REPORT TO THE UNITED STATES ARMY CORPS OF ENGINEERS REQUESTING A REVIEW OF CENTRAL AND SOUTHERN FLORIDA FLOOD CONTROL PROJECT FACILITIES IN THE C-111 BASIN, DADE COUNTY, FLORIDA

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Resource Planning Department
South Florida Water Management District
West Palm Beach, Florida

I. PURPOSE

The purpose of this report is to provide the United States Army Corps of Engineers (USCOE) with background data and appropriate support material for a reassessment of the C-111 Basin in South Dade County. The South Florida Water Management District (SFWMD) has identified a number of specific environmental, flood control and water supply problems in this area. The SFWMD is therefore requesting that the USCOE review the status of the C-111 Basin with the purpose of preparing a revised Design Memorandum report that addresses these problems.

In this report, the District has examined various alternative solutions to the water resources problems of the C-111 Basin. Generally these alternatives call for purchase with State and local funds of major portions of the basin for floodwater retention and environmental preservation; partial backfilling and elimination of portions of the existing canals; and construction of new works and pumping facilities to provide for optimal removal of excess stormwater runoff, dispersion of freshwater flow across marshlands and redistribution of flow away from Manatee Bay into the ENP panhandle and Florida Bay.

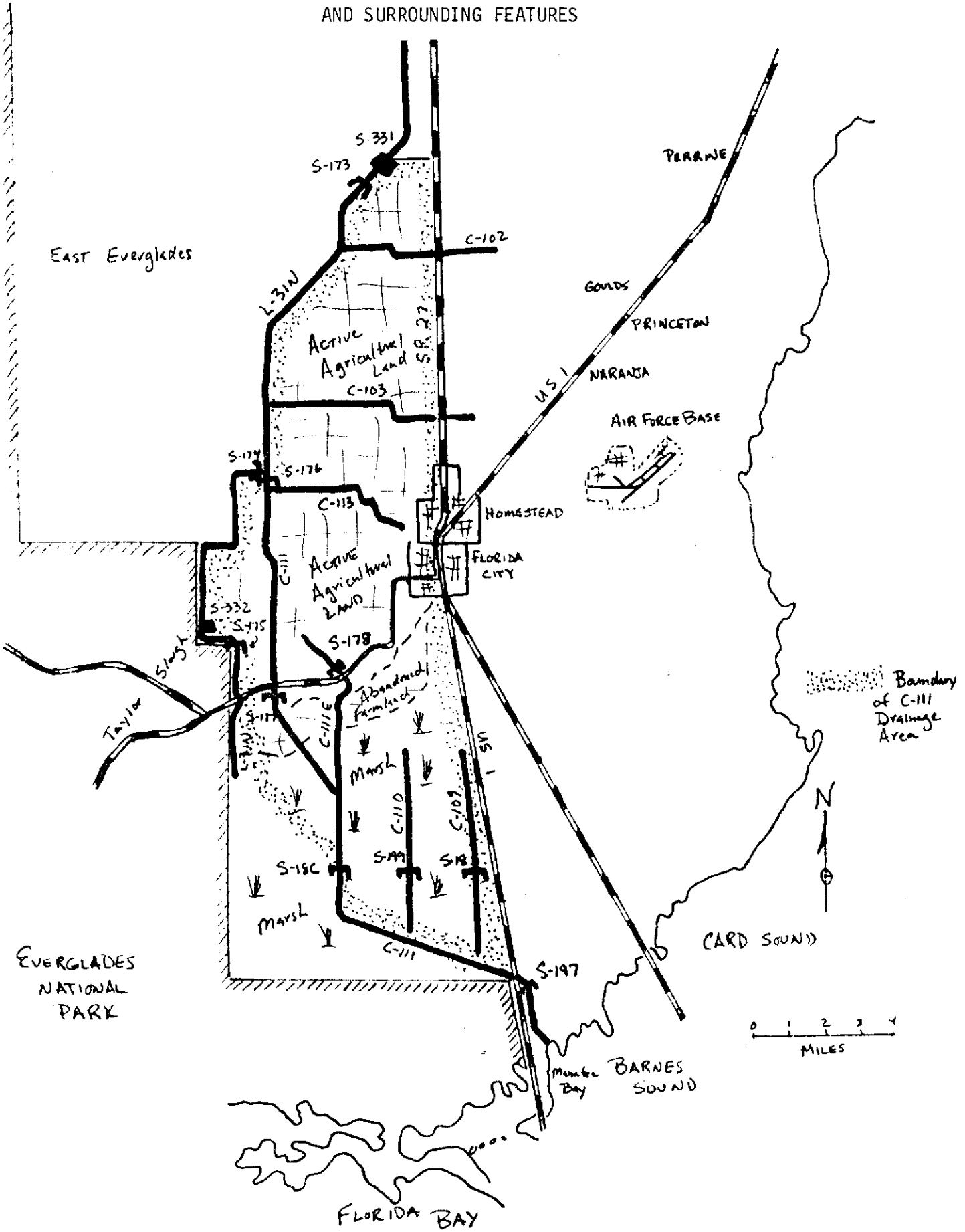
II. BASIS OF THE PROBLEM

A. DESCRIPTION OF THE AREA

1. Location and Contours. The C-111 drainage area occupies approximately 70 square miles in southeastern Dade County. The study area lies west of US 1, north and east of ENP and extends from S-331 to the ENP panhandle (Figure 1).

Figure 2 shows the approximate ground level contours within the southern portion of the C-111 area. Most of the active agricultural and urban land use occurs above 5 ft msl. The 3 to 5 ft msl interval is narrow and is

FIGURE 1 : C-111 DRAINAGE AREA, LAND USES
AND SURROUNDING FEATURES



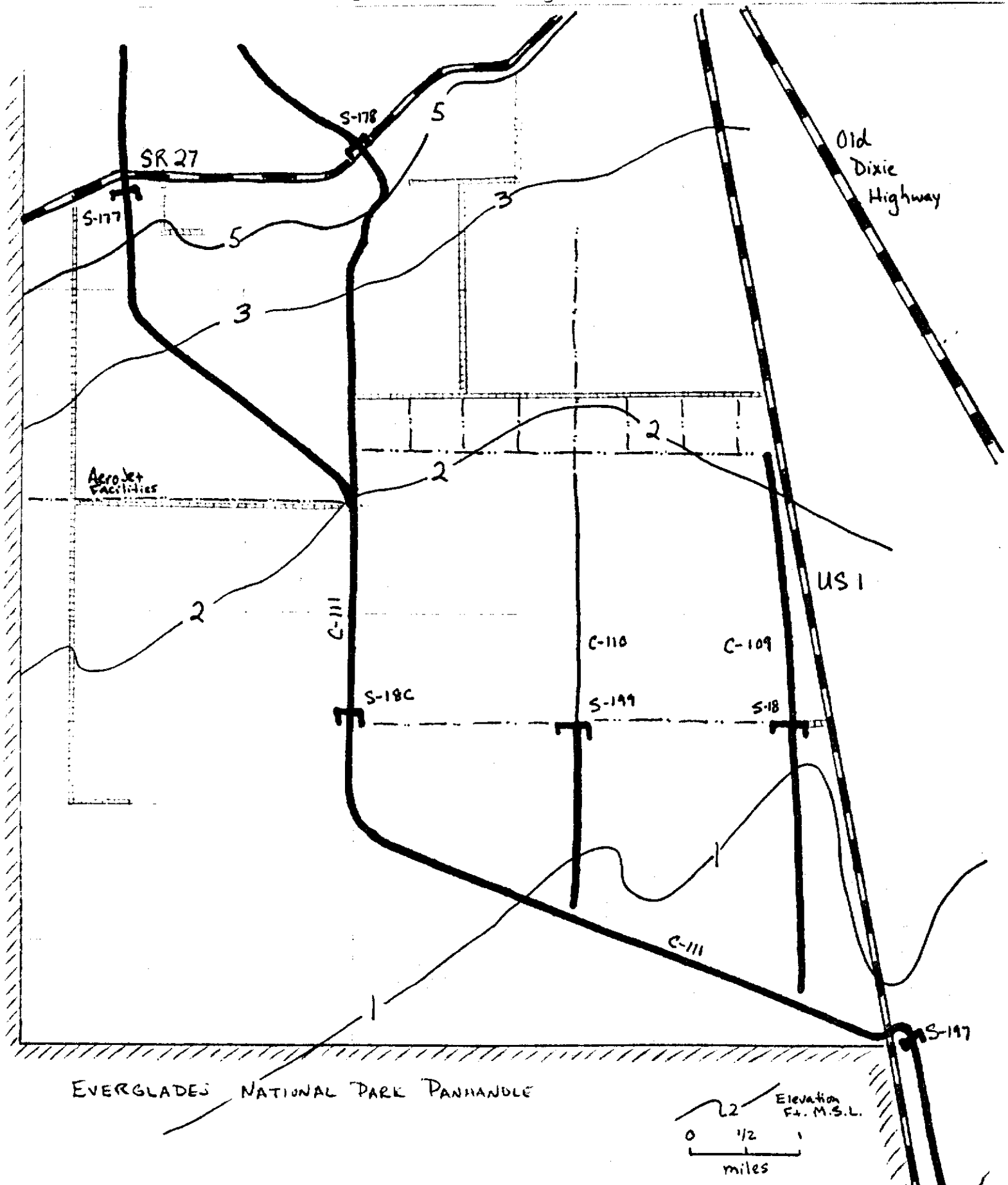


FIGURE 2 : APPROXIMATE LAND CONTOURS IN THE SOUTHERN PORTION OF THE C-111 DRAINAGE AREA

characterized by abandoned farmland. South of the 3 ft msl contour, land elevation slopes gradually for 11 miles to the southeast to Florida Bay.

2. Land Use Characteristics. Generalized land use characteristics for the study area are shown in Figure 1. Existing land uses are primarily agricultural in the northern portion of the basin, with some moderately urbanized areas near Florida City and Homestead. A major tract of land was purchased in the 1960's by the Aerojet General Corporation for aerospace testing facilities. However, this development is no longer a possibility, and this property and adjacent lands, comprising most of the southern portion of the basin below the 3 foot contour, remain largely as undeveloped natural wetlands.

3. Environmental Characteristics. The area south of US 27 is classified in the physiographic sub-area called the southern coastal glades. Vegetation includes freshwater marshes which intergrade with the mangrove swamps along the coast. The freshwater marshes in the vicinity of C-111 are interspersed with tropical hardwood hammocks, bayheads, willow heads, mangrove and buttonwood islands. Towards the north and west, the prairies become dominated by muhly grass (Muhlenbergia sp.) and muhly-beardgrass.

Northeast Florida Bay, south of C-111 and west of US 1, is lined by an extensive mangrove forest and pocketed with several isolated bays, including Long Sound and Joe Bay. Water depths in northeast Florida Bay average only 1 to 2 meters, and the shallow bottom sediments support extensive communities of seagrasses and algae.

B. CONCERNS WITHIN THE STUDY AREA

1. Land Use. Land use projections that were considered as part of the General Design Memorandum for South Dade County (Part V, Supp. 37) included increased agriculture and urban development in the Homestead-Florida City area

and industrial development within the Aerojet tract. In recent years, the pace of agricultural development in the northern portions of the C-111 Basin has been rapid. In addition, there has been a shift of agricultural land use away from seasonal crops to more extensive growth of tropical fruits, ornamental plants and other year-round crops. As a result, land values have increased as well as the potential damages that may occur from periodic flooding or deficient water supply. The industrial development in the Aerojet tract has not occurred and most of this land is being purchased for environmental preservation.

2. Environmental Values. The relatively undisturbed wetland and tropical hammock plant communities in this area provide important habitat for a variety of animals. Wildlife surveys throughout the entire East Everglades area have identified a total of 357 species of vertebrates, most of which could be expected to occur in this southern portion of the area. Included within these surveys were: 34 fish species, 18 amphibians, 47 reptiles, 28 mammals and 230 species of birds.

Many of the C-111 area wetlands are designated as critical habitat by the U. S. Department of the Interior for the Cape Sable sparrow and the American crocodile. The Muhlenbergia prairies are the major remaining habitat for the Cape Sable sparrow. Freshwater runoff from the C-111 Basin is critical to the survival of crocodiles to the south, since newly-hatched crocodiles may not be able to survive initially in salt or brackish water. Other endangered species that have been sighted within the C-111 area include the southern bald eagle and Florida panther. This area is also an important dry season feeding area for many colonial wading birds that nest in ENP. The estuaries of northeast Florida Bay provide important nursery areas for pink shrimp, spotted sea trout, red drum, mullet and a number of other commercially and recreationally important species.

3. Flood Protection. Due to changes in land use, the need for flood protection in the C-111 Basin has been considerably altered from the projected conditions for which the system was designed. Additional flood protection may be desirable for the increasingly-valuable agricultural and urban lands in the northern portion of the basin. Flood protection is not required in the southern portion of the basin because additional development will not occur in this area.

4. Water Supply. Increased agricultural development has resulted in increased water use in south Dade County. In recent years, when rainfall has been below average, groundwater levels in the C-111 basin have declined severely, to well below sea level, and resulted in increased saltwater intrusion into the base of the Biscayne Aquifer as well as the potential for saltwater seepage into the C-111 Canal. Although the South Dade Conveyance System was designed in part to deal with these conditions, further action is indicated. Methods need to be considered for holding higher groundwater stages in this area and for preventing saltwater seepage into the C-111 Canal.

C. RECENT EVENTS

1. Severe Storm Events. S-197 and the adjacent earthen plug were installed in June 1969 to prevent salt water intrusion into C-111 and to provide for design discharge from S-18C. During the first 12 years of operation floodwaters that passed through S-18C were effectively dispersed through the spoil gaps and S-197 culverts. However, on three recent occasions (August 18-27, 1981; September 27 - October 5, 1981; and June 3-5, 1982) the earthen plug at S-197 was removed to facilitate water releases through the system. Tables 1 and 2 provide a summary of discharges at S-18C and S-197, estimated flow through the gaps and estimated flow through the plug during these events. A recent District publication, "Report on Tropical Storm

TABLE 1. FLOW DISTRIBUTION THROUGH WATER CONTROL STRUCTURES AND OVERLAND DURING SEVERE STORM EVENTS IN AUGUST - OCTOBER 1981. FLOW REPORTED IN CFS.

		S-18C	S-197	Gap Flow[1]	Plug Flow[2]
Aug.	15	0	0		
	16	0	0		
	17	924	333	591	
	18*	2000	864	(348)	788
	19*	2260	588	(348)	1324
	20*	2260	540	(348)	1372
	21*	2270	498	(348)	1424
	22*	2220	483	(348)	1389
	23*	2210	459	(348)	1403
	24*	1990	438	(348)	1204
	25*	2030	432	(348)	1250
	26*	1930	414	(348)	1168
	27*	1540	366	(348)	826
	28	514	474	(348)	
	29	613	516	97	
	30	490	540	-50	
	31	0	150	-150	
Sept	1	429	144	285	
	2	538	285	253	
	3	329	273	56	
	4	563	288	275	
	5	590	270	320	
	6	693	258	435	
	7	768	330	438	
	8	874	484	390	
	9	1220	630	590	
	10	1230	600	630	
Sept.	11	979	600	379	
	12	1160	660	500	
	13	1130	630	500	
	14	910	585	325	
	15	1060	600	460	
	16	917	636	281	
	17	1030	690	340	
	18	937	705	232	
	19	905	690	215	
	20	152	510	-385	
	21	702	528	174	
	22	1200	615	585	
	23	1160	615	545	
	24	1050	600	450	
	25	1100	630	470	
	26	1260	624	636	
	27*	1580	483	(348)	749
	28*	1620	459	(340)	813
	29*	1570	399	(348)	823
	30*	1620	444	(348)	828
Oct.	1*	1540	480	(348)	712
	2*	1580	480	(348)	752
	3*	1480	465	(348)	667
	4*	1410	450	(348)	612
	5*	2100	417	(348)	1335
	6	995	624	371	
	7	91	208	-117	
	8	0	0	0	

[1]Flow through the gaps was calculated as S-18C cfs - S-197 cfs when the plug was in place. When the plug was pulled, gap flow was estimated as the mean gap flow for the period 8/17 and 8/29-9/26. Estimated values are in ( ). Negative gap flows are considered to equal 0.

[2]Flow through the plug area was calculated as (S-18C cfs) - (S-197 cfs) - (gap cfs)

*Dates when the plug was pulled

Total flow through plug and S-197 for 8/18-8/28 is 34,115 ac-ft (mean daily flow = 1723 cfs)

Total flow through plug and S-197 for 8/27-9/5 is 20,637 ac-ft (mean daily flow = 1158 cfs)

NOTE: On August 19, 1981, the USGS measured the flow through the plug area at 3429 cfs. During the preceeding day, ENP personnel observed water flowing north through the spoil gaps. The total flow towards Manatee Bay when the USGS measurement was made was approximately 3400 + 600 = 4000 cfs. Since 2260 cfs flowed through S-18C, an additional 1740 cfs was contributed from the area between S-18C and S-197.

TABLE 2. SUMMARY OF HYDROLOGIC CONDITIONS ASSOCIATED WITH THE JUNE 1982 PLUG REMOVAL IN C-111.

	discharges in c.f.s.			
Date	S-18C	S-197	Gaps[1]	Plug[2]
June 1	0	0	0	
2	732	321	411	
3*	1550	725	(600)	225
4*	1730	550	(600)	580
5*	1940	625	(600)	715
6	1550	820	730	
7	1470	810	660	
8	370	517	-147	
9	0	0	0	
10	0	0	0	

*Dates of plug removal

[1]Gap flow calculated (S-18C flow) - (S-197 flow)
Gap flow estimated during plug removal period as average of preceeding and subsequent gap flows

[2]Plug flow estimated as (S-18C flow) - (gap estimated flow) - (S-197 flow)

Dennis, August 16-18, 1981" described the climatic conditions and damages that occurred in August and September 1981.

2. Trust for Public Lands Acquisition. Everglades National Park has been threatened by encroachment and adverse land and water use practices in tributary basins and along its borders. Recently, ENP boundaries have received some protection by establishment of buffers and management policies in adjacent areas, from Dade County's East Everglades Resource Management Plan. Additionally, an environmentally concerned organization, the Trust for Public Lands (TPL), has acquired 50,000 acres of land in the East Everglades and adjacent to the park boundaries in the C-111 project area through a donation and purchase agreement with Aerojet General Corporation. Figure 3 shows the TPL property in the vicinity of C-111 study area. It is the intent of TPL to secure environmentally endangered lands until such time as these lands can be put back into public ownership.

This District is currently in a position, utilizing Save Our Rivers funding, to acquire portions of this TPL property. Consequently, these lands will be managed to promote and maintain environmentally desirable attributes through restoration of water levels above the land surface and overland sheet flow towards Florida Bay.

D. PROBLEM CONDITIONS IN THE C-111 BASIN

1. Quantity and Direction of Overland Flow. Due to the presence of levees, highways, roadways, and canals the southeasterly flow of surface water has been altered. The canal systems pull both groundwater and surface water from the surrounding marshland, resulting in lowered groundwater stages and shortened hydroperiods. In other locations water tends to pond where its flow has been impounded, such as north of the Aerojet Canal and in the southeast portion of the impoundment formed by the C-111 north levee and US 1. Overland

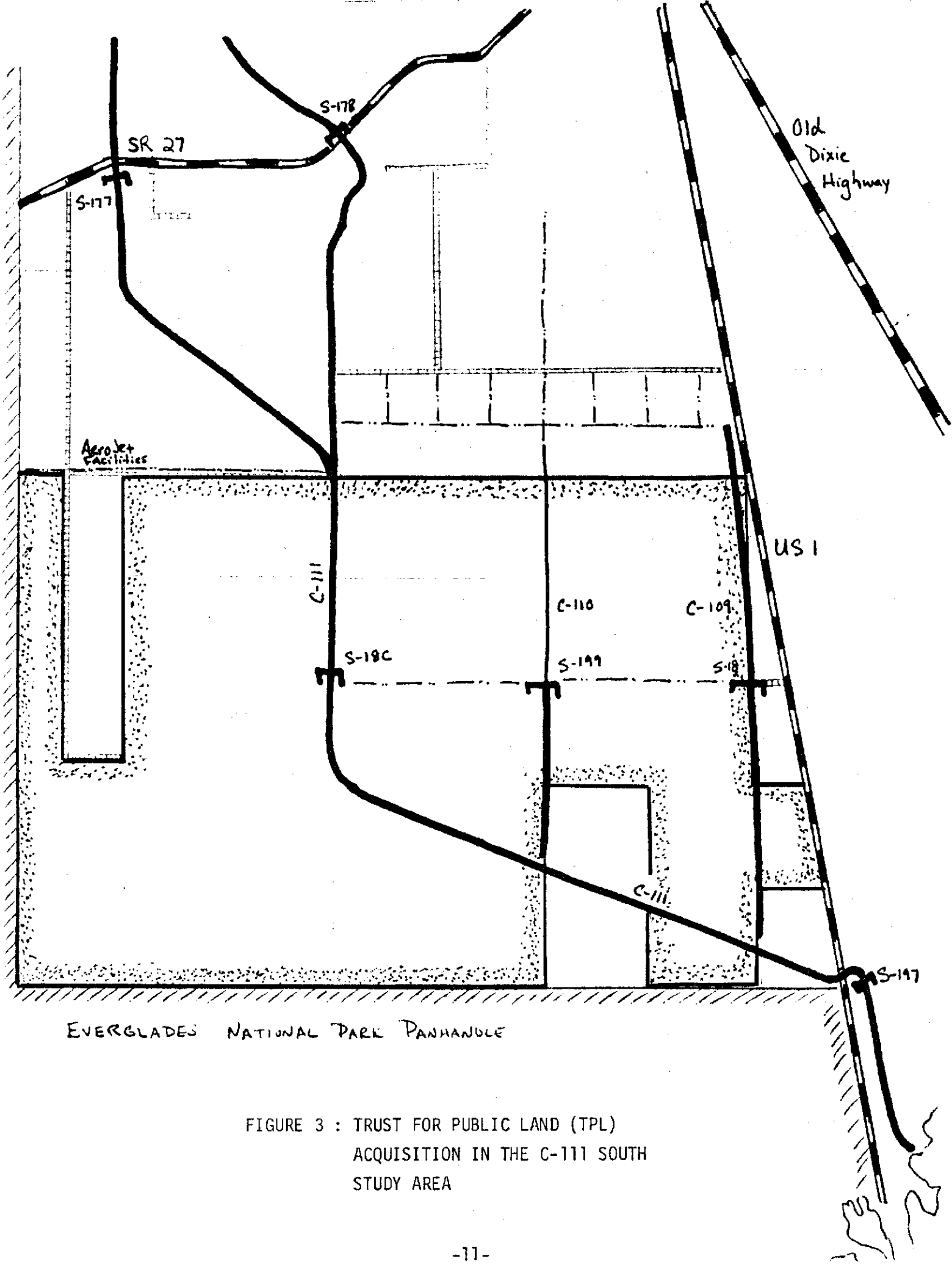


FIGURE 3 : TRUST FOR PUBLIC LAND (TPL)
ACQUISITION IN THE C-111 SOUTH
STUDY AREA

flow from C-111 south of S-18C through the spoil gaps towards Florida Bay is poorly distributed. The land elevation slopes from northwest to southeast, causing the highest flow of water to occur through the gaps near US 1.

2. Estuarine Impacts. Water that is discharged through S-197 to Manatee Bay does not flow into northeast Florida Bay. Freshwater releases through S-197 to Manatee Bay occur at a single point and can cause rapid and unseasonal salinity changes. Extremely large freshwater releases, which occur when the plug is pulled (August and September 1981 and June 1982), can rapidly upset the salinity regime and the biota. The increased turbidity levels that may be associated with these releases can have long-term adverse effects on grass beds and other productive communities as well as dissolved oxygen levels and light transparency.

Florida Bay is a vast, shallow, tropical lagoon situated between the emergent barrier reefs of the upper Florida Keys and the mangrove swamps of peninsular Florida. Variation in salinity of nearshore waters is vital for providing estuarine conditions for many species and depends upon rainfall, upland runoff and overall climatic conditions. Results of unpublished studies by Tabb during 1965-66 and Schmidt during 1973-76 have documented the occurrence of wide ranges of salinities in this area, ranging from freshwater (0 ppt) to hypersaline (near 50 ppt) conditions for several months duration. Both of these studies occurred during drought periods followed by periods of normal to above normal rainfall. Figures 4 and 5 represent near shore salinity measurements for similar locations during these two studies.

3. Everglades National Park - Water Deliveries. A portion of the minimum annual allotment of 315,000 ac-ft of water guaranteed for ENP is reserved for the eastern panhandle area, immediately south of C-111. A total of 260,000 ac-ft is delivered through the S-12 structures. Of the remaining 55,000 ac-ft, 37,000 ac-ft should be pumped by S-332 into Taylor Slough and 18,000 ac-ft

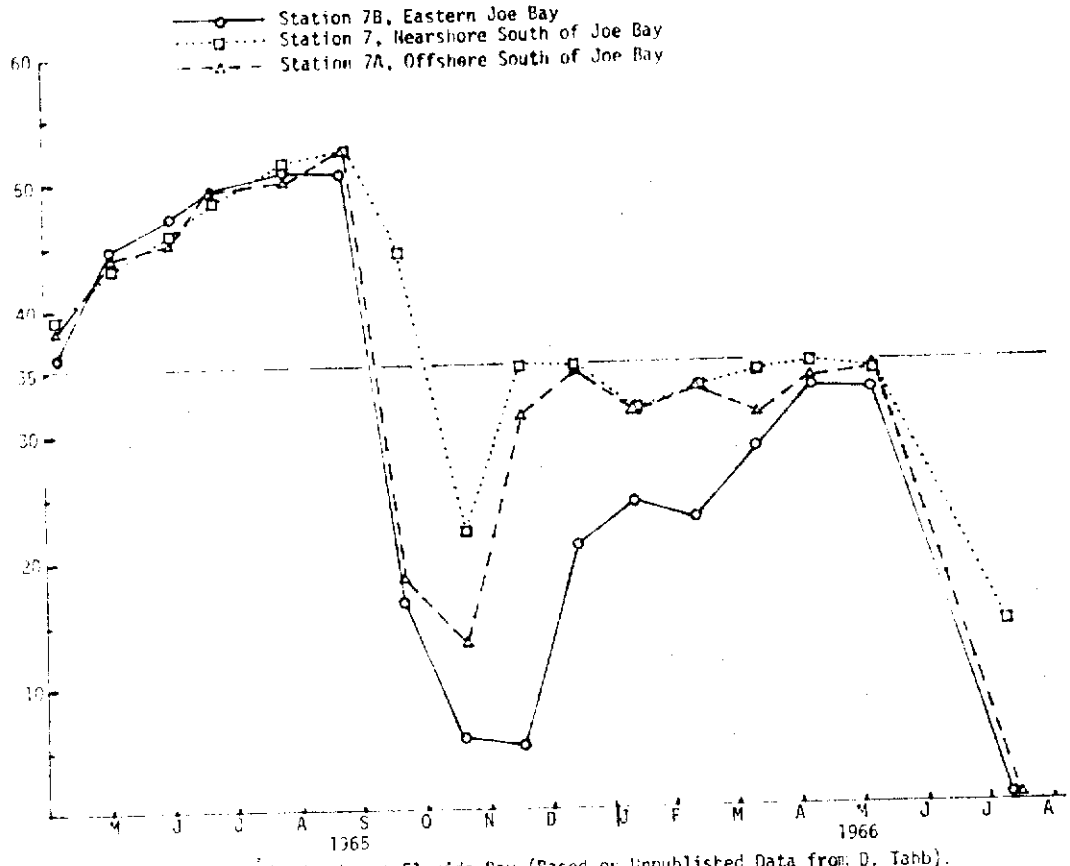


Figure 4 Salinity in Northeast Florida Bay (Based on Unpublished Data from D. Tabb).

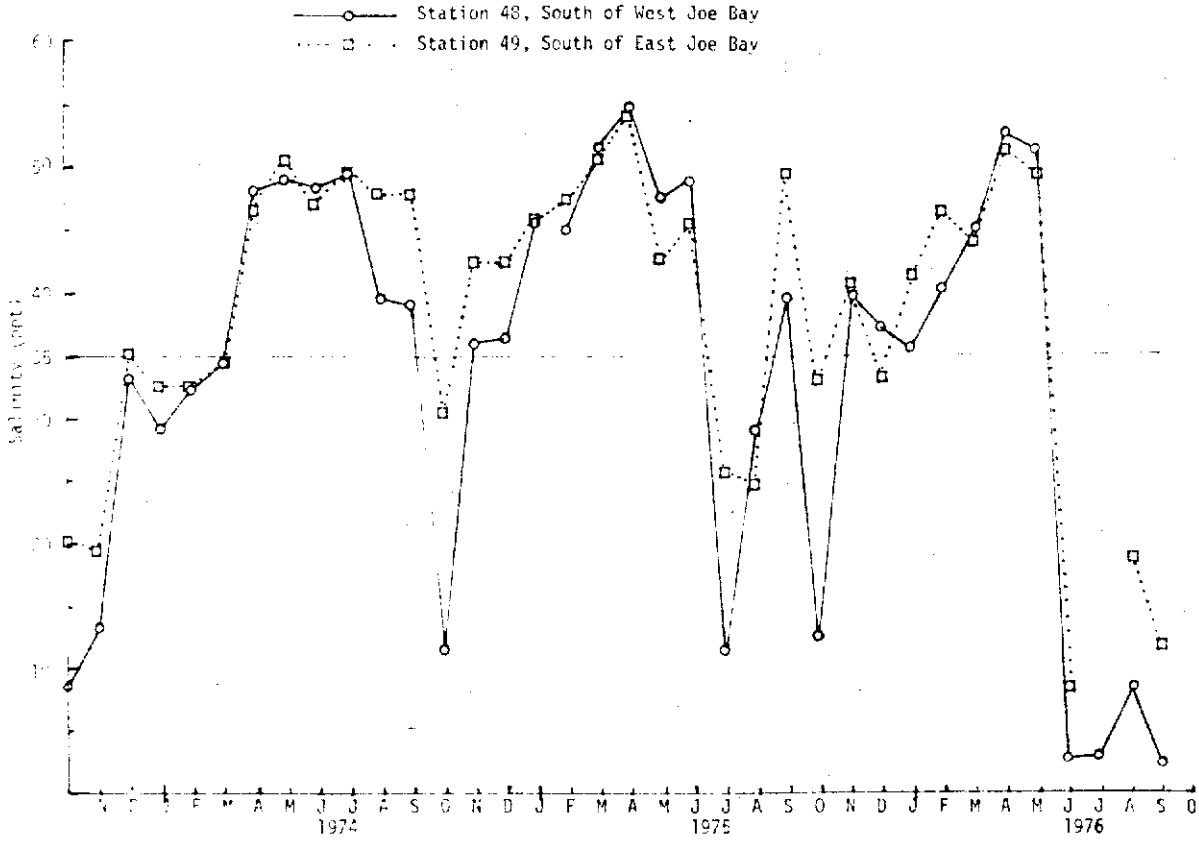


Figure 5. Salinity at Two Stations in Northeast Florida Bay (Data from Schmidt, 1979).

should be delivered through S-18C and flow through the gaps in C-111. To date, no scheduled water releases have been made to the panhandle because the south Dade water conveyance system is not complete.

4. Reevaluation of C-111 Basin Flood Protection. During the 1960's, the study area was already a predominantly agricultural and urban area, with a trend towards accelerated industrial expansion in the southerly reaches. The urban areas followed the coastal ridge along US 1 south to Homestead and Florida City and included the municipalities of Goulds, Princeton, Naranja and Leisure City.

a. Land Use Changes. According to the Water Quality Management Plan of Dade County, the agricultural land use for Dade County was projected to decline by about 5% during the period from 1970 to the year 2000. Within the C-111 Basin study area, however, there is indication that the amount of agricultural land is increasing. In the past, the study area predominantly supported tropical seasonal vegetables and field crops. However, in recent years ornamental nurseries and annual fruit crop trees are replacing seasonal vegetable crops.

b. Flooding Incidents and Damages. Before the project construction, damaging floods occurred in the study area repeatedly during 1947, 1948, 1951, 1952, 1953, 1956, 1958 and 1960.

Recently, this study area was subjected to a severe storm event with the passage of Tropical Storm Dennis during August 1981. Maximum recorded 5-day rainfall exceeded 25 inches just north of Homestead. Extensive flooding of agricultural land occurred in the upper portion of the C-111 basin, and overall throughout Dade County, agricultural damages exceeded $18 million. However, if one adds the value of tropical fruits and vegetables that could have been harvested annually and sold in the open market, then the total loss

suffered by the south Dade farmers would be substantially higher than $18 million.

c. Florida City Problems. Since C-103S, which is designed to provide flood relief to the Florida City area, has not been completed, the C-111 system has to accommodate the runoff water generated from this semi-urbanized area. Under standard project flood conditions, C-103S should handle 880 cfs from a 5.9 mi^2 area, and 350 cfs under 40% SPF conditions. This runoff from Florida City adds an additional burden to C-111 that is beyond its design capacity.

III. DESCRIPTION OF THE EXISTING WATER MANAGEMENT SYSTEM

Canal 111 is located in southeast Florida in Dade County, west and southwest of Homestead and Florida City (Figure 1). C-111 originates about 4 miles west of Homestead at S-176 and is a southern extension of L-31W borrow canal. C-111 flows southerly about six miles from S-176 to S-177, at which point it flows alternately southerly and then southeasterly for another 14 miles to Manatee Bay. A short canal, C-111E, has a confluence with C-111 about 3 miles south of S-178. S-18C is located about 6 miles south of S-177 on C-111, and S-197 is situated just east of US 1, about 2 miles north of the terminus of C-111 at Manatee Bay. Two incomplete canals (C-109 and C-110) and water control structures (S-18 and S-199) run in a north-south direction, parallel to and west of US 1.

C-111 provides drainage and flood control for the agricultural areas south and west of Homestead and Florida City, and can convey freshwater to the eastern panhandle of ENP. The primary structures on C-111 (S-177, S-18C, and S-197) discharge excess flood waters, and during the dry season, maintain ground water levels and prevent salt water intrusion to the extent possible.

The optimum headwater levels maintained by these structures in C-111 and their design discharge characteristics are as follows:

		Opt. Headwater Elevation	Design Discharge	Operation
S-176	L-31W	5.5	630	automatic
S-177	C-111	4.5	1400	automatic
S-178	C-111	4.5	300	manual
S-18C	C-111	2.3	2100	automatic
S-197	C-111	1.4	550(2400*)	manual*

*S-197 is a culvert with a manually operated sluice gate, - accompanied by an earthen dam which is removed during high discharge events to attain maximum discharge of 2400 cfs.

Under current conditions, water flow through S-18C is essential in order to maintain necessary headwater-tailwater relationships at the two upstream structures, S-177 and S-178, which directly serve the developed agricultural areas north of SR 27. Water passing through S-18C flows southeasterly down C-111 towards US 1, and either flows through S-197 to Manatee Bay or flows southerly overland through 54 gaps in the spoil pile along the south side of C-111 towards northeast Florida Bay.

A. HYDRAULICS

The hydaulic features of the canal consist of S-18C, S-197, and the gaps. A brief description of the hydraulic system follows:

Structure 18C: According to General Design Memorandum Part V, Supplement 38, the standard project flood (SPF) from the area is estimated to be 3200 cfs and the 40% SPF is estimated to be 1470 cfs. However, S-18C is designed to pass a discharge of 2100 cfs with headwater and the tailwater stages of 2.6 and 2.1 ft msl respectively. The criteria for operation of S-197 are as follows:

a. When the tailwater stage at S-18C rises above 1.9 ft msl, then the S-197 culverts are opened.

b. When the tailwater stage at S-18C reaches 2.1 ft msl, S-176 and S-177 structures are at or near design stage, and the S-197 culverts are open, then the plug is removed.

Examination of discharge records from 1968-1982 shows that as much as 2270 cfs (8/21/81) has been released through the structure. In order to discharge this flow, however, the plug was removed and S-197 was fully opened. During the month of August 1981, there were six consecutive days when discharge in excess of 2100 was released through S-18C.

Structure 197: This structure is designed to discharge 550 cfs at headwater of 1.40 ft msl, and will discharge 650 cfs with a headwater stage of 1.7 ft msl. When stages exceed 2.1 ft msl and upstream basin conditions are serious the earthen plug alongside S-197 is removed. This plug has only been removed on three occasions, all since 1981.

C-111 Gaps: The maximum discharge available to ENP through the gaps in the south levee of C-111 depends upon the water levels in the canal, either from direct surface discharge or groundwater flow. The estimation of the amount of water discharged depends on which curve (the U.S.G.S. or the Corps of Engineers rating curve) one uses. Presented here are the estimated discharges through the gaps, based on these sources.

S-18C Discharge T.W. Stages FT MSL	Discharge to the Park Through Gaps		
	U.S.G.S.	C/E	SFWMD
2.0	2100	500	600
1.5	600	110	150
1.0	20	5	5

The flow values that were calculated by the SFWMD agree with the USCOE estimates. The U.S.G.S. rating curve provides higher estimates of the discharge through the gaps. A detailed study of flow through the C-111 gaps was conducted in 1967 and 1968 by the USGS. This study indicated that due to the natural slope in land elevation, substantially more water flowed through the gaps at the eastern end of C-111 near the plug than flowed through the gaps at the western end, below S-18C.

Examination of discharge records for S-18C and S-197 in recent years, however, indicates that on occasion as much as 1000 to 1500 cfs of the flow that enters C-111 from S-18C is not discharged at S-197. This water is being released to the Park as flow through the gaps and groundwater seepage. Flow rates of 500 to 600 cfs are probably representative of the maximum flow that can occur through the gaps during periods of high water stages, downstream of the gaps.

B. HYDROGEOLOGY

A typical boring log of C-111 near S-18C shows the formation to be composed of medium hard to hard solution riddled limestones to a depth of 23 feet.

The hydraulics of the groundwater formation is characterized by its transmissivity and storage coefficient. The storage coefficient of the Biscayne aquifer is reported to be 0.2. A transmissivity contour map prepared by the U. S. Geological Survey shows a value of $2.0\text{-}4.0 \times 10^6$ gpd/ft for this area. However, near the Homestead wellfield, it is reported to be as high as 12.0×10^6 gpd/ft. The above hydraulic characteristics reveal that the formation in the study area is very porous and a large quantity of groundwater seeps towards the canal. Thus, during storm events, a significant quantity of water may seep into the canal system thereby reducing its runoff removal capacity.

C. GROUNDWATER

Data for groundwater levels in the C-111 area indicate that substantial seasonal and spatial variations can occur. For example, the average yearly lowest groundwater level for the period 1965-78 indicates a 0 ft msl isocontour in the vicinity of Florida City, whereas this same area had an average yearly highest groundwater level of 4.5 ft msl. During 1980, groundwater levels near Florida City were stable at about 3.5 ft msl during May and October.

D. HYDROLOGY

Daily rainfall and evaporation data for this area are collected at the Homestead Experimental Station, and groundwater levels are recorded at a monitoring well about 5 miles north of S-18C. Stages throughout C-111 and discharges at the water control structures are collected continuously.

As expected, this area is subjected to extreme fluctuations in rainfall amounts and water levels, with recent monthly rainfall totals ranging from 0.12 inches to 27.31 inches. Both ground and surface water levels have dropped to below sea level during rainfall deficient periods, and have caused flooded conditions during periods of excessive rainfall.

IV. PLAN FORMULATION AND ANALYSIS

A. DESIGN OBJECTIVES

In order to propose a major revision in the water management system in south Dade County, it is essential to identify the major objectives for such a revision. The primary objectives that were considered include the following:

1. To eliminate the point discharge of floodwaters from the C-111 Basin into Manatee Bay.
2. To provide an adequate flow of freshwater to the Everglades National Park panhandle and Florida Bay.
3. Maintain higher groundwater elevations to improve overland flow and natural wetland conditions in the area and protect regional water supplies during dry periods.
4. Provide adequate flood control for land users upstream of S-18C in the C-111 Basin, and provide for distribution of excess runoff south of the S-18C structure.
5. Provide for partial or complete backfilling of C-111 to reduce saltwater intrusion.

A cost-effective plan should be devised that will meet four general criteria:

1. Serve as an effective flood control system for upstream users.
2. Serve as an effective water delivery system for the ENP panhandle.
3. Maintain natural attributes of the southern coastal glades ecosystem.
4. Protect water resources of the region.

B. MODIFICATIONS OF THE SYSTEM TO MEET DESIGN OBJECTIVES

1. Eliminate Freshwater Discharges to Manatee Bay. Backfilling of the portion of C-111 east of US 1 and removal of the S-197 structure is a design feature of each of the alternatives presented. These modifications would eliminate future releases of flood waters to Manatee Bay, and would provide for moderation of salinity conditions by eliminating point source discharges of freshwater during the wet season.

2. Increase Freshwater Flow to Everglades National Park. An analysis of historic discharges from S-18C and S-197 has shown that much of the time discharges through S-18C flow through the south side spoil gaps without utilizing S-197 (Table 3). The gaps could pass 1000-1500 cfs when preceding conditions were dry and about 500 cfs under extreme flood conditions.

At present, flow is greater through the lower elevation gaps at the southeastern end of C-111 than at the higher elevation gaps at the western end of C-111. In addition, during the dry season, the canal system drains the regional groundwater resources of the area. Groundwater from as far north as Florida City flows to C-109 and C-110 towards C-111 during the dry season. Filling of C-109 and C-110 would improve water supply to the Park by reducing over drainage and restoring groundwater and surface water flow. Complete filling of the C-111 below S-18C would be detrimental to water supply to ENP

TABLE 3. TOTAL MONTHLY AND ANNUAL DISCHARGES AT S-18C AND S-197 IN ACRE FEET.

S-18C	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	$\bar{x}$
JAN	10,660	1,660	0	4	85	17	0	0	0	0	0	0	0	956
FEB	2,550	1,000	0	6	0	0	0	0	0	4,170	0	0	7,823	1,196
MAR	3,110	267	0	0	0	0	0	0	0	0	0	0	0	260
APR	1,430	0	0	99	0	0	0	0	0	1,350	10,500	34	0	1,031
MAY	5,800	0	0	15,820	0	0	0	829	3,000	0	12,450	200	0	2,930
JUN	59,370	1,350	43	65,290	8	0	4,790	24,350	12,070	0	81	12,070	0	13,802
JUL	6,040	5,640	195	10,950	2,040	0	11,400	0	0	3,540	2,360	6,690	0	3,758
AUG	17,320	488	53	4,280	12,540	0	7,140	11,970	2,000	0	0	9,330	46,127	8,557
SEP	29,440	548	1,190	1,970	7,640	0	0	12,050	25,130	15,380	12,150	20,530	58,082	14,162
OCT	23,440	1,640	925	2,310	2,480	0	0	2,200	2,880	20,820	2,880	4,375	21,159	6,546
NOV	14,720	689	785	1,170	391	0	0	0	0	5,930	12	6,087	0	2,291
DEC	1,880	0	84	117	308	0	0	0	0	0	3,830	8,124	0	1,103
TOT.	175,800	13,270	3,280	102,016	25,490	17	23,340	51,410	45,070	51,180	44,250	67,444	133,191	

S-197														
JAN		0	0	0	0	0	0	0	0	0	0	0	0	0
FEB		0	0	0	0	0	0	0	0	0	0	0	3,291	274
MAR		0	0	0	0	0	0	0	0	0	0	0	0	0
APR		0	0	0	0	0	0	0	0	0	0	0	0	0
MAY		0	0	1,002	0	0	0	0	0	0	3,860	0	0	321
JUN		0	0	4,709	0	0	0	0	4,552	0	0	0	0	772
JUL		0	0	2,261	179	0	0	0	0	0	0	3,874	0	485
AUG	1,839	0	0	770	2,206	0	268	0	0	0	0	3,705	14,073	1,758
SEP	1,416	0	0	390	1,371	0	0	0	0	1,490	2,721	13,397	30,278	3,927
OCT	7,694	0	0	186	0	0	0	0	0	885	3,043	2,279	6,196	1,560
NOV	6,786	0	0	0	0	0	0	0	0	0	0	6,877	0	1,051
DEC	6,635	0	0	0	0	0	0	0	0	0	0	0	0	510
TOT.		0	0	9,318	3,755	0	268	0	4,552	2,375	9,624	30,131	53,838	

since it would eliminate the ability to discharge water through the 5.0 mile long series of gaps.

3. Maintain Higher Water Levels. The ground elevation along the southern portion of C-111 is approximately +1.6 ft msl at S-18C, and is 0.6 ft msl near the south end at US 1.

In order to maintain surface water stages at or above land surface elevation in the southern portion of C-111, some discharge must be released from S-18C. A discharge of 150 cfs is adequate to maintain a water surface profile of +1.6 ft msl.

Under the present system configuration, groundwater as well as surface water stages cannot be maintained at adequate elevations, because no conveyance facility presently exists to supply the necessary additional water to S-18C. However, when the South Dade Conveyance System, and especially S-331 are operational, additional capabilities will exist.

4. Provide Adequate Flood Protection. A review of major rainfall events that have occurred in the past few years indicated that only a limited quantity of water can be discharged through S-18C and S-197 even during the storm events. As a result, extensive and costly flooding occurs in the study area. C-111 drains approximately 70 square miles of area and was designed to pass a discharge of 2100 cfs. Therefore, the runoff removal capacity (R) of this canal is $R = (2100 \times 1.98 \times 12)/(70 \times 640) = 1.11$ inches/acre/day under present conditions. The design water surface profile of C-111, as computed by the U. S. Army Corps of Engineers, indicates that S-18C will have a headwater and tailwater elevation of 2.6 and 2.1 ft msl, respectively, when 2100 cfs is released through the structure. Near the plug at U. S. 1, the headwater will have an elevation of 1.0 ft msl. The design discharge of 2100 cfs is substantially less than the 3200 cfs discharge that would be required to meet Standard Project Flood (SPF) conditions. Under SPF conditions, C-111

would remove 1.70 inches of runoff per acre/day. The existing protection is adequate to protect against the 1-in-10 year rainfall event but not adequate to protect against the 1-in-25 year event. Considering the costly flooding that has occurred in recent years, substantial benefits may be gained by providing additional flood control to this basin.

5. Backfilling of C-111 Canal. If the canal is completely backfilled, the backwater effects on the headwater and tailwater stages at S-18C will extend throughout the entire basin. An analysis of the projected flooding impacts of backfilling C-111 is presented in Appendix A of this report. Examination of ground elevations of the area indicates the impact of the water surface build-up (Figure 2). The topographic elevation of the area 1.5 miles south of S-177 along C-111 and in the vicinity of C-111(E) is 3.0 ft msl. The flooding analysis indicates that the water stage below S-18C will reach 3.9 ft msl, and upstream stages north of S-18C will be progressively higher for a storm of 1-in-25 year frequency. Therefore, backfilling the canal will immediately flood most of the area between S-18C and S-177, 178 and will have a chain reaction that may lead to flooding as far north as Florida City during severe storm events.

If C-111 is backfilled as described in Alternative 1 below, a portion of the design discharge (approximately 600 cfs) can still be released to the Park. The remaining 1500 cfs (2100-600) would be handled by two additional features: (1) a pump station to provide 1500 cfs discharge capacity towards the east and (2) a containment levee to prevent backflow toward the Florida City area.

V. PROPOSED ALTERNATIVES AND ANALYSIS OF IMPACTS

Two major alternative plans for the C-111 south basin are presented and discussed along with their positive and negative impacts. Additionally, a

number of options which may be incorporated into these or other alternatives are also described.

Alternative #1 - Eastern Floodway

Description

This proposal will eliminate nearly all of C-111 and its levees from S-18C south, and will create a large, continuous marsh, about 4 miles wide, extending from a point 2 miles north of S-18C to northeast Florida Bay. Overland sheet flow in this marsh will be dependent on local rainfall plus supplemental water pumped into the north end of the area from C-111. The major components of this plan, as depicted in Figure 6 are as follows:

1. Fill C-111 from the bend south of S-18C to Manatee Bay.
   a. Remove north and south spoil levees east of the bend.
   b. Remove S-197 culvert structure.
   c. Remove nine inlet structures from north side of C-111
2. Extend C-111 south of S-18C for an additional mile
   a. The bottom profile will gradually slope upwards to ground elevation
   b. Retain and construct spoil levee along east and west sides of the C-111 extension
3. Backfill incomplete C-110 and partially backfill incomplete C-109
4. Retain eastern levee of C-109 for containment dike
5. Construct a pump station on east side of C-111, two miles north of S-18C
   a. Excavate east-west distribution channel at the north end of the TPL land from the pump station to C-109
   b. Construct a training dike south of the distribution channel, to achieve uniform overland flow

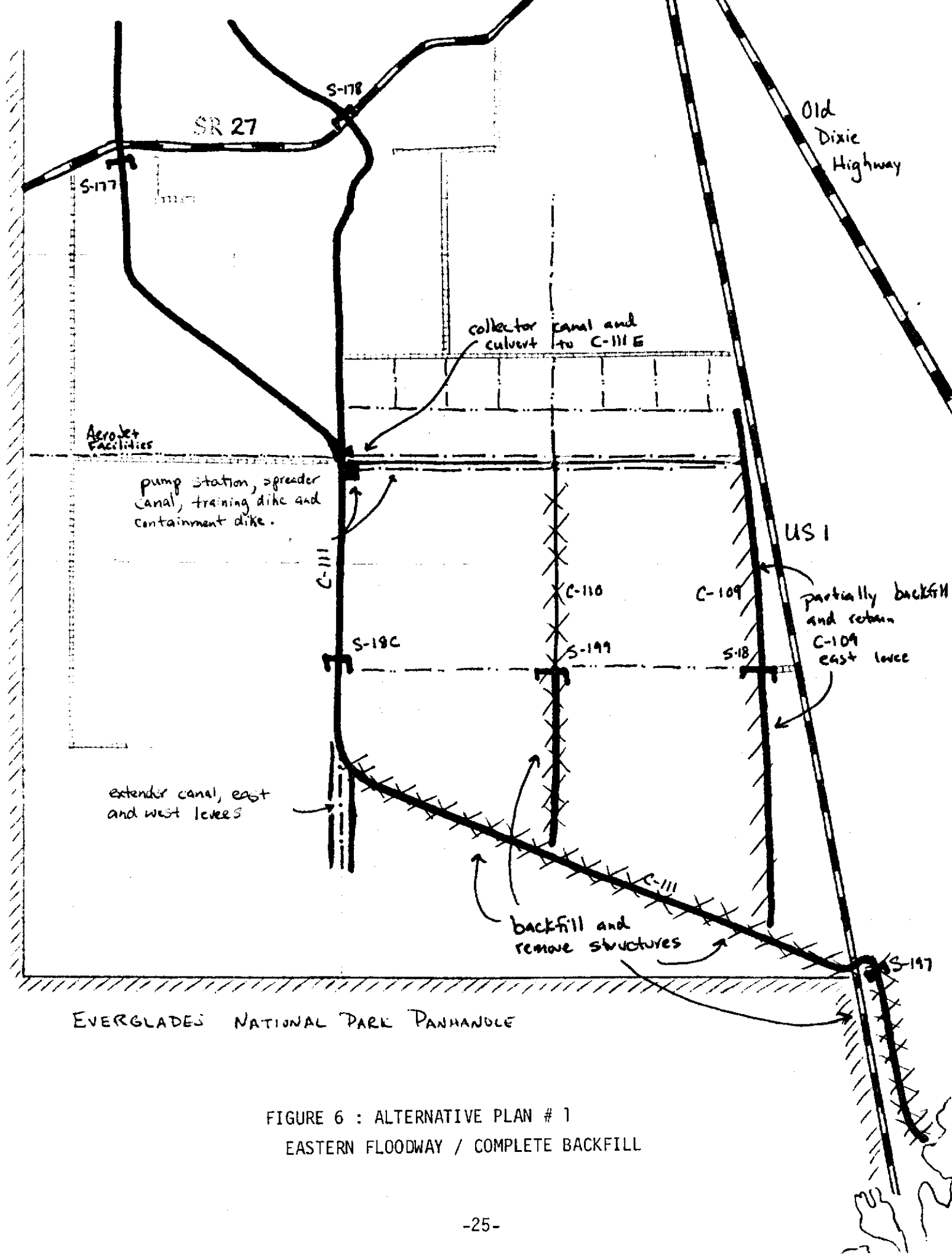


FIGURE 6 : ALTERNATIVE PLAN # 1
EASTERN FLOODWAY / COMPLETE BACKFILL

c. Create a northern containment dike from the spoil obtained from the get-away channel

d. Install a collection channel north of the containment levee to drain water from the north and route this water toward C-111

6. Acquire 18+ sections of land east of S-18C and C-111 and 13+ sections to the west from from TPL.

Impacts

Alternative 1 will create a four mile wide, natural floodway contiguous with the eastern four miles of ENP panhandle area and northeast Florida Bay. The discharge capacity of S-18C will be reduced to an estimated 500-800 cfs with this proposed southern extension of C-111. Consequently, the pump capacity upstream of S-18C would be 1300-1600 cfs to provide the existing level of flood protection. A larger pump capacity of 2700 cfs would be required to handle 100% SPF conditions (3200 cfs -500 cfs at S-18C). This option can be expected to have the following management and environmental impacts:

a. Storm water discharges from the C-111 drainage basin of less than 800 cfs will flow through S-18C and be distributed as a point discharge into the marsh floodway. Based on normal operating experience during the period 1975-1980, water will be discharged through S-18C an average of 48 times/year. Volumes in excess of 800 cfs, which would require supplemental pumping, would occur for an average of 8 days/year (Table 4).

b. Monthly allocations of water to the ENP panhandle would be delivered either as a point source through S-18C, or pumped into the north end of the eastern marsh, some 8-10 miles from the estuaries. During the dry season this water would probably not reach Florida Bay as sheet flow.

TABLE 4. Frequency of Discharge Events at S-18C Based on Average Daily Flow in cfs for Period 1970-1981.

Daily Discharge in cfs	Number of Daily Events 1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	Total Days	%	% of Discharge Days
0	125	229	138	197	360	344	330	310	315	308	297	311	3264	74.5	
1-50	234	136	180	134	5	1		9		20	2		721	16.4	64.4
51-100			1	14						5		1	21	0.5	1.9
101-200	1		2	2		2		3	6	1	12	1	30	0.7	2.7
201-300	3		1	3		2	6	9	8	1	9		42	1.0	3.8
301-400			2	3		4	2	6	6	1	9	1	34	0.8	3.0
401-500	1		1	6			6	9	7	6	8	4	48	1.1	4.3
501-600				3		2	6	1	6	3	8	5	34	0.8	3.0
601-700			4	1		2		5	3	6	6	3	30	0.7	2.7
701-800	1		2	2		2	4	3	6	4	4	1	29	0.7	2.6
801-900			7			2	1	4		4	3		21	0.5	1.9
901-1000			5			3	2	2	5	3	4	6	30	0.7	2.7
1000+			23			1	9	4	3	3	4	32	79	1.8	7.1
Total Number Days Discharge	240	136	228	168	5	21	36	65	50	57	69	54	1119	25.5	100.1

c. No water from the C-111 drainage will be diverted to Manatee Bay. Salinities in the estuaries of Northeast Florida Bay may be reduced, relative to existing conditions, since these estuaries will receive freshwater from local rainfall and subsequent overland/subsurface flow in the basin, and supplemental storm water runoff handled by S-18C and the pump station.

d. This plan should not be detrimental to the animal species which inhabit or frequent this area. Special considerations should be addressed to the following endangered species:

1) Crocodile - Much of the area in the vicinity of this project is considered as critical habitat for the American crocodile. Although crocodiles nest on beaches and in mangrove areas of Florida Bay, the condition of the upstream drainage basin is critical because crocodile hatchlings cannot tolerate high salinity and need a source of freshwater. To coincide with the hatching, high freshwater flows into the estuaries would be required in mid-summer through late fall.

2) Cape Sable seaside sparrow - Recent surveys indicate that substantial numbers of sparrows inhabit the Muhlenbergia prairies in the vicinity of this project, particularly on the southeast side of Taylor Slough. Muhlenbergia prairies occur in areas that are flooded no more than 6 months annually, and generally are flooded about 4 months. Muhlenbergia prairies have probably developed in this area in recent years as the result of hydroperiod reduction, due to canal construction. All sparrows were located west of C-111, and south of the Aerojet lateral canal. Under this plan, no additional overland flow will be introduced into the lands west of C-111 and south of the Aerojet canal.

Alternative #2 - Impoundment

Description

This alternative involves only partial backfilling of C-111, from US 1 to Manatee Bay, does not create a 4x10 mile unimpeded flow way to northeast Florida Bay, but disperses excessive storm water discharges into a 15 mi^2 impoundment. The major components of this alternative, as depicted in Figure 7 are as follows:

1. Completely backfill C-111 from US 1 to Manatee Bay and partially backfill towards the west
   a. Remove culvert structure S-197
   b. Use some of spoil from south side of C-111 to partially fill the canal (from 12 feet to 6 feet deep) for 5 miles west of US 1
2. Retain the gaps along the south side of C-111
   a. Widen gaps to increase their capacity to pass water
   b. Proportionally enlarge the western gaps to more evenly distribute flow along the 5 mile front
3. Retain the north levee and nine inlet structures along C-111
   a. Set adjustable riser boards at 2.5 feet msl
   b. Seasonally lower riser boards to release water if available, from north to flow through gaps during dry season, and to simulate desirable conditions in the wetlands north of C-111
4. Maintain eastern levee of C-109, breach other levees and plug portions of C-109 and C-110
5. Install pump station on east side of C-111, 2 miles north of S-18C
   a. Excavate an east-west distribution channel and training dike at the north end of the TPL property
   b. Place spoil on the north side of the impoundment to form a containment levee and protect property to the north.

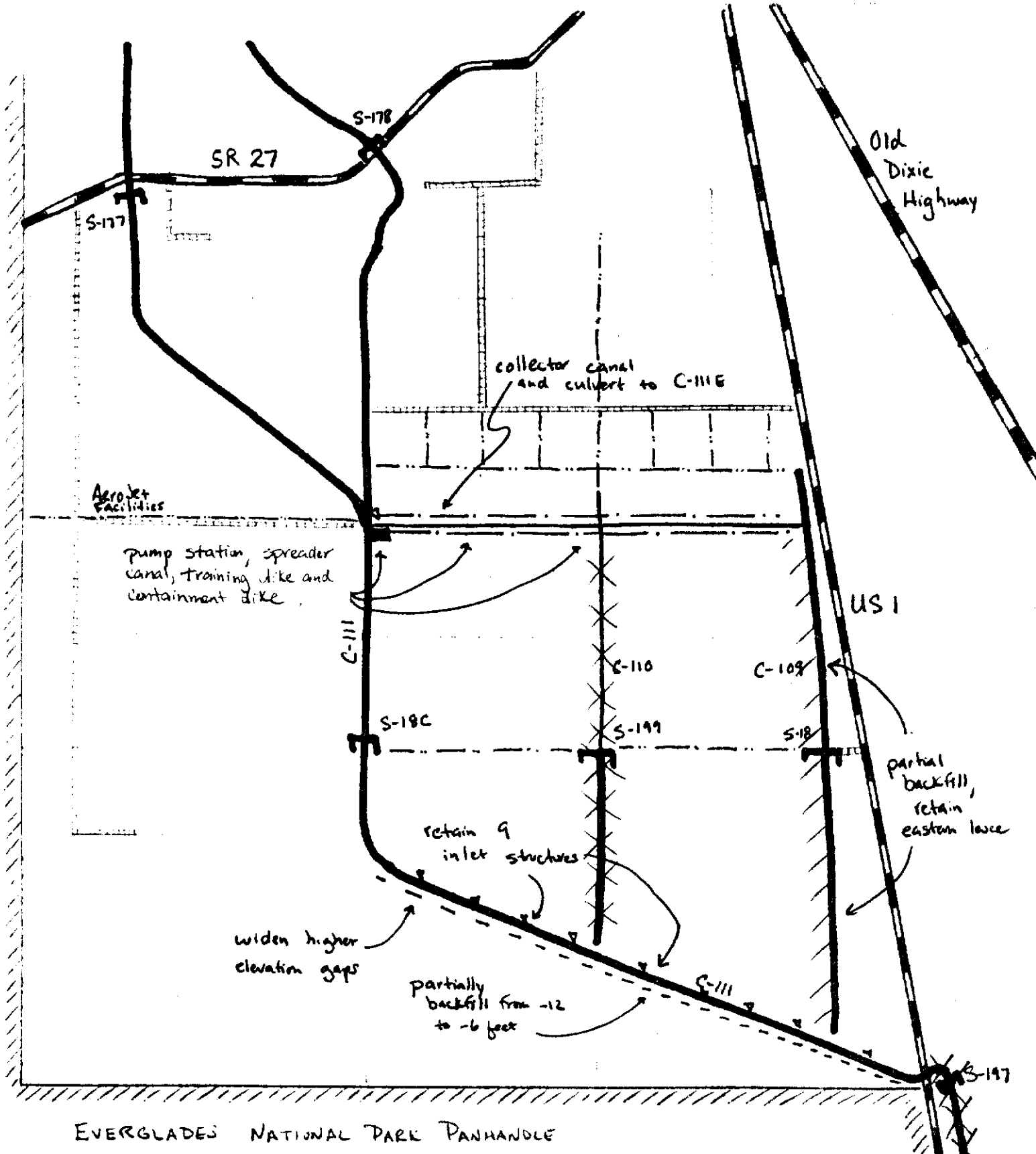


FIGURE 7 : ALTERNATIVE PLAN # 2
EASTERN IMPOUNDMENT / PARTIAL BACKFILL

c. Provide a collection channel north of the containment dike to divert runoff to C-111.

6. Acquire TPL property east and west of C-111.

Impacts

The discharge capacity of S-18C will be reduced during severe storm events to about 500 to 800 cfs with the elimination of S-197 and the earthen plug. This capacity may be increased substantially by widening of the spoil gaps. Nevertheless, the pump upstream of S-18C must have a capacity of about 1300 to 1600 cfs to provide existing flood protection. Alternative 2 can be expected to have the following impacts:

a. This alternative will create an impounded flow way east of S-18C and west of US 1 to Florida Bay consisting of approximately 15 mi^2 of marshland between C-111, US 1 and the northern containment dike. Surface flow from local rainfall can pass from this area through the nine culvert structures into C-111, then through the gaps and southward to Florida Bay.

b. The majority of stormwater discharges from the C-111 basin, in quantities less than about 800 cfs in normal conditions or 500 cfs during extremely wet periods, will flow through S-18C and be distributed along a five mile front through the gaps. Supplemental pumping into the impoundment area would occur infrequently, whenever discharges at S-18C exceeded the ability of the gaps to pass water.

c. Routine monthly allocations of water to the ENP panhandle would be delivered through S-18C and distributed through the gaps along a five mile front, approximately 4-5 miles north of the estuary. It is estimated that in order to maintain a surface water elevation of 1.6 ft msl in C-111 downstream of S-18C in the dry season and pass water through all gaps, a minimum discharge of 150 cfs is required at S-18C.

d. No water will be diverted from the C-111 drainage area into Manatee Bay. Consequently, northeast Florida Bay salinities will be dependent on local rainfall, subsequent runoff and supplemental stormwater runoff. Excess storm water runoff will be pumped into the impoundment area north of C-111 for temporary storage, after which time water can pass through the culverts and gaps to Florida Bay, thereby reducing peak stormwater flows.

e. Maintenance of higher water stages in the impoundment will reduce the likelihood of saltwater intrusion into the canal during the dry season. In addition, removal of the majority of the spoil mounds and partial backfilling of the eastern portion of C-111 from a depth of 12 to a depth of 6 ft will enhance the aesthetics of the area.

f. Both the crocodile and Cape Sable Sparrow should benefit, or be unaffected by this plan as indicated for the previous alternative.

Option 1 - Increased Pump Station Capacity

Description

Alternatives #1 and 2 provide for a pump station on the east side of C-111, 2 miles north of S-18C, of a size sufficient to handle the discharge capacity lost at S-18C due to elimination of S-197 and the earthen plug. The capacity of this pump station has been estimated at about 1300-1600 cfs to meet existing conditions. However, since substantial flood damages occurred in the Florida City area from tropical storm Dennis, increased flood protection for this area may be desirable. This increased protection could be provided by a pump station capacity of 2400-2700 cfs. Enlargement of canal cross-sections and structure capacities in C-111 northward to S-177, and in C-111E to S-178 may be required to improve conveyance capacity to the larger pump.

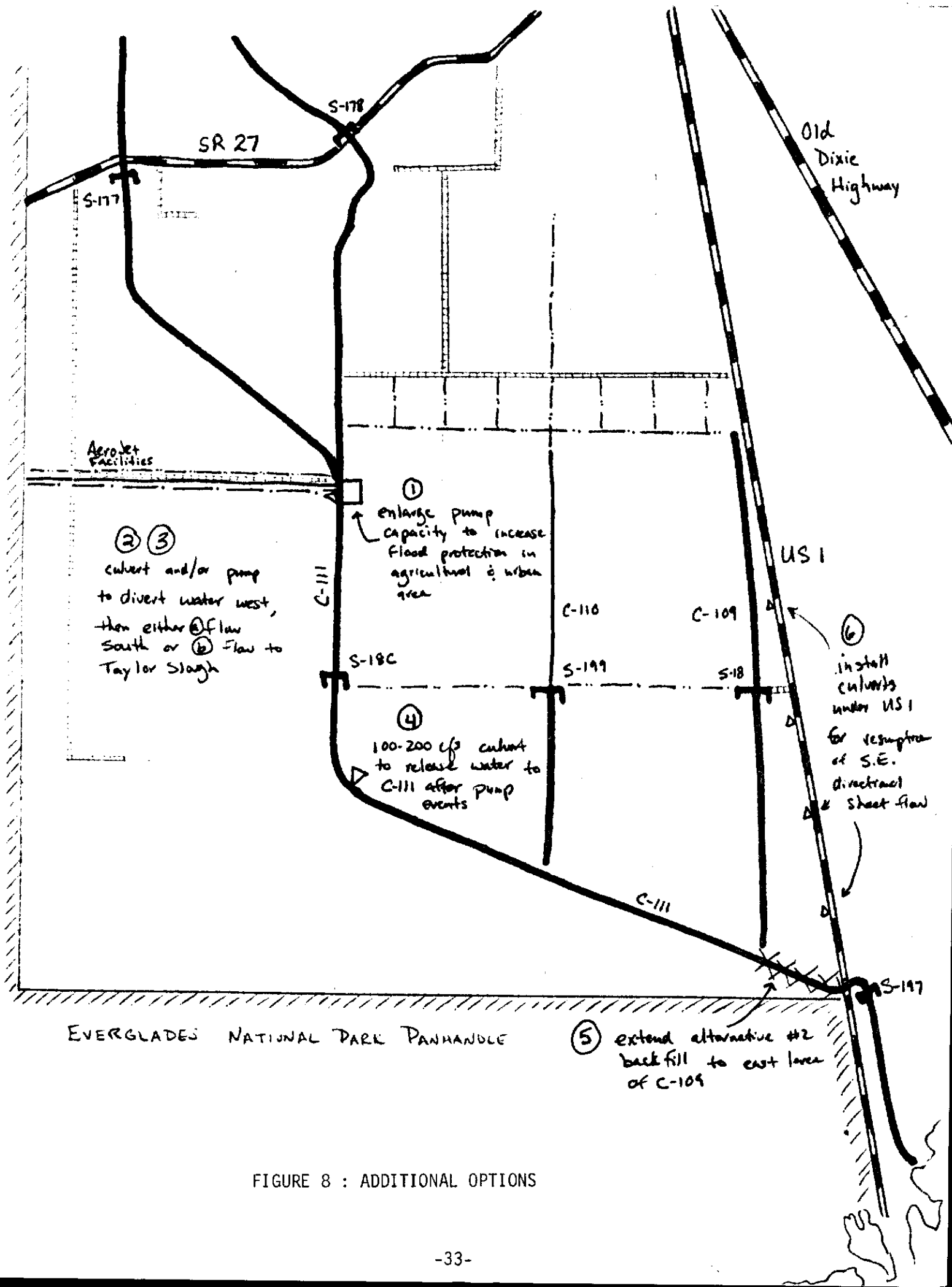


FIGURE 8 : ADDITIONAL OPTIONS

Impacts

Use of a larger pump will provide improved flood protection during the infrequent (greater than 1 in 10 year) storm events. Excessive amounts of water will be pumped into the marsh area east of S-18C and C-111 during these infrequent events. From a water quantity standpoint, this option would be more detrimental if added to alternative #2, since overall water levels would rise higher in an impounded marsh than in an unimpeded flowway.
Two examples are presented below:

Example #1

1500 cfs pump x 5 days =

2970 ac-ft/day x 5 days = 14,850 ac-ft

15 mi^2 x 640 = 9600 acres

14850 ac-ft ÷ 9600 acres = 1.55 ft addt'l water

Example #2 (with enlarged pump)

2600 cfs x 5 days = 25,740 ac-ft

25,740 ac-ft ÷ 9600 acres = 2.68 feet addt'l water

Option 2 - Western Floodway

Description

Both Alternatives provide a means to transport excess water to the east of C-111. It is anticipated that TPL land will be acquired east and west of C-111. A culvert or flap gate structure located in the western levee of C-111, 2 miles north of S-18C, could distribute excess water into an improved channel alongside the AeroJet access road. Water could then flow:

a) south by spilling out the south side of the canal and flowing overland towards Florida Bay or,

b) west through a leveed channel terminating near Taylor Slough.

Impacts

Option 2 (a) will provide for additional overland flow in this project area towards the ENP panhandle and may help to restore a more natural hydroperiod in this section of marsh. It would adversely affect the population of Cape Sable sparrows which currently inhabit the Mulhenbergia prairies in this area.

Option 2 (b) will not impact the Cape Sable sparrows and will increase water supply in Taylor Slough. With proper design, this alternative could provide supplemental water to Taylor Slough for much of the year. However, that would be at the expense of water diverted from ENP panhandle and the Florida Bay estuaries. Additionally, S-332 should provide more water to Taylor Slough with the completion of the south Dade Conveyance System.

Additional Options

3. Option #2 above was based on the use of gravity to discharge water from C-111 westward. Greater amounts of water could be transferred to the west, under a wider range of hydrologic conditions, with a pump station along the west levee to supplement flows.

4. Under Alternative #2, water pumped from C-111 to the east will be impounded by levees. With the existing nine inlet structures at the south end of the area, surface outflow is limited to about 50 cfs. In order to reduce the environmental impact of prolonged excessive water stages in this impounded marsh, a larger culvert of 100-200 cfs capacity could be installed in the southwest corner of the area, to be operated after peak floodwater flows have ceased, and reduce the duration of the high water stages in the impoundment area.

5. Since the C-109 east levee is to form the boundary of the impoundment, another option is to backfill C-111 from C-109 eastward and create an additional 1-mile wide unimpeded marsh drainage area. This

modification would also eliminate a source of ponding water above C-111, and remove the 7 gaps that are at the lowest elevation. This modification will also eliminate direct access to the levee system from U. S. Highway 1.

6. Purchase of additional land north of the TPL property. Another option is to purchase the four additional square miles of Aerojet property to provide additional reflooded marshland to the north. This will require relocation of the pump station, levees and canals as appropriate.

7. Presently, the structures on C-102 and C-103 have limited discharge capacity, even though the canal cross-sections are capable of accommodating increased flows. A detailed reevaluation of these canals and structures may provide for additional discharge to the east and thereby reducing the need for additional pump capacity above S-18C (Option 1).

VI. SUMMARY

Analysis of the C-111 basin, using the current environmental, hydrological, hydrogeological, and hydraulic information, reveals that the south end of the C-111 Canal system cannot be backfilled unless additional discharge capacity, such as a pump, is provided to supplement S-18C. Filling the entire canal would eliminate the means that is currently available for distributing water flow to the ENP across a broad front that resembles sheet flow. The canal can be effectively backfilled south of U. S. Highway 1. This backfilling would retain the present gravity discharge capacity to the Park and allow for more efficient movement of water toward Florida Bay.

Partial backfilling of C-111 would cause upstream water stages to rise above the land elevation. Therefore, a pump with a minimum discharge capacity of approximately 1600 cfs would be needed to meet the existing level of flood protection. Should additional flood protection be justified, the maximum pump capacity would be about 2700 cfs. As gravity discharge would

transmit the flow the majority of the time, the total pump capacity could be achieved by the installation of several small capacity pumps in series.

This system would require construction of a containment levee at the north end of the TPL property, a collection channel north of the levee to divert runoff water west to the pump station, and a getaway channel immediately south of the levee to provide for an even distribution of pumped water across the marsh.

VII. RECOMMENDATIONS

1. Backfill C-111 from C-109 south to Manatee Bay.
2. Retain C-111 from S-18C to C-109 but reduce the canal depth from 12 feet to 6 feet at the eastern end.
3. Enlarge western gaps to evenly distribute overland flow of water.
4. Determine the quantity of groundwater seeping into the canal system during storm events to determine the appropriate pump size for total water removal.
5. Install a series of pumps on east side of C-111, 2 miles north of S-18C.
6. Create a containment dike and distribution channel at north end of TPL lands.
7. Excavate a collection channel north of the containment dike to collect runoff from the north and divert this water west to C-111.
8. Plug and/or backfill C-110 and C-109, but retain C-109 east leveee.
9. Provide an additional 100-200 cfs culvert to release water from SW corner of the impoundment to C-111.
10. Provide a channel for westward routing of water to Aerojet marshes or Taylor Slough. Operation of this canal would be at ENP discretion.

It is felt that this recommended plan will best provide for even distribution of water through the ENP panhandle and into northeast Florida Bay under the widest range of climatic conditions, while providing flood protection and a delivery system for supplemental freshwater to the area.

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APPENDIX A

FLOOD PROTECTION ANALYSIS

In order to gain a better understanding of the C-111 basin, flood stages generated by storm events of 1-in-10 and 1-in-25 year return frequencies were analyzed by use of a modified Santa Barbara Urban Hydrograph Method. This modified model was developed by Charles Alan Hall, Director of the Water Management Division at the SFWMD. It was assumed in the analysis that the canal south of S-18C would be completely backfilled, and discharge from any storm event would occur as gravity flow. Runoff generated from the basin upstream of S-18C was retained in a 3 mile x 5 mile impoundment, and then allowed to discharge by gravity across the 5 mile width of the marsh to the Everglades National Park.

The following parameters were used to generate the depth of flooding, stages south of structure S-18C, and the gravity discharge through the marsh to ENP under different hydraulic head conditions.

n(Mannings Roughness Coeff.) = 1.3

Width of flow (w) = 5 miles

Slope (gradient) (s) = 1 foot/ 3 miles

A modified Mannings formula of the form:

$$Q = \frac{1.486}{n} (D)^{5/3} \cdot S^{1/2} \cdot W$$

was used to develop the stage discharge relationship. Presented below is the stage, discharge and the depth of ponding of the area south of S-18C.

Stage ft.msl	Discharge cfs	Depth of Ponding feet
1.7	5.0	.10
1.8	16.0	.20
1.9	32.0	.30
2.0	52.0	.40
2.5	201.0	.90
3.0	420.0	1.40
3.5	700.0	1.90
4.0	962.0	2.30

The land elevation around S-18C is only 2.0 ft msl. Therefore, whenever the flood stage exceeds this stage, flooding will occur in the area.

The areas that contribute runoff to the 3 x 5 mile impoundment were subdivided into two subareas: (1) semi-urbanized, and (2) agricultural as shown in Figure A-1. Out of a total of 60 square miles of the area, 49 square miles were semi-urbanized and 10 square miles were agricultural.This method of calculation overestimates the runoff generated, rather than underestimating the instantaneous runoff, which provides a factor of safety.

The time of concentration (TC) from the two sub-basins was calculated as follows:

Semi-urbanized Area - $TC = 2 \times Area$

Agricultural Area - $TC = 4 \times Area$

where,

Area = square miles

In order to develop the stage-storage relationship, the area below each contour (Figure A-2) was calculated and is presented below in Tables A-1 and A-2.

Figure A-1. Assumed Land Use and Area Boundaries for Calculation of Impacts of 1-in-10 and 1-in-25 Year Storm Events

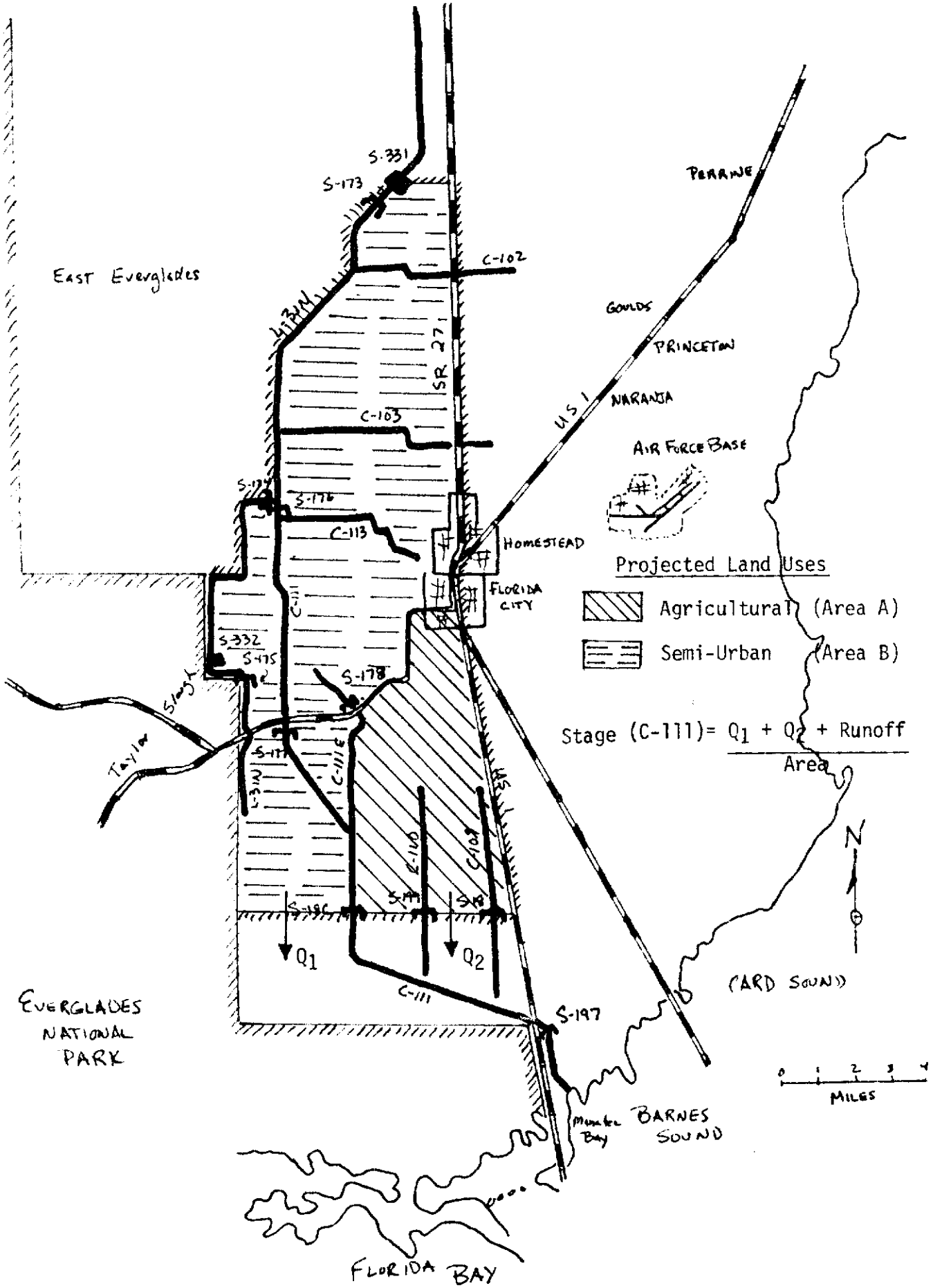


Table A-1. Stage-Storage Computations for Area A on Figure A-1.

AREA A

STAGE - STORAGE COMPUTATIONS

STAGE FEET ABOVE INVERT	4632AC BELOW2 STORAGE AC-FT	3600AC BELOW3 STORAGE AC-FT	1092AC BELOW4 STORAGE AC-FT	2000AC BELOW5 STORAGE AC-FT	20323AC BELOW10 STORAGE AC-FT	TOTAL STORAGE AC-FT
	*2	*3	*4	*9	*10	
	**	**	**	**	**	
	***	***	***	***	***	
	****	****	****	****	****	
	*****1	*****2	*****3	*****4	*****5	
1	0	0	0	0	0	0
1.5	579	0	0	0	0	579
	2316	0	0	0	0	2316
2.5	4632	450	0	0	0	5082
3	6948	1800	0	0	0	8748
3.5	9264	3600	136.5	0	0	13000.5
4	11580	5400	546	0	0	17526
4.5	13896	7200	1092	250	0	22438
	16212	9000	1638	1000	0	27850
5.5	18528	10800	2184	2000	508.07	34020.1
6	20844	12600	2730	3000	2032.3	41206.3
6.5	23160	14400	3276	4000	4572.67	49408.7
	25476	16200	3822	5000	8129.2	58627.2
7.5	27792	18000	4368	6000	12701.9	68861.9
8	30108	19800	4914	7000	18290.7	80113.7
8.5	32424	21600.	5460	8000	24895.7	92379.7
9	34740	23400	6006	9000	32516.8	105663.
9.5	37056	25200	6552	10000	41154.1	119962.
10	39372	27000	7098	11000	50807.5	135278.

STAGE VS STORAGE

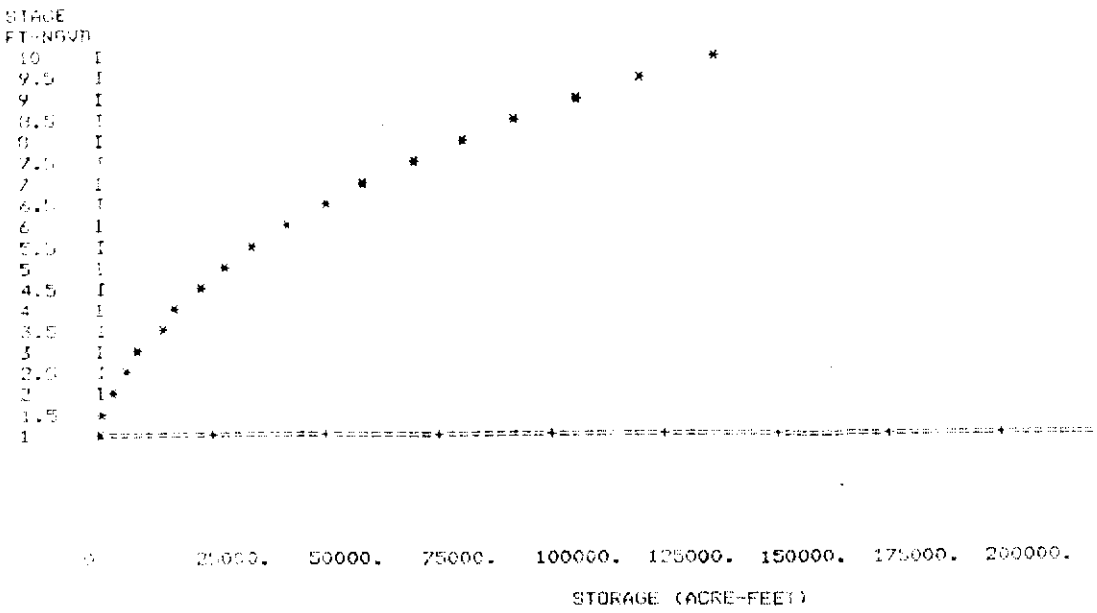


Table A-2. Stage- Storage Computations for Area B on Figure A-1.

AREA B

STAGE - STORAGE COMPUTATIONS

STAGE FEET NGVD	4380AC BELOW2 STORAGE AC-FT *2	1980AC BELOW3 STORAGE AC-FT *3	750AC BELOW4 STORAGE AC-FT *4	TOTAL STORAGE AC-FT
1	0	0	0	0
1.5	547.5	0	0	547.5
2	2190	0	0	2190
2.5	4380	235	0	4615
3	6570	940	0	7510
3.5	8760	1880	93.75	10733.8
4	10950	2820	375	14145
4.5	13140	3760	750	17650
5	15330	4700	1125	21155
5.5	17520	5640	1500	24660
6	19710	6580	1875	28165
6.5	21900	7520	2250	31670
7	24090	8460	2625	35175
7.5	26280	9400	3000	38680
8	28470	10340	3375	42185
8.5	30660	11280	3750	45690
9	32850	12220	4125	49195
9.5	35040	13160	4500	52700
10	37230	14100	4875	56205

STAGE VS STORAGE

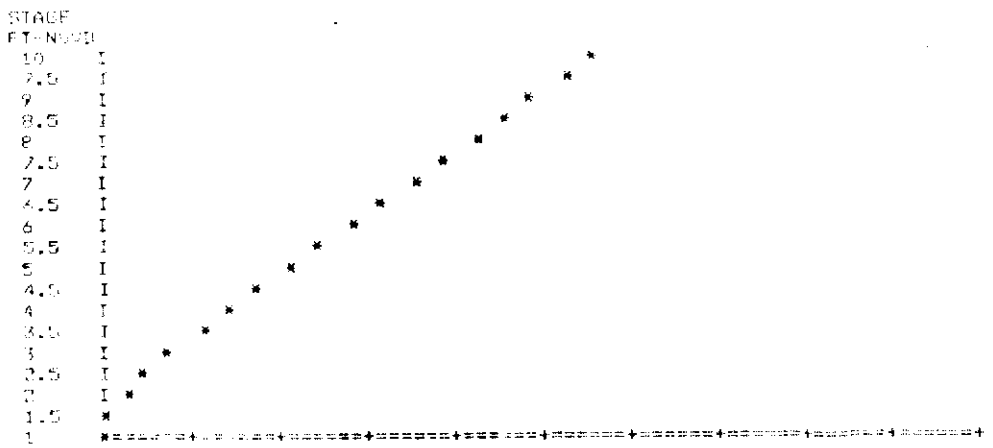
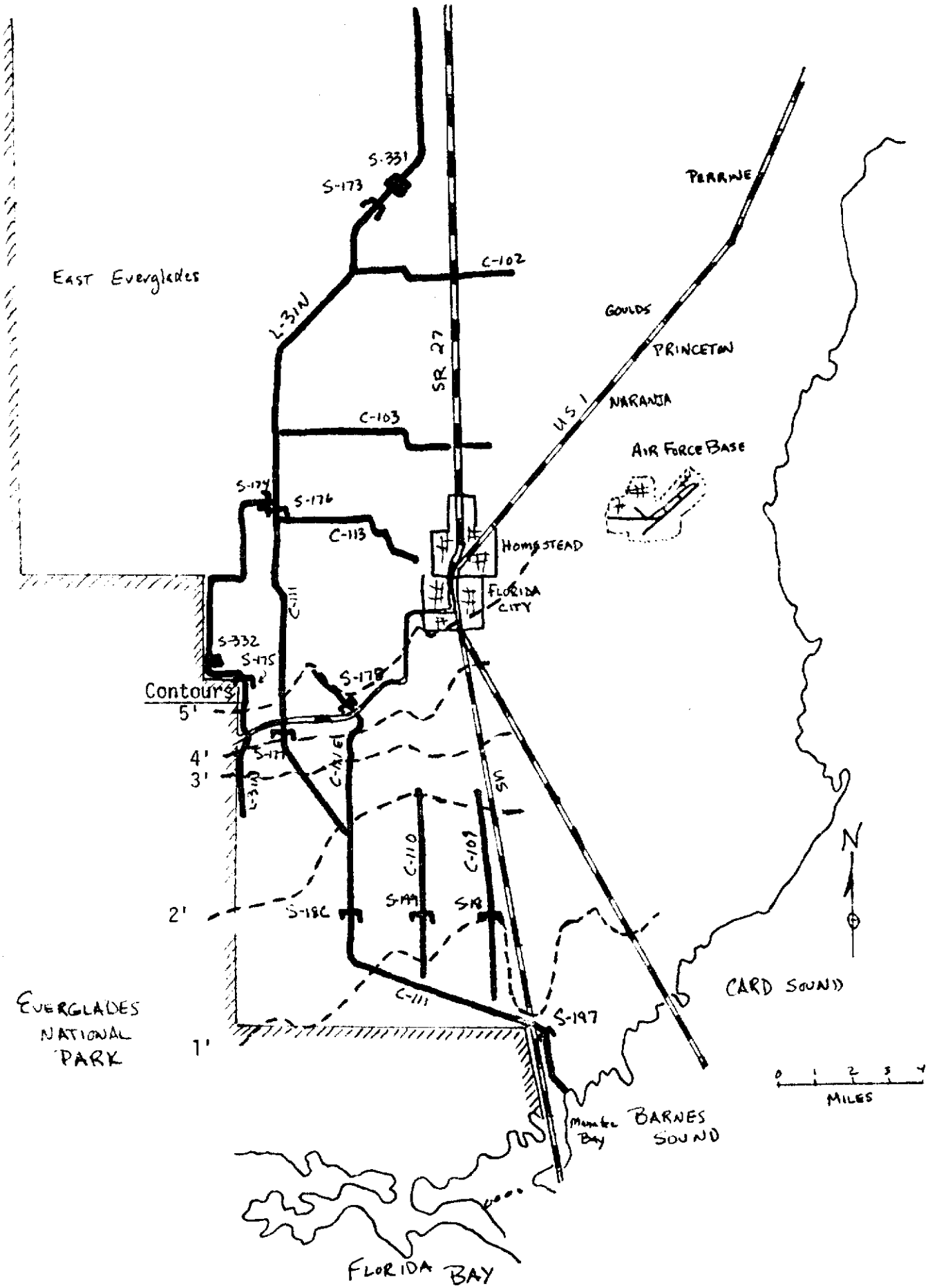


Figure A-2. Contour Elevations at the South End of the C-111 Canal System (Based on USCOE Map in the GDM for South Dade County).



ROUTING

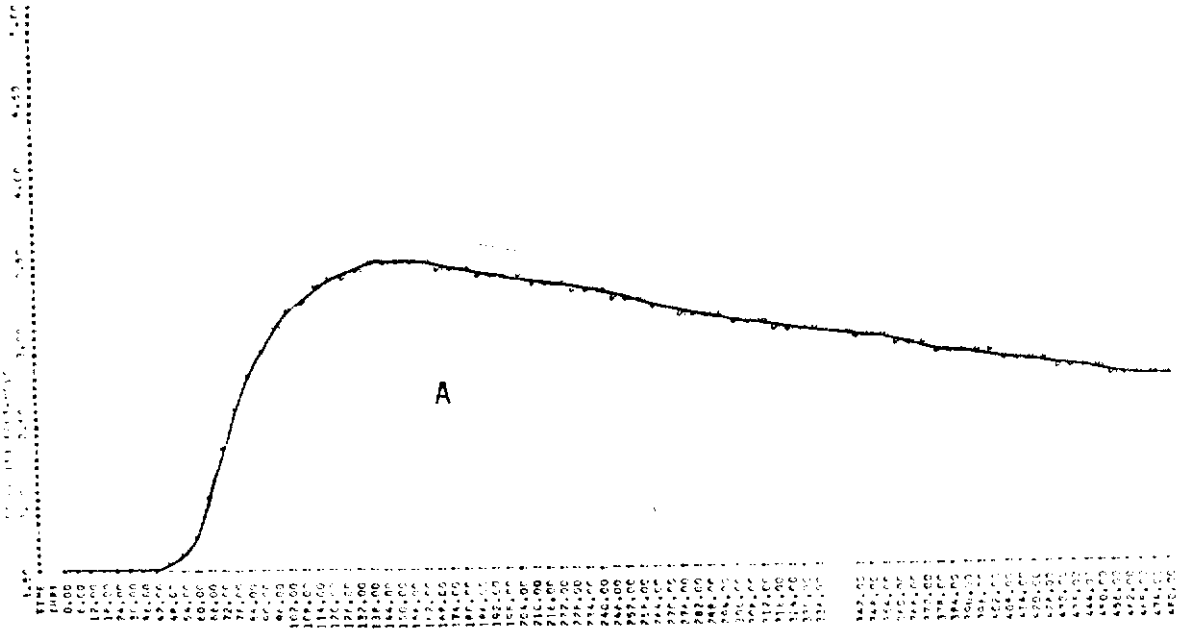
One in 10 year return frequency storm

A storm with 7 inches of rainfall and a 5 day duration had a return frequency of 1-in-10 years, was routed through the C-111 basin under completely backfilled conditions. It was assumed that out of the 7 inches of rain, 3 inches would be absorbed by ground storage. Presented below in Figures A-3, and Table A-3 are the inflow and outflow hydrographs, the stage duration curve, and the tabular data that were generated from the model.

A 1-in-10 year frequency storm will generate a stage of 3.41 feet. A maximum discharge of 649.2 cfs will occur under this condition from the 5 mile wide marsh.

One in 25 year return frequency storm

A 1-in-25 year, 5 day duration storm event was also routed using the above described model (See Figures A-4, and Table A-4). This storm event will generate a stage of 3.90 ft msl downstream of S-18C. Stages upstream of S-18C will be higher than the predicted values for downstream of the structure. Therefore, areas upstream of the structure need to be protected by providing a levee and suitable pumps to reduce the peak flood stages.



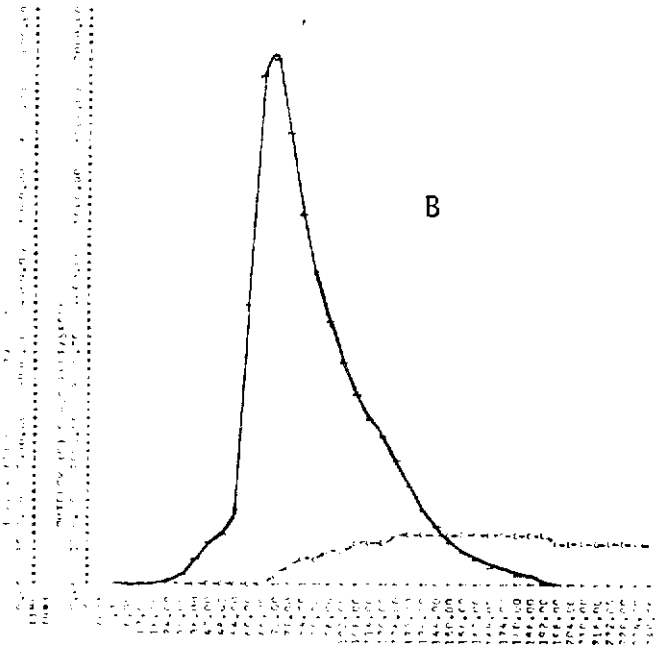


Figure A-3. Stage (A) and Inflow-Outflow (B) Hydrographs for the 1-in-10 Year Storm Event in the C-111 Basin

Table A-3. Routing of 1-in-10 Year Storm Event in C-111 Basin.

PROJECT NAME	C-111
REVIEWER	KHANAL
PROJECT AREA	38657.00 ACRES
GROUND STORAGE	3.00 INCHES
TERMINATION DISCHARGE	100.00 CFS
TIME OF CONCENTRATION	24.00 HOURS
TIME STEP	6.00 HOURS
DISTRIBUTION TYPE	SFWMD
RETURN FREQUENCY	10.00 YEARS
RAINFALL DURATION	3 DAY
24 HOUR RAINFALL	7.00 INCHES
REPORTING SEQUENCE	INCREMENTAL

STAGE (FT)	STORAGE (AF)	DISCHARGE (CFS)
1.50	0.00	0.00
2.00	3565.00	52.00
2.50	8697.00	201.00
3.00	15258.00	420.00
3.50	22734.00	700.00
4.50	30671.00	962.00

TIME (HR)	RAIN FALL (IN)	ACCUM. RUNOFF (IN)	BASIN DISCHGE (CFS)	ACCUM. INFLOW (AF)	RESERVOIR VOLUME (AF)	ACCUM. OUTFLOW (AF)	INSTANT DISCHGE (CFS)	AVERAGE DISCHGE (CFS)	STAGE (FT)
0.00	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	1.50
6.00	.26	0.00	0.0	0.0	0.0	0.0	0.0	0.0	1.50
12.00	.51	0.00	0.0	0.0	0.0	0.0	0.0	0.0	1.50
18.00	.77	.01	6.3	1.6	0.0	.0	.0	.0	1.50
24.00	1.02	.05	42.5	13.7	13.6	.1	.1	.1	1.50
30.00	1.30	.17	146.9	60.6	60.4	.2	.0	.3	1.51
36.00	1.77	.33	312.8	174.6	173.8	.8	1.7	1.1	1.52
42.00	2.14	.52	500.1	376.1	374.0	2.1	4.1	2.9	1.54
48.00	2.51	.74	670.7	671.4	666.3	5.1	7.7	5.9	1.57
54.00	3.09	1.13	977.3	1085.0	1074.8	10.2	10.9	10.5	1.62
60.00	7.11	4.45	3435.9	2179.2	2159.9	19.4	23.9	18.4	1.73
66.00	8.00	6.13	4273.6	4586.2	4548.7	37.5	49.6	34.0	1.98
72.00	8.43	6.67	6478.7	7747.7	7666.6	81.1	126.1	87.0	2.39
78.00	8.76	6.82	5569.0	10734.7	10569.4	165.3	253.4	169.0	2.73
84.00	9.91	7.94	4099.4	13255.8	12962.8	293.0	331.3	243.0	2.93
90.00	10.11	7.23	3845.3	15349.6	14809.5	460.1	322.8	256.0	3.09
96.00	10.30	7.41	3260.5	17111.5	16451.9	659.6	431.7	329.5	3.21
102.00	10.47	7.57	2705.0	18610.3	17723.6	886.7	484.3	409.0	3.31
108.00	10.64	7.73	2595.5	19894.7	18757.3	1137.4	541.8	484.4	3.39
114.00	10.84	7.89	2072.8	21007.5	19600.1	1407.4	581.8	554.4	3.46
120.00	10.98	8.05	1817.8	21987.3	20394.0	1673.0	590.3	606.0	3.52
126.00	10.98	8.05	1560.0	22834.4	20843.0	1991.4	633.6	631.0	3.57
132.00	10.98	8.05	1213.4	23502.0	21222.2	2099.0	630.0	631.7	3.60
138.00	10.98	8.05	943.7	24076.0	21441.6	2615.0	641.6	635.0	3.62
144.00	10.98	8.05	734.0	24470.1	21538.0	2934.0	647.4	644.7	3.63
150.00	10.98	8.05	570.9	24796.3	21540.1	3256.2	649.-	650.-	3.63
156.00	10.98	8.05	444.0	25048.0	21470.1	3577.9	648.0	649.-	3.63
162.00	10.98	8.05	345.4	25243.4	21340.4	3898.7	643.3	645.-	3.62
168.00	10.98	8.05	268.6	25391.-	21179.-	4216.4	636.-	640.6	3.59
174.00	10.98	8.05	209.9	25514.3	20982.7	4531.6	630.0	633.8	3.56
180.00	10.98	8.05	162.5	25606.4	20767.2	4843.0	624.-	627.-	3.53
186.00	10.98	8.05	126.4	25677.0	20537.4	5150.-	614.-	619.-	3.50
192.00	10.98	8.05	98.3	25732.2	20294.8	5453.9	602.-	611.-	3.47
198.00	10.98	8.05	76.5	25777.0	20024.4	5752.6	597.2	602.4	3.42
204.00	10.98	8.05	59.5	25810.7	19764.1	6046.6	589.1	592.9	3.39
210.00	10.98	8.05	46.3	25837.0	19501.1	6335.9	578.4	583.7	3.35
216.00	10.98	8.05	35.0	25857.3	19237.1	6620.2	568.6	573.5	3.32
222.00	10.98	8.05	28.0	25873.2	18973.4	6899.0	558.9	563.8	3.29
228.00	10.98	8.05	21.8	25885.5	18711.0	7174.5	549.1	554.0	3.26
234.00	10.98	8.05	16.9	25895.1	18450.7	7444.4	539.4	544.7	3.23
240.00	10.98	8.05	13.2	25902.6	18195.1	7709.5	529.8	534.1	3.20
246.00	10.98	8.05	10.2	25908.4	17943.5	7969.9	520.5	525.0	3.18
252.00	10.98	8.05	8.0	25912.9	17697.4	8225.5	510.9	515.6	3.16
258.00	10.98	8.05	6.2	25916.4	17439.8	8476.6	501.7	506.3	3.14
264.00	10.98	8.05	4.9	25919.1	17196.1	8723.0	492.5	497.1	3.13
270.00	10.98	8.05	3.7	25921.3	16956.2	8965.1	483.6	488.0	3.11
276.00	10.98	8.05	2.9	25922.9	16720.3	9202.6	474.7	479.1	3.10
282.00	10.98	8.05	2.3	25924.0	16488.3	9435.9	466.1	470.4	3.08
288.00	10.98	8.05	1.8	25925.2	16260.3	9664.9	457.0	461.8	3.07
294.00	10.98	8.05	1.4	25926.0	16036.3	9889.7	449.1	453.3	3.05
300.00	10.98	8.05	1.1	25926.6	15816.2	10110.4	440.9	445.0	3.04
306.00	10.98	8.05	.8	25927.0	15600.1	10326.9	432.8	436.8	3.02
312.00	10.98	8.05	.6	25927.4	15387.8	10539.6	424.9	428.8	3.01
318.00	10.98	8.05	.5	25927.7	15179.3	10749.4	417.4	421.1	2.99
324.00	10.98	8.05	.4	25927.9	14974.2	10953.7	410.5	413.9	2.98
330.00	10.98	8.05	.3	25928.1	14772.5	11155.6	403.8	407.2	2.97
336.00	10.98	8.05	.2	25928.2	14574.0	11354.3	397.2	400.5	2.96
342.00	10.98	8.05	.2	25928.3	14378.8	11549.5	390.7	393.9	2.95
348.00	10.98	8.05	.1	25928.4	14186.8	11741.6	384.2	387.4	2.93
354.00	10.98	8.05	.1	25928.5	13997.9	11930.6	378.9	381.5	2.92
360.00	10.98	8.05	.1	25928.5	13810.1	12116.4	371.7	374.8	2.91
366.00	10.98	8.05	.1	25928.6	13629.6	12299.2	360.6	366.2	2.90
372.00	10.98	8.05	.1	25928.6	13449.5	12479.1	359.6	359.6	2.88
378.00	10.98	8.05	.0	25928.6	13272.6	12656.0	353.7	356.-	2.87
384.00	10.98	8.05	.0	25928.6	13098.7	12829.9	347.9	350.9	2.86
390.00	10.98	8.05	.0	25928.6	12927.5	13001.0	342.0	345.1	2.85
396.00	10.98	8.05	.0	25928.7	12759.3	13169.4	336.6	339.4	2.84
402.00	10.98	8.05	.0	25928.7	12593.8	13334.9	331.1	333.8	2.83
408.00	10.98	8.05	.0	25928.7	12431.0	13497.7	325.8	328.4	2.82
414.00	10.98	8.05	.0	25928.7	12270.8	13657.9	320.5	323.0	2.81
420.00	10.98	8.05	.0	25928.7	12113.3	13815.4	315.0	317.7	2.80
426.00	10.98	8.05	.0	25928.7	11958.4	13970.3	309.9	312.4	2.79
432.00	10.98	8.05	.0	25928.7	11806.0	14122.7	304.8	307.3	2.78
438.00	10.98	8.05	.0	25928.7	11656.1	14272.6	299.8	302.3	2.77

SUMMARY INFORMATION

MAXIMUM STAGE WAS 3.41 FEET AT 150.00 HOURS
MAXIMUM DISCHARGE WAS 645.2 CFS AT 150.00 HOURS

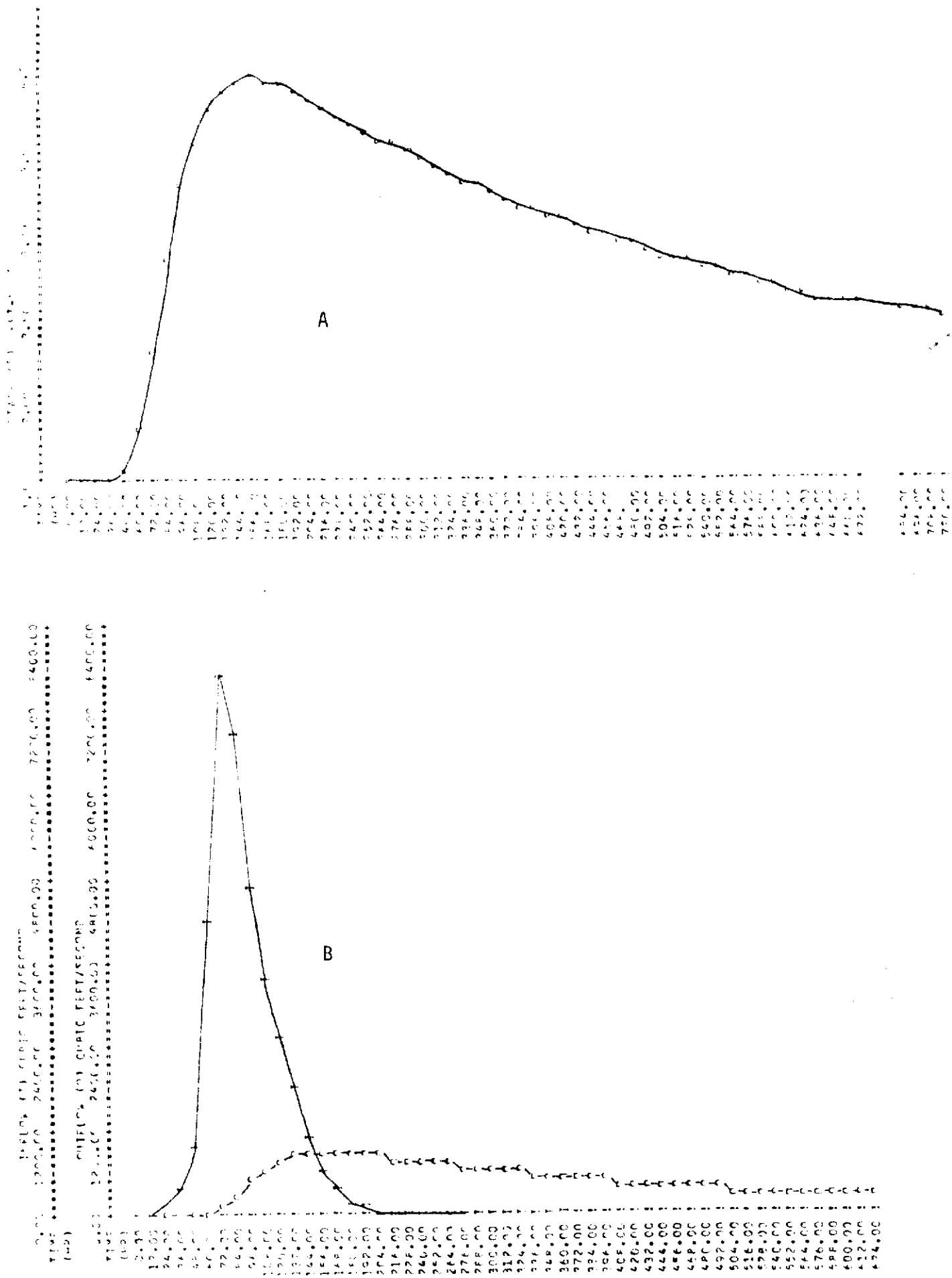


Figure A-4. Stage (A) and Inflow-Outflow Hydrographs (B) for the 1-in-25 Year Storm Event in the C-111 Basin

Table A-4. Routing of 1-in 25 Year Storm Event in C-111 Basin.

SANTA BARBARA PROGRAM

PROJECT NAME	C-111
REVIEWER	KHAWAL
PROJECT AREA	38457.00 ACRES
GROUND STORAGE	3.00 INCHES
TERMINATION DISCHARGE	200.00 CFS
TIME OF CONCENTRATION	24.00 HOURS
TIME STEP	12.00 HOURS
DISTRIBUTION TYPE	SFWMD
RETURN FREQUENCY	25.00 YEARS
RAINFALL DURATION	3-DAY
24-HOUR RAINFALL	9.00 INCHES
RETURNING SEQUENCE	INCREMENTAL

STAGE (FT)	STORAGE (AF)	DISCHARGE (CFS)
1.50	0.00	0.00
2.00	3506.00	52.00
2.50	8697.00	201.00
3.00	15278.00	420.00
3.50	22700.00	700.00
4.00	30671.00	962.00

TIME (HR)	RAIN FALL (IN)	ACCUM. RUNOFF (IN)	BASIN DISCHGE (CFS)	ACCUM. INFLOW (AF)	RESERVOIR VOLUME (AF)	RESERVOIR ACCUM. OUTFLOW (AF)	RESERVOIR INSTANT DISCHGE (CFS)	RESERVOIR AVERAGE DISCHGE (CFS)	STAGE (FT)
0.00	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	1.50
12.00	.66	.00	.7	.3	.3	0.0	.0	.0	1.50
24.00	1.31	.14	89.6	45.1	44.9	.2	.3	.2	1.50
36.00	2.27	.60	442.0	308.7	307.1	1.6	2.6	1.5	1.52
48.00	3.23	1.23	974.6	1011.2	1003.4	7.8	9.7	6.1	1.57
60.00	9.14	6.32	4293.6	3626.0	3596.6	29.4	34.0	21.8	1.83
72.00	12.23	9.25	7787.3	9618.9	9504.3	114.6	130.2	86.1	2.29
84.00	12.74	9.73	6893.4	16898.6	16546.1	352.5	341.5	237.8	2.82
96.00	13.25	10.22	4770.7	22682.5	21883.0	799.5	559.8	450.7	3.25
108.00	13.68	10.64	3450.9	26759.3	25326.1	1433.2	718.3	639.0	3.53
120.00	14.11	11.06	2612.3	29765.8	27574.7	2191.1	810.2	764.2	3.71
132.00	14.11	11.06	1838.5	31972.8	29949.1	3023.7	848.7	839.5	3.83
144.00	14.11	11.06	1103.1	33431.4	29530.6	3900.8	900.3	894.5	3.88
156.00	14.11	11.06	661.9	34306.6	29508.5	4798.1	909.2	904.7	3.90
168.00	14.11	11.06	397.1	34831.7	29135.2	5696.5	902.6	905.9	3.89
180.00	14.11	11.06	238.3	35146.8	28562.7	6584.1	887.2	894.9	3.86
192.00	14.11	11.06	143.0	35335.8	27882.0	7453.8	866.8	877.0	3.82
204.00	14.11	11.06	85.8	35449.3	27147.2	8302.1	848.8	857.3	3.77
216.00	14.11	11.06	51.5	35517.3	26390.4	9126.9	819.6	831.7	3.71
228.00	14.11	11.06	30.9	35558.1	25630.7	9927.6	794.9	807.3	3.66

TIME (HR)	RAIN FALL (IN)	ACCUM. RUNOFF (IN)	BASIN DISCHGE (CFS)	ACCUM. INFLOW (AF)	RESERVOIR VOLUME (AF)	RESERVOIR ACCUM. OUTFLOW (AF)	RESERVOIR INSTANT DISCHGE (CFS)	RESERVOIR AVERAGE DISCHGE (CFS)	STAGE (FT)
240.00	14.11	11.06	18.5	35582.6	24879.0	10703.6	770.4	782.7	3.61
252.00	14.11	11.06	11.1	35597.3	24141.4	11455.7	746.2	758.3	3.59
264.00	14.11	11.06	6.7	35606.2	23422.1	12184.1	722.6	734.4	3.54
276.00	14.11	11.06	4.0	35611.5	22722.3	12889.2	699.5	711.0	3.50
288.00	14.11	11.06	2.4	35614.6	22044.3	13570.3	674.1	686.0	3.45
300.00	14.11	11.06	1.4	35616.5	21389.8	14226.7	649.6	661.9	3.41
312.00	14.11	11.06	.9	35617.7	20758.5	14859.2	626.0	637.8	3.37
324.00	14.11	11.06	.5	35618.4	20149.6	15469.8	603.2	614.6	3.33
336.00	14.11	11.06	.3	35618.8	19562.7	16056.1	581.2	592.3	3.29
348.00	14.11	11.06	.2	35619.0	18997.1	16621.9	560.0	570.7	3.25
360.00	14.11	11.06	.1	35619.2	18451.9	17167.3	539.6	549.8	3.21
372.00	14.11	11.06	.1	35619.3	17926.6	17692.7	519.9	529.8	3.18
384.00	14.11	11.06	.0	35619.3	17420.4	18198.9	501.0	510.5	3.14
396.00	14.11	11.06	.0	35619.3	16932.7	18686.6	482.7	491.9	3.11
408.00	14.11	11.06	.0	35619.4	16462.7	19156.7	465.1	473.9	3.08
420.00	14.11	11.06	.0	35619.4	16009.8	19609.6	448.2	456.6	3.05
432.00	14.11	11.06	.0	35619.4	15573.5	20045.9	431.8	440.0	3.02
444.00	14.11	11.06	.0	35619.4	15152.8	20466.6	416.5	424.2	2.99
456.00	14.11	11.06	.0	35619.4	14746.5	20872.9	402.9	409.7	2.96
468.00	14.11	11.06	.0	35619.4	14353.4	21266.0	389.0	396.4	2.93
480.00	14.11	11.06	.0	35619.4	13973.1	21646.3	377.1	383.5	2.90
492.00	14.11	11.06	.0	35619.4	13605.2	22014.2	364.8	371.0	2.87
504.00	14.11	11.06	.0	35619.4	13249.3	22370.1	353.0	358.9	2.85
516.00	14.11	11.06	.0	35619.4	12905.0	22714.4	341.5	347.2	2.82
528.00	14.11	11.06	.0	35619.4	12571.8	23047.6	330.3	335.9	2.80
540.00	14.11	11.06	.0	35619.4	12249.6	23369.8	319.6	325.0	2.77
552.00	14.11	11.06	.0	35619.4	11937.8	23681.6	309.2	314.4	2.75
564.00	14.11	11.06	.0	35619.4	11634.2	23983.2	299.1	304.1	2.73
576.00	14.11	11.06	.0	35619.4	11344.4	24273.0	289.4	294.2	2.70
588.00	14.11	11.06	.0	35619.4	11062.1	24557.3	279.9	284.7	2.68
600.00	14.11	11.06	.0	35619.4	10789.0	24830.4	270.8	275.4	2.66
612.00	14.11	11.06	.0	35619.4	10524.7	25094.7	262.0	266.4	2.64
624.00	14.11	11.06	.0	35619.4	10267.1	25350.3	253.5	257.7	2.62
636.00	14.11	11.06	.0	35619.4	10021.8	25597.6	245.2	249.3	2.60
648.00	14.11	11.06	.0	35619.4	9782.6	25836.8	237.2	241.2	2.58
660.00	14.11	11.06	.0	35619.4	9551.2	26068.2	229.5	233.4	2.57
672.00	14.11	11.06	.0	35619.4	9327.2	26292.2	222.0	225.8	2.55
684.00	14.11	11.06	.0	35619.4	9110.6	26508.8	214.8	218.4	2.53
696.00	14.11	11.06	.0	35619.4	8901.1	26718.3	207.8	211.3	2.52
708.00	14.11	11.06	.0	35619.4	8698.3	26921.1	201.0	204.4	2.50
720.00	14.11	11.06	.0	35619.4	8501.7	27117.7	195.4	198.2	2.48

SUMMARY INFORMATION

MAXIMUM STAGE WAS 3.90 FEET AT 156.00 HOURS
MAXIMUM DISCHARGE WAS 909.2 CFS AT 156.00 HOURS