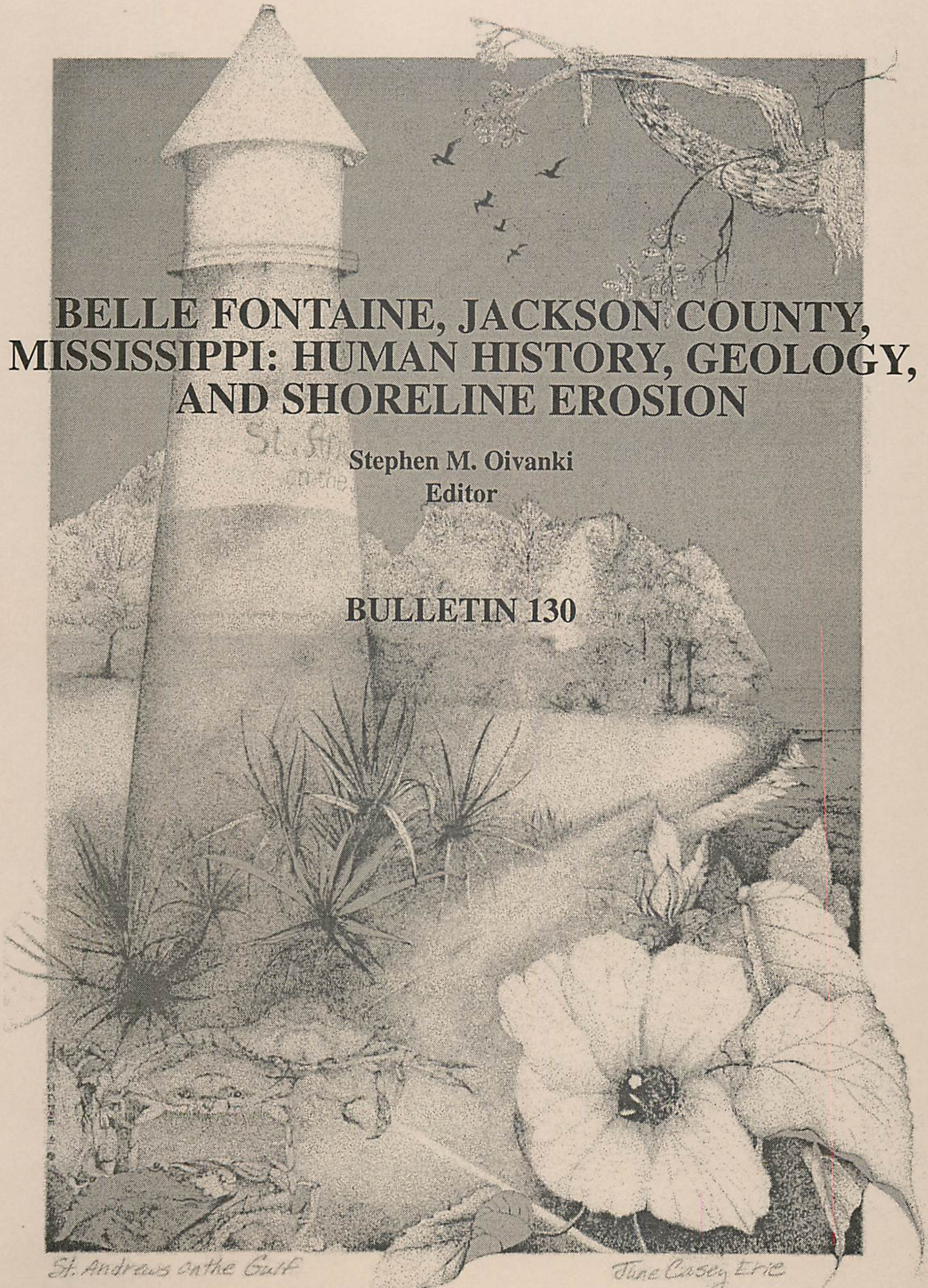
BELLE FONTAINE, JACKSON COUNTY, MISSISSIPPI: HUMAN HISTORY, GEOLOGY, AND SHORELINE EROSION

Stephen M. Oivanki
Editor

BULLETIN 130



MISSISSIPPI DEPARTMENT OF ENVIRONMENTAL QUALITY, OFFICE OF GEOLOGY

S. CRAGIN KNOX, Director
Jackson, Mississippi
1994

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Belle Fontaine, Jackson County, Mississippi: human history, geology, and shoreline erosion / Stephen M. Oivanki, ed.

(Mississippi. Office of Geology. Bulletin 130)

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2. Shore Protection--Mississippi--Jackson County. 3. Mississippi--History. I. Oivanki, Stephen M.

STATE OF MISSISSIPPI

DEPARTMENT OF ENVIRONMENTAL QUALITY

JAMES I. PALMER, JR.
EXECUTIVE DIRECTOR

July 15, 1994

Mr. R. B. Flowers, Chairman, and
Members of the Commission
Commission on Environmental Quality

Commissioners:

The Office of Geology is pleased to transmit to you Bulletin 130, entitled "Belle Fontaine, Jackson County, Mississippi: Human History, Geology, and Shoreline Erosion," edited by Stephen M. Oivanki of my staff.

This publication is the culmination of a co-operative, multi-year study of the Belle Fontaine area by the Office of Geology and the Department of Marine Resources to determine the human history and development of the area, its geology, and the causes of and possible solutions to the coastal erosion problems there. The papers included in this publication will provide a valuable resource for the citizens of the area and coastal planners in understanding and solving this and other similar erosion problems along the Gulf coast.

Respectfully submitted,

S. Cragin Knox
Director & State Geologist

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BELLE FONTAINE, JACKSON COUNTY, MISSISSIPPI: HUMAN HISTORY, GEOLOGY, AND SHORELINE EROSION

INTRODUCTION

Stephen M. Oivanki
Mississippi Office of Geology

The Belle Fontaine area is located on the gulf coast in Jackson County, Mississippi, between the towns of Ocean Springs and Gautier (see Figure 1). On a Mississippi mainland shoreline that is over 56% altered by seawalls, artificial beaches, harbors, and other development, the beach at Belle Fontaine is one of the few natural scenic areas on the Mississippi coast, and the only remaining natural beach on the Mississippi mainland. Since the mid-1850s, when the first reliable coastal maps were made by the U. S. Coast Survey, the Belle Fontaine area has shown a steady trend of erosion along the shoreline. Over the 136-year period from the 1850s to 1986 the area has lost 473 acres due to erosion of the shoreline. Since the first settlement at Belle Fontaine in the late 1600s the area has been developed into several communities with numerous homesites located along the shoreline. Continued erosion now threatens many of these homes with destruction.

I first became acquainted with the Belle Fontaine area in the mid-1960s, when my family visited for vacations during the summer months. At that time, prior to most of the development of the beach area, there were few roads and many opportunities to observe the natural beauty of the shoreline. A wide sand beach fronted most of the shoreline, and erosion was not a concern. Development was limited to only a handful of vacation homes scattered along the beach.

As more people became aware of this natural scenic landscape, development increased, and soon permanent dwellings were established and the shoreline gradually filled with homes. Hurricane Camille in 1969 destroyed all but a couple of these homes, but post-hurricane development again filled the shoreline with houses. As the houses provided a permanent reference for the shoreline position, erosion became more noticeable, and many residents began to express public concern about the problem. Since all of the shoreline is privately owned, public officials were limited in their response. Aside from placing riprap and fill to prevent access roads from being eroded away as the beach retreated, public aid to solve the erosion problem was not forthcoming. This report is designed to address the erosion problem at Belle Fontaine, and to provide some scientific basis for the residents there to enact shore protection measures which will have a reasonable chance of success.

The Mississippi Office of Geology, under a grant from the U. S. Geological Survey, and the Mississippi Bureau of Marine Resources, under a grant from the U. S. Environmental Protection Agency, initiated this joint research project to study the erosion problem at Belle Fontaine and to aid in future coastal management policy development along the coast. Several tasks are addressed in this report: Dr. Klaus J. Meyer-Arendt, a professor in the Department of Geosciences at Mississippi State University, was retained to document the history of human development and impacts in the area; the geologic history and framework of Belle Fontaine as well as the current physical setting were researched by myself and Dr. Ervin G. Otvos, the head of the Geology Section at the Gulf Coast Research Laboratory; Dr. Joseph N. Suhayda, a professor in the Civil Engineering Department at Louisiana State University, developed a physical processes model of the Belle Fontaine shoreline to predict future erosion and evaluate possible shore protection measures in response to processes predicted by the model; and Cathy Z. Hollomon, with the Mississippi Bureau of Marine Resources, provided a summary of coastal management policies and regulations in Mississippi as a reference for those who might be interested in pursuing some of the remedial suggestions in this report.

Field research for this report was conducted during the winter, spring, and early summer of 1992 and the first half of 1993. A wave meter was deployed by Joseph Suhayda from February 14th to May 3rd, 1992. Beach profiles, sediment sampling, and bathymetric surveys were done by the Office of Geology Coastal Section staff in April of 1992, and vibracores were collected in June 1992. A current shoreline position was measured with Global Positioning System (GPS) equipment in June of 1993. The Office of Geology will continue to monitor the area to document future changes.

This Bulletin is composed of four reports prepared by different authors for inclusion here. Each report deals with the individual authors' specialty field of interest concerning the Belle Fontaine area. The conclusions and suggestions presented in these reports are based on the best scientific evidence available; however, the reader is cautioned to use appropriate judgement and not rely solely on this report when attempting to remedy any of the erosion problems addressed here. It is hoped that this report will serve as a catalyst for future research and a basis for future efforts to preserve this area in as close to a natural state as possible.

ACKNOWLEDGMENTS

The research and results presented in this report were funded in part by grants from the U. S. Geological Survey and the U. S. Environmental Protection Agency. The con-

tents of this publication do not necessarily reflect the views and policies of the U. S. Government, nor does the mention of trade names or commercial products constitute their endorsement by the U. S. Government. Final drafts of the illustrations in this report were done by Barbara Yassin at the Office of Geology.

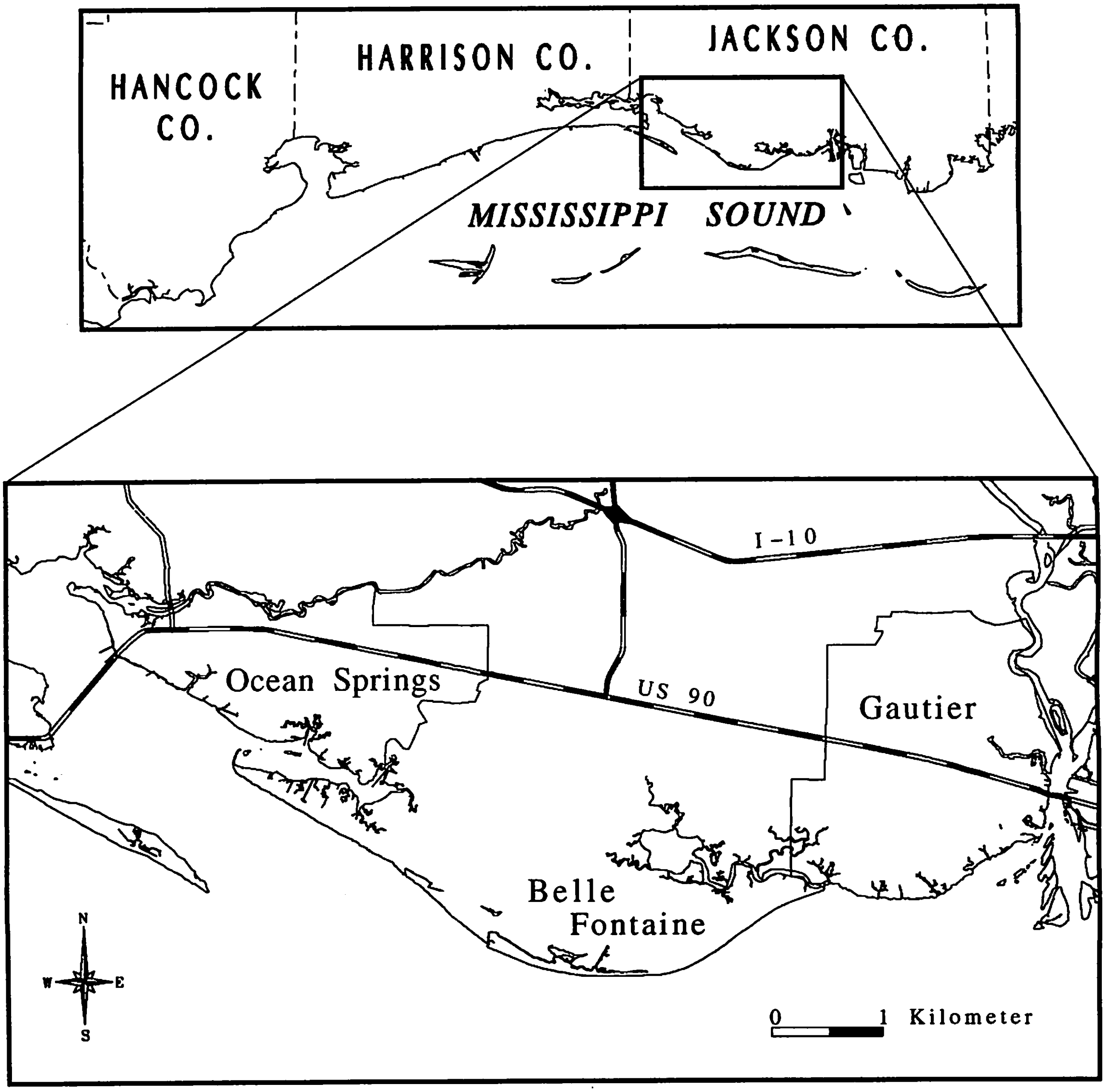

Figure 1. Belle Fontaine location reference map.

HUMAN SETTLEMENT OF THE "ISLAND OF BELLE FONTAINE," JACKSON COUNTY, MISSISSIPPI

Klaus J. Meyer-Arendt
Department of Geosciences
Mississippi State University

THE STUDY AREA

The "Island of Belle Fontaine" (a.k.a. the study area) comprises a convex-shaped landmass of marsh-fringed uplands approximately 9 miles long and 2.5 miles wide located between Ocean Springs and Gautier in Jackson County (Figure 1). The core of the landmass--perhaps 75% of the total surface area--consists of a barrier ridge complex which ranges from about 8 to 20 feet above sea level, and can readily be delineated by the +10 ft. contour. The beach ridge complex has been truncated by wave action at the eastern end, where a narrow sand beach occupies the base of eroded cliffs. More recent dune ridges over 10 feet high extend westward from this zone of truncation along the shoreline for about 3 miles. A low-elevation beach/dune complex, highly susceptible to erosion, extends northeastward to the mouth of Graveline Bayou. The name Belle Fontaine Beach is now used for the entire convex beach area of which Belle Fontaine Point marks the southernmost point. The western end of the beach ridge pinches off in a trailing spit which recurves northward into marsh (the eastern end of the Marsh Point peninsula). Historically, the westernmost beach ridges (Pointe aux Chênes) were fronted by a narrow strip of salt marsh, but over the past several decades waves have eroded the marshes and encroached upon the dunes directly. As a result of this erosion, a narrow beach has been created in this area as well as along the front of the highly erosive Marsh Point peninsula immediately to the west.

The "Island of Belle Fontaine" is separated from the "mainland" by a sinuous depression occupied by cypress swamp forest and brackish-to-saline marshes and drained by Simmons Bayou which empties westward into Davis Bayou, an embayment of Biloxi Bay, and Crossway Bayou, which drains eastward into Graveline Bay and on into Graveline Bayou and Mississippi Sound. In addition to the extensive wetlands flanking these waterbodies, tidal marshes are found north of the Belle Fontaine Point dune ridge complex and into the Marsh Point peninsula. Natural springs flowed profusely in numerous locations during historic times, especially along upland/wetland contact zones where aquifers discharged their flow. Although the original springs that gave rise to the name 'la belle fontaine' ('good fountain' or 'good spring') have long ceased to flow permanently, several lesser known springs, especially immediately north of the Simmons Bayou/Crossway Bayou depression, flowed freely until the 1980s (Lawton, personal communication, 1992).

The use of the geographic placenames of Belle Fontaine, Belle Fountain, and Fontainebleau has been a source of confusion. The original name of Belle Fontaine was adopted by Jean Baptiste LeMoyne, Sieur de Bienville (brother of d'Iberville) in 1719 during a move of the headquarters of French operations along the Gulf Coast from Mobile back to Biloxi. At the entrance to Biloxi Bay (incorrectly identified as Bay St. Louis) about 5 leagues WNW of Round Island, Bienville referred to the fountain of water that flowed from "the hills" as "the best water on the coast" (Bilbo, 1941). From Bienville's measured distance and geographic description, that location is identified as the present Pointe aux Chênes (Oak Point), from which spring water flowed freely to the beach as recently as the late 1920s (White, 1986). The name Belle Fontaine referred to Pointe aux Chênes throughout the 18th century, and references to a Baudreaux residence at the "presque isle" (peninsula or sand spit) called Belle Fontaine are numerous. (Because the Belle Fontaine uplands were surrounded entirely by marsh or water, the word "Ile" or island became used in conjunction with Belle Fontaine early in the colonial period.)

A second, and later, theory holds that the name Belle Fontaine stems from springs that flowed until the early 1900s at the zone of truncation, along present-day Belle Fontaine Beach, where an estate called Belle Fontaine was built in the 1890s (Walsh, 1937). In any case, the name Belle Fontaine subsequently became applied to the entire area south of the Simmons Bayou/Crossway Bayou depression, both in its French or Anglicized (Belle Fountain, Bell Fountain) forms.

The first significant Anglo settlement in the region (in the 1830s and 1840s, on the higher ground extending from Pointe aux Chênes to north of the Simmons Bayou/Crossway Bayou depression) was known as Belle Fountain. When the first railroad was built in the late 1870s (along the approximate route of the old Fort Road, which ran from Fort Louis in Mobile to Fort Maurepas in Old Biloxi), Belle Fountain became the first flag stop east of Ocean Springs. By 1892, a post office was established. Inspired by the town of Fontainebleau, France, as well as a variation of nearby Belle Fontaine, the name Fontainebleau was adopted for the post office by the community's first and only postmistress, Louise Richter (Hines, 1988). When the railroad built a depot the name Fontainebleau was used, and it soon replaced Belle Fontaine in referring to the entire region. The post office was closed in 1912 and the railroad station shut down in 1934, yet the name Fontainebleau remains on the map, mostly associated with the dispersed community astride the Old Spanish Trail (in 1918 the first motor road through the area) and U. S. Highway 90 (see Figure 1).

Subdivisions began appearing in the Belle Fontaine region in the 1950s, and today the western portion of the study area is increasingly being absorbed into a rapidly expanding Ocean Springs. The older regional toponyms (Belle Fontaine, Belle Fountain, Fontainebleau) increasingly are being replaced by subdivision names such as Gulf Park Estates and St. Andrews, and the placename Belle Fontaine now is used almost exclusively to refer to the Belle Fontaine Beach area.

ABORIGINAL OCCUPANTS

Little is known of Indian occupation of the Belle Fontaine region in the pre-European times. At the time of establishment of the first French outpost, Fort Maurepas in Old Biloxi (present-day Ocean Springs), in 1699 under direction of the authorized French-Canadian explorer/colonist Pierre LeMoyne, Sieur d'Iberville, Indians (whose name was interpreted as "Biloxi") were frequenting the coast to harvest abundant seafood resources, notably oysters (Sullivan et al., 1985). Initial European contacts were with three (and perhaps four) politically distinct Indian groups (not truly tribes, although they are often referred to as such) within a broader Choctaw cultural realm: the Bayougoula ("people of the bayou"), the Pascagoula ("bread nation"), and the Biloxi ("first people") (Kniffen et al., 1987; Sullivan et al., 1985; WPA, 1938). Except for the Bayougoula, who had entered the area on hunting expeditions from their home along the Mississippi River, the other two groups lived in a series of villages along the Pascagoula River about 12 leagues upriver from the mouth (WPA, 1938). Within two years of contact, the Biloxi had abandoned their village and moved westward. It is quite likely that any of the Indian groups or their cultural predecessors also frequented the Belle Fontaine region on hunting, fishing, or shell-gathering expeditions.

At least six known prehistoric Indian sites have been identified, although most are minor and are characterized by small shell or dirt middens and/or a small assemblage of tools, arrowheads, or fragments of ceramic pottery. An interesting find was made along Belle Fontaine Beach in the mid-1980s when a "bucketful" of projectile points became exposed as a consequence of wave erosion of the shore. The only prominent ceremonial midden complex is found at Pointe aux Chênes (although often incorrectly shown on maps to be elsewhere in the region) where two mounds were found to contain extensive potsherds of Tchefuncte age (Morgan, personal communication, 1992). Numerous areas, especially in the beach ridges, are potential Indian midden sites, but official archeological surveys have uncovered no more.

THE COLONIAL PERIOD, 1699-1810

Throughout the French (1699-1763), British (1763-1780), and Spanish (1780-1810) colonial periods (Sullivan et al., 1985) the Island of Belle Fontaine remained sparsely settled and most closely associated with a Jean Baptiste Baudreaux dit (French for alias, although "de" is sometimes substituted) Graveline, a colorful character who had several descendants of the same name and equally colorful disposition. This close association would form the basis of land claims following the acquisition of this territory by the United States in 1811.

On the second of d'Iberville's trips to what is now the Mississippi coast, in 1700, he was accompanied by about sixty Canadians, including a Jean Baptiste Baudreaux (alternately spelled Baudreau, Beaudreaux, Beaudreau, Baudro, Boudraux, or Budreau) dit Graveline (Giraud, 1974). Born into a wealthy merchant family in Montreal in 1671 and a well-to-do merchant himself at the time of his arrival in the new Louisiana territory, J. B. Baudreaux helped at Fort Maurepas and accompanied d'Iberville on explorations of the Indian settlements of the Pascagoula River. Employed by the French colonial government until 1701, Baudreaux was let go due to his "crafty buying and selling" (Higginbotham, 1977). By the time Ft. Louis was established near present-day Mobile, Baudreaux was a wealthy businessman who had built one of the finer homes in the city. Subsequent business ventures, including trading with Veracruz and acquiring ships to establish trade with Canada, got him into some trouble with French authorities, and in 1709 he moved to Massacre Island (Dauphin Island).

The enterprising Baudreaux imported "horned cattle" from Cuba to raise on the barrier island for subsequent sale to both the French as well as the Spanish at Pensacola (Higginbotham, 1977). By 1710, only sixteen residents lived on Dauphin Island, but by that time Baudreaux had built the "finest home in the colony" on the bay side, facing what is today called Graveline Bay. Baudreaux soon became regarded as one of the few merchants to profit from the French Louisiana colony (Higginbotham, 1977). By 1715, Baudreaux had obtained a French land grant (Sullivan et al., 1985) to "all lands between the Pascagoula River and Biloxi Bay, including the 'Ile de Bellefontaine'," although the original deeds were later not found. Apparently these lands, perhaps along with Horn Island, were used for grazing cattle (vâcherie) prior to 1718.

Because of the 1717 hurricane that destroyed the French settlement at Dauphin Island, Baudreaux moved his permanent residence to his west bank property by 1718. The main house was built on the bluffs above Lake Farragut, just south of Martin's Bluff (near the present-day westbound rest area of Interstate 10, where a historical marker has been erected). He had by that time two children, including Jean Baptiste Baudreaux II (about age 8) and Magdelaine. There

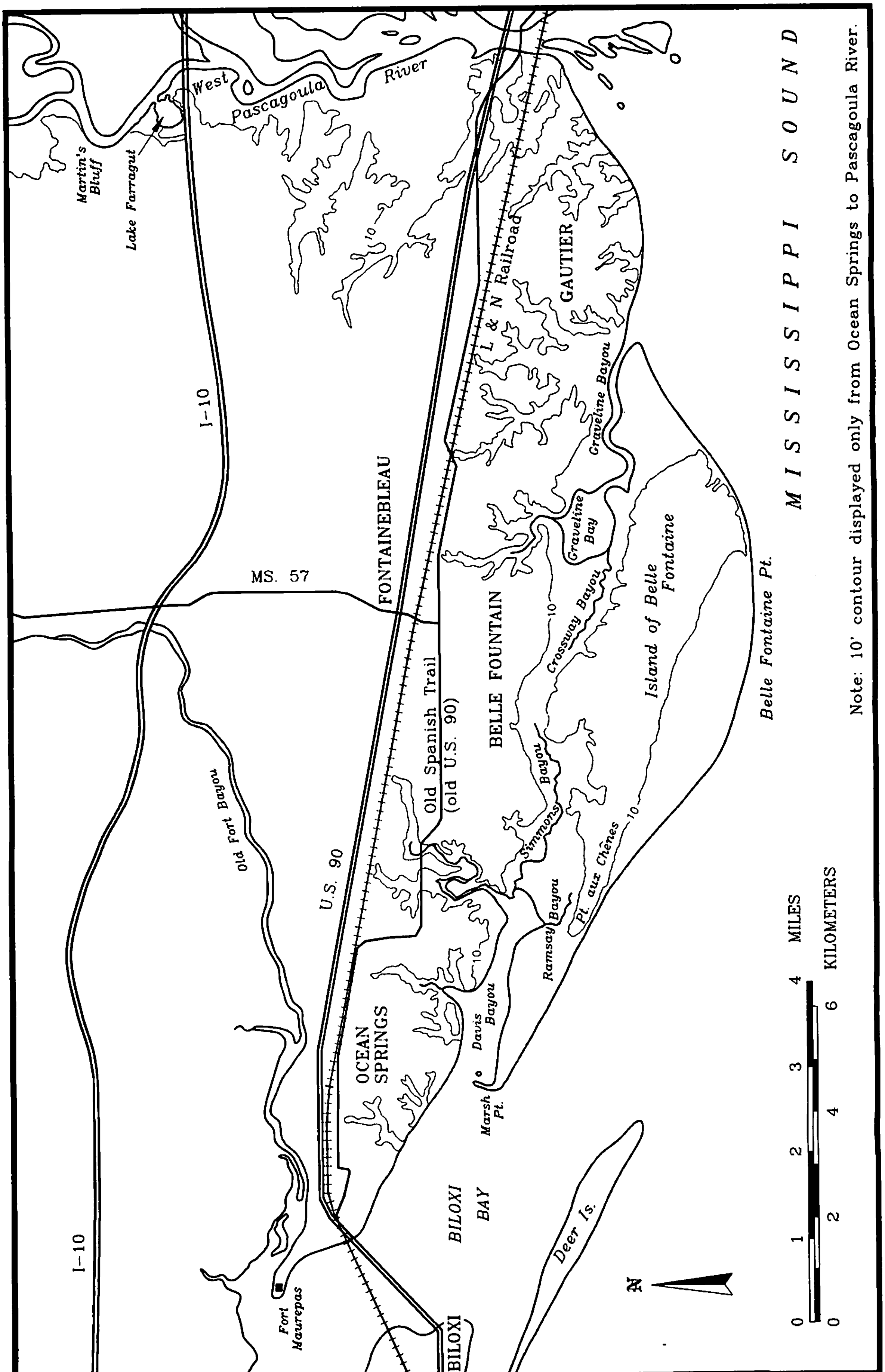

Figure 1. The Island of Belle Fontaine and vicinity.

is still debate as to the mother of Baudreaux II. In his will, dated 1750, the senior Baudreaux states that Baudreaux II was the result of an illegitimate union with an Indian woman (apparently the daughter of a Mactobi warrior, or "chief") whom he later married. However, Baudreaux had brought back a Protestant wife, Suzanne, from a trip to France in 1708. Allegedly pregnant soon after arrival at Dauphin Island, she died in 1713, and little more mention of child or children was made. In any case, Jean Baptiste II was the son of Jean Baptiste Baudreaux I.

After his 1734 marriage in Mobile (he was listed as a "Creole of Dauphin Island"), Jean Baptiste Baudreaux II and Mary Catherine Vinconneau settled on the west bank of the Pascagoula, near the home of his father. They had four children, including a Jean Baptiste Baudreaux III, born in 1736. Unlike the gentlemanly wheeler-dealer Baudreaux I, the son Baudreaux II was a lawless scoundrel who "drank too much, gambled, and was a libertine" (Adkinson, 1987). In 1752, Baudreaux II and his wife were divorced, and much of the common property was assigned to Mary Catherine. Also, the senior Baudreaux disinherited his son at about the same time, and a few years later, Baudreaux II was imprisoned and put to death for his part in the unlawful salvaging of a Spanish ship at Cat Island and a subsequent insurrection (MCHGS, 1983).

During the late 1700s, Mary Catherine Baudreaux amassed a considerable amount of real estate. Following the 1762 death of Baudreaux I at age 91 (the last survivor of the original colonists that arrived with d'Iberville), Mary Catherine and her children inherited the family lands along the Pascagoula as well as the adjoining Island of Belle Fontaine to the south. Although few formal French land grants were ever made, Mary Catherine Baudreaux petitioned the Spanish crown for formal title during the Spanish period (1780-1810, although Spanish West Florida was not a formal political entity until after the 1783 Treaty of Paris [Sullivan et al., 1985]). In 1781 she was granted Horn Island, and in 1786, in recognition of the previous French grants, Spanish land grants were awarded for 10,000 arpents of the Island of Belle Fontaine and 40,000 arpents on the west bank of the Pascagoula River. In addition to the grants, Mary Catherine bought much land near the mouth of the Pascagoula River, at present-day Gautier, where homes were subsequently built. Mary Catherine Baudreaux apparently maintained residence at various locations, including at the former home of her late father-in-law at Pointe aux Chênes on the Island of Belle Fontaine.

When the United States government took formal control of coastal Mississippi in 1811 (following a brief independence as part of the Republic of West Florida), the burden of proving ownership of Belle Fontaine and other family lands fell to Jean Baptiste Baudreaux III. Baudreaux III had a deep feeling for the land of his forebears and spoke fondly of his youth spent on the bluffs of the Pascagoula River and along the shining white beaches of Belle Fontaine (probably Belle Fontaine Beach rather than Pointe aux Chênes). Following the death of his mother circa 1790, Baudreaux III took over possession of the family property. However, in his petition to claim his land on the basis of both family occupancy and the Spanish land grants, the latter were not found. Several documents dated in the early 1800s attested to the Baudreaux claims.

The fight with the U. S. government dragged on for decades, and after Baudreaux III's death in about 1812, his son-in-law Edwin A. Lewis pursued the land claims on behalf of the heirs of Jean Baptiste Baudreaux. The 10,000 arpent Belle Fontaine property was claimed on the basis of: 1) French land donations, legitimized by the Spanish land grant of February 21, 1786, 2) no other prior inhabitation of or claims to the property, 3) historic use of the lands for cattle grazing, and 4) the existence of "several homes and dwellings" dating to the 1720s (Lewis, 1829). Although no maps of the period verify any actual houses on Belle Fontaine in the 1700s, circumstantial evidence does seem to indicate that at least seasonally occupied dwellings were found on the site. In his last will and testament of J. B. Baudreaux I, dated September 16, 1750, he listed his address as "la Bellefontaine at old Beloxy" (MCHGS, 1983). The Land Claims Office of the U. S. Government, not recognizing any Spanish land grants on the basis of insufficient documentation, nonetheless allowed the heirs of Jean Baptiste Baudreaux to petition for deeds to the property, but these petitions could be only for a maximum of 1280 acres (two sections of the township-and-range system, or two square miles).

THE EARLY AMERICAN PERIOD, 1811-1890

So far as determined by deeds on file at the Jackson County courthouse in Pascagoula, the Belle Fontaine land claims finally recognized by the United States government between the 1820s and 1840s consisted of multiple parcels assigned to various heirs of J. B. Baudreaux I, including E. A. Lewis and his son A. E. Lewis. These parcels include: 1) a 1238-acre piece of land containing Pointe aux Chênes and comprising the present Sections 9, 10, 11, and 14 of T.8S./R.8W. was awarded to the J. B. Baudreaux heirs (E. A. Lewis, agent), 2) Sections 3 and 4 of T.8S./R.8W. (comprising mostly the Marsh Point peninsula) was deeded to E. A. Lewis and a Mr. Krebs, 3) a 1226.35-acre piece containing the entire Belle Fontaine Beach and now identified as Section 19 of T.8S./R.7W. was awarded to J. B. Baudreaux, presumably J. B. Baudreaux IV, the son of J. B. Baudreaux III (in a letter dated Sept. 14, 1818, J. B. Baudreaux's sisters Marie Angelique and Margaret relinquished their inherited land claims to their brother), 4) a 1067-acre parcel consisting of most of Sections 7 and 8 and all of 17 and 18 of T.8S./R.7W. was recognized in 1824, 5) Section 13 of

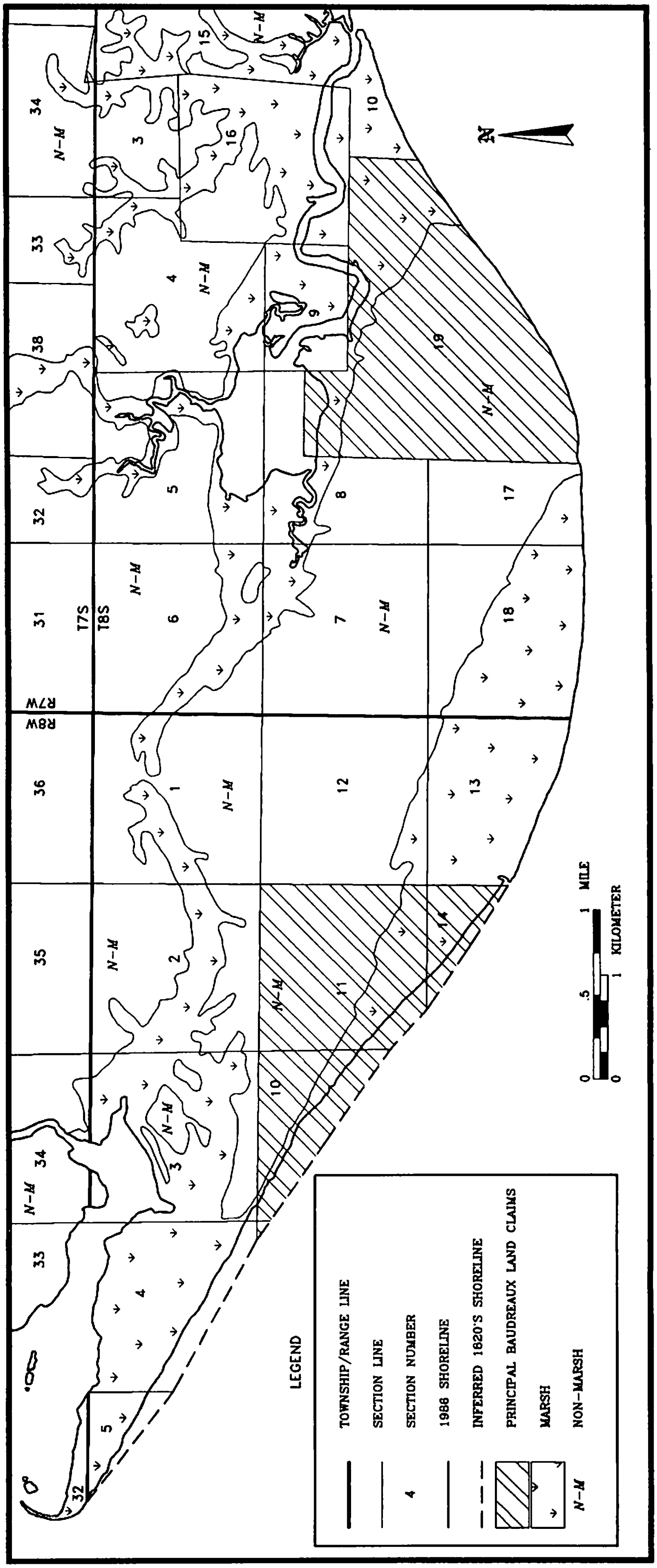

Figure 2. Survey sections on the Island of Belle Fontaine and vicinity.

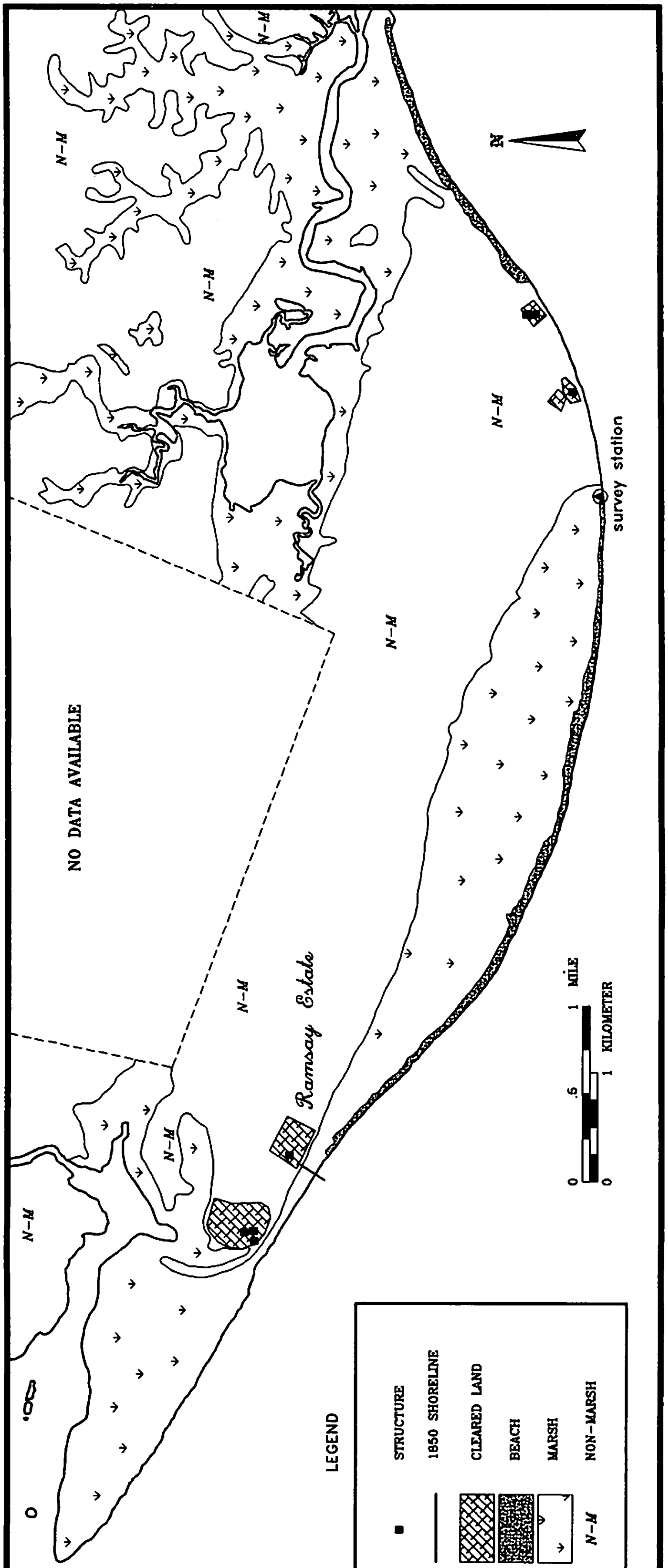

Figure 3. The Island of Belle Fontaine, 1851 (USCS, 1850-51).

T.8S./R.8W., a Baudreaux claim, was acquired by A. E. Lewis, and 6) Sections 1 and 12 of T.8S./R.8W., also a Baudreaux claim, were acquired jointly by A. E. Lewis and a Mr. McRae in 1854 (Figure 2).

The Island of Belle Fontaine was apparently used for little more than cattle grazing lands throughout the remainder of most of the nineteenth century. According to deed books at the Jackson County courthouse in Pascagoula, there was frequent turnover of property in the region, and increasing landownership by newer Anglo arrivals. In addition to E. A. Lewis, who had married Marguerritte Baudreaux and (at least temporarily) settled down on the Pointe aux Chênes family property, settlers by names of Ramsay, Davis, Webb and Bilbo moved into the region. The Ramsays bought property from Lewis and settled at Pointe aux Chênes, where they built a home and where their grave markers remain today (White, personal communication, 1992). The Bilbos, who settled along the Pointe aux Chênes Road north of Simmons Bayou, later built the Baptist church which they named Belle Fountain.

The only reliable large-scale map is the coastal survey map of 1850-51 (U. S. Coast Survey, 1850-51). Aside from two properties at Pointe aux Chênes containing houses and cleared land (the Ramsay estate and possibly a relict Lewis or Baudreaux structure) and two small houses along Belle Fontaine Beach (former Baudreaux properties?), few signs of other land use are evident (Figure 3).

Little is known of the Civil War and Reconstruction periods in the Belle Fontaine region, but the Louisville & Nashville Railroad, connecting New Orleans with Mobile, opened the region to potential development in 1870. By 1890, J. B. Lyon of Chicago, "a large landowner in five states," had purchased a tract of 93,000 acres in the area for purposes of lumbering and agricultural improvement. Somewhere near the springs of Belle Fontaine Beach, Mr. Lyon built a home, where his daughter Caroline remembered growing up (Walsh, 1937).

THE LAND DEVELOPMENT AND SPECULATION ERA, 1890-1950

Because of the railroad and a good national economic climate at the time, Mr. Lyon (and his Gulf of Mexico Land & Improvement Co., later incorporated into the Lyon Company) was able to bring prosperity to the Belle Fontaine area largely on the basis of lumbering and cattle grazing. It was during this time of increased commerce that the Fontainebleau post office (1892-1912) and the Fontainebleau train depot were established (Hines, 1988). (As stated earlier, this marked the beginning of the discarding of the names "Bellefontaine" and "Belle Fountain" in favor of the newer "Fontainebleau," especially north of the Simmons Bayou/Crossway Bayou depression.) Lyon apparently used most of his Belle Fontaine holdings as cattle range.

Lyon Company bookkeeper Robert W. Hamill (also a Chicagoan) married Caroline Lyon and continued to develop the region after J. B. Lyon's death in 1910. Between his acquisitions and his wife's inheritance, Hamill (and the Hamill Corporation) acquired 57,000 acres of the former Lyon property (Hines, 1988) and converted much of the cutover land to pecan, citrus, and tung (for tung oil) production. Also, general truck farming was begun, and even turtle farms were allegedly established to supply the demand for turtle soup, which was popular at the time. Most of the development and land use changes were in the vicinity of Fontainebleau, just north of the Island of Belle Fontaine, which still remained mostly cattle range. Exceptions include some pine lumbering and agricultural conversion (mostly pecan orchards) in the area just south of Simmons Bayou and limited exclusive residential development along the beaches of Belle Fontaine. In 1912 the Hamills built a new residence at the Belle Fontaine Beach springs (at the exact site of one of the structures shown on the 1851 map). The rambling Hamill Estate, named Belle Fontaine, consisted of 15 rooms and 9 fireplaces in addition to tennis courts and a nearby lodge for parties and out-of-town guests (Hines, 1988).

In spite of some grandiose plans, only limited construction took place on the Island of Belle Fontaine in the 1920s and 1930s. During the Roaring 20s, the Hamills contemplated improving the highway to the beach and developing a new townsite complete with a "modern hotel" (Anonymous, 1925). These plans never materialized, and a few years later the national economic depression led to financial ruin of the Hamill Corporation. Parts of the agricultural operations of Hamill Farms were reorganized as Fontainebleau Farms, of which a Henry Flateau was overseer in the 1930s. In 1929, the 2000-acre Pointe aux Chênes Estate was sold by the Ramsays and bought by an L. L. Cook, described as "a Chicago capitalist," and several associates (Walsh, 1937; White, 1992). In 1930, nine 15-acre lots were carved out of the giant tract as the Pointe aux Chênes Subdivision. One of these associates, the Chicago banker James Leavell, built a rambling pink stucco Spanish-style house called Doonesgate on the site of the old Ramsay house near the Indian mounds and the 19th-century graves of the Ramsays. Henry Flateau built a lodge, "a most delightful bachelor's retreat," at the water's edge near Doonesgate, where a pier jutted out into the sound (Walsh, 1937). Both Leavell and Flateau made significant improvements to their properties (Walsh, 1937), perhaps including the "oak alley" that was planted from Pointe Aux Chênes Road to the waterfront. Also, nearby marshes on the Marsh Point peninsula and south of Pointe aux Chênes were ditched in the early 1930s as part of a federal conservation project to reduce mosquito breeding grounds (White, personal communication, 1992; Figure 4). Flateau's home and pier succumbed to hurricanes, primarily the Hurricane of 1947, but

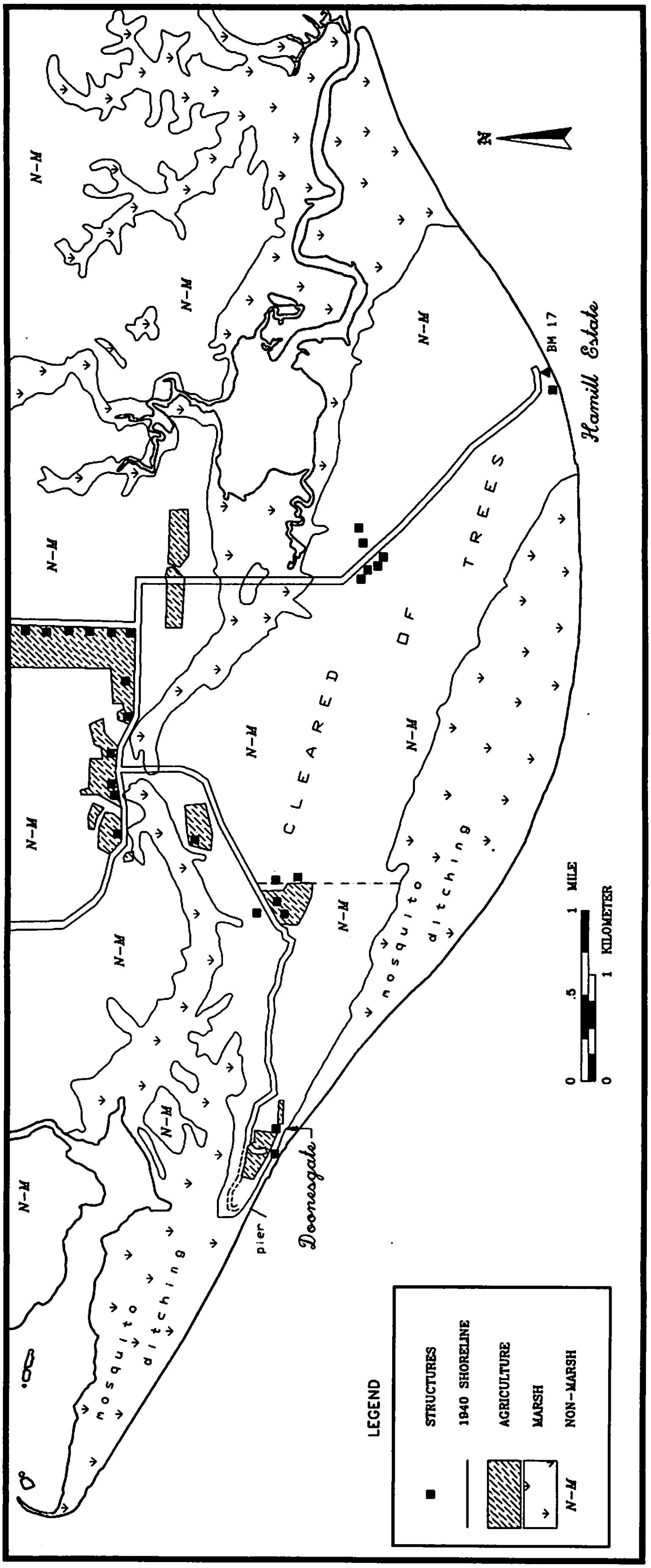

Figure 4. The Island of Belle Fontaine, 1940 (Tobin Research, Inc., 1940).

the decaying Doonesgate estate still stands.

The incipient regional affluence that began in 1890 had more or less ended by the early 1930s, because of both a major freeze in 1918 that wiped out most of Hamill Farms' citrus (satsuma) and vegetable farms and also the Great Depression that followed the infamous Stock Market Crash of 1929. Banks took over the property in 1934, and by the late 1930s they began cutting the remaining pine forests on Belle Fontaine, including the largest (at 3,000 acres) stand of virgin yellow pine in the state. A sawmill complex with several workers' cottages, operated by Barnes and Davis of Meridian, was constructed near the present site of the grocery store at the entrance to St. Andrews (Hines, 1988), and by 1940 most of the Belle Fontaine pine lands had been cut over (Tobin Research, Inc., 1940). One of the few properties not cut was the remnant 58-acre Hamill Estate property which still today remains under control of the Chicago-based Hamill Corporation (Germany, personal communication, 1992).

SUBDIVISION AND SETTLEMENT OF BELLE FONTAINE, 1950-PRESENT

Following World War II, land speculation and subdivision activity began anew, and this time the Island of Belle Fontaine witnessed a substantial change in patterns of settlement. After the first wave of pre-subdivision beach cottage construction began about 1950, real estate developers (individual as well as corporate) became aware of the demand for homesites on the Island of Belle Fontaine. They quickly set out to provide a supply, and most of the big tracts of land on the Island were subdivided by the later 1970s. Although demand existed for seasonal vacation homesites, the greatest demand was for permanent homesites. This was made possible by a greatly improved postwar economic climate, specifically the development of Pascagoula shipyards such as Ingalls and the growth of military bases such as Keesler Air Force Base in Biloxi. As both Pascagoula and Biloxi contained little open land for residential expansion, communities such as Ocean Springs and Gautier on the fringes of vast tracts of formerly productive farm land witnessed record levels of population growth and areal expansion. Belle Fontaine was well situated to attract increasing numbers of residents. The types of residential subdivisions that were developed after 1950 may be grouped into three broad categories: 1) beachfront, 2) suburban, and 3) golf-oriented.

Even before the first formal beachfront subdivisions appeared, several private individuals had acquired small parcels of property and built beach cottages, mostly along Belle Fontaine Beach immediately east of the old Hamill Estate. (The only other non-marsh beachfront real estate was at Pointe aux Chênes, but this was already subdivided into large, exclusive estates.) In 1951, a total of four cottages, or camps, faced the Belle Fontaine Beach (Germany, personal communication, 1992). In 1954, Bacot Beach was platted east of this small cluster of camps, and to the west of the present St. Andrews water tower/lighthouse, the elongate Belle Fontaine Beach Subdivision began Phase I of construction in 1956. The construction of mostly simple beach camps accelerated during the 1960s (up to 32 houses by 1970, according to the 1970 General Highway Map), at least until the onslaught of Hurricane Camille in 1969. Only three or four structures survived total destruction by this storm, including the now famous piling-reinforced 6-sided house just west of the St. Andrews water tower designed by Kaarlo Oivanki and owned by Mr. Bob Erie of Baton Rouge (Erie, personal communication, 1992). Although the hurricane temporarily slowed beachfront development, the final phases of construction in the Belle Fontaine Beach subdivision began in 1970, and soon bigger and fancier homes were being built. This trend has continued to the present day.

The second category of subdivision is classed as suburban. This is typified by Gulf Park Estates, a huge subdivision just east of Pointe aux Chênes, in which lots were first sold in 1958. Regarded as a southeastern extension of Ocean Springs (Beach View Drive was built to provide a more direct access road), Gulf Park Estates was essentially completely subdivided by 1968 and is today almost completely filled in with houses. One smaller subdivision to the east, Treasure Acres, was platted in 1967, but it remains undeveloped today. Also, the entire Section 12 of T.8S., R.8W. has been cleared of pine trees but it remains undeveloped. It is unclear whether this entire section is part of Gulf Park Estates. In any case, the land is not suitable for development without extensive drainage improvements. The old Pointe aux Chênes subdivision, which dates to 1930, may now be regarded as a high-class suburb, the residents of which mostly commute to jobs in nearby cities. A less successful suburban subdivision is West Ocean Beach Estates. Not as closely linked to a city (as Gulf Park Estates), the vast subdivision has experienced only limited residential construction. A newer (1973) subdivision, Pinehurst, has been more successful in terms of development.

The final category of subdivision is one oriented around a golf course. The prime example of that in the Belle Fontaine region is St. Andrews on the Gulf, which was first platted in 1978 just to the west of West Ocean Beach. Consisting of both residences and condominiums built around an 18-hole fairway, St. Andrews has been popular since it first opened, and the placename "St. Andrews" has almost replaced "Belle Fontaine" in popular usage. A second golf course, although not residentially oriented, is the Pine Island Golf Club built upon small upland outliers within the marsh just south of Simmons Bayou off of Beach View Drive. The westernmost outlier, west of the golf course, was platted as Banana Island Subdivision in 1976, but by 1992 only two homes had been built.

There are still subdivisions that have many vacant lots

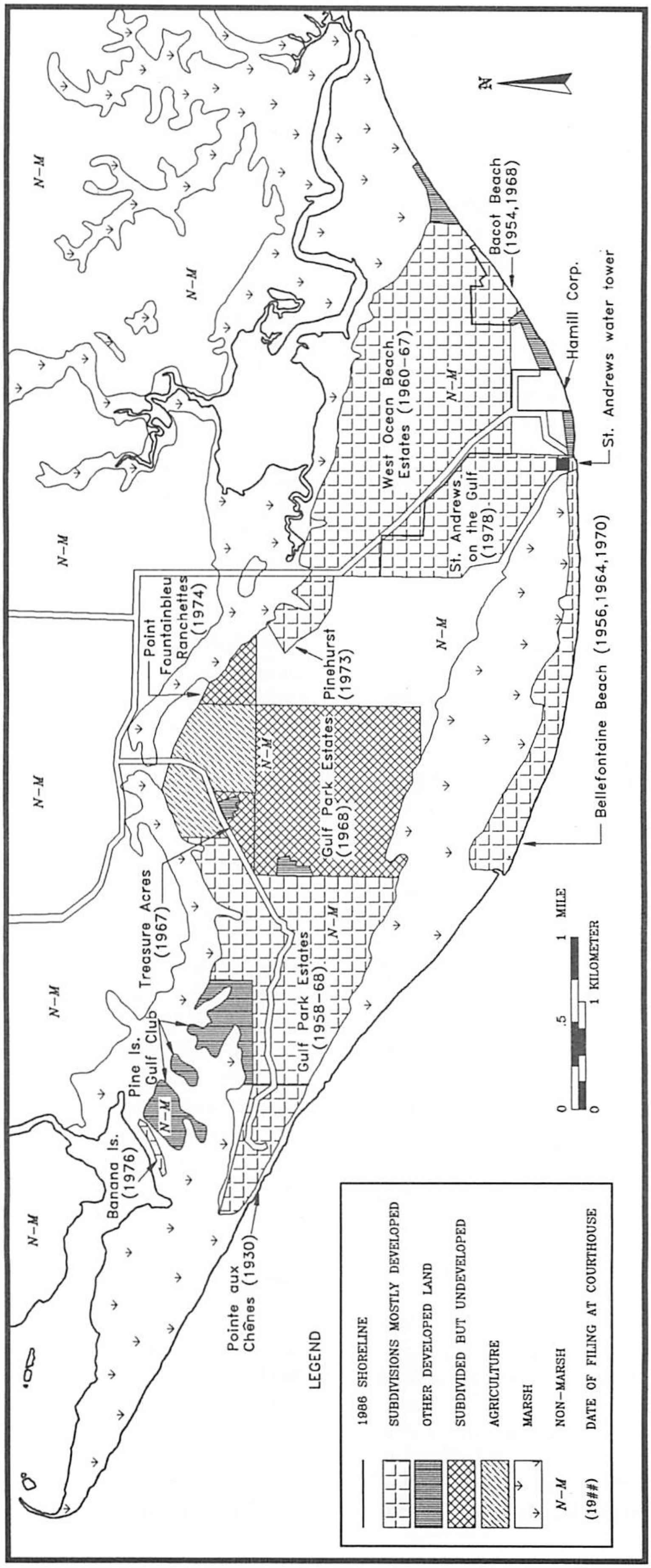

Figure 5. Subdivisions and land use on the Island of Belle Fontaine, 1992.

Shoreline Segment	Piers	Groins	Bulkheads
Pointe aux Chênes	9	8	6
Belle Fontaine Beach Subdivision	11	7	10
Belle Fontaine (east of water tower)	15	10	20
TOTAL	35	25	36

Table 1. Beach structures along the shores of Belle Fontaine.

(especially West Ocean Beach), and there is still much undeveloped land on the Island of Belle Fontaine. The greatest amount of growth in the early 1990s is still along the beachfront (along the western two-thirds of Belle Fontaine Beach Subdivision, the number of homes directly on the beach has increased from 10 to 38 over the past 10 years), but it is anticipated that even interior portions of the island will gradually fill in with houses as long as the Mississippi Coast economy remains relatively healthy.

HUMAN RESPONSE TO STORMS AND SHORELINE EROSION

The general erosive nature of the Belle Fontaine/Pointe aux Chênes shoreline, coupled with the human predilection for building homes along the beachfront, has stimulated much shoreline modification since Hurricane Camille struck in 1969. Prior to the storm, most beachfront structures were piers (used for fishing, boat docking, or partying), although a combination jetty/groin had been built at the western end of the Belle Fontaine Beach Subdivision. Since 1970 (and especially since 1982, the date of the most recent USGS topographic map), increasing numbers of groins and bulkheads have been built. The 1982 topographic map showed only 6 piers, 3 east of the St. Andrews water tower and 3 to the west. By 1992, a total of 35 piers were identified from 1) U. S. Army Corps of Engineers 1:24,000 color infrared photographs of 20 Jan. 1992, 2) oblique slides taken from rented aircraft in mid-Dec. 1991, and 3) field inspection on May 18-19, 1992. Also, a total of 25 groins (built to trap longshore-drifting sands) were identified, and at least 35 lots had been bulkheaded. In addition, about 1000 feet of riprap "bulkhead" have been built and backfilled at a public park south of Gulf Park Estates, where a public fishing pier now extends 400 feet into the Sound. If we divide the study area into three coastal segments, the distribution of these human modifications is as shown in Table 1.

While most of the shorefront of the Island of Belle Fontaine is eroding because of natural conditions, the human modifications also have contributed to the severity of the problem. Locally, individual groins have contributed to erosion of the downdrift property. Construction of bulkheads along naturally eroding (especially cliffed) shorelines temporarily reduces the potential supply of sand for downdrift beach nourishment. The greatest single negative impact appears to be the jetty/groin at the west end of the Belle Fontaine Beach Subdivision. At least 8000 feet of shoreline to the west of the groin have experienced accelerated erosion since the 1960s. This shoreline consists mostly of marsh, and except for the riprap/fishing pier construction at the public park, little development has been affected by this accelerated erosion.

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GEOLOGIC FRAMEWORK, EROSION HISTORY, AND PHYSICAL SETTING OF THE BELLE FONTAINE AREA

Stephen M. Oivanki
Mississippi Office of Geology

Ervin G. Otvos
Gulf Coast Research Laboratory

INTRODUCTION

Belle Fontaine, the only remaining natural beach on the mainland Mississippi coast, provides a unique opportunity for harmonizing man's desire to stabilize the shoreline with the natural processes that have shaped that shoreline. An understanding of the geologic framework of the area that has been modified in time to form the present setting provides insight into the geological processes active today. The geological history of this area from the Pliocene through the present time was reconstructed from cores and drillholes as well as from offshore seismic records.

Since 1970, the Gulf Coast Research Laboratory has recovered numerous drill cuttings and cores from the area, and 10 shallow vibracores (core numbers 1-10) were taken by the Mississippi Office of Geology in 1992 for this study. The U. S. Geological Survey drilled three continuous deep coreholes in the area in 1990. Conventional analyses of the granulometric and microfossil composition of the cores were performed at the Gulf Coast Research Laboratory. Shallow seismic surveys were conducted offshore of Belle Fontaine in 1991 and 1992 as part of a joint U. S. Geological Survey/ Office of Geology cooperative study. All of these data have been incorporated into the present account of the geologic framework.

Offshore bathymetric data of the area were collected by the Office of Geology, as well as nearshore beach profiles and sediment distribution along the beach and nearshore. Historical shoreline positions were reconstructed from U. S. Geological Survey and National Ocean Survey digitized T-sheets and recent aerial photographs. The purpose of this report is to present the development history of the Belle Fontaine area as completely as possible by using all available data. Our purpose was to understand the natural processes that have shaped the shoreline and aid in developing shoreline stabilization techniques which are in harmony with the natural evolution of the area.

GEOLOGIC FRAMEWORK

Undifferentiated Upper Neogene Sequence

The Pleistocene units of the Mississippi-Alabama coast are underlain by a maximum 900-1500 m (3000-5000 ft.) thick sequence of dominantly light and dark green-gray and gray muds and clays, and sandy mud and clay beds, interspersed with sand beds and gravelly sand zones. Marine Upper Miocene and Pliocene units are recognizable only in offshore Mississippi-Alabama and eastward beneath the Florida Panhandle coastal plain (Table 1). The sediment interval between the Lower Miocene and basal Citronelle unconformities was designated as the (expanded) Miocene-Pliocene Pensacola Formation (Otvos, in press). In the absence of stratigraphic means to subdivide the shallowest datable marine intervals (Middle and Upper Miocene) in southern Mississippi, previously employed Miocene and Pliocene formation names, such as the Hattiesburg, Pascagoula, and Graham Ferry, are used here (Table 1) as members of the Pensacola Formation (Otvos, 1994). When assignment of a certain sediment interval to the Pensacola is not feasible, the term undifferentiated late Neogene is being used instead (Otvos, 1985, 1988, 1991).

The Neogene units are better consolidated than the younger deposits. Recognizable lower Upper Miocene marine deposits under the coastal plain occur only in Harrison County (Otvos, unpublished data). The youngest datable, paralic-terrestrial (late Middle?-) late Miocene units contain discontinuous scattered lenses with the small, generally low-salinity bivalve *Rangia johnsoni* (Campbell and Otvos, 1992). The interval which contains this bivalve is not sharply defined by stratigraphic boundaries and readily identifiable in the subsurface. Named the "undifferentiated Late Neogene" (Upper Miocene-Lower Pliocene) interval by Otvos (1985), the landward portion of the Upper Neogene sequence was deposited mostly in various fresh water, alluvial environments. Interspersed thin brackish (estuarine) intervals are also common. The thick sandy horizons are artesian aquifers, suppliers of residential and commercial water for communities on the coast.

The likely Pliocene age of the upper part of the sequence (Otvos, 1988, in press) is also supported by the presence of *Pterocarya* tree pollen at 26.6 m (87.3 ft.) depth in the U.S.G.S. Belle Fontaine No. 1 drillhole. Dinoflagellate dinocysts of *Impagidinium fenestroseptatum* were found nearby in the U.S.G.S. Ocean Springs Police Dept. Corehole No. 1 in Ocean Springs at 51.2 m (168 ft.) depth, and in the U.S.G.S. corehole on Horn Island (Willard and Edwards, in press). The species has also been reported on two occasions from Lower Pliocene sediments elsewhere (Dr. Lucy Edwards, U.S.G.S., personal communication). Pliocene pollen spectra from Belle Fontaine and Ocean Springs corehole samples closely resemble certain local Mississippi

EPOCH	AGE	Ma	SEA LEVEL STANDS	GEOLOGICAL EVENTS / FORMATIONS
HOLOCENE			Gradual rise of sea level to current high	Formation of barrier islands, coastal sedimentation after c. 6 ka: Marine, fluvial, and lagoon deposits
		0.01		
PLEISTOCENE			Wisconsinan glacial record lowstand; low but rising since 18 ka	Time of non-deposition and erosion along whole Gulf coast
		0.08		
PLEISTOCENE			Sangamonian inter-glacial highstand (+6m)	Transgression and regression Prairie Fm. - alluvial complex Biloxi Fm. - inshore & offshore marine Gulfport Fm. -coastal barrier
		0.13		
PLEISTOCENE			not represented in Mississippi	Time of non-deposition and erosion in Mississippi
		?		
PLEISTOCENE			probably an early interglacial high	Alluvial deposits in Big Ridge terrace
		?		
PLEISTOCENE			not represented in Mississippi	Time of non-deposition and erosion on Mississippi coast
		1.6		
PLIOCENE	Calabrian		low sea level coastal uplift	Citronelle Fm. - regional alluvial deposition (redbeds), subtropical climate, time of regression
PLIOCENE	Piacenzian Zanclean		Numerous sediment cycles; low and highstands, alternating fluvial, deltaic, estuarine sediments	Upper units of Pensacola Fm. (Graham Ferry muds and clays), paralic and terrestrial deposition, no marine beds in Mississippi
		5.3		
MIOCENE, Upper	Messinian		major lowstand numerous sediment cycles	Middle units of Pensacola Fm.(Pascagoula member) deltaic, estuarine, and alluvial deposits
MIOCENE, Upper	Tortonian		marine highstand in lower Tortonian	
		10.0		
MIOCENE, Middle	Serravallian		regression, numerous sediment cycles	Lower intervals of Pensacola Fm. incl. regressive Amos sand member
MIOCENE, Middle	Langhian		major marine high-stand, peak of transgression in lower Serravallian	Inner-to-outer neritic marine deposition
		17.0		

Table 1. Stratigraphic sequence of Mississippi Coast region.
(from Otvos, 1994) (Ma=million years)

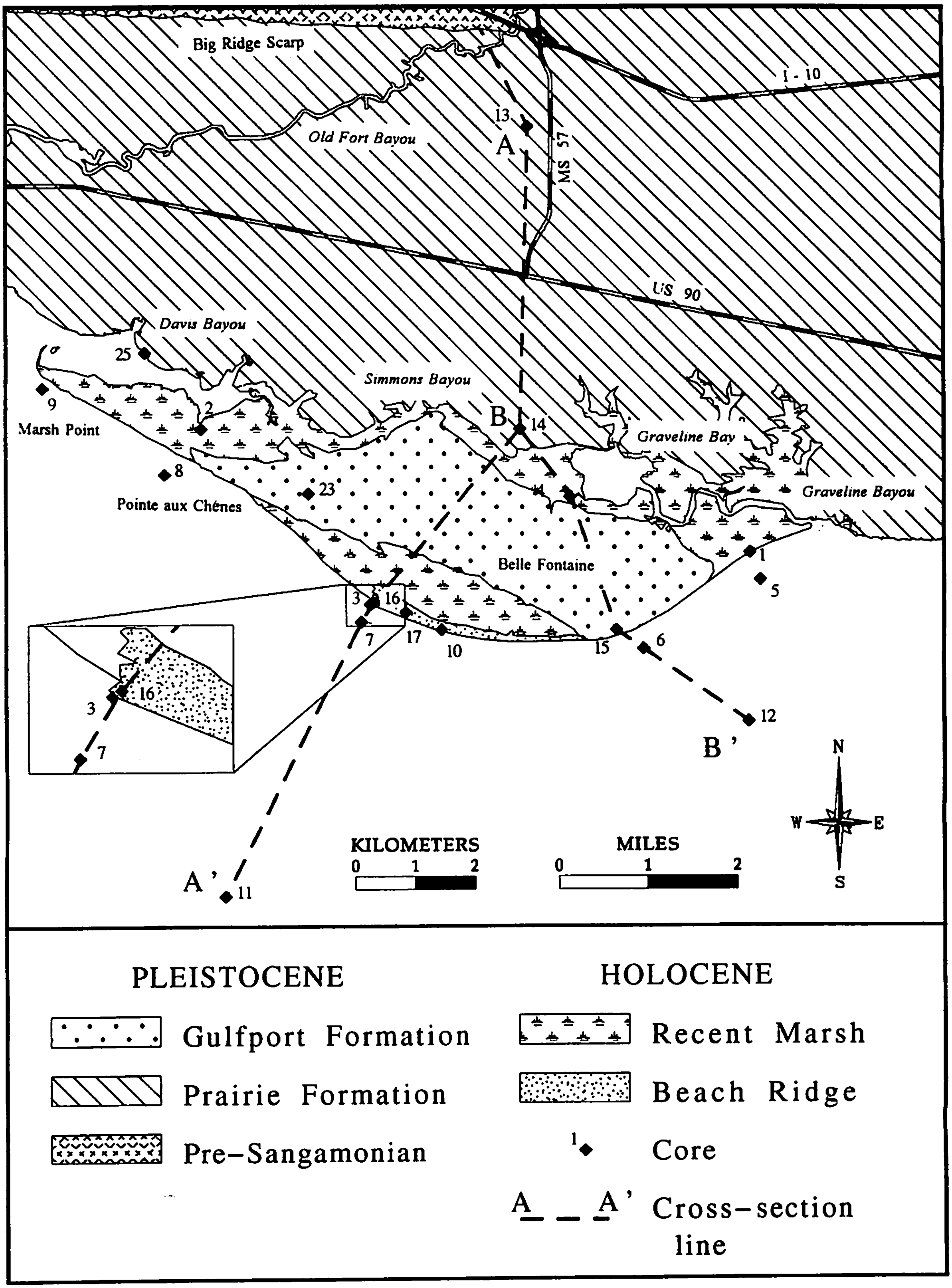

Figure 1. Geologic map of the Belle Fontaine area. (Cross section locations for Figures 2 and 3)

and Atlantic coastal assemblages, with oak and pine as the most common taxa (Willard and Edwards, in press).

In the coastal uplands area, above elevations of approximately 9-15 m (30-50 ft.), the terrestrial-paralic Pliocene beds are overlain by alluvial Citronelle Formation beds across a sharp unconformity. The Citronelle consists of orange-red, occasionally gravelly, silty-sandy redbeds that were deposited in coalescing flood plains under warm, perhaps subtropical, climate conditions. Petrified logs are often eroded from the Citronelle beds into present creek beds. The Citronelle Formation and its bounding summit plain occur several miles north of the Belle Fontaine area and extend far north, as well as into coastal Louisiana and Alabama.

Early Pleistocene Alluvial Unit

Big Ridge Scarp, a 5-6 m (16-20 ft.) high, 20 km (12.4 mi.) long, seaward-facing feature in Harrison and Jackson counties, probably formed along a long-inactive fault (Otvos, 1985). It is located just south of the Interstate 10 highway at Highway 57, from where it runs westward north of Biloxi Bay and the Back Bay of Biloxi, past Ocean Springs. The Scarp separates a higher coastal surface to the north from the Sangamonian Prairie surface, coastward, north of the Belle Fontaine area (Figure 1). The higher surface lies approximately 6-7.5 m (20-25 ft.) above the adjacent Prairie land surface.

The Pleistocene unit north of the Scarp consists of silty-sandy stream overbank deposits, including peaty-woody lenses in organic-rich clays, with cones of yellow pine and branch fragments, probably relics of ancient stream logjams. The flora is similar to the extant flora of the area, indicating climate conditions not unlike those present today (Otvos, 1985, in press). The terrace surface and the deposits that underlie it may be correlative with one of the pre-Sangamonian coastwise terraces in the Louisiana coastal plain.

Sangamonian Interglacial Sedimentary Cycle

High sea level stages during the last (Sangamonian) interglacial (approximately 128 to 82 thousand years ago) resulted in the deposition of transgressive, fossil-rich, marine-paralic inshore sediments seaward of alluvial coastal plain units. The high sea level stage along many Gulf shoreline sectors produced seaward progradation of sets of subparallel beach ridges separated by low swales. The Prairie Formation is the alluvial, coastal plain facies, and it is time-equivalent to the beach ridge facies, called the Gulfport Formation. These Gulfport beach ridge segments occur Gulfwide in a discontinuous chain, except in Louisiana (Otvos, 1985, 1991). Marine and nearshore equivalent facies of the Prairie and Gulfport are present in the Biloxi Formation. All of the major Sangamonian units occur at Belle Fontaine (Table 1).

Biloxi Formation

The unconsolidated, gray, muddy-sandy, fossil-rich sediments of the Biloxi Formation represent a set of depositional facies which existed in shelf-to-nearshore/inshore environments (Otvos, 1985). The Biloxi interfingers with alluvial beds of the Prairie and overlies early Pleistocene deposits. Highly to moderately brackish deposits with *Crassostrea virginica* oyster reefs characterize the landward "feather edge" of the formation. Agglutinated foraminifer species and *Ammonia beccarii* dominate this facies. These deposits were laid down in estuaries, bays and lagoons, and in fresh water runoff-influenced, reduced salinity, nearshore water bodies.

As the transgression continued and the shoreline shifted farther northward, highly saline, open marine conditions developed along the present Mississippi Sound shoreline. At this time the Gulf stood about 6-7.5 m (20-25 ft.) higher than today, and lapped directly against the Mississippi mainland shore. In Drillhole No. 16 (Figures 1 and 2) this open-marine environment is characterized by a foraminifer fauna of great species diversity, dominated by *Rosalina columbiensis, Nonion depressulum matagordanum, Elphidium galvestonense, Elphidium incertum mexicanum,* and two subspecies of *Ammonia beccarii.* The fauna also includes *Buliminella elegantissima, Nonionella atlantica, Nonionella opima, Brizalina lowmani, Hanzawaia strattoni, Cribroelphidium poeyanum,* eight *Quinqueloculina* (planktonic) species, and many others. This interval also contains a pine/oak-dominated pollen assemblage with modern analogues in the adjacent modern coastal area. A similar flora was found at 5.7 m (18.7 ft.) depth in Prairie Formation clays in the U.S.G.S. Ocean Springs corehole (Willard and Edwards, in press).

Prairie Formation

The Prairie Formation consists of a highly variable, sandy, muddy, and clayey deposit with sandy and gravelly alluvial deposits, and forms the wide, level coastal plain landward of the Sangamonian coast in Jackson County. Depositional environments included flood plains, river channels, oxbow lakes, and natural levees (Otvos, 1985). Vertebrate fossils are much rarer in this formation than in its Texas equivalent. A characteristic yellowish-brown and orange-yellow oxidized color typifies the top few feet of the formation. Interfingering with brackish Biloxi deposits occurs at shallow depths. The pollen spectra from peaty coastal plain Prairie swamp deposits also reflect current flora and climate conditions on the coast (Otvos, in press), with yellow pine and oak species predominant. Locally, as along the Harrison County Industrial Seaway, gravel- and sand-filled Prairie stream channels cut into Biloxi deposits.

The Prairie Formation crops out in the study area between the Graveline and Davis Bayou marsh on the south

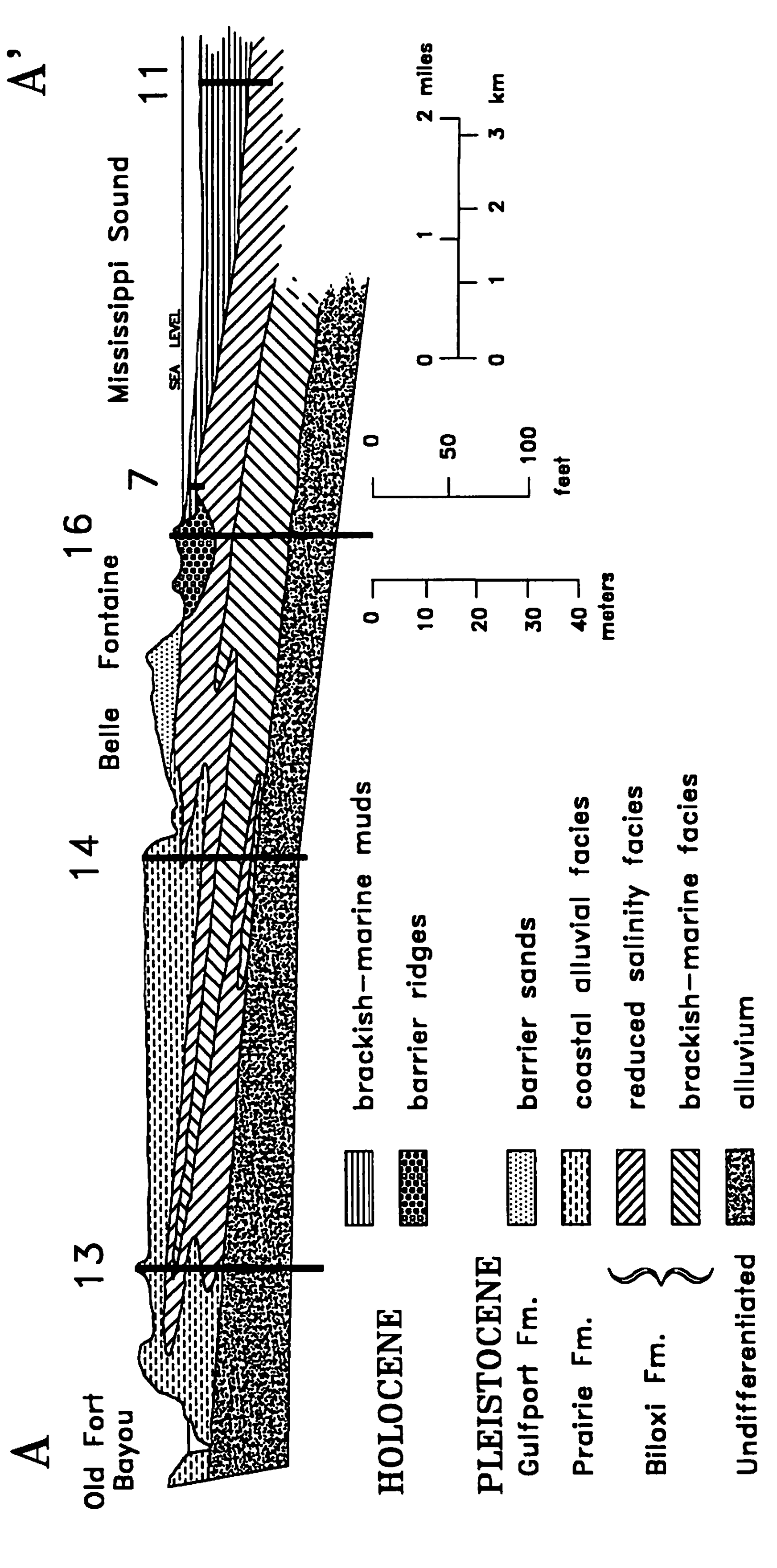

Figure 2. Geologic cross section A - A'. (location in Figure 1)

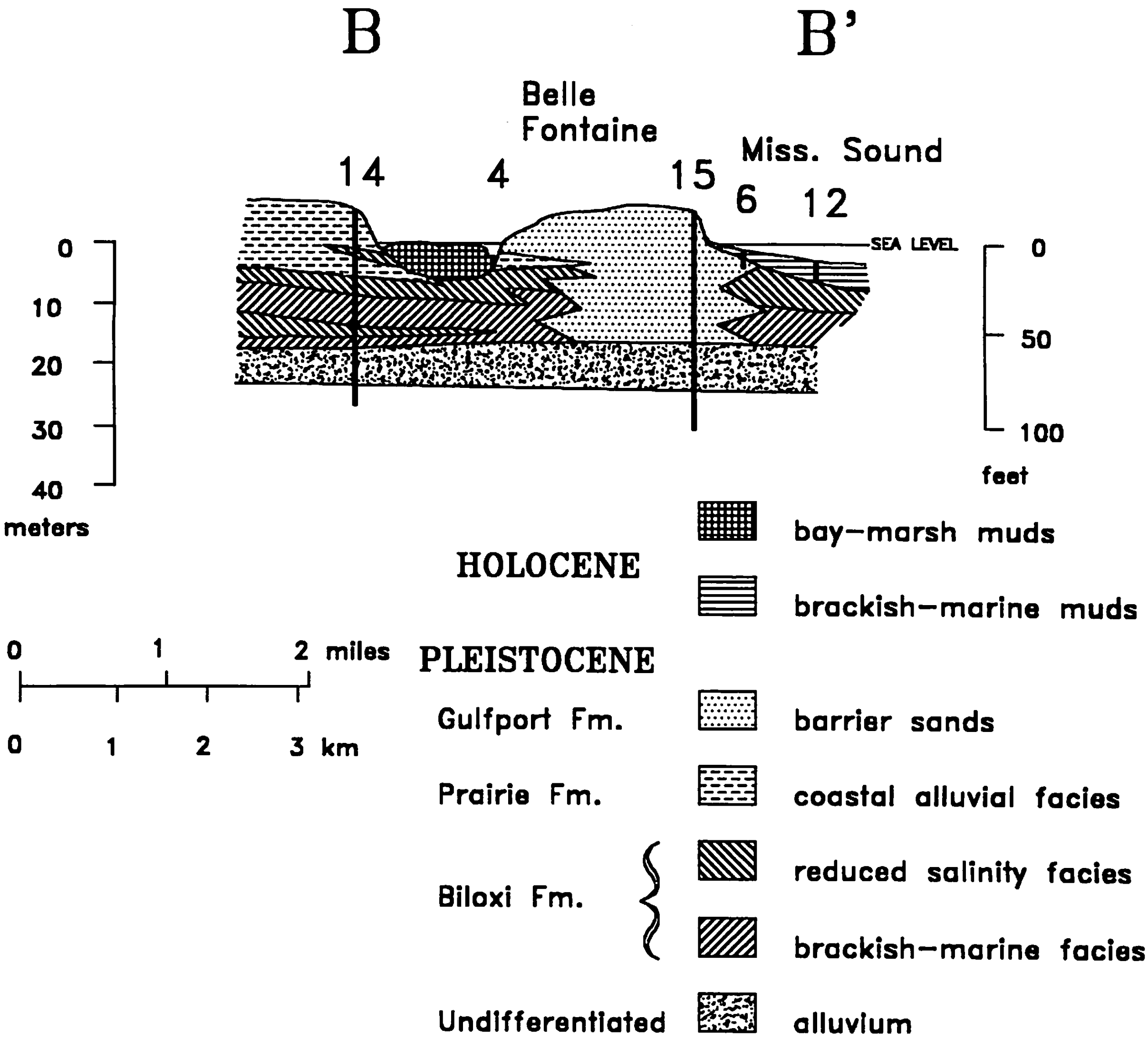

Figure 3. Geologic cross section B - B'. (location in Figure 1)

and Old Fort Bayou and the Big Ridge Scarp on the north (Figure 1). In the subsurface it was found underlying Holocene muds in Core No. 4, just south of the Graveline marsh adjacent to the Gulfport outcrop (Figure 3).

Gulfport Formation

The Gulfport Formation represents shallow subtidal, intertidal, and supratidal Gulf barrier/strand plain deposits, composed of moderately well- to very well-sorted fine- and medium-grained sands. The oldest of the strand plain ridges formed over alluvial deposits along the Prairie-fringed mainland shoreline. The Gulfport is unusually thick (c. 21 m, 70 ft.) in Drillhole No. 15. White sands of the lower 9-12 m (30-40 ft.) interval in the drillhole may have accumulated in submarine bars and shoals. They are time-correlative with the muddier Biloxi interval in adjacent Drillhole No. 16 (Figure 2). Horizontal, subparallel and gently inclined ripple-sand wave cross stratification characterizes the sand that, except for *Ophiomorpha* trace fossils (shrimp burrow pipes) (Figure 4) and infrequently encountered molluscan bivalve molds, is devoid of fossils.

As at numerous other Sangamonian-age barrier locations elsewhere on the northern Gulf coast (Swanson and Palacas, 1965), the Gulfport at Belle Fontaine also exhibits postdepositional cementation by downward percolating humic acids. The cemented zones form multiple semiconsolidated, erosion-resistant, dark yellow-orange to dark brown-black sandstone horizons. Some of the ledges and lenses within the white sand beds extend 2-2.5 m (6-8 ft.) above present sea level (Figures 5 and 6). Abrupt and often irregular lateral and vertical termination of the semiconsolidated humate sandstone lenses against white and oxidized, dark and light yellowish-orange sand bodies in the bluff at Belle Fontaine indicates selective precipitation of humic acids and/or subsequent selective leaching of the humate cement. The presence of a poorly sorted humate barrier sand lens 2.5 m (8.2 ft.) below sea level in Core No. 6 offshore of Central Belle Fontaine indicates that the Gulfport extends at least half a mile seaward below the Holocene muds. Highly brackish, transitional, muddy fine sands of the Biloxi, rich in *Ammotium salsum* foraminifers, occur beneath the Gulfport.

The Gulfport plain formed through progradation, steadily covering previously deposited nearshore marine Biloxi sands and muds. By successive addition, new generations of beach-dune ridges grew on the seaward side. One Gulfport ridge reaches 6.4 m (21 ft.) elevation at Pointe aux Chênes, southeast of Marsh Point in the northwestern strand plain area. More than a dozen semi-parallel, gently arcing ridges accreted at Belle Fontaine, and these are plainly visible on aerial photographs of the area. Younger ridges occasionally truncate older ridge sets. Construction of new beach ridges on the Gulfport strand plain gradually shifted the Sangamonian shoreline seaward by at least 2 km (1.3 mi.).

Holocene Deposits and Development History

Worldwide warming at the end of the Wisconsinan resulted in the rise of Gulf sea level from a low stage of approximately -107 m (-350 ft.). At this time, approximately 18,000 years ago, the shore was located about 110-130 km (70-80 mi.) south of Belle Fontaine. The rising Holocene sea converted the Gulfport strand plain with its marshy Holocene fringe zones (Marsh Point and Graveline areas) into the "island" of Belle Fontaine, surrounded almost completely by water and marshland. The transgression turned the 1.2 km (3/4 mi.) wide Graveline Bayou valley and the present Simmons and Davis Bayou area between the Prairie and Gulfport areas into an embayment. It was subsequently colonized by tidal marshland that today fringes Graveline Bayou and surrounds Graveline Bay.

Core No. 4 penetrated nearly 1.2 m (4 ft.) of organic-rich, very poorly sorted, late Holocene, silty, fine sand and muddy, medium sand marsh-creek deposits. This hole was drilled at the bottom of the 2.4 m (8 ft.) deep Graveline Bayou immediately north of the Gulfport Formation distribution area. The Holocene deposits overlie slightly oxidized, fossil-free, muddy, medium-fine Prairie sands, sandy muds, and moderately to well sorted, medium-grained, stream channel sands (Figure 3).

Holocene sandy muds and muddy sands, including some rare ripple sand lenses and laminae, cover Biloxi deposits in the Sound offshore of West Belle Fontaine Beach. In Core No. 7, about 0.5 km (0.3 mi.) offshore from Drillhole No. 16, the Holocene is 2.7 m (8.9 ft.) thick. Near Marsh Point, Core No. 9 bottomed in 4.1 m (13.5 ft.) thick dark greenish-gray, very soft, Holocene muds. Core No. 8, southeast of No. 9, is identical. It contains 6.7 m (22 ft.) of muds that probably fill an early Holocene stream channel. Nearshore, in Core No. 6, the Holocene interval is only 1.3 m (4.2 ft.) thick, and in Core No. 5 the Holocene muds are more than 4 m (13 ft.) thick.

Most of the Holocene was deposited in highly brackish environments, as shown by the presence of *Ammotium salsum* dominated (80-100%) faunas, with only small percentages of *Ammonia beccarii, Nonion depressulum matagordanum, Elphidium galvestonense*, and other species. *Miliammina fusca, Arenoparella mexicana, Ammoastuta inepta, Haplophragmoides, Trochammina*, and *Ammobaculies* agglutinate foram species are found in fewer samples or in very small quantities.

In rare shallow marsh sediment samples (Core Nos. 1 and 10) *Arenoparella mexicana* was represented by high concentrations (45 - 83%). Foram faunas within the top 0.6-1.5 m (2-5 ft.) interval in Core Nos. 1 and 5 through 9 display a thin zone with somewhat higher depositional salinities than reflected by the *Ammotium salsum* faunas predominant in the rest of the core intervals. The assemblages of this highest salinity interval found in the Holocene deposits are dominated by *Ammonia beccarii tepida, Ammonia beccarii parkinsoniana, Elphidium galvestonense*, and *Ammotium salsum*. Less abundant calcareous species include *Palmerinella gardenislandensis, Elphidium latispatium pontium, Nonion depressulum matagordanum*, and miliolid species.

A Holocene interval, dominated by *Ammonia beccarii* subspecies, not by agglutinate foraminifers of the highly brackish facies, was encountered between 3.6 to 4.3 m (12 to 14 ft.) below sea level in Core No. 1 and between 2.7 and 3.1 m (8.8 and 10.2 ft.) below sea level in Core No. 9. These relatively higher salinities may have been produced by occasional opening and/or widening of passes between the islands. This would allow a more intensive influx of the more saline nearshore Gulf waters to penetrate the Mississippi Sound. An alternate hypothesis would explain these salinities by a reduction in rainfall and fresh-water runoff, which would have increased salinities in Mississippi Sound.

Despite the close spacing of these core locations, it is clear that the record of these high-salinity episodes was not preserved equally at different localities, possibly due to different rates of seafloor erosion in the past. Microfossil data of high-salinity facies in island chain and other Mississippi Sound drillholes indicates the absence of barrier islands and higher salinity to marine depositional conditions in the present Sound area when the transgression reached this area

Figure 4. *Ophiomorpha* trace fossils in the Gulfport Formation, Central Belle Fontaine. (scale is in inches and centimeters)

Figure 5. Humate-cemented portion of Gulfport Formation, Central Belle Fontaine. (scale is in inches and centimeters)

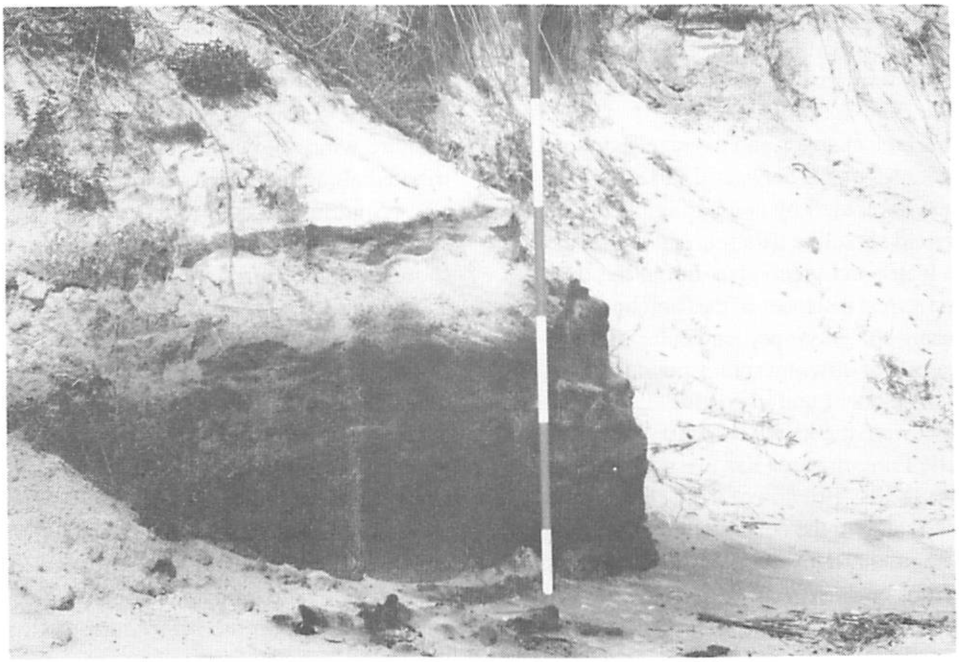

Figure 6. Humate sandstone ledge in the Gulfport Formation, Central Belle Fontaine. (scale is in feet)

in the Late Holocene times (Otvos, 1981). Abundant stream runoff at this stage kept salinities still fairly low in the nearshore area. The absence of higher salinity facies in Holocene deposits offshore of Belle Fontaine and elsewhere along the mainland shoreline of the Sound (Otvos, 1981, 1985) suggests the brevity of this episode and points to seafloor erosion which removed these thin units from the sediment record.

Prior to the Late Holocene development of a protective barrier island chain and the Mississippi Sound landward of it (Otvos, 1981), the southeast-facing Gulfport barrier shore area was subjected to powerful open-Gulf wave erosion. Sand produced from this receding shoreline was transported westward by longshore drift. It constructed the present narrow Belle Fontaine barrier spit. The spit enclosed the shallow nearshore area behind it, which was soon converted into marshland. Spit development was terminated by the reduction of wave energy following separation of the Mississippi Sound from the Gulf by the emerging barrier island chain. Nearshore waters along Belle Fontaine Beach are very shallow and muddy, reflecting this protected environment and the lack of higher energy waves to systematically remove mud from the sediment and leave sand behind as happened earlier on the open Gulf shore.

HISTORICAL SHORELINE CHANGE AND DEVELOPMENT

The first official maps of the Mississippi coastal zone and shoreline position were made by the National Coast Survey in the 1850s. Belle Fontaine shoreline positions were digitized from these maps and entered into ARC/Info to provide a starting point for measuring shoreline change. T-sheets constructed by the U. S. Coast and Geodetic Survey and the U. S. Geological Survey approximately in 1917 and 1950 were also digitized to provide additional shoreline position data. A 1986 aerial photo set was interpreted for the high tide line and digitized also. A 1993 high tide shoreline interpretation was made from a Global Positioning System (GPS) survey of the area in the summer of 1993. All of these data were corrected to the North American Datum of 1983 for projection and overlay to determine changes between surveys.

For analysis purposes, based on similar physical setting and history, the Belle Fontaine shoreline was divided into four segments (Figure 7). The East Belle Fontaine segment extends from the east end of the Gulfport Formation scarp to the Graveline Bayou channel. Central Belle Fontaine includes the area fronted by the Gulfport Formation scarp line. West Belle Fontaine stretches from the west end of the Gulfport scarp line, at the St.Andrews water tower, to the western end of Belle Fontaine Beach. The Pointe aux Chênes sector is the western part of the study area from Belle Fontaine Beach to Marsh Point.

Table 2 illustrates area changes and average shoreline retreat rates for these four segments between 1850 and 1986. Total area changes were computed by comparing the difference between two overlaid shoreline data sets and noting the changes from land to water and vice versa during the time period studied. Average retreat distances of the shoreline were determined by measuring the shore-perpendicular distance between overlaid shorelines of different survey periods at random points within each segment and averaging the results. All of the measurements were made in ARC/Info.

Overall, the Belle Fontaine area has lost 473 acres to shore erosion since the 1850s. Erosion of the Central Belle Fontaine shore provided sand for the construction of beaches east and west of this segment. However, all beach sectors show a general erosive trend.

East Belle Fontaine

East Belle Fontaine shows the only positive shoreline addition. This change occurred between 1917 and 1950. A sand spit that fronts the Graveline Bayou marsh was built during this period by sand eroded from the Gulfport scarp to the west. Given the current predominant southeasterly wave incidence direction and westward longshore drift, this former spit progradation may be best explained by a change to a southerly or southwesterly predominant wind direction during that time period. The result was a net eastward-directed longshore drift. Between 1950 and 1986 this trend was reversed and the large sand spit area removed by erosion, leaving a broad underwater shoal immediately offshore. A low, narrow, sand beach remains in front of Graveline Bayou marsh (Figure 8). This beach is occasionally overwashed into the marsh as shoreline retreat continues.

East Belle Fontaine has the lowest relief in the area. The shoreline is easily overwashed by late winter and spring storms, and the marsh is retreating landward as sand is eroded and thrown over the berm during high tides. A marsh root mat crops out just in front of the diminishing sand beach along this shoreline. Most of the property owners along the built-up shore zone have bulkheaded their shorefronts. Several have constructed small timber groins to trap what little sand is moving eastward along the shore (Figure 9). Without a significant change in predominant wind direction and sand availability, this area will continue to experience rapid erosion.

Central Belle Fontaine

Central Belle Fontaine has been eroding since late Holocene time. The height of the erosional scarp ranges from only a few feet high near the east and west ends of the area, to about 3 m (10 ft.) near the center (Figure 10). Erosion here is caused by undercutting of the scarp by wave action during periods of especially high tides. This occurs during the spring, or at any time when prolonged strong onshore winds blow in the area. The eroding sand is distributed along the beach sectors.

Significant shore retreat is primarily caused by occasional hurricane impact. According to reports by owners of shore property, Hurricane Camille in 1969 caused as much as 10 m (33 ft.) of scarp retreat. A piling located in 1993 about 26 m (85 ft.) offshore of the property of Mr. James N. Germany stood at the scarp face before Camille. This change translates into an average annual retreat rate of over 1 m (3 ft.) between 1969 and 1993. Hurricane erosion associated with temporarily elevated sea levels has also cut a narrow terrace into the bluff east of the St. Andrews water tower.

Additional factors that contribute to erosion at Central Belle Fontaine include the presence in the foreshore of indurated humate sandstone cobbles and blocks which may aid in breaking up the scarp during wave attack. During wet, rainy periods, fresh-water springs are common in the scarp face as ground water flows through the Gulfport sand over the humate-cemented layers, which act as an aquiclude. These springs loosen sand in the scarp face and erode the fronting beach with outflow channels prior to the erosive high spring tides.

Many property owners along this segment have bulkheaded the scarp face to prevent further erosion and shore retreat (Figure 11). While this temporarily saves their property from the waves, it also decreases the amount of sand being released from the Gulfport Formation to the longshore drift system, and thus contributes to increased erosion of the East and West Belle Fontaine areas.

West Belle Fontaine

West Belle Fontaine is a 4 km- (2.5 mi.-) long, narrow (90-275 m, 300-900 ft.) sand spit which accreted as a result of longshore transport of Gulfport sand eroded from the Central Belle Fontaine area. Both in Drillhole No. 16 and in the adjacent 1990 U.S.G.S. corehole near the western end of the spit, the Holocene is 6 to 7 m (20 to 23 ft.) thick. A 2540 year B.P. radiocarbon date, reported from subtidal deposits at 3.7 m (12 ft.) depth in the U.S.G.S. corehole (J. Reinhardt, personal communication) indicates that the top 1.8 m (6 ft.) sand interval accumulated quite recently. Two older spit generations bifurcate landward (northward) into the marsh from this barrier spit.

The beach at West Belle Fontaine is experiencing moderate erosion along its entire length, except adjacent to the groin at the west end, where sand has collected on the updrift side. Dunes of 3 m (10 ft.) elevation have formed behind certain foreshore sectors. As evidenced by homes and pine

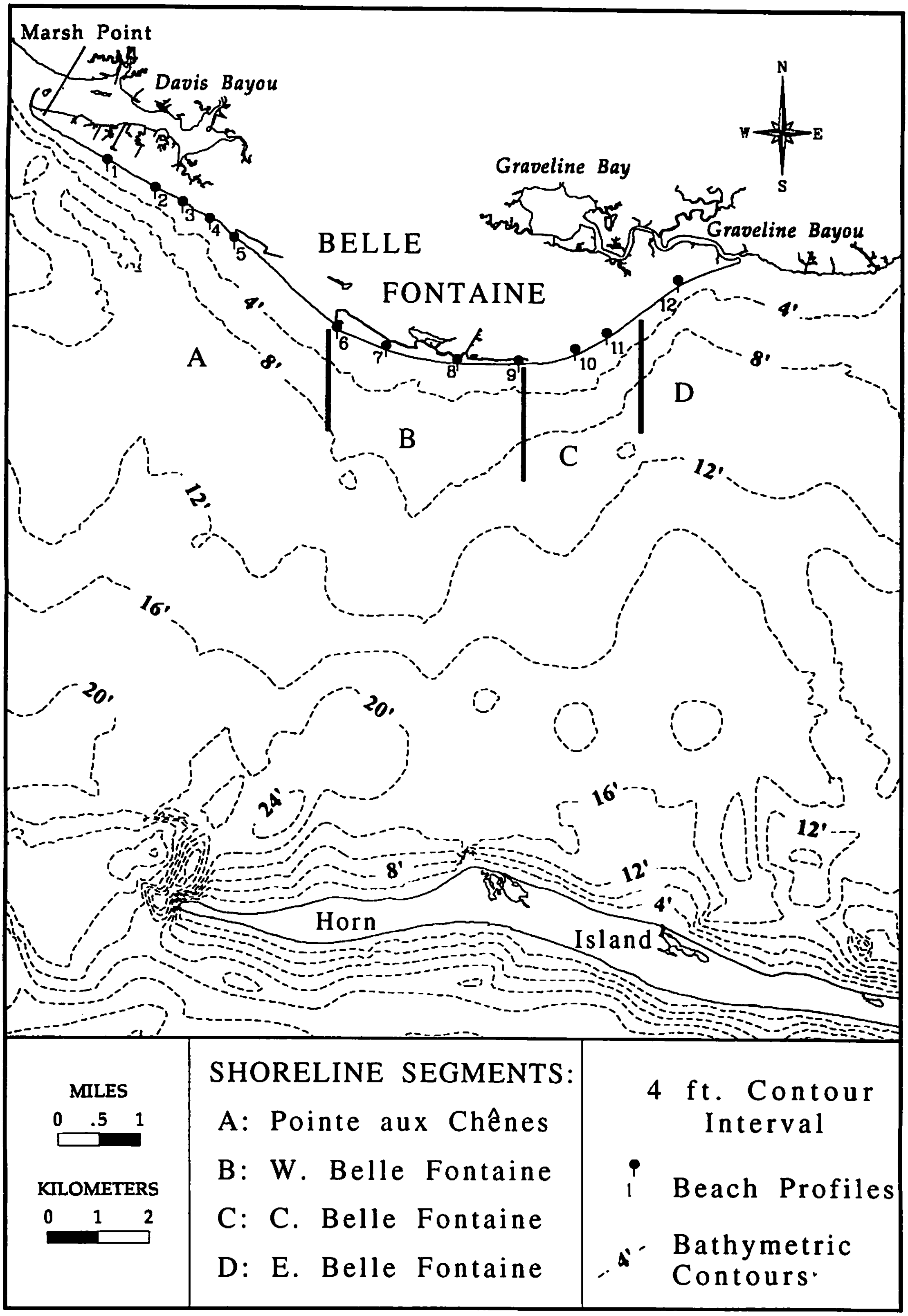

Figure 7. Belle Fontaine shoreline location map.

Time Periods	1850-1917	1917-1950	1950-1986	1850-1986
Avg. Shore Retreat (meters)				
E. Belle Fontaine	-129.6	46.2	-35.8	-118.9
C. Belle Fontaine	-48.3	-0.7	-10.7	-60.9
W. Belle Fontaine	-15.1	-4.4	-5.7	-25.2
Pointe aux Chênes	-84.3	-36.2	-45.6	-166.3
Total Area Change (acres)				
E. Belle Fontaine	-88.1	29.2	-19.5	-78.3
C. Belle Fontaine	-36.9	0.4	-9.2	-45.7
W. Belle Fontaine	-10.9	-4.1	-6.3	-21.2
Pointe aux Chênes	-183.9	-64.1	-79.7	-327.6

Table 2. Average shore retreat rates and total area change for Belle Fontaine.

trees in the surf zone (Figure 12), portions of the beach show rapid erosion and retreat. Storm erosion has threatened the access road at several points, and Jackson County has installed riprap protection along those sections (Figure 13). Numerous homeowners have bulkheaded their property where erosion threatens to undermine their foundations. Without additional sand sources to replace the sand lost due to stabilization of the Gulfport scarp at the Central Belle Fontaine sector, this area will experience continued erosion and shoreline retreat.

Pointe aux Chênes

The Pointe aux Chênes sector has lost the greatest acreage (328 acres) to erosion on the Belle Fontaine coast since the 1850s. This in part was due to the greater length of this shoreline segment. However, the sector also has the highest average shoreline retreat rate for the study period. This area is farthest from the main Gulfport Formation sand source at Central Belle Fontaine, and therefore did not receive as much sand supply as the other areas do. A significant portion of the acreage loss since 1950 was caused by the construction of a large timber groin at the west end of Belle Fontaine Beach in the 1960s to protect the outlet of a dredged canal from being blocked by sand migration (Figure 14). This groin halted further westward longshore sand movement. The marsh area immediately west of the groin has suffered severe erosion. The only other sand source for the Pointe aux Chênes sector is a Gulfport bluff (Pointe aux Chênes) near the center of that sector. However, most of that outcrop has been bulkheaded by landowners to prevent further erosion. This sand source was also isolated from the beach.

The Pointe aux Chênes sector is divided into two segments. The eastern half of the section consists of a marsh shoreline, with minor amounts of sand in the immediate shoreface. This segment is experiencing the most rapid rate of retreat. Sand that previously drifted westward to reach this shoreline section has been diverted offshore by the groin at the west end of Belle Fontaine Beach and by ebb tides from the dredged channel just west of the groin. That sand is now deposited in a shoal area about 600 m (2000 ft.) offshore where there is insufficient shore-normal wave transport to bring it back into the surf zone in a down-drift direction. As a result, the marsh has been significantly eroded, causing a major shoreline offset (Figure 15). In an attempt to slow shore retreat, a county park and pier area in the eastern part of this section was recently filled and protected by riprap (Figure 16).

The western half of the Pointe aux Chênes sector extends from the narrow Gulfport outcrop on the beach, westward to Marsh Point (Figure 1). Erosion of this outcrop in the past has provided a limited amount of sand to the westward-directed drift. However, many homeowners have built bulkheads and small groins to protect their property from continued erosion, thus eliminating this sand source. Erosion is now threatening the marsh shoreline as far west as

Marsh Point. A small recurved sand spit has been built into Davis Bayou at Marsh Point. The remaining minor sand volumes are transported westward into Biloxi Bay.

Offshore Bathymetry

Off the Belle Fontaine area the Mississippi Sound is very shallow. Water depths of 0.6 to 1.2 m (2 to 4 feet) occur as far as 1.2 km (3/4 mile) from the shore. The bottom sediments consist primarily of mud, with varying amounts of sand and shell material. This shallow lagoon bottom causes wave energy to impact the bottom far from the shoreline during times of normal tide levels. The result is a very cloudy, muddy water column.

Bathymetric profiles were surveyed between Belle Fontaine and Horn Island in 1992 by the use of a Lowrance X-16 chart depth recorder with GPS position equipment, deployed in a small boat. Once the data were compiled, they were compared with the most recent NOAA navigation chart of the area (November 1991). After corrections to bring the two data sets into agreement, NOAA soundings were incorporated in the profile data to produce an integrated new bathymetric map (Figure 7). The bathymetric data were used by Joseph Suhayda to construct the Shoreline Evolution Model, discussed in his paper in the present volume.

Twelve beach and nearshore profiles were measured with a total station and prism in 1992 (Figure 7). The slope of the nearshore bottom is fairly consistent and ranges between 0.2 and 0.5 degrees for a distance of about 490 m (1600 ft.) offshore. The foreshore slope above mean tide level varies from 7.5 to 9.5 degrees. The beach profile data were incorporated into the Shoreline Evolution Model by Suhayda and used to calculate beach volumes in the model. Appendix B displays the measured profiles.

Beach Sand Grain Size and Distribution

Fifteen samples of the Belle Fontaine beach foreshore were collected at evenly-spaced intervals between Graveline Bayou and Marsh Point. Standard sieve analyses were run using half-phi mesh diameter intervals. Results were tabulated and statistical analysis performed in order to obtain kurtosis, skewness, standard deviation, mean, median, and mode for each sample. Statistical methods used are described by Folk (1968). A graphic display of the statistical parameters and their distribution for the samples is shown in Figure 17.

Mean grain size is the average grain size of a sample. Graphic Mean (M_Z) is used for the mean grain size:

$$M_Z = (\text{Ø}16\% + \text{Ø}50\% + \text{Ø}84\%)/3$$

Median grain size is simply the diameter about which half of the sample is coarser and half is finer. The modal grain size is the most frequently occurring grain diameter. Standard deviation is a measure of uniformity or sorting, and the Inclusive Graphic Standard Deviation (σ_I) is used:

$$\sigma_I = \frac{\text{Ø}84\% - \text{Ø}16\%}{4} + \frac{\text{Ø}95\% - \text{Ø}5\%}{6.6}$$

Kurtosis is a quantitative measure used to describe the departure from normality of the size distribution of a sediment sample. It is a measure of sorting. Kurtosis measures used are derived from the formula:

$$K_G = \frac{\text{Ø}95\% - \text{Ø}5\%}{2.44(\text{Ø}75\% - \text{Ø}25\%)}$$

where K_G is the Graphic Kurtosis of Folk (1968). Skewness defines the departure from symmetry of the normal distribution curve for sediment size distribution. Samples with excess fine sediment will have positive skewness while excess coarse sediment will exhibit negative skewness. Skewness measure is defined by the formula for Inclusive Graphic Skewness (Sk_I) where:

$$Sk_I = \frac{\text{Ø}16\% + \text{Ø}84\% - 2\text{Ø}50\%}{2(\text{Ø}84\% - \text{Ø}16\%)} + \frac{\text{Ø}5\% + \text{Ø}95\% - 2\text{Ø}50\%}{2(\text{Ø}95\% - \text{Ø}5\%)}$$

Although the statistical values show little variation between individual samples, certain trends are discernible in Figure 17. Samples 5 and 6 were obtained immediately adjacent to the Gulfport Formation bluffs. The mean, median, and modal grain size values of these samples are higher, reflecting the composition of the Gulfport source sand. At sample locations east and particularly west of there, these parameter values decrease as sand from the source area is winnowed and spread along the beach. A similar trend occurs at sample numbers 13 and 14, where another Gulfport source is located at Pointe aux Chênes. These results confirm that the Gulfport Formation is the source for all of the sand found on Belle Fontaine beaches. Skewness and kurtosis values show a similar though less obvious trend, reflecting better sorting and winnowing of the finer sediment matter as sand is being transported downdrift from its source areas.

SUMMARY AND CONCLUSIONS

The Belle Fontaine area reveals a consistent history of development and erosion during the post-glacial sea level rise. The beach ridge plain, around which Belle Fontaine beach developed, formed at the peak of the Late Pleistocene high sea level stage. Subsequent sea level drop resulted in stream erosion. This drainage network of creeks and rivers during the Late Holocene invasion of the sea was replaced by marine embayments and marshy creeks. The rise of sea level following the end of glaciation in the north has caused erosion of the Pleistocene deposits and evolution of the

Figure 8. Narrow beach in front of the Graveline Bayou marsh.

Figure 9. Bulkheads and groins along the East Belle Fontaine shoreline.

Figure 10. Erosional scarp along Central Belle Fontaine shoreline. (scale is in feet)

Figure 11. Isolated bulkhead, Central Belle Fontaine. (scale is in feet)

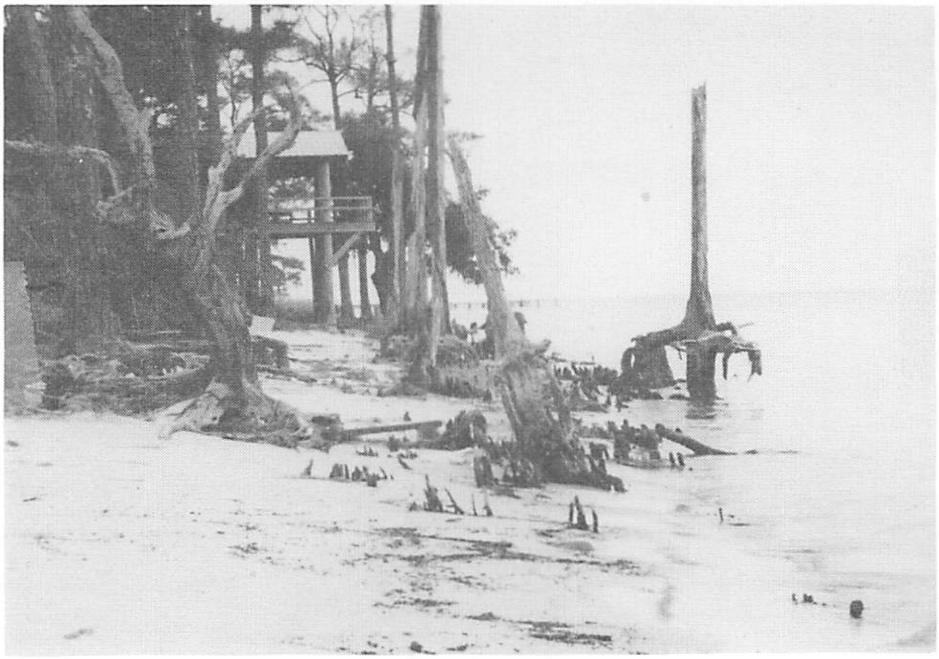

Figure 12. Eroding shoreline in the West Belle Fontaine area.

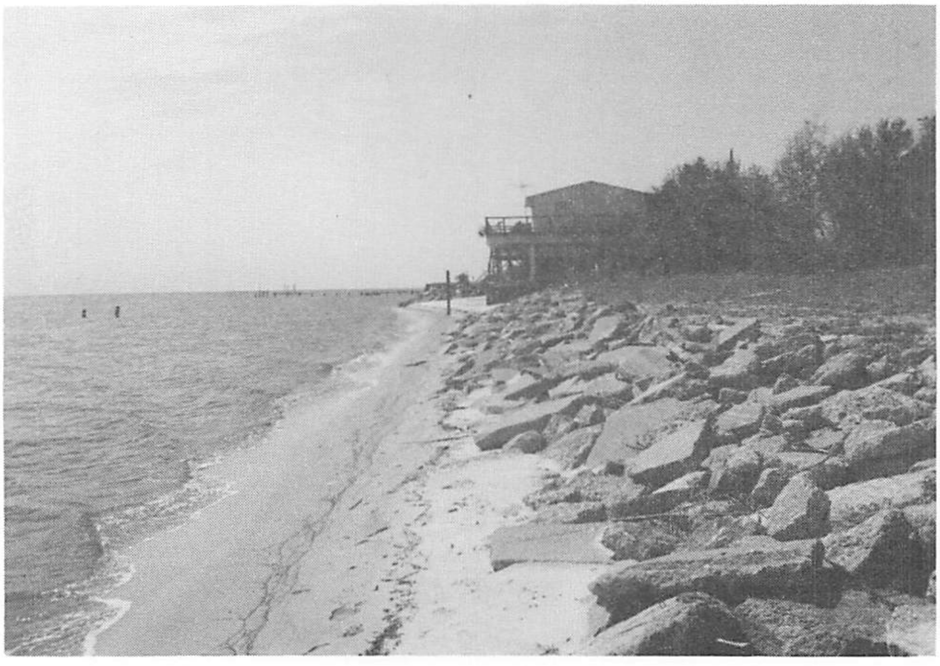

Figure 13. Riprap protection along the West Belle Fontaine shoreline.

Figure 14. Timber groin at the west end of Belle Fontaine Beach.

Figure 15. Shoreline offset caused by groin construction at the west end of Belle Fontaine Beach.

Figure 16. Park and pier area protected by riprap in the Pointe aux Chênes area.

present Belle Fontaine landscape. The geologically recent emergence of the barrier islands and consequent establishment of the Mississippi Sound reduced wave energy on the Belle Fontaine shoreline and at the same time halted growth of the West Belle Fontaine sand spits. Slow but steady erosion impacted the shore zone. Erosion of the Gulfport Formation sand bluffs in Central Belle Fontaine maintains the beaches today, but with a reduced sand budget and at lower wave energies.

Gulfport Formation bluff erosion contributes sediment to beaches east and west of the bluff outcrops. If homeowners would stabilize the bluffs to prevent erosion, the flank areas would also suffer from sand deficiency and start to erode. Continued placement of groins along the shoreline to trap sand only aggravates the situation, since the problem is the result of sand shortage, and all of the sand is derived from bluff sources at some distance. Addition of sand from the outside to the system is the most logical solution to the problem. This would preserve the natural beauty of the area and take advantage of the natural processes at work there.

ACKNOWLEDGMENTS

On behalf of the Mississippi Office of Geology the following persons assisted with the field work and in compiling this report: Michael Fayard, Peter Hutchins, Jim McMullin, Jack Moody, Lindsey Stewart, Kelly Peace, and Philip White. Grain size analysis of cores was performed at the Gulf Coast Research Laboratory by Howard Newby, and foraminifer analysis and classification was undertaken by Wade Howat. Barbara Yassin of the Office of Geology statistically analyzed the historical shoreline data in ARC/Info and prepared the final maps and illustrations.

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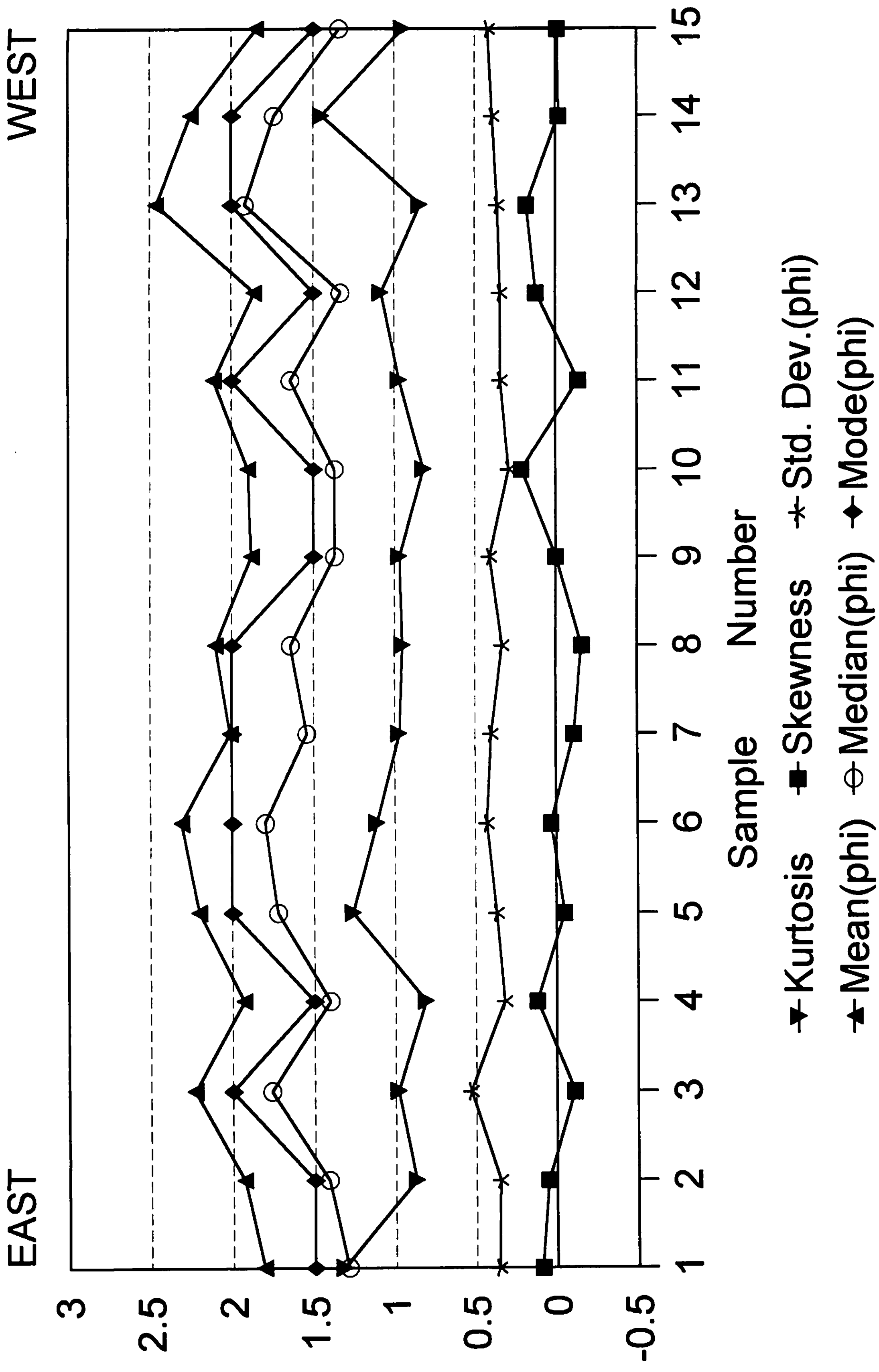

Figure 17. Grain size distribution of beach foreshore sands along Belle Fontaine shoreline.

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Appendix A.

Belle Fontaine Vibracore Descriptions

Belle Fontaine Drillhole Descriptions

Core and drillhole locations are shown in Figure 1.

Depths are measured from land surface, seafloor, and creek floor respectively.

CORE No. 1

Location: Just behind the storm berm at East Belle Fontaine in the Graveline Bayou marsh, about 200 feet east of the end of Beach Blvd.

Latitude: 30° 21.461'N Longitude: 88° 40.611'W
Elevation: -0.4 feet
Date: 6-02-92

Depth Description

0.0' Holocene, loose plant fragments mixed with sand.

0.4' Sand, white to green, fine to medium grained, loose plant fragments.

0.7' Sandy mud and muddy fine sand, brown to black, very organic, abundant plant fragments and fibers. Forams: *Arenoparella mexicana*-45%, *Miliammina fusca*-22%, *Ammotium salsum*-15%, *Trochammina inflata*-8%, *Trochammina comprimata*-4%.

0.9' Clay, sandy, dusky brown to black, very organic, scattered sand lenses. Forams: *Ammotium salsum*-46%, *Miliammina fusca*-29%, *Haplophragmoides subinvolutum*-16%, *Haplophragmoides* sp.(collapsed test)-6%.

2.4' Mud and clay, soft to medium texture, moderate grayish-blue to green, paleo-soil dried clay lumps, scattered plant fragments. Forams: *Arenoparella mexicana*-41%, *Haplophragmoides subinvolutum*-33%, *Trochammina inflata*-12%, unidentified marsh-type sp.-11%.

4.6' Muddy fine sand mixed with sandy-silty mud, dark gray to dark brown, scattered plant fragments, large shell fragment at 6.4'. Forams: *Ammonia beccarii tepida*-35%, *Palmerinella gardenislandensis*-26%, unidentified calcareous fragments-23%, *Elphidium galvestonense*-10%.

7.6' Clayey fine sand and mud, poorly sorted, olive gray to dark gray, carbonized plant fragments, scattered light gray sand pockets. Forams: *Ammotium salsum*-67%, *Ammonia beccarii tepida*-14%, *Nonion depressulum matagordanum*-6%, *Elphidium galvestonense*-3%.

9.7' Fine sandy clay and mud, dark gray, scattered shell fragments and plant fragments. Forams (10.4'): *Ammonia beccarii parkinsoniana*-67%, *Ammotium salsum*-8%, *Ammonia beccarii tepida*-7%, *Elphidium galvestonense*-6%, *Nonion depressulum matagordanum*-6%, *Elphidium latispatium pontium*-5%; (12.2'): *Ammonia beccarii tepida*-35%, *Ammonia beccarii parkinsoniana*-28%, *Nonion depressulum matagordanum*-15%, *Ammotium salsum*-11%, *Elphidium galvestonense*-6%.

13.4' Fine sandy mud, soft, dark gray to dark greenish-gray, few sand lenses, scattered plant fragments. Forams: *Ammotium salsum*-100%.

16.3' Total depth.

CORE No. 2

Location: Ramsey Bayou, south side of Davis Bayou in the marsh north of Pointe aux Chênes.

Latitude: 30° 22.592'N Longitude: 88° 46.852'W
Elevation: -4 feet
Date: 6-03-92

Depth Description

0.0' Holocene, mud, very soft, dark greenish-gray, scattered shell fragments. Forams: *Ammotium salsum*-69%, *Miliammina fusca*-24%, *Haplophragmoides* sp.-7%.

3.0' Mud, very soft, moderate greenish-black.

6.3' Muddy fine sand mixed with mud, dark gray to black, fine sand lens at 6.5' and at 7.1'.

7.5' Fine sandy mud, soft, moderate olive gray, 3/4 inch sand pocket at 8.6'. Forams: *Ammotium salsum*-98%.

12.0' Fine sandy mud, moderate olive gray, soft becoming firm at base, sand pocket at 13.6'. Forams: *Ammotium salsum*-100%.

14.0' Total depth.

CORE No. 3

Location: West end of Belle Fontaine Beach on sand spit west of the terminal groin on the beach.

Latitude: 30° 20.898'N Longitude: 88° 44.915'W
Elevation: -1.5 feet
Date: 6-04-92

Depth Description

0.0' Holocene, sand, medium grained, mottled light tan to white, grading to medium-fine near base.

1.7' Sand, fine-medium grained, light tan to gray, horizontal streaks of black clay concentrations near top grade down to sharp contact with clay at base.

3.0' Clay, black, silty, gradational contact with sand at base.

3.4' Sand, medium grained, light gray to white, horizontal streaks of black clay, sharp contact with clay at base.

4.7' Clay, silty, black, firm, scattered plant fragments.

6.0' Total depth.

CORE No. 4

Location: Graveline Bayou, southwest of Graveline Bay near the north edge of the Gulfport outcrop.

Latitude: 30° 21.970'N Longitude: 88° 42.650'W
Elevation: -8 feet
Date: 6-30-92

Depth Description

0.0' Holocene, sandy peat and mud, dark gray to black, abundant plant fragments. Forams: *Ammotium salsum*-100%, abundant diatoms.

1.5' Sand, medium grained, massive muddy organics, poorly sorted, moderate brownish-gray, wood fragments at 2.8' and 3.2'. Forams: *Ammotium salsum*-70%, *Miliammina fusca*-30%, abundant diatoms.

3.8' Top of Pleistocene, Prairie Formation, sand, medium grained, muddy, yellowish-gray, becoming brownish-gray at 5.6', forams absent.

7.3' Mud, dark gray to black, soft, with light olive gray medium sand pockets, carbonized wood fragment at 7.3', forams absent.

8.2' Sand, medium grained, white to light gray, plant fragments, becoming coarse white sand at 9.2', with medium olive gray soft mud lenses, forams absent.

9.7' Total depth.

CORE No. 5

Location: Offshore south of Graveline Bayou marsh area, 2000 feet south of Core No. 1.

Latitude: 30° 20.502'N Longitude: 88° 41.790'W
Elevation: -4 feet
Date: 7-01-92

Depth Description

0.0' Holocene, very fine sandy mud, very soft, moderate greenish-gray, scattered shell fragments. Forams: *Ammonia beccarii tepida*-42%, *Elphidium galvestonense*-24%, *Ammotium salsum*-15%, *Ammonia beccarii parkinsoniana*-13%, *Nonion depressulum matagordanum*-7%, *Palmerinella gardenislandensis*-6%, *Miliammina fusca*-2%, salinity peak indicated at 2.0'.

3.0' Very fine sandy mud, very soft, greenish-gray. Forams: *Ammotium salsum*-100%.

6.0' Very fine sandy mud, soft, dark greenish-gray. Forams: *Ammotium salsum*-99%, *Ammobaculites* sp.-1%.

9.0' Very fine sandy mud, dark greenish-gray. Forams: *Ammotium salsum*-98%, *Ammonia beccarii tepida*-1%, *Miliammina fusca*-1%.

13.2' Total depth.

CORE No. 6

Location: Offshore south of Germany property in Central Belle Fontaine area.

Latitude: 30° 20.502'N Longitude: 88° 41.790'W
Elevation -4 feet
Date: 7-01-92

Depth Description

0.0' Holocene, muddy fine sand, very soft, moderate greenish-gray, scattered mud lenses and shells, carbonized wood fragment at 2.0'. Forams (0.9'): *Ammonia beccarii parkinsoniana*-51%, *Ammotium salsum*-20%, *Ammonia beccarii tepida*-14%, *Elphidium galvestonense*-11%; Forams (2.0'): *Ammotium salsum*-87%, *Arenoparella mexicana*-3%.

2.8' Muddy medium sand, moderate olive gray. Forams: *Ammotium salsum*-100%.

4.2' Top of Pleistocene, Gulfport Formation, humate sand, medium to fine grained, muddy, dusky yellowish-brown to dark yellowish-brown, pale orange sand pocket at 5.0', no forams, diatoms scattered.

5.8' Top of Biloxi Formation, fine sand, poorly sorted, dark yellowish-brown, mud lenses. Forams: *Ammotium salsum*-100%.

8.8' Muddy medium sand, poorly sorted, bioturbated, very pale orange. Forams: *Ammotium salsum*-100%.

9.6' Total depth.

CORE No. 7

Location: Offshore of west end of Belle Fontaine Beach, 1800 feet southwest of Core No. 3.

Latitude: 30° 20.722'N Longitude: 88° 45.015'W
Elevation: -5.5 feet
Date: 7-01-92

Depth Description

0.0' Holocene, muddy fine sand, very soft, greenish-black, scattered small shell fragments, whole molluscan shell at 1.7'. Forams (0.5'): *Ammotium salsum*-42%, *Elphidium galvestonense*-33%, *Ammonia beccarii parkinsoniana*-12%, *Ammonia beccarii tepida*-6%, *Miliammina fusca*-4%; Forams (2.6'): *Ammotium salsum*-85%, *Haplophragmoides subinvolute*-4%, *Haplophragmoides* sp.-4%, *Arenoparella mexicana*-2%.

2.9' Muddy fine sand, soft, scattered clay lenses, dark olive gray to dark greenish-gray, grades downward to muddy medium sand at 6.5', moderate brown to dark yellowish brown, scattered limonite nodules at base. Forams: *Ammotium salsum*-97%, *Ammonia beccarii parkinsoniana*-2%, *Trochammina inflata*-1%.

8.9' Top of Pleistocene, mud, oxidized, dark yellowish-orange, mottled with light greenish-gray mud, medium sand at base, forams absent.

11.6' Total depth.

CORE No. 8

Location: Offshore south of Pointe aux Chênes area, 3/4 mile southwest of Core No. 2.

Latitude: 30° 20.143'N Longitude: 88° 47.231'W
Elevation -6 feet
Date: 7-01-92

Depth Description

0.0' Holocene, muddy fine sand, soft, moderate greenish-gray, fragments of *Crassostrea virginica*, becoming fine sandy mud at 2.0'. Forams (0.5'): *Ammotium salsum*-42%, *Ammonia beccarii parkinsoniana* & *Ammonia beccarii tepida*-36%, *Elphidium galvestonense*-11%, *Nonion depressulum matagordanum*-3%, salinity peak indicated; Forams (2.0'): *Ammotium salsum*-92%, *Ammonia beccarii parkinsoniana* & *Ammonia beccarii tepida*-7%.

3.4' Muddy fine sand, very soft, dark greenish-gray, becoming fine sandy mud at 5.6' with sand lenses. Forams: *Ammotium salsum*-97%, *Ammonia beccarii parkinsoniana*-1%.

7.6' Fine sandy mud, soft, dark greenish-gray, sand lenses. Forams: *Ammotium salsum*-73%, *Nonion depressulum matagordanum*-27%.

8.9' Fine sandy clay, dark greenish-gray. Forams: *Ammotium salsum*-100%.

12.5' Medium silt, dark greenish-gray. Forams: *Ammotium salsum*-100%.

13.9' Clay, soft, dark greenish-gray. Forams: *Ammotium salsum*-100%.

21.7' Total depth.

CORE No. 9

Location: Offshore south of Marsh Point.

Latitude: 30° 22.974'N Longitude: 88° 48.663'W
Elevation: -4.5 feet
Date: 7-01-92

Depth Description

0.0' Holocene, mud, very soft, dark greenish-gray, scattered shell fragments, salinity peak indicated at 1.4'. Forams (0.3'): *Ammonia beccarii parkinsoniana* & *Ammonia beccarii tepida*-70%, *Ammotium salsum*-11%, *Elphidium galvestonense*-8%, miliolid spp.-6%, *Trochammina* sp.-2%; (3.5'): *Elphidium galvestonense*-24%, *Ammonia beccarii parkinsoniana* & *Ammonia beccarii tepida*-23%, unidentified calcareous test-20%, *Elphidium latispatium pontium*-10%, *Palmerinella gardenislandensis*-9%, *Nonion depressulum matagordanum*-7%, *Ammotium salsum*-4%.

4.3' Very fine sandy mud, very soft, dark greenish-gray. Forams: *Elphidium galvestonense*-34%, *Ammonia beccarii tepida* & *Ammonia beccarii parkinsoniana*-27%, *Ammotium salsum*-18%, *Nonion depressulum matagordanum*-6%, *Elphidium latispatium pontium*-2%.

5.7' Very fine sandy mud, soft, dark greenish-gray. Forams: *Ammotium salsum*-88%, *Nonion depressulum matagordanum*-8%.

9.3' Very find sandy mud, very soft, dark olive gray. Forams: *Ammotium salsum*-80%, *Ammonia beccarii parkinsoniana*-8%, *Ammonia beccarii tepida*-8%, *Nonion depressulum matagordanum*-4%.

12.9' Very fine sandy mud, very soft, moderate olive gray. Forams: *Ammotium salsum*-99%, *Nonion depressulum matagordanum*-1%.

13.5' Total depth.

CORE No. 10

Location: On beach at Belle Fontaine Beach about 3500 feet east of Core No. 3.

Latitude: 30° 20.689'N Longitude: 88° 44.405'W
Elevation: -1 foot
Date: 7-02-92

Depth Description

0.0' Holocene, sand, medium grained, yellowish-gray to medium light gray. Forams: *Ammotium salsum*-100%.

0.7' Mud, soft, dark olive gray, silty. Forams: *Arenoparella mexicana*-83%, *Ammotium salsum*-9%, *Haplophragmoides* sp.-4%, *Miliammina fusca*-4%.

2.0' Sand, medium grained, light gray, forams absent.

2.4' Sandy mud, dark greenish-gray, plant fragments, sand pockets and lenses. Forams: *Ammotium salsum*-71%, *Arenoparella mexicana*-13%.

3.3' Medium silt, dark greenish-gray, sand lenses. Forams: *Ammotium salsum*-85%.

4.2' Muddy fine sand and mud, dark greenish-gray, sand lenses.

5.0' Mud and muddy fine sand, intercalated, dark greenish-gray. Forams: *Ammotium salsum*-100%.

6.7' Muddy medium-fine sand, dark greenish-gray, shell fragments.

7.6' Muddy fine sand, dark greenish-gray, grades down to mud, oxidized light gray with dark yellowish-orange mottling at 8.0', possible post-drilling exposure oxidation.

8.9' Top of Pleistocene, Biloxi Formation, fine sandy mud, mottled light yellowish-gray and dark yellowish-gray, bioturbated, soil horizon, forams absent.

9.4' Fine sandy mud, light to medium gray and pale bluish-green to medium bluish-gray, mottled, forams absent.

10.5' Fine sand and fine sandy mud, mottled light gray and dark greenish-gray, soil horizon with light olive brown mottling, some woody material, fine white sand lenses intercalated from 11.4' to total depth. Forams: *Ammotium salsum*-100%.

12.1' Total depth.

Core 12

Location: Offshore of Belle Fontaine Point.

Latitude: 30° 19.8'N Longitude: 88° 40.6'W
Elevation: -8 feet

Depth Description

0.0' Holocene, very fine sandy mud, plant fibers, moderate greenish-gray.

1.7' Fine sandy mud, plant fibers, few shell fragments.

6.0' Clayey fine sand, some clean sand, plant fibers.

11.0' Muddy fine sand, scattered gypsum and clean sand.

13.6' Top of Pleistocene, clayey fine sand, ferruginous nodules, plant fibers, gypsum, carbonized wood fragments.

16.5' Clayey fine sand, yellowish-brown oxidized grains, gypsum crystals at total depth.

19.6' Total depth.

Drillhole 13

Location: Sunplex Industrial Complex west of Gautier.

Latitude: 30° 25' 36" N Longitude: 88° 43' 11" W
Elevation: 26 feet

Depth Description

0.0' Prairie Formation, very fine sandy mud and clay, dark yellowish-orange.

10.0' Fine sand, moderately well sorted.

12.0' Fine sandy clay, soft, dark yellowish-orange, iron nodules, sand lenses.

13.5' Biloxi Formation with Prairie Fm. lenses, very fine sandy clay, medium dark gray, small shell fragments scattered throughout, carbonized wood fragments, sand lenses.

19.0' Clayey fine sand, medium dark gray, bioturbation.

23.0' Massive muddy, silty fine sand, poorly sorted, moderate greenish-gray, white sand pockets, carbonized plant fragments.

25.0' Muddy fine sand, sandstone fragments, medium gray.

30.0' Fine sandy mud, light olive gray with dark yellowish-olive mottles, bioturbation, white sand lenses, carbonized woody plant fragments.

35.2' Undifferentiated fluvial Pleistocene and/or undifferentiated Neogene, very fine sandy, medium silt, pale yellowish-brown, mud stringers.

39.5' Fine sand, moderately sorted, very light gray.

43.0' Muddy fine sand, poorly sorted, very light gray.

45.5' Fine sand, poorly sorted.

53.0' Fine sand, well sorted, very light gray, carbonized wood fragments.

60.0' Medium sand, moderately well sorted, plant fragments.

68.0' Undifferentiated Neogene, muddy fine sand, poorly sorted, very light bluish-gray.

82.0' Total depth.

Drillhole 14

Location: Applewhite/Fontainbleau area.

Latitude: 30° 22' 39" N Longitude: 88° 44' 53" W
Elevation: 20 feet

Depth Description

0.0' Prairie Formation, clayey fine sand, poorly sorted, pale yellowish-brown with dark yellowish-orange mottles.

7.0' Fine sand, poorly sorted, very pale yellowish-brown.

10.0' Muddy fine sand, poorly sorted, very light gray.

12.0' Fine sand, moderately well sorted, shell fragments,

Depth	Description
	yellowish-orange with pale mottles.
14.0'	Fine sandy medium silt.
14.5'	Fine sand, well sorted, very light gray, carbonized plant fragments.
17.5'	Very fine sandy mud, mud with very fine sand laminations.
21.0'	Coarse silt, very sandy, with mud, light olive gray, plant fragments, gypsum crystals.
25.0'	Biloxi Formation, mud.
25.5'	Fine sand, white to very light gray, plant fragments.
26.0'	Mud, moderate greenish-gray, *Crassostrea* fragments, salt lenses, gypsum crystals.
32.0'	Clay, ferruginous nodules.
32.5'	Mud, medium stiff, dark greenish-gray.
39.5'	Fine sandy mud, stiff, dark greenish-gray.
42.0'	Clayey fine sand, dark greenish-gray, lenses of shell fragments.
46.0'	Fine sandy mud, moderately dark greenish-gray, few shells.
46.5'	Coarse silty medium sand, very poorly sorted.
50.0'	Muddy medium sand, very poorly sorted, greenish-black, abundant shells.
52.5'	Fine sand, moderately well sorted, white.
59.0'	Medium sand, moderately sorted, light gray.
64.0'	Fine sand, poorly sorted, light gray.
70.2'	Neogene, mud, very stiff, medium greenish-gray with dark yellowish-orange mottles.
72.0'	Total depth.

Drillhole 15

Location: Belle Fontaine Point, Germany property.

Latitude: 30° 20' 41"N Longitude: 88° 42' 06"W
Elevation: 15 feet
Date: 10-25-77

Depth	Description
0.0'	Gulfport Formation, medium sand, well sorted, dark yellowish-orange.
3.0'	Medium sand, well sorted, white with dark yellowish-orange streaks.
13.0'	Medium sand, very well sorted, dusky brown, humate cement.
17.0'	Fine sand, well sorted, dusky brown, humate cement.
27.0'	Fine sand, moderately well sorted, grayish-olive.
32.0'	Fine sand, well sorted, grayish-olive.
35.0'	Medium sand, moderately well sorted, grayish-olive.
40.5'	Fine sand, moderately well sorted, white.
46.0'	Medium sand, well sorted, white with grayish-orange streaks.
51.0'	Fine sand, moderately well sorted, white.
65.5'	Fine sand, very well sorted, white.
70.0'	Undifferentiated Neogene, medium sand, moderately well sorted, medium light gray with dark greenish-gray mud lenses.
85.0'	Fine sand, moderately well sorted, medium light gray.
104.0'	Medium sand, well sorted, white.
114.0'	Fine sand, moderately well sorted, white.
117.0'	Muddy very fine sand, poorly sorted, light grayish-blue-green.
121.0'	Very fine sandy mud, light grayish blue-green.
151.0'	Total depth.

Drillhole 16

Location: Belle Fontaine Point at the west end of Belle Fontaine Beach Road.

Latitude: 30° 20' 55"N Longitude: 88° 44' 53"W

Elevation: 5.0 feet

Depth Description

0.0' Holocene, sand, medium grained, very pale orange to white, moderately well sorted, no forams.

5.0' Sand, fine grained, light gray, well sorted. Forams: *Haplophragmoides subinvolutum*-49%, *Arenoparella mexicana*-27%, *Trochammina inflata*-17%, *Haplophragmoides manilaensis*-6%.

7.0' Fine sandy mud, soft, dark gray, sand lenses. Forams: *Haplophragmoides subinvolutum-64%*, *Arenoparella mexicana*-28%, *Trochammina inflata*-7%.

10.0' Medium muddy sand, poorly sorted, medium olive black grading to medium dark gray at base.

16.0' Top of Pleistocene, Biloxi Formation, muddy medium sand, dark gray.

25.0' Fine sand, moderately well sorted, dark greenish-gray and white. Forams: *Ammonia beccarii tepida*-1 specimen; (28'-29'): *Buliminella elegantissima*-13%, *Nonion depressulum matagordanum*-11%, *Ammonia beccarii tepida*-9%, *Cibicides floridanus*-9%, *Elphidium incertum mexicanum*-9%, *Elphidium galvestonense*-7%, *Hanzawaia strattoni*-7%, *Nonionella atlantica*-7%, *Rosalina columbiensis*-7%, *Quinqueloculina subpoeyana*-4%.

33.0' Clay, greenish-black. Forams: *Elphidium galvestonense*-28%, *Ammonia beccarii tepida*-22%, *Ammonia beccarii parkinsoniana*-20%, *Neoconorbina orbicularis*-7%, *Nonionella opima*-5%, *Cribroelphidium poeyanum*-5%, *Globigerina bulloides*-3%, *Hanzawaia strattoni*-3%.

40.0' Fine sand, moderately well sorted, moderate greenish-gray. Forams: *Rosalina columbiensis*-24%, *Nonion depressulum matagordanum*-8%, *Textularia candeiana*-8%, *Textularia mayori*-7%, *Elphidium galvestonense*-7%, *Hanzawaia strattoni*-5%, *Buliminella elegantissima*-4%, *Quinqueloculina* fragments-4%, *Cribroelphidium poeyanum*-4%, *Elphidium incertum mexicanum*-4%, *Ammonia beccarii tepida*-3%, *Ammonia beccarii parkinsoniana*-3%.

43.5' Very fine sandy mud, dark greenish-gray. Forams: *Ephidium galvestonense*-18%, *Nonion depressulum matagordanum*-18%, *Rosalina columbiensis*-17%, *Buliminella elegantissima*-6%, *Ammonia beccarii tepida*-5%, *Ammonia beccarii parkinsoniana*-4%, *Elphidium incertum mexicanum*-4%, *Brizalina lowmani*-3%, *Nonionella opima*-3%.

55.0' Fine sandy mud and muddy medium sand, dark gray, wood fragments. Forams: *Rosalina columbiensis*-28%, *Elphidium galvestonense*-22%, *Ammonia beccarii tepida*-8%, *Elphidium incertum mexicanum*-5%, *Ammonia beccarii parkinsoniana*-5%, *Buliminella elegantissima*-5%, *Nonionella atlantica*-4%, *Nonion depressulum matagordanum*-3%.

60.5' Pre-Sangamonian Pleistocene, alluvium, muddy medium sand, dark gray, with wood fragments.

63.0' Medium sand, well sorted, white.

70.0' Top of definite Neogene, gravel, fine sand, and stiff, light greenish-gray mud.

71.0' Fine sand, moderately well sorted, white.

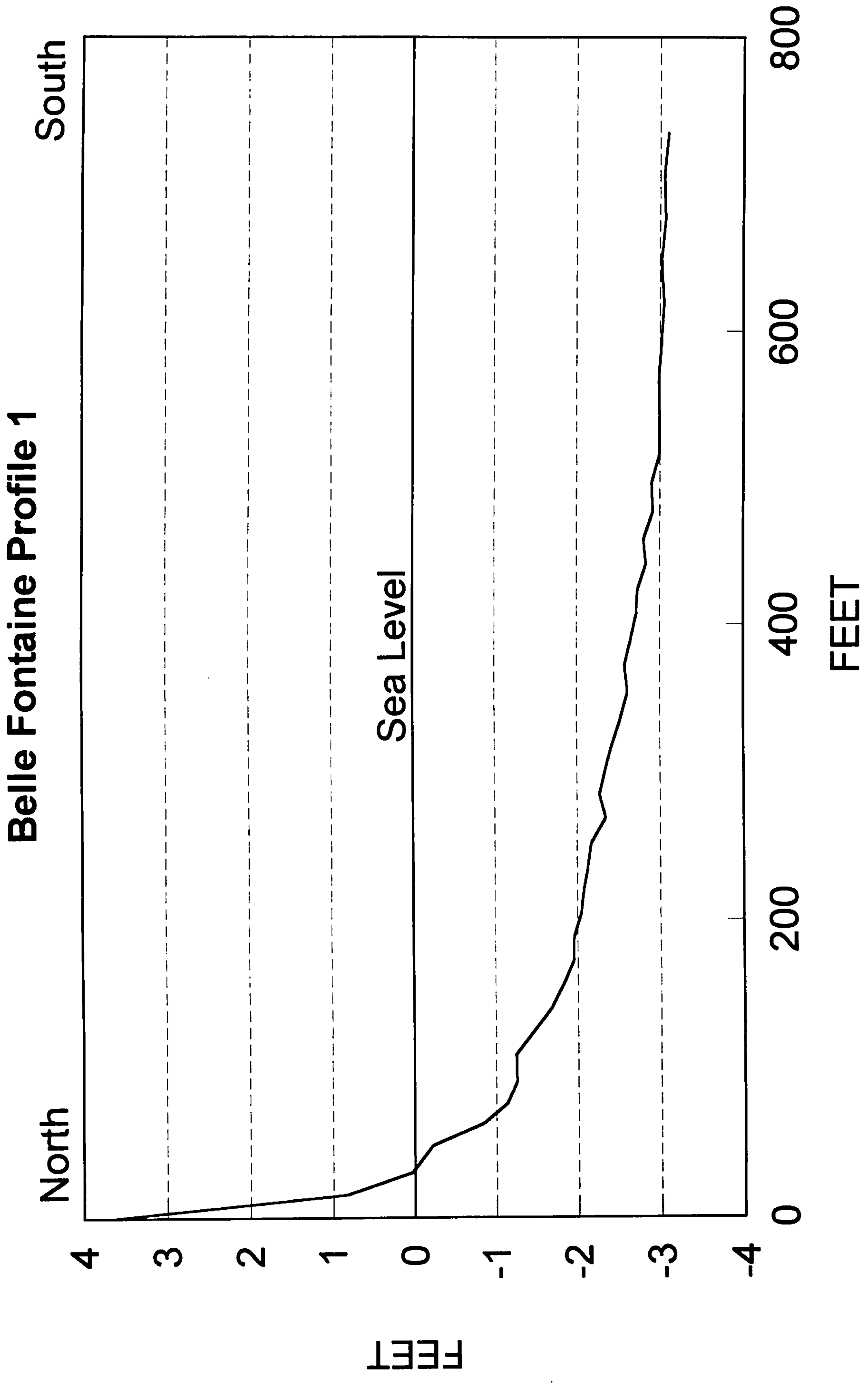
74.0' Mud, stiff, light greenish-gray.

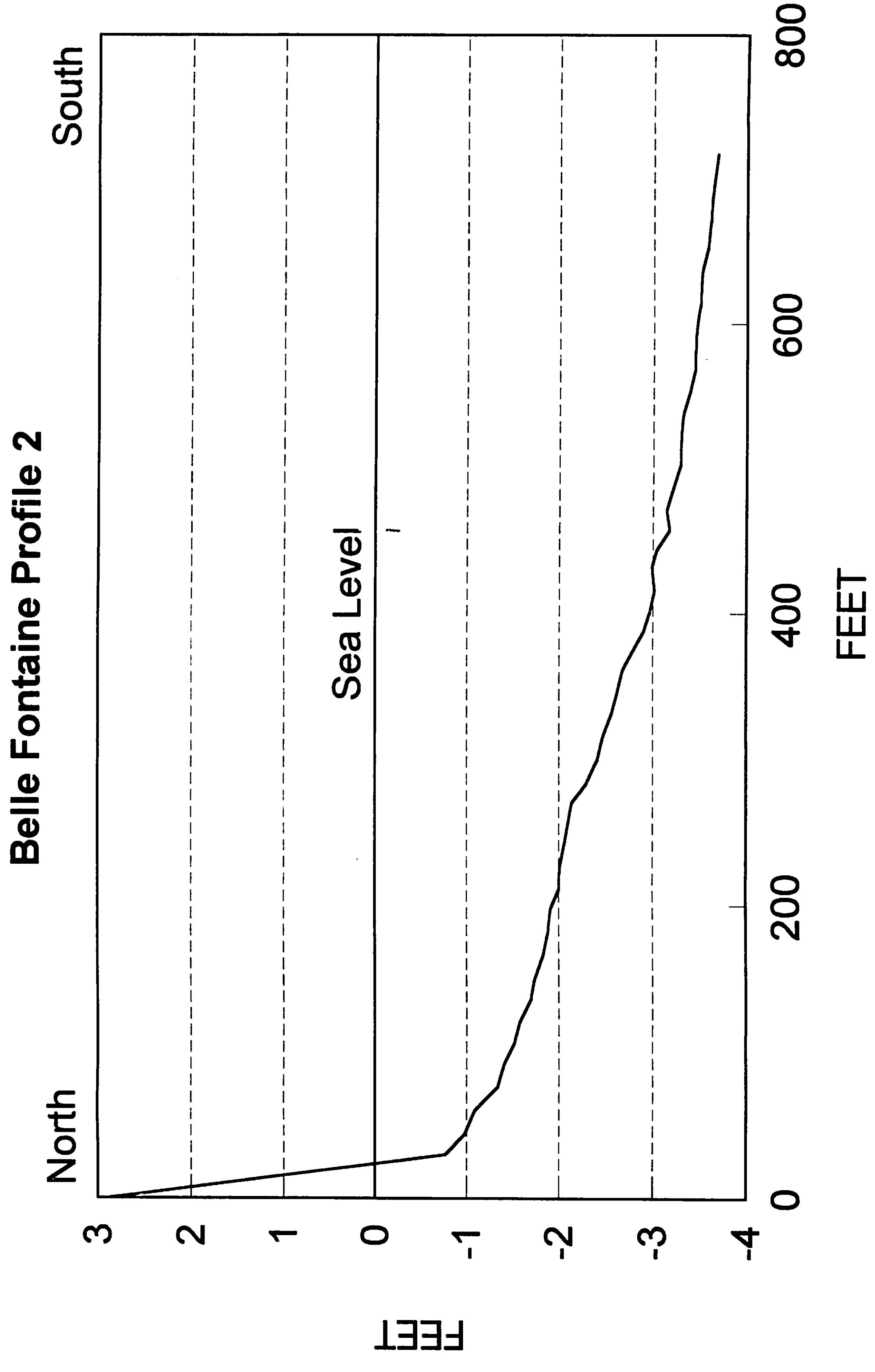
85.0' Clay, stiff, dark greenish-gray.

87.5' Total depth.

Appendix B.

Beach and Nearshore Profiles at Belle Fontaine
(Location of profiles in Figure 7)


Belle Fontaine Profile 1
North
South
Sea Level
FEET
FEET
4
3
2
1
0
-1
-2
-3
-4
0
200
400
600
800


Belle Fontaine Profile 2
North
South
Sea Level
FEET
FEET
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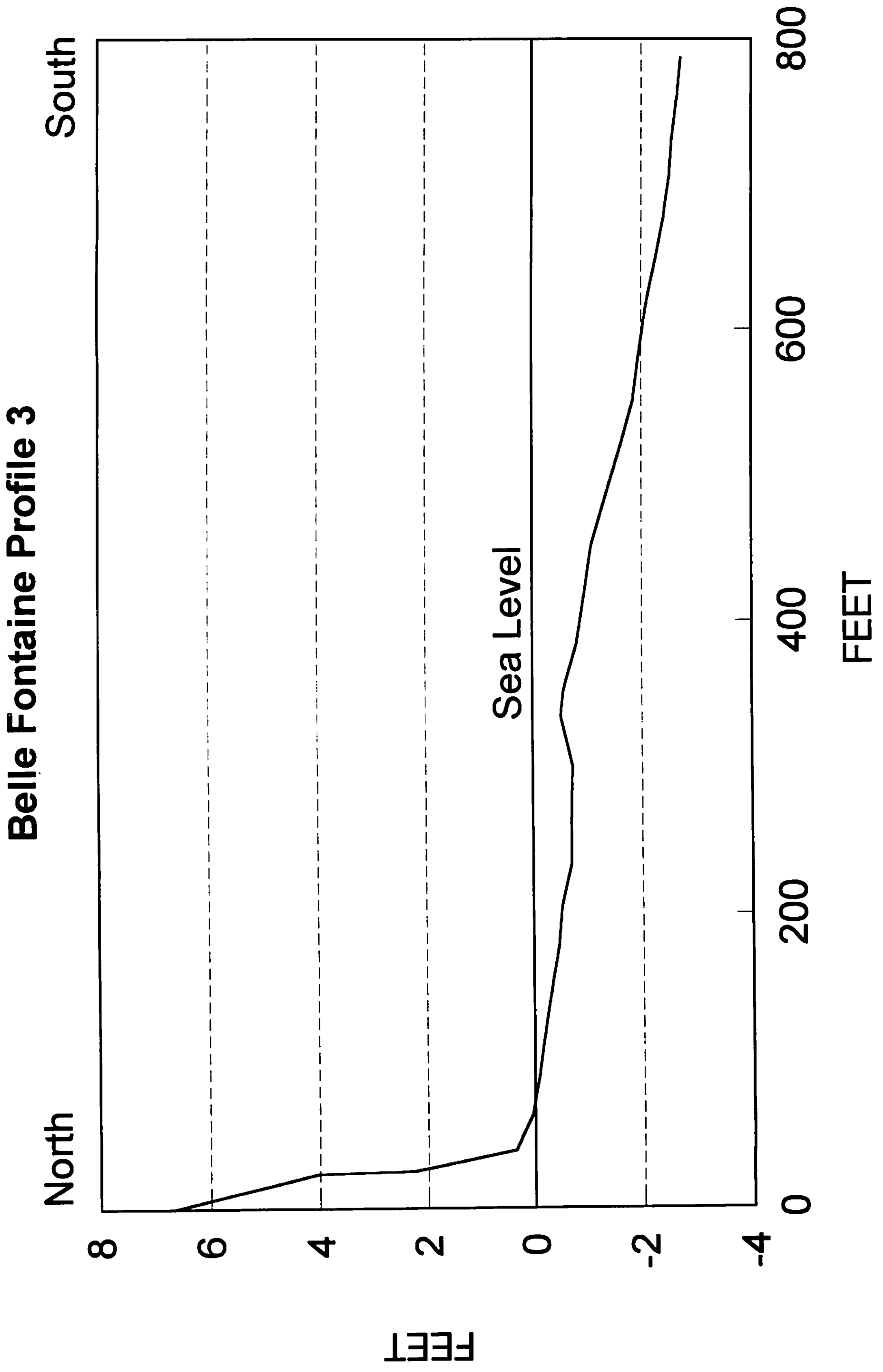
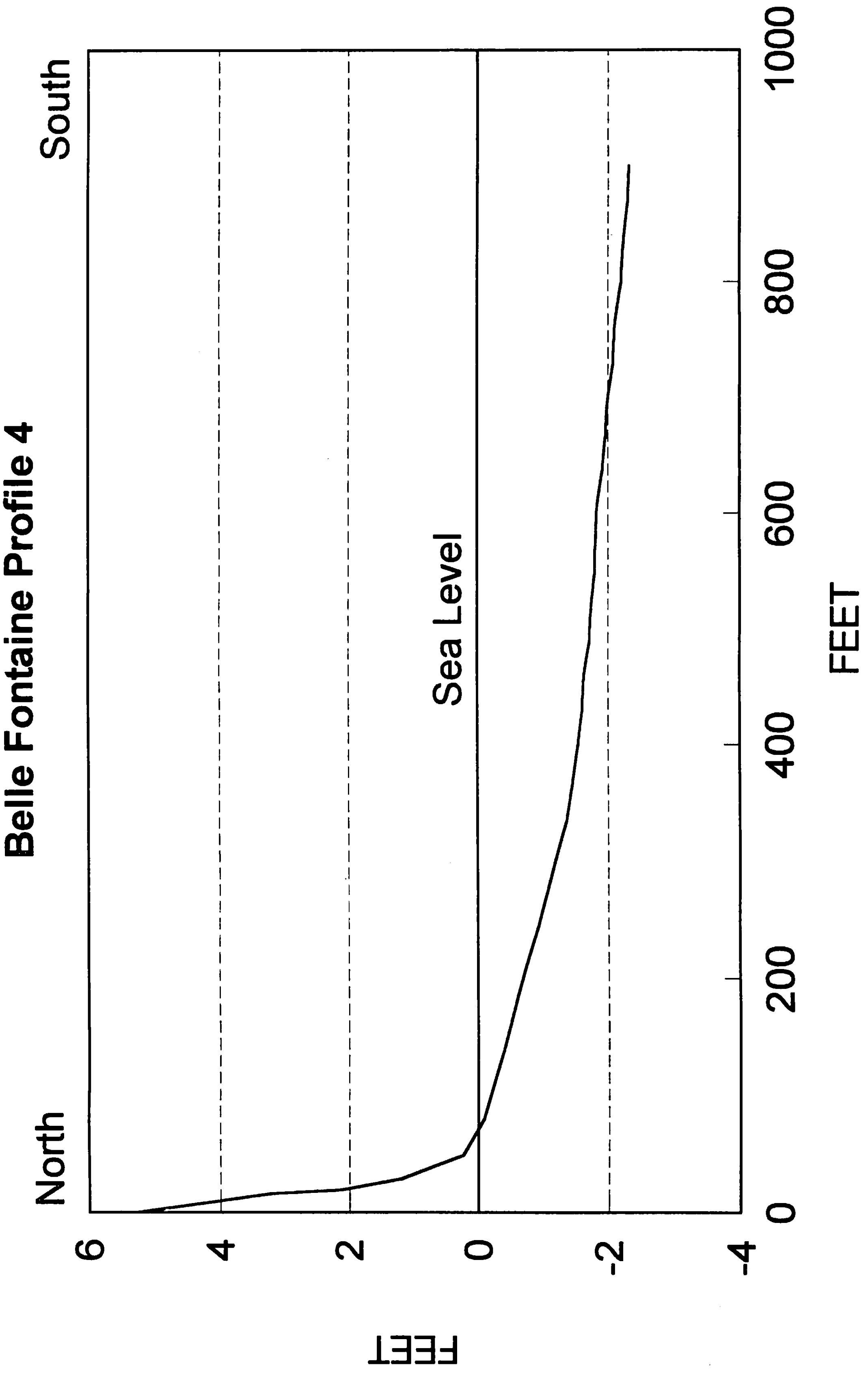
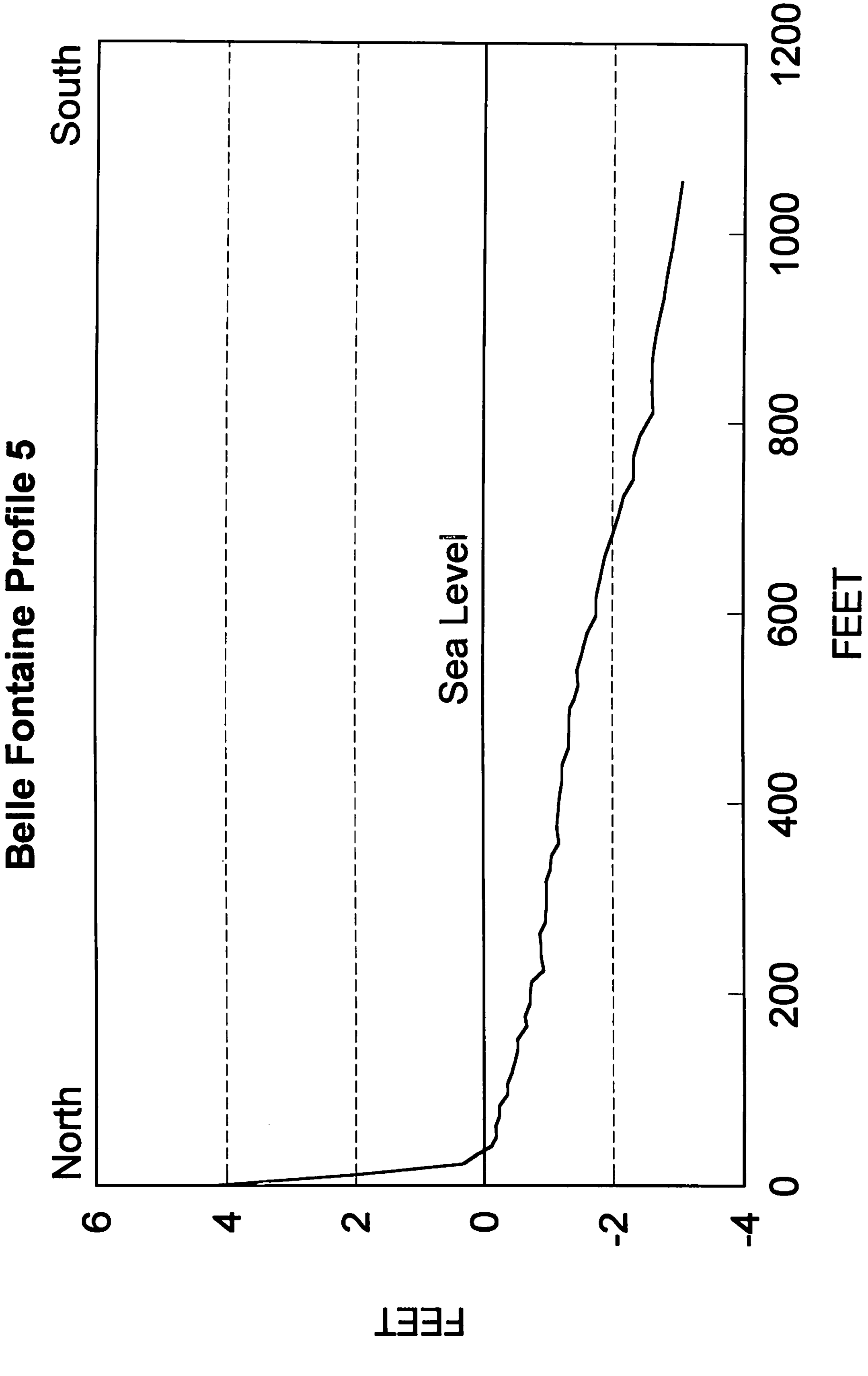
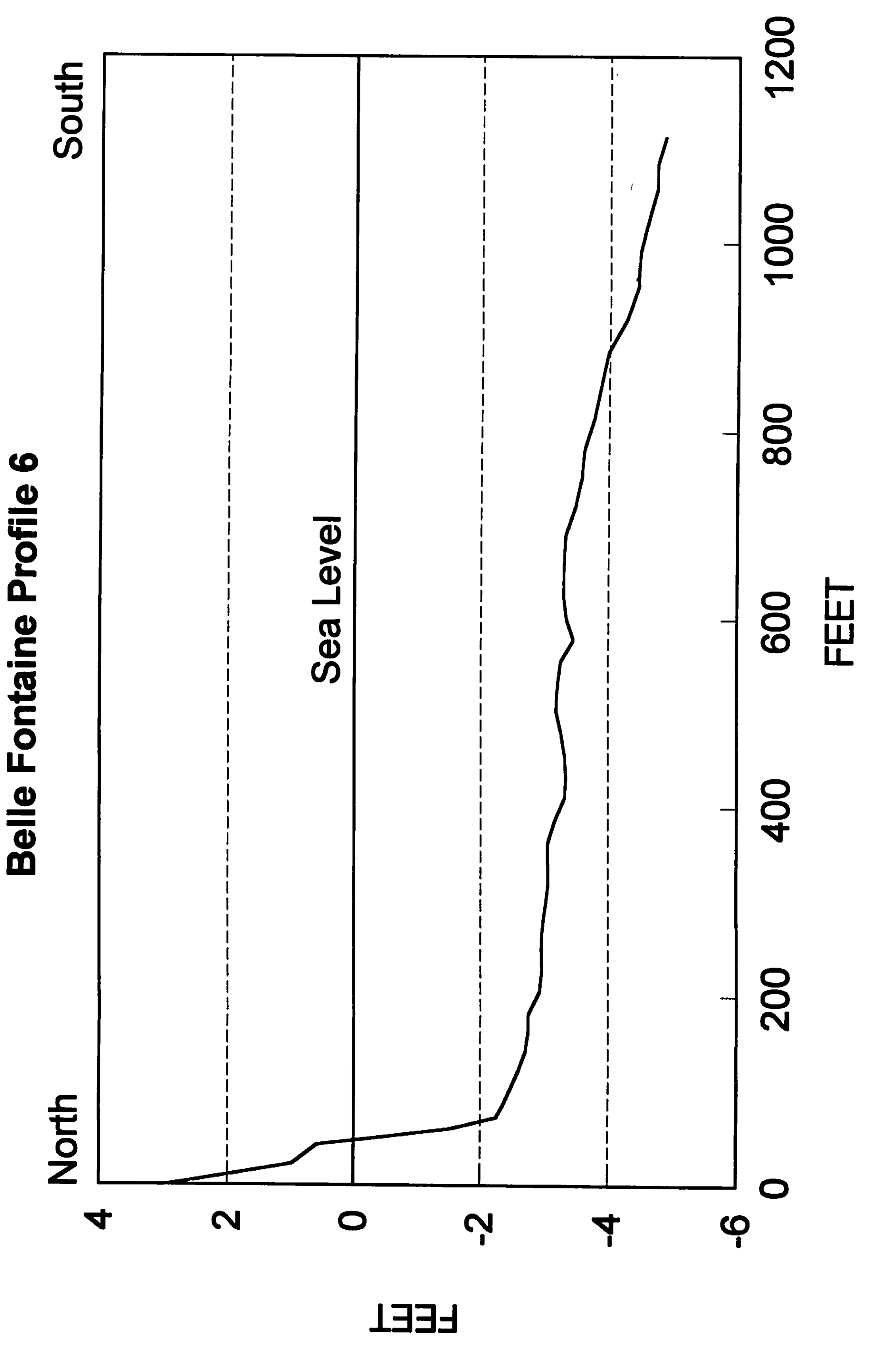
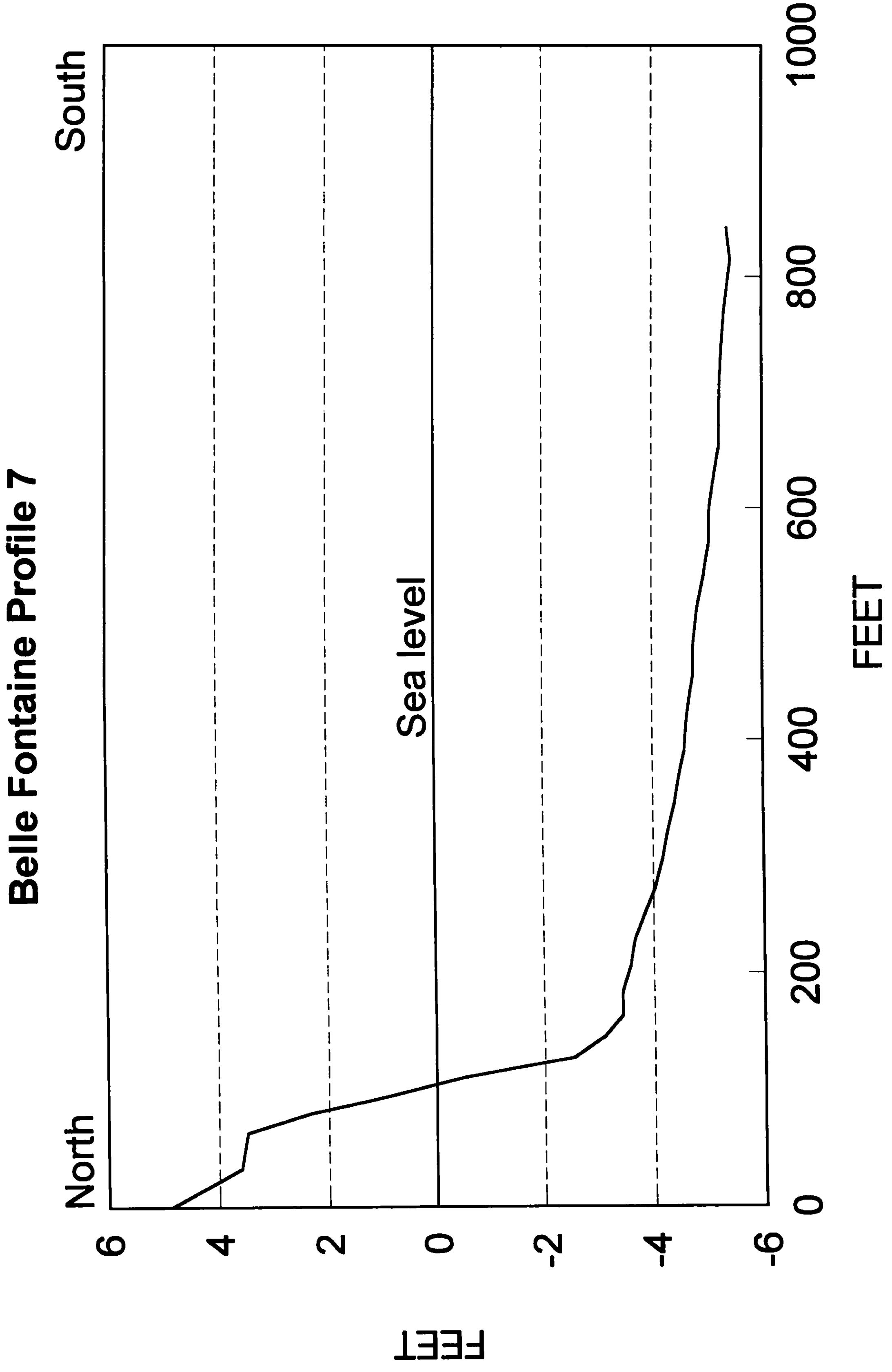
2
1
0
-1
-2
-3
-4
0
200
400
600
800

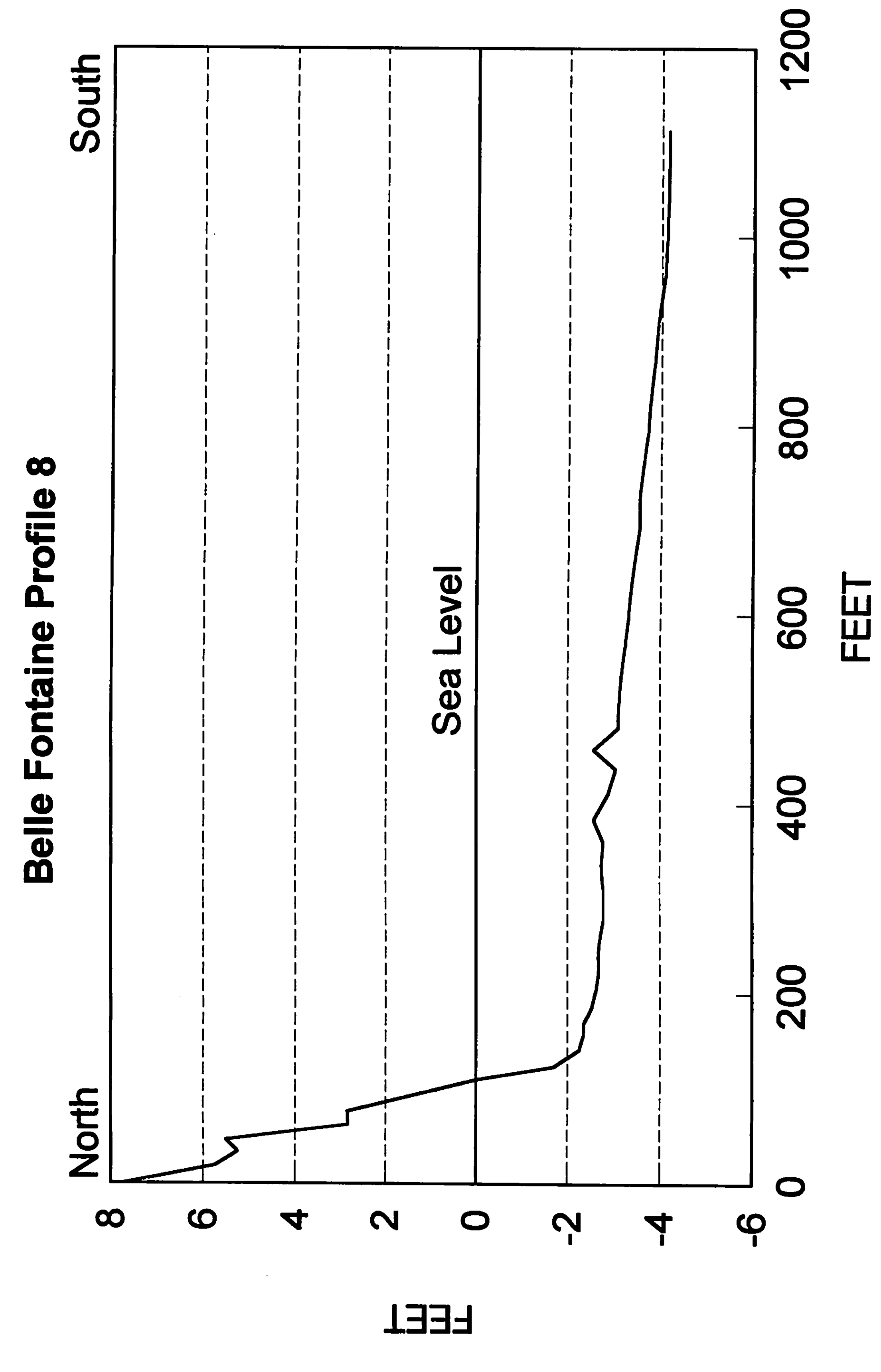

Belle Fontaine Profile 3
North
South
Sea Level
FEET
FEET
8
6
4
2
0
-2
-4
0
200
400
600
800


Belle Fontaine Profile 4
North
South
Sea Level
FEET
FEET
6
4
2
0
-2
-4
0
200
400
600
800
1000


Belle Fontaine Profile 5
North
South
Sea Level
6
4
2
0
-2
-4
FEET
0
200
400
600
800
1000
1200
FEET


Belle Fontaine Profile 6
North
South
Sea Level
FEET
FEET
4
2
0
-2
-4
-6
0
200
400
600
800
1000
1200


Belle Fontaine Profile 7
North
South
Sea level
FEET
FEET
0
200
400
600
800
1000
6
4
2
0
-2
-4
-6


Belle Fontaine Profile 8
North
South
Sea Level
FEET
FEET
8
6
4
2
0
-2
-4
-6
0
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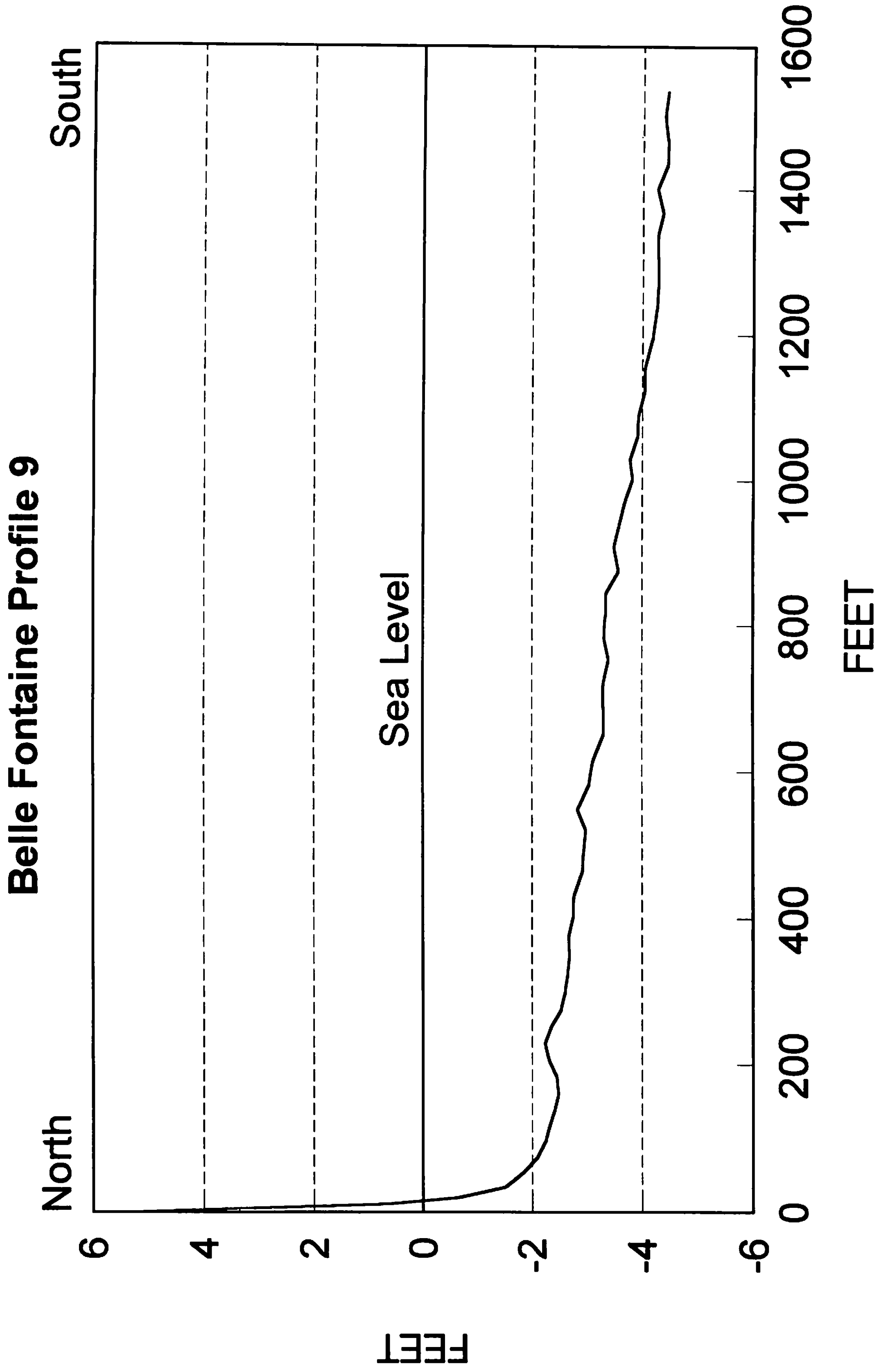
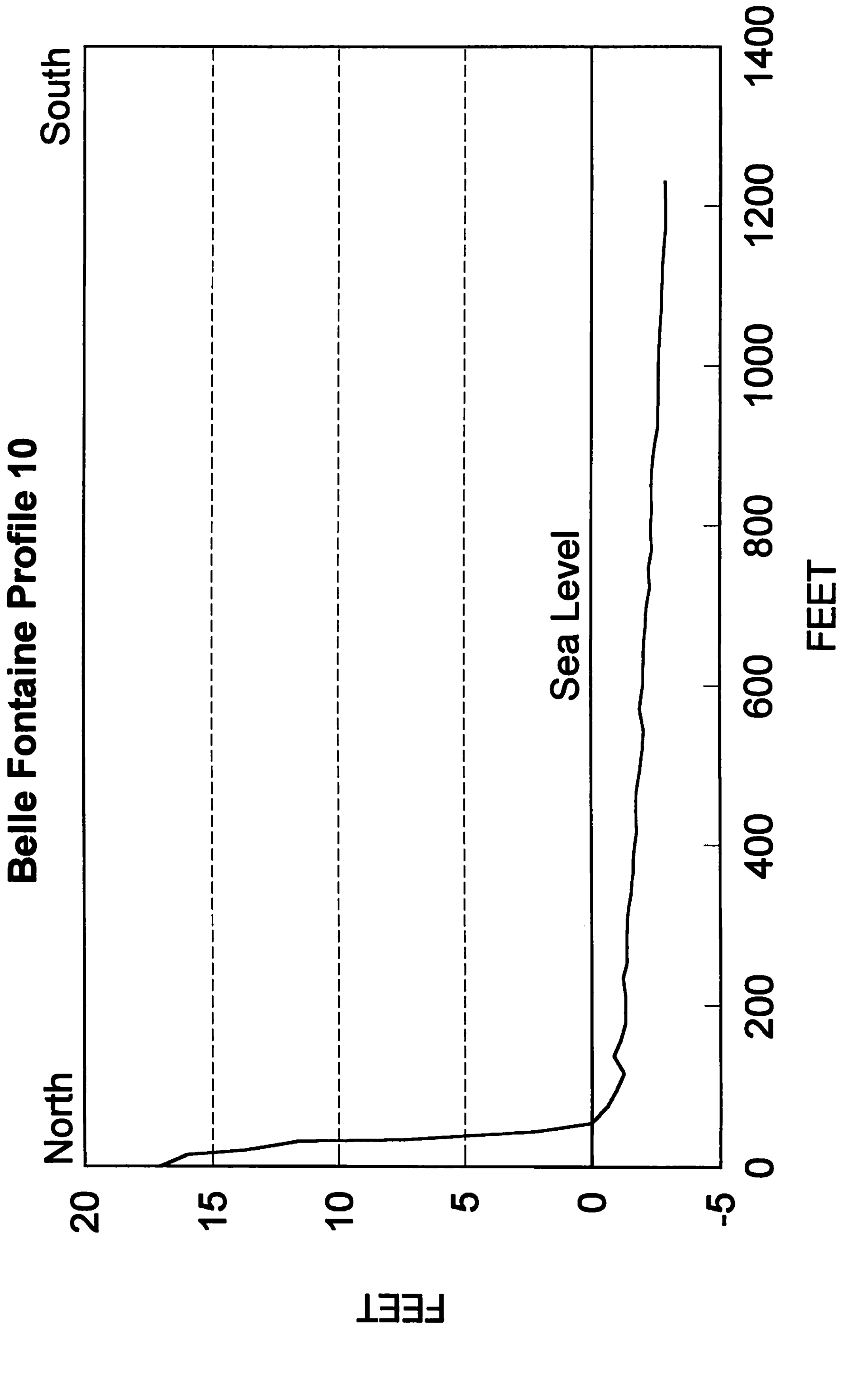
400
600
800
1000
1200


Belle Fontaine Profile 9
North
South
Sea Level
FEET
FEET
6
4
2
0
-2
-4
-6
0
200
400
600
800
1000
1200
1400
1600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Sea Level
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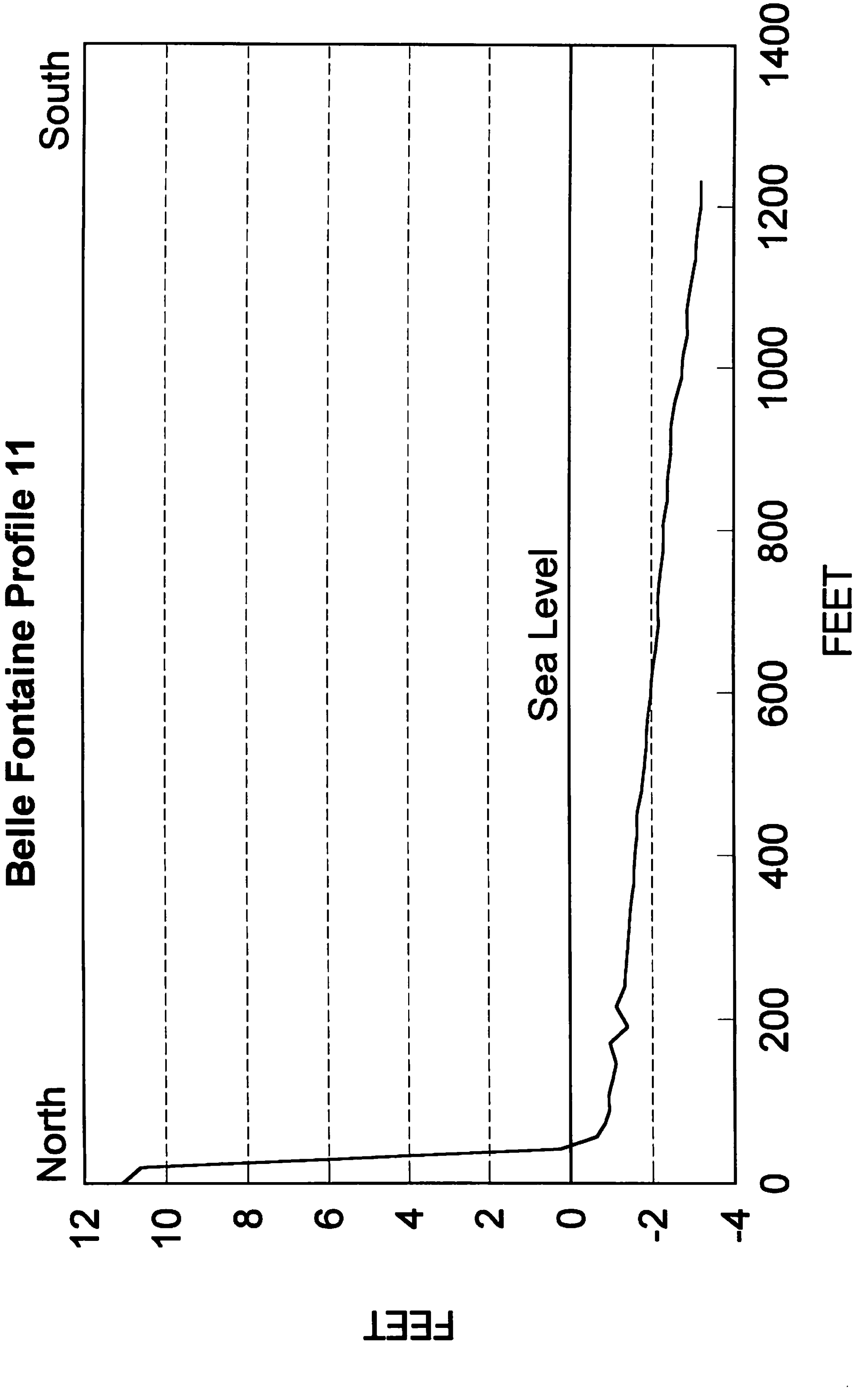
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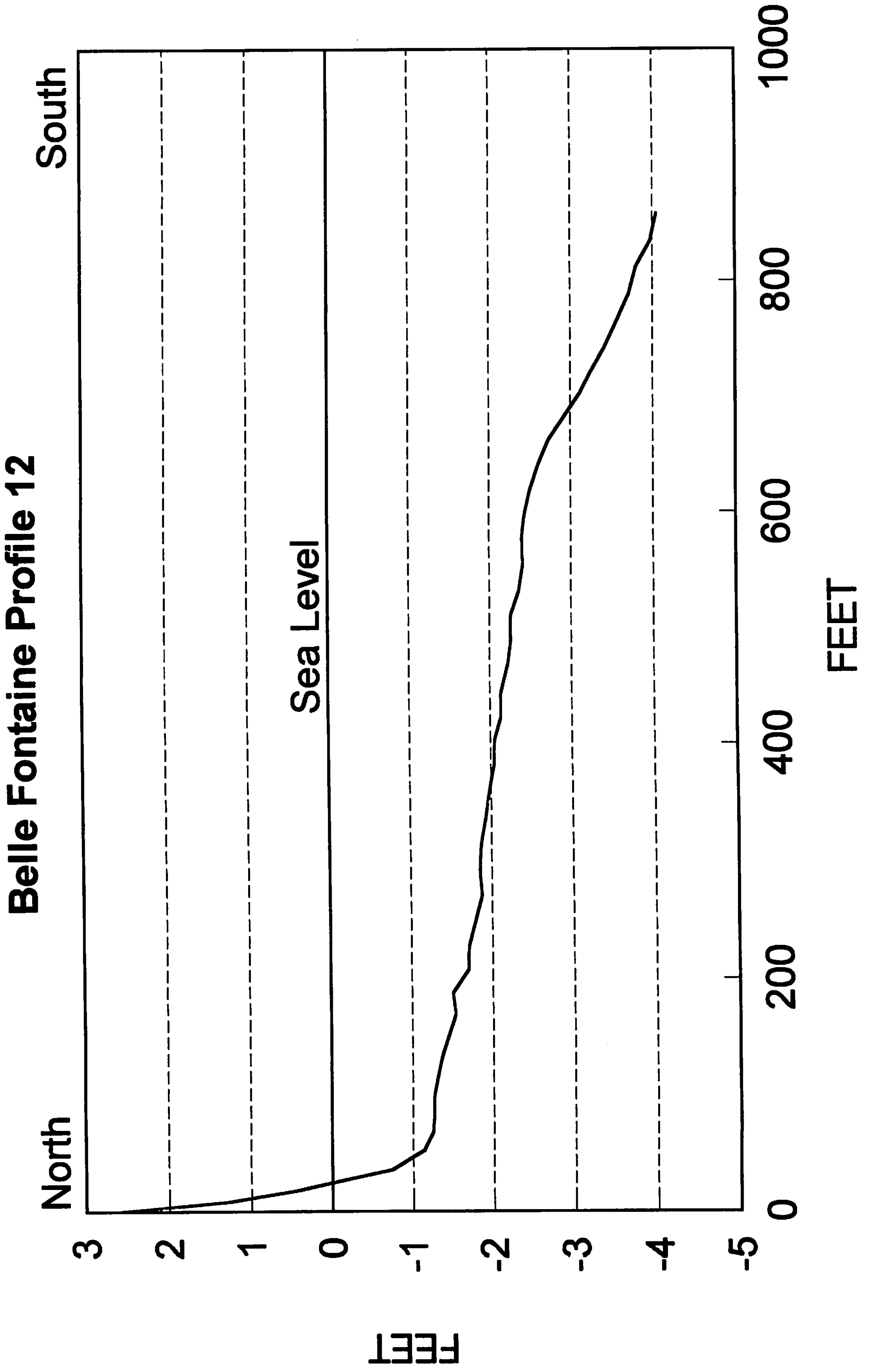
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BELLE FONTAINE SHORELINE EROSION PROJECT: DEVELOPMENT OF SHORELINE EVOLUTION MODEL AND EVALUATION OF EROSION CONTROL ALTERNATIVES

Joseph N. Suhayda
Department of Civil Engineering
Louisiana State University

INTRODUCTION

This paper is a summary of the final report for the Belle Fontaine Shoreline Erosion Project (Contract CZM NA 170Z0363-01/4.3) and presents the recommendations for controlling shoreline erosion at Belle Fontaine. The scope of work for the project consisted of three main tasks: Task 1, wave climate data acquisition; Task 2, data analysis and assimilation; and Task 3, a technical evaluation of erosion control measures for the Belle Fontaine site.

Methodology

The method used to achieve the project objectives was to quantify the coastal processes controlling beach erosion and develop a computer model which simulates beach evolution at the site. The model, called SEM (Shoreline Evolution Model), is described in detail later in this report. It assimilates geologic data into a quantitatively predictive tool that can be used to evaluate alternatives for erosion control. The model can also be used to assess the future of the area under a no-action alternative. The data needed to set up the model include wave parameters, shoreline orientation, offshore and nearshore water depths, beach sediment size and distribution, and historical wind statistics.

Episode	Start	End
BMR01	2/12/92	2/21/92
BMR02	2/26/92	3/06/92
BMR03	3/06/92	3/13/92
BMR04	3/13/92	3/22/92
BMR05	3/23/92	3/31/92
BMR06	3/31/92	4/08/92
BMR07	4/08/92	4/16/92
BMR08	4/16/92	4/25/92
BMR09	4/29/92	5/03/92

Table 1. Wave and tide data collection.

WAVE CLIMATE DATA ACQUISITION

Objective

Wave data were acquired to allow the wave climate at the site to be documented. The duration of the data collection was to be limited to the time period from late winter and early spring of 1992. This amount of time was used so that the wave action associated with frontal passages could be observed. Previous experience with coastal processes along the northern Gulf of Mexico has indicated that most of the longshore transport of sediments was associated with winter storms. While not as severe as hurricanes, the winter storms occur frequently enough to be the dominant source of energy causing beach erosion.

Wave/Tide Data Collection

The instrument used to collect the hydrodynamic data was a Sea-Bird Electronics SBE 26 SEAGAUGE Wave and Tide Recorder. The instrument is self-contained in a waterproof cylinder which houses electronics to measure and record water pressure and temperature. From these measurements water elevation and wave heights can be determined. The pressure measurements made by the instrument are absolute pressures and are measured to an accuracy of 0.0001 psi (pounds per square inch), representing a resolution of about 0.5 mm in water height. The pressure is measured continuously and the mean pressure over 15 minutes is recorded. Waves were measured every 3 hours by taking bursts of 1200 samples taken at 0.25-second intervals. The instrument was located near the southernmost point of Belle Fontaine, at beach segment 15, shown in Figure 1. The instrument was about 138 m (450 ft.) southward from the shoreline and was deployed into a water depth of about 1 m (3.3 ft.). Water level varied at the site with tides and wind set-up, and the instrument became exposed upon one occasion. The wave and tide measurements were initiated on February 12, 1992, and were concluded on May 3, 1992. Nine data collection episodes were obtained, each lasting about 7 to 8 days. The data collection episodes are summarized in Table 1.

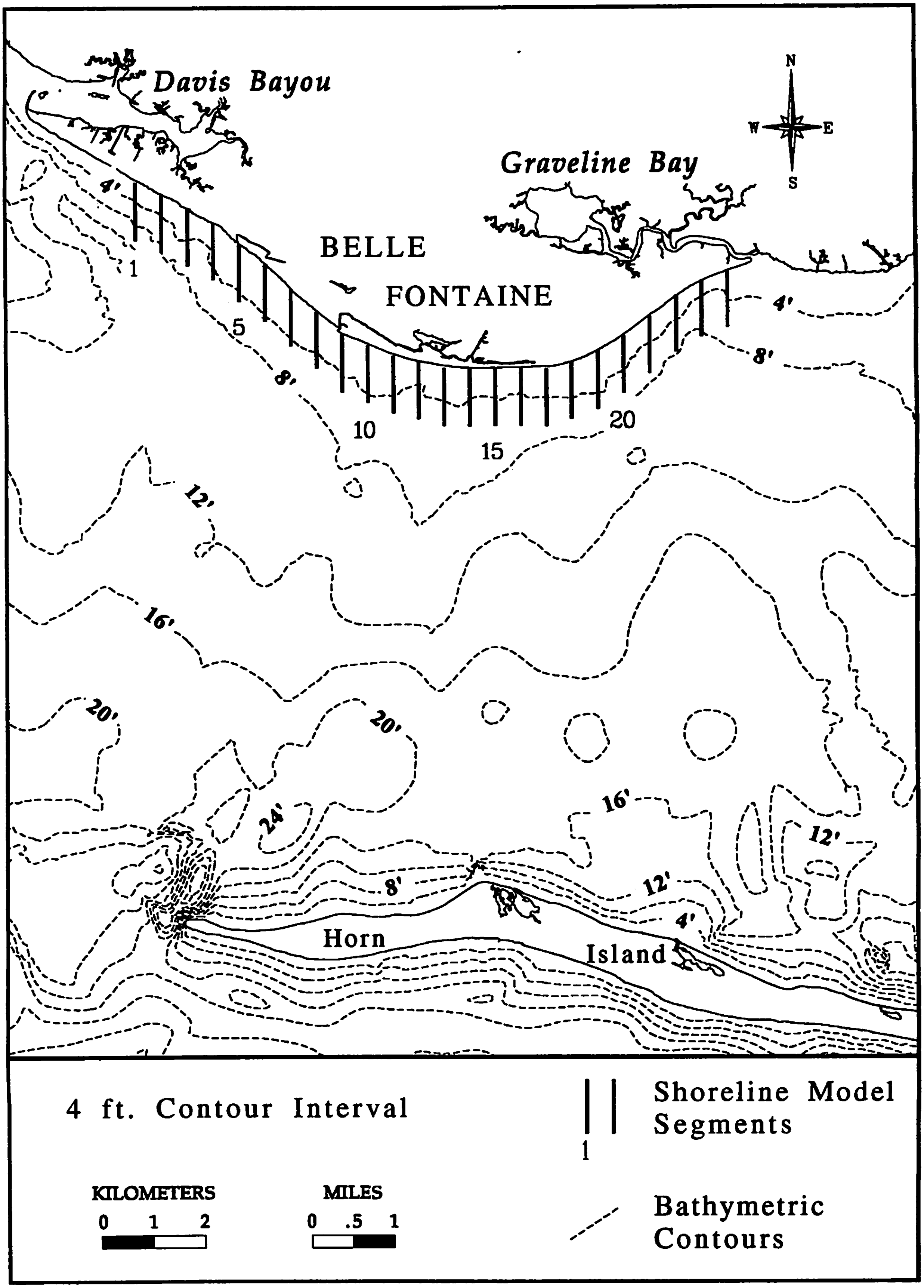


Figure 1. Belle Fontaine study area map showing location of shoreline segments.

Site	Shoreline Bearing (deg.)	Breaker Height (feet)	Breaker Crest Bearing (deg.)
1	286	0.7	273
2	280	0.8	256
3	270	1.1	241
4	270	1.0	256
5	235	1.4	232
6	237	1.4	237

Table 2. Nearshore wave observations on April 19, 1992. Wind direction is from the southeast.

The complete set of tide data is presented in Appendix C, giving for each episode the pressure and temperature measured. The vertical scale is in pounds per square inch absolute (psia), with each small division equaling an elevation change of about 10 cm (4 in.). The astronomical and wind-driven tides are clearly delineated. The highest water level was recorded during the BMR08 episode at hour 99 (about noon on April 20, 1992). The water level was about 1 meter (3.3 ft.) above normal water level.

Shoreline longshore current and breaker data were collected on April 19, 1992. These data are listed in Table 2. The measurement sites were spaced along the entire Belle Fontaine beach system. Site 1 was at the extreme western end of the Belle Fontaine beach near beach segment transect number 8. Site 2 was at beach segment transect number 10. Site 3 was at the location of the wave/tide instrument at beach segment transect 15. Site 4 was at beach segment transect 16. Site 5 was at beach segment 18. Site 6 was about 6.4 km (4 mi.) east of the instrument site at beach segment 22. These data were collected to document the breaker angle variation along the Belle Fontaine beach, which is one of the parameters controlling the magnitude and direction of sediment transport. This also provided data to verify the predicted breaker angles in the computer program used to make an evaluation of the erosion control alternatives.

Meteorological Data

Meteorological data for the period of January 1 to April 30, 1992, were obtained from Keesler AFB. These data consist of hourly readings of wind speed and direction, as well as other data. The wind speed is recorded to 1-knot precision and the wind direction is recorded to 10 degrees precision. Several fronts were recorded in this data set, as indicated in Table 3. The table gives the time period and maximum wind recorded at Keesler. The frontal passages were characterized by a wind vector which rotated clockwise starting with a direction of about 45 degrees. The wind speed increases as the direction changes through 90, then 180, and generally decreases as the wind swings to the north. The direction of the wind at maximum wind speed varied among the frontal passages. In some cases it occurred early, producing strong easterly winds, while in other cases the time of maximum wind was delayed until the wind direction had swung to the west.

Several fronts were selected for use in calibrating the wave forecasting portion of the shoreline evolution model. The wind speed and direction for these fronts are listed in Table 4. Each of the frontal passages showed a wind speed and wind direction variation, with winds initially out of the east and, in most cases, changing in a clockwise manner to winds from the north. The first front on March 9, 1992, lasted about 21 hours and had a prolonged period of eastward winds. The wind was from the east-southeast and southeast for 15 hours and then intensified and changed to the south and west within 6 hours. The second front was also about 21 hours in duration and had the strongest winds from the east, having an 8-hour period of winds over 10 knots. The third front had a duration of about 5 hours, and included a 4-hour period of winds over 10 knots from the southeast. A fourth pre-frontal event was also used; it had a prolonged wind from the southeast on April 17 through April 21, 1992 (Table 5). The wind was from the southeast for about 84 hours, varying in speed between 8 and about 18 knots.

Wind statistics for the central Gulf of Mexico were also developed from several sets of long term observations in the area, i.e., the U. S. Navy's Summary of Synoptic Meteorological Observations data. The wind speed and direc-

Date	Maximum Wind Speed (knots)	Direction Maximum Wind (deg. from)
January 13-14	15	220
January 18-19	18	45
February 25-26	14	240
March 9-10	15	200
March 22-23	15	350
March 30-31	12	340
April 6-7	13	110
April 17-20	16	120
April 22	13	140

Table 3. Fronts and strong winds during the period of January 1 through April 30, 1992.

tion statistics for the area are given in Table 6. The table gives the percent of an average year that winds occur in various speed and direction ranges. The most frequently occurring wind is from the southeast at a speed of 9-21 mph (8-18 knots). Winds from the southeast, south, and southwest account for about 47% of the observations. These wind statistics reflect the average number and intensity of the frontal passages which occurred over several years during the period of ship observations, and are therefore more representative of the expected long term wind patterns than are the short term data which covered the period of wave observations during the first few months of 1992.

DATA ANALYSIS

Wave Data

The wave data collected at the site were analyzed for the periods of high wave heights which occurred during frontal passages. Wave records were analyzed for the significant wave height and period. Four frontal passages were selected as given in Tables 4 and 5. For each frontal passage, the observed wave heights and periods were determined from the pressure sensor data. The wave height and period time series for the prolonged winds on April 17 through 20 are given in Table 7. The wave period and height increase in response to the wind speed and still-water elevation. The highest observed wave heights occurred on or near high tides. The observed wave periods ranged from 2.2 to 3.4 sec. These waves have deep-water wavelengths in the range of 6-18 m (20-60 ft.). The waves reach shallow water at water depths from 0.6 to about 1.8 m (2-6 ft.). Therefore, for most of the Mississippi Sound, which has water depths in the range of 4.5-6 m (15-20 ft.), the waves are propagating in deep water. This means that the bathymetry of the Sound does not substantially control wave heights and directions through wave refraction, shoaling and bottom interactions, and that the wind speed and direction will control wave properties. A typical wave meter output is illustrated in Appendix D.

To assess the wave generation process, the observed wave heights were compared with values forecast using the shallow water graphs in the Shore Protection Manual (U. S. Army Corps of Engineers, 1984). These graphs predict wave height and period based upon a wind speed, open water fetch, and duration. The fetch for various directions of approach to the instrument site varied from essentially unlimited to the west of the site to 12.2 km (40,000 ft.) to the east, 18.3 km (60,000 ft.) to the southeast, 9.1 km (30,000 ft.) to the south, and 15.2 km (50,000 ft.) to the southwest. The forecasting graphs in the Shore Protection Manual indicate a duration of about 2 hours for the wind speed and fetch which occurred during the storm conditions. Thus, the wave field around Belle Fontaine can be defined as fetch limited, since wind duration is much greater than 2 hours. The forecast wave height was corrected for wave shoaling and refraction, but was not corrected for bottom friction, since this is accounted for in the forecasting graphs. The comparison for the prolonged period on April 17 through 20 indicates

	Storm 1		Storm 2		Storm 3	
Time (hr)	Dir. (deg.)	Speed (knots)	Dir. (deg.)	Speed (knots)	Dir. (deg.)	Speed (knots)
1	120	3	60	5	70	4
2	140	10	40	5	50	3
3	130	10	30	7	170	4
4	130	10	350	6	150	9
5	130	8	330	8	160	11
6	130	10	20	9	140	13
7	120	8	60	10	160	11
8	130	9	90	4	150	10
9	120	7	100	20	170	7
10	130	10	90	10	150	4
11	130	10	100	10	140	4
12	130	8	100	13	160	2
13	150	7	100	12		
14	160	10	110	10		
15	160	10	110	10		
16	180	15	110	12		
17	210	10	110	8		
18	190	15	100	8		
19	200	15	120	6		
20	230	18	110	10		
21	250	12	110	7		
Storm 1 starts at 09:00 (ST) on March 9, 1992 Storm 2 starts at 00:00 (ST) on April 6, 1992 Storm 3 starts at 09:00 (ST) on April 22, 1992						

Table 4. Storms selected for detailed wave analysis.

Time (day/hr)	Wind Dir. (deg.)	Wind Speed (knots)	Time (day/hr)	Wind Dir. (deg.)	Wind Speed (knots)
17/8	90	5	19/8	130	10
10	120	10	10	140	8
12	130	10	12	140	12
14	110	10	14	130	10
16	130	8	16	130	12
18	150	9	18	120	10
20	120	8	20	110	10
22	120	7	22	130	8
24	130	9	24	130	10
18/2	140	12	20/2	130	13
4	130	9	4	140	10
6	110	7	6	140	12
8	100	8	8	130	12
10	110	17	10	150	16
12	110	19	12	200	16
14	120	14	14	160	10
16	120	10	16	130	12
18	90	8	18	150	9
20	100	7	20	160	13
22	110	8	22	150	16
24	110	8	24	160	6
19/2	130	6	21/2	330	7
4	130	10	4	330	10
6	150	10			
Note: Data start at 08:00 on April 17, 1992.					

Table 5. Prolonged high wind period on April 17-20, 1992.

	Wind Speed (mph)					
Wind Dir.	0-8	9-21	22-35	36-51	51+	Total %
N	1.4 %	5.6 %	4.4 %	1.2 %	0.1 %	12.7 %
NE	2.0 %	7.1 %	2.4 %	0.3 %	-	11.8 %
E	3.7 %	13.2 %	2.8 %	0.1 %	-	19.8 %
SE	4.1 %	19.5 %	6.7 %	0.3 %	-	30.6 %
S	2.5 %	8.3 %	2.5 %	0.2 %	-	13.5 %
SW	0.9 %	1.4 %	0.3 %	-	-	2.6 %
W	0.7 %	1.1 %	0.4 %	0.1 %	-	2.3 %
NW	0.8 %	2.2 %	1.6 %	0.4 %	-	5.0 %
Calm	1.7 %	-	-	-	-	1.7 %
Total %	17.8 %	58.4 %	21.1 %	2.6 %	0.1 %	100 %

Table 6. Percentages of long term wind statistics for the Belle Fontaine area.

that the SPM graphs overestimate the wave heights at the recording site by about 30%. This is probably due to the effect of the nearshore muds providing an additional energy loss due to the forcing of mud motion.

Some tendency for the wave heights to be limited by water depth is also indicated in the wave data. This again can be caused by wave/sea bottom interactions which increase for shallow water conditions. The wave height to water depth ratio for areas having muddy bottom sediments has been observed to be in the range of 0.3 to 0.4, which is close to the observed ratio at Belle Fontaine. This is considerably less than the breaking criteria, and suggests that the muddy sediments in front of the Belle Fontaine beach may be providing some beach protection.

Geologic Data

The geologic data for the area consist of beach and bathymetric profiles, a bathymetric map generated from the profiles, and sediment data at selected sites. The bathymetric profiles indicate that the nearshore zone is a relatively flat, low sloping bottom, with the beach and beach sediments forming a scarp at the shoreline. The beach sediment size is about 0.3 mm. These beach sands are concentrated at the shoreline and do not extend into Mississippi Sound. At the eastern central portion of Belle Fontaine, a section of cliffs with heights to 15 feet backs a narrow beach.

The geological data have an important bearing on the sediment budget and transport rates at the site. For Belle Fontaine, the sediment budget appears to be relatively simple. Sand is primarily confined to the beach face and backshore in the form of a berm or cliff. The primary source of the sand appears to be the cliffs of Belle Fontaine, with a secondary source along Pointe aux Chênes. There are no sources of sand from nearby rivers. The sand is transported in both westward and eastward directions and accumulates at the western end of Belle Fontaine Beach, due to the presence of a groin at that location. The groin, which protects an inlet, prevents sediment from reaching the beaches to the west. Some beach sands are transported into Mississippi Sound as sediments bypass the inlet mouth. Much of the sand contained in the beach berm is unavailable for transport during normal water levels. The mechanism for initiating and continuing sediment movement is wave action. The transport mechanism is longshore transport of sand driven by waves which move sand in both directions from the cliffs, but primarily in a westward direction. Little sand appears to be transported offshore and dune accretion is not taking place.

This sediment budget is determined by the shape of the Belle Fontaine shoreline and the prevailing wind patterns. Belle Fontaine is a broad point having an east/west bearing at

Date/Time	Sig. Wave Height (cm)	Wave Period (sec)
18/0	13	2.2
3	14	2.5
6	14	2.5
9	25	3.0
12	30	3.3
15	19	3.0
18	15	3.0
21	14	2.7
19/0	19	2.7
3	30	3.3
6	19	3.3
9	19	3.0
12	13	2.9
15	14	2.6
18	16	2.9
21	14	2.7
20/0	19	3.0
3	20	3.1
6	25	3.1
9	25	3.0
12	30	3.4

Table 7. Observed wave height and wave period during April high winds.

its southern point and flanks that sharply turn in a northerly direction. Sediments that are eroded from the point are moved into areas of increasing longshore transport and so are moved northward away from the point area. Even with the wide variations in the wind and wave direction occurring in the area, the longshore transport returns little sediment to the point area. At the extreme eastern and western ends of Belle Fontaine, the shoreline trends northeast and northwest so the longshore transport is reduced. Sediments are deposited at the extreme eastern and western ends of Belle Fontaine.

DATA ASSIMILATION - SHORELINE EVOLUTION MODEL

A computer model, Shoreline Evolution Model (SEM), was developed for this study to assimilate the geological data and evaluate erosion control alternatives. The model quantitatively describes the sediment budget at the site and allows the effects of erosion control alternatives on the sediment budget to be quantitatively evaluated. The model accomplishes these objectives by computing the sediment longshore transport rate and the change in the shoreline position along Belle Fontaine. These calculations are based upon the current shape of the shoreline and the variations in the amount of wave energy occurring along the shoreline. The dominant coastal process controlling sediment transport at Belle Fontaine is longshore transport of sediment, and therefore it was incorporated into the simulation model.

Longshore Transport of Sediments

The longshore transport of sediments is determined by the amount of wave power exerted in a longshore direction, given by the formula:

$$Pls = 1/16\ \gamma Hb^2\ Cgb\ \sin(2\ \alpha b)$$

where *Pls* is the longshore wave power, γ is the unit weight of water, *Hb* is the breaking wave height, *Cgb* is the breaking wave group velocity, and αb is the breaking wave angle. The breaking wave angle is the angle between the wave crest and the shoreline. The units of *Pls* are energy per unit length per unit time. The longshore transport of sediment is related to the longshore power by the formula:

$$Is = K\ Pls$$

where *Is* is the longshore transport rate of sediments and *K* is an efficiency coefficient. The value of the efficiency factor *K* has been estimated from field studies to be a function of sediment grain size; it has a value of 0.4 when *Hb* is the significant wave height. Due to the fact that only a fraction of the beach profile is occupied by sand at Belle Fontaine, a reduced value of 0.2 was used in the program. The units of *Is* are weight per unit time. The longshore sediment transport can be expressed as the volume of sediment moved per unit time by the formula:

$$Q = Is / (\rho s - \rho w)\ G\ a$$

where *Q* is the longshore volume transport, ρs is the density

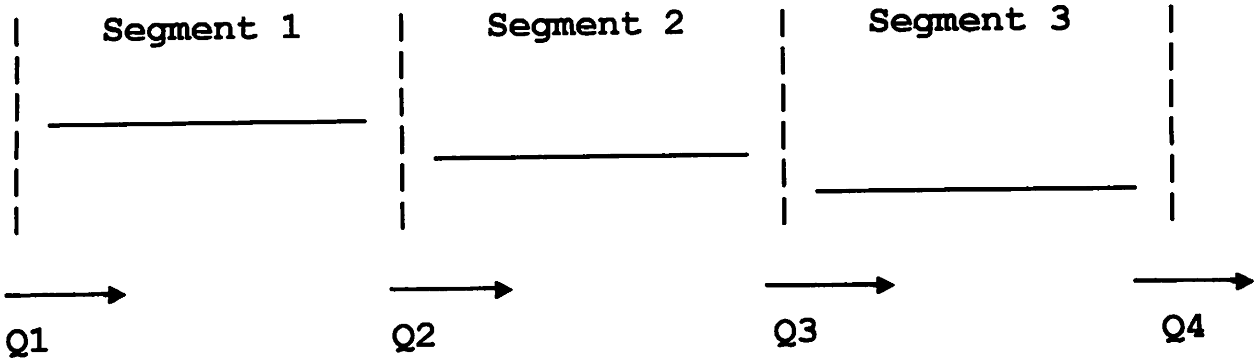


Figure 2. Shoreline segments scheme used in the Shoreline Evolution Model.

of the sediment grains, ρw is the density of water, G is the gravitational acceleration, and a is the volume concentration of the sediment. The units of Q are volume per time. This relationship between wave action and sediment transport is the physical basis for beach erosion and, therefore, must be incorporated into the evaluation of erosion prevention alternatives.

The concept underlying the SEM is the conservation of beach sediment; that is, that the volume of beach sediment along a section of coast will vary depending upon the net amount of addition or removal of sediment. If more sediment comes into a beach area than leaves, then the beach accretes. If more sediment leaves than comes in, then the beach volume decreases and the beach erodes. Sediment can be supplied to a beach by rivers, longshore transport, or from offshore. Likewise, sediment can leave a beach by longshore transport, movement offshore, and/or movement inland.

The equation that expresses this balance or conservation of beach sediment is

$$dVol/dT = S - d(U\ Vol)/dx$$

where Vol is the volume of beach sediment for a section of beach, T is time, S is a source (or sink) of sediment, and U is the longshore transport velocity of the sediment. The last term on the right hand side of this equation shows that it is the gradient of the longshore movement of sediment that controls beach erosion.

Shoreline Evolution Model

The above equations form the basis for a beach evolution model for Belle Fontaine. The change in the volume of sand along sections of the Belle Fontaine beach through either erosion or accretion is due to changes in the longshore transport. As indicated by the sediment samples and cores taken at Belle Fontaine, there is a small amount of sand transported into the Mississippi Sound and there is little overwash to the backshore. Also, there are no rivers currently supplying sediment to the Belle Fontaine beach system. Thus, it appears that the amount of beach sediment along each section of Belle Fontaine depends upon the net amount of longshore transport occurring at that section. If the gradient of the transport flux is positive, that is the flux increases over the section, then erosion will occur. If the gradient is negative, then accretion will occur. A stable beach system will occur when there is no change in the longshore transport along the beach, that is, when the transport is a constant.

Unfortunately, the Belle Fontaine beach system is not in equilibrium because the shoreline geometry dictates that the longshore transport will vary. The geometry of the shoreline along Belle Fontaine is that of a broad point with the direction of the shoreline changing. When waves from a particular direction strike the shoreline the breaking wave angle, that is the angle that the wave crest has with the shoreline, will be different for different locations. Therefore, the longshore transport power, Pls, will be different and Q will be different. From the present depositional patterns of beach sediment it appears that there is a net westward transport of sediment along the Belle Fontaine shoreline. This is in response to the predominant wave direction having an easterly approach angle.

Computer Model

In order to allow for a quantitative evaluation of erosion control alternatives, a computer model was developed to predict the changes in the beach volume of sediment along Belle Fontaine. The model is called SEM (Shoreline Evolution Model). The listing of the model is given in Appendix A. The model incorporates the geometry of Belle

Wind Speed (mph)	Wind Dir. (deg)	Duration (days)
10	140	2
10	145	2
20	145	0.5
10	150	2
20	150	1
30	155	0.25
30	155	0.25
10	165	0.5
20	165	0.5
10	180	1
20	180	0.5
10	195	0.5
20	195	0.5
10	210	0.5
20	210	0.5
10	220	0.5

Table 8. Wind speed variations associated with a frontal event. Wind direction is the angle from which the wind blows.

Fontaine and computes the amount of sediment in each of several beach segments along the shoreline. Changes in the amount of sediment in each segment are controlled by longshore transport, as illustrated in Figure 2. As beach segment volume changes, the shoreline geometry in the model changes and this causes additional changes in the longshore transport rate. Thus, the model describes the evolution of the Belle Fontaine beach and shoreline geometry.

The energy source for the longshore transport comes from waves and so the model incorporates the generation of wave energy by winds. Formulas were developed for forecasting wave heights and periods for each major compass direction of approach, based upon the assumption of fetch-limited waves. Wave conditions are predicted for each beach segment based upon these forecast wave heights and the processes of wave shoaling and wave refraction. Because the waves are in deep water for most of the wave fetches involved, and because the wave generation was calibrated as the net wave height produced by wind, bottom friction was not separately treated.

The wind speed variations for an average frontal event were defined, as given in Table 8. These wind speed and direction variations are associated with a pre-frontal and frontal wind system. The duration of each wind speed is given in days and fractions of days, i.e., the wind before the front is from the southeast at a speed of 15 mph (13 knots) and blows for several days. As the front approaches, the wind speed increases and swings to the south. As the front initially moves into the area, the wind speed increases and swings to the west. Later, of course, the wind is from the north after the frontal passage, but these winds do not generate waves which cause longshore transport along Belle Fontaine, and so are not included in the model. Twelve frontal events are assumed to occur in each year.

The shoreline along Belle Fontaine is represented by shoreline segments, each having a length of 0.5 km (1640 ft.). The segments start at a position corresponding to the Universal Transverse Mercator easting of 330,500 for Zone 16. The average position of the shoreline for each segment was determined from the map position. There are 24 segments defined for the area, covering the coast from westward of the Pointe aux Chênes area to the eastern end of Belle Fontaine near the mouth of Graveline Bayou. The height and width of the beach for each segment were taken from the nearest beach profile data. The initial beach segment data are given in Table 9.

The model computes the breaking wave height and direction for each beach segment, based upon wave refraction and wave shoaling. These values are used to compute the magnitude and direction of longshore transport. The existing groin at the western end of the central part of Belle Fontaine causes sediments to be moved into deeper water and makes them subject to the inlet currents. To account for a loss of sediments into Mississippi Sound, 30% of the sediment moving westward past the inlet was removed from the longshore transport.

A typical output from the model is shown in Table 10. The output gives the segment number, position of the shoreline, beach segment sediment volume, volume change from the initial conditions, beach volume change over previous year, beach width, shoreline position change from the initial position, an alternative indicator, and an alternative parameter.

EVALUATION OF EROSION CONTROL MEASURES

Methodology

The effectiveness of various erosion control alternatives was evaluated by incorporating these alternatives into the SEM and then forecasting the future evolution of the system with the alternative in place. This approach gives a quantitative assessment of the effect of the particular alternative. The erosion control alternatives are incorporated into the model by simulating their effect on the longshore sediment transport process. Several alternatives were considered: no action, structural protection, process control, and process augmentation. The no action alternative describes the future beach changes if no erosion control is attempted. The structural protection alternative describes methods to immobilize beach sediments. The process control alternatives describe methods to reduce adverse wave action and longshore sediment transport. The process augmentation alternatives describe methods for increasing beneficial wave action and sediment transport.

Each alternative is expressed as an effect on one or more of the parameters in the SEM, as described in Table 11. The alternatives for beach erosion control are incorporated into the model as follows:

No Action - This is evaluated using the SEM with no modifications to any parameters.

Process Augmentation - This is accomplished by beach nourishment and is represented in the model as an addition of sediment that changes the volume and shoreline position of a beach segment.

Structural Protection - This is accomplished using bulkheads and revetments. Revetments are represented in the model as a reduction in the amount of beach sediment available for transport. Bulkheads are represented in the model as a constraint on the shoreline position of a beach segment.

Process Control - This is accomplished using groins and offshore breakwaters. The groins are represented in the model as a threshold beach width for longshore transport The offshore breakwaters are represented in the model as a reduction of the breaking wave height.

Each of these approaches has its own advantages as far as engineering effectiveness and aesthetics. The aesthetical considerations should not be ignored in making the final decision about which alternatives to implement; however, it is beyond the scope of this study to deal with the aesthetics issue.

Evaluation of Alternatives

Alternative 0 - No Action

The model was run with no control alternatives in place to determine the no action future condition. The model

Seg. No.	Beach Pos. (ft)	Beach Width (ft)	Beach Hgt. (ft)
1	13465	30	5
2	12771	30	5
3	11804	30	6
4	10514	50	5
5	9083	40	4
6	7485	40	4
7	6057	40	4
8	4764	40	4
9	4030	30	4
10	3435	40	4
11	2976	50	4
12	2692	60	6
13	2545	70	7
14	2538	80	7
15	2597	60	6
16	2664	50	11
17	2939	40	15
18	3680	70	17
19	4643	70	17
20	5866	50	11
21	7078	40	7
22	8055	30	6
23	8733	30	6
24	9276	30	6

Table 9. Beach segment data.

Seg No.	Shore Pos. (ft)	Beach Vol. (cyd)	Vol. Change (cyd)	Annual Change (cyd)	Beach Width (ft)	Shore Change (ft)	Alt. No.	Par.
1	13321	52903	43792	8306	174.2	144.2	0	0.0
2	12775	7842	-1270	-22	25.8	-4.2	0	0.0
3	11807	9686	-1247	-12	26.6	-3.4	0	0.0
4	10526	11563	-3623	-1134	38.1	-11.9	0	0.0
5	9095	6726	-2992	-202	27.7	-12.3	0	0.0
6	7493	7808	-1910	-1239	32.1	-7.9	0	0.0
7	6075	5331	-4388	-78	21.9	-18.1	0	0.0
8	4728	18508	8790	1847	76.2	36.2	2	0.0
9	4030	7336	47	-2	30.2	0.2	0	0.0
10	3439	8626	-1093	-226	35.5	-4.5	0	0.0
11	2989	8958	-3191	-626	36.9	-13.1	0	0.0
12	2703	17691	-4176	-842	48.5	-11.5	0	0.0
13	2558	24358	-5405	-1058	57.3	-12.7	0	0.0
14	2545	30984	-3031	-609	72.9	-7.1	0	0.0
15	2600	20812	-1054	-416	57.1	-2.9	0	0.0
16	2686	18459	-14948	-3977	27.6	-22.4	0	0.0
17	2960	17642	-18802	-1953	19.4	-20.6	0	0.0
18	3693	58884	-13397	-3296	57.0	-13.0	0	0.0
19	4653	62079	-10202	-2024	60.1	-9.9	0	0.0
20	5865	33967	559	138	50.8	0.8	0	0.0
21	7057	25828	8821	1708	60.7	20.7	0	0.0
22	8034	18545	7612	1480	50.9	20.9	0	0.0
23	8733	10982	48	79	30.1	0.1	0	0.0
24	9252	19816	8882	1749	54.4	24.4	0	0.0
Total Sediment Volume (cyd) = 505333.2 Year = 5 Month = 12								

Table 10. Sample output from SEM program.

Alternative	Effect	Parameter
0	No Action	None
1	Beach Nourishment	Beach Seg. Volume
2	Groin	Length of Groin
3	Revetment	Transport Coef. Reduction
4	Breakwater	Wave Hgt. Reduction
5	Bulkhead	Beach Position
6	Combination	Various

Table 11. Beach erosion control alternatives and model representation.

was run for a 5-year time period, with the resulting annual beach position and volume given in Table B-1. The results show that the beach will be seriously eroded along most beach segments of Belle Fontaine. Segment 8 is predicted to build by 36 feet after five years. The cliff areas of Belle Fontaine, segments 16 through 18, will experience erosion of about 6 m (20 ft.). Sediment accumulates at the western end of the system, in segment 1, and the eastern end of the system, segments 21, 22 and 24. The net annual longshore transport rate varies greatly along Belle Fontaine, from a value of about 500 to 1000 cubic yards per year for beach segments 4 through 15, to 2000 to 4000 cubic yards per year for segments 16 through 19.

Alternative 1 - Beach Nourishment

The first erosion control option evaluated involved placing sediment along the beach segments forecasted to undergo the greatest amount of erosion. Table B-2 illustrates the effect of a one-time beach nourishment of 5000 cubic yards at segment 5, 10,000 cubic yards at segment 16, and 10,000 cubic yards at segment 19. This type of nourishment produced reduced erosion for the nourished segments and the segments immediately to the west; however, other segments still showed erosion. Table B-3 shows the effect of distributed nourishment. The beaches at segments 4, 5, 6, 11, 12, 13 and 14 were nourished artificially by 2000 cubic yards each. Beach erosion is reduced along all of these beach segments. Beach segments 16, 17 and 18 still show erosion. A biannual distributed beach nourishment scheme is evaluated in Table B-4. The erosion is eliminated along most of Belle Fontaine, except for the cliff area. This suggests that low-volume distributed nourishment is more effective in controlling beach erosion than high-volume concentrated nourishment.

Alternative 2 - Groins

Groins were placed at beach segments 11, 12, 13 and 14. The results are shown in Table B-5. The groins trap sand and prevent it from moving westward, hence the beach segments containing groins do not erode. The beach segments to the east experience the same amount of erosion as in the no action alternative, while the segments to the west, 10, 9, 8 and 7, had increased erosion.

Alternative 3 - Revetments

Revetments were placed at beach segments 11 through 14. The resulting shoreline changes are given in Table B-6. The revetments reduce the erosion of sediment and permit movement of sediment through the beach segments. The results in Table B-6 show a decrease in erosion at segments 11 through 14 and increased erosion in the segments to the west of those protected when compared to the no action alternative.

Alternative 4 - Breakwater

An offshore breakwater was placed along beach segments 17, 18 and 19. The breakwater was assumed to reduce the incoming wave height by 60%. The results of the forecast are given in Table B-7. The erosion of beach segments 17 through 19 was effectively eliminated; however, segments 11 through 16 experienced increased erosion when compared to the no action alternative for those segments. This is due to the reduction in the volume of sediments transported westward from the cliff area.

Alternative 5 - Bulkheads

The model was run with bulkhead-type protection at several beach segments experiencing the most natural erosion. The result of placing a bulkhead at segments 11 through 14 is given in Table B-8. This option prevents erosion of the beach segment but does not prevent longshore transport of sediment from taking place in either direction and therefore does not lead to erosion of the beach along segments to the west.

Alternative 6 - Combination of Alternatives

Because each of the erosion control alternatives only partially reduced the beach erosion, a combined approach was considered. Numerous combinations of the various alternatives were modeled to find the best combination approach that reduced erosion along most of the Belle Fontaine shoreline. The combined approach which best eliminated erosion involves beach nourishment and breakwaters. As an example of this approach, breakwaters were placed along segments 16, 17, 18, 19 and 20. Beach segments 4, 5, 11, 12, and 14 were each nourished with 2000 cubic yards of sediment. Beach segment 6 received 1000 cubic yards, while segment 13 received 3000 cubic yards. Segment 15 received 5000 cubic yards. The results of the forecast are shown in Table B-9. This combination of options seems to produce an overall effect of greatly reducing or eliminating erosion for much of the Belle Fontaine shoreline.

CONCLUSIONS AND RECOMMENDATIONS

The results of the study indicate that the Belle Fontaine area will experience erosion along most of the length of the beach in varying amounts if no action is taken to prevent it. The erosion rates vary along the shoreline depending upon the magnitude of the longshore sediment transport at that point. Structural controls such as bulkheads and revetments produce benefits only at the beach segment where they are placed and have adverse effects downdrift. Breakwaters and groins can prevent sediment movement alongshore and updrift from a site, but cause increased erosion downdrift. Beach nourishment has a net positive effect on the Belle Fontaine system.

It appears that a combination of beach nourishment and breakwaters may be required to control shoreline erosion along Belle Fontaine. The combination approach prevents shoreline erosion along the cliff areas with breakwaters and augments the lost sediment with beach nourishment. The combined approach of Alternative 6 was further refined by varying the parameters at individual segments in numerous runs of the model to produce a final solution which would economically eliminate erosion for all of the occupied shoreline at Belle Fontaine. The breakwaters are placed along segments 16, 17, 18, 19, and 20 to reduce erosion of the cliffs. Sand nourishment would be placed on the beach at segments 4, 5, and 6, and at segments 11, 12, 13, 14, and 15 to replace the sand which would be lost due to reduced erosion of the cliffs. Annual placement of about 13,000 cubic yards of sediment should provide enough sediment to offset the erosion along the southern shoreline of Belle Fontaine. The model results of this plan are shown in Table B-10.

The cost for implementing the recommended erosion control plan is difficult to determine because of two main factors. First, the cost of each structure will directly depend upon the design criteria specified for the structure. Breakwaters need to perform under routinely occurring weather conditions and survive under extreme conditions. The cost of the structure is a function of the survivability under extreme conditions. Second, the impact of in-kind services on project costs can be considerable. If state, county, or local donated equipment could be used to accomplish the construction of the structures and in moving beach sediment, the cost could be reduced.

Assuming no in-kind support and a 20-year design life for the structures, a general cost estimate can be made for the recommended plan. Beach nourishment costs are about $4.00 per cubic yard, giving an annual cost of $52,000. The breakwater costs are about $100 per foot of beach, or about $550,000 for the length needed. Amortizing the breakwater costs over a functional life of twenty years produces an annual cost of about $27,500. Adding the annual beach nourishment costs of $52,000 to the breakwater annual cost gives a total annual cost of about $79,500. This would protect about 75,000 feet of shoreline at an average cost per year of about $1.06/foot. This would average about $212 annually for each property owner having 200 feet of shoreline.

REFERENCES CITED

U. S. Army Corps of Engineers, 1984, Shore Protection Manual, Vols. I & II: Coastal Engineering Research Center, Dept. of the Army, U. S. Government Printing Office.

U. S. Naval Weather Service, 1970, Summary of Synoptic Meteorological Observations: Vol. 6, Area 17.

Appendix A.

Listing of the program SEM.BAS. Program is written in Q-Basic.

```
10         REM SEM.BAS PROGRAM   FINAL VERSION 4/93
20 OPEN "INP.SEM" FOR INPUT AS #1
30 OPEN "OUT.SEM" FOR OUTPUT AS #2
40 INPUT#1,TITLE$
50 PRINT#2,TITLE$
60 REM - ALT = 0, NO ACTION
70 REM - ALT = 1, NOURISHMENT (PAR=CUBIC YARDS PLACED)
80 REM - ALT = 2, GROIN (PAR=GROIN LENGTH, FT)
90 REM - ALT = 3, REVETMENT (PAR=FRACTION OF BEACH COVERED)
100 REM - ALT = 4, BREAKWATER (PAR=WAVE HEIGHT REDUCTION FRACTION)
110 REM - ALT = 5, BULKHEAD (PAR=MIN BEACH WIDTH, FT)
120        REM INPUT FOR PROGRAM
130 INPUT#1,TITLEX$
140 INPUT#1,NI,NW,NY
150 DIM ALT(NI),HB(NI+1),HBANG(NI+1),PLS(NI+1),T(NT+1),Q(NI+1)
160 DIM BETA(NI+1),BHGT0(NI),SPOSN(NI+1),BWTHN(NI),BVOLN(NI),PAR(NI)
170 DIM WS(NW),WD(NW),DUR(NW),BWTHO(NI),BWTH0(NI),SCHG(NI),DBWTH(NI)
180 DIM SPOS0(NI+1),SPOSO(NI+1),BVOLO(NI),BVOL0(NI),PRN(NI),PRT(NW)
190 DIM YRA(25),SEGN(25),PARN(25),ABVOL(NI)
200 DEF FNTH(QQ)=1-EXP(-2.507*SQR(QQ)*(1.15+4*QQ))
210 DEF FNN(QQ)=.5+(P2*QQ)/(.5*(EXP(P4*QQ)-EXP(-P4*QQ))
220 G=32.2  : PI=3.142 : P2=2*PI : P4=4*PI  : AP=.6
230        REM BEACH INITIAL CONDITIONS AND ALTERNATIVES
240 SLEN=1640 :  VOLT0=0
250 PRINT#2,"        INITIAL BEACH CONDITIONS"
260 PRINT#2,"    SEGMENT  SHORE  BEACH  BEACH  BEACH   BEACH   ALT   PAR  PRN"
261 PRINT#2,"       NUM    POS    ANGLE  WIDTH  HEIGHT  VOLUME"
270 PRINT#2,"             (FT)   (DEG)  (FT)    (FT)   (CYD)"
280 SPOSO(0)=13600
290 INPUT#1,TITLEX$
300     FOR I=1 TO NI
310 INPUT#1,SEG,SPOS0(I),BWTH0(I),BHGT0(I),ALT(I),PAR(I),PRN(I)
320 BWTHO(I)=BWTH0(I)
330 SPOSO(I)=SPOS0(I)
340  IF ALT(I)=1 THEN DBWTH(I)=27*PAR(I)/(SLEN*BHGT0(I))
350  IF ALT(I)=1 THEN SPOSO(I)=SPOS0(I)-DBWTH(I)
360  IF ALT(I)=1 THEN BWTHO(I)=BWTH0(I)+DBWTH(I)
370 BVOL0(I)=BWTHO(I)*BHGT0(I)*SLEN
380 BVOLO(I)=BVOL0(I)
390 VOLT0=VOLT0+BVOL0(I)
400 BETA(I)=-57.3*ATN((SPOSO(I)-SPOSO(I-1))/(SLEN))
410 PRINT#2,USING"      ##  ######  ###.#  ###      ##  ########   #  #####.#
#";I;SPOS0(I);BETA(I);BWTH0(I);BHGT0(I);BVOL0(I)/27;ALT(I);PAR(I);PRN(I)
420     NEXT I
430 INPUT#1,TITLEX$
440 KXX=0
450      FOR K=1 TO 25
460 INPUT#1,YRA(K),SEGN(K),PARN(K)
```

```
470  IF YRA(K)=0 THEN GOTO 500
480 KXX=KXX+1
490      NEXT K
500 PRINT#2,"        TOTAL BEACH SEDIMENT VOLUME (CYD) =";VOLT0/27
510          REM FRONTAL DATA
520     FOR J=1 TO NW
530 READ WS(J),WD(J),DUR(J),PRT(J)
540     NEXT J
550 DATA 10,-40,2,0
560 DATA 10,-35,2,0
570 DATA 20,-35,.5,0
580 DATA 10,-30,2,0
590 DATA 20,-30,1,0
600 DATA 30,-25,.25,0
610 DATA 30,-25,.25,0
620 DATA 10,-15,.5,0
630 DATA 20,-15,.5,0
640 DATA 10,0,1,0
650 DATA 20,0,.5,0
660 DATA 10,15,.5,0
670 DATA 20,15,.5,0
680 DATA 10,30,.5,0
690 DATA 20,30,.5,0
700 DATA 10,40,.5,0
710          REM MULTIYEAR LOOP
720  XX=0: FOR III=1 TO NI:XX=PRN(III)+XX:NEXT III
730     FOR Y=1 TO NY
740 FOR II=1 TO NI: ABVOL(II)=BVOLO(II) : NEXT II
750     FOR M=1 TO 12
760  IF M=12 THEN PRINT#2,"       YEAR =";Y;"          MONTH =";M
770  IF XX=0 THEN GOTO 800
780 PRINT#2,"        BS WS  WD DUR  H   T    KS   KR  HB   CGB   BRAG   PLS    Q"
790 PRINT#2,"         (MPH)(DG)(HR)(FT) (S)          (FT)  (FPS) (DEG) (LB/S)(CYH)"
800          REM BEACH SEGMENT LOOP
810     FOR IT=1 TO NW
820 IF WD(IT)>-100 THEN H=.114*(WS(IT)^.75)  : T=.84*WS(IT)^.35
830 IF WD(IT)>-67.5 THEN H=.129*(WS(IT)^.75)  : T=.91*WS(IT)^.35
840 IF WD(IT)>-22.5 THEN H=.107*(WS(IT)^.75)  : T=.81*WS(IT)^.35
850  IF WD(IT)>22.5 THEN H=.122*(WS(IT)^.75)  : T=.87*WS(IT)^.35
860 KB=1! :  DT=3600*24*DUR(IT)
870 GLEN=0
880      FOR I0=2 TO NI
885  IF(I0)>21 AND WD(IT)<-15 THEN H=((21/I0)^2)*H
890  IF KXX=0 THEN GOTO 1040
910        FOR K1=1 TO KXX
920  IF Y=YRA(K1) AND M=1 THEN GOTO 940
930 GOTO 1030
940  IF IT=1 AND I0=SEGN(K1) THEN GOTO 960
```

```
950 GOTO 1030
960 PAR(I0)=PARN(K1)
970 ALT(I0)=1
980 DBWTH(I0)=27*PAR(I0)/(SLEN*BHGT0(I0))
990 SPOSO(I0)=SPOSO(I0)-DBWTH(I0)
1000 BWTHO(I0)=BWTHO(I0)+DBWTH(I0)
1010 BVOLO(I0)=BWTHO(I0)*BHGT0(I0)*SLEN
1020 PRINT"Y,M,IT,I0,DBWTH =";Y;M;IT;I0;DBWTH(I0)
1030      NEXT K1
1040 BETA(I0)=-57.3*ATN((SPOSO(I0)-SPOSO(I0-1))/(SLEN))
1050 RANG=WD(IT)-BETA(I0)
1060 C0=5.12*T  :  L0=C0*T  : HBX=H
1070    FOR IX=1 TO 5
1080 DB=1.28*HBX
1090 CGB=SQR(32.2*DB)
1100 C=C0*FNTH(DB/L0) : L=C*T
1110 ZR=(C/C0)*SIN(RANG/57.3)
1120 HBANG(I0)=ATN(ZR/SQR(1-ZR*ZR))*57.3
1130 KRX=(COS(RANG/57.3)/COS(HBANG(I0)/57.3))
1140 KR=SQR(KRX)
1150 KS=SQR(C0/(2*CGB))
1160  IF ALT(I0)=4 THEN KB=PAR(I0)
1170 HBX=H*KS*KR*KB
1180    NEXT IX
1190 HB(I0)=HBX
1200        REM LONGSHORE TRANSPORT CALCULATION
1210 PLS(I0)=4*HB(I0)*HB(I0)*CGB*SIN(2*HBANG(I0)/57.3)
1220 COEFK=.2
1230  IF ALT(I0)=3 THEN COEFK=PAR(I0)*COEFK
1240 IL=COEFK*PLS(I0)
1250 Q(I0)=IL/(3.4*G*AP)
1260  IF Q(I0)<0 AND BWTHO(I0)<30 THEN Q(I0)=(BWTHO(I0)/30)*Q(I0)
1270  IF Q(I0)>0 AND BWTHO(I0-1)<30 THEN Q(I0)=(BWTHO(I0-1)/30)*Q(I0)
1275  IF ALT(I0)=5 THEN BWTHMIN=PAR(I0) : IF BWTH0(I0)<BWTHMIN AND Q(I0)<0 THEN
Q(I0)=0
1280  IF ALT(I0)=2 THEN GLEN=PAR(I0):IF BWTHO(I0)-BWTH0(I0)<GLEN AND Q(I0)<0
THEN Q(I0)=0
1281  IF ALT(I0)=2 THEN GLEN=PAR(I0):IF BWTHO(I0)-BWTH0(I0)<GLEN AND Q(I0-1)>0
THEN Q(I0-1)=0
1290  IF PRN(I0)=0 THEN GOTO 1310
1300 PRINT#2,USING"       ## ## ### ##.# ##.# #.# #.## #.## ##.# ##.# ###.# ###.#
###.#";I0;WS(IT);WD(IT);24*DUR(IT);H;T;KS;KR;HB(I0);CGB;HBANG(I0);PLS(I0);3600*Q(I0)/27
1310    NEXT I0
1320 Q(1)=0 : Q(NI+1)=0 : PLS(1)=0 : HBANG(1)=0
1330        REM BEACH VOLUME CALCULATION
1340 VOLT=0
1350    FOR I1=1 TO NI
1360 DBVOL=DT*(Q(I1+1)-Q(I1))
```

```
1370 IF I1=7 AND Q(I1+1)<0 THEN DBVOL=DT*(.7*Q(I1+1)-Q(I1))
1380 BVOLN(I1)=BVOLO(I1)-DBVOL
1390  IF BVOLN(I1)<0 THEN BVOLN(I1)=0
1400 VOLT=VOLT+BVOLN(I1)
1410 BWTHN(I1)=BVOLN(I1)/(BHGT0(I1)*SLEN)
1420 SPOSN(I1)=SPOSO(I1)-(BWTHN(I1)-BWTHO(I1))
1430 SCHG(I1)=BWTHN(I1)-BWTH0(I1)
1440     NEXT I1
1450 REM SPOSN(NI+1)=SPOSN(NI)
1460 IF PRT(IT)<1 THEN GOTO 1500
1470 PRINT#2,"       WIND SPEED (MPH) = ";WS(IT);"    WIND DIRECTION (DEG) =";WD(IT)
1480 PRINT#2,"       SEG  OBVOL  Q*DT   NBVOL   DVOL   BWTH  SCHG ALT PAR"
1490 PRINT#2,"            (CYD)  (CYD)  (CYD)  (CYD)   (FT)  (FT)"
1500     FOR I4=1 TO NI
1510 IF PRT(IT)<1 THEN GOTO 1530
1520 PRINT#2,USING "       ## ####### ##### ####### ####  ###.# ###.#  #
#####.#";I4;BVOLO(I4)/27;DT*Q(I4)/27;BVOLN(I4)/27;(BVOLN(I4)-BVOLO(I4))/27;BWTHN(I4);SC
HG(I4);ALT(I4),PAR(I4)
1530 BWTHO(I4)=BWTHN(I4)
1540 SPOSO(I4)=SPOSN(I4)
1550 BVOLO(I4)=BVOLN(I4)
1560  NEXT I4
1570     NEXT IT
1580  IF M<12 THEN GOTO 1660
1590 PRINT#2,"  SEGMENT SHORE  BEACH  VOLUME  ANNUAL  BEACH  SHORE  ALT
PAR"
1591 PRINT#2,"    NUM   POS   VOLUME CHANGE  CHANGE  WIDTH  CHANGE"
1600 PRINT#2,"          (FT)  (CYD) (CYD)  (CYD)  (FT)   (FT)"
1610     FOR I3=1 TO NI
1620 PRINT#2,USING "      ## ###### ###### ######   #####   ###.# ####.#   #
#####.#";I3;SPOSN(I3);BVOLN(I3)/27;(BVOLN(I3)-BVOL0(I3))/27;(BVOLN(I3)-ABVOL(I3))/27;BWT
HN(I3);SCHG(I3);ALT(I3),PAR(I3)
1630 IF ALT(I3)=1 THEN ALT(I3)=0 : PAR(I3)=0
1640     NEXT I3
1650 PRINT#2,"       TOTAL SEDIMENT VOLUME (CYD) =";VOLT/27
1660 PRINT"Y,M=";Y;M
1670     NEXT M
1680  IF IT=NW-1 GOTO 1700
1690     NEXT Y
1700 PRINT#2,"       END OF PROGRAM"
1710 END
```

Appendix B.

Belle Fontaine model results; SEM.BAS program printouts for all alternatives discussed in the text.

Table B-1. No action results - Alternative 0

PROGRAM SEM.BAS - BELLE FONTAINE PROJECT
INITIAL BEACH CONDITIONS

SEG NUM	SEG POS (FT)	SEG ANGLE (DEG)	SEG WIDTH (FT)	SEG HEIGHT (FT)	SEG VOLUME (CYD)	ALT	PAR	PRN
1	13465	4.7	30	5	9111	0	0.0	0
2	12771	22.9	30	5	9111	0	0.0	0
3	11804	30.5	30	6	10933	0	0.0	0
4	10514	38.2	50	5	15185	0	0.0	0
5	9083	41.1	40	4	9719	0	0.0	0
6	7485	44.3	40	4	9719	0	0.0	0
7	6057	41.1	40	4	9719	0	0.0	0
8	4764	38.3	40	4	9719	2	50.0	0
9	4030	24.1	30	4	7289	0	0.0	0
10	3435	19.9	40	4	9719	0	0.0	0
11	2976	15.6	50	4	12148	0	0.0	0
12	2692	9.8	60	6	21867	0	0.0	0
13	2545	5.1	70	7	29763	0	0.0	0
14	2538	0.2	80	7	34015	0	0.0	0
15	2597	-2.1	60	6	21867	0	0.0	0
16	2664	-2.3	50	11	33407	0	0.0	0
17	2939	-9.5	40	15	36444	0	0.0	0
18	3680	-24.3	70	17	72281	0	0.0	0
19	4643	-30.4	70	17	72281	0	0.0	0
20	5866	-36.7	50	11	33407	0	0.0	0
21	7078	-36.5	40	7	17007	0	0.0	0
22	8055	-30.8	30	6	10933	0	0.0	0
23	8733	-22.5	30	6	10933	0	0.0	0
24	9276	-18.3	30	6	10933	0	0.0	0

TOTAL BEACH SEDIMENT VOLUME (CYD) = 517511.2

YEAR = 1 MONTH = 12 SEDIMENT VOL (CYD) = 517510

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13434	18636	9525	9525	61.4	31.4	0	0.0
2	12773	8575	-536	-536	28.2	-1.8	0	0.0
3	11806	10189	-745	-745	28.0	-2.0	0	0.0
4	10516	14605	-580	-580	48.1	-1.9	0	0.0
5	9086	9012	-706	-706	37.1	-2.9	0	0.0
6	7488	8964	-755	-755	36.9	-3.1	0	0.0
7	6083	3508	-6211	-6211	14.4	-25.6	0	0.0
8	4723	19586	9868	9868	80.6	40.6	2	50.0
9	4030	7305	16	16	30.1	0.1	0	0.0
10	3436	9507	-211	-211	39.1	-0.9	0	0.0
11	2979	11498	-650	-650	47.3	-2.7	0	0.0
12	2694	21039	-828	-828	57.7	-2.3	0	0.0
13	2548	28658	-1105	-1105	67.4	-2.6	0	0.0
14	2539	33410	-605	-605	78.6	-1.4	0	0.0
15	2597	21770	-97	-97	59.7	-0.3	0	0.0
16	2667	31233	-2174	-2174	46.7	-3.3	0	0.0
17	2945	31265	-5179	-5179	34.3	-5.7	0	0.0
18	3682	70103	-2179	-2179	67.9	-2.1	0	0.0
19	4645	70219	-2063	-2063	68.0	-2.0	0	0.0
20	5866	33492	84	84	50.1	0.1	0	0.0
21	7074	18829	1821	1821	44.3	4.3	0	0.0
22	8051	12510	1577	1577	34.3	4.3	0	0.0
23	8733	10842	-92	-92	29.7	-0.3	0	0.0
24	9271	12757	1824	1824	35.0	5.0	0	0.0

YEAR = 2 MONTH = 12 SEDIMENT VOL (CYD) = 515861

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13404	27599	18488	8964	90.9	60.9	0	0.0
2	12774	8171	-940	-404	26.9	-3.1	0	0.0
3	11807	9876	-1057	-313	27.1	-2.9	0	0.0
4	10518	14028	-1157	-578	46.2	-3.8	0	0.0
5	9090	7958	-1760	-1054	32.8	-7.2	0	0.0
6	7500	6018	-3700	-2945	24.8	-15.2	0	0.0
7	6080	4145	-5573	638	17.1	-22.9	0	0.0
8	4708	23315	13597	3729	96.0	56.0	2	50.0
9	4030	7297	8	-8	30.0	0.0	0	0.0
10	3437	9292	-426	-215	38.2	-1.8	0	0.0
11	2981	10854	-1294	-644	44.7	-5.3	0	0.0
12	2697	20207	-1660	-832	55.4	-4.6	0	0.0
13	2550	27566	-2197	-1092	64.8	-5.2	0	0.0
14	2541	32805	-1210	-605	77.2	-2.8	0	0.0
15	2598	21635	-232	-135	59.4	-0.6	0	0.0
16	2671	29032	-4375	-2201	43.5	-6.5	0	0.0
17	2950	26199	-10245	-5066	28.8	-11.2	0	0.0
18	3684	67866	-4415	-2237	65.7	-4.3	0	0.0
19	4647	68170	-4112	-2049	66.0	-4.0	0	0.0
20	5866	33590	183	99	50.3	0.3	0	0.0
21	7069	20621	3613	1792	48.5	8.5	0	0.0
22	8046	14052	3118	1542	38.6	8.6	0	0.0
23	8733	10822	-111	-20	29.7	-0.3	0	0.0
24	9266	14543	3610	1786	39.9	9.9	0	0.0

YEAR = 3 MONTH = 12 SEDIMENT VOL (CYD) = 513490

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13376	36196	27085	8597	119.2	89.2	0	0.0
2	12775	7955	-1156	-216	26.2	-3.8	0	0.0
3	11807	9749	-1185	-127	26.7	-3.3	0	0.0
4	10521	13002	-2183	-1026	42.8	-7.2	0	0.0
5	9098	6136	-3582	-1822	25.3	-14.7	0	0.0
6	7503	5431	-4287	-587	22.4	-17.6	0	0.0
7	6077	4855	-4863	710	20.0	-20.0	0	0.0
8	4700	25305	15587	1990	104.2	64.2	2	50.0
9	4030	7285	-4	-13	30.0	-0.0	0	0.0
10	3438	9074	-645	-219	37.3	-2.7	0	0.0
11	2984	10216	-1932	-638	42.0	-8.0	0	0.0
12	2699	19371	-2495	-836	53.2	-6.8	0	0.0
13	2553	26486	-3277	-1080	62.3	-7.7	0	0.0
14	2542	32200	-1815	-605	75.7	-4.3	0	0.0
15	2598	21457	-409	-177	58.9	-1.1	0	0.0
16	2675	26109	-7298	-2923	39.1	-10.9	0	0.0
17	2955	22302	-14143	-3897	24.5	-15.5	0	0.0
18	3687	65219	-7062	-2647	63.2	-6.8	0	0.0
19	4649	66132	-6149	-2037	64.0	-6.0	0	0.0
20	5866	33703	295	112	50.4	0.4	0	0.0
21	7065	22384	5377	1764	52.6	12.6	0	0.0
22	8042	15568	4635	1516	42.7	12.7	0	0.0
23	8733	10848	-85	26	29.8	-0.2	0	0.0
24	9261	16310	5376	1766	44.8	14.8	0	0.0

YEAR = 4 MONTH = 12 SEDIMENT VOL (CYD) = 511127

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13348	44598	35487	8402	146.8	116.8	0	0.0
2	12775	7867	-1244	-88	25.9	-4.1	0	0.0
3	11807	9710	-1224	-39	26.6	-3.4	0	0.0
4	10529	10707	-4479	-2296	35.3	-14.7	0	0.0
5	9101	5377	-4342	-759	22.1	-17.9	0	0.0
6	7502	5482	-4236	51	22.6	-17.4	0	0.0
7	6076	5094	-4625	239	21.0	-19.0	0	0.0
8	4692	27321	17603	2016	112.4	72.4	2	50.0
9	4030	7272	-17	-12	29.9	-0.1	0	0.0
10	3439	8851	-868	-223	36.4	-3.6	0	0.0
11	2987	9584	-2564	-632	39.4	-10.6	0	0.0
12	2701	18533	-3334	-839	50.9	-9.1	0	0.0
13	2555	25417	-4346	-1069	59.8	-10.2	0	0.0
14	2544	31594	-2421	-606	74.3	-5.7	0	0.0
15	2599	21229	-638	-229	58.2	-1.8	0	0.0
16	2680	22437	-10971	-3672	33.6	-16.4	0	0.0
17	2957	19595	-16850	-2707	21.5	-18.5	0	0.0
18	3690	62181	-10101	-3039	60.2	-9.8	0	0.0
19	4651	64103	-8178	-2029	62.1	-7.9	0	0.0
20	5865	33828	421	126	50.6	0.6	0	0.0
21	7061	24120	7112	1736	56.7	16.7	0	0.0
22	8038	17065	6131	1497	46.8	16.8	0	0.0
23	8733	10903	-30	55	29.9	-0.1	0	0.0
24	9256	18066	7133	1757	49.6	19.6	0	0.0

YEAR = 5 MONTH = 12 SEDIMENT VOL (CYD) = 508774

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13321	52911	43800	8313	174.2	144.2	0	0.0
2	12775	7834	-1277	-32	25.8	-4.2	0	0.0
3	11808	9530	-1404	-180	26.1	-3.9	0	0.0
4	10537	8108	-7078	-2599	26.7	-23.3	0	0.0
5	9102	5184	-4535	-193	21.3	-18.7	0	0.0
6	7502	5592	-4127	109	23.0	-17.0	0	0.0
7	6076	5163	-4555	70	21.3	-18.7	0	0.0
8	4683	29362	19644	2041	120.9	80.9	2	50.0
9	4030	7267	-22	-5	29.9	-0.1	0	0.0
10	3440	8623	-1096	-228	35.5	-4.5	0	0.0
11	2989	8958	-3191	-626	36.9	-13.1	0	0.0
12	2703	17691	-4176	-842	48.5	-11.5	0	0.0
13	2558	24358	-5405	-1058	57.3	-12.7	0	0.0
14	2545	30984	-3031	-609	72.9	-7.1	0	0.0
15	2600	20812	-1054	-416	57.1	-2.9	0	0.0
16	2686	18459	-14948	-3977	27.6	-22.4	0	0.0
17	2960	17642	-18802	-1953	19.4	-20.6	0	0.0
18	3693	58884	-13397	-3296	57.0	-13.0	0	0.0
19	4653	62079	-10202	-2024	60.1	-9.9	0	0.0
20	5865	33967	559	138	50.8	0.8	0	0.0
21	7057	25828	8821	1708	60.7	20.7	0	0.0
22	8034	18545	7612	1480	50.9	20.9	0	0.0
23	8733	10982	48	79	30.1	0.1	0	0.0
24	9252	19816	8882	1749	54.4	24.4	0	0.0

END OF PROGRAM

Table B-2. Beach Nourishment - Alternative 1, One Time

PROGRAM SEM.BAS - BELLE FONTAINE PROJECT
INITIAL BEACH CONDITIONS

SEG NUM	SEG POS (FT)	SEG ANGLE (DEG)	SEG WIDTH (FT)	SEG HEIGHT (FT)	SEG VOLUME (CYD)	ALT	PAR	PRN
1	13465	4.7	30	5	9111	0	0.0	0
2	12771	22.9	30	5	9111	0	0.0	0
3	11804	30.5	30	6	10933	0	0.0	0
4	10514	38.2	50	5	15185	0	0.0	0
5	9083	41.1	40	4	9719	0	0.0	0
6	7485	44.6	40	4	14719	1	5000.0	0
7	6057	40.6	40	4	9719	0	0.0	0
8	4764	38.3	40	4	9719	2	50.0	0
9	4030	24.1	30	4	7289	0	0.0	0
10	3435	19.9	40	4	9719	0	0.0	0
11	2976	15.6	50	4	12148	0	0.0	0
12	2692	9.8	60	6	21867	0	0.0	0
13	2545	5.1	70	7	29763	0	0.0	0
14	2538	0.2	80	7	34015	0	0.0	0
15	2597	-2.1	60	6	21867	0	0.0	0
16	2664	-1.8	50	11	43407	1	10000.0	0
17	2939	-10.0	40	15	36444	0	0.0	0
18	3680	-24.3	70	17	72281	0	0.0	0
19	4643	-30.2	70	17	82281	1	10000.0	0
20	5866	-36.9	50	11	33407	0	0.0	0
21	7078	-36.5	40	7	17007	0	0.0	0
22	8055	-30.8	30	6	10933	0	0.0	0
23	8733	-22.5	30	6	10933	0	0.0	0
24	9276	-18.3	30	6	10933	0	0.0	0

TOTAL BEACH SEDIMENT VOLUME (CYD) = 542511.1

YEAR = 1 MONTH = 12 SEDIMENT VOL (CYD) = 542510

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13434	18636	9525	9525	61.4	31.4	0	0.0
2	12773	8575	-536	-536	28.2	-1.8	0	0.0
3	11806	10189	-745	-745	28.0	-2.0	0	0.0
4	10516	14606	-579	-579	48.1	-1.9	0	0.0
5	9086	8925	-794	-794	36.7	-3.3	0	0.0
6	7467	14093	-626	-626	58.0	18.0	1	5000.0
7	6083	3465	-6253	-6253	14.3	-25.7	0	0.0
8	4723	19586	9868	9868	80.6	40.6	2	50.0
9	4030	7305	16	16	30.1	0.1	0	0.0
10	3436	9507	-211	-211	39.1	-0.9	0	0.0
11	2979	11498	-650	-650	47.3	-2.7	0	0.0
12	2694	21039	-828	-828	57.7	-2.3	0	0.0
13	2548	28658	-1105	-1105	67.4	-2.6	0	0.0
14	2539	33412	-603	-603	78.6	-1.4	0	0.0
15	2597	21907	41	41	60.1	0.1	0	0.0
16	2653	40931	-2477	-2477	61.3	11.3	1	10000.0
17	2945	31428	-5017	-5017	34.5	-5.5	0	0.0
18	3682	70189	-2092	-2092	68.0	-2.0	0	0.0
19	4635	80066	-2215	-2215	77.5	7.5	1	10000.0
20	5866	33558	150	150	50.2	0.2	0	0.0
21	7074	18829	1822	1822	44.3	4.3	0	0.0
22	8051	12510	1577	1577	34.3	4.3	0	0.0
23	8733	10842	-92	-92	29.7	-0.3	0	0.0
24	9271	12757	1824	1824	35.0	5.0	0	0.0

YEAR = 2 MONTH = 12 SEDIMENT VOL (CYD) = 540861

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13404	27599	18488	8964	90.9	60.9	0	0.0
2	12774	8171	-940	-404	26.9	-3.1	0	0.0
3	11807	9876	-1057	-313	27.1	-2.9	0	0.0
4	10518	14030	-1155	-576	46.2	-3.8	0	0.0
5	9089	8152	-1567	-773	33.6	-6.4	0	0.0
6	7480	10862	-3856	-3230	44.7	4.7	0	0.0
7	6080	4106	-5613	640	16.9	-23.1	0	0.0
8	4708	23316	13597	3729	96.0	56.0	2	50.0
9	4030	7297	8	-8	30.0	0.0	0	0.0
10	3437	9292	-426	-215	38.2	-1.8	0	0.0
11	2981	10854	-1294	-644	44.7	-5.3	0	0.0
12	2697	20207	-1660	-832	55.4	-4.6	0	0.0
13	2550	27566	-2197	-1092	64.8	-5.2	0	0.0
14	2541	32812	-1203	-600	77.2	-2.8	0	0.0
15	2597	21898	32	-9	60.1	0.1	0	0.0
16	2656	38456	-4952	-2475	57.6	7.6	0	0.0
17	2950	26495	-9950	-4933	29.1	-10.9	0	0.0
18	3684	68047	-4235	-2142	65.9	-4.1	0	0.0
19	4638	77868	-4413	-2198	75.4	5.4	0	0.0
20	5866	33720	313	162	50.5	0.5	0	0.0
21	7069	20622	3615	1793	48.5	8.5	0	0.0
22	8046	14052	3118	1542	38.6	8.6	0	0.0
23	8733	10822	-111	-20	29.7	-0.3	0	0.0
24	9266	14543	3610	1786	39.9	9.9	0	0.0

YEAR = 3 MONTH = 12 SEDIMENT VOL (CYD) = 538490

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13376	36196	27085	8597	119.2	89.2	0	0.0
2	12775	7955	-1156	-216	26.2	-3.8	0	0.0
3	11807	9748	-1186	-128	26.7	-3.3	0	0.0
4	10520	13453	-1732	-577	44.3	-5.7	0	0.0
5	9093	7406	-2313	-746	30.5	-9.5	0	0.0
6	7489	8751	-5967	-2111	36.0	-4.0	0	0.0
7	6077	4815	-4904	709	19.8	-20.2	0	0.0
8	4700	25306	15588	1991	104.2	64.2	2	50.0
9	4030	7285	-4	-13	30.0	-0.0	0	0.0
10	3438	9074	-645	-219	37.3	-2.7	0	0.0
11	2984	10216	-1932	-638	42.0	-8.0	0	0.0
12	2699	19371	-2495	-836	53.2	-6.8	0	0.0
13	2553	26486	-3277	-1080	62.3	-7.7	0	0.0
14	2542	32215	-1800	-597	75.8	-4.2	0	0.0
15	2597	21839	-28	-60	59.9	-0.1	0	0.0
16	2661	35343	-8064	-3112	52.9	2.9	0	0.0
17	2954	22622	-13823	-3873	24.8	-15.2	0	0.0
18	3687	65521	-6761	-2526	63.5	-6.5	0	0.0
19	4640	75686	-6596	-2182	73.3	3.3	0	0.0
20	5865	33894	486	174	50.7	0.7	0	0.0
21	7065	22388	5380	1765	52.7	12.7	0	0.0
22	8042	15568	4635	1516	42.7	12.7	0	0.0
23	8733	10848	-85	26	29.8	-0.2	0	0.0
24	9261	16310	5376	1766	44.8	14.8	0	0.0

YEAR = 4 MONTH = 12 SEDIMENT VOL (CYD) = 536128

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13348	44597	35486	8401	146.8	116.8	0	0.0
2	12775	7863	-1248	-92	25.9	-4.1	0	0.0
3	11807	9699	-1235	-49	26.6	-3.4	0	0.0
4	10522	12650	-2536	-803	41.7	-8.3	0	0.0
5	9095	6888	-2831	-518	28.3	-11.7	0	0.0
6	7496	7074	-7645	-1677	29.1	-10.9	0	0.0
7	6076	5063	-4656	248	20.8	-19.2	0	0.0
8	4692	27323	17604	2017	112.5	72.5	2	50.0
9	4030	7272	-17	-12	29.9	-0.1	0	0.0
10	3439	8851	-868	-223	36.4	-3.6	0	0.0
11	2987	9584	-2564	-632	39.4	-10.6	0	0.0
12	2701	18533	-3334	-839	50.9	-9.1	0	0.0
13	2555	25418	-4345	-1069	59.8	-10.2	0	0.0
14	2544	31618	-2396	-596	74.4	-5.6	0	0.0
15	2597	21720	-147	-119	59.6	-0.4	0	0.0
16	2667	31508	-11900	-3835	47.2	-2.8	0	0.0
17	2957	19918	-16526	-2704	21.9	-18.1	0	0.0
18	3689	62601	-9681	-2920	60.6	-9.4	0	0.0
19	4642	73515	-8767	-2171	71.2	1.2	0	0.0
20	5865	34079	671	185	51.0	1.0	0	0.0
21	7061	24126	7118	1738	56.7	16.7	0	0.0
22	8038	17065	6131	1497	46.8	16.8	0	0.0
23	8733	10903	-30	55	29.9	-0.1	0	0.0
24	9256	18066	7133	1757	49.6	19.6	0	0.0

YEAR = 5 MONTH = 12 SEDIMENT VOL (CYD) = 533774

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13321	52903	43792	8306	174.2	144.2	0	0.0
2	12775	7842	-1269	-21	25.8	-4.2	0	0.0
3	11807	9687	-1246	-11	26.6	-3.4	0	0.0
4	10527	11289	-3896	-1361	37.2	-12.8	0	0.0
5	9097	6263	-3456	-625	25.8	-14.2	0	0.0
6	7500	6190	-8528	-884	25.5	-14.5	0	0.0
7	6076	5145	-4573	82	21.2	-18.8	0	0.0
8	4683	29365	19646	2042	120.9	80.9	2	50.0
9	4030	7267	-22	-5	29.9	-0.1	0	0.0
10	3440	8623	-1096	-228	35.5	-4.5	0	0.0
11	2989	8958	-3191	-626	36.9	-13.1	0	0.0
12	2703	17691	-4176	-842	48.5	-11.5	0	0.0
13	2558	24360	-5403	-1058	57.3	-12.7	0	0.0
14	2545	31022	-2993	-596	73.0	-7.0	0	0.0
15	2598	21537	-330	-183	59.1	-0.9	0	0.0
16	2673	27204	-16203	-4304	40.7	-9.3	0	0.0
17	2959	18006	-18438	-1912	19.8	-20.2	0	0.0
18	3692	59420	-12861	-3180	57.5	-12.5	0	0.0
19	4644	71353	-10928	-2162	69.1	-0.9	0	0.0
20	5865	34274	866	195	51.3	1.3	0	0.0
21	7057	25837	8830	1711	60.8	20.8	0	0.0
22	8034	18545	7612	1480	50.9	20.9	0	0.0
23	8733	10982	48	79	30.1	0.1	0	0.0
24	9252	19816	8882	1749	54.4	24.4	0	0.0

END OF PROGRAM

Table B-3. Beach Nourishment - Alternative 1, Distributed

PROGRAM SEM.BAS - BELLE FONTAINE PROJECT
INITIAL BEACH CONDITIONS

SEG NUM	SEG POS (FT)	SEG ANGLE (DEG)	SEG WIDTH (FT)	SEG HEIGHT (FT)	SEG VOLUME (CYD)	ALT	PAR	PRN
1	13465	4.7	30	5	9111	0	0.0	0
2	12771	22.9	30	5	9111	0	0.0	0
3	11804	30.5	30	6	10933	0	0.0	0
4	10514	38.3	50	5	17185	1	2000.0	0
5	9083	41.1	40	4	11719	1	2000.0	0
6	7485	44.3	40	4	11719	1	2000.0	0
7	6057	40.9	40	4	9719	0	0.0	0
8	4764	38.3	40	4	9719	2	50.0	0
9	4030	24.1	30	4	7289	0	0.0	0
10	3435	19.9	40	4	9719	0	0.0	0
11	2976	15.9	50	4	14148	1	2000.0	0
12	2692	9.7	60	6	23867	1	2000.0	0
13	2545	5.1	70	7	31763	1	2000.0	0
14	2538	0.2	80	7	36015	1	2000.0	0
15	2597	-2.2	60	6	21867	0	0.0	0
16	2664	-2.3	50	11	33407	0	0.0	0
17	2939	-9.5	40	15	36444	0	0.0	0
18	3680	-24.3	70	17	72281	0	0.0	0
19	4643	-30.4	70	17	72281	0	0.0	0
20	5866	-36.7	50	11	33407	0	0.0	0
21	7078	-36.5	40	7	17007	0	0.0	0
22	8055	-30.8	30	6	10933	0	0.0	0
23	8733	-22.5	30	6	10933	0	0.0	0
24	9276	-18.3	30	6	10933	0	0.0	0

TOTAL BEACH SEDIMENT VOLUME (CYD) = 531511.1

YEAR = 1 MONTH = 12 SEDIMENT VOL (CYD) = 531510

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13434	18633	9522	9522	61.4	31.4	0	0.0
2	12773	8569	-543	-543	28.2	-1.8	0	0.0
3	11806	10171	-762	-762	27.9	-2.1	0	0.0
4	10509	16625	-560	-560	54.7	4.7	1	2000.0
5	9078	11019	-700	-700	45.4	5.4	1	2000.0
6	7480	10981	-738	-738	45.2	5.2	1	2000.0
7	6083	3491	-6228	-6228	14.4	-25.6	0	0.0
8	4723	19586	9868	9868	80.6	40.6	2	50.0
9	4030	7305	16	16	30.1	0.1	0	0.0
10	3436	9527	-191	-191	39.2	-0.8	0	0.0
11	2971	13465	-684	-684	55.4	5.4	1	2000.0
12	2689	23047	-820	-820	63.2	3.2	1	2000.0
13	2543	30663	-1099	-1099	72.1	2.1	1	2000.0
14	2535	35366	-648	-648	83.2	3.2	1	2000.0
15	2597	21813	-53	-53	59.9	-0.1	0	0.0
16	2667	31234	-2174	-2174	46.7	-3.3	0	0.0
17	2945	31265	-5179	-5179	34.3	-5.7	0	0.0
18	3682	70103	-2179	-2179	67.9	-2.1	0	0.0
19	4645	70219	-2063	-2063	68.0	-2.0	0	0.0
20	5866	33492	84	84	50.1	0.1	0	0.0
21	7074	18829	1821	1821	44.3	4.3	0	0.0
22	8051	12510	1577	1577	34.3	4.3	0	0.0
23	8733	10842	-92	-92	29.7	-0.3	0	0.0
24	9271	12757	1824	1824	35.0	5.0	0	0.0

YEAR = 2 MONTH = 12 SEDIMENT VOL (CYD) = 529861

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13404	27585	18474	8952	90.8	60.8	0	0.0
2	12774	8157	-955	-412	26.9	-3.1	0	0.0
3	11807	9851	-1083	-320	27.0	-3.0	0	0.0
4	10511	16068	-1117	-558	52.9	2.9	0	0.0
5	9080	10345	-1374	-674	42.6	2.6	0	0.0
6	7493	7662	-4057	-3319	31.5	-8.5	0	0.0
7	6080	4130	-5589	639	17.0	-23.0	0	0.0
8	4708	23315	13597	3729	96.0	56.0	2	50.0
9	4030	7297	9	-8	30.0	0.0	0	0.0
10	3437	9331	-387	-196	38.4	-1.6	0	0.0
11	2973	12789	-1360	-676	52.6	2.6	0	0.0
12	2691	22222	-1645	-825	61.0	1.0	0	0.0
13	2545	29576	-2187	-1088	69.6	-0.4	0	0.0
14	2536	34721	-1294	-645	81.7	1.7	0	0.0
15	2597	21718	-149	-95	59.6	-0.4	0	0.0
16	2671	29035	-4373	-2199	43.5	-6.5	0	0.0
17	2950	26199	-10245	-5066	28.8	-11.2	0	0.0
18	3684	67866	-4415	-2237	65.7	-4.3	0	0.0
19	4647	68170	-4112	-2049	66.0	-4.0	0	0.0
20	5866	33590	183	99	50.3	0.3	0	0.0
21	7069	20621	3613	1792	48.5	8.5	0	0.0
22	8046	14052	3118	1542	38.6	8.6	0	0.0
23	8733	10822	-111	-20	29.7	-0.3	0	0.0
24	9266	14543	3610	1786	39.9	9.9	0	0.0

YEAR = 3 MONTH = 12 SEDIMENT VOL (CYD) = 527490

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13376	36162	27051	8577	119.1	89.1	0	0.0
2	12775	7936	-1175	-221	26.1	-3.9	0	0.0
3	11807	9719	-1214	-132	26.7	-3.3	0	0.0
4	10513	15511	-1674	-557	51.1	1.1	0	0.0
5	9086	9103	-2616	-1242	37.5	-2.5	0	0.0
6	7500	6051	-5668	-1611	24.9	-15.1	0	0.0
7	6077	4843	-4875	713	19.9	-20.1	0	0.0
8	4700	25306	15587	1990	104.2	64.2	2	50.0
9	4030	7285	-4	-13	30.0	-0.0	0	0.0
10	3437	9131	-587	-200	37.6	-2.4	0	0.0
11	2976	12120	-2028	-669	49.9	-0.1	0	0.0
12	2693	21393	-2474	-829	58.7	-1.3	0	0.0
13	2548	28499	-3264	-1077	67.0	-3.0	0	0.0
14	2538	34078	-1937	-643	80.1	0.1	0	0.0
15	2598	21578	-288	-140	59.2	-0.8	0	0.0
16	2675	26114	-7293	-2921	39.1	-10.9	0	0.0
17	2955	22302	-14143	-3897	24.5	-15.5	0	0.0
18	3687	65219	-7062	-2647	63.2	-6.8	0	0.0
19	4649	66132	-6149	-2037	64.0	-6.0	0	0.0
20	5866	33703	295	112	50.4	0.4	0	0.0
21	7065	22384	5377	1764	52.6	12.6	0	0.0
22	8042	15568	4635	1516	42.7	12.7	0	0.0
23	8733	10848	-85	26	29.8	-0.2	0	0.0
24	9261	16310	5376	1766	44.8	14.8	0	0.0

YEAR = 4 MONTH = 12 SEDIMENT VOL (CYD) = 525127

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13348	44539	35428	8377	146.7	116.7	0	0.0
2	12775	7841	-1270	-95	25.8	-4.2	0	0.0
3	11807	9668	-1266	-51	26.5	-3.5	0	0.0
4	10515	14953	-2233	-559	49.2	-0.8	0	0.0
5	9094	7047	-4671	-2056	29.0	-11.0	0	0.0
6	7502	5699	-6019	-351	23.5	-16.5	0	0.0
7	6076	5087	-4631	244	20.9	-19.1	0	0.0
8	4692	27322	17603	2016	112.5	72.5	2	50.0
9	4030	7273	-16	-12	29.9	-0.1	0	0.0
10	3438	8927	-792	-205	36.7	-3.3	0	0.0
11	2979	11458	-2690	-662	47.2	-2.8	0	0.0
12	2696	20559	-3307	-833	56.4	-3.6	0	0.0
13	2550	27432	-4331	-1066	64.5	-5.5	0	0.0
14	2539	33436	-2579	-642	78.6	-1.4	0	0.0
15	2598	21384	-482	-194	58.7	-1.3	0	0.0
16	2680	22445	-10962	-3669	33.6	-16.4	0	0.0
17	2957	19595	-16849	-2707	21.5	-18.5	0	0.0
18	3690	62181	-10101	-3039	60.2	-9.8	0	0.0
19	4651	64103	-8178	-2029	62.1	-7.9	0	0.0
20	5865	33828	421	126	50.6	0.6	0	0.0
21	7061	24120	7112	1736	56.7	16.7	0	0.0
22	8038	17065	6131	1497	46.8	16.8	0	0.0
23	8733	10903	-30	55	29.9	-0.1	0	0.0
24	9256	18066	7133	1757	49.6	19.6	0	0.0

YEAR = 5 MONTH = 12 SEDIMENT VOL (CYD) = 522774

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13321	52819	43708	8280	173.9	143.9	0	0.0
2	12775	7818	-1294	-24	25.7	-4.3	0	0.0
3	11807	9654	-1279	-13	26.5	-3.5	0	0.0
4	10520	13386	-3799	-1566	44.1	-5.9	0	0.0
5	9099	5819	-5900	-1229	23.9	-16.1	0	0.0
6	7502	5665	-6053	-34	23.3	-16.7	0	0.0
7	6076	5160	-4558	73	21.2	-18.8	0	0.0
8	4683	29363	19645	2042	120.9	80.9	2	50.0
9	4030	7267	-22	-5	29.9	-0.1	0	0.0
10	3439	8718	-1001	-209	35.9	-4.1	0	0.0
11	2982	10803	-3346	-655	44.5	-5.5	0	0.0
12	2698	19723	-4144	-837	54.1	-5.9	0	0.0
13	2553	26376	-5387	-1056	62.0	-8.0	0	0.0
14	2541	32794	-3221	-643	77.1	-2.9	0	0.0
15	2599	21002	-865	-382	57.6	-2.4	0	0.0
16	2686	18470	-14937	-3975	27.6	-22.4	0	0.0
17	2960	17643	-18802	-1952	19.4	-20.6	0	0.0
18	3693	58884	-13397	-3296	57.0	-13.0	0	0.0
19	4653	62079	-10202	-2024	60.1	-9.9	0	0.0
20	5865	33967	559	138	50.8	0.8	0	0.0
21	7057	25828	8821	1708	60.7	20.7	0	0.0
22	8034	18545	7612	1480	50.9	20.9	0	0.0
23	8733	10982	48	79	30.1	0.1	0	0.0
24	9252	19816	8882	1749	54.4	24.4	0	0.0

END OF PROGRAM

Table B-4. Beach Nourishment - Alternative 1, Biannual Distributed

PROGRAM SEM.BAS - BELLE FONTAINE PROJECT
INITIAL BEACH CONDITIONS

SEG NUM	SEG POS (FT)	SEG ANGLE (DEG)	SEG WIDTH (FT)	SEG HEIGHT (FT)	SEG VOLUME (CYD)	ALT	PAR	PRN
1	13465	4.7	30	5	9111	0	0.0	0
2	12771	22.9	30	5	9111	0	0.0	0
3	11804	30.5	30	6	10933	0	0.0	0
4	10514	38.3	50	5	17185	1	2000.0	0
5	9083	41.1	40	4	11719	1	2000.0	0
6	7485	44.3	40	4	11719	1	2000.0	0
7	6057	40.9	40	4	9719	0	0.0	0
8	4764	38.3	40	4	9719	2	50.0	0
9	4030	24.1	30	4	7289	0	0.0	0
10	3435	19.9	40	4	9719	0	0.0	0
11	2976	15.9	50	4	14148	1	2000.0	0
12	2692	9.7	60	6	23867	1	2000.0	0
13	2545	5.1	70	7	31763	1	2000.0	0
14	2538	0.2	80	7	36015	1	2000.0	0
15	2597	-2.2	60	6	21867	0	0.0	0
16	2664	-2.3	50	11	33407	0	0.0	0
17	2939	-9.5	40	15	36444	0	0.0	0
18	3680	-24.3	70	17	72281	0	0.0	0
19	4643	-30.4	70	17	72281	0	0.0	0
20	5866	-36.7	50	11	33407	0	0.0	0
21	7078	-36.5	40	7	17007	0	0.0	0
22	8055	-30.8	30	6	10933	0	0.0	0
23	8733	-22.5	30	6	10933	0	0.0	0
24	9276	-18.3	30	6	10933	0	0.0	0

TOTAL BEACH SEDIMENT VOLUME (CYD) = 531511.1

YEAR = 1 MONTH = 12 SEDIMENT VOL (CYD) = 531510

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13434	18633	9522	9522	61.4	31.4	0	0.0
2	12773	8569	-543	-543	28.2	-1.8	0	0.0
3	11806	10171	-762	-762	27.9	-2.1	0	0.0
4	10509	16625	-560	-560	54.7	4.7	1	2000.0
5	9078	11019	-700	-700	45.4	5.4	1	2000.0
6	7480	10981	-738	-738	45.2	5.2	1	2000.0
7	6083	3491	-6228	-6228	14.4	-25.6	0	0.0
8	4723	19586	9868	9868	80.6	40.6	2	50.0
9	4030	7305	16	16	30.1	0.1	0	0.0
10	3436	9527	-191	-191	39.2	-0.8	0	0.0
11	2971	13465	-684	-684	55.4	5.4	1	2000.0
12	2689	23047	-820	-820	63.2	3.2	1	2000.0
13	2543	30663	-1099	-1099	72.1	2.1	1	2000.0
14	2535	35366	-648	-648	83.2	3.2	1	2000.0
15	2597	21813	-53	-53	59.9	-0.1	0	0.0
16	2667	31234	-2174	-2174	46.7	-3.3	0	0.0
17	2945	31265	-5179	-5179	34.3	-5.7	0	0.0
18	3682	70103	-2179	-2179	67.9	-2.1	0	0.0
19	4645	70219	-2063	-2063	68.0	-2.0	0	0.0
20	5866	33492	84	84	50.1	0.1	0	0.0
21	7074	18829	1821	1821	44.3	4.3	0	0.0
22	8051	12510	1577	1577	34.3	4.3	0	0.0
23	8733	10842	-92	-92	29.7	-0.3	0	0.0
24	9271	12757	1824	1824	35.0	5.0	0	0.0

YEAR = 2 MONTH = 12 SEDIMENT VOL (CYD) = 529861

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13404	27585	18474	8952	90.8	60.8	0	0.0
2	12774	8157	-955	-412	26.9	-3.1	0	0.0
3	11807	9851	-1083	-320	27.0	-3.0	0	0.0
4	10511	16068	-1117	-558	52.9	2.9	0	0.0
5	9080	10345	-1374	-674	42.6	2.6	0	0.0
6	7493	7662	-4057	-3319	31.5	-8.5	0	0.0
7	6080	4130	-5589	639	17.0	-23.0	0	0.0
8	4708	23315	13597	3729	96.0	56.0	2	50.0
9	4030	7297	9	-8	30.0	0.0	0	0.0
10	3437	9331	-387	-196	38.4	-1.6	0	0.0
11	2973	12789	-1360	-676	52.6	2.6	0	0.0
12	2691	22222	-1645	-825	61.0	1.0	0	0.0
13	2545	29576	-2187	-1088	69.6	-0.4	0	0.0
14	2536	34721	-1294	-645	81.7	1.7	0	0.0
15	2597	21718	-149	-95	59.6	-0.4	0	0.0
16	2671	29035	-4373	-2199	43.5	-6.5	0	0.0
17	2950	26199	-10245	-5066	28.8	-11.2	0	0.0
18	3684	67866	-4415	-2237	65.7	-4.3	0	0.0
19	4647	68170	-4112	-2049	66.0	-4.0	0	0.0
20	5866	33590	183	99	50.3	0.3	0	0.0
21	7069	20621	3613	1792	48.5	8.5	0	0.0
22	8046	14052	3118	1542	38.6	8.6	0	0.0
23	8733	10822	-111	-20	29.7	-0.3	0	0.0
24	9266	14543	3610	1786	39.9	9.9	0	0.0

YEAR = 3 MONTH = 12 SEDIMENT VOL (CYD) = 541490

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13376	36159	27048	8574	119.1	89.1	0	0.0
2	12775	7929	-1182	-227	26.1	-3.9	0	0.0
3	11807	9701	-1232	-149	26.6	-3.4	0	0.0
4	10506	17529	343	1461	57.7	7.7	1	2000.0
5	9075	11709	-9	1365	48.2	8.2	1	2000.0
6	7494	7465	-4254	-197	30.7	-9.3	1	2000.0
7	6077	4832	-4887	702	19.9	-20.1	0	0.0
8	4700	25306	15587	1990	104.2	64.2	2	50.0
9	4030	7285	-4	-13	30.0	-0.0	0	0.0
10	3437	9150	-568	-181	37.7	-2.3	0	0.0
11	2968	14087	-61	1298	58.0	8.0	1	2000.0
12	2688	23401	-466	1179	64.2	4.2	1	2000.0
13	2543	30504	-1259	928	71.7	1.7	1	2000.0
14	2533	36035	20	1314	84.8	4.8	1	2000.0
15	2598	21622	-245	-97	59.3	-0.7	0	0.0
16	2675	26115	-7293	-2920	39.1	-10.9	0	0.0
17	2955	22302	-14143	-3897	24.5	-15.5	0	0.0
18	3687	65219	-7062	-2647	63.2	-6.8	0	0.0
19	4649	66132	-6149	-2037	64.0	-6.0	0	0.0
20	5866	33703	295	112	50.4	0.4	0	0.0
21	7065	22384	5377	1764	52.6	12.6	0	0.0
22	8042	15568	4635	1516	42.7	12.7	0	0.0
23	8733	10848	-85	26	29.8	-0.2	0	0.0
24	9261	16310	5376	1766	44.8	14.8	0	0.0

YEAR = 4 MONTH = 12 SEDIMENT VOL (CYD) = 539128

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13348	44524	35413	8365	146.6	116.6	0	0.0
2	12775	7827	-1284	-102	25.8	-4.2	0	0.0
3	11807	9642	-1291	-59	26.5	-3.5	0	0.0
4	10508	16989	-196	-539	55.9	5.9	0	0.0
5	9080	10555	-1163	-1154	43.4	3.4	0	0.0
6	7499	6219	-5500	-1246	25.6	-14.4	0	0.0
7	6076	5077	-4642	245	20.9	-19.1	0	0.0
8	4692	27322	17604	2016	112.5	72.5	2	50.0
9	4030	7273	-16	-12	29.9	-0.1	0	0.0
10	3438	8965	-754	-186	36.9	-3.1	0	0.0
11	2971	13393	-755	-694	55.1	5.1	0	0.0
12	2690	22574	-1292	-826	61.9	1.9	0	0.0
13	2546	29441	-2321	-1062	69.2	-0.8	0	0.0
14	2535	35353	-662	-682	83.1	3.1	0	0.0
15	2598	21468	-399	-154	58.9	-1.1	0	0.0
16	2680	22447	-10960	-3667	33.6	-16.4	0	0.0
17	2957	19595	-16849	-2707	21.5	-18.5	0	0.0
18	3690	62181	-10101	-3039	60.2	-9.8	0	0.0
19	4651	64103	-8178	-2029	62.1	-7.9	0	0.0
20	5865	33828	421	126	50.6	0.6	0	0.0
21	7061	24120	7112	1736	56.7	16.7	0	0.0
22	8038	17065	6131	1497	46.8	16.8	0	0.0
23	8733	10903	-30	55	29.9	-0.1	0	0.0
24	9256	18066	7133	1757	49.6	19.6	0	0.0

YEAR = 5 MONTH = 12 SEDIMENT VOL (CYD) = 536774

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13321	52785	43674	8260	173.8	143.8	0	0.0
2	12775	7798	-1313	-29	25.7	-4.3	0	0.0
3	11808	9622	-1311	-20	26.4	-3.6	0	0.0
4	10510	16462	-723	-527	54.2	4.2	0	0.0
5	9087	8665	-3053	-1890	35.7	-4.3	0	0.0
6	7501	5835	-5884	-384	24.0	-16.0	0	0.0
7	6076	5154	-4564	77	21.2	-18.8	0	0.0
8	4683	29364	19646	2042	120.9	80.9	2	50.0
9	4030	7268	-21	-5	29.9	-0.1	0	0.0
10	3439	8774	-945	-191	36.1	-3.9	0	0.0
11	2974	12708	-1441	-686	52.3	2.3	0	0.0
12	2692	21744	-2123	-831	59.7	-0.3	0	0.0
13	2548	28389	-3374	-1053	66.8	-3.2	0	0.0
14	2536	34673	-1342	-680	81.5	1.5	0	0.0
15	2599	21123	-743	-345	58.0	-2.0	0	0.0
16	2686	18474	-14933	-3973	27.6	-22.4	0	0.0
17	2960	17643	-18801	-1952	19.4	-20.6	0	0.0
18	3693	58884	-13397	-3296	57.0	-13.0	0	0.0
19	4653	62079	-10202	-2024	60.1	-9.9	0	0.0
20	5865	33967	559	138	50.8	0.8	0	0.0
21	7057	25828	8821	1708	60.7	20.7	0	0.0
22	8034	18545	7612	1480	50.9	20.9	0	0.0
23	8733	10982	48	79	30.1	0.1	0	0.0
24	9252	19816	8882	1749	54.4	24.4	0	0.0

END OF PROGRAM

Table B-5. Groin - Alternative 2

PROGRAM SEM.BAS - BELLE FONTAINE PROJECT
INITIAL BEACH CONDITIONS

SEG NUM	SEG POS (FT)	SEG ANGLE (DEG)	SEG WIDTH (FT)	SEG HEIGHT (FT)	SEG VOLUME (CYD)	ALT	PAR	PRN
1	13465	4.7	30	5	9111	0	0.0	0
2	12771	22.9	30	5	9111	0	0.0	0
3	11804	30.5	30	6	10933	0	0.0	0
4	10514	38.2	50	5	15185	0	0.0	0
5	9083	41.1	40	4	9719	0	0.0	0
6	7485	44.3	40	4	9719	0	0.0	0
7	6057	41.1	40	4	9719	0	0.0	0
8	4764	38.3	40	4	9719	2	50.0	0
9	4030	24.1	30	4	7289	0	0.0	0
10	3435	19.9	40	4	9719	0	0.0	0
11	2976	15.6	50	4	12148	2	0.0	0
12	2692	9.8	60	6	21867	2	0.0	0
13	2545	5.1	70	7	29763	2	0.0	0
14	2538	0.2	80	7	34015	2	0.0	0
15	2597	-2.1	60	6	21867	0	0.0	0
16	2664	-2.3	50	11	33407	0	0.0	0
17	2939	-9.5	40	15	36444	0	0.0	0
18	3680	-24.3	70	17	72281	0	0.0	0
19	4643	-30.4	70	17	72281	0	0.0	0
20	5866	-36.7	50	11	33407	0	0.0	0
21	7078	-36.5	40	7	17007	0	0.0	0
22	8055	-30.8	30	6	10933	0	0.0	0
23	8733	-22.5	30	6	10933	0	0.0	0
24	9276	-18.3	30	6	10933	0	0.0	0

TOTAL BEACH SEDIMENT VOLUME (CYD) = 517511.2

YEAR = 1 MONTH = 12 SEDIMENT VOL (CYD) = 517510

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13434	18636	9525	9525	61.4	31.4	0	0.0
2	12773	8575	-536	-536	28.2	-1.8	0	0.0
3	11806	10189	-745	-745	28.0	-2.0	0	0.0
4	10516	14605	-580	-580	48.1	-1.9	0	0.0
5	9086	9012	-706	-706	37.1	-2.9	0	0.0
6	7488	8964	-755	-755	36.9	-3.1	0	0.0
7	6083	3508	-6211	-6211	14.4	-25.6	0	0.0
8	4723	19586	9867	9867	80.6	40.6	2	50.0
9	4030	7381	92	92	30.4	0.4	0	0.0
10	3449	6244	-3475	-3475	25.7	-14.3	0	0.0
11	2976	12071	-77	-77	49.7	-0.3	2	0.0
12	2692	21950	83	83	60.2	0.2	2	0.0
13	2545	29756	-7	-7	70.0	-0.0	2	0.0
14	2538	34008	-6	-6	80.0	-0.0	2	0.0
15	2597	21778	-89	-89	59.8	-0.2	0	0.0
16	2667	31233	-2174	-2174	46.7	-3.3	0	0.0
17	2945	31265	-5179	-5179	34.3	-5.7	0	0.0
18	3682	70103	-2179	-2179	67.9	-2.1	0	0.0
19	4645	70219	-2063	-2063	68.0	-2.0	0	0.0
20	5866	33492	84	84	50.1	0.1	0	0.0
21	7074	18829	1821	1821	44.3	4.3	0	0.0
22	8051	12510	1577	1577	34.3	4.3	0	0.0
23	8733	10842	-92	-92	29.7	-0.3	0	0.0
24	9271	12757	1824	1824	35.0	5.0	0	0.0

YEAR = 2 MONTH = 12 SEDIMENT VOL (CYD) = 515871

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13404	27599	18488	8964	90.9	60.9	0	0.0
2	12774	8171	-940	-404	26.9	-3.1	0	0.0
3	11807	9876	-1057	-313	27.1	-2.9	0	0.0
4	10518	14028	-1157	-578	46.2	-3.8	0	0.0
5	9090	7954	-1764	-1058	32.7	-7.3	0	0.0
6	7500	6009	-3710	-2955	24.7	-15.3	0	0.0
7	6080	4136	-5583	628	17.0	-23.0	0	0.0
8	4712	22459	12740	2873	92.4	52.4	2	50.0
9	4035	5953	-1336	-1428	24.5	-5.5	0	0.0
10	3454	5151	-4567	-1092	21.2	-18.8	0	0.0
11	2976	12201	53	130	50.2	0.2	2	0.0
12	2692	21940	73	-10	60.2	0.2	2	0.0
13	2545	29635	-128	-121	69.7	-0.3	2	0.0
14	2538	34002	-12	-6	80.0	-0.0	2	0.0
15	2598	21663	-204	-115	59.4	-0.6	0	0.0
16	2671	29033	-4374	-2200	43.5	-6.5	0	0.0
17	2950	26199	-10245	-5066	28.8	-11.2	0	0.0
18	3684	67866	-4415	-2237	65.7	-4.3	0	0.0
19	4647	68170	-4112	-2049	66.0	-4.0	0	0.0
20	5866	33590	183	99	50.3	0.3	0	0.0
21	7069	20621	3613	1792	48.5	8.5	0	0.0
22	8046	14052	3118	1542	38.6	8.6	0	0.0
23	8733	10822	-111	-20	29.7	-0.3	0	0.0
24	9266	14543	3610	1786	39.9	9.9	0	0.0

YEAR = 3 MONTH = 12 SEDIMENT VOL (CYD) = 513491

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13376	36196	27085	8597	119.2	89.2	0	0.0
2	12775	7955	-1156	-216	26.2	-3.8	0	0.0
3	11807	9749	-1185	-127	26.7	-3.3	0	0.0
4	10521	12998	-2188	-1030	42.8	-7.2	0	0.0
5	9098	6130	-3588	-1824	25.2	-14.8	0	0.0
6	7503	5430	-4289	-579	22.3	-17.7	0	0.0
7	6077	4867	-4851	731	20.0	-20.0	0	0.0
8	4714	21983	12265	-475	90.5	50.5	2	50.0
9	4038	5274	-2015	-680	21.7	-8.3	0	0.0
10	3455	4890	-4829	-262	20.1	-19.9	0	0.0
11	2976	12209	61	9	50.3	0.3	2	0.0
12	2692	21886	19	-54	60.1	0.1	2	0.0
13	2545	29635	-128	-0	69.7	-0.3	2	0.0
14	2538	33996	-18	-6	80.0	-0.0	2	0.0
15	2598	21518	-349	-145	59.0	-1.0	0	0.0
16	2675	26111	-7297	-2922	39.1	-10.9	0	0.0
17	2955	22302	-14143	-3897	24.5	-15.5	0	0.0
18	3687	65219	-7062	-2647	63.2	-6.8	0	0.0
19	4649	66132	-6149	-2037	64.0	-6.0	0	0.0
20	5866	33703	295	112	50.4	0.4	0	0.0
21	7065	22384	5377	1764	52.6	12.6	0	0.0
22	8042	15568	4635	1516	42.7	12.7	0	0.0
23	8733	10848	-85	26	29.8	-0.2	0	0.0
24	9261	16310	5376	1766	44.8	14.8	0	0.0

YEAR = 4 MONTH = 12 SEDIMENT VOL (CYD) = 511355

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13348	44598	35487	8402	146.8	116.8	0	0.0
2	12775	7867	-1244	-88	25.9	-4.1	0	0.0
3	11807	9710	-1224	-39	26.6	-3.4	0	0.0
4	10529	10691	-4494	-2307	35.2	-14.8	0	0.0
5	9101	5342	-4377	-789	22.0	-18.0	0	0.0
6	7503	5336	-4382	-93	22.0	-18.0	0	0.0
7	6078	4686	-5033	-182	19.3	-20.7	0	0.0
8	4714	21800	12081	-183	89.7	49.7	2	50.0
9	4039	5047	-2242	-227	20.8	-9.2	0	0.0
10	3456	4642	-5077	-248	19.1	-20.9	0	0.0
11	2976	12137	-11	-72	50.0	-0.0	2	0.0
12	2692	21886	19	-0	60.1	0.1	2	0.0
13	2545	29758	-5	123	70.0	-0.0	2	0.0
14	2538	34056	41	60	80.1	0.1	2	0.0
15	2598	21334	-533	-184	58.5	-1.5	0	0.0
16	2680	22440	-10967	-3670	33.6	-16.4	0	0.0
17	2957	19595	-16849	-2707	21.5	-18.5	0	0.0
18	3690	62181	-10101	-3039	60.2	-9.8	0	0.0
19	4651	64103	-8178	-2029	62.1	-7.9	0	0.0
20	5865	33828	421	126	50.6	0.6	0	0.0
21	7061	24120	7112	1736	56.7	16.7	0	0.0
22	8038	17065	6131	1497	46.8	16.8	0	0.0
23	8733	10903	-30	55	29.9	-0.1	0	0.0
24	9256	18066	7133	1757	49.6	19.6	0	0.0

YEAR = 5 MONTH = 12 SEDIMENT VOL (CYD) = 509384

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13321	52911	43800	8312	174.2	144.2	0	0.0
2	12775	7831	-1280	-36	25.8	-4.2	0	0.0
3	11808	9504	-1429	-206	26.1	-3.9	0	0.0
4	10538	8007	-7178	-2684	26.4	-23.6	0	0.0
5	9103	4976	-4743	-366	20.5	-19.5	0	0.0
6	7504	5136	-4583	-201	21.1	-18.9	0	0.0
7	6079	4458	-5260	-227	18.3	-21.7	0	0.0
8	4714	21820	12101	20	89.8	49.8	2	50.0
9	4040	4949	-2340	-98	20.4	-9.6	0	0.0
10	3456	4654	-5065	12	19.2	-20.8	0	0.0
11	2976	12103	-45	-35	49.8	-0.2	2	0.0
12	2692	21892	25	6	60.1	0.1	2	0.0
13	2545	29767	4	9	70.0	0.0	2	0.0
14	2538	34032	17	-24	80.0	0.0	2	0.0
15	2599	20973	-893	-360	57.5	-2.5	0	0.0
16	2686	18465	-14942	-3975	27.6	-22.4	0	0.0
17	2960	17643	-18802	-1952	19.4	-20.6	0	0.0
18	3693	58884	-13397	-3296	57.0	-13.0	0	0.0
19	4653	62079	-10202	-2024	60.1	-9.9	0	0.0
20	5865	33967	559	138	50.8	0.8	0	0.0
21	7057	25828	8821	1708	60.7	20.7	0	0.0
22	8034	18545	7612	1480	50.9	20.9	0	0.0
23	8733	10982	48	79	30.1	0.1	0	0.0
24	9252	19816	8882	1749	54.4	24.4	0	0.0

END OF PROGRAM

Table B-6. Revetment - Alternative 3

PROGRAM SEM.BAS - BELLE FONTAINE PROJECT
INITIAL BEACH CONDITIONS

SEG NUM	SEG POS (FT)	SEG ANGLE (DEG)	SEG WIDTH (FT)	SEG HEIGHT (FT)	SEG VOLUME (CYD)	ALT	PAR	PRN
1	13465	4.7	30	5	9111	0	0.0	0
2	12771	22.9	30	5	9111	0	0.0	0
3	11804	30.5	30	6	10933	0	0.0	0
4	10514	38.2	50	5	15185	0	0.0	0
5	9083	41.1	40	4	9719	0	0.0	0
6	7485	44.3	40	4	9719	0	0.0	0
7	6057	41.1	40	4	9719	0	0.0	0
8	4764	38.3	40	4	9719	2	50.0	0
9	4030	24.1	30	4	7289	0	0.0	0
10	3435	19.9	40	4	9719	0	0.0	0
11	2976	15.6	50	4	12148	3	0.5	0
12	2692	9.8	60	6	21867	3	0.5	0
13	2545	5.1	70	7	29763	3	0.5	0
14	2538	0.2	80	7	34015	3	0.5	0
15	2597	-2.1	60	6	21867	0	0.0	0
16	2664	-2.3	50	11	33407	0	0.0	0
17	2939	-9.5	40	15	36444	0	0.0	0
18	3680	-24.3	70	17	72281	0	0.0	0
19	4643	-30.4	70	17	72281	0	0.0	0
20	5866	-36.7	50	11	33407	0	0.0	0
21	7078	-36.5	40	7	17007	0	0.0	0
22	8055	-30.8	30	6	10933	0	0.0	0
23	8733	-22.5	30	6	10933	0	0.0	0
24	9276	-18.3	30	6	10933	0	0.0	0

TOTAL BEACH SEDIMENT VOLUME (CYD) = 517511.2

YEAR = 1 MONTH = 12 SEDIMENT VOL (CYD) = 517510

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13434	18636	9525	9525	61.4	31.4	0	0.0
2	12773	8575	-536	-536	28.2	-1.8	0	0.0
3	11806	10189	-745	-745	28.0	-2.0	0	0.0
4	10516	14605	-580	-580	48.1	-1.9	0	0.0
5	9086	9012	-706	-706	37.1	-2.9	0	0.0
6	7488	8964	-755	-755	36.9	-3.1	0	0.0
7	6083	3508	-6211	-6211	14.4	-25.6	0	0.0
8	4724	19442	9724	9724	80.0	40.0	2	50.0
9	4032	6700	-589	-589	27.6	-2.4	0	0.0
10	3452	5472	-4247	-4247	22.5	-17.5	0	0.0
11	2978	11775	-373	-373	48.5	-1.5	3	0.5
12	2693	21453	-413	-413	58.9	-1.1	3	0.5
13	2546	29227	-536	-536	68.7	-1.3	3	0.5
14	2531	36893	2878	2878	86.8	6.8	3	0.5
15	2597	21811	-56	-56	59.8	-0.2	0	0.0
16	2667	31233	-2174	-2174	46.7	-3.3	0	0.0
17	2945	31265	-5179	-5179	34.3	-5.7	0	0.0
18	3682	70103	-2179	-2179	67.9	-2.1	0	0.0
19	4645	70219	-2063	-2063	68.0	-2.0	0	0.0
20	5866	33492	84	84	50.1	0.1	0	0.0
21	7074	18829	1821	1821	44.3	4.3	0	0.0
22	8051	12510	1577	1577	34.3	4.3	0	0.0
23	8733	10842	-92	-92	29.7	-0.3	0	0.0
24	9271	12757	1824	1824	35.0	5.0	0	0.0

YEAR = 2 MONTH = 12 SEDIMENT VOL (CYD) = 516036

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13404	27599	18488	8964	90.9	60.9	0	0.0
2	12774	8171	-940	-404	26.9	-3.1	0	0.0
3	11807	9876	-1057	-313	27.1	-2.9	0	0.0
4	10518	14028	-1157	-577	46.2	-3.8	0	0.0
5	9090	7908	-1811	-1104	32.5	-7.5	0	0.0
6	7501	5883	-3835	-3080	24.2	-15.8	0	0.0
7	6081	3878	-5841	370	16.0	-24.0	0	0.0
8	4714	21793	12074	2350	89.7	49.7	2	50.0
9	4039	5109	-2180	-1591	21.0	-9.0	0	0.0
10	3458	4205	-5514	-1267	17.3	-22.7	0	0.0
11	2980	11284	-864	-491	46.4	-3.6	3	0.5
12	2694	21038	-829	-415	57.7	-2.3	3	0.5
13	2547	28725	-1038	-502	67.6	-2.4	3	0.5
14	2525	39672	5657	2779	93.3	13.3	3	0.5
15	2597	21790	-77	-21	59.8	-0.2	0	0.0
16	2671	29035	-4372	-2198	43.5	-6.5	0	0.0
17	2950	26199	-10245	-5066	28.8	-11.2	0	0.0
18	3684	67866	-4415	-2237	65.7	-4.3	0	0.0
19	4647	68170	-4112	-2049	66.0	-4.0	0	0.0
20	5866	33590	183	99	50.3	0.3	0	0.0
21	7069	20621	3613	1792	48.5	8.5	0	0.0
22	8046	14052	3118	1542	38.6	8.6	0	0.0
23	8733	10822	-111	-20	29.7	-0.3	0	0.0
24	9266	14543	3610	1786	39.9	9.9	0	0.0

YEAR = 3 MONTH = 12 SEDIMENT VOL (CYD) = 514159

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13376	36196	27085	8597	119.2	89.2	0	0.0
2	12775	7955	-1156	-216	26.2	-3.8	0	0.0
3	11807	9749	-1184	-127	26.8	-3.2	0	0.0
4	10522	12897	-2288	-1131	42.5	-7.5	0	0.0
5	9099	5926	-3792	-1981	24.4	-15.6	0	0.0
6	7505	4959	-4760	-925	20.4	-19.6	0	0.0
7	6081	3969	-5750	91	16.3	-23.7	0	0.0
8	4714	21789	12070	-4	89.7	49.7	2	50.0
9	4042	4327	-2962	-782	17.8	-12.2	0	0.0
10	3459	3872	-5847	-333	15.9	-24.1	0	0.0
11	2982	10760	-1388	-524	44.3	-5.7	3	0.5
12	2695	20620	-1247	-418	56.6	-3.4	3	0.5
13	2549	28256	-1507	-469	66.5	-3.5	3	0.5
14	2518	42356	8341	2684	99.6	19.6	3	0.5
15	2597	21795	-71	5	59.8	-0.2	0	0.0
16	2675	26118	-7289	-2917	39.1	-10.9	0	0.0
17	2955	22302	-14143	-3897	24.5	-15.5	0	0.0
18	3687	65219	-7062	-2647	63.2	-6.8	0	0.0
19	4649	66132	-6149	-2037	64.0	-6.0	0	0.0
20	5866	33703	295	112	50.4	0.4	0	0.0
21	7065	22384	5377	1764	52.6	12.6	0	0.0
22	8042	15568	4635	1516	42.7	12.7	0	0.0
23	8733	10848	-85	26	29.8	-0.2	0	0.0
24	9261	16310	5376	1766	44.8	14.8	0	0.0

YEAR = 4 MONTH = 12 SEDIMENT VOL (CYD) = 512515

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13348	44599	35488	8403	146.8	116.8	0	0.0
2	12775	7867	-1244	-88	25.9	-4.1	0	0.0
3	11807	9712	-1221	-37	26.6	-3.4	0	0.0
4	10530	10226	-4960	-2671	33.7	-16.3	0	0.0
5	9103	4843	-4876	-1083	19.9	-20.1	0	0.0
6	7507	4492	-5227	-467	18.5	-21.5	0	0.0
7	6082	3699	-6020	-270	15.2	-24.8	0	0.0
8	4714	21808	12090	19	89.8	49.8	2	50.0
9	4043	4037	-3251	-289	16.6	-13.4	0	0.0
10	3459	3776	-5942	-95	15.5	-24.5	0	0.0
11	2984	10230	-1919	-530	42.1	-7.9	3	0.5
12	2697	20200	-1667	-420	55.4	-4.6	3	0.5
13	2550	27818	-1945	-438	65.4	-4.6	3	0.5
14	2512	44949	10934	2593	105.7	25.7	3	0.5
15	2597	21812	-55	16	59.8	-0.2	0	0.0
16	2680	22458	-10950	-3661	33.6	-16.4	0	0.0
17	2957	19595	-16849	-2707	21.5	-18.5	0	0.0
18	3690	62181	-10101	-3039	60.2	-9.8	0	0.0
19	4651	64103	-8178	-2029	62.1	-7.9	0	0.0
20	5865	33828	421	126	50.6	0.6	0	0.0
21	7061	24120	7112	1736	56.7	16.7	0	0.0
22	8038	17065	6131	1497	46.8	16.8	0	0.0
23	8733	10903	-30	55	29.9	-0.1	0	0.0
24	9256	18066	7133	1757	49.6	19.6	0	0.0

YEAR = 5 MONTH = 12 SEDIMENT VOL (CYD) = 510960

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13321	52899	43788	8300	174.2	144.2	0	0.0
2	12775	7772	-1339	-95	25.6	-4.4	0	0.0
3	11809	9211	-1722	-501	25.3	-4.7	0	0.0
4	10540	7258	-7927	-2968	23.9	-26.1	0	0.0
5	9106	4247	-5471	-596	17.5	-22.5	0	0.0
6	7508	4161	-5557	-331	17.1	-22.9	0	0.0
7	6083	3513	-6206	-186	14.5	-25.5	0	0.0
8	4714	21802	12084	-6	89.7	49.7	2	50.0
9	4044	3939	-3350	-98	16.2	-13.8	0	0.0
10	3460	3747	-5972	-29	15.4	-24.6	0	0.0
11	2986	9701	-2448	-529	39.9	-10.1	3	0.5
12	2698	19778	-2089	-422	54.3	-5.7	3	0.5
13	2551	27409	-2354	-409	64.5	-5.5	3	0.5
14	2506	47454	13439	2505	111.6	31.6	3	0.5
15	2597	21704	-163	-108	59.6	-0.4	0	0.0
16	2686	18492	-14915	-3965	27.7	-22.3	0	0.0
17	2960	17644	-18800	-1951	19.4	-20.6	0	0.0
18	3693	58884	-13397	-3296	57.0	-13.0	0	0.0
19	4653	62079	-10202	-2024	60.1	-9.9	0	0.0
20	5865	33967	559	138	50.8	0.8	0	0.0
21	7057	25828	8821	1708	60.7	20.7	0	0.0
22	8034	18545	7612	1480	50.9	20.9	0	0.0
23	8733	10982	48	79	30.1	0.1	0	0.0
24	9252	19816	8882	1749	54.4	24.4	0	0.0

END OF PROGRAM

Table B-7. Breakwater - Alternative 4

PROGRAM SEM.BAS - BELLE FONTAINE PROJECT
INITIAL BEACH CONDITIONS

SEG NUM	SEG POS (FT)	SEG ANGLE (DEG)	SEG WIDTH (FT)	SEG HEIGHT (FT)	SEG VOLUME (CYD)	ALT	PAR	PRN
1	13465	4.7	30	5	9111	0	0.0	0
2	12771	22.9	30	5	9111	0	0.0	0
3	11804	30.5	30	6	10933	0	0.0	0
4	10514	38.2	50	5	15185	0	0.0	0
5	9083	41.1	40	4	9719	0	0.0	0
6	7485	44.3	40	4	9719	0	0.0	0
7	6057	41.1	40	4	9719	0	0.0	0
8	4764	38.3	40	4	9719	2	50.0	0
9	4030	24.1	30	4	7289	0	0.0	0
10	3435	19.9	40	4	9719	0	0.0	0
11	2976	15.6	50	4	12148	0	0.0	0
12	2692	9.8	60	6	21867	0	0.0	0
13	2545	5.1	70	7	29763	0	0.0	0
14	2538	0.2	80	7	34015	0	0.0	0
15	2597	-2.1	60	6	21867	0	0.0	0
16	2664	-2.3	50	11	33407	0	0.0	0
17	2939	-9.5	40	15	36444	4	0.4	0
18	3680	-24.3	70	17	72281	4	0.4	0
19	4643	-30.4	70	17	72281	4	0.4	0
20	5866	-36.7	50	11	33407	0	0.0	0
21	7078	-36.5	40	7	17007	0	0.0	0
22	8055	-30.8	30	6	10933	0	0.0	0
23	8733	-22.5	30	6	10933	0	0.0	0
24	9276	-18.3	30	6	10933	0	0.0	0

TOTAL BEACH SEDIMENT VOLUME (CYD) = 517511.2

YEAR = 1 MONTH = 12 SEDIMENT VOL (CYD) = 517510

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13434	18636	9525	9525	61.4	31.4	0	0.0
2	12773	8575	-536	-536	28.2	-1.8	0	0.0
3	11806	10189	-745	-745	28.0	-2.0	0	0.0
4	10516	14605	-580	-580	48.1	-1.9	0	0.0
5	9086	9012	-706	-706	37.1	-2.9	0	0.0
6	7488	8964	-755	-755	36.9	-3.1	0	0.0
7	6083	3508	-6211	-6211	14.4	-25.6	0	0.0
8	4723	19586	9868	9868	80.6	40.6	2	50.0
9	4030	7305	16	16	30.1	0.1	0	0.0
10	3436	9507	-211	-211	39.1	-0.9	0	0.0
11	2979	11498	-650	-650	47.3	-2.7	0	0.0
12	2694	21039	-828	-828	57.7	-2.3	0	0.0
13	2548	28658	-1105	-1105	67.4	-2.6	0	0.0
14	2539	33409	-605	-605	78.6	-1.4	0	0.0
15	2597	21741	-126	-126	59.7	-0.3	0	0.0
16	2673	27549	-5859	-5859	41.2	-8.8	0	0.0
17	2940	35839	-605	-605	39.3	-0.7	4	0.4
18	3680	72032	-250	-250	69.8	-0.2	4	0.4
19	4643	72043	-239	-239	69.8	-0.2	4	0.4
20	5866	33416	9	9	50.0	0.0	0	0.0
21	7077	17219	212	212	40.5	0.5	0	0.0
22	8054	11117	184	184	30.5	0.5	0	0.0
23	8733	10917	-16	-16	30.0	-0.0	0	0.0
24	9275	11146	212	212	30.6	0.6	0	0.0

YEAR = 2 MONTH = 12 SEDIMENT VOL (CYD) = 515861

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13404	27599	18488	8964	90.9	60.9	0	0.0
2	12774	8171	-940	-404	26.9	-3.1	0	0.0
3	11807	9876	-1057	-313	27.1	-2.9	0	0.0
4	10518	14028	-1157	-578	46.2	-3.8	0	0.0
5	9090	7958	-1760	-1054	32.8	-7.2	0	0.0
6	7500	6018	-3700	-2945	24.8	-15.2	0	0.0
7	6080	4145	-5573	638	17.1	-22.9	0	0.0
8	4708	23315	13597	3729	96.0	56.0	2	50.0
9	4030	7297	8	-8	30.0	0.0	0	0.0
10	3437	9292	-426	-215	38.2	-1.8	0	0.0
11	2981	10854	-1294	-644	44.7	-5.3	0	0.0
12	2697	20207	-1660	-832	55.4	-4.6	0	0.0
13	2550	27566	-2197	-1092	64.8	-5.2	0	0.0
14	2541	32803	-1212	-606	77.2	-2.8	0	0.0
15	2598	21526	-340	-215	59.1	-0.9	0	0.0
16	2681	21780	-11627	-5769	32.6	-17.4	0	0.0
17	2940	35224	-1221	-615	38.7	-1.3	4	0.4
18	3680	71782	-500	-250	69.5	-0.5	4	0.4
19	4643	71804	-478	-239	69.5	-0.5	4	0.4
20	5866	33426	18	9	50.0	0.0	0	0.0
21	7077	17430	423	211	41.0	1.0	0	0.0
22	8054	11300	367	183	31.0	1.0	0	0.0
23	8733	10903	-30	-15	29.9	-0.1	0	0.0
24	9275	11357	424	211	31.2	1.2	0	0.0

YEAR = 3 MONTH = 12 SEDIMENT VOL (CYD) = 513490

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13376	36196	27085	8597	119.2	89.2	0	0.0
2	12775	7955	-1156	-216	26.2	-3.8	0	0.0
3	11807	9749	-1185	-127	26.7	-3.3	0	0.0
4	10521	13002	-2183	-1026	42.8	-7.2	0	0.0
5	9098	6136	-3582	-1822	25.3	-14.7	0	0.0
6	7503	5431	-4287	-587	22.4	-17.6	0	0.0
7	6077	4855	-4863	710	20.0	-20.0	0	0.0
8	4700	25305	15587	1990	104.2	64.2	2	50.0
9	4030	7285	-4	-13	30.0	-0.0	0	0.0
10	3438	9074	-645	-219	37.3	-2.7	0	0.0
11	2984	10216	-1932	-638	42.0	-8.0	0	0.0
12	2699	19371	-2495	-836	53.2	-6.8	0	0.0
13	2553	26486	-3277	-1080	62.3	-7.7	0	0.0
14	2542	32190	-1825	-613	75.7	-4.3	0	0.0
15	2600	20714	-1153	-813	56.8	-3.2	0	0.0
16	2689	16637	-16770	-5143	24.9	-25.1	0	0.0
17	2941	34579	-1866	-645	38.0	-2.0	4	0.4
18	3681	71531	-751	-251	69.3	-0.7	4	0.4
19	4644	71565	-716	-239	69.3	-0.7	4	0.4
20	5866	33435	28	9	50.0	0.0	0	0.0
21	7076	17641	634	211	41.5	1.5	0	0.0
22	8053	11483	549	182	31.5	1.5	0	0.0
23	8733	10890	-44	-13	29.9	-0.1	0	0.0
24	9274	11568	634	211	31.7	1.7	0	0.0

YEAR = 4 MONTH = 12 SEDIMENT VOL (CYD) = 511127

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13348	44598	35487	8402	146.8	116.8	0	0.0
2	12775	7867	-1244	-88	25.9	-4.1	0	0.0
3	11807	9710	-1224	-39	26.6	-3.4	0	0.0
4	10529	10707	-4479	-2296	35.3	-14.7	0	0.0
5	9101	5377	-4342	-759	22.1	-17.9	0	0.0
6	7502	5482	-4236	51	22.6	-17.4	0	0.0
7	6076	5094	-4625	239	21.0	-19.0	0	0.0
8	4692	27321	17603	2016	112.4	72.4	2	50.0
9	4030	7272	-17	-12	29.9	-0.1	0	0.0
10	3439	8851	-868	-223	36.4	-3.6	0	0.0
11	2987	9584	-2564	-632	39.4	-10.6	0	0.0
12	2701	18533	-3334	-839	50.9	-9.1	0	0.0
13	2555	25416	-4347	-1070	59.8	-10.2	0	0.0
14	2544	31538	-2477	-652	74.2	-5.8	0	0.0
15	2607	18264	-3602	-2449	50.1	-9.9	0	0.0
16	2694	13225	-20183	-3412	19.8	-30.2	0	0.0
17	2942	33870	-2574	-708	37.2	-2.8	4	0.4
18	3681	71279	-1002	-251	69.0	-1.0	4	0.4
19	4644	71327	-955	-238	69.1	-0.9	4	0.4
20	5866	33445	37	10	50.1	0.1	0	0.0
21	7076	17852	845	211	42.0	2.0	0	0.0
22	8053	11665	731	182	32.0	2.0	0	0.0
23	8733	10878	-55	-12	29.8	-0.2	0	0.0
24	9274	11778	845	210	32.3	2.3	0	0.0

YEAR = 5 MONTH = 12 SEDIMENT VOL (CYD) = 508774

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13321	52911	43800	8313	174.2	144.2	0	0.0
2	12775	7834	-1277	-32	25.8	-4.2	0	0.0
3	11808	9530	-1404	-180	26.1	-3.9	0	0.0
4	10537	8108	-7078	-2599	26.7	-23.3	0	0.0
5	9102	5184	-4535	-193	21.3	-18.7	0	0.0
6	7502	5592	-4127	109	23.0	-17.0	0	0.0
7	6076	5163	-4555	70	21.3	-18.7	0	0.0
8	4683	29362	19644	2041	120.9	80.9	2	50.0
9	4030	7267	-22	-5	29.9	-0.1	0	0.0
10	3440	8623	-1096	-228	35.5	-4.5	0	0.0
11	2989	8958	-3191	-626	36.9	-13.1	0	0.0
12	2703	17691	-4176	-842	48.5	-11.5	0	0.0
13	2558	24356	-5407	-1060	57.3	-12.7	0	0.0
14	2546	30814	-3201	-724	72.5	-7.5	0	0.0
15	2617	14758	-7109	-3506	40.5	-19.5	0	0.0
16	2698	10976	-22431	-2248	16.4	-33.6	0	0.0
17	2943	33120	-3325	-751	36.4	-3.6	4	0.4
18	3681	71027	-1254	-252	68.8	-1.2	4	0.4
19	4644	71089	-1193	-238	68.8	-1.2	4	0.4
20	5866	33455	47	10	50.1	0.1	0	0.0
21	7075	18062	1055	210	42.5	2.5	0	0.0
22	8052	11846	913	181	32.5	2.5	0	0.0
23	8733	10867	-66	-11	29.8	-0.2	0	0.0
24	9273	11987	1054	209	32.9	2.9	0	0.0

END OF PROGRAM

Table B-8. Bulkhead - Alternative 5

PROGRAM SEM.BAS - BELLE FONTAINE PROJECT
INITIAL BEACH CONDITIONS

SEG NUM	SEG POS (FT)	SEG ANGLE (DEG)	SEG WIDTH (FT)	SEG HEIGHT (FT)	SEG VOLUME (CYD)	ALT	PAR	PRN
1	13465	4.7	30	5	9111	0	0.0	0
2	12771	22.9	30	5	9111	0	0.0	0
3	11804	30.5	30	6	10933	0	0.0	0
4	10514	38.2	50	5	15185	0	0.0	0
5	9083	41.1	40	4	9719	0	0.0	0
6	7485	44.3	40	4	9719	0	0.0	0
7	6057	41.1	40	4	9719	0	0.0	0
8	4764	38.3	40	4	9719	2	50.0	0
9	4030	24.1	30	4	7289	0	0.0	0
10	3435	19.9	40	4	9719	0	0.0	0
11	2976	15.6	50	4	12148	5	50.0	0
12	2692	9.8	60	6	21867	5	60.0	0
13	2545	5.1	70	7	29763	5	70.0	0
14	2538	0.2	80	7	34015	5	80.0	0
15	2597	-2.1	60	6	21867	0	0.0	0
16	2664	-2.3	50	11	33407	0	0.0	0
17	2939	-9.5	40	15	36444	0	0.0	0
18	3680	-24.3	70	17	72281	0	0.0	0
19	4643	-30.4	70	17	72281	0	0.0	0
20	5866	-36.7	50	11	33407	0	0.0	0
21	7078	-36.5	40	7	17007	0	0.0	0
22	8055	-30.8	30	6	10933	0	0.0	0
23	8733	-22.5	30	6	10933	0	0.0	0
24	9276	-18.3	30	6	10933	0	0.0	0

TOTAL BEACH SEDIMENT VOLUME (CYD) = 517511.2

YEAR = 1 MONTH = 12 SEDIMENT VOL (CYD) = 517510

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13434	18636	9525	9525	61.4	31.4	0	0.0
2	12773	8575	-536	-536	28.2	-1.8	0	0.0
3	11806	10189	-745	-745	28.0	-2.0	0	0.0
4	10516	14605	-580	-580	48.1	-1.9	0	0.0
5	9086	9012	-706	-706	37.1	-2.9	0	0.0
6	7488	8964	-755	-755	36.9	-3.1	0	0.0
7	6083	3508	-6211	-6211	14.4	-25.6	0	0.0
8	4723	19586	9868	9868	80.6	40.6	2	50.0
9	4030	7305	16	16	30.1	0.1	0	0.0
10	3436	9507	-211	-211	39.1	-0.9	0	0.0
11	2979	11498	-650	-650	47.3	-2.7	5	50.0
12	2694	21039	-828	-828	57.7	-2.3	5	60.0
13	2548	28658	-1105	-1105	67.4	-2.6	5	70.0
14	2539	33410	-605	-605	78.6	-1.4	5	80.0
15	2597	21770	-97	-97	59.7	-0.3	0	0.0
16	2667	31233	-2174	-2174	46.7	-3.3	0	0.0
17	2945	31265	-5179	-5179	34.3	-5.7	0	0.0
18	3682	70103	-2179	-2179	67.9	-2.1	0	0.0
19	4645	70219	-2063	-2063	68.0	-2.0	0	0.0
20	5866	33492	84	84	50.1	0.1	0	0.0
21	7074	18829	1821	1821	44.3	4.3	0	0.0
22	8051	12510	1577	1577	34.3	4.3	0	0.0
23	8733	10842	-92	-92	29.7	-0.3	0	0.0
24	9271	12757	1824	1824	35.0	5.0	0	0.0

YEAR = 2 MONTH = 12 SEDIMENT VOL (CYD) = 515861

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13404	27599	18488	8964	90.9	60.9	0	0.0
2	12774	8171	-940	-404	26.9	-3.1	0	0.0
3	11807	9876	-1057	-313	27.1	-2.9	0	0.0
4	10518	14028	-1157	-578	46.2	-3.8	0	0.0
5	9090	7958	-1760	-1054	32.8	-7.2	0	0.0
6	7500	6018	-3700	-2945	24.8	-15.2	0	0.0
7	6080	4145	-5573	638	17.1	-22.9	0	0.0
8	4708	23315	13597	3729	96.0	56.0	2	50.0
9	4030	7297	8	-8	30.0	0.0	0	0.0
10	3437	9292	-426	-215	38.2	-1.8	0	0.0
11	2981	10854	-1294	-644	44.7	-5.3	5	50.0
12	2697	20207	-1660	-832	55.4	-4.6	5	60.0
13	2550	27566	-2197	-1092	64.8	-5.2	5	70.0
14	2541	32805	-1210	-605	77.2	-2.8	5	80.0
15	2598	21635	-232	-135	59.4	-0.6	0	0.0
16	2671	29032	-4375	-2201	43.5	-6.5	0	0.0
17	2950	26199	-10245	-5066	28.8	-11.2	0	0.0
18	3684	67866	-4415	-2237	65.7	-4.3	0	0.0
19	4647	68170	-4112	-2049	66.0	-4.0	0	0.0
20	5866	33590	183	99	50.3	0.3	0	0.0
21	7069	20621	3613	1792	48.5	8.5	0	0.0
22	8046	14052	3118	1542	38.6	8.6	0	0.0
23	8733	10822	-111	-20	29.7	-0.3	0	0.0
24	9266	14543	3610	1786	39.9	9.9	0	0.0

YEAR = 3 MONTH = 12 SEDIMENT VOL (CYD) = 513490

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13376	36196	27085	8597	119.2	89.2	0	0.0
2	12775	7955	-1156	-216	26.2	-3.8	0	0.0
3	11807	9749	-1185	-127	26.7	-3.3	0	0.0
4	10521	13002	-2183	-1026	42.8	-7.2	0	0.0
5	9098	6136	-3582	-1822	25.3	-14.7	0	0.0
6	7503	5431	-4287	-587	22.4	-17.6	0	0.0
7	6077	4855	-4863	710	20.0	-20.0	0	0.0
8	4700	25305	15587	1990	104.2	64.2	2	50.0
9	4030	7285	-4	-13	30.0	-0.0	0	0.0
10	3438	9074	-645	-219	37.3	-2.7	0	0.0
11	2984	10216	-1932	-638	42.0	-8.0	5	50.0
12	2699	19371	-2495	-836	53.2	-6.8	5	60.0
13	2553	26486	-3277	-1080	62.3	-7.7	5	70.0
14	2542	32200	-1815	-605	75.7	-4.3	5	80.0
15	2598	21457	-409	-177	58.9	-1.1	0	0.0
16	2675	26109	-7298	-2923	39.1	-10.9	0	0.0
17	2955	22302	-14143	-3897	24.5	-15.5	0	0.0
18	3687	65219	-7062	-2647	63.2	-6.8	0	0.0
19	4649	66132	-6149	-2037	64.0	-6.0	0	0.0
20	5866	33703	295	112	50.4	0.4	0	0.0
21	7065	22384	5377	1764	52.6	12.6	0	0.0
22	8042	15568	4635	1516	42.7	12.7	0	0.0
23	8733	10848	-85	26	29.8	-0.2	0	0.0
24	9261	16310	5376	1766	44.8	14.8	0	0.0

YEAR = 4 MONTH = 12 SEDIMENT VOL (CYD) = 511127

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13348	44598	35487	8402	146.8	116.8	0	0.0
2	12775	7867	-1244	-88	25.9	-4.1	0	0.0
3	11807	9710	-1224	-39	26.6	-3.4	0	0.0
4	10529	10707	-4479	-2296	35.3	-14.7	0	0.0
5	9101	5377	-4342	-759	22.1	-17.9	0	0.0
6	7502	5482	-4236	51	22.6	-17.4	0	0.0
7	6076	5094	-4625	239	21.0	-19.0	0	0.0
8	4692	27321	17603	2016	112.4	72.4	2	50.0
9	4030	7272	-17	-12	29.9	-0.1	0	0.0
10	3439	8851	-868	-223	36.4	-3.6	0	0.0
11	2987	9584	-2564	-632	39.4	-10.6	5	50.0
12	2701	18533	-3334	-839	50.9	-9.1	5	60.0
13	2555	25417	-4346	-1069	59.8	-10.2	5	70.0
14	2544	31594	-2421	-606	74.3	-5.7	5	80.0
15	2599	21229	-638	-229	58.2	-1.8	0	0.0
16	2680	22437	-10971	-3672	33.6	-16.4	0	0.0
17	2957	19595	-16850	-2707	21.5	-18.5	0	0.0
18	3690	62181	-10101	-3039	60.2	-9.8	0	0.0
19	4651	64103	-8178	-2029	62.1	-7.9	0	0.0
20	5865	33828	421	126	50.6	0.6	0	0.0
21	7061	24120	7112	1736	56.7	16.7	0	0.0
22	8038	17065	6131	1497	46.8	16.8	0	0.0
23	8733	10903	-30	55	29.9	-0.1	0	0.0
24	9256	18066	7133	1757	49.6	19.6	0	0.0

YEAR = 5 MONTH = 12 SEDIMENT VOL (CYD) = 508774

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13321	52911	43800	8313	174.2	144.2	0	0.0
2	12775	7834	-1277	-32	25.8	-4.2	0	0.0
3	11808	9530	-1404	-180	26.1	-3.9	0	0.0
4	10537	8108	-7078	-2599	26.7	-23.3	0	0.0
5	9102	5184	-4535	-193	21.3	-18.7	0	0.0
6	7502	5592	-4127	109	23.0	-17.0	0	0.0
7	6076	5163	-4555	70	21.3	-18.7	0	0.0
8	4683	29362	19644	2041	120.9	80.9	2	50.0
9	4030	7267	-22	-5	29.9	-0.1	0	0.0
10	3440	8623	-1096	-228	35.5	-4.5	0	0.0
11	2989	8958	-3191	-626	36.9	-13.1	5	50.0
12	2703	17691	-4176	-842	48.5	-11.5	5	60.0
13	2558	24358	-5405	-1058	57.3	-12.7	5	70.0
14	2545	30984	-3031	-609	72.9	-7.1	5	80.0
15	2600	20812	-1054	-416	57.1	-2.9	0	0.0
16	2686	18459	-14948	-3977	27.6	-22.4	0	0.0
17	2960	17642	-18802	-1953	19.4	-20.6	0	0.0
18	3693	58884	-13397	-3296	57.0	-13.0	0	0.0
19	4653	62079	-10202	-2024	60.1	-9.9	0	0.0
20	5865	33967	559	138	50.8	0.8	0	0.0
21	7057	25828	8821	1708	60.7	20.7	0	0.0
22	8034	18545	7612	1480	50.9	20.9	0	0.0
23	8733	10982	48	79	30.1	0.1	0	0.0
24	9252	19816	8882	1749	54.4	24.4	0	0.0

END OF PROGRAM

Table B-9. Combination Nourishment-Breakwater - Alternative 6

PROGRAM SEM.BAS - BELLE FONTAINE PROJECT
INITIAL BEACH CONDITIONS

SEG NUM	SEG POS (FT)	SEG ANGLE (DEG)	SEG WIDTH (FT)	SEG HEIGHT (FT)	SEG VOLUME (CYD)	ALT	PAR	PRN
1	13465	4.7	30	5	9111	0	0.0	0
2	12771	22.9	30	5	9111	0	0.0	0
3	11804	30.5	30	6	10933	0	0.0	0
4	10514	38.3	50	5	17185	1	2000.0	0
5	9083	41.1	40	4	11719	1	2000.0	0
6	7485	44.2	40	4	10719	1	1000.0	0
7	6057	41.0	40	4	9719	0	0.0	0
8	4764	38.3	40	4	9719	2	50.0	0
9	4030	24.1	30	4	7289	0	0.0	0
10	3435	19.9	40	4	9719	0	0.0	0
11	2976	15.9	50	4	14148	1	2000.0	0
12	2692	9.7	60	6	23867	1	2000.0	0
13	2545	5.2	70	7	32763	1	3000.0	0
14	2538	0.2	80	7	36015	1	2000.0	0
15	2597	-1.7	60	6	26867	1	5000.0	0
16	2664	-2.8	50	11	33407	4	0.3	0
17	2939	-9.5	40	15	36444	4	0.3	0
18	3680	-24.3	70	17	72281	4	0.3	0
19	4643	-30.4	70	17	72281	4	0.3	0
20	5866	-36.7	50	11	33407	4	0.3	0
21	7078	-36.5	40	7	17007	1	0.0	0
22	8055	-30.8	30	6	10933	0	0.0	0
23	8733	-22.5	30	6	10933	0	0.0	0
24	9276	-18.3	30	6	10933	0	0.0	0

TOTAL BEACH SEDIMENT VOLUME (CYD) = 536511.1

YEAR = 1 MONTH = 12 SEDIMENT VOL (CYD) = 536510

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13434	18633	9522	9522	61.4	31.4	0	0.0
2	12773	8569	-543	-543	28.2	-1.8	0	0.0
3	11806	10171	-762	-762	27.9	-2.1	0	0.0
4	10509	16625	-560	-560	54.7	4.7	1	2000.0
5	9078	11036	-682	-682	45.4	5.4	1	2000.0
6	7484	9955	-764	-764	41.0	1.0	1	1000.0
7	6083	3499	-6219	-6219	14.4	-25.6	0	0.0
8	4723	19586	9868	9868	80.6	40.6	2	50.0
9	4030	7305	16	16	30.1	0.1	0	0.0
10	3436	9527	-191	-191	39.2	-0.8	0	0.0
11	2971	13465	-683	-683	55.4	5.4	1	2000.0
12	2689	23063	-804	-804	63.3	3.3	1	2000.0
13	2541	31628	-1135	-1135	74.4	4.4	1	3000.0
14	2535	35430	-585	-585	83.3	3.3	1	2000.0
15	2600	20759	-6107	-6107	57.0	-3.0	1	5000.0
16	2664	33284	-124	-124	49.8	-0.2	4	0.3
17	2939	36140	-304	-304	39.7	-0.3	4	0.3
18	3680	72155	-127	-127	69.9	-0.1	4	0.3
19	4643	72160	-121	-121	69.9	-0.1	4	0.3
20	5866	33412	5	5	50.0	0.0	4	0.3
21	7078	17115	107	107	40.3	0.3	1	0.0
22	8055	11027	93	93	30.3	0.3	0	0.0
23	8733	10925	-8	-8	30.0	-0.0	0	0.0
24	9276	11041	108	108	30.3	0.3	0	0.0

YEAR = 2 MONTH = 12 SEDIMENT VOL (CYD) = 534861

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13404	27585	18474	8952	90.8	60.8	0	0.0
2	12774	8157	-955	-412	26.9	-3.1	0	0.0
3	11807	9851	-1083	-320	27.0	-3.0	0	0.0
4	10511	16067	-1118	-558	52.9	2.9	0	0.0
5	9081	10312	-1406	-724	42.4	2.4	0	0.0
6	7497	6686	-4032	-3268	27.5	-12.5	0	0.0
7	6080	4138	-5580	639	17.0	-23.0	0	0.0
8	4708	23315	13597	3729	96.0	56.0	2	50.0
9	4030	7297	9	-8	30.0	0.0	0	0.0
10	3437	9331	-387	-196	38.4	-1.6	0	0.0
11	2973	12789	-1359	-676	52.6	2.6	0	0.0
12	2691	22253	-1614	-810	61.1	1.1	0	0.0
13	2543	30506	-2257	-1122	71.7	1.7	0	0.0
14	2536	34692	-1322	-738	81.6	1.6	0	0.0
15	2616	14805	-12062	-5954	40.6	-19.4	0	0.0
16	2664	33151	-257	-133	49.6	-0.4	4	0.3
17	2940	35836	-608	-304	39.3	-0.7	4	0.3
18	3680	72028	-253	-127	69.8	-0.2	4	0.3
19	4643	72039	-242	-121	69.8	-0.2	4	0.3
20	5866	33417	9	5	50.0	0.0	4	0.3
21	7077	17222	215	107	40.5	0.5	0	0.0
22	8054	11120	186	93	30.5	0.5	0	0.0
23	8733	10917	-16	-8	30.0	-0.0	0	0.0
24	9275	11148	215	107	30.6	0.6	0	0.0

YEAR = 3 MONTH = 12 SEDIMENT VOL (CYD) = 532490

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13376	36162	27051	8577	119.1	89.1	0	0.0
2	12775	7936	-1175	-221	26.1	-3.9	0	0.0
3	11807	9719	-1214	-132	26.7	-3.3	0	0.0
4	10513	15516	-1669	-551	51.1	1.1	0	0.0
5	9088	8475	-3244	-1838	34.9	-5.1	0	0.0
6	7502	5666	-5052	-1020	23.3	-16.7	0	0.0
7	6077	4850	-4868	712	20.0	-20.0	0	0.0
8	4700	25305	15587	1990	104.2	64.2	2	50.0
9	4030	7285	-4	-13	30.0	-0.0	0	0.0
10	3437	9131	-587	-200	37.6	-2.4	0	0.0
11	2976	12121	-2027	-668	49.9	-0.1	0	0.0
12	2693	21437	-2430	-816	58.8	-1.2	0	0.0
13	2546	29392	-3371	-1114	69.1	-0.9	0	0.0
14	2539	33576	-2439	-1116	79.0	-1.0	0	0.0
15	2632	9236	-17631	-5569	25.3	-34.7	0	0.0
16	2665	33005	-402	-146	49.4	-0.6	4	0.3
17	2940	35533	-912	-304	39.0	-1.0	4	0.3
18	3680	71901	-380	-127	69.6	-0.4	4	0.3
19	4643	71918	-364	-121	69.6	-0.4	4	0.3
20	5866	33421	14	5	50.0	0.0	4	0.3
21	7077	17329	322	107	40.8	0.8	0	0.0
22	8054	11212	279	93	30.8	0.8	0	0.0
23	8733	10909	-24	-8	29.9	-0.1	0	0.0
24	9275	11256	322	107	30.9	0.9	0	0.0

YEAR = 4 MONTH = 12 SEDIMENT VOL (CYD) = 530127

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13348	44539	35428	8377	146.7	116.7	0	0.0
2	12775	7841	-1270	-95	25.8	-4.2	0	0.0
3	11807	9668	-1266	-51	26.5	-3.5	0	0.0
4	10515	14735	-2450	-782	48.5	-1.5	0	0.0
5	9097	6401	-5317	-2074	26.3	-13.7	0	0.0
6	7502	5559	-5160	-108	22.9	-17.1	0	0.0
7	6076	5091	-4627	241	21.0	-19.0	0	0.0
8	4692	27321	17603	2016	112.5	72.5	2	50.0
9	4030	7273	-16	-12	29.9	-0.1	0	0.0
10	3438	8927	-792	-205	36.7	-3.3	0	0.0
11	2979	11459	-2689	-661	47.2	-2.8	0	0.0
12	2695	20616	-3250	-821	56.6	-3.4	0	0.0
13	2549	28257	-4506	-1135	66.5	-3.5	0	0.0
14	2547	30035	-5980	-3542	70.6	-9.4	0	0.0
15	2640	6156	-20711	-3080	16.9	-43.1	0	0.0
16	2665	32820	-587	-185	49.1	-0.9	4	0.3
17	2940	35229	-1215	-304	38.7	-1.3	4	0.3
18	3681	71774	-507	-127	69.5	-0.5	4	0.3
19	4643	71797	-485	-121	69.5	-0.5	4	0.3
20	5866	33426	19	5	50.0	0.0	4	0.3
21	7077	17436	429	107	41.0	1.0	0	0.0
22	8054	11305	372	93	31.0	1.0	0	0.0
23	8733	10902	-31	-7	29.9	-0.1	0	0.0
24	9275	11363	429	107	31.2	1.2	0	0.0

YEAR = 5 MONTH = 12 SEDIMENT VOL (CYD) = 527774

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13321	52820	43709	8281	173.9	143.9	0	0.0
2	12775	7819	-1292	-22	25.7	-4.3	0	0.0
3	11807	9659	-1275	-9	26.5	-3.5	0	0.0
4	10522	12701	-4484	-2033	41.8	-8.2	0	0.0
5	9100	5545	-6174	-856	22.8	-17.2	0	0.0
6	7502	5615	-5103	57	23.1	-16.9	0	0.0
7	6076	5162	-4556	71	21.2	-18.8	0	0.0
8	4683	29363	19644	2042	120.9	80.9	2	50.0
9	4030	7267	-22	-5	29.9	-0.1	0	0.0
10	3439	8718	-1001	-209	35.9	-4.1	0	0.0
11	2982	10805	-3343	-654	44.5	-5.5	0	0.0
12	2698	19790	-4077	-826	54.3	-5.7	0	0.0
13	2551	27057	-5706	-1200	63.6	-6.4	0	0.0
14	2559	24959	-11056	-5076	58.7	-21.3	0	0.0
15	2644	4702	-22164	-1454	12.9	-47.1	0	0.0
16	2665	32611	-796	-209	48.8	-1.2	4	0.3
17	2941	34926	-1518	-303	38.3	-1.7	4	0.3
18	3681	71647	-634	-127	69.4	-0.6	4	0.3
19	4644	71676	-606	-121	69.4	-0.6	4	0.3
20	5866	33431	23	5	50.0	0.0	4	0.3
21	7077	17543	536	107	41.3	1.3	0	0.0
22	8054	11398	464	93	31.3	1.3	0	0.0
23	8733	10895	-38	-7	29.9	-0.1	0	0.0
24	9275	11470	536	107	31.5	1.5	0	0.0

END OF PROGRAM

Table B-10. Combination Nourishment-Breakwater - Alternative 6

PROGRAM SEM.BAS - BELLE FONTAINE PROJECT
INITIAL BEACH CONDITIONS

SEG NUM	SEG POS (FT)	SEG ANGLE (DEG)	SEG WIDTH (FT)	SEG HEIGHT (FT)	SEG VOLUME (CYD)	ALT	PAR	PRN
1	13465	4.7	30	5	9111	0	0.0	0
2	12771	22.9	30	5	9111	0	0.0	0
3	11804	30.5	30	6	10933	0	0.0	0
4	10514	38.3	50	5	17185	1	2000.0	0
5	9083	41.1	40	4	11719	1	2000.0	0
6	7485	44.2	40	4	10719	1	1000.0	0
7	6057	41.0	40	4	9719	0	0.0	0
8	4764	38.3	40	4	9719	2	50.0	0
9	4030	24.1	30	4	7289	0	0.0	0
10	3435	19.9	40	4	9719	0	0.0	0
11	2976	15.9	50	4	14148	1	2000.0	0
12	2692	9.7	60	6	23867	1	2000.0	0
13	2545	5.2	70	7	32763	1	3000.0	0
14	2538	0.2	80	7	36015	1	2000.0	0
15	2597	-1.7	60	6	26867	1	5000.0	0
16	2664	-2.8	50	11	33407	4	0.3	0
17	2939	-9.5	40	15	36444	4	0.3	0
18	3680	-24.3	70	17	72281	4	0.3	0
19	4643	-30.4	70	17	72281	4	0.3	0
20	5866	-36.7	50	11	33407	4	0.3	0
21	7078	-36.5	40	7	17007	0	0.0	0
22	8055	-30.8	30	6	10933	0	0.0	0
23	8733	-22.5	30	6	10933	0	0.0	0
24	9276	-18.3	30	6	10933	0	0.0	0

TOTAL BEACH SEDIMENT VOLUME (CYD) = 536511.1

YEAR = 1 MONTH = 12 SEDIMENT VOL (CYD) = 536510

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13434	18633	9522	9522	61.4	31.4	0	0.0
2	12773	8569	-543	-543	28.2	-1.8	0	0.0
3	11806	10171	-762	-762	27.9	-2.1	0	0.0
4	10509	16625	-560	-560	54.7	4.7	1	2000.0
5	9078	11036	-682	-682	45.4	5.4	1	2000.0
6	7484	9955	-764	-764	41.0	1.0	1	1000.0
7	6083	3499	-6219	-6219	14.4	-25.6	0	0.0
8	4723	19586	9868	9868	80.6	40.6	2	50.0
9	4030	7305	16	16	30.1	0.1	0	0.0
10	3436	9527	-191	-191	39.2	-0.8	0	0.0
11	2971	13465	-683	-683	55.4	5.4	1	2000.0
12	2689	23063	-804	-804	63.3	3.3	1	2000.0
13	2541	31628	-1135	-1135	74.4	4.4	1	3000.0
14	2535	35430	-585	-585	83.3	3.3	1	2000.0
15	2600	20759	-6107	-6107	57.0	-3.0	1	5000.0
16	2664	33284	-124	-124	49.8	-0.2	4	0.3
17	2939	36140	-304	-304	39.7	-0.3	4	0.3
18	3680	72155	-127	-127	69.9	-0.1	4	0.3
19	4643	72160	-121	-121	69.9	-0.1	4	0.3
20	5866	33412	5	5	50.0	0.0	4	0.3
21	7078	17115	107	107	40.3	0.3	0	0.0
22	8055	11027	93	93	30.3	0.3	0	0.0
23	8733	10925	-8	-8	30.0	-0.0	0	0.0
24	9276	11041	108	108	30.3	0.3	0	0.0

YEAR = 2 MONTH = 12 SEDIMENT VOL (CYD) = 547861

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13404	27585	18474	8952	90.8	60.8	0	0.0
2	12774	8157	-955	-412	26.9	-3.1	0	0.0
3	11807	9851	-1083	-320	27.0	-3.0	0	0.0
4	10511	16068	-1117	-558	52.9	2.9	0	0.0
5	9081	10311	-1408	-726	42.4	2.4	0	0.0
6	7481	10707	-11	753	44.1	4.1	1	4000.0
7	6080	4118	-5600	619	16.9	-23.1	0	0.0
8	4708	23316	13597	3729	96.0	56.0	2	50.0
9	4030	7298	9	-8	30.0	0.0	0	0.0
10	3437	9350	-368	-177	38.5	-1.5	0	0.0
11	2965	14729	581	1264	60.6	10.6	1	2000.0
12	2691	22325	-1542	-738	61.3	1.3	0	0.0
13	2539	32435	-328	807	76.3	6.3	1	2000.0
14	2536	34859	-1155	-571	82.0	2.0	0	0.0
15	2603	19670	-7197	-1090	54.0	-6.0	1	5000.0
16	2664	33158	-249	-125	49.6	-0.4	4	0.3
17	2940	35836	-608	-304	39.3	-0.7	4	0.3
18	3680	72028	-253	-127	69.8	-0.2	4	0.3
19	4643	72039	-242	-121	69.8	-0.2	4	0.3
20	5866	33417	9	5	50.0	0.0	4	0.3
21	7077	17222	215	107	40.5	0.5	0	0.0
22	8054	11120	186	93	30.5	0.5	0	0.0
23	8733	10917	-16	-8	30.0	-0.0	0	0.0
24	9275	11148	215	107	30.6	0.6	0	0.0

YEAR = 3 MONTH = 12 SEDIMENT VOL (CYD) = 552490

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13376	36162	27051	8577	119.1	89.1	0	0.0
2	12775	7936	-1175	-221	26.1	-3.9	0	0.0
3	11807	9719	-1214	-132	26.7	-3.3	0	0.0
4	10513	15475	-1710	-593	51.0	1.0	0	0.0
5	9075	11597	-122	1286	47.7	7.7	1	2000.0
6	7469	13647	2929	2940	56.2	16.2	1	5000.0
7	6077	4788	-4930	670	19.7	-20.3	0	0.0
8	4700	25306	15588	1991	104.2	64.2	2	50.0
9	4030	7285	-4	-13	30.0	-0.0	0	0.0
10	3437	9168	-550	-182	37.7	-2.3	0	0.0
11	2968	14004	-144	-725	57.6	7.6	0	0.0
12	2693	21577	-2289	-748	59.2	-0.8	0	0.0
13	2541	31259	-1504	-1176	73.5	3.5	0	0.0
14	2538	34134	-1881	-726	80.3	0.3	0	0.0
15	2619	13733	-13134	-5937	37.7	-22.3	0	0.0
16	2665	33024	-384	-135	49.4	-0.6	4	0.3
17	2940	35533	-912	-304	39.0	-1.0	4	0.3
18	3680	71901	-380	-127	69.6	-0.4	4	0.3
19	4643	71918	-364	-121	69.6	-0.4	4	0.3
20	5866	33421	14	5	50.0	0.0	4	0.3
21	7077	17329	322	107	40.8	0.8	0	0.0
22	8054	11212	279	93	30.8	0.8	0	0.0
23	8733	10909	-24	-8	29.9	-0.1	0	0.0
24	9275	11256	322	107	30.9	0.9	0	0.0

YEAR = 4 MONTH = 12 SEDIMENT VOL (CYD) = 562128

NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13348	44539	35428	8377	146.7	116.7	0	0.0
2	12775	7841	-1270	-94	25.8	-4.2	0	0.0
3	11807	9668	-1265	-51	26.5	-3.5	0	0.0
4	10515	14879	-2306	-596	49.0	-1.0	0	0.0
5	9078	10845	-873	-751	44.6	4.6	0	0.0
6	7463	15061	4342	1414	62.0	22.0	1	3000.0
7	6076	4998	-4720	210	20.6	-19.4	0	0.0
8	4692	27324	17605	2018	112.5	72.5	2	50.0
9	4030	7273	-16	-12	29.9	-0.1	0	0.0
10	3438	8982	-737	-187	37.0	-3.0	0	0.0
11	2971	13316	-832	-688	54.8	4.8	0	0.0
12	2689	22787	-1080	1210	62.5	2.5	1	2000.0
13	2540	32061	-702	802	75.4	5.4	1	2000.0
14	2539	33431	-2584	-702	78.6	-1.4	0	0.0
15	2622	12805	-14061	-927	35.1	-24.9	1	5000.0
16	2665	32888	-520	-136	49.2	-0.8	4	0.3
17	2940	35229	-1215	-303	38.7	-1.3	4	0.3
18	3681	71774	-507	-127	69.5	-0.5	4	0.3
19	4643	71797	-485	-121	69.5	-0.5	4	0.3
20	5866	33426	19	5	50.0	0.0	4	0.3
21	7077	17436	429	107	41.0	1.0	0	0.0
22	8054	11305	372	93	31.0	1.0	0	0.0
23	8733	10902	-31	-7	29.9	-0.1	0	0.0
24	9275	11363	429	107	31.2	1.2	0	0.0

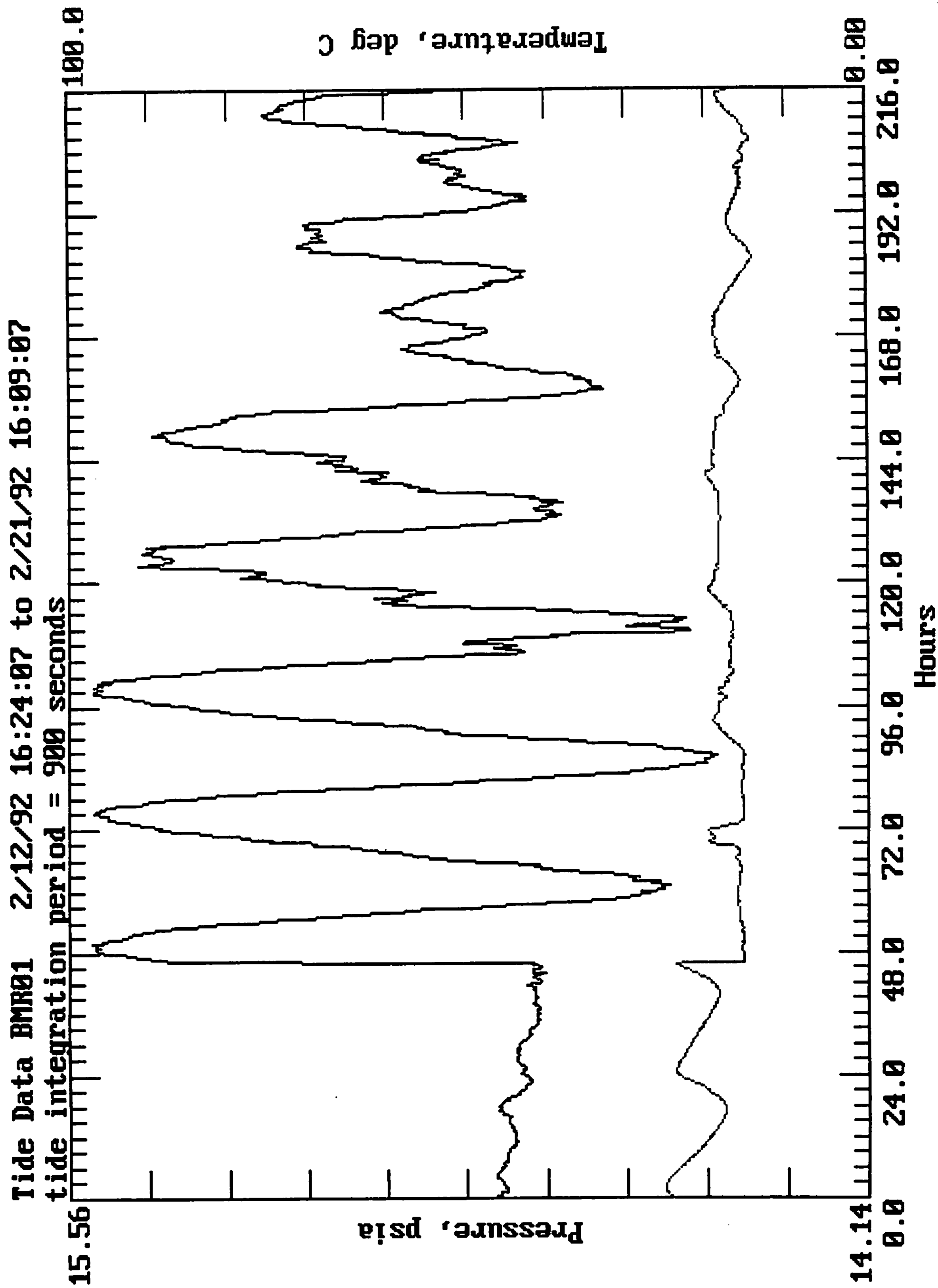
YEAR = 5 MONTH = 12 SEDIMENT VOL (CYD) = 569775

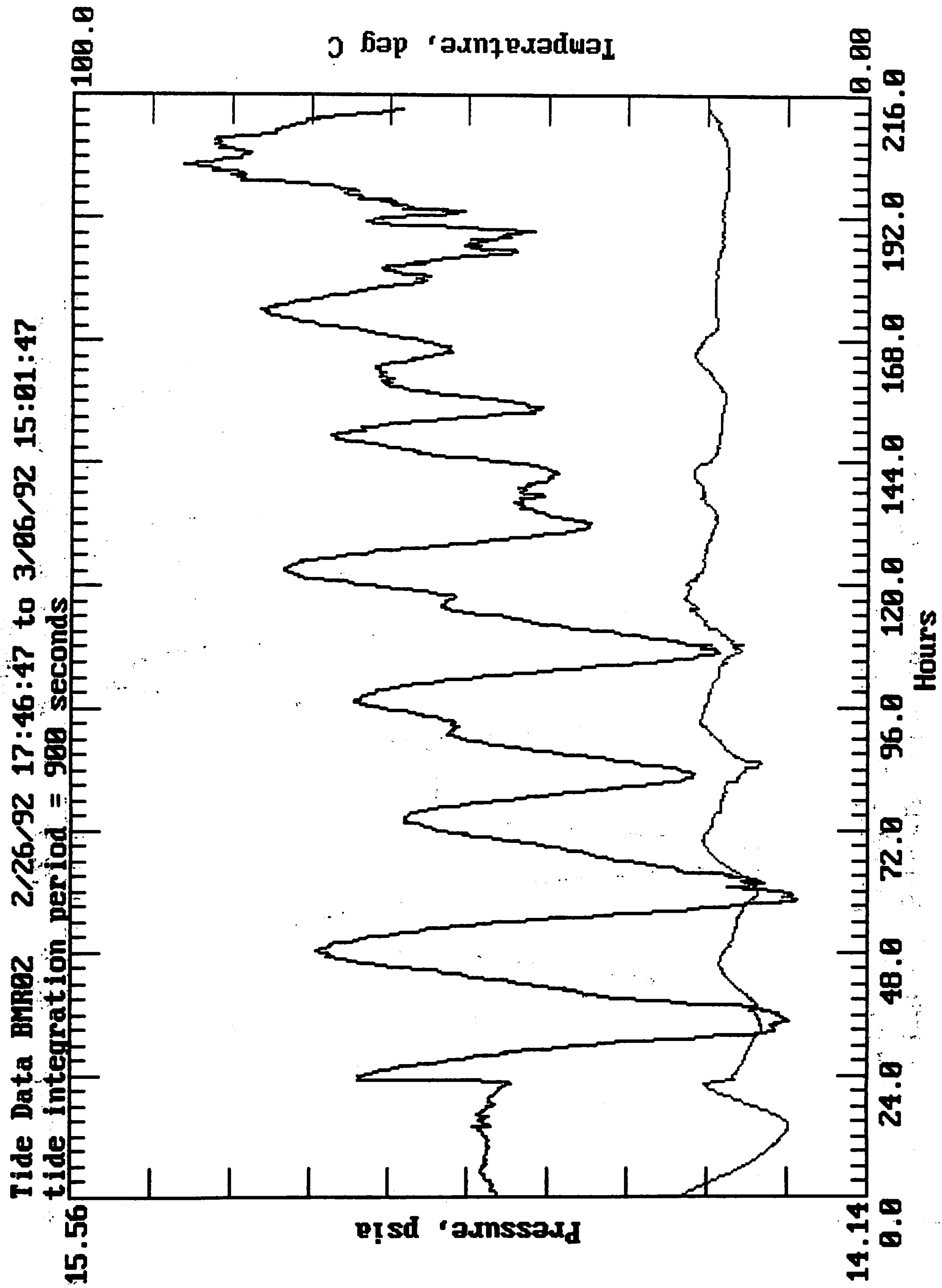
NUM	POS (FT)	VOL (CYD)	NCHG (CYD)	ACHG (CYD)	WIDTH (FT)	PCHG (FT)	ALT	PAR
1	13321	52820	43709	8280	173.9	143.9	0	0.0
2	12775	7817	-1294	-24	25.7	-4.3	0	0.0
3	11807	9652	-1282	-16	26.5	-3.5	0	0.0
4	10517	14280	-2905	-599	47.0	-3.0	0	0.0
5	9081	10103	-1616	-743	41.6	1.6	0	0.0
6	7469	13580	2861	-1481	55.9	15.9	0	0.0
7	6076	5067	-4651	69	20.9	-19.1	0	0.0
8	4683	29368	19650	2044	120.9	80.9	2	50.0
9	4030	7270	-19	-3	29.9	-0.1	0	0.0
10	3435	9778	59	796	40.2	0.2	1	1000.0
11	2974	12685	-1463	-631	52.2	2.2	0	0.0
12	2684	24893	1026	2106	68.3	8.3	1	3000.0
13	2542	30934	-1829	-1127	72.8	2.8	0	0.0
14	2541	32737	-3278	-695	77.0	-3.0	0	0.0
15	2622	12860	-14006	55	35.3	-24.7	1	6000.0
16	2665	32752	-655	-136	49.0	-1.0	4	0.3
17	2941	34926	-1518	-303	38.3	-1.7	4	0.3
18	3681	71647	-634	-127	69.4	-0.6	4	0.3
19	4644	71676	-606	-121	69.4	-0.6	4	0.3
20	5866	33431	23	5	50.0	0.0	4	0.3
21	7077	17543	536	107	41.3	1.3	0	0.0
22	8054	11398	464	93	31.3	1.3	0	0.0
23	8733	10895	-38	-7	29.9	-0.1	0	0.0
24	9275	11470	536	107	31.5	1.5	0	0.0

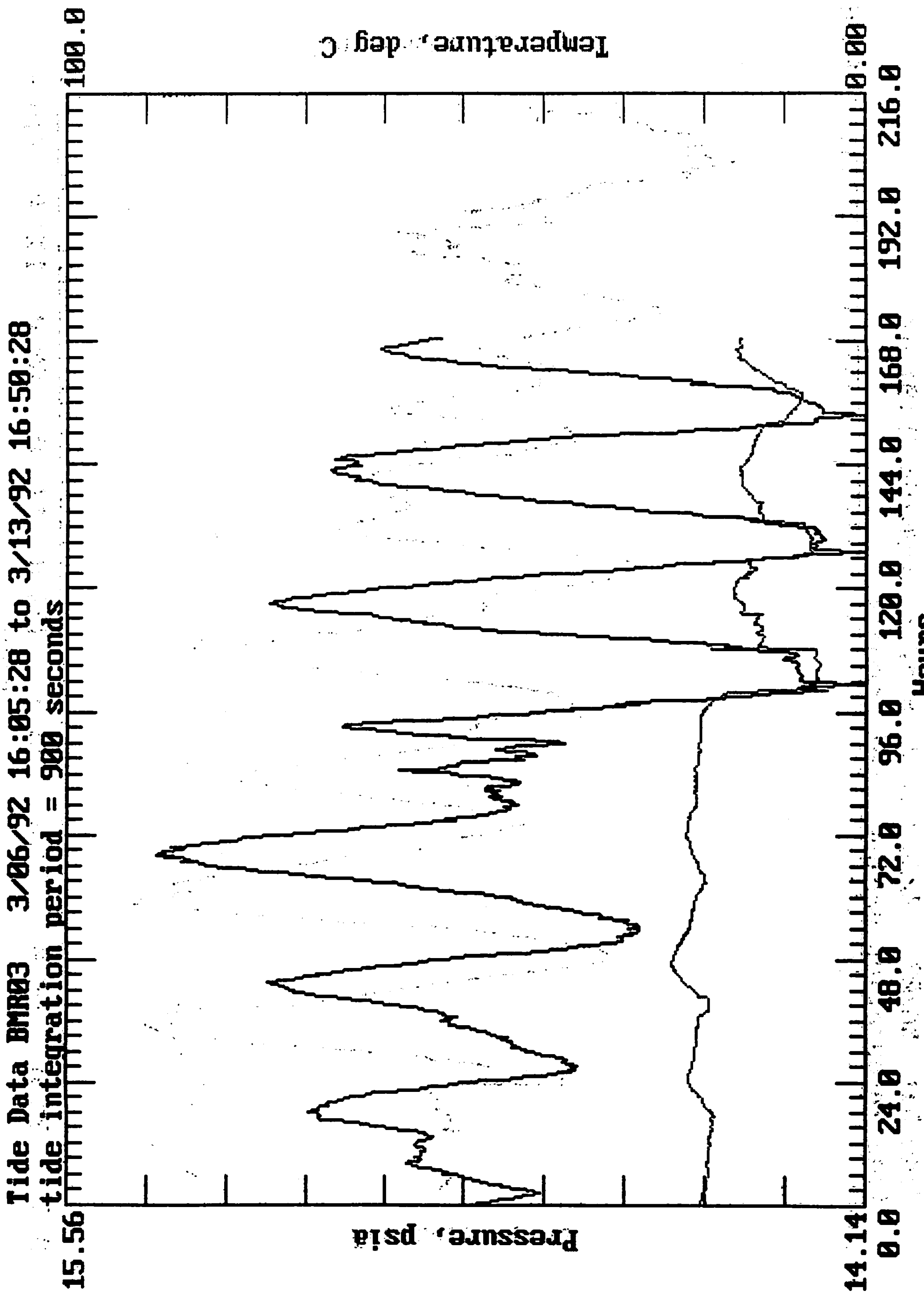
END OF PROGRAM

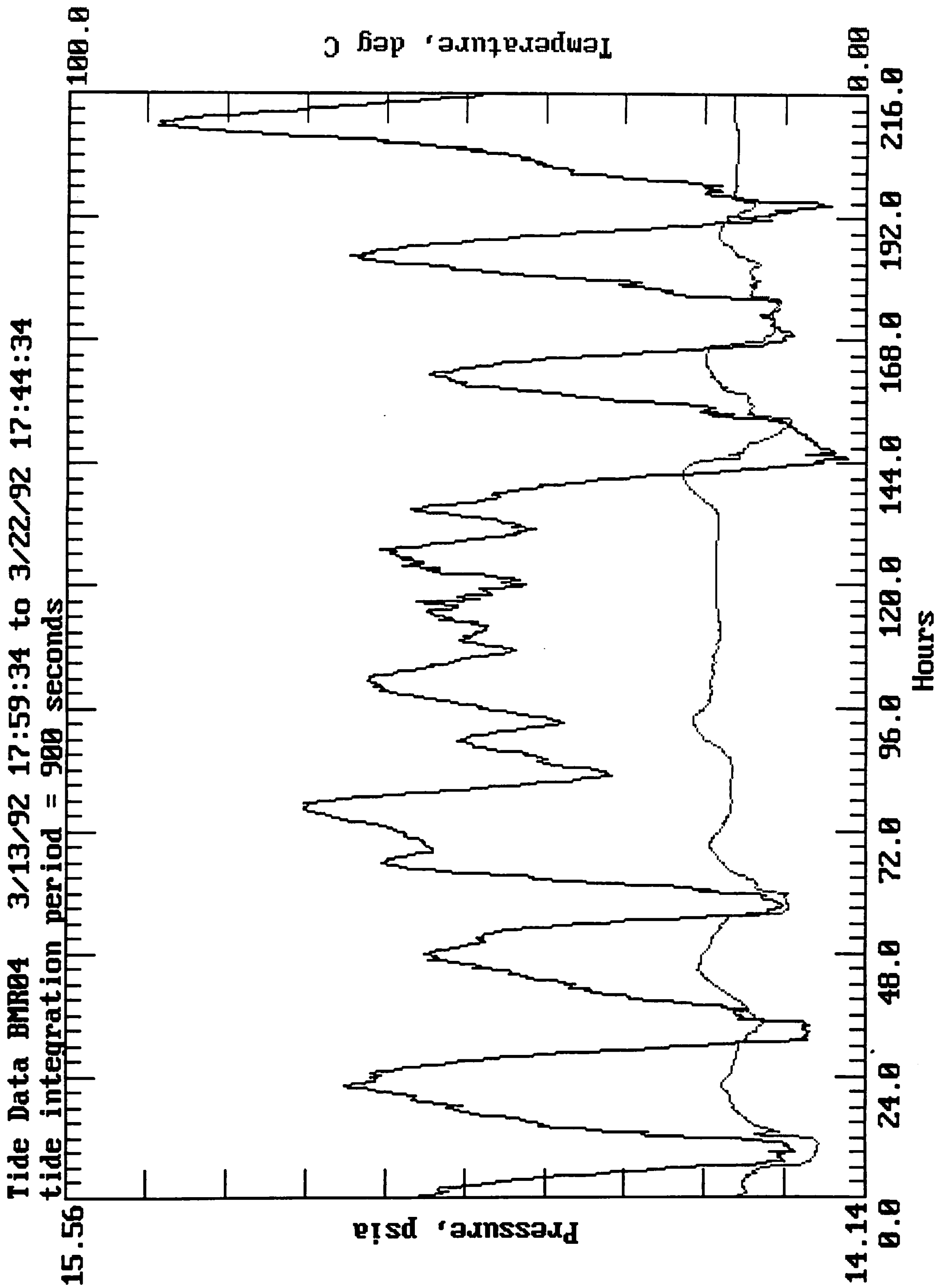
Appendix C.

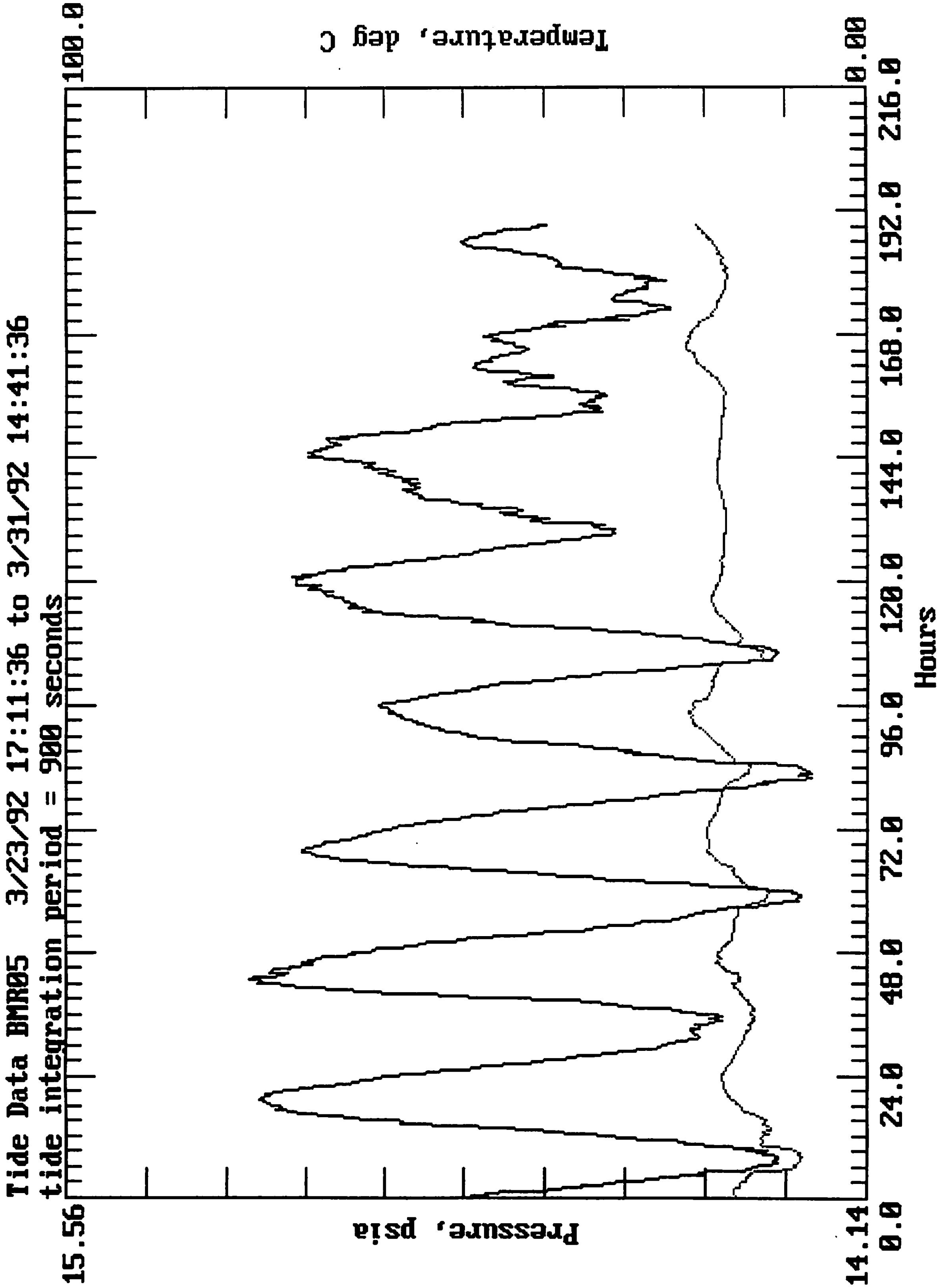
Tide data (upper line) and temperature data (lower line) from Belle Fontaine for the period of February 12 to May 3, 1992. The pressure scale is in pounds per square inch absolute and 1 division is equivalent to an elevation change of 10 centimeters.


Tide Data BMR01 2/12/92 16:24:07 to 2/21/92 16:09:07
tide integration period = 900 seconds
Temperature, deg C
Pressure, psia
Hours
100.0
0.00
15.56
14.14
0.0
24.0
48.0
72.0
96.0
120.0
144.0
168.0
192.0
216.0

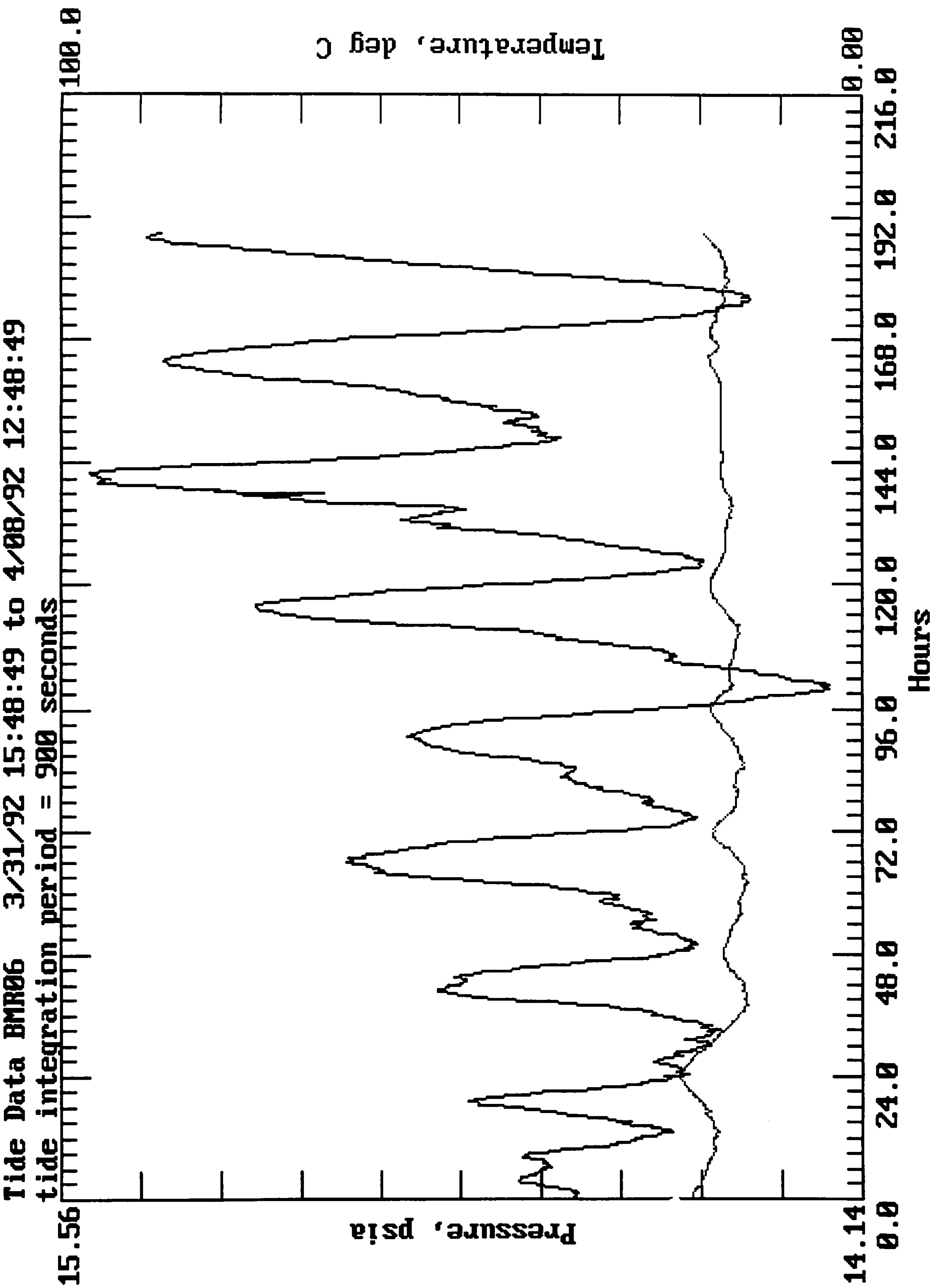

Tide Data BMR02 2/26/92 17:46:47 to 3/06/92 15:01:47
tide integration period = 900 seconds
Pressure, psia
15.56
14.14
Temperature, deg C
100.0
0.00
Hours
0.0
24.0
48.0
72.0
96.0
120.0
144.0
168.0
192.0
216.0

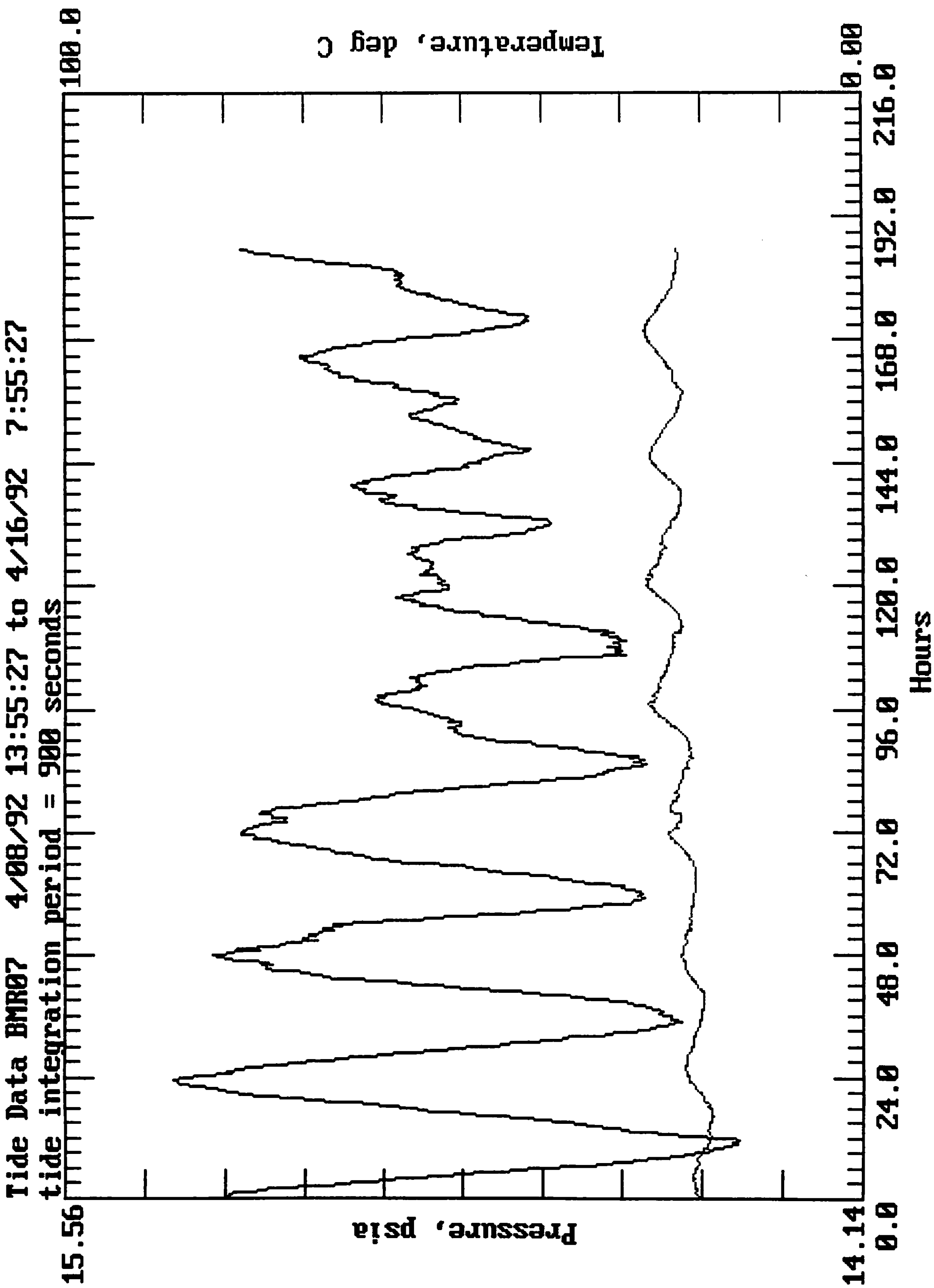

Tide Data BMR03 3/06/92 16:05:28 to 3/13/92 16:50:28
tide integration period = 900 seconds
Pressure, psia
15.56
14.14
Temperature, deg C
100.0
0.00
Hours
0.0
24.0
48.0
72.0
96.0
120.0
144.0
168.0
192.0
216.0

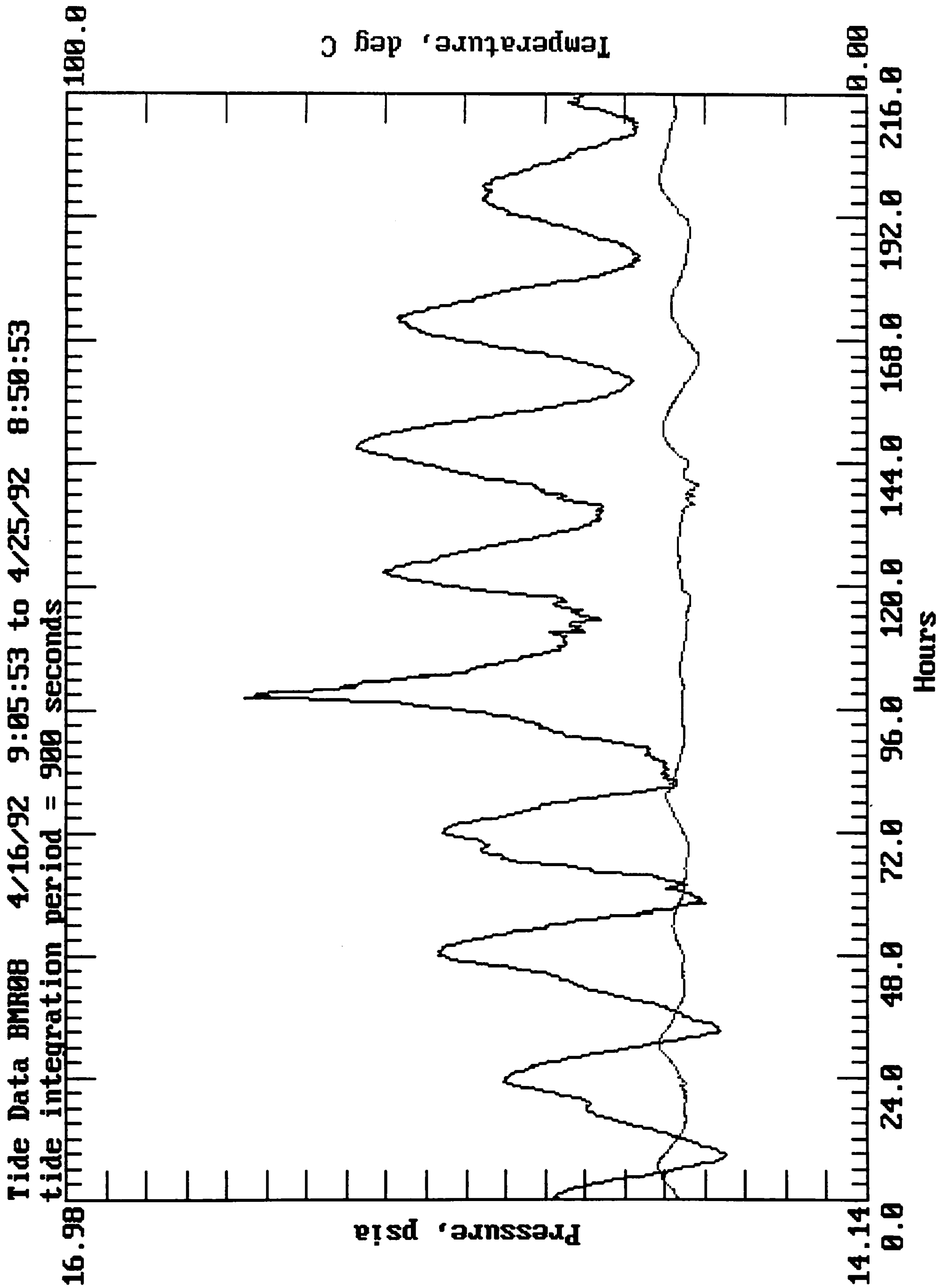

Tide Data BMR04 3/13/92 17:59:34 to 3/22/92 17:44:34
tide integration period = 900 seconds
Pressure, psia
Temperature, deg C
Hours
15.56
14.14
100.0
0.00
0.0
24.0
48.0
72.0
96.0
120.0
144.0
168.0
192.0
216.0

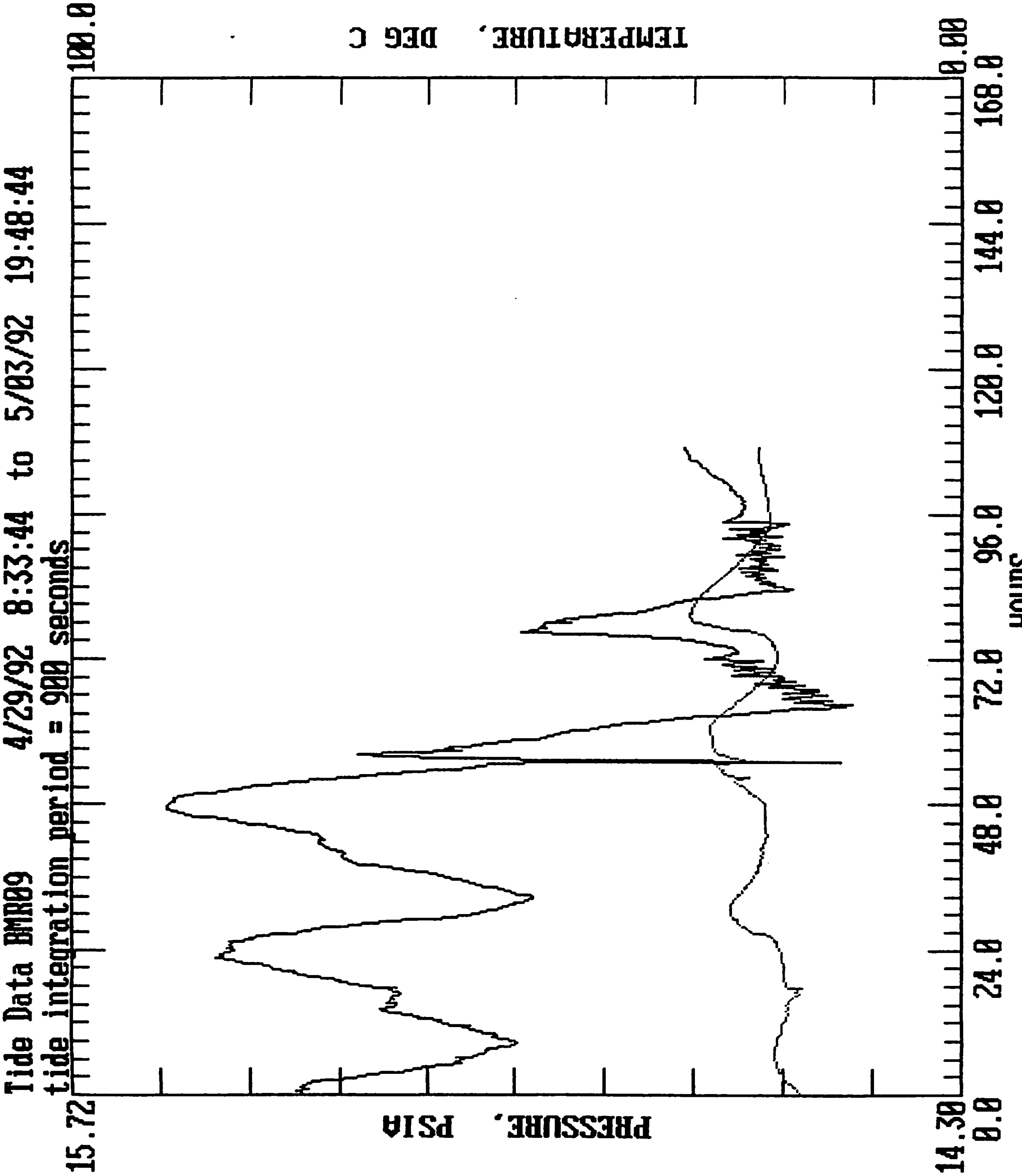


Tide Data BMR05 3/23/92 17:11:36 to 3/31/92 14:41:36
tide integration period = 900 seconds
Temperature, deg C
100.0
0.00
Pressure, psia
15.56
14.14
Hours
0.0
24.0
48.0
72.0
96.0
120.0
144.0
168.0
192.0
216.0


Tide Data BMR06 3/31/92 15:48:49 to 4/08/92 12:48:49
tide integration period = 900 seconds
Temperature, deg C
100.0
0.00
Pressure, psia
15.56
14.14
Hours
0.0
24.0
48.0
72.0
96.0
120.0
144.0
168.0
192.0
216.0


Tide Data BMR07 4/08/92 13:55:27 to 4/16/92 7:55:27
tide integration period = 900 seconds
Temperature, deg C
100.0
0.00
Pressure, psia
15.56
14.14
Hours
0.0
24.0
48.0
72.0
96.0
120.0
144.0
168.0
192.0
216.0


Tide Data BMR08 4/16/92 9:05:53 to 4/25/92 8:50:53
tide integration period = 900 seconds
Pressure, psia
16.98
14.14
Temperature, deg C
100.0
0.00
Hours
0.0
24.0
48.0
72.0
96.0
120.0
144.0
168.0
192.0
216.0

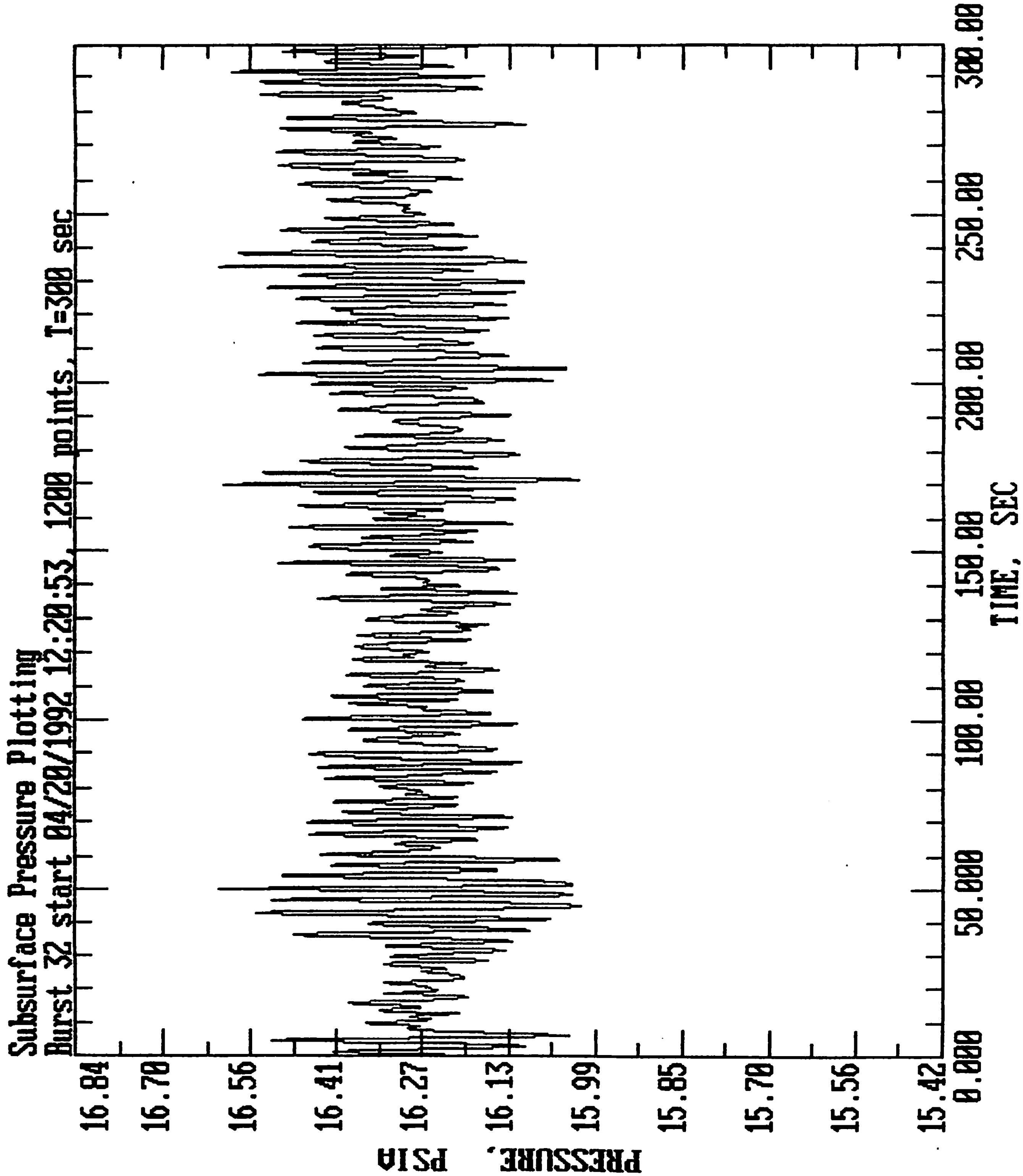

Tide Data BMR09 4/29/92 8:33:44 to 5/03/92 19:48:44
tide integration period = 900 seconds
TEMPERATURE, DEG C
PRESSURE, PSIA
HOURS
0.0
24.0
48.0
72.0
96.0
120.0
144.0
168.0
15.72
14.30
100.0
0.00

Appendix D.

Examples of wave meter data collected at Belle Fontaine.

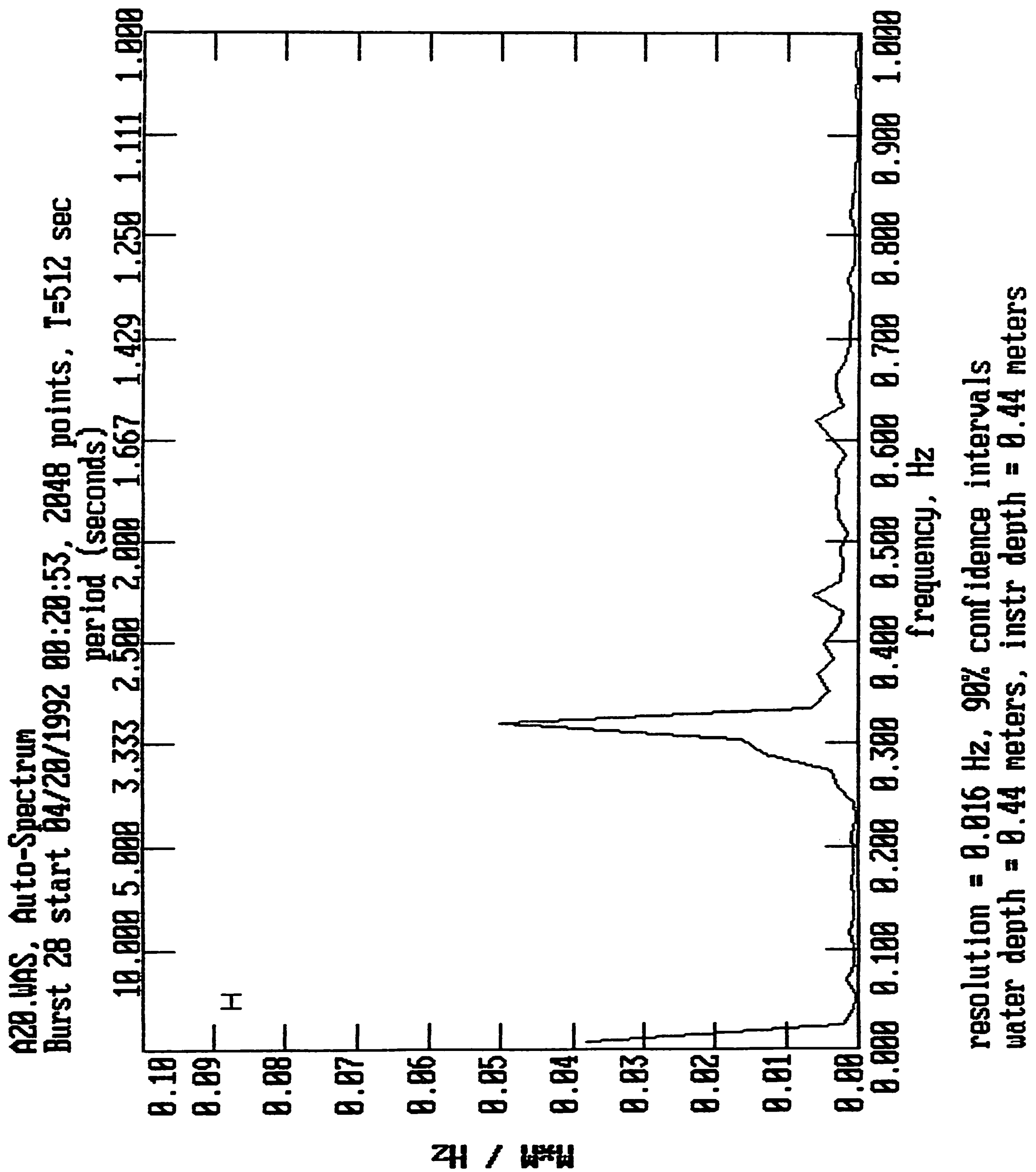
D-1

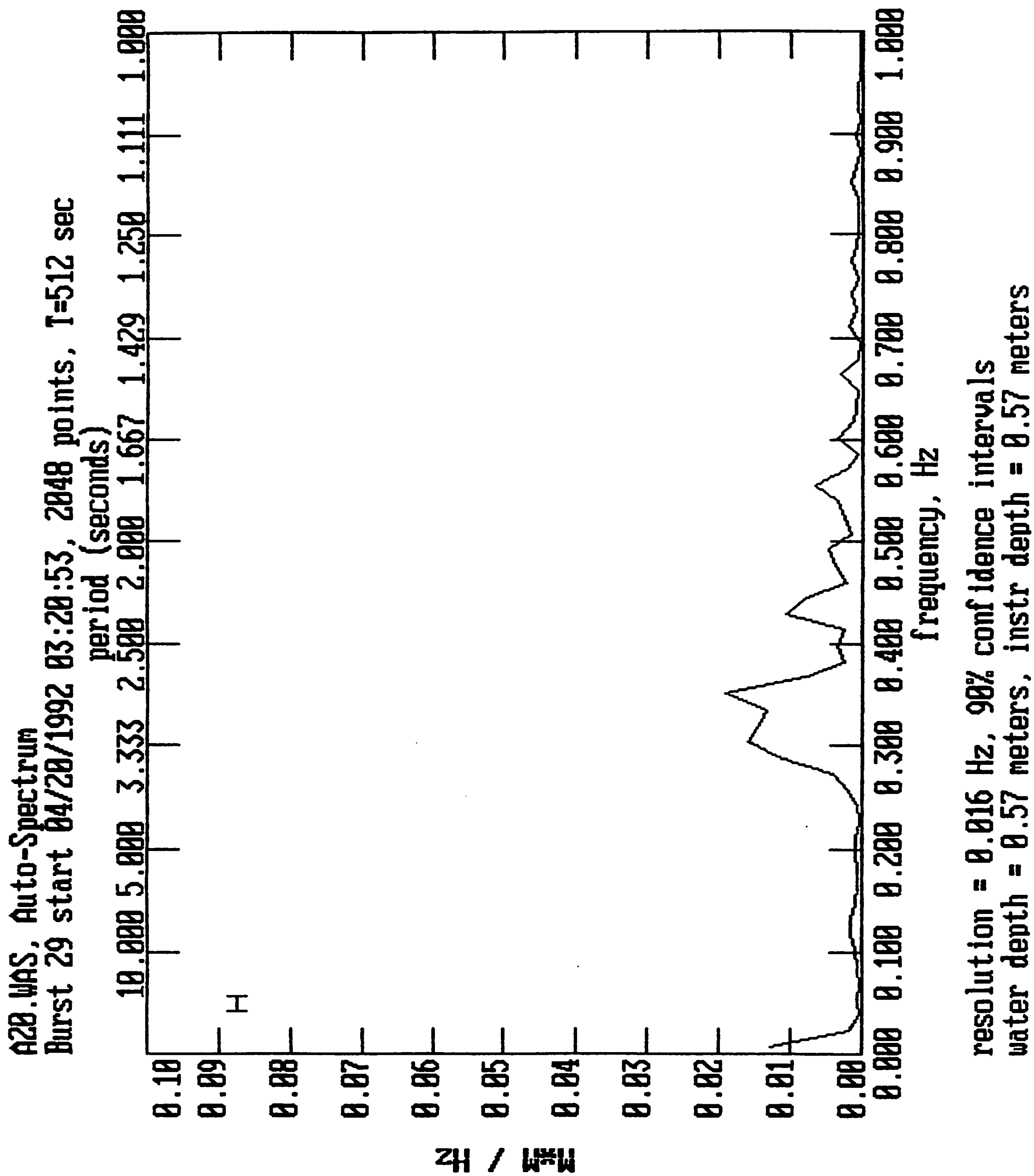
Wave-induced pressure record for Belle Fontaine on April 20, 1992, starting at 12:20:53. The record shows wave data for a full 300 second (5 minute) sample at the time of maximum wave action.

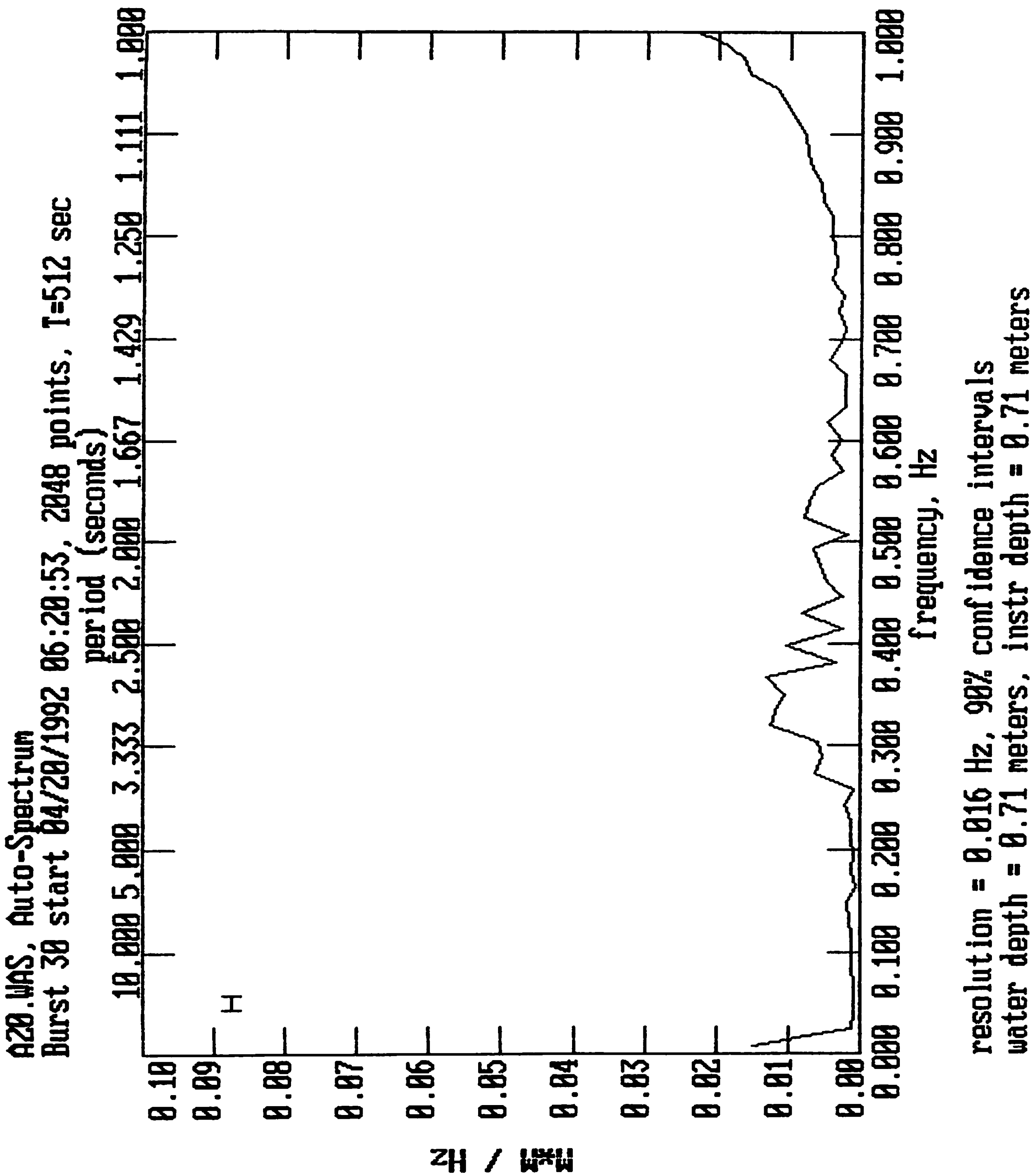


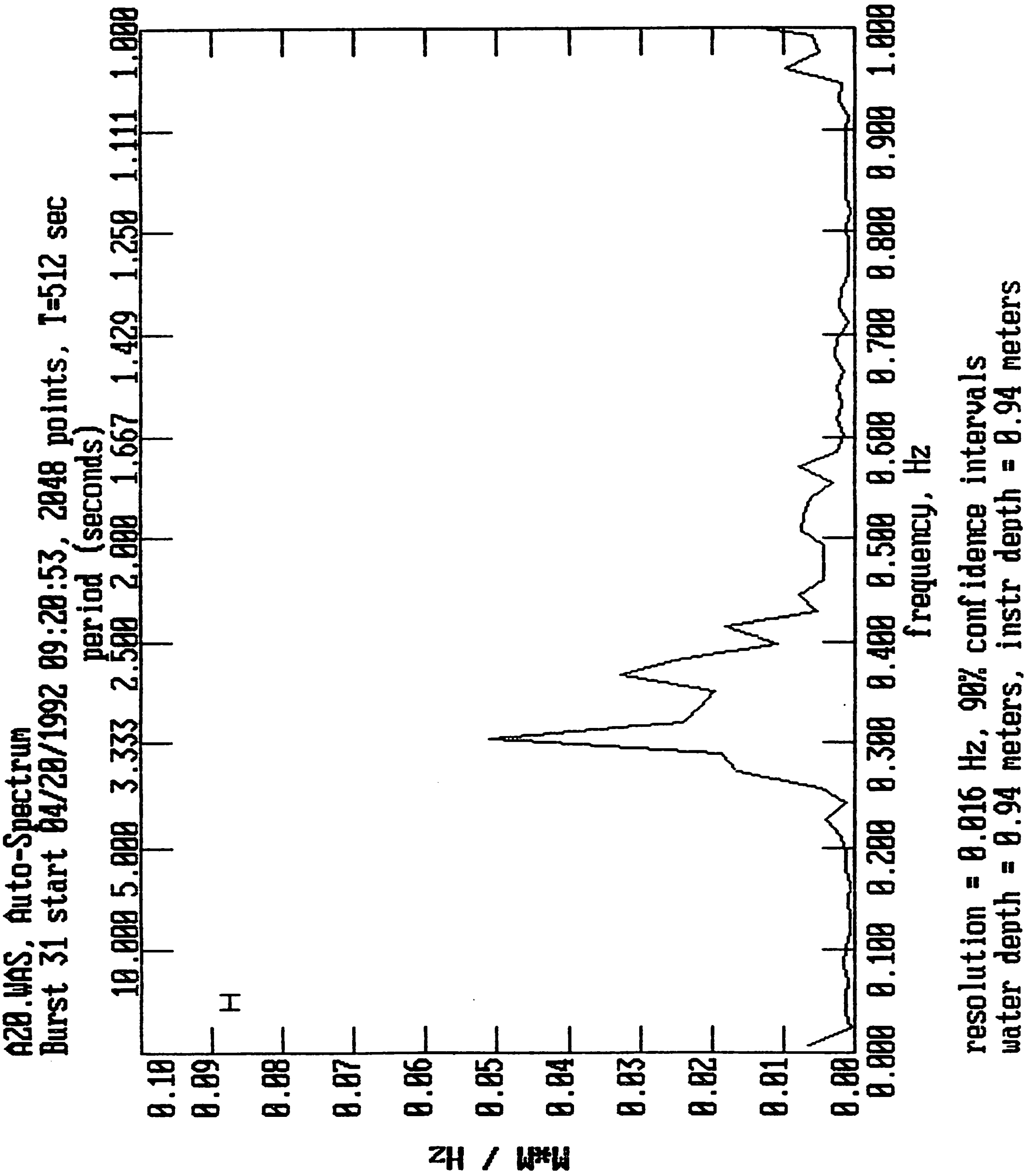
D-2

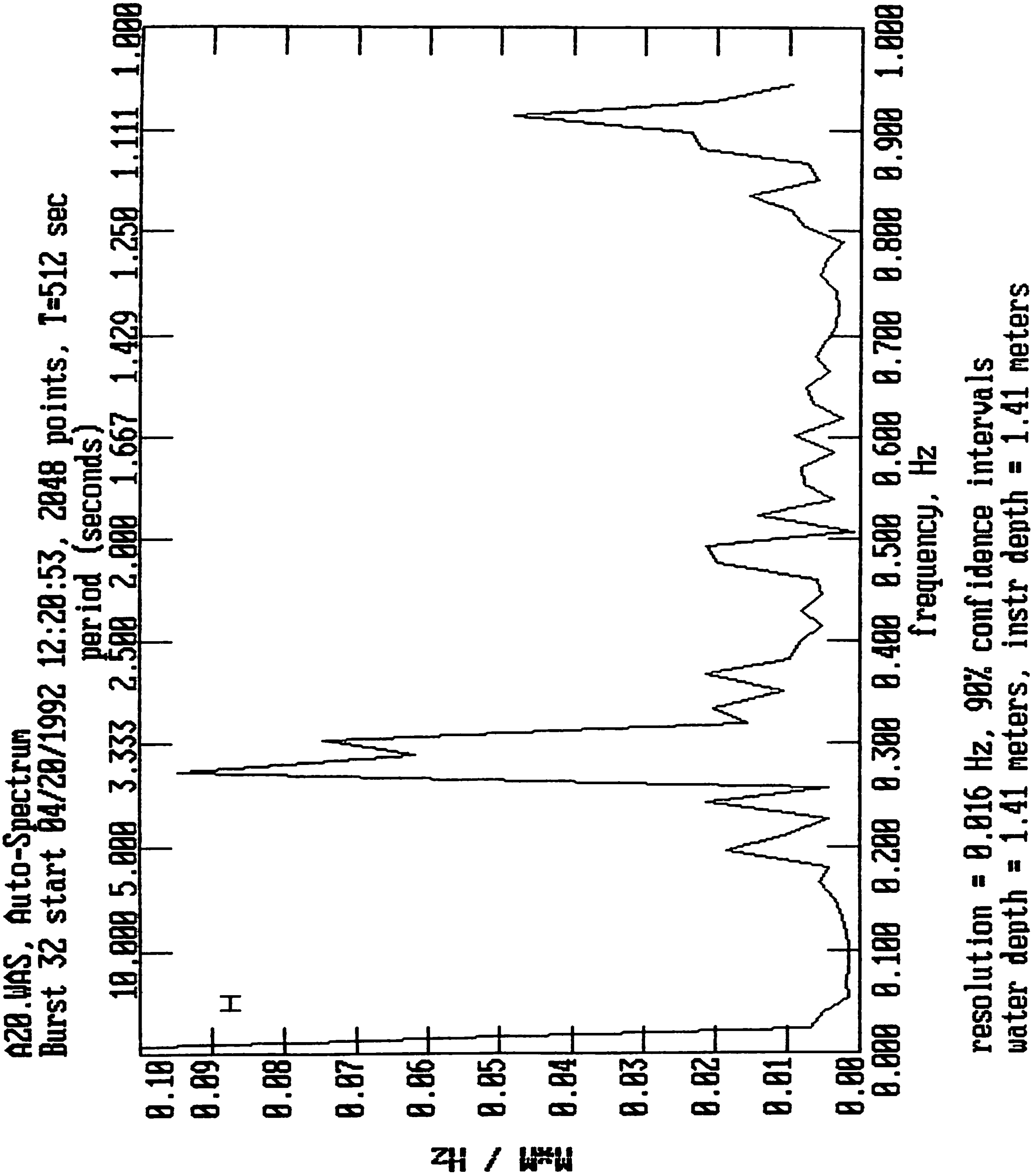
Wave spectra for the time period 00:20:53 to 12:20:53 on April 20, 1992, showing the development of storm waves.




A20.WAS, Auto-Spectrum
Burst 29 start 04/20/1992 03:20:53, 2048 points, T=512 sec
period (seconds)
10.000 5.000 3.333 2.500 2.000 1.667 1.429 1.250 1.111 1.000
0.000 0.100 0.200 0.300 0.400 0.500 0.600 0.700 0.800 0.900 1.000
frequency, Hz
0.10 0.09 0.08 0.07 0.06 0.05 0.04 0.03 0.02 0.01 0.00
M*M / Hz
resolution = 0.016 Hz, 90% confidence intervals
water depth = 0.57 meters, instr depth = 0.57 meters


A20.WAS, Auto-Spectrum
Burst 30 start 04/20/1992 06:20:53, 2048 points, T=512 sec
period (seconds)
10.000 5.000 3.333 2.500 2.000 1.667 1.429 1.250 1.111 1.000
0.10 0.09 0.08 0.07 0.06 0.05 0.04 0.03 0.02 0.01 0.00
M*M / Hz
0.000 0.100 0.200 0.300 0.400 0.500 0.600 0.700 0.800 0.900 1.000
frequency, Hz
resolution = 0.016 Hz, 90% confidence intervals
water depth = 0.71 meters, instr depth = 0.71 meters


A20.WAS, Auto-Spectrum
Burst 31 start 04/20/1992 09:20:53, 2048 points, T=512 sec
10.000 5.000 3.333 2.500 2.000 1.667 1.429 1.250 1.111 1.000
period (seconds)
0.000 0.100 0.200 0.300 0.400 0.500 0.600 0.700 0.800 0.900 1.000
frequency, Hz
0.10 0.09 0.08 0.07 0.06 0.05 0.04 0.03 0.02 0.01 0.00
M*M / Hz
resolution = 0.016 Hz, 90% confidence intervals
water depth = 0.94 meters, instr depth = 0.94 meters


A20.WAS, Auto-Spectrum
Burst 32 start 04/20/1992 12:20:53, 2048 points, T=512 sec
period (seconds)
10.000 5.000 3.333 2.500 2.000 1.667 1.429 1.250 1.111 1.000
0.000 0.100 0.200 0.300 0.400 0.500 0.600 0.700 0.800 0.900 1.000
frequency, Hz
resolution = 0.016 Hz, 90% confidence intervals
water depth = 1.41 meters, instr depth = 1.41 meters
0.10 0.09 0.08 0.07 0.06 0.05 0.04 0.03 0.02 0.01 0.00
M*M / Hz

THE GOVERNMENT'S ROLE IN COASTAL MANAGEMENT IN MISSISSIPPI

Cathy Z. Hollomon
Mississippi Department of Wildlife, Fisheries and Parks
Bureau of Marine Resources

INTRODUCTION

The coastline bordering the Gulf of Mexico consists of a complex integrated system of beaches, dunes, barrier islands, marshes, bays, tidal flats, and inlets. People's desire to live and work in these coastal environments has always existed but has intensified significantly in the past few decades. Presently, approximately 50 percent of the U.S. population lives within an hour's drive of a coast. It is projected that by the year 2010 this proportion will increase to 75 percent. The expanding population results in increased pressures on the natural environment, resulting in major conflicts between industry, fisheries, recreation, and the preservation of coastal resources. Also, as the coastal population grows, so does the need for additional transportation networks, recreational facilities, potable water, waste disposal systems, and other facilities. Air and water pollution are concerns in and around coastal communities where impacts to the fisheries industry, recreational activities, and wildlife survival are already prevalent.

Coastlines are dynamic environments and are, therefore, inherently unstable. They continually change shape and location in response to complex natural processes and human activities. Breaking waves carry sands along the shoreline, eroding sand from one area and depositing it on an adjacent beach. Storm waves carry sands from the beaches seaward, depositing them on offshore bars. Often these sands are transported back to the beach during periods of calm weather. Rivers also help shape the coastline by supplying additional sediment that builds deltas out into the open water. These changes occur daily and can result in significant long-term morphologic changes. Together these processes create an intricate system that continually attempts to achieve a dynamic balance. In addition, human activities such as dredging, urban or residential development, and recreational uses affect the coastlines by interrupting and altering, both directly and indirectly, the natural processes that shape them.

In the past, we have regarded wetlands to be vast wastelands and encouraged their destruction in an effort to convert them to other land uses. Wetlands and marshes are now widely recognized as important and fragile parts of the coastal environment. They are one of the world's most productive and valuable ecosystems. A few of the important functions that wetlands provide include: food and shelter for aquatic and terrestrial wildlife, storage for floodwater that may otherwise inundate developed areas, filtering nutrients and toxins from surface waters, and recreational opportunities. The preservation of wetlands is imperative if we are to assure the continued health and prosperity of our own existence.

Recognizing the need to maintain a balance between the development pressures of an increasing coastal population and the preservation of our natural resources, Congress has passed numerous acts and legislative mandates designed to preserve and protect our natural resources. With the passage of these various laws, Congress recognized and declared the need for a national interest in land use decisions that were previously viewed as local in nature. Congress acknowledged the necessity for a unified effort between federal, state, and local authorities to properly plan for and manage the projected increase in development along the coastlines. Accordingly, the State of Mississippi enacted the Coastal Wetlands Protection Law governing the management practices within the coastal zone.

EXISTING LEGISLATION

In the United States, tidal and navigable waters, the lands beneath, as well as the living resources inhabiting these waters are held in trust by the states for the benefit of the public. The states, therefore, are charged with the responsibility of managing our coastlines and assuring that our coastal resources are preserved and protected in the best interests of the general public. To this end, legislation specifically intended to manage our coastlines and associated natural resources has been passed and implemented at all government levels. A brief discussion of existing federal and state legislative mandates designed to effectively manage our coastal resources follows. It is suggested that the reader refer to the references at the end of the chapter for more detailed explanations of the individual laws.

Coastal Zone Management Act

In 1966, the Commission of Marine Science, Engineering, and Resources, known as the Stratton Commission, released a study on the conflict between the increasing development pressures and the need to preserve our coastal resources. In the final report, the Commission concluded that the states were in the best position to manage coastal resources but that federal funds should be provided to help the states alleviate the financial burden of administering a coastwide management program. Accordingly, Congress enacted the Coastal Zone Management Act (CZMA) in 1972. The purpose of the CZMA is to effectively manage the unique values of all coastal resources by encouraging states to develop land and water use plans for coastal protection.

The CZMA encouraged a program of cooperative planning between federal and state authorities. By developing federally approved coastal management programs, states are given the opportunity to participate in a joint federal-state initiative to protect and enhance their coastal lands and waters. A couple of incentives that the CZMA provided the states to encourage the development of their own coastal management plans were 1) federal financial and technical assistance and 2) promises that any federal activity conducted within a state's coastal zone must be consistent with that state's coastal management program. The federal consistency requirement is a strong element of the CZMA that encourages most states to participate in the program. The requirement that federal activities be consistent with a state's coastal management program is an important and powerful management tool for coastal states.

Prior to developing coastal management plans, the states needed to define the coastal zone boundary within their own state boundary. In brief, the CZMA defines a coastal zone as the coastal waters and the adjacent shorelands strongly influenced by each other and in proximity to the shorelines of the coastal states, including islands, transitional and intertidal areas, salt marshes, wetlands, and beaches. This definition of the coastal zone was purposefully vague, giving states a great deal of discretion in defining their own jurisdictional limits. This discretion is necessary because of the different types of areas that may exist within a single state's coastal zone, both developed and undeveloped. The only clear boundary defined in the CZMA for the coastal zone is the seaward limit of the state's ownership. The coastal zone within Mississippi includes all the land and water resources of Hancock, Harrison, and Jackson counties.

Coastal Zone Reauthorization Amendments of 1990

The CZMA came before the 101st Congress for reauthorization in 1990. Major changes to the CZMA were made with the passage of the Reauthorization Amendments in 1990. Among other changes, the amendments provide additional federal funding to state coastal management agencies, encourage state ocean resources planning, and institute a program that seeks to implement coastal land use management measures for controlling nonpoint-source pollution. In addition, the new, amended act strengthens the federal consistency requirement by establishing that any federal agency activity that takes place either in or outside the coastal zone is subject to consistency review if it affects (directly or indirectly) any natural resource, land use, or water use in the coastal zone.

Coastal Barrier Resources Act

The first environmental law that coordinated federal fiscal policy with environmental preservation was the Coastal Barrier Resources Act (CBRA) enacted in 1982. The purposes of the CBRA are to minimize danger to or loss of human life from poorly located coastal development, to end federal expenditures for such development, and to preserve the natural resources of the coastal barriers. The CBRA accomplishes these purposes by removing federal subsidies for flood insurance and by prohibiting new federal expenditures or financial assistance for construction or purchase of structures, roads, bridges, facilities, and related infrastructure within certain coastal barrier areas. The bottom line is that developers and/or property owners are responsible for the costs of development and the costs of the risks to that development. In this manner, the CBRA departs significantly from the more traditional forms of land use and environmental protection such as regulation, acquisition, and land planning.

The coastal barriers affected by the CBRA are those areas designated in the Coastal Barrier Resources System. Included in this system are undeveloped coastal barriers on the Atlantic and Gulf coasts that are designated on maps entitled "The Coastal Barrier Resources System." This system of barriers consists of 186 units totaling approximately 1080 km (670 mi.) of shoreline and 183334 hectares (452,834 acres) of undeveloped, unprotected coastal barriers from Maine to Texas. Areas located within the coastal zone of Mississippi that are protected by the CBRA include: Deer and Round Islands, Belle Fontaine Point and Graveline Bayou, Marsh Point, Heron Point, and portions of Cat Island.

Through the conservation of federal funds rather than the distribution of them, the Coastal Barrier Resources Act offers another measure for coastal protection should federal funding for the Coastal Zone Management Act diminish.

OTHER FEDERAL REGULATORY/PRESERVATION PROGRAMS

Clean Water Act

The Clean Water Act (CWA), which amended the 1972 amendments to the Federal Water Pollution Control Act, was passed by Congress in 1977. The objective of the CWA is to restore and maintain the chemical, biological, and physical integrity of the nation's inland and coastal waters. Although it does not authorize a comprehensive wetlands management program, Section 404 of the act provides the primary legislative authority behind federal efforts to control and manage wetlands use which, in turn, manages coastal erosion efforts. Section 404 of the CWA requires obtaining a permit from the U.S. Army Corps of Engineers (Corps) for all discharges of dredged or fill materials into navigable waters including wetlands. Also included in this permit requirement are activities resulting in the implementation of hard (structural) and soft (vegetative/fill) methods of shoreline erosion protection. The Corps must coordinate review of the permit applications with the Environmental Protection Agency and other federal agencies. Evaluation of the permits is accomplished through informal rule and policy-making that includes a public notice and comment period.

The permitting process is often confusing and time consuming. Before a permit is issued, the applicant must show that 1) there is no practicable alternative, 2) there will be no significant adverse impacts on aquatic resources, 3) all reasonable mitigation is employed, and 4) there will be no statutory violations by the proposed activity. In addition, section 401 of the CWA empowers the state to determine compliance of the proposed activity with state water quality standards. If a project does not meet state water quality standards and the applicant refuses to adapt to such standards, certification may be denied, resulting in full permit denial.

The Corps may also issue another type of permit called General Permits for discharges on a state, regional, or nationwide basis. General permits are issued for activities that cause minimal adverse environmental impact and have only minimal cumulative adverse impact on the environment. Obtaining a general permit for minor activities is a relatively simple and quick process.

The National Estuary Program

The National Estuary Program was established under amendments to the Clean Water Act and mandates the development of comprehensive conservation and management plans that recommend priority corrective actions to restore and maintain water quality in estuaries of national significance. This includes restoring and maintaining indigenous populations of fish and wildlife, as well as recreational opportunities.

MISSISSIPPI'S COASTAL MANAGEMENT PROGRAM

The Mississippi Coastal Program was approved by the Commission on Wildlife Conservation on August 22, 1980, and has been updated throughout its implementation. The State of Mississippi, acting as trustee for the public, is responsible for seeing that coastal resources are managed in the general public's best interest. The Mississippi Coastal Program deals primarily with the management of coastal resources such as air, water, marine life, historical and archaeological sites, and public trust wetlands. Unlike other states, Mississippi's Coastal Program does not regulate uses on private property in the entire coastal area, only in those areas directly affected by the ebb and flow of the tide. However, there are provisions in the law that allow regulation of indirect impacts if the impacts are considered detrimental to the coastal resources. While Mississippi has not yet enacted legislation specifically designed to manage coastal erosion, the Mississippi Coastal Program does provide measures that regulate what type of structures can be constructed and how a structure should be constructed along a shoreline and in coastal wetland areas.

The Mississippi Coastal Program is built around ten goals which guide decisions affecting the development of Mississippi's coastal resources. These goals include but are not limited to the following:

o Providing for reasonable industrial expansion in the coastal area and insuring the efficient utilization of waterfront industrial sites so that suitable sites are conserved for water-dependent industry.

o Favoring the preservation of the coastal wetlands and ecosystems, except where a specific alteration of coastal wetlands would serve a higher public interest in compliance with the purposes of the public trust in which the coastal wetlands are held.

o Encouraging the preservation of natural scenic qualities in the coastal area.

o Considering the national interest involved in planning for and in the siting of facilities in the coastal area.

These goals set clear objectives for the state to achieve when making decisions about the use of public resources including management of the shoreline. They promote decisions that balance development with the environment.

The agencies responsible for the implementation of the Coastal Program are the Bureau of Marine Resources (BMR), the Office of Pollution Control (OPC), the Office of Land and Water Resources, and the Department of Archives and History. Together these agencies manage coastal resources through direct regulation, policy coordination, special management area planning, and other management activities aimed at accomplishing the program goals. The BMR is the lead agency responsible for the overall administration of the coastal program and exercises the regulatory authority in the coastal area.

The Mississippi Coastal Program also provides for accurate, long-range assessment of shoreline erosion based on scientific research. The subjects where research will be concentrated include: wave refraction diagrams, long-term changes in the shoreline, wind transport, littoral transport rates, wave spectra, source materials for beach nourishment, and erosion by boat wakes. This research and assessment will aid local communities in planning efforts to mitigate damage. The program also calls for support for erosion control projects from the Corps of Engineers and from local governments. These projects include beach replenishment and dredged material disposal techniques. The BMR has established marine construction standards for shoreline erosion protection and shorefront access. Recommendations from these standards address protection methods which are best for each type of shoreline, definitions of these methods, explanation of the impacts of each type of erosion control option, and recommendation of specific designs for bulkheads, revetments, and vegetation.

THE PERMITTING PROCESS

Most construction, restoration, or mitigation activities planned in coastal wetlands or coastal waterbottoms must first obtain a permit from the Bureau of Marine Resources and the U. S. Army Corps of Engineers. This includes structures or activities associated with shoreline erosion control. There are two types of permits that regulate activities in coastal wetlands and waterbottoms. The nature of the activity determines the type of permit that must be obtained. General permits are issued for certain minor activities that result in minimal environmental impact and require application to the Bureau of Marine Resources only. Individual permits are issued for other larger, more complex projects and require securing permits from both the BMR and the Corps.

Whether a proposed activity requires a general or an individual permit is determined by the BMR after receipt of a joint permit application. If the proposed activity is authorized under a general permit, the permit, often with conditions, is issued to the applicant within a 30-day review period (water quality certification as required in Section 401 of the Clean Water Act has been made by the State of Mississippi for all general permits). However, if it is determined that the proposed activity requires an individual permit, the applicant must obtain a permit from both the BMR and the Corps, a process that may take up to six months.

Each individual permit requires public notice and an opportunity for public comment. When objections to a permit application are received by BMR during the public comment period, a public hearing will be held to address the concerns. A detailed description of the steps required to move an individual permit through the BMR can be found in the wetlands law and the Mississippi Coastal Program. Issued permits often include specific conditions relating the mitigation that must be conducted by the applicant as compensation for adverse impacts to the environment.

SUMMARY

Legislative mandates have been enacted at both the federal and state levels of government to assure the protection and preservation of our coastal resources. The majority of the legislation is focused on protecting sensitive environments while trying to balance the need for water-dependent development.

The Coastal Zone Management Act, enacted in 1972, encouraged a cooperative effort between federal and state authorities to help develop land and water use plans to more efficiently manage our coastal resources. The Clean Water Act of 1977 targeted efforts to restore and maintain the chemical, biological and physical integrity or our nation's inland and coastal waters. Section 404 of the Clean Water Act requires obtaining permits prior to placing dredge or fill material into wetlands or waters of the United States. The Coastal Barrier Resources Act of 1982 was the first law enacted that coordinated federal fiscal policy with environmental preservation. The Coastal Barrier Resources Act attempts to preserve the natural resources of the coastal barrier islands by prohibiting new federal funding for poorly located development that may pose a threat or loss to human life.

Mississippi's Coastal Management Program was adopted in 1980. The program is based upon ten goals that together attempt to maintain a balance between the protection and preservation of our coastal resources and the need to allow for reasonable industrial expansion in the coastal area. Several agencies are charged with the responsibility of implementing the coastal program. Together these agencies manage the coastal resources through direct regulation, policy coordination, land acquisition, special management area planning, and other management activities aimed at accomplishing the program goals.

Most activities proposed in wetlands or lands and waterbottoms below the mean high tide line require obtaining a permit from the U.S. Army Corps of Engineers and/or the Mississippi Bureau of Marine Resources. Minor activities below the mean high tide line that result in minimal environmental impact qualify for a general permit issued by the Mississippi Bureau of Marine Resources. Larger, more complex projects require obtaining an individual permit from both the U.S. Army Corps of Engineers and the Mississippi Bureau of Marine Resources. Processing time for a general permit is approximately 30 days or less. Individual permits, including the public comment period, can take up to 90 days for the state and six months for the Corps to process. Permits are denied for a small percentage of projects. More often, agreements are reached between the applicant and the regulatory agencies through modifications of the original project plans.

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SUMMARY AND CONCLUSIONS

Stephen M. Oivanki
Mississippi Office of Geology

The Belle Fontaine area and its sparkling white beaches are the only remaining natural reminder of what the Mississippi coast was like before the intrusion of man. While man has begun to alter this natural landscape, it continues as a relatively untouched vestige of the natural Mississippi shore when compared with the extensively modified shorelines on either side. Here, the forces of nature still sculpt the shoreline much as they have done for the past 10,000 years.

In the first paper in this volume, Klaus Meyer-Arendt documented the known history of the area since the arrival of civilization. Erosion and modification of the shoreline were not much of a problem during the early days of man's occupation, when large estates were common. Hurricane damage to structures onshore was common, but rebuilding was simple, since the structures could be relocated farther away from the shoreline and out of immediate danger. As population density increased, the estates became small lots, each individually owned and cherished, and the retreat of the shoreline relative to the many homes on these lots became immediately apparent. The lack of mobility of the structures, confined to their small lots, created a concern for what had always been a continuing natural process.

As erosion forced the shoreline closer to homes, many homeowners began to fortify their lots against the continuous encroachment of the sea. Bulkheads and riprap were used to fix the position of the shoreline and stop the sacrifice of solid ground to feed the mobile sediment stream along the shore. While this temporarily eased the danger to their homes, it created a shortage of sediment in the longshore drift system, which continued to move the remaining sediment along the beach to the west. Continuation of this practice of armoring the shoreline will eventually cut off all sediment contributions to the beach, and the base of the bulkheads and riprap will be undermined by the surf.

Rather than force the shoreline to conform to a rigid, fixed, and engineered set of parameters, this report has shown that by working with natural forces instead of against them, man can preserve the natural beauty of the landscape and still utilize its resources. If allowed to evolve in the same manner as the Harrison County shoreline, with seawalls and commercial development, this shore would lose all of the qualities which drew human inhabitants to it in the first place.

The geologic foundation of Belle Fontaine has been thoroughly researched in the paper by Oivanki and Otvos, and it provides some clues as to the methods which must be employed to maintain development here in harmony with natural processes. The cliff area in the Central Belle Fontaine portion of this coast is an ancient sand deposit which cannot be replaced by any mechanical means now economically feasible. Therefore, it must be preserved in its present state and location as long as homes are situated there. The beaches in the East Belle Fontaine and West Belle Fontaine areas, however, depend on the destruction of the cliffs in Central Belle Fontaine to provide sand necessary for their continued existence. It is these conflicting needs for diminishing sand resources which this report addresses.

Up to now, the control of erosion at Belle Fontaine has been the responsibility of each individually threatened landowner. The result has been a scattering of bulkheads, riprap, and small groins all along the Belle Fontaine shoreline. The individual responsibility for erosion control on private property still exists; however, a unified approach to erosion control on an area-wide basis with a pooling of individual resources can accomplish the task more effectively. The results of individual landowner erosion control efforts are shown by the Shoreline Evolution Model (SEM) in Joseph Suhayda's paper to have only limited short-term success and a generally negative impact on neighboring shorelines. A combined nourishment and breakwater approach on an area-wide basis, on the other hand, can effectively halt shoreline retreat, but only if all landowners participate collectively. The SEM was developed to gauge the probability of success of such an effort, and to help estimate the individual prorated annual cost of maintaining the system. Considering the cost of "beachfront" property at Belle Fontaine, the calculated annual cost of this approach is quite reasonable.

The SEM developed by Suhayda is founded on sound engineering principles, but there are still some unknown factors which must be resolved before the model can be acclaimed as a success. The model assumes 100% conservation of sand in the longshore drift system, and it then predicts the movement of this sand along the shoreline based on predicted weather conditions. There is no known way to predict how much, if any, of the sand on the beach face is lost offshore and taken out of the system. The muddy bottom sediments offshore of Belle Fontaine do contain sand, occasionally in significant amounts. The wave fields generated by the model are based on a relatively short wavemeter observation period extrapolated over several years. Actual long-term conditions may differ from those predicted by the model.

In order to refine the model and define some of these unknown parameters, the model must be tested under actual conditions. Such a test is underway at this writing (1994). The U. S. Environmental Protection Agency through the Gulf of Mexico Program awarded a grant in 1993 to Jackson County to test the SEM with a sand nourishment project. The grant covers the cost of purchasing sand from an inland sand pit for placement on the beach at Belle

Fontaine. Jackson County provides matching funding to transport and distribute the sand on the beach. The Office of Geology Coastal Section monitors the movement of this new sand as it responds to actual weather conditions. Twenty-five thousand cubic yards of sand are being placed on the beach at Segments 15 and 16, and 10,000 cubic yards at Segment 20. The sand is almost identical in grain size to that now present on the beach, so it should respond well to the model predictions. Any variations from predicted results are being noted and incorporated into the model.

Once the model has been proven under actual conditions, it is hoped that the homeowners association at Belle Fontaine can generate the necessary support to begin a unified area-wide implementation of the erosion control measures recommended by this report. The successful model can also be used as supporting evidence for future permit requests to implement the erosion control system.

The history of coastal management in Mississippi has been outlined by Cathy Hollomon in her paper. She also listed steps which must be taken and permits which must be acquired to implement any shoreline modifications at Belle Fontaine. As the test project nourishment of the beach at Belle Fontaine is the first on a private beach in Mississippi since the inception of state and federal coastal management practices, it will set a precedent for future "soft-structure" erosion control efforts on private rather than public property. Since the area being filled by the nourishment is state-owned water bottoms, there can be no private claim to ownership of the artificially created land area.

Since the first occupation of the Belle Fontaine area by the Indian tribes, through the discovery by d'Iberville and Baudreaux, much has been written about the appreciation of the natural beauty of the place. Beauty, however, is fleeting. The shoreline at Belle Fontaine began the process of erosion and recycling of the sediment as soon as it was formed. For man to live in harmony with natural forces at Belle Fontaine he must learn to adapt and augment those forces rather than struggle against them. This report has shown how that might be accomplished in an economically feasible manner with a reasonable chance for success. If the strategy to control erosion here at Belle Fontaine is successful, then the same strategy might be used elsewhere along the Gulf of Mexico shoreline where similar problems exist.