PROFESSIONAL PAPER SJ2014-PP1

GROUNDWATER WITHDRAWALS FOR PUBLIC SUPPLY USE IN THE CENTRAL FLORIDA COORDINATION AREA (CFCA) AND VICINITY, 1945–2010

2014

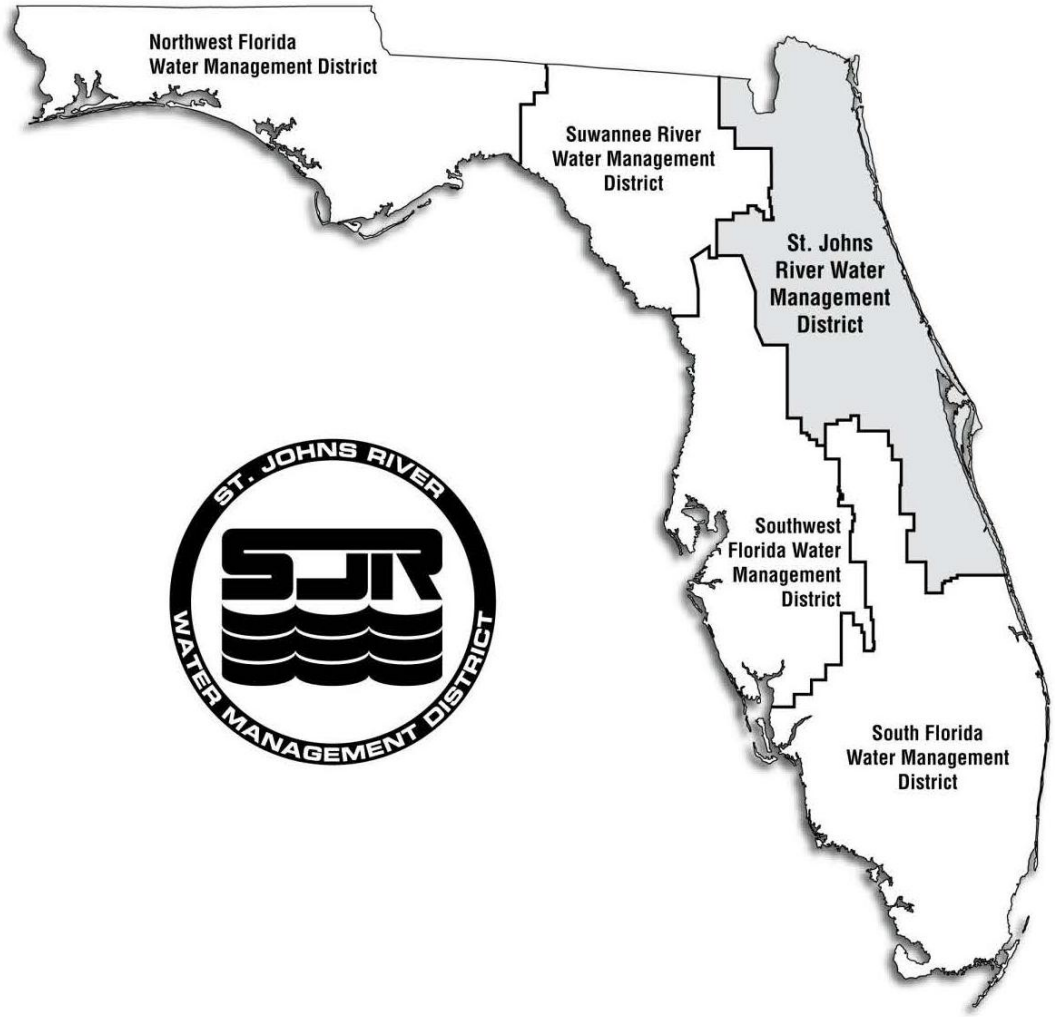
Professional Paper SJ2014-PP1

GROUNDWATER WITHDRAWALS FOR PUBLIC SUPPLY USE IN THE CENTRAL FLORIDA COORDINATION AREA AND VICINITY, 1945–2010

Douglas Munch, P.G.

St. Johns River Water Management District
Palatka, Florida

2014



The St. Johns River Water Management District was created in 1972 by passage of the Florida Water Resources Act, which created five regional water management districts. The St. Johns District includes all or part of 18 counties in northeast and east-central Florida. Its mission is to preserve and manage the region's water resources, focusing on core missions of water supply, flood protection, water quality and natural systems protection and improvement. In its daily operations, the District conducts research, collects data, manages land, restores and protects water above and below the ground, and preserves natural areas.

This document is published to disseminate information collected by the District in pursuit of its mission. Electronic copies are available at *floridaswater.com/technicalreports* or by calling the District at the number below.

Scientific Reference Center
St. Johns River Water Management District
4049 Reid Street/P.O. Box 1429
Palatka, FL 32178-1429 (32177 for street deliveries)
(386) 329-4500

Professional Paper SJ2014-PP1

Groundwater Withdrawals for Public Supply Use in the Central Florida Coordination Area and Vicinity, 1945–2010

Douglas Munch, P.G.

St. Johns River Water Management District, Palatka, Florida

ABSTRACT

The data presented in this paper are part of a larger study carried out by the U.S. Geological Survey titled "Simulation of the effects of rainfall and groundwater use on historical lake water levels, groundwater levels, and spring flows in central Florida." The Central Florida Coordination Area (CFCA), which is part of the planning effort known as the Central Florida Water Initiative (CFWI), consists of all or part of Lake, Polk, Orange, Osceola, and Seminole counties. The objective of this effort was to develop a database to build a decision support model that encompasses the CFCA and vicinity. The data presented in this paper are from a variety of sources and were used to develop historical estimates and reported quantities of public supply utility groundwater withdrawals during the period 1945 to 2010. These estimated or reported quantities are for public supply water utilities that withdraw or deliver to service more than 100,000 gallons per day. This information, in combination with agricultural estimates found in McLeod and Munch (2012*)* can be used to develop data needed to support groundwater modeling efforts in the future.

To meet the ever-increasing demand for potable water, there has been steady growth in the number of private and public utilities providing water for public supply. Since 1945, the number of utilities with recorded information has grown from 16 to well over 180 operating more than 183 water treatment plants. Up until the late 1970s, moderate growth in groundwater withdrawals occurred in all three water management districts in the CFCA. Water withdrawals increased in association with increasing population from 1980 through 2006. Since 2006, withdrawals have decreased to levels observed in the early 2000s. The maximum groundwater withdrawals occurred in 2006 with a total of 471 million gallons per day (mgd) delivered within the three water management districts. The year 2007 was the second highest at approximately 460 mgd, and the year 2000 was the third highest at 445 mgd. Within the CFCA and in the vicinity, groundwater withdrawals have increased from 8.1 mgd in 1945 to approximately 408 mgd in 2010.

INTRODUCTION

This paper presents data from a variety of sources that was used to develop historical estimates and reported quantities of individual and total public supply utility groundwater withdrawals during the period 1945 to 2010 within the Central Florida Coordination Area (CFCA), which is part of the planning effort known as the Central Florida Water Initiative (CFWI). The CFCA consists of all or part of Lake, Orange, Osceola, Polk, and Seminole, counties (Figure 1). The data presented in this paper contributes to a larger study carried out by the U.S. Geological Survey (USGS) titled "Simulation of the effects of rainfall and groundwater use on historical lake water levels, groundwater levels, and spring flows in central Florida" (O'Reilly, 2014) The St. Johns River Water Management District (SJRWMD) and the Southwest Florida Water Management District (SWFWMD) cooperatively funded this "Data Mining" modeling project.

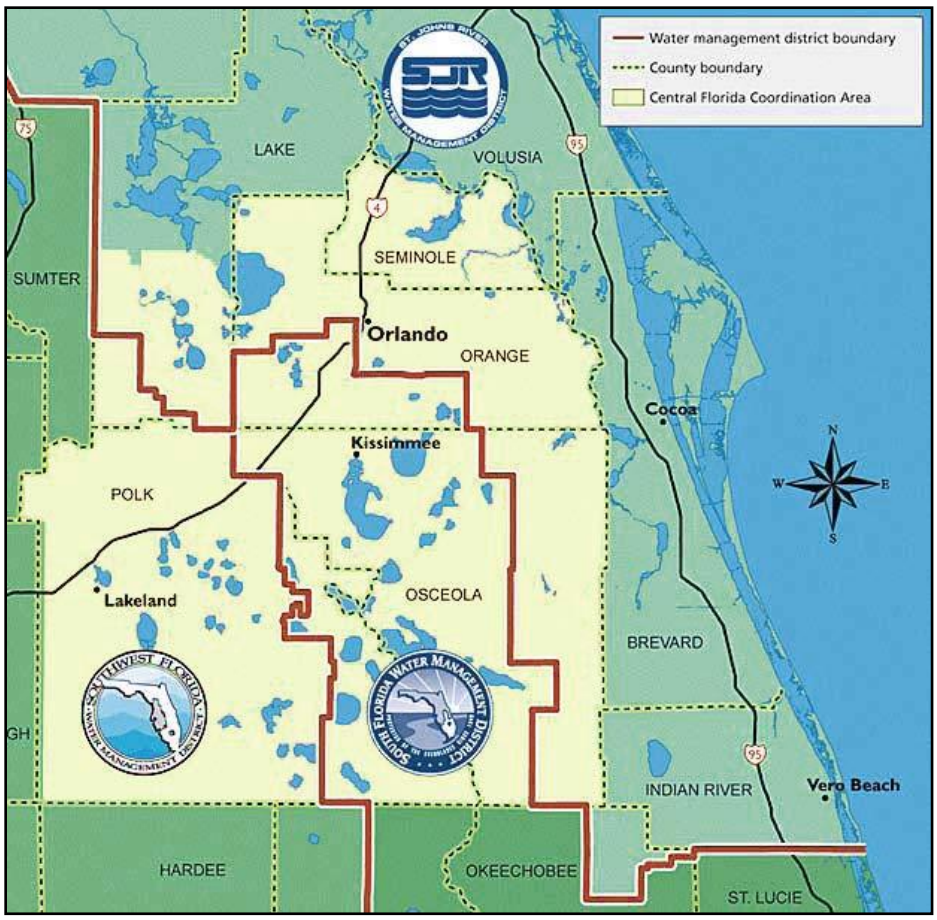


Figure 1. Boundary of the Central Florida Coordination Area (CFCA)

The overall objective of the USGS study is to evaluate the degree to which anthropogenic stresses influence the groundwater flow system. This project seeks to leverage existing climatic, hydrologic, and groundwater withdrawal data to inform a self-teaching model in the form of spatially interpolated artificial neural networks (ANN) model. This model will also be used in a feedback loop with the East-central Florida Transient (ECFT) groundwater flow model (Figure 2; Sepulveda 2012).

Both the USGS ECFT Model and the Data Mining model will be used in a water supply planning effort within the CFCA area which is carried out through the CFWI. Information on the water supply planning efforts can be found at (CFWI; *cfwiwater.com*). While Sumter and Volusia counties are not formally a part of the CFCA, public water supply groundwater withdrawal data from nearby utility water treatment plants (WTPs) in these counties were included in the ANN and ECFT models. A report by McLeod and Munch (2012) contains estimates of the historical trends in agricultural groundwater use within CFCA from 1950 to 2010, and was prepared to provide agricultural water use estimates for the USGS Data Mining project.

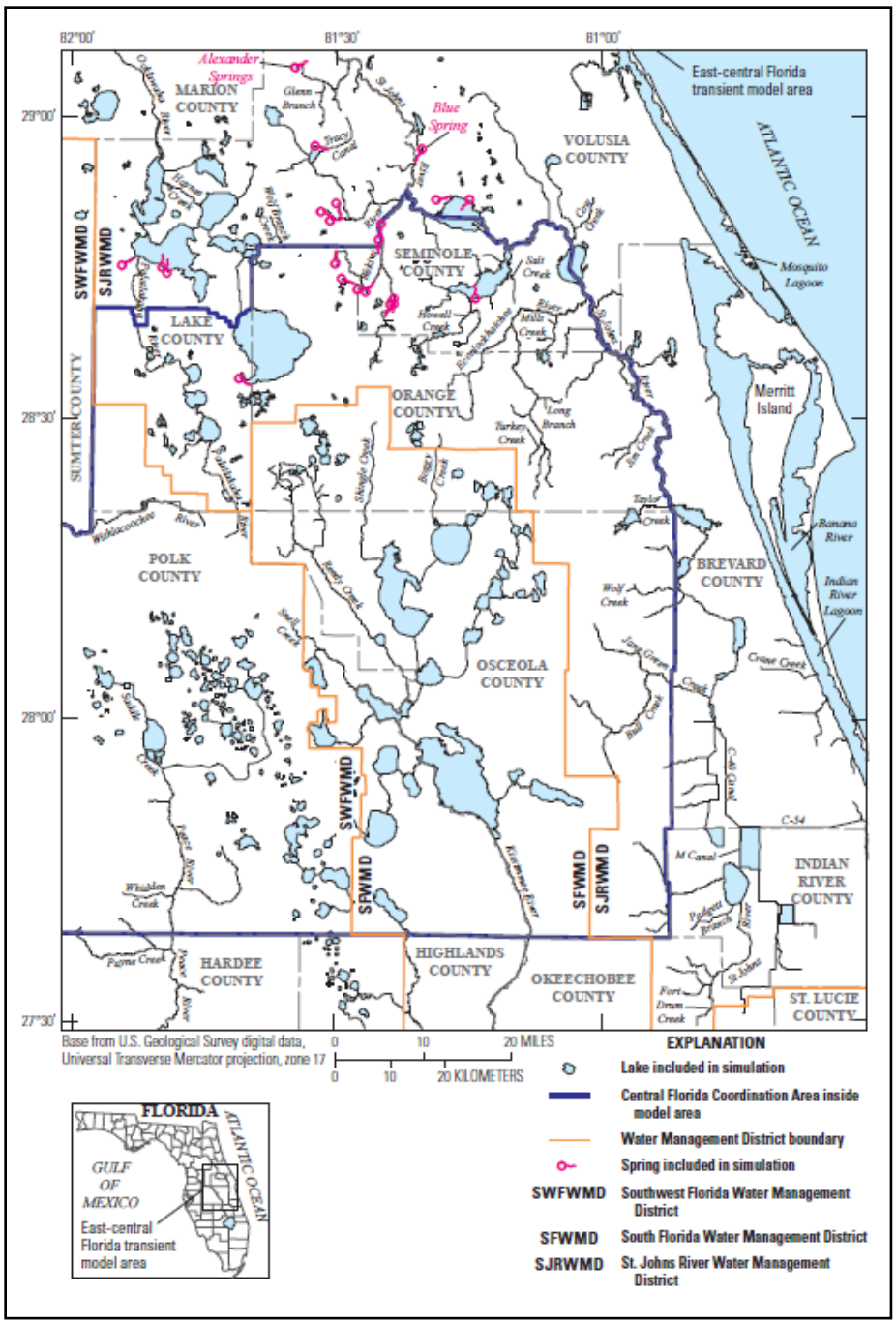


Figure 2. Areal extent of the East-central Florida Transient (ECFT) groundwater flow model

In general terms, the ANN model assumes that the physics of the hydrogeology is represented by the relationships that exists among a set of inputs (e.g., rainfall, evapotranspiration, groundwater pumping) and corresponding outputs or responses at given observation locations that measure groundwater levels, surface water levels,

and spring flows. The ANN model becomes more robust when longer time series information is used. A Decision Support System is a tool that resulted from the Data Mining project. This tool relies on a method that integrates historical databases and results from individual ANN models to provide a simulation of the effects of rainfall and groundwater withdrawals on 51 hydrologic features of interest such as water levels at Floridan aquifer observation wells, lakes, and springs (Figure 3).

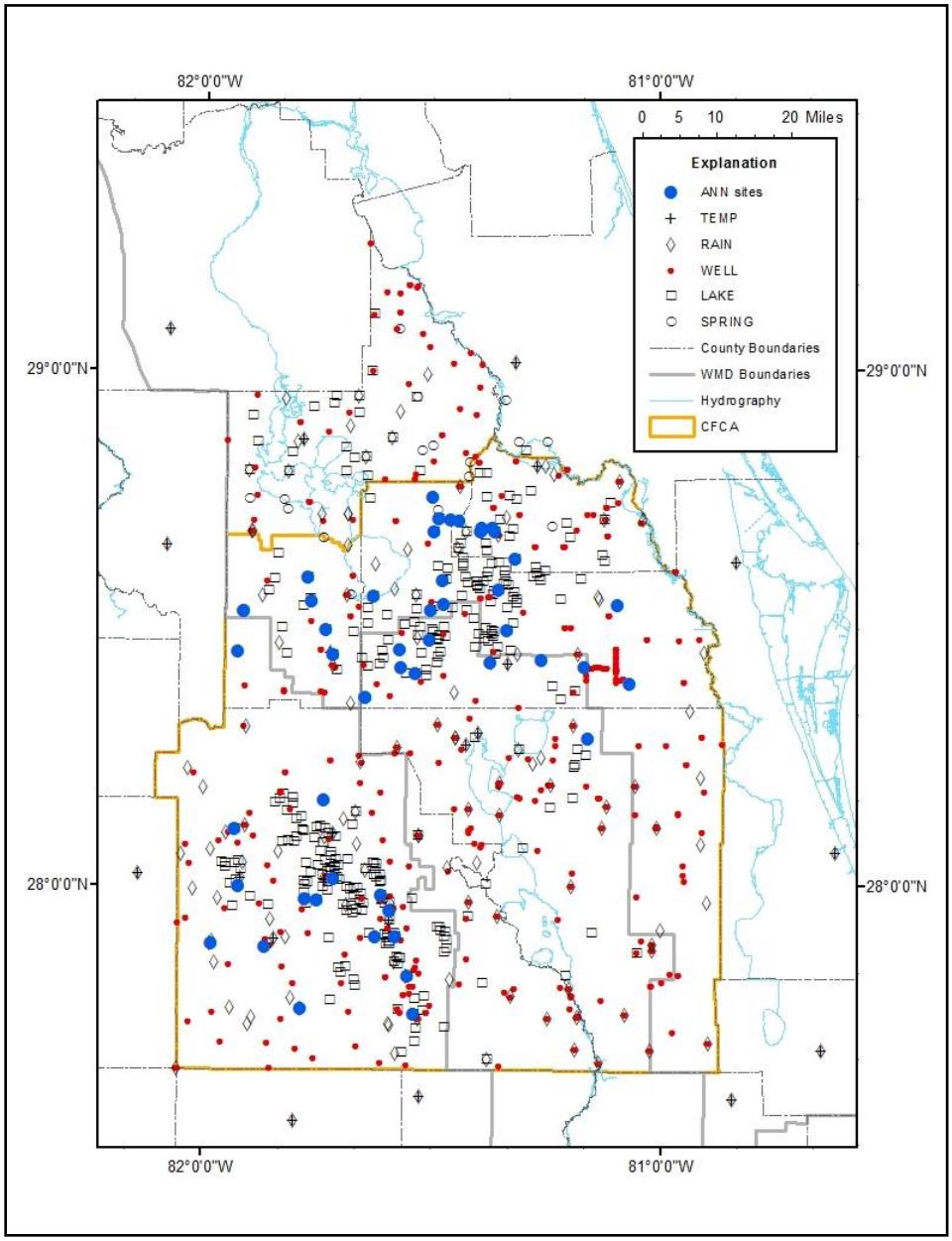


Figure 3. Location of hydrologic features of interest and artificial neural network (ANN) model sites within the Central Florida Coordination Area (CFCA)

OBJECTIVE

The magnitude and spatial attributes of water use are critical components of any groundwater modeling project. Historical documentation for any given public water supply utility prior to 1978 is limited. By 1978, the Florida Department of Environmental Regulation (now Florida Department of Environmental Protection; DEP) and the water management districts were collecting and publishing monthly and yearly water use information for individual public water supply utilities. To develop the database needed to build the USGS simulation models, the data are from a variety of sources and were used to develop historical estimates and reported quantities of individual public supply utility groundwater withdrawals during the period 1945 to 2010. This information, in combination with agricultural estimates found in McLeod and Munch (2012), can be used to develop data needed to support groundwater modeling efforts in the future.

PREVIOUS INVESTIGATIONS

The earliest recorded information related to all categories of water use can be found in reports published by the Florida Geological Survey (FGS) from 1960 through the late 1970s. These early reports focus on the surface and groundwater resources of specific counties and are referred to as Reports of Investigation (RI). These reports are listed in the bibliography. However, they also contain estimates of water use by category, including listings for specific public supply entities.

Since 1950, USGS has been publishing a statewide summary of water use data, which continues to this day on a five-year cycle. Data are reported by water use category and county and is performed in cooperation with DEP and the water management districts. Summaries of the information can be found at the USGS website: *http://fl.water.usgs.gov/infodata/wateruse/historical.html*. In 1977, USGS published a detailed report on public water supplies of selected Florida municipalities (Healy 1977). This report provides a description of water supply and wastewater systems and tabulated average monthly withdrawal data for the years 1945, 1947, 1956, 1965, and 1970 to 1975 in an appendix.

Other reports used in this project include the U.S. Department of Health, Education, and Welfare (USDHEW) 1955, 1960, 1963, 1964a and 1964b that provide a summary of municipal water facilities serving communities with populations of 25,000 and over in the U.S. These reports provide information on source type, withdrawal quantities, and the inception date of the utility as well as many other physical attributes of the municipal system.

With the creation of the water management districts in 1972, interest in accounting for water use was heightened. In 1978, SJRWMD began annual reporting of surface water and groundwater use for all water use categories. Reports published from 1978 until the present can be found at the SJRWMD website: *floridaswater.com/technicalreports*. The reports rely on utility monthly operating reports (MORs) submitted to DEP. Through 1998, the MORs were paper copies that the water management districts had to sort and tabulate. Today, DEP maintains a publicly accessible database of this information (1999 to current), which is located at the DEP website: *http://www.dep.state.fl.us/water/drinkingwater/flow.htm*.

METHODS

Each water supply utility or entity is required by the DEP to submit a MOR that accounts for the total water delivered from each utility's WTP. For the purposes of this tabulation of public supply groundwater use, only systems that deliver more than 100,000 gallons of water per day were tabulated (Appendix A). Within the CFCA area of interest, there are approximately 198 public supply water utilities (Figure 4) that produce more than 100,000 gallons per day and submit MORs to DEP. This accounts for 394 WTPs that provide drinking water to customers. While Sumter and Volusia counties are not formally a part of the CFCA, the water withdrawals from nearby utility WTPs in these counties were included in the ANN and ECFT models. Each WTP has a unique identification number and spatial location. To start building a data set, the most current list of WTP identifications was used to build an Excel database and work back through time. As expected, some WTPs had been taken out of service or abandoned, some WTPs or utilities had been bought by or sold, and some WTP names listed in the permit were different than local names or aliases.

The Excel database was populated with reported monthly and annual values from DEP MORs and historical information found during the literature review. For historical information used, the Excel worksheet contains commentary tabs within the cells to reference the reader as to the source of information. The next step was to contact the directors of the various water utilities to identify any unreported information that might be available. If records were still missing, the information was estimated. While a degree of uncertainty remains in the estimated data, it still captures the trend in groundwater withdrawals.

Generally, three approaches were used to estimate missing information depending on the time frame: average value calculation was used when only a single missing values was needed, monthly interpolation (linear regression), and annual interpolation for when more than one month or year was missing from the record. For most of the years 1945 through 1978, where only annual amounts of water delivered were tabulated. In some cases, average values were calculated for missing years that occurred between years with known values. Some estimates of yearly values were made based on the population estimates obtained from the Florida Statistical Abstracts. That is, for a year in which the population of a given city was known, the closest yearly calculated per capita water use was multiplied by the population estimates to fill the missing value.

For some records available prior to 1978 and all the records after 1978, based on the DEP MORs, missing values were estimated by several different methods. Following is a description of these methods. Estimated missing values are color coded in the Excel database according to the method used to obtain a value (Appendix A).

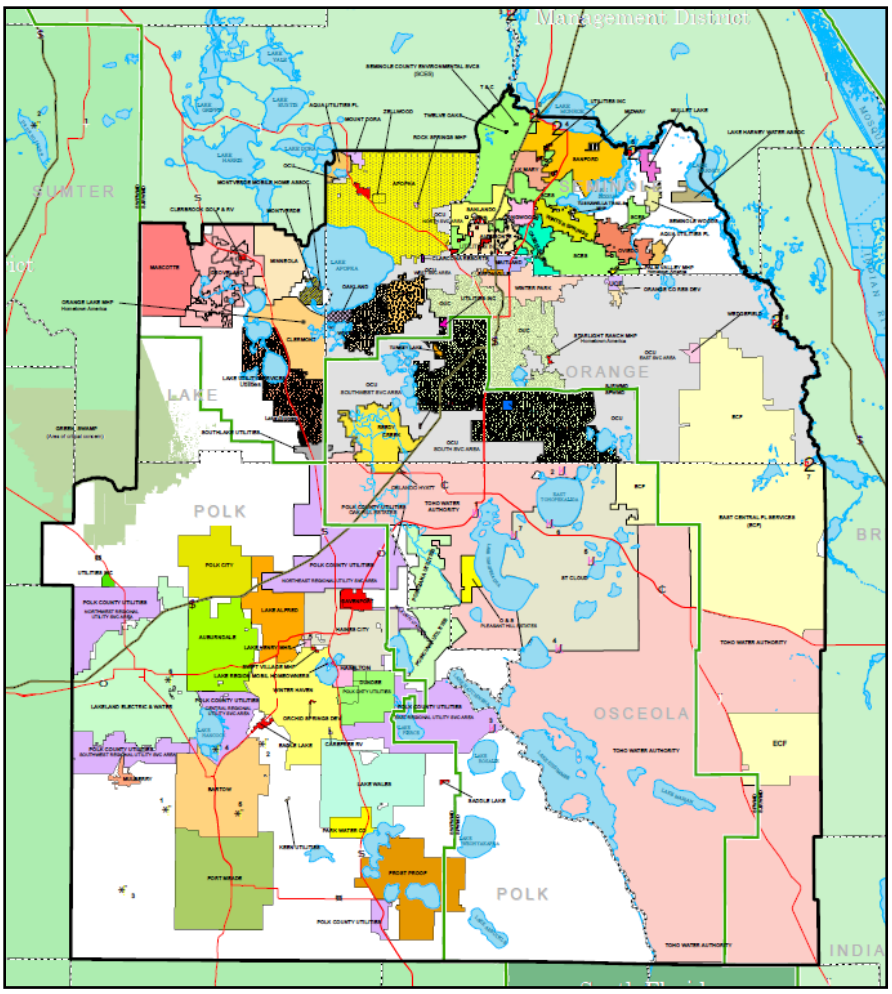


Figure 4. Public water supply utility service areas in the Central Florida Coordination Area (CFCA)

- **Yellow**: Monthly/annual average data exist for the month/year before and after the missing data. An average of the months/years before and after the missing value is applied. The missing value was assigned the calculated average for its value.
- **Orange**: These are utilities deemed inactive by DEP. When the data ended, it was assumed the utility became inactive and Orange zeros were used for the rest of that year.
- **Red**: The start-up date of the utility is known; however, data start later than the start-up date. Existing data were graphed and an exponential trend line was fitted to the data. With an equation based on the fitted trend line, missing years were interpolated. Months from 1978 forward were highlighted in Red and interpolated using the Green method.
- **Green**: Data are missing for more than one month in a row. There is no reason to believe that the utility was inoperable for these months, unless there was a scheduled shutdown with the intention to re-start at a later date. An example of the interpolation method can be found in the

Excel database under a tab called Monthly Interpolation_1978.

- **Purple**: Several years of annual averages were missing. These were estimated using linear regression.
- **Blue**: To estimate monthly values, an interpolation similar to the Green method (taking an average from existing data) was used. Annual values were calculated with the Purple method (linear regression).
- **Light Pink**: The original data set contained a decimal error, which was determined by comparing values within a data set. The highlighted Pink cell is the corrected value.
- Additional information about the methods are described in the Excel database (Appendix A) under a similar titled tab.

RESULTS

The results for annual average water withdrawals are graphically presented below for counties, water management districts, and the CFCA. For each utility WTP, monthly and annual water withdrawals are presented in Appendix A.

Counties

Lake County. The earliest documented groundwater source plant is operated by Montverde beginning in 1926 followed by Clermont in 1939. Currently, there are 32 reporting utilities in the portion of Lake County that is within the CFCA. These utilities operate 65 WTPs. About half of the WTPs were in operation by 1987. In 2004, the remaining WTPs came on line and are reporting today. The maximum average annual withdrawal of 37.1 million gallons per day (mgd) occurred in 2007. Groundwater withdrawals for public supply use in Lake County have increased from 0.1 mgd in 1945 to approximately 29 mgd in 2010 (Figure 5).

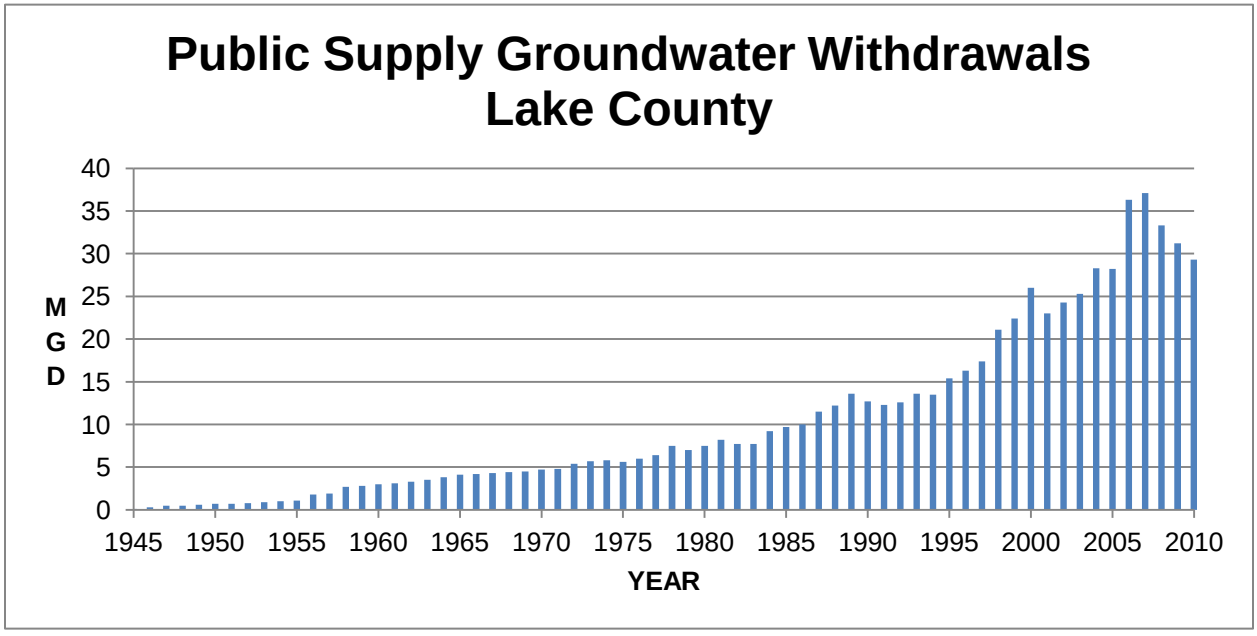


Figure 5. Public supply groundwater withdrawals in Lake County, 1945–2010

Orange County. The earliest documented groundwater source plant began in 1923 in Ocoee, with Oakland and Maitland starting in 1926. For the City of Orlando, USDHEW (1955) indicates that operation started in 1888, with a WTP built in 1949. Water sources were lakes and four wells with an average plant output of 11.67 mgd. During these early years, wells were used to augment lakes for power plant cooling and drinking water (R. Teagarden, [Orlando Utilities Commission] pers. comm. 2011). Between 1958 and 1959, the city stopped using surface water and shifted to the Floridan aquifer as the primary source. Currently there are 28 reporting utilities operating numerous WTPs within Orange County. Estimates of surface water withdrawals are recorded in the spreadsheets in Appendices A and B but are not accounted for in Figure 6. The maximum average annual total withdrawal of 224.4 mgd occurred in 2006 with 62 plants reporting. Groundwater withdrawals for public supply use in Orange County increased from 0.6 mgd in 1945 to approximately 207 mgd in 2010.

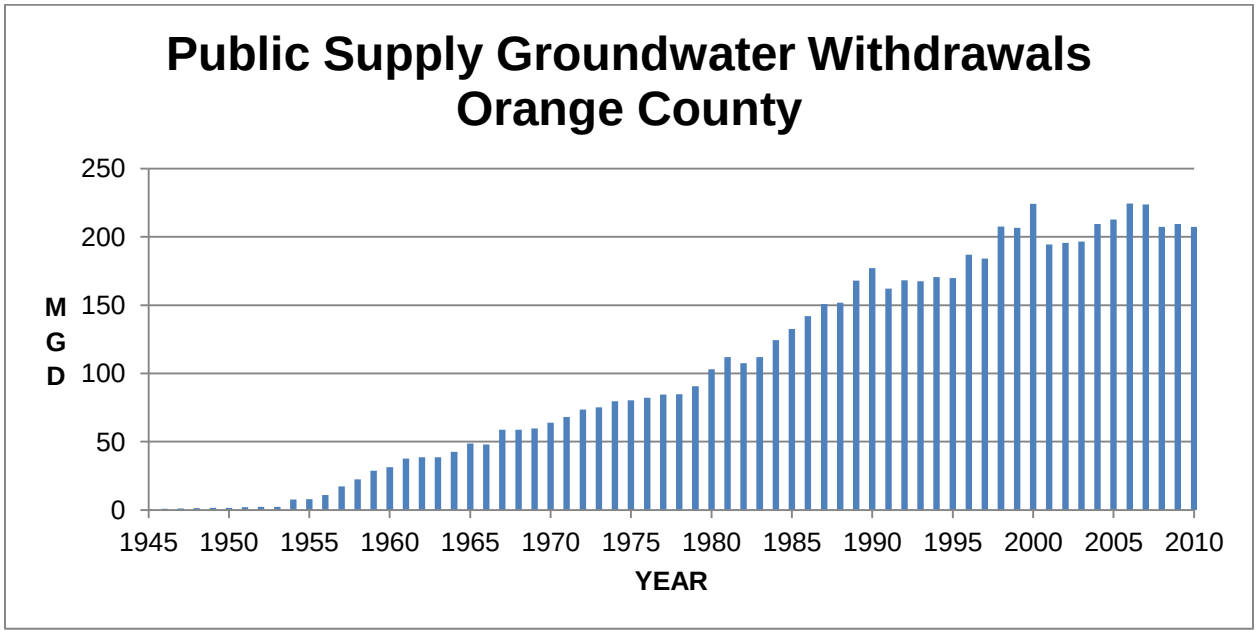


Figure 6. Public supply groundwater withdrawals in Orange County, 1945–2010

Osceola County. Healy (1977) suggests the cities of St. Cloud and Kissimmee were using groundwater in 1945, if not earlier. There are 19 active DEP permits associated with the WTPs in Osceola County. In 2000, 30 plants were in operation, producing 36.5 mgd of water. As of 2010, 26 plants were producing 38.8 mgd of water with Toho Water Authority (Kissimmee) and St. Cloud accounting for the largest share of water withdrawals. The maximum average annual withdrawal for public water supply of 43.8 mgd occurred in 2006 with 27 plants reporting. Public supply groundwater withdrawals in Osceola County increased from 1.2 mgd in 1945 to approximately 39 mgd in 2010 (Figure 7).

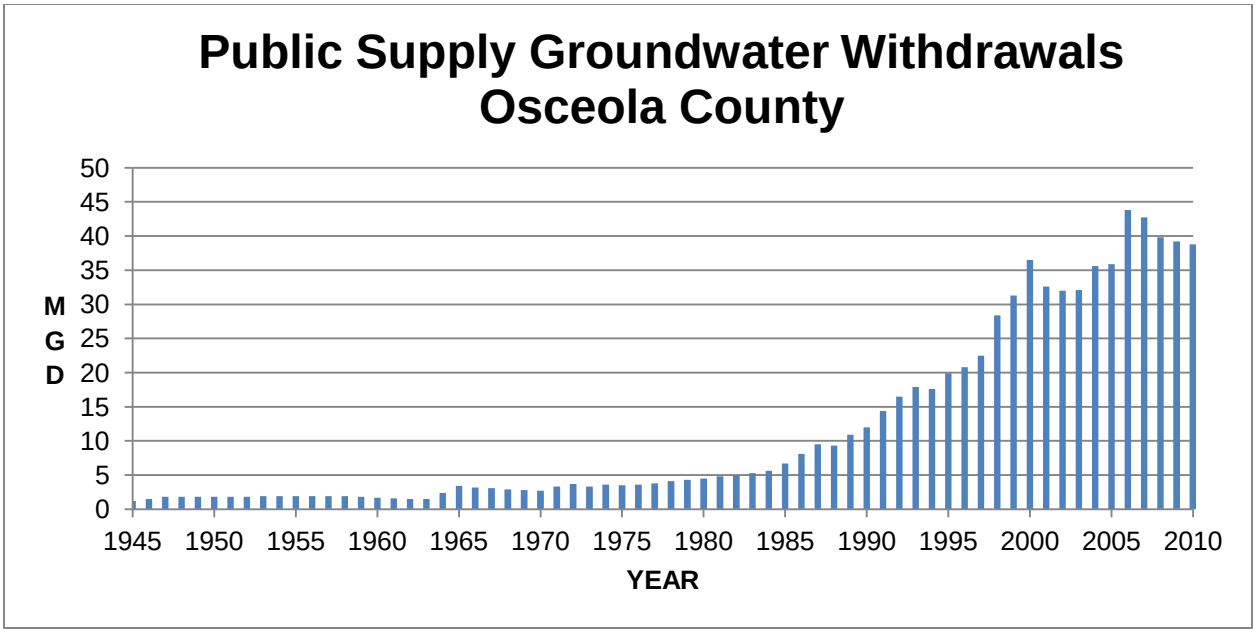


Figure 7. Public supply groundwater withdrawals in Osceola County, 1945–2010

Polk County. The earliest documented groundwater source utility was the City of Fort Meade in 1910, followed by Lakeland in 1922, Highland Park and Mulberry in 1924, Davenport in 1925, and Polk City in 1926. Currently there are 38 reporting utilities operating 116 WTPs within Polk County. In 2002, there were 126 WTPs reporting information to DEP. The maximum annual average public supply withdrawal of 84 mgd occurred in 2006 with 123 plants reporting. Groundwater withdrawals for public supply use in Polk County increased from 5.5 mgd in 1945 to 63 mgd in 2010 (Figure 8).

Seminole County. The earliest documented groundwater source utility supplied the City of Chuluota in 1925, followed by Longwood in 1926, and Sanford in 1938. Currently there are 24 reporting utilities operating 32 WTPs. In 1997, the largest number of WTPs (46) were in operation, producing 55.4 mgd. The maximum average annual withdrawal of 71.3 mgd occurred in 2000 with 46 plants reporting. Public supply groundwater withdrawals in Seminole County increased from 0.7 mgd in 1945 to approximately 57 mgd in 2010 (Figure 9).

Sumter County. Sumter County is not delineated as part of the CFCA. However, groundwater withdrawals from this area are considered in both USGS modeling efforts; and two Sumter County utilities were inventoried for this paper. The earliest documented groundwater source utility supplied the City of Center Hill that started in 1926, followed by the City of Wildwood in 1952. The Center Hill utility operates two WTPs. Wildwood currently operates six plants, and the amounts in the Excel database (Appendix A) represent a system total for Wildwood. The maximum average annual public supply groundwater withdrawal of 2.24 mgd occurred in 2006 with six plants reporting. Public supply groundwater withdrawals in Sumter County increased from0.23 mgd in 1958 to slightly over 2.0 mgd in 2010 (Figure 10).

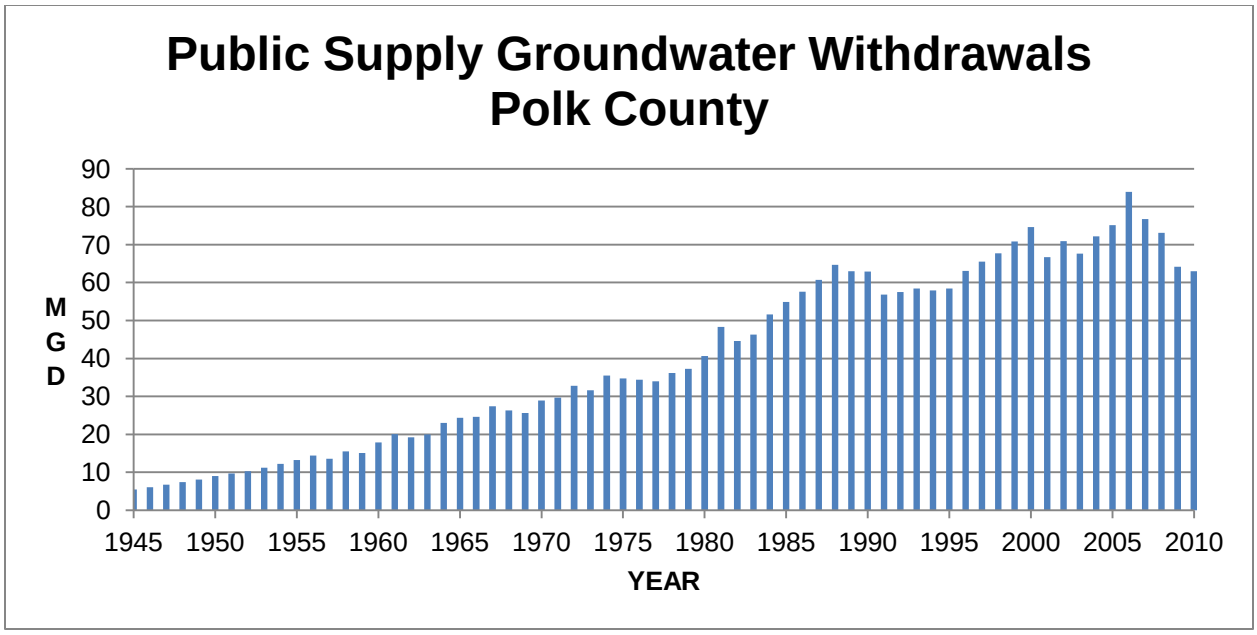


Figure 8. Public supply groundwater withdrawals in Polk County, 1945–2010

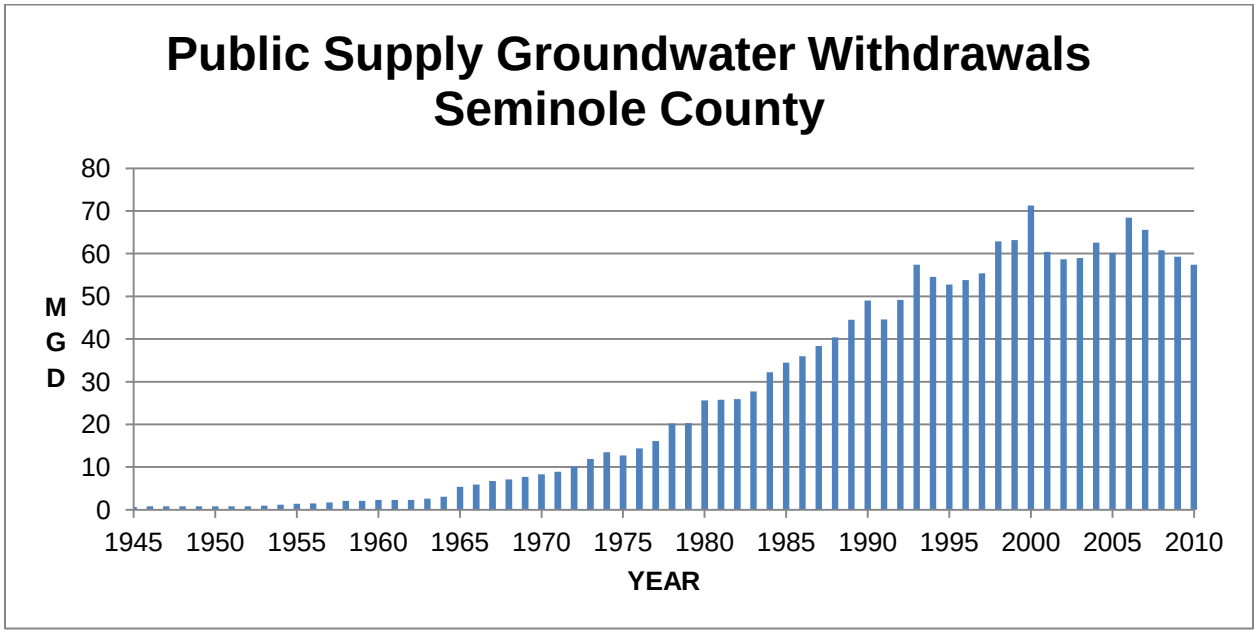


Figure 9. Public supply groundwater withdrawals in Seminole County, 1945–2010

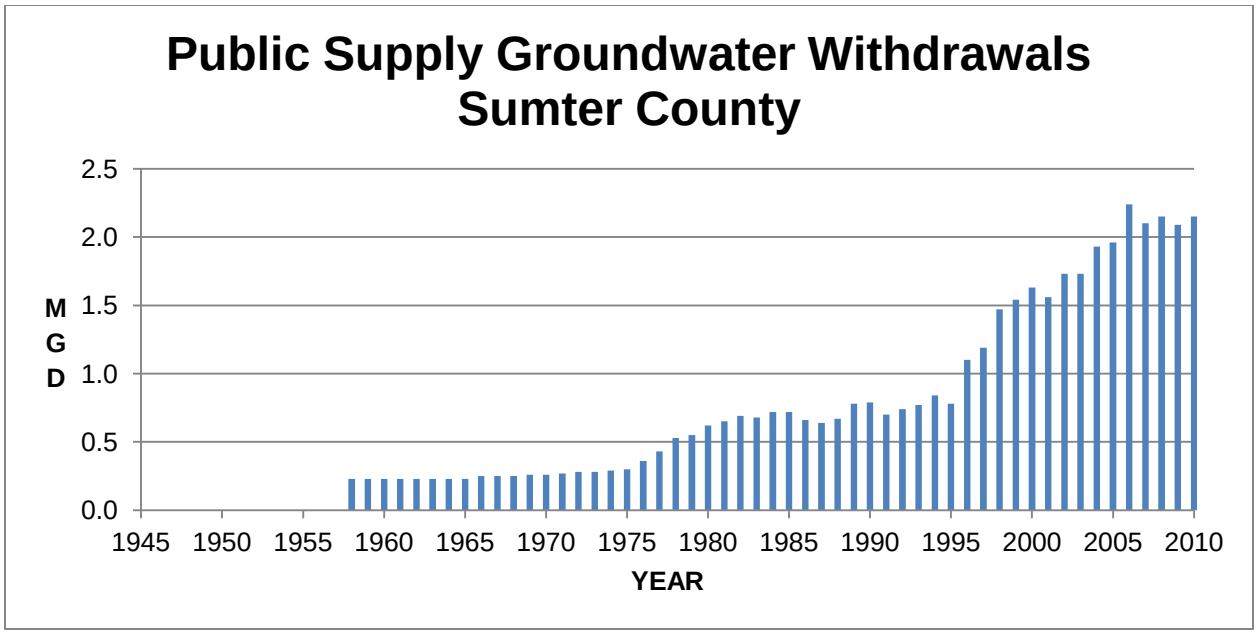


Figure 10. Public supply groundwater withdrawals in Sumter County, 1958–2010

Volusia County. Volusia County is not delineated as a part of the CFCA; however, groundwater withdrawals are considered in both USGS modeling efforts. Currently there are three reporting utilities operating 15 WTPs in the area of interest. The earliest documented plant was Orange City in 1881, followed by Deltona 1975, and Western Volusia (Volusia County Utilities) in 1985. Groundwater use was relatively low until 1975 when the utility supplying the Deltona area was added (now owned by the City of Deltona). Since 1990, groundwater withdrawals for these three utilities has averaged approximately 10 mgd. The maximum average annual withdrawal of 12.22 mgd occurred in 2006 with 14 plants reporting. Public supply groundwater withdrawals in Volusia County increased from 0.12 mgd in 1958 to approximately 10 mgd in 2010 (Figure 11).

Comparison of County Totals

Figure 12 illustrates a comparison of the county totals for the information collected. Orange County has experience the fastest growth in public supply water demand. Polk and Seminole counties have also experience significant demand but at a much lower rate. For the time period reviewed, all the counties have essentially doubled the use of groundwater for public supply purposed since the early 1980s.

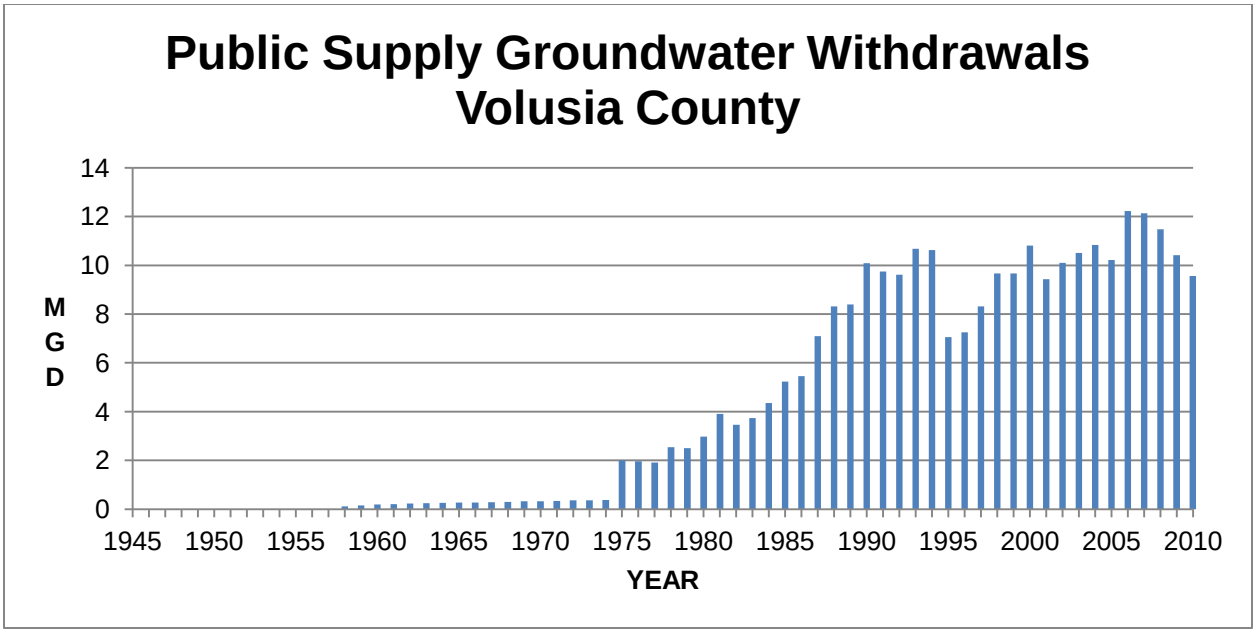


Figure 11. Public supply groundwater withdrawals in Volusia County, 1958–2010

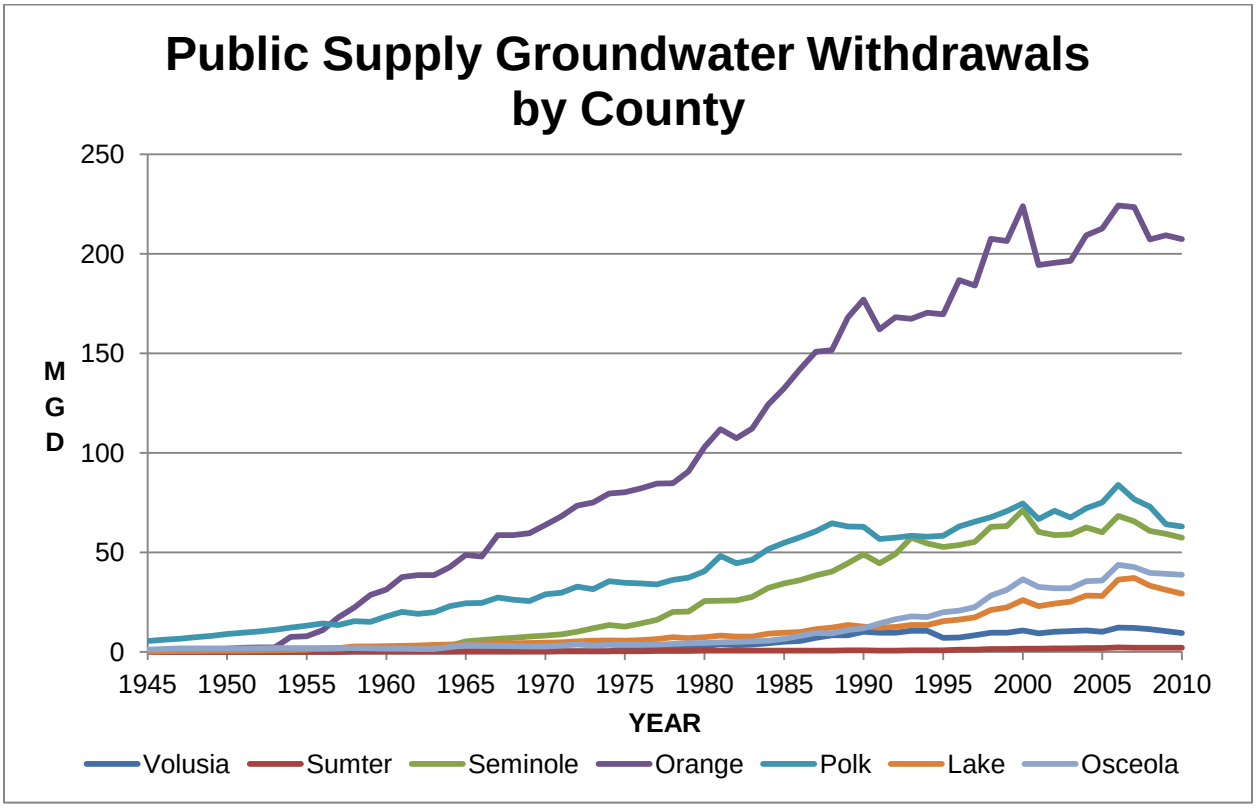


Figure 12. Public supply groundwater withdrawals by county, 1945–2010

Water Management Districts

The CFCA is divided among three water management districts, with SJRWMD covering 36% of the area followed by the South Florida Water Management District (SFWMD) and SWFWMD at approximately 32% each. The SJRWMD portion of the CFCA includes the counties of Lake, Marion, Seminole, Volusia, most of Orange, and a small portion of Osceola. The SJRWMD portion contains nearly 100 public water suppliers producing 0.1 mgd or more and operating approximately 170 WTPs. The SWFWMD portion of the CFCA includes Polk and Sumter counties, and a small portion of Lake County. There are nearly 60 water supply utilities in the SWFWMD portion of the CFCA, which operate 133 WTPs. The SFWMD portion of the CFCA includes most of Osceola County and a small portion of Orange County. The SFWMD portion contains 23 public water supply utilities operating 62 WTPs of similar capacity.

Up until the late 1970s, moderate growth in groundwater withdrawals occurred in all three water management districts. There was also an increasing trend in withdrawals associated with increasing population from 1980 through 2006. Since 2006, withdrawals decreased to levels reported for the early 2000s. While not specifically addressed in this paper, the observed decrease in groundwater withdrawals is likely associated with increased use of reclaimed water to offset potable water use along with some level of water conservation practices (T. Bartol, SJRWMD, pers. comm. 2013).

Noticeable peaks above the growth trend for the years 1981, 1990, 2000, and 2006 (Figure 13) are consistent among water management districts. These peaks in withdrawals are likely associated with the increased groundwater demand during periods of significantly below normal annual rainfall (Florida Climate Center 2013) for the Orlando metropolitan area as highlighted in red in Figure 14. The maximum groundwater withdrawals occurred in 2006 with a total of 471 mgd delivered within the three water management districts. The second highest occurred in 2007 at approximately 460 mgd, and the third highest occurred in 2000 at 445 mgd. By comparison, groundwater withdrawal in 1981 was approximately 203 mgd.

From 1981 to 2010, groundwater withdrawals doubled from approximately 200 mgd to slightly more than 400 mgd. From 1990 to 2010, groundwater withdrawals in SFWMD almost doubled to 117 mgd. A similar trend occurred in SJRWMD over the same time period as withdrawals increased from approximately 50 mgd to just less than 125 mgd by 2010. In SWFWMD, groundwater withdrawals doubled from 1971 to 2010 to approximately 62 mgd. For 2010 public supply groundwater withdrawals, SJRWMD accounts for 56%, followed by SFWMD at 29%, and SWFWMD at 15% (Figure 15).

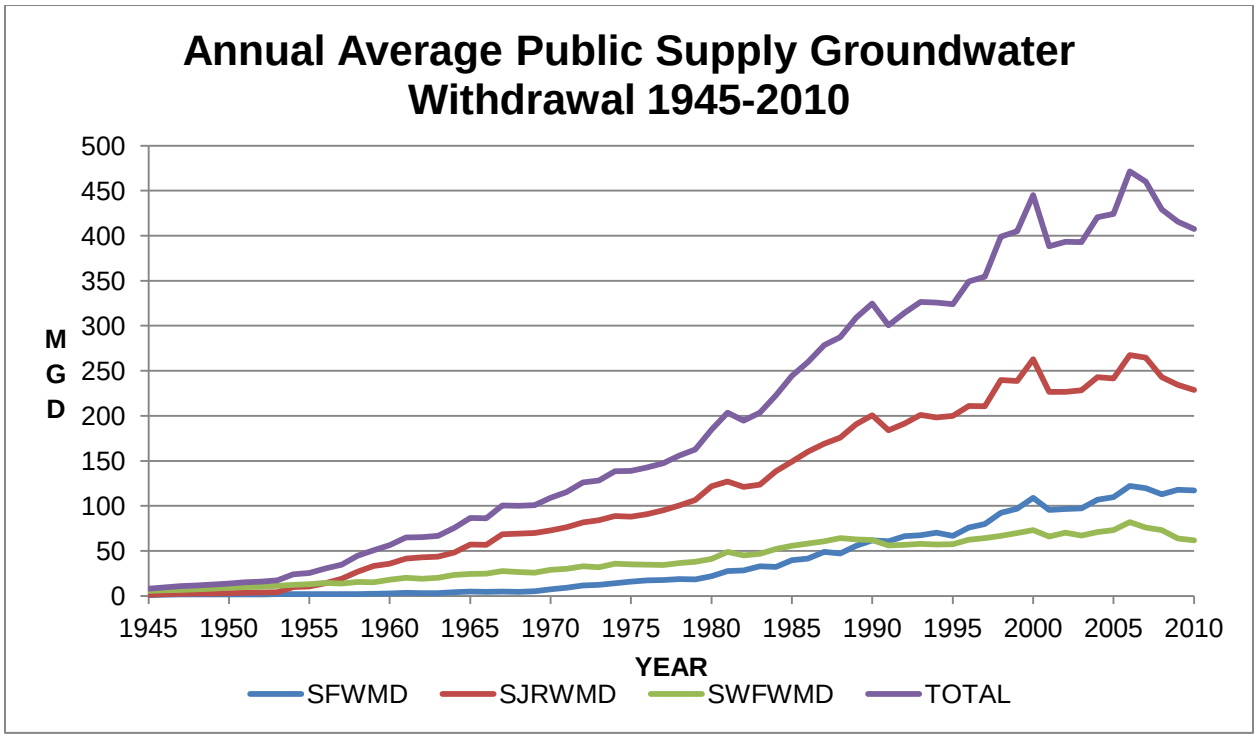


Figure 13. Annual average public supply groundwater withdrawals in St. Johns River Water Management District (SJRWMD), South Florida Water Management District (SFWMD), and Southwest Florida Water Management District (SWFWMD), areas of the CFCA, 1945–2010

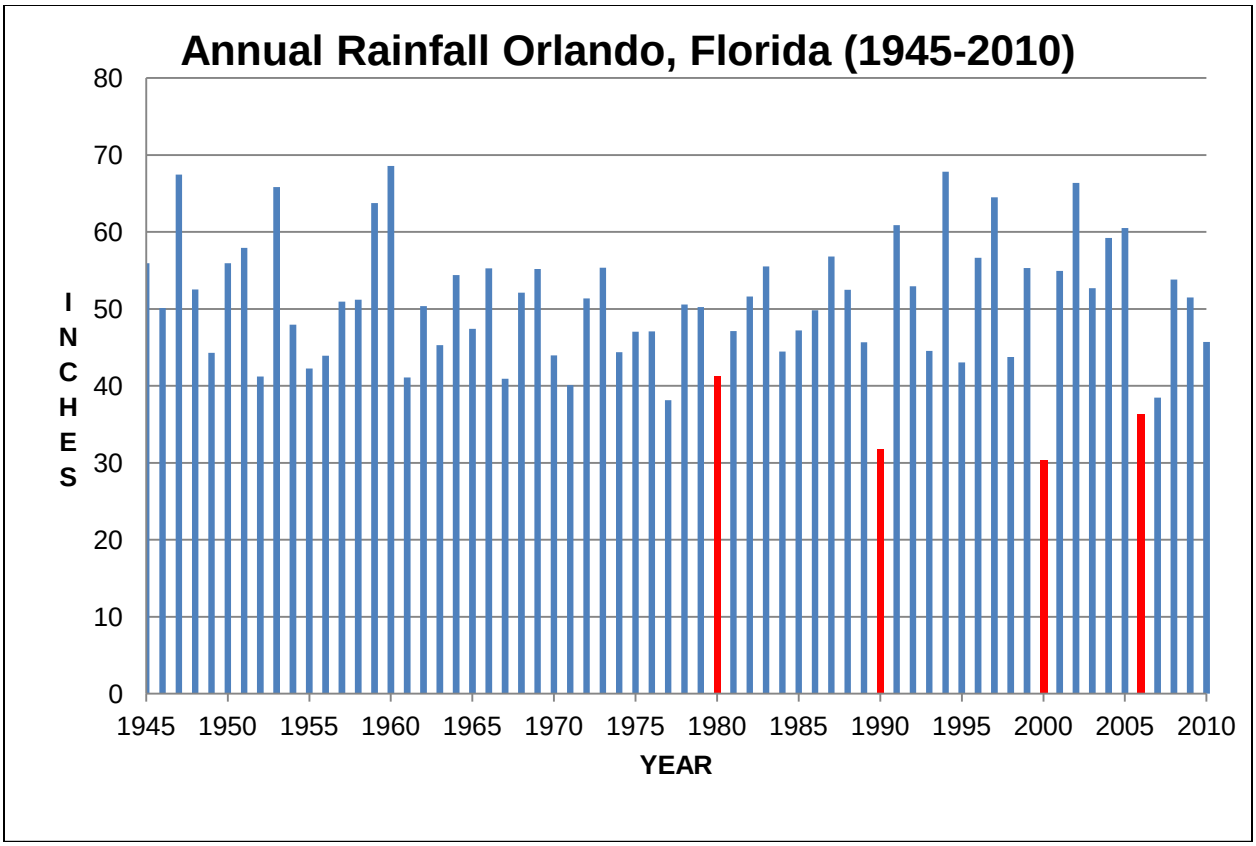


Figure 14. Annual rainfall in Orlando, Florida, 1945–2010

Note: Red bars represent years with significantly below normal rainfall.

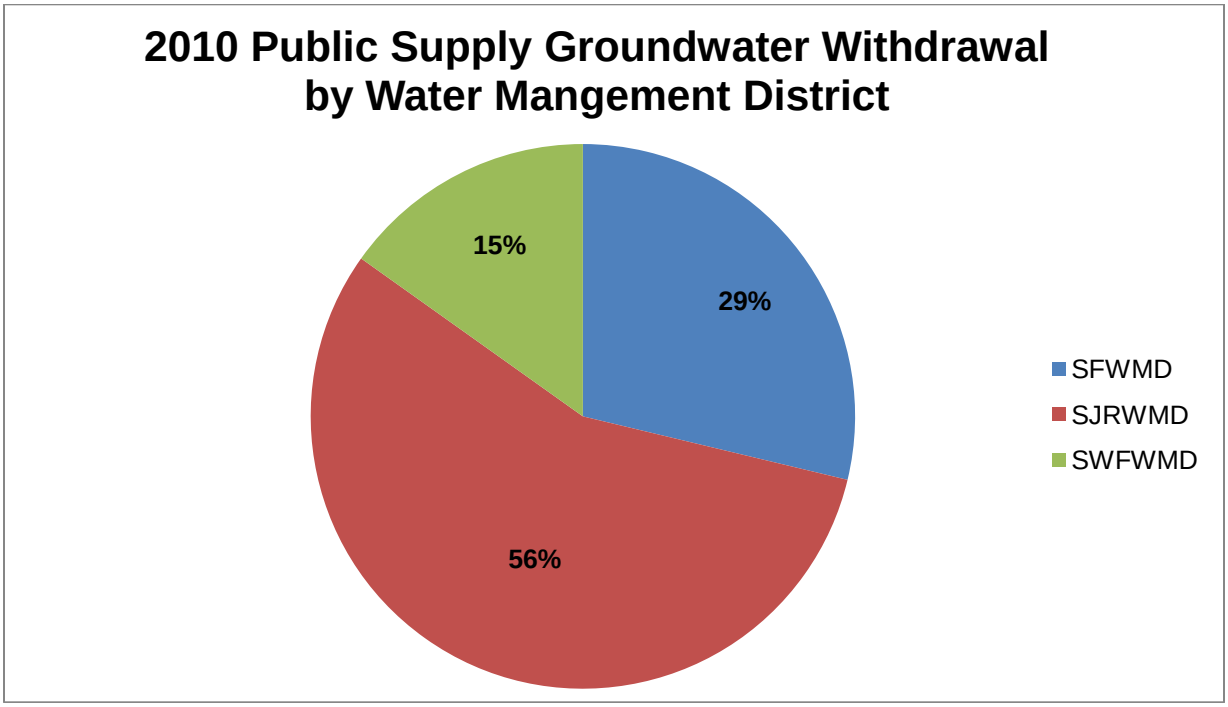


Figure 15. Public supply groundwater withdrawal by water management district in the CFCA, 2010

Central Florida Coordination Area (CFCA) and Vicinity

Within the CFCA and the vicinity, groundwater withdrawals for public water supply steadily increased from 8.1 mgd in 1945 to approximately 408 mgd in 2010 (Figure 16). From 1945 to 1955, the growth in groundwater withdrawals was 1.7 mgd per year. From 1955 to 1980, groundwater withdrawals increased 59 mgd at a rate of 2.36 mgd per year. From 1980 to 2005, groundwater withdrawals increased at a rate of 9.56 mgd per year ending in a total of approximately 424 mgd. In 2006, water withdrawals peaked at almost 471 mgd and then declined by 63 mgd to 408 mgd in 2010. The 10-year average public supply groundwater withdrawal from 2000 to 2010 in the CFCA and vicinity is 422 mgd. The overall trend in the data compiled fits well to a 2-year moving average (Figure 17).

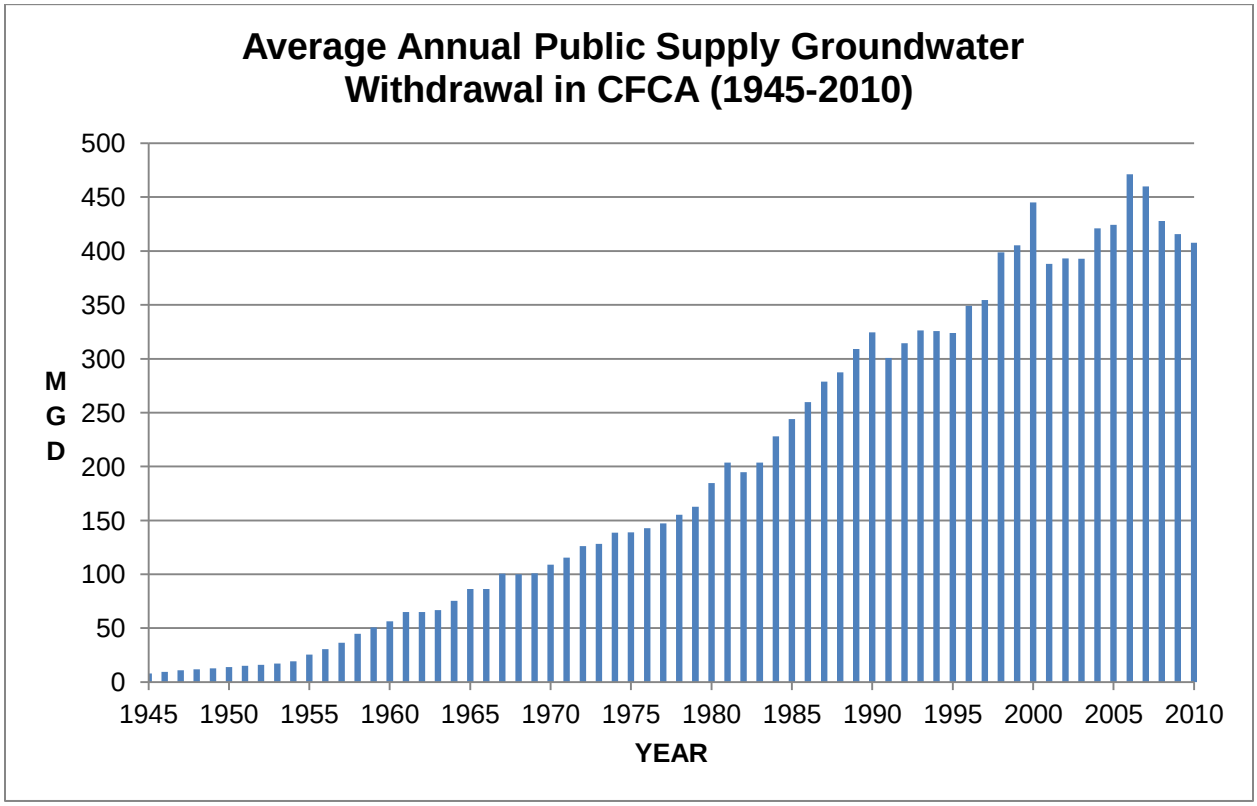


Figure 16. Average annual public supply groundwater withdrawals in the Central Florida Coordination Area (CFCA), 1945–2010

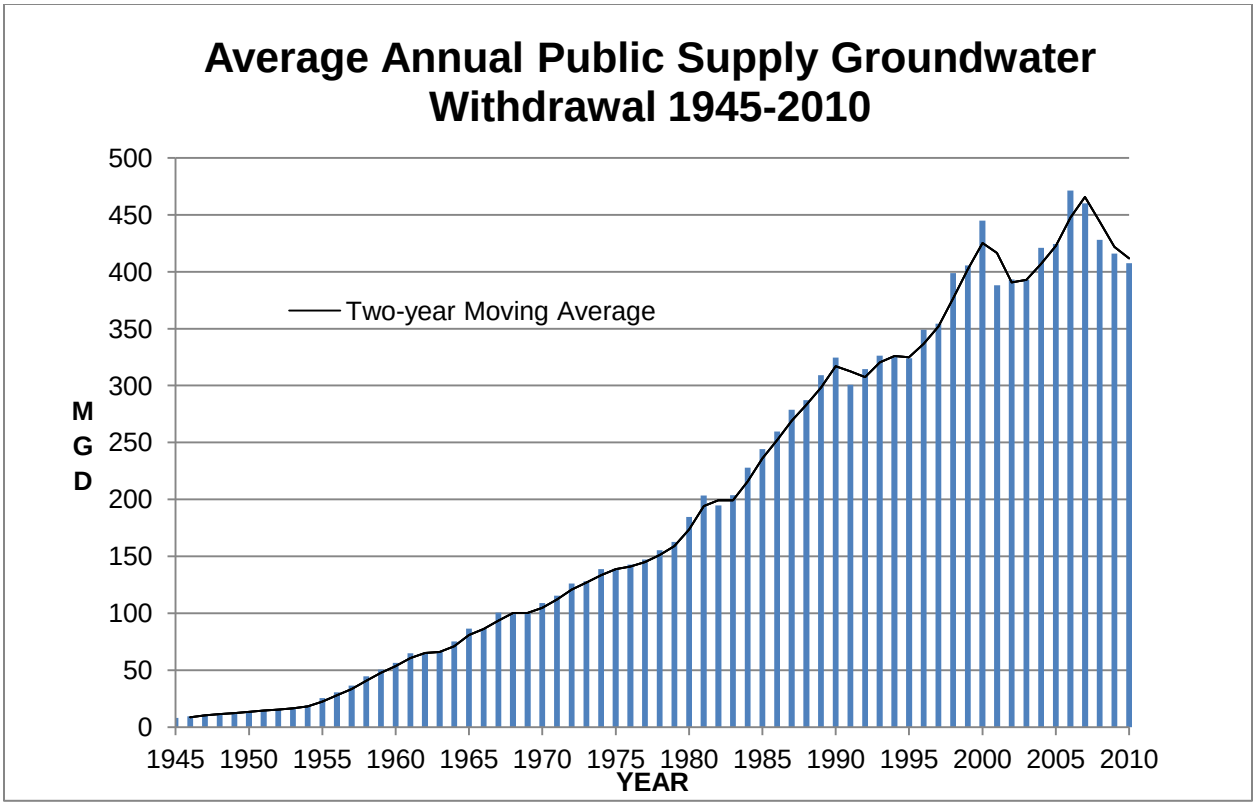


Figure 17. Two-year moving average based on the average annual public supply groundwater withdrawals, 1945–2010

SUMMARY

Within the CFCA and vicinity, the preferred source for potable water is groundwater. To meet the ever-increasing demand for potable water there has been steady growth in the number of private and public utilities serving public supply water use. The collection and tabulation of groundwater production data by public supply utilities has made it possible to develop a source of information, which can be used in scientific endeavors.

Since 1945, the number of utilities with recorded information has grown from 16 to well over 180; these utilities are operating more than 183 WTPs. Up until the late 1970s moderate growth in groundwater withdrawals occurred in all three water management districts. There was also an increasing trend in withdrawals associated with increasing population from 1980 through 2006. Since 2006, withdrawals decreased to a level of the early 2000s. The years 1981, 1990, 2000, and 2006 show noticeable peaks above the growth trend, a pattern that is consistent among water management districts. These peaks in withdrawals are likely associated with the increased groundwater demand during periods of drought.

The Excel worksheets assembled for this paper were provided to the USGS to complete work on the water resources investigation "Quantification of Natural and Anthropogenic Effects in Groundwater and Lake-level Data in the Central Florida Coordination Area." This data can be easily updated in the future because the

information is tabulated by DEP Permit ID and can be used to construct groundwater model input files required to do steady-state or transient modeling.

BIBLIOGRAPHY

Barraclough, J. T. 1962. *Ground-water resources of Seminole County, Florida,* Report of Investigation No. 27, Tallahassee, Fla.: U.S. Geological Survey.

Florida Climate Center. 2013. Precipitation Data for Orlando, Florida. 2013, at the Florida Climate Center, Florida State University website at *http://climatecenter.fsu.edu/products-services/data/precipitation/orlando.*

[DEP] Florida Department of Environmental Protection. 2013. Flow Data for 1999–2013. Accessed 2013, on the DEP website at *http://www.dep.state.fl.us/water/drinkingwater/flow.htm*.

Florida Statistical Abstracts. *Selected years*. Bureau of Economic and Business Research, College of Business Administration, University of Florida. Gainesville, Fla: The University Presses of Florida.

Healy, H. G. 1977. *Public water supplies of selected municipalities in Florida, 1975.* Water Resources Investigations 77–53, Tallahassee, Fla.: U.S. Geological Survey.

Knochenmus, D. D., and M. E. Beard. 1971. Evaluation of the quantity and quality of the water resources of Volusia County, Florida. Report of Investigations–Florida Geological Survey No. 57. Tallahassee, Fla.: U.S. Geological Survey.

Lichtler, W. A. 1972. *Appraisal of water resources in the East Central Florida region.* Report of Investigations–Florida Geological Survey No. 61. Tallahassee, Fla.: U.S. Geological Survey.

Lichtler, W. F., W. Anderson, and B. F. Joyner. 1968. *Water resources of Orange County, Florida.* Report of Investigations–Florida Geological Survey No. 50. Tallahassee, Fla.: U.S. Geological Survey.

McLeod, J., and D. Munch. 2012. *Methodology for estimating historical agricultural groundwater use in the Central Florida Coordination Area (CFCA), 1957–2010*. Technical Publication SJ2012-2. Palatka, Fla.: St. Johns River Water Management District.

O'Reilly, A.M., Roehl, E.A., Jr ., Conrads, P.A., Daamen, R.C., and Petkewich, M.D., 2014, Simulation of the effects of rainfall and groundwater use on historical lake water levels, groundwater levels, and spring flows in central Florida: U.S. Geological Survey Scientific Investigations Report 2014–5032

Sepulveda, N.; C. R. Tiedeman, A. M. O'Reilly; J. B. Davis, and P. Burger. 2012. *Groundwater flow and water budget in the surficial and Floridan aquifer systems in east-central Florida.* Scientific Investigations Report 2012-5161. Reston, Va.: U.S. Geological Survey.

Stewart, Jr., H. G. 1966. *Ground-water resources of Polk County, Florida.* Report of Investigations–Florida Geological Survey No. 44. Tallahassee, Fla.: U.S. Geological Survey

[USDHEW] U.S. Department of Health, Education and Welfare. 1955. Inventory, municipal water facilities for larger communities, Florida: a cooperative state-federal report. Unnumbered Public Health Service Publication (revised). Washington, D.C.: U.S. Department of Health, Education and Welfare, Public Health Service, Division of Sanitary Engineering, Water Supply and Water Pollution Control Branch.

———. 1960. *Municipal water facilities inventory as of January 1, 1958. Volume 4.* Unnumbered Public Health Service Publication. Washington, D.C.: U.S. Department of Health, Education and Welfare, Public Health Service, Division of Sanitary Engineering, Water Supply and Water Pollution Control Branch.

———. 1964a. *Municipal water facilities, communities of 25,000 population and over, United States and possessions, as of January 1, 1964*: a cooperative state-federal report. Public Health Service Publication No. 661. Washington, D.C.: U.S. Department of Health, Education and Welfare, Public Health Service, Division of Sanitary Engineering, Water Supply and Water Pollution Control Branch.

———. 1964b. *1963 Inventory of municipal water facilities, region IV*: a cooperative state-federal report. Public Health Service Publication No. 775 (revised). Washington, D.C.: U.S. Department of Health, Education and Welfare, Public Health Service, Division of Sanitary Engineering, Water Supply and Water Pollution Control Branch.