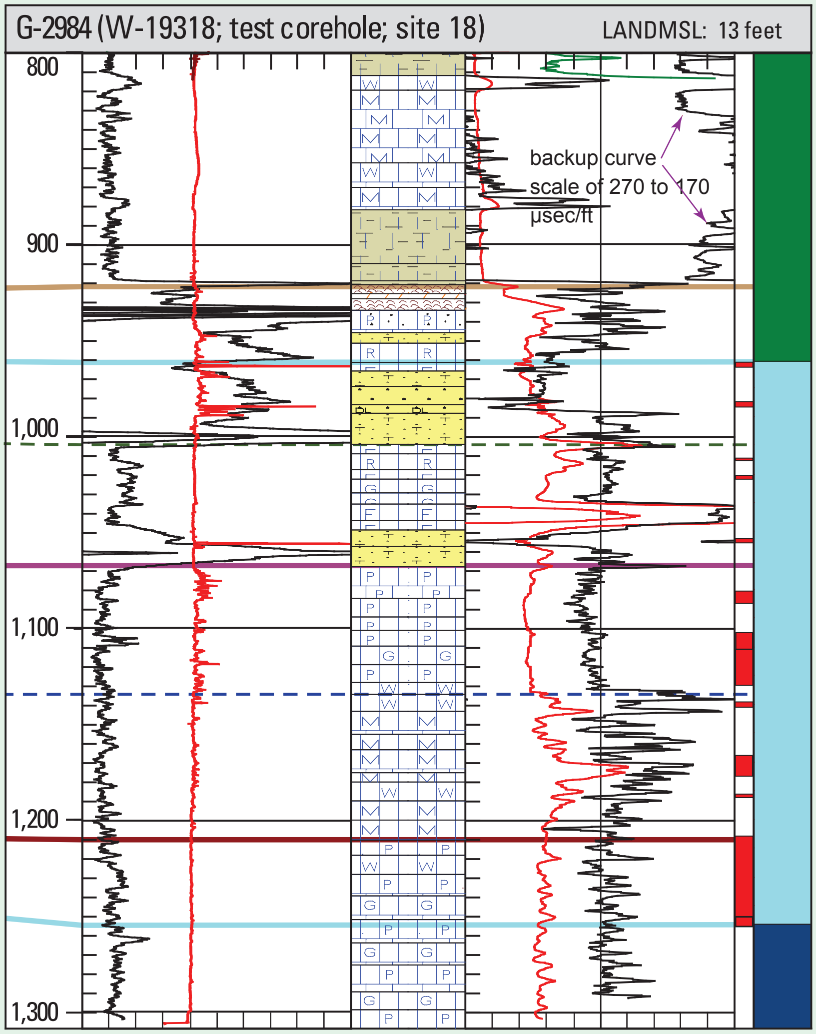
Prepared in cooperation with Broward County, Florida

Preliminary Stratigraphic and Hydrogeologic Cross Sections and Seismic Profile of the Floridan Aquifer System of Broward County, Florida



Open-File Report 2013–1141

U.S. Department of the Interior
U.S. Geological Survey

Preliminary Stratigraphic and Hydrogeologic Cross Sections and Seismic Profile of the Floridan Aquifer System of Broward County, Florida

By Ronald S. Reese and Kevin J. Cunningham

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U.S. Department of the Interior
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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)

Abbreviations

ABI	acoustic borehole image (log)
APPZ	Avon Park permeable zone
ASR	aquifer storage and recovery
bls	below land surface
FAS	Floridan aquifer system
GR	gamma-ray
GWSI	Groundwater Site Inventory (database)
LF1	uppermost major permeable zone of the Lower Floridan aquifer
LFA	Lower Floridan aquifer
MC1	middle semiconfining unit 1
MC2	middle semiconfining unit 2
OBI	optical borehole image (log)
Ω•m	ohm-meter
RO	reverse osmosis
SFWMD	South Florida Water Management District
Δt	sonic borehole geophysical log interval transit time, in microseconds per foot
UFA	Upper Floridan aquifer
USGS	U.S. Geological Survey

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

°F=(1.8×°C)+32

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

°C=(°F-32)/1.8

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29).

Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27) or North American Datum of 1983 (NAD 83).

Altitude, as used in this report, refers to distance above the vertical datum.

*Transmissivity: The standard unit for transmissivity is cubic foot per day per square foot times foot of aquifer thickness [$(ft^3/d)/ft^2$]ft. In this report, the mathematically reduced form, foot squared per day (ft^2/d), is used for convenience.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L)

Preliminary Stratigraphic and Hydrogeologic Cross Sections and Seismic Profile of the Floridan Aquifer System of Broward County, Florida

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Abstract

To help water-resource managers evaluate the Floridan aquifer system (FAS) as an alternative water supply, the U.S. Geological Survey initiated a study, in cooperation with the Broward County Environmental Protection and Growth Management Department, to refine the hydrogeologic framework of the FAS in the eastern part of Broward County. This report presents three preliminary cross sections illustrating stratigraphy and hydrogeology in eastern Broward County as well as an interpreted seismic profile along one of the cross sections. Marker horizons were identified using borehole geophysical data and were initially used to perform well-to-well correlation. Core sample data were integrated with the borehole geophysical data to support stratigraphic and hydrogeologic interpretations of marker horizons. Stratigraphic and hydrogeologic units were correlated across the county using borehole geophysical data from multiple wells. Seismic-reflection data were collected along the Hillsboro Canal. Borehole geophysical data were used to identify and correlate hydrogeologic units in the seismic-reflection profile. Faults and collapse structures that intersect hydrogeologic units were also identified in the seismic profile. The information provided in the cross sections and the seismic profile is preliminary and subject to revision.

Introduction

The Biscayne aquifer of southeastern Florida is shallow and prolific, and has provided most of the water supply in eastern Broward County during the last century. Concerns about water-level declines and saltwater intrusion in the Biscayne aquifer have limited the increase in municipal withdrawals and restricted the issuance of new water-supply well-field permits. Therefore, Broward County is considering the potential use of the brackish Floridan aquifer system (FAS) as an alternative water supply, either by direct withdrawal from supply wells or by aquifer storage and recovery (ASR, Reese and Alvarez-Zarikian, 2007), reverse osmosis (RO), or blending with freshwater from the Biscayne aquifer. The ability to select new well locations based on aquifer properties conducive to these alternative water-supply technologies requires an improved definition of the stratigraphic and hydrogeologic frameworks. In general, a stratigraphic framework describes the 3-dimensional distribution of stratigraphic units and their boundaries as identified by distinct and pervasive vertical and lateral changes in lithologic characteristics and depositional sequences. Likewise, a hydrogeologic framework describes the 3-dimensional distribution of hydrogeologic units and their boundaries as identified by distinct and pervasive vertical and lateral changes in hydrologic characteristics. The U.S. Geological Survey (USGS), in cooperation with Broward County, initiated a study in 2008 to refine the stratigraphic and hydrogeologic frameworks of the FAS in eastern Broward County to address this need.

Purpose and Scope

The purpose of this report is to present three preliminary stratigraphic and hydrogeologic cross sections and an interpreted seismic profile of the FAS in eastern Broward County (fig. 1) to help water-resource managers evaluate the FAS as an alternative water supply. The cross sections and profile provide a basis for refinement of the existing stratigraphic and hydrogeologic frameworks of the FAS in Broward County (fig. 2) described in Reese and Richardson (2008), including the introduction of subdivisions within the Arcadia and Avon Park Formations. As part of this study, a 1,308-foot-deep test corehole (G-2984) was drilled in northeastern Broward County along Hillsboro Canal (fig. 1). Data collected from G-2984 were interpreted using both a traditional lithostratigraphic approach and a sequence-stratigraphic methodology, and correlated with existing data across the

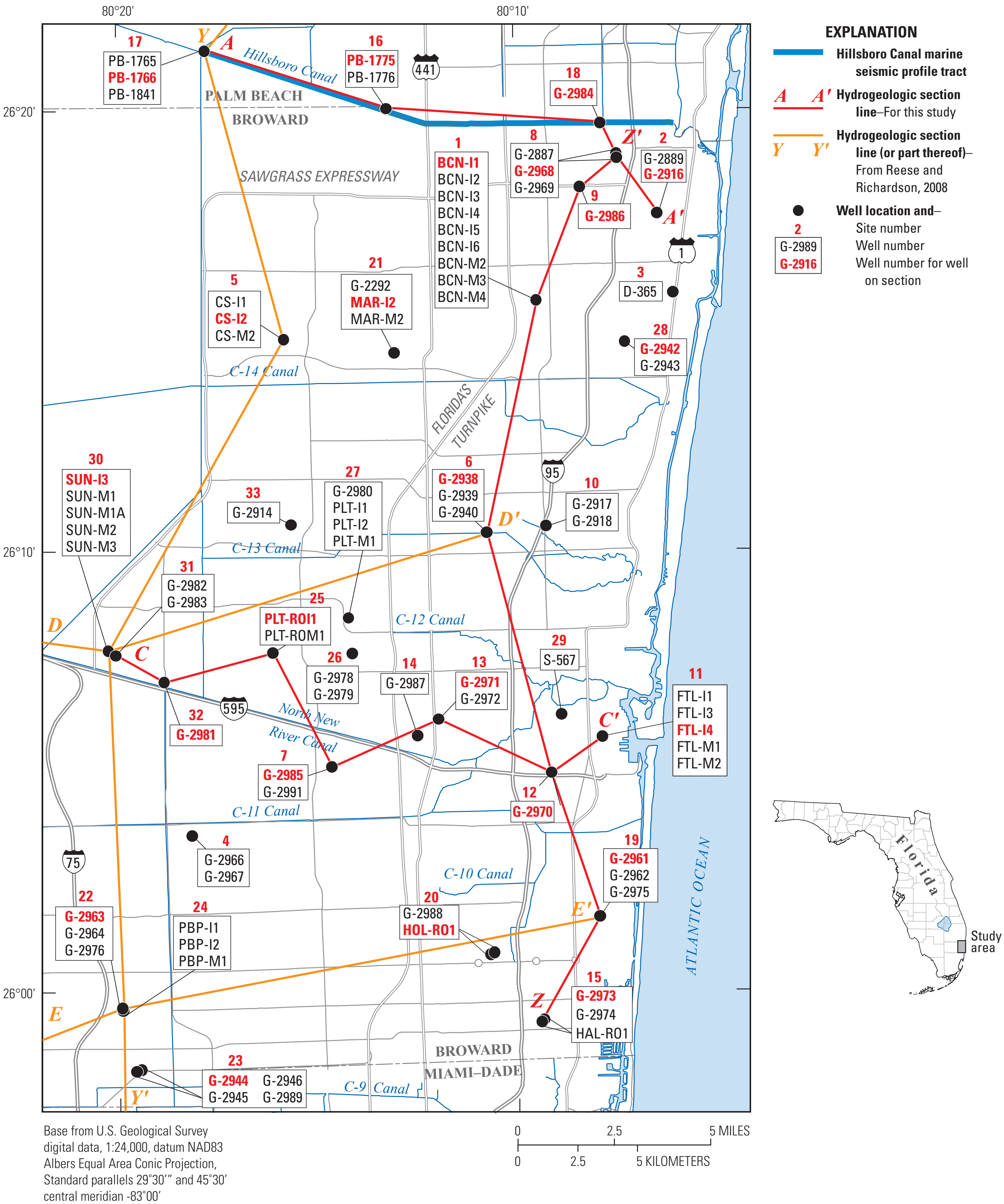
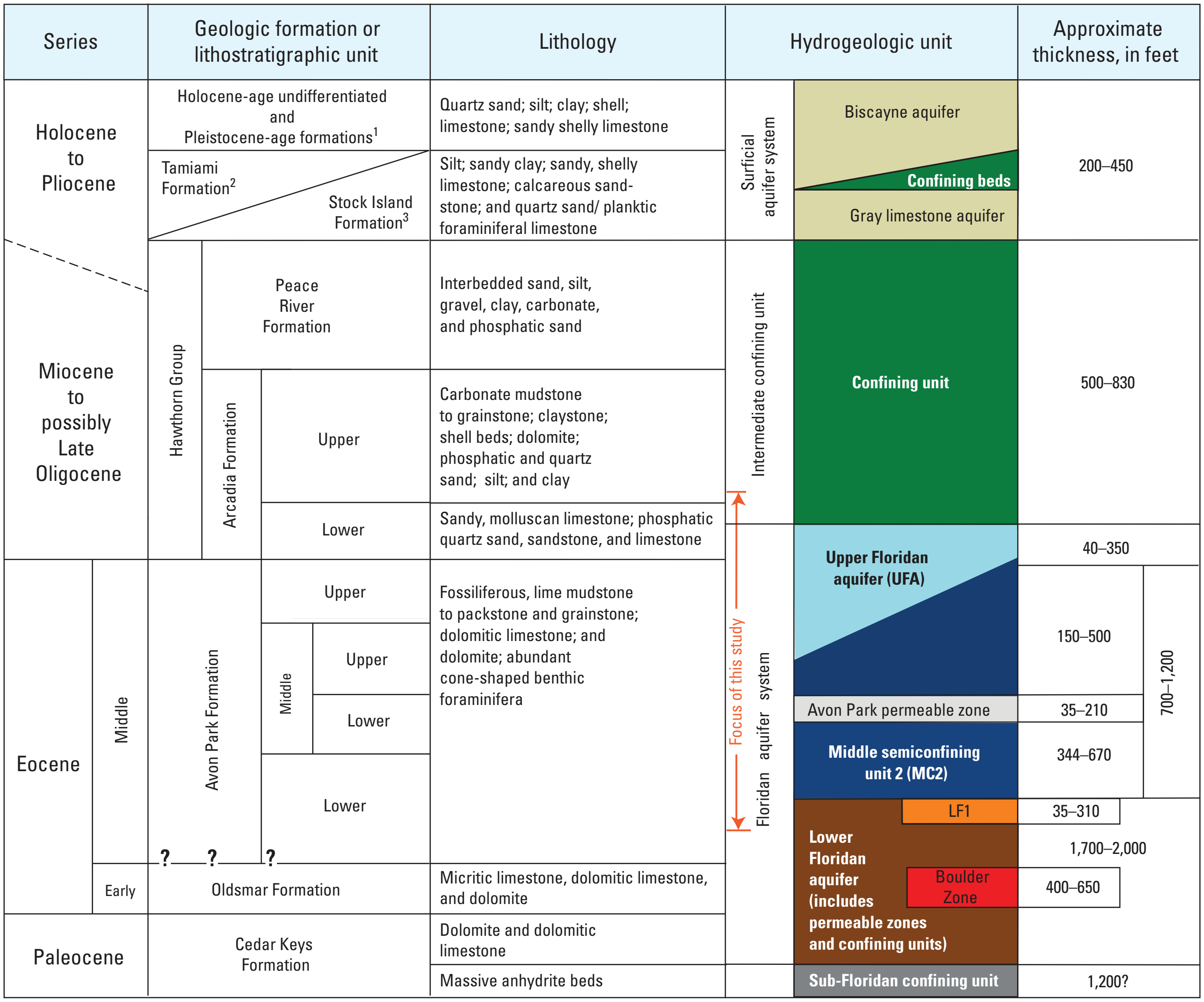


Figure 1. Location of the study area in southeastern Florida, wells used in the study, and location of hydrogeologic sections and seismic-reflection profile. Site numbers and well information are provided in table 1.



[1] Pleistocene-age formations in southeastern Florida (Pamlico Sand, Miami Limestone, Anastasia Formation, Fort Thompson Format

[2] Tamiami Formation (Pinecrest Sand Member, Ochopee Limestone Member).

[3] Stock Island Formation, after Cunningham and others, 1998.

EXPLANATION

LF1 **Uppermost major permeable zone of the Lower Floridan aquifer**

Figure 2. Stratigraphic units in the study area, generalized lithology, and correlation to hydrogeologic units. Subdivisions of the Arcadia and Avon Park Formations defined in this study are informal.

county. Seismic-reflection data acquired along the Hillsboro Canal were used mainly to define hydrogeologic units in profile, and to identify structural features that vertically intersect hydrogeologic units and provide potential pathways for the vertical transport of groundwater in the FAS. Water-quality data obtained from other studies were used to delineate the base of the brackish-water zone within the FAS in the three cross sections. The information provided in the cross sections and the seismic profile will be used to refine the stratigraphic and hydrogeologic frameworks in Broward County. This information should be considered preliminary and subject to revision.

Hydrogeologic Setting

The FAS is the deepest of three principal hydrogeologic units present in the study area and is overlain by the intermediate confining unit and shallow surficial aquifer system (fig. 2). The intermediate confining unit separates the FAS from the surficial aquifer system (fig. 2). The Biscayne aquifer, which is the primary source of freshwater in Broward County, is included within the surficial aquifer system (fig. 2). The FAS in southeastern Florida comprises a thick sequence of highly permeable carbonate strata of Paleocene to Miocene age and is part of the broad carbonate Florida Platform that extends beneath peninsular Florida. In descending order, the FAS has generally been divided into the Upper Floridan aquifer (UFA), the middle confining unit or middle semiconfining units (MC1 and MC2), and the Lower Floridan aquifer (LFA) (Miller, 1986). Reese and Richardson (2008) identified a permeable unit within the middle semiconfining unit, specifically, the Avon Park permeable zone (APPZ, fig. 2). Permeable units of the Lower Floridan aquifer include the uppermost major permeable zone of the Lower Floridan aquifer (LF1) and the Boulder Zone (fig. 2).

Sources of Data

Well data acquired for this study and existing well data (fig. 1) were used to delineate hydrogeologic units in the upper part of the FAS. Lithostratigraphic and sequence-stratigraphic units were identified in the sections and form the foundation of the stratigraphic framework. Seismic-reflection data were recorded along Hillsboro Canal (fig. 1), interpreted, and used for delineation of hydrogeologic, lithostratigraphic, and sequence stratigraphic units.

Well and Corehole Data

Information from 84 wells at 33 sites (fig. 1; table 1) was used to construct cross sections and maps of stratigraphic and hydrogeologic units. This information includes data obtained from previously drilled wells and from test corehole G-2984, drilled by the Florida Geological Survey for this study. Well identification, location, and construction information were compiled from a series of well construction reports (table 2). The data are stored in the USGS Groundwater Site Inventory (GWSI) database and can be accessed using the USGS local well identifiers (table 1).

Test corehole G-2984 (site 18) was continuously cored from the surface into the UFA to a depth of 1,308 feet (ft) below land surface. Stratigraphic markers were identified using core samples from G-2984 and correlated with optical and acoustic borehole images (OBIs and ABIs, respectively). Standard borehole geophysical data also collected from G-2984 include natural gamma-ray (GR) activity, caliper, induction resistivity, spontaneous potential, single point resistance, borehole-fluid conductivity and temperature, and sonic-interval transit time (sonic Δt) (plate 1). Logs of these types of geophysical data were used to indicate vertical changes in the rock, fluid properties, or both, within G-2984, and to correlate identified markers and units with those in other wells. Recognizable patterns in the borehole geophysical logs were used to correlate stratigraphic or hydrogeologic units between wells (plates 1, 2, and 3). Sonic Δt data collected in G-2984 provide information about relative porosity of the hydrogeologic units and spinner flowmeter data were used to locate flow zones.

Borehole geophysical data were also acquired in three additional FAS wells for this investigation, (G-2916 at site 2 and G-2939 and G-2940 at site 6; fig. 1, table 1) and include OBI, caliper, spinner flowmeter, borehole fluid properties, and induction resistivity data. Borehole geophysical data from other previously drilled wells were compiled and include GR, caliper, spontaneous potential, dual-induction and shallow resistivity, sonic Δt, borehole fluid properties, and spinner flowmeter data. In addition, existing borehole image data collected by commercial logging companies, including acoustic televiewer and formation microresistivity images, were used in this investigation.

Lithology and depositional sequences were described for cores from test corehole G-2984 and well PB-1766, and for cuttings from well G-2968 (plate 1). A total of 255 ft of FAS core material was recovered in the 355-ft interval in well G-2984; a total of 43 ft was recovered in the 248-ft intervals in well PB-1766. Additional lithologic data from wells in the study area were compiled from (1) the Florida Geological Survey online lithologic database (http://www.dep.state.fl.us/geology/gisdatamaps/litholog-temp.htm), (2) South Florida Water Management District (SFWMD) well-construction reports available at the DBHYDRO website (http://www.sfwmd.gov/portal/page/portal/xweb%20environmental%20monitoring/dbhydro%20application), and (3) SFWMD technical reports (table 2). Because lithologic descriptions provided by well-construction reports are generally based on cuttings, lithologic information from these sources was only used to support stratigraphic and hydrogeologic interpretations based on borehole geophysical data.

Marine Seismic Data

Digital, high-resolution, multichannel, water-based seismic-reflection data were acquired by the Walker Marine Geophysical Company along approximately 14 miles of the Hillsboro Canal as part of another USGS study with Broward County. These data were correlated with borehole geophysical data, OBI data, and lithologic descriptions from test corehole G-2984 and wells PB-1766 and PB-1775 (figs. 1, 3 and 4). Stratigraphic units, including some depositional sequences, and hydrogeologic units identified in the three wells were correlated with seismic reflections displayed on the 2-dimensional seismic profile (figs. 3 and 4). A sequence boundary that has been mapped regionally coincides with the top of the Arcadia Formation (Cunningham and others, 1998).

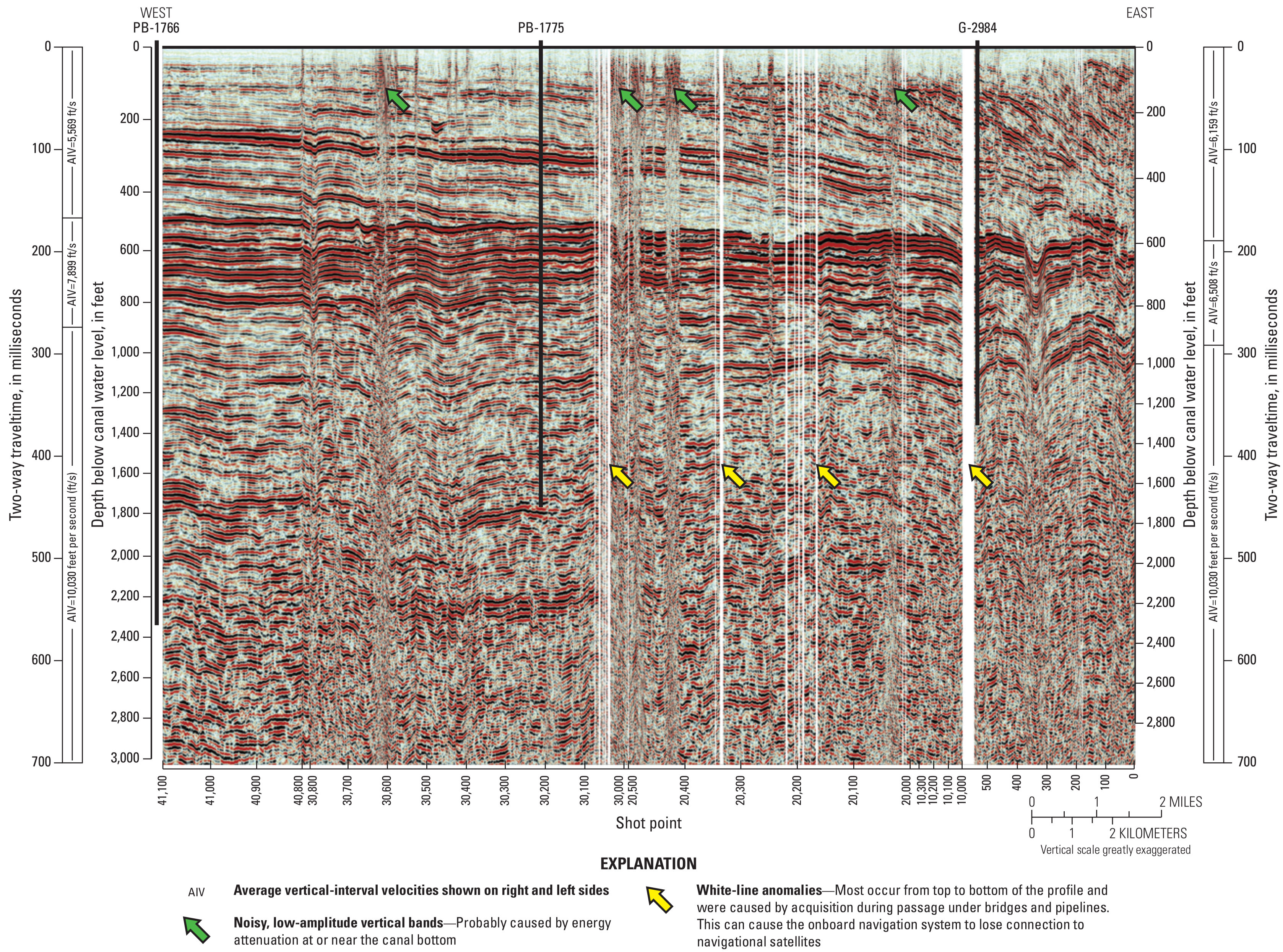


Figure 3. Uninterpreted seismic-reflection profile along Hillsboro Canal (fig. 1).

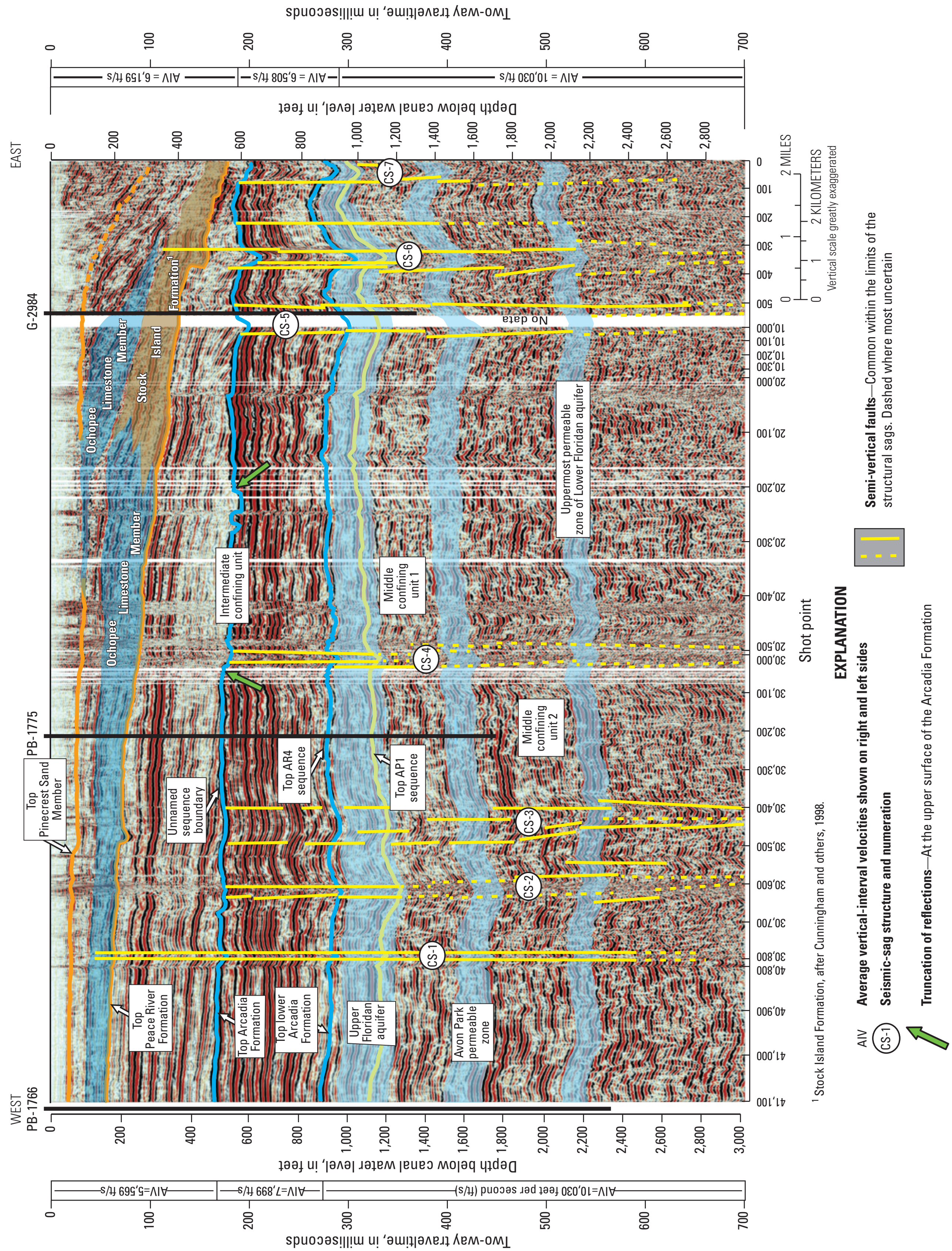


Figure 4. Preliminary interpreted seismic-reflection profile along Hillsboro Canal (fig. 1). AR4 is the top of Arcadia depositional sequence 4. AP1 is the top of Avon park depositional sequence 1.

Preliminary Stratigraphic and Hydrogeologic Cross Sections and Seismic Profile of the Floridan Aquifer System in Eastern Broward County

The cross sections and interpreted seismic profile presented herein are part of a study to refine the stratigraphic and hydrogeologic framework of the FAS in Broward County. Most of the stratigraphic and hydrogeologic units in eastern Broward County delineated here are based on Reese and Richardson (2008). The cross sections presented here provide greater vertical and lateral resolution of the distribution of hydraulic characteristics deemed important to consider in planning alternative water-supply practices. In addition, subdivisions within the Avon Park and Arcadia Formations are introduced, including the upper, upper-middle, lower middle and lower Avon Park Formation, and the upper and lower Arcadia Formation (fig. 2). Sequence stratigraphic units are also introduced, including AP1, AP2, AR1, AR2, AR3, and AR4 (plates 1, 2, and 3). Stratigraphic and hydrogeologic units were identified based on geophysical, lithologic, and hydraulic characteristics, and in the case of depositional sequences, the character of bounding surfaces. Stratigraphic boundaries in the upper part of the FAS were identified by distinct vertical changes in lithology observed in core samples from test corehole G-2984 and correlated with marker horizons identified in borehole geophysical logs (table 3). Where lithologic changes could not be identified or lithologic data were unavailable, characteristic patterns in borehole geophysical data, such as gamma-ray logs, sonic Δt logs, or both, were used to identify distinct and pervasive geophysical marker horizons that reflect changes in lithology.

In the study area, boundaries between hydrogeologic units in the FAS were determined using borehole-flowmeter and fluid-property data, borehole geophysical data, hydraulic test data (such as from aquifer and packer tests), well-to-well correlative relations, and drilling characteristics (table 4). Hydrogeologic units may be composed of one or more flow zones that were typically identified by abrupt and substantial changes in vertical borehole flow or borehole fluid properties (temperature, conductivity, or both). Where hydraulic test data or borehole flowmeter and fluid properties data were not available, hydrologic unit boundaries were based on correlation of other data between wells, including lithologic descriptions and borehole geophysical data. The geophysical data included formation resistivity, sonic Δt, natural gamma ray, borehole diameter, and spontaneous potential.

West-to-east cross sections *A–A*' and *C–C*' (plates 1 and 2), and south-to-north cross section *Z–Z*' (plate 3) show the correlation of stratigraphic and hydrogeologic units between wells in the study area. Borehole flowmeter analyses were used to indicate discrete flow zones within the intervals tested. Observed lithologic characteristics are shown for cored intervals in test corehole G-2984 and well PB-1766 as well as for well cuttings in well G-2968. Other lithologic information shown is based on well-cutting descriptions compiled from sources listed in table 2. Depositional sequences and the base of the brackish-water zone in the FAS are shown on these cross sections.

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