Lower Coast OCS Offshore Sand Source Survey: Historic Data Review and Survey Plan Development Report

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Contributing Authors: Beau Suthard (Aptim Environmental & Infrastructure, LLC [APTIM]) was the Project Manager for this survey and the primary author of this report. He was responsible for project formulation and execution, including data analyses, interpretations, and report preparation. Mr. Suthard was supported by Jeffrey Andrews, Beth Forrest, Patrick Bryce and Alexandra Valente who provided support throughout the study and contributed to written sections of the report. Mike Miner, John Swartz and Rob Hollis from The Water Institute of the Gulf contributed to survey planning, synthesis of existing geologic and geophysical data and literature, data interpretation and development of conceptual geologic models, and report preparation.

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List of Abbreviations and Acronyms

A&M	Agricultural & Mechanical
APTIM	Aptim Environmental & Infrastructure, LLC
APTIM-CPE	Coastal Planning & Engineering, Inc.
ASP	Academic *Seismic* Portal
AWOIS	Automated Wreck and Obstruction Information System
BOEM	Bureau of Ocean Energy Management
BSEE	Bureau of Safety and Environmental Enforcement
CBRS	Coastal Barrier Resource System
CEPRA	Coastal Erosion Planning and Response Act
EFH	Essential Fish Habitat
EPA	U.S. Environmental Protection Agency
FS	Falling Stage
ft	feet
GLO	General Land Office
HAPC	Habitat Areas of Particular Concern
HS	Highstand
km	kilometers
LST	Lowstand
m	meters
MFS	maximum flooding surface
MGDS	Marine Geoscience Data System
MIS	Marine Isotope Stage
mm	millimeters
MMIS	Marine Minerals Information System
MMP	Marine Minerals Program
MPRSA	Marine Protection, Research, and Sanctuaries Act
nm	nautical miles
NOAA	National Oceanic and Atmospheric Administration
OCS	Outer Continental Shelf
REST	Representational State Transfer
SEPM	Society for Sedimentary Geology
SMP	Sediment Management Plan
TST	Transgression
TWI	The Water Institute
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WMA	Wildlife Management Areas
yrs	years

1 Executive Summary

The Texas General Land Office (GLO) and the Bureau of Ocean Energy Management (BOEM) contracted Aptim Environmental & Infrastructure, LLC (APTIM) with team member The Water Institute (TWI), to conduct geophysical surveys along the Lower, Central, and Upper Texas continental shelf. The goal of the project is to assist in a multi-agency response to categorizing sediment resources offshore for development of policies and inventories for coastal restoration, with the purpose of better maintaining ports and navigation channels (dredging), determining appropriate sediment disposal sites, and determining the location of sediment deposits for their restoration efforts aimed to mitigate for the beach erosion caused by storms and currents.

APTIM proposes to collect up to 1,790 nautical miles (nm) or 3315.1 kilometers (km) of geophysical data, of which 88 nm (163 km) of survey lines will be allocated to allow the field crew to investigate areas of high probability for future sediment sources along the Lower Outer Continental Shelf (OCS) study area. This provides the field crew with the flexibility necessary to collect additional data coverage that will provide enhanced characterization and improved vibracore placement in areas that indicate a higher sediment source potential. APTIM's survey team will be identifying areas where additional survey lines will be collected in real-time. Some areas that will likely be recommended for additional data collection include the regions previously identified as the Rio Grande River and its associated paleovalley systems.

2 Introduction

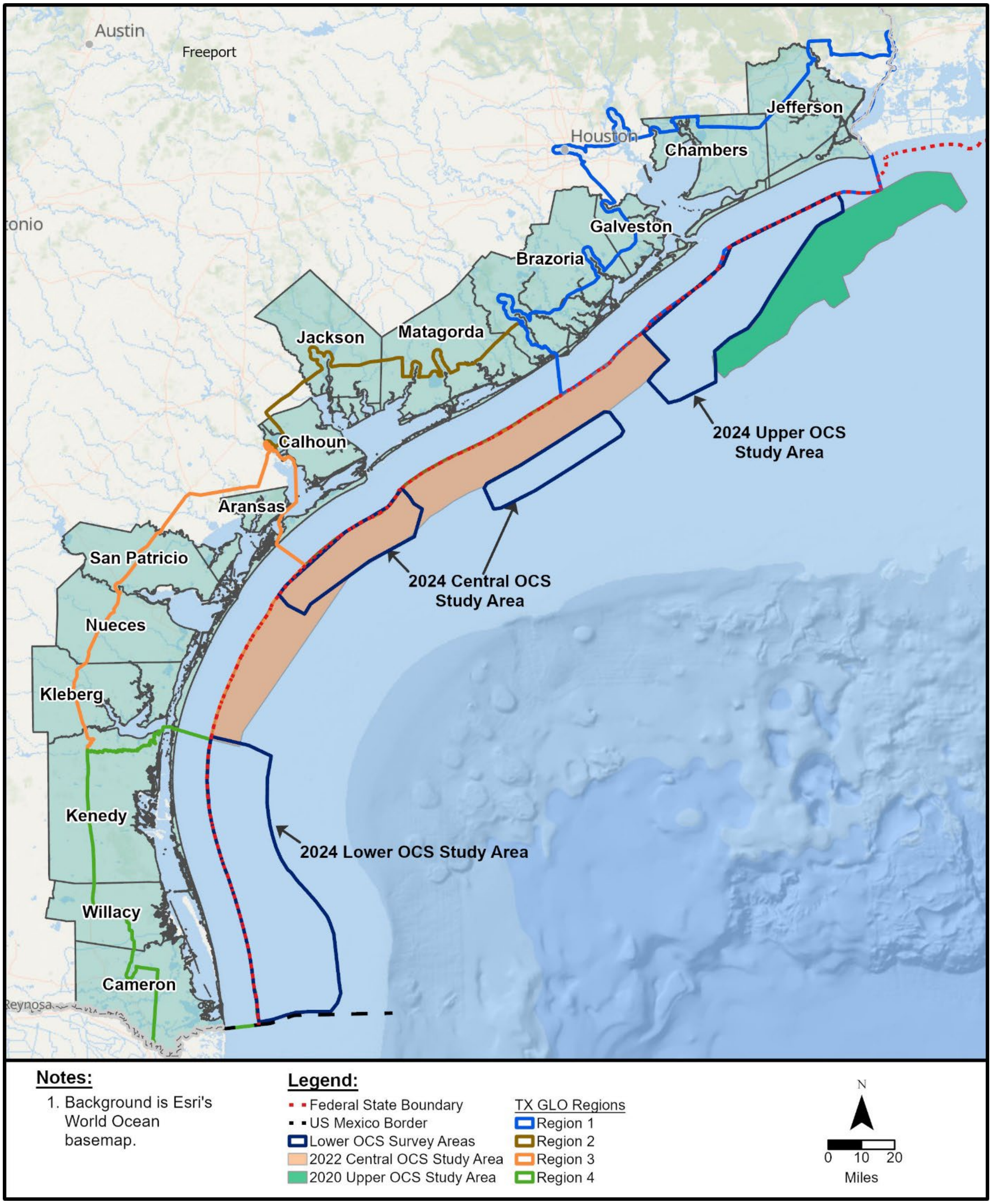
The Texas General Land Office (GLO) and the Bureau of Ocean Energy Management (BOEM) contracted Aptim Environmental & Infrastructure, LLC (APTIM), with team member The Water Institute (TWI), to conduct geophysical surveys along the Lower, Central, and Upper Texas continental shelf and deliver a framework and path forward for understanding how these sediments could be used to support state resiliency efforts. BOEM has partnered with the Texas GLO to fund and implement sediment resource evaluations in federal waters in parallel with the state effort, capitalizing on the opportunity to provide a synoptic view of where potential restoration-compatible sediments exist and optimize management strategies. The goal is to assist the GLO with its statewide mandate to protect and maintain the Texas coastline as part of the GLO's Sediment Management Plan (SMP) in support of the Texas Coastal Resiliency Master Plan project. The SMP aims to establish an inventory of coastal data to support the identification and management of sediment resources along the Texas coastline in order to implement policies, plans, and programs for beach nourishment, dune restoration, and habitat creation/restoration. By coordinating a state-wide, standardized survey of its coastline and Outer Continental Shelf (OCS), the GLO will be able to better plan for future infrastructure needs, maintain its ports and navigation channels through identification of erosional and depositional patterns, determine appropriate sediment disposal sites for future dredging projects, and determine the location of beach or marsh compatible sediment deposits that are suitable for Texas coastline restoration efforts aimed to mitigate beach erosion, land loss, and increased coastal flood risk caused by storms and currents.

To implement its holistic coastal management strategy, the GLO divided the Texas coastal zone and associated state continental shelf waters into four regions and the adjacent federal OCS into three sections: Upper, Central, and Lower. This study focuses on the Lower OCS, which corresponds with GLO Region 4 and the following state counties: Kenedy, Willacy, and Cameron (Figure 1) with additional lines being collected along the Central and Upper OCS regions to augment the previous investigations conducted by APTIM in 2022 and 2023 (APTIM and TWI 2022 and APTIM and TWI 2024b). In order to efficiently plan and coordinate this investigation, the GLO and APTIM have developed a two-phase project approach. Phase 1, referred to as a desktop analysis, consists of an initial data review, synthesis of prior investigations, and development of specific sediment resource target hypotheses to be tested. The results of this analysis will be used to inform, plan, and implement a reconnaissance-level geophysical survey to construct an initial geologic framework, identify the most promising potential sediment resource locations, and plan additional geotechnical data collection to quantify sediment resource reserves. Upon completion of the historic data review and survey planning (Phase 1), APTIM will move onto Phase 2 of the investigation, which consists of a full-suite geophysical data collection effort (chirp sub-bottom, sidescan sonar, magnetometer, and single beam fathometer) along the Lower, Central, and Upper OCS, as well as data processing and interpretation and report writing.

Phase 1 consisted of compilation of available existing datasets, followed by a review of the data for its suitability to advance GLO SMP objectives, prominent data coverage gaps, and the construction of an initial geologic framework through a relevant literature review. As part of this first phase, APTIM compiled bathymetric and sub-bottom data as well as geotechnical information (vibracores and grab samples) and analyzed previously delineated sediment deposits. These data were correlated with scientific reports to assist in the identification of potential sand resources and construct preliminary hypotheses of resource occurrence. Within the Lower OCS region Phase 1 resulted in the development of a roughly 3-nautical mile (nm) or 5.6-kilometer (km) survey plan square grid survey plan with additional 5% of base mileage to be allocated in the field for further investigate promising results.

Along the Central and Upper OCS region, APTIM, TWI the GLO, and BOEM reviewed the geophysical data collected in 2020 and 2022 (APTIM and TW, 2022 and APTIM and TWI 2024b) and identified specific areas that would benefit from additional data collection to further assist in the understanding of the geologic framework and constrain potential resources (Figure 1). Within the Central OCS, three (3) areas were identified for the collection of 353 nm (653.8 km) geophysical data. These identified areas will supplement the existing dataset and further assist in constraining features (channel systems and deposits) identified as being potential resources of sand. Within the upper region, 548 nm (1014.9 km) of geophysical data will be collected covering the area between the state and federal data collection efforts from 2020. This will allow for a better understanding and merging of the two datasets. Information on the compiled data, resources, and data types used for Phase 1 that support the survey plan are described within this report.

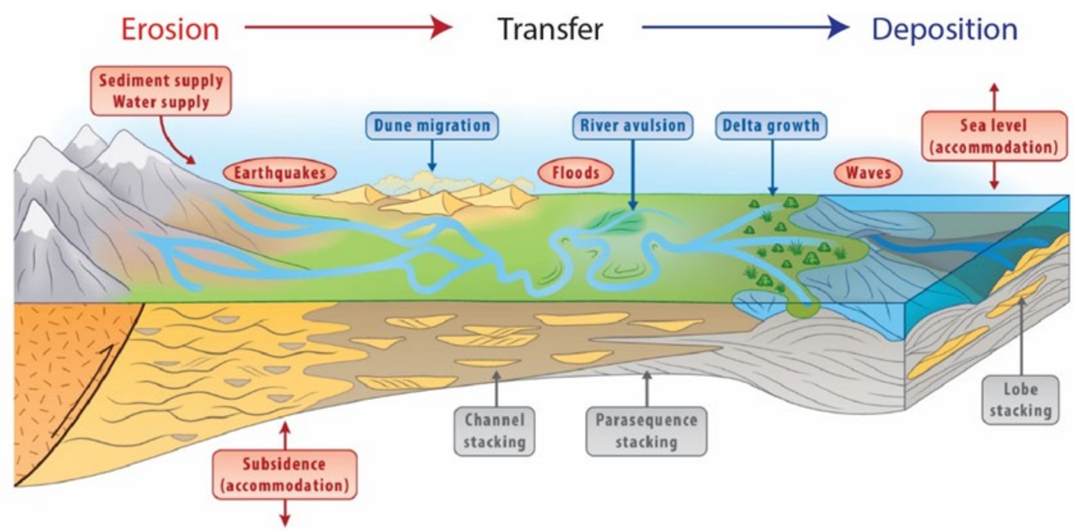
Figure 1. Location of BOEM OCS Study Areas and GLO Regions



3 Geologic Approach to Sediment Resource Prospecting

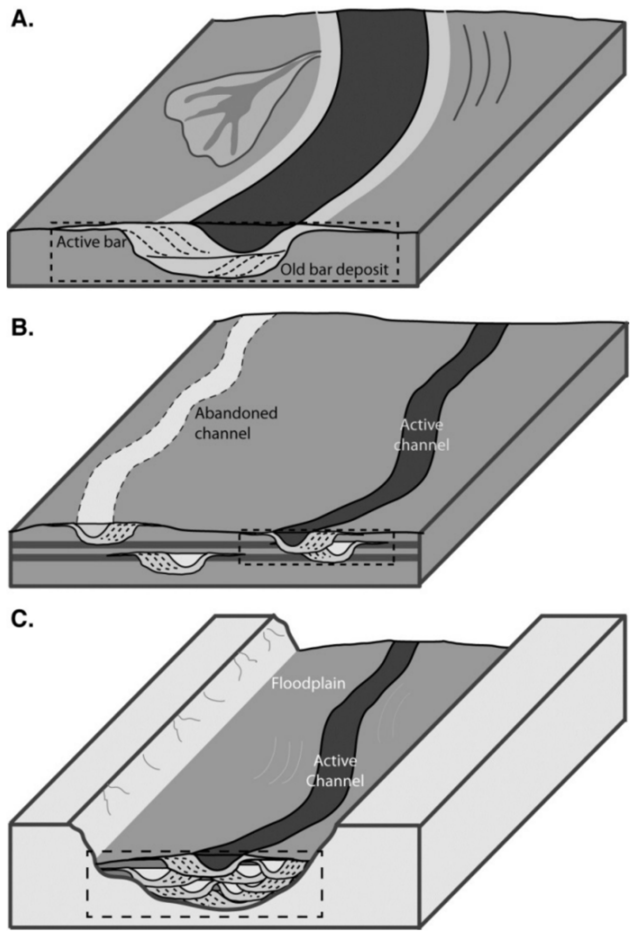
Accurate identification and quantification of potential sediment resources, as well as the prediction of further occurrence, is greatly aided by the development of an initial geologic framework. Coastal systems and continental shelves may have very localized processes and geologic history, but a region-specific synthesis of this evolution allows for high-grading of the most promising areas and the potential processes responsible for deposition and preservation of sediment resources, which in turn allows for economically efficient targeted data collection and science-based de-risking of geotechnical properties of identified geologic resource deposits. This investigation employs a source-to-sink approach to develop a geologic model that predicts sand resource occurrence and quantifies sand resource estimates at a reconnaissance scale to inform future detailed exploration. In simple terms, the source-to-sink approach considers the Texas coastal system and associated continental shelf holistically throughout its evolution with a focus on coarse-grained sediment delivery to the coast from upland fluvial sources via the fluvial channel belts and potential subsequent reworking and concentration of sands by coastal processes. This source-to-sink approach involves creation of a regional framework geology based on an understanding of the processes and drivers of sediment erosion, transport, and deposition in the fluvial to marine transition zone over various timescales. In this way, areas of sediment production (e.g., fluvial inputs, erosional sources, etc.) are linked to sediment transfer or dispersal corridors (fluvial channel belts, deltaic distributary channels, tidal channels, and shorelines) and ultimately locations of restoration-quality sediment deposition and preservation (Figure 2). Key to the regional geologic models built here is the incorporation of foundational, depositional, and erosional processes associated with specific landforms and environments; how they interact over time, and what the overall pattern of resulting sedimentary deposits are likely to be. Fluvial systems that built the Texas shelf consist of vastly different drainage basins, climates, and therefore sediment delivery to the coast as sea level positions changed throughout geologic time. Importantly, the approach employed here allows for prediction of potential deposit occurrence (e.g., where are sandy deposits located on the shelf) with constraints to their potential geotechnical variability and relation to surrounding subsurface stratigraphy (Figure 3). An accurate understanding of the relative history and formational processes of each specific region is required to explain the patterns of occurrence for sand resource deposits.

Figure 2. General Illustration of Source-to-Sink Concepts. The Texas Coastal Plain is Located within the Transfer and Deposition Domains



Note: Synoptic views of rivers and delta systems emphasize the predictability of changes in sedimentary processes and potential deposits as a function of location along the axis of the total system. Key to recognition and effective use of sediment resources is placing observed sediments within a broader process context that aids in the prediction of deposit size, continuity, geotechnical properties, and compatibility with restoration projects. Modified from Hajek and Straub 2017.

Figure 3. Conceptual Block Diagrams of the Hierarchy and Relationship of Sand-Rich Deposits Formed by an Ancient River Relative to the Surrounding Floodplain



Note: A) Lateral migration of a meandering river creates complex stratigraphy but potentially high net to gross sand deposits. B) Avulsive river systems can create discrete sand-rich channel belts within a larger mud-dominated floodplain system, requiring dense data coverage to accurately quantify position and volumes of restoration-quality sediment. C) River erosion can lead to formation of an incised valley, which constrains the lateral extent of an ancient river. Modified from Chamberlin and Hajek 2015.

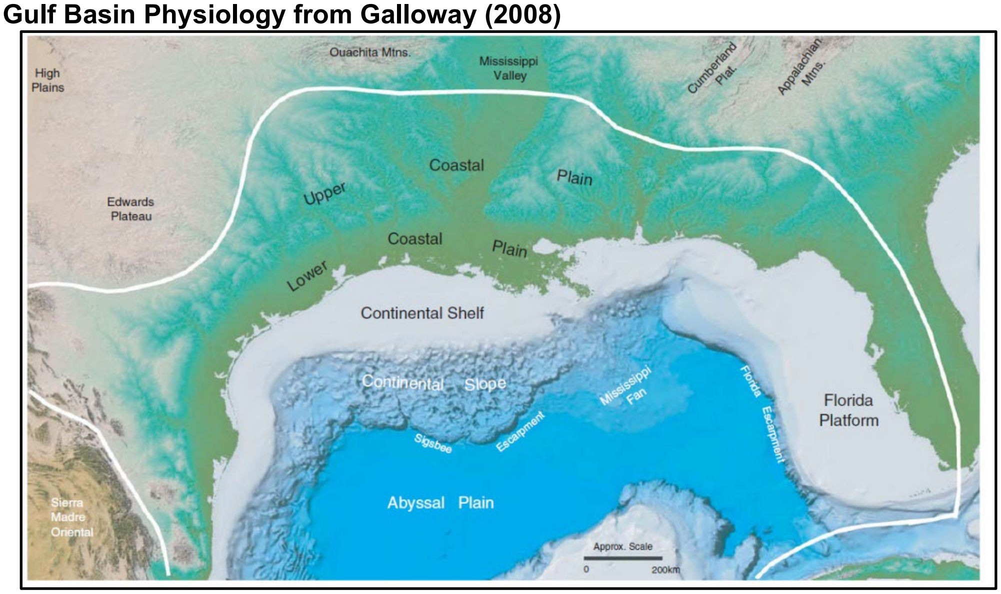
4 Sediment Resource Relevant Geologic History of the Gulf of Mexico

Below is a description of the formation of the Gulf of Mexico Basin, the coastal plain of Central and Southern Texas, and the development of the Rio Grande River. This geologic context is required for understanding the origin, evolution, and specific properties of observed deposits that make up the current continental shelf in order to identify promising sediment resources in the Lower Coast OCS.

4.1 Gulf Basin Evolution and Early Gulf of Mexico Formation

The Gulf of Mexico Basin is the product of crustal extension, rifting, and seafloor spreading during the breakup of the supercontinent Pangea as the North American Plate separated from the South American and African Plates (Salvador 1991; Buffler et al. 1994; Galloway 2008). The basin is filled with up to 9.5-mile-thick sedimentary deposits that range from Jurassic to recent ages with some older Triassic sedimentary rocks preserved locally in graben structures associated with Triassic rifting (Salvador 1991). Extension continued through early Jurassic when flooding of the basin from the Pacific Ocean and subsequent evaporation of sea water resulted in deposition of thick evaporite deposits, primarily the Jurassic L Salt (Burke 1975; Galloway 2008). Widespread salt deposition in this period has greatly influenced subsequent surface morphology, brittle deformation, development of shelf stratigraphic sequences, and hydrocarbon production (Galloway 2008). Subsequent to salt deposition, a later phase of seafloor spreading continued opening the basin to develop basaltic oceanic crust that underlies much of the deepwater Gulf of Mexico (Nguyen and Mann 2016). Early Cretaceous carbonate reefs and platforms rimmed the basin and defined its modern extent; however, by the late Cretaceous the area of the North American continent draining into the Gulf increased as did associated terrigenous deposition, inhibiting further carbonate development. This continental scale drainage reorganization led to burial of carbonates by thick clastic (sandstones and mudstones) deposits that persisted from late Cretaceous through Quaternary time producing the broad continental shelf and slope of the northern Gulf (Figure 4; Galloway 2008).

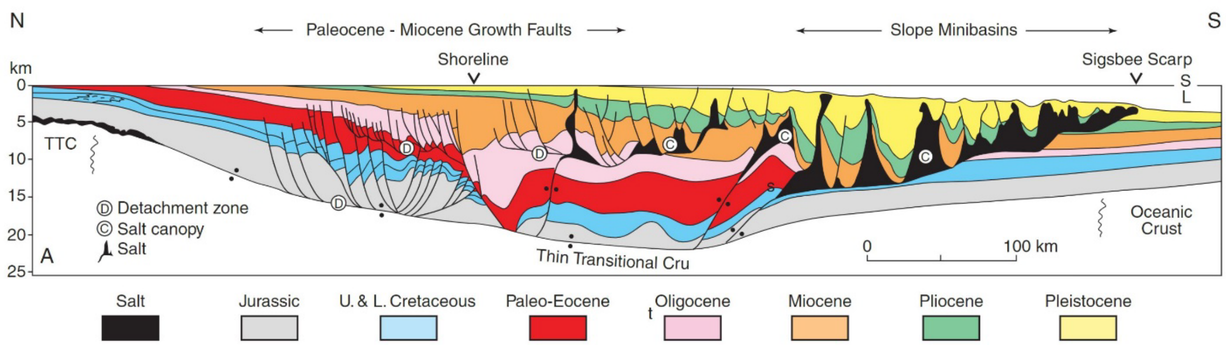
Figure 4. Gulf Basin Physiology from Galloway (2008)



Note the broad continental shelf and Sigsbee Escarpment along the base of the continental slope that is the result of basinward salt extrusion.

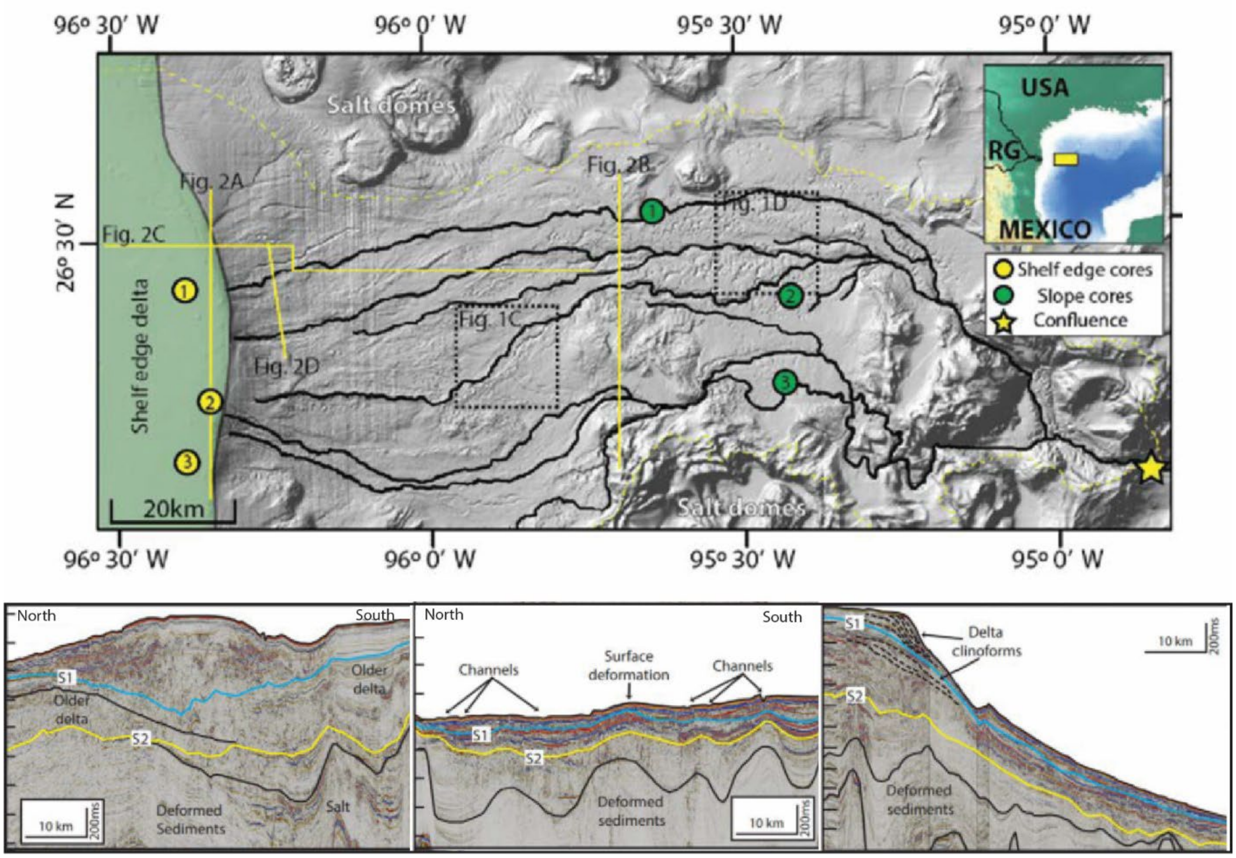
Loading of the Louann salt resulted in extrusion of salt vertically upward through overlying Jurassic through Cenozoic sections in the form of salt diapirs and tongues, as well as laterally basinward to form sheets that extrude to the surface as observed along the Sigsbee Escarpment (Figure 4 and Figure 5; Diegel et al. 1995). This deforming basal deposit greatly influenced Cenozoic structural evolution of the Gulf as younger, prograding deposits forced salt motion and attendant brittle deformation of the overlying strata (halotectonics) that is characterized by development of uplift in areas where salts are migrating vertically or laterally and subsidence over areas of salt withdrawal (Diegel et al. 1995). This process of creating accommodation space for sediment deposition over evacuating salts facilitates a feedback loop where sediment loading forces extrusion and continued subsidence facilitates further loading and extrusion. Surficial expression of salt domes and associated deformation along the coast and on the inner continental shelf of the Western Gulf of Mexico are not commonly observed or documented, with the majority of the modern shelf dominated by the Oligo-Miocene detachment province (Diegel et al. 1995), although it is underlain by significant shale and salt masses that link to the contractional foldbelt provinces at the base of the western Gulf slope such as the Perdido Foldbelt (Weimer and Buffler 1992). Recent investigations of the continental slope offshore of the Western Gulf continental shelf have observed significant salt and mud diapir structures that have been wholly buried by deposition sourced from the Rio Grande River (Figure 6; Swartz 2019). The modern Rio Grande River also marks the approximate transition from the Corsair Faults Zone and associated Miocene minibasin province to the north and the Lamprea Trend and Burgos Basin of Mexico to the south (Vasquez-Garcia 2018).

Figure 5. Generalized Dip-Oriented Stratigraphic Cross-Section of the Northern Gulf Basin



Note the basinward dipping Jurassic to Pleistocene deposits and influence of salt diapirism. From Galloway (2008).

Figure 6. Bathymetric Map and Multi-Channel Seismic Cross Sections from the Continental Slope Offshore the Lower OCS

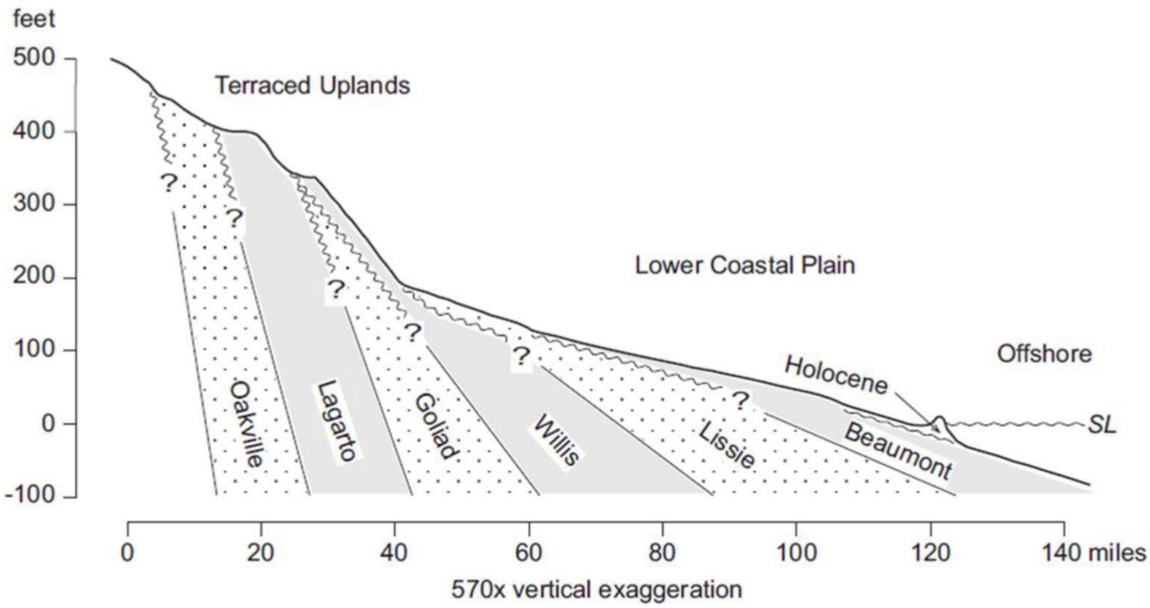


Note: The continental slope is dominated and built by a submarine fan sourced from the ancient Rio Grande River feeding shelf edge delta systems, with high sedimentation rates that buried and suppressed diapirism and associated surface deformation. Construction of such fans requires sustained transport of coarse-grained material across the continental shelf and predicts the occurrence of significant fluvial and deltaic deposits in the Lower OCS study area. Modified from Swartz 2019.

4.1.1 Quaternary Geology

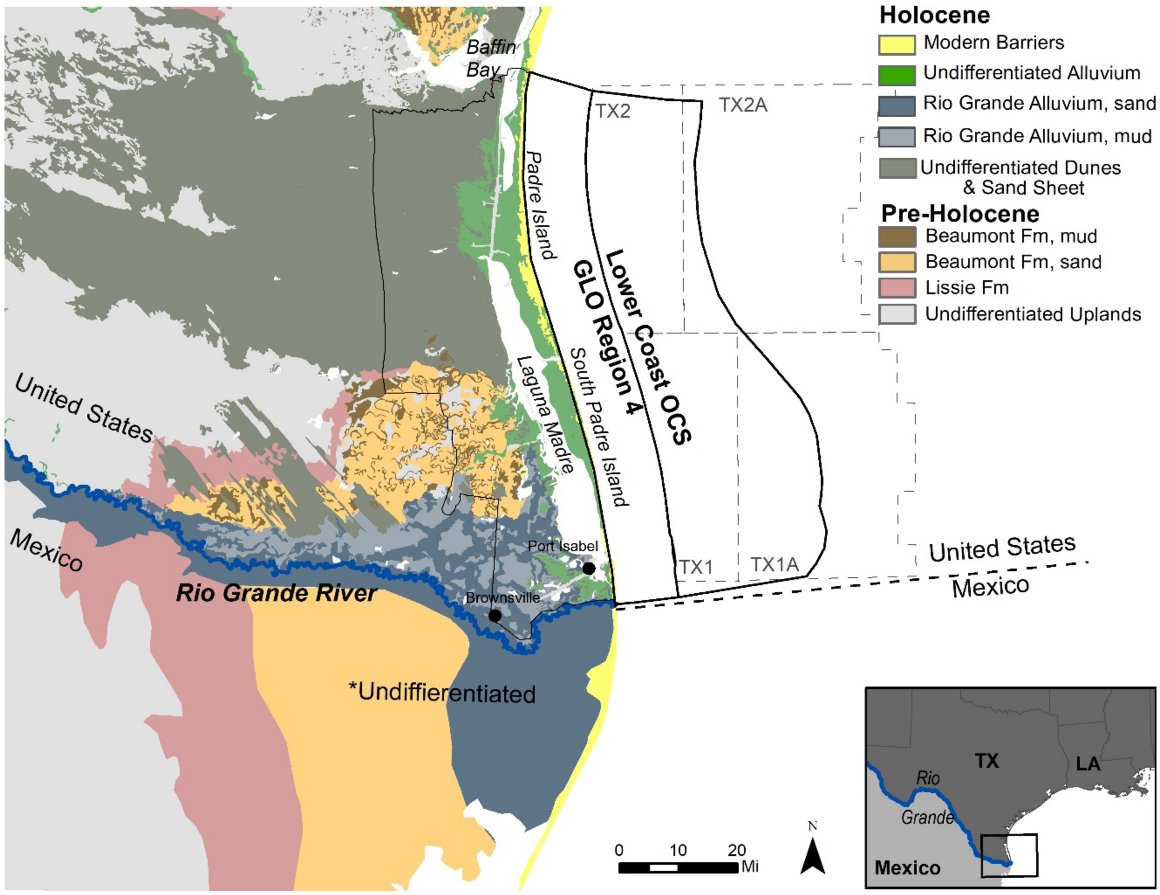
The Quaternary coastal plain of Texas and the offshore inner continental shelf consists of fluvial deposits and coastal deposits associated with sea-level fluctuations and basin subsidence. Stratigraphically, this has resulted in a series of unconformity-bounded, seaward dipping clastic wedges that are Pliocene to Late Pleistocene age producing coast-parallel terraces due to variations in erosional resistance (Brown et al. 1976; Fisher et al. 1972, 1973; Young et al. 2012; Heinrich et al. 2020). Each of these wedge units are characterized by terrestrial deposits that grade basinward into coastal and shallow marine deposits (Figure 7. Of interest to this discussion is the most recent Pleistocene unit, the Beaumont Formation that comprises a complex of Pleistocene depositional units. While initially built for East Texas, the generalized structure is broadly similar to the Central and Lower Texas coastal plain geology as well (Young et al. 2012). Primary differences for the Lower Texas coastal plain are the dominance of the Rio Grande delta system, colloquially referred to as the Rio Grande Valley (Swartz et al. 2022). The surface of the Beaumont Formation is often characterized by oxidized sands and stiff clays (paleo-soil horizons) due to subaerial exposure during the most recent sea-level lowstand. In most areas of the lower coastal plain, the Beaumont Formation forms the land surface where Holocene coastal and alluvial deposits are absent. Detailed discussion of the Quaternary geology of the Texas coastal plain can be found in Young et al. (2012) and the Environmental Geologic Atlas of the Texas Coastal Zone series produced by the Texas Bureau of Economic Geology (McGowen et al. 1976; Fisher et al. 1972, 1973). See Figure 8 for study area location and Quaternary geologic features of interest.

Figure 7. Idealized Dip Cross Section for the Upper Texas Coastal Plain (Young et al. 2012)



Note the Beaumont Formation and Rio Grande Alluvium have been subdivided into its mud- and sand-dominated members within United States boundaries (Modified from McGowen et al. 1976; Brown et al. 1976; Page et al. 2005; Moore et al. 2021). Only general Beaumont Formation and Rio Grande Alluvium are presented within Mexican boundaries.

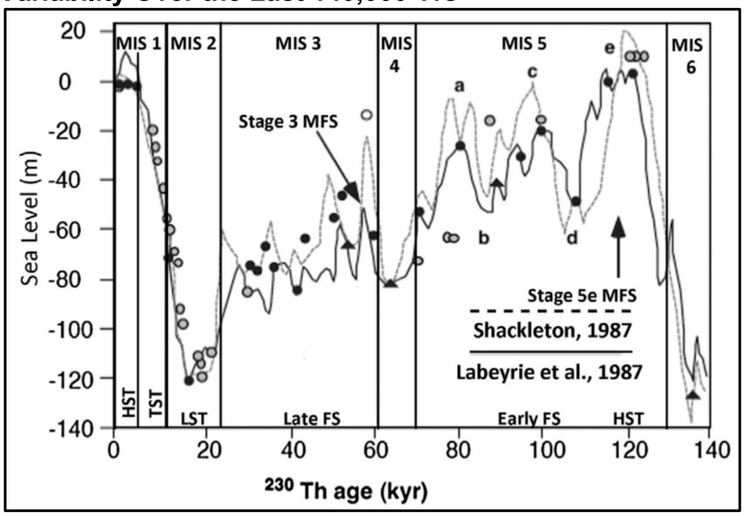
Figure 8. Region 4 and Lower OCS Coastal Zone and Surrounding Quaternary Geology. Major Rivers Denoted in Blue



4.1.2 Late Quaternary Sea-Level Changes (120,000 Years Ago to Present)

Coastal and fluvial response to sea-level changes in the study area has dominated the geomorphic evolution (deposition and erosion of sediments) of the study area since the mid-Pleistocene (~900,000 years [yrs] ago). These changes in sea level are the results of periodic growth of continental ice sheets that reduce the volume of seawater and lower sea levels on the order of hundreds of feet and result in Gulf shorelines migrating basinward, referred to as *regression*, to coincide with the shelf edge during maximum lowstands of sea-levels. Conversely, melting glacial ice results in sea-level rise, a term referred to as *transgression*. Sea-level, or base-level, is not the only control as coincident with such changes are climatic driven shifts in water discharge and sediment flux, which can overprint the eustatic signal or overwhelm it. For the purpose of this discussion relative to sediment resources within the study area, an understanding of the most recent glacio-eustatic cycle (beginning ~120,000 yrs ago) is crucial to interpreting the resulting stratigraphic record as observed in the continental shelf (Figure 9). During this time sea-level was approximately 30 feet (ft) or 9.1 meters (m) above present levels (Simms et al. 2013) and the shoreline correlated with the preserved Ingleside Shoreline that extends from eastern Louisiana to Corpus Christi, Texas. The Ingleside Shoreline represents the highstand barrier island shoreline dating to approximately 120,000 yrs (Price 1933; Otvos and Howat 1996, Simms et al. 2013). Subsequent to this highstand, sea-level began to fall until about 70,000 yrs ago when it was approximately 250 ft (76.2 m) below present levels. This was followed by a warming period where sea-level rose to approximately 50 ft (15.2 m) below present and then fell to about 400 ft (121.9 m) below present by 22,000 yrs ago with the shoreline located at the shelf edge (Anderson et al. 2004, 2016). This most recent lowstand of sea-level persisted from approximately 22,000 to 17,000 yrs ago (Anderson et al. 2004). Between 17,000 and 4,000 yrs ago sea level rose ~400 ft (121.9 m), to close to its present position along the modern coastline (Anderson et al. 2016).

Figure 9. Sea-Level Variability Over the Last 140,000 Yrs



Note the present and 120,000 yr highstands (HS), falling stage (FS) between 120,000 and 22,000 yrs ago, the lowstand (LST) from 22,000 to 17,000, and transgression (TST) from 17,000 to 4,000 yrs ago. Marine Isotope Stage (MIS). Maximum flooding surface (MFS). From Anderson et al. (2016).

The following sections discuss depositional and erosional response within the study area to changes in sea-level and the development of shelf sand deposits. The discussion is divided into falling stage and lowstand, transgression (sea-level rise), and highstand deposits.

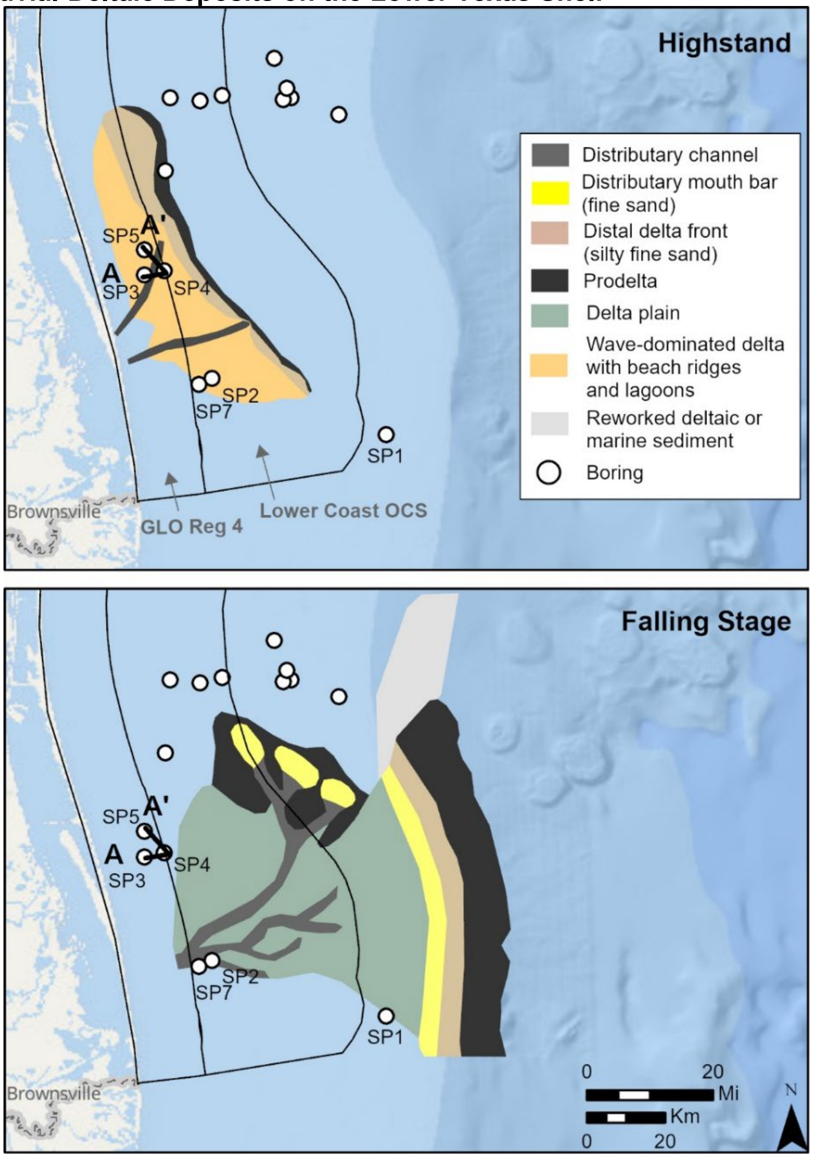
4.1.3 Highstand, Falling Stage and Lowstand (~120,000-17,000 Yrs Ago)

During the falling stage of sea-level ~120,000 – 22,000 yrs ago, river channels began vertically incising down into pre-existing shelf deposits (e.g., Beaumont Formation and older); however, development of deep incised valleys did not dominate until late falling stage and into the lowstand (Anderson et al. 2016; Anderson et al. 2022). The south Texas shelf was a steep, ramp-like setting during the highstand (120,000 yrs ago) and provided large accommodation space for the early falling stage (120,000- 80,000 yrs ago) elongate wave-dominated deltas of the Rio Grande (Banfield and Anderson 2004; Figure 10A). Wave-dominated deltas display concentrated sand deposits from the modern Brazos River delta (Rodriguez et al. 2000). Sediment supply was thought to increase during the falling stage (80,000 – 22,000 yrs ago), which allowed for the construction of expansive deltas, building the modern shelf (Banfield and Anderson 2004; Figure 10B). The fluctuations in sea level during the falling stage impacted the progradation of large fluvially- dominated deltas that shifted periodically to wave-dominated deltas or backstepping deltas during sea level rise (Anderson et al. 2016). The shifting between elongate and lobate external form, clinoform packages and a few sediment borings are the basis for interpretation of wave-dominated vs fluvial-dominated delta switching throughout the Pleistocene. Erosion and reworking of previous deltaic deposits partially supplied sediment for new delta growth during incisional stage falling sea-levels. Archival sediment borings sampling the relict 120,000 yr old Rio Grande sandy wave-dominated delta show a coarsening upward sequence of medium sand about 50 ft (15.2 m) thick (Banfield and Anderson 2004).

Sandy deposits potentially associated with younger early falling stage to lowstand deposits (80,000-22,000 yrs ago) are exposed at the seafloor (Banfield and Anderson 2004). These grey-brown fine sands and silty sands packages are roughly 75 ft (22.9 m) thick (Figure 11; SP-3, SP-4), likely have cross-shore continuity, and warrant further investigation in the current sand resource mapping effort within the Lower OCS.

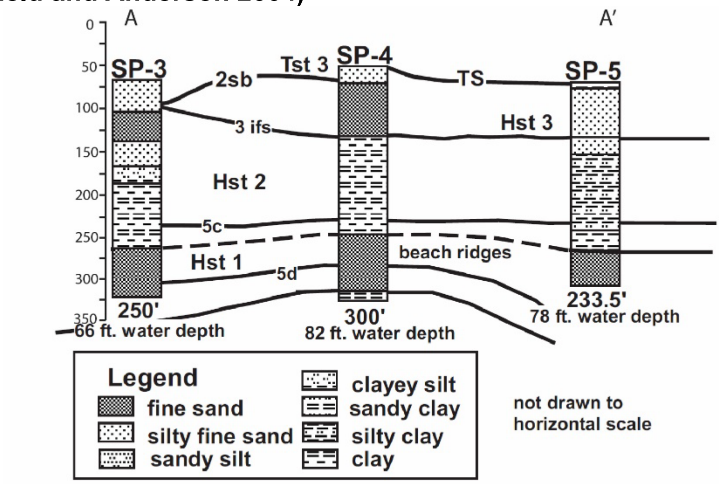
Two lowstand valleys are mapped on the inner shelf offshore the Rio Grande, the smaller northern valley or feeder channel was related to the MIS3 delta system (Banfield and Anderson 2004). The larger southern incised valley system begins as a wide shallow system on the inner shelf, deepening towards the shelf margin with an incisional depth of up to 300 ft (91.4 m) near the shelf margin (Banfield and Anderson 2004). The Rio Grande has an extensive shelf edge delta (Figure 12) and fan system (Figure 13) associated with this lowstand valley (Swartz 2019, Banfield and Anderson 2004, Suter and Berryhill 1985). As the fluvially-dominated deltas built seaward, Banfield and Anderson (2004), interpret sandy silt and silty sand packages as mouth bar deposits incising into prodelta muds. Cores, located outside the current mapping effort, from this sandy deltaic sequence show over 100 ft (30.48 m) of fine sand with shells with no overburden (Banfield and Anderson 2004; SP-1). However, archival seismic data show continuation of this package within planned Lower OCS data coverage out to the 50m isobath. The falling stage to lowstand delta-fan complex is made up of stacked submarine channel-levee deposits and sand-rich reworked mass-transport complexes (Swartz 2019). The modern submarine channel systems initiate below the shelf-slope break at roughly the ~100m isobath and coalesce downslope into the Perdido Canyon (Rothwell et al. 1991; Damuth and Olson 2015; Swartz 2019). Piston cores of these channels indicate transport of sand from the shelf edge delta systems to the slope during the last glacial maximum (~22,000 yrs ago) based on foraminiferal analysis (Damuth and Olson 2015; Olson et al. 2016). Supporting these geologic observations of sustained sediment transport and building of large depositional complexes far above what would be expected for the modern Rio Grande River is paleoclimate evidence and modeling for significantly higher precipitation within the Rio Grande basin during the last glacial maximum, and likely associated higher sediment flux (Oster et al. 2015; Figure 14).

Figure 10. Highstand (A) Wave-Dominated Deltaic Deposits and Falling Stage (B) Regressive Fluvial-Deltaic Deposits on the Lower Texas Shelf



Note that these deposits are not fully preserved due to subsequent erosion during transgression. Modified from in Banfield (1998).

Figure 11. Cross Section A-A' Showing Vertical Relationships of Stacked Fluvial-Deltaic Deposits (Banfield and Anderson 2004)



Note these borings are within Region 4 state waters and boring description sheets are found in Banfield (1998).

Figure 12. Late Falling Stage and Lowstand Valleys and Shelf Fan Deposits (C) and Lowstand Shelf Margin Deltas of the Rio Grande System (modified from Banfield and Anderson 2004)

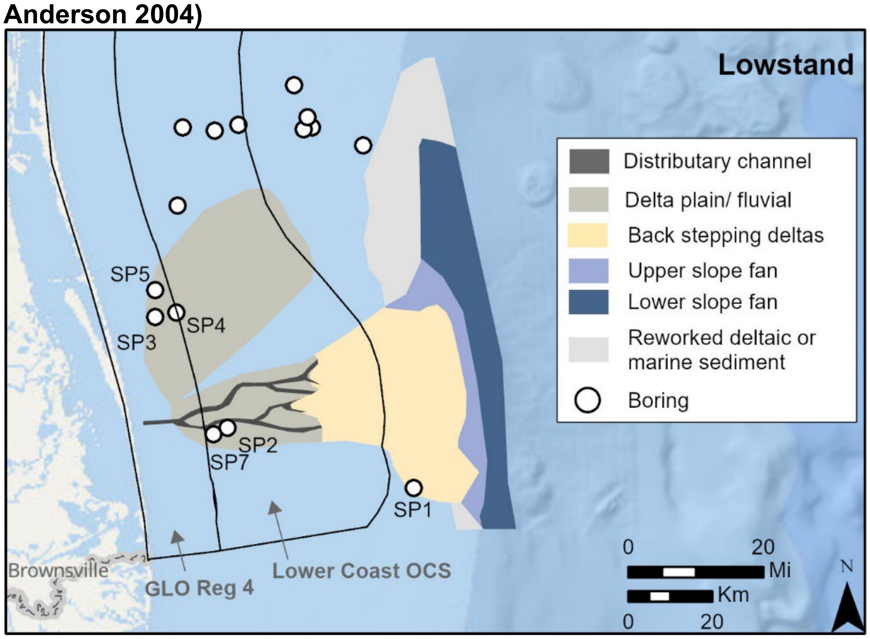


Figure 13. Lowstand Valleys and Fans of the Southern Texas Systems (Anderson et al. 2016)

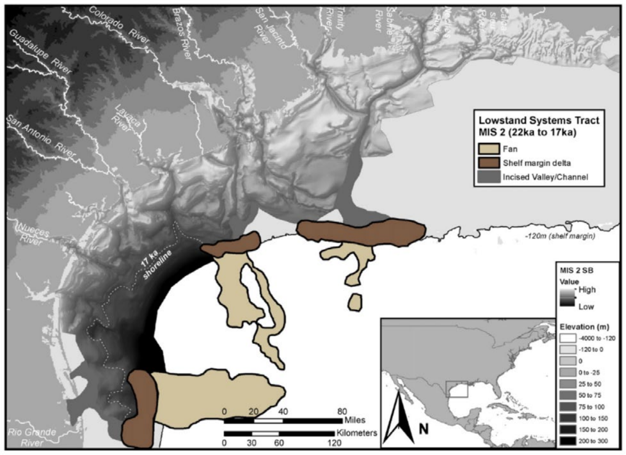
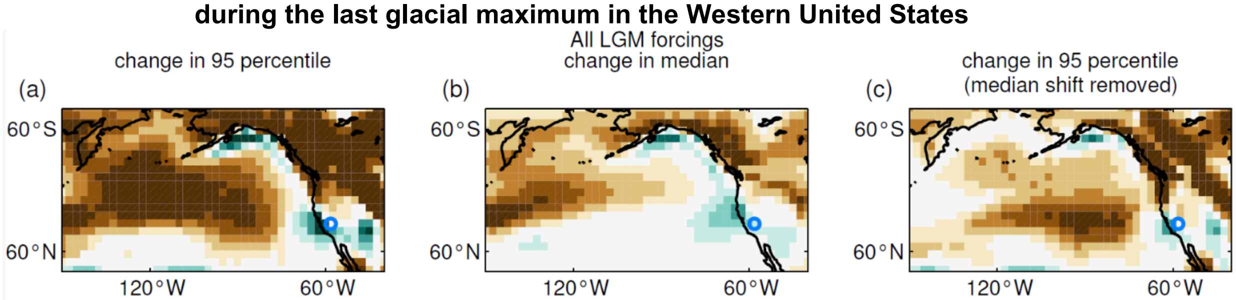


Figure 14. Community Earth System Model (CESM-1) Paleoclimate Reconstruction of Precipitation during the last glacial maximum in the Western United States



Note: Significant increases in extreme precipitation events are observed within the Rio Grande basin in these models which could explain higher sediment flux and associated observed depositional architecture (Oster et al. 2015).

4.1.4 Transgression (~17,000 – 4,000 Yrs Ago)

During transgression, lowstand deposits filled the inner shelf incised valley and began building a series of transgressive deltas (Banfield and Anderson 2004). High sediment supply built a fluvial-dominated delta (TST 2) and shifted to more of a wave-dominated delta (TST3; Figure 15) as sediment supply diminished slightly in times of sea level rise rates of nearly a centimeter a year during the transgression (Figure 9). The uppermost deltaic shelf-edge sands were dated between 11,000 to 9,000 yrs old (Swartz 2019), indicating persistent sediment delivery across the modern shelf to the shelf edge delta and slope systems through the early Holocene (Swartz 2019; Olson et al. 2016). These transgressive deltas are seaward of the 50m isobath, or Lower OCS planned data coverage in this study. The inner shelf chronology and stratigraphy is poorly constrained. As sea levels rose, transgressive reworking of prior Rio Grande shelf deltas supplied fine-grained sediment through shelf currents to the Central Texas Mud Blanket (Weight et al. 2011; Anderson et al. 2016; Figure 16). This marine mud deposit has been previously mapped over 150 ft (45.7 m) thick within the Lower OCS region and pinches out in Region 4 state waters to less than 5 ft (1.5 m) thick (Weight et al. 2011; Banfield and Anderson 2004). While not of importance for utilization as sediment resources, it is critical to understand overburden distribution to underlying sandy deltaic and fluvial deposits.

Figure 15. Transgressive Stage Deltas (modified from Banfield and Anderson 2004)

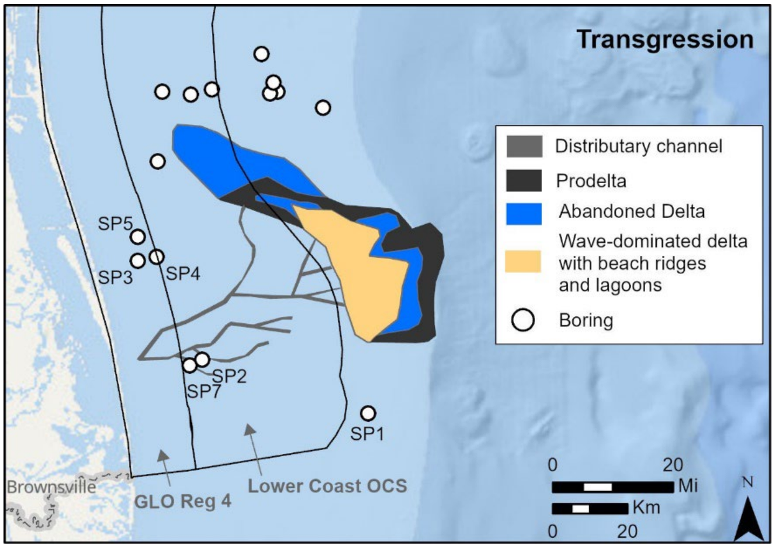
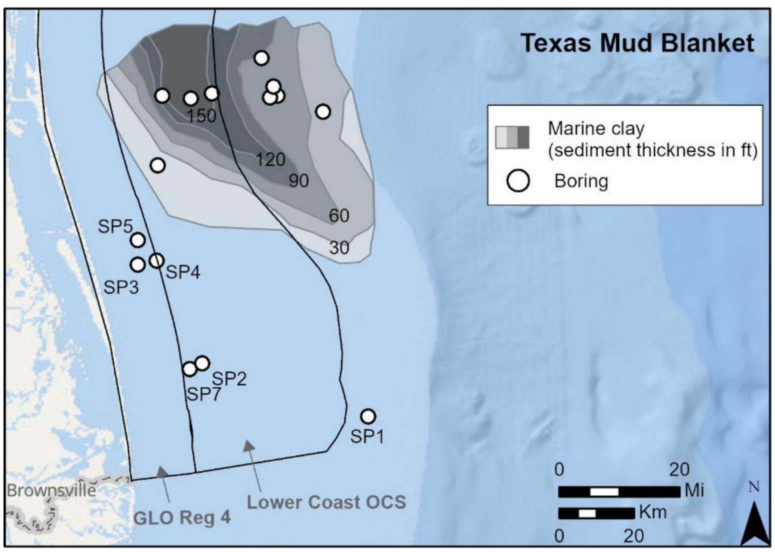


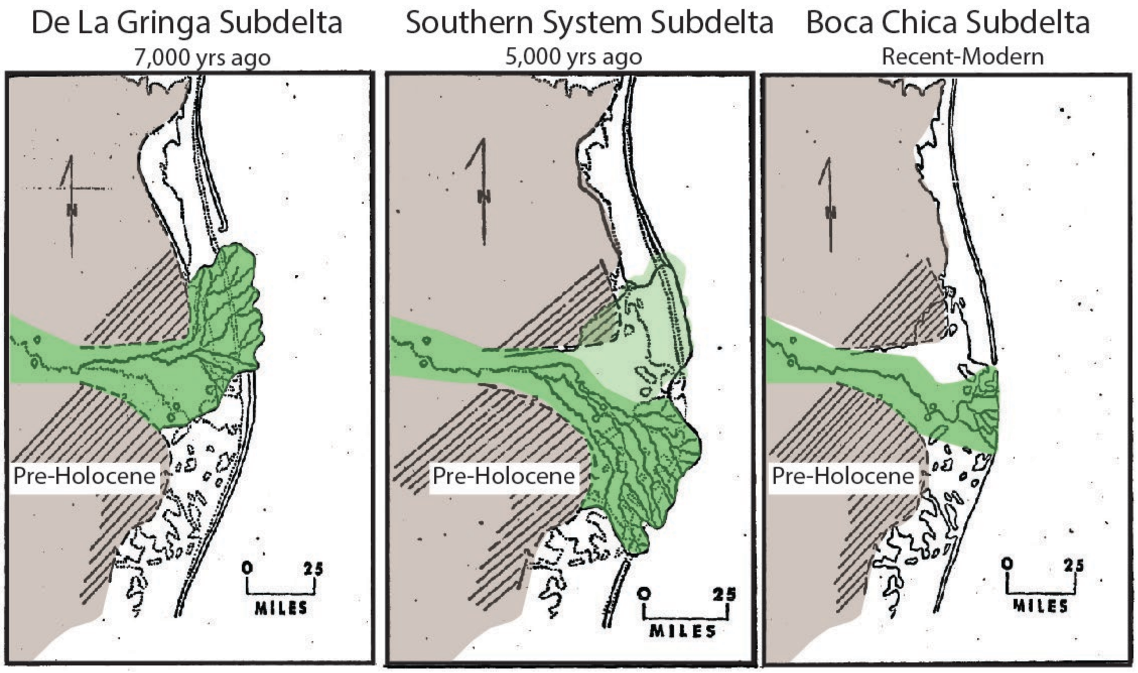
Figure 16. The Southern Portion of the Texas Mud Blanket Extent and Thickness (modified from Banfield and Anderson 2004)



Note isopach contours in feet.

Onshore, delta building remained throughout the mid Holocene from 7,000 to 5,000 yrs ago (Fulton 1976; Figure 17) before diminished sediment supply due to climatic shifts from a wet humid to arid environment led to transgressive reworking occurred (Banfield and Anderson 2004; Anderson et al. 2016). Onshore, Fulton (1976) and Lohse (1952, 1958) delineate the Resaca De la Gringa subdelta being active about 7,000 yrs ago. Avulsions led to lobe switching and progradation of the onlapping southern System subdelta, dated to 5,000 yrs before present. Fluviatile point bar sands associated with meandering channel belts can be up to 30 ft (9.1 m) thick and up to 80 percent sand (Fulton 1976). The best developed, most continuous channel belts maintain widths of 1.3 nm (2.4 km) (across and up to 15 ft [4.6 m] of positive relief) (Fulton 1976).

Figure 17. Mid-Holocene to Modern Rio Grande Subdelta Lobes (modified from Fulton 1976)



4.1.5 Incised Valley Fills

Within the study area, the Rio Grande Valley is an overfilled valley (Simms et al. 2006) displaying avulsive, constructional channel belts as evident in modern lidar (Figure 18). The southern valley fill from onshore to the inner shelf is comprised of variable Late-Pleistocene basal transgressive sand deposits, relatively thin deltaic sequences, but almost entirely with fluvial fill consisting of muddy flood plain with isolated channel sands (Fulton 1976; Banfield and Anderson 2004; Anderson et al. 2014; Figure 19). The inner shelf portion of the study area is poorly constrained, yet it is reasonable to assume these fluvial feeder channel systems continue onto the shelf where a series of extensive deltas and lowstand fans are mapped by (Banfield and Anderson 2004; Anderson et al. 2016; Swartz 2019). Fluvial deposits mapped onshore show good continuity and are up to 30 ft (9.1 m) thick of fine sand (Fulton 1976) and thicken offshore to more than 50 ft (15.2 m) (Banfield 1998).

Figure 18. Lidar Showing the Overfilled Valley Mapped from Borings, not the Aggradational Alluvial Ridges (from Swartz 2019)

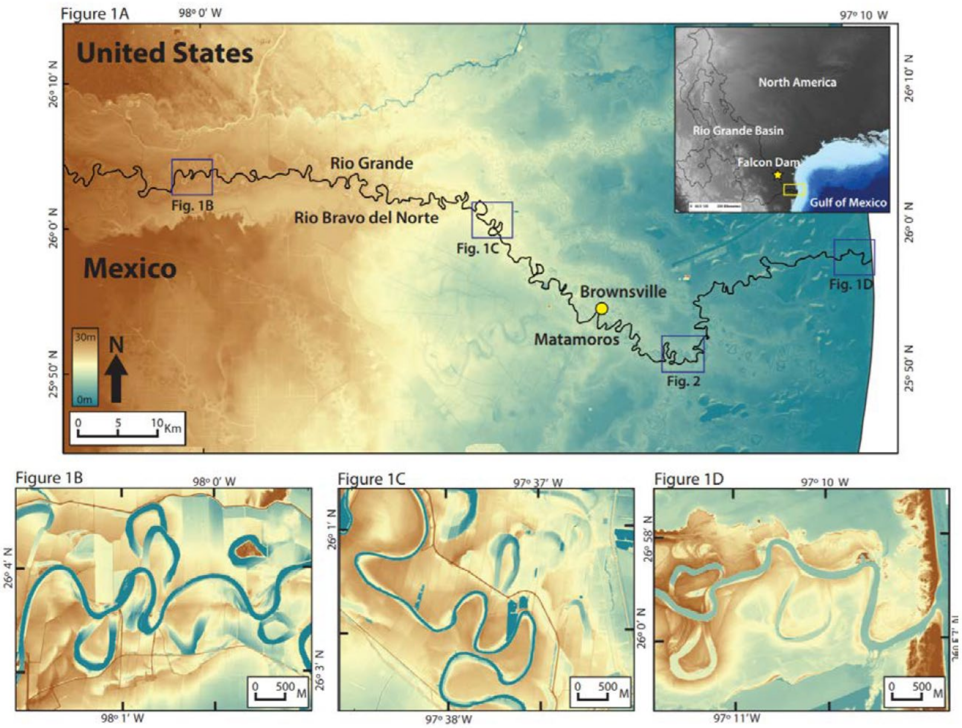
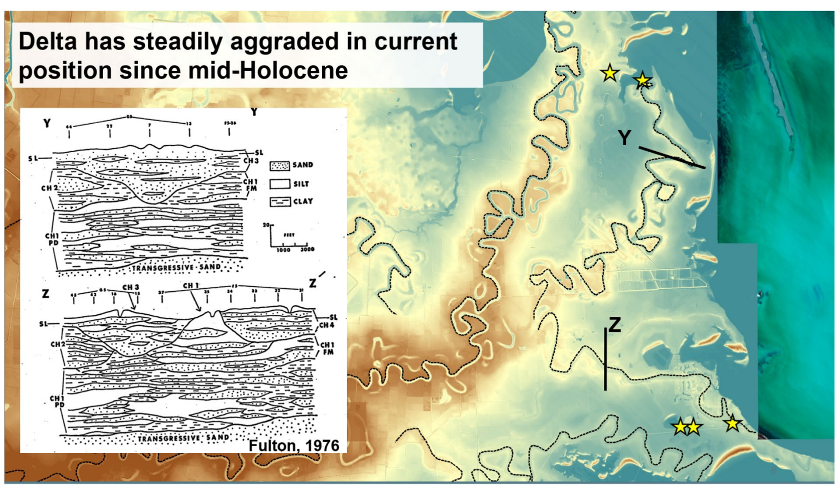


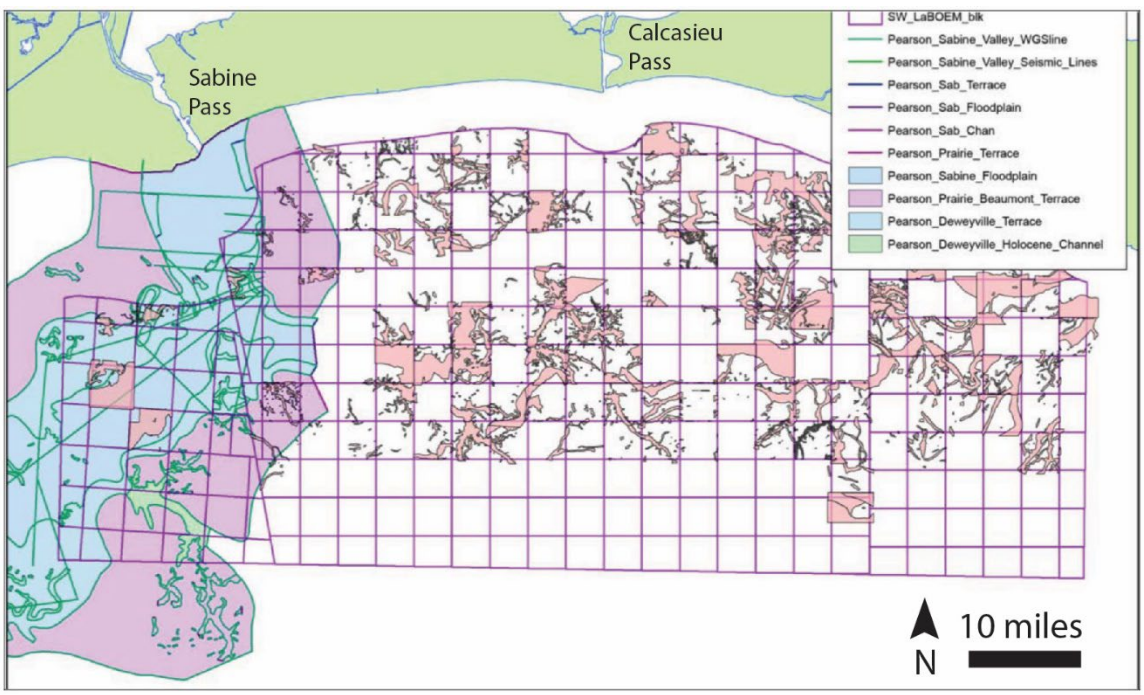
Figure 19. Cross Section Showing Holocene Fluvial-Deltaic in place Aggradation and Avulsion Over the Last 7,000 years (modified from Fulton 1976)



4.1.6 Paleo-Channel Fills

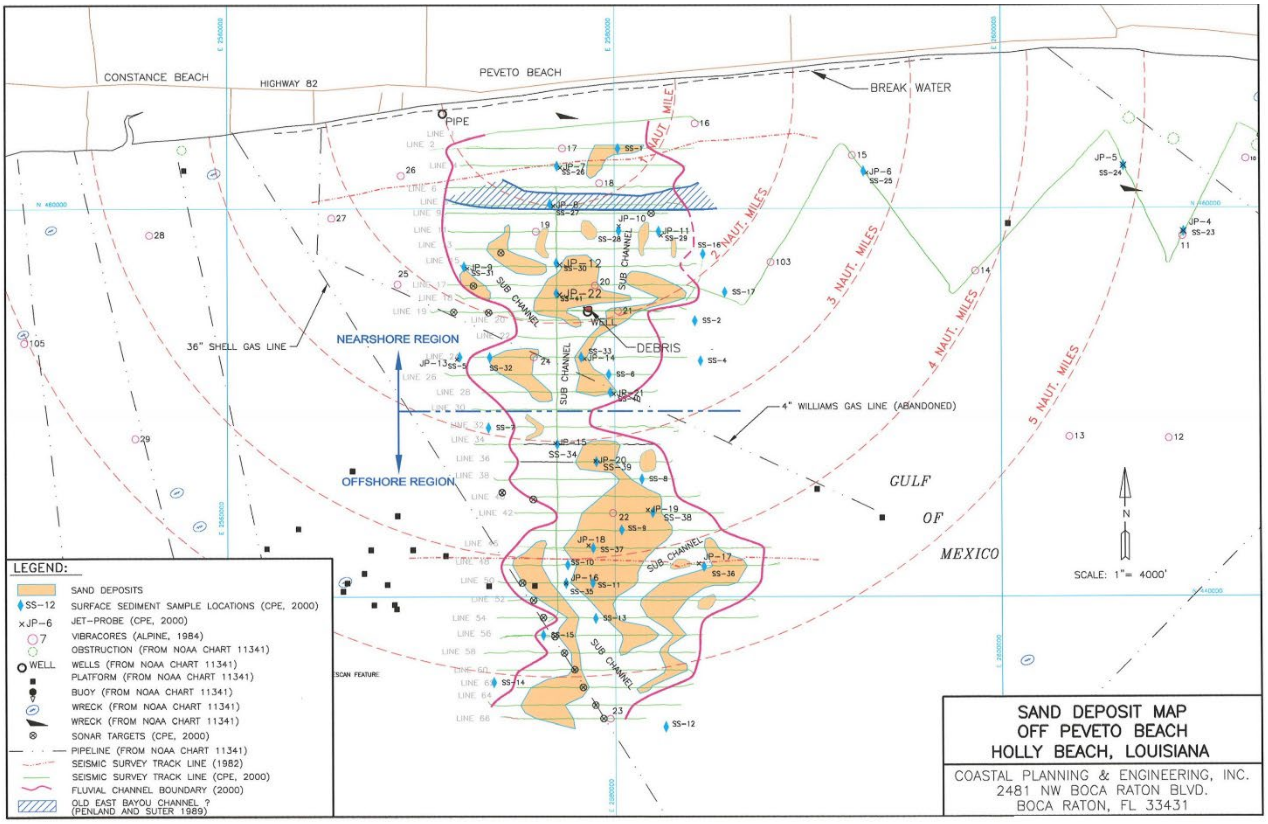
In contrast to incised valley fills that contain multiple channel belts, discrete near-surface channel fills have been observed throughout the study area representing stream systems that incised into interfluves during lowstand or were preserved basal channel fills from previous highstand or falling stage streams. Compared to the Upper Coast of Texas detailed investigations of potential paleo-channel systems in Lower Texas are minimal, while some of those that do exist point to similar form as those observed elsewhere in the Gulf of Mexico (Meckel and Mulcahey 2016). Here we describe a series of highly detailed investigations of channel forms located in the Upper Coast OCS and Central Coast OCS that are likely to be representative of those encountered in the Lower Coast OCS due to similarities in geologic setting, and in some cases, likely formative river systems (Young et al. 2012). In an analysis that mosaiced of over 300 shallow hazards surveys conducted for oil and gas development offshore western Louisiana and East Texas, Heinrich et al. (2020), demonstrated the ubiquity of these features in the study area (Figure 20). Dellapenna et al. (2009) collected sediment cores in some of these features that had been identified from geophysical data and sand content was minimal or below the depth of core penetration. However, as demonstrated by Coastal Planning & Engineering, Inc. (APTIM-CPE) (2001) in support of Holly Beach, Louisiana Restoration, high density geophysical and geological data can identify the elusive channel sands that occur within sinuous ribbons of muddy sediment within the fluvial channel belt Figure 21, Figure 22; Heinrich et al., 2020). Adjacent to the study area, a previously unidentified laterally migrating channel belt, likely related to a Pleistocene Brazos system, was located with a high-density grid of geophysical data offshore of Follet's Island (Figure 23; APTIM 2021). The trend of this system aligns with updip sandy fluvial deposits of the Pleistocene-aged Beaumont Formation. A similar system was mapped offshore of Matagorda Bay (Figure 24) where the age is unknown but likely resembles offshore components of a Pleistocene Colorado River system identified in Blum and Aslan (2006). These isolated systems provide a reference strategy for other potential sand resources with updip Pleistocene equivalents within the study area.

Figure 20. Paleochannel and Paleovalley Deposits as Interpreted on Over 300 Individual Oil and Gas Hazards Survey Reports Conducted on Federal Offshore Lease Blocks (Defined by Irregular Purple Grid) Offshore Sabine and Calcasieu Passes



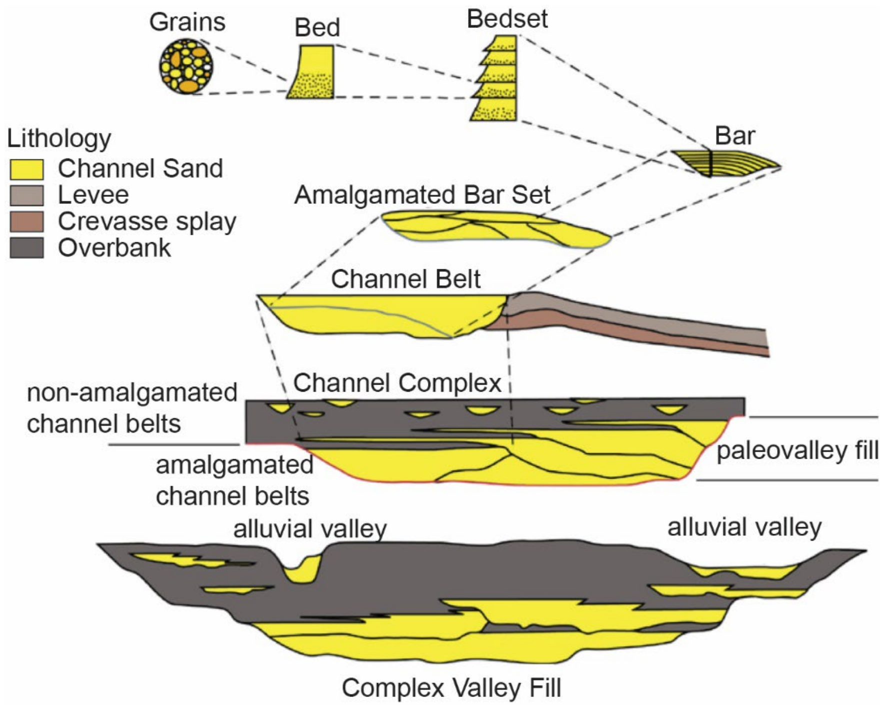
Note: The interpretations were mosaiced to develop this map. From Heinrich et al. (2020).

Figure 21. Sand Deposit Map of the Peveto Paleochannel Offshore Holly Beach, Louisiana Demonstrating the Complexity of Location Channel Sands within the Channel Fill and Floodplain Muddy Deposits



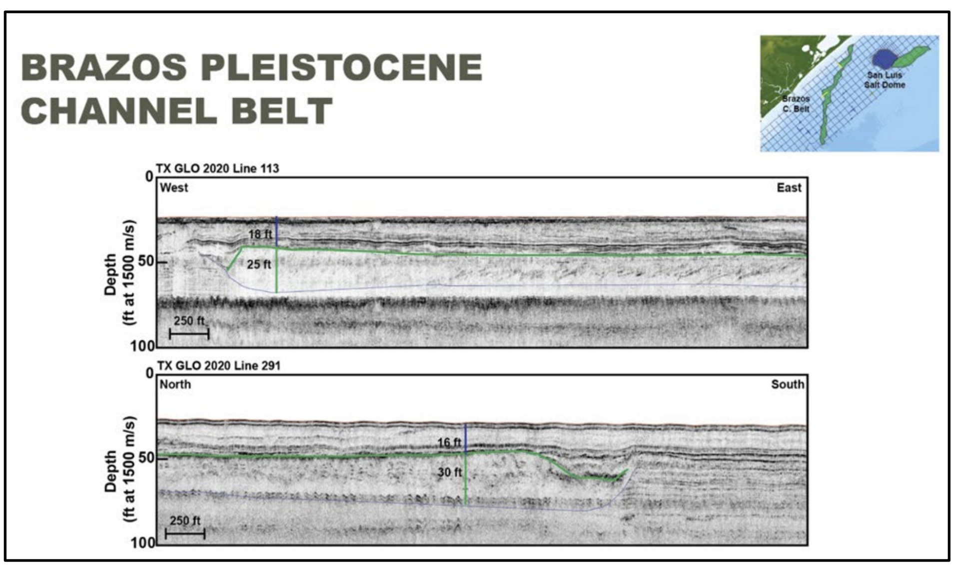
Note: The southernmost deposits on this map were ultimately extracted to construct the Holly Beach Restoration Project. See Figure 22 for a conceptual model of paleochannel fills. From Heinrich et al. (2020), modified from Coastal Planning & Engineering, Inc. (APTIM-CPE 2001).

Figure 22. Conceptual Hierarchy of Fluvial Deposits



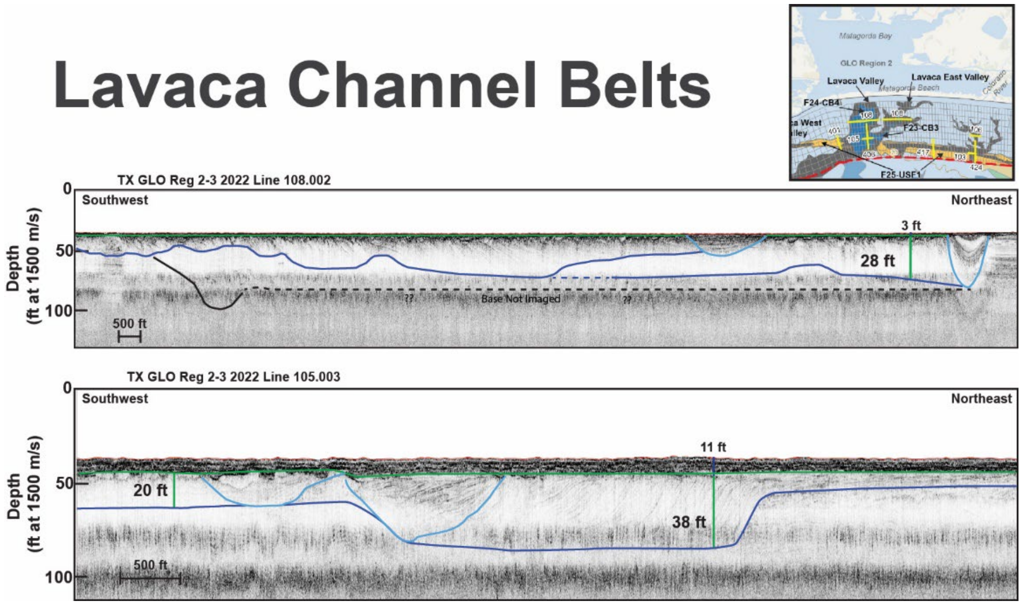
From Heinrich et al. (2020) modified from SEPM web.

Figure 23. Example of Preserved Channel Belt Adjacent to this Study Area, Likely Related to a Pleistocene Brazos System



Note: The blue horizon marks the basal unconformity separated layered Beaumont stratigraphy from the above dipping clinoforms and variable transparent/chaotic seismic reflectors. The green horizon is the top of the dipping reflector package. Note the transition from dipping clinoforms to channel form at the edge of the feature. (From APTIM 2021)

Figure 24. Example of Preserved Channel Belt Adjacent to this Study Area, Likely Related to a Pleistocene Colorado River System



Note: The purple horizon marks the basal unconformity separated layered Beaumont stratigraphy from the above dipping clinoforms and variable transparent/chaotic seismic reflectors, light blue reflectors represent the channel form. The green horizon is the transgressive ravinement surface and top of the dipping reflector package. The black and dotted black line represents the inferred valley base where it could be mapped (From APTIM 2024a)

4.1.7 Transgressive Ravinement

While the depositional response to sea-level rise is manifested as incised valley fills and shelf sand bodies, response to wave and tidal current erosion (ravinement) dominated the study area and has resulted in removal of much of the upper sections of fluvial and coastal deposits associated with falling sea level (falling stage deltas and channel systems), lowstand (landforms that developed on interfluves), and early transgression (upper sections of incised valley fills and barrier shoreline deposits). Preservation of coastal deposits is extremely rare with the exception of the sand banks discussed above (Rodriguez et al. 2004; Anderson et al. 2016). Smaller stream channels that did not incise valleys or that were perched on interfluves are also rarely preserved (Anderson et al. 2016). The effective depth of transgressive ravinement in the study area was approximately 25-35 ft (7.6-10.7 m) (and still is today along the modern shoreface; Wallace et al. 2010); therefore, the upper 25-35 ft (7.6-10.7 m) of all antecedent deposits were removed as the coastline migrated landward during the transgression (Wilkinson 1975; Siringan and Anderson 1994; Rodriguez et al. 2001).

4.1.8 Highstand (~4,000 Yrs Ago to Present)

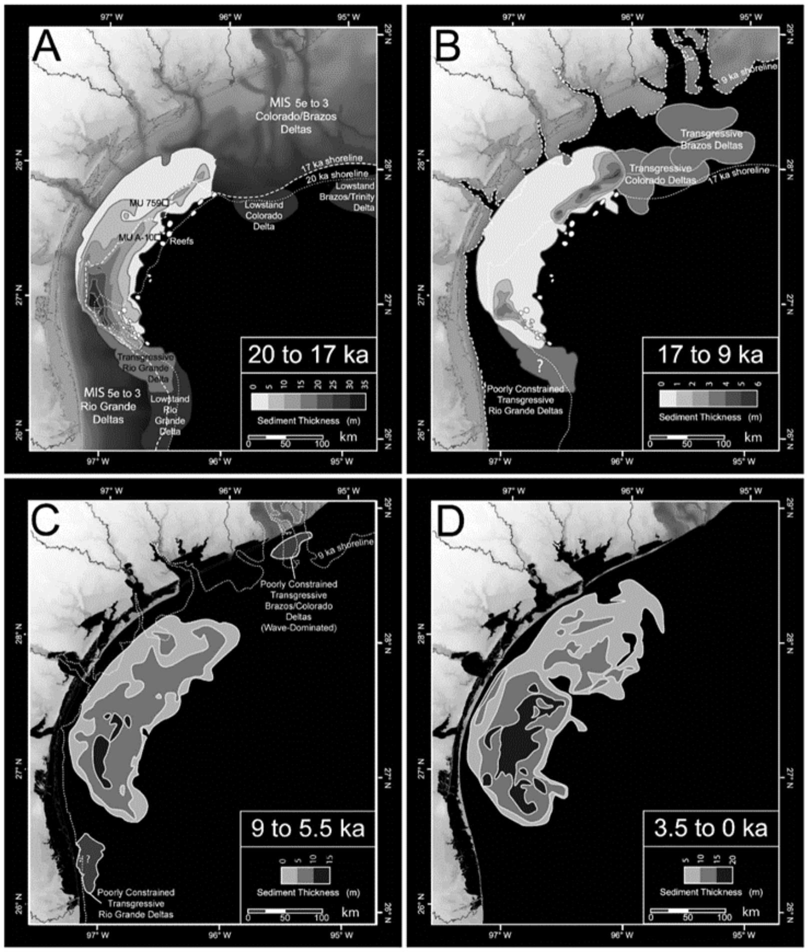
Approximately 4,000 yrs ago the rate of sea-level rise drastically slowed to an almost stable ~0.5 mm/yr allowing for the modern coastal system to mature as barrier islands prograded seaward and significant lateral spit accretion from headlands developed peninsulas such as South Padre Island (Anderson et al. 2014). Much of the sand that exists in the modern coastal system was provided during transgressive ravinement of antecedent deposits on the shelf (e.g., falling stage deltas, transgressive barrier islands, shallow stream channels; Weight et al. 2011; Anderson et al. 2016; Hollis et al. 2019). This concept of the modern coastal system being genetically related to preserved fluvial deposits on the shelf is an important consideration for assessing sand source suitability for beach nourishment. The exact evolution of the Rio

Grande delta is not well constrained, but deltaic deposition is thought to have ceased between 4,000 and 2,600 yrs before present with lagoonal formation around 2,500 yrs before present (Fulton 1976; Morton and McGowen 1980). Recent studies suggest that lagoonal bay mud deposition started around 5,500 yrs before present (Wallace and Anderson 2010). As the Rio Grande delta system reached its current position, it began building the modern delta plain and near-surface stratigraphy through numerous cycles of aggradation and avulsion (Swartz et al. 2022; Fulton 1976). The modern Rio Grande maintains a near constant slope and sinuosity across the ~300 km of the Rio Grande delta, with historical analysis indicating significant rates of lateral migration along the coastal reach (Swartz et al. 2022). Rates of avulsion are unknown, but at least 17 abandoned Rio Grande channels are observed on the modern delta surface burying at least ~30 m of Holocene fluvial sediment (Fulton 1976; Swartz et al. 2022), indicating an avulsion timescale of hundreds of years. Together, these observations indicate that the late Holocene to historical Rio Grande system maintained a relatively high sediment flux (albeit lower than that observed of the Pleistocene/Early Holocene system) until anthropogenic modification greatly reduced water and sediment delivery to the coast (Swartz et al. 2022; Goudge et al. 2023).

4.1.9 Texas Mud Blanket

The accommodation of the Central Texas shelf embayment created by subsidence and lack of large falling stage to lowstand shelf deltas was infilled with transgressive muds of the Texas Mud Blanket (Weight et al. 2011). Deposition took place since the beginning of the transgression with the majority of sedimentation occurring after 3,500 yrs ago (Figure 25). Major sediment inputs were fine-grained plume sediments sourced from the Mississippi, Brazos and Colorado Rivers, as well as local ravinement of the Colorado/Brazos and Rio Grande shelf deltas to the north and south (Eckles et al. 2004; Weight, et al. 2011). This creates a seaward thickening wedge of overburden overlying the falling stage strandplain deposits and paleo-delta systems associated with the Rio Grande and Colorado rivers. The expansion of the Texas Mud Blanket in the middle to late Holocene led to a shutting down of sand sources from the shelf to the modern coastline, leading to rapid landward retreat of the shoreline in the late Holocene (Odezulu et al. 2020). Again, noting that the mud blanket reaches thicknesses of up to 150 ft (45.7 m) within the Region 4/Lower OCS mapping area according to Banfield and Anderson (2004).

Figure 25. Evolution and Thickness of the Fine-Grained Texas Mud Blanket Since the Lowstand (from Weight et al. 2011).



Note the sediment thickness scale changes between panels.

4.1.10 Upper and Central Texas Shelf Stratigraphy

In addition to the proposed Lower OCS coast acquisition, the proposed geophysical acquisition for this study includes an area offshore of GLO Region 1 (Figure 1), where a significant data gap existed between prior collected surveys. This study proposes to in-fill this area with an equivalent and comprehensive geophysical survey to bridge the gap between the GLO Region 1 and Federal Upper OCS. The following is a brief summary of the previous findings of GLO/BOEM investigations of sand resources within Region 1 and the Upper OCS that support the need for additional constraints of this area.

The low-gradient, slowly subsiding inner shelf is composed of multiple cycles of fluvial and deltaic sedimentation and progradation, which is then reworked and redistributed during subsequent cycles of sea level rise and fall by coastal, marine, and alluvial processes (Anderson et al. 2016). Using a source-to-sink approach, as depocenters shift, identifying major sediment pathways and sinks of sand deposits allows for the prediction of resource occurrence. A summary of depositional systems relevant to sand resource exploration of the Upper and Central Texas shelf are presented here, a detailed review of the geologic evolution these areas see previous reports (APTIM and TWI 2020; APTIM and TWI 2022; APTIM and TWI 2024a; APTIM and TWI 2024b).

In Region 1 from the Brazos River to Sabine Point, Texas state waters contain numerous potential sand resources contained within regional-scale geologic systems such as the Trinity and Sabine Incised Valleys, the Brazos Alluvial Plain, and the previously unidentified Pleistocene channel belt systems (Figure 26). The Trinity and Sabine Incised Valleys, related to the falling and lowstand stages (~120,000 to 20,000 yrs ago), contain large amounts of concentrated basal fluvial sands. However, these potential sand deposits are overlain with thick sections of muddy deltaic, estuarine, and marine sediment due to rising sea levels from about 17,000 yrs ago to present, making them uneconomic potential sand resources. However, along sections of the Trinity and Sabine valleys are preserved terrace deposits substantially larger than modern or Holocene Sabine fluvial systems. These thick deposits have less overburden compared to the basal fluvial sands contained with lowstand valleys. Fluvial terrace deposits have a high potential for sediment resources, estimated to contain 265 MCY of sand in Region 1 state waters (Figure 26) and 1.28 BCY underlying Sabine Bank (Figure 27).

Region 1 state waters contain 11 previously un-identified Pleistocene channel belts estimated contain to 2.3 BCY of sand (Figure 26). These discrete channel belts are likely related to fluvial systems of the Beaumont Formation, with very little overburden. Similarly, in the area of Sabine Bank, five (5) previously unidentified Pleistocene channel belts are estimated to contain 694 MCY of sand (Figure 27). Due to the low subsidence and fluvial reoccupation throughout the Late Quaternary, the upper section Holocene and Pleistocene fluvial systems may occur at equivalent depths below the seafloor rather than being separated by large thicknesses of deltaic or marine deposition. This amalgamation and reworking leads to the "perching" of Pleistocene stratigraphic elements close to the modern seafloor. The Central Texas shelf (GLO Regions 2 and 3, BOEM Central OCS) similarly contains numerous Quaternary fluvial channel belts and incised valleys (Figure 28). Currently, these interpretations are preliminary until they are verified by geologic sampling. by characterizing these deposits in a geologic framework, there is a high probability that the fluvial channel belts or their respective major depocenters, are at least partially preserved further offshore.

Figure 26. Cross Section of the Region 1 Subsurface Stratigraphy and Sand-Bearing Facies

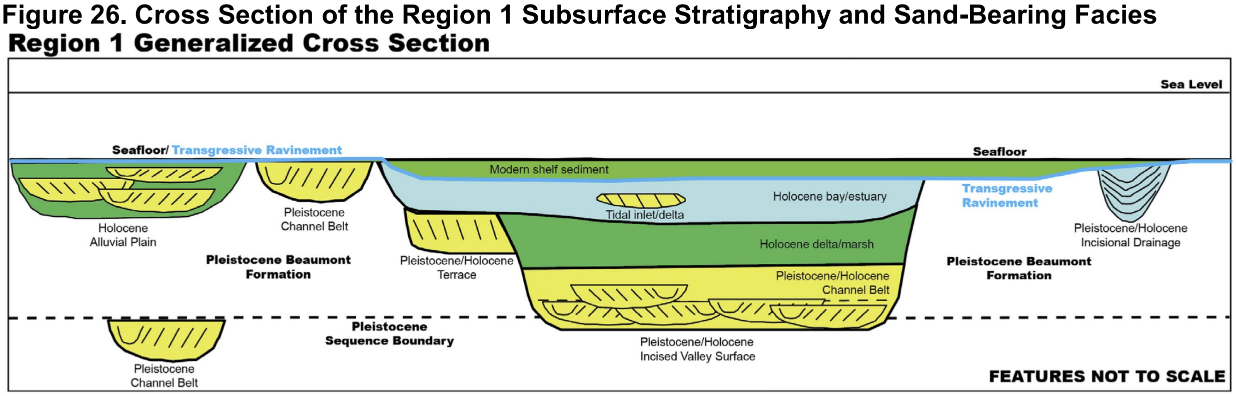


Figure 27. Generalized Cross Section of Major Features Observed in the OCS

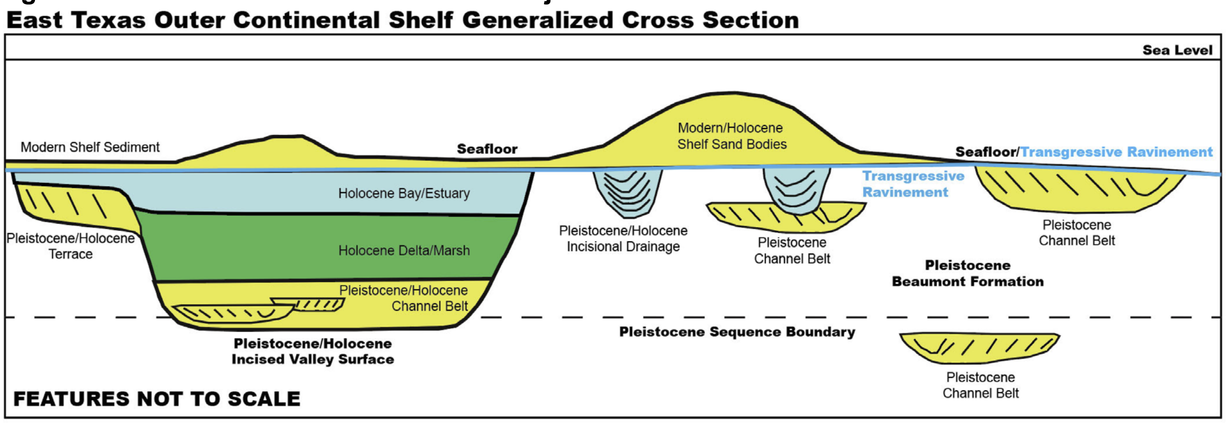
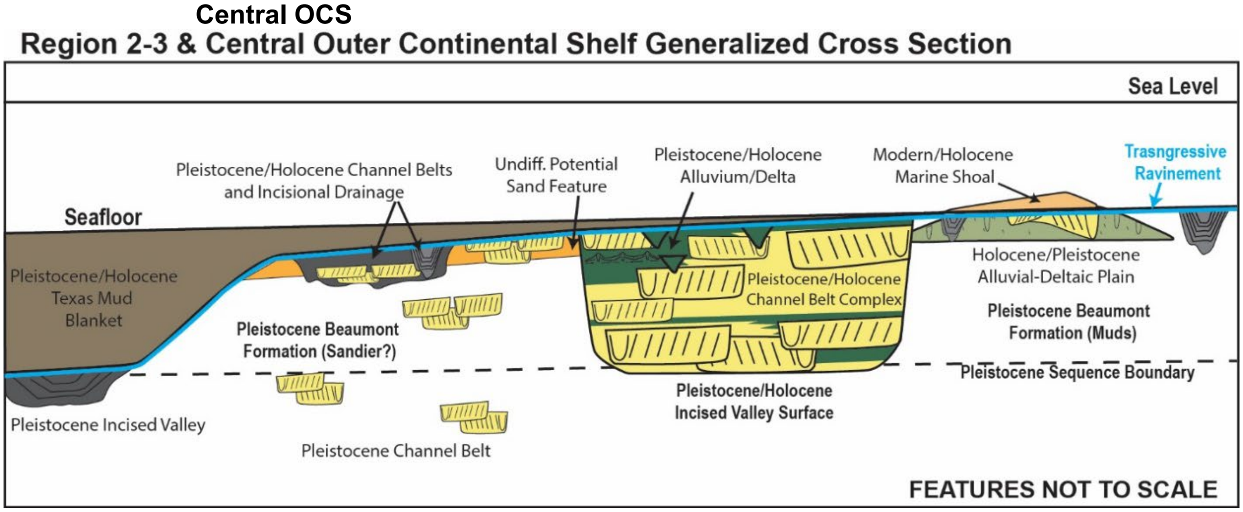


Figure 28. Generalized Cross Section of Major Features Observed in the GLO Regions 2-3 and Central OCS



5 Historical Data Compilation and Analysis

The APTIM Team conducted an extensive review of existing geophysical and geotechnical data to provide the information needed to develop an informed survey plan within the OCS study area. Historic geologic and geophysical data, marine hazard and resource data were acquired, compiled, reviewed, and incorporated during this phase to be used to further develop the geophysical survey plan. Marine hazard data included oil and gas infrastructure, benthic resources, and other sensitive/hazard areas that need to be avoided during survey acquisition. Maps are provided in Appendix A. APTIM reviewed the existing data to assess seafloor depth, seafloor hazards, base of overburden, top of sand, base of sand, channels/paleochannels and ravinement surfaces. Based on this evaluation, the APTIM Team developed a survey plan that made the most efficient use of existing data while avoiding collecting duplicate data. The survey plan is also provided in Appendix B.

5.1 Data Sources

A range of data sources were reviewed to compile the existing geophysical and geotechnical data. These are briefly discussed below.

5.1.1 Bureau of Ocean Energy Management (BOEM) Marine Mineral Resource Evaluation

The Marine Mineral Resource Evaluation is available at https://www.boem.gov/marine-mineral-resource-evaluation. Over the past 35 yrs the Marine Minerals Program (MMP) has worked with 18 states (Alabama, California, Delaware, Florida, Georgia, Louisiana, Maine, Maryland, Massachusetts, Mississippi, New Hampshire, New Jersey, New York, North Carolina, Rhode Island, South Carolina, Texas, and Virginia) on cooperative agreements through which hundreds of millions of cubic yards of OCS sediment has been identified for use in beach nourishment and coastal restoration projects. BOEM has also invested in research offshore Alaska, Connecticut, Hawai'I, Oregon, Puerto Rico, and Washington.

5.1.2 Marine Geoscience Data System (MGDS)

The MGDS is a database founded by the U.S. National Science Foundation and is part of the Interdisciplinary Earth Data Alliance. This database is an interactive digital data repository and metadata catalog which includes an archive of seismic data collected by various institutions across the globe and allows for the download of seismic files for interpretation and analysis. This database is available at http://www.marine-geo.org/index.php.

5.1.3 Marine Minerals Information System (MMIS)

BOEM maintains MMP datasets through the Marine Minerals Information System (MMIS) viewer at https://mmis.doi.gov/BOEMMMIS/. The MMIS application is intended to aid ocean use planning and development of potential agreements for sand from the OCS. The MMIS consolidates offshore data from multiple sources, notably BOEM-funded work. The MMIS includes sediment sample, geophysical (sub-bottom, magnetometer, side scan sonar) and hydrographic (bathymetric) data. It covers the Gulf of Mexico and the U.S. Atlantic coast.

5.1.4 NOAA Data Discovery Portal

The National Oceanic and Atmospheric Administration (NOAA) Data Discovery Portal provides two approaches to enable searching NOAA's vast data holdings: the traditional NOAA Data Catalog for all data and the new NOAA OneStop catalog which initially includes only the archived datasets but will eventually replace the traditional catalog. Both are available at https://data.noaa.gov/datasetsearch/.

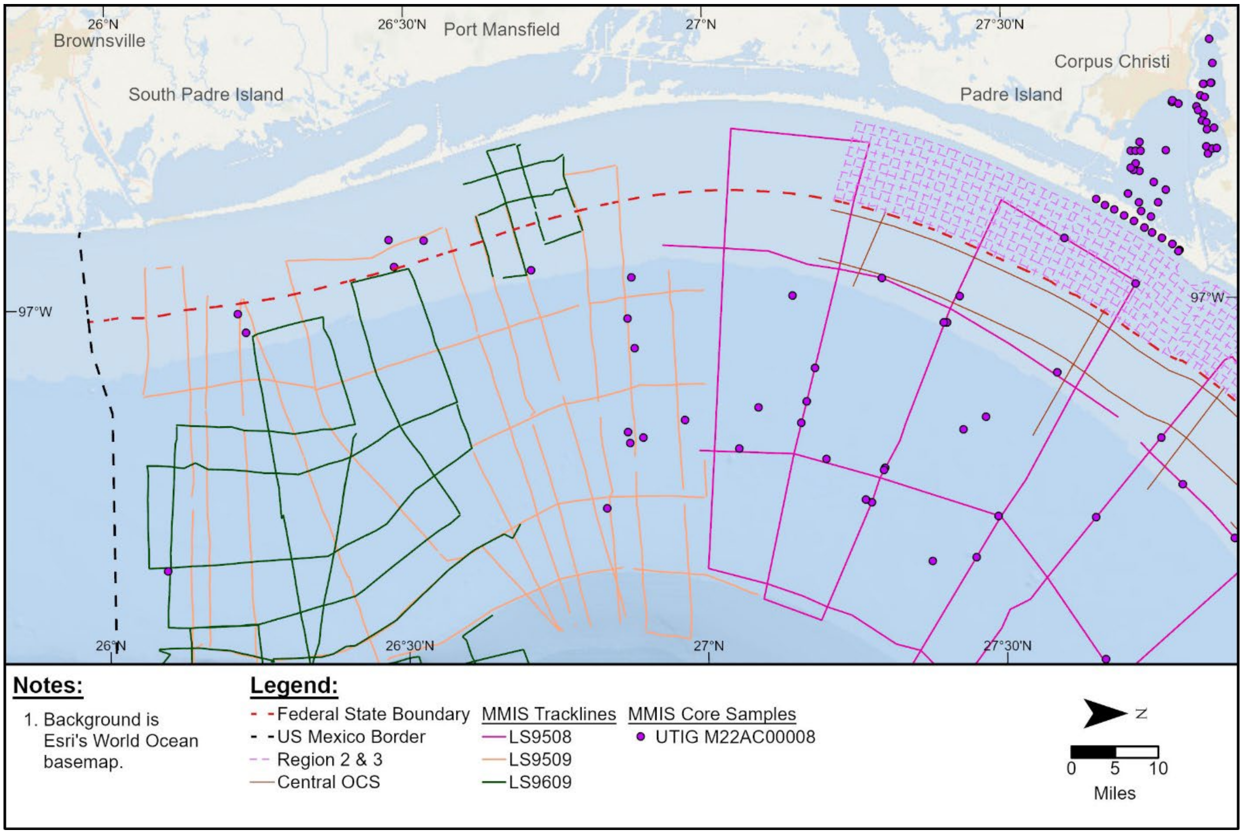
5.2 Seismic/Sub-bottom Profiler Data

Existing seismic/sub-bottom profiler data collected within the vicinity of the proposed investigation areas were compiled from different sources, including NOAA, MMIS and the MGDS (Table 1). These seismic tracklines (Figure 29) were collected between 1969 and 2012 by various contractors and the surveys were funded by institutions, such as the Minerals Management Service, U.S. Geological Survey (USGS) Woods Hole, Rice University and The University of Texas at Austin.

Table 1. Existing Seismic/Sub-bottom Track lines and Vibracores in the Vicinity of the Study Area

Project or Cruise Name	Year	Contractor/Author	Source
LS9609	1996	UTIG	MMIS/MGDS
LS9508	1995	UTIG	MMIS/MGDS
LS9509	1995	UTIG	MMIS/MGDS
BOEM Cooperative Agreement Number M22AC00008	2023	UTIG	MMIS
TX GLO Region 2 and 3 Geophysical Survey Tracklines	2024	APTIM and TWI	APTIM
TX GLO Central OCS Geophysical Survey Tracklines	2024	APTIM and TWI	APTIM

Figure 29. Seismic Track Lines and Vibracores in the Vicinity of the Lower OCS Proposed Investigation Area



As previously discussed, survey planning along the Central OCS and Upper OCS regions were based on the information gathered from previous desktop studies as well as results from the geophysical investigations conducted by APTIM and TWI. A breakdown of previously identified studies and tracklines along Central OCS and Upper OCS are presented in Table 2 as well as Figure 30 and Figure 31 below.

Table 2. Central and Upper OCS Historic Geophysical tracklines

Project	Year	Contractor/Author	Source
KA939009	1969	Navoceano	NOAA
LSSALE58	1978	Minerals Management Service	NOAA
LSALE58A	1978	Minerals Management Service	NOAA
LSSALE66	1980	Intersea Research, Inc.	NOAA
FRNL85-1	1985	USGS Woods Hole	NOAA
Archive of Digitized Analog Boomer Seismic Reflection Data Collected from the Northern Gulf of Mexico: Intersea 1980	1990-1991	Stephen T. Bosse, James G. Flocks, and Arnell S. Forde	USGS
Physical and Environmental Assessment of Sand Resources-Texas Continental Shelf	1993	Robert A, Morton James C Gibeaut	APTIM Library
Modern Shoreface and Inner Shelf Storm Deposits off the East Texas Coast, Gulf of Mexico	1994	Fernando P. Siringan John B. Anderson	APTIM library

Project	Year	Contractor/Author	Source
LS9607	1996	J. Anderson (Rice University)	ASP
LS906TS	1996	Rice University	MGDS
Sedimentary Facies and Genesis of Holocene Sand Banks on the East Texas Inner Continental Shelf	1999	Antonio B. Rodriguez John B. Anderson Fernando P. Siringan Marco Taviani	SEPM (Society for Sedimentary Geology)
Holly Beach Sand Management Project (CS-01)	2001	APTIM-CPE	APTIM, LASARD
USS Data Series 93 Cruises 94CCT01 and 95CCT01	2004	U.S. Geological Survey, St. Petersburg, FL 33701. ETI Professionals, Inc., St. Petersburg, FL.	USGS LASED
Jefferson and Galveston County Sand Search Investigation	2004	APTIM-CPE	APTIM Library
Jefferson and Galveston County Sand Search Investigation	2006	APTIM-CPE	APTIM Library
ACAD0801	2008	Institute for Geophysics, University of Texas at Austin	MGDS
MNT0901	2009	Sean Gulick & John A. Goff (The University of Texas at Austin)	ASP
USGS Data Series 526 Cruise 09CCT01	2009	U.S. Geological Survey, St. Petersburg, FL Texas Agricultural & Mechanical (A&M) University at Galveston, Galveston, TX.	USGS
Cameron Parish Shoreline Restoration	2009	Coast & Harbor Engineering	LASARD
ACAD1001	2010	Institute for Geophysics, University of Texas at Austin	MGDS
MNT1201	2012	Sean Gulick & John A. Goff (The University of Texas at Austin)	ASP
MNT1301	2013	Institute for Geophysics, University of Texas at Austin	MGDS
Archive of Digital Chirp Sub-bottom Profile Data Collected Offshore of the Galveston, Texas, During Three Expeditions in 2017 and 2018: The Trinity River Paleovalley Project (TRiPP)	2017 and 2018	The University of Texas Institute for Geophysics	MGDS
Geophysical and Geotechnical Investigations for PSN7199 and PSN12579	2018	APTIM	APTIM Library
Field Investigations for Panther Interstate Pipeline Energy Assets PSN3493 And PSN5895 in Significant Sediment Resource Areas	2018	APTIM	APTIM Library
TX GLO Region 1 Geophysical Survey Tracklines	2021	APTIM and TWI	APTIM
TX GLO Upper OCS Geophysical Tracklines	2021	APTIM and TWI	APTIM

Figure 30. Seismic Track Lines in the Vicinity of the Central OCS Proposed Investigation Area

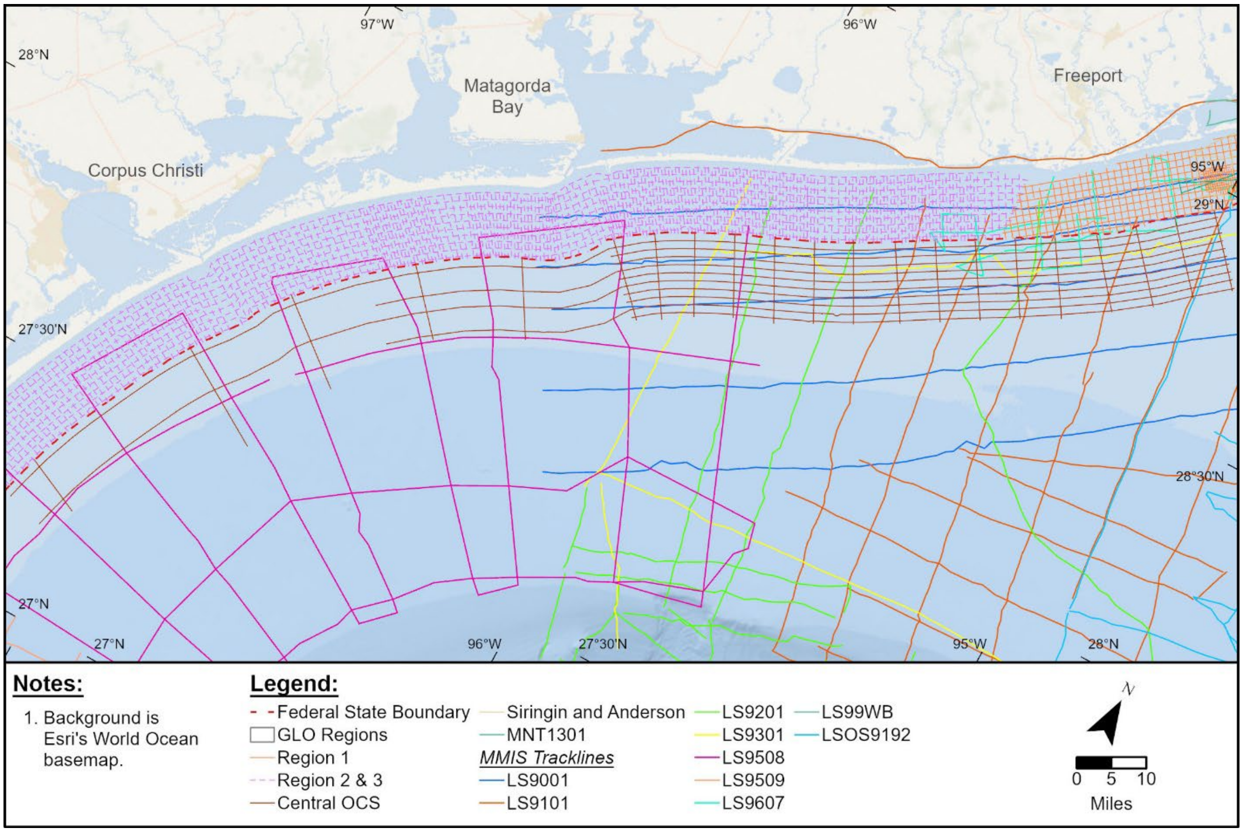
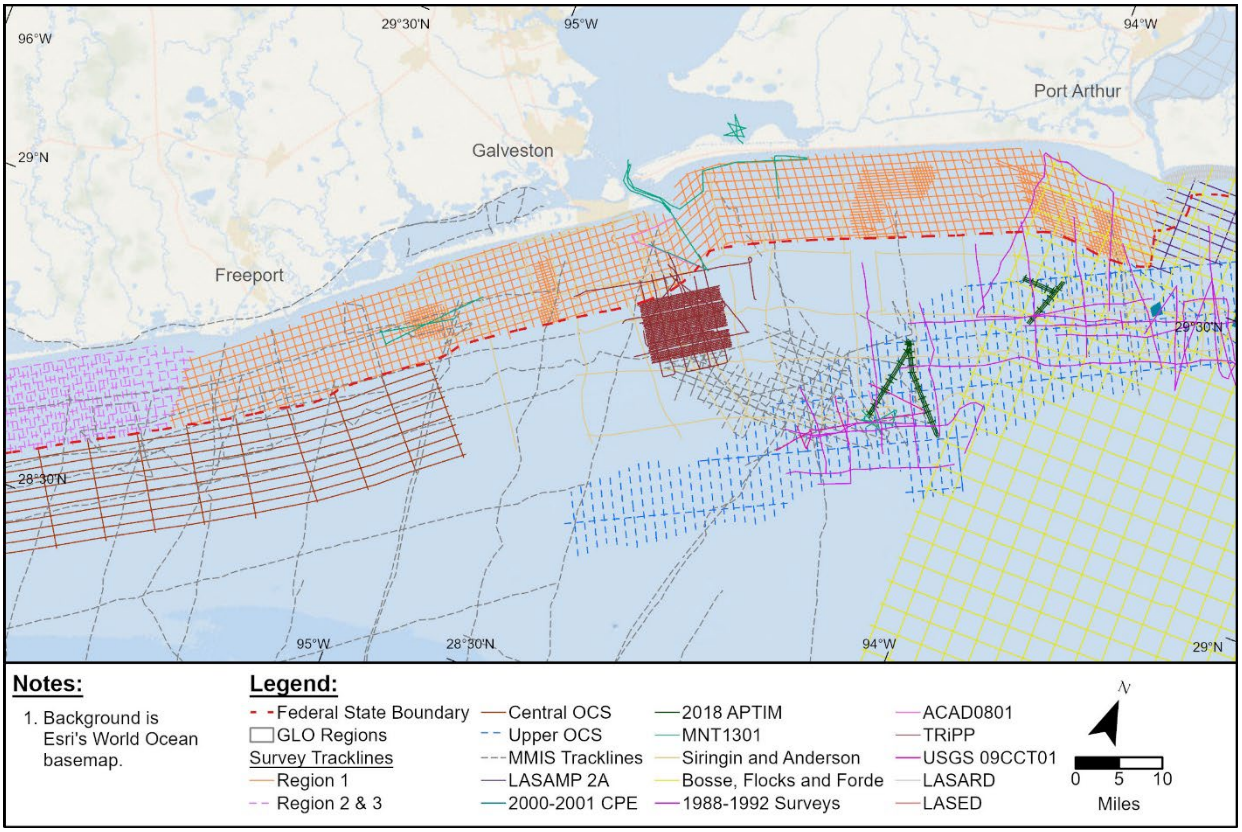


Figure 31: Seismic track lines in the vicinity of the Upper OCS proposed investigation area.



5.3 Delineated Sand Deposits/Depositional Environments

Several potential depositional areas and environments that may contain sand have been delineated along Texas Region 4/Lower OCS (Table 3 and Figure 32). Shore parallel sands have been distributed post-Wisconsin on the surface and shallow subsurface. Comprised mostly of quartz, these deposits formed in the same manner as the modern shoreline, thus the sand is like that of the beach (Paine et al., 1988). The distribution is nearshore in the northern part of the area, nearshore to offshore in the central part of the area, and intermediate in extent in the southern part of the study area. This sand may contain shell and are suitable for beach nourishment, industrial use, and construction (Paine et al., 1988). Sands from the Rio Grande are mineral rich (Paine et al., 1988). Four foundation borings were taken in the region showing sand thicknesses of more than 24.5 ft (7.5 m) no more than 50 ft (15.2 m) below the seafloor (Paine et al., 1988). Paine et al., (1988) purported this sand layer is found throughout the subsurface in the coastal waters of the study area. As previously described, the geologic framework of the area and geological evolution of the Gulf of Mexico has led to the formation of the incised river valley associated with the Rio Grande that, due to sea level fall and subsequent sea level rise during the Wisconsin period, may be infilled with sandy sediment.

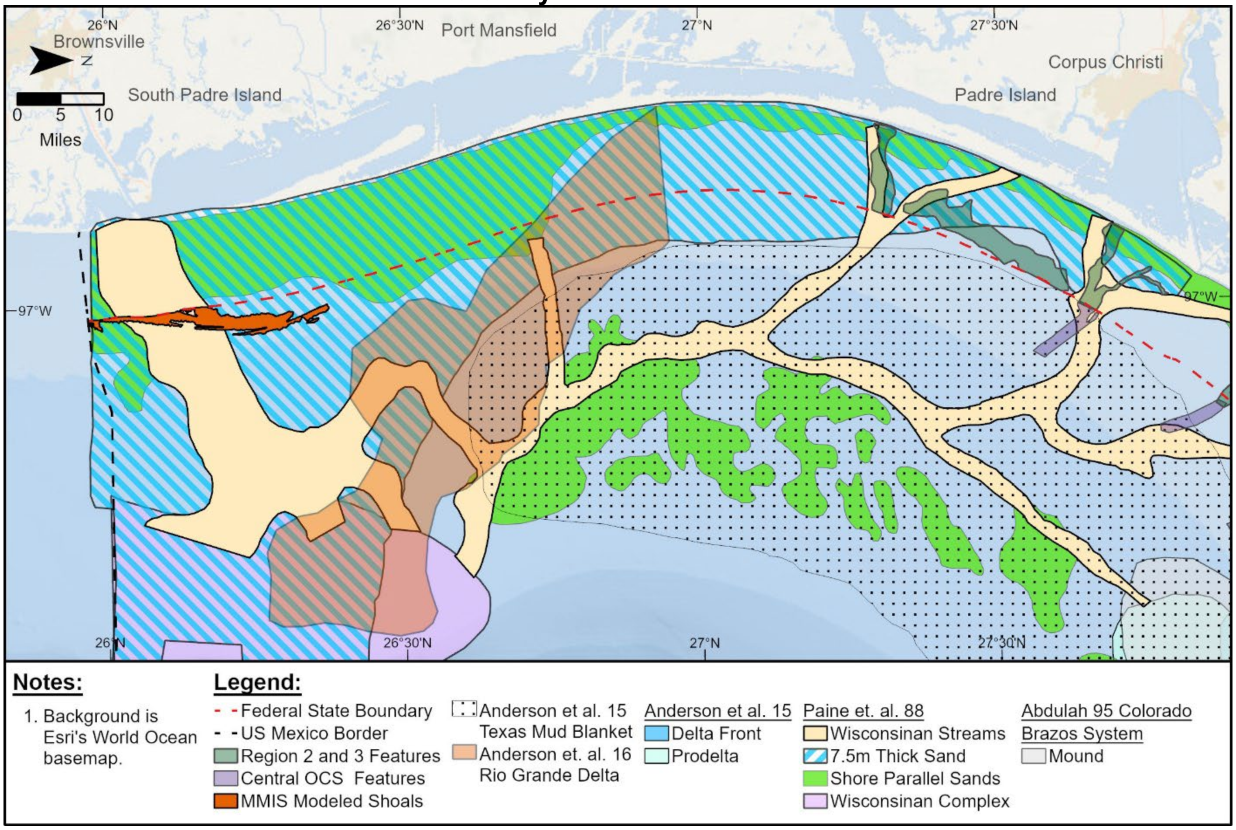
Table 3. Delineated Sand Deposit Data in the Vicinity of the Study Area

Deposit Name	Project/Report	Year	Contractor/Author	Source
7.5m Thick Sand **Wisconsinan Streams** **Wisconsinan Deltaic Complex** **Shore Parallel Sand**	Preliminary Assessment of Nonfuel Minerals on the Texas Continental Shelf	1988	Jeffrey G Paine Robert A Morton William A White	Bureau of Economic Geology. The University of Texas at Austin

Deposit Name	Project/Report	Year	Contractor/Author	Source
Paleo Brazos and Colorado Deltaic System	The Evolution of the Brazos and Colorado Fluvial /Deltaic Systems During the Late Quaternary: An Integrated Study, Offshore Texas	1995	Kenneth Christopher Abdulah	Rice University
Falling Stage Deltas Texas Mud Blanket Rio Grande Delta	Recycling sediments between source and sink during a eustatic cycle: Systems of Late Quaternary northwestern Gulf of Mexico Basin	2015	John B. Anderson Davin J.Wallace, Alexander R. Simms, Antonio B. Rodriguez, Robert W.R. Weight, Z. Patrick Taha	Earth-Science Reviews
Modeled Shoals	Modeled shoals	2019	NOAA, Quantum Spatial, Inc., BOEM MMIS	MMIS
TX GLO Region 2 and 3 Features	Texas GLO Geophysical Investigation	2024	APTIM and TWI	APTIM
TX GLO Central OCS Features	Texas GLO Geophysical Investigation	2024	APTIM and TWI	APTIM

As previously described, the most recent geologic history of the Texas continental shelf begins with sea level fall during the early Quaternary period. In the early Pleistocene, a drop in sea level led to the formation of several fluvial incisions (Anderson et al. 2004), which enabled the deposition of sands along the new shoreline. Following incision, there were several flooding events and then sea level rise. During this period, deposited shoreline deltaic sands were re-worked and deposited along the exposed continental shelf as well as in paleochannels (Paine et al. 1988; Anderson et al. 2004, 2016; Rodriguez et al 1999, 2001, 2004). During sea level rise, channels and valleys were infilled with a transgressive sequence (coarser sands and gravel at the bottom, followed by finer deltaic sands and muds, then estuary muds and lastly gulf deposits) (Paine et al. 1988). The infill is typically several feet thick. Further offshore, in the valleys, there is a thick layer of overburden before reaching the sand layer. Therefore, the most economically feasible resources are near the coastline, where there are shallow waters and thinner overburden. Additionally, during the last glacial period, several deltaic complexes formed along the exposed continental shelf with some having sand deposits up to 25 ft (7.6 m) thick (Paine et al 1988). Sediment samples around these major deltas indicate that there are some areas where there is a 25 ft (7.6 m) thick sand layer within the upper 50 ft (15.2 m) below shows the Rio Grande Valley, the Wisconsinan stream digitized from Paine et al. (1988), as well as the shore parallel sand areas from Paine et al. (1988).

Figure 32. Historic Features, Delineated Deposits and Potential Sand Bearing Features Identified within the Lower OCS Study Area



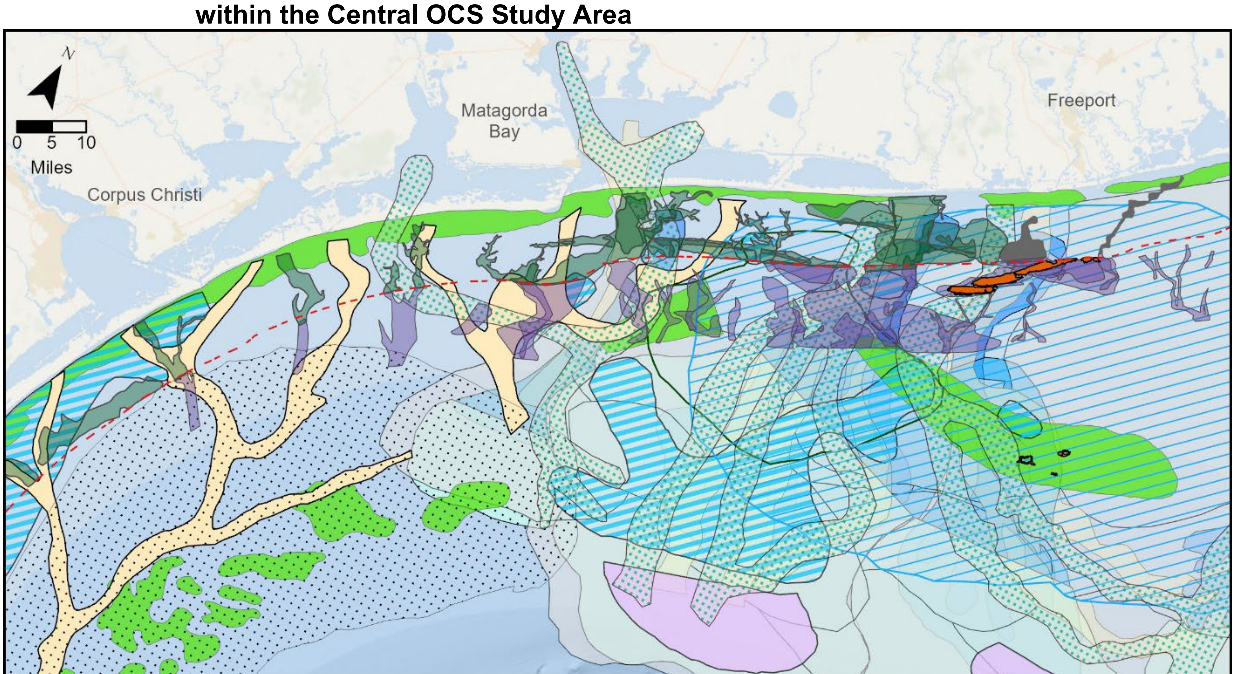
Survey planning along the Central OCS and Upper OCS regions were based on the information gathered from previous desktop studies as well as results from the geophysical investigations conducted by APTIM and TWI. A breakdown of previously identified studies, geologic framework features and potentially sand-bearing features along Central OCS and Upper OCS are presented in Table 4 as well as Figure 33 and Figure 34 and below.

Table 4. Delineated Sand Deposit Data within the Central and Upper OCS Study Area

Deposit Name	Project/Report	Year	Contractor/Author	Source
Colorado Delta	Sedimentary Facies and Evolution of Late Pleistocene to Recent Coastal Lithosomes on the East Texas Shelf	1999	Antonio B. Rodriguez	Rice University
Sand Shoal	Sedimentary Facies and Genesis of Holocene Sand Banks on the East Texas Inner Continental Shelf	1999	Antonio B Rodriguez John B Anderson Fernando P. Siringan Marco Taviani	Society of Sedimentary Geology
Lowstand Incised Valley	Late Quaternary Stratigraphic Evolution of The Northern Gulf of Mexico Margin: A Synthesis	2004	John B. Anderson Antonio Rodriguez Kenneth C. Abdulah Richard H. Fillon Laura A. Banfield Heather A. Mckeown Julia S. Wellner	Late Quaternary Stratigraphic Evolution of the Northern Gulf of Mexico Margin SEPM Special Publication No. 79,

Deposit Name	Project/Report	Year	Contractor/Author	Source
Trinity/Sabine Incised Valley	Tracking the Holocene evolution of Sabine Lake through the interplay of eustasy, antecedent topography, and sediment supply variations, Texas and Louisiana, USA	2008	K. T. Milliken John B. Anderson Antonio B. Rodriguez	The Geological Society of America
Paleo Brazos and Colorado Deltaic System	Texas Coastal Sediment Sources General Evaluation Study	2016	Freese and Nichols, Inc	Texas GLO
TX GLO Region 1 Potential Sand Features	Texas GLO Geophysical Investigation	2021	APTIM and TWI	APTIM
Texas GLO Upper OCS Features Q1	Texas GLO Geophysical Investigation	2021	APTIM and TWI	APTIM
TX GLO Region 2 and 3 Features	Texas GLO Geophysical Investigation	2024	APTIM and TWI	APTIM
TX GLO Central OCS Features	Texas GLO Geophysical Investigation	2024	APTIM and TWI	APTIM

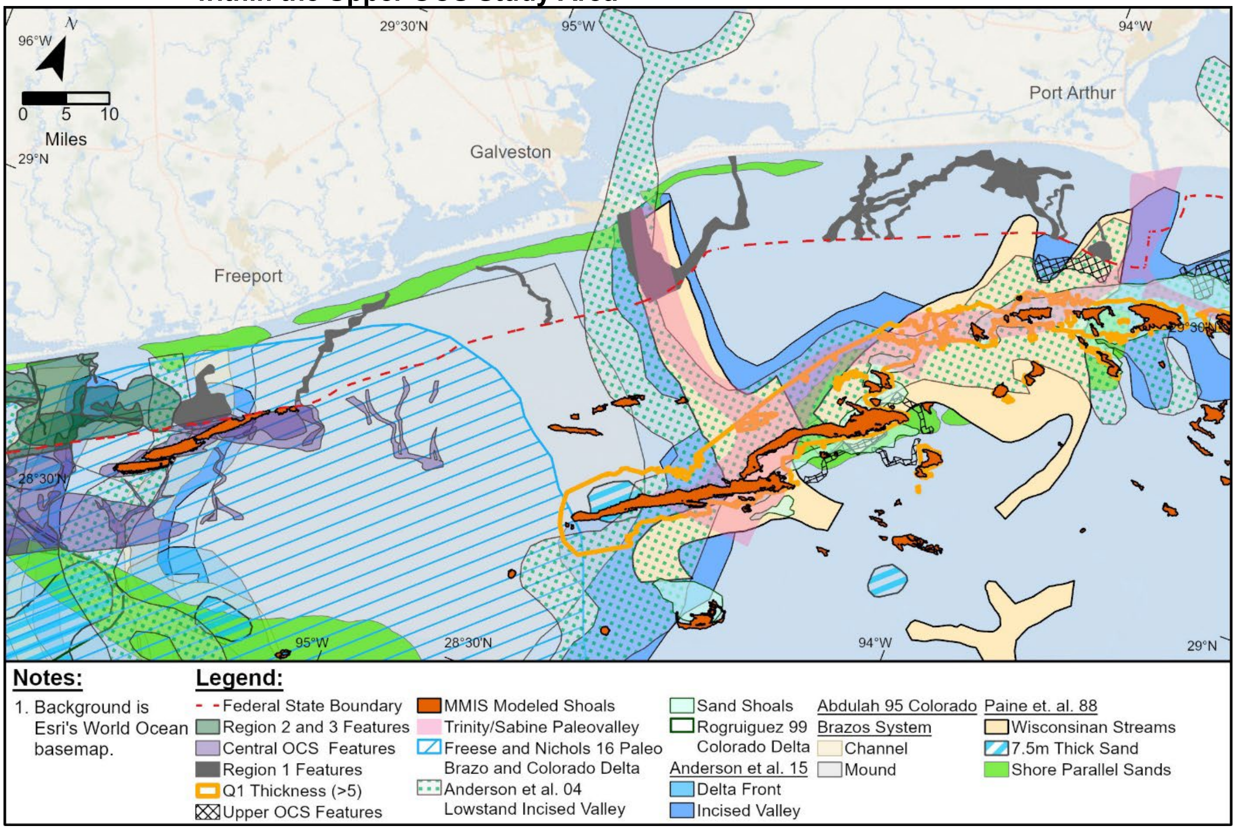
Figure 33. Historic Features, Delineated Deposits and Potential Sand Bearing Features Identified within the Central OCS Study Area



Notes:
1. Background is Esri's World Ocean basemap.

Legend:
- Federal State Boundary
- Region 2 and 3 Features
- Central OCS Features
- Region 1 Features
- Rogruiguez 99 Colorado Delta
- Anderson et al. 04 Lowstand Incised Valley
- Anderson et al. 15 Texas Mud Blanket
- Freese and Nichols 16 Paleo Brazo and Colorado Delta
- MMIS Modeled Shoals
- Abdulah 95 Colorado Brazos System
  - Channel
  - Mound
- Anderson et al. 15
  - Delta Front
  - Incised Valley
  - Prodelta
- Paine et. al. 88
  - Wisconsinan Streams
  - 7.5m Thick Sand
  - Shore Parallel Sands
  - Wisconsinan Complex

Figure 34. Historic Features, Delineated Deposits and Potential Sand Bearing Features Identified within the Upper OCS Study Area



5.4 Marine Hazard and Resource Data

In addition to previous/historic geologic and geophysical data, marine hazard, and resource data were acquired and compiled, reviewed, and incorporated during this phase to be used to further develop the geophysical survey plan. These data are shown in Figure 35, Figure 36 and Figure 37 and included oil and gas infrastructure, benthic resources, and other sensitive/hazard areas for avoidance during survey acquisition.

5.4.1 Artificial Reefs

Artificial reef locations and boundaries were provided by the GLO.

5.4.2 Automated Wreck and Obstruction Information System (AWOIS)

There are many types of marine cultural resources including shipwrecks, archaeological sites, artifacts, and remains of historic structures. The management and protection of these resources is crucial. Depending on their significance, they must be avoided during dredging and restoration activities. The Coast Survey's AWOIS contains information on over 10,000 submerged wrecks and obstructions in the coastal waters of the United States. Information includes the latitude and longitude of each feature along with brief historic and descriptive details. It is important to note that AWOIS records are not comprehensive. There are wrecks in AWOIS that do not appear on the nautical charts and vice versa. Additionally, some wrecks are not reported due to confidentiality concerns. Recorded wrecks that have been salvaged or disproved by further investigation are also not included in the database. According to the

NOAA website at https://nauticalcharts.noaa.gov/data/wrecks-and-obstructions.html, which was last updated on June 8. 2018, the Office of the Coast stopped updating the AWOIS database in 2016.

5.4.3 Coastal Barrier Resource System

The Federal Emergency Management Agency Coastal Barrier Resource System (CBRS) Act of 1982 restricts development within the designated system units to prevent future flood damage and protect the barrier system. The units extend seaward to 20 or 30 ft (6.1 or 9.1 m) water depth. These designations are included as part of the analysis tool due to potential restrictions on sediment removal and placement within the federal designated unit as well as funding restrictions. During the development of this report, the Act was updated for the interpretation of beach nourishment projects. The new interpretation allows for the removal of sand from a CBRS to replenish beaches located within and outside the CBRS, if the proposed project is consistent with the purposes of the Act and meets the statutory exception for “nonstructural projects for shoreline stabilization that are designed to mimic, enhance, or restore natural stabilization systems.” This change still requires the project manager to be aware of these units and the project may need to be evaluated by federal agencies. The CBRS polygons were obtained from https://www.fws.gov/cbra/metadata.html.

5.4.4 Habitat Areas of Particular Concern

Regional managers have identified many Habitat Areas of Particular Concern (HAPC) for enhanced EFH conservation. Per NOAA, "HAPCs are now defined as subsets of EFH that exhibit one or more of the following traits: rare, stressed by development, provide important ecological functions for federally managed species, or are especially vulnerable to anthropogenic (or human impact) degradation. They can cover a specific location (a bank or ledge, spawning location) or cover habitat that is found at many locations (e.g., coral, nearshore nursery areas, or pupping grounds). These areas of high priority for EFH conservation have the following conditions: major ecological functions, sensitivity to decline, stress from development and rare habitat. For example, coastal estuaries, canopy kelp, shallow corals, seagrass, and rocky reefs merit special attention from NOAA Fisheries." HAPC data are available through the EFH Mapper at https://www.habitat.noaa.gov/apps/efhmapper/. No HAPCs lie in GLO Region 4.

5.4.5 National Wildlife Refuges

National Wildlife Refuges were digitized by the GLO from hardcopy maps provided by the U.S. Fish and Wildlife Service Realty Division. This dataset was provided by the GLO for a previous APTIM project.

5.4.6 Ocean Disposal Sites/Dredged Material Placement Sites

In 1972, Congress enacted the Marine Protection, Research, and Sanctuaries Act (MPRSA, also known as the Ocean Dumping Act) to prohibit the dumping of material into the ocean that would unreasonably degrade or endanger human health or the marine environment. Virtually all material ocean dumped today is dredged material (sediments) removed from the bottom of waterbodies to maintain navigation channels and berthing areas. Other materials that are currently ocean disposed include fish waste and vessels. Ocean dumping cannot occur unless a permit is issued under the MPRSA. In the case of dredged material, the decision to issue a permit is made by the U.S. Army Corps of Engineers (USACE), using U.S. Environmental Protection Agency (EPA) environmental criteria and subject to environmental protection concurrence. For all other materials, EPA is the permitting agency. EPA is also responsible for designating recommended ocean dumping sites for all types of materials. The locations of these sites were obtained from https://www.epa.gov/ocean-dumping/ocean-disposal-map.

5.4.7 Wildlife Management Areas (WMA)

Texas Wildlife Management Areas (WMA) are divided into seven regions of the Texas Parks and Wildlife Department with the goal of managing and conserving the natural and cultural resources of Texas. There are 714,094 acres (about the area of Yosemite National Park) under management of the Division of Wildlife often referred to as a WMA. These areas are available from https://tpwd.texas.gov/gis/.

Figure 35. Environmental and Critical Habitat Datasets Identified in the Lower OCS Study Area

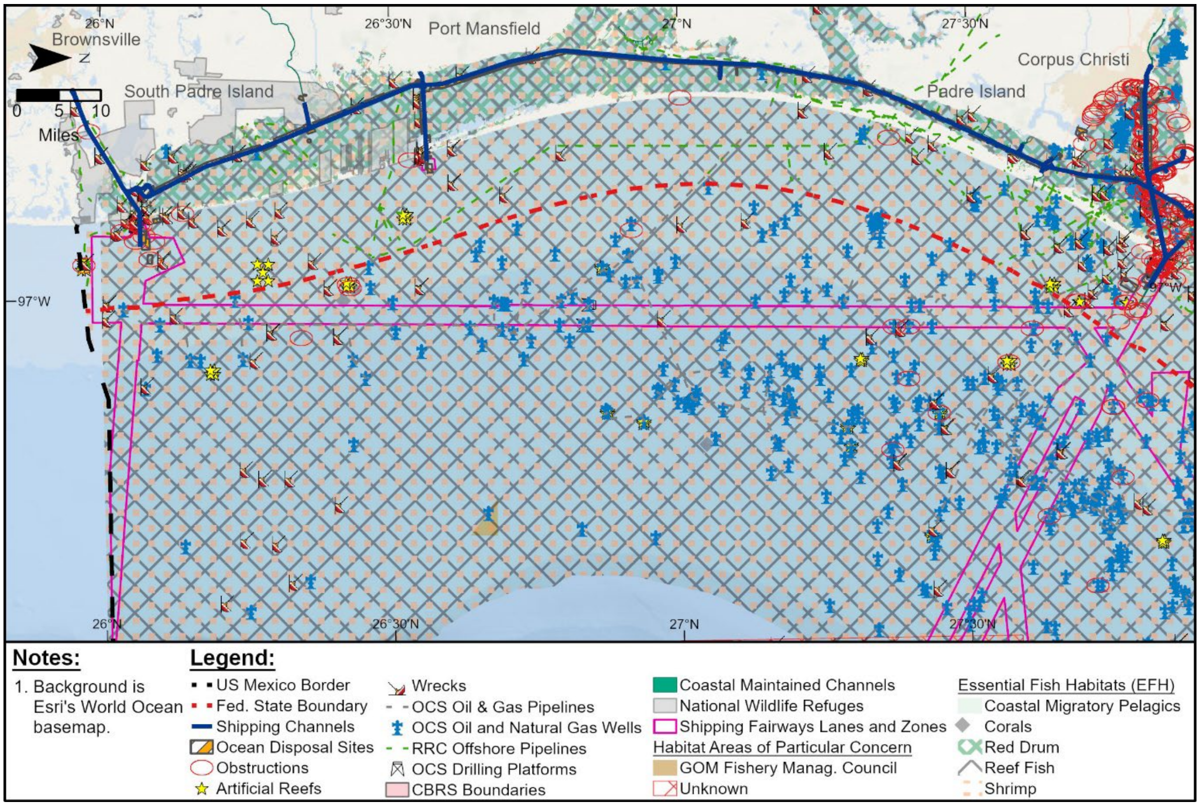


Figure 36. Environmental and Critical Habitat Datasets Identified in the Central OCS Study Area

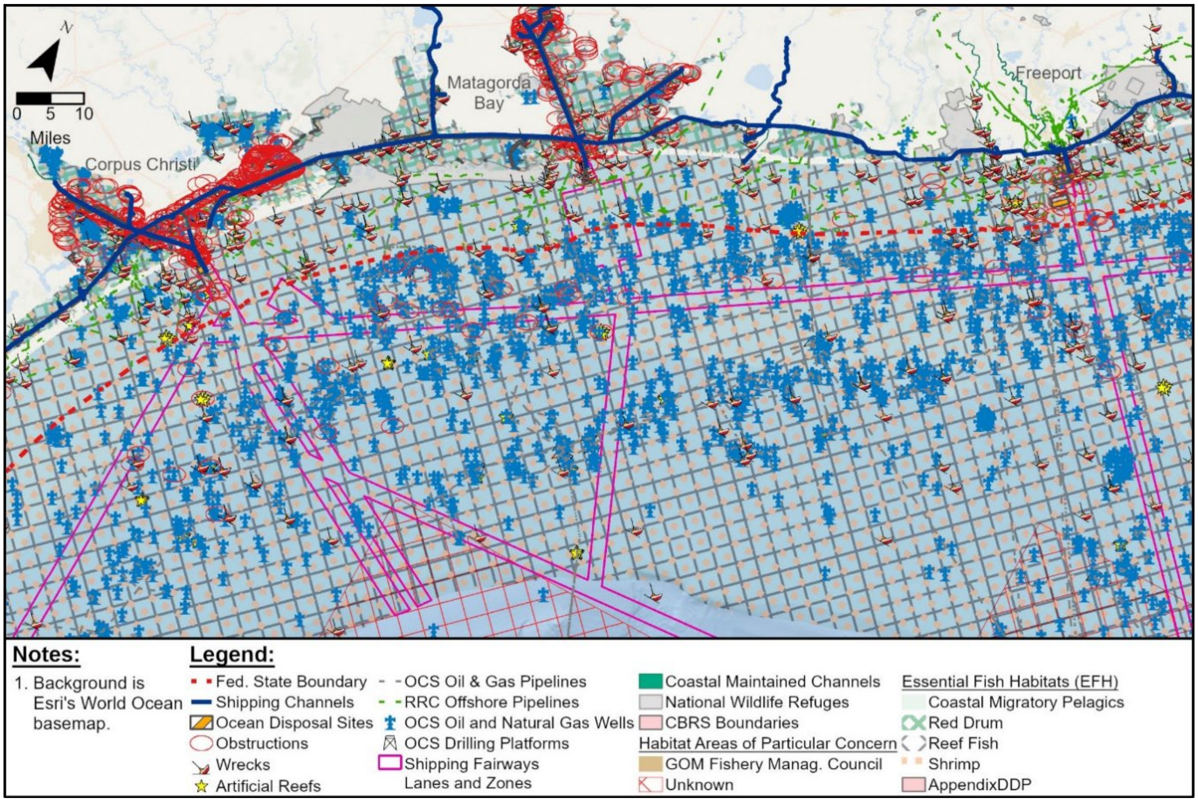
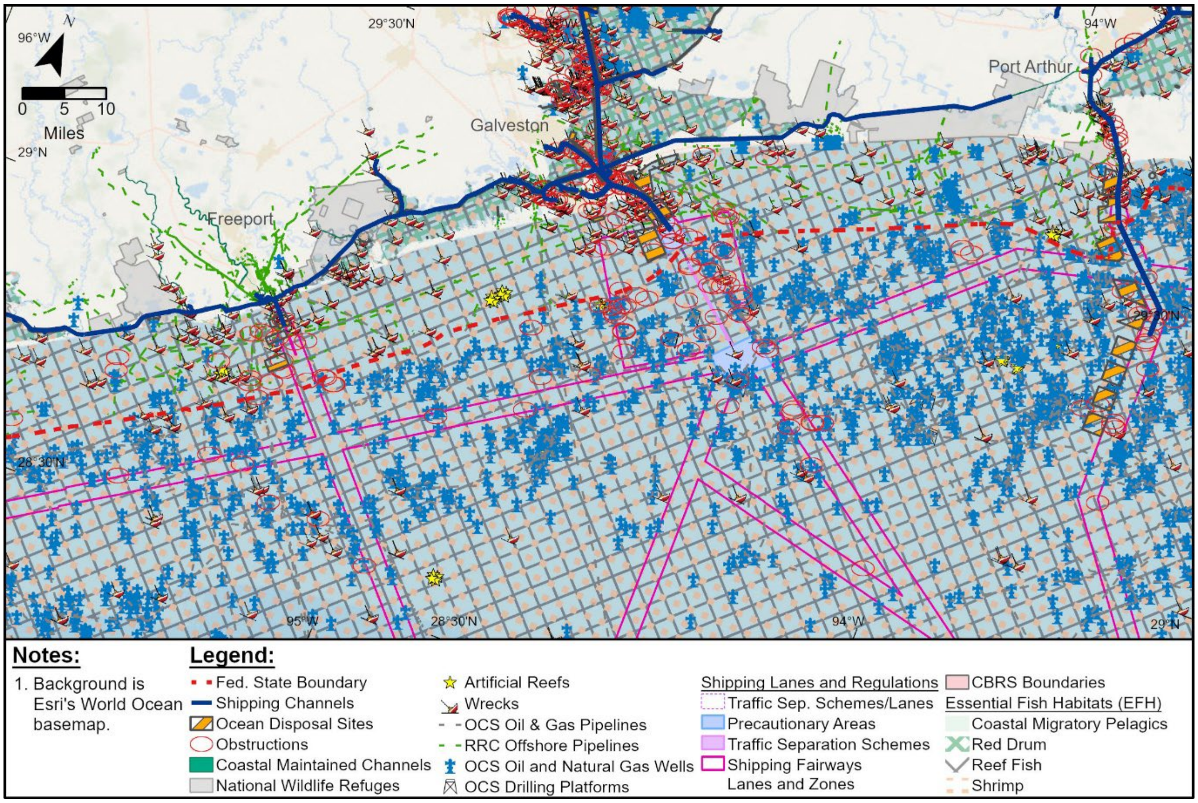


Figure 37. Environmental and Critical Habitat Datasets Identified in the Upper OCS Study Area



6 Survey Plan

APTIM compiled and evaluated available reports, geophysical data and geotechnical data to develop a geophysical data collection survey plan in the Lower OCS. The final survey plan consists of a survey grid with various dimensions. The Lower OCS survey will be conducted from the offshore state-federal boundary to the 50 meter depth contour. Both the Central and Upper OCS additional survey lines are designed to fill data gaps. The sum of which totaled approximately 1,790 nm (3315.1 km) (Figure 38).

APTIM proposes to collect up to 1,790 nm (3315.1 km) of geophysical data, where 800 nm (1481.6 km) of data will be collected along the Lower Coast. This will be followed up by the collection 353 nm (653.8 km) of geophysical data within the Central Texas region (Corpus Christi to Freeport, Texas Figure 39). This investigation into the Central Coast follows up on the survey APTIM conducted in 2022. APTIM will then collect 549 nm (1016.7 km) to investigate potential sand bearing resources within the Upper OCS region (defined as Freeport to Sabine) (Figure 40) This upper region investigation is a follow-up from an APTIM 2020 survey in Region 1 and Upper OCS. Finally, the APTIM Team has allocated 88 nm (163 km) (5 percent of total base mileage) for investigations into potential sand-bearing resources and/or high priority shallow paleochannels that will be allocated in the Lower OCS study area upon real time review of the data being collected in order to properly target features of interest.

Figure 38. Planned Lines Along the Lower OCS Study Area

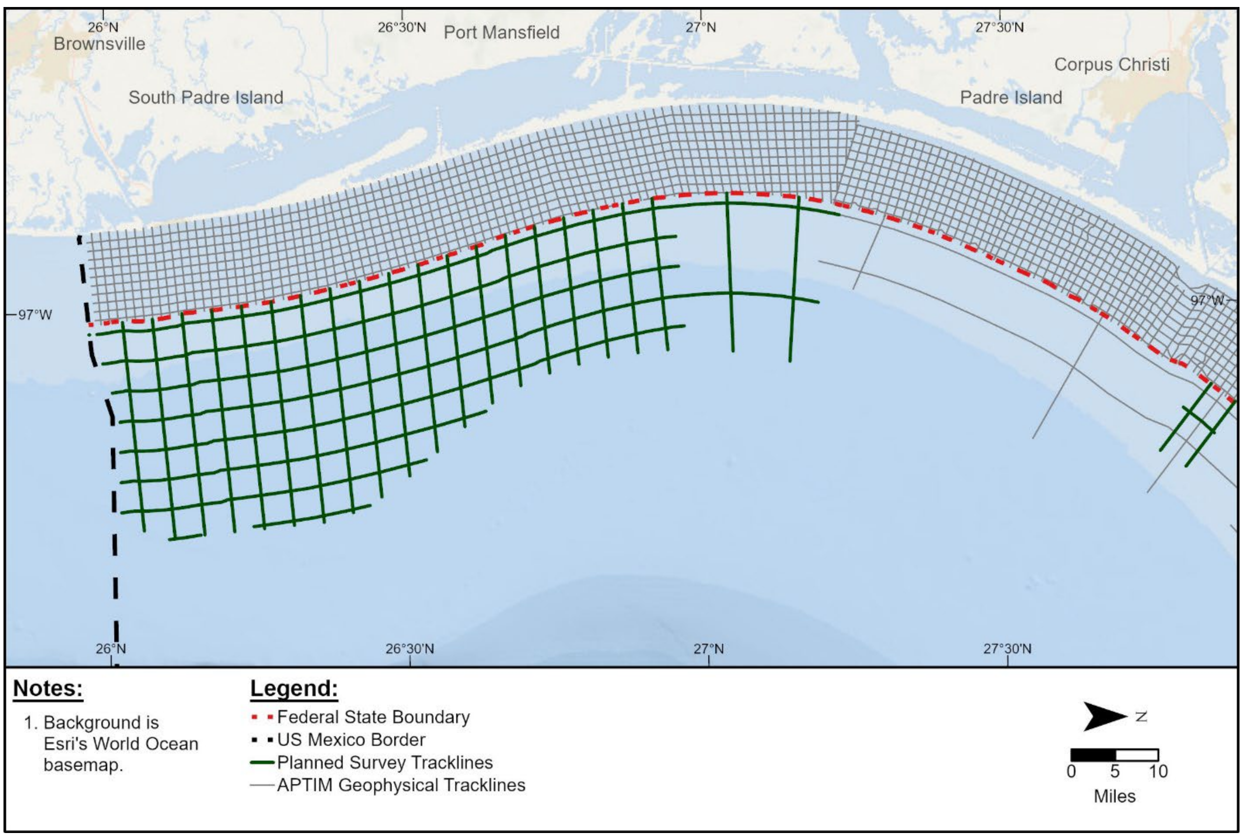


Figure 39. Planned Lines Along the Central OCS Study Area

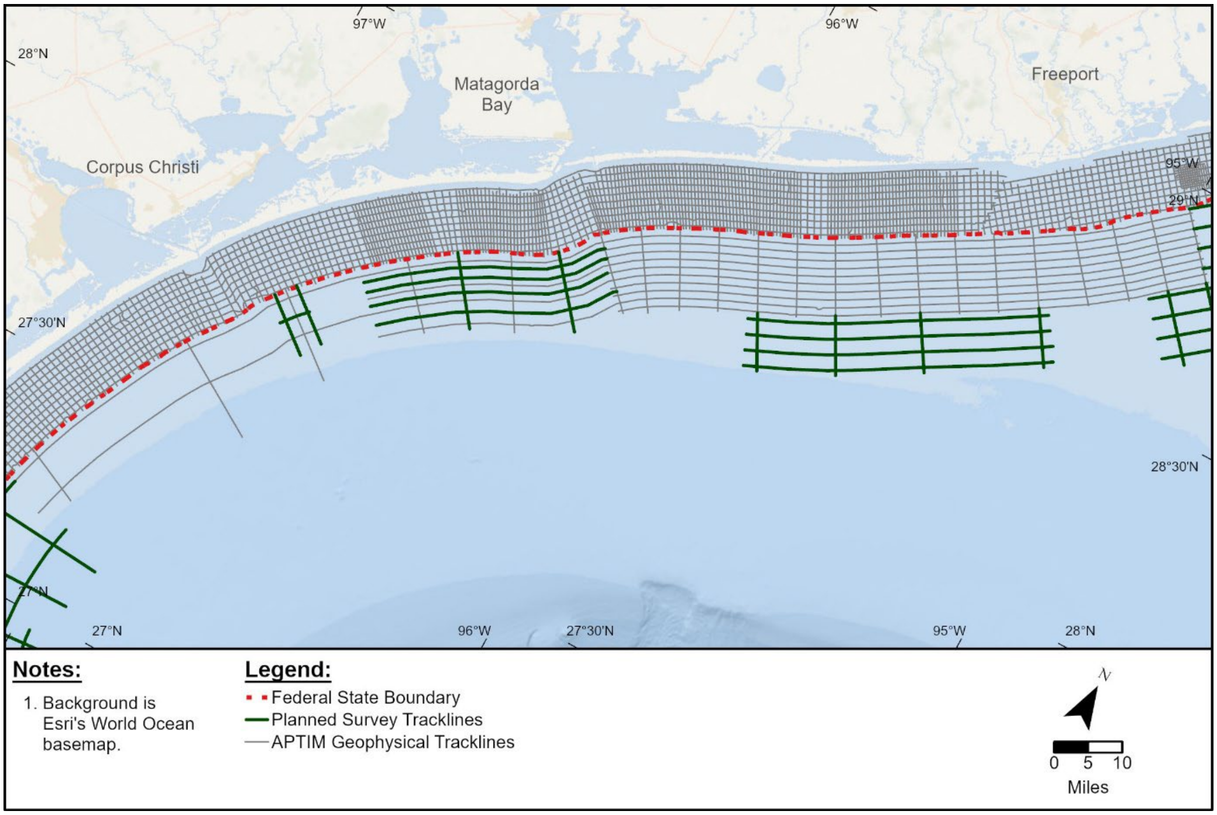
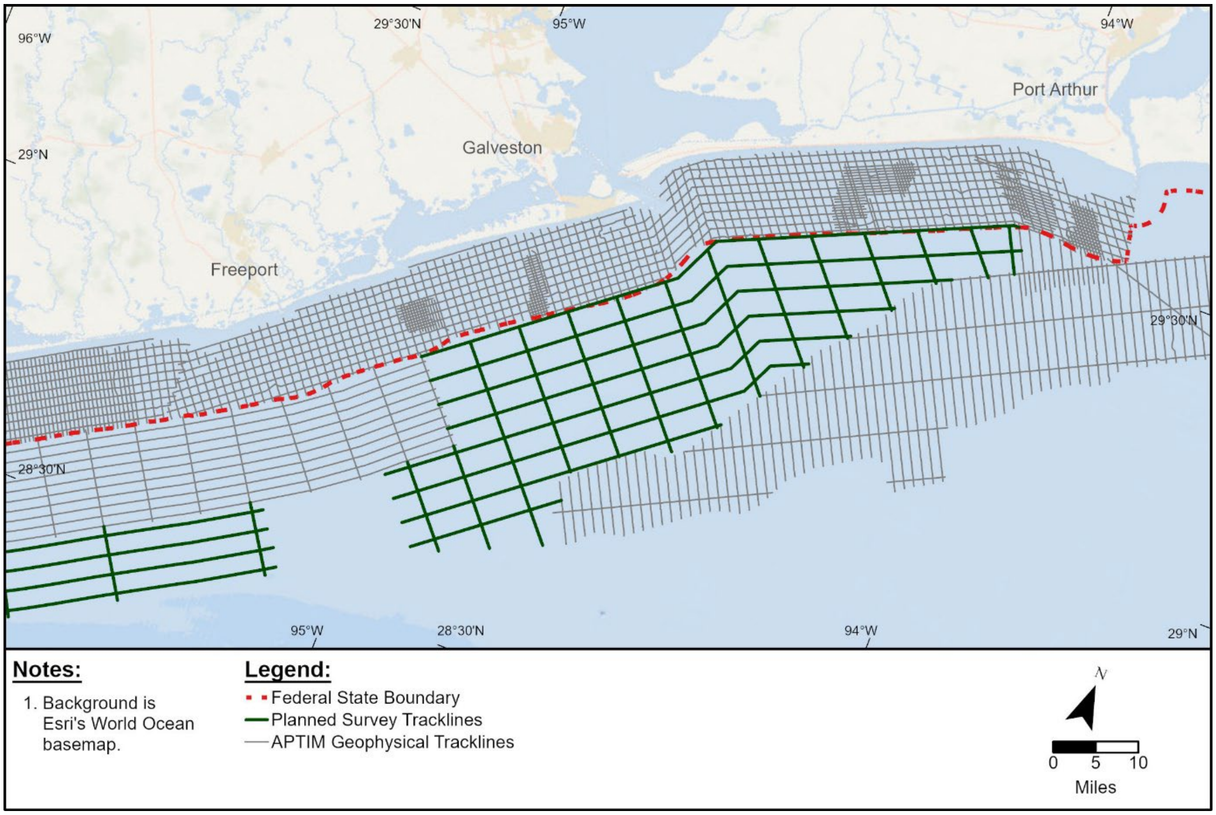


Figure 40. Planned Lines Along the Upper OCS Study Area



7 References

Anderson, J.B., Rodriguez, A., Abdulah, K.C., Fillon, R.H., Banfield, L.A., McKeown, H.A., Wellner, J.S. 2004. Late Quaternary stratigraphic evolution of the northern Gulf of Mexico: a synthesis. In: Anderson, J.B., Fillon, R.H. (Eds.), Late Quaternary Stratigraphic Evolution of the Northern Gulf of Mexico Margin. Society for Sedimentary Geology, Special Publication 79, pp. 1–23.

Anderson, J.B., D.J. Wallace, A.R. Simms, A.B. Rodriguez, K.T. Milliken. 2014. Variable response of coastal environments of the northwestern Gulf of Mexico to sea-level rise and climate change: implications for future change. Mar.Geol.352,348–366.

Anderson, J.B., Wallace, D.J., Simms, A.R., Rodriguez, Robert, W., Weight, Z., and Patrick Taha. 2016. Recycling sediments between source and sink during a eustatic cycle: Systems of late Quaternary Northwestern Gulf of Mexico Basin. Earth-Science Reviews 153 (2015) 111–138. http://dx.doi.org/10.1016/j.earscirev.2015.10.014.

Anderson, J. B., Wallace, D. J., Rodriguez, A. B., Simms, A. R., & Milliken, K. T. 2022. Holocene Evolution of the Western Louisiana–Texas Coast, USA: Response to Sea-Level Rise and Climate Change. In Holocene Evolution of the Western Louisiana–Texas Coast, USA: Response to Sea-Level Rise and Climate Change. Geological Society of America. https://doi.org/10.1130/2022.1221(01).

Aptim Environmental & Infrastructure, LLC (APTIM) and The Water Institute of the Gulf (TWI). 2021. Texas General Land Office Region 1 Offshore Reconnaissance Geophysical Sand Search Survey: Geophysical Investigation. Final Report prepared for the Texas General Land Office. Contract No. 18-127-014: 86 p.

Aptim Environmental & Infrastructure, LLC (APTIM) and The Water Institute of the Gulf. 2022. Texas General Land Office Offshore Sediment Resource Inventory: Geological and Geophysical Data Collection and Processing for Identification of Outer Continental Shelf Mineral Resources Offshore of Texas. Final Report prepared for the Texas General Land Office. Contract No. 18- 127-014: 94 p.

Aptim Environmental & Infrastructure, LLC (APTIM) and The Water Institute (TWI). 2024a. Texas General Land Office Regions 2 & 3 Offshore Reconnaissance Geophysical Sand Search Survey: Geophysical Investigation. Final Report prepared for the Texas General Land Office. Contract No. 22-004-003: 112 p.

Aptim Environmental & Infrastructure, LLC (APTIM) and The Water Institute (TWI). 2024b. Texas General Land Office Central Outer Continental Shelf Offshore Sand Source Survey. Final Report prepared for the Texas General Land Office. Contract No. 18-127-014: 93 p.

APTIM-CPE. 2001. Holly Beach Breakwater Enhancement and Sand Management Plan. Preliminary Evaluation of Offshore Sand Sources Near Holly Beach Louisiana. Boca Raton, FL: Coastal Planning & Engineering, Inc., 115p (Prepared for Louisiana Department of Natural Resources).

Banfield, L. 1998. The Quaternary Evolution of the Rio Grande System, offshore south Texas. PH. D. dissertation. Rice University, Houston Texas.

Banfield, L., and Anderson, J.B. 2004. The Late Quaternary evolution of the Rio Grande Delta: Complex response to eustasy and climate change, in Anderson, J.B., and Fillon, R.H., eds., Late Quaternary Stratigraphic Evolution of the Northern Gulf of Mexico Basin: Society for Sedimentary Geology (SEPM) Special Publication 79, p. 289–306. https://doi.org/10.2110/pec.04.79.0289.

Blum, M.D, Aslan, A. 2006. Signatures of climate vs. sea-level change within incised valley-fill successions: Quaternary examples from the Texas Gulf Coast. Sedimentary Geology. 190, 177-211.

Brown, L. F. Jr., J. L. Brewton, W. A. White, and F. Owens. 1976. Geologic Atlas of Texas, McAllen-Brownsville Sheet, by. Color map, scale 1:250,000.

Buffler, R.T., Thomas, W.A. and Speed, R.C. 1994. Crustal structure and evolution of the southeastern margin of North America and the Gulf of Mexico basin. Phanerozoic evolution of North American continent-ocean transitions: Boulder, Colorado, Geological Society of America, Decade of North American Geology, Continent-Ocean Transect Volume, pp.219-264.

Burke, K. 1975. Atlantic evaporites formed by evaporation of water spilled from Pacific, Tethyan, and Southern oceans: Geology, v. 3, p. 613–616.

Chamberlin, E.P., and Hajek, E.A. 2015. Interpreting paleo-avulsion dynamics from multistory sand bodies. Journal of Sedimentary Research, Vol. 85, p. 82-94.

Damuth, J.E. and Olson, H.C. 2015. Latest Quaternary sedimentation in the northern Gulf of Mexico Intraslope Basin Province: I. Sediment facies and depositional processes. Geosphere, 11(6), pp.1689-1718.

Dellapenna, T. M., A. Cardenas, K. Johnson, and J. Flocks. 2009. Report of the Sand Source Investigation of the Paleo-Sabine-Trinity Marine Features (PSTMF). Texas General Land Office/U.S. Minerals Management Service. Pp. 900.

Diegel, F. A., J. F. Karlo, D. C. Schuster, R. C. Shoup, and P. R. Tauvers. 1995. Cenozoic structural evolution and tectono-stratigraphic framework of the northern Gulf coast continental margin, in M. P. A. Jackson, D. G. Roberts, and S. Snelson, eds., Salt tectonics: a global perspective: AAPG Memoir 65, p. 109-151.

Eckles, B., Fassell, M., and Anderson, J.B. 2004, Late Quaternary Evolution of the wave-storm-dominated Central Texas Shelf, in Anderson, J.B., and Fillon, R.H., eds., *Late Quaternary Stratigraphic Evolution of the Northern Gulf of Mexico Basin: Society for Sedimentary Geology (SEPM) Special Publication 79*. Doi: https://doi.org/10.2110/pec.04.79.0271.

Fisher, W.L., Brown, L.F., McGowen, J.H., and Groat, C.G. 1972. Environmental geologic atlas of the Texas coastal zone—Galveston-Houston area: The University of Texas at Austin, Bureau of Economic Geology, 91 p.

Fisher, W.L., Brown, L.F., McGowen, J.H., and Groat, C.G. 1973. Environmental geologic atlas of the Texas coastal zone—Beaumont-Port Arthur area: The University of Texas at Austin, Bureau of Economic Geology, 93 p.

Freese and Nichols Inc. 2016. Texas Coastal Sediment Sources General Evaluation Study. Texas General Land Office, GLO Contract No. 13-333-004.

Fulton, K.J. 1976. Subsurface stratigraphy, depositional environments, and aspects of reservoir continuity- Rio Grande Delta, Texas (PhD dissertation).

Galloway, W.E. 2008. Chapter 15 Depositional Evolution of the Gulf of Mexico Sedimentary Basin, in: Sedimentary Basins of the World. Elsevier, pp. 505–549. https://doi.org/10.1016/S1874-5997(08)00015-4.

Hajek EA, Straub KM. 2017. Autogenic Sedimentation in Clastic Stratigraphy. Annu Rev Earth Planet Sci. 45(1):681–709. doi:10.1146/annurev-earth-063016-015935.

Goudge, T.A., Swartz, J.M., Dong, T.Y., and Mohrig, D.C. 2023. Characterizing the response of the coastal Rio Grande to Upstream Damming. Geomorphology. Vol 426

Heinrich, P.V., Miner, M., Paulsell, R., McCulloh, R.P. 2020. Response of Later Quaternary Valley Systems to Holocene Sea Level Rise on the Continental Shelf Offshore Louisiana: Preservation Potential of Paleolandscapes 109.

Hollis, R.J., Wallace, D.J., Miner, M.D., Gal, N.S., Dike, C. and Flocks, J.G. 2019. Late Quaternary evolution and stratigraphic framework influence on coastal systems along the north-central Gulf of Mexico, USA. Quaternary Science Reviews, 223, p.105910.

Lohse, A.E. 1952. Shallow sediments of the Rio Grande Delta, Unpublished Ph. D., Dissertation, The University of Texas, Austin, Texas, 113 p.

Lohse, A.E. 1958. Mouth of the Rio Grande, in Sedimentology of South Texas, Field Trip Guidebook, Gulf Coast Association of Geological Societies Annual Meeting, 1958, p 55-57.

McGowen, J.H., Proctor, C.V., Brown Jr, L.F., Evans, T.J., Fisher, W.L. and Groat, C.G. 1976. Environmental geologic atlas of the Texas coastal zone–Port Lavaca area: The University of Texas at Austin. Bureau of Economic Geology.

Meckel, T.A., and F.J., Mulcahy. 2016. Use of novel high-resolution 3D marine seismic technology to evaluate Quaternary fluvial valley development and geologic controls on shallow gas distribution, inner, shelf, Gulf of Mexico. Interpretation, Vol. 4, No. 1 http://dx.doi.org/10.1190/INT-2015-0092.1.

Moore, S., Heise, E.A., Grove, M., Reisinger, A., and Benavides, J.A. 2021. Evaluating the impacts of dam construction and longshore transport upon modern sedimentation within the Rio Grande Delta (Texas, U.S.A.): Journal of Coastal Research, v. 37, p. 26–40.

Morton, R. A., and J. H. McGowen. 1980. Modern depositional environments of the Texas Coast: Texas Bureau of Economic Geology Guidebook 20, Austin, 167 p.

Nguyen, L.C. and Mann, P. 2016. Gravity and magnetic constraints on the Jurassic opening of the oceanic Gulf of Mexico and the location and tectonic history of the Western Main transform fault along the eastern continental margin of Mexico. Interpretation, 4(1), pp.SC23-SC33.

Odezulu, C.I., Swanson, T., and Anderson, J.B. 2020. Holocene progradation and retrogradation of the Central Texas Coast regulated by alongshore and cross-shore sediment flux variability: The Depositional Record: Journal of the International Association of Sedimentologists, v. 7, p. 77–92, https://doi.org/10.1002/dep2.130.

Olson, H.C., Damuth, J.E., and Nelson, C.H. 2016. Latest Quaternary sedimentation in the northern Gulf of Mexico intraslope basin province II. Stratigraphic analysis and relationship to glacioeustatic climate change. Interpretation 4, pp81-95.

Oster, J., Ibarra, D., Winnick, M. et al. 2015. Steering of westerly storms over western North America at the Last Glacial Maximum. *Nature Geosciences* 8, 201–205. https://doi.org/10.1038/ngeo2365.

Otvos, E.G., Howat, W.E. 1996. South Texas Ingleside Barrier; coastal sediment cycles and vertebrate fauna. Late Pleistocene stratigraphy revised. Trans. Gulf Coast Assoc. Geol. Soc. 46, 333–344.

Page, W.R., VanSistine, D.P., and Turner, K.J. 2005. Preliminary Geologic Map of Southernmost Texas, United States, and Parts of Tamaulipas and Nuevo Leon, Mexico: Environmental Health Investigations in the United States-Mexico Border Region. Denver, Colorado: United States Geological Survey, Open-file report2005– 1409, 11 p., scale1:250,000.

Paine, J.G., Morton, R.A., White, W.A. 1988. Preliminary Assessment of Nonfuel Minerals on the Texas Continental Shelf. Final report prepared for Louisiana Geological Survey, Louisiana State University, under Minerals Management Service contract no. 14-12-0001-30404, by the Bureau of Economic Geology at the University of Texas at Austin.

Price, W.A. 1933. Role of diastrophism in topography of Corpus Christi area, south Texas. AAPG Bull. 17, 907–962.

Rodriguez, A.B., Anderson, J.B., Siringan, F.P. and Taviani, M. 1999. Sedimentary Facies and Genesis of Holocene Sand Banks on the East Texas Inner Continental Shelf, SEPM (Society for Sedimentary Geology) ISBN 1-56576-057-3 p.165-178.

Rodriguez, A.B., Anderson, J.B., Siringan, F.P. and Taviani, M. 2004. Holocene Evolution of the East Texas Coast and Inner Continental Shelf: Along-Strike Variability in Coastal Retreat Rates. Journal of Sedimentary Research Vol 74 No. 3p 405-421.

Rodriguez, A.B., Fassell, M.L., Anderson, J.B. 2001. Variations in Shoreface Progradation and Ravinement Along the Texas Coast, Gulf of Mexico. Sedimentology, Vol 48 p. 837-853.

Rodriguez, A.B., Hamilton, M.D. and Anderson, J.B. 2000. Facies and evolution of the modern Brazos Delta, Texas: wave versus flood influence. Journal of Sedimentary Research, 70(2), pp.283-295.

Rothwell, R.G., Kenyon, N.H., and McGregor, B.A. 1991, Sedimentary features of the South Texas continental slope as revealed by side-scan sonar and high-resolution seismic data: American Association of Petroleum Geologists Bulletin, v. 75, no. 2, p. 298–312.

Salvador, A. (Ed.). 1991. Origin and development of the Gulf of Mexico basin, in: The Gulf of Mexico Basin. Geological Society of America, U.S.A, pp. 389–444. https://doi.org/10.1130/DNAG-GNA-J.389.

Simms, A.R., Anderson, J.B., Taha, Z.P., Rodriguez, A.B. 2006. Overfilled versus underfilled incised valleys: lessons from the Quaternary Gulf of Mexico. In: Dalrymple, R., Leckie, D., Tillman, R. (Eds.), Incised Valleys in Time and Space. SEPM Special Publication 85, pp. 117–139.

Simms, A.R., Anderson, J.B., DeWitt, R., Lambeck, K. and Purcell, A. 2013. Quantifying rates of coastal subsidence since the last interglacial and the role of sediment loading. Global and planetary change, 111, pp.296-308.

Siringan, F.P. and Anderson, J.B. 1994. Modern shoreface and inner-shelf storm deposits off the east Texas coast, Gulf of Mexico. Journal of Sedimentary Research, 64(2b), pp.99-110.

Suter, J.R., and H.L. Berryhill. 1985. Late Quaternary shelf-margin deltas, northwest Gulf of Mexico. The American Association of Petroleum Geologists Bulletin. v69, p77-91.

Swartz, J. 2019. Channel processes and products in subaerial and submarine environments across the Gulf of Mexico, Thesis submitted in partial fulfilment of the requirements for the degree Doctor of Philosophy. The University of Texas at Austin.

Swartz, J. M., Cardenas, B. T., Mohrig, D., & Passalacqua, P. 2022. Tributary channel networks formed by depositional processes. Nature Geoscience, 15(3), 216–221. https://doi.org/10.1038/s41561-022-00900-x.

Vasquez-Garcia, O. 2018. *Tectonic synthesis of the deepwater Lamprea thrust and fold belt, offshore Burgos Basin, western Gulf of Mexico* [Master's Thesis, Colorado School of Mines]. Mines Repository.

Wallace, D.J., Anderson, J.B. and Fernández, R.A. 2010. Transgressive ravinement versus depth of closure: A geological perspective from the Upper Texas coast. Journal of Coastal Research, 26(6), pp.1057-1067.

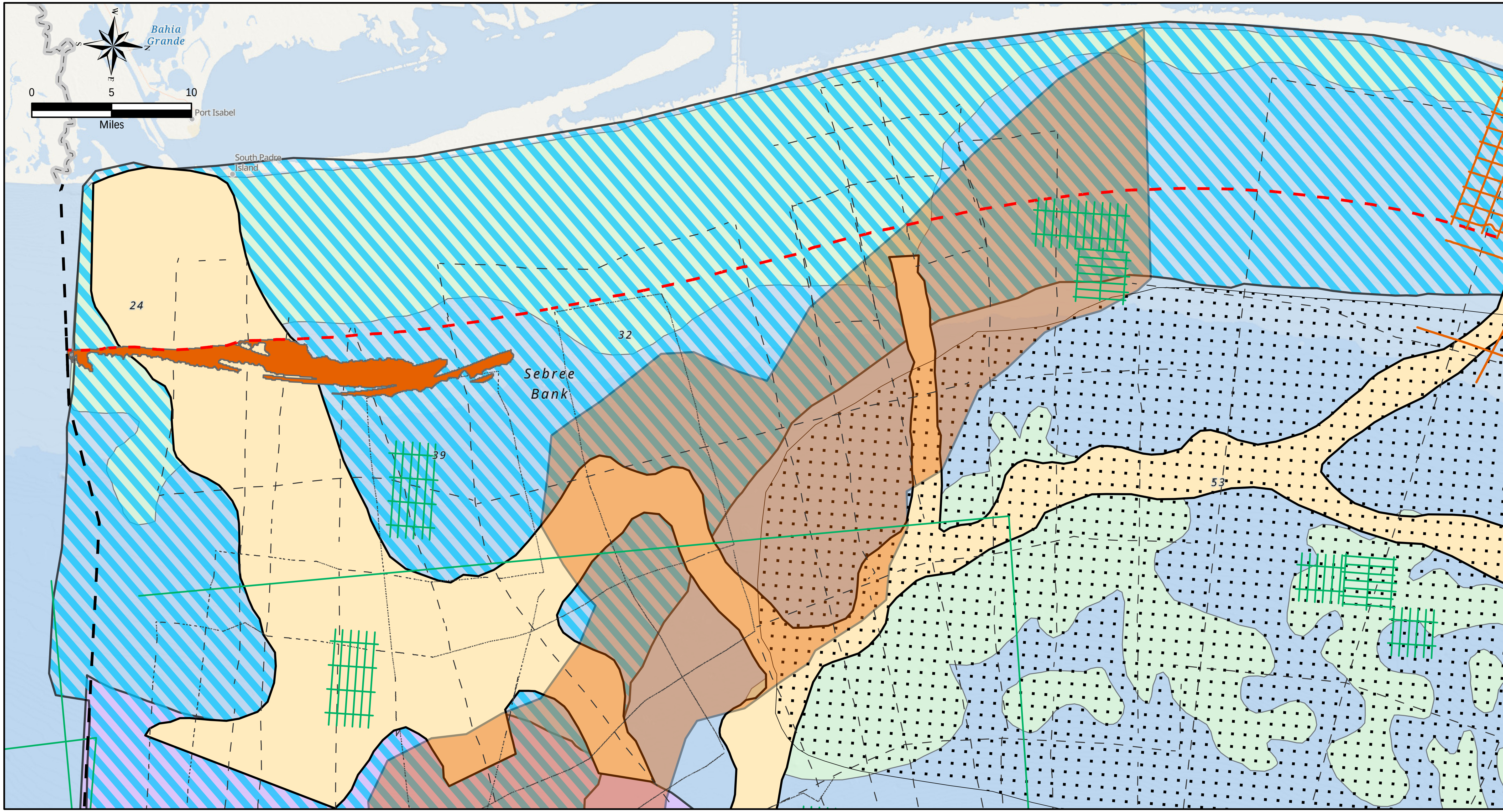
Weight, R.W.R., J.B. Anderson, and R. Fernandez. 2011. Rapid Mud Accumulation on the Central Texas Shelf Linked To Climate Change and Sea-Level Rise. Journal of Sedimentary Research 81, 743–764. https://doi.org/10.2110/jsr.2011.57.

Weimer, P., and R. T. Buffler. 1992. Structural geology and evolution of the Mississippi Fan fold belt, deep Gulf of Mexico, AAPG Bull., 76(2), 225 – 251.

Wilkinson, B.H. 1975. Matagorda Island, Texas: the evolution of a Gulf Coast barrier complex. Geological Society of America Bulletin, 86(7), pp.959-967.

Young, S.C., Ewing, T., Hamlin, S., Baker, E., Lupton, D. 2012. Updating the Hydrogeologic Framework for the Northern Portion of the Gulf Coast Aquifer 285.

Appendix A: Desktop Study Maps



Notes:

1. Background is Esri's World Ocean basemap.

Legend:

- Fed. State Boundary
- US Mexico Border
- 2020-2023 APTIM As Run Tracklines
- MMIS Survey Tracklines
- NOAA Seismic Tracklines
- Anderson et al. 2015 Texas Mud Blanket
- MMIS Modeled Shoals
- Anderson et. al. 16 Rio Grande Delta

Paine et. al. 88 Features

- Shore Parallel Sands
- Wisconsinan Complex
- 7.5m Thick Sand
- Wisconsinan Streams

Title:

Texas General Land Office Lower Outer Continental Shelf Texas Sediment Surveys

Desktop Study Appendix A: Geophysical and Historic data Lower OCS Study Area

APTIM

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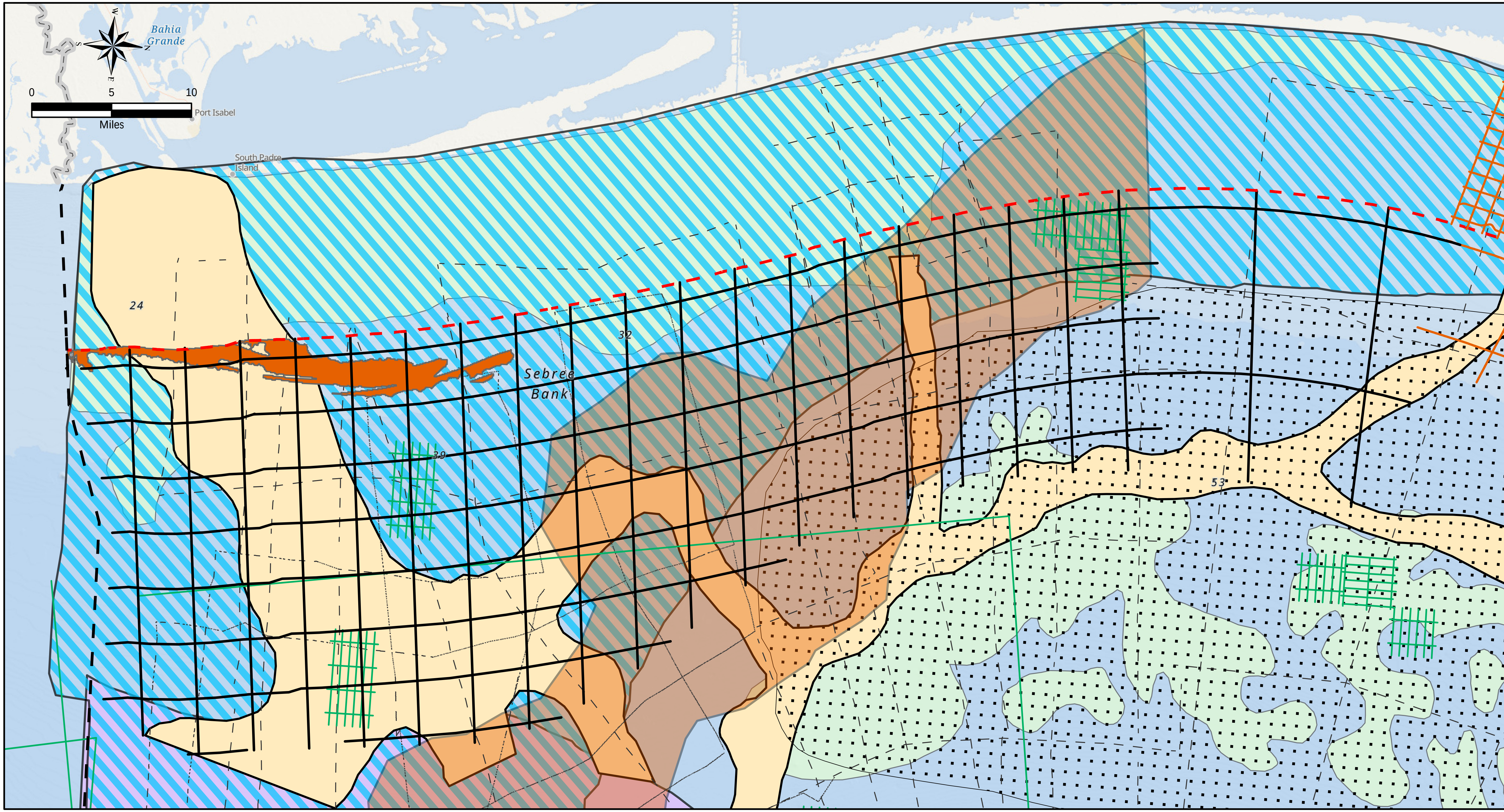
Date: 03/28/2024	Drawn By: AV	Commission No.: 631027330	**Figure No. 1-1a**



Notes:

1. Background is Esri's World Ocean basemap.

Legend:

- Fed. State Boundary
- US Mexico Border
- Planned Survey Tracklines
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Paine et. al. 88 Features

- Shore Parallel Sands
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- Wisconsinan Streams

Title:

Texas General Land Office Lower Outer Continental Shelf Texas Sediment Surveys

Desktop Study Appendix A: Planned Lines, Geophysical and Historic data: Lower OCS Study Area

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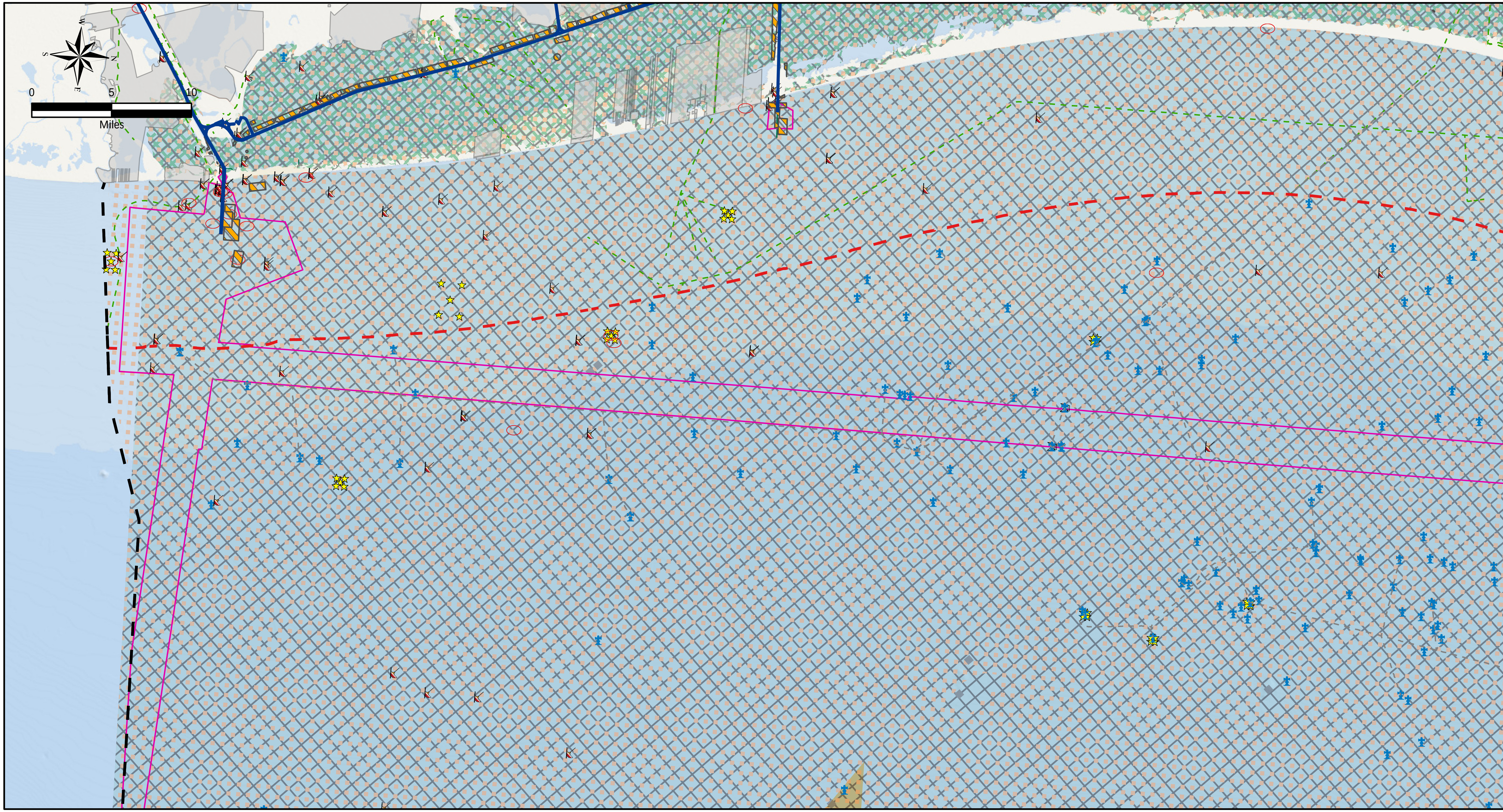
Date: 03/28/2024	Drawn By: AV	Commission No.: 631027330	**Figure No. 1-1b**



Notes:

1. Background is Esri's World Ocean basemap.

Legend:

- Fed. State Boundary
- US Mexico Border
- Artificial Reefs
- Wrecks
- Obstructions
- OCS Drilling Platforms
- OCS Oil and Natural Gas Wells
- OCS Oil & Gas Pipelines
- RRC Offshore Pipelines
- Ocean Disposal Sites
- Shipping Channels
- National Wildlife Refuges
- Coastal Maintained Channels

Habitat Areas of Particular Concern

- GOM Fishery Manag. Council

Shipping Lanes and Regulations

- Shipping Fairways Lanes and Zones

Essential Fish Habitats (EFH)

- Coastal Migratory Pelagics
- Corals
- Red Drum
- Reef Fish
- Shrimp

Title:

Texas General Land Office Lower Outer Continental Shelf Texas Sediment Surveys

Desktop Study Appendix A: Hazards and Avoidance Areas Lower OCS Study Area

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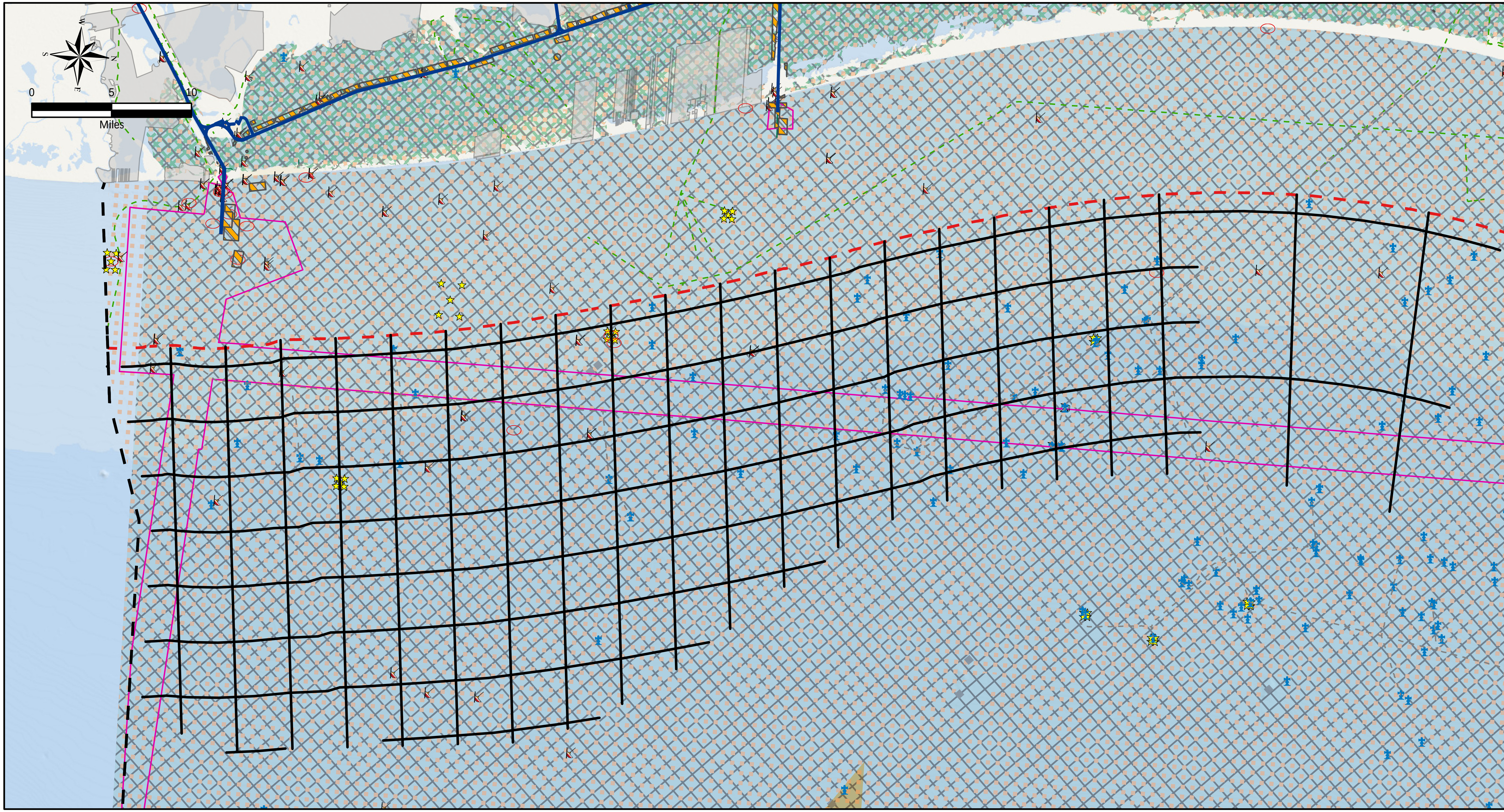
Date: 03/28/2024	Drawn By: AV	Commission No.: 631027330	**Figure No. 2-1a**



Notes:

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Legend:

- Fed. State Boundary
- US Mexico Border
- Planned Survey Tracklines
- Artificial Reefs
- Wrecks
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- OCS Drilling Platforms
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Habitat Areas of Particular Concern

- GOM Fishery Manag. Council

Shipping Lanes and Regulations

- Shipping Fairways Lanes and Zones

Essential Fish Habitats (EFH)

- Coastal Migratory Pelagics
- Corals
- Red Drum
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- Shrimp

Title:
Texas General Land Office Lower Outer Continental Shelf Texas Sediment Surveys

Desktop Study Appendix A: Planned Lines, Hazards and Avoidance Areas: Lower OCS Study Area

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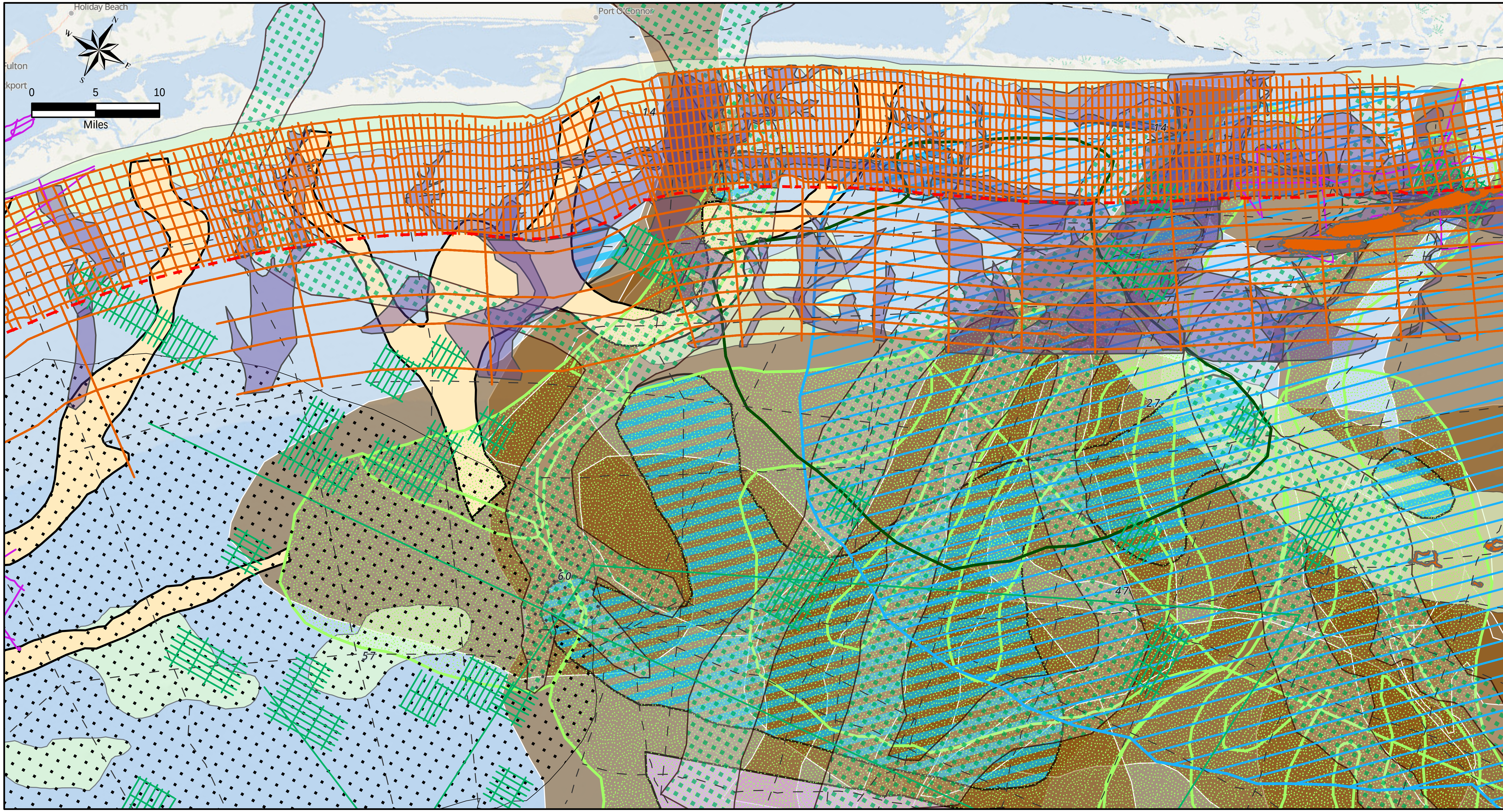
Date: 03/28/2024	Drawn By: AV	Commission No.: 631027330	Figure No. 2-1b



Notes:

1. Background is Esri's World Ocean basemap.

Legend:

- Fed. State Boundary
- 2020-2023 APTIM As Run Tracklines
- UTIG Seismic Tracklines
- MMIS Survey Tracklines
- NOAA Seismic Tracklines
- MMIS Modeled Shoals
- 2020-2022 APTIM/TWI Geologic Features
- Anderson et al. 2004 Lowstand Incised Valley
- Freese and Nichols 2016 Paleo Brazo and Colorado Delta
- Anderson et al. 2015 Delta System
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- Anderson et al. 2015 Texas Mud Blanket
- Abdulah 1995 Colorado Brazos System

Paine et. al. 88 Features

- Shore Parallel Sands
- Wisconsinan Complex
- 7.5m Thick Sand
- Wisconsinan Streams

Title:

Texas General Land Office Lower Outer Continental Shelf Texas Sediment Surveys

Desktop Study Appendix A: Geophysical and Historic data Central OCS Study Area

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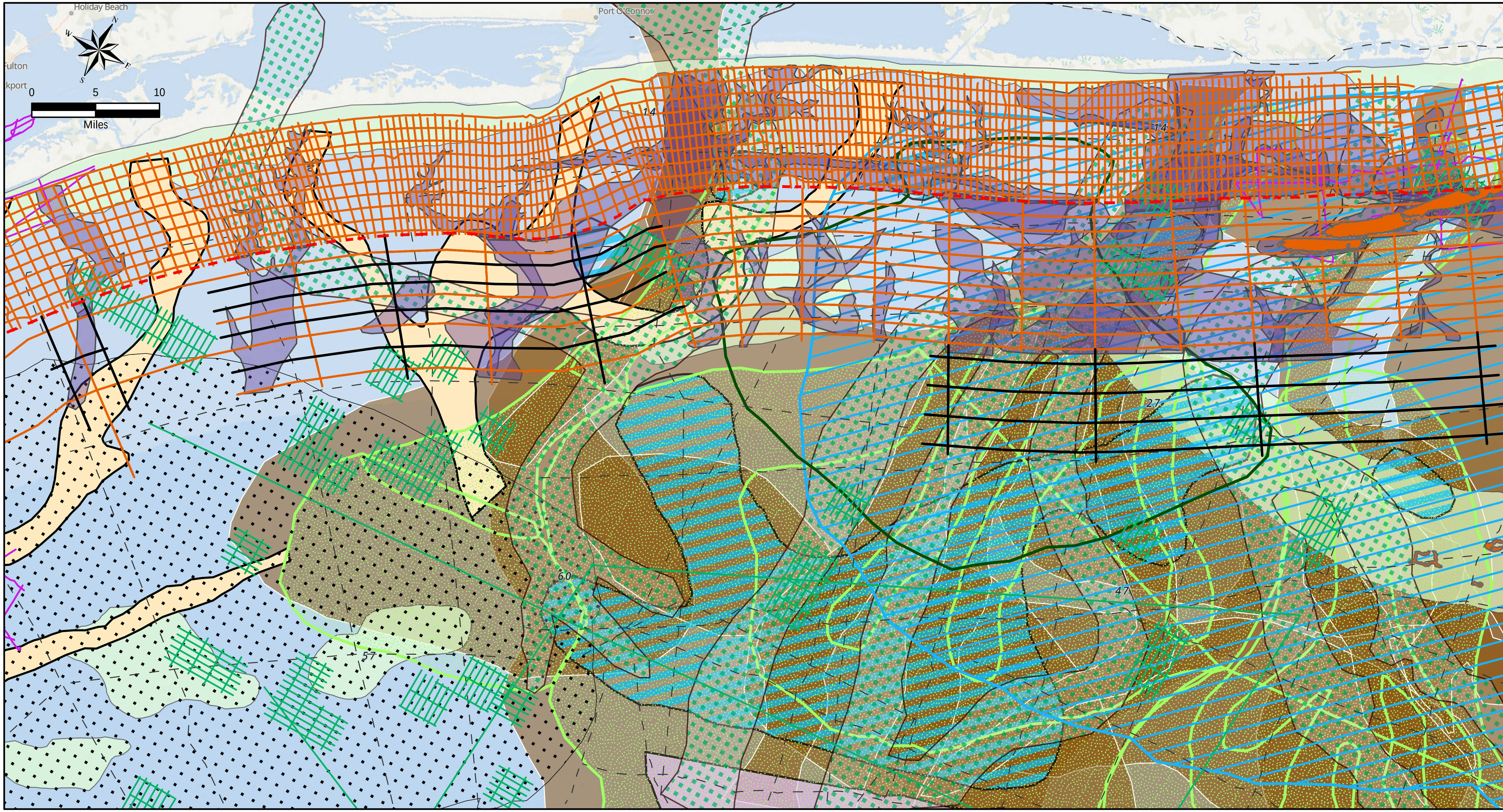
Date: 03/28/2024	Drawn By: AV	Commission No.: 631027330	**Figure No. 1-2a**



Notes:

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Paine et. al. 88 Features

- Shore Parallel Sands
- Wisconsinan Complex
- 7.5m Thick Sand
- Wisconsinan Streams

Title:

Texas General Land Office Lower Outer Continental Shelf Texas Sediment Surveys

Desktop Study Appendix A: Planned Lines, Geophysical and Historic data: Central OCS Study Area

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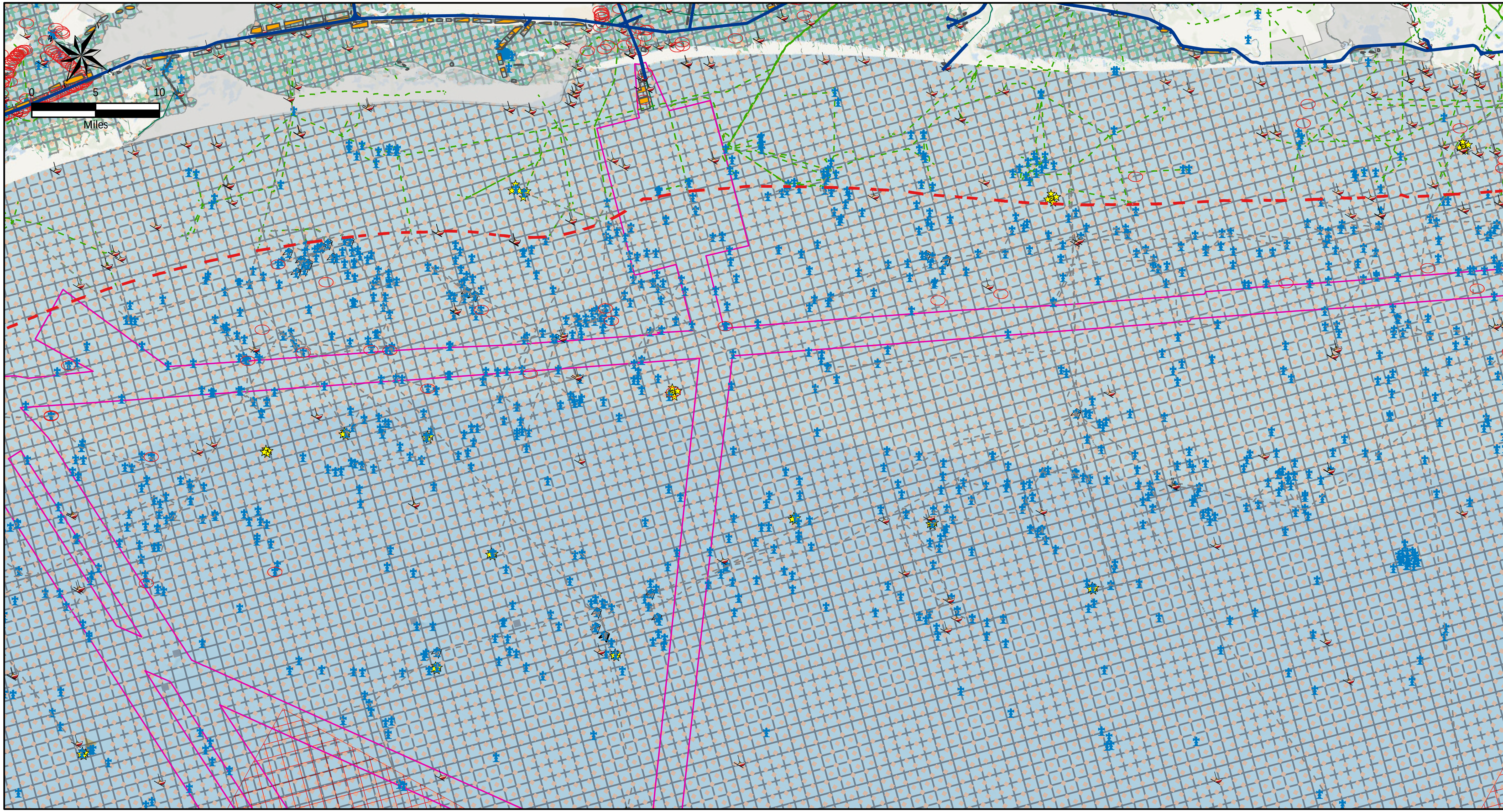
Date: 03/28/2024	Drawn By: AV	Commission No.: 631027330	**Figure No. 1-2b**



Notes:

1. Background is Esri's World Ocean basemap.

Legend:

- Fed. State Boundary
- Artificial Reefs
- Wrecks
- Obstructions
- OCS Drilling Platforms
- OCS Oil and Natural Gas Wells
- OCS Oil & Gas Pipelines
- RRC Offshore Pipelines
- Ocean Disposal Sites
- Shipping Channels
- National Wildlife Refuges
- Coastal Maintained Channels

Habitat Areas of Particular Concern

- GOM Fishery Manag. Council
- Unknown

Shipping Lanes and Regulations

- Shipping Fairways Lanes and Zones

Essential Fish Habitats (EFH)

- Coastal Migratory Pelagics
- Corals
- Red Drum
- Reef Fish
- Shrimp

Title:
Texas General Land Office Lower Outer Continental Shelf Texas Sediment Surveys

Desktop Study Appendix A: Hazards and Avoidance Areas
Central OCS Study Area

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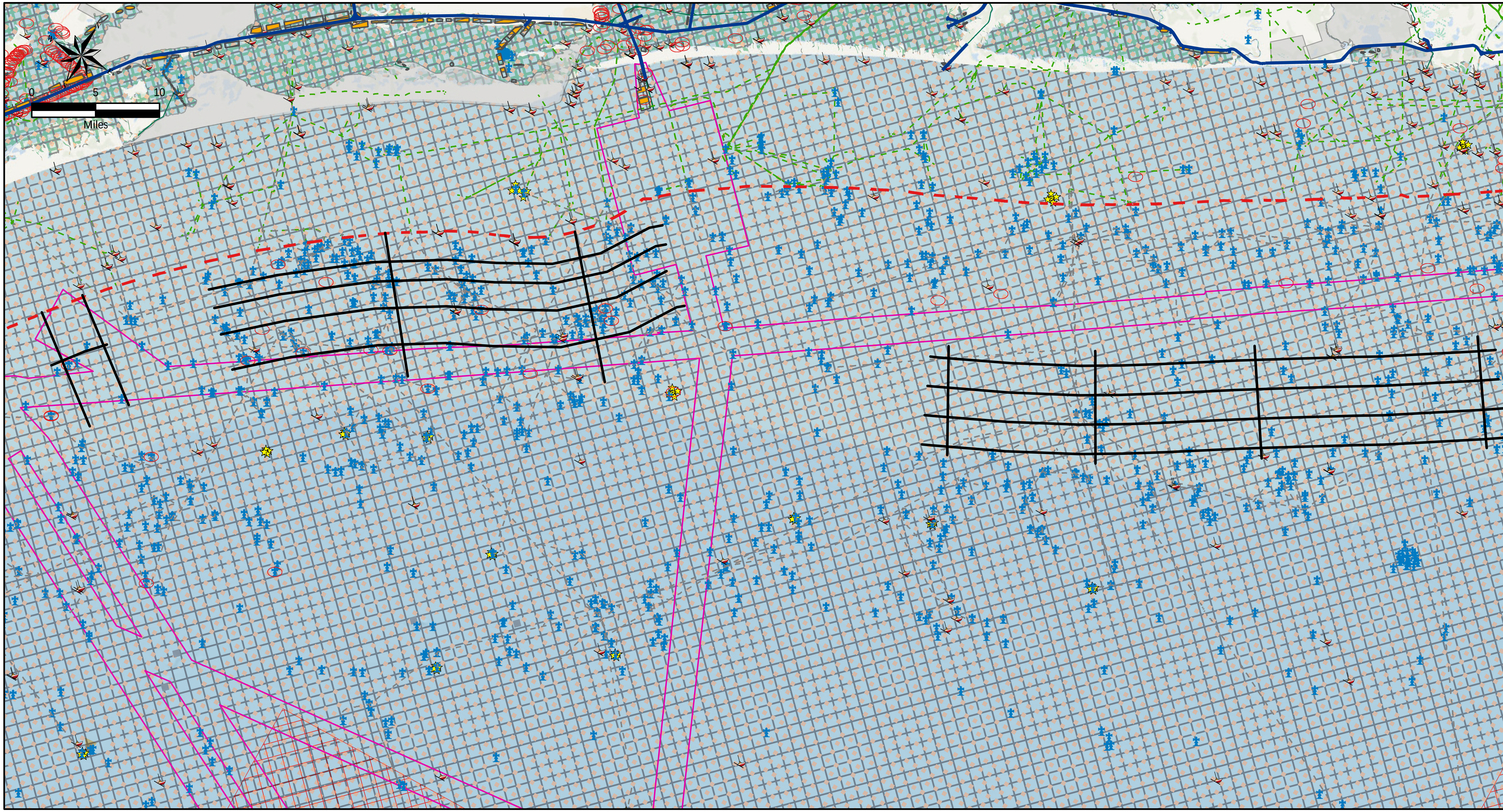
Date: 03/28/2024	Drawn By: AV	Commission No.: 631027330	Figure No. 2-2a



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Legend:

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- Red Drum
- Reef Fish
- Shrimp

Title:

Texas General Land Office Lower Outer Continental Shelf Texas Sediment Surveys

Desktop Study Appendix A: Planned Lines, Hazards and Avoidance Areas: Central OCS Study Area

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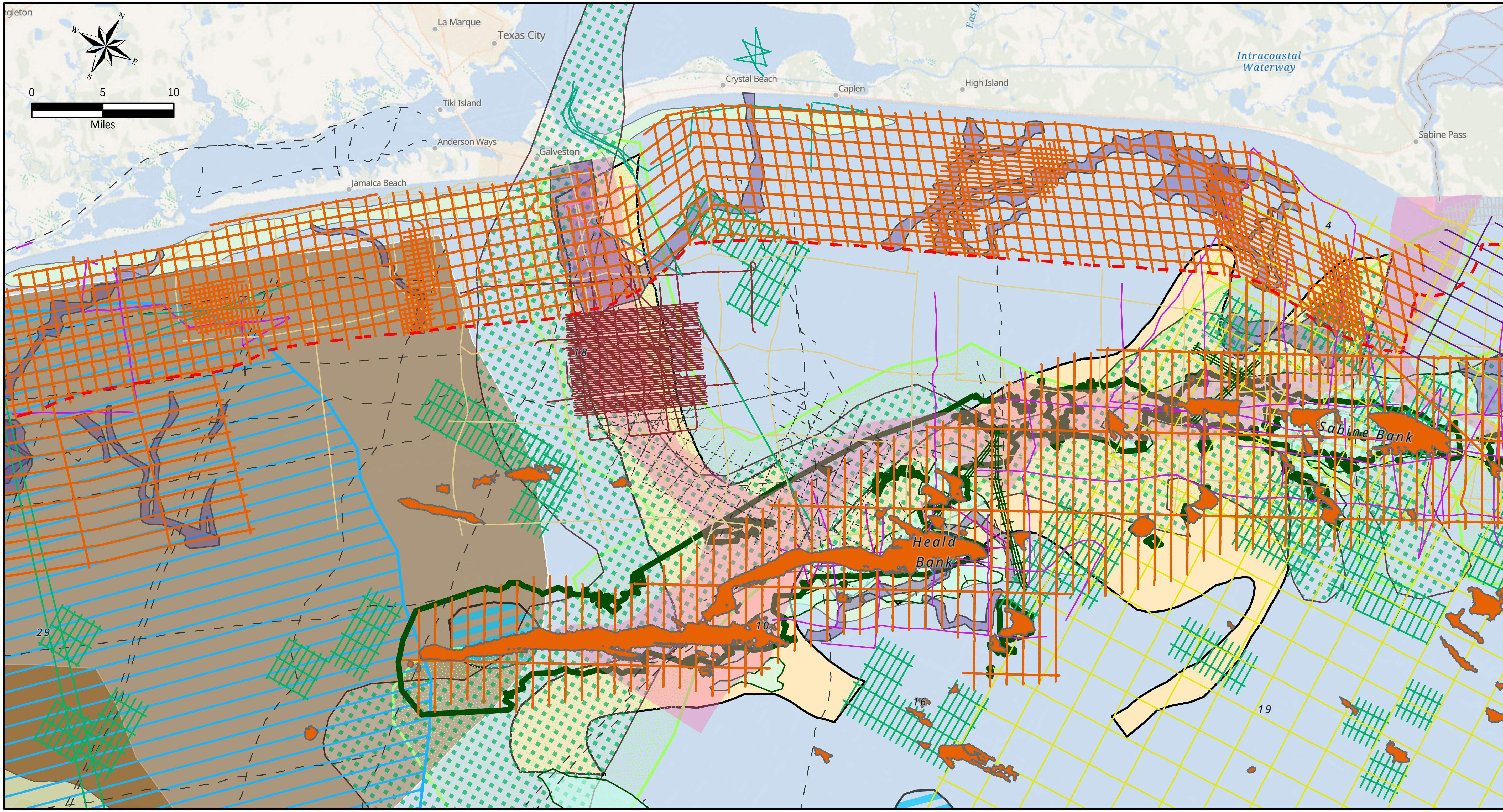
Date: 03/28/2024	Drawn By: AV	Commission No.: 631027330	**Figure No. 2-2b**



Notes:

1. Background is Esri's World Ocean basemap.

Legend:

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- 2020-2023 APTIM As Run Tracklines
- UTIG Seismic Tracklines
- MMIS Survey Tracklines
- NOAA Seismic Tracklines
- MNT1301
- USGS 09CCT01
- TRiPP
- ACAD0801
- LASARD
- 2018 APTIM
- LASED
- 1988-1992 Surveys
- 2000-2001 CPE
- Bosse, Flocks and Forde
- Siringin and Anderson
- MMIS Modeled Shoals
- Trinity/Sabine Paleovalley
- Q1 Thickness (>5)
- Sand Shoals
- Paine et. al. 88 Features
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Title:
Texas General Land Office Lower Outer Continental Shelf Texas Sediment Surveys

Desktop Study Appendix A: Geophysical and Historic data Upper OCS Study Area

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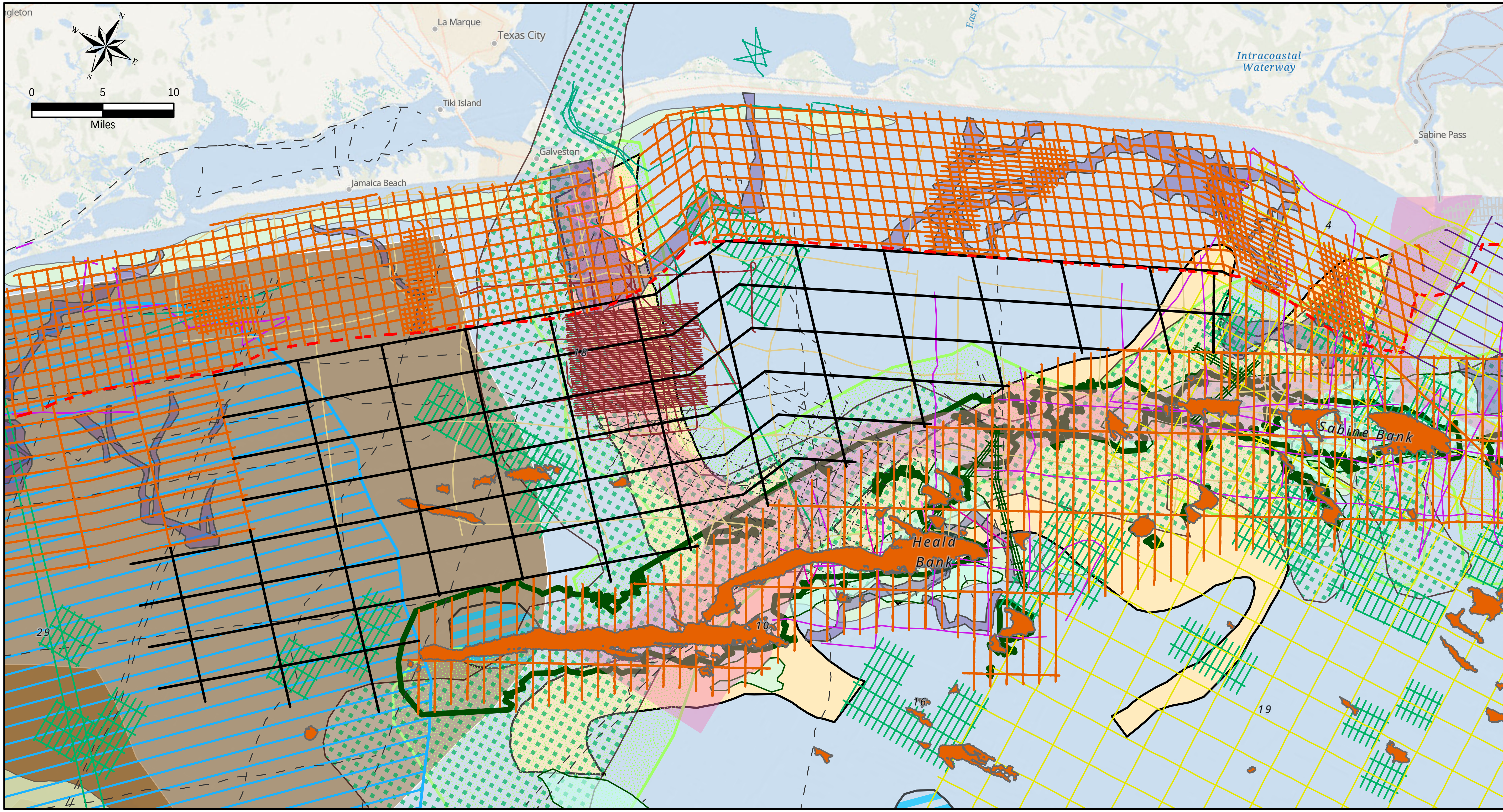
Date: 03/28/2024	Drawn By: AV	Commission No.: 631027330	Figure No. 1-3a



Notes:

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- Planned Survey Tracklines
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Paine et. al. 88 Features

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Title:

Texas General Land Office Lower Outer Continental Shelf Texas Sediment Surveys

Desktop Study Appendix A: Planned Lines, Geophysical and Historic data: Upper OCS Study Area

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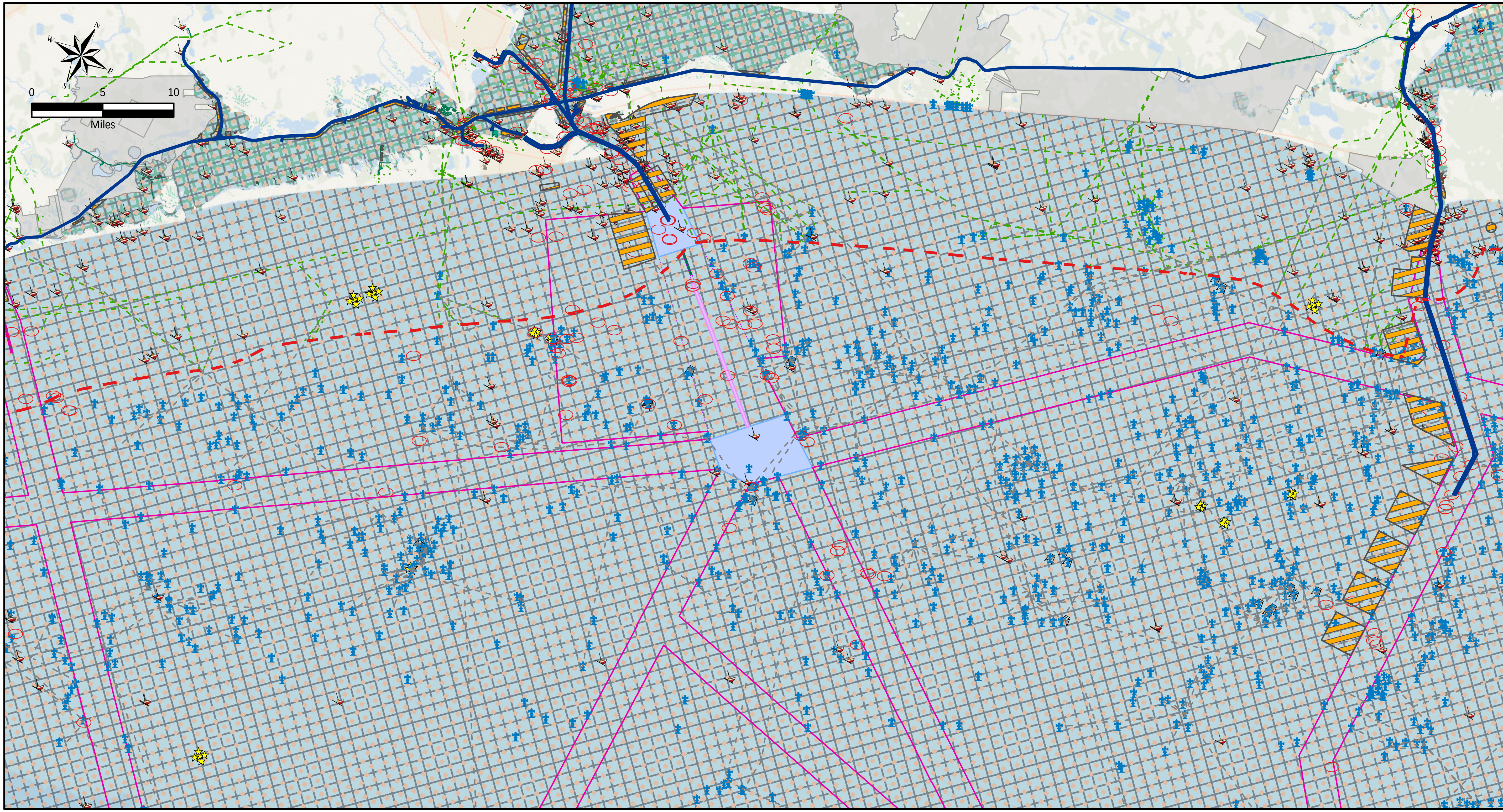
Date: 03/28/2024	Drawn By: AV	Commission No.: 631027330	**Figure No. 1-3b**



Notes:

1. Background is Esri's World Ocean basemap.

Legend:

- Fed. State Boundary
- Artificial Reefs
- Wrecks
- Obstructions
- OCS Drilling Platforms
- OCS Oil and Natural Gas Wells
- OCS Oil & Gas Pipelines
- RRC Offshore Pipelines
- Ocean Disposal Sites
- Shipping Channels
- National Wildlife Refuges
- Coastal Maintained Channels

Shipping Lanes and Regulations

- Traffic Sep. Schemes/Lanes
- Precautionary Areas
- Traffic Separation Schemes
- Shipping Fairways Lanes and Zones

Essential Fish Habitats (EFH)

- Coastal Migratory Pelagics
- Red Drum
- Reef Fish
- Shrimp

Title:
Texas General Land Office Lower Outer Continental Shelf Texas Sediment Surveys
Desktop Study Appendix A: Hazards and Avoidance Areas
Upper OCS Study Area

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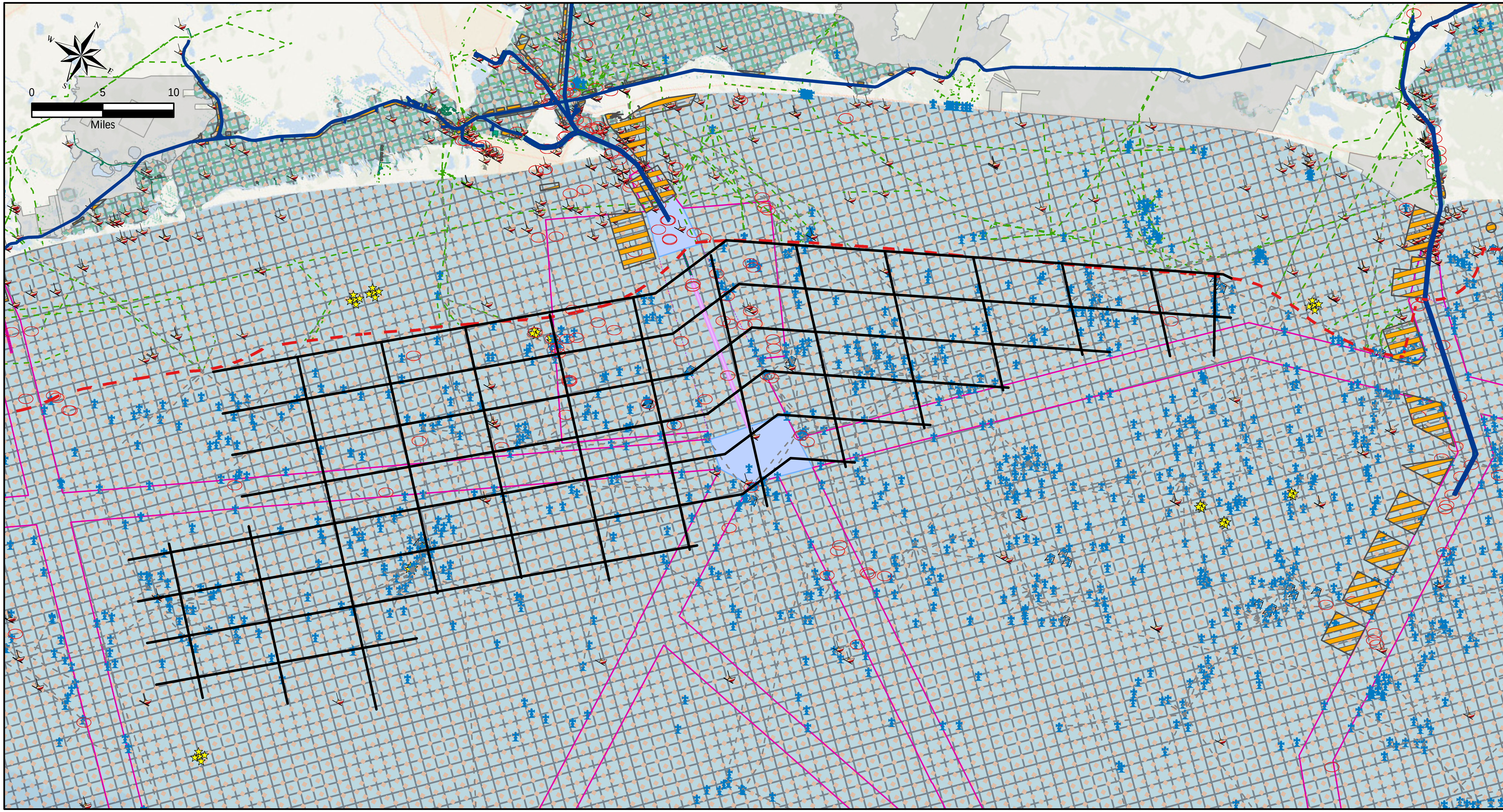
Date: 03/28/2024	Drawn By: AV	Commission No.: 631027330	**Figure No. 2-3a**



Notes:

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- Wrecks
- Obstructions
- OCS Drilling Platforms
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Essential Fish Habitats (EFH)

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Title:
Texas General Land Office Lower Outer Continental Shelf Texas Sediment Surveys

Desktop Study Appendix A: Planned Lines, Hazards and Avoidance Areas: Upper OCS Study Area

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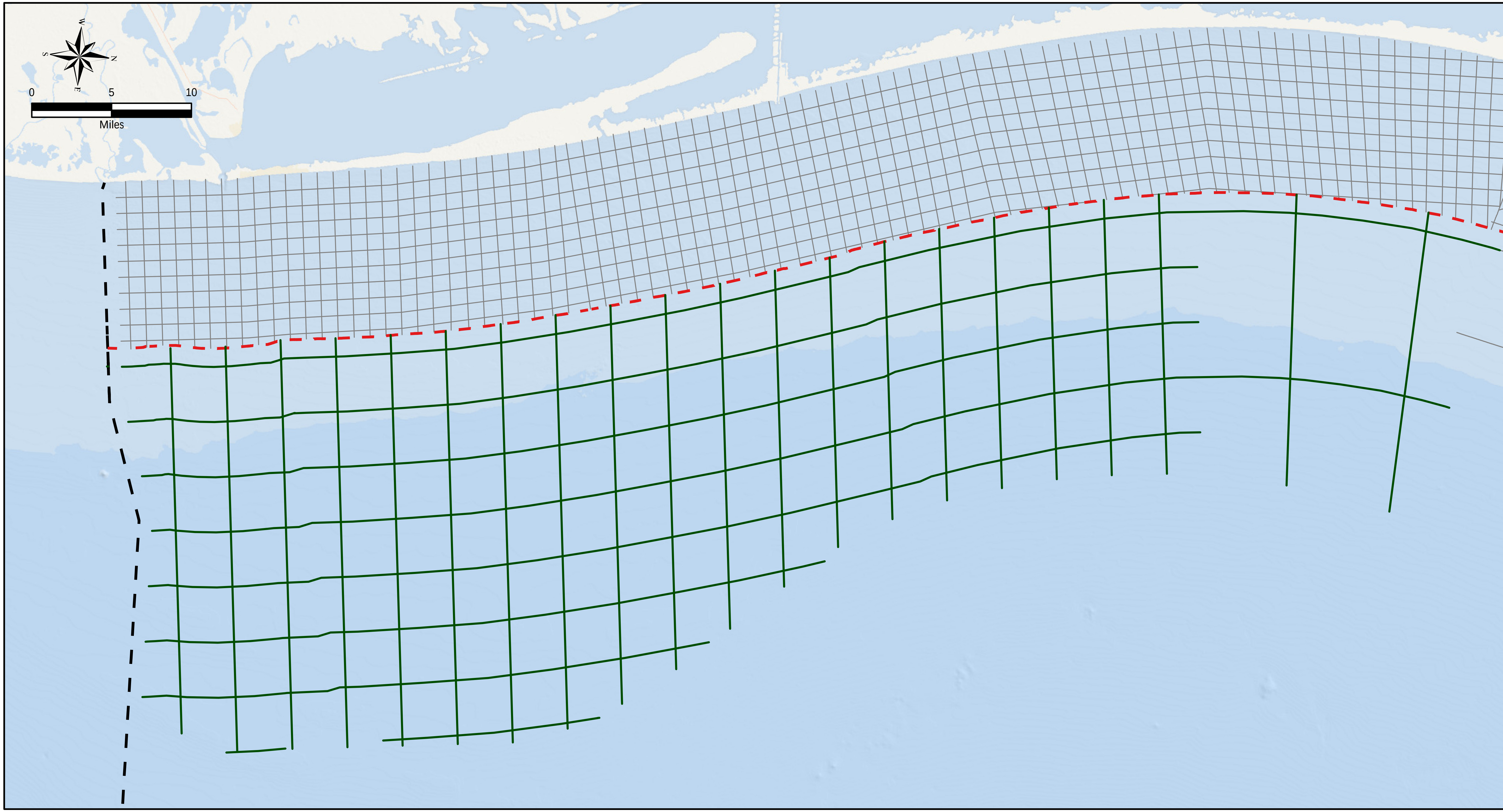
Date: 03/28/2024	Drawn By: AV	Commission No.: 631027330	**Figure No. 2-3b**

Appendix B: Survey Planning Map



Notes:

1. Background is Esri's World Ocean basemap.

Legend:

- Federal State Boundary
- US Mexico Border
- Planned Survey Tracklines
- APTIM Geophysical Tracklines

Title:

Texas General Land Office Lower Outer Continental Shelf Texas Sediment Surveys

Desktop Study Appendix B: Planned Survey Tracklines
Lower OCS Study Area

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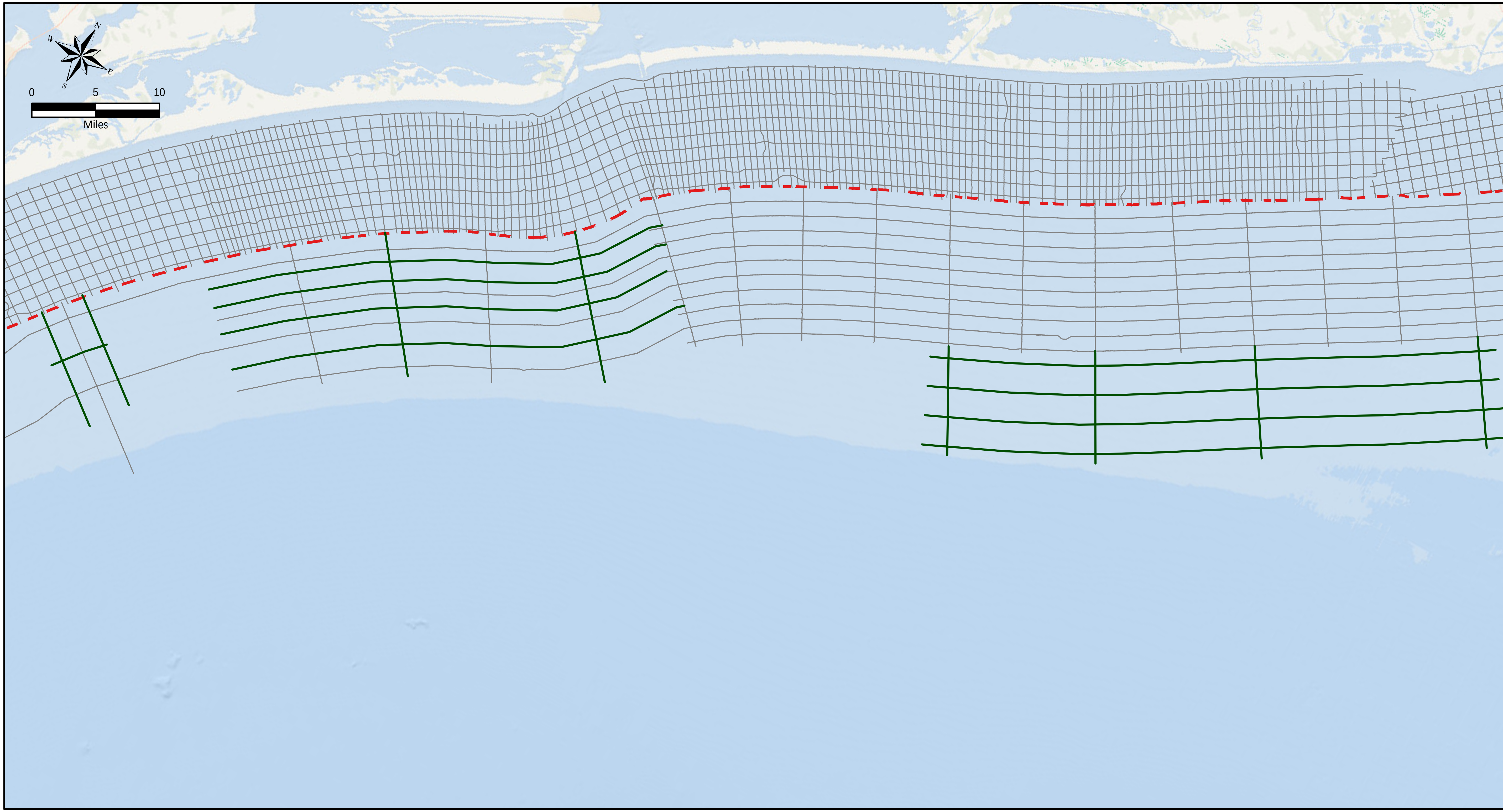
Date: 03/28/2024	Drawn By: AV	Commission No.: 631027330	**Figure No. 01**



Notes:

1. Background is Esri's World Ocean basemap.

Legend:

- Federal State Boundary
- Planned Survey Tracklines
- APTIM Geophysical Tracklines

Title:
Texas General Land Office Lower Outer Continental Shelf Texas Sediment Surveys

Desktop Study Appendix B: Planned Survey Tracklines
Central OCS Study Area

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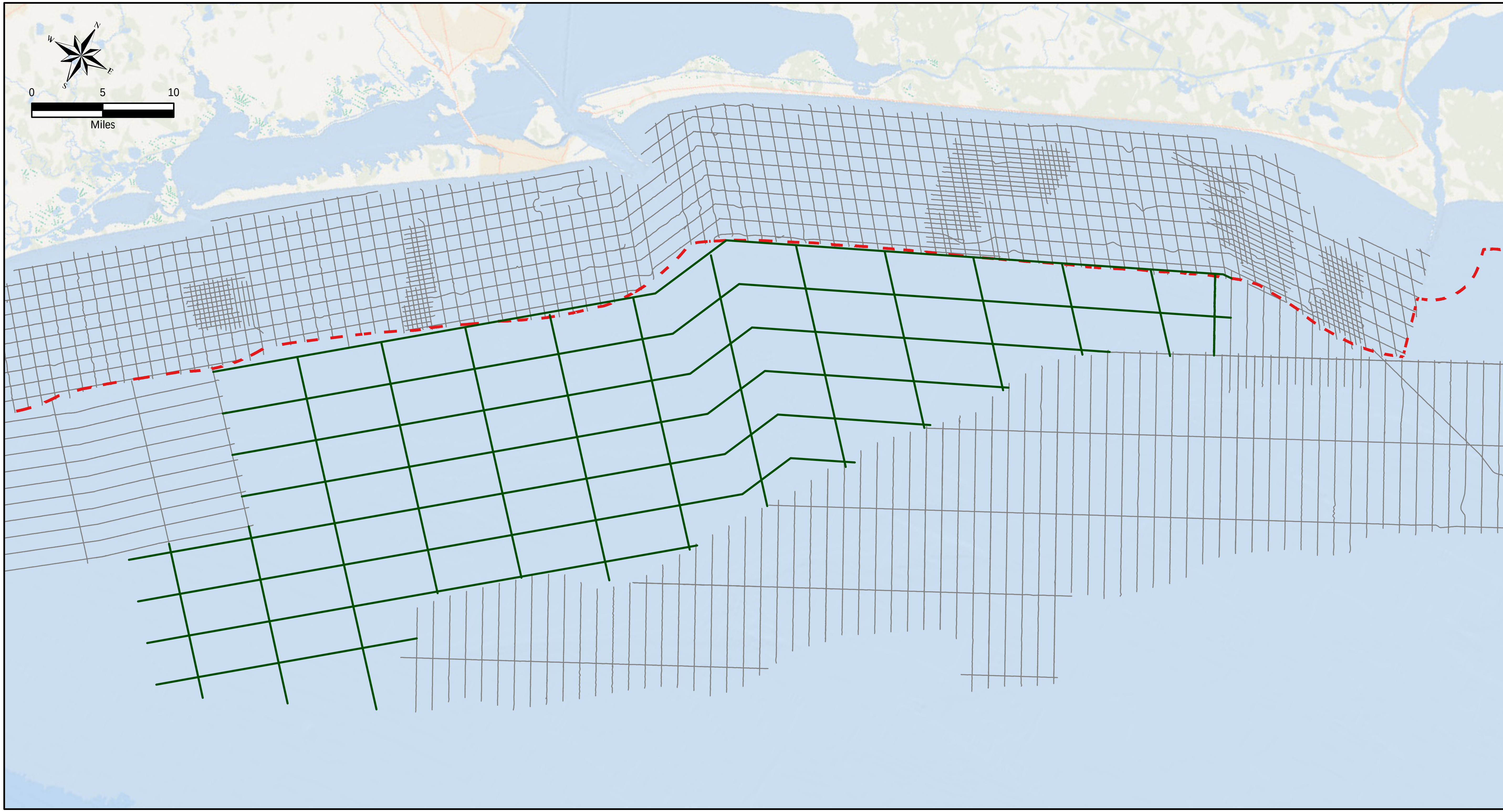
Date: 03/28/2024	Drawn By: AV	Commission No.: 631027330	**Figure No. 02**



Notes:

1. Background is Esri's World Ocean basemap.

Legend:

- Federal State Boundary
- Planned Survey Tracklines
- APTIM Geophysical Tracklines

Title:
Texas General Land Office Lower Outer Continental Shelf Texas Sediment Surveys

Desktop Study Appendix B: Planned Survey Tracklines
Upper OCS Study Area

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Date: 03/28/2024	Drawn By: AV	Commission No.: 631027330	**Figure No. 03**