MISSISSIPPI RIVER DELTA OVERVIEW

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Introduction

- Basics of the Mississippi Delta
- Natural and Human-Induced Land Loss
- Impact of Sea Level Change
- Projections of Sea Level-Subsidence
Delta Type by Dominant Process
(modified from Galloway, 1975)

Delta Characteristics = Fluvial vs. Receiving Basin Processes
Deltas are Part of Much Larger System Modulated by Sea Level
Components of a River-Delta System

- Drainage Basin
- Alluvial Valley
- Deltaic Plain
- Receiving Basin
Six Major Drainage Basins of the Mississippi River Watershed
Mississippi River Delta
Holocene History of Delta Growth

- 6 major coupled channel belts and delta complexes
- Like most major deltas, growth occurred after ca. 7000 yrs BP
<table>
<thead>
<tr>
<th>Event</th>
<th>Timescale</th>
<th>Impact</th>
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</table>
| River switching              | 1,000-1,500 yrs    | Deltaic lobe formation  
Net advance of deltaic landmass, Barrier Island Formation |
| Major river floods           | 50-100 yrs         | Channel switching initiation  
Crevasse splay formation  
Major deposition |
| Major storms                 | 5-20 yrs           | Major deposition  
Enhanced production |
| Average river floods         | Annual             | Freshening (lower salinity)  
Nutrient input  
Enhanced 1º and 2º production |
| Normal storm events          | Weekly             | Enhanced production  
Organism transport  
Net material transport |
| Tides                        | Daily              | Drainage/marsh production  
Low net transport |

Modified from John Day
Active delta
Progradational deltaic headland

Stage 1
Erosional headland: flanking barriers

Interdeltaic bay

Stage 2
Shoreline retreat: transgressive barrier arc

Restricted interdeltaic bay

Shoal crest

Stage 3
Shoreline retreat: inner shelf sand shoal

Reoccupation

Abandonment

Submergence

Landward-migrating barrier

Tidal inlets

Shoal base

Shell reef

Intra-deltaic lagoon

Washover terrace
Factors Causing Land Loss – Mississippi Delta

- Natural:
  - Tectonic Subsidence
  - Delta Switching (subsidence under load)
  - Consolidation
  - Sea Level Rise
  - Hurricanes
  - Faulting
  - Biological

- Man-Induced
  - Dams, Levees, Impoundments
  - Fluid Withdrawal
  - Canal Dredging
  - Salt Water Intrusion
Dynamic Shifting of the Modern Mississippi River

(Fisk, 1944)
Environmental Transformation

- Historic-period levees decoupled delta plain from fluvial sediment source
- Global sea level rise started accelerating

No doubt, the great benefit to the present and two or three following generations accruing from a complete system of absolutely protective levees, excluding the flood waters entirely from the great areas of the lower delta country, far outweighs the disadvantages to future generations from the subsidence of the Gulf delta lands below the level of the sea and their gradual abandonment due to this cause (Corthell 1897)
Mississippi Delta Land Loss and Gain

Barras et al. (2003)
Context for Modern Delta by Summarizing Geological History of Lower Mississippi Valley and Delta Region

Geological Framework
Mississippi Embayment Formed, began to focus sediment input to GOM during Late Cretaceous

- Mississippi Embayment formed, focused sediment in late Cretaceous
- Modern land-surface dynamics
  - Conditioned by longer-term processes indigenous to the Mississippi depocenter
Paleogene 65.6 to 23 MYA

Series of Smaller-Scale River Systems entered GOM in what is now south Louisiana

Shelf Margin at New Orleans 34-24 MYA
Miocene 23 to 5.3 MYA

Mississippi Embayment Emerged as Primary Focus for Sediment Input

~200 km of shelf margin progradation

Foundation for Modern Delta Region
Plio-Pleistocene < 5 MYA
Sediment Loading

Depocenter extends ~400 km along Mississippi and Louisiana Coasts

Foundations for the Modern Delta reflect evolution of Depocenter
Delta region is inherently unstable, with subsidence processes that are driven by depocenter loading.

Fluvial to shallow marine sediments >500 m thickness

Sediment thickness > 4,000 m
Modern alluvial-deltaic landscape directly reflects the response of the Mississippi system to climate and sea-level changes from the last interglacial period to the present.

Sea Level History
Sea Level History

Oxygen Isotope Stages

- Start of Holocene Delta
- Meandering River Deposits
- Valley Incision
- Valley Fill
- Braided River Deposits
- Prairie Terrace

Sea Level (m)

Kyr BP

Shackleton (1987)
Labeyrie et al. (1987)
Marine Isotope State 5 ca. 125-80 KYA

Lower Mississippi and Delta
Looked Much Like Today

MI5 Delta Plain (or Prairie Terrace) extended further west

Meandering channels characterized alluvial valley
Large Scale Changes in Channel Morphology and Climate and Sea-Level Changes

Lower MS channel was braided and routed meltwater, incised through Prairie Terrace. Shoreline located at shelf margin and up to 120 m lower in elevation.
The Lower Mississippi River and Delta

- Glacial-period braided streams within incised valley
- Holocene valley filling and delta construction
- Valley fill reflects interactions between climate and sea-level change
Delta Plain Landscape
Glacial Period Incised Valley and Complex Deltaic Deposits

Modified from Autin et al 1991
Initiation of Holocene World Deltas

[Graph showing depth vs. age for Holocene Delta-Building with various datasets and radiometric dates for Recent World Deltas with a histogram indicating ages and number of dates (n = 36).]
Most Holocene Delta Plains Similarly Constructed, after SLR Decelerated

- Lena 43,563 km²
- Mekong 93,781 km²
- Yangtze-Kiang 66,669 km²
- Huang He (Yellow) 36,272 km²
- Indus 29,524 km²
- Mississippi 28,568 km²
- Ganges-Brahmaputra 105,641 km²

Gulf of Mexico
Sediment Storage in the System Before Human Intervention
The Lower Mississippi River and Delta

- Glacial-period braided streams within incised valley
- Holocene valley filling and delta construction
- Valley fill reflects interactions between climate and sea-level change
Longitudinal Profile of the Lower Mississippi Valley and Delta

Tracing Late Pleistocene Braided Streams into the Subsurface Using Base of Backswamp Deposits

Based on 325 USACE boreholes from Blum et al. (2008)
Total storage = 1860-2300 km$^3$ or 2790-3450 BT of sediment
Storage rate = $\sim$230-290 MT/yr over 12,000 yr post-glacial period

sediment isopachs adapted from Kulp (2000)
Coastal Plain Elevations

The map illustrates the coastal plain elevations with various color coding for different elevation ranges:
- NOAA 100 cm
- LIDAR 60–100 cm
- LIDAR 50–59 cm
- LIDAR < 50 cm
- Spot elevation < 50 cm

The map shows major cities and geographic features such as Lafayette, Baton Rouge, New Orleans, Grand Isle, Lake Pontchartrain, Mississippi Sound, and Chandeleur Sound.
Projected Submergence: 2000 vs 2100

- Prairie Terrace
- Lake Pontchartrain Marshes
- Modern Alluvial Ridge
- Lafourche Alluvial Ridges
- Lafourche Barrier
- Lower Lafourche Marshes
- Submerged Pontchartrain Marshes
- Submerged Lafourche Delta Plain Marshes
- Submerged Lower Lafourche Marshes
- 2000 Land Surface
- 2100 Land Surface

Longitude: 30.5°N to 29.0°N

Elevation (m):
- a: 5
- b: 5

Distance (km):
- 0 to 50 km
Global Sea-Level Rise

Sea-Level Change Data and Projections

from IPCC 2007
The Louisiana Coast in 2000
The Louisiana Coast in 2100?

Projected future land loss of $10,500-13,500 \text{ km}^2$

New accommodation $\sim 12-16 \text{ km}^3$
(Requires $\sim 18-24 \text{ BT}$ to fill accommodation)
The Louisiana Coast in 2100?

Mass balance considerations present tough choices for diversion scenarios.

Projected future land loss of 10,500-13,500 km$^2$

LSU CLEAR model creates 700-900 km$^2$ with 25% of sediment load.
Questions?
Delta Switching

Delta Cycle 1:
- Initial fluvial-dominated phase
- Rapid delta growth
- Relative stability
- Delta switching
- Marine-dominated transgressive phase

Delta Cycle 2:
- Rapid delta abandonment
- Barrier islands
- Submarine shoals

Physical/Sedimentary Processes:
- Increasing discharge & sediment flux
- Shelf deltas
- Rapid delta growth
- Stream capture
- Decreasing hydraulic efficiency
- Decreasing discharge
- Delta switching

Time (~1000-2000 years):
- Interior-filling lake deltas
- Bay-filling delta
- Shelf delta progradation
- Channel abandonment
- Delta deterioration (subsidence driven)
- Waning sediment supply
- Erosion of downdrift coasts and submergences of delta surface
- Increasing sediment availability
- Renewed progradation of downdrift coasts/backwater effects
- Crevasse development
- Splays and bay-fills
- Increasing influence of marine transgressive processes
- Stream capture
- Increasing discharge diversion to cycle 2

Sediment supply > relative sea level change
Sediment supply < relative sea level change

(Roberts, 1997)