U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Prepared in cooperation with the
SOUTH FLORIDA WATER MANAGEMENT DISTRICT and U.S. ARMY CORPS of ENGINEERS
as part of the
COMPREHENSIVE EVERGLADES RESTORATION PLAN

SCIENTIFIC INVESTIGATIONS MAP I-2846
Cunningham, K.J. and others, 2004, Hydrogeology and ground-water flow at Levee 31N, Miami-Dade County, Florida, July 2003 to May 2004

Sequence Stratigraphy

In this report, sequence stratigraphic relations are described for the Pleistocene carbonate rocks that form the Biscayne aquifer. Critical to defining this sequence stratigraphy was delineation of the lithofacies of the Miami Limestone and Fort Thompson Formation. Sixteen lithofacies comprise the upper Fort Thompson Formation and Miami Limestone (Cunningham and others, 2004b). Eleven of these facies form important stratal components in the Fort Thompson Formation and Miami Limestone at the Levee 31N study area. Cunningham and others (2004b) defined these facies to include: (1) peloid grainstone and wackestone; (2) peloid wackestone and packstone; (3) gastropod floatstone and rudstone; (4) mudstone and wackestone; (5) pedogenic limestone (laminated calcrete, massive calcrete, and root-mold limestone); (6) skeletal grainstone and packstone; (7) pelecypod floatstone and rudstone; (8) sandy pelecypod floatstone and rudstone; (9) touching-vug (Lucia, 1999) pelecypod floatstone and rudstone; (10) sandy, touching-vug pelecypod floatstone and rudstone; and (11) quartz sandstone and skeletal sandstone (fig. 3).

Delineation of Vertical Lithofacies Successions and High-Frequency Cycles

Vertical lithofacies successions (VLSs) are the smallest set of genetically related lithofacies that form the fundamental building blocks of the Biscayne aquifer. Individual high-frequency cycles (HFCs) are defined by single or repetitive VLSs (fig. 3). Kerans and Tinker (1997) indicated that HFCs are comparable to the parasequences of Van Wagoner and others (1988). Marine flooding surfaces occur at or near the upper and lower boundaries of each VLS and HFC. A marine flooding surface is a surface separating younger from older strata across which water depth abruptly increases (Van Wagoner and others, 1988). All bounding surfaces of HFCs contain evidence of alteration by subaerial exposure; however, surfaces bounding VLSs and associated host rock do not always display such evidence of subaerial exposure (fig. 3). Alveolar textures (Goldstein, 1988) in host rock below upper bounding surfaces of VLSs in the Fort Thompson Formation provide evidence for subaerial exposure in some instances (fig. 4). Nonetheless, surfaces bounding VLSs with or without evidence of subaerial exposure are flooding surfaces (fig. 3). Subaerial exposure surfaces bounding HFCs are regional in extent across the southern part of the Florida platform (Perkins, 1977), with those unique to VLSs having an indeterminate extent.

In this study, VLSs are related to a single rise and fall in relative sea level in the less than 10- to 100-kiloyear duration range (fifth order and higher). The HFCs develop during fifth-order 10- to 100-kiloyear sea-level cycles (Kerans and Tinker, 1997). As shown in figure 3, the HFCs of the Miami Limestone and Fort Thompson Formation are equivalent to the Quaternary (Q) units of Perkins (1977), which have been interpreted to be the result of eustatic sea-level oscillations (Perkins, 1977; Multer and others, 2002; Hickey, 2004). Bundled VLSs might be related to allocyclic forces such as high-frequency, sub-Milankovitch sea-level cycles (Locker and others, 1996; Mundil and others, 1996) or tectonically driven sea-level changes (Galli, 1991). Alternatively, bundled VLSs may be associated with repeated autocyclic progradation and marine flooding of paralic environments that include freshwater marshes and ponds, or migration of shallow-water mud mounds and islands similar to those in Florida Bay (Enos and Perkins, 1979).

Most VLSs and HFCs can be correlated using unique attributes such as the vertical arrangement of lithofacies at the cycle scale, diagenetic overprints, and the vertical order of the stacking of VLSs and HFCs. The one-dimensional sequence stratigraphic framework or fingerprint of each well permitted discrete correlation of VLSs and HFCs and the hydraulic interconnection between wells (well-to-well connection of corresponding ground-water flow classes).

High-Frequency Cycles of the Levee 31N Study Area

Stratigraphic research conducted since the late 1970s has improved the resolution of the sequence stratigraphic framework of the Fort Thompson Formation and Miami Limestone in southeastern Florida as reported by previous investigators. Perkins (1977) first divided the two rock formations into five unconformity-bound or Q units (fig. 3). Galli (1991) further delineated the Fort Thompson Formation as a single depositional sequence containing eight parasequences defined "as sequences representing higher frequency, short-term phases of sedimentation." Harrison and others (1984) and Multer and others (2002) subdivided the Q4 and Q5 units of Perkins, and Multer and others (2002) refined ages of some of the Q units (Q3, Q5e, and post Q5e). Droxler and others (2003) and Hickey (2004) discussed various correlation scenarios of Q-units of Perkins (1977) and Multer and others (2002) to late Pleistocene interglacial marine isotope stages. Cunningham and others (2004b) recognized two subaerial exposure bounded units within the Q3 unit of Perkins (1977), which may be related to a sea-level fluctuation discussed by Multer and others (2002).

In the vicinity of the Levee 31N study area, only HFC2 to HFC5 corresponded to the Q2 to Q5 units of Perkins (1977) as shown in figure 3. The four HFCs are each bound at the upper surface by laminated calcretes (fig. 3) correlated throughout southeastern Florida (Perkins, 1977; Multer and others, 2002). Preliminary mapping of the sequence stratigraphy of the Fort Thompson Formation in north-central Miami-Dade County suggests that the Q1 unit of Perkins (1977) is not present in the Levee 31N study area. In fact, this unit may onlap onto the top of the Tamiami Formation east of the study area.

Ideal Cycles in the Levee 31N Study Area

Paralic cycles and subtidal cycles are two types of ideal cycles that occur in the Pleistocene limestone of the Biscayne aquifer. These cycles have similarities in that both shallow upward; however, subaerial exposure features may or may not be evident at the upper surface of the paralic cycles, which typically are capped by freshwater deposits (fig. 3). Incomplete paralic cycles are capped by brackish or restricted marine deposits (fig. 3). Evidence of tidal flat deposition, such as algal laminations and mud cracks (Shinn and others, 1969), are rare occurrences in the paralic cycles. The middle part of the paralic cycles can be composed of skeletal packstone or grainstone lithofacies, whereas the lower part typically is either touching-vug pelecypod rudstone or floatstone or sandy, touching-vug pelecypod rudstone or floatstone. Common benthic foraminifers (archaiasinids, soritids, and peneroplids) in the lower and middle units are consistent with relatively open-marine shelf deposition (Rose and Lidz, 1977). Upper brackish beds have an abundance of the benthic foraminifera *Ammonia* and smooth-shelled ostracodes; less commonly, the beds contain charophytes, the benthic foraminifer *Elphidium*, and gastropods that can include *Planorbella*. Rose and Lidz (1977) suggested modern Florida Bay sediments that contain large populations of *Ammonia* and *Elphidium* and that contain relatively few total species are indicative of a brackish interior environment. Upper freshwater strata are composed of gastropod floatstone and rudstone containing *Planorbella* (commonly in abundance), smoothed-shelled ostracodes, and charophytes and were probably deposited in a freshwater marsh or pond (Galli, 1991).

Subtidal cycles represented by HFC4 and HFC5 may be restricted to only the Miami Limestone (fig. 3). These subtidal cycles are described in detail by Cunningham and others (2004b).

Pore System

Vacher and Mylroie (2002) described the Biscayne aquifer as an eogenetic karst aquifer system that best fits a dual-porosity conceptual model. Pore system type in the Biscayne aquifer is related to lithofacies, and has a predictable vertical distribution within fundamental cycles. Each carbonate lithofacies, and its typically associated pore system type, has been assigned to one of three ground-water flow classes defined by Cunningham and others (2004b): (1) horizontal conduit flow; (2) diffuse-carbonate flow; and (3) leaky, low-permeability flow (fig. 3). Holocene sediments of the Biscayne aquifer have been assigned to the low-permeability peat, muck, and marl ground-water flow class (Cunningham and others, 2004b). Discussion of the pore system of the Biscayne aquifer is restricted to the Fort Thompson Formation. Details of the Miami Limestone pore system are discussed in Cunningham and others (2004b).

Characteristic lithofacies associated with the horizontal conduit ground-water flow class are touching-vug pelecypod rudstone and floatstone or sandy, touching-vug pelecypod rudstone and floatstone; both are common in the lower parts of paralic cycles of the Fort Thompson Formation. These lithofacies typically are characterized by large fossil molds, solution-enlarged fossil molds, or vugs with shapes and spatial relations, suggesting they are either molds of burrows or voids that surround casts of burrow molds. Accordingly, the lower part of many of the paralic cycles is the most porous and permeable. Porous-zone maps in north-central Miami-Dade County suggest a tabular three-dimensional geometry (Cunningham and others, 2004b) for these zones. Therefore, an accurate correlation of cycles produces a realistic linkage of permeable or preferential flow zones. Ground-water flow for the horizontal conduit flow class is conceptualized as ground water flowing from vug to vug in a pore system characterized by touching vugs (Lucia, 1999, p. 26 and 31). Ground-water flow associated with this ground-water flow class is not through pipes or underground streams, but along a passage (typically tabular in shape) formed by touching vugs that act as a major route for ground-water flow.

The middle part of the ideal paralic cycle of the Fort Thompson Formation is characterized by a skeletal packstone or grainstone lithofacies, which are associated with the diffuse-carbonate ground-water flow class. These lithofacies are characterized by interparticle, intraparticle, and irregular separate vug pore space that facilitates ground-water movement through vug-to-matrix-to-vug connections.

Gastropod floatstone and rudstone or mudstone and wackestone lithofacies typically cap the paralic cycles, which are associated with the leaky, low-permeability ground-water flow class. Secondary porosity common to these lithofacies includes bedding plane vugs, thin semivertical solution pipes, and gastropod molds. The matrix porosity of these lithofacies is relatively low, and the gastropod molds and solution pipes are localized and typically separated. Bedding plane vugs that have a sheet-like geometry, however, could represent significant conduits for moving large volumes of ground water.

GROUND-WATER FLOW

The highest water levels in Miami-Dade County are maintained in Water Conservation Areas (WCA) 3A and 3B (fig. 1). In a regional sense, ground water moves from WCA 3A and 3B eastward and southward to the ocean (Fish and Stewart, 1991). Canals, control structures, or large well fields cause local variations in the flow pattern. During the wet season, ground-water seepage from WCA 3A and 3B is partly captured by peripheral canals, but large quantities pass under the canals or across the canals (Fish and Stewart, 1991). Ground-water flow directions interpreted by Fish and Stewart (1991) generally show that ground-water flows toward the study area from the west and northwest during the wet and dry seasons.

Data collected for use in delineating ground-water flow beneath Levee 31N included water-level data and borehole-flowmeter, fluid-conductivity, and fluid-temperature data. The water-level data were obtained as continuous ground- and surface-water-level readings. Borehole flowmeters can be used to measure vertical flow within a single well and to use these data to identify water-producing zones in open-hole wells. For this study, flowmeter data were used to quantify vertical ground-water flow under existing hydraulic conditions in wells along Levee 31N in order to examine differences in the vertical hydraulic gradient between hydrostratigraphic zones of the Biscayne aquifer (fig. 5). Stationary heat-pulse flowmeter measurements within the limestone of the Biscayne aquifer were obtained from wells G-3671, G-3778, G-3782, G-3783, G-3784, G-3788, and G-3789.

Logs of fluid conductivity, the reciprocal of fluid resistivity, were used to assess changes in borehole-fluid column salinity. Fluid-temperature logs were used in combination with flowmeter data to define movement of water through wells, including delineation of intervals that produce or accept water; thus, these logs can provide information about permeability. Fluid-conductivity and fluid-temperature logs were collected from wells G-3671, G-3778, G-3782, G-3783, G-3784, G-3788, and G-3789 (fig. 1).

In the subsequent sections, water-level data are reported for a period from February 12 to May 4, 2004, during the dry season; flowmeter measurements are reported for a period from August 8 to September 16, 2003; and borehole-fluid conductivity and fluid temperature are reported for a period from July 7 to September 16, 2003. Both summer time periods were during the wet season. Water-level, flowmeter, conductivity, and temperature data were not collected during synoptic conditions and were recorded in a hydrologic system subject to transient changes in hydraulic gradient. A comparative analysis between ground-water levels, surface-water levels, flowmeter, conductivity, and temperature data is considered to be inappropriate. Additionally, flowmeter, conductivity, and temperature data were collected quasi-synoptically and should be treated with caution.

Water-Level Data

Ground-water-level data were collected from the northern and southern monitoring well clusters, each composed of four monitoring wells completed in the surficial aquifer system, and wetland surface-water stage was obtained from a recorder (NESRS2) in ENP about 4 miles southwest of the northern well cluster (figs. 1 and 6). Rainfall was monitored at a station (K8652) located at structure S-334 (figs. 1 and 6). At both monitoring well clusters, each well was completed with a single 2-foot screened interval, but at different depths to isolate separate hydrogeologic zones. The deepest well is screened in the semiconfining unit that includes the upper clastic unit of the Tamiami Formation (fig. 4). The other three wells are completed in separate highly permeable flow zones contained in the lower, middle, and upper parts of the Biscayne aquifer (figs. 4 and 5).

Two well-construction strategies influenced selection of the screened interval depths in the two wells completed in the semiconfining unit that includes the upper confining unit of the Tamiami Formation and the six wells screened in the Biscayne aquifer (figs. 4 and 5). The depths of the screened intervals in the upper semiconfining unit of the Tamiami Formation were selected on the basis of three criteria: porosity, depth, and log signature. The depths correspond to a: (1) hydrogeologic unit characterized by relatively high porosity and assumed relatively high permeability based on low SPT blow counts and geologic evaluation of SPT samples; (2) depth of about 90 feet below NAVD 88; and (3) geologic interval with correlativity using gamma-ray log signatures (fig. 4). Depth selection of screened intervals in the six monitoring wells (figs. 4 and 5) completed within the Biscayne aquifer was based on different criteria. The depths correspond to a: (1) hydrologic zone interpreted as representing the horizontal conduit ground-water flow class, and (2) zone of high permeability assumed to have lateral continuity between the two monitoring well clusters. Both conditions were met with the screened intervals constructed within the upper Biscayne aquifer or HFC5 (figs. 4 and 5). However, inaccurate well depth accounting procedures employed during monitoring well construction resulted in a partially screened middle Biscayne conduit flow zone (VLS3a in well G-3785), and mismatched VLS screened intervals within the lower Biscayne aquifer (VLS2c in well G-3779 and VLS2d in well G-3785) (figs. 4 and 5). It is not known whether well-construction screen-completion errors that result in "miscorrelated" flow units at wells G-3779 and G-3785 significantly impact comparison of lower Biscayne aquifer vertical hydraulic gradients.

Comparison of hydrographs from February 12 to May 4, 2004, at the northern and southern monitoring well clusters and surface-water stage in ENP indicates there was good hydraulic connection between the wetlands and the aquifer, as demonstrated by changes in surface-water stage reflected in water-level trends within the aquifer (fig. 6). Precipitation-driven changes in surface-water stage produced a rapid increase in ground-water levels. At both monitoring well clusters, vertical head differences between the upper semiconfining unit of the Tamiami Formation and various flow zones of the Biscayne aquifer were generally less than 0.4 foot (fig. 6A-B). Additionally the vertical gradients at both monitoring well clusters generally had a similar response to rainfall events and periods of ground-water decline (fig. 6). The vertical hydraulic gradient of the semiconfining unit (Tamiami Formation) was upward at the northern monitoring well cluster, whereas the overlying lower Biscayne was downward; an upward vertical gradient characterized both the middle and upper Biscayne aquifer relative to the lower Biscayne aquifer (fig. 6A). Vertical gradients at the southern monitoring well cluster were temporally variable. Between middle February to late March 2004, water levels in the upper and middle Biscayne aquifer and in the semiconfining unit were approximately equivalent; the lower Biscayne aquifer exhibited a downward vertical gradient (fig. 6B). In late March to early May 2004, the vertical hydraulic gradient of the semiconfining unit (Tamiami Formation) was upward, whereas nearly equivalent water levels within the Biscayne aquifer were downward (fig. 6B).

Flowmeter Data

The direction of vertical borehole flow in test coreholes and monitoring wells between August 8 and September 16, 2003, varied within the Biscayne aquifer (figs. 7 and 8). In general, the direction of vertical borehole flow in test coreholes G-3782, G-3783, and G-3788 and monitoring well G-3784 was downward within the Biscayne aquifer, whereas in test coreholes G-3671 and G-3789, the direction was upward. The vertical borehole flow direction in monitoring well G-3678 was mixed, with upward flow in much of the middle and most of the lower Biscayne aquifer, except near the lower part of the middle. The varying flow directions in G-3778, G-3782, G-3783, and G-3788 suggest possible confinement or semiconfinement between the more permeable flow zones of the Biscayne aquifer. Semiconfinement is defined as a leaky confining unit or units (Wilson and Moore, 1998).

Borehole-Fluid Conductivity and Temperature Data

Borehole-fluid conductivity and temperature data were collected between July 7 and September 16, 2003, from the wells (test coreholes and monitoring wells) in the Biscayne aquifer with varying results (figs. 7 and 8). Borehole-fluid conductivity ranged from about 280 to 725 µS/cm (microsiemens per centimeter) throughout the Biscayne aquifer along the Levee 31N canal reach between wells G-3671 and G-3789. The conductivity of the surface water in the Levee 31N canal was 855µS/cm near the southern monitoring well cluster on June 22, 2004, which is about 130 µS/cm higher than any measurements of borehole fluid in any of the wells. The lowest borehole-fluid conductivity was in the shallow subsurface and was highest in the lower part of the Biscayne aquifer.

Fluid conductivity is directly related to salinity, with low and high values of conductivity corresponding to low and high values of salinity, respectively. The fluid conductivity measured along the canal reach indicates that the salinity of borehole fluid mostly decreased upward within the Biscayne aquifer in each of the seven wells shown in figure 7. Relatively low conductivities were observed in wells G-3782, G-3783, G-3784, and G-3788 and correspond to the same area where there was mostly downward movement of borehole fluid. The conductivity data suggest that the Biscayne aquifer may be recharged mostly by lower salinity surface water from the ENP wetlands in the reach of the Levee 31N canal spanning wells G-3782 and G-3788. Surface water in the Levee 31N canal was probably excluded as a source of recharge of the Biscayne aquifer by the markedly higher conductivity (855 µS/cm) than measured in the boreholes. Additionally, the conductivity pattern shown in figure 7 suggests that higher salinity Biscayne aquifer ground water may have dominated the ground-water flow field west of Levee 31N, and there was more limited surface-water recharge in the southern and northern parts of the study area.

Between wells G-3671 and G-3789, the measured borehole-fluid temperature in the Biscayne aquifer between July 7 and September 16, 2003, ranged from about 75.2 to 87.8 degrees Fahrenheit (fig. 8). Thick sections of relatively high temperatures were observed in wells G-3782, G-3783, G-3784, and G-3788 and correspond to the same area where, on the basis of heat-pulse flowmeter measurements, there was downward movement of borehole fluid. Therefore, the temperature data suggest that the Biscayne aquifer may have been recharged mostly by warmer surface water from the ENP wetlands in the reach of the Levee 31N canal spanning wells G-3782 and G-3788. Borehole-fluid temperature diminished with depth in most wells; temperatures were lowest at the southernmost and northernmost parts of the study area as shown in figure 8. This latter temperature pattern suggests that cooler Biscayne aquifer ground water may have dominated the flow field west of Levee 31N, and there was more limited surface-water recharge in the southern and northern parts of the study area.

SUMMARY

The stratigraphy of the Biscayne aquifer at the Levee 31N study area is characterized by vertical lithofacies successions (VLSs) that occur individually or bundled within high-frequency cycles (HFCs). The VLSs are the smallest set of genetically related lithofacies and represent the fundamental building blocks of the Biscayne aquifer. The HFCs are defined on the occurrence of regional-scale bounding upper and lower exposure surfaces and their likely relation to fifth-order, 10-to100-kiloyear cyclic sea-level events. The VLSs are related to a single rise and fall in relative sea level in the less than 10- to 100-kiloyear duration range (fifth order or higher), suggesting an association with sub-Milankovitch frequencies observed in patterns of cyclic deposition within the Fort Thompson Formation.

Two types of ideal cycles have been defined for the Pleistocene limestone of the Biscayne aquifer: paralic and subtidal cycles. Paralic cycles are typically composed of shallow-marine shelf facies that shallow upward and are capped by freshwater deposits. Incomplete paralic cycles are capped by brackish or restricted marine deposits. The thicknesses of paralic cycles largely mimic the accommodation (plus decompaction) that occurs during the deposition of each cycle. Subtidal cycles are typical of the Miami Limestone and represented by HFC4 and HFC5.

A dual-porosity conceptual model is used to characterize the eogenetic karst Biscayne aquifer. This system contains vertically stacked interlayered conduit and diffuse-carbonate flow zones and leaky, low-permeability zones, which are placed within the context of a nested arrangement of VLSs and HFCs. The porosity and permeability of the Biscayne aquifer are highly heterogeneous and anisotropic, and mostly related to secondary porosity that overprints vertically stacked lithofacies within VLSs.

Three ground-water flow classes were defined for the Biscayne aquifer based on subdividing the range of types of ground-water flow that occurs in the aquifer according to unique categories of lithologies and kinds of pore systems that are contained in each flow class: (1) horizontal conduit; (2) diffuse carbonate; and (3) leaky, low permeability. Throughout much of the aquifer, horizontal conduit flow zones are characterized by touching-vugs that have coalesced to form a tabular shape. These porous zones typically occur directly above flooding surfaces. Ground-water flow for the conduit flow class is envisioned as a system in which ground-water movement occurs from vug to vug, rather than a system of pipes or subsurface streams; water moves along a tabular-shaped passage formed by touching vugs that function as a major route for ground-water flow. Diffuse-carbonate flow is envisioned within lithofacies devoid of touching-vug porosity; the movement of ground water occurs within a small-scale network of interparticle, intraparticle, and separate-vug porosity as flow through vug-to-matrix-to-vug connections. Ground-water flow within the leaky, low-permeability flow zones probably occurs at a relatively small scale within semivertical vugs and irregular pores that transect a very low permeability matrix, except where bedding plane vugs are present. Bedding plane vugs, which have a sheet-like geometry, could represent significant conduits for moving large volumes of ground water.

Multiple lines of evidence, including water-level data, flowmeter measurements, fluid conductivity, fluid temperature, and mapped zones of stratigraphically controlled high relative porosity strongly suggest that the limestone of the Biscayne aquifer is a mosaic of semiconfining units and preferential flow zones. The geologic attributes of each VLS and HFC and their combined vertical arrangement was critical to correlation of flow zones in the Levee 31N study area. As shown herein, sequence stratigraphy is useful in predicting the spatial distribution of ground-water flow zones within an eogenetic karst carbonate aquifer.

Comparison of hydrographs (during a dry season period in 2004) at the two monitoring well clusters along Levee 31N and surface-water stage in ENP indicates there was good hydraulic connection between the wetlands and the aquifer. Precipitation-driven changes in surface-water stage produced a rapid increase in ground-water levels. For a wet-season period in 2003, borehole flowmeter, fluid-conductivity, and fluid-temperature data suggest that: (1) the Biscayne aquifer beneath Levee 31N was mostly recharged by relatively low-salinity, warm surface water from the ENP wetlands along the canal reach spanning wells G-3782 and G-3788; and (2) there was possible confinement or semiconfinement between the more permeable flow zones of the Biscayne aquifer. Mapped patterns of borehole-fluid conductivity and temperature suggest that relatively higher salinity, cooler Biscayne aquifer ground water may have dominated the flow field west of Levee 31N, and there was more limited surface-water recharge in the most southern and northern parts of the study area.

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88), except for figure 2 where the 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 1983 (NAD 83). Altitude, as used in this report, refers to distance above the vertical datum.

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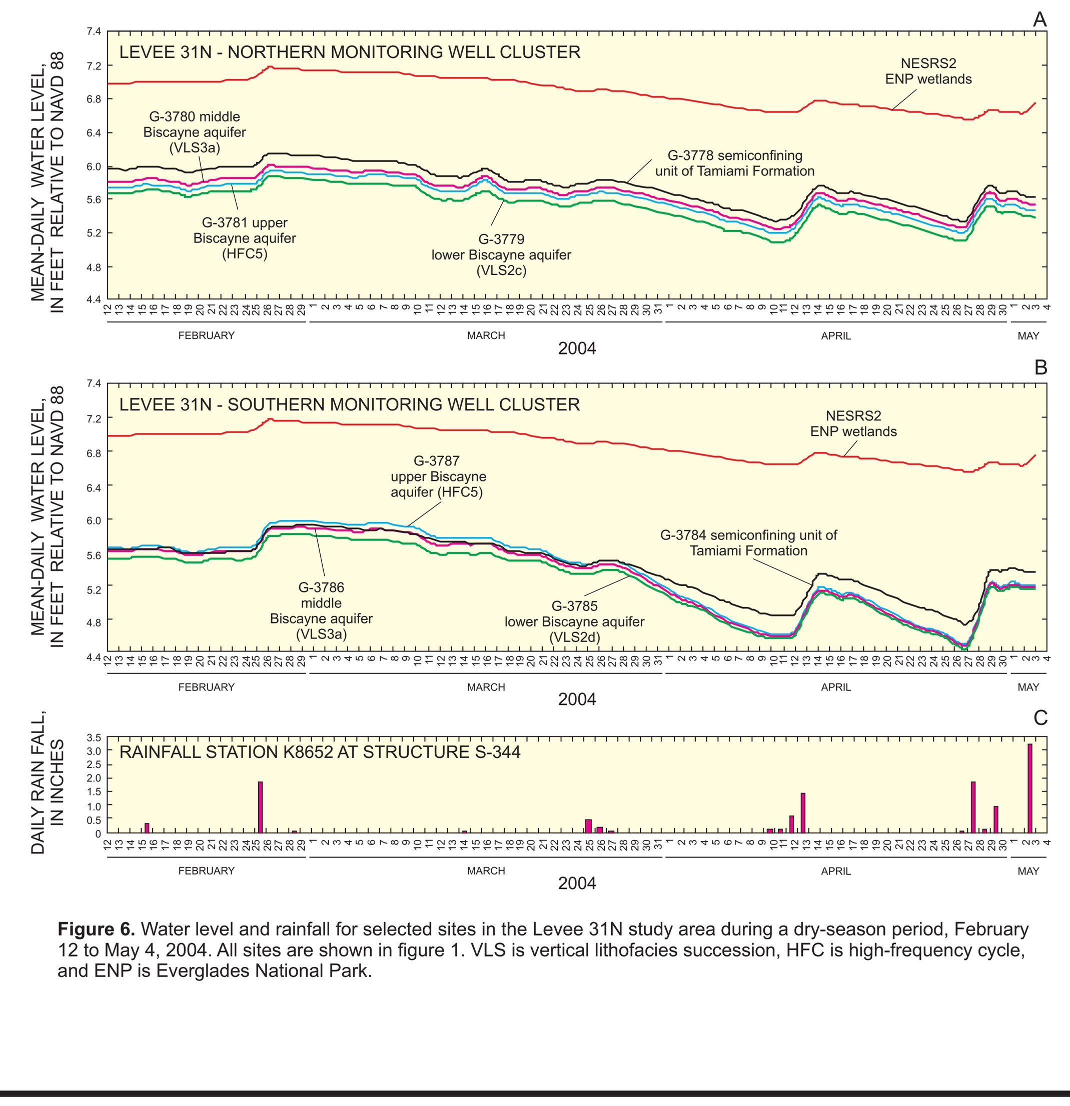

Figure 6. Water level and rainfall for selected sites in the Levee 31N study area during a dry-season period, February 12 to May 4, 2004. All sites are shown in figure 1. VLS is vertical lithofacies succession, HFC is high-frequency cycle, and ENP is Everglades National Park.

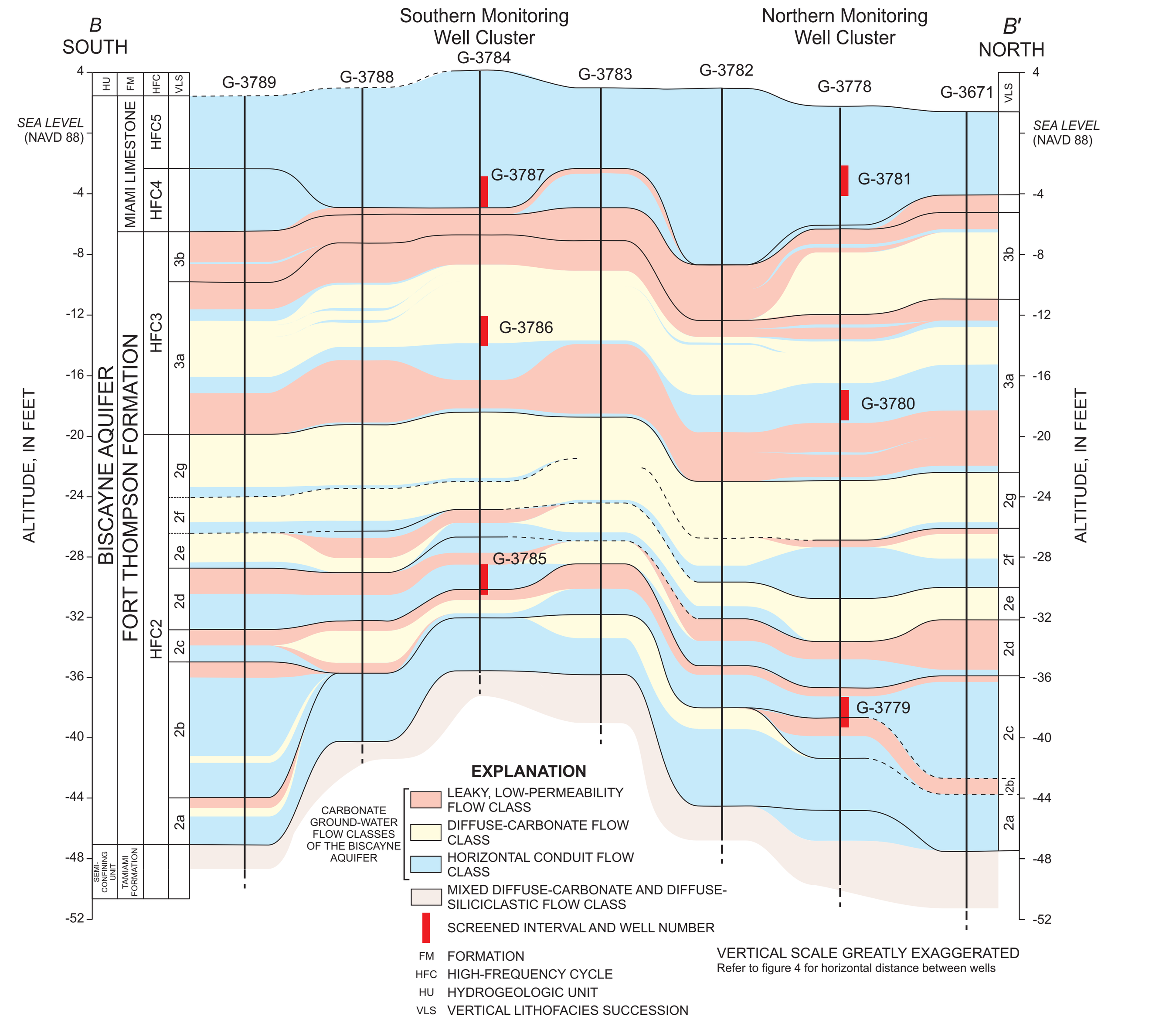

Figure 5. Hydrogeologic section showing ground-water flow classes in the Biscayne aquifer along Levee 31N (section *B-B′*). Line of section is shown in figure 1.

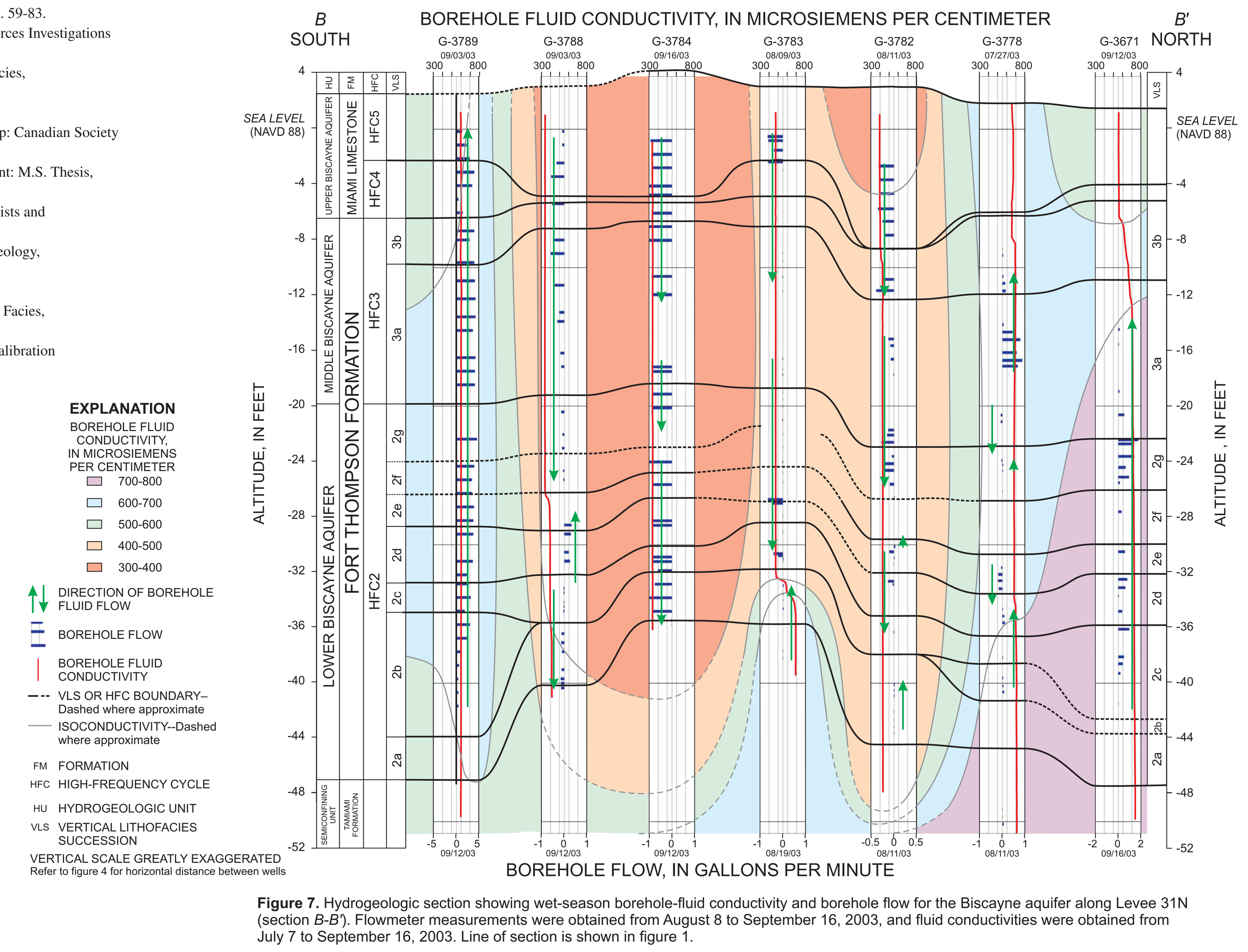

Figure 7. Hydrogeologic section showing wet-season borehole-fluid conductivity and borehole flow for the Biscayne aquifer along Levee 31N (section *B-B′*). Flowmeter measurements were obtained from August 8 to September 16, 2003, and fluid conductivities were obtained from July 7 to September 16, 2003. Line of section is shown in figure 1.

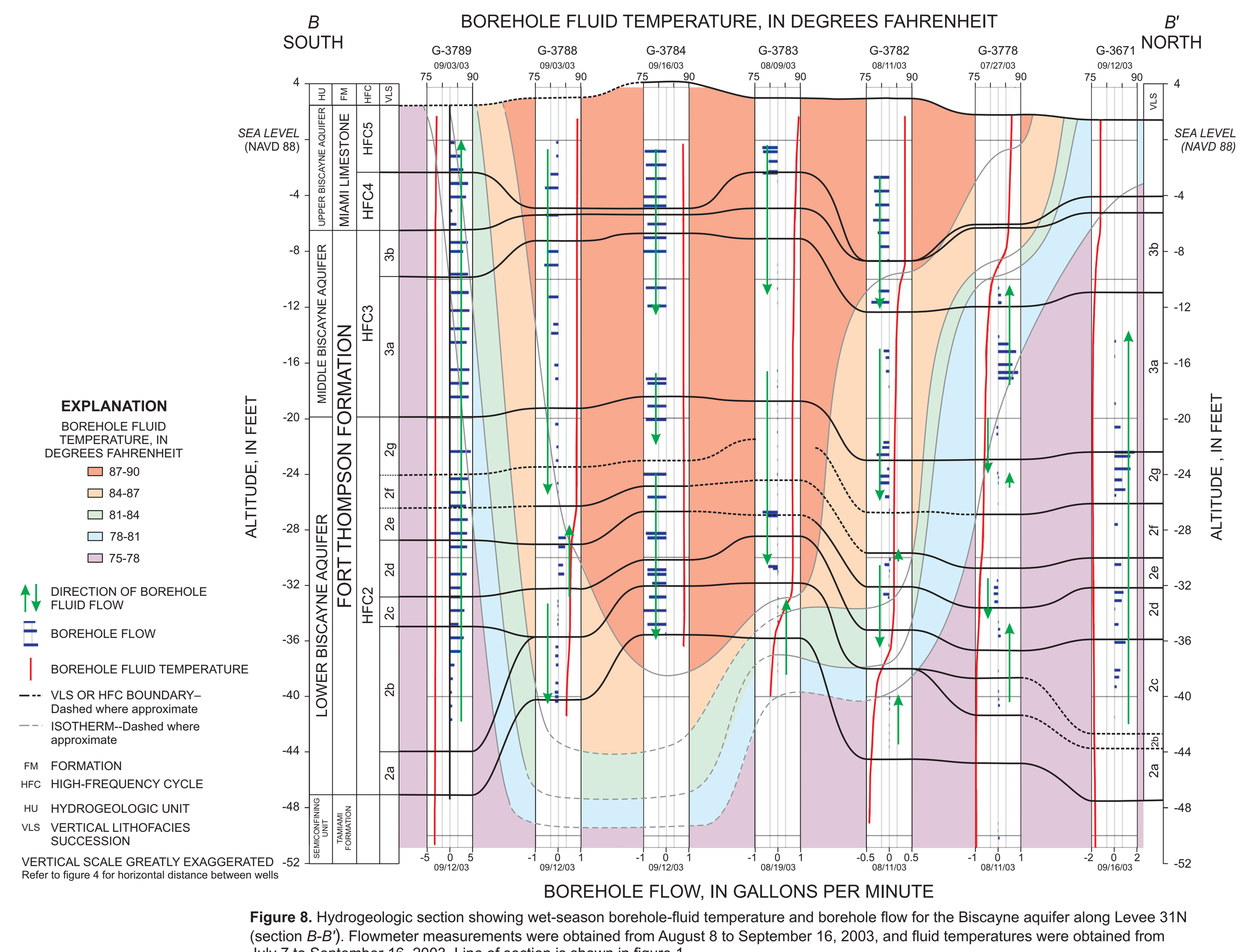

Figure 8. Hydrogeologic section showing wet-season borehole-fluid temperature and borehole flow for the Biscayne aquifer along Levee 31N (section *B-B′*). Flowmeter measurements were obtained from August 8 to September 16, 2003, and fluid temperatures were obtained from July 7 to September 16, 2003. Line of section is shown in figure 1.

HYDROGEOLOGY AND GROUND-WATER FLOW AT LEVEE 31N, MIAMI-DADE COUNTY, FLORIDA, JULY 2003 TO MAY 2004

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2004