 36 and 67 days in early summer and late fall, respectively, the total bank-fishing pressure was 9,218 persons. In 1958, a year with several freezes and a cold spring and almost continuous fresh-water discharge through the dam from January to September, 15,776 persons bank-fished at the structure. Despite a very poor use in June because of the necessity of maximum fresh-water releases, over 9,000 persons fished in the area during the first 6 months of 1959. Thus, the St. Lucie Lock and Dam recreational area has rapidly developed and, as local fishermen become familiar with the periods of seasonal abundance for various species, it is becoming increasingly popular each year as a desirable fishing spot in its own right, regardless of fishing conditions elsewhere.

H. THE LOCAL PROBLEM IN THE LIGHT OF RESULTS

24. General problem of Corps of Engineers.--a. With regard to Lake Okeechobee and St. Lucie Estuary.--The Corps of Engineers did not construct St. Lucie Canal, which was provided as a result of the growth and settlement in the area and was, in a sense, inherited. Under the present situation, the water can go only to the east or to the west and there are some objections from groups on both coasts. Lake Okeechobee must be controlled in height for the benefit of the rich farming area to the south of the lake, but at the same time it must not get so high as to become dangerous to the communities around the lake, where in the past on two occasions several thousand people were drowned as the result of hurricanes. Lastly, St. Lucie Canal has become a very important waterway for commercial traffic as a part of the cross-State Okeechobee Waterway. That waterway is the link between the Atlantic and Gulf coasts which cuts several hundred miles from the travel distance by way of the Keys. The object of the work reported in this report was to determine whether or not the strong contentions of local interests concerning sports fishing have any validity. The following discussion is based on the local contentions; a number of technical and theoretical biological considerations, which will be discussed in a technical report, are not entered into. The local contentions have been outlined in paragraph 8 (pages 7 and 8) above. They are discussed one by one, as follows:

(1) The small fish, and sometimes larger ones, are killed.

There seems to be no truth in this claim whatsoever, and, in fact, the converse seems to be true. A fish killed by fresh water was never encountered in this study, and, as far as is known, has not been found by other investigators. This idea is contrary to general biological principles, because the fishes found in an estuary, such as the St. Lucie, practically all belong to the group known as euryhaline--that is, they are capable of withstanding very wide salinity variations from fresh water to sea water. Saliniphilous (high salinity) species which sometimes enter the lower estuary near Indian River may leave the area at times of higher fresh-water discharges but they are not killed. Moderate fresh-water discharges through the locks enhance the situation for the common forage fishes--the mullet, the menhaden, the silversides, and the anchovies. It may be stated categorically that small fishes not only are not killed but their populations increase with discharges through St. Lucie Lock.

(2) The marine game and sport fishes leave the area.

Tarpon, snook, croakers, spot, whiting, jack, spotted trout, white trout (squeteague), sand perch (mojarras), drum, sheepshead, flounder, and the tenpounder are the common sport fishes in the estuary area. The first and the last are not considered to be edible. Pompano, bluefish, and occasionally mackerel and some few fishes of the snapper and grunt families are transients in the lower estuary. The first group is very little affected by fresh water; the latter group does leave the estuary. Many dead tarpon, snook, sand perch, tenpounder, and mullet were killed by cold both in the salt waters of the lower estuaries and the fresh waters of the upper estuaries in February 1958 following 2 months of discharge through St. Lucie Canal. They had not left the area because of fresh water.

(3) Sport fishes disperse throughout the estuary so that they are not easily caught.

Fish do not seem to be evenly distributed on a water bottom under any conditions and there is no known reason why an influx of fresh water would cause them to disperse. Aside from the fact that this contention is contrary to number two, it should be noted that snook concentrate around the tailrace of St. Lucie Lock and Dam and the fishery for them there has increased greatly in recent years.

In this connection, it should be noted that completion of the new bridge in the outer estuary in 1957 has taken away most of the former fishing pressure of the two upper bridges. On the Palm City bridge, fishing now is primarily for sheepshead during dry periods, when salinities are highest, and for snook during evening and night in certain seasons. Fishing pressures on both the Palm City and Roosevelt (U.S. 1) bridges are low and damages to fishing from any discharges are likewise more than offset by benefits from increased production of forage fishes. Fishing in the outer estuary is good on low flows and some is still available on high flows, since bottom salinities are still present.

(4) Sport fishes won't take bait or lures when the water is turbid.

In the above discussion, it is well demonstrated that fishes bite voraciously in the turbid waters of St. Lucie Canal right after they come through the lock. Insofar as this is the water which causes the turbidity farther down in the estuary, this contention is obviously groundless. The main problem in the estuary is that the local fishermen desire continuous good fishing. To achieve that end, an abundance of food fishes and organisms and large crops of young game fishes, associated with productive estuaries, are essential. Both high production and good fishing can be produced by controlled fresh-water flows, but not always at the same time every year. The history of good fishing in St. Lucie Estuary is attributable to the fact that high fresh-water discharges have occurred every few years and produced good crops of game and food fishes. High discharges every year would not be good; neither would many consecutive years of no discharge of fresh water into the estuary.

(5) Marine organisms such as clams, snails, and oysters, unable to leave the area, are killed by the fresh water.

There are no commercial mollusk beds in the estuary. The mollusks of that area are of a euryhaline type and can undergo wide variations in salinity; for instance, oysters can withstand fresh water up to a period of 3 weeks and can live indefinitely in salinities of 5 o/oo. There is no evidence that the mollusks or the barnacles of that area have been killed by fresh water.

(6) Deposits of silt and ooze blanket the bottom, smothering bottom animals and destroying aquatic habitats.

Studies by the Corps have shown that shoaling has taken place above Palm City bridge but that erosion of the estuary in an equally large amount has taken place in the estuary below that point. This demonstrates that there has been no overall blanket sedimentation of the bottom.

(7) Commercial fishing, inside and outside the estuary, is damaged.

Data on commercial fishing collected by the Fish and Wildlife Service and presented in part in this report demonstrate that this contention is untrue. The University of Miami report agrees.

(8) Crabs and shrimp are driven from the area.

Crabs are euryhaline organisms and Gunter (1938) has demonstrated that the common blue crab occurs naturally in rivers over 100 miles from the sea. The greatest shrimp production area in the world is the Louisiana coast where salinities are extremely low. The greatest crab-producing areas in the United States are the Louisiana coast and Chesapeake Bay, both low-salinity areas. Table 26 above indicates that blue crabs and two species of commercial shrimp were taken during this investigation in water that was fresh enough to drink.

(9) The effects on fish, organisms, and their habitats endure long after the discharge stops.

If the statement were correct, it would be all to the good, for it would mean that the forage fishes mentioned above would remain in vast abundance for a long time. However, the effects upon salinity are transient and do not last more than a few months. Between September and November 1957, salinity of the inner and outer estuaries rose by a multiple of ten when discharges were stopped. Low salinities such as are caused by even the heaviest discharges are transient in nature and do not long endure.

(10) Sailfishing off the coast has been seriously affected.

Sailfish are animals of the high seas and they live in full sea water. Statement (10) would have validity only if discharges through St. Lucie Estuary would seriously modify the inshore salinity of the Atlantic Ocean. It has no validity whatsoever.

(11) Shoal areas are formed in the river mouths and near the inlet, and boat navigation is affected.

Shoaling at the mouth of the estuary has no relation to St. Lucie Lock and, in fact, such shoaling would probably have been greater if there were no outflow of fresh water through the estuary. Recent studies of passes and inlets in Texas have shown that those inlets closed when river drainage dropped to an extreme low during droughts.

(12) Real estate values around the estuary suffer.

No information was obtained during this survey relative to the validity of this contention. If this contention is true, it is due to a false atmosphere created by publicity given incorrect assumptions and in part is related to the next statement.

(13) Tourists won't come to or stop in Stuart during discharge periods and the business economy suffers.

If this statement is correct, it is due to the general publicity given to opinions derived from lack of biological knowledge and assumptions contrary to fact. Actually, fishing license sales in Martin County increased from 808 in 1948-49 to 2,323 in 1957-58. Commercial fishing in the area has not declined and fishing pressure in St. Lucie Canal intself near the locks has increased tremendously with fresh-water discharges. Those discharges let nutrients into the water and better the condition for the chief forage fishes. These facts are documented in this report. This increased fertility must inevitably result in an increased fish population. These advantages greatly outweigh the disadvantage of the few saliniphilous forms which will be run out of the lower estuary by the lowered salinities.

Newspaper articles and editorials from Stuart about the bad effects of lake discharge have probably done as much to keep fishermen and tourists away from the Stuart area as the fresh-water discharge. There is no evidence of any real damage from the fresh water to the fishes and animals in the estuary and loss in fishing time for some species is only a temporary condition. Even with complete fresh water throughout most of the estuary, there are some kinds of fishing available nearby in the North Fork and fresh-water canals, below St. Lucie Lock, and in Indian River and the ocean. The fact that fishermen caught fish daily at the lock during all rates of discharge is evidence of that. Although particular desired species may not be available at a specific time, as a result of high discharges, the situation is no different from conditions that occur everywhere near the mouths of rivers because of floods, the migratory habits of various species, seasonal peaks of abundance, spawning activity, adverse weather, and a host of other factors, some known and others not known, why fish are not present, or, if present, not taking artificial lures or live bait at the time fishermen would like them to do so. There appears to be no valid reason why the controlled discharge of fresh water through St. Lucie Canal should be vociferously blamed for all the unsuccessful fishing trips in St. Lucie Estuary any more than those that occur on other tidal streams or bays. It behooves all fishermen to know their waters and fish habits under various physical conditions and to pick their time and place for particular species. Even then, they may not be successful. Very seldom, if ever, will all desired kinds be caught under the same conditions, regardless of whether St. Lucie Canal is discharging fresh water.

b. General.--A few more general remarks should be made. Sport and commercial fishery interests should recognize that St. Lucie Estuary--along with all other estuaries--is a nursery area for the young of sport and commercial species and for small bait fishes which furnish food and stock for the outer estuaries and the offshore areas. Those small fishes require the productive conditions found in low-salinity waters for food, growth, and protection from larger marine predators which inhabit more salty waters. In estuaries, there are always periods of poor sports fishing, but these periods may contribute to the growth and survival of the young fish and thus to better future conditions.

The muddy water of St. Lucie Estuary is no different from that which occurs in any other bay after a storm. The same fan-shaped area of turbid water can be seen at the mouths of rivers all along the Atlantic coast when it rains. The productivity of an estuary is increased by the nutritive materials brought in by fresh water and this drainage is probably necessary for high fertility.

I. SUMMARY AND CONCLUSIONS

25. St. Lucie Canal is one of the two available outlets from Lake Okeechobee, whose level must be controlled for irrigation and hurricane-tide control. The other outlet discharges to the Gulf of Mexico through Caloosahatchee River. St. Lucie Canal was originally constructed by the Everglades Drainage District between 1916 and 1924. It was taken over by the Corps of Engineers in 1930, following serious hurricane damage and the loss of many lives on the shores of Lake Okeechobee. The canal leaves Lake Okeechobee at Port Mayaca and extends northeast 25.6 miles to the south fork of St. Lucie River. St. Lucie Lock and Dam are located 1.9 miles west of the easterly end of the canal and about 23.7 miles from Lake Okeechobee. St. Lucie Canal is part of the main channel of east and west boat traffic between the Gulf of Mexico and the Atlantic Ocean. Navigable depth is 8 feet.

26. St. Lucie Estuary consists of a North Fork and South Fork and a main estuary roughly in the shape of a Y. It empties into a coastal lagoon--Indian River--near the entrance to the Atlantic Ocean. The surface area is 5,530 acres; the water volume is 41,150 acre-feet; and length of the shoreline is 35.5 miles.

27. Discharge through St. Lucie Lock and Dam into the South Fork of the estuary has a peak rate of about 9,000 cubic feet a second when the Lake Okeechobee level is near 18.0 feet. Peak flood drainage into the North Fork through creeks, drainage ditches, and small canals is at about the same rate.

28. Discharges through St. Lucie Canal between 1945 and 1958 ranged from zero in 1950 and 1956 to 2,687,000 acre-feet in 1947. The years 1947, 1948, 1953, 1954, and 1958 were those of high discharges. In other years, the discharge was moderate, low, or zero. The average annual discharge during that period was 1,062,000 acre-feet. The heaviest discharge has been from August to December in most years, with lesser peaks from January to April in a few years.

29. Strong, well-publicized contentions from local interests have maintained that the flow of fresh water through St. Lucie Canal is destroying the estuary as a sport and commercial fishery resource, with consequent bad results for the community in general. Because of these contentions, six investigations of the area have been made. In addition to the present study, they are as follows:

a. In 1953-54, the University of Miami Marine Laboratory made a study for the Corps of Engineers. The Laboratory collected data on salinities and turbidities in relation to discharge, analyzed fish catch statistics, and collected statements from local citizens. No biological samples were taken. It was concluded that:

(1) Rapid salinity changes could cause exodus of saliniphilous fishes and could cause death of animals unable to migrate.

(2) There was no serious reduction in commercial fishing.

(3) Sports fishing is seriously harmed temporarily, but there is no damage to fish stocks.

(4) Sediments are deposited and retransported in the estuary following lake releases.

(5) Salinity changes and sediment deposition are sufficient to cause substantial ecological and fisheries damage.

(6) The only possible means of alleviating damage is to reduce the rate of flow and increase its duration. Detailed ecological investigations--with particular relation to sediment and salinity changes--were recommended.

b. (1) In 1953-54, the Jacksonville District conducted sediment studies. Analyses were made of all hydrographic surveys dating back to 1883. Suspended sediment samples were taken between Port Mayaca and St. Lucie Inlet (the pass between Indian River and the Atlantic Ocean). Secchi disk observations of turbidity were made between Lake Okeechobee and St. Lucie Inlet. The Corps made chemical and mineral analyses of water flowing through the canal and made studies of the material in the water that would be flocculated upon mixing with sea water. Studies were also made of the soils along the banks of the canal.

(2) (a) It was found that large quantities of very fine organic material were suspended in the lake water--giving it a dark, turbid appearance. That turbid water replaces portions of the salt water in the estuary. Most of the suspended material is carried into the ocean. That turbid water is objectionable to the people in the area. Under high-flow conditions, there is rather uniform turbidity between Lake Okeechobee and Stuart. Turbid conditions clear rapidly when canal discharge is discontinued, unless there is heavy runoff from the North Fork.

(b) Sand material in St. Lucie Canal comes from bank caving, only a minor part of which gets below the secondary spillways. The principal shoaling area in the South Fork is just south of Palm City bridge. That shoal increased by 1,183,000 cubic yards between 1932 and 1954. Dredging is required at intervals to maintain navigable depths. Major sedimentation in St. Lucie Canal does not occur below the Palm City area. Some shoaling and turbidity are caused by drainage through the North Fork. The Lake Okeechobee discharge water contains about 0.8 parts per million of total nitrogen. Based on this figure, St. Lucie Estuary was fertilized with over 2,000 tons of nutrient material from the canal discharge in 1958.

c. During Fiscal Year 1957, the United States Fish and Wildlife Service investigated the effects on fishes and wildlife of proposed drainage canals into the North Fork. Basic biological data were not presented, but it was estimated that damage to the North Fork by increased frequency of higher discharges would be $46,000 a year, based on estimated fisherman-use of that area.

d. The Fish and Wildlife Service also made a biological study of the estuary during Fiscal Year 1958. That report has not been submitted.

e. At the request of the Central and Southern Florida Flood Control District, the State Board of Conservation--through its marine laboratory--began investigating the effects of all project discharges in St. Lucie Estuary in 1957. A preliminary report submitted to the Flood Control District in October 1957 contained numerous conclusions as to expected damages, but no basic biological data.

30. a. The present investigation was begun in January 1957 and was terminated in January 1959. The chief aim was to sample the population of fishes in all three branches of St. Lucie Estuary as well as it could be done by trawls and by small seines on shore. This method does not sample the larger fishes very well, but it is generally good for the small fishes and invertebrates. This matter is of particular importance because of local contentions that the small fishes were killed by the fresh water and because bays and estuaries are primarily nursery grounds (Cf. Gunter 1945, page 119). Seven trawl stations and six seine stations were set up at localities described in the text. Bottom and surface temperatures and salinities were determined at each trawl station, and one salinity and one temperature were taken at the shallow shore stations. Each station was visited roughly every 3 months and a complete round of all stations was made 10 times during the 2-year period. Thus, the data give some information on seasonal changes.

b. Five of these biological surveys of the area were made during times of no discharge; five were made during periods of discharge; and three were made during very heavy discharges. One of the surveys was made following one of the most extreme cold spells the region has experienced since the Weather Bureau records were started in south Florida.

c. In the course of this study, 68 trawl hauls and 103 seine hauls were made. All animals caught were identified and measured, except in certain instances when there were hundreds of small fishes with a size range of only a few millimeters. In such cases, only the maximum and minimum sizes were determined. Organisms which could not be identified in the field were preserved and studied more carefully at the Gulf Coast Research Laboratory. Secchi disk determinations of turbidity were made at each station. Air temperatures were also taken at each station and they were supplemented by the study of maximum and minimum daily air temperatures at Stuart.

31. Eighty-three species of fishes and 24,783 specimens were taken. Sixty-four of those species were marine, and the total number of marine specimens was 24,151. Nineteen species of fresh-water fishes and 632 specimens were taken. Although the salinity of the water at various stations was often very low, and in or near the fresh-water range, the predominance of marine fishes was overwhelming. The 13 species which were taken more than 100 times each made up 95.2 percent of the total catch and the remaining 70 species made up only 4.8 percent of the catch. The white catfish and the black crappie were the only fresh-water fishes taken more than 100 times.

b. Five species--the striped mullet, menhaden, croaker, salt-water silverside, and the bay anchovy--were taken more than 1,000 times each. They made up 89 percent of the catch. Those fish are all forage fishes and they are extremely important to the biological economy of the area. Small mullet alone made up almost 50 percent of the catch. Those fishes regularly grow up in estuarine areas at low salinities, and their condition is evidently enhanced by the release of fresh water into the estuary. This is shown by the fact that the greatest number of specimens was taken in January and February 1958 when the releases through the lock were at 7,380 and 4,000 cubic feet a second respectively. During these two surveys, 14,016 fishes were taken--considerably more than half of the total.

c. The greatest numbers of species taken during any one survey (40) were taken in January 1958. At that time, there was no particular diminution in the number of marine species, but an increased number of fresh-water fishes was taken. During November 1957, only 269 fishes were taken. During October 1958, only 562 were taken. The locks were closed at those times. In January 1959, when the locks were closed, 1,408 fish were taken--a decrease of more than 78 percent from the previous year when the locks were open. This figure is due largely to the diminution of the numbers of the five forage fishes mentioned above.

d. Many large snook were taken in the trawls when the water was extremely turbid. Sand perch, croakers, spot, and white trout were also taken in the trawls and they did not leave the area when the salinities were low. The pompano and the small snappers were absent from the low-salinity water.

e. Fishes which live in estuaries are capable of standing quite large variations in salinity, especially towards the lower side, and the general population of fishes in St. Lucie Estuary is very similar to that of other areas. Their condition seems to be generally enhanced by moderately low salinities and they are not produced in great numbers when the salinity is high, as in a salt-water lagoon. Thus, their numbers increased when there was a flow of water through St. Lucie Lock.

f. Table 21 indicates that the greatest numbers of mullet, menhaden and croakers, silversides, and anchovies were taken when the salinity of the water was less than 0.5 o/oo. In fact, the numbers of those species taken at that salinity--which is drinkable water--was almost three-fourths of the total catch of the investigation.

32. Thirty-six species of invertebrates were caught and there were several differences between the invertebrate and the fish catch. Less than 2,000 specimens were taken, if the comb jelly "Mnemiopsis" is discounted. This little jellyfish was extremely abundant at salinities above 13.8 o/oo and often the trawl catch was a mass of jelly, quite indistinguishable so far as numbers are concerned. Aside from that animal, seven species were taken more than 100 times. These, in order of abundance, were the brown shrimp, the pink shrimp, the cloverleaf jellyfish, the blue crab, a small clam, *Mulinia*, the ornate crab, and *Nassarius*, a marine snail. One hundred and fourteen specimens of that snail were taken. Four hundred and ninety-one brown shrimp and 224 pink shrimp were taken. There were 186 blue crabs. White shrimp were also found in the estuary, but they are not abundant and only 17 were taken. One species of grass shrimp, a river shrimp--*Macrobrachium*, and one specimen of fresh-water snail were the only fresh-water species taken. They numbered less than 75 specimens. Thus, the

salt-water contingent of the invertebrates greatly outnumbered the fresh-water specimens, similar to the case with the fishes. Most of those animals were smaller. The blue crab, the brown shrimp, and the pink shrimp are the only animals of commercial importance. The first two were taken at times below 0.22 o/oo salt. This is fresh water and below the salinity of hard fresh water. It is a well known fact that these two species raise in estuarine water of low salinity, as off the Louisiana coast, and it is obvious that the influx of fresh water does them no damage. The salinity ranges at which the most important invertebrates were taken are given in table 26.

33. Salinity maps of the area (plates 11 through 19) show that there is a wedge of salt water in the lower part of the main estuary above about 25.0 o/oo at all times except during the very highest discharges from St. Lucie Lock and Dam--such as occurred in January and February 1958. This means that even the most saliniphilous species of fishes can find a refuge to their liking in the lower estuary during all but the most extreme discharges. It would suggest that they might even be concentrated there.

34. Data furnished by the Fish and Wildlife Service on commercial fishing in the estuary from January to June 1958 (table 28) reveal that more commercial fishes were taken at what was said to be salinity zero than at salinities of 5.0 o/oo. The only species more abundant at the higher salinities were trout, marine catfish, tripletail, and jacks. The only fish not taken in the lower salinities were tripletail and jacks. This verifies the information gathered by trawling and the observations on cold-killed fishes observed in the estuary following high discharges. It also verifies the previous conclusions of the University of Miami group.

35. The cold kill of many large fishes--tenpounders, sandperch, tarpon, and others--noted in the estuary in February 1958 followed the lowest recorded average weekly air temperature at Stuart. These fishes are predominantly of tropical distribution. Numbers of croakers, spot, pigfish, and gobies--fishes of temperate distribution--were taken alive in the trawls at the same time.

36. Numbers of bank fishermen at St. Lucie Lock and Dam increased from 1,800 in 1955 to 15,774 in 1958. Fishing from boats increased commensurately, but exact counts are not available. This fishery is largely for snook, mullet, and fresh-water catfish. An estimated 46,000 pounds of fish were taken by those fishermen in 1958. Table 30 indicates that the catch was highest during discharge periods and shortly thereafter, but declined in November and December when there was no outflow.

37. The outflow of water through St. Lucie Lock and Dam does not damage commercial fishing. It causes turbid conditions which clear up quickly when the flows are stopped. A few high-salinity species are pushed into the lower estuary and--at times of the heaviest discharge--into Indian River or the ocean. No fishes are killed by fresh water and, to the contrary, the reproduction of common estuarine forms is enhanced.

These produce forage fishes which serve as food for other larger fishes, and the total production and fertility of the area are increased by outflows of fresh water. Fishing from the St. Lucie Lock and Dam area and possibly from the bridge in the main estuary is benefited by low to moderate fresh-water outflow and this compensates in part, if not altogether, for the migration of certain saliniphilous species. A great many of the common sports fishes do not leave the area even when the salinities are quite low. This study produced no evidence as to whether they bite less during such periods.

38. St. Lucie Estuary is characterized as an area of high production of a wide variety of sport and food fishes, a condition which has developed and been enhanced by periodic discharges of fresh water and nutrient materials. From the overall and long-range viewpoint, moderate flows of fresh water through St. Lucie Lock and Dam (2,500 to 3,500 c.f.s., or thereabout), especially during certain periods of the year, would continue to benefit the fisheries of St. Lucie Estuary.

J. RESULTS AND APPLICATION OF FINDINGS TO OPERATIONS

39. General proposals.--Based on the results of findings in these biological investigations and consideration of other factors, the following operations for discharges at St. Lucie Lock and Dam would provide for fishery benefits within the scope of necessary operations for flood control and other purposes.

a. Whenever possible, the lake discharge through St. Lucie Canal should be held below 3,500 cubic feet a second. This proposal is made recognizing that during certain periods, when the lake stage is at a damaging flood level, such a rate of discharge would not permit a rapid-enough removal of water for safe operation. At such times, benefits or decreased losses of fishing time for certain species must give way to consideration of protection of human lives and property. Nevertheless, there would undoubtedly be certain times when a lower rate of discharge over a longer period might be as feasible as the higher rate over a shorter period. At the same time, it is recognized that there might be some advantage to discharging excess waters as rapidly as possible in order to effect a more rapid return of brackish and high salinity conditions in the estuary. All factors considered, however, if lake waters must be released, it is the opinion of the biologists that the least damages to fishing and greatest overall benefits to fishes would be obtained by low rather than high rates of discharge.

b. If no lake releases are necessary through the St. Lucie outlet for two consecutive winters, a controlled discharge of 2,500 cubic feet a second every other year for 6 to 8 weeks beginning on January 1 would permit recently spawned bait fishes--mullet, menhaden, silversides, etc.--and young game and food fishes--croaker, spot, redfish, and trout--

a growth period free from marine predators and assure increased production and survival at least every second year. This low rate would not interfere greatly--if at all--with fishing in the outer estuary and should enhance fishing at the lock during that time and in the estuary shortly thereafter. If excess water is available, such a discharge every winter may provide the best fishery condition on a continuing basis, but the alternate-year winter discharges and continued observations are recommended as the initial step in the development of the most beneficial operation schedule.

c. Discharges between 2,000 and 2,500 cubic feet a second every summer for 2 months beginning on June 1 would improve snook fishing both at the lock and in the inner estuary. There is evidence of improved lock fishing available with such outflows. It has also been observed that with fresh-water conditions available in the open, inner estuary, snook tend to be more abundant in the open water; otherwise, with higher salinities they probably tend to stay back in the mangrove areas where they are more difficult to catch. There was improvement in snook fishing on Palm City bridge and more snook were taken in nets and trawls in early summer months when fresh-water conditions prevailed.

40. Discussion of regulation schedules.--Examination of both the interim and future recommended regulation schedules for Lake Okeechobee indicates that some of the above observations and proposals could be implemented by slight modifications of portions of those schedules. The two schedules are shown on plates 8 and 24 and summarized as follows:

a. Interim regulation schedule (plate 8).--Used prior to 1958 for regulation of lake levels between elevations 12.5 and 15.5 feet.

b. Recommended regulation schedule (plate 24).--For use after lake levees are raised and the Caloosahatchee outlet improved, at which time the lake levels will be regulated between elevations 15.5 and 17.5 feet.

41. Both regulation schedules are divided into three zones, as follows, based on lake stages, wet and dry seasons, and the necessity for discharge at different times of the year according to experiences over long periods of record.

Zone A.--Lake stages are well above a safe level or even at damaging levels and all available outlets must be used to lower the lake as soon as possible to decrease flood damages. Modification of the schedule in this zone to lower the rate of discharge so as to lessen fishery damages is not possible.

Zone B.--Lake stages are somewhat above a safe level in advance of the forthcoming wet and hurricane seasons; to prevent possible damaging stages, the lake must be lowered to definite safe levels. However, the stages are not critical and some choice of outlets is available. Minor modifications of the schedule in this zone for fishery benefit appear possible without interference with regulation for other project purposes.

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a growth period free from marine predators and assure increased production and survival at least every second year. This low rate would not interfere greatly--if at all--with fishing in the outer estuary and should enhance fishing at the lock during that time and in the estuary shortly thereafter. If excess water is available, such a discharge every winter may provide the best fishery condition on a continuing basis, but the alternate-year winter discharges and continued observations are recommended as the initial step in the development of the most beneficial operation schedule.

c. Discharges between 2,000 and 2,500 cubic feet a second every summer for 2 months beginning on June 1 would improve snook fishing both at the lock and in the inner estuary. There is evidence of improved lock fishing available with such outflows. It has also been observed that with fresh-water conditions available in the open, inner estuary, snook tend to be more abundant in the open water; otherwise, with higher salinities they probably tend to stay back in the mangrove areas where they are more difficult to catch. There was improvement in snook fishing on Palm City bridge and more snook were taken in nets and trawls in early summer months when fresh-water conditions prevailed.

40. Application of findings.--The following modifications to interim and future regulation schedules are suggested to provide additional benefits for fisheries in the estuaries.

a. When excess water is available in Lake Okeechobee and forecasts indicate the lake can be maintained near the desired elevation without making releases at the full capacity of all outlets, releases through St. Lucie Dam should be held below 3,500 c.f.s.

b. When the lake is near the top of the conservation pool and forecasts indicate water supplies are adequate, releases of about 2,500 c.f.s. should be made through St. Lucie Canal in January and February and June to August.

c. Should a Red Tide outbreak occur along the gulf coast, it is considered that all necessary lake discharges during that period should, if possible, be released to St. Lucie Estuary rather than through Caloosahatchee River. After more than 3 years of investigation of Red Tide, Federal and State researchers have failed to establish evidence that drainage from Caloosahatchee River is any more of a contributor to Red Tide outbreaks than other streams and watersheds of the gulf coast. Nevertheless, it is known that the organism blooms are in some way connected with fresh-water drainage. Therefore, minimum

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Zone C.--Lake stages are below normal and no excess water is available for discharge through St. Lucie Lock and Dam for fishery benefits.

42. Application of findings.--Inasmuch as modifications of the regulation schedules in Zone A (lower rates to minimize lost fishing time) and Zone C (small releases for fishery benefit) are not feasible within the authorized project, recommendations of operation for fishery purposes are confined to Zone B of the Lake Okeechobee regulation shedules as follows:

a. While operating in Zone B under both the interim and future regulation schedules it is considered from the biological data that a discharge of 2,500 cubic feet a second in January and February and June to August through St. Lucie Canal and 2,500 cubic feet a second less out Caloosahatchee River would be more beneficial to fisheries than the reverse condition as presently proposed, which is up to 4,500 cubic feet a second out of Caloosahatchee River and none out St. Lucie Canal (plate 24).

b. Should a Red Tide outbreak occur along the gulf coast, it is considered that all necessary lake discharges during that period should, if possible, be released to St. Lucie Estuary rather than through Caloosahatchee River. After more than 3 years of investigation of Red Tide, Federal and State researchers have failed to establish evidence that drainage from Caloosahatchee River is any more of a contributor to Red Tide outbreaks than other streams and watersheds of the gulf coast. Nevertheless, it is known that the organism blooms are in some way connected with fresh-water drainage. Therefore, minimum fresh-water discharges to the gulf via Caloosahatchee River during outbreak periods would tend to avoid undue publicity in that regard. Outbreaks generally occur in some, not all, wet years between June and November.

No change

K. RECOMMENDATIONS

43. On the basis of the biological investigation and the data presented in this report it is recommended to the District Engineer, Jacksonville District, that consideration be given to regulation of Lake Okeechobee Zone B discharges through St. Lucie Lock and Dam as described in paragraph 42 above, which, in essence, would require the following changes in operations:

When available in January and February and June to August, 2,500 of the 4,500 cubic feet a second presently scheduled to be discharged down Caloosahatchee River would be released through St. Lucie Lock and Dam. The recommended Zone B lake regulation schedule by months is shown in the following table. Slight modification of the St. Lucie Lock and Dam operations for such purposes was recognized by the Jacksonville District during preparation of the approved future recommended lake regulation schedule (plate 24) and denoted by asterisk therein. This investigation and report have served to identify more exactly the periods when such operations would be of greatest benefit. It is further recommended that such measures be considered for use in the interim regulation schedule.

This portion added in revision

fresh-water discharges to the gulf via Caloosahatchee River during outbreak periods would tend to avoid undue publicity in that regard. Outbreaks generally occur in some, not all, wet years between June and November.

GORDON GUNTER
Biological Consultant

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Zone	Period	Discharge	
		St. Lucie Canal	Caloosahatchee River
A		No change	No change
B	Dec. and March	Zero	Up to 4,500 c.f.s.
	Jan. and Feb.	Up to 2,500 c.f.s. in alternate years	Up to 4,500 c.f.s.
	April, May, Sept., Oct., and Nov.	Up to 3,500 c.f.s.*	Up to 4,500 c.f.s.*
B	June, July, and Aug.	Up to 2,500 c.f.s.*	Up to 4,500 c.f.s.*
C		No change	No change

NOTE: *From July through November, when a Red Tide outbreak occurs on the gulf coast the necessary Zone B lake discharge should be made through St. Lucie Canal rather than through Caloosahatchee River, if possible.

/s/ GORDON GUNTER
Biological Consultant

(A 12-22-60)

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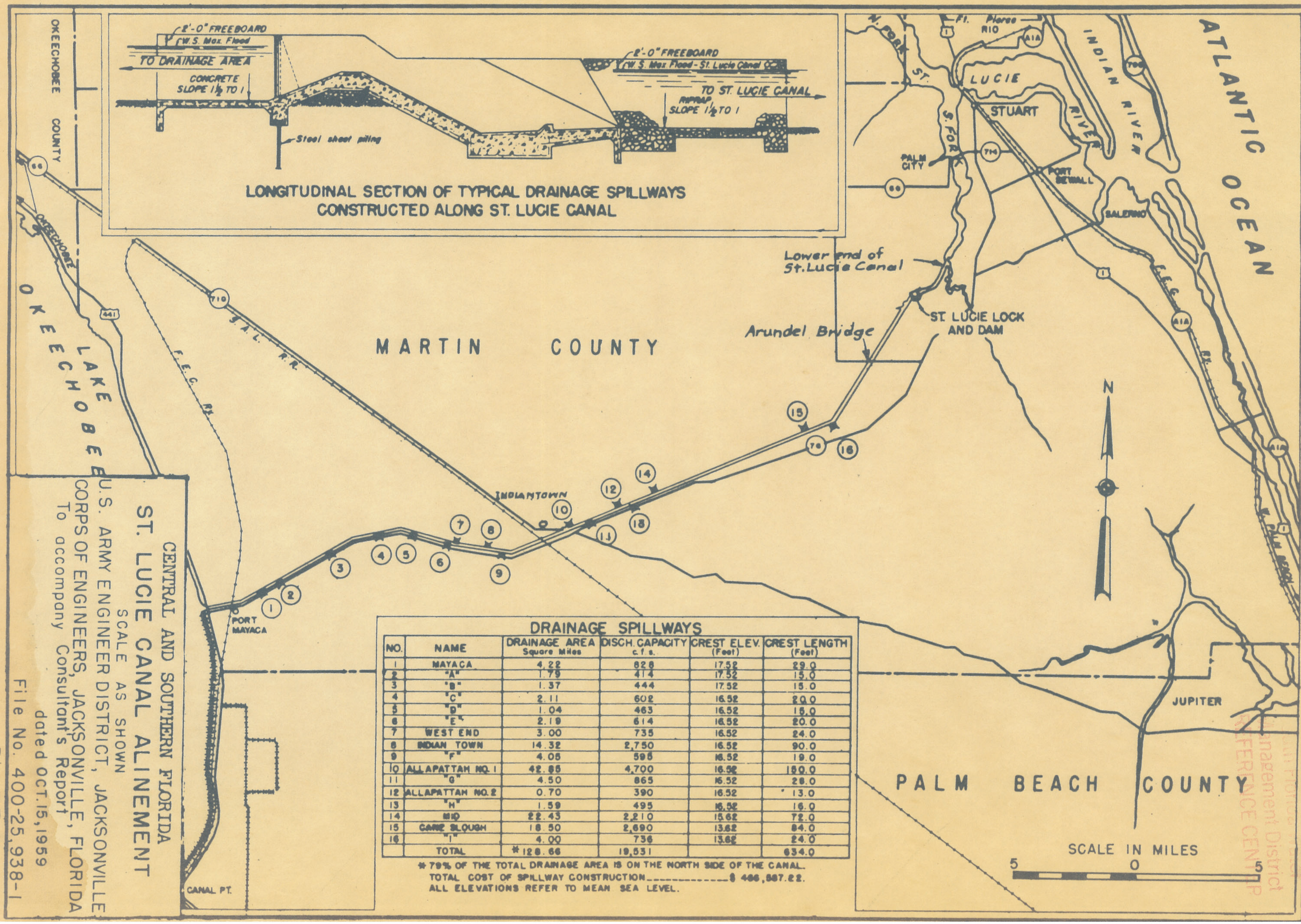

DRAINAGE SPILLWAYS

NO.	NAME	DRAINAGE AREA Square Miles	DISCH. CAPACITY c.f.s.	CREST ELEV. (Feet)	CREST LENGTH (Feet)
1	MAYACA	4.22	828	17.52	29.0
2	"A"	1.79	414	17.52	15.0
3	"B"	1.37	444	17.52	15.0
4	"C"	2.11	602	16.52	20.0
5	"D"	1.04	463	16.52	15.0
6	"E"	2.19	614	16.52	20.0
7	WEST END	3.00	735	16.52	24.0
8	INDIAN TOWN	14.32	2,750	16.52	90.0
9	"F"	4.05	595	16.52	19.0
10	ALLAPATTAH NO. 1	42.85	4,700	16.52	180.0
11	"G"	4.50	865	16.52	28.0
12	ALLAPATTAH NO. 2	0.70	390	16.52	13.0
13	"H"	1.59	495	16.52	16.0
14	MID	22.43	2,210	15.62	72.0
15	CANE SLOUGH	18.50	2,690	13.62	84.0
16	"I"	4.00	736	13.62	24.0
	TOTAL	*128.66	19,531		634.0

* 79% OF THE TOTAL DRAINAGE AREA IS ON THE NORTH SIDE OF THE CANAL.
TOTAL COST OF SPILLWAY CONSTRUCTION .... $ 466,887.22.
ALL ELEVATIONS REFER TO MEAN SEA LEVEL.

CENTRAL AND SOUTHERN FLORIDA
ST. LUCIE CANAL ALINEMENT
SCALE AS SHOWN
U.S. ARMY ENGINEER DISTRICT, JACKSONVILLE
CORPS OF ENGINEERS, JACKSONVILLE, FLORIDA
To accompany Consultant's Report
dated OCT. 15, 1959
File No. 400-25,938-1

PLATE 1

a growth period free from marine predators and assure increased production and survival at least every second year. This low rate would not interfere greatly--if at all--with fishing in the outer estuary and should enhance fishing at the lock during that time and in the estuary shortly thereafter. If excess water is available, such a discharge every winter may provide the best fishery condition on a continuing basis, but the alternate-year winter discharges and continued observations are recommended as the initial step in the development of the most beneficial operation schedule.

c. Discharges between 2,000 and 2,500 cubic feet a second every summer for 2 months beginning on June 1 would improve snook fishing both at the lock and in the inner estuary. There is evidence of improved lock fishing available with such outflows. It has also been observed that with fresh-water conditions available in the open, inner estuary, snook tend to be more abundant in the open water; otherwise, with higher salinities they probably tend to stay back in the mangrove areas where they are more difficult to catch. There was improvement in snook fishing on Palm City bridge and more snook were taken in nets and trawls in early summer months when fresh-water conditions prevailed.

40. Discussion of regulation schedules.--Examination of both the interim and future recommended regulation schedules for Lake Okeechobee indicates that some of the above observations and proposals could be implemented by slight modifications of portions of those schedules. The two schedules are shown on plates 8 and 24 and summarized as follows:

a. Interim regulation schedule (plate 8).--Used prior to 1958 for regulation of lake levels between elevations 12.5 and 15.5 feet.

b. Recommended regulation schedule (plate 24).--For use after lake levees are raised and the Caloosahatchee outlet improved, at which time the lake levels will be regulated between elevations 15.5 and 17.5 feet.

41. Both regulation schedules are divided into three zones, as follows, based on lake stages, wet and dry seasons, and the necessity for discharge at different times of the year according to experiences over long periods of record.

Zone A.--Lake stages are well above a safe level or even at damaging levels and all available outlets must be used to lower the lake as soon as possible to decrease flood damages. Modification of the schedule in this zone to lower the rate of discharge so as to lessen fishery damages is not possible.

Zone B.--Lake stages are somewhat above a safe level in advance of the forthcoming wet and hurricane seasons; to prevent possible damaging stages, the lake must be lowered to definite safe levels. However, the stages are not critical and some choice of outlets is available. Minor modifications of the schedule in this zone for fishery benefit appear possible without interference with regulation for other project purposes.

This portion added in revision

a growth period free from marine predators and assure increased production and survival at least every second year. This low rate would not interfere greatly--if at all--with fishing in the outer estuary and should enhance fishing at the lock during that time and in the estuary shortly thereafter. If excess water is available, such a discharge every winter may provide the best fishery condition on a continuing basis, but the alternate-year winter discharges and continued observations are recommended as the initial step in the development of the most beneficial operation schedule.

c. Discharges between 2,000 and 2,500 cubic feet a second every summer for 2 months beginning on June 1 would improve snook fishing both at the lock and in the inner estuary. There is evidence of improved lock fishing available with such outflows. It has also been observed that with fresh-water conditions available in the open, inner estuary, snook tend to be more abundant in the open water; otherwise, with higher salinities they probably tend to stay back in the mangrove areas where they are more difficult to catch. There was improvement in snook fishing on Palm City bridge and more snook were taken in nets and trawls in early summer months when fresh-water conditions prevailed.

40. Application of findings.--The following modifications to interim and future regulation schedules are suggested to provide additional benefits for fisheries in the estuaries.

a. When excess water is available in Lake Okeechobee and forecasts indicate the lake can be maintained near the desired elevation without making releases at the full capacity of all outlets, releases through St. Lucie Dam should be held below 3,500 c.f.s.

b. When the lake is near the top of the conservation pool and forecasts indicate water supplies are adequate, releases of about 2,500 c.f.s. should be made through St. Lucie Canal in January and February and June to August.

c. Should a Red Tide outbreak occur along the gulf coast, it is considered that all necessary lake discharges during that period should, if possible, be released to St. Lucie Estuary rather than through Caloosahatchee River. After more than 3 years of investigation of Red Tide, Federal and State researchers have failed to establish evidence that drainage from Caloosahatchee River is any more of a contributor to Red Tide outbreaks than other streams and watersheds of the gulf coast. Nevertheless, it is known that the organism blooms are in some way connected with fresh-water drainage. Therefore, minimum

VOID SEE REVISED SHEET

VOID SEE REVISED SHEET

VOID SEE REVISED SHEET

Zone C.--Lake stages are below normal and no excess water is available for discharge through St. Lucie Lock and Dam for fishery benefits.

42. Application of findings.--Inasmuch as modifications of the regulation schedules in Zone A (lower rates to minimize lost fishing time) and Zone C (small releases for fishery benefit) are not feasible within the authorized project, recommendations of operation for fishery purposes are confined to Zone B of the Lake Okeechobee regulation shedules as follows:

a. While operating in Zone B under both the interim and future regulation schedules it is considered from the biological data that a discharge of 2,500 cubic feet a second in January and February and June to August through St. Lucie Canal and 2,500 cubic feet a second less out Caloosahatchee River would be more beneficial to fisheries than the reverse condition as presently proposed, which is up to 4,500 cubic feet a second out of Caloosahatchee River and none out St. Lucie Canal (plate 24).

b. Should a Red Tide outbreak occur along the gulf coast, it is considered that all necessary lake discharges during that period should, if possible, be released to St. Lucie Estuary rather than through Caloosahatchee River. After more than 3 years of investigation of Red Tide, Federal and State researchers have failed to establish evidence that drainage from Caloosahatchee River is any more of a contributor to Red Tide outbreaks than other streams and watersheds of the gulf coast. Nevertheless, it is known that the organism blooms are in some way connected with fresh-water drainage. Therefore, minimum fresh-water discharges to the gulf via Caloosahatchee River during outbreak periods would tend to avoid undue publicity in that regard. Outbreaks generally occur in some, not all, wet years between June and November.

No change.

K. RECOMMENDATIONS

43. On the basis of the biological investigation and the data presented in this report it is recommended to the District Engineer, Jacksonville District, that consideration be given to regulation of Lake Okeechobee Zone B discharges through St. Lucie Lock and Dam as described in paragraph 42 above, which, in essence, would require the following changes in operations:

When available in January and February and June to August, 2,500 of the 4,500 cubic feet a second presently scheduled to be discharged down Caloosahatchee River would be released through St. Lucie Lock and Dam. The recommended Zone B lake regulation schedule by months is shown in the following table. Slight modification of the St. Lucie Lock and Dam operations for such purposes was recognized by the Jacksonville District during preparation of the approved future recommended lake regulation schedule (plate 24) and denoted by asterisk therein. This investigation and report have served to identify more exactly the periods when such operations would be of greatest benefit. It is further recommended that such measures be considered for use in the interim regulation schedule.

This portion added in revision

Also, next

fresh-water discharges to the gulf via Caloosahatchee River during outbreak periods would tend to avoid undue publicity in that regard. Outbreaks generally occur in some, not all, wet years between June and November.

GORDON GUNTER
Biological Consultant

VOID
SEE REVISED SHEET

VOID
SEE REVISED SHEET

VOID
SEE REVISED SHEET

Zone	Period	Discharge	
		St. Lucie Canal	Caloosahatchee River
A		No change	No change
B	Dec. and March	Zero	Up to 4,500 c.f.s.
	Jan. and Feb.	Up to 2,500 c.f.s. in alternate years	Up to 4,500 c.f.s.
	April, May, Sept., Oct., and Nov.	Up to 3,500 c.f.s.*	Up to 4,500 c.f.s.*
B	June, July, and Aug.	Up to 2,500 c.f.s.*	Up to 4,500 c.f.s.*
C		No change	No change

NOTE: *From July through November, when a Red Tide outbreak occurs on the gulf coast the necessary Zone B lake discharge should be made through St. Lucie Canal rather than through Caloosahatchee River, if possible.

/s/ GORDON GUNTER
Biological Consultant

(A 12-22-60)

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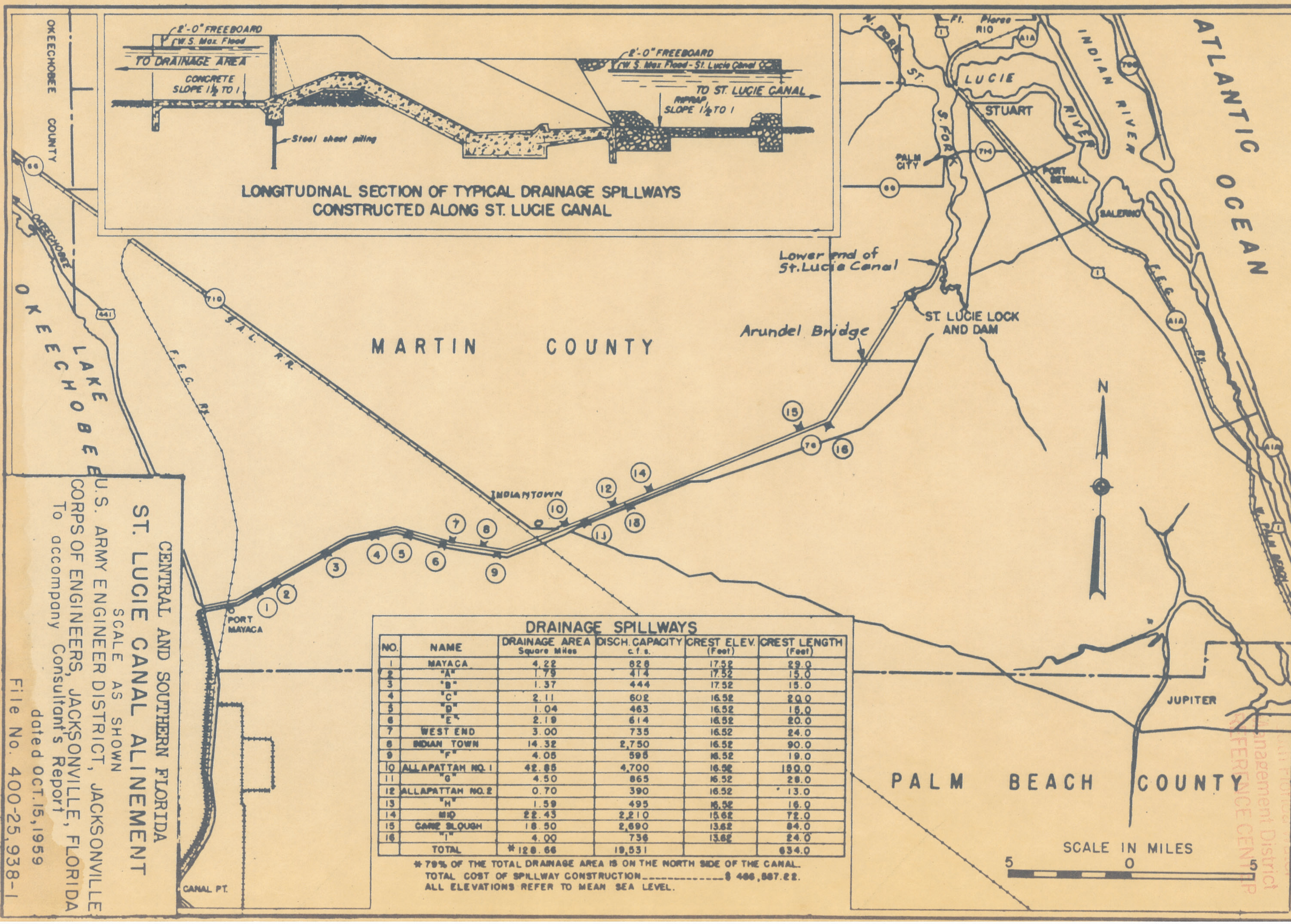
CORPS OF ENGINEERS U.S. ARMY



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NO.	NAME	DRAINAGE AREA Square Miles	DISCH. CAPACITY c.f.s.	CREST ELEV. (Feet)	CREST LENGTH (Feet)
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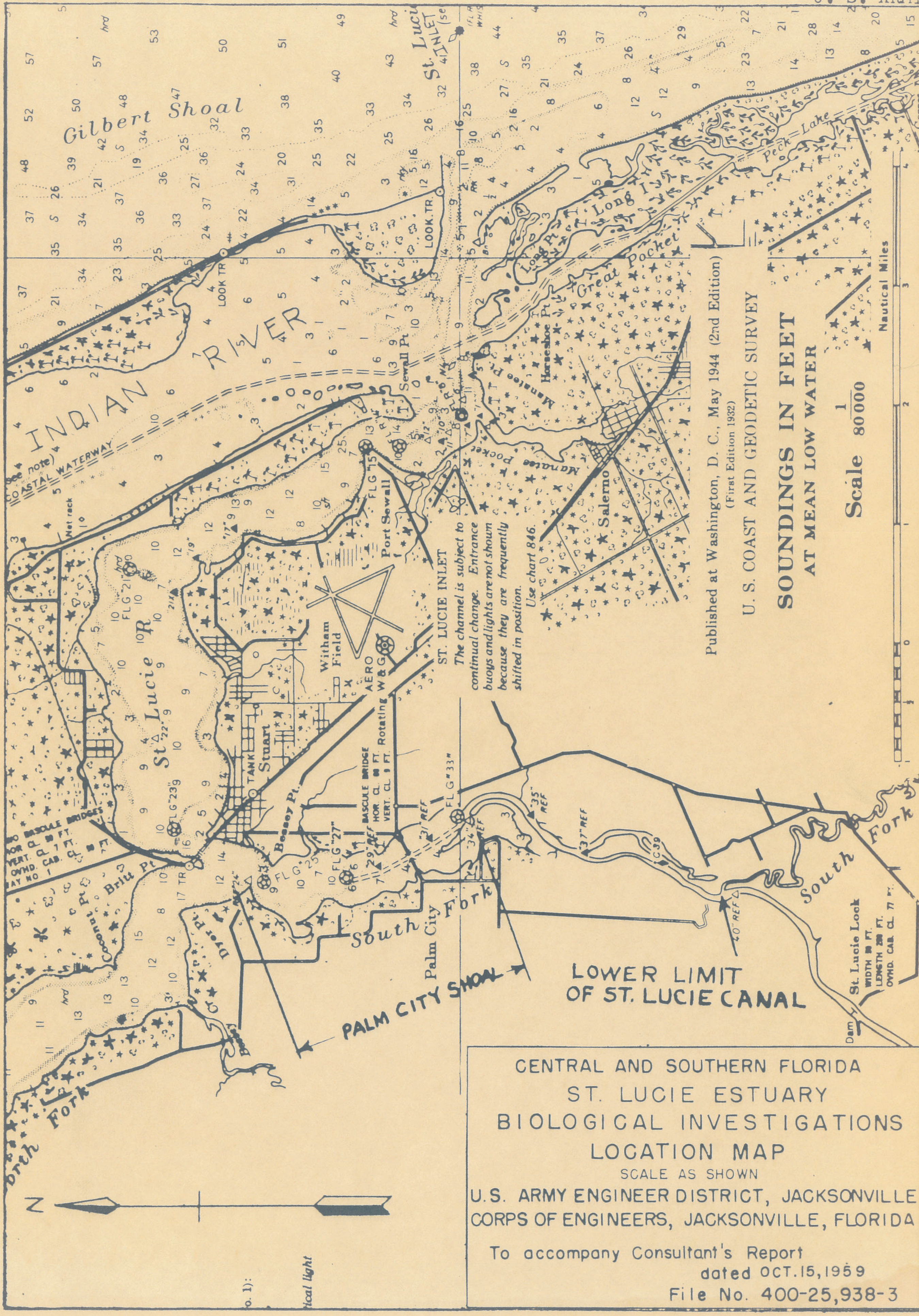
ALL ELEVATIONS REFER TO MEAN SEA LEVEL.

CENTRAL AND SOUTHERN FLORIDA
ST. LUCIE CANAL ALINEMENT
SCALE AS SHOWN
U.S. ARMY ENGINEER DISTRICT, JACKSONVILLE
CORPS OF ENGINEERS, JACKSONVILLE, FLORIDA
To accompany Consultant's Report
dated OCT. 15, 1959
File No. 400-25,938-1

PLATE 1

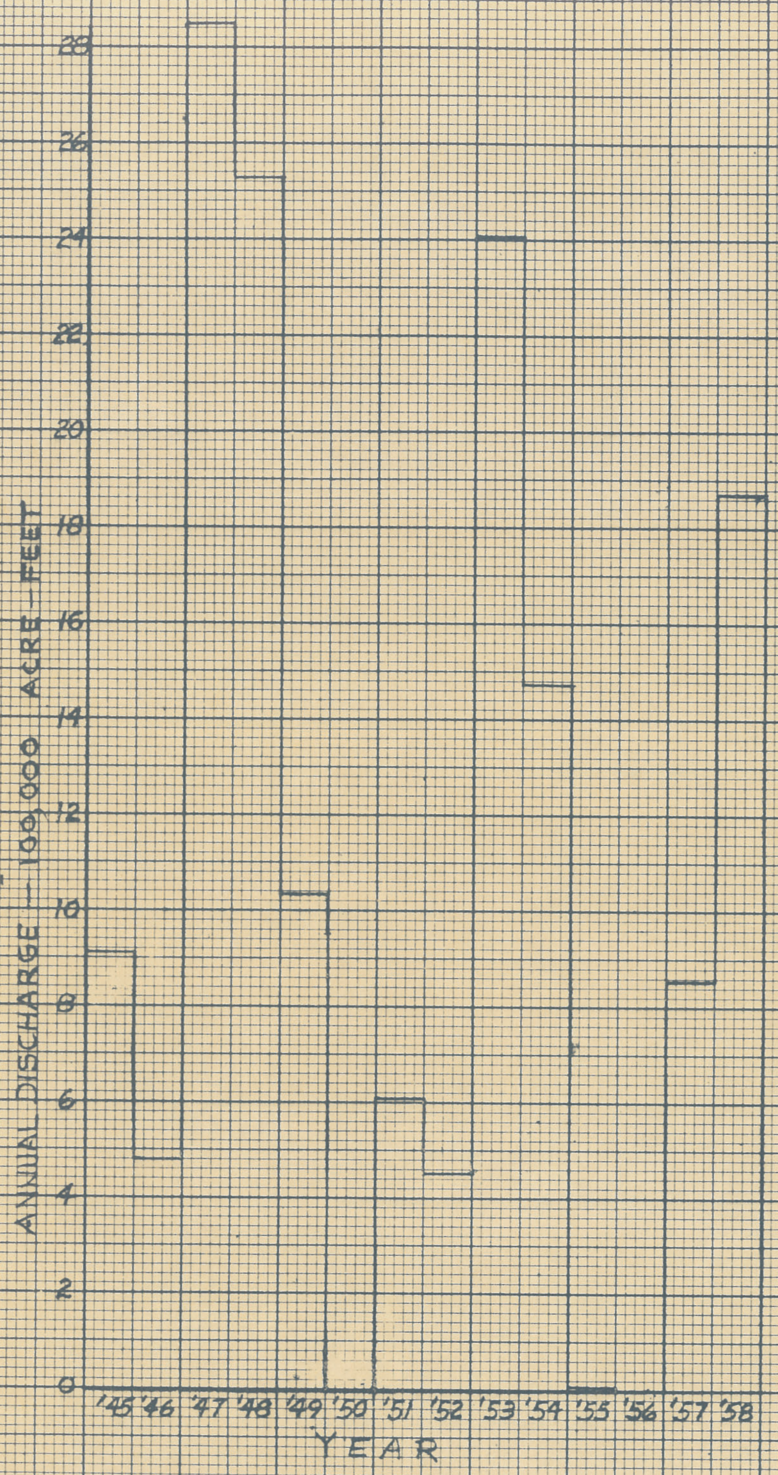
CORPS OF ENGINEERS U. S. ARMY



CENTRAL AND SOUTHERN FLORIDA
ST. LUCIE ESTUARY
BIOLOGICAL INVESTIGATIONS
LOCATION MAP
SCALE AS SHOWN
U.S. ARMY ENGINEER DISTRICT, JACKSONVILLE
CORPS OF ENGINEERS, JACKSONVILLE, FLORIDA

To accompany Consultant's Report
dated OCT. 15, 1959
File No. 400-25,938-3

PLATE 3



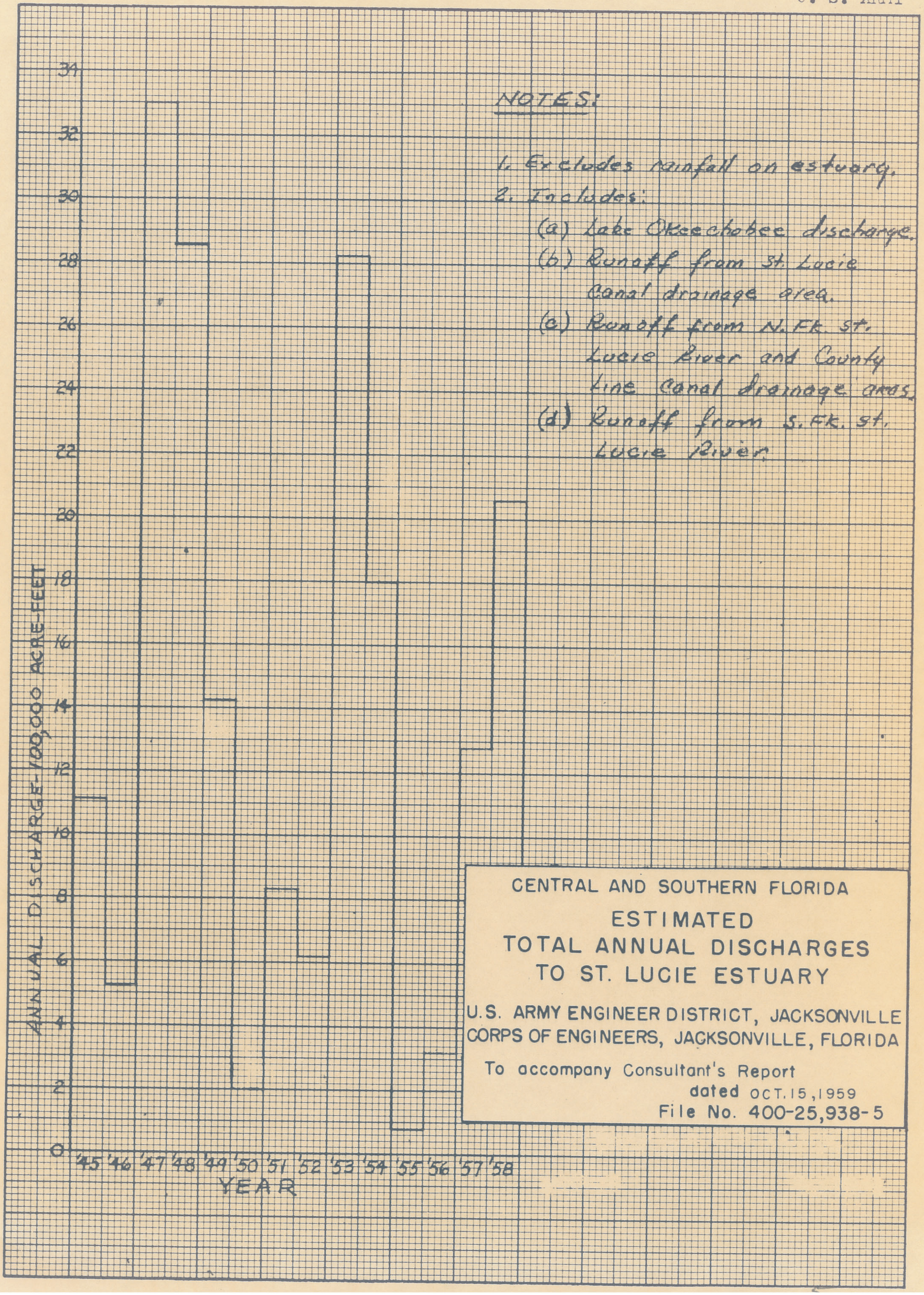
CENTRAL AND SOUTHERN FLORIDA
ST. LUCIE CANAL AT
ST. LUCIE LOCK AND DAM
(NEAR STUART)
TOTAL ANNUAL DISCHARGES

U.S. ARMY ENGINEER DISTRICT, JACKSONVILLE
CORPS OF ENGINEERS, JACKSONVILLE, FLORIDA

To accompany Consultant's Report
dated OCT. 15, 1959
File No. 400-25,938-4

CORPS OF ENGINEERS

U. S. ARMY

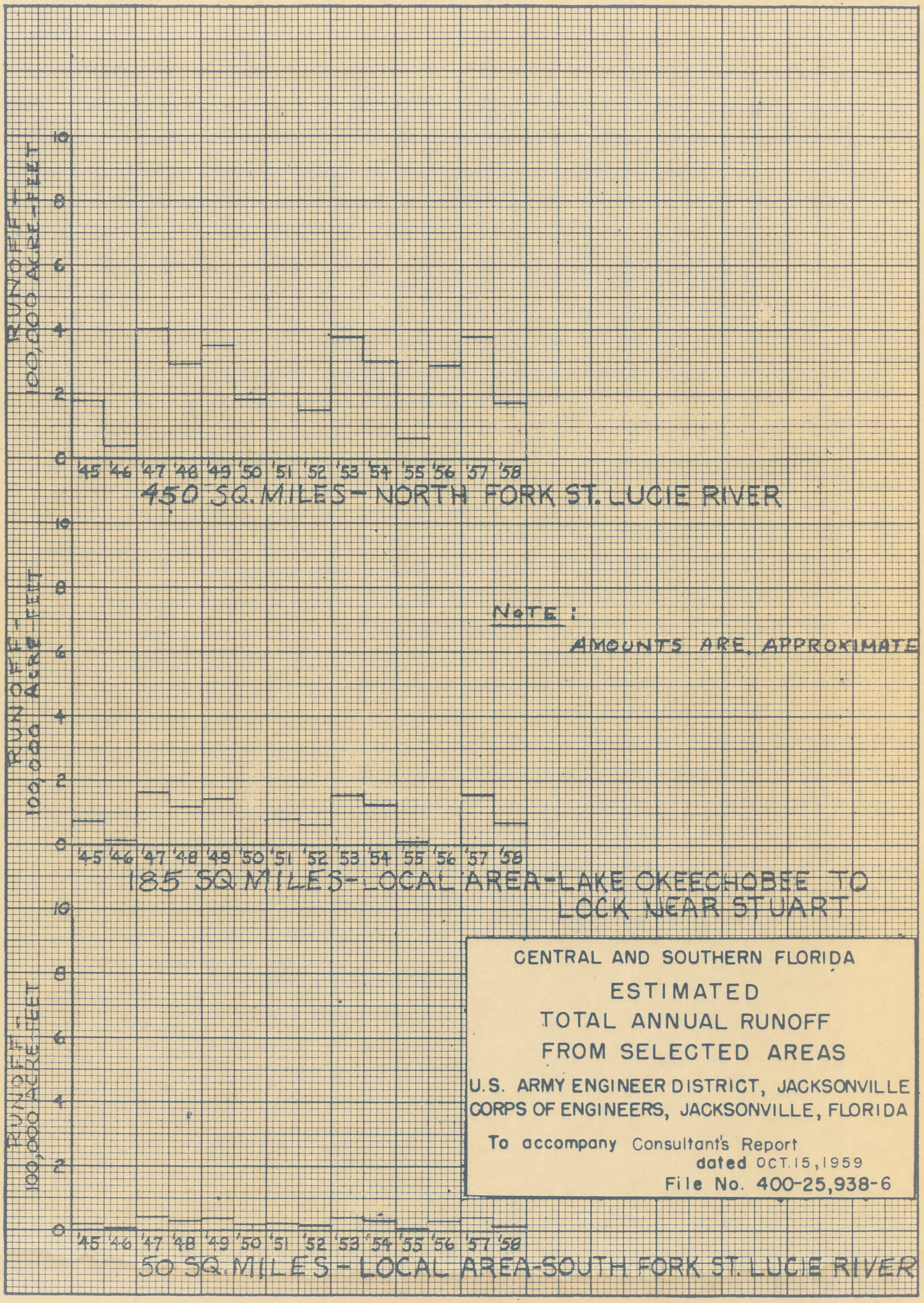


CENTRAL AND SOUTHERN FLORIDA

ESTIMATED
TOTAL ANNUAL DISCHARGES
TO ST. LUCIE ESTUARY

U.S. ARMY ENGINEER DISTRICT, JACKSONVILLE
CORPS OF ENGINEERS, JACKSONVILLE, FLORIDA

To accompany Consultant's Report
dated OCT. 15, 1959
File No. 400-25,938-5

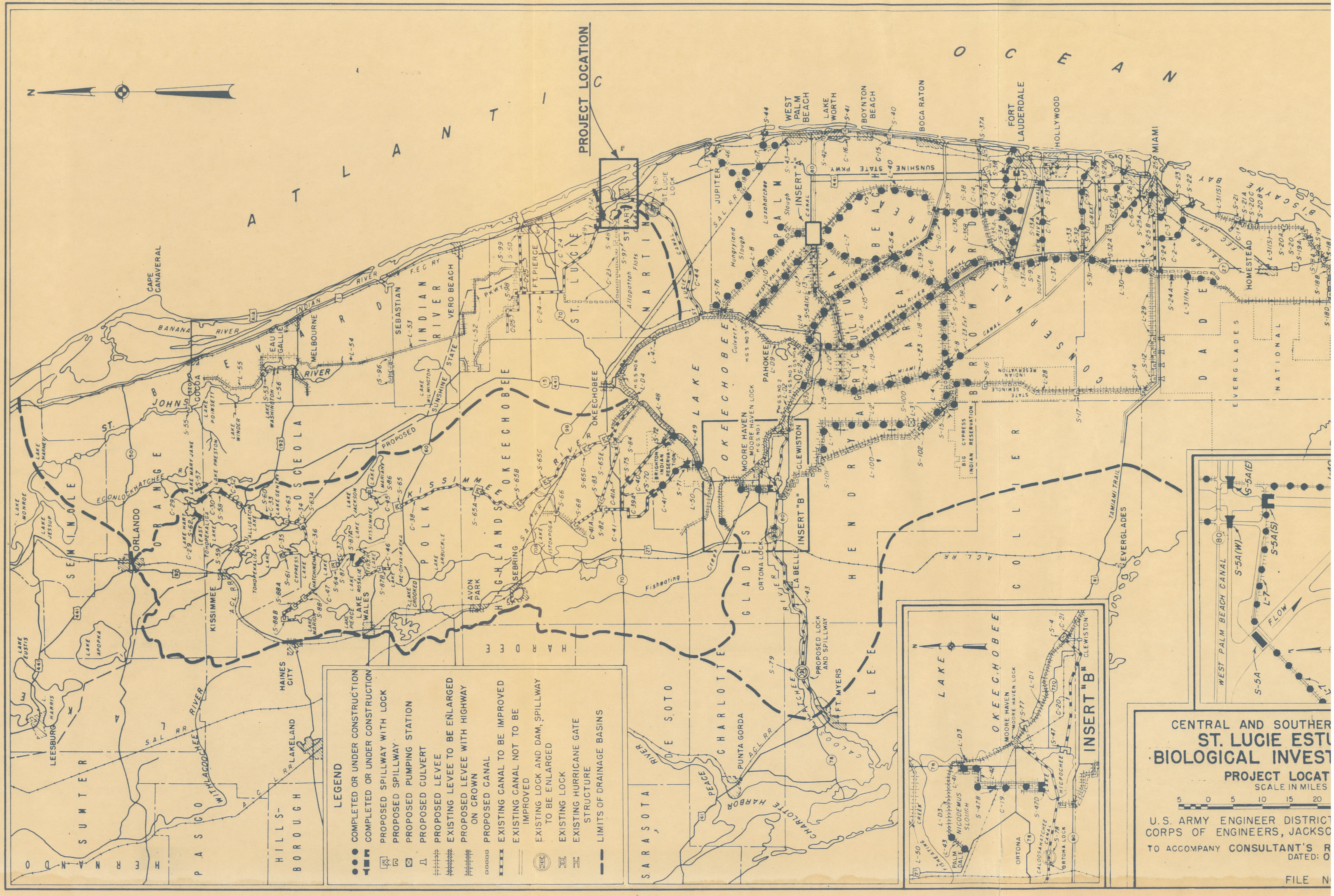


CENTRAL AND SOUTHERN FLORIDA

ESTIMATED
TOTAL ANNUAL RUNOFF
FROM SELECTED AREAS

U.S. ARMY ENGINEER DISTRICT, JACKSONVILLE
CORPS OF ENGINEERS, JACKSONVILLE, FLORIDA

To accompany Consultant's Report
dated OCT. 15, 1959
File No. 400-25,938-6


PROJECT LOCATION
ATLANTIC OCEAN
LEGEND
COMPLETED OR UNDER CONSTRUCTION
COMPLETED OR UNDER CONSTRUCTION
PROPOSED SPILLWAY WITH LOCK
PROPOSED SPILLWAY
PROPOSED PUMPING STATION
PROPOSED CULVERT
PROPOSED LEVEE
EXISTING LEVEE TO BE ENLARGED
PROPOSED LEVEE WITH HIGHWAY ON CROWN
PROPOSED CANAL
EXISTING CANAL TO BE IMPROVED
EXISTING CANAL NOT TO BE IMPROVED
EXISTING LOCK AND DAM, SPILLWAY TO BE ENLARGED
EXISTING LOCK
EXISTING HURRICANE GATE STRUCTURE
LIMITS OF DRAINAGE BASINS
INSERT "B"
CENTRAL AND SOUTHER
ST. LUCIE ESTU
BIOLOGICAL INVEST
PROJECT LOCAT
SCALE IN MILES
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U.S. ARMY ENGINEER DISTRICT
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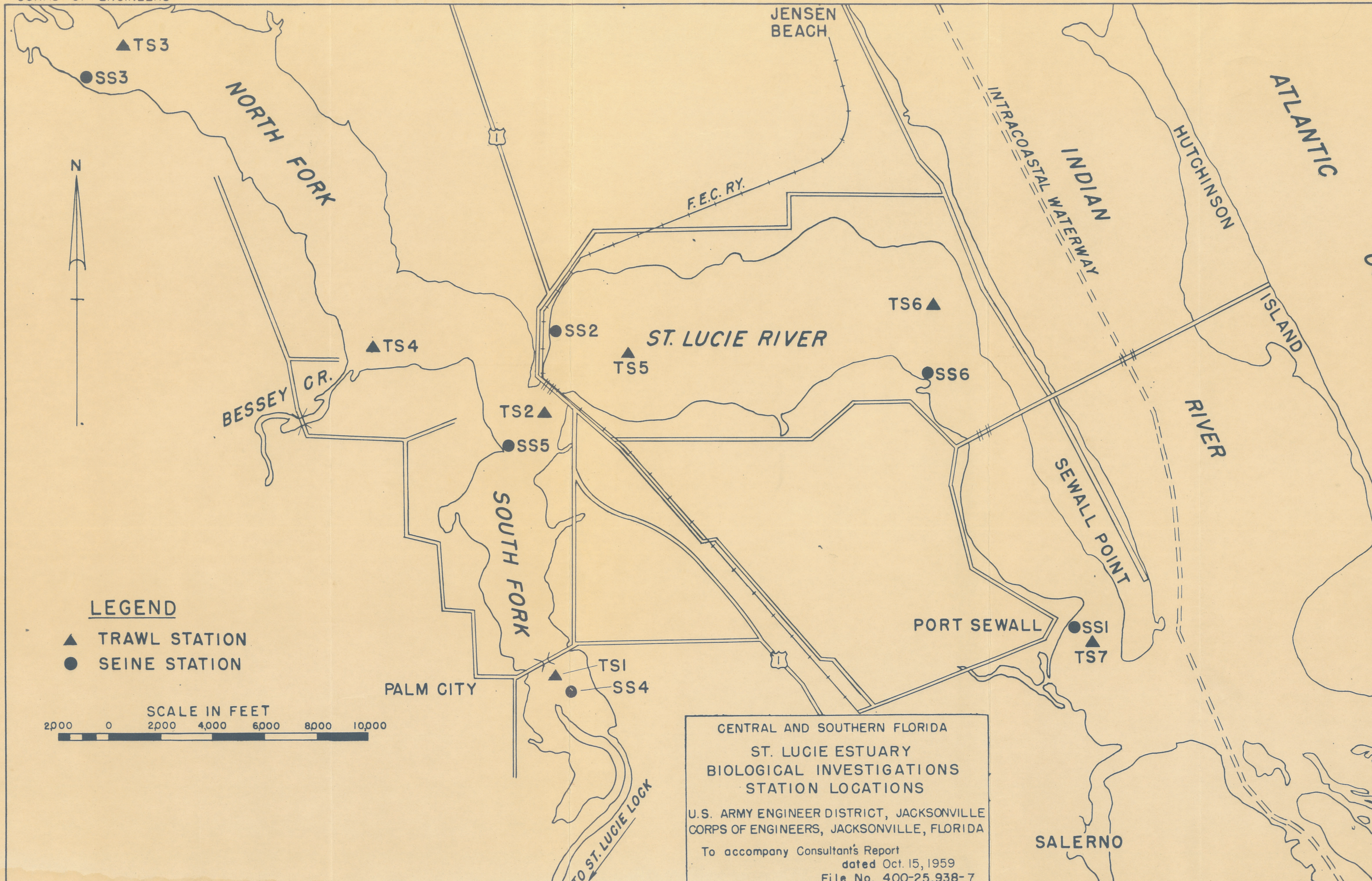
TO ACCOMPANY CONSULTANT'S R
DATED: O
FILE N

CORPS OF ENGINEERS

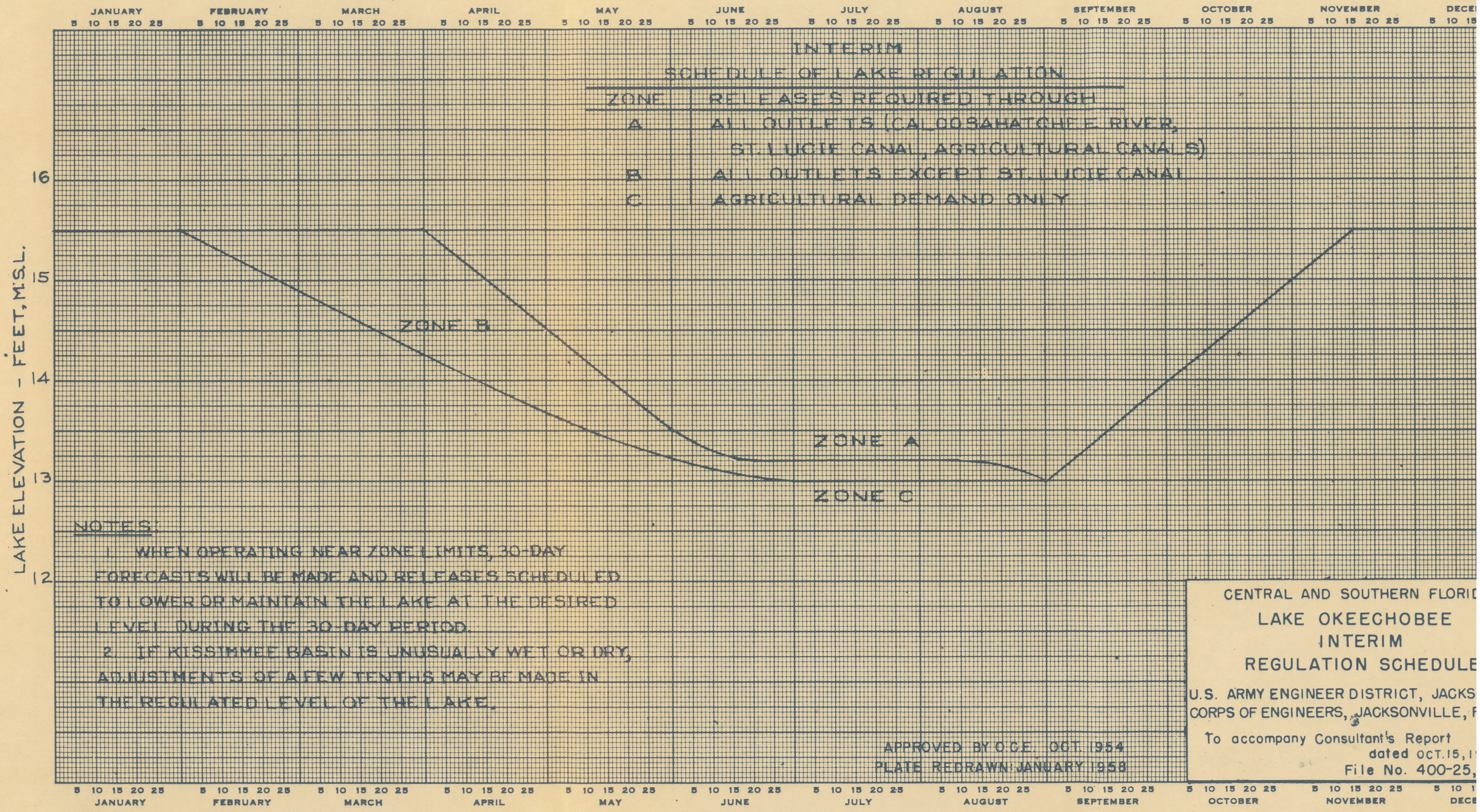


CENTRAL AND SOUTHERN FLORIDA

ST. LUCIE ESTUARY
BIOLOGICAL INVESTIGATIONS
STATION LOCATIONS

U.S. ARMY ENGINEER DISTRICT, JACKSONVILLE
CORPS OF ENGINEERS, JACKSONVILLE, FLORIDA

To accompany Consultant's Report
dated Oct. 15, 1959
File No. 400-25,938-7

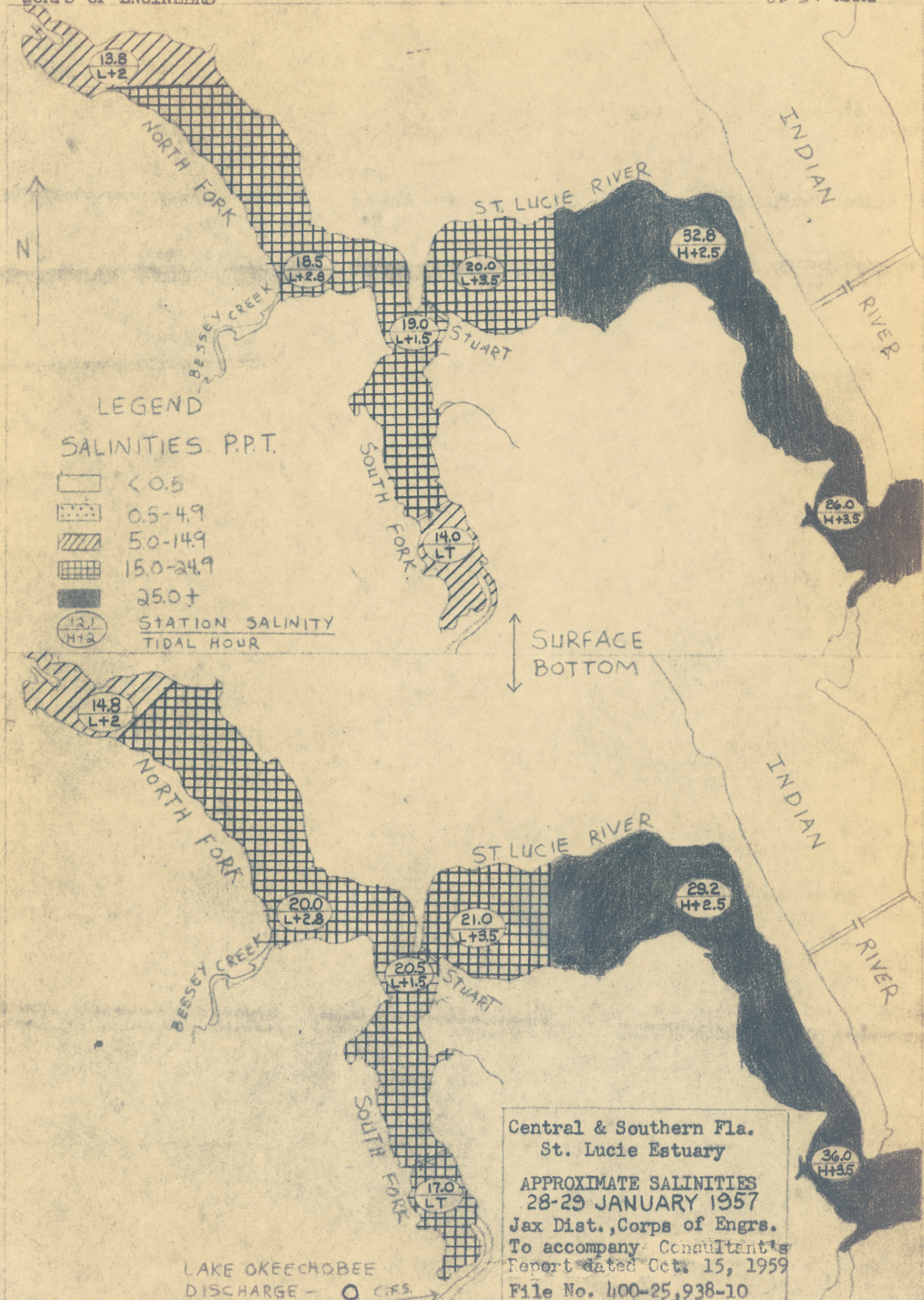

JANUARY FEBRUARY MARCH APRIL MAY JUNE JULY AUGUST SEPTEMBER OCTOBER NOVEMBER DECE
5 10 15 20 25
INTERIM
SCHEDULE OF LAKE REGULATION
ZONE RELEASES REQUIRED THROUGH
A ALL OUTLETS (CALOOSAHATCHEE RIVER, ST. LUCIE CANAL, AGRICULTURAL CANALS)
B ALL OUTLETS EXCEPT ST. LUCIE CANAL
C AGRICULTURAL DEMAND ONLY
LAKE ELEVATION - FEET, M.S.L.
16
15
14
13
12
ZONE B
ZONE A
ZONE C
NOTES:
1. WHEN OPERATING NEAR ZONE LIMITS, 30-DAY FORECASTS WILL BE MADE AND RELEASES SCHEDULED TO LOWER OR MAINTAIN THE LAKE AT THE DESIRED LEVEL DURING THE 30-DAY PERIOD.
2. IF KISSIMMEE BASIN IS UNUSUALLY WET OR DRY, ADJUSTMENTS OF A FEW TENTHS MAY BE MADE IN THE REGULATED LEVEL OF THE LAKE.
APPROVED BY O.C.E. OCT. 1954
PLATE REDRAWN: JANUARY 1958
CENTRAL AND SOUTHERN FLORID
LAKE OKEECHOBEE
INTERIM
REGULATION SCHEDULE
U.S. ARMY ENGINEER DISTRICT, JACKS
CORPS OF ENGINEERS, JACKSONVILLE, F
To accompany Consultant's Report
dated OCT. 15, 1
File No. 400-25,

CENTRAL AND SOUTHERN FLORIDA

ST. LUCIE CANAL AT
ST. LUCIE LOCK AND DAM
DISCHARGES, 1957-58

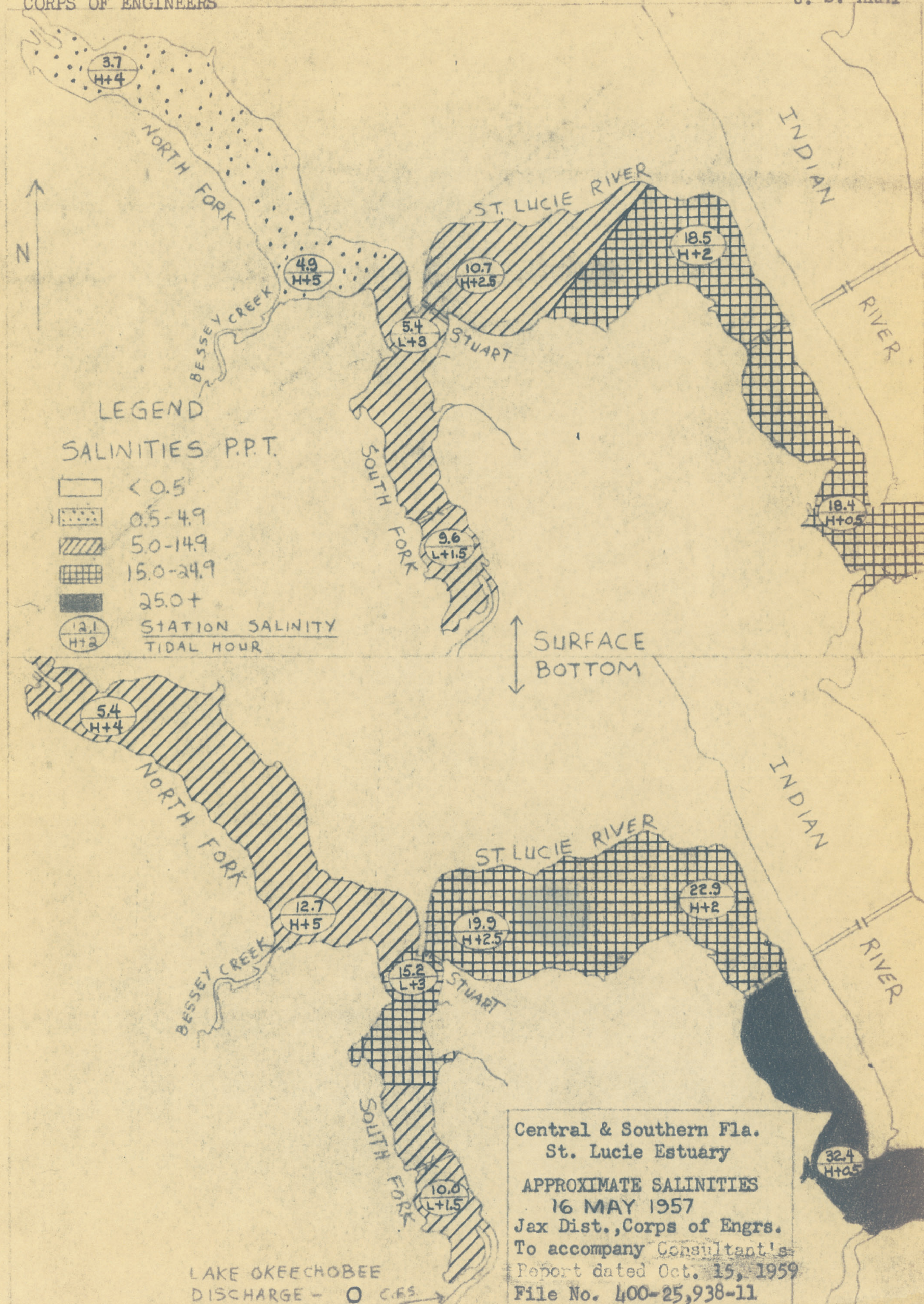
U.S. ARMY ENGINEER DISTRICT, JACKSONVILLE
CORPS OF ENGINEERS, JACKSONVILLE, FLORIDA

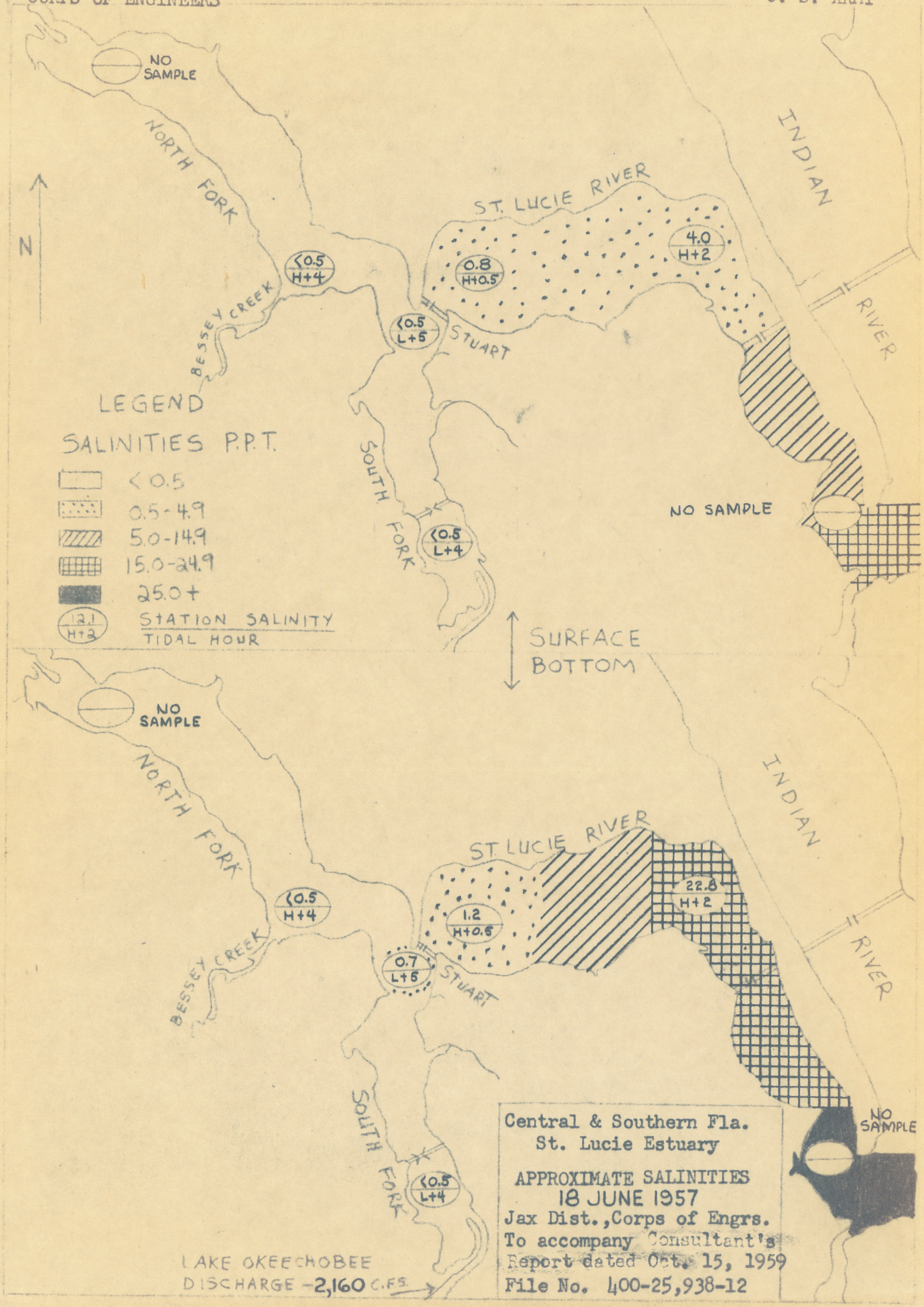
To accompany Consultant's Report
dated OCT. 15, 1959
File No. 400-25,938-9



Central & Southern Fla.
St. Lucie Estuary

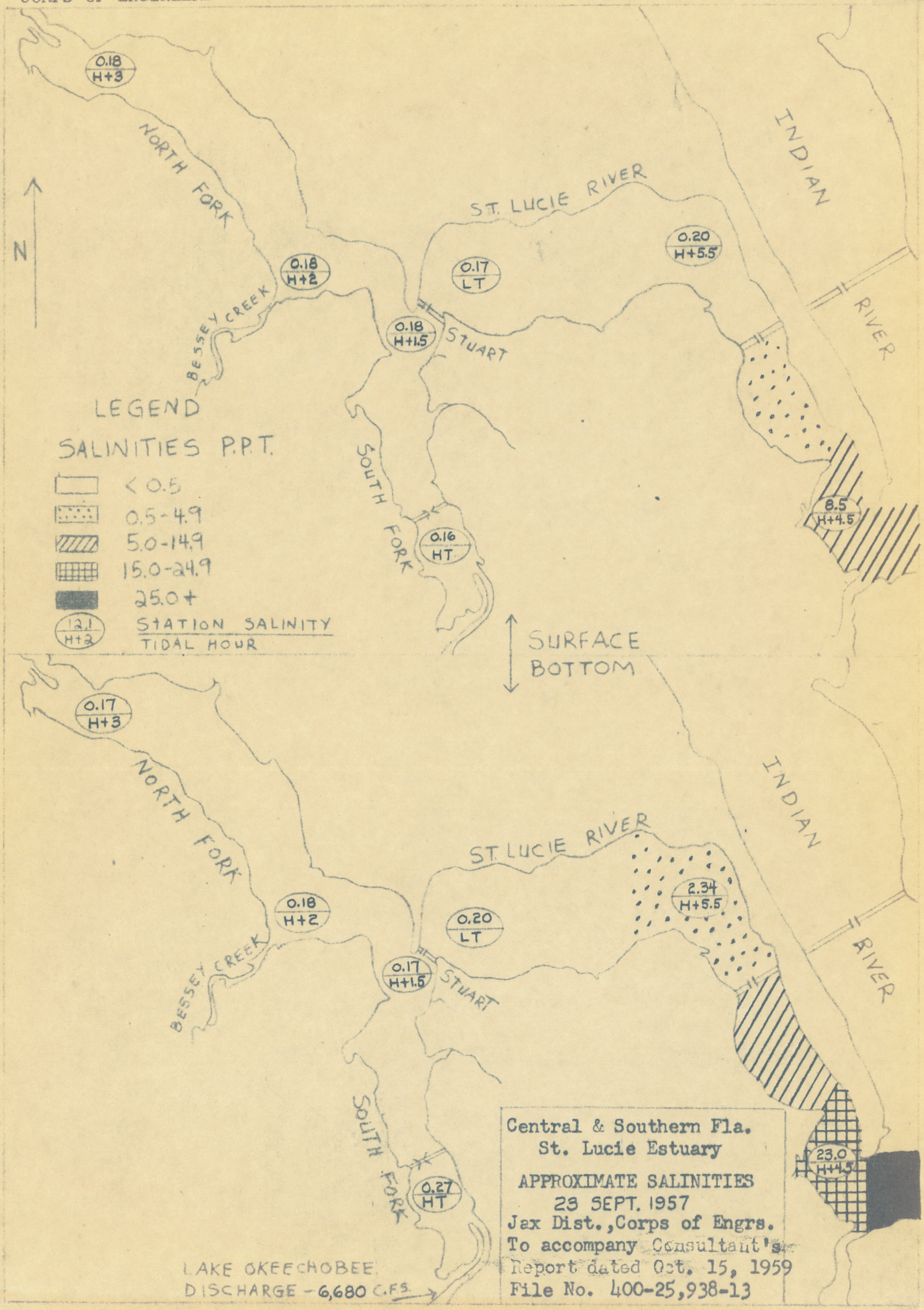
APPROXIMATE SALINITIES
28-29 JANUARY 1957
Jax Dist., Corps of Engrs.
To accompany Consultant's
Report dated Oct. 15, 1959
File No. 400-25,938-10


N
NORTH FORK
3.7
H+4
4.9
H+5
BESSEY CREEK
ST. LUCIE RIVER
10.7
H+2.5
18.5
H+2
INDIAN
RIVER
5.4
L+3
STUART
SOUTH FORK
9.6
L+1.5
18.4
H+0.5
LEGEND
SALINITIES P.P.T.
< 0.5
0.5-4.9
5.0-14.9
15.0-24.9
25.0+
12.1
H+2
STATION SALINITY
TIDAL HOUR
SURFACE
BOTTOM
5.4
H+4
NORTH FORK
12.7
H+5
BESSEY CREEK
ST LUCIE RIVER
19.9
H+2.5
22.9
H+2
INDIAN
RIVER
15.2
L+3
STUART
SOUTH FORK
10.0
L+1.5
32.4
H+0.5
LAKE OKEECHOBEE
DISCHARGE - 0 C.F.S.
Central & Southern Fla.
St. Lucie Estuary
APPROXIMATE SALINITIES
16 MAY 1957
Jax Dist., Corps of Engrs.
To accompany Consultant's
Report dated Oct. 15, 1959
File No. 400-25,938-11



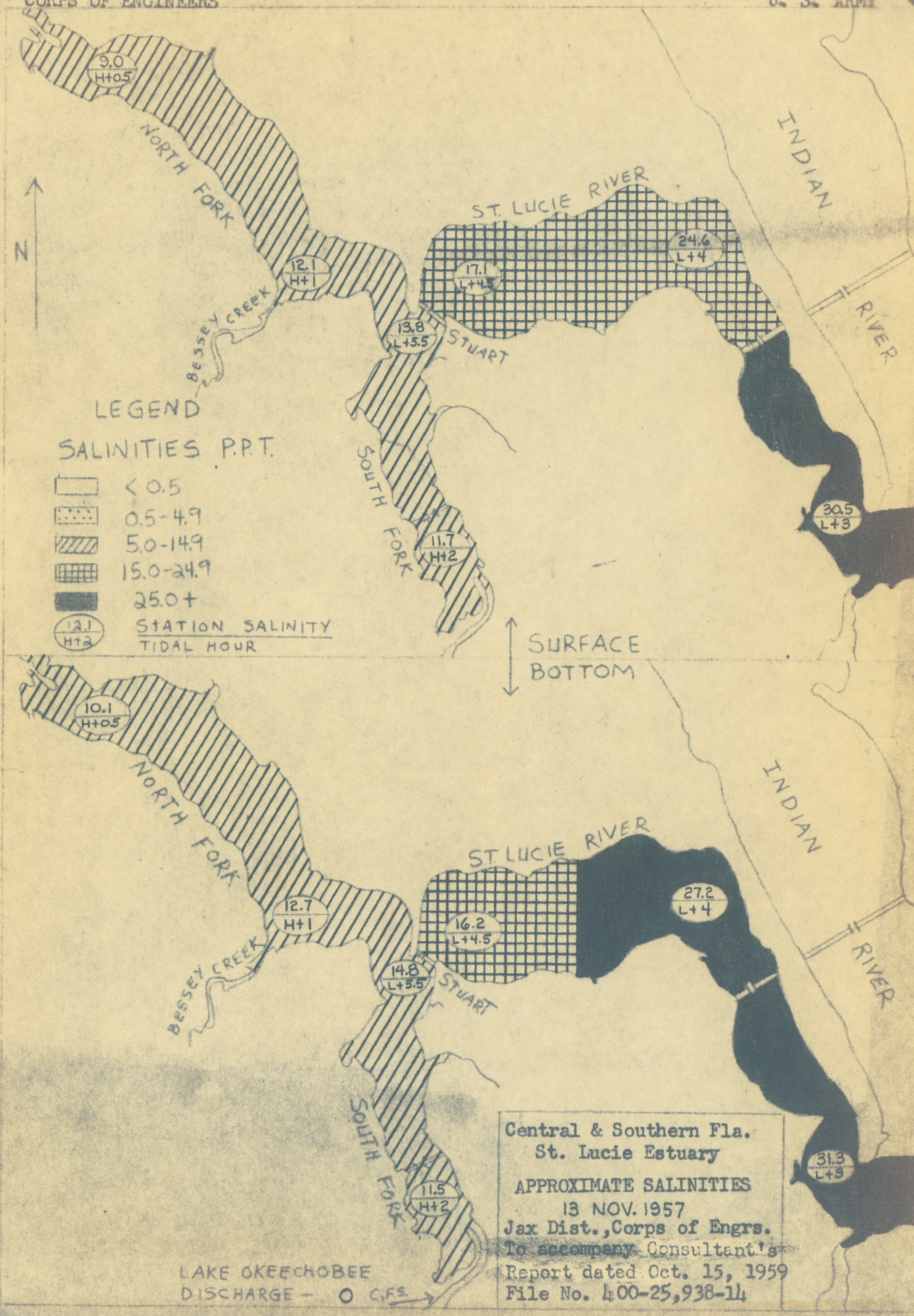
Central & Southern Fla.
St. Lucie Estuary

APPROXIMATE SALINITIES
18 JUNE 1957
Jax Dist., Corps of Engrs.
To accompany Consultant's
Report dated Oct. 15, 1959
File No. 400-25,938-12



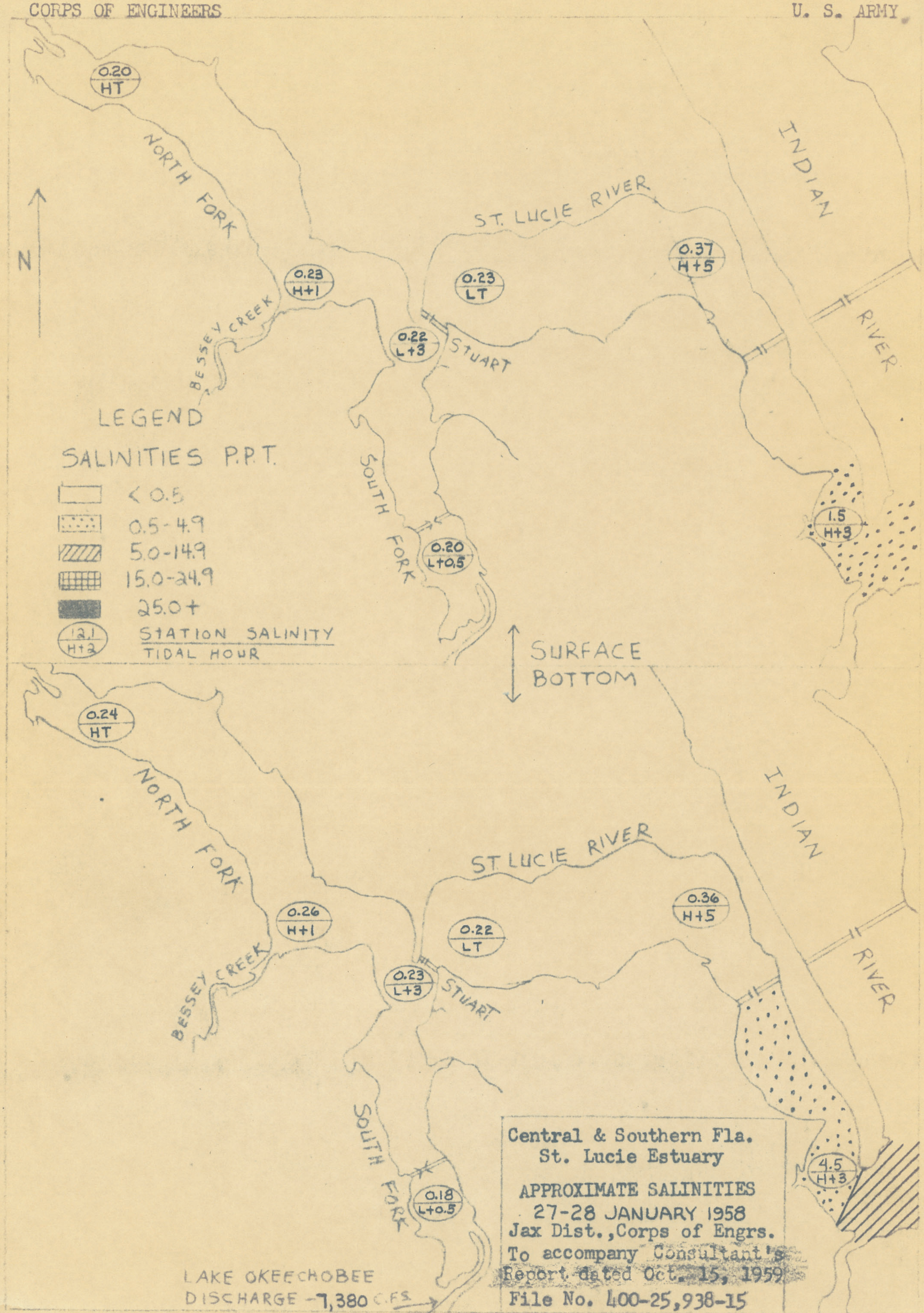
Central & Southern Fla.
St. Lucie Estuary

APPROXIMATE SALINITIES
23 SEPT. 1957
Jax Dist., Corps of Engrs.
To accompany Consultant's
Report dated Oct. 15, 1959
File No. 400-25,938-13



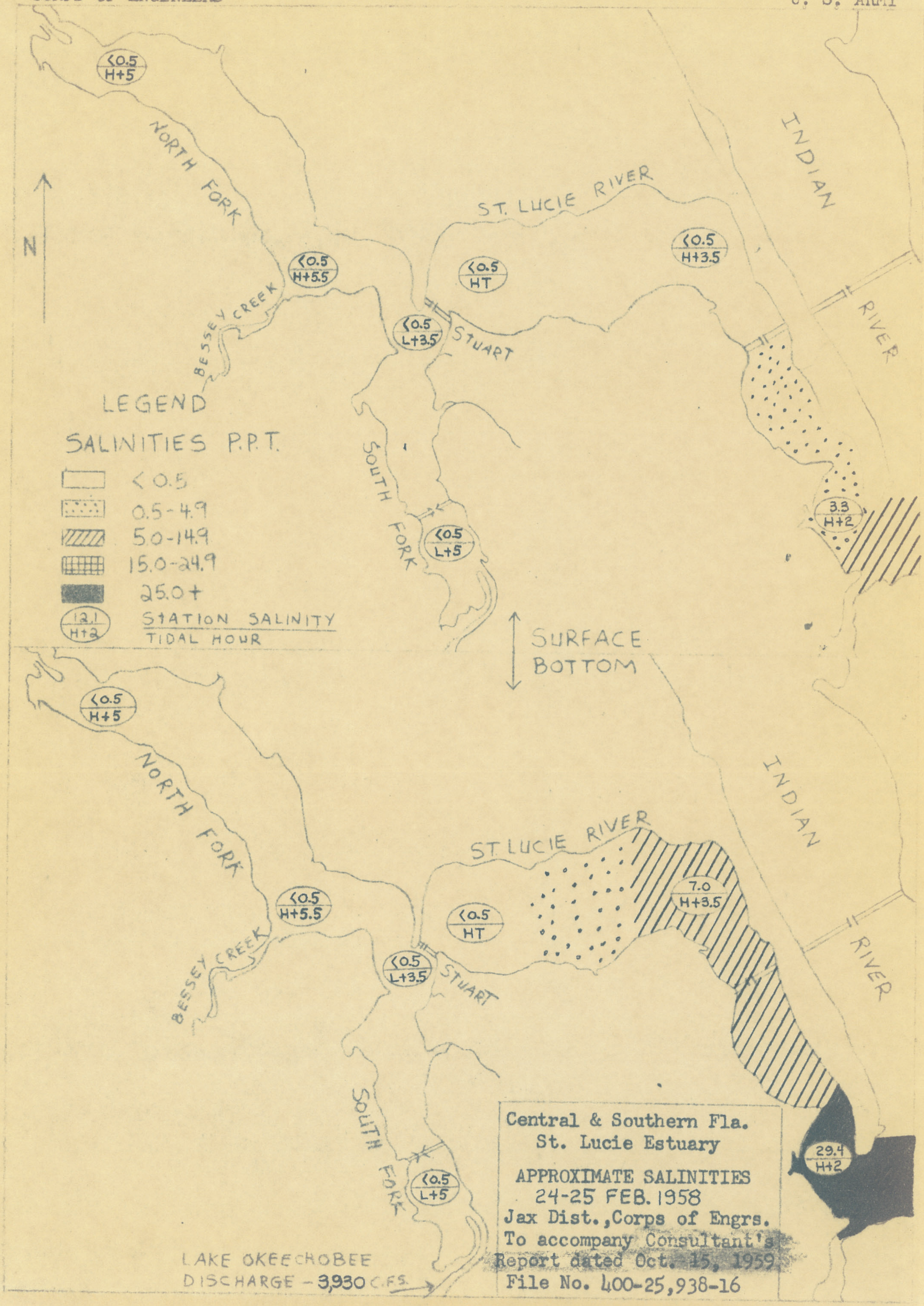
Central & Southern Fla.
St. Lucie Estuary

APPROXIMATE SALINITIES
13 NOV. 1957
Jax Dist., Corps of Engrs.
To accompany Consultant's
Report dated Oct. 15, 1959
File No. 400-25,938-14



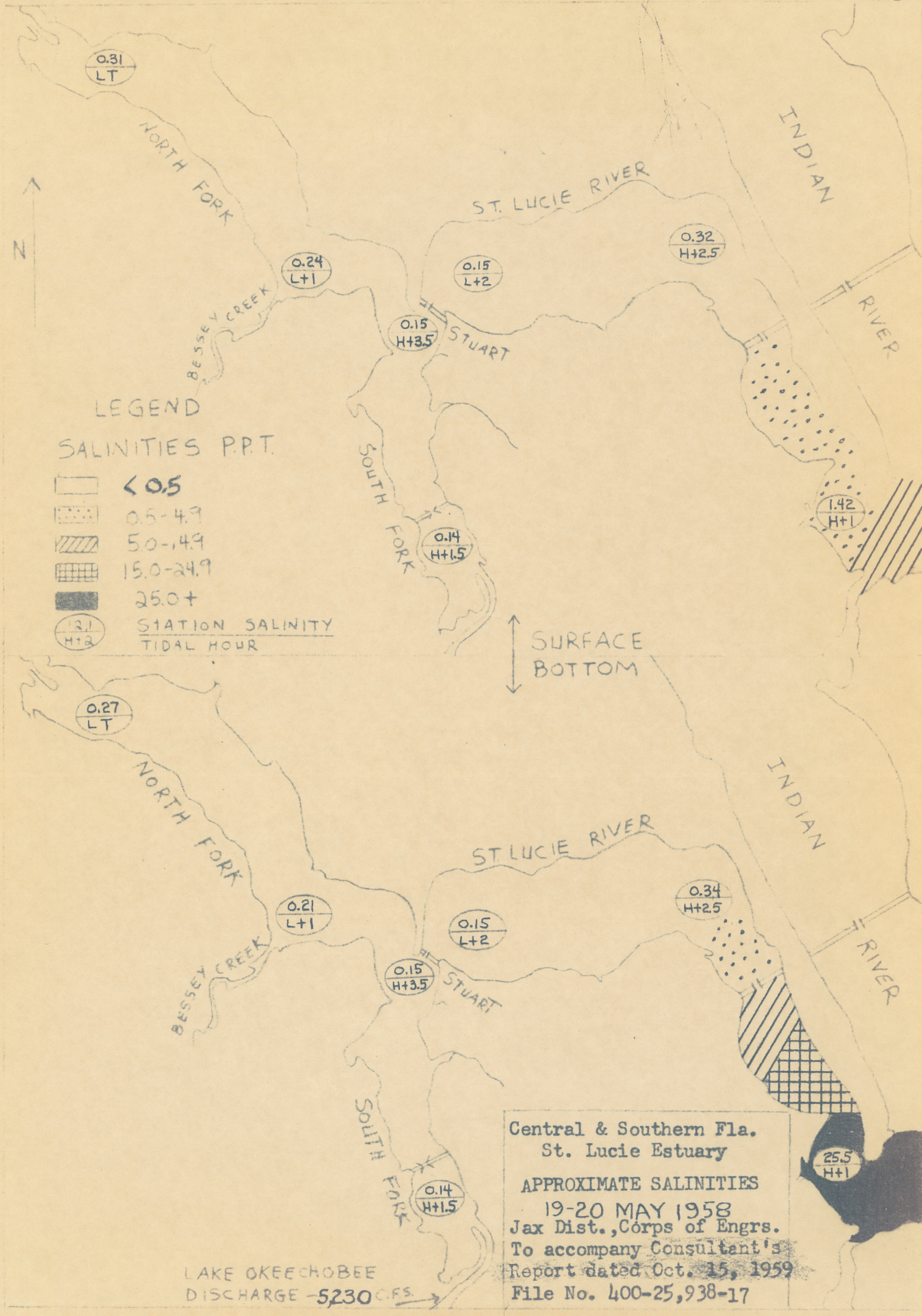
Central & Southern Fla.
St. Lucie Estuary

APPROXIMATE SALINITIES
27-28 JANUARY 1958
Jax Dist., Corps of Engrs.
To accompany Consultant's
Report dated Oct. 15, 1959
File No. 400-25,938-15



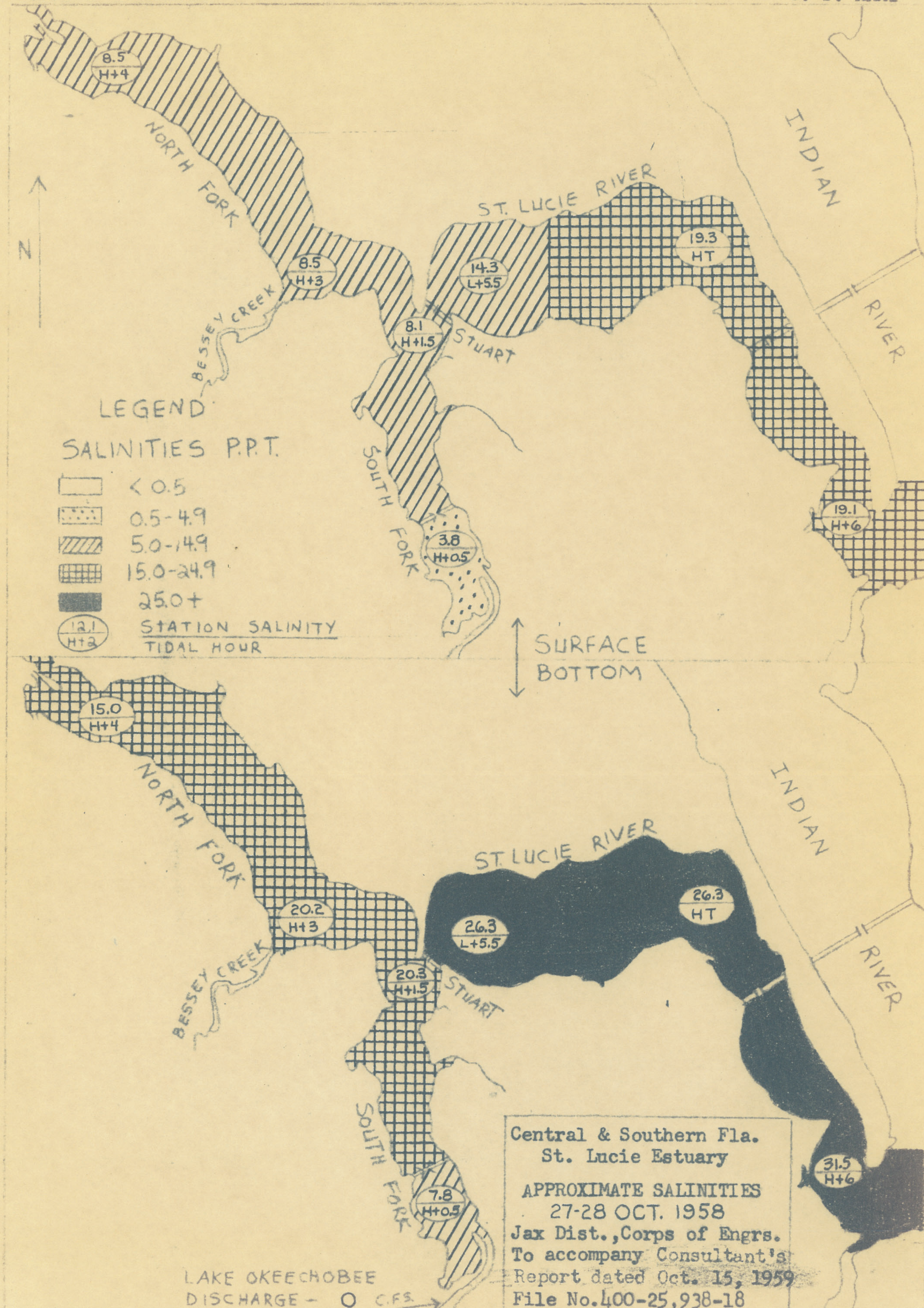
Central & Southern Fla.
St. Lucie Estuary

APPROXIMATE SALINITIES
24-25 FEB. 1958
Jax Dist., Corps of Engrs.
To accompany Consultant's
Report dated Oct. 15, 1959
File No. 400-25,938-16



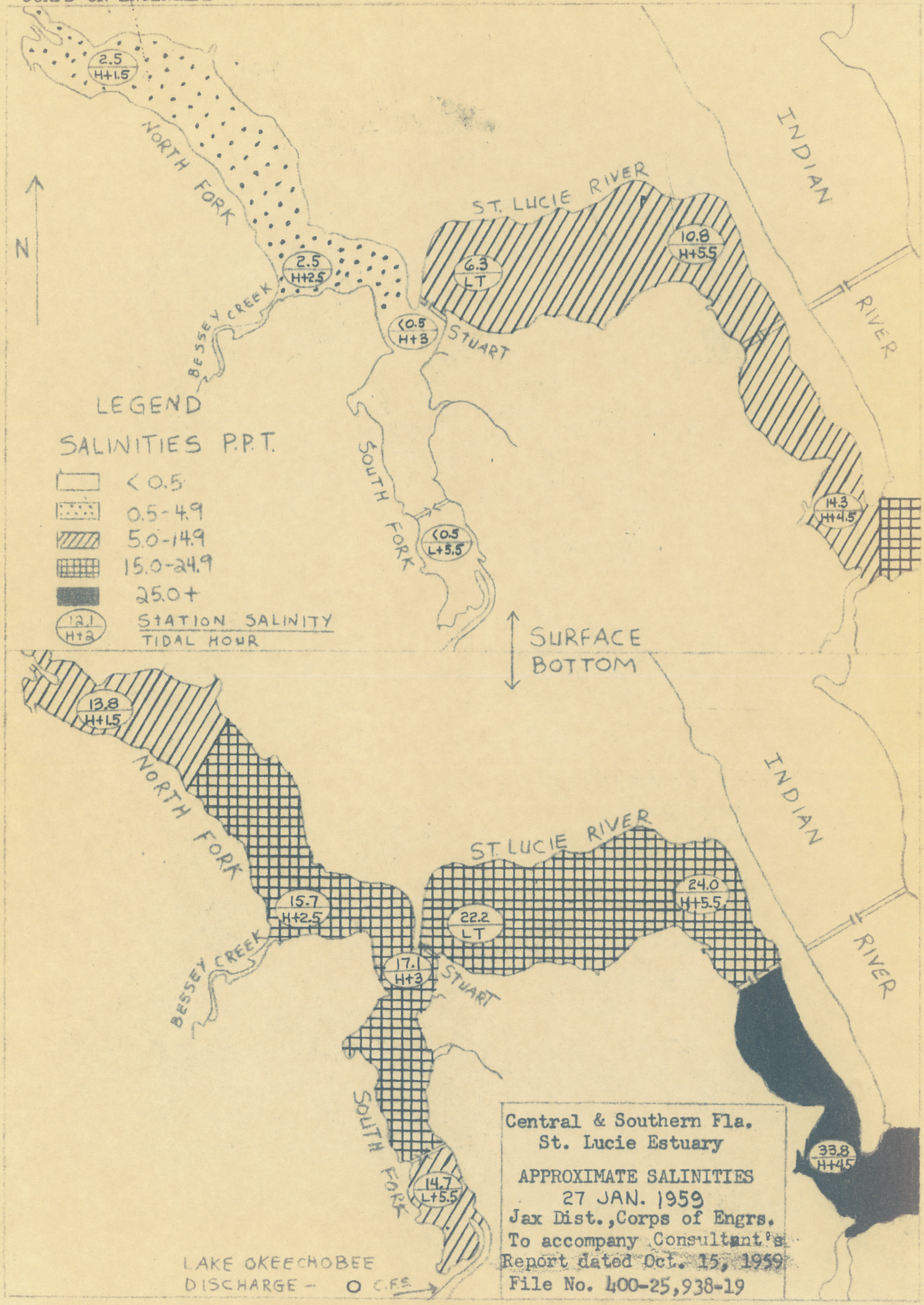
Central & Southern Fla.
St. Lucie Estuary

APPROXIMATE SALINITIES
19-20 MAY 1958
Jax Dist., Corps of Engrs.
To accompany Consultant's
Report dated Oct. 15, 1959
File No. 400-25,938-17



Central & Southern Fla.
St. Lucie Estuary

APPROXIMATE SALINITIES
27-28 OCT. 1958
Jax Dist., Corps of Engrs.
To accompany Consultant's
Report dated Oct. 15, 1959
File No. 400-25,938-18



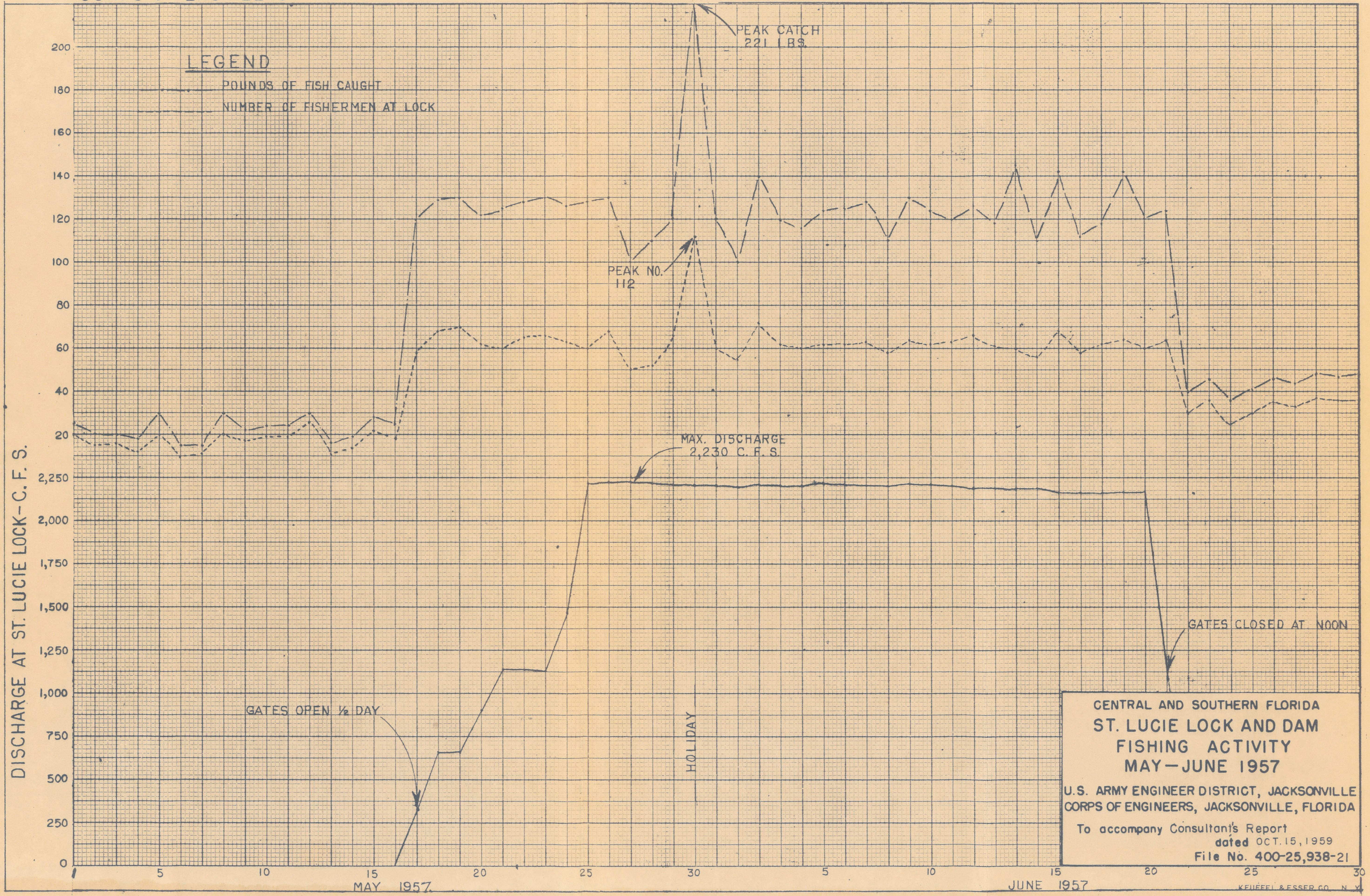
Central & Southern Fla.
St. Lucie Estuary

APPROXIMATE SALINITIES
27 JAN. 1959
Jax Dist., Corps of Engrs.
To accompany Consultant's
Report dated Oct. 15, 1959
File No. 400-25,938-19

CENTRAL AND SOUTHERN FLORIDA
ST. LUCIE ESTUARY
BIOLOGICAL INVESTIGATIONS
TOTAL FISH COLLECTED AND ST. LUCIE CANAL DISCHARGES DURING EACH SAMPLING PERIOD, 1957-59
U.S. ARMY ENGINEER DISTRICT, JACKSONVILLE
CORPS OF ENGINEERS, JACKSONVILLE, FLORIDA
To accompany Consultant's Report
dated OCT. 15, 1959
File No. 400-25,938-20

CORPS OF ENGINEERS

U.S. ARMY



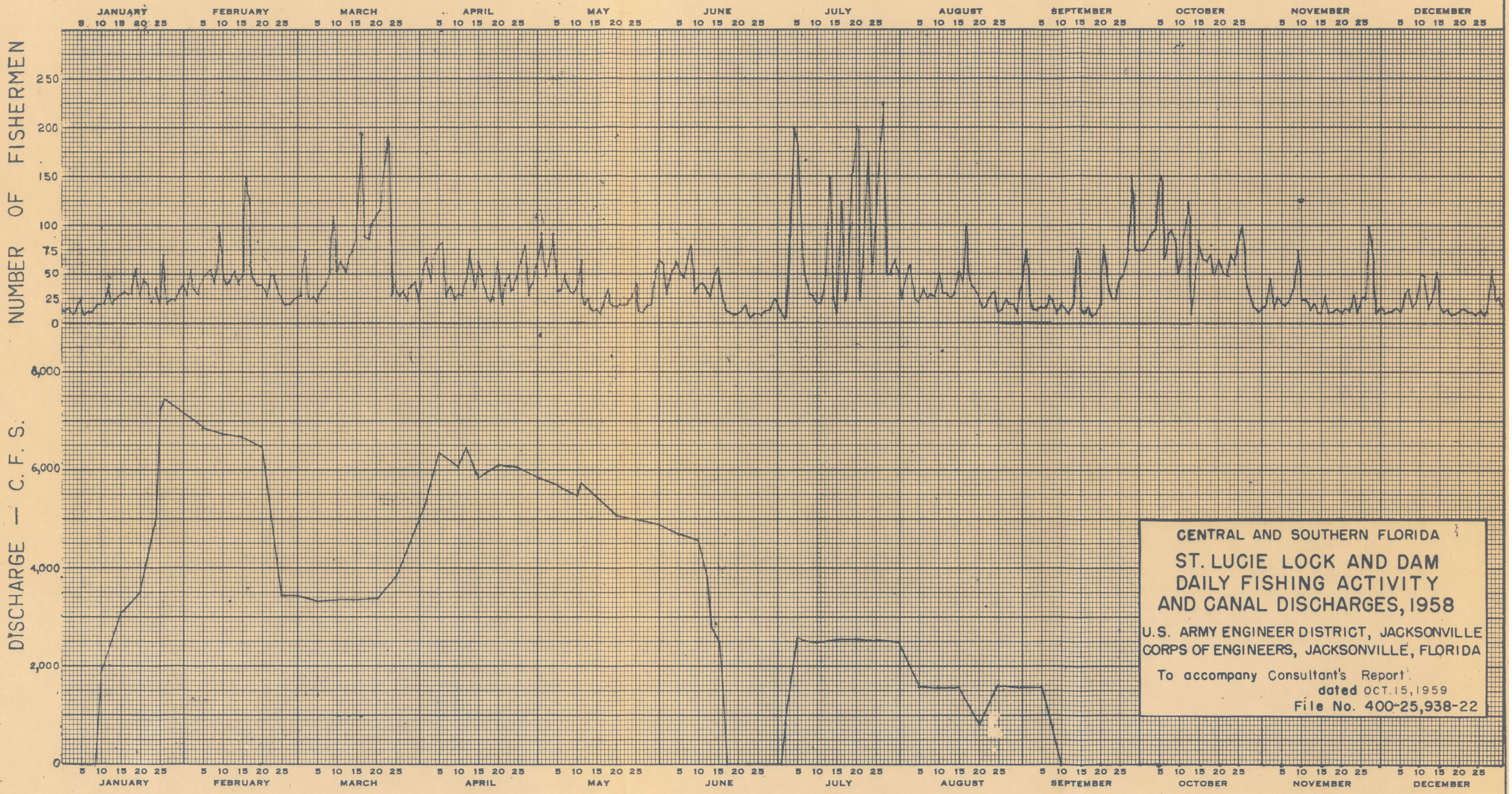
CENTRAL AND SOUTHERN FLORIDA

ST. LUCIE LOCK AND DAM FISHING ACTIVITY MAY—JUNE 1957

U.S. ARMY ENGINEER DISTRICT, JACKSONVILLE
CORPS OF ENGINEERS, JACKSONVILLE, FLORIDA

To accompany Consultant's Report dated OCT. 15, 1959
File No. 400-25,938-21

PLATE 21

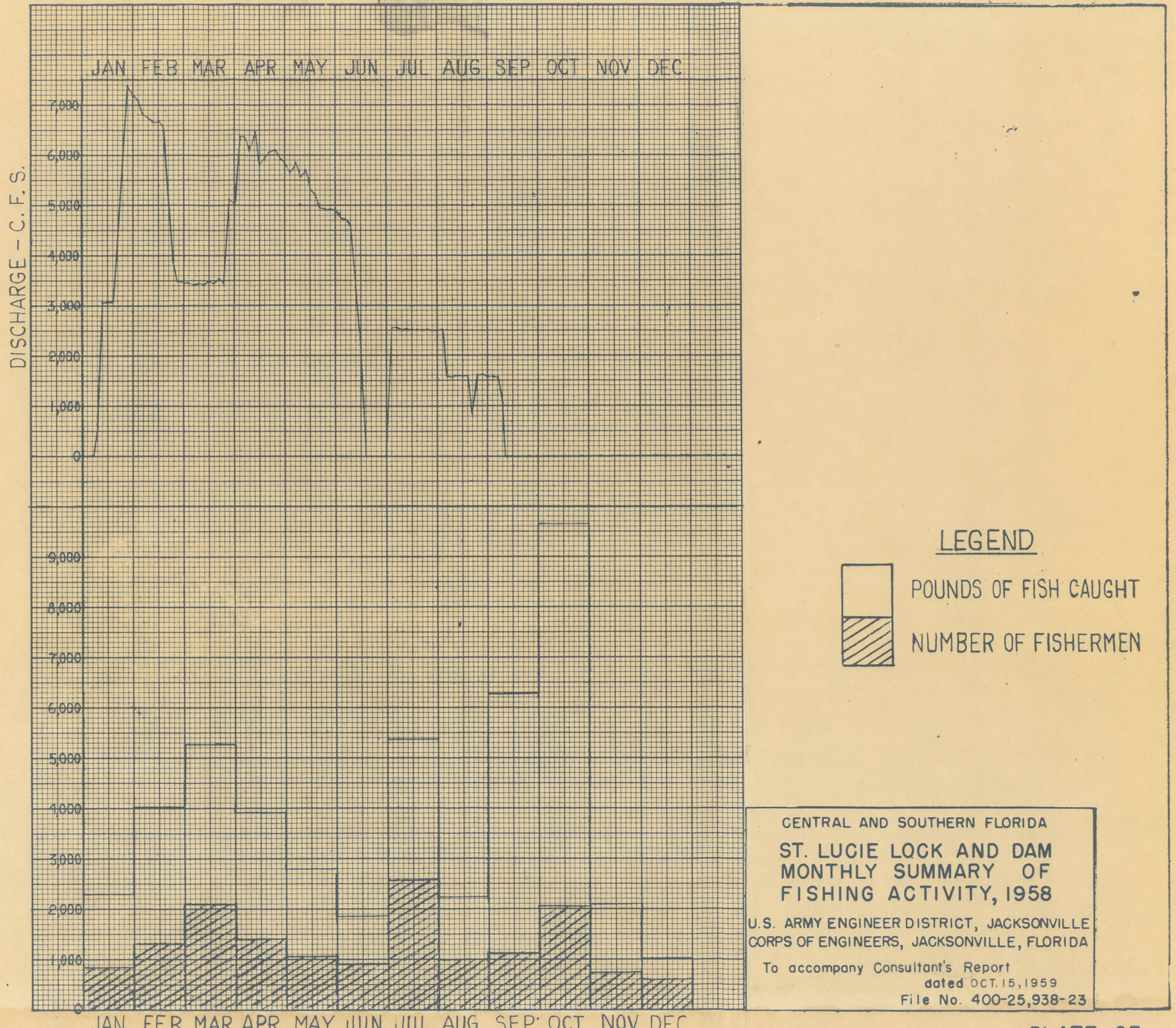


CENTRAL AND SOUTHERN FLORIDA

ST. LUCIE LOCK AND DAM DAILY FISHING ACTIVITY AND CANAL DISCHARGES, 1958

U.S. ARMY ENGINEER DISTRICT, JACKSONVILLE
CORPS OF ENGINEERS, JACKSONVILLE, FLORIDA

To accompany Consultant's Report
dated OCT. 15, 1959
File No. 400-25,938-22

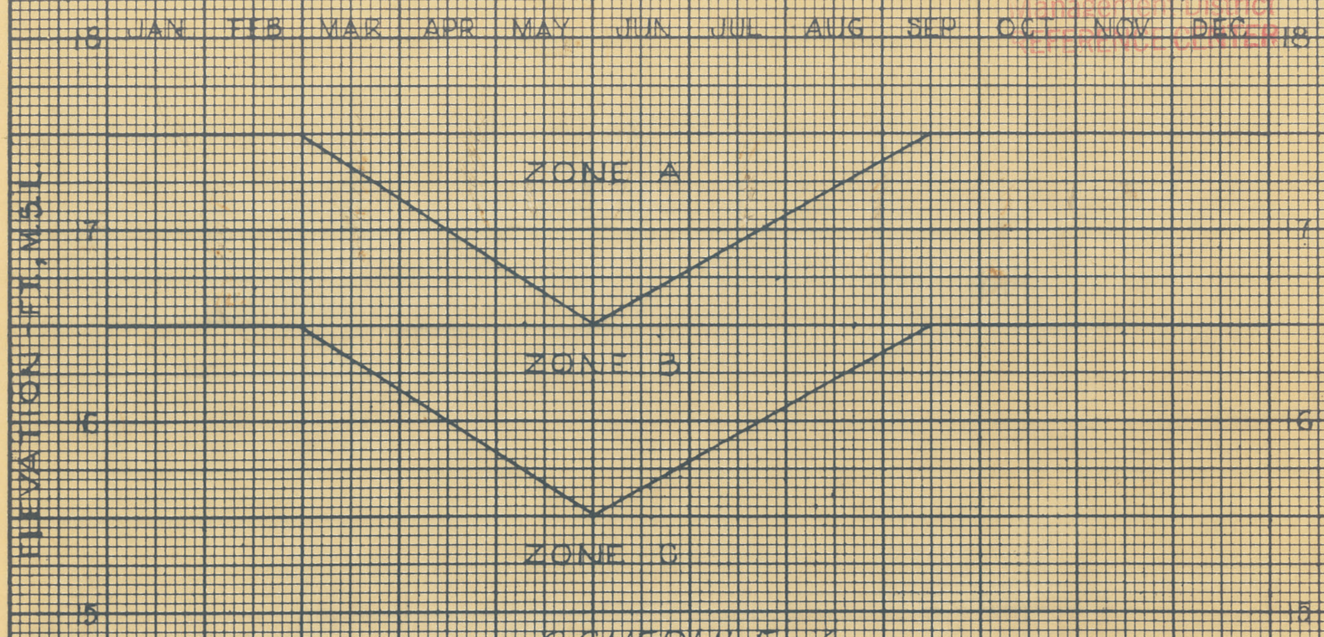


CENTRAL AND SOUTHERN FLORIDA

ST. LUCIE LOCK AND DAM
MONTHLY SUMMARY OF
FISHING ACTIVITY, 1958

U.S. ARMY ENGINEER DISTRICT, JACKSONVILLE
CORPS OF ENGINEERS, JACKSONVILLE, FLORIDA

To accompany Consultant's Report
dated OCT. 15, 1959
File No. 400-25,938-23



SCHEDULE I

SCHEDULE OF REGULATION

ZONE	ST. LUCIE CANAL	CALOOSAHATCHEE R.	AG. CANALS
A	MAXIMUM DISCHARGE	MAXIMUM DISCHARGE (9,300 CFS)	MAXIMUM DISCHARGE AFTER REMOVAL OF LOCAL INFLOW
B*	DEC. JAN.-FEB.-MAR. NO DISCHARGE APR.-MAY-SEP.-OCT.-NOV. UP TO 3,500 C.F.S. JUN.-JUL.-AUG. UP TO 1,500 C.F.S.	UP TO 4,500 C.F.S.	MAXIMUM GRAVITY DISCHARGE AFTER REMOVAL OF LOCAL INFLOW
C	NO DISCHARGE	NO DISCHARGE	FOR AG. DEMAND ONLY DOWN TO 10.5 FT. M.S.L.

PRIORITY OF RELEASES

1. GRAVITY RELEASES - AG. CANALS
2. ST. LUCIE CANAL UP TO ZONE B LIMIT, THEN CALOOSAHATCHEE R. UP TO CAPACITY, THEN BACK TO ST. LUCIE TO CAPACITY IF NEEDED IN ZONE A.
3. PUMPED RELEASES - AG. CANALS.

* Releases through various outlets may be modified to minimize damages or obtain additional benefits.

CENTRAL AND SOUTHERN FLORIDA

LAKE OKEECHOBEE
REGULATION SCHEDULE
RECOMMENDED IN
PART IV, SUPP. 2, SEC. 7

U.S. ARMY ENGINEER DISTRICT, JACKSONVILLE
CORPS OF ENGINEERS, JACKSONVILLE, FLORIDA

To accompany Consultant's Report
dated OCT. 15, 1959
File No. 400-25,938-24

CONSULTANT'S REPORT

BIOLOGICAL INVESTIGATIONS OF ST. LUCIE ESTUARY

APPENDIX A

CORRESPONDENCE AND SUPPORTING DATA FROM OTHER SOURCES

This appendix presents letters containing information pertinent to and emphasizing various aspects of biological and physical conditions in St. Lucie Estuary as discussed in this report.

The letter on pages A-1 through A-3 is the summary letter of transmittal of the United States Fish and Wildlife Service, dated April 22, 1959, with respect to the probable effects on fish and wildlife values of the District Engineer's recommended plan of improvement for the St. Lucie County canals. The District Engineer's reply, dated May 14, 1959, follows the Fish and Wildlife Service's summary letter on page A-4. The Service's report is considered of interim nature, since it did not include the effects of discharges into the North Fork on the fisheries of the main St. Lucie Estuary. The latter are felt to be inseparable from certain effects of regulated discharges from Lake Okeechobee through St. Lucie Canal. Both will be discussed in more detail in another report of the Service now in progress.

The series of letters on pages A-6 through A-19 are replies from various State and Federal wildlife agencies and university laboratories in response to a request from the District Engineer for information on fish kills which may have occurred in coastal waters as a result of the cold weather during January and February 1958.

The letter on page A-20 is a request by the District Engineer of the University of Miami Marine Laboratory for information on sailfish populations off the lower Florida east coast and the effects thereon of discharging fresh water through St. Lucie Inlet. The laboratory's reply follows on page A-21.

UNITED STATES
DEPARTMENT OF THE INTERIOR

FISH AND WILDLIFE SERVICE
BUREAU OF SPORT FISHERIES AND WILDLIFE

OFFICE OF REGIONAL DIRECTOR
Peachtree-Seventh Building
Atlanta 23, Georgia

CE-SE-sf (St. Lucie County Canals)

April 22, 1959

District Engineer
Corps of Engineers, U. S. Army
Jacksonville, Florida

Dear Sir:

Pursuant to your request and in accordance with the provisions of the Fish and Wildlife Coordination Act, 48 Stat. 401, as amended; 16 U. S. C. 661 et. seq., the Bureau of Sport Fisheries and Wildlife has studied the probable effects of the St. Lucie County Canals Project on fish and wildlife. The findings of this study are submitted in the accompanying report for your guidance and consideration in the formulation of this and other related segments of the overall Central and Southern Florida Flood Control Project.

To expedite the runoff of floodwaters from potentially valuable agricultural lands, the enlargement and extension of Canals C-23, C-24, and C-25 and the enlargement of a 0.9 mile stretch of the lower North Fork River (C-23A) are planned. Water control structures are designed to allow for flood control, drainage and distribution of irrigation waters.

Provisional data indicate that the maximum discharge of Canals C-23, C-24, and the North Fork River would be increased to about 11,000 c.f.s. or roughly twice their present total capacity. With enlargement, Canal C-25 would have a capacity of about 5,000 c.f.s.

Our report treats the fishery resources in two sections: (1) the North Fork River area of influence and (2) the Canal C-25 area of influence. This distinction was necessary because the drainage canals discharge in widely separate coastal areas and problems of fish conservation within the areas of influence are not comparable.

Through a near-doubling of the instantaneous rates of storm runoff through the North Fork, the project will be detrimental to fisheries in the North Fork River and Estuary and in the main St. Lucie Estuary. The project would increase some now harmless discharges to proportions damaging to fisheries. Apparently fishing success for marine species declines during periods of high discharge; as a result fishing pressure also declines. The average annual loss of fishery values that will result from the project in the North Fork and its estuary is estimated to be $46,000.

The effects of North Fork drainage are complicated by operation of the St. Lucie Canal which discharges water from Lake Okeechobee into the South Fork of the St. Lucie Estuary. This fresh water discharge greatly modifies the environment within the North Fork Estuary. Releases from the St. Lucie Canal may either mask or accentuate the effects of the project in the North Fork Estuary and in the main estuary, depending upon their relative volumes of outflow.

Enlargement of Canal C-25, which discharges into Indian River opposite Fort Pierce Inlet, will have a small effect on the local fishery. The annual loss from this segment of the project is estimated to be $8,000.

The St. Lucie County Canals Project will have little immediate influence upon wildlife although better drainage and flood control will lead to more intensive land development with resulting shrinkage of wildlife habitat. In view of the inflated property values of coastal Florida this trend seems inevitable. Local residents reported a heron and egret roost on the North Fork that may be endangered by the project. This loss can be avoided by not placing spoil under or immediately adjacent to the site of the roost.

The Bureau feels that the plan for flood control proposed by local interests for the conservation of fish and wildlife resources has merit. This plan envisions the routing of waters from Canals C-23 and C-24 southward to Lake Okeechobee by constructing an auxiliary channel linking Canal C-23 with the St. Lucie Canal just above the St. Lucie Locks. Modification in this manner may safeguard existing fishery resources in the St. Lucie Estuaries. It would also provide for storage of water in Lake Okeechobee for irrigation, municipal and industrial uses.

The effectiveness of the proposed modification cannot be evaluated until you have established regimens for regulating water levels in Lake Okeechobee and have completed studies of other lake outlets. During periods when regulatory releases are being made from the lake through the St. Lucie Canal, the proposed modification would afford little improvement.

The town of Stuart and nearby communities have developed a part of their economies on the abundance of fish in the adjacent estuaries, including the North Fork. Therefore, project modifications for the conservation of fish and wildlife resources should be carefully considered. Consideration should also be given to the possible effects of this project in the main St. Lucie Estuary; an area which has not been considered in this report.

In summary, the Bureau concludes that the plan for enlargement of Canals C-23 and C-24 will result in losses to the fishery resources in the St. Lucie Estuaries and that losses to these resources may be reduced or prevented by modification of project plans to provide for routing a part of flood flows into Lake Okeechobee. Furthermore, we are apprehensive that this system of canals may be later employed to divert portions of flows of the Upper St. Johns River into the St. Lucie Estuaries. Should this occur, fish and wildlife resources valued at about $750,000 annually would be severely damaged, along with associated commercial enterprises in and about the community of Stuart.

The Bureau of Sport Fisheries and Wildlife therefore recommends that:

1) The Corps of Engineers provide assurance that flood waters from the Upper St. Johns River Basin would not be discharged into the St. Lucie County Canals system.

2) The Corps of Engineers determine the feasibility of constructing a canal to divert surface run-off collected by the St. Lucie County Canals system southward into Lake Okeechobee, in conjunction with plans for regulated lake discharge which will be formulated following completion of current inter-agency studies.

3) Detailed hydrographic and fish and wildlife studies be conducted within the St. Lucie Estuary by all agencies concerned; findings to be employed as basis for such additional modifications in project design as may be found feasible and justifiable.

The Bureau of Commercial Fisheries has reviewed and concurs with our findings and recommendations.

Your comments and proposed action are requested.

Sincerely yours,

W. L. Towns
Acting Regional Director

U. S. ARMY ENGINEER DISTRICT, JACKSONVILLE
OFFICE OF THE DISTRICT ENGINEER
CORPS OF ENGINEERS
JACKSONVILLE, FLA.

SAKGW 14 May 1959

Regional Director
U. S. Fish and Wildlife Service
Peachtree-Seventh Building
Atlanta, Ga.

Dear Sir:

This will acknowledge receipt of your letter of 22 April 1959 which transmitted 55 copies of your interim report on the effects of the St. Lucie County canals plan of improvement on fish and wildlife.

As stated earlier in the comments on your preliminary report, it is felt that some of the aspects concerning expected project damages that you have developed are subject to interpretation, particularly since those damages are tied directly to future fisherman use. There remains a question as to whether the present use would continue to increase without the project as you expect, or whether, in view of present local urban and agricultural developments, the North Fork Estuary would not, in any case, remain an area with comparatively low fishing pressure. Conversely, it is conceivable that the total annual fisherman use could continue to increase even though conditions at some period of the year might be less desirable with than without this project. In the design memorandum, it was stated that with the project works there would probably continue to be periods of discharge, as now, when much of the North Fork Estuary would be fresh and during which certain marine fishes would move out of the fresh-water zone, with resulting temporary reduction in area use and fisherman catch. Your report makes similar statements and indicates that the project works are expected to increase the frequency of those periods. The question then appears to be in the degree of expected future use of that area and the possible reduction in that use directly attributable to the project. It is recognized that existing damages from present flood discharges, as well as those that would occur without the project, are difficult to determine with available discharge data. Nevertheless, it is believed that they should receive consideration in any estimate of total project damages.

With reference to the three recommendations in your report, the following comments are furnished:

SAKGW
Regional Director
U. S. Fish and Wildlife Service

14 May 1959

1. The function of project Structure 98 leading from the upper St. Johns River Marsh is only to furnish needed irrigation water during dry periods. There is not now nor was there ever any intention that this structure would be used to discharge floodwaters from the upper St. Johns River Marsh south to St. Lucie Estuary.

2. Resolutions adopted by the Senate Public Works Committee on 22 July 1950 and 12 November 1958 call for review of the report on Central and Southern Florida (H. Doc. 643, 80th Cong., 2d sess.) with a view to determining (a) "the advisability of any modification ** of the recommendations contained therein affecting Martin County, Florida," and (b) "whether the existing project should be modified**, with particular reference to the need for additional outlet capacity for the discharge of surplus waters from Lake Okeechobee," respectively. The study authorized by the first resolution would investigate the feasibility of a proposal by the Martin County Water Conservation Committee for consideration of a comprehensive water-control plan for that county. The second resolution authorizes a study of additional lake-regulating facilities, including an outlet to the south. Both investigations will be made through the usual survey-report procedure when funds become available.

3. As you are aware, there are no suitable storage areas in the drainage area of the St. Lucie County canals, so that moderate releases of floodwaters into the North Fork Estuary are not possible. Nevertheless, the project provides for continued observation of discharge conditions and other factors in the area. Any proposals by local interests for additional modifications in project design would be studied when authorized and funds are made available by Congress.

Your continued cooperation in furnishing information on the fish and wildlife resources for use in planning of the Central and Southern Florida Project is appreciated.

Sincerely yours,

PAUL D. TROXLER
Colonel, Corps of Engineers
District Engineer

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
Bureau of Sport Fisheries and Wildlife
1012 - 20th Place
Burks Building
Vero Beach, Florida

Refer to: CE-SE
(C & SF)

20 March 1958

District Engineer
Jacksonville District
Corps of Engineers
575 Riverside Avenue
Jacksonville, Florida

Dear Sir:

I have little information available on coastal fish-kills during January and February 1958, except in this general area.

About the last of January, Mr. Walker observed some dead fish along the shallow ditches near Indian River. The species reported were: mullet, mojarra, drum and mangrove snapper. Other people have also noted some dead fish along Indian River in Brevard and Indian River Counties. The species were not reported but these fish probably succumbed to the cold.

In response to several local requests, I checked the kill in the Stuart area on February 28th. I toured Tarpon Bay, Pruitt's Canal, and part of the North Fork by boat. In this area there were several thousand fish floating or stranded on the beaches. In order of abundance, the species observed included mojarra, ladyfish, snook, and tarpon. The size ranges observed varied from tarpon up to 5 feet long, to snook as small as 6 inches, and a number of mojarra about 4 inches in total length. All of these fish had been dead for some time, and were partially decomposed.

I also checked along the main estuary in the vicinity of Rio and the new bridge. There were a good many dead fish stranded on the beaches in these areas. In order of abundance the species observed included ladyfish, mojarra, snook, mullet, tarpon, sea cat (3 specimens), crappie (also 3 specimens), and weakfish (2 specimens). Mr. Bert Pruitt reported that fish began to show distress in the vicinity of his camp in the North Fork about February 17th. This was substantiated by Mr. Walker who reported seeing a large snook and a large tarpon stranded at Pruitt's camp on the 17th. It was not until the 22nd that the first dead fish were reported to us. These were two large snook which were recovered near the inlet. Dead fish began to show up in numbers in the North Fork and in the vicinity of Rio about February 26th.

Since most of this kill is believed to be due to cold, it is significant that Stuart reported the lowest weekly average temperature of record just prior to the observed kill. However, it is obvious that the crappie and probably the weakfish did not die from the cold, although the cause of their death is not known.

I do not know of any other fish kills in the State, although there may have been some.

Sincerely yours,

H. A. Hunter
Field Supervisor

HAH:dlb

Fulton Lovell
Director

STATE GAME & FISH COMMISSION
412 STATE CAPITOL
ATLANTA 3, GEORGIA

March 20, 1958

Mr. Edwin W. Eden, Jr.
Chief, Planning and Reports Branch
Engineering Division
U. S. Army Engineer District, Jacksonville
Corps of Engineers
P. O. Box 4970
Jacksonville 1, Florida

Dear Mr. Eden: Re: File #SAKGW

I received your letter dated March 18th requesting information concerning fish kills which may have occurred in coastal waters as a result of the cold weather during January and February 1958.

Along our Georgia coast, we had mullet, weak-fish, and shrimp to die near the mouth of the St. Mary's River. We had the same species to die in Sassebow Sound. These fish died mainly during February 24, 25, and 26, 1958. I was not able to determine the extent of the kills. The man that saw the kills was absent.

Hoping this will be of some help to you, I am,

Yours very truly,

Fred J. Dickson, Chief
Fish Management

FJD/mg

GULF COAST RESEARCH LABORATORY

Ocean Springs, Mississippi

March 21, 1958

Mr. Edwin W. Eden, Jr.
Corps of Engineers, U. S. Army
Jacksonville 2, Florida

Dear Mr. Eden:

This is in reply to your letter of March 18.

On the northern Gulf coast we do not often have cold kills of fishes. The Florida region around Sanibel Island and the south Texas coast are notorious areas for cold kills. This is probably due to the fact that these areas are warmer and the fishes are not acclimated or accustomed to the cold waves which sometimes appear. Concerning cold kills in these regions during January and February 1958 I shall refer you to Mr. Howard T. Lee, Director, Marine Laboratory, Game and Fish Commission, Rockport, Texas and Dr. Robert F. Hutton, Director, Marine Laboratory, Florida State Board of Conservation, Bayboro Harbor, St. Petersburg. Doctor Hutton told me in a conversation that there had been two or three cold kills on the west Florida coast this winter.

I also heard that there had been a cold kill of fishes in South Carolina and that Mr. G. Robert Lunz, Jr., Director of the Bears Bluff Laboratories, Wadmalaw Island, South Carolina, was intending to write up a short note or paper on this subject.

On February 10 and 11 there was a kill of fishes, chiefly mullet, in Fort Bayou, Jackson County, Mississippi. This bayou is a tributary of Biloxi Bay. One of our staff biologists, Mr. William J. Demoran, told me that he had made some checks upon this kill and had come to the conclusion that it was caused by the hard cold wave which struck this area at that time. This is one of the few instances of a cold kill occurring on the central Gulf coast. We have no particular information upon the numbers of fishes killed, except that there were several thousand and it attracted considerable attention from the residents of the area.

In the Treatise on Marine Ecology and Paleoecology, Volume 1, Ecology, Memoir 67, Geological Society of America, Chapter 29, pp. 941-1010 is entitled, "Mass Mortality in the Sea." This article is by Dr. Margaretha Brongersna-Sanders. It takes up, among other things, mass mortalities caused by temperature change and it annotates such instances all over the world, including Texas and the southern and western coasts of Florida. It has a very complete bibliography covering some twenty-one pages. This reference should be consulted by anyone collecting information for the Corps of Engineers. The whole work costs $12.50 and may be purchased from the Geological Society of America, 419 W. 117 Street, New York 27, New York.

Sincerely yours,

Gordon Gunter
Director

University of Miami

THE MARINE LABORATORY
#1 Rickenbacker Causeway
Virginia Key
Miami 49, Florida

March 28, 1958

Mr. Edwin W. Eden, Jr.
Chief, Planning and Reports Branch
Engineering Division
Corps of Engineers, U. S. Army
575 Riverside Avenue
Jacksonville 4, Florida

Dear Mr. Eden:

Before replying to your query of March 18th I wish to supply some background information. Few fishes live in the bay and estuarine waters of Florida for all of their life cycle. Those that do are very tolerant species and rarely turn up in any fish kills other than those caused by Red Tide. Other species occur offshore when young and move inshore when adult. The group that we are most interested in are those that occur inshore during the young stages. The spawning and nursery grounds of many of our most important game and commercial species are in the bays and estuaries. The weakfishes, sea trout, channel bass, striped bass, the croakers and drums are such fish. Silting may have a serious effect on the eggs and young but cold temperature doesn't seem important. Very warm summer temperatures sometimes kill them off in small quantities.

In southern Florida, kills result from Red Tide, storms and cold and hot water temperatures. I enclose an article on storm kills and its bibliography will refer you to a number of papers on winter kills due to cold water.

This past winter we have had severe kills of fishes from Biscayne Bay through the Keys and in the freshwater canals. The species effected were tropical species which are at the northern end of their winter range in Florida. Snappers, grunts, tarpon, snook and many others moved out into deeper water but were trapped in the bay and killed in large numbers. Water temperatures in Mangrove areas on Matecumbe Key dropped to 11°C and all tarpon there which were under study by Marine Laboratory personnel were killed. Species like the drums, croakers, etc., mentioned above range quite far northward and did not seem to be effected by the cold water.

I hope this will be of aid to you.

Sincerely,

C. Richard Robins,
Research Assistant Professor

CRR:lsl

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

Bureau of Commercial Fisheries
Shellfishery Laboratory
Gulf Breeze, Florida

31 March 1958

District Engineer
Corps of Engineers
U. S. Army Engineer District
575 Riverside Avenue
Jacksonville 2, Florida

Dear Sir:

Reference is made to your letter dated 18 March, File No. SAKGW, from the Chief, Planning and Reports Branch of your office, requesting information concerning fish kills observed in coastal waters as a result of the cold weather during January and February 1958.

The following observations were made at the U. S. Shellfishery Laboratory at Gulf Breeze, Florida, which is located on the small island near Sabine Point (Pensacola Beach), C & G Chart #1265.

January 13--After minimum water temperature of 6.1°C on the 8th and 6.0°C on the 9th, scattered cowfish (Lactophrys) and spiny box fish (Chilomycterus) were found along rocky shore, less than 25 total.

February 14-A few of same types noted near dock after minimum water temperature of 4.9°C for the preceding 24 hour period.

February 19-Minimum water temperature 5.2°C. No dead fish noted in the period February 20 - 22.

There was almost a complete absence of pelagic fish during January and February, while swarms of jelly fish and Ctenophores were present. On January 30 there was an unprecedented bloom of the dinoflagellate, Noctiluca along the shore.

Sincerely yours,

Philip A. Butler, Chief
Gulf Oyster Investigations

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

Post Office Box 3098
Galveston, Texas

April 1, 1958

District Engineer
Corps of Engineers
U. S. Army Engineer District
575 Riverside Avenue
Jacksonville 2, Florida

Dear Sir:

Reference is made to your letter dated 18 March 1958 to our Regional Director at St. Petersburg, and forwarded to us for the requested information.

Following several days of cold weather, when the temperature dropped to 28° F. on successive nights, a minor fish kill took place in East Lagoon, a narrow mile-long body of water located in the northeast end of Galveston Island. This lagoon is man-made, with an average depth of 4 feet, with several "holes" approximately 12 feet in depth in its southwest portion. Tidal exchange takes place via 5 culverts connecting the lagoon with Bolivar Roads.

Approximately one ton of spade-fish (3/4-3 lbs.) Chaetodipterus faber, 500 lbs. of 2-3 foot silver eels or cutlass fish, Trichiurus lepturus, and scattered adult striped mullet, Mugil cephalus, were observed along the shores of said lagoon.

We checked with the local Texas Fish and Game Commission office, and this East Lagoon fish kill was the only one of which they were aware. Thus it appears that the foregoing is the only record of fish kills by cold in this area during the past winter.

Very sincerely,

George A. Rounsefell
Chief
Gulf Fishery Investigations

BEARS BLUFF LABORATORIES

WADMALAW ISLAND, S. C.

April 3, 1958

Mr. Edwin W. Eden, Jr., Chief
Planning & Reports Branch
U. S. Army Corps of Engineers
575 Riverside Avenue
Jacksonville 4, Fla.

Re: SAKGW

Dear Mr. Eden:

Here is some more information on fish kills in South Carolina. We have not yet published the manuscript referred to in my letter of March 21, but we do mention it in our Progress Report No. 35, a copy of which is enclosed.

Very truly yours,

G. Robert Lunz
Director

GRL/je

BEARS BLUFF LABORATORIES

WADMALAW ISLAND, S. C.

PROGRESS REPORT No. 35

January through March

1958

Oyster Research

A continuing study on growth and mortality of oysters, both in their natural environment and in the experimental ponds, showed that none grew during this quarter. Ordinarily oyster growth during this period of the year is good, and it must be assumed that the extreme temperatures of this winter is the primary cause for the lack of growth.

Despite the cold, only from 3 to 5 per cent of the experimental oysters in the pond and in We Creek have died. This is not an alarming mortality, and many of those killed were destroyed by blue crabs.

In addition to studies at the Laboratory proper, natural oyster reefs in the vicinity were examined in mid-March. Several square-yard samples were taken at low water upward to the limit of oyster growth. The 11 per cent mortality found is not unusually high for South Carolina. The percentage of marketable oysters in these samples is low, only 6 per cent are over 3 inches, with an additional 25 per cent barely large enough to be used for canning purposes. A detailed study of the reproductive organs indicated that their development had been retarded, and that only a minute percentage showed any sexual development. Apparently spawning will be delayed this year.

The sub-normal winter temperature has given impetus to a study, now under way, on the extremes of temperatures to which South Carolina oysters are subjected. Unlike oysters in the Chesapeake Bay, for example, South Carolina oysters are exposed to air temperatures for several hours during the time of low water. The air temperatures to which they are subjected then are a great deal more extreme than the temperature of the water in which they are submerged in other areas.

Shrimp Research

Low water temperatures in this quarter quite apparently caused most shrimp and fish to leave their usual habitat. This is shown by their scarcity in the 105 experimental trawl hauls made during the quarter at the 17 regular shrimp survey stations. No white shrimp were taken in 74 experimental trawls during February and March. The availability of white shrimp in January was quite low, being about one-third of what it was in January of 1957.

Likewise, commercial fish - that is trout, whiting, croaker and spot - were scarce during this quarter. Excluding an abnormally large catch of spot taken in one drag off Kiawah Island in February, the catch per unit of effort of commercial fishes is 8 times less this year compared to last.

Several times slush ice was noted along the edge of the marsh and shore. Fish kills were reported and recorded in both inshore and off-shore waters. The most drastic kill was reported by Mr. Wm. North who found 26 small (2-4 in.) channel bass per lineal foot frozen and dead along the edge of Wando River.

Although sub-normal temperatures have resulted in a definite reduction in the productivity of experimental trawls, only continued sampling can determine what the final effects of the extreme cold will be. Toward the end of the quarter, young croaker and spot, and other fishes began to reappear in the experimental catches.

On Feb. 21, Bears Bluff Laboratories' vessel, the T-19, made a run southeastward 135° from the North Edisto sea buoy. In 11 fathoms of water at approximately 32°17'N x 79°52'W a few dead fish were noted floating on the surface. These proved to be angel fish (*Angelichthys isabelita*, Jordan & Rutter). On the same day the Trawler *Hope*, C. A. Magwood, Jr., Captain, a few miles to the southward and a few miles further offshore than the T-19, reported running through about 15 miles of scattered dead fish. Most of the fish which Captain Magwood saw were angel fish, but he also reported a few dead porgy and vermilion snapper.

On Feb. 24 and 25, the T-19 again resurveyed the general area, taking water temperatures and making occasional sample trawls. The presence of several species of live fishes in the trawls, with the observation that the dead fish found on the surface were mostly of one species (angel fish) eliminates man made devices such as depth charges as the cause of this fish kill. The survey indicated that there was a mass of cold water ranging from 40° to 50° lying along the shore out to approximately 15 fathoms. Beyond the 15-fathom curve, the temperature rose rapidly, and at 23 fathoms had reached a temperature of 64°. The angel fish, being largely a tropical fish, could not survive the low temperatures of this mass of cold water.

Pond Cultivation

This winter, the coldest on record since 1918, the 5 salt water experimental ponds at Bears Bluff were frozen over, and the water temperature under the ice dropped to 32.5 degrees. Most of the experimental fishes in the ponds had already been killed by a previous cold spell, so that this temperature was of more theoretical than practical importance. The freezeover did not kill the blue crabs in the ponds however, and as soon as the water temperatures warmed again, the crab population became active. When one of the ponds was drained on March 11, the crab population was reported as being about normal. Oysters in the ponds were not killed.

All the experimental ponds are now being prepared for stocking with shrimp and fish for a continued study of the productivity of these salt water ponds.

Crab Research

In mid-January, a crab tagging program was begun in cooperation with the U. S. Fish & Wildlife Service. This program, planned several years previously, is an attempt to determine whether or not South Carolina crabs migrate from one river system to another. Through the combined efforts of 3 biologists of the Bureau of Commercial Fisheries at Beaufort, N. C., and 3 members of the Staff of Bears Bluff Laboratories, some 1600 crabs were tagged and released in the North Edisto River.

There is no trawl fishery for crabs in the North Edisto River, nor at sea in the vicinity of the river mouth. There is normally an intense trawl fishery a few miles to the northward in the vicinity of Charleston and to the southward in the vicinity of St. Helena Sound. Through these tagged crabs it was hoped to determine whether or not the crabbing industry could recruit its catch from other geographical areas. To date tag returns have been few - 2 from the area of release, one up river 2-1/2 miles, and one 5 miles southward along the coast.

Bears Bluff Laboratories has recommended to the General Assembly that the crab trawling season be extended by two weeks. This was done after an examination of the catch records of the Laboratories' 2 research vessels; fishermen's catches; and the landing reports of the Branch of Statistics of the U. S. Fish & Wildlife Service. Monthly landings indicated that the commercial crab catch is off by at least 650,000 pounds during this quarter, coincident with cold weather. Extension of the season for two weeks would not put an undue strain on South Carolina's crab resources.

Miscellaneous

During this quarter one publication was released: the "Annual Report for 1956-1957," which was published as Contribution No. 26 from Bears Bluff Laboratories.

In addition, the February issue of Quick Frozen Foods carried an article about Bears Bluff entitled "If Research Licks Problem, Salt Water Ponds Can Raise Shrimp Cheaper Than the Sea Trawl Can Catch Them."

The March issue of National Fisherman contained an article entitled "Research at Bears Bluff Has Practical Slant." Newspaper coverage of the Laboratory activities was extensive, particularly in reporting the investigation of the winter kill of fish 25 miles off the coast.

As part of the extension work, one talk on the possible changes in fishing due to the extremely cold winter was given to one of the Service Clubs by the Director. He also appeared on the television program "Afloat and Afield" to discuss the kill of fishes due to the cold weather.

Respectfully submitted,

G. Robert Lunz
Director

GRL/je
Mar. 31, 1958

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF COMMERCIAL FISHERIES
Gulf and South Atlanta Regional Office
St. Petersburg Beach, Florida

April 16, 1958

District Engineer
Corps of Engineers
U. S. Army Engineer District
Jacksonville, Florida

Dear Sir:

Further reference is made to your letter of 18 March, file SAKGW, requesting information concerning fish kills observed in coastal waters as a result of cold weather during January and February 1958.

The following is quoted from a report on this subject by Mr. F. C. June, Chief, Menhaden Investigations, Beaufort, North Carolina:

"I recently learned of an occurrence of a mass mortality in the Neuse River, North Carolina. Dr. Earl Deubler of the University of North Carolina Institute of Fisheries Research has been conducting a series of trawl samplings in this area. On February 25 he caught substantial quantities of dead fish at four locations in the river system. The locations included: Garbacon Shoal, Adams Creek, Wilkinson Point, and Hampton Shoal (Ref. C & GS 538). From three to five - 10-minute hauls were made at each location. It was estimated that each haul contained an average of 100 dead fish of the following species: Spot (*Leiostomus xanthurus*), mullet (*Mugil sp.*), croaker (*Micropogon undulatus*), menhaden (*Brevoortia tyrannus*), spotted weakfish (*Cynoscion nebulosus*), flounder (*Paralichthys lethostigmus*), anchovy (*Anchoviella sp.*) and shrimp (*Panaeus sp.*). Mortality was restricted almost exclusively to juveniles of these species.

"The trawl stations were occupied several days following break-up of ice which had completely blocked the area for about four weeks. Bottom water temperatures at the various locations varied slightly about 3.8°C. Dr. Deubler reported the occurrence of dead fish over extensive areas of the bottom. While the kill cannot be attributed to cold water temperatures with certainty, Dr. Deubler believed that this was strongly indicated, since there was no evidence of industrial pollution."

Sincerely yours,

Seton H. Thompson
Regional Director

U. S. ARMY ENGINEER DISTRICT, JACKSONVILLE
OFFICE OF THE DISTRICT ENGINEER
CORPS OF ENGINEERS
JACKSONVILLE, FLA.

SAKGW 26 January 1959

Dr. F. G. Walton Smith, Director
Marine Laboratory
University of Miami
Coral Gables, Fla.

Dear Dr. Smith:

A recent item in the Conservation News of the National Wildlife Federation, which discussed the Stuart fishing picture, quoted charter-boat captains as saying that there had been a general decline in sail-fishing off Stuart in the last 10 years. It was further indicated that fresh-water discharges from St. Lucie Canal were probably responsible for the decline in numbers of sailfish.

It is known that scientists at your laboratory are conducting quite extensive investigations on the life histories, growth rates, and migrations of all billfishes, including the Atlantic sailfish. It would be helpful to know whether results of those studies to date have furnished evidence of any general decline in sailfish numbers as reported, and particularly in the Stuart area.

Information is also desired as to whether the discharge of fresh water into estuaries, at the maximum rate of 6,000 to 9,000 c.f.s., would be likely to have any effect on the movements and spawning of fishes several miles out in the ocean. Published materials on sail-fishes in the National Geographic Magazine and in reports of the U. S. Fish and Wildlife Service indicate that spawning and early life of Atlantic sailfish are closely associated with the Gulf stream beyond the 100 fathom line. Between Jupiter and Stuart, the 100-fathom line lies from 7 to 12 miles off the coast.

Your comments in this matter and copies of any available reports dealing with sailfish would be greatly appreciated.

Sincerely yours,

LEO L. BURNET
Assistant Chief
Engineering Division

UNIVERSITY OF MIAMI
THE MARINE LABORATORY
#1 Rickenbacker Causeway
Virginia Key
Miami 49, Florida

February 2, 1959

Mr. Leo L. Burnet
U. S. Army Engineer District, Jacksonville
Corps of Engineers
575 Riverside Avenue
Jacksonville 2, Florida

Dear Mr. Burnet:

Your letter of January 26th to Dr. Smith has been given to me for reply. Before writing this answer, I checked with Al Pflueger, the taxidermist, and others who are very familiar with sailfishing up and down the coast of the United States. We are all in agreement that there has been no general decline in sailfish numbers over the last ten years. During the fall and winter, there is a large concentration of small sailfish whose position varies with local conditions. A year ago, during our very cold winter, the sailfishes disappeared from the area but showed up again in the spring of the year. This year, with a very warm winter, the main concentration seems to be off Ft. Pierce and Melbourne. Such a shift in concentration depends on the overall weather conditions of the winter and has nothing to do with the discharge of fresh water into estuaries at any place along the coast.

Sailfish are pelagic fishes throughout their life and I cannot see that the discharge of fresh water from the St. Lucie inlet has any bearing whatsoever on their life cycle. In addition, when the concentration does occur between Jupiter and Stuart, it is well off shore; not close in as it often is in the Miami region.

In summary, I can say that there is no evidence of any decline in numbers of sailfishes along the Florida coast, although the point of greatest concentration will vary with the overall winter conditions; being farther north during warm winters and occurring far south or even out of our region during unseasonably cold years. The discharge of fresh water into estuaries has no bearing whatsoever on the sailfish life cycle. I hope that this information will be of aid to you.

Sincerely,

C. Richard Robins

CRR:cp
cc: Dr. F.G.W. Smith