CHAPTER 107

DETERIORATION AND RESTORATION OF COASTAL WETLANDS

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ABSTRACT

Coastal Louisiana wetlands are a product of Mississippi River delta building that has occurred over a period of 5,000 years The building process was a gradual one, for riverine and marine processes were very nearly balanced In modern times man's use of the area (flood control, navigation improvement, exploitation of petroleum and other minerals, road building, etc) has seriously altered the natural balance As a result, overbank flooding has been virtually eliminated and river flow is confined to channels discharging into the outer shelf area Most transported sediment is now deposited in the deep Gulf of Mexico or along the continental shelf Saltwater encroachment in the deltaic estuaries has been detrimental to fauna and flora Even though considerable sediment deposition has resulted from the historic Atchafalaya River diversion and growth of subdeltas, comparative map studies indicate a net land loss rate of 16 5 $miles^2$/year during the last 25 to 30 years Land loss is only one symptom of general environmental deterioration

A dynamic management plan is proposed for better utilization of combined freshwater discharge - dissolved solid and transported sediment input from the Mississippi River Controlled flow into estuaries will reduce salinity encroachment and supply badly needed nutrients Large areas of new marshland and estuarine habitat can be built by controlled subdelta diversion Studies of natural subdeltas indicate that these systems are amenable to environmental management, salinities and sediment deposition may be manipulated to enhance desired conditions

INTRODUCTION

Southern Louisiana is a 300-mile coastal lowland consisting of large tracts of marshes and swamps and innumerable lakes and bays This extensive near-sea-level area, estimated at 4,000,000 acres (O'Neil, 1949), makes up the deltaic plain and marginal components of the Mississippi River delta system and is the result of deposition of river sediment during the past 5,000 years (Fig 1) Like all deltas, that of the Mississippi is a zone of interactions between fluvial and marine processes and constitutes one of the most dynamic situations in nature The interaction of these processes through time results in a dynamically changing complex of environments within delta regions Deposition of sediments vies with subsidence and erosion in a never-ending exchange of land and

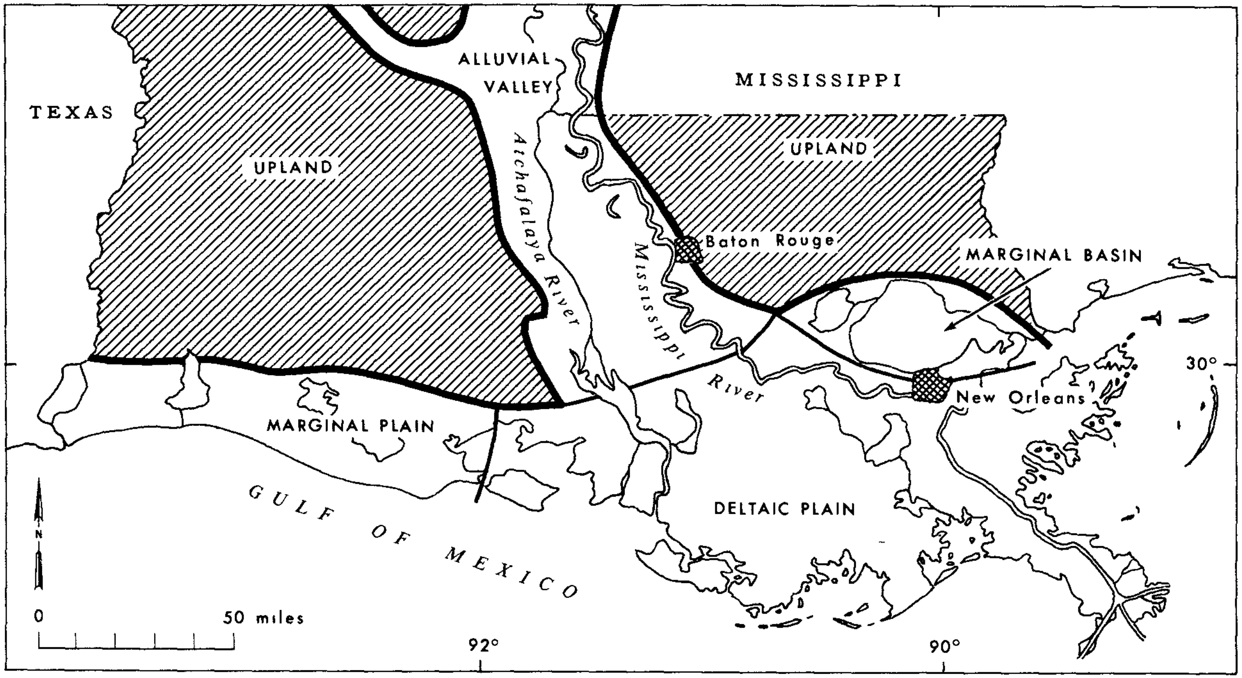

Fig 1 Major components of the Mississippi River delta system Modern components of the delta system are bounded by geologically older Pleistocene terracelands (uplands) Marginal components lie updrift (marginal basin) and downdrift (marginal plain) of the area directly influenced by river distributary deposition (deltaic plain)

water areas The balance between rates of deposition and the combined effects of subsidence and erosion by the sea causes shorelines of deltas alternately to advance seaward and to retreat Seaward growth occurs at the mouths of active streams, whereas erosion results near the mouths of inactive streams which no longer transport sufficient sediment to sustain their seaward advance This is the reason that delta building is so often depicted as a contest between the river and the sea If the river deposits sediment faster than the sea is able to remove it, new land is added to the shore, and the delta is said to prograde As the delta is extended, it gradually builds upward or aggrades by processes associated with lateral shifting of channels, by sediment deposition during overbank flooding, and by accumulation of plant and animal remains

DETERIORATION OF THE DELTAIC COAST

Under Natural Conditions

Deterioration of the delta occurs if all or part of it is deprived of the necessary supply of river-borne sediment for its continued outward growth This deprivation results in the reworking and/or removal of the seaward edge by wave attack, and the combined effects of compaction, consolidation, and subsidence lower the surface below sea level

Under natural conditions progradation along any given segment of the deltaic shoreline is cyclic During Recent geologic times southern Louisiana has witnessed development of numerous lobate extensions of the delta in areas of active discharge and sedimentation After building one delta lobe, the Mississippi channel usually has shifted as a result of upstream diversion, and a new lobe has been built Many repetitions of this process have produced a deltaic plain that is an aggregate of abandoned or inactive delta lobes, each of which has undergone a degree of deterioration dependant on its relative age

Before the Mississippi occupied its present course, the river emptied its water and sediment discharge into shallow waters of the inner continental shelf, building lobes rapidly and efficiently Under these circumstances the rate of new land building was always higher than that of land loss occurring concurrently in abandoned delta lobes

From the preceding discussion it might be concluded that when viewed through geologic time a delta system is always in delicate balance--that is, on one side of the fulcrum there is an input of discharge and transported sediment and on the other side there are such factors as coastal erosion and subsidence, which cause shoreline retreat The very existence of south Louisiana bears witness to the fact that there has been net progradation over the past 5,000 years

Man's Effect on the System

Man's intervention in coastal Louisiana has seriously upset the natural balance in the delta system In modern years it has been necessary to alter natural processes in order to prevent flooding and to improve navigation As a result, virtually all overbank flow has been eliminated Furthermore, the modern birdfoot delta is nearing the edge of the continental shelf, and most transported sediments are now disappearing into the abyss The river's attempt to divert to a new course that would allow development of a shallow-water delta lobe was aborted The well-known attempted capture of the Mississippi by the Atchafalaya River has now been arrested by control structures, and the Atchafalaya is restricted to only 30 percent of the total Mississippi flow (U S Army Corps of Engineers, 1951, Fisk, 1952) As a result of these control measures the amount of land building has been sharply reduced, but the rate of land loss in abandoned portions of the deltaic plain continues

These restrictions in themselves would have serious repercussions, but other developments have caused further imbalance in the delta system Diking and drainage of marshland for agricultural purposes has been widespread and in many instances unsuccessful After drainage organic marsh soils oxidize and shrink, reducing the drained land surface to below-sea-level elevations Inundation by hurricane-generated storm surge has often resulted in abandonment, numerous rectangular lakes being left as mute testimony to land reclamation failure (Harrison, 1961) Equally serious has been the dredging of innumerable canals to provide access to oil well drilling sites and pipeline right-of-ways These invariably alter circulation patterns in the estuaries, resulting in a general saltwater encroachment of the brackish swamps and marshes

<u>Map Studies of Land Loss</u>

A fundamental question posed for this investigation, therefore, was, "Is the delta, and for that matter the coastal area on the whole, building or retreating?" The question has been approached by a number of workers (Morgan and Larimore, 1957, Treadwell, 1955, Kwon, 1969, Saucier, 1963, Russell, 1936, Peyronnin, 1962, Welder, 1959), who cited specific instances of shoreline advance or retreat However, it has long been a common misconception that erosion occurring along some parts of the Louisiana coast is more than offset by the building of new land in other areas We have attempted to reevaluate this problem by quantitative map studies, we used the ratio of land to water in a given sample area as an index of net loss or gain of land

Fortunately, systematic planimetric mapping of coastal Louisiana was initiated in the 1890's by the U S Geological Survey In the 1930's this area was remapped, and use was made of controlled aerial photomosaics Mapping and remapping have continued since the 1940's, so that at present most of the 15-minute quadrangle areas have been covered at least twice An example of changes that occurred in one small area between 1935 and 1953 is shown in Figure 2 This careful periodic remapping has made it possible to determine the ratio of land to water for a particular area and mapping interval, these values in turn can easily be converted into land loss or gain in acres per year

The map shown in Figure 3 was constructed by contouring the land loss or gain rate obtained for each 7 1/2-minute quadrangle From the map several things are immediately apparent As indicated by the patterns, most of the deltaic plain is in a serious condition of deterioration During the last 30 to 40 years land gain has been significant in only a few areas (notably in the lacustrine deltas of the Atchafalaya Basin) Areas of maximum loss generally occur inland from the Gulf shore, where brackish

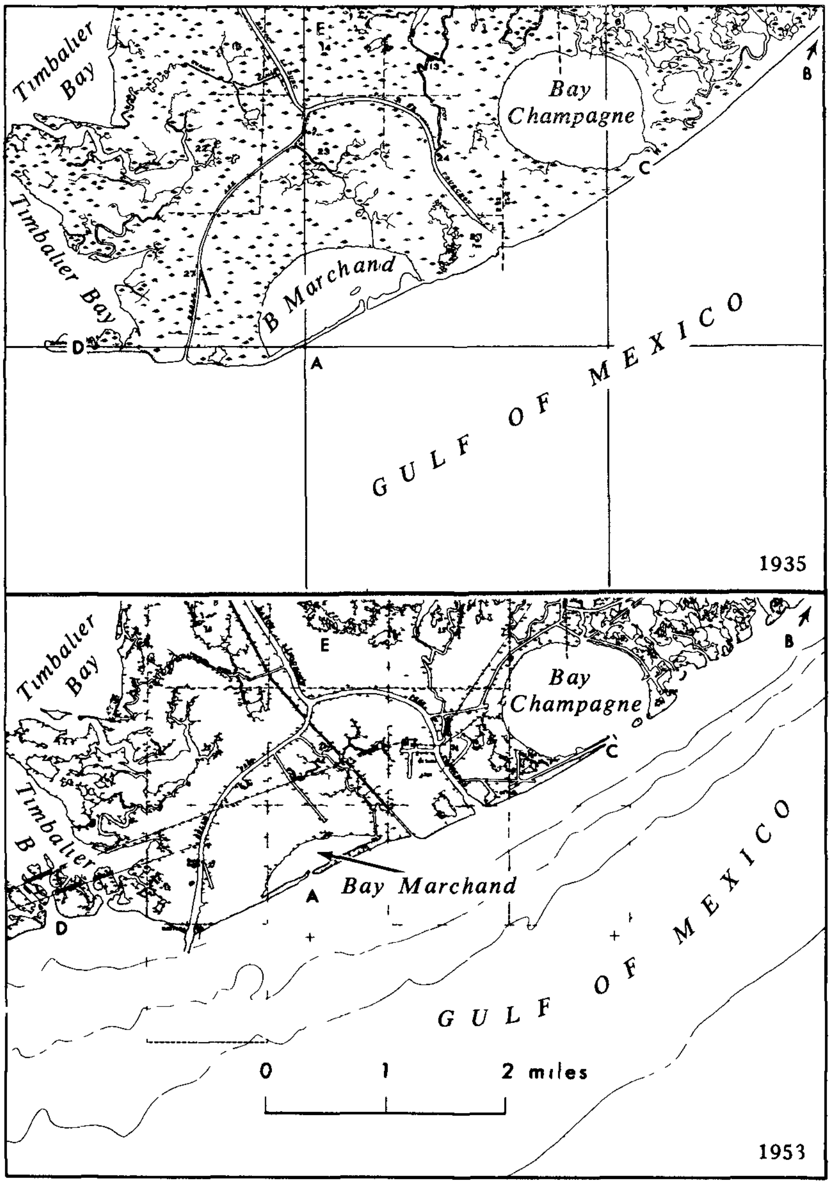

Fig 2 Land loss and shoreline change in the area covered by the Belle Pass quadrangle, south central Louisiana, 1935-1953 Several types of changes have occurred A, B, and C, Gulf shoreline retreat, D, washover fan development downdrift of retreating shoreline, E, marsh opening

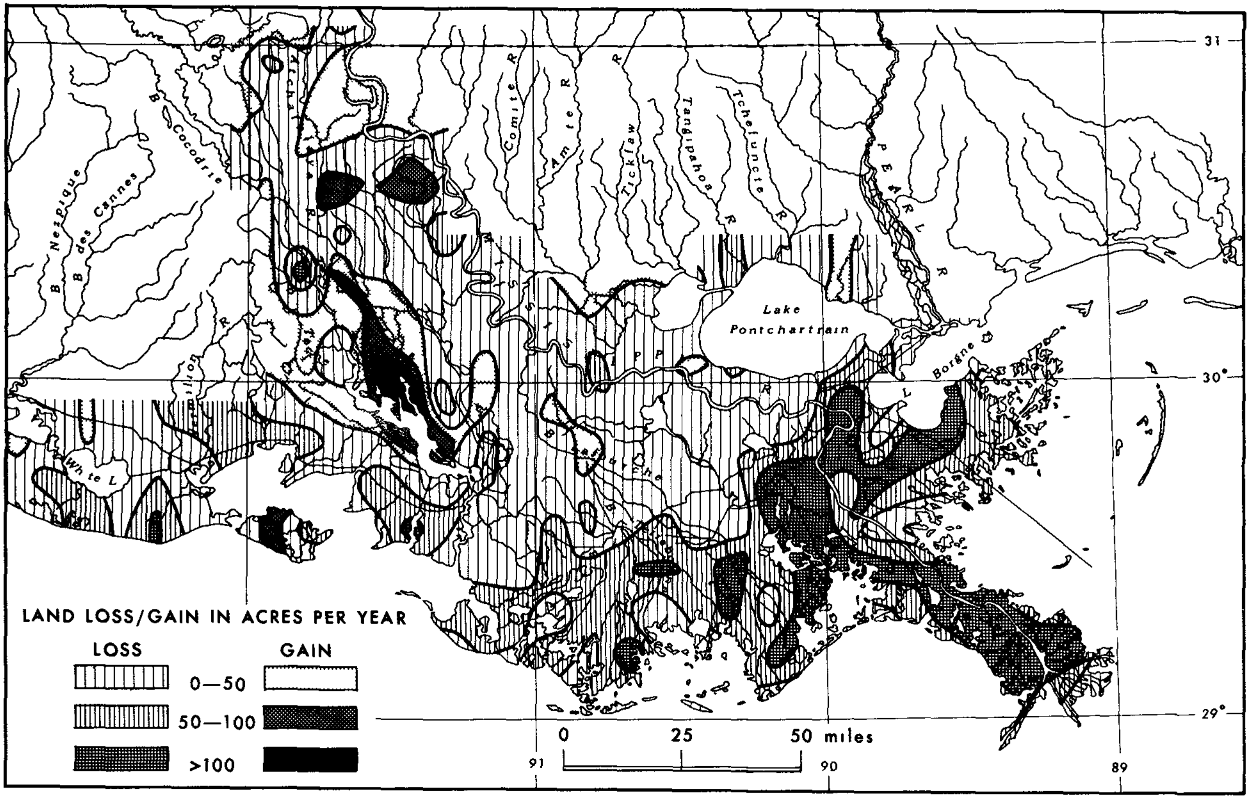

Fig 3 Rates of land loss and land gain in the Louisiana wetlands area Rates are calculated in acres per year per 7 1/2-minute quadrangle unit area An average 7 1/2-minute quadrangle covers 41,267 acres (After Gagliano and van Beek, 1970)

and fresh marshes are being subjected to saltwater intrusion (Chabreck, 1970, Palmisano, 1970) Subsidence is also undoubtedly a factor, as radiocarbon datings of buried marsh peats indicate that these are also areas of high subsidence rates (Coleman and Smith, 1964, Frazier and Osanik, 1969)

The net land loss figures are most impressive For the coastal Louisiana wetlands the land loss amounts to approximately 16 1/2 square miles per year (Gagliano and van Beek, 1970) This is an average for the last 25 to 30 years

The rates of change of land-to-water ratios established for each 7 1/2-minute quadrangle map can be analyzed in a number of ways One technique involves projection of the rates to establish land-water ratios for specific years within and beyond the period of map coverage Although such projections are based on the assumption that rates of change remain constant, the approach has some validity as a tool for prediction The map presented in Figure 4 depicts successive positions of the 50 percent land-water isopleth in the Mississippi deltaic plain for the years 1930, 1970, and 2000 The lines were constructed by determining land-water ratios for each 7 1/2-minute quadrangle for each year indicated Values were plotted at quadrangle center points, and contours were drawn on the basis of the points The 50 percent land-water line was selected as an index for analyzing the rate of land deterioration along the highly indented and irregular deltaic coast

The map indicates a progressive landward march of this line across the area The predicted position of the line in the year 2000 aids in identifying the most critical areas of deterioration Major estuaries are clearly undergoing rapid and drastic changes Within the estuaries the landward retreat of the line implies increases in both salinity and volume of the tidal prism

PROSPECTS FOR COASTAL RESTORATION

Areas of Active Sediment Deposition

The earlier discussion has attempted to define the symptoms of a disease, what are the prospects of a cure?

The key is obviously to be found in those areas where land gain is occurring For example, the Atchafalaya River--the Mississippi's only major distributary--is actively building a lacustrine delta (U S Army Corps of Engineers, 1951, Fisk, 1952) During the past 50 years Atchafalaya sediments have filled a series of large lakes, and the river is expected to construct a delta lobe into the Gulf within the next few decades

In the active delta, where one might anticipate the highest rates of land building, an anomalous situation exists As shown in Figure 5, approximately 75 percent of the total river flow and an equal proportion of transported sediment are discharged through four major outlets or passes As previously mentioned, and as shown in the figure, the mouths of these major passes lie in close proximity to deep water Consequently, most of the sediment transported by the Mississippi is simply dumped into the deep

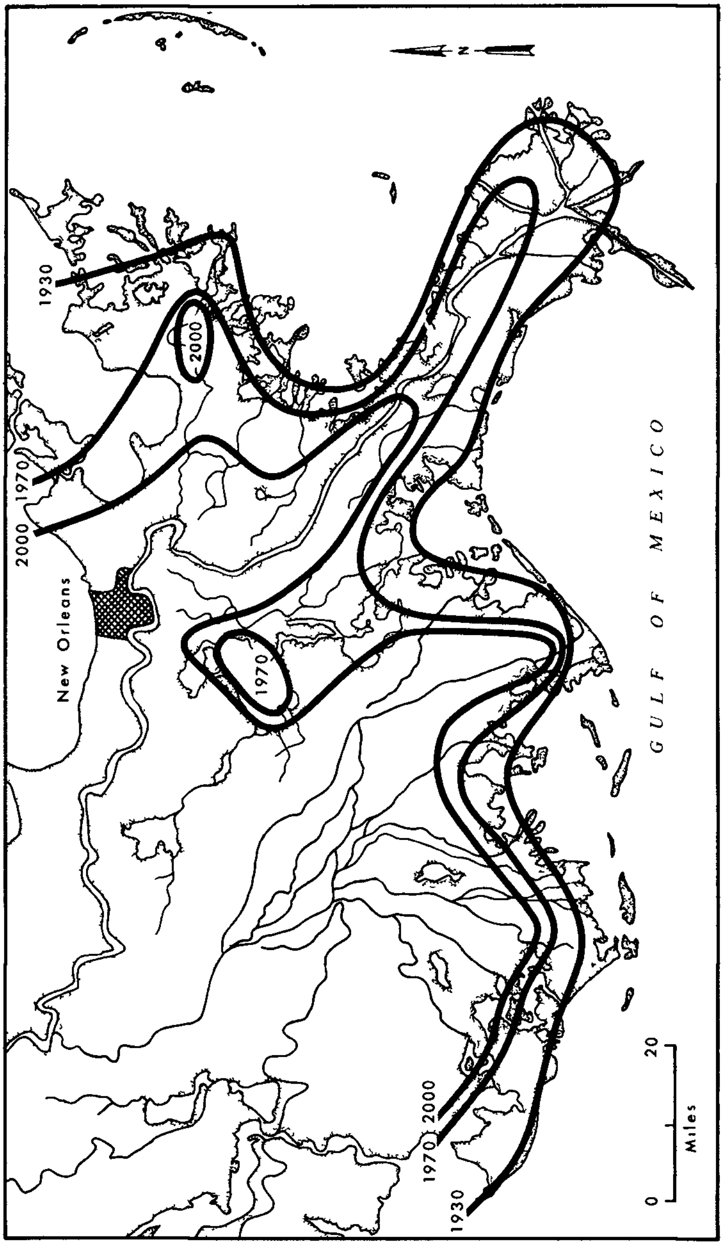

Fig 4 Progressive position of the 50 percent land-water isopleth in the deltaic plain of the Mississippi River

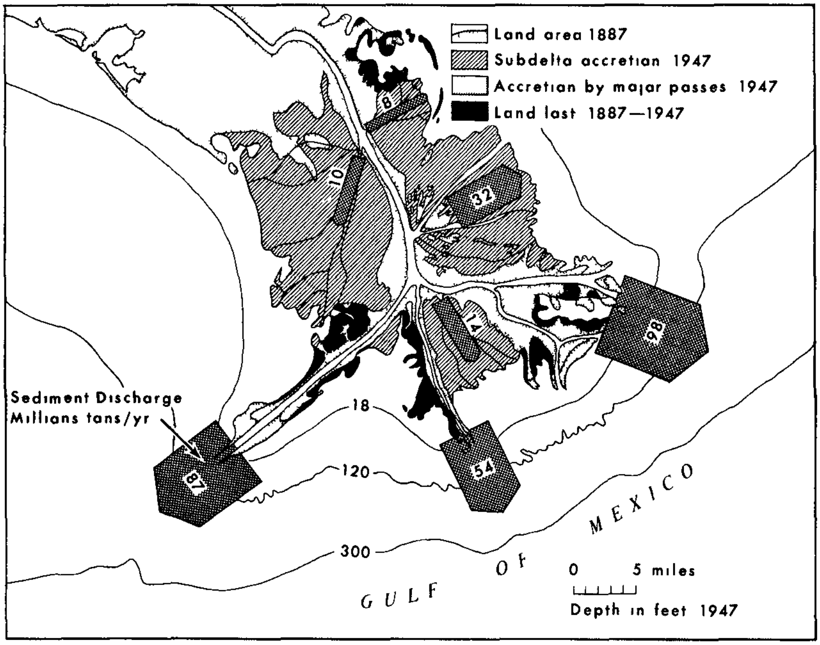

Fig 5 Relative sediment discharge and land accretion in the active birdfoot delta of the Mississippi River

Gulf, and there is little accretion of new land

In sharp contrast to the major passes, the 25 percent of river flow and transported sediment discharged through minor outlets has built a considerable landmass during historic times This landmass is shown as subdelta accretion in Figure 5 From the standpoint of land building, then, these minor outlets, related to subdeltas, are of primary interest

Subdeltas, which are appendages of major delta lobes, are usually active for periods of 50 to 100 years As illustrated in Figures 5 and 6, much of the landmass of the lower delta has been constructed by such subdeltas during historic times The dates shown in Figure 6 indicate the time of subdelta initiation Prior to their development these areas were occupied by embayments Comparative map studies reveal that the subdeltas account for over 80 percent of the new land built in the active delta during historic times

One of the most interesting aspects of subdeltas is their cyclic nature--that is, during a period of 50 to 100 years they progress through a sequence of stages dictated by interaction of such factors as stream gradient, subsidence, and vegetation change (Welder, 1959, Coleman and Gagliano, 1964, Morgan, 1970) Figure 7 traces the life cycle of the

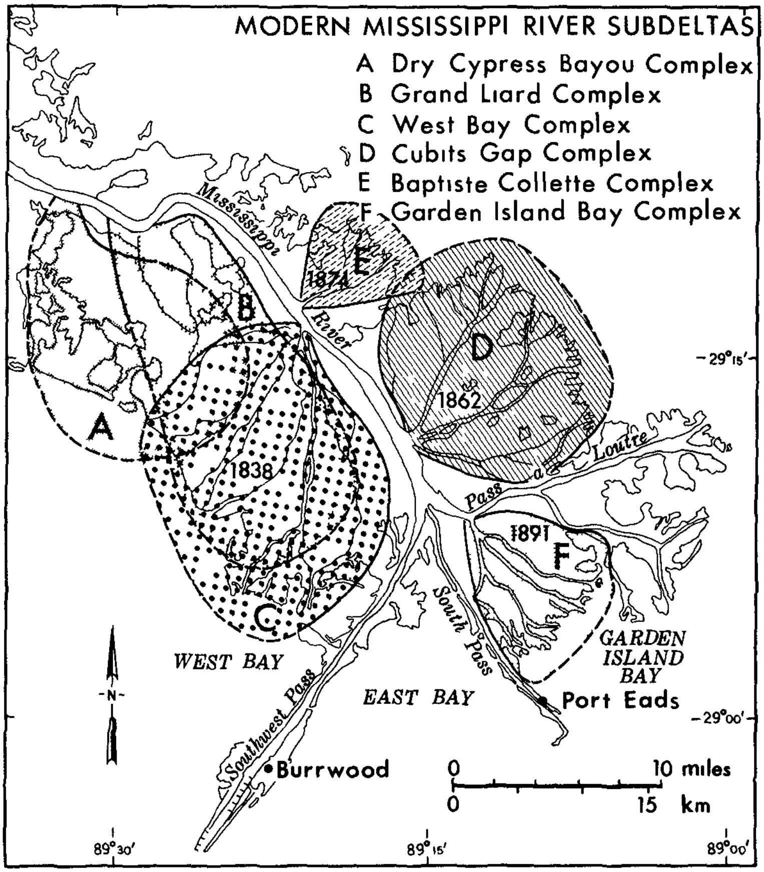

Fig 6 Subdeltas of the modern birdfoot delta Dates indicate year of crevasse breakthrough (After Coleman and Gagliano, 1964)

Garden Island Bay subdelta, as expressed by the gradual gain and loss of land area Note that this subdelta was initiated by a crevasse or break in the natural levee of one of the major distributaries in 1891 It went through a short initial stage of subaqueous development until around 1900, when it started to increase in area rapidly During this stage of fast subaerial growth land was added at an average rate of 0 75 miles^2/year Map measurements indicate that by 1940 the subdelta had built more than 30 square miles of land, utilizing less than 3 percent of the total flow of the river

Since 1940 the Garden Island Bay subdelta has been in a stage of

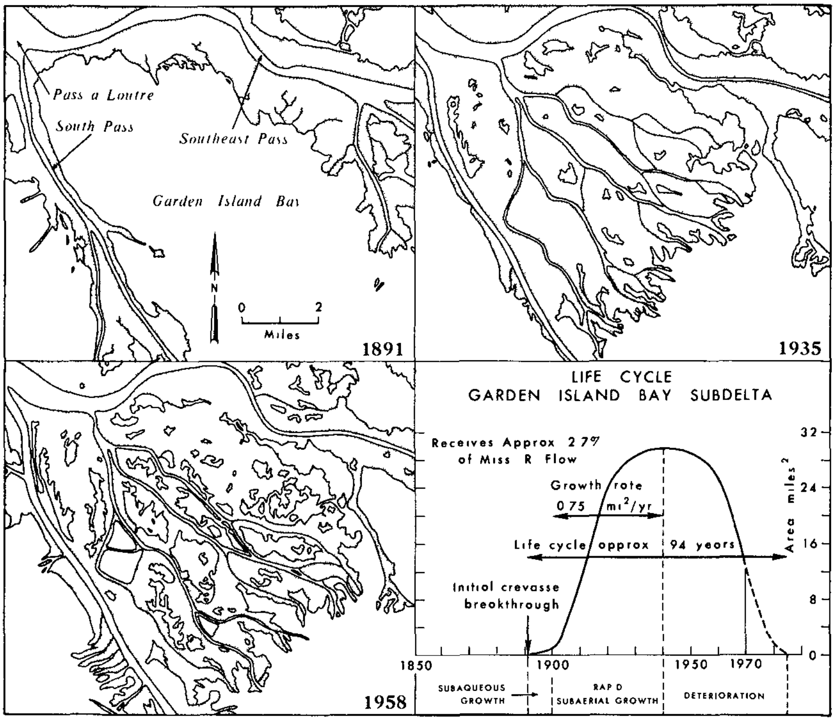

Fig 7 Progressive development of the Garden Island Bay subdelta after the crevasse breakthrough in 1891 Maps from U S C G S navigation charts

deterioration and has progressively decreased in land area as a consequence of subsidence and coastal erosion This example clearly illustrates the relative rapidity of geological processes associated with subdelta building and deterioration and suggests that subdeltas are highly amenable to manipulation Controlled diversions which will create new subdeltas are believed to be part of the solution to the environmental problem in coastal Louisiana

A study correlating subdelta growth with sediment input has been conducted to provide a basis for estimating the likely effectiveness of controlled diversions of river flow in creating new land This study centered on the four major historic subdeltas (indicated as C, D, E, and F in Fig 6) The average growth rate for the four subdeltas was found to be 0 7 square mile per year, using 5 percent of the total flow (Sporadic discharge measurements have been made in the major subdelta channels by the New Orleans District, U S Army Corps of Engineers) The efficiency of sediment retention ranged from about 50 to over 90 percent, and the average rate of retention was 70 percent

Controlled Diversions

Seven potential sites for the creation of new subdeltas have also been identified and evaluated three east of the Mississippi and four to the west (Fig 8) Assuming a configuration and size similar to one of the smaller modern subdeltas, average depth and volume for each of the proposed diversion sites have been determined

Long-term measurements indicate that the average sediment load of the Mississippi is 300 million tons per year If a 70 percent sediment retention efficiency figure for subdelta deposition is used, our data show that the river would be capable of building 12 3 square miles of new land per year if diversions were to be initiated along the lower reaches This is about 75 percent of the current net annual land loss of 16 5 square miles per year Thus it might be concluded that reestablishment of dynamic equilibrium in the Mississippi deltaic plain can only be approached However, other aspects of our studies indicate that relatively small volumes

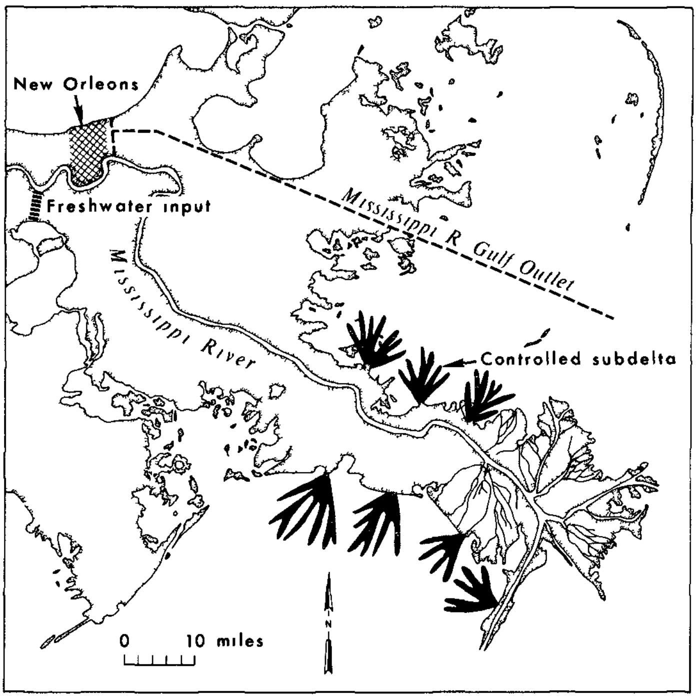

Fig 8 Suggested locations for controlled subdeltas and freshwater input canal in southeastern Louisiana

of fresh water introduced into the upper ends of interdistributary estuary systems could be used to offset salinity intrusion and introduce badly needed nutrients, both of which would offset conditions leading to rapid deterioration of brackish and fresh marshes (see Fig 8)

Such a dynamic management plan would have a number of benefits

1 The trend of land loss could be reversed,

2 Extension of the landmass would provide a valuable buffer zone for reducing hurricane-generated storm surges,

3 A highly irregular subdelta coast with maximum length of land-sea interface could be created, which would enhance productivity of fisheries and wild life,

4 Judicious spacing of controlled subdeltas could create new estuaries and increase the total areas of existing ones

During early settlement and initial utilization of the Mississippi valley and delta it was absolutely essential to prevent annual flooding and to improve navigation Accomplishment of these tasks has made possible the unprecedented growth and development that south Louisiana is experiencing today However, we have entered an era of total utilization of the Mississippi delta system Because of the delicate natural balance associated with the delta, it is mandatory that a new long-term dynamic management plan be devised for orderly development and use of the area It is the aim of our present studies to contribute to that goal

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