SOUTH FLORIDA RESEARCH CENTER

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Hydrologic Effects of the 1984 through 1986 L-31 Canal Drawdowns on the Northern Taylor Slough Basin of Everglades National Park

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EXECUTIVE SUMMARY

A large portion of the headwaters region of Taylor Slough lies within the lower East Everglades and an adjacent agricultural area referred to as the "Frog Pond". For this reason, the management of water levels in these areas is critical to the water resources of the basin. In early 1984, Frog Pond area farmers requested that a plan be developed to lower water levels in the area allowing land preparation and planting to begin in mid-October. An experimental one-year agreement was negotiated between the National Park Service and the Frog Pond farmers to lower water levels to 3.50 feet by October 15 in the L-31W and C-111 canals adjacent to the Frog Pond. This one-year experiment was undertaken to evaluate the effects of the drawdown on the water resources of Taylor Slough. The canal drawdown operations were continued through the 1985-86, 1986-87, and 1987-88 growing seasons, in conjunction with water delivery experiments in the Shark Slough basin. This experimental test was established by an agreement between the South Florida Water Management District and a group of south Dade farmers.

This report documents the results of hydrologic investigations conducted by the National Park Service, evaluating the impacts of 1984 through 1986 L-31W canal drawdown operations on the water resources of the northern Taylor Slough basin of Everglades National Park. Drawdown impacts on the hydrologic conditions in the central and southern portions of the Taylor Slough Basin were not investigated. The 1984 drawdown period began on the morning of October 15. Control structure S-175 remained open for seven days to stabilize L-31W canal stages at the required 3.50 feet. During the first 24 hours, S-175 headwater stage dropped 0.58 feet. Maximum water level declines of 0.42 feet occurred in the adjacent Taylor Slough wetlands over the same period.

In 1985, rainfall and upstream water management operations associated with the Shark Slough experimental agreement prompted nearly continuous use of the L-31W control structures. The drawdown began on the afternoon of October 10, 1985, and lasted approximately five days. Between the 11th and the 16th, S-175 headwater stage dropped 0.82 feet. Maximum water level declines of 0.71 feet occurred in the Taylor Slough wetlands over the same five-day period. Rainfall between October 16 and the 19th raised L-31W canal stage above the growing season regulation level prompting a second drawdown. Structure S-175 remained open until November 6 to maintain the growing season regulation stage.

During the 1986 study period, headwater stage at S-175 dropped below the growing season regulation level prior to October 15 following a long period of below normal rainfall. Rainfall during the evening of October 15 raised canal stages above the growing season regulation level prompting a 24-hour period of S-175 operation. Between October 16 and the 17th, S-175 headwater stage dropped 0.55 feet. Maximum water level declines of 0.39 feet occurred in the adjacent Taylor Slough wetlands over the same period.

Water level recessions in the L-31W canal below 3.50 feet by October 15 were almost unprecedented prior to the 1984 experimental agreement occurring only once during the previous 14 years. The average date of water level recessions to 3.50 feet under previous water management operations was November 20, five weeks later than the date of the 1984 experimental drawdown. Prior to the 1984 drawdown experiment,

date of the 1984 experimental drawdown. Prior to the 1984 drawdown experiment, there was no formal agreement to use the L-31W canal to provide additional flood protection below the established 4.50-foot operational setting. The hydrologic investigations conducted during the 1984 through 1986 study periods indicate that the L-31W canal agricultural drawdown operations produced water level reductions throughout northern Taylor Slough, particularly in the areas adjacent to the L-31W canal. All of these drawdowns occurred during years when the total annual rainfall was over 10 inches below normal and monthly total rainfall during the September through November study periods was also below normal (Table 1).

The L-31W borrow canal was designed "to convey flow to replenish the fresh water supply in the Taylor Slough area of the park" (U.S. Army Corps of Engineers 1967). Structure S-175 was originally designed to "maintain water levels up to 5.00 feet and provide a means of either diverting borrow canal discharge overland into Taylor Slough or passing it south to be distributed overland from the borrow canal south of State Road 27" into central Taylor Slough (U.S. Army Corps of Engineers 1963). Following this initial design study, S-175 headwater stage was reduced by 0.50 feet and set to maintain upstream optimum water levels of up to 4.50 feet for as long as local rainfall remained adequate (U.S. Army Corps of Engineers 1973).

The overall results of this study indicate that management of wet season stages below 4.50 feet in the upper portion of the L-31W canal causes drainage of the adjacent Taylor Slough wetlands. Review of water level data collected during the last four and one-half years of the Frog Pond drawdown study indicate that during the months of June through November, L-31W canal stages generally remained well below the stage in the Taylor Slough wetlands. Under these conditions, the L-31W canal acts as a groundwater sink draining the adjacent wetlands. This is inconsistent with the initial design purpose of the L-31W canal which states that the canal should replenish the fresh water supply to the Taylor Slough basin. The lowering of L-31W canal stages to allow earlier land preparation and planting in the Frog Pond agricultural area further exacerbates the drainage effects of the canal system and is incompatible with the system design intent of restoring fresh water flows to the Taylor Slough basin.

INTRODUCTION

On June 4, 1984, Everglades National Park and the individuals and corporations farming in the "Frog Pond" agricultural area reached an agreement outlining an experimental drawdown in the L-31W and C-111 canals for the 1984-85 growing season. The purpose of the experiment was to determine the hydrologic effects of lowering canal stages in the Frog Pond area which had been requested by the farmers to permit earlier planting of seasonal row crops. In a letter dated June 22, 1984, the executive director of the South Florida Water Management District stated that the District considered the agreement acceptable and would honor its terms within the context of concurrent flood control and water supply commitments. The experiment began in October 1984 and continued through the 1984-85 growing season as planned. Following the experiment, the canal drawdown operations were extended through the 1985-86, 1986-87, and 1987-88 growing seasons in conjunction with Everglades National Park water delivery experiments authorized by Public Laws 98-181 and 99-190 (U.S. Congress 1983, 1985).

The purpose of this document is to report the results of hydrologic investigations undertaken by Everglades National Park to evaluate the effects of the 1984 through 1986 L-31W canal drawdown operations on the water resources of the northern Taylor Slough basin in Everglades National Park. The general goals of the hydrologic investigations included:

1. Determination of the water level recession rates, response times, and maximum water level declines attributable to the agricultural canal drawdowns as well as the areal extent of these impacts in the northern Taylor Slough basin.

2. Comparison of L-31W canal management during the 1984 through 1986 drawdown periods with design stages and pre-drawdown management practices.

STUDY AREA

Taylor Slough, a 158 square mile freshwater wetland, extends more than 20 miles from its headwaters north of the Frog Pond agricultural area to the coastal mangrove fringe along Florida Bay (Fig. 1). The basin is situated along the northeastern boundary of Everglades National Park and is the area of the park that is in closest proximity to nearby agricultural activities. The Taylor Slough basin has been divided into five distinct physiographic zones by Schomer and Drew (1982). These zones include the headwaters, upper, middle, lower slough, and the coastal swamps and lagoons. The hydrologic investigations described in this report include only data collected from portions of the headwaters, upper, and middle slough areas of the basin.

Taylor Slough Headwaters

The headwaters zone of Taylor Slough is bordered on the north by a narrow strip of land known locally as the Rocky Glades and extends southward to the point where the main channel of Taylor Slough intersects the L-31W canal (location of the S-332 pump station). Most of the headwaters area lies outside of Everglades National Park in the southern portion of the East Everglades. The area is characterized by rocky, open, muhly prairies (*Muhlenbergia filipes*) with thin eroded marl soils overlying a solution riddled limestone surface. The hydroperiods in this area are short with surface inundations of generally less than two months (Schomer and Drew 1982).

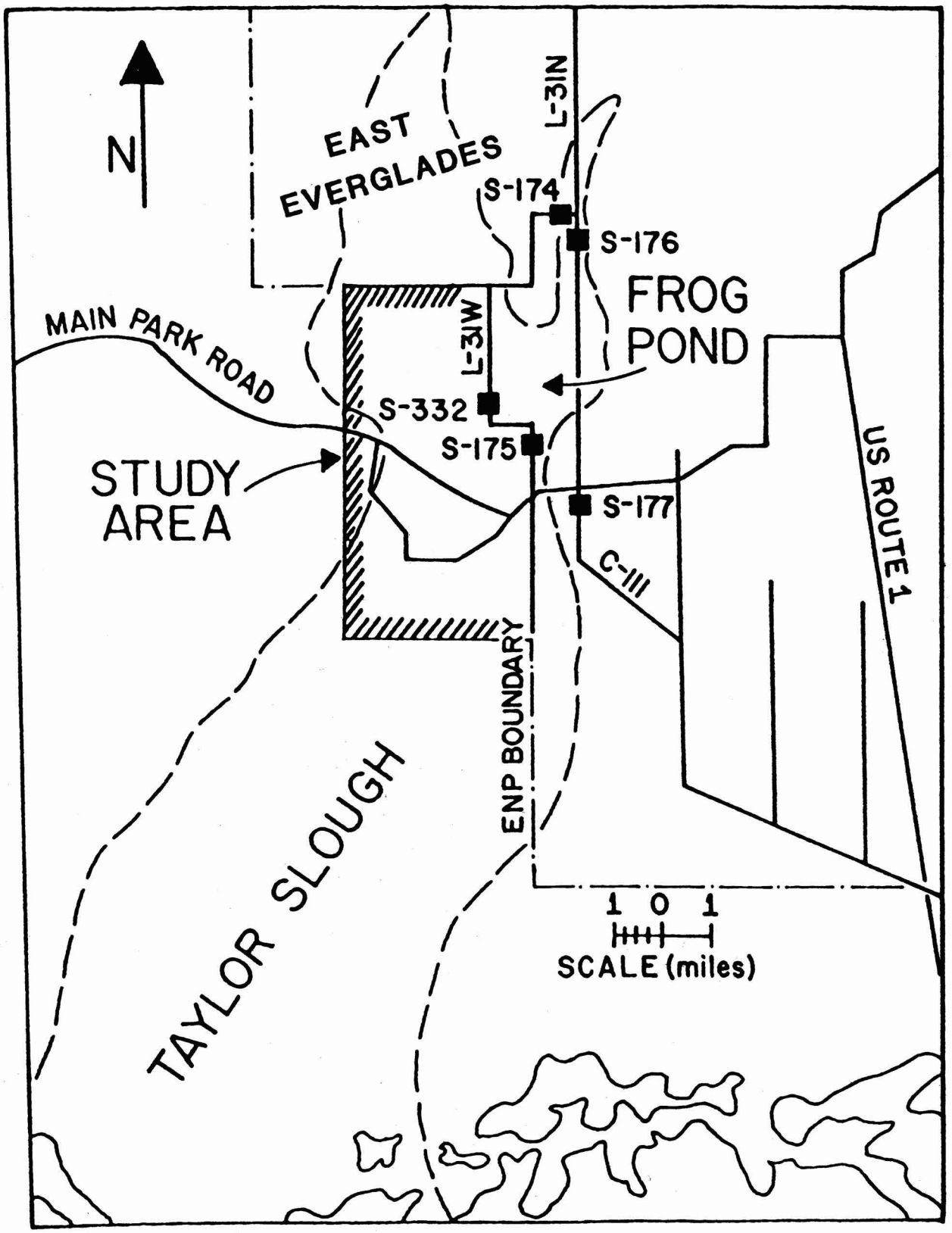

Figure 1. Map of the Taylor Slough Drainage Basin showing the study area, the Frog Pond agricultural area, and the L-31W and C-111 canal systems. The dashed line represents the historical boundaries of Taylor Slough. Within the study area, the park boundary follows the L-31W canal alignment.

Upper Taylor Slough

The upper portion of Taylor Slough extends from the intersection of the slough and the L-31W canal southward nearly two miles below the main park road. The central portion of this zone maintains a distinct dry season flow channel because of S-332 pump station discharges. This wetter depression has hydroperiods generally exceeding nine months and is dominated by sawgrass (*Cladium jamaicensis*) and spike rush (*Eleocharis cellulosa*) with small scattered willow stands (*Salix Caroliniana*). The depression thins laterally into muhly prairies with scattered small hardwood hammocks on higher exposed limestone outcroppings. The muhly prairies of the upper portion of the basin have shallow marl soils with scattered limestone outcrops. These open prairies have intermediate hydroperiods with surface inundations of approximately two to four months (Rintz and Loope 1978). The upper zone of Taylor Slough forms a breach in the Coastal Ridge system separating the upland areas west of the L-31W canal (Long Pine Key) from the major portion of the ridge system to the east of the slough (Schomer and Drew 1982).

Middle Taylor Slough

The middle portion of Taylor Slough extends from a point two miles south of the park road southward approximately four miles. At that point the main part of the slough is joined by a large area of extended hydroperiods which is supplemented by discharges from the southern end of the L-31W canal. This middle portion of the slough has thicker marl soils overlying scattered peat substrates. This zone is dominated by large areas of mixed sawgrass and spike rush with smaller areas of dense sawgrass and willow stands. The middle slough zone has longer hydroperiods with surface inundations of approximately four to eight months (Rintz and Loope 1978).

The Frog Pond Agricultural Area

The Frog Pond is a 5,000-acre agricultural area lying just east of the upper zone of Taylor Slough. The area is bordered on the east by the C-111 canal and on the north and west by the L-31W canal (Fig. 1). The dashed line defining the predrainage borders of Taylor Slough was drawn from U. S. Soil Conservation Service soil survey maps (U.S.D.A. 1958) which showed the various phases of the Perrine Marl as wetland soils. Figure 1 indicates that a large portion of the Frog Pond area lies within the historic marsh. The remaining portions of the Frog Pond occur on the higher areas of the Coastal Ridge system.

TAYLOR SLOUGH HYDROLOGY

Rainfall

The study area has a tropical savanna climate with a relatively long and intense dry season occurring from approximately November through April and a wet season occurring from approximately May through October. Dry season rainfall results from large scale winter frontal storms which produce relatively uniform rainfall over a large area. Dry season rainfall contributes approximately 20 percent of the total annual precipitation. Wet season rainfall is primarily from local convective storms which produce variable rainfall over a small area. Wet season rainfall is usually intense and of a short duration with less frequent day-long storms associated with tropical disturbances. Wet season rainfall contributes approximately 80 percent of the total annual precipitation (Schromer and Drew 1982).

There are a large number of rain gages throughout the study region with three stations (R3110, S-332, and Royal Palm) occurring within the upper portion of the Taylor Slough basin (Figs. 3 and 4, pp. 12-13). The rain gage at R3110 was not installed until September 1985 and did not provide reliable data for the first few months. For this reason, daily rainfall totals reported throughout this report were based on rainfall amounts recorded at the S-332 pump station in northern Taylor Slough. The rain gage at Royal Palm has the longest available record (37 years) and was used in this report for period of record comparisons. Monthly rainfall totals for the three study years and the period of record monthly means for the Royal Palm rain gage are summarized in Table 1. For this rain gage, the annual, dry, and wet season period of record averages are 56.9, 12.0, and 45.0 inches, respectively.

Table 1. Summary of Royal Palm Ranger Station Rainfall Conditions During the Study Period and Over the Period of Record (1950 - 1987).

	PERIOD OF RECORD		1984	1985	1986
MONTH	MEAN	ST. DEV.	TOTAL	TOTAL	TOTAL
January	1.66	2.05	0.20	0.30	1.73
February	2.02	1.55	1.15	0.26	1.52
March	1.76	1.59	2.98	2.67	4.09
April	2.78	2.83	0.33	1.08	1.65*
May	6.15	4.48	10.09	4.69*	0.47
June	9.37	5.52	3.62	3.32*	6.12*
July	7.16	2.86	9.21	11.82	5.16
August	7.90	3.48	7.87	4.15	8.13
September	8.65	3.35	8.30	7.76	4.53
October	5.73	3.20	0.46	5.63	1.12
November	2.24	1.77	1.69	2.75	1.64
December	1.46	1.36	0.28	0.84*	4.47
ANNUAL	56.93	13.25	46.18	45.29	40.63

Monthly and annual rainfall amounts are in inches. *(Indicates months with missing data during the study period.)

Surface Water Hydrology

Prior to the construction of the L-31W canal system, surface water in the Taylor Slough basin was derived principally from local rainfall. Under high water conditions, sheetflow from the Shark Slough basin, north of the headwater area, contributed additional surface water to Taylor Slough. This water then flowed southward down the slough as sheetflow to Florida Bay or served to recharge the underlying aquifer.

Surface water discharge through the headwaters zone of the basin was initially measured as it passed through 80 culverts along a 7.5-mile stretch of Context Road north of the park boundary. These measurements were done by the U. S. Geological Survey beginning in 1976 and were discontinued in 1980. Surface water discharge into the upper zone of Taylor Slough is measured as it passes beneath a three mile stretch of the main park road known as the Taylor Slough Near Homestead flow section. These measurements began in August 1960 by the U. S. Geological Survey and were taken over in 1985 by Everglades National Park. Early studies by the U. S. Geological Survey (Earle and Hartwell 1973) showed that prior to the construction of the L-31W canal

mean annual discharge through the Taylor Slough Near Homestead flow section, for the period from October 1960 through September 1968, was 34,300 acre-feet per year. For the same period, there was zero flow 46 percent of the time. Later studies by the National Park Service (Rose et al. 1981) showed that mean annual discharge through the Taylor Slough Near Homestead flow section, following construction of the L-31W canal, was 20,600 acre-feet per year over the period of October 1968 through September 1978. For the same period there was zero flow 52 percent of the time.

Groundwater Hydrology

Taylor Slough and the Frog Pond agricultural area overlie the Biscayne Aquifer, a highly permeable unconfined aquifer extending throughout southeastern Florida. Groundwater recharge occurs via rainfall and surface water infiltration as well as through seepage losses from the adjacent conveyance canals. Left undisturbed by canals, groundwater movement in the area follows local hydraulic gradients from the headwaters area of Taylor Slough toward Florida Bay.

The Biscayne Aquifer is defined by hydrogeologic properties rather than formational boundaries (Jarosewich and Wagner 1985) and is approximately 40 feet thick within the study area. Geologic well logs of a borehole drilled just north of structure S-175 indicate that the upper portion of the aquifer consists of Miami Limestone with a total thickness of approximately eight feet. An oolitic facies of this unit forms surface exposures throughout the headwaters and upper portion of the basin. Below this is a thin limestone unit known locally as the Fort Thompson Formation. The Tamiami Formation underlies the Fort Thompson Formation. The base of the Biscayne Aquifer is defined as the bottom of the upper permeable limestone unit in the Tamiami Formation. Within the study area, the Fort Thompson Formation and the upper limestone unit of the Tamiami Formation have a total combined thickness of approximately 32 feet. Pump tests of deep boreholes in the study region give estimated transmissivities in the range of 700,000 to 1,000,000 feet squared per day and storage coefficients in the range of 0.20 to 0.25 with the most permeable and highest yielding zones within the Biscayne Aquifer.

THE DADE COUNTY WATER MANAGEMENT SYSTEM

The Central and Southern Florida Project

The conveyance canals and control structures within Dade County are part of the Central and Southern Florida Project constructed by the Army Corps of Engineers for flood protection and water control purposes. The first phase of the project was authorized by the Flood Control Act of 1948 in accordance with the Comprehensive Report Plan (U.S. Congress 1948a). This first phase included most of the existing water control works in the Everglades Agricultural Area south of Lake Okeechobee along with the early flood control and drainage canals in the developed areas of the lower east coast. The remaining works of the Comprehensive Report Plan as well as other refinements and modifications were authorized by the Flood Control Acts of 1954, 1962, and 1968 (U.S. Congress 1954, 1962, and 1968).

The first overall plan for flood protection and water control for southern Dade County was presented in the Survey Review Report on the Central and Southern Florida Project, South Dade County (U. S. Army Corps of Engineers 1961). The L-31W canal system was not included as part of this plan. The remaining major flood control and water supply facilities for southern Dade County were addressed by the General Design

Memorandum, South Dade County (U. S. Army Corps of Engineers 1963). The L-31W canal and control structures S-174 and S-175 were added to the project as part of this memorandum following recommendations by the National Park Service and the Fish and Wildlife Service.

The first major canal constructed in Dade County was the southern end of the Miami Canal, which was built in 1912 to drain the northern Everglades basin to the Atlantic coast (Fig. 2). In 1951 construction began on the L-30 and the northern portion of the L-31N canal and levee systems. These were built as part of the eastern protective levee system to protect the populated east coast from the Everglades during periods of flooding. In 1961 construction began on the L-29 canal and levee system which largely completed the closure of Water Conservation Area 3 (WCA 3) along the northern boundary of the park. At this time there was no connection between WCA 3 and the L-30 and L-31N canal systems so the canal systems south of the conservation areas could be used for flood protection but not for water supply.

The earliest canal construction in southeastern Dade County began in 1955 with completion of the Snapper Creek canal (C-2) and later, in 1960, the Black Creek canal (C-1). Both of these canals were initially constructed for drainage and were uncontrolled. During 1964 and 1965 a number of additional canals were added to the system (C-100, C-102, C-103, and C-111) and control structures were added to all of the new and existing canals to reduce saltwater intrusion. In 1966 construction began on the remainder of the L-31N canal and structures S-173, S-176, and S-177 were added to control flows southward into the C-111 canal. At the same time several of the canals constructed earlier (C-1, C-102, and C-103) were extended westward to the L-31N canal to improve flood protection and allow for water supply to these basins. Construction of the L-31W canal and structures S-174 and S-175 began in 1968 and was completed in early 1970. At this time the system still lacked sufficient control structures to move surplus water in WCA 3 to the lower east coast.

The South Dade Conveyance System

Concerns voiced by Everglades National Park that more freshwater was needed for Taylor Slough and the downstream areas of Florida Bay prompted Congress to authorize the construction of the South Dade Conveyance System as part of the Flood Control Act of 1968 (U.S. Congress 1968). This system of canals, control structures, and pumping stations was added to the Central and Southern Florida Project for the purposes of "conservation and conveyance of additional water supplies for Everglades National Park and for expanding agricultural and urban needs" along the lower east coast (U.S. Congress 1968). The system was primarily designed to provide 55,000 acre-feet per year of supplemental water to the eastern portion of Everglades National Park to meet the congressionally mandated minimum delivery schedule which went into effect in October 1970.

The first connection between Water Conservation Area 3A and the lower east coast canals occurred with the completion of structures S-333 and S-334 in the L-29 canal in 1978 (Fig. 2). These were installed to provide additional dry season water deliveries to the L-31N canal. At this time the movement southward of this water was limited by the conveyance capabilities of the canal and structure S-173. By 1983, the enlargement of the canal system, completion of pump station S-331, and a new bridge over the L-31N canal at Howard Drive removed this limitation.

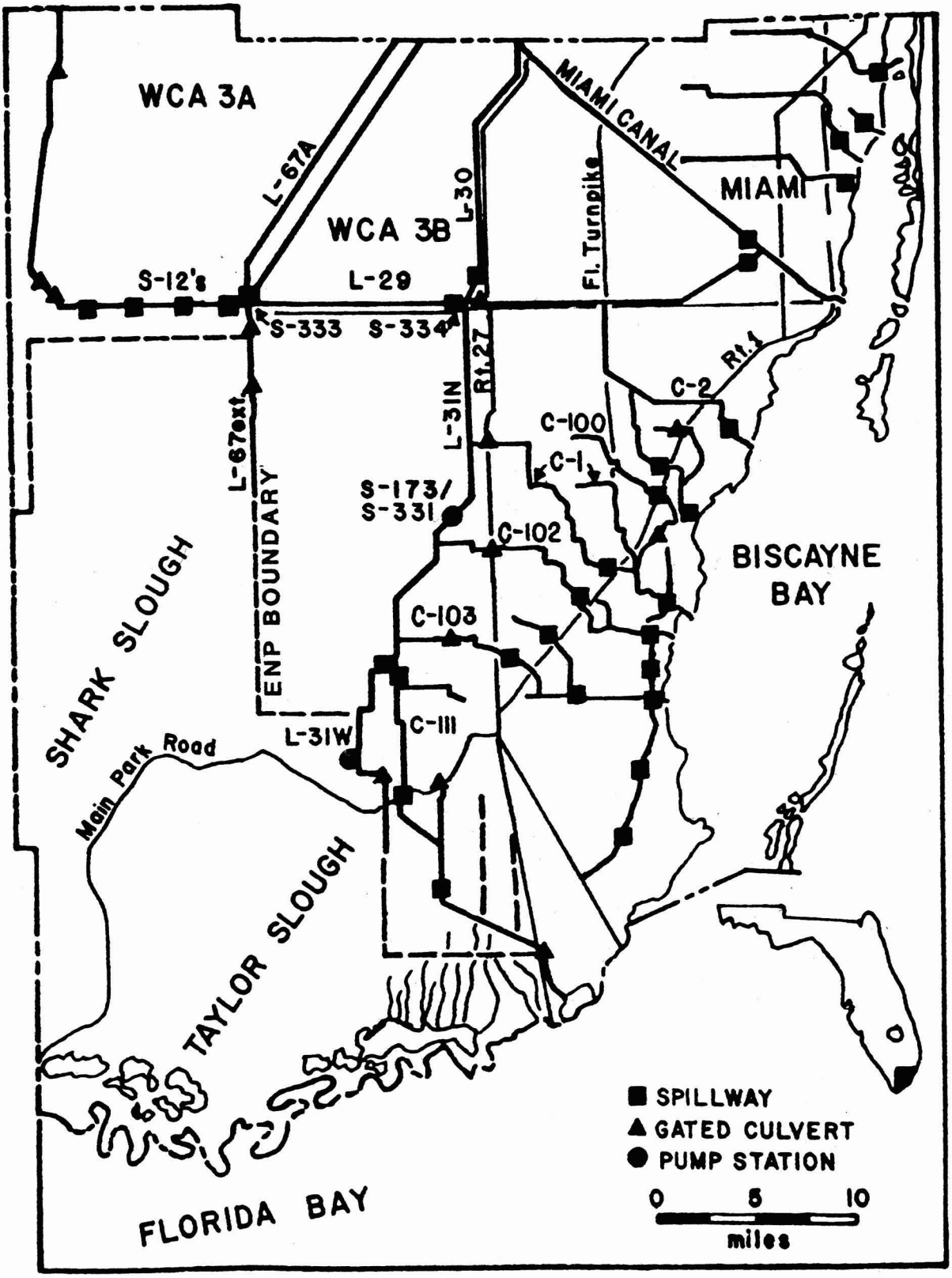

Figure 2. Map of Dade County showing the canals and water control structures in the general study area. The area below the L-29 canal and lying between L-31N and the L-67 extension canals is referred to as Northeast Shark Slough. This area is outside the boundaries of the Everglades National Park.

The L-31W Canal System

The L-31W canal and its associated control structures were initially designed as a part of the east coast protective levee system. The L-31W canal was designed for flood protection and to "convey flow to replenish the fresh water supply in the Taylor Slough area of the park." Conversely the levee was constructed to "prevent flooding from the Everglades National Park into agricultural and industrial areas lying to the east" (U. S. Army Corps of Engineers 1967). The canal and its associated levee are 11.1 miles long running from its confluence with the L-31N canal southward to a point approximately 2.4 miles south of the main park road (Fig. 1). Structure S-174 is located at the upstream end of the canal just west of its confluence with the L-31N canal. The structure is an automatic gated spillway originally designed to pass a discharge of 500 cubic feet per second (cfs) at a headwater stage of 6.00 feet and a tailwater stage of 5.50 feet (all stages listed in this report are referenced to the National Geodetic Vertical Datum of 1929). Structure S-175 is located 1.4 miles north of the main park road. The structure is a set of three culverts with manually operated gates, originally designed to pass a discharge of 500 cfs at a headwater stage of 5.00 feet with a 0.50 foot head loss. The portion of the canal system downstream of structure S-175 is uncontrolled and stages fluctuate with the adjacent wetlands.

TAYLOR SLOUGH/FROG POND WATER MANAGEMENT

The Survey Review Report of the Central and Southern Florida Project for South Dade County (U. S. Army Corps of Engineers 1961) established the first plans for the water management system in the C-111 canal east of the Frog Pond agricultural area. Later, the General Design Memorandum for South Dade County (U. S. Army Corps of Engineers 1963) added plans for the L-31W canal system along the eastern park boundary in northern Taylor Slough. Provisions of these plans included flood protection for developed areas of southern Dade County and facilities to convey supplemental water to Taylor Slough to compensate for the estimated drainage effects of upstream canal systems on the basin's headwaters.

Pump station S-332 was authorized by the Flood Control Act of 1968, as part of the South Dade Conveyance System, and was added to the L-31W canal to provide supplemental flows to upper Taylor Slough (U.S. Congress 1968). The 1968 authorization specifically recognized provision of adequate water supplies to the Everglades National Park as a project purpose in order to preserve and restore its natural state and to maintain and protect its unique ecology. Construction began on the S-332 pump station in 1979 and it became operational by October 1980. Funds for construction were provided as part of the Monetary Authorization Act of 1970, which also established the first monthly delivery schedule for this structure (U.S. Congress 1970). This section was designed (1) to assure construction as soon as possible of the conveyance facilities necessary to deliver water to the drier eastern portions of the park and (2) to remove any uncertainty the amount of water the project is required to deliver to the park, by in effect amending, through this additional legislation, the project authorization. This pumping schedule was later revised by the "Agreement and Permit" for operation signed in 1976 by the Army Corps of Engineers, the South Florida Water Management District, and the National Park Service. The final approved pumping schedule provided 37,000 acre-feet per year to be delivered through the S-332 pump station. The approved minimum monthly pumpages were 740, 370, 185, 185, 370, 6660, 7400, 2960, 5920, 7770, 3700, and 740 acre-feet for the months of January through December, respectively.

L-31W Design Stages and Operational Changes

The first operations logs for control structures S-174 and S-175 began in August 1970. Structure S-174 remained closed and off until July 1971, when it was first set to operate on automatic. Prior to May 1979, S-174 was operated on automatic according to the established operations settings except during short periods of time when the structure was turned off due to low water levels. After May 1979, S-174 was routinely operated manually, and was opened at stages well below the established automatic gate settings. Structure S-175 remained closed until September 1977. Prior to this date, L-31W canal water levels were generally low with a mean stage of 2.79 feet at the S-175 headwater recorder. During this period, the few high canal stages that exceeded the S-175 operations criteria were allowed to recede naturally. Between September 1977 and the start of the Frog Pond experiment, canal stages were higher with a mean stage of 3.46 at the S-175 headwater recorder. During this period, S-175 was used routinely whenever canal stages exceeded the established operations criteria. In addition, S-175 was operated at stages below the established criteria to lower stages for agricultural flood protection once the canal stage had receded naturally below approximately 3.50 feet.

Structure S-174 was originally designed to "maintain optimum water levels up to 6.00 feet in the L-31N borrow canal and discharge up to 500 cfs to the borrow canal of levee 31W." Structure S-175 was originally designed to "maintain water levels up to 5.00 feet and provide a means of either diverting borrow canal discharge overland into Taylor Slough or passing it south to be distributed overland from the borrow canal south of State Road 27" (U.S. Army Corps of Engineers 1963). Table 2 shows the original design stages and changes in the operating criteria for structures S-174 and S-175. Apparently, the first operations setting for S-175 had been lowered to 4.50 feet following the completion of the Detailed Design Memorandum in 1967 (personal communications, USACOE and the SFWMD). In 1973, a General Design Memorandum was released describing the South Dade Conveyance System improvements (U.S. Army Corps of Engineers 1973). This was the first document to list the S-175 optimum headwater stage at 4.50 feet. The original design settings at S-174 were lowered by 0.20 feet following a request by the Central and Southern Florida Flood Control District in March 1968. This request was made following an examination of ground surface elevations in the area above S-174 which indicated higher stages could not be tolerated during the agricultural growing season. All subsequent operational changes were taken from the structure operations logs provided by the South Florida Water Management District. S-174 and S-175 were constructed to pass the design discharge with a 0.50-foot head loss across the structures. For this reason, all stages listed in Table 2 are for the headwater recorder only.

From July 1971 to June 1982, S-174 was set to maintain an upstream stage of up to 5.50 feet in the L-31N canal and to open full when the headwater stage exceeded 5.80 feet. Two minor short term operational changes (lowering of the open setting from 5.80 to 5.70 at S-174) occurred during July 1979 and from November 1981 to May 1982. In June 1982 the operational settings at structure S-174 were reset to maintain a stage of up to 4.60 feet upstream of the structure in the L-31N canal and open full when headwater stage exceeded 4.90 feet. This change allowed lower water levels to be maintained in the upstream reaches of the L-31N canal providing additional flood protection for the residential and agricultural areas adjacent to the canal. The change also greatly increased flow into the L-31W canal. One additional minor change in the operations settings occurred in June 1983 when the settings for S-174 were raised by 0.10 feet.

Table 2. Summary of Initial Design Settings and Operational Changes at Structures S-174 and S-175.

INITIAL DESIGN SETTINGS
(L31W Detail Design Memorandum, 1967 and correspondence dated March 1968)

S-174 SPILLWAY	S-175 CULVERTS
5.50 ft. open	5.00 open
5.30 ft. static	
5.10 ft. closed	

FIRST OPERATIONS SETTINGS*
(SFWMD Operations logs, July 1971, prior to this date structures were closed or off)

S-174 SPILLWAY	S-175 CULVERTS
5.80 ft. open	4.50 open
5.50 ft. static	
5.10 ft. closed	

NEW OPERATIONS SETTINGS
(SFWMD Operations logs, June 1982)

S-174 SPILLWAY	S-175 CULVERTS
4.90 ft. open	4.50 open
4.60 ft. static	
4.40 ft. closed	

NEW OPERATIONS SETTINGS
(SFWMD Operations logs, June 1983)

S-174 SPILLWAY	S-175 CULVERTS
5.00 ft. open	4.50 open
4.70 ft. static	
4.50 ft. closed	

NEW OPERATIONS SETTINGS
(Shark Slough Delivery Test Agreement, July 1985)

S-174 SPILLWAY	S-175 CULVERTS
4.50 ft. open	4.50 open
4.30 ft. static	
4.10 ft. closed	

*The only definite settings for S-175 that could be found are those from the initial design settings listed above and the settings listed in the South Dade Conveyance System General Design Memorandum (U.S. Army Corps of Engineers 1973). For all other dates they were assumed to have remained unchanged.

Operations criteria for the control structures in the L-31W canal have been controversial since the late 1970's. Farmers have requested that stages be lowered in the Frog Pond area late in the wet season to allow earlier land preparation and planting. Everglades National Park argued that this would be detrimental to park water resources since it causes drainage of northern Taylor Slough. In 1981, representatives from the Water Management District, the National Park Service, and the Frog Pond farmers met to develop recommendations for Frog Pond area water management. The group agreed that wet season optimum water levels of 4.50 feet should be maintained at the upstream side of structures S-175 and S-177 for as long as local rainfall remained adequate. It was further agreed that the South Dade Conveyance System facilities should be utilized to maintain 3.00-foot headwater stages at these structures in up to a one in 10 year drought as long as sufficient water was available. It was expected at that time that planting in the Frog Pond area would begin when water levels receded naturally below a headwater stage of 4.00 feet at structure S-177. During the growing season, structures S-175, S-177, and S-332 would be operated to alleviate any agricultural flooding problems that might occur as a result of large rainfall events (approximately five inches or more).

Between August and November 1984, the operational settings at structure S-174 were lowered by 0.20 feet as part of a wet season field test of water deliveries to Northeast Shark Slough. The operational settings were lowered by an additional 0.20 feet in July 1985 in conjunction with a two-year experimental water delivery test in Northeast Shark Slough. These changes were part of an agreement between south Dade farming interests and the South Florida Water Management District. The operational changes allowed lower stages to be maintained in the upstream reaches of the L-31N canal providing greater flood protection for the residential and agricultural areas during the tests. The change also increased flows into the L-31W canal and prompted increased use of structure S-175.

The Frog Pond Experimental Drawdown Agreement

In early 1984, Frog Pond area farmers stated that market conditions required that a schedule be developed allowing for earlier land preparation and planting. Negotiations with the National Park Service began, which lead to the Frog Pond experimental drawdown agreement. The agreement specified that water levels in the Frog Pond area would be lowered to allow preparation and planting to begin in mid-October as a one-year experiment evaluating the effects of the drawdown on the water resources of Taylor Slough (the full text of the agreement appears in Appendix A). Key terms of the 1984 Frog Pond Agreement regarding structure operations were as follows:

1. Water levels in the L-31W canal were to be operated such that on October 15, 1984, the tailwater stage at structure S-174 and the headwater stage at structure S-175 would be no higher than 3.50 feet NGVD. After the crops were planted, tailwater stages at S-174 and headwater stages at S-175 would be maintained at or below 3.50 feet NGVD until the end of the growing season and harvest.

2. Water levels in the C-111 canal were to be operated such that on October 15, 1984, the tailwater stage at structure S-176 and the headwater stage at structure S-177 would be no higher than 3.50 feet NGVD. After the crops were planted, tailwater stages at S-176 and headwater stages at S-177 would be maintained at or below 3.70 feet NGVD until the completion of the growing season and harvest.

STUDY METHODS

The Field Monitoring Network

The Taylor Slough study area described in Figure 1 was divided into two subareas for most of the evaluation methods. The northern subarea extends from the park boundary west of structure S-174 southward to the main park road (Fig. 3). The southern subarea extends from the main park road southward to approximately 2,500 feet below the end of the L-31W canal (Fig. 4). The initial hydrologic investigations, undertaken to evaluate the 1984-85 experimental canal drawdown, concentrated in the northern portion of Taylor Slough above the main park road. Only one water level station (R127) was examined south of this area. The results of this first-year study were summarized in an internal report (Wagner et al. 1985). The results of this study suggested that additional investigations were needed below the main park road to evaluate the effects of the large volumes of water released through structure S-175 during the experiment. Prior to the 1985 drawdown period, new discontinuous monitoring stations were added to the study area south of the park road along with several new stations in key areas within the northern part of Taylor Slough.

Tables 1 and 2 in Appendix B list the water level stations used for evaluation of the 1984 through 1986 drawdown periods and identify the years of the study for which data were collected at each station. Three rainfall stations were also examined. These included continuous recording rain gages located at the S-332 pump station, maintained by the South Florida Water Management District, and stations R3110 and Royal Palm, maintained by the park (Figs. 3 and 4).

Techniques for Documenting Drawdown Effects

A number of approaches were used to determine the hydrologic effects of the 1984 through 1986 drawdown periods including:

1. Examination of continuous water level records to determine water level recession rates, response times, and maximum water level declines attributable to the canal drawdown operations.

2. Development of water level contour maps to spatially describe the pattern of water levels in the northern Taylor Slough basin and allow comparisons of these patterns throughout the study periods.

Drawdown Responses at Continuous Stage Recorders

The first step in examining the effects of the canal drawdowns was to construct stage hydrographs for the continuous water level recorders in the L-31W canal and in Taylor Slough. This was done by tabulating four-hour stage data for the 12 continuous stage recorders within the study area. The length of this collection period varied each year in an attempt to include the period of time that was most affected by the drawdown operations. In 1984 this period was from October 12 to October 24. In 1985 the period was from October 8 to October 24 and in 1986 the period was from October 8 to October 26. The longer time periods for 1985 and 1986 were the result of significant L-31W stage reductions occurring prior to October 15 in each of these years.

A series of plots of these stage hydrographs have been provided in the results section of this report. There are two figures for each year of the study. The first is a plot of S-175 headwater stage versus a series of stations in Taylor Slough north of pump station

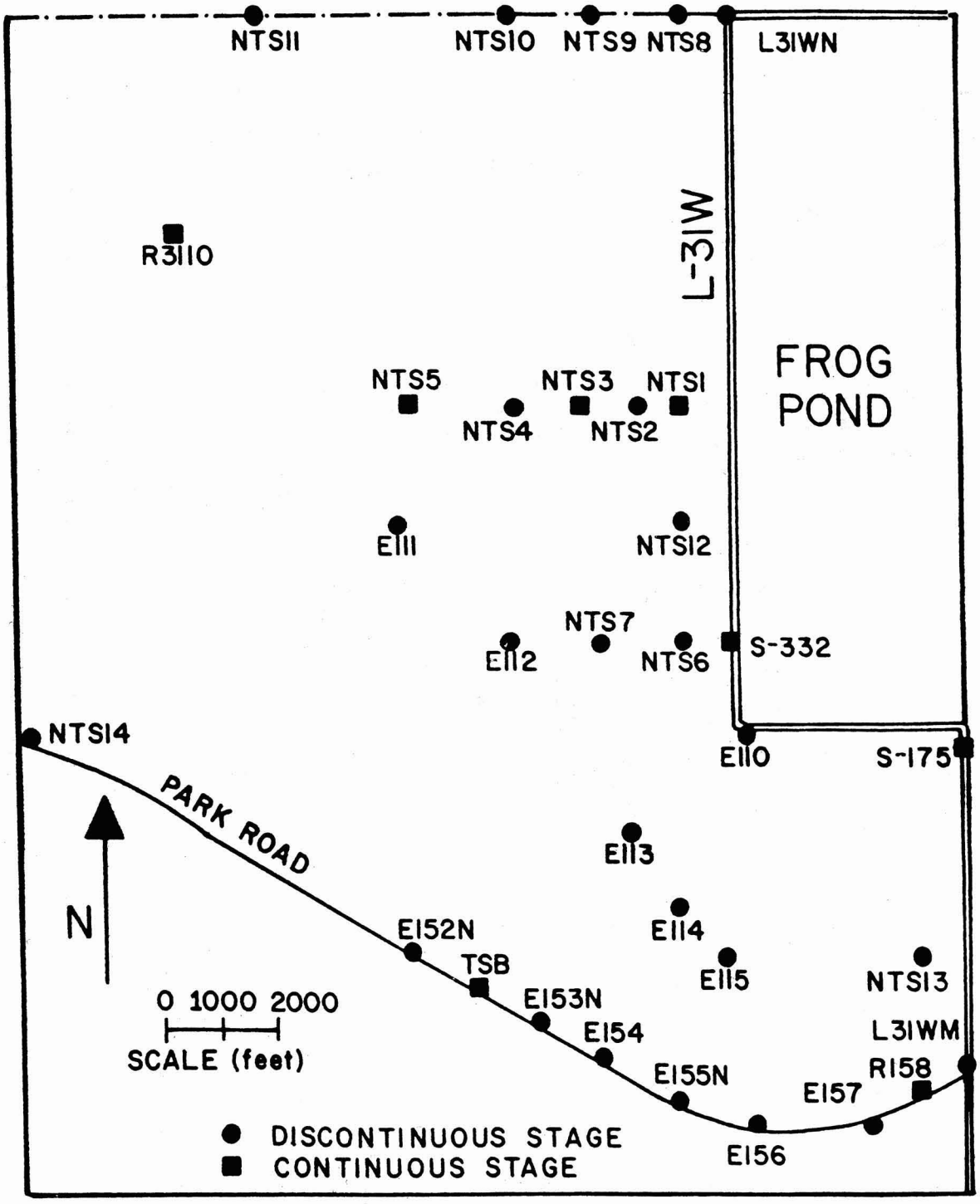

Figure 3. Map of the northern subarea showing the locations of the monitoring stations for the canal drawdown study.

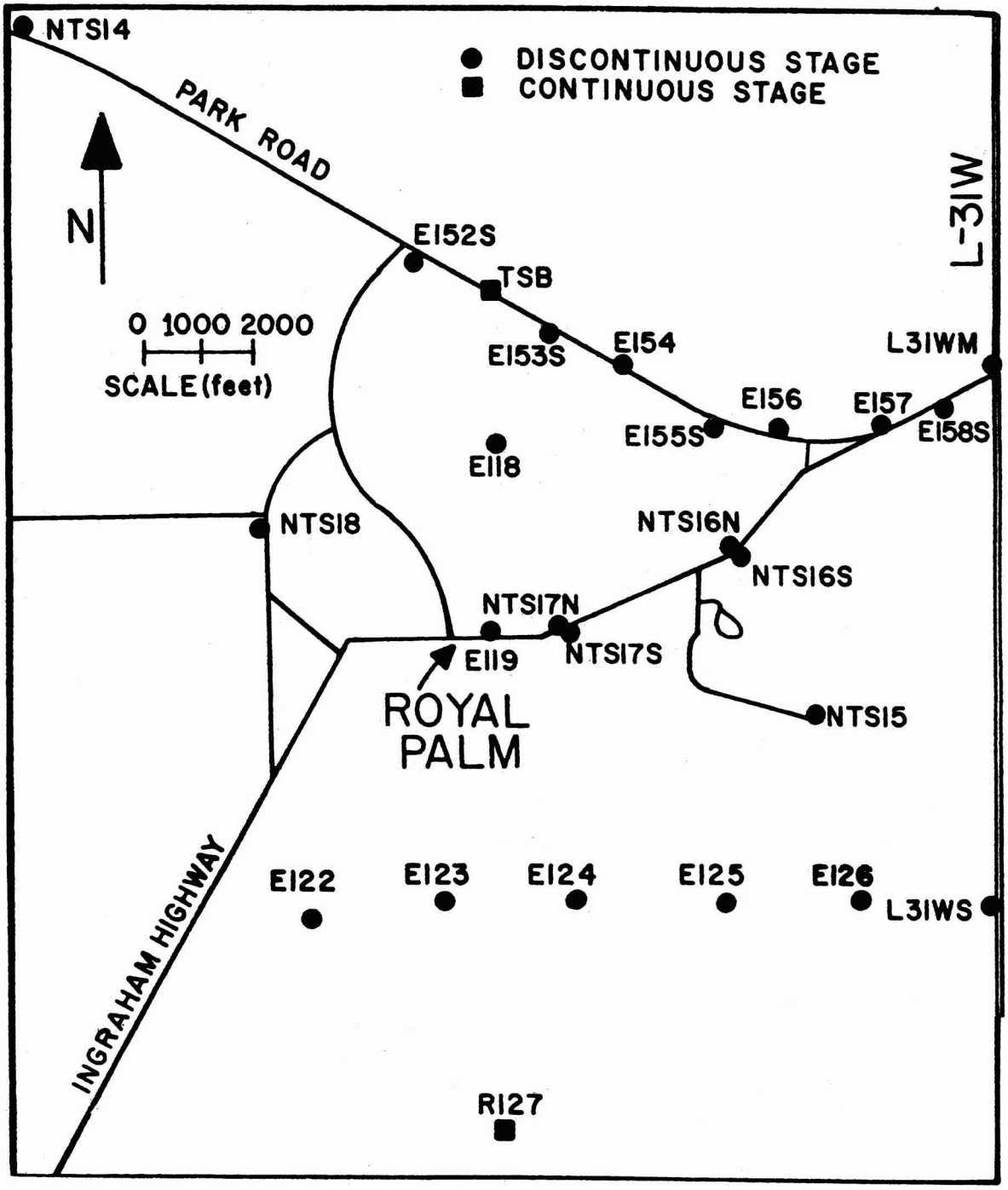

Figure 4. Map of the southern subarea showing the locations of the monitoring stations for the canal drawdown study.

S-332. The second is a plot of S-175 tailwater stage versus a series of stations downstream of this structure. This has been done because the portion of Taylor Slough above the S-332 pump station showed the effect of the decreases in L-31W stage while the portion of the basin below S-332 primarily showed the effect of increased discharges through structure S-175 as a result of the drawdown operations.

Determination of Background Recession Rates

The effects of the canal drawdown operations were assessed by comparing the observed water level declines which occurred during the drawdowns with water level declines before and after the drawdowns. To do this, daily water level recession rates were determined for station R3110 in the northern portion of the basin during selected periods in 1984, 1985, and 1986. Station R3110 was selected because it is approximately 12,000 feet west of the L-31W canal and was originally assumed to fall outside of the influence of the major canal drawdown effects. Daily water level recession rates were calculated for station R3110 during a three-month period from September 1 to November 30 for each of the three years. This three-month sample for each of the three years of the drawdown study covered a wide range of hydrologic conditions. A few general characteristics were common to all of the study years. For all three years of the study, the average daily water level recession rate was calculated at 0.06 feet per day, and fell within a relatively narrow range of 0.03 to 0.09 feet per day. For each year the highest daily water level recessions (0.09 to 0.10 feet per day) occurred following large rainfall events. The lowest daily water level recessions in each year (0.01 to 0.03 feet per day) occurred following long periods of little or no rainfall, generally coupled with the absence of L-31W structure operations. The calculated average background recession rates and other pertinent statistics for station R3110 during the three study periods are listed in Table 3. The specific time periods used were selected based on the following criteria:

1. The periods began at least two days after any recorded rainfall event and were within a period of receding water levels. (Water level recession rates tended to stabilize within 48 hours after a rainfall event.)

2. The periods contained no discharges through structure S-175 and only minor discharges through structure S-174 (inflows less than 40 cfs). (This provided relatively constant stages in the L-31W canal and stable gradients between the canal, and the water level recorders in northern Taylor Slough.)

3. Pumpages at structure S-332 during this period remained relatively constant and close to the required minimum delivery schedule. (This made the downstream water level mounding effects of the pump station as constant as possible.)

Periods fitting the above criteria ranged from two to 12 days in length, and began and ended at least five days from the October 15 drawdown date when water levels appeared to be stable. During 1984 and 1986, 23 days were used for the background recession rate estimates. In 1985 only 14 days fit the above criteria due to numerous rainfall events and extensive use of structures S-174 and S-175.

Development of Water Level Contour Maps

Water level contour maps were developed using average daily stages for three dates bracketing the October 15 drawdown date during the 1984 and 1985 study periods. The 1986 study period was not contoured because the discontinuous field stations were not monitored and insufficient spatial data were available. The contour maps were

constructed using the network of stage stations in northern Taylor Slough described in Figure 3. These maps are included in Appendix C. A listing of the stations used for the contour maps is provided in Table 1, Appendix B.

Several computer contouring packages were investigated but they were abandoned because of their inability to accurately contour the near constant water level boundary in the L-31W canal at the S-332 pump station. The final water level contour maps were created by interpolating between a minimum of the three nearest field monitoring stations. From this interpolation, one-quarter-foot contour intervals were plotted by hand. Additional water level control points were added in the L-31W canal between the control structures to provide a more realistic estimate of the actual canal stages. The water levels at these points were linearly interpolated from the headwater and tailwater stages at each structure. This process forced the contour lines to intersect the canal at the control structures where the actual stage changes occurred, and allowed the canal to be treated as a near constant water level boundary.

Table 3. Estimated Background Recession Rates in feet per day for Station R3110 during the Study Periods.

1984 STUDY PERIOD					
PERIOD	**MEAN**	**ST. DEV.**	**MAX.**	**MIN.**	**N**
10/22-10/24	0.09	0.01	0.10	0.08	3
10/29-10/30	0.09	0.00	0.09	0.09	2
11/10-11/21	0.04	0.02	0.07	0.01	12
11/25-11/30	0.06	0.02	0.08	0.04	6
OVERALL	0.06	0.03	0.10	0.01	23

1985 STUDY PERIOD					
PERIOD	**MEAN**	**ST. DEV.**	**MAX.**	**MIN.**	**N**
09/06-09/07	0.06	0.02	0.07	0.04	2
11/08-11/14	0.05	0.02	0.08	0.02	7
11/26-11/30	0.08	0.01	0.09	0.07	5
OVERALL	0.06	0.02	0.09	0.02	14

1986 STUDY PERIOD					
PERIOD	**MEAN**	**ST. DEV.**	**MAX.**	**MIN.**	**N**
09/24-09/29	0.07	0.01	0.09	0.06	6
10/02-10/04	0.05	0.01	0.06	0.04	3
10/07-10/10	0.06	0.01	0.06	0.05	4
11/03-11/05	0.06	0.01	0.07	0.05	3
11/18-11/20	0.03	0.01	0.04	0.03	3
11/24-11/27	0.04	0.02	0.07	0.03	4
OVERALL	0.06	0.02	0.09	0.03	23

RESULTS AND DISCUSSION

Hydrologic Conditions and Structure Operations during 1984

Daily rainfall, structure discharges, and average S-175 headwater stages for the period from September to December 1984 are summarized in Figure 5. This four-month period was selected because it covered the hydrologic conditions prior to the drawdown and included the most significant operational changes occurring in association with the Frog Pond drawdown agreement. Rainfall in the Taylor Slough basin during August and September 1984 was just slightly below the 37-year mean measured at Royal Palm Ranger Station (Table 1). During October, November, and December, rainfall dropped off rapidly and was well below average with no large rainfall events occurring after late September. During September and early October, prior to the agricultural drawdown, L-31W canal stages generally remained above 4.00 feet (Fig. 5).

From September 20 to October 11, structure S-174 remained open full to lower stages in the L-31N canal system in association with a 90-day wet season test of water releases into Northeast Shark Slough. S-174 was closed at 0855 on October 12, and remained closed until January 21, 1985, except for minor releases on October 16 and the 17th. From September 20 to October 4, structure S-175 was used repeatedly to move excess water through the L-31W canal system. S-175 was closed from October 4 until 1120 on the 15th, when gates 2 and 3 were opened full for approximately three hours to achieve the required drawdown. By 0730 on October 16, gate 3 was closed, while gate 2 remained partially opened until October 21. S-175 remained closed until March 21, 1985, except for minor releases between November 4 and the 9th, following several days of rainfall (Fig. 5).

Structure S-175 remained open for seven days beginning on October 15, in order to stabilize water levels at the required 3.50 foot level. A total of 1,263 acre-feet passed through S-175 during this period with 589 acre-feet discharged during the first two days. During this same period, a total of 97 acre-feet passed through structure S-174. This indicates that a net total of 1,166 acre-feet was removed from the L-31W canal via S-175 as a result of the 1984 drawdown. This water was presumably derived from several sources including storage in the L-31W canal, seepage around S-174, and from the aquifer underlying northern Taylor Slough and the Frog Pond agricultural area. Discharges from pump station S-332 were erratic throughout the month, but no attempt was made to modify pumpages during the drawdown experiment.

1984 Drawdown Effects at Continuous Stage Recorders

Stage hydrographs for the S-175 headwater recorder and three recorders west of the canal in northern Taylor Slough are summarized in Figure 6A for the period from 0000 on October 12 to 2400 on the 23d. The hydrographs were developed using water level data taken every four hours from the recorder charts at each station. On October 11, the Water Management District conducted flow tests on structure S-174. At 0805, the structure was turned off and the gates were closed. At 1405, the structure was opened full and was not closed until 0855 on the 12th. From 0800 on October 13 to 0800 on the 15th, headwater stage at structure S-175 dropped 0.37 feet (from 4.18 to 3.81 feet) in response to closing S-174 on the 12th. This closure was in response to upstream canal stages dropping below 4.50 feet, and was not related to the canal drawdown agreement. Between 0800 on the 15th and 2400 on the 15th, headwater stage at S-175

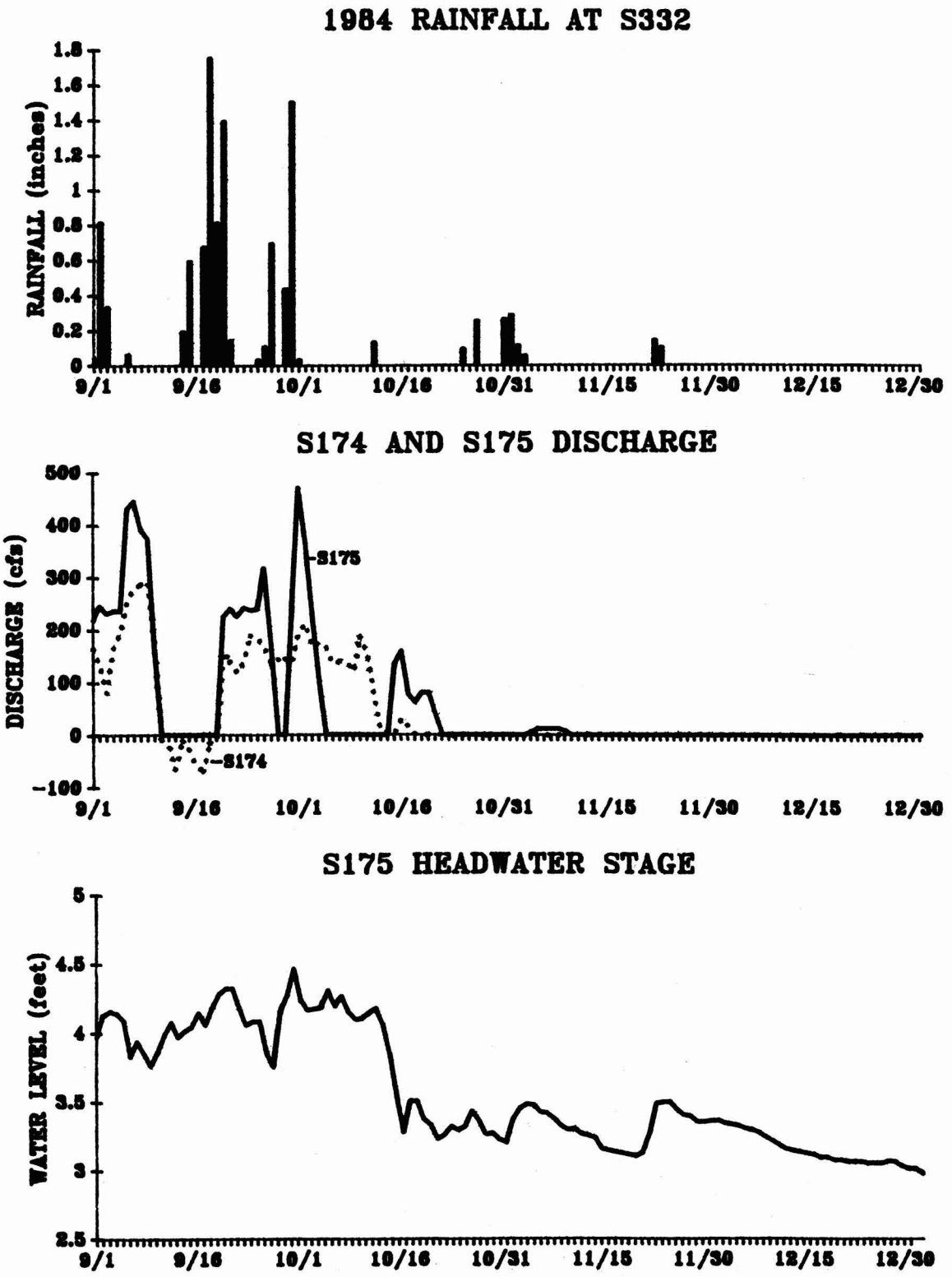

Figure 5. S-332 rainfall, S-174 and S-175 structure discharges, and S-175 headwater stage during the 1984 drawdown period.

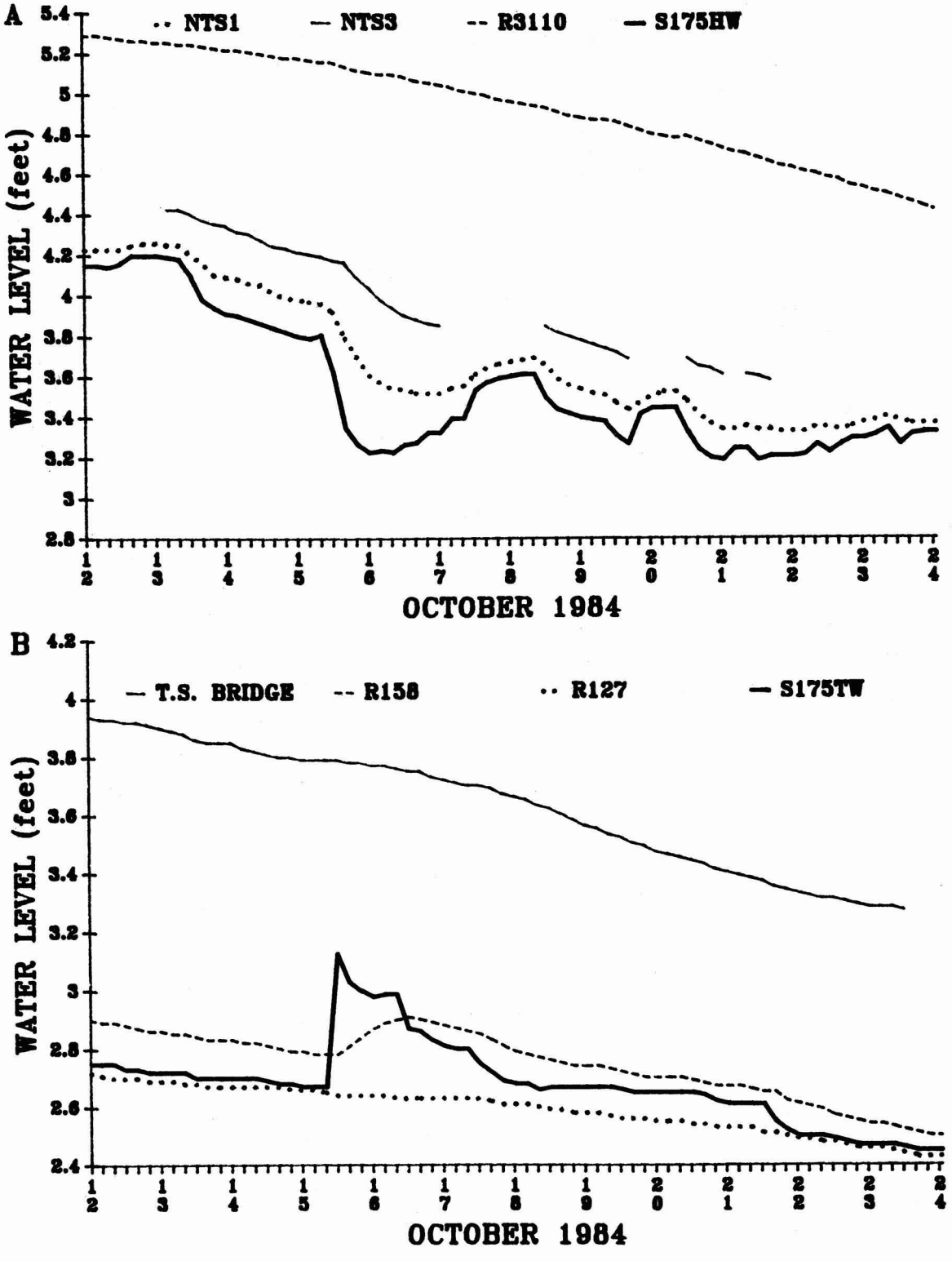

Figure 6 (A and B). Stage hydrographs for the continuous recorders upstream of S-175 (A) and downstream of S-175 (B) during the 1984 study period.

dropped an additional 0.58 feet (from 3.81 to 3.23 feet) in response to opening S-175. In summary, the combined effects of the manual closing of S-174 on the 12th and the opening of S-175 on the 15th was a 0.95-foot decline in S-175 headwater stage (Fig. 6A).

In response to structure operations, large water level declines were observed at the continuous recorders in northern Taylor Slough close to the canal. These stage reductions diminished rapidly moving west. At station NTS1, located 1,000 feet west of the canal, water level dropped 0.42 feet between 0800 on October 15 and 0800 on the 16th. Station NTS3, located 3,300 feet west of the canal, showed a much lower stage reduction, dropping 0.25 feet during the same 24-hour period (Fig. 6A). At station R3110, located 12,000 feet west of the canal, the stage decreased 0.06 feet over the 24-hour period. Water levels at this station had been receding at a rate of 0.04 feet per day prior to the 15th. After the 24-hour period, the recession rate increased to 0.09 feet per day.

The effects of increased discharges through structure S-175, resulting from the canal drawdown experiment, are summarized in Figure 6B for the tailwater recorder at S-175 and several downstream stations, during the period from 0000 on October 12 to 2400 on the 23d. The tailwater recorder at S-175 and the recorder at station R158 show clear responses to the increased discharges following the gate changes at S-175 on the 15th. The recorder at Taylor Slough bridge showed only a slight reduction in its recession rate over this period. This station appeared to be controlled more by the operation of pump station S-332 than by the operational changes at S-175. Station R127, at the southern end of the study area, showed a slight decrease in its recession rate during the S-175 drawdown period.

Hydrologic Conditions and Structure Operations during 1985

Daily rainfall, structure discharges, and average S-175 headwater stages for the period from September to December 1985 are summarized in Figure 7. Rainfall in the Taylor Slough basin during August and September 1985 was below the period of record mean at Royal Palm and was significantly below average throughout October (Table 1). During September and early October, L-31W canal stages remained well above 4.00 feet. Large rainfall events occurred in mid-October and again in mid-November, prompting extensive use of structure S-175 to maintain L-31W canal stages below the 3.50-foot criteria established by the agreement between the farmers and the Water Management District (Fig. 7).

On July 22 the operations settings for structure S-174 were lowered by 0.40 feet in association with the water delivery experiment in Northeast Shark Slough. At 1155 on October 11, S-174 was taken off automatic and opened full to lower L-31N and L-31W canals in preparation of the October 15 drawdown agreement. At 0845 on October 15, the gate was partially closed to begin the process of lowering L-31W canal stages to the 3.50 foot level. S-174 was not completely closed until November 19, except for several short periods in late October and early November, when it was closed temporarily to lower water levels following rainfall (Fig. 7). S-174 was operated manually throughout most of this period because of numerous rainfall events that required repeated gate changes to maintain the 3.50-foot downstream criteria. S-174 remained closed through late February 1986 except for a minor release in early December.

Structure S-175 was closed from October 3 until October 8 in order to maintain headwater stages as close to 4.50 feet as possible at the request of Everglades National Park. On October 8, gate 2 at S-175 was partially opened when the headwater stage

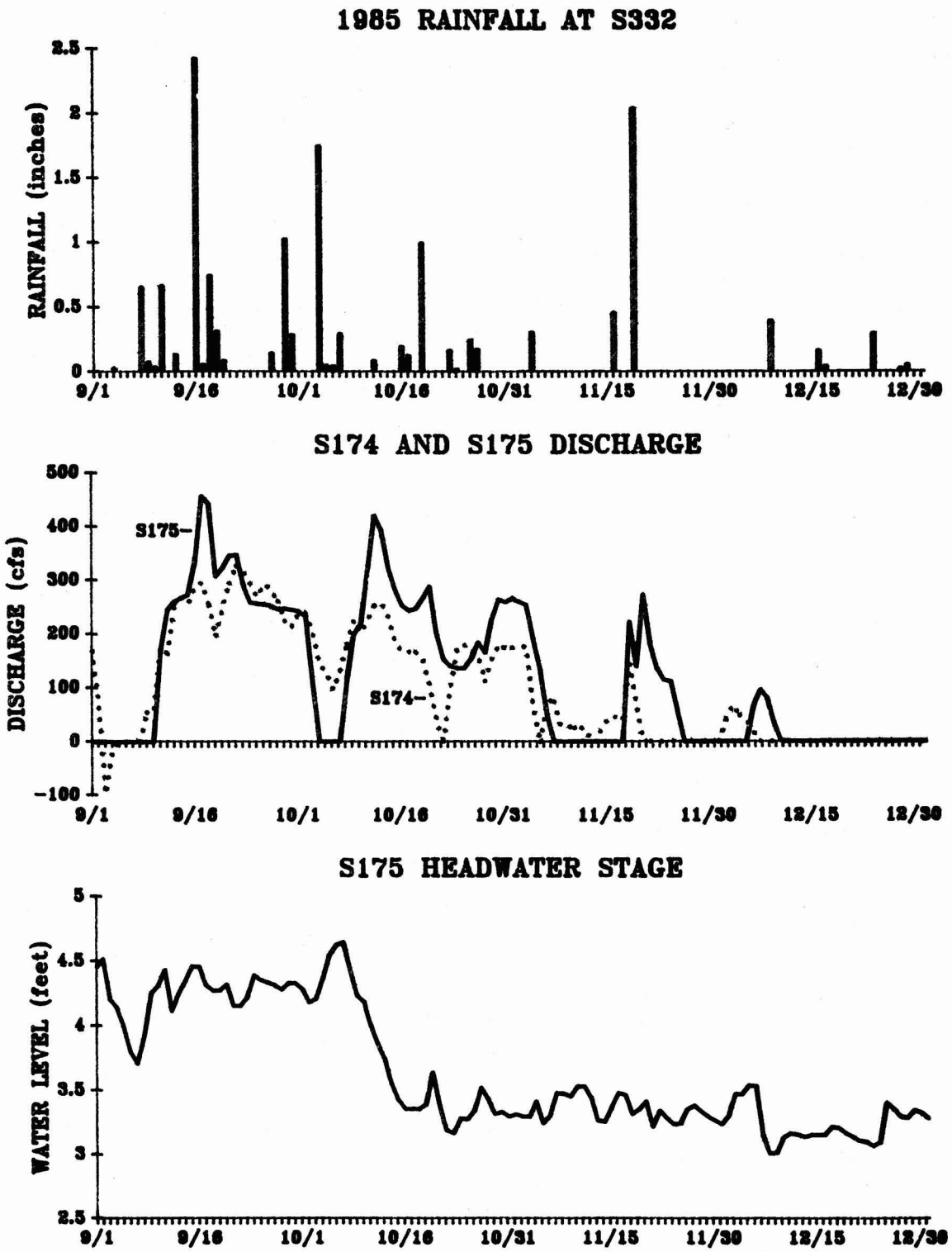

Figure 7. S-332 rainfall, S-174 and S-175 structure discharges, and S-175 headwater stage during the 1985 drawdown period.

exceeded 4.50 feet. At 1307 on October 10, gate 2 was opened full and by 1200 on the 11th gate 1 was also opened full. At 0836 on October 12, gate 3 was opened full and the three gates remained fully opened until the 23d when gates 1 and 3 were closed. The operations logs for structure S-175 indicate that gate changes beginning on October 10 were for the purpose of lowering L-31W canal stages to begin the drawdown to the 3.50-foot level required by the water delivery test agreement. On October 29, all three gates were again opened full, following rainfall events on the 16th and 17th, and remained open until November 6. S-175 was used again between November 18 and the 25th and between December 6 and the 9th to maintain the 3.50-foot growing season criteria following rainfall events (Fig. 7). By October 16, S-175 headwater stage had stabilized at approximately 3.40 feet. For this reason, the 16th was used as the end of the canal drawdown period. Between October 10 and the 16th, S-174 discharged 3,024 acre-feet into the L-31W canal. During this same seven-day period, a total of 4,386 acre-feet was discharged down the canal through structure S-175. This indicates that a net total of 1,362 acre-feet was removed from the L-31W canal via S-175 as a result of the 1985 drawdown. Structure S-175 was used from the end of the drawdown period on October 16 until November 6 to maintain stages below the 3.50-foot level. This was prompted by numerous rainfall events during this period. S-175 was closed on November 6 but was opened full again on November 18 and the 20th due to several rainfall events and the threat from Hurricane Kate. Between October 16 and November 6, S-175 discharged 8,352 acre-feet down the L-31W canal. During this time, S-174 discharged 5,362 acre-feet into the canal. This indicates that a net total of 2,990 acre-feet were removed from the L-31W canal via S-175 as a result of this second drawdown. Although much of this water was due to local rainfall, these discharges were all made at canal stages below the established operational stage of 4.50 feet and would not have been required if the growing season drawdown agreement was not in effect.

1985 Drawdown Effects at Continuous Stage Recorders

Stage hydrographs for the S-175 headwater recorder and the four recorders west of the L-31W canal in northern Taylor Slough are summarized in Figure 8A, for the period from 0000 on October 8 to 2400 on October 23. The large water level increases observed on the 19th were in response to a rainfall event in excess of one inch. From 0000 on October 8 to 2400 on the 15th, headwater stage at structure S-175 was reduced from 4.60 feet to 3.38 feet, a decline of 1.22 feet. This reduction was accomplished by four separate gate changes at S-175 occurring on October 8, 10th, 11th, and 12th. As stated earlier, the gate opening on October 8 was prompted by the S-175 headwater stage exceeding the 4.50-foot operating criteria established for the L-31W canal and was not related to the water delivery test agreement. Between 2400 on October 10 and 2000 on October 11, S-175 headwater stage dropped 0.32 feet (from 4.20 to 3.88 feet) in response to a change in the settings at gate 2 on October 10 and the opening of gate 1 on the 11th. From 2000 on October 11 to 2400 on the 15th, the headwater stage at S-175 dropped an additional 0.50 feet (from 3.88 to 3.38 feet) in response to the opening of gate 3 at S-175 on October 12 (Fig. 8A). In summary, the combined effects of the structure operations at S-175 between October 10 and the 16th produced a decline of 0.82 feet at the S-175 headwater recorder.

Large water level declines were observed for the two park recorder stations closest to the L-31W canal during the canal drawdown period. Smaller declines were observed at the stations further west of the canal. Station R3110 had mechanical problems and was not operational until 1200 on October 15. At station NTS1, located 1,000 feet west of the canal, water level dropped 0.71 feet between 0000 on the 11th and 2400 on the

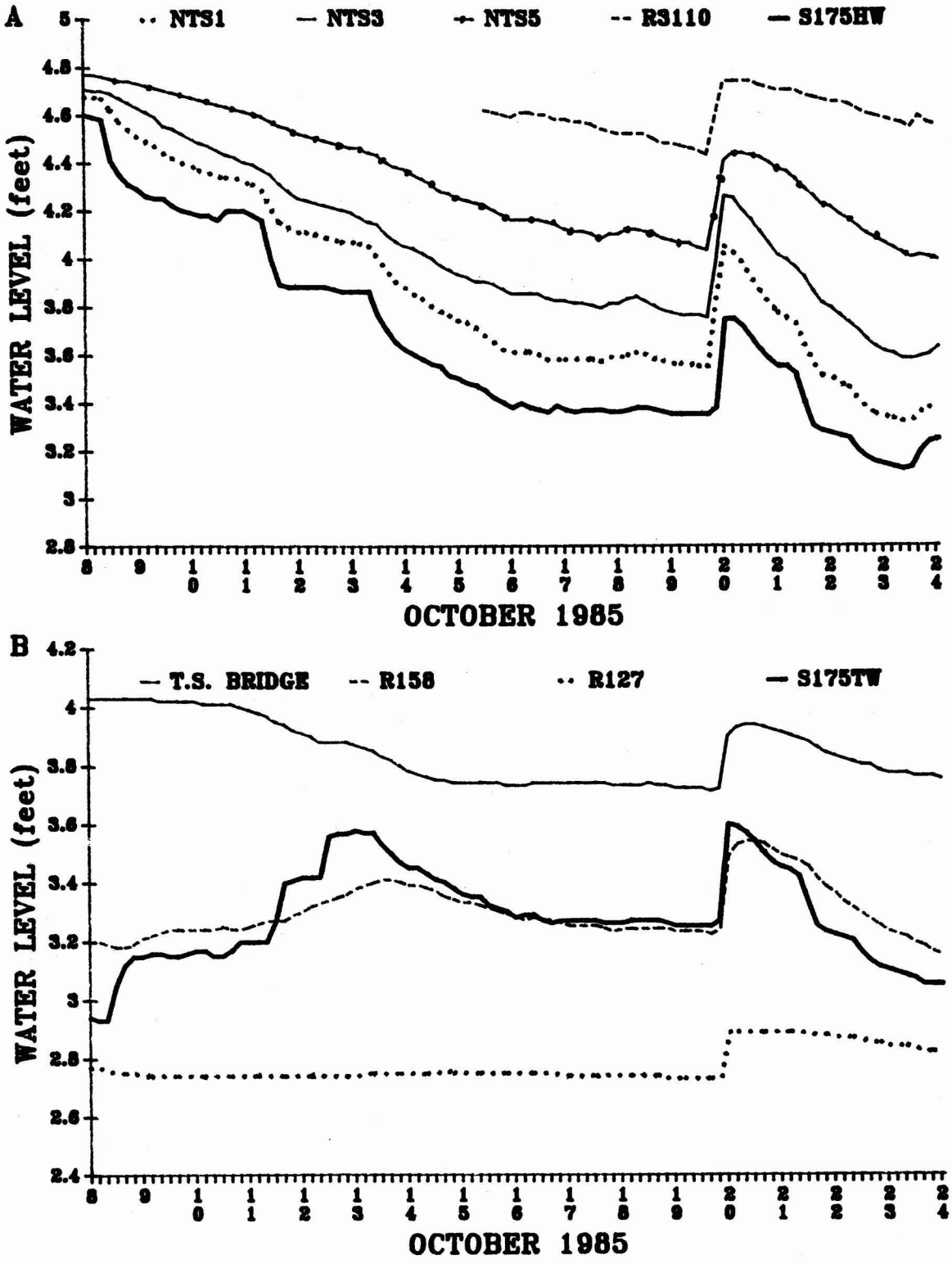

Figure 8 (A and B). Stage hydrographs for the continuous recorders upstream of S-175 (A) and downstream of S-175 (B) during the 1985 study period.

15th. At station NTS3, located 3,300 feet west of the canal, water level dropped 0.55 feet during the same five-day period. At station NTS5, located 6,800 feet west of the canal, water level dropped 0.45 feet over the same period (Fig. 8A).

Rainfall, between October 16 and the 19th, produced a 0.40-foot rise in the headwater stage at structure S-175 (Fig. 8A). This prompted a second period of canal drawdowns to maintain the 3.50-foot canal stage required by water delivery test agreement. From 0800 on October 20 to 0800 on the 23d, S-175 headwater stage dropped 0.60 feet (from 3.72 to 3.12 feet) in response to a reduction in the gate setting at structure S-174 on the 20th and the closure of S-174 on the 21st. The S-174 operations log indicates that these changes were made to maintain the required growing season criteria. At station NTS1, water level dropped 0.66 feet over the same three-day period. At stations NTS3 and NTS5, water levels dropped 0.62 and 0.42 feet, respectively, over the same period (Fig. 8A). At station R3110 water level dropped 0.18 feet during this period which is equal to the calculated background recession rate for this station.

Stage hydrographs for the S-175 tailwater recorder and several downstream stations are summarized in Figure 8B, during the period from 0000 on October 8 to 2400 on the 23d. The tailwater recorder below S-175 and the recorder at station R158 showed clear responses to the increased discharges following the gate changes at S-175 beginning on the 10th. The Taylor Slough bridge recorder did not appear to respond to the increased discharges at S-175. This station did show an increased water level recession rate between the 10th and the 13th that appeared to be related to decreased discharges through the S-332 pump station. R127 again showed only a slight reduction in its natural recession rate during this period.

Hydrologic Conditions and Structure Operations during 1986

Daily rainfall, structure discharges, and average S-175 headwater stages for the period from September to December 1986 are summarized in Figure 9. Rainfall in the Taylor Slough basin during September, October, and November 1986 was well below the period of record mean at Royal Palm (Table 1). This trend continued until several large rainfall events occurred between December 24 and January 4. During September and early October, L-31W canal stages were generally below 4.00 feet (Fig. 9).

Structure S-174 was turned off and opened full from September 3 to the 19th, following several large rainfall events and high stages in the upstream reaches of L-31N. S-174 was closed on September 19 and remained closed until May 1987, except for a nine-day period beginning on November 12 when required deliveries were made to Taylor Slough. Structure S-175 was opened full from August 11 to September 2, when all three gates were closed. Gate 2 was partially opened again on September 5, when headwater stages approached 4.50 feet. By September 8, all three gates were opened full. S-175 remained open full until September 19, when all three gates were closed coinciding with the closure of S-174 (Fig. 9). By October 8, S-175 headwater stage dropped below 3.50 feet and continued to decline until the 15th. Between 1600 on October 15 and 0800 on the 16th, headwater stage at S-175 rose 0.89 feet (from 2.96 to 3.85 feet) following a 1.50-inch rainfall event on the 15th. At station R3110, water level rose 1.55 feet (from 3.18 to 4.73 feet) in response to this rain event (Fig. 9). At 1400 on October 16, gate 2 at S-175 was partially opened for approximately 24 hours to lower canal stages down to the required 3.50 feet. During this period, S-174 remained closed and S-175 discharged a total of 173 acre-feet down the canal.

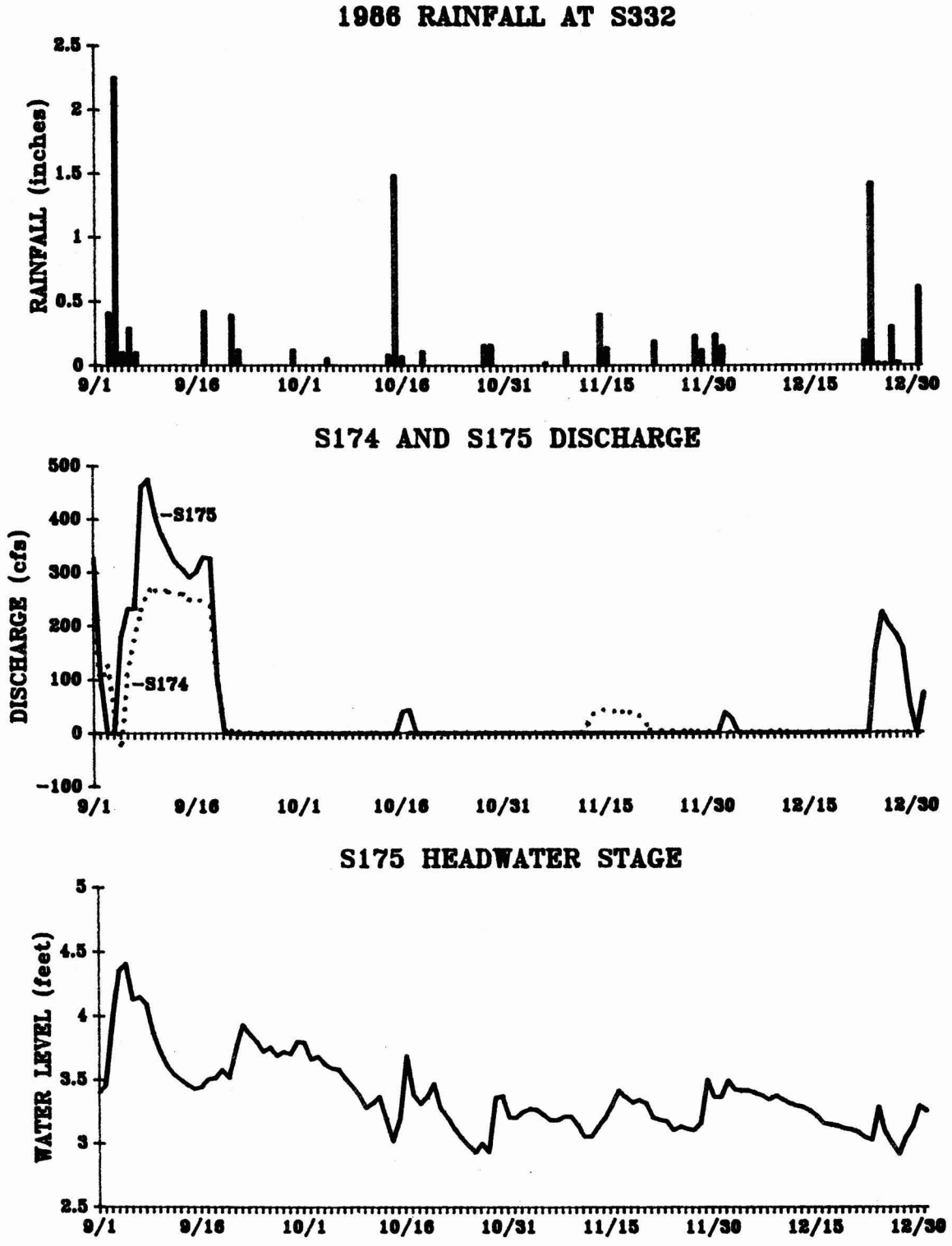

Figure 9. S-332 rainfall, S-174 and S-175 structure discharges, and S-175 headwater stage during the 1986 drawdown period.

1986 Drawdown Effects at Continuous Stage Recorders

Stage hydrographs for the S-175 headwater recorder and the four recorders west of the canal are summarized in Figure 10A, for the period from 0000 on October 8 to 2400 on the 25th. From 0800 on October 16 to 2400 on the 17th, S-175 headwater stage dropped 0.55 feet (from 3.85 to 3.30 feet). At stations NTS1, NTS3, and NTS5, water levels dropped 0.39, 0.28, and 0.11 feet, respectively, over the same period (Fig. 10A). At station R3110, water level dropped 0.16 feet which was slightly greater than the average background recession rate calculated for the station.

Stage hydrographs for the tailwater recorder at S-175 and the three downstream recorders are summarized in Figure 10B, for the period from 0000 October 8 to 2400 October 25. Large water level increases were observed at the three recorders north of the park road in response to a rainfall event on the 15th. Only minor discharges were made through S-175 following the rainfall event and their impact could not be isolated. The recorder at station R127, located at the southern end of the study area, received much less rainfall and showed only a slight decrease in the normal recession rate.

Summary of Water Level Declines

The water level declines observed at the headwater recorder at structure S-175 and the four park water level recorders west of the canal in northern Taylor Slough are summarized in Table 4, for the 1984 through 1986 drawdown periods. The periods selected in each year correspond to the peak drawdown periods observed in Figures 6, 8, and 10 in the previous sections. For each period, the actual observed water level reductions for each station are listed along with the calculated average background recession for station R3110. The 1984 canal drawdown occurred during a period of below normal rainfall. For this reason, the 0.06 feet per day average background recession is slightly greater than the observed water level decline at station R3110 prior to the canal drawdown. The canal drawdowns during 1985 and 1986 occurred during periods of moderate to high rainfall when the background recession rate would have been slightly greater than average. The data set used for the background recession rate estimation was too small to estimate the rate under all conditions; as a result, Table 4 contains the calculated background recession for all periods based on a recession rate of 0.06 feet per day.

During the 1984 drawdown period, S-175 headwater stage declined 0.58 feet between 0800 on October 15 and 0800 on the 16th, following the opening of S-175. The average background recession for this period was 0.06 feet, producing a net decline of 0.52 feet as a result of canal drawdown operational changes. At NTS1 and NTS3 west of the canal, net water level declines of 0.36 and 0.19 feet, respectively, were estimated for the 24-hour period, after the 0.06 foot background recession was subtracted. At station R3110, water level declined 0.06 feet which was equal to the calculated average background recession rate.

During the 1985 drawdown period, the headwater stage at S-175 was reduced 0.82 feet between 0000 on October 11 and 2400 on the 15th. This followed three gate changes at S-175. Net water level declines at stations S-175, NTS1, NTS3, and NTS5 of 0.52, 0.41, 0.25, and 0.15 feet, respectively, were calculated for the five-day period, after the 0.30 feet background recession was subtracted. Station R3110 was not functional during this period. Rainfall was under 0.10 inches which supported the appropriateness of the average background recession rate. Large water level declines were again observed between 0800 on October 20 and 0800 on the 23d, following a large rainfall event on the 19th. Net water level declines at stations S-175, NTS1, NTS3, and NTS5 of 0.42,

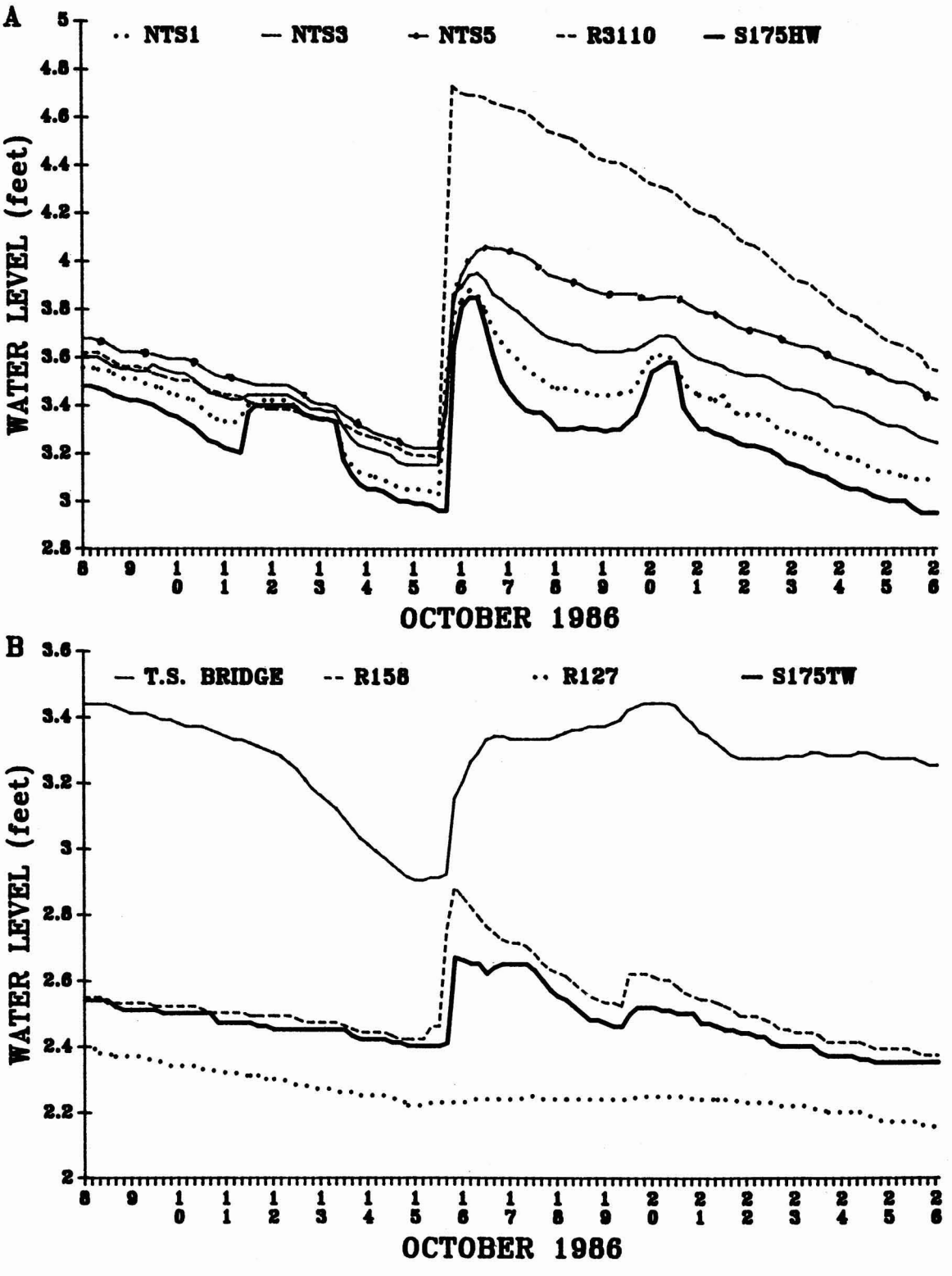

Figure 10 (A and B). Stage hydrographs for the continuous recorders upstream of S-175 (A) and downstream of S-175 (B) during the 1986 study period.

Table 4. Summary of Observed Water Level Declines during the 1984 through 1986 Drawdown Periods.

START OF PERIOD	END OF PERIOD	S-175 STAGE	NTS1 STAGE	NTS3 STAGE	NTS5 STAGE	R3110 STAGE	BACK. REC.
1984 DRAWDOWN PERIOD							
0800 10/15	0800 10/16	0.58	0.42	0.25	----	0.06	0.06
1985 DRAWDOWN PERIOD							
0000 10/11	2400 10/15	0.82	0.71	0.55	0.45	----	0.30
0800 10/20	0800 10/23	0.60	0.66	0.62	0.42	0.18	0.18
1986 DRAWDOWN PERIOD							
0800 10/16	2400 10/17	0.55	0.39	0.28	0.11	0.16	0.10

All water level declines are in feet. Back. Rec. represents the background recession calculated for the period based on a water level recession rate of 0.06 feet per day.

0.48, 0.44, and 0.24 feet, respectively, were observed for the above three-day period, after subtracting the 0.18 feet background recession. Station R3110 had a water level decline of 0.18 feet during this period, which agrees exactly with the calculated background rate.

During 1986 water levels in the L-31W canal were well below the 3.50 foot drawdown criteria prior to October 15. Large water level declines were observed between 0800 on the 16th and 2400 on the 17th following 1.49 inches of rainfall on the 15th. Most of the water level declines can be attributed to the increased recession rates produced by the rainfall event. Net water level declines at stations S-175, NTS1, and NTS3 of 0.39, 0.23, and 0.12 feet, respectively, were estimated for the 40-hour period. These net declines were calculated by subtracting the 0.16-foot observed recession rate at station R3110 during this period. It should be noted that the recession rate in the canal was more than double that of station R3110. These increased recession rates at the stations in and adjacent to the canal are presumably in response to the opening of S-175.

Water Level Contouring Results

A few general statements can be made about the spatial water level patterns in the northern Taylor Slough basin during the study periods. All of the water level contour maps (Figs. 1 through 6 in Appendix C) indicate that the regional groundwater flow direction in the northern Taylor Slough basin was toward the southeast. This general trend was disturbed by the canal drawdown operations which produced a strong west to east hydraulic gradient, with the L-31W canal acting as a groundwater sink. This change in the regional flow direction was reflected in the shape of the water level contour lines in the areas adjacent to the canal.

The S-332 pump station produced a downstream mound in the water level patterns whenever it was in operation. The difference in head across the pump station created a large hydraulic gradient between the canal and the wetlands adjacent to the structure.

This promoted flow of a portion of the S-332 discharges back into the canal making the pump station less effective as a water supply structure. Downstream of the pump station, flow appeared to diverge with surface water flows heading southwest through the bridge and culverts along the main park road while the groundwater flow continued toward the southeast. A large head difference was maintained across structure S-175 whenever the culverts were closed. This produced another large hydraulic gradient toward the canal in the sections immediately downstream of the structure.

1984 Contour Results

The contour map for October 9, 1984, shows the regional groundwater flow pattern in the study area prior to the October 15 canal drawdown (Fig. 1, Appendix C). Structure S-175 had remained closed for the previous five days while S-174 was manually opened full to lower stages upstream in the L-31N canal. L-31W stage was much lower than the adjacent wetlands even with the continuous inflows through S-174. This caused the canal to drain the adjacent areas producing the west to east gradient in the groundwater contour lines north of the S-332 pump station. On the 9th, this canal drainage effect appears to extend west of the canal to a distance of approximately 7,000 feet. West of this point, groundwater flow maintained the southeastern regional flow direction. The S-332 pump station had a relatively localized effect on the general water level pattern on this date. Downstream of S-175 another large west to east gradient was produced by the head difference across the closed structure.

By October 15, the canal drainage effect extended west of the canal to a distance of approximately 8,000 feet (Fig. 2, Appendix C). In the area north of the S-332 pump station, water levels declined by approximately 0.50 feet between the two contour dates. These declines were slightly greater then the estimated background recession rate for the period. The accelerated declines appeared to be in response to the closing of S-174 on the 12th and the opening of S-175 on the morning of the 15th. As the water levels fell throughout the study area, the downstream mounding effect of the S-332 pump station became much more apparent. By the 15th, this mounding effect extended westward approximately 3,500 feet. At the same time, the gradient downstream of S-175 was reduced following the opening of the structure on the morning of the 15th.

By October 23, the canal drainage effect had stabilized, with the area of influence remaining approximately 8,000 feet west of the canal (Fig. 3, Appendix C). Between the 15th and the 23d, water levels had dropped an additional 0.50 feet in the area north of the S-332 pump station; but the overall pattern had changed only slightly from that of the 15th. The downstream mounding effect of the S-332 pump station continued to expand. By this date, the water level mound extended approximately 4,500 feet west of the canal. Downstream of S-175, the gradient increased again following a reduction in discharges on the 17th and the closure of S-175 on the 21st.

1985 Contour Results

The contour map for October 7, 1985, shows the regional groundwater flow pattern in the area prior to the canal drawdown (Fig. 4, Appendix C). Structure S-175 was closed on October 3d and remained closed until the 8th. S-174 had remained open full since early September to maintain upstream stages below 4.50 feet, as part of the Northeast Shark Slough experimental agreement. The contour map indicates that October 1985 water levels were much higher in the area adjacent to the L-31W canal than in 1984. The higher water levels were the result of continuous inflows into the canal via S-174, and rainfall between the 4th and the 7th. This produced a relatively flat water table in the area north of the S-332 pump station. Under these higher stage conditions, the

mounding effect of the pump station remained localized. High rainfall and the closure of S-175 on October 3 produced a gradient of 1.72 feet across structure S-175. This created a large west to east gradient downstream of the structure.

The October 15 contour map shows the effect of the lowering of L-31W canal stages beginning on the 8th (Fig. 5, Appendix C). As stated earlier, this initial opening was in response to S-175 headwater stage exceeding 4.50 feet and is not related to the drawdown agreement. The structure was opened further on the 10th and by the 12th, S-175 was opened full. Both of these operational changes were made to begin the canal drawdown process. The headwater stage at S-175 declined 1.23 feet between the 7th and the 15th. The October 15 contour map indicates that the canal drainage effect extended west of the canal to a distance of approximately 7,000 feet. As water levels fell throughout the study area, the mounding effect of the S-332 pump station became much more apparent. By the 15th, this mounding effect extended westward approximately 4,500 feet. The gradient downstream of S-175 was reduced as a result of the continuous use of S-175 which equalized upstream and downstream stages.

By the 21st, the canal drainage effect appeared to have stabilized and the area of influence was reduced to approximately 6,000 feet (Fig. 6, Appendix C). Between the 15th and the 21st, the L-31W canal and adjacent stage recorders had declined less than 0.10 feet. The western stage recorders had a slight increase in water levels which produced a flattening out of the water table in this area. The contour map for the 21st also indicates that the downstream mounding effect of S-332 was reduced. This was the result of a discontinuation of pumping on the 20th. The gradient downstream of S-175 was further reduced following 14 days of continuous operation of S-175.

The 1984 through 1986 Canal Drawdown Operations in Relation to Operations During Prior Periods

Prior to the 1984 drawdown agreement, planting in the Frog Pond agricultural area would normally begin after stages in the C-111 canal had naturally receded below approximately 4.00 feet. During this period, there was no formal agreement to use the L-31W and C-111 canals to provide additional flood protection below the established operational settings summarized in Table 2. The daily water level records for structure S-175 were examined to determine the approximate dates at which the L-31W canal stages had receded to 3.50 feet prior to the 1984 agreement. Table 5 shows the dates that the L-31W canal stage (S-175 headwater) receded to 3.50 feet after October 1 of each year during the period from 1970 to 1983. The table indicates that recessions to 3.50 feet prior to October 15 occurred only once during the 14-year period. The average date of recessions to that level was November 20, five weeks after the October 15 date specified by the Frog Pond and Northeast Shark Slough experimental agreements.

SUMMARY AND CONCLUSIONS

Examination of the historic boundaries of Taylor Slough (Fig. 1) indicates that the majority of the Frog Pond agricultural area and a large portion of the East Everglades lie within the headwaters of the basin. For this reason, management of water levels in the Frog Pond area and the lower L-31N canal system is crucial to the water resources of the Taylor Slough basin in Everglades National Park. Examination of stage hydrographs and water level contour maps generated in this study indicate a strong interaction between the drawdown operations in the L-31W canal and water levels in

Table 5. Dates at which L-31 Stages Receded to 3.50 feet after October 1, 1970, to 1985.

YEAR	DATE
1970	November 12
1971*	October 4
1972	November 3
1973	November 8
1974	October 21
1975	November 12
1976	November 25
1977	October 31
1978	November 27
1979	November 21
1980	December 7
1981	December 9
1982	January 17
1983	December 20

The mean date for recession to a stage of 3.50 feet was November 20. L-31W canal stage was considered to be the headwater stage at S-175. * S-175 was unavailable, so S-174 tailwater was substituted.

northern Taylor Slough. Water level declines were observed throughout the northern portion of the Taylor Slough basin during the 1984 through 1986 canal drawdown operations. The 1984 canal drawdown was undertaken as a one-year experiment through an agreement between the National Park Service and a group of farmers in the Frog Pond area. The canal drawdowns during 1985 and 1986 were made in association with a two-year experimental delivery test in Northeast Shark Slough. This experimental test was established by an agreement between the South Florida Water Management District and a larger group of south Dade farmers, and authorized by Public Laws 98-181 and 99-190 (U. S. Congress 1983, 1985).

During the 1984 drawdown period, water level declines were observed in response to two major operational changes. Between October 13 and the morning of the 15th, S-175 headwater stage fell 0.37 feet in response to the closing of structure S-174. This closure was related to routine upstream water management practices and was not associated with the drawdown agreement. The 1984 drawdown period began on the morning of October 15. By the morning of the 16th, S-175 headwater stage had dropped 0.58 feet. At park stations NTS1, NTS3, and R3110 west of the canal, water levels dropped 0.42, 0.25, and 0.06 feet, respectively, over the same period. Structure S-175 remained open for seven days to stabilize L-31W canal stages at the required 3.50 feet. During this period, the drawdown operations removed a total of 1,166 acre-feet from the L-31W canal via S-175. Water level recession rates at station R3110 showed a two-fold increase during the week of the drawdown. This indicates that the drawdown impact extended west of the canal at least 12,000 feet into Everglades National Park.

The largest water level declines of the three study years occurred during 1985. Rainfall and upstream water management operations associated with the Northeast Shark Slough experimental agreement prompted nearly continuous use of structures S-174 and S-175 throughout the 1985 study period. Reduction of L-31W canal stage to 3.50 feet as required by the Northeast Shark Slough experimental agreement was accomplished through three separate operational changes. Operations logs for structure S-175 indicate that the 1985 canal drawdown began on October 10. Between October 11 and the 15th, S-175 headwater stage dropped 0.82 feet. At park stations NTS1, NTS3, and NTS5, water levels dropped 0.71, 0.55 and 0.45 feet, respectively, during the same period. By October 16, S-175 headwater stage had stabilized at 3.40 feet. Between the 11th and the 16th, the canal drawdown operations had removed a total of 1,362 acre-feet from the L-31W canal via S-175. Rainfall between October 16 and 19, 1985, prompted a second canal drawdown. S-175 had remained open full throughout this period so the canal stage lowering was accomplished by reducing S-174 inflows. From October 20 to the 23d, S-175 headwater stage dropped 0.60 feet. At park stations NTS1, NTS3, NTS5, and R3110, water levels dropped 0.66, 0.62, 0.42, and 0.18 feet, respectively, over the same period. Structure S-175 continued to be used until November 6. Between October 16 and November 6, canal drawdown operations removed an additional 2,990 acre-feet from the L-31W canal via S-175.

During the 1986 study period, headwater stage at S-175 had dropped below 3.50 feet prior to the October 15 date established in the Northeast Shark Slough experimental agreement. By the morning of October 15, S-175 headwater stage had declined to 2.98 feet following a long period of below normal rainfall. Rainfall during the evening of the 15th produced a 0.87-foot rise in stage at the S-175 headwater recorder. S-175 was opened on the 16th for a 24-hour period to lower canal stages to the required 3.50 feet. During this period, S-175 discharged a total of 173 acre-feet down the L-31W canal. From the 16th to the 17th, S-175 headwater stage dropped 0.55 feet. At park stations NTS1, NTS3, NTS5, and R3110, water levels dropped 0.39, 0.28, 0.11, and 0.16 feet, respectively, over the same period. The relatively small discharge through S-175 during this period suggests that most of these declines were a natural response to the higher recession rates produced by the rainfall event. The two-fold increase in recession rates at the stations in and adjacent to the L-31W canal was presumably in response to the opening of S-175 on the 16th.

Water level recessions in the L-31W canal below 3.50 feet by October 15 were almost unprecedented prior to the 1984 experimental agreement occurring only once during the previous 14 years. The average date of water level recessions to 3.50 feet under previous water management operations was November 20, five weeks later than the date of the 1984 experimental drawdown. During the period from 1980 through 1983, L-31W canal stages never receded below 3.50 feet prior to December 7. Prior to the 1984 drawdown experiment, there was no formal agreement to use the L-31W canal to provide additional flood protection below the established 4.50-foot operational setting. The hydrologic investigations conducted during the 1984 through 1986 study periods indicate that the L-31W canal agricultural drawdown operations produced significant water level reductions throughout northern Taylor Slough, particularly in the areas adjacent to the L-31W canal. All of these drawdowns occurred during years when the total annual rainfall was over 10 inches below normal and monthly total rainfall during the September through November study periods was also below normal (Table 1). This suggests that the hydrologic impacts of future agricultural canal drawdowns could be much greater.

The L-31W borrow canal was designed "to convey flow to replenish the fresh water supply in the Taylor Slough area of the park" (U.S. Army Corps of Engineers 1967). Structure S-175 was originally designed to "maintain water levels up to 5.00 feet and provide a means of either diverting borrow canal discharge overland into Taylor Slough or passing it south to be distributed overland from the borrow canal south of State Road 27" into central Taylor Slough (U.S. Army Corps of Engineers 1963). Following this initial design study, S-175 headwater stage was reduced by 0.50 feet and set to maintain upstream optimum water levels of up to 4.50 feet for as long as local rainfall remained adequate (U.S. Army Corps of Engineers 1973).

The overall results of this study indicate that management of wet season stages below 4.50 feet in the upper portion of the L-31W canal causes drainage of the adjacent Taylor Slough wetlands. Review of water level data collected during the last four and one-half years of the Frog Pond drawdown study indicate that during the months of June through November, L-31W canal stages generally remained well below the stage in the Taylor Slough wetlands. Under these conditions, the L-31W canal acts as a groundwater sink draining the adjacent wetlands. This is inconsistent with the initial design purpose of the L-31W canal which states that the canal should replenish the fresh water supply to the Taylor Slough basin. The lowering of L-31W canal stages to allow earlier land preparation and planting in the Frog Pond agricultural area further exacerbates the drainage effects of the canal system and is incompatible with the system design intent of restoring fresh water flows to the Taylor Slough basin.

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Appendix A. The 1984 "Frog Pond" Drawdown Agreement.

AGREEMENT RE: "FROG POND" DRAWDOWN

THIS AGREEMENT entered into this 4th day of ~~May~~ June, 1984, by and between the Individuals and Corporations farming in the "Frog Pond" area (hereinafter collectively called "Farmers") and the Everglades National Park will apply to the 1984-1985 planting season, and is not to be construed as having any precedential or binding effect whatsoever on the Farmers or Everglades National Park in other future years or operations.

The parties hereto being advised that the South Florida Water Management District will honor any agreement entered into by them concerning "drawdowns" in the area of Dade County, Florida known as the "Frog Pond," it is thereupon agreed that for the 1984-1985 planting season, the parties agree that the following water levels are acceptable:

1. Water levels in L-31W shall be operated in such a manner so that on October 15, 1984 the headwater level at Structure S-175 and the tailwater level at S-174 will be no higher than 3.5 msl. Thereafter, after the Farmers have planted their crops, headwater levels at S-175 and tailwater levels at S-174 will not be allowed to exceed 3.5 msl until the crops are harvested.

2. Water levels in Canal C-111 will be operated in such a manner so that on October 15, 1984 the headwater level at Structure S-177 and the tailwater level at S-176 will be no higher than 3.5 msl. Thereafter, after the Farmers have planted their crops, headwater levels at S-177 and tailwater levels at S-176 shall not be allowed to exceed 3.7 msl until the crops are harvested.

3. The Everglades National Park will monitor a series of wells in the Park west of L-31 West. The South Florida Water Management District will monitor discharges and upstream/downstream stage at structures S-174, S-175,

S-176, S-177 and S-332, and will establish and monitor a water level recorder in the Frog Pond. All water level and discharge data gathered from these wells and structures will be made available to all the undersigned.

4. By this Agreement, the Farmers do not concede that either Everglades National Park or the South Florida Water Management District have any authority to do anything in the "Frog Pond" area to diminish the flood protection given the area under the Central & Southern Flood Control Project.

DATED this 4th day of ~~May~~ June, 1984.

EVERGLADES NATIONAL PARK

By _____
John M. Morehead,
Superintendent,
Everglades National
Park

_____
William G. Earle, as Attorney for Individuals and Corporations farming in the "Frog Pond" area.

STATE OF FLORIDA)
) SS:
COUNTY OF DADE)

BEFORE ME, the undersigned authority, personally appeared JOHN M. MOREHEAD, known to me to be the person referred to in the foregoing Agreement and who acknowledged before me that he had authority to execute this Agreement and to enter into this Agreement on behalf of Everglades National Park.

My Commission expires:

_____
NOTARY PUBLIC

NOTARY PUBLIC STATE OF FLORIDA AT LARGE
MY COMMISSION EXPIRES MAY 22 1986
BONDED THRU GENERAL INS. UNDERWRITERS

STATE OF FLORIDA)
) SS:
COUNTY OF DADE)

BEFORE ME, the undersigned authority, personally appeared WILLIAM G. EARLE, ESQ., known to me to be the person referred to in the foregoing Agreement and who acknowledged before me that he had authority to execute this Agreement and to enter into this Agreement on behalf of the individuals and corporations farming in the "Frog Pond" area.

My Commission expires:

_____
NOTARY PUBLIC

Appendix B.

Table 1. Stations in the Northern Subarea used in the 1984 through 1986 L-31W canal drawdown study.

STATION NAME	TYPE OF DATA	SAMP. FREQ.	N	YEARS STUDIED	
S-174TW	CANAL STAGE	CONT.	32	84-86	
L-31WN	CANAL STAGE	DISC.	11	85	*
NTS8	WETLAND STAGE	DISC.	29	84-85	*
NTS9	WETLAND STAGE	DISC.	19	84-85	*
NTS10	WETLAND STAGE	DISC.	28	84-85	*
NTS11	WETLAND STAGE	DISC.	13	85	*
R3110	WETLAND STAGE	CONT.	32	84-86	*
NTS1	WETLAND STAGE	CONT.	29	84-86	*
NTS2	WETLAND STAGE	DISC.	31	84-85	*
NTS3	WETLAND STAGE	CONT.	31	84-86	*
NTS4	WETLAND STAGE	DISC.	32	84-85	*
NTS5	WETLAND STAGE	CONT.	30	84-86	*
NTS12	WETLAND STAGE	DISC.	12	85	
E111	WETLAND STAGE	DISC.	32	84-85	*
S-332HW	CANAL STAGE	CONT.	32	84-86	*
S-332TW	WETLAND STAGE	CONT.	32	84-86	*
NTS6	WETLAND STAGE	DISC.	32	84-85	*
NTS7	WETLAND STAGE	DISC.	19	85	*
E112	WETLAND STAGE	DISC.	31	84-85	*
E110	WETLAND STAGE	DISC.	30	84-85	*
S-175HW	CANAL STAGE	CONT.	32	84-86	*
S-175TW	CANAL STAGE	CONT.	32	84-86	*
E113	WETLAND STAGE	DISC.	30	84-85	*
E114	WETLAND STAGE	DISC.	30	84-85	*
E115	WETLAND STAGE	DISC.	32	84-85	*
NTS13	WETLAND STAGE	DISC.	12	85	*
L31WM	CANAL STAGE	DISC.	10	85	*
R158	WETLAND STAGE	CONT.	32	84-86	*
E158S	WETLAND STAGE	DISC.	13	85	
E157	WETLAND STAGE	DISC.	32	84-85	*
E156	WETLAND STAGE	DISC.	32	84-85	*
E155N	WETLAND STAGE	DISC.	12	85	*
E155S	WETLAND STAGE	DISC.	31	84-85	*
E154	WETLAND STAGE	DISC.	30	84-85	*
E153N	WETLAND STAGE	DISC.	32	84-85	*
E153S	WETLAND STAGE	DISC.	13	85	
TSB	WETLAND STAGE	CONT.	32	84-85	*
E152N	WETLAND STAGE	DISC.	31	84-85	*
E152S	WETLAND STAGE	DISC.	13	85	
NTS14	WETLAND STAGE	DISC.	12	85	*

* Indicates that the station was used in the 1984 or 1985 water level contour analysis.

Table 2. Stations in the Southern Subarea used in the 1984 through 1986 L-31W canal drawdown study.

STATION NAME	TYPE OF DATA	SAMP. FREQ.	N	YEARS STUDIED
E118	WETLAND STAGE	DISC.	13	85
NTS18	WETLAND STAGE	DISC.	10	85
NTS16N	WETLAND STAGE	DISC.	10	85
NTS16S	WETLAND STAGE	DISC.	10	85
NTS17N	WETLAND STAGE	DISC.	11	85
NTS17S	WETLAND STAGE	DISC.	11	85
E119	WETLAND STAGE	DISC.	4	85
NTS15	WETLAND STAGE	DISC.	12	85
L31WS	CANAL STAGE	DISC.	11	85
E126	WETLAND STAGE	DISC.	13	85
E125	WETLAND STAGE	DISC.	13	85
E124	WETLAND STAGE	DISC.	13	85
E123	WETLAND STAGE	DISC.	13	85
E122	WETLAND STAGE	DISC.	13	85
R127	WETLAND STAGE	CONT.	20	85-86

SAMP. FREQ. -- Refers to type of water level measuring equipment used at the station.

CONT. = Continuous water level recorder.
DISC. = Discontinuous measurements taken from a staff gage or a well, observed every six to 32 days.

N -- Refers to the number of times during the 1984 and 1985 field collection period that water levels were collected at this station.

Appendix C. Water Level Contour Maps (1984-85)

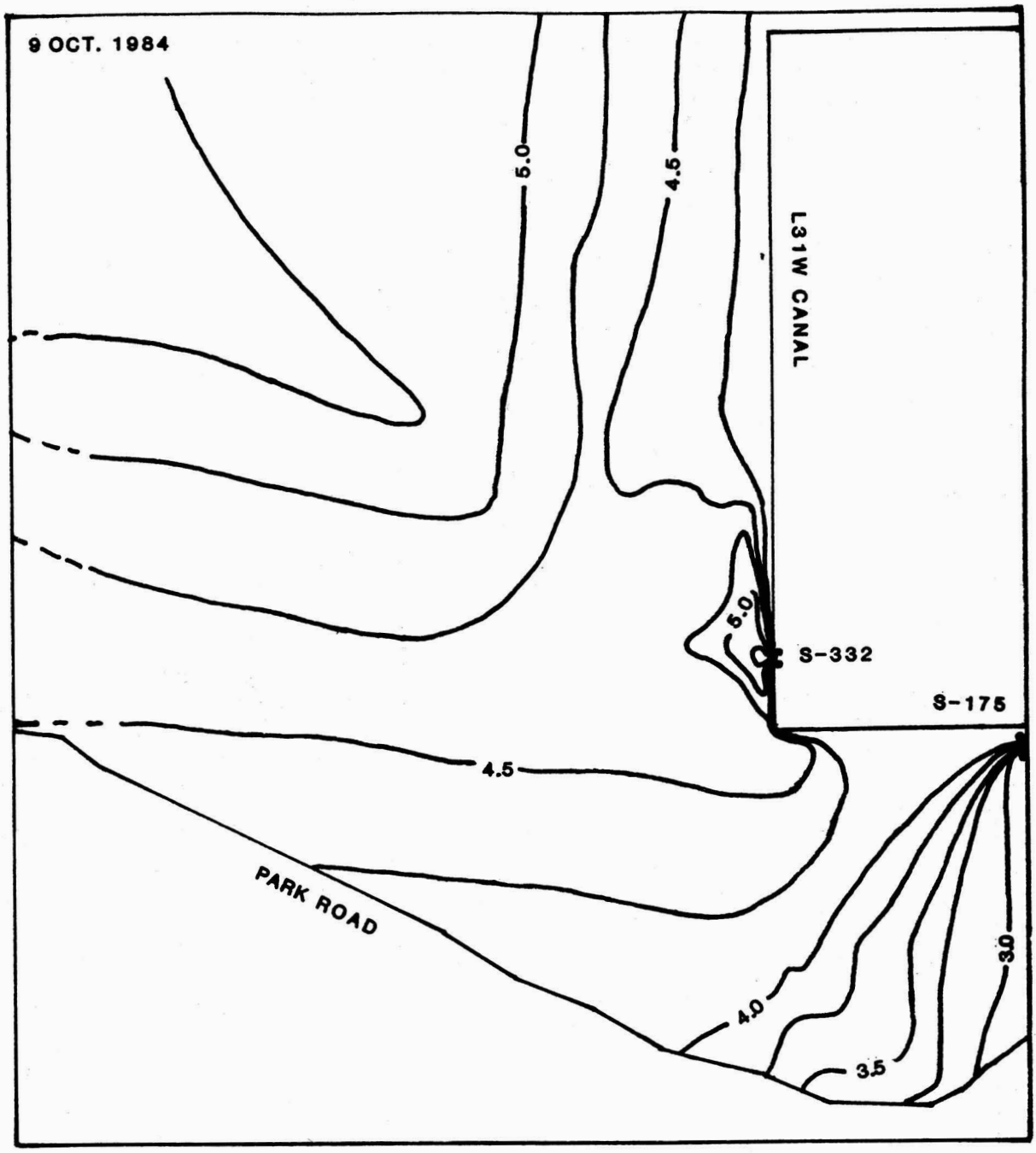

Figure 1. Water Level Contour Map for October 9, 1984. Average Daily Water Levels were 4.10HW/2.83TW at S-175 and 4.15HW/5.31TW at S-332.

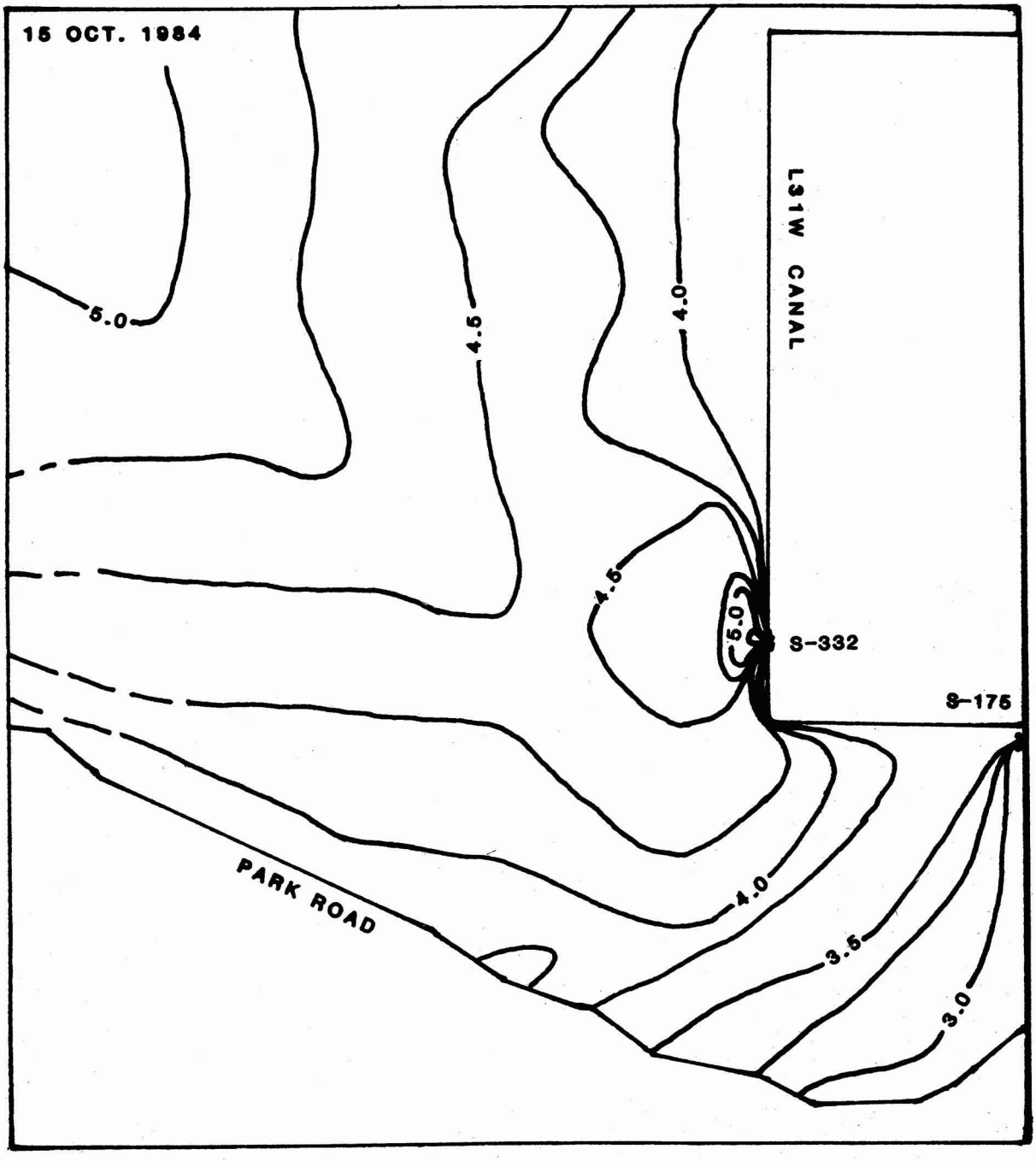

Figure 2. Water Level Contour Map for October 15, 1984. Average Daily Water Levels were 3.54HW/2.87TW at S-175 and 3.59HW/5.27TW at S-332.

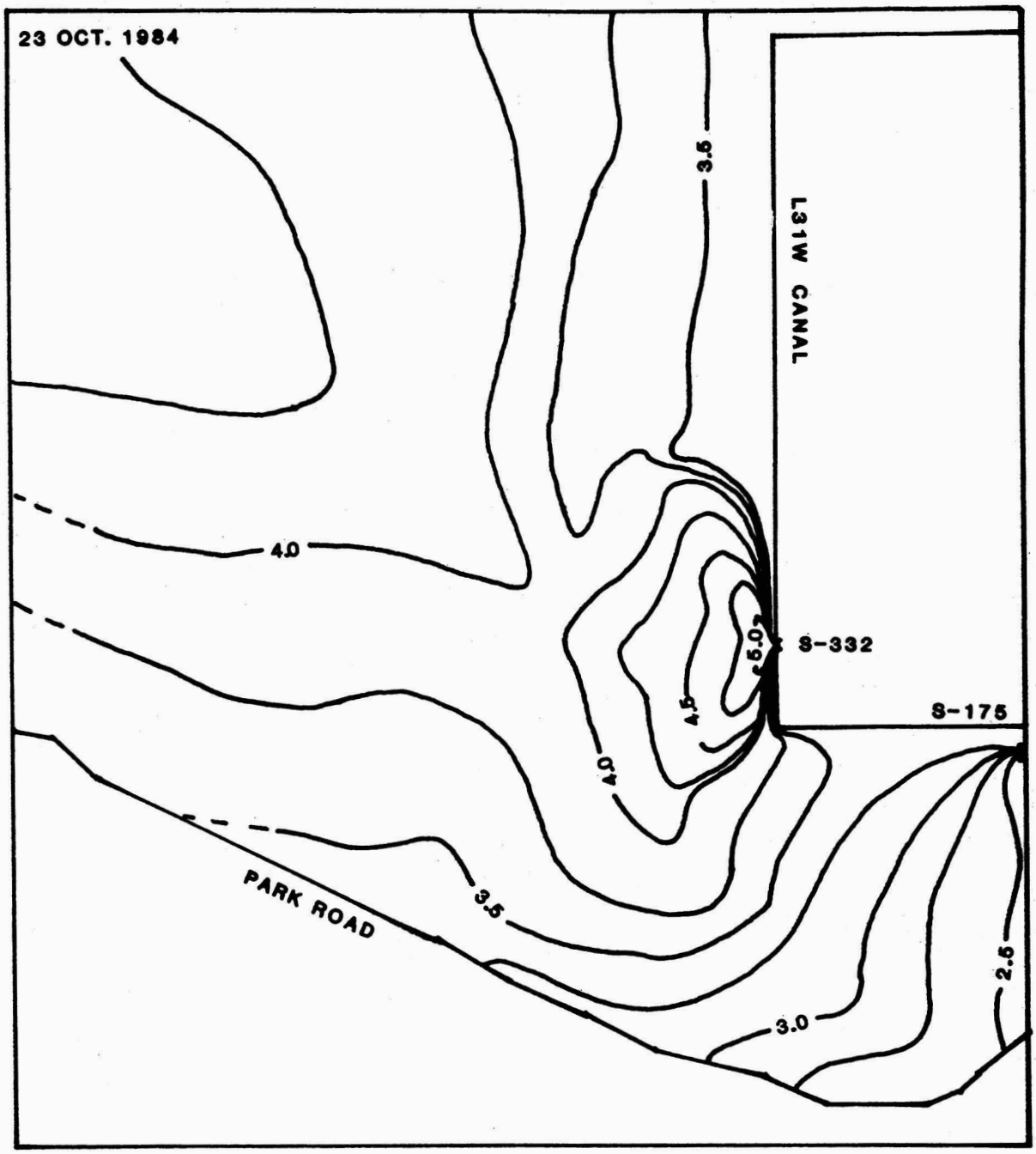

Figure 3. Water Level Contour Map for October 23, 1984. Average Daily Water Levels were 3.32HW/2.46TW at S-175 and 3.35HW/5.13TW at S-332.

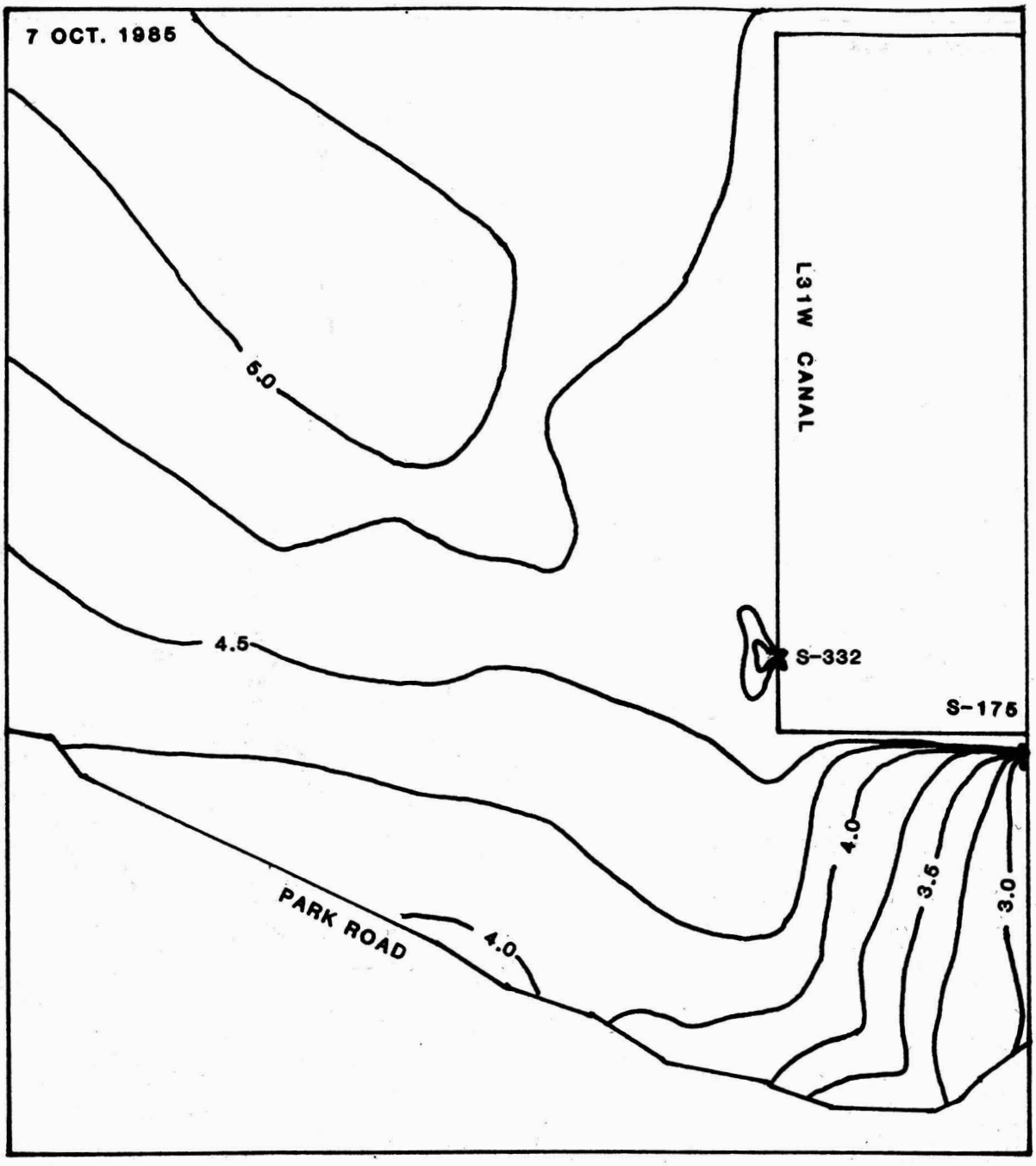

Figure 4. Water Level Contour Map for October 7, 1985. Average Daily Water Levels were 4.65HW/2.93TW at S-175 and 4.73HW/5.02TW at S-332.

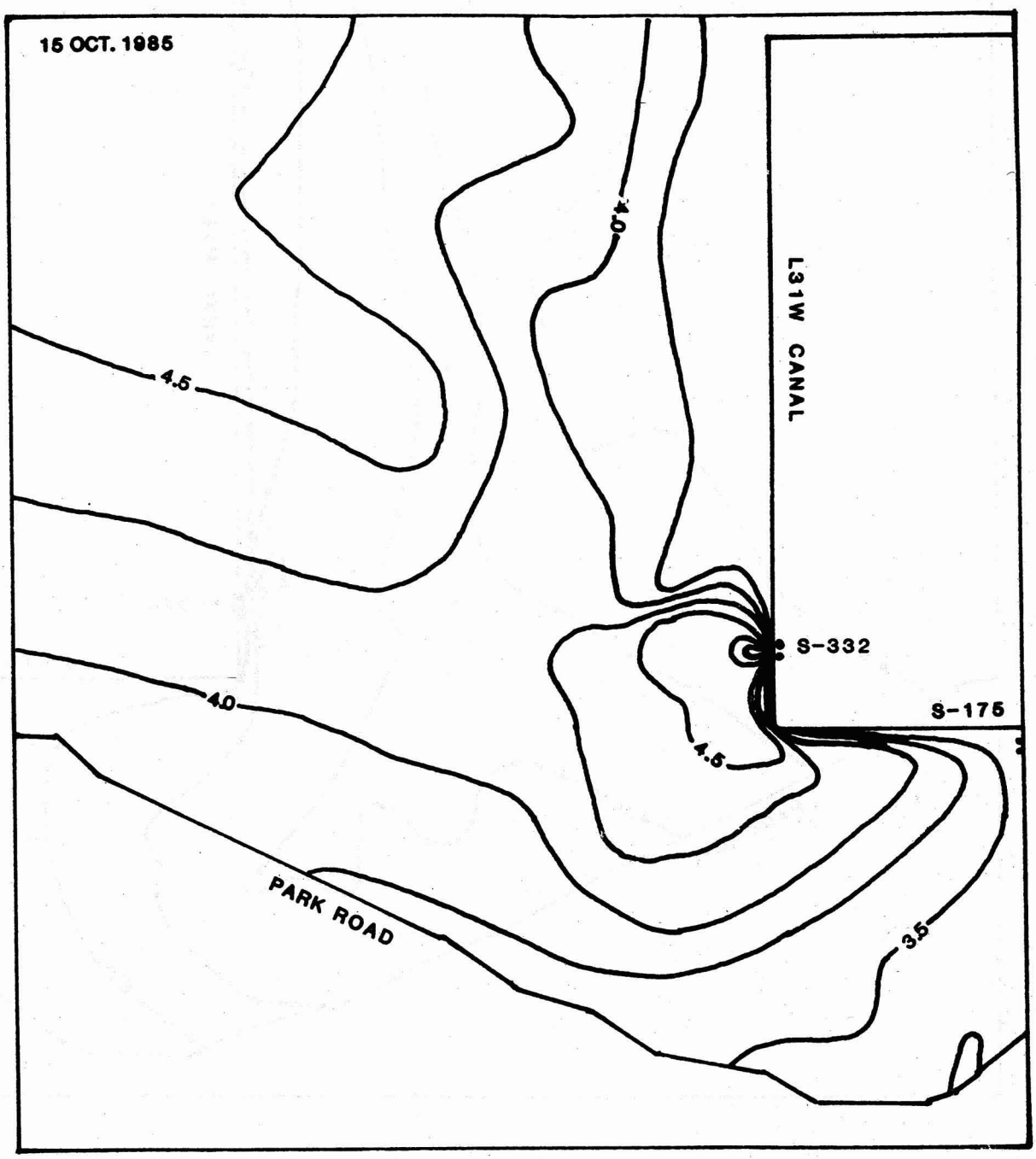

Figure 5. Water Level Contour Map for October 15, 1985. Average Daily Water Levels were 3.42HW/3.31TW at S-175, and 3.51HW/5.24TW at S-332.

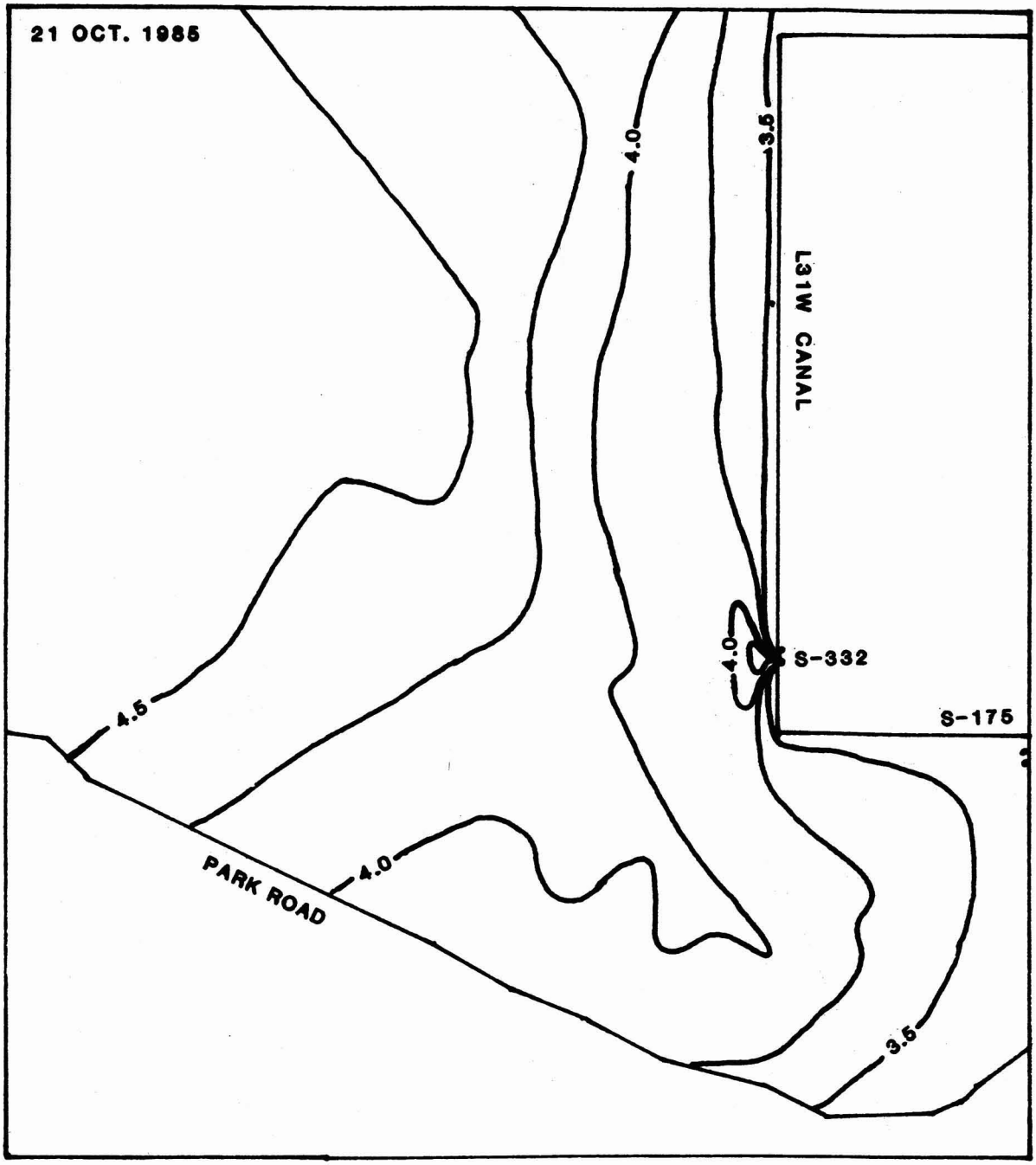

Figure 6. Water Level Contour Map for October 21, 1985. Average Daily Water Levels were 3.37HW/3.31TW at S-175 and 3.45HW/4.43TW at S-332.