# U.S. Geological Survey Caribbean-Florida Water Science Center Newsletter

## Hurricanes and Floods

Hurricane Hermine made landfall as a Category 1 storm at St. Marks in the Florida panhandle on September 2, 2016. A storm surge of approximately 6 feet over the normal high tide was recorded at the USGS stream gage Aucilla River near Mouth, near Nutall Rise, Florida (*02326550)*. CFWSC staff from Tallahassee and Orlando deployed 5 storm tide sensors along the coast from Apalachicola to Cedar Key just hours before landfall.

The highest rainfall total (17.61 inches during August 30 – September 3) was recorded at McKay Creek near Largo, Florida (*02309110*). CFWSC staff from the Lutz and Ft. Myers offices made more than 25 discharge measurements at stream gages along the west-central and southwest coasts of Florida. Discharge measurements at six stations were the maximum for the period of record. Five stations in the coastal Tampa Bay area were damaged or destroyed by storm surge.

**Water-level sensor deployed in advance of Hurricane Hermine.**

**Beach erosion near Ponte Vedra Beach, FL.**

Hurricane Matthew tracked parallel to the Florida coast as a Category 2 storm on October 7-8, 2016. This powerful storm caused 12 deaths in Florida, and more than one million people were left without power throughout the State.

The USGS CFWSC documented the hydrologic effects of Hurricane Matthew on Florida's coastline and rivers with continuous data from stream-gaging stations, rapid deployment gages, and storm-tide sensors, as well as high-water marks and measurements of streamflow (discharge).

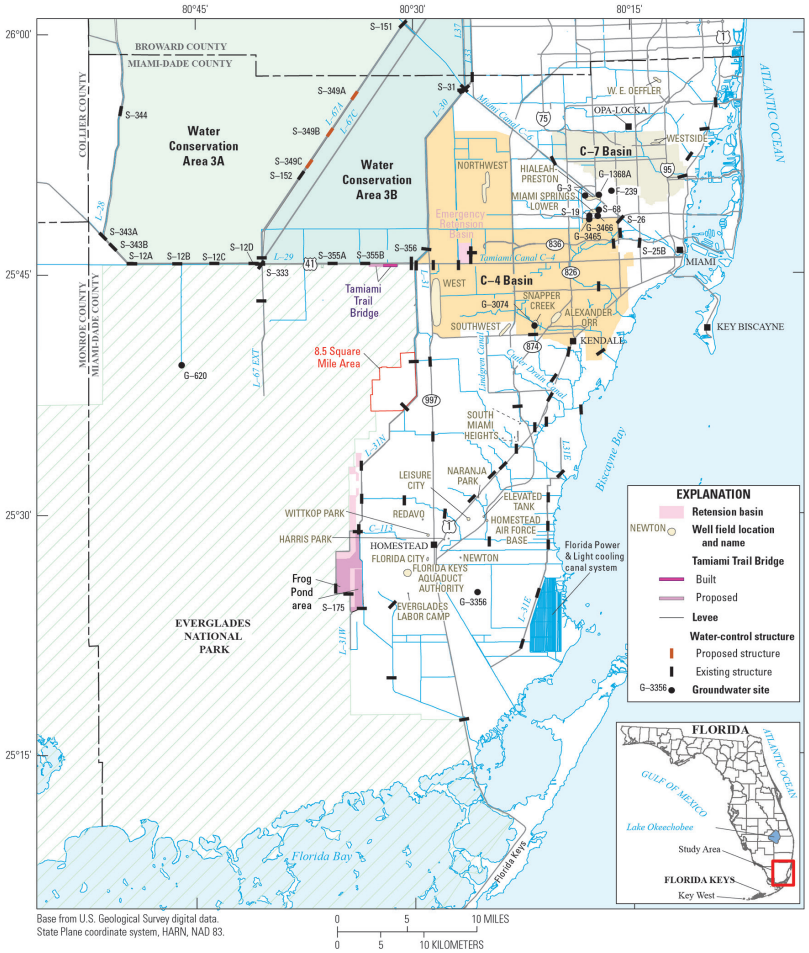
Matthew caused storm-tide elevations of 5-12 ft above North American Vertical Datum of 1988 (NAVD 88) along the northeast Florida coastline from Daytona to Jacksonville, and rainfall in northeast Florida also caused record flood levels at several streams. Seventeen USGS field crews deployed 61 water-level sensors, 17 barometers, and 3 rapid-deployment gages along 350 miles of coastline from Nassau Sound to Biscayne Bay two days before Hurricane Matthew began to impact the coast.

The deployment was part of a larger mission assignment from the Federal Emergency Management Agency, which also included USGS staff in Georgia, South Carolina, and North Carolina. The sensors supplemented over 500 real-time USGS streamflow gaging stations in Florida. In addition, 155 high-water marks were flagged and surveyed by 15 USGS crews along 75 miles of coastline from St Mary's River inlet to Palm Coast within two weeks after the storm. Peak elevations from high water marks ranged from 3 to 16 ft above NAVD 88.

Rainfall from Hurricane Matthew measured almost 8 inches at USGS precipitation sensors along the northeast Florida coast. Flood discharge measurements were made by 21 USGS staff at twelve streamflow-gaging stations, and period-of-record peak discharges were measured at five of those stations.

The data from the storm-tide sensors, rapid deployment gages, and high-water marks are accessible from the USGS Flood Event Viewer (*http://water.usgs.gov/floods/FEV/*), and the data from the stream-gaging stations and precipitation gages are accessible from NWISWeb (*http://waterdata.usgs.gov/nwis*).

## Mapping water levels in the Biscayne aquifer




**Map showing location of the study area.**

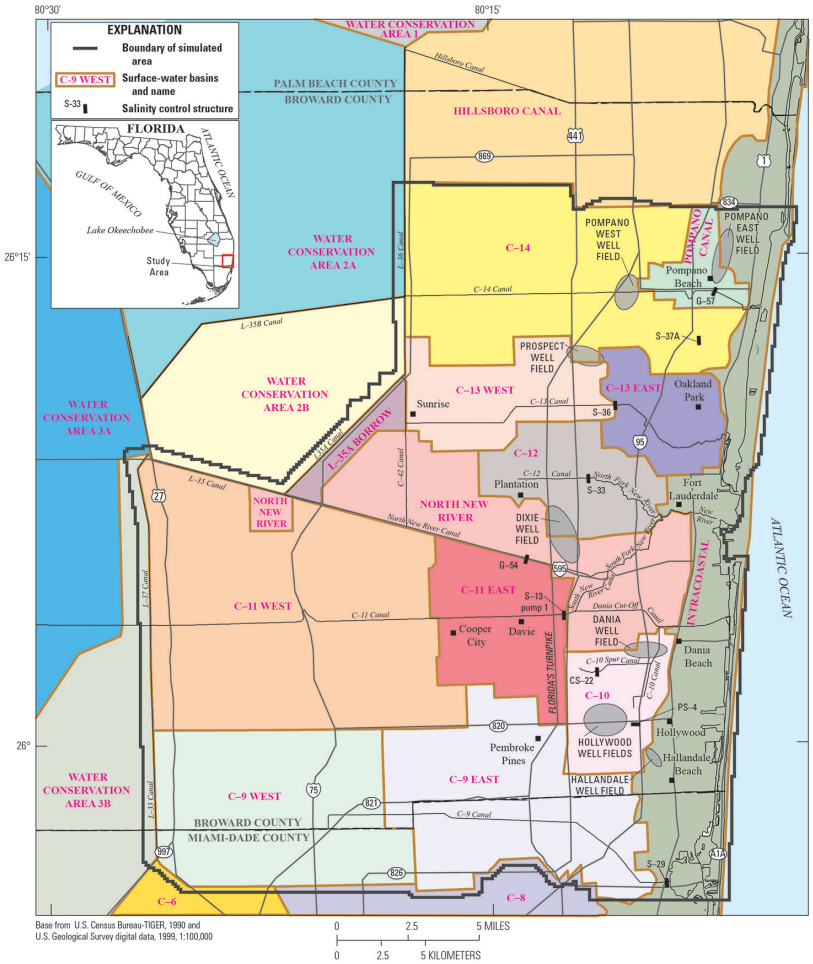
To help inform decisions necessary for urban planning and development, Miami-Dade County Department of Regulatory and Economic Resources partnered with USGS to produce statistical analyses and maps representing mean, high, and low water-level conditions in the surface water and groundwater of Miami-Dade County. The results of analysis and mapping were recently published in *Scientific Investigations Report 2016-5005*, authored by Scott T. Prinos and Joann F. Dixon. A companion *Data Release* includes the GIS files and other data pertaining to the report.

Sixteen maps were created that show contours of (1) the mean of daily water levels at each site during October and May for the 2000–2009 water years; (2) the 25th, 50th, and 75th percentiles of the daily water levels at each site during October and May and for all months during 2000–2009; and (3) the differences between mean October and May water levels, as well as the differences in the percentiles of water levels for all months, between 1990–1999 and 2000–2009. The 80th, 90th, and 96th percentiles of the annual maximums of daily groundwater levels during 1974–2009 (a 35-year period) were computed to provide an indication of unusually high groundwater-level conditions. These maps and statistics provide a generalized understanding of the variations of water levels in the aquifer, rather than a survey of concurrent water levels. Water-level measurements from 473 sites in Miami-Dade County and surrounding counties were analyzed to generate statistical analyses. The monitored water levels included surface-water levels in canals and wetland areas and groundwater levels in the Biscayne aquifer,

Maps were created by importing site coordinates, summary water-level statistics, and completeness of record statistics into a geographic information system, and by interpolating between water levels at monitoring sites in the canals and water levels along the coastline. Raster surfaces were created from these data by using the triangular irregular network interpolation method. The raster surfaces were contoured by using geographic information system software. These contours were imprecise in some areas because the software could not fully evaluate the hydrology with the available information; therefore, contours were manually modified where necessary.

The ability to evaluate differences in water levels between 1990–1999 and 2000–2009 is limited in some areas because most of the monitoring sites did not have 80 percent complete records for one or both of these periods. The quality of the analyses was limited by (1) deficiencies in spatial coverage; (2) the combination of pre- and post-construction water levels in areas where canals, levees, retention basins, detention basins, or water-control structures were installed or removed; (3) an inability to address the potential effects of the vertical hydraulic head gradient on water levels in wells of different depths; and (4) an inability to correct for the differences between daily water-level statistics. Contours are dashed in areas where the locations of contours have been approximated because of the uncertainty caused by these limitations. Although the ability of the maps to depict differences in water levels between 1990–1999 and 2000–2009 was limited by missing data, results indicate that near the coast water levels were generally higher in May during 2000–2009 than during 1990–1999; and that inland water levels were generally lower during 2000–2009 than during 1990–1999. Generally, the 25th, 50th, and 75th percentiles of water levels from all months were also higher near the coast and lower inland during 2000–2009 than during 1990–1999. Mean October water levels during 2000–2009 were generally higher than during 1990–1999 in much of western Miami-Dade County, but were lower in a large part of eastern Miami-Dade County.

# Effects of hydrologic system alterations on salinity in the Biscayne aquifer in Broward Co. suwannee




**Map of the study area in southeastern Florida.**

To address concerns about the effects of water-resource management practices and rising sea level on saltwater intrusion, the U.S. Geological Survey in cooperation with the Broward County Environmental Planning and Community Resilience Division, initiated a study to examine causes of saltwater intrusion and predict the effects of future alterations to the hydrologic system on salinity distribution in eastern Broward County, Florida. The results of the study are presented in a recently released *Scientific Investigations Report 2016-5022* authored by Joseph D. Hughes, Dorothy F. Sifuentes, and Jeremy T. White. A companion *Data Release* provides public access to the SEAWAT model and associated data used in the study.

A three-dimensional, variable-density solute-transport model was calibrated to conditions from 1970 to 2012, the period for which data are most complete and reliable, and was used to simulate historical conditions from 1950 to 2012. These types of models are typically difficult to calibrate by matching to observed groundwater salinities because of spatial variability in aquifer properties that are unknown, and natural and anthropogenic processes that are complex and unknown; therefore, the primary goal was to reproduce major trends and locally generalized distributions of salinity in the Biscayne aquifer. The methods used in this study are relatively new, and results will provide transferable techniques for protecting groundwater resources and maximizing groundwater availability in coastal areas. The model was used to (1) evaluate the sensitivity of the salinity distribution in groundwater to sea-level rise and groundwater pumping, and (2) simulate the potential effects of increases in pumping, variable rates of sea-level rise, movement of a salinity control structure, and use of drainage recharge wells on the future distribution of salinity in the aquifer.

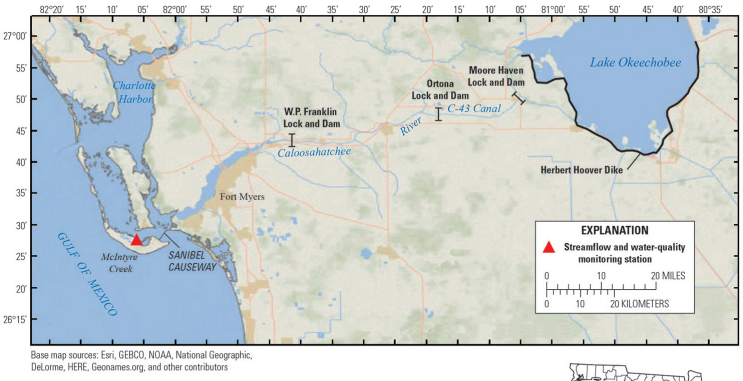
Results from the simulation of historical conditions indicate that the model generally represents the observed greater westward extent of elevated salinity in the central part of the intruded area relative to the northern and southernmost parts of the intruded area. Results of sensitivity testing indicate that the extent of elevated salinity is most sensitive to pumping in areas where the source of saltwater is largely offshore, from the Atlantic Ocean, and is most sensitive to sea-level rise in areas where the source of salinity is downward leakage of brackish water from canals.

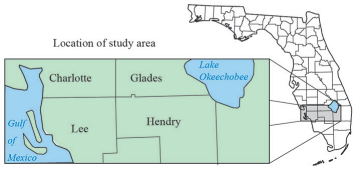
**Surface-water and salinity control stucture G-54, on the North New River Canal, Broward County, Florida.**

Simulations of future scenarios indicate that increases in pumping near the existing interface may cause the interface to advance and decreases in pumping may cause it to retreat. Climatic effects, such as periods of prolonged drought or high precipitation, may augment or counteract long-term effects of changes in pumping on aquifer salinity at well fields. With increasing rates of sea-level rise, the freshwater-saltwater interface advances progressively inland, and salinities at well fields near the existing interface increase commensurately. Hypothetical southeastward (downstream) re-positioning of the existing G–54 salinity-control structure may prevent the interface from moving northwestward along and near the North New River canal, but beneficial effects are localized. Implementation of freshwater recharge wells in the city of Hallandale Beach may also have only a localized freshening effect in the aquifer and little appreciable effect on the freshwater-saltwater interface or on concentrations of salinity at well fields.

Model accuracy and use are limited by uncertainty in the physical properties and boundary conditions of the system, uncertainty in historical and future conditions, and generalizations made in the mathematical relationships used to describe the physical processes of groundwater flow and transport. Because of these limitations, model results should be considered in relative rather than absolute terms. Nonetheless, model results do provide useful information on the relative scale of response of the system to changes in pumping distribution, sea-level rise, and mitigation activities.

## Characteristics of flow through the Franklin lock and their effects on downstream water-quality



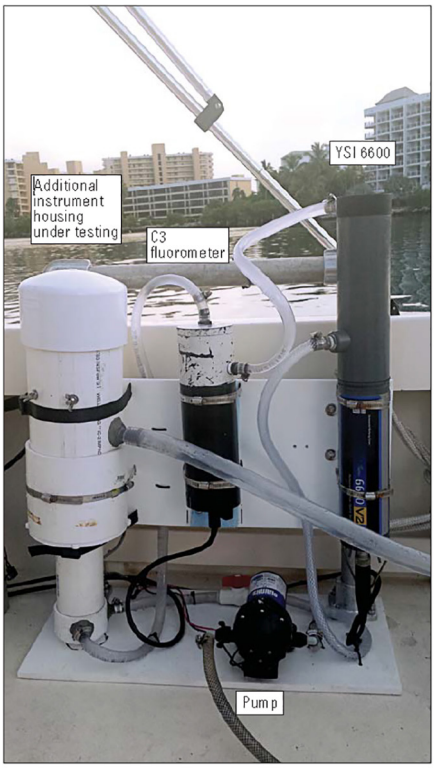

**Lake Okeechobee, Moore Haven Lock and Dam, Ortona Lock and Dam, and W.P. Franklin Lock and Dam.**

The USGS recently completed a study to investigate correlations between flow rates and volumes through the W.P. Franklin Lock and Dam and water-quality constituents inside the J.N. "Ding" Darling National Wildlife Refuge from March 2010 to December 2013. *Scientific Investigations Report 2016-5033,* authored by Amanda Booth, Lars Soderqvist, and Travis Knight, summarizes the results of the study. A companion *Data Release* provides public access to data associated with the study.

**Boat leaving the dock at the beginning of a water-quality survey.**

Outflow from Lake Okeechobee, and flows from Franklin Lock, tributaries to the Caloosahatchee River Estuary, and the Cape Coral canal system were examined to determine the sources and quantity of water entering the study area. Salinity, temperature, dissolved-oxygen concentration, pH, turbidity, and fluorescence of chromophoric dissolved organic matter (FDOM) were measured during moving-boat surveys and at a fixed location in McIntyre Creek. Chlorophyll fluorescence was also recorded in McIntyre Creek. Water-quality surveys were completed on 20 days between 2011 and 2014 using moving-boat surveys.

Franklin Lock contributed the majority of flow to the Caloosahatchee River. Between 2010 and 2013, the monthly mean flow rate at Franklin Lock ranged from 29 cubic feet per second in May 2011 to 10,650 cubic feet per second in August 2013. Instantaneous near-surface salinity in McIntyre Creek ranged from 12.9 parts per thousand on September 26, 2013, to 37.9 parts per thousand on June 27, 2011. Salinity in McIntyre Creek decreased with increasing flow rate through Franklin Lock. Flow rates through Franklin Lock explained 61 percent of the variation in salinity in McIntyre Creek.




**Water-quality sensors and pump system used for moving-boat surveys.**

Salinity data from moving-boat surveys also indicate that an increase in flow rate at Franklin Lock decreases salinity in the Caloosahatchee River Estuary, and a reduction or elimination in flow increases salinity. The FDOM in McIntyre Creek was positively correlated with flow at Franklin Lock, and 54 percent of the variation in FDOM can be attributed to the flow rate through Franklin Lock. Data from moving-boat surveys indicate that FDOM increases when flow volume from Franklin Lock increases.

Chlorophyll fluorescence was positively correlated with flow at Franklin Lock, with 23 percent of the variation explained by the flow rate at Franklin Lock. An increase in flow rate at Franklin Lock resulted in a decrease in pH (21 percent of variation explained by flow rates). Data from the pH surveys indicate an increase in pH with distance from Franklin Lock. Turbidity and dissolved oxygen near the surface in McIntyre Creek were not correlated with flow rate at Franklin Lock. Moving-boat surveys did not document a change in turbidity or dissolved oxygen with a change in distance from the Franklin Lock. Correlations between Franklin Lock flow rate and water quality in McIntyre Creek indicate that releases at Franklin Lock affect water quality in the Caloosahatchee River estuary and Ding Darling Refuge.

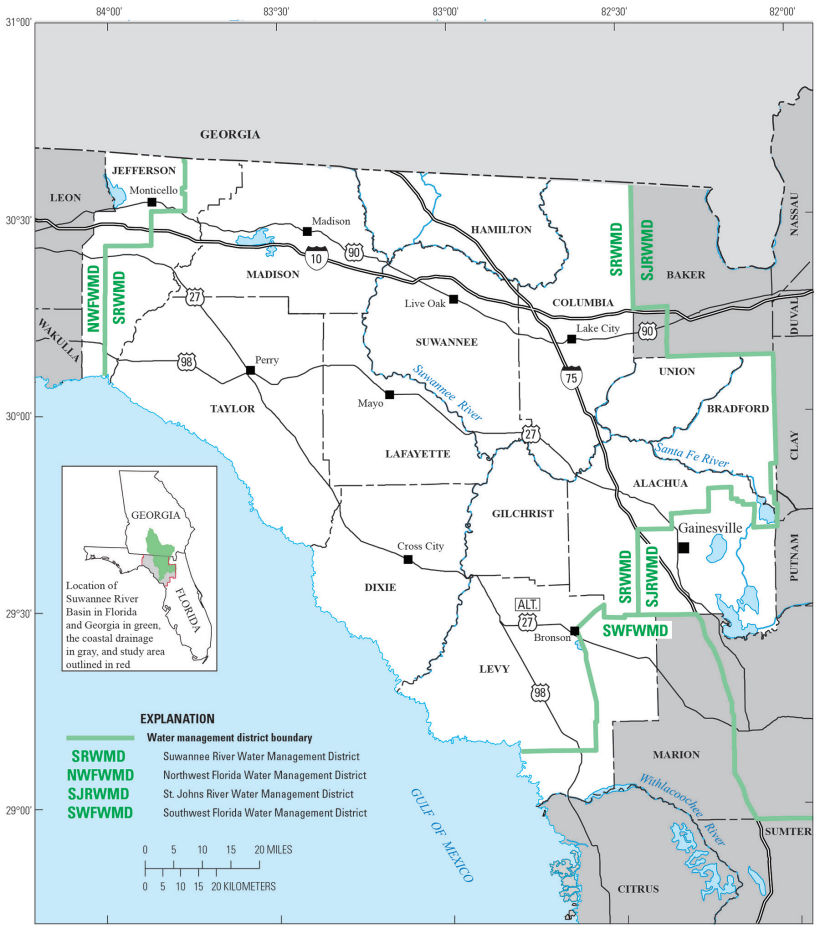
# Agricultural land-use inventory in counties of Suwannee River Water Management District

A detailed inventory of irrigated crop acreage is not available at the level of resolution needed to accurately estimate agricultural water use or to project future water demands in many Florida counties. A detailed digital map and summary of irrigated acreage during the 2015 growing season was developed for 13 of the 15 counties that compose the Suwannee River Water Management District (SRWMD). The map and summary were recently published in *Open-File Report 2016-1111*, authored by Richard Marella, Joann Dixon, and Darbi Berry. A companion *Data Release* provides public access to the GIS data and tables pertaining to the report.

The irrigated areas were delineated using land-use data, orthoimagery, and information obtained from State of Florida Water Management Districts consumptive water-use permits that were then field verified between May and November of 2015. Selected attribute data were collected for the irrigated areas, including crop type, primary water source, and type of irrigation system. Results indicate that an estimated 113,134 acres were either irrigated or had potential for irrigation in all or part of the 13 counties within the SRWMD during 2015. This estimate includes 108,870 acres of field-verified, irrigated crops and 4,264 acres of irrigated land observed as (1) idle (with an irrigation system visible but no crop present at the time of the field-verification visit), (2) acres that could not be verified during field visits, or (3) acres that were located on publicly owned research lands.

Of the total field-verified crops, 83,721 acres were field crops; 20,962 acres were vegetable (row) crops; 3,089 acres were in tree nurseries, ornamentals, and sod production; and 1,098 acres were fruit crops. Specific irrigated crops included 32,468 acres of corn; 28,170 acres of peanuts; and 10,331 acres of hay. About 40 percent of the vegetable acreage (8,340 acres) was double cropped (planted with both a spring and a fall crop on the same field). Beans, carrots, and watermelons were the most commonly grown vegetable crops in these 13 counties in 2015.

Sprinkler irrigation systems including center pivots, portable or traveling guns, and permanent or solid overhead fixtures accounted for nearly 91 percent (102,874 acres) of the total irrigated acreage in the SRWMD, whereas microirrigation systems including drip irrigation accounted for 9 percent (10,260 acres) of the irrigated acreage. A total of 1,466 center pivots were observed during field verification in 2015 and accounted for 93,093 irrigated acres (82 percent of the total irrigated acreage). Most center pivots were in use at the time of the field verification, although about 3 percent appeared idle. No flood irrigation systems were observed during field verification in 2015. Overall, groundwater was used to irrigate nearly all of the field-verified acreage (99.8 percent).




Base from ESRI and U.S. Geological Survey digital data 1:2,000,000 scale, 2003.

**Suwannee River Water Management District and surrounding counties.**

County. Other counties with substantial irrigated acreage included Levy (10,122 acres), Alachua (9,547 acres), and Lafayette (8,110 acres); these three counties, combined with Suwannee, Madison, Hamilton, and Gilchrist Counties, accounted for 88 percent of the irrigated acreage in the SRWMD.

The irrigated acreage that was field verified in 2015 for the 13 counties in the SRWMD (113,134 acres) is about 6 percent higher than the estimated acreage published by the U.S. Department of Agriculture (USDA) (107,217 acres) for 2012; however, this 2012 value represents acreage for the entirety of all 13 counties, not just the SRWMD portion. Differences between the 2015 field-verified acreage totals and those published by the USDA for 2012 may occur because (1) irrigated acreage for some specific crops increased or decreased substantially during the 3-year interval due to commodity prices or economic changes, (2) calculated field-verified irrigated acreage may be an overestimate because irrigation was assumed if an irrigation system was present, when in fact that may not have been the case as some farmers may not have used their irrigation systems during this growing period even if they had a crop in the field, or (3) the amount of irrigated acreages published by the USDA for selected crops may be underestimated in some cases.

## Recent Publications from the Caribbean-Florida Water Science Center


Booth, A.C., Soderqvist, L.E., and Knight, T.M., 2016, Effects of variations in flow characteristics through W.P. Franklin Lock and Dam on downstream water quality in the Caloosahatchee River Estuary and in McIntyre Creek in the J.N. "Ding" Darling National Wildlife Refuge, southern Florida, 2010–13: U.S. Geological Survey Scientific Investigations Report 2016–5033, 33 p. *https://pubs.er.usgs.gov/publication/sir20165033*

Booth, A.C., Knight, T.M., and Soderqvist, L.E., 2016, Near-Surface Water-Quality Surveys of the Caloosahatchee River and Downstream Estuaries, Florida, USA: U.S. Geological Survey data release *http://dx.doi.org/10.5066/F70863BC*

Gómez-Fragoso, Julieta, and Torres-Sierra, Heriberto, 2016, Dam failure analysis for the Lago El Guineo Dam, Orocovis, Puerto Rico: U.S. Geological Survey Scientific Investigations Report 2016–5070, 49 p., 4 pl. *http://dx.doi.org/10.3133/sir20165070*

Gómez-Fragoso, Julieta, and Torres-Sierra, Heriberto, 2016, Spatial Data for Dam failure analysis for the Lago El Guineo Dam, Orocovis, Puerto Rico: U.S. Geological Survey data release, U.S. Geological Survey data release *https://dx.doi.org/10.5066/F72V2D7Q*

Gómez-Fragoso, Julieta, 2016, Sedimentation survey of Lago Lucchetti, Yauco, Puerto Rico, September 2013–May 2014: U.S. Geological Survey Scientific Investigations Map 3364, 1 sheet *http://dx.doi.org/10.3133/sim3364*

Gómez-Fragoso, J., 2016, Data points corresponding to the bathymetric survey of Lago Lucchetti, Puerto Rico, September 2013-May 2014: U.S. Geological Survey data release *http://dx.doi.org/10.5066/F7V122WZ*

Hughes, J.D., Sifuentes, D.F., and White, J.T., 2016, Potential effects of alterations to the hydrologic system on the distribution of salinity in the Biscayne aquifer in Broward County, Florida: U.S. Geological Survey Scientific Investigations Report 2016–5022, 114 p. *http://dx.doi.org/10.3133/sir20165022*

Hughes, J.D., Sifuentes, D.F., and White, J.T., 2016, SEAWAT model used to evaluate the potential effects of alterations to the hydrologic system on the distribution of salinity in the Biscayne aquifer in Broward County, Florida: U.S. Geological Survey data release *http://dx.doi.org/10.5066/F7PV6HFR*

King, J.N., and Davis, J.H., 2016, Preliminary investigation of groundwater flow and trichloroethene transport in the surficial aquifer system, Naval Industrial Reserve Ordnance Plant, Fridley, Minnesota: U.S. Geological Survey Open File Report 2016–1066, 120 p. *http://dx.doi.org/10.3133/ofr20161066*

King, J.N. and Davis, J.H., 2016, MODFLOW 2000 and MT3DMS models of potentiometric head and trichloroethene concentration at the Naval Industrial Reserve Ordnance Plant, Fridley, Minnesota: U.S. Geological Survey data release *http://dx.doi.org/10.5066/F798853M*

Marella, R.L., Dixon, J.F., and Berry, D.R., 2016, Agricultural irrigated land-use inventory for the counties in the Suwannee River Water Management District in Florida, 2015: U.S. Geological Survey Open-File Report 2016–1111, 18 p., *http://dx.doi.org/10.3133/ofr20161111*.

Marella, R.L., Dixon, J.F, and Berry, D.R., 2016, GIS data and tables pertaining to the agricultural Irrigated land-use inventory for the counties in the Suwannee River Water Management District, 2015 - Scientific data associated with the USGS Open-File Report 2016-1111: U.S. Geological Survey data release *http://dx.doi.org/10.5066/F7NK3C4V*.

Prinos, S.T., and Dixon, J.F., 2016, Statistical analysis and mapping of water levels in the Biscayne aquifer, water conservation areas, and Everglades National Park, Miami-Dade County, Florida, 2000–2009: U.S. Geological Survey Scientific Investigations Report 2016–5005, 42 p. *http://dx.doi.org/10.3133/sir20165005*

Prinos, S.T., and Dixon, J.F., 2016, Data, statistics, and Geographic Information System files pertaining to mapping of water levels in the Biscayne aquifer, Water Conservation Areas, and Everglades National Park, Miami-Dade County, Florida, 2000-2009: U.S. Geological Survey data release *http://dx.doi.org/10.5066/F7M61H9W*

Shoemaker, B.W., 2016, Daily Reference (RET) and Potential (PET) Evapotranspiration data over Florida, 2015: U.S. Geological Survey data release *http://fl.water.usgs.gov/et/*

Torres-González, Sigfredo, and Rodríguez, J.M., 2016, Hydrologic conditions in the South Coast aquifer, Puerto Rico, 2010–15: U. S. Geological Survey Open-File Report 2015-1215, 32 p. *http://dx.doi.org/10.3133/ofr20151215*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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*. 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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