Louisiana W.P.

ROCKEFELLER STATE WILDLIFE REFUGE AND GAME PRESERVE:

Evaluation of Wetland Management Techniques

COASTAL ENVIRONMENTS, INC.
BATON ROUGE, LA., 70802
504-383-7455

JANUARY 1983

ROCKEFELLER STATE WILDLIFE REFUGE AND GAME PRESERVE: EVALUATION OF WETLAND MANAGEMENT TECHNIQUES

By

Karen M. Wicker, Project Director
Donny Davis
David Roberts

Prepared for

Coastal Management Section
Louisiana Department of Natural Resources
P. O. Box 44396
Baton Rouge, Louisiana 70804

Funded by

Office of Coastal Zone Management
National Oceanic and Atmospheric Administration
Department of Commerce
3300 Whitehaven Street, N. W.
Washington, D. C. 20235

January, 1983

This document was published at a cost of $1.71 per copy by the Louisiana Department of Natural Resources, P. O. Box 44396, Baton Rouge, Louisiana, for the purpose of carrying out the requirements of the Louisiana Coastal Zone Management Program under the authority of Act 361 of 1979. This material was printed in accordance with the standards for printing by state agencies established pursuant to R. S. 43:31 and was purchased in accordance with the provisions of Title 43 of the Louisiana Revised Statutes. This project was financed through a grant provided under the Coastal Management Act of 1972, as amended, which is administered by the U. S. Office of Coastal Zone Management, National Oceanic and Atmospheric Administration.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

ACKNOWLEDGEMENTS

We wish to thank the Louisiana Department of Natural Resources, Coastal Management Section, for their support and funding of this project. We especially wish to thank Mr. Joel Lindsey, Mr. Dave Chambers, and Mr. Frank Monteferrante of the Coastal Management Section for identifying the tasks and directing the scope of the research.

The results of this project would have been severely limited had it not been for the generous help provided by all the personnel we met at the Rockefeller State Wildlife Refuge and Game Preserve. In particular, we wish to thank Mr. Allan Ensminger, Chief of the Refuge Division, Mr. Johnnie Tarver, Assistant Chief of the Refuge Division; and Mr. Ted Joanen, Research Leader of the Refuge Division, for taking the time to answer our many questions about management operations and results, and in general, the changes that have occurred on the refuge over the past 40 years. In addition to answering questions, Mr. Larry McNease and Mr. Guthrie Perry, biologists on the refuge, provided us with an abundance of reference material, both published and unpublished, from the refuge files. Mr. Perry also conducted an informative tour of the refuge.

Current information on environmental conditions on the refuge, especially with regard to fisheries productivity, was provided by Dr. R. H. Chabreck, Professor, School of Forestry and Wildlife Management, Louisiana State University, Baton Rouge, and his graduate assistant, Mr. Bruce Davidson.

Mr. John J. Lynch, a retired biologist, formerly with the U.S. Fish and Wildlife Service in Lafayette, Louisiana provided us with valuable information on the changes in the refuge habitats over the past 50 years. He took the time to answer our many questions, as well as providing us with copies of unpublished data from his files.

Acknowledgements also must be made of the many people involved in the final preparation of this report. The drafting was done by Mr. Curtis Latiolais and Ms. Debra Faiers; the editing was undertaken by Ms. Linda Richard; and the typing was performed by Ms. Ree Musso, Ms. Ludy Dyason, and Ms. Susan Crump.

EXECUTIVE SUMMARY

Introduction

The objective of this study is to document the management techniques that have been implemented on the Rockefeller State Wildlife Refuge and Game Preserve over the past 50 years and to discuss the effectiveness of these techniques in preserving fish and wildlife habitat. The execution of this project involved literature research, evaluation of refuge data, reconnaissance on the refuge, air photo interpretation and habitat mapping, and interviews with present and retired personnel of the Louisiana Department of Wildlife and Fisheries and the United States Fish and Wildlife Service.

The Rockefeller Refuge was purchased by the Rockefeller Foundation in 1914 and deeded to the State of Louisiana in 1920. Mr. E. A. McIlhenny, often called the "Father of Louisiana Wild Life Refuges," was the moving force behind this acquisition and donation, having recognized that the area "was highly adapted for a winter feeding and resting refuge for migratory wild fowl" (McIhenny 1930:137). In addition to being "one of the most important wildlife areas in the United States" (Joanen 1969:3), the refuge functions as a natural laboratory for research on "marsh management, plant ecology, pond culture and life history studies of the many forms of fish and wildlife found on the refuge" (Joanen 1969:10). The information gained in these research efforts "demonstrates what man can do to improve on nature to benefit wildlife" (Joanen 1969:10) and can serve as management guidelines for other state and Federal management areas, as well as private property owners.

Management Techniques

The Rockefeller Refuge occupies approximately 76,000 ac of low-lying marshland bordered on the south by a low beach ridge along the Gulf of Mexico and on the north by a slightly higher, abandoned beach ridge (chenier). Most of the marsh has an elevation of approximately 1.1 ft MSL and the average tidal fluctuation is 1 ft. Prior to major man-made modification (i.e., drainage, navigation and petroleum canals, spoil deposition and ongrade road construction), the vegetation consisted of bands of marsh zones stretching in an east-west direction parallel to the beach ridges and ranging from fresh near the chenier ridge, through intermediate and brackish, to saline along the Gulf of Mexico. While high tides associated with storms flooded (and still flood) the marshes with saline waters on the average of once every three years, the daily tides were historically, normally confined within the natural levees of the tidal channels and a freshwater head remained in the interior marshes sustaining deep, freshwater marsh vegetation. Natural events, such as geese and muskrat eatouts and deep burns associated with droughts, and man-made processes, such as canal dredging, initiated changes in the vegetation communities. By the mid-1950s, it was evident that active marsh management would be required to maintain habitat suitable for wildlife, especially waterfowl — the primary target species for management on the refuge.

The wetland management techniques implemented on the refuge since 1954 have developed in response to, and with an awareness of, numerous factors:

1. natural and man-induced processes that affect habitats,
2. need for intensive management to maximize habitat value, especially for waterfowl,
3. utilization of petroleum canals and levees to create and maintain management units,
4. climate and weather, especially hurricanes, excessive rainfall, and droughts,
5. environmental setting, (i.e., marsh habitat experiencing subsidence, shoreline erosion, marsh breakup, saltwater intrusion and canal dredging), and
6. damage associated with eatouts, sawgrass die-off, and deep marsh burns which require amelioration.

After evaluating the 17 "management units" on the refuge in terms of management techniques and objectives, it is evident that there are four major management programs in effect on 13 units on the refuge:

1.	Passive Estuarine:	Price Lake, Pigeon Bayou to Rollover Bayou
2.	Controlled Estuarine:	Units 4, 5, 6
3.	Gravity Drainage:	Units 2, 3, 15
4.	Forced Drainage:	Units 1, 8, 10, 13, 14.

Units 7 and 9 and areas south of Price Lake and south of Unit 6 are not actively managed with control structures. The distinguishing characteristic of each management program is the extent to which water and salinity levels are controlled in response to meteorological conditions in order to promote specific vegetation communities (i.e., emergent annuals, emergent perennials and aquatics) to support wildlife, especially waterfowl.

The gravity and forced drainage systems are implemented in units near the chenier ridge which contain brackish-to-intermediate marshes. Water and salinity levels can be controlled, to a limited extent, in conjunction with meteorological conditions in those leveed units managed with gravity drainage. This management system is hydrologically self-contained with limited inflow of estuarine water. This system also has been relatively successful in increasing vegetation suitable for waterfowl through spring draw-down for seed germination and flooding in late spring and summer for growth and duck feeding in the fall. The success of this program requires proper maintenance of the gravity drainage structures (concrete variable crest reversible flap-gates, 36-in flap-gate culverts and 48-in marine aluminum flap-gates) and favorable meteorological conditions.

Units under forced drainage management have encircling levees, double divergent pumps and have water flux controlled on a routine, seasonal basis similar to that practiced under gravity drainage. Forced drainage, as opposed to gravity drainage, allows better control of water levels in the impoundments and encourages the production of excellent stands of waterfowl foods. This is the most expensive management program because of the cost of maintenance and energy to run the pumps.

The controlled and passive estuarine management units are nearer the Gulf of Mexico and contain brackish-to-saline vegetation communities. The passive management units can be leveed or unleveed and water levels are stabilized by constructing Wakefield weirs (these have largely replaced previous earthern plugs) in natural bayous and canals. The weir crest is normally set at -0.5 ft marsh level to prevent complete dewatering of the drainage basin behind the weir during low tides. The main objective is to increase production of aquatics, especially widgeongrass which is a desirable waterfowl food, by stabilizing water levels and salinity regimes and decreasing turbidity. Data indicate that passive management appears to foster estuarine fisheries usage, but is only marginally successful in improving wildlife habitat for very large units such as Price Lake. Passive management using weirs is perhaps best suited to small marsh pond systems.

In the controlled estuarine management units, various control structures (i.e., radial lift gates and concrete variable crest reversible flap-gates) implanted in the encircling levees can be manipulated on a seasonal basis to permit multi-use of the units by estuarine organisms, such as brown and white shrimp, crabs and menhaden, and other wildlife species, such as waterfowl, alligators, furbearers, and wading and shore birds.

Conclusions

The major, initial management objective on the Rockefeller Refuge was to enhance the quality of wintering waterfowl habitat. The major factors controlling management programs have been natural edaphic and hydrologic conditions, meteorological conditions, man-made alterations of the landscape, and the availability of funds and personnel to implement and maintain management programs. Where forced and gravity drainage management systems were feasible in the northern portions of the refuge, consistency of wildlife food production increased, directly benefiting waterfowl and indirectly benefiting other wildlife species such as nutria, muskrats, deer and predators such as coyotes and alligators. In the southern, brackish-to-saline marshes of the refuge, passive and controlled estuarine management systems have sustained waterfowl food production to some extent, but the major benefit has been to estuarine organisms which utilize these low salinity habitats during their juvenile stages. A summary of the management programs and target species is illustrated in the following matrix.

Habitat Type, Vegetative Cover, and Fish and Wildlife Values Achieved With Water Management Programs Operating on the Rockefeller Refuge

TARGET HABITAT TYPE [1]	WATER MANAGEMENT PROGRAMS					
	PASSIVE ESTUARINE	CONTROLLED ESTUARINE		GRAVITY DRAINAGE	FORCED DRAINAGE	UNCONTROLLED
	Wakefield Weirs at -0.5 ft MSL	Concrete Variable Crest Reversible Flap-Gates	Concrete Radial Lift Gates	36 in and 48 in Flap-Gates Concrete Variable Crest Reversible Flap-Gates	Pumps	Non-existing or Non-operable Structures
EMERGENT PERENNIAL VEGETATION:						
Fresh	Ve-A	Ve-A	Ve-A	Ve-A	Ve-A	Ve-H[3]; Du-P, Mu-P, Nu-F
Intermediate	Ve-A	Ve-M; Du-P, Mu-F, Nu-F, Ge-F	Ve-H; Ge-G, Du-P, Mu-F, Nu-G, De-F	Ve-M; Du-P, Mu-F, Ge-G, Nu-F, De-P	Ve-L; Du-P, Mu-P, Nu-P, De-P	Ve-A
Brackish	Ve-M; Du-P, Mu-F[2], Ge-F, Nu-F	Ve-M; Du-P, Mu-F, Nu-F, De-P, Ge-F	Ve-H; Du-P, Mu-F, Nu-F, De-P, Ge-G	Ve-M; Du-P, Mu-F, Ge-G, Nu-F, De-P,	Ve-A	Ve-H; Du-P, Mu-F, Nu-F, Ge-G
Saline	Ve-H; Du-P, Mu-P, Nu-P, Ge-G	Ve-A	Ve-A	Ve-A	Ve-A	Ve-H; Du-P, Mu-P, Nu-P, Ge-G
EMERGENT ANNUAL VEGETATION:						
Fresh	Ve-A	Ve-A	Ve-A	Ve-A	Ve-A	Ve-A
Intermediate	Ve-A	Ve-M; Du-G, Nu-F, Mu-P	Ve-L; Du-F, Mu-P, Nu-P, Ge-P	Ve-H; Du-E, Mu-P, Ge-P, Nu-F, De-F	Ve-H[4]; Du-E, Mu-P, Nu-F, De-F	Ve-A
Brackish	Ve-L; Du-F, Nu-P, Ge-P	Ve-M; Du-G, Mu-P, Nu-F, De-P, Ge-P	Ve-L; Du-F, Mu-P, Nu-P, De-P, Ge-P	Ve-H; Du-E, Mu-P, Nu-F, De-F, Ge-P	Ve-A	Ve-L; Du-F, Mu-P, Nu-P, Ge-P
Saline	Ve-L; Du-P, Mu-P, Nu-P, Ge-P	Ve-A	Ve-A	Ve-A	Ve-A	Ve-L; Du-F, Mu-P, Nu-P, Ge-P
AQUATIC VEGETATION:						
Fresh	Ve-A	Ve-A	Ve-A	Ve-A	Ve-A	Ve-M[3]; Du-G; Mu-P, Nu-P
Intermediate	Ve-A	Ve-M; Du-G, Mu-P, Nu-F, Ge-P	Ve-L; Du-F, Mu-P, Ge-F, Nu-P, De-P	Ve-L; Du-F, Mu-P, Ge-P, Nu-P, De-P	Ve-M; Du-G, Mu-P, Nu-G, De-F	Ve-A
Brackish	Ve-M; Du-G, Nu-F, Mu-P, Ge-P	Ve-M; Du-G, Mu-P, Nu-F, De-P, Ge-P	Ve-L; Du-F, Mu-P, Nu-P, De-P, Ge-P	Ve-L, Du-F, Mu-P, Ge-P, Nu-P, De-P	Ve-A	Ve-L; Du-F, Mu-P, Nu-P, Ge-P
Saline	Ve-A	Ve-A	Ve-A	Ve-A	Ve-A	Ve-A
FRESH-TO-INTERMEDIATE WATER BODIES	—	Ff-G, Cr-P, Wb-E, Al-E, Ot-G		Ff-P, Cr-P, Ot-P, Al-F, Wb-P	Cr-G, Ff-P, Wb-G, Wb-G, Al-F, Ot-F	Ff-G[3], Cr-F[3], Al-F, Ot-F, Wb-F
ESTUARINE WATER BODIES	Ef-E, Al-F, Sh-E, Ot-G, Wb-E, Sb-G	Ef-E, Sh-E, Ot-G, Al-G, Wb-E, Sb-F		Ef-P, Ot-P, Al-P, Wb-F	—	Ef-G, Sh-G, Al-P, Ot-F, Sb-E, Wb-G

SPECIES SYMBOLS

Vegetation	Ve
Geese	Ge
Dabbling ducks	Du
Shorebirds	Sb
Wading birds	Wb
Muskrats	Mu
Nutria	Nu
Deer	De
Alligators	Al
Shrimp	Sh
Crayfish	Cr
Freshwater Fish	Ff
Estuarine Fish	Ef
Otters	Ot

RATING OF MANAGEMENT TECHNIQUE FOR PRODUCING FLORA AND FAUNA

FLORA (Relative vegetative cover):

High	H
Medium	M
Low	L
Absent	A

FAUNA (Habitat value):

Excellent	E
Good	G
Fair	F
Poor	P

SPECIAL NOTES

[1] Water salinities in these zones are as follows:

Fresh	0-2 ppt
Intermediate	2-5 ppt
Brackish	5-15 ppt
Saline	over 15 ppt

[2] Furbearer populations on Rockefeller are presently at a low point in their cycle but this management technique has been successfully used in other areas, especially with proper burning.

[3] This applies only to Unit 9

[4] All forced drainage units are of intermediate salinities

CHAPTER 1: INTRODUCTION

Objective

The objective of this study is to document the management techniques that have been implemented on the Rockefeller State Wildlife Refuge and Game Preserve (hereafter referred to as the Rockefeller Refuge) over the past 50 years and to discuss the effectiveness of these techniques in preserving fish and wildlife habitat. This report is segmented into four major parts: History of the Refuge, Physical Setting, Description and Results of Recent Management Programs, and Summary and Conclusions. Chapter 2 discusses the history of the refuge and provides a review of the evolution of management ideas, objectives, and experimentations that distinguish the refuge as a natural research laboratory as well as a wildlife refuge. Chapter 3 provides an understanding of the magnitude of the environmental problems confronting the refuge managers and the constraints governing all management implementation by detailing the physical environment and processes. Chapter 4 focuses on recent management programs implemented on the refuge. The management programs are grouped into four major types and an example of a refuge unit that best exemplifies each management type is discussed in terms of physical description, management objectives, and management results. Chapter 5 provides a summary of the information and conclusions on the results of the various management programs.

Scope and Methodology

The execution of this project involved primarily literature research, photo interpretation, and interviews with Louisiana Wildlife and Fisheries personnel on the refuge to determine the effectiveness of management techniques in preserving fish and wildlife habitat. Personnel from Coastal Environments, Inc. (CEI) attended a Chenier Plain Conference at the refuge on August 5, 6, and 7 and met with refuge personnel. A subsequent trip was made to the refuge on August 25 and 26 to research their files and to meet with refuge biologists to discuss management techniques and results. Numerous data, both published and unpublished, on vegetation, water levels and water salinity changes, and various fisheries and wildlife research conducted on the refuge were acquired for evaluation. CEI personnel interviewed Mr. A. Ensminger and Mr. J. Tarver of the Louisiana Department of Wildlife and Fisheries, Refuge Division, on October 14, 1982, to gather further information on management objectives and techniques practiced on the refuge over the past 40 years. This meeting was especially informative because Mr. Ensminger shared with us his observations on changes that have occurred on the refuge since the mid-1940s in addition to his opinions on the results of various management structures and programs. In another interview, Mr. John Lynch, a retired U.S. Fish and Wildlife biologist and author of several reports on the refuge and its wildlife, provided an insightful perspective of the refuge in the late 1930s and 1940s and the changes that have occurred over the past 40 years.

In order to depict and quantify changes in refuge habitats through time, three north-south transects through the refuge, representing approximately 32 percent of the present area of the refuge, were interpreted from black and white (Tobin Research, Inc. 1930, 1955/56) and color infrared (National Aeronautics and Space Administration [NASA] 1978) photographs and U.S. Geological Survey [USGS] topographic maps (USGS 1974/79). An evaluation of data obtained in this exercise, when viewed in conjunction with the unpublished data obtained from the Rockefeller Refuge, provides a better understanding of the effects of management programs for different units. It also identifies those areas where additional management effort is needed.

In the process of researching this project, many interesting aspects of the refuge that could be documented in further detail were discovered. However, because the objective of this project was to demonstrate the effectiveness of the management techniques in preserving fish and wildlife habitat, the scope of the project was confined to gathering data relevant to this objective.

CHAPTER 2: HISTORY OF THE REFUGE

The idea of preserving Louisiana marshes as refuges for wintering waterfowl was perhaps originally conceived in the spring of 1891. In March of that year, Edward A. McIlhenny, a young man of 19, was camped at the mouth of Freshwater Bayou where it enters the Gulf of Mexico just west of Chenier aux Tigre in Vermilion Parish (McIlhenny 1932). From March 14 to March 21, he witnessed the gathering of one of the large bands of Blue Geese readying for the spring migration and, evidently, it was an experience that left a lasting impression. The congregation, numbering in the hundreds of thousands of birds, was flocked within a couple of hundred yards from his camp. Their constant, noisy vigilance filled the air with their shrill calls and left McIlhenny's ears ringing for days after (McIlhenny 1932).

The period 1850-1900 has been called the Era of Exploitation in natural resource management in this country, while the period 1900-1935 has been called the Era of Preservation. McIlhenny's life (1872-1949), which spanned a large segment of these two eras, reflects the transition in attitudes that eventually brought to an end the gratuitous slaughter of wildlife. By the year 1891, when McIlhenny was camped at Freshwater Bayou, the huge bison herds of the Great Plains had already been extirpated a decade before (Trefethan 1964). The Passenger Pigeon, which once migrated in unbelievably huge flocks sometimes numbering in excess of 2 billion birds (Trefethen 1964), was considered a rarity in 1890 and eventually became extinct. Market hunting had reached a peak by the late 1800s and included the taking of large numbers of waterfowl and wading birds in Louisiana. In the meantime, Yellowstone National Park had been created in 1872, and in 1894, Congress passed the Yellowstone Park Protection Act making Yellowstone Park the first inviolate wildlife refuge in fact (Trefethen 1964). The Lacey Act of 1900 prohibited the interstate shipment of illegally killed wild game and, to a large extent, precipitated the decline of market hunting as a major industry. The election of Theodore Roosevelt as president in 1901 gave the conservation movement a dynamic leader. In 1903, he created the nation's first national wildlife refuge on Pelican Island, Florida to protect a colony of nesting wading birds from plume hunters. Amidst the conflicting wildlife resource use attitudes of exploitation and preservation, McIlhenny was forming his own ideas within the conservation movement. In fact, he had already taken action to offset the damage done by plume hunters in Louisiana by creating a protected, artificial pond on Avery Island. Here, in 1893, he started a heronry with a few pairs of egrets in an effort to save them from extermination; later, the pond served as a duck sanctuary (McIlhenny 1930). This experiment proved successful (15,000 pairs of nesting birds by 1910) and was the first demonstration of the wildlife sanctuary idea for migratory birds (McIlhenny 1930). McIlhenny, very much a competent naturalist in his own right, was also a hunter, sportsman, businessman, and entrepreneur who became a major force in the conservation movement. With his keen interest and concern for Louisiana's wintering migratory waterfowl, he was directly responsible for the creation of three state wildlife refuges.

Aided by C. W. Ward of Michigan, McIlhenny bought and, in 1911, eventually donated to the State of Louisiana the 13,000 ac adjacent to Vermilion Bay now known as the Louisiana State Wildlife Refuge and Game Preserve. He then decided that a much greater area of wintering habitat must be preserved to support the migratory wildlife of the Mississippi Valley (McIlhenny 1930) and began acquiring options on land known as Marsh Island. After securing pledges from sportsmen in Chicago and New York, he and his friends were able to convince Mrs. Russell Sage to buy the entire tract of property; this was accomplished July 22, 1912. On August 12, 1913 this property was placed under the control of the Conservation Commission of Louisiana as a wildlife refuge for a period of five years. By this time his attention was focused on an 86,000-ac tract of marsh in Cameron and Vermilion Parishes. He knew the waterfowl potential of this area, as he had hunted ducks and geese here many times (McIlhenny 1930). In a similar manner as before, problems of property title were solved, options acquired, and pledges secured from associates in the North. The merits of his wildlife refuge plan were then brought to the attention of the Rockefeller Foundation. A deal was eventually reached and the Rockefeller Foundation purchased the 86,000 ac as a permanent wildlife refuge on May 20, 1914. His work still not completely finished, McIlhenny convinced the Russell Sage Foundation and the Rockefeller Foundation to deed to the State of Louisiana these recently acquired marshlands. This was finally accomplished by December 1919, and these tracts became known as the Rockefeller State Wildlife Refuge and Game Preserve and the Russell Sage or Marsh Island Wildlife Refuge and Game Preserve. Thus, by 1920, Louisiana had acquired through the initiative of McIlhenny, three parcels of land totaling over 174,000 ac dedicated as refuges for wildlife, especially migratory waterfowl.

During the early years, management practices at the Rockefeller Refuge consisted primarily of patrolling the area against poaching and trespassing, burning the marsh to encourage production of preferred geese and muskrat foods, and a trapping program aimed particularly at muskrats. Each refuge at this time was held to be self-supportive; that is, any funds needed for management or patrolling on the refuge had to be generated from within that refuge (J. J. Lynch 1982). Thus, the sale of fur hides, and especially those of the abundant muskrat, was an important source of revenue in the refuge's early history.

A combination of factors started to bring about important changes during the 1930s and 1940s. The old Intracoastal Waterway that connected White Lake with Grand Lake and continued east-west was initially dredged during the 1930s. This canal interrupted the natural, freshwater drainage south of these lakes toward Rockefeller and produced a more lateral, east-west flow. This process tended to deprive the marshes in the Rockefeller Refuge of some of their freshwater input (J. J. Lynch 1982). During the late 1930s and early 1940s, muskrat populations were on the increase in southwest Louisiana with a subsequent occurrence of eat-outs throughout an extensive area of the Vermilion Parish marshes (Lynch 1975; Lynch et al. 1947). In 1944, the first access canal for oil exploration was dug from the Gulf of Mexico through Joseph Harbor Bayou into the interior of the Rockefeller Refuge. Although the mid-1940s was a period of abundant rainfall and moisture surpluses in southwest Louisiana, beginning in 1948, a severe drought affected this area. The years 1948, 1951, and 1954 were extremely dry with an especially severe moisture deficit recorded in 1954 (Muller 1970). Together, these factors permitted saltwater intrusion into the refuge, resulting in areas of marsh die-off at the junction of the deep freshwater marshes and slightly brackish marshes where the vegetation was composed predominantly of cutgrass (Zizaniopsis miliacea), sawgrass (Cladium jamaicense), and bulrush (Scirpus californicus) (Lynch 1952). These sites of formerly dense marsh were thus transformed into several open water bodies in the 1950s.

At this point in its history, following the series of eat-outs, saltwater intrusion, and drought, the refuge probably reached a low point in terms of wildlife productivity and habitat quality, particularly for waterfowl and furbearers. In order to comply with stipulations contained in the deed of donation--that is, to preserve, maintain, and improve, whenever practical, the refuge lands for wildlife in perpetuity--the managers of the Rockefeller Refuge embarked upon an ambitious expansion program that would intensify wildlife management programs. This was made possible by the increasing revenues from mineral exploration and recovery operations on the refuge. Initial efforts, aimed primarily at enhancing habitat for wintering waterfowl, included both active and passive management strategies.

During the 1954-55 period, several impoundments varying in size from 146 to 5680 ac were created (Louisiana Wildlife and Fisheries Commission [LWFC] 1956). Existing spoilbanks along oil access canals were used, wherever possible, as part of the impoundment levees, and additional levees were constructed to fully enclose the impoundments. Location of levees was determined, to a large extent, by the area's geomorphology. Nichols (1959a) conducted a geologic study of the refuge to locate geological features, such as emergent and buried beach ridges containing the firmer soils suitable for levee construction. The configurations of the impoundments were designed, as much as possible, to enclose those marsh areas just south of the chenier ridge that had recently been partially transformed to open water because of damages caused by eat-outs and saltwater intrusion. An initial management objective was to revegetate those areas to a substantial degree with fresh-to-slightly brackish marsh vegetation and to increase productivity of waterfowl foods.

Techniques for management of waterfowl impoundments in coastal marshes were in relatively early stages of development at the time the Rockefeller impoundments were constructed (Baldwin 1967). Although the basic concept of a spring-summer draw-down of water levels to encourage the germination of annual plants important as waterfowl foods was well known, the most proficient methods to achieve draw-down were not. Originally, no one was sure what size the impoundments should be (Ensminger 1982). It was known that the impoundments on Sabine and Lacassine National Wildlife Refuges were too large and unmanageable. These two refuges served primarily as resting areas and refuge sites for waterfowl. At the time these large impoundments were built, the surrounding marshes consisted of vast, unbroken stands of sawgrass with little open water. Because open water was at such a premium, the impoundments on the Sabine and Lacassine Refuges were valuable resting areas. Hurricane Audrey, in 1957, created many open water bodies over extensive areas of this marsh when it swept away stands of dead sawgrass. These large impoundments became less valuable as a result of the greater amount of open water after Hurricane

Audrey; however, the Rockefeller Refuge already contained a large amount of open water before the hurricane (Ensminger 1982).

Water control structures for the impoundments on the Rockefeller Refuge originally consisted of 36-in culverts implanted in the levees with a flap-gate on the outside and a lift gate on the inside coupled with a funnel-type stand pipe. One such culvert was installed for each section (640 ac) of marsh in impounded Units 1, 2, 3, 4, 8, 10, 13, 14, and 15 (Plate 1). These impoundments were drained through the flap-gates by gravity drainage and flooded by rainfall, primarily in the fall. One problem associated with these structures occurred when north winds raised water levels on the south end of the impoundments and permitted more water than was desirable to drain out of the impoundments through the stand pipe.

Through subsequent years and with deterioration of the culvert structures, other methods to improve water control have been tried in the impoundments with varying degrees of success. Both wooden and concrete control structures with stop-logs and flap-gates have been used in place of the culverts to gain better control of water levels. The concrete structures, installed in the fall of 1967 (LWFC 1968) in Units 2, 3, and 4, have been more successful and are equipped with reversible flap-gates. These gates add versatility to the structure in that water can either be drained from or let into the impoundments, depending on the placement of the gates.

Forced drainage through pumping has also been an important impoundment management technique. Initially, one-way pumps were used on Units 1, 2, 8, 10, 13, and 14 (Ensminger 1982). With these pumps, water could be forced out of the impoundments to allow germination of important herbaceous annuals, but the system was dependent upon rainfall in the fall months to reflood the units to attract wintering waterfowl. Later, in 1969, double divergent pumps were installed in Units 8, 13, and 14 to allow water to be pumped in or out of the impoundments, and these, of all the various techniques, give the greatest water-level control. They are expensive to operate, however, because of the fuel expenditure required during the hundreds of hours of pumping time necessary to move 1000 ac-ft of water (Ensminger 1982).

In addition to these active management techniques for the impoundments in which intensive water-level control is desired, more passive systems were incorporated into the management program for the unimpounded marshes. After the experience of drought and saltwater intrusion during 1948-1954, a large concrete control structure with radial gates was constructed on Rollover Bayou in 1955 (LWFC 1956). This type of structure prohibits saltwater intrusion and stabilizes water levels, but still permits boat passage as needed.

Initially, earthen dams were also used in various tributaries as a protective measure against saltwater encroachment. However, these usually washed out in a short time and were never more than temporary installations. Subsequently, low level, Wakefield weirs that tend to stabilize marsh water conditions but still allow tidal exchange were installed in many tributaries of the Rollover Bayou drainage area, in Joseph Harbor Bayou northwest of Miller Lake, and on Pigeon, East Little Constance, and Little Constance Bayous. In the early 1960s, additional levees were constructed to enclose Units 5 and 6 with concrete gated structures placed in Little Constance and Big Constance Bayous and a plug placed in Dyson Bayou (Plate 1).

Beginning in 1954, the Rockefeller Refuge has been subjected to a great deal of structural management, with the emphasis on improving the marshes for wintering waterfowl. However, during the mid-1960s, an expansion of programs to include multi-use management was initiated, thus leading to the development of a resident flock of Canada Geese (Branta canadensis) at Rockefeller. This program was undertaken in response to the decreasing numbers of migratory wintering birds reaching Rockefeller because of the short-stopping efforts being practiced mostly in the midwestern United States. Research into the life history, ecological requirements, and management of the American alligator (Alligator mississippiensis) at Rockefeller has led to a resurgence of alligator populations throughout most of coastal Louisiana. The result has been a subsequent delisting of the alligator as an endangered species and the institution of a controlled harvest to take advantage of this renewable, natural resource. In addition, research on the refuge is constantly ongoing in both the fisheries and wildlife fields in conjunction with the Cooperative Wildlife Research Unit and the Cooperative Fisheries Research Unit at Louisiana State University in Baton Rouge. Some of the impoundments are under multi-use management. For example, Unit 1 is managed for waterfowl and for production of crayfish, when conditions are conducive to their growth. Unit 4 is managed as a nursery area for penaeid shrimp by proper manipulation of the control structures. Of course, all the impoundments provide habitat not only for wintering waterfowl, but for a variety of other wildlife such as Mottled Ducks (Anus fulvigula), furbearers, wading birds, shorebirds, songbirds, and white-tailed deer. Thus, it is evident that the Rockefeller Refuge is a rather complex network of structurally managed systems that function as enhanced wintering waterfowl habitat, multi-use fisheries environments, and fish and wildlife research laboratories.

CHAPTER 3: PHYSICAL SETTING

Introduction

In order to fully comprehend the environmental changes that have occurred on the Rockefeller Refuge and to appreciate the types of management techniques that are practical, as well as desirable, it is necessary to understand the physical setting. This chapter contains a discussion of the physical forms and processes that govern habitat distribution, especially vegetation communities, on the refuge. The function and value of the refuge for wildlife and research is described, and changes in habitat distribution over the past 40 years are depicted on vegetation maps prepared by early researchers. Habitat changes and marsh loss were quantified by interpreting and planimetering habitats from aerial photographs along three north-south transects which covered 32 percent of the refuge.

Location and Boundaries

The refuge lies within the southeastern portion of the Chenier Plain Region between approximately 92°55' and 92°30' west longitude (Plate 1). It is bordered on the south by the Gulf of Mexico and on the north by the Grand Chenier Ridge Complex. The refuge boundaries are very linear because the land was purchased by sections or portions thereof and some section boundaries serve as the refuge boundaries. Planimetering of the most recent USGS topographic maps (1974/79) reveals that the refuge contains approximately 76,042 ac, excluding 640 ac inside the refuge boundary belonging to the Vermilion Parish School Board. This figure indicates a loss of approximately 10,000 ac since 1914 due to shoreline erosion along the Gulf of Mexico. The acreage of the original purchase is given as 86,000 by McIlhenny (1930) and "85,000 acres more or less" according to the Deed of Donation (1920).

Regional Setting

The Chenier Plain, consisting of recent sediments overlying unconformably the eroded surface of the Prairie Formation, emerged concurrently with the development of the Mississippi River Deltaic Plain (Gould and Morgan 1962). The sediments have a minimal thickness along their interface with the Pleistocene Prairie Terrace, the northern boundary of the Chenier Plain, and range from 20 to 40 ft thick along the present Gulf of Mexico shoreline (Gould and Morgan 1962).

During the period of Mississippi River Delta progradation in the western portion of the Deltaic Plain, fine-grained sediments were transported west to the Chenier Plain by littoral currents, and the shoreline prograded through the development of mud flats and coastal marsh deposits. When the Mississippi River shifted eastward, sediment supplies decreased and the gulfward progradation of the Chenier Plain slowed. In some instances, marine processes eroded the shoreline, creating beach ridges. This alternating progradation and erosion of the Chenier Plain was cyclic and resulted in a series of abandoned beach ridges, both emergent and submergent in the marsh, which mark ancient shorelines and stretch in an east-west direction roughly parallel to the coast.

The oldest ridges are the Chenier-Little Pecan Island trend, the back ridge of Belle Isle, Junius Ridge, and Wildcat Ridge. These ridges have been radiocarbon dated at 2800 yrs before present (B.P.) and formed well after sea level reached a still stand about 4600 yrs B.P. (Gould and Morgan 1962). One of the longest ridges is Grand Chenier, which extends eastward from the Mermentau River for almost 70 mi and marks the northern boundary of the refuge. Like most ridges, this one is narrow, about 400 yds wide, except where prongs curve inland over the marsh, and seldom exceeds 10 ft in elevation (Russell and Howe 1935). However, cheniers are very distinctive features, naturally vegetated by live oaks (Quercus virginiana), on the otherwise low-lying, low-relief, coastal marshlands. Because of their prominence, the region is labeled Chenier Plain; Chene is the French word for oak (Gould and Morgan 1962).

Physical Geography

The geomorphology and meteorology of the Chenier Plain region influence the distribution of vegetation zones and distinguish it from the Deltaic Plain Region of coastal Louisiana. Historically, the chenier ridges played a strategic role in the regional hydrology by restricting the movement of water to and from the Gulf of Mexico and the interior marshes (Chabreck 1972, Palmisano 1972). The well-defined beach rim, approximately 5 ft in elevation (Nichols 1959b) and extending along the southern border of the Rockefeller Refuge, restricts regular tidal inundation to the eight tidal channels and one canal connecting interior marshes and the gulf. The number of channel openings to the gulf has increased from five to nine over the past 30 years because of canal dredging and shoreline erosion, which has breached lakes and meandering tidal channels, creating additional openings where there was previously only one or no openings. The average elevation of the refuge marshes is 1.1 ft above mean sea level (msl) (Chabreck 1960b). Normal tides are contained within the channels and canals, and the amount of water covering the marsh is governed by meteorological conditions, primarily precipitation and wind direction (Nichols 1959b). During periods of drought or prolonged offshore winds, which cause low winter tides, the marsh is subject to extreme low water. Extended low-water periods expose the marsh to the threat of fire, which often pockmarks the region with new lakes. While the average tidal fluctuation in the area is 1 ft, extremely high tides associated with onshore winds from storms flood the interior marshes at least once or twice a year, bringing in marine mud and saltwater (Chabreck 1960b, Lynch 1942). The introduction of saline muds creates a firmer marsh than is present in the Deltaic Plain because it prevents the formation of highly organic marsh peats (Lynch 1942). Creation of leveed impoundments on the refuge, beginning in 1954, has restricted, to some degree, the input of saline water and mud to only the unimpounded areas nearest the gulf (Chabreck 1960b). However, extreme highwater can overtop, or even break, the levees and cause the impounded areas to be subjected to higher salinities than are desirable under the management program. When this happens, management plans are modified until the levees are repaired and the salt is flushed out of the impounded areas either through pumping or normal precipitation and drainage cycles.

The marshes on the Rockefeller Refuge occupy an elongated basin confined by the high Grand Chenier Ridge to the north and the lower sea rim beach to the south (Figure 3-1). Prior to major man-made landscape changes, freshwater reached this basin through precipitation and drainage from surrounding ridges, thus creating deep freshwater rush marshes near the chenier ridge. The rush marsh zone was vegetated primarily by bulrush, cutgrass, sawgrass, and cattail (<u>Typha</u> sp.)(Lynch 1942). Freshwater ponds in this zone contained various species of algae, frogsbit (<u>Limnobium</u> sp.), bladderwort (<u>Utricularia</u> sp.), water parsley (<u>Hydrocotyle ranunculoides</u>), duckweeds (<u>Lemna</u> spp. and <u>Wolfiella</u> spp.) and water hyacinth (<u>Eichhornia crassipes</u>) (Lynch 1942).

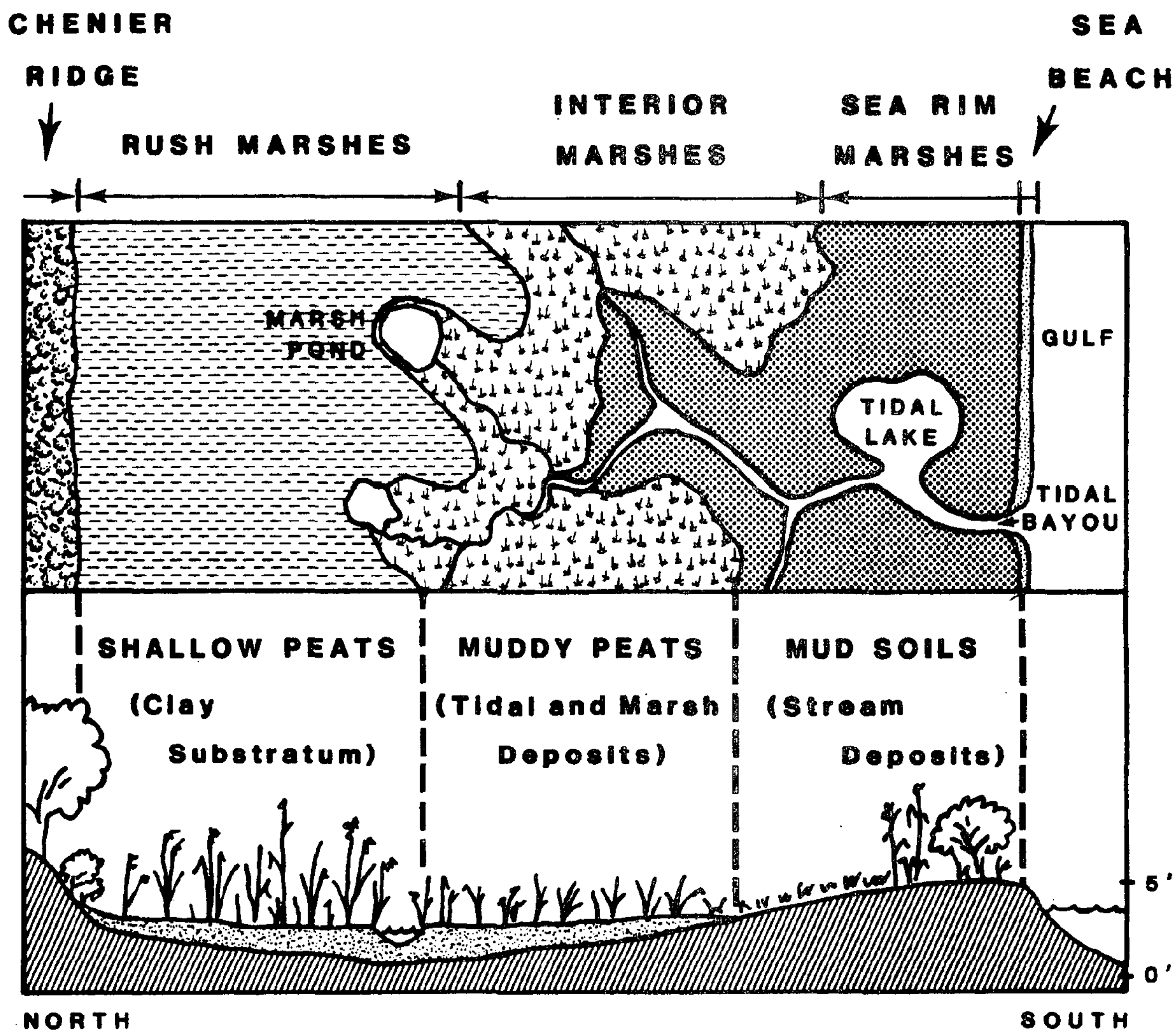


Figure 3-1. Idealized diagram of physiography, drainage, and marsh types (Lynch 1942).

Brackish (interior marsh zone) to saline (sea rim marsh zone) marshes occupied the lower two-thirds of the area which was drained by dendritic tidal channels. A series of low salinity marsh ponds were situated at the inland extremities of the tidal marsh and supported grey duck moss and widgeongrass (Ruppia maritima) (Lynch 1942). The brackish interior marshes were densely vegetated with coco (Scirpus robustus) and wiregrass (Spartina patens), while the sea rim marshes contained saltgrass (Distichlis spicata), hogcane (Spartina cynosuroides), iva (Iva frutescens), and oystergrass (Spartina alterniflora) (Lynch 1942).

The distribution of vegetation zones that constitute major wildlife habitat types on the refuge has been altered considerably over the past 40 years, as shown in Plates 2 through 4. The base map for these plates is drawn from 1974/79 USGS topographic maps, but the vegetation distribution, as shown for three different time periods, is taken from maps compiled by O'Neil (1949), Nichols (1959b), and Chabreck and Linscombe (1978).

In the 1940s, the refuge contained three bands of vegetation stretching in an east-west direction parallel to the coast according to O'Neil's (1949) interpretation. The most salt-tolerant species grew near the gulf, and the vegetation zones became progressively fresher toward the Grand Chenier Ridge (Plate 2, Table 3-1). Prior to construction of the Humble Oil Company Canal in 1944 (Ensminger 1982), which entered from Joseph Harbor Bayou and extended northward to what is now called the Headquarters Canal, the only canals in the refuge were small, shallow canals used by trappers and local travelers and for drainage. Aerial photographs taken in 1930 (Tobin Research, Inc. 1930) show extensive, unbroken expanses of marsh and minimal open water bodies despite a severe drought and subsequent deep burns throughout the entire Chenier Plain Region in 1924 (Lynch 1982). The marsh had apparently recovered from these earlier burns, and dense stands of tall grasses covered the marshes. The natural dendritic patterns permitted slow flooding and slow drainage regimes, and the only man-made burns were undertaken by trappers, usually after the last equinox when the danger of hurricanes (i.e., saltwater flooding) had passed (Lynch 1982).

The setting for major vegetation changes began in the mid-1930s with construction of the Intracoastal Waterway north of Grand and White Lakes. This waterway helped change the drainage from one that was primarily north-south to one that was more

Table 3-1. Vegetation Zones in 1949 (O'Neil 1949)

Sawgrass Marsh[1] (Fresh to Intermediate Marsh)	sawgrass (Cladium jamaicense) cattail (Typha spp.) bulrush (Scirpus californicus) roseau cane (Phragmites australis) bulltongue (Sagittaria lancifolia) hogcane (Spartina cynosuroides) spikerush (Eleocharis spp.) yellow cutgrass (Zizaniopsis miliacea)
Leafy Three-Cornered Grass or Coco Marsh (Brackish Marsh)	coco (Scirpus robustus) wiregrass (Spartina patens) hogcane (Spartina cynosuroides)
Excessively Drained Salt Marsh (Saline Marsh)	black rush (Juncus roemerianus) wiregrass (Spartina patens) oystergrass (Spartina alterniflora) sawgrass (Cladium jamaicense)
Sea Rim	sand and shell deposits

1 These marsh zones correspond to the rush marshes, interior marshes, sea rim marshes and sea beach, respectively, shown in Figure 3-1.

east-west (Lynch 1982). Construction of deep oil company canals in the mid-1940s permitted rapid ingress of saline gulf waters to the low-lying interior, formerly freshwater, basin and rapid egress of freshwater which collected in the basin from precipitation and local drainage. Under natural conditions, freshwater never really drained out of the marshes but floated on top of any saltwater wedge that entered the refuge (Lynch 1982). In place of the dendritic patterns, the marsh began to acquire drainage systems with sharp corners and straight sides, which dictated the hydrologic regime and, consequently, the marsh vegetation began to acquire geometric patterns which conformed to the segmented drainage units (Lynch 1982).

Between 1942 and 1952, large expanses of fresh marsh vegetation were partly or entirely destroyed on the refuge as a result of saltwater intrusion into deep water - rush marshes (cutgrass-sawgrass-bulrush) (Plate 5) (Lynch 1952). Most of the die-off areas appear to be at the junction of man-made canals and the fresh and faintly brackish marsh boundary.

A vegetation map (Plate 3) (Table 3-2) prepared by Nichols (1959b) illustrates the inlandmost expansion of brackish marsh communities into the refuge in the mid-1950s. The marsh hay cordgrass zone (i.e., brackish marsh) extended almost to the chenier ridge, and a broad area of saltwater intrusion lay north of the Humble Canal between Grand Chenier and the North Island Canal. The area supported little intermediate marsh, and the fresh marsh (deep marsh complex) occurred east of the Humble Canal adjacent to the chenier ridge remnants. The mid-1950s, prior to construction of the leveed impoundments along the northern portion of the refuge, represent a period when saline to brackish marshes reached their most inland extent.

The sawgrass die-off was the most noticable die-off and probably the one most responsible for the increasingly open-water-appearance of the marsh. While Valentine (1976) asserted that the massive sawgrass die-off in southwest Louisiana was the result of saltwater flooding by Hurricane Audrey in 1957, others (Ensminger 1982, Lynch 1982) have noted that the sawgrass was dead prior to 1957 and that the flooding associated with the hurricane merely washed the dead grass out of the marsh, exposing bare mud flats (i.e., broken marsh). The disappearance of sawgrass seems to be one of the mysteries associated with vegetation change in southwest Louisiana. This disappearance and the failure of other perennial species to recolonize its former range

Table 3-2. Vegetation Zones in 1959 (Nichols 1959b)

Deep Marsh Complex (Fresh Marsh)	bulrush (Scirpus californicus) cattail (Typha spp.) sawgrass (Cladium jamaicense) cutgrass (Zizaniopsis miliaceae) bulltongue (Sagittaria lancifolia) roseau cane (Phragmites australis)
Intermediate Marsh Complex	bulrush (Scirpus californicus) roseau cane (Phragmites australis) hogcane (Spartina cynosuroides) bulltongue (Sagittaria lancifolia)
Marsh Hay Cordgrass Zone (Brackish Marsh)	wiregrass (Spartina patens) saltgrass (Distichlis spicata) coco (Scirpus robustus) oystergrass (Spartina alterniflora) needlegrass rush (Juncus roemerianus)
Seashore Saltgrass Zone (Saline Marsh)	saltgrass (Distichlis spicata) wiregrass (Spartina patens) oystergrass (Spartina alterniflora)
Gulfshore and Levee Complex	iva (Iva frutescens) sea oxeye (Borrichia frutescens) saltgrass (Distichlis spicata) saltwort (Batis maritima) hogcane (Spartina cynosuroides) oystergrass (Spartina alterniflora)

are the major factors accounting for the seasonally erratic broken marsh appearance on much of the interior portions of the refuge today. Lynch (1982) postulates that the sawgrass was already under stress because of the altered hydrologic regimes and that the additional stress of saltwater intrusion and possibly dry burning in some areas caused it to die initially. Because sawgrass is an edaphic climax species, the altered hydrologic regime probably prohibited its reestablishment even in areas where salinities were lowered through water management and where there are abundant seeds in the marsh muck. The prolific nutria population may also have helped to retard its reestablishement by eating the newly sprouted seedlings.

By late 1978, the success of the construction of leveed impoundments and marsh management to control the effects of saltwater intrusion into interior marshes was evident (Plate 4, Table 3-3). Management Units 1, 2, 8, 9, 10, 13, 14, the northern half of Unit 6, and most of the northern reaches of Units 3 and 4 had been converted to intermediate marsh. The northernmost portions of Units 1, 4, 8, 9, 10, 13 and 14 contained very low salinity to almost freshwater habitats. Table 3-4 summarizes the distinguishing features, water management, wildlife usage, and vegetation types of the management units found on the refuge in 1982.

Habitat Change Between 1930 and 1978

In order to depict and quantify habitat change and marsh loss on the refuge between 1930 and 1978, the habitats along three north-south transects (Miller Lake, Grassy Lake, and Flat Lake) were interpreted for four time periods using black and white (Tobin Research, Inc., 1930; 1955/56) and color infrared (NASA 1978) aerial photographs and topographic maps (USGS 1974/79) (Plates 6, 7, and 8). Interpretations for three of the time periods (1930, 1955/56, and 1974/79) were planimetered in order to quantify habitat changes (Tables 3-5, 3-6, 3-7). Data on vegetative zones present on the refuge during this period were obtained from Lynch (1982), Ensminger (1982), Chabreck and Linscombe (1978), Nichols (1959b) and O'Neil (1949), and from field reconnaissance during the fall of 1982. The three transects covered 24,992 ac in 1974/79 and represented approximately 32 percent of the refuge area (76,682 ac) in 1974/79. The areal data for the Flat Lake Transect includes 640 ac within the refuge that are owned by the Vermilion Parish School Board.

Table 3-3. Vegetation Zones in 1978 (Chabreck and Linscombe 1978)

Intermediate Marsh	wiregrass (Spartina patens)
	deer pea (Vigna repens)
	bulltongue (Sagittaria spp.)
	wild millet (Echinochloa walteri)
	bull rush (Scirpus californicus)
	sawgrass (Cladium jamaicense)
Brackish Marsh	wiregrass (Spartina patens)
	three-cornered grass (Scirpus olneyi)
	coco (Scirpus robustus)*
	widgeongrass (Ruppia maritima)
Saline Marsh	oystergrass (Spartina alterniflora)
	salicornia (Salicornia spp.)
	black rush (Juncus roemerianus)
	batis (Batis maritima)
	saltgrass (Distichlis spicata)

*more prevalent than three-cornered grass on the refuge

Table 3-4. Distinguishing Features, Water Management, Wildlife Usage, and Vegetation Zones for Rockefeller Management Units in 1982.

UNIT	APPROXIMATE AREA (AC)	DISTINGUISHING FEATURE	WATER MANAGEMENT	WILDLIFE USAGE*	VEGETATION ZONE
1	1,250	Showcase Unit for 1980s; Demonstration Unit	Forced Drainage	Waterfowl, Crayfish Holding Ponds & Pens Deer	Fresh to Intermediate
2	1,400	Least Impacted By Saltwater Intrusion in 1950s; Highest Elevation	Gravity Drainage	Waterfowl, Deer & Alligator Pens, Coyotes, Goose Pasture	Fresh to Intermediate
3	3,700	Old Eatout From 1940s; Too Large a Unit; Lower Elevation	Gravity Drainge	Waterfowl	Intermediate to Brackish
4	5,680	Open Water in 1950s; Original Management Objective: Revegetate	Controlled Estuarine	Waterfowl, Shrimp Fish, Crabs	Intermediate to Brackish
5	4,900	Created as Result of Oil Levees; Hard to Manage: Too Near Gulf	Controlled Estuarine	Waterfowl, Estuarine Organisms, Furbearers	Brackish
6	13,500	One of Most Interesting Ecosystems; Connected to White Lake System	Controlled Estuarine	Waterfowl, Wading and Shorebirds, Shrimp, Crabs, Alligators, Deer, Furbearers	Intermediate to Brackish
7	500	Management Awaits Outcome of Oil Industry in Area	Basically Unmanaged	Estuarine Organisms	Saline
8	1,030	Good Size for Unit; One of Most Productive	Forced Drainage	Waterfowl, Crayfish	Fresh to Intermediate
9	100	Permanently Flooded	Gravity Drainage (not presently managed)	Fish (freshwater)	Fresh to Intermediate
10	480	Good Size for Unit; Productive	Forced Drainge	Waterfowl, Crayfish	Intermediate
13	1,770	Good Size for Unit; Productive	Forced Drainge	Waterfowl, Crayfish	Intermediate
14	2,400	Good Size for Unit; Productive	Forced Drainge	Waterfowl, Crayfish	Intermediate
15	900	Construction Objective: Does Linear Impoundment Offer Management Advantages	Gravity Drainage	Waterfowl, Furbearers, Alligators	Brackish
Price Lake	7,500	Newest Impoundment; Excellent Area for Birds and Waterfowl	Passive Estuarine	Wading and Shorebirds, Waterfowl, Shrimp, Crabs, Fish, Alligators, Furbearers	Brackish
South of Price Lake	5,200	Higher Sea Rim Marsh With Little Management	Basically Unmanaged	Estuarine Organisms, Waterfowl, Shorebirds	Brackish to Saline
Pigeon B. to Rollover B.	16,500	Needs More Mangement; Marsh Breakup is Problem	Passive Estuarine	Estuarine Organisms, Waterfowl, Shorebirds	Brackish to Saline
South of Unit 6	7,200	Needs More Management; Marsh Breakup is Problem	Basically Unmanaged	Estuarine Organisms Waterfowl, Shorebirds	Brackish to Saline

* Alligators are found throughout the fresh, intermediate and brackish marsh areas, especially in the waterways. Waterfowl utilize most of area in winter. Furbearers are common in lower salinity areas thoughout refuge.

Table 3-5. Habitat Area in Miller Lake Transect for 1930, 1955/56 and 1974/79*

	HABITAT AREA IN ACRES			
HABITAT TYPE	1930	1955/56	1974/79	CHANGE
Fresh Marsh	0	0	0	0
Intermediate Marsh	2,672	1,661	1,648	-1,024
Brackish Marsh	4,181	4,753	3,668	-513
Saline Marsh	1,026	1,157	504	-522
Canals	24	117	197	+173
Other Water	522	599	1,814	+1,292
TOTAL	8,425	8,287	7,831	-594

*Interpretations made from aerial photographs (Tobin Research, Inc. 1930; 1955/56) and USGS topographic maps (1974/79). Habitat data from O'Neil (1949), Nichols (1959b) and Chabreck and Linscombe (1978).

Table 3-6. Habitat Area in Grassy Lake Transect for 1930, 1955/56 and 1974/79*

HABITAT TYPE	HABITAT AREA IN ACRES 1930	1955/56	1974/79	CHANGE
Fresh Marsh	0	1,201	0	0
Intermediate Marsh	1,303	0	2,553	+1,250
Brackish Marsh	6,013	5,157	4,322	-1,691
Saline Marsh	1,130	1,726	386	-744
Canals	4	252	291	+287
Other Water	1,056	919	1,524	+468
TOTAL	9,507	9,255	9,076	-431

*Interpretations made from aerial photographs (Tobin Research, Inc. 1930, 1955/56) and USGS topographic maps (1974/79). Habitat data from O'Neil (1949), Nichols (1959b) and Chabreck and Linscombe (1978).

Table 3-7. Habitat Area in Flat Lake Transect for 1930, 1955/56 and 1974/79*

HABITAT TYPE	HABITAT AREA IN ACRES 1930	1955/56	1974/79	CHANGE
Fresh Marsh	0	1,365	0	0
Intermediate Marsh	3,253	24	1,666	-1,587
Brackish Marsh	3,262	4,746	3,762	+500
Saline Marsh	1,149	788	893	-256
Canals	0	39	54	+54
Other Water	767	1,126	1,710	+943
TOTAL	8,431	8,088	8,085	-346

*Interpretations made from aerial photographs (Tobin Research, Inc. 1930, 1955/56) and USGS topographic maps (1974/79). Habitat data from O'Neil (1949), Nichols (1959b) and Chabreck and Linscombe (1978).

Vegetative transect data (Chabreck 1959, 1960b, 1961, 1962, 1963; Chabreck and Joanen 1964, 1965, 1966; Joanen et al. 1967, 1968, 1969, 1970, 1971, 1972, 1973, 1974) and aerial photographs indicate that marsh cover can be sustained best in those units in the northern portion of the refuge (i.e., Units 1, 2, 3, 8, 10, 13, and 14) where water levels can be lowered in spring and summer to encourage germination of annual marsh species such as wild millet and dwarf spikerush (Eleocharis parvula). Water levels can be lowered in Units 1, 8, 10, 13, and 14 through forced drainage and in Units 2 and 3 through gravity drainage. Unit 9, though capable of being drained through gravity drainage, is presently maintained in a flooded condition and supports extensive stands of bulltongue and bulrush. Water levels in Unit 15 could be lowered via gravity drainage, but the area is basically left as a brackish marsh with no active attempt to alter vegetation density or composition.

When reviewing the data on habitat changes, a few facts on photographic interpretation must be considered. The land-water interface shown on the 1974/79 USGS topographic maps (i.e., orthophotoquads) appears to reflect conditions at the time of photography (November 1974). The USGS maps were photo revised in 1979 but, apparently, only with respect to certain features such as canals and road beds. Interpretation of the 1978 photographs shows definite patterns of shoreline erosion, such as the breaching of the beach south of Big Constance Lake, which proves the 1974/79 USGS maps reflect 1974, rather than 1979, conditions.

Furthermore, all water bodies depicted on the 1974/79 USGS maps may not be permanent water bodies. In areas such as the Rockefeller Refuge, many water bodies are very shallow (i.e., less than 6 in deep) and, therefore, ephemeral. During low water periods, they may appear as vegetated flats or bare mud flats. A heavy rain can turn a marsh supporting short emergent vegetation, such as dwarf spikerush, into a lake within a few hours. And, of course, in leveed impoundments it is common practice to begin flooding the marshes in early fall (i.e., late August to September) so that photographs taken in late fall should show more open water than would normally be apparent on photographs taken in late summer. Such factors must be considered when analyzing data on land loss on the refuge in order to understand whether the apparent "land loss" is a desired result of management or an undesirable process that must be retarded or reversed through management.

The overall environmental trend for the Rockefeller Refuge has been an apparent decrease in marsh and an increase in open water. This trend can be quantified by averaging the areal habitat data for the three transects that cover 32 percent of the refuge (Table 3-8). Between 1930 and 1974/79, the land to water ratio changed from 91:9 percent to 78:22 percent. Analysis of aerial photographs and maps for the entire refuge supports the fact that habitat changes along these sample transects are representative of habitat changes on the entire refuge.

In addition to marsh breakup in the interior, the data show that the third of the refuge interpreted lost 1,370 ac because of marine erosion between 1930 and 1974/79 (Table 3-8). Furthermore, shoreline erosion appears to be more severe on the western portion of the refuge than on the eastern portion (Plates 6, 7, and 8).

Between 1930 and 1978, waterbodies in the marsh near the gulf filled in with sediment washed inland via marine erosional processes. Miller Lake (Plate 6), a round lake, decreased in diameter because of shoreline accretion, and Little Constance Lake (Plate 7) was completely filled with marine sediments entering through Little Constance Bayou. Breakup appeared to be less severe in the saline marshes along the gulf, probably because sediment was being added to this area via "over beach" flooding during high-water periods. However, this marsh zone decreased in area between 1930 and 1978 because the zone did not expand inland as fast as it was eroded along the gulf.

Breakup appears to be severe in the brackish interior marshes where there is little active water-level management (i.e., Unit 5, Price Lake, and between Pigeon Bayou and Rollover Bayou). Subsidence may be a contributing factor to marsh breakup in these units, because areas within these units which contain buried beach ridges that are less prone to compaction have a denser vegetation cover than lower areas adjacent to the ridges. The northwestern portion of Price Lake shows extensive marsh breakup. This section was the site of extensive deep marsh burns, and geese and muskrat eat-outs in the 1940s and 1950s. Water levels are apparently too high during most of the year to permit revegetation of the eat-out areas.

Those units where water levels are drawn down to encourage production of waterfowl foods, such as Units 1, 2, 3, 8, 10, 13, and 14, show dense vegetative cover (from both

Table 3-8. Habitat Change as Measured on Approximately 32% of the Refuge for 1930, 1955/56, and 1974/79 (summary of data from Tables 3-5 through 3-7).

HABITAT TYPE	HABITAT AREA						CHANGE IN AREA
	1930		1955/56		1974/79		1930-1974
	Acres	%	Acres	%	Acres	%	
Fresh	0	0	2,566	10	0	0	0
Intermediate	7,228	27	1,685	7	5,867	23	-1,361
Brackish	13,456	51	14,656	57	11,752	47	-1.704
Saline	3,305	13	3,671	14	1,783	7	-1,522
Canals	28	1	408	2	542	2	+514
Other Water	2,346	9	2,644	10	5,048	20	+2,703
TOTAL	**26,362**		**25,630**		**24,992**		**-1,370***

*Area lost to erosion along Gulf of Mexico between 1930 and 1974.

annual and perennial species) during the low water season. When the units are flooded in the fall or during heavy rainfall, much of the vegetation is covered and the units appear to be experiencing marsh breakup. During flooded conditions, the taller perennial species, such as wiregrass, oystergrass, and bulrush, constitute the emergent and therefore photographable marsh vegetation.

Unit 4 is an impounded unit that appears to have severe marsh breakup problems. Fires, eat-outs, and sawgrass die-offs removed much of the vegetation, especially in the northern portions of the unit in the late 1940s and 1950s. Early attempts to revegetate the area by drawing down the water did not have the desired effect of either reestablishing sawgrass or encouraging the expansion of wiregrass (Ensminger 1982). Therefore, it was decided to manage this as an estuarine area. It is now a prime area for estuarine organisms such as crabs and shrimp, and it supports extensive areas of widgeongrass, a major waterfowl food.

The previous discussion has touched on a few of the many factors that must be considered in interpreting photographs and making value judgements about land loss and the success of management programs for preserving fish and wildlife habitats. However, the interpretations (Plates 6, 7, and 8) and the areal measurements (Tables 3-5, 3-6, 3-7, and 3-8) do provide a preliminary basis for understanding the effects of wetland management techniques discussed in the remainder of this report.

CHAPTER 4: DESCRIPTION AND RESULTS OF RECENT MANAGEMENT PROGRAMS

Regional Hydrologic Regime

The Rockefeller Wildlife Refuge lies within Hydrologic Unit VIII of coastal Louisiana which encompasses the Mermentau River Basin, as well as, Grand and White Lakes and their local drainages. Among the highest priorities for water resource management in this region is maintenance of an adequate supply of freshwater for irrigation of rice. For this reason, control structures have been built to limit the intrusion of brackish water into Grand Lake and White Lake. As a result, water exchange between the fresh marshes north of the Grand Chenier-Pecan Island ridge complex (LA 82) and the brackish and saline marshes to the south, is controlled according to seasonal patterns of precipitation and water levels.

On the average, the annual water cycle exhibits large, late fall to early spring surpluses of freshwater with small deficits occurring from April through September (Figure 4-1). Summer freshwater deficits do occur even though this is the time of highest mean monthly rainfall. Water levels in Grand Lake at the Catfish Point Control Structure follow this pattern in falling from +2.5 ft msl in January to a low of +1.75 ft msl in July (Figure 4-2). During this same time period, mean monthly tide stages in the Mermentau River at Grand Chenier (seaward of the control structure) increase from +0.9 to +2.1 ft msl. As Figure 4-2 indicates, a potential for saltwater intrusion exists from mid-April to August, on the average. A similar situation exists at the eastern end of White Lake between the Schooner Bayou Locks and the Freshwater Canal (Figure 4-3). It would appear, then, that the control structures would remain closed throughout most of the spring and summer to prevent saltwater intrusion and remain open most of the winter to alleviate flooding within the basin. The mean monthly salinities resulting from the annual water cycle and operation of the control structures have been plotted in Figure 4-4. Salinity ranges from 0.5 to 3.5 parts per thousand (ppt) within the Grand Lake-White Lake system. In Freshwater Canal landward of the Freshwater Bayou Locks, mean monthly salinities range from 10 to 15 ppt. Since the Freshwater Bayou Locks must operate to accommodate heavy boat traffic between offshore oil facilities and Intracoastal City, it is relatively unsuccessful in preventing saltwater intrusion into the marshes south of Pecan Island and east of the Rockefeller Refuge. Although LA 82 prevents intrusion of this saline water into White Lake, the highway has also deprived marshes to the south of

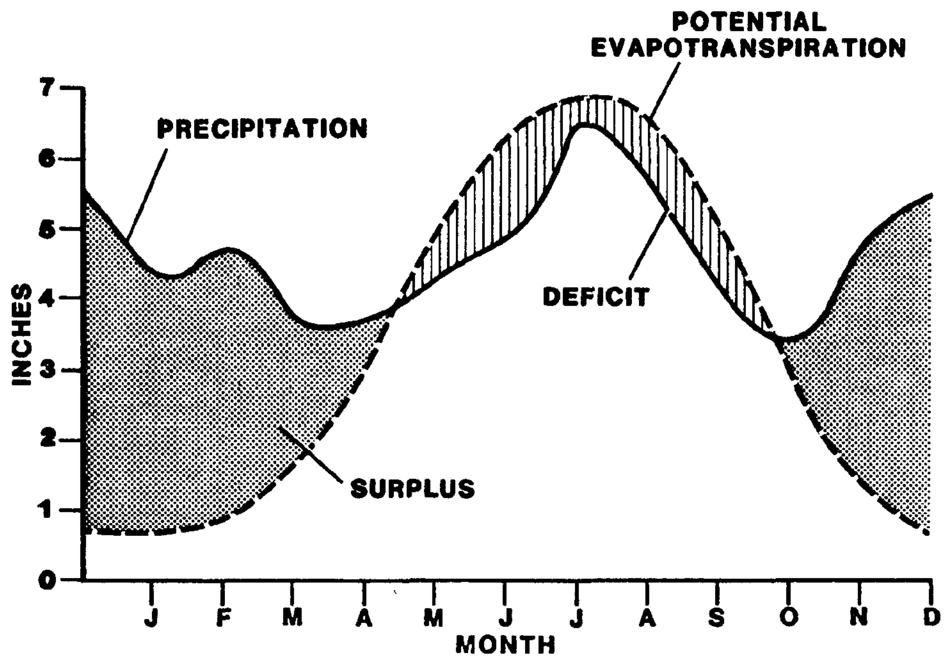


Figure 4-1. Average monthly water balance for Gueydan, Louisiana from 1945-1968.

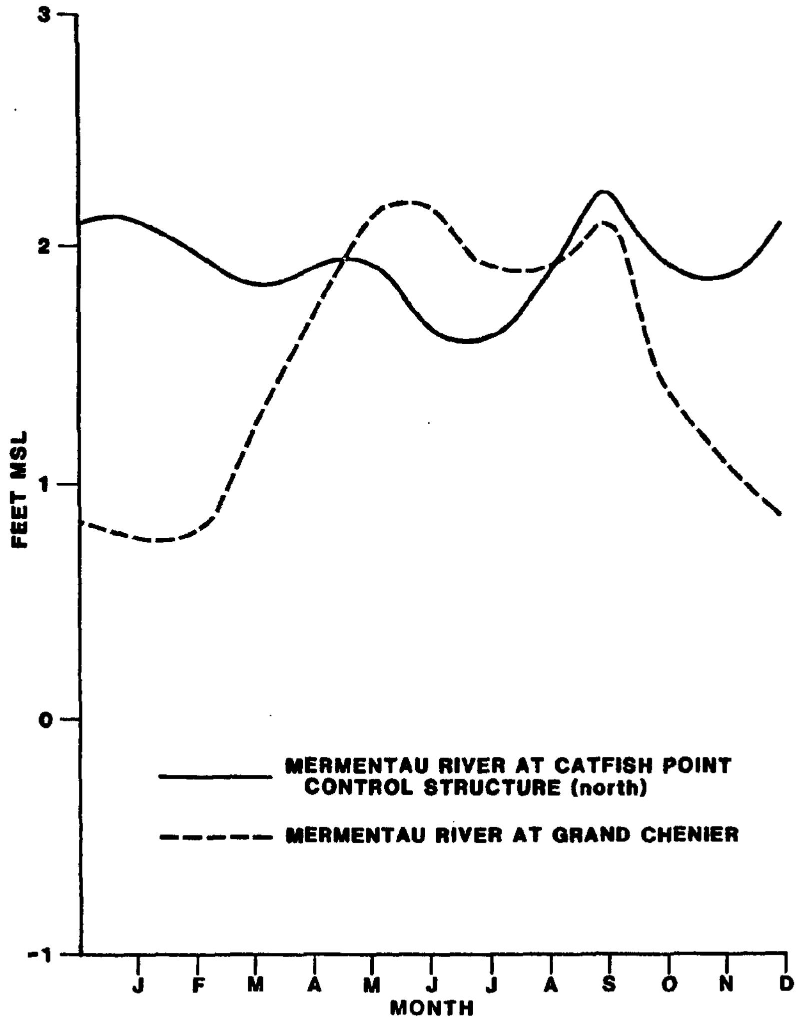


Figure 4-2. Mean monthly stages for the Mermentau River at the Catfish Point Control Structure and Grand Chenier (USACE 1970-1978).

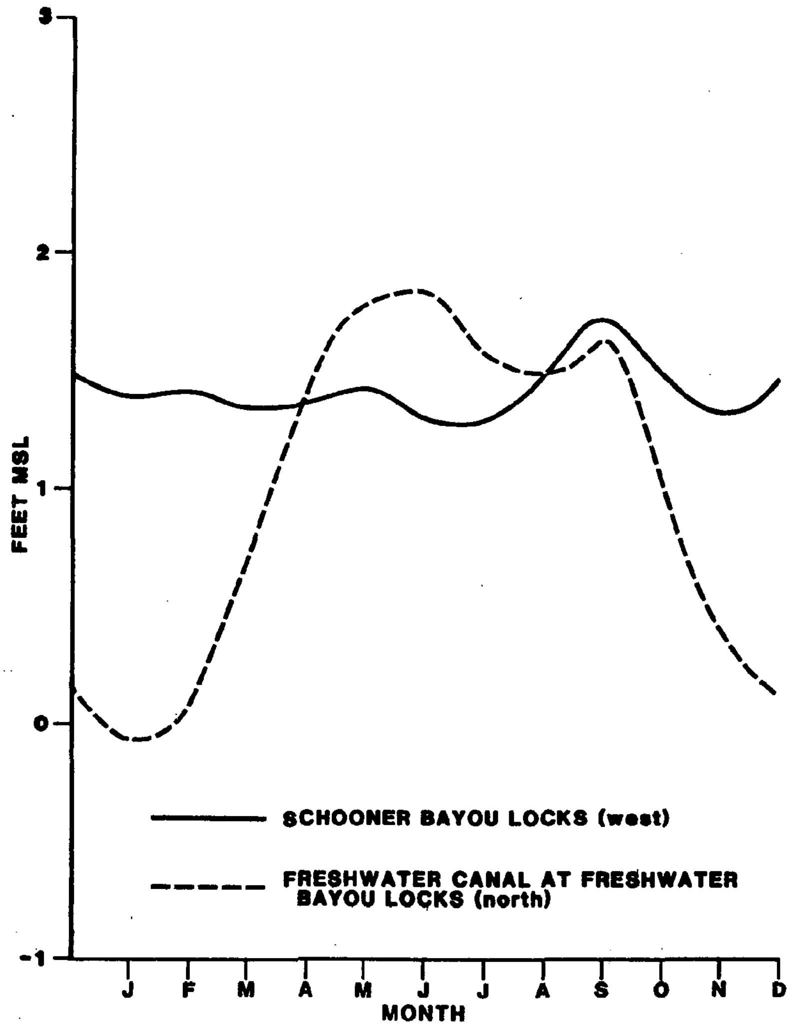


Figure 4-3. Mean monthly stages at the Schooner Bayou Locks (west) and the Freshwater Canal at the Freshwater Bayou Locks (north) (USACE 1970-1978).

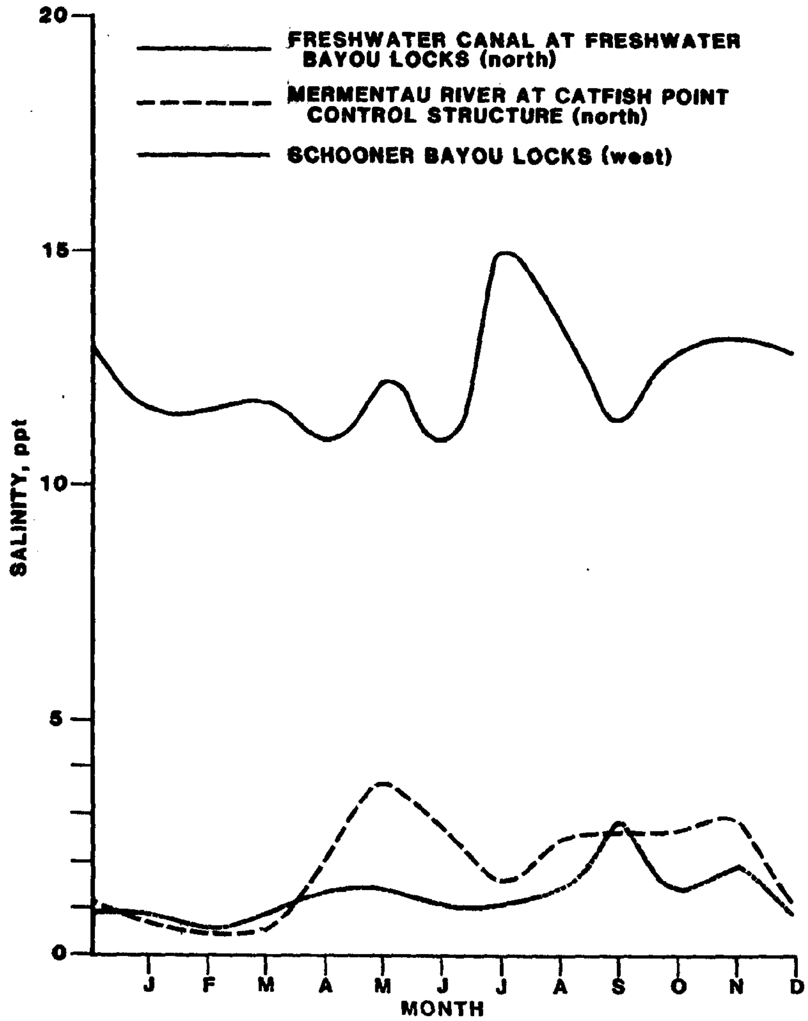


Figure 4-4. Mean monthly salinity regime at three stations in the Grand Lake-White Lake system (USGS 1970-1978).

freshwater. As a result, this area has experienced a high rate of marsh loss because salinities have risen above the tolerance level of fresh and intermediate marsh vegetation.

Much can be deduced about the hydrologic regime of the Rockefeller Refuge from Figures 4-1 through 4-4. Because the refuge lies approximately halfway between the tide gage stations on the Mermentau River at Grand Chenier and the Freshwater Canal, the mean monthly tide level should vary from a low of +0.4 ft msl in January to a May peak of +2.0 ft msl with a secondary peak of +1.85 ft msl in September (Figures 4-2 and 4-3). These conditions are experienced in the canals and bayous that are not controlled, such as the Humble Canal and Joseph Harbor Bayou. The refuge is also connected to the Grand Lake-White Lake system via the Superior Canal. The junction of the Superior Canal with Grand Lake is approximately 9.2 mi from the Catfish Point Control Structure and 27.4 mi from the Schooner Bayou Locks. The average head between the two structures is 0.507 ft from west to east (Figures 4-2 and 4-3), a water-surface gradient of 0.01 ft/mi. If this average water surface gradient continues down the Superior Canal, the mean monthly water level of the Superior Canal at its confluence with the refuge Property Line Canal would differ by only -0.18 ft from that depicted in Figure 4-2 for Catfish Point (See Plate 1). It is evident that the refuge would be a potential corridor for saltwater intrusion into Grand Lake were it not for the locks on the Property Line Canal and the control structures on Little Constance and Big Constance Bayous. These three structures, which control a large area of brackish to intermediate marsh called Unit 6, are also an important element in the overall plan of regional water resource management, which calls for structure openings to alleviate flooding and structure closures to prevent saltwater intrusion depending upon particular freshwater surpluses or deficits. These operating criteria, in turn, greatly influence the hydroperiod and salinity regime within the refuge.

Classification of Management Units

The Rockefeller Wildlife Refuge presently maintains 14 management units where hydrologic conditions are at least partially controlled to fulfill wildlife and fisheries management objectives. To facilitate a discussion of the various types of management scenarios and their results, these units will be classified according to the objectives and the annual level of effort expended to achieve these objectives. The four management categories are: (1) passive estuarine management, (2) controlled estuarine management, (3) gravity drainage management, and (4) forced drainage management. Four units have been chosen as an example of each of the management categories listed (Price Lake, Unit 4, Unit 3, and Unit 8, respectively), and a detailed discussion of management practices and results is presented.

Passive estuarine management units are those where the hydrologic regime has been stabilized through the placement of low-level weirs and earthen plugs in the primary natural drainage bayous and canals, with or without an encircling levee system around the management unit. No scheduled effort is expended in achieving management objectives. This category includes the Price Lake Unit and the Pigeon Bayou-Rollover Bayou section of the refuge (Plate 1).

For controlled estuarine management units, a levee system partitions the area and allows water flux with adjoining areas to be controlled on a routine, seasonal basis using various control structures inserted in the impounding levees. This allows management of the salinity and water level regimes within the unit, typically for multi-use by both estuarine fisheries and wildlife species. Units 4, 5, and 6 are presently under this type of management (Plate 1). While Unit 4 is discussed as an example of controlled estuarine managment, Unit 6 is also described because it is a special case.

Gravity drainage management units are also isolated from surrounding areas by a levee system and contain similar water control structures. However, these units are managed so as to be hydrologically self-contained with limited inflow of estuarine water being a primary management goal. Rainfall surpluses are conserved or discharged (as allowed by the tidal stage) with regular and scheduled effort in order to produce annually a "crop" of waterfowl food plants. Only when the pattern of rainfall is antagonistic to the goals are estuarine waters allowed to enter the managed area. Units 2, 3, and 15 are managed in this way (Plate 1).

Forced drainage management units are essentially the same as gravity drainage management units except for the type of control structures utilized in management.

As the name implies, the hydroperiod of these units is forceably controlled with pumps, and drainage of excess rainfall is not dependent upon the tidal regime of the surrounding area. This type of management requires the highest level of regular effort over the annual hydrologic cycle. Units 1, 8, 10, 13, and 14, are examples of this management category (Plate 1).

Passive Estuarine Management

Description of the Price Lake Unit

The Price Lake Unit, located in the southwestern corner of the refuge, contains approximately 7500 ac of brackish to saline marsh and shallow open water bodies (Plate 1). It is completely encircled by management levees constructed and maintained by refuge personnel.

The structural elements for the Price Lake Unit are two, low-level Wakefield weirs (Plate 1). Weirs are generally constructed of creosoted wooden planks with either flat or tongue-and-groove edges, or with interlocking steel or aluminum sheet piles. When wooden planks are used, timber pilings are driven at intervals (6 to 8 ft) to add support, often including batter piles driven at an angle and secured to the main piling. Horizontal wooden planks called "walers" connect the tops of the vertical planks to each other and to timber pilings to form a stable, submerged wall across the drain to be managed (Figure 4-5). Weirs may tie in to management levees, as in the Price Lake Unit, but more often they do not. As a general rule, planks and sheet piles are driven 3 ft into the ground for each foot of water depth and extend a minimum of 15 ft into the banks on either side of the weir to prevent erosion around the structure.

On the refuge, the crest of the weirs is set at 6 in below the average marsh level. The hydrological effect of this is to reduce the inflow and outflow of water over the average tidal cycle and to prevent excessive draining of marsh ponds during periods of sustained low tides. Weirs result in a stabilization of water levels and a reduction of hydrological energy.

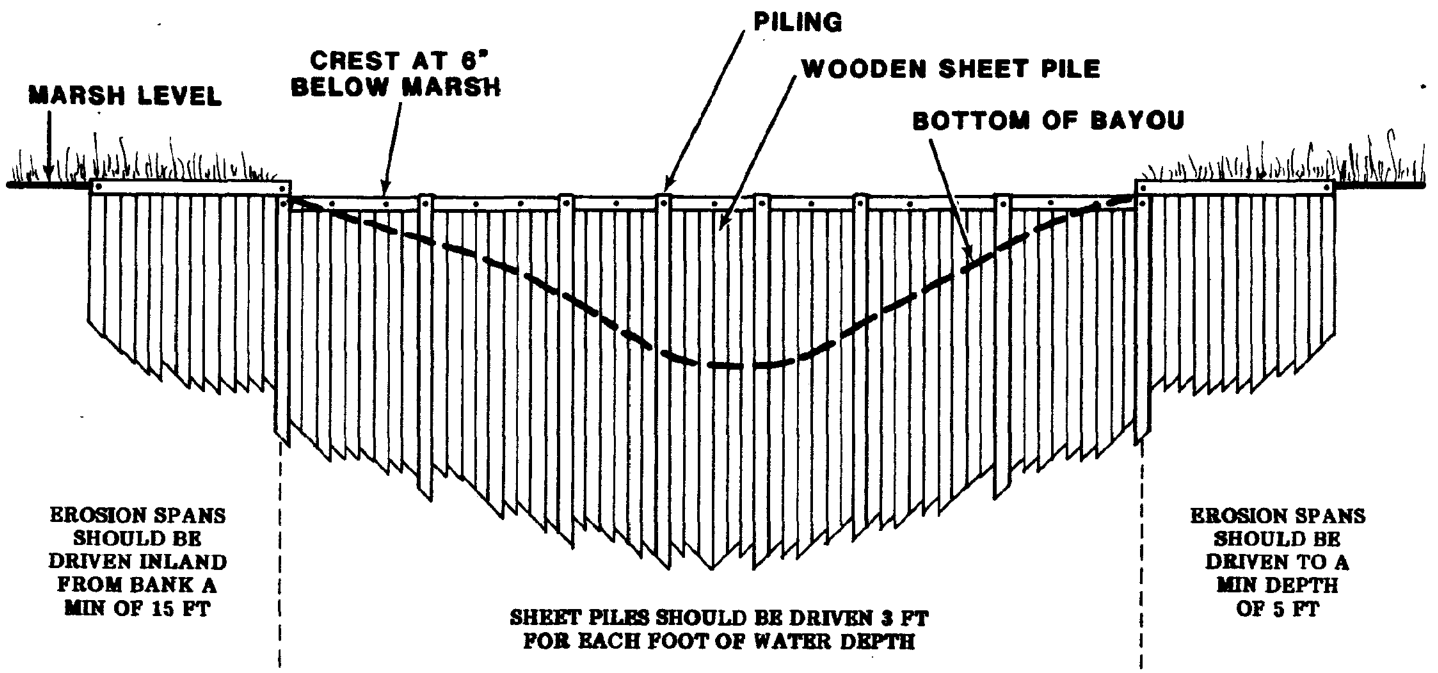


Figure 4-5. Schematic diagram of a typical Wakefield weir.

Objectives of Management

Initially, the implementation of passive management techniques at Rockefeller was intended to lessen the impact of saltwater intrusion into the unimpounded interior brackish marshes from the Gulf of Mexico. Earthern dams were originally employed as saltwater barriers, particularly north of Miller Lake to protect the Price Lake area, and in the Rollover Bayou drainage area (LWFC 1956). The earthen dams prohibited tidal exchange, freshened marsh water salinities, and tended to sustain water levels in the marsh behind the dams for a longer period of time. The more permanent water supply apparently increased usage of these marshes by wintering waterfowl, at least temporarily (LWFC 1956). However, the dams also tended to block natural tidal drainage of these areas and, due to the water being held behind them, water would soon cut around the dams, eventually washing out the structures.

Subsequently, the earthen dams were replaced by low-level Wakefield weirs set 6 in below marsh level. The objectives of management with weirs was to stabilize water levels behind the weirs and reduce tidal exchange. With the sill set at 6 in below marsh level, some tidal drainage is allowed but only to a prescribed level. This insures that the marsh ponds always hold water and are never completely drained as often happens in unmanaged marsh during periods of sustained offshore winds. The conditions that result from implementation of weirs, namely stabilized water levels and reduced turbidities in marsh ponds, are excellent for the establishment of widgeongrass. This submerged aquatic plant is one of the most important and preferred waterfowl foods along the Louisiana coast (Joanen and Glasgow 1965), particularly for Gadwalls (Anas strepera), American Wigeon (Anas americana) and Shovelers (Anas clypeata) (Chabreck 1979).

In addition, weirs, particularly in conjunction with a proper burning program (LWFC 1964), were thought to induce conditions favorable for the development of the sedges, leafy three-square and three-cornered grass. Leafy three-square produces an abundant seed crop that is utilized by ducks. Three-cornered grass is considered to be the most important muskrat food in Louisiana and is also a favorite food of both color phases of the wintering Lesser Snow Goose (Anser caerulescens).

Results of Management

Other than the installation of temporary earthern dams in the mid-1950s to inhibit saltwater intrusion, the Price Lake Unit was not brought under any structural management until 1967. At that time, Wakefield weirs were installed in Jospeh Harbor Bayou, north of Miller Lake, and in the canal north of Miller Lake connecting Joseph Harbor Bayou with the Humble Canal.

Personnel at the refuge have run marsh transects on an annual basis since 1958 to record water level and salinity and to sample vegetation to determine species composition and percent vegetated area (Chabreck 1959, 1960, 1961, 1962, 1963; Chabreck and Joanen 1964, 1966; Joanen et al. 1967, 1968, 1969, 1970, 1971, 1972, 1973, 1974). This data for Price Lake was analyzed to evaluate the success of passive management techniques. For each year of data, the plant species were grouped into one of three categories: emergent annuals, emergent perennials, and aquatics. Examples of emergent perennials in the Price Lake Unit include wiregrass, saltgrass, leafy three-square, and three-cornered grass. Dwarf spikerush (Eleocharis parvula) was the most abundant emergent annual, and widgeongrass was, by far, the dominant aquatic plant. The percent composition was summed for each group and multiplied by the percentage figure of area vegetated to compute the estimated percent coverage along the transect for each group. The results are graphed in Figure 4-6. The annuals and aquatic plants comprise the majority of the preferred duck foods so that the greater percentage composition of these groups indicates a favorable response to the management strategy for waterfowl in the Price Lake Unit. The vegetative transect data (Figure 4-6) show that waterfowl foods were produced each year. However, a rather inconsistent pattern emerges in terms of the production of either annuals or aquatics in the Price Lake Unit.

During the early 1960s, the refuge experienced relatively dry spring and summer periods (Figure 4-7) that allowed the germination and growth of a substantial cover (over 20 percent) of annuals (Figure 4-6), predominantly dwarf spikerush, in the Price Lake Unit. Widgeongrass production appeared to increase during the wetter years but never accounted for more than 16 percent, and usually much less, coverage along the transect. In September 1965, a severe marsh burn in this unit, followed by relatively

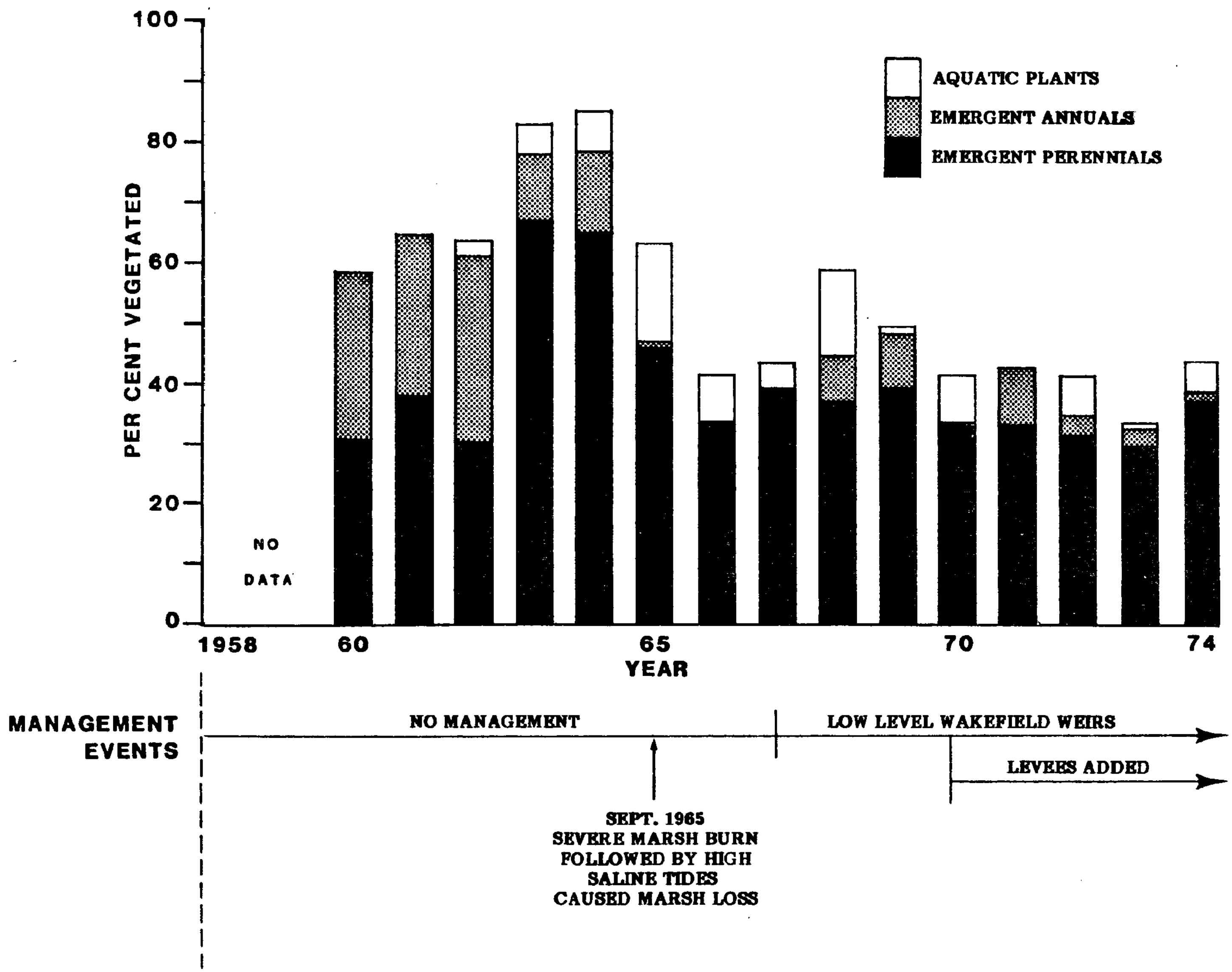


Figure 4-6. Vegetative transect data and management events for the Price Lake Unit, 1960-1974.

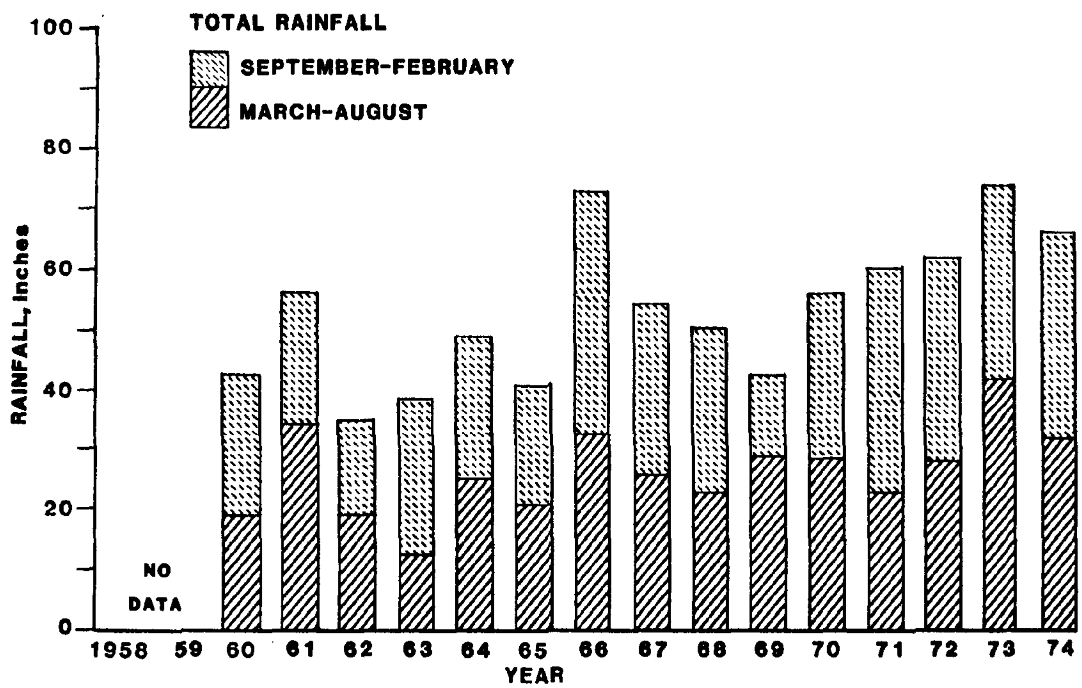


Figure 4-7. Seasonal patterns of annual precipitation recorded at the Rockefeller Refuge from 1960 through 1974.

saline tides, caused some loss of wiregrass (LWFC 1966). This loss appears in Figure 4-6 as a sharp reduction in the percent coverage of perennials from 1964 to 1965. The apparent increase in perennials from 1962 to 1963 was evidently due, in part, to a lengthening of the transect sample to include more of the relatively unbroken wiregrass-saltgrass marsh in the southern portion of the unit. After installation of the weirs in 1967, no substantial increase in widgeongrass production was evident and the total percent vegetative coverage along the transect hovered around 40 percent, meaning about 60 percent was unvegetated open water. During this time period, 1967-1973, water levels in the Price Lake Unit were, on the average, well above marsh level most of the year and average salinities ranged between 5 and 10 ppt (Figure 4-8). The levees that enclosed the unit in 1970, also, seemed to have had little influence on waterfowl food production (Figure 4-5). Recent aerial photography (NASA 1978) substantiates the fact that much of the Price Lake Unit has undergone a significant transition to open water. In fact, the large open water bodies now present may be responsible for the poor widgeongrass production, because the water bodies are more affected by wind action which increases turbidities. Average water levels and salinities do not appear to be limiting factors for widgeongrass production (Figure 4-7), although highly fluctuating water levels in a particular year, such as during periods of droughts or floods, could be.

Transect data was also investigated to determine whether the passive management procedure favored production of perennial sedges, such as Scirpus sp., which are preferred food items for muskrats and Snow Geese. The percent coverage of these species increased from 0 in the early 1960s to a peak of about 7 percent in 1966 and then fluctuated between 1 and 8 percent through 1974 (Figure 4-9). There is some indication that the passive management program, including the levee enclosure, has slightly increased Scirpus sp. composition and coverage, yet, this composition still remains relatively low because a maximum of only 8 percent coverage was noted. It must be remembered that a proper burning program is necessary, in addition to water level management, to increase Scirpus sp. composition at the expense of wiregrass, the climax species (O'Neil 1949).

Management at the Rockefeller Refuge has been aimed primarily at improving habitat for wintering waterfowl. However, many times such management results in improved habitat conditions for other fish and wildlife species. In conjuction with the research

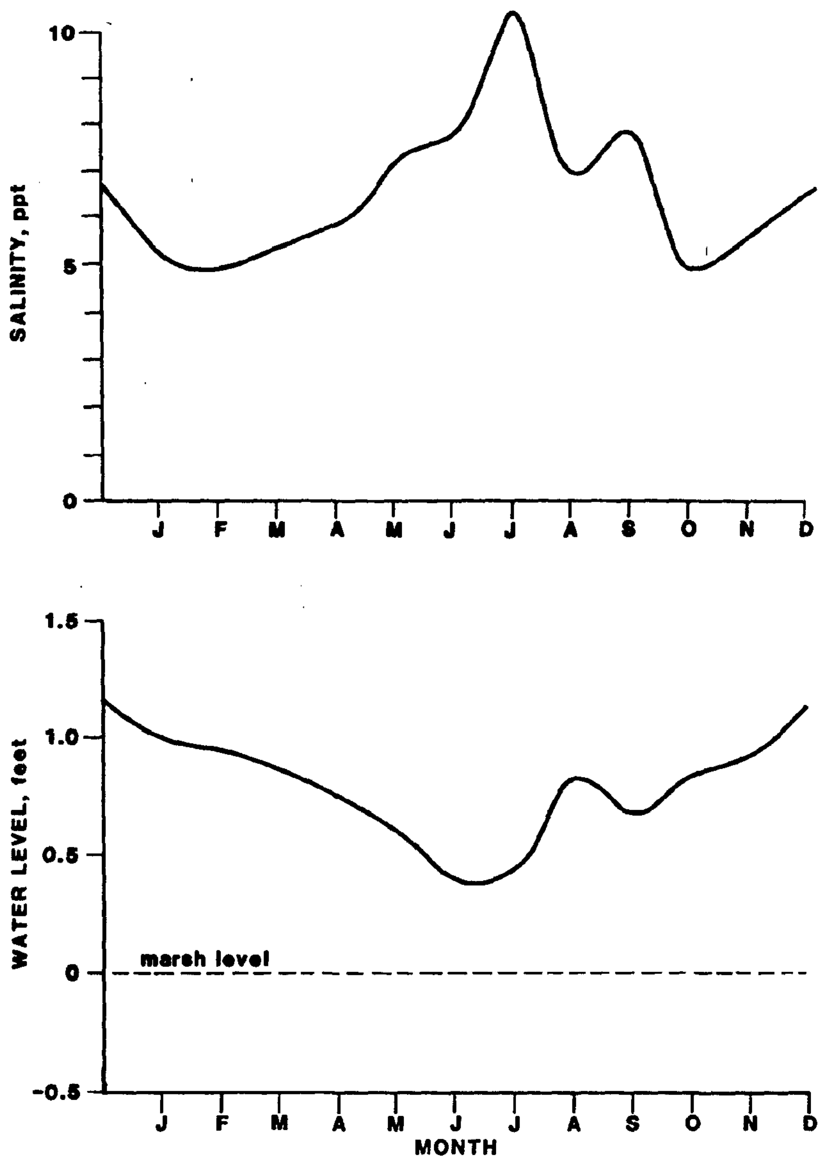


Figure 4-8. Mean monthly salinity and water levels recorded for the Price Lake Unit, 1967-1973.

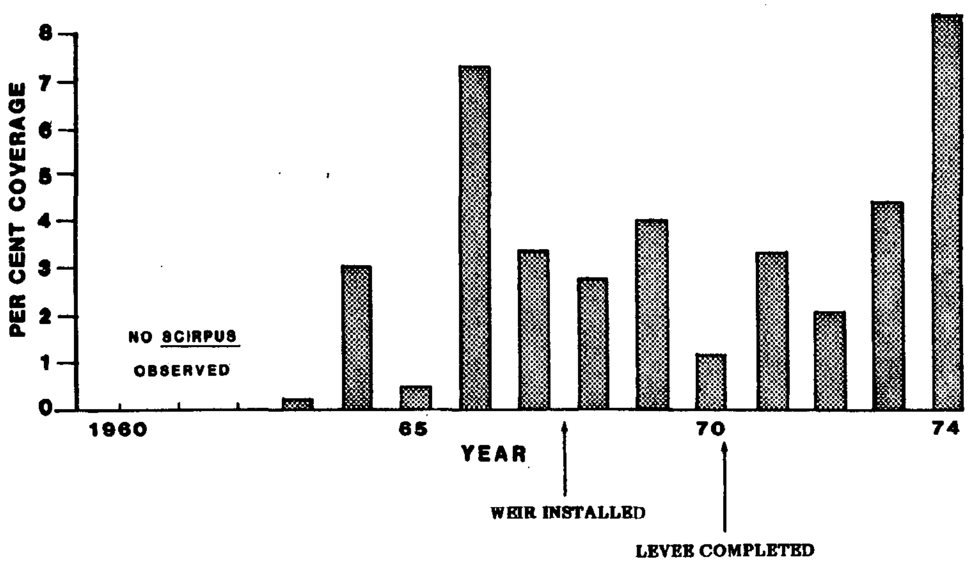


Figure 4-9. Per cent coverage of Scirpus sp. in the Price Lake Unit from 1960 through 1974.

by Dr. Robert Chabreck, Professor of Forestry and Wildlife Management, Louisiana State University, Baton Rouge, on the fish and wildlife values of brackish water impoundments, trawl samples were taken within the Price Lake Unit from April to December 1981 (Davidson 1982). Table 4-1 lists a summary of this unpublished data in the form of catch per effort of individuals by month and total number of individuals caught for each species. Some of the more abundant species included brown shrimp (Penaeus aztecus), white shrimp (Penaeus setiferus), blue crab (Callinectes sp.), black drum (Pogonias cromis), menhaden (Brevoortia sp.), sheepshead minnow (Cyprinodon variegatus), and grass shrimp (Palaeomonetes vulgaris). The data tends to exemplify the normal ingress of several estuarine dependent species in the spring from the gulf. The many important sport and commercial species on this list substantiates the fact that Price Lake, under a passive management system, is serving as an important nursery ground on the refuge.

To summarize, the passive management techniques utilized in the Price Lake Unit have been only marginally successful in producing either waterfowl foods or preferred muskrat and Snow Goose foods. This unit is experiencing continued marsh breakup with a subsequent increase in open water area. Evidently, the weir system does allow shrimp ingress and egress, as the Price Lake Unit is now considered an important shrimp nursery ground on the refuge (Ensminger 1982). The factors responsible for the increasing marsh breakup are difficult to delineate, but the levee enclosure and weirs may possibly contribute to the problem by maintaining higher-than-normal water levels.

Controlled Estuarine Management

Description of Unit 4

During the period of initial saltwater intrusion into the refuge, most of what is now Unit 4 became open water due to a die-off of the sawgrass marsh. At present, the unit encompasses about 5680 ac of brackish-to-intermediate marsh and large, semi-permanent open water areas. Management levees forming the northern and eastern boundaries of the unit were constructed by the refuge and are maintained by refuge personnel. However, the management levees forming the western and southern boundaries of the unit were constructed by oil companies. These companies are now

Table 4-1. Trawl Data for 1981, Inside Price Lake Unit: Full Species List

SPECIES	MONTHLY MEAN CATCH PER EFFORT									
	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL*
Penaeus aztecus (Brown shrimp)	8.33	452.67	151.00	167.67	8.00	20.67	1.33	1.33	4.00	2445
Penaeus setiferus (White shrimp)	1.00		62.00	133.00	63.00	55.00	188.33	91.33		1781
Callinectes sp. (Blue crab)	3.00	41.67	18.33	14.33	45.00	17.67	10.00	27.33	3.67	543
Brevoortia sp. (Menhaden)	3.67	125.00	37.33	52.33	13.33	11.00	21.67	0.33		794
Cynoscion nebulosus (Speckled trout)					0.33		0.33			2
Cynoscion arenarius (White trout)			9.00	7.00	4.67	3.67	2.67			81
Sciaenops ocellata (Redfish)		1.00	0.33			0.67				6
Pogonias cromis (Black drum)	0.33	104.67	15.00	18.67	9.67	8.00	10.67	239.00	11.00	1251
Micropogon undulatus (Atlantic croaker)	45.33	38.67	2.67	2.33						267
Leiostomus xanthurus (Spot)	2.33	136.33	3.00	5.33						441
Bairdiella chrysura (Silver perch)						0.67				2
Paralichthys lethostigma (Southern flounder)		1.67	2.00	2.67		0.33		1.67		25
Lepisosteus spatula (Alligator gar)	0.33	1.33	0.33			0.67				8
Lepisosteus oculatus (Spotted gar)										
Lepisosteus osseus (Longnose gar)	0.33									1
Dorosoma cepedianum (Gizzard shad)				1.67	17.67	0.67	5.00	0.33		76
Dorosoma petenense (Threadfin shad)				4.00	0.33	1.67	0.33			19
Menidia beryllina (Tidewater silverside)		1.33					0.33	0.33	34.33	109
Cyprinodon variegatus (Sheepshead minnow)		0.67						0.67	360.00	1084
Mugil cephalus (Striped mullet)	1.00	0.67	0.33			2.00		8.00	10.00	66
Chloroscombrus chrysurus (Atlantic bumper)						3.00				9
Anchoa mitchilli (Bay anchovy)	2.33	6.67	1.00	22.00	1.00	7.33	1.33	4.33		138
Lagodon rhomboides (Pinfish)		1.67	0.67	2.33						14

Table 4-1 concluded

SPECIES	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL*
Symphurus plagiusa (Blackcheek tonguefish)					0.33	0.33		0.33	1.00	6
Citharichthys spilopterus (Bay whiff)		3.00								9
Trinectes maculatus (Hogchoker)										
Urophycis floridanus (Southern hake)										
Arius felis (Sea catfish)										
Bagre marinus (Gafftopsail catfish)										
Synodus foetens (Inshore lizardfish)										
Gambusia affinis (Mosquitofish)										
Palaeomonetes vulgaris (Grass shrimp)	1.67	18.00	0.67	1.33	3.00			319.67	51,766.67	156,333

*Total number of individuals caught (3 replicates per month)

Source: Davidson 1982

charged with the responsibility of repairing damage to these levees at no expense to the refuge (Plate 1). In fact, the levees on either side of the Humble Canal have been completely re-built due to erosional damage caused by boat wakes. Refuge and oil company maintained levees are represented on Plate 1.

When Unit 4 was originally created, water levels were controlled by numerous 36-in flap-gated metal culverts. These culverts will be described in the following section on gravity drainage management. At present, water exchange is managed via a single concrete control structure containing seven variable crest, stainless steel flap-gates located in the southwest corner of the unit (Plate 1). A schematic drawing of a 5-gated structure of this type (Figure 4-10) shows that the main portion is composed of a series of vertical concrete walls topped with a concrete walkway. A cross-section of the structure would appear "T"-shaped. Steel sheet pile wing walls extend from the structure well into the levee on all sides to secure the structure against erosion. In addition, the outfall channel and levee berm are covered with articulated concrete mats (Gobi-mat) to prevent erosion. Within the vertical concrete walls, stop-log bays are formed by imbedding stainless steel "U" channels in the sides of 4 x 8 ft holes. Stop-logs, each equipped with a pair of protruding handling pins, are seated in the bays through slots in the walkway up to the elevation of the desired water level in the unit. The hinged flap-gates are attached to one side of a wooden frame that is the same width as the "U" channels and stop-logs. These gates are seated in the bays on top of the stop-logs. With stop-logs at the desired elevation, the flap-gates can be directed to discharge only excess precipitation from the managed area while preventing inflow of estuarine organisms and brackish water. The unit managed with these structures can be flooded or drained by adding or removing stop-logs, respectively, depending on tidal conditions and rainfall.

The controlled estuarine management classification can also be applied to Unit 6, although the structural elements and goals are much different for this unit than for Units 4 and 5. Unit 6, containing 13,500 ac, is completely leveed except for an open connection to Grand Lake through the Superior Canal. Although water levels can not be controlled in this unit, a navigation lock on the Property Line Canal and two concrete radial lift gate structures on Big Constance and Little Constance Bayous are operated to both alleviate flooding and prevent saltwater intrusion into Grand Lake. The concrete radial lift gate control structure is depicted in Figure 4-11. Three

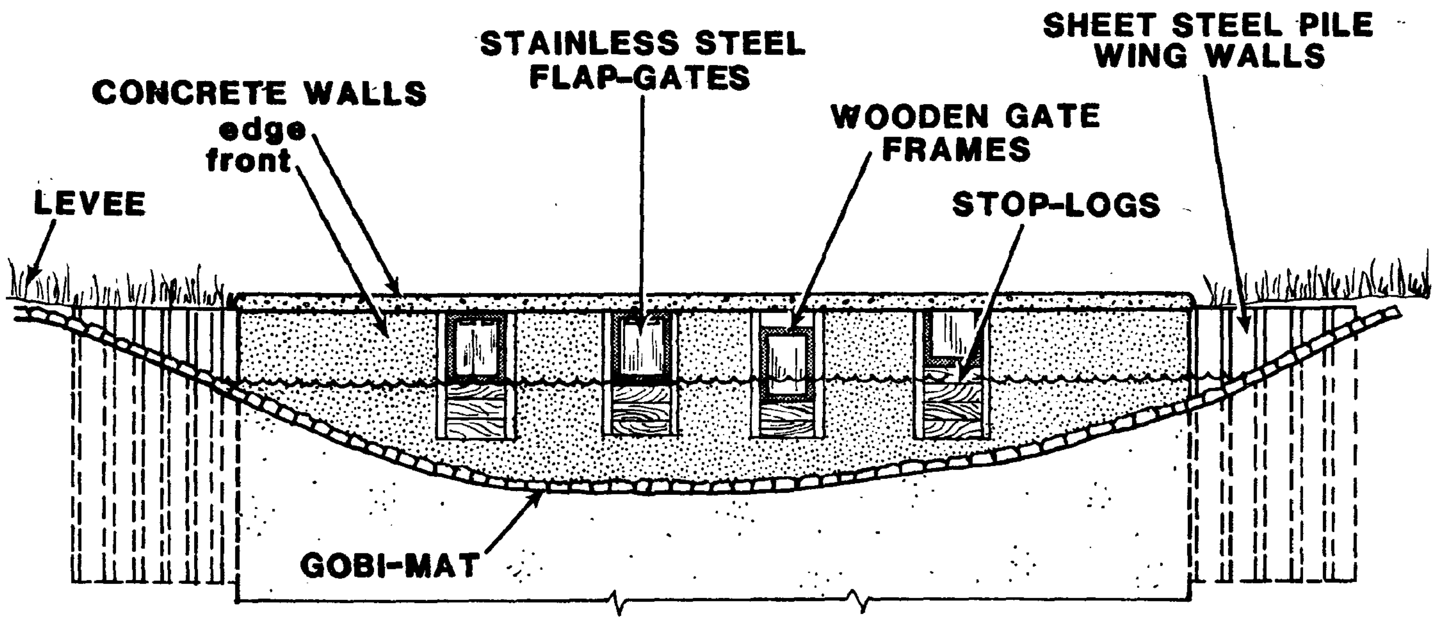


Figure 4-10. Schematic front view of a concrete, variable crest, reversible flap-gate control structure.

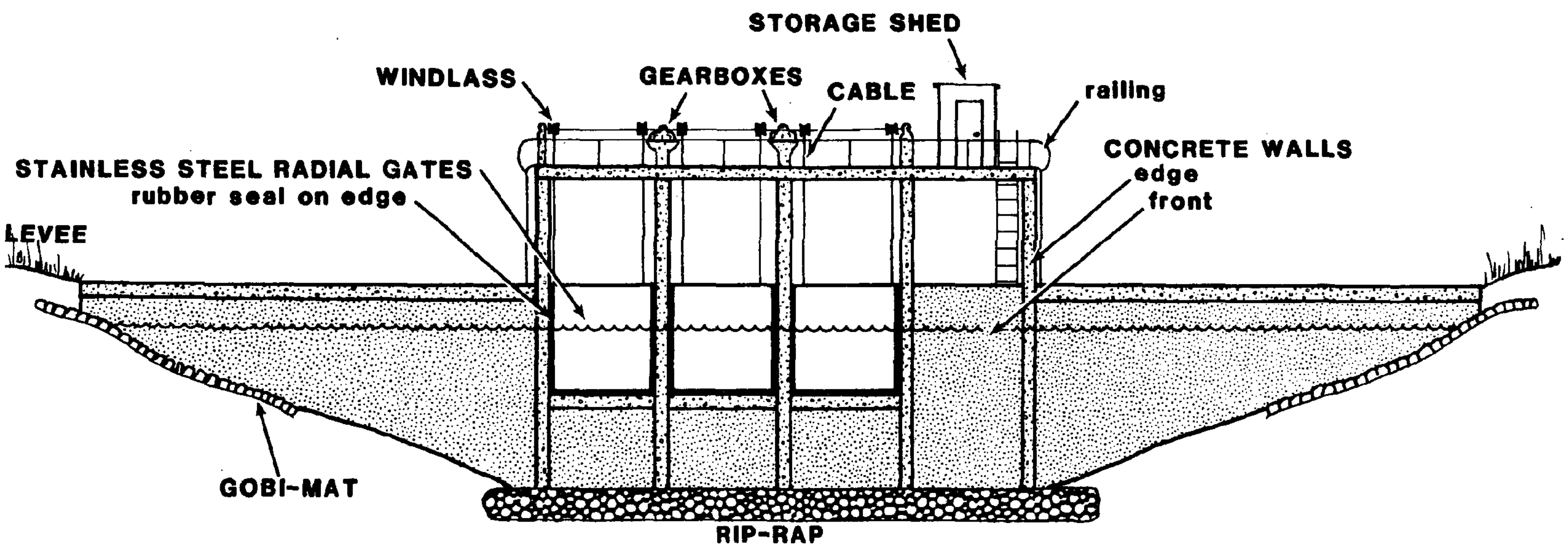


Figure 4-11. Schematic front view of a concrete and stainless steel radial lift gate control structure.

stainless steel gates (approximately 8 x 8 ft) are raised and lowered by cables connected to a windlass and gear boxes. Power is supplied either by a removable motor or hand cranks. Each gate is slightly curved and is connected to the concrete walls of the structure by an arm and a fixed hinge pin on each side. The gates can, therefore, be operated even with high water pressure on them. When the gates are fully raised, small boats normally can pass through the structures.

Objectives of Management

The objectives of controlled estuarine management are centered around multi-use of a unit by both estuarine fisheries species and waterfowl species. In Unit 4, the specific objectives are to admit to the unit adequate numbers of postlarval shrimp and fishes during times of peak abundance and, at the same time, to produce conditions that favor growth of widgeongrass for waterfowl food.

The main factor influencing growth of widgeongrass is turbidity. It has been found that draining shallow, open water areas allows consolidation and compaction of the soft bottom muds. Upon reflooding, the dried surface crust is more resistant to resuspension by wind action, thereby reducing turbidity. To allow compaction of bottom muds, the unit is drawn down one year out of three. This is accomplished, beginning in February, when stop-logs are removed and the flap-gates are lowered slightly on the Unit 4 control structure to begin releasing water. From March through June or July, the structure remains in this draw-down operation mode. Around August the unit is reflooded and stop-logs are added to raise the flap-gates and contain higher water levels. Water is then held at this level for growth of widgeongrass.

In conjunction with the statewide Department of Wildlife and Fisheries (formerly Louisiana Wildlife and Fisheries Commission) program, the monitoring of postlarval brown shrimp population is performed on the refuge in late February and March. When high concentrations of postlarvae are discovered in the vicinity of the structure, the gates are reversed for a short period of time to permit ingress of the postlarval shrimp. Before water levels within the unit begin to rise appreciably, the gates are switched back to the outflow position. It takes about 19.8 million cu ft of water to raise the level of Unit 4 by 1 in. It is, therefore, possible to introduce significant numbers of shrimp and other organisms into the unit without detrimentally increasing the water level, turbidity, and salinity. The same procedure is followed during peak immigration of postlarval white shrimp. Estuarine organisms are able to exit from the unit when the flap-gates are discharging at low tide.

The primary management objectives for Unit 6 are to alleviate flooding due to heavy rainfall and prevent saltwater intrusion during low rainfall periods. When the water level at the junction of the Superior Canal and the Property Line Canal reaches approximately +2.5 to +3.0 ft msl, the navigation lock and radial gate control structures are opened (Ensminger 1982). Because the radial gate control structures are far removed from refuge headquarters and must be manually operated, the gates tend to remain open for a period of time even after the water level falls below the critical level. After the first heavy rains of late fall and early winter (Figures 4-2 and 4-3), the structures can remain open until April, on the average. During the late winter and early spring, as surpluses begin to diminish, the marshes in the southern portion of the unit experience some gentle tidal action as the mean tide level begins to increase. Ingress of estuarine organisms takes place during this time and saltwater begins to enter the unit (Figure 4-12). When salinity increases become evident within the unit, the structures are closed. Figure 4-12 shows that the gates tend to remain closed from May through August, but must sometimes be reopened during September to lower the water level in the unit.

In reality, the structures may have to be opened in any month of the year to achieve desired water levels, but each time, an exchange of saline and fresh waters is allowed to occur before the gates are closed. This practice has led to a diverse wetland environment in Unit 6, ranging from saline-brackish marsh near the structures to fresh-intermediate marsh at the Property Line Canal.

Results of Management

An indication of the value of Unit 4 as a waterfowl impoundment can be seen from the graph of percent coverage by perennial, annual, and aquatic vegetation (Figure 4-12). During several years, annual and aquatic plants covered almost 40 percent of the area sampled (Figure 4-13). The dominant aquatic plant was widgeongrass, and the most abundant annual, due to the normally brackish water conditions present, was dwarf

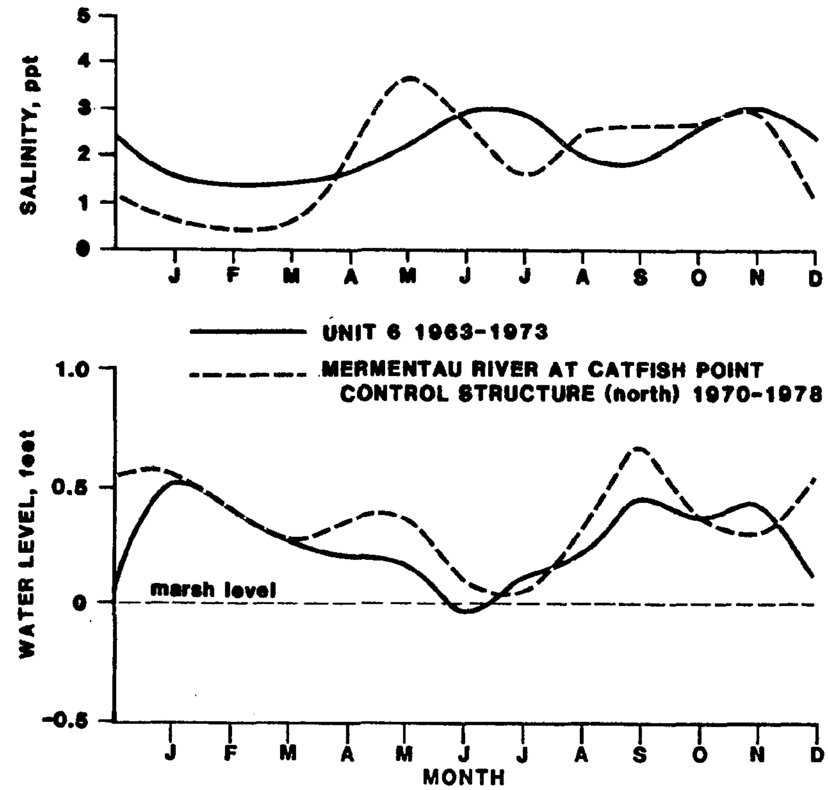


Figure 4-12. Comparison of mean monthly water levels and salinities behind control structures at Catfish Point and in Unit 6 (USGS 1970-78; USACE 1970-1978; Chabreck 1963; Chabreck and Joanen 1964-1966; Joanen et al. 1967-1973).

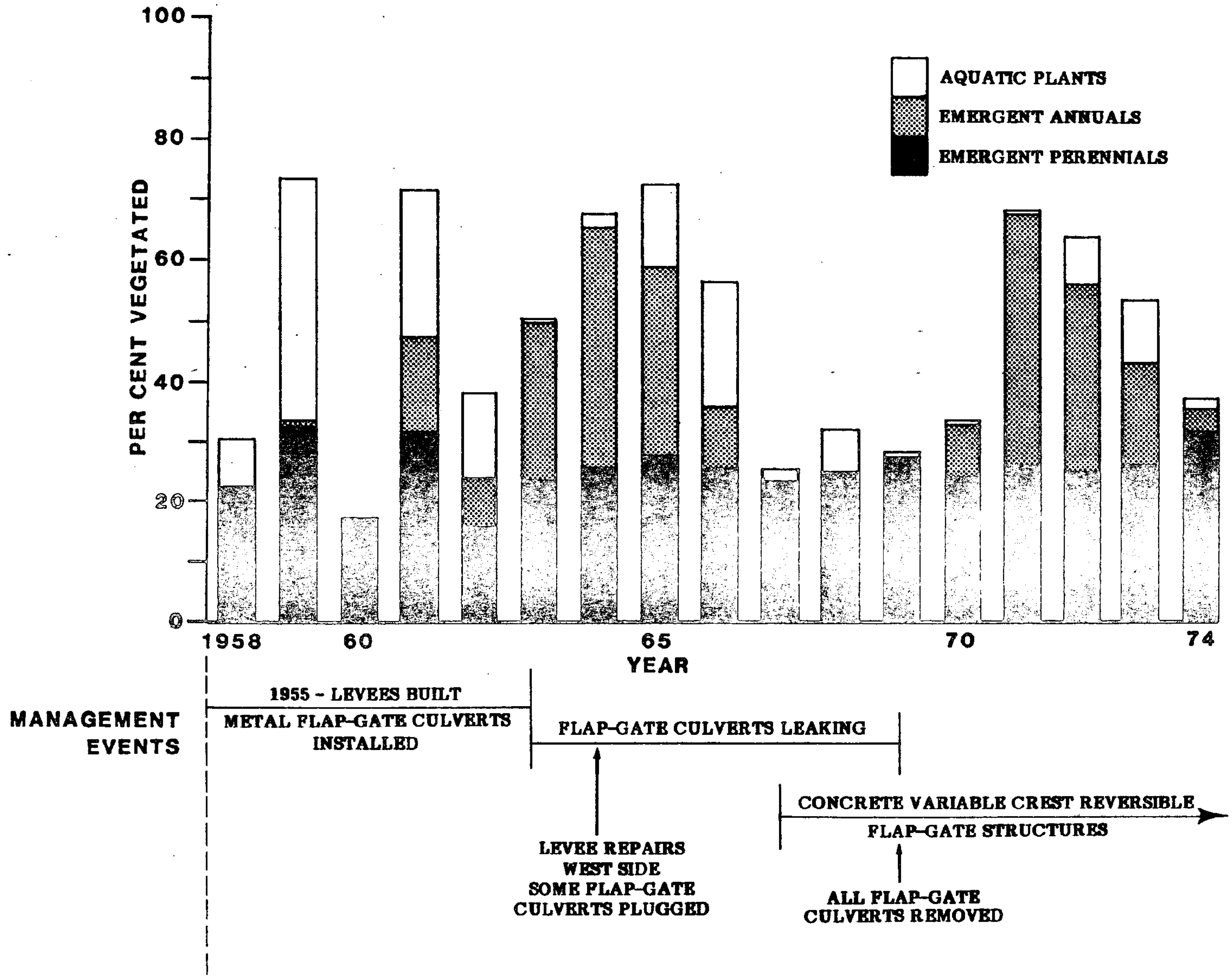


Figure 4-13. Vegetative transect data and management events for Unit 4, 1958-1974.

spikerush (Chabreck 1959, 1960b, 1961, 1962, 1963; Chabreck and Joanen 1964, 1965, 1966; Joanen et al. 1967, 1968, 1969, 1970, 1971, 1972, 1973, 1974). The leaves, stems, and seeds of both plants are fed upon by waterfowl, and up to 100,000 ducks have been observed in this unit (Ensminger 1982). The degree to which the impoundment dries in the spring and summer determines, to a large extent, whether widgeongrass or spikerush is produced. During extremely dry years, such as 1960, the production of both annuals and aquatics was low. The impoundment needs to be dried out approximately every third year to allow consolidation of the bottom in order to reduce turbidity upon reflooding and to encourage widgeongrass production. In years during which water was abundant and widgeongrass production poor, such as 1967 and 1969 (Figure 4-12), excessive turbidities were probably the reason for the low productivity. However, because multi-use is emphasized in this unit, less rigid controls of water levels are practiced in order to allow ingress of estuarine aquatic animals such as shrimp and fish.

In conjunction with Dr. Chabreck's research on fish and wildlife values of brackish water impoundments, trawl samples were taken from within (Table 4-2) and just outside of (Table 4-3) Unit 4 (Davidson 1982). These samples indicate substantial utilization within Unit 4 by brown and white shrimp, blue crab, white trout (Cynoscion arenarius), black drum, Atlantic croaker (Micropogon undulatus), and bay anchovy (Anchoa mitchilli). Although a few more species occurred in the canal outside of Unit 4 (Table 4-3), usage within the impoundment was equitable for most of the important sport and commercial species. Indications are that Unit 4 is functioning as a viable nursery ground which has, in turn, spawned an enthusiastic cast net fishery for shrimp for local sportsmen (Perry 1982). It has been estimated that Unit 4 may produce as much as 300,000 lbs of shrimp in some years (Ensminger 1982).

Unit 6 is under slightly different management in that the primary impetus is to prohibit saltwater intrusion with levees and concrete control structures. Although Unit 6 has been a fairly consistent producer of waterfowl foods (Figure 4-14), perennials are predominant and annuals and aquatics are usually sparse in percent coverage. In some years, however, fairly extensive stands of widgeongrass and Najas sp. do occur. The area is managed for multi-use purposes and utilizes the freshwater sources of Grand and White Lakes which enter the area through the Superior Canal

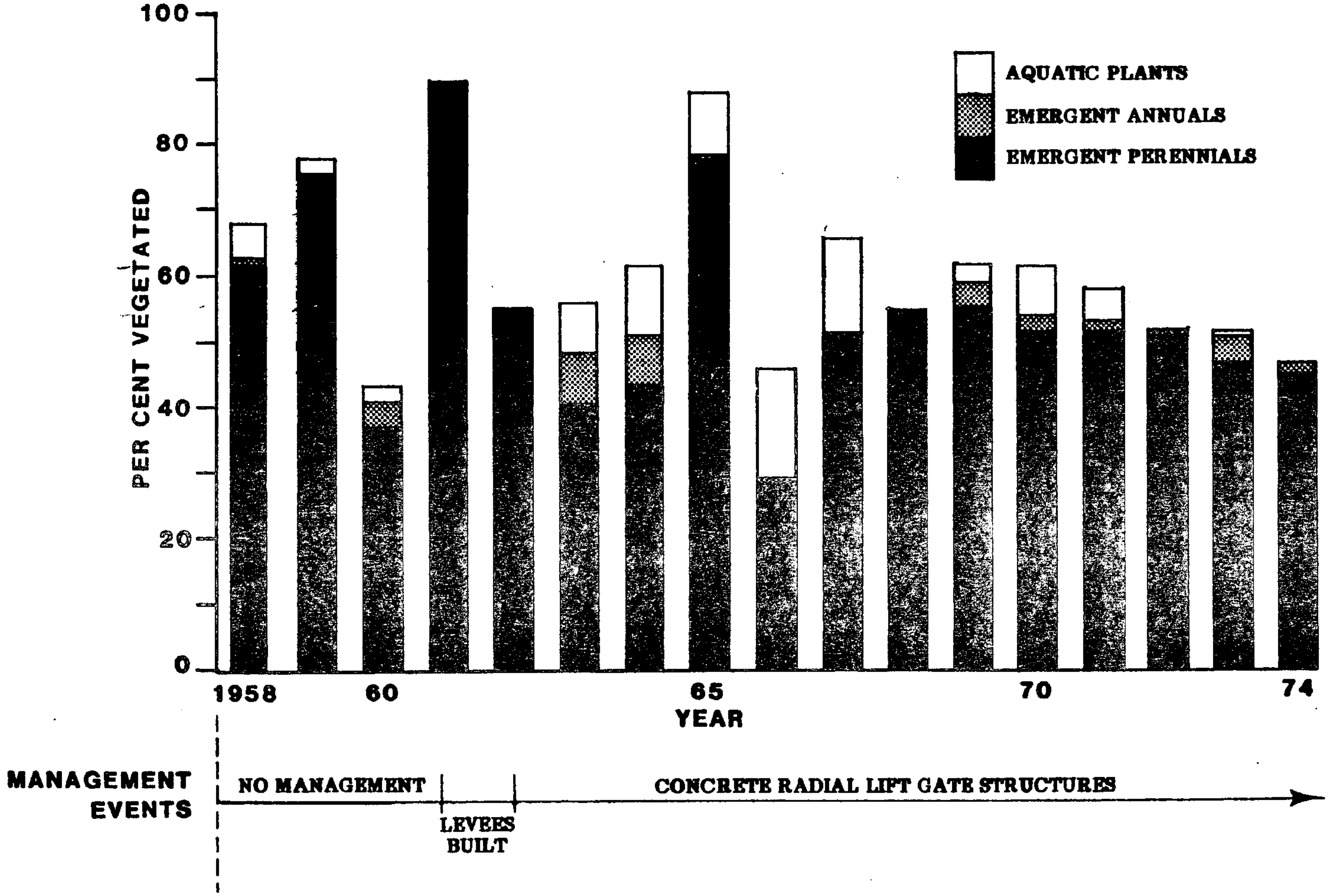


Figure 4-14. Vegetative transect data and management events for Unit 6, 1958-1974.

Table 4-2. Trawl Data for 1981, Inside Unit 4: Full Species List

	MONTHLY MEAN CATCH PER EFFORT									
SPECIES	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL*
Penaeus aztecus (Brown shrimp)		92.33	119.33	485.33	3.67	0.33		3.67		2114
Penaeus setiferus (White shrimp)	0.33		54.33	45.00	126.67	61.00	19.00	100.33	24.67	1294
Callinectes sp. (Blue crab)	2.00	2.67	10.67	3.00	1.00	6.00	4.67	4.67	3.00	113
Brevoortia sp. (Menhaden)		0.33				1.67			2.33	13
Cynoscion nebulosus (Speckled trout)								0.33	0.67	3
Cynoscion arenarius (White trout)			148.67	9.00	1.33	2.00		0.33		484
Sciaenops ocellata (Redfish)	1.00		0.33							4
Pogonias cromis (Black drum)	1.33	0.67	0.67	0.33	1.00			7.33	440.67	1356
Micropogon undulatus (Atlantic croaker)	80.67	42.33	4.00	2.00	0.33					388
Leiostomus xanthurus (Spot)	6.67	6.67	5.67	24.67	10.00	0.67				163
Bairdiella chrysura (Silver perch)								0.33		1
Paralichthys lethostigma (Southern flounder)		0.33								1
Lepisosteus spatula (Alligator gar)	1.00			0.67	0.67		0.33	1.00	0.33	12
Lepisosteus oculatus (Spotted gar)		0.33		0.67	0.67	0.33			0.67	8
Lepisosteus osseus (Longnose gar)										
Dorosoma cepedianum (Gizzard shad)				0.67						2
Dorosoma petenense (Threadfin shad)								1.67	2.67	13
Menidia beryllina (Tidewater silverside)	2.33							8.33	3257.33	9804
Cyprinodon variegatus (Sheepshead minnow)	6.67								1700.00	5120
Mugil cephalus (Striped mullet)	1.00			0.33	0.67	4.33		4.67	1.00	36
Chloroscombrus chrysurus (Atlantic bumper)						0.33				1
Gobiosoma bosci (Naked goby)	0.33	0.33	0.33	0.33						4
Anchoa mitchilli (Bay anchovy)		5.67	88.33	4.33	20.67	39.00	17.67	54.67	176.33	1220
Palaeomonetes vulgaris (Grass shrimp)	48.67	729.00	1.67			0.33				2339

*Total number of individuals caught (3 replicates per month)

Source: Davidson 1982

Table 4-3. Trawl Data for 1981, in Union Canal near Humble Canal: Full Species List

	MONTHLY MEAN CATCH PER EFFORT									
SPECIES	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL*
Penaeus aztecus (Brown shrimp)	7.33	99.67	148.00	13.00	3.67	0.33	3.00	1.00		828
Penaeus setiferus (White shrimp)	12.00	1.00	61.33	24.33	108.33	252.67	699.67	78.00	30.33	3803
Callinectes sp. (Blue crab)	23.00	26.67	10.33	38.67	1.33	2.00	2.33	2.67	7.00	342
Brevoortia sp. (Menhaden)	0.33		0.33	1.67				5.00	9.67	51
Cynoscion nebulosus (Speckled trout)								0.33	0.33	2
Cynoscion arenarius (White trout)		6.00	91.00	23.33	20.33	232.67	129.67	5.67	0.33	1527
Sciaenops ocellata (Redfish)										
Pogonias cromis (Black drum)			0.33		1.67	1.33	0.33	4.33	57.33	196
Micropogon undulatus (Atlantic croaker)	37.67	63.00	16.33	6.33	2.00	0.67	1.00	0.33		382
Leiostomus xanthurus (Spot)		1.67				0.33				6
Bairdiella chrysura (Silver perch)						0.67				2
Paralichthys lethostigma (Southern flounder)	3.00	2.00	16.67	1.33	4.67	5.00	6.33	2.00	3.00	132
Lepisosteus spatula (Alligator gar)	0.33									1
Lepisosteus oculatus (Spotted gar)										
Lepisosteus osseus (Longnose gar)										
Dorosoma cepedianum (Gizzard shad)								0.33		1
Dorosoma petenense (Threadfin shad)						1.33		0.67	1.33	10
Menidia beryllina (Tidewater silverside)								0.33		1
Cyprinodon variegatus (Sheepshead minnow)									9.33	28
Mugil cephalus (Striped mullet)								7.33	2.67	30
Chloroscombrus chrysurus (Atlantic bumper)						1.00	16.67			53
Gobiosoma bosci (Naked goby)										
Anchoa mitchilli (Bay anchovy)	5.00	4.00	8.67		126.67	95.00	122.00	32.67	3.00	1191
Lagodon rhomboides (Pinfish)										

Table 4-3 concluded

SPECIES	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL*
Symphurus plagiusa (Blackcheek tonguefish)				4.00		0.33		0.33	1.00	17
Citharichthys spilopterus (Bay whiff)		7.00								21
Trinectes maculatus (Hogchoker)				1.33						4
Urophycis floridanus (Southern hake)	0.33									1
Arius felis (Sea catfish)			2.00		1.00	0.33	2.00			16
Bagre marinus (Gafftopsail catfish)					1.33	0.33				5
Synodus foetens (Inshore lizardfish)							0.33	0.33		2
Gambusia affinis (Mosquitofish)				0.33						1
Palaeomonetes vulgaris (Grass shrimp)	0.67	3.33	5.67	3.00	0.67	1.00	2.00	1.33	7.67	76

*Total number of individuals caught (3 replicates per month)

Source: Davidson 1982

system. Utilization by estuarine fish and shellfish is dependent on the opening and closing of the control structures on Big and Little Constance Bayous and, therefore, is not always as substantial as in Unit 4. However, because water salinities are controlled in Unit 6 and are relatively fresh much of the time (Figure 4-12), this area has become valuable habitat for the American alligator. An extraordinary amount of research on the alligator has been done at the Rockefeller Refuge, most of it within Unit 6. Although data is not available to substantiate this fact, it is believed that this impoundment also serves as the main nesting area for Mottled Ducks on the refuge. The Mottled Duck is the only waterfowl species that nests in substantial numbers in the coastal marshes of Louisiana. Impoundment management that includes dewatering the marsh in spring and summer for waterfowl food production is not beneficial for Mottled Ducks because water is an essential requirement for them, especially during nesting. Although the Mottled Duck does eat some vegetation and seeds, it feeds heavily on animal matter such as insects, fish, snails, and crayfish (Bellrose 1976) and is not as dependent as the migratory waterfowl on water manipulations for food production. Unit 6 is serving an important function by insuring that favorable habitat is available for both the Mottled Duck and the alligator on the Rockefeller Refuge.

Gravity Drainage Management

Description of Unit 3

Unit 3, like Unit 4, has been severely impacted by saltwater intrusion and resultant marsh breakup. The 3,700 ac of Unit 3 (Plate 1) presently contain perennial brackish marsh plants in slightly elevated areas and fresher annual plant species and/or aquatic plants in the lower areas where marsh breakup has occurred.

Unit 3 is managed, presently, with a concrete, variable crest, reversible flap-gate control structure similar to the one described for Unit 4 (Figure 4-10). The structure is located on the Headquarters Canal in the northeast corner of the unit (Plate 1). Between 1955 and 1969, Unit 3 was managed, as were Units 1, 2, 4, 8, 10, 13, 14, and 15, using 36-in flap-gated metal culverts (Figure 4-15). One of these was installed through the management levees for each 640 ac of managed area. The structure consisted of a length of corrugated metal culvert with a hinged metal flap-gate on the

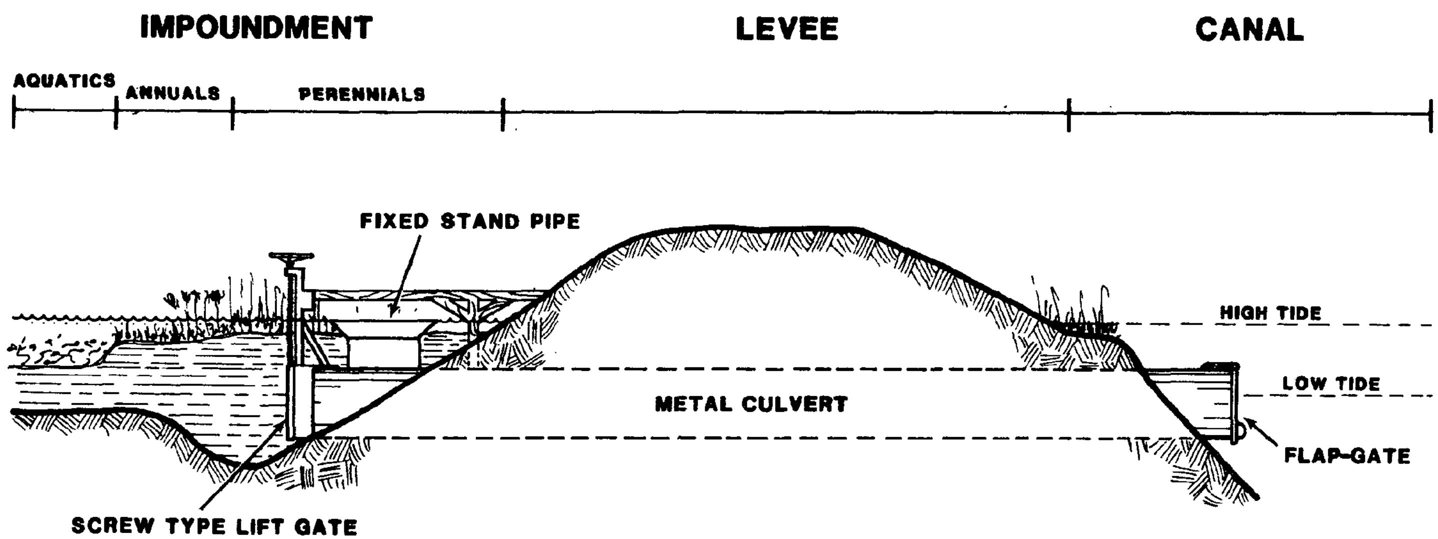


Figure 4-15. Schematic longitudinal section of a 36-inch flap-gated metal culvert.

tidal side and a screw-type lift gate and overflow stand pipe on the managed side. The unit was drained to the low-tide level by opening the lift gate. The flap-gate prevented re-entry of water on a rising tide. The unit was flooded by closing the lift gate and allowing rainfall to build up to the level of a fixed stand pipe.

These structures were removed from all units by 1969 because the metal was corroded and the structures were leaking. This design was prone to fouling of the flap-gate and clogging of the stand pipe by floating debris. The stand pipe did not allow enough flexibility in maintaining or changing the water level within the unit. However, the advantages of flap-gated culverts were their relative low cost, ease of installation, and stability with regard to bank erosion. Though not yet installed for gravity drainage management, a new design "all marine aluminum" 48-in flap-gate culvert has been fabricated for use on the refuge (Figure 4-16). The lift gate and stand pipe have been replaced with a stop-log bay and stop-logs to provide variable control of water levels. The flap-gate has been re-designed to prevent leakage. The end of the culvert is covered with a durable rubber gasket and the gate is double-hinged to give a watertight seal. An air pressure vent also acts to produce a tight seal by releasing trapped air. The aluminum is expected to have a much longer working life and to require less maintenance than the original corrugated metal.

Objectives of Management

The primary management objective for these gravity drainage units is to control water levels in the impoundment for the propagation of important waterfowl food plants. Many of the preferred waterfowl foods are herbaceous annual plants that must be reestablished each spring by germination of their seeds. To induce seed germination for the majority of these plants, water levels must be drawn down to near the level of the marsh floor so that a moist, not dry, surface exists. Once germination is achieved and a young stand of annuals is established, it is usually desirable to reflood the unit with a few inches of water to enhance growth and survival. After plant maturity is reached in the fall, the impoundment is allowed to flood further to insure the availability of foods for wintering waterfowl. The draw-down is initiated in the spring, usually in May, with reflooding scheduled for September.

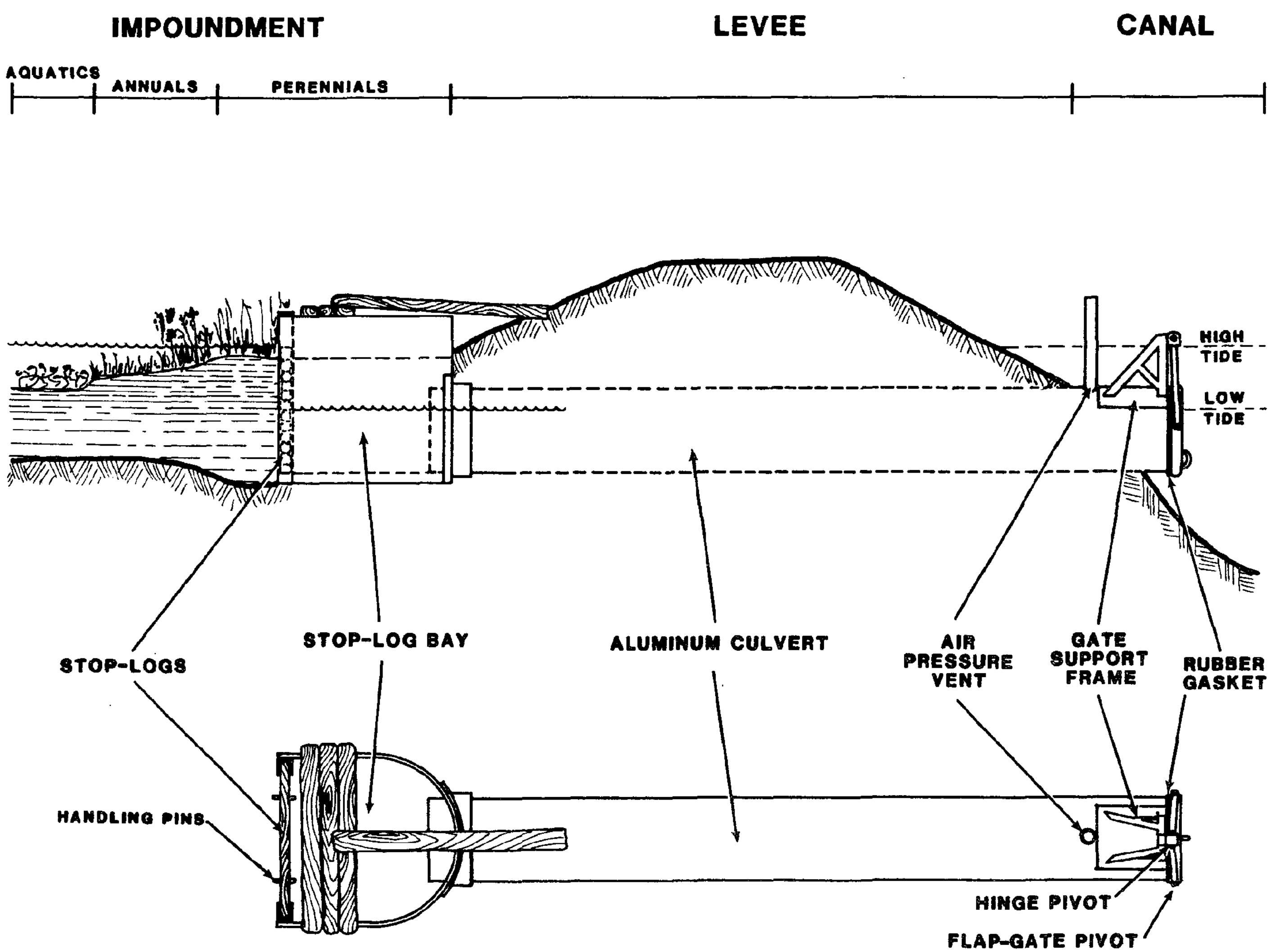


Figure 4-16. Schematic longitudinal and top views of a 48-in aluminum flap-gate culvert.

The ease with which draw-down is accomplished depends on local rainfall and tidal amplitudes. Gravity drainage can lower water levels only to the low-tide stage plus whatever is lost through evaporation. In some years, when heavy rainfall occurs in the spring, complete draw-down is impossible and there is no chance for germination and production of herbaceous annuals. In such cases, the unit is maintained as a flooded impoundment with the objective being to produce stands of widgeongrass. During periods of drought, there may be insufficient rainfall to reflood the impoundment after germination and establishment of the seed-producing annuals to promote growth and survival. In these instances, it may be necessary to allow brackish water to enter the impoundment through the water control structures. However, during dry years this will present problems because water salinities outside the impoundment may be so high that they are detrimental to the emergent annuals. Most of the emergent annuals produced during draw-down do best when salinities range between 0 and 3 ppt. Therefore, the decision must be made to either wait and hope for rain to replenish the impoundment and benefit the annuals, or reflood with brackish water of high salinity and attempt to produce a stand of widgeongrass. Reflooding with the present control structure is easy because it is equipped with reversible flap-gates. However, the original corrugated metal culverts with flap-gates were not so manageable, and reflooding the impoundments during drought periods was much more difficult.

The particular species of herbaceous annuals produced using the draw-down technique depends on several factors, including duration of draw-down, soil moisture content, water salinity, and plant competition. Some of the more important waterfowl foods produced by dewatering impoundments include dwarf spikerush, Walter's millet (Echinocloa walteri), bearded sprangletop (Leptochloa fascicularis), fall panicum (Panicum dichotomiflorum), and jointgrass (Paspalum distichum). Most of the annuals are important to waterfowl because their abundant seeds are preferred food by ducks such as Mallards (Anas platyrhynchos), Pintails (Anas acuta), and Green-winged Teal (Anas carolinensis) (Bellrose 1976). On the other hand, the vegetative parts of aquatics like widgeongrass are fed upon more by ducks such as Gadwalls, American Wigeon, and Shovelers (Bellrose 1976). One objective of management, then, is to manipulate conditions within impoundments to produce seed-bearing annuals in some units and aquatic plants in others. In this way, the refuge can provide a food source aimed at the various preferences of the many species of waterfowl throughout most of the wintering season--a season that normally lasts from September through much of March.

Results of Management

The gravity drainage management technique has been a relatively successful mode of operation for the production of waterfowl foods on the Rockefeller Refuge. Since the inception of impoundment management at the refuge in 1954, Unit 3 has been manipulated with water control structures based on gravity drainage. Using vegetative transect data supplied by refuge personnel, the percentage of the area vegetated by perennials, annuals, and aquatics has been graphed for the years 1958-1974 (Figure 4-17). During several of these years, sufficient dewatering was accomplished to propagate substantial stands of herbaceous annuals with dwarf spikerush being the predominant species. In 1963, almost 60 percent of the area sampled was vegetated by herbaceous annual plants. In eight of the years shown, total area vegetated was greater than 60 percent. Mean monthly water levels and salinities (Figure 4-18) exemplify the trend of dewatering during the summer and a salinity regime ranging between 2 - 5 ppt.

Unit 3 encompasses the site of a severe marsh die-off as a result of saltwater intrusion in the early 1950s (Lynch 1952). Because of this, the marsh surface in some areas of this unit may be slightly lower, making it more difficult to dewater with gravity drainage than some of the other impoundments. This fact and a slightly higher salinity regime have resulted in many years of production of dwarf spikerush and sea purslane (Sesuvium portulacastrum), two species that comprise the majority of the annuals composition. Both species tolerate brackish water conditions and are excellent duck foods.

In the early 1960s, lack of rainfall permitted drying of Unit 3 and seed germination, but drought conditions prevailed and plant survival was poor (Chabreck 1962). Another problem occurred in 1966, 1967, 1973, and 1974 when heavy rains made dewatering with gravity drainage impossible. It is interesting to note that, in these wet years, not only was production of annuals poor but widgeongrass production was also insignificant (Figure 4-17). In general, however, especially after the leaking culverts were replaced by the concrete flap-gate structures, waterfowl food production was excellent with

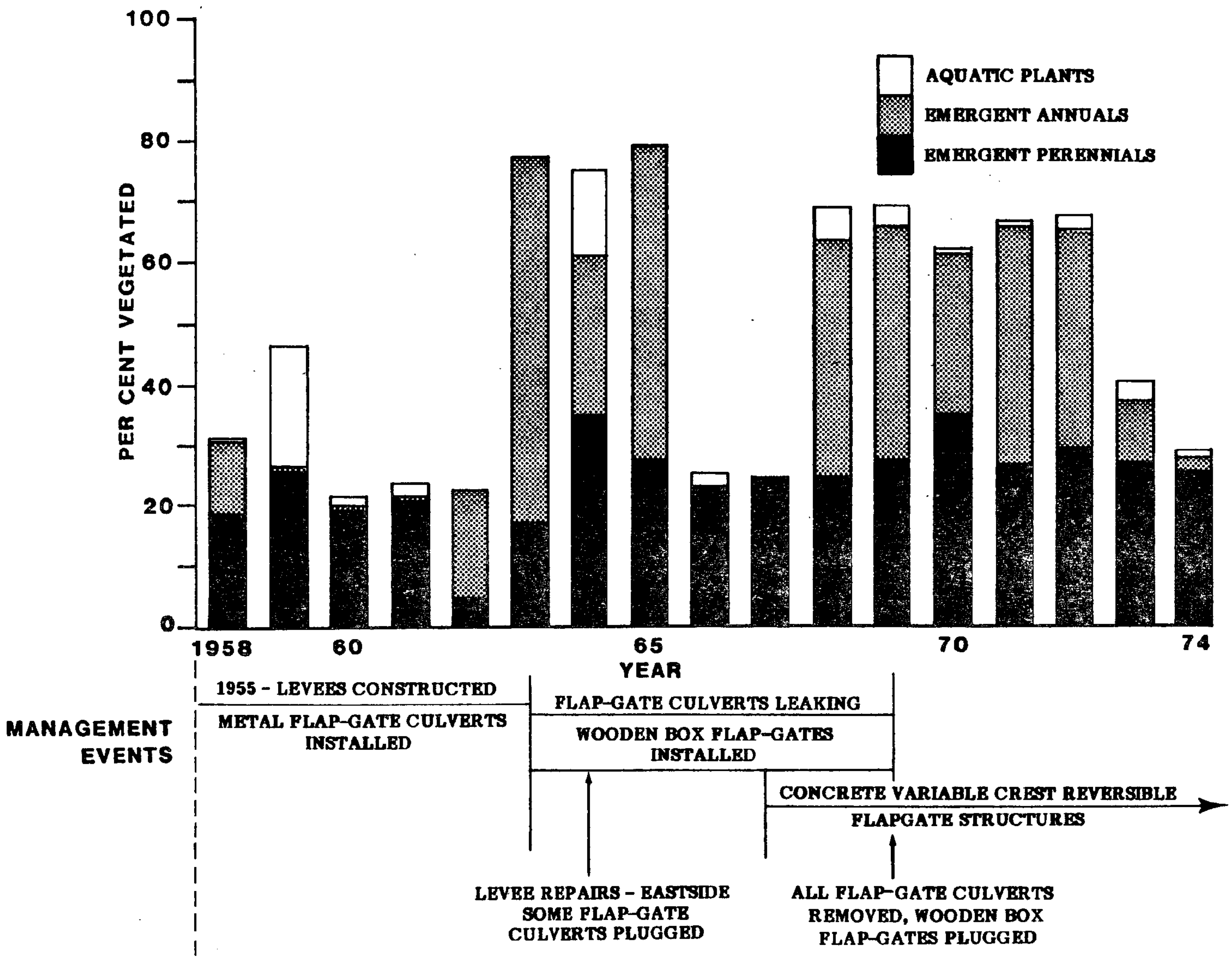


Figure 4-17. Vegetative transect data and management events for Unit 3, 1958-1974.

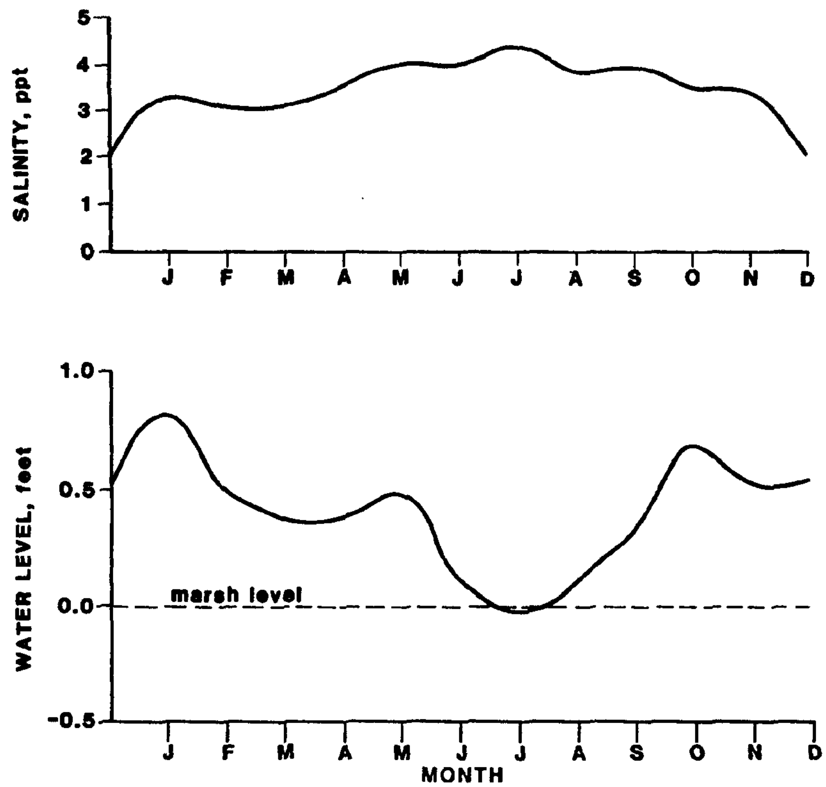


Figure 4-18. Mean monthly water levels and salinities for Unit 3, 1969-1974.

the implementation of the gravity drainage technique. Successful management of a unit with gravity drainage depends on the right amounts of rainfall at the right times.

Forced Drainage Management

Description of Unit 8

Unit 8 is a 1030-ac fresh to intermediate marsh impoundment just west of the Superior Canal in the north-central portion of the refuge. A double divergent pumping unit is used to manage water levels in this unit (Plate 1). The body of the structure is composed of concrete support walls that form two separate boxes joined to the levee system on each side (Figure 4-19). A concrete platform is situated on top of the walls. A diesel-powered pump is mounted in the center of the platform with its intake pipe in one of the boxes and its outfall pipe in the adjoining box. Stop-log bays and stop-logs allow water to enter or exit the boxes as desired. For example, to pump water out of the managed area, stop-logs are removed from A and added to B' in the intake box and removed from A' and added to B in the outfall box (Figure 4-19). Then the pump is started. By reversing the position of the stop-logs in the intake and outfall boxes, respectively, water can be pumped into the unit. However, this is not always necessary as the unit can sometimes be flooded to the desired level by removing an appropriate number of stop-logs from each bay.

Objectives of Management

In the late 1960s, the corrugated metal culverts with flap-gates, originally installed in the impoundments for gravity drainage, had become corroded and had started leaking, making effective manipulations of water levels inside the impoundments impossible. In response to these problems, double divergent pumps were installed in several of the impoundments so that water could be pumped into or out of each unit. By using the forced drainage technique, more complete control of the impoundment hydroperiod could be realized in order to induce establishment of waterfowl food plants.

Management objectives that utilize forced drainage are essentially the same as those for gravity drainage. Usually, pumping is begun in a spring month, such as May, and water levels are drawn down during late spring and summer. This procedure maintains

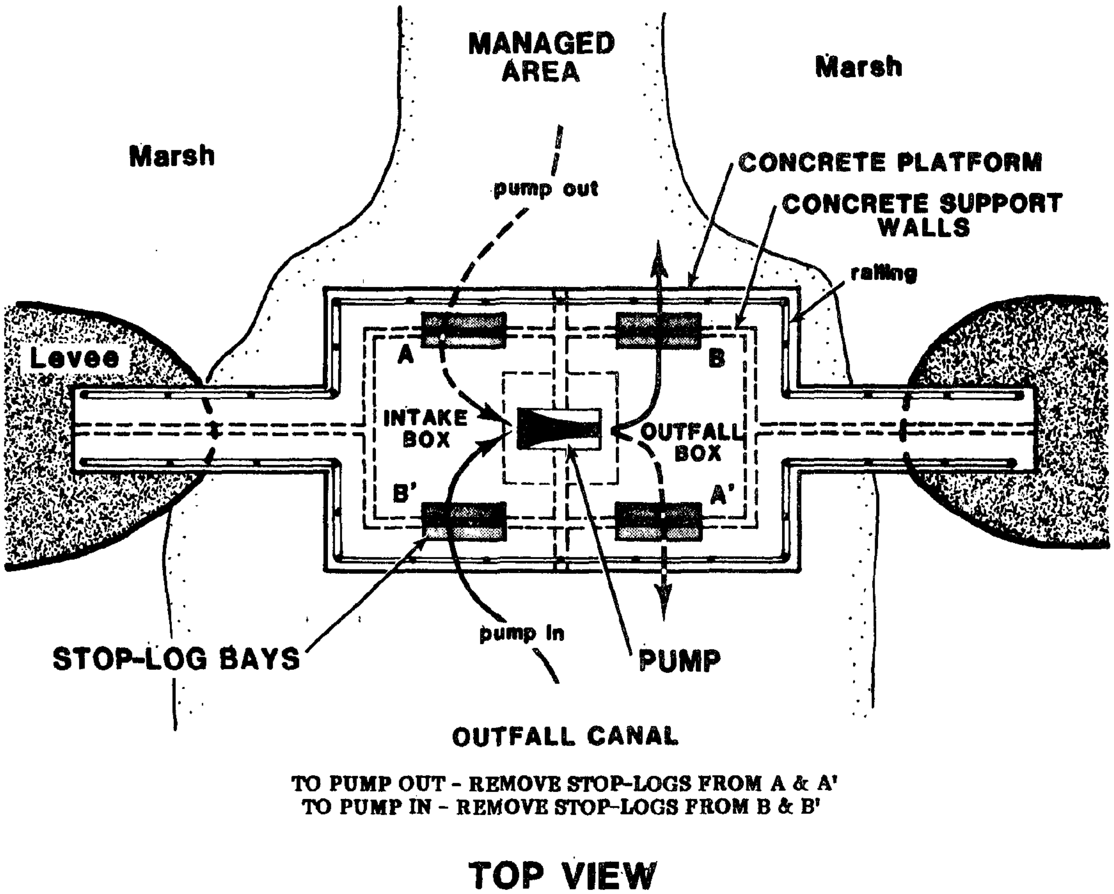


Figure 4-19. Schematic top view of a double divergent pumping unit.

a moist marsh surface and allows germination of herbaceous annuals that are important waterfowl food plants. After these annuals are well established, water levels are allowed to increase a few inches, ordinarily by allowing rainfall to collect in the impoundment to maximize plant growth. If heavy rains raise water levels too high, depths can be regulated by resuming pumping or, at times, simply by removing stop-logs. If insufficient rainfall occurs during dry years, water can be pumped into the impoundment from the Superior Canal system as long as water salinities are not prohibitively high. Reflooding of the impoundment to a depth of 6-9 in is usually begun in September to make the mature seed crop available to the waterfowl, which begin to arrive during the fall migration. In years when spring rains are heavy and it is impossible to dewater the impoundment even with pumping, the unit is allowed to remain flooded throughout the year for production of widgeongrass or other aquatics.

Results of Management

The percentage of area vegetated by perennials, annuals, and aquatics along a vegetation transect in Unit 8 for the years 1958-1974 is graphed in Figure 4-20. This unit was maintained as a permanent freshwater impoundment from 1958 through 1961, resulting in the diminishment of the perennial cover of bulrush. A large aquatic vegetation cover of duckweed (Lemna minor) was present in 1959 but disappeared in the drier years 1960-61 (Figure 4-20). The impoundment was drained in 1962 and was managed through 1968 by gravity drainage utilizing metal culverts and flap-gates. Excellent stands of annuals, primarily bearded sprangletop but also a diverse combination of flatsedge (Cyperus sp.), Walter's millet, and jointgrass, were produced with this drainage method through 1965. Aquatic vegetation was also abundant during this period but consisted, to a large degree, of coastal waterhyssop (Bacopa monnieri), which is only a fair duck food (McNease 1982).

During the period 1966-1968, leakage of the culverts prohibited adequate gravity drainage and resulted in the production of almost no annual plants. An abundant coverage of aquatic vegetation was present in both 1967 and 1968. It consisted of southern naiad (Najas sp.) and pondweed (Potamogeton pectinatus), both of which are good duck foods (Chabreck 1959, 1960b, 1961, 1962, 1963; Chabreck and Joanen 1964, 1965; Joanen et al. 1967, 1968, 1969, 1970, 1971, 1972, 1973, 1974). Forced drainage

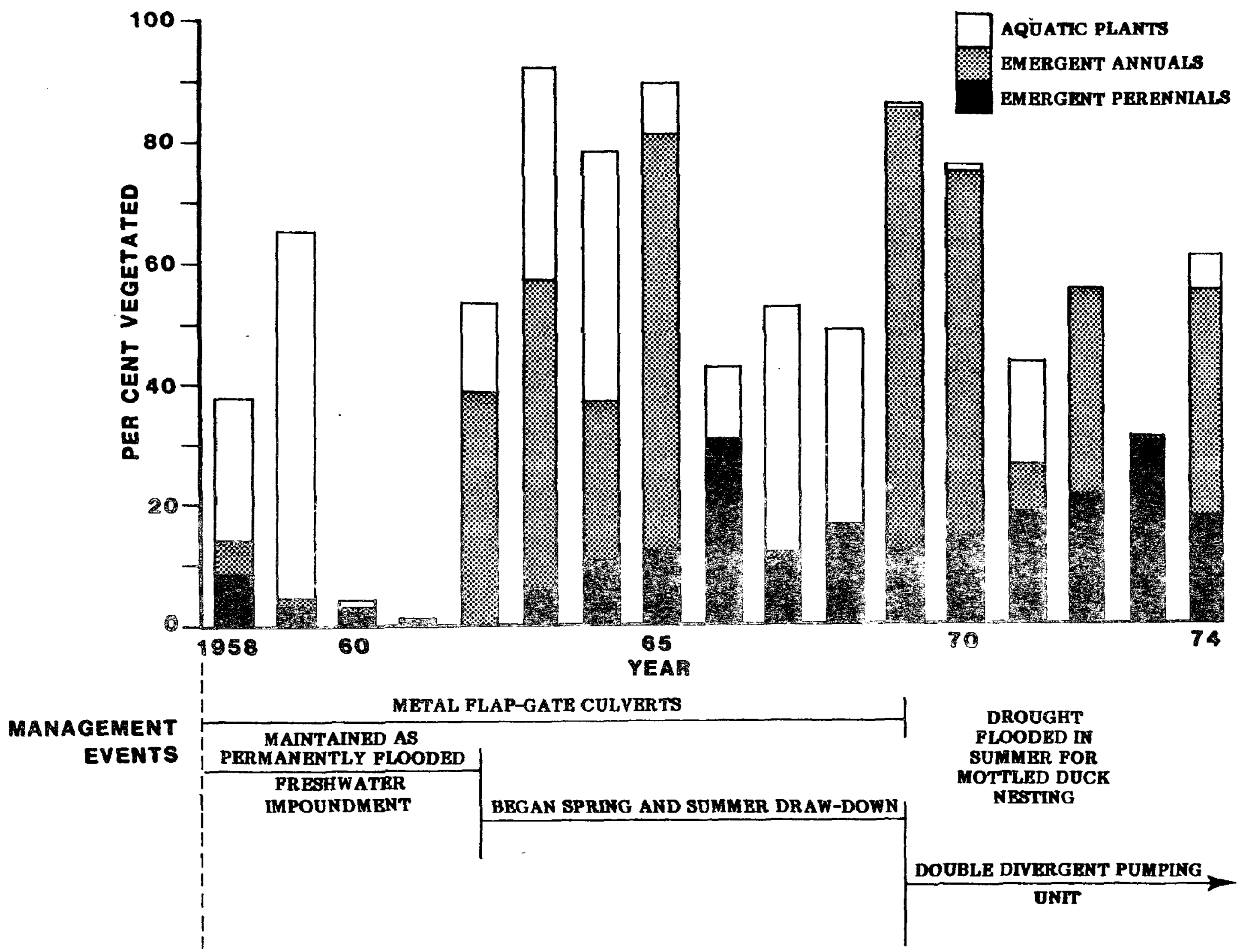


Figure 4-20. Vegetative transect data and management events for Unit 8, 1958-1974.

through pumping was initiated in the spring of 1969 and resulted in several years of excellent stands of herbaceous annual plants (Figure 4-20). The most important duck foods produced with pumping were Walter's millet and bearded sprangletop, the seeds of which are preferred duck foods. Vegetation was not abundant during 1971 and 1973. A drought occurred in 1971, and Unit 8 was flooded to provide suitable nesting habitat for Mottled Ducks. Heavy rainfall in 1973 prohibited effective drainage (Chabreck 1959, 1960b, 1961, 1962, 1963; Chabreck and Joanen 1964, 1965; Joanen et al. 1967, 1968, 1969, 1970, 1971, 1972, 1973, 1974). An analysis of average monthly salinities and water levels for Unit 8 for the years 1969-1974 (Figure 4-21) indicates that the unit has a low salinity regime (1 to 3 ppt) and that the unit can be effectively drained during the summer and reflooded in the fall. Forced drainage has obviously allowed better control of the impoundment water-level regime and has resulted in excellent stands of waterfowl foods. Although Unit 8 has almost always been one of the refuge's better duck impoundments, forced drainage has improved the unit and increased the consistency of food production (Figure 4-20).

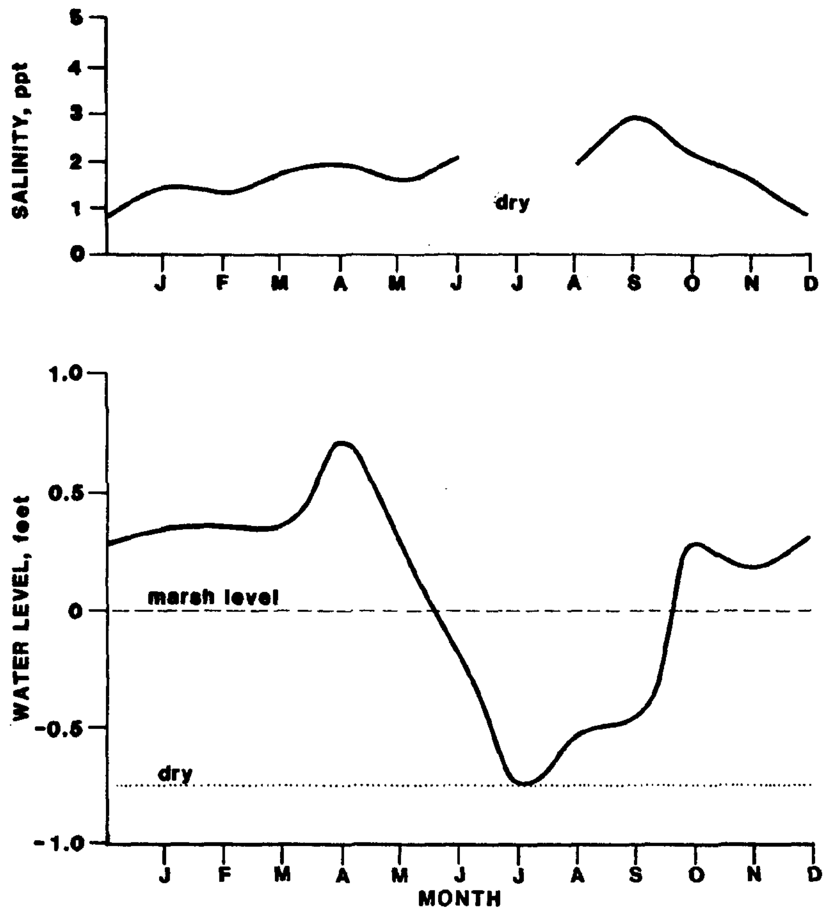


Figure 4-21. Mean monthly water levels and salinities for Unit 8, 1969-1974.

CHAPTER 5: SUMMARY AND CONCLUSIONS

The Rockefeller State Wildlife Refuge and Game Preserve, like many other areas of the Chenier Plain Region, has experienced high rates of marsh breakup and shoreline erosion over the past 50 years because of man-made and natural processes. Extrapolation from areal measurements made for selected transects for 1930, 1955/56, and 1974/79 show a rate of marsh breakup of approximately 192 ac per year between 1930 and 1974. During this period, the approximate rate of shoreline erosion along the entire refuge was 97 ac per year. Natural processes contributing to land loss are marine and estuarine (i.e., wave) erosion, subsidence, waterfowl and muskrat eat-outs, and deep burns during droughts. The major man-made process contributing to land loss is the alteration of the natural hydrologic regime in the absence of active wetland management. The natural hydrologic regime began to be altered significantly in the 1930s with construction of the Gulf Intracoastal Waterway to the north of the refuge. Subsequent projects, such as the construction of a road (LA 82) connecting the chenier ridges, the dredging of oil, gas, drainage and navigation canals, and the impounding of wetland areas through the deposition of spoil, gradually segmented the wetlands and disrupted the natural flow of water. In some areas, raised water levels drowned existing vegetation and prohibited the reestablishment of vegetation that had been destroyed by other means such as eat-outs or fires. Canals that permitted rapid flooding of interior freshwater marshes with saltwater and rapid drainage of the natural freshwater head that historically had remained in the marshes destroyed the freshwater environments. Brackish-to-saline marsh species have been slow to colonize the bare peat exposed in these former fresh-to-intermediate vegetation zones. In summary, vegetation zones that had become established with regard to specific natural edaphic conditions and hydrologic regimes were impacted, usually negatively, by changes in the hydrologic regime. The result has been a net loss in vegetation coverage.

Active management was initiated on the Rockefeller Refuge in the mid-1950s at a time when: 1) royalites from oil and gas operations on the refuge expanded the management opportunities (i.e., more money permitted more extensive and intensive management) and 2) habitat degradation from eat-outs, fires, saltwater intrusion and vegetation die-offs was approaching major proportions. Management operations, while founded on the best management principles of the time, were, and still are to some extent, experimental. Refuge personnel were instituting management plans, primarily a system of leveed impoundments and water control structures, to enhance wildlife habitat. While they had ideas on how the marsh should be managed to achieve the most productive habitat for wildlife, they were constantly trying to fine-tune the methods, as well as obtain a better understanding of the wildlife requirements with regard to habitat. Chapter 2 provided a summary of the early management objectives and results and emphasizes the fact that the refuge is continuously striving to improve itself as a complex network of structurally managed systems that function as enhanced wintering waterfowl habitat, multi-use fisheries environments, and fish and wildlife research laboratories.

While the original management objectives have not always been achieved, sometimes for undiscernable reasons, the search for improved management techniques continues. It is obvious that management is necessary to overcome the degradational, natural and man-made processes that are occurring outside, as well as inside, the refuge. Many of the biologists CEI consulted also felt that management was necessary, even if degradation was not occurring, in order to enhance the value (i.e., carrying capacity) of the refuge for wildlife species, especially waterfowl. One fact cited in favor of this philosophy is that the refuge, under management, supports over 400,000 wintering waterfowl; whereas, prior to management, only about 75,000 waterfowl wintered on the refuge (Joanen 1969). Over 80 percent of these waterfowl winter in the managed impoundments (Chabreck 1960a).

Chapter 4 provided a detailed discussion of the four major management programs (i.e., passive estuarine, controlled estuarine, gravity drainage, and forced drainage) implemented on the refuge (Table 3-4), as well as the results of these programs in general and for selected units (i.e., Price Lake, Units 3, 4, 6, and 8) in particular . The most control over salinity and water levels can be achieved in the forced drainage management units (Units 1, 8, 10, 13, and 14) because pumps can be utilized for pumping in water during low-water periods or pumping out excess water accumulated during storms. However, this is the most expensive management program because of the expense of pumping, maintaining the levees and pump systems, and monitoring the unit for objectives and results. The forced drainage management system is used primarily in those units that are farthest removed from the threat of saltwater flooding and where the objective is to increase the vegetative cover of waterfowl foods, especially annuals. When there is too much rain and it is impractical to totally drain the units for production of annuals, the units are allowed to remain flooded to produce widgeongrass, another desirable waterfowl food species. Analysis of the vegetative sample data for 1958 through 1974 for Unit 8 indicates that forced drainage is a successful management practice because it has increased the consistency of food production for waterfowl. Table 5-1 illustrates the type of habitat and the amount of vegetative cover and abundance of associated species that can be achieved with the four types of management programs.

Water and salinity levels can be controlled, to a limited extent, in conjunction with meteorological conditions in those leveed units managed with gravity drainage. The primary management goal of this system is to limit the inflow of estuarine water and to conserve or discharge rainfall surpluses in a systematic manner to produce annually a waterfowl food crop. This system, like the forced drainage program, is practiced in the northern units (Units 2, 3, and 15) farthest removed from saltwater flooding from the gulf. The vegetation in Units 2, 3, and 15 consists of perennial brackish marsh plants in slightly elevated areas and fresh annual emergent or aquatic plants in the lower areas where marsh breakup occurred in the past. Water-level control requires draw-down in the spring and summer to facilitate germination of the annuals and flooding in the fall to permit waterfowl feeding on the annuals produced. When draw-down is not possible because of heavy spring or summer flooding, aquatic plants, such as widgeongrass, are produced in these impoundments.

Analysis of the vegetative transect data for the refuge (Figure 3-17) indicates that the gravity drainage management technique has been relatively successful. However, proper maintenance of the gravity drainage structures and favorable climatic conditions are crucial to the achievement of the desired management objectives.

The controlled and passive estuarine management units are nearer the Gulf of Mexico and contain brackish-to-saline marsh zones as opposed to the lower salinity intermediate-to-fresh marsh zones more common to the forced drainage and gravity drainage units (Table 3-8). The passive estuarine management units can be leveed as in the Price Lake Unit or unleveed as in the Pigeon Bayou-Rollover Bayou section of the refuge. All of the units under controlled estuarine management (Units 4, 5, and 6) are leveed. The major distinction between the passive and controlled estuarine management programs is that under passive management no scheduled effort is

Table 5-1. Habitat Type, Vegetative Cover, and Fish and Wildlife Values Achieved With Water Management Programs Operating on the Rockefeller Refuge

TARGET HABITAT TYPE [1]	WATER MANAGEMENT PROGRAMS					
	PASSIVE ESTUARINE	CONTROLLED ESTUARINE		GRAVITY DRAINAGE	FORCED DRAINAGE	UNCONTROLLED
	Wakefield Weirs at -0.5 ft MSL	Concrete Variable Crest Reversible Flap-Gates	Concrete Radial Lift Gates	36 in and 48 in Flap-Gates Concrete Variable Crest Reversible Flap-Gates	Pumps	Non-existing or Non-operable Structures
EMERGENT PERENNIAL VEGETATION:						
Fresh	Ve-A	Ve-A	Ve-A	Ve-A	Ve-A	Ve-H[3]; Du-P, Mu-P, Nu-F
Intermediate	Ve-A	Ve-M; Du-P, Mu-F, Nu-F, Ge-F	Ve-H; Ge-G, Du-P, Mu-F, Nu-G, De-F	Ve-M; Du-P, Mu-F, Ge-G, Nu-F, De-P	Ve-L; Du-P, Mu-P, Nu-P, De-P	Ve-A
Brackish	Ve-M; Du-P, Mu-F[2], Ge-F, Nu-F	Ve-M; Du-P, Mu-F, Nu-F, De-P, Ge-F	Ve-H; Du-P, Mu-F, Nu-F, De-P, Ge-G	Ve-M; Du-P, Mu-F, Ge-G, Nu-F, De-P,	Ve-A	Ve-H; Du-P, Mu-F, Nu-F, Ge-G
Saline	Ve-H; Du-P, Mu-P, Nu-P, Ge-G	Ve-A	Ve-A	Ve-A	Ve-A	Ve-H; Du-P, Mu-P, Nu-P, Ge-G
EMERGENT ANNUAL VEGETATION:						
Fresh	Ve-A	Ve-A	Ve-A	Ve-A	Ve-A	Ve-A
Intermediate	Ve-A	Ve-M; Du-G, Nu-F, Mu-P	Ve-L; Du-F, Mu-P, Nu-P, Ge-P	Ve-H; Du-E, Mu-P, Ge-P, Nu-F, De-F	Ve-H[4]; Du-E, Mu-P, Nu-F, De-F	Ve-A
Brackish	Ve-L; Du-F, Nu-P, Ge-P	Ve-M; Du-G, Mu-P, Nu-F, De-P, Ge-P	Ve-L; Du-F, Mu-P, Nu-P, De-P, Ge-P	Ve-H; Du-E, Mu-P, Nu-F, De-F, Ge-P	Ve-A	Ve-L; Du-F, Mu-P, Nu-P, Ge-P
Saline	Ve-L; Du-P, Mu-P, Nu-P, Ge-P	Ve-A	Ve-A	Ve-A	Ve-A	Ve-L; Du-F, Mu-P, Nu-P, Ge-P
AQUATIC VEGETATION:						
Fresh	Ve-A	Ve-A	Ve-A	Ve-A	Ve-A	Ve-M[3]; Du-G; Mu-P, Nu-P
Intermediate	Ve-A	Ve-M; Du-G, Mu-P, Nu-F, Ge-P	Ve-L; Du-F, Mu-P, Ge-F, Nu-P, De-P	Ve-L; Du-F, Mu-P, Ge-P, Nu-P, De-P	Ve-M; Du-G, Mu-P, Nu-G, De-F	Ve-A
Brackish	Ve-M; Du-G, Nu-F, Mu-P, Ge-P	Ve-M; Du-G, Mu-P, Nu-F, De-P, Ge-P	Ve-L; Du-F, Mu-P, Nu-P, De-P, Ge-P	Ve-L, Du-F, Mu-P, Ge-P, Nu-P, De-P	Ve-A	Ve-L; Du-F, Mu-P, Nu-P, Ge-P
Saline	Ve-A	Ve-A	Ve-A	Ve-A	Ve-A	Ve-A
FRESH-TO-INTERMEDIATE WATER BODIES	—	Ff-G, Cr-P, Wb-E, Al-E, Ot-G		Ff-P, Cr-P, Ot-P, Al-F, Wb-P	Cr-G, Ff-P, Wb-G, Wb-G, Al-F, Ot-F	Ff-G[3], Cr-F[3], Al-F, Ot-F, Wb-F
ESTUARINE WATER BODIES	Ef-E, Al-F, Sh-E, Ot-G, Wb-E, Sb-G	Ef-E, Sh-E, Ot-G, Al-G, Wb-E, Sb-F		Ef-P, Ot-P, Al-P, Wb-F	—	Ef-G, Sh-G, Al-P, Ot-F, Sb-E, Wb-G

SPECIES SYMBOLS

Vegetation	Ve
Geese	Ge
Dabbling ducks	Du
Shorebirds	Sb
Wading birds	Wb
Muskrats	Mu
Nutria	Nu
Deer	De
Alligators	Al
Shrimp	Sh
Crayfish	Cr
Freshwater Fish	Ff
Estuarine Fish	Ef
Otters	Ot

RATING OF MANAGEMENT TECHNIQUE FOR PRODUCING FLORA AND FAUNA

FLORA (Relative vegetative cover):

High	H
Medium	M
Low	L
Absent	A

FAUNA (Habitat value):

Excellent	E
Good	G
Fair	F
Poor	P

SPECIAL NOTES

[1] Water salinities in these zones are as follows:

Fresh	0-2 ppt
Intermediate	2-5 ppt
Brackish	5-15 ppt
Saline	over 15 ppt

[2] Furbearer populations on Rockefeller are presently at a low point in their cycle but this management technique has been successfully used in other areas, especially with proper burning.

[3] This applies only to Unit 9

[4] All forced drainage units are of intermediate salinities

expended in achieving management objectives. Management consists primarily of constructing weirs and earthen plugs in natural drainage bayous and canals to stabilize the hydrologic regime. In the controlled estuarine management units, various control structures, implanted in the levees, can be manipulated on a seasonal basis to permit multi-use of the units by estuarine organisms and wildlife species.

Analysis of vegetative sample data and trawl sample data indicates that passive management of the Price Lake Unit appears to foster estuarine fisheries usage but has been only marginally successful in improving wildlife habitat. It is possible that the weirs used in Price Lake maintain water levels that are too high to permit revegetation of the open water bodies. In fact, open water bodies are increasing in this unit. Waterfowl foods in the form of both herbaceous annuals and aquatics have been produced in Unit 4 under controlled estuarine management, but successful production of the aquatic widgeongrass appears to be dependent on draw-down every third year to harden the exposed bottoms and thereby reduce turbidities on reflooding. Maintenance of low salinity conditions in Unit 6, another controlled estuarine management unit, has greatly enhanced the value of this area for alligator production and Mottled Duck habitat. The combination of these management strategies is important in that it diversifies wildlife habitat on the Rockefeller Refuge and, therefore, diversifies the wildlife community in general. Specifically, it allows the refuge, in many years, to produce both herbaceous annuals and aquatic vegetation as waterfowl foods. The herbaceous annuals produce seeds that are preferred foods for a particular set of waterfowl species (e.g. Mallards, Pintails, and Green-winged Teal), while the vegetative parts of the aquatics are preferred by other species (e.g., Gadwalls, American Wigeons, and Shovelers). In this way, the refuge is capable of suiting the various preferences of a large number of waterfowl species throughout the wintering season.

The conclusions to be derived from this study are that there are a variety of management programs being implemented on the refuge for the primary purpose of increasing the value or carrying capacity of the refuge for both fisheries and wildlife, especially waterfowl. The programs have evolved over the life of the refuge, with the successful management practices being maintained and the less successful ones being modified where necessary. The major factors controlling management programs are meteorological conditions, man-made alterations of the landscape, and the availability of funds and personnel to implement and maintain the management programs. It must be noted that the management programs, especially the categorizing of the management programs, discussed in the report result from CEI's analysis of information and data provided by the refuge personnel. The refuge has no written, long-term program nor a structured program for the evaluation of management objectives and results. Rather, the management of the Rockefeller Refuge presently rests upon the knowledgeable and dedicated efforts of refuge personnel, many of whom have made the refuge a lifetime career.

On the refuge, personnel are confronted by a variety of problems throughout the year. Tropical storms, saltwater intrusion, coastal subsidence, marsh breakup, oil and gas recovery operations, access canals, shoreline erosion, too little rainfall, and too much rainfall are a constant challenge to the efficient implementation and success of any marsh management program. These are the same kinds of problems that plague much of the remaining wetlands in coastal Louisiana. The Rockefeller Refuge fulfills an important role not only in managing fish and wildlife habitat, but also in acting as an experimental field laboratory to devise new structural solutions or improved strategies that can be utilized by landowners in other coastal areas to overcome these common management problems. The Rockefeller Refuge has the personnel and professional expertise to successfully accommodate this role.

Until 1973, the Chief of the Division of Refuges was required to write a report to be published in the Louisiana Wildlife and Fisheries Commission's Biennial Report documenting the annual programs undertaken on each refuge, the cost and methods for implementing construction projects and the results of management and research operations. These reports provided an opportunity for refuge personnel and the public to evaluate the status of refuge operations and to access future refuge goals and needs. In a governmental austerity move in the early 1970s, these Biennial Reports were discontinued and there is presently no forum for documenting either the present status or future goals of the state wildlife refuges. It appears that, given the complexity of refuge management and the need for comprehensiveness and continuity in long term management programs, it is desirable to reinstitute yearly evaluations of all state refuges and to provide for a comprehensive, yet feasible, long term management program for each refuge.

REFERENCES

Baldwin, W. P.
1967 Impoundments for waterfowl on South Atlantic and Gulf coastal marshes. Pages 127-133 In J.D. Newsom (ed.) Proceedings of the marsh and estuary management symposium, Louisiana State University, Division of Continuing Education, Baton Rouge. 250 pp.

Bellrose, F. C.
1976 Ducks, geese, and swans of North America. Stackpole Books, Harrisburg, Pennsylvania. 544 pp.

Chabreck, R. H.
1959 Vegetation survey of Rockefeller Refuge impoundments. Annual progress report, Louisiana Wild Life and Fisheries Commission, New Orleans. 19 pp (mimeo).

____ 1960a Coastal marsh impoundments for ducks in Louisiana. Proceedings of the Annual Conference of Southeastern Association of Game and Fish Commissioners. 14:24-29.

____ 1960b Vegetation survey of Rockefeller Refuge impoundments. Annual progress report, Louisiana Wild Life and Fisheries Commission, New Orleans. 11 pp (mimeo).

____ 1961 Vegetation survey of Rockefeller Refuge impoundments. Annual progress report, Louisiana Wild Life and Fisheries Commission, New Orleans. 11 pp (mimeo).

____ 1962 Vegetation survey of Rockefeller Refuge impoundments. Annual progress report, Louisiana Wild Life and Fisheries Commission, New Orleans. 10 pp (mimeo).

____ 1963 Vegetation survey of Rockefeller Refuge impoundments. Annual progress report, Louisiana Wild Life and Fisheries Commission, New Orleans. 11 pp (mimeo).

____ 1972 Vegetation, water and soil characteristics of the Louisiana coastal region. Louisiana State University Agricultural Experiment Station Bulletin 664. Baton Rouge. 72 pp.

____ 1979 Winter habitat of dabbling ducks - physical, chemical, and biological aspects. Pages 133-142 In T. A. Bookhout (ed.), Waterfowl and Wetlands - an integrated review. Proceedings of a symposium, Madison, Wisconsin, North Central Section, The Wildlife Society. 147 pp.

Chabreck, R. H. and T. Joanen
1964 Vegetation survey of Rockefeller Refuge impoundments. Annual progress report, Louisiana Wild Life and Fisheries Commission, New Orleans. 10 pp (mimeo).

——— 1965 Vegetation survey of Rockefeller Refuge impoundments. Annual progress report, Louisiana Wild Life and Fisheries Commission, New Orleans. 10 pp (mimeo).

——— 1966 Vegetation survey of Rockefeller Refuge impoundments. Annual progress report, Louisiana Wild Life and Fisheries Commission, New Orleans. 11 pp (mimeo).

Chabreck, R. H., and G. Linscombe
1978 Vegetative type map of the Louisiana coastal marshes. Louisiana Department of Wildlife and Fisheries, Baton Rouge.

Coastal Environments, Inc.
1972 Unpublished data. Baton Rouge.

Davidson, Bruce
1982 Trawl data for 1981 from the Rockefeller State Wildlife Refuge and Game Preserve. School of Forestry and Wildlife Management, Louisiana State University, Baton Rouge. Unpublished research data.

Deed of Donation by the Rockefeller Foundation to State of Louisiana, 30 September 1920. 16 pp.

Ensminger, A. B.
1982 Personal communication. Chief, Refuge Division, Louisiana Department of Wildlife and Fisheries, New Orleans.

Gould and Morgan
1962 Coastal Louisiana swamps and marshlands. Field Trip No. 9. Pages 287-341 In E. H. Rainwater and R. P. Zingula (ed.), Geology of the Gulf Coast and Central Texas and guidebook of excursions, Houston.

Joanen, T.
1969 Rockefeller Refuge: Haven for Wildlife. Wildlife Education Bulletin No. 105. Louisiana Wild Life and Fisheries Commission, Baton Rouge. 10 pp.

Joanen, T. and L. L. Glasgow
1965 Factors influencing the establishment of wigeongrass stands in Louisiana. Proceedings of the Annual Conference of Southeastern Association of Game and Fish Commissioners, 19:78-92.

Joanen, T., L. McNease, and H. Dupuie
1967 Vegetation survey of Rockefeller Refuge impoundments. Annual progress report. Louisiana Wild Life and Fisheries Commission, New Orleans. 12 pp. (mimeo).

Joanen, T., L. McNease, and H. Dupuie
1968 Vegetation survey of Rockefeller Refuge impoundments. Annual progress report. Louisiana Wild Life and Fisheries Commission, New Orleans. 11 pp. (mimeo).

——— 1969 Vegetation survey of Rockefeller Refuge impoundments. Annual progress report. Louisiana Wild Life and Fisheries Commission, New Orleans. 13 pp. (mimeo).

——— 1970 Vegetation survey of Rockefeller Refuge impoundments. Annual progress report. Louisiana Wild Life and Fisheries Commission, New Orleans. 12 pp.

——— 1971 Vegetation survey of Rockefeller Refuge impoundments. Annual progress report. Louisiana Wild Life and Fisheries Commission, New Orleans. 12 pp.

——— 1972 Vegetation survey of Rockefeller Refuge impoundments. Annual progress report. Louisiana Wild Life and Fisheries Commission, New Orleans. 12 pp. (mimeo).

——— 1973 Vegetation survey of Rockefeller Refuge impoundments. Annual progress report. Louisiana Wild Life and Fisheries Commission, New Orleans. 12 pp.

——— 1974 Vegetation survey of Rockefeller Refuge impoundments. Annual progress report. Louisiana Wild Life and Fisheries Commission, New Orleans. 12 pp.

Louisiana Wildlife and Fisheries Commission
1956 Report of the Division of Refuges, R. K. Yancey, Chief. 6th Biennial Report, 1954-55. Louisiana Wildlife and Fisheries Commission, New Orleans. pp. 115-121.

——— 1962 Report of the Division of Refuges, R. K. Yancey, Chief. 9th Biennial Report, 1960-61. Louisiana Wildlife and Fisheries Commission, New Orleans. pp. 173-177.

——— 1964 Report of the Division of Refuges, A. B. Ensminger, Chief. 10th Biennial Report 1962-63. Louisiana Wildlife and Fisheries Commission, New Orleans. pp. 175-181.

——— 1966 Report of the Division of Refuges, A. B. Ensminger, Chief. 11th Biennial Report, 1964-65, pp. 238-244. Louisiana Wildlife and Fisheries Commission, New Orleans.

Louisiana Wildlife and Fisheries Commission
1968 Report of the Division of Refuges, A. B. Ensminger, Chief. 12th Biennial Report, 1966-67. Louisiana Wildlife and Fisheries Commission, New Orleans. pp. 190-197.

Lynch, J. J.
1942 Louisiana's State Wildlife Refuges prepared for Louisiana Department of Conservation. Unpublished - from author's files, Lafayette, Louisiana. 24 pp.

____ 1952 Map of Rockefeller Refuge showing approximate extent of salt intrusion and die-off of fresh marsh, period from 1947 to 1952. U.S. Fish and Wildlife Service, Lafayette, Louisiana, unpublished.

____ 1975 Winter ecology of Snow Geese on the Gulf Coast, 1925 to 1975. Prepared for presentation at Snow Goose Symposium, 37th Midwest Fish and Wildlife Conference, Toronto, Ontario, Canada. December 8, 1975. 42 pp.

____ 1982 Personal communication. Retired biologist formerly with U.S. Fish and Wildlife Service, Lafayette, Louisiana.

Lynch, J. J., T. O'Neil, and D. W. Lay
1947 Management significance of damage by geese and muskrats to Gulf Coast marshes. Journal of Wildlife Management, 11(1):50-76.

McIlhenny, E. A.
1930 The creating of the Wild Life Refuges in Louisiana. In Louisiana Department of Conservation, Ninth Biennial Report of the Department of Conservation of the State of Louisiana. pp. 132-139.

____ 1932 The Blue Goose in its winter home. Auk, 49(3):279-306.

McNease, T.
1982 Personal communication. Biologist with Louisiana Wildlife and Fisheries Commission, Rockefeller State Wildlife Refuge and Game Preserve, Grand Cheniere, Louisiana.

Muller, R.
1970 Seasonal precipitation surplus and annual precipitation deficit maps of South Louisiana, 1945-1968. Hydrologic and geologic studies of coastal Louisiana. Report No. 6, Coastal Resources Unit, Center for Wetland Resources, Louisiana State University, Baton Rouge.

National Aeronautics and Space Administration
1978 Color infrared aerial photographs, (18" x 18"), October 1978, Roll 2691, frames 0090, 0088, 0086, 0084, 0082, 0018, 0016, 0014, Sioux Falls, South Dakota.

Nichols, L. G.
1959a Rockefeller Refuge Levee Study. Technical Bulletin, Louisiana Wildlife and Fisheries Commission, Refuge Division, New Orleans. 17 pp.

1959b Geology of Rockefeller Wild Life Refuge and Game Preserve, Cameron and Vermilion Parishes, Louisiana. Technical Bulletin, Louisiana Wild Life and Fisheries Commission, Refuge Division, New Orleans, Louisiana. 37 pp.

O'Neil, T.
1949 The Muskrat in Louisiana. Louisiana Wild Life and Fisheries Commission, New Orleans. 159 pp.

Palmisano, A. W.
1972 The distribution and abundance of muskrats (Ondatra zibethicus) in relation to vegetative types in Louisiana coastal marshes. 26th Annual Conference, Southeastern Association of Game and Fish Commissioners. 26:160-177.

Perry, W. Guthrie
1982 Personal communication. Biologist with Louisiana Department of Wildlife and Fisheries, Rockefeller State Wildlife Refuge and Game Preserve, Grand Cheniere, Louisiana.

Russell, R. J. and H. V. Howe
1935 Cheniers of southwestern Louisiana. The Geographic Review, 25(3):449-461.

St. Amant, L. S.
1959 Louisiana wildlife inventory and management plan. Pittman-Robertson Section - Fish and Game Division, Louisiana Wild Life and Fisheries Commission: 100-101.

Tobin Research, Inc.
1930 Black and white aerial photo mosaics at 1:24,000. 3S-57E-2815H, 3S-58E-2816H, 3S-59E-2817H, 3S-60E-2818H, 4S-58E-2819H, 4S-59E-2820H, 4S-60E-2821H. San Antonio, Texas.

______ 1955/1956 Black and white aerial photo mosaics at 1:24,000. 3S-57E, 3S-58E, 3S-59E, 3S-60E, 4S-58E, 4S-59E, 4S-60E. San Antonio, Texas.

Trefethen, J. B.
1964 Wildlife management and conservation. D. C. Heath and Company, Boston. 120 pp.

U.S. Army Corps of Engineers, New Orleans District
1970-1978 Stages and Discharges of the Mississippi River and Tributaries, New Orleans.

U.S. Geological Survey
1974/1979 Topographic maps at 1:24,000. Hog Bayou, Cow Island, Deep Lake, Floating Turf Bayou, Big Constance Lake, Rollover Bayou. Denver.

U.S. Geological Survey
1970- Water Quality Data for Louisiana, Vol. 3, Baton Rouge.
1978

Valentine, J. M.
1976 Plant Succession after sawgrass mortality in southwestern Louisiana. Proceedings, 30th Annual Conference, Southeast Association of Game and Fish Commissioners. pp. 634-640.

ROCKEFELLER STATE WILDLIFE REFUGE AND GAME PRESERVE

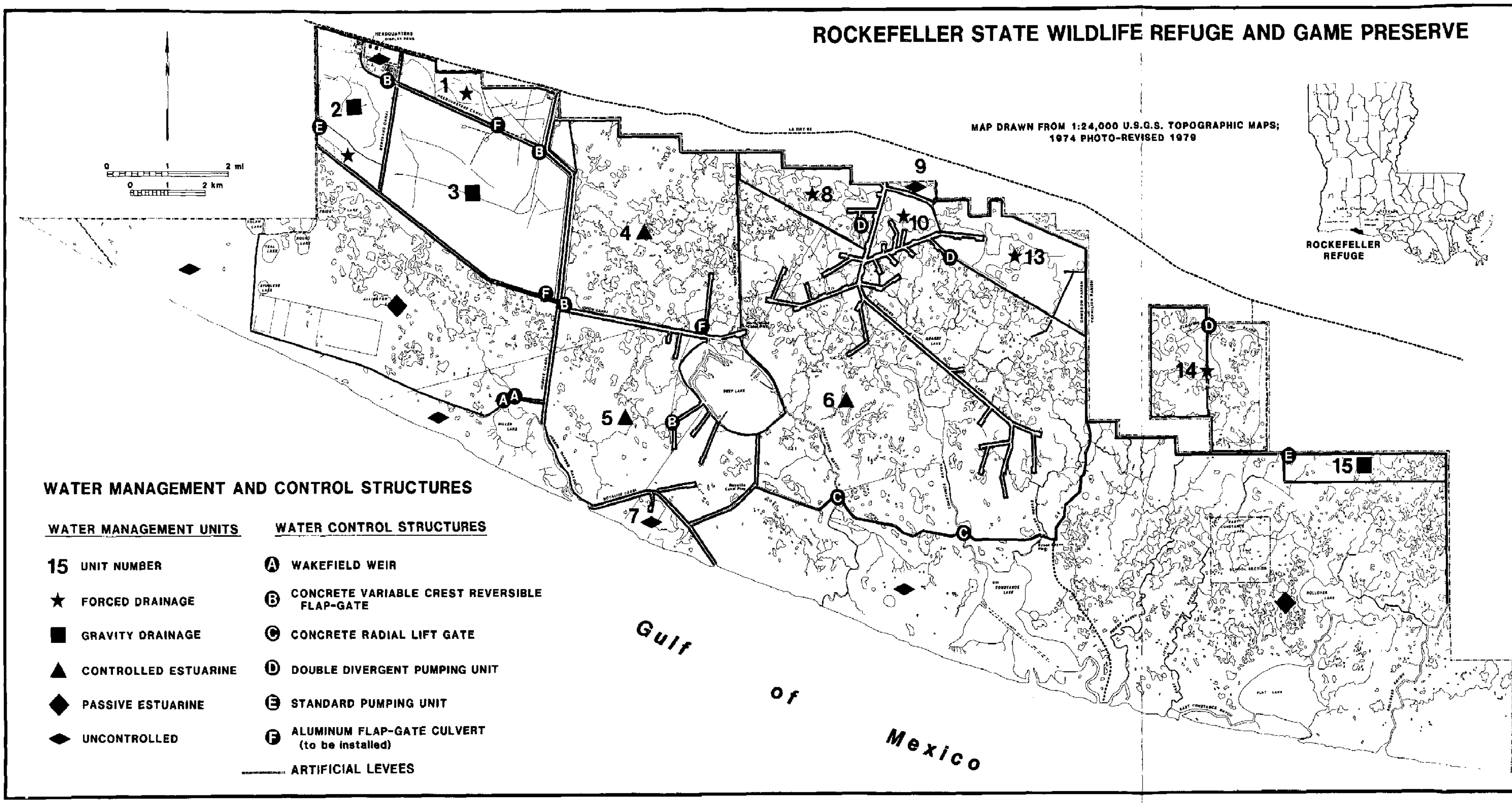


PLATE 1

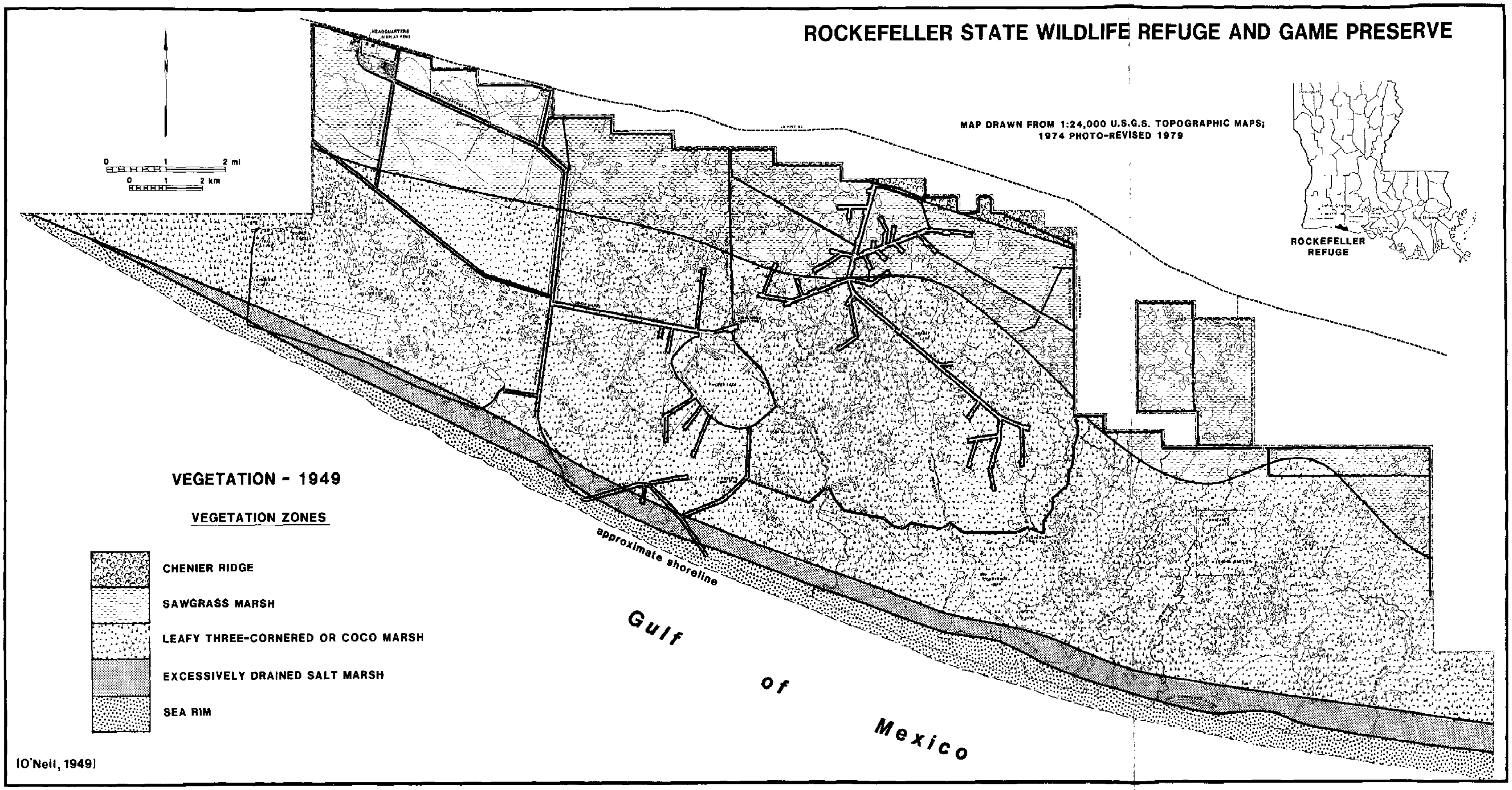

ROCKEFELLER STATE WILDLIFE REFUGE AND GAME PRESERVE
MAP DRAWN FROM 1:24,000 U.S.G.S. TOPOGRAPHIC MAPS;
1974 PHOTO-REVISED 1979
ROCKEFELLER REFUGE
0 1 2 mi
0 1 2 km
VEGETATION - 1949
VEGETATION ZONES
CHENIER RIDGE
SAWGRASS MARSH
LEAFY THREE-CORNERED OR COCO MARSH
EXCESSIVELY DRAINED SALT MARSH
SEA RIM
approximate shoreline
Gulf of Mexico
(O'Neil, 1949)

PLATE 2

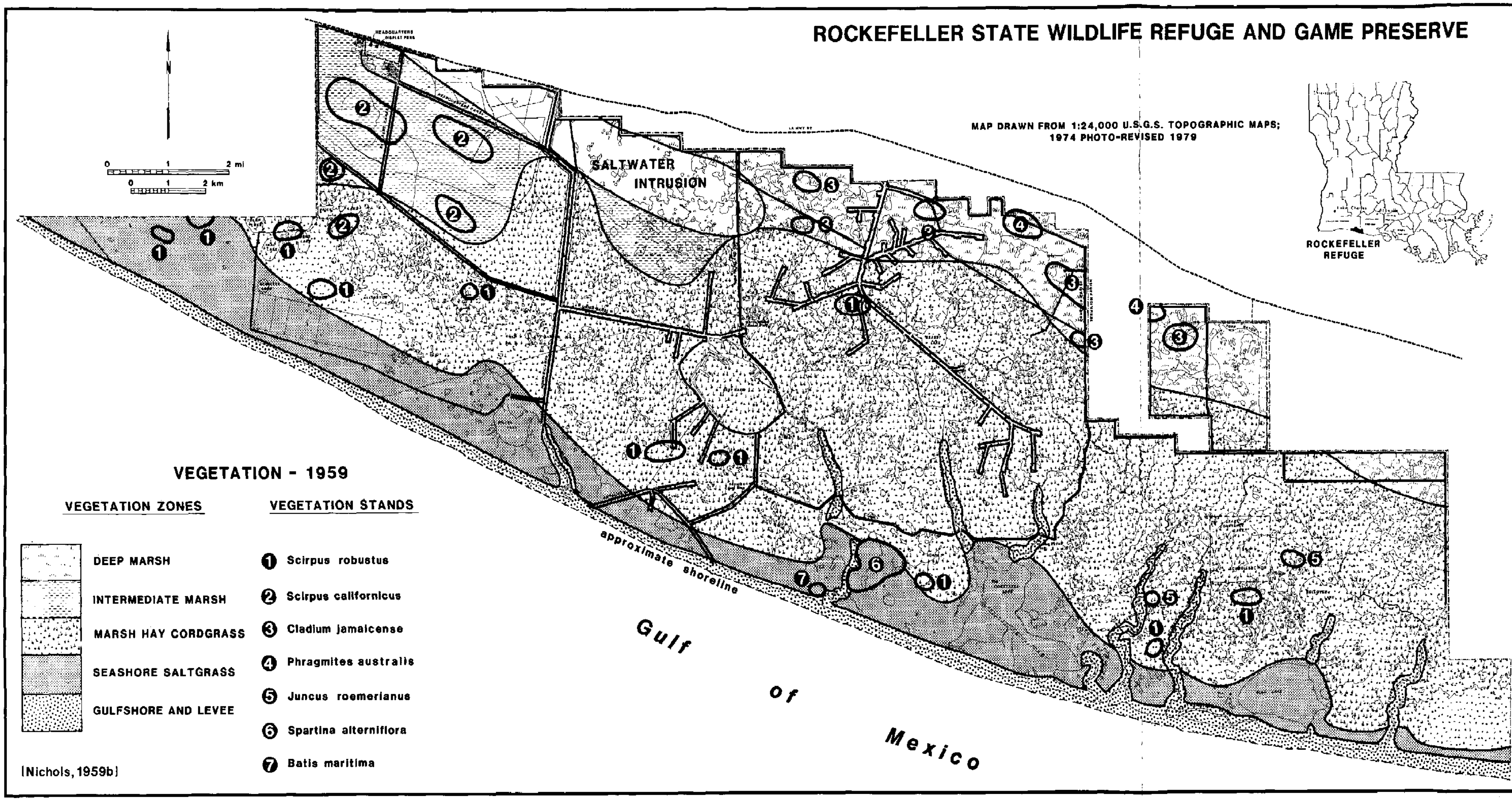

ROCKEFELLER STATE WILDLIFE REFUGE AND GAME PRESERVE
MAP DRAWN FROM 1:24,000 U.S.G.S. TOPOGRAPHIC MAPS;
1974 PHOTO-REVISED 1979
ROCKEFELLER REFUGE
0 1 2 mi
0 1 2 km
SALTWATER INTRUSION
approximate shoreline
Gulf of Mexico
VEGETATION - 1959
VEGETATION ZONES
DEEP MARSH
INTERMEDIATE MARSH
MARSH HAY CORDGRASS
SEASHORE SALTGRASS
GULFSHORE AND LEVEE
VEGETATION STANDS
1 Scirpus robustus
2 Scirpus californicus
3 Cladium jamaicense
4 Phragmites australis
5 Juncus roemerianus
6 Spartina alterniflora
7 Batis maritima
[Nichols, 1959b]

PLATE 3

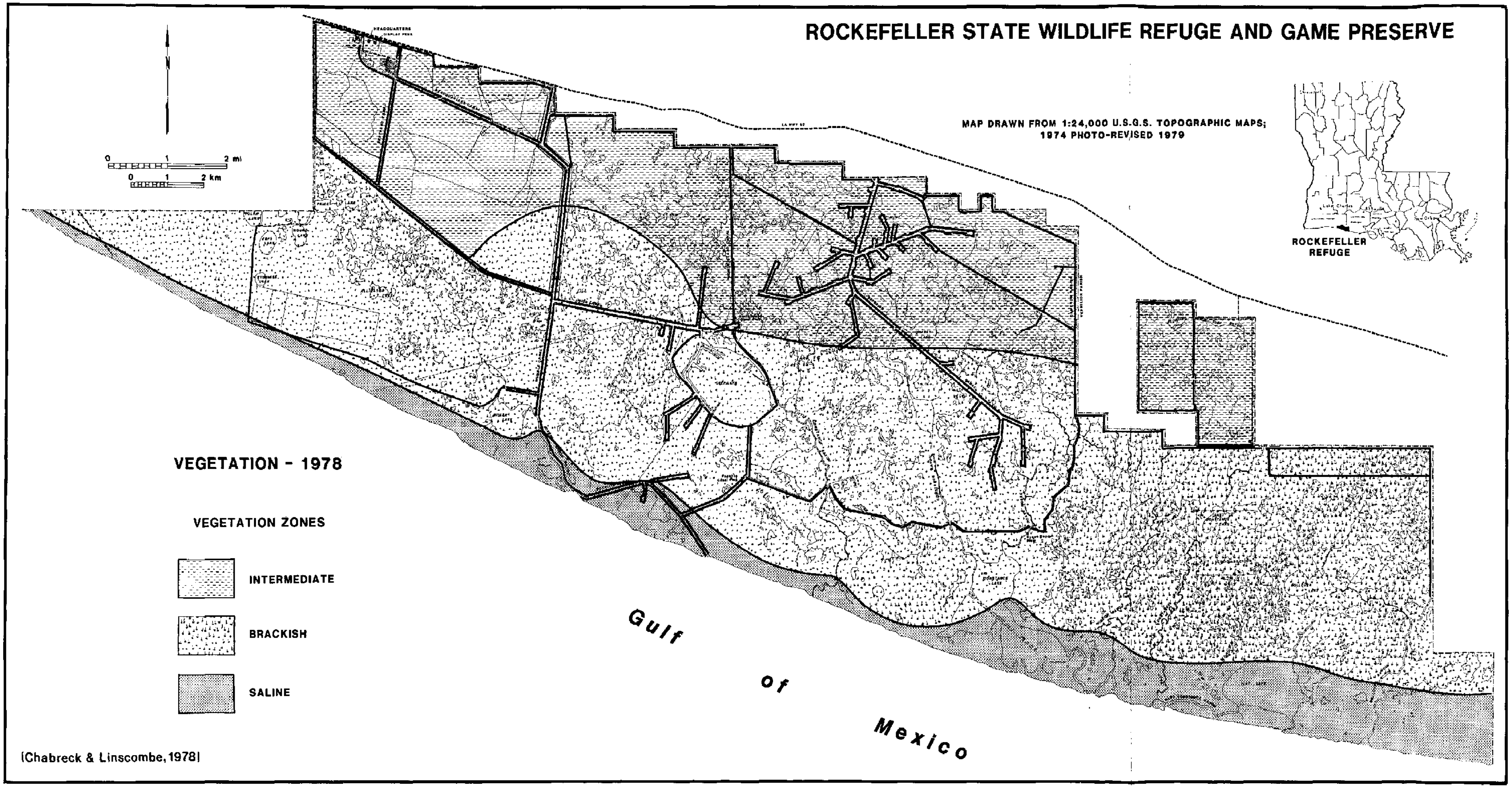

ROCKEFELLER STATE WILDLIFE REFUGE AND GAME PRESERVE
MAP DRAWN FROM 1:24,000 U.S.G.S. TOPOGRAPHIC MAPS;
1974 PHOTO-REVISED 1979
ROCKEFELLER
REFUGE
HEADQUARTERS
0 1 2 mi
0 1 2 km
VEGETATION - 1978
VEGETATION ZONES
INTERMEDIATE
BRACKISH
SALINE
Gulf of Mexico
(Chabreck & Linscombe, 1978)

PLATE 4

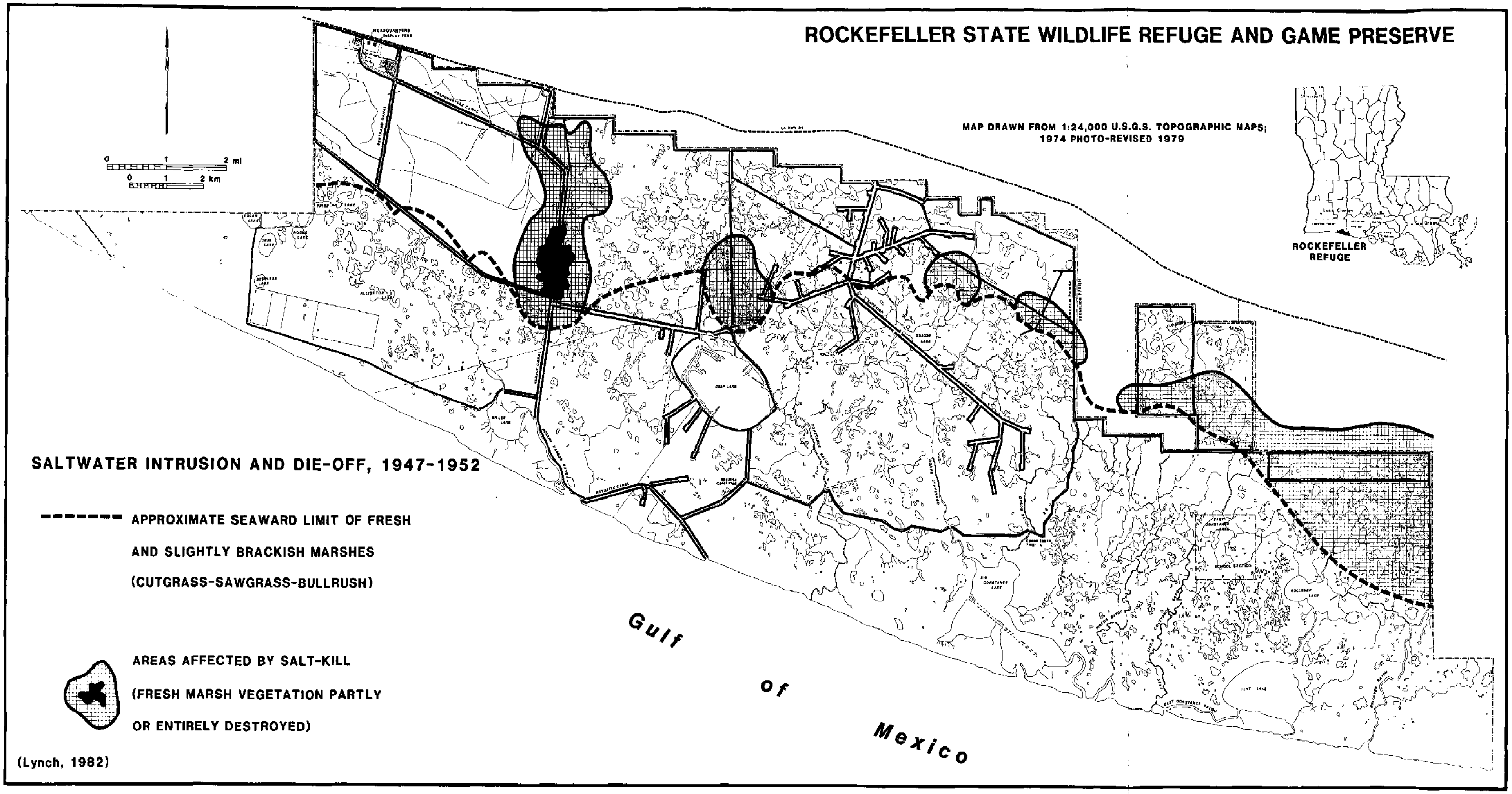

ROCKEFELLER STATE WILDLIFE REFUGE AND GAME PRESERVE
MAP DRAWN FROM 1:24,000 U.S.G.S. TOPOGRAPHIC MAPS; 1974 PHOTO-REVISED 1979
ROCKEFELLER REFUGE
0 1 2 mi
0 1 2 km
SALTWATER INTRUSION AND DIE-OFF, 1947-1952
APPROXIMATE SEAWARD LIMIT OF FRESH AND SLIGHTLY BRACKISH MARSHES (CUTGRASS-SAWGRASS-BULLRUSH)
AREAS AFFECTED BY SALT-KILL (FRESH MARSH VEGETATION PARTLY OR ENTIRELY DESTROYED)
Gulf of Mexico
(Lynch, 1982)

PLATE 5

MILLER LAKE-A

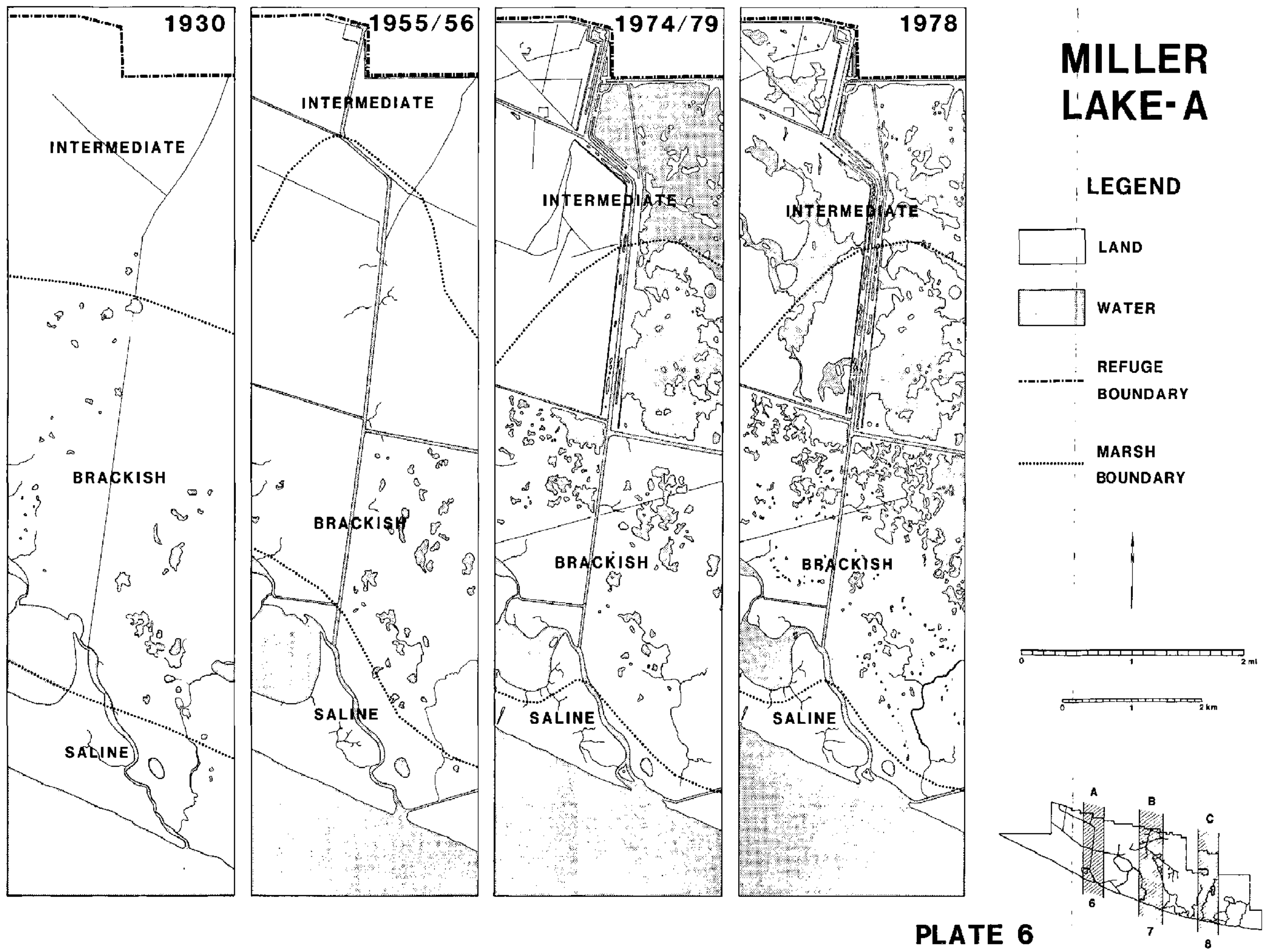
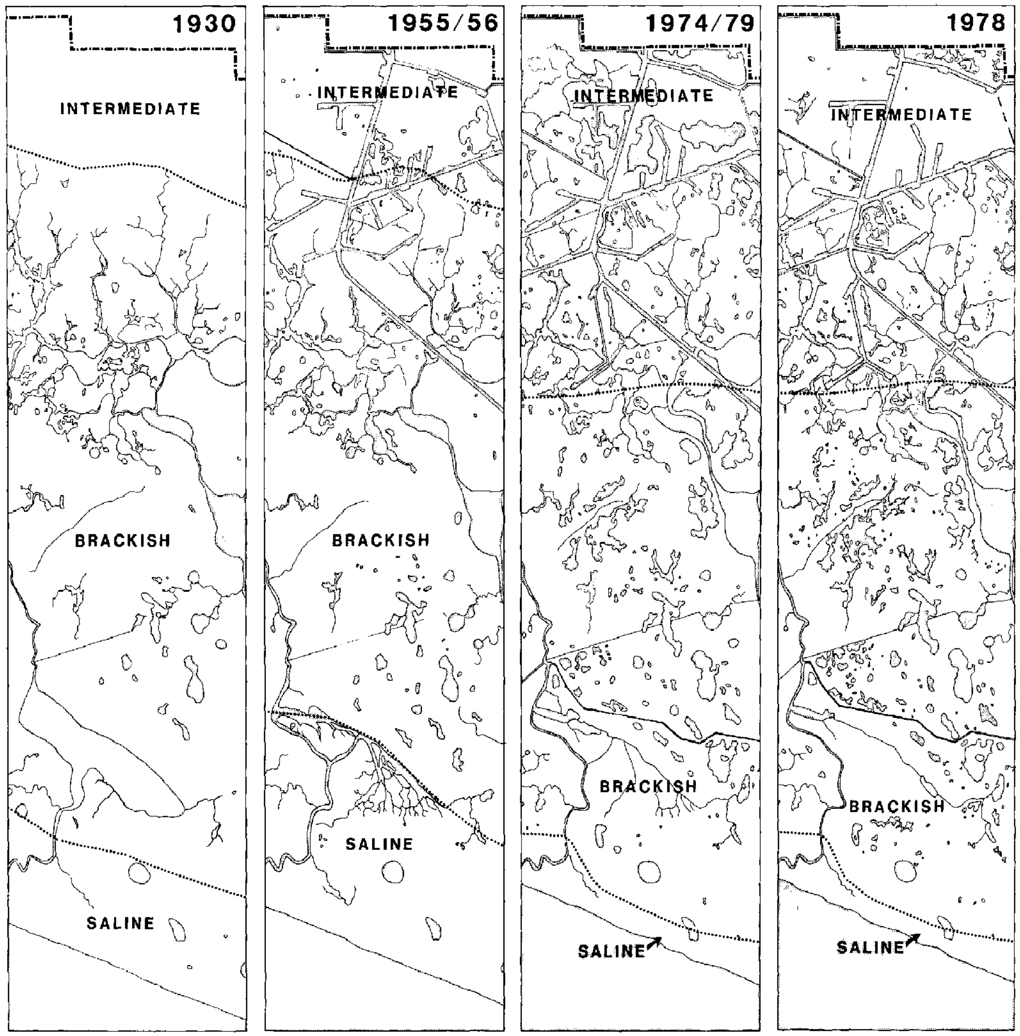


PLATE 6

GRASSY LAKE-B



LEGEND

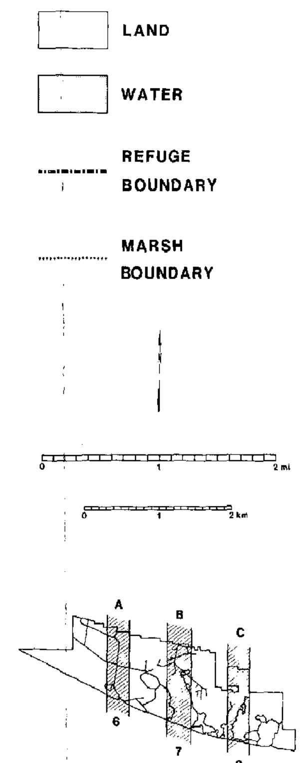


PLATE 7

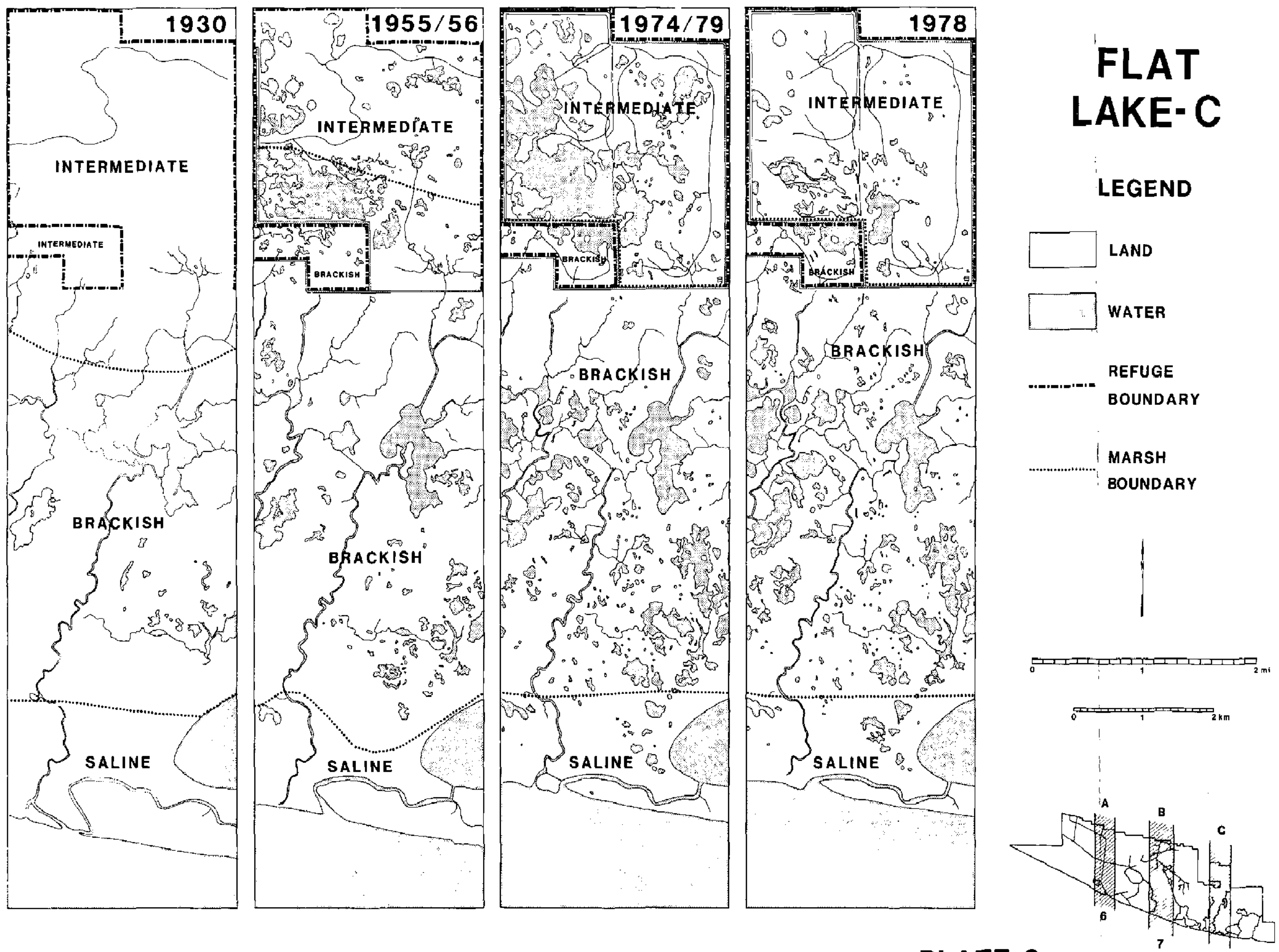

1930
INTERMEDIATE
INTERMEDIATE
BRACKISH
SALINE
1955/56
INTERMEDIATE
BRACKISH
BRACKISH
SALINE
1974/79
INTERMEDIATE
BRACKISH
BRACKISH
SALINE
1978
INTERMEDIATE
BRACKISH
BRACKISH
SALINE
FLAT
LAKE-C
LEGEND
LAND
WATER
REFUGE
BOUNDARY
MARSH
BOUNDARY
0
1
2 mi
0
1
2 km
A
B
C
6
7
8

PLATE 8