HYDROLOGIC RECONNAISSANCE OF CONSERVATION AREAS ONE, TWO, AND THREE OF THE CENTRAL AND SOUTHERN FLORIDA PROJECT

By

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June 17, 1971

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Final Report

To

Central and Southern Florida
Flood Control District
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I. Introduction

The purpose of this study was to make a preliminary reconnaissance of the hydrology of conservation areas one, two and three of the Central and Southern Florida project. This study was of a preliminary nature. A comprehensive analysis of this problem would have necessitated an extended investigation. The scope of the investigation includes the following phases:

1. Review of existing hydrologic data for the system and development of a study plan.
2. A two day reconnaissance of the study area (see Figure 1).
3. Formulation of a study plan for determining the water budget within the study area.
4. Analysis and evaluation of available information required to make this water budget.
5. Given the estimated water budget, determine the relationships and constraints that operate on manipulation of water levels and suggest changes in management practices where needed.
6. Prepare a report summarizing the findings of the investigation.

This report presents a summary of the research and a presentation of our findings. The discussion will follow the format delineated for the six phases.

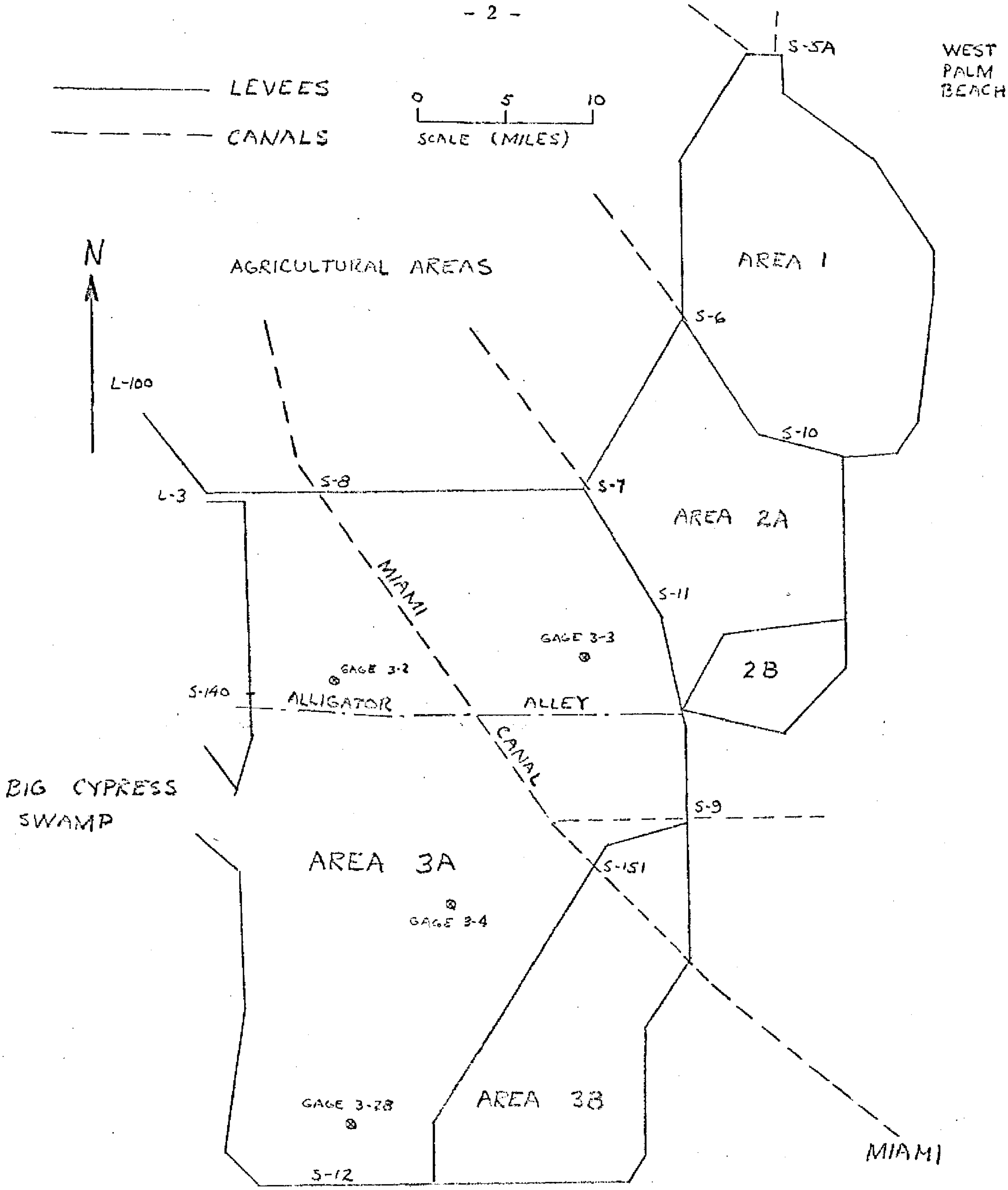


Figure 1. Map of conservation areas showing locations of selected structures.

II. *Phase 1:* Review of existing hydrologic data for the system and development of a study plan.

Procedure—The review of existing data for the study area was accomplished in the following steps:

1. Intensive oral briefing by Flood Control District (FCD) personnel.
2. Review of publications available at the FCD office.
3. Search for information at the University of Florida library.
4. Visit to the Corps of Engineers in Jacksonville, Fla. to acquire water budget data.
5. Visit to the U. S. Geological Survey in Miami, Fla. to obtain groundwater data.
6. Visit to the Southern Branch, Soil and Water Conservation Research Division, Agricultural Research Service, USDA, Fort Lauderdale, Fla. to obtain evapotranspiration estimates.
7. Follow-up visits to the FCD main office.

Overall Summary—We were unable to find a comprehensive appraisal of the hydrology of the areas in any report or small number of reports. Much information is available but it is necessary to contact a wide variety of agencies to obtain an understanding of the problem. A considerable step towards a comprehensive appraisal of the hydrology of the Everglades system will result from the forthcoming publication of a U.S.G.S. open file report titled "Hydrologic Effects of Water Control and Management of Southeastern Florida." However, details of the hydrology of the conservation areas must still be obtained by the reading of many individual reports, principally Corps design memoranda. It should be further noted that the "as built" details of structures in the conservation areas are apt to differ from those presented in the various preliminary reports.

In terms of a data base, an extensive array of rainfall, stage, flow and other records exists; however, it is necessary, in many cases, to obtain these data from the different agencies responsible for a particular set of measurements. The FCD eventually accumulates most of the data but not necessarily all. The FCD would be the logical location for a centralized file of all relevant hydrologic and hydraulic data. Computerization of such data (i.e., storage on punched cards or tapes) would make it considerably more accessible than it presently is. Observations on the adequacy of certain measurements are made below.

Adequacy of Raingage Network—It is apparent when conducting detailed analyses of the hydrology of the conservation areas that the raingage coverage is inadequate. The required number of gages may be determined using the techniques of Eagleson, who developed criteria for raingage densities based upon allowable errors in pertinent hydrologic variables (1). In particular, Eagleson determined the number of equally spaced gages necessary to predict runoff discharges within a certain tolerance and the number necessary to properly determine long-term spatial variations in point rainfalls. He also considered two storm patterns, convective and cyclonic. Cyclonic storms (e.g., hurricanes), typically are of a much greater areal extent than are convective (e.g., thunderstorms). Consequently, the density of gages required to monitor them is lower. Our attention is thus directed to convective storms which are typical of South Florida during much of the year.

Eagleson's method was used to assess the desired number of gages for the two purposes previously mentioned, runoff prediction and determination of the spatial variation of rainfall. For the former, the number of gages is based on an allowable error of 10% in predicted discharges. For the latter, the number is based on an allowable 10% error in the measured spatial variance of the point rainfalls. Assumptions and calculations are presented in Appendix A and the results given in Table 1.

Table 1 shows that the conservation areas are considerably undergaged. It should be pointed out that the case A values (runoff prediction) are approximately inversely proportional to the maximum storm depth and have been computed for depths of one and two inches. Examination of rainfall records indicates the vast majority of daily rainfall increments are less than one inch, so that the one-inch case A values are conservative only for the infrequent rainfalls of more than one inch. It should be further noted that the analysis assumes *equally spaced* gages (on a rectangular or triangular grid, for example). Although it is never possible to have a perfect geometrical spacing, there is room for considerable improvement. In particular, additional gages are needed in the interior of Area 3A, especially in the vicinity of Alligator Alley and C-123.

The required number of rain gages is a function of the use to which the data will be put. The case B analysis, for instance, requires less gages because it is concerned only with long term (e.g., annual) variations in point rainfalls. Table 1 shows that the present gaging network is not as deficient in this category as for the case A analysis where the gaging network is to be used to predict flows in one part of the system due to rainfall in another part. In this regard, the response of the system of conservation areas may be so dampened that a one-inch storm will have only a minor effect regardless of where it occurs, and it may be more appropriate to design the gaging network on the assumption of a two-inch storm. In this event,

TABLE 1

Required Number[a] of Equally Spaced Raingages in Conservation Areas

Case A: Limit error in runoff prediction to 10%.
Case B: Limit error in predicted long-term spatial variance of point rainfalls to 10%.
Calculations and assumptions in Appendix A.

Location	Area (Miles^2)	Number of Gages Case A		Case B	Present (1971)
		1" Storm	2" Storm		
Area 1	221	14	6	10	7
Area 2A	173	13	5	10	5
Area 2 (Total)	210	14	6	10	7
Area 3A	752	20	10	10	10
Area 3 (Total)	904	25	13	10	10
N.W. Corner, Area 3A[b]	100	6	4	5[c]	1

[a]All values rounded to nearest whole number.

[b]Bounded on the south by Alligator Alley and on the east by C-123.

[c]Value for error in prediction of 20%. Impractical to reduce beyond this value.

the principal effort should be in *spacing* of additional gages such that the coverage is as uniform as possible.

It should be noted that the required numbers given in Table 1 are only for rainfall and runoff in the conservation areas themselves. An adequate raingage density for portions of the Everglades that are tributary to the conservation areas should be determined using the same techniques.

The type of recording raingage and data reduction technique presently in use is adequate since daily totals are sufficient to define the response of a highly dampened natural catchment that is characteristic of the conservation areas. Finally, it is known that FCD personnel are presently installing some additional gages in Area 3A.

Adequacy of Stage Gage Network—A similar analysis to that performed by Eagleson on rain gages could be performed for stage gages taking into consideration the wave lengths of the surface waters as they move through the areas. Although such an analysis has not been performed in this study, it would most probably lead to the conclusion that the portions of the areas are again undergaged. From the hydrologic analyses that have been attempted, the interior of Area 3A stands out as the region in which it is most difficult to properly determine water levels from past records. Additional recording stage gages should be installed at locations in this area where it is important to have an accurate estimate of water levels. The region north of Alligator Alley immediately comes to mind.

Discharge Measurements—Most inflows into the conservation areas are regularly gaged by the U.S.G.S. on a daily basis. In the study of flow patterns in the areas it would be of considerable usefulness to have additional flow measurements within the area boundaries. This is presently done at monthly intervals by FCD personnel at the bridges along Alligator Alley and infrequently at other locations. Measurements at other locations along canals would give an indication of the amounts and directions of lateral inflows into these conveyance facilities. Such data would be considerably easier to interpret during periods of low water than during periods when stages rise above bank elevations. However, during periods of high water, an intensive short term survey of flows in a given region could be used to determine the effect of particular structures on the drainage of a particular region (e.g.,the effect of Alligator Alley and C-123 on the drainage of the northwest corner of Area 3A). Although such data would be open to the criticism that they represent the effect of a very particular storm and set of antecedent conditions, if the rainfall and water levels of the region were sufficiently well defined, it should be possible to make generalizations as to the hydrologic behavior of the region.

If at all possible, it would be desirable to gage the flows through Alligator Alley at more frequent intervals during periods of high water when drainage problems are anticipated. The use of such data will be illustrated in the discussion of Phase 5 of this report.

Area Topography—Recent measurements of ground contour elevations have been made only in Area 1. Contour measurements in the other areas predate the construction period. Uses for ground contours include both the formulation of stage-storage-water surface area relationships and the determination of runoff patterns. Interestingly, when the revised Area 1 contours were used to develop new stage-storage-area relationships, they differed little from the ones based on the old contours. This is logical because the effect of integration is to reduce errors. However, studies of overland flow, for example, would be highly dependent upon accurate contour information. A computer simulation model that predicted flows and stages could be used to test the sensitivity of the results to changes in contour locations. Such information could then be used to determine the need for additional surveys with which to update existing contour information.

It is also observed that contour locations must necessarily be averages of the actual land surface elevations because of the prevailing pattern of islands and sloughs.

III. *Phase 2:* A two day reconnaissance of study area.

An aerial reconnaissance of the conservation areas was made in the FCD amphibian aircraft. The trip provided a much better appreciation of the large size of the area and the extended residence time of water moving through the area. It does lead one to question the accuracy of the popular "river of grass" description of the natural movement of water from Lake Okeechobee to the Everglades National Park. The travel time of a parcel of water from Lake Okeechobee to the entrance of Everglades National Park is several months. Thus, the water entering the Park under natural conditions would more likely come from drainage of the land in the immediate vicinity.

IV. *Phase 3:* Formulation of a study plan for determining the water budget within the study area.

In order to understand the hydrology of such a complex and dynamic system and to make some judgments regarding system operation it was decided to perform three water budgets as described below:

1. Annual budget for the three conservation areas based on Corps of Engineers design memoranda.

2. Monthly budget for the three conservation areas for the period from July 1969 to June 1970 based on Corps of Engineers records.

3. Daily budget for water conservation area 3A for October 1969 and April and May 1970 using a computer simulation model.

V. *Phase 4:* Analysis and evaluation of available information related to the water budget.

Annual Budget—The annual budget provides a perspective on how the system might function if actual operation follows design and planning estimates (2,3,4). A comparison is made of how the system might function under full development of the authorized projects and the observed operation during July 1969 to June 1970. Also the impact of changes envisaged in the more recent plan (5) are discussed.

A comparison of design vs. actual flows for Water Conservation Area No. 1 is shown in Table 2. The annual rainfall is about five inches below the historical average. The budget shows that man-induced inflows were the largest single source of water and were much higher than expected. Other items in the budget differ by much less.

A comparison of design vs. actual flows for Water Conservation Area No. 2A is shown in Table 3. The annual rainfall is almost six inches above the historical average. Exogenous outflows are larger than anticipated and the outflow from Water Conservation Area No. 1 is the single most significant source of water.

Lastly, a comparison of design vs. actual flows for Water Conservation Area No. 3A is shown in Table 4. The annual rainfall is about nine inches higher than the historical average. Rainfall is seen to be the single most significant source of water for the area. Actual exogenous inflows are larger than for design conditions. Also, outflows are much larger than design conditions.

It is useful to examine the variation in rainfall that is observed on a long-term basis (1930 to 1955) with the study year. The results

TABLE 2

Annual Water Budget
Water Conservation Area No. 1

Commodity	Flow - 1000 A-F	
	Design Condition [a](2)	Actual F.Y. 1970 [b]
A. Sources		
1. Natural	746	676
2. Man	351	788
Sub-total, Item A	1097	1464
B. Sinks		
1. Natural		
Evapotranspiration	584	505
Seepage	118	106
2. Man		
Exogenous	52	132
Endogenous (to C.A. No. 2)	346	607
3. Change in Storage	0	-12
4. Unaccounted for	-3	126
Sub-total, Item B	1097	1464

[a]Results of average annual routing of 1930-1955 hydrologic trace. Average rainfall = 62.50 in./yr.

[b]Rainfall = 57.66 inches for period from July 1969 to June 1970.

TABLE 3

Annual Water Budget
Water Conservation Area No. 2A

Commodity	Flow - 1000 A-F	
	Design Conditions[a] (3)	Actual F.Y. 1970[b]
A. Sources		
1. Natural	520	576
2. Man		
a. Exogenous	261	235
b. Endogenous (from C.A. No. 1)	347	608
Sub-total, Item A	1128	1419
B. Sinks		
1. Natural		
a. Evapotranspiration	440	407
b. Seepage	78	162
2. Man		
a. Exogenous	7	286
b. Endogenous (to C.A. 3A)	603[c]	637
3. Unaccounted for and change in storage	0	-73
	1128	1419

[a]Results of average annual routing of 1930-1955 hydrologic trace. Average rainfall = 56.88 in./yr.

[b]Rainfall = 62.59 inches for period from July 1969 to June 1970.

[c]Calculated residual volume.

TABLE 4

Annual Water Budget
Water Conservation Area No. 3A

Commodity	Flow - 1000 A-F	
	Design Conditions[a] (4)	Actual F.Y. 1970[b]
A. Sources		
1. Natural	2221	2489
2. Man		
a. Exogenous	511	1035
b. Endogenous (from C.A. No. 2A)	603	637
Sub-total, Item A	3335	4161
B. Sinks		
1. Natural		
a. Evapotranspiration	1975	1718
2. Man (including seepage)[c]	1360	2823
3. Change in storage	0	-380
4. Unaccounted for	0	0
	3335	4161

[a]Results of average annual routing of 1930-1957 hydrologic trace. Average rainfall = 53.0 in./yr.

[b]Rainfall = 62.01 inches for period from July 1969 to June 1970.

[c]Calculated residual volume.

are shown in Table 5. The variation in long-term annual average rainfall is striking. There is almost a 10 inch/yr. variation in rainfall between No. 1 and No. 3A, much more than one would expect *a priori*.

TABLE 5

Comparison in Annual Rainfall on Study Areas

Study Area	Rainfall - Inches/Yr. 1930-1955	1969-70
Water Conservation Area No. 1	62.5	57.66
2A	56.9	62.59
3A	53.0	62.01

Currently, the operation is based on the conservation areas being used as the principal sink for water from the agricultural areas and as a third priority sink for water from Lake Okeechobee. Surplus water in Lake Okeechobee would be diverted first to the Caloosahatchee River and St. Lucie Canal and eventually directed to the ocean.

However, it is now being proposed to modify the system design and operation to permit more intensive utilization of the conservation areas (5). A summary of the salient modifications is presented below:

1. Raise the level of Lake Okeechobee about 4 feet above presently authorized levels.

2. Make pumpage of surplus waters to the conservation areas of first priority if they are below schedule.

3. Backpump drainage from several areas along the east coast into the conservation areas if excess storage capacity is available.

In addition to attempting to service a large agricultural and urban demand, backpumping into the conservation areas will provide additional inflows as outlined in Table 6.

Another significant source of water into the conservation areas will come as a result of its being the first priority sink for surplus water.

TABLE 6

Anticipated Backpumpage to Conservation Areas - Revised Plan (5)

Source	Additional Annual Amount 1000 A-F/Yr.	Sink
West Palm Beach Canal	303	Conservation Area No. 1
Hillsboro Canal	133	" " " 2A
Canal 11 Area	230	" " " 3A
Tamiami Canal	44	" " " "

The operating policy would be as follows (5g):

1. If conservation areas are below regulated stage, route water to No. 1, No. 2A and No. 3A.
2. If conservation areas are at, or above, regulated stage, route water to No. 3A.

This operating rule would appear to have a highly significant impact on the hydrologic regime of the conservation areas, particularly, No. 3A. However, we were unable to find any published estimates of the anticipated amount of water that would enter the three areas as a result of this policy.

This modified system is projected to be adequate until the year 2004. Suggested possible additional water to supply needs beyond that point in time are additional backpumping to Lake Okeechobee and to Water Conservation Area No. 3A and providing higher level subimpoundments in the northern portions of Water Conservation Areas Nos. 1 and 3A.

Based on the annual budget it appears that Water Conservation Areas No. 1, 2A and 3A are receiving a relatively balanced mix of inputs based on *average* conditions for the study year and design conditions. The wide variation in the spatial and temporal precipitation pattern in southern Florida renders conclusions based on *average* conditions quite tenuous.

Thus, about all that can be said thusfar is that there is no persistent dominance of the conservation areas by man or nature.

Monthly Budget—A monthly water budget was developed for the three conservation areas using historical records for the period from July 1969 to June 1970. This budget provides a way of evaluating the accuracy of various assumptions regarding seepage through the levees, evapotranspiration, movement to the groundwater system, and other hydrologic parameters. It also provides an evaluation of the relative contribution of natural and man-induced discharges of water through the system and the seasonal variations in these flows.

A summary of the monthly budget for Water Conservation Area No. 1 is shown in Table 7. Stages range from a maximum of 17.89' in November to 15.07' in May - a difference of 2.82'. The majority of the man-induced inflow comes from S-5A and most of the outflow is directed toward Water Conservation Area No. 2A. Beginning of the month storage fluctuates from

TABLE 7

Monthly Hydrologic Budget
Water Conservation Area No. 1
July 1969 - June 1970

Month	Stage-Ft. Maximum	Stage-Ft. Minimum	Rainfall In.	Rainfall 1000 A-F	Evapotranspiration In.	Evapotranspiration 1000 A-F	Inflows-1000 A-F S-5A	Inflows-1000 A-F S-6	Inflows-1000 A-F Total	Outflows-1000 A-F S-10	Outflows-1000 A-F S-39	Outflows-1000 A-F Seepage	Outflows-1000 A-F Total	Storage-1000 A-F Initial	Storage-1000 A-F Final
July	15.91	15.41	5.22	61	4.7	55	13	16	29	19	7	6	32	136	145
Aug.	16.23	15.76	6.65	78	5.0	59	51	27	78	58	10	6	74	145	152
Sept.	16.85	15.81	6.34	75	4.1	48	46	38	84	5	0	8	13	152	240
Oct.	17.38	16.62	8.33	98	3.7	44	79	39	118	29	1	10	40	240	372
Nov.	17.89	17.28	3.60	42	2.5	29	35	23	58	50	22	11	83	372	347
Dec.	17.57	17.00	0.63	7	1.7	20	6	9	15	23	26	10	59	347	282
Jan.	17.13	16.96	1.44	17	1.8	21	28	21	49	0	10	12	22	282	299
Feb.	17.30	16.52	2.16	25	2.2	26	17	15	32	71	1	13	85	299	215
Mar.	16.98	16.42	9.83	115	4.1	48	126	65	191	156	13	12	181	215	250
Apr.	17.01	15.49	0.28	3	3.5	41	25	4	29	129	24	11	164	250	60
May	15.52	15.07	4.48	53	4.1	48	35	21	56	0	12	2	14	60	102
June	16.11	15.47	8.70	102	5.6	66	31	18	49	67	6	5	78	102	124
TOTAL	17.89	15.07	57.66	676	43.0	505	492	296	788	607	132	106	845	-	-

a high of 372,000 acre-feet on Nov. 1 to a low of 60,000 acre-feet on May 1. There is a relatively wide variation in precipitation, inflows, and outflows.

A description of the relation of the conservation areas to the region is shown in two figures in Appendix E of the Survey report. These figures (see App. B) provide a description of the sources and sinks for the water under the projected modified plan with backpumping. A perusal of these two figures provides a perspective on the size of the storage areas relative to the total area to be drained and supplied with water. A monthly budgeting of these areas was done as part of the survey report. However, insufficient data were presented in the report to permit us to perform a similar analysis.

A summary of the monthly budget for Water Conservation Area No. 2A is shown in Table 8. Stages range from 15.46' to 12.63' - a difference of 2.83'. Inflow from Water Conservation Area No. 1 is the largest single source and most of the outflow is directed towards Water Conservation Area No. 3A. There is a wide variation of inflows and outflows.

Lastly, a summary of the monthly budget for Water Conservation Area No. 3A is shown in Table 9. Stages range from 11.55' to 9.51' - a difference of 2.04'. As with the other areas, there is a wide variation in the distribution of inflows and outflows.

Due to the sporadic nature of the phenomena occurring in these areas it is difficult to draw any general conclusions. It is possible to perform a time series analysis of the data with the hope of obtaining a basis for making predictions (6). Using time series analysis, an observation, say X_i, may be partitioned into two components, or

TABLE 8

Monthly Hydrologic Budget
Water Conservation Area No. 2A
July 1969 - June 1970

Month	Stage-Ft. Maximum	Stage-Ft. Minimum	Rainfall In.	Rainfall 1000 A-F	Evapotranspiration In.	Evapotranspiration 1000 A-F	Inflows-1000 A-F S-7	Inflows-1000 A-F S-10	Inflows-1000 A-F Total	Outflows-1000 A-F S-11	Outflows-1000 A-F S-38 + Others	Outflows-1000 A-F Seepage	Outflows-1000 A-F Total	Storage-1000 A-F Initial	Storage-1000 A-F Final
July	12.87	12.63	6.75	62	5.2	48	21	19	40	40	5	10	55	181	186
Aug.	13.50	12.85	4.96	46	4.3	39	26	58	84	53	19	12	84	186	244
Sept.	13.75	13.29	6.00	55	4.1	38	26	5	31	0	0	12	12	244	289
Oct.	14.90	13.82	10.20	94	4.4	40	43	29	72	0	0	15	15	289	420
Nov.	15.46	14.98	4.01	37	2.6	24	24	50	74	0	37	22	59	420	446
Dec.	15.15	14.35	1.21	11	1.7	16	10	23	33	23	55	22	100	446	361
Jan.	14.34	13.97	2.48	23	1.8	17	2	0	2	34	1	15	50	361	316
Feb.	14.18	13.80	1.92	18	2.2	20	1	71	72	105	0	13	118	316	289
Mar.	14.73	13.42	9.00	83	4.0	37	46	156	202	200	53	11	204	289	324
Apr.	14.22	13.15	0.03	0	3.5	32	0	130	130	120	75	11	206	324	209
May	13.10	12.47	6.16	56	4.7	43	16	0	16	0	7	11	18	209	201
June	13.57	12.90	9.87	91	5.8	53	20	67	87	62	34	8	104	201	253
TOTAL	15.46	12.63	62.59	576	44.3	407	235	608	843	637	286	162	1085	-	-

TABLE 9

Monthly Hydrologic Budget
Water Conservation Area No. 3A
July 1969 - June 1970

Month	Stage-Ft. Maximum	Stage-Ft. Minimum	Rainfall In.	Rainfall 1000-A-F	Evapotranspiration In.	Evapotranspiration 1000 A-F	Inflows-1000 A-F S-8	S-9	S-11	L-3	Other	Total	Outflows-1000 A-F S-12	Other	Total	Storage-1000 A-F Initial	Final
July	10.97	10.73	6.23	250	5.15	206	16	11	40	68	61	196	215	50	265	1180	1145
Aug.	10.81	10.73	4.61	185	4.30	172	33	23	53	40	46	195	195	52	247	1145	1115
Sept.	10.82	10.63	7.19	288	4.1	164	14	6	0	18	12	50	183	48	231	1115	1145
Oct.	11.38	10.51	13.90	560	4.0	160	48	27	0	16	27	118	191	49	240	1145	1385
Nov.	11.55	11.08	1.88	75	2.0	80	22	37	0	13	26	98	271	52	323	1385	1260
Dec.	11.07	10.52	0.87	35	1.7	68	16	0	23	5	7	51	220	50	270	1260	1030
Jan.	10.63	10.42	2.61	105	2.0	80	40	5	34	6	33	117	127	48	175	1030	966
Feb.	10.39	10.31	1.71	68	2.2	88	38	3	105	6	28	180	153	42	195	996	935
Mar.	10.80	10.25	8.36	335	3.5	140	22	22	200	49	25	318	182	80	261	935	1145
Apr.	10.81	10.21	0.06	2	3.5	140	0	0	120	51	51	223	188	98	286	1145	895
May	10.16	9.51	5.37	216	4.8	192	3	8	0	3	9	23	69	56	125	895	710
June	10.13	9.83	9.22	370	5.7	228	3	16	62	7	15	103	138	77	215	710	800
TOTAL	11.55	9.51	62.01	2489	42.95	1718	255	158	637	282	340	1672	2132	702	2834	-	-

$$\chi_i = \chi_i' + \chi_i''$$

where

χ_i' = deterministic element, and

χ_i'' = random element.

If the random element, χ_i'', is much larger than χ_i', then our ability to make predictions is correspondingly diminished. While time did not permit such a detailed analysis it appears that χ_i'' would be the dominant component. Hence our ability to make predictions using this approach is quite limited.

The monthly budgeting did provide a way to compare various estimates of evapotranspiration under the assumption that unaccounted for flow, $Q_{i,t}$ equals evapotranspiration ($ET_{i,t}$) plus or minus a constant (K_i) for the i^{th} study area, or

$$Q_{i,t} = ET_{i,t} + K_i \quad \text{for } \begin{array}{l} i = 1, 2, 3, \text{ and} \\ t = 1, 2, \ldots, 12 \end{array}$$

It was hypothesized that K_i, if nontrivial, is attributable to some constant source or sink. This analysis was done for each of the three study areas. The results should be most reliable for areas 1 and 2A. Water Conservation Area No. 3A has an opening on the west end which reduces the reliability of the estimates.

Three evapo-transpiration estimates were used:

1. Corps of Engineers,
2. U.S.D.A. estimates (7) and
3. pan-evaporation records at Station S-7.

Summary information for Water Conservation Area No. 1 is shown in Table 10. The results of this analysis, and similar analysis for the other

TABLE 10

Analysis of Unaccounted for Flow
Water Conservation Area No. 1
1969 - 1970

Period	Evapotranspiration Estimates-In./Mo. C. of E.	Stewart & Mills(7)	Pan-Evap.	Unaccounted for Flow Using C. of E. Estimate 1000 A-F/Mo.
7/69	4.7	4.8	4.3	- 7
8/69	5.0	4.8	4.3	+16
9/69	4.1	3.8	2.9	+ 9
10/69	3.7	3.4	3.8	+ 1
11/69	2.5	2.5	3.5	+12
12/69	1.7	1.9	3.2	+ 9
1/70	1.8	2.0	2.7	+ 6
2/70	2.2	2.5	3.0	+31
3/70	4.1	3.4	4.1	+41
4/70	3.5	4.2	6.4	+18
5/70	4.1	5.2	4.7	+ 4
6/70	5.6	4.2	4.3	-14

two areas, do not reveal any evapotranspiration estimating method which is superior. The residuals (K_i) while usually positive, varied widely. However, the magnitude of the residual, with few exceptions, was small relative to other sources and sinks.

Discussion with groundwater hydrologists indicated that the amount of water entering the groundwater system was not too significant. Thus, this problem was not analyzed in further detail in this preliminary study. We note, however, that a portion of areas 2 and 3 serves as a recharge area for the Biscayne Aquifer.

As with evapotranspiration, various methods are available to estimate seepage. However, insufficient information exists to consider seepage as a known source or sink. It remains a portion of the *other* sources or sinks of water.

A monthly inventory of sources of water was prepared for the northwest corner of Water Conservation Area No. 3A in order to assist in obtaining insight into system response during the high water periods of later 1969 and early 1970. The assumed area is bounded (artificially) on the east by the Miami Canal and on the south by Alligator Alley. It is assumed that one-half of the S-8 inflow and all of the L-3 and S-140 inflows enter this area of 64,000 acres. The results of this analysis are shown in Table 11. For the October 1969 storm it is seen that precipitation is the prime source of water. However, for the March-April 1970 storm inflow from L-3 was the largest source of water. Thus one can conclude that natural causes were of prime importance in the former case while the uncontrollable L-3 inflow provided the sustained source of water to extend the high water period during the latter period.

TABLE 11

Monthly Inflows (1000 A-F) to Northwest Corner
of Water Conservation Area 3A

Period	(S-8)/2	L - 3	S-140	Rainfall
7/69	8	68	-	30
8/69	16	40	-	20
9/69	7	18	-	22
10/69	24	16	-	58
11/69	11	13	-	11
12/69	8	5	-	9
1/70	20	6	-	11
2/70	19	6	-	12
3/70	11	49	-	51
4/70	0	51	16	0
5/70	1	3	2	35
6/70	1	7	0	44

Daily Budget—Lastly an attempt was made to perform a daily budget of Water Conservation Area No. 3A for the fall of 1969 and the spring of 1970. The purpose of the budget was to obtain a comprehensive evaluation of the separate effects of various sources of water (relative to any specified receptor point within the study area).

Due to the complexity of the problem and the lack of an adequate data base it was decided that a computer based simulation model was needed. Time did not permit developing a model for this purpose. Thus, we attempted to modify a model that has been developed for analyzing the hydrodynamics and water quality changes in lakes and estuaries.

Using a daily time step, the model accepts external inflows, precipitation, evapotranspiration, seepage losses, and outflows and then routes this water and the water already in the system according to the hydraulic characteristics of the area. The state of the system is determined at the end of each time period and the results printed in tabular and/or graphical form.

The study area is partitioned into a set of nodes and channels as illustrated in Figure 2.

The area associated with a given node is determined by constructing Thiessen polygons. Water moves from node to node along these channels and continuity of mass is satisfied by evaluating the inflow, outflow, and change in storage at each node.

Water Conservation Area No. 3A was partitioned into a descretized system of 40 nodes and 94 channels. We were successful in getting the program to run. However, it needs additional modifications and testing before it can be considered verified.

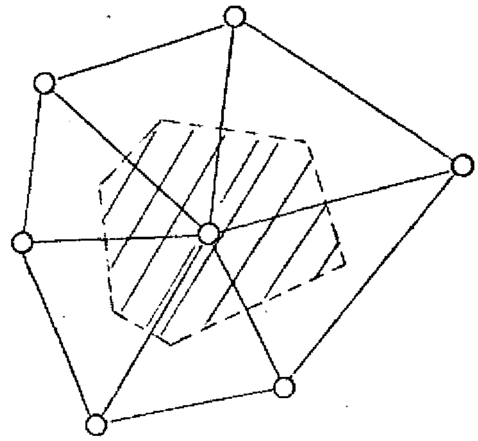


Figure 2. Sample partitioning of study area into nodes and channels.

The model can also be used for estimating water quality changes in the study area. Indeed, it was hoped to use this capability to permit us to follow the movement of water from a specific source as it moves through the study area. This can be accomplished by introducing a known concentration of a conservative commodity into the water entering at a given node. Since this is the only source of the commodity, it is possible to determine the portion of water at a given receptor that came from the source of interest.

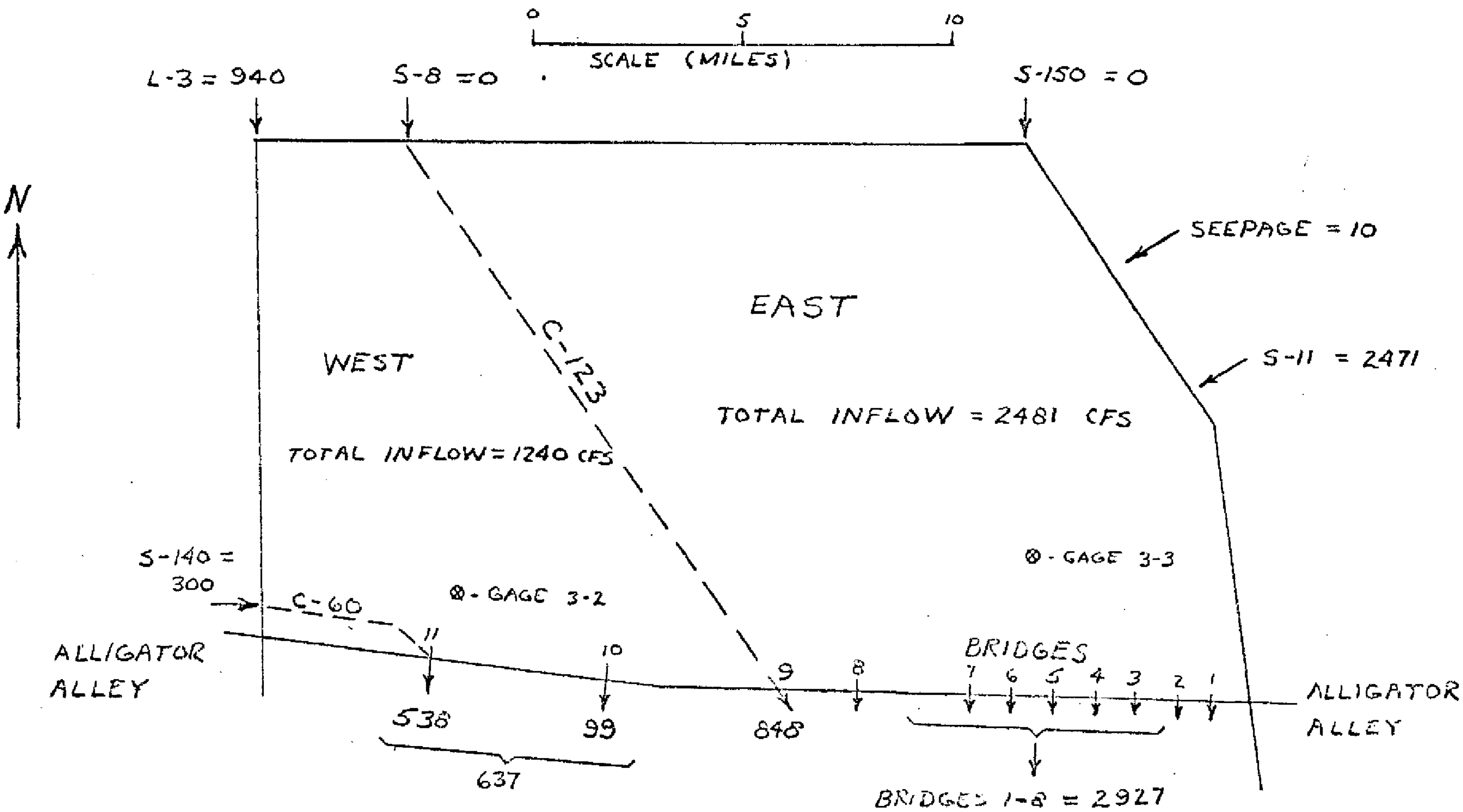
This capability would be extremely useful for conducting environmental impact studies as it provides a systematic way to evaluate the separate effects of changes in the system. Our intention, for this preliminary study, was to use this approach to evaluate sources of inflow to the Water Conservation Area No. 3A. Unfortunately, the model development had not proceeded to the point to permit us to perform such analyses. Consequently, an alternative approach was utilized. The procedures and findings are described in the next section.

Phase 5: Determination of the relationships and constraints operating on the manipulation of water levels and suggested changes in management practices where needed

Introduction—Area 3A is the largest of the conservation areas and open to the most variation in rainfall and flow patterns. It has also prompted the most interest in its hydrologic characteristics in recent months, particularly in the portion of Area 3A north of Alligator Alley. For these reasons, and because of the fact that there have been no substantial problems in the operation of Areas 1 and 2, the attention of this section will be directed principally towards Area 3A (see Figures 1 and 3).

Two broad structures, C-123 and Alligator Alley, cross the topography of Area 3A. The former was completed in December, 1969, with a capacity of 1000 cfs. The latter was completed in the fall of 1967 and contains 11 bridges to facilitate the movement of water from the north to the south, shown on Figure 3. Water levels in the interior of the northern portion of Area 3A (i.e. north of Alligator Alley) are measured only at gages 3-2 and 3-3, although some additional information may be obtained from daily stage records at S-8 and S-11 and monthly readings at three sites along Alligator Alley. Flows are measured at all points where they enter Area 3A except for the opening to Big Cypress Swamp, although recent measurements along Alligator Alley west of Area 3A by the U.S.G.S. give a good estimate of this inflow. All outflows are measured, and monthly flow measurements are made at the bridges along Alligator Alley.

FCD personnel have analyzed many data relevant to the study of problems of excess water in area 3A. Portions of the following analysis are based upon a review of these efforts.



West: Gage 3-2, 11.8 ft., Approximate water surface area = 72 mile^2
East: Gage 3-3, 11.6 ft., Approximate water surface area = 162 mile^2

Figure 3. Average inflows and outflows to northern portion of Area 3A, April 14-15, 1970. All flows in cfs.

Effects of Rainfall and Inflows on Stages—It is obvious that rainfall, external inflows, and outflows, influence water levels in a direct manner. Stage records at gages 3-2 and 3-3 clearly show a rise in water levels following rainfalls. However, the separate effects cannot be quantified because other inflows to the area are different at different times as are antecedent conditions. Nevertheless, rainfall will nearly always cause an immediate rise in water levels at points distant from canals, regardless of relative inflows and outflows in the area. The rate of recession, however,(in the absence of additional precipitation) reflects the influence of upstream overland flow of precipitation within the conservation area and the eventual impact of external inflows which provide an additional source of water. For example, inflows to Area 3A through S-8 and S-11 cause delayed rises in water levels at gages 3-2 and 3-3 respectively. The time lag varies, probably because of differences in initial water levels. Inflows at S-11 have little or no effect on stages at 3-2 because of the tendency of inflows from S-11 to move south. The effect of inflows at S-8 on stages at 3-3 is unclear, although it is probably small.

Overland flow in the areas is slowed greatly by the high roughness of the natural land surface. For example, estimates of Manning's roughness coefficient range from 0.2 to 1.0 (8). Furthermore, the roughness increases as the depth of flow decreases; overland flow at low depths through sawgrass is almost imperceptible. Under these circumstances, significant backwater effects can develop, retarding the drainage of regions far from canals. This, however, is very much in accordance with conditions prior to construction of drainage facilities; such regions will always drain slowly.

Effects of C-123 and Alligator Alley—It is apparent that recession rates are increased by some control structures, e.g., outlet structures, internal canals, and inhibited by other structures, e.g. Alligator Alley. The difficult part of the analysis is to quantify the relative importance of each of these factors.

Table 12 presents recession rates at gage 3-2 for two spring periods and four fall periods. Since C-123 was completed in December, 1969, an obvious idea is to compare recession rates in the spring and fall of 1970 with similar periods of prior years, however, the fact that the spring and fall 1970 recessions are the longest for their respective time periods of those listed in Table 12 does not mean that C-123 is ineffective in draining the area. The fall 1970 recession rate may be less because the initial stage is lower than any preceeding it. The spring 1970 recession rate may well be influenced by inflows at S-140 and L-3. Thus, the influence of external inflows on the stage in the northwest corner of Area 3A may be seen. (From the standpoint of drainage of this particular region, S-140 would probably have been better placed south of Alligator Alley.)

TABLE 12

Recession Rates at Gage 3-2 During Periods of No Rainfall

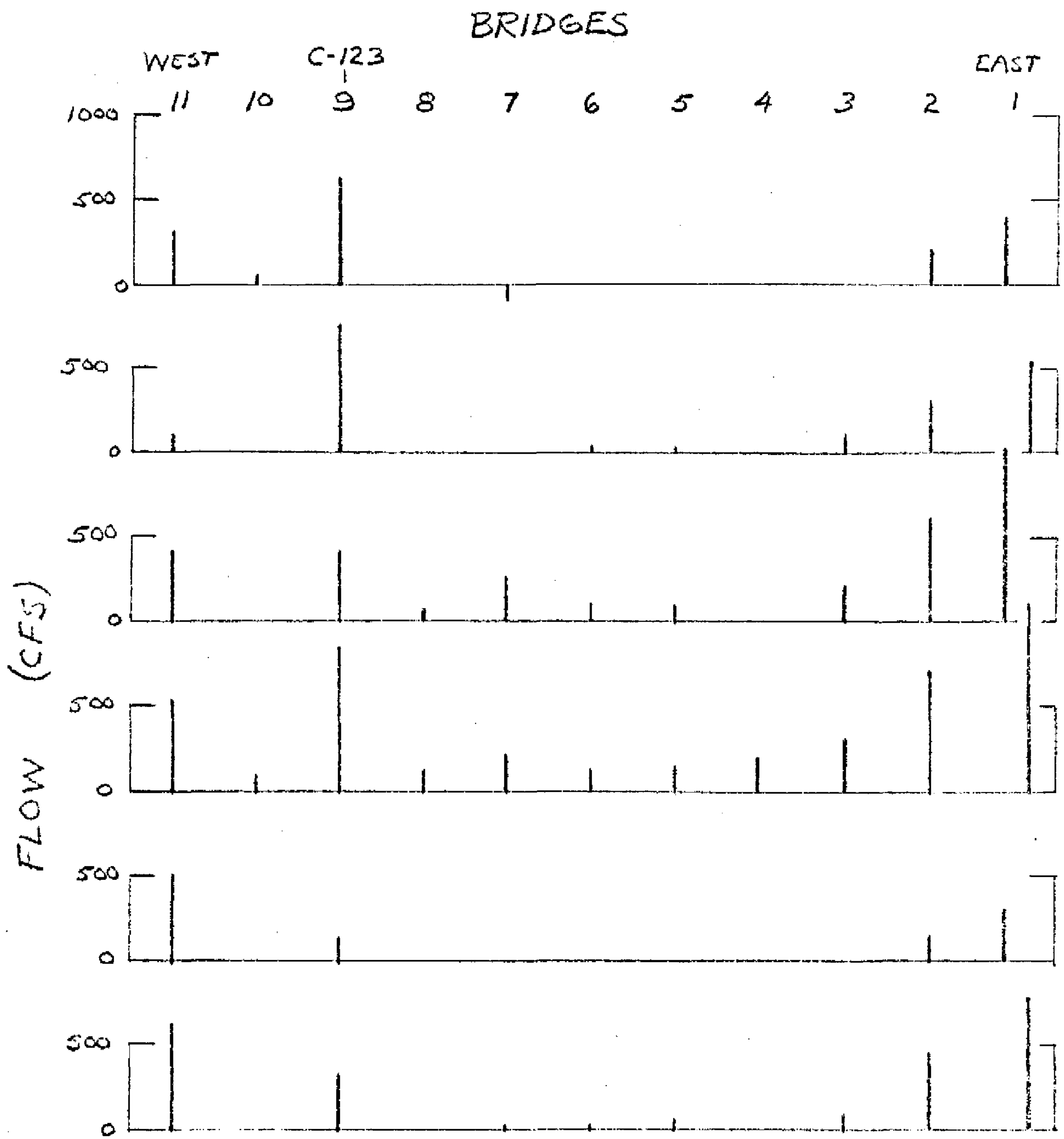
Recession rates computed from FCD data.

Time Period	Initial Stage (ft.)	Recession Rate
1966, Nov.-Dec.	12.7	1 ft./55 days
1968, Nov.-Dec.	11.9	1 ft./69 days
1969, Nov.-Dec.	12.5	1 ft./55 days
1970, Nov.-Dec.	11.5	1 ft./81 days
1968, Mar.-Apr.	10.5	1 ft./24 days
1970, Apr.-May	12.1	1 ft./45 days

The distribution of flows under Alligator Alley is shown in Figure 4 for the period January-June, 1970. The period of April and May was a time of recession of stages north of the highway following an unusually high March rainfall. The figure shows a reasonably uniform distribution of flows through bridges 1-8, with the higher flows at bridges 1 and 2 reflecting S-11 and S-150 discharge. During April, May and June, S-140 contributes some flow to bridge 11. Flow at Bridge 9 (C-123), consists mainly of S-8 discharge during January and February. There are no significant S-8 discharges during April, May or June so that the Bridge 9 flow on April 14, 15 consists entirely of runoff from adjacent areas and possibly a contribution from inflow at the northwest corner from L-3. The flow in C-123 will be examined in more detail later.

Figure 4 plainly illustrates the ineffectiveness of Bridge 10 in draining the upstream area. Most of the overland flow from the northwest corner of Area 3A apparently drains through Bridges 9 and 11. The hinderance to drainage in the vicinity of Bridge 10 can be further seen from an examination of staff gage readings at FCD site 2, located on Alligator Alley midway between Bridges 9 and 10. Readings are taken monthly on both sides of the highway. A selection of readings from the gages is presented in Table 13 along with readings at gage 3-2.

The stage differences range to over one foot across Alligator Alley. At the beginning of the April-May 1970 recession, stages at gage site 2 were only 0.1 foot apart. However, during the month of April while the stage at gage 3-2 dropped 0.8 feet and the stage on the south side of Alligator Alley dropped 1.03 feet, the stage on the north side dropped only 0.14 feet. The highway apparently impedes the southerly drainage



DATE (1970)	INFLOWS (CFS) S-140	L-3	S-8	S-11 + S-150
JAN. 6	–	70	551	556
JAN. 28, 29	–	84	788	518
FEB. 26, 27	–	54	185	1154
APR. 14, 15	300	940	0	2471
MAY 12, 13	86	43	0	0
JUN. 11, 12	233	57	0	1411

Figure 4 . Distribution of flows through Alligator Alley. Tabulated from monthly measurements by FCD. See Figure 3 for location of bridges. Inflows are average values on dates shown.

in that area while Bridge 10 concurrently carries little or no flow. A possible solution to this problem would be an extension from Bridge 10 of the borrow canal on the north side of Alligator Alley in both directions (east and west). Such an arrangement would be expected to channel much of the water that presently backs up against the highway toward Bridge 10, producing greater utilization of that structure.

TABLE 13

Staff Gage Readings at FCD Site 2

	Stage (Ft.)		
Date	North	South	Gage 3-2
2/27/69	9.32	9.28	10.7
3/8/69	10.98	10.34	10.7
4/8/69	11.30	10.58	11.2
5/6/69	11.08	10.60	11.2
2/6/70	10.92	10.80	11.3
4/1/70	11.50	11.40	12.1
5/6/70	11.36	10.37	11.3
6/2/70	11.50	10.20	11.3
7/8/70	11.62	10.26	11.4
8/4/70	10.90	10.72	11.4

Source of Inflows to C-123—This section presents an estimate of the origin of inflows to C-123. Flows are examined on April 14-15, 1970 - a time when discharge measurements through Alligator Alley are available. The time period corresponds to the April-May, 1970 recession previously discussed.

Measured inflows and outflows on these dates are shown on Figure 3. Quantities shown are averages for the two days. All inflows (S-140, L-3, S-11, seepage) were reasonably constant during the first two weeks of April, and there was no precipitation after March 31.

Flows through bridges 1-8 are assumed to originate from the region east of C-123 while flows through bridges 10 and 11 are assumed to originate from the region west of C-123. Since there is no inflow at S-8, the 848 cfs flowing in C-123 at Alligator Alley must have its origin either east or west of the canal. It was observed that at this time, the recession rates at gages 3-2 and 3-3 were equal. The recession rate is approximately equal to

$$\frac{\Delta \text{ stage}}{\Delta \text{ time}} \simeq \frac{\text{Outflows} - \text{Inflows}}{\text{Water Surface Area}}$$

The inflows to the system at the time are known and shown on Figure 3. Neglecting evapotranspiration and seepage, the total outflow equals the total flow through Alligator Alley, 4412 cfs. Let Q_{o_E} be the outflow from the region east of C-123 and Q_{o_W} be the outflow from the region west of C-123; both Q_{o_E} and Q_{o_W} are to be determined. One equation results from the known total outflow through Alligator Alley:

$$Q_{o_E} + Q_{o_W} = 4412 \text{ cfs}$$

The second equation is obtained by equating the recession rates in each area.

$$\frac{Q_{o_E} - 2481}{A_E} = \frac{Q_{o_W} - 1240}{A_W}$$

Water surface areas in the eastern and western regions were estimated to be A_E = 162 mile^2 and A_W = 72 mile^2 respectively.

Solution of the simultaneous equations yields Q_{O_E} = 2960, Q_{O_W} = 1452 cfs. The contribution to C-123 from the east region is thus 2960 - 2927 = 33 cfs. The contribution from the west region is 1452 - 637 = 815 cfs. Note that 815 + 33 = 848 cfs, the flow in C-123.

The above analysis cannot be regarded as strictly quantitative because of the several assumptions involved. However, it certainly indicates that the vast majority of flow in C-123 during this time period originates in the region to the west of the canal. Flow into C-123 from the east may well be impeded by the old Miami Canal and its spoil bank. How much of the flow in C-123 is due to the source L-3 and how much from overland flow has not been determined. It appears at the very least, that C-123 will carry a significant portion of the runoff due to precipitation and inflows to the northwest corner of Area 3A. The span of data is too short to accurately assess the effect of C-123 on the northern portion of Area 3A. However, the data do not contradict the intuitive feeling that the improvement over the old Miami Canal must assist in reducing water levels in the area.

Management alternatives—At present, there are relatively few decision making alternatives available to modify operation of the system for specified purposes. The regulation schedule provides the basic metric of system performance so that it would be possible to assess how well the system adheres to this static decision rule. Such an evaluation could be done with a simulation model. Given such an analysis one could then evaluate whether the current regulation schedule is appropriate or should be revised.

The use of regulation schedules is common in operating water resource systems. The currently used seasonal schedule has evolved as a compromise schedule that seeks to operate the system to the satisfaction of the various interest groups.

It appears that the FCD can exercise a significant control on the pattern of water movement within the three conservation areas. They have at present, relatively limited control over external inputs from, say, drainage of agricultural lands.

The immediate need is for a simulation model that will provide improved estimates on the actual performance of the system on a day to day basis. The output from this analysis would provide information regarding the impact of changing regulation schedules and varying procedures for routing water through the conservation areas. As demands on the system intensify, the model can be refined. This incremental approach should permit a smooth transition to be made in the use of these simulation models.

We do not feel able, at this time, to suggest general management alternatives. Many suggested alternatives have been reviewed but we do not feel that an adequate information base exists to analyze these alternatives. It is easy to become victimized by the isolated phenomenon syndrome in analyzing control alternatives in a complex system serving such a wide variety of purposes.

For example, the deer kill in the northwest portion of Water Conservation Area No. 3A during the spring of 1970 was attributable to the prolonged high water following the heavy rain in March. It is possible to obtain a rough approximation of the seasonal regulation schedule that would encourage development of the deer herd. Unfortunately, such a schedule is not necessarily compatible with other wildlife.

The recently imposed requirement for environmental impact studies should provide the catalyst for conducting the type of studies needed to provide the information base for suggesting long-term management alternatives.

VII. SUMMARY

The purpose of this four month study was to make a preliminary reconnaissance of the hydrology of conservation areas one, two, and three of the Central and Southern Florida project. The work was conducted under the sponsorship of the Central and Southern Florida Flood Control District.

The findings of this study are listed below:

1. At present, no comprehensive appraisal of the hydrology of the study area exists.

2. A central depository for relevent hydrologic, hydraulic, and related data is needed. The FCD would be a logical location for such a system.

3. The coverage of the existing system of raingages is inadequate. Our analysis indicates additional measurements are needed within and around the conservation areas.

4. Additional stage gages are needed, particularly within Water Conservation Area No. 3A.

5. Additional discharge measurements are needed along C-123 within Water Conservation Area No. 3A.

6. Current information regarding the topography within the conservation areas is probably adequate for aggregate studies due to the compensating effects of random errors. However, additional measurements might be needed to conduct overland flow analysis within a given conservation area.

7. The popular "river of grass" description of the hydrology tends to be misleading. The flow at a given point is normally a response to hydrologic conditions in the immediately surrounding area.

8. Results of performing an annual budget do not indicate any obvious dominance of the conservation areas by man or nature.

9. Significant differences in long-term average annual precipitation exist within the conservation areas.

10. Proposed plans for water resources development would further intensify the use of the conservation areas. The existing information base and analysis are inadequate to evaluate the impact of these proposed changes.

11. The seasonal pattern of inflows to the study area shows wide temporal and spatial variation and little regularity.

12. There does not appear to be any obviously preferred empirical estimate for evapotranspiration.

13. Groundwater has not been considered to be a major item in hydrologic budgeting within the conservation areas.

14. Insufficient information exists to consider seepage as a known source or sink. However some estimates are available.

15. Comparison of inflows to the northwest corner of conservation area No. 3A during the fall of 1969 and spring of 1970 indicates that natural inflows predominated in the former case while man induced inflows were the major source during the spring. The future portion of inflows from man is increasing due to S-140 and L-100.

16. A computer-based daily simulation model was developed for Water Conservation Area No. 3A. The model can describe the spatial movement through the study area and determine the separate impact of inflows from individual sources. Unfortunately the model, while operational, is not yet verified.

17. Due to the slow velocity of flow through the conservation areas, and their large sizes, a significant lag effect occurs. A typical response of a stage recorder to precipitation in the general area displays the interactive effects of several phenomena: the initial rise in the hydrograph is due to precipitation in the immediate vicinity of the gage. The rate of recession of the hydrograph (in the absence of additional precipitation) reflects the influence of upstream overland flow of precipitation within the conservation area and the eventual impact of external inflows which provide an additional source of water. Overland flow in the areas is slowed greatly by the high roughness of the natural land surface. Under these circumstances, significant backwater effects can develop, retarding the drainage of regions far from canals.

18. There is a non-uniform distribution of water flowing through the bridges along Alligator Alley.

19 Bridge No. 10 along the western end of the conservation area is ineffective. This situation can be alleviated by extending the borrow canal on the north end of Alligator Alley.

20. The majority of overland flow in C-123 comes from the west bank. Inflows from the east may be impeded by the old Miami Canal and its spoil bank.

21. At present, the FCD can exert significant control on the pattern of water movement within the conservation areas. However, they have limited control over external inputs.

22. A simulation model should be developed for testing the impact of operating procedures. This model should be refined as the need for more refined information evolves.

23. In the long run, the need for sophisticated decision rules will become evident and should be incorporated into the system. This would replace the current seasonal regulation schedule.

VIII. CONCLUSIONS

Water management in Central and Southern Florida has evolved from design and operation of single purpose facilities in a developing area to a complex, multipurpose management problem in a new setting of intense and often conflicting demands on the system. The strong pressures to promote continued growth are now being challenged by those who feel threatened that such growth will ultimately destroy the quality environment that has drawn people into the area.

In nearly all cases, the tendency is for man to attempt to dominate the system rather than accept a certain natural variation. Ironically, he subsequently attempts to insert a "natural" variation in the form of scheduled releases, stages, etc. It should be realized that it is not possible to "have it both ways," and that once man-made controls are established they can never restore a completely "natural" system nor be operated so that every interest group will be pleased.

We hope that the findings from this preliminary study assist in providing the information and insight needed to understand the complex system and hopefully direct its management in the long-term best interests of the people of Central and Southern Florida.

IX. ACKNOWLEDGEMENTS

In our attempt to collect and synthesize information regarding the conservation areas we met with several groups of people who provided the essential cooperation we required for such a short term study.

In particular, Mr. W. Storch, Mr. R. Taylor, and Mr. J. Chao and other members of the Flood Control District were extremely helpful. The assistance of the Jacksonville Office of the Corps of Engineers, particularly Mr. Tabita, Mr. White and Mr. Rowell is also appreciated.
Mr. Spier of the U.S.D.A., Fort Lauderdale, Florida provided much insight on evapotranspiration. U.S.G.S. personnel from the Miami office provided information on the groundwater situation.

The perseverance of Mrs. Nancy Townsend in typing and proofreading was extremely helpful.

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    5a. Main Report
    5b. Report authorization - App. A
    5c. Economic Development - App. B
    5d. Hydrology - App. C
    5e. Alternative Plans - App. D
    5f. Computer simulation program - App. E
    5g. Plan of improvement and costs - App. F
    5h. Benefits and economic justification - App. G
    5i. Preliminary recreation plan - App. H
    5j. Geology and soils - App. I
    5k. Additional sources of water - App. J
    5l. Comment of other agencies and consultants - App. K

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XI. APPENDIX A. CALCULATION OF REQUIRED NUMBER OF RAINGAGES

Following Eagleson's 1967 paper, the calculation of a "correlation radius," r_0, is required. The best method is to use the known spatial distribution of a typical convective storm, obtained from several closely spaced raingages. Alternatively, the spatial distribution could be obtained by examining the time history of a thunderstorm at one station if the velocity of the storm as it moved past the gage was known and was reasonably constant. These data were unavailable in this present study, however, they could be used to check the results. In lieu of rainfall data, Eagleson's general equation for convective storms was used in which $r_0 = 1.73\ P_0$, where r_0 is in miles and P_0 is the maximum storm depth in inches. Then for a one-inch storm, $r_0 = 1.73$ miles, and for a two-inch storm, $r_0 = 3.46$ miles.

The case A analysis (runoff prediction) utilizes Eagleson's Figure 6. The required parameters are

$$\lambda = \frac{w}{2\ell} = \frac{\text{catchment width}}{2 \times \text{catchment length}}$$

$$\beta_A = \frac{\ell}{r_0}$$

Values of these parameters and calculations are shown in Table A-1.

The case B analysis (long term spatial variance) utilizes Eagleson's Figure 9 in which $\beta_B = A^{1/2}/r_0$ where A is the catchment area in square miles. Values are shown in Table A-1.

TABLE A-1

Parameters Used in Calculation of Required Number of Raingages

Case A: Limit error in runoff prediction to 10%.
Case B: Limit error in predicted spatial variance to 10%.
N = Required number of raingages.

Location	Area (mile^2)	Width, w (miles)	Length, ℓ (miles)	λ	Case A: 1" Storm β_A	Case A: 1" Storm N	Case A: 2" Storm β_A	Case A: 2" Storm N	Case B: r_0 (miles)	Case B: β_B	Case B: N
Area 1	221	13.8	20	0.344	11.6	13.9	5.8	6	1.73	8.6	10
Area 2A	173	15	10	0.75	5.8	13.0	2.9	5.4	1.73	7.6	10
Area 2 (Total)	210	17.5	10	0.875	5.8	14.4	2.9	6.3	1.73	8.4	10
Area 3A	752	20	40	0.25	23.1	20.2	11.6	10.1	1.73	15.8	10
Area 3 (Total)	904	25	40	0.313	23.1	25.3	11.6	12.7	1.73	17.4	10
N.W. Corner, Area 3A	100	8.5	15	0.283	8.67	6.13	4.3	3.5	1.73	5.8	5[a]

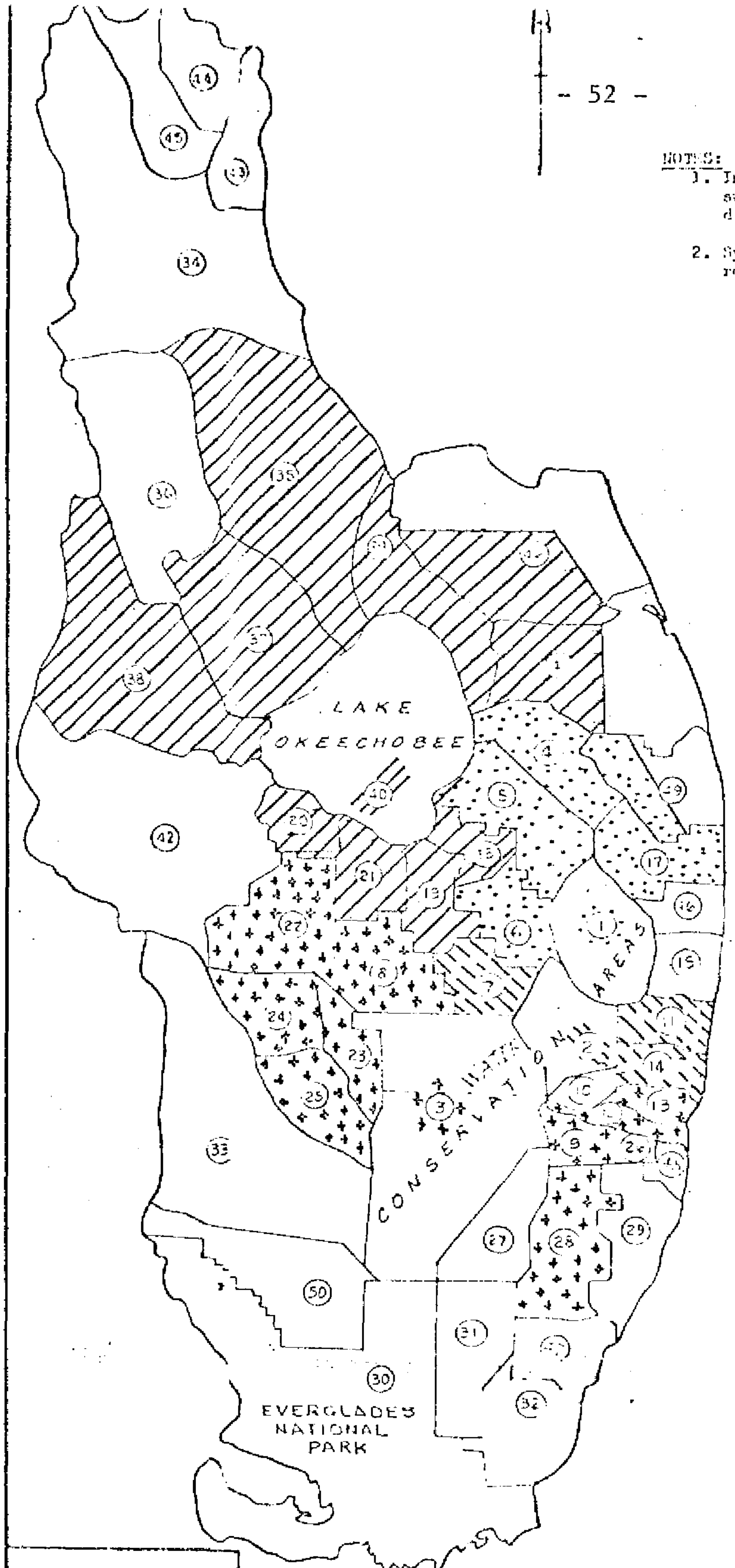
[a] Impractical to reduce error to less than 20%.

XII. APPENDIX B

Potential Water Supply and Water Demand Areas - Central and Southern Florida

NOTES:
1. In Kissimmee basin the potential water supply to each reservoir is from its own drainage area only plus upstream releases.

2. Symbols used are identified around each reservoir area number.

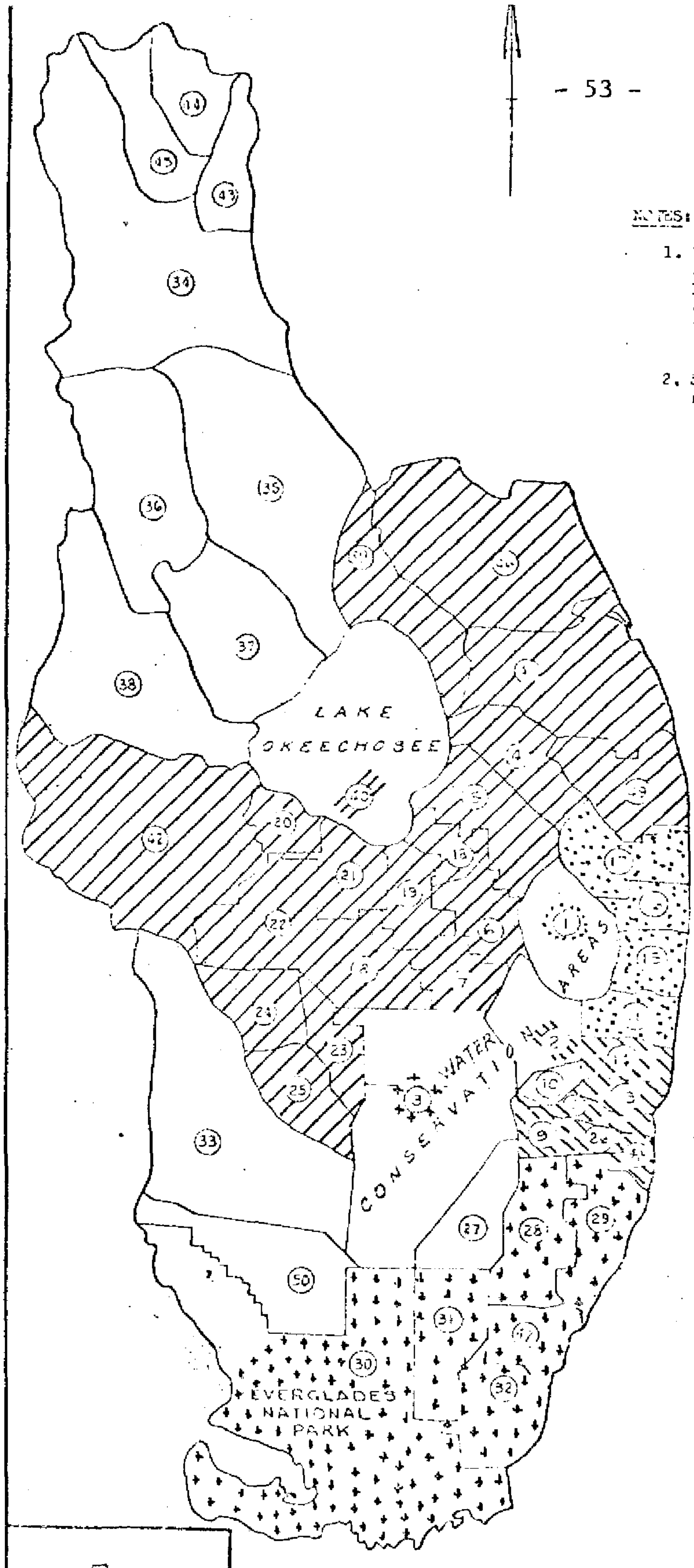


Area No.	Project unit	Area (sq. miles)
1	Conservation Area 1	221
2	Conservation Area 2A	173
3	Conservation Area 3A	752
4	Levee 8 Canal	136
5	Pump Station 5	230
6	Pump Station 6	146
7	Pump Station 7	125
8	Pump Station 8	208
9	SNR Canal S-9 to S-13A	71
10	Conservation Area 2B	37
11	Hillsboro Canal East S-39	85
12	NNR Canal East S-34	54
13	Canal 12 and Canal 13	38
14	Canal 14	76
15	Canal 15	74
16	Canal 16	72
17	WPB Canal East S-5A-E	226
18	Pump Sta. 2, Hillsboro Canal	72
19	Pump Sta. 2, NNR Canal	108
20	Canal 20	107
21	Pump Station 3	129
22	Hendry County S-15	261
23	Pump Station 140	110
24	L-28 Interceptor Canal	146
25	Collier County S-147	227
26	SNR Canal S-13A to S-13	27
27	Conservation Area 3B	152
28	Miami Area B	224
29	Miami Area A	164
30	Everglades National Park	1,442
31	Southwest Dade County	193
32	South Dade County	196
33	Collier County S-14	204
34	Lake Kissimmee S-65	848
35	Kissimmee River S-65-E	759
36	Lake Istokpoga S-68	622
37	Canal 41	415
38	Fisheating Creek	536
39	Northeast Shore	270
40	Lake Okeechobee	742
41	Martin County Canals	315
42	Caloosahatchee Canal S-77	906
43	Kissimmee East Chain	155
44	East Lake Tohopekaliga	300
45	Lake Tohopekaliga	327
46	St. Lucie County Canals	639
47	Cutler Canal and Canal 100	94
48	Canal 10	13
49	Canal 17 and Canal 18	195
50	Monroe County	336
	Total	14,562

POTENTIAL WATER SUPPLY AREAS TO RESERVOIRS

FIGURE E-2

U S ARMY ENGINEERS



<u>NOTES</u>:

1. Kissimmee basin reservoirs serve the area immediately downstream, except Lake Gentry complex serves Area 43 and Area 36 is supplied by Lake Kissimmee complex.

2. Symbols used are identified around each reservoir area number.

Area No.	Project unit	Area (sq. miles)
1	Conservation Area 1	221
2	Conservation Area 2A	173
3	Conservation Area 3A	752
4	Levee 8 Canal	136
5	Pump Station 5	230
6	Pump Station 6	146
7	Pump Station 7	125
8	Pump Station 8	208
9	SNR Canal S-9 to S-13A	71
10	Conservation Area 2B	37
11	Hillsboro Canal East S-39	85
12	NNR Canal East S-34	54
13	Canal 12 and Canal 13	38
14	Canal 14	76
15	Canal 15	74
16	Canal 16	72
17	WPB Canal East S-5A-E	226
18	Pump Sta. 2, Hillsboro Canal	72
19	Pump Sta. 2, NNR Canal	108
20	Canal 20	107
21	Pump Station 3	129
22	Hendry County S-15	261
23	Pump Station 140	110
24	L-28 Interceptor Canal	148
25	Collier County S-147	227
26	SNR Canal S-13A to S-13	27
27	Conservation Area 3B	152
28	Miami Area B	224
29	Miami Area A	164
30	Everglades National Park	1,442
31	Southwest Dade County	193
32	South Dade County	196
33	Collier County S-14	304
34	Lake Kissimmee S-65	848
35	Kissimmee River S-65-E	759
36	Lake Istokpoga S-68	622
37	Canal 41	415
38	Fisheating Creek	536
39	Northeast Shore	270
40	Lake Okeechobee	742
41	Martin County Canals	315
42	Caloosahatchee Canal S-79	906
43	Kissimmee East Chain	155
44	East Lake Tohopekaliga	300
45	Lake Tohopekaliga	329
46	St. Lucie County Canals	639
47	Cutler Canal and Canal 100	94
48	Canal 10	13
49	Canal 17 and Canal 18	195
50	Monroe County	116
	Total	14,662

SURVEY-REVIEW REPORT
WATER RESOURCES FOR
CENTRAL & SOUTHERN FLORIDA

DEMAND AREAS SERVED
FROM RESERVOIRS

FIGURE E-3