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Florida Water Science Center Newsletter Volume 1, Summer 2014

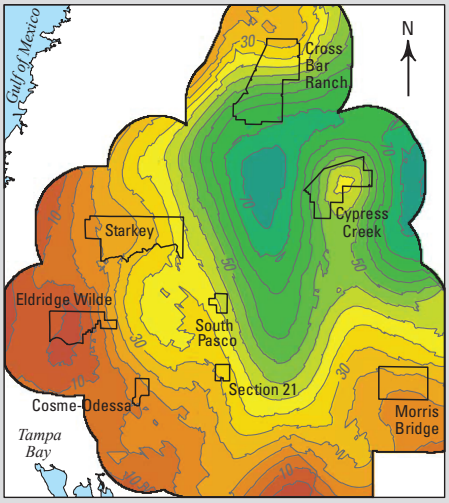
U.S. Geological Survey, Florida Water Science Center Newsletter

A Monthly Time Series of the Potentiometric Surface in the Upper Floridan Aquifer

Mapping a time series of the potentiometric surface in the Upper Floridan aquifer in Florida's karst terrain, where groundwater and surface waters interact, creates a versatile metric for assessing the hydrologic condition of both the aquifer and overlying streams and wetlands. Long-term groundwater monitoring data were used to generate a monthly time series of potentiometric surfaces in the Upper Floridan aquifer over a 573-square-mile (mi^2) area of west-central Florida between January 2000 and December 2009. Recorded groundwater elevations were collated for 260 groundwater monitoring wells in the Northern Tampa Bay area, and a continuous time series of daily observations was created for 197 of the wells by estimating missing daily values through regression relations with other monitoring wells. The mapped time series gives spatial and temporal coherence to groundwater monitoring data collected continuously over the decade at differing frequencies by three different organizations. Furthermore, the mapped time series describes the potentiometric surface beneath parts of six regionally important stream watersheds and 11 municipal well fields that collectively withdraw about 90 million gallons per day (Mgal/d) from the Upper Floridan aquifer.

Kriging, a statistical estimation technique, was used to interpolate the monthly average potentiometric-surface elevations between groundwater monitor wells and to quantify the uncertainty in the interpolated elevations. The effects of drawdown of the potentiometric surface within well fields was exhibited in the spatial variance in the observed data, and the spatial variance decreased markedly between 2002 and 2003, a period that coincided with decreases in well-field pumping.

The average estimation error in the interpolated potentiometric-surface elevations was 2 feet (ft) or less for about 70 percent of the map area. The spatially distributed error could be reduced in some parts of the area by collecting additional data at the 260 available monitoring wells. Reducing the estimation error in other parts of the map area would require adding new monitoring wells. Potentiometric-surface elevations fluctuated by as much as 30 ft during the 10-year study period, and the spatially-averaged elevation for the potentiometric surface rose by about 2 ft during the decade (Lee and Fouad, 2014, *http://pubs.usgs.gov/sir/2014/5038/*).



May 2000 potentiometric surface and well field locations in the northern Tampa Bay area, Florida.

Monthly potentiometric-surface elevations describe the lateral groundwater flow patterns in the aquifer and can be used to describe vertical groundwater recharge and discharge conditions for overlying surface-water features. Results from the current analysis will allow the groundwater conditions of streams and wetlands to be compared, over time, for watersheds and well fields in the Northern Tampa Bay area. This study expands on earlier work done by the USGS in central Florida, where groundwater recharge and discharge conditions were mapped below streams and wetlands in the 330 mi^2 Charlie Creek watershed (Lee and others, 2010, *http://pubs.usgs.gov/sir/2010/5189/*).

A Message from Rafael Rodriguez
Florida Water Science Center Director

Welcome to the first issue of the USGS Florida Water Science Center (FLWSC) Newsletter, a twice-yearly update about recent activities of the FLWSC. The FLWSC has more than 130 scientists, technicians, and support personnel in five offices that collect, interpret, and publish water-resource information for the State and the Nation. Each issue of the newsletter will highlight important hydrologic events and significant scientific projects and achievements by FLWSC staff.

USGS staff work with more than 40 Federal, State, and local cooperating agencies to provide the information needed to prepare for and respond to floods and droughts, and to address and manage water supply, power generation, and other water-resource issues. These partnerships provide increased awareness of water issues to citizens, agencies, and regulators.

The USGS streamflow program produces continuous records of river discharge at more than 500 streamgages in the State. The data are made available in near-real-time (every 15 minutes) on the World Wide Web. Groundwater wells are maintained at more than 600 sites throughout the State, and many provide continuous data. The south Florida coastal hydrology program operates and maintains hydrologic and water-quality-data collection platforms in support of Everglades restoration. Other activities are related to scientific investigations that help document and analyze water-resource issues. The USGS Florida Web page lists more than 40 investigations that are currently underway in Florida (*http://fl.water.usgs.gov/projects/*).

We look forward to continuing our work with you and to identifying new opportunities for work of mutual interest that addresses relevant water-resources issues. Please feel free to contact me about these or any other program opportunities you may wish to discuss.

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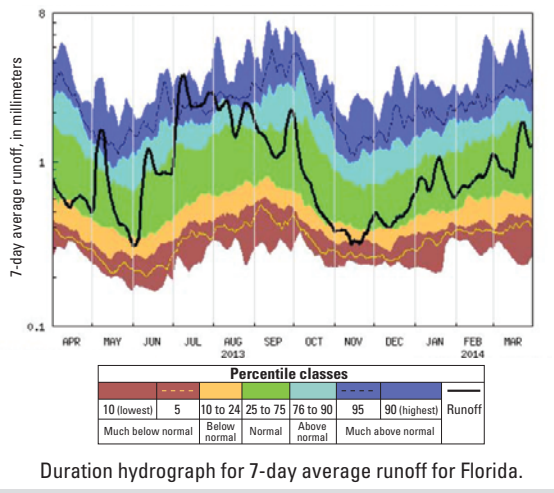
Hydrologic Conditions

Hydrologic Conditions in Florida, April 2013–March 2014

Rainfall

Rainfall was near normal (between 25 percent and 75 percent of the long-term average) at most of the precipitation-measurement sites (49) in the State during April 2013–March 2014. The long-term average rainfall in Florida ranges geographically from 48 to 56 inches. Tropical Storm Andrea (June 5–7, 2013) affected the Gulf Coast of Florida in the Big Bend area in early June and moved across northern Florida, including the Jacksonville area. Rainfall at USGS rain gages ranged from 2 to 4 inches during this storm event. Later in the season, Tropical Storm Dorian (July 23–August 3, 2013) affected southeast Florida and contributed to above-normal rainfall, but did not make landfall. Real-time data for precipitation can be found at on the National Water Information System Web page at *http://waterdata.usgs.gov/fl/nwis/current/?type=precip&group_key=basin_cd.*



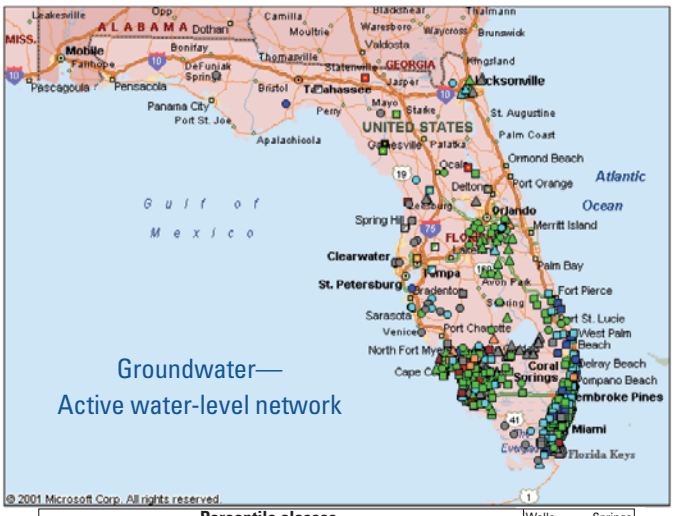
Duration hydrograph for 7-day average runoff for Florida.

Streamflow

Streamflow conditions across the State on average were normal in April–June, 2013. Streamflows were above normal from July to September, 2013. The above-normal streamflow conditions were the result of seasonal rainfall, and two tropical events which affected hydrologic conditions across the State. During October 2013, streamflows were in the normal range, but decreased consistently throughout the month and by November 2013 streamflow was below normal. Normal streamflow resumed in December 2013 where it remained through March 2014. Detailed descriptions of streamflow can be found on the Florida Water Watch Web page (*http://waterwatch.usgs.gov/index.php*).

Groundwater

Groundwater levels across the State were mostly normal during April 2013–March 2014. A few wells in north and west-central Florida had water levels were above normal. The Florida Active Water Level Network (*http://groundwaterwatch.usgs.gov/StateMaps/FL.html*) includes about 1,150 wells and springs in the State that are monitored and maintained by USGS. The network provides measurements of water levels in the surficial, intermediate, and Floridan aquifer systems. Water levels in wells in the Floridan aquifer system can be found at *http://groundwaterwatch.usgs.gov/FLS/CountyMaps/FLS_FL.html*. Water levels throughout the Network ranged from below normal to above normal during the past year, on average. In general, water levels in more wells in the intermediate aquifer in southwest Florida were below normal than in other parts of the State. Normal to above normal water levels were prevalent in the Biscayne aquifer in southeast Florida.



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Hydrologic Data Mining

Data Mining to Simulate the Effects of Rainfall and Groundwater Use on Historical Water Levels and Spring Flows in Central Florida

The Floridan aquifer system is the primary source of water for potable, industrial, and agricultural purposes in central Florida. Despite increases in groundwater withdrawals to meet the demand of population growth, recharge derived by infiltration of rainfall in the well-drained karst terrain of central Florida is still the largest component of the long-term water balance of the Floridan aquifer system. To complement existing physics-based groundwater flow models, artificial neural networks and other data-mining techniques were used to simulate historical lake water level, groundwater level, and spring flow at sites throughout the area.

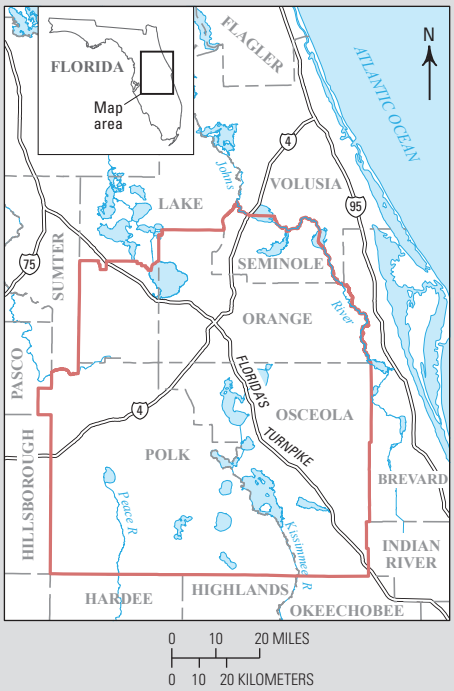
Linear trend analyses of meteorological and hydrologic data indicate 67 percent of sites exhibited upward trends in air temperature and 76 percent exhibited downward trends in rainfall over the period of record. Water levels in lakes were about evenly split between upward and downward trends, whereas water levels in 69 percent of wells and flows in 68 percent of springs exhibited downward trends. Total groundwater use in the study area increased from about 250 Mgal/d in 1958 to about 590 Mgal/day in 1980 and remained relatively stable from 1981 to 2008.

The Central Florida Artificial Neural Network Decision Support System was developed to integrate historical databases and the 102 site-specific artificial neural network models, model controls, and model output were put into a spreadsheet application with a graphical user interface that allows the user to simulate scenarios of interest.

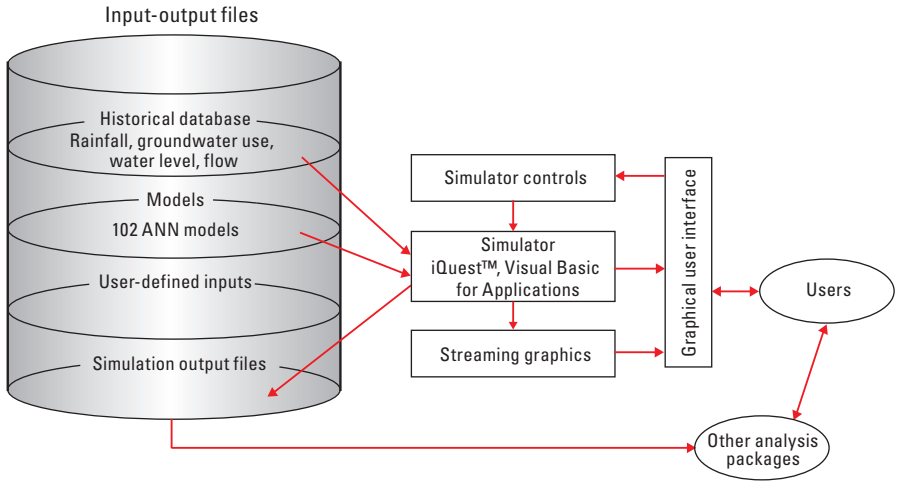
The data-mining analyses indicate that the Floridan aquifer system in central Florida is a highly conductive, dynamic, open system that is strongly influenced by external forcing. The most important external forcing appears to be rainfall, which explains much of the multiyear cyclic variability and long-term downward trends observed in lake water levels, groundwater levels, and spring flows. For most sites, groundwater use explains less of the observed variability in water levels and flows than rainfall.

The hydrologic system in central Florida is affected by groundwater use differently during wet periods, when little or no system storage is available (high water levels), compared to dry periods, when there is excess system storage (low water levels). By driving the overall behavior of the system, rainfall indirectly influences the degree to which groundwater use will affect persistent trends in water levels and flows. Groundwater-use impacts are more prevalent during periods of low groundwater levels and spring flows caused by low rainfall, and less prevalent during periods of high groundwater levels and spring flows caused by high rainfall.

The data-mining analyses indicate that available historical data, when used alone, do not contain sufficient information to definitively quantify the related individual effects of rainfall and groundwater use on hydrologic response. The knowledge gained from data-driven modeling and the results from physics-based modeling, when compared and used in combination, can yield a more comprehensive assessment and a more robust understanding of the hydrologic system than either of the approaches used separately. (O'Reilly, 2014, *http://pubs.usgs.gov/sir/2014/5032/*).



Central Florida Coordination Area.



Central Florida Artificial Neural Network Decision Support System.

Monitoring Saltwater Intrusion in South Florida

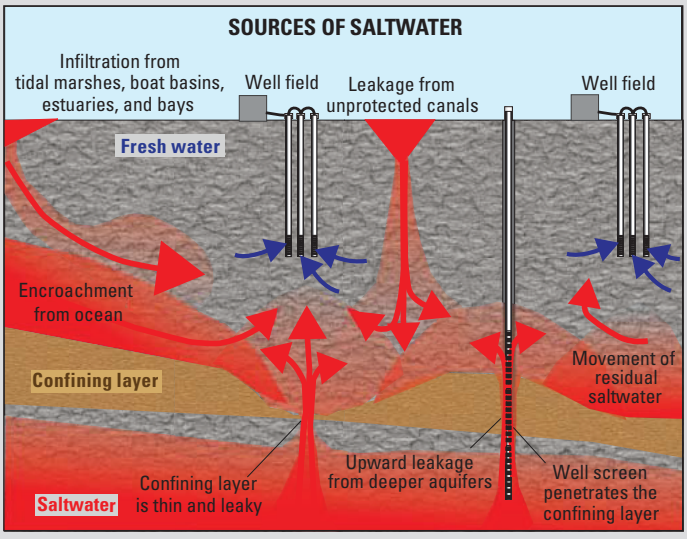
Saltwater intrusion of primary water-use aquifers in southwest Florida resulted from installation of drainage canals, leakage through poorly cased wells, and withdrawals from water-supply wells. Saltwater intruded through various pathways to create the current distribution of saltwater in southwest Florida's aquifers. Consequences of intrusion are substantial. For example, saltwater intrusion led to abandonment of the City of Naples first well field in 1945, and to the replacement of its second well field in 1954. Samples from wells in the active surface-water and groundwater monitoring network indicate that saltwater intrusion continues. Increasing population and associated water use have exacerbated the problem.

Installation of water-control structures, well-plugging projects, and regulation of water use have slowed saltwater intrusion, but the chloride concentration of samples from some of the monitoring wells in south Florida indicates that saltwater intrusion has not abated. Moreover, rising sea level could increase the rate and extent of saltwater intrusion.

Existing deficiencies in the monitoring network lead to uncertainty in the extent and distribution of saltwater within the aquifer. The existing saltwater intrusion monitoring network was examined in a recent USGS study and found to lack the necessary organization, spatial distribution, and design to properly evaluate saltwater intrusion. The most recent hydrogeologic framework of southwest Florida indicates that some wells may be open to multiple aquifers or have an incorrect aquifer designation. Some of the sampling methods in use could result in poor-quality data. Some older wells are badly corroded, obstructed, or damaged and may not yield useable samples. Saltwater in some of the canals is in close proximity to coastal well fields. In some instances, saltwater occasionally occurs upstream from coastal salinity control structures.

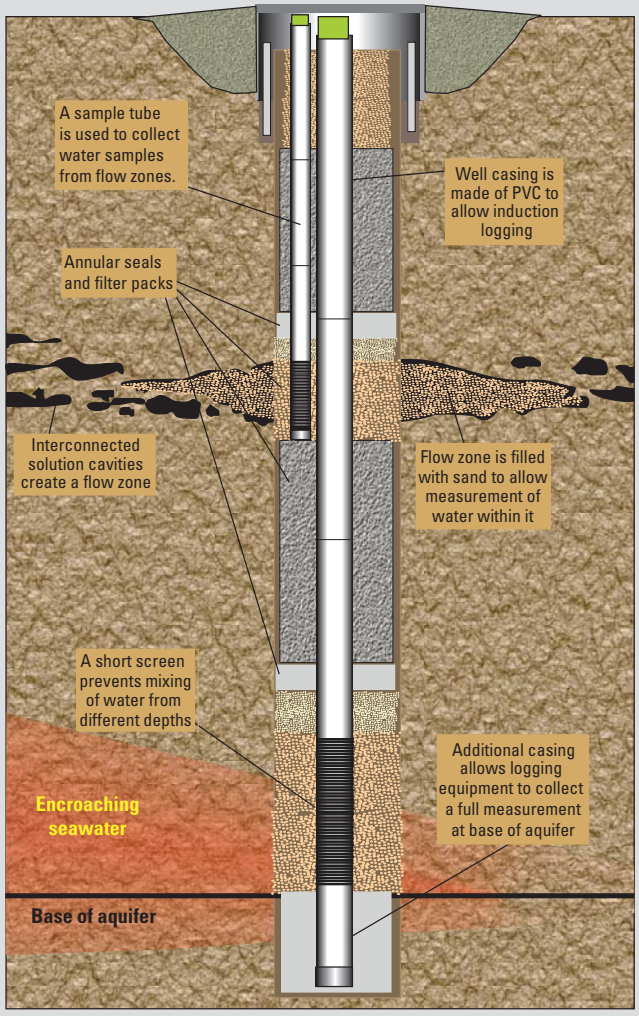
These factors lead to an incomplete understanding of the extent and threat of saltwater intrusion in southwest Florida.

A proposed plan to improve the saltwater intrusion monitoring network in the South Florida Water Management District's Big Cypress Basin describes improvements in (1) network management, (2) quality assurance, (3) documentation, (4) training, and (5) data accessibility (*http://pubs.usgs.gov/of/2013/1088/*). The plan describes improvements to hydrostratigraphic and geospatial network coverage that can be accomplished using additional monitoring, surface geophysical surveys, and borehole geophysical logging. Sampling methods and improvements to monitoring well design are described in detail. Geochemical analyses that provide insights concerning the sources of saltwater in the aquifers are described. The requirement to abandon inactive wells is discussed.



NOT TO SCALE

Sources of saltwater intruding the aquifers of southwestern Florida.



NOT TO SCALE

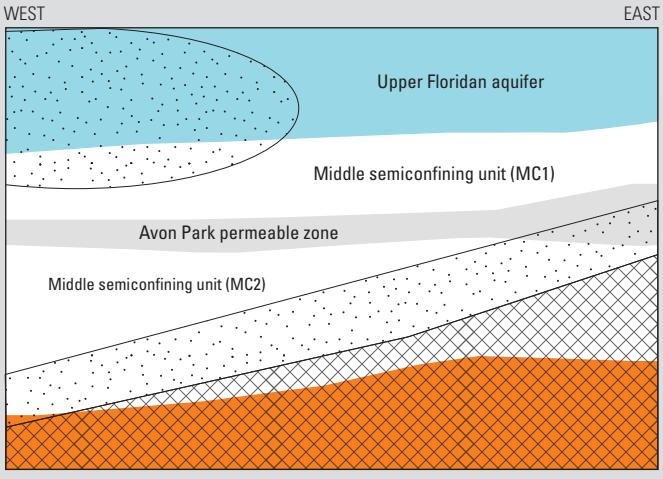
Schematic of a well designed for electromagnetic induction logging.

Describing the Hydrogeologic Framework and Salinity Distribution of the Floridan Aquifer System in Broward County, Florida

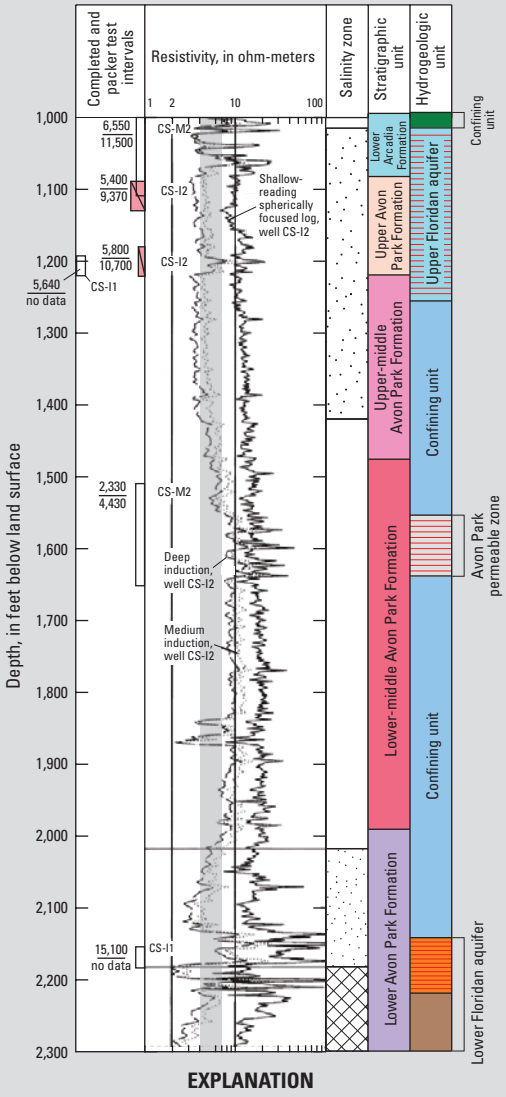
Concerns about water-level decline and seawater intrusion in the Biscayne aquifer, currently the principal source of water supply to Broward County, have resulted in mandated restrictions in groundwater withdrawals. These concerns prompted a USGS study to refine the hydrogeologic framework of the underlying brackish Floridan aquifer system (FAS) to evaluate its potential as an alternative source of supply. The study produced cross sections that illustrate the stratigraphy and hydrogeology in eastern Broward County; maps of the upper surfaces and thicknesses of two geologic formations within the FAS; and maps of two of the potentially productive water-bearing zones (Upper Floridan aquifer; Avon Park permeable zone) within the system.

An analysis of data on rock depositional textures, associated pore networks, and flow zones in the FAS indicates that groundwater moves through the system by two processes. In this conceptual model, groundwater moves either as concentrated flow in discrete, thin bedding-plane vugs (megaporous vugs between rock layers) or zones of vuggy megaporosity, or as diffuse flow through rocks with primarily interparticle and moldic-particle porosity (a type of vuggy porosity). Vugs are present as leached fossils or other grain types, fractures, and irregular voids created by limestone dissolution. Because considerable exchange of groundwater may occur between the zones of vuggy and matrix-dominated porosity, understanding the distribution of that porosity and flow-zone types is important to evaluating the suitability of the groundwater-production units within the FAS for managing the water resources through practices such as aquifer storage and recovery (ASR).

The salinity of the water in the FAS is highest in the central part of Broward County, and lower toward the north and south. Although salinity generally increases with depth, in the western part of the study area a zone of relatively high salinity water is perched above water of lower salinity in the underlying Avon Park permeable zone. Overall, the areas of highest salinity in the FAS coincide with those with the lowest estimated transmissivity, so that the occurrence of perched saline water in the FAS may be the consequence of incompletely flushed connate groundwater (groundwater entrapped in sedimentary rock at the time of its deposition) or intruded seawater. Structures revealed in a seismic reflection profile along the Hillsboro Canal, near the Broward-Palm Beach County boundary, may compromise the integrity of confinement between more permeable units in the FAS, and could allow for upconing of saline water from depth, which has implications for successful production of water from the FAS and its sustainability as an alternative water supply (Reese and Cunningham, 2014, *http://pubs.usgs.gov/sir/2014/5029/*).



Perched zone of elevated salinity in the Upper Floridan aquifer.



EXPLANATION

Dissolved-solids concentration in milligrams per liter

- 1,000 to less than 10,000 (no pattern)
- 10,000 to 35,000
- Greater than 35,000

EXPLANATION

- **Packer test interval in well CS-I2**
- **Completed interval in well CS-M2 or CS-I1**
- **Bottom of logged interval**
- **Salinity zone—Dissolved-solids concentration, in milligrams per liter (mg/L); depth of base of zone estimated by deep induction resistivity**
  - Brackish water—1,000 to less than 10,000 mg/L; less than 6 ohm-meters
  - Moderately saline water, upper zone—10,000 to 35,000 mg/L; less than 4 ohm-meters
  - Moderately saline water, lower zone—10,000 to 35,000 mg/L; less than 2 ohm-meters
  - Saline water–Greater than 35,000 mg/L
- 2,330 / 4,430 **Salinity in water samples collected from completed intervals and packer test intervals**—Upper number is chloride concentration, and lower number is dissolved-solids concentration. Concentrations shown in milligrams per liter

Recent Publications From the Florida Water Science Center

Bellino, J.C., and Spechler, R.M., 2013, Potential effects of deepening the St. Johns River navigation channel on saltwater intrusion in the surficial aquifer system, Jacksonville, Florida: U.S. Geological Survey Scientific Investigations Report 2013–5146, 34 p., *http://pubs.usgs.gov/sir/2013/5146/.*

Brakefield, L., Hughes, J.D., Langevin, C.D., and Chartier, K., 2013, Estimation of capture zones and drawdown at the Northwest and West Well Fields, Miami-Dade County, Florida, using an unconstrained Monte Carlo analysis: recent (2004) and proposed conditions: U.S. Geological Survey Open-File Report 2013–1086, 124 p., *http://pubs.usgs.gov/of/2013/1086/.*

Crandall, C.A., Katz, B.G., and Berndt, M.P., 2013, Estimating nitrate concentrations in groundwater at selected wells and springs in the surficial aquifer system and Upper Floridan aquifer, Dougherty Plain and Marianna Lowlands, Georgia, Florida, and Alabama, 2002–50: U.S. Geological Survey Scientific Investigations Report 2013–5150, 65 p., *http://pubs.usgs.gov/sir/2013/5150/.*

Cunningham, K.J., 2013, Integrating seismic-reflection and sequence-stratigraphic methods to characterize the hydrogeology of the Floridan aquifer system in southeast Florida: U.S. Geological Survey Open-File Report 2013–1181, 8 p., *http://pubs.usgs.gov/of/2013/1181/.*

Davis, J.H. and Verdi, R. 2013, Groundwater flow cycling between a submarine spring and an inland fresh water spring: Ground Water, *http://onlinelibrary.wiley.com/doi/10.1111/gwat.12125/full.*

Decker, Jeremy, Swain, Eric, Stith, Brad, and Langtimm, Catherine, 2013, Assessing factors affecting the thermal properties of a passive thermal refuge using three-dimensional hydrodynamic flow and transport modeling: Journal of Waterway, Port, Coastal, and Ocean Engineering, v. 139, no. 3, p. 209–220, *http://dx.doi.org/10.1061/(ASCE)WW.1943-5460.0000165.*

Green, T.W., Slone, D.H., Swain, E.D., Cherkiss, M.S., Lohmann, Melinda, Mazzotti, F.J., and Rice, K.G., 2013, Evaluating effects of Everglades restoration on American crocodile populations in south Florida using a spatially-explicit, stage-based population model: Wetlands, p. 1–12, *http://dx.doi.org/10.1007/s13157-012-0370-0.*

Katz, B.G., Berndt, M.P., and Crandall, C.A., 2013, Factors affecting the movement and persistence of nitrate and pesticides in the surficial and upper Floridan aquifers in two agricultural areas in the southeastern United States: Environmental Earth Sciences, v. 71, p. 2779–2795, *http://dx.doi.org/10.1007/s12665-013-2657-8.*

Langevin, C., and Zygnerski, M., 2013, Effect of sea-level rise on salt water intrusion near a coastal well field in southeastern Florida: Groundwater, vol. 51, p. 781–803, doi: 10.1111/j.1745-6584.2012.01008.x.

Prinos, S.T., 2013, Is a salinity monitoring network "Worth its salt"?: U.S. Geological Survey Fact Sheet 2013–3079, 2 p., *http://pubs.usgs.gov/fs/2013/3079/.*

Prinos, S.T., 2013, Saltwater intrusion in the surficial aquifer system of the Big Cypress Basin, southwest Florida, and a proposed plan for improved salinity monitoring: U.S. Geological Survey Open-File Report 2013–1088, 58 p., *http://pubs.usgs.gov/of/2013/1088/.*

Reese, R.S. and Cunningham, K.J., 2013, Preliminary stratigraphic and hydrogeologic cross sections and seismic profile of the Floridan aquifer system of Broward County, Florida: U.S. Geological Survey Open-File Report 2013–1141, 10 p., *http://pubs.usgs.gov/of/2013/1141/.*

Sacks, L.A., Lee, T.M., Swancar, Amy, 2013, The suitability of a simplified isotope-balance approach to quantify transient groundwater-lake interactions over a decade with climate extremes: Journal of Hydrology, *http://dx.doi.org/10.1016/j.jhydrol.2013.12.012.*

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The USGS Water Mission Area (WMA) has the principal responsibility within the Federal Government to provide the hydrologic information and interpretation needed by others to achieve the best use and management of the Nation's water resources. The WMA actively promotes the use of its information products by decision makers to:

- Minimize loss of life and property as a result of water-related natural hazards, such as floods, droughts, and land movement.
- Effectively manage groundwater and surface-water resources for domestic, agricultural, commercial, industrial, recreational, and ecological uses.
- Protect and enhance water resources for human health, aquatic health, and environmental quality.
- Contribute to wise physical and economic development of the Nation's resources for the benefit of present and future generations.

If you have an environmental or resource-management issue that you would like to investigate in partnership with the USGS, please contact any of our senior management staff (listed below). Projects are supported primarily through the USGS Cooperative Water Program (*http://water.usgs.gov/coop/*). This is a program through which any State, County, local, or regional agency may work with the USGS to fund and conduct a monitoring or investigation project.

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