ACCESS NUMBER: 30660-19917

STUDY TITLE: Coastal Marine Environmental Modeling

REPORT TITLE: Coastal Marine Environmental Modeling

CONTRACT NUMBER: 14-35-0001-30660-19917

SPONSORING OCS REGION: Gulf of Mexico

APPLICABLE PLANNING AREA: Gulf of Mexico

FISCAL YEARS OF PROJECT FUNDING: 1994-1997

COMPLETION DATE OF REPORT: September 1998

COSTS: FY 1994: $91,582; FY 1995: $64,096; FY 1996: $77,164; CUMULATIVE PROJECT COST: $232,842

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KEY WORDS: Louisiana estuaries; Gulf of Mexico; numerical simulation; transport; dispersion, mixing; coupled hydrodynamic-ecological modeling; Terrebonne/Timbalier Basin, Barataria Basin, Fourleague Bay

BACKGROUND: Estuaries are important coastal features, world-wide. Uses of these coastal systems present potentially conflicting demands, often requiring management based on extensive monitoring. One cost-effective alternative to extensive monitoring is modeling. Some monitoring is still required to calibrate the models, define forcing functions and boundary conditions and skill assess the model's usefulness, but the resulting savings over the cost of a complete monitoring program should be significant.

Louisiana's bar-built estuaries are broad and shallow with mean depths of only a meter or two. Tidal currents and local wind have significant impacts on these estuaries. Management decisions concerning these environments concern the dominant physical processes, sediment erosion, transport and deposition, eutrophication, and recruitment to the estuarine nursery grounds, among others. Arguably the most accurately modeled, at this time, are the physical processes. To date, though, no one has developed a modeling framework for these systems which has been carefully calibrated, skill-assessed and applied to practical problems.

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OBJECTIVES: This study is designed to examine detailed physical characteristics of estuaries in coastal Louisiana using a modeling approach, and to identify a class of models which can be used to study the environmental characteristics of these estuaries. Circulation, transport and flushing characteristics in two significantly different estuaries, Terrebonne/Timbalier Basin (a sediment-starved, low-runoff environment) and Barataria Basin (an estuary with an extensive network of small creeks and channels in the upper basin), are examined using a depth-integrated, two-dimensional numerical hydrodynamic model. Utilization of realistic forcing functions together with relatively fine model grid resolution, and a process of careful calibration and skill assessment of the hydrodynamic model against field observations form the core of this modeling study. Upon the successful application of the hydrodynamic model, it is coupled to an ecological model to study primary productivity in Fourleague Bay, an estuary significantly impacted by the nearby Atchafalaya River.

DESCRIPTION: A two-dimensional, depth-integrated, barotropic, numerical hydrodynamic model is developed to simulate the circulation and transport processes in the shallow bays characteristic of coastal Louisiana. The hydrodynamic model is forced by realistic tide and wind. The model is calibrated against observed tides and currents. Relatively large bottom friction is required, possibly reflecting wave-current interactions. Despite the microtidal environment of the northern Gulf of Mexico, tidal currents are an important component of the current spectrum within the bay systems, even during equatorial tides. Local wind forcing is also important in controlling the general flow direction in the broad open reaches of the bay systems. Flushing time, estimated by a particle tracking technique, is in good agreement with previous estimates derived from tidal prism modeling. Flushing time increases dramatically as one moves into the slowly-moving, crenelated and highly interconnected waters of the upper basin in Barataria Basin. Horizontal diffusivities estimated using the tracer particles are comparable to those compiled by Okubo (1974) at similar length scales. The largest diffusivities identified appear to be due to efficient dispersion caused by coastal topographic trapping caused by coastline irregularities and islands. The hydrodynamic model has been successfully coupled to a new ecological model and the coupled model applied to Fourleague Bay. The ecological model, which includes suspended sediments, nutrients and phytoplankton, is able to simulate a phytoplankton spring bloom in the bay.

SIGNIFICANT CONCLUSIONS: The two-dimensional hydrodynamic model is suitable for application to the shallow, bar-built estuaries of coastal Louisiana. Portability has been demonstrated by the successful application of the model to simulate circulation and dispersion in three different systems - Terrebonne/Timbalier Basin, Barataria Basin, and Fourleague Bay. These applications involve forcing with observed winds and tides and calibration to observed currents and water levels. The model has been successfully coupled to a simple ecological model to demonstrate its ability to capture time and space scale variability in circulation which is important to the accurate prediction of ecological processes.

STUDY RESULTS: The following important results have been derived from this study; using topographic and bathymetric data available from historical maps and photographs; 1) water level can be adequately represented within the modeling framework, even in the upper marsh regions, 2) water currents are well represented in the open water reaches of the lower bay systems and qualitatively represented in the upper bay regions of these system; 3) horizontal diffusion coefficients estimated from tracking of synthetic particles with the model indicate diffusion coefficients which are comparable with those synthesized by Okubo (1974). The large values estimated result from coastal topographic trapping (trapping by coastlines and islands), indicating the necessity for highly accurate topography and bathymetry to achieve accurate dispersion predictions in these systems and; 4) when coupled with an ecological model, the hydrodynamic model is able to reproduce the observed characteristics and scales of an estuarine, spring phytoplankton bloom.

STUDY PRODUCTS: Inoue, M. and W. J. Wiseman, Jr. 1994. Coastal Marine Environmental Modeling. MMS 14th Information Transfer Meeting, New Orleans, LA.

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