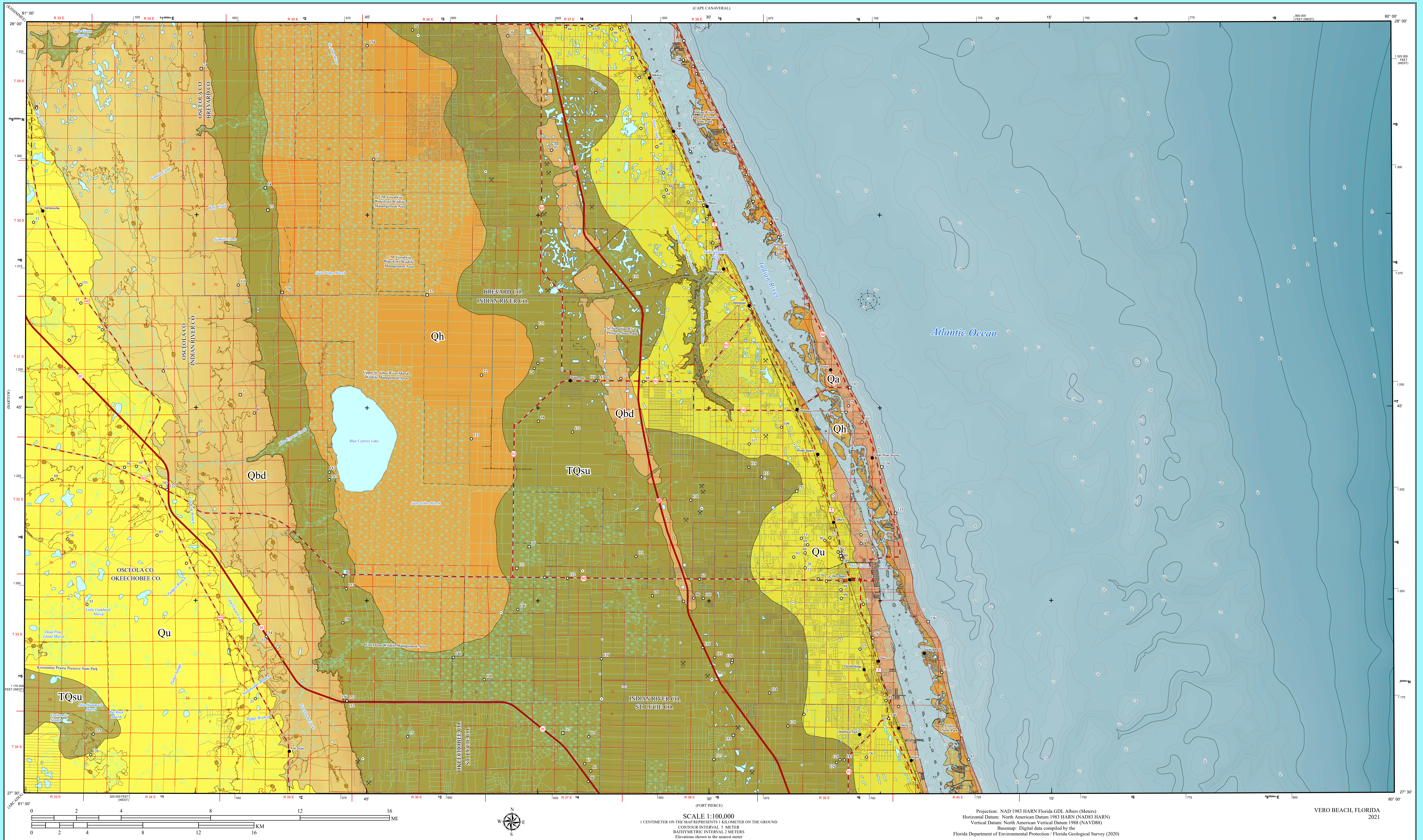


Jonathan D. Arthur
State Geologist and Director



OPEN-FILE MAP SERIES 112, Plate 1
GEOLOGIC MAP OF THE USGS VERO BEACH
30 X 60 MINUTE QUADRANGLE, CENTRAL FLORIDA
2021

BY
RICHARD C. GREEN, (P.G. # 1776), ALEXANDER G. LAMARCHE, CHRISTOPHER P. WILLIAMS, P.G.,
CRYSTAL L. HEBETS, GARRETT S. EVANS, AND CASEY K. ALBRITTON, P.G.



Holocene sediments
Qh Sediments mapped as Holocene (Qh) may include quartz sands, marls, organics, and minor carbonate sands and mud. They may also include fresh-water gastropods and modern shells. Within the study area, these occur near and along the present coastline in barrier islands on the Atlantic Ocean and the St. Johns River floodplain.

Quaternary beach ridge and dune sediments
Qbd Quaternary beach ridge and dune sediments (Qbd) are a subdivision of the undifferentiated Quaternary sediments that are noted based on surficial expression of relief beach ridges and dunes. While not a formally recognized lithostratigraphic unit, Qbd is mapped in order to facilitate a better understanding of Florida's geology. Beach ridge and dune sediments are dominantly siliclastic sands and are unconsolidated to poorly consolidated. Organics typically occur as disseminated organic matrix, roots and plant debris, carbonized remains, or charcoal.

Quaternary sediments
Qu While not a formally recognized lithostratigraphic unit, undifferentiated Quaternary (Qu) sediments are mapped in order to better understand Florida's geology. These undifferentiated Quaternary sediments consist of white to gray to orange, fine- to coarse-grained, clean to clayey unfossiliferous sands, sandy clays and clays with variable admixtures of organics.

Anastasia Formation
Qa The Anastasia Formation (Qa) is present within a narrow band along the eastern edge of the study area. The formation is composed of interbedded coquina limestone and quartz sands. It typically occurs as an coquina limestone to very-pale orange, unconsolidated to moderately indurated coquina consisting of whole and broken mollusk shells in a quartz and matrix. The coquina is commonly cemented by sparry calcite. The sands occur as light gray to tan and orange-brown, unconsolidated to moderately indurated, unfossiliferous to very fossiliferous beds. The unit sits unconformably on undifferentiated Tertiary/Quaternary shelly sediments.

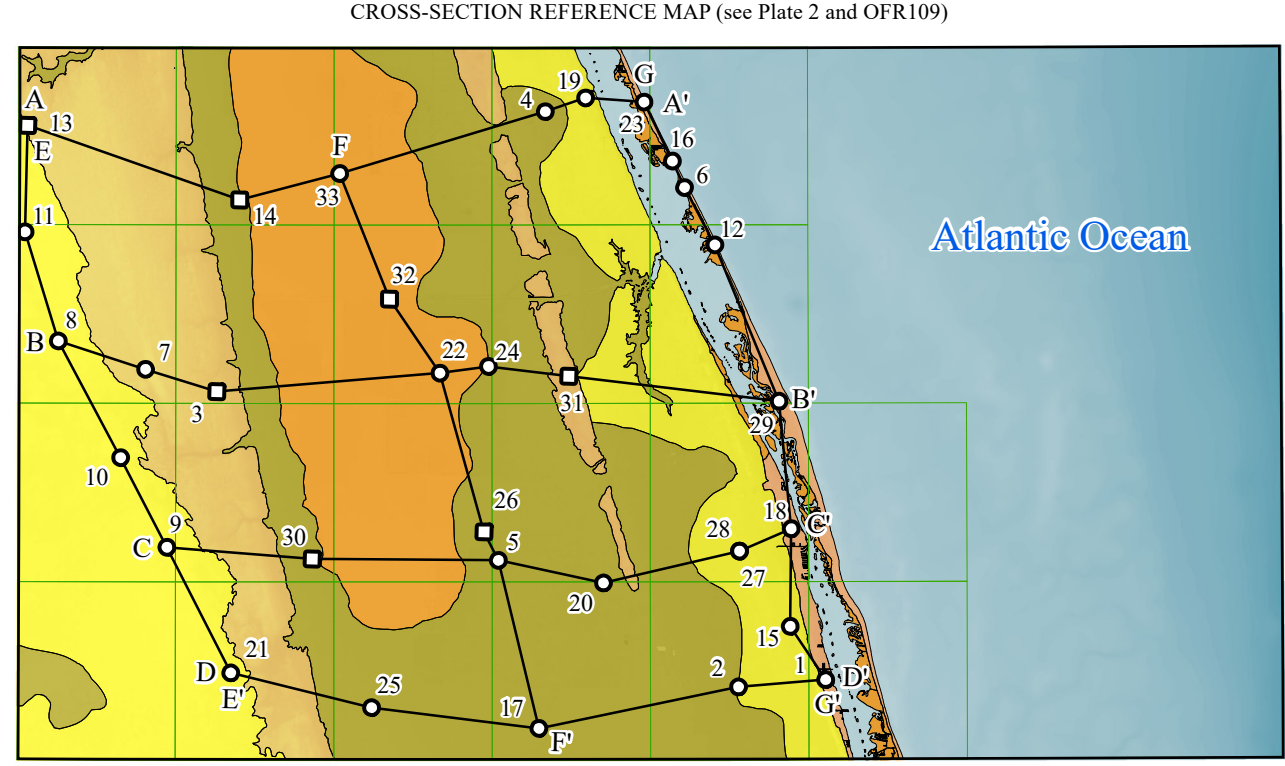
Undifferentiated Tertiary/Quaternary shelly sediments
TQsu Undifferentiated Tertiary/Quaternary shelly sediments (TQsu) typically consist of fine- to medium quartz sand with variable amounts of micrite, silt, marine mollusk shells, and clay. Shells, which may vary from whole to fragmented, can range from highly weathered and abraded to relatively intact, and may occasionally become the dominant lithology. Other accessory minerals may include calcite, aragonite, mica, heavy minerals, and phosphate sand and gravel. A basal phosphate lag is often present. Colors range from light gray to light-olive gray. In the study area, TQsu is predominantly in the form of unconsolidated sands, with varying percentages of shell fragments. The unit sits unconformably on the Peace River Formation throughout the mapped area.

SPOIL
The areas marked as spoil on the map are disturbed islands created by dredging in the Indian River along navigation channels. These are typically a mixture of sand and shells from either the undifferentiated Tertiary/Quaternary shelly sediments, the Anastasia Formation, or Holocene sediments.

LEGEND

- Primary highway
- Secondary highway
- Light duty road, principal street
- Railroad
- County boundary
- State lands and parks
- Contours (5m)
- Index
- Intermediate
- Bathymetry (2m)
- Index
- Intermediate
- Core
- Cuttings
- M-Series sample
- Outcrop/exposure
- Borrow pit
- Quarry / sand mine
- City/town
- USGS 1:24,000 Quadrangle tick mark
- Wells numbered 1 - 33 are used in cross-sections on OFMS 112, Plate 2
- Waterbody
- Wetland
- River or stream
- Cross section line
- U.S. Public Lands Survey Township/Range
- U.S. Public Lands Survey Section

Basemap Coordinate Explanation
10,000-meter grid, zone 17: Universal Transverse Mercator
25,000-foot grid ticks based on Florida coordinate system, east and west zones
9g = 9g000000
1710 = 1710000 (EAST)



ADJOINING MAPS

1	2
3	5

1 Kissimmee (OFMS 110)
2 Cape Canaveral
3 Bartow (OFMS 111)
4 Arcadia (OFMS 87/88)
5 Fort Pierce (to be mapped in 2021)

For more information or to order maps contact:
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Tallahassee, FL 32303
(850) 617-0316
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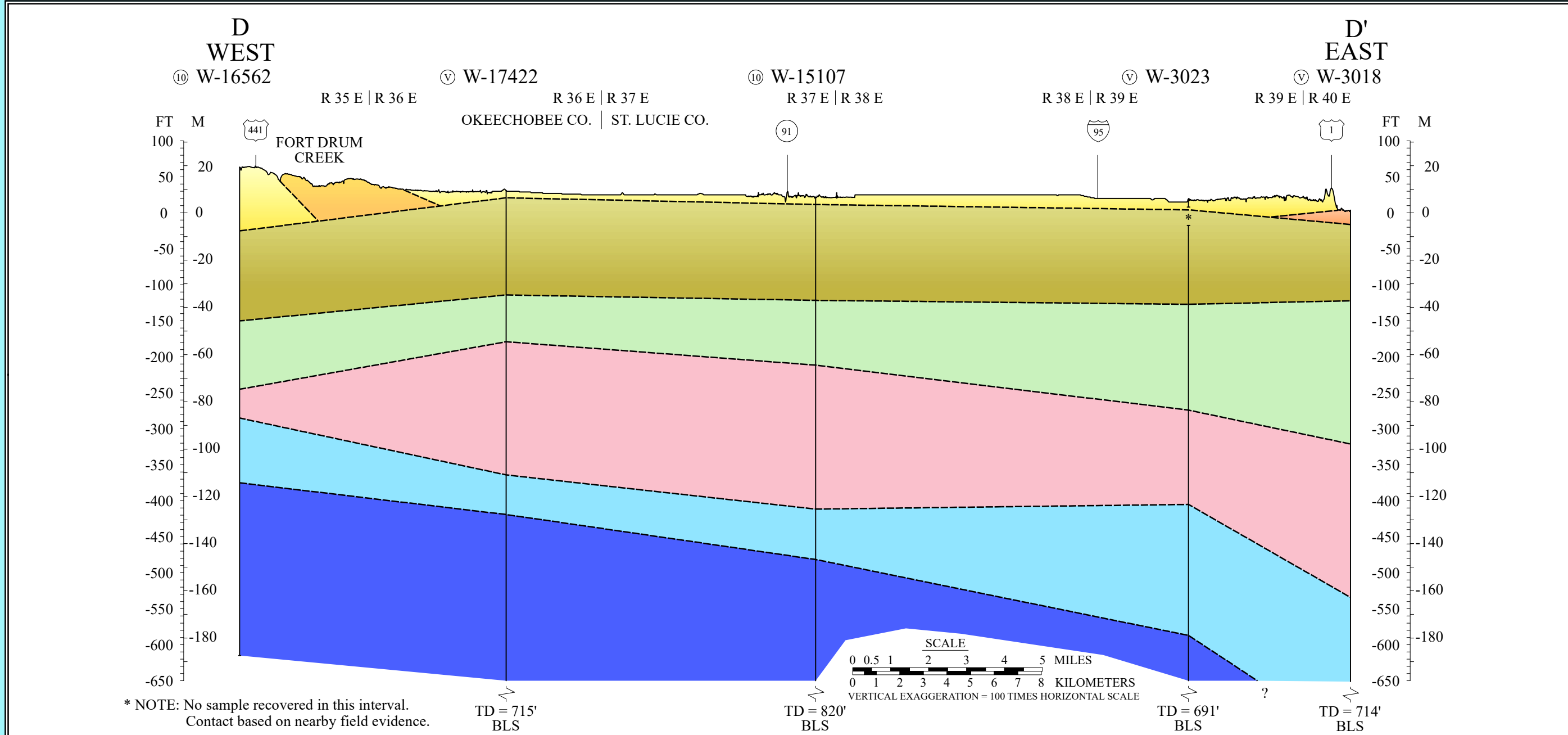
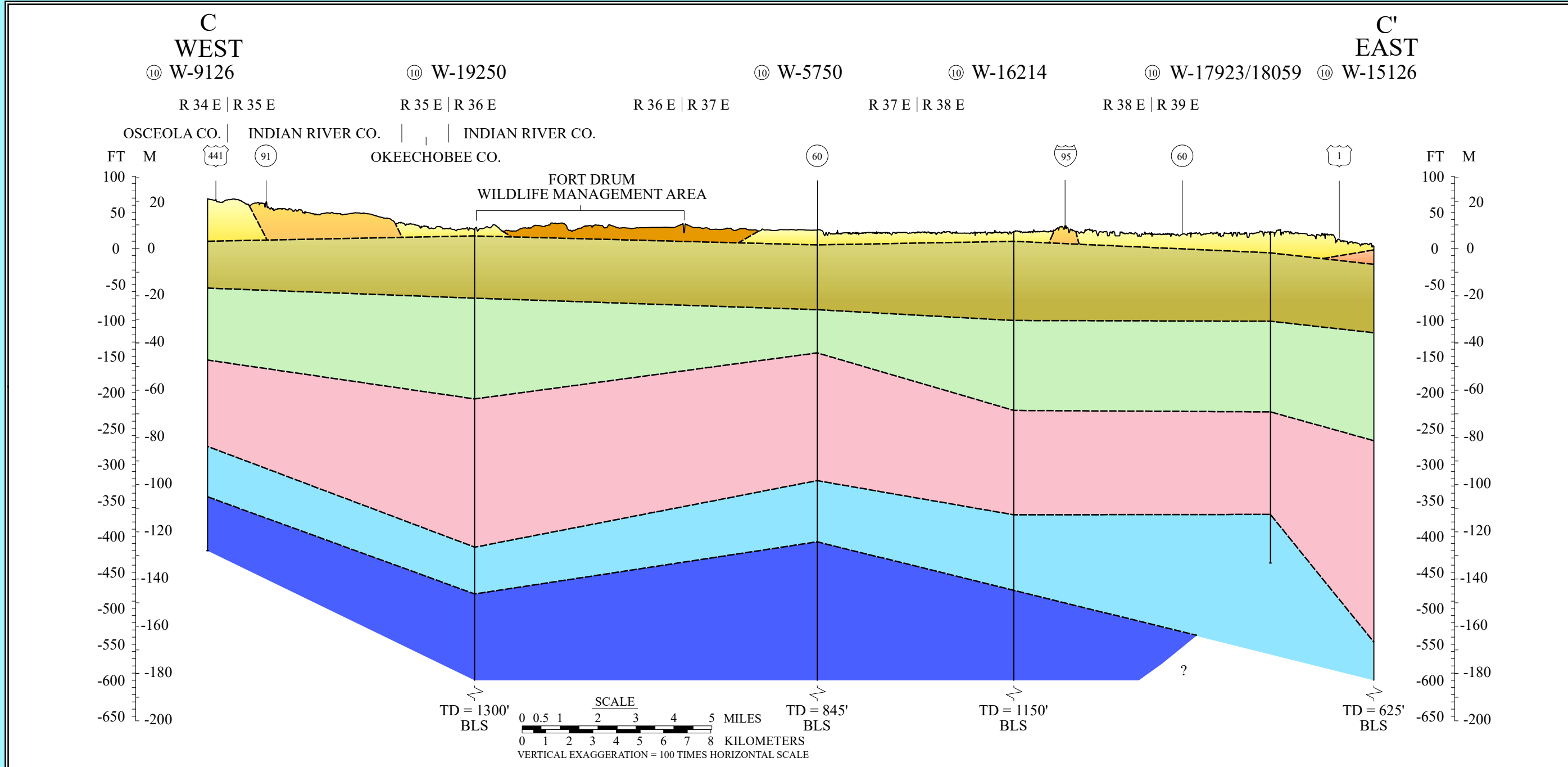
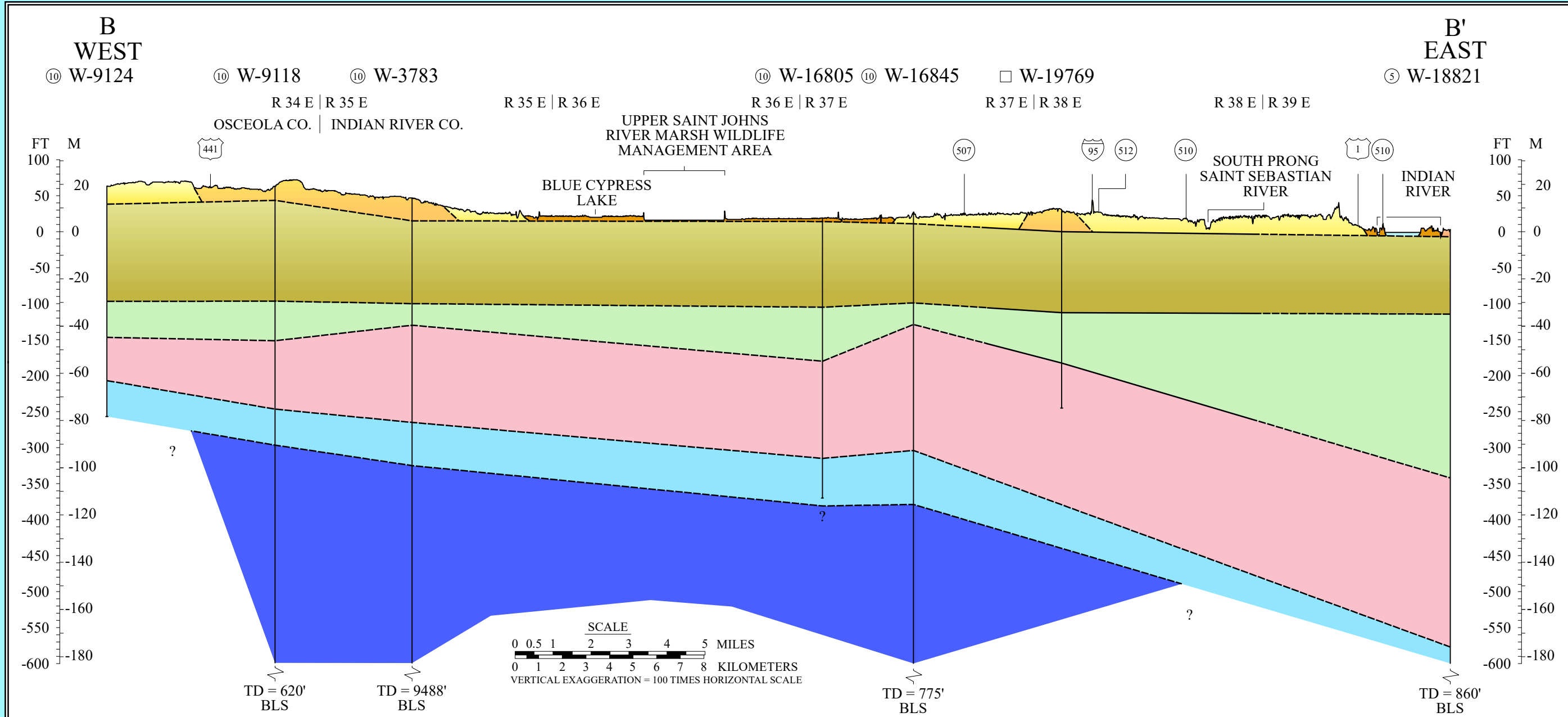
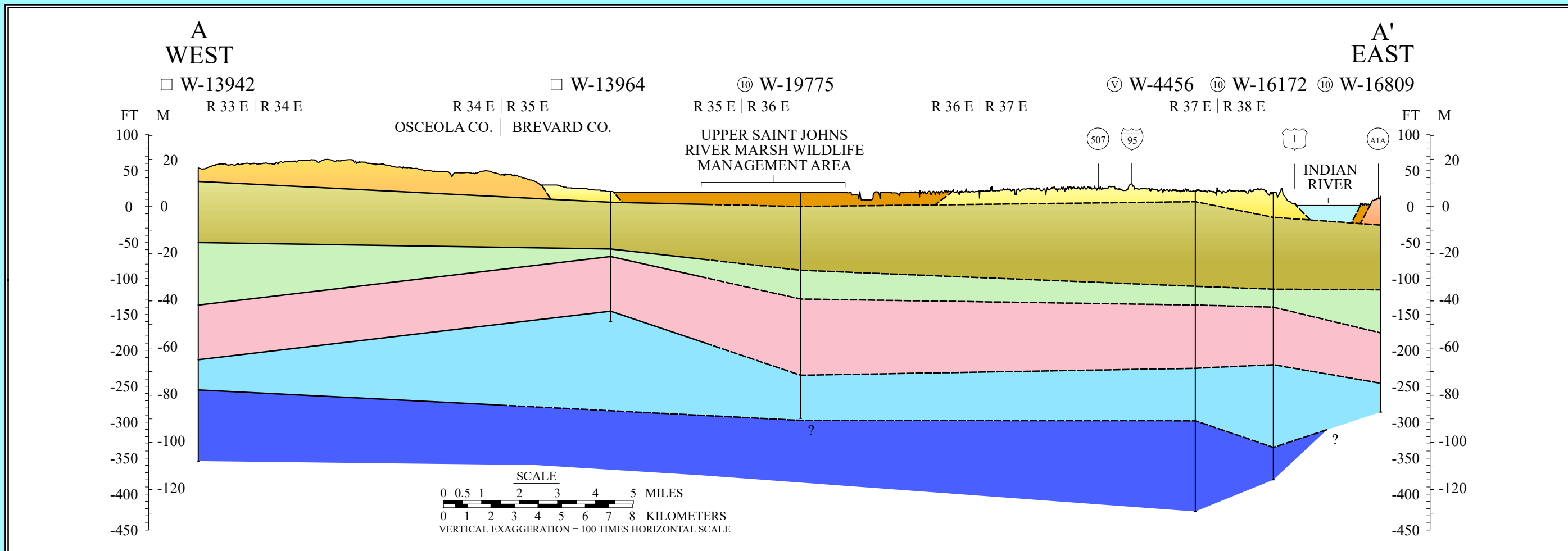
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OPEN-FILE MAP SERIES 112, Plate 2
GEOLOGIC CROSS-SECTIONS FOR THE USGS VERO BEACH
30 X 60 MINUTE QUADRANGLE, CENTRAL FLORIDA
2021

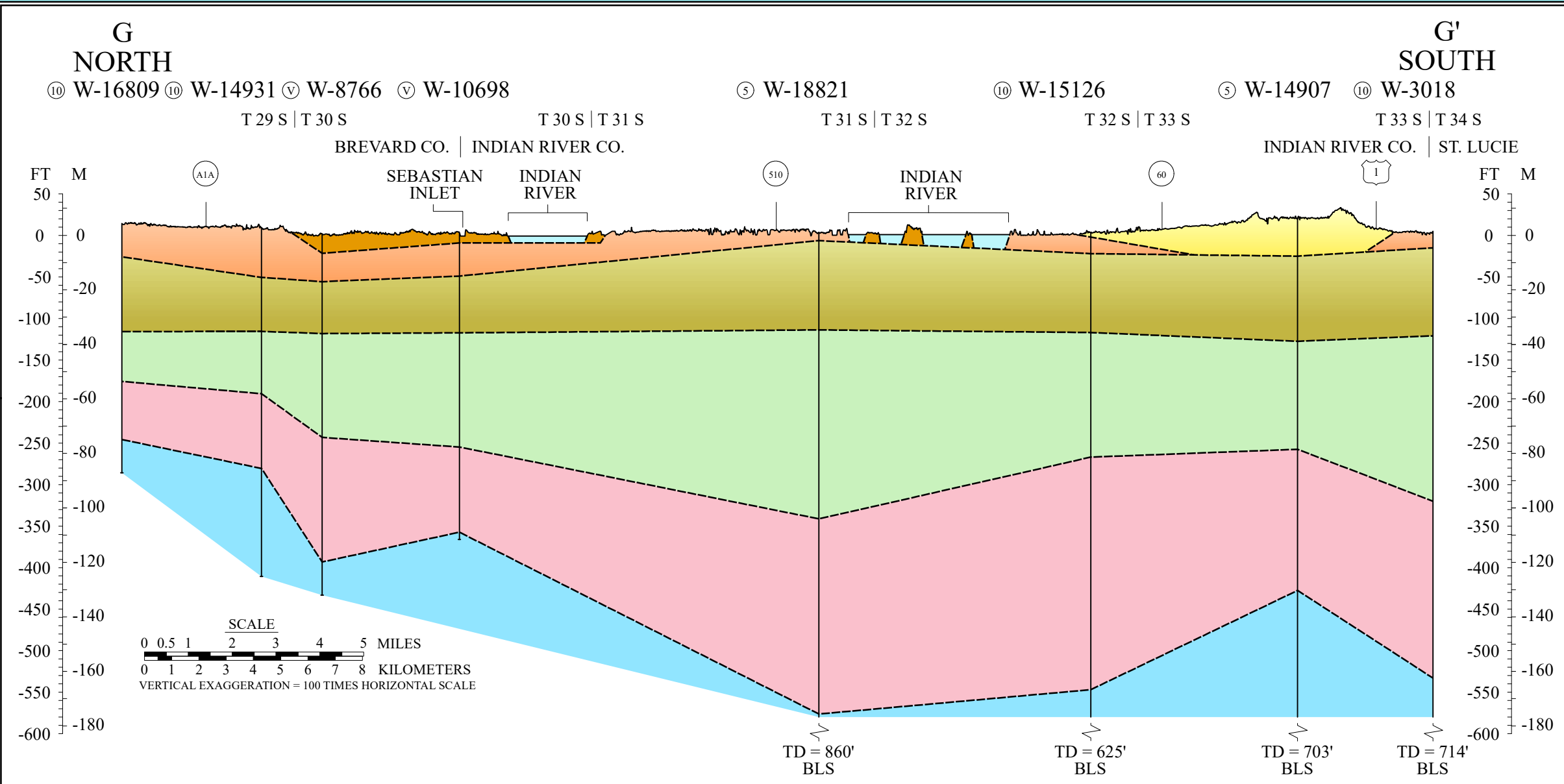
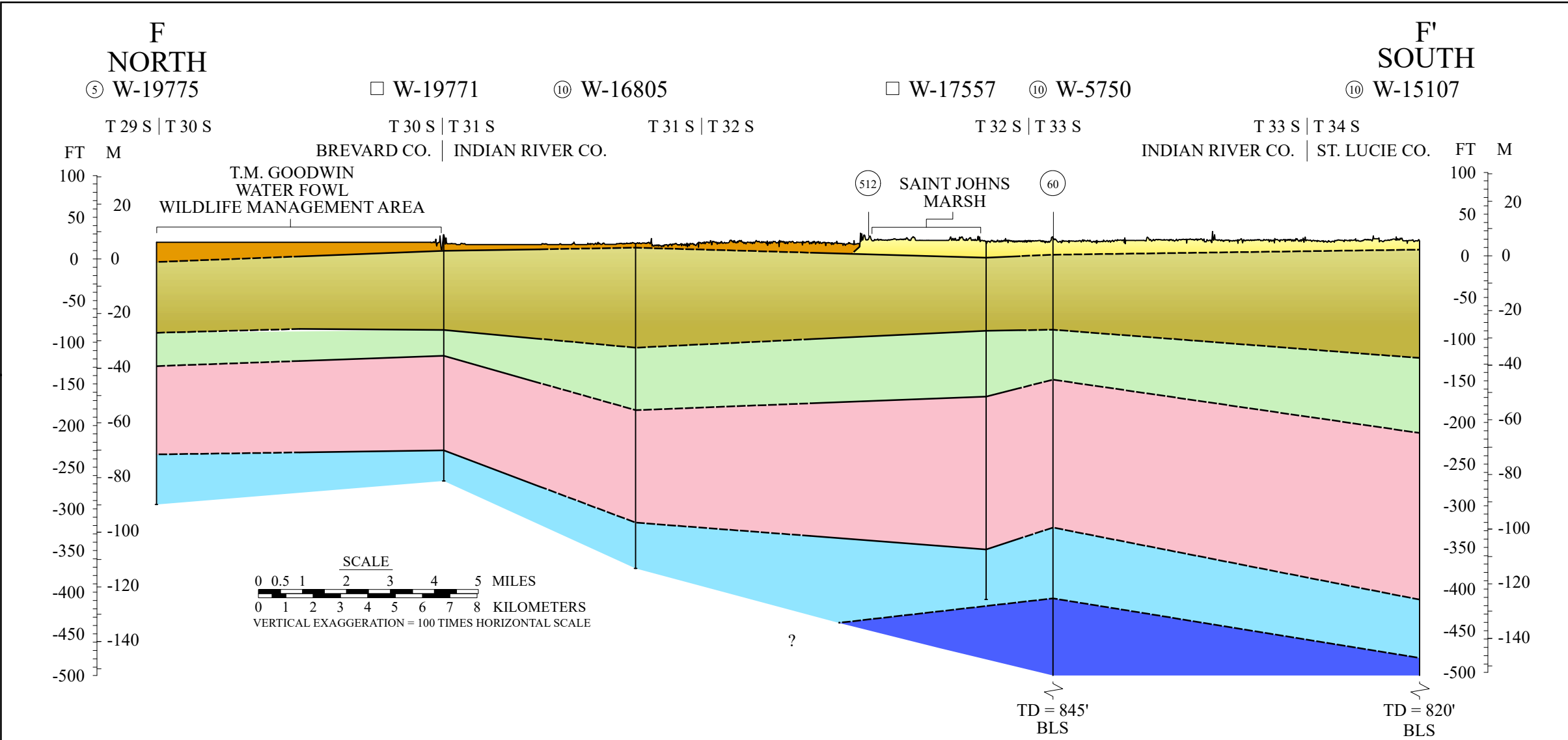
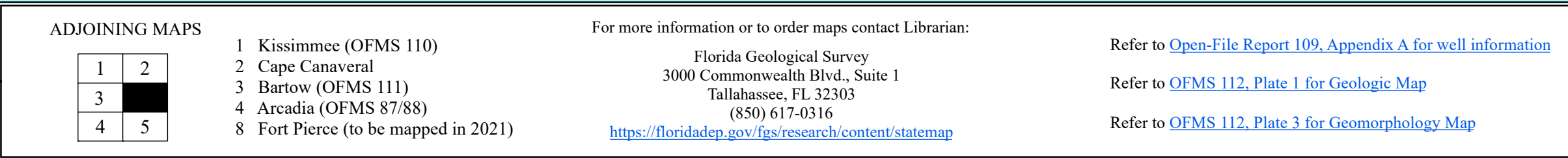
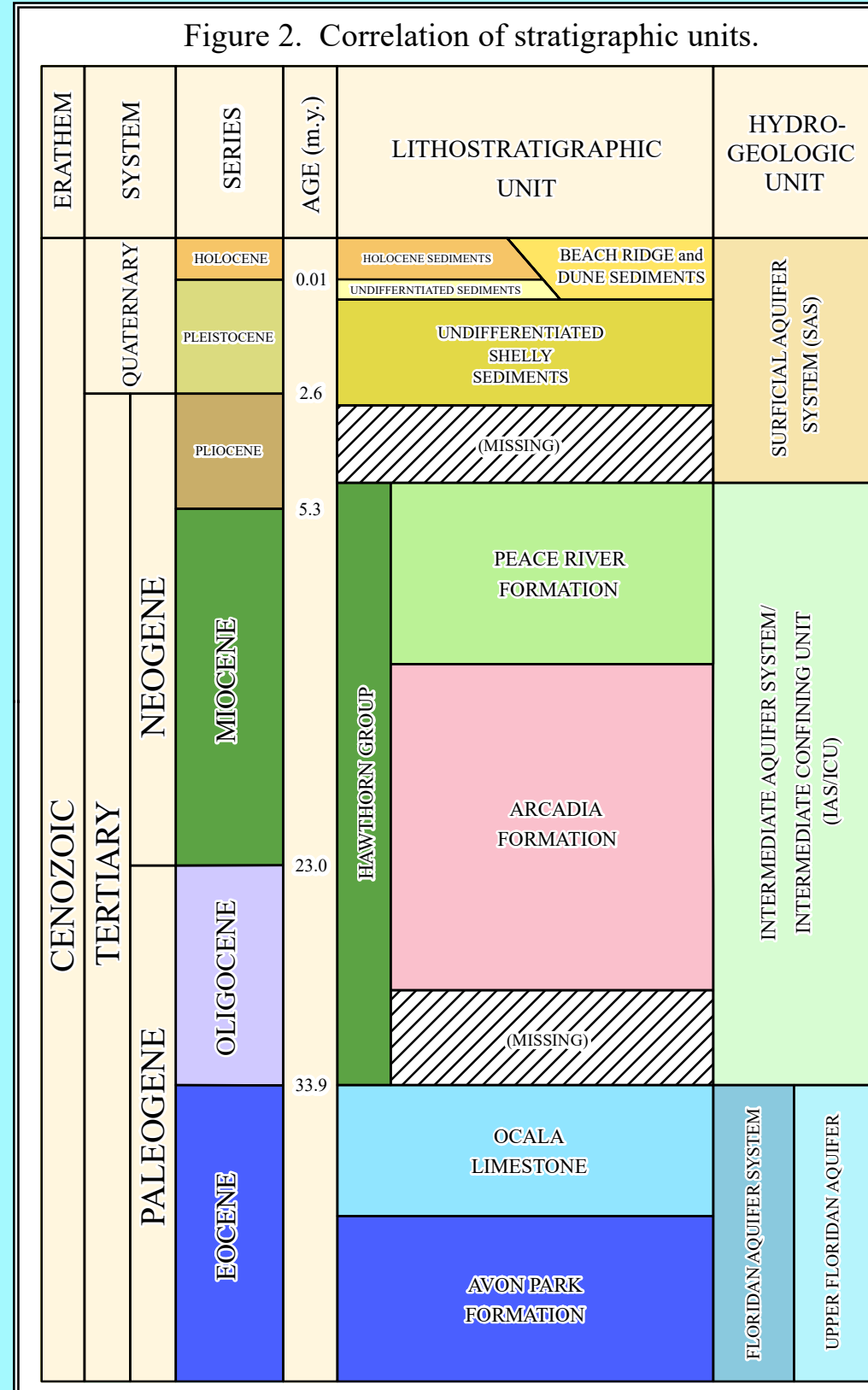
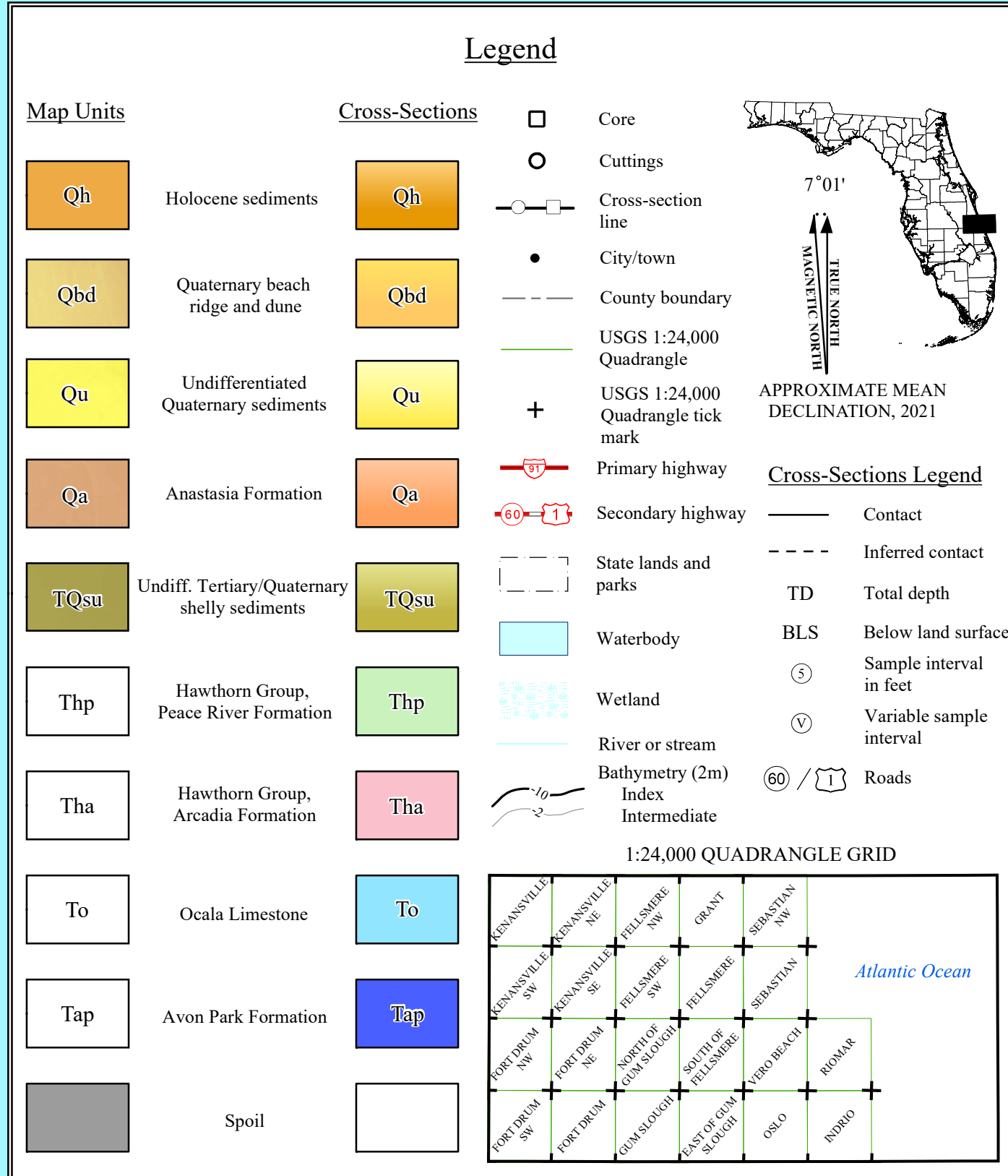
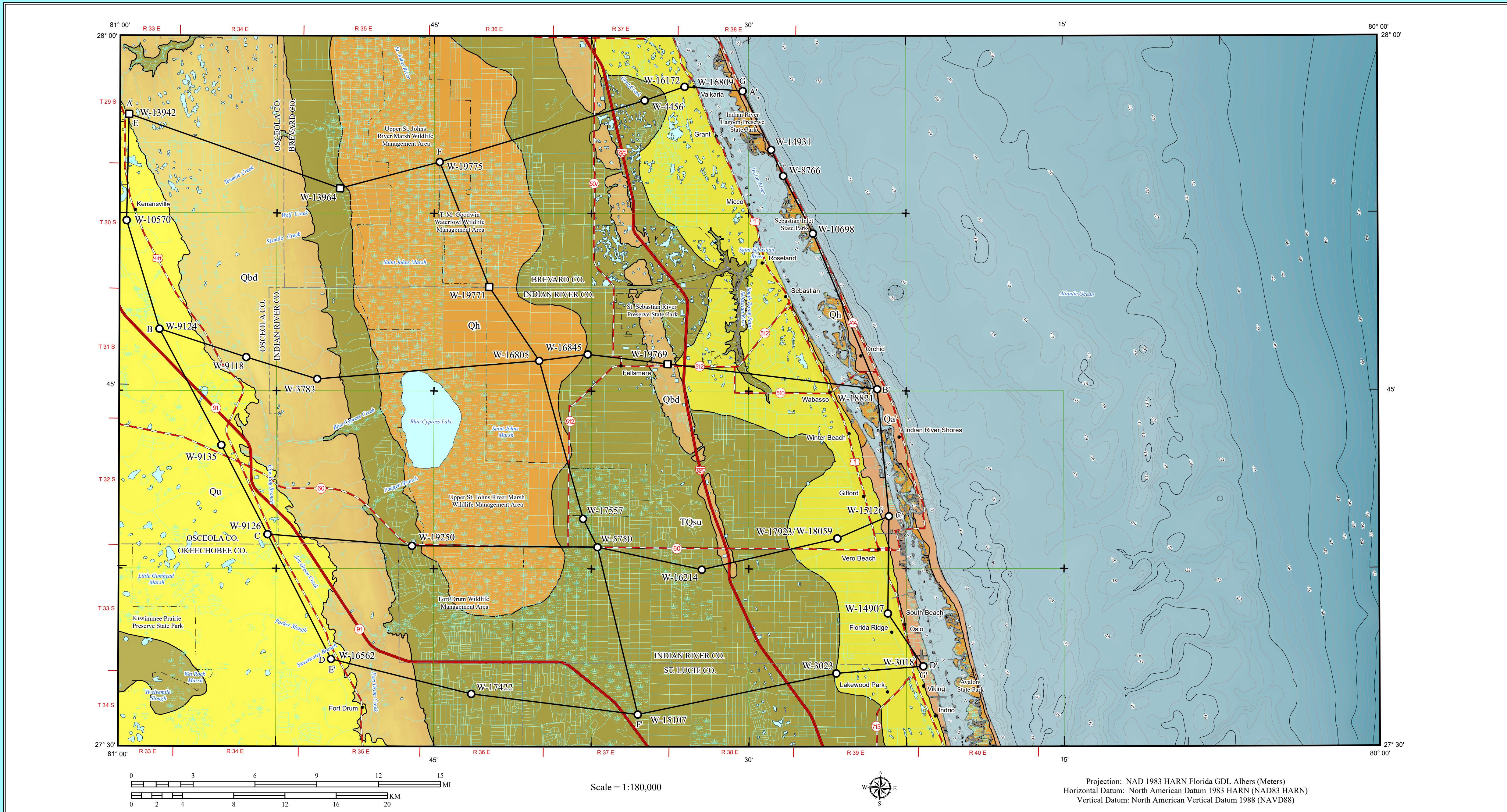
BY
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NOTE: Geologic map and geologic cross-sections may appear to disagree slightly when depicting the upper unit due to the conversion of not penetrating undifferentiated sediments on the geologic map unless they are thicker than 20 feet (6.1 meters), whereas cross-sections will show all undifferentiated sediments thickness. Additionally, cross-section contacts are based on straight-line projection between wells, which can lead to apparent thicknesses between wells on the cross-section that are not supported by field evidence or other wells.



Jonathan D. Arthur
State Geologist and Director



OPEN-FILE MAP SERIES 112, Plate 3
GEOMORPHOLOGY OF THE USGS VERO BEACH
30 X 60 MINUTE QUADRANGLE, CENTRAL FLORIDA

2021
BY
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CRYSTAL L. HEBETS, GARRETT S. EVANS, AND CASEY K. ALBRITTON, P.G.

Barrier Island Sequence District

The Barrier Island Sequence District, the only geomorphic district in the mapped area, occurs along the Atlantic Coast. It extends from Georgia (Clark and Zisa, 1976) into Florida, and south to the vicinity of Lake Okeechobee (Figure 3). Elevations of the district within Florida range from sea level to just over 300 feet (91.4 meters) above mean sea level (MSL). Elevations within the Vero Beach quadrangle portion of the district range from sea level at the Atlantic Coast in the Atlantic Coastal Complex Province, to just over 90 feet (27.4 meters) above MSL in the Ocala Plain Province (Figure 2). The eastern boundary of the Barrier Island Sequence District is along the Atlantic Coast. In Florida, it is bounded to the south by the Everglades District and to the west by the Lakes District and the Okefenokee Basin District (Figure 3). The Barrier Island Sequence District is subdivided within the mapped area into three provinces: the Ocala Plain, the Upper St. Johns River Valley, and the Atlantic Coastal Complex (Figure 4). Pleistocene-Pleistocene and Holocene coastal processes formed extensive barrier islands, beaches, lagoons, embayments, and shallow-water marine terraces in the district. While modern coastal processes are dominantly erosional along the Atlantic coast, with net longshore transport from north to south, there are many older depositional features in the mapped area. Strand plains and shore-parallel dunes represent the preserved depositional features of former shorelines created by beach accretion and/or declining relative sea-levels. The swales between beach ridges are often swampy and contain lakes, wetlands, linear swamps, and tributary streams. The swales control the development of lakes on portions of the Ocala Plain Province and the extensive linear wetlands of the Atlantic Coastal Complex Province. The modern estuarine coastline in the study area are dominated by mangrove swamps. Strand plains are common in the Barrier Island Sequence District. Outstanding examples of strand plains can be seen north of the study area on Merritt Island and Cape Canaveral in the Atlantic Coastal Complex Province and the eastern third of the Ocala Plain Province within the study area. Wetlands are commonly coast-parallel and found in the swales between the ridges of the strand plains and tidal marshes or mangrove swamps landward of the barrier islands. Inland, the broad, relatively flat Ocala Plain Province includes a marine escarpment and strand plain. The southern part of the Barrier Island Sequence District includes several important coastal drainage systems. The St. Sebastian River is the only significant overland stream flowing toward the Atlantic Coast within the study area, but the North and South forks of the St. Lucie River (south of the mapped area) are also important regionally. The Indian River is an estuarine lagoon that receives water from St. Sebastian River, St. Lucie River, and numerous small streams that drain east toward the Atlantic Ocean. The St. Johns River and its tributaries, Fort Drum and Blue Cypress creeks, are the other major streams of the Barrier Island Sequence District in the study area. The St. Johns River valley largely follows low areas in paleo-lagoons and ancient embayments, where the drainage patterns are consistent with the presence of coastal depositional landforms. In the study area, the St. Johns River is mostly within the marshes of the Upper St. Johns River Valley Province. Discrete flow in a distinct river channel is only apparent in the northwestern part of the mapped area. These marshes form the headwaters of the St. Johns River. In the district, much of the river and stream drainage is controlled by the relief ridges forming distinct, swale-induced, drainage patterns. Undifferentiated Tertiary/Quaternary shelly sediments underlie the Barrier Island Sequence District within the study area. The Pleistocene Anastasia Formation, Quaternary beach ridge and dune deposits, undifferentiated Quaternary sediments, and Holocene sediments overlie the Tertiary/Quaternary shelly sediments. The Anastasia Formation occurs at and near the coast and is sporadically exposed along the barrier island coastlines within the mapped area. Holocene sediments exist in river and stream valleys and along the Atlantic Coast (Plate 1). Karst features in the Barrier Island Sequence District are mostly related to dissolution of shell and carbonate beds within the undifferentiated Tertiary/Quaternary shelly sediments and the Anastasia Formation. Undifferentiated Tertiary/Quaternary shelly sediments occur near the land surface in the Upper St. Johns River Valley and Atlantic Coastal Complex provinces within the mapped area. Coquino limestone of the Anastasia Formation is at or near the land surface in coastal parts of the Atlantic Coastal Complex Province (Plates 1 and 2). Shallow karst depressions, including cover-subsidence sinkholes and solution pits, were formed by dissolution of shell and coquina (Schmidt and Scott, 1984). Cover-subsidence sinkholes often form wetlands. In areas where the Anastasia Formation crops out along the Atlantic Coast, microkarst surfaces have developed (Upchurch et al., 2018).

Ocala Plain

The Ocala Plain Province extends from Seminole County in the north to Martin County in the south (Figure 4). It is a subtle, but complex, geomorphic area that includes most of the Kissimmee River valley in the western two-thirds of the province and a strand plain in the eastern third (Green et al., 2019a; Figure 4). This strand plain is well developed from southeastern Seminole and eastern Orange counties into eastern Ocala County. The strand plain ends in westernmost Indian River County and northeastern Okeechobee County (Figure 4). The Ocala Plain Province has the low and flat topography of a marine terrace (White, 1970). The eastern third of the province includes a strand plain that White (1970) associated with the linear sets of lakes, streams, and beach ridges observed in the Geneva Hill Province and the Deland Ridge and Crescent City Ridge of the Lakes District (see Green et al., 2018a; Green et al., 2018b). In the western Ocala Plain Province, the land surface is relatively flat with an undulating surface. This area appears to have been a shallow marine platform. There are significant accumulations of dune and beach sand on the western boundary of the province, continuing onto the eastern flank of the Lake Wales Ridge Complex Province of the Lakes District (Figure 4). Some of the dune fields are well developed and have significant relief. Elevations of the Ocala Plain Province in the study area range from approximately 20 feet (6.1 meters) above MSL, along the ancient marine escarpment at the boundary with the Upper St. Johns River Valley Province (Figure 1), to over 90 feet (27.4 meters) above MSL along the western edge of the mapped area. Drainage in the province includes swale-controlled streams and wetlands associated with the Econlockhatchee River and the many streams that parallel the Atlantic Coast. Several creeks cut across the ridges and flow toward the St. Johns River. The Kissimmee River once meandered through a shallow, wetland valley south to Lake Okeechobee (Figure 4). In the 1960s, the Kissimmee River was channelized for flood control, and the landscape was significantly altered. In the late 1990s, efforts began to restore the natural flow of the river system, including meanders and other fluvial landforms. The headwaters of the Kissimmee River originate in a series of lakes at or near the base of the Lake Wales Ridge Complex Province in the northwestern part of the Ocala Plain Province. The surficial geologic units exposed on the Ocala Plain include undifferentiated Tertiary/Quaternary shelly sediments, undifferentiated Quaternary sediments, and Quaternary beach ridge and dune sediments (Figure 1). Undifferentiated Tertiary/Quaternary shelly sediments underlie the surficial sands in the province throughout the mapped area (Plate 2). Large karst landforms are not common in the Ocala Plain Province. The shallow depressions, sand ponds, and cover-subsidence sinkholes which are present are most likely due to dissolution of shell material in the shallow subsurface within the Tertiary/Quaternary shelly sediments which underlie the majority of the Ocala Plain Province.

Upper St. Johns River Valley

The Upper St. Johns River Valley Province follows a low-elevation drainage system that was an ancient embayment or lagoon between the Atlantic Coastal Complex Province to the east and the strand plain of the eastern Ocala Plain Province to the west (Figure 4). The main leg of the northward-flowing drainage system, the Upper St. Johns River, meanders through the province. The southern part of the province includes the headwaters of the St. Johns River in extensive wetlands and lakes, whereas the northern part of the province includes a distinct channel and several large lakes. The Upper St. Johns River Valley Province includes the fluvial/paludal valley from the headwaters of the St. Johns River, near the St. Lucie-Martin County boundary, northward to the outfall of Lake Monroe between Seminole and Volusia counties. Most of the Upper St. Johns River Valley Province is very flat with riverine floodplains, wetlands, and lakes. The southern part of the province is slightly higher in elevation and lacks the distinct river channel and fluvial landforms that are present in the northern part of the province. Lakes are present along the course of the river in the northern part of the province. There are many distributaries and oxbows, as is typical of a sediment-choked, low gradient stream system. Sediment transport in the system is negligible, but wetland development and the lacustrine/paludal sediments influence the presence of distributaries, lakes, and other landforms. Elevations in the Upper St. Johns River Valley Province in the mapped area range from five feet (1.5 meters) above MSL to about 60 feet (18.3 meters) above MSL. However, elevations above 35 feet (10.7 meters) MSL are generally restricted to the border regions with the Atlantic Coastal Complex Province and the Ocala Plain Province. The eastern boundary with the Atlantic Coastal Complex Province follows the change from coastal ridges to the east, and the wetland and river complex to the west. The boundary of the Upper St. Johns River Valley Province with the Ocala Plain Province is placed at the toe of a marine escarpment where elevations increase on to the Ocala Plain Province to the west. The concept that the province was once an embayment or lagoon is supported by the presence of coastal landforms on the margins of the Atlantic Coastal Ridge Complex Province to the east and the Ocala Plain Province to the west. The Upper St. Johns River Valley Province is a broad area where undifferentiated Tertiary/Quaternary shelly sediments and undifferentiated Quaternary sediments occur at or near the land surface. Holocene sediments overlie these deposits in many of the low, riverine, floodplains, wetlands, and lakes. Anthropogenic alteration of the southern portion of the Upper St. Johns River Valley Province is extensive. Regions that are relatively unaffected by ditching and drainage systems have common, but not abundant, shallow depressions that are cover-subsidence sinkholes. These formed as a result of dissolution of shell material in the underlying Tertiary/Quaternary shelly sediments.

Atlantic Coastal Complex

The Atlantic Coastal Complex Province consists of Quaternary barrier islands and related features on, and inland from, the Atlantic Coast. Water bodies and wetlands landward of the barrier islands include lagoons and small embayments. Within the study area, tidal ridges of the lagoons are dominated by mangrove swamps. The Atlantic Coastal Complex Province extends from the St. Johns River in Duval County to central Palm Beach County. Most of the Atlantic Coastal Complex Province is a Pleistocene strand plain. Many of the beach ridges and dunes in the Atlantic Coastal Complex Province are coast-parallel, although complex beach ridge patterns occur on Cape Canaveral and Merritt Island just north of the study area (Figure 4). In the study area, Holocene sediments of the tidal estuarine coastlines were deposited mostly within mangrove swamps. The ridge and dune topography of the Atlantic Coastal Complex Province gives way to slightly lower elevation and flatter topography along most of its western boundary with the Upper St. Johns River Valley Province within the mapped area. Elevations in the Atlantic Coastal Complex Province for the study area range from sea level along the Atlantic Coast to about 55 feet (16.8 meters) above MSL along the western boundary of the province. Sporadic exposures of the Anastasia Formation from St. Johns County to Palm Beach County create a series of rocky coastlines. Open lagoons and small embayments, located landward of the barrier islands, are locally termed "rivers" because of their historic uses for navigation. Drainage patterns in the Atlantic Coastal Complex Province are swale-dominated and coast-parallel in nature, with streams and wetlands occupying the swales between ridges. Some streams flow toward the Atlantic Ocean through breaks in the beach ridges, such as the St. Sebastian River and the north and south branches of the St. Lucie River, the latter to the south of the study area. Other streams flow toward the St. Johns River, including Fort Drum and Blue Cypress creeks. The surficial stratigraphic units that affect the landforms in the Atlantic Coastal Complex Province include undifferentiated Tertiary/Quaternary shelly sediments, the Pleistocene Anastasia Formation, undifferentiated Quaternary sediments, and Quaternary beach ridge and dune sediments (Scott et al., 2001). Undifferentiated Holocene sediments occur on many of the barrier islands and in the tidal mangrove estuaries. Cover-subsidence sinkholes and sand ponds occur in the Atlantic Coastal Complex Province where the undifferentiated Tertiary/Quaternary shelly sediments and the Pleistocene Anastasia Formation are at or near the land surface. Dissolution features can be seen where the Anastasia Formation is exposed along the modern coast and in the undifferentiated Tertiary/Quaternary shelly sediments exposed in mines and borrow pits.

*Note: See Open-File Report 109 for references

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Figure 1. Geomorphic provinces (modified from Williams et al., in preparation) with LiDAR and digital elevation model (DEM) mosaic.

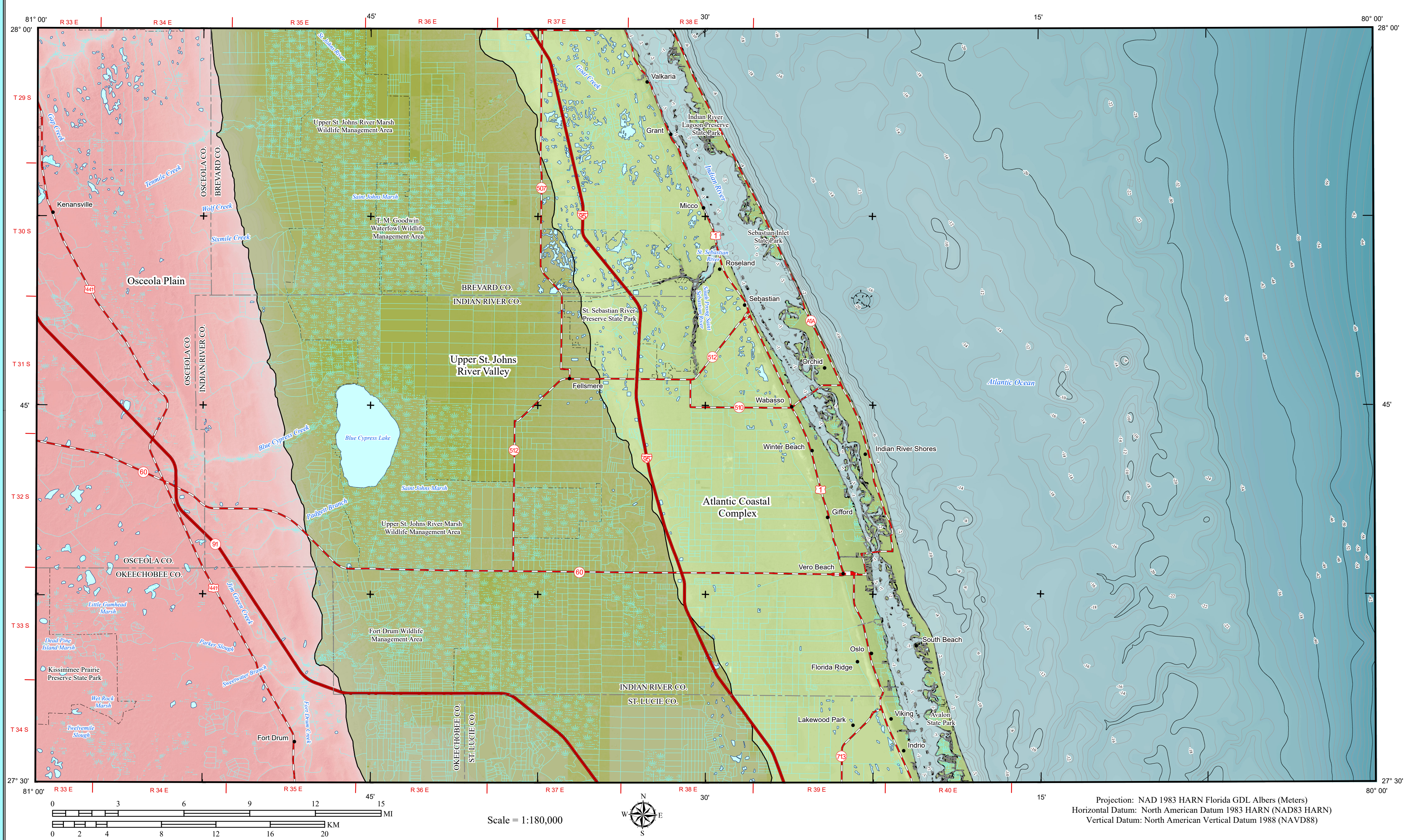


Figure 2. LiDAR and digital elevation model (DEM) mosaic.

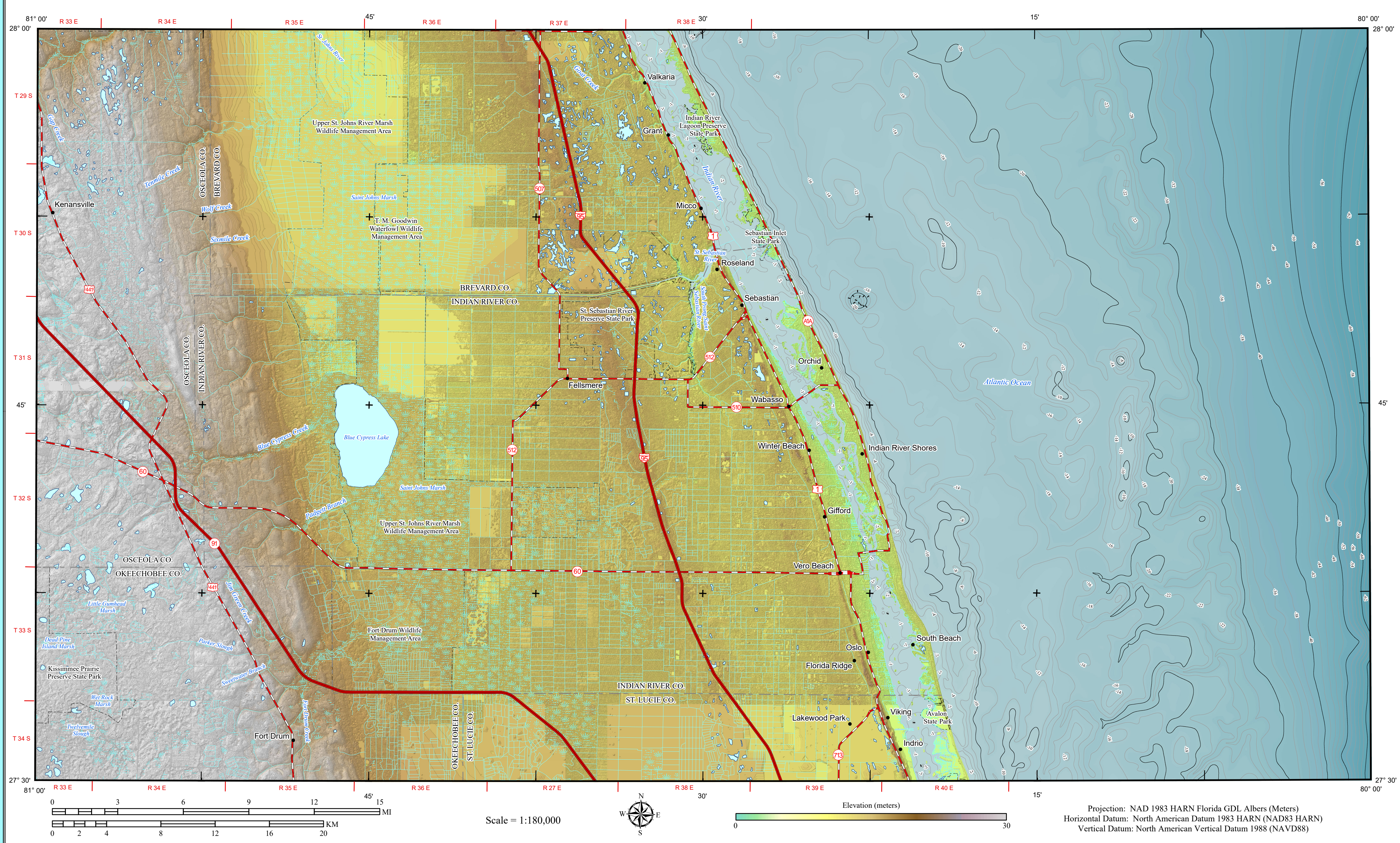


Figure 3. Geomorphic districts (modified from Williams et al., in preparation).

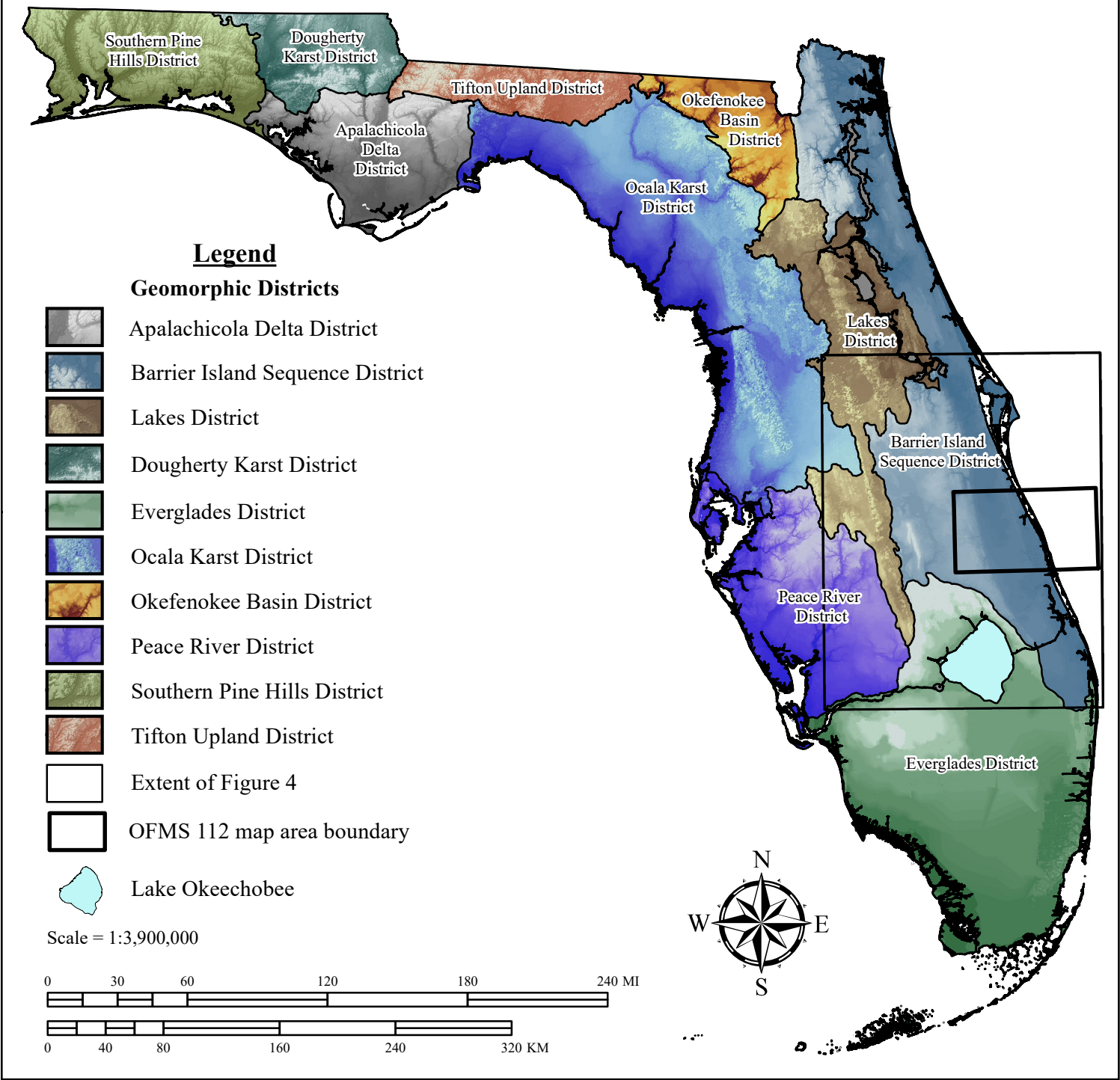
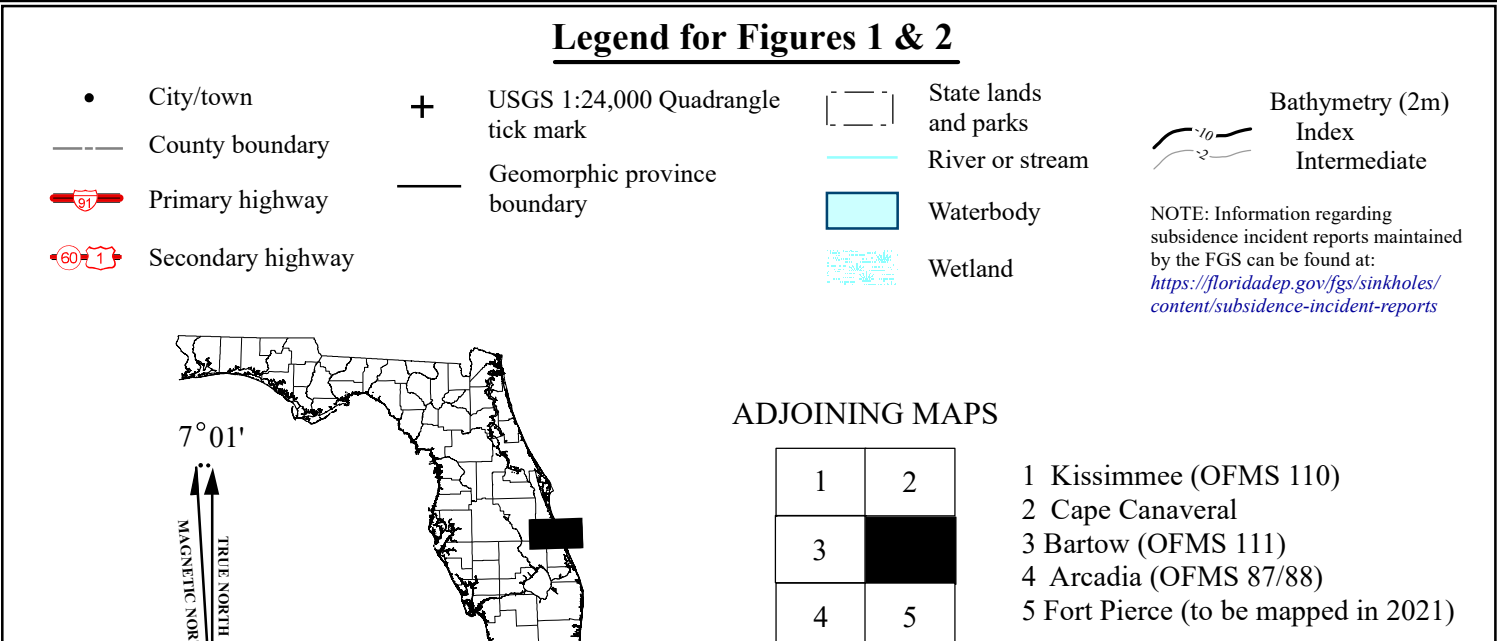
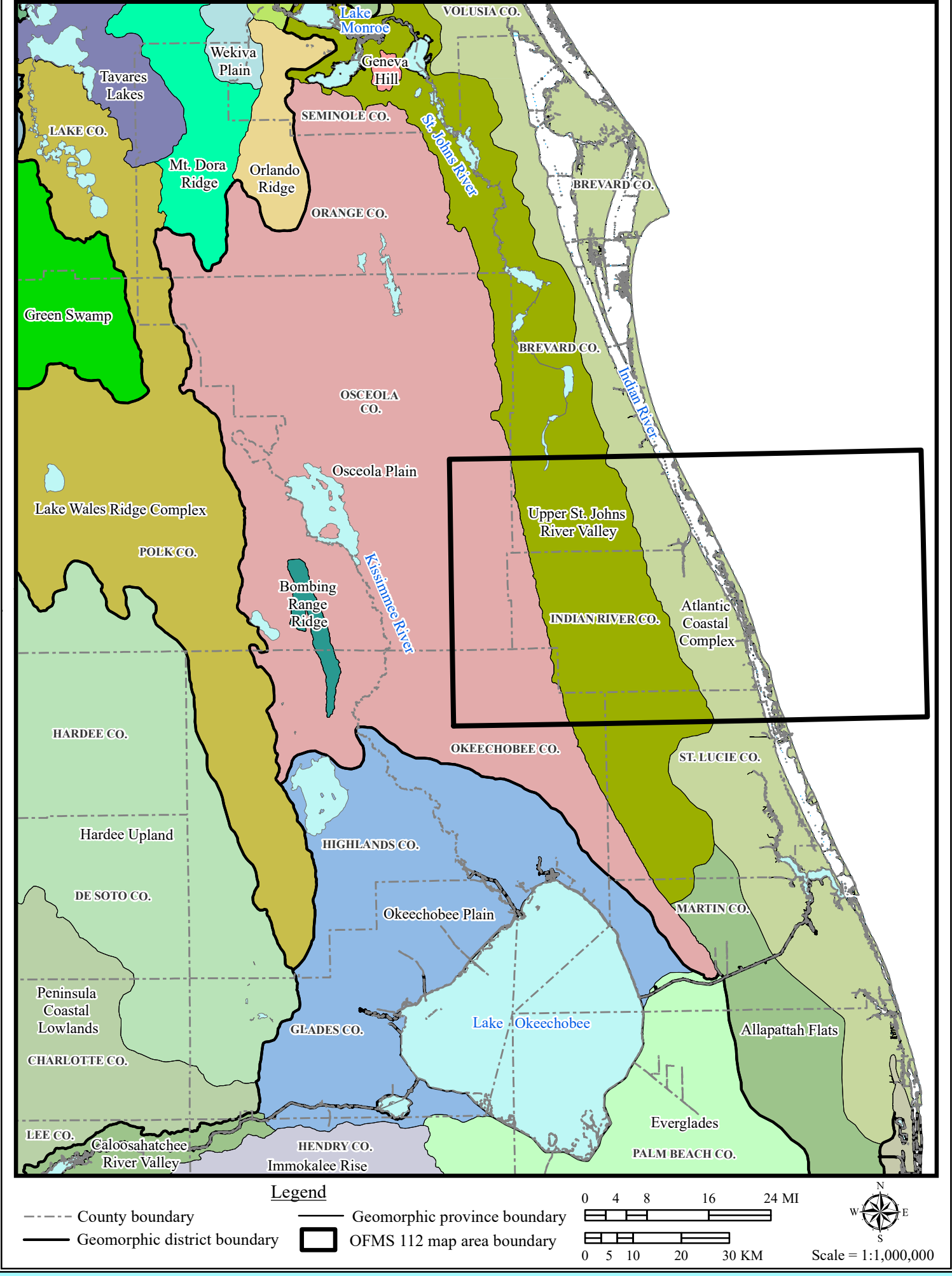


Figure 4. Geomorphic provinces (modified from Williams et al., in preparation).



STATE OF FLORIDA

FLORIDA GEOLOGICAL SURVEY

Jonathan D. Arthur, *State Geologist and Director*



OPEN-FILE REPORT 109

**Text to accompany geologic map of the
USGS Vero Beach 30 x 60 minute quadrangle, central Florida**

By

Richard C. Green, (P.G. # 1776), Alexander G. Lamarche, Christopher P. Williams, Crystal L. Hebets, Garrett S. Evans, and Casey K. Albritton

2021

ISSN (1058-1391)

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Text to accompany geologic map of the USGS Vero Beach 30 x 60 minute quadrangle, central Florida

Richard C. Green, (P.G. # 1776), Alexander G. Lamarche, Christopher P. Williams, Crystal L. Hebets, Garrett S. Evans, and Casey K. Albritton

ABSTRACT

The accompanying 1:100,000 scale geologic map (Open-File Map Series 112, Plate 1) depicts the areal distribution of bedrock and surficial geologic units for the U.S. Geological Survey (USGS) Vero Beach 30 x 60 minute quadrangle. The map was constructed using a combination of field mapping (at 1:24,000 scale), compilation of data from existing maps (various scales), core and cuttings analyses and descriptions, and analyses of various Geographic Information System (GIS) data sources. The resulting data were compiled in ESRI® ArcGIS® ArcMap™ 10.6.1 software for publication as part of the Florida Geological Survey Open-File Map Series. Mapped geologic units range in age from Pliocene to Holocene. Important resources in the mapped area include potable groundwater, sand, fossil shells, and limestone.

The geologic map and accompanying plates produced for this area not only provide a greater understanding of the interaction between the geologic units, associated karst, and ecosystems, but have utility as a land management tool for economic development, mineral and energy production, and environmental protection for Florida. Examples include designing new construction projects, siting new water supply wells, wastewater treatment plants, energy production facilities, waste management and storage facilities, locating sources of mineable resources, and protecting surface and groundwater quality.

Keywords: Florida, geologic map, Avon Park Formation, Ocala Limestone, Suwannee Limestone, Hawthorn Group, Arcadia Formation, Peace River Formation, undifferentiated Tertiary/Quaternary shelly sediments, Anastasia Formation, geomorphology, hydrogeology, Floridan aquifer system, Brevard County, Indian River County, Okeechobee County, Osceola County, St. Lucie County, Vero Beach.

INTRODUCTION

Florida Geological Survey (FGS) Open-File Report (OFR) 109 accompanies Open-File Map Series (OFMS) 112, which is comprised of three plates. Plate 1 depicts the near-surface geology of the USGS Vero Beach 30 x 60 minute quadrangle overlain on a digital elevation model (DEM). Plate 2 depicts seven geologic cross-sections, a stratigraphic correlation chart, and an index geologic map with cross-section lines for the study area. Plate 3 depicts a geomorphology map, along with a DEM.

The study area is in east-central Florida (Figure 1) covering portions of Brevard, Indian River, Okeechobee, Osceola, and St. Lucie counties. It includes the communities of Vero Beach, Sebastian, Fellsmere, and Roseland. The quadrangle is bounded to the northwest by the USGS Kissimmee 30 x 60 minute quadrangle, (Green et al., 2018a; Green et al., 2018b), to the west by the USGS Bartow 30 x 60 minute quadrangle (Green et al., 2019a; Green et al., 2019b), and to the southwest by the USGS Arcadia 30 x 60 minute quadrangle (Green et al., 1998; Green et al., 1999), all previously mapped under the STATEMAP program. It is bounded to the south by the USGS Fort Pierce quadrangle (mapping in progress in 2021-2022 under STATEMAP grant

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G20AC00368) and to the north by the Cape Canaveral quadrangle (proposed for 2022-2023 mapping).

One objective of this report is to provide basic geologic information for the accompanying OFMS 112. Information provided by this report and the plates in OFMS 112 is intended for a diverse audience of professionals in geology, hydrology, engineering, environmental and urban planning, and laypersons, all of whom have varying levels of geologic knowledge. The maps can help users identify and interpret geologic features which impact activities related to groundwater quality and quantity, as well as aid in locating mineral resources, land-use planning, and construction project design. Applied uses of the maps and data in this report include: 1) identifying potential new mineral resources, 2) characterizing zones of geologic hazards, 3) characterizing potential aquifer recharge, discharge, and confinement, 4) surface water, groundwater, and fate and transport modeling, 5) aiding water-management decisions on groundwater usage, 6) providing information on aquifer vulnerability to potential pollution, 7) characterizing ecosystems and wetlands, and 8) doing recreational activities.

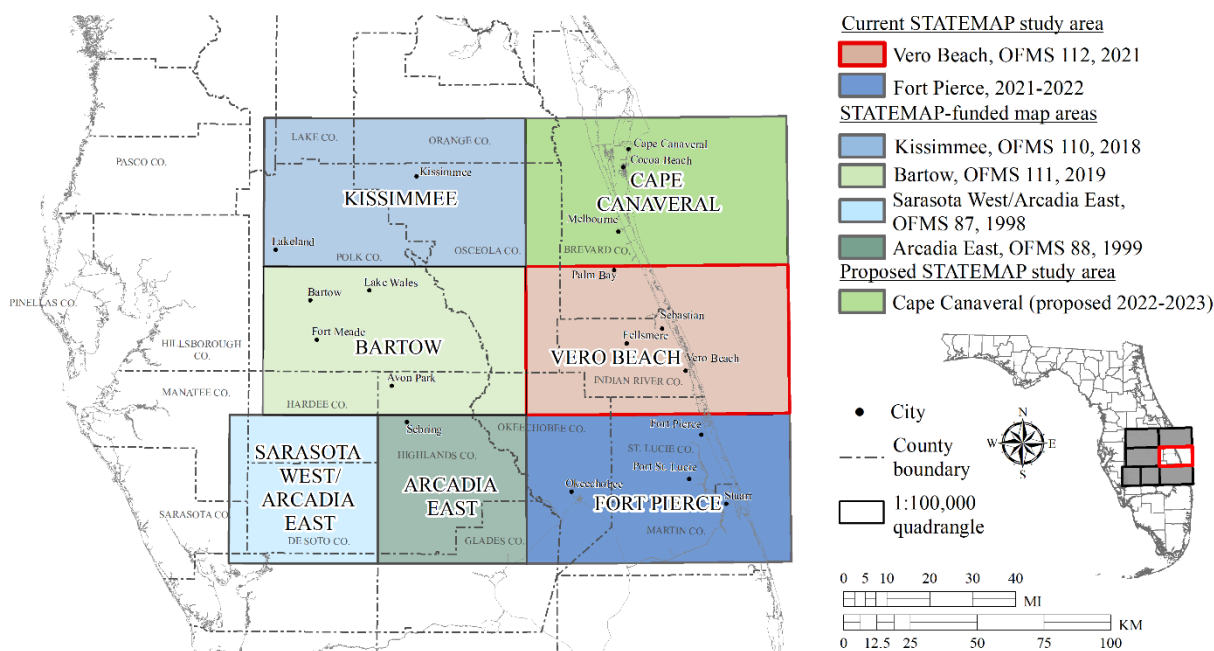


Figure 1. Nearby areas mapped under the FGS STATEMAP Program.

Methods

Mapping efforts consisted of: 1) reviewing and compiling existing geologic literature and data, 2) mapping geologic units in the field at 1:24,000 scale using standard techniques, 3) analyzing existing core and cuttings samples from the FGS sample repository, 4) drilling new cores, 5) collecting and describing outcrop samples, and 6) preparing a geologic map, geological cross-sections, and a geomorphic map of the area. Field work, performed during the fall of 2019 through the spring of 2021, consisted of sampling and describing numerous outcrops, as well as samples from river and pit exposures.

Eleven new geologic samples were added to the FGS surface-sample archives (M-Series) and two cores (565.8 feet [172.5 meters] total) were drilled. Approximately 45 outcrops were also examined during this project. In addition to the new M-series samples collected, 54 historical M-

series samples were examined. All data, including over 230 wells from the study area and a five-mile (8.0 kilometer) buffer from surrounding quadrangles, were compiled and analyzed by the authors. Figure 2 shows the locations of FGS cores, cuttings, outcrops, and M-series samples within the study area. The map and accompanying plates were developed in ESRI® ArcGIS® ArcMap™ 10.6.1 software for publication as part of OFMS 112.

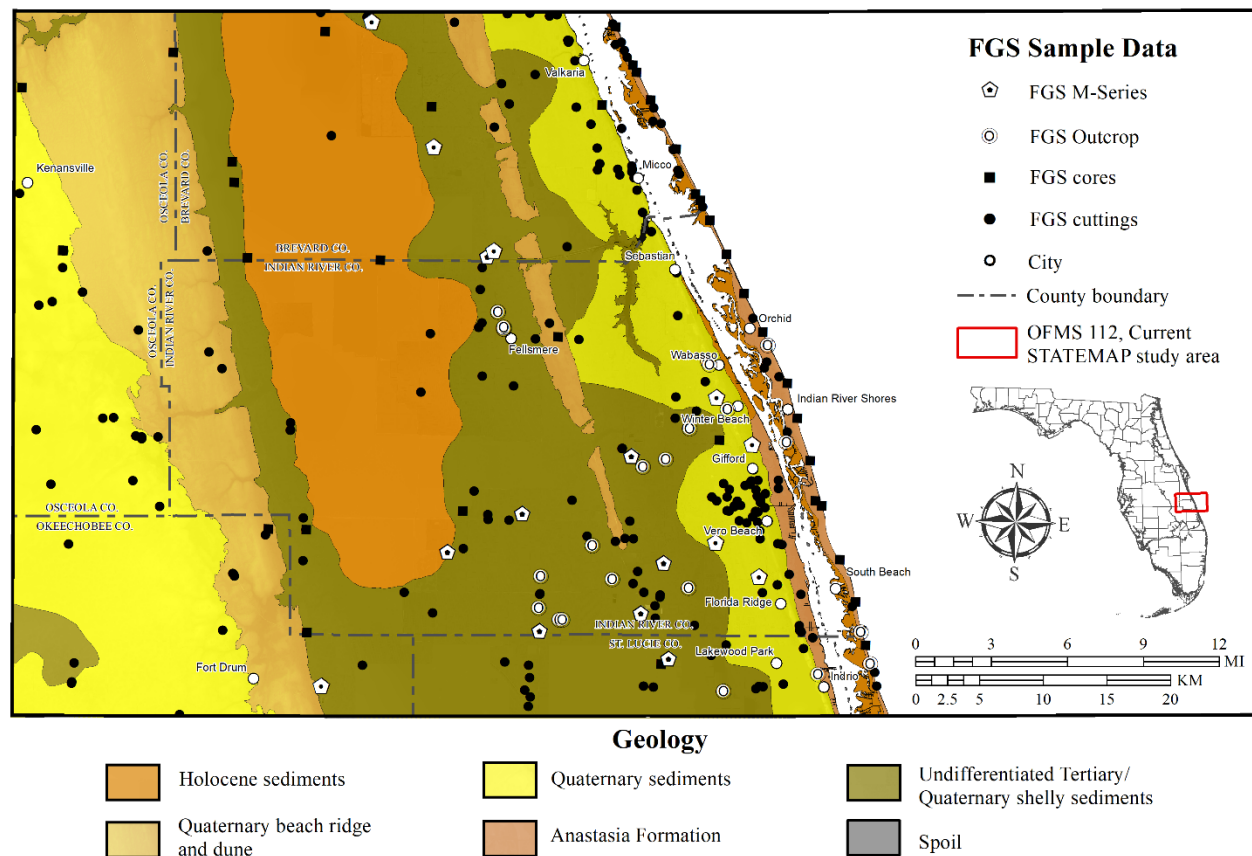


Figure 2. FGS cores, cuttings, outcrops, and M-series samples used for models.

Due to incomplete light detection and ranging (LiDAR) data, a custom elevation model was created for this study area. Six datasets were used to create this elevation model: standard LiDAR elevation models comprised of four different collection years and quality levels with horizontal resolutions ranging from one foot (0.3 meters) to 15 feet (4.5 meters), and two elevation models based on topographic contours with a horizontal resolution of 16 feet (4.9 meters) to 32 feet (9.2 meters). Vertical resolution was between one foot (0.3 meters) and five feet (1.5 meters). LiDAR data was obtained for the entirety of Osceola and St. Lucie counties. It was available for a majority of Indian River, Okeechobee, and Brevard counties; the missing areas were filled in using the contour-based DEM.

The hybrid elevation model was created by first combining all the existing LiDAR elevation models into a single raster (a matrix of cells [pixels] organized into a grid where each cell [pixel] contains a value representing an elevation). The lower-resolution, contour-based DEM was re-sampled and aligned to match the higher-resolution LiDAR elevation models. A conditional statement was then used in ArcGIS to create a new hybrid raster by selecting an elevation value

from the LiDAR grid, if available. Where LiDAR was not available, elevation values were drawn from the lower-resolution, contour-based DEM.

Top-of-unit rasters were created for several geologic units within the study area using the borehole descriptions completed during this study. In order to produce interpolated top-of-unit rasters, the borehole depth for the top of each unit was first converted from depths below land surface into elevations referenced to mean sea-level. This conversion was performed by taking the elevation value of the well point from the digital elevation model raster and subtracting the depth value, resulting in the mean sea-level elevation for the top-of-unit raster.

The mean sea-level elevation data for each geologic unit was used to create a Natural Neighbor (NN) interpolation of the top-of-unit surface, overburden, and isopachs. The NN method of interpolation is a simple and exact interpolation method that relies on Voronoi tessellation (a partitioning of a plane into regions based on distances to points) to select a local subset of points and determine a weighted influence at every raster grid cell. This method produces a surface that passes through every data point in the input data set and thus does not attempt to account for errors or outliers. The NN method is particularly useful for visualizing the ‘raw’ data for problematic areas and extreme outliers prior to building and optimizing the final model.

After examining the initial models created for units, it was evident that some of the predictive errors in the first model were directly attributable to either low data density, local outliers in the borehole data, or both. Outliers are a common occurrence in Florida geologic data for a variety of reasons, both human and natural, including: 1) Hawthorn Group units can be difficult to distinguish even for a trained professional geologist, and therefore some degree of uncertainty may exist in locating contacts, 2) Many of the borehole samples are based on cuttings taken at intervals of 10 feet (3.1 meters), which introduces uncertainty in the elevation of the contacts even when the contact is clearly evident and 3) Karst presence in carbonate units can produce significantly different unit elevations in boreholes that are a short distance apart.

In cases where the accuracy metrics of the modeled surfaces indicated large amounts of error due to outliers, an iterative modeling process was used to reduce the average standard error of the interpolated surface and the least-accurate boreholes were removed from the dataset via cross-validation to improve predictive accuracy. After the removal of outlier data points (generally fewer than ten boreholes per unit), a new interpolated surface was generated.

Figure 3 is a boxplot used to illustrate the distribution and range of elevation values, relative to mean sea level (MSL), for each mapped unit found within the study area. The crossbar within the box represents the median elevation value for each geologic unit. The upper and lower borders of each box correspond to the 25th and 75th percentiles, or the first and third quartiles, respectively; this area is also called the interquartile range and represents the middle 50% of the values in each group. The whiskers that extend from each boxplot reach no further than 150% of the interquartile range. Data that fall beyond the whiskers are considered outlier points and are represented by a dot.

Once the top-of-unit models were completed, they were exported to floating-point rasters whose cell size and borders were snapped to the hybrid digital elevation model. These interpolated surfaces were then subtracted from the elevation model to produce a raster showing overburden depth between each unit and land surface. The overburden rasters were then used to assist in drawing the final surficial geologic map for the study area.

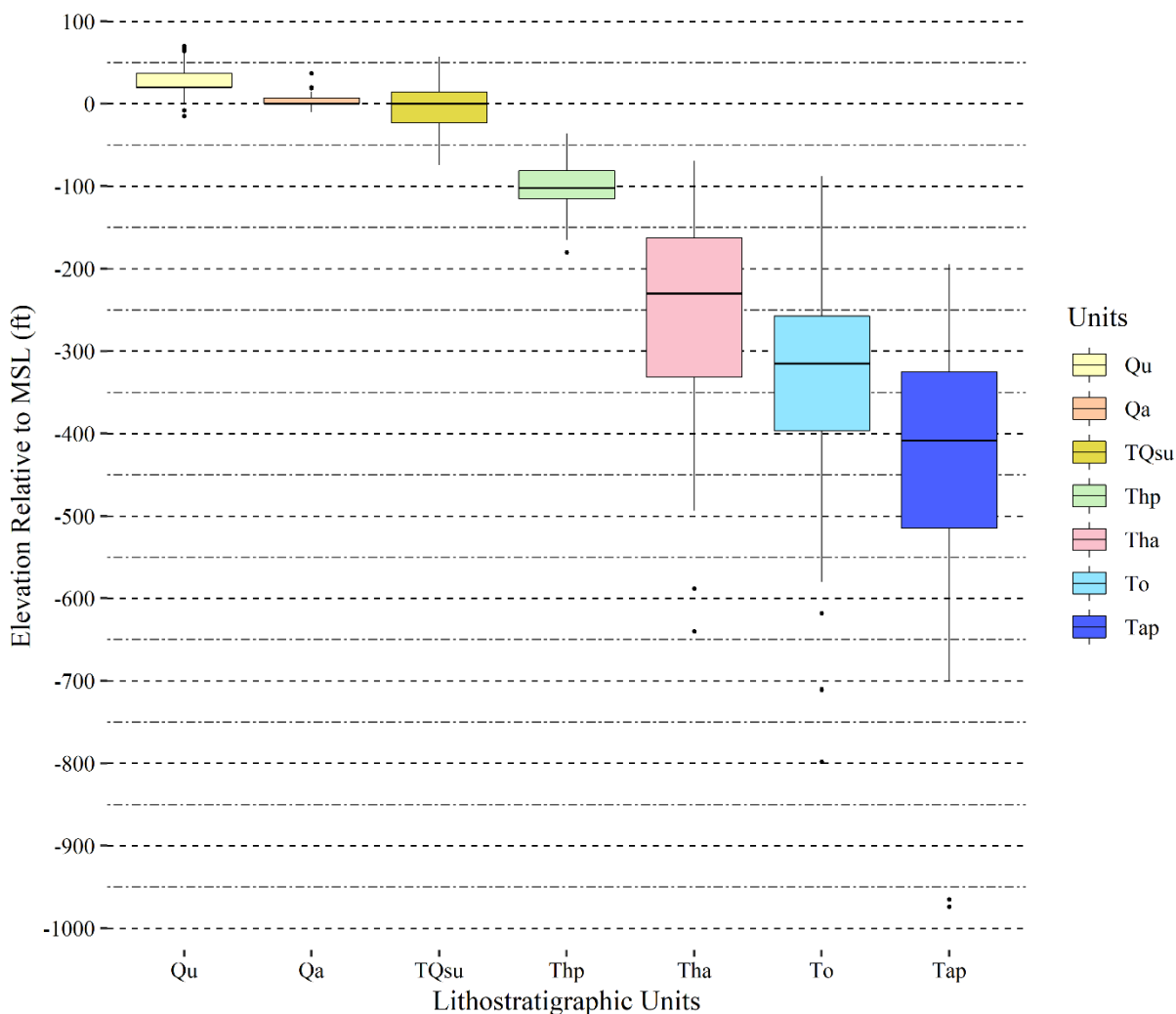


Figure 3. Boxplot of top of lithostratigraphic unit elevation ranges.

Much of the study area is blanketed by a veneer of undifferentiated Quaternary sediments. For this reason, and in keeping with geologic mapping practices developed by Scott et al. (2001), the authors have adopted the procedure of mapping the first named geologic unit within 20 feet (6.1 meters) of the surface. If undifferentiated Quaternary (Qu) sediments have a thickness greater than 20 feet (6.1 meters), they appear as the mapped unit. If these undifferentiated sediments are less than 20 feet (6.1 meters) thick, the underlying lithostratigraphic unit appears on the map. The geologic map (OFMS 112, Plate 1) and the geologic cross-sections (OFMS 112, Plate 2) may appear to disagree slightly when depicting the upper unit due to this convention. This is because geologic cross-section contacts are based on straight-line projection between wells, which may lead to apparent unit thicknesses between wells not supported by field evidence or other nearby wells.

Parts of the region are heavily vegetated, and public access in portions of the mapped area was hindered by the presence of numerous wetlands, mines, farms, ranches, and privately-owned land. Fieldwork access was typically limited to public roads, State-owned lands, and County-

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owned lands. As such, large sections of the mapped area were inaccessible. In these areas, the authors had to rely on historic core, cuttings, outcrop, and M-Series sample data.

Previous Work

The current study builds on many previous geologic investigations in and around the present map area. Preliminary county geologic maps for Brevard (Scott, 1993a), Indian River (Scott, 1993b), Okeechobee (Scott, 1993c), Osceola (Scott, 1993d), and St. Lucie (Duncan and Scott, 1993) counties were previously published at a 1:126,720 scale by the FGS. However, each of these OFMS geologic maps were constructed in an average time-frame of two weeks utilizing selected in-house geologic data with little-to-no extra field work. A statewide geologic map (Scott et al., 2001), published by the FGS, provided a framework for the current, more detailed mapping. Although these maps provided a starting point for the detailed geologic mapping undertaken for this project, significant refinement of prior geologic maps was possible because of this additional field work and data.

Scott (1988) published detailed descriptions, structure contour maps, and isopach maps for units of the Hawthorn Group. Brewster-Wingard et al. (1997) published lithostratigraphic, biostratigraphic, chronostratigraphic, and petrographic analysis work on the Oligocene deposits of southern peninsular Florida. This study also benefited from the work performed during geologic mapping of the USGS Bartow (Green et al., 2019a; Green et al., 2019b), Kissimmee (Green et al., 2018a; Green et al., 2018b), and Sarasota and Arcadia 30 x 60 minute quadrangles (Green et al., 1997; Green et al., 1998; Green et al., 1999). Some of the field relationships and stratigraphic problems were worked out during those projects.

GEOLOGIC SUMMARY

The near-surface geology of the USGS 30 x 60 minute Vero Beach quadrangle is composed of a complex mixture of Tertiary to Quaternary carbonate and siliciclastic sediments. A combination of factors, including fluvio-deltaic deposition, marine deposition and erosion of sediments as a result of eustatic changes in sea level, dissolution of underlying carbonates (karstification), and structural features have influenced the geology of the study area.

The oldest unit to crop out in the Vero Beach quadrangle is the undifferentiated Tertiary/Quaternary shelly sediments. The unit crops out at various locations and can be seen in numerous pits and quarries along the central and eastern parts of the map area (OFMS 112, Plate 1). The undifferentiated Tertiary/Quaternary shelly sediments overlie the Peace River Formation throughout the mapped area (OFMS 112, Plate 2). The oldest unit investigated for geologic cross-sections is the middle Eocene Avon Park Formation (OFMS 112, Plate 2).

Detailed descriptions of the lithology of all units found in the study area begin on page 14 of this publication. Along with lithologic criteria, several diagnostic foraminifera and echinoids aid in distinguishing the Ocala Limestone from the Avon Park Formation, which unconformably underlies the Ocala Limestone. The Avon Park Formation contains *Fallotella* sp. which is infrequently found at the base of the Ocala Limestone (personal communication, Jonathan Bryan), as well as *Discorinopsis gunteri*, which is not found in the Ocala Limestone. The occurrence of *Nummulites* spp. and *Lepidocyclina ocalana* in the Ocala Limestone helps to distinguish it from the Avon Park Formation in the study area.

The Vero Beach quadrangle encompasses portions of the Indian, Kissimmee, and Upper St. Johns river basins as well as the Florida Southeast Coast basin (Figure 4; Hydrologic Unit

Codes: Basins, 1993). It is noteworthy that some of these basin boundaries are based on political boundaries and not simply groundwater divides. There are no known springs within the study area.

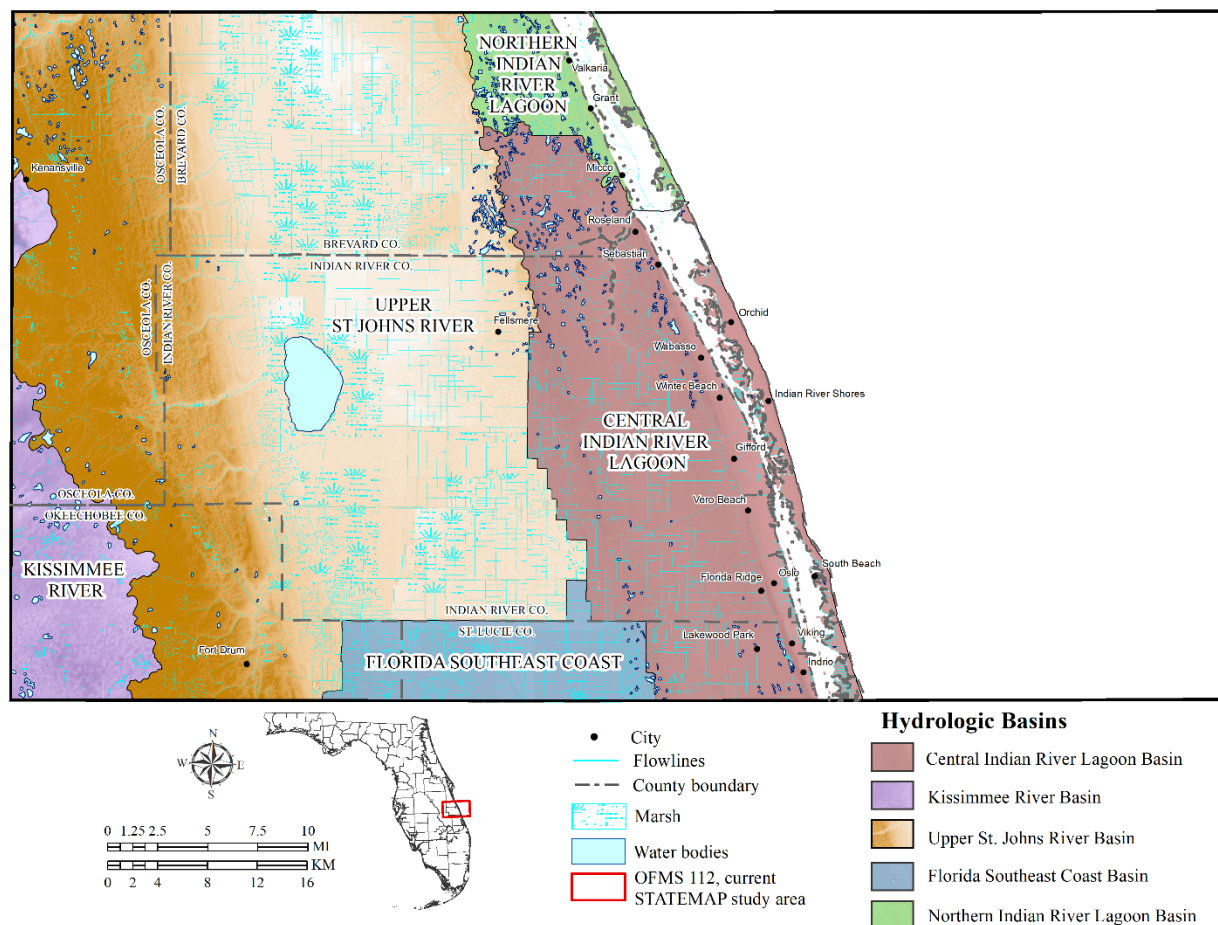


Figure 4. Location of selected river basins and other water bodies.

Karst features are not common in the study area. Shallow cover-subsidence features present in this area are likely related to dissolution of shells in the underlying undifferentiated Tertiary/Quaternary shelly sediments. Karst features, however, can be found in the central and eastern part of the study area.

Structure

Several structural features have affected the geology of the region (Figure 5). The Peninsular Arch, a structurally high area which affected deposition from the Cretaceous to the early Cenozoic, is the dominant subsurface feature of the Florida peninsula (Applin and Applin, 1944; Applin, 1951; Puri and Vernon, 1964; Williams et al., 1977; Schmidt, 1984; Miller, 1986; Scott, 1997). The axis of the Peninsular Arch, which cuts through the western portion of the study area, extends from southeastern Georgia to the vicinity of Lake Okeechobee in southern Florida in a general northwest to southeast trend. The crest of the arch passes beneath Alachua County and is highest in Union and Baker counties northwest of the study area. The arch was a topographic

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high during most of the Cretaceous Period and has Upper Cretaceous sediments deposited upon it (Applin, 1951). It formed a relatively stable base for Eocene carbonate deposition (Williams et al., 1977; Hine, 2013). The arch did not affect mid-Tertiary to Holocene sediment deposition (Williams et al., 1977; Scott, 1997; Hine, 2013).

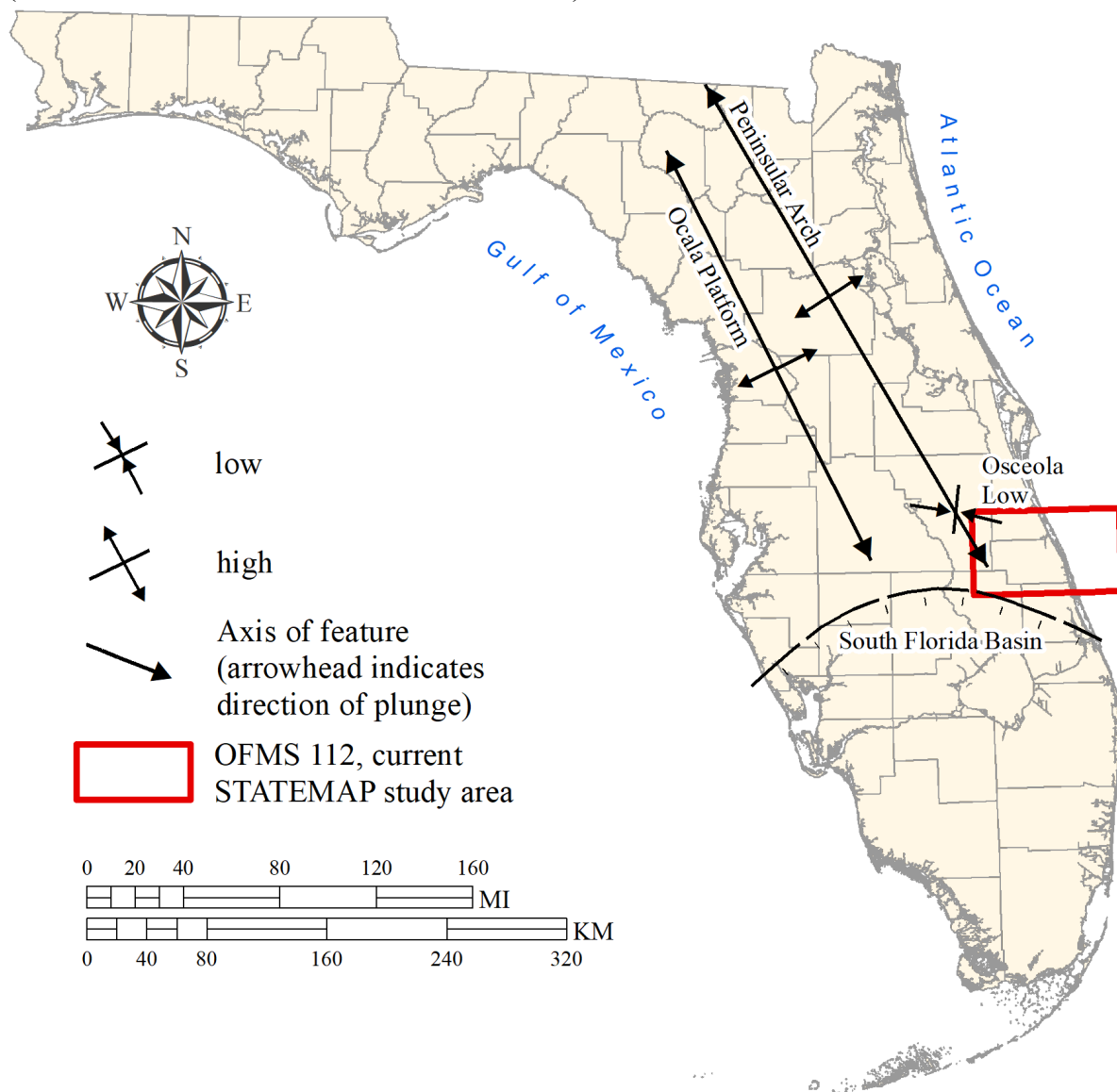


Figure 5. Principal subsurface structures of the Florida peninsula (modified from Scott, 1988).

The Ocala Platform is another prominent feature affecting the near-surface units within peninsular Florida. Hopkins (1920) originally named this feature the Ocala Uplift. Vernon (1951) described the Ocala Uplift as a gentle flexure developed in Tertiary sediments with a northwest-southeast trending crest. Because there is continuing uncertainty about the origin of this feature, Scott (1988) used the term Ocala Platform, rather than Ocala Uplift, or Ocala Arch, since it does not have a structural connotation. Although the Ocala Platform does not come into the mapped area, discussion of it is included because of its effects on the regional geology of several map units.

In addition to the Peninsular Arch, the Vero Beach quadrangle contains a portion of the Osceola Low (Figure 5), named by Vernon (1951). This feature, which occurs near the southern extents of the Peninsular Arch (Applin, 1951) and Ocala Platform, was described by Vernon (1951) to be the northwest boundary of a downfaulted triangular block with as much as 300 feet of displacement in the Ocala Limestone in Osceola County.

The South Florida Basin (Applin and Applin, 1965; Winston, 1971) is a stratigraphic basin which contributed to the southward thickening and deepening of Mesozoic and early Cenozoic lithostratigraphic units in the southern Florida peninsula. This is evident in several of the cross-sections (OFMS 112, Plate 2).

Several authors (Bermes, 1958; Lichtler, 1960; and Vernon, 1970) have discussed possible faulting along the eastern edge of the mapped area in reference to thickening and deepening of the Cenozoic units toward the Atlantic Coast. These authors relied on a few widely spaced wells with little in the way of marker beds to invoke these faults. Mooney et al. (1980) indicated that no hard evidence was found for proposed faults in the area and mentioned that an erosional surface at the top of an “unnamed calcilutite” found overlying the Ocala Limestone in the area might represent an Oligocene unconformity. See discussion below on the Suwannee Limestone for more discussion of this “unnamed calcilutite”. For a summary of these proposed faults, the reader is referred to Mooney et al. (1980).

While the results of this study confirm that the units thicken and deepen toward the east (see OFMS 112, Plate 2, cross-sections B-B', C-C', and D-D'), the authors of this study do not believe that there is enough evidence to attribute this to faulting. The gradient for these units in the vicinity of these proposed faults is approximately 50 feet per mile (9.5 meters per kilometer), or approximately one degree of dip. Given the unconformable nature of the contacts between these units, and their proximity to the Atlantic Coast, it is more likely that the offset and thickening of these units are related to erosion rather than faulting. Brewster-Wingard et al. (1997) discussed scouring and sediment removal as the result of the paleo-Gulf Stream during transgressions and sea-level high stands as a potential source for these changes in thickness and depths of the units. An extensive study was commissioned for siting of a nuclear power plant in St. Lucie, Florida (Florida Power and Light, 1981), which included several deep borings (700 feet [213.4 meters]), seismic lines, and geophysical studies. The study concluded that these elevation differences were due to monoclinical flexures and undulations in the underlying strata, and that these were not faults.

Geomorphology

The Florida Geological Survey is producing a new statewide geomorphic atlas of Florida (Williams et al., in preparation). The map will synthesize over a century of geomorphic writings and maps about Florida, along with the addition of new data and new interpretations of the geomorphology. *The Geomorphology of the Florida Peninsula* (White, 1970), in addition to work by former FGS colleague, Thomas M. Scott, is central to the new statewide map. Recent data and technology, including the addition of significant LiDAR coverages, and new possibilities for digital geomorphological mapping that employ spatiotemporal and geocomputational approaches to data analysis, are allowing the FGS to revise nomenclature and refine geomorphic district and province boundaries. In the following section, all geomorphic unit names and most discussions are from Williams et al. (in preparation).

The new atlas will show the geomorphology by regional units (districts; OFMS 112, Plate 3, Figure 3) and sub-regional to local units (provinces; Figure 6). Districts are defined by regional groupings in which the geomorphology and near-surface geology are combined to form map

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polygons that are distinct from adjacent districts. Defining the more localized provinces and their landforms is important for the characterization of the districts.

Given the significance of karst and marine erosion and deposition in Florida, the landforms derived via these processes are important to the identification of both province and districts. The study area falls entirely within the Barrier Island Sequence District (OFMS 112; Plate 3, Figure 3). This district is subdivided into provinces (Figure 6; OFMS 112; Plate 3, Figure 4). The geomorphic district and provinces below are discussed in order from west to east.

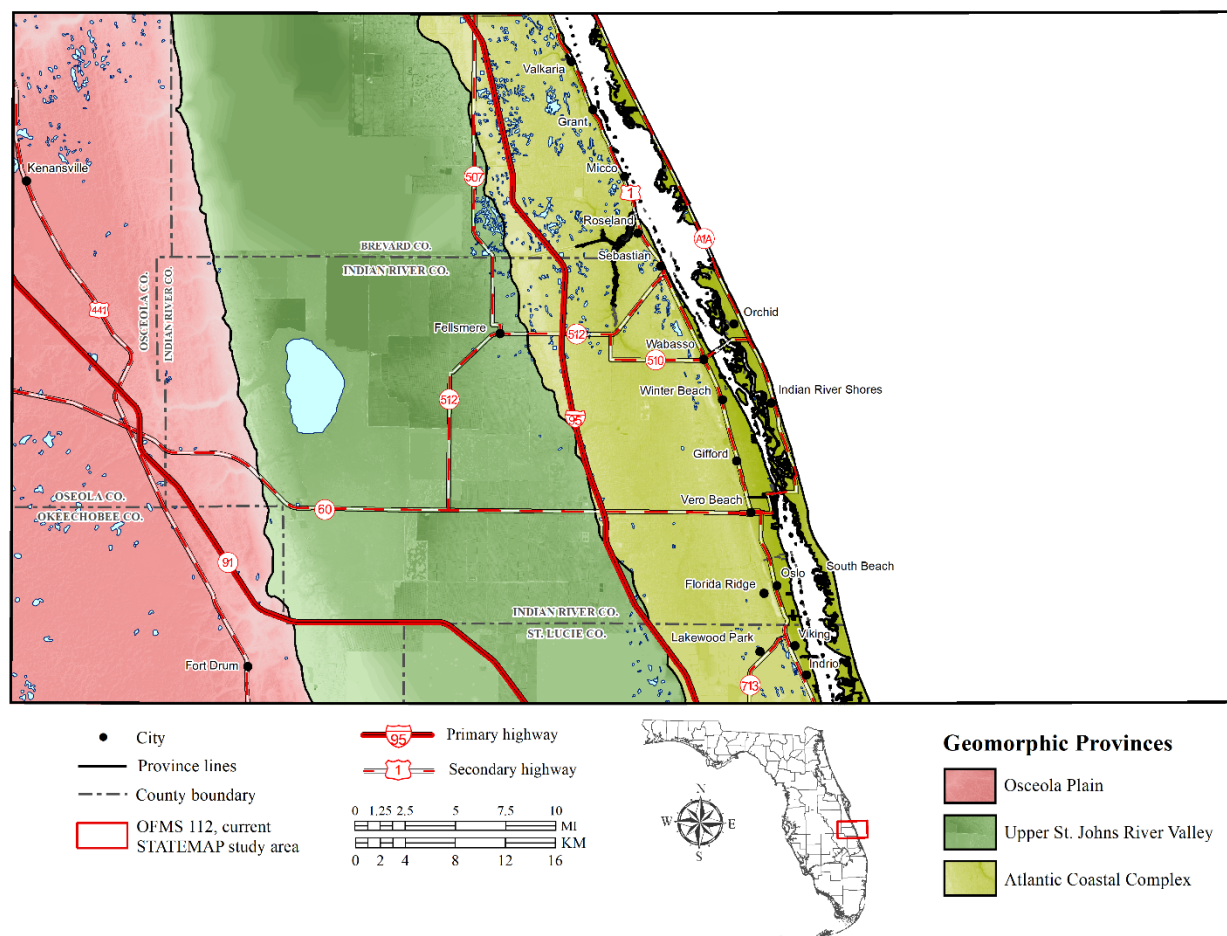


Figure 6. Geomorphic provinces within the Vero Beach quadrangle.

Barrier Island Sequence District

The Barrier Island Sequence District, the only geomorphic district in the mapped area, occurs along the Atlantic Coast. It extends from Georgia (Clark and Zisa, 1976) into Florida, and south to the vicinity of Lake Okeechobee (OFMS 112, Plate 3, Figure 3).

Elevations of the district within Florida range from sea level to just over 300 feet (91.4 meters) above mean sea level (MSL). Elevations within the Vero Beach quadrangle portion of the district range from sea level at the Atlantic Coast in the Atlantic Coastal Complex Province to just over 90 feet (27.4 meters) above MSL in the Osceola Plain Province (OFMS 112, Plate 3, Figure 2). The eastern boundary of the Barrier Island Sequence District is along the Atlantic Coast. In

Florida, it is bounded to the south by the Everglades District and to the west by the Lakes District and the Okefenokee Basin District (OFMS 112, Plate 3, Figure 3).

The Barrier Island Sequence District is subdivided within the mapped area into three provinces: the Osceola Plain, the Upper St. Johns River Valley, and the Atlantic Coastal Complex (OFMS 112, Plate 3, Figure 4). Pliocene-Pleistocene and Holocene coastal processes formed extensive barrier islands, beaches, lagoons, embayments, and shallow-water marine terraces in the district. While modern coastal processes are dominantly erosional along the Atlantic coast, with net longshore transport from north to south, there are many older depositional coastal features in the mapped area. Strand plains and shore-parallel dunes represent the preserved depositional features of former shorelines created by beach accretion and/or declining relative sea-levels. The swales between beach ridges are often swampy and contain lakes, wetlands, linear swamps, and tributary streams. The swales control the development of lakes on portions of the Osceola Plain Province and the extensive, linear wetlands of the Atlantic Coastal Complex Province. The modern estuarine coastlines in the study area are dominated by mangrove swamps.

Strand plains are common in the Barrier Island Sequence District. Outstanding examples of strand plains can be seen north of the study area on Merritt Island and Cape Canaveral in the Atlantic Coastal Complex Province and the eastern third of the Osceola Plain Province within the study area. Wetlands are commonly coast-parallel and found in the swales between the ridges of the strand plains, and tidal marshes or mangrove swamps landward of the barrier islands. Inland, the broad, relatively flat Osceola Plain Province includes a marine escarpment and strand plain.

The southern part of the Barrier Island Sequence District includes several important coastal drainage systems. The St. Sebastian River is the only significant overland stream flowing toward the Atlantic Coast within the study area, but the North and South forks of the St. Lucie River (south of the mapped area) are also important regionally. The Indian River is an estuarine lagoon that receives water from St. Sebastian River, St. Lucie River, and numerous small streams that drain east toward the Atlantic Ocean.

The St. Johns River and its tributaries, Fort Drum and Blue Cypress creeks, are the other major streams of the Barrier Island Sequence District in the study area. The St. Johns River valley largely follows low areas in paleo-lagoons and ancient embayments where the drainage patterns are consistent with the presence of coastal depositional landforms. Within the study area, the St. Johns River is mostly within the marshes of the Upper St. Johns River Valley Province. Discrete flow in a distinct river channel is only apparent in the northwestern part of the study area. These marshes form the headwaters of the St. Johns River. In the district, much of the river and stream drainage is controlled by the relict ridges forming distinct, swale-induced, drainage patterns.

Undifferentiated Tertiary/Quaternary shelly sediments underlie the Barrier Island Sequence District within the study area. The Pleistocene Anastasia Formation, Quaternary beach ridge and dune deposits, undifferentiated Quaternary sediments, and Holocene sediments overlie the Tertiary/Quaternary shelly sediments. The Anastasia Formation occurs at and near the coast and is sporadically exposed along the barrier island coastlines within the mapped area. Holocene sediments exist in river and stream valleys and along the Atlantic Coast (OFMS 112, Plate 1).

Karst features in the Barrier Island Sequence District within the study area are mostly related to dissolution of shell and carbonate beds within the undifferentiated Tertiary/Quaternary shelly sediments and the Anastasia Formation. Undifferentiated Tertiary/Quaternary shelly sediments occur near the land surface in much of the Upper St. Johns River Valley and Atlantic Coastal Complex provinces within the mapped area. Coquinoid limestone of the Anastasia Formation is at or near the land surface in coastal parts of the Atlantic Coastal Complex Province

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(OFMS 112, Plates 1 and 2). Shallow karst depressions, including cover-subsidence sinkholes and solutions pits, were formed by dissolution of shell and coquina (Schmidt and Scott, 1984). Cover-subsidence sinkholes often form wetlands. In areas where the Anastasia Formation crops out along the Atlantic Coast, microkarst surfaces have developed (Upchurch et al., 2018).

Osceola Plain Province

The Osceola Plain Province extends from Seminole County in the north to Martin County in the south (OFMS 112, Plate 3, Figure 4). It is a subtle, but complex, geomorphic area that includes most of the Kissimmee River valley in the western two thirds of the province and a strand plain in the eastern third (Green et al., 2019a; OFMS 112, Plate 3, Figure 4). This strand plain is well developed from southeastern Seminole and eastern Orange counties into eastern Osceola County. The strand plain ends in westernmost Indian River County and northeastern Okeechobee County (OFMS 112, Plate 3, Figure 4).

The Osceola Plain Province has the low and flat topography of a marine terrace (White, 1970). The eastern third of the province includes a strand plain that White (1970) associated with the linear sets of lakes, streams, and beach ridges observed in the Geneva Hill Province and the DeLand Ridge and Crescent City Ridge provinces of the Lakes District to the north-northwest (see Green et al., 2018a; Green et al., 2018b).

In the western Osceola Plain Province, the land surface is relatively flat with an undulating surface. This area appears to have been a shallow marine platform. There are significant accumulations of dune and beach sand on the western boundary of the province, continuing onto the eastern flank of the Lake Wales Ridge Complex Province of the Lakes District (OFMS 112, Plate 3, Figure 4). Some of the dune fields are well developed and have significant relief. Elevations of the Osceola Plain Province in the study area range from approximately 20 feet (6.1 meters) above MSL, along the ancient marine escarpment at the boundary with the Upper St. Johns River Valley Province (OFMS 112, Plate 3, Figure 1), to over 90 feet (27.4 meters) above MSL along the western edge of the mapped area.

Drainage in the province includes swale-controlled streams and wetlands associated with the Econlockhatchee River and the many streams that parallel the Atlantic Coast. Several creeks cut across the ridges and flow toward the St. Johns River. The Kissimmee River once meandered through a shallow, wetland valley south to Lake Okeechobee (OFMS 112, Plate 3, Figure 4). In the 1960s, the Kissimmee River was straightened and channelized for flood control, and the landscape was significantly altered. In the late 1990s, efforts began to restore the natural flow of the river system, including meanders and other fluvial landforms. The headwaters of the Kissimmee River originate in a series of lakes at or near the base of the Lake Wales Ridge Complex Province in the northwestern part of the Osceola Plain Province.

The surficial geologic units exposed on the Osceola Plain include undifferentiated Tertiary/Quaternary shelly sediments, undifferentiated Quaternary sediments, and Quaternary beach ridge and dune sediments (OFMS 112, Plate 1). Undifferentiated Tertiary/Quaternary shelly sediments underlie the surficial sands in the province in the mapped area (OFMS 112, Plate 2).

Large karst landforms are not common in the Osceola Plain Province. The shallow depressions, sag ponds, and cover-subsidence sinkholes which are present are most likely due to dissolution of shell material in the shallow subsurface within the Tertiary/Quaternary shelly sediments which underlie the majority of the Osceola Plain Province.

Upper St. Johns River Valley Province

The Upper St. Johns River Valley Province follows a low-elevation drainage system that was an ancient embayment or lagoon between the Atlantic Coastal Complex Province to the east and the strand plain of the eastern Osceola Plain Province to the west (OFMS 112, Plate 3, Figure 4). The main leg of the northward-flowing drainage system, the Upper St. Johns River, meanders through a large wetland complex. The southern part of the province includes the headwaters of the St. Johns River in extensive wetlands and lakes, whereas the northern part of the province includes a distinct channel and several large lakes.

The Upper St. Johns River Valley Province includes the fluvial/paludal valley from the headwaters of the St. Johns River, near the St. Lucie-Martin County boundary, northward to the outfall of Lake Monroe between Seminole and Volusia counties. Most of the Upper St. Johns River Valley Province is very flat with riverine floodplains, wetlands, and lakes. The southern part of the province is slightly higher in elevation and lacks the distinct river channel and fluvial landforms that are present in the northern part of the province. Lakes are present along the course of the river in the northern part of the province. There are many distributaries and oxbows, as is typical of a sediment-choked, low gradient stream system. Sediment transport in the system is negligible, but wetland development and the lacustrine/paludal sediments influence the presence of distributaries, lakes, and other landforms.

Elevations in the Upper St. Johns River Valley Province in the mapped area range from five feet (1.5 meters) above MSL to about 60 feet (18.3 meters) above MSL. However, elevations above 35 feet (10.7 meters) MSL are generally restricted to the border regions with the Atlantic Coastal Complex Province and the Osceola Plain Province.

The eastern boundary with the Atlantic Coastal Complex Province follows the change from coastal ridges to the east, and the wetland and river complex to the west. The boundary of the Upper St. Johns River Valley Province with the Osceola Plain Province is placed at the toe of a marine escarpment where elevations increase on to the Osceola Plain Province to the west. The concept that the province was once an embayment or lagoon is supported by the presence of coastal landforms on the margins of the Atlantic Coastal Ridge Complex Province to the east and the Osceola Plain Province to the west.

The Upper St. Johns River Valley Province is a broad area where undifferentiated Tertiary/Quaternary shelly sediments and undifferentiated Quaternary sediments occur at or near the land surface. Holocene sediments overlie these deposits in many of the low, river and wetland-related areas. Anthropogenic alteration of the southern portion of the Upper St. Johns River Valley Province is extensive. Regions that are relatively unaffected by ditching and drainage systems have common, but not abundant, shallow depressions that are cover-subsidence sinkholes. These formed as a result of dissolution of shell material in the underlying Tertiary/Quaternary shelly sediments.

Atlantic Coastal Complex Province

The Atlantic Coastal Complex Province consists of Quaternary barrier islands and related features on, and inland from, the Atlantic Coast. Water bodies and wetlands landward of the barrier islands include lagoons and small embayments. Within the study area, tidal regions of the lagoons are dominated by mangrove swamps. The Atlantic Coastal Complex Province extends from the St. Johns River in Duval County to central Palm Beach County.

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Most of the Atlantic Coastal Complex Province is a Pleistocene strand plain. Many of the beach ridges and dunes in the Atlantic Coastal Complex Province are coast-parallel, although complex beach ridge patterns occur on Cape Canaveral and Merritt Island just north of the study area (OFMS 112, Plate 3, Figure 4). In the study area, Holocene sediments of the tidal estuarine coastlines were deposited mostly within mangrove swamps.

The ridge and dune topography of the Atlantic Coastal Complex Province gives way to slightly lower elevation and flatter topography along most of its western boundary with the Upper St. Johns River Valley Province within the mapped area. Elevations in the Atlantic Coastal Complex Province for the study area range from sea level along the Atlantic Coast to about 55 feet (16.8 meters) above MSL along the western boundary of the province.

Sporadic exposures of the Anastasia Formation from St. Johns County to Palm Beach County create unique rocky coastlines. Open lagoons and small embayments, located landward of the barrier islands, are locally termed “rivers” because of their historic uses for navigation.

Drainage patterns in the Atlantic Coastal Complex Province are swale-dominated and coast-parallel in nature, with streams and wetlands occupying the swales between ridges. Some streams flow toward the Atlantic Ocean through breaks in the beach ridges, such as the St. Sebastian River and the north and south branches of the St. Lucie River, the latter to the south of the study area. Other streams flow toward the St. Johns River, including Fort Drum and Blue Cypress creeks.

The surficial stratigraphic units that affect the landforms in the Atlantic Coastal Complex Province include undifferentiated Tertiary/Quaternary shelly sediments, the Pleistocene Anastasia Formation, undifferentiated Quaternary sediments, and Quaternary beach ridge and dune sediments (Scott et al., 2001). Undifferentiated Holocene sediments occur on many of the barrier islands and in the tidal mangrove estuaries.

Cover-subsidence sinkholes and sag ponds occur in the Atlantic Coast Complex Province where the undifferentiated Tertiary/Quaternary shelly sediments and the Pleistocene Anastasia Formation are at or near the land surface. Dissolution features can be seen where the Anastasia Formation is exposed along the modern coast and in the undifferentiated Tertiary/Quaternary shelly sediments exposed in mines and borrow pits.

LITHOSTRATIGRAPHIC UNITS

Tertiary System

Eocene Series

Avon Park Formation

The middle Eocene Avon Park Formation, first named by Applin and Applin (1944), is entirely a subsurface unit within the USGS Vero Beach 30 x 60 minute quadrangle. It was encountered in many of the wells utilized for this study and efforts were made to include it in the geologic cross sections where suitable well coverages existed (see OFMS 112, Plate 2).

The lithology of the Avon Park Formation can vary between limestone and dolostone. The limestone is cream to light brown to tan, poorly- to well-indurated, variably fossiliferous grainstone and wackestone, with rare mudstone. It is often interbedded with tan to brown, very poorly to well-indurated, very fine to medium crystalline, fossiliferous (molds and casts), vuggy dolostones. Minor clay beds and organic-rich laminations may occur. Accessory minerals may

include pyrite and calcite. Although not common, sedimentary structures may include cross-beds and burrows.

Fossils present in the unit include mollusks, foraminifera (*Spirolina* sp., *Lituonella floridana*, *Fabiana cubensis*, and *Cushmania* [*Dictyoconus*] *americana*), echinoids (*Neolaganum* [*Peronella*] *dalli*), algae, and carbonized plant remains. Porosity in the Avon Park Formation is generally intergranular in the limestone section. Fracture porosity occurs in the more densely recrystallized dolostone, and intercrystalline porosity is characteristic of sucrosic textures. Pinpoint vugs and fossil molds are present to a lesser extent.

Distinguishing between the middle Eocene Avon Park Formation and the unconformably overlying unit, the upper Eocene Ocala Limestone, can at times be difficult in the study area. Fossil indicators are only somewhat helpful because the latest deposits of the Avon Park Formation and the earliest deposits of the Ocala Limestone are both bank assemblages, consistent with deposition in a shallow-water limestone bank or plateau, not unlike the present-day Bahama Banks (Bryan, 2004). In the mapped area, the contact with the Ocala Limestone and the Avon Park Formation was typically picked based on textural changes from a yellowish-gray grainstone, often containing *Lepidocyclina ocalana* and *Nummulites ocalanus*, to a less chalky, more recrystallized, muddy, packstone or wackestone with an increase in grain size, color change, and the appearance of organics. There is also a change in fossil assemblages from common Ocala Limestone benthic foraminifera to the benthic foraminifera *Fallotella* sp. and *Cushmania* [*Dictyoconus*] *americana*, found in the Avon Park Formation. Increases in fossil molds and Avon Park Formation fossils, including the echinoid *Neolaganum dalli*, generally become apparent below the contact.

The top of the Avon Park Formation ranges from approximately 200 feet (61.0 meters) below MSL in W-1380 (Appendix A) to approximately 975 feet (297.2 meters) below MSL in W-15307 (Appendix A). Due to limited coverage of deeper wells, the total thickness of the Avon Park Formation was not investigated in this study. The Avon Park Formation forms part of the Floridan aquifer system (FAS; Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition, 1986).

Ocala Limestone

The upper Eocene Ocala Limestone (To), first described by Dall and Harris (1892), is a biogenic marine limestone comprised largely of foraminifera, mollusks, echinoids, and bryozoans. The Ocala Limestone, which sits unconformably on the Avon Park Formation, is recrystallized to varying degrees within the study area.

Based on lithologic differences, the Ocala Limestone, in some areas, can be informally subdivided into an upper and lower unit (Scott, 1991). This subdivision, while often apparent in cores and quarries, is not readily apparent in cuttings. As a consequence of this, the geologic cross-sections do not depict the upper and lower Ocala Limestone. The upper unit is typically a white to cream, fine- to coarse-grained, poorly- to well-indurated, moderately- to well-sorted, very fossiliferous limestone (wackestone, packstone, and grainstone). Common fossils include foraminifera (*Lepidocyclina ocalana* and *Sphaerogypsina globulus*), bryozoans, mollusks, and a rich diversity of echinoids. The lower unit is typically a white to cream, fine- to medium-grained, poorly- to moderately- indurated, moderately- to well-sorted limestone (grainstone to packstone). Fossils include foraminifera (*Amphistegina pinarensis*, *Nummulites* [*Camerina*] *vanderstoki*, and *Nummulites* [*Operculinoides*] *ocalanus*), bryozoans, algae, mollusks, echinoids, and crustaceans. Porosity types in the unit range from intergranular to moldic depending on the lithology.

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The Ocala Limestone occurs throughout the study area (OFMS 112, Plate 2). The top of the Ocala Limestone ranges from approximately 90 feet (27.4 meters) below MSL in W-1380, to approximately 800 feet (243.8 meters) below MSL in W-14703 (Appendix A). The thickness of the Ocala Limestone ranges from approximately 10 feet (3.1 meters) in W-19495, to 260 feet (79.2 meters) in W-15307 (Appendix A).

The Ocala Limestone is generally thickest in the southeastern portion of the study area toward the coast. The Ocala Limestone forms part of the FAS (Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition, 1986).

Oligocene Series

Suwannee Limestone

Although the lower Oligocene Suwannee Limestone, named by Cooke and Mansfield (1936), has been discussed in the map area and vicinity by numerous authors (Bermes, 1995; Lichtler, 1960; Mooney et al., 1980), it was not found in the map area during this study. Mooney et al. (1980) discuss a thirty foot (9.1 meters) thick unnamed gray calcilutite, which contains varying amounts of quartz sand and phosphate, sitting between the base of the Hawthorn Formation (recognized as the Arcadia Formation, Hawthorn Group in this study) and the top of the Ocala Limestone in the area. However, this unit cannot be reliably correlated with known Suwannee Limestone outside of the quadrangle. The presence of quartz sand and phosphate in the unit pose a lithostratigraphic problem, since Suwannee Limestone typically does not contain these accessory minerals. Brewster-Wingard et al. (1997) describe a lower Oligocene, and possibly uppermost Eocene, unnamed limestone present along the east coast of Florida that is similar in age (based on dinocysts and mollusks) with Suwannee Limestone in northern Florida. They did not place it in the Suwannee Limestone due to the uncharacteristic lithology. Brewster-Wingard et al. (1997) stated that the unnamed limestone consists of a moderately indurated, fossiliferous and moldic limestone that is slightly quartz sandy and silty, and phosphatic.

Based on stratigraphic position and distinct lithologic differences from underlying Ocala Limestone, along with affinities to the Arcadia Formation (including the presence of sand and phosphate), the authors of this study consider this unit as part of the Arcadia Formation (Hawthorn Group). Additional stratigraphic work in southeast Florida is necessary to determine the true nature of this unit in the area.

Oligocene-Pliocene Series

Hawthorn Group

Sediments of the lower Oligocene to Pliocene Hawthorn Group are thought to have been deposited over the Ocala Platform throughout peninsular Florida, but post-Pliocene erosion and karstification have removed them from the crest of the Ocala Platform (Cooke, 1945; Espenshade and Spencer, 1963; Scott, 1981). Within the mapped area, the Hawthorn Group is composed of sediments from the Arcadia and Peace River formations. Arcadia Formation sediments lie unconformably over the Ocala Limestone throughout the mapped area (OFMS 112, Plate 2, cross-sections). The Peace River Formation lies unconformably over the Arcadia Formation throughout the quadrangle. The Hawthorn Group sediments are unconformably overlain by the undifferentiated Tertiary/Quaternary shelly sediments throughout the Vero Beach quadrangle. The

top of the Hawthorn Group ranges from approximately 50 feet (15.2 meters) below MSL in W-13942 (Appendix A) to 230 feet (70.1 meters) below MSL in W-2446 (Appendix A). The thickness of the Hawthorn Group ranges from approximately 75 feet (22.9 meters) in W-13964 (Appendix A) to 440 feet (134.1 meters) in thickness in W-18059 (Appendix A) along the eastern edge of the mapped area.

Arcadia Formation

The lower Oligocene to middle Miocene (Brewster-Wingard et al., 1997) Arcadia Formation is a yellowish-gray to white, carbonate with variable amounts of quartz sand and phosphorite, interbedded with siliciclastic-dominant sediments. Phosphate content can be highly variable, ranging up to 25 percent, but is more commonly in the 10 percent range (Scott, 1988). Although limestone is present, dolostone is most common, ranging in grain size from microcrystalline to medium, with the coarser material often having a sucrosic texture. Minor clay and chert beds (some composed of silicified clay) also occur (Upchurch et al., 1982; Scott, 1988). Porosity types include intergranular and moldic. Brewster-Wingard et al. (1997) have indicated that an unconformity, spanning the latter half of the early Oligocene into the earliest Miocene, exists in the region. The Arcadia Formation was identified in most wells within the study area based on the presence of sandy, phosphatic carbonate beds (30 feet or more), with occasional presence of bored phosphatic hardgrounds.

The Arcadia Formation ranges from approximately 70 feet (21.3 meters) below MSL (Appendix A; W-13964) to approximately 490 feet (149.4 meters) below MSL (Appendix A; W-14703). The unit is thickest in the southern portion of the study area and ranges from 5 feet; (1.5 meters) thick in W-16170 (Appendix A) to approximately 210 feet (64.0 meters) thick in W-15105 (Appendix A). The Arcadia Formation forms part of the intermediate aquifer system/intermediate confining unit (IAS/ICU) in the study area (Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition, 1986).

Peace River Formation

The middle Miocene to lower Pliocene (Scott, 1988; Covington, 1993) Peace River Formation is comprised of yellowish-gray to olive-gray, interbedded quartz sands, clays, and carbonates. Siliciclastics are the predominant component of the unit (Scott, 1988). Phosphatic sand and gravel are most common in the uppermost beds, although they are generally interspersed throughout the unit. The Peace River Formation contains a diverse fossil assemblage of marine and terrestrial fauna. Porosity types in the formation are generally intergranular.

The Peace River Formation unconformably overlies the Arcadia Formation throughout the mapped area (OFMS 112, Plate 2). In areas where the carbonate component of the Peace River Formation is high, or the siliciclastic component of the Arcadia Formation is high, identifying the contact between these formations can be difficult. In such cases, the contact of the Peace River Formation with the Arcadia Formation is best estimated based on the occurrence of sedimentary structures, and where the overall lithologic sequence becomes more carbonate-dominant (Scott, 1988). In most of the study area, the contact is readily recognized at the first occurrence of a light-colored, phosphatic and quartz-sandy dolosilt.

The Peace River Formation ranges from approximately 50 feet (15.2 meters) below MSL in W-13942, to 230 feet (70.1 meters) below MSL in W-2446. Thicknesses range from approximately 10 feet (3.1 meters) in W-13964, to 370 feet (112.8 meters) in W-14703 (Appendix

A).

The Peace River Formation sediments comprise a low-permeability confining- to semi-confining facies within the IAS/ICU within the study area (Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition, 1986).

Tertiary/Quaternary Systems

Pliocene/Pleistocene Series

Tamiami Formation

Johnson (1993) described two carbonate-rich facies of the Tamiami Formation in Indian River and Brevard counties: a gray-to-tan, moderately indurated, slightly phosphatic, quartz-sandy, partially recrystallized limestone with approximately 10-30 percent micrite cement, and a white-to-gray, well-indurated, slightly phosphatic, quartz-sandy, variably moldic (mollusks), very-finely recrystallized micrite with scattered well-preserved pelecypods shells. The total thickness of the Tamiami Formation discussed by Johnson (1993) ranged from less than 10 feet (3.0 meters) to just over 35 feet (10.7 meters). The thickest sections were north of the study area on Merritt Island. Johnson (1993) also mentions that the unit thins to the north, west, and south of Cocoa Beach, with an average thickness of 10-20 feet (3.0-6.1 meters). Given that most of the borehole samples available to examine were cuttings, many with 10-foot (3.0 meter) intervals., it is not possible to reliably map this unit in the Vero Beach quadrangle based on the samples available. Johnson (1993) used borehole geophysical logs (neutron and electric) to differentiate this material as Tamiami Formation, rather than using strictly lithologic criteria. Other authors (Weedman et al., 1995) have indicated that there is no molluscan paleontologic evidence of the occurrence of Tamiami Formation in wells they studied in Indian River County.

Based on the lack of correlation to the Tamiami Formation in southwest Florida (Collier County), where the unit was defined, the thin overall nature of the unit, absence of core control, and the fact that these lithologies can also exist in the undifferentiated Tertiary/Quaternary shelly sediments, these sandy micrite facies are placed in the undifferentiated Tertiary/Quaternary shelly sediments in this report. Further stratigraphic work in southeast Florida is needed to determine whether this limestone can be correlated to the Tamiami Formation.

Undifferentiated Tertiary/Quaternary shelly sediments

A sequence of undifferentiated Tertiary/Quaternary shelly sediments lies east of the Lake Wales Ridge Complex in peninsular Florida. Huddlestun (1988) named this unit the Nashua Formation. Much of the evidence listed by Huddlestun (1988) was based on biostratigraphic correlation and not lithology. Sediments located along the Econlockhatchee River were investigated during fieldwork for mapping in the Orlando quadrangle (Green et al., 2015a; Green et al., 2015b) and were determined to be very young (late Pleistocene-Holocene, Roger Portell, personal communication, 2015). Given the age uncertainty of these units, lack of adequate core control and lack of access to the type section, the authors decided to utilize the convention of Scott et al. (2001) and map these sediments as undifferentiated Tertiary/Quaternary shelly sediments. Huddlestun (1988) indicated that the unit grades laterally into the Cypresshead Formation in the vicinity of Trail Ridge (north of the mapped area). Evidence from mapping in the Orlando quadrangle (Green et al., 2015a; Green et al., 2015b), however, indicated that the unit is, at least

in part, older than the Cypresshead Formation. This may be a result of prograding of Cypresshead Formation sediments over Tertiary/Quaternary shelly marine sediments during changes in sea level. Some of these fossiliferous sands north of the study area (e.g., in the Daytona Beach quadrangle) are Pliocene (Roger Portell, personal communication, 2015).

There are problems in mapping these sediments as separate units because their historical definition is based on biostratigraphic, not lithostratigraphic, criteria (Scott and Allmon, 1990; Scott and Wingard, 1995). Scott and Campbell (1993) informally applied the name “Okeechobee formation” to these sediments in an effort to provide a lithostratigraphic framework, but the unit was never formalized. Therefore, the Florida Geological Survey is continuing to classify them as undifferentiated Tertiary/Quaternary shelly sediments at this time.

Undifferentiated Tertiary/Quaternary shelly sediments typically consist of fine-to-medium quartz sands and marine mollusk shell beds with variable amounts of micrite, silt, clay, and calcite cement. Colors range from light gray to light-olive gray. Fossil mollusk shells, which may vary from whole to fragments, are often highly weathered and abraded and regularly become the dominant lithology. Porosity is generally intergranular. Other accessory minerals may include calcite, aragonite, mica, heavy minerals, pyrite, and minor phosphate sand and gravel. A basal phosphate lag is occasionally present. In the study area, these undifferentiated Tertiary/Quaternary shelly sediments occur in the form of both unconsolidated sand with varying percentages of shell fragments and calcite-cemented sand and shell fragments, with occasional lithified carbonate beds.

The undifferentiated Tertiary/Quaternary shelly sediments present in the study area are generally less than 50 feet (15.2 meters) above MSL, with most of the unit being less than ten feet (3.0 meters) above MSL (OFMS 112, Plate 2, cross-sections). The elevation of the Tertiary/Quaternary shelly sediments is highest in the southwest portion of the mapped area in Okeechobee County and lowest along the Atlantic Coast (OFMS 112, Plate 2). It is postulated that these occurrences of higher elevation undifferentiated Tertiary/Quaternary shelly sediments are indicative of paleo-shorelines that have been “stranded” due to sea-level fluctuation. Additional studies, with much better core control than was available in this study, are needed to determine the exact nature and relationships of the unit in the region.

These undifferentiated Tertiary/Quaternary shelly sediments are overlain by undifferentiated Quaternary sediments and Quaternary beach ridge and dune sediments in the western portion of the mapped area (OFMS 112, Plate 2). The undifferentiated Tertiary/Quaternary shelly sediments are exposed in several quarries within the study area. In the eastern portion of the mapped area, the unit is unconformably overlain by Holocene sediments, undifferentiated Quaternary sediments, or the Anastasia Formation. Undifferentiated Tertiary/Quaternary shelly sediments disconformably overlie the Peace River Formation throughout the Vero Beach quadrangle.

The top of the undifferentiated Tertiary/Quaternary shelly sediments ranges from approximately 55 feet (16.8 meters) above MSL in the vicinity of Lake Okeechobee to 75 feet (22.9 meters) below MSL in W-9128. The thickness of the undifferentiated Tertiary/Quaternary shelly sediments in the mapped area varies from 15 feet (4.6 meters) in W-16977 to 170 feet (51.8 meters) in W-19627 (Appendix A).

Permeable sediments of the undifferentiated Tertiary/Quaternary shelly sediments form part of the surficial aquifer system (SAS; Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition, 1986).

Pleistocene/Holocene Series

Anastasia Formation

The Anastasia Formation is present within a narrow band along the eastern edge of the study area. The formation, named by Sellards (1912), is composed of interbedded coquinoid limestone and quartz sands. It typically occurs as an orangish-brown, poorly- to moderately-indurated coquinoid limestone consisting of whole and broken mollusk shells in a quartz sand matrix. The coquina is commonly cemented by sparry calcite. The sand occurs in beds that are light-gray-to-tan and orangish-brown, unconsolidated to moderately-indurated, and variably fossiliferous. Porosity is intergranular to intercrystalline but may be vuggy and even karstic in more cemented zones. In the study area, the Anastasia Formation occurs predominantly as a light-gray-to-tan and orangish-brown, unconsolidated to moderately-indurated quartz sand and shells, with coquinoid limestone being less common.

The Anastasia Formation can be difficult to distinguish from the undifferentiated Tertiary/Quaternary shelly sediments in some areas due to similarity in lithologic components. Typically, the Anastasia Formation is distinguished based on its fairly uniform fossil content, tendency to contain rounded sand and shell fragments (typical of beach material), orangish-brown color, and lack of clay and silt matrix. In localities where the Anastasia Formation-Tertiary/Quaternary shelly sediments cannot be easily distinguished, undifferentiated Tertiary/Quaternary shelly sediments were picked where the shell fragments become more diverse both in taxonomy and texture.

The unit sits on undifferentiated Tertiary/Quaternary shelly sediments (OFMS 112, Plate 2). The top of the Anastasia Formation ranges from approximately ten feet (3.0 meters) above MSL in W-16809, to five feet (1.5 meters) below MSL in W-19494. The thickness of the Anastasia Formation in the cross-section wells varies from five feet (1.5 meters) in W-3018, to 40 feet (12.2 meters) in W-16809 (Appendix A). This formation is considered part of the SAS (Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition, 1986).

Undifferentiated Quaternary sediments

While not a formally recognized lithostratigraphic unit, undifferentiated Quaternary sediments are mapped following the convention of Scott et al. (2001) in order to facilitate a better understanding of Florida's geology. The undifferentiated Quaternary sediments in the mapped area may be highly variable in thickness. Undifferentiated Quaternary sediments in the study area lie unconformably on Anastasia Formation or undifferentiated Tertiary/Quaternary shelly sediments (OFMS 112, Plate 2).

Generally, undifferentiated Quaternary sediments consist of white-to-gray to orange-to-brown, fine- to coarse-grained, clean-to-clayey (usually) unfossiliferous quartz sand, sandy clays and clays, with variable admixtures of organics. Minor shell fragments are sometimes present in undifferentiated Quaternary sediments near the coast. This makes distinction between undifferentiated Quaternary sediments and Anastasia Formation difficult at times. The undifferentiated Quaternary sediments form part of the SAS (Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition, 1986).

Quaternary beach ridge and dune

Quaternary beach ridge and dune sediments are a subdivision of the undifferentiated Quaternary sediments that are mapped on the basis of having a surficial expression of relict beach ridges and dunes. While not a formally recognized lithostratigraphic unit, the unit is mapped following the convention of Scott et al. (2001) in order to facilitate a better understanding of Florida's geology. The unit unconformably overlies undifferentiated Tertiary/Quaternary shelly sediments in the western part of the study area (OFMS 112; Plates 1 and 2).

Beach ridge and dune sediments are comprised of quartz sands with occasional shells and are unconsolidated to poorly consolidated. Organics typically occur as disseminated organic matrix, roots and plant debris, carbonized remains, or charcoal. The unit is considered part of the SAS (Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition, 1986).

HYDROGEOLOGY

Hydrostratigraphic units within the map area, in ascending order, consist of the FAS, the IAS/ICU, and the SAS (Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition, 1986). A correlation chart of the hydrostratigraphic units, and their relationship to lithostratigraphic units, can be seen on OFMS 112, Plate 2, Figure 2. The FAS, the primary source for drinking water in the region, is generally comprised of carbonate units of the Avon Park Formation and the Ocala Limestone. The sands, silts, clays, and carbonates of the Hawthorn Group comprise the IAS/ICU. The IAS/ICU is highly localized and laterally discontinuous in the study area. The SAS is comprised of Anastasia Formation, undifferentiated Tertiary/Quaternary shelly sediments, undifferentiated Quaternary sediments, Quaternary beach ridge and dune sediments, and Holocene sediments.

DERIVATIVE PRODUCTS

Several derivative products were developed in the process of completing this project. During the mapping efforts, data from 158 wells with samples were analyzed and used (Appendix A). Formation picks made on these cores and cutting samples will allow creation of structure contour and isopach maps for the top of several units in the area, as well as future 3-D models. Additional derivative products anticipated to come from this mapping effort include aquifer vulnerability assessment maps. Data derived from prior STATEMAP products have often been used to augment other Florida Geological Survey and Florida Aquifer Vulnerability Assessment (FAVA) projects in the state (Arthur et al., 2007; Baker et al., 2007; Kromhout et al., 2017). These geologic maps will also be compiled and published as part of the Statewide Surficial Geologic Map in the next decade.

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APPENDIX A: FLORIDA GEOLOGICAL SURVEY WELLS UTILIZED FOR STUDY

This table lists FGS wells within the boundaries of the USGS Vero Beach 30 x 60 minute quadrangle utilized for the project. Due to graphical constraints, not all wells will appear on Plate 1 of OFMS 112. The first 33 wells in the table were utilized for geologic cross-sections and appear on Plates 1 and 2 of OFMS 112.

Map ID	Well Label	Data Source	Sample Type	Latitude	Longitude	24K Quad	Elevation (ft.)	Total Depth (ft.)
1	W-3018	FGS	Cuttings	27.55639	-80.3617	INDRIO	4	714
2	W-3023	FGS	Cuttings	27.55142	-80.4306	OSLO	19	691
3	W-3783	FGS	Core	27.75833	-80.8428	KENANSVILLE SE	46	9488
4	W-4456	FGS	Cuttings	27.95447	-80.5827	GRANT	21	444
5	W-5750	FGS	Cuttings	27.64028	-80.6200	SOUTH OF FELLSMERE	27	845
6	W-8766	FGS	Cuttings	27.90139	-80.4725	SEBASTIAN NW	1	435
7	W-9118	FGS	Cuttings	27.77361	-80.8991	KENANSVILLE SW	63	620
8	W-9124	FGS	Cuttings	27.79341	-80.9680	KENANSVILLE SW	63	320
9	W-9126	FGS	Cuttings	27.64910	-80.8818	FORT DRUM NW	69	490
10	W-9135	FGS	Cuttings	27.71178	-80.9186	FORT DRUM NW	62	490
11	W-10570	FGS	Cuttings	27.86978	-80.9945	KENANSVILLE SW	72	495
12	W-10698	FGS	Cuttings	27.86083	-80.4489	SEBASTIAN	5	366
13	W-13942	FGS	Core	27.94447	-80.9928	KENANSVILLE	53	409
14	W-13964	FGS	Core	27.89252	-80.8248	KENANSVILLE NE	21	181
15	W-14907	FGS	Cuttings	27.59361	-80.3897	OSLO	21	703
16	W-14931	FGS	Cuttings	27.91973	-80.4821	SEBASTIAN NW	9	420
17	W-15107	FGS	Cuttings	27.51944	-80.5908	EAST OF GUM SLOUGH	23	820
18	W-15126	FGS	Cuttings	27.6620	-80.3888	VERO BEACH	5	625
19	W-16172	FGS	Cuttings	27.96419	-80.5509	GRANT	19	400
20	W-16214	FGS	Cuttings	27.62833	-80.5414	SOUTH OF FELLSMERE	20	1150
21	W-16562	FGS	Cuttings	27.56139	-80.8313	FORT DRUM	63	680
22	W-16805	FGS	Cuttings	27.77139	-80.6664	FELLSMERE SW	19	390
23	W-16809	FGS	Cuttings	27.96111	-80.5047	GRANT	13	300
24	W-16845	FGS	Cuttings	27.77583	-80.6278	FELLSMERE SW	21	775
25	W-17422	FGS	Cuttings	27.53694	-80.7200	GUM SLOUGH	30	715
26	W-17557	FGS	Core	27.66014	-80.6314	NORTH OF GUM	21	430
27	W-17923	FGS	Cuttings	27.64639	-80.4297	VERO BEACH	22	161
28	W-18059	FGS	Cuttings	27.64639	-80.4297	VERO BEACH	22	460
29	W-18821	FGS	Cuttings	27.75139	-80.3981	SEBASTIAN	4	860
30	W-19250	FGS	Core	27.64109	-80.7673	FORT DRUM NE	28	1300
31	W-19769	FGS	Cuttings	27.76917	-80.5644	FELLSMERE	31	270
32	W-19771	FGS	Core	27.82331	-80.7062	FELLSMERE SW	26	280
33	W-19775	FGS	Cuttings	27.91111	-80.7456	FELLSMERE NW	20	315
34	W-1380	FGS	Cuttings	27.99501	-80.7172	FELLSMERE NW	19	335
35	W-1908	FGS	Cuttings	27.63778	-80.4142	VERO BEACH	21	671
36	W-1947	FGS	Cuttings	27.99125	-80.6473	FELLSMERE NW	31	75
37	W-2446	FGS	Cuttings	27.74725	-80.3998	VERO BEACH	6	950
38	W-3017	FGS	Cuttings	27.74152	-80.6247	SOUTH OF FELLSMERE	21	494
39	W-3021	FGS	Cuttings	27.61068	-80.7675	FORT DRUM	28	730
40	W-3033	FGS	Cuttings	27.74651	-80.8325	FORT DRUM NE	45	504
41	W-3038	FGS	Cuttings	27.85711	-80.4970	SEBASTIAN	20	408
42	W-4423	FGS	Cuttings	27.88391	-80.4676	SEBASTIAN NW	1	404
43	W-4435	FGS	Cuttings	27.99667	-80.5653	GRANT	21	74
44	W-4440	FGS	Cuttings	27.99722	-80.6050	GRANT	17	74
45	W-4441	FGS	Cuttings	27.99772	-80.5869	GRANT	22	68
46	W-4445	FGS	Cuttings	27.99578	-80.5712	GRANT	24	74
47	W-4452	FGS	Cuttings	27.93129	-80.5497	GRANT	26	74
48	W-4455	FGS	Cuttings	27.91944	-80.5381	GRANT	22	74
49	W-4552	FGS	Cuttings	27.56028	-80.3708	INDRIO	19	122

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Map ID	Well Label	Data Source	Sample Type	Latitude	Longitude	24K Quad	Elevation (ft.)	Total Depth (ft.)
50	W-4791	FGS	Cuttings	27.6642	-80.4153	VERO BEACH	17	116
51	W-4793	FGS	Cuttings	27.6656	-80.4325	VERO BEACH	24	116
52	W-4796	FGS	Cuttings	27.6658	-80.4117	VERO BEACH	21	114
53	W-6173	FGS	Cuttings	27.6012	-80.8228	FORT DRUM	59	772
54	W-6175	FGS	Cuttings	27.6017	-80.8234	FORT DRUM	59	765
55	W-7659	FGS	Cuttings	27.6222	-80.9544	FORT DRUM SW	68	9840
56	W-9122	FGS	Cuttings	27.8003	-80.9439	KENANSVILLE SW	67	620
57	W-9125	FGS	Cuttings	27.8175	-80.9596	KENANSVILLE SW	68	500
58	W-9127	FGS	Cuttings	27.6645	-80.9685	FORT DRUM NW	67	697
59	W-9128	FGS	Cuttings	27.7111	-80.9273	FORT DRUM NW	63	400
60	W-9129	FGS	Cuttings	27.7031	-80.9803	FORT DRUM NW	66	667
61	W-9140	FGS	Cuttings	27.6672	-80.9033	FORT DRUM NW	74	350
62	W-10682	FGS	Cuttings	27.6228	-80.3872	OSLO	10	124
63	W-10866	FGS	Cuttings	27.8835	-80.5152	GRANT	21	97
64	W-11072	FGS	Cuttings	27.7672	-80.5478	FELLSMERE	25	90
65	W-11953	FGS	Cuttings	27.6247	-80.5186	EAST OF GUM SLOUGH	24	89
66	W-11968	FGS	Cuttings	27.8143	-80.4699	SEBASTIAN	22	61
67	W-11969	FGS	Cuttings	27.6391	-80.5071	SOUTH OF FELLSMERE	21	80
68	W-12004	FGS	Cuttings	27.6678	-80.3889	VERO BEACH	2	75
69	W-12055	FGS	Cuttings	27.7790	-80.6251	FELLSMERE SW	21	77
70	W-12067	FGS	Cuttings	27.6391	-80.4201	VERO BEACH	22	130
71	W-12192	FGS	Cuttings	27.6567	-80.4056	VERO BEACH	19	668
72	W-12524	FGS	Cuttings	27.9309	-80.4881	SEBASTIAN NW	10	362
73	W-13076	FGS	Core	27.8781	-80.8229	KENANSVILLE NE	23	242
74	W-13957	FGS	Core	27.9697	-80.8719	KENANSVILLE NE	37	232
75	W-13958	FGS	Core	27.6961	-80.4358	VERO BEACH	19	476
76	W-14133	FGS	Cuttings	27.6011	-80.3803	OSLO	5	91
77	W-14167	FGS	Cuttings	27.5850	-80.4833	OSLO	20	2490
78	W-14169	FGS	Cuttings	27.5236	-80.3851	OSLO	20	108
79	W-14217	FGS	Cuttings	27.5785	-80.3300	INDRIO	5	760
80	W-14268	FGS	Cuttings	27.6520	-80.4030	VERO BEACH	14	675
81	W-14449	FGS	Cuttings	27.9756	-80.5186	GRANT	1	341
82	W-14505	FGS	Cuttings	27.6558	-80.4041	VERO BEACH	14	660
83	W-14703	FGS	Cuttings	27.5221	-80.3107	INDRIO	5	1092
84	W-14838	FGS	Cuttings	27.8871	-80.5329	GRANT	23	101
85	W-14839	FGS	Cuttings	27.8815	-80.5038	GRANT	21	100
86	W-14840	FGS	Cuttings	27.8914	-80.5309	GRANT	21	102
87	W-14933	FGS	Cuttings	27.9214	-80.4886	SEBASTIAN NW	4	431
88	W-15003	FGS	Cuttings	27.6561	-80.4298	VERO BEACH	23	125
89	W-15004	FGS	Cuttings	27.6613	-80.4278	VERO BEACH	22	135
90	W-15105	FGS	Cuttings	27.5080	-80.5881	EAST OF GUM SLOUGH	22	900
91	W-15106	FGS	Cuttings	27.5147	-80.5864	EAST OF GUM SLOUGH	22	900
92	W-15108	FGS	Cuttings	27.5370	-80.5879	EAST OF GUM SLOUGH	20	900
93	W-15148	FGS	Cuttings	27.6533	-80.4381	VERO BEACH	18	140
94	W-15149	FGS	Cuttings	27.6321	-80.4036	VERO BEACH	18	145
95	W-15171	FGS	Cuttings	27.9172	-80.6152	GRANT	31	440
96	W-15174	FGS	Cuttings	27.8727	-80.5014	FELLSMERE	22	70
97	W-15175	FGS	Cuttings	27.9025	-80.5331	GRANT	23	80
98	W-15179	FGS	Cuttings	27.6268	-80.5111	SOUTH OF FELLSMERE	28	86
99	W-15191	FGS	Cuttings	27.6266	-80.4033	VERO BEACH	17	125
100	W-15247	FGS	Cuttings	27.9667	-80.5092	GRANT	11	310
101	W-15307	FGS	Cuttings	27.7408	-80.3881	VERO BEACH	6	1055
102	W-15399	FGS	Cuttings	27.9715	-80.5114	GRANT	11	550
103	W-15413	FGS	Cuttings	27.6988	-80.9009	FORT DRUM NW	62	300
104	W-15482	FGS	Cuttings	27.9772	-80.5560	GRANT	22	92
105	W-15486	FGS	Cuttings	27.6267	-80.5042	SOUTH OF FELLSMERE	23	100
106	W-15661	FGS	Cuttings	27.6194	-80.6397	GUM SLOUGH	22	834
107	W-15663	FGS	Cuttings	27.9164	-80.5136	GRANT	2	580

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Map ID	Well Label	Data Source	Sample Type	Latitude	Longitude	24K Quad	Elevation (ft.)	Total Depth (ft.)
108	W-15664	FGS	Cuttings	27.5739	-80.6642	GUM SLOUGH	23	901
109	W-15668	FGS	Cuttings	27.7375	-80.447	VERO BEACH	22	135
110	W-15669	FGS	Cuttings	27.7678	-80.5823	FELLSMERE	24	140
111	W-15727	FGS	Cuttings	27.6539	-80.5533	SOUTH OF FELLSMERE	23	350
112	W-16127	FGS	Cuttings	27.6397	-80.6033	SOUTH OF FELLSMERE	24	820
113	W-16170	FGS	Cuttings	27.7053	-80.4617	VERO BEACH	19	900
114	W-16213	FGS	Cuttings	27.5653	-80.4558	OSLO	19	900
115	W-16218	FGS	Cuttings	27.5884	-80.4959	OSLO	22	920
116	W-16275	FGS	Cuttings	27.5950	-80.5047	EAST OF GUM SLOUGH	22	930
117	W-16558	FGS	Cuttings	27.7270	-80.4706	VERO BEACH	18	900
118	W-16673	FGS	Cuttings	27.8295	-80.8444	KENANSVILLE SE	37	460
119	W-16785	FGS	Cuttings	27.7117	-80.4708	VERO BEACH	17	960
120	W-16810	FGS	Cuttings	27.5865	-80.483	OSLO	22	250
121	W-16828	FGS	Cuttings	27.8025	-80.6264	FELLSMERE SW	21	775
122	W-16850	FGS	Cuttings	27.6967	-80.8962	FORT DRUM NW	64	590
123	W-16932	FGS	Core	27.5394	-80.6068	EAST OF GUM SLOUGH	24	116
124	W-16964	FGS	Cuttings	27.5220	-80.4045	OSLO	20	142
125	W-16976	FGS	Cuttings	27.5381	-80.9495	FORT DRUM SW	67	140
126	W-16977	FGS	Cuttings	27.5247	-80.9514	FORT DRUM SW	66	520
127	W-17025	FGS	Cuttings	27.5223	-80.4964	OSLO	25	130
128	W-17137	FGS	Cuttings	27.5439	-80.4425	OSLO	20	1000
129	W-17147	FGS	Cuttings	27.5203	-80.4069	OSLO	15	105
130	W-17464	FGS	Core	27.9881	-80.5183	GRANT	20	10
131	W-17520	FGS	Cuttings	27.8329	-80.5572	FELLSMERE	24	410
132	W-17539	FGS	Cuttings	27.7345	-80.5998	SOUTH OF FELLSMERE	24	131
133	W-17556	FGS	Core	27.6462	-80.6404	NORTH OF GUM	20	30
134	W-17619	FGS	Core	27.7117	-80.3736	RIOMAR	1	6
135	W-17623	FGS	Core	27.6817	-80.3636	RIOMAR	5	7
136	W-17625	FGS	Core	27.6114	-80.34	INDRIO	6	5
137	W-17674	FGS	Cuttings	27.7300	-80.6737	NORTH OF GUM	17	121
138	W-17690	FGS	Cuttings	27.6903	-80.5133	SOUTH OF FELLSMERE	21	440
139	W-17694	FGS	Cuttings	27.5880	-80.5786	EAST OF GUM SLOUGH	21	480
140	W-17703	FGS	Cuttings	27.5884	-80.6868	GUM SLOUGH	21	110
141	W-17714	FGS	Core	27.7633	-80.3969	SEBASTIAN	13	8
142	W-17723	FGS	Cuttings	27.7083	-80.7775	FORT DRUM NE	22	146
143	W-17724	FGS	Cuttings	27.7678	-80.5823	FELLSMERE	24	136
144	W-17725	FGS	Cuttings	27.7033	-80.7775	FORT DRUM NE	23	440
145	W-17807	FGS	Cuttings	27.5218	-80.4013	OSLO	20	70
146	W-17886	FGS	Cuttings	27.5486	-80.3689	INDRIO	35	100
147	W-17923	FGS	Cuttings	27.6464	-80.4297	KENANSVILLE	53	161
148	W-19217	FGS	Core	27.6541	-80.4031	VERO BEACH	12	3210
149	W-19227	FGS	Core	27.6541	-80.4036	VERO BEACH	17	332
150	W-19494	FGS	Cuttings	27.8698	-80.4547	SEBASTIAN	2	360
151	W-19627	FGS	Cuttings	27.8294	-80.9597	KENANSVILLE SW	73	1350
152	W-19629	FGS	Cuttings	27.5600	-80.7644	FORT DRUM	34	490
153	W-19630	FGS	Cuttings	27.6328	-80.765	FORT DRUM NE	27	22
154	W-19762	FGS	Cuttings	27.9848	-80.7504	KENANSVILLE NE	15	385
155	W-19770	FGS	Core	27.5379	-80.4823	OSLO	25	50
156	W-19776	FGS	Cuttings	27.5599	-80.7644	FORT DRUM	34	31
157	W-19777	FGS	Cuttings	27.5600	-80.7644	FORT DRUM	34	300
158	W-19785	FGS	Core	27.8248	-80.8122	KENANSVILLE SE	23	268