TECHNICAL MEMORANDUM

December 1982

UPLAND RETENTION/-RETENTION DEMONSTRATION PROJECT

Fourth Annual Report

To the Coordinating Council on the
Restoration of the Kissimmee River Valley
and Taylor Creek/Nubbin Slough Basin

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

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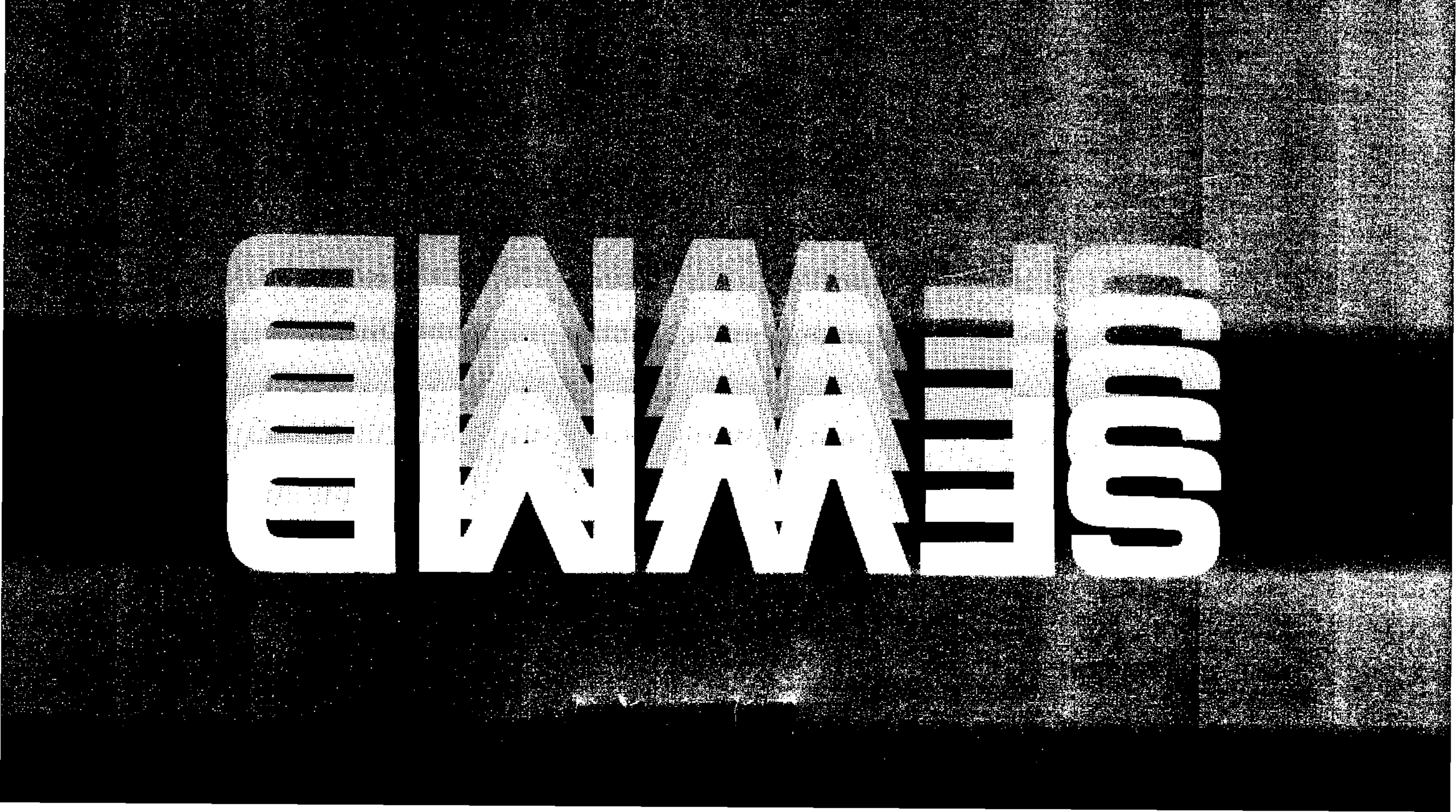

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UPLAND RETENTION/RETENTION DEMONSTRATION PROJECT

Fourth Annual Report

TO THE COORDINATING COUNCIL ON THE RESTORATION OF THE KISSIMMEE RIVER VALLEY AND TAYLOR CREEK/NUBBIN SLOUGH BASIN

by

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INTERIM REPORT

Any Findings, Conclusions, and Actual Data Are Subject to Change and/or Revision

Final Publication of these Data Will Be Included In a District Technical Publication

Section IV- (continued)

Peavine Pasture 67

Ash Slough 70

SEZ Dairy 73

Intersite Comparisons 73

1981 Water and Nutrient Budgets 79

Groundwater 84

Section V - Detention/Retention Systems 90

Introduction 90

Ash Slough 90

Armstrong Slough 91

SEZ Dairy 103

References Cited 116

TABLE OF CONTENTS

List of Figures iii

List of Tables vi

Introduction 1

Section I - Review of SFWMD Project Activities 3

- Introduction 3
- Construction 3
- Hydrology 3
- Water Quality Monitoring 3
- Water Quality Laboratory 4
- Reports 4

Section II - Literature Survey 5

- Introduction 5
- Land Use Practices - Impacts on Water Quality 6
- Impacts of Dairy Practices 8
- Nutrient Uptake by Wetlands (Detention/Retention) 11

Section III -Rainfall Analysis 18

- Introduction 18
- Methods 18
- Results 31
- Loading Rates 36

Section IV - Effects of Agricultural Practices on Water Quality . . . 50

- Introduction 50
- Water Quality Monitoring 50
- Armstrong Slough 57
- Wildcat Slough 64

Figure IV-12. Wildcat Slough - 1981 Total and Ortho Phosphorus Concentrations 66

Figure IV-13. Peavine Pasture - 1981 Total and Inorganic Nitrogen Concentrations 68

Figure IV-14. Peavine Pasture - 1981 Total and Ortho Phosphorus Concentrations 69

Figure IV-15. Ash Slough - 1981 Total and Inorganic Nitrogen Concentrations 71

Figure IV-16. Ash Slough - 1981 Total and Ortho Phosphorus Concentrations 72

Figure IV-17. SEZ Dairy at Wolf Creek - pH and Turbidity 74

Figure IV-18. SEZ Dairy at Wolf Creek - Conductivity and Color 75

Figure IV-19. SEZ Dairy at Wolf Creek - Total and Dissolved Inorganic Nitrogen Concentrations 76

Figure IV-20. SEZ Dairy at Wolf Creek - Total and Ortho Phosphorus Concentrations 77

Figure IV-21. SEZ Dairy - Daily Discharge from Holding Lagoon 1981 78

Figure IV-22. Upland Demonstration Project 1981 Intersite Comparisons - Time Series Nitrogen Species Concentrations 80

Figure IV-23. Upland Demonstration Project 1981 Intersite Comparisons - Time Series Phosphorus Species Concentrations 81

Figure IV-24. Conductivity in Groundwater 1981 85

Figure IV-25. Nutrient Concentrations in Groundwater 1981 - Nitrogen Species 86

Figure IV-26. Nutrient Concentrations in Groundwater 1981 - Phosphorus Species 87

Figure V-1. Armstrong Slough Detention Area 92

Figure V-2. Nitrogen Concentrations at Armstrong Slough Marsh Outfall 93

Figure V-3. Phosphorus Concentrations at Armstrong Slough Marsh Outfall 94

LIST OF FIGURES

Figure III-1. Wildcat Slough - Percent Historical Average of Monthly Rainfall During Upland Detention/ Retention Project Study Period 26

Figure III-2. Ash Slough - Percent Historical Average of Monthly Rainfall During Upland Detention/ Retention Project Study Period 27

Figure III-3. Armstrong Slough - Percent Historical Average of Monthly Rainfall During Upland Detention/ Retention Study Period 28

Figure III-4. Peavine Pasture - Percent Historical Average of Monthly Rainfall During Upland Detention/ Retention Study Period 29

Figure III-5. SEZ Dairy - Percent Historical Average of Monthly Rainfall During Upland Detention/ Retention Study Period 30

Figure IV-1. Drainage Pattern Armstrong Slough - Peavine Pasture Area 51

Figure IV-2. Wildcat Slough 52

Figure IV-3. Peavine Improved Pasture, El Maximo Ranch, Latt Maxcy Corp. 53

Figure IV-4. Ash Slough, Bass Ranch 54

Figure IV-5. SEZ Dairy 55

Figure IV-6. Armstrong Slough - 1981 Specific Conductance 58

Figure IV-7. Armstrong Slough North Channel - Nitrogen Concentrations 59

Figure IV-8. Armstrong Slough North Channel - Phosphorus Concentrations 60

Figure IV-9. Armstrong Slough South Channel - 1981 Inorganic and Total Nitrogen Concentrations 61

Figure IV-10. Armstrong Slough South Channel - 1981 Ortho and Total Phosphorus Concentrations 62

Figure IV-11. Wildcat Slough - 1981 Total and Inorganic Nitrogen Concentrations 65

LIST OF TABLES

Table II-1. Reduction in Nutrient Concentration in Water at Various Wetland Treatment Facilities . . . . 13 & 14

Table III-1. Total Mean Annual Rainfall - Upland D/R Project Area - Historical Period of Record 19

Table III-2. Historical Mean Monthly and Annual Rainfall at Stations in the Vicinity of Upland Project Sites . 21 & 22

Table III-3a. Monthly and Annual Rainfall on Upland Demonstration Project Sites, April-December 1979 23

Table III-3b. Monthly and Annual Rainfall on Upland Demonstration Project Sites, 1980 24

Table III-3c. Monthly and Annual Rainfall on Upland Demonstration Project Sites, 1981 25

Table III-4. Rainfall Quality Data Summary 35

Table III-5. Concentrations of Selected Nutrient Species Reported in Precipitation 37

Table III-6. Typical Historical Loading Rates Attributed to Precipitation on Upland D/R Project Study Sites for Entire Period of Record 38

Table III-7. Loading Rates for Selected Nitrogen and Phosphorus Species Reported in the Literature 40

Table III-8. Nutrient Loading Rates Attributed to Precipitation on Upland D/R Project Study Sites During 1981 41

Table III-9a. Monthly Nutrient Loads Attributed to Rainfall at Armstrong Slough . . . . 42 & 43

Table III-9b. Monthly Nutrient Loads Attributed to Rainfall at Ash Slough . . . . 44 & 45

Table III-9c. Monthly Nutrient Loads Attributed to Rainfall at Wildcat Slough . . . . 46 & 47

Table III-9d. Monthly Nutrient Loads Attributed to Rainfall at Peavine Pasture 48

Table III-9e. Monthly Nutrient Loads Attributed to Rainfall at SEZ Dairy 49

Table IV-1. Upland Demonstration Project - Project Sites, Areas, Land Uses 56

Figure V-4. Armstrong Slough - 1981 Inorganic and Total Nitrogen Concentrations 95

Figure V-5. Armstrong Slough - Station 1 - 1981 Ortho and Total Phosphorus Concentrations 96

Figure V-6. Armstrong Slough - Stations 2 and 3 - 1981 Ortho and Total Phosphorus Concentrations 97

Figure V-7. Residence Time vs Nutrient Reduction Efficiency at Armstrong Slough Marsh 102

Table IV-2. Upland Demonstration Project Sites - 1981 Annual Water and Nutrient Budgets . . . . 82 & 83

Table V-1. Nutrient Reduction Efficiency, Armstrong Slough Marsh 100

Table V-2. 1981 SEZ Dairy Estimated Monthly Barnwash Volume . . 104

Table V-3. SEZ Dairy Flow Weighted Lagoon Treatment Efficiency . . . . 106 & 107

Table V-4. SEZ Dairy Watershed Flow and Nutrient Budgets . . . . 113 & 114

are available from the District upon request.

The record drought in the south-central Florida area over the past year of study has minimized the data collected during the subject period, calendar year 1981. Many sampling locations were completely dry throughout most, if not all, of this time. While some project sites provided no information during this period, advantage was taken of the unique conditions to gain insight that might not have been otherwise possible.

As the latter stages of the current program are approached, more normal rainfall conditions have returned to the project area. Such conditions should increase the chances of making a more accurate evaluation of detention/retention as a feasible methodology of mitigating nonpoint source pollution under the type of meteorological conditions that more commonly occur.

INTRODUCTION

This report is the latest in an annual series of project status reports by the South Florida Water Management District's (SFWMD) Water Chemistry Division staff on the multi-year Upland Detention/Retention Demonstration Project. This intense multi-disciplinary research effort was initiated and funded through the efforts of the Coordinating Council for the Restoration of the Kissimmee River Valley and Taylor Creek/Nubbin Slough Basin (KRVCC). The purpose of this effort is to demonstrate the feasibility and effectiveness of detention/retention in natural or recreated wetlands to reduce and store nonpoint source nutrient loads in rainfall runoff in the Kissimmee River basin.

The SFWMD was contracted by the KRVCC to conduct a monitoring program of both water quantity and water quality and to perform analyses on these data to answer two basic questions. These were:

1. What effects do different types of agricultural land uses have on quality of runoff?
2. How effective are wetlands in storing and reducing the loads in agricultural nonpoint source runoff?

The SFWMD's activities in achieving and maintaining hydrological integrity at each site as well as methods of sampling, analyses, and determination of hydrological and loading budgets at each site have been described in previous annual project status documents in this series (Goldstein, et al., 1980; Goldstein and Ulevich, 1980; Goldstein, 1981). The scope of this document will be to provide preliminary results of an ongoing literature review and an analysis of data collected during calendar year 1981. These new data will be discussed in context with results and conclusions based on data collected throughout the project period to date. A listing of water quality data utilized in the evaluations in this report

WATER QUALITY LABORATORY

Water samples collected for the Upland D/R Project were analyzed at the Okeechobee Environmental Research Center (OERC) water chemistry laboratory during 1981. Activities got underway late in 1981 to shift the laboratory analysis process to the District's water chemistry laboratory in West Palm Beach.

REPORTS

The SFWMD provided the KRVCC with a third annual project progress report in July of 1981. In addition, oral presentations of the project's progress have been made at KRVCC meetings. This report is to document the District's continuing research efforts during 1981.

SECTION I

REVIEW OF SFWMD PROJECT ACTIVITIES

INTRODUCTION

The SFWMD continued to carry out routine surface water quality sampling and hydrological monitoring as per contractual obligations to the KRVCC. Ongoing groundwater and rainfall quality monitoring efforts also continued at last year's pace. A brief review of the status of each area of the SFWMD's contractual responsibilities on the Upland Detention/Retention (D/R) Project follows.

CONSTRUCTION

No major construction or maintenance on project sites or structures occurred during 1981.

HYDROLOGY

Daily flow volumes measured by the use of digital stage recorders at flow control structures (flumes and/or culverts) continued to be monitored throughout 1981. Routine servicing of these devices and data tape transfers to the Data Management Division occurred on a monthly basis.

WATER QUALITY MONITORING

Surface water quality monitoring occurred on a routine biweekly basis at most project sites. At SEZ Dairy, surface water quality monitoring at the outfall site was conducted on a daily basis when discharge occurred. Sampling methodology and rationale are described in previous annual reports to the KRVCC. Rainfall contributions of nutrients on each project watershed were estimated by using rainfall quality data collected at S-65B, S-65D, and the Okeechobee Field Station. Groundwater quality was monitored on a monthly basis.

LAND USE PRACTICES - IMPACTS ON WATER QUALITY

The overall problem of pollution control of agricultural nonpoint sources has been addressed by many people. Among these are Walter, et al (1979), Bigger and Corey (1969), McElroy (1976), and Loehr (1972). For the most part, these and others approach the nonpoint nutrient problem from agricultural runoff as predominantly one associated with sediment control. Stewart, et al (1975), discussed nutrient transport as a function of sediment transport by sediment-nutrient complexes. Wendt and Corey (1980) observed in a Wisconsin study that phosphorus transport could be positively correlated with sediment loss. Frere (1976) observed that quartz sand had low P sorption capacity while silicate clays had very high P sorption capacity. Sorption on these clay particles is identified as a major means of reduction of dissolved nutrients in the water column.

Comparisons have been made of impacts of various types of agricultural (non-urban) land uses on quality of surface runoff. Doran, et al (1981) found that agricultural watershed land uses in Nebraska impacted quality, as runoff from pasturelands was of generally better quality than cropland (worst quality was found in runoff of storm events that immediately followed fertilizer application). Interestingly enough, the study indicated that quality of runoff from grazed grassland was better than that from ungrazed. White, et al (1980), in Ohio found that nutrient flux from pasture was greater than from forested watersheds. Wendt and Corey (1980) report that P loss from forested land is generally less than from cropland. Loehr (1972) reviewed several studies of land use and concluded that intense uses such as feedlot contributed the largest amounts of N and P to runoff. Croplands contributed lesser

SECTION II

LITERATURE SURVEY

INTRODUCTION

A survey of relevant literature is an integral component of any comprehensive scientific study. The literature review conducted as part of the Upland Demonstration Project has been focused on three major areas. The first has been to investigate impacts of various land uses (especially agricultural) on stormwater runoff quality. An attempt has been made to focus emphasis on this subject to land uses typical of the southeastern United States or land uses in other parts of the country similar to those that predominantly occur in the Upland Demonstration Project area.

The second major area of investigation was to look at impacts of dairy herds and dairy practices on runoff water quality. Since dairy operations have been identified as the worst case polluters in the Upland Project area, this aspect of the review was quite appropriate.

The third major area of the review was an investigation into research conducted on impacts of wetlands on mitigating adverse impacts on water quality from either nonpoint runoff or point source discharge. These will help identify the types of impacts, improvements, and/or problems that might be expected with detention/retention as a nutrient control management practice.

Results of the review to date will be briefly described here. Since this is an ongoing aspect of the project, an updated version will be included in a final project report to be prepared in the future.

Seasonal phenomena (particularly leaf fall) appear to play a role in nutrient flux from agricultural watersheds. Sharpley, et al. (1981), report leaching of P from vegetative cover may be a primary means of P loss. Caporal, et al (1981), found NO_3-N concentrations from an agricultural watershed greatest in winter which also correlated with the time of fertilization and most rainfall. Wendt and Corey (1980) noted that losses of dissolved reactive phosphorus were greatest in the fall after foliage was killed by frost. Schreiber, et al (1976), reported that all dissolved nutrient losses from five pine-covered watersheds occurred in winter and early spring. The seasonal fluctuations were attributed to complex interactions of biological and rainfall-runoff factors.

Some investigators note that most watersheds act as nutrient sinks by continually absorbing more nutrients from rainfall than are exported in surface runoff (Burwell, et al (1975), Cambell (1976), Doran, et al. (1981)).

In central and south Florida, extensive ditching for drainage purposes is a common practice. Huber, et al (1976), have concluded that drainage ditch density (length of ditch/unit surface area) can be positively correlated with increased nutrient concentrations in surface runoff.

IMPACTS OF DAIRY PRACTICES

Intensive dairy operations have proven to be the worst case contributor to water pollution (in the form of enriched nutrients) in the Upland Demonstration Project area. This is not surprising when one considers herd sizes of 500 to 1,000 animals are not uncommon occurrences throughout the project area watersheds.

amounts and range, pasture, and woodlands were a third category of diffuse sources that come close to representing background or natural contributions. Caporal, et al (1981) found in a comparison of agricultural versus forested land uses in Italy that high concentrations of NO_3-N in runoff from agricultural land was the only observable quality impact. Douglas (1976) in New Jersey found that NO_3-N was contributed in the greatest amounts by urban, then croplands, and least by forest lands. Urban, crop, and forest lands contributed almost equal amounts of NH_4 and PO_4.

Hill (1981) in Ontario found P exports were positively correlated with crop area. Thomas and Crutchfield (1974) determined that local geological conditions had more impact on P concentrations in runoff in study watersheds in Kentucky than did agricultural land use.

Animal density has been found to play a major role in pasture runoff quality. Douglas (1976) reports that several investigators have concluded that in most agricultural systems, the main sources of NO_3-N are sites of animal habitation. Storch, et al (1976), concluded that feedlot situations are responsible for high levels of N and P in runoff, and that distance traveled from the waste source to the receiving waters is important in reducing N and P concentrations. White, et al (1980), found that carrying a herd of cattle continuously on one pasture, rather than isolating the animals over several pastures, did increase surface runoff and soil loss with an accompanying increase in nutrient flux from the area. Humenik (1980) found that the only significant difference in agricultural watershed practices with increased N and P discharges was greater animal production.

Nordstedt and Baldwin (1973) recommended that Florida dairy lagoons should have a design that would allow for 378-567 liters/animal/day and have a minimum detention time of 15 days. Discharge from the last holding lagoon should occur no more frequently than 5-10 day intervals so that the seepage irrigation field would have time to dry out and assimilate the load of material in the previous release.

Ferrara and Acvi (1982) investigated and modeled nitrogen removal mechanisms of a facultative waste stabilization pond in Utah. Their findings are probably applicable to the dairy lagoons in that mechanisms of nitrogen loss should be similar. They found that the primary mechanism of nitrogen removal was the result of settling of organic nitrogen in the sediment. The primary mechanism for ammonia removal was identified to be the biological uptake rather than volatilization. Temperature and pH were found to be important physical factors influencing the rate of nitrogen loss. Pano and Middlebrooks (1982) compared ammonia removal in the above described study with that observed in similar lagoon systems in New Hampshire and Kansas and then used the information to develop an ammonia loss model. They noted that annual removal of ammonia in all three systems was above 90 percent and the bulk of the removal occurs in the first pond of the series. They concluded that ammonia removal rates increase as pH, detention time, and temperature increase. Since temperature in south Florida does not suffer the cold extremes to which the above described systems are subject, one might suspect that pH and detention time would have a role of increased significance in the Upland Project area.

By nature of their physiology, dairy cattle need a continual source of phosphorus to support maximum milk production. Harris (1970) discusses nutritional needs of dairy cattle. Phosphorus is important in the proper utilization of feed for milk production, growth, and reproduction. Milk contains a relatively constant level of about 0.1 percent phosphorus. To supply this mineral need, the total ration for the animal should contain 0.4 percent or more of phosphorus. Roughly 0.09 kg per animal per day are included in normal feed rations for dairy animals. The true absorption of P in the dairy cow's digestive tract is estimated at between 50 to 65 percent.

Loehr (1977) reports that manure production from dairy cattle ranges from 33.2 to 65.0 kg/animal (average 39.1 kg). This is the equivalent of 11.14 metric tons of feces and urine per year. Each ton of wet manure contains about 4.0 kg of nitrogen and 1.6 kg of phosphorus. On a 500-head dairy, this would amount to approximately 36,000 kg of nitrogen and 7,300 kg of phosphorus per year deposited either in the milking barn, staging area, or pasture.

Fortunately, some of this material is collected at the barn during the milking operation, and is subsequently flushed into waste lagoon systems. Nordstedt, et al (1971) evaluated the efficiency of dairy waste lagoon systems at Bradenton, Florida. They found that a three-stage system resulted in removal efficiencies of 96.4 and 80.5 percent for BOD and ortho P on a concentration basis. The latter constituent was decreased from 27.2 to 5.3 mg/l. They also noted that some seepage to groundwater did occur from the first lagoon, but was no longer detectable at a 3-meter depth, 30 meters from the lagoon.

Phosphorus uptake in similar systems used for treatment of secondary sewage is described by Blumer (1978). The meadow/marsh/pond removed 75-92 percent of total P (mass) on a seasonal basis. The marsh/pond system removed 58-88 percent of total P. There has been some interest in utilizing wetlands for tertiary treatment of secondary sewage effluent. Major research efforts in this area were conducted by Kadlec and his coworkers in Houghton Lake, Michigan (Kadlec, 1976; Kadlec, et al, 1975; Kadlec and Tilton, 1979; Kadlec, et al, 1979; Kadlec and Hammer, 1981), in cypress domes around Gainesville, Florida (Ewel, 1976; Ewel and Odum, 1978; Ewel, 1980), and in a wetlands near the city of Clermont, Florida (Zoltec, et al, 1978 and 1979). Other research efforts in this area were done in Wisconsin (Spangler, et al, 1976; Fetter, 1978), Wildwood, Florida (Boyt, et al, 1977), Cootes Paradise, Ontario (Mudrock and Capobianco, 1979), Holland, Michigan (Greij, 1976), Hamilton River, Delaware (Whigham and Simpson, 1976), and Boney Marsh (Davis, 1981).

Kadlec and Tilton (1979) report hydraulic loading rates to marshes is important in maintaining peak efficiency for nutrient removal. They find that greater than one inch per week impedes efficiency. Water depth is also important in terms of predominant vegetative species (Greij, 1976) and nutrient removal efficiency (Tilton and Kadlec, 1979).

Variation in results of nutrient removal studies among sites is due to numerous factors including nutrient loading rate, water depth, season of discharge, soil type, vegetation density, wetland type, and hydrologic retention time. The general pattern that exists is of N and P absorption from the effluent by plants, microorganisms, and physical-chemical processes in soil. The accompanying table from Kadlec and Tilton (1979) (Table II-1) summarizes results of nutrient uptake studies in various locales.

NUTRIENT UPTAKE BY WETLANDS (DETENTION/RETENTION)

Detention/retention as a practice to reduce pollutant loads from nonpoint source runoff is a concept that has been addressed only recently. The initial impetus appears to have been from the standpoint of capturing urban stormwater runoff and thus most existing systems and studies have been designed with this type of criteria in mind. For urban systems, sedimentation appears to be the major mechanism of pollutant removal and such systems have been investigated and are discussed by Colston (1974), Herb (1980), Dunbar and Henry (1966), Carter and Bondurant (1976), Raush and Schreiber (1981), Morris, et al. (1975). Some of these addressed N and P reduction efficiencies. Raush and Schreiber (1981) noted 77 percent reduction of sediment associated P, 35 percent reduction of solution P, and 37 to 40 percent of inorganic N. Morris, et al (1975), note a 35 percent removal of total P and 15 percent removal of total N.

Utilization of wetlands as a detention/retention strategy for nutrient reduction in agricultural runoff in northern tributaries to Lake Okeechobee is suggested by Tourbier (1978), Small (1978), Blumer (1978), Peters and Lee (1978), and Jones and Lee (1978).

Small (1978) describes a meadow/marsh/pond or marsh/pond design to detain and treat runoff from farmland. He states that the marsh/pond system has been shown to trap 62 percent of the total N input and the meadow/marsh/pond system exhibits a 79 percent removal rate. These systems function at this level of efficiency as long as the input concentration of N does not exceed 30 ppm. In order to significantly reduce P, input loads cannot exceed 11 mg/l and pond vegetation would have to be regularly harvested and transported out of the watershed.

Table II-1. (cont.) Reduction in Nutrient Concentration in Water at Various Wetland Treatment Facilities

from Kadlec & Tilton (1979)

Location	Nutrient	Input	Output	Reduction %	Reference
Massachusetts	PO4-P	2.2 mg/l	0.7 mg/l	68	Yonika & Lowry (1978)
	NH4-N	8.8 mg/l	0.3 mg/l	97	
	NO3	1.4 mg/l	0.6 mg/l	57	
New York	NH4-N	8.4 mg/l	3.5 mg/l	58.3	Small (1976)
	NO3 + NO2	5.5 mg/l	2.6 mg/l	52.7	
	PO4-P	4.8 mg/l	1.3 mg/l	72.9	
Wisconsin	PO4-P	25 mg/l	12 mg/l	64	Spangler, Sloey & Fetter (1976)
	TP	24 mg/l	12 mg/l	64	

Table II-1. Reduction in Nutrient Concentration i

Location	Nutrient	Input
Michigan	NO3-N	1.11 mg/l
	NH4-N	0.11 mg/l
	TDP	1.57 mg/l
	NH4 + NOx	4.95 mg/l
	TDP	3.48 mg/l
Wisconsin	NO3-N	1.17 mg/l
	PO4-P	3.13 mg/l
Central Florida	TP	6.4 mg/l
	TN	15.3 mg/l
Hungary	TP	4.5 mg/l
	TN	19.97 mg/l
Canada	NH4-N	10.3 mg/l
	TP	11.0 mg/l
	PO4-P	9.95 mg/l
Louisiana	NH4-N	547 mg/l
California	NH4-N	8.3 mg/l
	NO3 + NO2	5.8 mg/l
Canada	NH4-N	11.2 mg/l

n Water at Various Wetland Treatment Facilities

from Kadlec & Tilton (1979)

Output	Reduction %	Reference
<0.10 mg/l	91	Kadlec & Tilton (1978)
0.03 mg/l	73	
0.07 mg/l	96	
0.46 mg/l	91	Kadlec & Tilton (1977)
0.11 mg/l	97	
0.57 mg/l	51.3	Fetter, Sloey & Spangler (1977)
2.93 mg/l	6.4	
0.12 mg/l	98	Boyt, Bayley & Zoltec (1977)
1.6 mg/l	89.5	
0.08 mg/l	98	Toth (1972)
0.81 mg/l	98	
0.39 mg/l	96	Hartland-Rowe & Wright (1975)
0.26 mg/l	97	
0.25 mg/l		
37 mg/l	93.2	Price (1975)
7.5 mg/l	9.6	Nute (1977)
1.3 mg/l	77.6	
0.5 mg/l	95.6	Semkin, McLarty & Craig (1976)

Capacity of wetlands to absorb nutrients is not unlimited. Steward and Ornes (1975)* found that continual loading of sawgrass communities eventually resulted in an increase in phosphorus in the water column. Tilton and Kadlec (1979) report that during the second year (1977) of their study on Houghton Lake marsh, N and P concentrations were not reduced to levels comparable with those of the years before until several meters furthur downstream from the effluent outfall. Evidently, some marsh situations don't function well as nutrient removal systems. Steward (1970) and Boyd (1970) have addressed the nutrient removal potential of various vascular aquatic plants; but harvesting of plant biomass appears to be incompatible with maximum nutrient absorption and not very economical (Tilton and Kadlec, 1979; Spangler, et al , 1976).

Finally, studies have been conducted investigating the ability of wetlands to remove nutrients from agricultural drainage. One of these (Peverly, 1982) found that managed wetlands in New York acted as nutrient sinks for N and P only during the second year of a two-year study when flow through the system was roughly half the volume of the previous year. He suggests that this system is close to equilibrium for N and P movements such that net differences between years in gains and losses may depend mainly on timing and quantity of water movement.

Federico, et al (1978), found a similar situation existed at the Chandler Slough marsh in Okeechobee County, Florida. The marsh received inflow from drainage originating from dairy, beef cattle, and some sod farm operations. A "first flush" of nutrients attributed to washout of decayed material from the previous growing season occurred during the first portion of the wet season. Phosphorus was generally retained thereafter during the season,

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*cited in Kadlec and Tilton (1979)

The majority of nutrients removed from wastewaters seems to occur in close proximity to the effluent outfall to the wetland. Kadlec and Hammer (1980) report 90% of the nitrogen and phosphorus removal is complete within 200 yards of the discharge point. Boyt, et al (1977), found that N and P removal was not quite as efficient at Wildwood, Florida, where, 3.7 km downstream from the outfall, organic N was reduced 75-85%, total N 89.5%, and total P 98.1%. Mudrock and Capobianco (1979) noted that higher concentrations of N, P, and organic C were found in the upper 5 cm of bottom sediment in the portion of Cootes Paradise, Ontario, marsh closest to the effluent source, while concentrations in sediments further downstream in more open waters were comparable to levels in unpolluted lakes and marshes.) McPherson, et al (1976), found a 2% reduction of P concentrations and a 4% reduction of N concentrations per mile in three south Florida canals. Nitrogen and phosphorus were enriched in canal sediment adjacent to pump stations as compared to concentrations in more remote areas.

Nutrient removal can be attributed to four general categories: (1) vascular plant uptake; (2) algae uptake; (3) bacterial and fungal uptake and transformation; (4) sediment processes (sorption, ion exchange, precipitation, etc.) (Kadlec and Tilton, 1979). Contact with sediment appears to play a significant role, particularly for microbial activity and root absorption. More nutrients are taken up during periods of active plant growth. Nutrients are exported during periods of plant senescence. Microbial processes are exceedingly important in decay of organic matter and for conversion of the various nitrogen species. For instance, Bartlett, et al (1979), found that 90-95% of the NO_3-N in a wetland soil suspension is reduced to NO_2 or N_2 gases with little or no transfer of nitrate to NH_3 or organic N.

but the marsh alternated between acting as a source and a sink for N. The amount of uptake or release of both N and P was not considered significant based on statistical analysis, thus suggesting that this wetland, too, exists in a state of equilibrium.

SECTION III

RAINFALL ANALYSIS

INTRODUCTION

The following discussion describes the impact of atmospheric contributions as sources of nitrogen and phosphorus on the watersheds of the Upland Demonstration Project study sites. The impacts of these sources during the study subject years 1979-81 are described and an attempt is made to put this information into context with historical rainfall data on these watersheds. Rainfall loading rates are calculated for each study watershed in the project area and applied in such a manner as to provide an estimate of total nutrient loads on the study watersheds that is necessary to compute land use nutrient budgets.

METHODS

An initial effort was made (Goldstein, 1981) to evaluate aeolian contributions to the Upland D/R Project site watersheds and their subsequent impacts on water quality data collected over the years 1979 and 1980. The rationale and method described in that report will be followed here. The sole difference is the inclusion of an additional year of record (1981) for both quantity and quality of rainfall.

An effort was made to determine how rainfall during the subject study period compared with what could be considered "normal" based on historical records. Monthly rainfall quantity records were obtained for eleven permanent SFWMD monitoring network stations in the vicinity of the Upland D/R Project sites for their entire period of record (Table III-1). Records from stations clustered in the immediate vicinity of each project site were evaluated as discreet groups to arrive at historical monthly and annual rainfall quantity totals typical of the specific project site area (Table III-2). The rainfall totals observed at the project sites during the study period,(Tables III-3a through III-3c) could be compared with this "historical" record and an evaluation could be made as to whether or not these data were consistent with long-term patterns. These comparisons are graphically depicted in Figures III-1 through III-5.

Rainfall quality was obtained by collecting samples for quality analysis at stations located at structures S-65B and S-65D on the Kissimmee River and at the SFWMD's Okeechobee Field Station. The samples were collected at least once per week and frequently more often. Analyses for nitrogen and phosphorus parameters were carried out at the SFWMD water chemistry laboratory in West Palm Beach. These data for each parameter were averaged. A Student's t-test was run to determine if differences observed among the sample means at the three monitoring stations were significant. Though the mean concentrations of nitrogen and phosphorus parameters were consistently highest at S-65B and lowest at the Okeechobee Field Station, no significant difference was found at the 95 percent level. To continue the anlaysis of rainfall contribution to watershed nutrient budgets, the mean concentration of each parameter obtained from summing the individual mean concentrations of that parameter at each of the three stations was considered "typical" aeolian input of that parameter in the Kissimmee River basin and Upland Demonstration Project sites.

Using this "typical" mean concentration of each parameter, monthly rainfall totals, and the surface area of each watershed, loading calculations were done to arrive at "typical" nitrogen and phosphorus loading rates on monthly and annual bases and nutrient loads to apply in computations of overall watershed nutrient budgets.

Table III-1. Total Mean Annual Rainfall
Upland D/R Project Area
Historical Period of Record

SFWMD Rainfall Network Monitoring Station	Period of Record	Total Years
S-68	1965-81	17
El Maximo Ranch	1972-81	10
Micco Bluff	1972-81	10
Basinger	1972-81	10
Peavine Trail	1972-81	10
Tick Island	1974-81	8
Maxcy South	1974-81	8
S-65	1965-81	17
S-65A	1965-81	17
S-65C	1966-81	16
Okeechobee Field Station	1960-81	22
Brighton	1960-81	22
Okeechobee Forest Service	1969-81	13

Table III-2 (continued). Historical Mean Monthly and Annual Rainfall at Stations in the Vicinity of Upland Project Sites.

SFWMD Rainfall Monitoring Station	Mean Monthly Rainfall Total (centimeters)												Annual Rainfall Total
	J	F	M	A	M	J	J	A	S	O	N	D	
- Armstrong Slough and Peavine Pasture Sites -													
El Maximo	5.4	4.1	4.0	5.7	17.4	16.0	20.7	14.8	16.3	4.7	5.5	4.7	119.3
S-65	5.7	6.0	5.6	4.8	13.7	20.7	20.4	18.0	17.0	9.0	4.6	5.6	128.1
S-65A	4.8	6.2	5.0	3.6	13.4	18.9	18.9	18.6	16.2	8.0	3.4	4.3	114.6
Historical Mean Rainfall for Study Site $(\bar{x})$	5.3	5.8	4.9	4.7	14.9	18.5	20.0	17.1	16.5	7.2	4.5	4.9	120.7
- SEZ Dairy -													
Okeechobee Field Station	4.3	5.8	5.4	4.3	13.0	18.6	17.0	17.7	14.8	8.4	5.0	4.3	119.8
Okeechobee Forest Serv.	6.0	5.6	7.9	4.0	18.0	21.4	25.3	21.7	18.1	7.0	6.1	6.4	147.5
Historical Mean Rainfall for Study Site $(\bar{x})$	5.1	5.7	6.6	4.2	15.5	20.0	21.2	19.7	16.4	7.7	5.6	5.4	133.6

Table III-2. Historical Mean Monthly and Annual Rainfall at Stations in the Vicinity of Upland Project Sites.

SFWMD Rainfall Monitoring Station	Mean Monthly Rainfall Total (centimeters)												Annual Rainfall Total
	J	F	M	A	M	J	J	A	S	O	N	D	
- Wildcat Slough -													
S-65C	4.85	5.74	5.79	4.42	13.87	19.61	17.60	15.57	15.72	6.91	4.39	4.45	120.70
Brighton	5.03	5.41	5.97	4.60	11.38	21.54	18.36	18.34	17.58	8.86	4.80	5.31	127.15
S-68	4.52	4.57	4.60	2.31	10.54	14.35	12.95	15.06	14.50	6.15	3.20	3.45	96.22
Historical Mean Rainfall for Study Site ($\bar{x}$)	4.80	5.23	5.46	3.78	11.94	18.49	16.31	16.33	15.93	7.32	4.14	4.39	114.68
- Ash Slough -													
Micco Bluff	3.6	5.2	3.2	3.6	13.1	17.8	16.5	15.8	11.1	3.3	4.9	4.9	110.1
Bassinger	5.1	3.4	5.1	3.5	14.7	11.0	16.5	15.5	16.0	4.1	4.6	4.3	107.9
Maxcy South	5.5	6.1	4.9	3.5	16.4	17.5	21.3	15.0	17.2	5.3	6.0	7.5	129.8
Historical Mean Rainfall for Study Site ($\bar{x}$)	4.7	4.9	4.4	3.5	14.7	15.4	18.1	15.4	14.8	4.3	5.2	5.5	116.0

Table III-3b. Monthly and Annual Rainfall on Upland Demonstration Project Sites 1980

(centimeters)

	Armstrong Slough	Ash Slough	Peavine	SEZ Dairy	Wildcat Slough
January	4.6	4.9	2.7	5.2	7.0
February	7.3	6.4	2.4	3.7	4.3
March	4.6	6.7	2.1	3.4	4.9
April	5.2	9.4	3.7	4.6	5.5
May	10.4	1.8	12.2	3.4	8.2
June	12.2	7.6	7.3	10.4	7.9
July	21.3	21.6	16.2	23.2	15.5
August	9.8	18.9	6.1	13.1	7.9
September	3.4	19.5	7.6	11.3	5.2
October	0.9	0.9	0.9	0.9	1.2
November	7.9	9.4	6.4	10.1	8.2
December	2.7	2.1	4.0	1.8	1.8
Annual Total	90.2	109.4	71.6	90.8	77.7

Table III-3a. Monthly and Annual Rainfall on Upland Demonstration Project Sites April - December 1979

(centimeters)

	Armstrong Slough	Ash Slough	Peavine	SEZ Dairy	Wildcat Slough
April	6.4	3.4	10.7	4.3	5.3
May	8.2	22.6	1.8	24.7	20.7
June	9.1	4.6	11.0	5.5	1.8
July	12.5	13.4	14.3	15.2	5.5
August	14.0	9.1	8.8	8.5	17.1
September	27.7	35.1	31.7	31.7	41.8
October	0.3	1.5	0	0.9	2.1
November	1.8	1.2	1.2	2.4	0.6
December	7.0	5.2	1.8	6.1	3.0
Annual Total	87.2	96.0	81.4	99.4	97.8

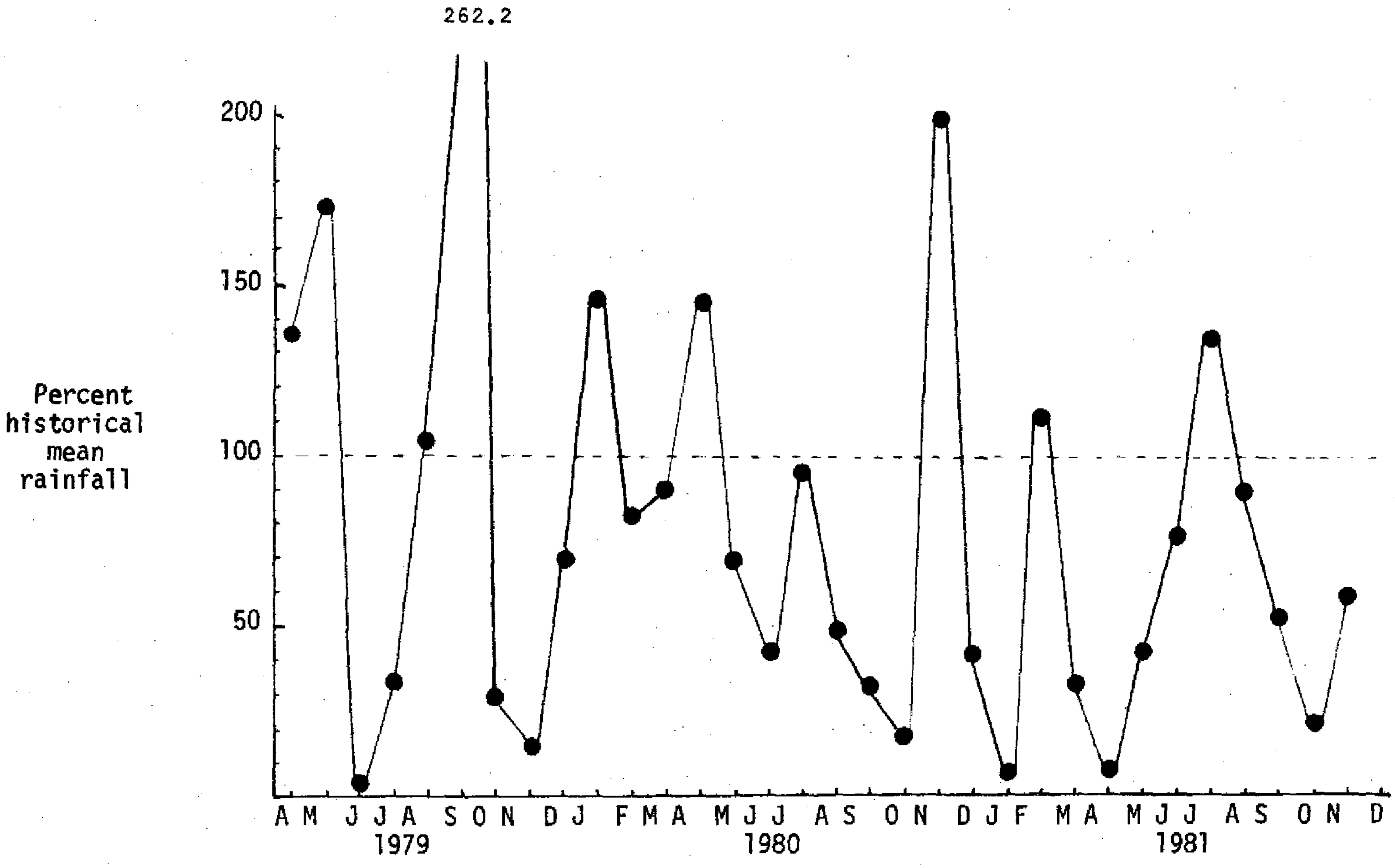


Figure III-1. Wildcat Slough - Percent Historical Average of Monthly Rainfall During Upland Detention/Retention Project Study Period

Table III-3c. Monthly and Annual Rainfall on Upland Demonstration Project Sites 1981

(centimeters)

	Armstrong Slough	Ash Slough	Peavine	SEZ Dairy	Wildcat Slough
January	0.9	0	0	0.6	0.3
February	5.8	7.0	5.8	4.0	5.8
March	3.4	1.5	4.3	0	1.8
April	0	0	0	0	0.3
May	6.7	3.4	4.3	8.5	5.2
June	11.3	5.2	11.3	14.9	14.0
July	11.3	11.9	9.1	15.8	21.9
August	28.0	16.8	14.6	18.6	14.6
September	14.0	10.1	13.7	17.4	8.2
October	5.5	1.2	4.3	0.3	1.5
November	3.4	2.4	7.3	0.3	2.4
December	0	0	0	0	0
Annual Total	90.2	59.4	74.7	80.5	76.2

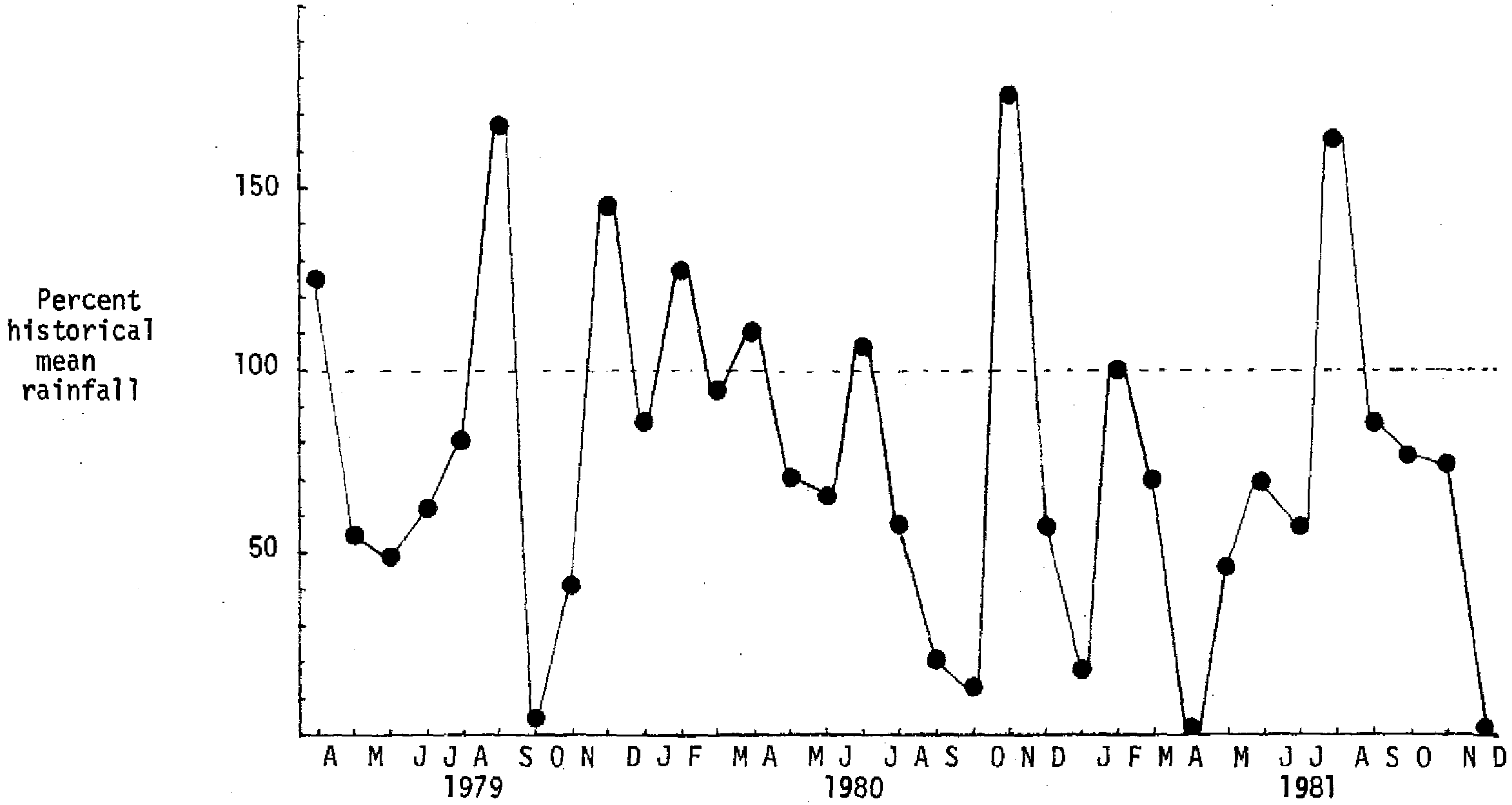


Figure III-3. Armstrong Slough - Percent Historical Average of Monthly Rainfall During Upland Detention/Retention Study Period

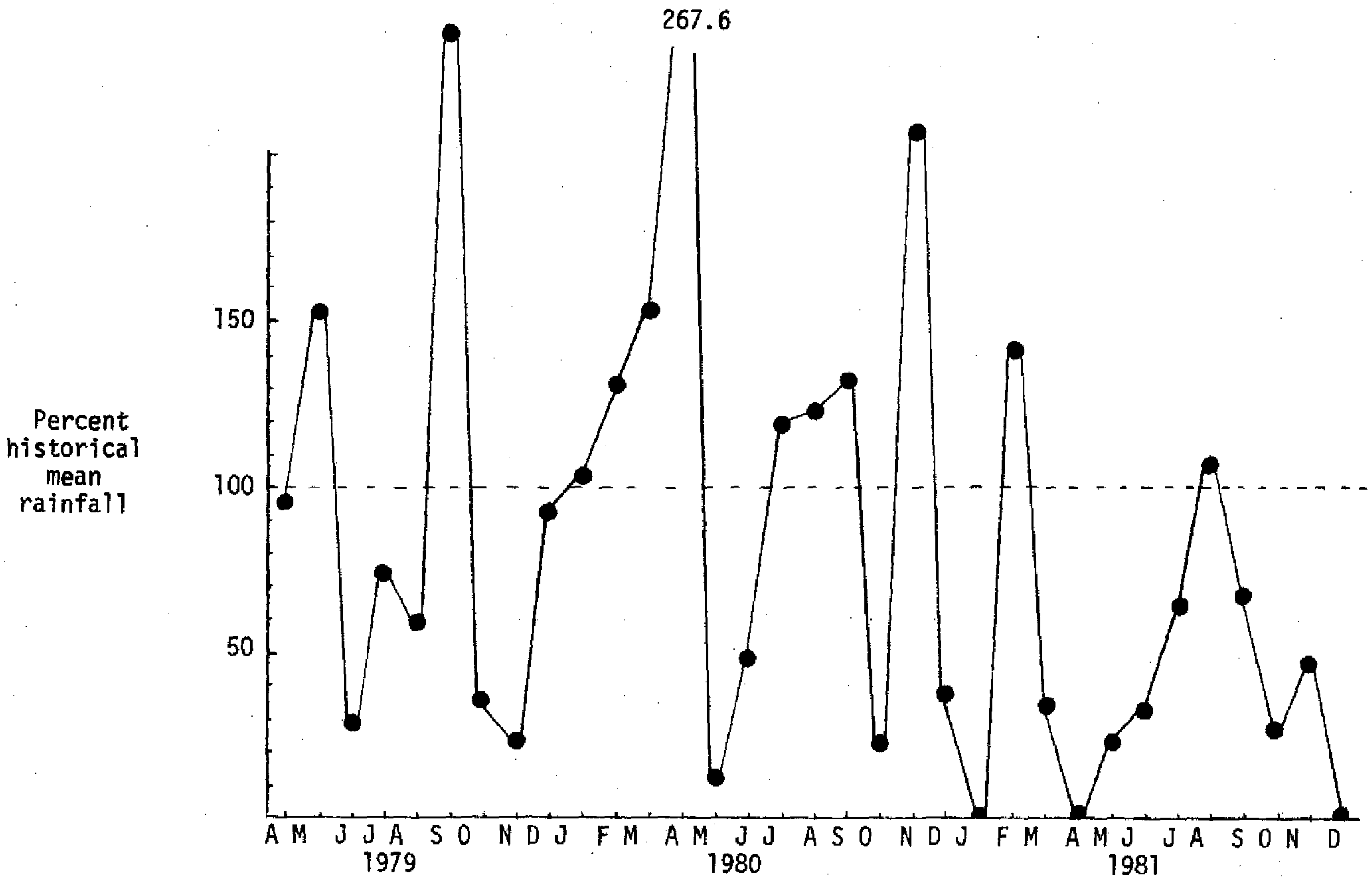


Figure III-2.
Ash Slough - Percent Historical Average of Monthly Rainfall During Upland Detention/Retention Study Period

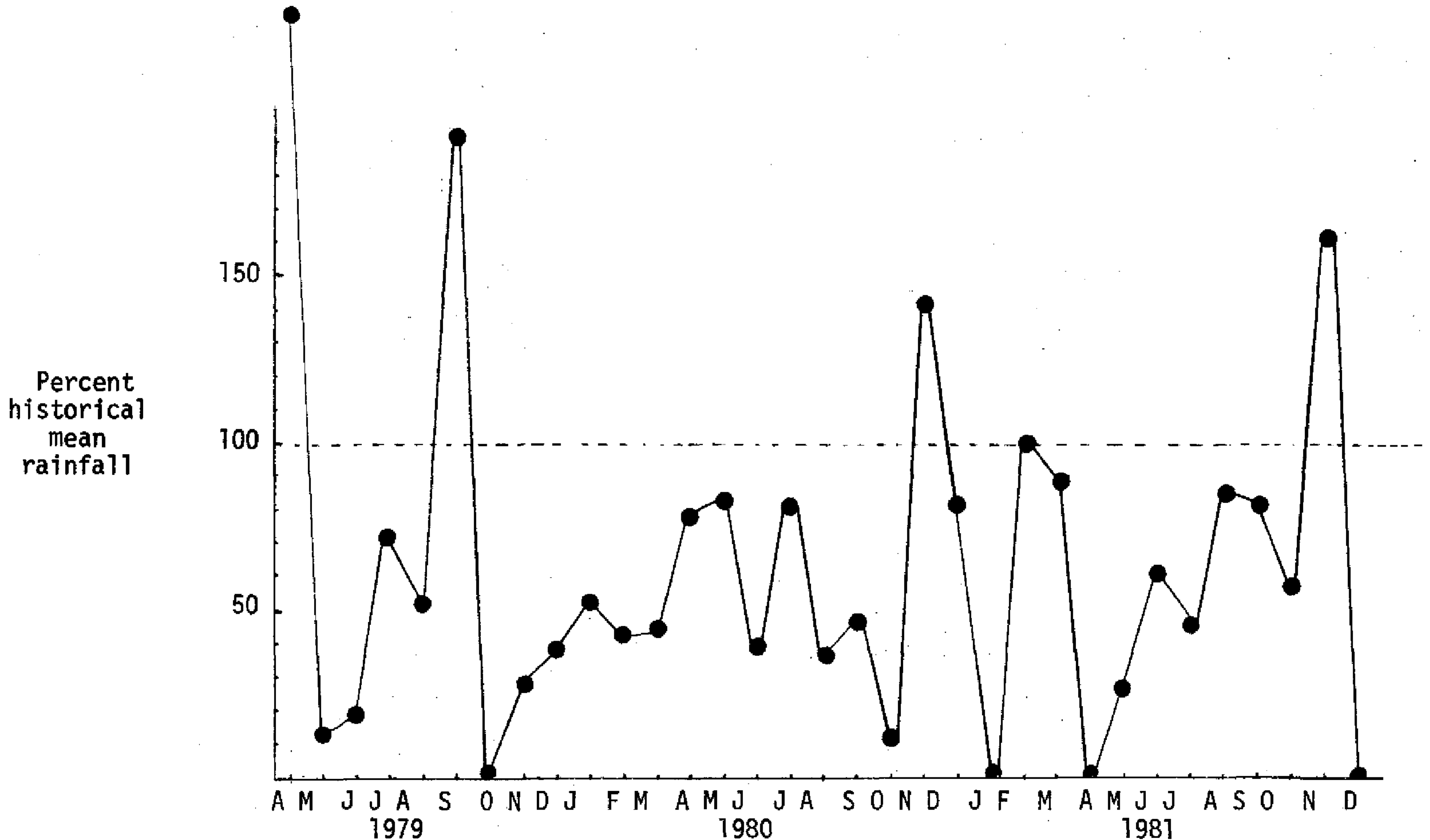


Figure III-4.

Peavine Pasture - Percent Historical Average of Monthly Rainfall During Upland Detention/Retention Project Study Period

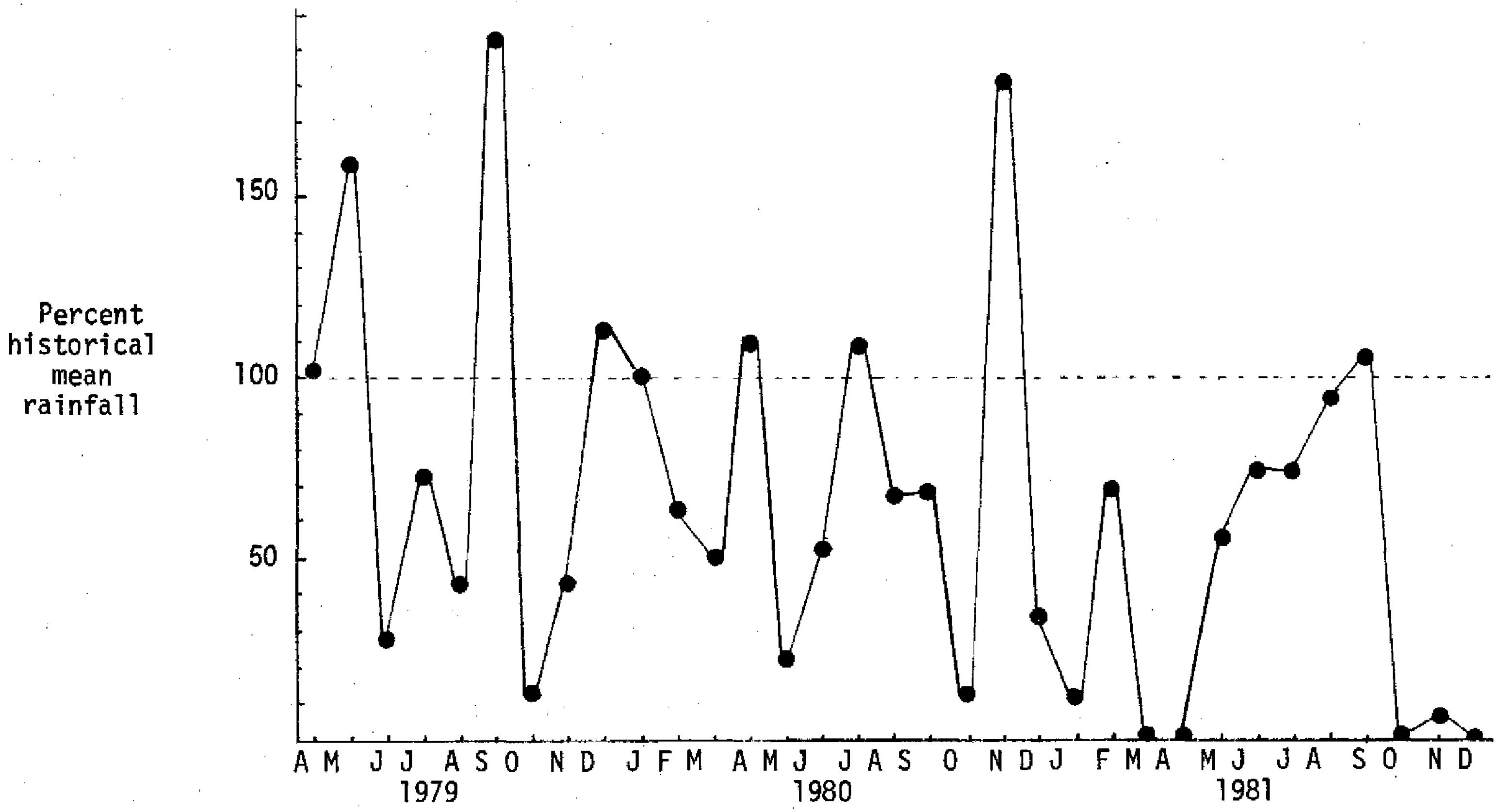


Figure III-5. SEZ Dairy - Percent Historical Average of Monthly Rainfall During Upland Detention/Retention Project Study Period

RESULTS

Rainfall Quantity

Wildcat Slough - Mean annual rainfall in and around the Wildcat Slough study site over the historical period of record has averaged 114.7 cm. Average monthly total rainfall amounts over this period confirm the existence of a distinct wet season where monthly rainfall totals exceed 6.4 cm,and a dry season where monthly rainfall totals are less than 6.4 cm. The wet season runs from May through October,while the remainder of the year constitutes the dry season. Historical average monthly rainfall amounts peak in June at 18.5 cm. Rainfall quantity monitoring at the Wildcat Slough study site began in April 1979 and has continued through the present. During the 33-month period from April 1979-December 1981, monthly rainfall totals at the site were greater than historical means on only 9 occasions, four of these occurring during April through September 1979 (Figure III-1). Beginning in October 1979, total monthly rainfall was less than mean monthly totals on 22 occasions. During the most recent 24 months of the study, total monthly rainfall was greater than the historical average on five occasions, while less than 50 percent of the historical average on 10 occasions. Seven of this latter group occurred during the May through September wet season, resulting in the greatest impact of below normal rainfall. Annual totals during 1980 and 1981 were 77.7 cm and 76.2 cm, respectively, or 67.8 and 66.4 percent of historical mean annual rainfall at this site.

Ash Slough - Mean annual rainfall calculated from monitoring stations in the vicinity of the Ash Slough study site totaled 116.0 cm. Historical mean monthly rainfall totals depict a distinct five-month wet season (May through September) when monthly rainfall totals average greater than 14.7 cm.

During the remaining seven months, mean rainfall totals fail to exceed 5.5 cm. Rainfall quantity monitoring began at the study site in April 1979 and has continued through the present. During this 33-month period, monthly rainfall totals have exceeded historical means on 13 occasions (Figure III-2). During 19 of the remaining 20 months, total rainfall was substantially less than average. Annual rainfall totals for the April-December 1979 and 1980 calendar year periods were 99.0 and 94.4 percent of the historical mean totals for the 9-month and 12-month periods, respectively. Rainfall totals at Ash Slough during 1981 reflected the record drought recorded throughout south Florida during this period. Total 1981 rainfall on the site was 59.4 cm,or approximately 51.3 percent of the historical mean annual total.

Armstrong Slough - Historical mean annual rainfall at the monitoring stations around the Armstrong Slough site is 120.7 cm. The typical south Florida wet/dry seasonal pattern as described earlier is repeated again here. May through September constitutes the wet months with average monthly rainfall totals from 14.9 cm to 20.0 cm. Mean monthly rainfall for the remaining seven months does not exceed 7.2 cm. Rainfall measured at the study site was below the normal 120.7 cm for the period April to December 1979 (80.5 percent) and calendar years 1980 and 1981 (74.8 percent of normal both years) (Figure III-3). Below normal monthly totals occurred during 24 of the 33 months of record. On only two occasions in 1981 was total monthly rainfall at or above the historical mean. During three months of the wet season, monthly rainfall totals were less than 61 percent of the normal amount expected.

Peavine Pasture - Historical rainfall monitoring records for the Peavine Pasture area are the same as those obtained at the SFWMD rainfall monitoring stations described for Armstrong Slough. The annual and monthly rainfall totals and trends obtained over the historical period of record are described in the above section. Monthly rainfall totals measured at the study site were below historical averages for the three periods April-December 1979, and calendar years 1980 and 1981 (75.1, 59.4, and 61.9 percent, respectively). Monthly rainfall totals were less than historical averages during 28 of the 33-months study period (Figure III-4). There was only one month (September 1979) during the wet seasons of the three years study when rainfall exceeded the historical monthly average. The more abundant rain at that time was associated with Hurricane David.

SEZ Dairy - Historically, the area including the SEZ Dairy has been the wettest of the Upland D/R Project study sites. Historical mean annual rainfall total is 133.6 cm. May through September are the wet months, with historical monthly mean rainfall totals ranging from 15.5 cm to 21.2 cm., while average monthly rainfall totals for the remainder of the year range from 4.2 to 7.7 cm. During the period of study, rainfall totals at the site for the period April-December 1979, and calendar years 1980 and 1981 were 86.0, 68.0, and 60.2 percent of the historical means for those time periods. Monthly rainfall totals were less than historical averages during 24 of the 33 months (Figure III-5). During 1981, total rainfall exceeded historical averages on only one occasion. During three months of the year, no rainfall at all was recorded at the site.

Rainfall Quality

As previously described, rainfall quality data typical of the study area was obtained by compiling quality data from three stations located in the Upland D/R Project area (S-65B and S-65D, both located on the Kissimmee River (C-38 canal), and the SFWMD's Okeechobee Field Station). Mean concentrations, ranges, and number of data points for each parameter of interest is depicted in Table III-4. "Rainfall", as used here, is defined as the total of all wet fall and dry fall (dust, debris, etc.) components that accumulate in the rainfall collection bottles.

As a trend, rainfall quality as measured by mean concentrations of nitrogen and phosphorus species appears to become cleaner as one moves south in the Upland Project study area. The mean pH is also somewhat lower at the southernmost collection station. Statistical comparison of the mean concentrations of each parameter at each station, with the mean concentrations of similar parameters at each of the other two stations by using a Student's t-test, failed to show any statistically significant differences. As can be gathered from looking at the range of concentrations recorded for each parameter, the variability factor is fairly large.

Given the absence of any better method, "typical" concentrations of nitrogen and phosphorus species that could be consistently attributed to the rainfall over the project area was arrived at by averaging the mean value of each parameter of interest among the three monitoring locations within the project area. Concentrations of nitrogen and phosphorus parameters in rainfall considered "typical" in the Upland D/R Project area are: 0.70 mg/l dissolved inorganic nitrogen (NO_x + NH_4), 1.69 mg/l total nitrogen (both as nitrogen), and 0.094 mg/l ortho phosphorus, and 0.138 mg/l total phosphorus (both as phosphorus). The predominance of both nitrogen and phosphorus in dissolved form suggests that contributions of these nutrients as particulates (dry fall or washout) is of lesser but not insignificant importance.

Though there exists a wide range between the maxima and minima in the individual station data, mean concentrations at each station compare favorably with other rainfall quality data appearing in the literature

Table III-4. Rainfall Quality Data Summary

S-65D

1979 - 1982

	NOx + NH4	Total N	O-PO4	T-PO4	pH
Mean	0.74	1.56	0.101	0.149	6.39
Range	0.07-2.96	0.27-5.12	0.004-0.655	<.010-0.845	4.44-8.24
No. of Observations	57	50	56	53	57

S-65B

1974 - 1982

	NOx + NH4	Total N	O-PO4	T-PO4	pH
Mean	0.88	2.42	0.151	0.220	
Range	0.03-6.80	0.21-11.91	0.002-1.296	0.003-2.036	
No. of Observations	163	136	182	171	

Okeechobee Field Station

1975 - 1982

	NOx + NH4	Total N	O-PO4	T-PO4	pH
Mean	0.49	1.10	0.029	0.046	5.61
Range	0.091-1.34	0.21-2.61	0.002-0.207	0.005-0.234	3.73-8.99
No. of Observations	91	78	92	87	51

(Table III-5), particularly with other data collected in the south Florida area. In an extensive analysis of the climatology of the Kissimmee River-Lake Okeechobee watershed, Echternacht (1975) concluded that, in general, minimum nitrogen and phosphorus concentrations occurred during the wet season. He also suggested that the large degree of variability noted in measurements of individual parameters was due to the temporal/spacial nature of the predominant rainfall patterns in the basin as well as the multiple potential sources of nutrients both in and outside of the watersheds. Analyses of the data collected at S-65D during the course of this study fail to show any statistically significant seasonal differences in either NO_x or $T\text{-}PO_4$ concentrations. The aforementioned observation that these data suggested an apparent north to south gradient of decreasing concentrations of nitrogen and phosphorus in rainfall in the Kissimmee River basin does support the observations by Davis and Wisniewski (1975) of similar trends throughout the south Florida area.

LOADING RATES

Loading rates in kg/ha/yr have been calculated for the Upland Demonstration Project sites. These rates are best estimates of "long-term" conditions as they were computed using both historical mean annual precipitation for the specific project area and typical mean concentrations of nutrient species of interest in rainfall. The rationale and methodology used to arive at these figures is described earlier in this Section. Typical expected annual loading rates of nitrogen and phosphorus on the project study watersheds are presented in Table III-6.

Comparison of mean annual loading rates, calculated for the Upland D/R Project sites with others found in the literature, indicates that on a per unit area basis, total nitrogen and total phosphorus loadings in

Table III-5. Concentrations of Selected Nutrient Species Reported in Precipitation (mg/l)

Source	Location	NOx	NH3	Total N	Ortho P	Total P	Date of Collection
Nicholls & Cox, 1978	Harp Lake, Ontario, Canada			1.91		0.105	1974
Haines, 1976	Georgia coast		0.135	0.234			
Echternacht, 1975	Fla. peninsula		0.15-1.255		.002-.074	.052-.124	Summer, 1972
Zoltec, et al., 1979	Winter Garden, Florida				0.03	0.04	05/77 - 02/78
"	Lake Apopka, Florida				0.008	0.014	03/78 - 05/79
Davis & Wisniewski, 1975	South Florida	.158-.341				.003-1.428	07/74 - 09/74
Davis	South Florida		0.17-2.20		.002-.200	.022-.304	Range of seasonal averages 1972-1973
Joyner, 1974	Lake Okeechobee			0.90		0.056	1969-1970
Brezonik, et al., 1969	Central Florida		0-0.86		.002-.230	.02-.07	02/68 - 12/68
Present Study*	Kissimmee River Basin	.261-.313	.24-.65	1.10-2.42	.029-.151	.046-.220	1974-1978

*Range of mean concentrations observed at rainfall collection stations in project study area.

Table III-6. Typical Historical Loading Rates Attributed to Precipitation On Upland D/R Project Study Sites for Entire Period of Record

(kg/ha/yr)

	NOx + NH4	Total N	Ortho P	Total P
Armstrong Slough	8.45	20.40	1.13	1.67
Ash Slough	8.12	19.60	1.09	1.60
Wildcat Slough	8.03	19.38	1.08	1.58
Peavine Pasture	8.45	20.40	1.13	1.67
SEZ Dairy	9.35	22.58	1.26	1.84

the Kissimmee River basin study area are generally of the same order of magnitude but somewhat greater than those calculated at many other locations (Table III-7). In general, these data compare favorably with loadings calculated by Zoltec, et al. (1979), in a study done of an area just north of the Kissimmee Lakes basin in central Florida. Since loading rates for nutrients attributable to rainfall are a function of both rainfall amounts and rainfall quality, it is not surprising to find the best agreement with data collected at close proximity to the project area. Loading rates calculated for the current study period January-December 1981 (Table III-8) reflect the dry conditions that prevailed during that time and range from 51 to 75 percent of those based on historical mean annual rainfall.

Watershed Nutrient Loadings - 1981

Using mean nutrient concentrations in rainfall and monthly rainfall totals measured during 1981, an estimate was made of monthly and total annual nutrient loading on each watershed in the Upland D/R Project area. These data are presented in Tables III-9a through III-9e.

With the exception of Wildcat Slough, maximum nutrient loads on each watershed occurred during August. At Wildcat Slough, maximum loads were estimated to have occurred in July. During months when no measurable rainfall occurred, aeolian loadings on the watershed were considered to be nonexistent. These data will be used to compute watershed and detention site nutrient budgets for 1981.

Table III-7. Loading Rates for Selected Nitrogen and Phosphorus Species Reported in the Literature (kg/ha/yr)

LOCATION	TOTAL P	ORTHO P	TOTAL N	NH4$^+$	NO3$^-$	NOx	SOURCE
Lake Valencia	1.68		7.45	2.43			Lewis, 1981
Brazil, Amazon basin	0.27		9.95	3.15	2.52		"
Venezuela, Amazon basin				21.4			"
Africa, Uganda and West Coast	1.20		19.1	6.6	4.9		"
Hubbard Brook, New Hampshire	0.06			2.26	4.3		"
Como Creek, Colorado	0.26		4.80	1.04	1.62		"
Ontario, Canada	0.32		6.35				"
Ontario, Canada	0.744		16.00				Nicholls & Cox, 1978
Mays Point, New York				2.12	0.38		Reuss, 1978
Winter Garden, Fla.	0.496	0.392					Zoltec, et al., 1979
Lake Apopka, Fla.	0.656	0.340					"
Clermont, Fla.			11.23	1.87		3.44	"
Kissimmee Sites	0.94-1.73	0.46-.084	12.9-25.5	~1.0-7.0			Goldstein, 1981

Table III-8. Nutrient Loading Rates Attributed to Precipitation
On Upland D/R Project Study Sites During 1981

(kg/ha/yr)

	NOx + NH4	Total N	Ortho P	Total P
Armstrong Slough	6.31	15.24	0.85	1.24
Ash Slough	4.16	10.04	0.56	0.82
Wildcat Slough	5.33	12.88	0.72	1.05
Peavine Pasture	5.23	12.62	0.70	1.03
SEZ Dairy	5.64	13.60	0.76	1.11

Table III-9a. Monthly Nutrient Loads Attributed to Rainfall at Armstrong Slough.
(kgs)

January-June 1981

	January	February	March	April	May	June
North Branch Watershed (Station 2)						
Inorganic N	518.1	3,281.2	1,899.2	0	3,799.3	6,389.7
Total N	1,250.8	7,921.7	4,586.3	0	9,172.5	15,426.5
Ortho P	69.5	440.6	255.1	0	510.2	858.0
Total P	102.1	646.9	374.5	0	749.0	1,259.7
South Branch Watershed (Station 3)						
Inorganic N	51.8	328.1	189.9	0	379.9	639.0
Total N	125.0	792.2	458.6	0	917.3	1,542.6
Ortho P	7.0	44.1	25.5	0	51.0	85.8
Total P	10.2	64.7	37.4	0	74.9	126.0
Ungauged Watershed (Marsh Area)						
Inorganic N	11.7	74.2	42.9	0	85.9	144.5
Total N	28.3	179.1	103.7	0	207.4	348.8
Ortho P	1.6	10.0	5.8	0	11.5	19.4
Total P	2.3	14.6	8.5	0	16.9	28.5

Table III-9a. Monthly Nutrient Loads Attributed to Rainfall at Armstrong Slough, 1981.
(continued) (kgs)

July-December 1981 and Annual Totals

	July	August	September	October	November	December	ANNUAL TOTALS
North Branch Watershed (Station 2)							
Inorganic N	6,389.7	15,887.8	7,943.9	3,108.5	1,899.6	0	51,117.4
Total N	15,426.5	38,357.8	19,178.9	7,504.8	4,586.3	0	123,412.1
Ortho P	858.0	2,133.5	1.066.8	417.4	255.1	0	6,094.2
Total P	1,259.7	3,132.2	1,566.1	612.8	374.5	0	10,077.5
South Branch Watershed (Station 3)							
Inorganic N	639.0	1,588.8	794.4	310.8	190.0	0	5,110.8
Total N	1,542.6	3,835.8	1,917.9	750.5	458.6	0	12,341.1
Ortho P	85.8	213.3	106.7	41.7	25.5	0	686.4
Total P	126.0	313.2	156.6	61.3	37.4	0	1,007.7
Ungauged Watershed (Marsh Area)							
Inorganic N	144.5	359.2	179.6	70.3	42.9	0	1,155.7
Total N	348.8	867.2	433.6	169.7	103.7	0	2,790.3
Ortho P	19.4	48.2	24.1	9.4	5.8	0	155.2
Total P	28.5	70.8	35.4	13.9	8.5	0	227.9

Table III-9b. Monthly Nutrient Loads Attributed to Rainfall at Ash Slough.
(kgs)

	January-June 1981					
	January	February	March	April	May	June
West Ditched Pasture						
Inorganic N	0	30.9	6.7	0	14.8	22.9
Total N	0	74.6	16.2	0	35.7	55.2
Ortho P	0	4.2	0.9	0	2.0	3.1
Total P	0	6.1	1.3	0	2.9	4.5
East Unditched Pasture	0	5.4	1.2	0	2.6	4.0
Inorganic N	0	5.4	1.2	0	2.6	4.0
Total N	0	13.0	2.8	0	6.2	9.6
Ortho P	0	0.7	0.2	0	0.3	0.5
Total P	0	1.1	0.2	0	0.5	0.8
Marsh (Ungauged) Area						
Inorganic N	0	10.3	2.2	0	0.9	1.3
Total N	0	24.9	5.4	0	2.1	3.2
Ortho P	0	1.4	0.3	0	0.1	0.2
Total P	0	2.0	0.4	0	0.2	0.3

Table III-9b. Monthly Nutrient Loads Attributed to Rainfall at Ash Slough, 1981.
(continued) (kgs)

July-December 1981 and Annual Totals

	July	August	September	October	November	December	ANNUAL TOTALS
West Ditched Pasture							
Inorganic N	52.4	73.9	44.4	5.4	10.8	0	262.2
Total N	126.6	178.5	107.1	13.0	26.0	0	632.9
Ortho P	7.0	9.9	6.0	0.7	1.4	0	35.2
Total P	10.3	14.6	8.7	1.1	2.1	0	51.6
East Unditched Pasture							
Inorganic N	9.1	12.9	7.8	9.4	1.9	0	54.3
Total N	22.1	31.2	18.7	2.3	4.5	0	110.4
Ortho P	1.2	1.7	1.0	0.1	0	0	5.7
Total P	1.8	2.5	1.5	0.2	0.4	0	9.0
Marsh (Ungauged) Area							
Inorganic N	3.0	4.3	2.6	3.1	0.6	0	28.3
Total N	7.4	10.4	6.2	7.1	1.5	0	68.2
Ortho P	0.4	0.6	0.3	<0.1	0	0	3.4
Total P	0.6	0.8	0.5	<0.2	0.1	0	5.1

Table III-9c. Monthly Nutrient Loads Attributed to Rainfall at Wildcat Slough.
(kgs)

Janary-June 1981

	January	February	March	April	May	June
East Branch Watershed (Station 3)						
Inorganic N	54.8	1,043.7	334.1	57.3	936.4	2,542.5
Total N	132.4	2,519.8	806.5	138.3	2,260.7	6,138.2
Ortho P	7.4	140.1	44.9	7.7	125.7	341.4
Total P	10.8	205.8	65.9	11.3	184.6	501.2
West Branch Watershed (Station 2)						
Inorganic N	36.6	696.3	222.9	38.2	624.7	1,696.3
Total N	88.3	1,681.1	538.1	92.3	1,508.3	4,095.3
Ortho P	4.9	93.5	29.9	5.1	83.9	227.8
Total P	7.2	137.3	44.0	7.5	123.2	334.4
Ungauged Watershed Upstream C-41A						
Inorganic N	44.6	849.1	271.8	46.6	761.8	2,068.5
Total N	107.7	2,050.1	656.2	112.5	1,839.2	4,994.0
Ortho P	6.0	114.0	36.5	6.3	102.3	277.8
Total P	8.8	167.4	53.6	9.2	150.2	407.8

Table III-9c. Monthly Nutrient Loads Attributed to Rainfall at Wildcat Slough.
(continued) (kgs)

July-December 1981 and Annual Totals

	July	August	September	October	November	December	ANNUAL TOTALS
East Branch Watershed (Station 3)							
Inorganic N	3,977.8	2,647.9	1,481.00	275.3	437.9	0	13,788.7
Total N	9,603.6	6,392.9	3,575.6	664.6	1,057.1	0	33,289.7
Ortho P	534.2	355.6	198.9	37.0	58.8	0	1,851.7
Total P	784.2	522.0	291.9	54.3	86.3	0	2,718.3
West Branch Watershed (Station 2)							
Inorganic N	2,653.9	1,766.6	988.1	183.7	292.1	0	9,199.4
Total N	6,407.4	4,265.2	2,385.6	443.4	705.3	0	22,210.3
Ortho P	356.4	237.3	132.7	24.7	39.2	0	1,235.4
Total P	523.2	348.3	194.8	36.2	57.6	0	1,813.7
Ungauged Watershed Upstream C-41A							
Inorganic N	3,236.3	2,154.3	1,204.9	224.0	356.2	0	11,218.1
Total N	7,813.4	5,201.2	2,909.1	540.7	860.0	0	27,084.1
Ortho P	434.6	289.3	161.8	30.1	47.8	0	1,506.5
Total P	638.0	424.7	237.6	44.2	70.2	0	2,211.7

Table III-9d. Monthly Nutrient Loads Attributed to Rainfall at Peavine Pasture, 1981.
(kgs)

	January	February	March	April	May	June
Inorganic N	0	98.5	72.6	0	72.6	191.8
Total N	0	237.8	175.2	0	175.2	463.1
Ortho P	0	13.2	9.7	0	9.7	25.8
Total P	0	19.4	14.3	0	14.3	37.8

	July	August	September	October	November	December	ANNUAL TOTALS
Inorganic N	155.5	248.9	233.3	72.6	124.4	0	1,270.2
Total N	375.5	600.8	563.3	175.2	300.4	0	3,066.5
Ortho P	20.9	33.4	31.3	9.7	16.7	0	170.4
Total P	30.7	49.1	46.0	14.3	24.3	0	250.2

Table III-9e. Monthly Nutrient Loads Attributed to Rainfall at SEZ Dairy, 1981.
(kgs)

	January	February	March	April	May	June
Inorganic N	14.1	91.5	0	0	197.1	345.0
Total N	34.0	221.0	0	0	476.0	832.9
Ortho P	1.9	12.3	0	0	26.5	46.3
Total P	2.8	18.0	0	0	38.9	68.0

	July	August	September	October	November	December	ANNUAL TOTALS
Inorganic N	366.1	429.5	401.3	7.0	17.0	0	1,858.6
Total N	883.9	1,036.9	968.9	17.0	17.0	0	4,487.6
Ortho P	49.2	57.7	53.9	0.9	0.9	0	249.6
Total P	72.2	84.7	79.1	1.4	1.4	0	366.5

SECTION IV

EFFECTS OF AGRICULTURAL PRACTICES ON WATER QUALITY

INTRODUCTION

The five Upland D/R Project site locations are depicted in Figures IV-1 through IV-5. Detailed site descriptions are provided in previous annual reports to the KRVCC and will not be included in this report. Details pertaining to the land uses of the study sites are presented in Table IV-1. The first part of this section will contain a description of the trends depicted by the time series water quality data collected at each site during 1981. The second major section will provide details of the 1981 water and nutrient budgets calculated for each study site. The last section will describe results of groundwater quality monitoring activities.

WATER QUALITY MONITORING

The dominant factor during 1981 was the severe drought that occurred during the calendar year. Rainfall on the project watersheds ranged from roughly half the historical annual average at Ash Slough to about 75 percent of the historical annual average at Armstrong Slough. The Peavine, SEZ, and Wildcat Slough sites had roughly 60 percent of the historical average annual total. The reduced rainfall on the watersheds resulted in lower groundwater tables and less surface runoff when rainfall did occur.

At one of the Wildcat Slough monitoring stations, discharge from rainwater runoff failed to occur even once during 1981. At all other study sites, it was significantly reduced. The lack of rainfall and runoff makes evaluation of impacts of land use practices difficult and probably unreliable. Data will be presented here, but general conclusions of land use impacts based on these should be made only with caution.

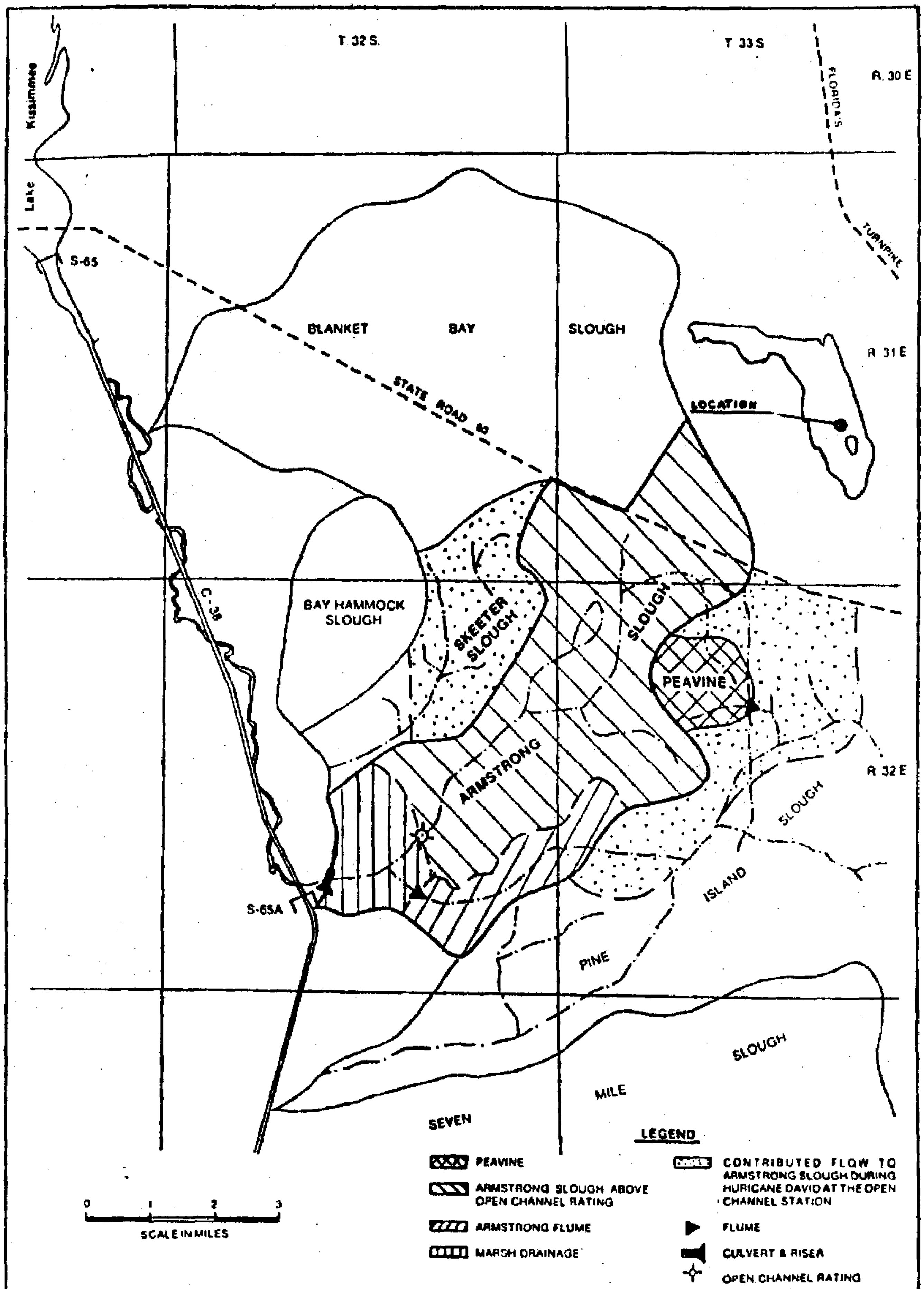


Figure IV-1. DRAINAGE PATTERN ARMSTRONG SLOUGH - PEAVINE PASTURE AREA

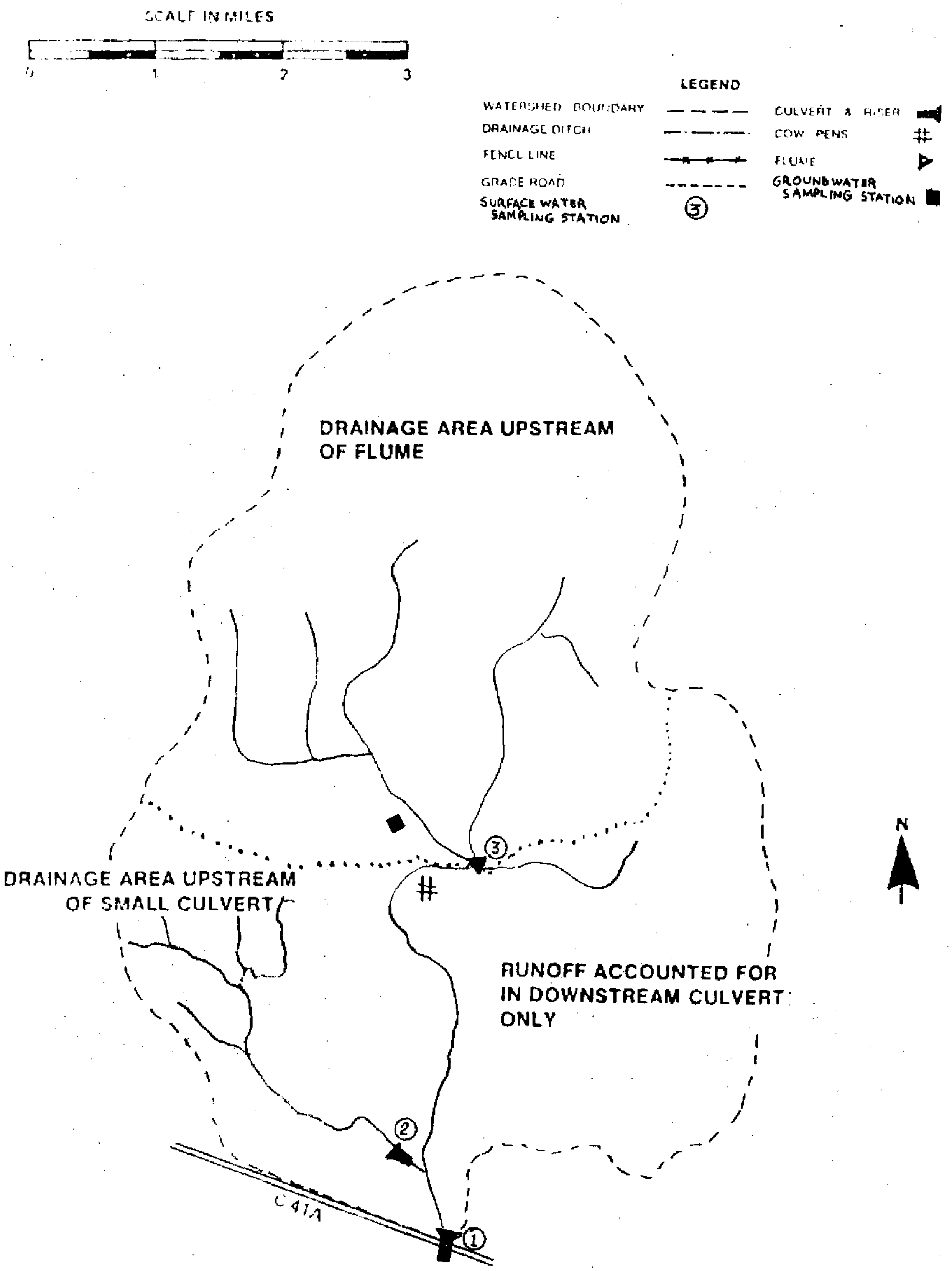


Figure IV-2.

WILDCAT SLOUGH
BRIGHTON RANCH
LYKES BROS.
INC.

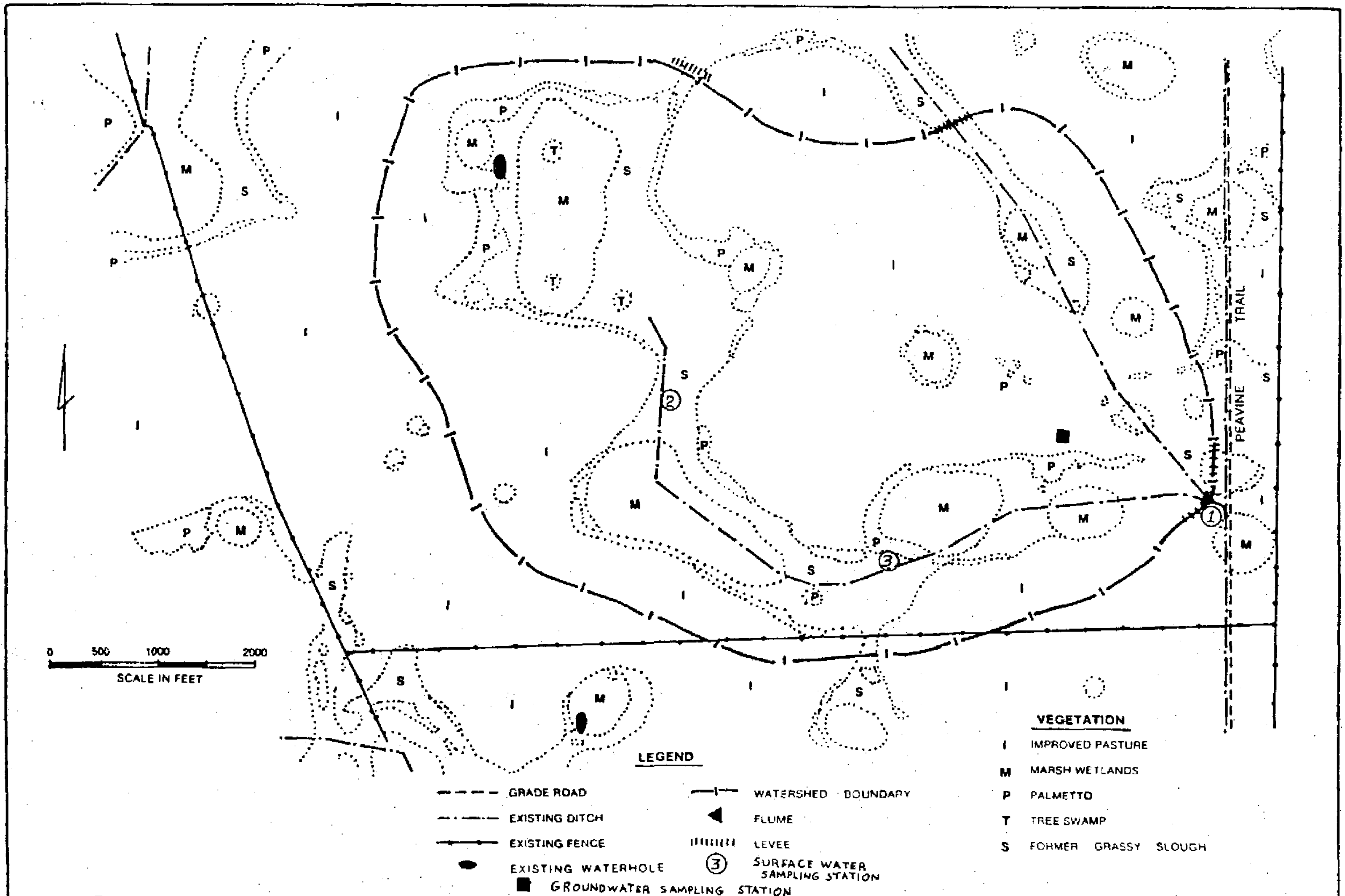


Figure IV-3. PEAVINE IMPROVED PASTURE, EL MAXIMO RANCH, LATT MAXCY CORP.

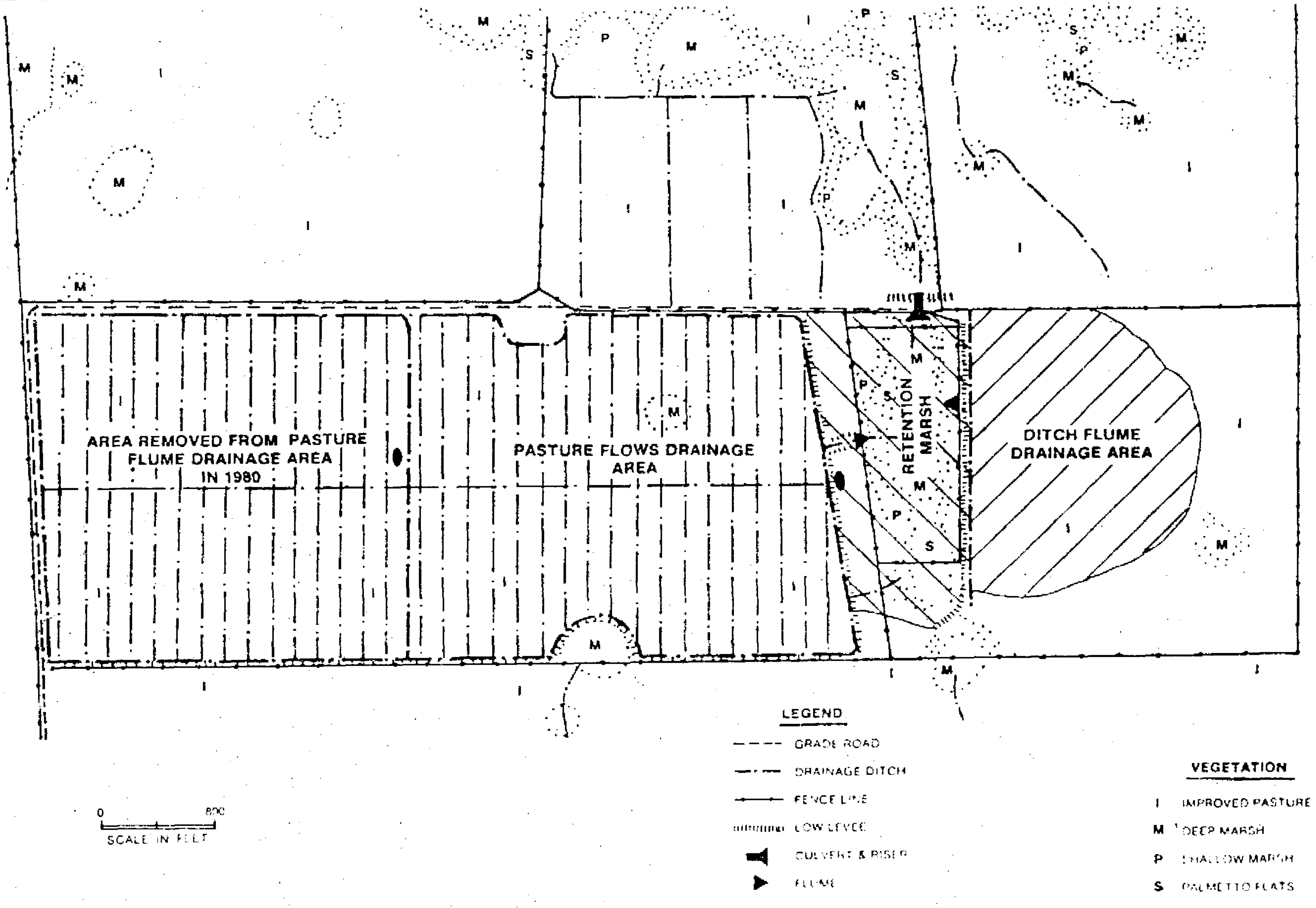


Figure IV-4. ASH SLOUGH, BASS RANCH

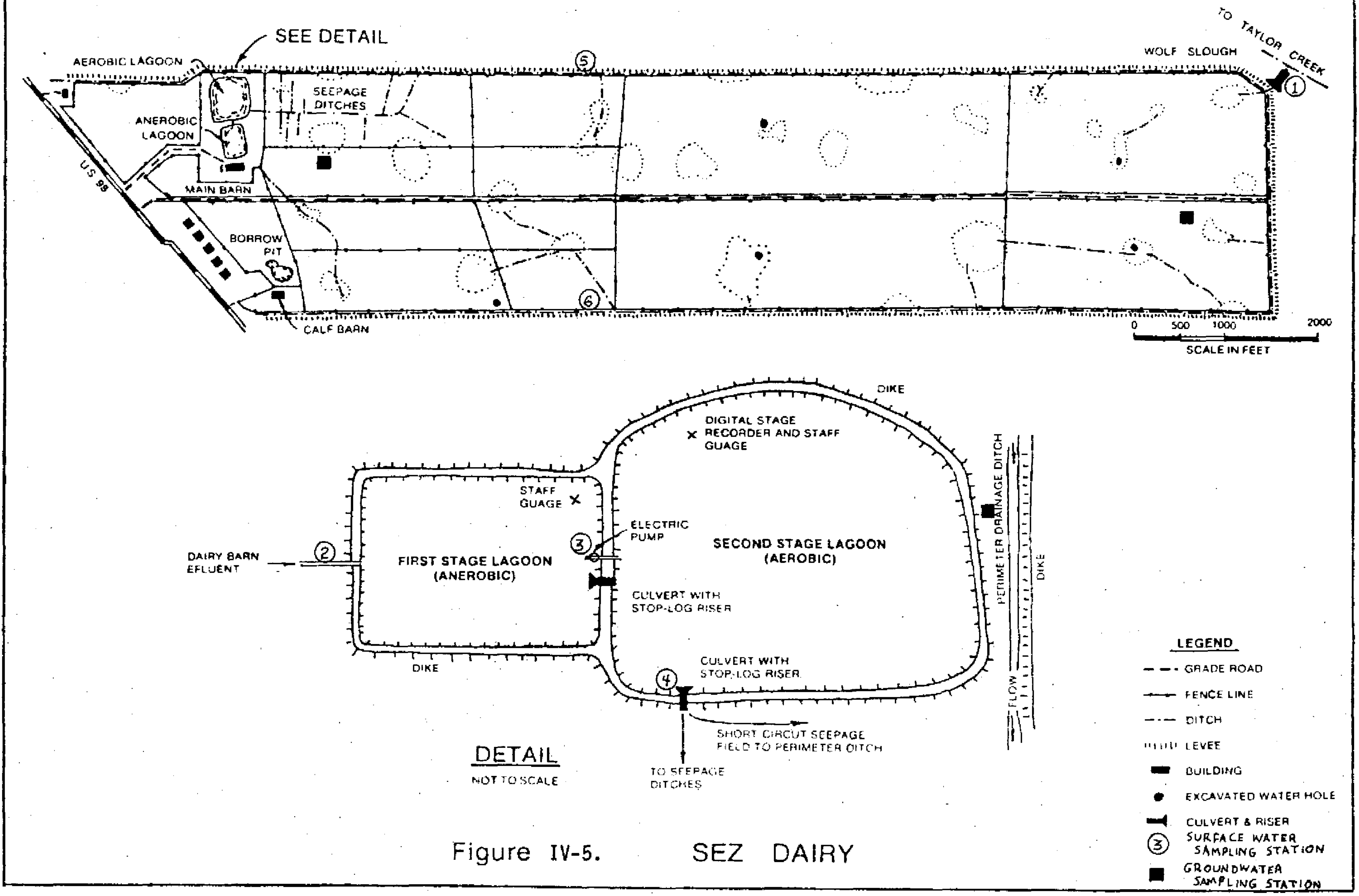


Figure IV-5. SEZ DAIRY

Table IV-1

Upland Demonstration Project

Project Sites - Areas - Land Uses

Project Site	Area	Use	Cattle Density
Wildcat Slough	6,400 acres (260 ha)	Native Range	1 cow/20 acres
Ash Slough-East	26 acres (10.5 ha)	Improved Pasture	1 cow/3 acres
Ash Slough-West	156 acres (63 ha)	Ditched - Improved Pasture	1 cow/3 acres
Peavine Pasture	600 acres (243 ha)	Improved Pasture	1 cow/5 acres
Armstrong-North	20,000 acres (8,100 ha)	Improved Pasture - Citrus	1 cow/5 acres
Armstrong-South	2,000 acres (810 ha)	Native Range	1 cow/5 acres
SEZ Dairy	817 acres (331 ha)	Dairy - Hay	1 cow/1.2 acres

ARMSTRONG SLOUGH

Time series data collected at Armstrong Slough are plotted in Figures IV-6 through IV-10. Conductivities in discharge from the north watershed (station 2) exhibit seasonal trends with highest concentrations occurring during December through June. Lower concentrations occur during the wet season, late June through November. This trend has been identified in previous data analyses and has been attributed to groundwater irrigation activity at a large citrus grove in the upper part of the watershed. During the dry season, irrigation runoff is probably the major source of flow in the north tributary channel. With the exception of brief spikes that occur in June and August, conductivity in the south channel remains constant and somewhat lower than the lowest concentrations from the north watershed. The June spike is attributed to concentration of salts due to the evaporation of water ponded behind the flume at that time. The August spike is either an incorrect data point or some anomaly associated with a "first flush" phenomenon that appeared to occur during that time. In either case, its appearance is not considered representative of typical conductivity levels associated with land uses at this site. Indeed, this one data point is the highest conductivity ever recorded at this site.

Total nitrogen concentrations increased dramatically during the wet season beginning in late June and peaking in late July and early August. Concentrations decreased to pre-June levels in December. These wet season high concentrations of total N were the highest measured at this station to date during the study period. There seems to be a seasonal trend in total N concentration which results in peaks during August-September and lows in December-January of each year, 1979-81. Inorganic N concentrations exhibit similar seasonal trends in that peaks have been observed in July-

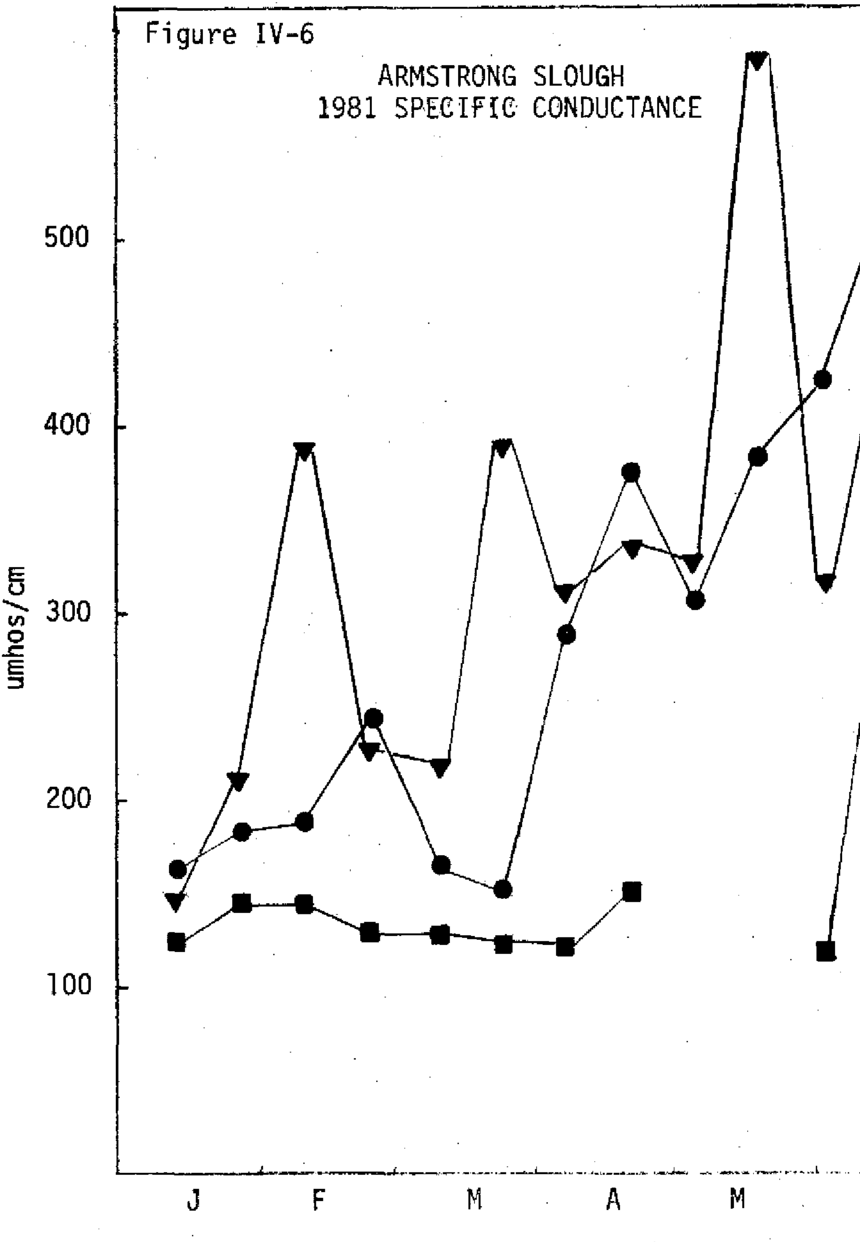
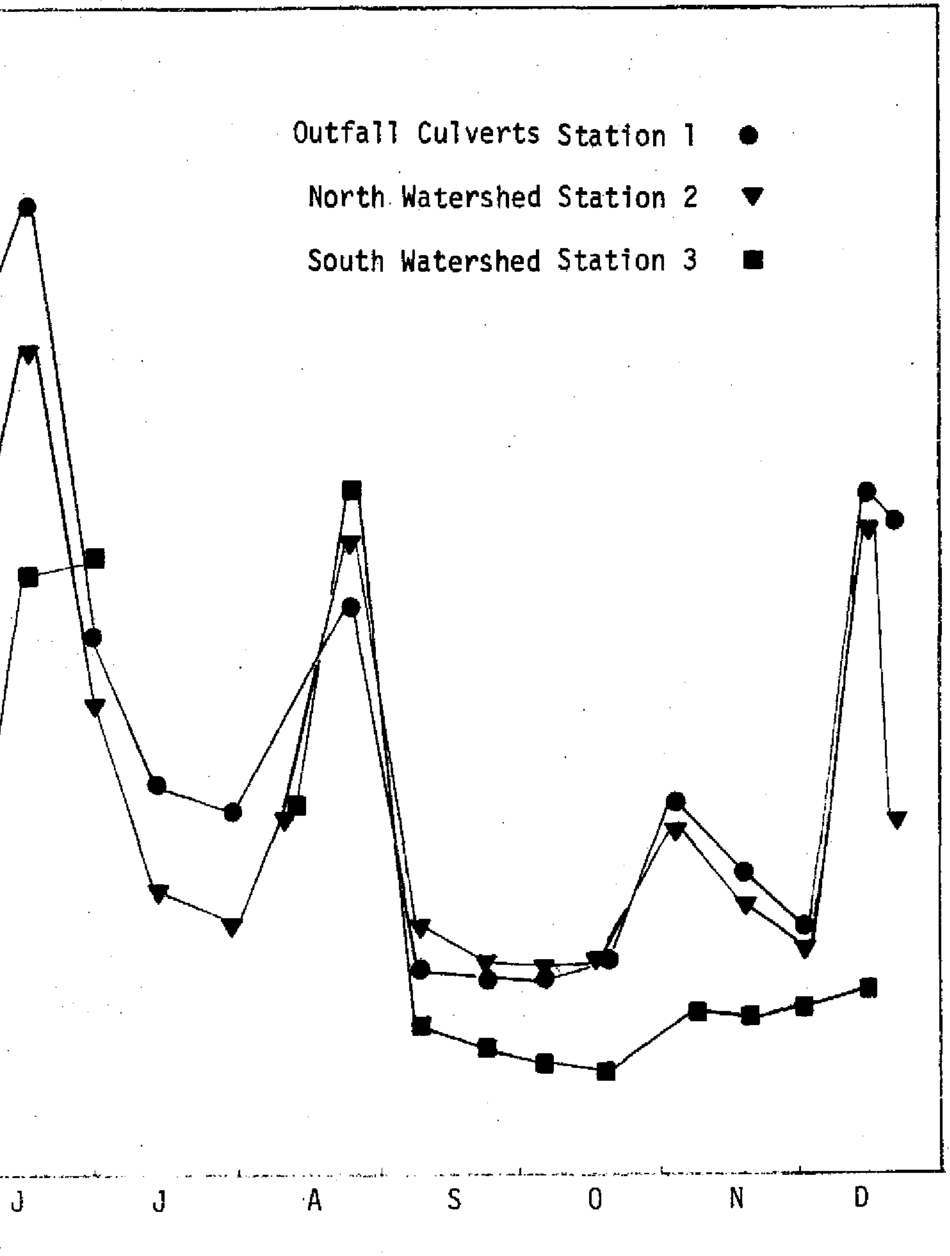


Figure IV-6

ARMSTRONG SLOUGH
1981 SPECIFIC CONDUCTANCE


Outfall Culverts Station 1 ●
North Watershed Station 2 ▼
South Watershed Station 3 ■
J
J
A
S
O
N
D

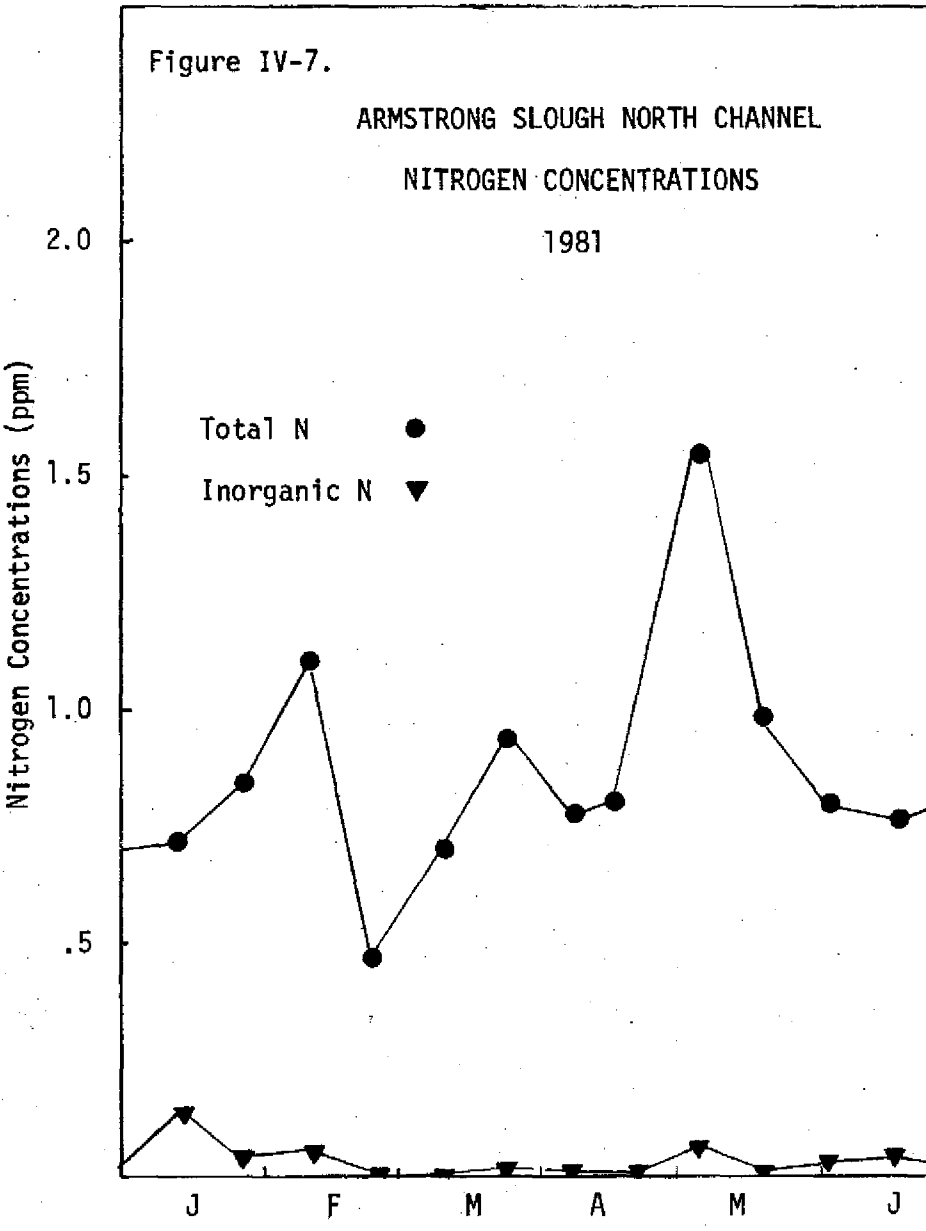
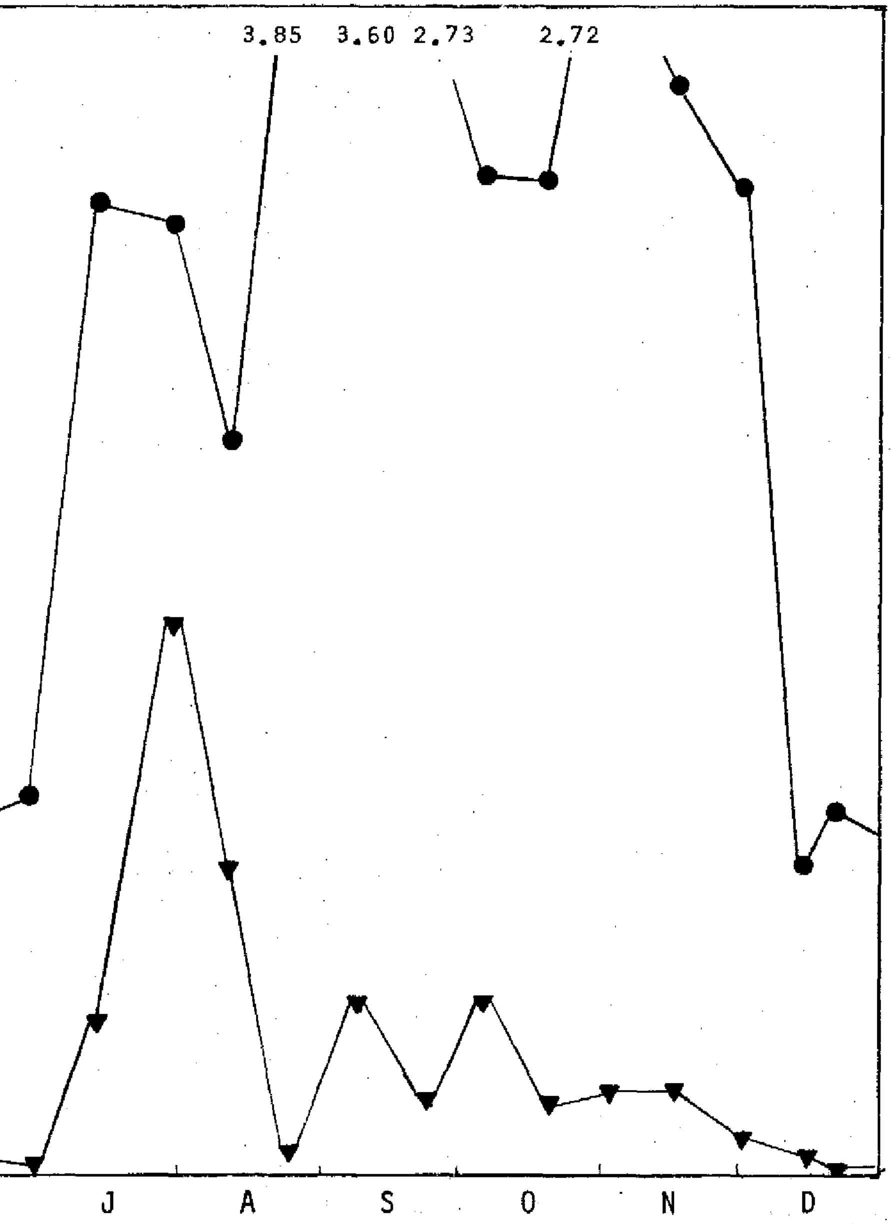


Figure IV-7.

ARMSTRONG SLOUGH NORTH CHANNEL

NITROGEN CONCENTRATIONS

1981


3.85
3.60
2.73
2.72
J
A
S
O
N
D

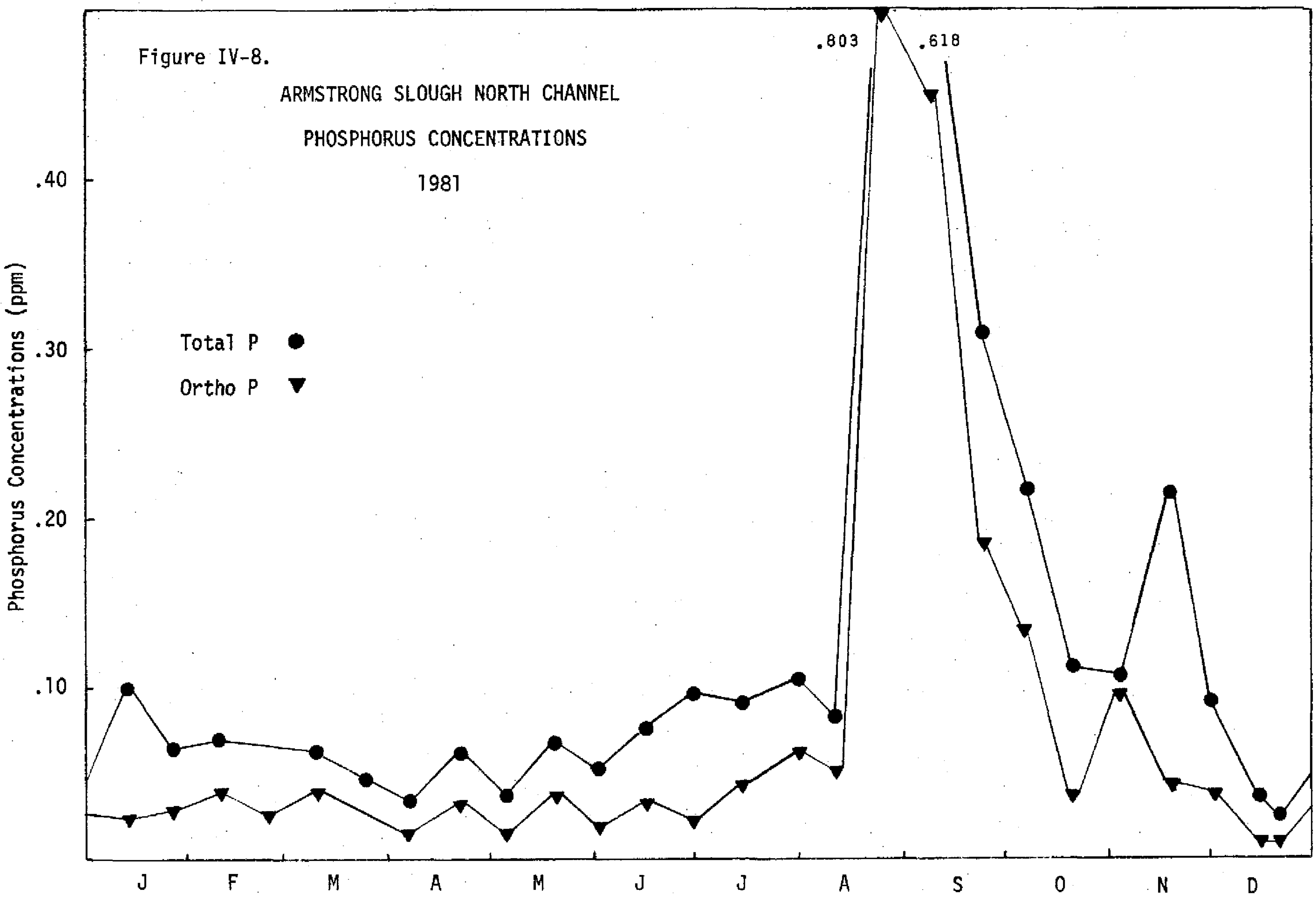


Figure IV-8.

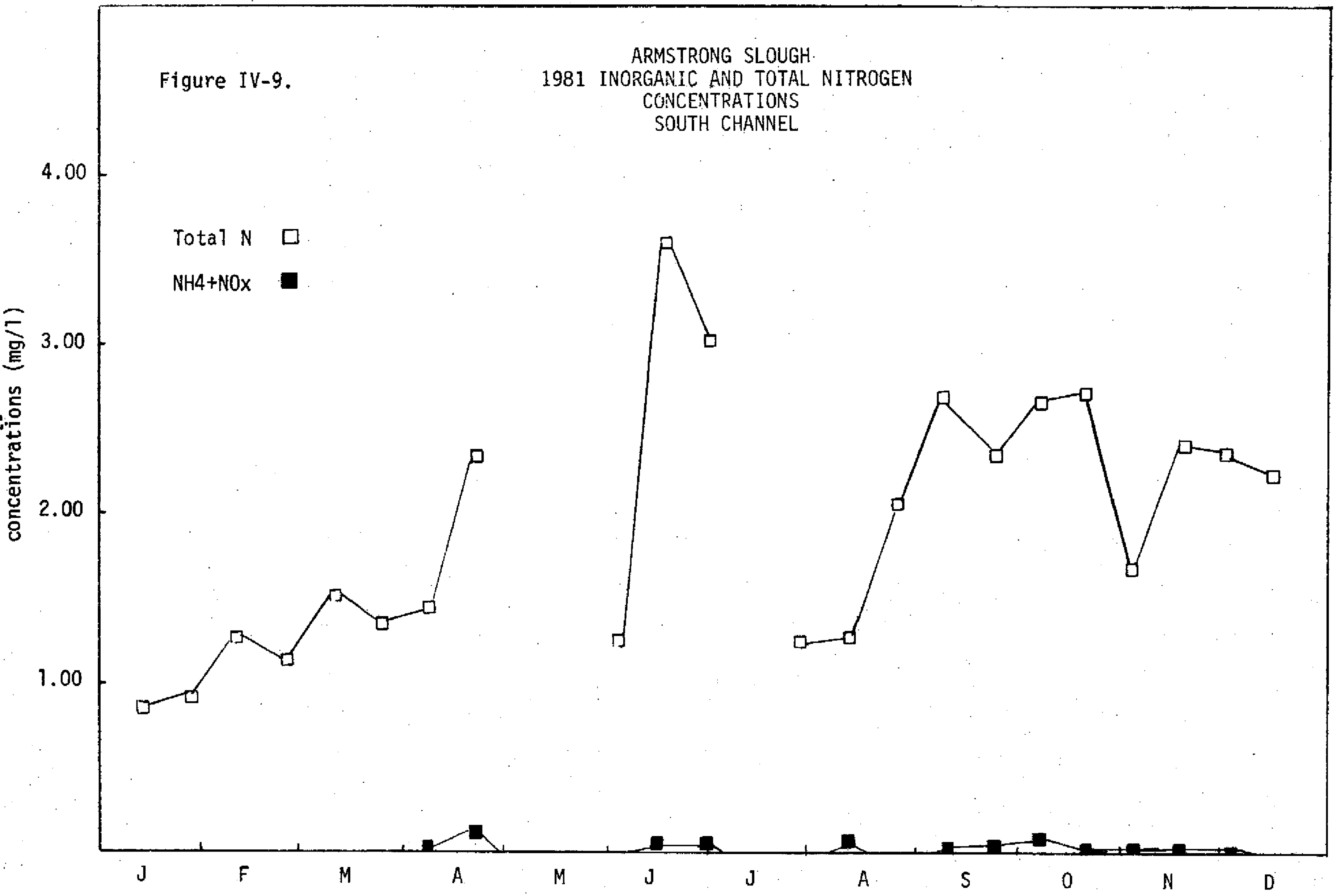
ARMSTRONG SLOUGH NORTH CHANNEL

PHOSPHORUS CONCENTRATIONS

1981

Figure IV-9.

ARMSTRONG SLOUGH
1981 INORGANIC AND TOTAL NITROGEN
CONCENTRATIONS
SOUTH CHANNEL



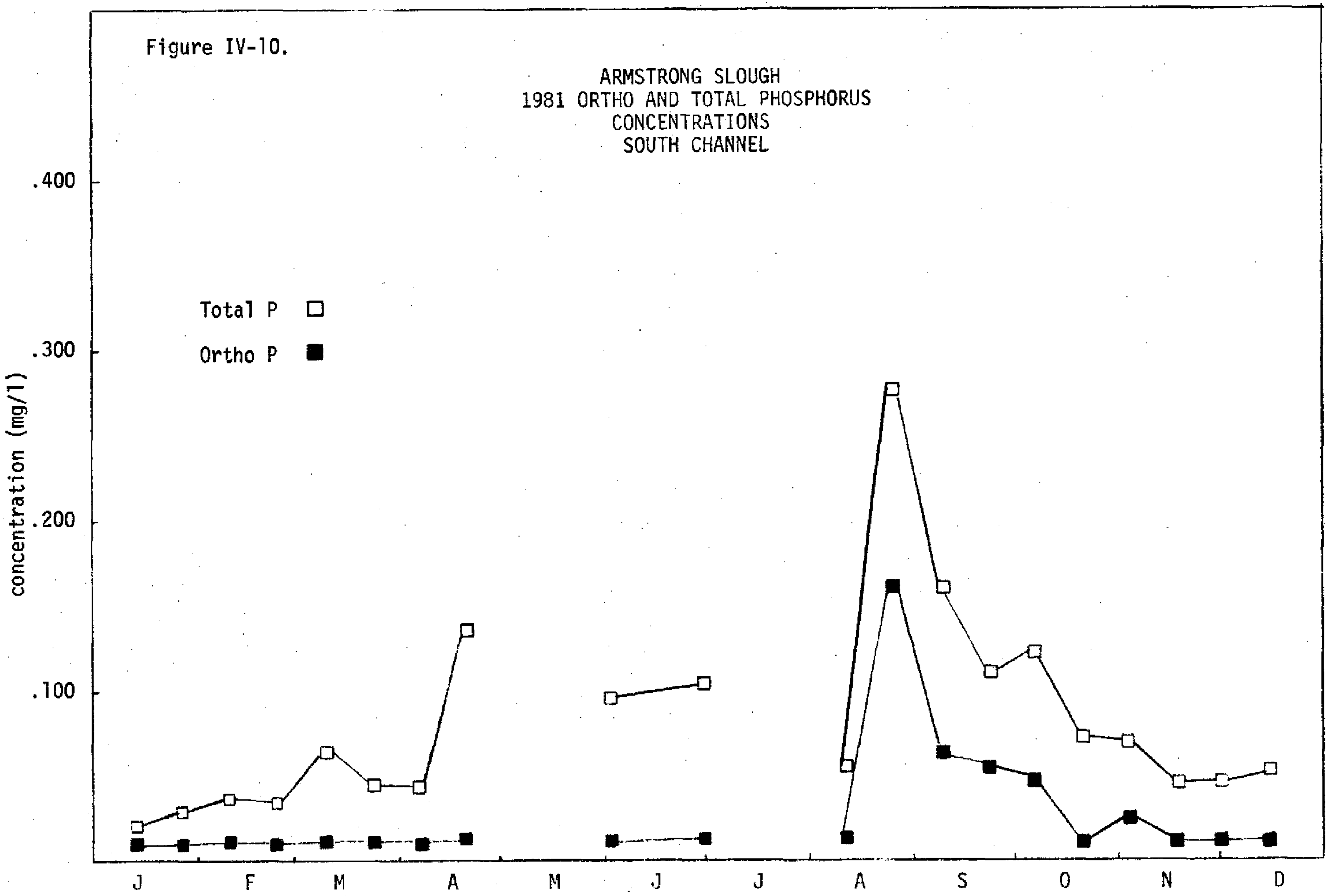


Figure IV-10.

ARMSTRONG SLOUGH
1981 ORTHO AND TOTAL PHOSPHORUS
CONCENTRATIONS
SOUTH CHANNEL

September in each year of the study. At other times, inorganic N concentrations are at or below detection limits. Total and inorganic N concentrations in the south tributary channel are of the same magnitude as those in the north channel. Highest concentrations in July occurred behind the flume in ponded, stagnant water that eventually evaporated.

Concentrations of total N were higher in the last half of the year during and following the wet season, than in the months prior to July. Total and inorganic N concentrations in runoff from the two watersheds appear to be very similar.

Total phosphorus concentrations in the north channel were slightly higher than those in the south channel. A dramatic peak in total P concentration associated with the "first flush" phenomenon occurred in August-September at both stations. Like conductivity and total N, these total P peaks were the highest measured at these stations during the course of the study to date. The ortho P component of the phosphorus load is well over half of the total during the flush periods August-October. In the north channel, the ortho portion of the load seems to consistently constitute about half of the total. In the south channel, the ortho component is less important, generally remaining at or near detection limits except for the August-September "flush" period of the wet season when it increases.

In conclusion, data collected at Armstrong Slough indicate that the land uses of the north watershed (citrus-improved pasture) result in higher conductivity and higher concentrations of phosphorus than do those of the south watershed (native range). Conductivity decreases seasonally with increased rainfall. Phosphorus and nitrogen concentrations increase seasonally with increased rainfall and runoff. Onset of rainfall and runoff following a prolonged antecedent dry period resulted in higher concentrations than during those years when dry seasons were less severe.

WILDCAT SLOUGH

The lack of rainfall in 1981 had severe impact on runoff at Wildcat Slough. Discharge from the site into the C-41A canal was observed to occur on only one of twenty-six visits to the watershed during the year. One upstream sampling location (station 2) was completely dry throughout the entire year and thus no runoff was contributed from the small watershed upstream of that station. The other monitoring location (concrete flume at station 3) draining a large marsh and native range watershed had some discharge occur only in July, September, and October.

Time series nitrogen and phosphorus concentrations at stations 1 and 3 are presented in Figures IV-11 and IV-12. Data obtained at station 1 was from samples of standing water behind the culverts at C-41A and probably reflects concentrations in C-41A which most likely was the source of the standing water through back seepage at the culvert stoplogs. Discharge into C-41A was observed once in mid-September, but N and P concentrations at that time did not seem to be affected.

Relatively high N and P concentrations in February 1981 were measured in standing water behind the flume. Some die-off and decomposition of vegetation, following a period of severe cold weather, could be the explanation for the extraordinarily high concentrations. A period of discharge across the flume occurred in July. This was accompanied by a slight increase in P concentration, followed by a drop to a consistent lower level throughout the discharge period. Total N concentrations remained constant throughout the wet season.

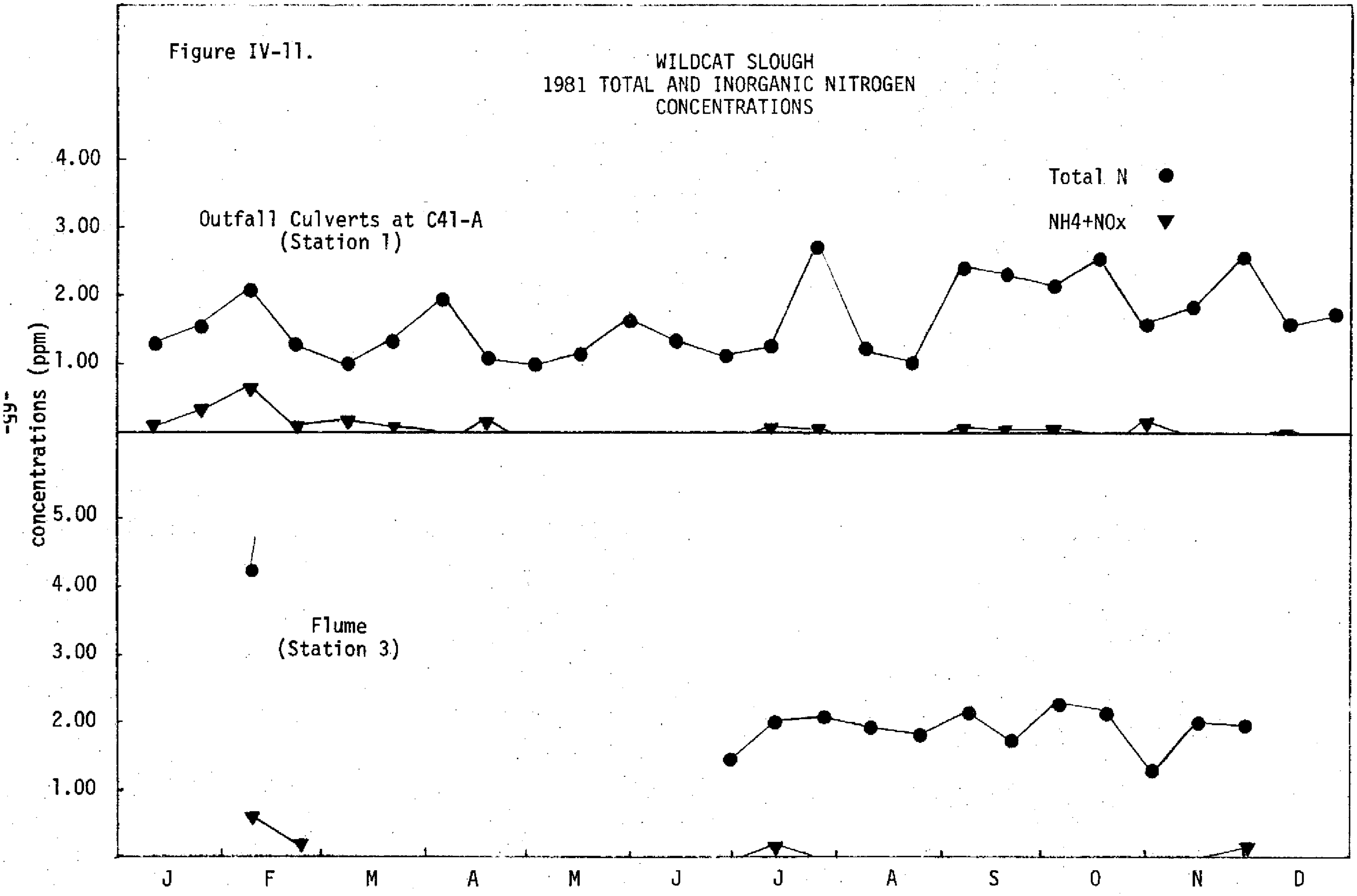


Figure IV-11.

WILDCAT SLOUGH
1981 TOTAL AND INORGANIC NITROGEN
CONCENTRATIONS

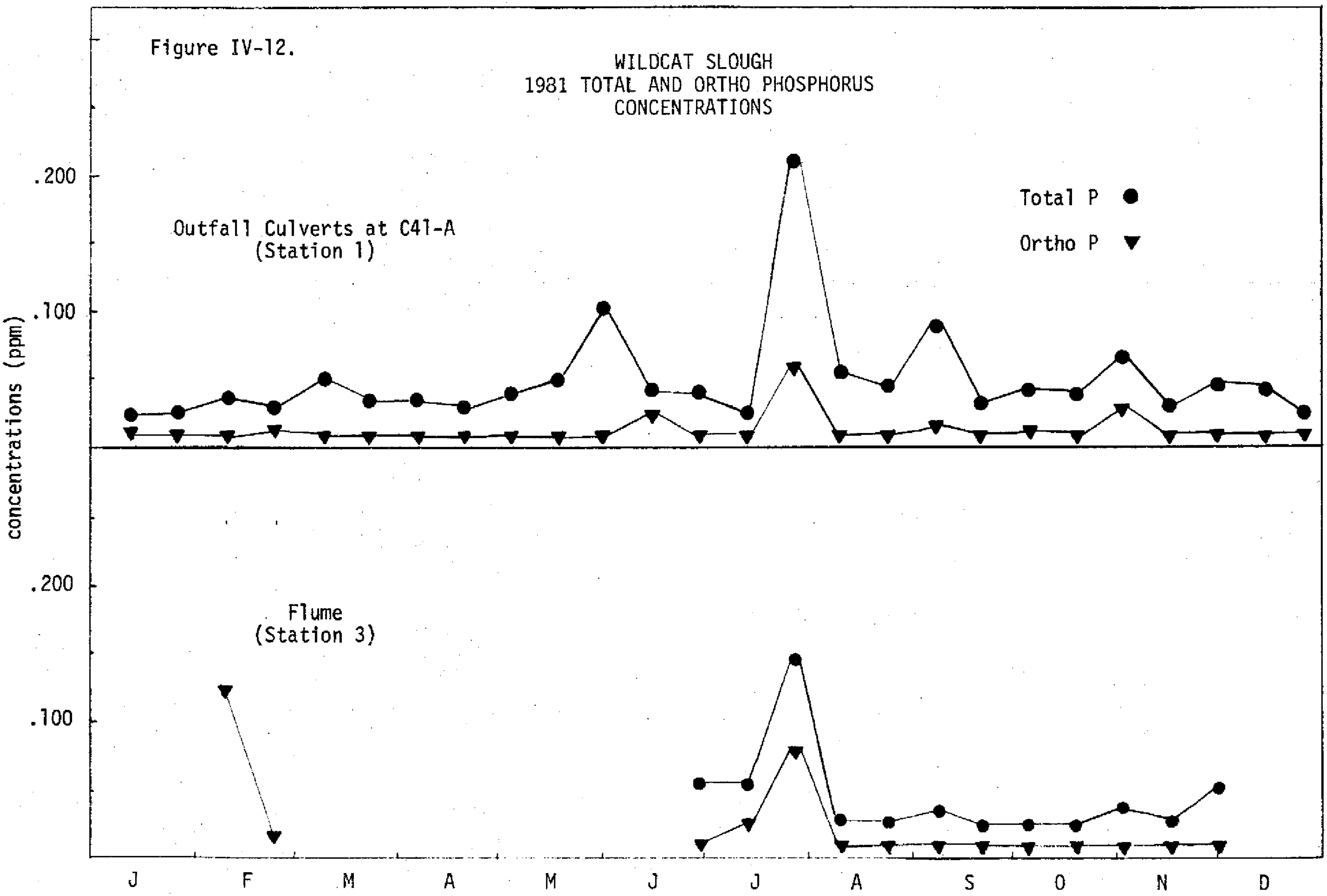


Figure IV-12.

WILDCAT SLOUGH
1981 TOTAL AND ORTHO PHOSPHORUS
CONCENTRATIONS

PEAVINE PASTURE

Like the other study sites, the drought conditions resulted in limited runoff and subsequent discharge from the Peavine Pasture watershed. Discharge did occur regularly though intermittently from July through November. Total and inorganic N concentrations remained relatively constant throughout the year (Figure IV-13). Inorganic N concentrations were at or below detection limits during the wet season when discharge occurred. They were slightly above detection limits in standing water that remained on the site during February and March.

Total and ortho P concentrations (Figure IV-14) seemed to follow a declining trend from July through November with total P concentrations in mid-November being roughly one-half to one-third of their levels during the spring and summer months.

A concentration peak of both N and P parameters was noted in mid-October. These peaks can be attributed to spikes in the dissolved constituents of those parameters that seem to occur on that date. These may be due to errors introduced during the sampling or analysis procedures or they may reflect biogeochemical activity occurring in the standing water pool behind the flume during this period of no discharge.

A "first flush" of nutrients from this site, beginning with the onset of rainfall and runoff in 1981, may have occurred as noted by slightly elevated N and P concentrations in mid-July. The magnitude of the phenomenon, however, was too slight to allow one to conclude that this is a mechanism for a major export of nutrients from this watershed.

Figure IV-13.

PEAVINE PASTURE
1981 TOTAL AND INORGANIC NITROGEN
CONCENTRATIONS
AT SITE OUTFALL

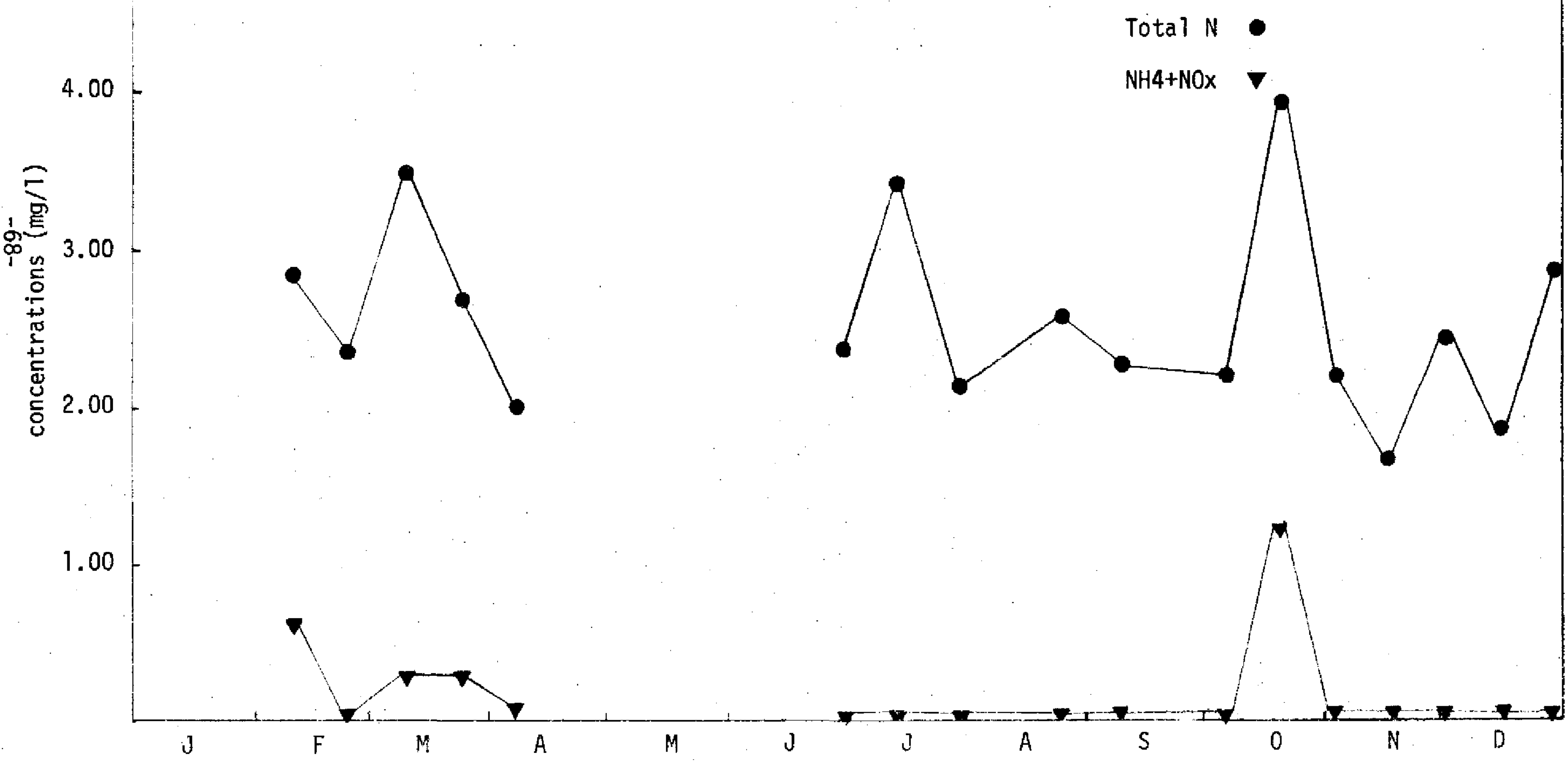
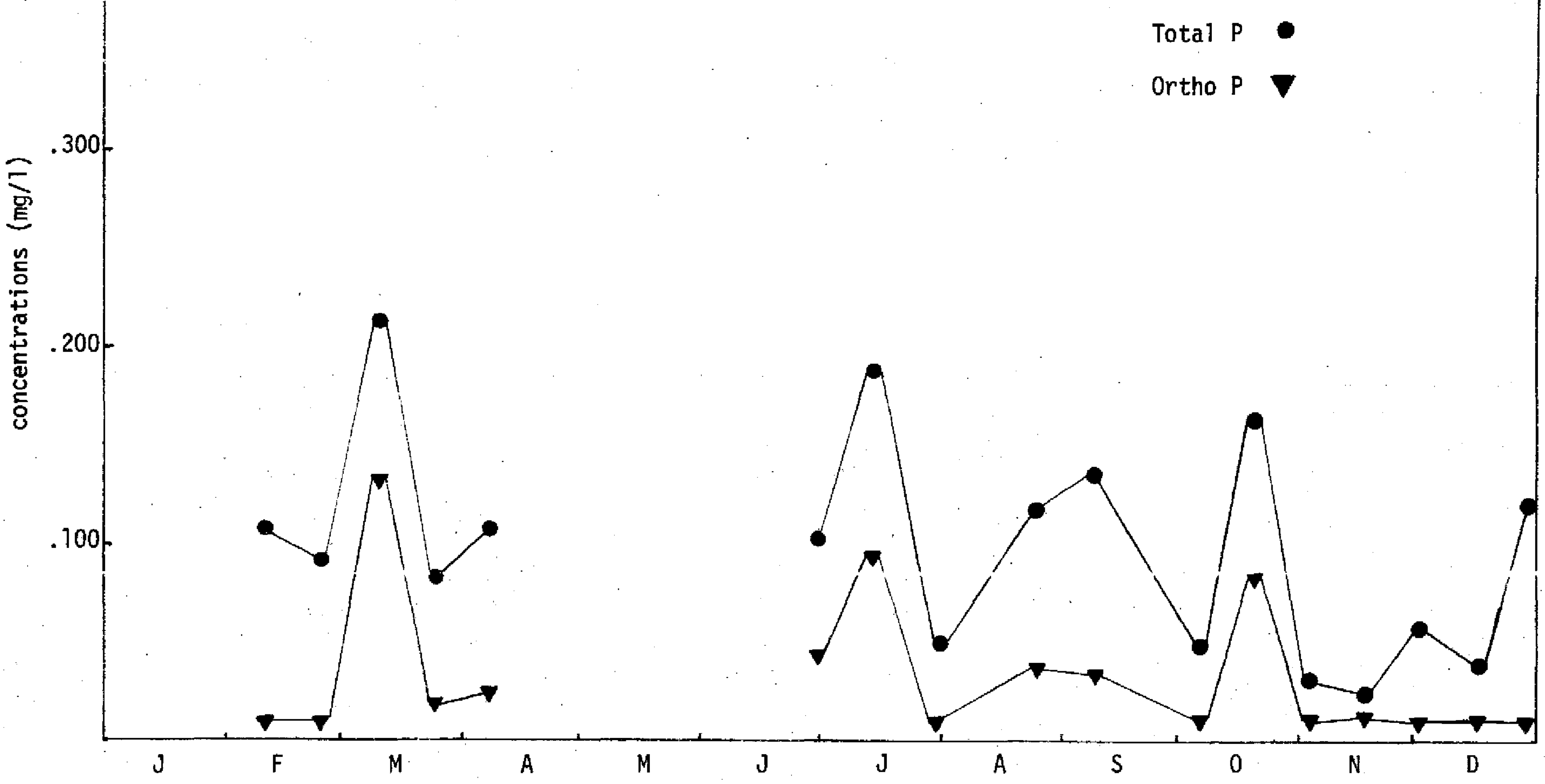


Figure IV-14.

PEAVINE PASTURE
1981 TOTAL AND ORTHO PHOSPHORUS
CONCENTRATIONS
AT SITE OUTFALL



ASH SLOUGH

Ash Slough was the one project site where runoff and discharge was most severely affected by the extraordinarily dry conditions of 1981. Rainfall on the site was estimated to have been about half of the historical annual average. Only twice during the year (February and September) did enough rainfall occur to result in water collecting in the interceptor and drainage ditches leading to the flow monitoring flume structures. It was only during September that enough rainfall occurred to actually result in discharge across the flumes into the detention/retention marsh.

Nutrient concentrations measured at Ash Slough during 1981 are depicted in Figures IV-15 and IV-16. Total nitrogen concentrations were of similar magnitude in both February and September, although they tended to increase in February and decrease in September. The initial high concentrations, followed by consistent and rapid decrease in total N levels at station 2 during the first 48 hours in the September event, can be attributed to the "first flush" phenomenon. The reciprocal trend noted in February is harder to explain but may only reflect a concentration of nutrients as standing water behind the flume evaporated. Inorganic N concentrations remained consistently low throughout both "wet" periods. Total and inorganic N concentrations measured at station 4 were slightly lower but similar in magnitude to those noted at station 2.

The dissolved reactive (ortho) component makes up the bulk of the total phosphorus loads during both the February and September events. P concentrations at station 4 were substantially lower than those measured at station 2 during the initial part of both events. A "first flush" phenomenon for P was noted at station 2 during both February and September.

Figure IV-15.

ASH SLOUGH
1981 TOTAL AND INORGANIC NITROGEN
CONCENTRATIONS

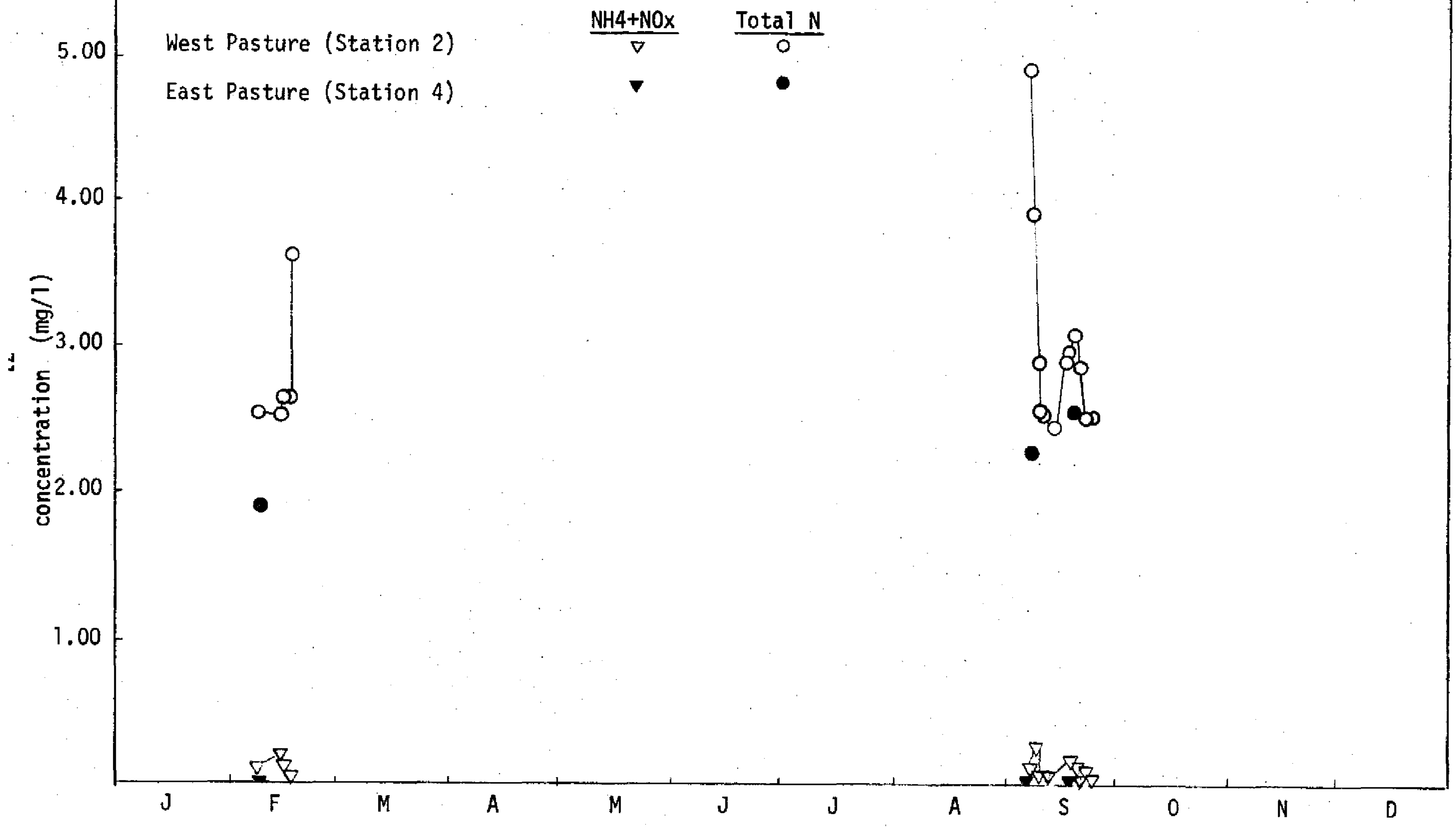
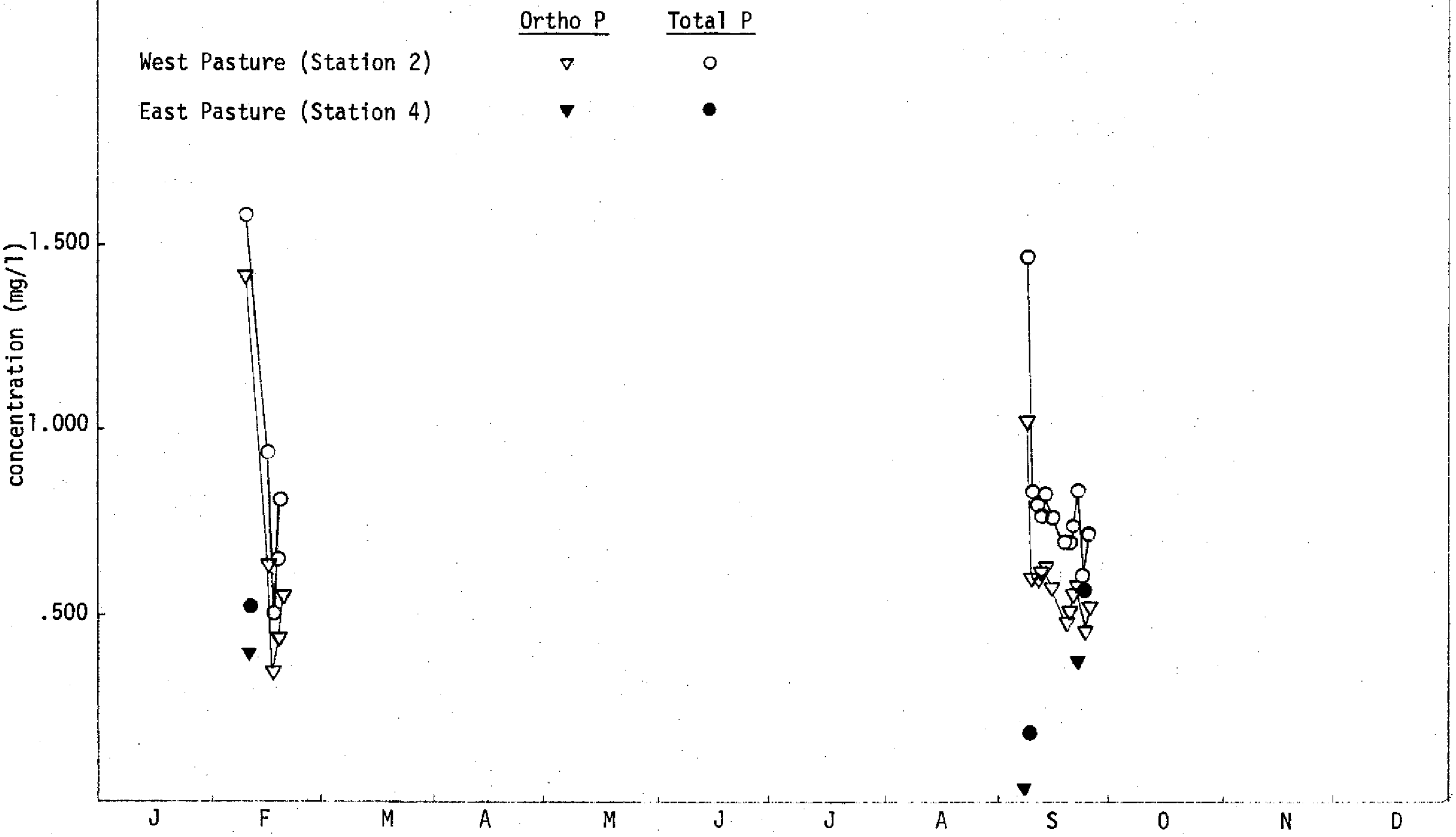


Figure IV-16.

ASH SLOUGH
1981 TOTAL AND ORTHO PHOSPHORUS
CONCENTRATIONS



P concentrations at station 2 gave indications of beginning to increase over time during September and were approaching levels similar to those being measured at station 2.

SEZ DAIRY

Impacts of dairy operations on rainfall runoff from the watershed are complicated by the simultaneous operations of the barn waste treatment system. The effects of the barn and lagoon operations during 1981, as well as overall impact at the site outfall, are discussed in Section V of this report.

Physical and chemical parameters measured at the site outfall were monitored on a daily basis and are depicted in Figures IV-17 through IV-20. Concentrations of N and P as well as conductivity, color, and turbidity remain quite variable, but peaks can be largely correlated to periods of discharge from the lagoon system (Figure IV-21).

During periods of low or no discharge from the lagoon, the majority of the total N concentration at the site outfall is in the particulate organic form. During periods of lagoon discharge and runoff, the inorganic N to total N ratio increases to become roughly half or more of the total N.

Total P concentrations on the other hand are predominantly composed of the ortho component. This is true during periods of lagoon discharge as well as for runoff during non-discharge periods.

INTERSITE COMPARISONS

Conclusions on land use impacts based on the 1981 data should be made cautiously, recognizing the fact that the meteorological conditions during that time were very atypical. Comparison of mean concentrations of N and P species at each of the watersheds monitored at the five sites do continue to exhibit trends that have been noted and documented in previous project

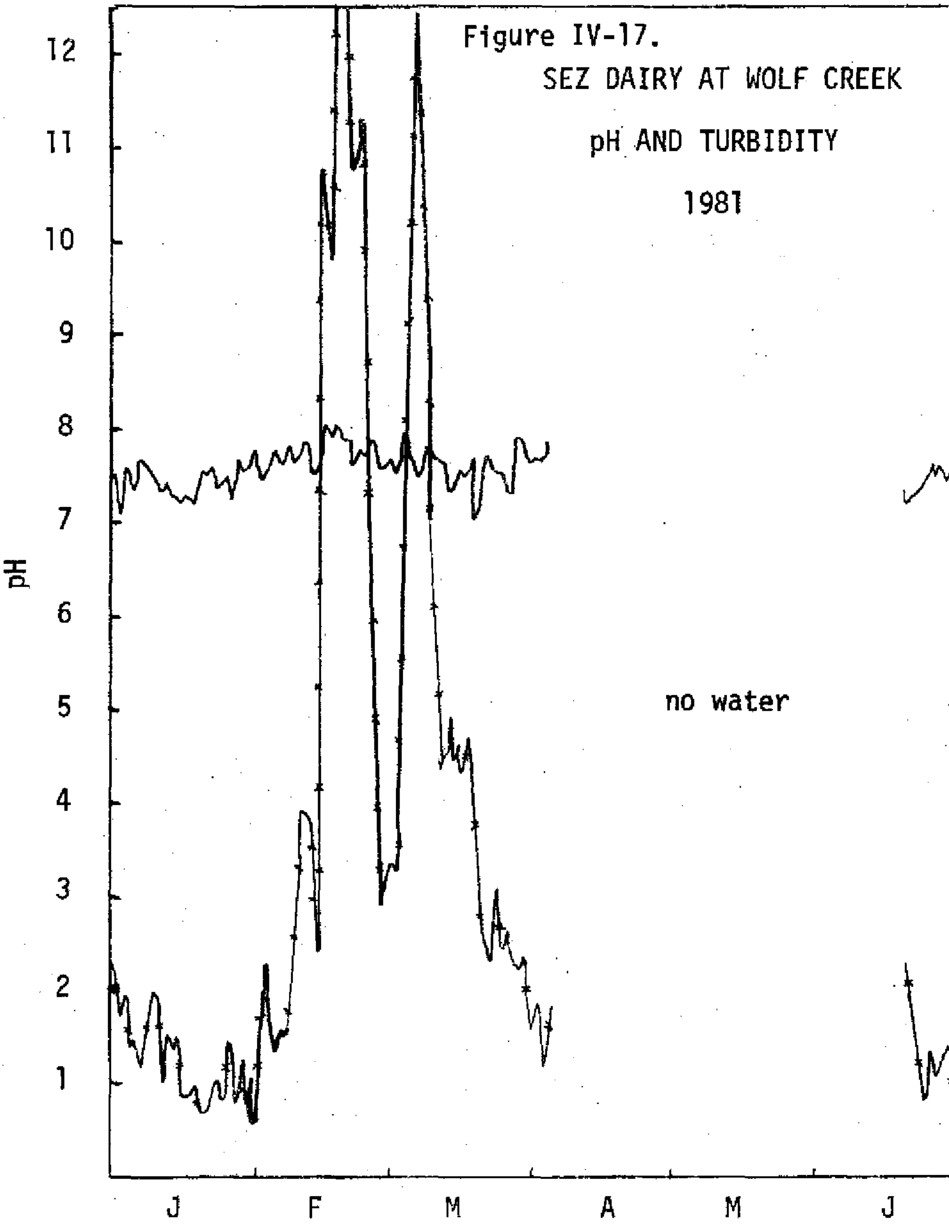
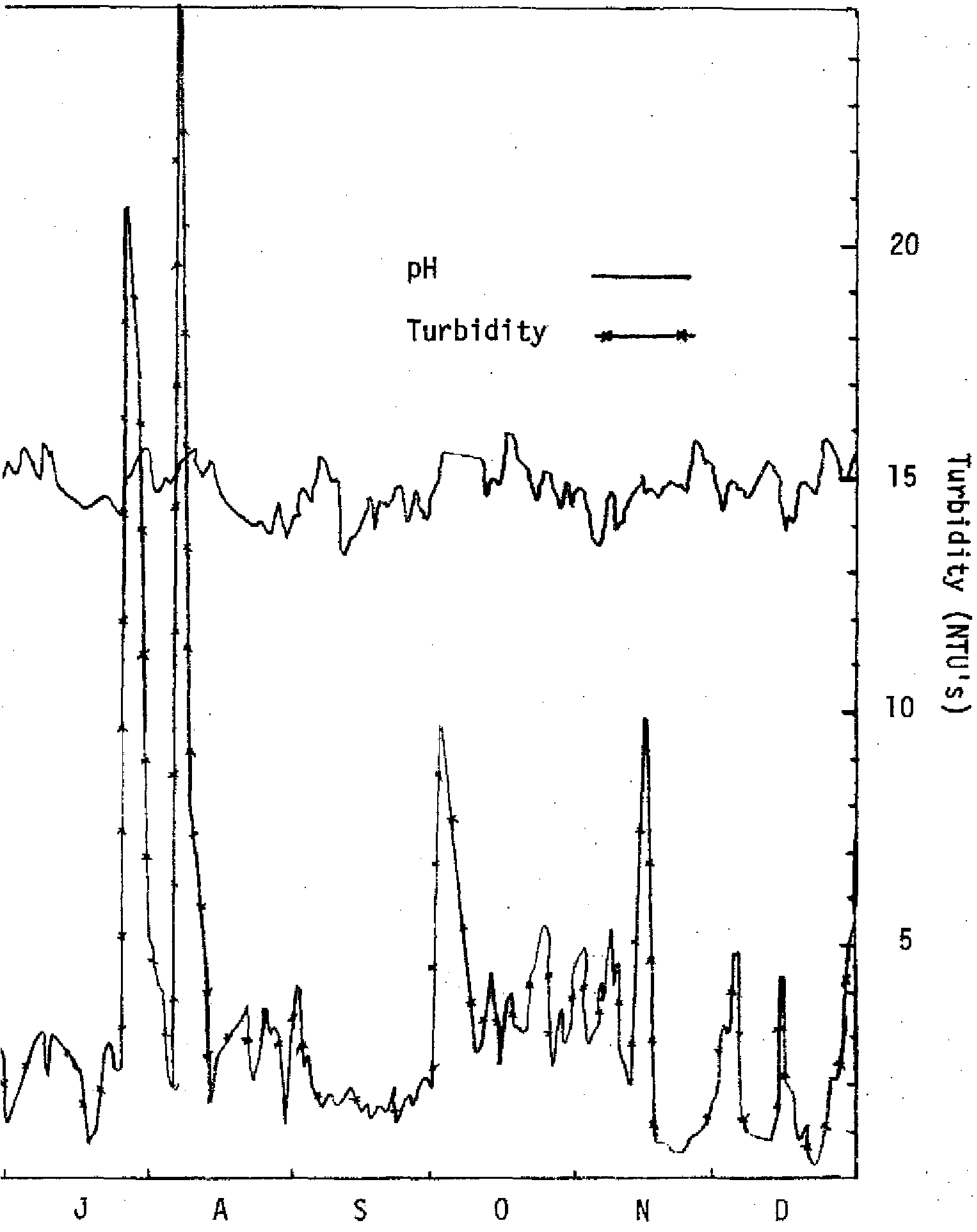


Figure IV-17.
SEZ DAIRY AT WOLF CREEK
pH AND TURBIDITY
1981


pH
Turbidity
20
15
10
5
Turbidity (NTU's)
J
A
S
O
N
D

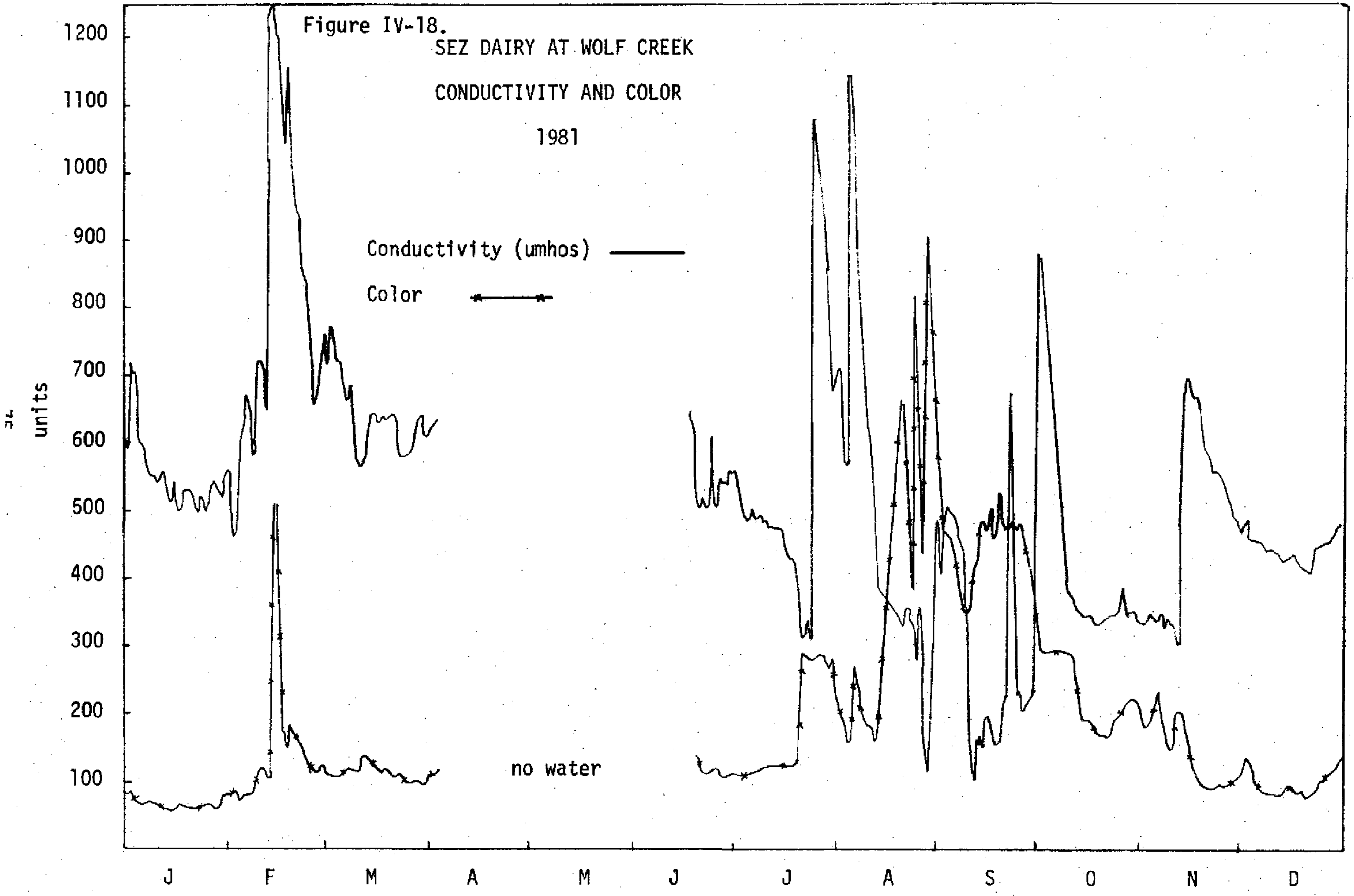


Figure IV-18. SEZ DAIRY AT WOLF CREEK

CONDUCTIVITY AND COLOR

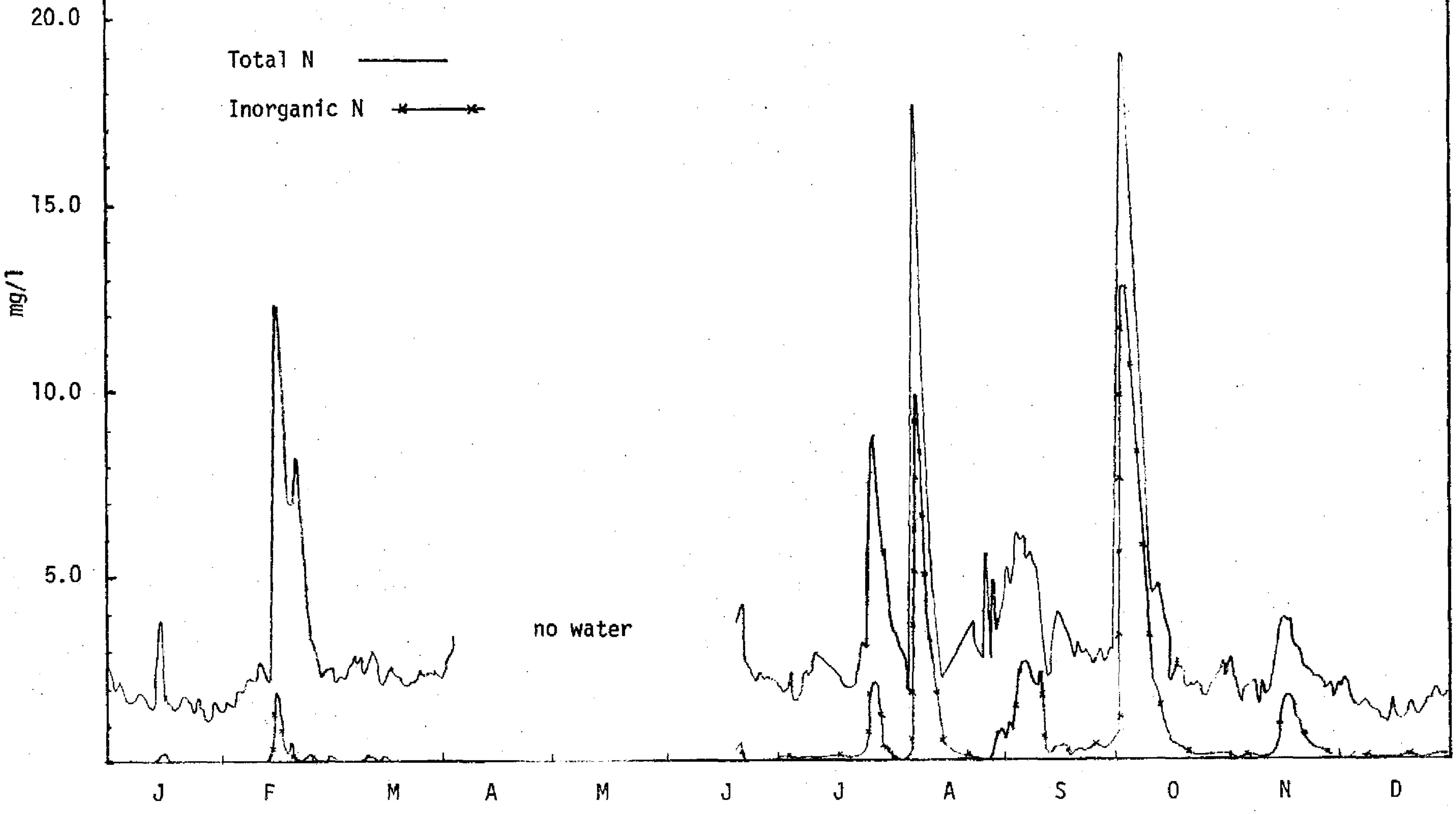
1981

Figure IV-19.

SEZ DAIRY AT WOLF CREEK

TOTAL AND DISSOLVED INORGANIC NITROGEN CONCENTRATIONS

1981



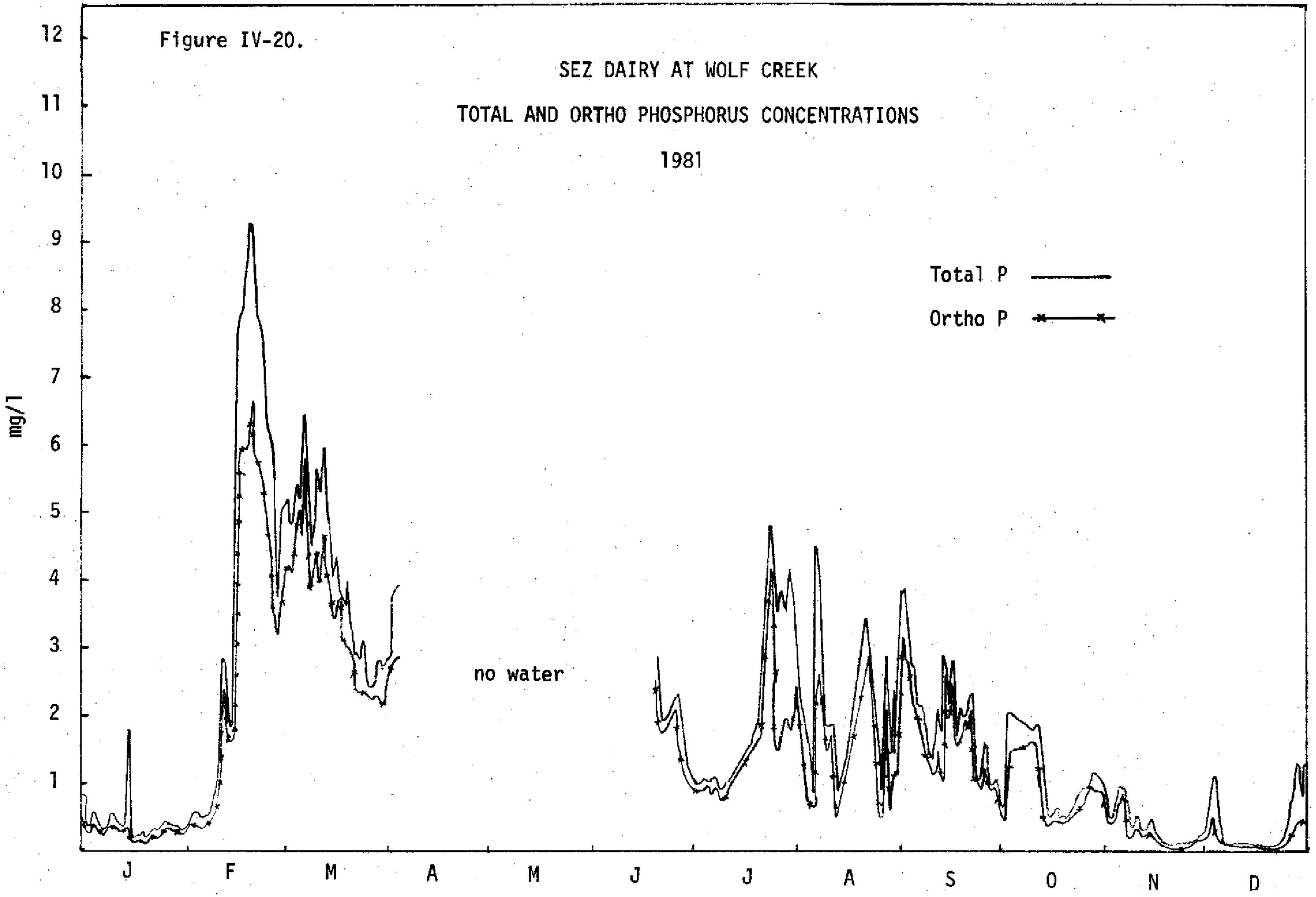


Figure IV-20.

SEZ DAIRY AT WOLF CREEK

TOTAL AND ORTHO PHOSPHORUS CONCENTRATIONS

1981

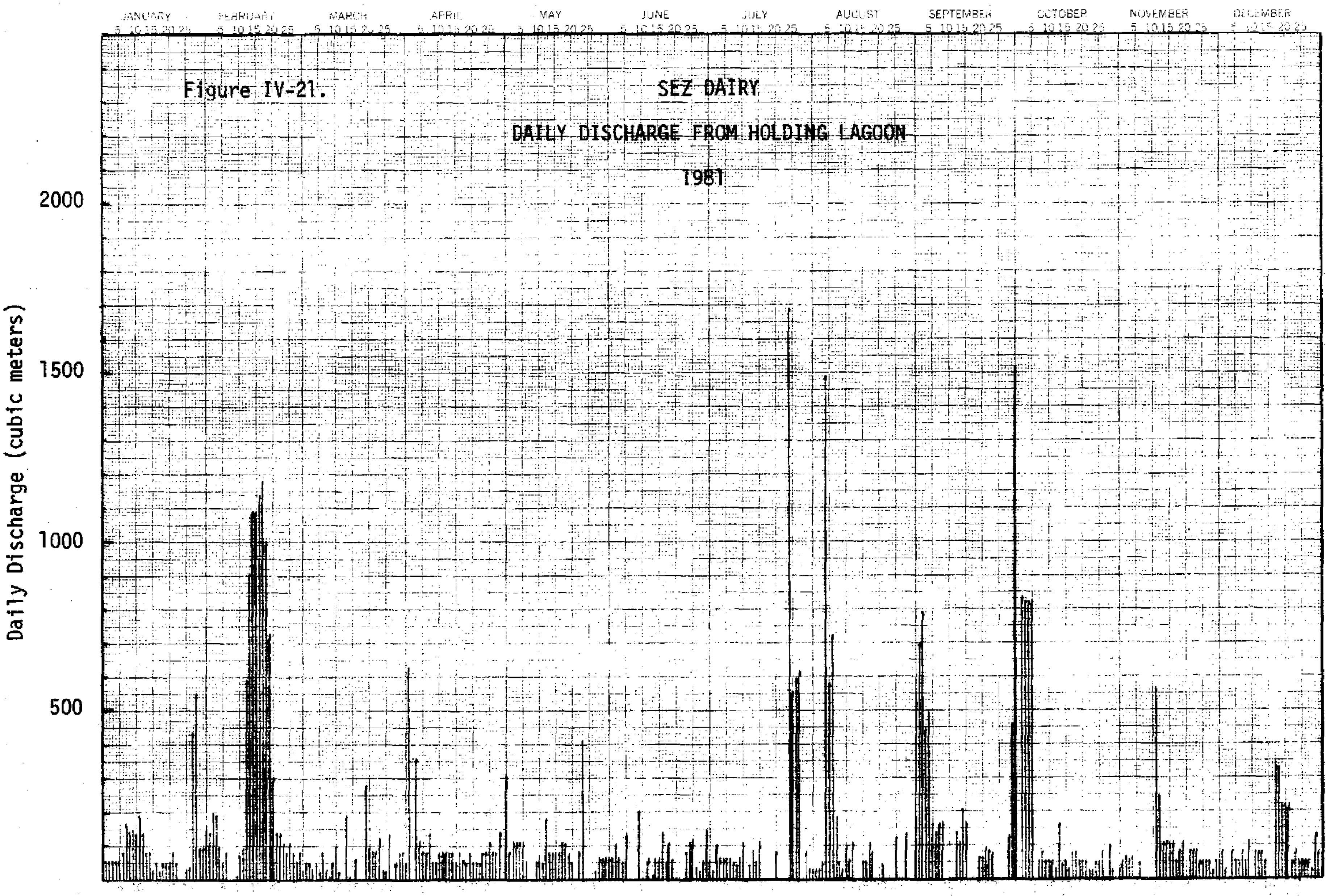


Figure IV-21. SEZ DAIRY

DAILY DISCHARGE FROM HOLDING LAGOON

1981

reports. These 1981 data are depicted in Figures IV-22 and IV-23. Concentrations of N and P continue to remain positively correlated with increasing land use intensity (cattle density per unit land area).

Dairy operations continue to be the contributor of the most heavily nutrient laden water, particularly phosphorus, while native range continues to be the lowest contributor. During 1981, land use practices seemed to have the least impact on total N concentrations in runoff. On the other hand, land use continued to have significant impact on phosphorus concentrations. These data continue to reflect trends on impacts of land use practices on receiving water quality presented in Goldstein (1981).

1981 WATER AND NUTRIENT BUDGETS

The scarcity of rainfall and runoff at project sites during 1981 prohibits utilizing 1981 data for making direct comparisons with contributions of nitrogen and phosphorus species on a mass per unit surface area basis for the project watersheds, nor does it permit a similar comparison within a single watershed for previous years of this study. At the project sites, runoff was either nonexistent or at most, occurred during only one or two months during the year. Under these circumstances, total impacts of various land uses on quality of runoff to receiving waters cannot be assessed.

Annual nutrient and water budgets for 1981 were calculated for the study watersheds and are presented in a comparative manner in Table IV-2.

With the exception of the Peavine site, over three-quarters of the rainfall on the watersheds was retained on the site. It is estimated that only half of the rainfall on Peavine was retained on site. No runoff at all occurred at the Wildcat Slough west watershed during 1981.

Nutrient uptake on the watersheds reflected the amount of rainfall

Figure IV-22.

UPLAND DEMONSTRATION PROJECT
1981 INTERSITE COMPARISONS
TIME SERIES NITROGEN SPECIES CONCENTRATIONS

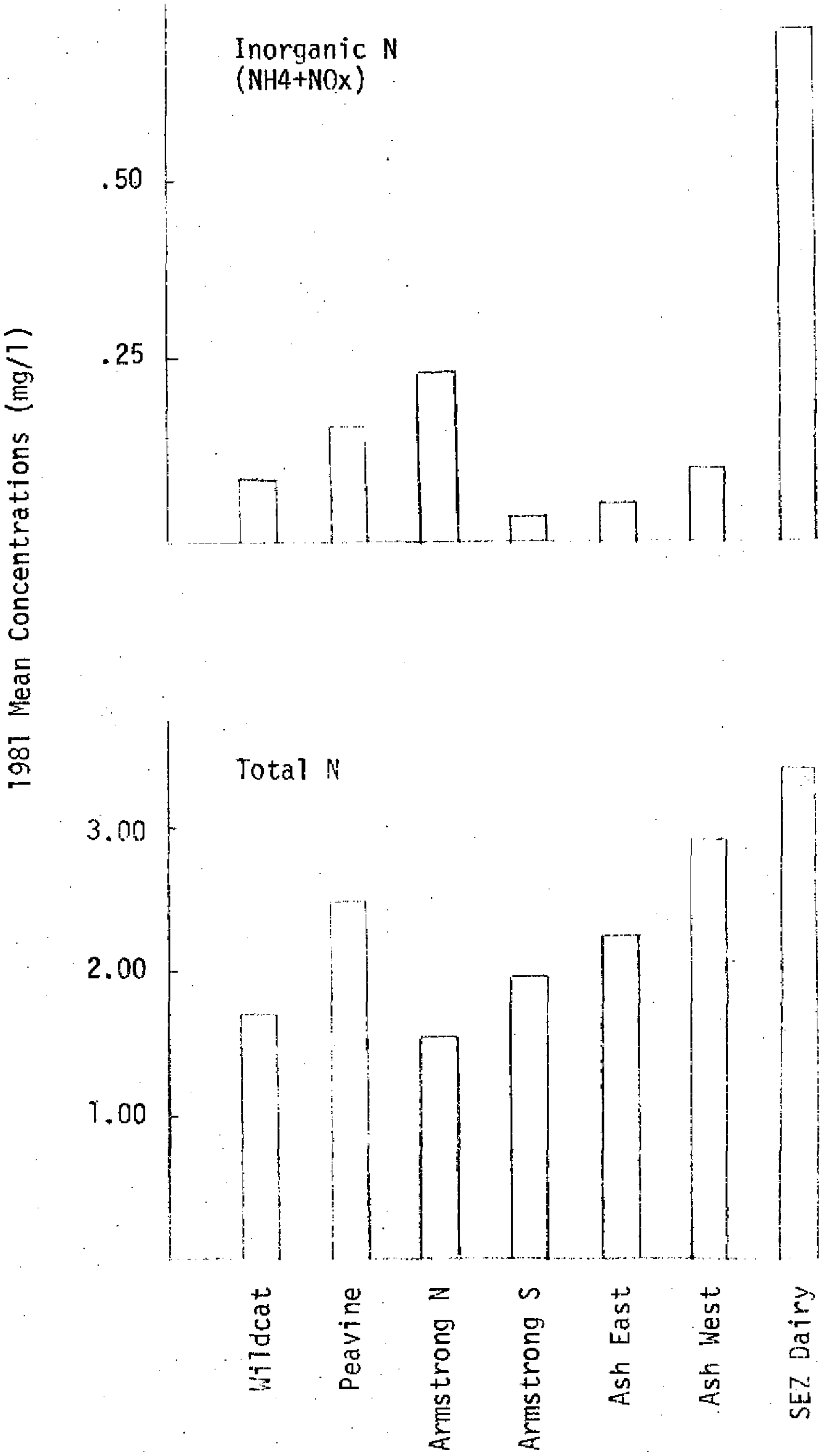


Figure IV-23.

UPLAND DEMONSTRATION PROJECT
1981 INTERSITE COMPARISONS
SERIES PHOSPHORUS SPECIES CONCENTRATIONS

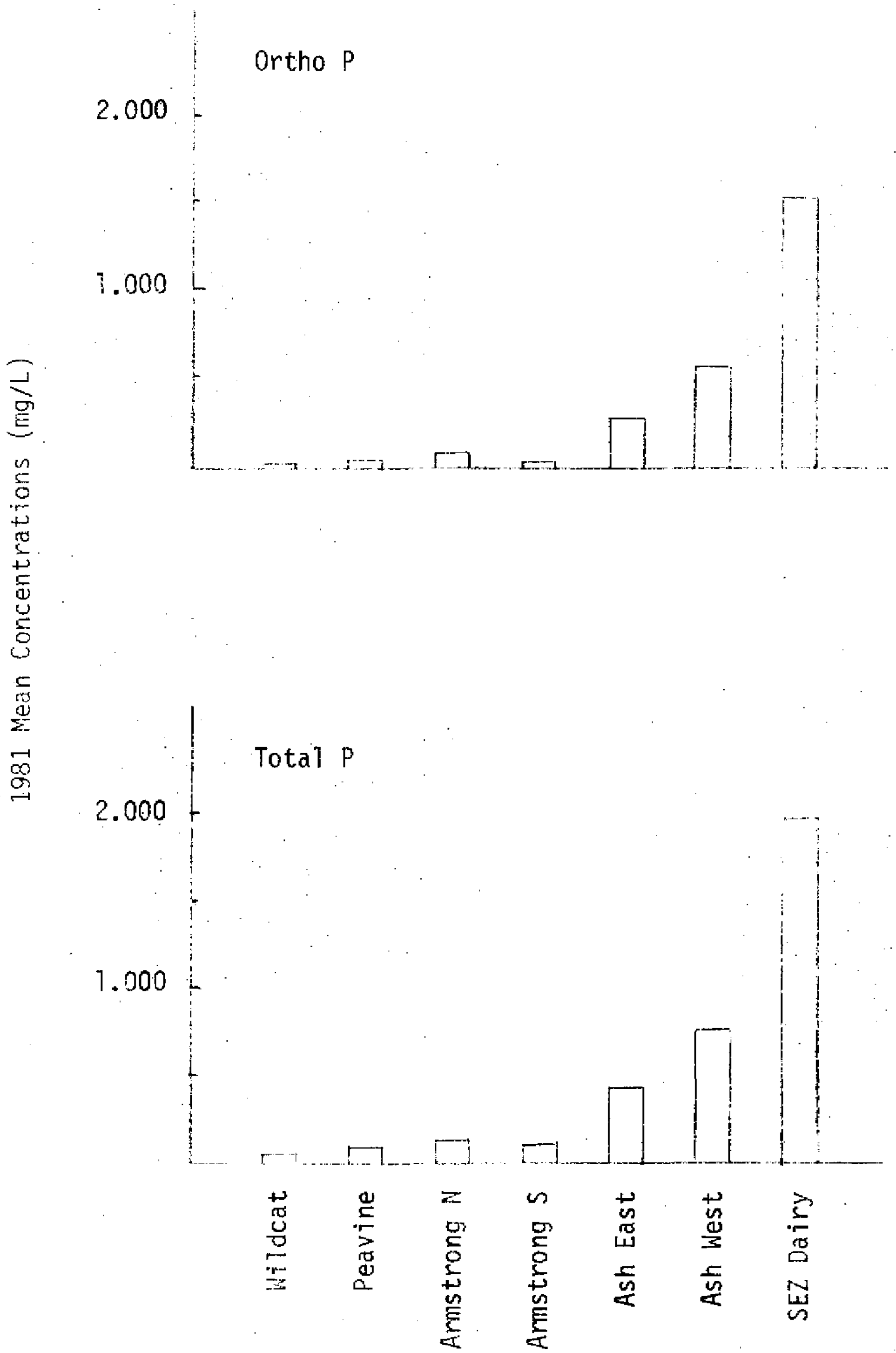


Table IV-2.

Upland Demonstration Project Sites
1981 Annual Water and Nutrient Budgets

	Wildcat West	Wildcat East	Peavine	Armstrong South	Armstrong North	Ash East	Ash West	SEZ Dairy*
Water Budget (m^3)								
Rainfall	13,168,894.0	19,737,920.0	1,813,424.0	7,969,179.0	73,030,256.0	62,544.0	375,268.0	2,710,978.0
Discharge	0	725,809.0	937,765.0	2,061,517.0	6,058,224.0	301.0	3,242.0	602,875.0
Uptake/Export	13,168,894.0	19,012,111.0	875,659.0	5,907,662.0	66,972,032.0	62,243.0	372,026.0	2,108,103.0
% Uptake/Export	100.0	96.3	48.3	74.1	91.7	99.5	99.1	77.8
Inorganic N Budget (kg)								
Loads on watershed	9,199.4	13,788.7	1,270.2	5,110.8	51,117.4	54.3	262.2	2,239.2
Loads in runoff	0	26.4	28.1	114.0	1,294.4	Trace	0.3	479.0
Uptake/Export	9,199.4	13,762.3	1,242.1	4,996.8	49,823.0	54.3	261.9	1,760.2
% Uptake/Export	100.0	99.8	97.8	97.8	97.5	100.0	99.9	78.6
Total N Budget (kg)								
Loads on watershed	22,210.3	33,289.7	3,066.5	12,341.1	123,412.1	110.4	632.9	5,673.9
Loads in runoff	0	1,365.6	2,119.1	4,969.6	17,091.6	0.7	9.1	2,317.4
Uptake/Export	22,210.3	31,924.1	947.4	7,371.5	106,320.5	109.7	632.8	3,356.5
% Uptake/Export	100.0	95.9	30.9	59.7	86.2	99.4	98.6	59.2

*SEZ Dairy loads on watershed include lagoon discharge.

Table IV-2. (continued)

Upland Demonstration Project Sites
1981 Annual Water and Nutrient Budgets
(continued)

	Wildcat West	Wildcat East	Peavine	Armstrong South	Armstrong North	Ash East	Ash West	SEZ Dairy*
Ortho P Budget (kg)								
Loads on watershed	1,235.4	1,851.7	170.4	686.4	6,094.2	5.7	35.2	525.7
Loads in runoff	0	13.2	23.1	111.0	1,775.5	0.1	1.8	1,118.3
Uptake/Export	1,235.4	1,838.5	147.3	575.4	4,318.7	5.6	33.4	-592.6
% Uptake/Export	100.0	99.3	86.4	83.8	70.9	98.2	94.9	-113.3
Total P Budget (kg)								
Loads on watershed	1,813.7	2,718.3	250.2	1,007.7	10,077.5	9.0	51.6	809.1
Loads in runoff	0	19.4	91.0	265.7	2,561.8	0.1	2.4	1,329.4
Uptake/Export	1,813.7	2,698.9	159.2	742.0	7,515.7	8.9	49.2	-520.3
% Uptake/Export	100.0	99.3	63.6	73.6	74.6	98.9	95.3	-64.3

*SEZ Dairy loads on watershed include lagoon discharge.

retention. The Wildcat Slough west watershed released no nitrogen and phosphorus during 1981. In those instances where percent nutrient uptake failed to equal or exceed the percent of water retention, one can argue that practices associated with these land uses result in greater quantities of nutrient release during periods of runoff and discharge. These practices might include accumulation of nutrients in excess of those from rainfall alone that occur as fertilizer applications to pasture grasses or residue from livestock feed or manure in densely stocked situations such as dairies.

Typically, inorganic N loads were reduced most effectively by all the watersheds. Total N was taken up by all watersheds, though somewhat less efficiently than the inorganic fraction.

Ortho and total P were effectively taken up at all sites during 1981, with the exception of SEZ Dairy where phosphorus was exported in excess of those loads that could be attributed to rainfall and the waste lagoon discharge. Per unit area P export rates calculated for the dairy during 1981 are likely to be even higher during years of normal or above average rainfall.

GROUNDWATER

Groundwater quality monitored during 1981 exhibited similar magnitudes of concentrations and low variation as observed during 1981 after the initial period of stabilization following the installation of the wells. A comparison of data from among sites (Figures IV-24, IV-25, and IV-26) shows concentrations of N, P, and conductivity remain relatively constant at each station. The one major exception to this rule is the groundwater at the Ash Slough ditched pasture. Groundwater from this station exhibited a wide range of variability of total P, total N, and conductivity. This is probably due to the intermittent nature of the presence of water at this station. This well was more subject to fluctuations in the groundwater

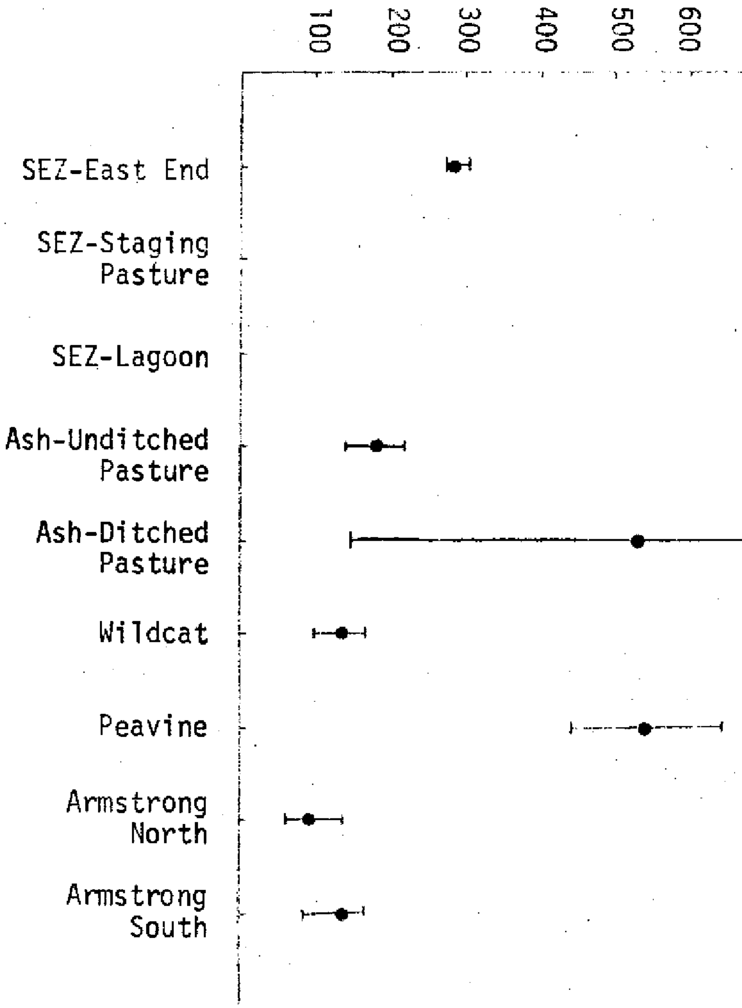
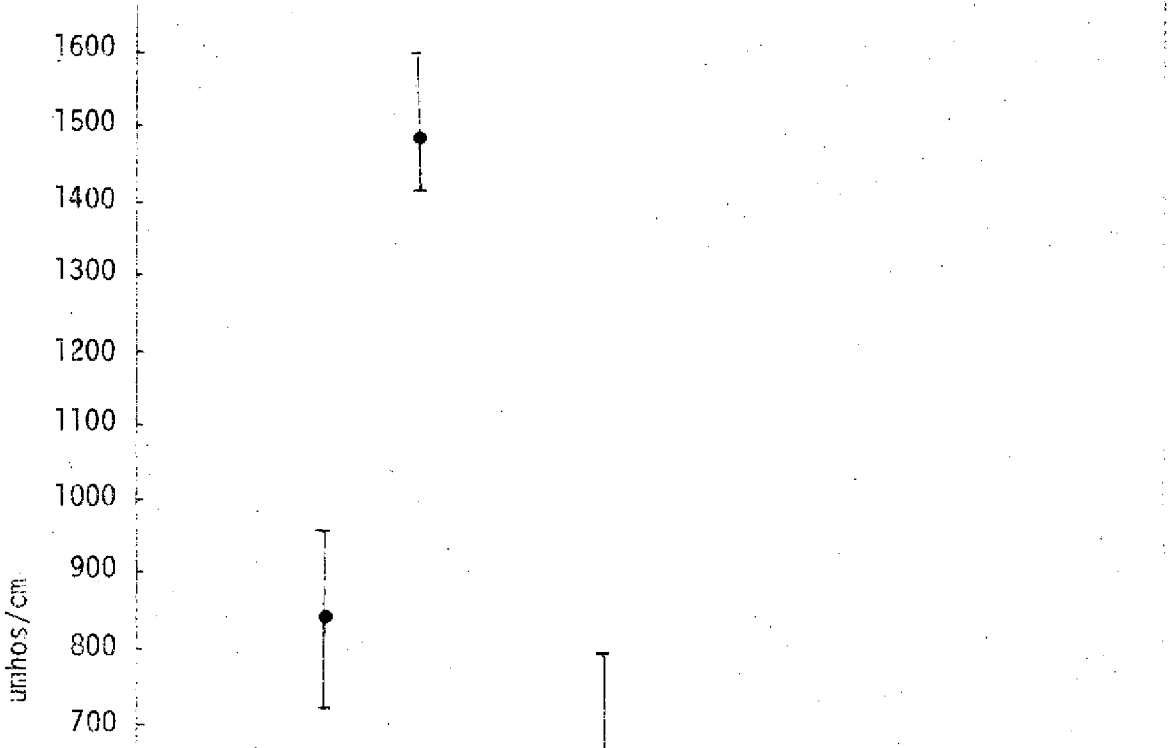

100
200
300
400
500
600
SEZ-East End
SEZ-Staging Pasture
SEZ-Lagoon
Ash-Unditched Pasture
Ash-Ditched Pasture
Wildcat
Peavine
Armstrong North
Armstrong South

Figure IV-24.

CONDUCTIVITY IN GROUNDWATER
1981
(MEANS AND RANGES)



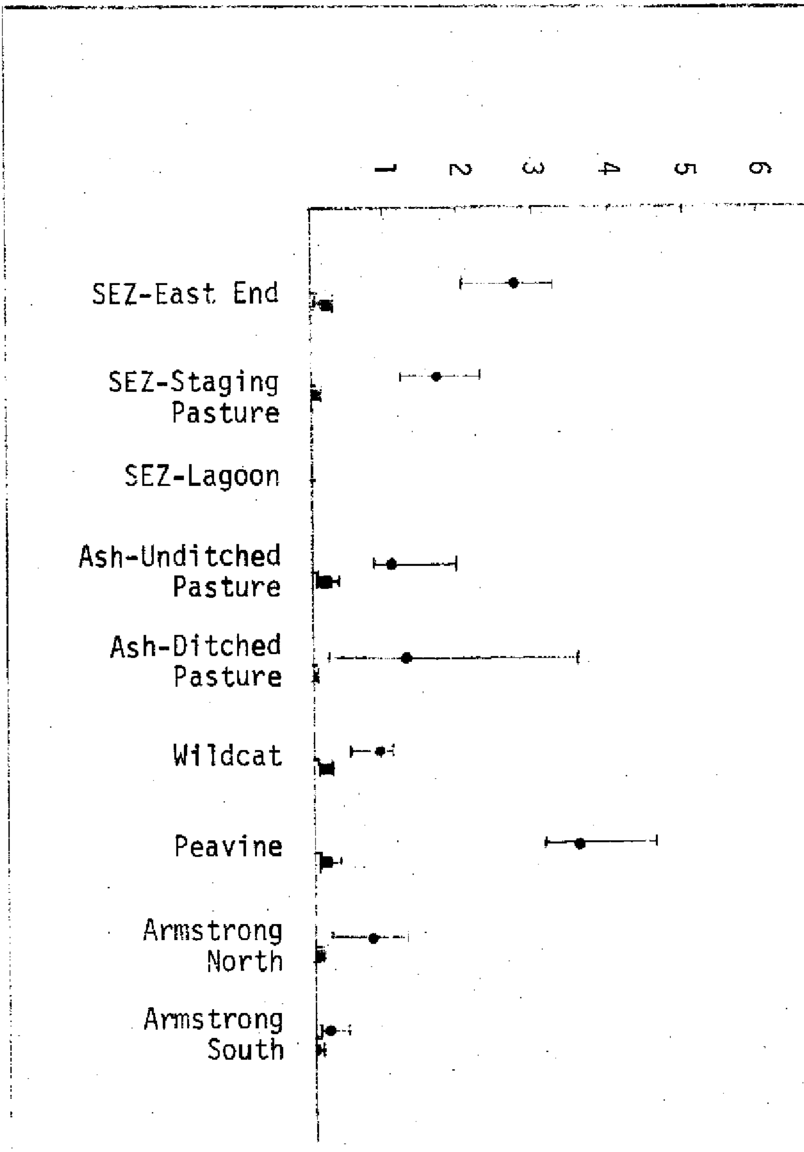
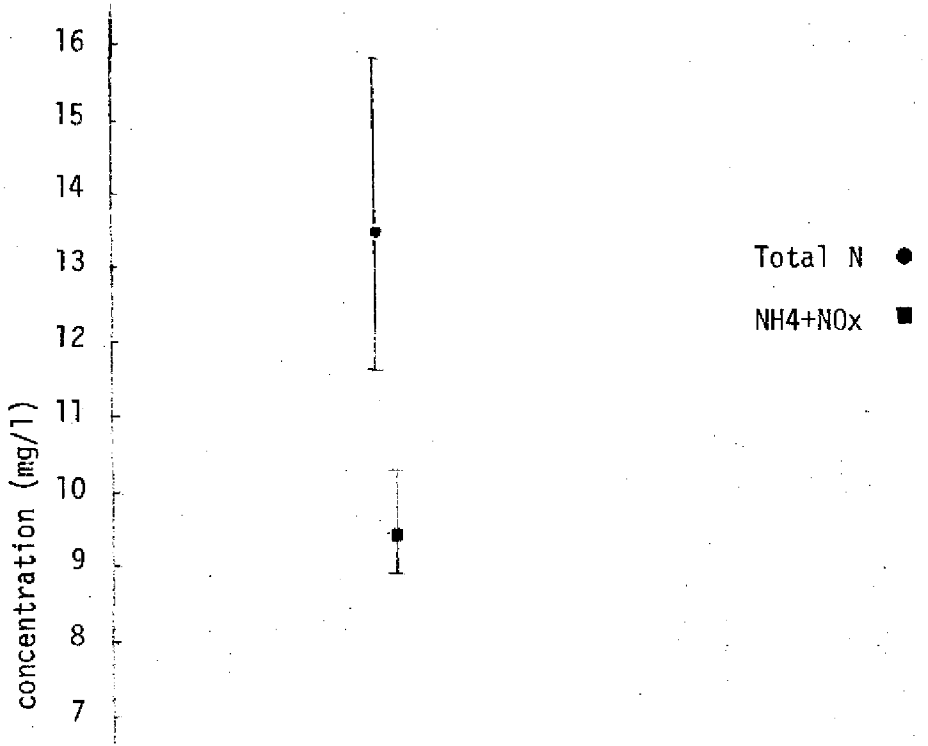

1
2
3
4
5
6
SEZ-East End
SEZ-Staging Pasture
SEZ-Lagoon
Ash-Unditched Pasture
Ash-Ditched Pasture
Wildcat
Peavine
Armstrong North
Armstrong South

Figure IV-25.

NUTRIENT CONCENTRATIONS IN GROUNDWATER
1981
NITROGEN SPECIES (MEANS & RANGES)



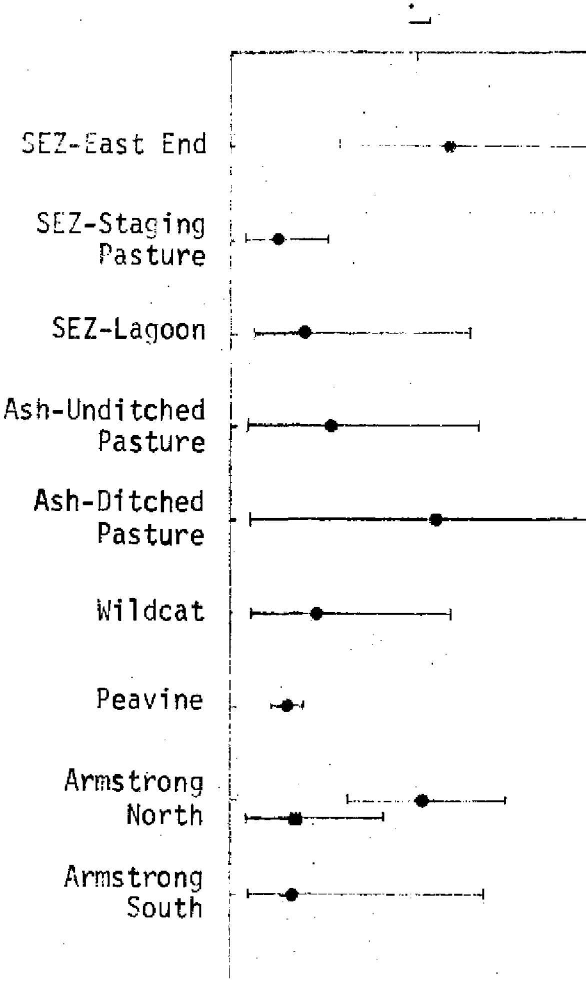

SEZ-East End
SEZ-Staging Pasture
SEZ-Lagoon
Ash-Unditched Pasture
Ash-Ditched Pasture
Wildcat
Peavine
Armstrong North
Armstrong South

Figure IV-26. NUTRIENT CONCENTRATIONS IN GROUNDWATER 1981 PHOSPHORUS SPECIES (MEANS & RANGES)

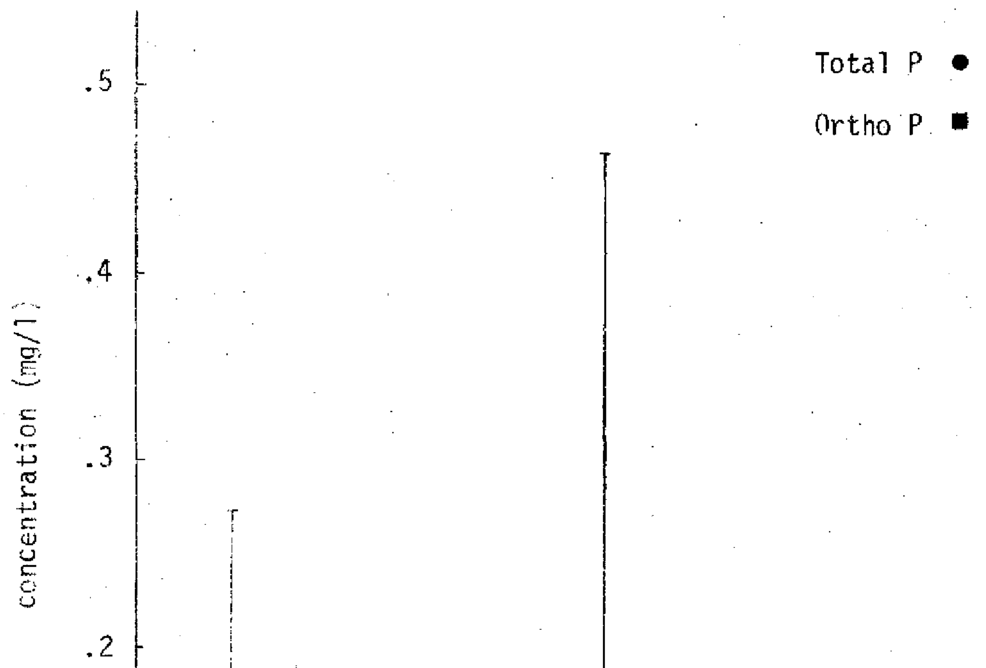


table than any of the others in the study, probably due to the extensive network of drainage ditches in the area. During March of the year, the water table was below the bottom of the well and no samples could be obtained.

In one other case, land use does seem to impact shallow groundwater quality. Conductivity is highest at the dairy site. There is also a gradient of increasing conductivity as one goes toward the barn and waste lagoon area. This probably reflects the use of massive amounts of more saline deep groundwater required for the barn operation and its subsequent loss from the lagoon system as lateral seepage.

Dissolved inorganic N concentrations are extremely low at all stations with the sole exception of the monitoring well just north of the waste treatment lagoons at the SEZ Dairy. The ammonia concentrations at this station are extremely high. The source of this species is undoubtedly the dairy lagoon system. This,in conjunction with high conductivity levels at this station as compared with other stations both on and off the dairy suggests that water loss from the lagoons due to lateral seepage in shallow groundwater does occur and,in this case at least,is confined to the area immediately adjacent to the lagoons.

Total N concentrations were the highest at the dairy (due to the high inorganic N component) and the Peavine Pasture sites. Variation was greatest at the dairy and the Ash Slough ditched pasture. Total N concentrations were lowest at the Armstrong Slough south site. With the exception of the higher concentrations at the SEZ lagoon site and the higher variation at the Ash Slough ditched pasture site (both already discussed), total N concentrations did not seem to be correlated with the types of land use intensity represented in this study.

Ortho P concentrations are consistently at or below detection limits at all stations with the sole exception of Armstrong Slough north, where the ortho component constitutes roughly one-third to one-half of the total P concentration. Variability is greatest at the Ash Slough ditched pasture site. Surprisingly, the total P concentrations at the SEZ Dairy lagoon and staging pasture stations are of similar magnitude as those measured at the Wildcat, Armstrong, and Ash Slough unditched pasture sites. In light of high concentrations of P in surface water and presumption of lateral seepage to groundwater as evidenced by high conductivity and inorganic N concentrations, one has to assume that P is retained in the sediment of the lagoon system or the soil surface of staging pastures.

It can be concluded that land use practices at the Upland Project sites, other than extensive ditching for drainage, have little, if any, observable impact on either ortho or total P concentrations in shallow groundwater. Nitrogen, on the other hand, appears to be more mobile. Groundwater wells in close proximity to a body of water containing exceedingly high N concentrations (dairy waste lagoons) do appear to be adversely impacted.

SECTION V

DETENTION/RETENTION SYSTEMS

INTRODUCTION

Evaluation of detention/retention system designs and impacts on water quality is one of the major goals of the Uplands Demonstration Project. Two types of wetlands and a dairy waste treatment lagoon system are being studied. Results of preliminary investigation over the study period April 1979 through December 1980 are discussed in Goldstein (1981). Evaluation of the roles of each of these systems during the 1981 calendar year will be presented in this section.

ASH SLOUGH

The Ash Slough detention/retention marsh is an intermittently flooded system that receives surface water runoff from rainfall which occurs over a roughly 200-acre (81 ha) watershed. Inflow to the system is therefore intermittent. When no rainfall occurs during long periods, standing water in the marsh evaporates leaving a dry shallow basin. During much of 1981, the marsh was completely dry. There were only two brief periods when enough rainfall and subsequent runoff occurred to result in measurable inflow into the marsh. At no time did water levels in the marsh rise to the point where discharge from the system occurred. The Ash Slough marsh under drought conditions does serve to effectively catch and retain on site runoff and associated nutrient loads from the contributing watershed. Abnormally low rainfall amounts during the subject period were never sufficient to produce enough rainfall to supercede the storage capacity of the detention/retention area. There were then no significant "events" at Ash Slough during 1981; therefore, no further progress was made in the evaluation of this system's ability to remove nutrients when flow-through conditions exist.

ARMSTRONG SLOUGH

Unlike Ash Slough, the Armstrong Slough D/R wetland (Figure V-1) is a continual flow-through system. It received inflow from a tributary which drains a 20,000 acre (8,100 ha) watershed continually throughout 1981. There were some periods in 1981 when evapotranspiration and seepage exceeded inflow and no surface discharge occurred from the marsh.

The marsh itself was enlarged and converted into a flow-through system by the installation of an earthen plug in the major drainage channel. This alteration, made in May 1980, was designed to force water out of the main channel and through the adjacent recreated wetland.

Time series water quality data for total and inorganic nitrogen species (Figure V-2) and total and ortho phosphorus species (Figure V-3), during the subject period April 1979-December 1980, illustrate typical concentrations of these parameters at the inflow and outfall stations prior to, during, and following installation of the channel plug and subsequent conversion to a flow-through marsh. For these parameters, the most immediate effect following plug installation appeared to be a reduction in variability and a general slight decrease in concentrations of each species at the station 1 outfall. While there was a noticeable reduction of total phosphorus concentrations, the most dramatic effect appeared to be the uptake of the ortho component. Following the plug installation in April 1980, concentrations of this species were practically undetectable at the marsh outfall.

Time series nitrogen and phosphorus concentration data for the period of record January 1981 through December 1981 are presented in Figures V-4, V-5, and V-6. These data, collected under drought conditions that prevailed

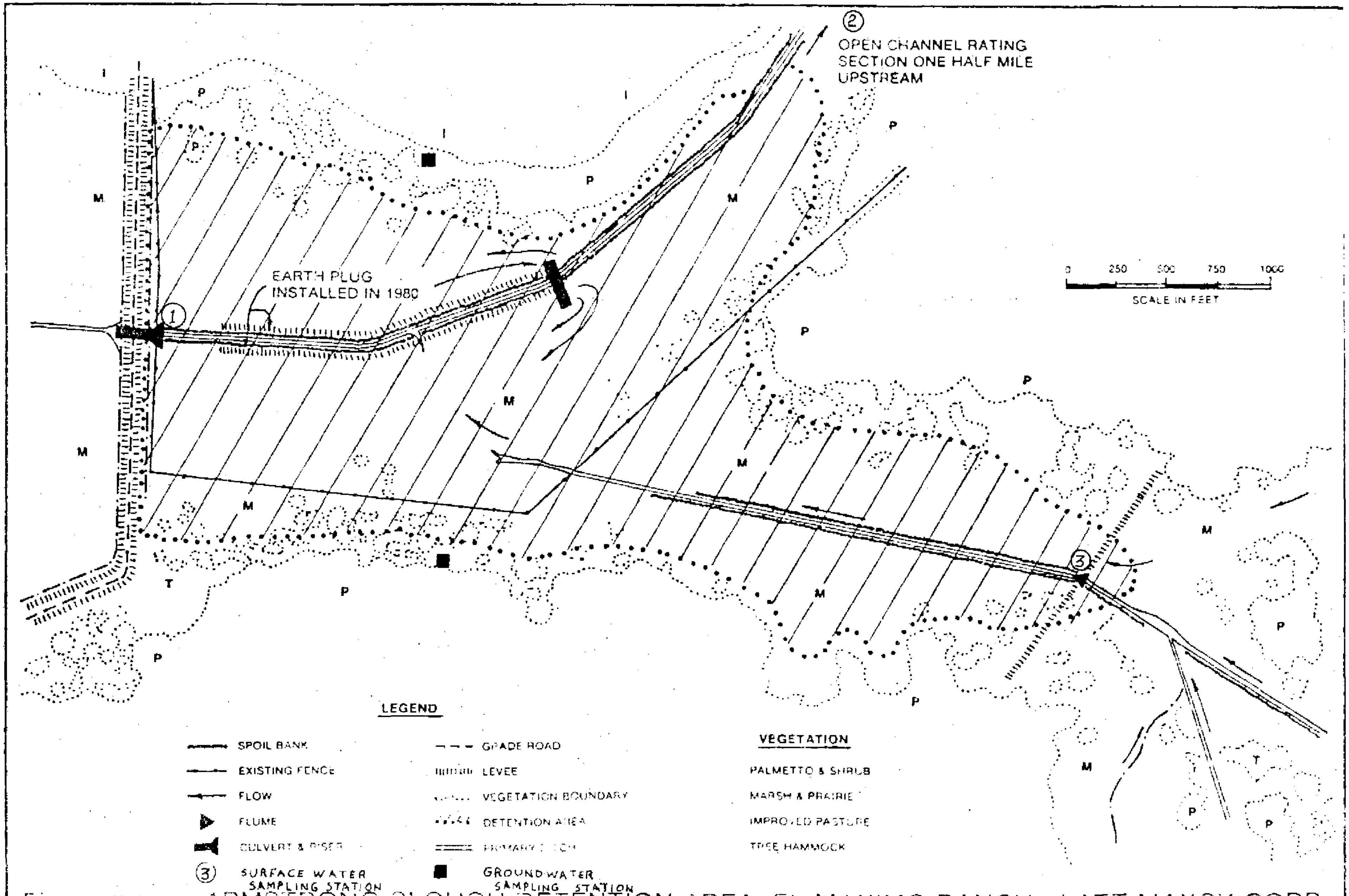


Figure V-1. ARMSTRONG SLOUGH DETENTION AREA, EL MAXIMO RANCH LATT MAXCY CORP.

Figure V-2. NITROGEN CONCENTRATIONS
AT
ARMSTRONG SLOUGH MARSH OUTFALL

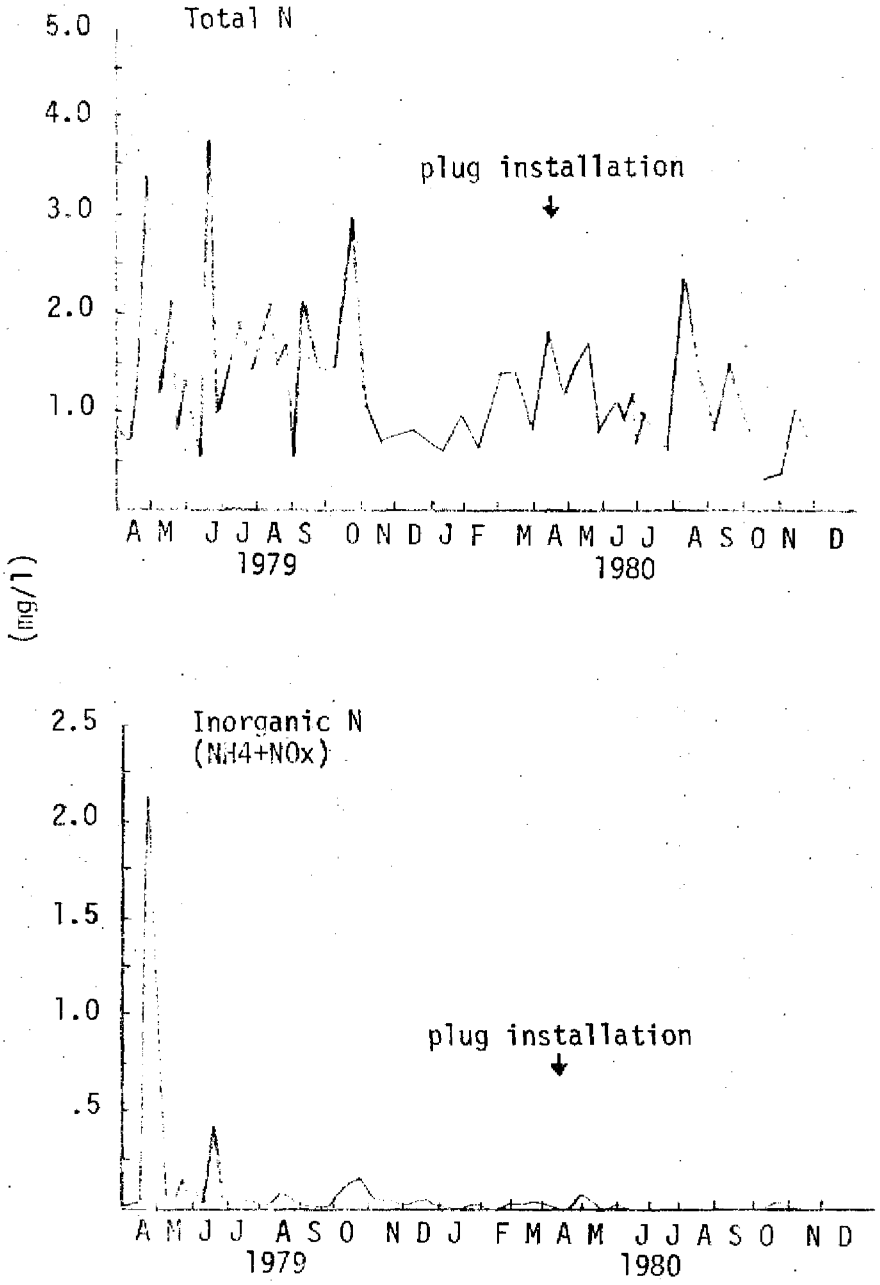


Figure V-3.

PHOSPHORUS CONCENTRATIONS
AT
ARMSTRONG SLOUGH MARSH OUTFALL

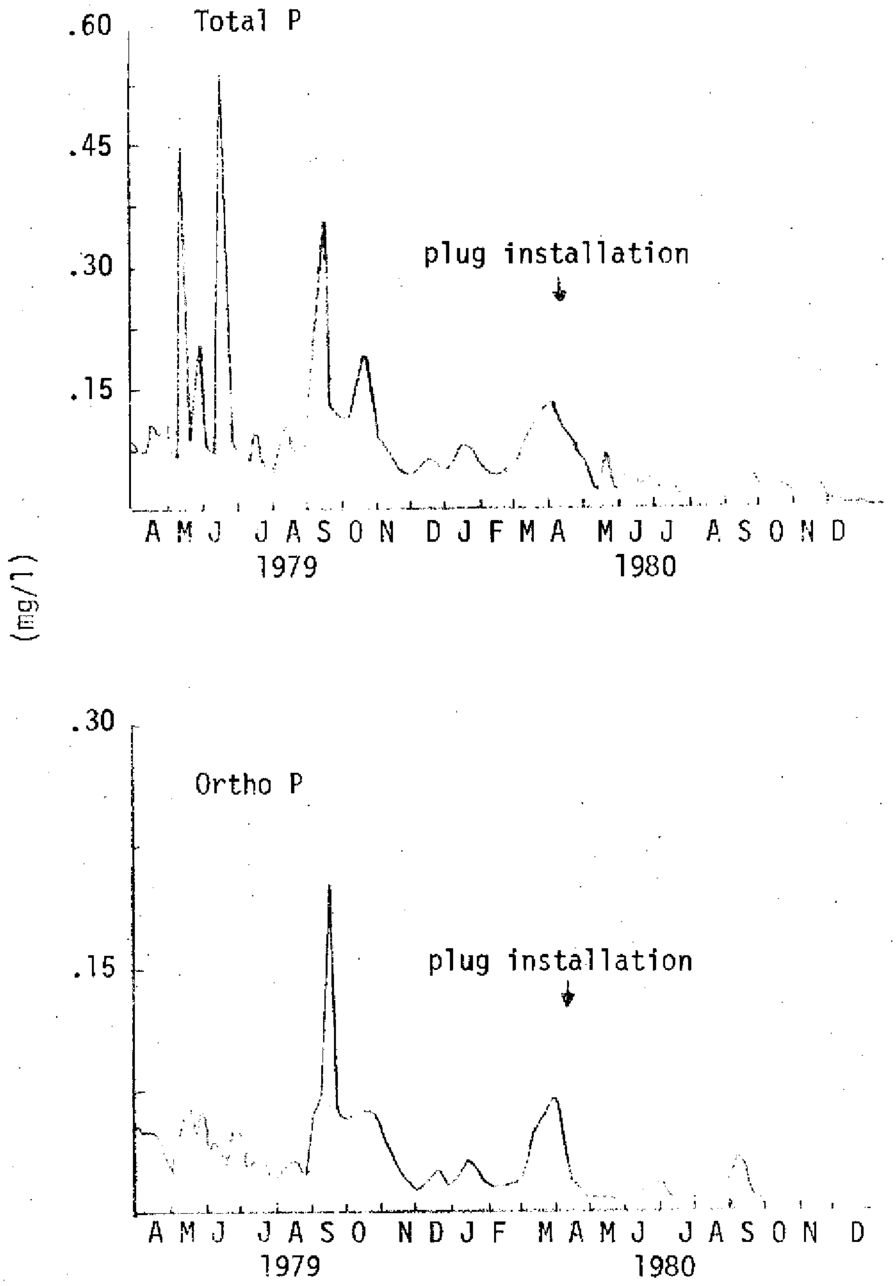
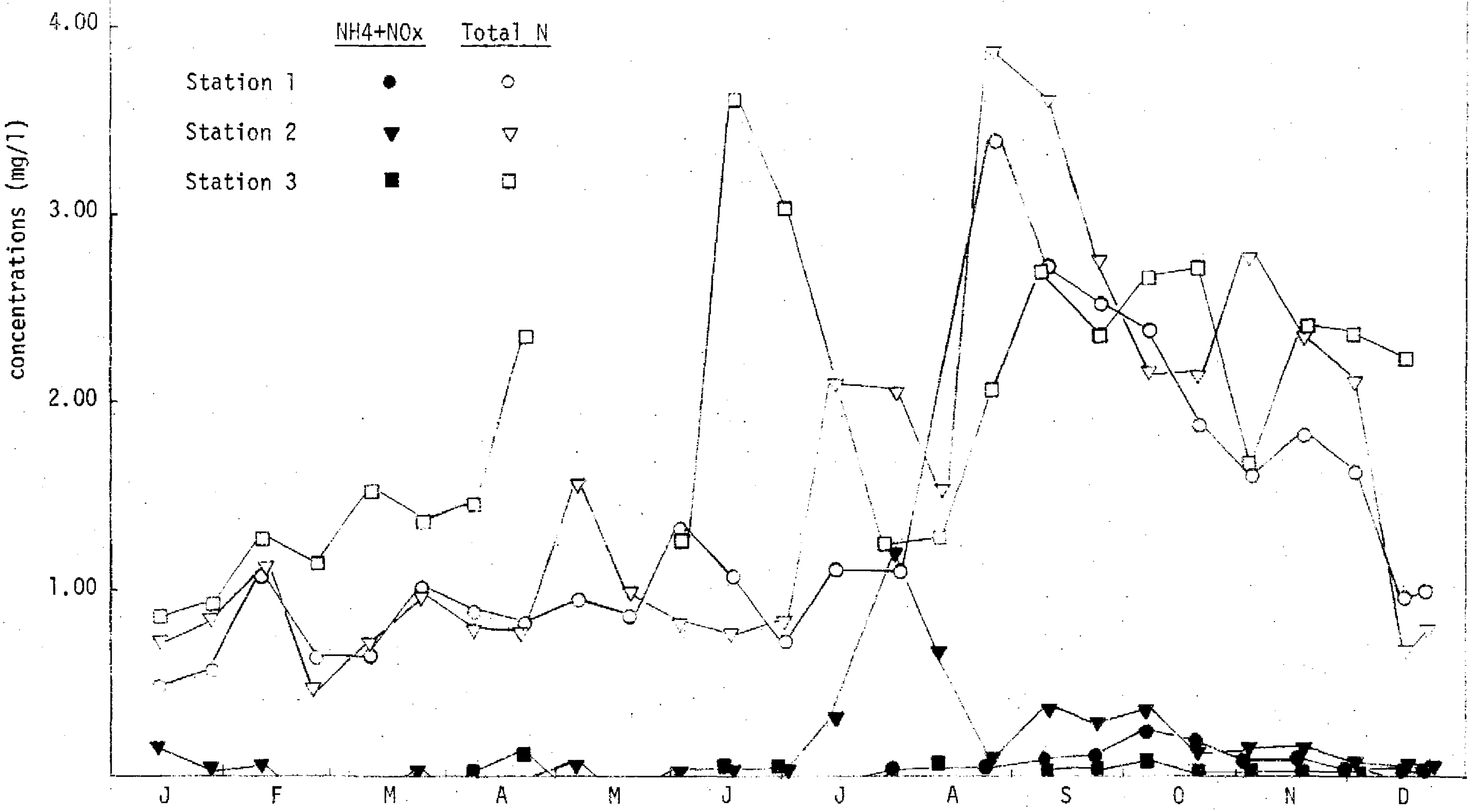


Figure V-4. ARMSTRONG SLOUGH
1981 INORGANIC AND TOTAL NITROGEN
CONCENTRATIONS



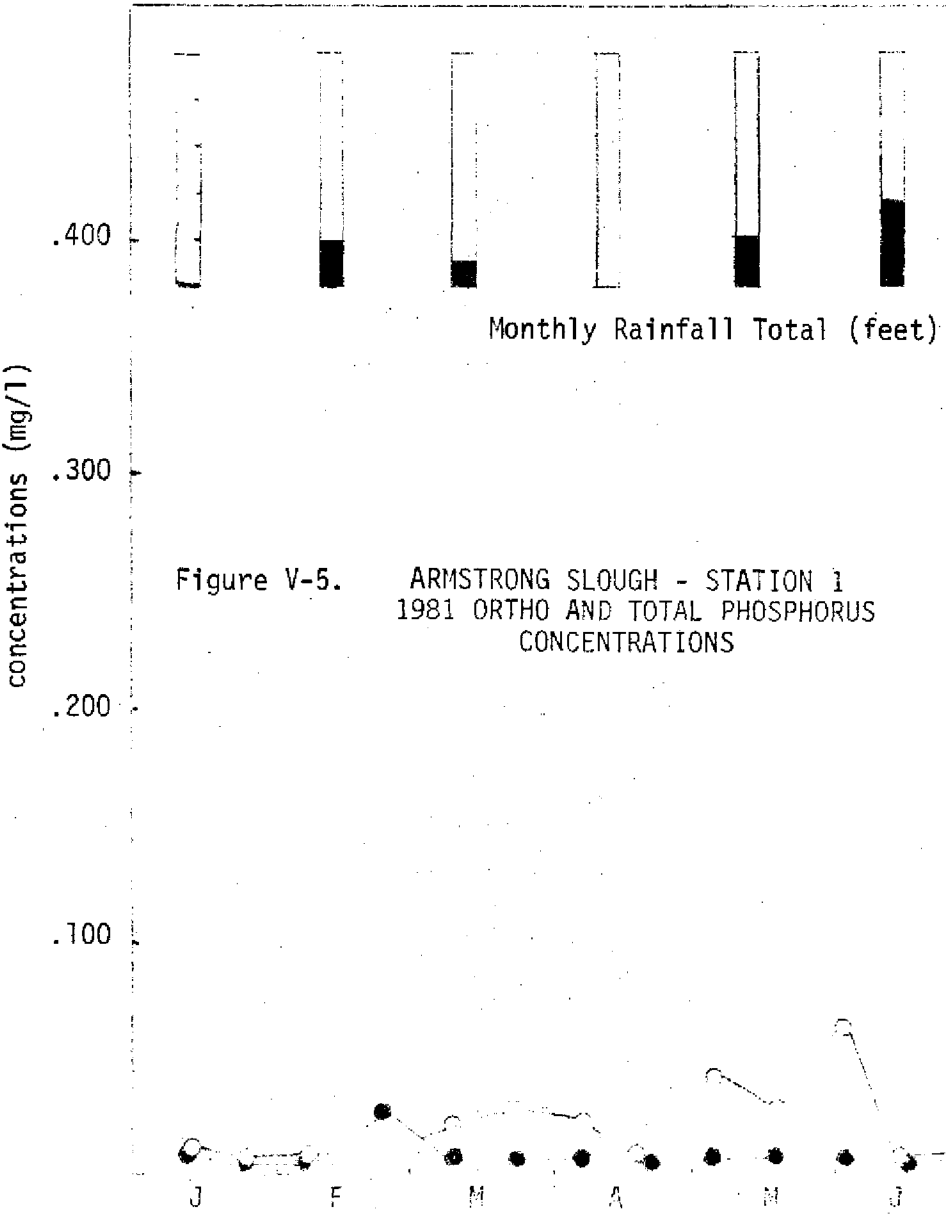
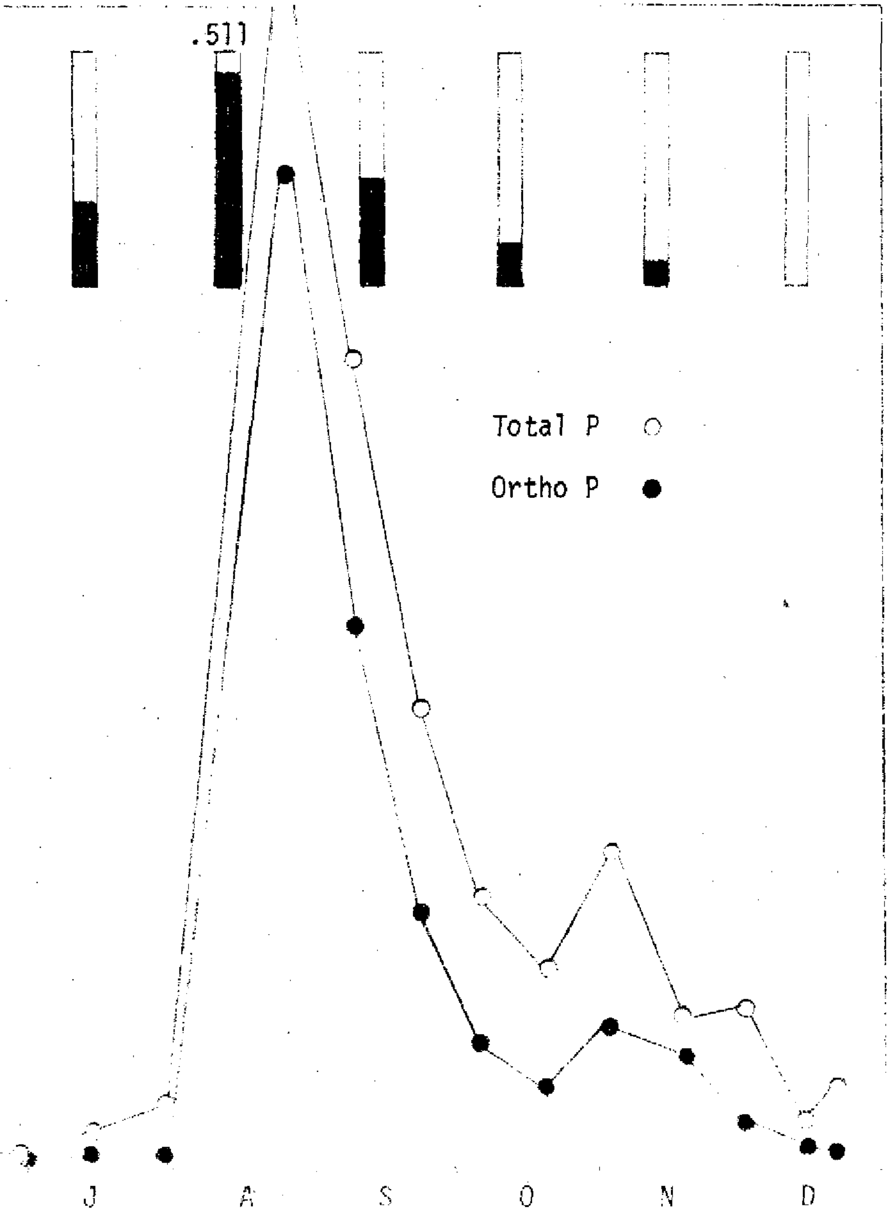


Figure V-5. ARMSTRONG SLOUGH - STATION 1
1981 ORTHO AND TOTAL PHOSPHORUS
CONCENTRATIONS


.511
Total P ○
Ortho P ●
J
A
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O
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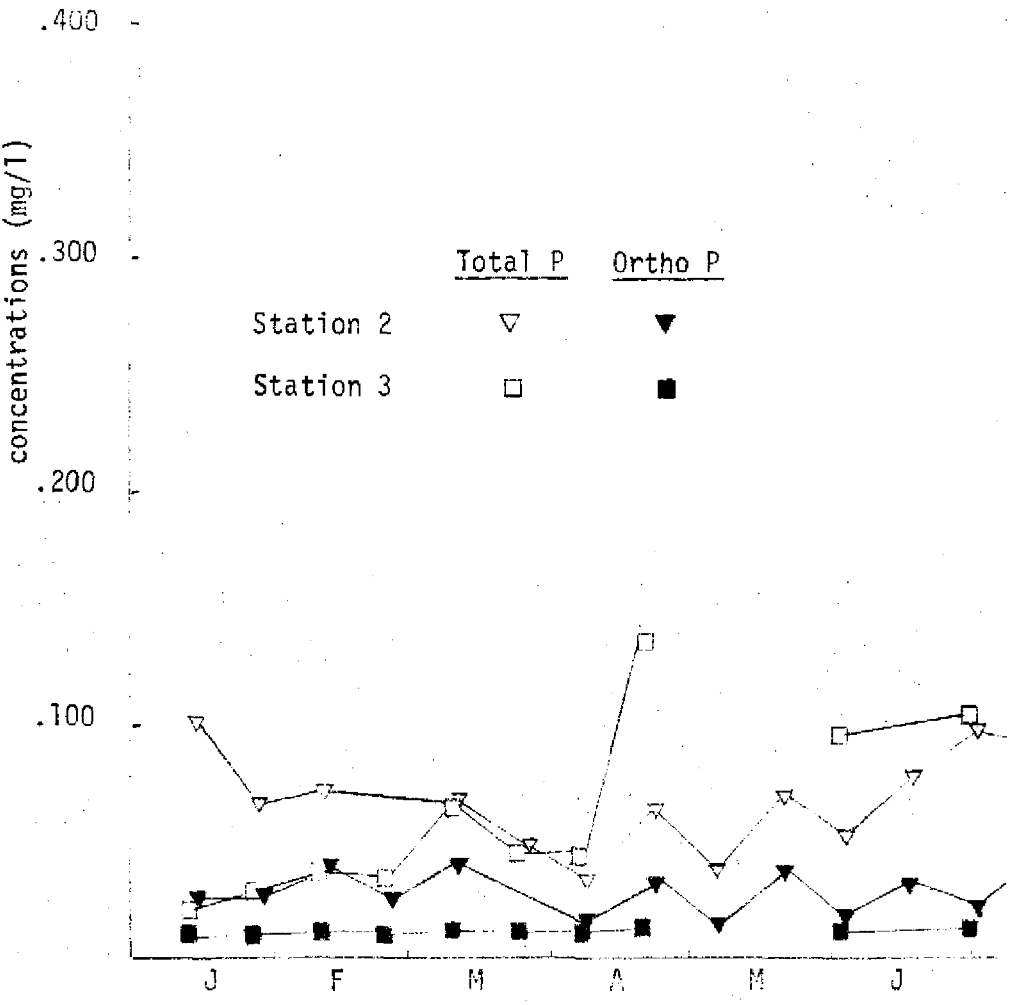
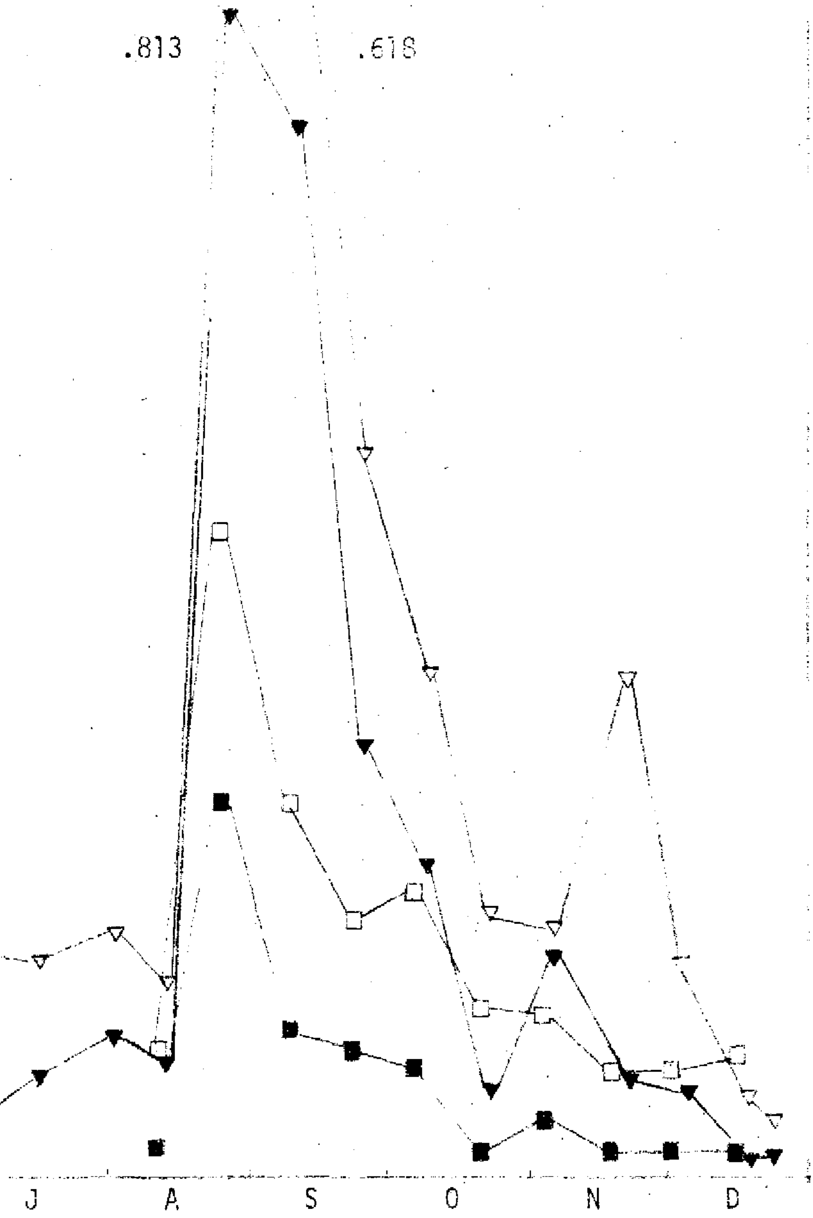
D

Figure V-6. ARMSTRONG SLOUGH - STATIONS 2 AND 3 1981 ORTHO AND TOTAL PHOSPHORUS CONCENTRATIONS




.813
.618
J
A
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O
N
D

during this portion of the study, show two things. The first is that trends in concentrations of nitrogen and phosphorus at the marsh outfall (station 1) reflect trends in concentrations of these parameters in the channel draining the largest portion of the watershed (station 2). Concentrations at station 1 continue to remain somewhat lower than concentrations of the same parameters measured at stations 2 and 3. Concentrations measured at station 3 represent conditions prevalent in an intermittently flowing channel, whereas flow in the other tributary channel was continuous. High total N concentrations observed at station 3 during June are merely an artifact of the intermittent nature of water at this site during this period of the study.

The second, and very obvious, point made by these data is the occurrence of a dramatic rise in concentrations of nutrient parameters during August 1981. This coincides with the onset of overland runoff from the watershed during the 1981 wet season. This "first flush" phenomenon does result in a rapid dramatic deterioration of water quality followed by a gradual return to pre-event conditions nearly 60 days later. The implications of this are twofold. The first is that the worst quality water comes during periods of greatest flow. The second is that the efficiency of the marsh to function in the desired manner may be impaired while in this overloaded state. This is suggested by the occurrence of the rise in nutrient concentrations at the marsh outfall during the same period.

Detention time appears to be at least one, if not the main, critical factor that impacts the marsh's ability to remove nutrients. The consequences of this are demonstrated by the reduction of this marsh's ability to effectively reduce nutrient loads during periods of peak stormwater runoff while in a hydraulically overloaded state. One can conclude that the size of a detention system will be critical in the design if it is to be able to handle some desired quantity of stormwater runoff.

Mean flow-weighted concentrations of nitrogen and phosphorus species calculated for December 1980 through December 1981 are presented in Table V-1. For this 12-month study period, there was a net reduction of total nitrogen concentration in the marsh of 3.9 percent and a reduction of phosphorus concentrations of 12.9 percent. At the same time, the detention area retained in storage or lost by seepage or evapotranspiration 75.9 percent of the total flow that was contributed to it. Under the low to moderate flow conditions that prevailed during this time, there was a net reduction in load to receiving waters. This reduction was accomplished by reducing both flow and nutrient concentrations in the marsh, with the majority of the reduction attributed to water retention in the marsh.

During the subject period, 24,851.5 kilograms of total nitrogen and 3,055.4 kilograms of total phosphorus were measured in inflow to the detention marsh. During the same period, 5,757.7 kilograms of total nitrogen and 643.6 kilograms of total phosphorus were measured leaving the marsh at the outfall culverts. The net uptake of total nitrogen over this period was about 19,093.8 kilograms, and of total phosphorus was about 2,411.8 kilograms. This translates to a net uptake efficiency of nitrogen and phosphorus by the marsh as 76.8 and 78.9 percent, respectively.

The inorganic N component of the total N load was relatively small (12.5 percent) and was effectively taken up by the marsh (93.2 percent reduction). The ortho P component was the major portion of the total P load (65.8 percent), but was taken up less effectively than inorganic N (77.7 percent reduction in load).

Water stage - marsh volume relationships were calculated by SFWMD

Table V-1.

Nutrient Reduction Efficiency
Armstrong Slough Marsh
Total Loads and Flow Weighted Mean Concentrations
1981

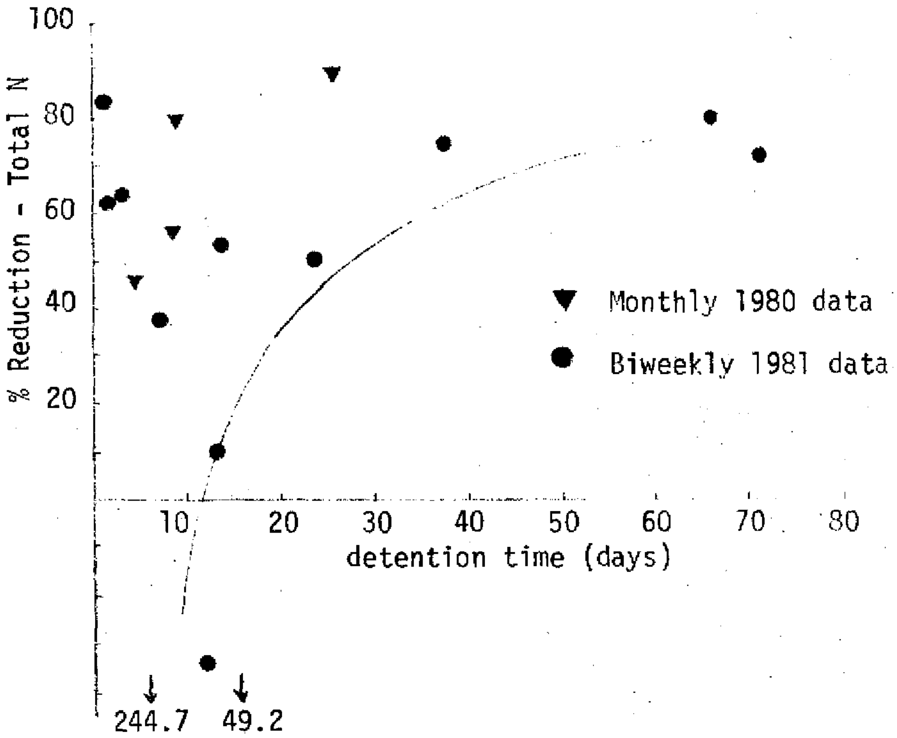
	Total N	Inorganic N	Total P	Ortho P	Total Flow (m³)
Marsh Inflow					
Total load (kg)	24,851.5	2,564.1	3,055.4	2,041.6	9,773,705.7
Mean concentration (mg/l)	2.54	0.26	0.31	0.21	
Marsh Outflow					
Total load (kg)	5,757.7	174.8	643.6	454.9	2,358,149.8
Mean concentration (mg/l)	2.44	0.07	0.27	0.19	
Total Reduction in Load (kg)	19,093.8	2,389.3	2,411.8	1,586.7	7,415,555.9
Percent Reduction					
Total load	76.8	93.2	78.9	77.7	75.9
Mean concentration	3.9	73.1	12.9	14.3	

hydrologists. Mean water stages in the marsh were calculated over each two-week routine sampling interval during 1981 to determine a mean marsh volume. Total hydraulic loading over the same sampling interval was divided by the mean marsh volume to arrive at an interval mean residence time for water in the marsh. Nutrient uptake efficiencies for these same intervals were calculated. The results were plotted as marsh nutrient uptake efficiency versus mean interval detention time. The results are presented in Figure V-7.

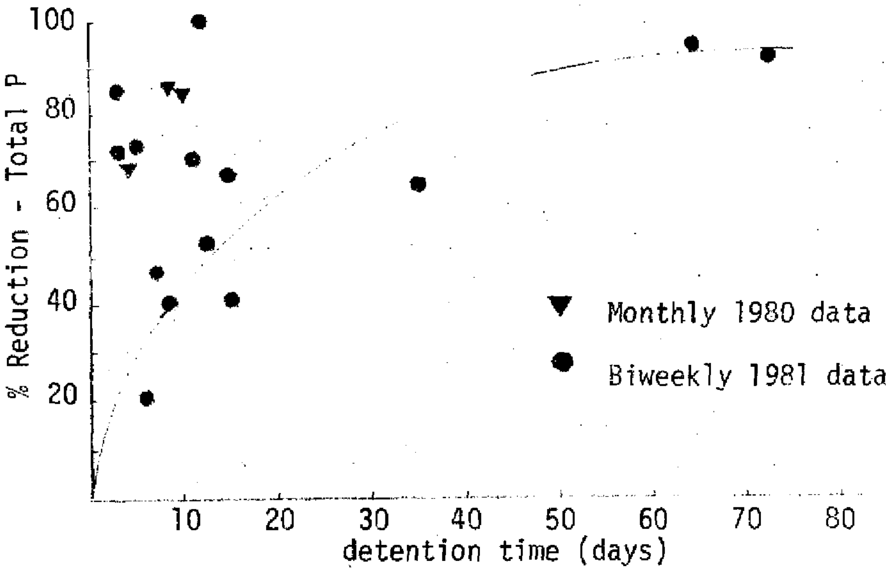
The curves are merely estimations and probably shifted somewhat to the right of lines of best fit based on least squares methodology. This approach has been taken to insure that,if this preliminary data were to be used for design purposes to estimate treatment efficiency of a given marsh, any error would probably be on the side that would result in a marsh more efficient than design needs dictate.

Using the curves, one can estimate the number of days necessary for the desired efficiency of uptake. For instance, 50 percent or better uptake of nitrogen might be expected given a 23-day detention time, whereas phosphorus uptake of 50 percent or better might be expected in roughly 10 days.

In the context of the meteorological and hydrological conditions that these data represent, some characteristics of the flow-through D/R wetland at Armstrong Slough are becoming evident. The marsh does serve as a sink for N and P loads. This occurs as a result of some reduction in concentrations, but predominantly as a result of water storage and/or loss from the system. By whatever mechanism, during 1981 it was estimated that the marsh acted as a sink for 19,094 kilograms of total N and 2,412 kilograms of total P. The amount of water retained



Detention Time/Nitrogen Reduction Efficiency



Detention Time/Phosphorus Reduction Efficiency

RESIDENCE TIME VS NUTRIENT REDUCTION EFFICIENCY AT ARMSTRONG SLOUGH MARSH

Figure V-7.

in the marsh through storage or lost by seepage and/or evapotranspiration was over 7,415,000 cubic meters. The efficiency of the marsh to remove N and P appears to be positively correlated with detention time, where longer times in the marsh result in increased percent of uptake. It must be emphasized that these conclusions are preliminary, and in the future these data will be reevaluated in the context of the overall study which will include data collected during periods of more normal rainfall and runoff.

SEZ DAIRY

Rationale and methodology for evaluating the efficiency of the SEZ Dairy wastewater treatment lagoons to remove nitrogen and phosphorus from barn effluent has been described in Goldstein (1981). This methodology was utilized with hydrological and water quality data collected during the 1981 calendar year to compute monthly and annual nutrient uptake in, and discharge from, the barnwater treatment facilities.

Estimated mean daily barnwash volume for each month of 1981 is given in Table V-2. The predicted range of barnwash volume for a 500-cow dairy (approximate number of animals at SEZ) is on the order of 189-284 m^3/day. Mean daily barnwash volume ranged from 136.2 m^3 in May to 245.4 m^3 in October, and while seven of the twelve monthly daily means of 1981 are lower than the minimum predicted, they are still of sufficient amplitude (particularly given the inaccuracies inherent in the method of estimation) to continue to justify 0.38-0.57 m^3/cow/day (Nordstedt and Baldwin, 1973) as a rule of thumb for wastewater production of typical dairy barn operations in south-central Florida.

With the exception of one lower data point for both ortho and total phosphorus, ranges of concentrations of water quality parameters monitored

Table V-2.

1981 Sez Dairy

Estimated Monthly Barnwash Volume
(cubic meters)

	Monthly Total	Daily Mean
January	5,087.6	164.1
February	5,891.7	210.4
March	4,345.5	140.2
April	4,954.5	165.2
May	4,222.3	136.2
June	5,398.3	179.9
July	4,258.1	137.4
August	5,320.2	171.6
September	6,917.6	230.6
October	7,606.2	245.4
November	4,982.1	166.1
December	6,487.5	209.3

during 1981 were well within those observed during the previous 21 months of this study. Mean concentrations of inorganic nitrogen and ortho phosphorus were somewhat lower during 1981 than those observed during the previous months of the study (roughly half in each case). Mean concentrations of total nitrogen and phosphorus as well as physical parameters in 1981 were very similar to those noted for the preceding 21 months.

For purposes of consistency, mean concentrations of parameters calculated over the subject study period 04/01/79 through 12/31/80 were used to calculate 1981 loads attributable to barnwash. These concentrations are representative of the means of the same parameters during 1981, except perhaps inorganic nitrogen and ortho phosphorus. In these cases, the 1981 barnwash loads may be overestimated. If this is the case, the implications are probable overestimation of treatment efficiency for these two parameters during 1981.

Efficiency of the wastewater lagoon system to reduce nitrogen and phosphorus loads was calculated on a flow-weighted basis for each month of 1981. The percent reduction of concentration of each nutrient species was compared with the monthly estimated water budgets for the lagoon system. These data are presented in Table V-3. For those instances where percent reduction of concentration of any particular nutrient species exceeded the percent reduction of discharge, one can conclude that the lagoon system is actively taking up that species. In those cases where treatment efficiency was equivalent to reduction in discharge, the apparent reduction in load can be attributed predominantly to the reduction in discharge. In those cases where the treatment efficiency is less than the reduction in flow, one can conclude that the waste treatment system is actually contributing to the enrichment of those species in the water column.

SEZ Dairy Flow Weighted Lagoon Treatment Efficiency

Table V-3.(continued)

1981

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Ortho P (kg/m^3)												
Load to Lagoon 1	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005
Load to Lagoon 2	.005	.007	.003	.003	.006	.007	.006	.005	.003	0	0	.010
Percent change	0	+40.0	-40.0	-40.0	+20.0	+40.0	+20.0	0	-40.0	-100.0	-100.0	+100.0
Discharge from Lagoon 2	.007	.009	.011	.006	.003	.002	.002	.002	.005	.006	.004	.006
Percent change	+40.0	+28.6	+266.7	+100.0	-50.0	-71.4	-66.7	-60.0	+40.0	-	-	-40.0
Total % reduction from barnwash	+40.0	+80.0	+120.0	+20.0	-40.0	-60.0	-60.0	-60.0	0	+20.0	-20.0	+20.0
Total P (kg/m^3)												
Load to Lagoon 1	.026	.026	.026	.026	.026	.026	.026	.026	.026	.026	.026	.026
Load to Lagoon 2	.020	.023	.028	.030	.029	.021	.018	.020	.023	0	0	.021
Percent change	-23.1	-11.5	+7.7	+15.4	+11.5	-15.4	-30.8	-23.1	-11.5	-100.0	-100.0	-19.2
Discharge from Lagoon 2	.010	.015	.014	.009	.005	.005	.004	.006	.007	.008	.009	.008
Percent change	-45.0	-34.8	-50.0	-70.0	-82.8	-76.2	-77.8	-70.0	-69.6	-	-	-61.9
Total % reduction from barnwash	-57.7	-42.3	-46.2	-65.4	-80.8	-80.8	-84.6	-76.9	-73.1	-69.2	-65.4	-69.2

Note: Negative percentages = reduction of load; positive percentages = increase of load.

SEZ Dairy Flow Weighted Lagoon Treatment Efficiency

Table V-3.

1981

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Flow (cubic meters)												
Barnwash	5,087.6	5,891.7	4,345.5	4,954.9	4,222.3	5,398.3	4,258.1	5,320.2	6,917.6	7,606.2	4,981.1	6,487.5
Lagoon 1 discharge	5,324.9	4,600.2	203.3	4,309.4	941.2	115.1	3,084.9	4,780.7	7,509.4	0	0	5,055.2
Percent change	+4.7	-21.9	-95.3	-13.0	-77.7	-97.9	-27.6	-10.1	+8.6	-100.0	-100.0	-22.1
Lagoon 2 discharge	3,259.3	9,787.7	1,928.7	3,311.0	2,459.0	1,925.0	4,743.3	4,589.3	6,218.5	4,668.9	2,400.3	4,916.6
Percent change	-38.8	+112.8	+848.7	-23.2	+161.3	+1,572.5	+53.8	-4.4	-27.0	-	-	-2.7
Total % reduction from barnwash	-35.9	+66.1	-55.6	-33.2	-41.8	-64.3	+11.4	-14.1	-10.1	-38.6	-51.8	-24.2
NO3 + NH4 (kg/m³)												
Load to Lagoon 1	.029	.029	.029	.029	.029	.029	.029	.029	.029	.029	.029	.029
Load to Lagoon 2	.035	.028	.036	.043	.049	.063	.053	.046	.045	0	0	.038
Percent change	+20.7	-3.4	+24.1	+48.3	+69.0	+117.2	+82.8	+58.6	+55.2	-100.0	-100.0	+31.0
Discharge from Lagoon 2	.013	.006	.002	.003	.003	.002	.005	.011	.009	.012	.010	.009
Percent change	-62.9	-78.6	-94.4	-93.0	-93.9	-93.4	-90.6	-76.1	-80.0	-	-	-76.3
Total % reduction from barnwash	-55.2	-79.3	-93.1	-90.0	-89.7	-86.2	-82.8	-62.1	-69.0	-58.6	-65.5	-69.0
Total N (kg/m³)												
Load to Lagoon 1	.145	.145	.145	.145	.145	.145	.145	.145	.145	.145	.145	.145
Load to Lagoon 2	.071	.050	.089	.088	.102	.110	.090	.083	.051	0	0	.076
Percent change	-51.0	-65.5	-38.6	-39.3	-29.7	-24.1	-37.9	-42.8	-64.8	-100.0	-100.0	-47.6
Discharge from Lagoon 2	.029	.022	.016	.020	.021	.019	.019	.024	.026	.034	.029	.020
Percent change	-28.2	-56.0	-82.0	-77.3	-79.4	-82.7	-78.9	-71.1	-49.0	-	-	-73.7
Total % reduction from barnwash	-80.0	-84.8	-89.0	-86.2	-85.6	-86.9	-86.9	-83.4	-82.1	-76.6	-80.0	-86.2

Note: Negative percentages = reduction of load; positive percentages = increase of load.

During 1981, the waste treatment lagoon system continued to operate in the same manner as described for 1979 and 1980 (Goldstein, 1981). There was a net reduction of total nitrogen throughout the system both in concentrations and loads. The first lagoon continued to serve as the location for the initial decomposition and conversion of organic nitrogen to the dissolved inorganic state (predominantly NH_3). This conversion continued in the second lagoon. In addition, the second lagoon served as the location of the nitrogen decreasing processes in the system as concentrations and loads were reduced either through vegetative uptake or volatilization of ammonia or other nitrogen gases. Reduction efficiency of total nitrogen on a per unit flow-weighted basis was consistently 80 percent or better during each month throughout the entire year. On an annual basis, total nitrogen reduction was about 84 percent. Water loss in the system through storage or evapotranspiration and seepage during the same period was only 23.3 percent of the incoming wastewater volume. It can be concluded that the lagoons do have significant impact in reduction of nitrogen from dairy barn operations.

On a monthly basis, reduction of total phosphorus in the lagoon system ranged from about 42 to 85 percent of load on a per unit volume basis. On an annual flow-weighted basis, this reduction was roughly 66 percent. Again, 23 percent of the loss could be attributed to loss through seepage, storage in the sediment, or uptake by vegetation. Like nitrogen, phosphorus in the lagoons undergoes breakdown and conversion attributed to biochemical processes.

The dissolved reactive (ortho) phosphorus component is the one nutrient species of interest that actually increases in both concentration and discharge load as barnwash water travels through the system. The increase is undoubtedly the product of the conversion of particulate forms to the dissolved state.

Loss processes must take place in either planktonic intake in the water column or sedimentation and/or absorption on mineral particles at the soil/water interface. It could be speculated that some of the dissolved constituent accompanies seepage and is lost from the system in this manner. Observations of a shallow groundwater monitoring well located a few yards north of the second lagoon at SEZ Dairy indicate that ortho phosphorus in the groundwater is consistently below detectable limits. The total phosphorus concentrations are, however, about two and one-half times greater than total phosphorus concentrations at observation wells located elsewhere on the dairy and more remote from the lagoon system. Mean total phosphorus concentrations at this well are the highest of any observed at the Upland Detention Project sites. There is then justification to believe that some phosphorus is lost through seepage into the shallow groundwater. The interesting fact is that at this depth, phosphorus occurs predominantly in a particulate rather than a dissolved form.

These data suggest that the major mechanism of phosphorus uptake in the system is probably sedimentation. The implications of this are important in that sediments in older lagoons are probably exceedingly rich in phosphorus. This storage reservoir, coupled with anaerobic conditions that prevail in the lagoons, serves to maintain an equilibrium of dissolved ortho phosphorus in suspension in the water column. This fact, along with the absence of dissolved ortho phosphorus in the shallow groundwater (3 meters), coupled with the presence of particulate phosphorus measurably greater than those concentrations observed at any other study sites, suggests that the soil/water interface of the lagoon may be the locale, and the microbial biochemical processes that occur there may be the mechanism of conversion of particulate to dissolved phosphorus in the lagoon system.

The presence of higher concentrations of particulate phosphorus in shallow groundwater adjacent to the dairy lagoon, in contrast to those noted at all other monitoring wells elsewhere in the project area, is probably indicative of at least some adsorptive capacity for phosphorus in the organic material deposited in the water constraining layer of the Immokalee soils typical at the SEZ Dairy site. The continual exposure to high concentrations of dissolved phosphorus from lagoon seepage would likely result in some uptake, at least at the interface of the relatively impermeable layer with the overlying highly permeable but low absorptive capacity sands.

Lagoon Impacts on Dairy Site Discharge

The waste stabilization lagoons at SEZ Dairy are operated in a largely passive manner. When the operator feels that the settling (first) lagoon has filled to a level such that it may begin to impede the discharge of water from the barn, he will switch on the pump that moves water from the first to the second lagoon. Water level in the second lagoon is controlled by a culvert and riser system. During 1981, stoplogs in the riser were never manipulated; the lagoon therefore maintained a more or less constant level. When the first lagoon was pumped and/or a significant amount of rainfall occurred to raise the water level in the second lagoon above the stoplogs, discharge from the lagoon system occurred. The effluent leaving the lagoons runs through a small marsh area adjacent to the holding lagoon and discharges directly into the perimeter ditch on the north side of the dairy. This ditch discharges into Wolf Creek roughly two miles from the point where the lagoon effluent enters. Discharge from the holding lagoon was monitored on a daily basis. These data were plotted (Figure IV-21) and compared with time series data for concentrations and levels of nutrient and physical parameters measured at the SEZ Dairy outfall site at Wolf Creek throughout the year (Figures IV-17 through IV-20).

Even though the outfall site is two miles downstream and discharges storm water runoff from the entire 800-acre (324 ha) dairy operation in addition to lagoon effluent, the peaks of increased concentrations of nitrogen and phosphorus species as well as conductivity, turbidity, and to some extent, color, at the site outfall coincide with those periods of significant discharge from the lagoon system. The implications of this are twofold. First, even though the waste stabilization lagoons do serve to significantly reduce nitrogen and phosphorus loads, the effluent is still richer in these materials than stormwater runoff or groundwater seepage from the remainder of the dairy operation. This indicates that in order to more effectively control nutrient export from dairy operations, the presently employed SCS-designed waste stabilization lagoon systems may need to be augumented by either other types of treatment facilities or implementation of effective waste management practices.

The second implication is that the worst quality coincides with peak flows and discharges occurring at the site outfall. This problem is enhanced by the fact that during the wet season the amount of effluent from the lagoon system increases. In addition, surface runoff from the pastures and hayfields is at a peak. This runoff is also a source of nutrients in the dairy effluent entering Wolf Creek. In fact, this source is estimated to contribute the major portion of the total nitrogen load in the discharge to Wolf Creek during August and September of 1981 (Table V-4). It also contributed the major portion of the loads of ortho phosphorus and total phosphorus in the effluent during July, August, and September of that year.

During 1981, 77.8 percent of the rainfall and lagoon discharge that occurred on and at the SEZ Dairy remained on the watershed. Potential nitrogen loads were also reduced by 78.6 percent for dissolved inorganic forms and 59.2 percent for total nitrogen. Phosphorus species on the other hand were exported in excess of total loads attributed to rainfall and lagoon discharge. Dairy activities resulted in a 112.7 percent increase of ortho phosphorus and a 64.3 percent increase of the total phosphorus loads at Wolf Creek over and above those loadings attributed to the lagoons and rainfall (Table V-4).

If one assumes that water and nutrient loads from the lagoon system

Table V-4. SEZ D
Flow and

	JAN	FEB	MAR	APR	MAY
FLOW (m^3)					
Rainfall	20,157	131,023	0	0	282,203
Lagoon Discharge	3,259	9,788	1,929	3,311	2,459
Total Input	23,416	140,811	1,929	3,311	284,662
Wolf Creek Outfall	3,797	25,383	1,050	0	0
Uptake -/Export +	-19,619	-115,428	-875	-3,311	-284,662
Percent Change	-83.8	-82.0	-45.4	-100.0	-100.0
INORGANIC N (kg)					
Rainfall	14.1	91.5	0	0	197.1
Lagoon Discharge	43.8	56.2	3.9	11.0	6.2
Total Input	57.9	147.7	3.9	11.0	203.3
Wolf Creek Outfall	0.3	11.8	0.1	0	0
Uptake -/Export +	-57.6	-135.9	-3.8	-11.0	-203.3
Percent Change	-99.5	-92.0	-97.4	-100.0	-100.0
TOTAL N (kg)					
Rainfall	34.0	221.0	0	0	476.0
Lagoon Discharge	96.0	214.1	30.7	66.0	51.2
Total Input	130.0	435.1	30.7	66.0	527.2
Wolf Creek Outfall	9.3	157.4	4.1	0	0
Uptake -/Export +	-120.7	-277.7	-26.6	-66.0	-527.2
Percent Change	-92.8	-63.8	-86.6	-100.0	-100.0

ry Watershed
Nutrient Budgets
1981

JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL
493,855	524,091	614,799	574,484	10,079	10,079	0	2,660,770
1,925	4,743	4,589	6,219	4,669	2,400	4,917	50,208
495,780	528,834	619,388	580,703	14,748	12,479	4,917	2,710,978
0	14,629	124,207	395,794	30,746	7,230	39	602,875
-495,780	-514,205	-495,181	-184,909	+15,998	-5,249	-4,878	-2,108,103
-100.0	-97.2	-79.9	-31.8	+108.5	-42.1	-99.2	-77.8
345.0	366.1	429.5	401.3	7.0	7.0	0	1,858.6
4.1	23.2	49.2	56.6	56.8	24.2	45.4	380.6
349.1	389.3	478.7	457.9	63.8	31.2	45.4	2,239.2
0	7.3	107.8	207.3	141.9	2.5	0	479.0
-349.1	-382.0	-370.9	-250.6	+121.9	-28.7	-45.4	-1,760.2
-100.0	-98.1	-77.5	-54.7	+191.1	-92.0	-100.0	-78.6
832.9	883.9	1,036.9	968.9	17.0	17.0	0	4,487.6
37.4	90.6	111.2	162.4	160.1	70.7	95.9	1,186.3
870.3	974.5	1,148.1	1,131.3	177.1	87.7	95.9	5,673.9
0	70.9	550.9	1,271.6	236.3	16.9	0	2,317.4
-870.3	-903.6	-597.2	+140.3	+59.2	-70.8	-95.9	-3,356.5
-100.0	-92.7	-52.0	+12.4	+33.4	-80.7	-100.0	-59.2

Table V-4 (continued)

	JAN	FEB	MAR	APR
<u>ORTHO P (kg)</u>				
Rainfall	1.9	12.3	0	0
Lagoon Discharge	22.3	85.5	20.4	21.1
Total Input	24.2	98.8	20.4	21.1
Wolf Creek Outfall	1.6	104.8	7.4	0
Uptake -/Export +	-22.6	+6.0	-13.0	-21.1
Percent Change	-93.4	+6.1	-63.7	-100.0
<u>TOTAL P (kg)</u>				
Rainfall	2.8	18.0	0	0
Lagoon Discharge	33.6	142.8	27.1	29.8
Total Input	36.4	160.8	27.1	29.8
Wolf Creek Outfall	2.1	142.0	8.5	0
Uptake -/Export +	-34.3	-18.8	-18.6	-29.8
Percent Change	-94.2	-11.7	-68.6	-100.0

SEZ Dairy Watershed
Flow and Nutrient Budgets
1981

MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL
26.5	46.3	49.2	57.7	53.9	0.9	0.9	0	249.6
7.6	4.0	8.4	10.1	28.2	25.8	10.3	31.4	276.1
34.1	50.3	57.6	67.8	82.1	26.7	11.2	31.4	525.7
0	0	38.2	209.8	713.0	41.0	2.5	0	1,118.3
-34.1	-50.3	-19.4	+142.0	+630.9	+14.3	-8.7	-31.4	+592.6
-100.0	-100.0	-33.7	+209.4	+768.5	+53.6	-77.7	-100.0	+112.7
38.9	68.0	72.2	84.7	79.1	1.4	1.4	0	366.5
11.5	10.4	21.2	25.7	42.9	37.1	21.7	38.8	442.6
50.4	78.4	93.4	110.4	122.0	38.5	23.1	38.8	809.1
0	0	53.4	259.2	792.5	68.2	3.5	0	1,329.4
-50.4	-78.4	-40.0	+148.8	+670.8	+29.7	-19.6	-38.8	+520.3
-100.0	-100.0	-42.8	+134.8	+549.8	+77.1	-84.8	-100.0	+64.3

pass to this site outfall and are discharged at Wolf Creek unaltered, then during 1981 the lagoon system accounted for approximately 8.3 percent of the total flow, 79.5 percent of the inorganic nitrogen, 51.2 percent of the total nitrogen, 24.7 percent of the ortho phosphorus, and 33.3 percent of the total phosphorus loads discharged from the site. The remainder can be attributed to surface runoff from rainfall events. In reality, some uptake of these nutrients from lagoon effluent is likely during the residence time of travel in the perimeter ditch. The actual contribution of nutrient loads in runoff from the watershed is probably therefore somewhat greater than that implied here. It should be reemphasized that the contribution of nutrients from the lagoon system is far out of proportion to the contribution of flow to the ultimate site outfall. However, the amount of surface runoff from the watershed during the wet season is an important, and in most cases, the major contributor of nutrient species in effluent from the site.

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