SOUTH
FLORIDA
RESEARCH
CENTER

Report M-621
Water Management Plan: Turner River Restoration

Everglades National Park, South Florida Research Center, P.O. Box 279, Homestead, Florida 33030

WATER MANAGEMENT PLAN: TURNER RIVER RESTORATION

INTRODUCTION

The Turner River is a small natural meandering stream originating within the mixed cypress swamps of the Big Cypress National Preserve and eventually emptying into the Chokoloskee estuary in Everglades National Park. This 9 mile-long river is special due to the relative paucity of such streams in the Everglades marsh and cypress swamp systems of south Florida. Experiencing the Turner River is to feel the jungle-like swamp hardwoods of its headwaters, the twisting and turning of its flow path through the open, wet prairies and the ultimate glide into the saline mangrove lined lower reaches as the freshwaters empty to the Gulf of Mexico.

The river is still there today, lying within the jurisdictional boundaries established in 1974 for the 570,000 acre national preserve administered by the United States National Park Service (NPS), but it has been altered and is begging for remedial action to restore it to its full natural potential. Construction of the Turner Canal and State Road 839 in 1960 severed its upper drainage basin (Figure 1), and surface water flows, which normally contributed to the river's natural stages and discharges, now by-pass 2 miles of the river making this portion of the natural stream virtually inaccessible.

NPS hydrologists began field investigations in 1978 with the objective to determine the possible hydrologic consequences of Turner River restoration. The results of these studies are presented within this report which also suggests alternatives for increasing water tables adjacent to SR 839 and SR 841 and improving surface flows to Deep Lake Strand.

The report discusses the hydrologic effects of water quantity and quality and describes the pertinent technical reports, Federal and State Legislation and existing Water Management Policies which all point to the urgent need for river restoration.

WATER MANAGEMENT POLICIES/LEGISLATION AND REPORTS

Management of the Big Cypress National Preserve by the National Park Service in 1974 allowed all of the Turner River to fall within the single jurisdiction of the NPS, complimenting those downstream river reaches already within Everglades National Park since 1947. The NPS policy guiding management of this river is first seen within the Organic Act which established the NPS in 1916:

> "which purpose is to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." (The National Park Service's Organic Act, 1916).

Within this broad objective includes the concepts of ecosystem maintenance and the protection of water related aesthetic features suggesting a perference for reestablishing natural hydrologic conditions within the Turner River Basin. More recently the President of the United States, acting in furtherance of the National Environmental Policy Act of 1969, the National Flood Insurance Act of 1968, and

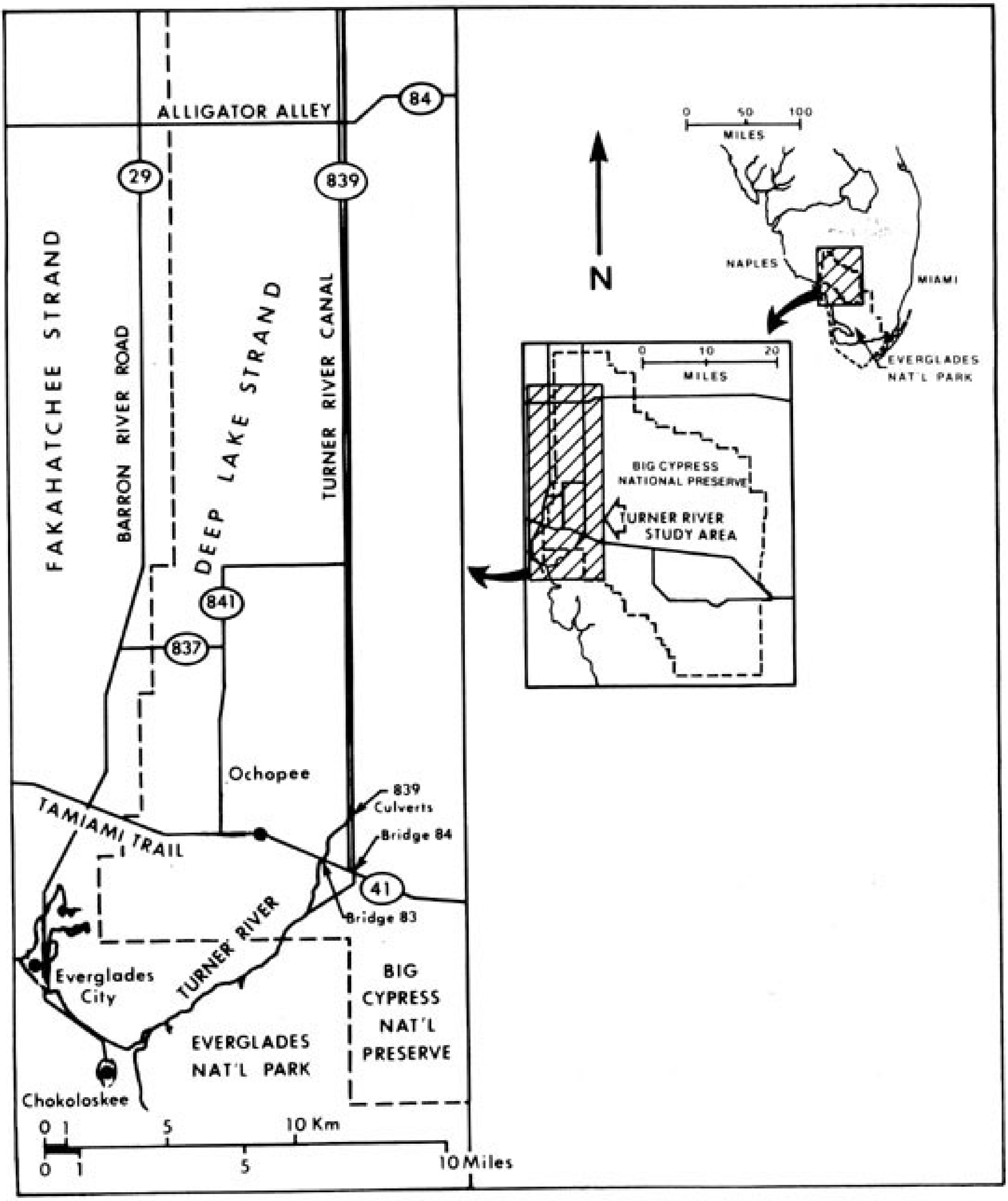


Figure 1. Turner River study area, Big Cypress National Preserve, Florida.

the Flood Disaster Protection Act of 1973, issued an executive order on floodplain management ordering each agency:

> ". . . to restore and preserve the natural and beneficial values served by floodplains in carrying out its responsibilities for acquiring, managing, and disposing of Federal lands and facilities. . . ." (Executive Order 11988, 1977).

The disturbed reaches of the Turner River lie within the Big Cypress National Preserve, suggesting that management strategies of this river be in accordance with the preserve's objectives. On October 11, 1974 Public Law 93-440 was enacted by the 93rd Congress requiring the National Park Service to administer the lands of the Big Cypress National Preserve: "in a manner which will assure their natural and ecological integrity in perpetuity . . ." In order to implement the provisions of this act the Secretary of the Interior published special rules and regulations for the Big Cypress National Preserve (DOI, NPS, 36 CFR 7, 1974). These rules emphasized that the major purpose for establishing the preserve was to protect the watershed, and stated that priority consideration must be given to insure that no significant alteration of the natural water courses nor changes in the quality or quantity of the water will occur. More specifically this document recognized the need (based primarily on public comments) to block or fill existing canals within and adjacent to the preserve in order to restore natural water levels. This however, was not a new idea, since in 1971 a report prepared as part of the South Florida Environmental Project specifically recommended that the Turner River be blocked or provided with structures (Gibbs and Robinson 1971). The most recent suggestion to repair the Turner River was contained in a report from the Everglades Protection Association to the U.S. Department of the Interior which listed the Turner River restoration as one of five measures for consideration within an overall South Florida Water Resources Restoration Plan (Marshall 1980).

Additional background and general literature pertaining to the management policies of the preserve can be found within the Big Cypress Final Environmental Statement which indicated that:

> "The purpose of the proposal (to acquire 570,000 acres) is to protect the freshwater resources in a principal part of Big Cypress Watershed and thereby protect the water quality, quantity and flow regime to the northwest portion of Everglades National Park, and to the estuarine regions in the Gulf of Mexico" (NPS, 1975).

Prior to the establishment of the preserve in 1974, the State of Florida designated the Big Cypress as an area of critical state concern, and made recommendations allowing for modifications on drainage facilities which would raise the ground water table or limit salt water intrusion (Florida DOA, 1973). A report prepared by representatives from 9 Federal agencies and chaired by the NPS, was submitted to the U.S. Secretary of the Interior, which discussed the values of the Big Cypress Watershed. This report eventually resulted in the purchase of lands now within the preserve (Everglades-Jetport Advisory Board, 1971).

This report recognized the dependence of Everglades National Park ecosystems on the quality, quantity, and timing of water flow from upstream Big Cypress lands, thus providing a general framework upon which to view management of the Turner River. Much of the technical data and background information contained within the Everglades-Jetport Advisory Board Report of 1971 were obtained from 4 Technical Reports which further provides useful comments on the Turner River vicinity, although not specifically addressing river restoration. These reports are as follows:

1. Environmental Impact of the Big Cypress Swamp Jetport (DOI - Leopold Report 1969)
2. Some Hydrologic and Biologic Aspects of the Big Cypress Swamp Drainage Area, Southern Florida (Klein et al. 1970)
3. A Synoptic Survey of Limnological Characteristics of the Big Cypress Swamp, Florida (Little et al. 1974)
4. Alternative Uses of Big Cypress Swamp (Everglades-Jetport Advisory Board, 1970).

The impetus and authority for the NPS to restore hydrologic conditions specifically within the Turner River Watershed are thus based on an array of public interests expressed in the laws and the foregoing documents. Other agencies are also active in pursuing restoration activities within similarly altered south Florida wetland areas. The U.S. Army Corps of Engineers (1979) is considering restoring sheetflow within the northeast Shark Slough and modifying the L-28 Levee along the eastern edge of the Big Cypress. The Florida Department of Transportation is considering making improvements along Alligator Alley to restore more natural surface water flow patterns to the north of the preserve (Lochner 1972). The State of Florida has proposed a plan to re-divert Barron River Canal flows into the Fakahatchee Strand, along the western edge of the preserve (McElroy and Alvarez 1975). The U.S. Army Corps of Engineers has completed a reconnaissance report on the Golden Gates Estates area of western Big Cypress, the objectives of which were to raise groundwater levels, increase hydroperiods and reduce discharge rates through the Fahka Union and Golden Gate Canals (Stottler, Stagg and Associates, 1980). The adverse environmental impacts of channelization documented in these reports concerned with adjacent restoration projects are also applicable to the Turner River study area and are consequently incorporated within the following chapters.

HYDROLOGICAL EFFECTS OF CHANNELIZATION WITHIN THE TURNER RIVER BASIN

The Turner River Canal was constructed specifically for the purpose of providing fill for the adjacent Turner River Road (SR 839). However, it also cuts through ground elevations of 14 feet (msl) north of Alligator Alley to 3 feet (msl) south of Tamiami Trail, thus, serving as a hydrologic link between the Big Cypress freshwater uplands and the saline Chokoloskee Estuary within Everglades National Park. The hydrology of this area is dominated by a distinct wet and dry cycle, typical of the south Florida region. Rainfall data analyzed for a 40-year period (1939-1979) at Everglades City located approximately 8 miles to the southwest of the study area indicated an annual mean amount of 53 inches (Figure 2a). Of this, 81% occurred during the 6 wet summer months, May-October, a phenomenon which also drives a seasonal fluctuation in water level (Figure 2b). Stage data (means and extremes) at Bridge 84 located within the Turner Canal are plotted for period of record (1963-1979) reflecting the seasonal fluctuation noted for precipitation but with a time lag effect. May rains did not affect raising stages until June and the

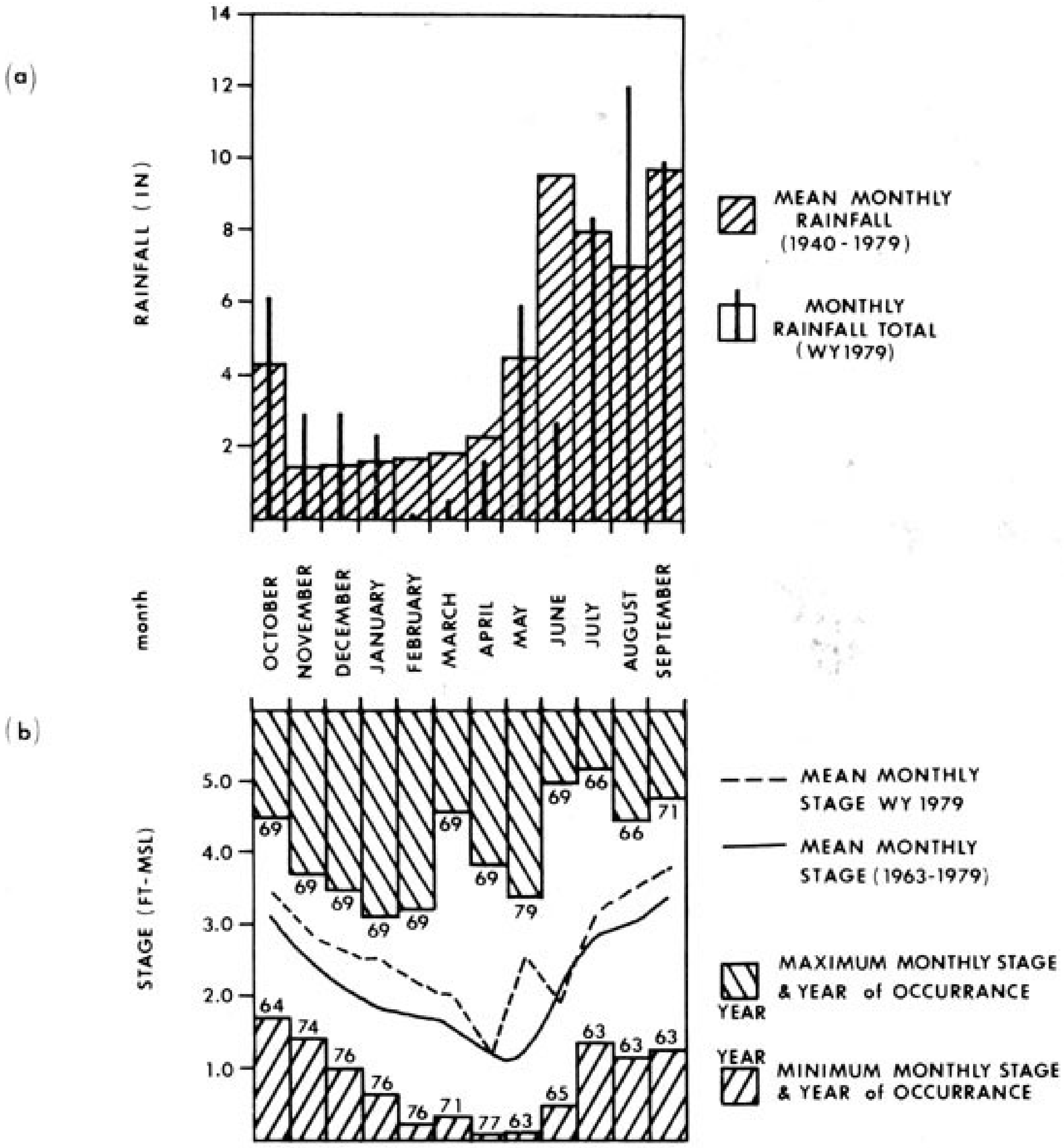


Figure 2. (a) Rainfall hydrograph at Everglades City.

(b) Stage hydrograph for Bridge 84.

reduction in rainfall observed for November and December did not result in an immediate stage reduction due to continued runoff from the earlier rains. Also depicted in Figure 2 are data obtained during water year 1979 (Oct. 1978-Sept. 1979) allowing for comparisons to be made between the period of this particular field investigation to the period of record data. Precipitation data for 1978, 1979 and 1980 are also tabulated in Appendix I allowing for further comparisons. It was found that 1979 was wetter than normal, experiencing 64 inches of rain or 19% above the mean, compared with and excess of 9% during 1978 and a deficit of 20% for 1980. The stage hydrograph for Bridge 84 during 1979 also reflected this above normal condition, except during April due to the less than normal precipitation that occurred during February and March 1979. The investigation presented within this report addresses both the impact that this canal has had on the quantity and quality of the adjacent wetlands and the Turner River.

Water Quantity Effects

The primary influence of the Turner Canal on the surrounding swamp/river system was to alter the groundwater table, disrupt natural surface flow patterns, and reduce river stages and flow rates. The canal cuts through the shallow aquifer which has been described as the principal source of fresh groundwater in Collier County (McCoy 1962). This aquifer attains its maximum thickness of 130 feet in Naples where the terrace sands, both the Anastasia and Tamiami formations are all present, and gradually thins to the east being only 50 feet thick near SR 29 (McCoy 1972). The hydraulic impact of canals draining this shallow aquifer were documented by investigators using field measurements of ground water within the adjacent Faka Union canal system (Swayze and McPherson 1977), and mathematical models were developed to estimate the impact of the Golden Gate Canal on ground water tables (Wang and Overman 1978). The most recent analysis of this problem, other than the investigation reported herein, is the ongoing U.S. Army Corps study concerning the Golden Gate Estates Canals (Stottler, Stagg and Assoc. 1980). These reports all point out that canals constructed within the swamp/shallow aquifer system of Collier County tend to lower adjacent ground water tables. Increased drainage may result in reduced productivity of adjacent wetland vegetation (Wang, Overman 1978) and be a causal factor of greater fire frequency (Stottler, Stagg and Assoc., 1980).

In order to ascertain hydrologic impacts of the canal in the adjacent swamp within the Turner Canal area, 9 wells were installed perpendicular to the canal in an east to west alignment (Figure 3). The wells were all surveyed to a common datum (msl) and monitored routinely during the period September 1979 to July 1980. The results of these investigations indicated that during high water periods the canal served as a conveyer of water from higher elevated areas to the north, elevating ground waters at the downstream transect. During dry season periods the canal captured adjacent ground waters, draining the surrounding swamp. An example of this phenomenon is shown for October 17, 1979 and January 9, 1980, representing wet and dry periods, respectively.

The full data base collected during these investigations are shown in Appendix II showing water level conditions lying between those presented in Figure 3. From these stage drawdown data, it is seen that during dry season periods, the water table may be reduced as much as one foot out to a lateral distance of 600 feet either side of the canal. This is considerably smaller than the gradient of 1.4 ft in

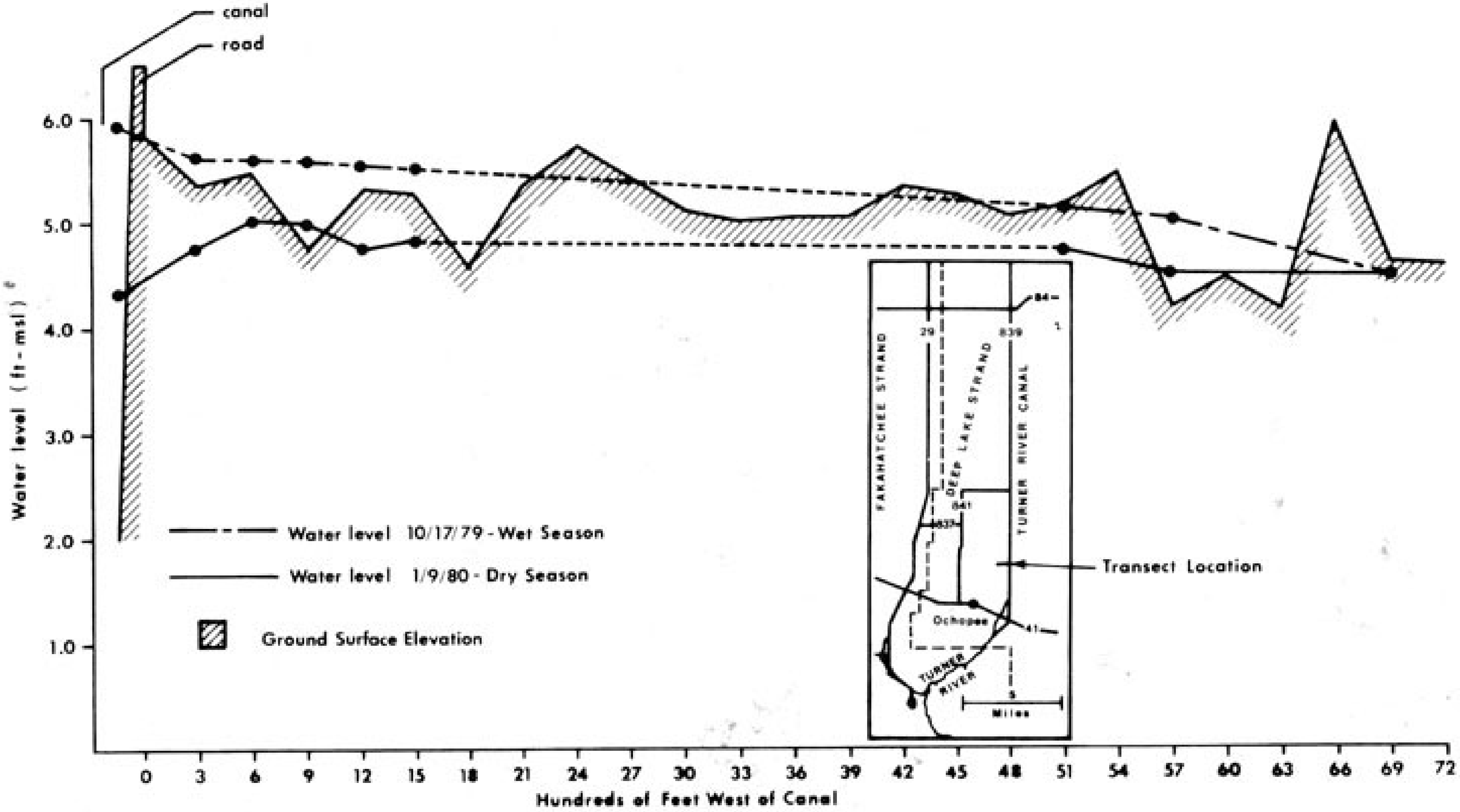


Figure 3. Water level transect perpendicular to the Turner Canal.

12,000 ft found at the end of the dry season, May 1975, by Swayze and McPherson (1977) for the Faka Union Canal Watershed or 1.5 ft in 2640 ft in the Golden Gate Canal Watershed reported by Wang and Overman (1978) indicating a lesser adverse environmental impact from the Turner Canal compared with these larger canal systems.

For the dry season time of January 9, 1980, an area of approximately 3000 acres of wetlands were impacted by Turner Canal drainage, assuming that drawdown effects were experienced equally on both sides of the canal and were equally distributed along its length. On this same date the stage at Bridge 84 was recorded as 2.61 ft msl, which based on the period of record (1963 to 1979), would be equalled or exceeded some 35 percent of the time (Figure 4). As stages are further lowered the canal would be expected to drain even larger areas of the adjacent marsh.

The pattern of surface water flow has been altered due to the presence of the Turner Canal and the adjacent state highway 839. As shown in Figure 5 surface waters flowing within the cypress mixed swamp, as mapped by Gunderson et al. (1980), are captured by the canal and shunted southward disrupting natural sheetflows. Except for the placement of 2 round culverts (839 culverts) of 3 feet in diameter, surface waters are restricted from their natural westward flow direction, disrupting a large portion of the cypress mixed swamp lying to the west of SR 839. Within this western portion of the swamp lies the natural Turner River Channel, becoming apparent at the 839 culverts and extending for approximately 2.5 miles until once again rejoining flows at the lower open end of the Turner Canal, south of Tamiami Trail.

Cross-sectional measurements were made at 4 sites within the reach of the Turner River lying between the 836 culverts and Bridge 83 and within one canal site (Figure 6). It was found that only a slight channel cross-section of approximately 40 ft^2 was present at Section A-A' compared to 260 ft^2 (Section D-D') near Tamiami Trail, while the canal cross-section taken at Section E-E' was 140 ft^2. It was also observed that sediments in excess of 5 ft in thickness were found at places between sections B and C in the river indicating the lack of sufficient scour velocity to suspend and transport these particles. The interception of overland flow by the Turner Canal resulted in the diversion of surface waters which under normal hydrologic conditions would have contributed to the river channel causing both a reduction in river discharge and water depth.

Prior to the construction of the canal in 1960, discharge and stage measurements were not made at Bridge 83, making the exact impact of water diversion difficult to ascertain. Beginning in 1963 daily stages have been recorded in the Turner Canal at Bridge 84 and bimonthly flow measurements representing combined flows through 19 culverts/bridges from Monroe to Carnestown, these values have been published as part of the joint NPS/USGS Cooperative Program (USGS, 1963-79). The difficulty however, in developing the hydrologic data required for this report was that individual flows and stages at both Bridges 83 and 84 were needed. It was thus necessary to obtain unpublished data from the USGS which were available during the period September 28, 1972 to January 29, 1981 representing actual biweekly field stage, and discharge measurements at Bridge 84 and discharge measurements only at Bridge 83 (Appendix III). Stages at Bridge 83 were not available prior to the installation of the continuous recording gauge in October 1978, but had to be reconstructed by statistically correlating Bridge 83 and 84 stages

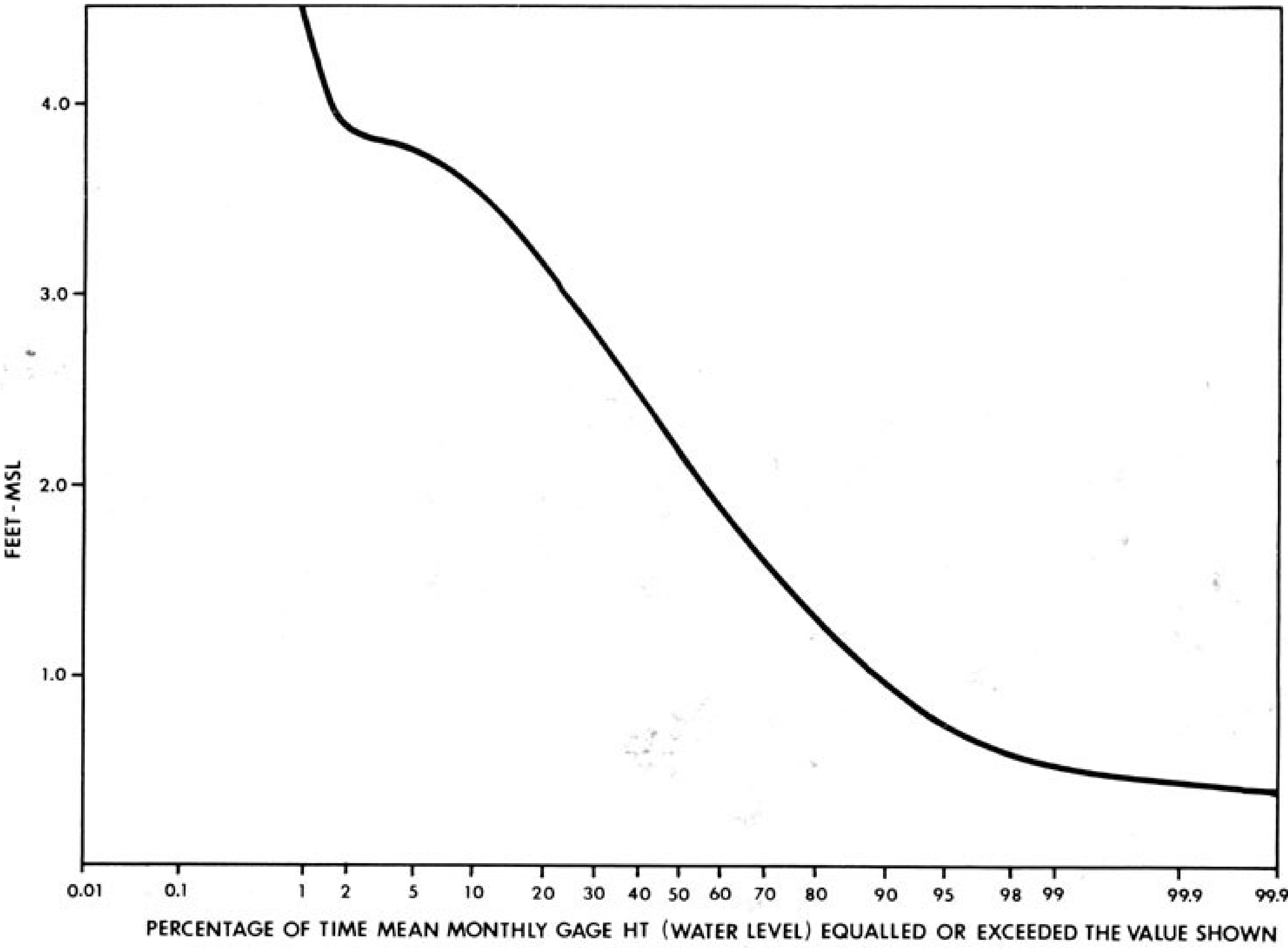


Figure 4. Stage-duration curve for Bridge 84.

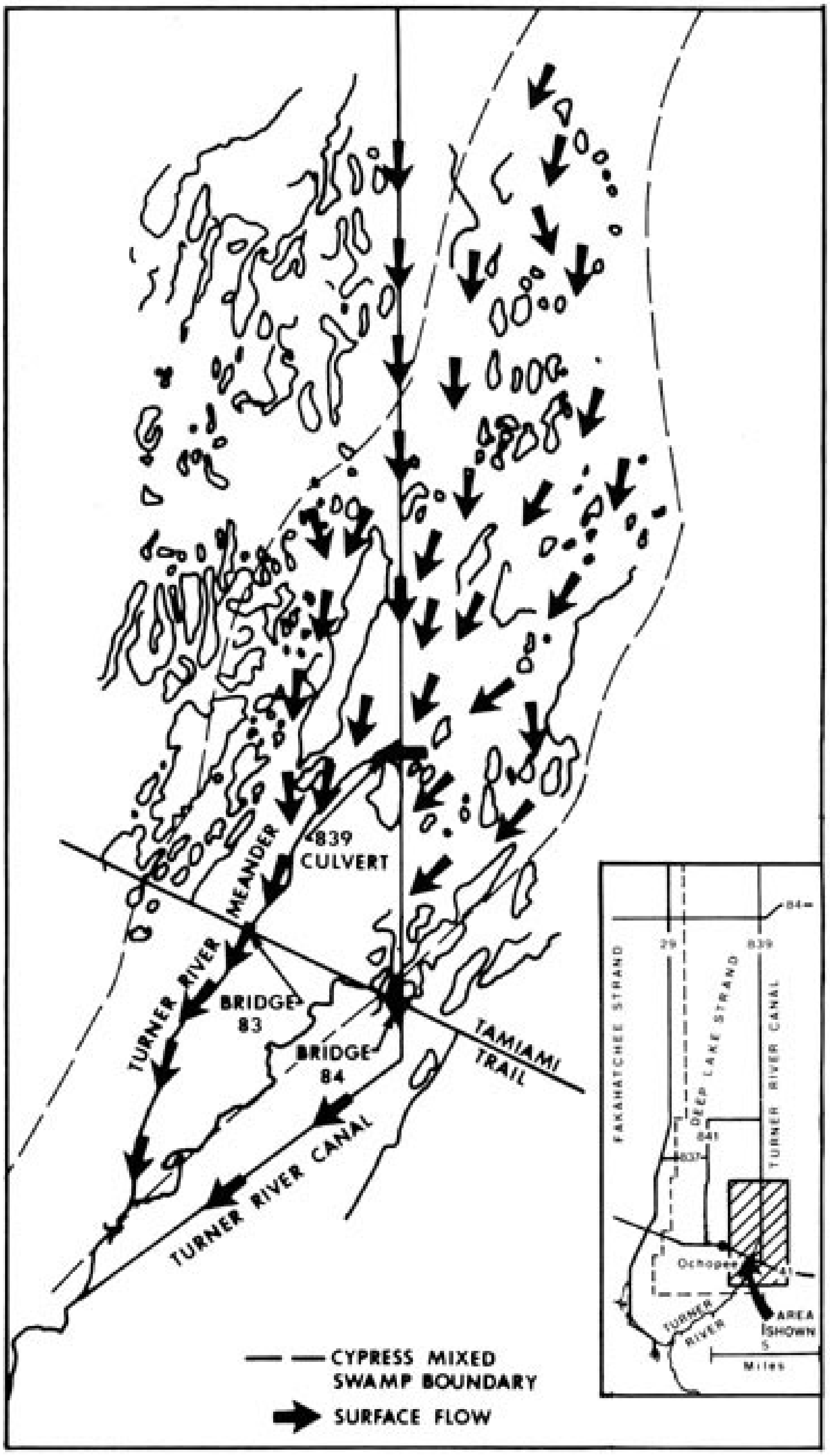


Figure 5. Surface water flow patterns.

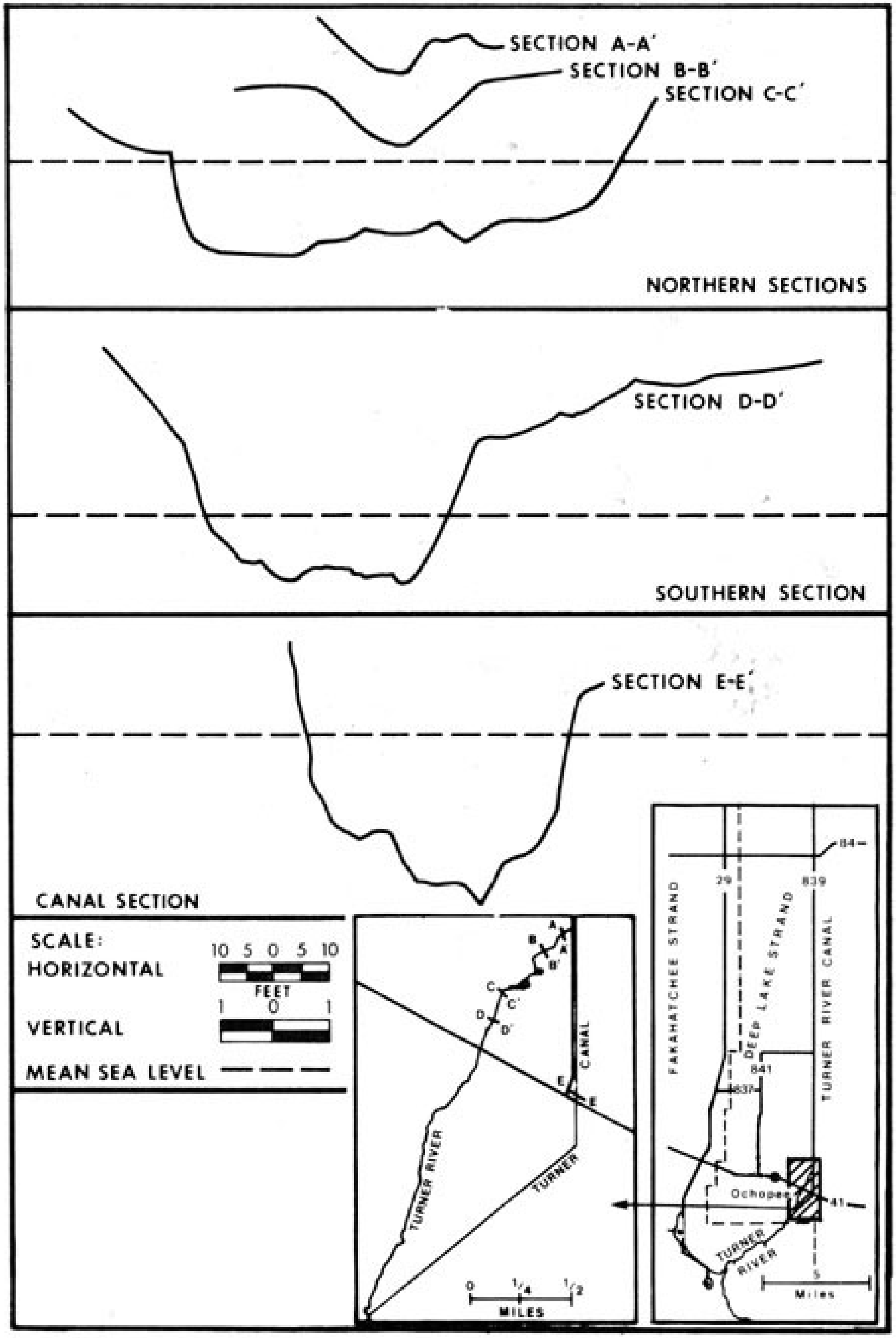


Figure 6. Turner River and Canal cross-sections.

measured during the course of this study (1978 and 1979) (Appendix IV). Mean monthly stages for the Turner River at Bridge 83 could then be computed from those historical stages at Bridge 84 presented in Appendix III allowing for the construction of Figure 7, showing the predicted stage/discharge conditions both before and after restoration of Turner River. During the 6 months of December-May, the river has had essentially no flow due to its headwaters being diverted, a condition which will be rectified after restoration as will be discussed in more detail the Phase I section later in this report.

Utilizing the data presented in Appendix III, stage and discharge duration curves were developed for conditions prior to restoration (Figure 8). Under present conditions in the river, stages at Bridge 83 equal or exceed 2.0 ft during 50 percent of the time, 10 percent of the time stages of 2.8 ft are exceeded, and 90 percent of the time water levels are equal to, or greater than 1.0 ft. There are presently surface water flows 38 percent of the time, and these equal or exceed 45 cfs only 10 percent of the time. As will be shown later in this report, rediversion of surface flows back into the river will increase both the river's stages and discharges.

Water Quality Effects

The construction of canals within wetlands often has the deleterious effect of degrading water quality. This has been the history of such activities within the adjacent drained wetlands in south Florida due primarily to urban and agricultural development made possible by drainage. These activities have pollutant by-products which enter the canal systems either by direct point discharges or by more subtle non-point entry. Often the ability of the natural system to assimilate these compounds is exceeded especially if the adjacent marsh/swamp has been already drained and only the canal channel remains.

An inspection of existing land uses within the Turner River basin shows that urban and agricultural developments are virtually non-existent except for a few scattered residential sites. Since the primary purpose of the canal was to obtain road fill for the construction of SR 839, its ability to provide adequate drainage has been minimal, discouraging any intensive development. Vehicular traffic on the semi-improved SR 839, is also slight since this road does not provide a link between any large population centers. The lack of appreciable development in the canal vicinity indicates that water quality impacts on this canal should also be minimal. In order to test this hypothesis, the existing water quality data base for the canal and river were analyzed.

Quality of these waters has been monitored since 1966 through a cooperative NPS/USGS program (USGS, 1967-1979) consisting of 40 parameters, including nutrients, dissolved inorganic ions, heavy metals and field measurements, and analyzed according to published procedures (Brown et al. 1970). In addition, the canal waters were analyzed as part of the NPS/USGS program for 15 pesticide species in March 1977, at which time none were found. Water quality data were collected intermittently at Bridges 83 and 84 during the period 1966-1979 and are summarized in Appendices V and VI. The results of water quality analysis conducted semi-annually within the Turner River during 1978 and 1979 are also presented allowing for some comparison of these data with the larger Turner Canal data base. These data were grouped as to representing periods of normal conductivities (158 to 590 micromhos/cm) or above normal conductivities (3,100

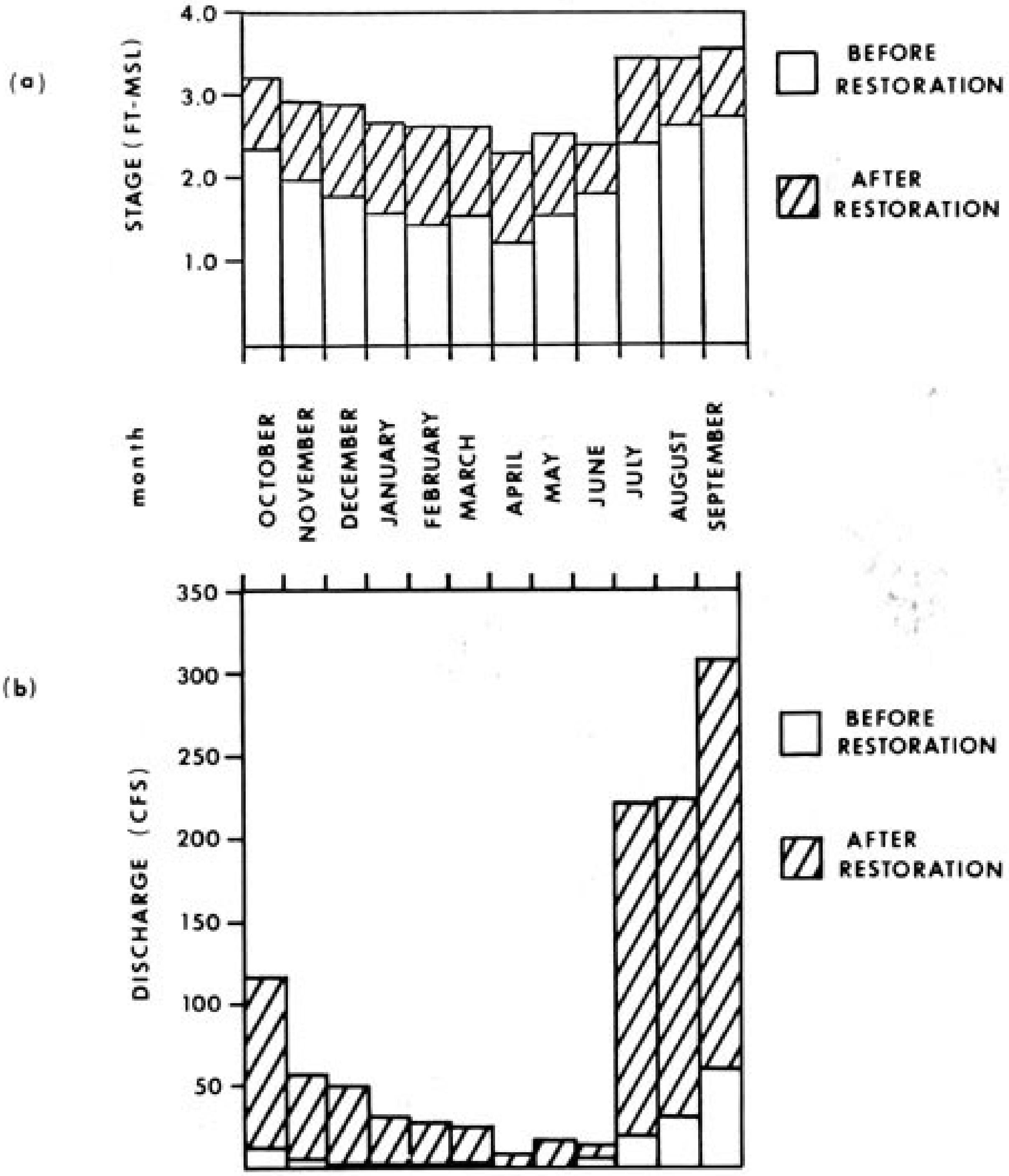


Figure 7. (a) Mean monthly stages at Bridge 83.

(b) Mean monthly discharges at Bridge 83.

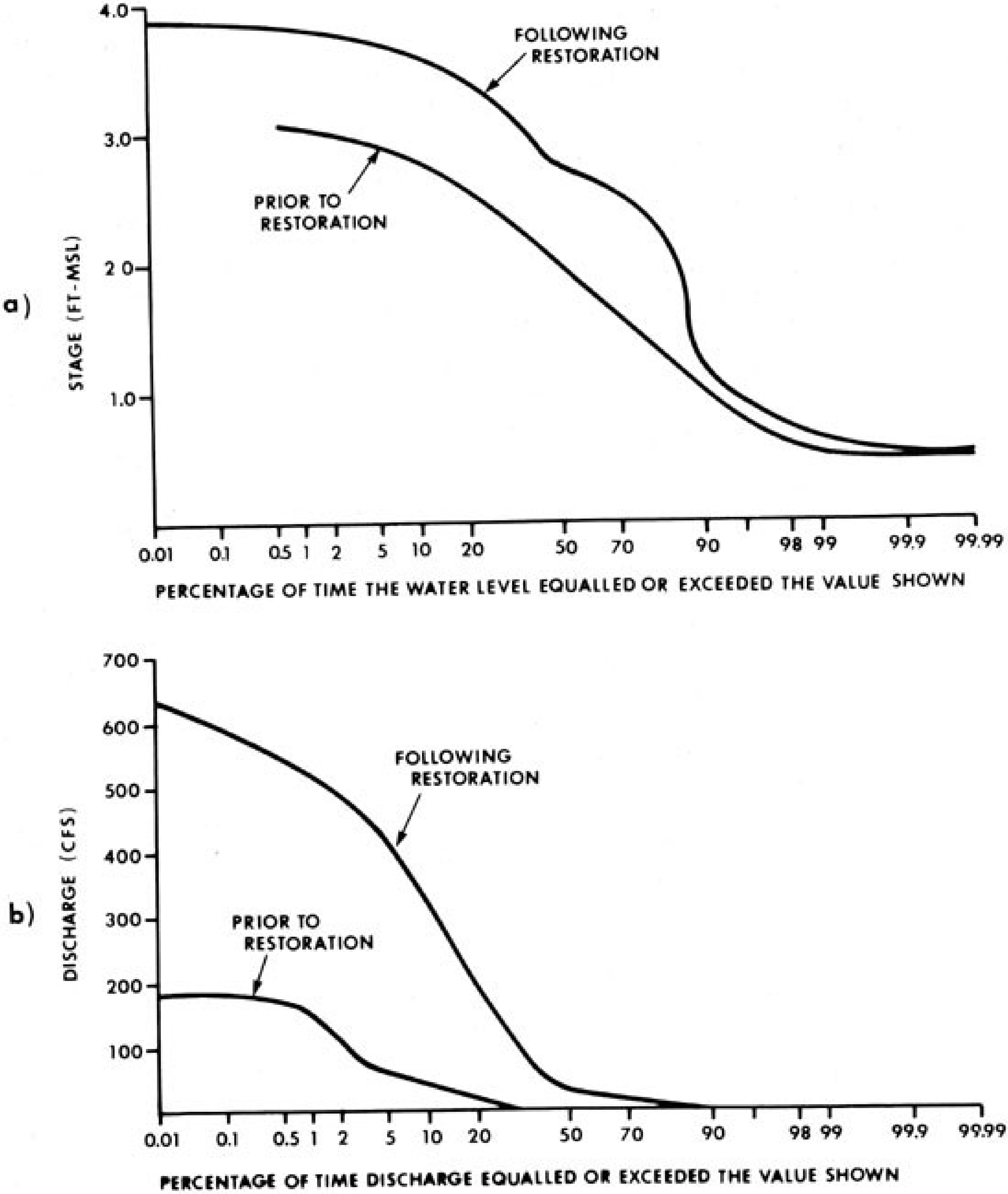


Figure 8. (a) Bridge 83 stage duration curves.

(b) Bridge 83 flow duration curves.

to 60,400 micromhos/cm). It was found that during normal times the river and canal waters were of good quality representative of undisturbed natural watersheds. These data (Appendix V) were compared with water quality standards previously developed for 36 parameters in the adjacent Everglades (Rosendahl and Rose 1979). It was found that the mean of the Turner River and Canal water quality parameters were well within the Everglades standards. Nutrients, inorganic ions and metals were all low in concentration, supporting the hypothesis that the Turner Basin is as yet relatively unpolluted.

During above normal conductivity periods a shift is noted in the quality of both the canal and river waters (Appendix VI). For canal waters it was found that dissolved inorganic ions such as calcium, magnesium, sodium, potassium, chloride and sulfate all increased, and in many cases this increase was over 3 orders of magnitude greater than those found during normal conditions. Lesser increases in inorganic ion concentrations were noted within the river but here also values exceeded the previously published Everglades standards. This large increase in ion concentration was reflected in increases in specific conductance values from a mean of 413 to 57,900 and 381 to 3850 micromhos/cm, for the canal and river, respectively.

Based on this analysis of the historic water quality data base it was suspected that such large shifts in ionic concentrations were the result of salt water intrusion. The canal and river eventually empty to the Chokoloskee Bay located approximately 9 miles south of Tamiami Trail, so during low water conditions it was conceivable that the salt wedge could migrate upstream due to the lowered hydrostatic head. During a low water period (May 1976) such tidal cycles were recorded adjacent to Bridge 84 in the Turner Canal even though the salinity wedge had not migrated upstream to that point (Figure 9a). Field investigations were undertaken during 1978 and 1979 in order to establish the relationship between conductivity at Bridges 84 and 83 with stages in the river and canal.

It was found that increases in stage resulted in a decrease in the conductivity indicating an inverse relationship for these two parameters (Figure 9b and c).

During the period of these studies the location of increased conductivity was usually some 5 miles or more south of Tamiami Trail, well below the intersection of the river and the canal located 2 miles south of the trail. During April 1979 however, stages were sufficiently depressed to allow saltwater to migrate upstream of this intersection (Figure 10). Conductivity as high as 35,000 micromhos/cm were recorded providing for full wedge development in a lateral distance of some 3,750 feet until conductivities of 290 micromhos/cm, typical of freshwater were measured. Density stratification was also observed with greater conductivity waters lying below the less dense fresh water.

By documenting the presence of this salinity wedge the mechanism of observed high conductivity in the Turner Canal data base became apparent, but an explanation of the salinity regime for the river was not as well documented. Shown in Table 1 are conductivities taken on specific dates representing above normal and normal conductivities for Bridges 83 and 84, also shown are the sulfate, calcium, magnesium, sodium and potassium levels relative to their chloride concentrations. A comparison of these ratios to those published for seawater (Smith 1974) allows for their origin to be ascertained. It is seen that the canal, during above normal conditions, has ionic concentration to chlorinity ratios identical to those

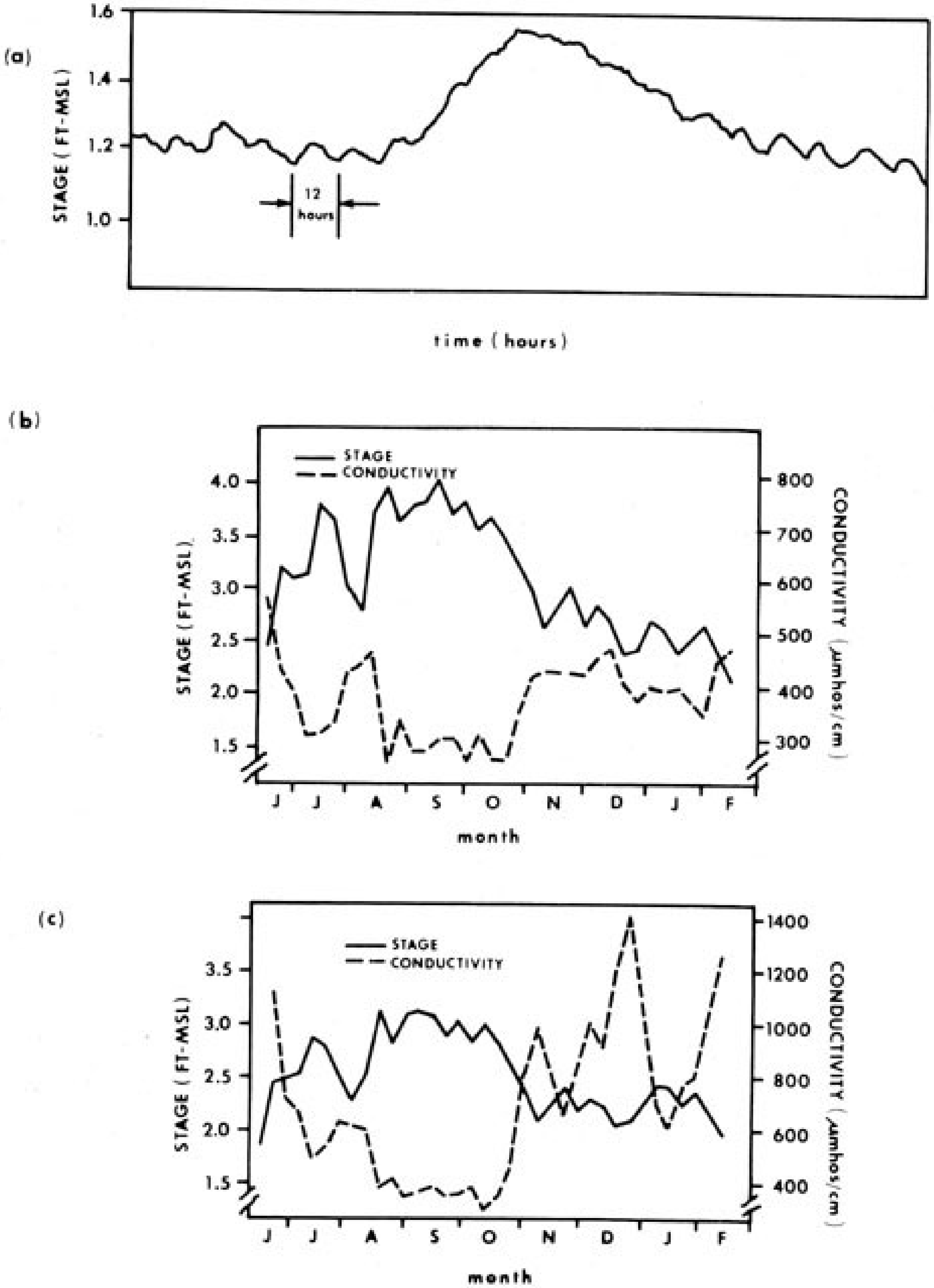


Figure 9. (a) Hourly stage hydrograph at Bridge 84 during part of May, 1976.

(b) Stage and conductivity versus time (June 1978 through February 1979) at Bridge 84.

(c) Stage and conductivity versus time (June 1978 through February 1979) at Bridge 83.

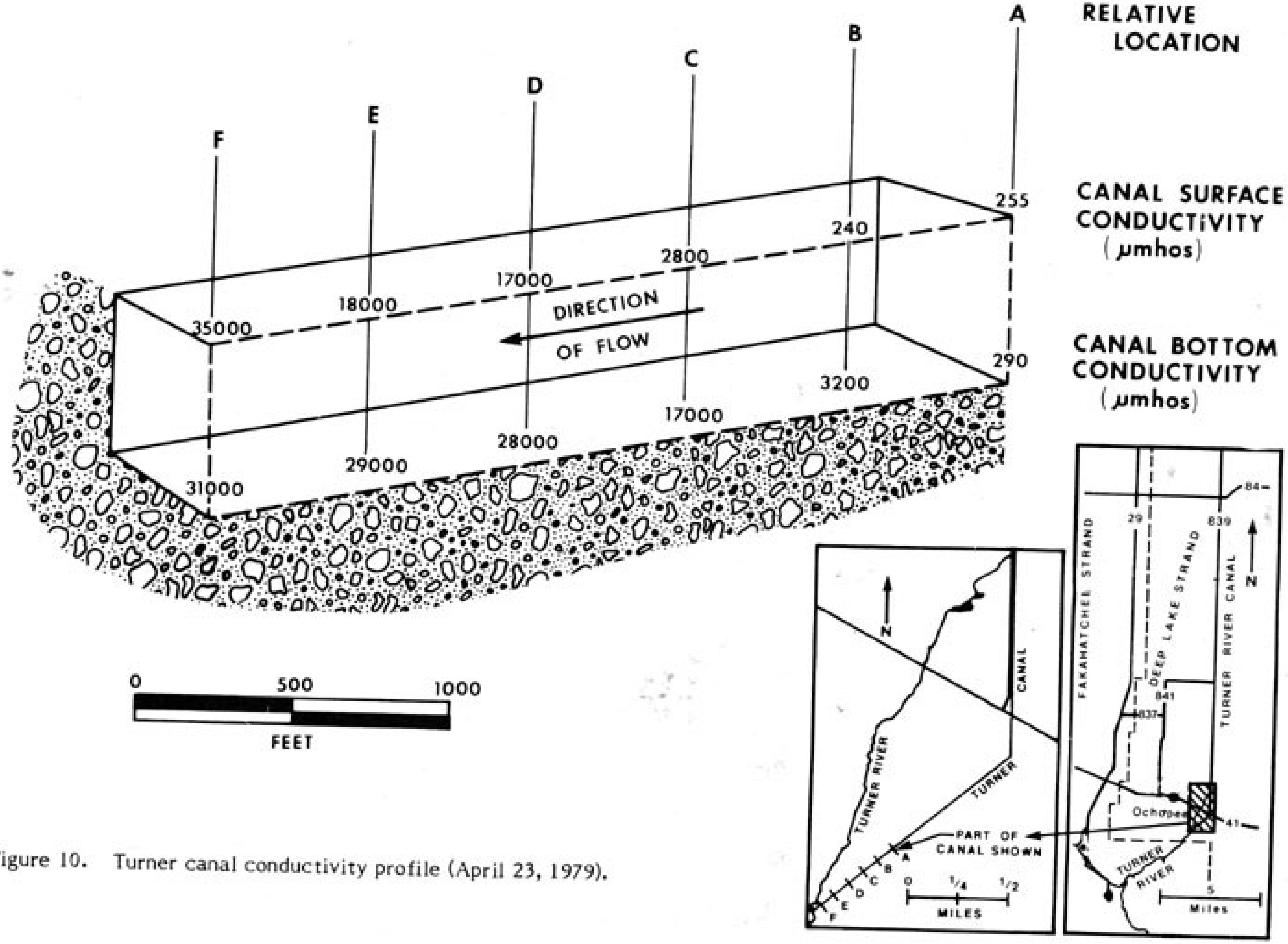


Figure 10. Turner canal conductivity profile (April 23, 1979).

Table 1. Ionic concentration to chlorinity ratios for Bridge 83, 84 and seawater.

		Conductivity * (Micromhos/cm)		Concentration to Chlorinity Ratios **				
Location	Sample Date	Condition	Values	So_4/Cl	Ca/Cl	Mg/Cl	Na/Cl	K/Cl
BR 83	6/13/78	Above Normal	4600	0.15	0.30	0.05	0.02	0.55
	9/13/78	Normal	375	0.01	2.19	0.14	0.03	0.58
BR 84	5/15/67	Above Normal	60200	0.13	0.02	0.07	0.55	0.02
	5/13/78	Normal	590	0.17	1.37	0.10	0.58	0.03
Sea Water	***	-----	52,300	0.14	0.02	0.07	0.55	0.02

* Normal conductivities ranged from 158 to 590 and above normal from 3,100 to 60,000 micromhos/cm.

** Ionic concentration taken form USGS, Water Resources Data for Florida, 1967-1978.

***From CRC Handbook of Marine Science, F. G. Walton Smith, editor. CRC Press, 1974. pp. 4 and 6.

for seawater, while such similarity is not found for the river. As would be expected, such similarities are not found either in the canal or river during normal conductivity conditions. It is not certain what the origin of the increased river conductivity was; perhaps they represent the concentrating of ions during evaporation of the meander waters, a phenomenon not observed in the canal which maintains a larger base flow, or simply represent the mixing of seawater with freshwater but not full strength seawater.

RESTORATION PLANS AND THEIR HYDROLOGICAL EFFECTS

Overall impacts within the Turner River Basin involve those affecting the flow regime within the Turner River, and the effects of the canal causing lowered water levels and providing an easy access route for saltwater intrusion. Because of the varied and large number of restoration actions which are required within the Turner River Basin, 2 phases of construction activities will be discussed. The highest priority is given to Phase I, which concerns Turner River flow and stage restoration (Figure 11). Phase II concerns 4 additional alternatives which relate to the entire Turner River and Deep Lake Strand watersheds, these include (Figure 11): 1) reestablishing flows to the upper reaches of the Deep Lake Strand; 2) water table restoration along the north/south alignment of SR 841; 3) restoration of prairie flows along the 3 mile east/west alignment of SR 841; 4) increase water levels within a 4½ mile reach of the Turner Canal between Deep Lake Strand and Turner River.

Phase I - Turner River Restoration

The Turner River is unique in south Florida since it is one of the few rivers readily available by road, thus having the potential for recreational fishing and canoeing. Prior to canal construction in 1960 the river was a tourist attraction with cruises taking visitors on boat trips along its meandering reaches. Today it is virtually inaccessible, due to reduced flows and stages, with small boat and fishing activities limited to the Turner Canal. Restoration of this river would consist of plugging the Turner Canal just south of the 839 culvert (P1) and placing additional culverts (C1) under SR 839 allowing for waters to be diverted westward from the canal back into the river. This plan also calls for plugging the canal (P2) approximately 2.5 miles further downstream where once again the canal intercepts the meander in order to prevent saltwater intrusion.

This plan will provide that all flows originating upstream of the 839 culverts be directed to the river resulting in increased river water levels and flows. To quantify the hydrologic effects of river restoration, a rating curve was developed for Bridge 83 (Appendix VII) utilizing the stages and discharges previously discussed and contained in Appendix III. This rating curve allowed stages to be predicted within the river by assuming that all flow previously experienced at Bridge 84 would be added to those found at Bridge 83. The effect of such diversion is seen in Figure 7 for both stage and discharge after restoration. At no time is the mean monthly discharge anticipated to be zero compared with 6 of the months experiencing zero or near zero mean flows prior to restoration. Mean stages will increase during all months with the highest mean monthly stages anticipated during the wet season months of June, July and August. Increases in water levels within the river after restoration are also depicted by the stage duration curve shown within Figure 8a. This curve was generated by selecting discrete percentiles and

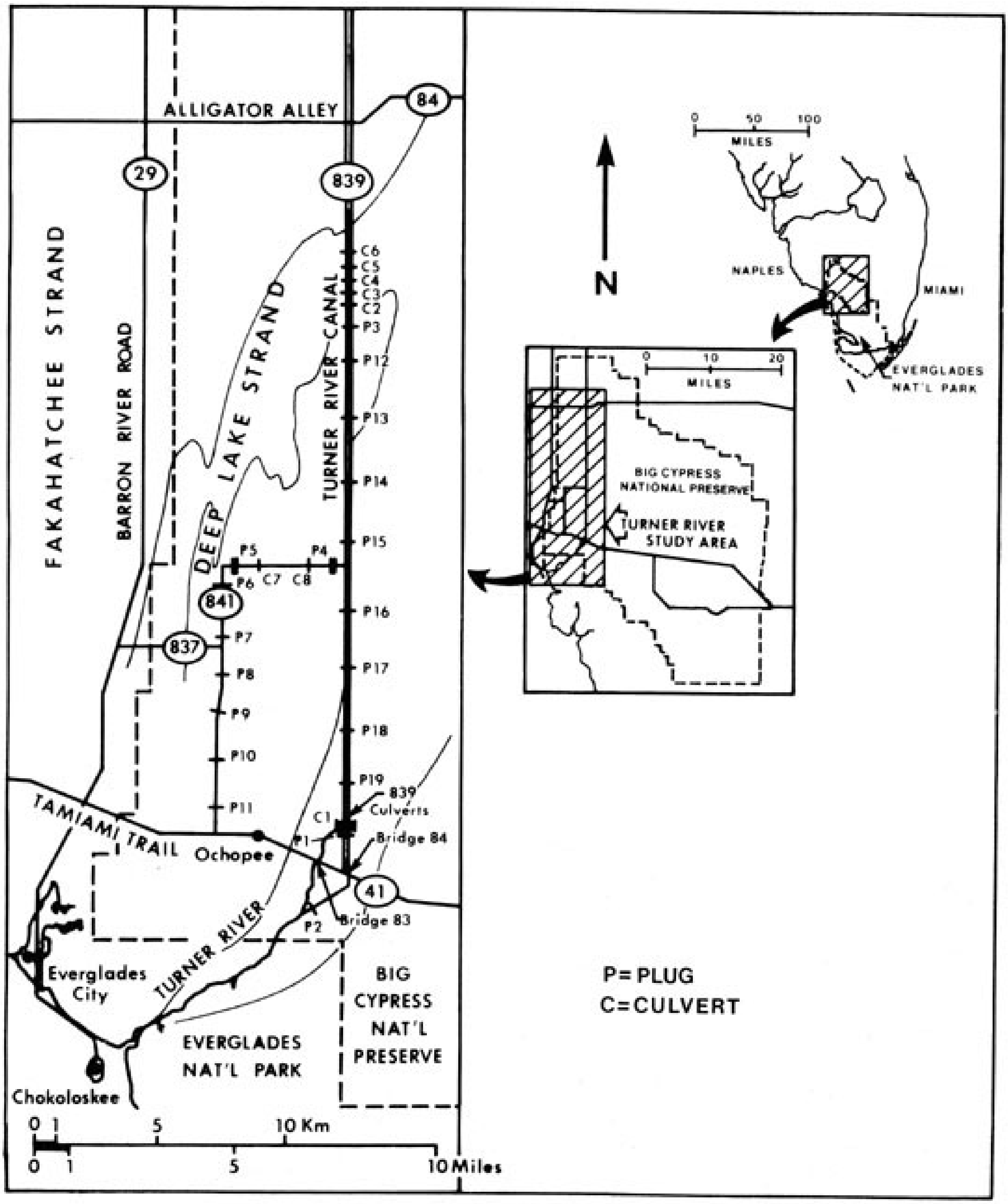


Figure 11. Location of proposed hydrologic appurtenances for restoration phases I and II.

their corresponding discharges from the flow duration curve for Bridge 83 (Figure 8b). The stages associated with these flows were obtained from the stage/discharge rating curves developed in Appendix VII. With these two parameters, the stage-duration curve was constructed. It is seen that 50 percent of the time stages at Bridge 83 in the river will increase to 2.75 feet compared to 2.0 feet prior to restoration. It is not anticipated that such water level increases will adversely impact any existing dwelling in the river vicinity since their pads are placed considerably higher than anticipated stages following restoration.

Flow within the river will also increase reflecting the contribution of the canal flows which currently by-pass the river's upper reaches. The hydrologic effect of river restoration can be seen in Figure 8b for discharges anticipated at Bridge 83. This flow/duration curve was constructed from the data presented in Appendix III utilizing the summation of measured discharges at Bridge 83 and 84 during the period September 28, 1972 to January 29, 1981. Presently, river flow is recorded only 38% of the time, while flow is anticipated 88% of the time after restoration. In addition to this, 10% of the time flow equalled or exceeded 45 cfs, which is anticipated to increase to 340 cfs after restoration. Such increases in the flow rates within the river channel should help to increase the sediment carrying capacity of the river, thus scouring out some of the sediment materials observed within the upper reaches. Such scouring coupled with anticipated stage increases will provide deeper channels for access to the river at Bridge 83. It is anticpated that implementation of Phase I will have the most immediate positive results with documentable increases of stage and discharge, and retardation of saltwater intrusion.

There are however, other restoration efforts which should be undertaken within the basin drainage area providing benefit to the Deep Lake Strand and adjacent water tables. These are presented as the 4 stages of Phase II.

Phase II - Additional Restoration Stages

Stage #1 - Deep Lake Strand

It was observed during the course of these investigations from 1978 to 1980 that construction of SR 839 and some additional secondary roads/canals within the Turner River Basin were impeding flow and possibly lowering water tables. The most notable was the lack of any culverts allowing surface waters within the Deep Lake Strand to move westward. Deep Lake Strand headwaters orginating within the East Hinston Strand are captured by the Turner Canal and shunted southward. It is suggested that a plug (P3) be placed within the Turner Canal approximately 5.4 miles south of the Alligator Alley/SR 839 intersection, and that seven 3 foot culverts (C2-C6) be placed ¼ mile apart under SR 839, originating at the plug and proceeding north for approximately 1.5 miles. The exact sizing and spacing may be modified depending on more detailed design analyses.

Stage #2 - Water Table Stages Along SR 841

Although the principal thrust of the hydrologic investigations reported herein addressed primarily the Turner Canal/River complex, it became apparent that hydrologic modifications of the SR 841 area, lying wholly within the Big Cypress National Preserve, were also warranted. The construction of SR 841 located approximately 3 miles west of SR 839 also utilized adjacent borrow material for elevating its semi-improved roadbed. This resulted in the creation of a borrow canal along the existing alignment of the road and serves as a water conduit for drainage within the adjacent wetlands. The placement of 6 plugs within this borrow ditch spaced 1 mile apart starting at the Tamiami Canal junction should restore water levels within a linear distance of 6 miles. Water level gradients of 10 inches/miles were measured within the SR 841 canal during the period 1978 and 1979 indicating that a head of approximately 10" would be held at each of the proposed plugs.

Stage #3 - Prairie Surface Flows from North to South along SR 841

Construction of the 3 mile-long east/west alignment of SR-841 made no provision for surface waters to flow from north to south in this wetland prairie area. Presently, surface flows are captured by the 841 borrow ditch, located north of the road alignment and diverted east to the Turner Canal and west to the SR 841 north/south aligned borrow canal. The placement of the plugs discussed in Stage #2 and plugs P4 and P5 coupled with the placement of culverts located under the SR-841 east/west alignment would reestablish normal surface water flow patterns in this prairie. There are no clearly defined slough or drainageways connecting the wetlands north and south of SR 841's east/west alignment, and it is not believed that an appreciable amount of surface flows are currently interrupted. It is proposed that initially only 2-3 foot diameter culverts (C7 and C8) be placed 1 mile apart located from either end of the SR 841, east/west aligned canal.

After placement, these 2 culverts should be monitored during wet periods to determine their adequacy in restoring overland flow to the prairies to the south. Additional culverts should be installed after monitoring efforts prove the existing culverts inadequate.

Stage #4 - Water Table Stages Along SR 839

The implementation of Phase I and Stage #1 will increase water level tables at the lower and upper ends of the Turner Canal, still leaving approximately 4½ miles of the Turner Canal unobstructed and available for lowering ground water levels. The placement of 8 plugs (P12-P19), placed 1 mile apart starting south of P3, along this canal reach having a hydraulic gradient of .6 feet/mile will serve to raise adjacent water levels. Anticipated increases in flow within the river after restoration were based on the assumption that all Turner Canal flows, as recorded at Bridge 84, were diverted back into the river. Flows which historically were measured during the past 2 decades at Bridge 84 are in fact representing the outflow from a wetland that has been overdrained. The placement of plug P3 and the associated recommended Deep Lake Strand culverts (Stage #1) will reestablish normal stages and flow patterns in the upper canal vicinity, but will reduce by some undetermined amount the waters available downstream for diversion to the Turner River. It is also possible that total canal flows are not greater than that which normally occurred for the Turner River but rather only altered the timing and flow duration of these flows. A similar phenomenon has been documented for the Kissimmee River where flow rates were measured before and after channelization at its inflow point to Lake Okeechobee (Hartwell 1972). It is thus possible that completion of Stage #4 will also serve to further reestablish near natural flows to the Turner River by retaining upland flows so as to reestablish natural flow duration rates at the same time not reducing total flow rates as measured at Bridge 83.

CONCLUSIONS

The construction of the Turner Canal as a borrow ditch for SR-839 construction in 1960 has had subtle but documentable hydrological impacts on the Turner River and its surrounding wetland watershed. The canal and adjacent road have altered surface flow patterns, lowered the water table, provided an access route for saltwater intrusion and severed the Turner River from its natural contributing flow basin. As a result, the Turner River has experienced reduced flow rates and lowered stages making access at the Bridge 83 location difficult, if not impossible, during the past 20 years. It was also found that the adjacent SR-841 road and borrow canal were constructed without culverts and plugs resulting in the further disruption of surface water flows and reduction of water tables.

Specific findings of this report are as follows:

- -The overall consensus of existing NPS Water Management Policies, Federal and State legislation and reports, as they relate to the Turner River, is that this river should be restored.
- -The hydroperiod for an area of 3,000 acres or greater is reduced 65% of the time adjacent to the Turner Canal.
- -Surface water flows are inhibited from entering the Turner River and are diverted southward along the Turner Canal.
- -Water levels in the Turner River presently equal or exceed 2.0 ft, 50 percent of the time. This would be increased to 2.75 ft after restoration.
- -Flow only occurs 38 percent of the time in the river and this would increase to almost 88 percent of the time after restoration.
- -River flow presently equals or exceeds 45 cfs, 10 percent of the time. This would increase to 340 cfs after restoration.
- -Without modifications to the Turner Canal, saltwater can be expected to intrude as far north as Bridge 84, 12 percent of the time.
- -Normal surface water flows to the Deep Lake Strand have been severed by some unquantified amount and diverted by the Turner Canal.
- -Ground water tables are being lowered by an unspecified amount throughout the Turner River Basin and vicinity due to the Turner Canal, and the SR 841 borrow canal.
- -The wetland prairie north and south of the SR 841, 3 miles east/west alignment has been severed due to the construction of SR 841 and the associated borrow canal.

RECOMMENDATIONS

Based on the findings contained in this report, the following plans are recommended (Figure 11):

- Phase I be given highest priority and implemented immediately to restore the Turner River by placing plugs P1, and P2, within the Turner Canal and additional culvert (C1) placed under SR-839 to provide for a maximum anticipated discharge of 600 cfs.
- Phase II be implemented in discrete stages pending available construction funds consisting of the following stages:
    - Stage #1 - Reestablish Deep Lake Strand flows by installing plug P3 and placing 5, 3-foot diameter culverts (C2-C6) under SR-839.
    - Stage #2 - Raise water table levels along SR 841 by placing 6 plugs (P6-P11) spaced 1 mile apart in the SR-841 borrow canal.
    - Stage #3 - Allow surface waters to flow from north to south across the SR 841 east/west alignment by placing plugs P4 and P5 at either end of the canal and installing 2, 3-foot diameter culverts (C7 and C8) under SR 841 spaced 1 mile apart.
    - Stage #4 - Raise water table levels between Deep Lake Strand and Turner River by placing 8 plugs (P12-P19) in the Turner Canal spaced 1 mile apart.
- The continuous recording gauge installed at Bridge 83 as part of this investigation be maintained indefinitely and used to obtain actual Turner River stage increases after restoration for comparison with the predicted values presented in this report.

ACKNOWLEDGEMENTS

The authors would like to thank the following for their review of this manuscript and earlier drafts: Dr. Gary Hendrix, Dr. William Robertson, Jr., Dr. Dale Taylor, Dr. James Kushlan, Mark Flora, Joel Wagner, Paul Rose and Rose Lew from the National Park Service; Howard Kline and James Hartwell from the U.S. Geological Survey; and Dr. Thomas Waite from the University of Miami. In addition, we would like to thank Dottie Anderson, Betty Curl, and Lu Setnicka for their assistance in typing the many drafts as well as the final manuscript.

LITERATURE CITED

Brown, E., M. W. Skougstad, and M. J. Fishman. 1970. Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases. U.S. Geological Survey. U.S. Government Printing Office, Washington, D.C.

Department of the Interior (Leopold Report). 1969. Environmental Impact of the Big Cypress Swamp Jetport.

Department of the Interior, National Park Service (36 CFR 7). 1974. Big Cypress National Preserve, Florida: Establishment of Special Regulations.

Department of the Interior, National Park Service. 1975. Final Environmental Statement (75-39). Proposal to establish Big Cypress National Freshwater Preserve.

Everglades-Jetport Advisory Board. 1970. Alternative Uses of Big Cypress Swamp.

Everglades-Jetport Advisory Board. 1971. The Big Cypress Watershed: A report to the Secretary of the Interior, April 19, 1971.

Executive Order 11988. 1977. Floodplain Management Federal Register, Vol. 42, No. 101.

Florida Department of Administration. 1973. Final Report and Recommendations for the Big Cypress Area of Critical State concern. Report No. CA 73-2.

Gibbs, R. F. and R. K. Robinson. 1971. Recommendations for Big Cypress Watershed. South Florida Environmental Project.

Gunderson, L., W. Maynard, L. Loope. 1980. Vegetation map of Turner River area, Big Cypress National Preserve, South Florida Research Center.

Hartwell, J. H. 1972. Hydrology of the Kissimmee-Okeechobee Basin," contained in a report to the Florida Cabinet, Tallahassee, Florida entitled "The Kissimmee-Okeechobee Basin" by the Division of Applied Biology, Center for Urban and Regional Studies, Univ. of Miami.

Klein, H., W. J. Schreiber, B. F. McPherson and T. J. Buchanan. 1970. Some Hydrologic and Biologic Aspects of the Big Cypress Swamp Drainage Area, Southern Florida. Open-File Report #70003, USGS.

Little, J. A., R. F. Schneider and B. J. Carroll. 1970. A synoptic survey of the limnological characteristics of the Big Cypress Swamp, Florida.

Lochner, H. W., Inc. 1972. Environmental/Section 4(f) Statement, Interstate Route 75.

Marshall, A. R. 1980. A proposal to the U.S. Dept. Interior. To develop a plan for instituting the first stage of restoring natural resources of the Everglades National Park, Florida. Everglades Protection Association, Inc., Islamorada, Florida.

McCoy, H. J. 1962. Ground-Water Resources of Collier County, Florida. Report of Investigations No. 31, United States Geological Survey.

McCoy, H. J. 1972. Hydrology of Western Collier County, Florida. Report of Investigations No. 63, United States Geological Survey.

McElroy, W. J., and K. C. Alvarez. 1975. Final report on the augmentation of superficial flow through the Fakahatchee Strand, Collier County, Florida. Fla. Dept. Environ. Reg. and Fla. Dept. Natl. Res. Water Resources Report Number 2, Tallahassee, Fla.

Rosendahl, P. C. and P. W. Rose. 1979. Water Quality Standards: Everglades National Park. Environmental Management, Vol. 3, No. 6, pp. 483-491.

Smith, F. G. Walton, Ed. 1974. CRC Handbook of Marine Science, CRC Press. pp. 4 and 6.

Stottler, Stagg and Associates. 1980. Reconnaissance Report for Golden Gate Estates, Collier County, Florida. U.S. Army Corps of Engineers, Jacksonville District, Florida.

Swayze, L. J. and B. F. McPherson. 1977. The effect of the Faka Union Canal System on water levels in the Fakahatchee Strand, Collier County, Florida. Water Resources Investigations 77-61, United States Geological Survey.

U.S. Army Corps of Engineers. 1979. Reconnaissance Report (Stage I): Central and Southern Florida Shark River Slough Area.

U.S. 16th Congress. 1916. 39 Sbat. 535, as amended, Act of August 25, 1916.

U.S. 93rd Congress, H.R. 10088. 1974. Public Law 93-440, An act to establish the Big Cypress National Preserve in the State of Florida, and for other purposes, October 11.

United States Geological Survey. 1963-1979. Water Resources Data for Florida, Southern Florida, Surface Water. USGS, Tallahassee, Florida.

United States Geological Survey. 1967-1979. Water Resources Data for Florida, Southern Florida, Water Quality. USGS, Tallahassee, Florida.

Wang, F. C., and A. R. Overman. 1978. Impacts of surface drainage on groundwater hydraulics. Projected at the 14th American Water Resources Conference Nov. 6-10, 1978, Lake Buena Vista, Florida.

Appendix I. Precipitation data at Everglades City for water years 1978, 1979, and 1980.

	1978			1979			1980		
	$\bar{x}$	Actual	% Deviation	$\bar{x}$	Actual	% Deviation	$\bar{x}$	Actual	% Deviation
Oct	4.24	0.33	-92%	4.28	6.16	44%	4.27	3.70	-13%
Nov	1.37	1.99	45%	1.41	2.91	106%	1.41	1.66	18%
Dec	1.46	2.57	76%	1.49	2.96	99%	1.53	2.97	94%
Jan	1.60	2.33	46%	1.62	2.31	43%	1.61	1.25	-22%
Feb	1.74	3.92	125%	1.70	0.05	-97%	1.69	1.19	-30%
Mar	1.85	5.44	194%	1.82	0.65	-64%	1.83	2.10	15%
Apr	2.19	1.82	-17%	2.18	4.45	104%	2.19	2.76	26%
May	4.44	3.39	-24%	4.48	5.97	33%	4.46	3.95	-11%
June	9.76	12.11	24%	9.58	7.72	-19%	9.37	1.05	-89%
July	7.99	7.18	-10%	8.00	8.42	5%	8.00	8.14	2%
Aug	6.89	6.48	-6%	7.02	12.05	72%	7.05	8.24	17%
Sept	9.68	10.54	9%	9.69	9.96	3%	9.59	5.47	-43%
ANNUAL	53.21	58.10	9%	53.27	63.61	19%	53.00	42.48	-20%

<u>Note:</u> % Deviation = $\frac{\text{Actual} - \bar{x}}{\bar{x}}(100)$

Appendix II. Water level data at nine wells along a perpendicular transect to the Turner Canal and at Bridge 84 (September 1979 to July 1980).

Benchmark Date	1	3	4	5	6	7	19	21	25	Bridge 84
9/19/79	5.61	5.60	5.58	5.56	5.53	5.49	5.14	5.02	4.85	3.56
10/10/79	5.96	5.62	5.61	5.58	5.53	5.50	N/A	N/A	N/A	3.63
10/17/79	5.94	5.61	5.62	5.58	5.54	5.50	5.12	5.01	4.49	N/A
10/31/79	5.64	5.57	5.69	5.52	5.49	5.43	N/A	N/A	N/A	3.02
11/7/79	5.63	5.57	5.57	5.62	5.46	5.40	N/A	N/A	N/A	2.91
11/14/79	5.51	5.53	5.54	5.49	5.43	5.39	5.16	4.83	4.94	2.91
11/28/79	4.73	5.14	5.17	5.15	5.11	5.07	N/A	N/A	N/A	2.54
12/5/79	4.44	4.75	4.96	4.95	4.93	5.02	N/A	N/A	N/A	2.36
12/12/79	5.56	5.51	5.51	5.44	5.38	5.37	5.02	4.92	4.75	3.36
12/26/79	4.94	5.33	5.41	5.25	5.25	5.26	N/A	N/A	N/A	3.03
1/3/80	4.52	4.92	5.13	5.03	5.08	5.13	N/A	N/A	N/A	2.76
1/9/80	4.34	4.75	5.02	4.93	4.75	4.88	4.71	4.51	4.51	2.61
1/16/80	4.14	4.56	4.92	4.79	4.88	4.62	N/A	N/A	N/A	2.55
1/22/80	4.21	4.51	4.58	4.57	4.47	4.61	N/A	N/A	N/A	2.43
1/30/80	4.86	5.15	5.20	5.11	5.28	5.20	N/A	N/A	N/A	2.96
2/6/80	4.80	5.13	5.20	5.09	5.10	4.99	4.65	4.47	4.40	2.77
2/13/80	4.65	4.99	5.12	4.97	4.99	4.85	N/A	N/A	N/A	2.69
2/28/80	4.57	4.89	5.10	5.00	5.16	4.96	N/A	N/A	N/A	2.56
3/5/80	5.24	5.44	5.43	5.25	5.39	5.28	4.98	4.79	4.67	3.17
3/12/80	5.02	5.26	5.30	5.19	5.27	5.14	N/A	N/A	N/A	2.94
3/25/80	4.44	4.69	4.80	4.65	4.61	4.64	N/A	N/A	N/A	2.32
4/2/80	4.01	4.19	4.40	4.30	4.32	4.49	3.97	3.38	3.26	2.04
4/16/80	4.45	4.74	4.96	4.86	4.83	4.90	N/A	N/A	N/A	2.80
4/23/80	3.85	4.14	4.34	4.20	4.06	4.12	N/A	N/A	N/A	2.49
5/5/80	3.32	3.54	3.64	3.55	3.51	3.60	N/A	N/A	N/A	N/A
5/28/80	3.76	4.12	4.27	4.19	4.29	4.38	3.95	3.68	N/A	N/A
6/3/80	3.16	3.39	3.72	3.59	3.49	3.55	N/A	N/A	N/A	2.60
7/9/80	3.08	3.41	3.35	3.53	3.54	3.59	N/A	N/A	N/A	2.58
7/23/80	4.38	4.83	4.79	4.88	4.89	4.92	4.77	4.57	4.42	N/A
7/29/80	3.84	4.21	4.36	4.29	4.30	4.39	N/A	N/A	N/A	2.56

Appendix III. Historical stage and discharge data for Bridge 84 and Bridge 83 (available data for period September 1972 through January 1981).

Date	Historical Stage Bridge 84 (ft)	Historical Discharge Bridge 84 (ft^3/sec)	Calculated Stage Bridge 83 (ft)	Historical Discharge Bridge 83 (ft^3/sec)
9/28/72	2.50	151.18	2.13	0
10/30/72	1.96	29.11	1.77	0
11/16/72	3.35	256.46	2.69	51.55
11/29/72	2.67	134.55	2.24	5.82
12/13/72	2.16	42.92	1.90	0.9
12/27/72	2.26	18.33	1.97	0
1/30/73	2.20	27.71	1.93	0
2/15/73	2.15	36.82	1.90	0
2/27/73	1.95	23.10	1.76	0
3/13/73	1.79	17.96	1.66	0
3/29/73	2.00	26.03	1.80	0
4/13/73	1.40	9.10	1.40	0
4/27/73	1.28	1.11	1.32	0
5/11/73	0.88	0	1.06	0
5/30/73	0.83	0	1.03	0
6/13/73	1.09	3.02	1.20	0
6/28/73	1.66	23.25	1.57	0
9/13/73	2.69	272.61	2.25	22.14
9/28/73	3.63	352.67	2.87	70.6
7/30/73	3.05	190.19	2.49	58.09
8/13/73	2.99	268.36	2.45	3.29
8/30/73	3.66	447.99	2.89	27.13
7/13/73	3.72	361.04	2.73	154.58
10/15/73	3.50	251.92	2.78	43.14
10/30/73	2.79	101.19	2.32	7.59
11/14/73	2.17	17.47	1.91	0
11/29/73	1.93	39.14	1.75	0
12/13/73	1.81	29.34	1.67	0.1

Appendix III (cont)

Date	Historical Stage Bridge 84 (ft)	Historical Discharge Bridge 84 (ft^3/sec)	Calculated Stage Bridge 83 (ft)	Historical Discharge Bridge 83 (ft^3/sec)
12/30/73	1.94	26.27	1.76	0
1/12/74	1.67	43.51	1.58	0
1/30/74	1.34	15.72	1.36	3.75
2/13/74	1.00	25.40	1.14	0
2/27/74	0.56	17.02	0.85	0
3/14/74	0.73	0.39	0.96	0
3/29/74	0.78	0	.99	0
4/12/74	0.14	0	0.57	0
4/29/74	0.21	0	0.62	0
5/30/74	0.68	0	0.93	0
6/11/74	0.88	0	1.06	0
6/27/74	2.55	172.034	2.16	0
7/11/74	3.56	415.384	2.82	13.31
7/30/74	3.56	557.34	2.82	76.49
8/12/74	2.96	325.88	2.42	55.91
8/29/74	3.35	N/A	2.69	72.17
9/11/74	3.09	178.11	2.51	48.27
9/27/74	3.43	208.36	2.74	55.43
10/11/74	2.67	95.09	2.24	20.78
10/30/74	1.89	30.94	1.72	0
11/12/74	1.66	11.91	1.57	0
11/27/74	1.83	31.59	1.68	14.15
12/13/74	1.65	82.15	1.57	0
12/30/74	1.37	42.57	1.38	0
1/13/75	1.18	6.37	1.26	0
1/30/75	1.01	18.96	1.14	0
2/12/75	1.10	0	1.20	0
2/27/75	0.95	0	1.10	0
5/29/75	1.36	0	1.37	0
6/9/75	1.12	0	1.22	0
6/27/75	2.31	192.66	1.99	0
7/14/75	2.54	183.21	2.15	0

Date	Historical Stage Bridge 84 (ft)	Historical Discharge Bridge 84 (ft^3/sec)	Calculated Stage Bridge 83 (ft)	Historical Discharge Bridge 83 (ft^3/sec)
7/30/75	2.15	99.00	1.90	14.66
8/8/75	2.11	69.80	1.87	2.08
8/28/75	2.65	156.57	2.22	12.41
9/10/75	2.93	182.83	2.41	48.52
9/29/75	3.83	329.91	3.00	85.58
10/10/75	3.37	181.78	2.70	27.14
10/30/75	3.27	139.31	2.63	14.75
11/21/75	1.92	31.88	1.74	0
12/15/75	1.35	22.02	1.37	0
12/30/75	1.06	6.39	1.18	0
1/13/76	0.70	0	0.94	0
1/29/76	0.69	6.98	0.93	0
2/11/76	0.43	14.28	0.76	0
2/26/76	0.68	11.50	0.93	0
3/12/76	1.27	36.44	1.32	0
3/30/76	0.77	1.94	0.98	0
4/29/76	0.66	0	0.91	0
5/12/76	1.41	20.88	1.41	0
5/27/76	1.86	44.92	1.70	0
6/9/76	3.35	297.67	2.69	56.44
6/29/76	3.17	206.70	2.57	32.03
7/12/76	3.28	261.28	2.64	34.92
7/29/76	3.02	215.59	2.47	23.44
8/12/76	3.40	375.73	2.72	99.94
8/30/76	2.97	249.66	2.44	26.83
9/13/76	2.58	138.96	2.17	0
9/29/76	3.30	289.19	2.65	34.16
10/12/76	2.94	227.68	2.42	14.40
10/28/76	2.10	76.64	1.86	0
11/12/76	1.71	26.11	1.61	0
11/29/76	1.52	4.31	1.48	0
12/13/76	1.41	2.89	1.41	0

Appendix III (cont)

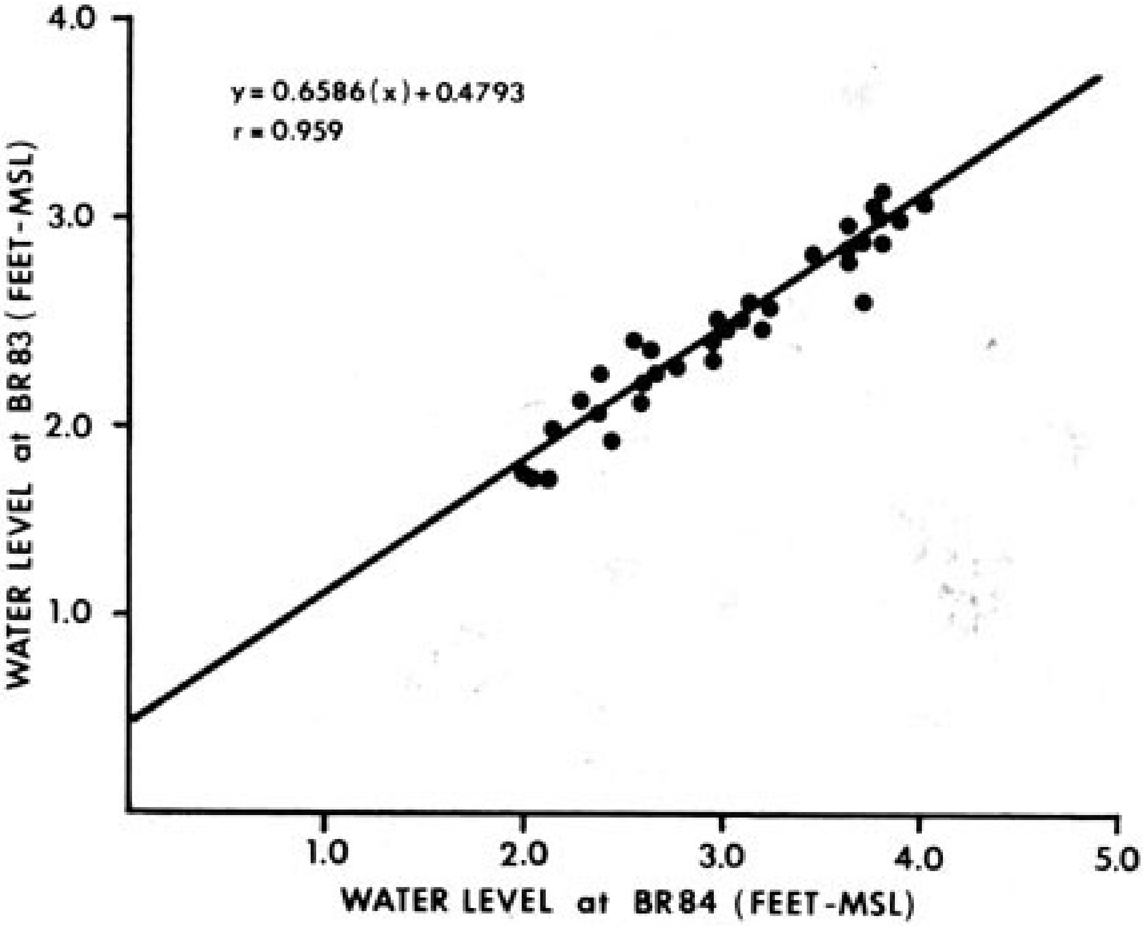
Date	Historical Stage Bridge 84 (ft)	Historical Discharge Bridge 84 (ft^3/sec)	Calculated Stage Bridge 83 (ft)	Historical Discharge Bridge 83 (ft^3/sec)
12/30/76	1.90	50.66	1.73	0
1/12/77	1.70	30.28	1.60	0
1/28/77	1.78	32.32	1.65	0
2/11/77	1.54	19.89	1.49	0
2/25/77	1.39	9.40	1.39	0
4/11/77	0.08	0	0.53	0
4/27/77	0.12	0	0.56	0
6/16/77	1.76	32.88	1.64	0
6/29/77	1.80	77.19	1.66	0
7/12/77	3.03	322.93	2.47	30.58
7/23/77	3.20	395.96	2.59	33.31
9/1/77	2.39	114.04	2.05	1.82
9/13/77	3.68	362.95	2.90	181.67
9/29/77	3.70	392.75	2.92	57.11
10/12/77	2.58	81.03	2.18	12.18
10/28/77	2.06	36.48	1.84	0
11/10/77	1.79	7.35	1.66	0
11/29/77	1.61	20.33	1.54	0
12/12/77	1.96	36.88	1.77	0
12/29/77	1.57	28.92	1.51	0
1/13/78	1.53	45.55	1.49	0
1/31/78	1.51	27.32	1.47	0
2/13/78	1.70	32.39	1.60	0
3/30/78	1.80	222.95	1.66	0
4/27/78	1.52	17.09	1.48	0
5/30/78	1.31	7.62	1.34	0
6/12/78	2.44	38.09	2.09	0
6/29/78	3.28	70.82	2.64	5.78
7/28/78	2.78	10.06	2.31	1.53
8/11/78	3.48	75.08	2.77	22.37
8/30/78	3.73	119.26	2.94	31.06
9/12/78	4.01	165.33	3.12	52.85

Appendix III (cont)

Date	Historical Stage Bridge 84 (ft)	Historical Discharge Bridge 84 (ft^3/sec)	Calculated Stage Bridge 83 (ft)	Historical Discharge Bridge 83 (ft^3/sec)
9/28/78	3.68	81.38	2.90	13.60
10/16/78	3.50	131.47	2.78	46.55
10/30/78	3.02	62.49	2.47	0
11/14/78	3.10	76.57	2.52	12.48
11/29/78	2.59	19.42	2.19	0
12/13/78	2.61	13.55	2.20	0
12/28/78	2.55	51.90	2.16	0
1/12/79	2.50	54.01	2.13	
1/30/79	2.60	85.23	2.19	0
2/13/79	2.12	51.56	1.88	0
2/27/79	2.05	31.67	1.83	0
3/13/79	2.00	19.03	1.80	0
3/29/79	1.72	18.49	1.61	0
4/13/79	1.10	0	1.20	0
4/27/79	1.61	0	1.54	0
5/14/79	2.83	40.46	2.34	0
5/30/79	2.51	26.39	2.13	0
6/28/79	2.54	4.30	2.15	0
7/13/79	3.00	24.18	2.46	0
7/30/79	3.37	43.65	2.70	0
8/16/79	3.36	64.66	2.69	20.90
8/30/79	3.80	249.48	2.98	30.19
9/13/79	3.87	398.24	3.03	65.36
9/27/79	3.68	308.43	2.90	77.13
10/16/79	3.62	305.10	2.86	42.47
10/29/79	3.08	201.93	2.51	10.34
11/14/79	2.91	116.03	2.40	14.91
11/29/79	2.53	57.75	2.15	0
12/14/79	3.35	291.07	2.69	17.72
12/27/79	2.98	106.03	2.44	15.95
1/29/80	2.98	117.59	2.44	8.19
2/12/80	2.72	71.70	2.27	13.13

Appendix III (cont)

Date	Historical Stage Bridge 84 (ft)	Historical Discharge Bridge 84 (ft^3/sec)	Calculated Stage Bridge 83 (ft)	Historical Discharge Bridge 83 (ft^3/sec)
2/28/80	2.56	61.35	2.17	2.60
3/12/80	2.94	92.99	2.42	30.11
3/27/80	2.25	27.43	1.96	1.20
4/15/80	2.84	47.67	2.35	0
4/29/80	2.33	26.40	2.01	0
5/19/80	1.52	18.46	1.48	0
5/29/80	2.76	44.22	2.30	0
6/16/80	1.61	0	1.54	0
6/26/80	0.92	0	1.09	0
7/17/80	2.55	16.21	2.16	0
7/30/80	2.41	15.42	2.07	0
8/12/80	3.58	67.69	2.84	21.78
8/28/80	3.98	120.82	3.10	26.19
9/16/80	3.80	134.84	2.98	59.44
9/29/80	3.88	132.89	3.03	96.58
10/17/80	3.40	20.79	2.71	0
10/30/80	2.92	29.94	2.40	0
11/12/80	3.00	31.91	2.46	0.55
11/26/80	2.97	33.92	2.44	0
12/16/80	2.20	4.02	1.93	0
12/30/80	2.06	24.90	1.84	0
1/14/81	1.76	10.26	1.64	0
1/29/81	1.82	9.83	1.68	0



Appendix IV. Stage at Bridge 84 versus stage at Bridge 83 with regression line and equation predicting the water level at Bridge 83 given the water level at Bridge 84.

Appendix V. Summary of Turner Canal and River water quality data during periods of normal conductivities *.

	Turner Canal Bridge 84 1966-1979			Turner Canal Bridge 84 1978-1979			Turner River Bridge 83 1978-1979		
Parameter (units)	Sample Size (n)	Mean $(\overline{X})$	Std Dev (σ)	Sample Size (n)	Mean $(\overline{X})$	Std Dev (σ)	Sample Size (n)	Mean $(\overline{X})$	Std Dev (σ)
Temperature ($^{\circ}$C)	56	24.4	4.1	6	25.7	2.7	2	25.3	1.8
Stream Flow (cfs)	Range 0-1380	-	-	-	-	-	0	-	-
Stream Stage (ft)	Range 0.90-4.0	-	-	Range 1.58-3.97	-	-	0	-	-
Turbidity (JTU)	41	3.3	2.6	10	1.7	0.7	1	2.0	0
Color (PCU)	41	19.3	21	5	36	15.6	2	42.5	3.5
Specific Conductance (μmhos)	41	413	127	7	386	104	2	381	7.8
O_2 Dissolved (mg/l)	37	4.9	2.1	7	2.6	1.1	1	1.6	0
BOD, 5-day (mg/l)	9	1.8	1.7	-	-	-	0	-	-
pH (units)	37	7.7	0.5	5	7.42	0.2	0	-	-
CO_2 Dissolved (mg/l as CO_2)	14	8.5	8.1	2	6.8	1.1	0	-	-
Alkalinity (mg/l as $CaCO_3$)	27	163	45	4	130	19.8	2	164	8.5
Bicarbonate (mg/l as HCO_3)	27	198	47	4	180	61	0	-	-
Carbonate (mg/l as CO_3)	22	0	-	3	0	-	0	-	-

	Turner Canal Bridge 84 1966-1979			Turner Canal Bridge 84 1978-1979			Turner River Bridge 83 1978-1979		
Parameter (units)	Sample Size (n)	Mean ($\overline{X}$)	Std Dev (σ)	Sample Size (n)	Mean ($\overline{X}$)	Std Dev (σ)	Sample Size (n)	Mean ($\overline{X}$)	Std Dev (σ)
Nitrogen, Total (mg/l as N)	35	0.71	0.30	10	0.58	0.1	1	0.72	0
Nitrogen Org. Total (mg/l as N)	39	0.62	0.30	10	0.53	0.1	1	0.70	0
Nitrogen Ammonia (mg/l as N)	41	0.04	0.04	10	0.03	0.02	1	0.02	0
Nitrogen Nitrite (mg/l as N)	43	0.004	0.005	2	0.01	0	1	0	0
Nitrogen Nitrate (mg/l as N)	44	0.023	0.040	9	0.01	0.006	1	0	0
Phosphorus Total (mg/l as P)	35	0.025	0.029	10	0.02	0.01	1	0.05	0
Phosphorus Ortho (mg/l as P)	28	0.015	0.015	9	0.004	0.005	1	0	0
Carbon Org Total (mg/l as C)	39	12.4	7.1	10	11	4.6	1	10	0
	33	45.5	12.1	8	45.3	10.1	0	-	-
Carbon Total (mg/l as C)	35	54.5	17.1	8	57	12	1	50	0
Hardness (mg/l)	21	160	53	4	140	16	2	170	14
Hardness Non Carbonate (mg/l)	15	7.1	9.1	-	-	-	2	3	4.2
Calcium Dissolved (mg/l as Ca)	20	56.6	20.1	4	51	6.5	2	60.5	4.9

Appendix V (cont)

	Turner Canal Bridge 84 1966-1979			Turner Canal Bridge 84 1978-1979			Turner River Bridge 83 1978-1979		
Parameter (units)	Sample Size (n)	Mean ($\bar{X}$)	Std Dev (σ)	Sample Size (n)	Mean ($\bar{X}$)	Std Dev (σ)	Sample Size (n)	Mean ($\bar{X}$)	Std Dev (σ)
Magnesium Dissolved (mg/l as Mg)	21	3.9	2	4	3.7	1.4	2	3.8	0.14
Sodium Dissolved (mg/l as Na)	21	12.7	12	4	7.2	8.3	2	13.5	2.1
Potassium Dissolved (mg/l as K)	21	0.7	0.4	4	0.48	0.15	2	0.65	0.21
Chloride Dissolved (mg/l as Cl)	21	19.7	18.1	4	17.5	6.4	2	23	4.2
Sulfate Dissolved (mg/l as SO_4)	21	2.0	2.5	4	1.5	0.9	2	1.2	1.4
Fluoride Dissolved (mg/l as F)	21	0.17	0.07	4	0.13	0.05	2	0.02	0
Silica Dissolved (mg/l as SiO_2)	21	3.5	2.4	3	4.2	4.6	2	3.8	1.3
Iron Total Recov. (μgm/l as Fe)	12	143	88	2	285	7.1	0	-	-
Iron Dissolved (μgm/l as Fe)	11	61	44	0	-	-	0	-	-
Strontium Dissolved (μgm/l as Sr)	17	179	72	4	133	31	2	130	28
Solids at 110° C (mg/l)	6	8	8.2	1	1	0	0	-	-
Solids at 180°C (mg/l)	19	188	68	3	148	71	2	234	1.4

	Turner Canal Bridge 84 1966-1979			Turner Canal Bridge 84 1978-1979			Turner River Bridge 83 1978-1979		
Parameter (units)	Sample Size (n)	Mean ($\overline{X}$)	Std Dev (σ)	Sample Size (n)	Mean ($\overline{X}$)	Std Dev (σ)	Sample Size (n)	Mean ($\overline{X}$)	Std Dev (σ)
Solids Const. (mg/l)	21	200	55	2	152	9.2	0	-	-
Solids Dissolved (tons/day)	13	159	164	2	0.24	0.007	0	-	-
Mercury Dissolved (μgm/l as Hg)	6	0.25	0.30	0	-	-	0	-	-

* Data from USGS: Wtr. Res. Data for Fla., 1966-1979, normal conductivities ranged from 158 to 590 micromhos/cm.

Appendix VI. Summary of Turner Canal and River water quality data during periods of above normal conductivities *.

	Turner Canal (BR 84)			Turner River (BR 83)		
Parameter (units)	Sample (n)	Mean ($\bar{x}$)	Std Dev (σ)	Sample (n)	Mean ($\bar{x}$)	Std Dev (σ)
Temperature (°C)	5	29.9	1.2	3	26.5	2.8
Stream Flow (cfs)	Range 0-43	-	-	0	-	-
Stream Stage (ft)	0.55-0.99	-	-	0	-	-
Turbidity (JTU)	3	9	5.6	3	2	1.4
Color (PCU)	5	35	7.1	3	55	23
Specific Conductance (μ mhos)	4	57900	5277	2	3850	1061
Dissolved O^2 (mg/l)	4	6.4	1.6	3	2.0	0.7
BOD, 5 Day (mg/l)	4	3.2	2.0	0	-	-
pH (units)	5	7.7	0.5	0	-	-
CO_2 Dissolved (mg/l as CO_2)	3	8.7	6.7	0	-	-
Alkalinity (mg/l as $CaCO_3$)	5	182	10.7	3	220	26.5
Bicarbonate (mg/l as HCO_3)	5	222	13	0	-	-
Carbonate (mg/l as CO_3)	4	0	0	3	0	0
Nitrogen, Total (mg/l as N)	2	1	0	2	1.5	0.7

Appendix VI (cont)

	Turner Canal (BR 84)			Turner River (BR 83)		
Parameter (units)	Sample (n)	Mean $(\bar{x})$	Std Dev (σ)	Sample (n)	Mean $(\bar{x})$	Std Dev (σ)
Nitrogen Org. Total (mg/l as N)	4	1.15	0.2	2	1.5	0.7
Nitrogen Ammonia (mg/l as N)	4	0.12	0.06	2	0.045	0.007
Nitrogen Nitrite (mg/l as N)	4	0.005	0.006	2	0.005	0.007
Nitrogen Nitrate (mg/l as N)	4	0.005	0.01	2	0	0
Phosphorus Total (mg/l as P)	4	0.04	0.03	2	1.5	0.7
Phosphorus Ortho (mg/l as P)	4	0.3	0.5	2	15.5	2.1
Carbon Org. Total (mg/l as C)	3	15.3	7.6	2	15.5	2.1
Carbon Inorg. Tot (mg/l as C)	3	42	7	1	49	0
Carbon Total (mg/l as C)	3	57.3	1.5	1	66	0
Hardness (mg/l)	5	6650	2167	3	393	64
Hardness Non-Carbonate (mg/l)	5	6478	2166	3	176	32
Calcium Dissolved (mg/l as Ca)	5	486	93	3	99	1.2

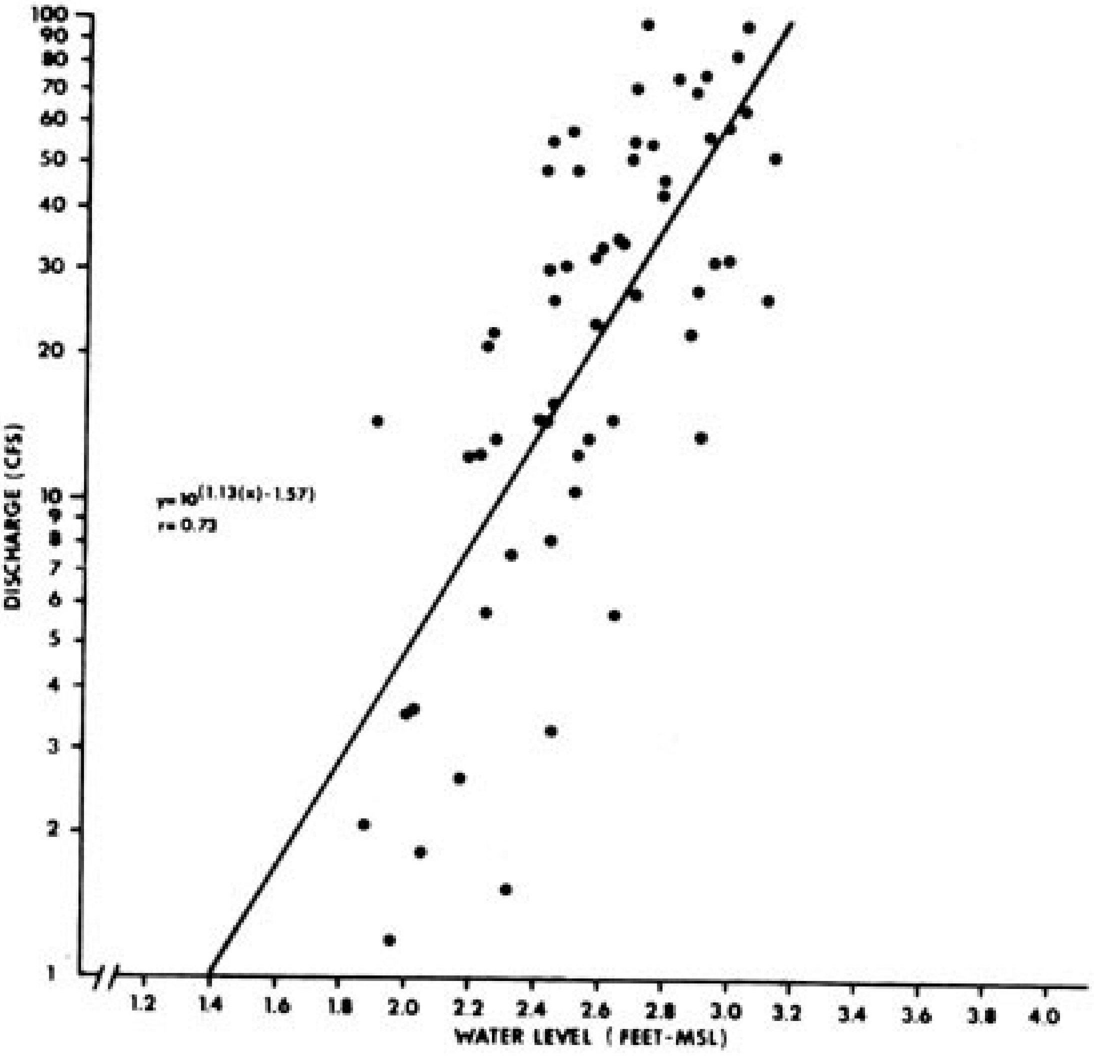
Appendix VI (cont)

Parameter (units)	Turner Canal (BR 84) Sample (n)	Turner Canal (BR 84) Mean $(\bar{x})$	Turner Canal (BR 84) Std Dev (σ)	Turner River (BR 83) Sample (n)	Turner River (BR 83) Mean $(\bar{x})$	Turner River (BR 83) Std Dev (σ)
Magnesium Dissolved (mg/l as Mg)	5	1322	466	3	35	14.7
Sodium Dissolved (mg/l as Na)	5	13360	1532	3	390	184
Potassium Dissolved (mg/l as K)	5	444	73	3	13	69
Chloride Dissolved (mg/l as Cl)	4	22550	2456	3	603	238
Sulfate Dissolved (mg/l as SO_4)	5	3002	236	3	97	40
Flouride Dissolved (mg/l as F)	4	1.6	0.1	3	0.13	0.06
Silica Dissolved (mg/l as SiO_2)	5	1.4	0.9	2	9.3	2.5
Iron Tot. Recov. (μgm/l as Fe)	3	400	327	0	-	-
Iron Dissolved (μgm/l as Fe)	5	122	66	0	-	-
Strontium Dissolved (μgm/l as Sr)	4	8825	1524	2	450	159
Solids @ 110° C (mg/l)	3	54	34	0	-	-
Solids @ 180° C (mg/l)	2	45850	2051	3	1459	486

Appendix VI (cont)

Parameter (units)	Turner Canal (BR 84) Sample (n)	Mean (x̄)	Std Dev (σ)	Turner River (BR 83) Sample (n)	Mean (x̄)	Std Dev (σ)
Solids Const. (mg/l)	4	40975	4334	0	-	-
Solids Dissolved (tons/day)	5	980	2175	0	-	-
Mercury Dissolved (μ gm/l as Hg)	4	0.18	0.13	0	-	-

* Data from USGS; Wtr. Res. Data for Fla., 1967-1978, higher than normal conductivities from 3100 to 60,400 micromhos/cm.



Appendix VII. Rating curve for Bridge 83 constructed from data found in Appendix III.