FINAL REPORT

RECONNAISSANCE LEVEL REGIONAL SAND SEARCH OF THE FLORIDA PANHANDLE

Prepared for
Florida Department of Environmental Protection
Bureau of Beaches and Coastal Systems
3900 Commonwealth Boulevard
Tallahassee, Florida 32399

May 19, 2004

URS

Project Number 12804169.00000

Preface

This is the final report for the Reconnaissance Level Regional Sand Search Project conducted for the Florida Department of Environmental Protection, Bureau of Beaches and Coastal Systems Contract No. BS007 by URS Corporation. The proper citation for this report is:

Alan W. Niedoroda, Lyle Hatchett and Joseph Donoghue, 2004. Reconnaissance Level Regional Sand Search Of The Florida Panhandle, URS (unpubl. consulting report), 60 p.

Other presentations of this material have been given in:

- Lyle Hatchett, R. Clark, Alan W. Niedoroda, Joseph F. Donoghue, S.D. Locker, 2003. Web-Based Presentation of Beach and Offshore Sand Characteristics for Discovering Offshore Sand Resources. Proceedings from The Fifth International Symposium on Coastal Engineering and Science of Coastal Sediment Processes, May 2003, 14 p.

- Lyle Hatchett, Alan W. Niedoroda, Thomas Campbell, Jeffrey Andrews, Elizabeth Henrie, Melany Larenas, Robert Brantley and Ralph Clark, 2004. The Reconnaissance Offshore Sand Search Database. Proceedings from the National Conference on Beach Preservation Technology, February 2004 (in press), 16 p.

TABLE OF CONTENTS

TABLE OF CONTENTS

Tables

Figures

The Reconnaissance Level Regional Sand Search project was originally designed to locate potential offshore sand resources of adequate quality to serve as beach nourishment material in the panhandle region of Florida. The project was conducted for the Florida Department of Environmental Protection (FDEP) Office of Beaches and Coastal Systems (OBCS). Over the course of this project, the agency has been reorganized and renamed the Bureau of Beaches and Wetland Resources (BBWR), and now is named the Bureau of Beaches and Coastal Systems (BBCS). All three of these names will be found in the text of this report. Also, for convenience the project name is sometimes shortened to Sandpan, and this was the original name of the project Web site.

During the course of this project, another project was launched. This new project area covers the southwest Florida Gulf Coast and teams URS with the coastal engineering and design firm Coastal Planning and Engineering Inc. (CPE). With this addition of a more project-focused coastal engineering firm, the goal was to add to the Sandpan reconnaissance framework an added dimension that would be more at the individual beach nourishment project level. With the union of these two fundamental ways of searching and viewing the available data, it was determined by BBCS that Sandpan needed to be expanded to include the new classes of data that can be of value in engineering beach nourishment operations. The addition of this new study area and expansion of the database caused the Sandpan name to be outdated. The resulting new name for the database and website is the Reconnaissance Offshore Sand Search or ROSS. Therefore, when referring to the database and website in the remainder of this report, it will be called ROSS.

This study is at a reconnaissance level, meaning that the resources need to be found and sufficiently delineated to understand their dimensions, volumes, and general grain size distributions. Those near beaches that have been identified as undergoing “critical” erosion (Clark, 2003) are of highest interest. Important changes between the 2000 edition and the agreed upon 2003 edition of the Bureau’s Critical Erosion Report include –

a) An eastward extension of the critically eroded shoreline in Pensacola Beach,
b) Deletion of the Santa Rosa Island area near Ft. Walton Beach,
c) Deletion of the western segment of Destin,
d) An eastward extension of the critically eroded shoreline segment in western Walton County,
e) Deletion of all but 2000 feet of the critically eroded shoreline at Inlet Beach in eastern Walton County,
f) Deletion of the Beacon Hill area in Gulf County,
g) Addition of the Cape Palms segment on St. Joseph Peninsula in Gulf County,
h) Deletion of most of the designated critically eroded shoreline of St. George Island State Park in Franklin County.

All these changes are reflected in the August 2003 edition and are shown in the Bureau’s GIS map coverage.

It is expected that when sand is needed for beach nourishment projects along this coast, there will be detailed sand searches that will explore the offshore sand bodies in more detail. Thus, the reconnaissance level sand search is to find places over the whole region where these detailed surveys may be later concentrated. Along with making the planning of these detailed surveys more effective, the results of the reconnaissance level work provide a regional framework for management decisions regarding the relative availability of sand resources for all of the critical erosion zones along the coast.

The project is organized into three tasks. The first task was an extensive review of available data that are useful in locating offshore sand deposits. The second task was primarily directed at evaluating the data found in the first task and delineating potential sand resources where the data were adequate. The third task concentrates on field work.

In the course of the first task, a Geographic Information System (GIS) Database was created to archive and manage the project data. This database has been created to be accessed by BBCS personnel, other state and local engineers and managers, members of the academic community, consulting company staff, and the general public via a Web site. Special attention has been given to make the design of the database and Web site efficient and accessible to this diverse group of users.

During the work of the first task, it was discovered that there were many more useful data available from previous studies and ongoing projects than was originally anticipated. This resulted in developing a richly populated database. The availability of this considerable amount of data also provided the motivation for carefully organizing the data in ways that made them available in a large variety of formats while providing a framework that can be expanded indefinitely as more data become available. To further this access to meaningful data, the Web site also provides access to related Web sites with even more data.

This report has been written to explain the overall project approach, to describe the database and Web site, to discuss and evaluate the acquired data, to present an overall geologic conceptual framework that can guide the use of project data to identify potential offshore sand deposits, to present results where such deposits are found, and to show how a reconnaissance-level field program has confirmed the use of the data base in anticipating the types of offshore deposits that exist.

2.1 BACKGROUND

The goal of this project is to identify useful offshore sand deposits along the Florida Panhandle coast. This information is to be used to make informed decisions within the context of the overall Florida Coastal Management Plan. Easily accessible data are important in these engineering and management processes. Two basic types of data are used. The spatial aspects of the data are fundamental and are preserved in a Geographic Information System (GIS). Tabular data are used to store information about the sediment properties at locations stored in the spatial data. Both the spatial and the tabular data are available over the project Web site.

2.2 THE DATABASE

A corporate database is a database serving an entire entity or organization such as a corporation, university, or in the case of the Internet, the public. Today, spatial features are housed in corporate relational databases, like ORACLE, as SDE (Spatial Database Engine) layers along with their attributes. In other words, spatial features are stored just like any other data type such as a number or string of characters. This affords the ability to take advantage of very fast and robust corporate database management systems to manipulate very large amounts of data and relate them to a location on the earth.

The project Oracle database also stores tabular data about sand samples. The original Sandpan database schema had 56 columns containing data associated with samples. The revised ROSS database now contains 294 columns. Documentation on the structure and content of the ORACLE database can be found in the Entity Relation Diagram and the Data Dictionary, which can be examined and downloaded from the project Web site.

Information associated with sand samples includes, but is not limited to, granulametric data, bathymetry, core photos, core logs, core descriptions, associated project, Munsell Color range, area based on latitude/longitude or state plane coordinates and metadata (or data about the data). The Sandpan column headings were:

OBJECTID
FK_PROJECT
SAMPLE_METHOD
SAMPLE_ID
SAMPLE_DATE
Y_COORD
X_COORD
TOP_OF_SAMPLE_INTERVAL
BOTTOM_OF_SAMPLE_INTERVAL
TOTAL_WEIGHT
PERCENT_FINES
ANALYTICAL_METHOD_PCT_FINES
MEAN
ANALYTICAL_METHOD_MEAN
MEDIAN
ANALYTICAL_METHOD_MEDIAN
STANDARD_DEVIATION
ANALYTICAL_METHOD_STANDARD_DEVIATION
SKEWNESS
ANALYTICAL_METHOD_SKEWNESS
KURTOSIS
ANALYTICAL_METHOD_KURTOSIS
PERCENT_CARBONATE
ANALYTICAL_METHOD_PCT_CARBONATE
PERCENT_SHELL_FRAGMENTS

ANALYTICAL_METHOD_PCT_SHELL_FRAGMENTS

PERCENT_HEAVY_MINERALS

ANALYTICAL_METHOD_PCT_ HEAVY_MINERALS

PERCENT_ORGANICS

ANALYTICAL_METHOD_PCT_ ORGANICS

COLOR

ANALYTICAL_METHOD_COLOR

PHI VALUES (IN ¼ PHI INTERVALS FROM 12 TO 14)

TRANSECT_LINE

LORAN_X

LORAN_Y

COMMENTS

CARBONATE_DISSOLVED

HEAVY_MINERALS_REMOVED

ORGANICS_REMOVED

SHELL_FRAGMENTS_REMOVED

PCT_PAN_FRACTION

GRAB_ELEVATION

COMPOSITE_SAMPLE

RANGE_MONUMENT

RM_TRANSECT_LOCATION

STATE_X

STATE_Y

CORE_ID

TIME_STAMP

LATITUDE

LONGITUDE

WENTWORTH SCALE VALUES

(FROM BOULDER TO COLLOID)

USC SCALE

(FROM COBBLE TO CLAY)

MUNSELL_COLOR

MUNSELL_VALUE

MUNSELL_CHROMA

For the reconnaissance level aspects of the Sandpan project these fields were adequate in providing data types for this scale. With the addition of the more project-focused analysis that includes storing data on core layers, the expanded database now contains these column headings:

AGENCY_ID

AGENCY_NAME

ANALYTICAL_METHOD_ID

ANALYTICAL_METHOD_NAME

ANALYTICAL_METHOD_DESCRIPTION

ANGULARITY_ID

ANGULARITY

PK_BIBSUMMARY

AUTHOR

AUTHOR_LAST_NAME

AUTHOR_INITIALS

TITLE

KEYWORDS

PAPER_YEAR

ABSTRACT

PUBLISHER

CALCULATION_METHOD_ID

CALCULATION_METHOD_NAME

CALCULATION_METHOD_DESCRIPTION

COLLECTION_METHOD_ID

COLLECTION_METHOD

COLLECTION_METHOD_DESCRIPTION

COLOR_DESCRIPTOR_ID

COLOR_DESCRIPTOR

COLOR_MATRIX_ID

CT_COLOR_TONE_ID

CD_DESCRIPTOR_ID

COL_COLOR_ID

COLOR_TONE_ID

COLOR_TONE

COLOR_ID

COLOR

CONTACT_ID
CONTACT_NAME
CONTACT_PHONE
CORE_LAYER_QUALIFIER_ID
CL_CORE_LAYER_ID
STX_SOIL_TEXTURE_ID
SD_SOIL_DESCRIPTOR_ID
ST_SOIL_TYPE_ID
L_LITHOLOGY_ID
S_SORTING_ID
QUALIFIER
CORE_LAYER_ID
CORE_CORE_ID
LS_LAYER_STRUCTURE_ID
USCS_USCS_CLASSIFICATION_ID
CMTX_COLOR_MATRIX_ID
BOTTOM_OF_LAYER_INTERVAL
TOP_OF_LAYER_INTERVAL
MUNSELL_HUE_WET
MUNSELL_VALUE_WET
MUNSELL_CHROMA_WET
CORE_LAYER_COMMENTS
CORE_LAYER_IDENTIFIER
CORE_ID
CM_COLLECTION_METHOD_ID
PRJ_PROJECT_ID
DRL_DRILLER_ID
COLLECTION_DATE
CORE_TOP_ELEVATION
CORE_LENGTH
CORE_DIAMETER
X_COORD
Y_COORD
STATE_X
STATE_Y
STATE_ZONE
LONGITUDE
LATITUDE
LORAN_X
LORAN_Y
PENETRATION_DEPTH
RECOVERED_LENGTH
DIRECTION
OVERBURDEN
DEPTH_RX
GROUNDWATER_ELEVATION
PERCENT_RECOVERED
CORE_IDENTIFIER
DRILLER_ID
DRILLER_NAME
DRILL_TYPE
AGN_AGENCY_ID
GUEST_NAME
PK_GUESTBOOK
GUEST_ORG
GUEST_EMAIL
GUEST_DATE_VISIT
GUEST_COMMENT
GUEST_EMAIL_UPDATE
LAB_ID
LAB_NAME
LAB_ADDRESS
LAYER_STRUCTURE_ID
LAYER_STRUCTURE
LAYER_STRUCTURE
LITHOLOGY
HUE
VALUE
CHROMA
CMTX_COLOR_MATRIX_ID
PROJECT_ID
AGN_AGENCY_ID_POSSESSING
AGN_AGENCY_ID_MANAGING
CON_CONTACT_ID
PROJECT_NAME
PROJECT_DATE
PROJECT_LOCATION
HORIZONTAL_COORDINATE_SYSTEM
HORIZONTAL_DATUM
VERTICAL_DATUM

PROJECTION

SAMPLE_ID

PRJ_PROJECT_ID

LAB_LAB_ID

AM_ANALYTICAL_METHOD

SLU_SPHERICITY_ID

ALU_ANGULARITY_ID

CM_COLLECTION_METHOD_ID

USCS_USCS_CLASSIFICATION_ID

CMTX_COLOR_MATRIX_ID

MUNSELL_HUE_DRY

MUNSELL_VALUE_DRY

MUNSELL_CHROMA_DRY

MUNSELL_HUE_WET

MUNSELL_VALUE_WET

MUNSELL_HUE_WASHED

MUNSELL_VALUE_WASHED

MUNSELL_CHROMA_WASHED

MUNSELL_HUE_UNKNOWN

MUNSELL_VALUE_UNKNOWN

MUNSELL_CHROMA_UNKNOWN

SAMPLE_IDENTIFIER

SAMPLE_DATE

SAMPLE_COMMENTS

ANALYSIS_DATE

LAB_REMARKS

X_COORD

Y_COORD

STATE_X

STATE_Y

STATE_ZONE

LORAN_X

LORAN_Y

LONGITUDE

LATITUDE

RANGE_MONUMENT

RM_TRANSECT_LOCATION

TOP_OF_SAMPLE_INTERVAL

BOTTOM_OF_SAMPLE_INTERVAL

GRAB_ELEVATION

MEAN

MEDIAN

STD

SKEWNESS

KURTOSIS

MEAN_ORIGINAL

MEDIAN_ORIGINAL

STD_ORIGINAL

SKEWNESS_ORIGINAL

KURTOSIS_ORIGINAL

CALC_CALC_METHOD_ID_MEAN

CALC_CALC_METHOD_ID_MEDIAN

CALC_CALC_METHOD_ID_STD

CALC_CALC_METHOD_ID_SKEW

CALC_CALC_METHOD_ID_KURT

PCT_FINES

PCT_PAN_FRACTION

PCT_CARBONATE

PCT_SHELL_FRAGMENTS

PCT_HEAVY_MINERALS

PCT_ORGANICS \

CARBONATE_DISSOLVED

HEAVY_MINERALS_DISSOLVED

ORGANICS_REMOVED

SHELL_FRAGMENTS_REMOVED

PHI

USCS_COBBLE

USCS_COARSE_GRAVEL

USCS_FINE_GRAVEL

USCS_COARSE_SAND

USCS_MEDIUM_SAND

USCS_FINE_SAND

USCS_SILT

USCS_CLAY

WW_BOULDER

WW_COBBLE

WW_GRAVEL

WW_PEBBLE

WW_VERY_COARSE_SAND

WW_COARSE_SAND

WW_MEDIUM_SAND

WW_FINE_SAND

. WW_VERY_FINE_SAND

WW_SILT

WW_CLAY

WW_COLLOID

SAMP_SAMPLE_ID

CL_CORELAYER_ID

VIRTUAL_SAMPLE

PK_SITEINFO

SITE_QUESTION

SITE_INFO

USERMAN

USERMAN_LOCATION

COLUMN_NAME

ALIAS

DESCRIPTION

DISPLAY_ORDER

DISPLAY_YN

PHI_RANGE

SAMPLE_DATA_YN

CORE_DATA_YN

DISPLAY_GROUP

SOIL_DESCRIPTOR_ID

SOIL_DESCRIPTOR

SOIL_TEXTURE_ID

OIL_TEXTURE

SOIL_TYPE_ID

SOIL_TYPE

SORTING_ID

SORTING

STANDARD_DEVIATION

SPHERICITY_ID

SPHERICITY

USCS_CLASSIFICATION_ID

CLASSIFICATION_NAME

CLASSIFICATION_DESCRIPTION

Another important issue is that the user understands the restrictions and caveats involved with any of the data sets. To accomplish this goal, metadata (or data about the data) have been created for each data set and each spatial layer. These metadata conform to the Federal Geographic Data Committee (FGDC) requirements. The Federal Geographic Data Committee coordinates the development of the National Spatial Data Infrastructure (NSDI). The NSDI encompasses policies, standards, and procedures for organizations to cooperatively produce and share geographic data. The 17 federal agencies that make up the FGDC are developing the NSDI in cooperation with organizations from state, local and tribal governments, the academic community, and the private sector. For more information, see www.fgdc.gov.

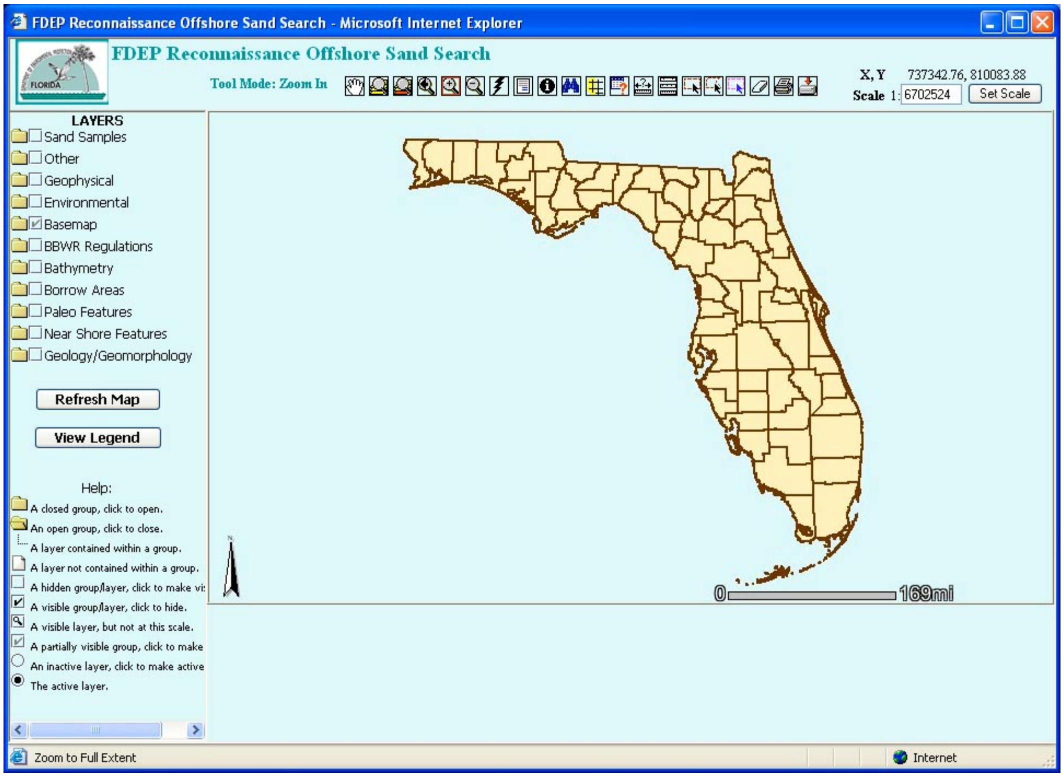
Legacy data gathered for this project originated from several different sources and were in many different formats. Dealing with this myriad of formats led to the "open door" approach to data gathering and storage. Under this approach the database developed for the Sandpan project and that being currently developed for ROSS is large and versatile to accommodate all the different forms of data that are found for these and subsequent projects. These current data span over 40 years, with the earliest data set from 1959, and include more than 18 different projects and studies.

It was decided that the data in its original format needed to be preserved, but also served up in a manner compatible with a general set of conventions. For example, location information for many of the data sets is in latitude/longitude coordinates. The requirement of the BBCS is that spatial data is to be in state plane coordinates. The database allows for conversion from one coordinate system to the other for spatial compatibility. This allows the legacy data to be preserved in their original format.

2.3 ARCIMS

The tool used for manipulating, analyzing and displaying spatial and tabular data is a Geographic Information System (GIS). GIS provides a "spatial" view of information to be used to display and interpret results.

The ESRI suite of products was chosen as the GIS for the ROSS site. This suite includes Arc Interactive Map Server (ArcIMS), and ArcView. ArcIMS provides the foundation for disseminating high-end Geographic Information Systems (GIS) and mapping services via the Internet. ArcIMS software enables users to integrate local data sources with Internet data sources for display, query, and analysis in an easy-to-use Web browser. For more information, see www.esri.com.

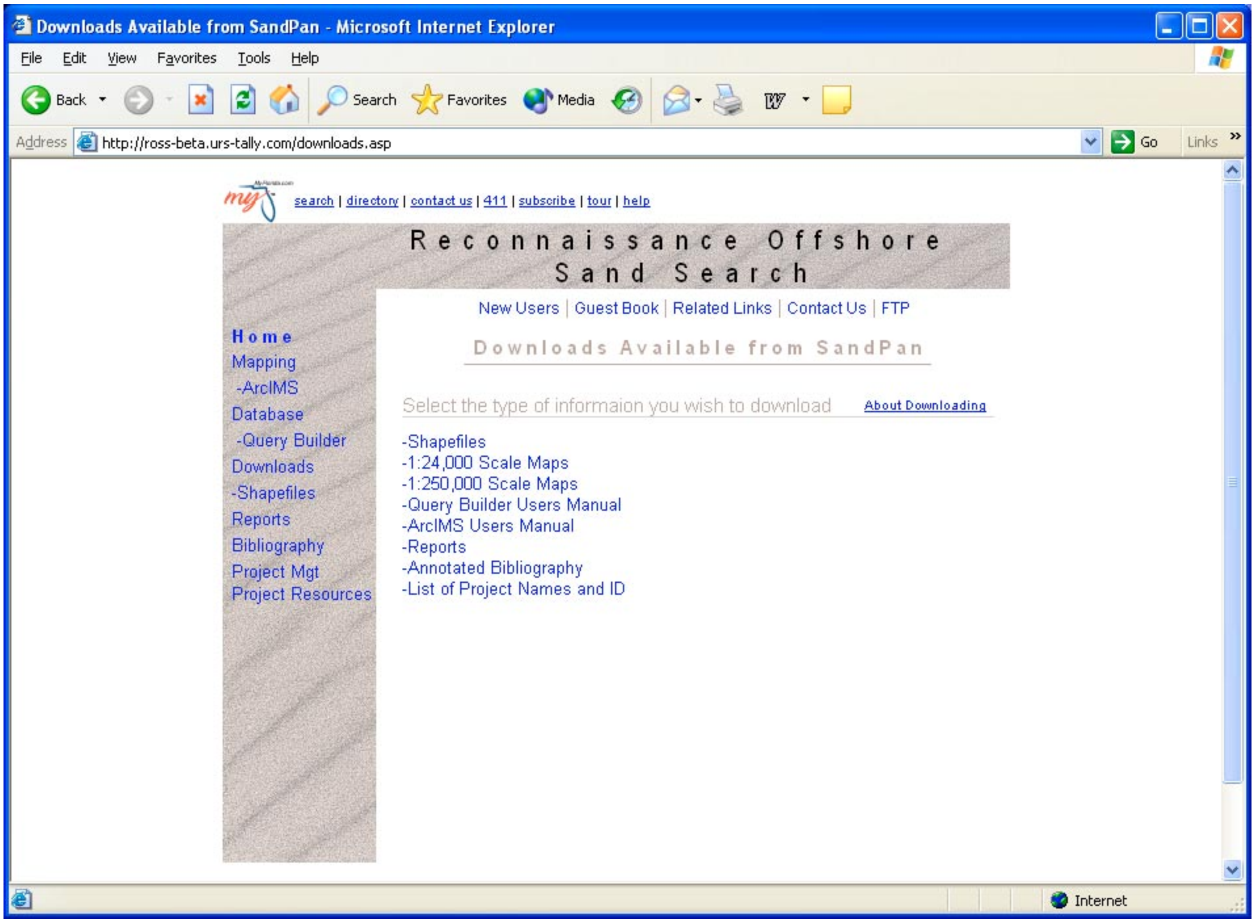


Help:
A closed group, click to open.
An open group, click to close.
A layer contained within a group.
A layer not contained within a group.
☐ A hidden group/layer, click to make vi
☑ A visible group/layer, click to hide.
A visible layer, but not at this scale.
A partially visible group, click to make
○ An inactive layer, click to make active
● The active layer.

Figure 2.3.1: Screen capture of the ROSS on-line mapping page

Figure 2.3.1 is a screen capture of the on-line mapping page within the ROSS Web site. On the left side of the image are folders, which contain the many different "layers" with which the user may interact. These layers are the spatial representations of the tabular data residing in the Oracle database. Most of these layers have been created especially for this project, with data generated by this project. However, some of these layers, including the Artificial Reefs, NOAA Obstacles, and others were downloaded from other sites and incorporated in the ROSS on-line mapping. This illustrates the versatility of on-line mapping. Designers can combine data and information accessed over the Internet with local data for display, query, and analysis. For instance, environmental issues in potential renourishment areas are a concern. An on-line search was conducted of state government spatial data repositories. This resulted in many shapefiles dealing with environmental issues being found at the Florida Geographic Data Library (FGDL).

These shapefiles were subsequently downloaded from the FGDL site, re-projected and added to the ROSS site. This ability to download and transfer data works both ways. The data on the ROSS site is also downloadable for use on other Web sites. Figure 2.3.2 shows the data downloads page from the ROSS site.



search | directory | contact us | 411 | subscribe | tour | help

Reconnaissance Offshore Sand Search

New Users | Guest Book | Related Links | Contact Us | FTP

Home
Mapping
-ArcIMS
Database
-Query Builder
Downloads
-Shapefiles
Reports
Bibliography
Project Mgt
Project Resources

Downloads Available from SandPan

Select the type of informaion you wish to download About Downloading

-Shapefiles
-1:24,000 Scale Maps
-1:250,000 Scale Maps
-Query Builder Users Manual
-ArcIMS Users Manual
-Reports
-Annotated Bibliography
-List of Project Names and ID

Figure 2.3.2 – Screen capture of the downloads page

2.4 ARCVIEW

One of the tools in the ESRI suite of products is ArcView. Using ArcView and the data downloaded from the ROSS site, the user may perform many different types of spatial analysis on a local workstation. For example, the user may want to look at mean grain size by spreading out the phi interval within the dataset. Figure 2.4.1 illustrates this.

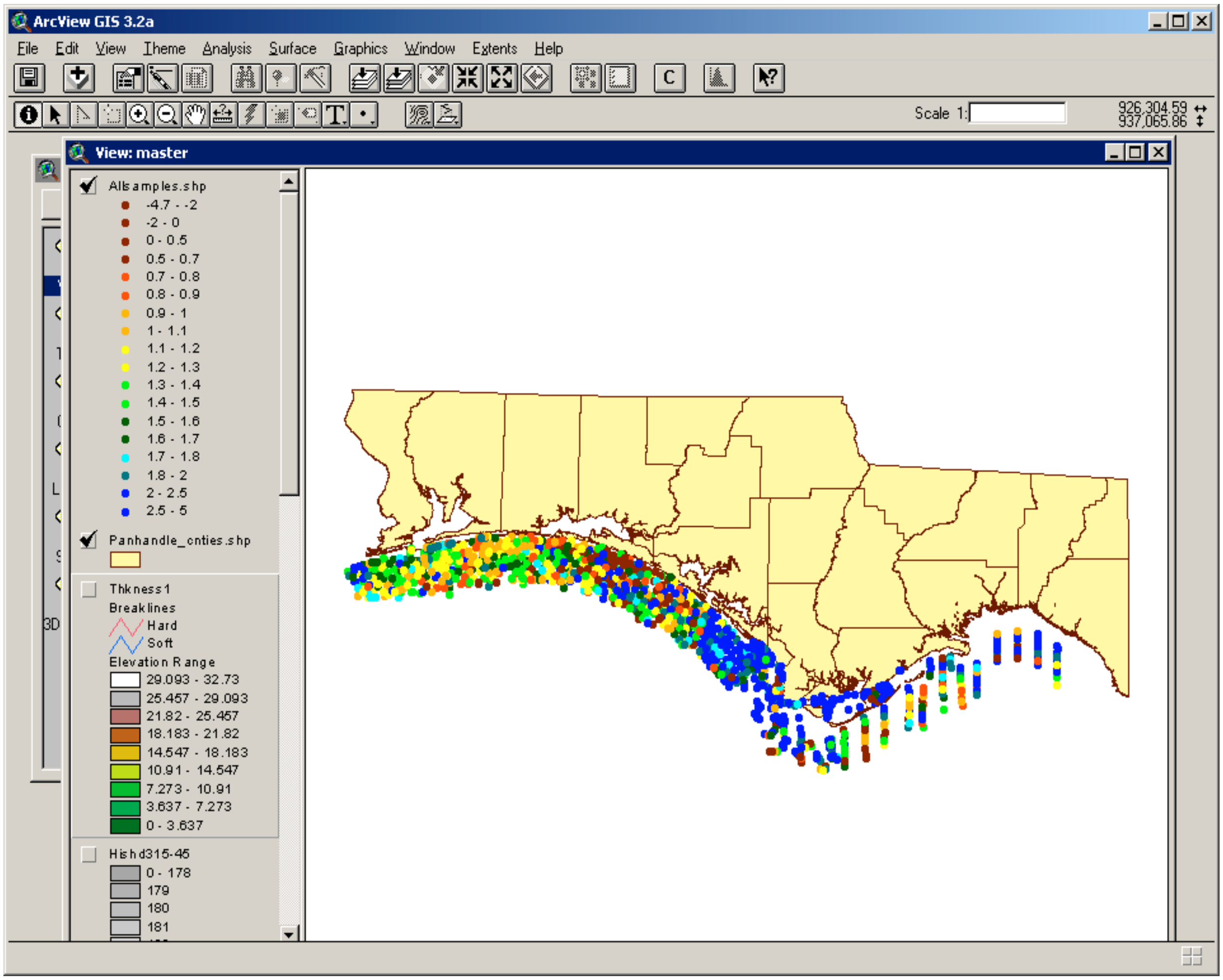


Figure 2.4.1 - Visualization of mean grain size spatial distribution

Another example is to contour the sediment samples dataset by using thickness values for selected sample locations (see Figure 2.4.2).

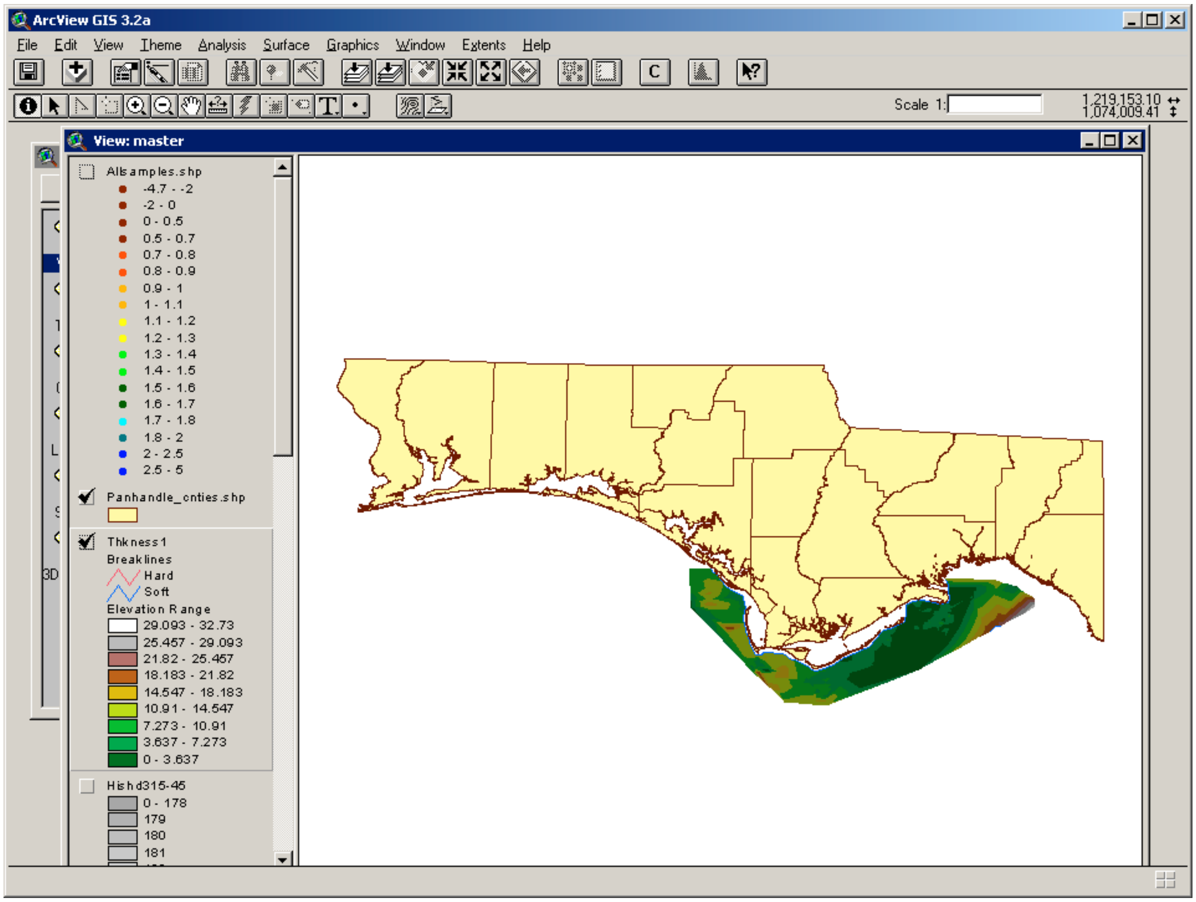


Figure 2.4.2 – Contours of surface sand layer

Data may also be downloaded in CSV format. This format is compatible with Excel and many graphing packages.

2.5 WEB SITE (ROSS.URS-TALLY.COM)

The Panhandle Sand Search Web site is the means to an end. By navigating through the Web site, all the ROSS data, pre-made static maps of the study area, on-line interactive mapping, query builders to access the database, data downloads, reports, shapefiles, the annotated bibliography, and project management information are available at the touch of a button. There is a Guest Book for users to register and if they choose, to leave comments and suggestions. There is also a New Users page with frequently asked questions that may help in understanding the functions of this Web site. New questions and answers will be posted as they are received and answered.

A conceptual geologic model has been developed to provide guidance about the feature types and locations where offshore sand deposits suitable for beach nourishment are likely to occur. The utility of the conceptual model is that when the modes of origins of the major sand deposits are understood, then relatively subtle spatial patterns and trends in the bathymetric, sub-bottom and sediment data can be interpreted more reliably. This is useful in guiding the selection of sites for more detailed evaluations.

3.1 MAJOR SEDIMENTARY PROCESSES

Over the past decade it has become increasingly clear to researchers studying marine sediment dynamics that most of the sand that makes up beaches is not readily transported far offshore (e.g., Dean 2001). The settling velocity of grains larger than fine sand is too high for the particles to be supported in the suspended mode by the level of turbulence associated with even considerable storm currents beyond the surf zone. Somewhat farther offshore, the fluid stress applied to the seabed decreases with increasing depth to the point that episodes of bedload entrainment are limited to only very major events. The result is that the time-scale for morphological change increases dramatically with depth (Stive and DeVriend, 1995, Niedoroda et al., 1995). In the surf zone this time-scale is measured in hours to days. Just beyond the surf zone, in the shoreface environment, this time-scale varies from months to decades. On the continental shelf it increases to centuries to millennia.

It is well recognized (Locker et al., 1988, Balsillie and Clark, 2001; Donoghue, 1992, 1993, among others), and the project data shows, that sand comprises the bottom sediment across all of the shoreface and continental shelf in the project area. This sand originated from coastal transport systems that existed during the Pleistocene ice ages when sea level was as much as 120 m lower than its present level. As the sea level cycled, the shoreline advanced across the entire continental shelf and then transgressed landward during the subsequent period of rising sea level. Waves and currents have subsequently reworked coastline deposits left behind during these times. Most of the characteristic features of coastal deposits have been partially or completely erased. On the other hand, the huge volume of sand in many shoreline features prevents their total destruction as sea level rises over them.

Another aspect of the effect of major sea level cycles on sediment processes is how the delivery of sand-size sediments changes. When sea level is slowly rising, the coastal lowlands are continually becoming more inundated. Estuaries are common features on these coasts. As the rivers deliver both suspended and bedload to their mouths, a sorting occurs. Sand is deposited at the head of the estuaries commonly forming a delta. Although some silt and clay are deposited in the delta too, most is carried to the estuary and beyond. Little to no sand makes it to the open beaches. Conversely, if sea level is falling, the estuaries drain and the rivers extend themselves to the shoreline. Sand is delivered directly to the open coastal transport system. Figure 3.1.1 shows a schematic representation of these differences in sand delivery systems.

The landward “retreat” of barrier islands driven by the present slow rate of sea level rise is well known (Godfrey and Godfrey, 1976). Sand is carried behind the islands as a result of flood tide delta formations and through storm overwashing channels distributed along the length of the barrier islands. Figure 3.1.2 illustrates these features. In the presence of chronic sea level, these processes serve to extend the land area behind the barrier island while the seaward side erodes. The effect is that the barrier island “retreats” up the regional land gradient with its basic form maintained. Because much of the sand is carried up and over the barrier islands as storm-driven overwash, the overall retreat of the barrier island is sometimes called “barrier island rollover.”

Figure 3.1.3 shows a wider view of barrier island processes extending offshore to the lower shoreface. In this view it is seen that there are two major zones of sand deposition as the general profile of the shoreface, surf zone, beach and barrier island shifts upward and landward. One area is where the back-barrier sands are deposited as inlet and overwash deposits. The other area is on the lower shoreface. Because these deposits can trail out extended distances as sea level rises and the shoreline retreats, these offshore sand layers can be very extensive. Between the upper and lower shoreface there is an area where the finer sediment layer of ancient bay deposits can outcrop. This zone can be mantled by a thin layer of modern sand or by a series of shoreface connected sand waves. Figure 3.1.4 shows that where the shoreline position has remained relatively constant over an extended period of time during which there have been minor fluctuations of sea level (like the ones considered during the discussion of Figure 3.1.1), there can be a complex series of interfingering sedimentary layers within the overall barrier island complex.

From the viewpoint of distinguishing useful offshore sand deposits there are two considerations. First, a trailing sand sheet is formed as sand is deposited on the lower shoreface and the whole system continues its slow landward migration. The second major consideration is that the continued rollover of the barrier island system leads to the outcropping of sediment layers that were deposited in the bays and lagoons behind the islands. These sediments are usually much finer and muddier than the sands on the open beach, so it is advisable to avoid these deposits. Because the general courses of rivers tend to persist in the same zone along the coast, with minor realignments, the coastal estuaries often formed when sea level was significantly lower and they too migrated landward as it rose to its present level. This means that the mid-shoreface outside of the barrier islands and spits defining the lagoons are likely to exhibit outcrops of unsuitable sediment layers. This is not always the case; but when exploring for beach nourishment sand, it is well to start with this concern and then eliminate it with survey data.

Another consequence of long-term rises of sea level is that major coastal features translate almost bodily in a landward direction. One example is provided by elongated “trailing” ebbtide tide shoals (or ebbtide tide deltas) outside of barrier island complexes (see Figure 3.1.5). Where the wave and current conditions are moderate, the large volume of an ebbtide tide delta inhibits destruction. If the sea level rise is relatively rapid, this feature will persist as a bathymetric high even though it no longer is dynamically coupled to the morphology of the active portion of the ebbtide tide delta.

Sand spits and barrier islands are dramatically influenced by sea level rise. Both must “grow” upwards and “retreat” landward to persist. Spits also tend to increase their length. This combination of evolutionary developments gives the submerged portions of spit complexes somewhat of a “pork-chop” planform. Figure 3.1.6 shows a schematic of an idealized spit complex. This geometry of deposits is easily disrupted by other factors, so it is hard to identify a real case that matches the idealization given on Figure 3.1.6. However, some of the elements are exhibited by Alligator Spit and St. Joseph Peninsula in the project area.

The geologically recent major excursions of sea level have meant that river and stream systems once crossed the entire continental shelf. Their channels down-cut into the dry surface. Also, deltas formed at various places that are now far offshore. During the rising phase of the last sea level excursions these channels filled with sediment. Both the filled channels and ancient deltas offer the potential for large volumes of sand that might be suitable for beach nourishment.

After sea level rose to near its present height, there have been further modifications of the shelf and nearshore sand deposits. A prominent feature of the western half of the project area is the large sand waves with crests aligned nearly parallel and obliquely to the shoreline. Recent work by Nemeth et al., (2001) and Caballeria et al., (2001) has shown that these features grow from the combined action of currents and waves. Both must be large to entrain sand-size sediments at the shelf depths so the growth is episodic and occurs most during storm events. Nemeth et al., (2001) has shown that the time duration for similar sand waves to grow on the continental shelf off Long Island, New York is on the order of millennia. These values are consistent with the findings of Stive and deVriend (1995) and Niedoroda et al., (1995) that the time-scale for morphological change increases from hours in the surf zone to millennia on the mid-shelf.

There are several types of depositional features that are part of the present coast processes system. Most commonly these consist of ebbtide tide deltas and shoals deposited adjacent to an inlet throat. Of the 14 inlets in the project area, eight require episodic dredging while six do not. This sand is often suited for use in beach nourishment. In contrast to pre-1970 practice, sand from all eight of these inlets have been used on the adjacent beaches in recent years. Exploitation of the sand in ebbtide tide deltas requires considerable caution because these are usually active parts of the longshore sand transport systems. Dredging can alter the morphology and create problems on the beaches adjoining the inlet.

3.2 REGIONAL PATTERNS IN OFFSHORE SEDIMENT CHARACTERISTICS

The project data have been examined to determine whether there are major trends in the sediment type, grain size distributions, mineralogy, and color. A number of trends and patterns have been noted.

The grain size distributions of granular sediment (gravel, sand and silt) are characterized by a number of measures including the mean and median grain sizes, as well as the moment measures of standard deviation, skewness and kurtosis (Komar, 1976). Of these the mean, median and standard deviation are the most useful in deciding the compatibility of potential borrow material and the beach sand of the target critical erosion area (Dean, 2001). Other descriptors such as the percent of fine (or coarse) grains lying outside of the measured range, mineralogy and color can also be considerations.

To assist in the examination of large-scale spatial trends in the grain size distributions a simple system of colored dots has been used to portray the mean grain sizes on maps. Experience shows that this is a more discriminating way to view these patterns than using contours of the mean grain size. This is because available automated contouring routines are prone to exhibiting exaggerated or false patterns. Furthermore, with these routines contours are usually evenly spaced over the whole range of the parameter values to be mapped. In an area such as the Panhandle shelf, all of the sand is well sorted, and there are only subtle differences. The size classes associated with the colored dots can be binned in uneven intervals. This allows finer resolution near the center of the frequency distribution of the mean grain size values. By doing this the more subtle spatial patterns can be discerned. Figure 3.2.1 illustrates the assigning of color bins differentially across the distribution of the mean grain sizes of the individual samples over the project area.

Figures 3.2.2 and 3.2.3 show how the bins for mean grain sizes were allocated and the spatial patterns of mean grain sizes of all of the surface sediment samples across the whole project area, respectively. Four populations are suggested by the color patterns. The coarser means are shown in yellow and green. These predominate in the area of the west Florida shelf sand sheet. There appears to be a transitional region offshore between Choctawhatchee Bay and St. Andrews Bay. The finest mean grain sizes appear offshore of Cape San Blas, within Apalachicola Bay and in Apalachee Bay. Another population with intermediate values is seen offshore of the barrier islands and spits between Alligator Harbor and St. Vincent Island. We have labeled these four zones the western area, the center left area, the center right area and the east area, respectively.

The exploration of subtle trends in the distribution of mean grain sizes was pushed further by isolating the data for each of the four subareas and repeating the process of defining colored dots to a uneven range of size categories (or bins). The results are shown on Figures 3.2.4 through 3.2.7. On these figures a histograph showing the relative distribution of mean grain size values is given in an upper panel. Another panel shows a legend relating the dot colors to the size ranges, and a map shows the corresponding spatial pattern. There is a minor trend for slightly larger sand closer to shore in the area shown on Figure 3.2.4 and the western portion of the area shown on Figure 3.2.5. The eastern half of this area has somewhat smaller mean grain sizes, possibly reflecting a source from the Apalachicola River. There are relatively small mean grain sizes in the St. Joseph and Apalachicola Bays. The offshore sands are also smaller in the area covered by Figure 3.2.6. The mean grain sizes in the eastern subarea are relatively larger again, with a weak trend towards smaller values towards the east as shown in Figure 3.2.7.

There is a considerable amount of information about the color of the samples from the western half of the study area. Figure 3.2.8 shows the Munsell Color Classification Scheme, which has been applied to the sediment samples. The range of the Value Color Parameter has been converted to a series of colored dots, which are shown in map view on Figure 3.2.9. The top panel on this figure shows that the same area of the western shelf where the mean grain sizes are larger is where lighter-colored sand exists. The area shown with the red box on the top panel is expanded in the bottom panel. A strip of dots indicating lighter-colored sand is seen to extend westward near the shore from Cape San Blas.

The spatial patterns in the mean grain size and color parameters suggest that there have been significant large-scale processes at work across the project area. These observations need to be explained in the geologic conceptual model. However, before discussing this model it is well to develop an understanding of the history of sea level change in the Florida Panhandle area as developed from project data.

3.3 SEA LEVEL HISTORY OF THE FLORIDA PANHANDLE COAST AND SHELF

3.3.1 Introduction

The geologic and environmental history of Florida has been strongly influenced by sea level change over both the long and short term. This is in large part due to the low average elevation and extensive coastline. Evidence for the influence of sea-level change is manifest in the geomorphology and sediments in all of Florida.

Identification of offshore sand resources is assisted by detailed knowledge of sea level history because many of these deposits were formed on or near ancient shorelines related to lowered sea levels. There have been many sea level cycles of varying amplitude and duration. Most of the features containing sand deposits were formed during the last major glaciation. But shorter and more recent cycles are important, as are the earlier large-scale glacial-interglacial cycles. The following review of the present state of knowledge begins with the large-scale cycles during the whole Quaternary epoch.

3.3.2 Quaternary Sea Level Change

Florida was a submarine environment throughout most of its history. The past few million years, however, have witnessed the onset of terrestrial conditions. During that time global sea level has generally been lower than the long-term norm. In addition, the onset of the ice-age climate cycles approximately three million years ago brought radical change to coastal environments worldwide.

During the final phase of the Tertiary period, about three million years ago, a long episode of global cooling began, leading to cycles of growth and decay of the continental ice sheets. It is commonly believed that this deterioration of global climate, which continues to the present day, is a response to long-term astronomic cycles (Hays et al., 1976; Mesolella et al., 1969; Imbrie and Imbrie, 1979). Oxygen isotope ($^{18}O/^{16}O$) records from the carbonate shells of microfossils found in deep-sea sediment cores, including the deep basins of the northern Gulf of Mexico, serve as a proxy record of continental ice sheet volume changes during the glacial eras. The $^{18}O/^{16}O$ ratio in seawater changes with ocean temperature which, in turn, is a record of the glacial and interglacial epochs. According to oxygen isotope records, glacial ice volumes began to increase and ocean bottom water temperature began to decrease, about 2.7 million years ago.

This event marked the beginning of the period of climate deterioration that led directly into the Quaternary Ice Ages. Dramatic and relatively short-period climatic fluctuations, and similar sea level changes, have been the hallmark of the Quaternary period. Glacial and interglacial stages have alternated in dozens of climate cycles during that time, and continue into the present. Figure 3.3.1 depicts these cycles over the past three million years, as interpreted from the deep-sea sediment record. Note that the amplitude and period of the fluctuations are greater during the last 700,000 years. Also, there is a tendency for the duration of the cooling phases to be longer. There appears to be considerable fine detail in this record suggesting that even within the major glacial periods there were significant short-period fluctuations in ocean temperature and probably sea level as well. The time resolution of these data is limited because of the low sedimentation rate where the cores were taken. Where more detailed data are available, more small-scale fluctuations are evident.

Florida’s low-lying coast has been markedly affected by these events. During most of the Quaternary epoch time global ice sheet volume has been considerably greater, temperatures cooler, and sea level lower than at present. According to the oxygen isotope record, the present (Holocene) interglacial period, in the past approximately 10,000 years, is quite anomalous in Quaternary history. Only a few of the earlier interglacials have been as warm as the present one (Raymo, 1992).

Drastic sea-level fluctuations have accompanied these changes in continental ice volume. The most recent full-glacial cycle began approximately 120,000 years ago (Bloom, 1998; Baranola, et al., 1987), marking what is known as Oxygen Isotope Stage 5e (OIS-5e). Global sea level and temperatures at that time were perhaps slightly higher than present levels. The inset graph in Figure 3.3.2 depicts global sea-level history from that time to present. Recent evidence from the West Indies indicates that Stage 5e sea levels stood 2.5 – 6 m above present sea level (Vezina, et al., 1999). During the subsequent glacial period, global sea level and temperatures fluctuated but generally fell, reaching a minimum approximately 18,000 radiocarbon years ago. At that time of maximum extent of the ice sheets, the surface of the world ocean stood about 120 meters below present-day sea level (Fairbanks, 1989; Fairbanks, 1990).

The ocean temperature record shown on Figure 3.3.1 probably bears close resemblance to a time series of sea levels. The saw-toothed pattern of the falling stages mean that there were at least four times when the sea level fall was arrested or reversed. At these times shoreline complexes must have developed and maintained themselves within a limited portion of the shelf profile. These stages are on the order of 15,000 years in duration. Interpolation of the sea level elevation scale given on the figure indicates that the peaks of the falling phase still-stands occur near –25 m, -33 m and –60 m relative to present sea level. These elevations must be taken cautiously as the interpolation is not robust and there can be significant differences due to local crustal warping over these time spans.

Figure 3.3.2 presents published sea-level histories since the last glacial maximum (LGM) from Barbados and the northern Gulf of Mexico. The Barbados (Fairbanks, 1990) sea-level curve is widely accepted as a typical global “eustatic” curve (i.e., an accurate representation of the effect of the last episode of glacial retreat on world sea level). The glaciers began to retreat and sea level underwent a rapid rise during the period from 18,000 - 11,000 radiocarbon years ago, at an average rate of approximately 0.9 cm/yr. The rise of sea level slowed or reversed briefly during short-duration climate fluctuations. One of these is especially well documented. It is a brief cooling period known as the Younger Dryas, from 11,000 - 10,000 radiocarbon years ago, as shown by the blue horizontal bar in the figure (Fairbanks, 1990; Flower and Kennett, 1990).

The more rapid rate of rise then recommenced until approximately 6,000 - 7,000 radiocarbon years ago. Over the past 7,000 radiocarbon years global sea level has risen considerably more slowly, as shown in Figure 3.3.2, from about –15 m to the present level, rising at an average rate of 2 mm/yr (Fairbanks, 1989; Fairbanks, 1990).

The effect of the slowdown in the rate of postglacial sea level rise on global coastlines, including those of north Florida, has been dramatic. The result has been to enable the extensive development of coastal sedimentary environments. This has in particular meant the development and growth of river-mouth environments such as deltas, estuaries, coastal wetlands and barrier islands. Rapid sea-level rise, such as that which occurred during the early part of the deglaciation, discourages development of such environments due to the swift landward retreat of the shoreline. During the period 18,000 to 7,000 radiocarbon years ago, a shoreline on a continental shelf with gradient 1:1000 would have been retreating landward at a rate of about 9 m/yr. However, there is evidence that the sea level rise rate fluctuated due to climate cycles on the time-scale of centuries to millennia. Furthermore, the exposed shelf surface would not be a simple sloped surface. Instead, this surface must have had relief that had been imprinted by still-stands of the shoreline positions during the falling phase of the last major glaciation. There is not enough information about the sea level variations to establish a tight picture. But, undoubtedly the fluctuations in the sea level rise rate and the pre-existing topographic features must have interacted. Re-activation of some previous shoreline complexes must have occurred.

The slowdown of sea level rise, which commenced about 7,000 radiocarbon years ago, brought considerably slower rates of shoreline retreat and enabled coastal environments to develop in greater abundance. The rapid development of coastal environments and the proliferation of their associated human populations on a global basis, beginning around 7,000 years ago, has been well documented (e.g., Stanley and Warne, 1994).

3.3.3 Sea-Level Change in the Northeastern Gulf of Mexico and Northwest Florida

The glacially driven fluctuations in global sea level over the past 2.7 million years have had their greatest effect on the inner margins of the continents. The lower parts of the present-day coastal plains and the inner continental shelf have witnessed dozens of excursions of the shoreline, as sea level has responded to the waxing and waning of the continental glaciers. However, the time-scale of the major advances of the continental glaciers was long compared to the rate of other geologic processes that affect local elevations. Coasts on many oceanic islands are subject to sinking as the weight of the volcanic core of the island causes the earth’s crust to sag. On tectonically active continental margins the sum of vertical crustal movements during earthquake-generating faulting causes displacements at rates similar to those of the glacial induced sea level fluctuations. In northern zones the weight of the continental glaciers themselves (ice about two miles thick) caused the crust to depress and then rise again as the ice retreated. Therefore, both crustal elevations and sea levels are constantly changing. Sea level curves must be adjusted to fit the coastal region of interest.

The types of geologic material that can be age-dated further complicate determining detailed sea level histories. Radiocarbon dating is most common and is often based on organic sediments such as peat or shells. However, peat formed in salt marsh bogs compacts over time, and shells can either come from animals that live deep below the sea surface or from shell remains that have been transported far from their point of origin. These, and other effects such as age-dating errors, are well known, and care is exercised in assessing ancient sea levels. Nevertheless, these effects contribute to the notorious scatter in the measured data.

Figure 3.3.2 includes three LGM sea-level curves from the northern Gulf of Mexico, as defined by carbon-dated samples of peat and shell collected from the Louisiana-Texas shelf (Frazier, 1974; Curray, 1960; Nelson and Bray, 1970). It can be observed that, in general, the Gulf of Mexico sea level curves are similar in trend to the "global" curve from Barbados (Fairbanks, 1989), although there is some evidence that sea level may have risen episodically in the northern Gulf of Mexico during the latest deglacial era. This episodicity, even if short-lived, would have encouraged the development of coastal sedimentary features during the periods of slower or briefly reversed sea-level change. The periods of slowing of postglacial sea level rise for one of the sea level histories for the northern Gulf (Frazier, 1974) are indicated by the red horizontal bars at the base of Figure 3.3.2.

Figure 3.3.3 is a compilation of most of the available dated sea level indicators for the Florida and Alabama Gulf coast. The Fairbanks (1990) Barbados sea level curve is superimposed for reference. Of interest is the fact that, with two exceptions, all of the northeastern Gulf sample data sets lie above the Barbados curve. The exceptions are the McBride (1997) dates for shells collected from the Alabama and northwest Florida shelf (1988) dates for shell samples from beach ridges in southwest Florida. The former may have been affected by the original depth at which the shell-bearing organisms lived or transport after death. The latter, which cover only the past 3,000 years, may be evidence of minor high stands of sea level during the past few millennia. The positions of the remainder of the sea level indicators for the northeastern Gulf generally follow the Barbados global sea level trend, but lie entirely above the curve. This may indicate that the northeastern Gulf coast has been uplifted during the deglacial era.

Figure 3.3.4 expands the most recent 6,000 years of sea level history for the northeastern Gulf, as taken from Figure 3.3.3. Again, there appears to be evidence that the northeastern Gulf coast has been elevated slightly with respect to the global trend of sea level change. A composite sea level curve is superimposed on these data. The red portion of the curve that extends back to about 2,500 years ago is from Stapor et al., (1991). His curve and the portion that we extend further back in time show low amplitude fluctuations on the order of 1 to 2 m. The average duration of these cycles is about 1,000 years. The Stapor data indicate that there have been two recent episodes of sea level higher than present and the whole curve indicates that there have been four times when sea level has been at or above its present level on the northeast Gulf coast.

Figure 3.3.5 from Dorsey (1997) comes from an independent evaluation of sea level data and it portrays a very similar recent sea level history. The implications of sea level fluctuations of this magnitude and period are very significant to understanding how sand deposits have been formed.

Due to the unusually wide and low-gradient shelf, few places in the world have been as profoundly affected by these sea level fluctuations as that of the northeastern Gulf of Mexico. Figure 3.3.6 displays the bathymetry of the continental margin of northwest Florida. For most locations on the western coast of the Florida peninsula and the eastern panhandle, the shoreline during the last glacial maximum, 18,000 radiocarbon years ago, stood near the present-day shelf edge, approximately 150 - 200 km offshore from the modern coastline. During the period of rapid sea level rise 18,000 - 7,000 radiocarbon years ago, the shoreline at the Ocklocknee River mouth, at the eastern margin of the study area, was retreating northward across the continental shelf at an average rate of approximately 18 m/yr.

Just as with global sea level records, sea level on the west coast of Florida slowed its rate of rise during the past 7,000 years. Sea level data from southwest Florida indicates that Florida sea level slowed even further over the past 4,000 years (Scholl et al., 1969). On parts of the west Florida coast where productivity has been high or sediment influx has been great, this slowdown has enabled some coastal environments to begin to prograde seaward during that time, despite the rise of sea level (Parkinson, 1989; Stapor et al., 1989, 1991; Evans et al., 1985; Hine et al., 1988). Many of the sedimentary features of the innermost shelf owe their development to this combination of conditions.

3.4 GEOLOGIC MODEL

The information about the processes that form sand deposits, the large-scale spatial trends in sediment data, and the sea level history of the Florida Panhandle has been combined to generate a comprehensive explanation of the offshore sand deposits in the project area. This is called the Geologic Conceptual Model. This model is useful because it shows how individual seafloor features fit into the regional and historical context with adjoining or similar features. It provides guidance into which areas warrant detailed surveys in search of sand resources. It also identifies a number of areas where sediments unsuitable for beach nourishment are likely to be encountered.

The Geologic Conceptual Model is based on a number of well accepted points. First, the sand is derived from the major alluvial rivers that drain watersheds that extend well into Georgia and Alabama. The sand is redistributed primarily by longshore transport processes acting in the nearshore zone, although there is much slower but continuous reworking of the sands on the continental shelf. There have been a number of major glacial epochs over the past 700,000 years where sea level fell more than 100 m below the present level. These major glacial epochs had durations on the order of 100,000 years, with lesser fluctuations on time-scales of 10^3 to 10^4 years and sea level ranges on the orders of 10^0 to 10^1 m. The combination of the major and lesser sea level fluctuations produced a number of "still-stand" periods across the whole coastal region. These occurred during both the falling and rising phases of the major glacial epochs. Shoreline features that formed during falling phase "still-stands" persisted and provided locations where the coastal processes systems could be reestablished during the subsequent major rising phase. Because of the huge contrast in the effectiveness of nearshore processes in transporting sand compared to the minor transport of sand as it is reworked by continental shelf processes, most of the existing offshore sand deposits are related to former locations of the shoreline on the shelf. These deposits tend to be clustered in places where there was a virtual still-stand of the shoreline for an extended duration.

The river systems that provide sand to the coast occupy upland watersheds that have changed little during the past million years. Thus, the primary sediment sources remain the same. The clastic sediments, which now cover the beaches and inner shelf of north Florida, are derived from upland watersheds in Alabama and Georgia. Much of this sediment may ultimately have been derived from the weathering and erosion of the southern Appalachians. The sediments were transported to the north Florida coastline by large river systems. The river systems providing sediments to the Panhandle coast, in order of importance, include: 1) the Alabama-Tombigbee System that becomes the Mobile River, 2) the Flint-Chattahoochee System that becomes the Apalachicola River, and 3) the Escambia-Blackwater System that feeds into Pensacola Bay. The other coastal rivers, such as the Perdido, the Choctawhatchee, and the Ocklocknee Rivers are of minor importance to the coastal sediment system. Figure 3.4.1 is a geologic map in which the major river systems are prominently displayed.

Figure 3.4.2 shows artificially shaded, detailed bathymetry of the project area. A number of patterns appear. Some have clear and easily understood explanations, and others are more difficult. Figure 3.4.3 associates these bathymetric features with names indicating their modes of origins. Figure 3.4.4 shows another set of sedimentary features that do not appear as bathymetric features but have been identified from the sub-bottom geophysical survey data.

The sequence of events that controlled the development of the sand deposits is shown on Figure 3.4.5. This sequence begins at the last major low stand of sea level, which occurred about 18,000 years ago. In creating the conceptual model of the sequence of development of the shelf sand features, we have relied on the sea level curves discussed previously, the morphology of the seabed, the sub-bottom profiles, and, to a lesser degree the trends in sediment types and grain sizes. Our interpretations of the data have been strongly influenced by the work of McBride (1996a and b, 1997a and 1997b) who showed that many features developed at lower sea level are recognizable today, but they are masked by a reworked sand sheet 2 – 3 m thick. We have extended McBride's interpretation of features much further to the east than he was able to do.

The oldest offshore deposits that could provide adequate borrow sand for beach nourishment projects are infilled and buried river channels. Sub-bottom seismic profiling data indicate that the river systems of north Florida extended well beyond their present mouths during sea-level lowstands, creating extensive networks of fluvial features on what is now the inner shelf. Many of the smaller rivers, which terminate at the modern coast, were tributaries of the larger rivers during lowstands. Figure 3.4.6 presents a reconstruction of the paleodrainage systems underlying parts of the north Florida shelf, based on the sub-bottom seismic database. Many of the sub-bottom records also reveal that the paleo-rivers were generally larger than at present (implying wetter conditions), and that the drainage was in many places dominated by karst processes (Faught and Donoghue, 1997; Chen, 1999; Schnable and Goodell, 1968).

As an example, the Apalachicola, Florida's largest river, enters the northern Gulf of Mexico through the middle of the panhandle. Sub-bottom records from the inner shelf off the modern Apalachicola River mouth (shown to the right of center in Figure 3.4.6) reveal a drainage system that existed during the last glacial era and its aftermath. The paleo-Apalachicola was significantly larger than the modern river system, and incorporated many karst features and now-buried sediment bodies (Donoghue, 1992; Donoghue, 1993; Chen et al., 2000).

Not only did the rivers extend across the present shelf, they also had higher discharges of water and sediment during the glacial epoch. There is little direct evidence of the magnitude of these larger discharges in the Florida Panhandle area. However, farther west, various lines of evidence indicate that the paleo-Mississippi was also a considerably larger river during parts of the glacial epoch, with water and sediment discharge perhaps as much as six times modern levels. Paleo-Mississippi discharge peaks have been recorded at 13,000 years before present (ybp) and again at 10,000 ybp, based on oxygen isotope and sediment studies (Emiliani, et al., 1978; Leventer et al., 1982; Perlmutter, 1985). These large variations in river magnitude are a reflection of the fact that the retreat of the ice sheets did not occur without interruptions. The interruptions, times of stagnation or even minor advance of the ice front, were reflected not only in river discharge but also in climate and sea level. These anomalous periods in the general trend of climate and sea level change would also have encouraged the development of shoreline features on what is now the inner shelf.

Not all of the paleo-channels shown on Figure 3.4.6 originated during the last glacial epoch. Some are deeper and probably represent river channels cut during earlier glacial epochs. Because the major upland watersheds did not change in major ways, the river channels from subsequent periods of maximum glaciation can overprint each other. A detailed study would be needed to accurately differentiate between channels of different ages, but this would contribute little to the search for exploitable offshore sand deposits.

Some shoreline features originating during the times of 9,000 ybp and 8,000 ybp can be found in the bathymetric and sub-bottom data. These are shown on Figures 3.4.7 and 3.4.8, respectively. There was a shoreline complex in the western third of the project area. At the western extend, this complex had estuaries which were probably connected to some combination of the Perdido, Escambia and Blackwater watersheds. The reason that a shoreline complex developed at this location is not known. Because it is regionally extensive in longshore extent and fairly wide (4 km) it is likely that this shoreline complex was associated with a still-stand of the shoreline position. This may have been the result of a fluctuation in the rate of sea level rise, but the resolution of our sea level curve is too coarse to resolve it. The still-stands could also have resulted from the coincidence of the shorelines with a pre-existing shore complex formed during the retreating phase of the last glacial cycle. The steeper relief of a pre-existing shore complex could arrest the rate of shoreline progression and bring about an extended period where the ancient shore complex was re-activated. As sea level continued to rise, the shoreline complex appears to have been over-stepped. That is, the normal process of barrier island rollover and retreat in the face of sea level rise was overwhelmed by a too rapid rise rate.

The barrier island system of the western third of the project area appears to have re-established itself farther landward about 7,600 ybp. This system was also characterized by one or more estuaries in the west. These occupied pre-existing topographic lows that were flooded by the rising sea level. The shoreline in the eastern portion of the project area was far from the present shoreline. No features have been found here, and the shoreline is inferred to have been along the same elevation contour as it occupies to the west.

A third system of coastal sand deposits can be identified along about two-thirds of the Panhandle area. From its depth below the present sea level this system functioned for a long time around 7,000 ybp. Retreating barrier islands and coastal spits, with bays and estuaries behind, were evident along much of the coastline. Figure 3.4.9 shows this shoreline and several of the sand deposit features that have been preserved. By this time it is clear that major sand deposits were formed at, or near, the shoreline at the locations where the major rivers came to the shoreline. These are evident adjacent to what would have been the Apalachicola and Escambia River mouths. From what remains of the geometry of these deposits it is clear that there were what one author calls transgressive shoreface massifs (Swift et al., 1972 and Swift, 1973). Similar features can now be found off Cape Hatteras, Cape Lookout and Cape Fear in North Carolina. They are thought to result when river systems deliver sand faster than littoral transport systems can disperse it. They are a form of delta, which is heavily reworked by waves and nearshore currents. The presence of these large sand masses can locally retard the rate of shoreline retreat. Capes and sand spits can result. They differ from other deltas that have been identified in the project area because they appear to have formed at or near the shoreline where fine sediments were winnowed out. During rising sea level, estuaries are common because river valleys are inundated and deltas normally form in the protected head ends of these estuaries.

Figure 3.4.10 shows conditions about 7,300 ybp. In the western half of the study area, the shoreline was within a few miles of its present location, and early versions of St Andrews, Choctawhatchee, Pensacola, Apalachicola and possibly St. Josephs Bays existed. In the eastern third of the project area the shoreline was much farther from its present location.

During the interval between 7,000 and 6,000 ybp the shoreline in the western half of the project area appears to have slowly retreated and maintained many of the features such as estuaries and ebbtide shoals that are still there. The lower slope of the offshore area in the east caused the shoreline to retreat much more rapidly as sea level continued to rise. The Ocklocknee formed another delta at a different location. Figure 3.4.11 shows conditions about 7,000 ybp.

By the time of 6,000 years ago the shoreline over most of the project area was close to its present location (Figure 3.4.12). A number of processes have acted since then that influence the location and quality of offshore sand resources. From about Panama City westward the shoreline position changed little, even with the short-period sea level fluctuations defined on Figure 3.3.4. However, these sea level excursions probably contributed to forming a series of interleaved sediment layers within the barrier island complexes. In the center of the project area the Cape San Blas spit extended northward during this period. The barrier islands fronting Apalachicola Bay underwent a series of realignments as evidenced by the beach ridge complexes visible today. As sea level rose and fell 2 m to 3 m due to the short-term fluctuations, Apalachicola Bay alternately filled and emptied. This situation is diagramed on Figure 3.1.1. During the low-stands the river sand is delivered to the littoral transport system and moves rapidly alongshore. At high-stands this transport is much less vigorous. It appears that the white sands of the Panama City beaches originate from offshore deposits of river sand that were formed during the low-stands. Some of this sand is driven onshore during the high-stands. Offshore there was a development of the extensive sand wave field as the shelf sands were reworked. Figure 3.4.13 shows the features that are present today which developed during the last 6,000 years.

All of the features discussed in this section have the potential for being good sources of offshore borrow sand. However, the conceptual model explained above also provides some cautions about places where it can be difficult to identify good quality beach sands offshore. These are shown on Figure 3.4.14. Generally these places correspond to locations where the barrier islands have been retreating landward and bay bottom sediments may be near the seafloor on the shoreface. There are also places where there is evidence of deposits from ancient muddy deltas lying at, or close to, the seafloor.

One of the project goals was to find and evaluate a number of potential offshore sand borrow sites. Because of the large amount of data contained in the database, it was possible to make reconnaissance-level identification and evaluations of potential sites. This also illustrates the use of the project tools.

The sediment database and GIS interactive map tools created as part of this project were designed for use in sand reconnaissance surveys for possible beach renourishment projects. In order to demonstrate the utility of these new tools, this section describes several sediment features of the inner shelf in the Florida Panhandle study area. The methodology employed to identify and characterize the sediment features is as follows:

- Identify potential inner-shelf sediment bodies using the high-resolution bathymetric database and hillshade Feature available on the ArcIMS interactive mapping system.
- Outline the sediment features and the adjacent seafloor using the polygon select feature of the interactive mapper.
- Highlight all of the sediment sample locations (surface grabs and cores) and sub-bottom seismic tracklines on or near the sediment feature. Identify all samples and seismic shotpoints using the Identify tool of the interactive mapper.
- Download the seismic profiles which cross the feature, in order to view the cross-section and quantify the dimensions (area and thickness) of the sediment body. Annotate the seismic lines to delineate the sediment feature.
- Using the Query tool, download all sediment data (grain size, color, etc.) for all of the samples on or near the sediment feature.
- Collate sediment grain size and color data for the sediment feature and compare with average values for seafloor sediments adjacent to the feature.
- Describe the sediment body in terms of the nature of the sediments (texture, color, composition), areal extent, volume of sediment, and thickness of overburden (if any).

Each of the features described below was identified and characterized in the above manner. The sedimentary characteristics of each are described, along with an interpretation of the possible origin of each feature and its relation to sea level and climate history. Additionally, the characteristics of each feature are summarized in Table 4.1.1.

4.1 FEATURE A-1

Feature A-1 can be observed as a topographic high in the high-resolution bathymetry images (Figure 4.1.1 and Figure 4.1.4). Compilation of the sediment texture from the sediment database (Figure 4.1.2) indicates that the surface sediments on the feature are finer than those off the feature, with a mean of 1.8 (medium sand). A t-test comparison (0.04, Table 4.1.1) of the mean diameters of samples on the feature versus those from samples off the feature indicates that the two sets of samples come from distinctly different populations. From the sediment color database, it can be observed that sediment samples on this feature exhibit light sediment colors (Munsell Value >7)(Figure 4.1.3). Light-colored sediment is indicative of well-sorted quartz sand. Geophysical data in the form of sub-surface profiles were collected along a gridded pattern in the area (Locker and others, 1988, Locker and Doyle, 1992). Selected profile lines and the associated timestamps, displayed in yellow on Figure 4.1.4, were used in the analysis of this site. These profiles extracted from the subsurface seismic database (Figure 4.1.5 to Figure 4.1.11) indicate that the feature is associated with a depositional wedge that may be related to a sea level still-stand and resultant progradation of beach and shoreline sedimentary environments. The high-angle sedimentary beds (clinoforms) imaged by the seismic reflection data (e.g., Line 5 in Figure 4.1.6) suggest that this feature represents prograding beach or shoal deposits. Based on the seismic profiles, the area of the feature is approximately 120 sq. km, and it extends as close as 3 km to the modern coastline. Sediment thickness in the feature ranges from 4 m to 9 m. Volume of sediment contained in the feature is approximately 786 million cubic meters. Located in approximately 15 m water depth, the feature appears to be a product of the period when Holocene sea level rise began to slow, approximately 7,000 to 9,000 years ago. Its origin would therefore be similar to that of Features W-1 and W-2 below.

4.2 FEATURE W-1

Feature W-1 is prominently expressed in the high-resolution bathymetry (Figures 4.2.1 and 4.2.4) and is likewise readily apparent in the subsurface seismic record. It appears to be a paleoshoreline feature, although its orientation is northeast to southwest, as compared to the nearly east-west orientation of the modern coast. Changes in oceanographic conditions in the northeastern Gulf have apparently altered the orientation of the shoreline in the Escambia-Santa Rosa County region. Sediment texture data from the sediment database (Figure 4.2.2 and Table 4.1.1) indicate that the surface sediments on the feature are slightly coarser (mean diameter 1.3 phi, medium sand) than those from the adjacent seafloor. The sediment color database indicates that surface sediments on the feature exhibit mid-range values (Figure 4.2.4). Geophysical data in the form of sub-surface profiles were collected along a gridded pattern in the area (Locker and others, 1988, Locker and Doyle, 1992). Selected profile lines and the associated timestamps, displayed in yellow on Figure 4.2.4, were used in the analysis of this site. These profiles from the seismic database (Figures 4.2.5 to 4.2.8) suggest that the feature may be a portion of a drowned barrier or other coastal sand body, with seaward-dipping reflectors on the Gulf side and landward-dipping reflectors on the landward side. Mean present-day depth of the feature is approximately 28 m MSL. Based on the sea level curves for the northern Gulf of Mexico (Figure 3.3.3), the rising early Holocene seas would have reached approximately the elevation of Feature W1 by about 8,000 to 9,000 years ago. At that time the rate of sea-level rise was beginning to slow, allowing development of coastal sedimentary features, such as barriers and estuaries. Feature W-1 may be a product of that event. Its area totals about 32 sq. km. The volume of sediment in the feature is approximately 285 million cubic meters.

4.3 FEATURE W-2

Feature W-2, like Feature W-1, is easily distinguishable in the high resolution bathymetry and equally apparent in the subsurface seismic record (Figures 4.3.1 and 4.3.4). The sediment database indicates that surface sediments on the feature are slightly coarser (mean diameter 1.3. phi, medium sand) than those on the adjacent seafloor (Figure 4.3.2). The sediment color database indicates that the surface sediments are light in color, again indicative of quartz sand (Figure 4.3.3). Geophysical data in the form of sub-surface profiles were collected along a gridded pattern in the area (Locker and others, 1988, Locker and Doyle, 1992). Selected profile lines and the associated timestamps, displayed in yellow on Figure 4.3.4, were used in the analysis of this site. These profiles from the geophysical database (Figures 4.3.5 to 4.3.9) indicate that this sediment feature may be a paleoshoreline. Its age may be equivalent to that of Feature W-1, due to its similar depth and northeast-southwest orientation with respect to the modern coast. Its mean depth, approximately 19 meters, is similar to that of an early Holocene still-stand suggested in the Frazier (1974) sea level history, occurring approximately 7,000-9,000 years ago (Figure 3.3.3). Like Feature W-1, this feature may be a portion of a drowned barrier or other coastal sand body. The feature's area totals about 102 sq. km. The volume of sediment in the feature is approximately 759 million cubic meters.

4.4 FEATURE W-3

Similar in size and orientation (northeast to southwest) to Features W-1 and W-2, Feature W-3 is likewise readily apparent in the high-resolution bathymetry (Figures 4.4.1 and 4.4.4). The database reveals that sediments on the feature are finer (mean diameter 1.5 phi, medium sand) than those off the feature (Figure 4.4.2). Color values of surface sediments on the feature are medium to light (Figure 4.4.3). Geophysical data in the form of sub-surface profiles were collected along a gridded pattern in the area (Locker and others, 1988, Locker and Doyle, 1992). Selected profile lines and the associated timestamps, displayed in yellow on Figure 4.4.4, were used in the analysis of this site. These seismic data corroborate the existence of a large near-surface sedimentary unit (Figures 4.4.5 to 4.4.8). The mean water depth of this feature is approximately 25 m, making it deeper than Feature W-2. It may represent an earlier Holocene shoreline deposit. Like the other two similar features nearby, this feature may be a portion of a drowned barrier or other coastal sand body. Its area totals about 72 sq. km. The volume of sediment in the feature is approximately 487 million cubic meters.

4.5 FEATURE W-4

Feature W-4 was also easily identifiable using the high-resolution bathymetry database (Figures 4.5.1 and 4.5.4). It is similar to Feature W-8 below, in that it appears to be related to the development of a coastal embayment, in this case Choctawhatchee Bay. Surface sediments on the feature are slightly coarser (mean diameter 1.2 phi, medium sand) than those on the adjacent seafloor (Figure 4.5.2). Sediment color values on the feature are in the mid-range of color values (Figure 4.5.3). Geophysical data in the form of sub-surface profiles were collected along a gridded pattern in the area (Locker and others, 1988, Locker and Doyle, 1992). Selected profile lines and the associated timestamps, displayed in yellow on Figure 4.5.4, were used in the analysis of this site. These seismic profiles beneath the bathymetric feature reveal a relatively thick surficial sediment unit that is apparently related to the retreat of the inlet or the associated rivers that feed the modern bay (Figures 4.5.5 to 4.5.10). Like Feature W-8, it appears to be a retreat path of a river mouth or inlet complex in response to Holocene sea level rise. The area of the feature totals about 40 sq. km. The volume of sediment in the feature is approximately 203 million cubic meters.

4.6 FEATURE W-5

Feature W-5 is a sediment body that is quite evident in the high-resolution bathymetric data (Figures 4.6.1 and 4.6.4). It lies on the shelf off Choctawhatchee Bay in water depths of approximately 22 m. The database reveals that sediments on the feature are significantly finer-grained (mean diameter 1.5 phi, medium sand) than those off the feature (Figure 4.6.2). The average standard deviation (a measure of sorting) is smaller for samples on the feature than for samples off the feature. Sorting also increases towards the offshore side of the feature. A t-test (0.02, Table 4.1.1) comparing mean diameters indicates that the two sets of samples come from quite different populations. As with Feature A-1, the sediment color in the database (Figure 4.6.3) is useful in analyzing this feature. The surficial sediments exhibit a color contrast with the surrounding sediments. The Value (lightness) of the sediments on the surface of the feature averages greater than 7, a characteristic of quartz sands. Geophysical data in the form of sub-surface profiles were collected along a gridded pattern in the area (Locker and others, 1988, Locker and Doyle, 1992). Selected profile lines and the associated timestamps, displayed in yellow on Figure 4.6.4, were used in the analysis of this site. The subsurface seismic data indicate that the feature is a moderately thick sediment body, averaging about 5 m thickness (Figures 4.6.5 to 4.6.8). It trends northeast-southwest, at an angle of approximately 40 degrees to the modern coastline. In map view it curves, becoming concave to the modern coast. The feature may represent a drowned shoreline complex. Its area totals about 57 sq. km. The volume of sediment in the feature is approximately 269 million cubic meters. The surface sediments in some of the more seaward areas have been reworked into large sand waves (e.g., Line 86, Figure 4.6.6).

4.7 FEATURE W-6

Feature W-6 is a small sediment body, which rises several meters above the floor of the shelf in approximately 28 m water depth (Figures 4.7.1 and 4.7.4). That depth that would have represented the north Florida shoreline 9,000-10,000 years ago (Figure 3.3.3). The sediment database indicates that samples on the feature are slightly coarser grained (mean diameter 1.3 phi, medium sand) than those off the feature (Figure 4.7.2). Geophysical data in the form of sub-surface profiles were collected along a gridded pattern in the area (Locker and others, 1988, Locker and Doyle, 1992). Selected profile lines and the associated timestamps, displayed in yellow on Figure 4.7.4, were used in the analysis of this site. These profiles from the subsurface seismic database (Figures 4.7.5 and 4.7.6) indicate that the feature is approximately 4 m thick. It is the smallest of the sediment features identified, with an area of about 23 sq. km, and a volume of approximately 94 million cubic meters.

4.8 FEATURE W-7

Feature W-7 was initially identified on the basis of the high-resolution bathymetric data (Figures 4.8.1 and 4.8.4). Examination of the database (Figure 4.8.2) indicates that surface sediments on the feature (0.7 phi, coarse sand) are significantly coarser than those off the feature (1.4 phi, medium sand). The database additionally reveals a high percentage of carbonate sediments on this feature. Geophysical data in the form of sub-surface profiles were collected along a gridded pattern in the area (Locker and others, 1988, Locker and Doyle, 1992). Selected profile lines and the associated timestamps, displayed in yellow on Figure 4.8.4, were used in the analysis of this site. The analysis of the subsurface seismic data beneath the feature (Figures 4.8.5 to 4.8.9) indicates that no near-surface sand bodies are apparent at this site, and that the sediment textural differences might be a reflection of a concentration of carbonate sediments on the surface of the feature. This case provides an example of the way in which the sediment and seismic databases and the interactive mapper can be utilized to test the hypothesis that a sand resource exists at a suggested borrow site.

4.9 FEATURE W-8

Feature W-8 was initially identified using the high-resolution bathymetry. Its bathymetric signature implies it is related to the development of St. Andrew Bay (Figures 4.9.1 and Figure 4.9.4). The database indicates that surface sediments on the feature are significantly coarser (mean diameter 1.2 phi, medium sand) and better sorted than those of the adjacent seafloor (Figure 4.9.2). Again, the t-test comparing the means of the two sets of samples indicates that the two sets are from quite different populations. The sediment color database shows that the surface sands on the feature are light in color value, implying quartz sand composition (Figure 4.9.3). Color lightness increases toward the landward side of the feature. Geophysical data in the form of sub-surface profiles were collected along a gridded pattern in the area (Locker and others, 1988, Locker and Doyle, 1992). Selected profile lines and the associated timestamps, displayed in yellow on Figure 4.9.4, were used in the analysis of this site. Examination of the seismic profiles reveals that the sediment body has a significant subsurface component (Figures 4.9.5 to 4.9.11). It appears to be a retreat feature, similar in origin to Feature W-4 above, created as a coastal inlet or river mouth retreated across the inner shelf in response to Holocene sea level rise. It lies in water depths of approximately 20 m. Sediment thickness in the feature is high, nearly 10 m. The area of the feature is approximately 52 sq. km, and its volume is approximately 514 million cubic meters.

4.10 FEATURE W-9

Feature W-9 is a large, filled paleofluvial channel system. There is some relief in the high-resolution bathymetry (Figures 4.10.1 and 4.10.4), but most of the feature is observed in the subsurface. The database (Figure 4.10.2) indicates that the overburden is relatively fine-grained (mean diameter 2.3 phi, fine sand), poorly sorted and dark in color value (Figure 4.10.3). Geophysical data in the form of sub-surface profiles were collected along a gridded pattern in the area (Locker and others, 1988, Locker and Doyle, 1992). Selected profile lines and the associated timestamps, displayed in yellow on Figure 4.10.4, were used in the analysis of this site. The subsurface seismic database (Figures 4.10.5 to 4.10.8) reveals high-angle sediment beds (clinoforms) in the near-subsurface. These deposits appear to be result of lateral migration of the channels during the time when they were active. This feature may be a late Pleistocene (or older) paleochannel system of one or more of the coastal rivers that presently enter St. Andrew Bay. A less likely, but possible, scenario is that it represents a paleo-distributary system of the Apalachicola River, during a time when the Apalachicola's course lay farther west than the present-day river. The paleochannel features lie in water depths of approximately 24 m. An estimate of their surface area is 40 sq. km. Their thickness is large, approximately 11 m. Approximate sediment volume is 462 million cubic meters. This channel fill feature is a potential borrow sand source, but the overburden would need to be removed prior to extracting the sand.

4.11 FEATURE E-1

Feature E-1 was identified via the high-resolution bathymetric database. It is a sediment feature which stands out in relief on the eastern flank of the inner portion of Cape St. George Shoal (Figures 4.11.1). The feature lies in water depths averaging 7 m, approximately 8 km southwest of Sikes Cut, the inlet through St. George Island. Figures 4.11.2 and 4.11.3 show that there are no data on the sediment grain size and color. Geophysical data in the form of sub-surface profiles were collected in the area (Donoghue, 1993). Selected profile lines and the associated timestamps, displayed in yellow on Figure 4.11.4, were used in the analysis of this site. In the seismic cross-section (Figures 4.11.4), its apparent north-south length is approximately 2,800 m. Its location and structure indicate that it is likely to be either a portion of a drowned paleo-delta of the Apalachicola River or a sand shoal created by the retreat of Cape St. George. Its thickness averages 6 m (Figures 4.11.5a and 4.11.5b). Assuming a width approximately equivalent to its length, the volume of sand contained in the feature is approximately 48 million cubic meters. It is readily accessible at the surface and close to shore, making this feature a potential candidate for borrow sand.

4.12 FEATURE E-2

Feature E-2 is a buried paleodelta lying in the near-surface below the inner shelf in approximately 12 m water depth, approximately 14 km southeast of Cape St. George. It is evident in the high-resolution bathymetric database (Figures 4.12.1). Figure 4.13.2 and 4.12.3 indicate no grain size or color data for this feature. Geophysical data in the form of sub-surface profiles were collected in the area (Donoghue, 1993). Selected profile lines and the associated timestamps, displayed in yellow on Figure 4.12.4, were used in the analysis of this site. The length of the feature shown in the seismic cross-section (Figure 4.12.4) is approximately 1,350 m. Its mean thickness is 4.3 m.

Assuming a similar width, the volume of sand contained in the paleodelta would be approximately eight million cubic meters. There is a sediment overburden, which averages approximately 4 m thick in the cross-section pictured (Figure 4.12.5). Several paleodeltas of the Apalachicola can be identified from seismic data in this region of the shelf, all of which represent the position of the active Apalachicola Delta during lower stages of sea level. Given its depth and the history of sea-level change in the northern Gulf of Mexico (Figure 3.3.3), Feature E-2 would have been at or near sea level approximately 6,000 to 7,000 years ago. The younger of Apalachicola paleodeltas, located in shallow depths closer to shore, are obvious targets to explore for potential renourishment sand. All of them are near to the surface of the shelf and readily identified and quantified using the seismic database.

4.13 FEATURE E-3

Feature E-3 is a large, filled paleofluvial channel system. There is little surface evidence of its presence (Figure 4.13.1). As shown on Figures 4.13.2 and 4.13.3, there are no grain size or color data for this feature. The feature was detected on the basis of the subsurface seismic database. Geophysical data in the form of sub-surface profiles were collected in the area (Donoghue, 1993). Selected profile lines and the associated timestamps, displayed in yellow on Figure 4.13.4, were used in the analysis of this site. It is similar in origin and shape to Feature W-9, but considerably larger. Given its position on the inner shelf south of the present-day position of the

Apalachicola River mouth, it is almost certainly a paleochannel of the Apalachicola River. The paleochannel features lie in water depths of approximately 8.8 m. The cross-section of the paleochannel, as shown in Figure 4.13.4, is approximately 150 m wide. The channel fill is approximately 9.4 m (Figure 4.13.5). The paleochannel system extends over the full width of the seismic data set on the inner shelf in the Apalachicola region. Its length, therefore, is at least 30 km. Based on these approximate dimensions taken from the seismic database, the amount of channel fill sand in this paleochannel is approximately 42 m million cubic meters. The overburden shown in the seismic section pictured is approximately 6.9 m thick, which would have to be removed before accessing the sand resource. In places on the shelf the overburden is considerably thinner, based on the seismic database.

4.14 POTENTIAL BORROW AREAS SURVEYED DURING PHASE III

Three potential offshore borrow areas were surveyed as part of the Phase III field plan. These are the Panama City Beach area, the East Pass area and the Santa Rosa area. Analysis of these sites included collection and review of geophysical data in the form of sub-bottom profiles, and sediment grain size analysis on sand samples collected from within the vibracores taken at each of these sites. Also included in the review were radiometric dates from three organic samples retrieved in the cores; one sample each from cores PC1, EP1, and SR3.

A review of the geophysical data collected during Phase III in August 2003 revealed a very distinct sub-surface reflector underlying the entire study area. Figures 4.14.1 through 4.14.3 show this reflector in relation to the three core locations that produced the datable samples. This reflector was determined to be the Maximum Flooding Surface (MSF). This is an erosional surface created during the last glacial maximum. This flooding surface represents either an upland or lagoonal feature or a broad shallow estuary analogous to Florida Bay today. This surface is an unconformity representing a period of non-deposition or erosion. The results from the dated samples, calibrated to a corrected calendar age using Bards (1998) calibration curve allowed for minimum age of this surface to be around 47,000 ybp. This then determines that the sediments found above this surface are less than this age placing them in the Holocene Epoch.

Taking these dates and comparing them to the sea level curves (Figure 3.3.2) it is possible to determine that these ages correspond to a sea level still stand at these locations of around 9,000 ybp. With the understanding that the sediments on top of MSF have been determined to be less than 9,000 years in age, it follows that in the three sites surveyed, if the grain size and composition are within native beach parameters, then these bodies of sand could serve as potential borrow sand for future nourishment projects.

A description of each of the radiocarbon dated samples follows:

- The sample from core PC1 referred to as sample PC1A was taken at a core depth of 15.3 feet, for a total depth of 62.8 feet (19.1 m) below present Mean Sea Level (MSL). This sample is composed of organic sediment interpreted as lagoonal or deltaic in origin. The organic sediment was described as medium to dark gray to black, fine silty sand, and peaty. This section of the core was fining downward with silty sand at the top of the unit. Sample PC1A was dated by standard beta analysis and yielded a conventional radiocarbon age of 37,470 y BP +/- 1,060 y BP. Using Bard’s (1998) calibration curve, PC1A yields a calculated calendar age of 47,316 y BP.

- The sample from core EP1 referred to as sample EP1A was taken at a core depth of 12.2 feet, for a total depth of 88.9 feet (27.1 m) below present Mean Sea Level (MSL). This sample is composed of wood (root) and is thought to be deltaic in origin based on the silty, organic sediment surrounding the root. This portion of the core was mottled with dark organic mud and silty sand. The sand portion contained ~15% shell and a trace of heavy minerals. The quartz sand was coated with silt. After reviewing the seismic record for this core, this sample appears to be from the edge of a paleo-channel. Sample EP1A was dated by AMS analysis and yielded a conventional radiocarbon date of >46,850 y BP, meaning that the age of the sediment is beyond the limit of radiocarbon dating. Using Bard's (1998) calibration curve, PC1A yields a calculated calendar age of 59,413 y BP.
- The sample from core SR3, referred to as SR3A, was taken at a core depth of 12.2 feet, for a total depth of 105.6 feet (32.2 m) below present MSL. This sample is composed of wood (stem or branch) and is thought to be deltaic in origin. This section of the core was described as silty fine sand that has been slightly burrowed. Three larger burrows (0.1-0.3 feet long) were seen in this ~5 foot section. Sample SR3A was dated by AMS analysis and yielded a conventional radiocarbon date of 38,370 y BP. Using Bard's (1998) calibration curve, SR3A yielded a calculated calendar age of 48,477 y BP.

The age dating proved to be a great aid in understanding both the mode of origin and the volume of the Holocene sand in each of the features. By clearly delineating these volumes the limits to which the grain size and composition data from the older grab samples and newer vibracores were also determined. This allows a reconnaissance-level estimation of both these sand sources and the sand resources in other similar features.

Potential Borrow Sites

The value of the sediments above the MFS as potential sources of nourishment sands was determined. Fifty-four grab samples were collected from nine transects on Florida Panhandle beaches. They are distributed across the whole project area from Mashes Sands in Wakulla County to Perdido Key in Escambia County. In reviewing the granulametric data determined by sieve analysis, it was found that mean grain size of these samples ranged from 0.62 phi to 2.56 phi with an average mean for all samples of 1.88 phi and a standard deviation of 0.32. Using the Unified Soils Classification (USCS) scheme all of these samples fall within the medium to fine sand categories.

Using the existing data in the database it was determined from the surface grab samples on the Panama City Beach feature that the range of means was from 0.25 to 1.47 phi with an average mean for all samples of 1.46 phi and standard deviation of 0.51, for the East Pass feature the range of means was from 1.01 to 2.26 phi with an average mean for all samples of 1.46 phi and standard deviation of 0.35, and for the Santa Rosa feature the range of means was from 0.96 to 2.57 phi with an average mean for all samples of 1.45 phi and standard deviation of 0.42.

The next step was to determine the mean grainsize values of the sub-surface sediment samples collected above the MFS on the shelf features. From the nine cores collected at the three sites, 64 sand samples were selected for sieve analysis. From these 64 only 48 underwent this analysis because the other 16 samples had a high silt content. Of these 48 a total of 39 samples were above the MFS. These include nine samples from the Panama City site, 13 from the East Pass site, and seventeen from the Santa Rosa site. The nine samples from the Panama City site have a range of means from 1.43 to 2.43 phi with an average mean for all samples of 2.10 phi and standard deviation of 0.36. The thirteen samples from the East Pass site have a range of means from 1.40 to 2.68 phi with an average mean for all samples of 1.90 phi and standard deviation of 0.39. The seventeen core samples from the Santa Rosa site have a range of means from 1.09 to 3.17 phi with an average mean for all samples of 1.85 phi and standard deviation of 0.61 (Table 4.14.1). These values place all 39 core samples within the USCS medium to fine classification.

Table 4.14.1
Sample Mean Grain Size Comparison

	Total Samples	Min Mean Phi	Max Mean Phi	Avg. Mean Phi	Standard Deviation
Beach Samples	54	0.62	2.56	1.88	0.32
Sub Surface Grab					
Panama City Beach	14	0.25	1.47	1.46	0.51
East Pass	10	1.01	2.26	1.46	0.35
Santa Rosa	9	0.96	2.57	1.45	0.42
Phase III Core Samples					
Panama City Beach	9	1.43	2.43	2.10	0.36
East Pass	13	1.40	2.68	1.90	0.39
Santa Rosa	17	1.09	3.17	1.85	0.61

In summary, using the mean of the means for all sites, the majority of samples collected during the previous studies (surface grab samples) and the Phase III Field program were in the USCS fine classification.

Potential Sand Source Volume Calculations

In order to calculate volumes for the potential borrow designated in the Phase II study, two sources of data were analyzed in the Panama City and East Pass sites. These are the boomer sub-bottom profile data and the GeoPulse 3.5 KHz collected during Phase III. In the Santa Rosa site a third data source was used. This data came from an earlier version of 3.5 KHz records collected by Alpine (Olsen, 2001). After a review of the boomer data it was determined that the records produced from this type of sub-bottom profiler did not resolve the near-surface information to an adequate degree to distinguish the MFS.

Overlaying the Phase III trackline coverage on the artificially shaded relief grid, four areas were delineated for which sediment volumes will be calculated. Figures 4.14.4 – 4.14.6 shows these delineated areas outlined in orange. The GeoPulse and vibracore data support the concept that all of the features above the MFS were formed in a known set of processes. Therefore, grain size properties may be extrapolated over each feature. Using the geophysical data gathered during Phase III, the thickness of sediment deposits overlying the MFS was determined at every tenth shot point. These amounts were then averaged, and this average was multiplied by the total square footage of the polygon outlining the area. This figure was then converted to cubic yards (Table 4.14.2).

Table 4.14.2
Sediment Thickness Overlying the MFS

Site	Average Thickness	Area sq. ft	Volume ft^3	Volume yards^3
EP-A	15.72	307,319,103	4831,056,299	178,928,011
PC-A	17.23	479,583,880	8,266,511,616	306,167,096
PC-B	15.199	138,962,946	2,111,340,244	781,977,862
SR-A	17.16	371,332,714	6,372,548,511	236,020,315

As stated above, these values represent the amount of sediment found on top of the MFS. With using a dataset of limited geophysical and vibracore data, these estimates are presented in a reconnaissance level framework. Several limitations need to be pointed out. The areas were delineated based only on the mean grain size of the sediments analyzed in the nine cores and those grab and core samples residing in the database. Layers of unusable material due to color inconsistencies, and trace content amounts of silt, carbonate, heavy mineral, and shell may reside in the sediments used to calculate the volumes. What this suggests is that these areas have been reviewed at a level, which is not appropriate for an individual beach nourishment project. They have been delineated to give the BBCS and future contractors a base knowledge of where a potential borrow area may reside and with the understanding that further study needs to be undertaken for more resolved answer.

The third project task is for field work. Although this task was scaled down considerably because of the volume of existing data that were obtained, it is still an important element of the overall project. From the immense size of the project area it has been clear from the outset that the field work would need to be specifically designed to address only priority needs. The work plan described below identifies these needs and describes the surveying and sampling operation that will be used.

5.1 MAJOR FIELD WORK COMPONENTS

The field work will consist of two components. They are: a) beach sampling and b) offshore operations. At the beginning of this project there was very limited data on the beach sand across the project area. Some of the data that do exist come from a time when locating and positioning techniques were primitive and difficult to apply, so that the true positions that the data represent are not known. Finally, there has not been a comprehensive sampling program for all beaches across the project area. Such a program, with standard procedures and sampling protocols, is needed to provide a true basis of comparison for sand from offshore potential borrow sites.

Finally, the great majority of the potential offshore sand borrow sites are on the continental shelf. Over the past few years deposits in water depths up to 80 feet have been deemed economic for beach nourishment based on the expected use of hopper dredges. Deposits in even greater water depths will be useful in the near future. These sites will need to be surveyed and sampled from a substantial vessel that can operate on sites that are located on the open shelf at water depths that make sampling from small craft inadvisable on a 24-hour-per-day schedule.

5.2 BEACH SAMPLING

The beach sampling concentrated on the critical erosion areas as identified in the Critical Erosion Report (2003). Samples were taken along transects that are keyed to the FDEP beach monuments.

We selected six widely separated beaches in critical erosion areas representing a wide range of expected beach morphologies.

Between one and four transects from FDEP profiling monuments were pre-selected for each of the critical erosion areas. This resulted in 13 transects and a total of 54 sand samples on six beaches in the 2003 designated Critical Erosion Areas (Figure 5.2.1).

Sampling was conducted on the beach and to swimming depths in the surf zone. Sample sites were located according to the range monuments. Taped distances and a hand-held GPS was used as a backup. Samples were sieved using standard methods by Sea Inc. of Melbourne Florida. The presence and approximate percentage of dark and heavy minerals and shell content were estimated by eye, using magnification. Sample locations from the GPS were entered into the GIS system and are available for display on the website. In some cases, the locations of the samples have been adjusted slightly by hand so that the positions agree with those determined from the distances measured from the FDEP monuments. All data is archived in the project database.

5.3 OFFSHORE OPERATIONS

The offshore surveying was carried out by Alpine Geophysical aboard the research vessel *Atlantic Twin*. This vessel is a 90-foot catamaran hull designed boat. The overall plan consisted of selecting three features that have been described in Section 4 of this report for detailed reconnaissance. A series of geophysical tracklines were run across the feature to establish its surface and sub-surface geometry. Three vibracores were taken on each feature. The cores are important because at this time we have only surface grab sample grain size data available at the offshore locations. We are using them to infer the grain size distribution within the sand bodies, under the assumption that the post-depositional reworking of the deposits did not seriously change the sand composition. These cores will allow us to validate this assumption.

The following details the plan for sampling and surveying:

Three areas were surveyed as part of the offshore phase. The first area is located offshore of Panama City, Florida, and consists of 28 line miles of survey and three vibracore locations. The second area is located offshore of Destin, Florida and consists of 15 line miles of survey and three core locations. The third area, located offshore of Pensacola, Florida, consists of ten line miles of survey and three core locations. Alpine deployed the following equipment onto the *Atlantic Twin* for the basic geophysical survey:

- Trimble NT300D DGPS system with Coast Guard generated corrections
- Hypack Max software with PC for navigation data storage
- Fluxgate compass
- Innerspace 448 digital single beam echo sounder
- Geo-Acoustics GeoPulse 3.5 KHz subbottom profiler system
- EPC model 1086 recorder
- TSS 320B ceave compensator for subbottom data

Positioning of the vessel was accomplished by deploying a Trimble NT300D Series DGPS system using differential corrections received from Coast Guard operated base stations. In order to control the quality of the differential navigation system, the ship-born navigation system was removed from the vessel and transported to a previously surveyed control point. The navigation antenna of the mobile unit was positioned over the survey point and data captured and logged using Hypack software. The observed Lat-Long of the unit using differential corrections from the base station was compared to the surveyed location to ascertain that navigation accuracy meets project specifications. The fluxgate compass was calibrated using the systems automatic calibration routines. Prior to commencement of operations, offset positions were measured from the GPS antenna on-board the survey vessel to the relevant equipment (Echosounder, Subbottom Profiler). Data from the Trimble NT300D series DGPS unit on board the vessel was fed into the HypackMax navigation software. The helmsman and lab was provided with a visual display of location in relation to the planned line. Positioning data was recorded on magnetic media for post-processing. Closures were transmitted to graphic recorders every 100 meters. Navigation data was transmitted from the navigation system to the subbottom acquisition system in real time for coordination of acquired seafloor data. Data from the echosounder was recorded directly onto the navigation system files. Prior to starting data collection all equipment was tested and calibrated. For single beam echosounding an Innerspace 448, or similar, with an over-the-side mounted transducer was used. The 448 was calibrated via the bar check method to determine index of error. A GeoAcoustics GeoPulse system was used to collect subbottom data. The unit was connected to a 3.5Khz transducer set and the data recorded on an EPC GSP 1086 recorder.

A navigation/event log book was kept in the field. The information included in this log book contains the date, line number, start and end times, laybacks, and beginning and end fix numbers, line abandonment, significant changes in course and any other events relevant to survey operations. A separate Line Log was kept with data logged for the operational settings, on each line, of each survey instrument, including but not limited to power settings and transmit frequency settings, firing rate, displayed data width, and timing line settings, etc. All analogue charts rolls were marked with the beginning and end fix numbers, the lines included, the date and project number. These data were transferred to the Norwood office at the end of the job.

Alpine collected (1) 20-foot vibracore sample at each of nine locations in accordance with marine sampling protocol. Alpine used the R/V *Atlantic Twin* fully equipped with an Contractor model 271 pneumatic vibracore ancillary.

A Trimble NT300D DGPS system, interfaced into a PC with Hypack Max Hydrographic software was used to accurately locate the vessel at the proposed sampling site. The DGPS antenna was mounted on the main A-frame used to lower the vibracore to the sea floor. Vibracore locations were determined to within +/- 3 meters. A position was classified as valid if it was within 50 feet of the intended position. The R/V *Atlantic Twin* anchored using a single point mooring before commencing core operations.

Depth and rate of penetration below the sea floor of the vibracore sampler was monitored and recorded continuously at each core site. The data collected by Corelog was later used to generate and plot penetration graphs for each core. Water depths were recorded at each core site using a calibrated echo sounder. Measured water depths were tidally corrected to datum elevation based on actual tides at the closest primary tide stations. The primary tides were corrected for phase and amplitude variations at selected locations closest to the work sites as contained in the NOAA Predicted Tide tables.

Alpine took cores with a maximum penetration of 20 feet and a minimum acceptable penetration of 16 feet**.** The minimum acceptable core recovery was 80 percent of the penetrated depth. Once desired penetration was achieved at a given core site, the core rig was raised and secured along the side of the vessel where the filled core liner was extracted from the core pipe. The filled core liner was then placed on deck, measured for recovery length, cut into five-foot sections and capped. A small sediment sample was collected from each cut for initial visual analysis of the recovered sediments. The cores were labeled and stored in a vertical position on the vessel in order to maintain sediment stratification. Core descriptions and selection of samples was carried out by URS at the URS office location in Tallahassee, Florida.

The Phase III portion of this project was undertaken to verify the use of the ROSS database to identify offshore sand source deposits and to corroborate the conceptual geologic model. The plan was that these field surveys and sampling locations were to confirm or falsify the ideas and concepts developed in the geologic conceptual model. We picked examples of three major elements described in the conceptual model. These were an ebb tide delta inlet retreat path, a drowned shore complex and a major shoal with the idea that if they prove out to be true then other similar features, identified from data in the database and the conceptual model, should also prove to be true. Three sites were chosen for study. These are located offshore of Panama City Beach, East Pass, and Santa Rosa Island. A total of nine cores, three at each site and approximately 57 miles of geophysical data in the form of sub-bottom profiles were collected.

A second objective of Phase III was to collect beach sediment samples along selected beach perpendicular transects in Critical Erosion Areas (see Section 4.14).

Offshore

Three offshore sites were chosen to verify the accuracy of the data residing in the database. These data include sediment samples, geophysical data in the form of sub-bottom profiles, and artificially shaded relief image of the sea floor geomorphology created from the NOAA GEODAS high-resolution bathymetry (http://www.ngdc.noaa.gov/mgg/gdas/gd_sys.html). Site 1 offshore of Panama City Beach was chosen because of its position on a paleo ebb tide delta, Site 2 offshore of East Pass was chosen because of its position on a drowned barrier/shore complex, and Site 3 offshore of Santa Rosa Island, was chosen to compare results of new data to the data currently in the database. This data includes the Florida Feasibility Study For Beach Restoration (Olsen, 2001) data and the Boomer data (Locker et al., 1988).

6.1 SITE 1: EAST PASS SITE

Geophysical Data

The East Pass study area was selected to confirm the interpretation of existing data that this feature is a drowned barrier island or shore complex. We use the term “shore complex” to include a zone between the lower shoreface and the landward limit of back-barrier overwash deposits. This interpretation was based on the artificially shaded relief image, as well as existing sub-bottom profiles collected with a high-resolution single channel “boomer” (Locker et al., 1988). Figure 6.1.1 shows the location of the interpreted feature. Using the bathymetric data and gray-scale image to view geomorphic patterns on the sea floor, this feature stands out very prominently.

To substantiate the explanation of this feature a review of the boomer data residing in the ROSS database was undertaken. Figure 6.1.2 shows the trackline coverage, with the relevant tracklines and the trackline number highlighted in yellow. Time stamp numbers in red, are used as navigation markers along a trackline to determine location on the sub-bottom images.

Line # 105 crosses this feature at its northeastern end. Between time stamp 1405 and time stamp 1420 (Figure 6.1.3) there is a wide, flat, slightly seaward dipping feature. Each five-minute increment is approximately one kilometer. The highlighted lines on the east or seaward side are consistent with lower shoreface depositional patterns analogous to those found on the existing shoreface today, indicating the same type of depositional environment. Line # 97 between timestamp 0015 and 0050 exhibits the same types of sedimentation pattern. At this point the feature increases in width to about five kilometers. Here again are found seaward dipping layers on the east side and landward dipping layers on the west side (Figure 6.1.4).

These data showed the feature to be a probable drowned barrier island or shore complex. A field plan was developed to confirm this hypothesis. A geophysical survey of this site as well as the collection of three vibracores, in locations that could substantiate the data in the database, was designed. To do this a cruise pattern was established that would cross the feature on three northwest to southeast transects. This pattern intersects several of the existing boomer lines thereby allowing a cross check of old and new data. The planned tracklines cover approximately sixteen nautical miles. The three vibracores would be taken in locations that would give information on the lower shoreface, back beach and center of the feature (Figure 6.1.5). The Phase III tracklines are highlighted in blue and the vibracore locations are in green.

Phase III Geophysical Data

A total of eight tracklines were run over the study area. Five cross the feature perpendicular to its long axis. These are lines EP-2, EP-5, EP-6, and EP-8A&B. One line, EP-3 was run parallel to the feature along the probable lower shoreface zone.

Line EP-2 (Figure 6.1.6) is shown to illustrate the agreement of transgressive and regressive depositional patterns seen on boomer lines 105 and 97. These data establish that the feature is indeed a drowned barrier island or shore complex.

East Pass Vibracores

The series of cores from East Pass, (EP-1, EP-2, and EP-3), support the interpretation of this feature as a drowned barrier complex. This interpretation fits with the bathymetric expression. As sea level dropped or reached a still-stand, a barrier island or shore complex built out to the location of EP-3. At location EP-2, a back bay environment (or possibly lagoonal environment) is overlain by a beach/barrier. At location EP-1, a back barrier/lagoonal environment existed behind the barrier at EP-2. This entire area was then overstepped and drowned by rising sea level.

Vibracore EP1 (Table 6.1.1) is interpreted as a back barrier marsh to lagoonal environment. The top of the core is sandy with a large amount of heavy minerals and is burrowed, indicating a lagoonal depositional environment. A 0.3-foot shell hash is located at 9.2 feet and the core begins to fine from this point down. Black to dark gray organic muds appear at ~11.5 feet and are mottled. A thin root was found at 12.2 feet.

Table 6.1.1
Vibracore EP1

Core #	Core Division	Description	Comments
EP1	0-2.85 ft	fine to medium	with burrows
		quartz sand	
		speckled black and medium gray	
		little heavy minerals	
		few shell fragments	
	2.85-9.2 ft	fine to medium	
		quartz sand	
		trace shell fragments	
		trace heavy minerals	
EP1		trace carbonate	
	9.2-9.5 ft	shelly quartz sand	
		some shell hash	
		some fine to medium quartz sand	
		some heavy minerals	
	9.5-11.55 ft	fine to very fine silty sand	
		trace heavy minerals	
		trace shell fragments	
		trace carbonates	
	11.55-13.6 ft	black to dark gray	root present @ 12.2ft
		fine to very fine silty sand	dark organic mud
		little shells	
	13.6-14.5 ft	dark gray	
		very fine to medium silty sand	
	14.5-15.6 ft	medium gray	
		very fine to medium	
		quartz sand	
		trace heavy minerals	
		trace shell fragments	
		trace clay	
	15.6-18.55 ft	dark gray to black	
		fine to medium	
		quartz sand	
		trace shell fragments	
		trace heavy minerals	
	18.55-19.6 ft	light gray	clay nodules and burrows present
		very fine to medium	
		quartz sand	
		trace heavy minerals	
		trace shell fragments	
		some clay	
	19.6 ft	bottom of core	

Vibracore EP2 (Table 6.1.2) is interpreted as a beach/barrier that has built out over a lagoonal environment. Sediment mean grain size in the core becomes finer towards the bottom and is burrowed throughout. The shell content increases upwards and numerous large, complete shells are found at ~5 feet down-core. The top of Core EP2 is a well sorted, medium to coarse sand, typical of modern beaches in this area of the Panhandle of Florida.

Table 6.1.2
Vibracore EP2

Core #	Core Division	Description	Comments
EP2-R2	0-2.9 ft	light tan	complete shells @ .7 inch and 1.2 ft from top
		medium to coarse	mostly frosted grains
		quartz sand	
		trace shell fragments	
EP2-R2	2.9-6.4 ft	light tan	mostly frosted grains
		medium to fine	dark gray burrows 3.2-4.5 ft
		quartz sand	
		trace shell fragments	large complete shells @ 4.7,5.0,5.1, 5.3 ft
		trace heavy minerals	
	6.4-8.7	light gray	large complete shells @ 6.8,7.0,7.6,8.1 ft
		medium to fine	little frosted grains
		quartz sand	
		trace shell fragments	
	8.7-9.1 ft	tannish gray	shell lag
		medium to fine	
		quartz sand	
		some shell hash	
		trace heavy minerals	
	9.1-11.65 ft	light to medium gray	mottled
		fine to very fine	
		quartz sand	
		trace clay	
		trace shell fragments	
		trace heavy minerals	
	11.65-13.7 ft	dark gray	mottled
		very fine silty	
		quartz sand	
		trace shell fragments	
	13.7-14.6 ft	light gray to dark gray	mottled
		very fine to fine	possible burrows
		quartz sand	
	14.6	bottom of core	

The vibracore furthest offshore, EP-3 (Table 6.1.3). The base of Core EP-3 is estuarine, possibly lagoonal, with burrowed silty sand, shell hashes and incomplete shells. Urchin spines and foraminifera are also seen in the bottom section of the core. The remainder of the sediments in the core (the top 14.7 feet) increase in mean grain size upwards which shows a transgressive sequence created as the barrier island complex migrates shoreward.

Table 6.1.3
Vibracore EP3

Core #	Core Division	Description	Comments
EP3	0.0-6.5 ft	light tan to dark tan	dark tan mottles
		fine to medium	some frosted grains
		quartz sand	
		trace heavy minerals	
		trace carbonates	
		trace foraminifera	
		trace shell fragments	
	6.5-7.4 ft	dark grayish tan to light tan	trace frosted grains
		very fine to fine	
		quartz sand	
		trace carbonates	
		trace heavy minerals	
	7.4-9.2 ft	light greenish-gray to medium greenish gray	
		very fine to fine	
		quartz sand	
		trace heavy minerals	
		trace carbonates	
		trace urchin spines	
		trace foraminifera	
	9.2-17.7 ft	dark greenish gray to dark gray	mottling
		silty	
		quartz sand	
		trace heavy minerals	
		trace shell fragments	
		trace sea urchin spines	
	17.7 ft	bottom of core	

6.2 SITE 2: PANAMA CITY

Geophysical Data

This site was selected after a review of the existing geophysical data along with the artificially shaded relief image, indicated this feature was an ebb tide delta inlet retreat path. Figure 6.2.1 shows the location of this feature.

Six existing boomer lines cross this feature: four from northwest to southeast and two from northeast to southwest. These lines are shown in Figure 6.2.2, highlighted in yellow. Time stamps are shown in red. Figure 6.2.3 is the section of line 133; between time stamps 930 and 900, which best shows this feature. At this crossing the feature is approximately 4.8 kilometers in width.

The Phase III field plan developed to substantiate the interpreted data was designed to include approximately thirty-one miles of geophysical tracklines and three vibracores. The vibracores would be taken in locations that could provide information to corroborate this feature as an ebb tide delta/inlet retreat path.

Phase III Geophysical Data

The nine tracklines transected this main feature as well as the related feature to the east. Four of the tracklines criss-cross the main feature and the other five cover the eastern feature and the area between the two features. The pattern resulted in several crossings of the original boomer lines.

Figure 6.2.4 shows a section of line PC-4 between shotpoint 414 and 420, which shows the edge of the feature as it is approached from the west.

Panama City Vibracores

The vibracores taken at the Panama City site were taken to assess the interpretation of this feature as a possible ebb-tidal delta or inlet retreat path. The cores taken confirm this interpretation. Core PC-3 is based in an estuarine/marine environment that is the first stage in the growth of the ebb tide delta. As sea level then begins to rise, the ebb delta begins to retreat landward, leaving deltaic deposits behind. Cores PC-1 and PC-2 both reveal a once deltaic environment that became possibly lagoonal or nearshore environments before being drowned by rising sea level.

Core PC-1 is located on the east side of the feature. It is interpreted as being an ebb tide delta environment (at the bottom) that has begun to erode and create a quiet nearshore or lagoonal-type setting with clay filled burrows and large complete shells. Table 6.2.1 is the core description for PC1.

Table 6.2.1
Vibracore PC1

Core #	Core Division	Description	comments
PC1-R2	0.0-5.9 ft	medium light tan	<1% forams present
		fine	burrows present
		quartz sand	
		trace heavy minerals	
		trace shell fragments	
	5.9-10.5 ft	light grayish tan	trace frosted grains
		very fine to medium	<1% forams present
		quartz sand	
		trace shell fragments	turitella shell at 8.9 ft
		trace heavy minerals	
	10.5-13.7 ft	light tannish gray	<1% forams present
		very fine to coarse	<1% coral present
		quartz sand	
		trace carbonates	large burrow
		trace shell fragments	complete shells at 12.5 and 13.0 ft
	13.7-15.6 ft	medium gray to black	section fines downward to organic mud (peat)
		silty to medium	
		quartz sand	
		trace heavy minerals	
PC1-R2	15.6-17.3 ft	medium to dark gray	<1% forams present
		silty to fine	
		quartz sand	
		trace shell fragments	
		trace carbonates	
	17.3-19.5 ft	medium tannish gray	<1% forams present
		very fine to fine	

Table 6.2.1
Vibracore PC1

		quartz sand	
		trace heavy minerals	
		trace shell fragments	
		trace carbonates	
	19.5 ft	bottom of core	

Core PC-2 is located on the west of the feature. The core fines upward, contains roots (at 3.2-7 feet), and is mainly silty sand. The core is interpreted as a marshy environment that is a back barrier deposit. Table 6.2.2 is PC2 vibracore description.

Table 6.2.2
Vibracore PC2

Core #	Core Division	Description	Comments
PC2	0.0-2.25 ft	medium to dark gray	carbonate cemented concretions throughout
		coarse	<1% forams present
		quartz sand	
		trace shell fragments	
	2.25-11.75 ft	medium gray	root (or plant matter) @ 3.2 ft, 0.3 ft in length
		silt to very fine	thin root @ 7.78 ft, 0.4 ft in length
		quartz sand	<1% forams present
			<1% sea urchin spines present
	11.75-16.3 ft	medium to dark gray	14-15 ft large shell (~1 inch) hash
		silty to medium	
		quartz sand	
		trace heavy minerals	
		trace shell fragments	
	16.3-19.5 ft	light gray	mottling from roots
		fine	one large burrow
		quartz sand	
		trace heavy minerals	trace frosting
	19.5 ft	bottom of core	

Core PC3 is furthest offshore and is located on the edge of this feature. The core changes environment from marine or estuarine at the bottom to ebb delta at the front. The top portion of this core shows the effects of reworking by storm waves since sea level rise over the feature. Table 6.2.3 is the core description for vibracore PC3.

Table 6.2.3
Vibracore PC3

Core #	Core Division	Description	Comments
PC3	0.0-12.3 ft	light tannish gray	little frosted grains
		fine to very coarse	<1% bryozoan present
		quartz sand	
		trace heavy minerals	incomplete shells at 5.5 ft
		trace carbonates	

Table 6.2.3
Vibracore PC3

	12.3-15.6 ft	light to medium gray	trace frosted grains
		very fine to medium	<1% sea urchin spines present
		quartz sand	
		trace shell fragments	<1% bryozoans present
		trace heavy minerals	<1% foraminifera present
	15.6-16.5 ft	medium gray	matrix is silty quartz sand around shells
		shelly silty to fine	50% shell by volume
		quartz sand	
	16.5-17.95 ft	dark gray	
		mostly shell	50% shell by volume
		some silty to fine	
		quartz sand	
		trace shell fragments	(freshwater shells)
		trace heavy minerals	<1% foraminefera present
	17.95-18.6 ft	dark gray	
		fine to very fine	<1% foraminefera present
		quartz sand	
		trace carbonates	
		trace heavy minerals	
		trace shell fragments	
	18.6-19.2 ft	dark gray	
		fine to very fine	carbonate cemented sand pieces
		quartz sand	
		few shell fragments	
	19.2 ft	bottom of core	

6.3 SITE 3: SANTA ROSA SITE

Geophysical Data

The Santa Rosa site was selected because it was thought to be a major sand shoal. It was also chosen because there were already two separate geophysical datasets in the ROSS database covering this feature, therefore with the FDEP Phase III study a correlation between datasets could be accurately completed and a comparison of data resolution between geophysical profiling systems could be done. Using the artificially shaded relief image and existing ROSS geophysical data from the Pensacola Beach, Florida Feasibility Study For Beach Restoration (Olsen, 2001), and existing boomer data, this site was mapped as a large positive relief feature extending southwest for approximately five miles beginning three miles off Escambia County (Figure 6.3.1).

Alpine Ocean Seismic Survey, Inc., using a 3.5 KHz system, collected the geophysical records for Phase III of the Olsen Study. This area was designated the “Offshore Borrow Site” (Olsen, 2001). These lines will be referred to as OBS for the remainder of this report. These lines, as well as the boomer lines, are shown in Figure 6.3.2. The Alpine lines are in green, the boomer lines are in red, and the associated time stamps are also in red. The lines of interest are highlighted in yellow.

Both the OBS and boomer line images show this feature as a large mound on the sea floor (Figure 6.3.3 and 6.3.4). However the resolution of the previous geophysical lines was not as clear as the resolution of the Phase III data taken with a Geo-Acoustics GeoPulse 3.5 KHz Sub-bottom Profiler system.

Santa Rosa Cores

As sea level dropped and the MFS was sub-aerial, a mound of sand was already located at this position. As sea level began to rise this mound became an island and the sediments comprising this feature were reworked.

Core SR-1 contains one unit that is well-sorted, fine, clean quartz sand. Sand and shell fragment filled burrows are found throughout. Table 6.3.1 is the description for vibracore SR1.

Table 6.3.1
Vibracore SR1

Core #	Core Division	Description	Comments
SR1	0.0-18.6 ft	light tan	
		medium to very fine	burrows @ 3 ft, 9.6 ft, 10-10.9 ft
		quartz sand	
		trace heavy minerals	12.2 ft, 13.2-13.6, 13.8-13.9 ft, 18.6 ft
		trace shell fragments	some frosting on grains
		trace carbonates	<1% forams
	18.6 ft	bottom of core	

Core SR-2 overall coarsens upward and is a medium to dark gray fine to very fine sand. The top 0.65 feet is mottled and burrowed. Foraminifera and shell fragments are found in the section from 3.7-8.25 feet. From 10.4 feet to the bottom of the core, the core is layered, becomes increasingly organic, looses all shell content, and contains a few wood fragments. Table 6.3.2 is the description for vibracore SR2.

Table 6.3.2
Vibracore SR2

Core #	Core Division	Description	Comments
SR2	0.0-0.65 ft	light to medium gray	mostly frosted grains
		fine to medium	Mottling
		quartz sand	
		trace shell fragments	
	0.65-3.7 ft	medium to dark gray	Mottling
		very fine to medium	
		quartz sand	
SR2		trace heavies	
		trace shell fragments	
	3.7-8.25 ft	medium gray	mica present
		very fine to medium	little frosted grains
		quartz sand	
		little shell fragments	
		trace heavy minerals	
		trace carbonates	
	8.25-10.4 ft	medium tannish gray	little frosted grains

Table 6.3.2
Vibracore SR2

		very fine to medium	unit grades downward
		quartz sand	
		trace heavy minerals	mottling
		trace shell fragments	
		trace carbonates	
		trace foraminefera	
	10.4-10.8 ft	light to dark gray	
		silty to very fine	
		quartz sand	
		few heavy minerals	
		trace mica	
	10.8-11.1 ft	medium gray	
		very fine	
		quartz sand	
		trace heavy minerals	
	11.1-12.45 ft	medium gray	little frosted grains
		very fine to fine	mottling
		quartz sand	
		trace heavy minerals	
	12.45-13.6 ft	medium to dark gray	layered sand
		very fine	dark layers contain plant fragments
		quartz sand	
		Trace organics	<1% mica
		trace heavy minerals	
		trace mica	
	13.6-14.25 ft	medium gray	
		very fine silty	
		quartz sand	
		trace heavy minerals	
	14.25-16.9 ft	light to medium gray	heavy organic smell
		very fine to fine	layered sand
		quartz sand	wood fragment
			little frosted grains
	16.9-17.9 ft	medium gray	<1% mica
		very fine silty	little frosted grains
		quartz sand	
		trace heavy minerals	
SR2	17.9-20.0 ft	dark gray	
		very fine silty	
		quartz sand	
	20.0 ft	bottom of core	

The core furthest offshore, SR-3 contains a large amount of overwash atop a medium to dark gray, fine to medium sand. This sand is most likely lagoonal with landward overwash of a seaward barrier. Table 6.3.3 is the description for vibracore SR3.

Table 6.3.3
Vibracore SR3

Core #	Core Division	Description	Comments
SR3	0.0-1.2 ft	medium tannish gray	mostly frosted grains
		fine	mottling
		Quartz sand	
		trace shell fragments	
		trace heavy minerals	
		trace carbonates	
	1.2-1.5 ft	light to medium gray	possible overwash
		very fine to fine	mostly frosted grains
		Quartz sand	
		trace heavy minerals	<1% foraminefera
		trace shell fragments	
		trace carbonates	
	1.5-2.1 ft	light tannish gray	shell hash at top
		very fine to fine	large incomplete shells
		Quartz sand	mostly frosted grains
		trace shell fragments	<1% foraminefera
		trace carbonates	
		trace heavy minerals	
	2.1-2.25 ft	medium to dark gray	possible overwash
		very fine to fine	some frosted grains
		Quartz sand	
		trace shell fragments	
		trace heavy minerals	
	2.25-3.1 ft	medium to dark brown	possible iron staining
		fine to medium	some frosted grains
		Quartz sand	
		trace heavy minerals	
	3.1-3.85 ft	medium brown	
		very fine to fine	
		Quartz sand	
		trace heavy minerals	
SR3	3.85-4.55 ft	medium to dark gray	burrows present
		very fine to fine	some frosted grains
		Quartz sand	
		trace heavy minerals	
	4.55-6.1 ft	dark gray	some frosted grains
		very fine to fine	urchin spine
		Quartz sand	
		trace heavy minerals	
		trace shell fragments	
	6.1-8.2 ft	light gray	<1% foraminefera
		silty	
		quartz sand	
		trace shell fragments	
	8.2-9.7 ft	medium gray	transition zone
		very fine to fine	few frosted grains
		Quartz sand	

Table 6.3.3
Vibracore SR3

		trace shell fragments	
		trace carbonates	
		trace heavy minerals	
	9.7-14.65 ft	medium to dark gray	<1% mica
		silty	burrows present
		quartz sand	
		trace heavy minerals	
		trace carbonates	
	14.65-17.05 ft	medium to dark gray	
		silty to fine	
		Quartz sand	
		trace shell fragments	
		trace heavy minerals	
		trace carbonates	
	17.05-19.6 ft	medium gray	mostly frosted grains
		fine	<1% coral present
		Quartz sand	<1% plagioclase
		trace shell fragments	
		trace carbonates	
		trace heavy minerals	
	19.6 ft	bottom of core	

Balsille, J.H., Clark, R. 2001. Annotated and illustrated bibliography of marine subaqueous sand resources of Florida's Gulf of Mexico. Fla. Geol. Survey, Special Publication No. 48, 254 pps.

Baranola, J.M., D. Raynaud, Y.S. Korotkevich, and C. Lorius. 1987. Vostok ice core provides 160,000-year record of atmospheric CO2. Nature, 329, 408-414.

Bard, E., 1998. Geochronologic and geophysical implications of radiocarbon calibration: Geochimica et Cosmochimica Acta, v. 62, p. 2025-2038.

Bloom, A.L. 1998. Geomorphology. Prentice Hall, Upper Saddle River, New Jersey, 482 p.

Chen, Z.Q. 1999. Late Quaternary history of the northeastern Gulf of Mexico coast, northwest Florida: unpubl. Ph.D. dissertation, Florida State University, 341 p.

Chen, C.S. 1965. The regional lithostratigraphic analysis of Paleocene and Eocene rocks of Florida. Florida Geological Survey Bull. No. 45. Tallahassee, Florida Bureau of Geology, 105 p.

Chen, Z.Q., J.F. Donoghue, R.W. Hoenstine, F.R. Rupert, S.M. Spencer, L.J. Ladner, and E. Lane. 2000. A buried karst plain on the northeastern Gulf of Mexico shelf. NW Florida: Origin and relation to onshore karst. p. 22-35 in Schmidt, W., J.M. Lloyd, and C. Collier, (eds.), Woodville Karst Plain Symposium Transactions: Florida Geological Survey Special Publication 46.

Clark, R. 2000 (2003). Critical Erosion Report, Panhandle Gulf Coast Region. FDEP Office of Beaches and Coastal Systems Report.

Corso, W., J.A. Austin, and R.T. Buffler. 1989. The early Cretaceous platform off northwest Florida: Controls on morphologic development of carbonate margins. Marine Geology, 86, 1-14.

Curray, J.P. 1960. Sediments and history of the Holocene transgression, continental shelf, northwest Gulf of Mexico, in Recent Sediments, northwest Gulf of Mexico (F.P. Shepard, F.B. Phleger, and T.H. van Andel, Eds.), pp. 221-266. Am. Assoc. Petroleum Geol., Tulsa, Oklahoma.

Davies, T.D. 1980. Peat formation in Florida Bay and its significance in interpreting the recent vegetational and geological history of the Bay area. Unpubl. Thesis, Pennsylvania State University, University Park, PA.

Dean, R.G. 2001. Thirty years of beach nourishment in Florida, where is all the beach nourishment sand going? Annual Conf. 45th Florida Shore and Beach Preservation Association, 2001.

Donoghue, J.F. 1992. Late Quaternary coastal and inner shelf stratigraphy, Apalachicola Delta region, Florida. Sedimentary Geology, 80, 293-304.

Donoghue, J.F. 1993. Late Wisconsinan and Holocene depositional history, northeastern Gulf of Mexico. Marine Geology, 112, 185-205.

Dorsey, R.A. 1997. Predicted sea level changes, Florida Gulf Coast over the past 21,000 years. Gulf Arch. Res. Inst. G ARI Research Series No 9, 26 pps.

Emiliani, C., C. Rooth, J.J. and Stipp. 1978. The late Wisconsin flood into the Gulf of Mexico. Earth and Planetary Science Letters, 41, 159-162.

Evans, M.W., A.C. Hine, D.F. Belknap, and R.A. Davis. 1985. Bedrock controls on barrier island development: West-central Florida coast. Marine Geology, 63, 263-283.

Fairbanks, R.G. 1989. A 17,000-year glacio-eustatic sea-level record: Influence of glacial melting rates on the Younger Dryas event and deep-ocean circulation. Nature, 342, 637-642.

Fairbanks, R.G. 1990. The age and origin of the "Younger Dryas climate event" in Greenland ice cores. Paleoceanography, 5, 937-948.

Faught, M.K. 1996. Clovis origins and underwater prehistoric archaeology in northwestern Florida. Unpublished Ph.D. dissertation, University of Arizona, Tucson, Arizona, 665 p.

Faught, M.K., and J.F. Donoghue. 1997. Marine inundated archaeological sites and paleofluvial systems: Examples from a karst-controlled continental shelf setting in Apalachee Bay, Northeastern Gulf of Mexico. Geoarchaeology, 12, 417-458.

Flower, B.P., and J.P. Kennett. 1990. The Younger Dryas as a cool episode in the Gulf of Mexico. Paleoceanography, 5, 949-961.

Frazier, D.E. 1974. Depositional episodes: their relationship to the Quaternary stratigraphic framework in the northwestern portion of the Gulf basin. Geologic Circular 74-1. Austin, Texas Bureau of Economic Geology. 28 p.

Godfrey, P.J. and M.M. Godfrey. 1976. Barrier Island Ecology of Cape Lookout National Seashore and Vicinity, North Carolina, Natl. Park Service. Scientific Monograph Series 9, 160 pp.

Hays, J.D., J. Imbrie, and N.J. Shackleton. 1976. Variations in the earth's orbit: Pacemaker of the Ice Ages. Science, 194, 1121-1132.

Hine, A.C., D.F. Belknap. J.G. Hutton. E.B. Osking. and M.W. Evans. 1988. Recent geological history and modern sedimentary processes along an incipient, low-energy, epicontinental-sea coastline: northwest Florida. Jour. Sed. Petrology, 58, 567-579.

Imbrie, J., and K.P. Imbrie. 1979. Ice Ages: Solving the Mystery. Enslow Publ., Hillside, New Jersey, 224 p.

Koch (in press), PhD. Dissertation, Floirda State Univ., Department of Geological Sciences.

Komar, P.D. 1976. Beach processes and sedimentations. Prentice-Hall, Inc., Englewood Cliffs, N. J., 429 pp.

Kuehn, D.W. 1980. Offshore transgressive peat deposits of southwest Florida: Evidence of a late Holocene rise of sea level. Geology. Unpubl. thesis, Pennsylvania State University, University Park, PA.

Leventer, A., E.F. Williams. and J.P. Kennett. 1982. Dynamics of the Laurentide ice sheet during the last deglaciation: Evidence from the Gulf of Mexico. Earth and Planetary Science Letters, 59, 11-17.

Locker, S.D., K.T. Logue and L.O. Doyle. 1988. Neogene Stratigraphy, Bedroms and Surface Sediments: NW Florida State Waters. U.S.F. Report, 75 pp.

Locker, S.D. and L.J. Doyle. 1992. Neogene to recent stratigraphy and depositional regimes of the northwest Florida inner continental shelf. Marine Geology, v. 104, p. 123-138.

McBride, R.A. 1996a. Holocene and late Pleistocene sedimentary facies of a sand-rich continental shelf; a standard section for the northeastern Gulf of Mexico. Transactions - Gulf Coast Association of Geological Societies 46: 287-299.

McBride, R.A. 1996b. Shelf sedimentary facies offshore southwestern Alabama and western Florida Panhandle; northeastern Gulf of Mexico. AAPG Bulletin 80(9): 1509.

McBride, R.A. 1997a. Seafloor Morphology, Geologic Framework, and Sedimentary Processes of a Sand-rich Shelf Offshore Alabama and Northwest Florida: Northeastern Gulf of Mexico. Oceanography and Coastal Sciences. Louisiana State University, Baton Rouge.

McBride, R.A. 1997b. Late Quaternary stratigraphic architecture of a sand-rich shelf and the origin of linear shoals; northeastern Gulf of Mexico. Conference American Association of Petroleum Geologists 1997 annual convention. Dallas, TX: 79.

McBride, R.A. 1999. Holocene Stratigraphic Architecture of a Sand-rich Shelf and the Origin of Linear Sand Shoals: Northeastern Gulf of Mexico. Isolated Shallow Marine Sand Bodies: Sequence Stratigraphic Analysis and Sedimentologic Interpretation. Society for Sedimentary Geology: 95-126.

Mesolella, K.J., R.K. Mathews, W.S. Broecker and D.L. Thurber. 1969. The astronomical theory of climatic change: Barbados data. Jour. Geology, 77, 250-274.

National Geophysical Data Center NGDC)http://www.ngdc.noaa.gov/mgg/gdas/gd_sys.htmlBalsillie, J.H. and R.R. Clark. 2001.

Nelson, H.F., and E.E. Bray. 1970. Stratigraphy and history of the Holocene sediments in the Sabine-High Island area, Gulf of Mexico, in Deltaic Sedimentation, Modern and Ancient. SEPM Spec. Publ. 15, (J.P. Morgan, ed.), p. 48-77, SEPM, Tulsa Oklahoma.

Niedoroda, A.W., C.W. Reed, D.J.P. Swift, H. Arato and K. Hoyanagu. 1995. Modeling shore – normal, large-scale coastal evolution. Marine Geol., v. 126, n.1/4, p. 181-201.

Neumann. 1958. Texas A&M. Coll. Research Foundation Proj. 24. IMR Ref. 58-FT. (cited in Curray, 1960).

Parkinson, R.W. 1989. Decelerating Holocene sea-level rise and its influence on southwest Florida's coastal evolution: A transgressive-regressive stratigraphy. Jour. Sed. Petrology, 59, 960-972.

Perlmutter, M.A. 1985. Deep water clastic reservoirs in the Gulf of Mexico: A Depositional Model. Geo-Marine Letters, 5, 105-112.

Raymo, M.E. 1992. Global climate change: A three million year perspective, in Start of a Glacial (G.J. Kent and E. Went, eds.). Heidelberg, Springer-Verlag, 353 p.

Rupert, F. 1993. Karst features of northern Florida, in geologic gield studies of the coastal Plain in Alabama, Georgia and Florida (S.A. Kish, ed.). p. 49-61, Southeastern Geological Society Guidebook 33, Tallahassee, Florida.

Rupert, F.R., and J.D. Arthur. 1997. Geology and geomorphology: p. 35-52 in Coultas, C.L., and Hsieh, Y.P., eds., Ecology and Management of Tidal Marshes, St. Lucie Press, Delray Beach, FL.

Rupert, F.R., and S. Spencer. 1988. Geology of Wakulla County, Florida. Florida Geological Survey Bulletin no. 60, Tallahassee, Florida Bureau of Geology, 46 p.

Schnable, J.E., and H.G. Goodell. 1968. Pleistocene-recent stratigraphy, evolution, and development of the Apalachicola coast, Florida. Geological Society of America Special Paper No. 112. Boulder, Colorado: Geological Society of America, 72 p.

Scholl, E.W., F.C. Craighead, and M. Stuiver. 1969. Florida submergence curve revisited: Its relation to sedimentation rates. Science, 163, 562-564.

Scholl, D., and Stuiver, M., 1967, Recent submergence of southern Florida--a comparison with adjacent coasts and other eustatic data: Geol. Soc. America Bull., v. 78, p. 437-454.

Schroeder, W.W., A.W. Shultz, and O.H. Pilkey. 1995. Late Quaternary oyster shells and sea-level history, inner shelf, northeast Gulf of Mexico. Journal of Coastal Research 11(3): 664-674.

Shier, D.E. 1969. Vermetid reefs and coastal development in the Ten Thousand Islands, southwest Florida. Geological Society of America Bulletin 80: 485-508.

Smith, W.G. 1968. Sedimentary environments and environmental change in the peat-forming area of south Florida. Unpubl. thesis, Pennsylvania State University, University Park, PA.

Spackman, Jr., W., C.P. Dolsen, et al., 1966. Phytogenic organic sediments and sedimentary environments in the Everglades mangrove complex; Part I: Effects if the transgressing sea on environments of the Shark River area of southwest Florida. Paleontographica 117: 135-152.

Stanley, D.J., and A.G. Warne. 1994. Worldwide initiation of Holocene marine deltas by deceleration of sea-level rise. Science, 265, 228- 231[GLY2].

Stapor, F.W., T.D. Mathews, and F.E. Lindfors-Kearns. 1989. Episodic barrier island growth in southwest Florida: a response to fluctuating Holocene sea level? In Mauresse, J.R. ed., Symp. On South Fla. Geol, Miami Geol. Soc Memoir No. 3, p. 149-202.

Stapor, F.W., T.D. Mathews, and F.E. Lindfors-Kearns. 1991. Barrier island progradation and Holocene sea level history in southwest Florida. Jour. Coastal Res., 7, 815-838.

Stive, M.J.F., and H.J. deVriend. 1995. Modelling shoreface profile evolution. Marine Geol., v. 1276, n1/4, p 235-249.

Swift, D.J.P. 1973. Delaware Shelf Valley: estuary retreat path, not drowned river valley. Geol. Soc. Am. Bull., v. 84, p 2743-2748.

Swift, D.J.P. 1976. Coastal sedimentation. In: D.J. Stanley and D.J.P. Swift (Editors), Marine Sediment Transport and Environmental Management. Wiley, New York, NewYork, 255-31.

Swift, D.J.P., J.W. Dofoed, F.P.Saulsbury, and P. Sears. 1972. Holocene evolution of the shelf surface central and southern Atlantic shelf of North America. In: Shelf Sediment Transport, Process and Pattern (Eds. Swift, D.J.P., Duane, D.B. & Pilkey, O.H.) p 100-148.

Vezina, J., B. Jones, and D. Ford. 1999. Sea-level highstands over the last 500,000 years: Evidence from the Ironshore Formation on Grand Cayman, British West Indies. Jour. Sedimentary Research, 69, 317-327.

Yon, J.W. 1966. Geology of Jefferson County, Florida. Florida Geological Survey Bulletin No. 48, Tallahassee, Florida Bureau of Geology, 119 p.

TABLE 4.1.1: Geometry, Sediment Texture and Color Data for Bathymetric/Seismic Features, Northwest Florida Shelf

Sediment Feature No.	Sediment Grain-Size Data from GIS Database								t-test[1]	Feature Sediment Color Value [2]	Approx. Mean Water Depth (m)	Water Depth Range (m)	Feature Dimensions			Sed. Feature Thick-ness (m)	Sed. Feature Volume (x 10^6 m^3)
	Samples ON Sediment Feature				Samples OFF Sediment Feature								Width (m)	Length (m)	Approx. Area (sq. km)		
	Average of mean grain sizes		Average of standard deviations		Average of mean grain sizes		Average of standard deviations										
	(phi)	Description	(phi units)	Description	(phi)	Description	(phi units)	Description									
A-1	1.8	medium sand	0.7	mod. well sorted	1.4	medium sand	0.7	mod. well sorted	0.04	light	15.0	12 - 18	11000	11000	121	6.5	786.5
W-1	1.3	medium sand	0.7	mod. well sorted	1.4	medium sand	0.7	mod. well sorted	0.25	mid-range	28.0	26 - 31	4962	6474	32	8.9	285.3
W-2	1.3	medium sand	0.7	mod. well sorted	1.4	medium sand	0.7	mod. well sorted	0.28	light	19.0	18.5 - 20	9040	11300	102	7.4	759.3
W-3	1.5	medium sand	0.6	mod. well sorted	1.3	medium sand	0.8	mod. well sorted	0.34	med. to light	25.0	24.5 - 27.5	5550	13000	72	6.8	487.0
W-4	1.2	medium sand	0.8	mod. well sorted	1.3	medium sand	0.8	mod. well sorted	0.60	mid-range	23.0	18.5 - 24.5	5333	7433	40	5.1	202.6
W-5	1.5	medium sand	0.7	mod. well sorted	1.2	medium sand	0.9	mod. sorted	0.02	light	22.0	21.5 - 24.5	3500	16200	57	4.8	269.3
W-6	1.3	medium sand	0.8	mod. well sorted	1.4	medium sand	0.9	mod. sorted	0.80	n.d.	28.0	27.5 - 30.5	2739	8217	23	4.2	94.0
W-7	0.7	coarse sand	1.1	mod. sorted	1.4	medium sand	0.9	mod. sorted	0.26	n.d.			0	0	0	0.0	0.0
W-8	1.2	medium sand	0.8	mod. well sorted	1.5	medium sand	0.9	mod. sorted	0.03	light	19.6	18.5 - 24.5	3625	14475	52	9.8	513.9
W-9	2.3	fine sand	1.5	poorly sorted	2.3	fine sand	1.3	mod. sorted	0.90	dark	24.0	24 - 25	2008	20000	40	11.5	461.8
E-1										n.d.	7.0		2830	2830	8	6.0	48.1
E-2										n.d.	11.8		1350	1350	2	4.3	7.8
E-3										n.d.	8.8		148	30000	4	9.4	41.7
Mean	*1.4*		*0.8*		*1.5*		*0.9*										

NOTES:

n.d. = no data

1. Student's t-test comparison of ON-feature sample means versus OFF-feature sample means (probability that the two sets of samples came from the same population)
2. Based on Munsell color value rating.

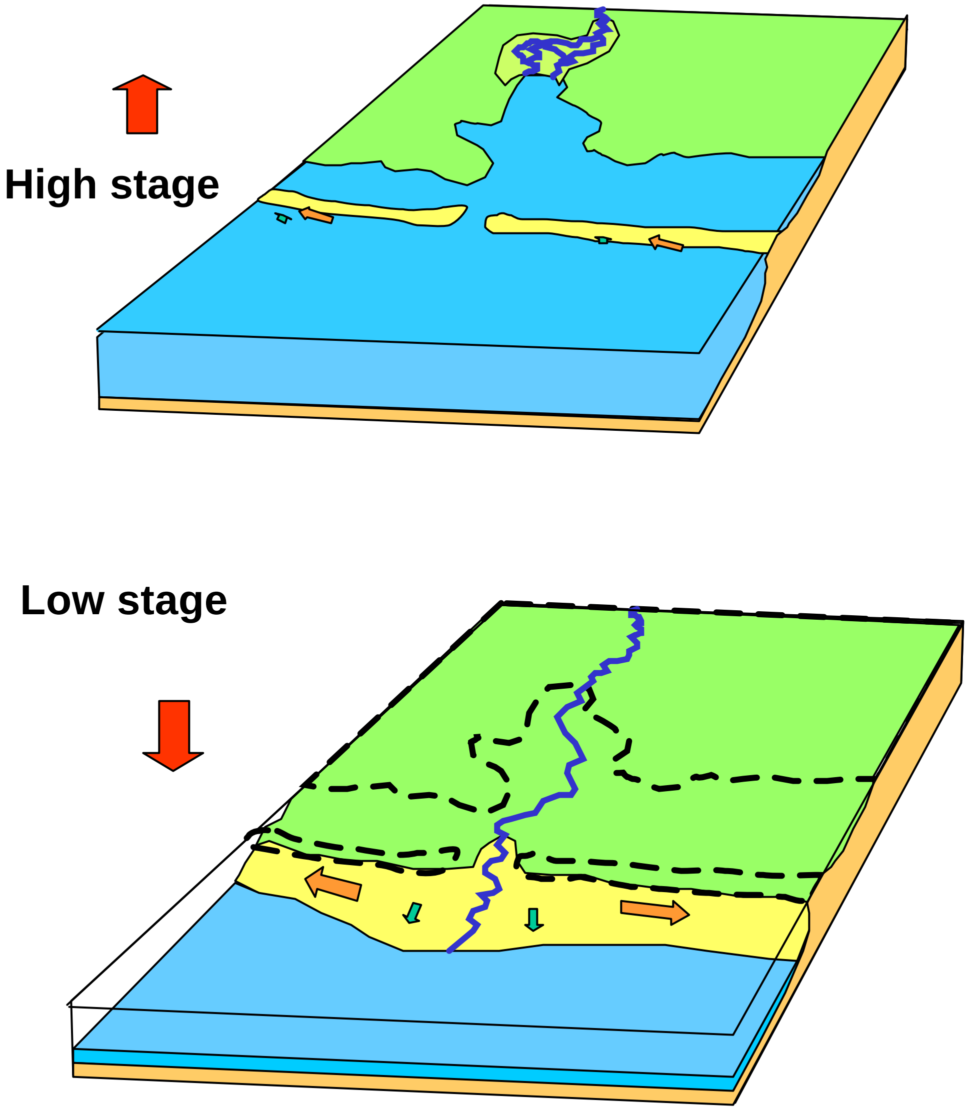


Figure 3.1.1 River sand delivery during high and low stages of low-amplitude sea level fluctuations with sand transport patterns shown as arrows

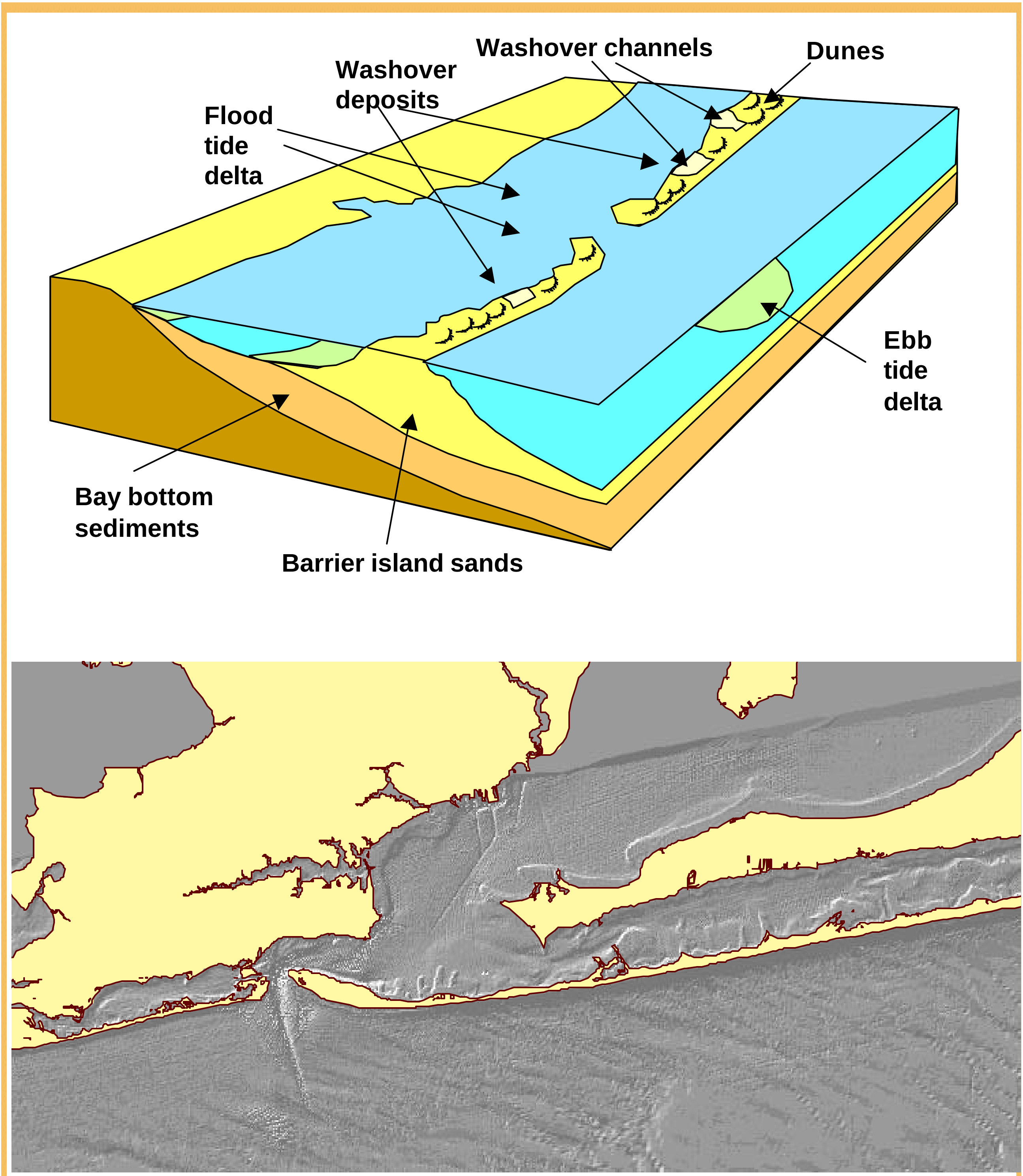


Figure 3-1-2 Washover, flood-tide delta, and ebb-tide delta deposits on a ‘retreating’ barrier island complex

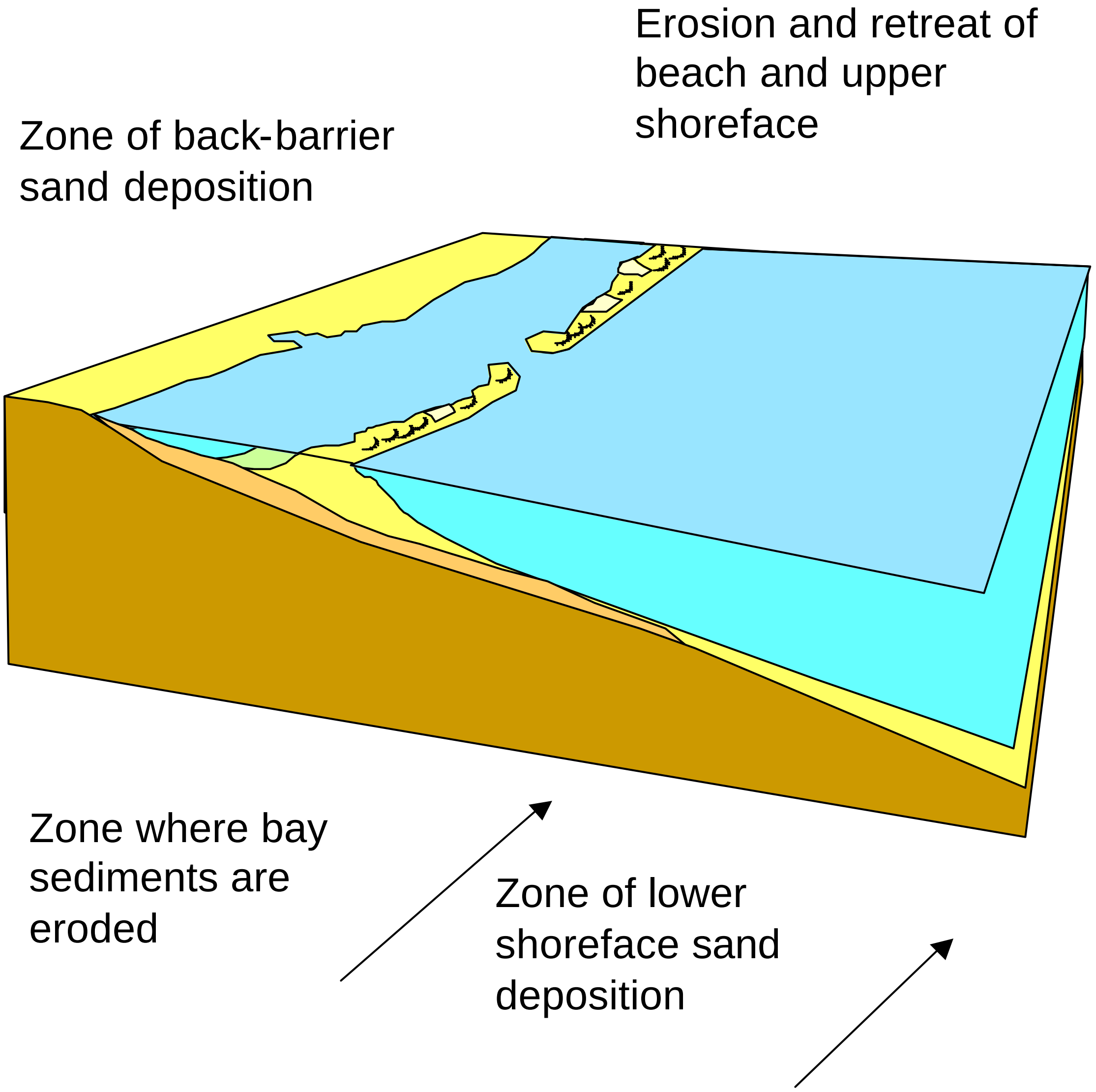


Figure 3.1.3 Barrier island ‘roll over’ due to rising sea level

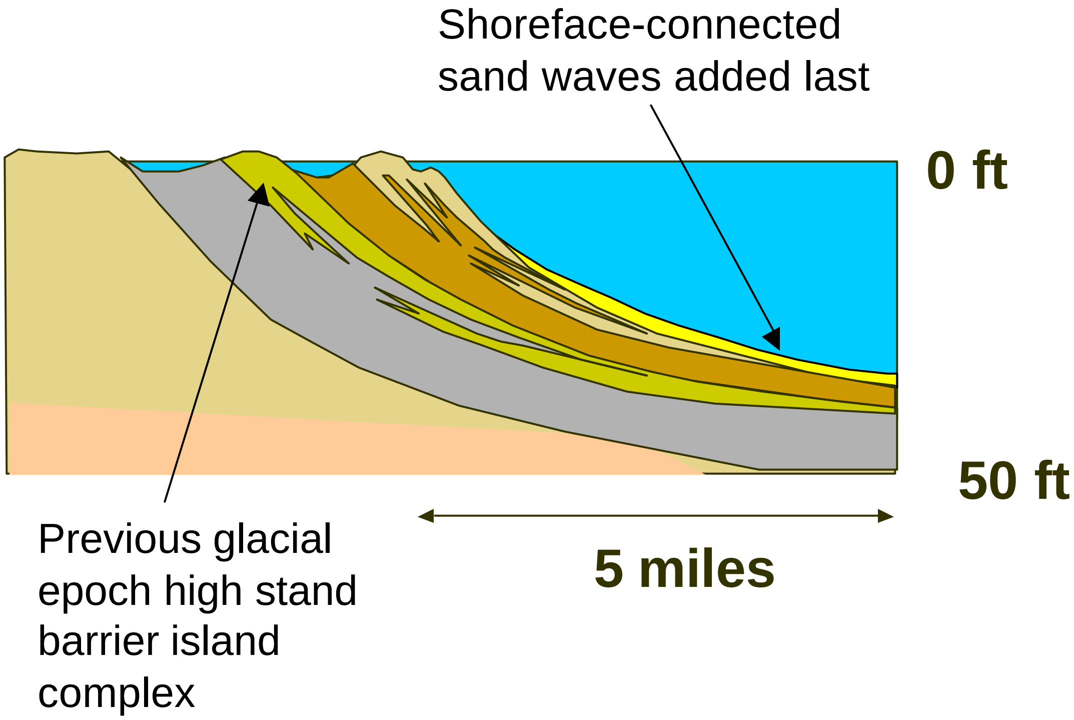


Figure 3.1.4 Detailed internal layering of barrier island deposits caused by high-frequency sea level variations and subsequent formation of shoreface-connected sand waves

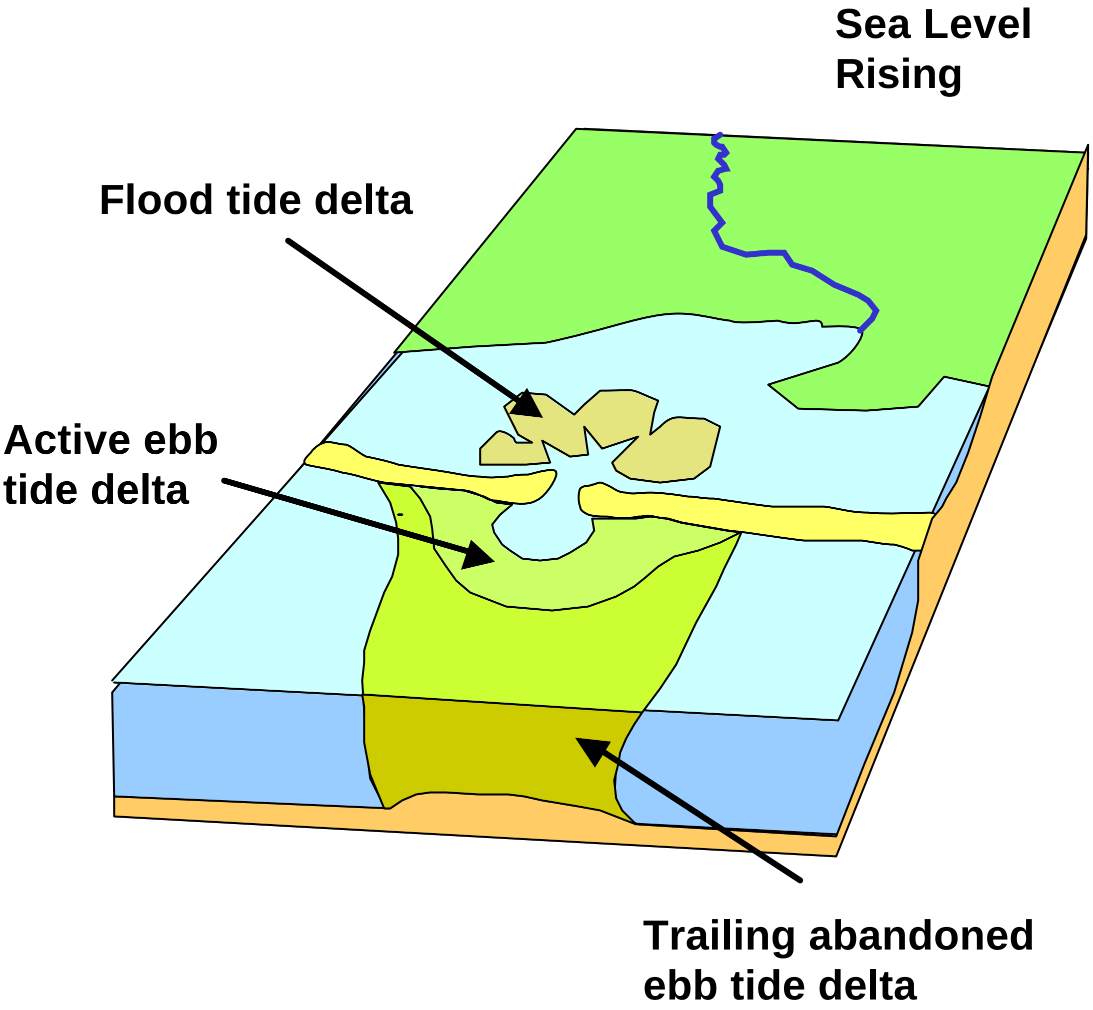


Figure 3.1.5 Extended and abandoned ebb tide delta deposits caused by barrier island retreat as sea level rises

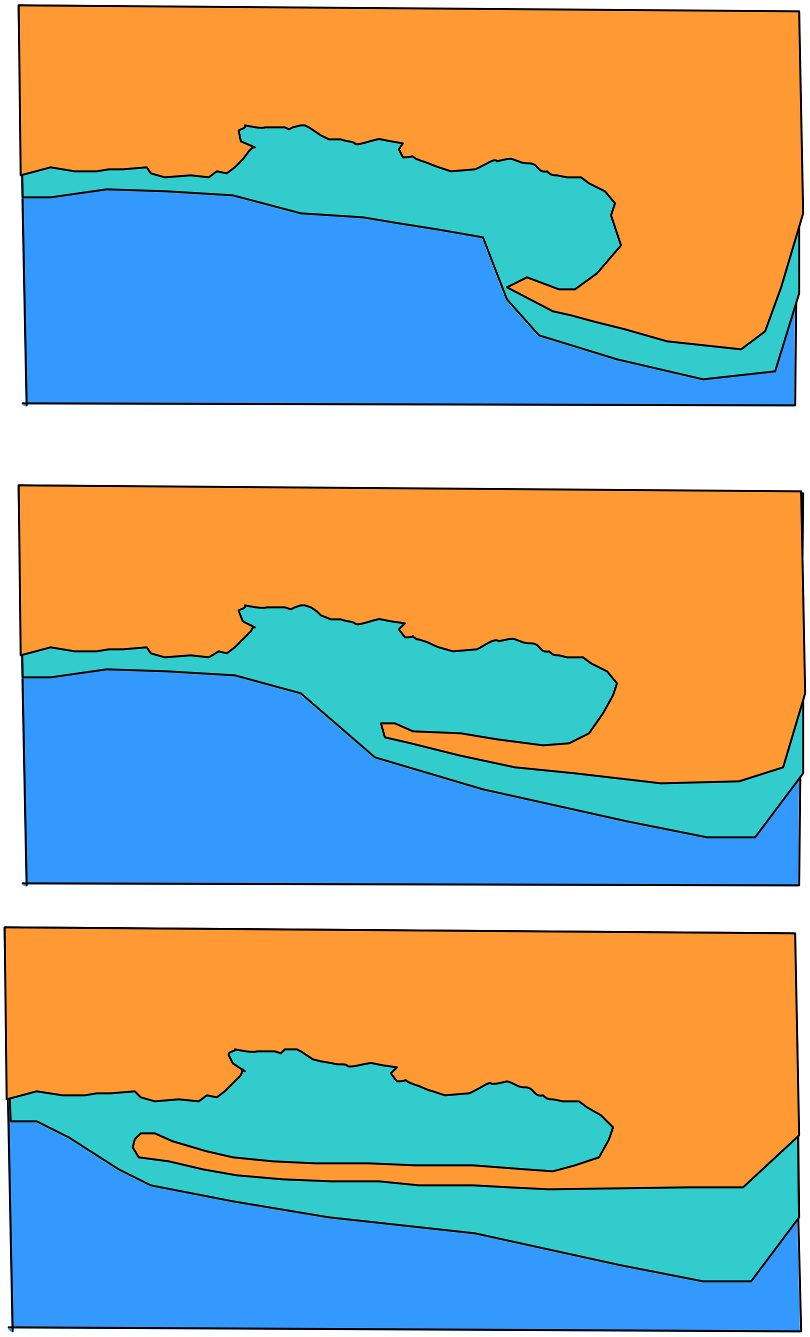


Figure 3.1.6 Schematic of idealized sand spit growth pattern

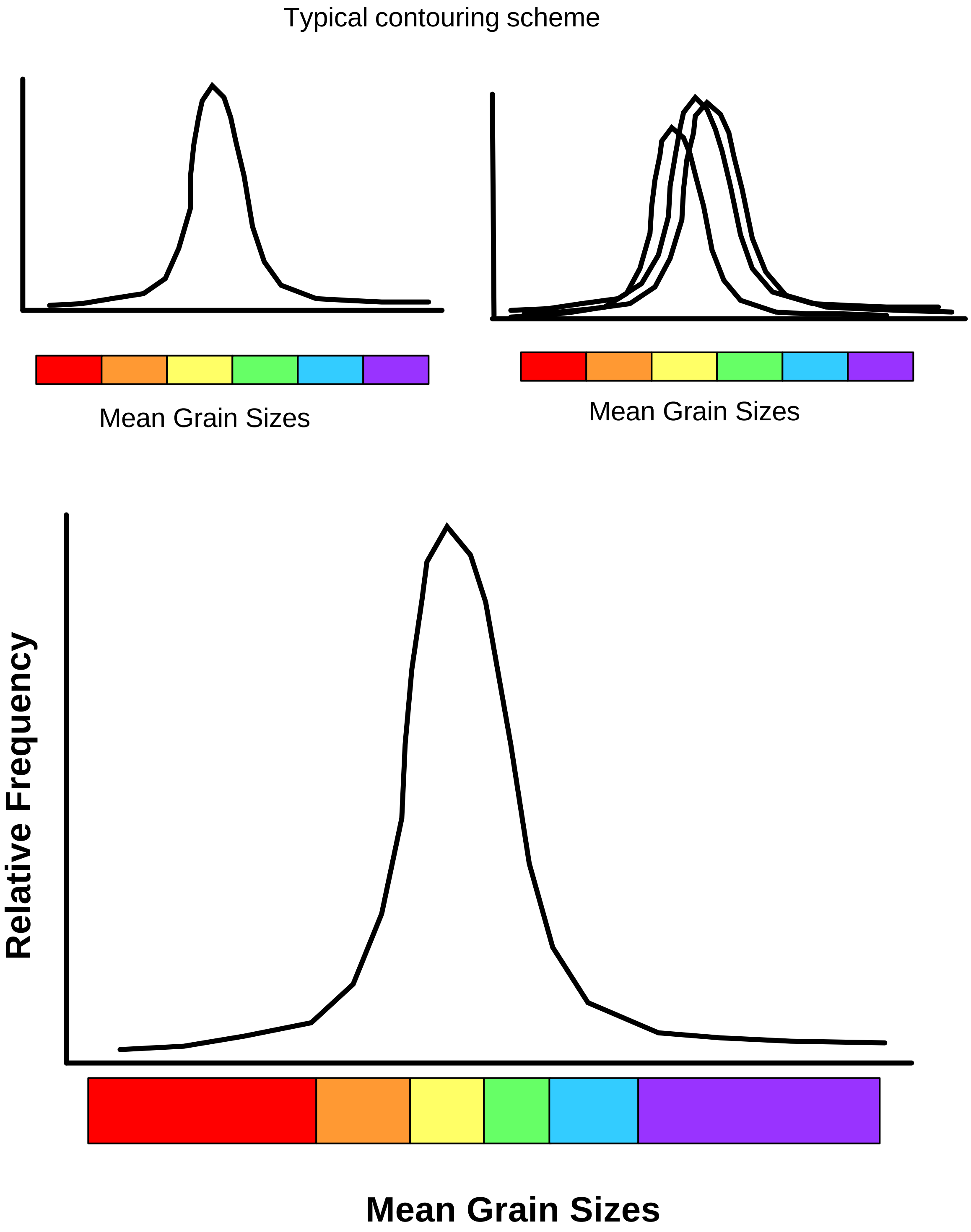


Figure 3.2.1 Comparison of even, and enhanced binning of populations of mean grain size values.

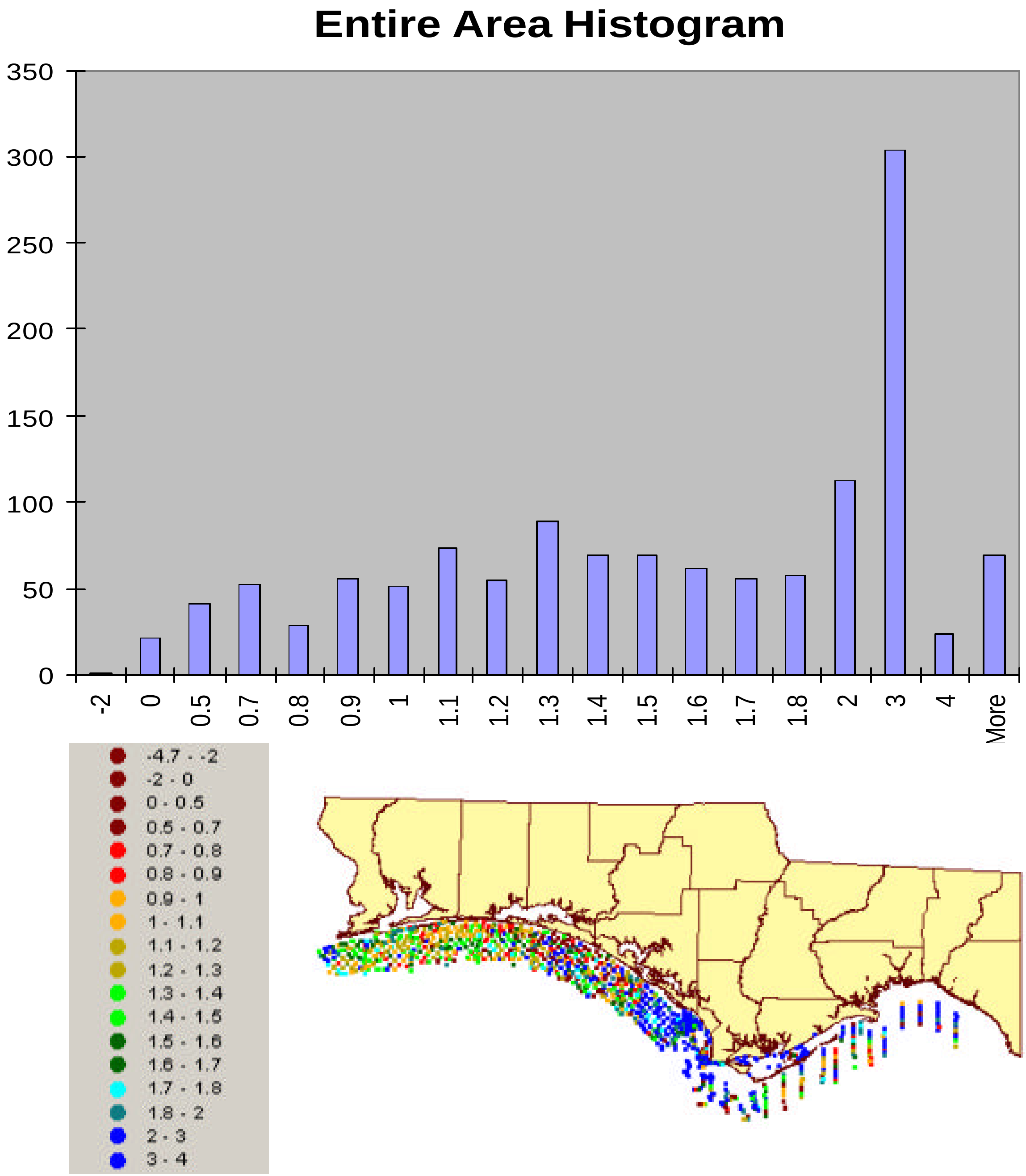


Figure 3.2.2 Histograph and color bins used for area-wide mean grain size

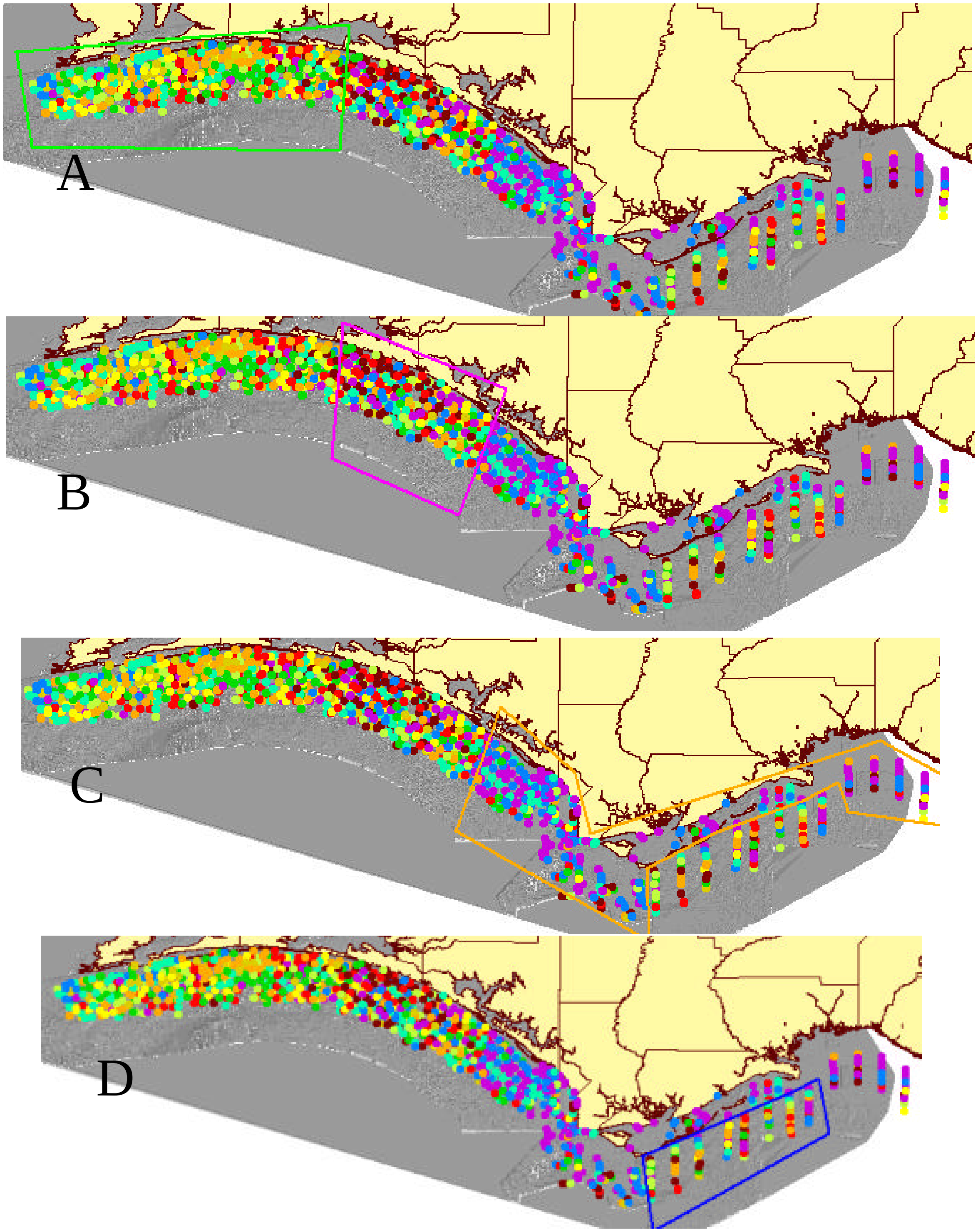


Figure 3.2.3 Spatial distribution of mean grain sizes identifying the western (A), left central (B), right central (C) and eastern (C) sub-areas

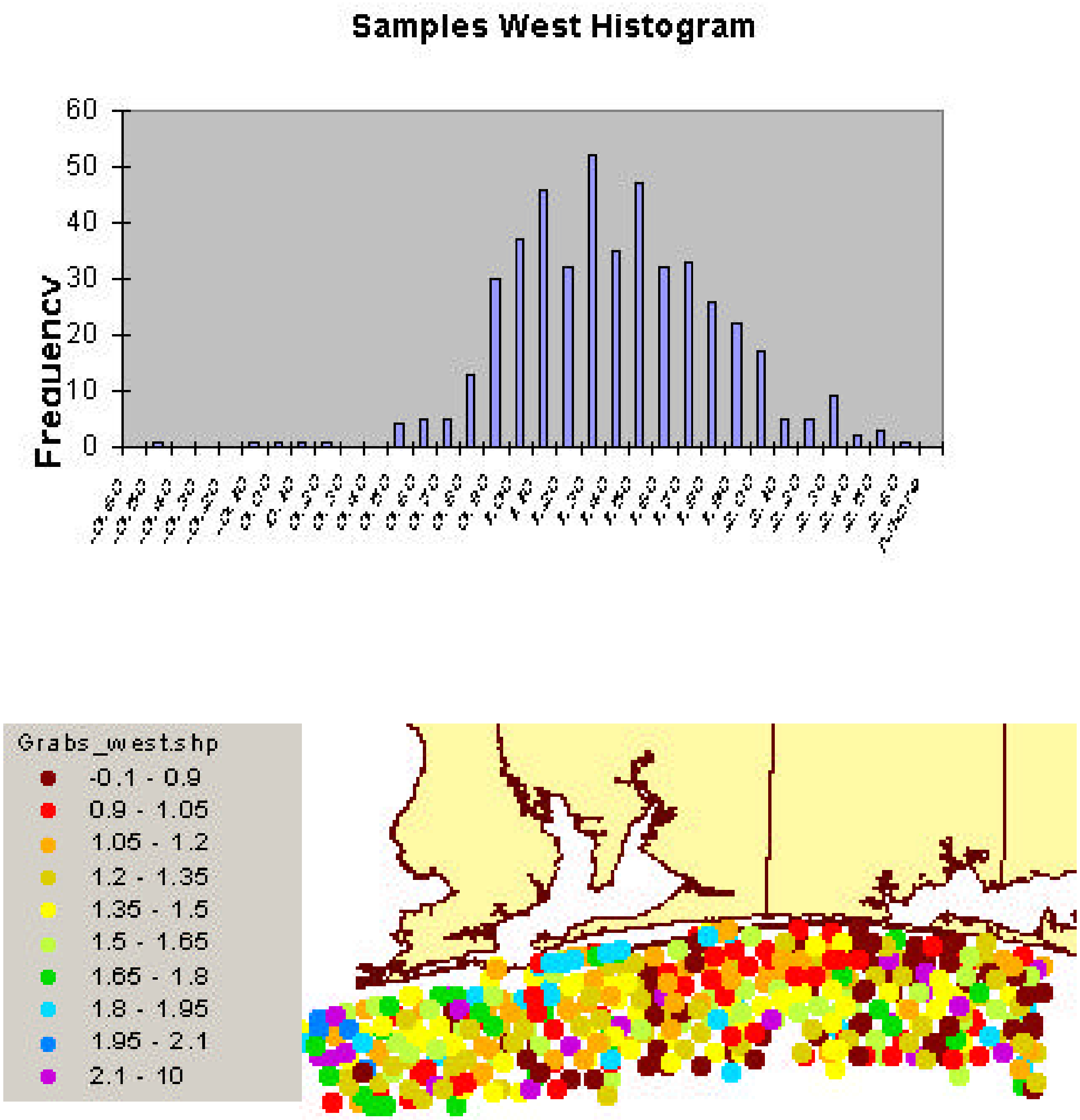


Figure 3.2.4 Pattern of mean grains sizes in the western sub-area

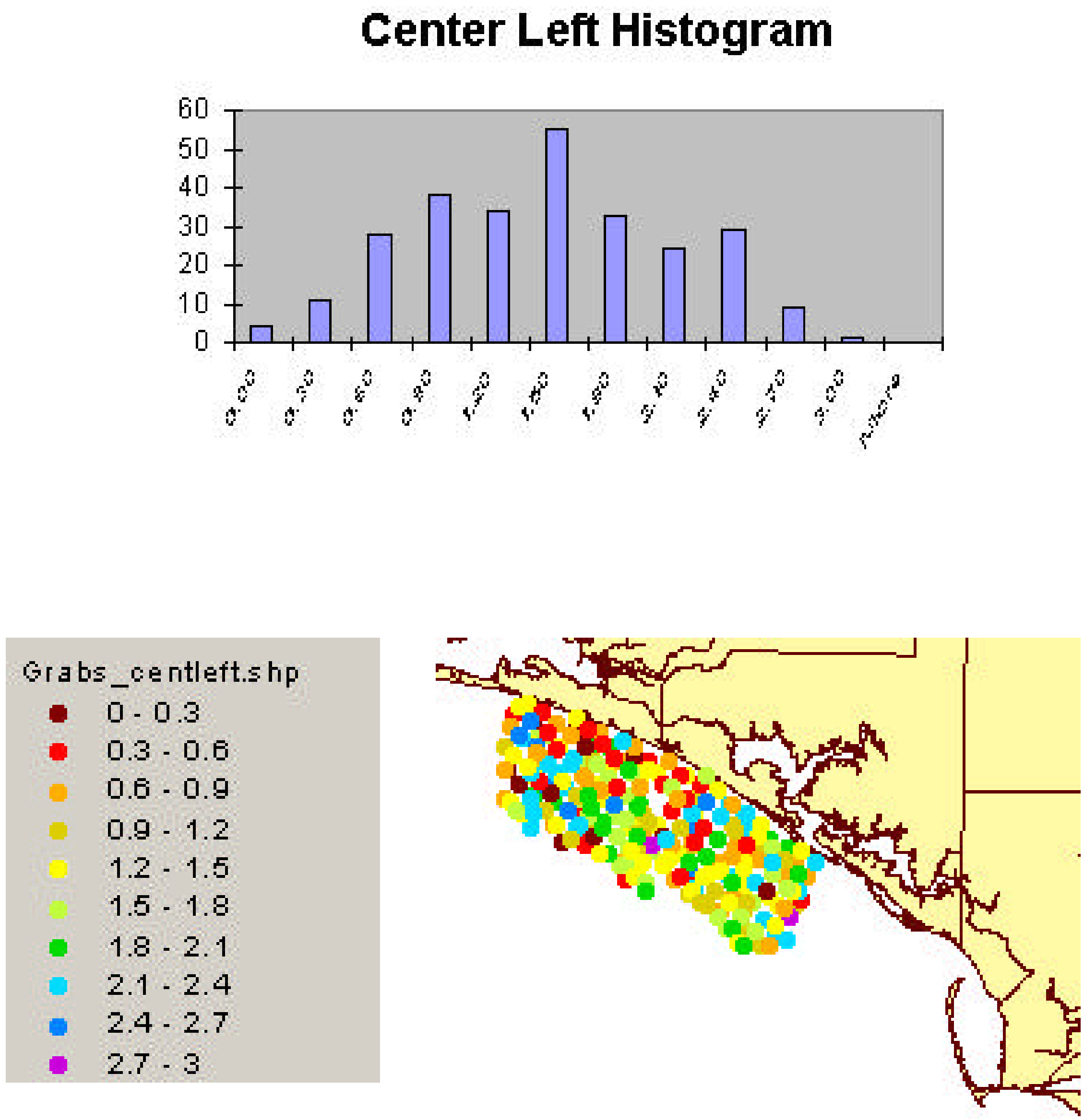


Figure 3.2.5 Pattern of mean grains sizes in the left center sub-area

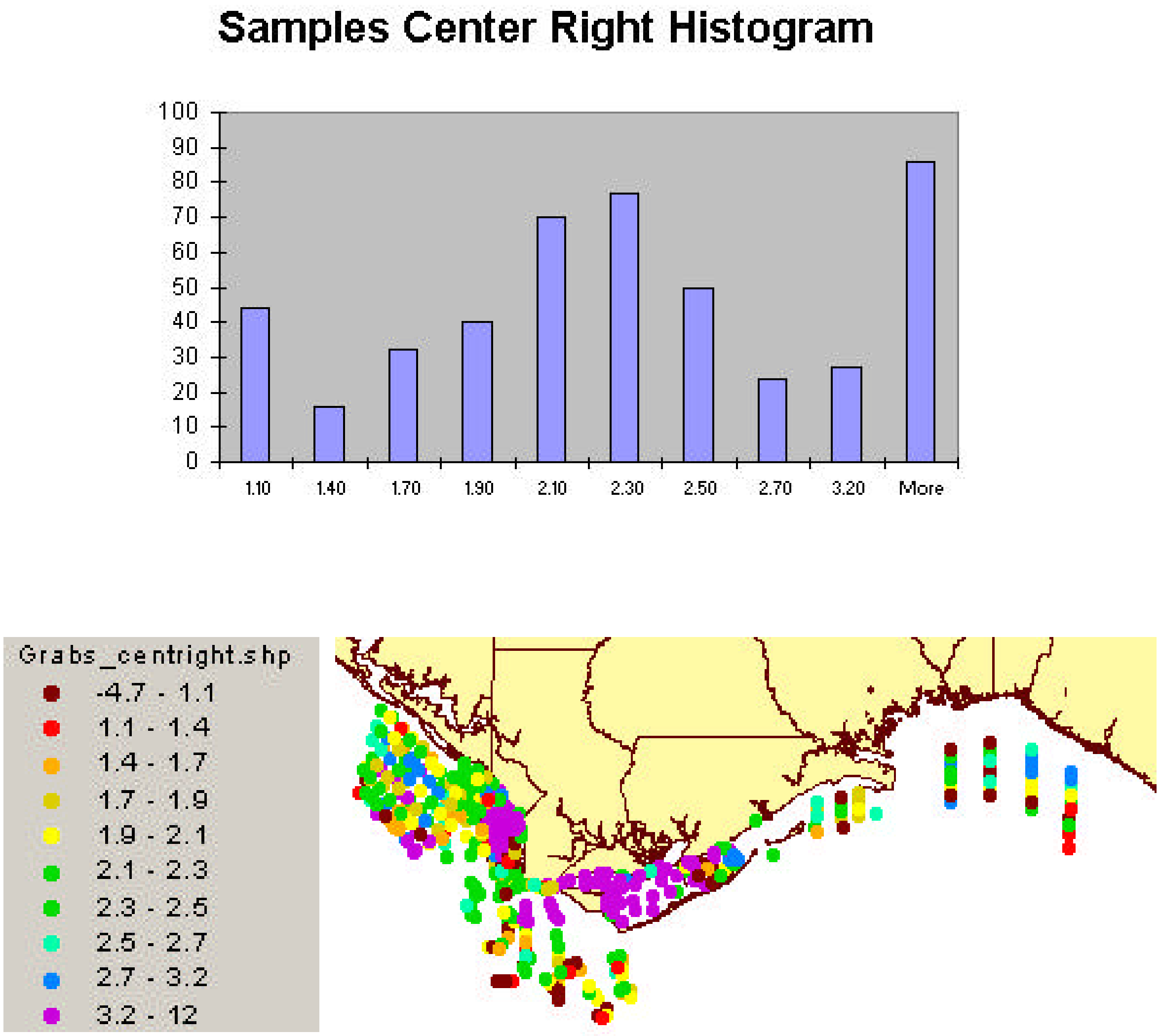


Figure 3.2.6 Pattern of mean grains sizes in the right center sub-area

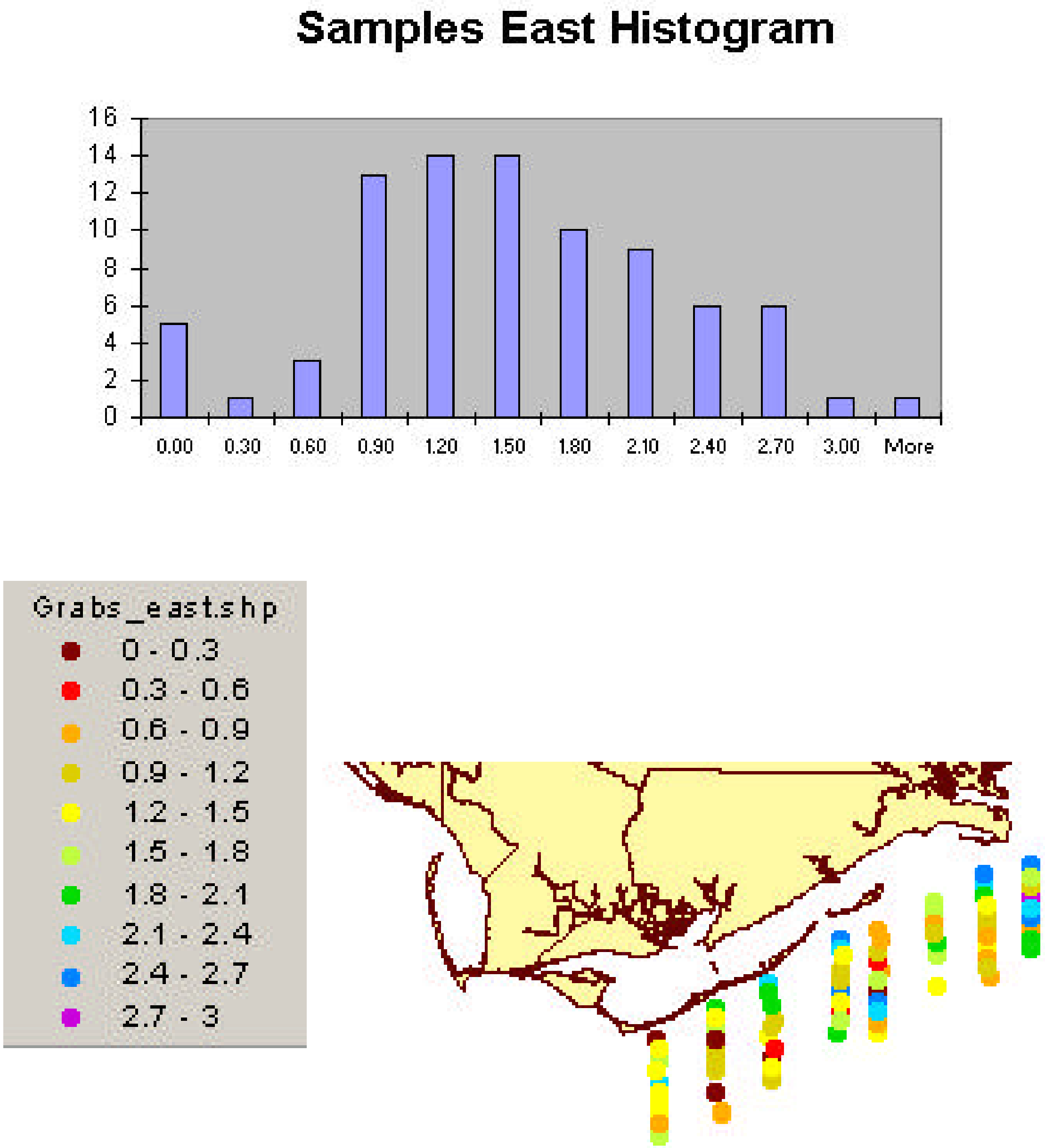


Figure 3.2.7 Pattern of mean grains sizes in the eastern sub-area

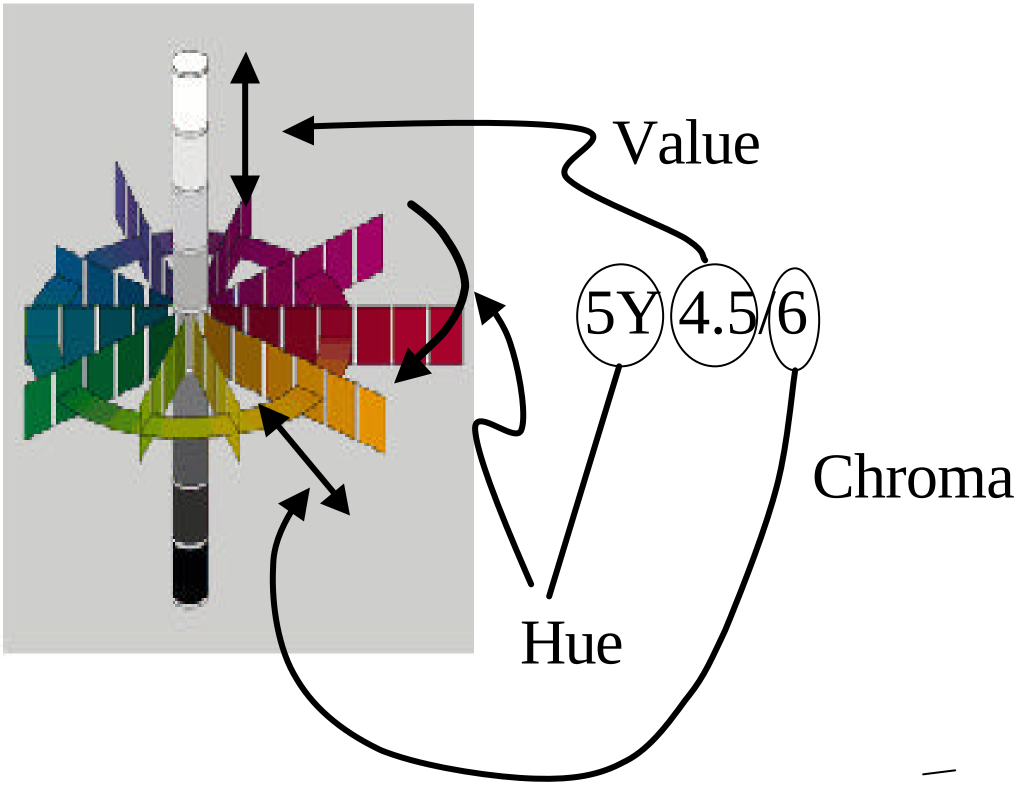


Figure 3.2.8 Definition diagram of the Munsel color classification scheme - (source: www.munsel)

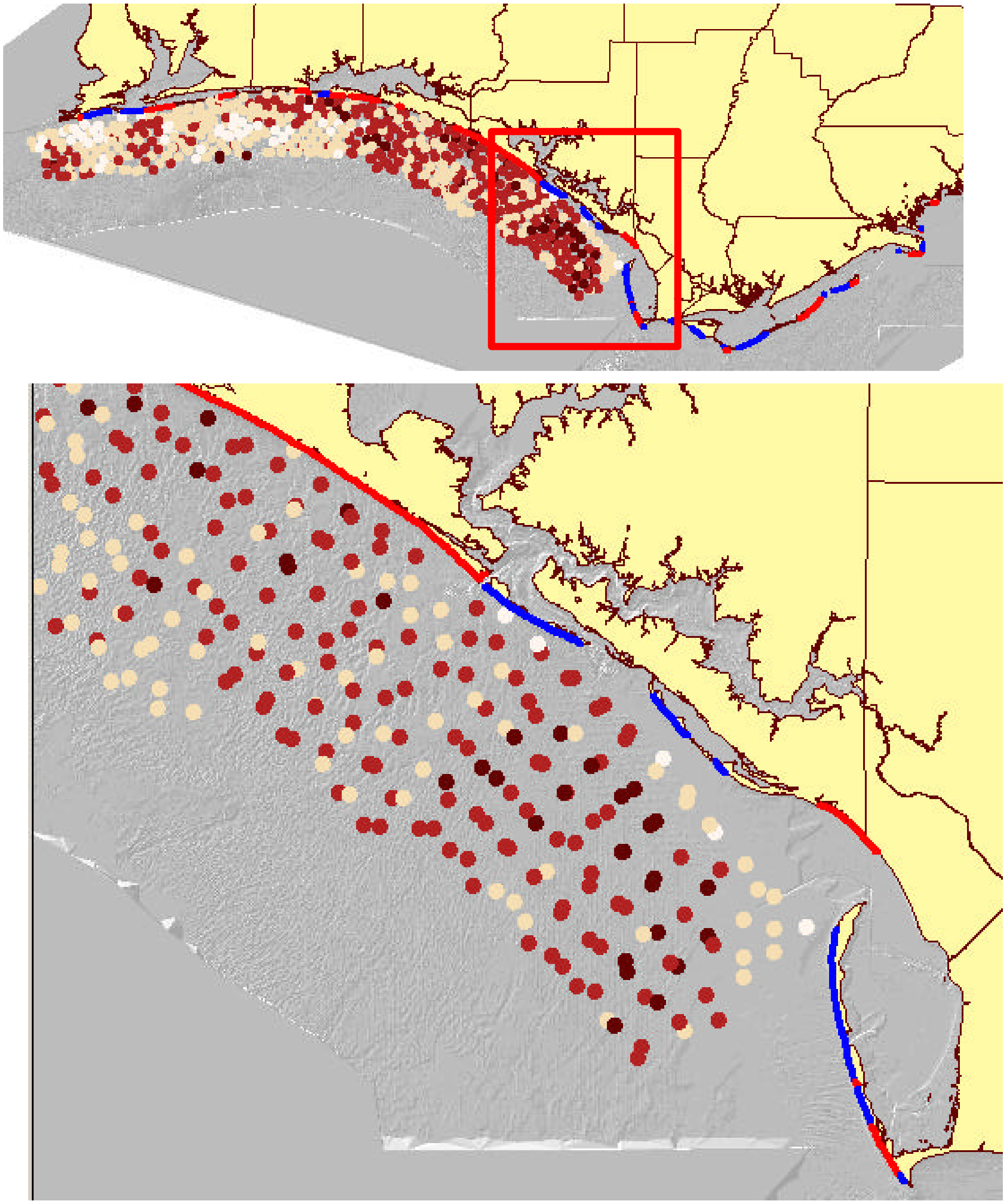


Figure 3.2.9 The color value parameter for sand samples (darkest dots to lightest are values from 3.5 to 8.0)

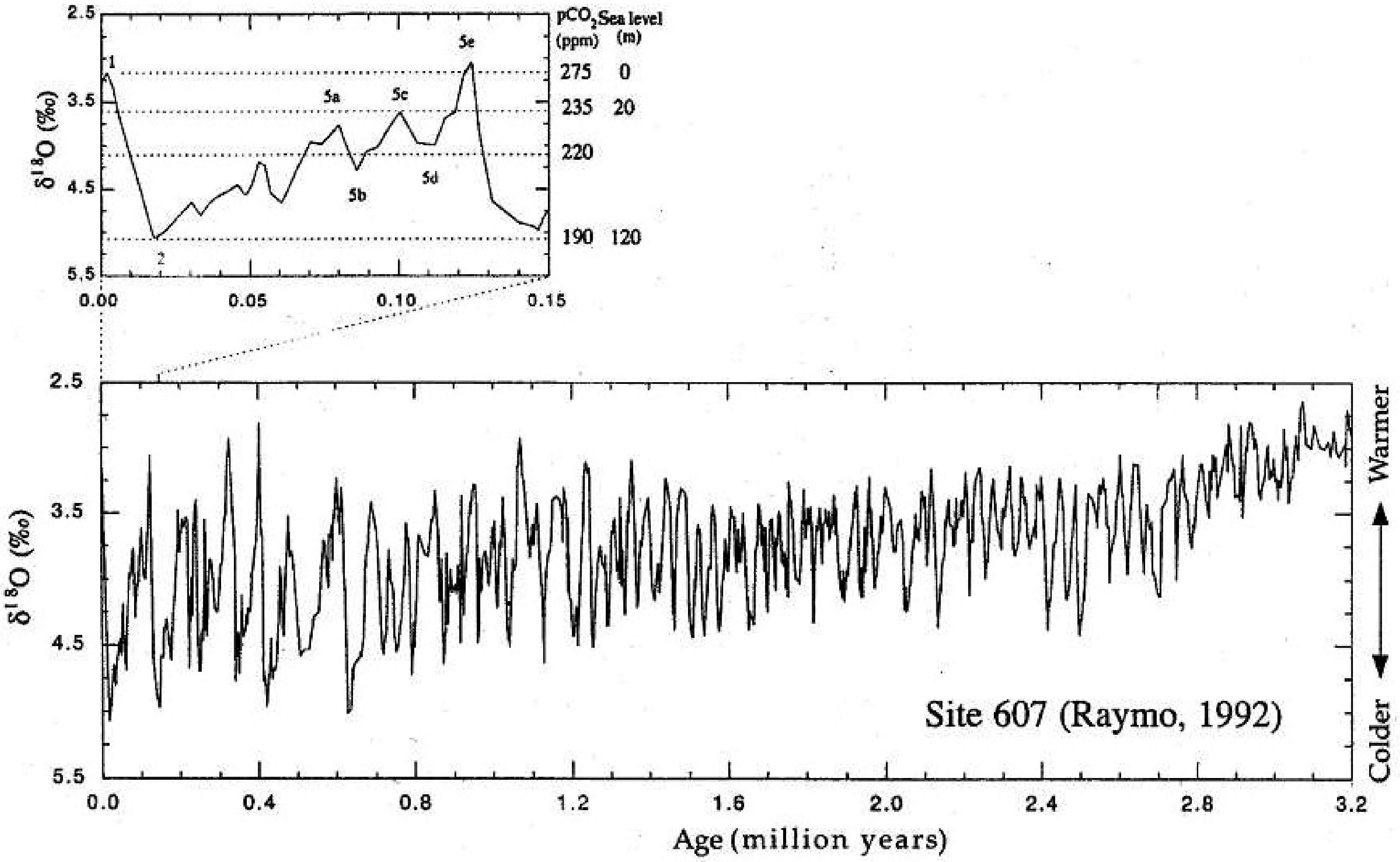


Figure 3.3.1
Pliestocene glacial advances and retreats during the past 3 million years

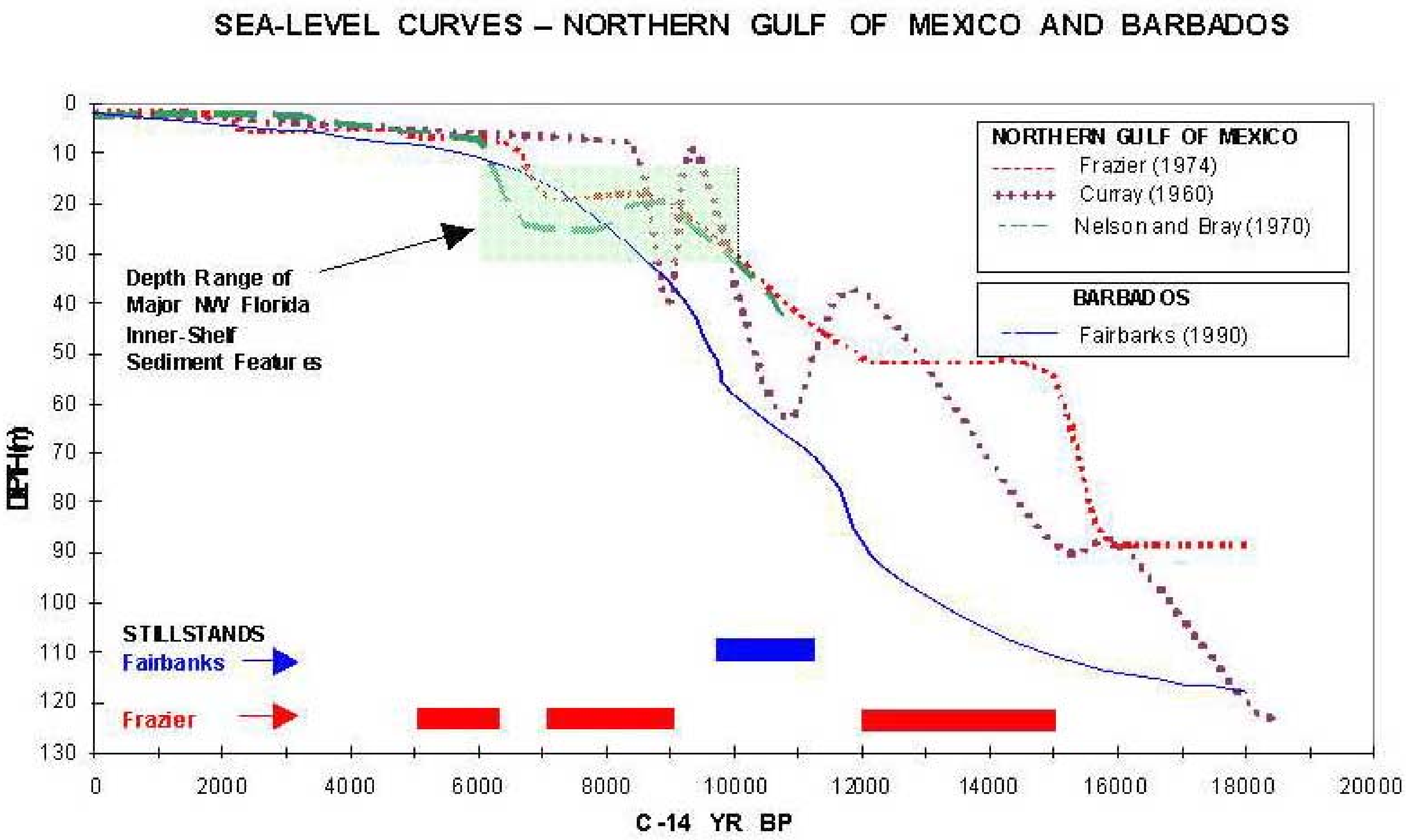


Figure 3.3.2
Late Quaternary sea level history since the last glacial maximum, approximately 18 ka.

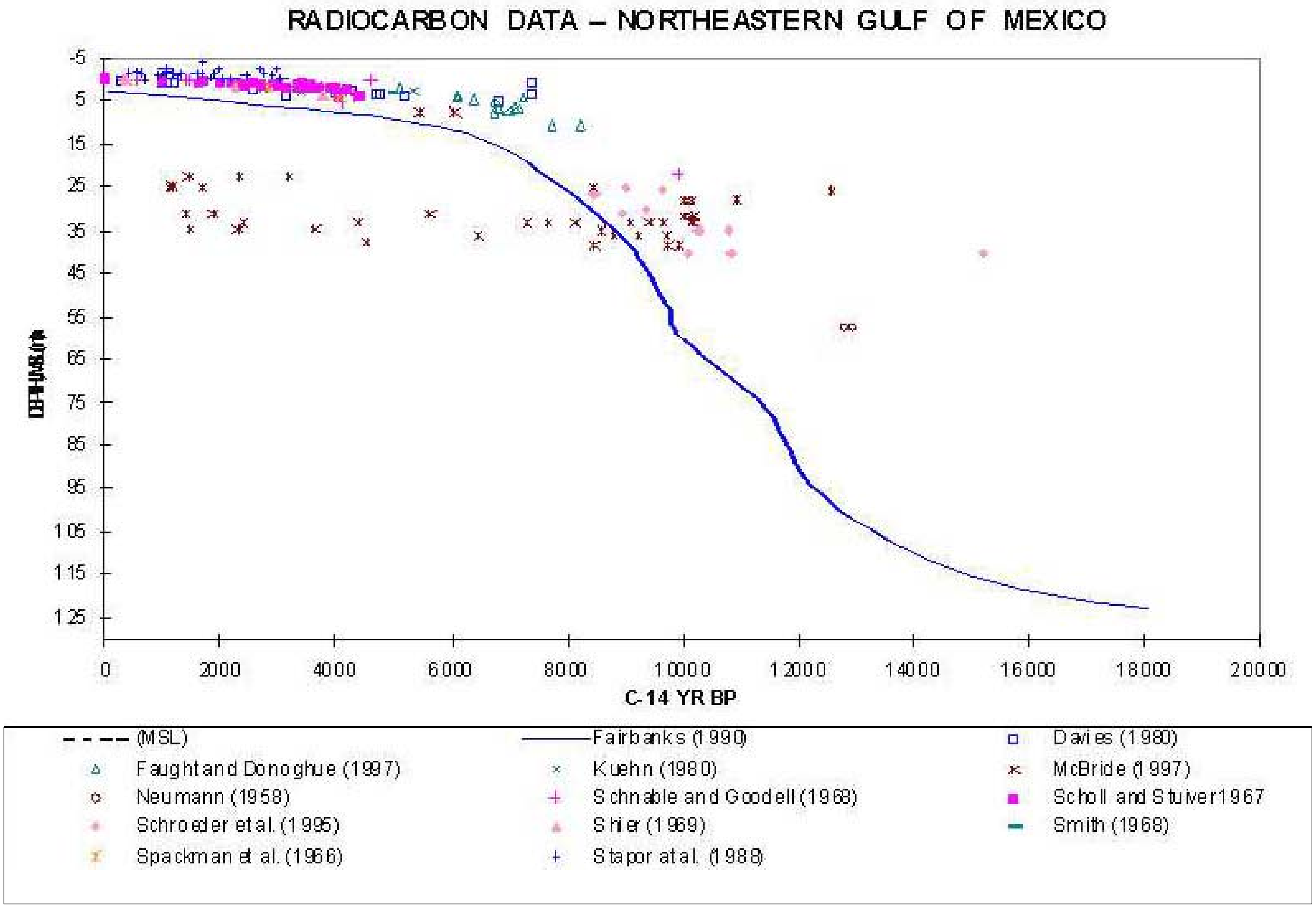


Figure 3.3.3
Compilation of sea level data for the Florida and Alabama coasts

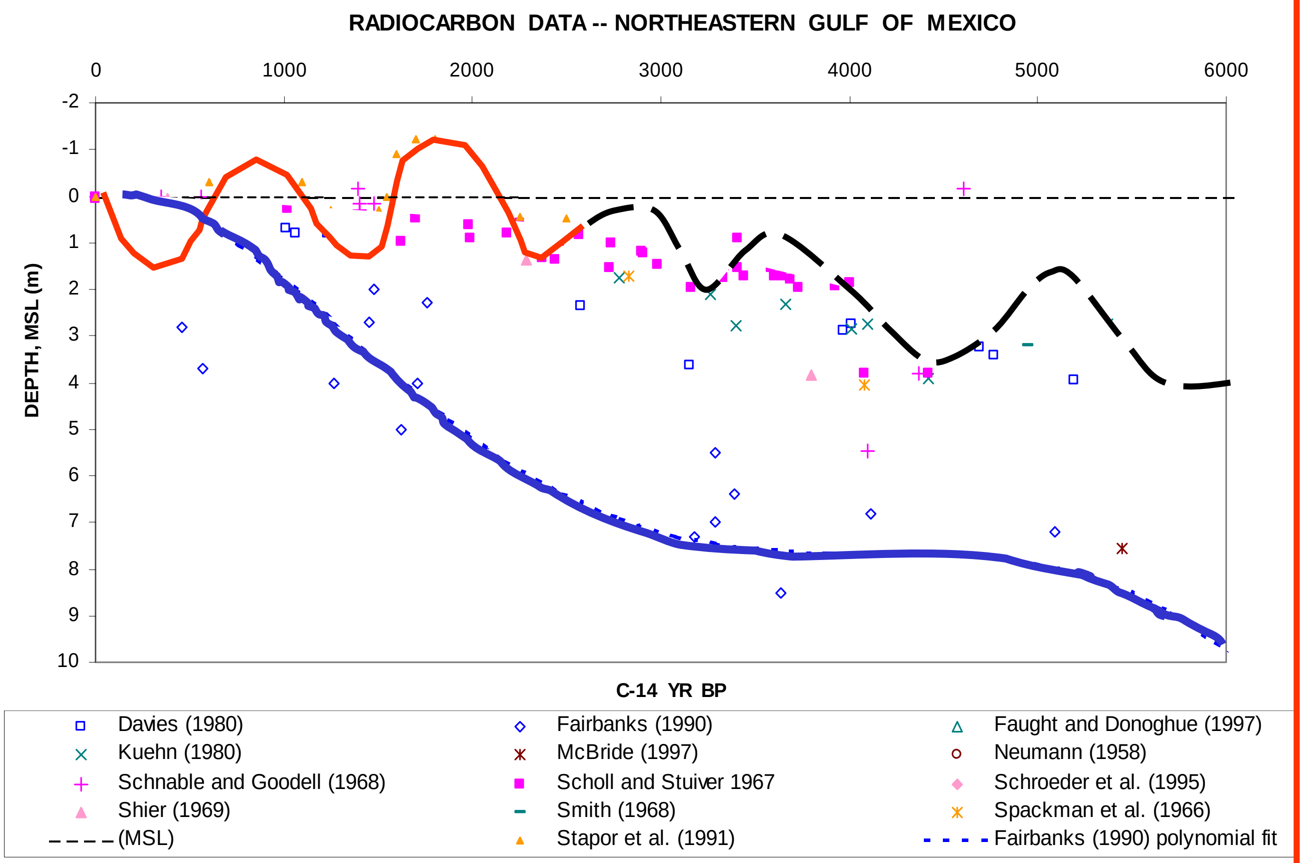


Figure 3.3.4
North Florida sea level data and curve over the past 6,000 years

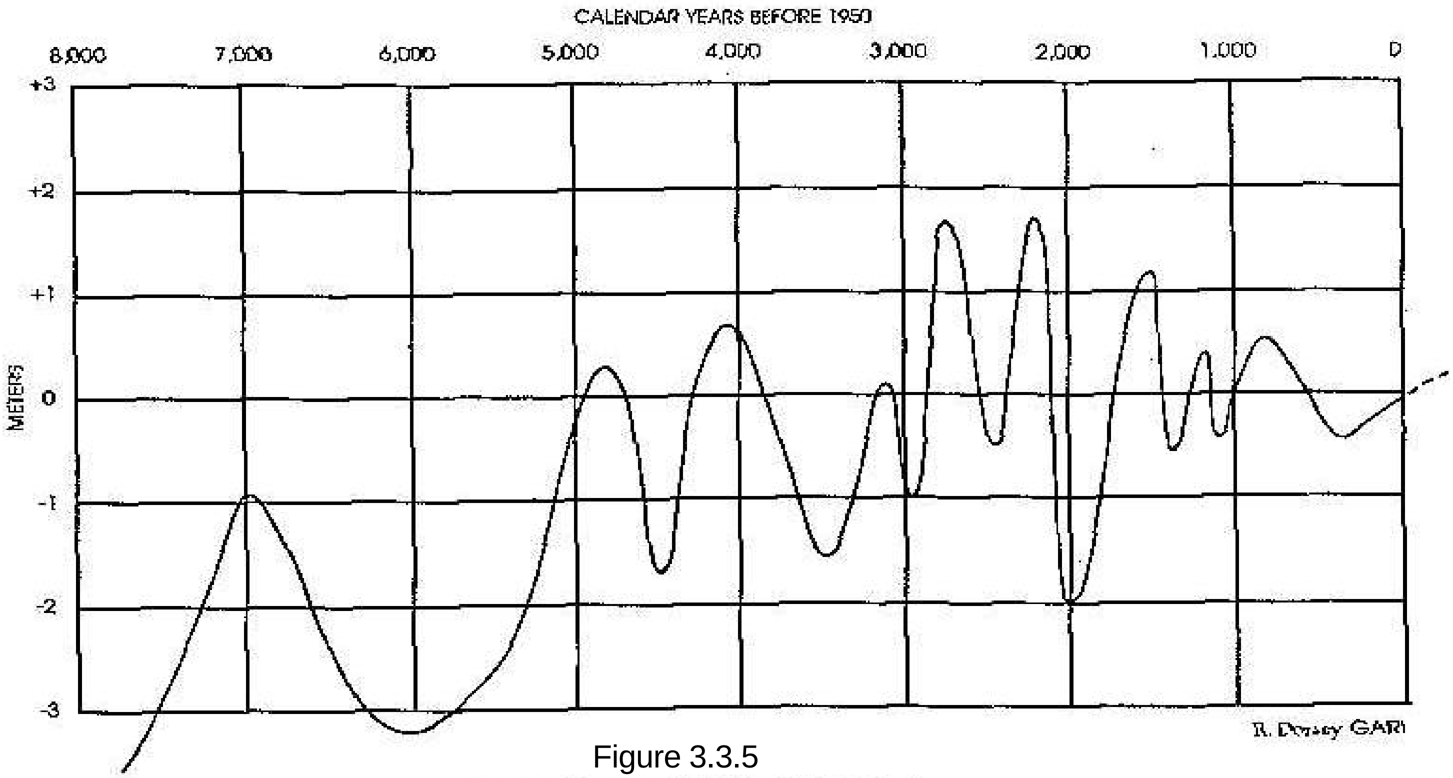


Figure 3.3.5

PREDICTED GULF COAST FLORIDA
POST 7,000 B.P. DETAIL SEA LEVEL HISTORY

Paleo Sea Level.
See Text for a Description of Each 1,000 Year Interval.

North Florida sea level curve from archeological studies

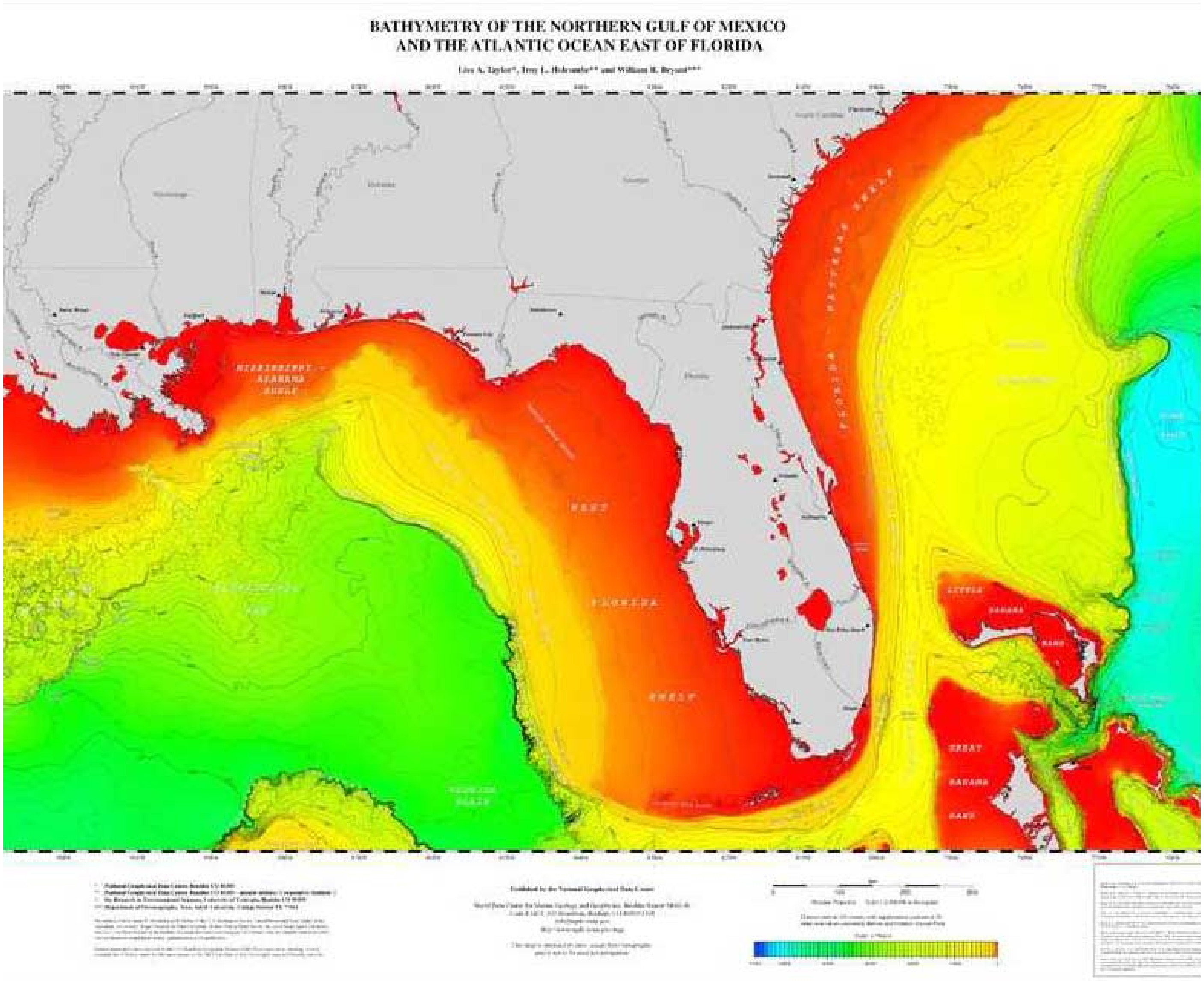
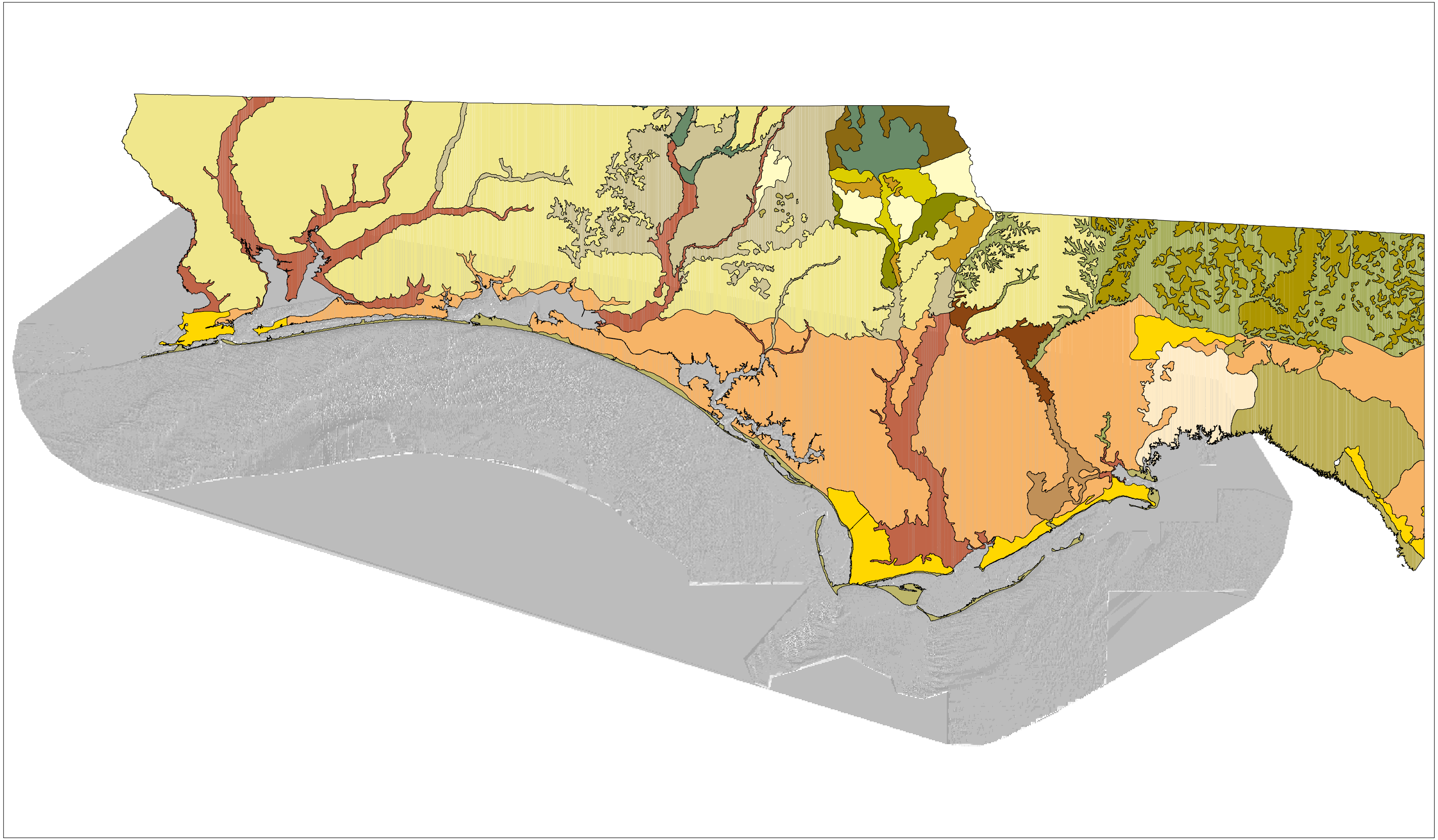


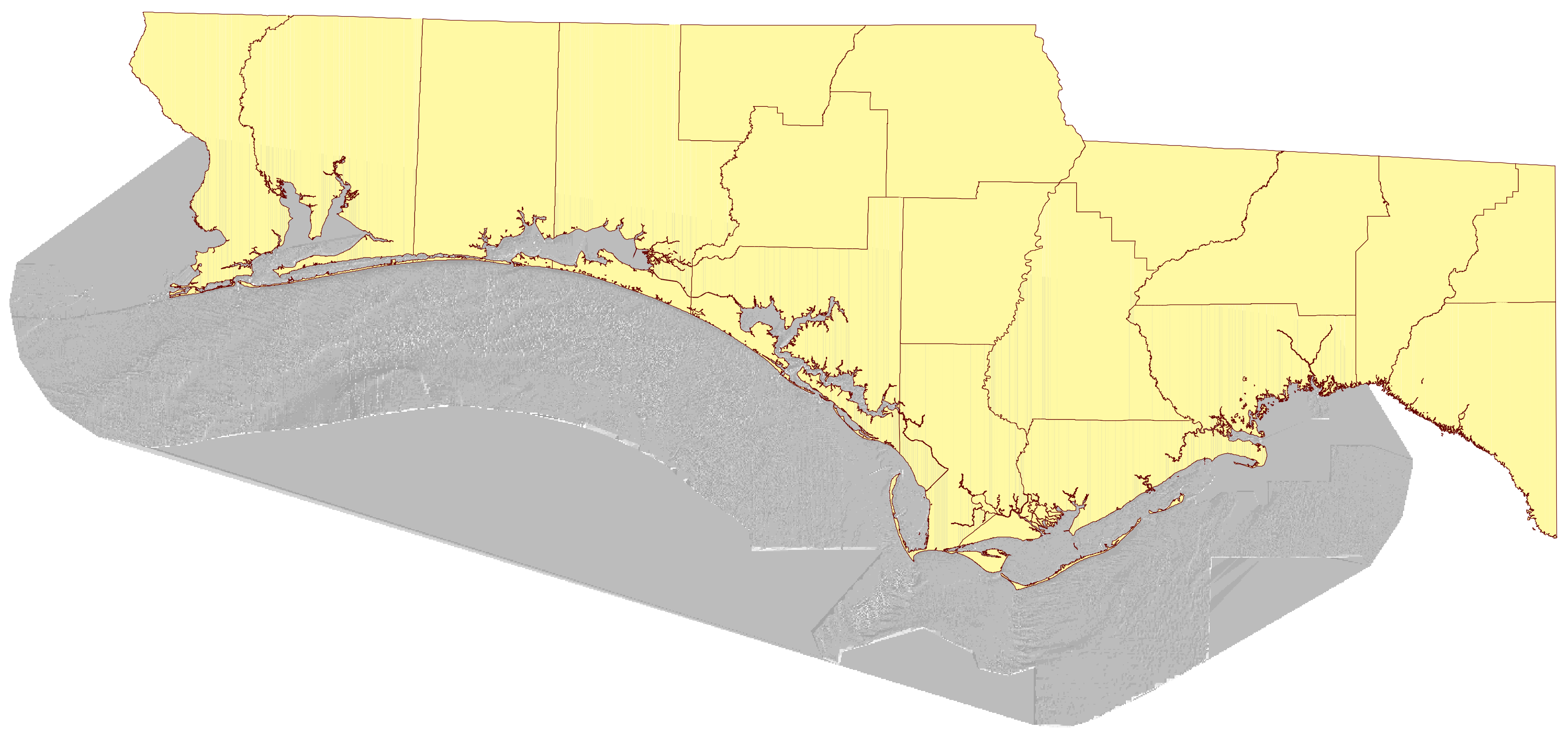
Figure 3.3.6
The bathymetry of the continental margin of northwest Florida



GEOLOGIC MAP

Figure 3-4-1

g:\FDEP\beachcoastal\deliverables\report_figures.apr



🟨 Panhandle counties

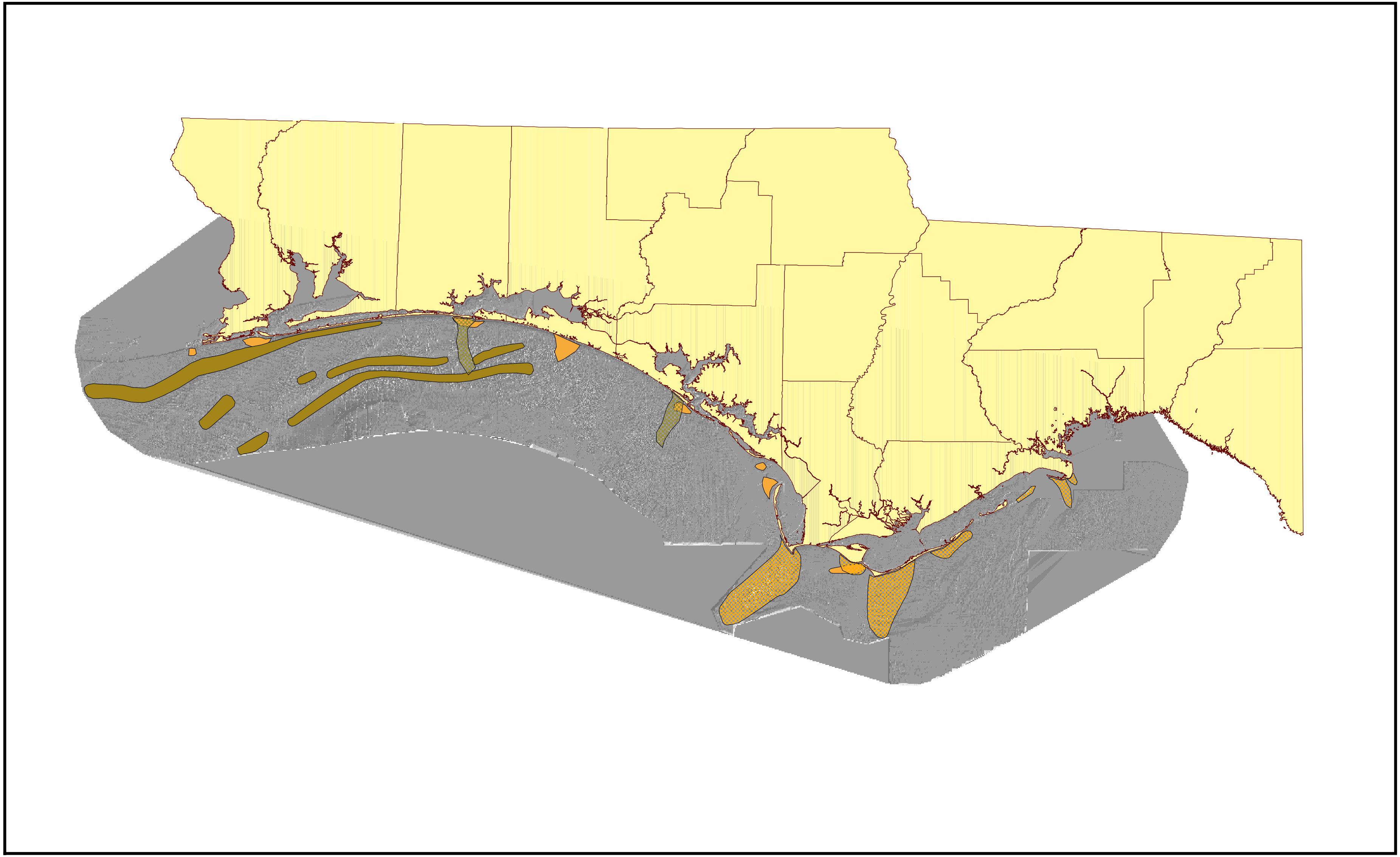
SHADED BATHYMETRY OF ENTIRE STUDY AREA

20 0 20 40 Kilometers

10 0 10 20 Miles

Figure 3-4-2

g:\FDEP\beachcoastal\deliverables\report_figures.apr

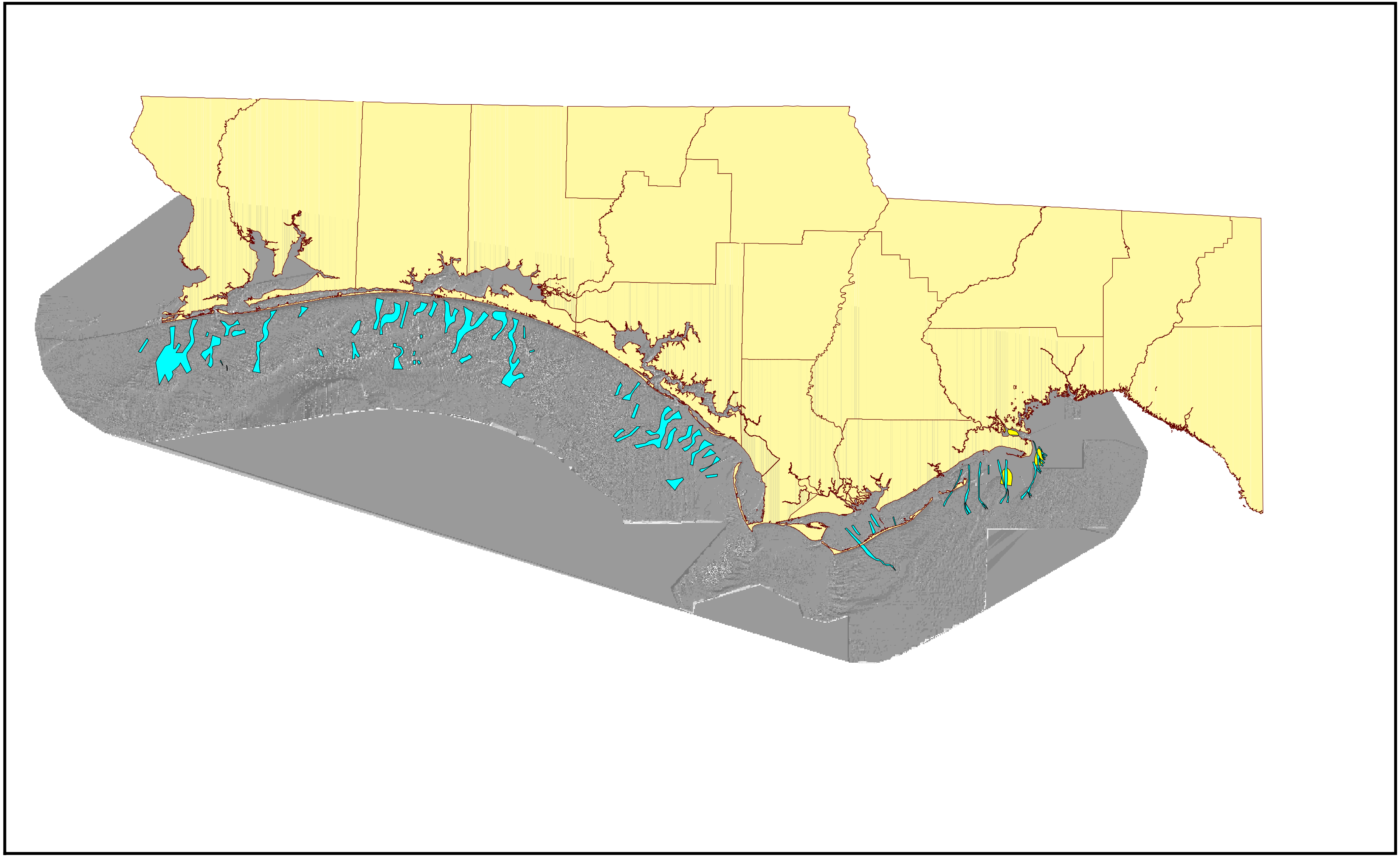


🟧 Delta
🟨 Panhandle Counties
▨ Inlet Path
🟫 Shoreline Complex
🟧 Ebb Delta

Identified Shelf Features

FIGURE 3-4-3

g:\FDEP\beachcoastal\deliverables\sealevel_changes.apr



🟨 Panhandle Counties
🟦 Paleo Channel
🟨 Paleo Ebb Delta

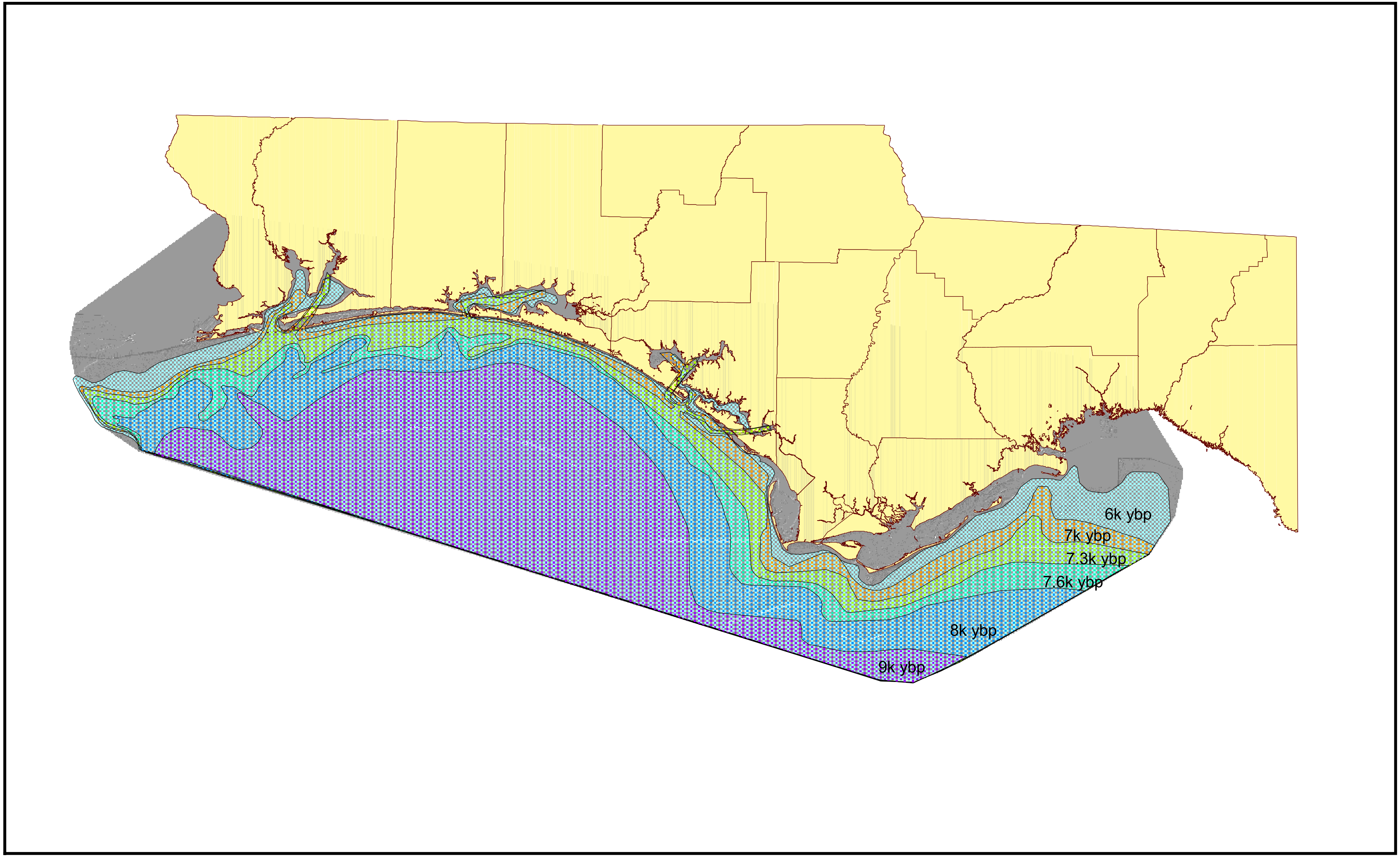
Additional Major Sedimentary Features

FIGURE 3-4-4

10 0 10 20 Miles

20 0 20 40 Kilometers

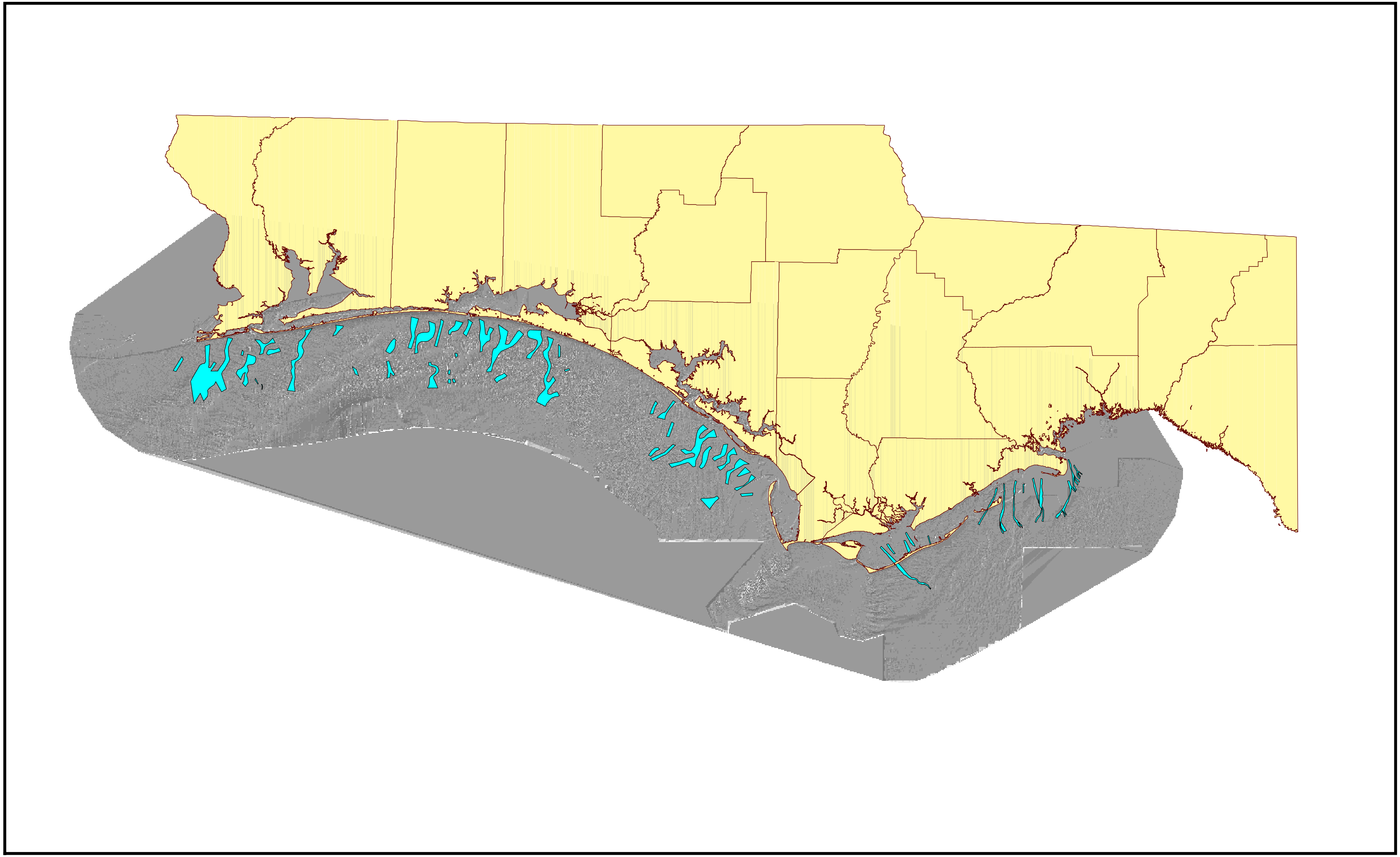
g:\FDEP\beachcoastal\deliverables\sealevel_changes.apr



Sequence of Shorelines During the Last Sea Level Rise

FIGURE 3-4-5

g:\FDEP\beachcoastal\deliverables\sealevel_changes.apr

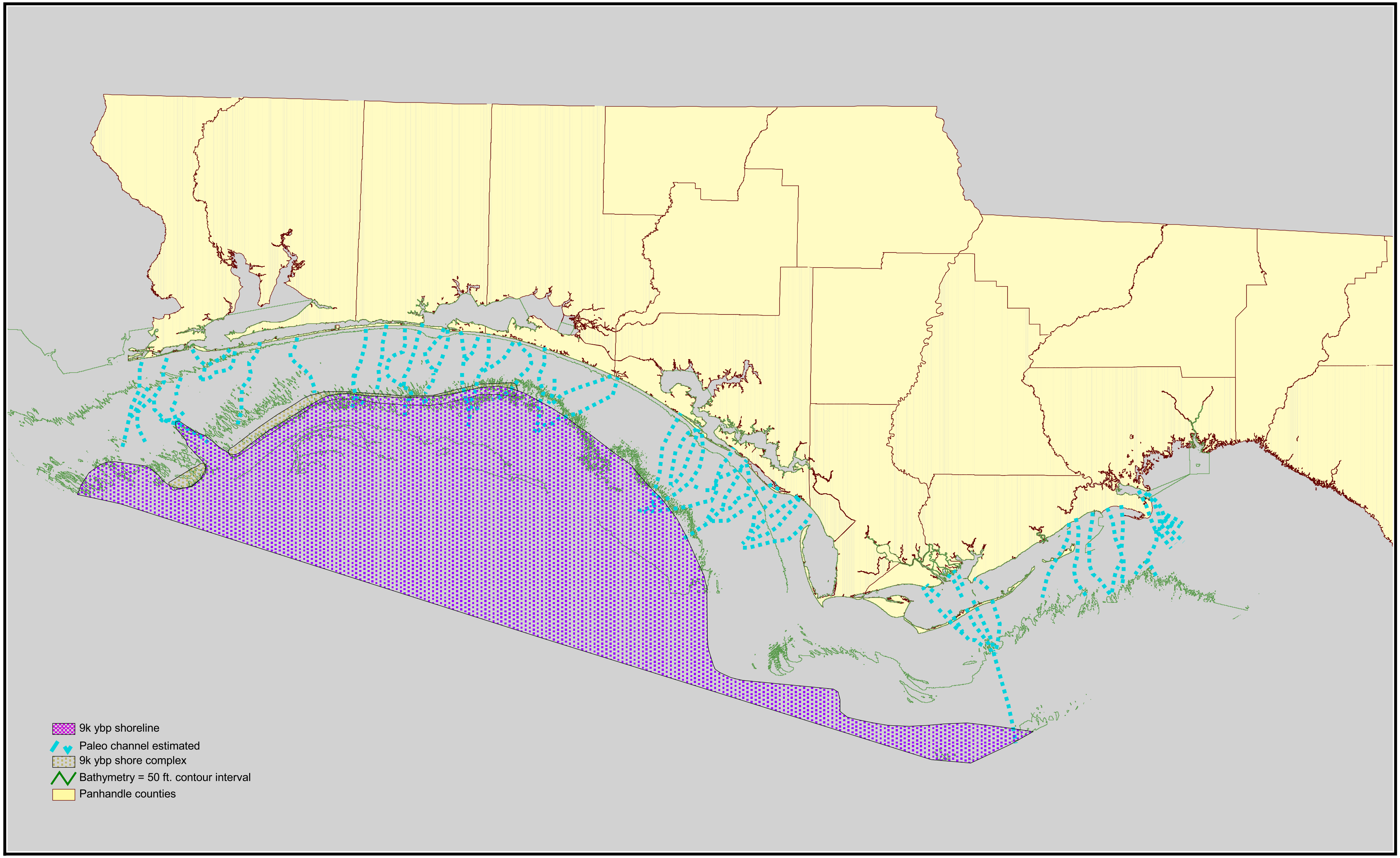


🟨 Panhandle Counties
🟦 Paleo Channel

Reconstructed Paleo-Drainage Systems

FIGURE 3-4-6

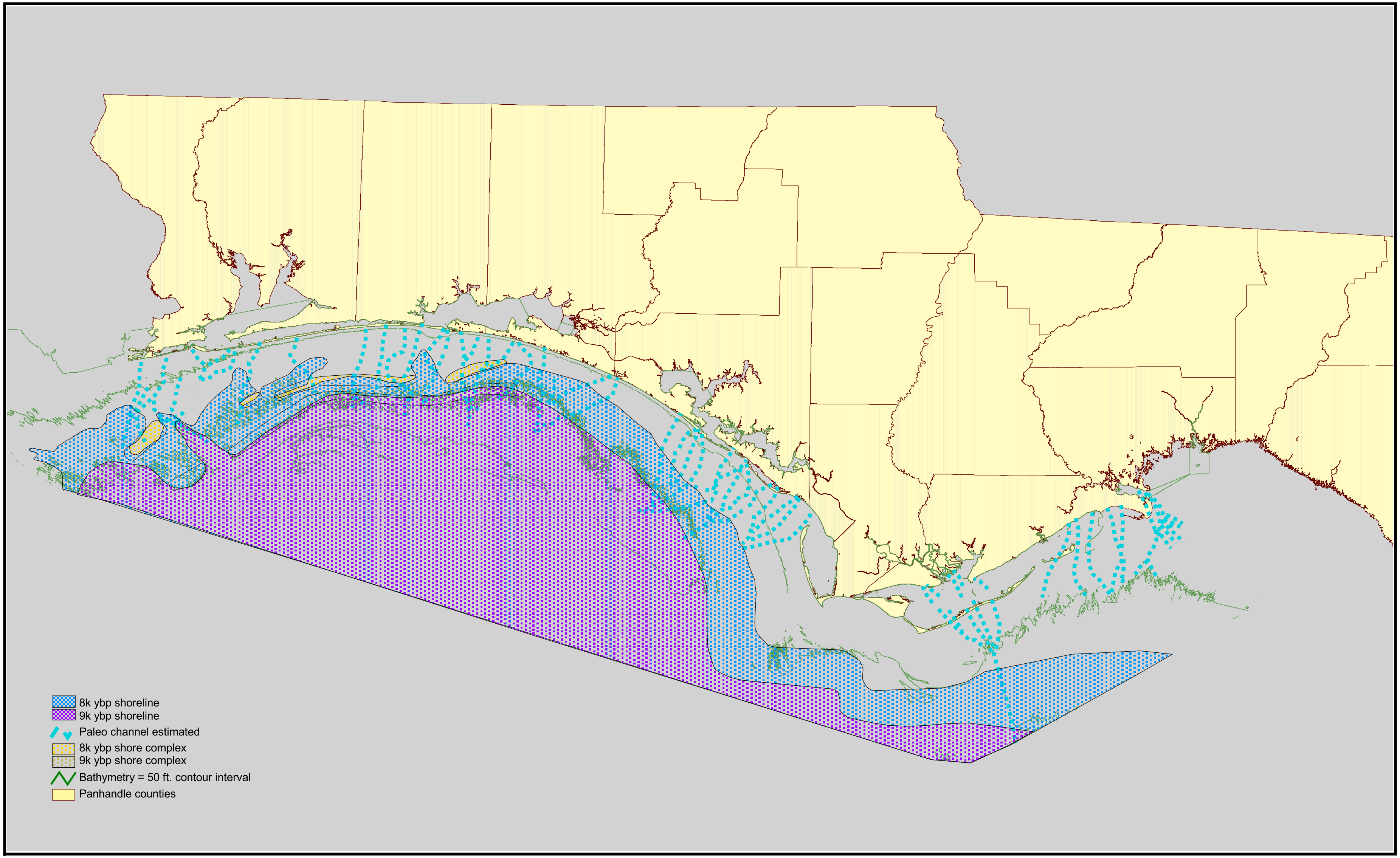
g:\FDEP\beachcoastal\deliverables\sealevel_changes.apr



Paleo Shoreline Position
9k ybp

FIGURE 3-4-7

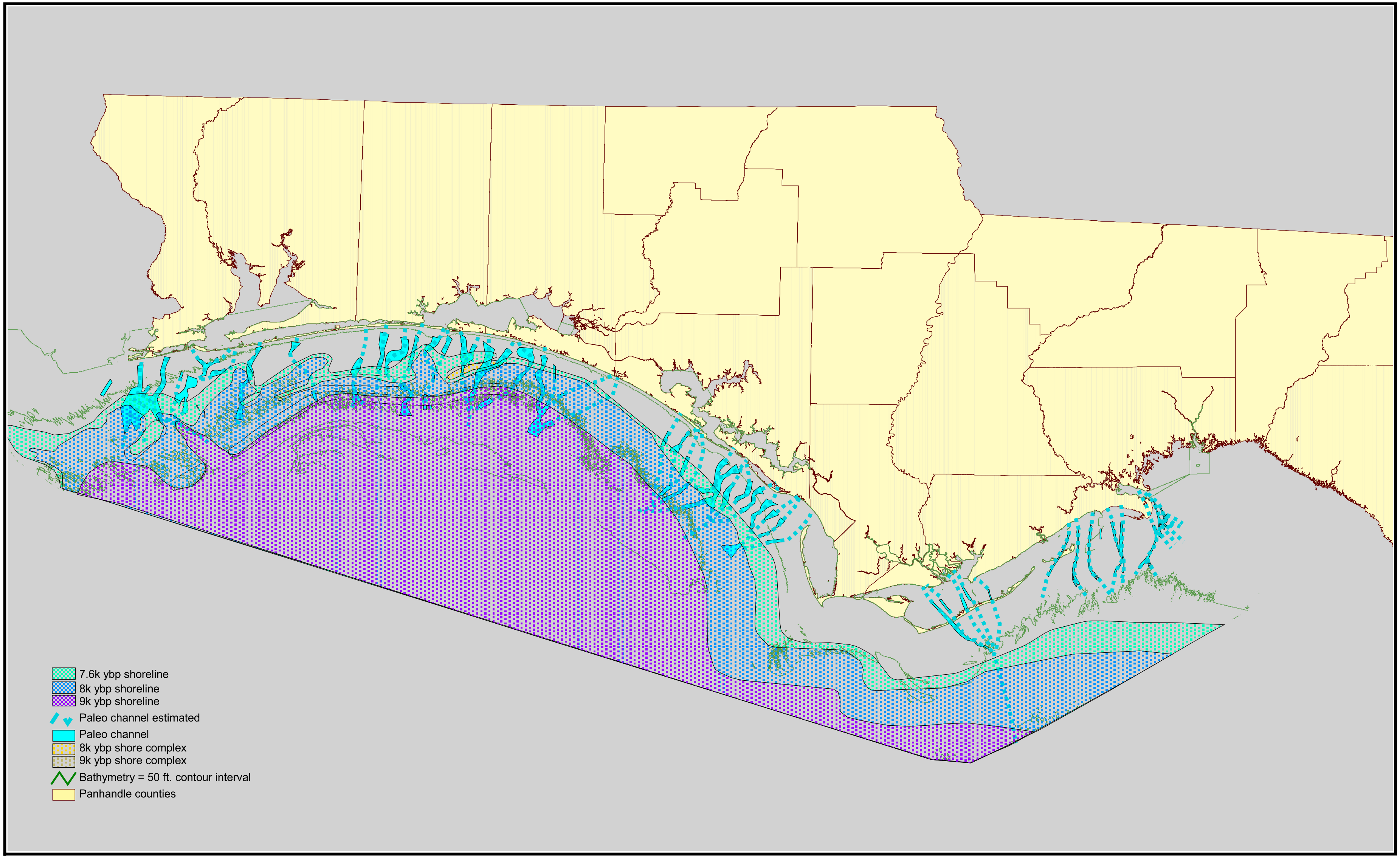
g:\FDEP\beachcoastal\deliverables\sealevel_changes.apr



Paleo Shoreline Position
8k ybp

FIGURE 3-4-8

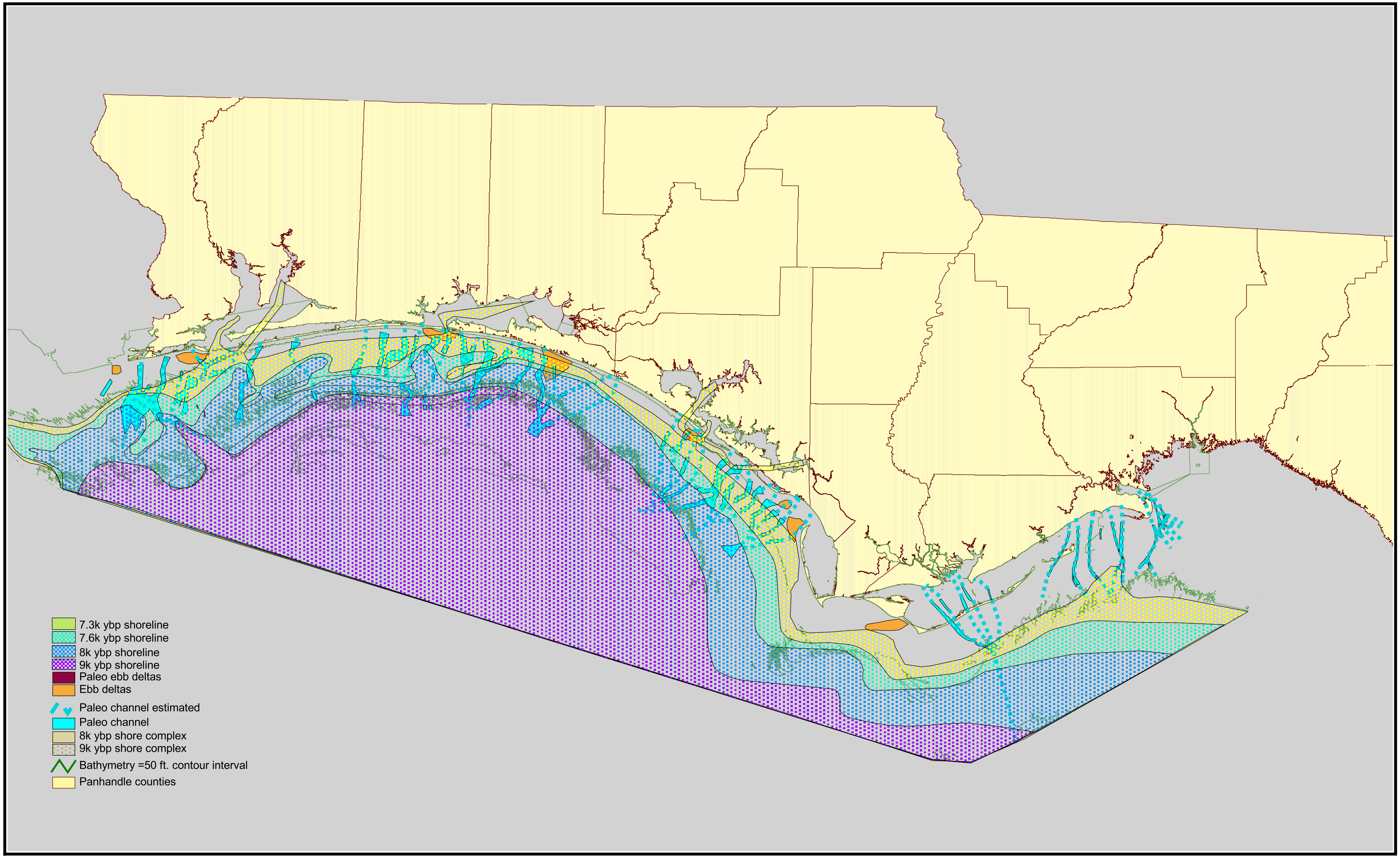
g:\FDEP\beachcoastal\deliverables\sealevel_changes.apr



Paleo Shoreline Position
7.6k ybp

FIGURE 3-4-9

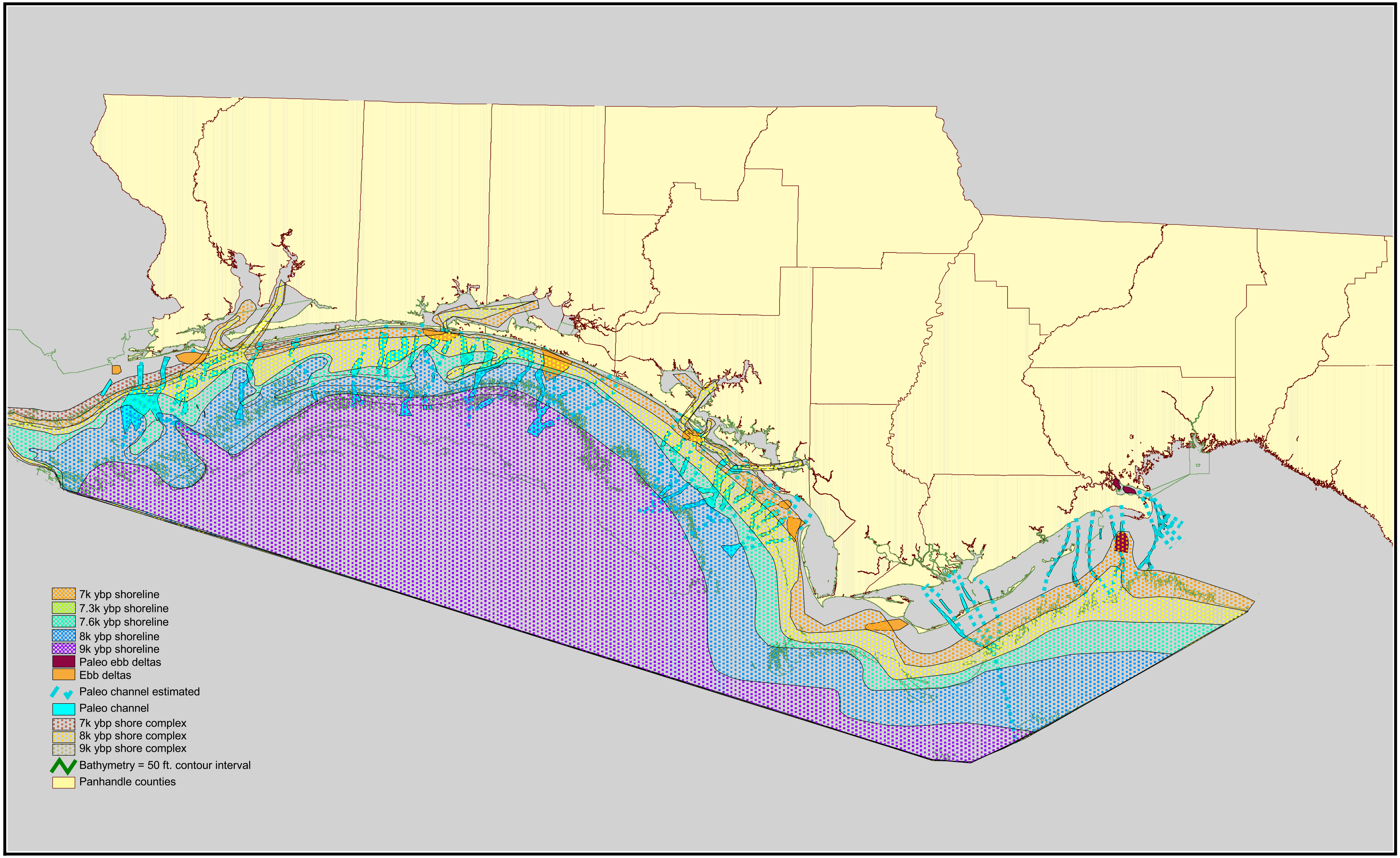
g:\FDEP\beachcoastal\deliverables\sealevel_changes.apr



Paleo Shoreline Position
7.3k ybp

FIGURE 3-4-10

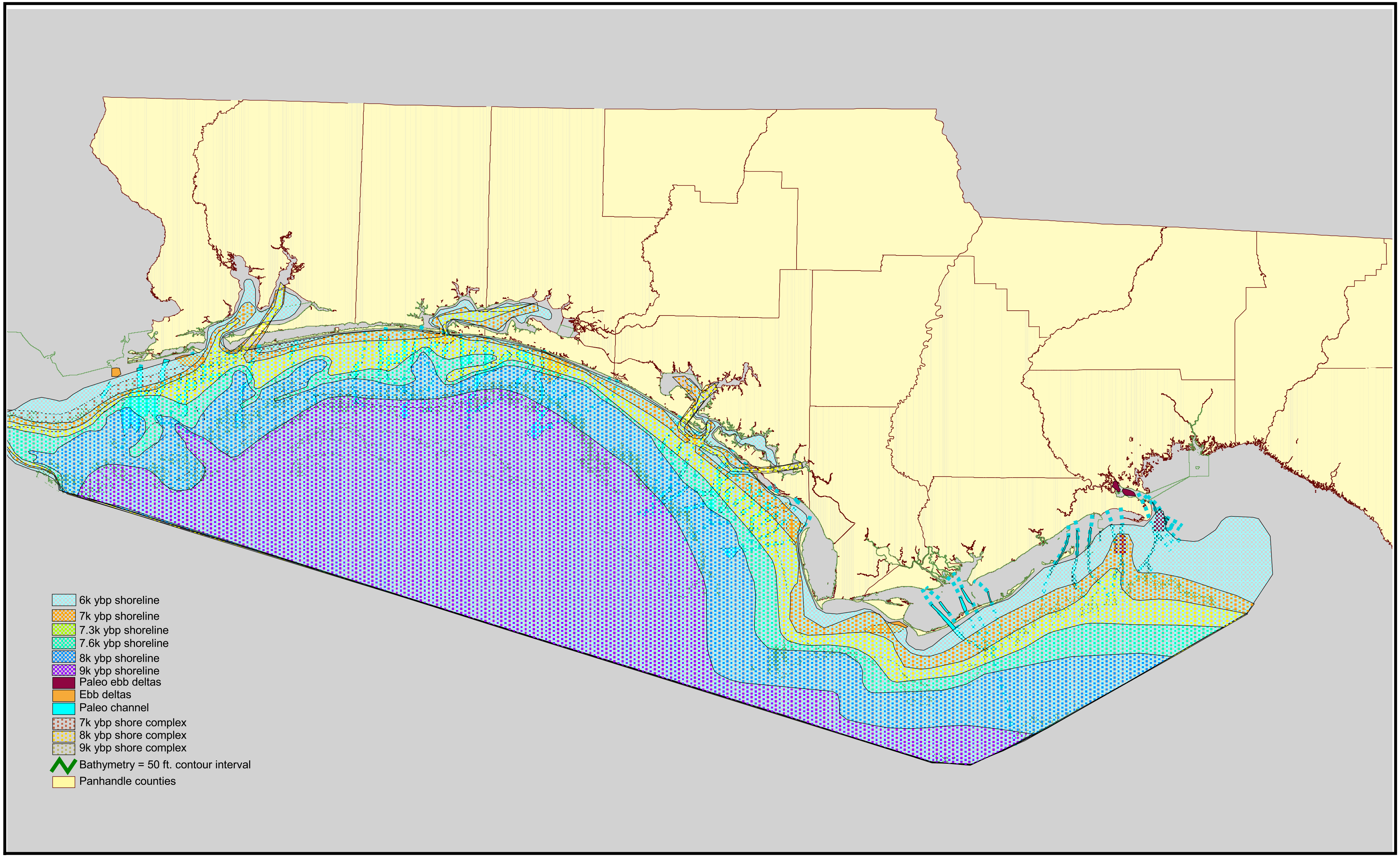
g:\FDEP\beachcoastal\deliverables\sealevel_changes.apr



Paleo Shoreline Position
7k ybp

FIGURE 3-4-11

g:\FDEP\beachcoastal\deliverables\sealevel_changes.apr



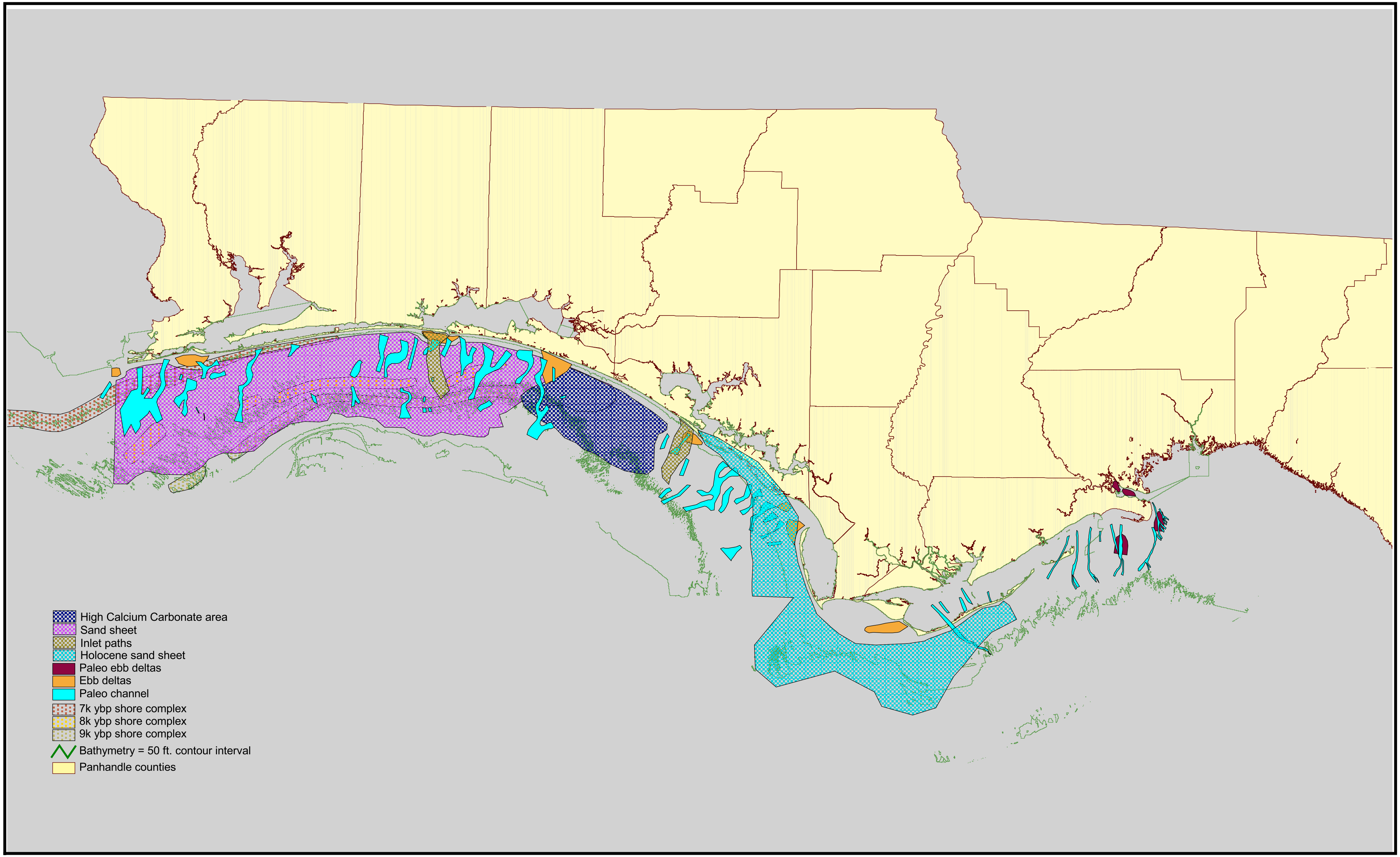
Paleo Shoreline Position
6k ybp

FIGURE 3-4-12

10 0 10 20 Miles

20 0 20 40 Kilometers

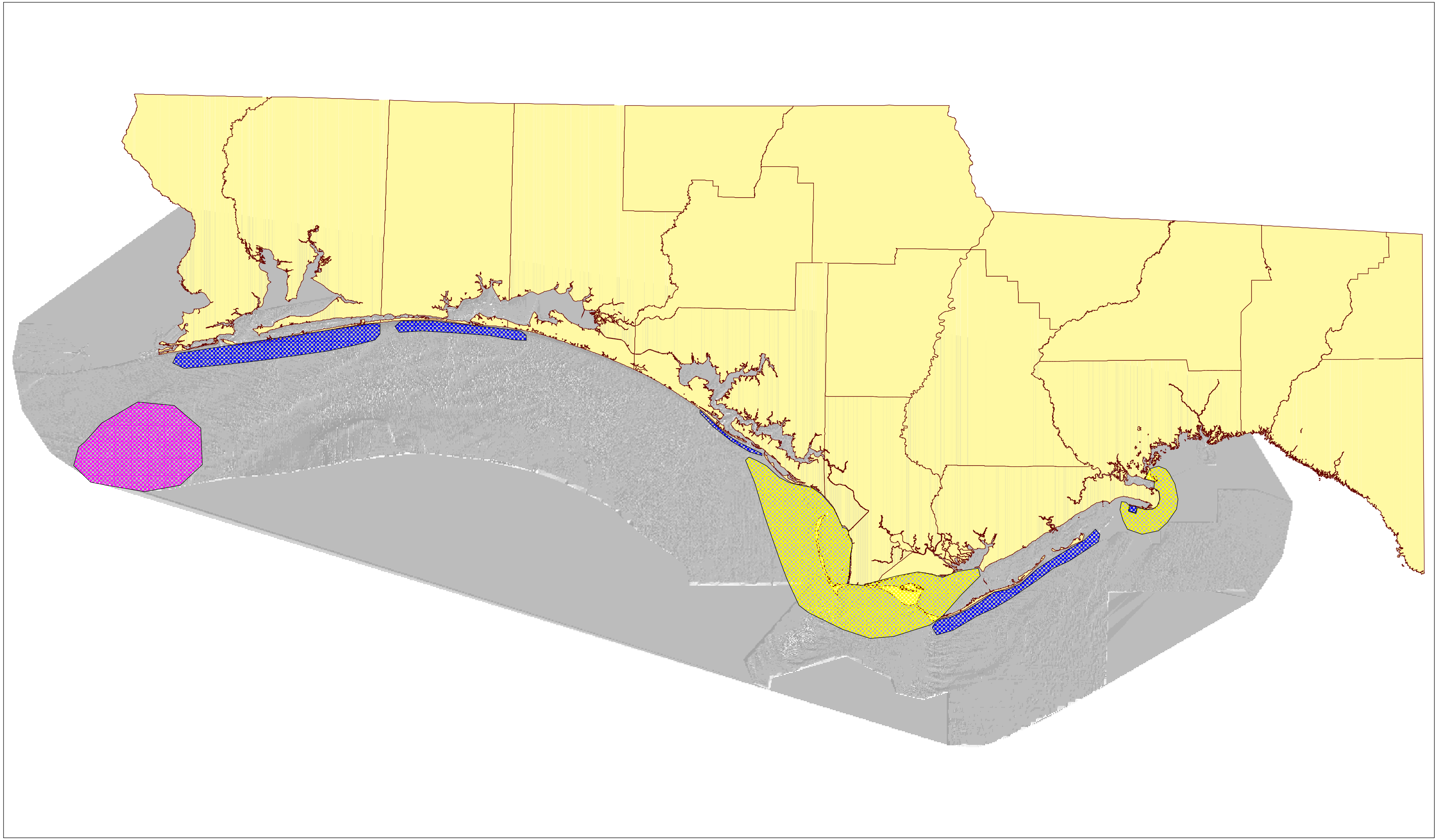
g:\FDEP\beachcoastal\deliverables\sealevel_changes.apr



Paleo Shoreline Position
< 6k ybp

FIGURE 3-4-13

g:\FDEP\beachcoastal\deliverables\sealevel_changes.apr

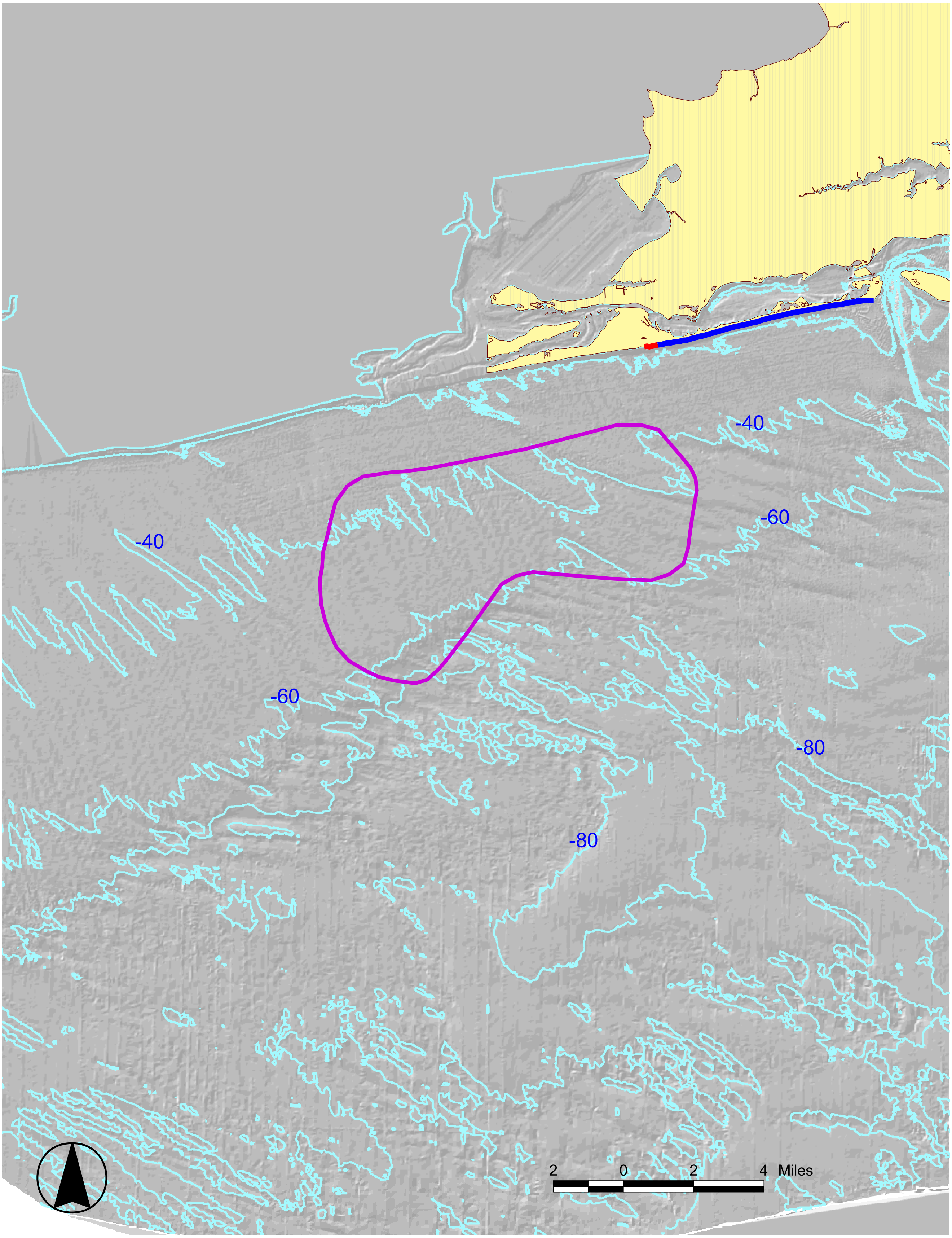


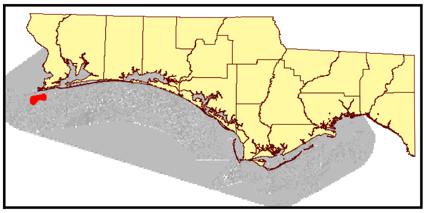
- ▨ Subject to ancient bay sediments at or near the sea floor
- ▨ Subject to fine to muddy delta deposits at or near the sea floor
- ▨ Subject to outcropping of ancient bay sediments due to barrier island retreat
- 🟨 Panhandle counties

Areas Where Sediments Unsuitable for Beach Nourishment May Occur

Figure 3-4-14

g:\FDEP\beachcoastal\deliverables\report_figures.apr





FEATURE A-1

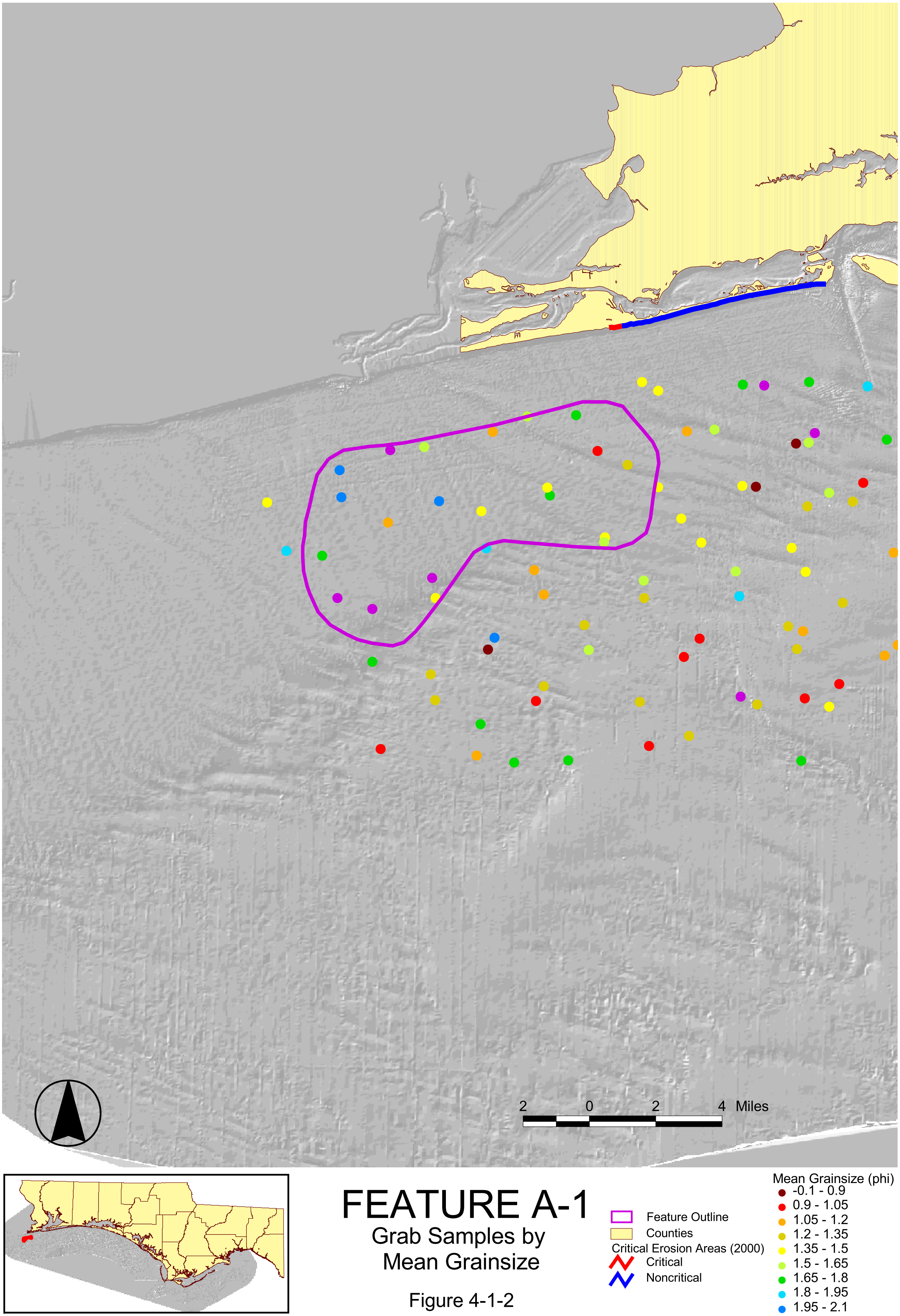
Contour Map

Figure 4-1-1

- ▭ Feature Outline
- ╱╲ Contour Line 20 contour interval
- 🟨 Counties

Critical Erosion Areas (2000)
- 🟥 Critical
- 🟦 Noncritical

g:\FDEP\beachcoastal\deliverables\report_figures.apr

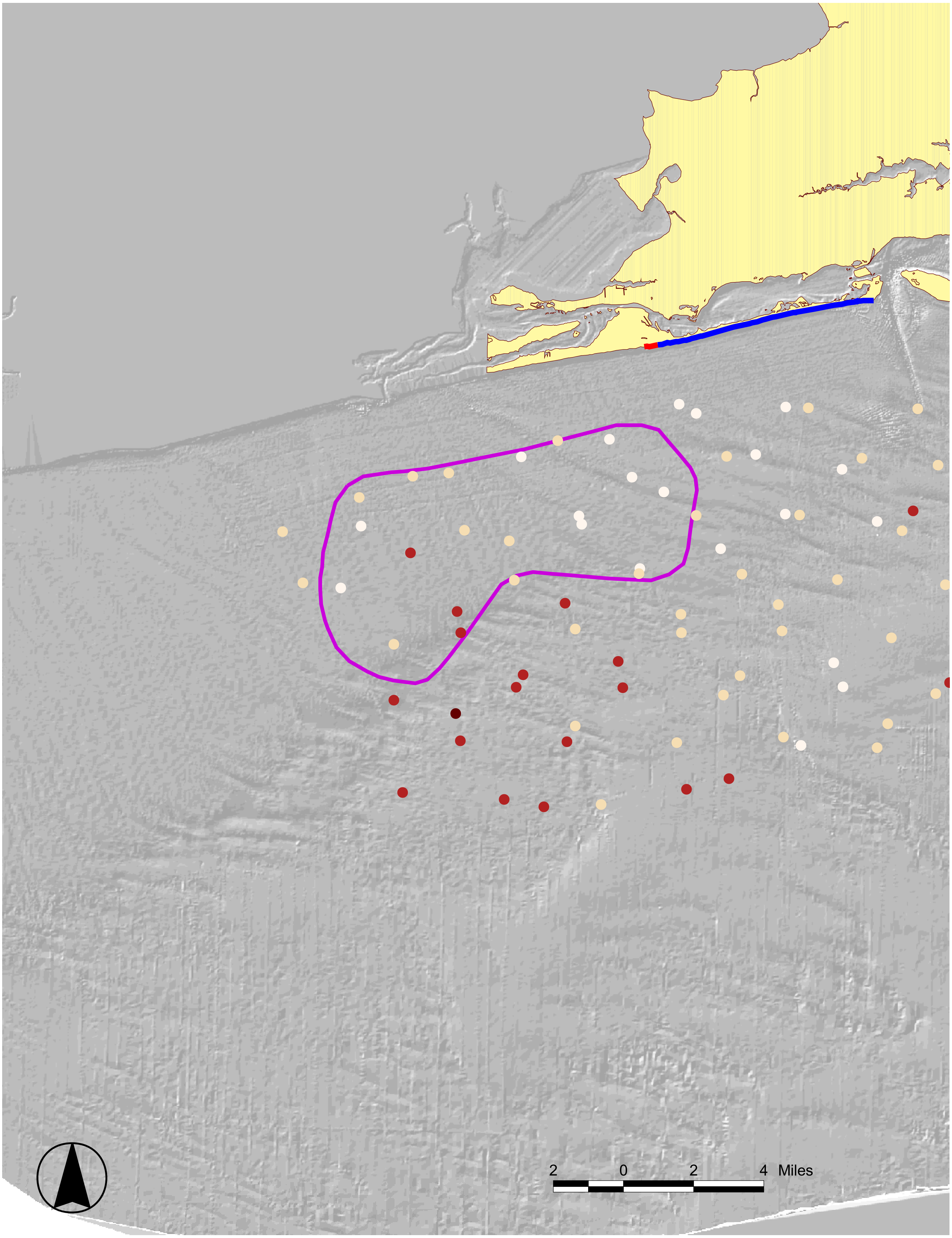


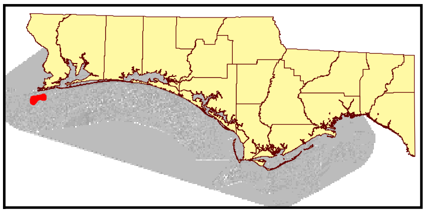
FEATURE A-1

Grab Samples by Mean Grainsize

Figure 4-1-2

g:\FDEP\beachcoastal\deliverables\report_figures.apr



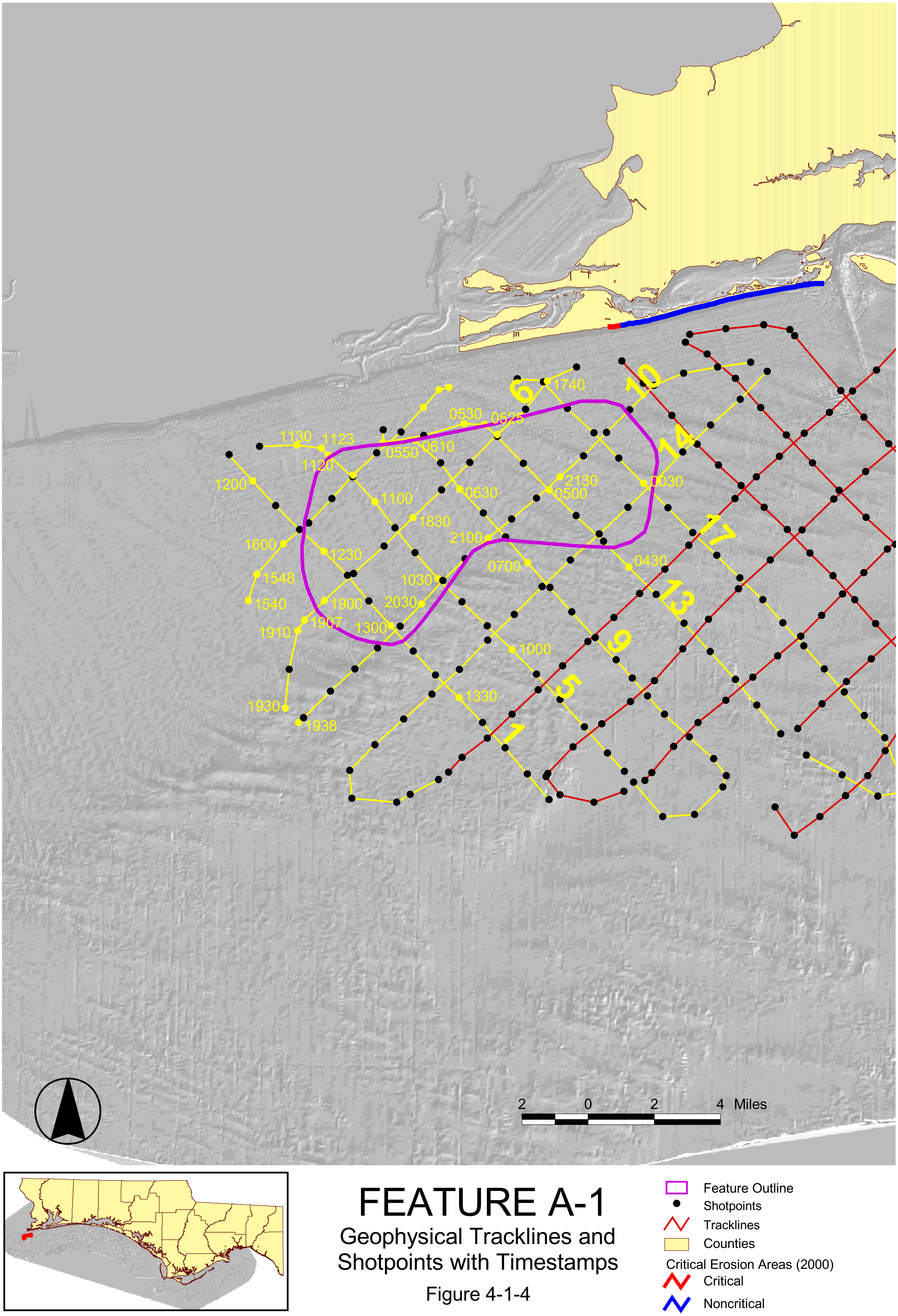


FEATURE A-1

Grab Samples Normalized by Munsell Value

Figure 4-1-3

g:\FDEP\beachcoastal\deliverables\report_figures.apr

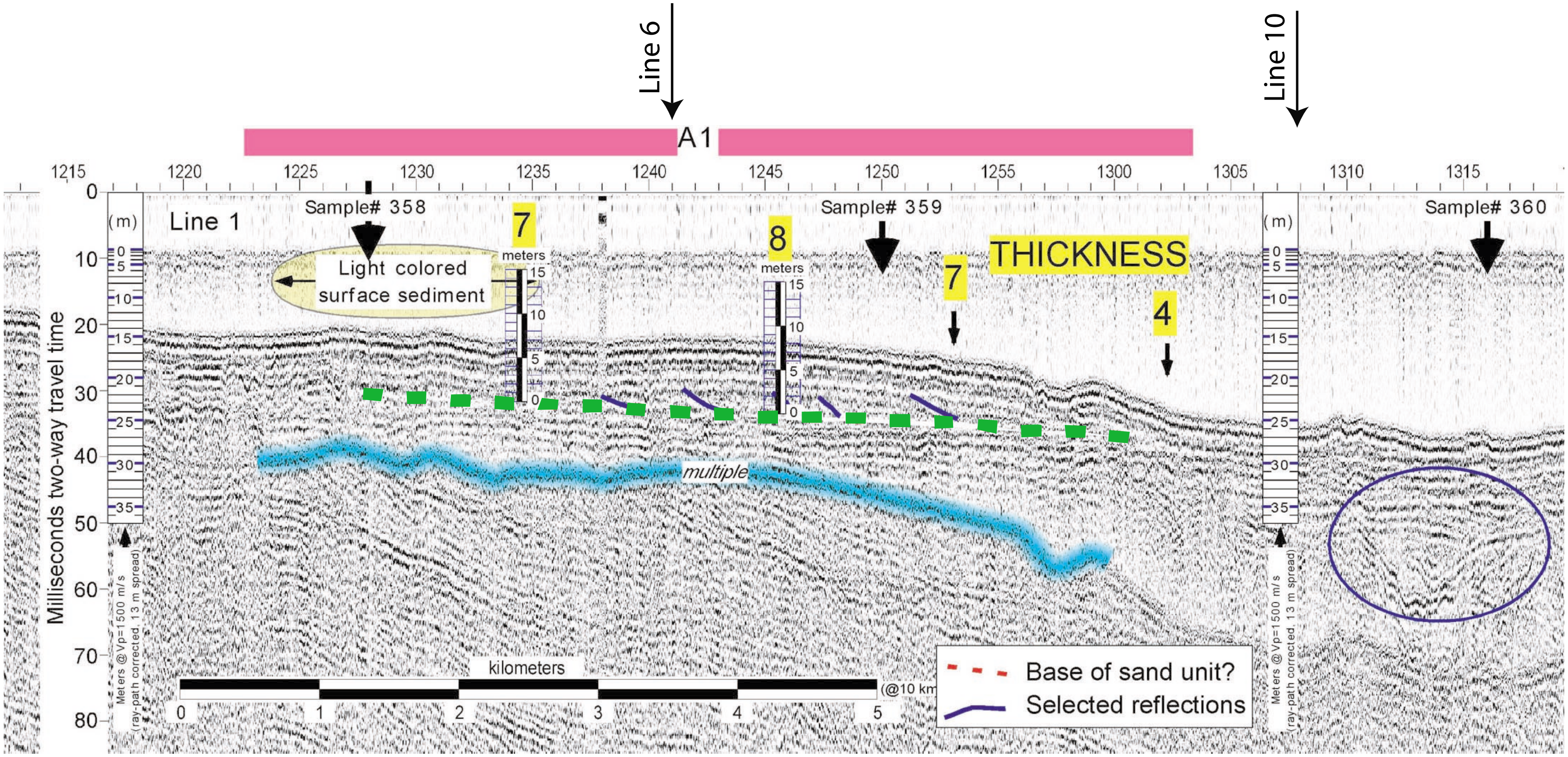


FEATURE A-1

Geophysical Tracklines and Shotpoints with Timestamps

Figure 4-1-4

g:\FDEP\beachcoastal\deliverables\report_figures.apr



Feature A-1

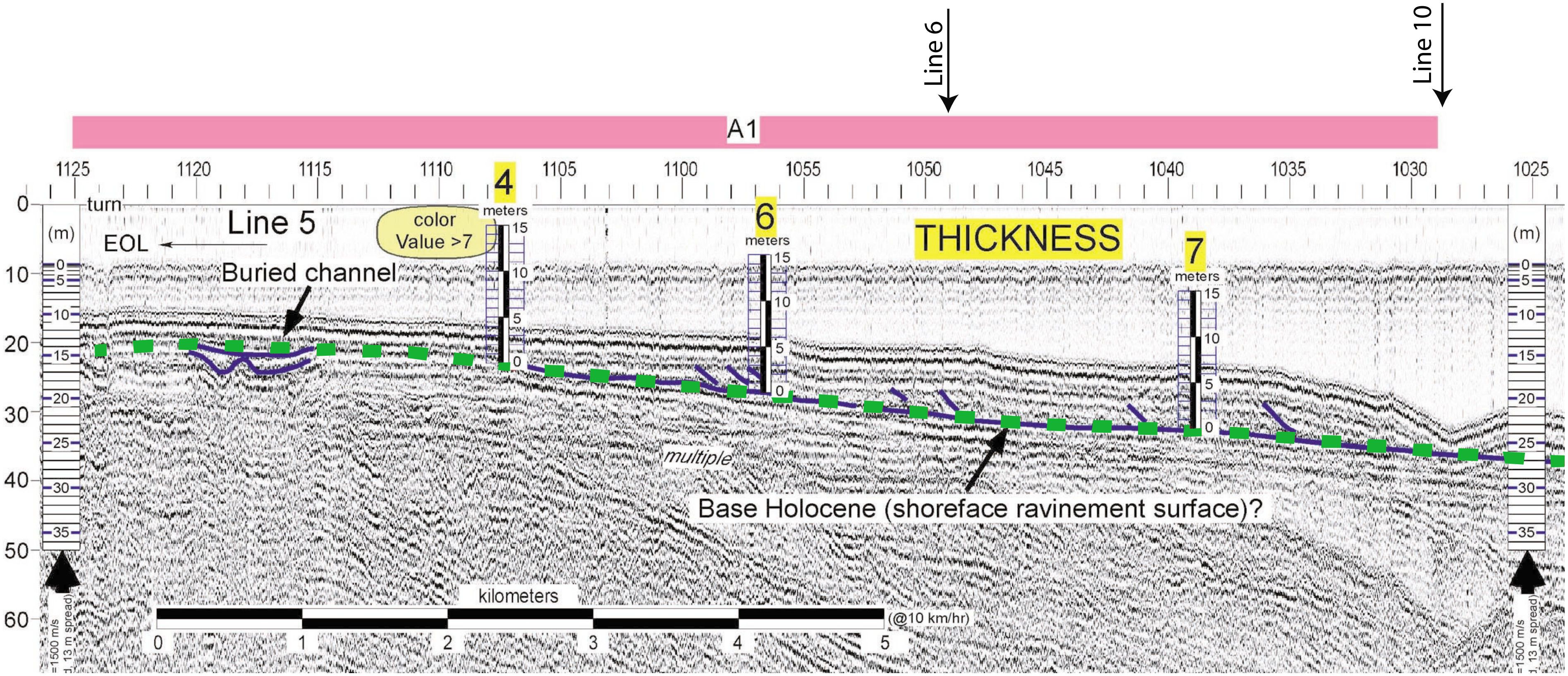
Line 1

Figure 4.1.5

LEGEND:

🟩 🟩 🟩 = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



Feature A-1

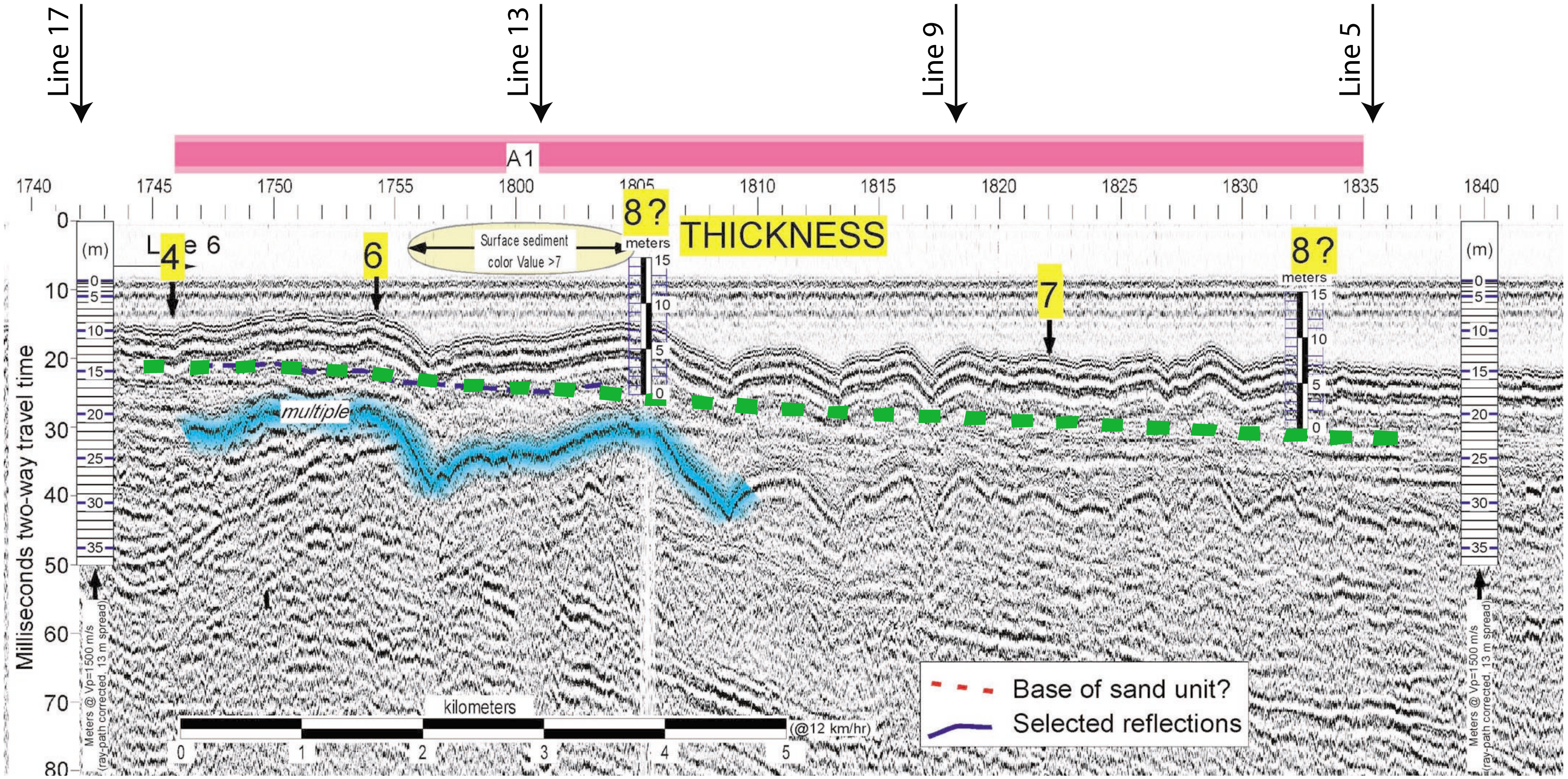
Line 5

Figure 4.1.6

LEGEND:

🟩 🟩 🟩 = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



Feature A-1

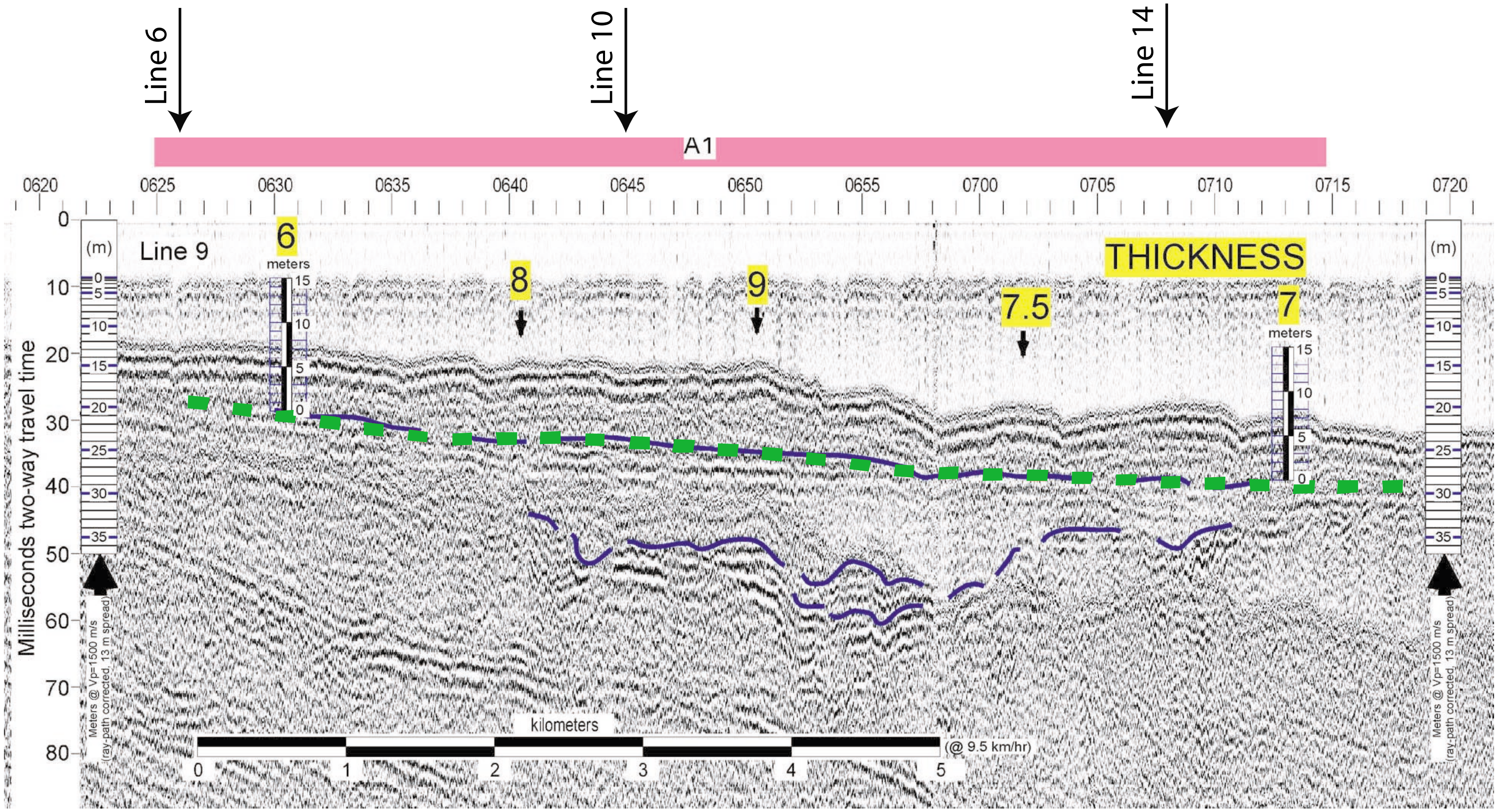
Line 6

Figure 4.1.7

LEGEND:

🟩 🟩 🟩 = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



Feature A-1

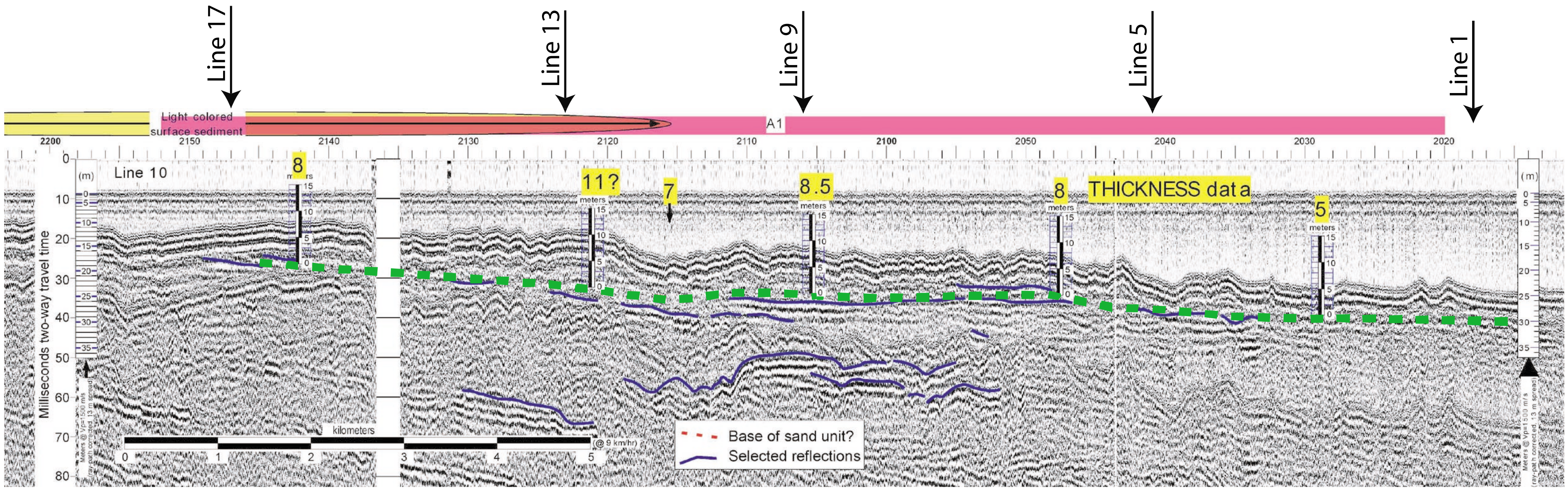
Line 9

Figure 4.1.8

LEGEND:

- - - = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



Feature A-1

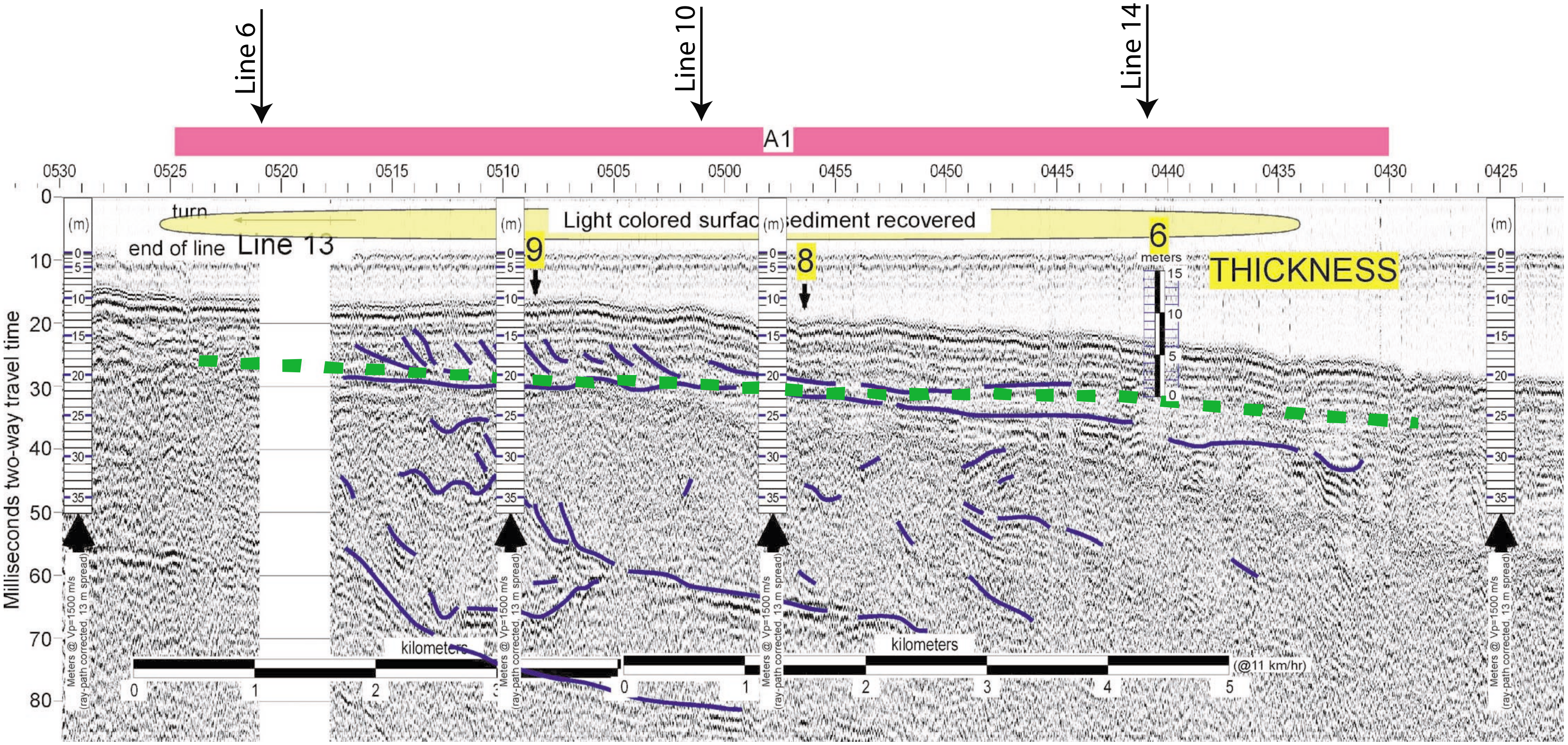
Line 10

Figure 4.1.9

LEGEND:

🟩 🟩 🟩 = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



Feature A-1

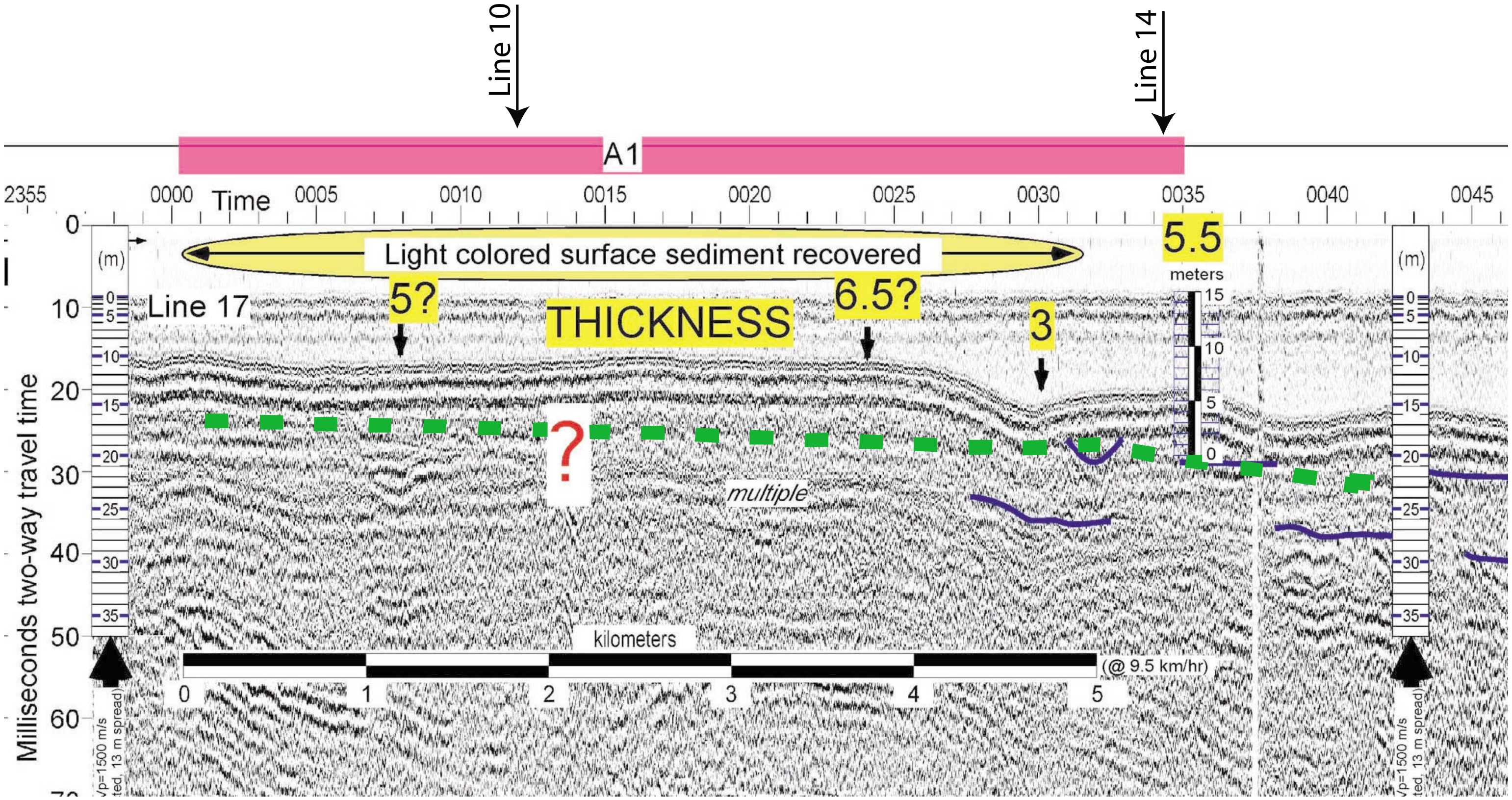
Line 13

Figure 4.1.10

LEGEND:

▬ ▬ ▬ = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



Feature A-1

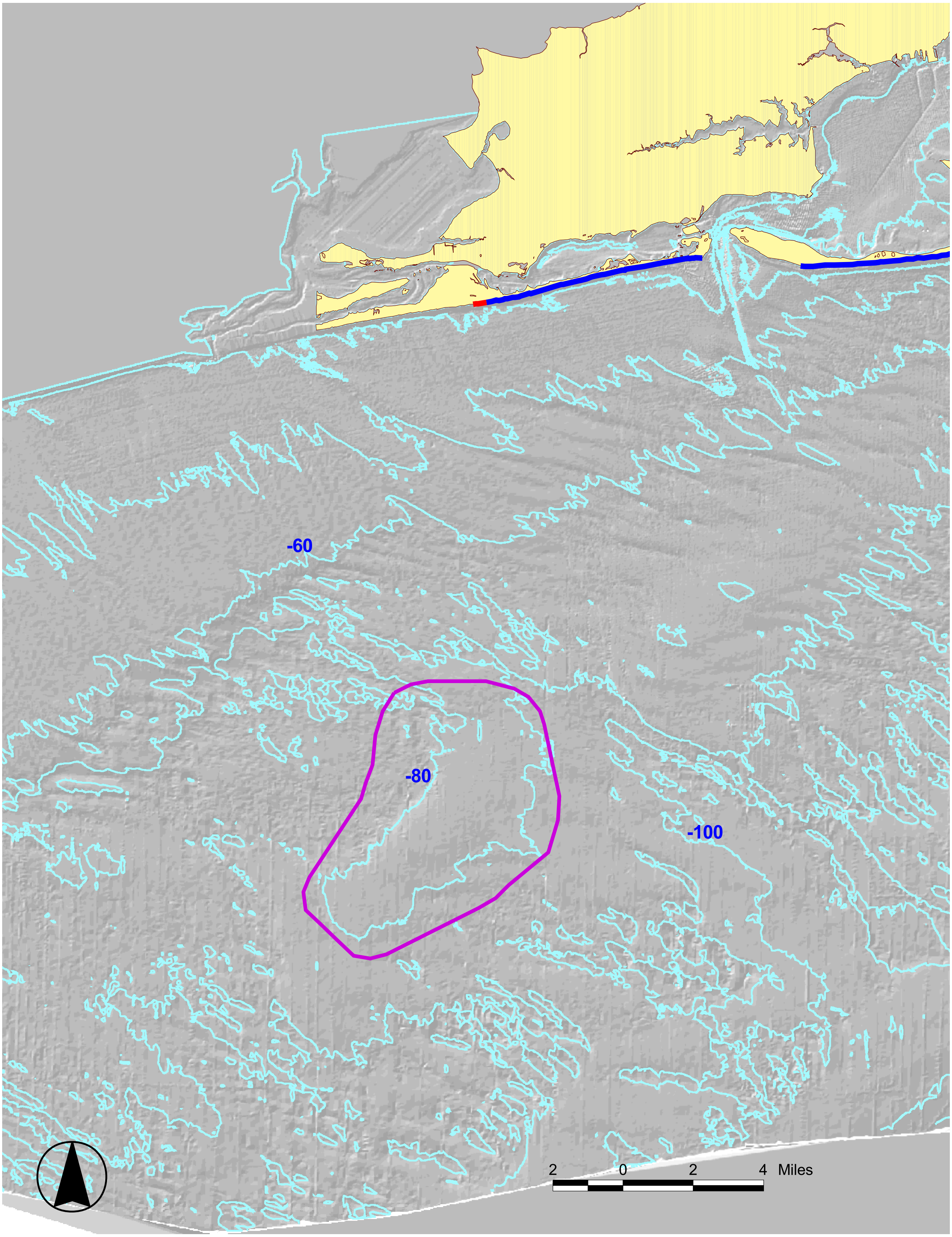
Line 17

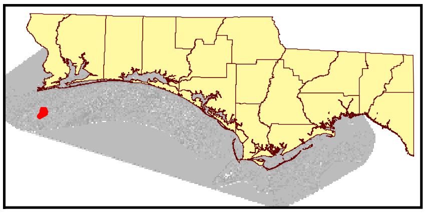
Figure 4.1.11

LEGEND:

▬ ▬ ▬ = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line





FEATURE W-1

Contour Map

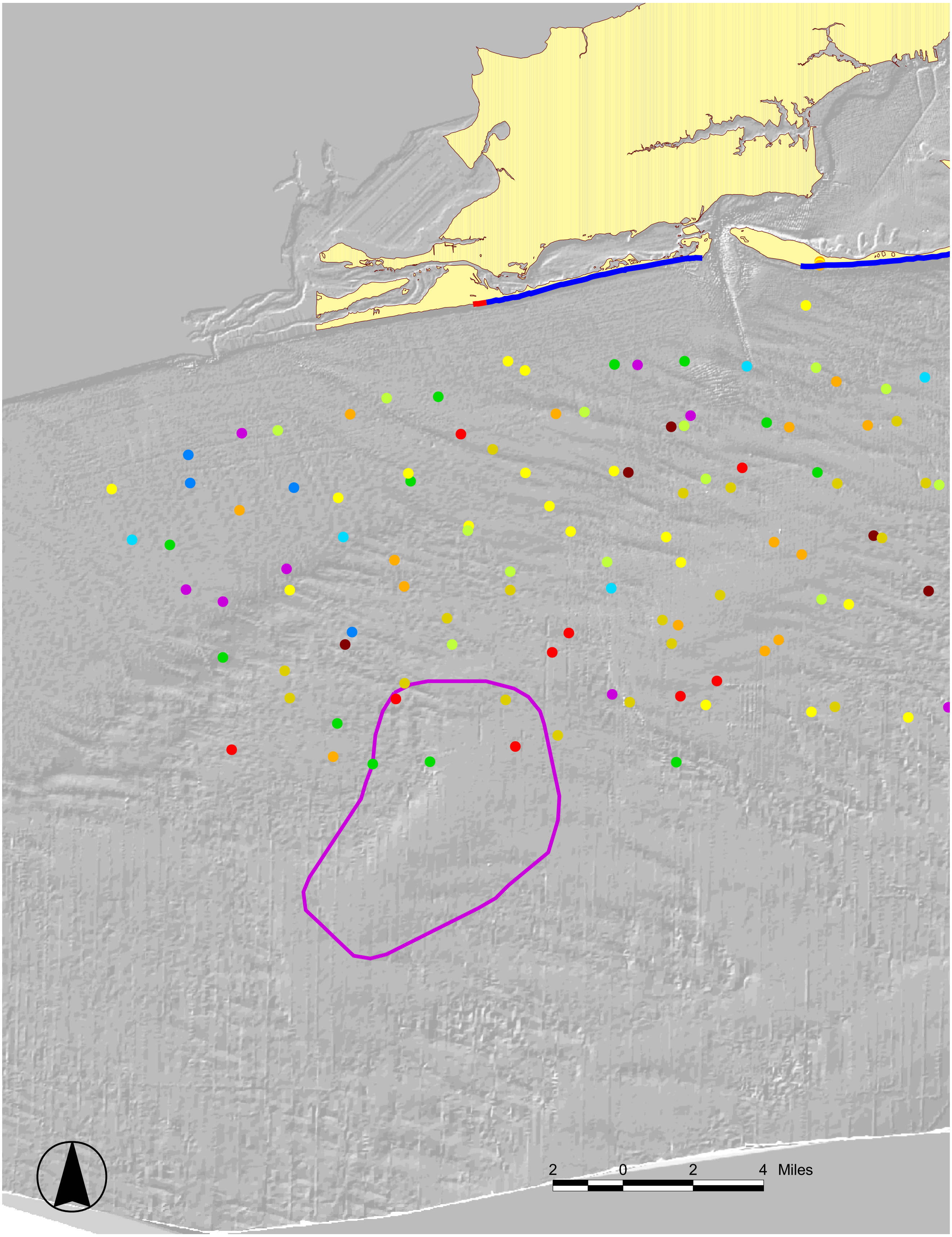
Figure 4-2-1

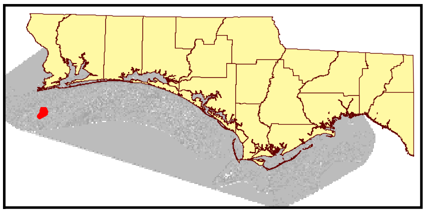
- ▭ Feature Outline
- Contour Line 20 contour interval
- 🟨 Counties

Critical Erosion Areas (2000)

- Critical
- Noncritical

g:\FDEP\beachcoastal\deliverables\report_figures.apr



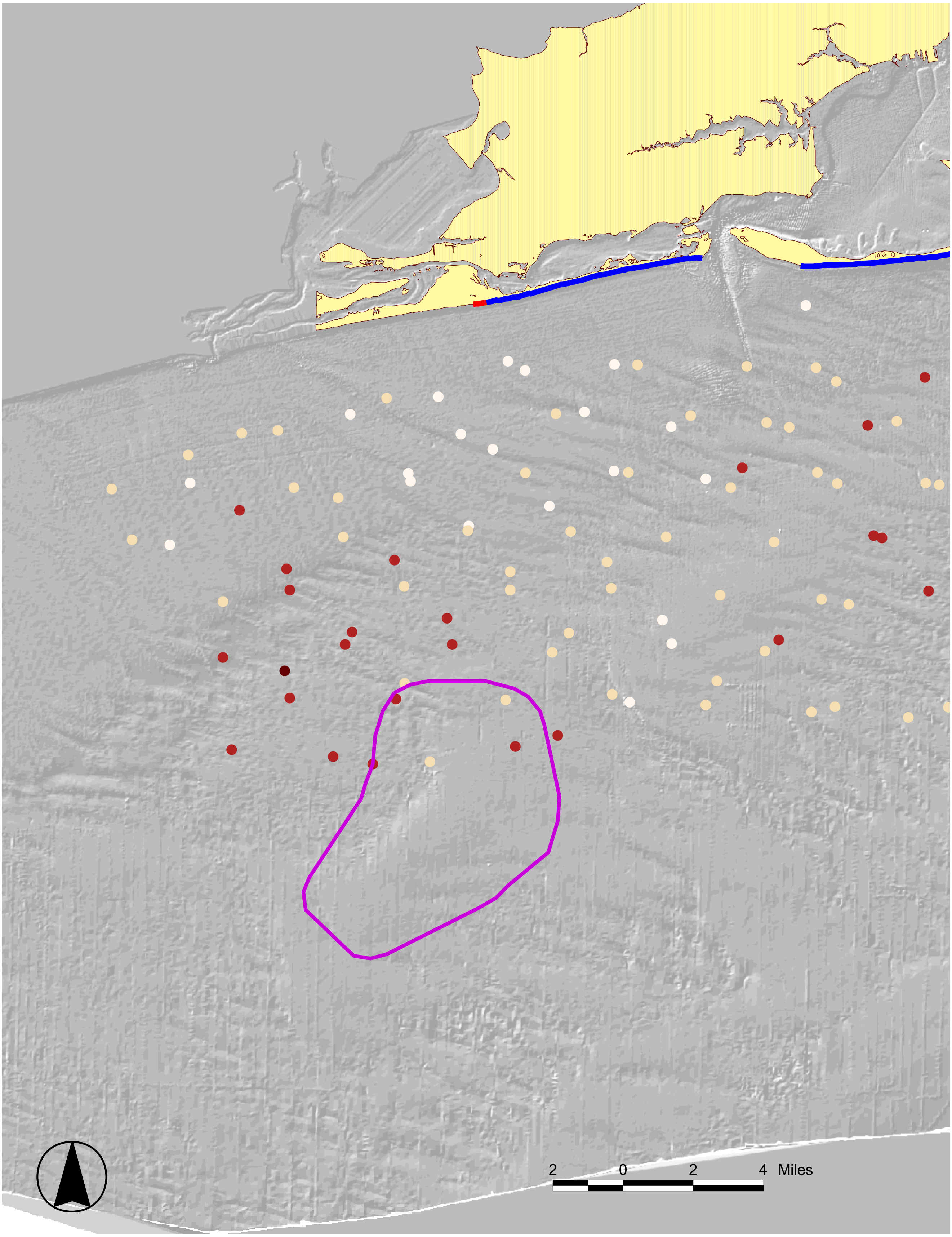


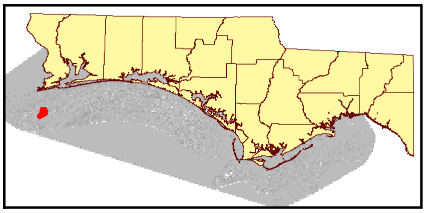
FEATURE W-1

Grab Samples by Mean Grainsize

Figure 4-2-2

g:\FDEP\beachcoastal\deliverables\report_figures.apr





FEATURE W-1

Grab Samples Normalized by Munsell Value

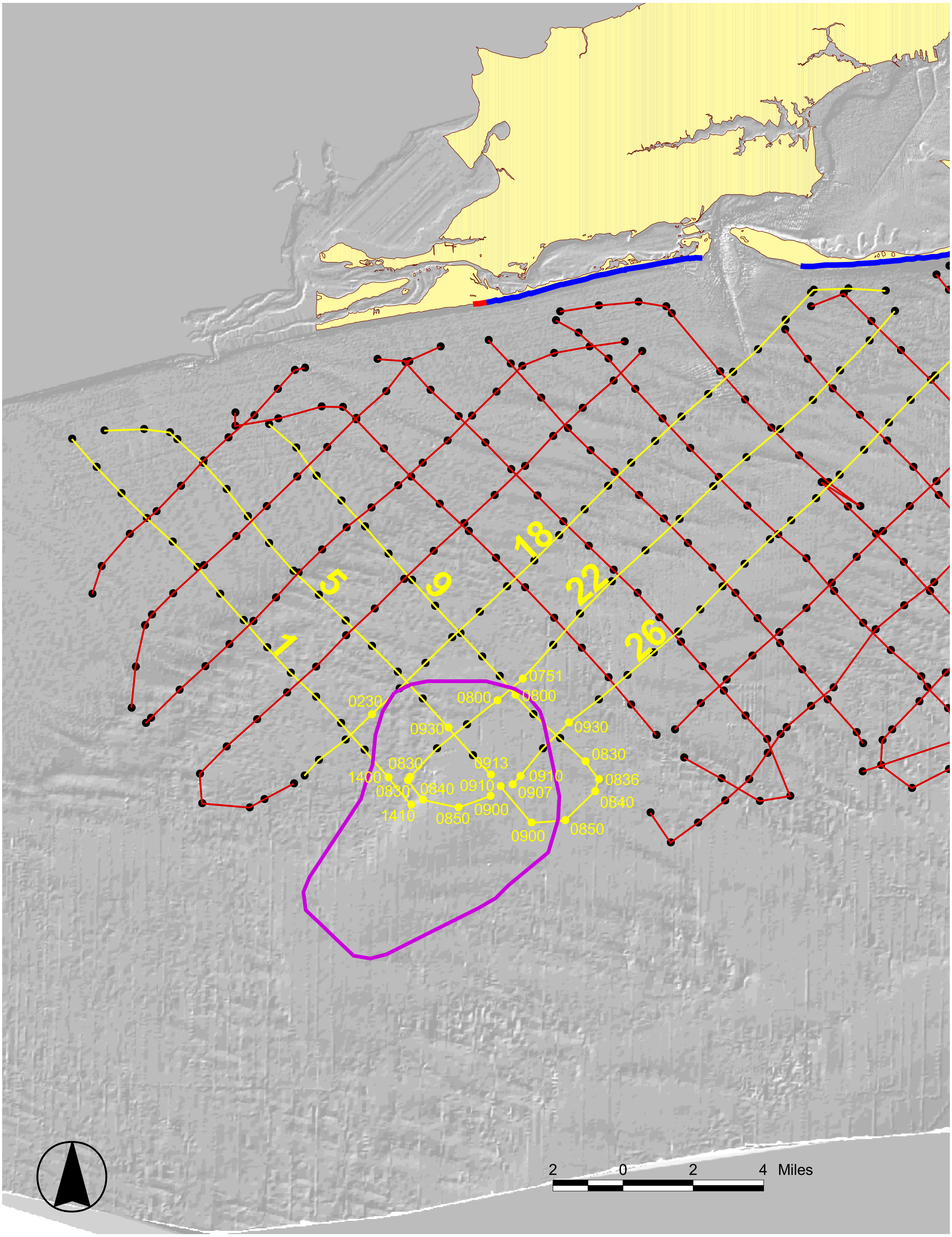
Figure 4-2-3

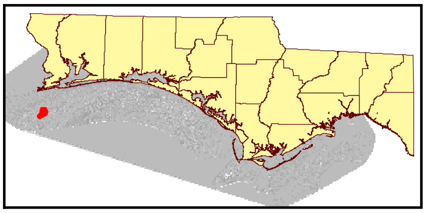
Mean grainsize by Munsell Value
- ● 1 - 5
- ● 5.1 - 6
- ● 6.1 - 7
- ● 7.1 - 11

☐ Feature Outline
▨ Counties

Critical Erosion Areas (2000)
- Critical
- Noncritical

g:\FDEP\beachcoastal\deliverables\report_figures.apr





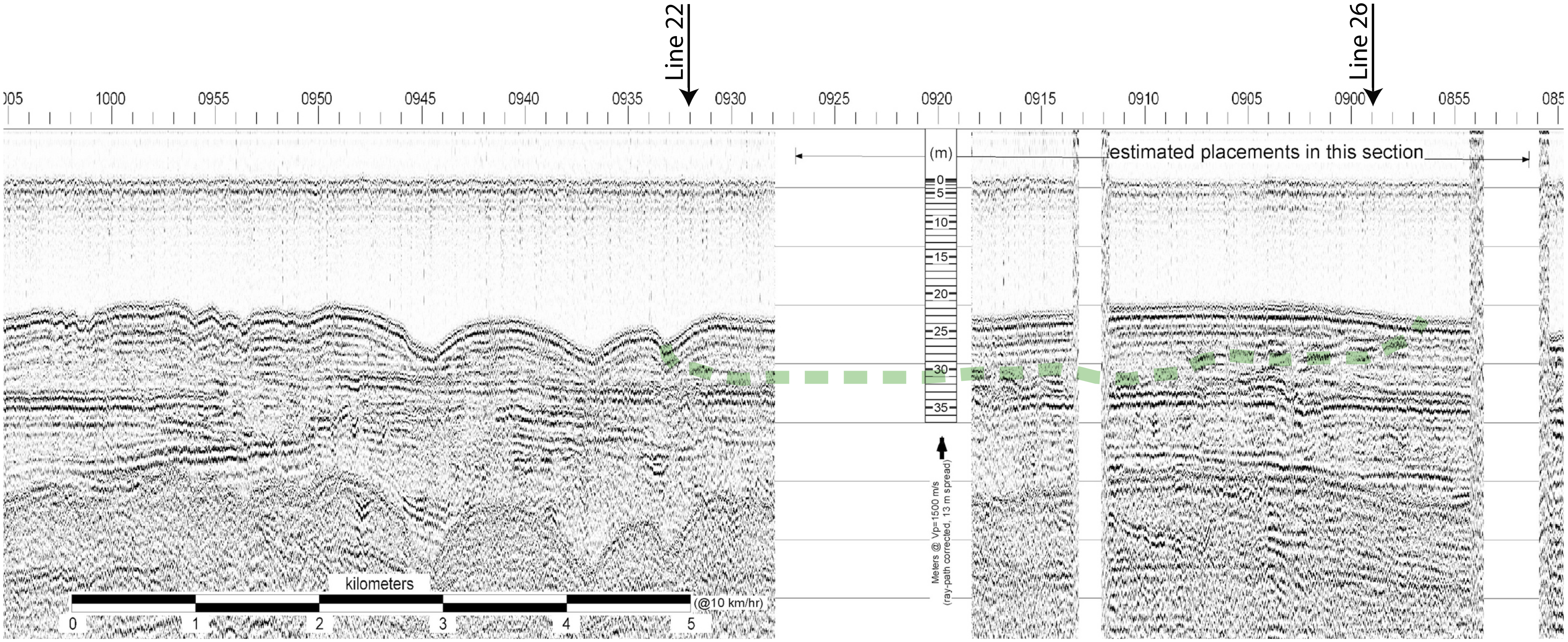
FEATURE W-1

Geophysical Tracklines and Shotpoints with Timestamps

Figure4-2-4

▭ Feature Outline
● Shotpoints
╱╲ Tracklines
▭ Counties
Critical Erosion Areas (2000)
🟥 Critical
🟦 Noncritical

g:\FDEP\beachcoastal\deliverables\report_figures.apr



Feature W-1

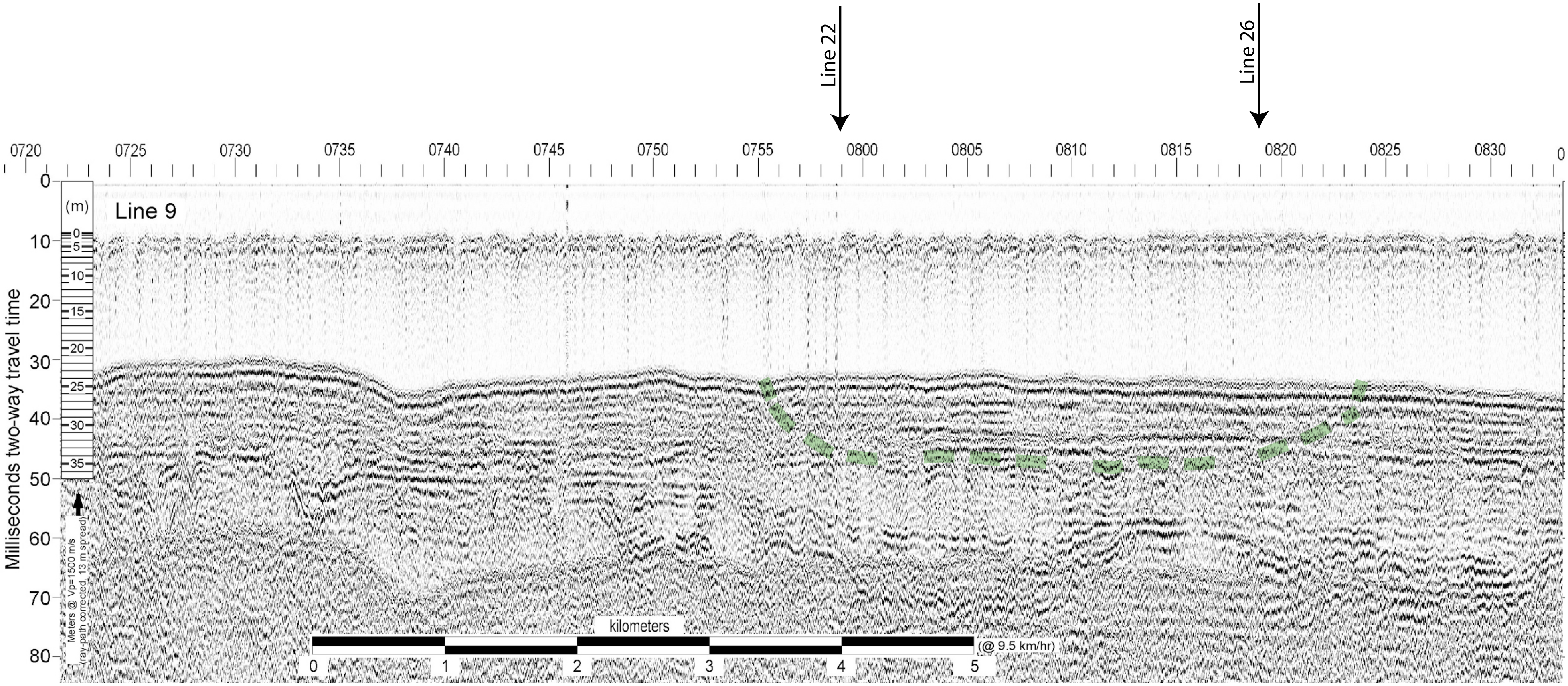
Line 5

Figure 4.2.5

LEGEND:

▬ ▬ ▬ = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



Feature W-1

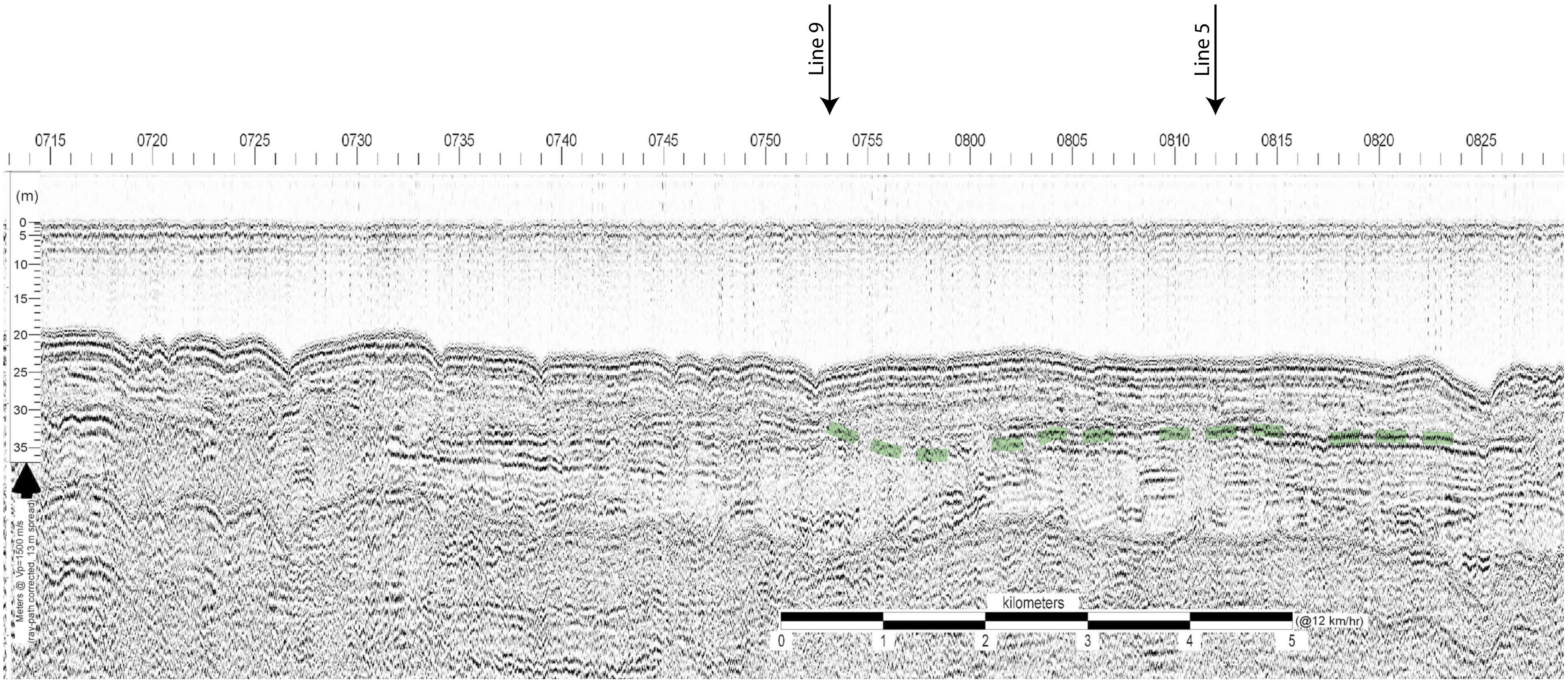
Line 9

Figure 4.2.6

LEGEND:

🟩 🟩 🟩 = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



Feature W-1

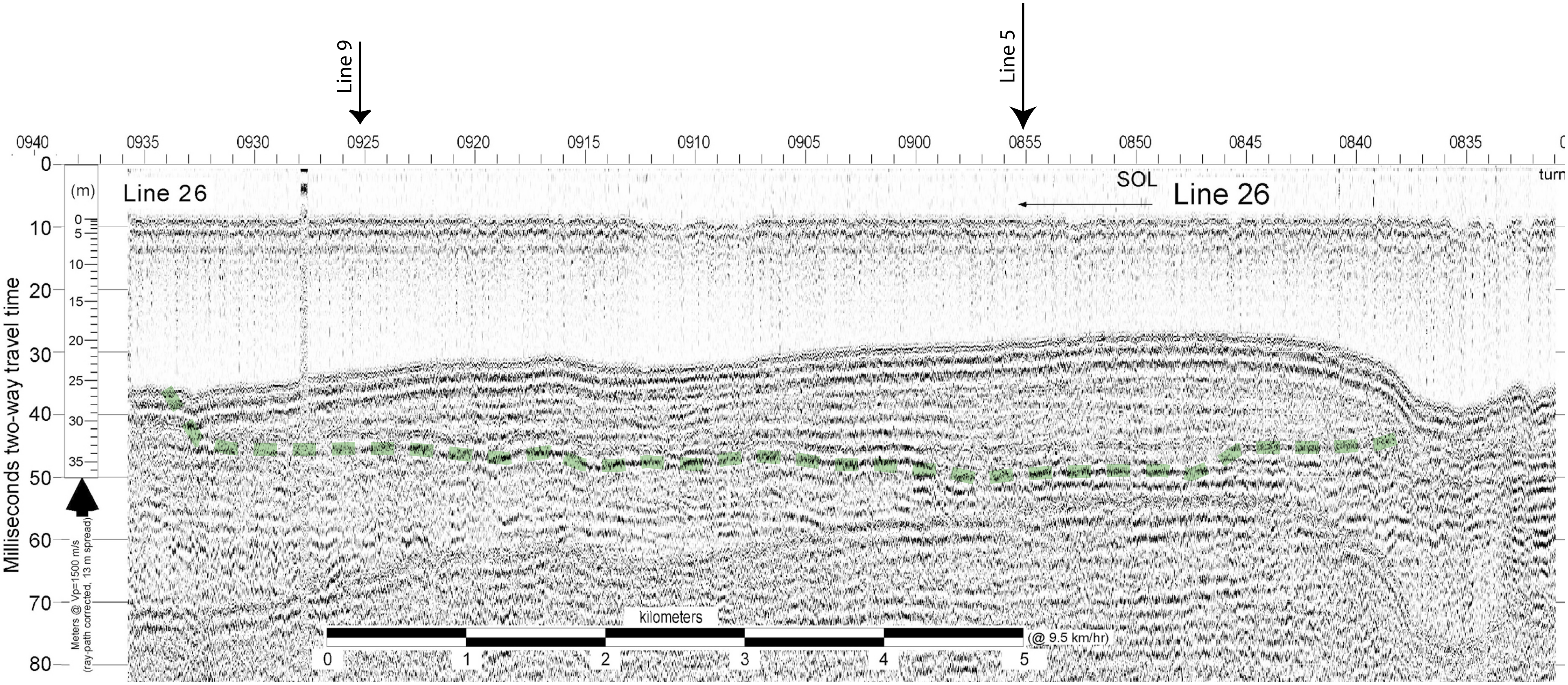
Line 22

Figure 4.2.7

LEGEND:

\- - - = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



Feature W-1

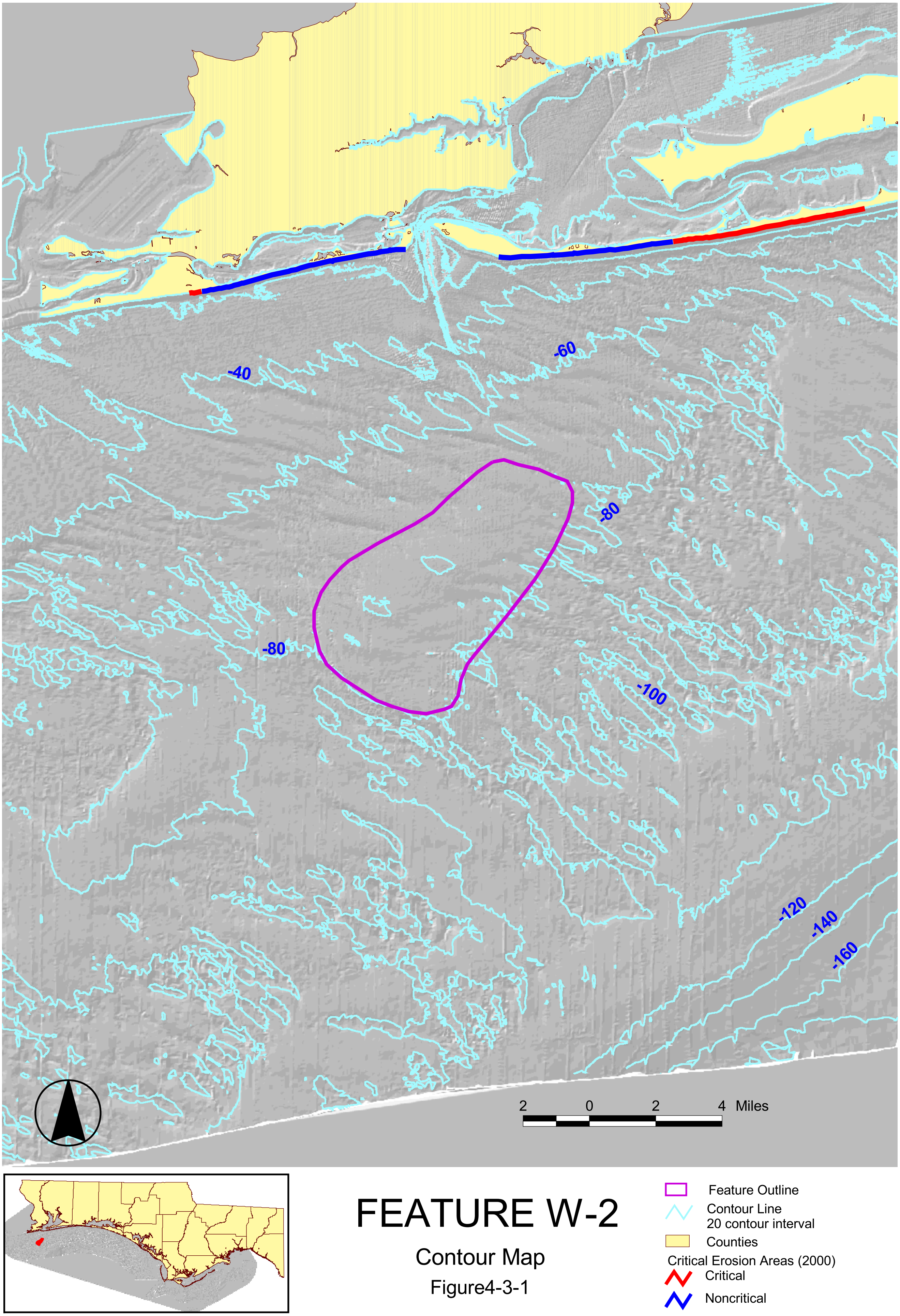
Line 26

Figure 4.2.8

LEGEND:

🟩 🟩 🟩 = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line

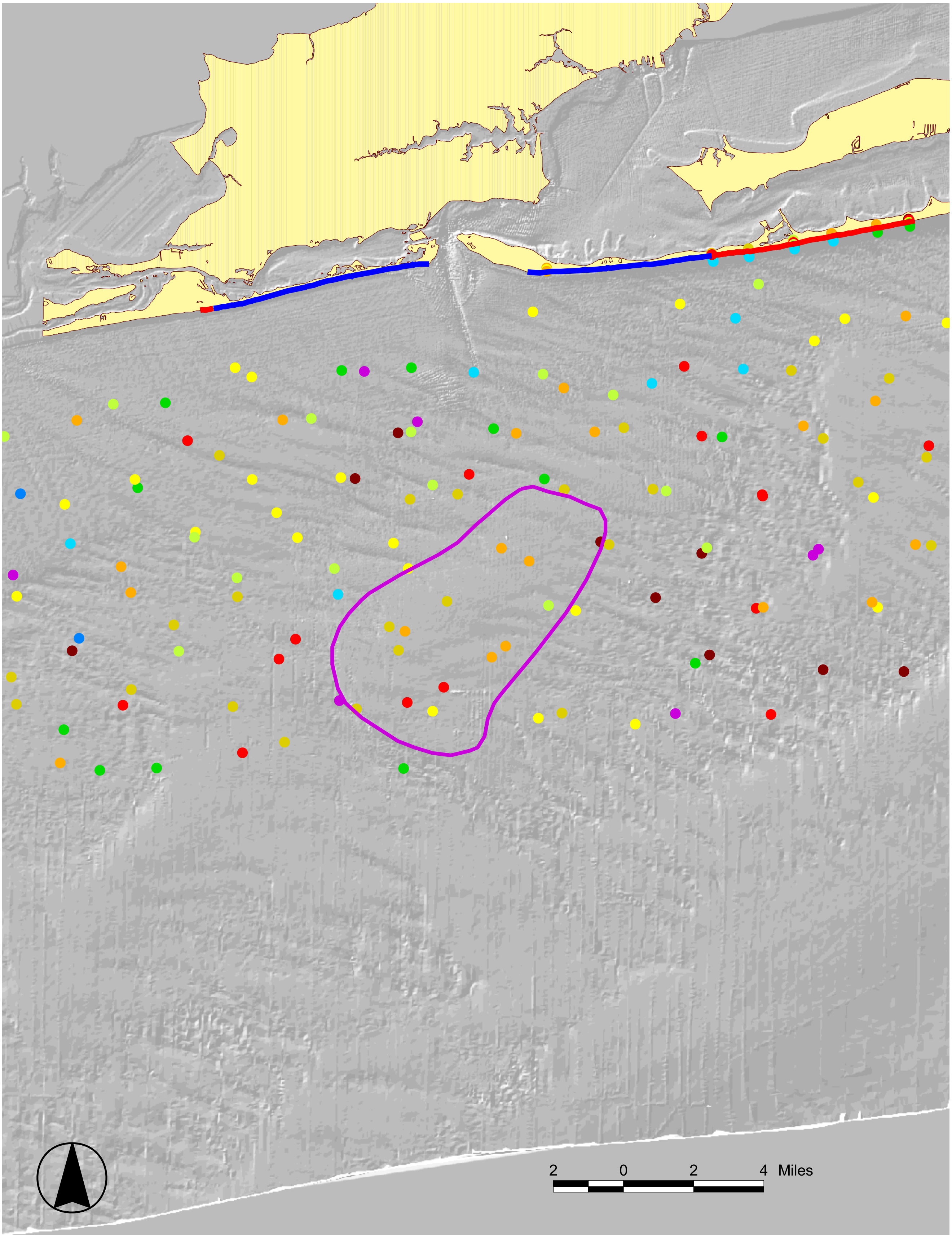


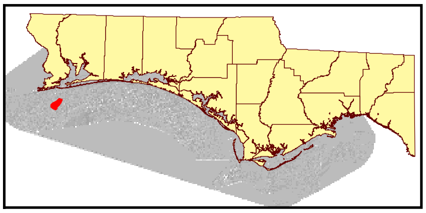
FEATURE W-2

Contour Map

Figure4-3-1

g:\FDEP\beachcoastal\deliverables\report_figures.apr



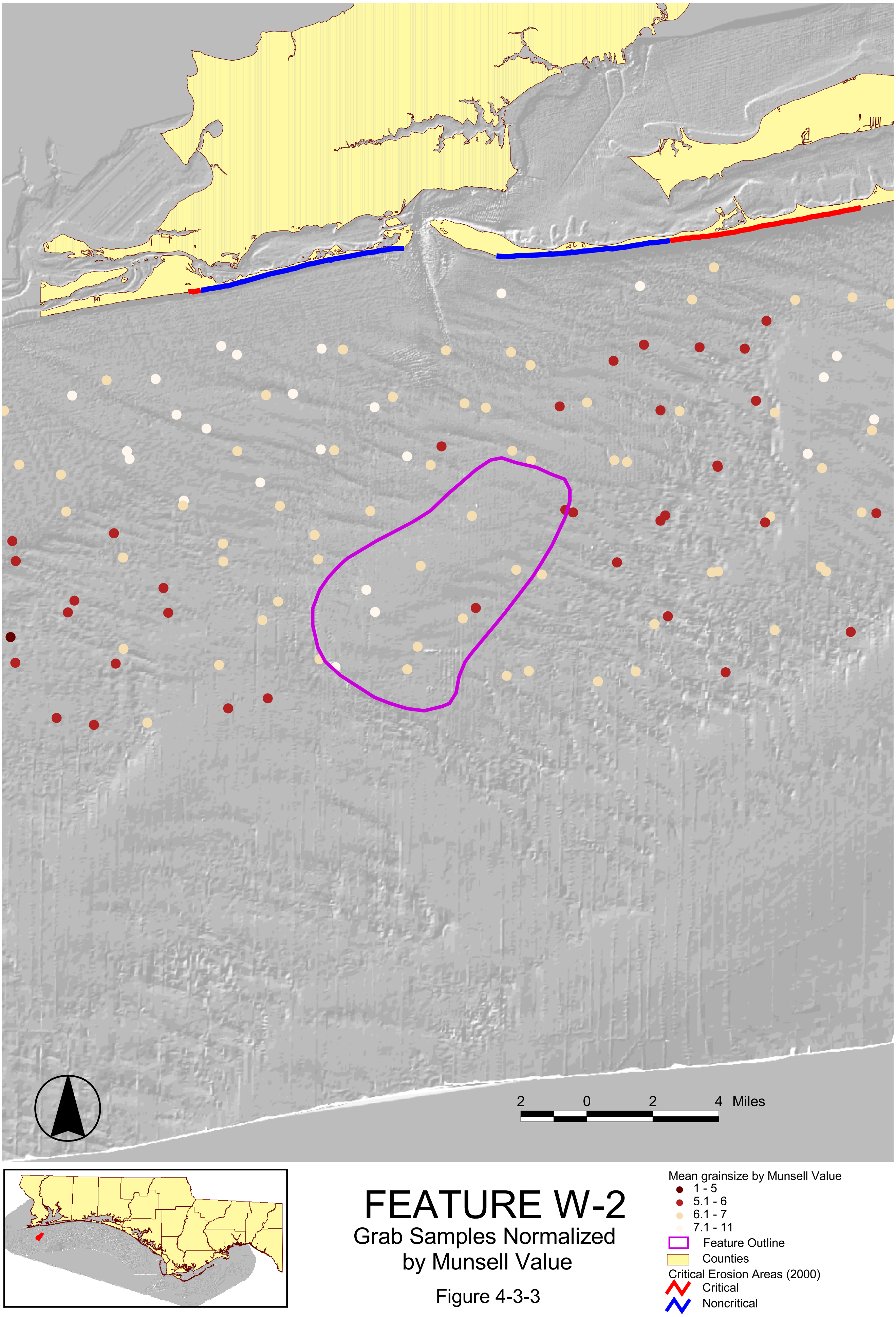


FEATURE W-2

Grab Samples by Mean Grainsize

Figure 4-3-2

g:\FDEP\beachcoastal\deliverables\report_figures.apr

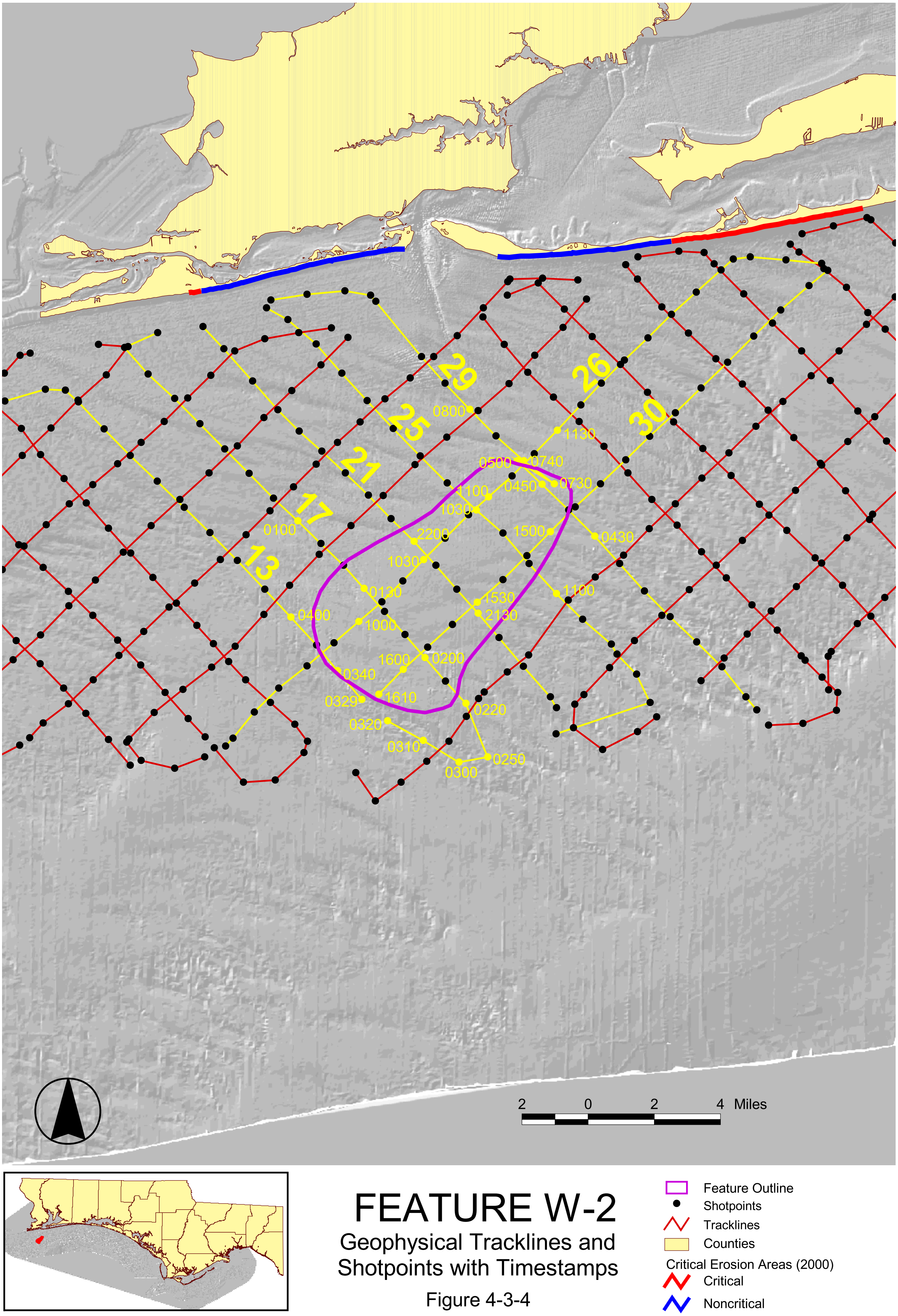


FEATURE W-2

Grab Samples Normalized by Munsell Value

Figure 4-3-3

g:\FDEP\beachcoastal\deliverables\report_figures.apr

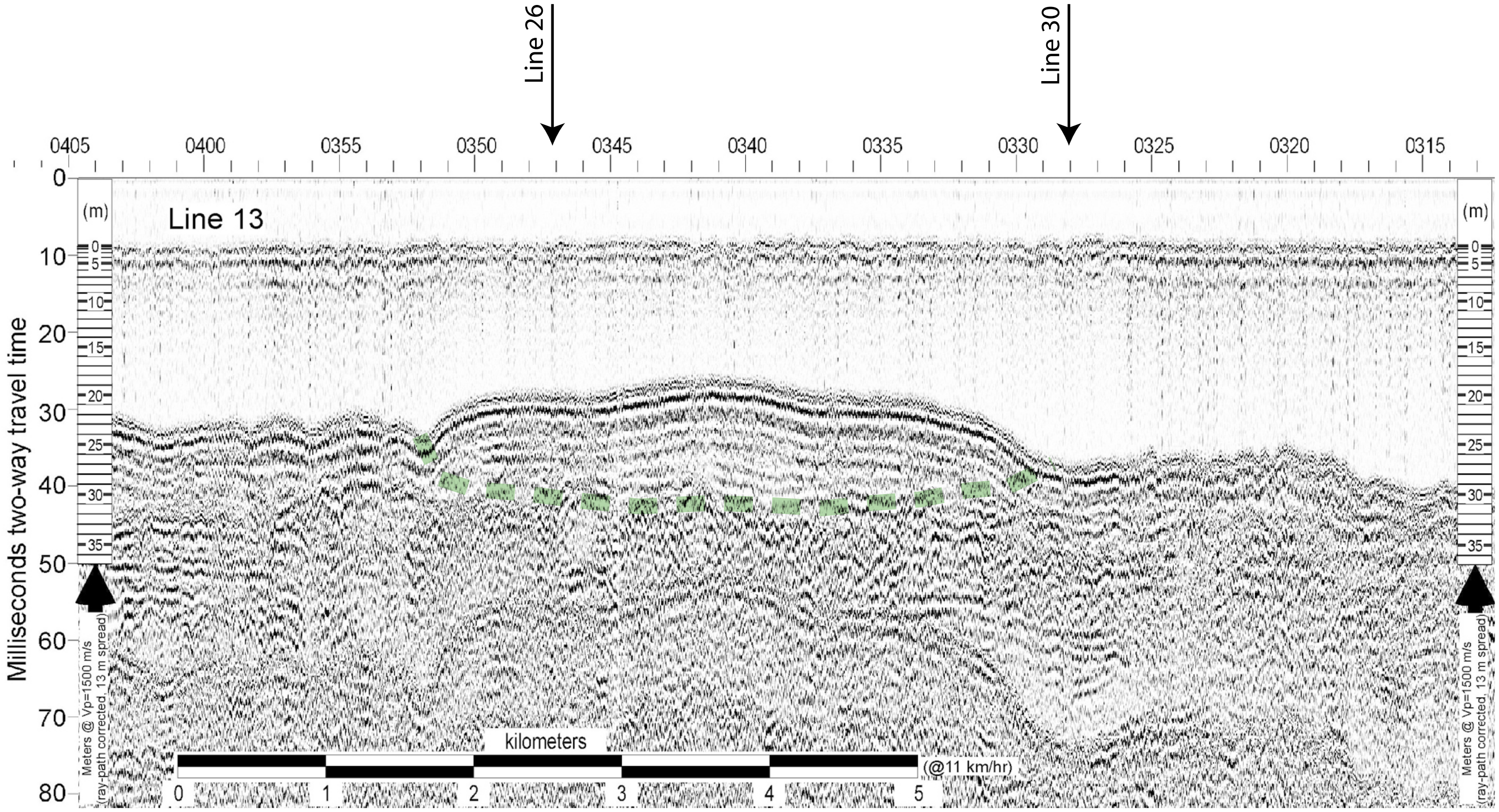


FEATURE W-2

Geophysical Tracklines and Shotpoints with Timestamps

Figure 4-3-4

g:\FDEP\beachcoastal\deliverables\report_figures.apr



Feature W-2

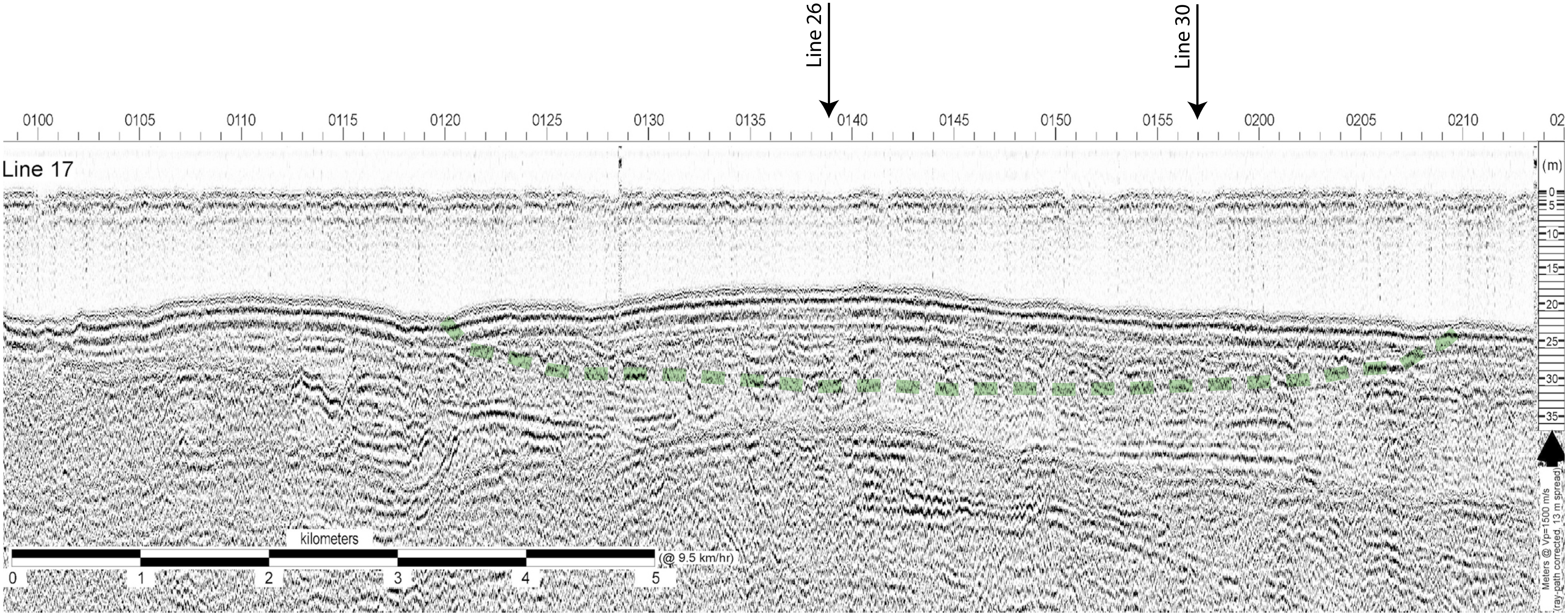
Line 13

Figure 4.3.5

LEGEND:

🟩 🟩 🟩 = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



Feature W-2

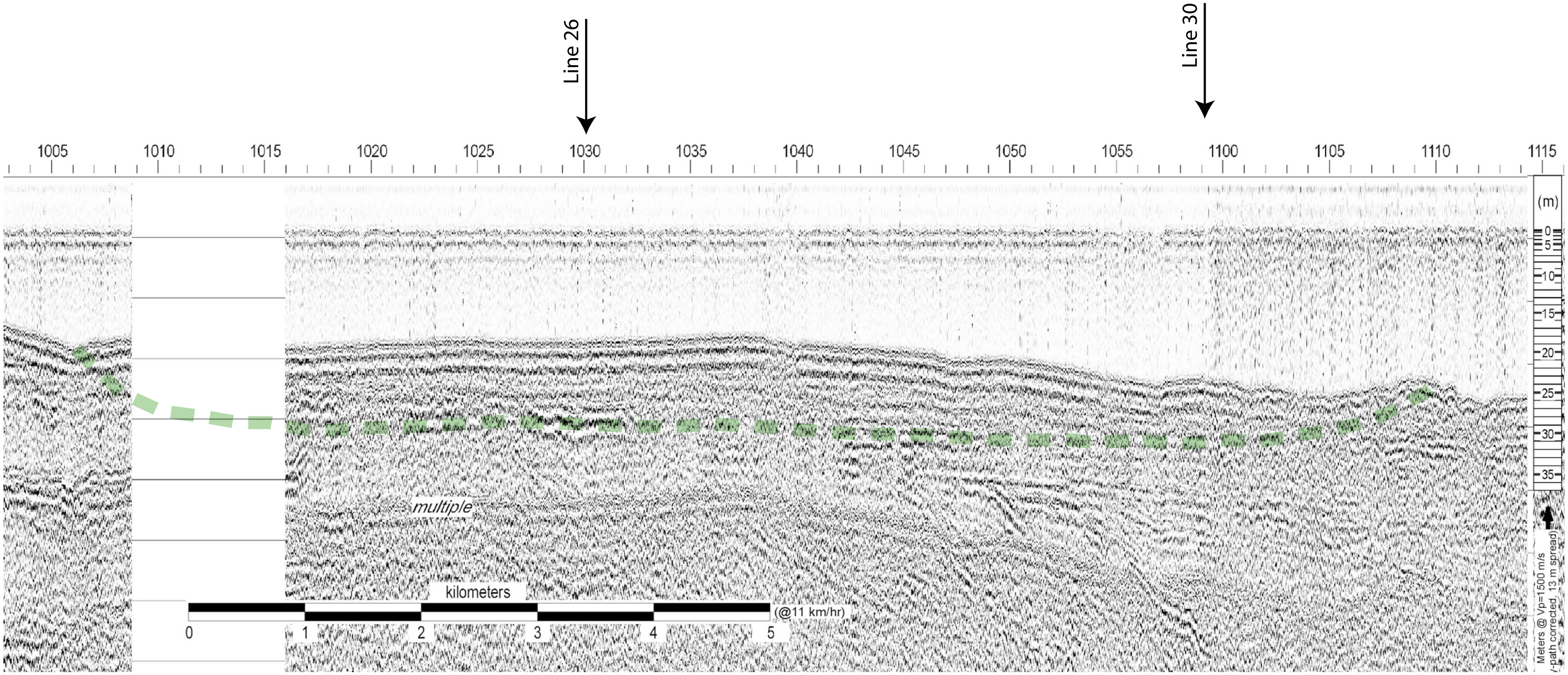
Line 17

Figure 4.3.6

LEGEND:

▬ ▬ ▬ = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



Feature W-2

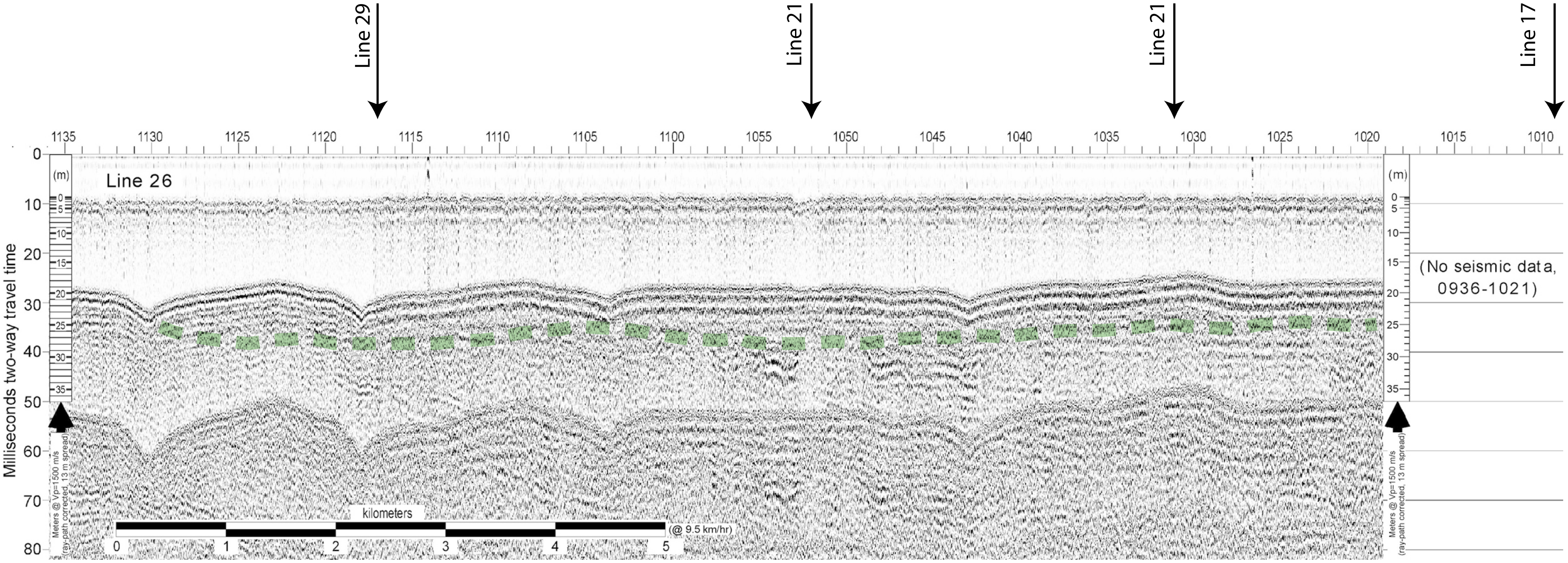
Line 25

Figure 4.3.7

LEGEND:

– – – = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



Feature W-2

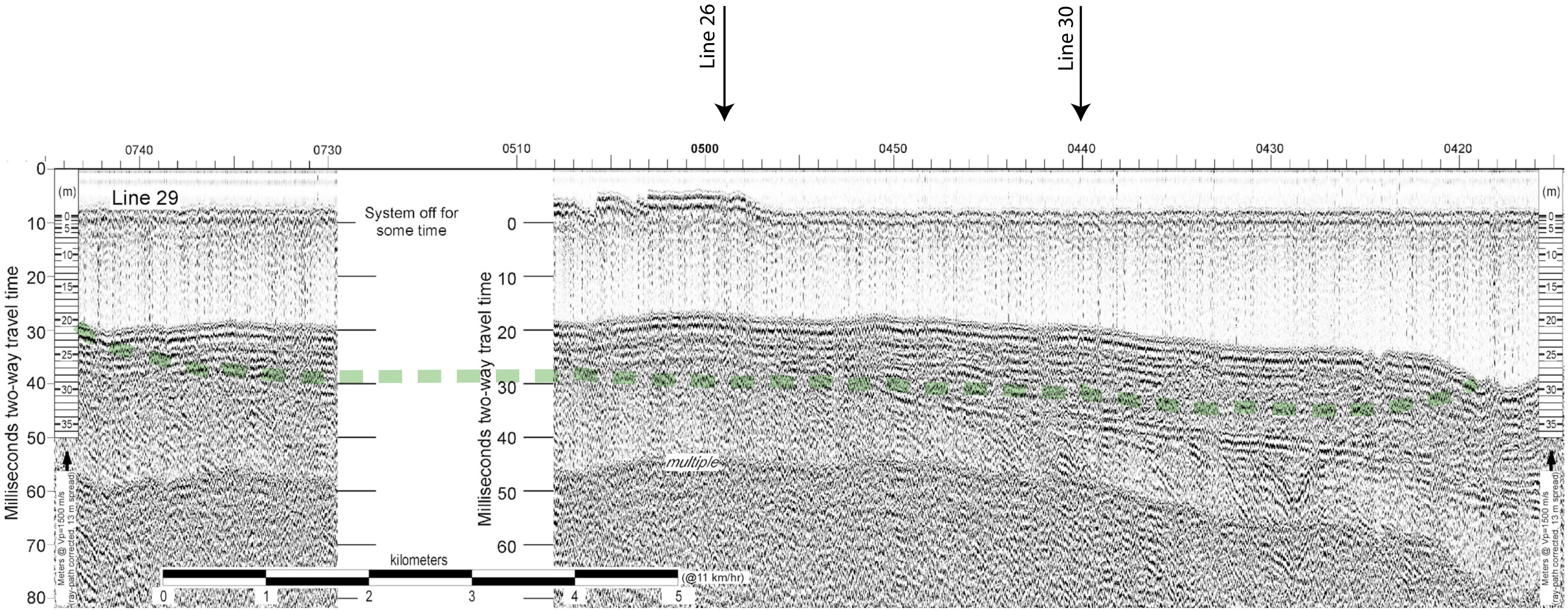
Line 26

Figure 4.3.8

LEGEND:

- - - = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



Feature W-2

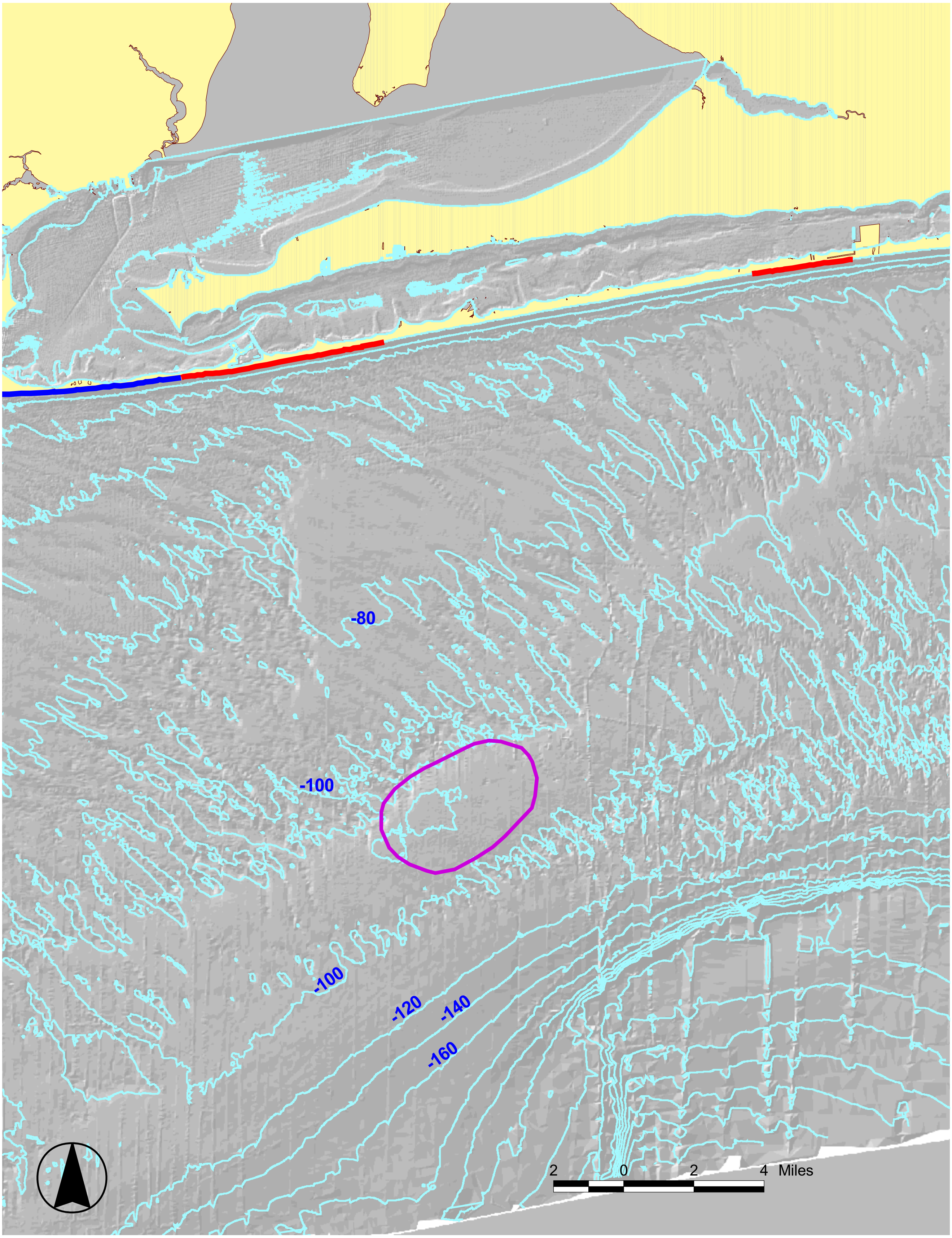
Line 29

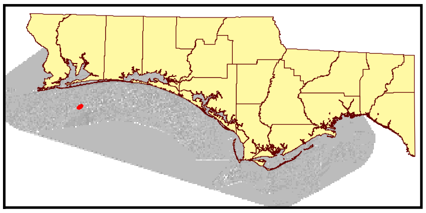
Figure 4.3.9

LEGEND:

🟩 🟩 🟩 = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



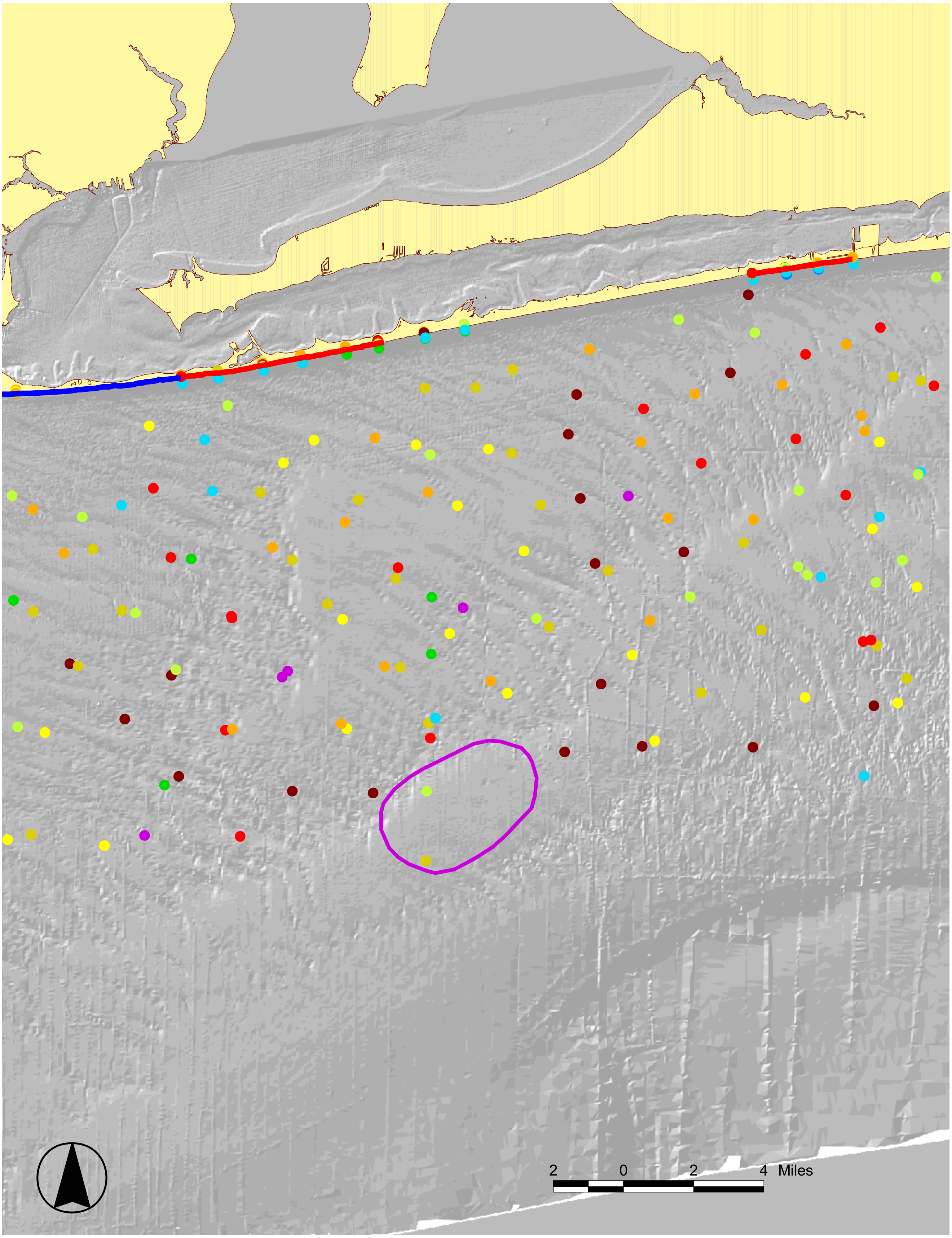


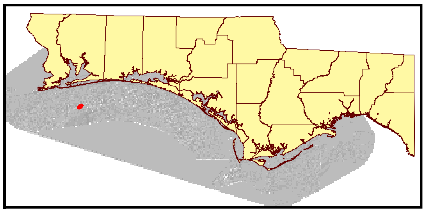
FEATURE W-3

Contour Map

Figure 4-4-1

g:\FDEP\beachcoastal\deliverables\report_figures.apr





FEATURE W-3

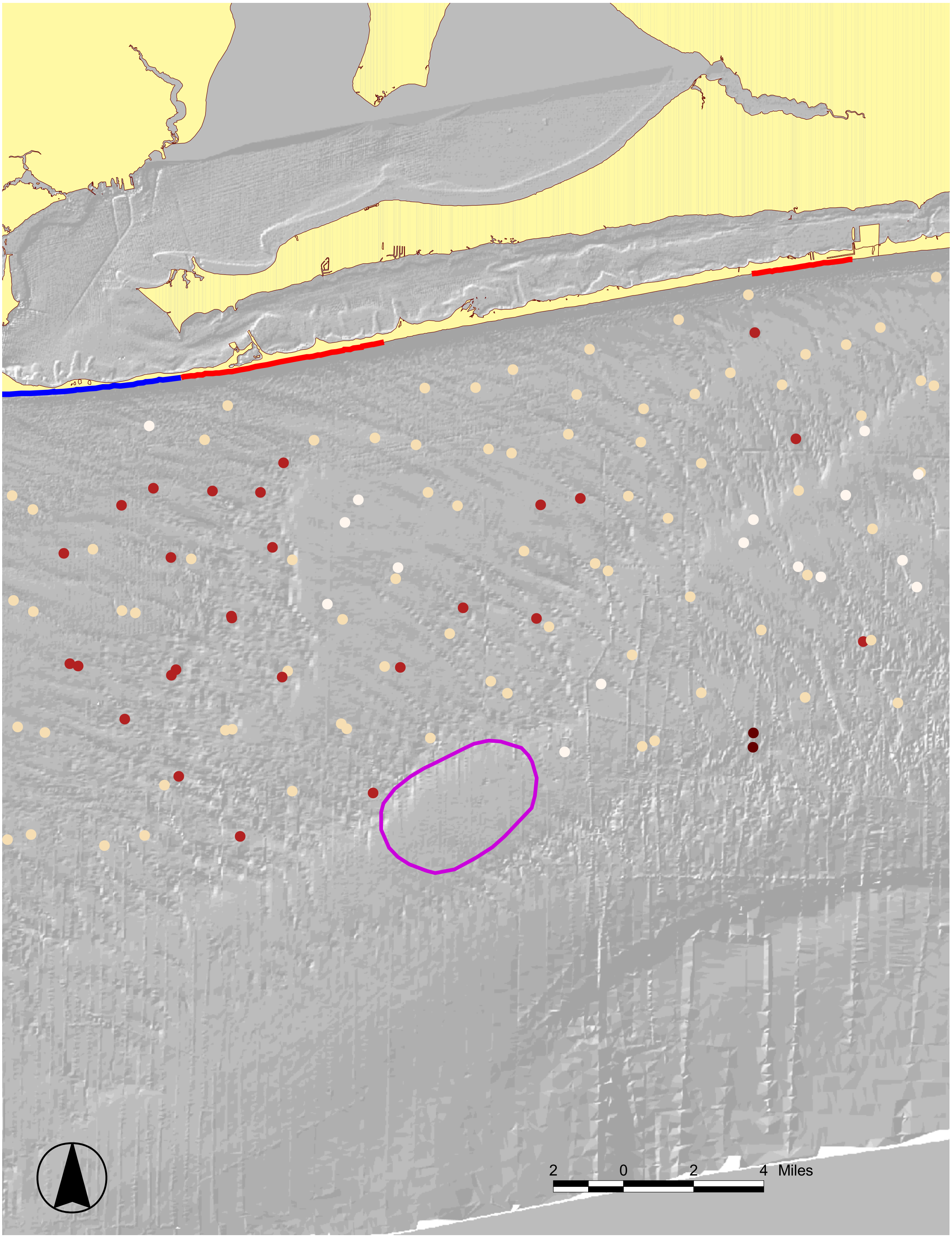
Grab Samples by Mean Grainsize

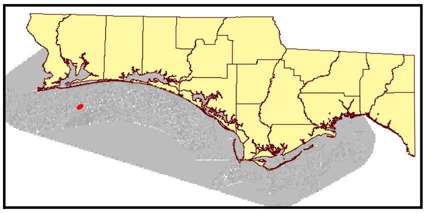
Figure 4-4-2

▭ Feature Outline
▭ Counties
Critical Erosion Areas (2000)
Critical
Noncritical

Mean Grainsize (phi)
● -0.1 - 0.9
● 0.9 - 1.05
● 1.05 - 1.2
● 1.2 - 1.35
● 1.35 - 1.5
● 1.5 - 1.65
● 1.65 - 1.8
● 1.8 - 1.95
● 1.95 - 2.1
● 2.1 - 10

g:\FDEP\beachcoastal\deliverables\report_figures.apr





FEATURE W-3

Grab Samples Normalized
by Munsell Value

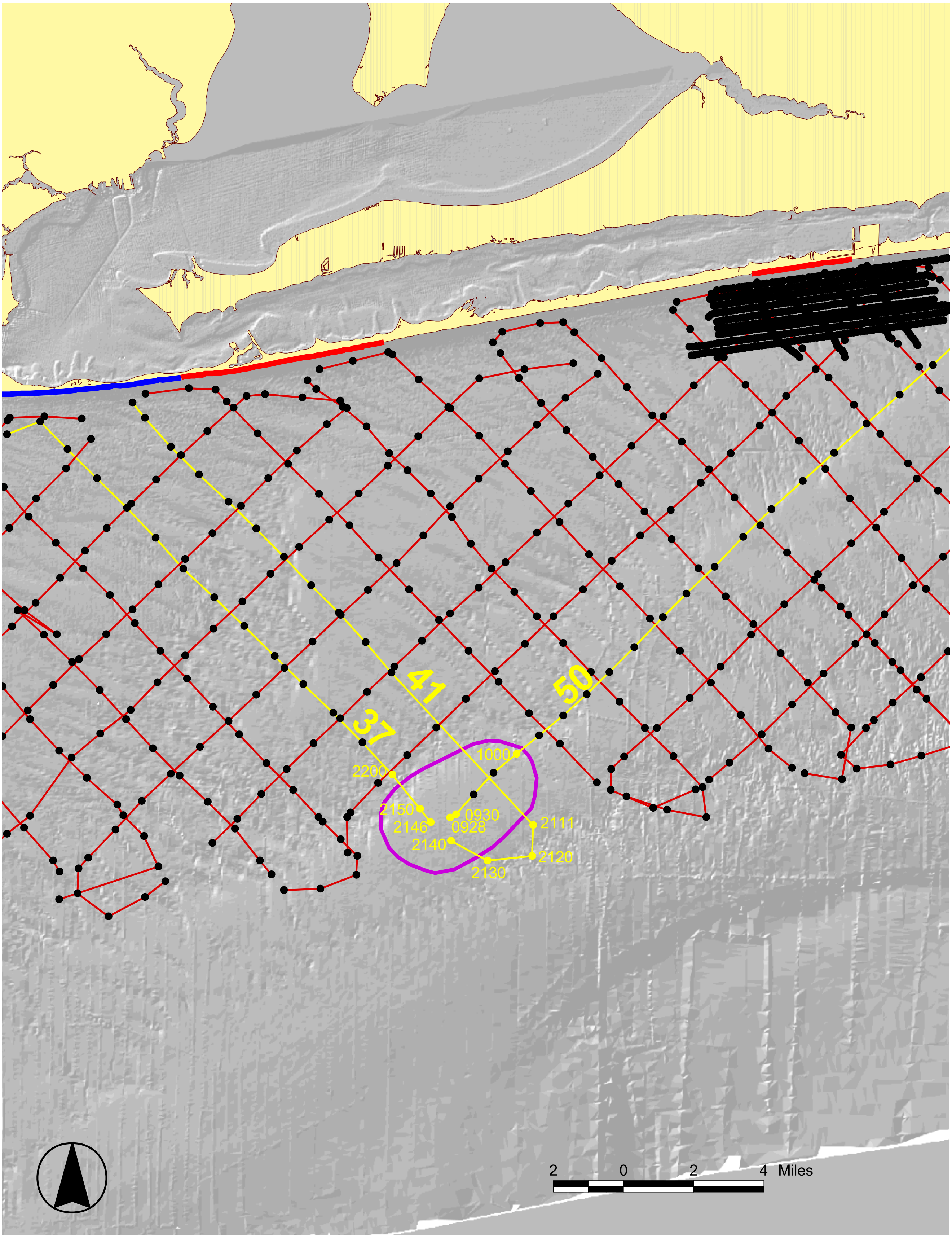
Figure 4-4-3

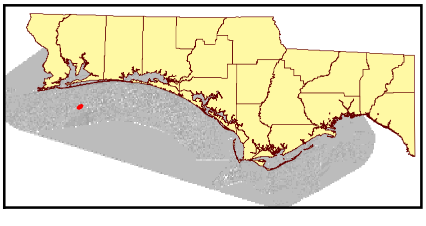
Mean grainsize by Munsell Value
- ● 1 - 5
- ● 5.1 - 6
- ● 6.1 - 7
- ● 7.1 - 11

▭ Feature Outline
🟨 Counties

Critical Erosion Areas (2000)
- 🟥 Critical
- 🟦 Noncritical

g:\FDEP\beachcoastal\deliverables\report_figures.apr





FEATURE W-3

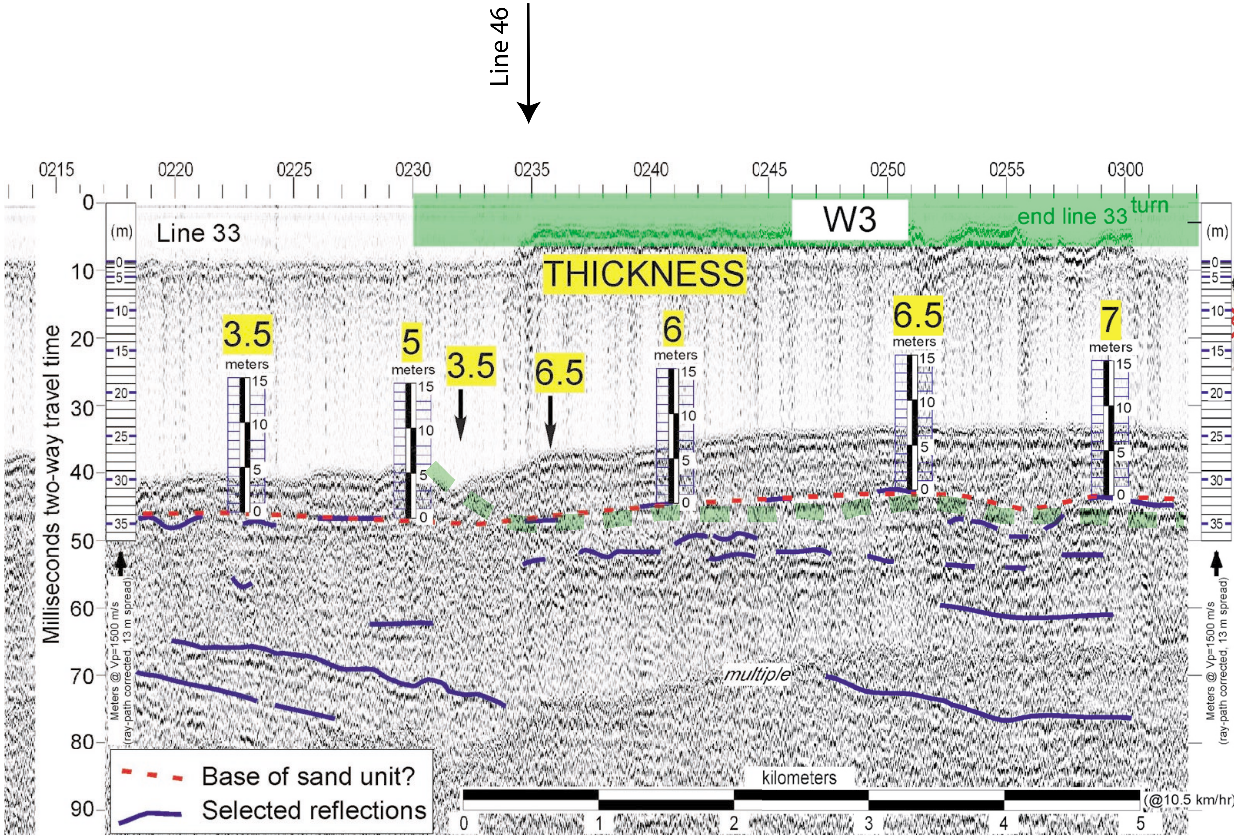
Geophysical Tracklines and Shotpoints with Timestamps

Figure 4-4-4

- ▭ Feature Outline
- ● Shotpoints
- ╱╲ Tracklines
- ▭ Counties

Critical Erosion Areas (2000)

- ╱╲ Critical
- ╱╲ Noncritical



Feature W-3

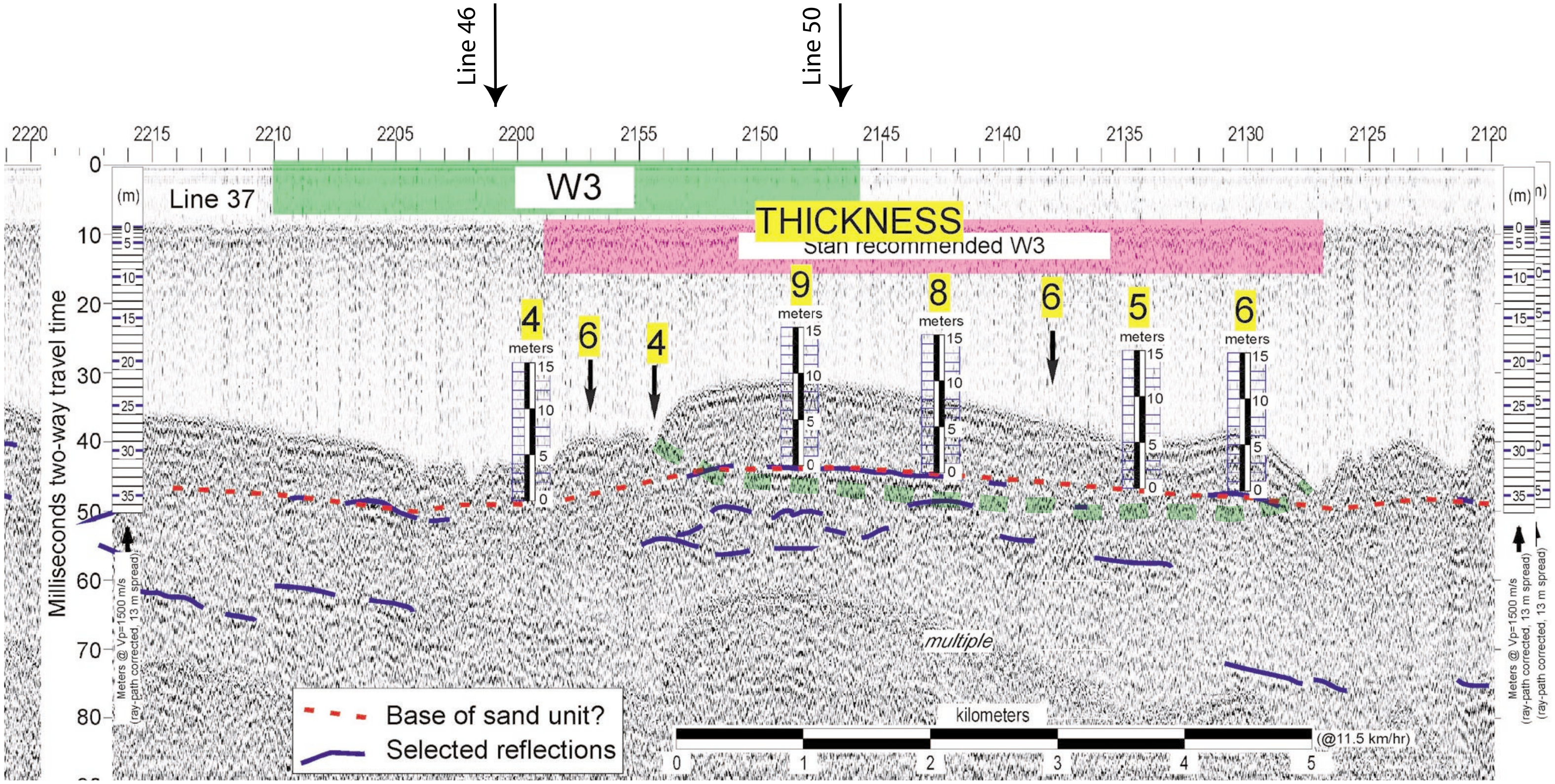
Line 33

Figure 4.4.5

LEGEND:

🟩 🟩 🟩 = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



Feature W-3

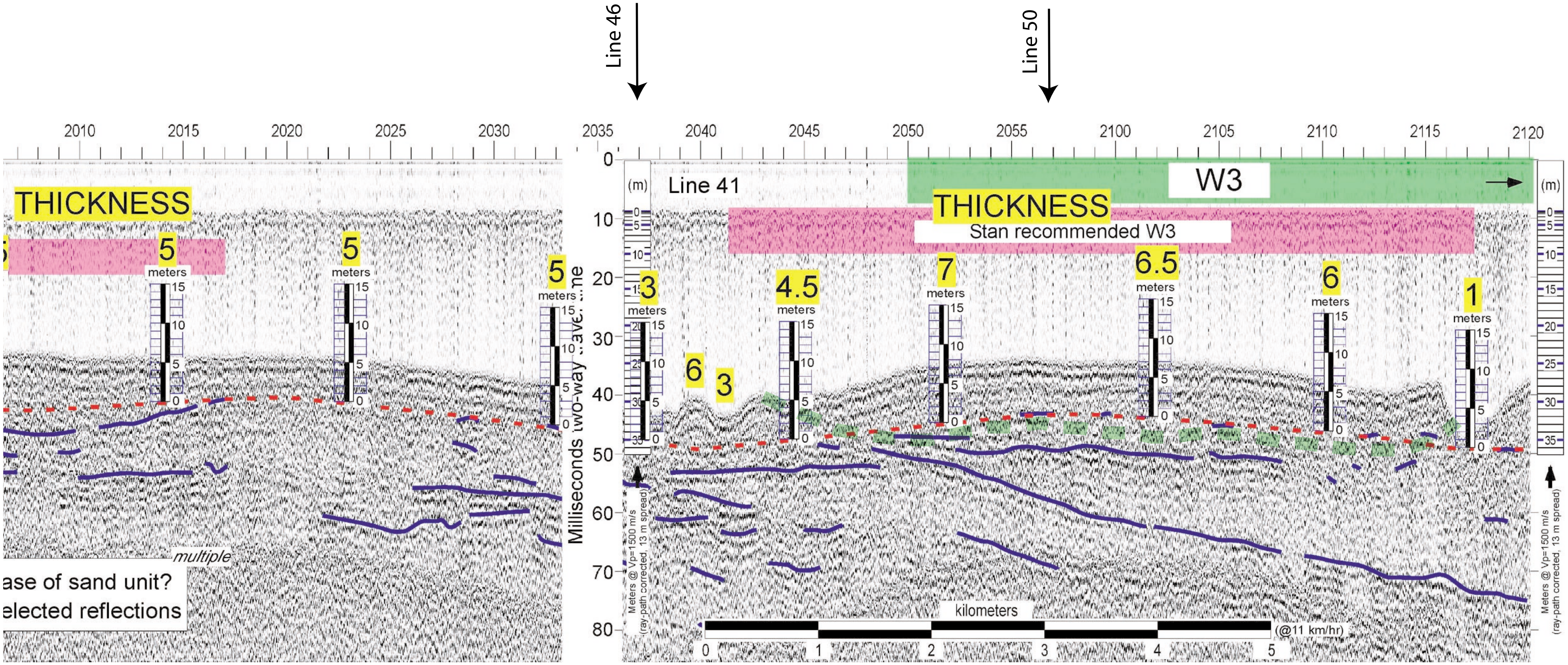
Line 37

Figure 4.4.6

LEGEND:

- - - = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



Feature W-3

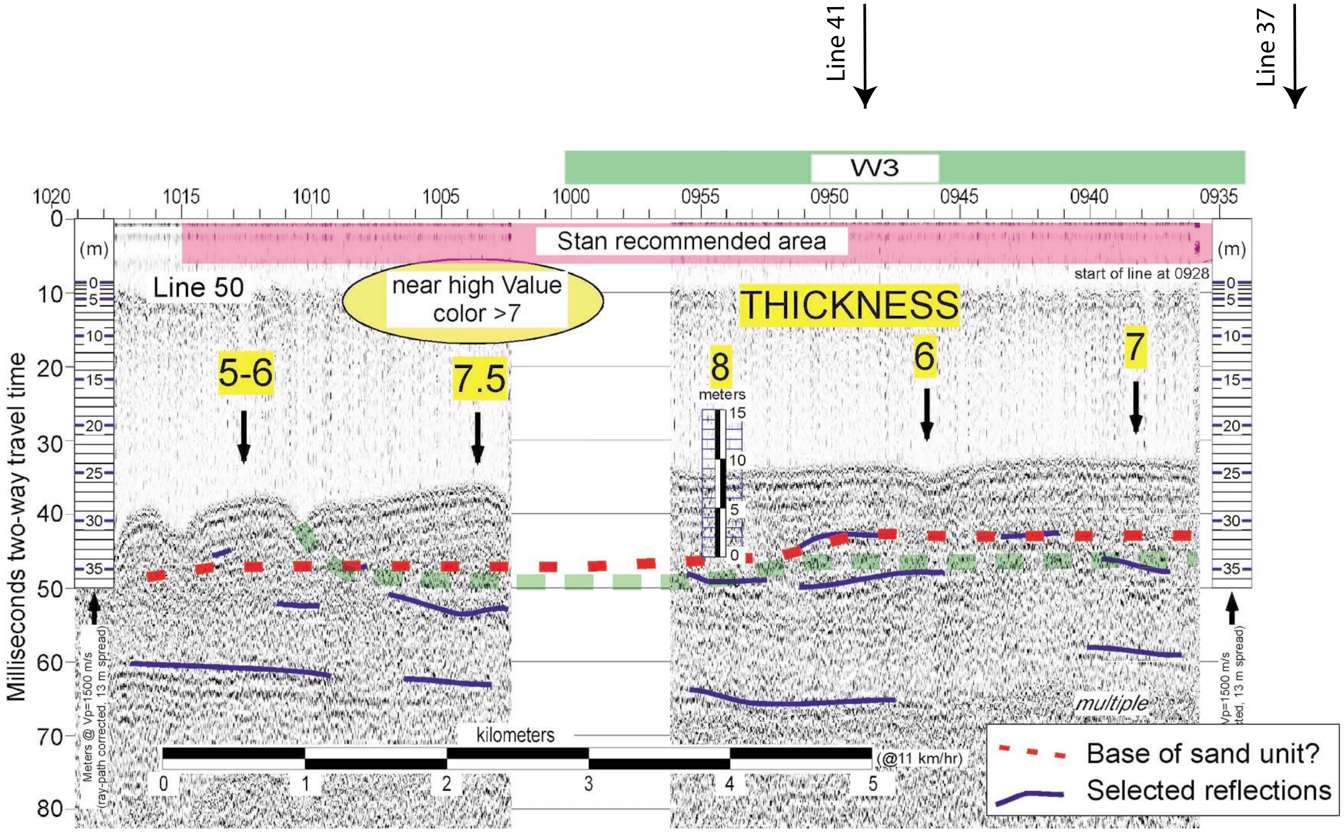
Line 41

Figure 4.4.7

LEGEND:

– – – = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



Feature W-3

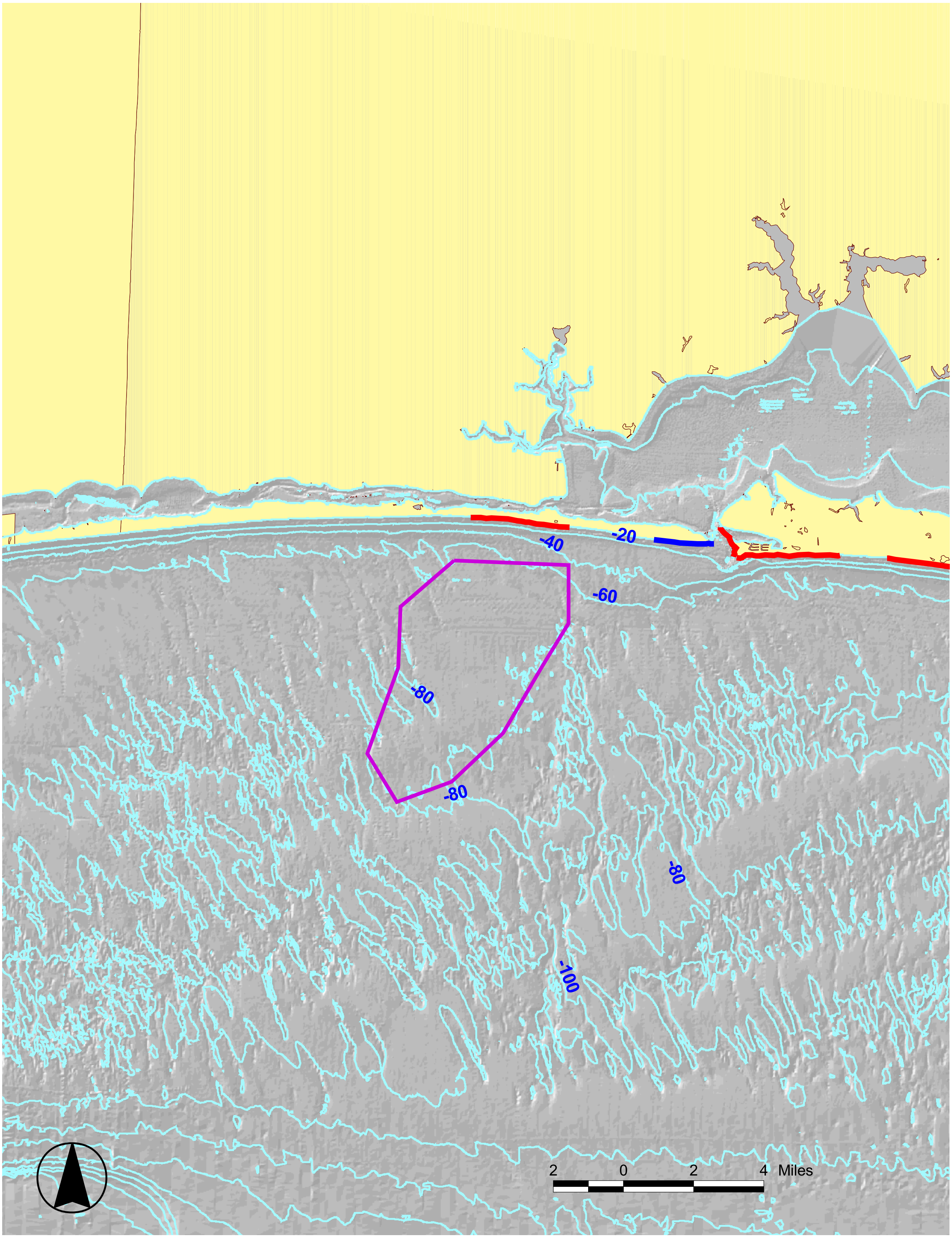
Line 50

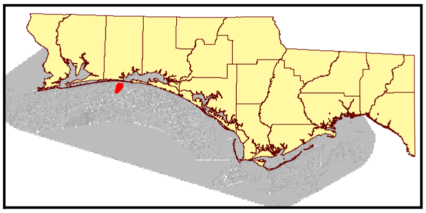
Figure 4.4.8

LEGEND:

🟩 = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



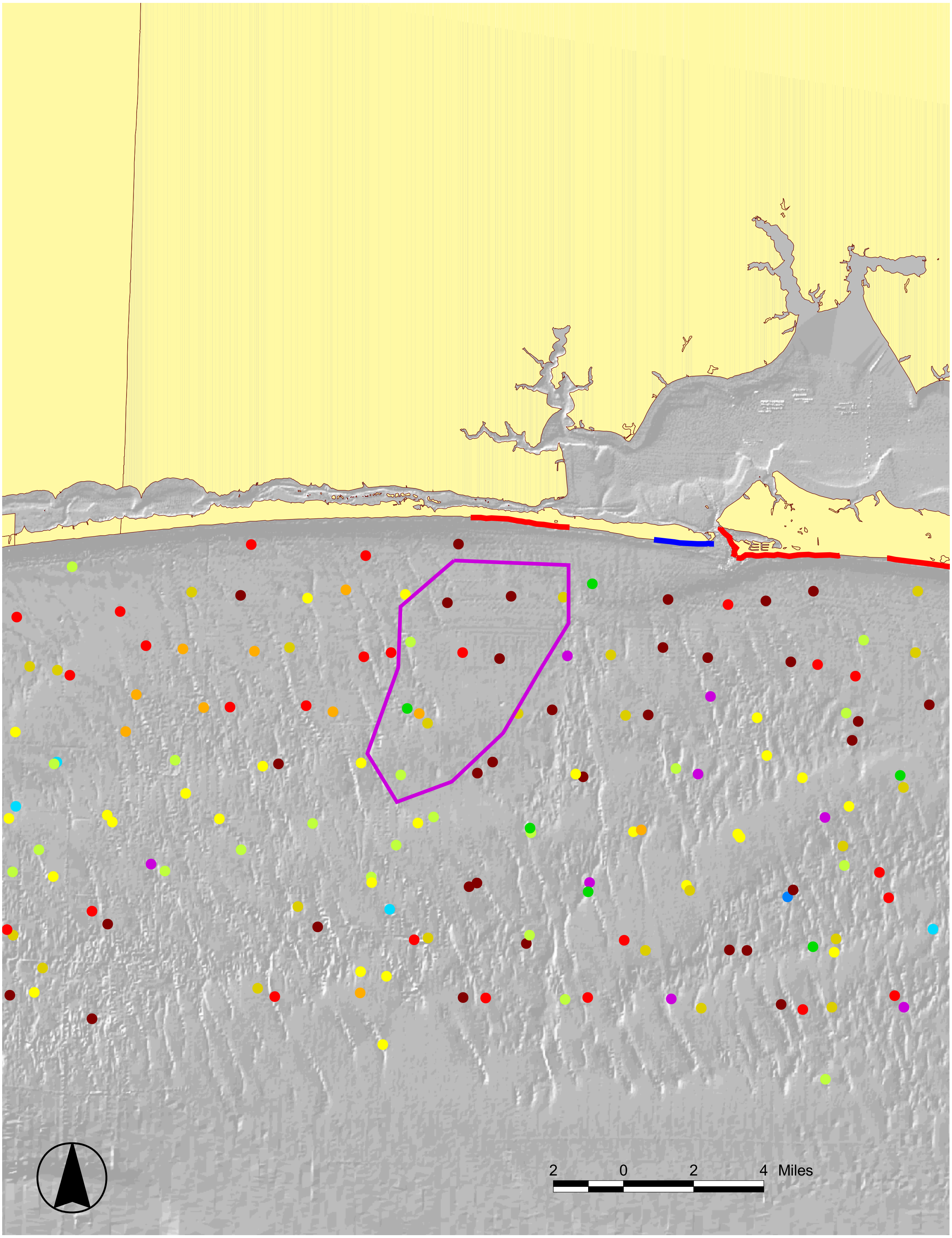


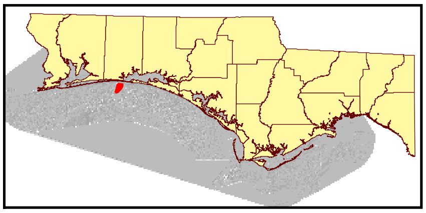
FEATURE W-4

Contour Map

Figure 4-5-1

g:\FDEP\beachcoastal\deliverables\report_figures.apr





FEATURE W-4

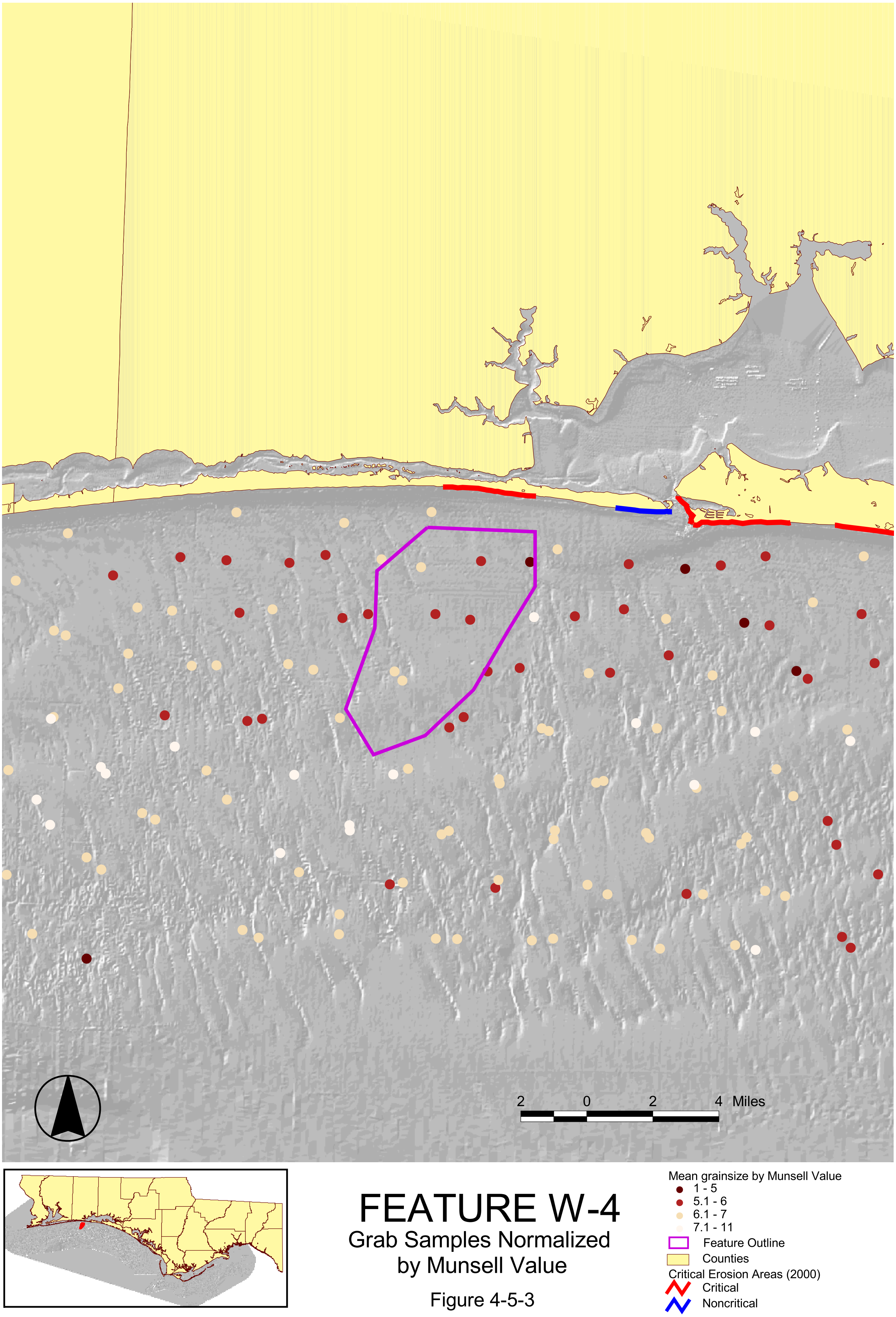
Grab Samples by Mean Grainsize

Figure 4-5-2

▭ Feature Outline
▭ Counties
Critical Erosion Areas (2000)
🟥 Critical
🟦 Noncritical

Mean Grainsize (phi)
● -0.1 - 0.9
● 0.9 - 1.05
● 1.05 - 1.2
● 1.2 - 1.35
● 1.35 - 1.5
● 1.5 - 1.65
● 1.65 - 1.8
● 1.8 - 1.95
● 1.95 - 2.1
● 2.1 - 10

g:\FDEP\beachcoastal\deliverables\report_figures.apr



FEATURE W-4

Grab Samples Normalized by Munsell Value

Figure 4-5-3

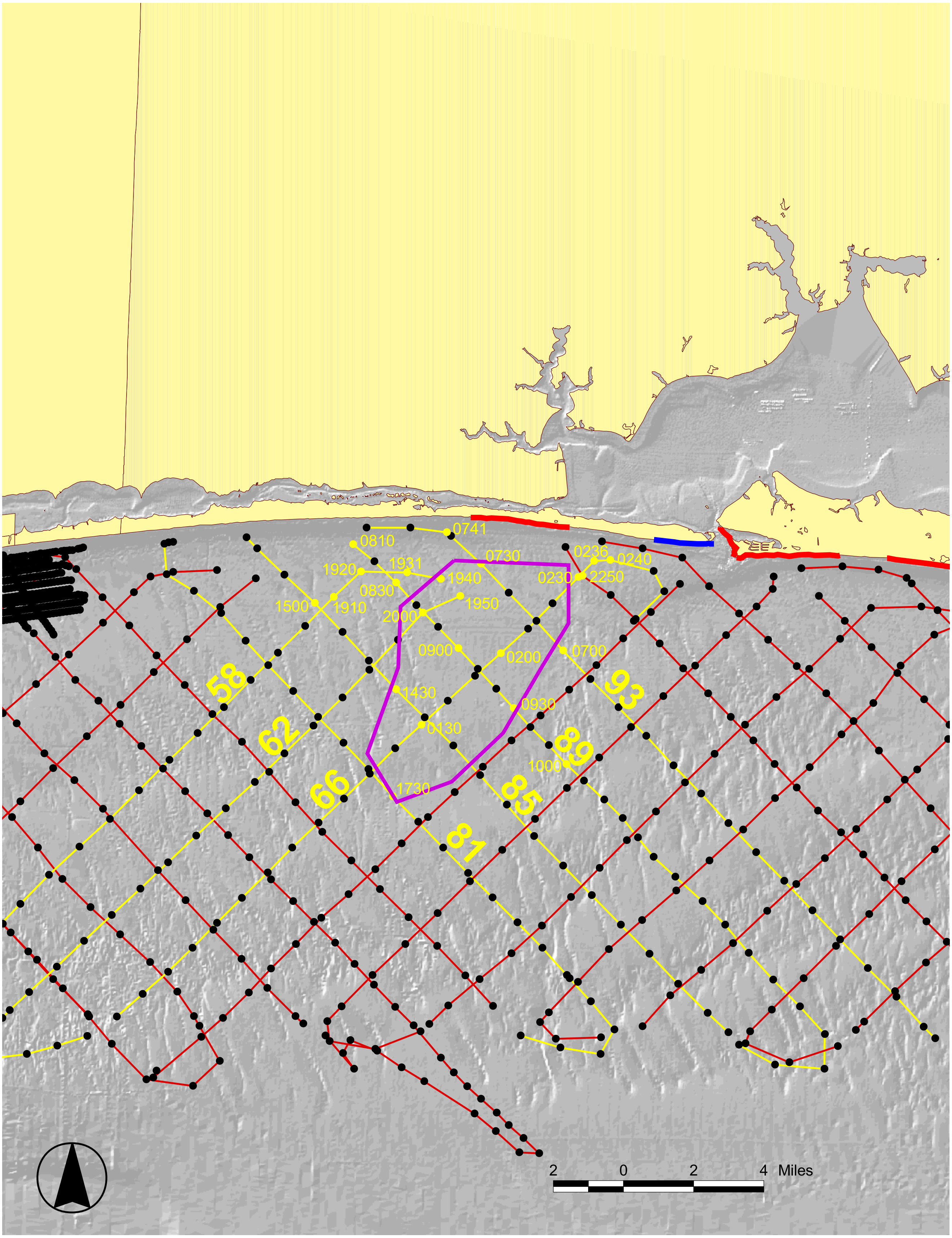
Mean grainsize by Munsell Value
- ● 1 - 5
- ● 5.1 - 6
- ● 6.1 - 7
- ● 7.1 - 11

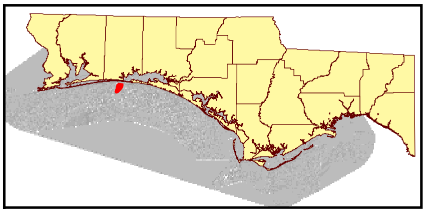
▭ Feature Outline

🟨 Counties

Critical Erosion Areas (2000)
- Critical
- Noncritical

g:\FDEP\beachcoastal\deliverables\report_figures.apr





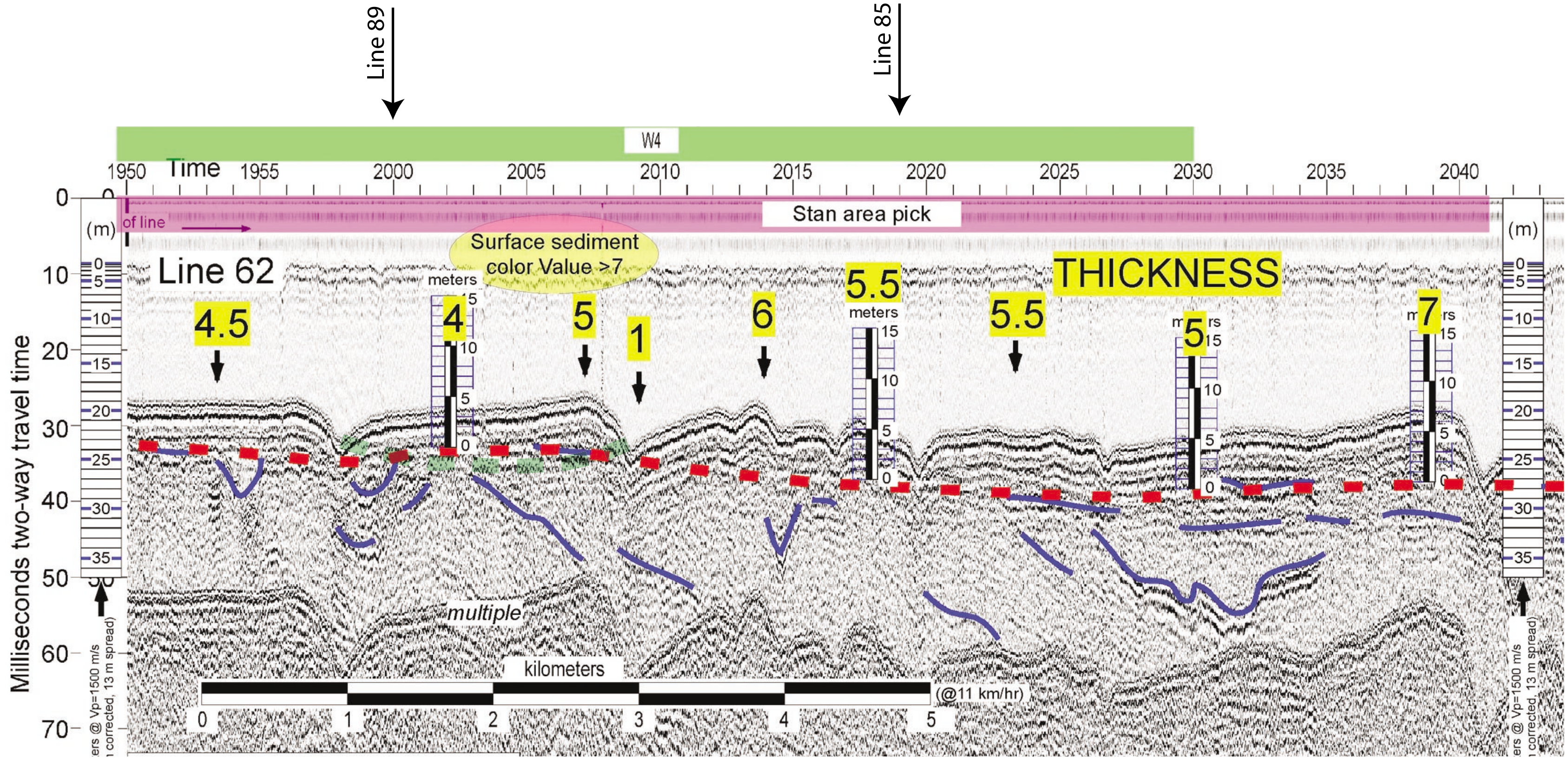
FEATURE W-4

Geophysical Tracklines and Shotpoints with Timestamps

Figure 4-5-4

▭ Feature Outline
● Shotpoints
Tracklines
🟨 Counties
Critical Erosion Areas (2000)
Critical
Noncritical

g:\FDEP\beachcoastal\deliverables\report_figures.apr



Feature W-4

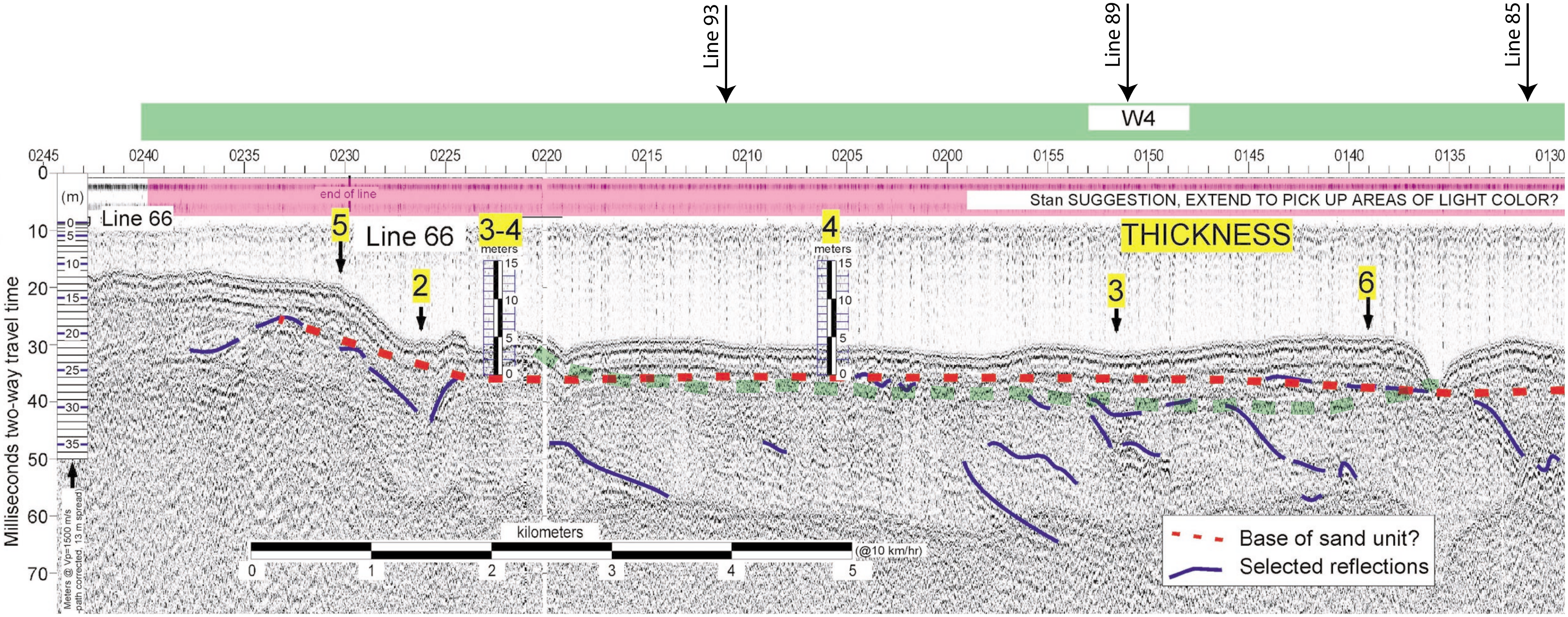
Line 62

Figure 4.5.5

LEGEND:

– – – = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



Feature W-4

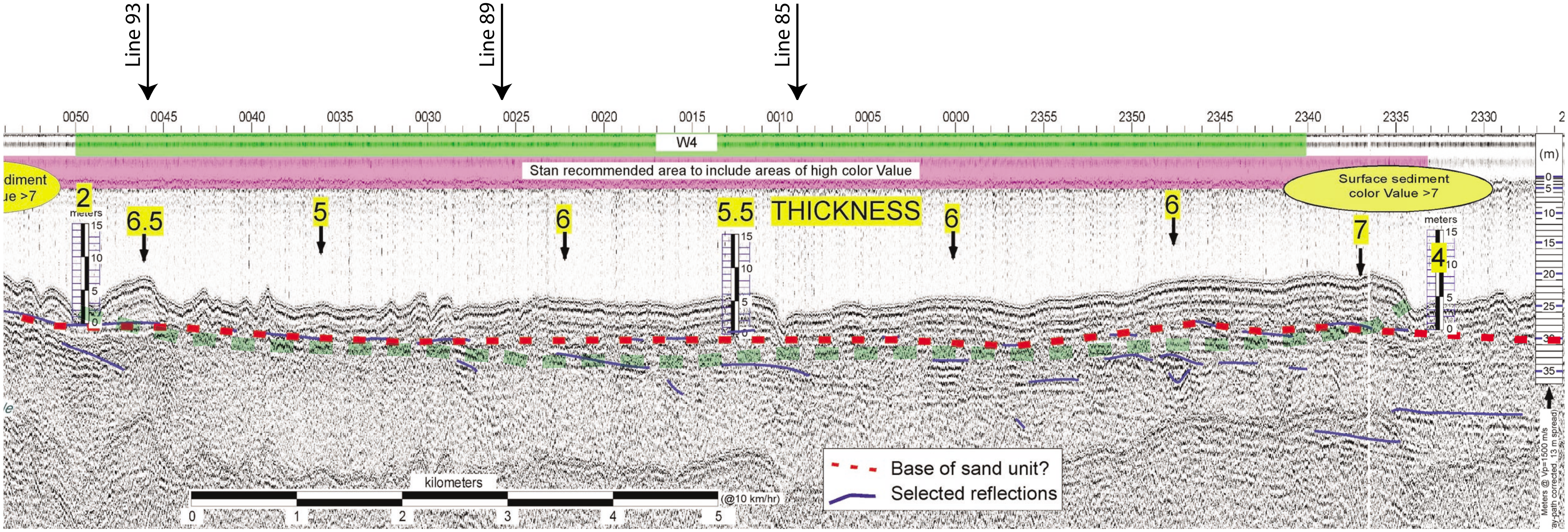
Line 66

Figure 4.5.6

LEGEND:

— — — = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



Feature W-4

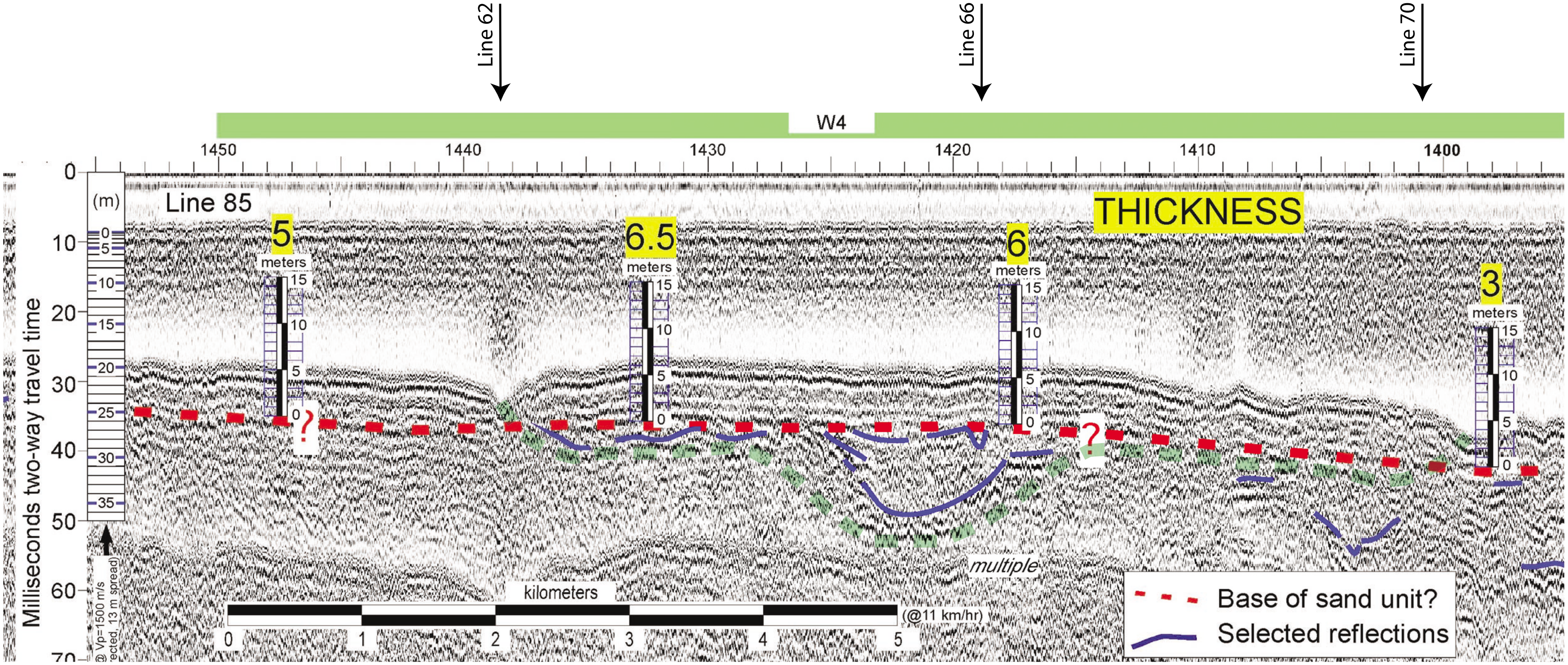
Line 70

Figure 4.5.7

LEGEND:

▬ ▬ ▬ = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



Feature W-4

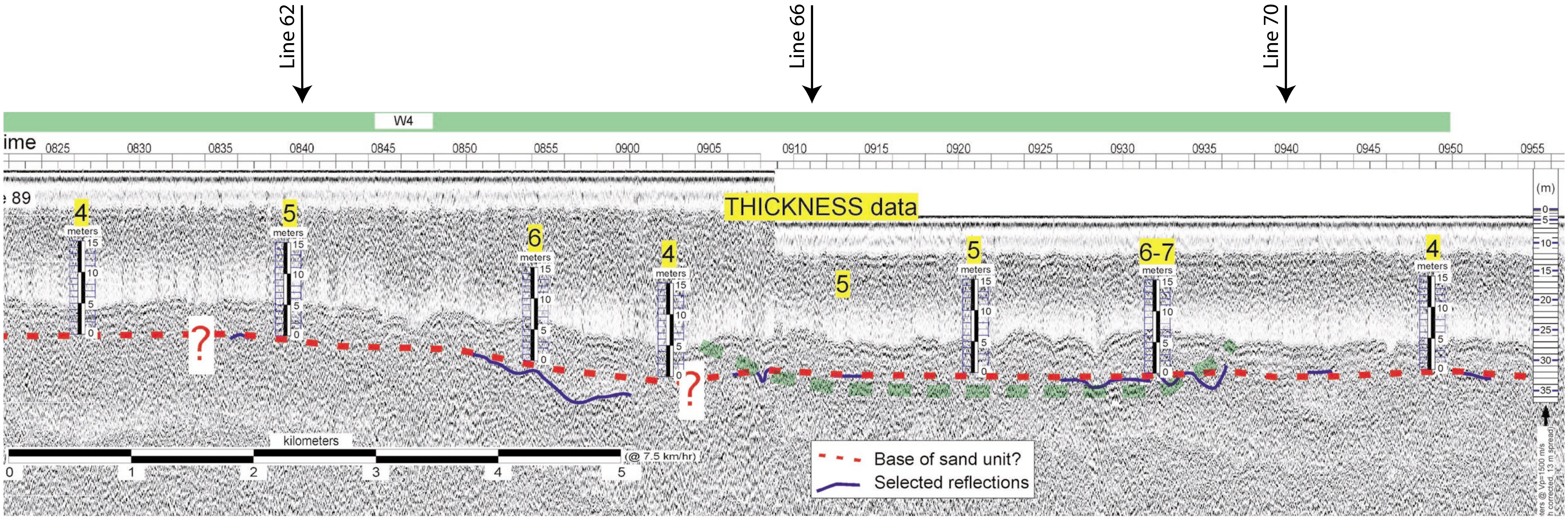
Line 85

Figure 4.5.8

LEGEND:

🟩 🟩 🟩 = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



Feature W-4

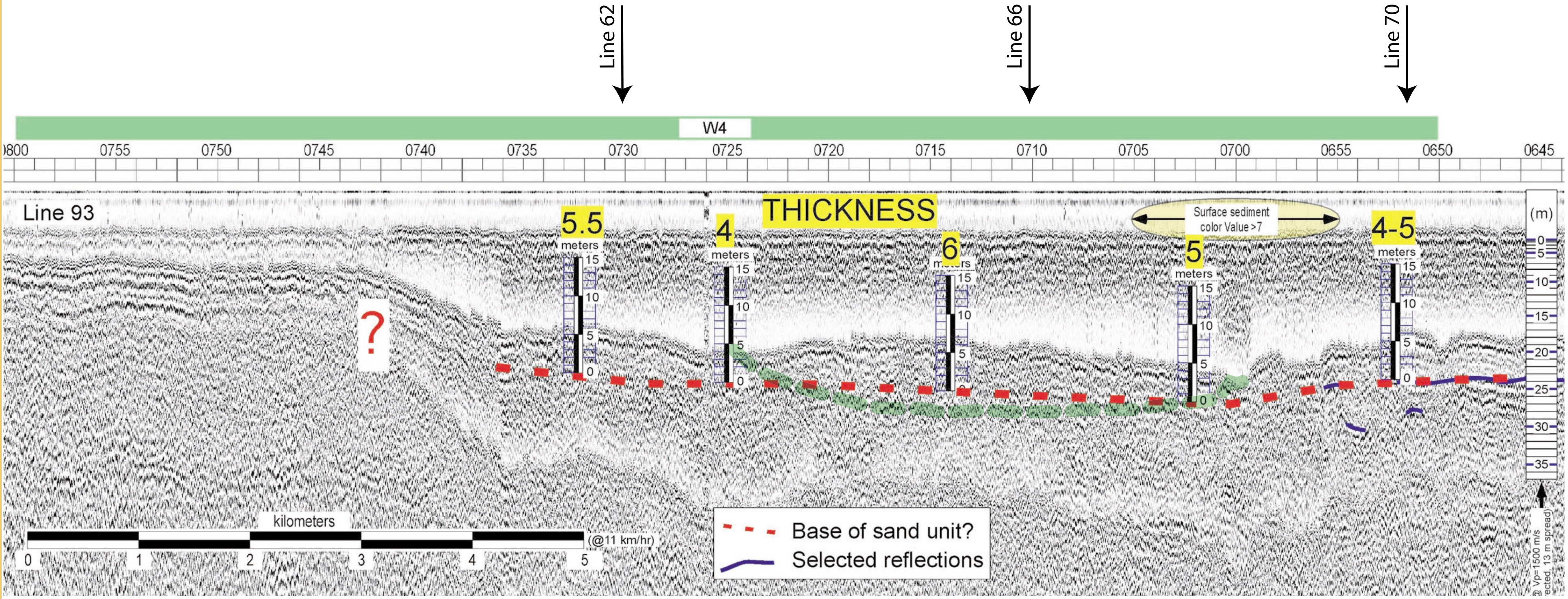
Line 89

Figure 4.5.9

LEGEND:

▬ ▬ ▬ = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



Feature W-4

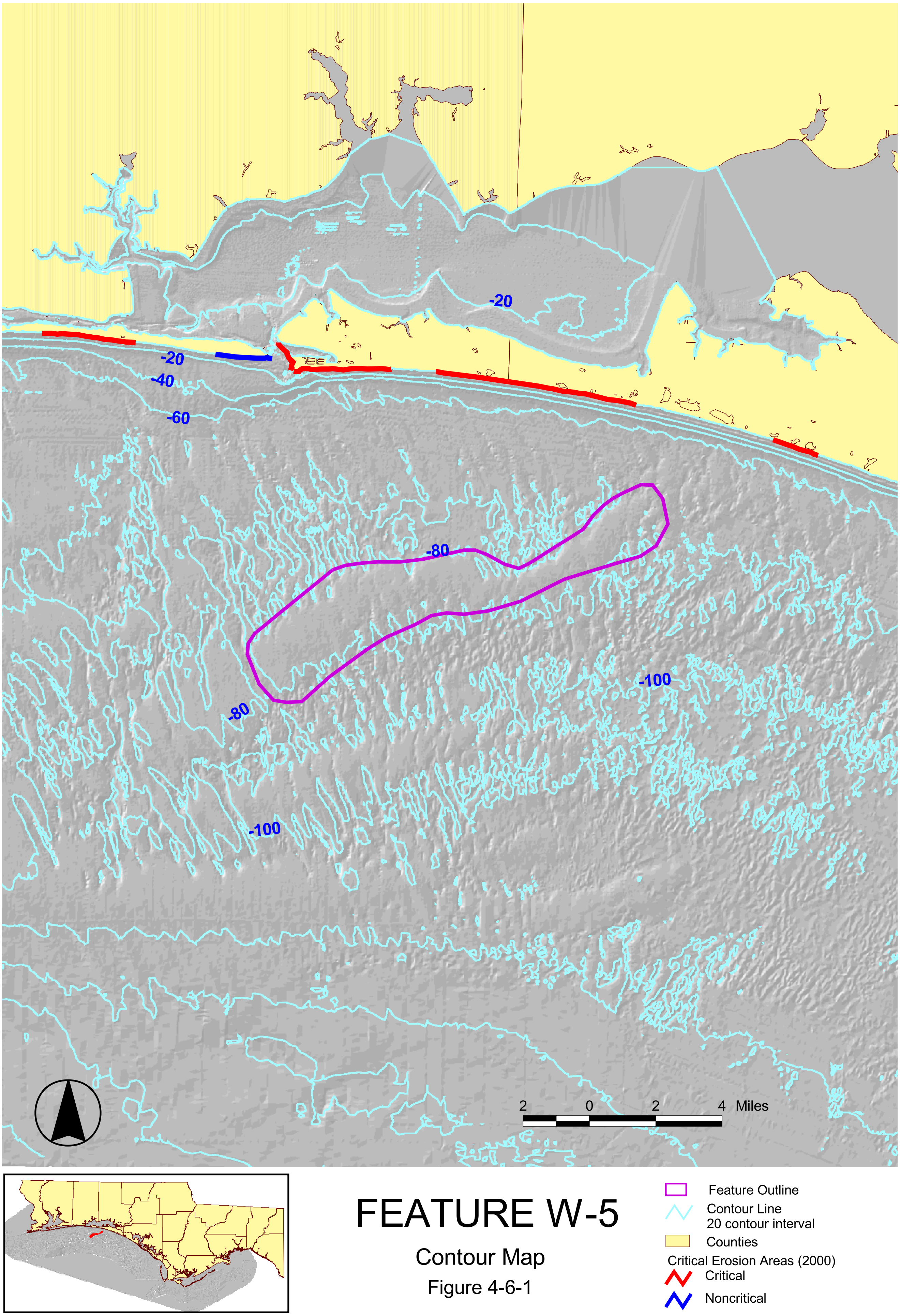
Line 93

Figure 4.5.10

LEGEND:

- - - = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line

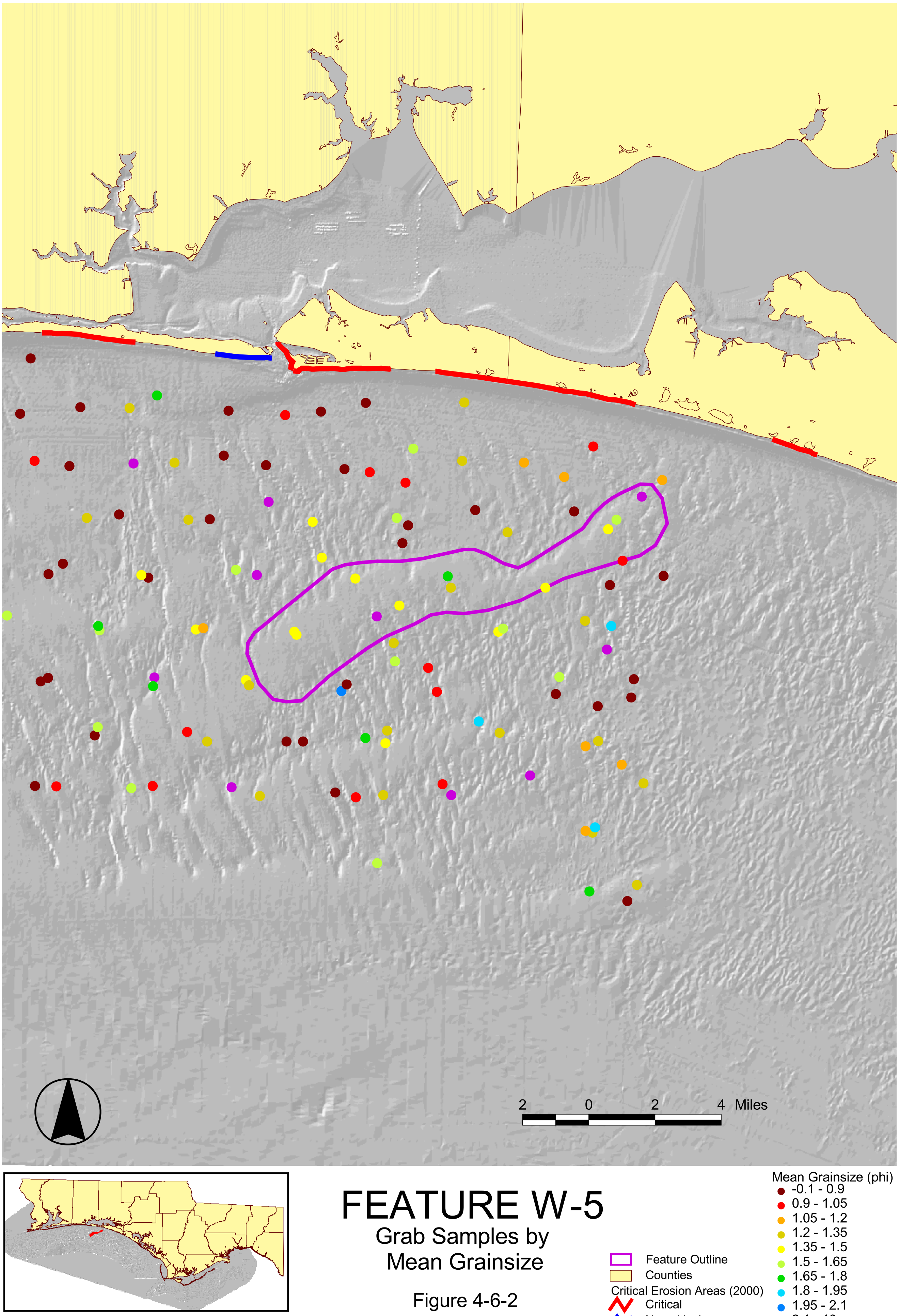


FEATURE W-5

Contour Map

Figure 4-6-1

g:\FDEP\beachcoastal\deliverables\report_figures.apr

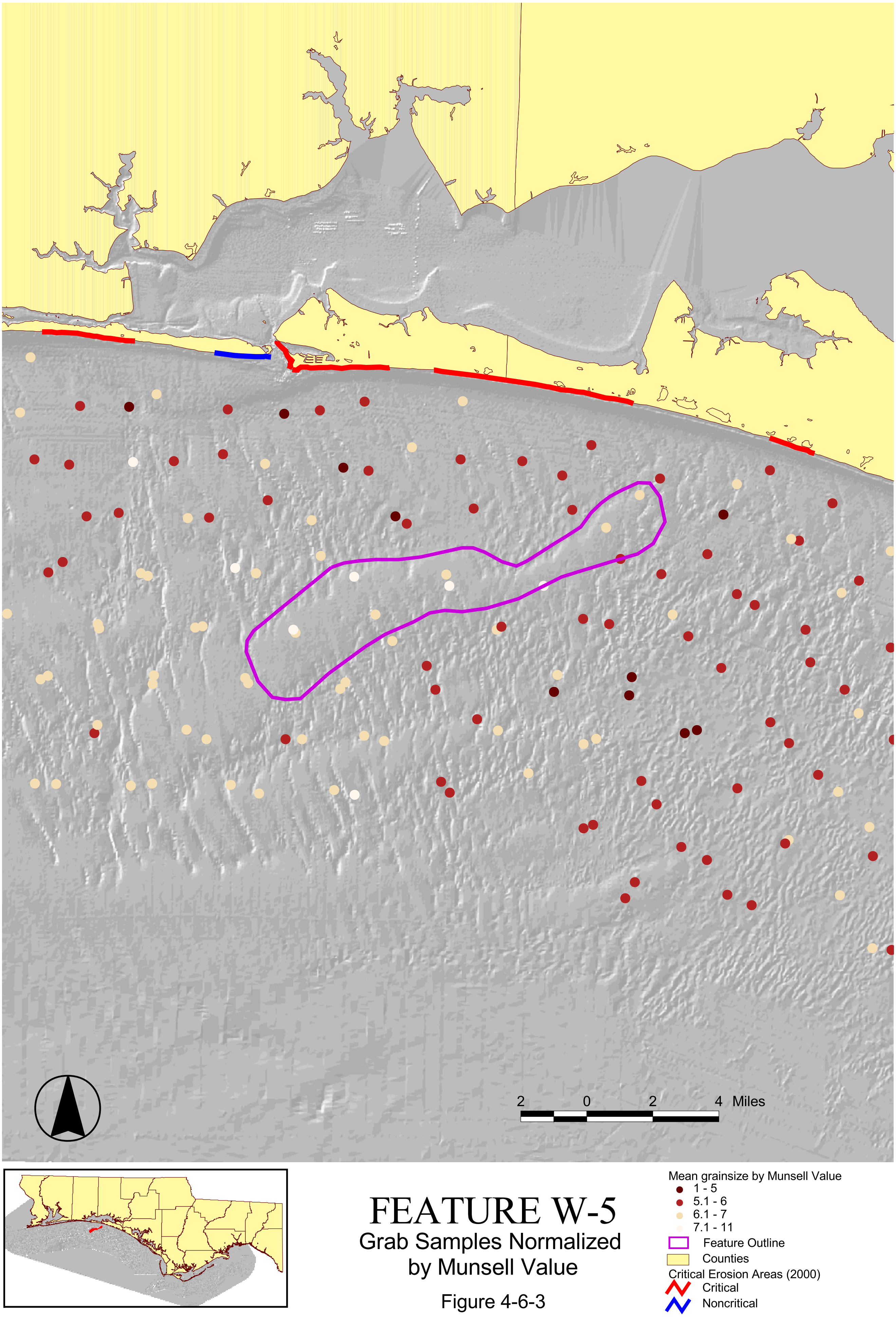


FEATURE W-5

Grab Samples by Mean Grainsize

Figure 4-6-2

g:\FDEP\beachcoastal\deliverables\report_figures.apr

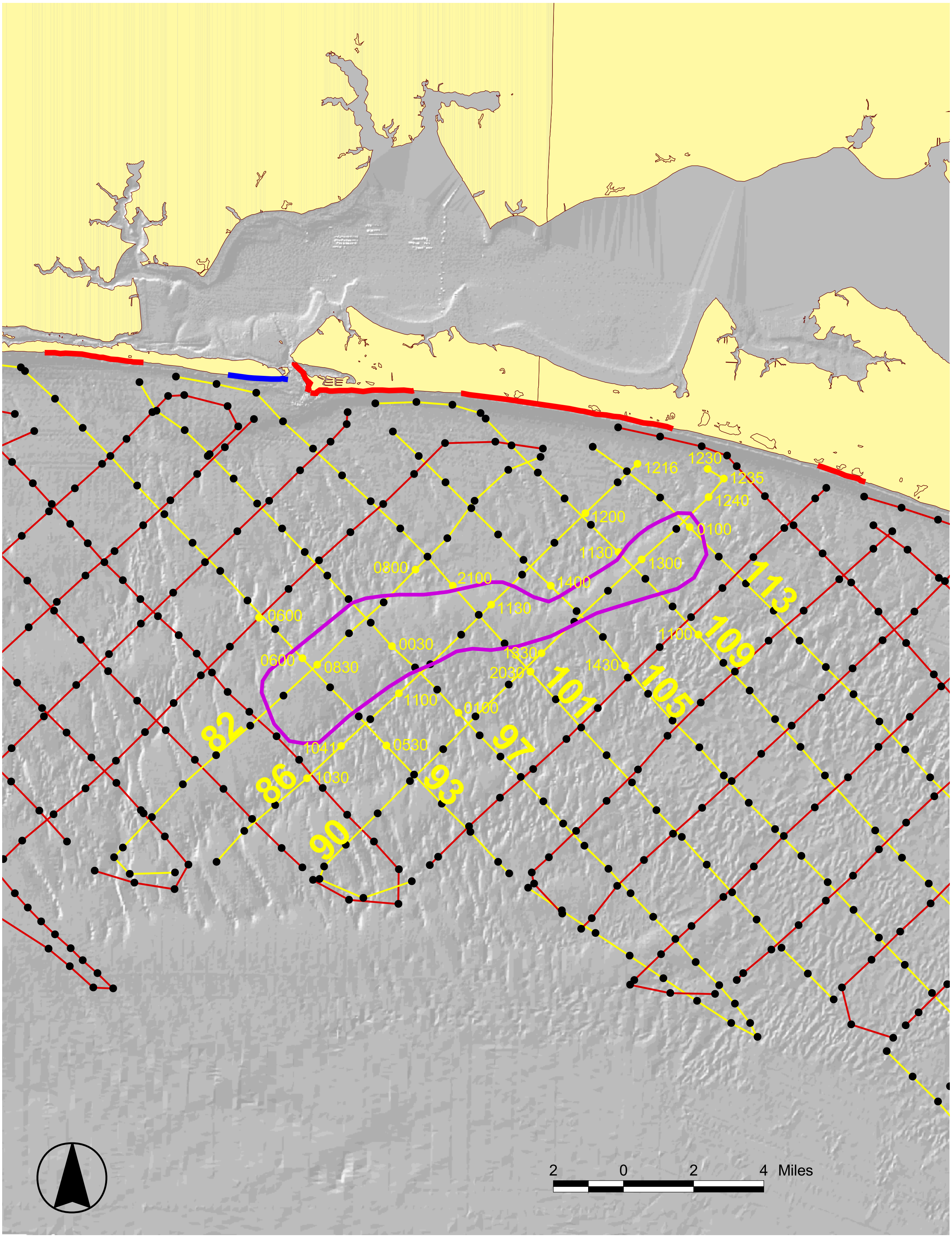


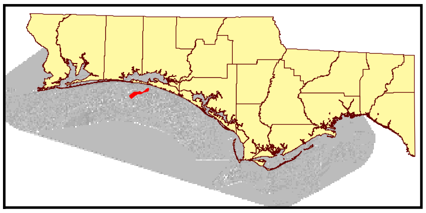
FEATURE W-5

Grab Samples Normalized by Munsell Value

Figure 4-6-3

g:\FDEP\beachcoastal\deliverables\report_figures.apr





FEATURE W-5

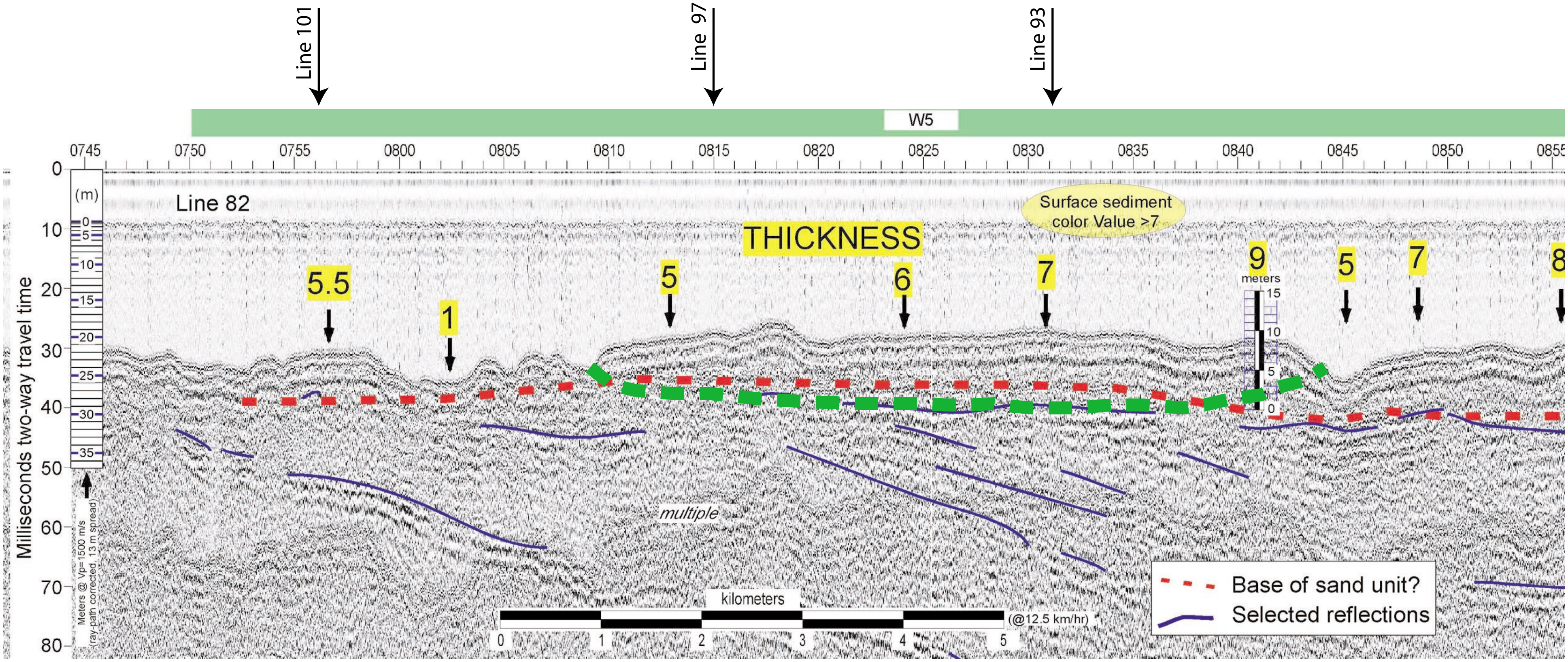
Geophysical Tracklines and Shotpoints with Timestamps

Figure 4-6-4

- ☐ Feature Outline
- ● Shotpoints
- ╱╲ Tracklines
- ☐ Counties

Critical Erosion Areas (2000)
- ╱╲ Critical
- ╱╲ Noncritical

g:\FDEP\beachcoastal\deliverables\report_figures.apr



Feature W-5

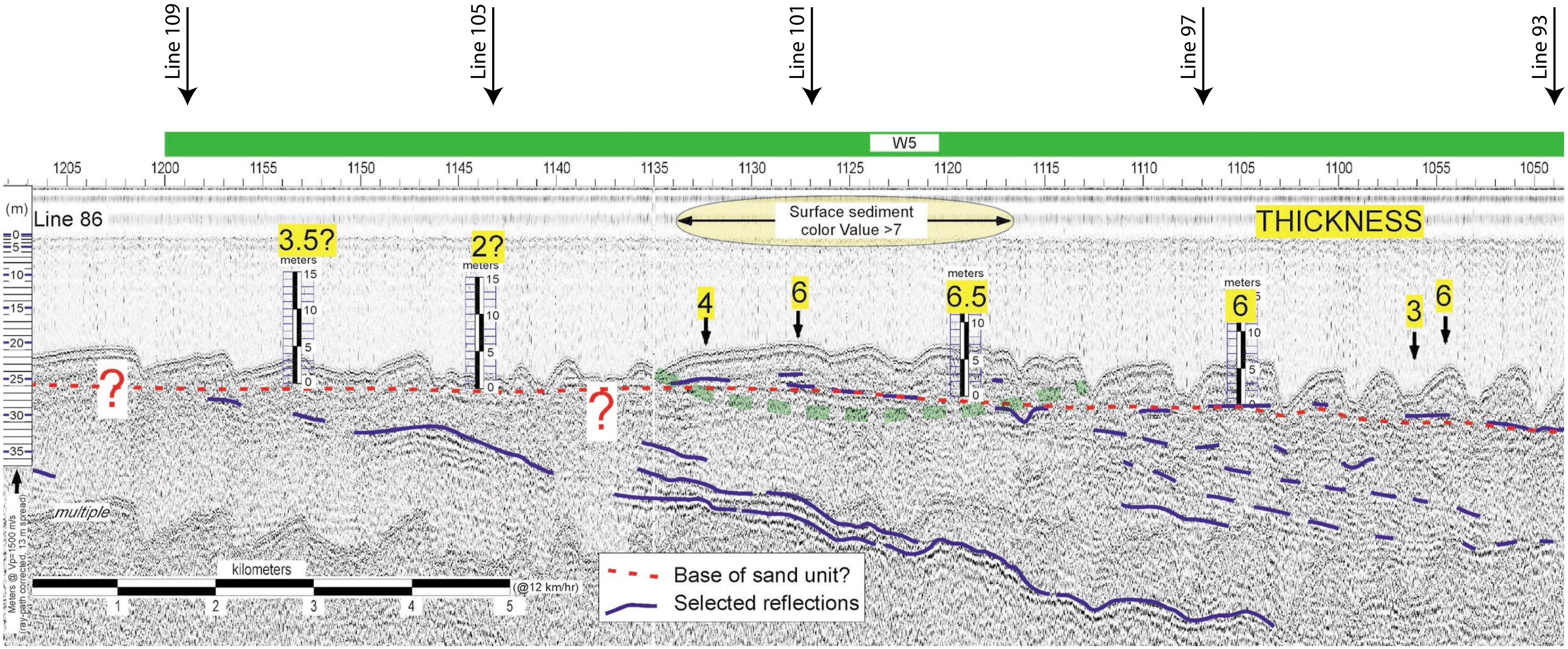
Line 82

Figure 4.6.5

LEGEND:

▬ ▬ ▬ = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



Feature W-5

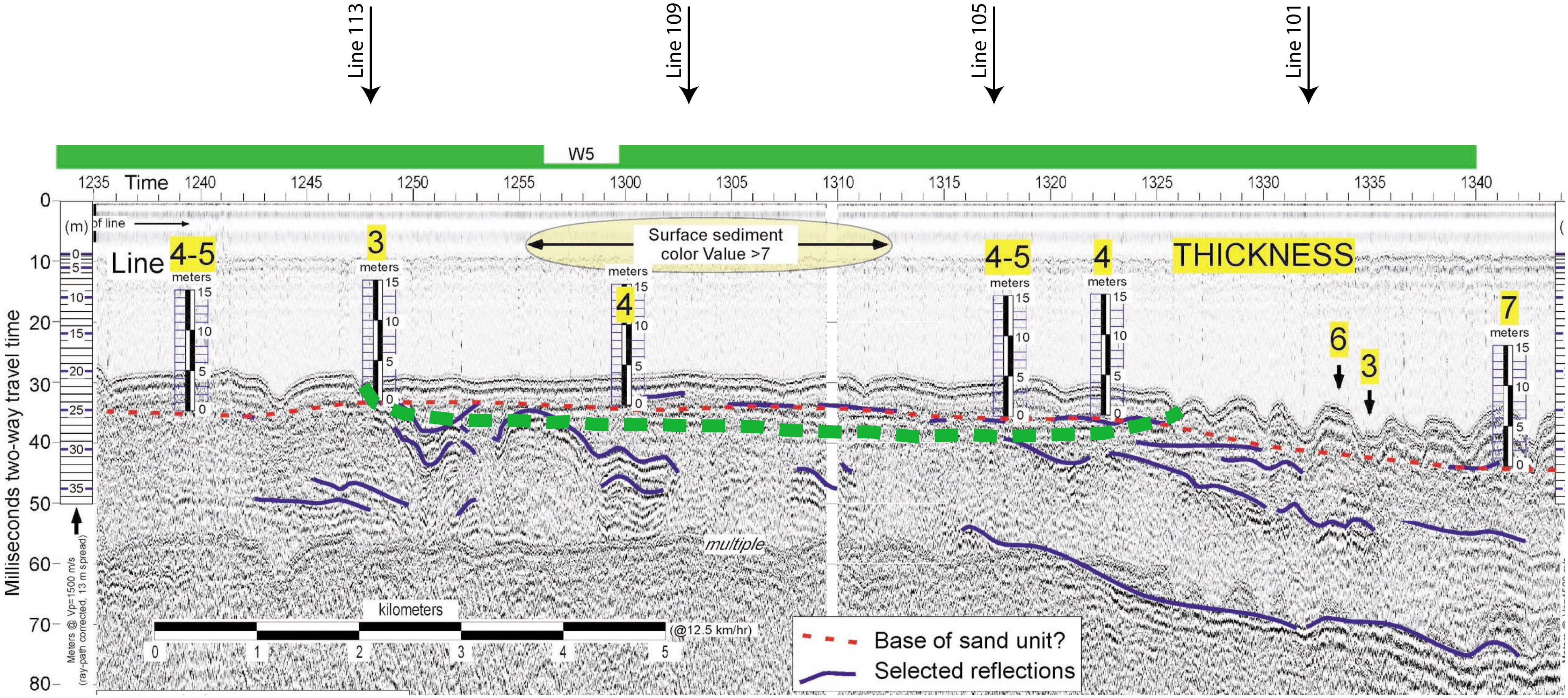
Line 86

Figure 4.6.6

LEGEND:

🟩 = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



Feature W-5

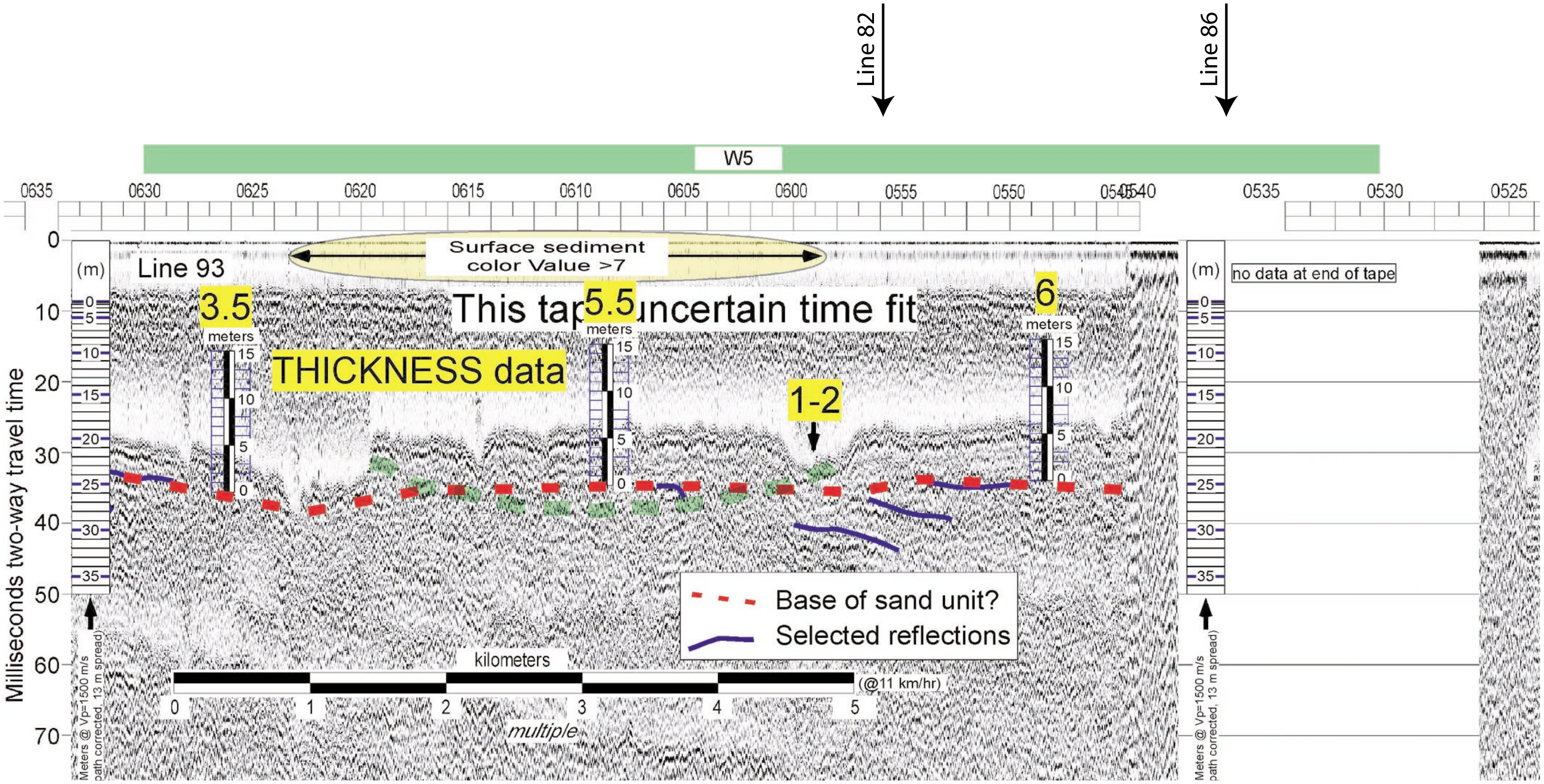
Line 90

Figure 4.6.7

LEGEND:

▬ ▬ ▬ = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



Feature W-5

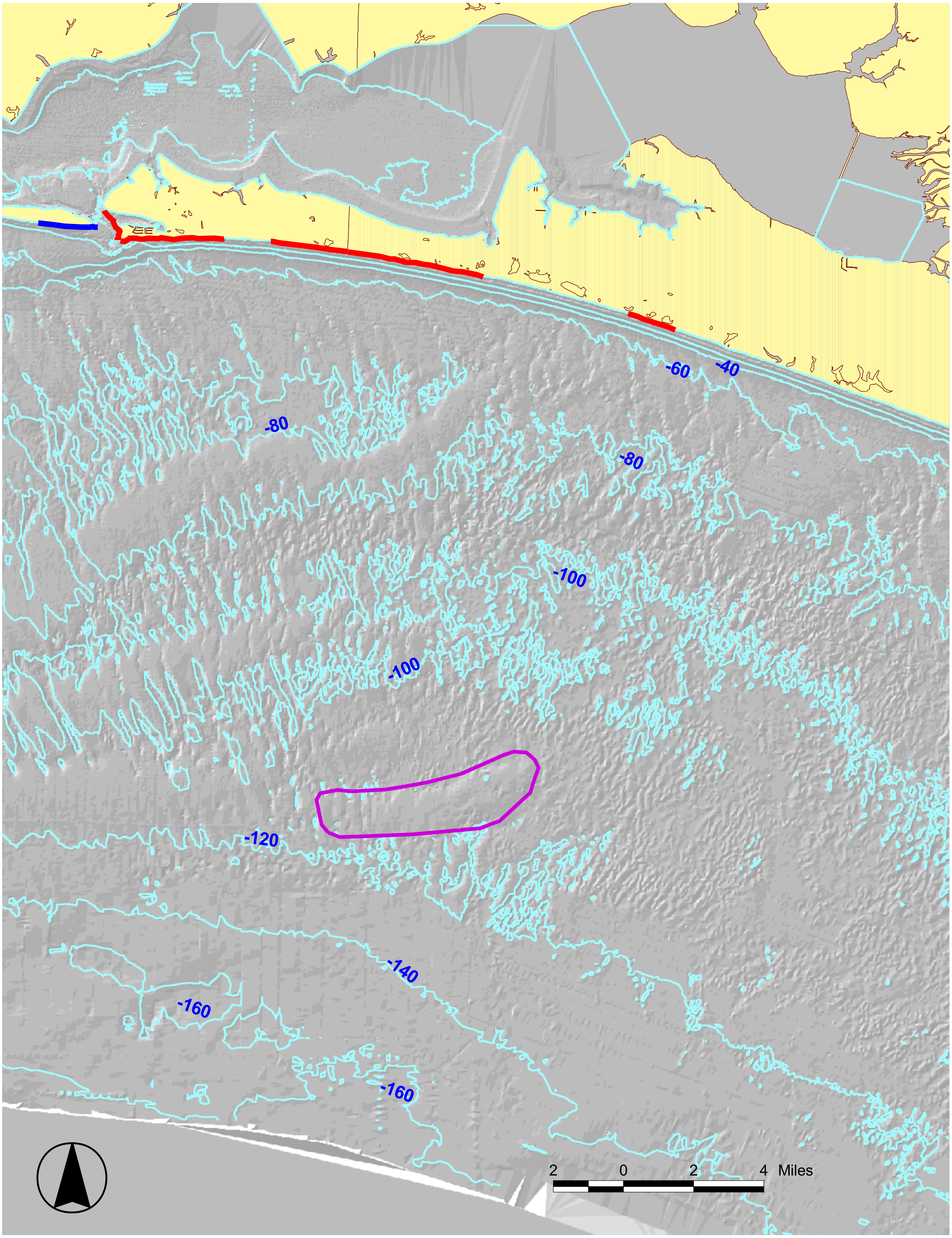
Line 93

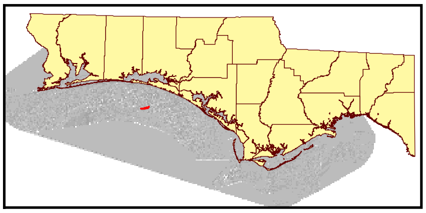
Figure 4.6.8

LEGEND:

🟩 🟩 🟩 = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



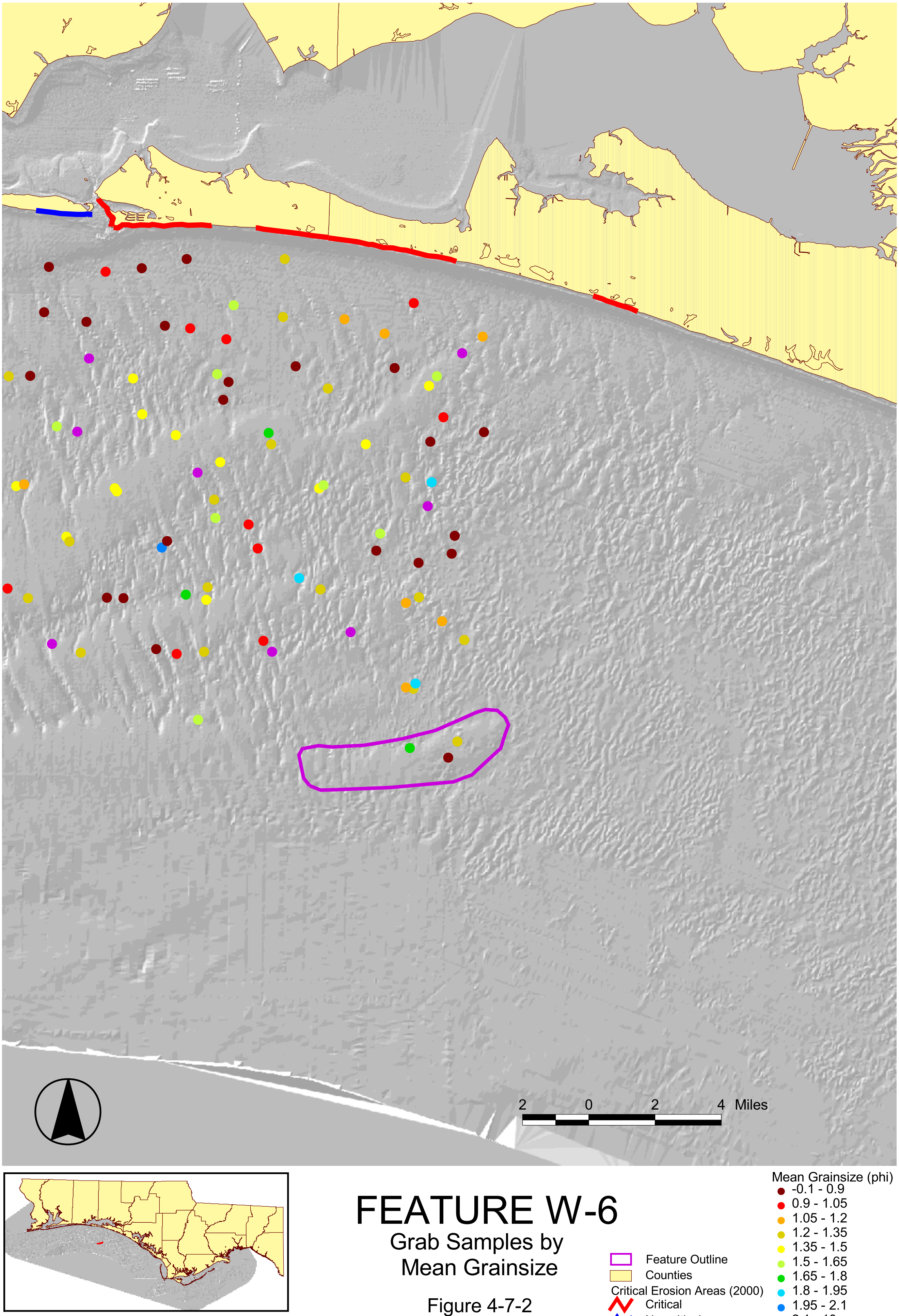


FEATURE W-6

Contour Map

Figure 4-7-1

g:\FDEP\beachcoastal\deliverables\report_figures.apr

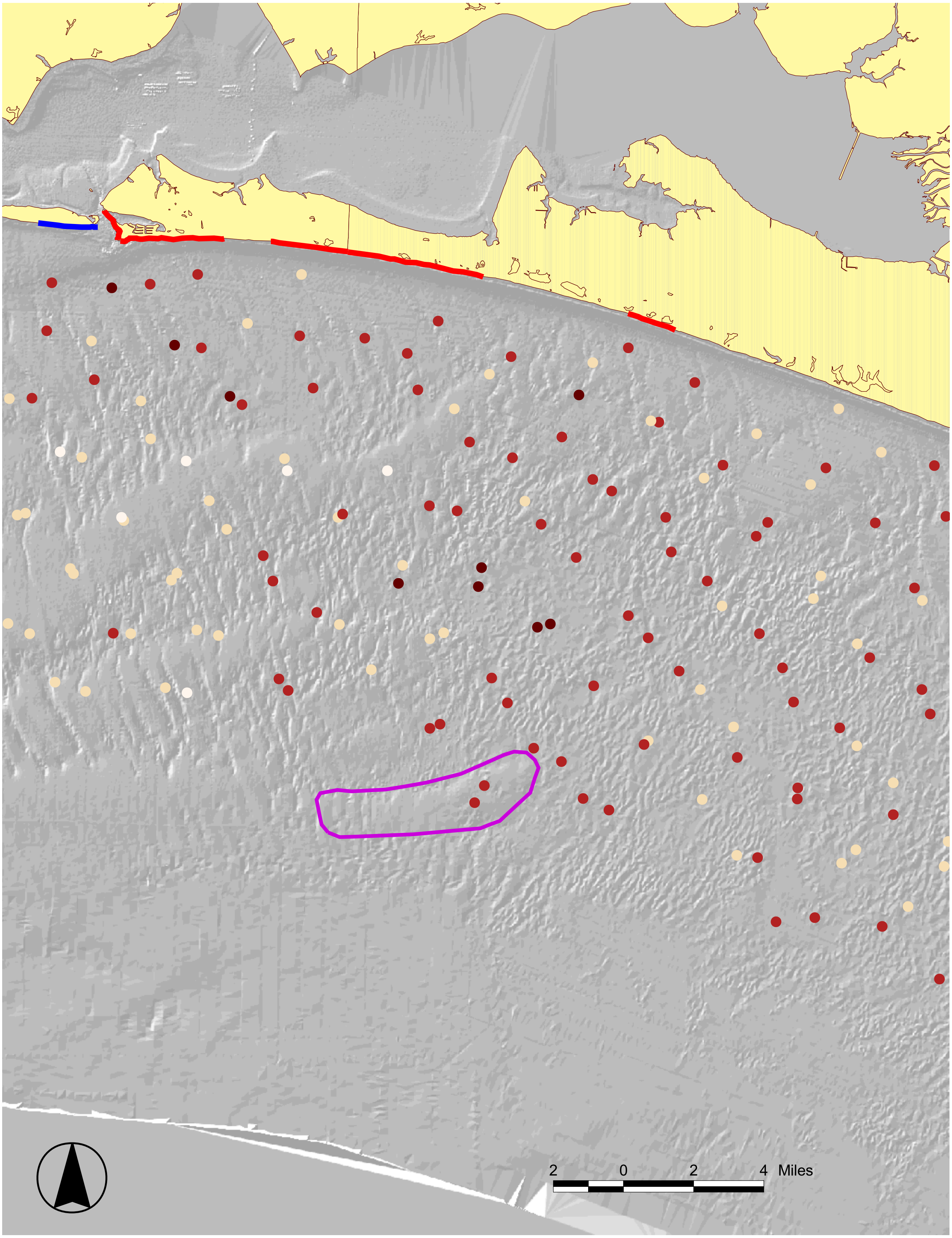


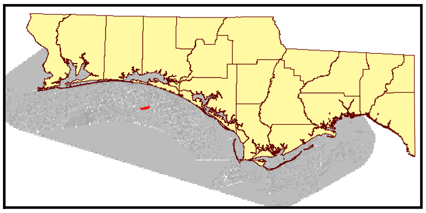
FEATURE W-6

Grab Samples by Mean Grainsize

Figure 4-7-2

g:\FDEP\beachcoastal\deliverables\report_figures.apr





FEATURE W-6

Grab Samples Normalized by Munsell Value

Figure 4-7-3

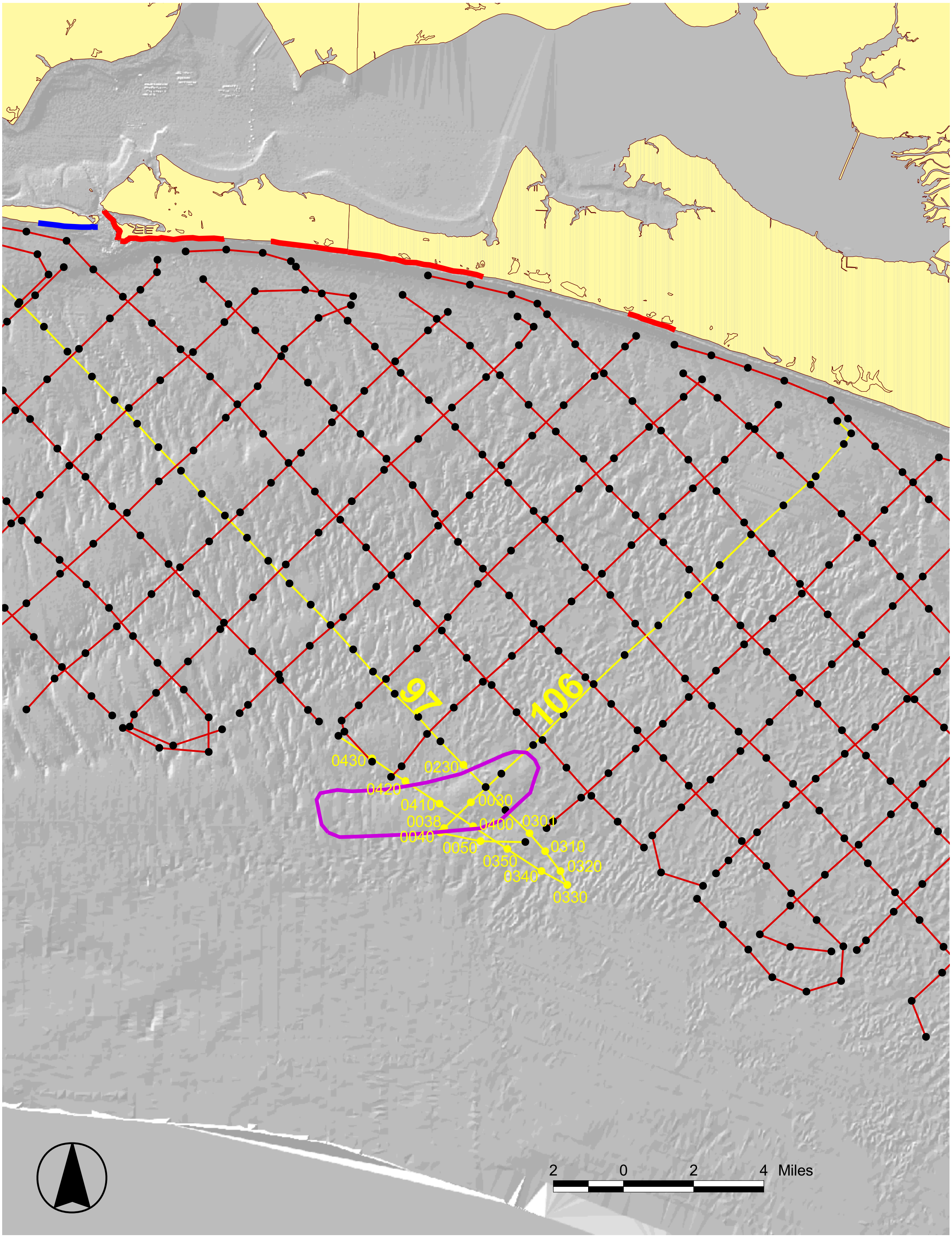
Mean grainsize by Munsell Value
- ● 1 - 5
- ● 5.1 - 6
- ● 6.1 - 7
- ● 7.1 - 11

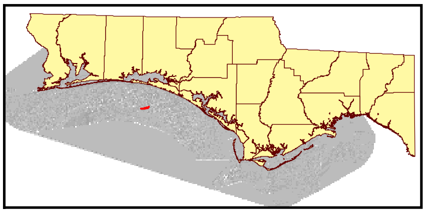
▭ Feature Outline

▨ Counties

Critical Erosion Areas (2000)
- Critical
- Noncritical

g:\FDEP\beachcoastal\deliverables\report_figures.apr





FEATURE W-6

Geophysical Tracklines and Shotpoints with Timestamps

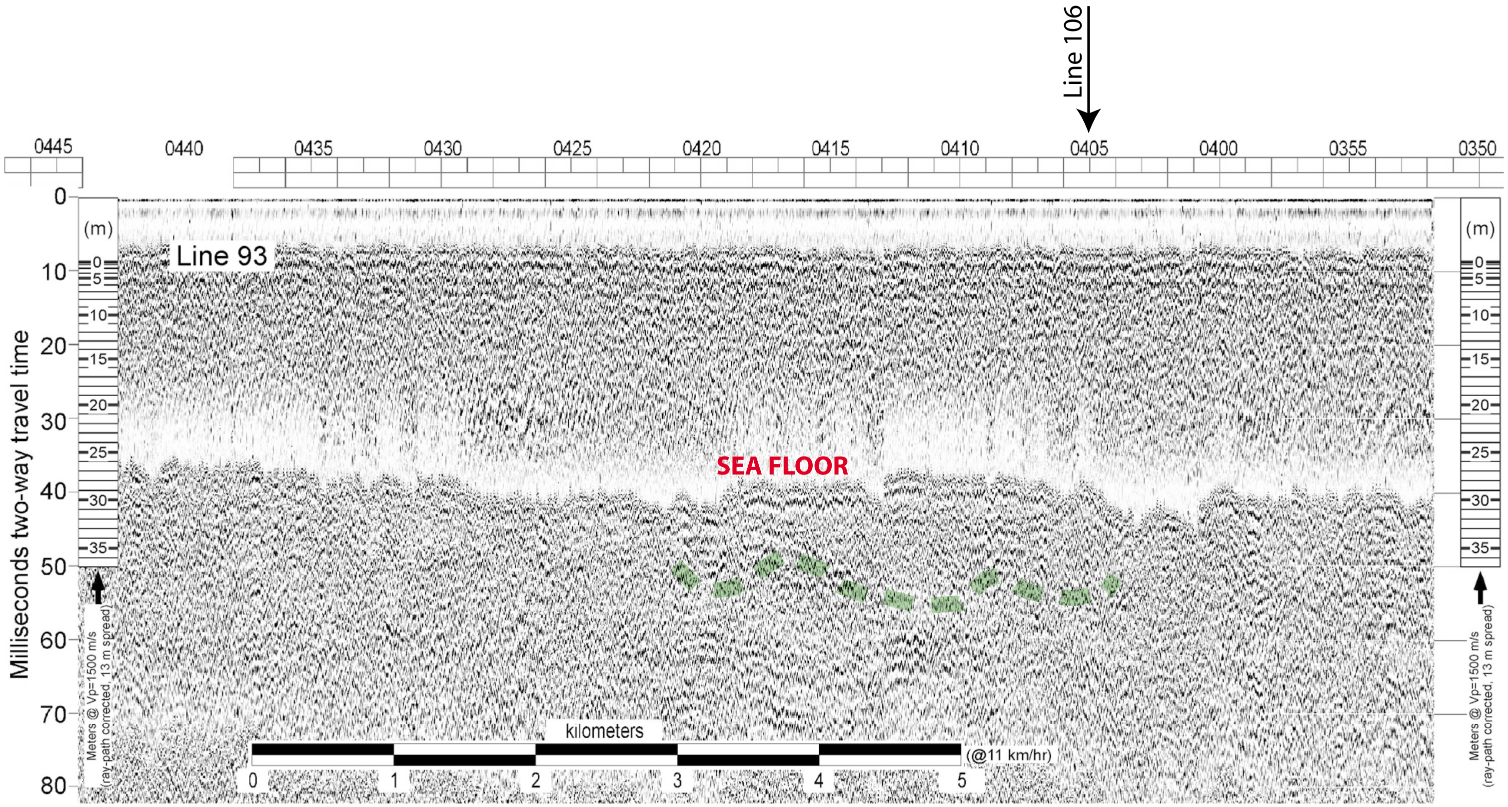
Figure 4-7-4

- ▭ Feature Outline
- ● Shotpoints
- Tracklines
- 🟨 Counties

Critical Erosion Areas (2000)

- Critical
- Noncritical

g:\FDEP\beachcoastal\deliverables\report_figures.apr



Feature W-6

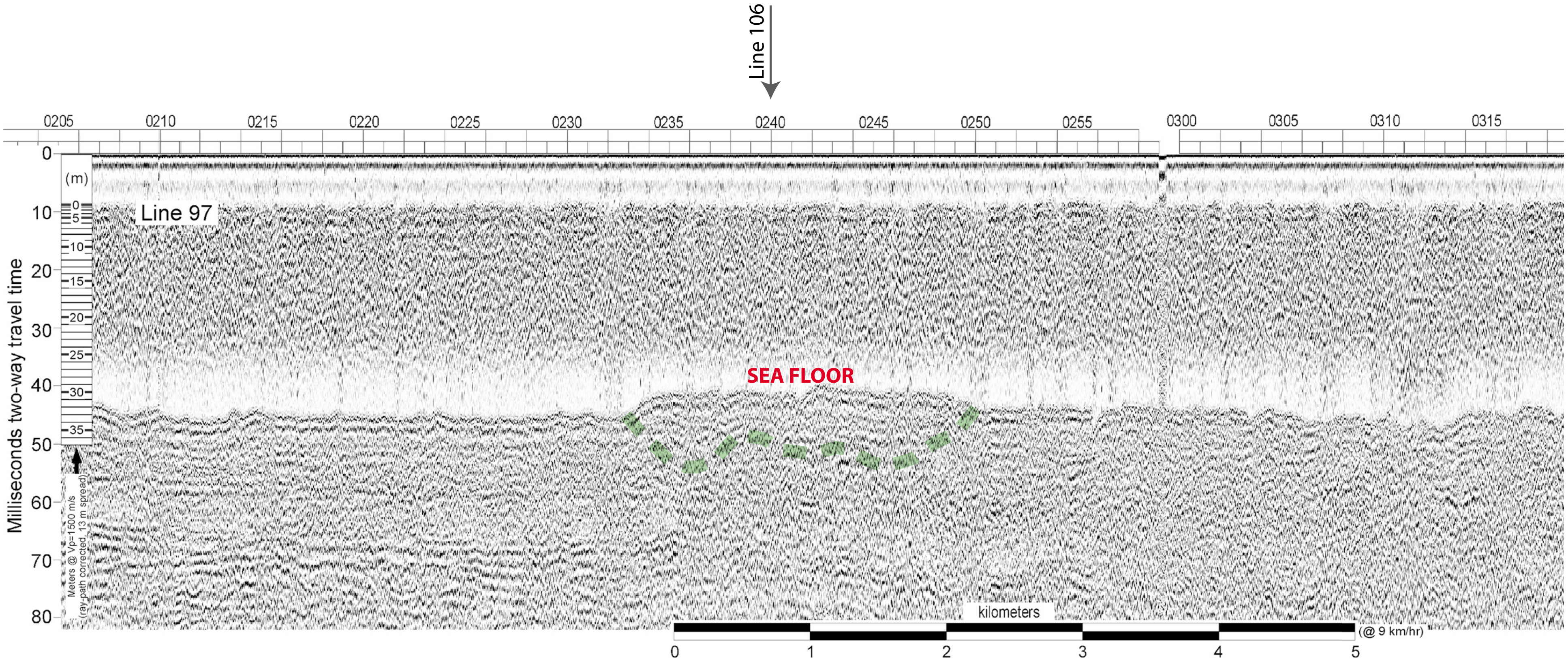
Line 93

Figure 4.7.5

LEGEND:

– – – = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



Feature W-6

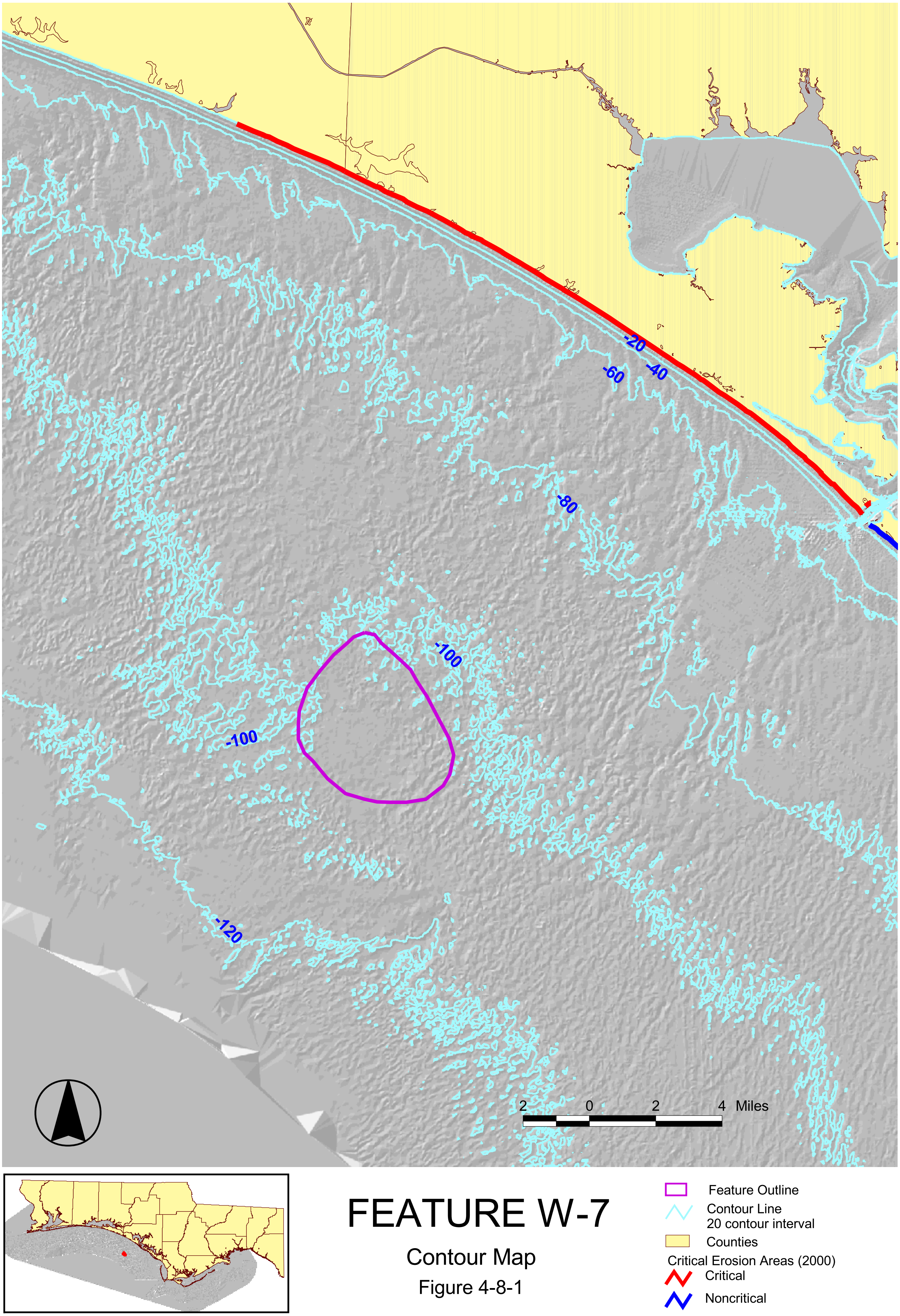
Line 97

Figure 4.7.6

LEGEND:

🟩 🟩 🟩 = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line

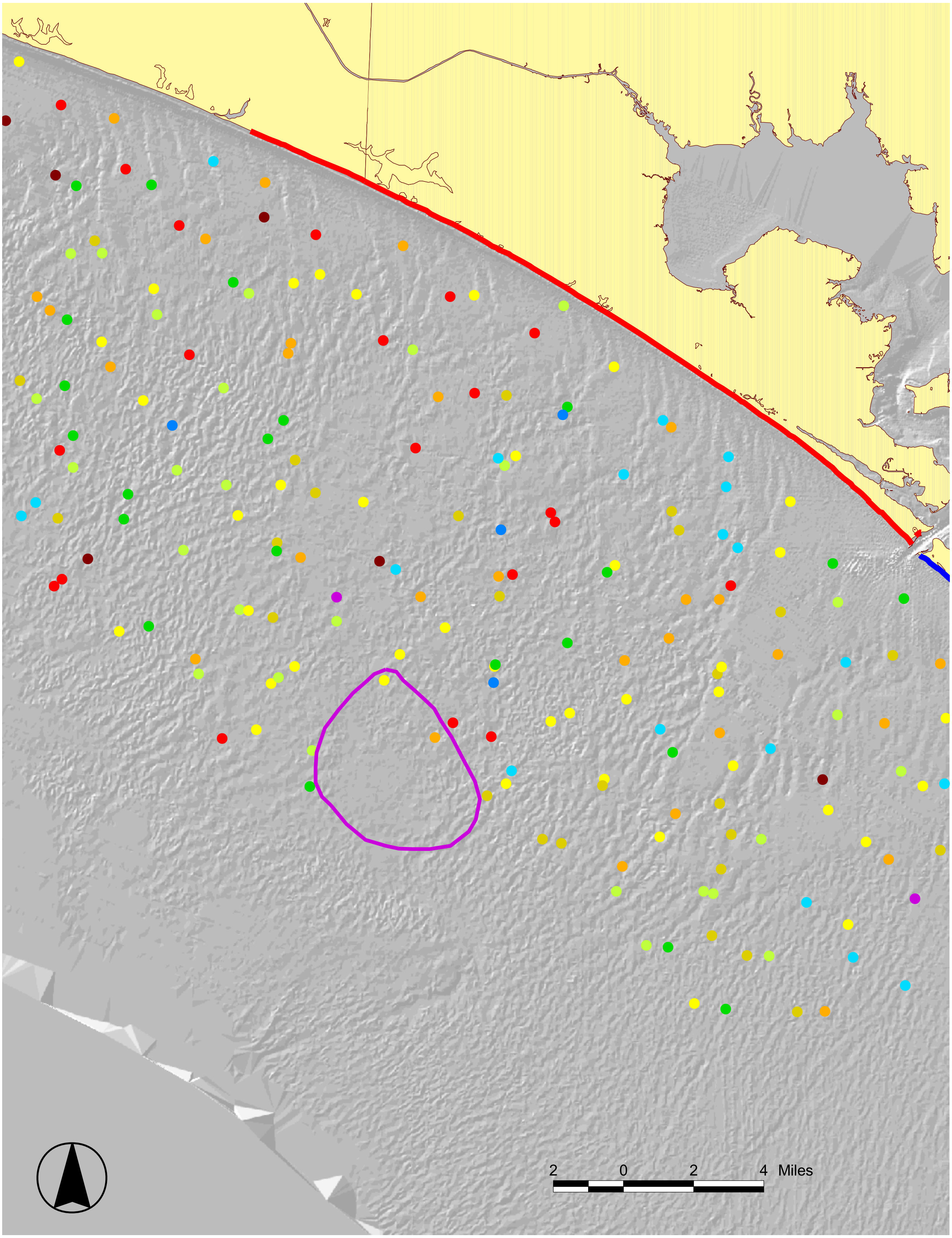


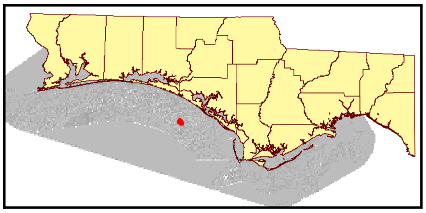
FEATURE W-7

Contour Map

Figure 4-8-1

g:\FDEP\beachcoastal\deliverables\report_figures.apr





FEATURE W-7

Grab Samples by Mean Grainsize

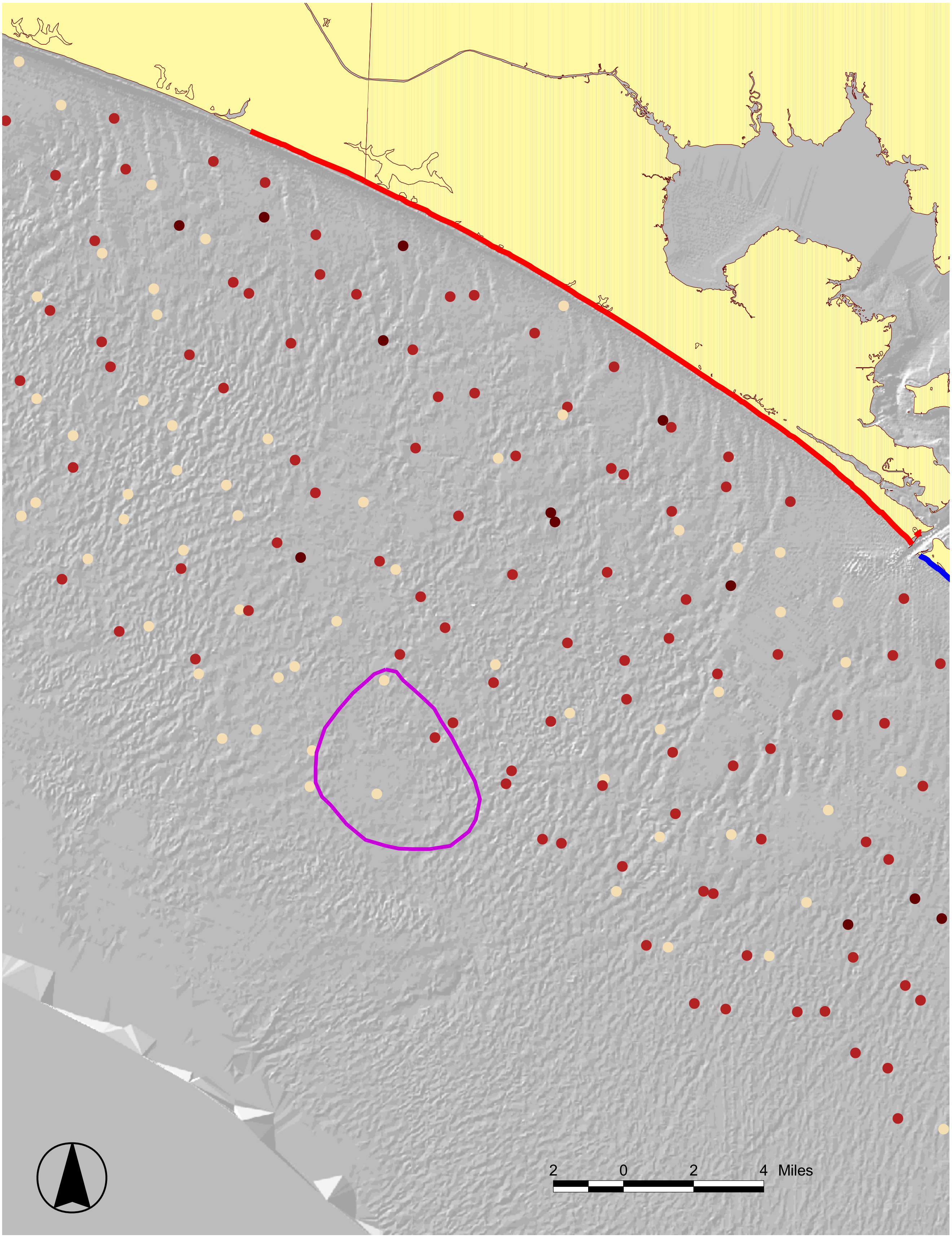
Figure 4-8-2

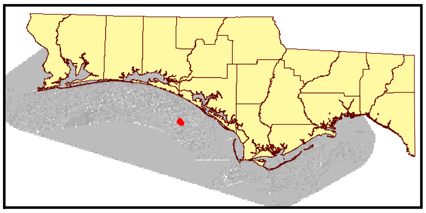
- ▭ Feature Outline
- 🟨 Counties

Critical Erosion Areas (2000)
- Critical
- Noncritical

Mean Grainsize (phi)
- ● -0.1 - 0.9
- ● 0.9 - 1.05
- ● 1.05 - 1.2
- ● 1.2 - 1.35
- ● 1.35 - 1.5
- ● 1.5 - 1.65
- ● 1.65 - 1.8
- ● 1.8 - 1.95
- ● 1.95 - 2.1
- ● 2.1 - 10

g:\FDEP\beachcoastal\deliverables\report_figures.apr



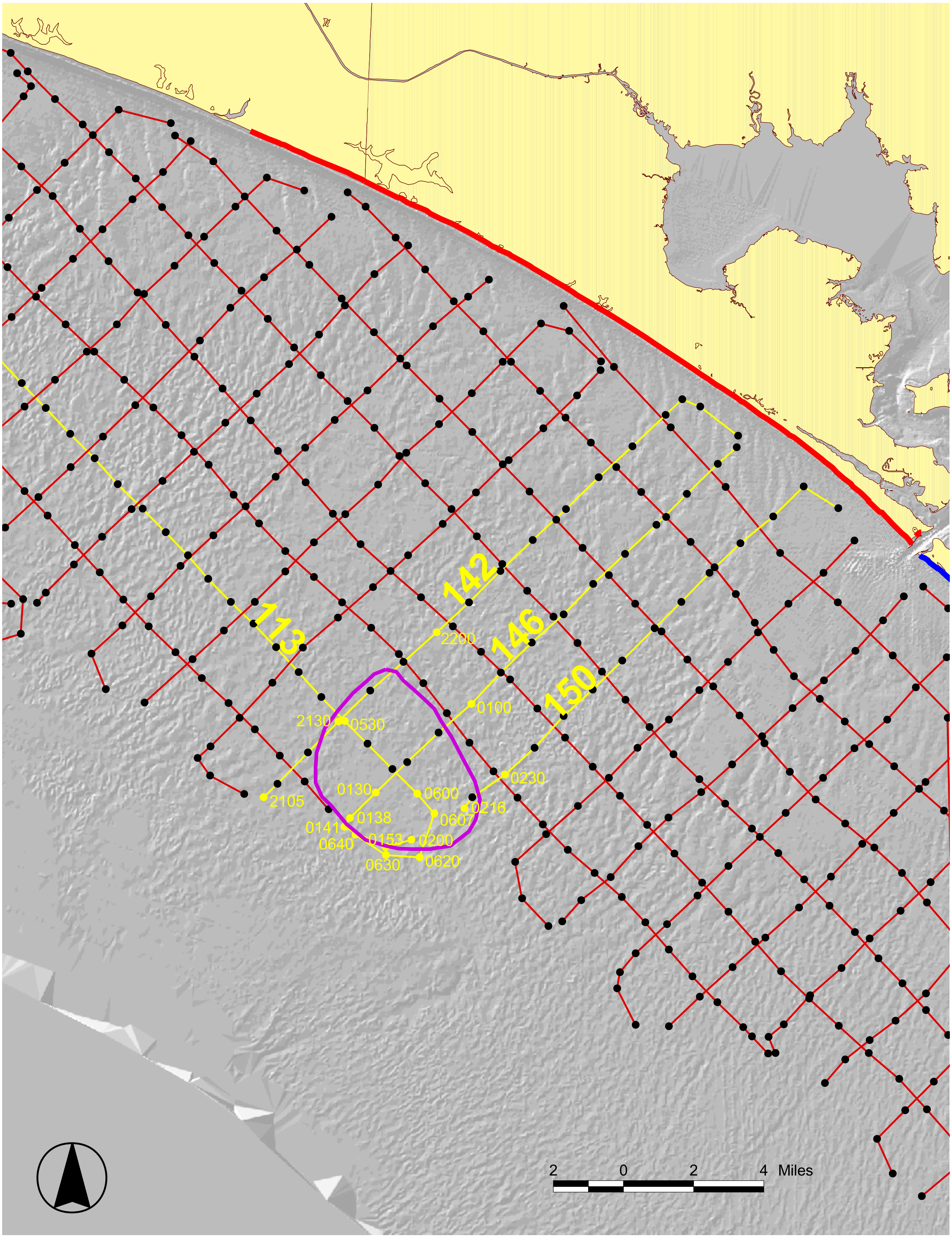


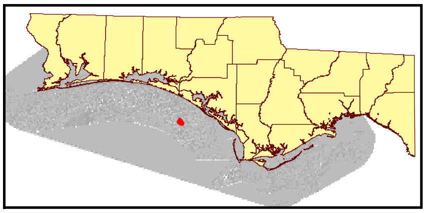
FEATURE W-7

Grab Samples Normalized by Munsell Value

Figure 4-8-3

g:\FDEP\beachcoastal\deliverables\report_figures.apr





FEATURE W-7

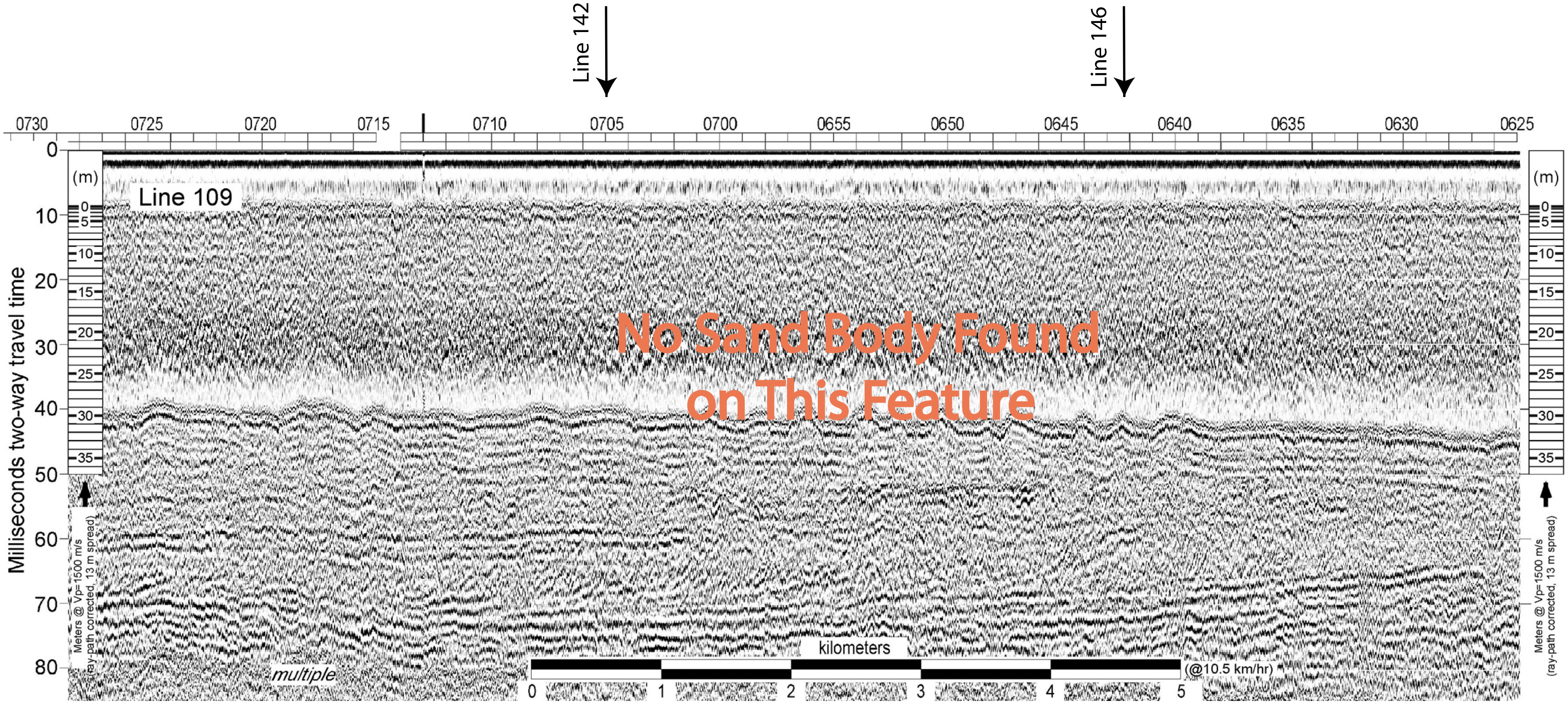
Geophysical Tracklines and
Shotpoints with Timestamps

Figure 4-8-4

▭ Feature Outline
● Shotpoints
Tracklines
🟨 Counties

Critical Erosion Areas (2000)
Critical
Noncritical

g:\FDEP\beachcoastal\deliverables\report_figures.apr

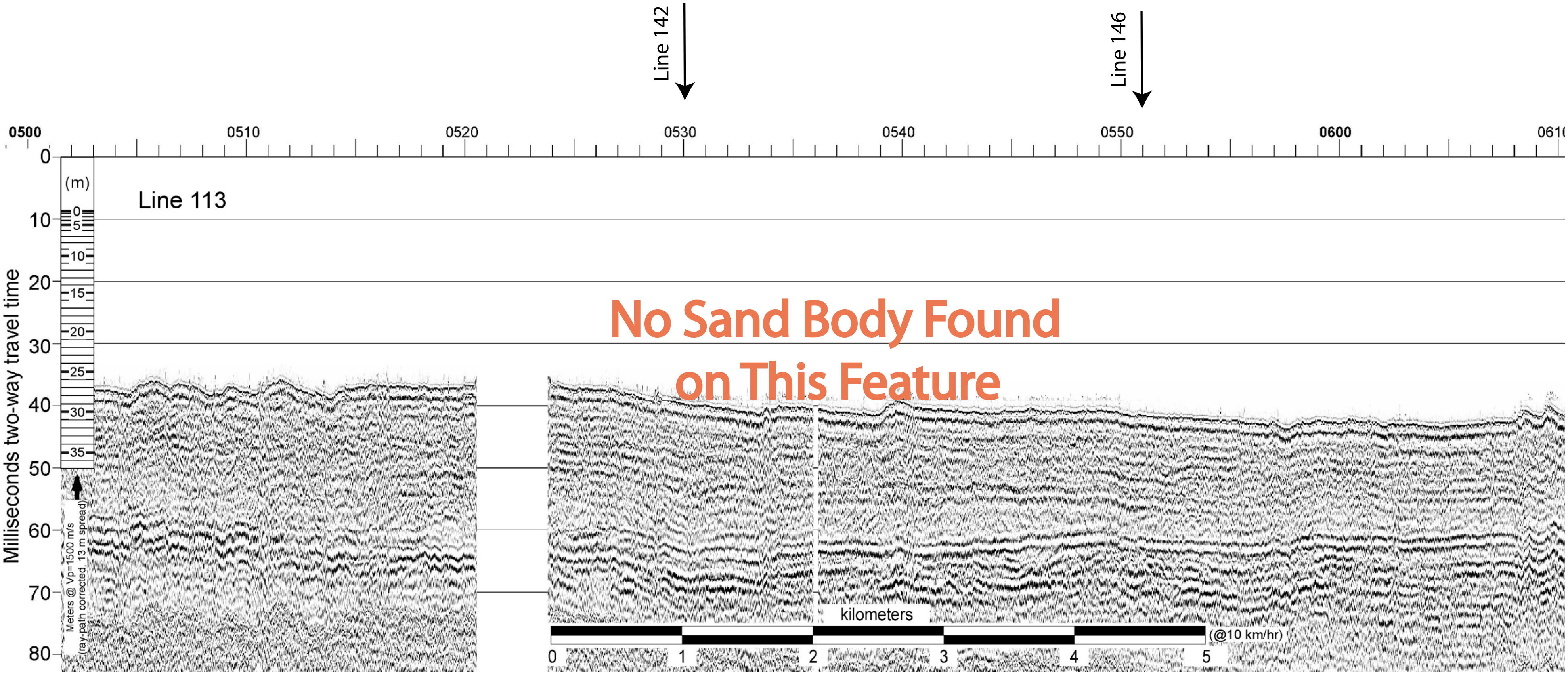


No Sand Body Found on This Feature

Feature W-7

Line 109

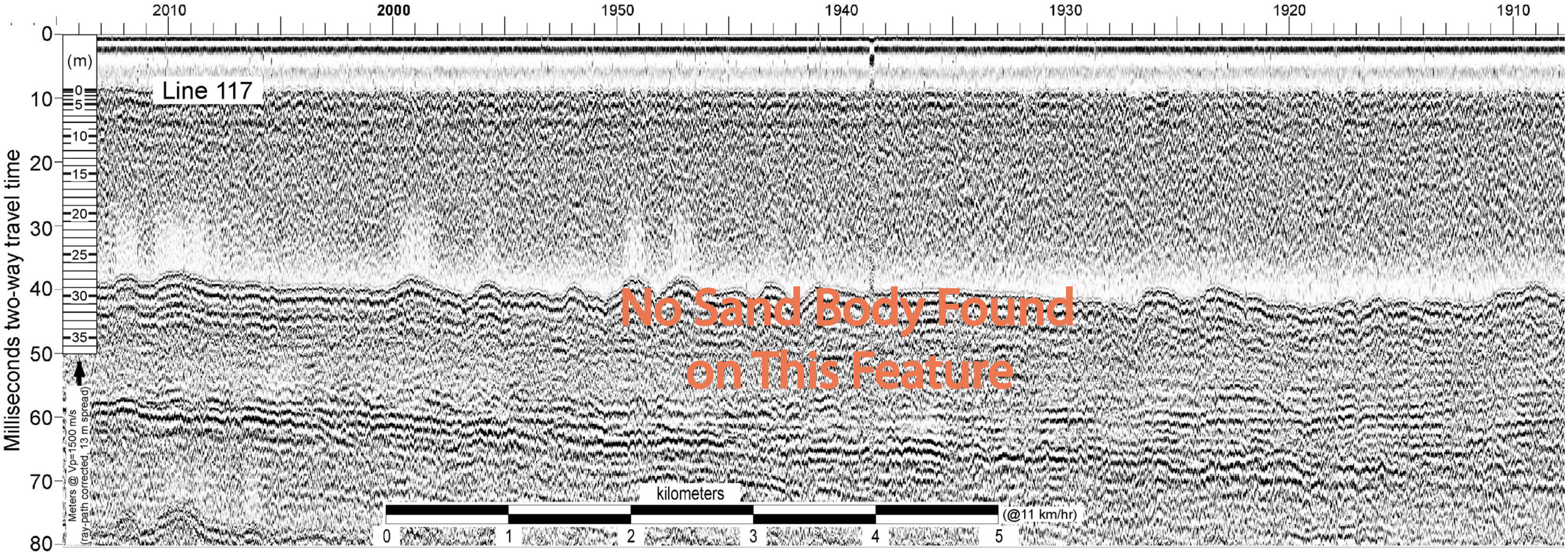
Figure 4.8.5



Feature W-7

Line 113

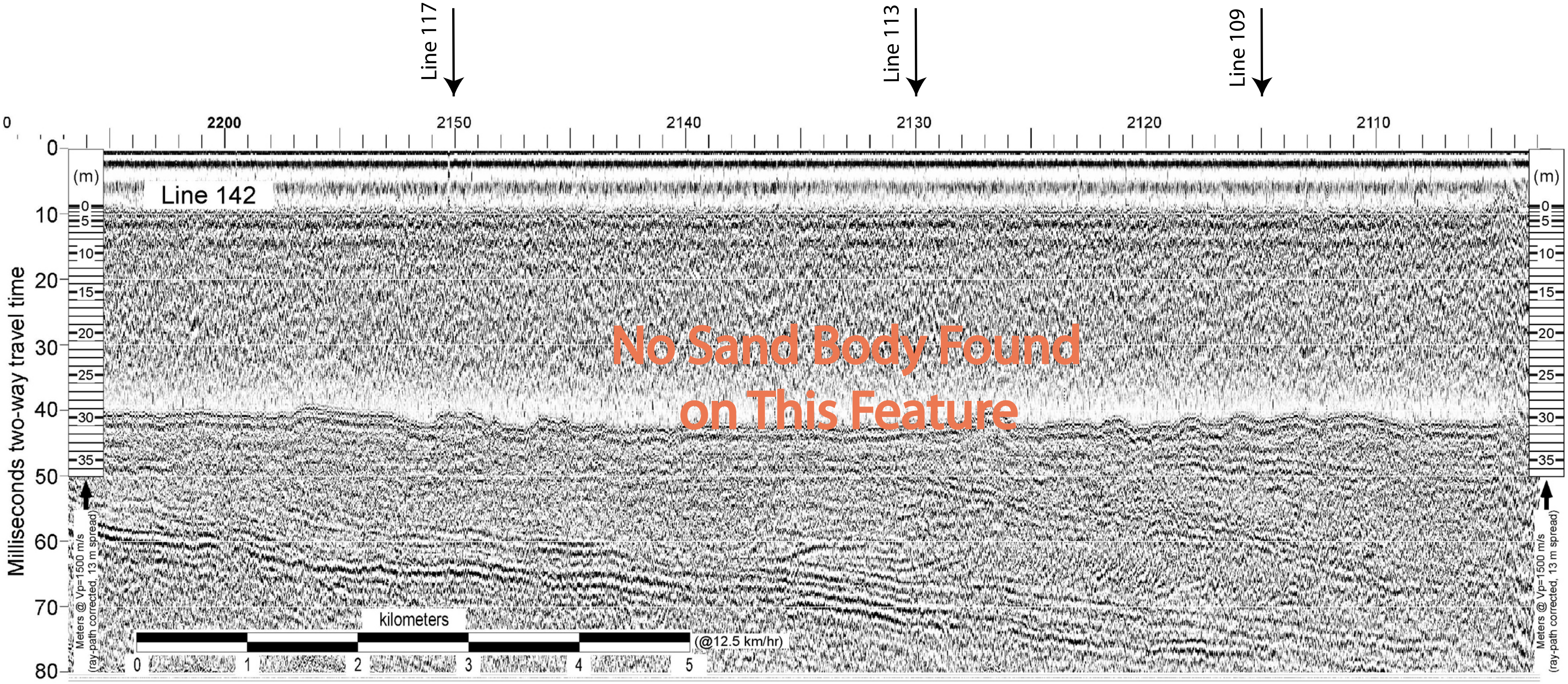
Figure 4.8.6



Feature W-7

Line 117

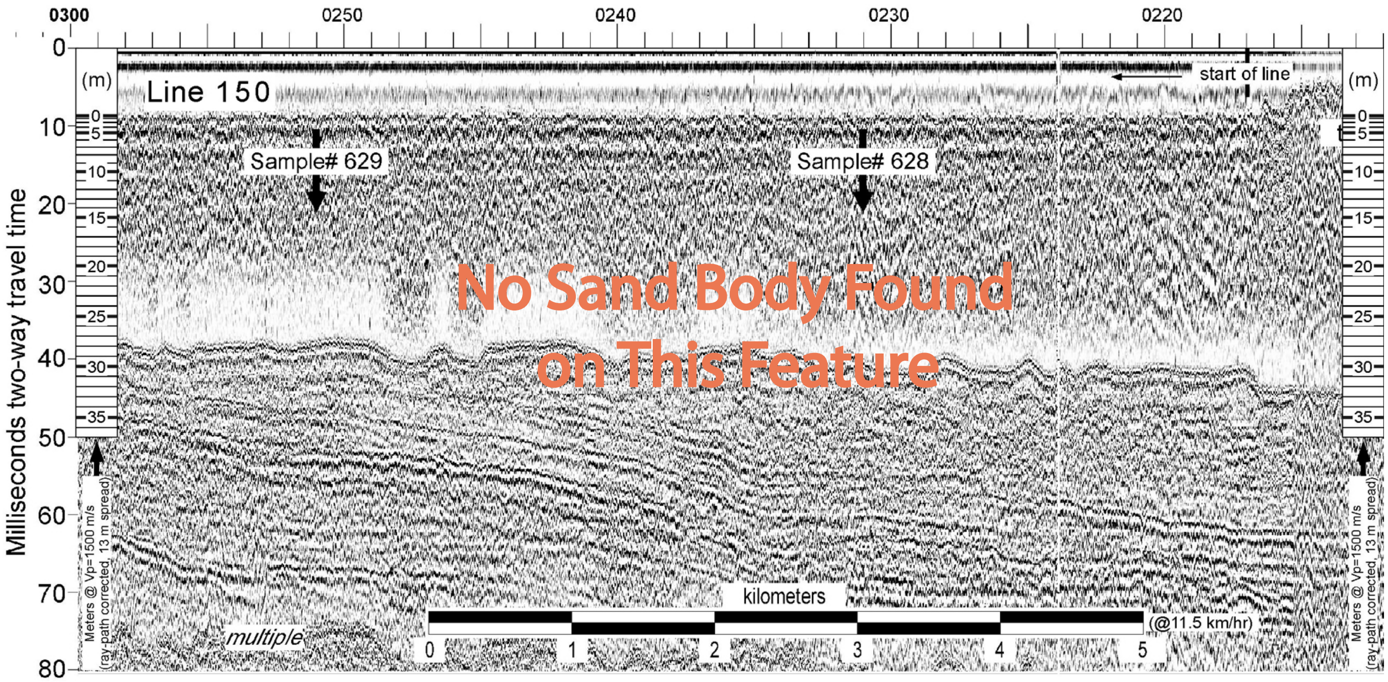
Figure 4.8.7



Feature W-7

Line 142

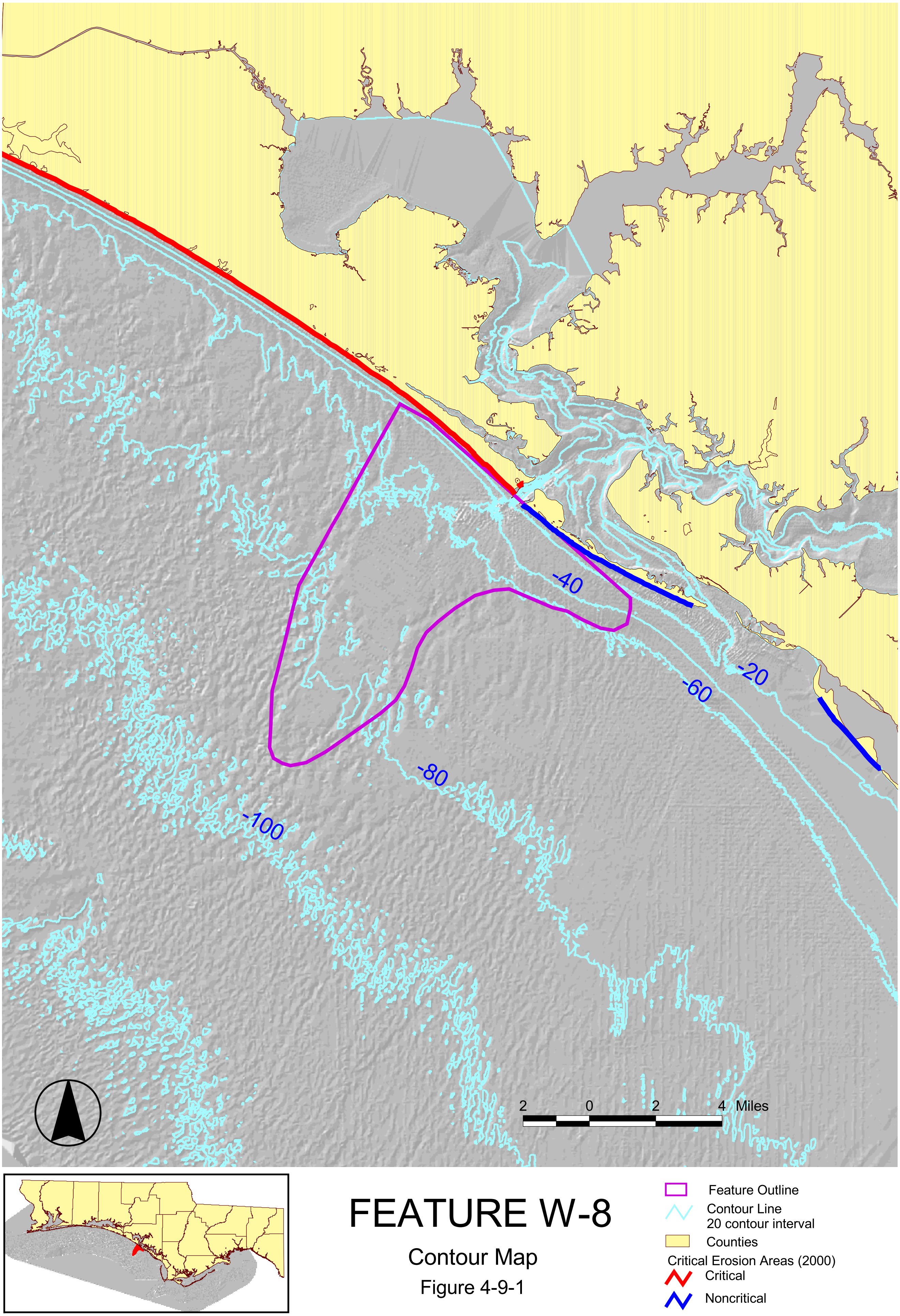
Figure 4.8.8



Feature W-7

Line 150

Figure 4.8.9

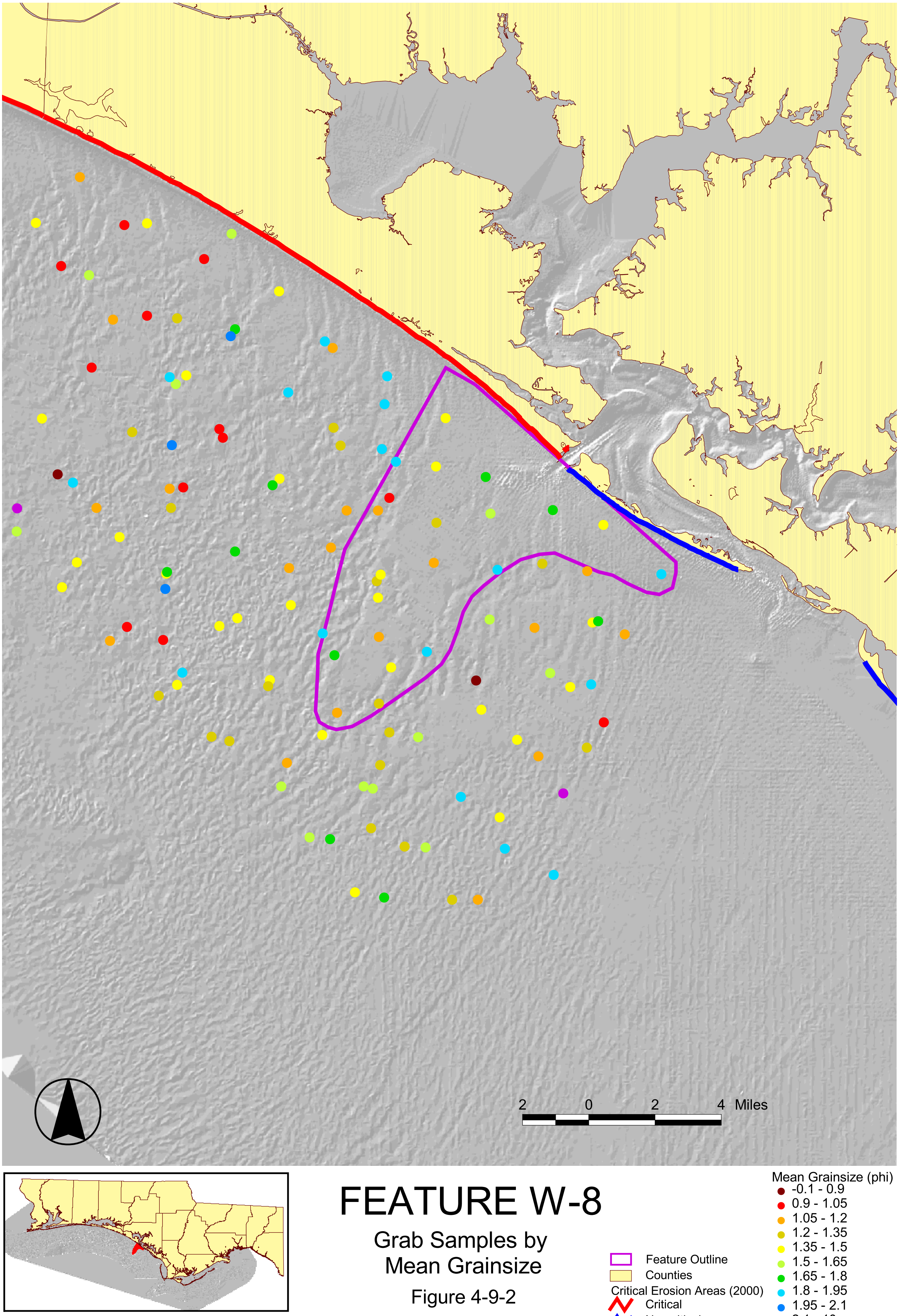


FEATURE W-8

Contour Map

Figure 4-9-1

g:\FDEP\beachcoastal\deliverables\report_figures.apr

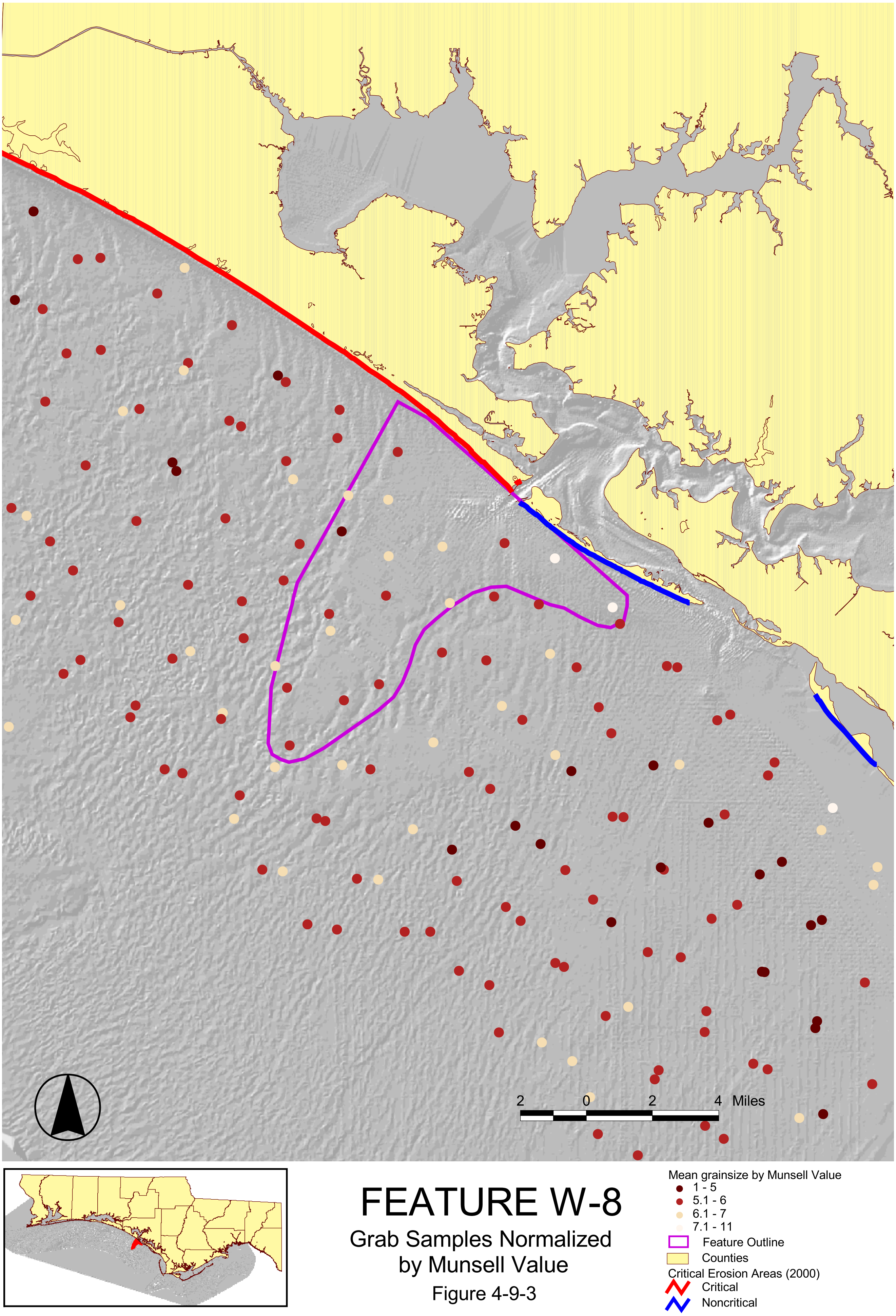


FEATURE W-8

Grab Samples by
Mean Grainsize

Figure 4-9-2

g:\FDEP\beachcoastal\deliverables\report_figures.apr

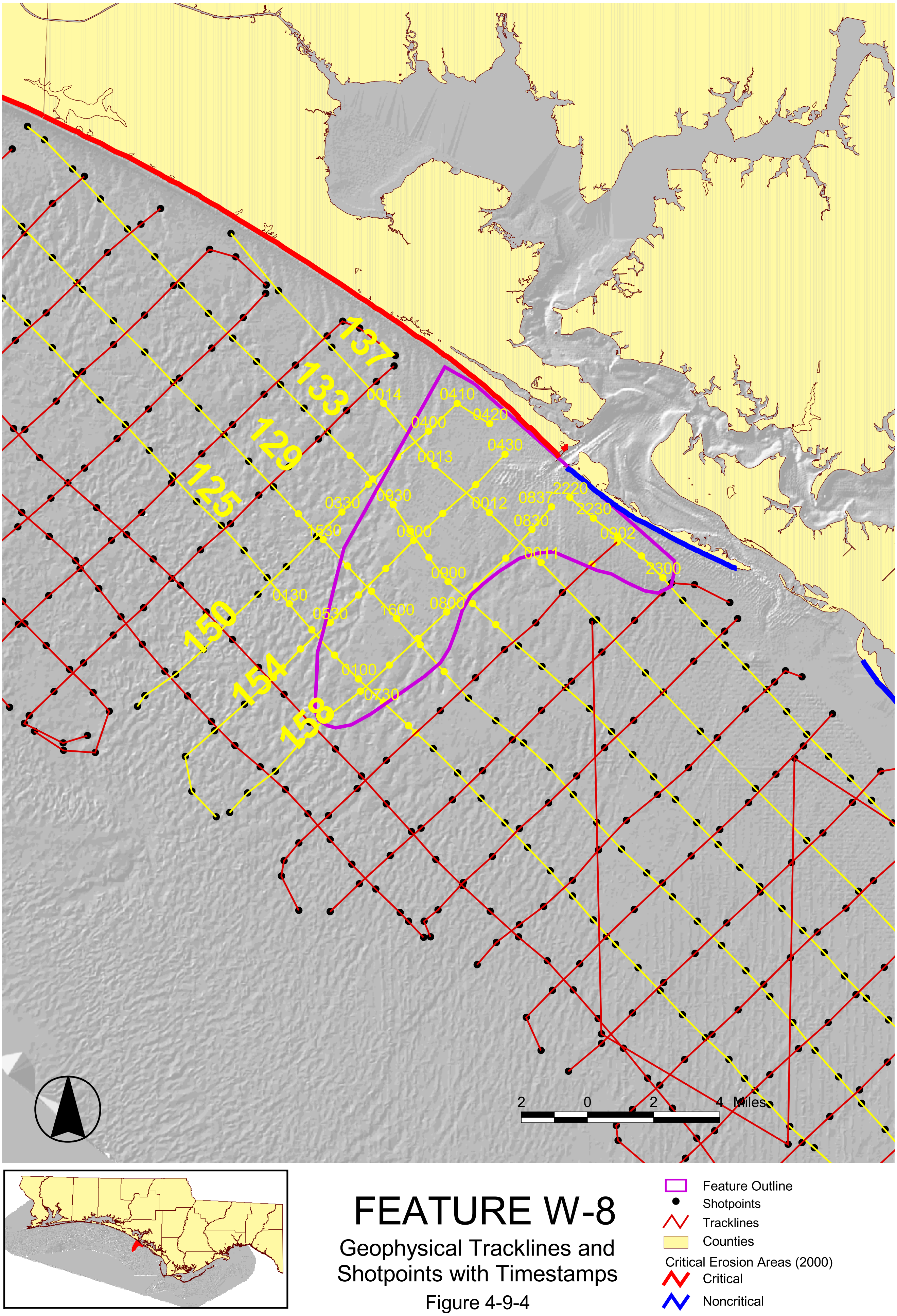


FEATURE W-8

Grab Samples Normalized by Munsell Value

Figure 4-9-3

g:\FDEP\beachcoastal\deliverables\report_figures.apr

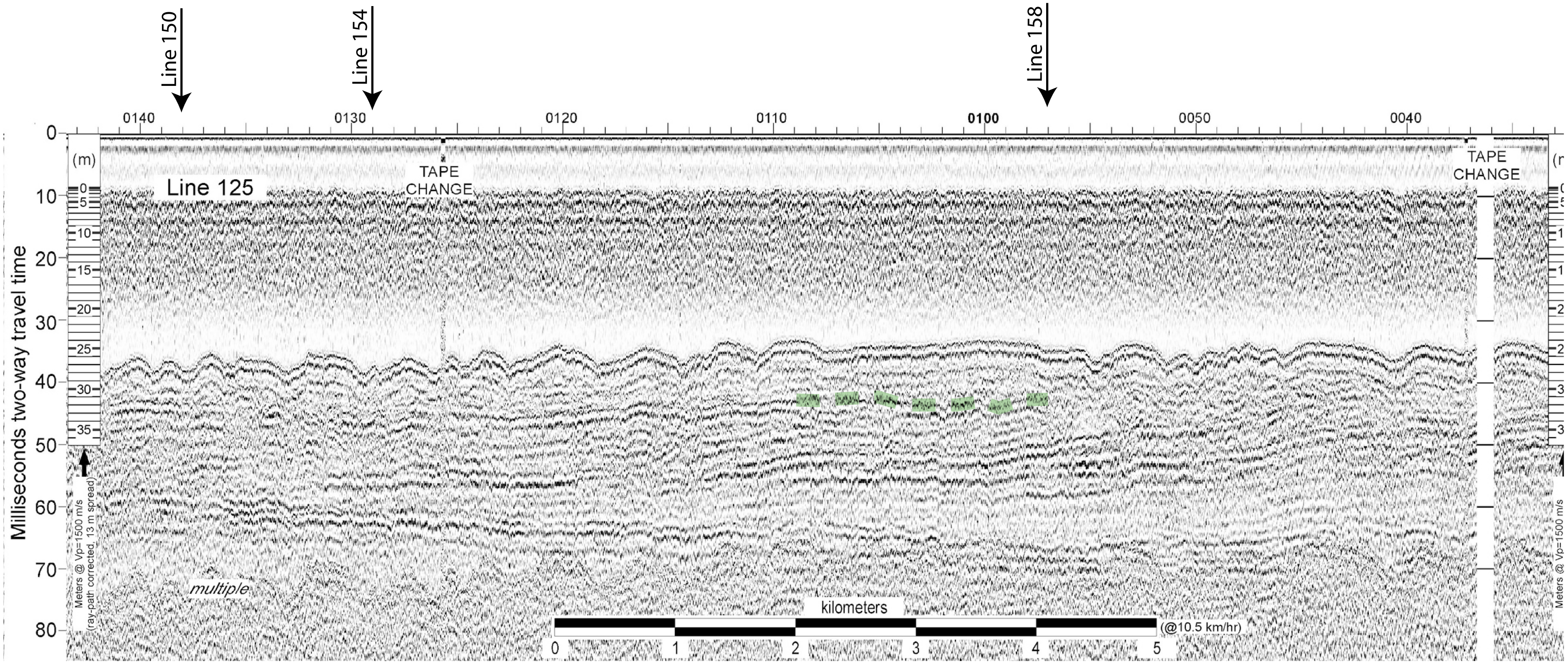


FEATURE W-8

Geophysical Tracklines and Shotpoints with Timestamps

Figure 4-9-4

g:\FDEP\beachcoastal\deliverables\report_figures.apr



Feature W-8

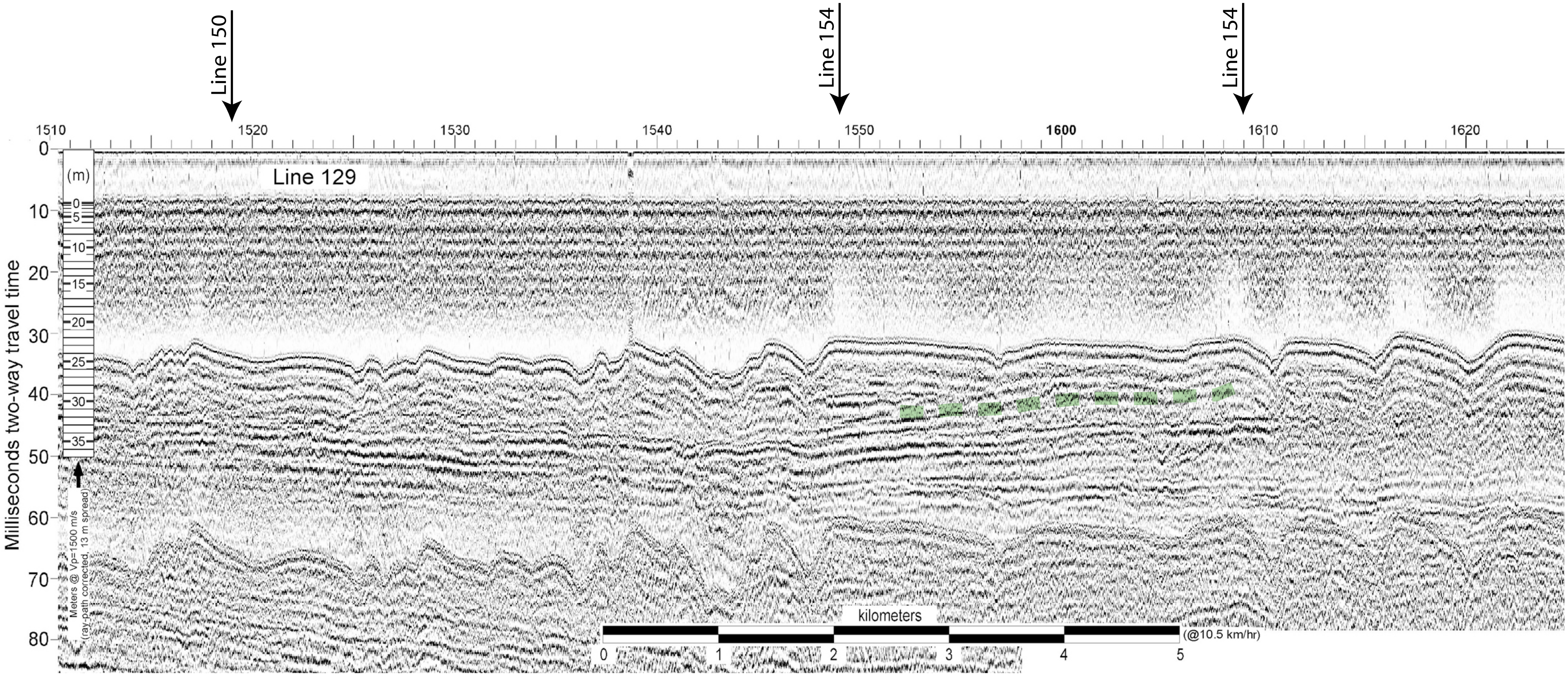
Line 125

Figure 4.9.5

LEGEND:

🟩 🟩 🟩 = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



Feature W-8

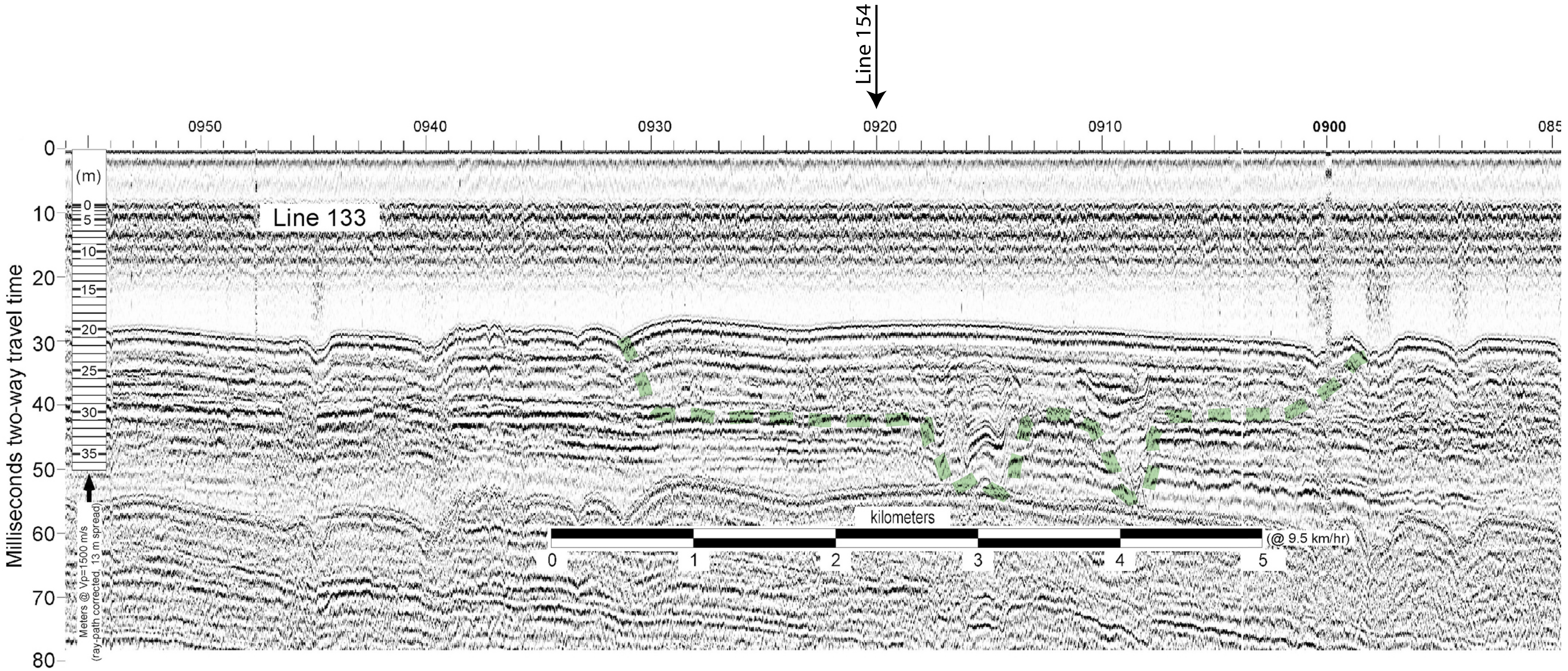
Line 129

Figure 4.9.6

LEGEND:

- - - = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



Feature W-8

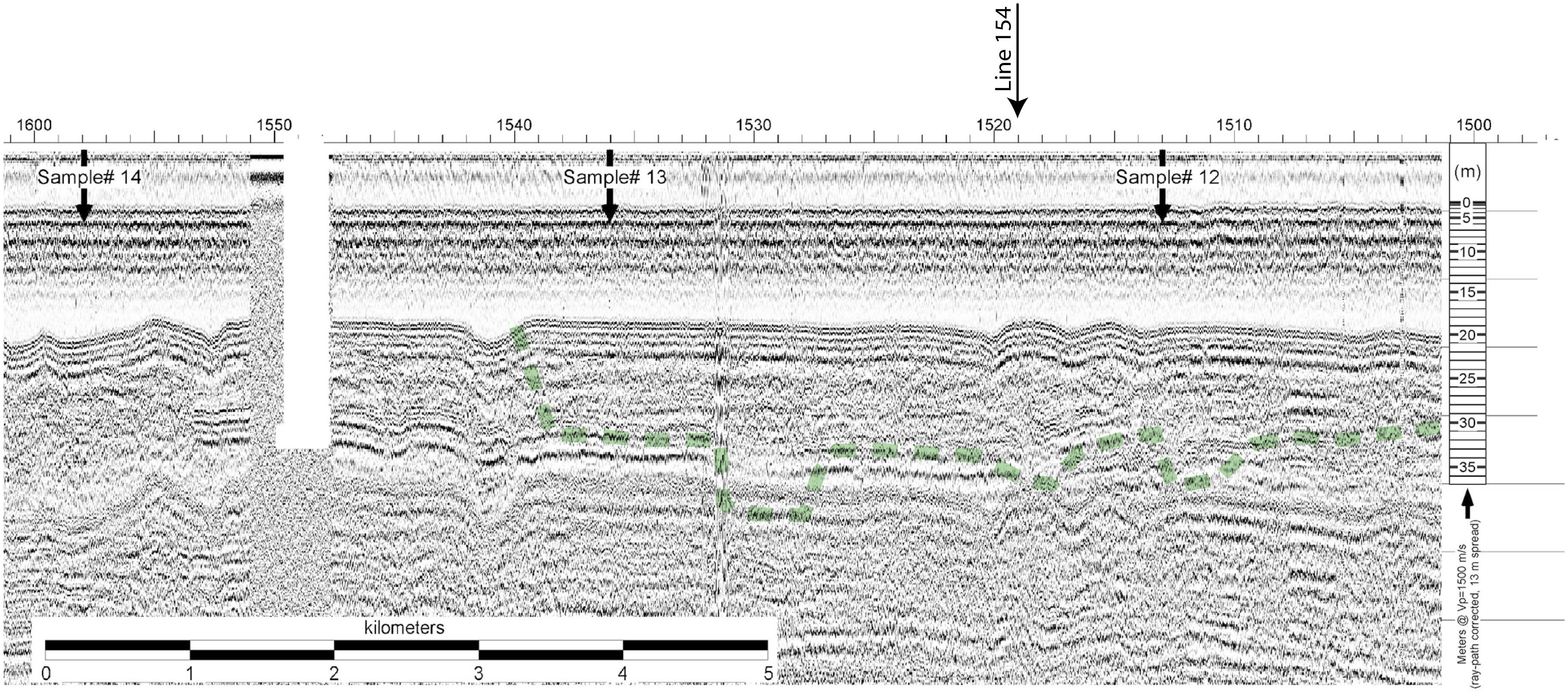
Line 133

Figure 4.9.7

LEGEND:

🟩 🟩 🟩 = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



Feature W-8

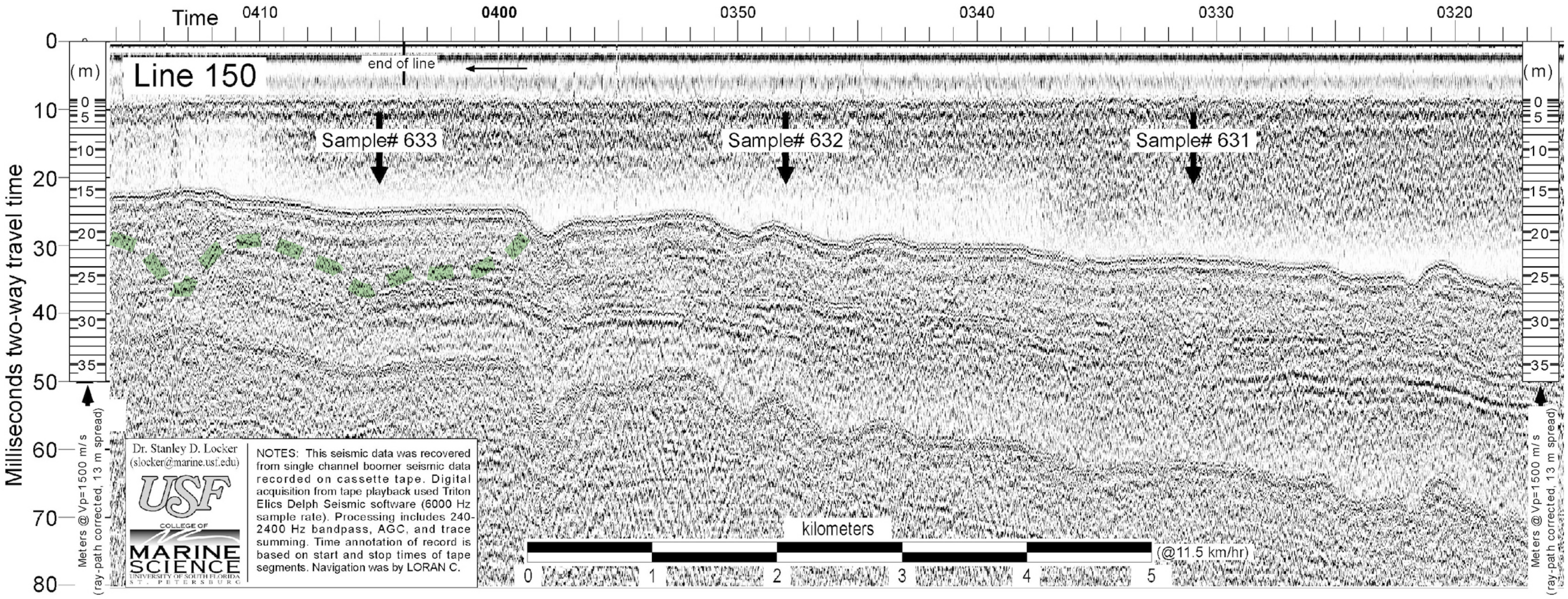
Line 137

Figure 4.9.8

LEGEND:

- - - = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



Dr. Stanley D. Locker
(slocker@marine.usf.edu)

NOTES: This seismic data was recovered from single channel boomer seismic data recorded on cassette tape. Digital acquisition from tape playback used Triton Elics Delph Seismic software (6000 Hz sample rate). Processing includes 240-2400 Hz bandpass, AGC, and trace summing. Time annotation of record is based on start and stop times of tape segments. Navigation was by LORAN C.

Feature W-8

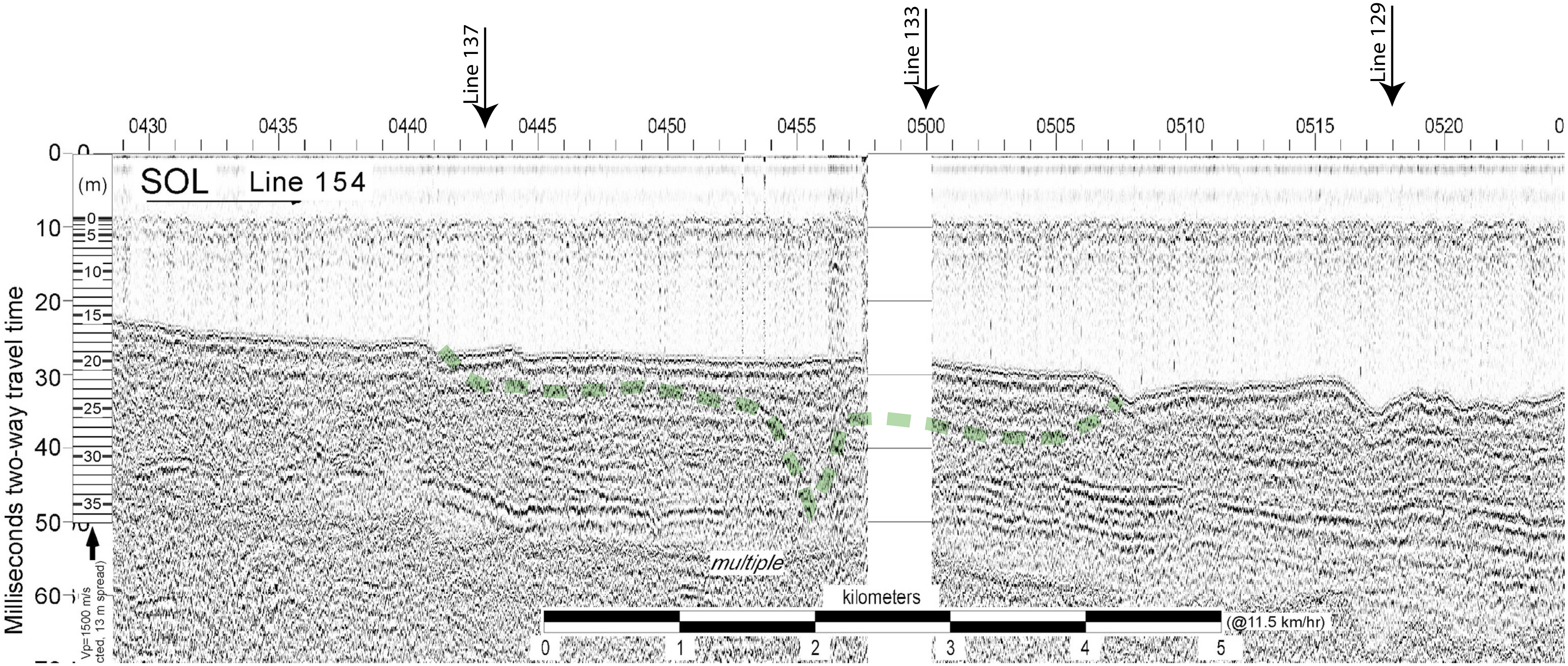
Line 150

Figure 4.9.9

LEGEND:

▬ ▬ ▬ = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



Feature W-8

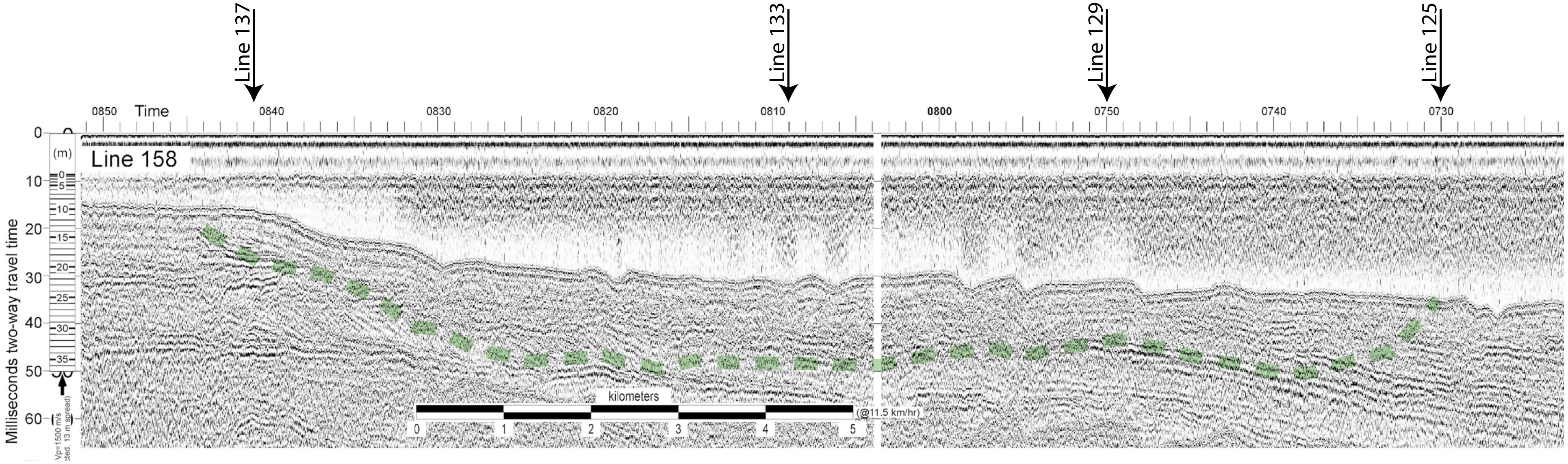
Line 154

Figure 4.9.10

LEGEND:

- - - = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



Feature W-8

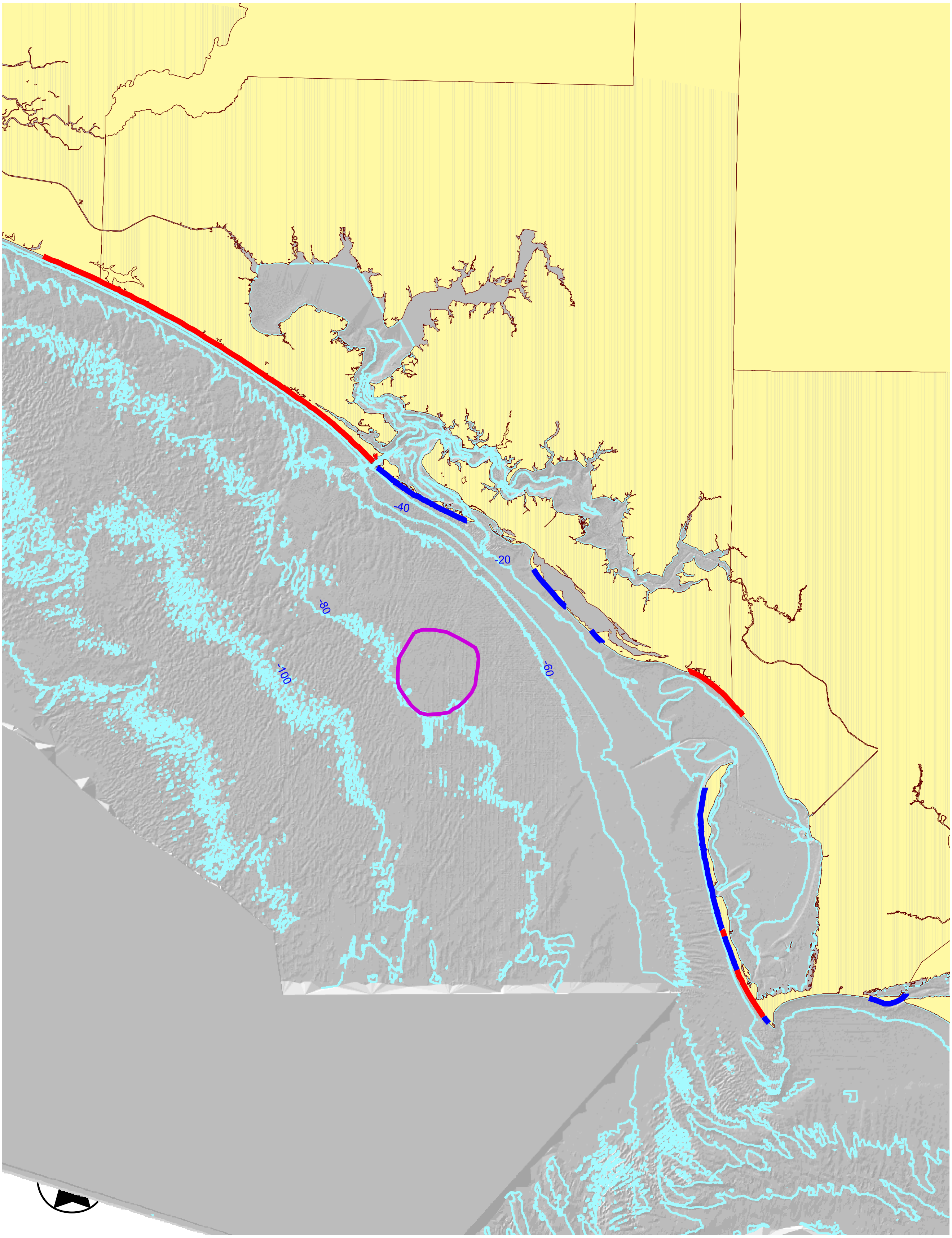
Line 158

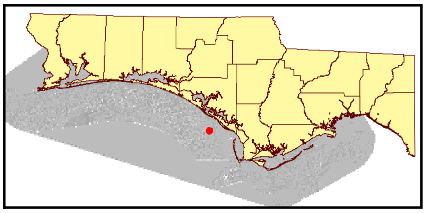
Figure 4.9.11

LEGEND:

🟩 🟩 🟩 = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line





FEATURE W-9

Contour Map

Figure 4-10-1

▭ Feature Outline

╱╲ Contour Line
20 contour interval

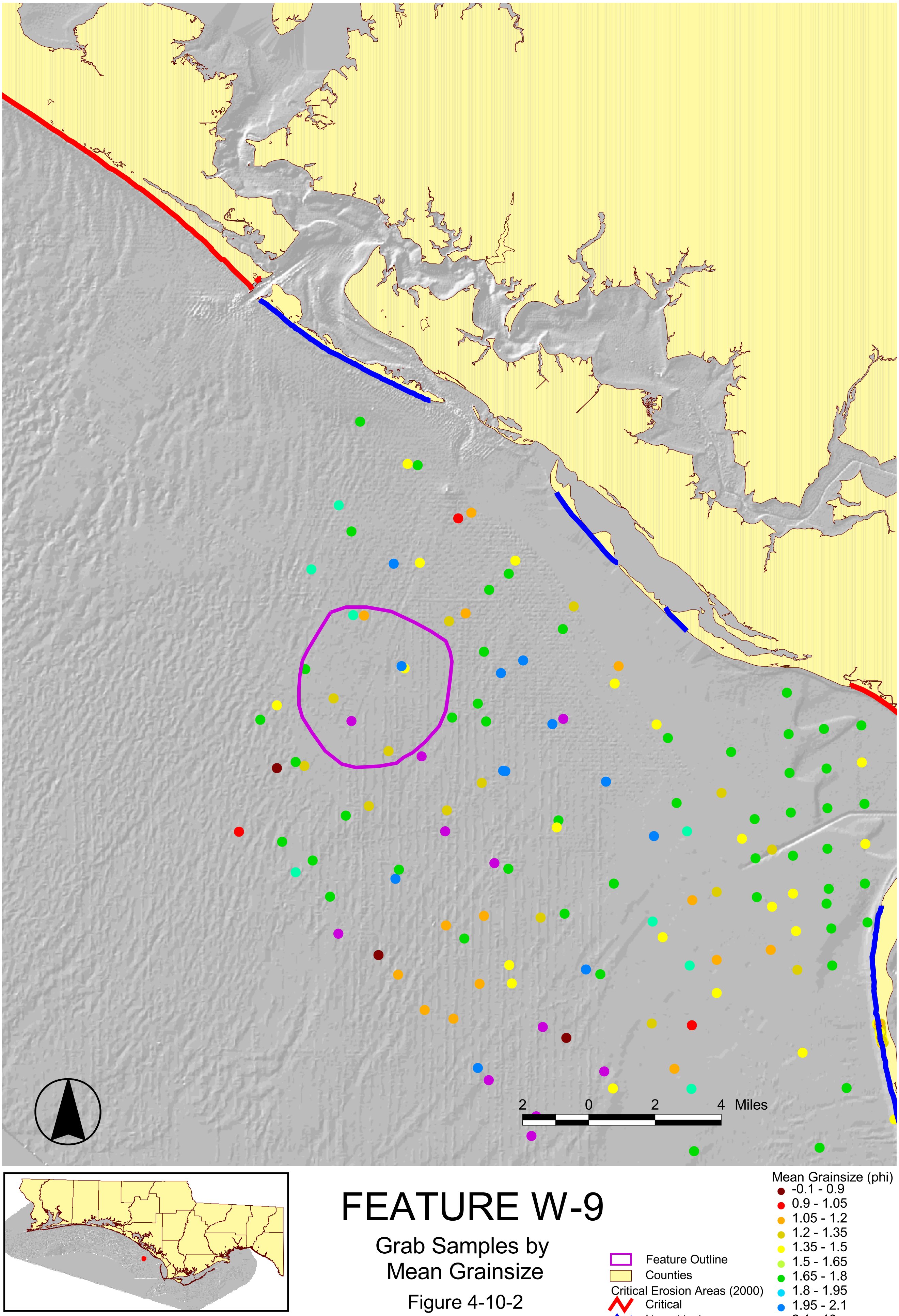
▭ Counties

Critical Erosion Areas (2000)

╱╲ Critical

╱╲ Noncritical

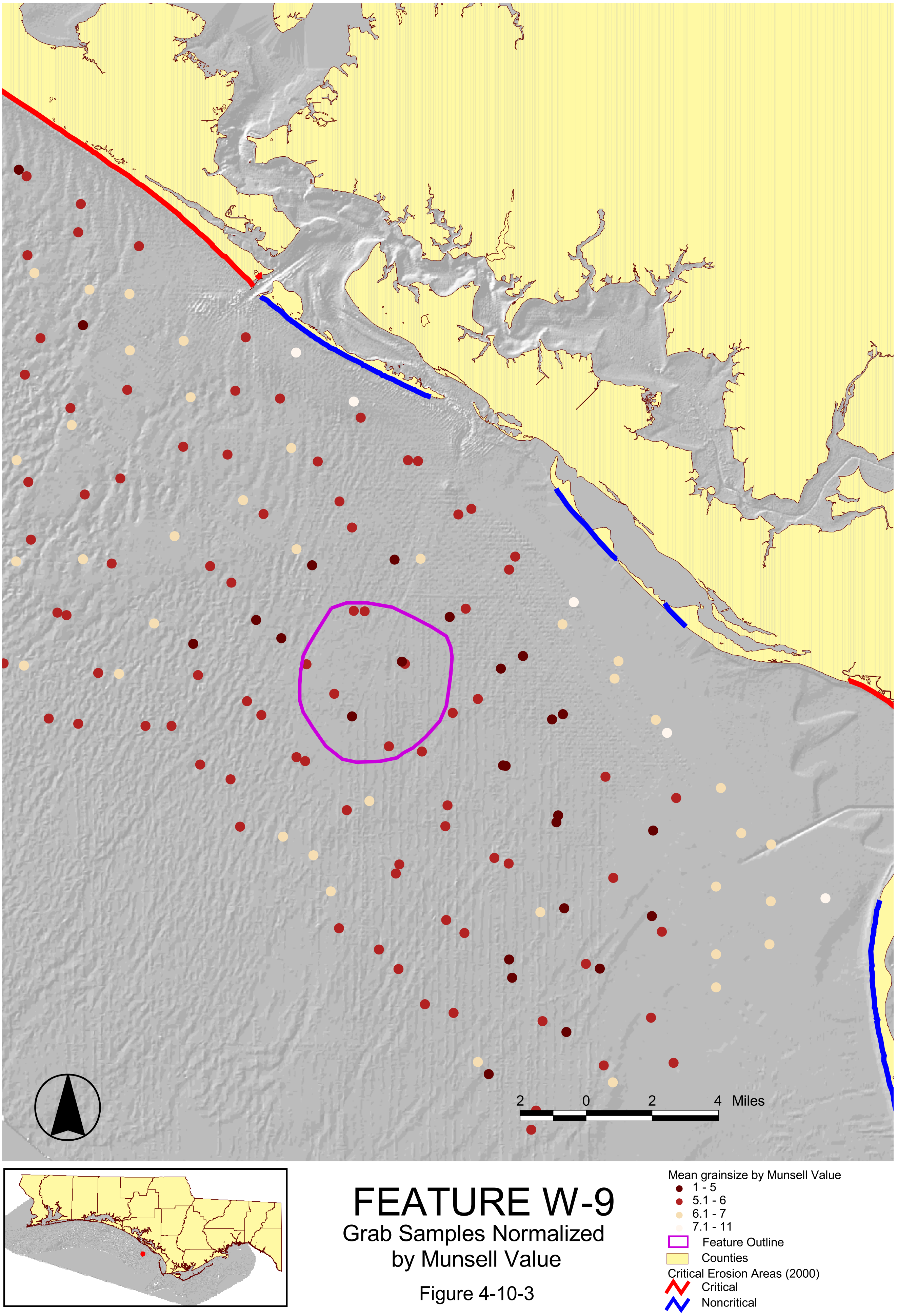
g:\FDEP\beachcoastal\deliverables\report_figures.apr



FEATURE W-9

Grab Samples by
Mean Grainsize

Figure 4-10-2

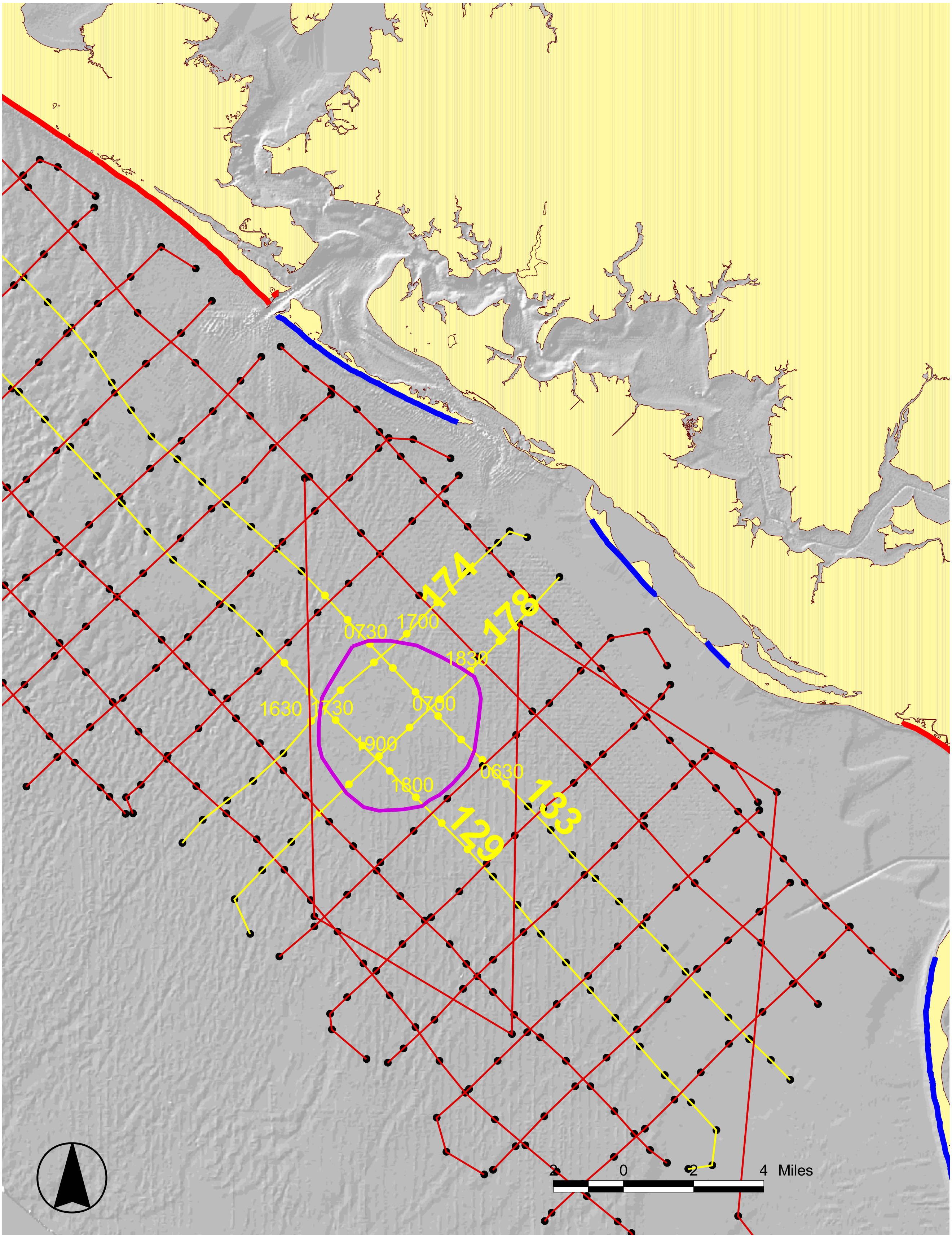


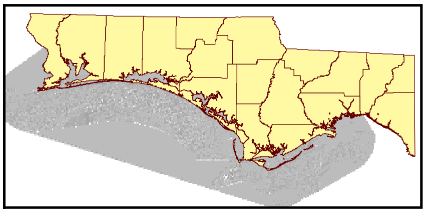
FEATURE W-9

Grab Samples Normalized by Munsell Value

Figure 4-10-3

g:\FDEP\beachcoastal\deliverables\report_figures.apr





FEATURE W-9

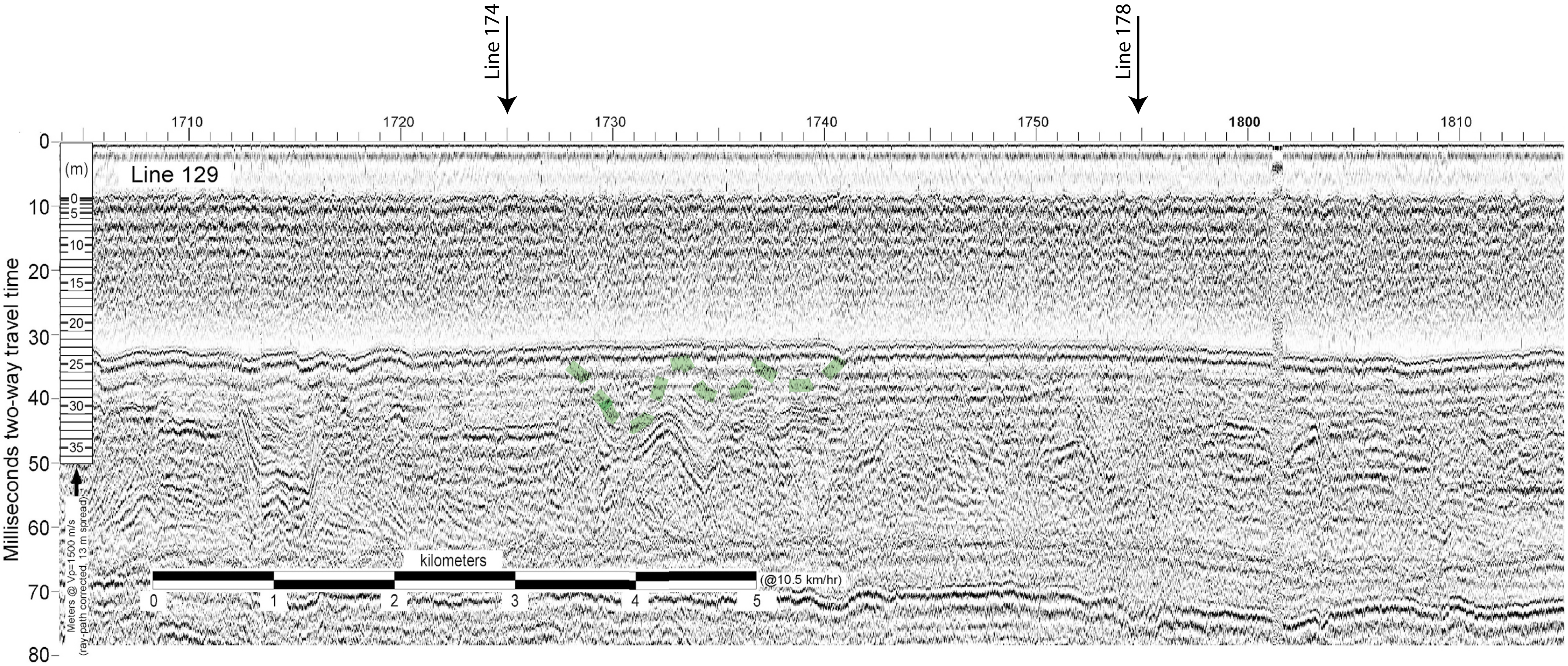
Geophysical Tracklines and Shotpoints with Timestamps

Figure 4-10-4

▭ Feature Outline
● Shotpoints
⁄\ Tracklines
▭ Counties

Critical Erosion Areas (2000)
🟥 Critical
🟦 Noncritical

g:\FDEP\beachcoastal\deliverables\report_figures.apr



Feature W-9

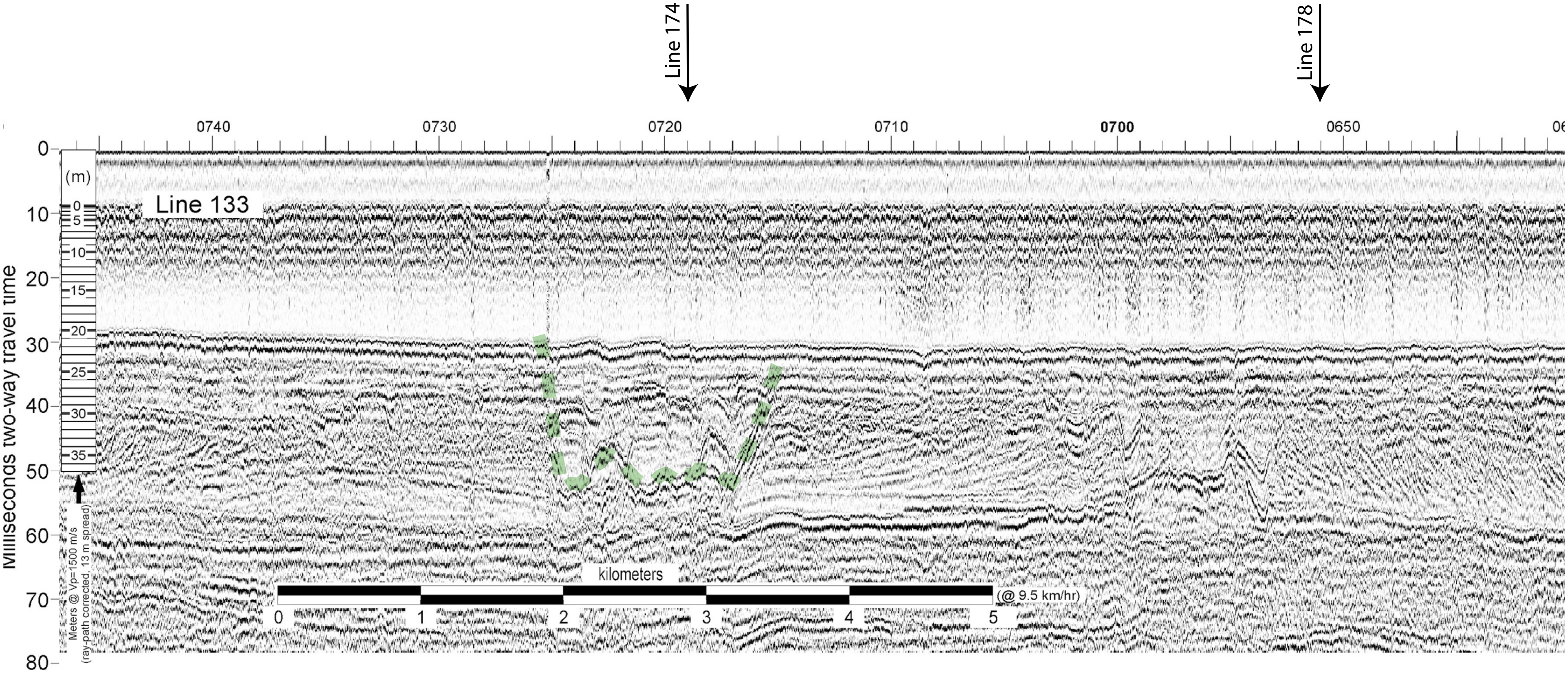
Line 129

Figure 4.10.5

LEGEND:

🟩 🟩 🟩 = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



Feature W-9

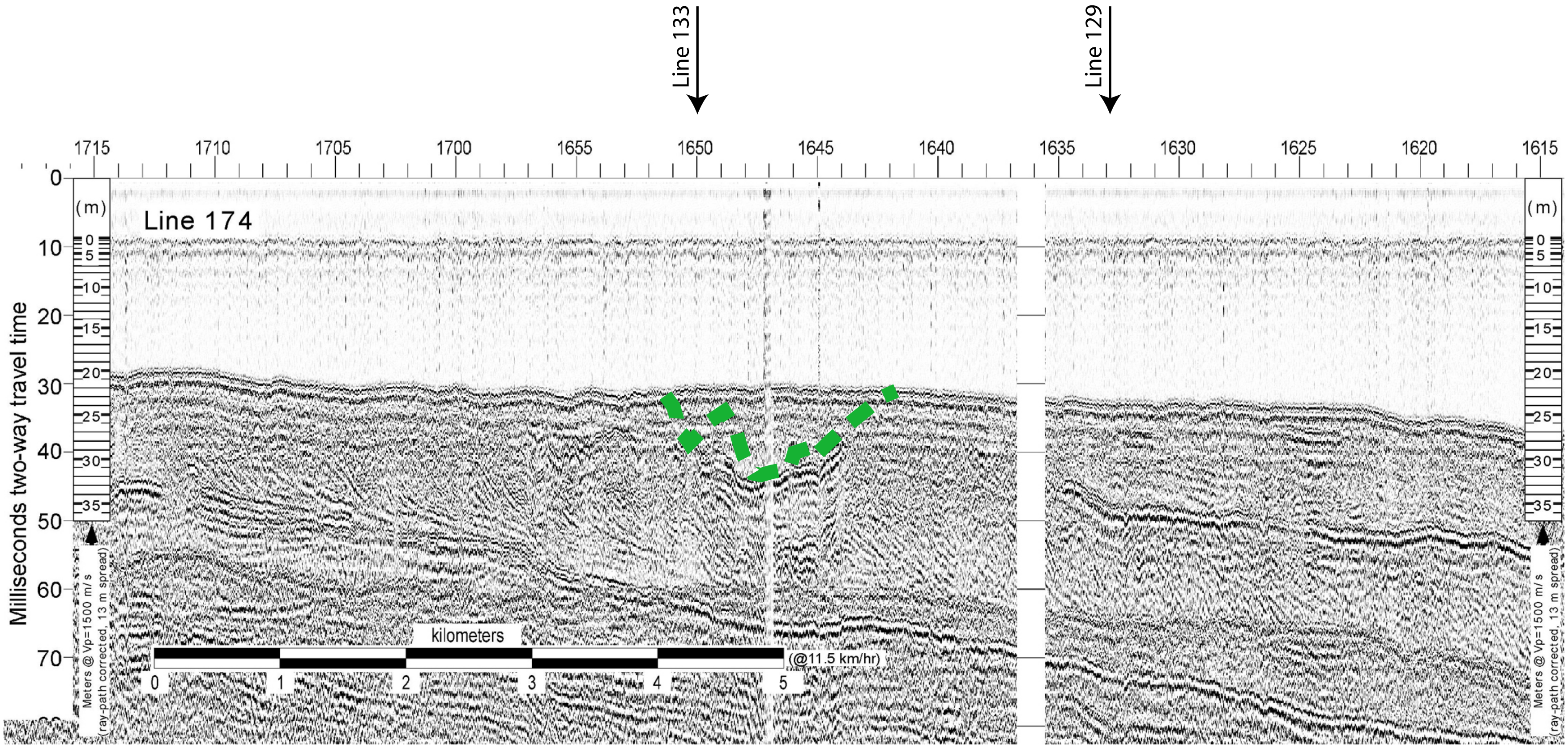
Line 133

Figure 4.10.6

LEGEND:

🟩 🟩 🟩 = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



Feature W-9

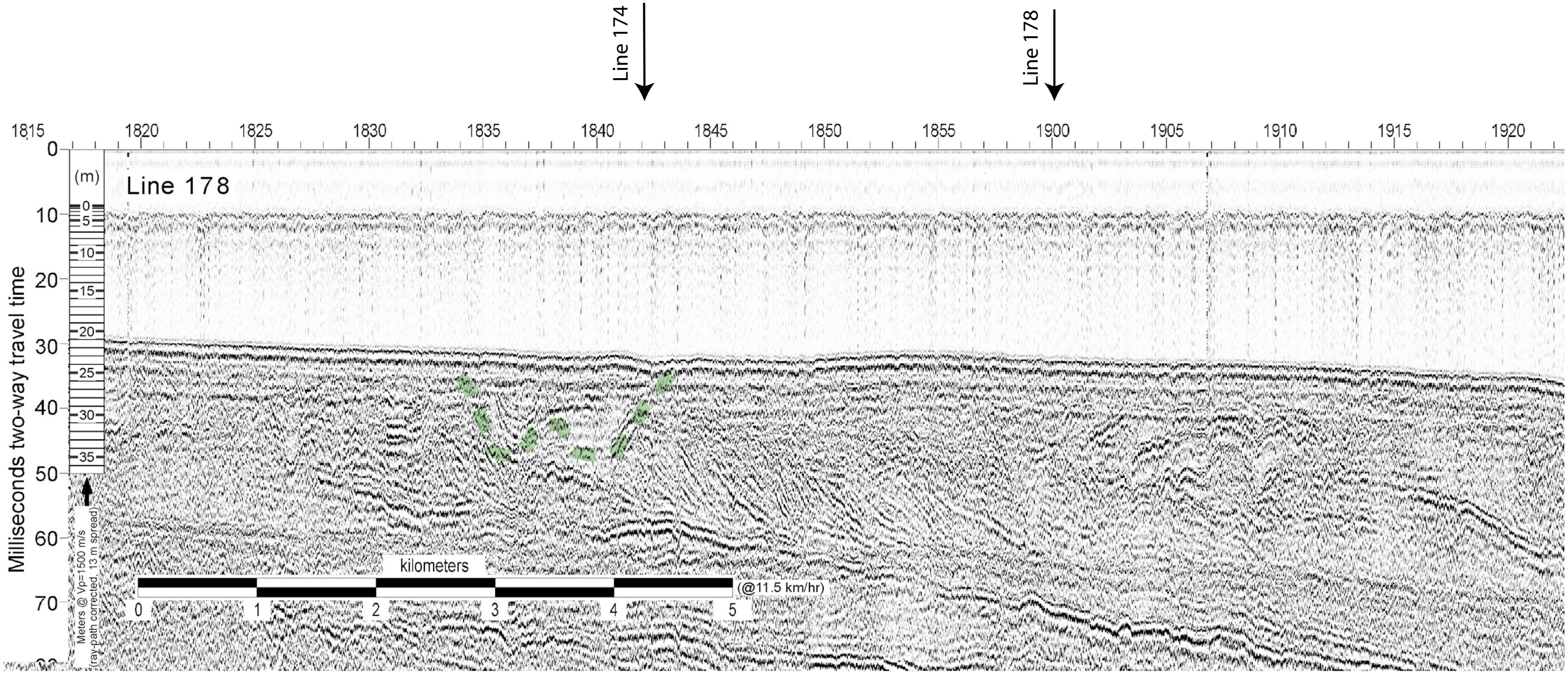
Line 174

Figure 4.10.7

LEGEND:

▬ ▬ ▬ = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



Feature W-9

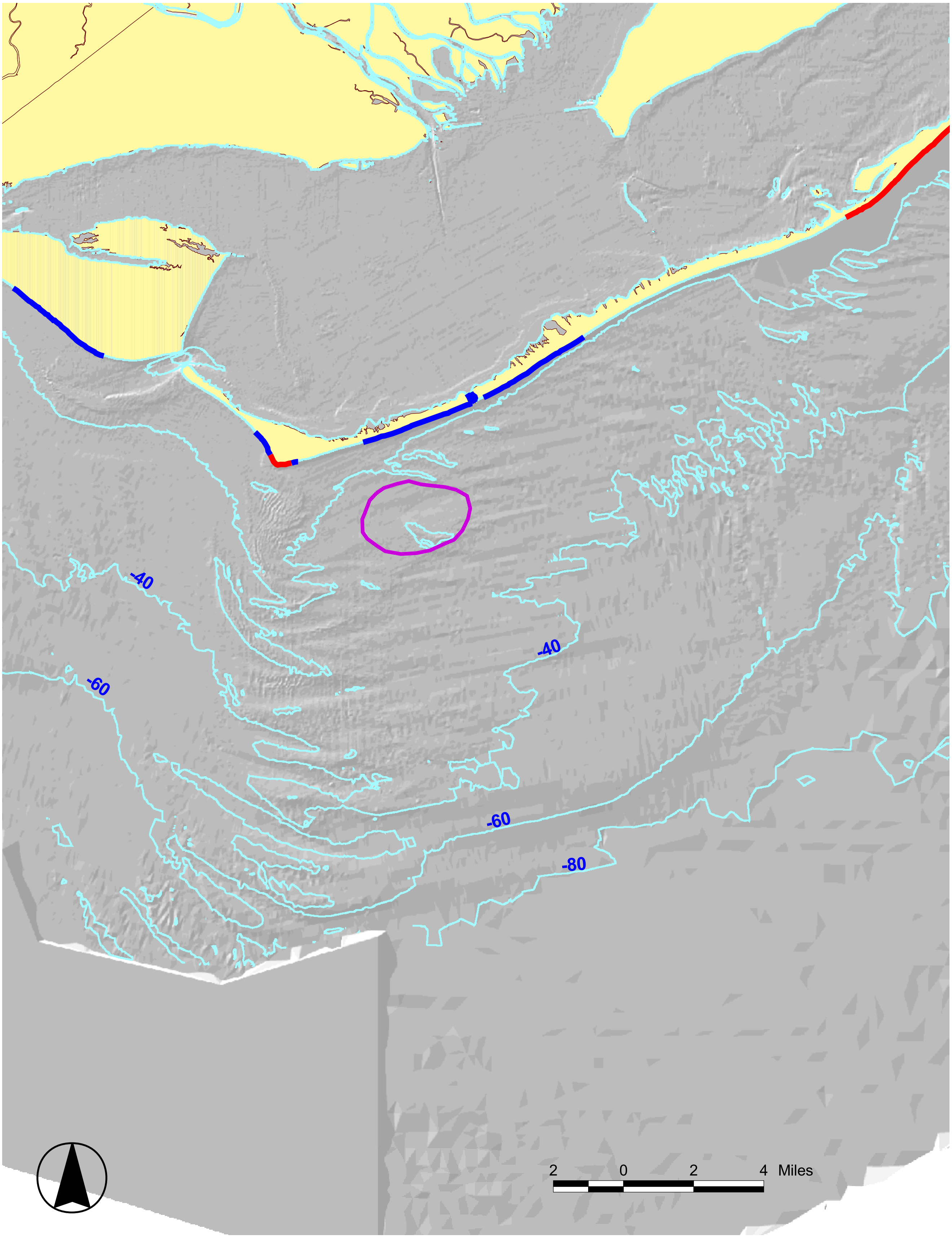
Line 178

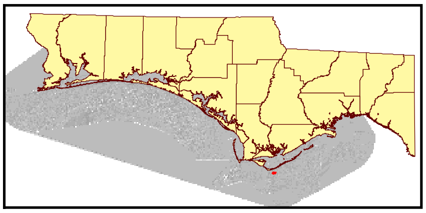
Figure 4.10.8

LEGEND:

▬ ▬ ▬ = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line





FEATURE E-1

Contour Map

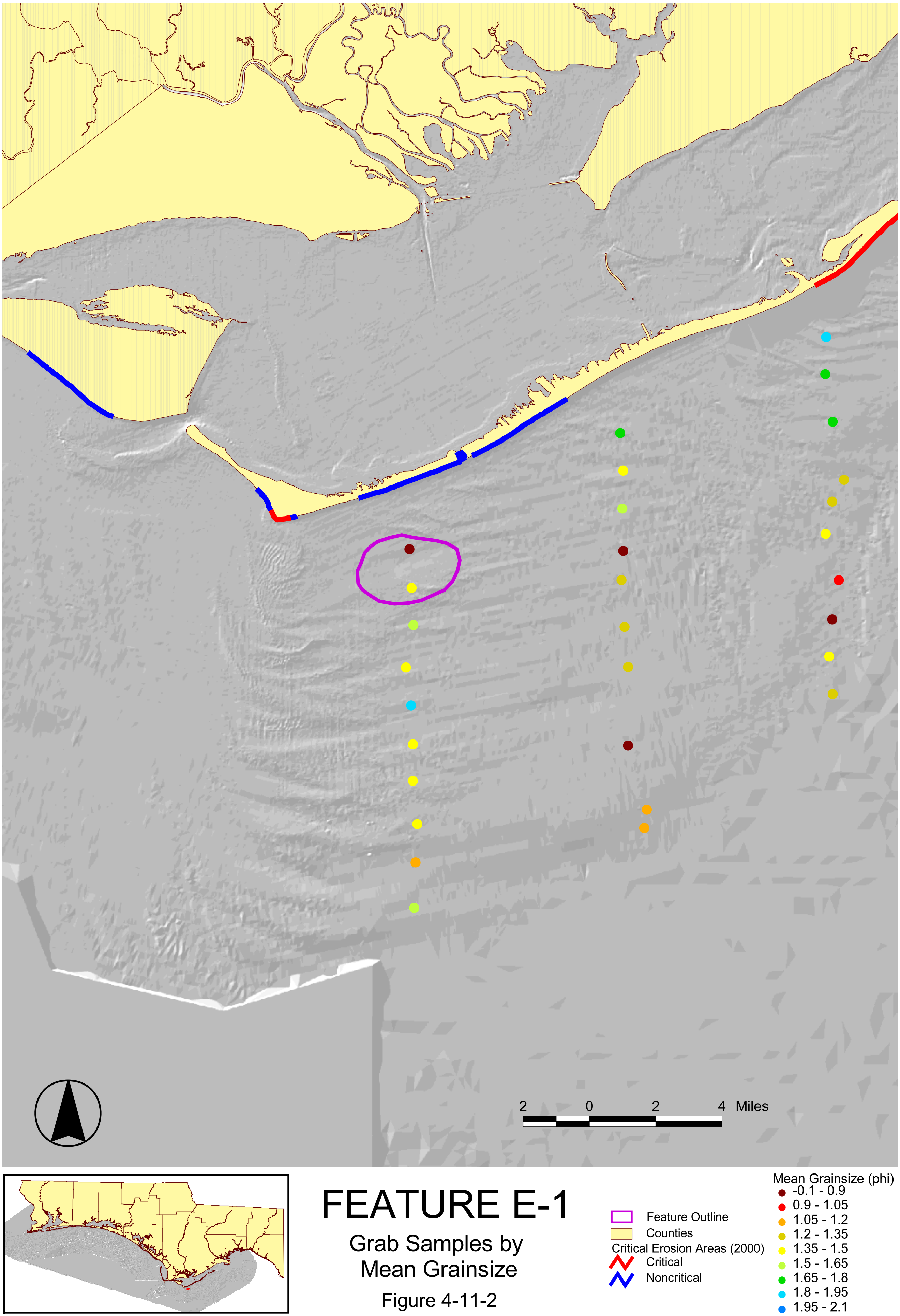
Figure 4-11-1

▭	Feature Outline
╱╲	Contour Line 20 contour interval
🟨	Counties

Critical Erosion Areas (2000)

🟥	Critical
🟦	Noncritical

g:\FDEP\beachcoastal\deliverables\report_figures.apr

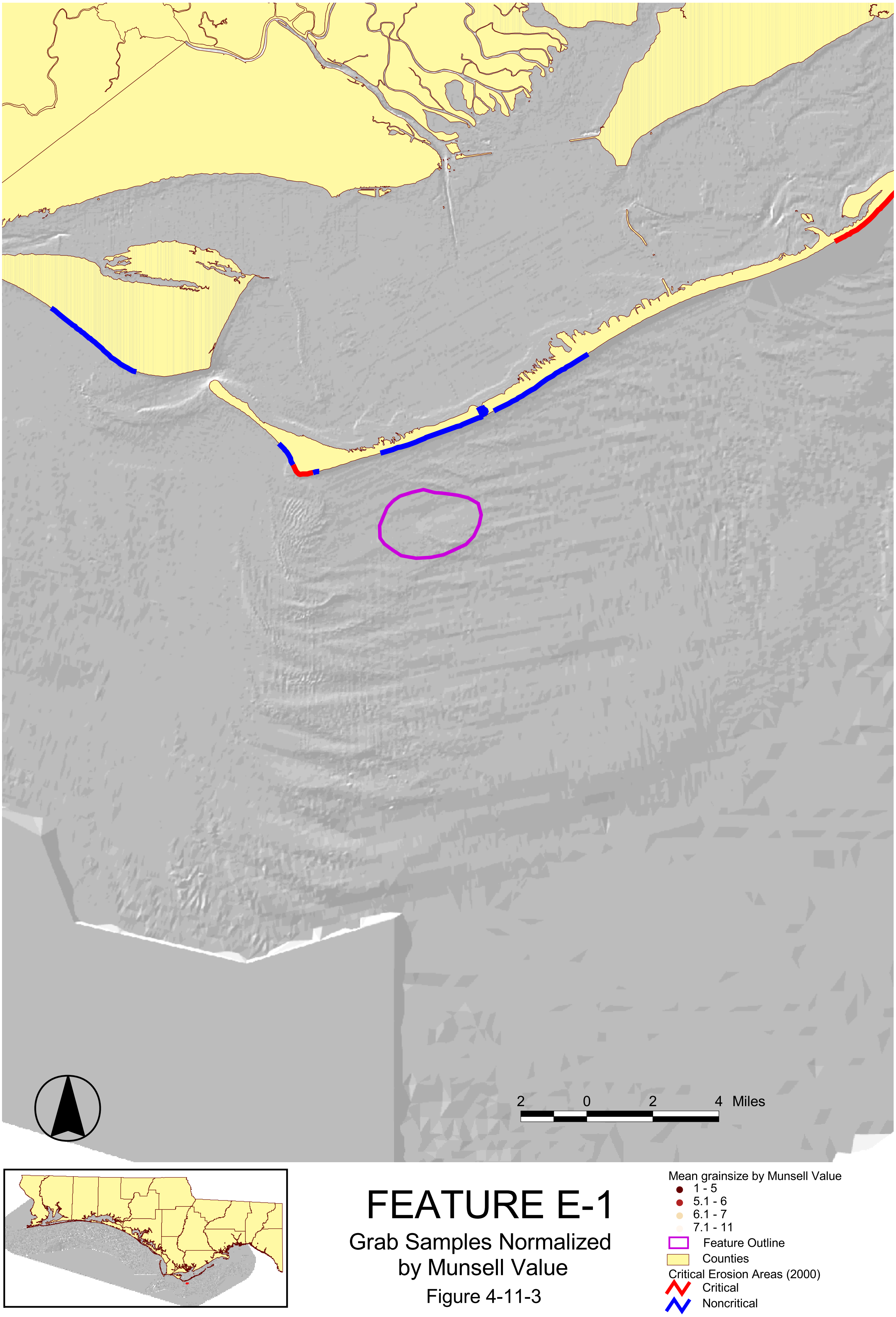


FEATURE E-1

Grab Samples by
Mean Grainsize

Figure 4-11-2

g:\FDEP\beachcoastal\deliverables\report_figures.apr

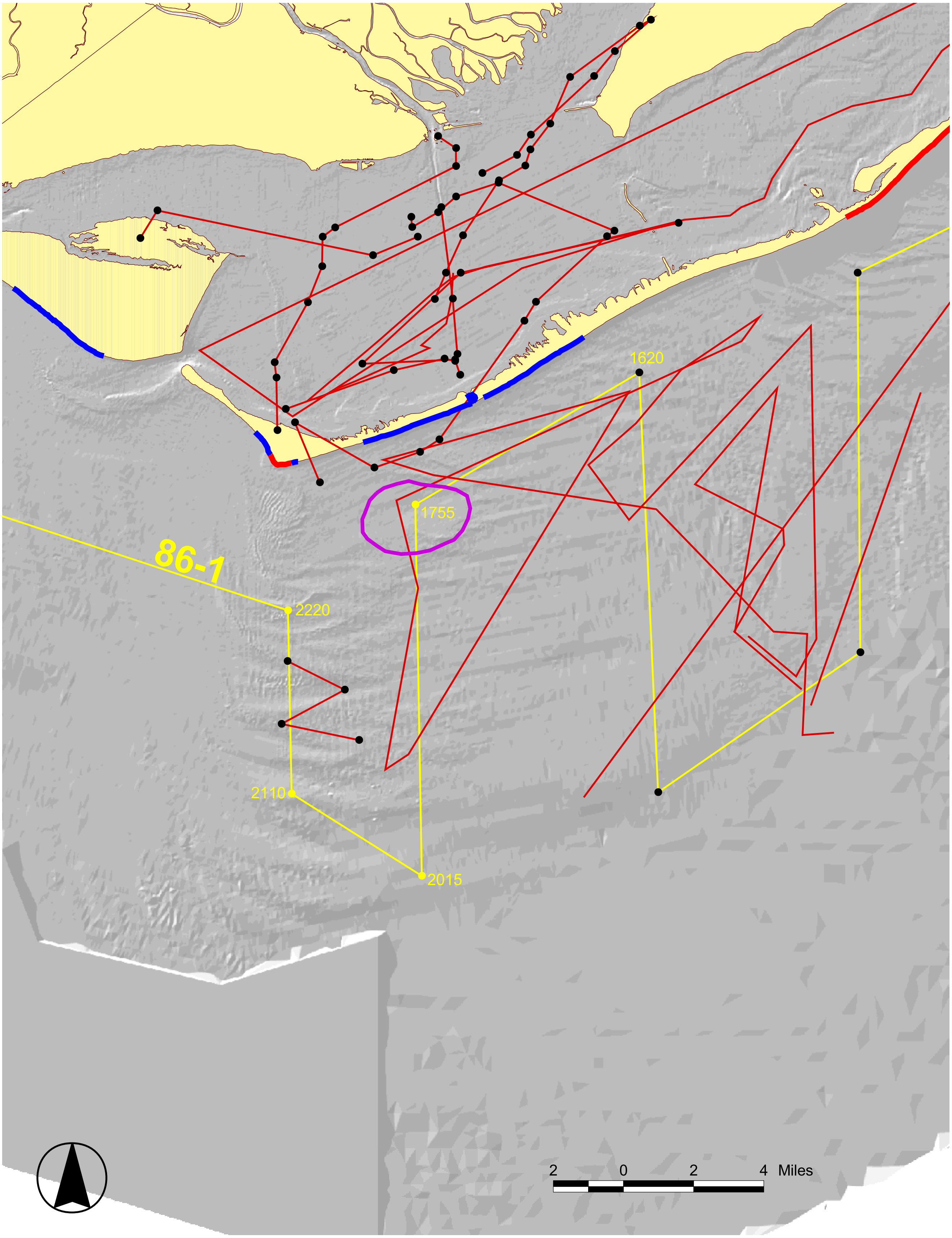


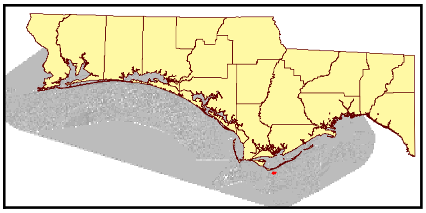
FEATURE E-1

Grab Samples Normalized by Munsell Value

Figure 4-11-3

g:\FDEP\beachcoastal\deliverables\report_figures.apr





FEATURE E-1

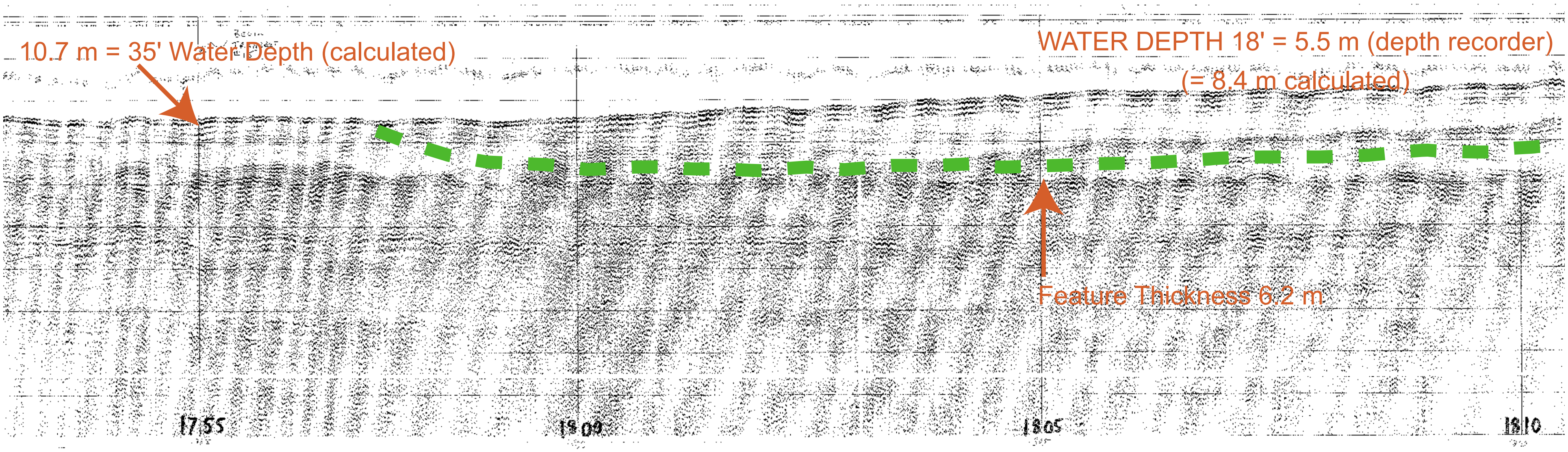
Geophysical Tracklines and Shotpoints with Timestamps

Figure 4-11-4

- ▭ Feature Outline
- ● Shotpoints
- ╱╲ Tracklines
- 🟨 Counties

Critical Erosion Areas (2000)

- 🟥 Critical
- 🟦 Noncritical



Feature E-1

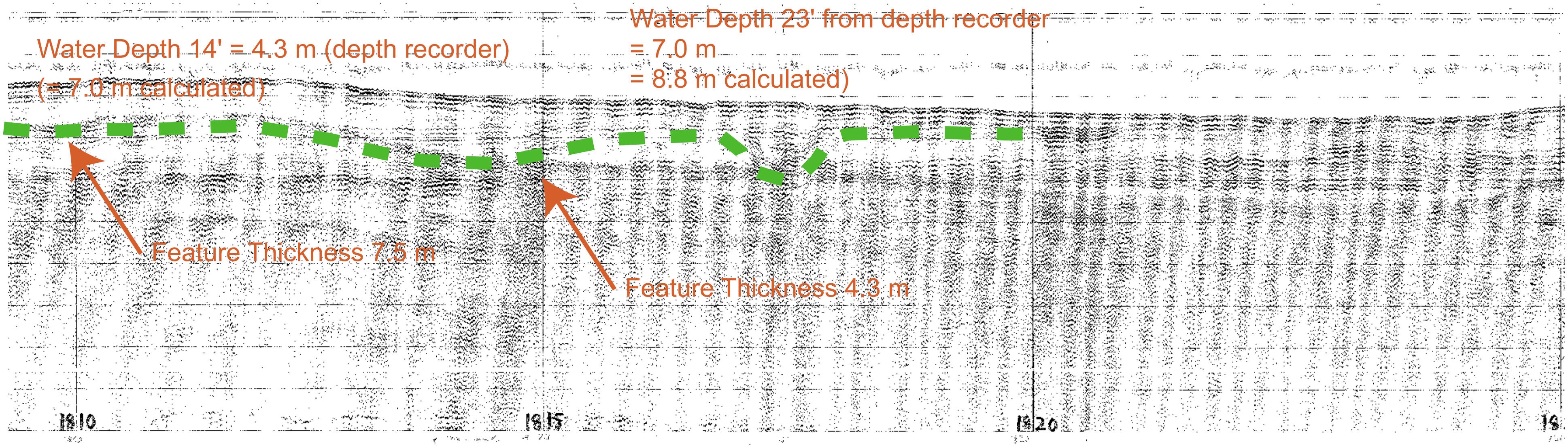
Line 86-2

Figure 4.11.5 A

LEGEND:

- - - = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



Feature E-1

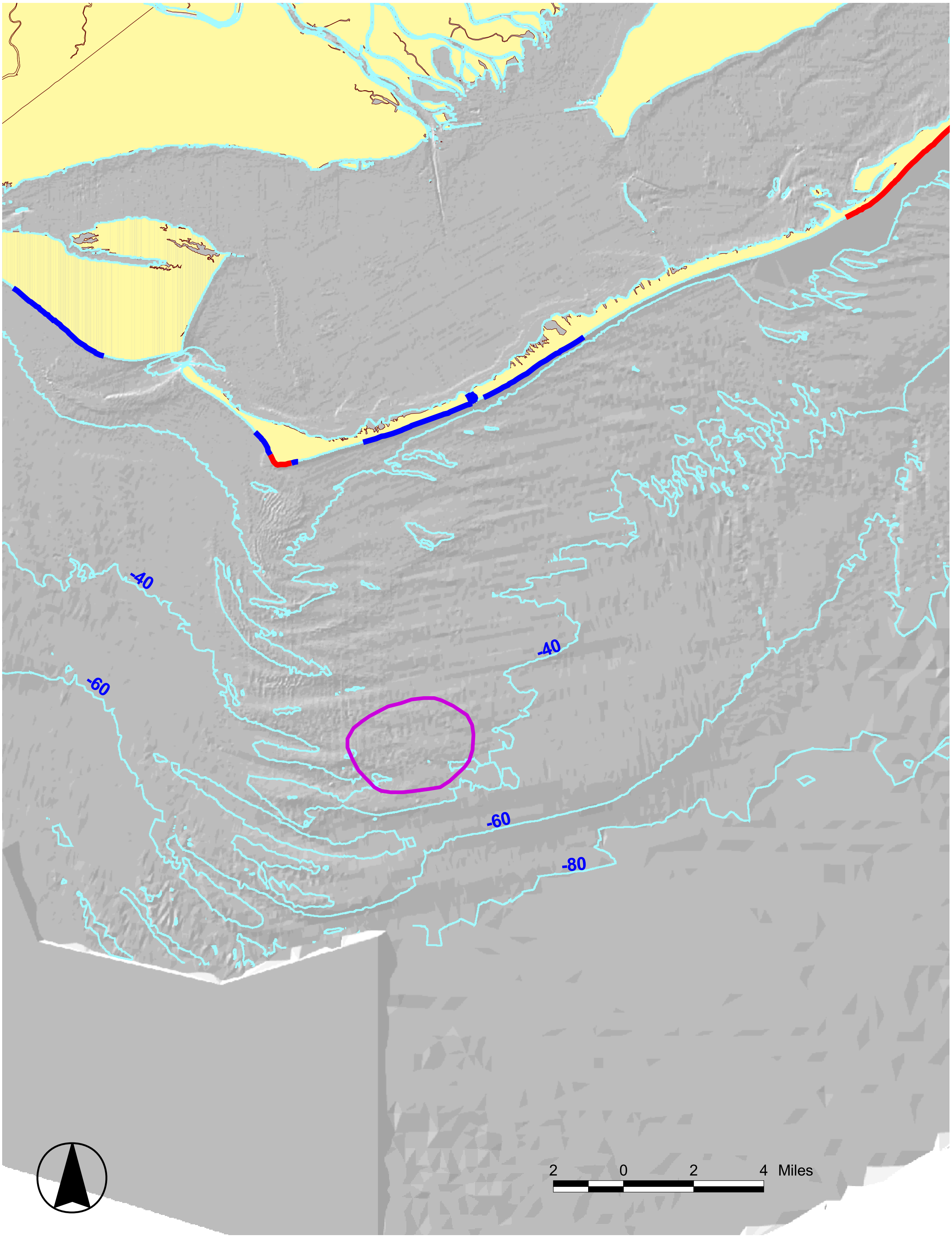
Line 86-2

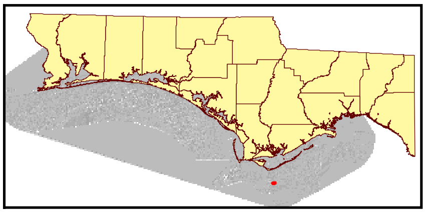
Figure 4.11.5 B

LEGEND:

▬ ▬ ▬ = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line





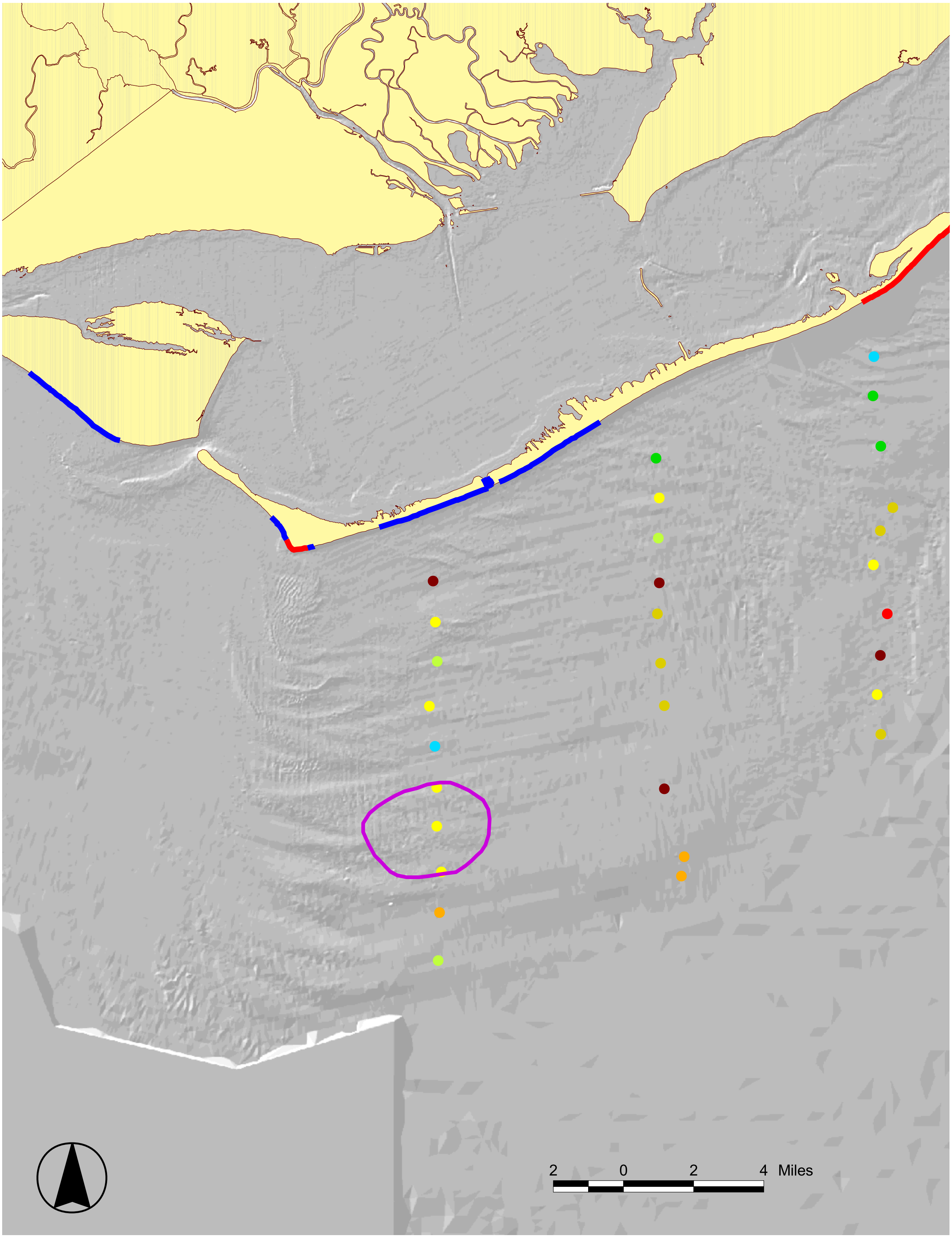
FEATURE E-2

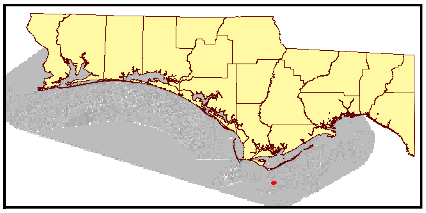
Contour Map

Figure 4-12-1

▭ Feature Outline
╱╲ Contour Line
20 contour interval
🟨 Counties
Critical Erosion Areas (2000)
╱╲ Critical
╱╲ Noncritical

g:\FDEP\beachcoastal\deliverables\report_figures.apr





FEATURE E-2

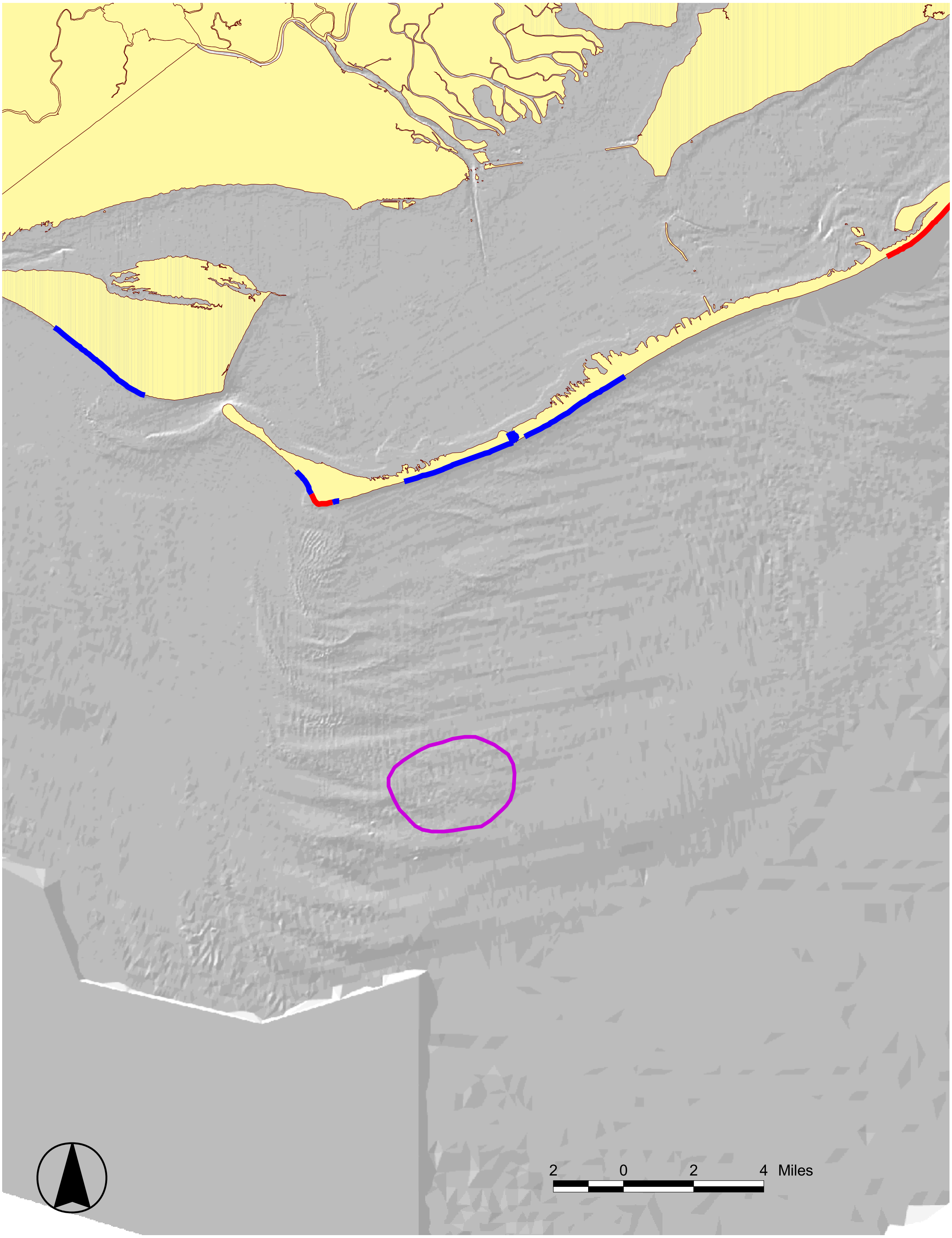
Grab Samples by Mean Grainsize

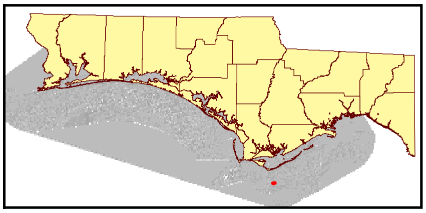
Figure4-12-2

▭ Feature Outline
▨ Counties
Critical Erosion Areas (2000)
～ Critical
～ Noncritical

Mean Grainsize (phi)
● -0.1 - 0.9
● 0.9 - 1.05
● 1.05 - 1.2
● 1.2 - 1.35
● 1.35 - 1.5
● 1.5 - 1.65
● 1.65 - 1.8
● 1.8 - 1.95
● 1.95 - 2.1
● 2.1 - 10

g:\FDEP\beachcoastal\deliverables\report_figures.apr





FEATURE E-2

Grab Samples Normalized by Munsell Value

Figure 4-12-3

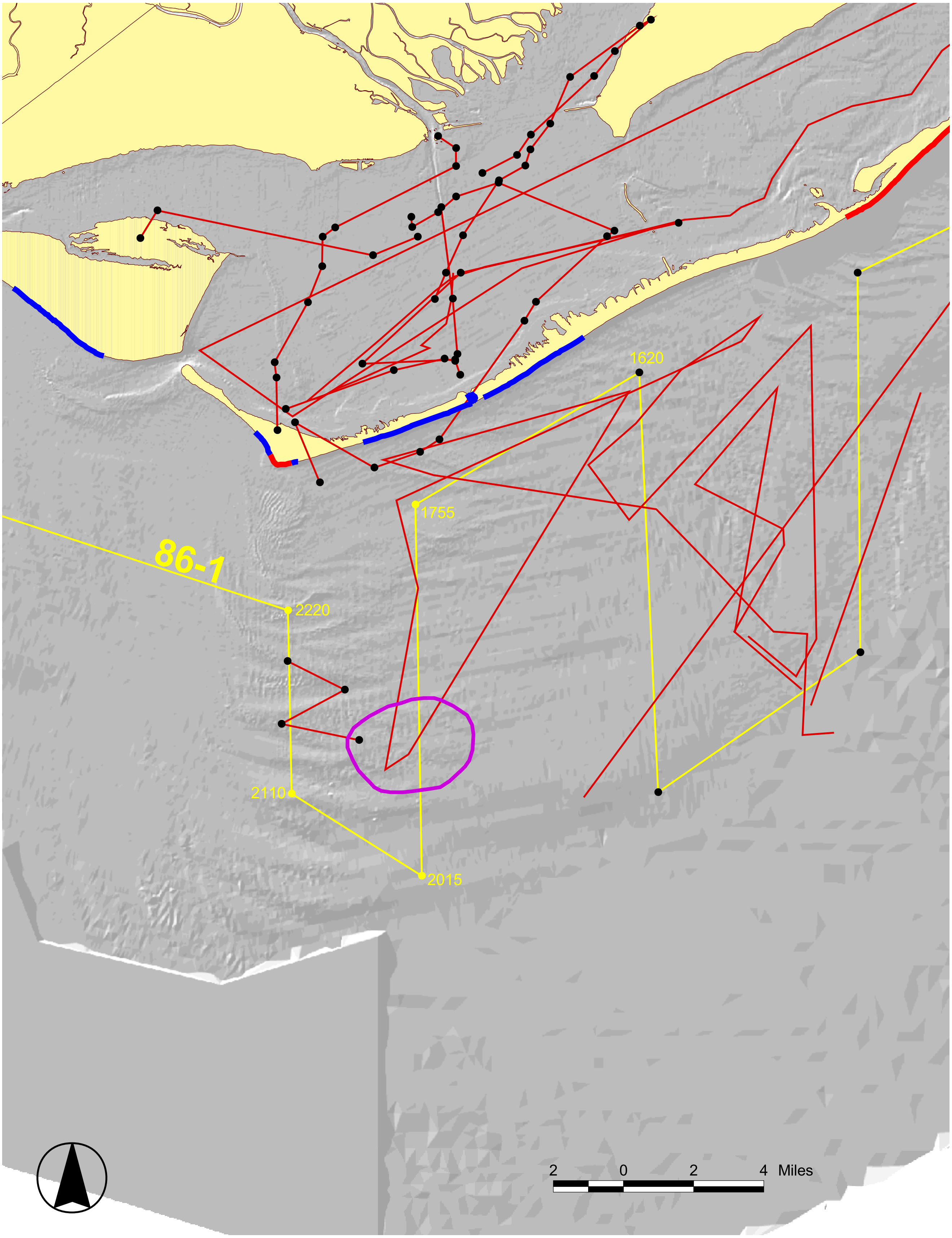
Mean grainsize by Munsell Value
- ● 1 - 5
- ● 5.1 - 6
- ● 6.1 - 7
- ● 7.1 - 11

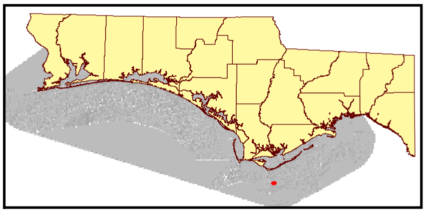
☐ Feature Outline

▨ Counties

Critical Erosion Areas (2000)
- 🟥 Critical
- 🟦 Noncritical

g:\FDEP\beachcoastal\deliverables\report_figures.apr





FEATURE E-2

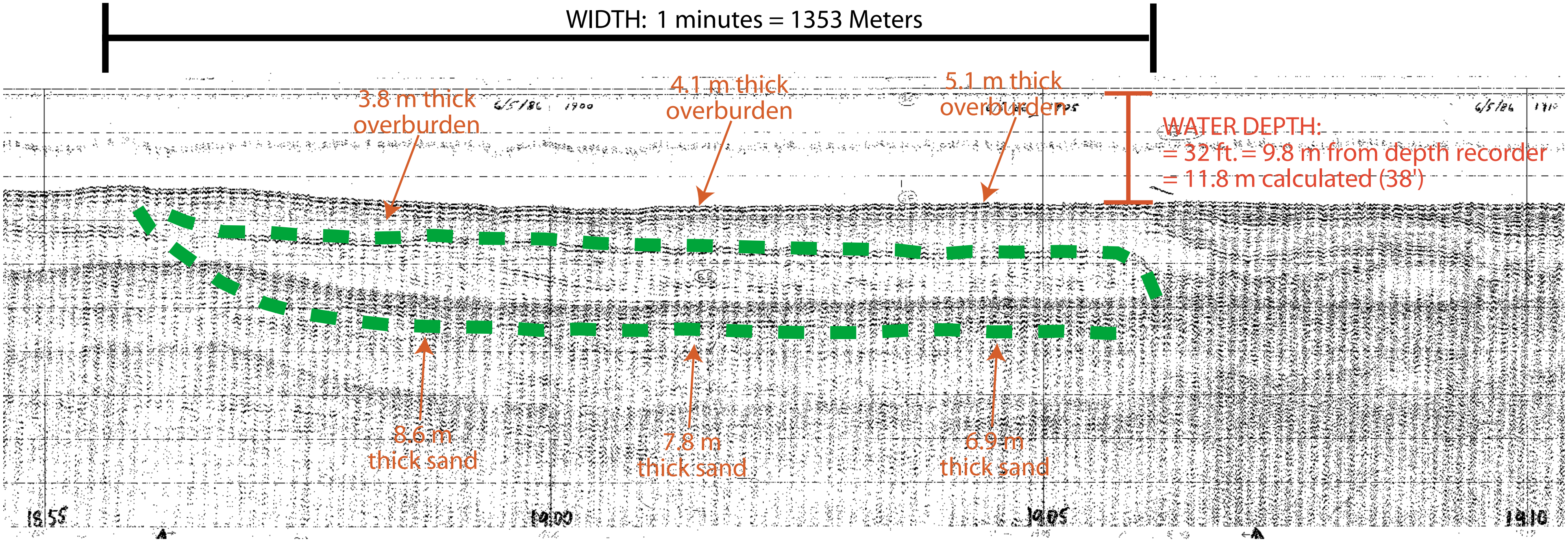
Geophysical Tracklines and Shotpoints with Timestamps

Figure 4-12-4

▭ Feature Outline
● Shotpoints
∧ Tracklines
🟨 Counties

Critical Erosion Areas (2000)
🟥 Critical
🟦 Noncritical

g:\FDEP\beachcoastal\deliverables\report_figures.apr



Feature E-2

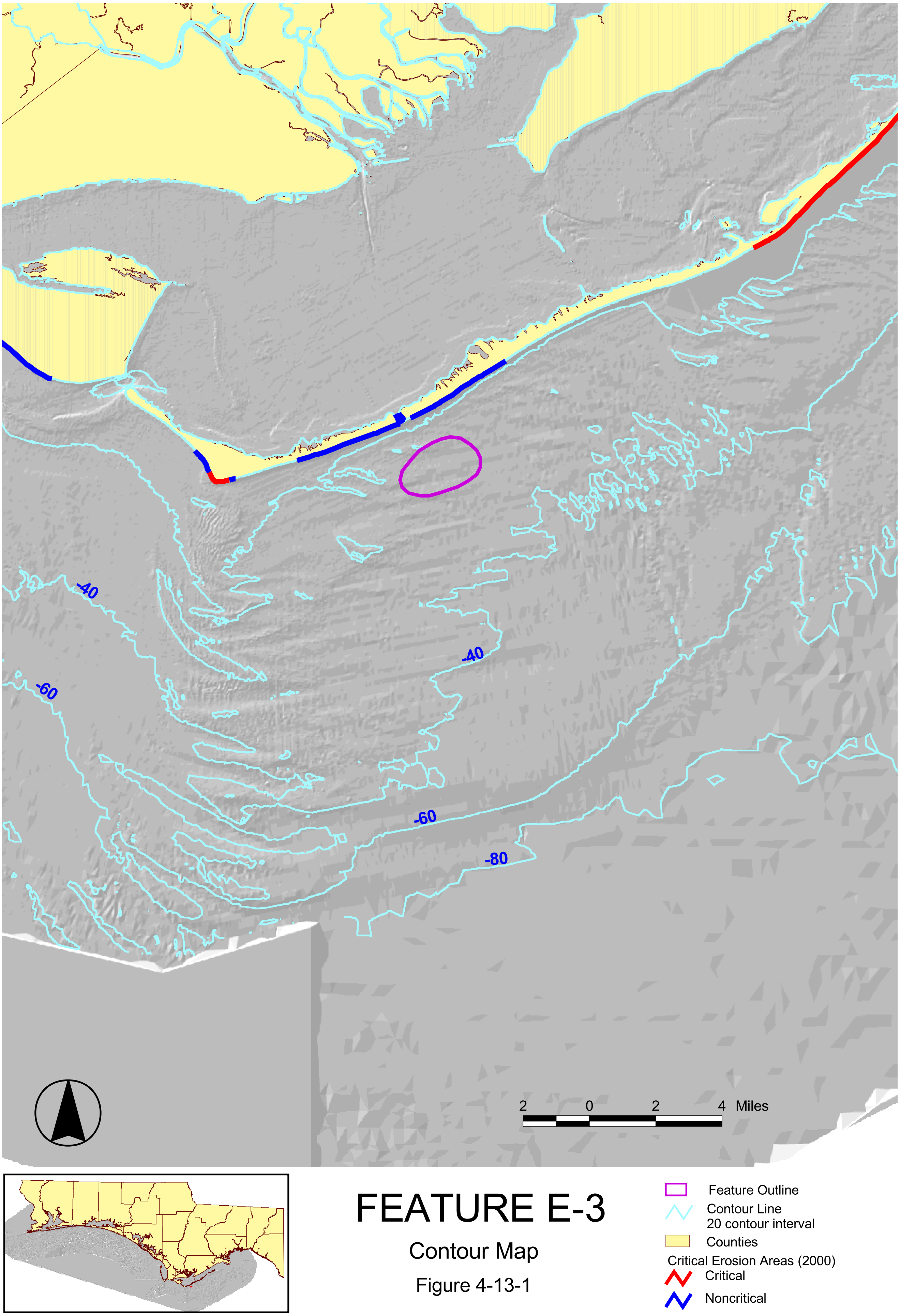
Line 86-2

Figure 4.12.5

LEGEND:

- - - = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line



FEATURE E-3

Contour Map

Figure 4-13-1

Feature Outline

Contour Line
20 contour interval

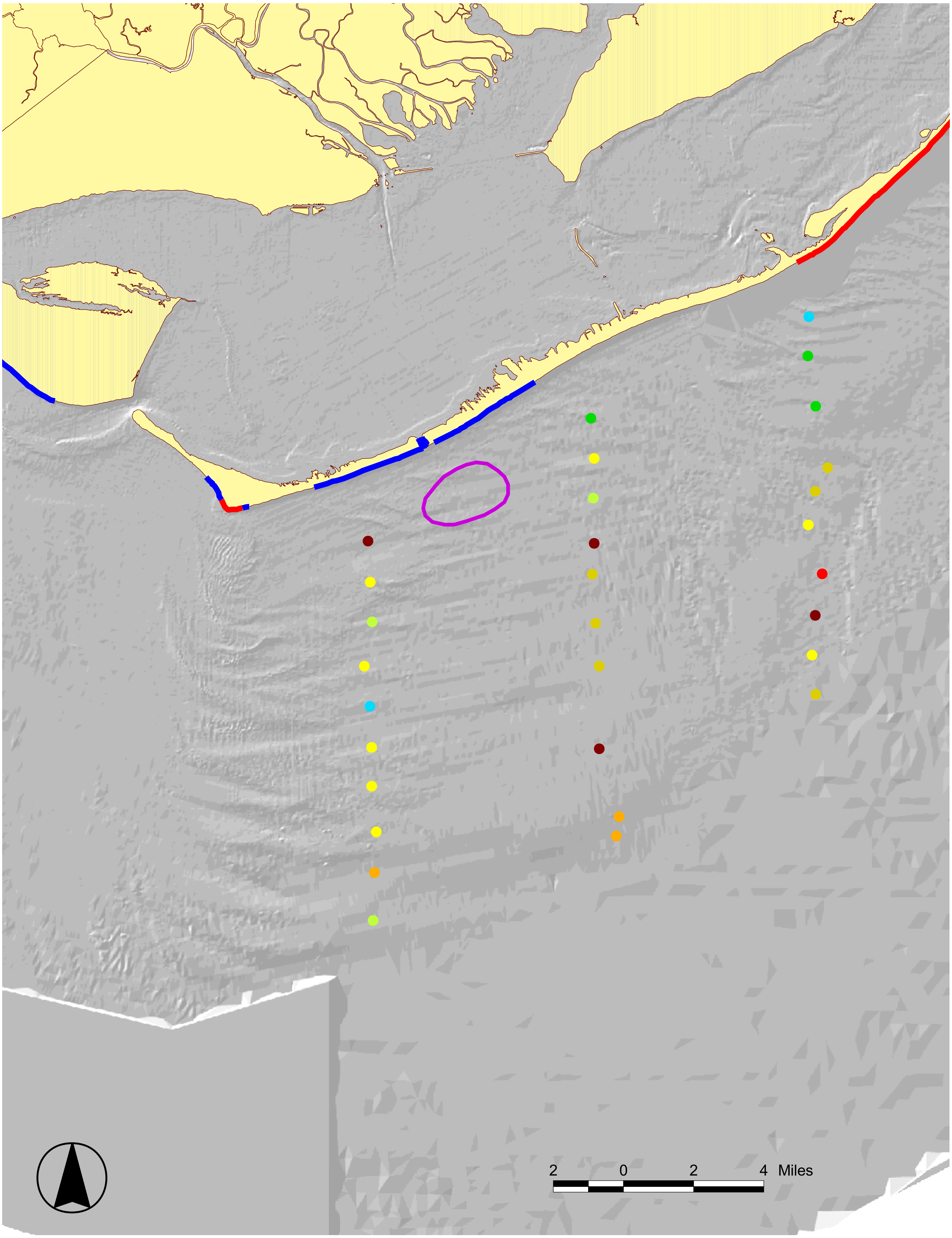
Counties

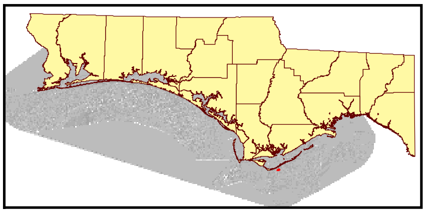
Critical Erosion Areas (2000)

Critical

Noncritical

g:\FDEP\beachcoastal\deliverables\report_figures.apr



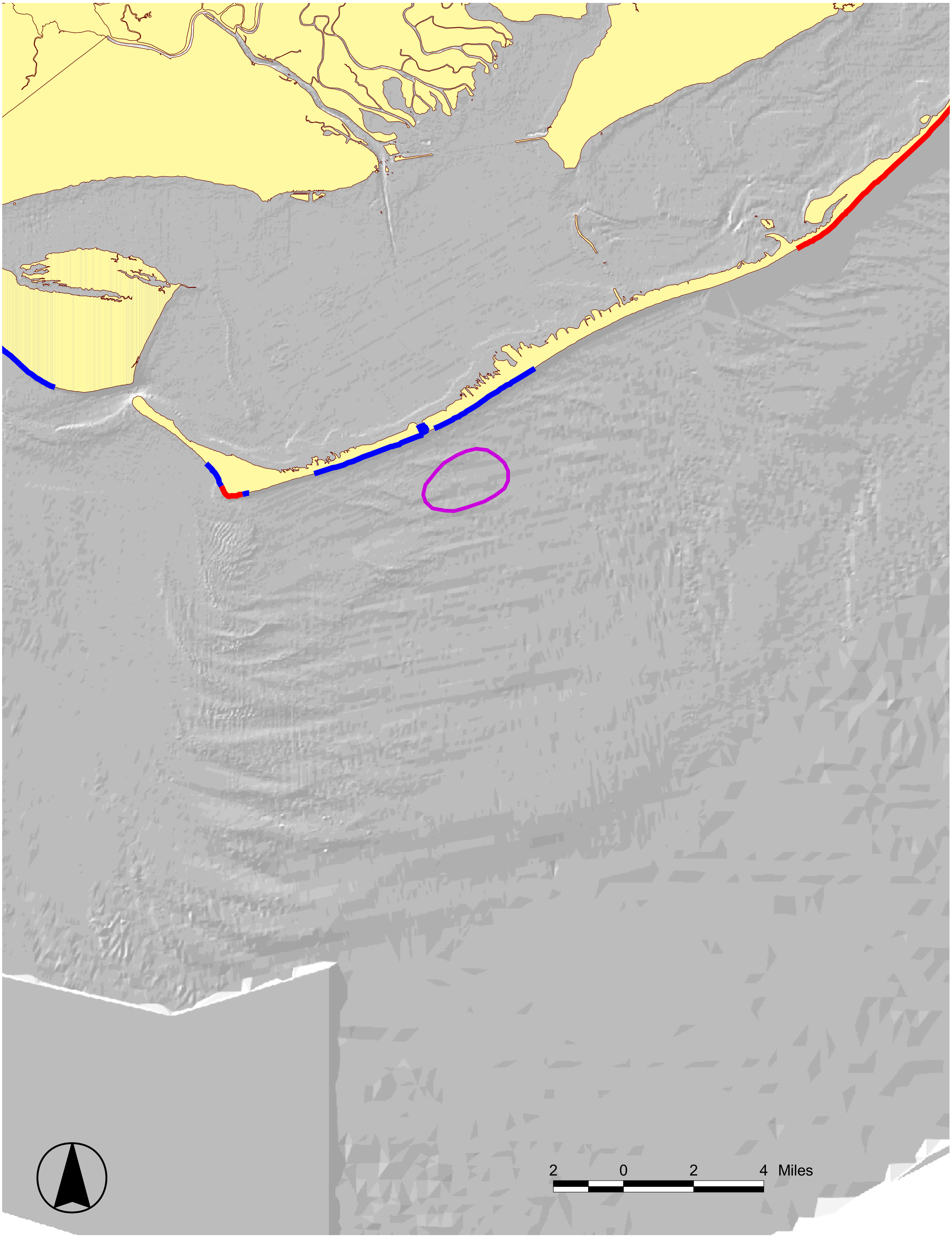


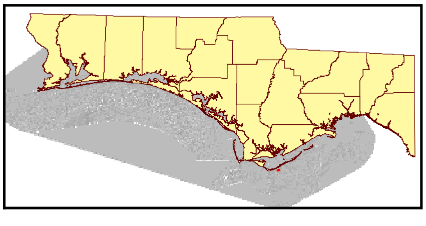
FEATURE E-3

Grab Samples by
Mean Grainsize

Figure 4-13-2

g:\FDEP\beachcoastal\deliverables\report_figures.apr





FEATURE E-3

Grab Samples Normalized by Munsell Value

Figure 4-13-3

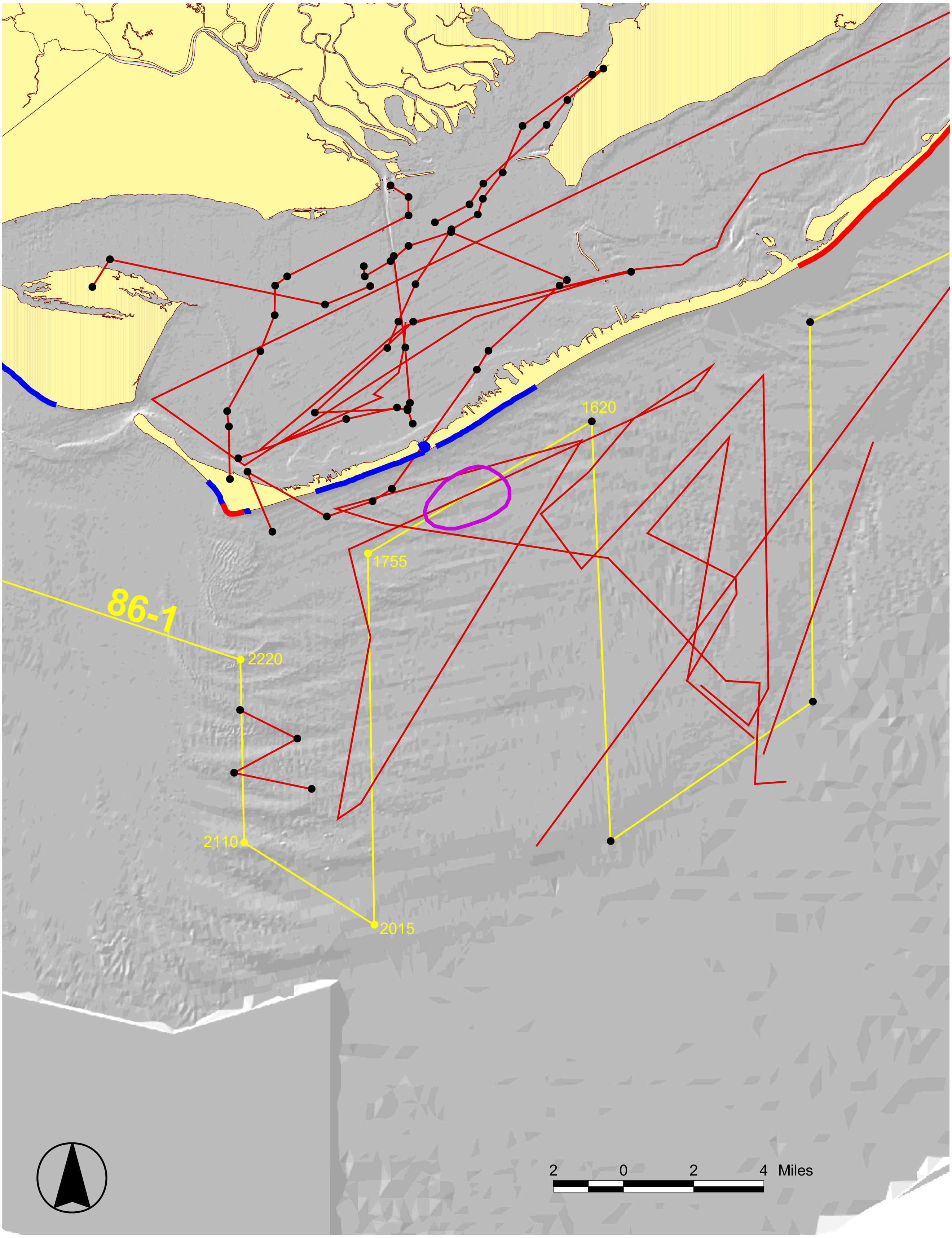
Mean grainsize by Munsell Value
- ● 1 - 5
- ● 5.1 - 6
- ● 6.1 - 7
- ● 7.1 - 11

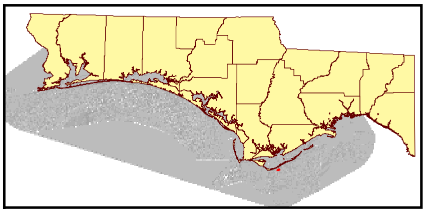
☐ Feature Outline

▨ Counties

Critical Erosion Areas (2000)
- Critical
- Noncritical

g:\FDEP\beachcoastal\deliverables\report_figures.apr





FEATURE E-3

Geophysical Tracklines and Shotpoints with Timestamps

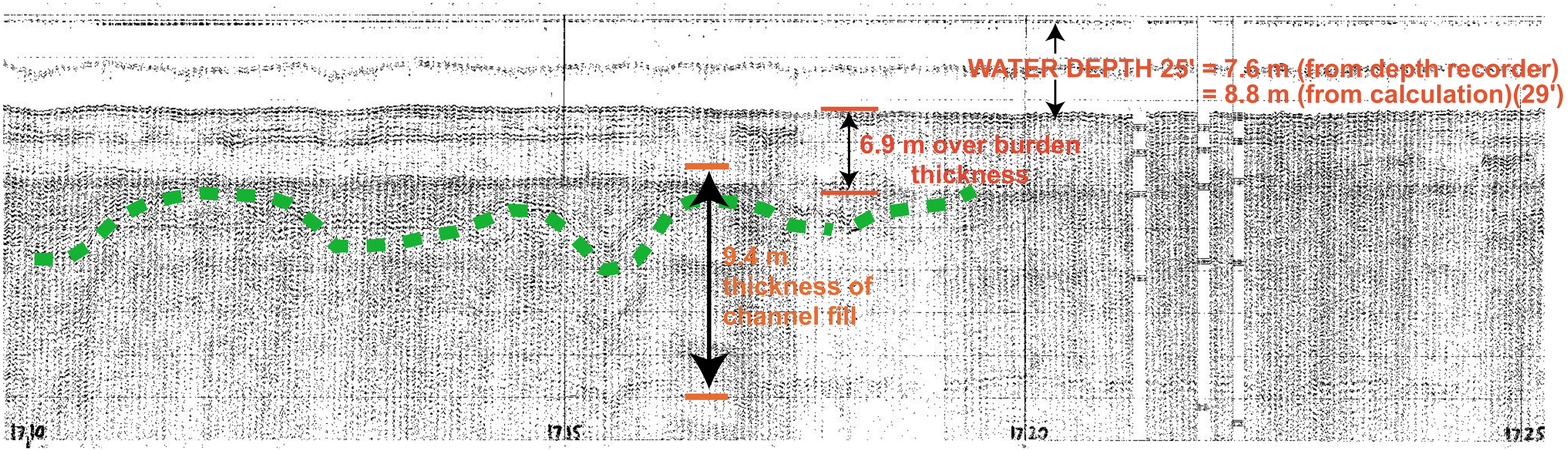
Figure 4-13-4

▭ Feature Outline
● Shotpoints
╱╲ Tracklines
🟨 Counties

Critical Erosion Areas (2000)

🟥 Critical
🟦 Noncritical

g:\FDEP\beachcoastal\deliverables\report_figures.apr



Feature E-3

Line 86-2

Figure 4.13.5

LEGEND:

▬ ▬ ▬ = Lower Surface of the Sand Feature

↓ = Crossing Geophysical Track Line

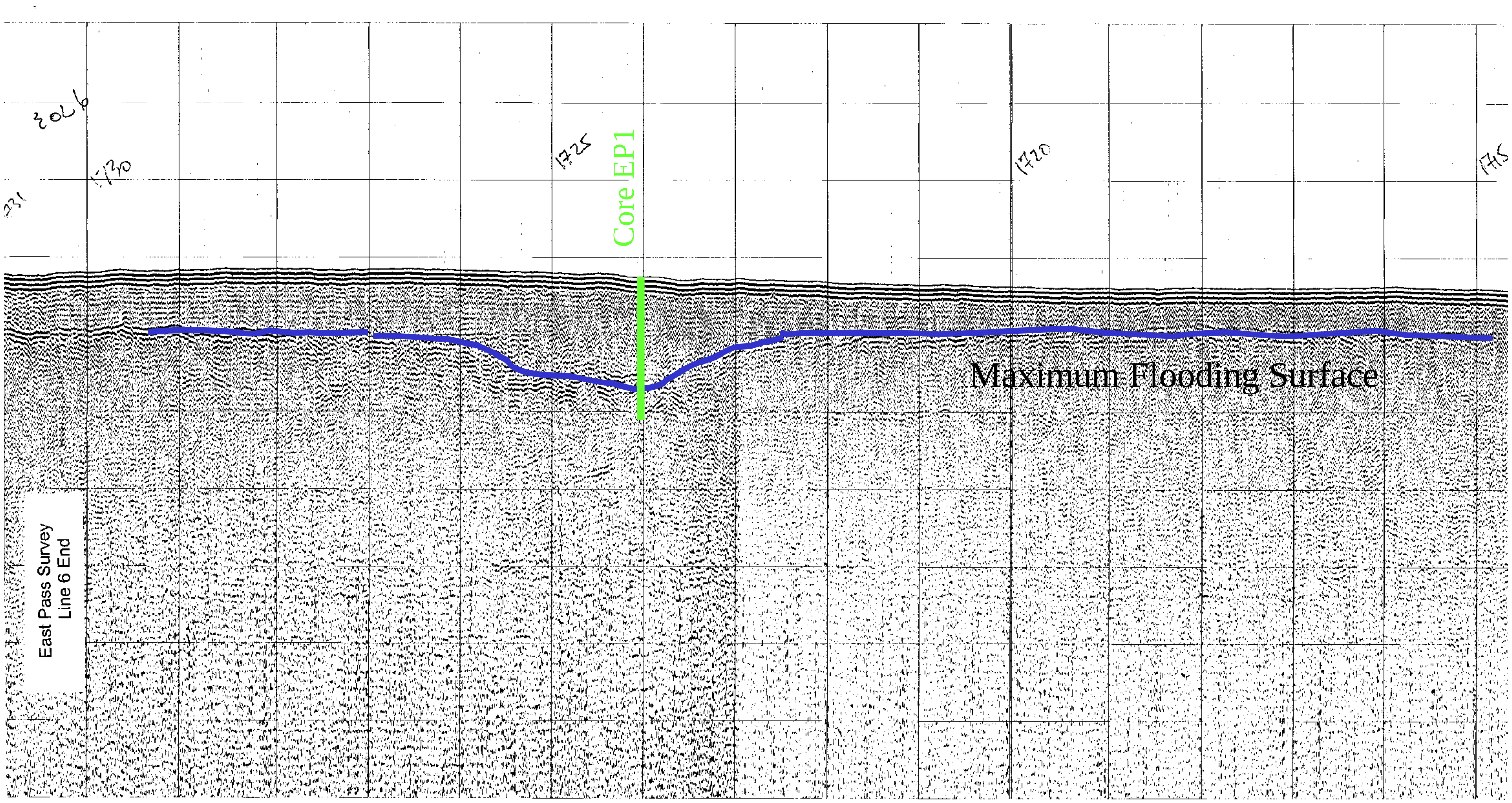


Figure 4.14.1

Maximum Flooding Surface Reflector With Vibracore EP1 Location

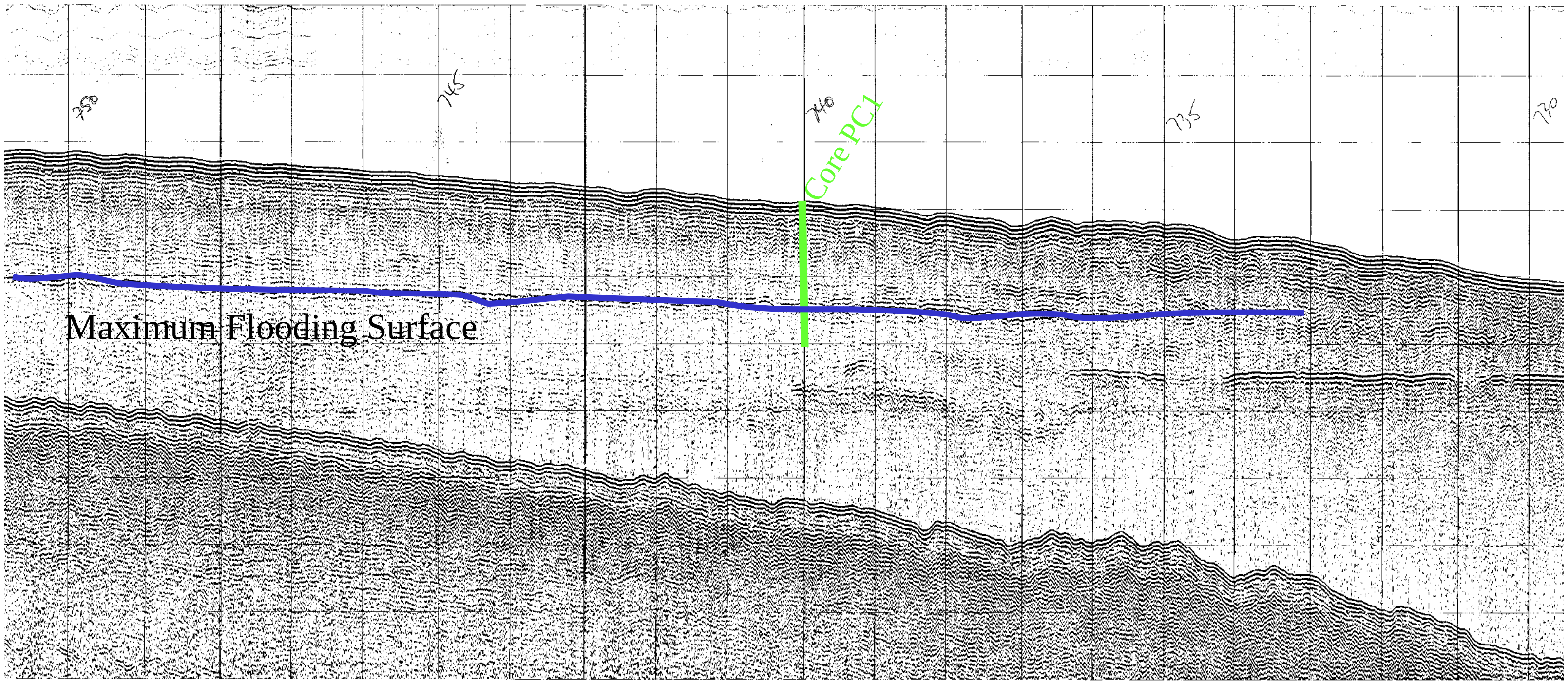


Figure 4.14.2

Maximum Flooding Surface Reflector With Vibracore PC1 Location

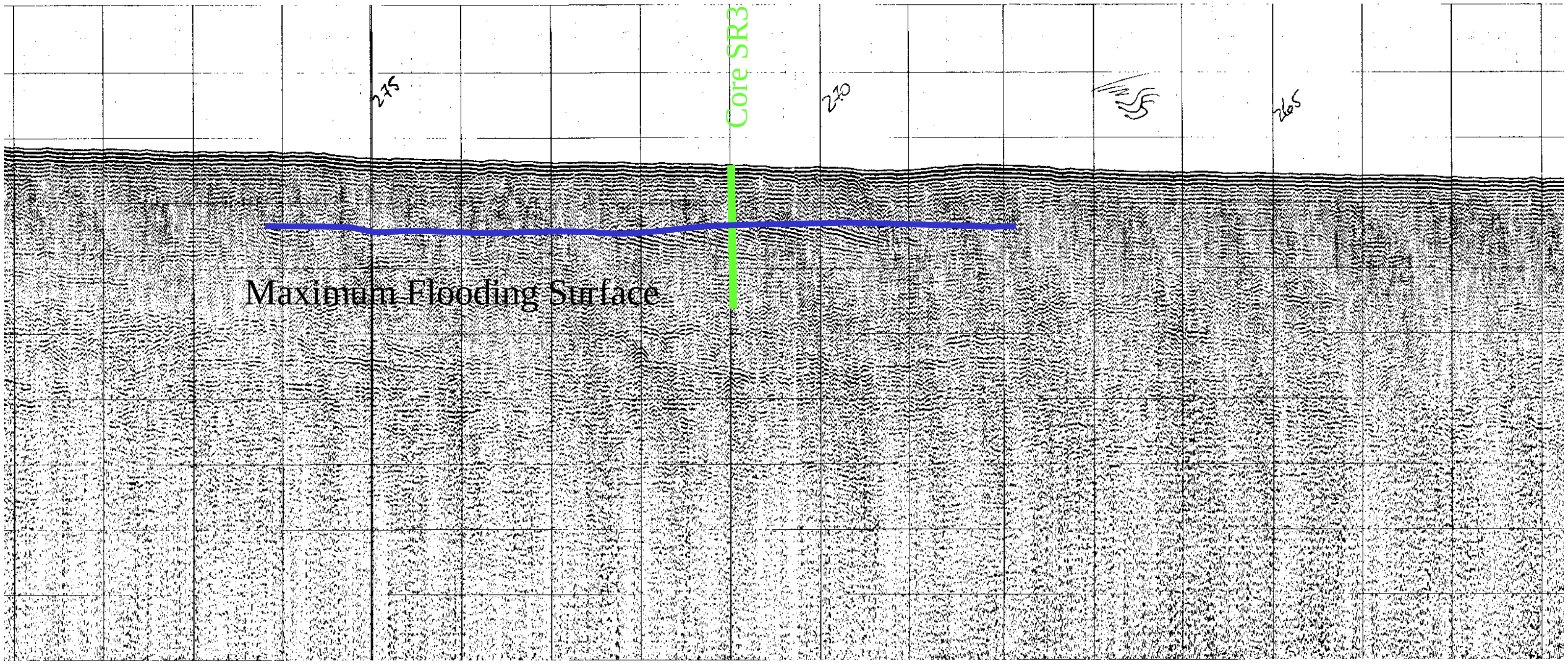


Figure 4.14.3

Maximum Flooding Surface Reflector With Vibracore SR3 Location

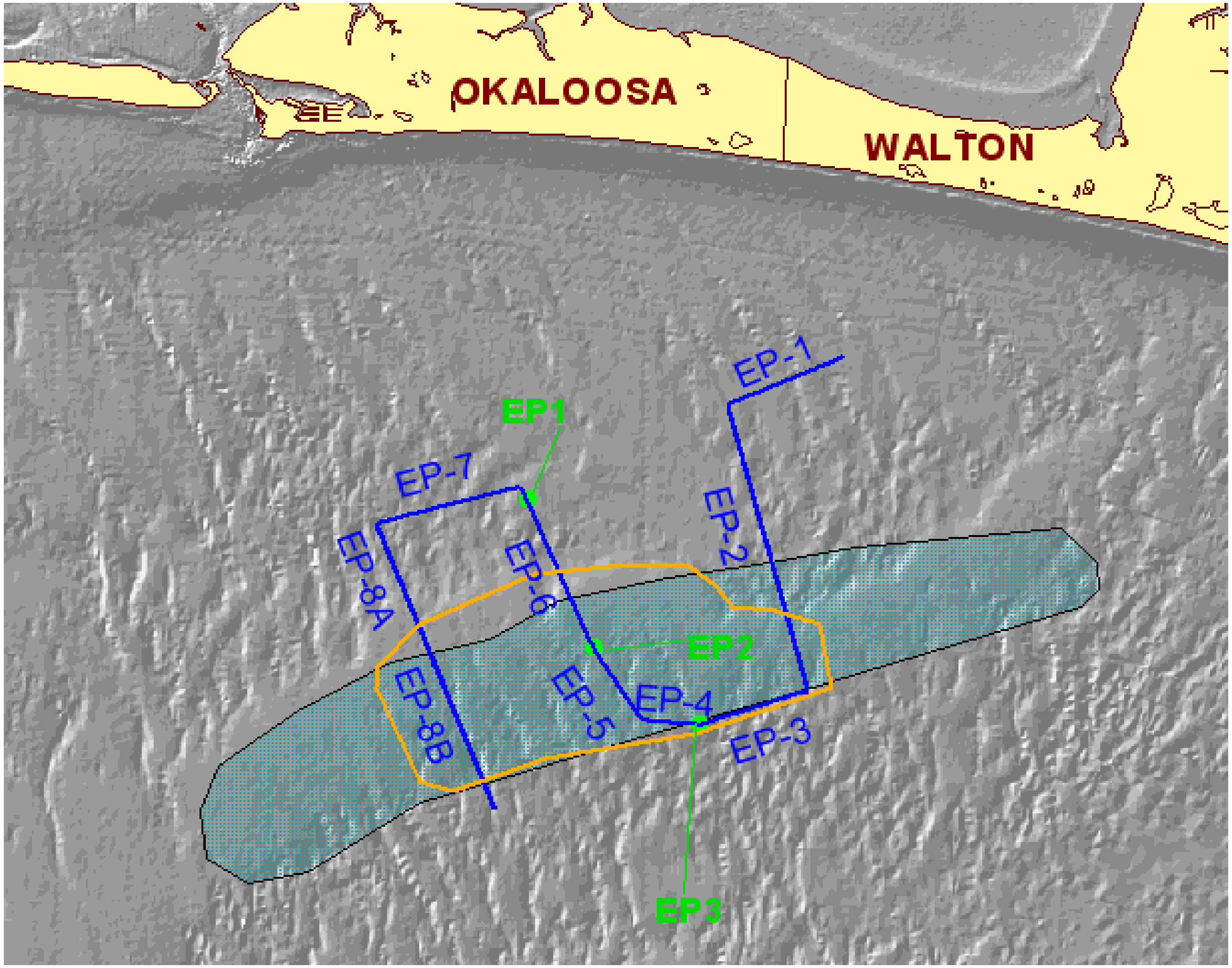


Figure 4.14.4

Delineated Areas For Sediment Volume Calculations. Site EP-A

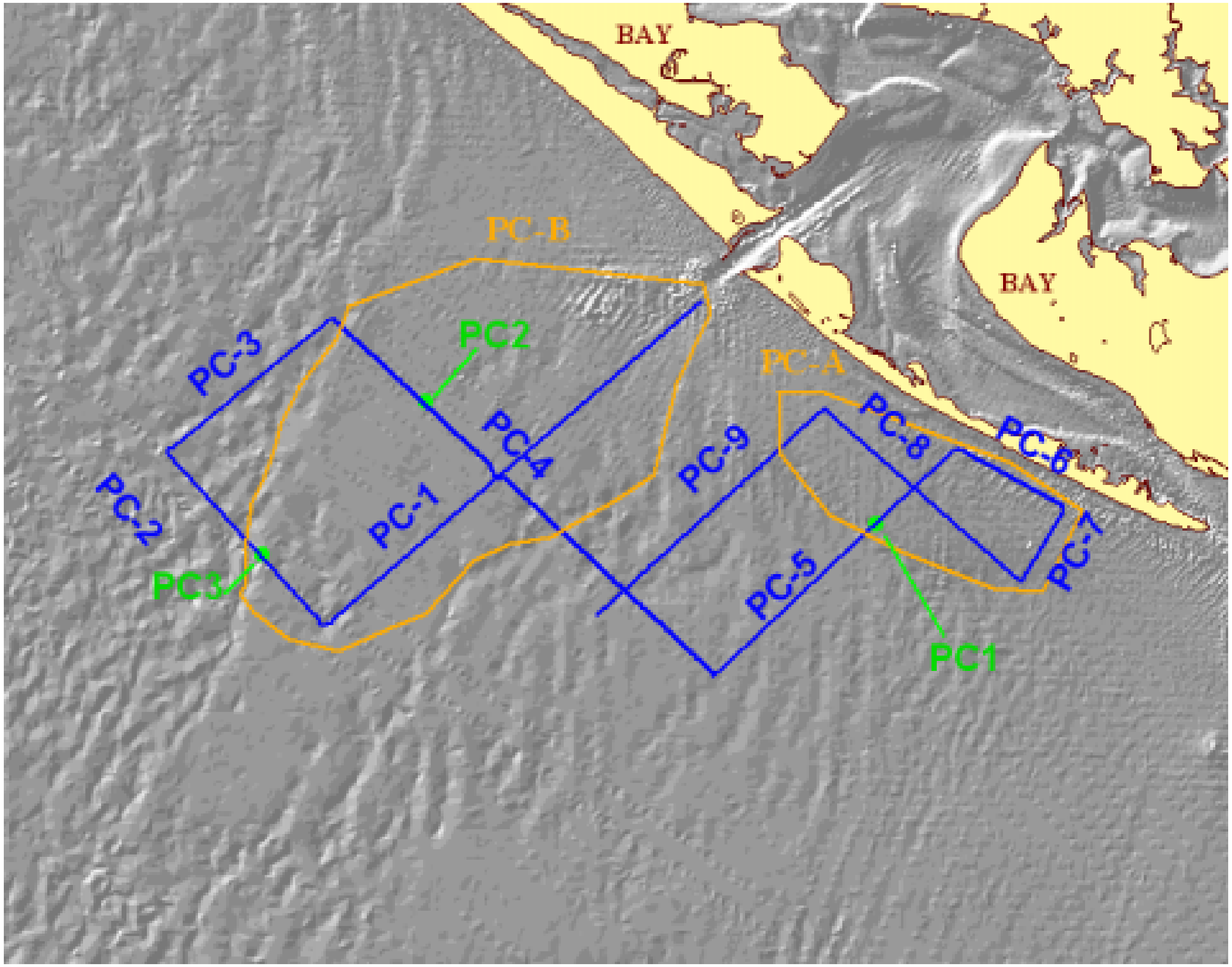


Figure 4.14.5

Delineated Areas For Sediment Volume Calculations. Sites PC-A and PC-B

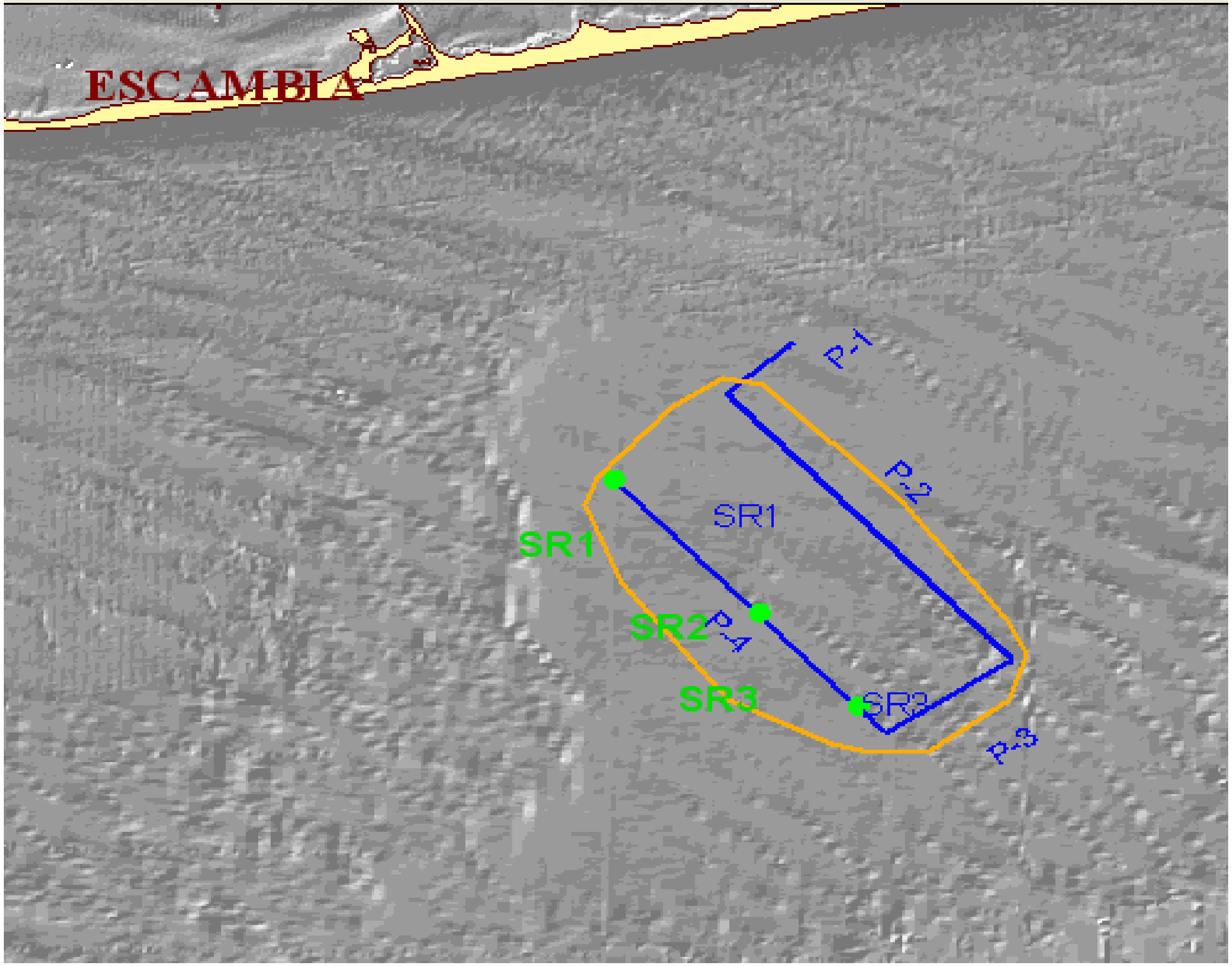


Figure 4.14.6

Delineated Areas For Sediment Volume Calculations. Site SR-A

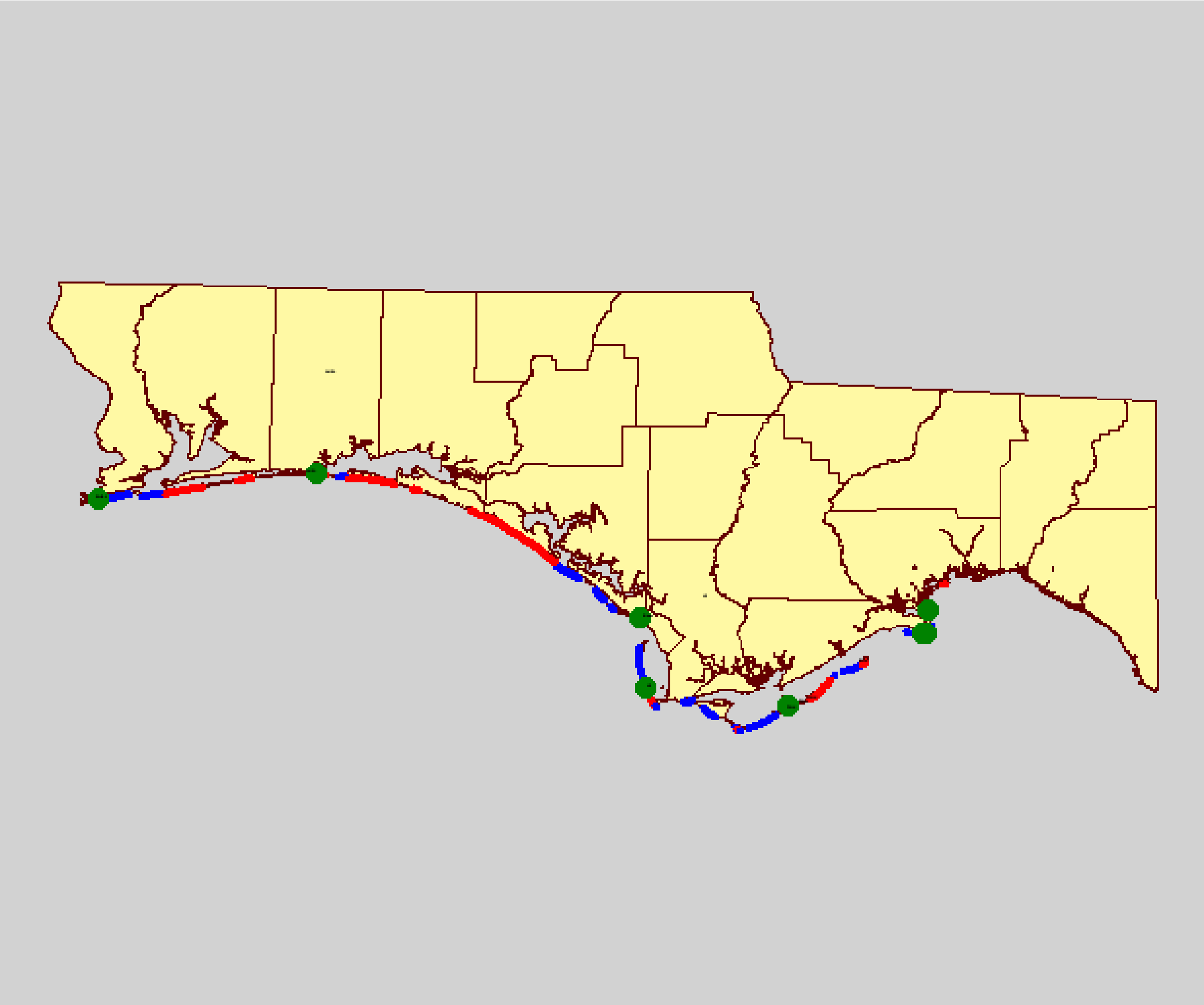


Figure 5.2.1

Phase III Beach Sample Locations (Green Dots)

In Relation To Critical Erosion Areas

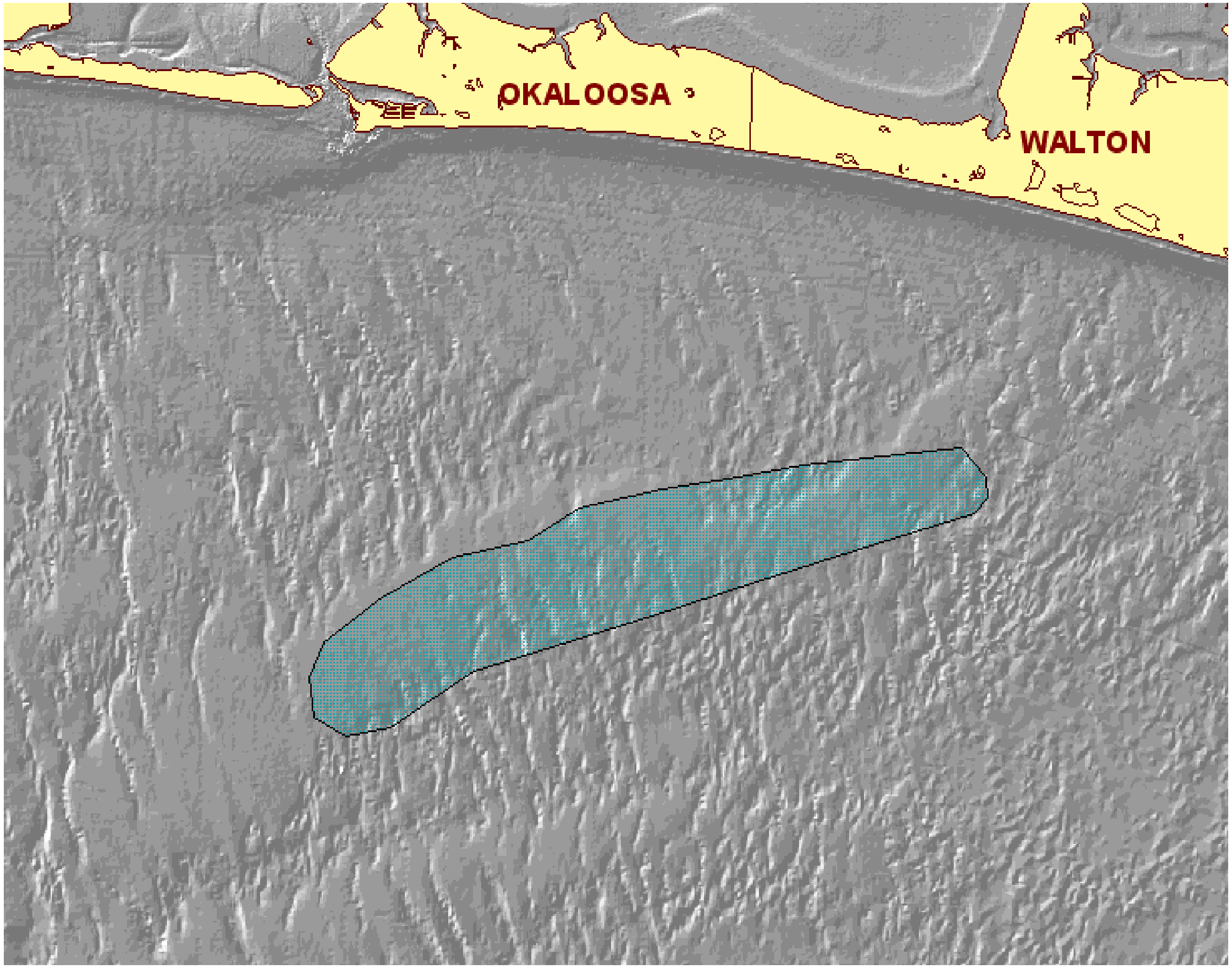


Figure 6.1.1

East Pass Site

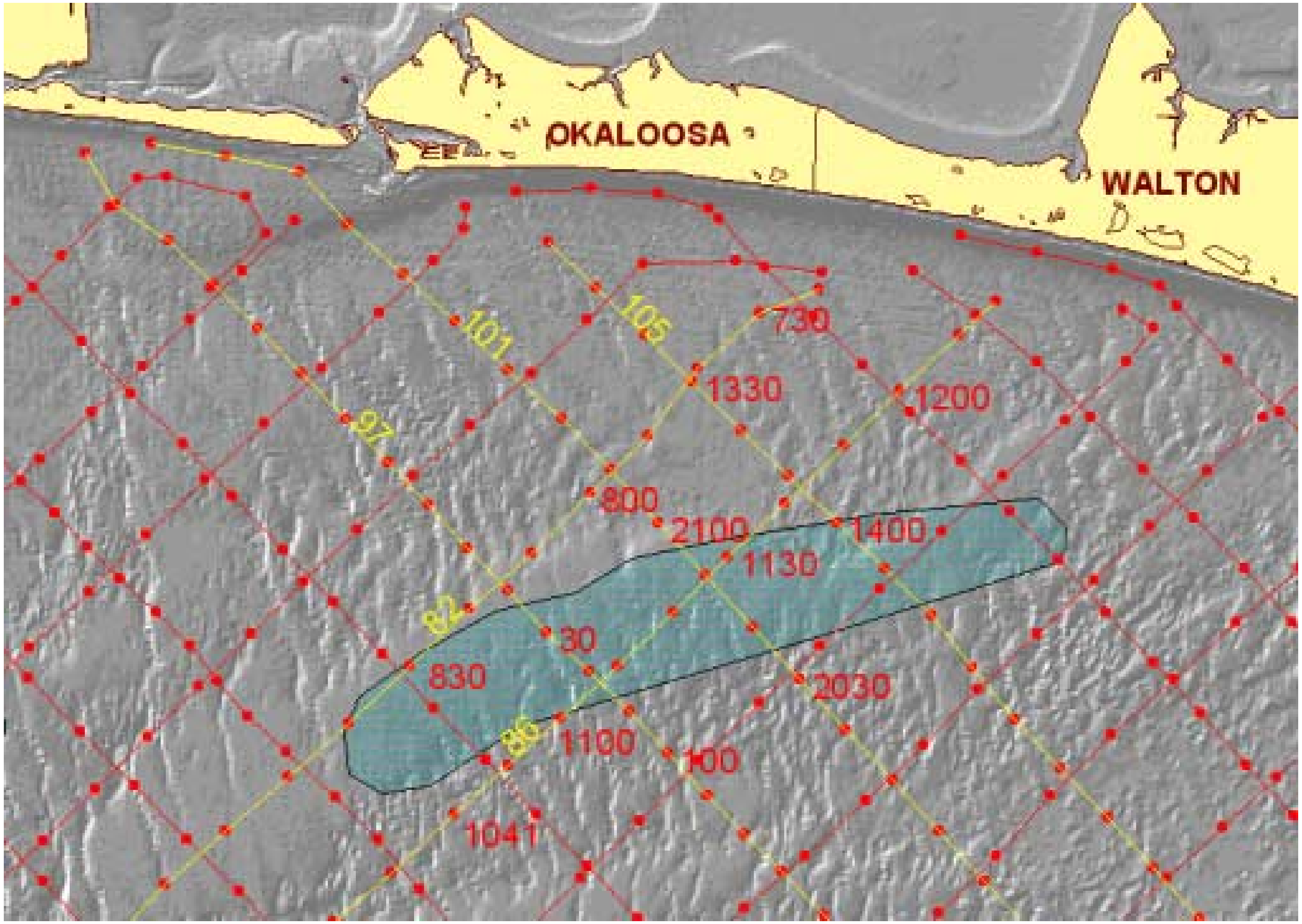


Figure 6.1.2

Track line Coverage of Boomer Data

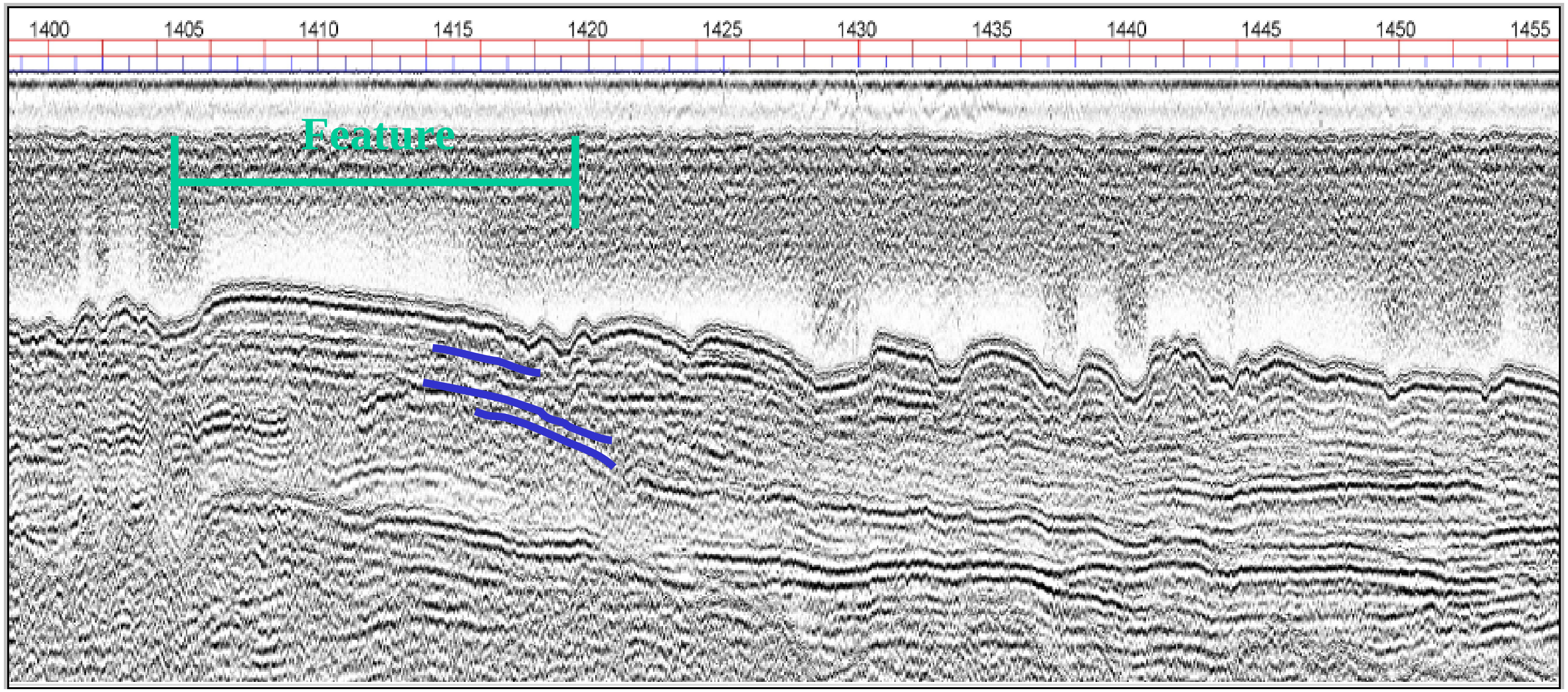


Figure 6.1.3

Boomer Line #105 Showing East Pass Feature

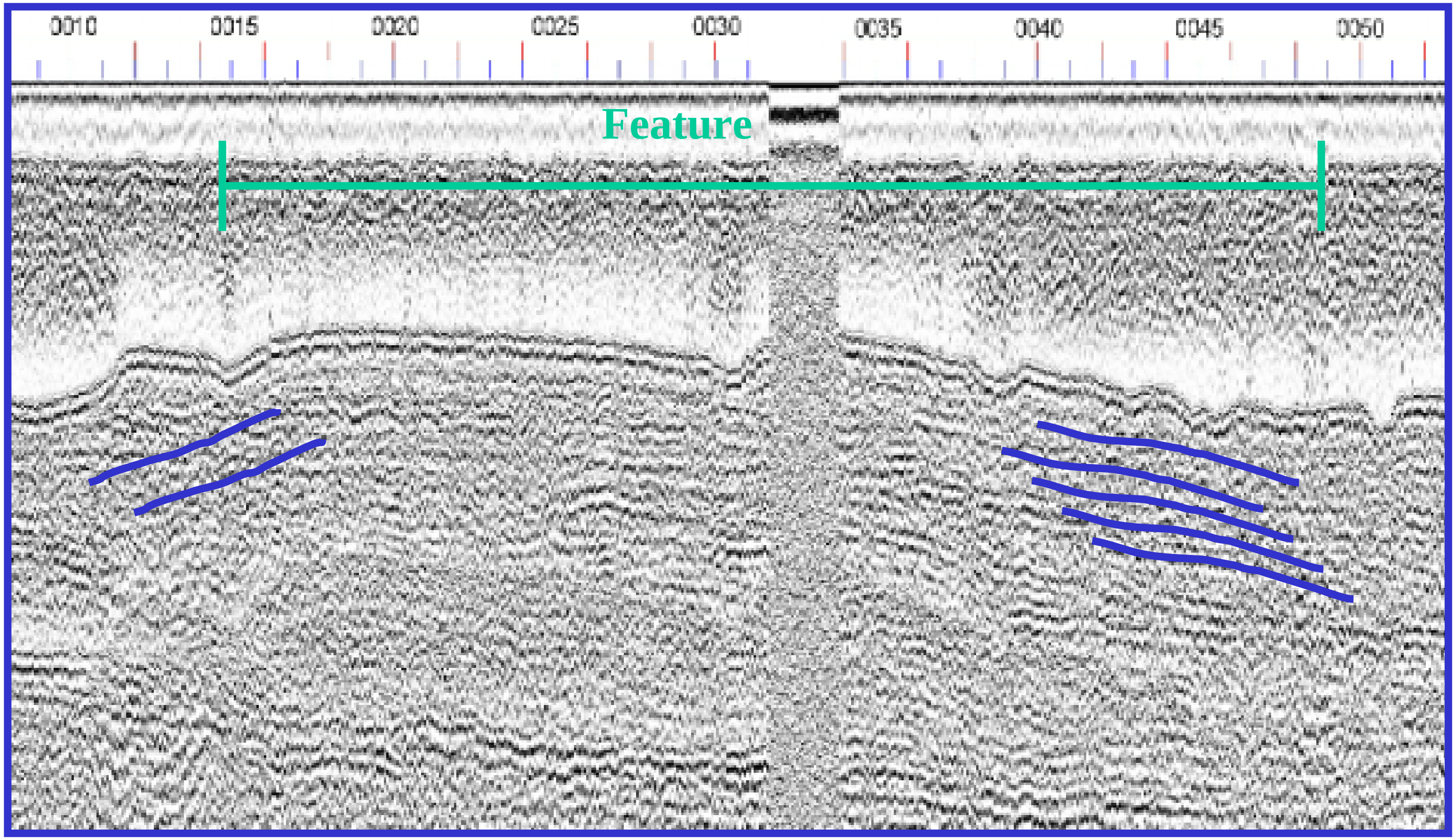


Figure 6.1.4

Boomer Line #97 Showing East Pass Feature

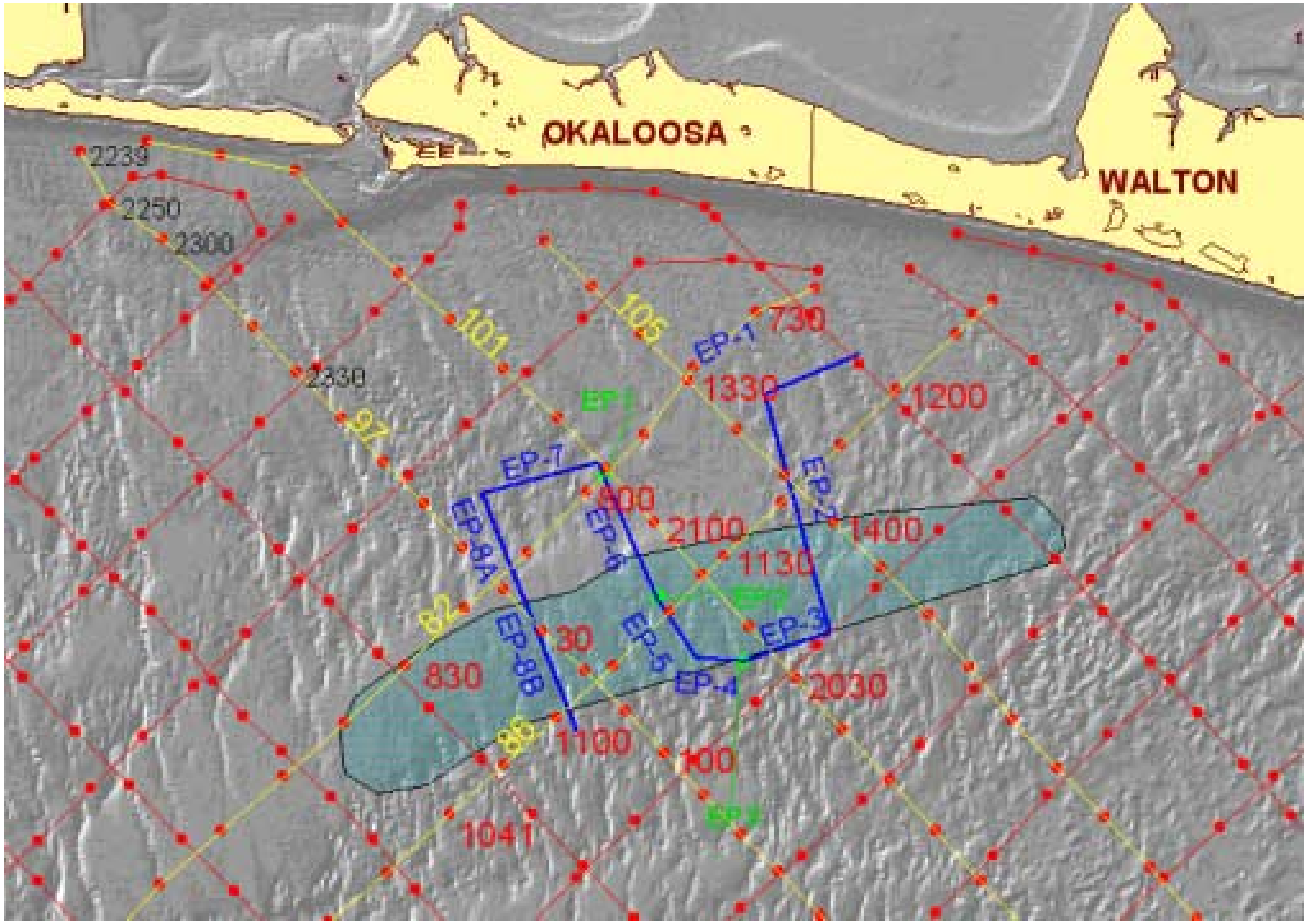


Figure 6.1.5

East Pass Site Vibracore Locations

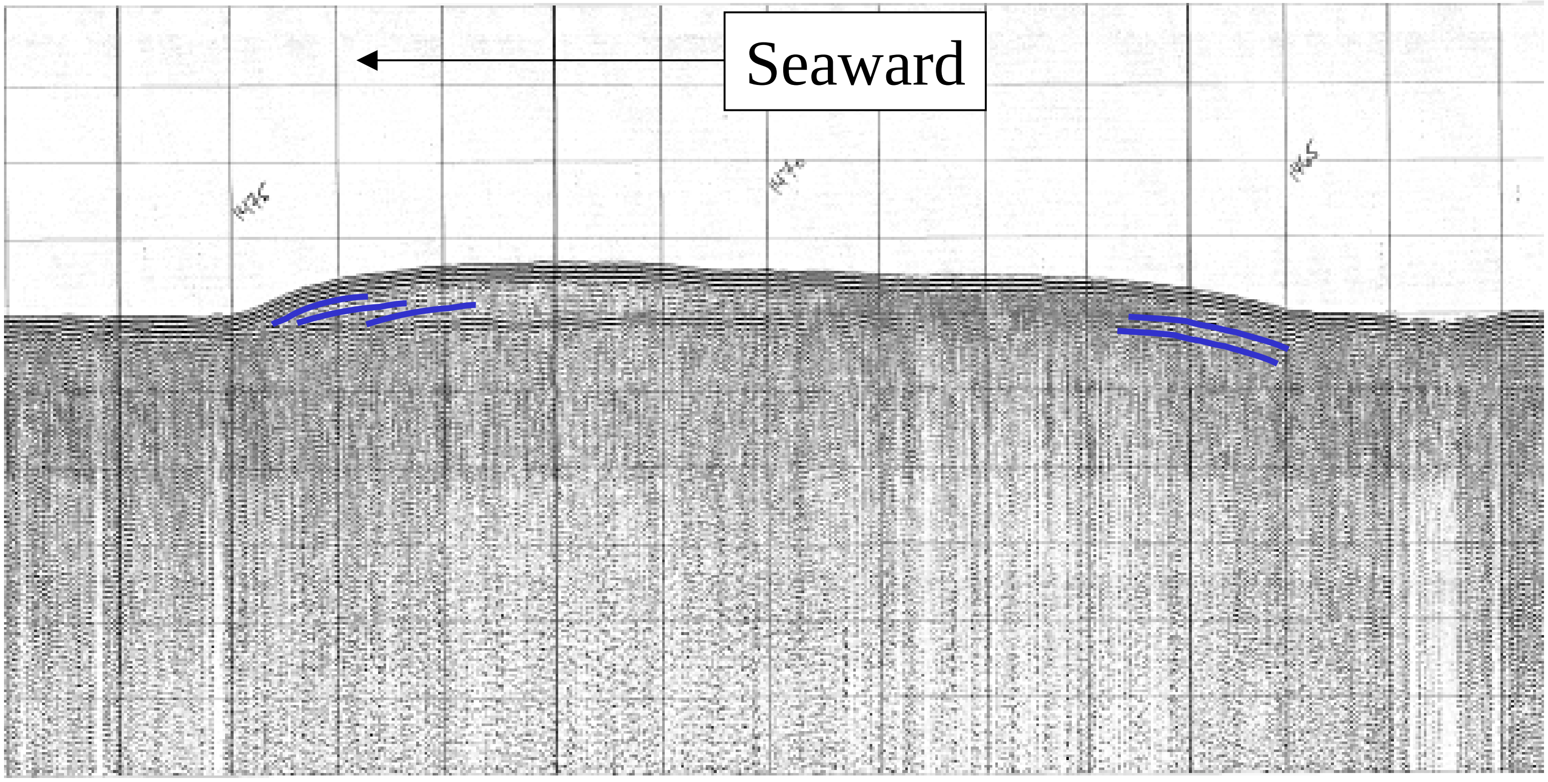


Figure 6.1.6

Phase III Trackline # EP-2

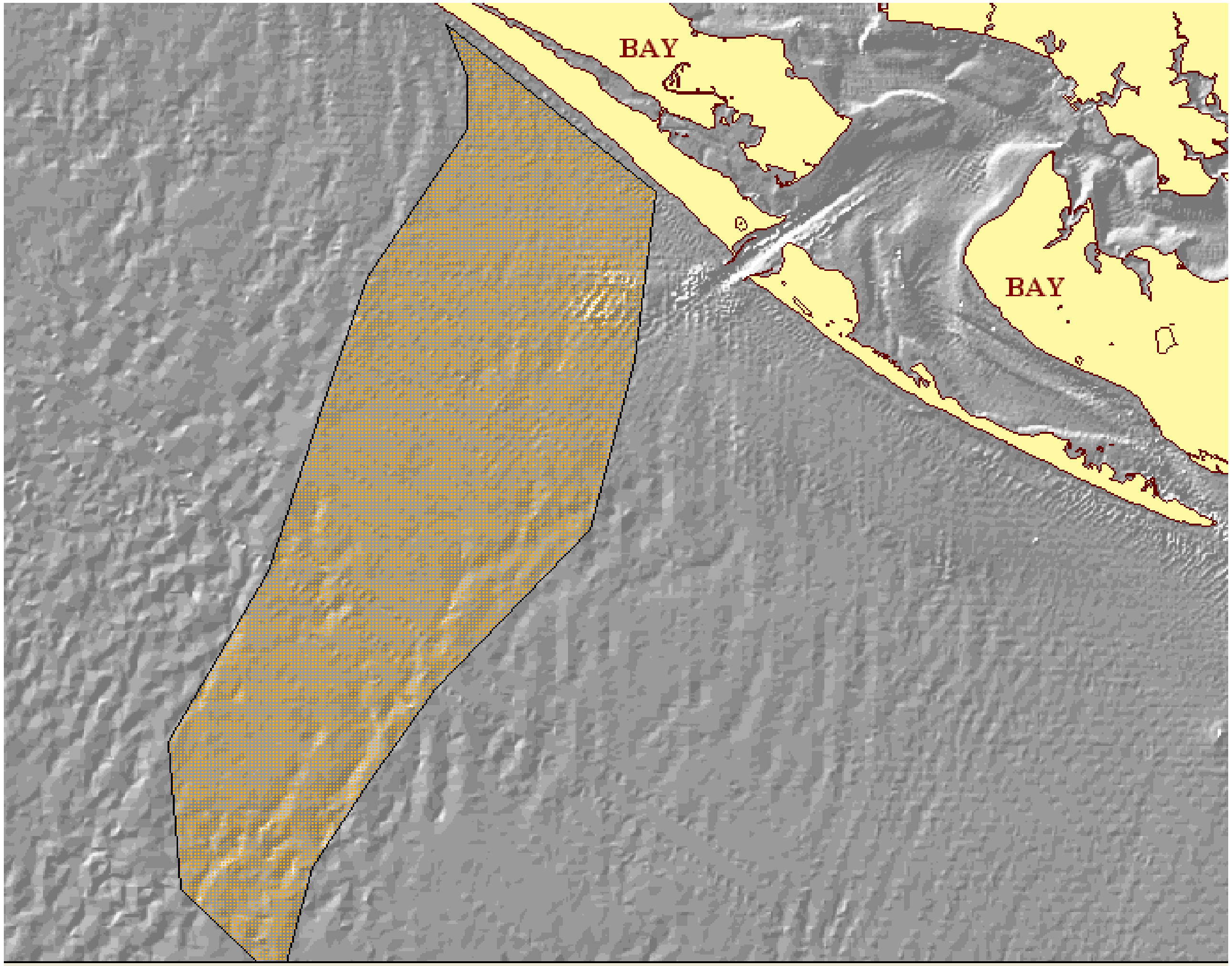


Figure 6.2.1

Panama City Site

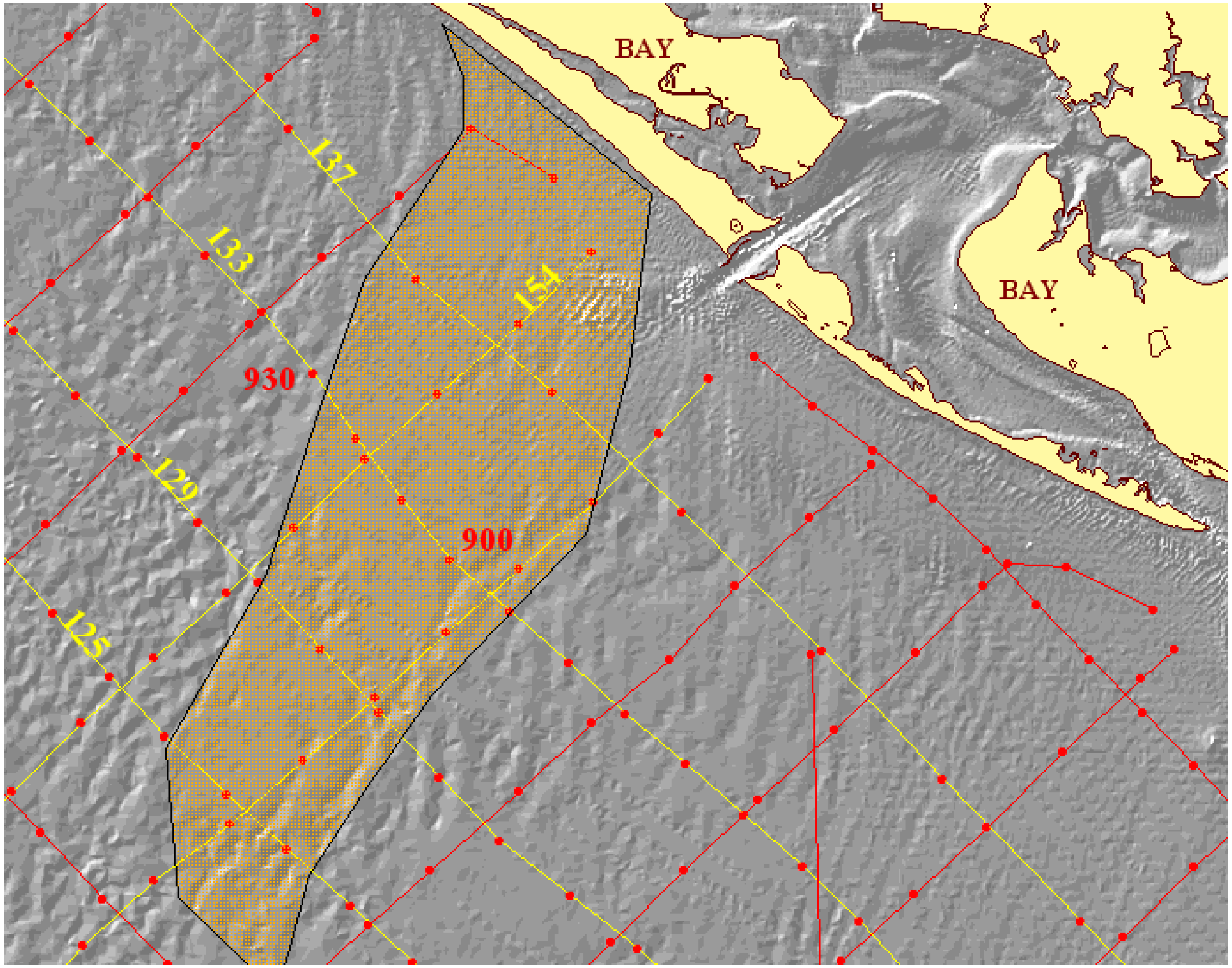


Figure 6.2.2

Track line Coverage of Boomer Data

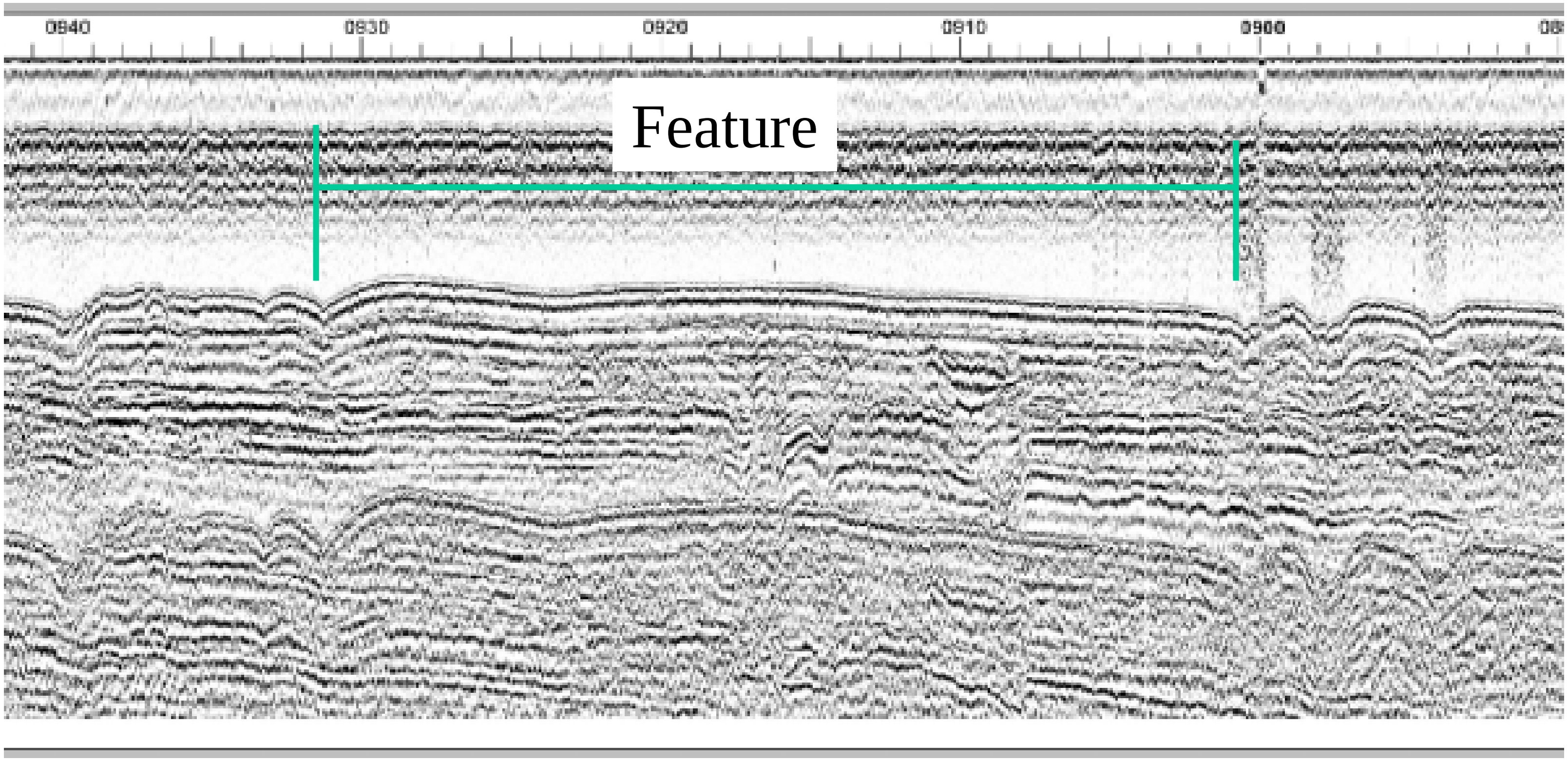


Figure 6.2.3

Boomer Line #133 Showing Panama City Feature

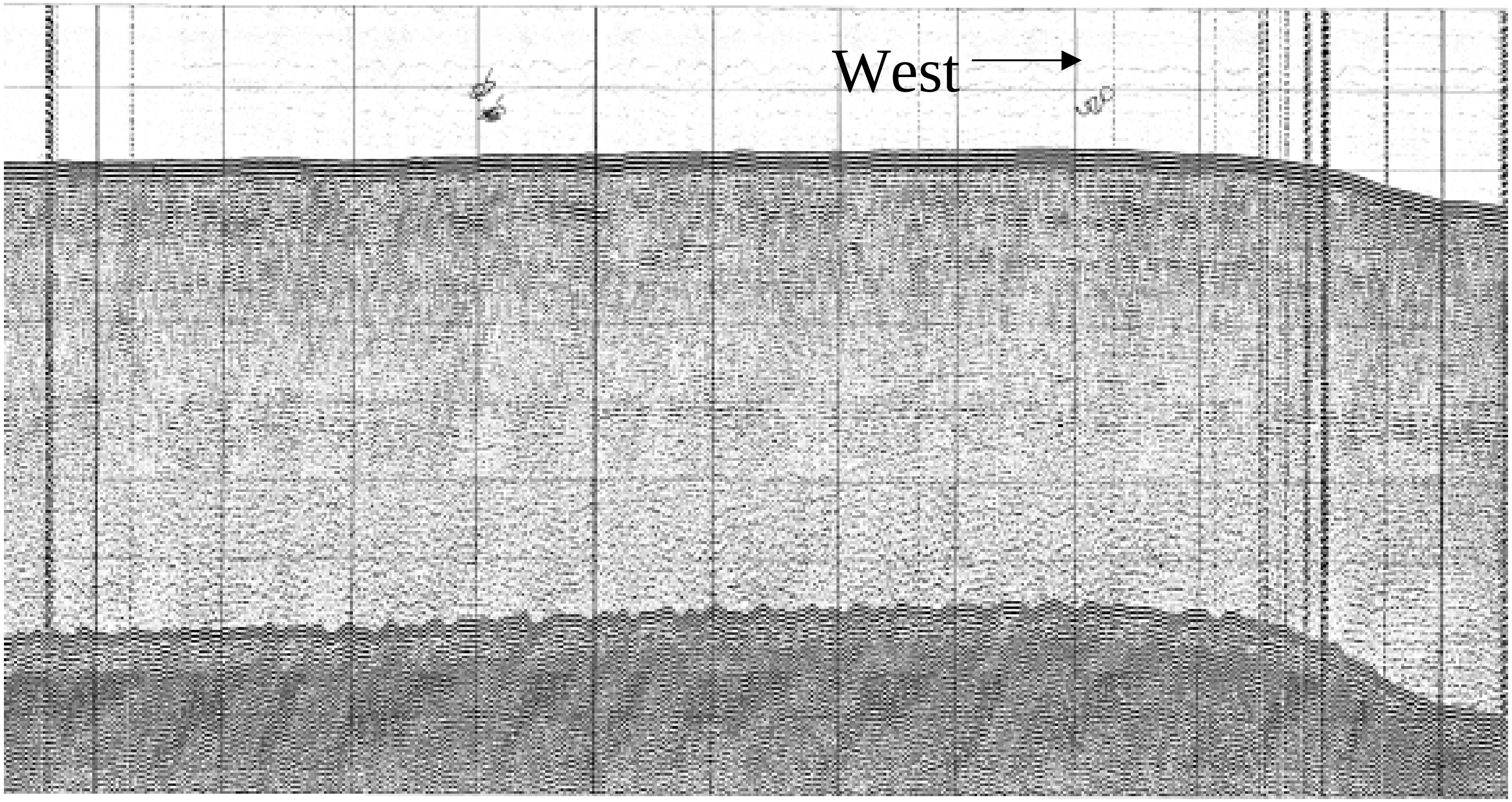


Figure 6.2.4

Phase III Line #PC-4 Showing Edge of Panama City Feature

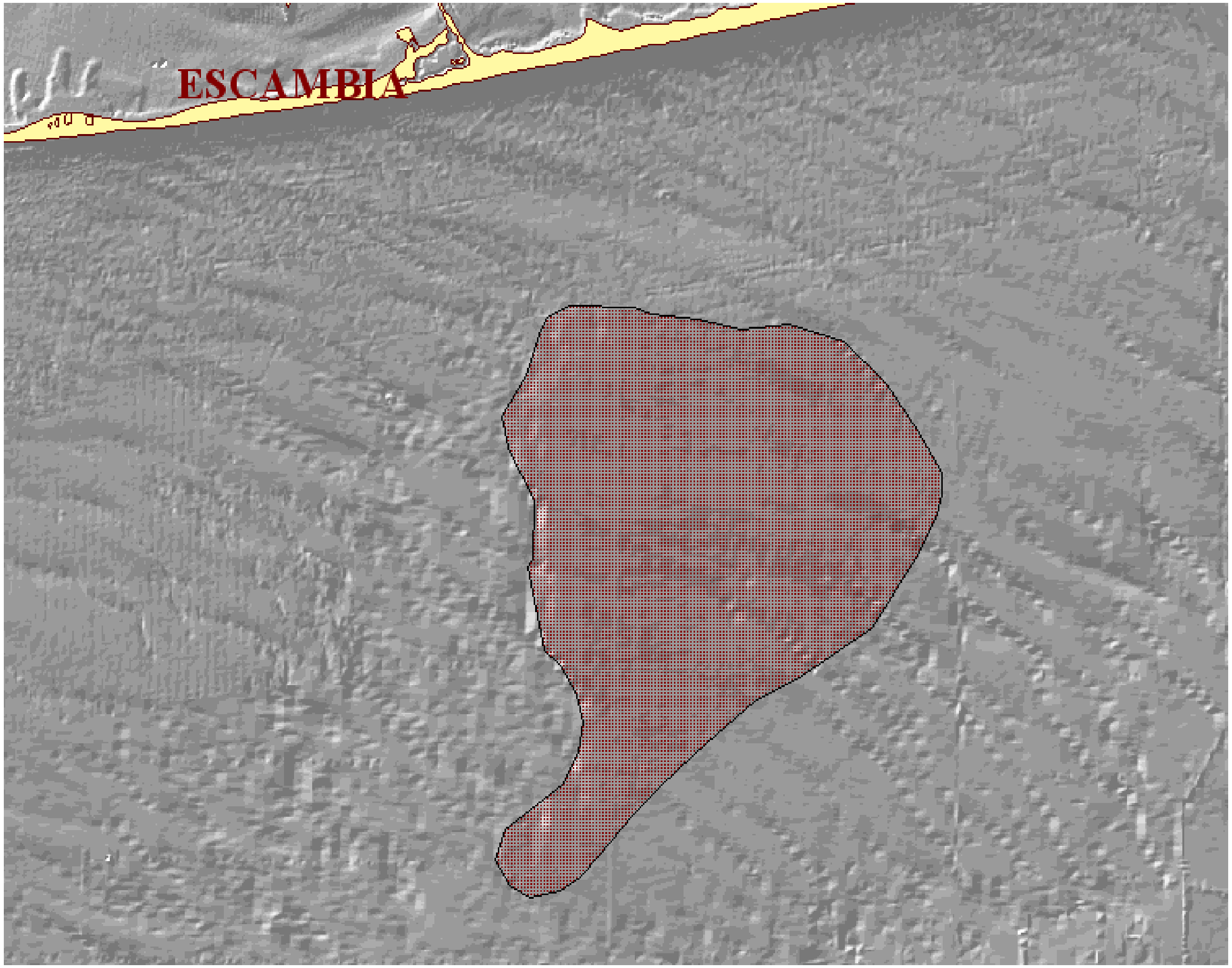


Figure 6.3.1

Santa Rosa Site

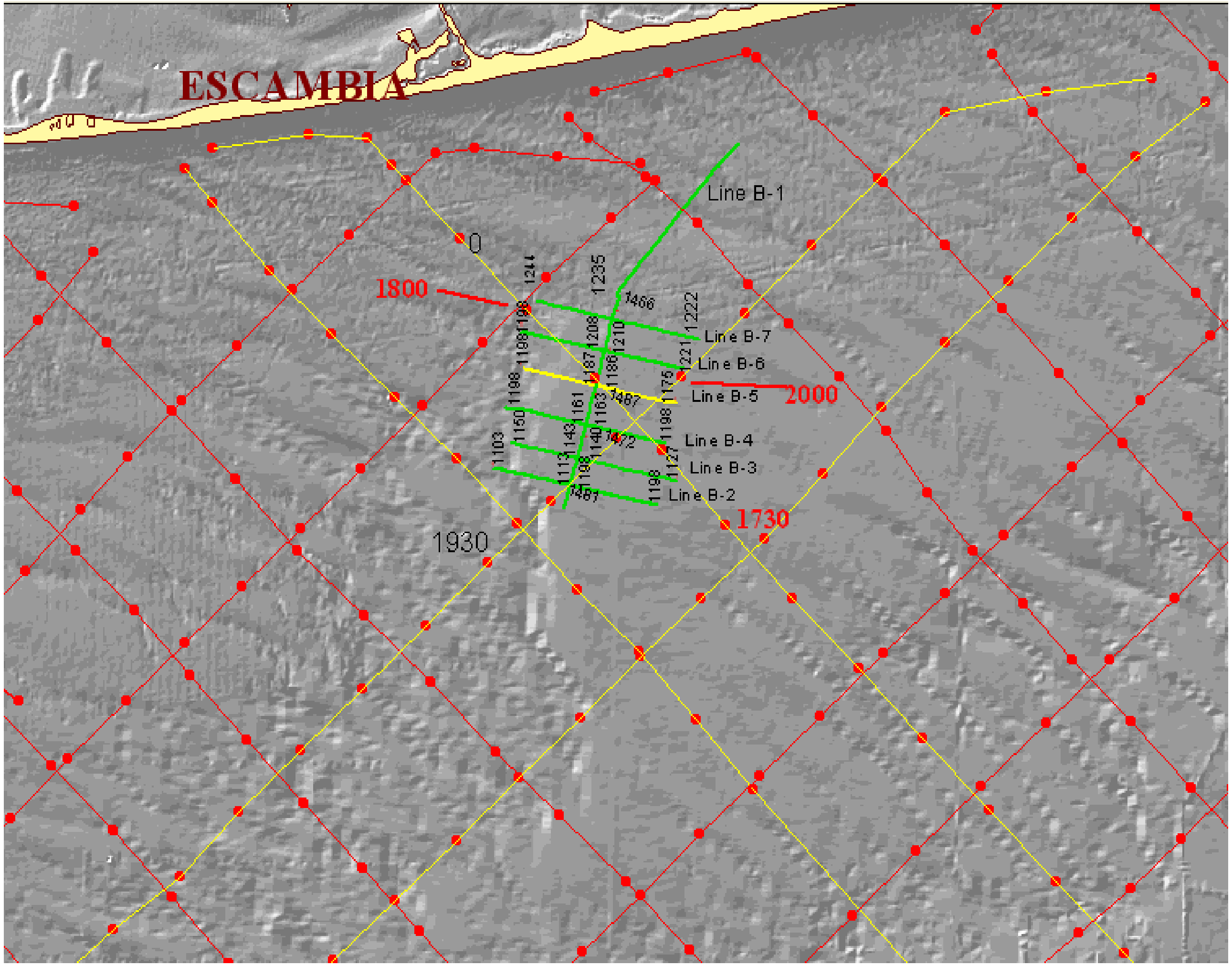


Figure 6.3.2

Track line Coverage of Boomer Data

EAST →

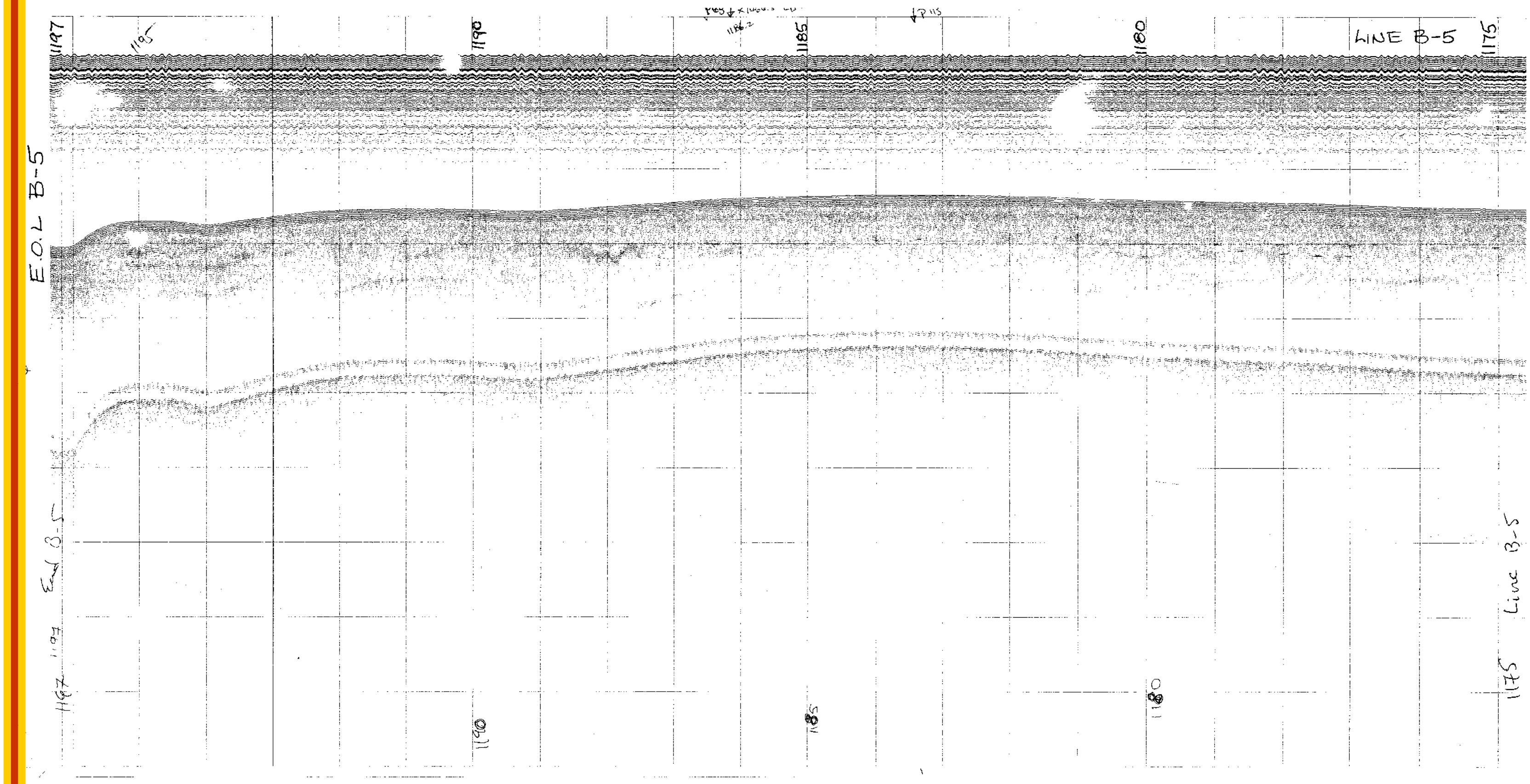


Figure 6.3.3

OBS Track line Coverage of Santa Rosa Feature

EAST →

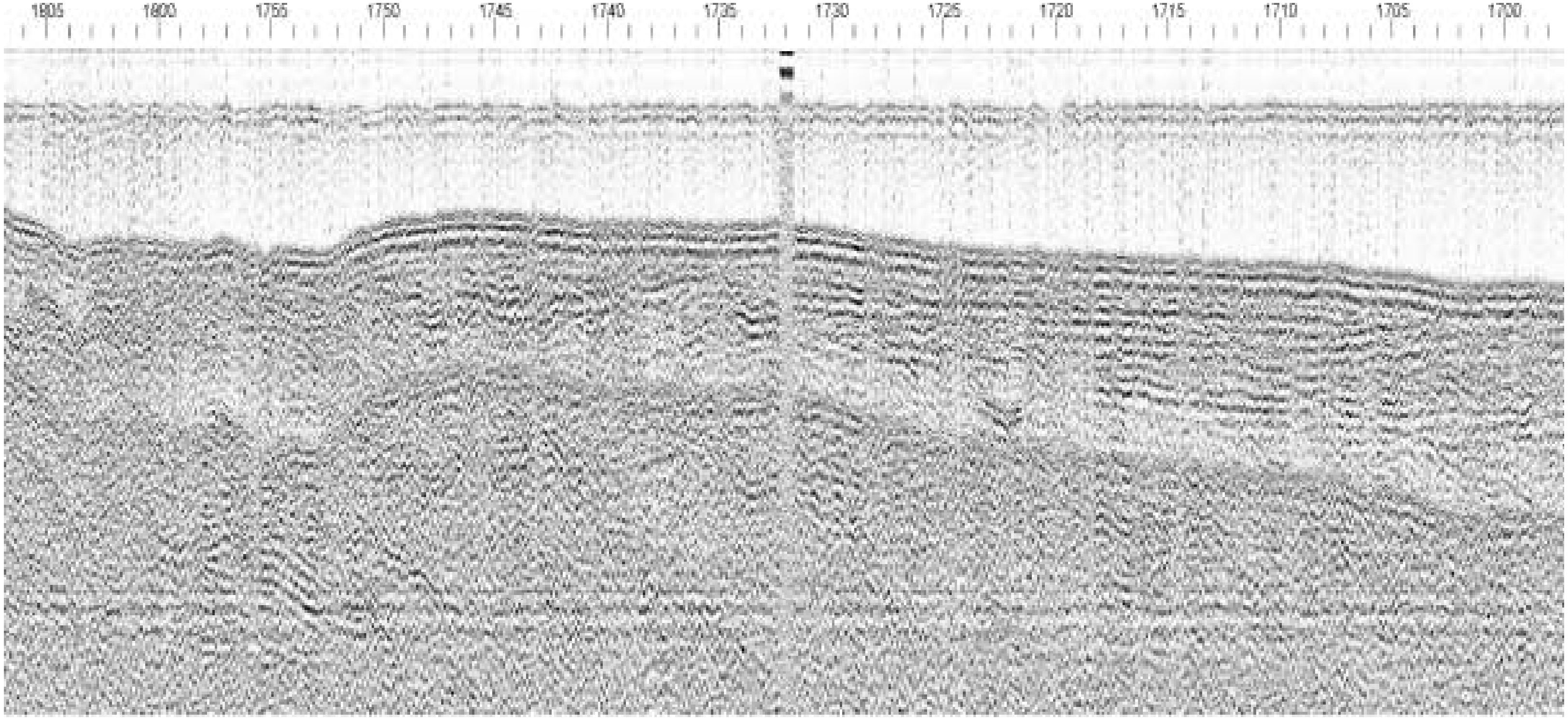


Figure 6.3.4

Boomer Track line Coverage of Santa Rosa Feature