# Chapter Seven: Aquatic Environments

U.S. Geological Survey scientists conducted many studies devoted to analyzing waters and sediments affected by the flooding from the storms of 2005, especially that of Katrina in the New Orleans area and Rita's storm surge in southwestern Louisiana. The following articles are about the chemical composition of contaminated sediments off the shelf of Louisiana; the flood waters of Louisiana including New Orleans; the Mississippi River Delta; shallow aquifers along Lake Pontchartrain's northern shoreline; Lake Pontchartrain itself and other Gulf of Mexico outlets; and potential implication for human health and the environment.

# Examining Offshore Sediment-hosted Contaminant Transport from Hurricane Katrina

By Peter W. Swarzenski, Pamela L. Campbell, Richard Z. Poore, Lisa E. Osterman, and Robert J. Rosenbauer

*A rapid-response expedition was organized after the passage of Hurricane Katrina to investigate potential offshore environmental impacts and storm-induced sediment-transport processes. Both water-column and sediment samples were collected on the Louisiana shelf for a full complement of organic, inorganic, and geochronological tracers. Based on excess lead-210 (210Pb) inventories in cores collected before and after Katrina, the surface sediments and their associated geochemical signatures were considerably affected by the passage of this storm.*

## Introduction

Fueled by warm open waters of the Gulf of Mexico, Katrina escalated into a catastrophic hurricane before making landfall on the deltaic coast of south Louisiana on August 29, 2005. While effects from the storm were felt across most of the northern Gulf of Mexico, the storm's center passed immediately west of the modern delta of the Mississippi River (fig. 1). A rapid-response research expedition aboard the Research Vessel *Cape Hatteras* was led by U.S. Geological Survey (USGS) scientists in mid-October 2005 to study potential offshore impacts on the Louisiana shelf related to the passage of Hurricane Katrina. The voyage was jointly funded by the National Science Foundation (NSF) and the USGS Coastal and Marine Geology (CMG) and Earth Surface Dynamics (ESD) Programs to address potential downriver environmental impacts, as well as to assess storm-related sediment transport within the northern Louisiana shelf.

Katrina directly affected the natural gas and petroleum facilities closest to the Mississippi River Delta and caused widespread coastal destruction and purported oil spills (Rykhus, 2005). Importantly, the storm's energy also disrupted the occurrence of oxygen-depleted (hypoxic) waters in the previously stratified water column of the northern Louisiana shelf and thus abruptly ended the occurrence of widespread hypoxic conditions typically observed in this region during summer (LUMCON, 2005).

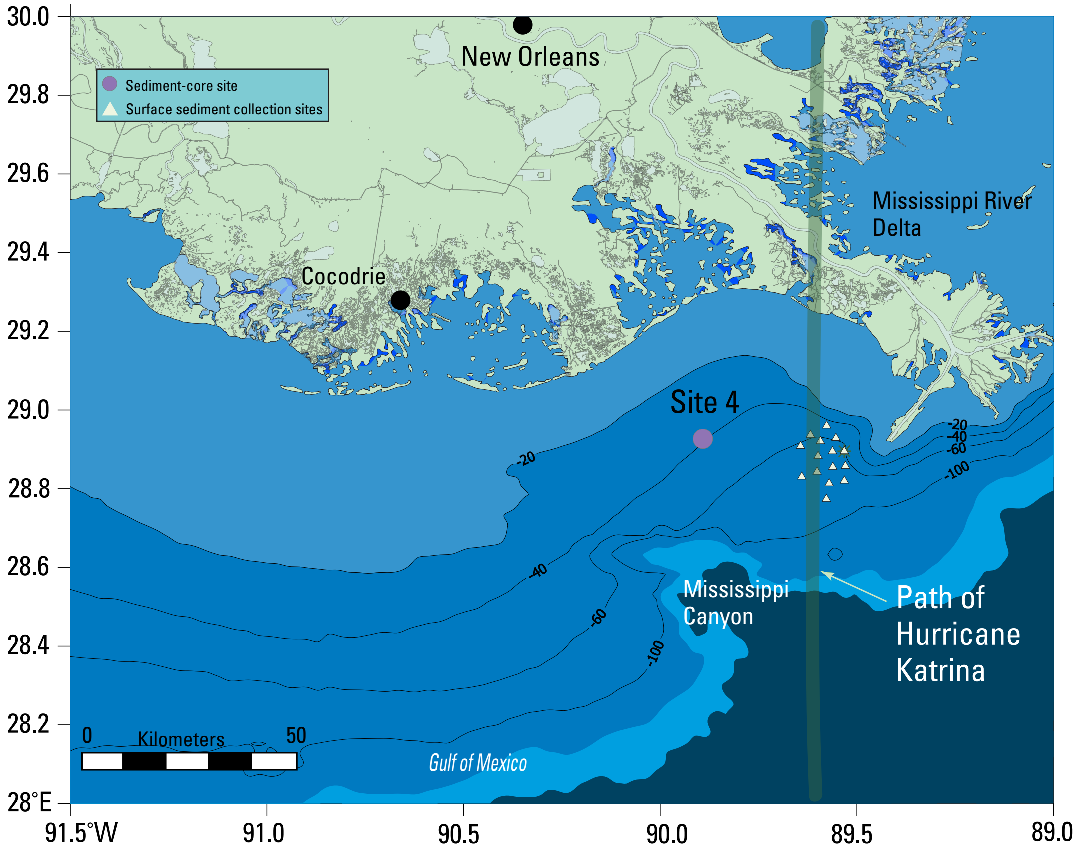


**Figure 1.** Site location map showing the sediment-core location (site 4) as well as the surface-sediment collection sites closest to the Mississippi River Delta. Depths of water, in meters, are shown as negative numbers on figure.

A highly productive fisheries industry may potentially be at risk from seasonal hypoxia, storm-related pollution,and sediment transport.

The research cruise had the following broad objectives:

- to assess hurricane effects on sediment erosion, resuspension, deposition, and accumulation;
- to examine storm impacts on estuarine biogeochemical transformations;
- to investigate potential riverine or human signals of both organic and inorganic contaminants in sediments immediately adjacent to the river mouth;
- to continue research on historical oxygen-depletion (i.e., hypoxia) events and storm-induced benthic ecosystem changes by using foraminifer assemblages; and
- to complement a study of the cycling of mercury and methyl mercury in the shelf water column and pore waters under recurring hypoxia.

To achieve these objectives, the water column and bottom sediments were sampled at sites (fig. 1) across the Louisiana shelf with traditional sampling and coring devices. Current analyses of sediments include a suite of organic compounds and contaminants, inorganic trace elements, mercury and methylmercury, beryllium-7 ($^{7}$Be), thorium-234 ($^{234}$Th), excess lead-210 ($^{210}$Pb), cesium-137 ($^{137}$Cs), foraminifer assemblages, and sediment-grain size.

Because powerful hurricanes such as Katrina generate tremendous surface waves with effects that can extend well into the seabed, they likely play a fundamental role in the erosion, transport, deposition, and burial of coastal sediments. For example, using pre- versus poststorm comparisons of the seabed in response to the passage of hurricanes, Riggs and others (1998) observed mostly an erosional response off North Carolina, with widespread bedform migration/resuspension, while Thieler and others (2001) found shore-parallel transport of large (about 0.6-mi (1-km) wavelength), shore-oblique sand ridges. In contrast, Hayes (1967) documented extensive sand layers on the inner shelf off south Texas. From a recent study of the direct seabed impact from the passage of two tropical storms across the Atchafalaya River Delta, Allison and others (2005) observed the presence of a basal erosional surface that was subsequently overlain by a silty clay storm deposit less than 7.5 inches (19 cm) thick. Because each storm is unique in terms of its strength, velocity, and geographic location, the impact to the seabed and its response to the passage of a hurricane are also likely to be highly specific. A useful suite of natural tracers to study storm-related seabed processes includes select radionuclides that occur naturally as decay products of uranium and thorium.

## Radionuclide Geochronometers

Discrete 0.39-inch (1-cm) sediment sections collected were analyzed for the following particle-reactive radionuclides: $^{234}$Th (half-life, $t_{1/2}$ = 24.5 days), $^{7}$Be (53 days), $^{210}$Pb (22.3 years), and $^{137}$Cs (30 years). Because of their disparate source functions, this suite of radionuclides can provide unique information on the source of coastal particles and can also provide a robust sediment geochronology (Swarzenski and others, 2006). Thorium-234 is a naturally occurring, highly particle-reactive radionuclide that is present in the seabed because of decay of its radiogenic parent uranium (called "supported" $^{234}$Th) and also because some thorium may be adsorbed from particle contact with the water column (called "excess" xs$^{234}$Th). Beryllium-7 is a natural, atmospheric spallation product that will fall out during both wet and dry precipitation. Riverine particles tend to be enriched in $^{7}$Be relative to marine particles because of sediment-focusing processes within river catchments. Cesium-137 is a bomb tracer released into the atmosphere during thermonuclear weapons testing beginning in 1954. The fallout and transport pathway of $^{137}$Cs to shelf sediments is similar to that of $^{7}$Be. Unlike $^{7}$Be, however, the supply of $^{137}$Cs reached its peak worldwide during the 1964–65 atmospheric testing and has been in steady decline since 1972. Lead-210, like $^{234}$Th, is a naturally occurring uranium decay product that is produced both in situ (supported $^{210}$Pb) and from the decay of dissolved uranium. Excess (xs) $^{210}$Pb, which is used to develop a geochronology, is defined as total $^{210}$Pb minus the supported activity ($^{210}Pb_{xs} = {}^{210}Pb_{tot}$ - Radium-226 ($^{226}$Ra)). A specific isotope ratio that can potentially fingerprint unique particle sources—for example, $^{7}$Be/xs$^{234}$Th or $^{7}$Be/xs$^{210}$Pb—may prove particularly useful as a storm-seabed process tracer (Allison and others, 2005).

Figure 2 shows before- and after-Katrina xs$^{210}$Pb activities (disintegration per minute/grams (dpm/g)) as a function of cumulative mass depth (g cm$^{-2}$ yr$^{-1}$) at site 4, a station immediately west of Katrina's path. Although $^{210}$Pb integrates over a much longer time relative to the passage of Katrina, it is evident from xs$^{210}$Pb inventories (dpm/cm$^{2}$) that the depth of the erosional surface at the base of the Katrina deposit is at ~ 5 g cm$^{-2}$ yr$^{-1}$, which corresponds to a linear depth of 3.1–3.5 inches (8–9 cm). This implies that Katrina not only eroded tremendous volumes of sediment at site 4 but also destroyed more than 25 years (linear sedimentation rate = 0.1 inch/year or 0.3 cm/year; 8 cm/0.3 cm yr$^{-1}$) of intact sediment record.

## Organic Biomarkers

Quantification of several classes of organic compounds and contaminants—including aliphatic hydrocarbons (n-alkanes), polycyclic aromatic hydrocarbons (PAHs), and sterols—was completed from eight surface-sediment samples immediately adjacent to the Mississippi River Delta (fig. 1). The n-alkanes are hydrocarbons whose occurrence and molecular weight profile may be used to source organic matter. In general, PAHs are widespread, often harmful organic compounds which are found in crude oils, combustion byproducts and higher plant lipids (R.J. Rosenbauer, W.H. Orem, P.S. Swarzenski, C. Kendall, and F.D. Hostettler, written commun.). Many are carcinogenic and may cause mutations or birth defects and may be classified as

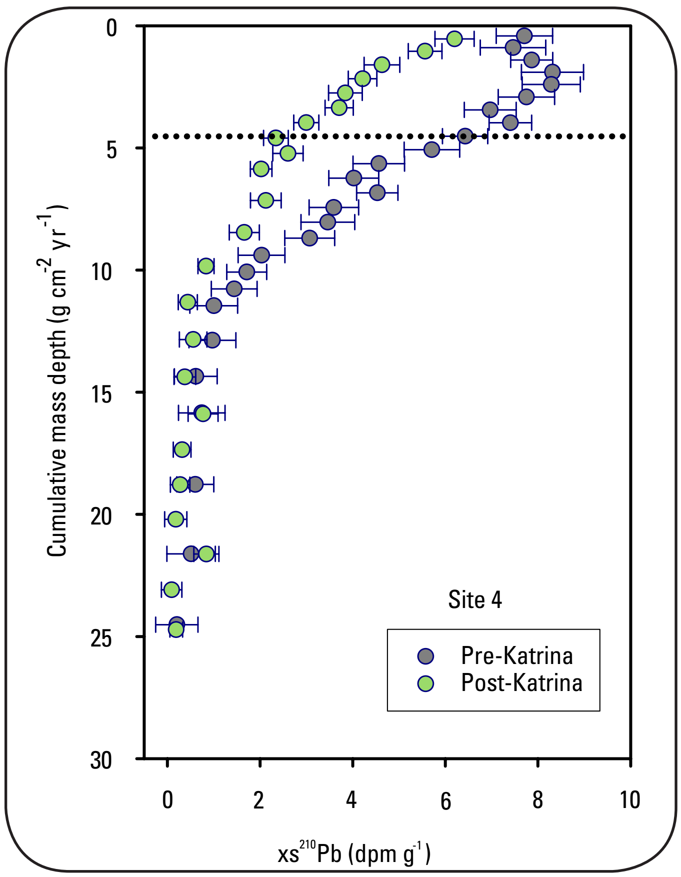


**Figure 2.** A comparison of pre- and post-Hurricane Katrina excess lead 210 (xs$^{210}$Pb) activities (disintegration per minute/gram (dpm/g)) as a function of cumulative mass depth (g cm$^{-2}$ yr$^{-1}$) at site 4, just west of the path of Katrina (which made landfall in 2005) (see fig. 1 for site location). The dashed line represents the likely depth (linear depth = 3.1–3.5 inches (8–9 cm)) of the erosional surface at this site. Based on a post-Katrina xs$^{210}$Pb-derived geochronology at site 4 of 0.1 inches (0.3 cm) per year, more than 25 years of sediment record were destroyed by the passage of this hurricane.

Environmental Protection Agency (EPA) designated priority pollutants. Sterols are a class of lipid biomarkers which can be used to differentiate between organic matter derived from mammalian, plant, algal, and fungal sources.

We observed PAHs in all surface samples (fig. 1), albeit in low concentrations. Alkylated (methyl groups attached to parent compound) PAHs that are present in crude oils were not found in our samples. The n-alkanes extracted and quantified from surface samples had a dominant odd over even carbon number hydrocarbon preference with major peaks at carbon 15 (pentadecane), indicative of a bacterial or algal source, and at carbon 27 (heptacosane), indicative of a land-based plant source. There did not appear to be any petroleum-related n-alkanes. The major sterols present in all samples were cholesterol (zooplankton and animal tissue source), stigmasterol (higher plant source), and β-sitosterol (higher plant source). The dominant human sewage indicators, coprostanol and epicoprostanol, were absent.

In summary, while dominant human sewage biomarkers were generally absent in the shallow sediments immediately adjacent to the Mississippi River, from a comparison of excess $^{210}$Pb inventories in pre- and post-Katrina sediments, it is evident that the passage of Katrina did cause significant erosion and remobilization of the upper sediment column. The effect of this large-scale impact on the sediment geochemistry still needs further investigation.

## Acknowledgments

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