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Geologic Framework and Processes of Lake Pontchartrain, Louisiana

Wetland loss and pollution are critical environmental concerns within the Pontchartrain Basin. U.S. Geological Survey scientists and collaborators have conducted a multidisciplinary study of lake-bottom sediments, sediment transport, and distribution of contaminants to assist future remediation efforts.

INTRODUCTION

Lake Pontchartrain and adjacent lakes in Louisiana form one of the larger estuaries in the Gulf Coast region. The estuary drains the Pontchartrain Basin (fig. 1), an area of over 12,000 square kilometers situated on the eastern side of the Mississippi River delta plain. In Louisiana, nearly one-third of the State population lives within the 14 parishes of the basin.

Over the past 60 years, rapid growth and development within the basin, along with natural processes, have resulted in significant environmental degradation and loss of critical habitat in and around Lake Pontchartrain. Human activities associated with pollutant discharge and surface drainage have greatly affected the water quality in the lake. This change is evident in the bottom sediments, which record the historic changes of the lake. Also, land-altering activities such as logging, dredging, and flood control in and around the lake have led to shoreline erosion and loss of wetlands. The effects of pollution, shoreline erosion, and wetland loss on the lake and surrounding areas have become a major public concern.

To better understand the basin's origin and the processes driving its development and degradation requires a wide-ranging study involving many organizations and personnel. When the **U.S. Geological Survey (USGS)** began the study of Lake Pontchartrain in 1994, information on four topics was needed: (1) geologic framework, (2) sediment characterization, (3) shoreline and surrounding wetland change over time, and (4) water circulation.

Figure 1. Lake Pontchartrain and the Pontchartrain Basin are located in Louisiana and Mississippi.

Geologic framework.—The geologic framework is an assessment of how the sediments accumulated in the area during the geologic past. The sedimentary layers below the lake bottom were imaged using a radar-like technique called high-resolution seismic profiling. Sidescan-sonar images of the lake floor also were collected. These images are similar to aerial photographs of the land. Sediment samples were collected and their compositions were analyzed to guide interpretations of seismic profiles.

Sediment characterization.—The sediment samples were also used to measure the natural concentration of chemical elements known as trace metals. Trace metals today are associated with pollution; knowing the amount of trace metals present before humans affected the area allows the level of pollution to be determined. From surface sediments, scientists can also locate modern areas of contamination.

Shoreline and wetland change.—To determine shoreline and wetland change, historical charts and aerial photographs were analyzed digitally. These analyses were compared with recent surveys and charts. Because of this work, scientists can use information on shoreline change over the past 100 years to predict areas of future change.

Water circulation.—Water circulation in Lake Pontchartrain was characterized by wind, current, tide, turbidity, salinity, and temperature measurements. Satellite images were studied to observe water quality over time. Water circulation, especially waves, resuspends polluted bottom sediments, and knowledge of circulation is key to predicting where the contaminants are likely to be concentrated. The objective was to construct a computer model of circulation patterns.

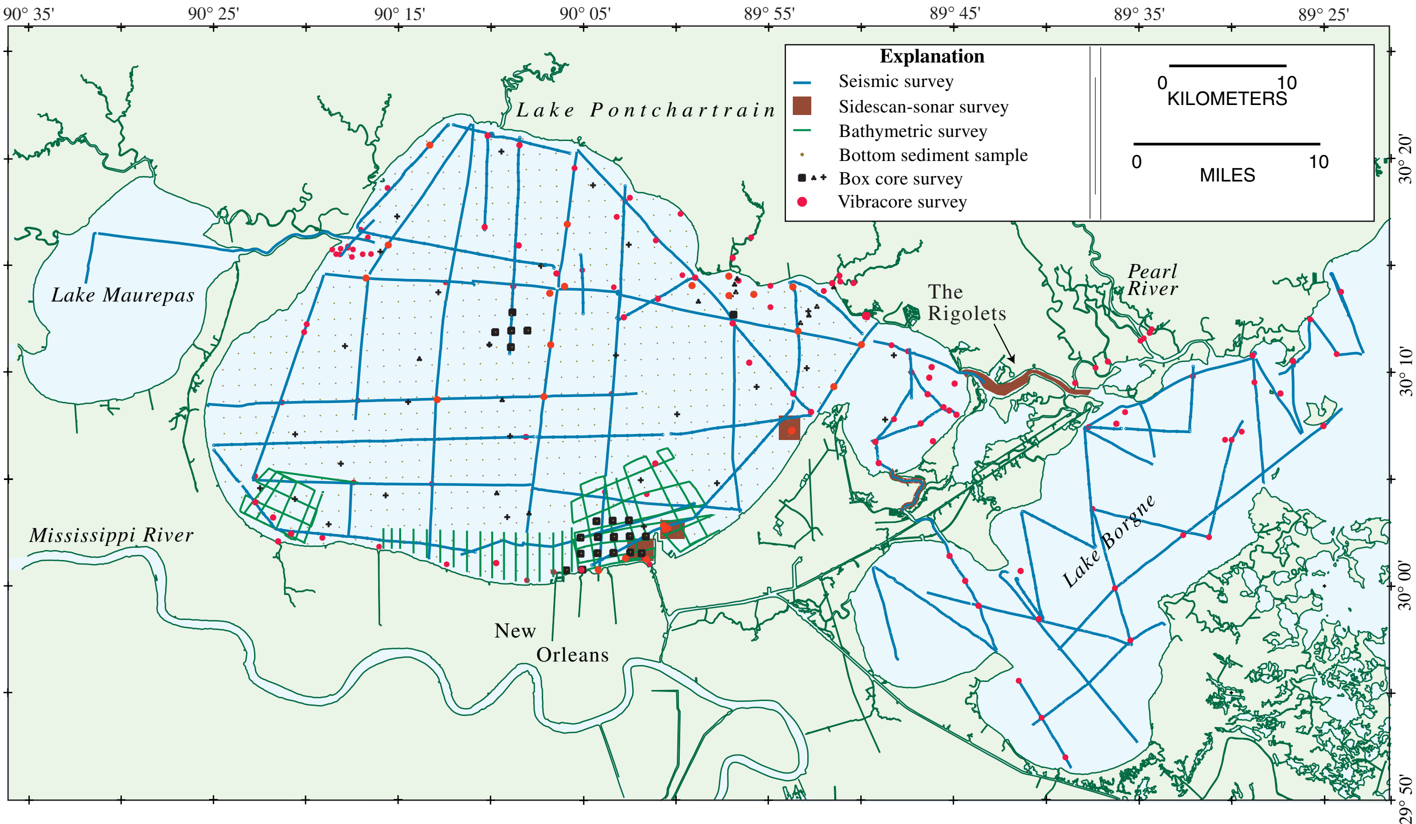

Figure 2. Location of remote-sensing and sediment sampling surveys of Lakes Maurepas, Pontchartrain, and Borgne.

INVESTIGATIONS

Between 1994 and 1998, surveys were conducted in Lakes Pontchartrain, Maurepas, and Borgne by the USGS, in cooperation with private, State, and Federal institutions (see box, figs. 2 and 3). The acquired data are critical in characterizing the lake system and in providing information for environmental management of the basin.

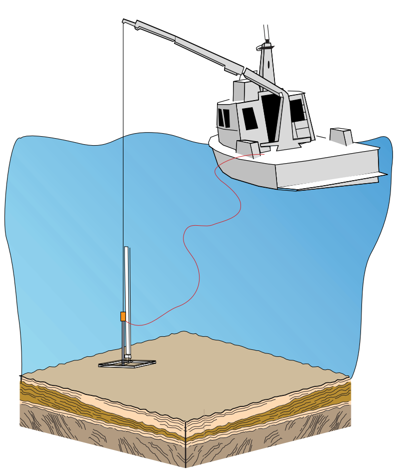

Figure 3. Most of the surveys were conducted from the USGS Research Vessel *G.K. Gilbert*, depicted here acquiring a Vibracore.

Studies include the following:

Sediment Sample Data

- 100+ Vibracores in lakes
- Data from 100+ U.S. Army Corps of Engineers boreholes across lake
- 80+ box cores in lakes
- 1,700 bottom sediment samples

Geologic Analyses

- Sediment composition
- Stratigraphy (layering)
- Palynology (pollen and spores)
- Sediment ages
- Trace-metal concentrations
- Models of water and atmospheric circulation

Remote Sensing

- 650 line km of single-channel seismic profiling
- Five sidescan-sonar grids
- Four bathymetric surveys (>200 km)
- Continuous wave, turbidity, salinity, and temperature measurements (five sites up to five months each)
- AVHRR (advanced very high resolution radiometer) satellite imagery

COLLABORATORS

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C. Holmes (age determination)
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R. Stumpf (remote sensing)
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GEOLOGIC FRAMEWORK

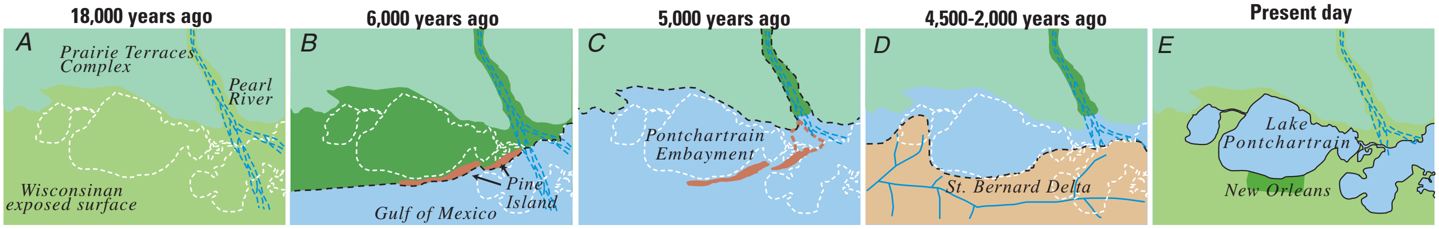


Figure 4. Evolutionary model for basin development from 18,000 years ago (*A*) to today (*E*).

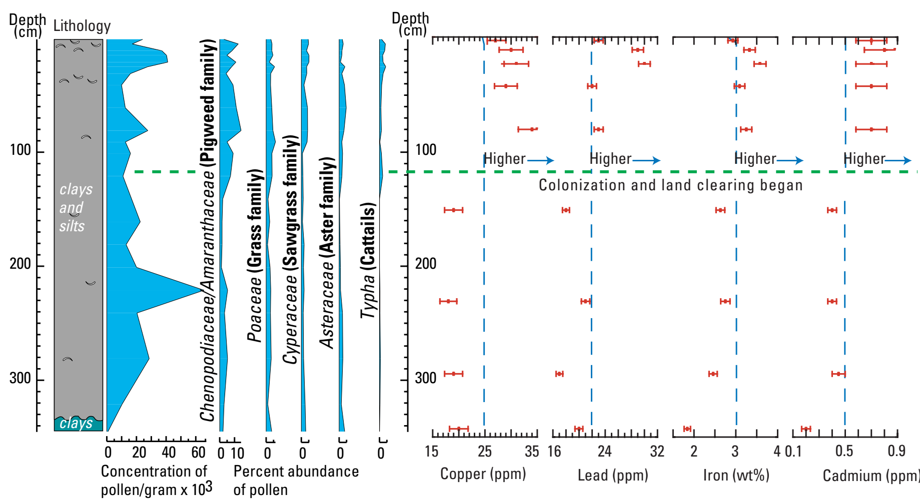
An evolutionary model (fig. 4*A*–*E*) for the Lake Pontchartrain area was developed by using seismic and sedimentologic data. Following the late Wisconsinan sea-level lowstand (~18,000 years ago), the sea rose and flooded the area (fig. 4*A*, *B*). By 6,000 years ago, sea-level rise had slowed, and longshore sediment transport began developing a barrier-beach system (fig. 4*B*). As sea level continued to rise, the barrier system was bypassed, forming the Pine Island Barrier trend, while flooding created the Pontchartrain Basin embayment (fig. 4*C*). By 4,500 years ago, the Mississippi River moved into the area and began depositing the St. Bernard Delta lobe (on which the city of New Orleans is located), enclosing the embayment (fig. 4*D*). Modern stabilization and subsidence of the delta lobe began about 2,000 years ago, developing Lakes Maurepas, Pontchartrain, and Borgne and creating the land surface seen today (fig. 4*E*).

SEDIMENT CHARACTERIZATION AND CIRCULATION MODELING

Evidence for environmental change can be seen in a Lake Pontchartrain sediment core (fig. 5). Percent abundances of selected pollen taxa and trace-metal concentrations show that about 120 centimeters (4 feet) beneath the lake bottom, pollen assemblages changed from pine/oak (common Gulf Coast) to herbaceous species that indicate human colonization and land clearing. At the same level, the concentrations of trace metals increased, also an indication of human activity.

Depositional patterns in Lake Pontchartrain were determined from current and circulation modeling and from rates of sediment deposition (fig. 6). The current model was based on prevailing wind speed and direction and bathymetry. Current direction and magnitude (size of arrows) show a predominantly northwest flow from the eastern side of the lake (Rigolets) during a prevailing northwest wind, which sets up gyres of circulation in the central part of the lake. Recent sediment deposition (darker red areas) appears to coincide with areas of decreased circulation (short arrows).

Figure 5. Pollen and trace-metal abundances in (Vibracore) Ipon 97–1.
Note: ppm=parts per million, wt%=weight percent.



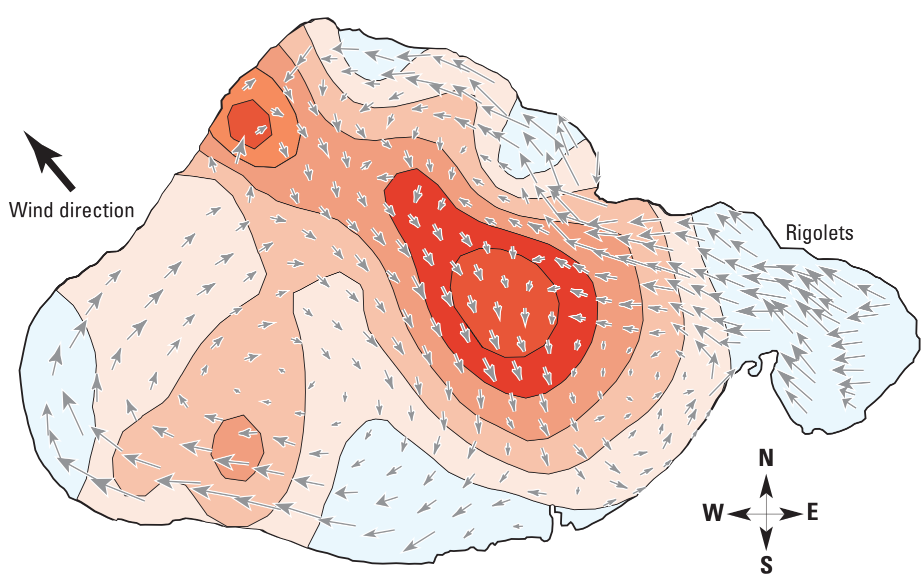
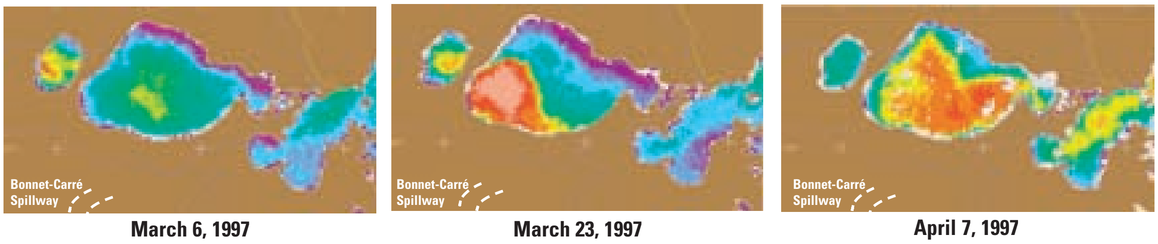


Figure 6. Circulation and sediment accumulation patterns in Lake Pontchartrain. Current direction and magnitude (size of arrows) were generated from a computer model based on bathymetry and wind speed and direction. Areas filled by shades of red show beryllium-7 (Be^7) isotope activity obtained from lake-bottom sediment samples. Darker red areas have higher concentrations of Be^7, which indicate recent sediment deposition because Be^7 forms in the atmosphere and dissipates rapidly with a half-life of 53 days. Light-blue areas lack Be^7.

AVHRR IMAGERY

Images of Lakes Pontchartrain, Maurepas, and Borgne were derived from data collected by the advanced very high resolution radiometer (AVHRR) onboard polar-orbiting weather satellites. In March 1997, the Bonnet-Carré flood-control structure was opened, and the water from the Mississippi River was diverted through Lake Pontchartrain to avoid potential flooding of New Orleans. The images in figure 7 illustrate the increase in suspended material in the lake as a result of the diversion of floodwaters. The sediment-laden water enters from the Bonnet-Carré Spillway in the west, travels through the lake, and exits via the Rigolets into Lake Borgne and the Mississippi Sound.

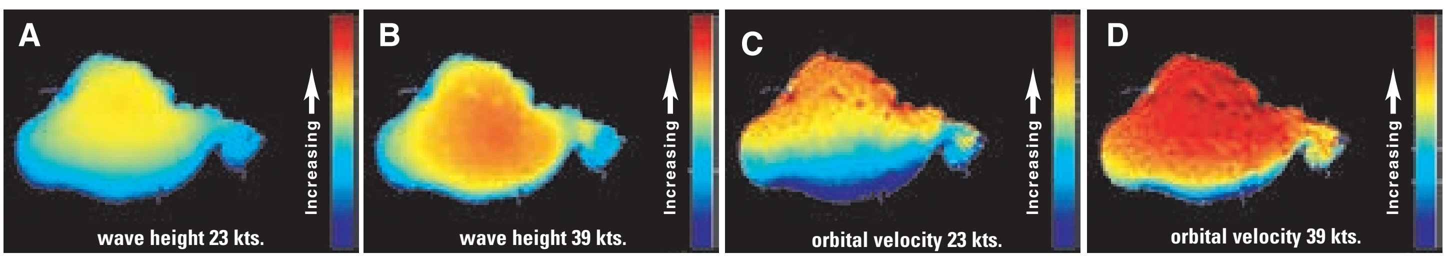
Figure 7. Turbidity in Lake Pontchartrain after the Bonnet-Carré Spillway opening. The darker red has more suspended sediment.



WAVE MODELING

Resuspension and transport of bottom sediments due to wave action are important physical components of sediment distribution in Lake Pontchartrain. Wave height and associated bottom orbital velocity (current motion) are functions of wind stress at the surface and of bathymetry. This action can be simulated by using the numerical wave-prediction model HISWA (Hindcasting Shallow Water Waves). Figure 8 shows the HISWA predictions for significant wave height (fig. 8*A*, *B*) and maximum orbital velocity (fig. 8*C*, *D*). Results indicate that although waves may be higher in the central portions of the lake, increased bottom orbital velocities at the shorelines drive resuspension and transport of fine-grained sediment.

Figure 8. Wave modeling for Lake Pontchartrain shows the increase in wave height and lake bottom orbital velocity (turbulence) generated as south winds increase from 23 to 39 knots.



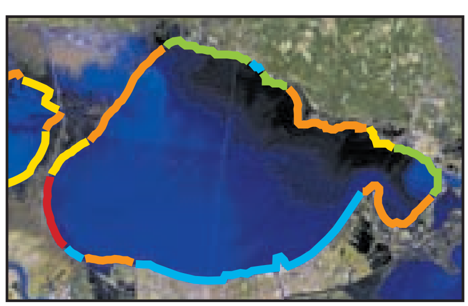
SHORELINE/WETLAND CHANGE

Having information about shoreline erosion and wetland change is crucial for improved management in the Pontchartrain Basin. In the past 60 years, more than 76,000 hectares (188,000 acres) of land in the basin have been lost due to a complex suite of causes (fig. 9). Erosion rates are derived from comparison of recent measurements with historic data. Where the shoreline has not been stabilized by sea walls or other structures, erosion averages 2 to 4 meters per year.

Wetlands have been lost to urbanization and natural submergence. Changes include cypress swamps converting to freshwater marsh, freshwater marshes converting to higher salinity marsh, and complete submergence.

Figure 9. Shoreline erosion rates around Lake Pontchartrain.

Erosion Rate (m/yr)
0-1
1-2
2-4
4+
Stabilized



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