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Preliminary Assessment of Nonfuel Minerals on the Texas Continental Shelf

by

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Table of Contents

Figures

Tables

Introduction

As part of a passive continental margin with a long depositional history, the Texas continental shelf has been richly endowed with mineral resources. Exploitation of oil and gas resources on the shelf extends back decades and the economic value of these deposits has long been recognized. The depositional setting that made the Texas offshore so rich in hydrocarbons has left it barren of exotic nonfuel minerals (polymetallic sulfides and ferromanganese cobalt crusts) such as those found in active tectonic settings near Hawaii and at the Juan de Fuca Ridge along the Pacific Northwest. Nonetheless, there are significant accumulations of potentially economic nonfuel minerals in the Texas Exclusive Economic Zone (EEZ). The most promising of these are sand and gravel deposited on the continental shelf during the sea-level fluctuations of the late Pleistocene and Holocene. Requirements for sand and gravel created by the burgeoning Texas coastal population and the need for compatible sands for beach nourishment projects such as those contemplated for rapidly eroding beaches at south Padre Island, the Brazos delta, and Galveston Island combined with the depletion of nearby onshore sand and gravel resources could make shelf mining operations economically feasible in the future. Before economic feasibility can be determined, however, the location, size, and character of potentially economic shelf deposits must be assessed.

Purpose of study

The primary objective of this study was to prepare a preliminary assessment of nonfuel mineral resources of the EEZ (fig. 1) from the gulf shoreline to near the shelf edge (approximately 200 m water depth). Several steps are required to satisfy this objective, including (1) inventory available geological information, both published (a bibliography) and unpublished (high-resolution seismic surveys, piston cores, vibracores, seafloor samples, and foundation borings) ; (2) locate potentially economic offshore deposits (prospects) using available data; (3) characterize these prospects as accurately as possible

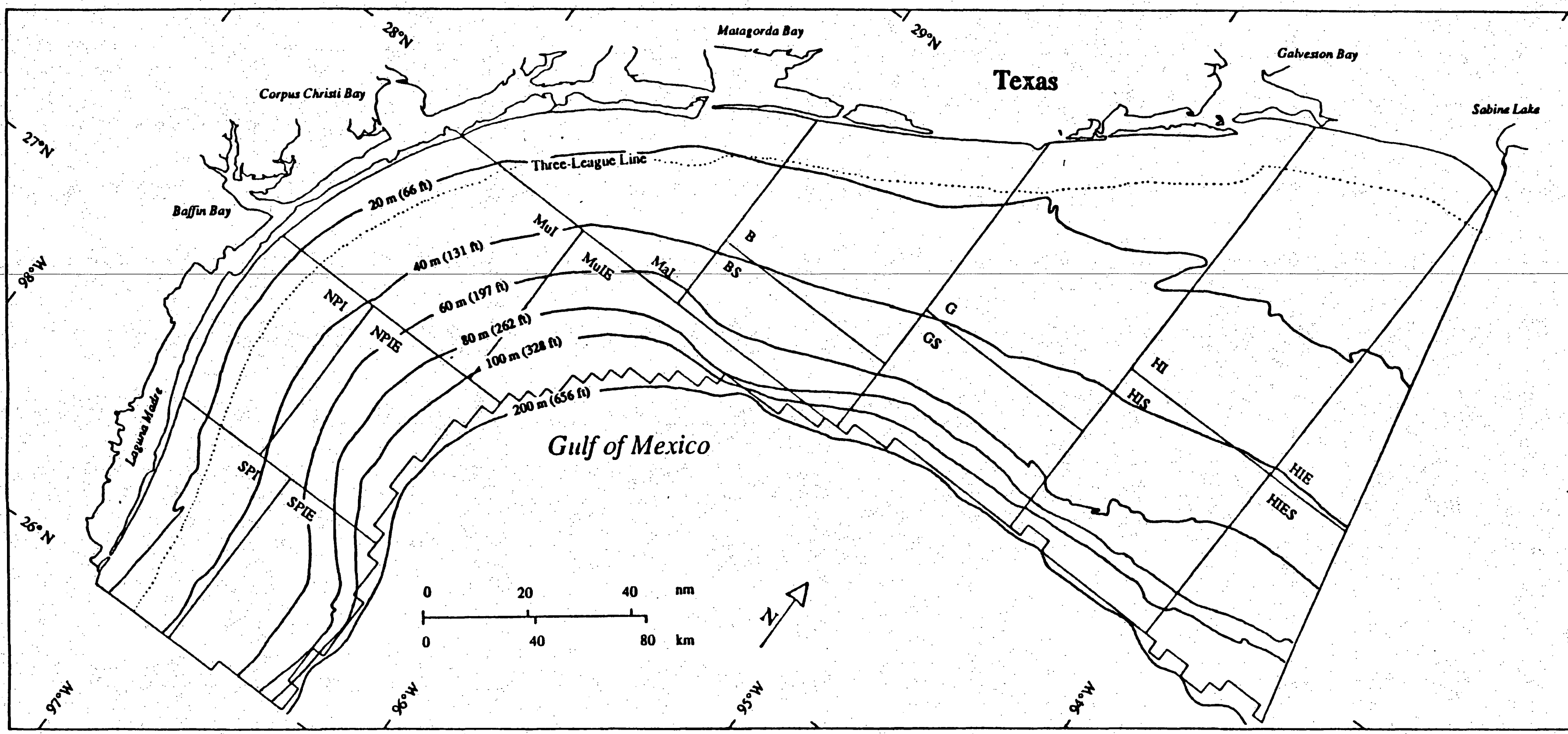

Figure 1. Bathymetry and lease areas of the Texas continental shelf. HI: High Island; HIE: High Island East Addition; HIS: High Island South Addition; HIES: High Island East Addition South Extension; G: Galveston; GS: Galveston South Addition; B: Brazos; BS: Brazos South Addition; MaI: Matagorda Island; MuI: Mustang Island; MuIE: Mustang Island East Addition; NPI: North Padre Island; NPIE: North Padre Island East Addition; SPI: South Padre Island; SPIE: South Padre Island East Addition.

with existing data, including areal extent, thickness, and sediment composition and texture; and (4) determine whether exploitation of the prospect is economically feasible if sufficient data exist; if data are insufficient, recommend a research program that would help determine whether poorly-known prospects are economic.

Geological Framework

Knowledge of the geology of the Texas continental shelf is helpful in predicting and understanding the distribution of nonfuel minerals. Currently, very little deposition of economically important minerals takes place on the shelf beyond the nearshore zone. However, there are significant concentrations of sand and gravel that occur far offshore. These relict deposits owe their placement to large-scale fluctuations in sea level during the Quaternary (fig. 2); most important for this study are the sea-level lowstand during last glaciation (late Wisconsinan) and the subsequent sea-level rise as the glaciation ended (late Wisconsinan and early to middle Holocene).

Late Wisconsinan Lowstand

As sea level was falling during the onset of the late Wisconsinan glaciation, shelf-phase deltas prograded across the Texas continental shelf leaving relatively thin and discontinuous deltaic deposits. At the shelf edge, however, these deltas encountered steeper gradients that allowed them to reach thicknesses of 90 m or more (Suter and Berryhill 1985). These shelf-margin deltas are largely composed of sand and mud, with sand more abundant in proximal, shallow-water areas such as near distributary channels and at distributary mouth bars. Four major shelf-margin deltaic complexes have been located offshore from Texas (Suter and Berryhill 1985); though they now occur in water that is too deep (more than 90 m) for the deposits to be economic, they represent substantial sand resources that may someday be exploited.

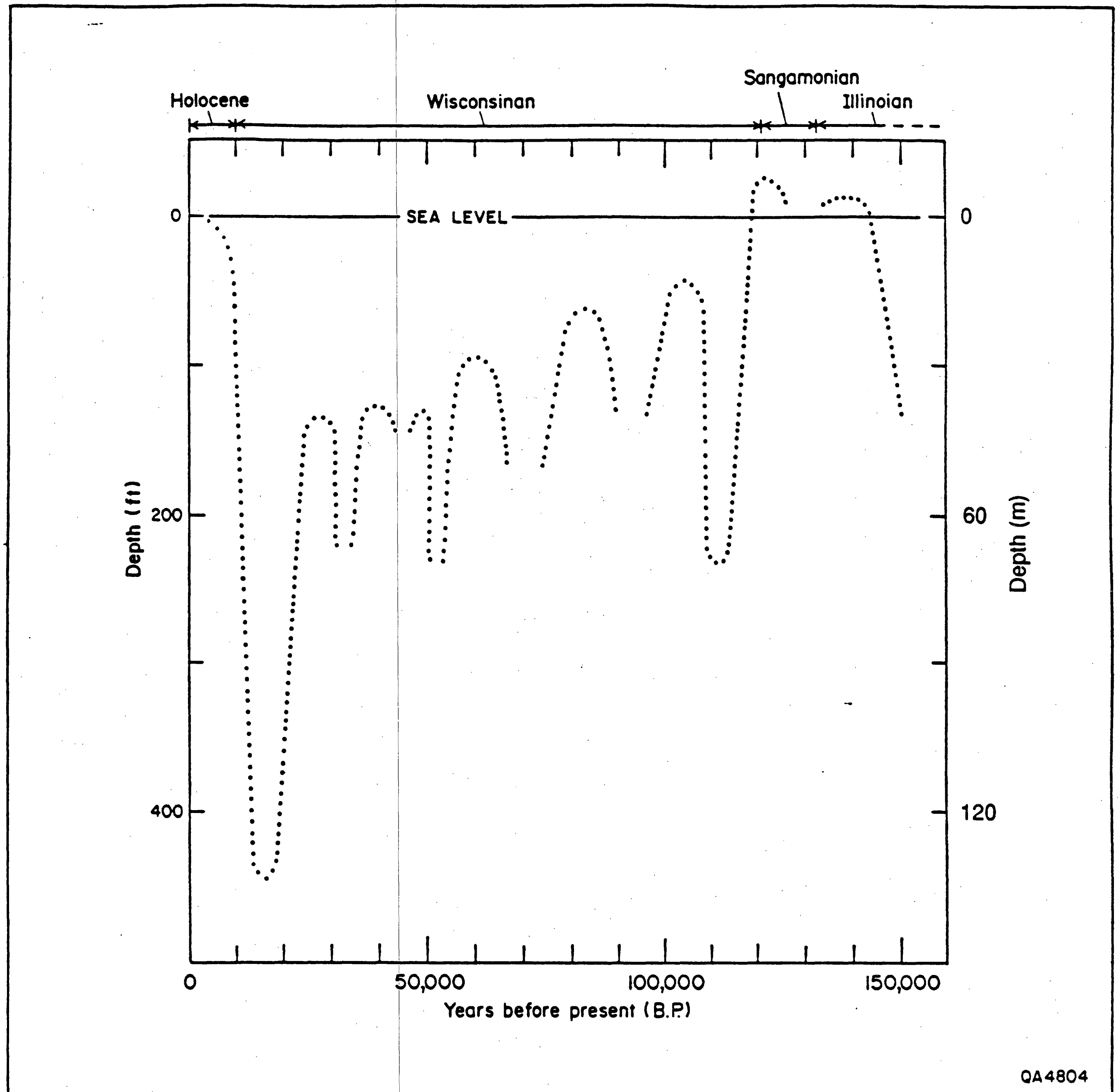

Figure 2. Late Pleistocene sea-level curve. Adapted from Moore (1982).

Also during the late Wisconsinan lowstand, streams associated with the shelf-margin deltas coursed across the Texas continental shelf. As they do onshore today, these streams transported and deposited large quantities of sand and gravel on the shelf. Similar deposits in the Texas coastal zone are commonly exploited for use in the construction industry.

Late Wisconsinan and Holocene Sea-Level Rise

As sea level rose at the end of the last glaciation, thin transgressive deposits composed of reworked deltaic sands capped the shelf margin deltas, and deltaic, estuarine, and finally marine deposits filled the late Wisconsinan streamcourses. These deposits covered fluvial sands and gravels that became the basal postglacial deposits. During minor stillstands and reversals of sea-level rise, waves and longshore currents redistributed relict sediment and sediment brought to the coast by rivers to produce elongate, shore-parallel sandy deposits that were subsequently submerged and partly reworked when sea level began rising again. These shore-parallel sands represent a potentially compatible material for nourishment of Texas beaches because they were formed from sediment similar to beach sand and because they were transported by processes similar to those acting on beaches today.

Existing Information

Several types of data have been collected that can be used to directly or indirectly determine the distribution, texture, and composition of surface and shallowly-buried shelf sediments. These data, including surface samples, pipe and box cores, foundation borings, and high-resolution seismic lines, each have advantages and disadvantages in terms of assessing nonfuel mineral resources. More surface samples have been taken from the Texas continental shelf than any other type of sediment sample, but penetration is only a few centimeters and little information on the vertical extent of potential nonfuel mineral deposits can be gained from these samples. Pipe cores achieve slightly greater penetration (up to a few meters), but are not as widespread as grab samples. Foundation borings, commissioned by petroleum companies in preparation for drilling or production activities, are perhaps best suited for determinations of vertical sediment distribution because they extend 100 m or more into the subsurface. However, uneven distribution across the Texas continental shelf and questionable visual descriptions of sediment reduce their usefulness. High-resolution seismic profiles are most useful in locating structural elements and constructing three-dimensional models of depositional systems, but they provide only indirect information on sediment texture.

Surface Samples

Investigations of surface sediment distribution along the northwest Gulf of Mexico (Texas and western Louisiana continental shelves) during Project 51 of the American Petroleum Institute (API) included collection of about 1,350 dredge samples and short gravity cores (Curray 1960). About two thirds of these samples were obtained by Scripps Institution of Oceanography in Texas offshore waters out to depths of 200 m (fig. 1). Analysis of these shallow sediments included grain size determinations (Curray 1960) and the heavy mineral suite (van Andel 1960; van Andel and Poole 1960). Textural data from cores and dredge samples were combined to produce a sediment distribution map for the Texas and Louisiana continental shelves.

In the mid-1970's, the United States Geological Survey (U.S.G.S.) completed a study of the south Texas outer continental shelf, consisting of the South Padre Island, North Padre Island, Mustang Island, and Matagorda Island areas (Berryhill 1976; Berryhill et al. 1976). During this study, many types of geological data were collected from near the State-Federal ownership boundary out to a depth of about 200 m, including surface samples, shallow cores, and seismic reflection profiles. Surface samples were taken at 264 stations along 27 dip-oriented transects; most of these samples were analyzed for grain size distribution and heavy mineral content.

Surface samples and seismic profiles on State-owned submerged lands (to 16 km offshore) were collected and analyzed by the Bureau of Economic Geology in the mid- to late 1970's (McGowen and Morton 1979). About 3,500 surface samples were collected 1.6 km apart on the Texas continental shelf; these samples were analyzed for grain-size distribution and for several geochemical constituents (White et al. 1983, 1985a, 1985b, 1985c, 1986a, 1986b, 1987).

There have been many other studies of surface sediment distribution, but these studies, such as the Sabine Bank area (Nelson and Bray 1970) and offshore from the Brazos River (Nienaber 1963) cover relatively small areas. Adequate data exist for accurate regional characterizations of sediment texture only for the south Texas outer continental shelf and the State-owned inner continental shelf.

Shallow Cores

Pipe cores, piston cores, box cores, and vibracores are characterized by relatively shallow penetration into the subsurface, ranging from a few centimeters to a few meters. They are more useful than surface samples for determining vertical dimensions of potentially economic deposits, but few systematic studies of the continental shelf have been completed. Most notable among the completed studies are one covering the entire Texas continental shelf (Curray 1960; see previous section), another covering the south Texas outer continental shelf (Berryhill et al. 1976), and a third focusing on Sabine and Heald Banks in the High Island area (Nelson and Bray 1970).

As a part of the South Texas Outer Continental Shelf study, the U.S.G.S. collected pipe cores at 90 stations and box cores at 74 stations (fig. 3) within the South Padre Island, North Padre Island, Mustang Island, and Matagorda Island areas (Berryhill et al. 1976). Box cores penetrated about 40 cm of sediment, whereas pipe cores penetrated from less

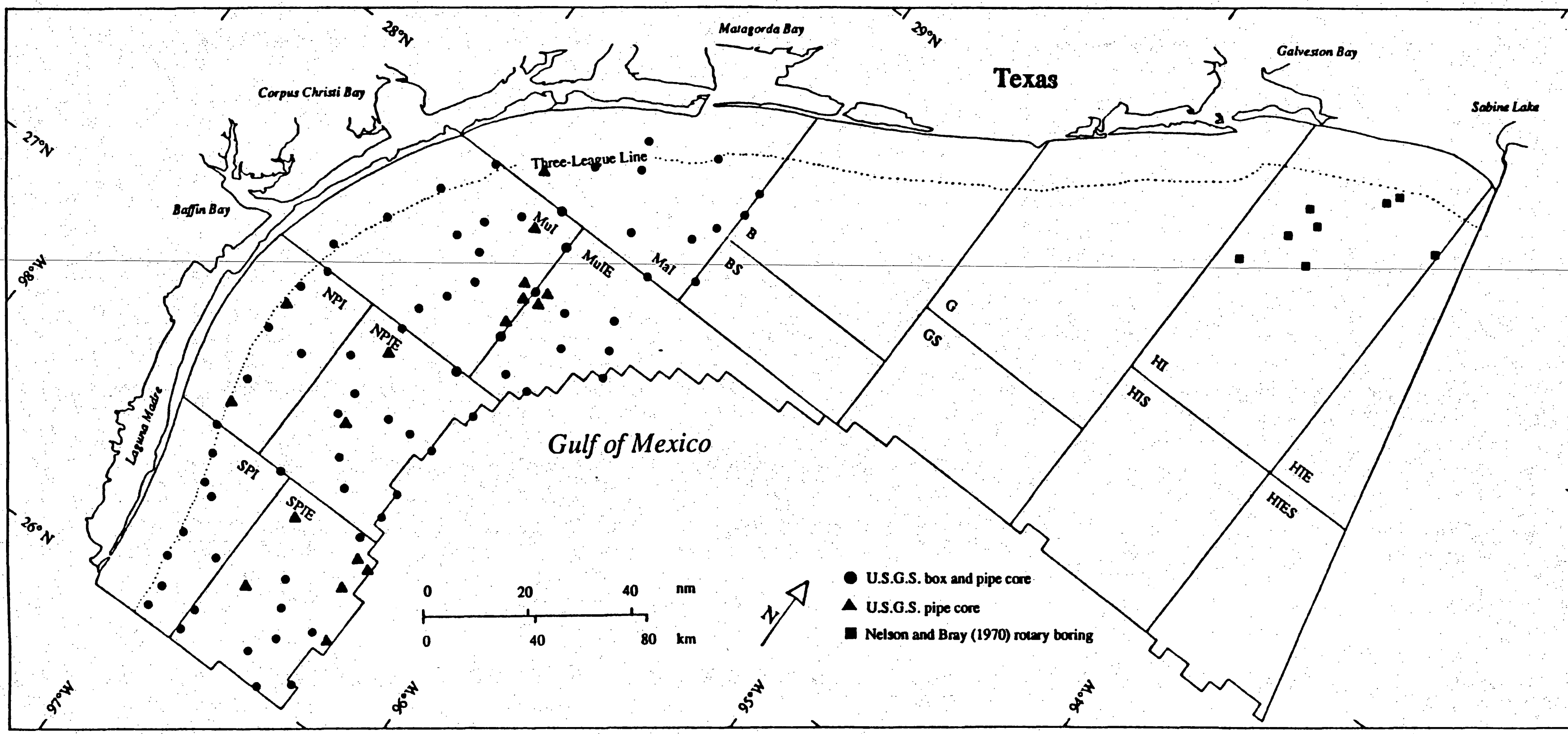

Figure 3. Location of short cores on the Texas continental shelf.

than 30 cm to more than 2 m. Textural analyses were not done on samples from these cores, but sand lenses and other sedimentary features were noted.

In the Sabine and Heald Bank area, Nelson and Bray (1970) collected numerous short gravity cores as well as 12 rotary cores (8 of which were taken in the High Island area of the Texas continental shelf). The rotary cores penetrated 1 to 25 m below the surface, with sediment recovery ranging from less than 25 percent to 100 percent. Textural analyses were completed for 750 surface samples; textural characteristics of cored sediments were estimated from drilling characteristics and recovered sediment. In the same general area, 18 vibracores were collected in a single lease block during a study of potential archeological resources (Pearson et al. 1986). These cores achieved penetrations ranging from 5 to 12 m, with recovered lengths ranging from 3 to 6 m. Many analyses, including grain size and geochemistry, were conducted on sediment from these cores.

Foundation Borings

Foundation borings are perhaps the most useful tool for documenting the vertical distribution of near-surface sediment on the Texas shelf. These borings, commonly obtained by engineering firms under contract to oil companies preparing to drill offshore wells or build production platforms, may extend more than 100 m below the seafloor. A computerized database created at the Bureau of Economic Geology contains 410 borings from the Texas continental shelf (fig. 4 and appendix). Reports of these borings were obtained from the Houston offices of McClelland Engineers and PSI, two of the major engineering firms operating on the Texas continental shelf. The reports include visual descriptions, textural analyses, and various engineering properties of the sediments encountered in the borings. Attributes of the borings entered in the database include location, water depth, length of boring, visual description of sediments encountered, and depths of boundaries between sedimentary types. Water depths for borings in the database range from nearshore borings in 5 m of water to shelf-margin borings in 132 m of water.

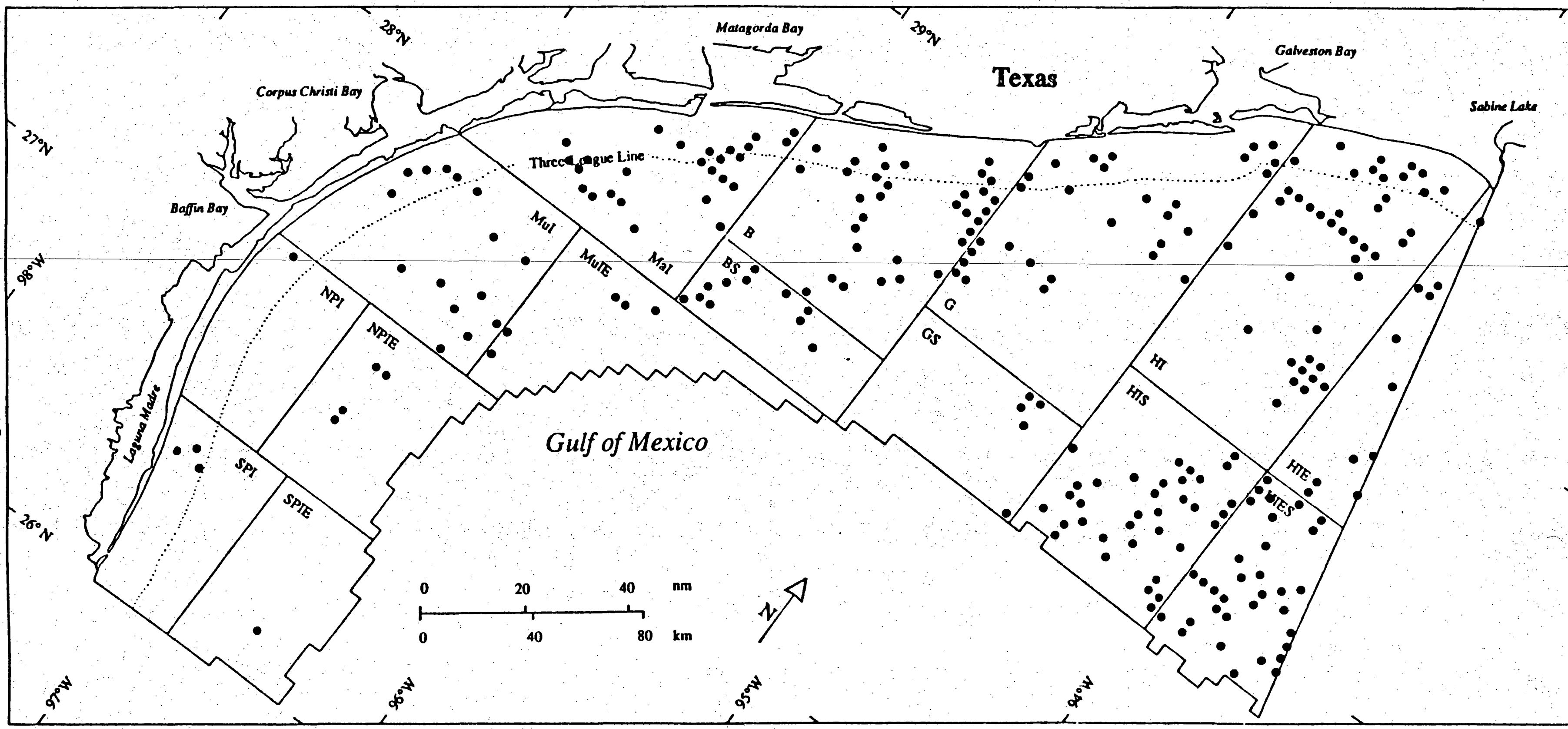

Figure 4. Location of foundation borings on the Texas continental shelf.

Subsurface penetration ranges from 5 to 170 m, with most borings extending at least 30 m below the seafloor.

Drawbacks of the foundation borings are (1) uneven geographic distribution and (2) uncertainty about the accuracy of the visual sediment descriptions. Although foundation borings are located in every lease area on the Texas continental shelf, boring distribution is controlled by hydrocarbon leasing and some lease areas have more borings than others. The geographic distribution is most dense in the High Island, Matagorda, Brazos, and Galveston areas; foundation borings are sparse in the North and South Padre Island areas (fig. 4). Because sediment descriptions of the borings are commonly confirmed by textural analyses, these records should be adequate for locating significant sand and gravel deposits in the subsurface, but not for evaluating resource quality.

Geophysical Data

There are several regional geophysical surveys of the Texas continental shelf that help locate potential nonfuel mineral resources. These surveys consist of high-resolution seismic reflection data acquired by various State and Federal agencies and by oil companies. The surveys are useful because features such as buried stream channels, filled river valleys, and drowned shelf-margin deltas can be located with this information. Although lithologic information is not obtained directly from seismic data, knowledge of the types of sediment characteristic of depositional systems located by seismic profiles gives strong indirect information about lithology.

Approximately 6,500 km of high-resolution seismic data was collected on the Texas inner continental shelf (nearshore to 16 km offshore) in a cooperative effort between the U.S.G.S. and the Bureau of Economic Geology in the mid-1970's (McGowen and Morton 1979). The seismic data collected during this project consisted of 232 dip lines spaced 2.4 km apart and tied together by 2 strike lines spaced 6.5 km apart. The primary energy source was an 800 joule minisparker; some 3.5 khz subbottom profiler data were also collected. The U.S.G.S. also collected more than 9,200 km of high-resolution seismic data on the south Texas outer continental shelf between 1974 and 1976 (fig. 5). Most of this additional seismic coverage (8,900 km) was completed using either a 1,000 to 1,500 joule Acoustipulse source or a 10,000 joule sparker source (Berryhill et al. 1976).

Regional high-resolution coverage of the Texas shelf edge and upper slope (fig. 5) was completed by the U.S.G.S. as part of a gulfwide continental slope study. Using a 400 to 1,000 joule minisparker source and a subbottom profiler, Texas shelf edge and slope (200 to 1,000 m water depth) coverage was obtained on an approximate 9-km grid (Berryhill 1987a; Suter and Berryhill 1985).

Although most of the seismic coverage was acquired for the Louisiana shelf, two high-resolution seismic surveys commissioned by the U.S.G.S. in 1979 and 1980 covered part of the Texas continental shelf (fig. 5). In 1979, a 400 joule sparker source and a 7 khz subbottom profiler were used to collect shallow subsurface information from the mid shelf to the upper slope in the High Island East Addition South Extension (Berryhill 1984b); in 1980, a similar system was used to extend the coverage from the mid-shelf to inner shelf in the High Island East area (Berryhill 1984a). North-south and east-west lines were completed on a 5.5-km grid over this area.

Regional high-resolution seismic coverage over most of the Galveston Area South Addition was conducted by Texaco in 1972 and 1973 (fig. 5). This survey consisted of 19 north-south and 5 east-west lines covering an area of about 65 by 65 km (Lewis 1984). Unlike other regional studies listed above that used sparker or Acoustipulse energy sources, this survey used a 650 cm^3 airgun source.

Many other geophysical studies have been completed on the Texas continental shelf, including side scan sonar, magnetometer surveys, gravimetric surveys, and a multitude of other high-resolution seismic surveys. Most of these other seismic surveys, such as those required for lease block geohazard analysis, are of little practical use for regional characterizations of potential nonfuel mineral resources because of the effort

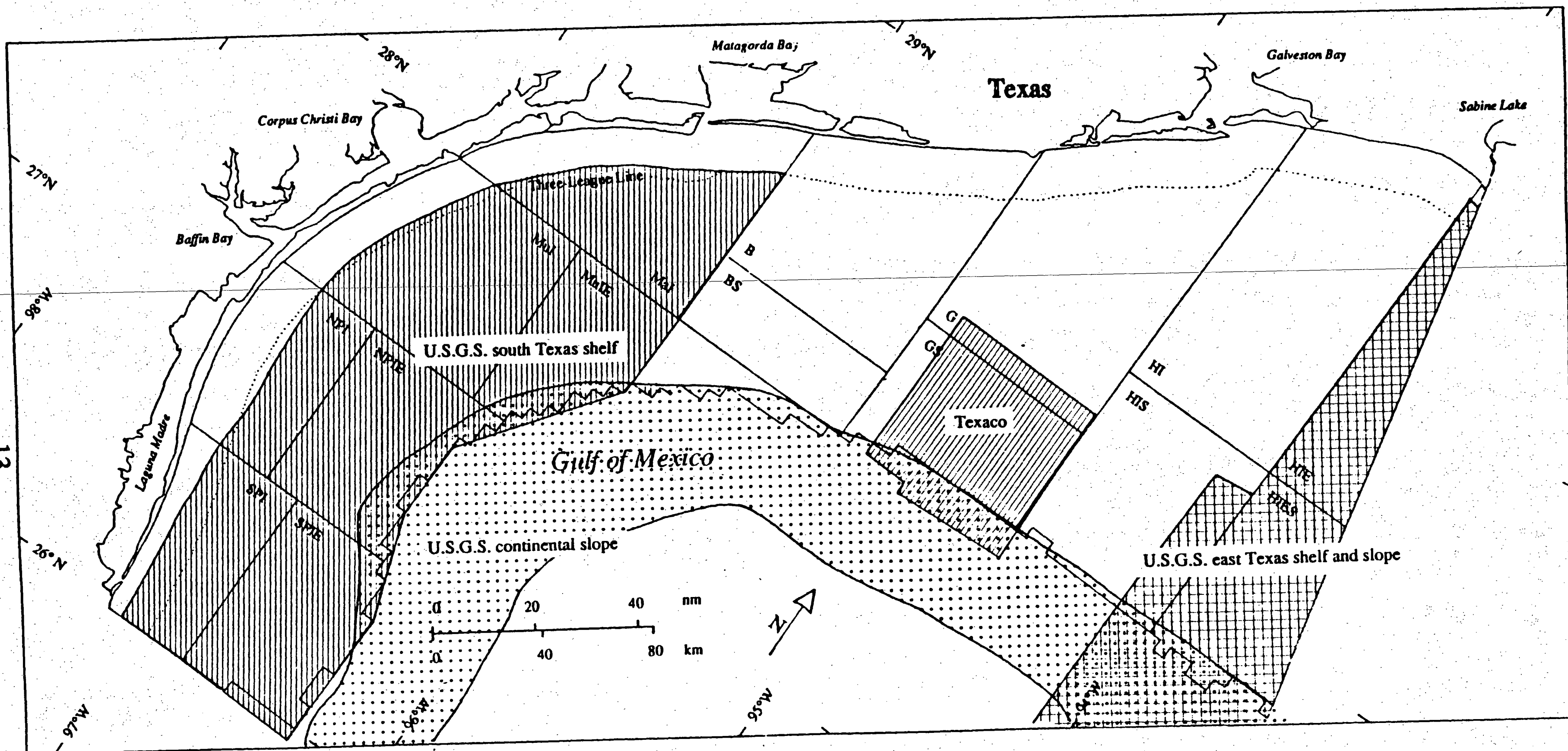

Figure 5. Location of high-resolution seismic surveys on the Texas continental shelf and slope.

required to obtain them and their limited geographic extent. However, they could be extremely useful once promising sites have been located.

Nonfuel Mineral Prospects

Several potentially economic nonfuel mineral deposits have been located in previous investigations and through analysis of existing offshore data. Because of the sparseness of the data, the extent and quality of the deposits are generally not well known. The potentially economic deposits can be subdivided by type and potential use (table 1). These types include shore-parallel deposits composed of sand and some shell fragments (shoreline-like deposits), thick and lobate shelf-margin deposits composed of sand and mud (shelf-margin deltas), predominantly shore-normal deposits composed of sand and, in places, gravel (ancient fluvial systems), and heavy mineral concentrations on the south Texas shelf (transgressive sheet sands). Possible economic uses for these deposits include reconstruction of eroding beaches (beach nourishment), landfill, roadbase, and in the production of various concrete products. Potentially economic concentrations of heavy minerals offshore from the Rio Grande have several industrial uses.

Shore-Parallel Sands

Many shore-parallel sandy deposits on the Texas continental shelf (fig. 6) are interpreted as shoreline or nearshore sands that mark late Pleistocene or early Holocene positions of sea level. These sandy deposits are likely to be suitable for nourishment of eroding Texas beaches because they formed from processes, conditions, and sediments similar to those forming Texas' present-day beaches. As such, they are probably relatively mature sediments composed mainly of quartz.

Heald and Sabine Banks, interpreted as submerged shoreline and shallow marine sands, are located 40 to 50 km offshore in the High Island area of the upper Texas coast in water depths of 6 to 17 m (fig. 7). These elongate surface sand deposits roughly parallel

Table 1. Attributes of prospect types on the Texas continental shelf. BN = beach nourishment; Ind = industrial uses; Con = construction.

Prospect Type	Resource	Best Example	Time of Formation	Suitable for BN	Suitable for Ind	Suitable for Con	Comments
Shore-parallel sands	sand	Sabine and Heald Banks	post-Wisconsinan	yes	yes	yes	May contain shell
Streamcourses	sand, gravel	Mustang Island Area	late Wisconsinan to early Holocene	no	yes	yes	May be covered by several meters of overburden
Shelf-margin deltas	sand	Rio Grande delta	Wisconsinan	no	?	?	May contain silt and clay
Transgressive sands	sand, heavy minerals	South Padre Island Area	post-Wisconsinan	yes	yes	yes	May contain shell; Rio Grande area promising

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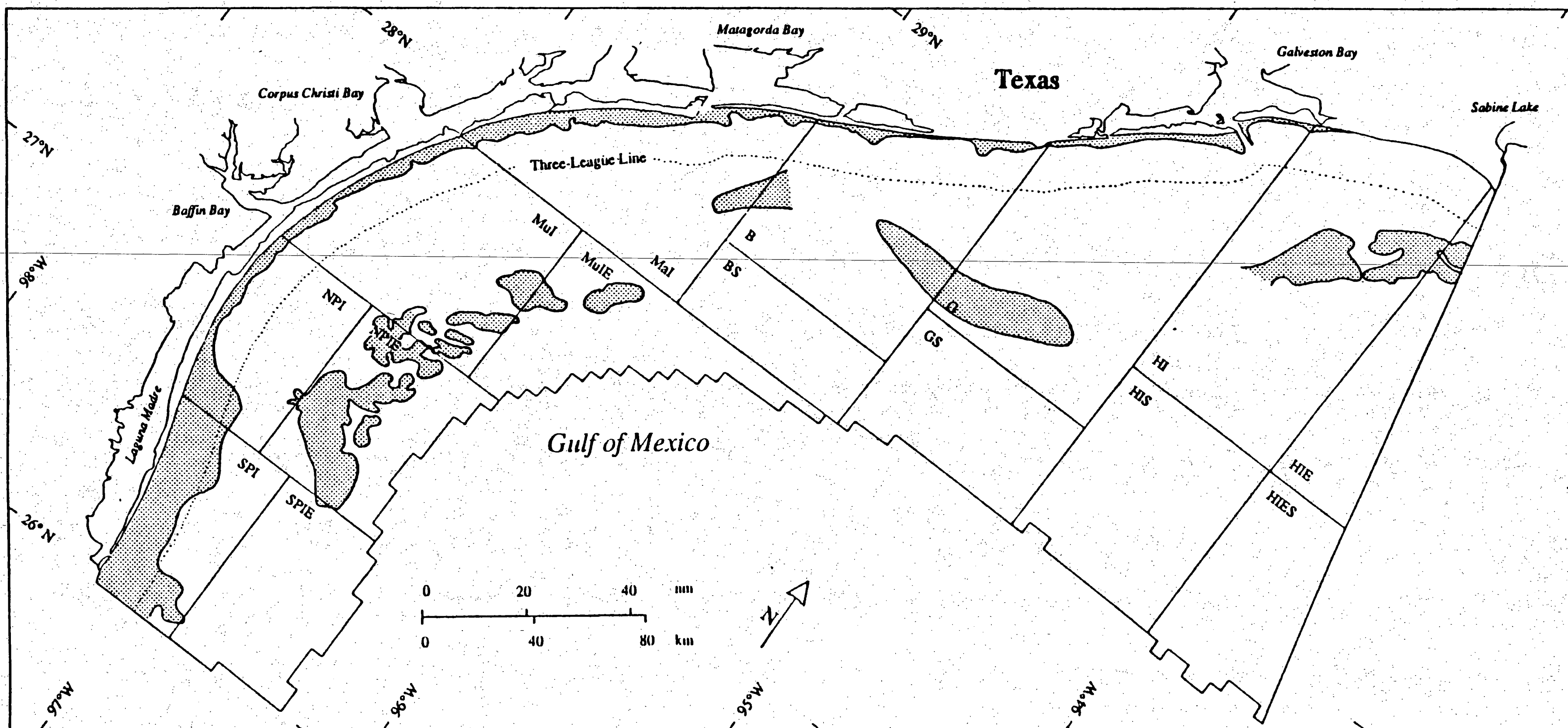

Figure 6. Distribution of shore-parallel sands at the surface or shallowly buried on the Texas continental shelf. Compiled from Grady (1970); Berryhill et al. (1976); McGowen and Morton (1979); and Nelson and Bray (1970).

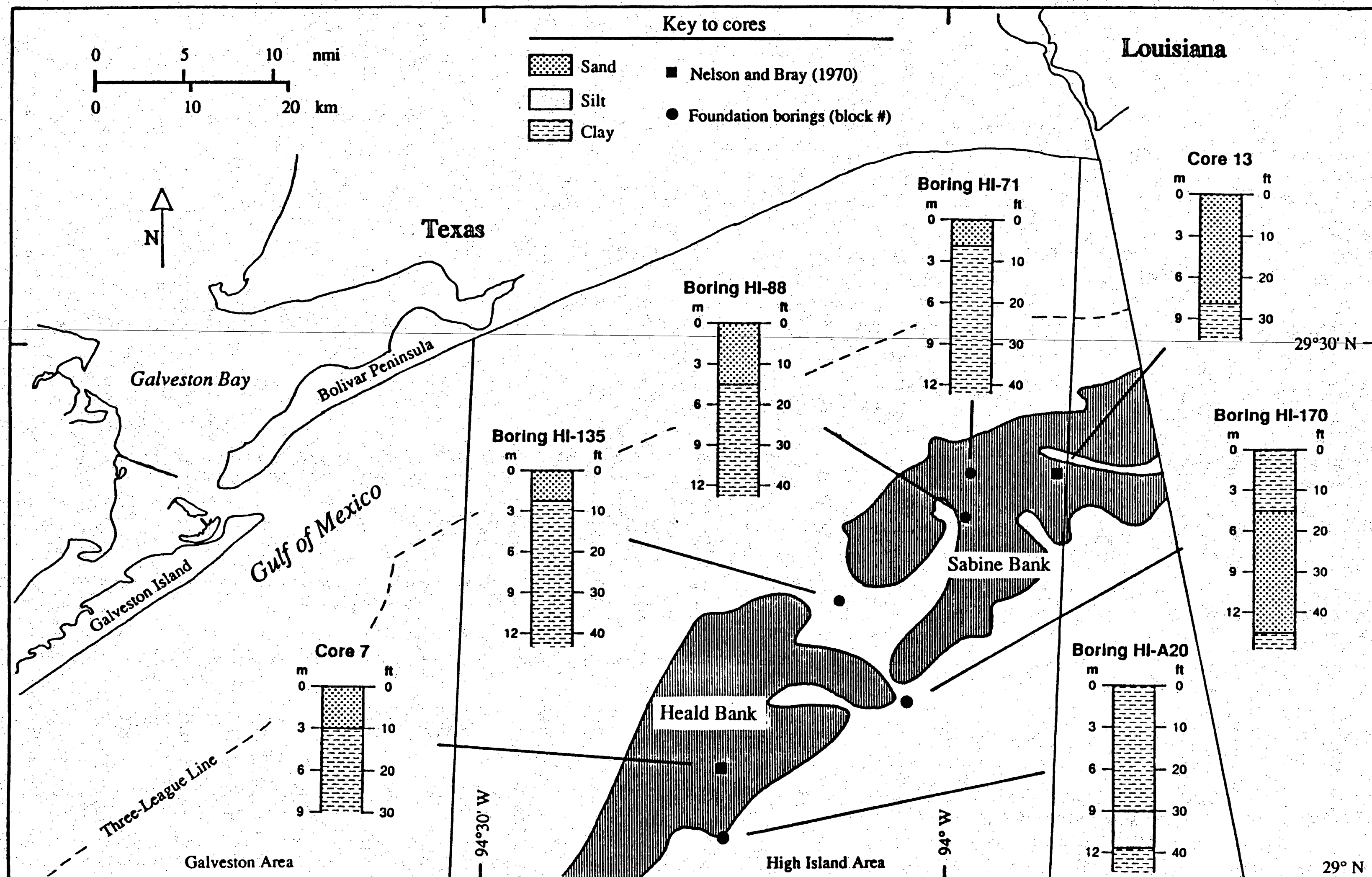

Figure 7. Sabine and Heald Banks, eastern Texas shelf. Location and areal extent of sandy deposits from Nelson and Bray (1970); vertical distribution of sediment from two cores published by Nelson and Bray (1970) and five foundation borings.

the present shoreline; Sabine Bank occurs east of Heald Bank and extends into offshore Louisiana. Much of what is known about the geology of the banks is based on short cores, grab samples, and a sonoprobe survey (Nelson and Bray 1970). In addition, the eastern part of Sabine Bank falls within an area studied by Berryhill et al. (1984) using high-resolution seismic data; the area north of Sabine Bank was studied by Pearson et al. (1986) using seismic data and vibracores. Nine soil foundation borings also penetrate the area. From these data, it is known that sands associated with these banks cover more than 1,000 km^2 of the sea floor and range up to 8 m thick. Cores and seismic records indicate an average thickness of about 3 m. Multiplying these values yields an estimated volume of more than 3 billion m^3 of sediment within Heald and Sabine Banks. Grain size analyses performed by Nelson and Bray (1970) indicate the deposit is composed dominantly of fine to very fine sand, similar to most Texas beach sand (Bullard 1942).

Shelf-Margin Deltas

Deltas constructed at the outer shelf margin and upper continental slope during late Pleistocene lowstands of sea level contain significant accumulations of sand. Four major shelf-margin deltas have been located at the edge of the Texas shelf (fig. 8), from the ancestral Rio Grande delta to the south to deltas 'A', 'B', and 'C' to the east (Berryhill 1987b; Berryhill and Suter 1987; Morton and Price 1987; Suter and Berryhill 1985; Lewis 1984). Although these deltas each cover hundreds of square kilometers, they each also contain abundant silt and clay. Greatest concentrations of sand are likely to be found near the top of the deposits and also in the more shallow proximal deltaic areas. All of the deltas are too distant from potential markets to be economic at the present time.

Rio Grande Delta

The Rio Grande delta, located in the South Padre Island East Addition area in water depths of 45 to 200 m (fig. 8), is the largest of the shelf-margin deltaic complexes on the

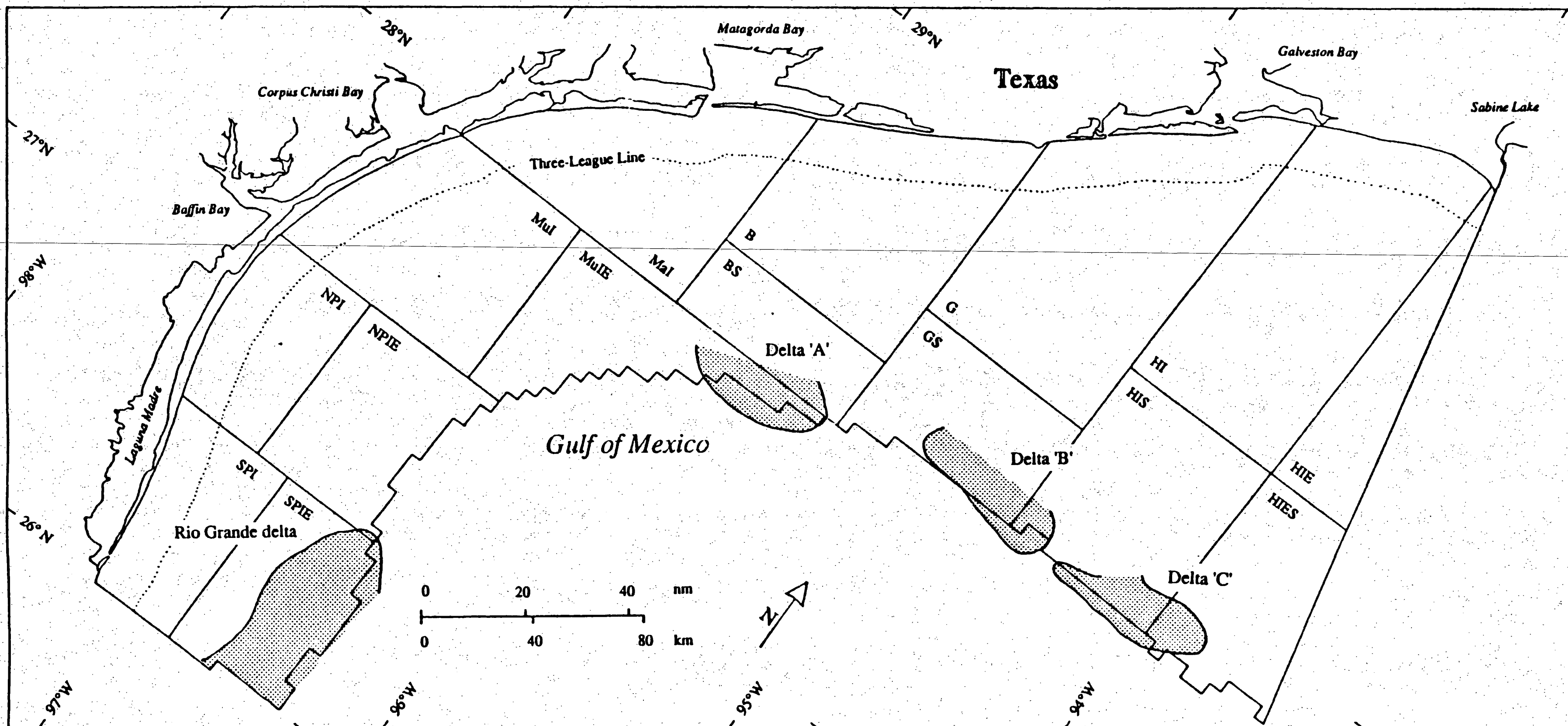

Figure 8. Location of Wisconsinan shelf-margin deltaic complexes (after Suter and Berryhill 1985).

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Texas continental shelf. As a sand resource, it has potential uses in the construction industry and, depending on size characteristics, could be used for beach nourishment along south Padre Island. The nearest potential market is south Padre Island, which is 55 to 100 km away.

Knowledge of the Rio Grande delta comes primarily from high-resolution seismic surveys, box cores, and pipe cores acquired by the U.S.G.S. during the South Texas Outer Continental Shelf project (Berryhill et al. 1976). Additional information on the distal edge of the delta was collected during a U.S.G.S. seismic survey of the Gulf of Mexico continental slope (Berryhill 1987b; Suter and Berryhill 1985). The shelf-margin part of the delta covers about 65 km along the shelf and about 35 km across the shelf, not including the part extending into Mexico. Pipe cores extending as much as 2 m into the delta encountered abundant shelly sand and interbedded mud and sand, but give no indication of the maximum sand thickness. The only foundation boring that penetrates the shelf-margin delta encountered 36 m of sand, silty sand, and sandy silt overlying a coarsening-upward sequence of clay to sandy silt. This sequence is probably typical of most of the shelf-margin delta, although sediments would tend to be thinner and generally coarser toward shore and thicker and generally finer toward the shelf margin. Interpretations from seismic data indicate that the delta thickness increases seaward from 20 m near the landward limit to more than 100 m near the edge of the continental shelf. Most of the delta, however, is probably composed of muddy sediments (silt and clay).

Delta 'A'

Delta 'A' is the southwesternmost of three smaller deltaic complexes located on the southern edge of the eastern Texas continental shelf (fig. 8) and may represent lowstand deltaic deposits associated with the ancestral Colorado or Brazos Rivers. Water depths over the shelf-margin phase of this deltaic complex range from about 60 m to 200 m. The delta is primarily composed of sand and mud; as a potential sand resource for beach nourishment and the construction industry, the nearest market is Galveston at a distance of about 185 km.

The delta is located within the Brazos South and Mustang Island East Addition areas, but few cores penetrate it. Knowledge of this delta mainly comes from high-resolution seismic data collected by the U.S. Geological Survey (Berryhill et al. 1976; Suter and Berryhill 1985). From these data, it is known that the delta is composed of two vertically-stacked lobes with a total thickness of up to 100 m covering an area of about 50 km along strike and about 16 km along dip. One core taken from the eastern flank of the delta in about 200 m of water encountered a 50-m thick coarsening-upward sequence of clay to sandy clay (Sidner et al. 1978). A second core, located updip from the delta, sampled coarser sediments from the contributing fluvial system. Surficial shelly sands cover much of the delta (Suter and Berryhill 1985).

Delta 'B'

Delta 'B' is a Wisconsinan shelf-margin delta located mostly in the Galveston Area South Addition (fig. 8) in water depths of 60 to 200 m. It is composed of sand and mud; the nearest potential market for the sands contained in the delta is Galveston, which is located about 135 km away.

Knowledge of this delta comes from high-resolution seismic surveys conducted by the U.S.G.S. (Suter and Berryhill 1985) and Texaco (Lewis 1984). In addition, four foundation borings penetrate the seafloor on or near the delta. Delta B extends about 65 km in an east-west direction (along strike) and about 16 km in a north-south direction (along dip); maximum thickness is about 60 m. One boring in relatively deep water (130 m) encountered clay from the surface to a depth of 130 m; other borings in shallower water (78 to 102 m) encountered silty fine sand with thicknesses varying from 2 to 40 m. Surficial sediments of sand and silty fine sand cover the shallower-water parts of the delta (Suter and Berryhill 1985).

Delta 'C'

This multi-lobe deltaic complex is located at the southern edge of the High Island South Addition and High Island South Addition East Extension areas (fig. 8), extending east-west (strike) about 65 km and north-south (dip) about 16 km (Suter and Berryhill 1985). At least two U.S.G.S. seismic surveys have encountered part of this delta, including the Gulf of Mexico continental slope survey and the 1979 mid- to outer shelf survey which covered the eastern part of the delta (Berryhill et al. 1984). Direct knowledge of sediments associated with this delta has been obtained from seven foundation borings that penetrate it. Like the other shelf-margin deltas, this potential sand resource occurs in water depths of 60 to 200 m and is relatively remote from potential markets. The nearest local market is Galveston, about 160 km distant.

Analysis of seismic records indicates that this deltaic complex reaches a maximum thickness of more than 140 m (Suter and Berryhill 1985). Five of the seven foundation borings in the area penetrate silty fine sand, with three borings encountering sands at the surface. These surface sand deposits range from 4 to 12 m thick. These sands cap a coarsening-upward sequence of sediment that includes clays at the base, overlain by interbedded clay and silty sands. The uppermost coarsening-upward sequence is 41 to 82 m thick. This sequence is typical of deltaic depositional systems and reinforces the original seismic interpretation.

Foundation borings that penetrate the seafloor in the vicinity of the four shelf-margin deltaic complexes indicate that substantial thicknesses of sand are found near the surface of these deltas (figs. 8 and 9). Most of the foundation borings that encountered more than 7.5 m of sand in the upper 15 m of the boring are located within these deltas or their updip stratigraphic equivalents (fig. 9).

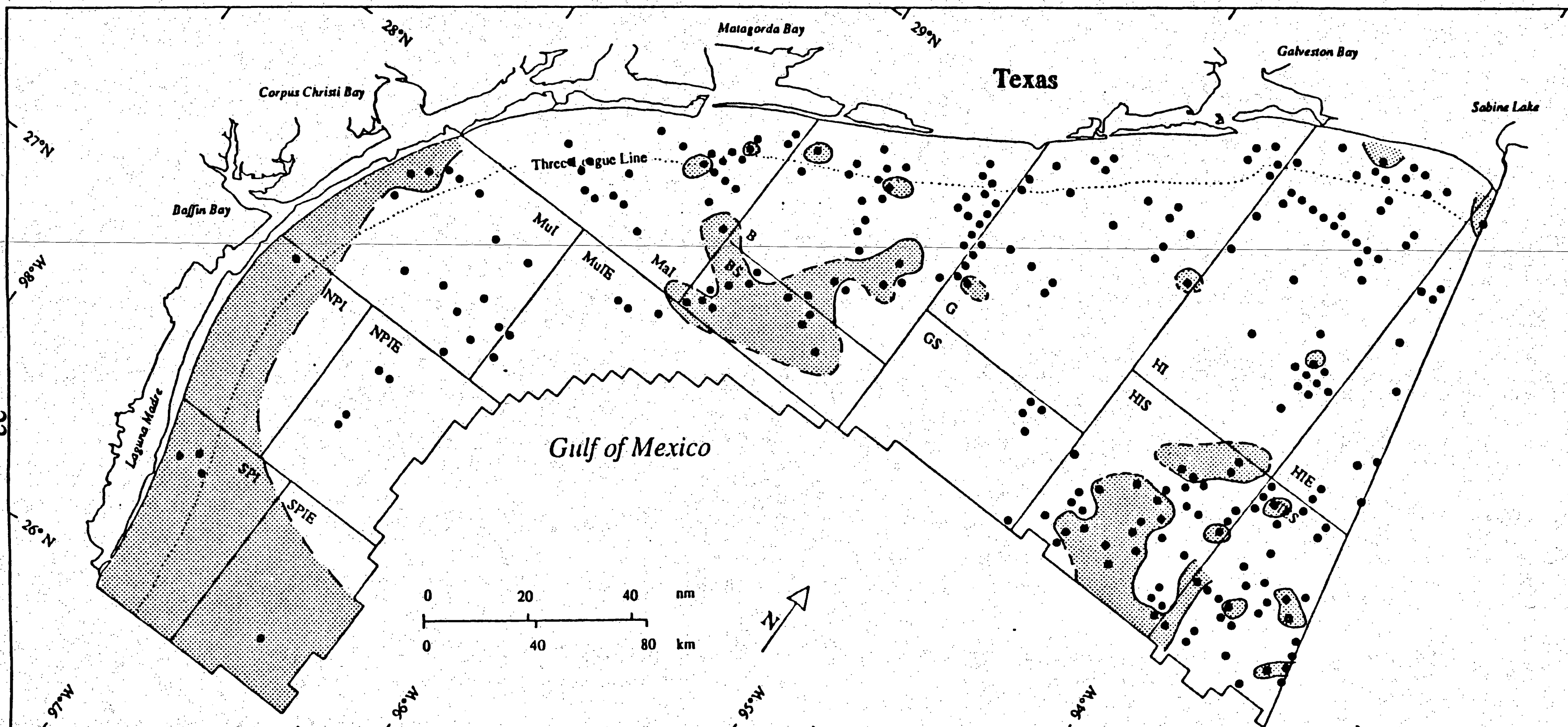

Figure 9. Distribution of foundation borings (shaded) containing more than 7.5 m of sand in the top 15 m of sediment below the seafloor.

Streamcourses and Valley Fill

Many sand and gravel quarries in the Texas coastal zone are located along major streams. During the Wisconsinan glaciation, extensions of these streams flowed across the exposed continental shelf to the Gulf of Mexico. Along their courses these streams deposited sediments similar to those found in onshore quarries. At the end of the last glaciation, rising sea level caused these lowstand channels and incised valleys to fill with a transgressive sequence of sediment, from relatively coarse fluvial channel deposits (sand and some gravel) to finer deltaic deposits (sand and mud) to generally fine estuarine deposits (mostly mud) and finally to open gulf deposits (shelf muds and possibly nearshore sands). Probably the only significant shallowly-buried gravel deposits on the Texas continental shelf will be found with the sands occurring in these submerged streamcourses. Unfortunately, these gravels will be at the base of the transgressive sequence, which may be tens of meters thick. The greatest chance for economically attractive sand and gravel deposits will be on the inner continental shelf, where shallow water, a relatively thin overburden, and proximity to potential markets will minimize the costs of extraction and transportation. In addition to exploitation difficulties arising from greater water depths farther offshore, gravels are likely to be less abundant and more deeply buried under late Pleistocene and Holocene deltaic, estuarine, and marine sediments.

High-resolution seismic surveys indicate that many kilometers of ancient streamcourses are preserved on the Texas continental shelf (fig. 10). Various seismic and coring surveys of Texas bays have shown where many of Texas' rivers entered the continental shelf during the last glaciation (Rehkemper 1969; Behrens 1963; Wright 1980), but these streams generally did not flow straight across the shelf to build shelf-margin deltas (Suter and Berryhill 1985). Seismic reflection data collected and interpreted by the U.S.G.S. on the south Texas outer continental shelf (Berryhill 1980, 1981a, 1981b) show several streams entering the shelf from the present-day Rio Grande to Matagorda Bay; all the streams from Copano Bay southward flowed to the Rio Grande delta (fig. 10). Seismic

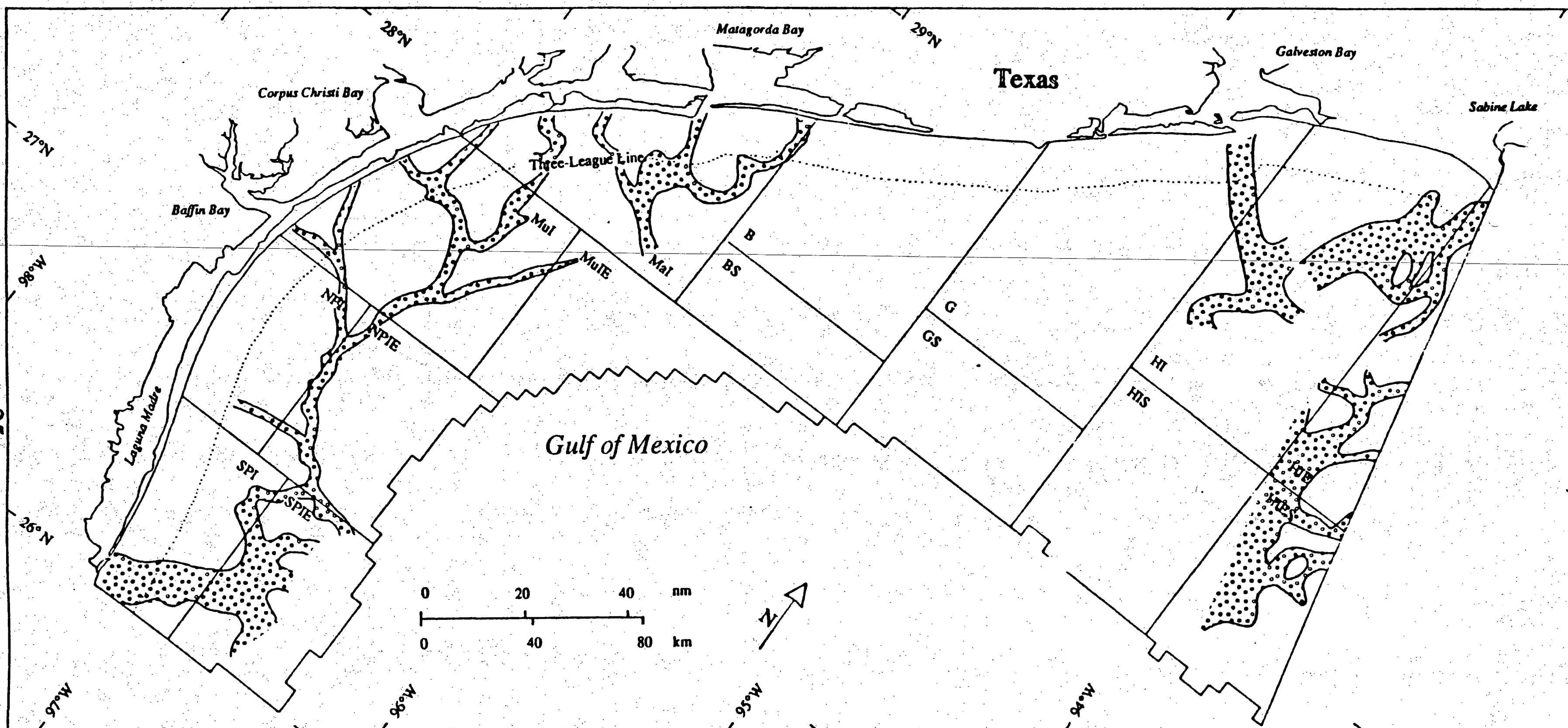

Figure 10. Location of Wisconsinan streamcourses. Compiled from Aten (1983), Berryhill (1980, 1981a, and 1981b), Nelson and Bray (1970), and Suter and Berryhill (1985).

data collected by the U.S.G.S. from the eastern Texas shelf also show numerous submerged streamcourses (Berryhill et al. 1984; Suter 1987).

Relatively little seismic data exist for the continental shelf in the Brazos, Galveston, and western High Island areas (fig. 5) that would help locate ancient courses of the Trinity, Brazos, Sabine/Neches, and possibly the Colorado rivers. The Trinity, Brazos, and Colorado are currently three of the largest streams in Texas, and substantial shelf sand and gravel deposits are associated with ancient channels of these streams. Nelson and Bray (1970), using cores and sonoprobe data, found an ancient valley of the Sabine/Calcasieu system, which turns abruptly southwestward near the confluence of the Sabine and Calcasieu rivers (fig. 10). Pearson et al. (1986) studied sediments associated with this paleovalley with high-resolution seismic surveys and several vibracores. Using cores, seismic surveys, and bathymetry, Aten (1983) constructed a paleogeographic map showing the late Pleistocene and early Holocene inner shelf courses of the Sabine/Neches, Trinity, and Calcasieu rivers, and showed the ancient Sabine/Calcasieu streamcourse merging with the Trinity streamcourse 50 to 65 km southeast of Galveston (fig. 10). It is not known where these combined streams flowed gulfward from this inferred confluence. Even less is known about late Pleistocene and early Holocene streamcourses of the Brazos and Colorado rivers, although one ancient course trending southward from Matagorda Bay (Berryhill 1981b) may be related to the Colorado River system. In summary, there is very little regional seismic data in an area of the shelf that has a high probability of containing significant fluvial sand and gravel deposits.

In addition to inferred fluvial sand and gravel deposits located along streamcourses revealed by seismic data, gravels which are almost certainly fluvial in origin have been encountered in foundation borings on the Texas shelf. Of the 26 borings that encountered gravels (fig. 11), 17 were located in the Brazos or Galveston areas and are probably associated with the ancient Brazos, Colorado, and possibly the Trinity rivers. All but two of these gravel deposits were too thin or too deeply buried to be economical. One of the

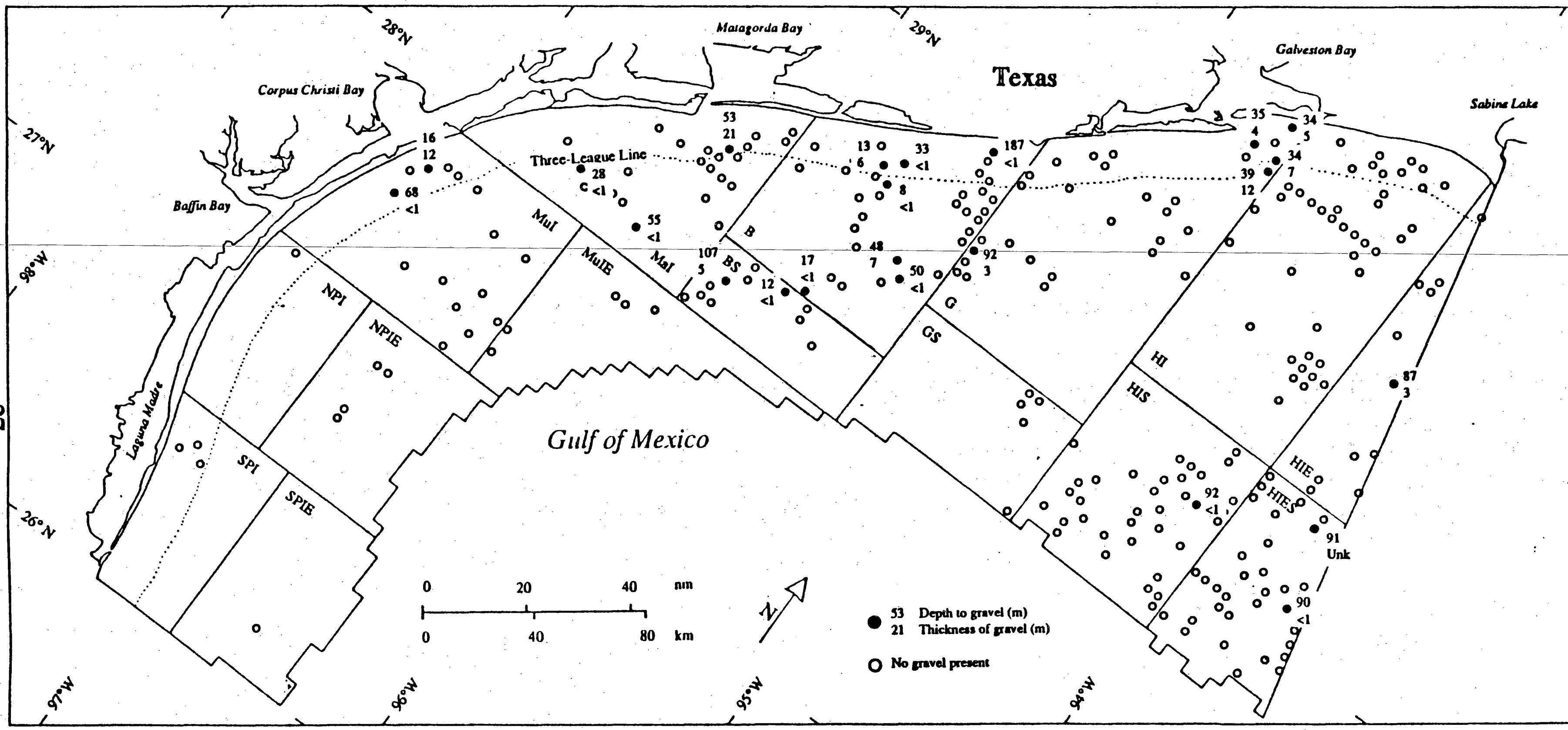

Figure 11. Distribution of foundation borings containing gravel. Depth below seafloor and thickness of gravelly strata included for borings that encountered gravel.

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potentially economic deposits is located in the Brazos Area and the other is in the Mustang Island Area (figs. 11 and 12)

Brazos Area Gravels

Although 9 of 75 foundation borings in the Brazos and Brazos South Areas encountered gravels, only one of these borings penetrated a significant thickness of gravelly sediment with less than 30 m of overburden. This boring, located in Brazos Block 409 about 14 km offshore from Matagorda Peninsula (fig. 11), extends 113 m into the subsurface in 19 m of water. Fine to coarse sands containing gravel and shell fragments occur between subsurface depths of 13 to 19 m; these deposits are overlain by clay containing wood fragments, sandstone fragments, and calcareous nodules. The areal extent of this gravel-bearing deposit is not known, but nearby borings in adjacent lease blocks to the northeast and southeast contain thin gravel lenses with overburden thicknesses of 8 and 33 m.

Mustang Island Area Gravels

Perhaps a more promising gravel deposit was encountered in a foundation boring located about 8 km offshore of Mustang Island in Mustang Island Block 772 (figs. 11 and 12). This boring, taken in 16 m of water, penetrated 12 m of sandy gravel underneath 16 m of a fining-upward sequence that included 12 m of dominantly silty fine sand. This boring apparently encountered basal transgressive valley-fill deposits near the confluence of ancestral Nueces, Aransas, and possibly Mission rivers, which were located through interpretation of high-resolution seismic reflection surveys conducted by the U.S.G.S. (Berryhill 1981a). Although nearby foundation borings located off the axis of these streamcourses did not encounter gravel, it is likely that similar deposits exist both upstream and downstream from this boring. Numerous sand and gravel quarries are operating in similar deposits along the Nueces River near Corpus Christi.

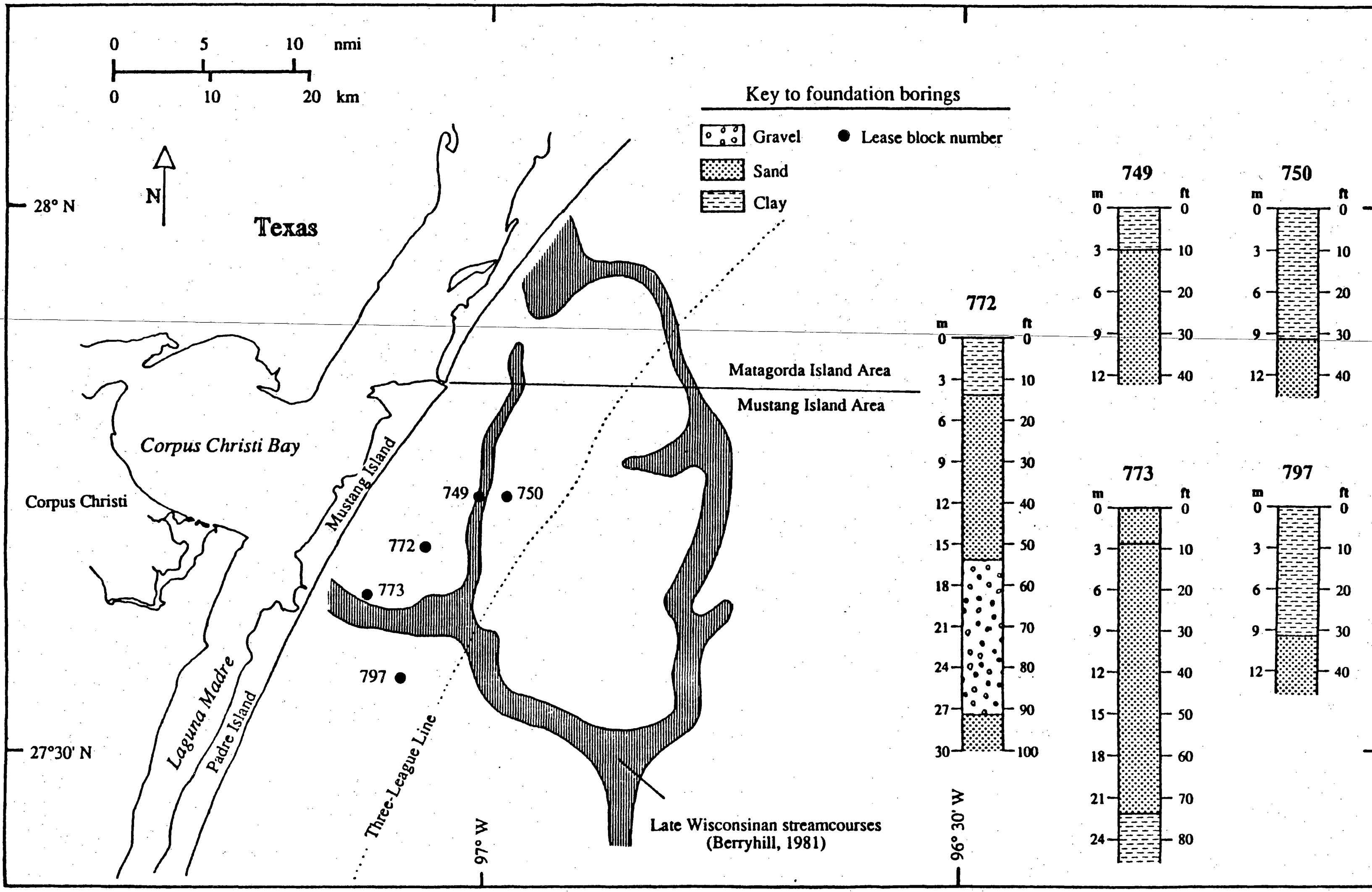

Figure 12. Sand and gravel prospect offshore of Mustang Island, Texas. Areal extent of Wisconsinan streamcourses from Berryhill (1981).

Heavy Minerals

The only systematic determination of heavy mineral content of Texas shelf sediments was conducted by the U.S.G.S. on the south Texas outer continental shelf (Berryhill et al. 1976). During this survey, 276 grab samples spaced on an approximate 5-km grid were analyzed for total heavy mineral content in the sand fraction. Heavy mineral concentrations determined during this study ranged from only a trace to 32 percent by weight. Heavy mineral concentrations generally increased southward toward the Rio Grande delta, with most of the higher concentrations (greater than 2 percent by weight) recorded off south Padre Island (fig. 13). Heaviest concentrations are located 16 to 72 km offshore in water depths of 20 to 100 m. The thickness of sediments with high concentrations of heavy minerals is not known because grab samples only penetrate a few centimeters below the seafloor. However, the heavy mineral deposits are probably relatively thin (less than one meter) because they occur in transgressive sandy sediments that cap the Rio Grande delta complex.

Heavy minerals in the grab samples collected by the U.S.G.S. were not identified because extensive work with the shelf heavy mineral suite was done during API Project 51 (Curray 1960; van Andel 1960; van Andel and Poole 1960). Analyses of seven samples (table 2) taken in the vicinity of the heavy mineral concentrations indicate that the suite is dominated by hornblende, epidote, zircon, and garnet (van Andel and Poole 1960). Minor amounts of staurolite, tourmaline, and kyanite are also present. These minerals have largely been brought to the shelf by the Rio Grande, which carries an assemblage of heavy minerals (table 2) similar to that found on the shelf (van Andel 1960).

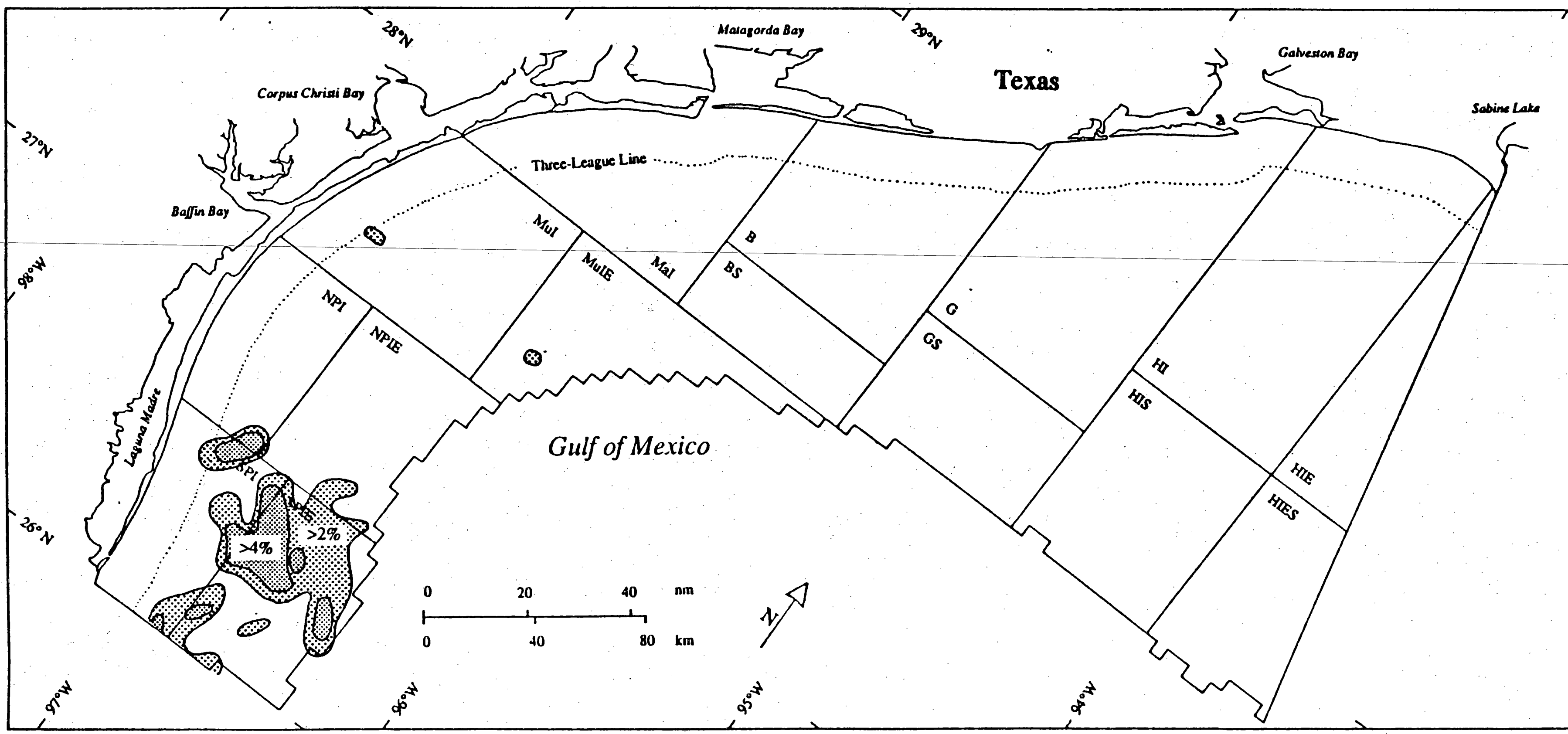

Figure 13. Heavy mineral concentrations (in weight percent) in the sand fraction of seafloor samples collected from the Matagorda Island, Mustang Island, North Padre Island, and South Padre Island lease areas (adapted from Berryhill et al. 1976).

Table 2. Heavy mineral suite in sand fraction of Rio Grande fluvial deposits and on the continental shelf, South Padre Island Area. River abundances are averaged; shelf abundance given as range among seven samples. Data from van Andel (1960) and van Andel and Poole (1960).

Mineral	River Abundance (percent)	Shelf Abundance (percent)
Epidote	22	4 - 19
Hornblende	20	17 - 38
Basaltic hornblende	10	2 - 7
Tourmaline	2	0 - 2
Zircon	5	4 - 17
Garnet	6	2 - 17
Staurolite	1	0 - 3
Kyanite	3	0 - 1
Others	4	0 - 7

Potential Markets for Nonfuel Minerals

Many of the nonfuel mineral prospects located on the Texas continental shelf are located too far from potential markets to economically compete with abundant local, onshore deposits. However, two nonfuel resources that could be economically competitive in the future are sand for beach nourishment and sand and gravel for use in the concrete and construction industry.

Beach Nourishment (Sand)

Demand

Beach nourishment, the artificial restoration of a beach by adding sediment to offset beach erosion, can be attempted where substantial human investments in recreation, residence, or industry would be damaged by continued erosion. Long-term erosional trends of Texas beaches and heavy beach use near population centers makes beach nourishment an attractive alternative to other methods of shoreline stabilization. Beach nourishment has been considered for Galveston Island to re-create a beach that once existed seaward of the Galveston seawall, to offset high rates of erosion (averaging up to 3 m/yr since the 1850's; Morton 1974) on beaches west of the seawall, to replace the estimated 1 million cubic yards of sand eroded from the western part of the island during a recent hurricane (Morton and Paine 1985), and to replace contaminated beach sand removed from the island after oil from the wrecked tanker *Alvenus* washed ashore in 1984.

Recent extensive development along south Padre Island has placed hotels, residences, and businesses near a beach that is eroding rapidly. Since 1867, average annual rates of erosion at the southern tip of Padre Island have been as high as 5 m/yr (Morton and Pieper 1975); recent rates as high as 6 m/yr (Paine and Morton 1988) indicate that erosion is likely to continue. As the shoreline retreats, endangered structures will either be destroyed, moved (if possible), or will be protected by engineered structures such as seawalls, groin fields, and breakwaters or by beach nourishment. Because the principal industry in this area is tourism, beach nourishment will likely be the chosen alternative.

Sources and Cost

Size of the material to be added to an eroding beach is of critical importance. If the material is too fine, it will erode rapidly; if too coarse, the aesthetics of the beach will not be preserved. One of the most promising sources of sand for nourishment of Texas' gulf beaches are shore-parallel sand bodies formed from similar materials and in a similar manner to today's Texas beaches and nearshore sands; thus they are closer to ideal size parameters than are onshore fluvial or deltaic sands. In addition, sands dredged offshore can be transported to the beach over water rather than hauled over land by trucks.

There are potential sources of beach-compatible sands located offshore from both south Padre Island and Galveston Island. Sand is particularly abundant off south Padre Island (figs. 6 and 9), where the postglacial sea-level rise has caused reworking of the sand-rich Rio Grande delta and produced a transgressive sand sheet across much of the south Texas shelf. Sand is not as abundant offshore from Galveston, yet potential sources such as Heald Bank (65 km distant) and Sabine Bank (95 km distant) do exist.

Despite the attractiveness of some offshore sands for beach nourishment, recent studies have shown that offshore sources are more expensive to exploit than are nearby onshore sources. At Galveston Island, offshore sources of sand much nearer Galveston Island than Heald Bank were considered for a beach nourishment project, but were rejected in favor of compatible sand that could be piped or trucked from a site at the eastern end of the island (U.S. Army Corps of Engineers 1983). Costs of sand obtained in this manner were budgeted at $6.75 per cubic yard; sand obtained by hopper dredge from nearby offshore sources was more than three times as expensive ($21 per cubic yard). It is clear that as long as nearby compatible sands are available, use of offshore sand will not be economically feasible for beach nourishment.

Construction and Industry (Sand and Gravel)

Demand

There are diverse industrial and construction uses for sand and gravel. Industrial sand is used as an abrasive, as a refractory material in metal casting, as a propping agent in hydraulic fracturing of hydrocarbon reservoirs, and in glassmaking. Sand and gravel are also used by the construction industry in the making of concrete, as road base, and as fill; together these uses make the sand and gravel industry the second largest nonfuel mineral industry in the United States (Davis and Tepordei 1985).

By far the largest sand and gravel market on the coast of Texas is the Houston Metropolitan Area (HMA). During 1985, the HMA consumed an estimated 19.3 to 25.0 million tons of aggregate (Bureau of Mines 1987a). Other Texas population centers that consume smaller but substantial quantities of aggregate are Corpus Christi on the central coast and Brownsville on the southern coast. As abundant local supplies of sand and gravel are exhausted, each of these areas may look to nearby offshore sources of sand and gravel.

Sources and Cost

Houston, Corpus Christi, and Brownsville are all located within major stream basins (Trinity/San Jacinto, Nueces, and Rio Grande). Fluvial sand and gravel similar to deposits found along these streams on land can also be expected to occur offshore along the downstream continuations of these streams. Many of these drowned streamcourses have been located by seismic surveys (see section on streamcourses and valley fill) and the presence of sand and gravel has been verified in some areas by coring.

Cost of sand at onshore pits and quarries is relatively low, ranging from $1 to $3 per ton in Houston (Bureau of Mines 1987a) to about $4 per ton in the Corpus Christi area. Gravel is more expensive, ranging from $4 to $8 per ton in Houston to about $8.50 per ton in Corpus Christi. The relatively low cost of sand and gravel at the quarry is offset by high transportation costs, making local sources much cheaper than distant sources. As nearby sources are depleted, delivered costs of sand and gravel to each of the metropolitan areas will rise and may increase interest in offshore sand and gravel deposits.

Despite the probable abundance of near surface sand and gravel on the Texas continental shelf, these deposits must be competitive with equally abundant sand and gravel on land. In a recent study of the potential for offshore sand and gravel production in the Houston area, it was estimated that despite the large consumption rate, more than 40 years of on-land supply remained (Bureau of Mines 1987a). Similar abundances in areas of lower demand, such as Corpus Christi and Brownsville, will last even longer.

Conclusions

There are abundant sand, gravel, and heavy mineral deposits on the Texas continental shelf. Significant sand accumulations at or near the seafloor occur as shore-parallel sands and transgressive sheet sands that were deposited during the post-Wisconsinan rise in sea level and in shelf-edge deltas built during the late Wisconsinan sea-level lowstand. Fluvial sand and gravel occur along Wisconsinan streamcourses across the continental shelf; however, these basal valley-fill deposits may be covered by tens of meters of overburden. Surface accumulations of heavy minerals occur on the south Texas continental shelf offshore from the Rio Grande.

Potential markets for sand and gravel mined offshore exist in Texas. Sand such as that contained in drowned shoreline and nearshore deposits have the greatest near-term economic potential because they can be used for beach nourishment projects which would not require expensive overland transport. Industrial and construction sand and gravel, though abundant offshore, are also abundant onshore. With onshore supplies adequate for 40 years or more, near-term exploitation of offshore sand and gravel for industry and construction is not likely.

Recommendations

It is not anticipated that nonfuel minerals on the Texas continental shelf (principally sand and gravel) will become generally economic in the near future because the onshore supply is adequate for many years. As long as this remains true, demand for offshore deposits will be low. However, specific local accumulations, such as sand particularly suitable for nearby beach nourishment, could become economic at any time. Uneven distribution of sediment samples, cores, and high-resolution seismic coverage makes a comprehensive inventory of potentially economic deposits impossible, but has led to the discovery of some deposits. The following recommendations reflect the combination of low and sporadic demand, sparse data, and marginal economics for nonfuel minerals on the Texas continental shelf.

Recommendation 1. Leasing the Texas continental shelf for nonfuel mineral extraction should be done in a manner that will accommodate anticipated sporadic, single-user demand for specific offshore deposits rather than multi-user competition for widely-distributed resources.

Recommendation 2. Fill existing data gaps with a regional high-resolution seismic survey of the Brazos, Galveston, and western High Island areas. Seismic coverage is adequate for the remainder of the continental shelf. The recommended seismic survey will reveal potentially significant accumulations of sand and gravel along Wisconsinan courses of the Brazos, Colorado, and Trinity rivers.

Recommendation 3. If the Minerals Management Service anticipates needing to demonstrate the economic potential of offshore deposits, then characterization studies are recommended for three sites: Heald Bank sands, sand and gravel offshore from Mustang Island, and sand and heavy mineral concentrations off the Rio Grande. These studies should be tailored for each site, but would include surface samples, cores, and high-resolution seismic surveys. Of these three sites, Heald Bank has the highest potential for use. Heald Bank sands are attractive for beach nourishment because (1) there is a nearby market at Galveston Island, (2) size requirements for beach nourishment are strict, suitable on-land deposits are limited, and Heald Bank is composed of sediment similar to that on Galveston Island, and (3) offshore sand may have a transportation advantage over truck-hauled sand from distant on-land borrow sites.

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Appendix

Foundation borings on the Texas continental shelf.
Lon, X, W refers to either longitude, X-coordinate, or distance (in feet) from eastern edge of lease block.
Lat, Y, S refers to either latitude, Y-coordinate, or distance (in feet) from northern edge of lease block.

Lease Area	Block	Name	Lon, X, W	Lat, Y, S	Water Depth (ft)	Boring Length (ft)	Source	Date
Brazos	337	Brazos 37	1902	14762	50.0	40.0	McClelland Engineers	1/1/75
Brazos	340	Brazos 60	13291	2764	43.0	304.0	McClelland Engineers	2/18/82
Brazos	340	Brazos 64	12140	7080	50.0	305.5	McClelland Engineers	5/5/82
Brazos	340	CB-1			52.0	304.0	National Soil Services	6/20/78
Brazos	341	Brazos 30	13208	7508	60.0	40.0	McClelland Engineers	1/1/73
Brazos	341	Brazos 38	13959	8555	59.0	40.0	McClelland Engineers	1/1/75
Brazos	364	Brazos 52	15327	6253	65.0	256.0	McClelland Engineers	10/26/80
Brazos	364	Brazos 53	8265	10019	71.0	120.0	McClelland Engineers	10/30/80
Brazos	365	Brazos 39	6171	12285	63.0	40.0	McClelland Engineers	1/1/75
Brazos	376	Brazos 82	3040	4080	56.0	200.0	McClelland Engineers	5/16/87
Brazos	378	Brazos 29	14906	5200	75.0	40.0	McClelland Engineers	1/1/73
Brazos	396	Brazos 40	11014	9066	84.0	40.0	McClelland Engineers	1/1/75
Brazos	397	Brazos 72	9193	5713	80.0	381.0	McClelland Engineers	2/10/84
Brazos	398	Brazos 81	12567	12713	78.0	181.0	McClelland Engineers	11/1/85
Brazos	403	Brazos 1	15540	900	47.0	109.5	Greer & McClelland	10/1/48
Brazos	405	Brazos 2	4905	10840	50.0	210.0	McClelland Engineers	8/1/66
Brazos	409	Brazos 50	831	15146	61.0	371.0	McClelland Engineers	1/1/80
Brazos	417	Brazos 41	6993	3436	95.0	40.0	McClelland Engineers	1/1/75
Brazos	430	Brazos 42	1103	2514	96.0	40.0	McClelland Engineers	1/1/75
Brazos	430	Brazos 44	4719	14882	98.0	150.0	McClelland Engineers	1/1/75
Brazos	437	CB-1			68.0	256.0	National Soil Services	5/23/80
Brazos	438	Brazos 45	11742	1301	56.0	277.0	McClelland Engineers	1/1/78
Brazos	438	Brazos 59	15336	479	56.0	250.0	McClelland Engineers	6/21/81
Brazos	438	Brazos 61	2020	528	59.0	302.0	McClelland Engineers	1/27/82
Brazos	438	Brazos 67	11325	972	57.0	308.0	McClelland Engineers	8/6/82
Brazos	440	Brazos 4	9840	1000	52.0	226.0	McClelland Engineers	1/1/66
Brazos	440	Brazos 78			59.0	316.0	McClelland Engineers	6/21/85
Brazos	446	Brazos 3	10840	5500	50.0	165.0	McClelland Engineers	1/1/66
Brazos	446	Brazos 58	5683	13833	58.0	305.5	McClelland Engineers	11/7/81
Brazos	446	Brazos 62	6436	14557	53.5	358.0	McClelland Engineers	7/13/81

Lease Area	Block	Name	Lon, X, W	Lat, Y, S	Water Depth (ft)	Boring Length (ft)	Source	Date
Brazos	446	Brazos 63	6436	14557	53.0	300.0	McClelland Engineers	2/12/82
Brazos	446	Brazos 65	6712	14549	57.0	79.0	McClelland Engineers	5/4/82
Brazos	446	Brazos 66	6943	14623	57.0	301.0	McClelland Engineers	5/7/82
Brazos	446	CB-1			56.0	358.0	National Soil Services	3/12/80
Brazos	449	Brazos 77	13352	14159	59.0	255.0	McClelland Engineers	5/1/85
Brazos	452	Brazos 70	4601	738	73.0	352.0	McClelland Engineers	12/8/83
Brazos	474	Brazos 8	843	14852	86.0	25.0	McClelland Engineers	1/1/70
Brazos	489	Brazos 79	70	3982	70.0	435.0	McClelland Engineers	9/3/85
Brazos	495	Brazos 9	11076	8214	86.0	25.0	McClelland Engineers	1/1/70
Brazos	502	Brazos 57	15254	10983	110.0	383.0	McClelland Engineers	8/2/81
Brazos	506	Brazos 5	7759	13041	102.0	196.0	McClelland Engineers	1/1/68
Brazos	510	Brazos 10	126	10516	88.0	247.0	McClelland Engineers	1/1/70
Brazos	510	Brazos 11	140	10550	91.0	248.5	McClelland Engineers	1/1/70
Brazos	538	Brazos 6	8328	7289	97.0	310.0	McClelland Engineers	1/1/68
Brazos	542	Brazos 56	4131	14865	121.0	345.0	McClelland Engineers	3/1/81
Brazos	A-007	Brazos 54	8838	9401	121.0	303.0	McClelland Engineers	1/13/81
Brazos	A-019	Brazos 48	12752	9311	129.0	418.0	McClelland Engineers	1/1/79
Brazos	A-020	Brazos 46	487	10639	125.5	402.0	McClelland Engineers	1/1/79
Brazos	A-020	Brazos 47	8580	1457	123.0	364.0	McClelland Engineers	1/1/79
Brazos	A-039	Brazos 51	13332	4613	141.0	308.5	McClelland Engineers	1/1/81
Brazos	s386	Brazos 28	1378	3759	46.0	290.0	McClelland Engineers	1/1/72
Brazos	s405	Brazos 43	2309	2250	16.0	40.0	McClelland Engineers	1/1/75
Brazos	s412	Brazos 35	2989	2816	23.0	309.0	McClelland Engineers	1/1/75
Brazos	s415	Brazos 31	3975	3940	44.5	44.5	McClelland Engineers	1/1/73
Brazos	s438	Brazos 36	3279	3016	30.0	307.0	McClelland Engineers	1/1/75
Brazos	s468	Brazos 69	1014	2240	38.0	49.0	McClelland Engineers	1/29/84
Brazos South	A-047	Brazos 55	7598	7930	142.0	387.0	McClelland Engineers	1/28/81
Brazos South	A-050	Brazos 75	5500	11000	161.0	329.5	McClelland Engineers	12/18/84
Brazos South	A-052	Brazos 71	9703	7033	165.0	373.0	McClelland Engineers	12/15/83
Brazos South	A-052	Brazos 73	2671	7473	164.0	366.0	McClelland Engineers	8/24/84
Brazos South	A-052	Brazos 74	14523	4216	160.0	363.0	McClelland Engineers	10/8/84
Brazos South	A-065	Brazos 76	13532	13963	166.0	383.0	McClelland Engineers	3/14/84
Brazos South	A-070	Brazos 33	8585	8017	157.0	400.5	McClelland Engineers	2/1/75
Brazos South	A-076	Brazos 7	6311	7998	165.0	400.0	McClelland Engineers	11/22/69
Brazos South	A-084	Brazos 12	14840	1000	183.0	386.5	McClelland Engineers	1/1/71
Brazos South	A-102	CB-1			178.0	57.0	National Soil Services	11/11/71
Brazos South	A-102		95° 59' 07.82"	27° 56' 20.11"	176.0	80.0	National Soil Services	12/19/71
Brazos South	A-105	Brazos 32	11625	1809	188.0	408.0	McClelland Engineers	1/1/74

Lease Area	Block	Name	Lon, X, W	Lat, Y, S	Water Depth (ft)	Boring Length (ft)	Source	Date
Brazos South	A-105	CB-1			196.0	59.0	National Soil Services	1/22/72
Brazos South	A-105				190.0	66.0	National Soil Services	3/8/72
Brazos South	A-105	CB-2			196.0	44.0	National Soil Services	1/23/72
Brazos South	A-106	Brazos 49	13321	15037	197.0	375.0	McClelland Engineers	1/1/79
Brazos South	A-133	Brazos 34	12826	3484	202.0	401.0	McClelland Engineers	1/1/75
Brazos South	A-133	Brazos 68	5082	3718	206.0	303.0	McClelland Engineers	9/17/83
Brazos South	A-133	Brazos 80	8283	9563	203.0	400.0	McClelland Engineers	11/29/85
Galveston	100	Galveston 65	6820	3732	36.0	302.5	McClelland Engineers	12/16/79
Galveston	102	Galveston 62	9365	6976	33.0	357.0	McClelland Engineers	3/11/79
Galveston	102	Galveston 63	5840	4345	33.0	277.5	McClelland Engineers	3/30/79
Galveston	102	Galveston 64	8384	4179	30.0	321.0	McClelland Engineers	4/15/79
Galveston	104	CB-1	94° 32' 23.46"	29° 19' 37.39"	43.0	300.0	National Soil Services	7/20/77
Galveston	144	CB-1			48.0	300.0	National Soil Services	7/22/77
Galveston	144	Galveston 22	250	8700	50.0	200.0	McClelland Engineers	1/1/56
Galveston	146	CB-1			36.0	292.0	National Soil Services	7/6/77
Galveston	241	Galveston 70	4745	2082	60.0	304.0	McClelland Engineers	2/18/83
Galveston	247	Galveston 6	6500	14385	49.0	214.0	McClelland Engineers	1/1/55
Galveston	248	Galveston 1	9015	14135	51.0	150.0	Greer and McClelland	1/1/48
Galveston	249	Galveston 2	11700	975	46.0	120.0	Greer & McClelland	12/1/54
Galveston	249	Galveston 4	5725	1595	51.0	157.5	McClelland Engineers	1/1/55
Galveston	249	Galveston 5	8025	2670	49.0	117.0	McClelland Engineers	1/1/55
Galveston	249	Galveston 7	4140	755	49.0	320.0	McClelland Engineers	1/1/55
Galveston	253	Galveston 8	12140	10440	66.0	139.0	McClelland Engineers	1/1/56
Galveston	255	Galveston 43	11503	2618	64.0	223.0	McClelland Engineers	1/1/71
Galveston	257	Galveston 77	13959	14346	57.0	300.0	McClelland Engineers	3/23/87
Galveston	278	Galveston 3	1650	8500	55.0	145.0	Greer and McClelland	1/1/48
Galveston	288	Galveston 31	2739	12968	67.0	329.0	McClelland Engineers	1/1/64
Galveston	288	Galveston 33	3540	9950	69.0	251.0	McClelland Engineers	1/1/64
Galveston	293	Galveston 28	10050	9893	58.0	245.0	McClelland Engineers	1/1/60
Galveston	296	Galveston 32	1320	3375	68.0	273.0	McClelland Engineers	1/1/64
Galveston	296	Galveston 34	4215	2155	68.0	243.0	McClelland Engineers	1/1/64
Galveston	300	Galveston 71	11116	3838	60.0	368.0	McClelland Engineers	4/9/84
Galveston	304	Galveston 76			69.0	151.0	McClelland Engineers	11/14/85
Galveston	310	Galveston 49	2956	14701	61.0	271.0	McClelland Engineers	1/1/75
Galveston	310	Galveston 50	4372	15626	64.0	26.0	McClelland Engineers	1/1/75
Galveston	310	Galveston 68	2874	2491	59.0	305.0	McClelland Engineers	1/29/82
Galveston	334	Galveston 51	5851	824	64.0	26.0	McClelland Engineers	1/1/75
Galveston	334	Galveston 52	7304	1820	63.5	26.0	McClelland Engineers	1/1/75

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Lease Area	Block	Name	Lon, X, W	Lat, Y, S	Water Depth (ft)	Boring Length (ft)	Source	Date
Galveston	334	Galveston 53	8830	2876	61.0	278.0	McClelland Engineers	1/1/75
Galveston	389	Galveston 72	11040	13584	100.0	299.0	McClelland Engineers	6/22/84
Galveston	389	Galveston 73	11140	7550	98.0	302.0	McClelland Engineers	6/23/84
Galveston	391	CB-1			98.0	363.0	National Soil Services	5/19/79
Galveston	393	CB-1			96.0	356.0	National Soil Services	11/14/79
Galveston	418	Galveston 48	14955	6317	94.0	40.0	McClelland Engineers	1/1/73
Galveston	424	Galveston 74	2001	1939	102.0	403.0	McClelland Engineers	8/20/84
Galveston	429	Galveston 47	4413	12371	102.0	40.0	McClelland Engineers	1/1/73
Galveston	429	Galveston 54	13199	12454	99.0	335.0	McClelland Engineers	1/1/75
Galveston	429	Galveston 55	12569	12961	98.0	330.0	McClelland Engineers	1/1/75
Galveston	429	Galveston 58	5346	10491	102.0	150.0	McClelland Engineers	1/1/75
Galveston	460	Galveston 56	14884	4624	106.0	150.0	McClelland Engineers	1/1/75
Galveston	460	Galveston 57	7156	2481	101.0	150.0	McClelland Engineers	1/1/75
Galveston	464	Galveston 44	10138	1794	111.0	330.0	McClelland Engineers	1/1/73
Galveston	464	Galveston 45	9138	10126	115.0	121.0	McClelland Engineers	1/1/73
Galveston	464	Galveston 46	2875	326	113.0	120.0	McClelland Engineers	1/1/73
Galveston	465	Galveston 75	2682	9149	113.0	304.0	McClelland Engineers	10/14/85
Galveston	s174	CB-2	3,390,695.87	602,555.85	26.0	150.0	National Soil Services	6/6/76
Galveston	s175	Galveston 66	1300	2197	27.0	356.0	McClelland Engineers	8/22/80
Galveston	s182	CB-1	3,387,676.40	598,067.57	26.5	150.5	National Soil Services, Inc	6/5/76
Galveston	s226	Galveston 23	3000	4000	31.0	107.5	McClelland Engineers	1/1/59
Galveston South	A-126	Galveston 67	6941	11156	169.0	300.5	McClelland Engineers	10/9/80
Galveston South	A-127	Galveston 69	4906	2687	161.0	327.0	McClelland Engineers	11/29/82
Galveston South	A-131	Galveston 61	6500	6007	177.5	471.5	McClelland Engineers	7/17/78
Galveston South	A-157	Galveston 60	10768	10568	186.0	401.5	McClelland Engineers	7/16/78
Galveston South	A-248	Galveston 59	2738	9264	433.0	432.0	McClelland Engineers	1/1/75
High Island	007	High Island 32	14515	14547	35.0	251.5	McClelland Engineers	1/1/68
High Island	008	High Island 83	1150	15373	42.0	37.0	McClelland Engineers	1/1/75
High Island	010	CB-1			36.0	249.0	National Soil Services	2/19/79
High Island	022	High Island 172	6522	12413	38.0	301.0	McClelland Engineers	7/29/83
High Island	022	High Island 178	2934 (E)	2056	40.0	308.0	McClelland Engineers	10/4/85
High Island	024	High Island 31	10833	3046	37.0	249.5	McClelland Engineers	1/1/68
High Island	026	High Island 159	3913	473	35.0	401.0	McClelland Engineers	11/15/81
High Island	027	High Island 182	29° 30' 0.62"	94° 22' 57.3"	32.0	184.0	McClelland Engineers	6/13/84
High Island	027	High Island 183			30.0	222.0	McClelland Engineers	7/12/84
High Island	030	High Island 96			42.0	321.0	McClelland Engineers	1/1/75
High Island	031	High Island 160	14829	5939	44.0	401.3	McClelland Engineers	11/15/81
High Island	052		3,540,634	617,285	43.0	174.0		

Lease Area	Block	Name	Lon, X, W	Lat, Y, S	Water Depth (ft)	Boring Length (ft)	Source	Date
High Island	055	High Island 153	9759	5272	43.0	278.5	McClelland Engineers	4/15/81
High Island	068	High Island 168	2223	1595	42.0	414.0	McClelland Engineers	2/18/84
High Island	071	High Island 33	2501	15840	37.0	329.0	McClelland Engineers	1/1/69
High Island	088	High Island 173	1501	2572	44.0	405.0	McClelland Engineers	3/25/85
High Island	098	High Island 97			42.0	303.0	McClelland Engineers	1/1/76
High Island	110	High Island 104	1542	14340	50.0	348.0	McClelland Engineers	1/1/76
High Island	110	High Island 52	100	8394	45.0	276.0	McClelland Engineers	1/1/74
High Island	134	High Island 187	13304	10256	50.0	350.0	McClelland Engineers	4/29/87
High Island	135	High Island 28	14520	12945	50.0	369.0	McClelland Engineers	1/1/64
High Island	136	High Island 29	100	11340	50.0	270.0	McClelland Engineers	1/1/66
High Island	137	High Island 149	4001	5466	49.0	439.0	McClelland Engineers	7/12/80
High Island	138	High Island 152	8175	618	50.0	394.0	McClelland Engineers	2/7/81
High Island	139	High Island 137	14178	6318	51.0	355.0	McClelland Engineers	1/29/79
High Island	140		3,485,360	550,720	50.0	191.0		
High Island	141	High Island 2	660	7100	50.0	134.0	McClelland Engineers	1/1/56
High Island	142	High Island 123	333	15175	53.0	284.5	McClelland Engineers	9/22/77
High Island	154	High Island 105			51.0	29.0	McClelland Engineers	1/1/76
High Island	154	High Island 106			51.0	206.0	McClelland Engineers	1/1/76
High Island	154	High Island 107			52.0	49.0	McClelland Engineers	1/1/76
High Island	154	High Island 108			52.0	28.0	McClelland Engineers	1/1/76
High Island	154	High Island 99	400	7082	50.0	451.0	McClelland Engineers	1/1/75
High Island	161	High Island 26	5277	6838	52.0	250.0	McClelland Engineers	1/1/60
High Island	161	High Island 30	15640	7840	51.0	250.0	McClelland Engineers	1/1/66
High Island	170	High Island 163	4195	15230	58.0	81.0	McClelland Engineers	8/26/82
High Island	193	High Island 112	6553	6198	55.0	317.0	McClelland Engineers	1/1/76
High Island	236	High Island 27			62.0	245.0	McClelland Engineers	1/1/60
High Island	A-020	High Island 176	13417	619	61.0	332.0	McClelland Engineers	8/25/85
High Island	A-033	High Island 166	10143	678	66.0	99.0	McClelland Engineers	12/21/82
High Island	A-052	High Island 184	5101	13164	80.0	299.4	McClelland Engineers	2/21/86
High Island	A-053	High Island 181	3122	7735	84.0	77.0	McClelland Engineers	2/26/86
High Island	A-068	High Island 186	4776	11830	83.0	305.0	McClelland Engineers	3/9/87
High Island	A-072	High Island 8	13200	13200	82.0	200.0	McClelland Engineers	1/1/56
High Island	A-072	High Island 9	13700	13200	82.0	60.0	McClelland Engineers	7/30/56
High Island	A-073	High Island 21	2600	10600	81.0	191.0	McClelland Engineers	1/1/56
High Island	A-073	High Island 22	600	10600	81.0	80.0	McClelland Engineers	7/27/56
High Island	A-073	High Island 23	2600	12600	82.0	79.0	McClelland Engineers	7/28/56
High Island	A-073	High Island 24	2600	8600	81.0	80.0	McClelland Engineers	7/28/56
High Island	A-073	High Island 25	4600	8500	81.0	80.0	McClelland Engineers	7/28/56

Lease Area	Block	Name	Lon, X, W	Lat, Y, S	Water Depth (ft)	Boring Length (ft)	Source	Date
High Island	A-073	High Island 5	13200	13200	82.0	193.0	McClelland Engineers	1/1/56
High Island	A-073	High Island 6	12,200	13,200	82.0	80.0	McClelland Engineers	7/26/56
High Island	A-073	High Island 7	14200	13200	82.0	80.0	McClelland Engineers	7/26/56
High Island	A-074	High Island 20	4300	5400	80.0	80.0	McClelland Engineers	8/9/56
High Island	A-075	High Island 180	6117	2896	79.0	61.2	McClelland Engineers	2/25/86
High Island	A-077	High Island 10	13200	14600	85.0	198.0	McClelland Engineers	1/1/56
High Island	A-077	High Island 12	13200	9400	82.0	80.0	McClelland Engineers	8/6/56
High Island	A-077	High Island 13	13200	4100	83.0	80.0	McClelland Engineers	8/6/56
High Island	A-077	High Island 14	7900	9400	84.0	78.0	McClelland Engineers	8/6/56
High Island	A-077	High Island 15	8500	9400	84.0	68.0	McClelland Engineers	8/6/56
High Island	A-077	High Island 18	7900	4100	82.0	81.0	McClelland Engineers	8/8/56
High Island	A-078	High Island 11	1300	12400	83.0	70.0	McClelland Engineers	8/5/56
High Island	A-078	High Island 16	2600	9300	85.0	78.0	McClelland Engineers	8/7/56
High Island	A-078	High Island 19	1300	12000	85.0	78.0	McClelland Engineers	8/9/56
High Island	A-104	High Island 1	2640	2640	92.0	200.0	McClelland Engineers	1/1/55
High Island	s087	High Island 154	4630	2150	27.5	303.0	McClelland Engineers	4/10/81
High Island	s095	High Island 4	500	750	27.0	199.0	McClelland Engineers	1/1/56
High Island	s140	High Island 74	1625	2400	29.0	307.5	McClelland Engineers	1/1/75
High Island East	014	CB-1			45.0	193.0	National Soil Services	1/1/78
High Island East	119	High Island 70	13841	10745	50.0	337.0	McClelland Engineers	1/1/75
High Island East	129	High Island 34			50.0	275.5	McClelland Engineers	1/1/69
High Island East	129	High Island 35	1368	3861	48.0	293.0	McClelland Engineers	1/1/71
High Island East	130	High Island 170	1567	6723	51.0	351.0	McClelland Engineers	8/2/84
High Island East	A-178	High Island 177	5417	2700 (N)	61.0	400.0	McClelland Engineers	11/23/85
High Island East	A-193	High Island 171	167	1000	71.0	347.0	McClelland Engineers	7/24/84
High Island East	A-218	High Island 86	9837	?	74.0	16.0	McClelland Engineers	1/1/75
High Island East	A-228	High Island 87	1110	4462	78.0	16.0	McClelland Engineers	1/1/75
High Island East	A-228	High Island 88	2356	668	86.0	16.0	McClelland Engineers	1/1/75
High Island East	A-244	High Island 161	5036	15106	123.0	310.0	McClelland Engineers	8/8/82
High Island East	A-244	High Island 162	4567	986	119.0	300.0	McClelland Engineers	8/7/82
High Island East	A-248	High Island 89	480	9478	123.0	17.0	McClelland Engineers	1/1/75
High Island East	A-255	High Island 90	1740	1242	126.0	15.0	McClelland Engineers	1/1/75
High Island East	A-255	High Island 91	3056	3860	131.0	15.0	McClelland Engineers	1/1/75
High Island East	A-255	High Island 92	4254	8134	135.0	15.0	McClelland Engineers	1/1/75
High Island East	A-255	High Island 93	5546	14134	147.0	16.0	McClelland Engineers	1/1/75
High Island East South	A-262	High Island 165	6205	4857	156.5	305.0	McClelland Engineers	10/30/82
High Island East South	A-264	High Island 57	7925	7947	154.0	455.0	McClelland Engineers	1/1/74
High Island East South	A-264	High Island 94	6780	3411	146.0	16.0	McClelland Engineers	1/1/75

Lease Area	Block	Name	Lon. X, W	Lat. Y, S	Water Depth (ft)	Boring Length (ft)	Source	Date
High Island East South	A-264	High Island 95	7730	7257	151.0	16.0	McClelland Engineers	1/1/75
High Island East South	A-267	High Island 155	15219	3094	142.0	353.0	McClelland Engineers	10/7/81
High Island East South	A-268	High Island 169	9322	12832	166.0	353.0	McClelland Engineers	3/15/84
High Island East South	A-269	High Island 82	34	8361	164.0	323.0	McClelland Engineers	1/1/75
High Island East South	A-273	High Island 130	9085	7609	164.0	314.0	McClelland Engineers	5/25/78
High Island East South	A-273	High Island 131	8912	7775	163.0	315.0	McClelland Engineers	5/24/78
High Island East South	A-281	High Island 175	1777	514 (N)	170.0	340.5	McClelland Engineers	10/13/84
High Island East South	A-283	CB-2	93° 53' 27.932"	28° 22' 24.418"	172.0	423.0	National Soil Services	11/23/77
High Island East South	A-283	CB-3	93° 53' 57.445"	28° 23' 42.525"	167.0	388.0	National Soil Services	12/2/77
High Island East South	A-298	High Island 77	12709	4000	192.0	455.0	McClelland Engineers	1/1/75
High Island East South	A-309	High Island 80	9011	8565	213.0	424.0	McClelland Engineers	1/1/75
High Island East South	A-309	High Island 81	8838	8739	210.0	436.0	McClelland Engineers	1/1/75
High Island East South	A-313	High Island 117	2500	11931	213.0	318.0	McClelland Engineers	1/1/77
High Island East South	A-315	High Island 148	6505	5097	216.0	353.0	McClelland Engineers	12/26/79
High Island East South	A-317	High Island 110	5955	6892	217.0	429.5	McClelland Engineers	1/1/76
High Island East South	A-317	High Island 111	5747	7113	217.0	374.5	McClelland Engineers	1/1/76
High Island East South	A-323	High Island 38	14351	10843	234.0	382.0	McClelland Engineers	1/1/73
High Island East South	A-323	High Island 54	7852	8093	236.5	498.5	McClelland Engineers	1/1/74
High Island East South	A-325	High Island 134	11548	10628	227.0	360.0	McClelland Engineers	9/26/78
High Island East South	A-325	High Island 37	6059	6084	227.0	380.0	McClelland Engineers	1/1/73
High Island East South	A-327	High Island 68	10433	14331	225.0	335.5	McClelland Engineers	1/1/74
High Island East South	A-327	High Island 69	9592	15537	227.0	334.0	McClelland Engineers	1/1/75
High Island East South	A-330	B-1			257.0	72.0	National Soil Services	12/23/73
High Island East South	A-330	High Island 49			266.0	408.0	McClelland Engineers	1/1/73
High Island East South	A-330	High Island 72	1033	12703	260.0	408.0	McClelland Engineers	1/1/75
High Island East South	A-330	High Island 75	7006	12861	257.0	420.0	McClelland Engineers	1/1/75
High Island East South	A-334	High Island 55	13656	2625	237.0	430.5	McClelland Engineers	1/1/74
High Island East South	A-334	High Island 56	12856	7014	231.0	436.5	McClelland Engineers	1/1/74
High Island East South	A-340	High Island 66	11179	723	236.0	376.5	McClelland Engineers	1/1/74
High Island East South	A-341	High Island 125	11036	3386	237.0	381.0	McClelland Engineers	1/5/78
High Island East South	A-342	High Island 113	4812	3395	235.5	407.0	McClelland Engineers	1/1/76
High Island East South	A-343	High Island 109	9220	5412	237.0	339.0	McClelland Engineers	1/1/76
High Island East South	A-343	High Island 62	10178	5100	239.0	392.0	McClelland Engineers	1/1/74
High Island East South	A-343	High Island 78	3122	3007	235.6	392.4	McClelland Engineers	1/1/75
High Island East South	A-349	High Island 115	403 (East)	6146	277.0	334.5	McClelland Engineers	1/1/77
High Island East South	A-349	High Island 116	530 (East)	6427	277.0	150.0	McClelland Engineers	1/1/77
High Island East South	A-350	High Island 53	777	9049	316.0	350.0	McClelland Engineers	1/1/74
High Island East South	A-355	High Island 122	7005	4492	289.0	400.0	McClelland Engineers	7/31/77

Lease Area	Block	Name	Lon. X, W	Lat. Y, S	Water Depth (ft)	Boring Length (ft)	Source	Date
High Island East South	A-356	High Island 119	9232	3661	257.0	401.5	McClelland Engineers	7/26/77
High Island East South	A-368	High Island 133	10359	500	311.0	411.0	McClelland Engineers	6/17/78
High Island East South	A-368	High Island 40	8142	7367	329.0	72.0	McClelland Engineers	1/1/73
High Island East South	A-368	High Island 41	3275	3390	320.0	71.0	McClelland Engineers	1/1/73
High Island East South	A-368	High Island 42	11827	11589	338.0	72.0	McClelland Engineers	1/1/73
High Island East South	A-368	High Island 43	8820	7198	331.0	71.0	McClelland Engineers	1/1/73
High Island East South	A-368	High Island 44	10827	9333	333.0	72.0	McClelland Engineers	1/1/73
High Island East South	A-368	High Island 45	9358	8855	336.0	72.0	McClelland Engineers	1/1/73
High Island East South	A-368	High Island 46	8814	4004	319.0	50.5	McClelland Engineers	1/1/73
High Island East South	A-368	High Island 47	8955	3863	320.0	51.0	McClelland Engineers	1/1/73
High Island East South	A-368	High Island 48	8800	5600	325.0	61.0	McClelland Engineers	1/1/73
High Island East South	A-370	High Island 67	2568	5248	352.0	391.5	McClelland Engineers	1/1/74
High Island East South	A-376	High Island 141	9171	1114	329.0	419.0	McClelland Engineers	6/17/79
High Island East South	A-376	High Island 64	11848	23	323.0	404.5	McClelland Engineers	1/1/74
High Island East South	A-379	High Island 157	11162	3664	312.0	373.0	McClelland Engineers	1/27/82
High Island East South	A-382	High Island 179	14406	6829	341.0	500.0	McClelland Engineers	11/16/85
High Island East South	A-384	High Island 164	5454	5450	350.0	501.0	McClelland Engineers	9/23/82
High Island East South	A-389	High Island 127	9637	6302	410.0	248.0	McClelland Engineers	4/1/78
High Island East South	A-389	High Island 128	9809	6177	405.0	446.5	McClelland Engineers	3/31/78
High Island East South	A-389	High Island 129	9567	6389	408.0	250.0	McClelland Engineers	4/1/78
High Island South	A-414	CB-1			135.0	328.5	National Soil Services	1/5/79
High Island South	A-419	High Island 144	11736	13246	153.0	314.0	McClelland Engineers	10/6/79
High Island South	A-443	High Island 135	12004	4829	182.0	376.0	McClelland Engineers	7/29/78
High Island South	A-446	High Island 138	10027	7631	162.0	446.5	McClelland Engineers	4/17/79
High Island South	A-447	High Island 139	12866	4945	160.0	321.0	McClelland Engineers	4/27/79
High Island South	A-447	High Island 143	3764	3790	163.0	358.0	McClelland Engineers	10/6/79
High Island South	A-448	High Island 132	220	5513	161.0	427.0	McClelland Engineers	5/25/78
High Island South	A-464	High Island 36			172.0	326.0	McClelland Engineers	1/1/67
High Island South	A-468	High Island 151	9541	7926	196.0	104.0	McClelland Engineers	11/7/80
High Island South	A-469	High Island 59	3671	6216	206.0	512.0	McClelland Engineers	1/1/74
High Island South	A-471	High Island 142	13904	8392	188.0	302.0	McClelland Engineers	5/21/79
High Island South	A-472	High Island 156	2431	7630	187.0	390.0	McClelland Engineers	10/29/81
High Island South	A-474	High Island 58	12826	13077	177.0	456.0	McClelland Engineers	1/1/74
High Island South	A-487	High Island 158	1363	473	171.0	506.0	McClelland Engineers	6/7/82
High Island South	A-489	High Island 101	4967	6910	177.0	476.0	McClelland Engineers	1/1/76
High Island South	A-499	High Island 147	8731	5534	193.0	411.0	McClelland Engineers	1/28/80
High Island South	A-507	High Island 150	13,382	13,560	182.0	420.0	McClelland Engineers	5/2/80
High Island South	A-511	High Island 71	4187	13190	195.0	428.0	McClelland Engineers	1/1/75

Lease Area	Block	Name	Lon, X, W	Lat, Y, S	Water Depth (ft)	Boring Length (ft)	Source	Date
High Island South	A-511	High Island 85	6092	12937	196.0	438.0	McClelland Engineers	1/1/75
High Island South	A-515	High Island 167	4291	3664	204.0	400.0	McClelland Engineers	5/5/83
High Island South	A-517	High Island 124	6032	2269	210.0	308.0	McClelland Engineers	8/13/77
High Island South	A-519	High Island 61	7928	7935	222.0	473.0	McClelland Engineers	1/1/74
High Island South	A-519	High Island 73	7932	11411	220.0	437.0	McClelland Engineers	1/1/75
High Island South	A-526	High Island 174	6378	7085	202.0	399.5	McClelland Engineers	2/13/85
High Island South	A-531	High Island 84	6820	14664	191.0	406.0	McClelland Engineers	1/1/75
High Island South	A-536	High Island 100	4467	11760	199.0	424.0	McClelland Engineers	1/1/76
High Island South	A-537	High Island 98	7189	7879	203.0	401.0	McClelland Engineers	1/1/76
High Island South	A-542	High Island 136	7190	8467	230.0	461.5	McClelland Engineers	8/16/78
High Island South	A-548	High Island 114	1758	771	244.0	452.0	McClelland Engineers	1/1/77
High Island South	A-553	High Island 65	15693	13736	270.0	366.5	McClelland Engineers	1/1/74
High Island South	A-555	High Island 121	15840	0	260.0	450.0	McClelland Engineers	8/26/77
High Island South	A-555	High Island 50	12635	5910	277.0	373.0	McClelland Engineers	1/1/74
High Island South	A-555	High Island 51	8575	13665	250.0	326.0	McClelland Engineers	1/1/74
High Island South	A-561	High Island 79	9468	5326	256.0	509.0	McClelland Engineers	1/1/75
High Island South	A-563	High Island 102	2985	15843/3	332.0	450.0	McClelland Engineers	1/1/76
High Island South	A-563	High Island 118	3816	9667	307.0	552.0	McClelland Engineers	1/1/77
High Island South	A-563	High Island 120	3197	10245	296.0	423.0	McClelland Engineers	7/24/77
High Island South	A-563	High Island 63	4504	13587	337.0	410.0	McClelland Engineers	1/1/74
High Island South	A-567	High Island 145	11471	3849	291.0	423.0	McClelland Engineers	8/18/79
High Island South	A-567	High Island 146	11383	4080	292.0	427.0	McClelland Engineers	8/19/79
High Island South	A-571	High Island 126	13088	8517	276.0	427.0	McClelland Engineers	2/24/78
High Island South	A-572	B-1			298.0	377.0	National Soil Services	11/13/73
High Island South	A-572				298.0	339.0	National Soil Services	10/4/74
High Island South	A-573	Boring No. 1			345.0	351.0	National Soil Services	9/30/73
High Island South	A-573	High Island 103	3964	7949	340.0	454.0	McClelland Engineers	1/1/76
High Island South	A-582	High Island 140	5805	967	333.0	358.0	McClelland Engineers	3/9/79
Matagorda Island	444	Matagorda 4	14310	6990	40.0	256.0	McClelland Engineers	1/1/76
Matagorda Island	481	Matagorda 3	1631	11839	58.0	232.0	McClelland Engineers	5/9/67
Matagorda Island	485	Matagorda 16			57.0	254.0	McClelland Engineers	1/20/82
Matagorda Island	485	Matagorda 2			55.0	262.0	McClelland Engineers	1/1/67
Matagorda Island	520	Boring No. 1			58.0	194.0	National Soil Services, Inc	2/15/76
Matagorda Island	520				61.0	405.0	National Soil Services	2/10/77
Matagorda Island	520	CB-1			61.0	336.0	National Soil Services	5/18/78
Matagorda Island	526	Matagorda 10	4715	5594	67.0	306.0	McClelland Engineers	6/20/80
Matagorda Island	526	Matagorda 5	13839	10040	64.0	300.0	McClelland Engineers	7/4/77
Matagorda Island	527	Matagorda 9	12305	14180	71.0	303.0	McClelland Engineers	2/5/80

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Lease Area	Block	Name	Lon, X, W	Lat, Y, S	Water Depth (ft)	Boring Length (ft)	Source	Date
Matagorda Island	557	Matagorda 29	5045	7771	73.0	254.5	McClelland Engineers	1/25/87
Matagorda Island	558	Matagorda 6	5682	11647	71.0	308.0	McClelland Engineers	2/3/78
Matagorda Island	561	CB-1			40.0	300.0	National Soil Services	9/9/77
Matagorda Island	563	Matagorda 27			69.0	304.0	McClelland Engineers	5/9/84
Matagorda Island	565	Matagorda 13	130	2007	76.0	357.0	McClelland Engineers	3/26/81
Matagorda Island	566	Matagorda 12	1697	5907	77.0	149.5	McClelland Engineers	4/14/81
Matagorda Island	567	Matagorda 28			80.0	74.0	McClelland Engineers	1/1/85
Matagorda Island	568	Matagorda 18	4215	6916	80.0	97.0	McClelland Engineers	10/20/82
Matagorda Island	605	Matagorda 30	96° 10' 10"	28° 09' 25"	99.0	70.0	McClelland Engineers	2/7/87
Matagorda Island	616	Matagorda 25	1219	6745	110.0	288.0	McClelland Engineers	2/8/84
Matagorda Island	634	Matagorda 17	9215	6694	86.0	86.5	McClelland Engineers	10/17/82
Matagorda Island	657	Matagorda 21	7527	6502	71.0	350.5	McClelland Engineers	6/26/83
Matagorda Island	657	Matagorda 23	6853	7666	72.0	303.0	McClelland Engineers	12/12/83
Matagorda Island	659	Matagorda 19	1544	5333	55.0	299.0	McClelland Engineers	12/20/82
Matagorda Island	664	CB-1			70.0	350.0	National Soil Services	3/11/78
Matagorda Island	665	CB-1			73.0	302.0	National Soil Services	12/15/77
Matagorda Island	665	Matagorda 7	10271	1010	73.0	343.0	McClelland Engineers	2/10/79
Matagorda Island	668	Matagorda 15	4174	4167	95.0	392.5	McClelland Engineers	6/26/82
Matagorda Island	669	Matagorda 11	12655	646	97.0	399.5	McClelland Engineers	1/26/81
Matagorda Island	669	Matagorda 14	2644	8851	108.0	89.0	McClelland Engineers	5/16/82
Matagorda Island	681	Matagorda 24	13589	8545	132.0	349.5	McClelland Engineers	11/28/83
Matagorda Island	685	Matagorda 20	4030	4040	95.0	390.0	McClelland Engineers	11/23/82
Matagorda Island	686	Matagorda 8	1591	2378	91.0	405.0	McClelland Engineers	4/2/79
Matagorda Island	s690	CB-1			41.5	150.0	National Soil Services	9/9/77
Matagorda Island	s692	Matagorda 1	9340	700	42.0	158.0	Greer and McClelland	6/30/54
Matagorda Island	s706	Matagorda 26	1828	665	40.0	65.5	McClelland Engineers	11/30/83
Matagorda Island	s825	Matagorda 22	2,679,956	41,896	44.0	324.5	McClelland Engineers	9/25/83
Matagorda Island	s827	CB-1	467 (W)	467	46.0	300.0	National Soil Services	5/17/83
Mustang Island	739	Mustang Island 26	3125	5455	122.0	393.0	McClelland Engineers	3/13/85
Mustang Island	740	Mustang Island 30	600	11840	122.0	301.0	McClelland Engineers	10/20/86
Mustang Island	749	CB-1	2,481,262.66	751,088.06	59.0	31.0	National Soil Services	8/31/72
Mustang Island	749	CB-2	2,484,165.23	755,190.15	59.0	30.0	National Soil Services	8/31/72
Mustang Island	749	Mustang Island 6			63.0	308.0	McClelland Engineers	1/1/69
Mustang Island	750	Mustang Island 15	13140	4820	66.0	245.0	McClelland Engineers	12/12/80
Mustang Island	752	Mustang Island 32	6999	15064	86.5	299.0	McClelland Engineers	4/4/87
Mustang Island	772	CB-3	2,458,774.71	745,312.5	46.0	30.0	National Soil Services	8/31/72
Mustang Island	772	Mustang Island 17	10137	8417	54.0	250.0	McClelland Engineers	8/1/82
Mustang Island	773	Mustang Island 21	7286	6919	52.0	301.5	McClelland Engineers	5/18/84

Lease Area	Block	Name	Lon. X, W	Lat. Y, S	Water Depth (ft)	Boring Length (ft)	Source	Date
Mustang Island	773	Mustang Island 22	4286	6919	55.0	100.0	McClelland Engineers	5/19/84
Mustang Island	773	Mustang Island 25	1104	6525	48.0	199.0	McClelland Engineers	3/3/85
Mustang Island	781	Mustang Island 31	15283	14357	129.0	306.0	McClelland Engineers	4/1/87
Mustang Island	784	Mustang Island 24			183.0	342.0	McClelland Engineers	9/25/84
Mustang Island	797	Mustang Island 20	2055	1135	68.0	302.0	McClelland Engineers	8/24/83
Mustang Island	831	Mustang Island 8			165.0	435.5	McClelland Engineers	1/1/75
Mustang Island	847	Mustang Island 27			123.0	402.0	McClelland Engineers	8/25/84
Mustang Island	A-11	Mustang Island 29	13247	13124	210.0	400.0	McClelland Engineers	11/27/85
Mustang Island	A-16	Mustang Island 12	4963	403	273.0	400.0	McClelland Engineers	11/17/79
Mustang Island	A-20	Mustang Island 13	14060	13043	213.0	393.5	McClelland Engineers	3/30/80
Mustang Island	A-20	Mustang Island 14	12787	11425	212.0	376.5	McClelland Engineers	3/26/80
Mustang Island	A-25	Mustang Island 28	7113	189	268.0	141.0	McClelland Engineers	11/7/85
Mustang Island	A-36	Mustang Island 23	573	7011	281.0	245.0	McClelland Engineers	9/11/84
Mustang Island	s881	Mustang Island 5	2500	3700	40.0	59.0	McClelland Engineers	1/1/57
Mustang Island	s883	Boring No. 1			46.0	254.0	National Soil Services	9/13/73
Mustang Island	s926	CB-1	2,425,035.0	690,679.0	47.0	203.0	National Soil Services	4/16/83
Mustang Island	s943	Mustang Island 16	4572	2918	42.0	204.5	McClelland Engineers	4/14/82
Mustang Island	s945	Mustang Island 2	650	3750	40.0	161.0	Greer & McClelland	1/1/54
Mustang Island	s947	Mustang Island 4	2691	2783	44.0	130.0	Greer & McClelland	1/1/57
Mustang Island	s948	Mustang Island 1	2500	1200	38.0	121.5	Greer & McClelland	1/1/54
Mustang Island	s952	Mustang Island 3	2750	1000	42.0	89.5	McClelland Engineers	1/1/56
Mustang Island East	A-065	Mustang Island 18			258.0	400.0	McClelland Engineers	11/7/82
Mustang Island East	A-085	Mustang Island 10	12774	5338	258.0	448.5	McClelland Engineers	1/1/77
Mustang Island East	A-085	Mustang Island 9	12796	5480	260.0	463.0	McClelland Engineers	1/1/76
Mustang Island East	A-086	Mustang Island 11	827	9519	264.0	439.0	McClelland Engineers	1/1/77
Mustang Island East	A-152	Mustang Island 19			281.0	303.0	McClelland Engineers	10/30/82
Mustang Island East	A-164	Mustang Island 33	8712	6306	322.0	369.0	McClelland Engineers	3/28/87
North Padre Island	882	North Padre Island 1	14615	1194	61.0	249.0	McClelland Engineers	6/23/81
North Padre Island East	A-29	North Padre Island 4	8333	7162	230.0	370.0	McClelland Engineers	3/22/84
North Padre Island East	A-30	North Padre Island 3	5271	13425	257.0	390.0	McClelland Engineers	1/1/83
North Padre Island East	A-61	North Padre Island 5	3825	1378	242.0	400.0	McClelland Engineers	9/23/84
North Padre Island East	A-72	North Padre Island 2	7594	3729	244.0	134.0	McClelland Engineers	1/26/83
South Padre Island	1048	Boring No. 1			77.5	233.5	National Soil Services	7/13/73
South Padre Island	1064	CB-1			82.0	300.0	National Soil Services	11/13/79
South Padre Island	1064				82.0	300.0	National Soil Services	11/13/79
South Padre Island	1066	Boring No. 1			60.0	254.0	National Soil Services	1/5/74
South Padre Island	1066	Well #1			60.0	254.0	National Soil Services	1/3/74
South Padre Island East	A-71	South Padre Island 1	501	14757	199.0	350.0	McClelland Engineers	10/3/84

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