**ACCESS NUMBER: 30660-19911b**

**STUDY TITLE:** Wave Climate and Boundary Layer Dynamics with Implications for Offshore Sand Mining and Barrier Island Replenishment, South-Central Louisiana

**REPORT TITLE:** Wave Climate and Bottom Boundary Layer Dynamics with Implications for Offshore Sand Mining and Barrier Island Replenishment in South-Central Louisiana

**CONTRACT NUMBER:** 14-35-0001-30660-19911b

**SPONSORING OCS REGION:** Gulf of Mexico

**APPLICABLE PLANNING AREA**: South-Central Louisiana Coast

**FISCAL YEARS OF PROJECT FUNDING:** FY 1994 through FY 1999

**COMPLETION DATE OF REPORT:** 2000

**COSTS:** FY 1994, $93,897: FY 1995, $83,102; FY 1996, $94,363; FY 1997, $91,138; FY 1998, $31,171: **CUMULATIVE PROJECT COST**: $393,671

**PROJECT MANAGER:** Gregory W. Stone

**AFFILATION OF PROJECT MANAGER:** Coastal Studies Institute, Louisiana State University

**ADDRESS:** 331 Howe Russell, Louisiana State University, Baton Rouge, Louisiana 70803

**PRINCIPLE INVESTIGATORS:** Gregory W. Stone, J.P. Xu, K. Henderson, and J.M Grymes

**KEY WORDS:** Numerical models, sediment transport, hydrodynamics, Ship Shoal

**BACKGROUND:** In an earlier MMS-funded project conducted by the PI of the current report, three numerical modeling objectives were undertaken: (1) to develop a numerical model of wave energy transformation and decay across the inner shelf encompassing Ship Shoal and the nearshore adjacent to the Isles Dernieres; (2) to develop a nearshore sediment transport model along the Isles Dernieres; and, (3) to quantify changes in (1) and (2) due to removal of various sediment quantities based on likely scenarios provided by MMS.

**OBJECTIVES:** The current project included three additional field measurement objectives: (1) to procure and fabricate an additional bottom boundary layer instrumentation system; (2) to obtain direct field measurements of temporally- and spatially-varying directional wave spectra at two locations; and, (3) to obtain direct field

measurements of bottom boundary layer hydrodynamic processes and suspended sediment transport. All experiments were conducted at Ship Shoal.

**DESCRIPTION:** Instrumentation was deployed on the Louisiana inner shelf during two winter periods, between November 24, 1998 and February 2, 1999, and February 9 and March 25, 2000. The three instrumentation packages consisted of two types of frame-mounted systems, both of which included a self-contained data recorder module. System 1 was a unique multi-sensor package nicknamed WADMAS, which consisted of a Paroscientific pressure sensor, a sonar altimeter, and a vertical array of three co-located Marsh-McBirney electromagnetic current meters and Seapoint optical backscatter sensors (OBS's). This instrumentation enabled WADMAS to measure water level, directional wave parameters, and seabed elevation, as well as current velocity and suspended sediment concentration at heights of 20, 60, and 100 cm above the seabed. Systems 2 and 3 each consisted of a pressure sensor and a SonTek$_{TM}$ downward-looking Acoustic Doppler Velocimeter (ADV) that measured seabed elevation, relative particulate concentration and three-dimensional currents at an elevation of approximately 20 cm above the bed. During the first deployment, Systems 1 and 2 were deployed in approximately 8.5 m of water on the seaward side of Ship Shoal, while System 3 was deployed in about 7 m of water on the landward side. During the second deployment, Systems 1 and 3 were deployed in the same locations as previously, while System 2 was placed at a 3.5 m water depth in the middle of the Shoal. During each deployment and retrieval, divers collected sediment from the bed, and water samples from the water column, and observed and measured any visible bed forms. Data were then processed and analyzed using conventional methods found in the literature.

**STUDY RESULTS:** Hydrodynamic, bottom boundary layer, and sedimentary processes on the Louisiana inner shelf during the winter are characterized by episodic variability, largely as a result of the quasi-periodic cycle of recurring extratropical storm passages in the region. Extratropical storms are generally characterized by increases in: wave height, near-bed orbital, and mean current speed, shear velocity, suspended sediment concentration, and sediment transport. Decreases in wave period and apparent bottom roughness are also apparent. Despite these regularities, considerable variability between storms, as well as during storms themselves, is reflected in hydrodynamic, bottom boundary layer, and sedimentary processes. During strong storms, some indices were several orders of magnitude greater than during fair weather, while during weak storms they were lower.

The following extratropical storm classification, consisting of two storm types, is proposed on the basis of their influence on the Louisiana inner shelf. Type 1 storms are characterized by weak southerly pre-frontal and strong northeasterly post-frontal winds that cause strong post-frontal responses including high, short-period, southerly waves, strong, southwesterly currents, and moderately high southwesterly sediment transport. Type 2 storms include periods of both strong southerly pre-frontal winds, which generate high, long-period northerly swell waves, and strong northerly post-frontal winds, which cause energetic southerly storm waves. Rotational, net southeasterly

currents and high shear velocity occurs during both the pre- and post-frontal phases, while sediment transport occurs predominantly during the post-frontal phase, when it is southeasterly. Local extratropical storms are apparently not the only cause of high-energy responses on the Louisiana inner shelf. Distant storms apparently cause high, long-period waves, accompanied by moderate rotational currents that can create high sediment transport. Results suggest that resuspension and transport of bottom sediment may sometimes occur during winter fair weather conditions, although it has previously been considered unlikely.

**SIGNIFICANT CONCLUSIONS:** Differences between the seaward and landward sides of Ship Shoal are apparent. Waves tend to be higher and longer in period on the seaward side, while mean currents are generally higher landward, where they are directed onshore, unlike the offshore site, where seaward currents predominated. It is apparent, therefore, that Ship Shoal exerts a significant influence on regional hydrodynamics, reducing wave energy and modulating current velocity. The short-term evolution of Ship Shoal appears to be the result of a balance between fair weather influences, which cause erosion and landward migration, and winter storm influences (particularly Type 2 storms), which cause accretion and seaward migration.

**STUDY PRODUCTS:** Stone, G.W. and J.P. Xu. 1995. Wave Climate Modeling and Evaluation Relative to Sand Mining on Ship Shoal, Offshore Louisiana, for Coastal and Barrier Island Restoration. Report prepared for Minerals Management Service, OCS Study, MMS 96-0059.

Stone, G.W. and J. P. Xu. 1995. Wave and nearshore transport modeling Louisiana coast. Coastal Morphodynamics Laboratory Technical Paper 95-5, 18 pp.

Stone, G. W., J. P. Xu, and X. P. Zhang. 1995. Estimation of the wave field during Hurricane Andrew and morphological impacts along the Louisiana coast. In: Stone, G.W. and C.W. Finkl, eds. Impacts of Hurricane Andrew on the Coastal Zones of Florida and Louisiana: *Journal of Coastal Research Special Issue* 21:234-253.

Stone, G.W., J. P. Xu, and X. P. Zhang. 1995. Wave climate modeling and evaluation relative to sand mining on Ship Shoal, offshore Louisiana, for coastal and barrier island restoration. U.S. Minerals Management Service International Transfer Meeting, New Orleans, LA. (invited).

Xu, J.P., G. W. Stone and X. P. Zhang. 1995. Impacts of Ship Shoal on storm wave propagation across south-central Louisiana shelf, a simulation study. Geological Society of America Annual Meeting, New Orleans, LA.

Stone, G.W., J. P. Xu and X. P. Zhang. 1996. Ship Shoal wave climate modeling and evaluation. *Transactions,* International Transfer Meeting, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA.

Stone, G.W., J. P. Xu and X. P. Zhang. 1996. Physical and environmental studies within the Ship Shoal area: wave climate study and ongoing physical field study. U.S. Minerals Management Service International Transfer meeting, New Orleans, LA. (invited).

Xu, J.P. and G. W. Stone. 1996. Wave climate modeling and evaluation relative to sand mining on Ship Shoal, offshore Louisiana, for coastal barrier island restoration. American Geophysical Spring Meeting, Baltimore, MD.

Zhang, X.P. and G. W. Stone. 1997. Application of GIS to assist in wave modeling for the central Louisiana coast. 13th. Louisiana remote Sensing and Geographical Information Systems Conference, Lafayette, LA.

Pepper, D.A., G. W. Stone and P. Wang. 1998. A preliminary assessment of wave, current, and sediment interaction on the Louisiana shoreface adjacent to the Isles Dernieres. Recent Research in Coastal Louisiana, Lafayette, LA.

Stone, G.W. 1998. The significance of frontal boundaries, tropical storms and hurricanes on the morphodynamics of Gulf Coast barriers, USA." International Coastal Symposium, West Palm Beach, FL.

Stone, G.W. 1998. Numerical wave modeling of wave energy increases in Louisiana's bays, USA. International Coastal Symposium, West Palm Beach, FL.

Stone, G.W. and R. A. McBride. 1998. Louisiana barrier islands and their importance in wetland protection: forecasting shoreline change and subsequent response of wave climate. *Journal of Coastal Research* 14, 3, 900-916.

Stone, G.W., X. P. Zhang and P. Wang. 1998. Forecasting wave energy changes along the Louisiana coast and implications for accelerated wetland loss. International Deltas Symposium, New Orleans, LA.

Zhang, X.P. and G. W. Stone. 1998. Development of a Louisiana coastal processes geographic information system. Recent Research in Coastal Louisiana, Lafayette, LA.

Pepper, D.A., G. W. Stone and P. Wang. 1999. Bottom boundary layer parameters and sediment transport on the Louisiana inner shelf during cold front passages. *Transactions*, Gulf Coast Association of Geological Societies, Lafayette, LA., XLIX: 432-438.Stone, G.W. and P.

Wang. 1999. The importance of cyclogenesis on the short-term evolution of Gulf Coast barriers. *Transactions,* Gulf Coast Association of Geological Societies, Lafayette, LA., XLIX:478-486.

Pepper, D.A., G. W. Stone and P. Wang. 1999. Bottom boundary layer parameters and predicted sediment transport. Association of American Geographers, 95th Annual Meeting, Honolulu, HI.

Pepper, D.A., G. W. Stone and P. Wang. 1999. The significance of mid latitude cyclones on the inner continental shelf of the northern Gulf of Mexico: the impact of Hurricane Camille: A Storm Impacts Symposium to Mark the 30th Anniversary, New Orleans, LA.

Pepper, D.A., G. W. Stone and P. Wang. 1999. Bottom boundary layer parameters and sediment transport on the Louisiana inner shelf during cold front passages. Gulf Coast Association of Geological Societies, Lafayette, LA.

Stone, G.W. 1999. The importance of cyclogenesis on the short-term evolution of Gulf Coast Barriers. Association of American Geographers, 95th Annual Meeting, Honolulu, HI.

Stone, G.W. 1999. Storm impacts and the importance of subsidence on the Mississippi River delta plain, Louisiana, USA. 52nd NGMSO Lecture Series, University of Utrecht, The Netherlands.

Stone, G.W. and P. Wang. 1999. The importance of cyclogenesis on the short-term evolution of Gulf Coast barriers. Gulf Coast Association of Geological Societies, Lafayette, LA.

Stone, G.W., P. Wang and D. Pepper. 1999. Importance of hurricanes, tropical storms and mid-latitude cyclones on the short-term evolution of Gulf Coast barriers: the impact of Hurricane Camille: A Storm Impacts Symposium to Mark the 30th Anniversary, New Orleans, LA.

Stone, G.W., P. Wang and X. P. Zhang. 1999. Development of a wave-current information system for Louisiana bay-shelf environments. Estuarine Research Federation'99, 15th Biennial International Conference, New Orleans, LA.

Pepper, D.A., G. W. Stone P. Wang. 2000 A preliminary assessment of wave, current, and sediment interaction on the Louisiana shoreface adjacent to the Isles Dernieres. *Recent Research in Coastal Louisiana*: 35-45.

Pepper, D.A. and G.W. Stone submitted to Geo-Marine Letters, 2001 Atmospheric Forcing of Fine Sand Transport on a Low-Energy Inner Shelf: South-Central Louisiana, USA

Pepper, D.A. and G.W. Stone 2001 Extratropical Storms in the Northern Gulf of Mexico: Their Characteristics and Importance to Coastal Processes: Presentation to the American Meteorological Society: Central Louisiana Chapter, Baton Rouge, LA (invited).

Pepper, D.A. and G.W. Stone in preparation Hydrodynamic, Bottom Boundary Layer and Sedimentary Responses to Two Contrasting Winter Storms on the Low-Energy Inner Shelf of the Northern Gulf of Mexico.

*P.I.'s affiliation may be different than that listed for Project Manager(s).