



Wetland Engineering in Coastal Louisiana: Naomi Siphon

PURPOSE: This technical note describes a demonstration project for evaluating wetland restoration designs in coastal Louisiana. The goal of the demonstration project was to provide general insight into an alternative method for engineering creation and/or restoration of wetlands. Siphons are used to draw water and sediment from the Mississippi River into wetland zones that have been cut off from the river by flood levees. Siphons may offer an alternative for restoration of degraded freshwater marsh by providing water to counteract saltwater intrusion and sediments to restore freshwater wetland that is being converted to brackish marsh, salt marsh, and open water due to regional subsidence.

BACKGROUND: The Naomi Siphon is located approximately 20 miles (32 km) below New Orleans on the west bank of the Mississippi River, as shown in Figure 1.

The wetlands of coastal Louisiana are the result of the interaction of the Mississippi River with the Gulf of Mexico. The lower Mississippi River has experienced several major changes in course over the past 7,000 years. The wetlands west of the current Mississippi River route to the Gulf have experienced dramatic rates of wetland conversion to open water in recent years (Britsch and Dunbar 1993, Dunbar and others 1992). This is due primarily to reduced sediment supply to the area and the effects of subsidence. Additionally, enlargement of open-water areas leads to greater saltwater intrusion, stressed freshwater vegetation, and increased erosion due to wave action (Boesch and others 1994).

The precise underlying contributions to and rates of subsidence are a matter of debate. Some investigators emphasize the natural processes of river deltas and view human activities as secondary. Others emphasize contemporary human intervention as the primary cause of subsidence (for example, oil and gas extraction). In any case, it is generally accepted that a decrease in supply of sediment to coastal Louisiana wetlands is a significant factor in the accelerated degradation being observed. It has been documented that a significant part of this decrease in sediment supply is due to soil conservation techniques in upstream watersheds and the effects of the levee system along the Mississippi River through Louisiana (Kesel 1988, 1989). The loss of coastal Louisiana wetlands has been dramatic for several decades. About 1,526 square miles (>3,950 km²) of wetland loss has been documented over the period 1930-1990 (Boesch and others 1994). One author has calculated the current rate of loss of wetlands in the Barataria Basin at 2 percent per year (Britsch and Dunbar 1993). This compares with the 0.4 percent per year overall loss rate for the entire Mississippi Deltaic Plain.

CONCEPT OF SIPHON: The purpose of the Naomi Diversion Siphon is to divert water and associated nutrients and sediments from the Mississippi River as a means of wetland conservation and restoration. The diverted river water is routed into an area of adjacent marshes that have been rapidly deteriorating as a result of saltwater intrusion and subsidence (Wetland Conservation and Restoration Task Force 1990). The location of the siphon structure is near the community of Naomi in Plaquemines Parish. The marshes adjacent to the Mississippi River on the west side are part of the Barataria Bay system.

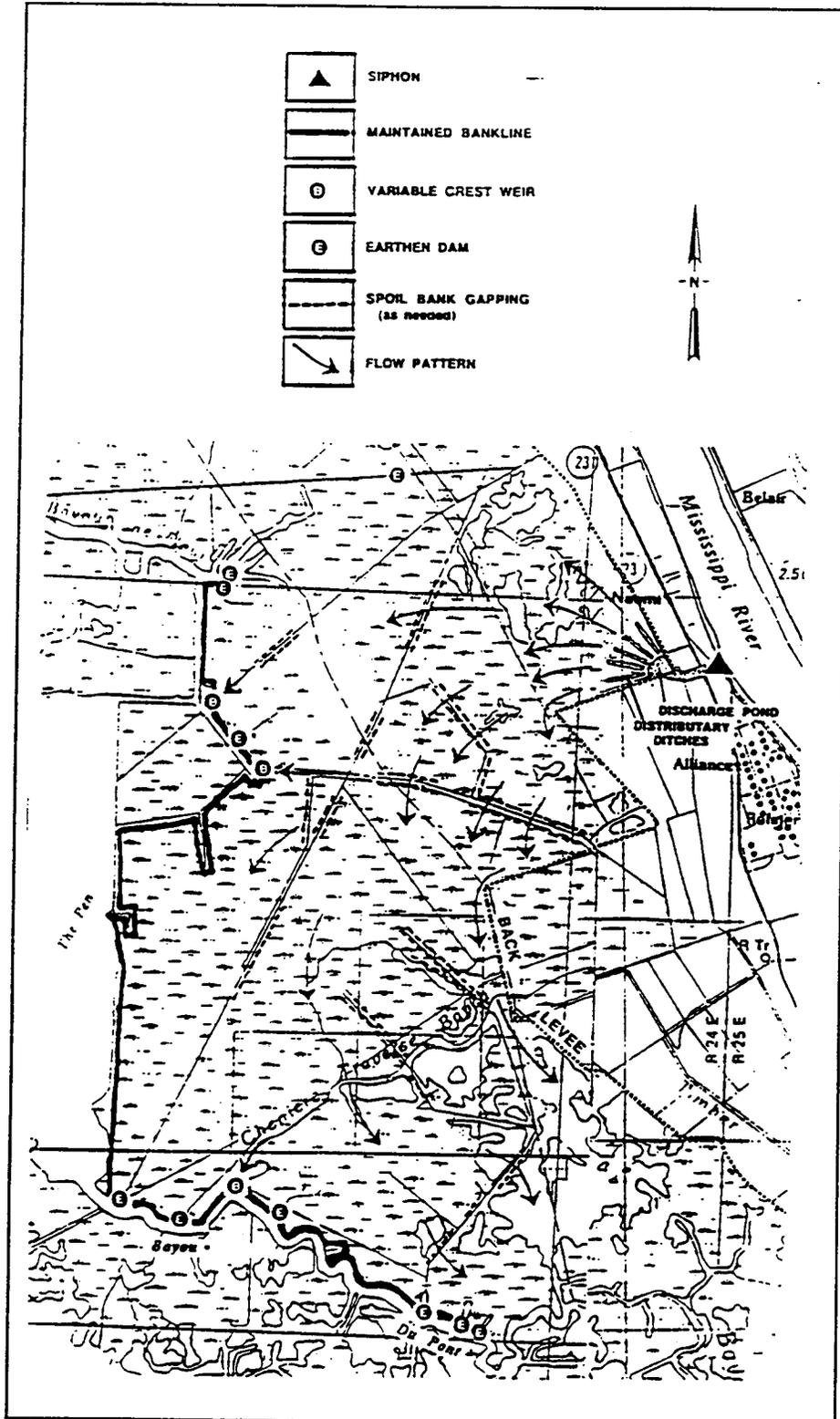


Figure 1. Site map showing location of Naomi Siphon

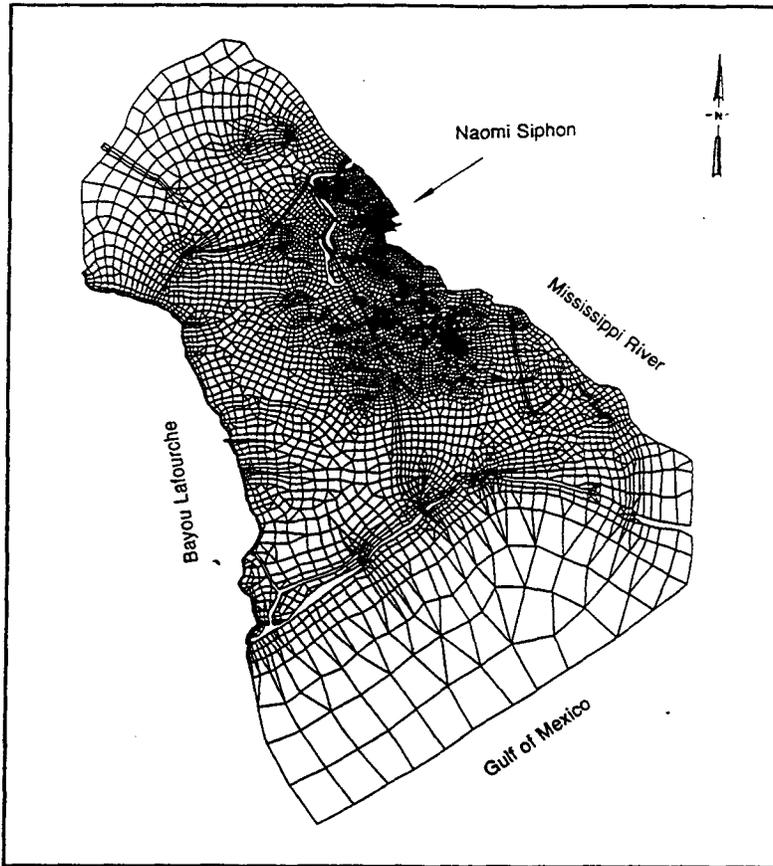
DESIGN OF SIPHON: The original siphon design called for eight 6-ft (1.8-m)-diameter pipes. These were constructed so as to route water from the river, over the river levee, under the roadways, and through a back protection levee to the marsh, a total distance of 2,750 ft (838 m). The design discharge for this battery of siphons is 2,400 cfs (68 m³/sec) during the spring high water on the river. The original design documentation predicted that sediment deposition would be enhanced over an area of 8,200 acres (33 km²) of marsh (Wetlands Conservation and Restoration Task Force 1990). The design called for an additional piping to increase the capacity to as much as 6,000 cfs (170 m³/sec). Also, a continuous bank line was constructed along a nearby lake, The Pen, and along Bayou Dupont in an effort to guide the discharge southward toward the most severely deteriorated wetland areas. Several control weirs were also constructed to allow diversion of some of the flow to the west. The goal of the placement of the siphon structure and the containment structures is to increase the residence time of the diverted waters.

ENGINEERING EVALUATION: The design of the siphon structure from an environmental point of view becomes a problem of sizing the capacity of the project. In turn the sizing of the capacity of the structure will be constrained by the hydraulic conditions posed by the river in the form of the driving hydraulic head and its variability over a typical year. However, more important is the establishment of the size of the domain to be contained as the receiving basin for the diversion, as defined by the location of the auxiliary containment structures. Most important is the establishment of the expected response of the receiving basin, for the salinity regime and sedimentation environment. Simplistic techniques for estimating the response of the system often fall short because of the complexity of the geometry and driving forces. The technique demonstrated in this study was the development of a comprehensive numerical model of the entire Barataria Bay system capable of directly simulating the response to the Naomi Siphon within the surrounding wetlands. The numerical model demonstrates the ability to define the response zone of the basin in terms of salinity and sedimentation response as a function of the discharge of the siphon.

MODELING APPROACH: The TABS-MD numerical modeling system was used to compute water levels, flow velocities, and salinities over the finite-element mesh shown in Figure 2. The TABS-MD system is a U.S. Army Engineer system of two-dimensional (depth-integrated) numerical models and associated user interface programs (Thomas and McAnally 1990). These computer programs have been used successfully by the Corps and other investigators to model a wide variety of riverine and estuarine systems.

The hydrodynamic model RMA-2 computes water levels and flows using a finite-element method to obtain an approximate solution to the Reynolds form of the Navier-Stokes equations. The transport model RMA-4 solves the convection-diffusion equation for constituent transport using the same numerical method and employing flow velocities and depths from RMA-2. Both RMA-2 and RMA-4 were developed under contract by Resource Management Associates of Suisun City, CA, and modified by the Waterways Experiment Station for use in the TABS-MD system.

SIMULATION DESIGN: The development of the computational mesh for the study used information from a wide range of sources; topographic charts, land loss maps, navigation charts, and other data sources were compiled to define elevations over the system. This information was digitized and organized by 15-min quadrangle and provides a digital terrain map of the majority of lower coastal Louisiana for use in future studies.



The computational mesh shown in Figure 2 was generated from these digital terrain maps with the extensive resolution needed to define the majority of significant channels through the Barataria Bay system. The mesh has 35,780 nodes and 12,591 elements. Even with this high level of resolution, the size of the system being modeled required that many features be schematized. The highest levels of resolution were assigned to the zone near the location of the siphon (see Figure 3). The modeling approach includes a method of describing the geometry of the wetlands statistically over subelemental spatial scales (Roig 1995). The technique, often referred to as marsh porosity by Corps modelers, allows for incorporation of the effects of the myriad of small tidal channels without their being explicitly resolved in the mesh.

Figure 2. Finite-element mesh of Barataria basin

The numerical model has the flexibility to apply any combination of boundary forcings appropriate. These include gulf tidal conditions, local rainfall, upstream runoff via Bayou Des Allemands, wind conditions, and siphon diversion flows, including a no-flow "existing" condition as a baseline for comparison of siphon diversion effects.

HYDRODYNAMIC RESPONSE: For the demonstration simulation, a repeating 2-ft (0.6-m) diurnal tide range was applied at the Gulf of Mexico boundary of the model. The inflow from Bayou Des Allemands at the northwestern boundary of the mesh was set to a typical value of 10,000 cfs (283 m³/sec). A baseline simulation was made without any siphon diversion, and then siphon discharge simulations were performed with siphon flows of 2,400 and 6,000 cfs (68 and 170 m³/sec). The modeling procedure was designed to evaluate the impact of the siphon diversion on the

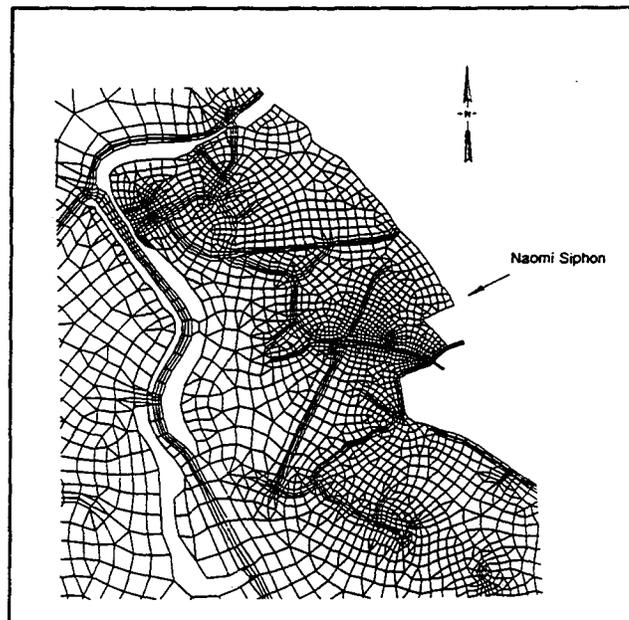


Figure 3. Inset of finite-element mesh showing location of Naomi Siphon

far field, and the model resolution was not included to address near-field detailed initial mixing at the point of discharge from the siphon pipes. Consequently, the diversion was modeled as a mass loading within a single element at the general siphon location.

The hydrodynamic response of the model matched the observed field behavior. The tide range is reduced significantly as the tides propagate up through the wetlands to as low as 0.5 ft (0.2 m) in Lake Salvador. The influence of the diversion siphon on current velocities is not readily visible except for immediately adjacent to the outlet location. When the siphon flows are incorporated within the baseline tidal flows, their influence is barely discernible. The barrier islands forming the southern side of Barataria Bay allow tidal incursion through only a limited number of inlets, resulting in the strongest tidal currents localized in those inlets. Figure 4 presents the currents in the vicinity of the barrier island inlets.

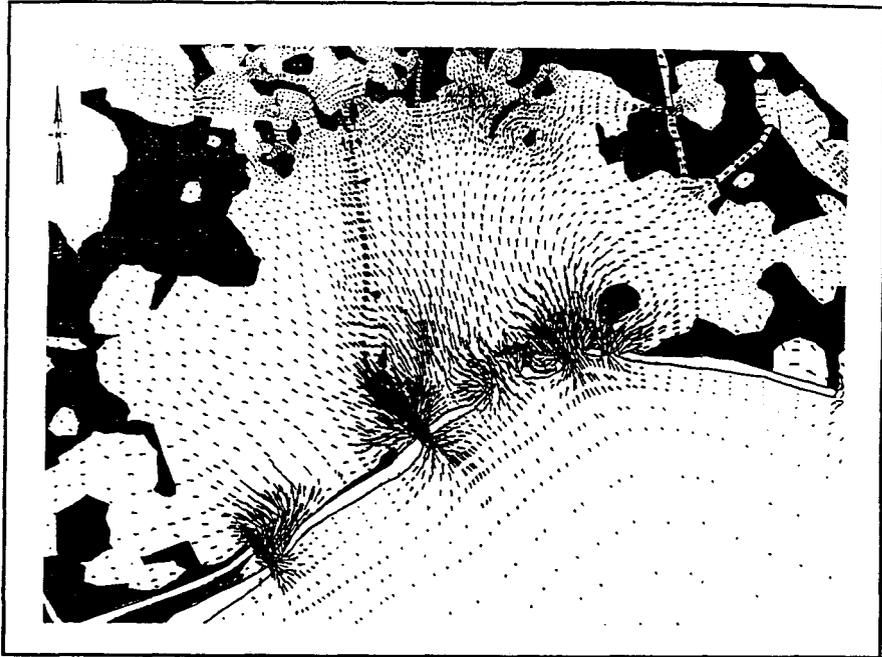


Figure 4. Peak flood currents in lower Barataria Bay

SALINITY RESPONSE: Salinity intrusion demonstration simulations were performed for each of the hydrodynamic conditions described above. The salinity simulations were performed using RMA-4 with the hydrodynamics provided from RMA-2, as described above. For all simulations, the same initial salinity distribution field was assigned to the system. That salinity distribution was derived from a limited amount of field salinity data, using the numerical model itself to interpolate the salinities over the entire computational mesh. As the individual simulations proceed, any subtle differences observed are directly associated with differences in the discharge level from the siphon.

As a baseline for comparison, Figure 5 shows the isohalines at hour 25 in the tidal cycle for the overall model with no diversion flow from the siphon. This salinity distribution was found to be a reasonable reproduction of that actually observed in the field. Figures 6 and 7 show the isohalines that result from modeling 2,400 cfs and 6,000 cfs diversions, respectively, through the siphon. Both of these figures show the salinity distribution predicted at hour 25 in the tidal cycle. These figures show isohalines in the vicinity of the siphon. The only difference between the conditions for the model runs illustrated in Figures 6 and 7 is that of the 2,400- versus 6,000-cfs diversion. The difference in isohaline patterns between these two simulations can therefore be attributed to the diversion alone.

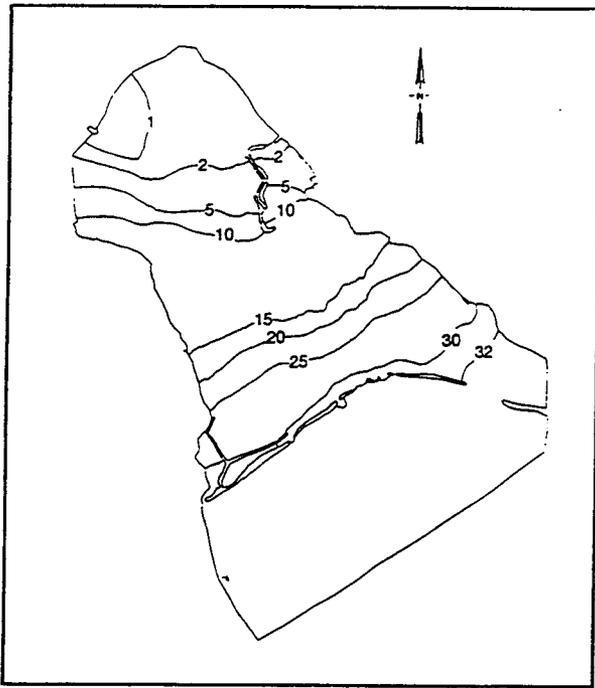


Figure 5. Isohalines in Barataria basin at hour 25 with no diversion

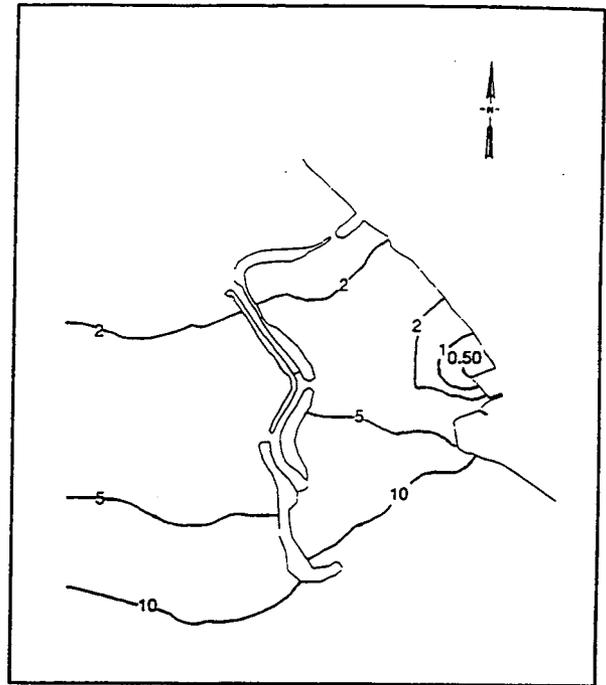


Figure 6. Isohalines in vicinity of Naomi Siphon at hour 25 (2,400 cfs)

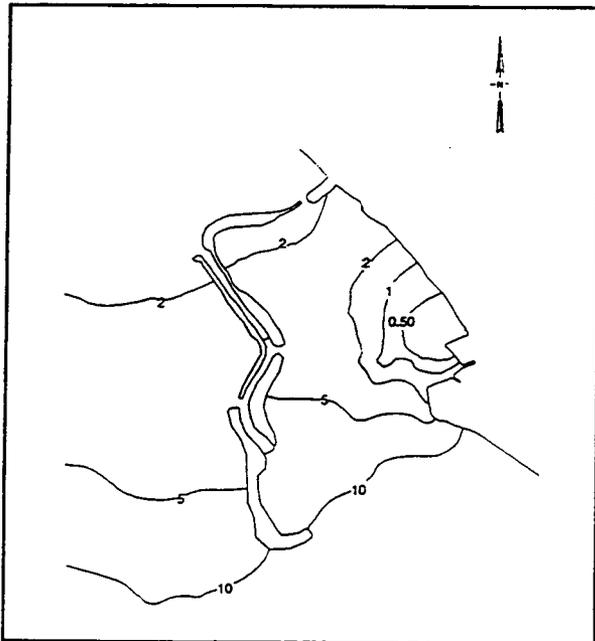


Figure 7. Isohalines in vicinity of Naomi Siphon at hour 25 (6,000 cfs)

The influence of the diversion on the salinity levels is very subtle, with progressive movement of the isohalines southward as the diversion flow is increased. The isohalines shown in Figure 6 indicate that the higher flow diversion is causing the water to become somewhat fresher in the vicinity of the siphon. These results illustrate the limited zone of significant influence of the specified diversion relative to the vast expanse of the Barataria Bay system and the magnitude of the problem faced for the basin as a whole.

CONCLUSIONS: The results of the simulations shown are reasonable. The figures show isohaline patterns that resemble what would be expected to occur in the vicinity of the freshwater discharge of the siphon. Specifically, the growth of the lower salinity area in the vicinity of the siphon suggests that the model is capturing the effect of the siphon with regard to local salinity reduction. It has been demonstrated that the numerical model has the potential to realistically simulate the hydraulic and salinity transport phenomena in Barataria Bay.

Furthermore, the zone of influence of the siphon diversion on salinities seen in the limited simulations performed for this demonstration project supports the appropriateness of the surface area delineated for containment of the receiving basin for the diversion flows.

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