Appendix VI
Water Use and Injection Well Hindcasting

APPENDIX VI - PART 1
WATER USE HINDCASTING

1.0 INTRODUCTION

The purpose of this appendix is to document the data and methods used in estimating historical groundwater use throughout the North Florida Southeast Georgia Groundwater Model (NFSEG) Domain, including counties in Florida, Georgia, and South Carolina (Figure 1). The hindcasted data is an estimate of historical groundwater use back to 1900. The hindcasted groundwater use estimates were prepared for each county by use type (e.g. agriculture, public supply, industrial). Interpolation between published population and water use estimates as detailed in this section were used to estimate groundwater use on an annual time step. The historical groundwater use estimates form the basis for an evaluation of the impact of historical groundwater use on baseflow groundwater contributions to water bodies within the model domain.

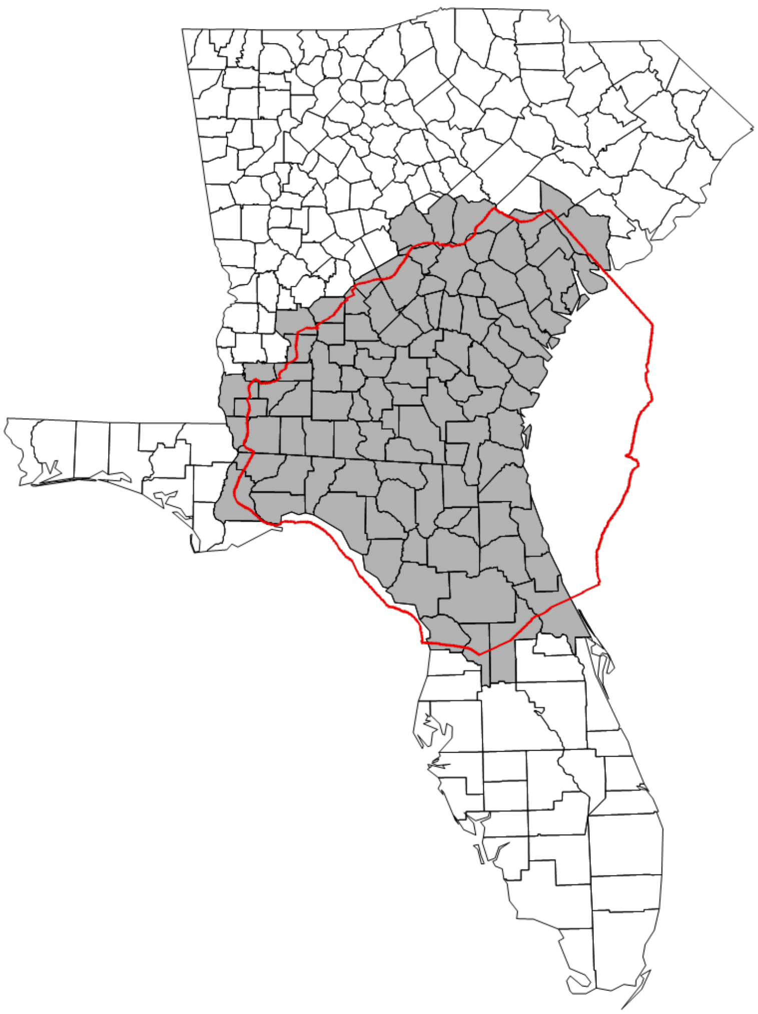

Figure 1. NFSEG Domain. Counties in gray are included in the effort to estimate historical groundwater use

2.0 OVERVIEW OF PROCESS

The timeline and data sources used to estimate historical groundwater use by region are summarized in Figure 2. The methods used to estimate historical groundwater use differed by region based on data availability and are provided in detail in the following sections. For each region water use estimates were prepared for the groundwater use categories summarized in Table 1.

Water use estimates between 1900 and approximately 1960 (Figure 1: gray time periods) were prepared based on historical estimates of population and an estimate of per capita water usage. Historic population data sources are detailed for each region in the following sections. Missing data between published county level population estimates were interpolated in MS Excel using an exponential growth assumption (Excel RATE function) to create annual population estimates. The annual population was multiplied by an estimate of per capita groundwater usage for the categories summarized in Table 1. The per capita water estimates were prepared based on population data and county level groundwater use data summarized by use type from the earliest published groundwater use estimate. In some counties, the timing of initiation of groundwater use within categories or industries could be identified, even though county level estimates were not available. Adjustments made based on historic use data are described in detail for each region and are based on data availability.

Beginning in approximately 1960 (Figure 2: blue, red, purple, and orange time periods) published water use estimates were used to estimate groundwater use by category. Published county level groundwater use estimates were used when available. Missing data between published county level groundwater use were estimated in MS Excel using an exponential growth assumption (Excel RATE function) to create a complete annual groundwater use estimate. Groundwater use was interpolated to produce annual water use estimates. Where available, historical data regarding the initiation of industrial and power generation facilities were used to refine historic water use estimates. For each region, groundwater use was summarized into the categories in Table 1.

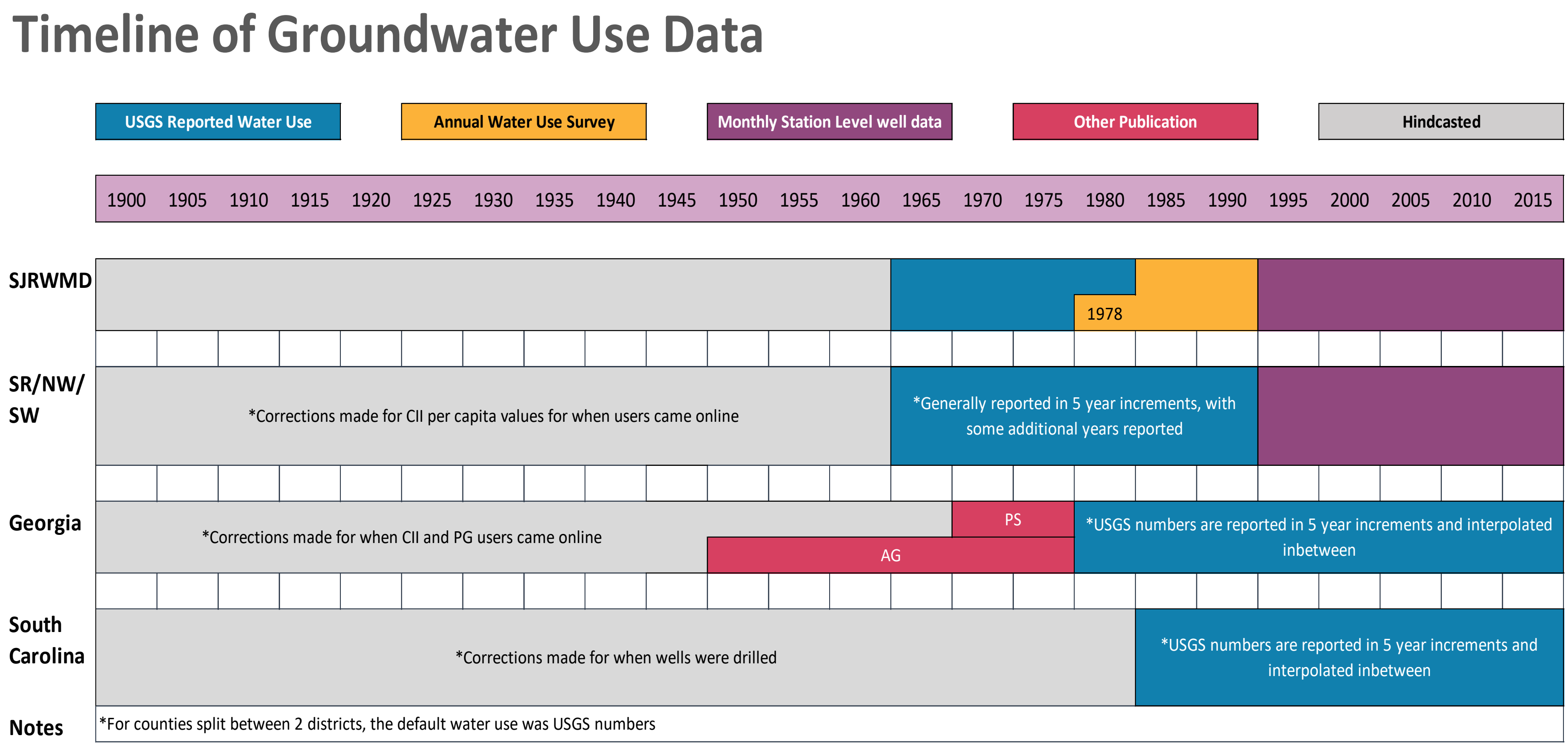

Figure 2. Timeline of sources and methods used to estimate historic groundwater use

Use Type	Abbreviation	Definition
Public Supply	**PS**	**Large municipal, public, and private systems that supply potable water to the public**
Domestic Self-Supply	**DSS**	**Domestic water uses generally associated with residential dwellings that are not served by a central public supply utility**
Agricultural	**AG**	**Irrigation of crops, water used to raise livestock, and other miscellaneous water uses associated with agricultural production**
Commercial/Industrial/Institutional/ Mining/Dewatering	**CII/MD**	**-Self-Supply from wells -General businesses, office complexes, commercial cooling/heating, etc. -Manufacturing, chemical processing plants, other industrial facilities -Hospitals, assisted living facilities, churches, prisons, schools, etc. -Water associated with extraction, transport, and processing of minerals**
Power Generation	**PG**	**Water associated with power plant facilities which includes consumptive use of water for steam generation, cooling, and replenishment of cooling reservoirs from self-supply wells**
Landscape/Recreation/Aesthetics	**LRA**	**Irrigation, maintenance, and operation of golf courses, cemeteries, parks, medians, attractions, etc. from self-supply wells**
Other (only for Florida)	**OTH**	**Fire protection, environmental**

Table 1. Abbreviations and Definitions of Water Use Types

2.1 Partial Counties in NFSEG Domain

For counties that were partially inside the model domain the amount of water use estimated for the 2010 NFSEG model run was summed by county and divided by the amount of water reported from the United States Geological Survey (USGS) in 2010 by county. This ratio was then applied to estimate the amount of water that was attributed to Florida, Georgia, and South Carolina counties that were partially in the model domain. The water use for each category was then multiplied by that ratio for every year of recorded and hindcasted data.

2.2 Data Aggregation

The use categories documented in the USGS water databases for Florida, Georgia, and South Carolina (see References) are as follows:

- State Code
- State Name
- County Code
- County Name
- Year
- Total population of area, in thousands
- Public supply population served by groundwater, in thousands
- Domestic self-supplied groundwater withdrawals, fresh, in million gallons per day (MGD)
- Commercial self-supplied groundwater withdrawals, fresh, in MGD
- Industrial self-supplied groundwater withdrawals, fresh, in MGD
- Total thermoelectric power self-supplied groundwater withdrawals, fresh, in MGD
- Mining self-supplied groundwater withdrawals, fresh, in MGD
- Livestock self-supplied groundwater withdrawals, fresh, in MGD
- Livestock (Animal Specialties) self-supplied groundwater withdrawals, fresh, in MGD
    - Used in South Carolina up until year 2000
- Aquaculture self-supplied groundwater withdrawals, fresh, in MGD
- Irrigation, Crop self-supplied groundwater withdrawals for crops, fresh, in MGD
- Irrigation, Crop self-supplied groundwater withdrawals for crops, fresh, in MGD
    - Used for years 2000 and later

To coincide with the water use categories used in Florida, certain water use types were aggregated together. These categories are as follows:

- PS - Public supply population served by groundwater, in thousands
- DSS - Domestic self-supplied groundwater withdrawals, fresh, in MGD
- AG - Livestock self-supplied groundwater withdrawals, fresh, in MGD, Livestock (Animal Specialties) self-supplied groundwater withdrawals, fresh, in MGD (only in South Carolina), Aquaculture self-supplied groundwater withdrawals, fresh, in MGD, and Irrigation, Crop self-supplied groundwater withdrawals for crops, fresh, in MGD

- CII - Commercial self-supplied groundwater withdrawals, fresh, in MGD, Industrial self-supplied groundwater withdrawals, fresh, in MGD, and Mining self-supplied groundwater withdrawals, fresh, in MGD
- PG - Total thermoelectric power self-supplied groundwater withdrawals, fresh, in MGD
- LRA - Irrigation, Crop self-supplied groundwater withdrawals for crops, fresh, in MGD

Things to note:

- Prior to 2000, water used for golf course irrigation in Georgia was incorporated in the Agricultural irrigation category.

3.0 GROUNDWATER USE ESTIMATES BY STATE

3.1 Florida

Population data for all counties in Florida from 1860-1990 in ten-year increments was obtained from the U.S. Census Bureau (Forstall March 1996). The same interpolation approach used for groundwater use was employed between ten-year and five-year population increments to estimate population for in-between years. Hindcasting was completed by multiplying the water use specific GPCD (gallons per capita daily) value by the population for the corresponding year. For example, in Alachua County the 1965 Public Supply water use was 8.60 MGD with a population of 88,092, therefore the per capita value was 98 GPCD. This GPCD was applied to the population of all previous years to calculate the MGD of that given year. For example, in 1950, the population of Alachua County was 57,026 people, the 98 GPCD was then multiplied by the county population and divided by 1,000,000 to get the Public Supply MGD water use value which resulted in 5.57 MGD. The annual hindcasting was completed in Excel.
Historical statewide water use estimates were published by the USGS in 1945, 1950, 1955, 1960, 1965, 1970, 1975, and 1980 for all states in the United States (Guyton 1950) (MacKichan 1951) (MacKichan 1957) (MacKichan 1957) (MacKichan and Kammerer 1961) (Murray 1968) (Murray and Reeves 1977) (Murray and Reeves 1972) (Solley, Chase and Mann, IV 1983). The statewide water use estimates used to evaluate whether groundwater estimates produced from the population-based method detailed above were reasonable.

The NFSEG model domain incorporates counties from all or part of four different water management districts throughout the state of Florida. Since the St. Johns River Water Management District (SJRWMD) started estimating water use earlier than the other three, the methodology varies slightly between districts, in order to include the best available estimates of water use. Historical water use in the Suwannee River Water Management District (SRWMD), Northwest Florida Water Management District (NWFWMD), and Southwest Florida Water Management District (SWFWMD) are grouped together because of similar data locations and methods. A monthly timestep of water use was generated for all Florida counties located in the NFSEG model domain. Monthly values were later averaged across the year to obtain an annual timestep.

3.1.1 St. Johns River Water Management District (SJRWMD)

The USGS publishes county-level water use, for the following types of water use, every 5 years starting in 1965: Public Supply, Domestic Self-Supply, Commercial-Industrial-Mining, Agricultural, Landscape and Recreational Irrigation, and Power Generation. Some interim years are also available in the USGS data between the five-year intervals from 1965-1995 (Historical Water-Use in Florida Accessed August 2018). The SJRWMD publishes county-level water use by category annually in their Annual Water Use Survey (AWUS), starting in 1978 (SJRWMD Accessed August 2018). Using these two sources, groundwater use data were aggregated to the county and use type category for every five-year period from 1965 to 1994, and some intervening years between 1965-1994. Missing years for each county and use category were estimated using an exponential growth assumption to create a complete aggregate table. If USGS and AWUS estimates were not equal, published AWUS data were used.

The SJRWMD maintains an estimate of historical water use in a dataset with monthly use and station (i.e., well)-level detail for each well point for the years 1995-2015 for Florida counties in the NFSEG domain. For each station, an evaluation was made to determine if missing data should be gap filled. For each year that has more than 5 months of reported data for a given station, missing months were estimated. To do this, a station's average proportion of water use for each month was determined, using all available data from 1995-2015. The missing month's corresponding average proportion was applied to the annual water use for the year with missing data to develop an estimate of water use for that month. This was done for all stations.

3.1.2 Suwannee River Water Management District (SRWMD)/Northwest Florida Water Management District (NWFWMD)/Southwest Florida Water Management District (SWFWMD)

The USGS groundwater use data from 1965-1994 was used to estimate groundwater use in counties not located in the SJRWMD (Historical Water-Use in Florida Accessed August 2018). Groundwater use data was aggregated to the county and use type category for every five-year period from 1965 to 1994, and some intervening years between 1965-1994. Missing years for each county and use category were estimated using an exponential growth assumption. The historical water use database with monthly use and station level detail for each well point from 1995-2015 was used to fill in the remaining years of data.

3.1.3 Florida Adjustments

Two counties in SRWMD and one county in SJRWMD had large industrial users prior to 1965. The water use attributed to these industrial users was removed from the per capita water use estimate for the CII use category prior to the year the industry came online.

- Taylor County – Buckeye/Foley Cellulose, now known as the Georgia-Pacific Foley Plant, came online in 1954; therefore, Taylor county's CII water use category has two different GPCD values that were used for hindcasting (Georgia-Pacific 1993 (estimated)). The first one uses the 1965 per capita value as is with all CII use, including Buckeye water use. The second GPCD value uses the

1965 water use value minus the 1965 Buckeye water use, which creates a smaller GPCD value. The 1965 Buckeye water use value came from USGS paper documents on CII water use. The Buckeye operation came online in 1954; therefore, the first large GPCD was used to estimate 1954-1964 water use for the CII category and the second, smaller GPCD was used to estimate 1900-1953 water use.

- Hamilton County – The PCS Phosphate mine, now known as Nutrien, came online in 1965. Hamilton county's 1965 water use value for the CII category was 10.3 MGD. Prior to 1965, any water use from PCS should not be used in the GPCD value that estimates 1900 - 1964 water use. The reported 10.3 MGD of CII water use was only from the PCS operation, according to USGS paper records on 1965 CII water use (U.S. Geological Survey Accessed October 2018). Therefore, the GPCD value for CII prior to 1965 was set to zero.
- Nassau County – Industrial pumping in Fernandina Beach – St. Mary's area was very low prior to 1938, therefore CII water use was set to zero in 1937 and all years prior. Information regarding this area came from "Impact of Development on Availability and Quality of Ground Water in Eastern Nassau County, Florida, and Southeastern Camden County, Georgia" (Brown 1984).

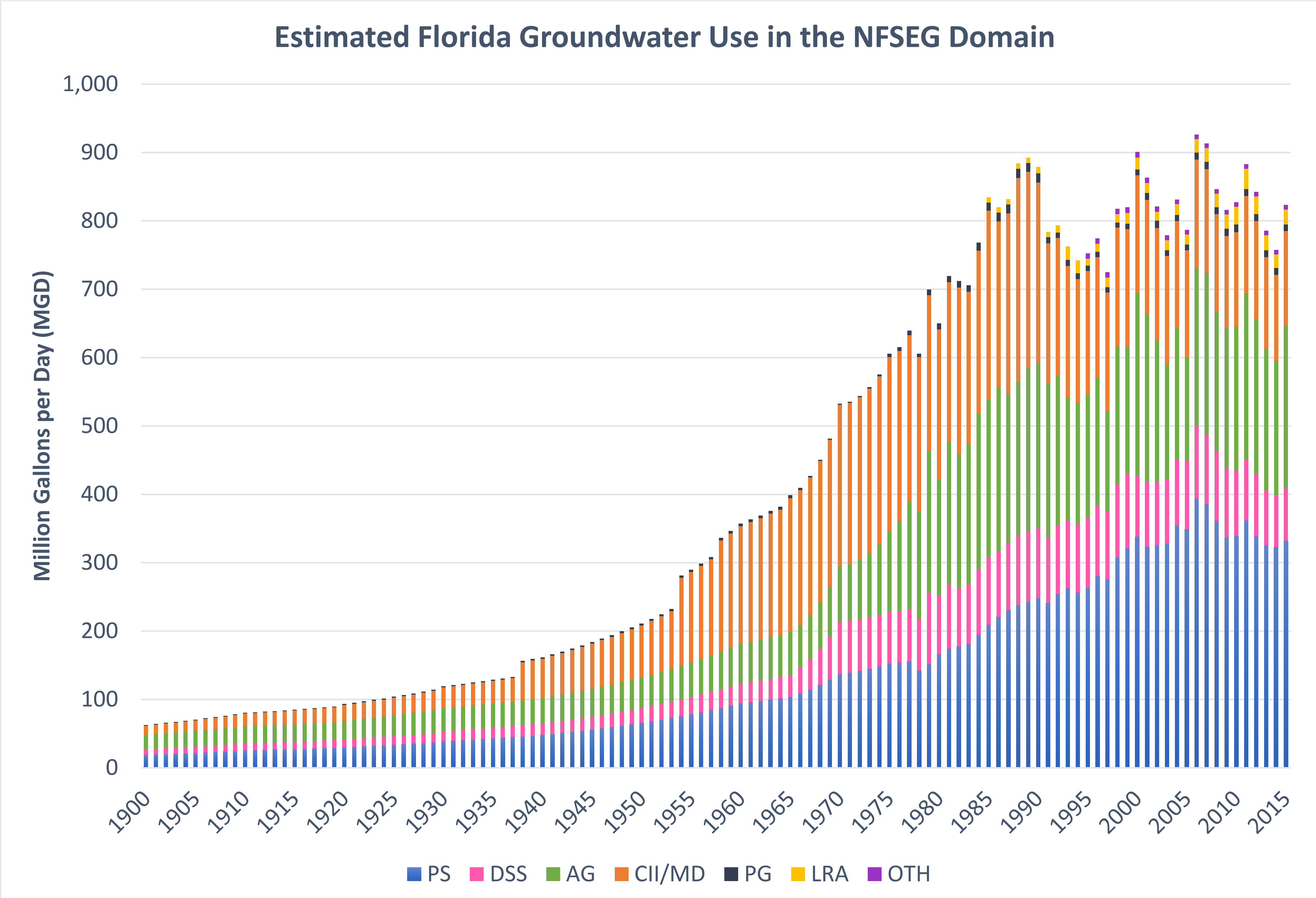

Figure 3. Estimated groundwater use in the Florida portion of the NFSEG Domain through time by water use category

3.2 Georgia

Population for Georgia was obtained from the Georgia Governor's Office of Planning and Budget and was downloaded as an Excel file (Historical Census Data Accessed September 2018). Data include county level estimates from 1900 through 2000 in ten-year increments. The estimates for in-between years were interpolated using an exponential RATE function in Excel.

County data for each water use category was obtained from the USGS with groundwater use estimates dating back to 1985 (U.S. Geological Survey Accessed September 2018). Additional county groundwater data for Georgia in 1980 was published in "Water Use in Georgia By County For 1980" (Pierce, Barber and Stiles 1982). County level Public Supply water use estimates were obtained from "Use of water in Georgia, 1970, with projections to 1990" (Carter and Johnson 1974). The GPCD values were calculated for each water use type in each county for the earliest year in which water use data was reported (1970 for Georgia PS, 1980 for all other categories except agriculture, which is described below). The GPCD value was calculated by dividing the groundwater use (in MGD) for each category by the population for that county and multiplying by 1,000,000. For example, in Appling County, Georgia, the 1980 Domestic Self-Supply groundwater use was 1.12 MGD with a population of 15,565, therefore the per capita value was 71.956 GPCD. The calculated GPCD values were held constant dating back to either 1900, or back to the earliest year in which population data was recorded.

Historical statewide water use estimates published by the USGS in 1945, 1950, 1955, 1960, 1965, 1970, 1975, and 1980 for all states in the United States were used to refine agricultural groundwater use estimates in Georgia (Guyton 1950) (MacKichan 1951) (MacKichan 1957) (MacKichan 1957) (MacKichan and Kammerer 1961) (Murray 1968) (Murray and Reeves 1977) (Murray and Reeves 1972) (Solley, Chase and Mann, IV 1983). Agricultural irrigation and other agricultural groundwater use was assumed to be zero prior to 1950 in Georgia, based on agricultural irrigation trends and published statewide water use (Harrison and Tyson March 1997) (Georgia Water Coalition November 2017). Agricultural groundwater use for Georgia was estimated between 1950 and 1980 using statewide groundwater estimates. Statewide estimates of groundwater use by category were published in five-year increments starting in 1945. The agricultural groundwater use for Georgia in 1945 was reported as zero, and as "negligible" in 1950. The total AG groundwater use in Georgia in 1980 was estimated to be 397 MGD. Since agricultural groundwater use in 1950 was said to be "negligible," a value of 0.1 MGD was used (0.1 MGD was used because it is the lowest value that can be input into the Excel equation). This value was then multiplied by the AG groundwater use in each county for the corresponding year and divided by 397 MGD.

3.2.1 Statewide Georgia AG values from USGS publications

- 1945 – 0 MGD
- 1950 – "negligible" – assigned as 0.1 MGD
- 1955 – 12 MGD
- 1960 – 21.8 MGD
- 1965 – 19.1 MGD

- 1970 – 37.6 MGD
- 1975 – 33.6 MGD (center pivot irrigation systems introduced)
- 1980 – 397 MGD

The main assumption is that the percent of water use in each individual county compared to the total statewide water use was the same in 1950 as it was in 1980. For example, Appling County had a reported 2.89 MGD of water used for AG in 1980, which represents 0.73 percent of the total agricultural water use in 1980. To estimate water use prior to 1980, the estimated percentage calculated in 1980 was used. Therefore, water use in 1950 for Appling County was estimated to be 0.00073 MGD. Water use was then interpolated between 1950-1955 using the exponential RATE function in Excel. This methodology was applied for every five-year increment from 1950-1980. In 1955, the 1980 percentage for Appling County was multiplied by the statewide estimate of 12 MGD. Water use was then interpolated between 1955-1960.

Adjustments were made for counties in Georgia where the initiation date of CII and PG water use could be estimated. The adjustments made were based on the best estimate of the timing for initiation of groundwater use based on records of when large users came online. The estimated use for the affected use category was set to zero prior to initiation of the identified entity. These adjustments are documented below. adjustments for Power Generation facilities were also made and based on the in-service year (Fanning, et al. 1991).

For example, in Charlton County, GA, the Humphreys Mining Company started mining operations in Folkston, GA in 1965. The CII water use for Charlton County was then assumed to be zero prior to when it came online in 1965.

3.2.2 Georgia Adjustments to CII and PG users

- Appling – Edwin I. Hatch plant with Georgia Power Company in 1975 (Fanning, et al. 1991)
- Bacon – American Protein came online in 1949 (Tyson May 15, 2018)
- Berrien – Propex Operating Company came online in 1968 (Propex Accessed October 2018)
- Camden – Gilman Paper Company came online in 1940s (Gilman Paper Company Accessed October 2018)
- Charlton – Humphreys Mining Company started mining in 1965 (Fanning, et al. 1991)
- Chatham – Savannah Sugar came online in 1917 (Savannah Foods & Industries, Inc. Accessed October 2018) and Union Camp, (later known as International Paper) in 1920s and 1930s (Union Camp Corporation November 23, 2017), Riverside Plant with Savannah Electric and Power Company in 1949 (Fanning, et al. 1991)
- Clinch – BWAY came online in 1957 (BWAY CORP Accessed October 2018)
- Colquitt – National Beef came online in 1914 (Hall November 29, 2017)
- Decatur – BASF came online in 1921 (Neshat September 2019)
- Dougherty – FL Rock Industries came online in 1965 (Florida Rock & Tank Lines Accessed October 2018), Mitchell Plant with Georgia Power Company in 1948 (Fanning, et al. 1991)

- Early – Great Southern Paper Company came online in 1963 (GP Cedar Springs October 9, 2013)
- Effingham – McIntosh Plant with Savannah Electric and Power Company came online in 1979 (Fanning, et al. 1991)
- Evans – Claxton Poultry came online in 1949 (Claxton Poultry Farms Accessed October 2018)
- Glynn – Pinova Inc. came online in 1911 (Pinova Accessed October 2018), King and Prince Shrimp in 1924 (King & Prince Seafood Accessed October 2018), Mead Corporation/Scott Paper in 1937 (The Mead Corporation Accessed October 2018), and SeaPak Shrimp in 1948 (SeaPak Shrimp & Seafood Co. Accessed October 2018), McManus Plant with Georgia Power company in 1952 (Fanning, et al. 1991)
- Grady – Grace Fertilizer came online in 1954 (W.R. Grace & Company October 2018) and Oil-Dri in the early 1960s (Oil-Dri Corporation of America Accessed October 2018)
- Jeff Davis – Propex Operating Company came online in 1953 (Propex Accessed October 2018)
- Laurens – J.P. Stevens came online in 1947 (Thompson July 9, 2012)
- Liberty – Interstate Paper (now DS Smith) came online in 1968 (Interstate Paper Accessed October 2018)
- Lowndes – Georgia-Pacific came online in 1927 (Georgia-Pacific Accessed October 2018)
- Sumter – McClesky Cotton Company came online 1929 (Bland September 20, 2017)
- Thomas – Flowers Foods came online in 1919 (Flowers Foods Accessed October 2018) and Oil-Dri in the early 1960s (Oil-Dri Corporation of America Accessed October 2018)
- Ware – CSX Railroad formerly known as Seaboard System Railroad Inc. came online in 1944 (CSX GATX Rail Corp Accessed October 2018) and Flanders Provision in 1958 (Flanders June 25, 2020)
- Washington - Thiele Kaolin Company came online in 1947 (Thiele Kaolin Company Accessed October 2018)
- Wayne - Rayonier's Cellulose Specialties came online in 1954 (Rayonier Accessed October 2018))
- Worth – Olam Edible Nuts formerly known as Universal Blanchers LLC came online in 1978 (Universal Blanchers Accessed October 2018)

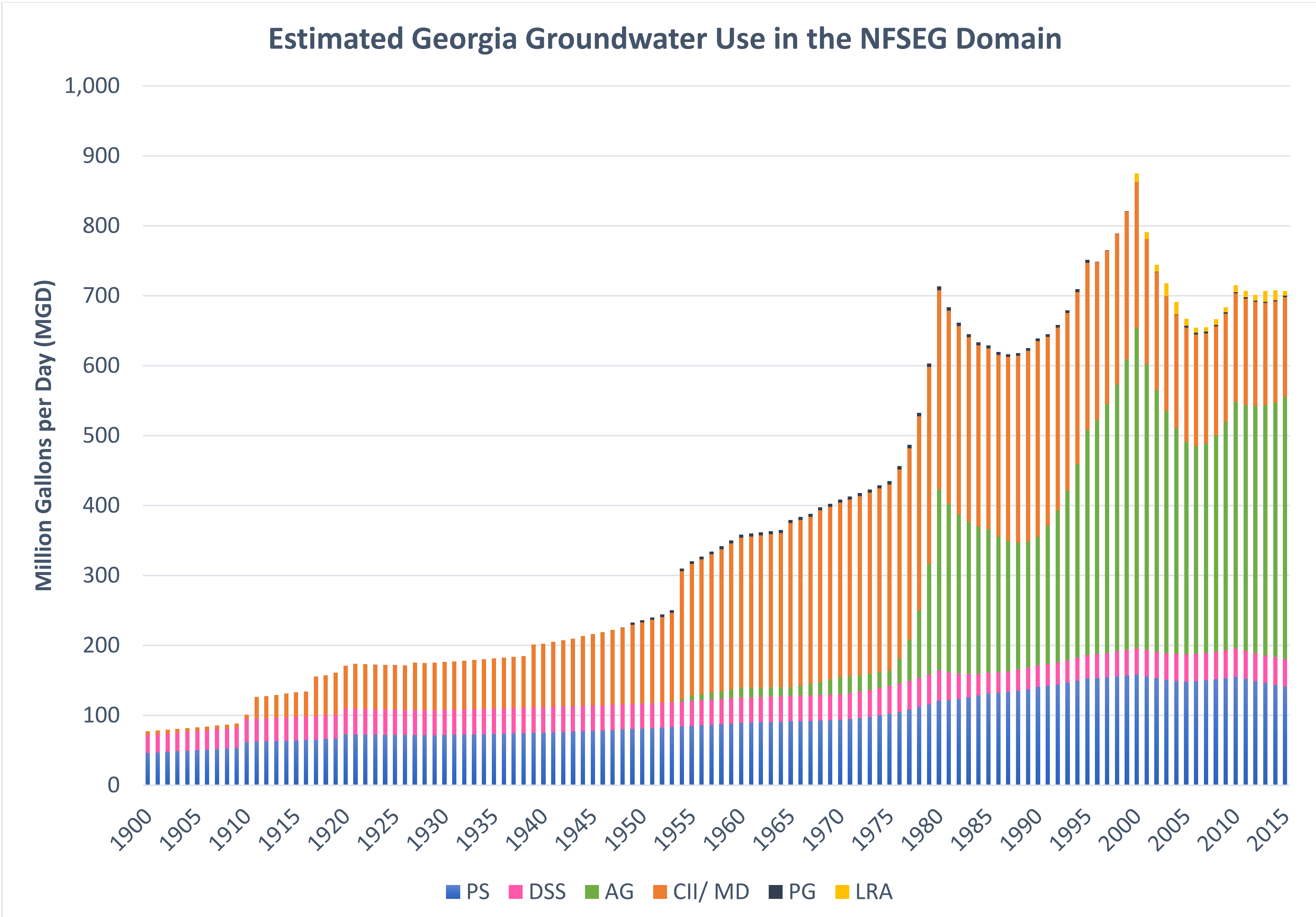

Figure 4. Estimated groundwater use in the Georgia portion of the groundwater domain through time by water use category

3.3 South Carolina

Population data for South Carolina was obtained from the US Census Bureau (Forstall March 1995). Data include county level estimates from 1900 through 2000 in ten-year increments. The estimates for in-between years were interpolated using an exponential RATE function in Excel.

County data for each water use category was obtained from the USGS (U.S. Geological Survey Accessed September 2018). Water use estimates dating back to 1985 were used for counties in South Carolina that are in the model domain. The GPCD values were calculated for each water use type in each county for the earliest year in which water use data was reported. The GPCD value was calculated by dividing the estimated groundwater use (in MGD) for each category by the population for that county and multiplying by 1,000,000. The calculated GPCD values were held constant dating back to 1900, or back to the earliest year in which population data was recorded.

Adjustments were made for counties in South Carolina using the Coastal Plain Water Well Inventory (South Carolina Department of Natural Resources Accessed September 2018). This provided information on when the earliest well was drilled for each water use category. These dates were then used to adjust the water use for each use type in each county.

3.3.1 South Carolina Adjustments

- Allendale
    - Earliest DSS well - 1905
    - Earliest AG well – 1950
    - Earliest PS well – 1952
    - Earliest CII well – 1960
- Bamberg
    - Earliest DSS well - 1952
    - Earliest AG well – 1950
    - Earliest PS well – 1938
- Beaufort
    - Earliest DSS well - 1900
    - Earliest AG well – 1955
    - Earliest PS well – 1941
    - Earliest CII well – 1966
- Colleton
    - Earliest DSS well - 1917
    - Earliest AG well – 1955
    - Earliest PS well – 1942
- Hampton
    - Earliest DSS well - 1880
    - Earliest AG well – 1927

- Earliest PS well – 1898
- Earliest CII well – 1942

- Jasper
  - Earliest DSS well - 1900
  - Earliest AG well – 1928
  - Earliest PS well – 1941
  - Earliest CII well – 1953

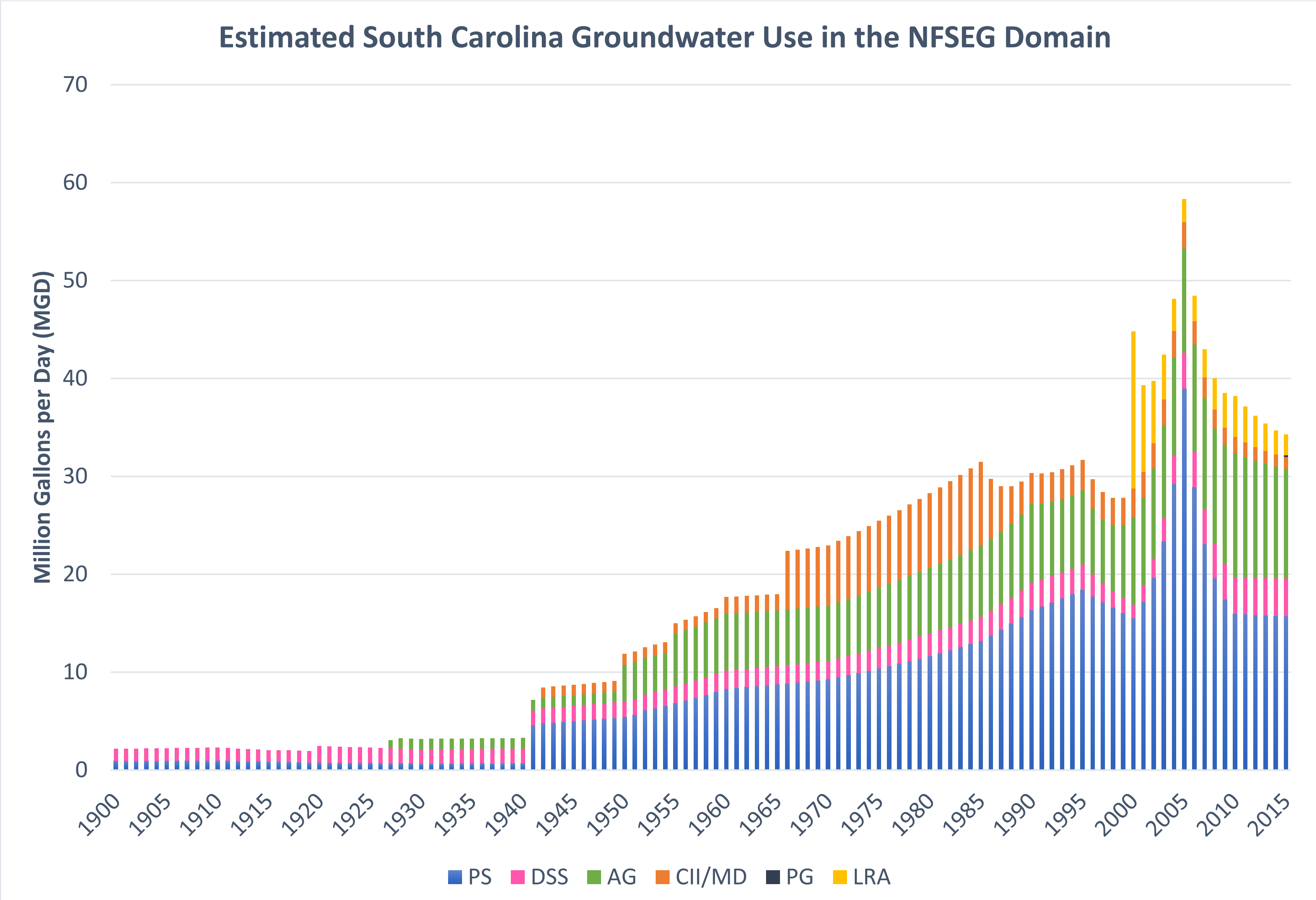

Figure 5. Estimated groundwater use in the South Carolina portion of the NFSEG domain through time by water use category

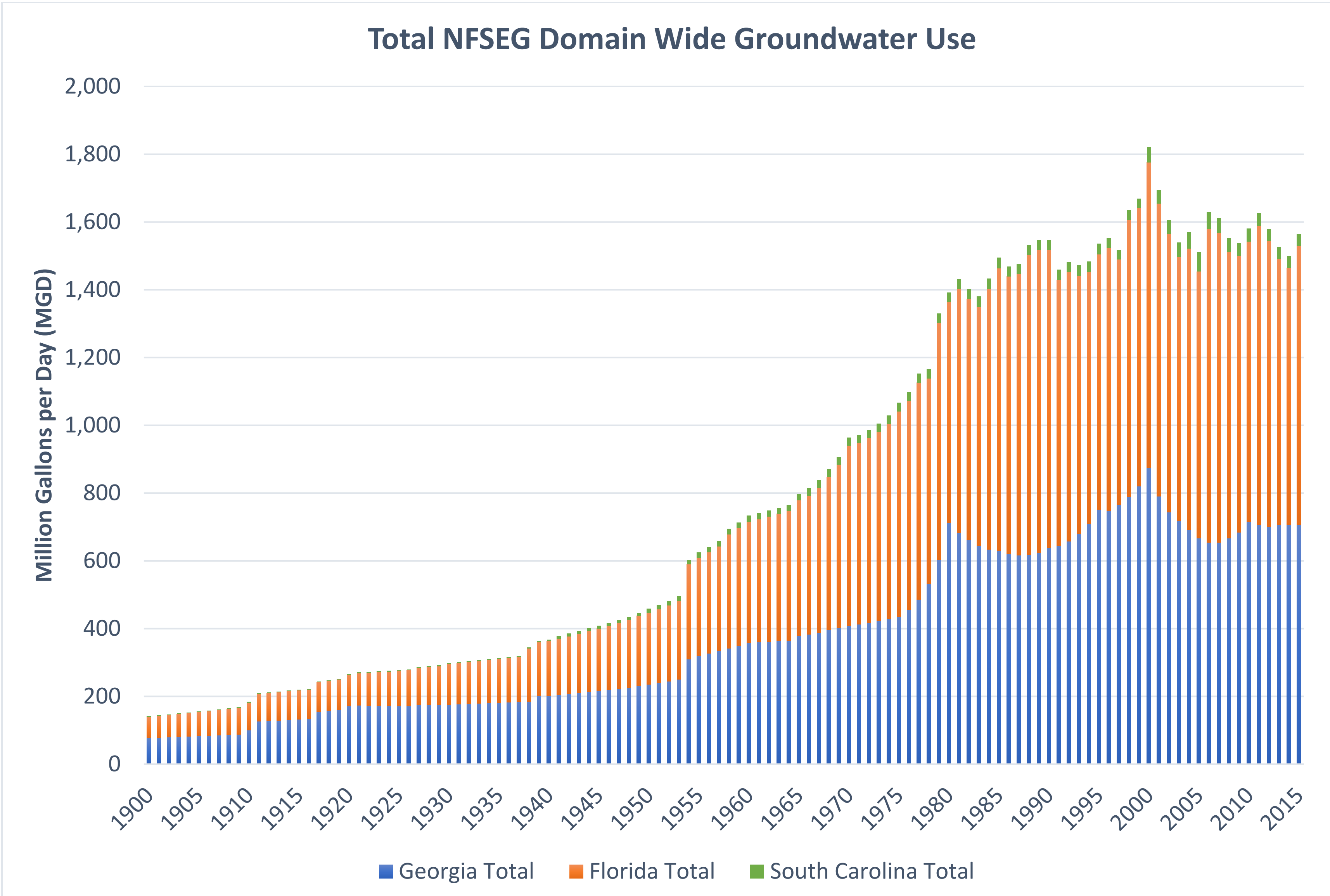

Figure 6. Hindcasted groundwater use in the NFSEG domain by state

4.0 MOVING AVERAGE CALCULATION

For each county and use type combination a moving five-year average was calculated. The average was computed based on the current year and the four years preceding that year. For example, the five-year moving average in 1930 included the years 1930, 1929, 1928, 1927, and 1926. This moving average was then calculated for all years starting with 1904. Results for each state, county, and use-type combination in the model domain were then merged into one dataset. Water use-type categories for Georgia and South Carolina were merged into three categories, AG, DSS, and NOT_AG_OR_DSS (this includes PS, CII/MD, PG, and LRA). This was done to coincide with the categories used in the NFSEG model. Results for these estimates are shown for Florida, Georgia, and South Carolina in Figure 7, Figure 8, and Figure 9. Figure 10 shows the estimated moving average groundwater use broken out by state for the entire model domain. The results of this water use estimation process relative to the single-year estimates for the NFSEG are summarized in Table 2 (Durden, et al. 2019).

Year	NFSEG Output (MGD)	Hindcasting Output (MGD)	Hindcasting Five-Year Moving Average Output (MGD)
2001	1,568	1,694	1,659
2009	1,557	1,538	1,562
2010	1,487	1,580	1,576

Table 2. Comparison between water use in the NFSEG model, hindcasting, and five-year moving average

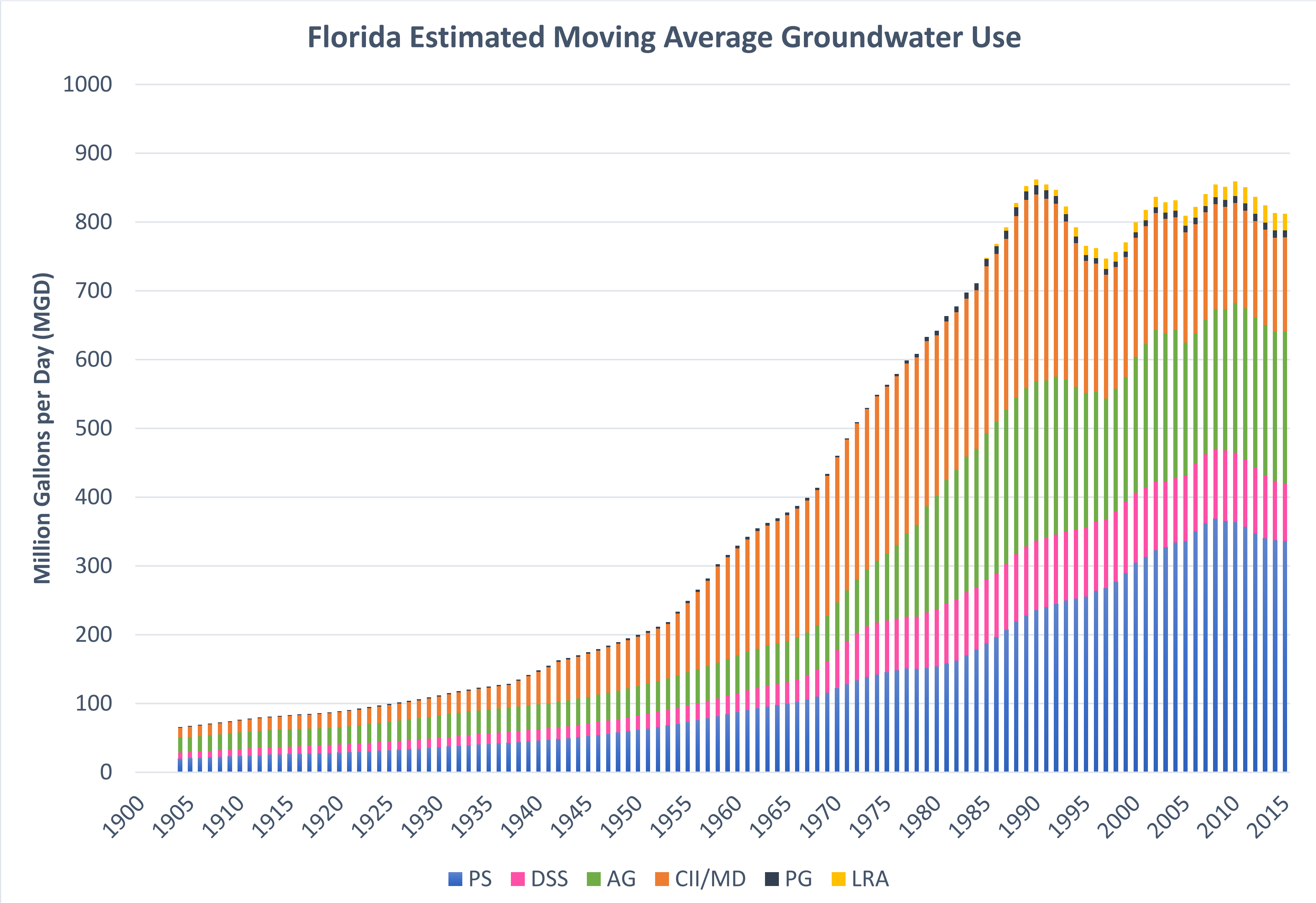

Figure 7. Estimated moving average groundwater use in Florida by water use category

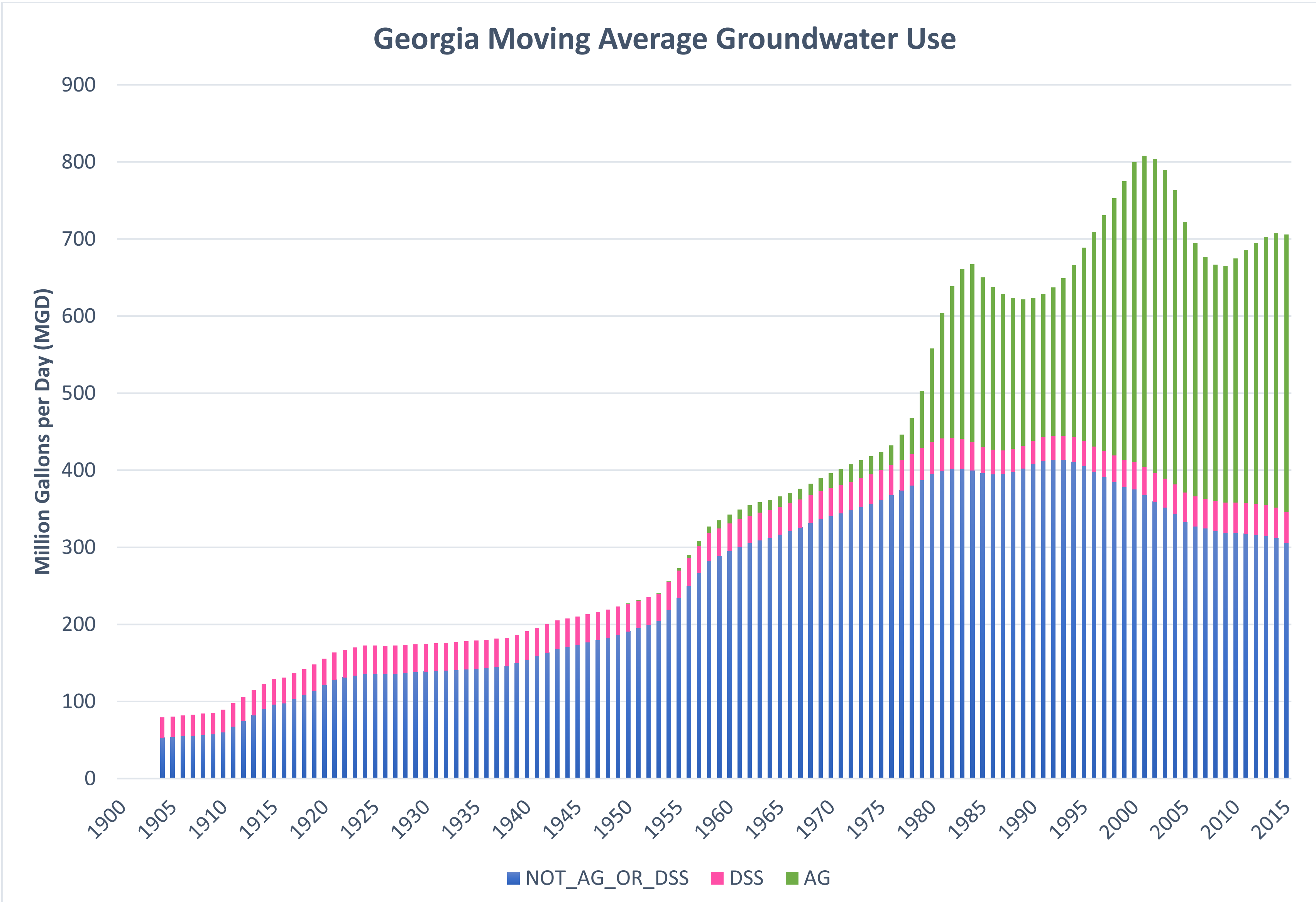

Figure 8. Estimated moving average groundwater use in Georgia by water use category

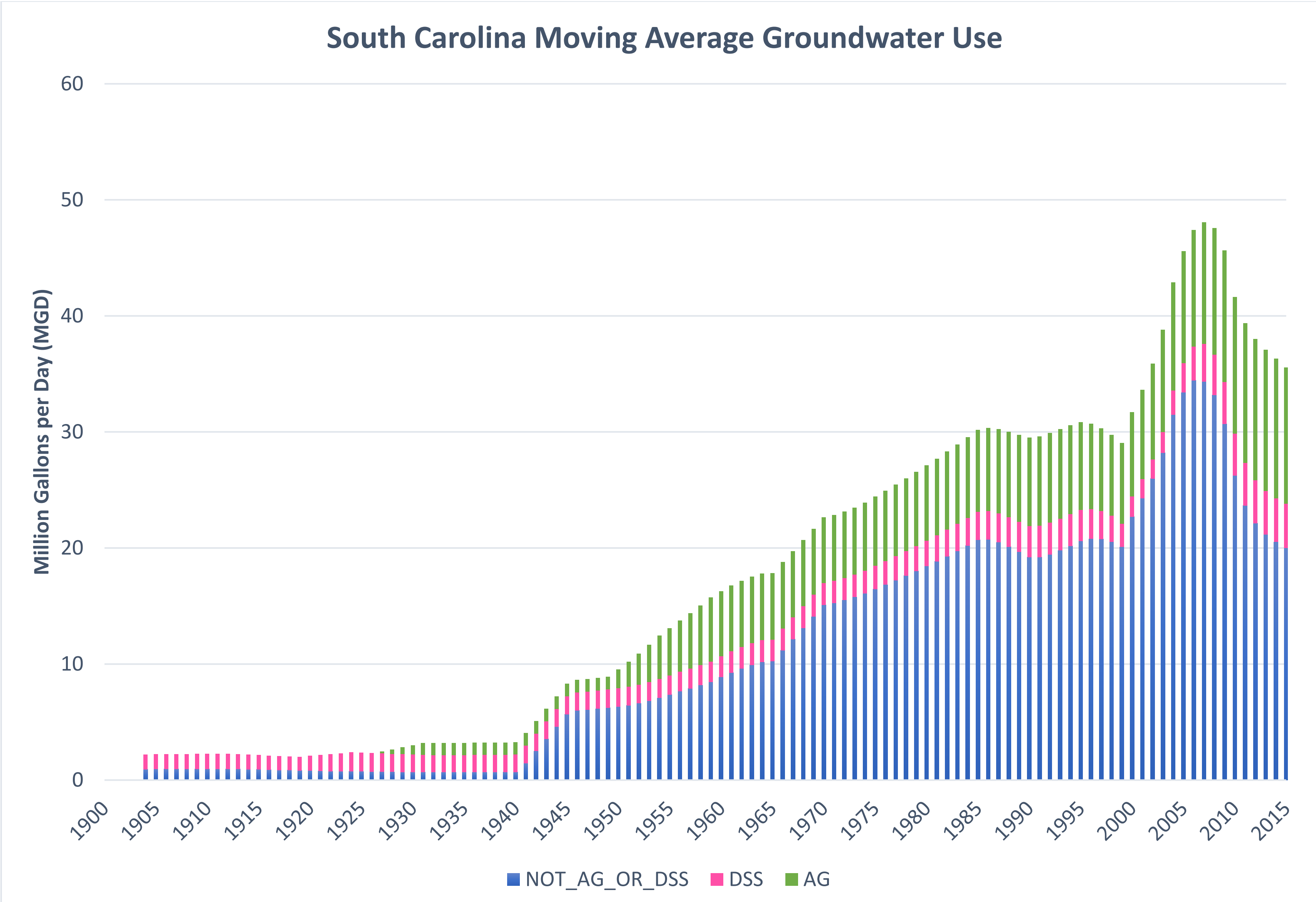

Figure 9. Estimated moving average groundwater use in South Carolina by water use category

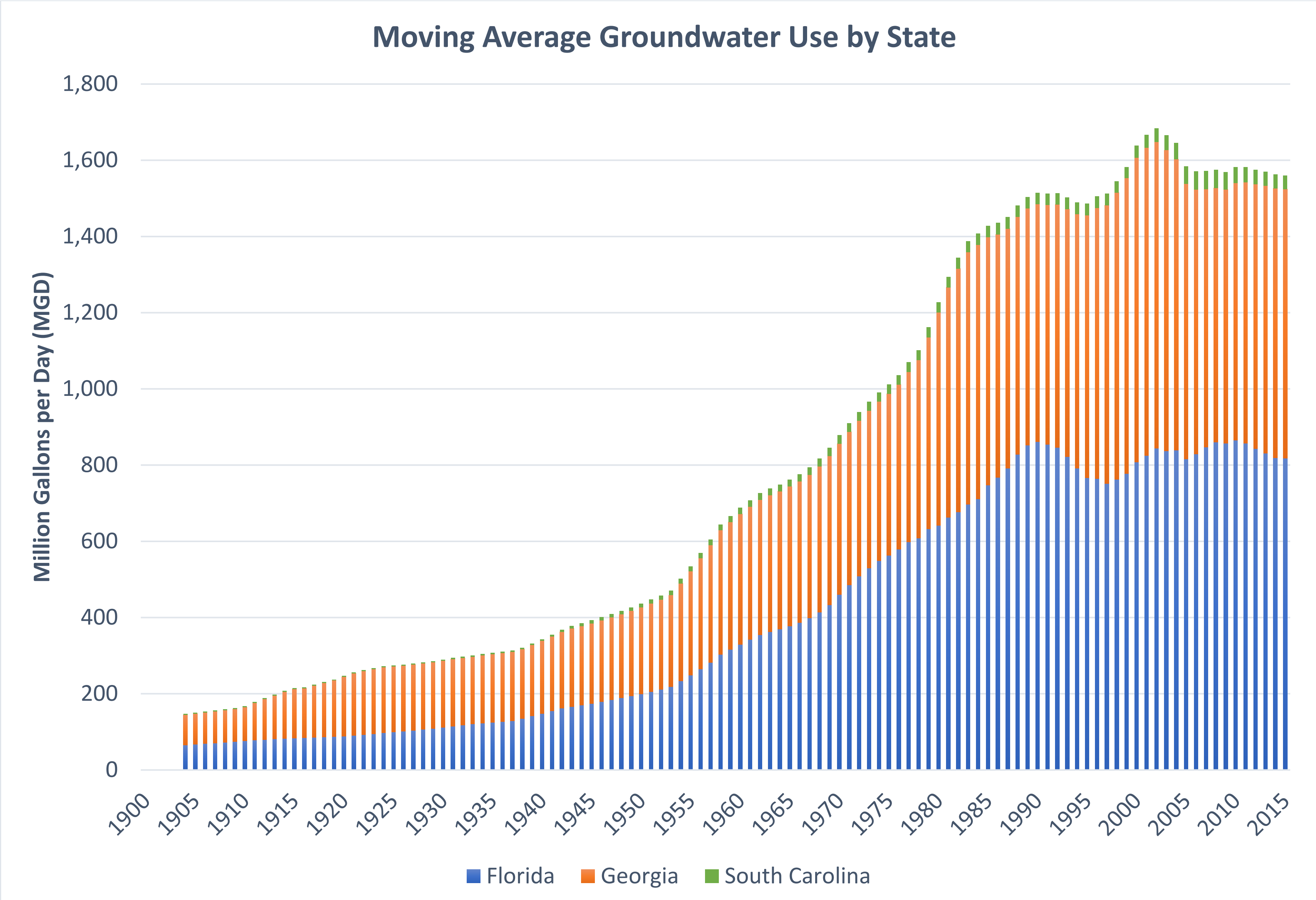

Figure 10. Estimated moving average groundwater use by state

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APPENDIX VI - PART 2

INJECTION WELL HINDCASTING

1.0 INTRODUCTION

The purpose of this appendix is to document the data and methods that were used to hindcast groundwater injection flows for the injection wells that were simulated in the North Florida Southeast Georgia Groundwater Model (NFSEG).

Public water utilities operate two wastewater treatment plants (WWTPs) in Gainesville, FL. The discharges from these WWTPs is later returned to the groundwater system. These facilities include the older Main Street facility and the newer Kanapaha facility, both of which are in the SJRWMD portion of the county. The treated wastewater discharged from the Main Street facility goes to Alachua Sink, while treated wastewater from the Kanapaha facility is injected into the aquifer through the Kanapaha well. The University of Florida also operates its own wastewater treatment plant and has two injection wells. Table 1 shows the reclaimed water flows that were estimated for injection wells in the NFSEG model. Figure 1 shows a map of the locations of injection wells.

Injection wells reclaimed water flows in NFSEG Domain	Q 2001 million gallons per day	Q 2009 million gallons per day	Q 2010 million gallons per day
Kanapaha	7.83	7.46	6.94
Alachua Sink	7.04	6.37	5.76
University of Florida	1.53	1.51	1.48

Table 1. Injection well reclaimed water flows as estimated in the NFSEG model

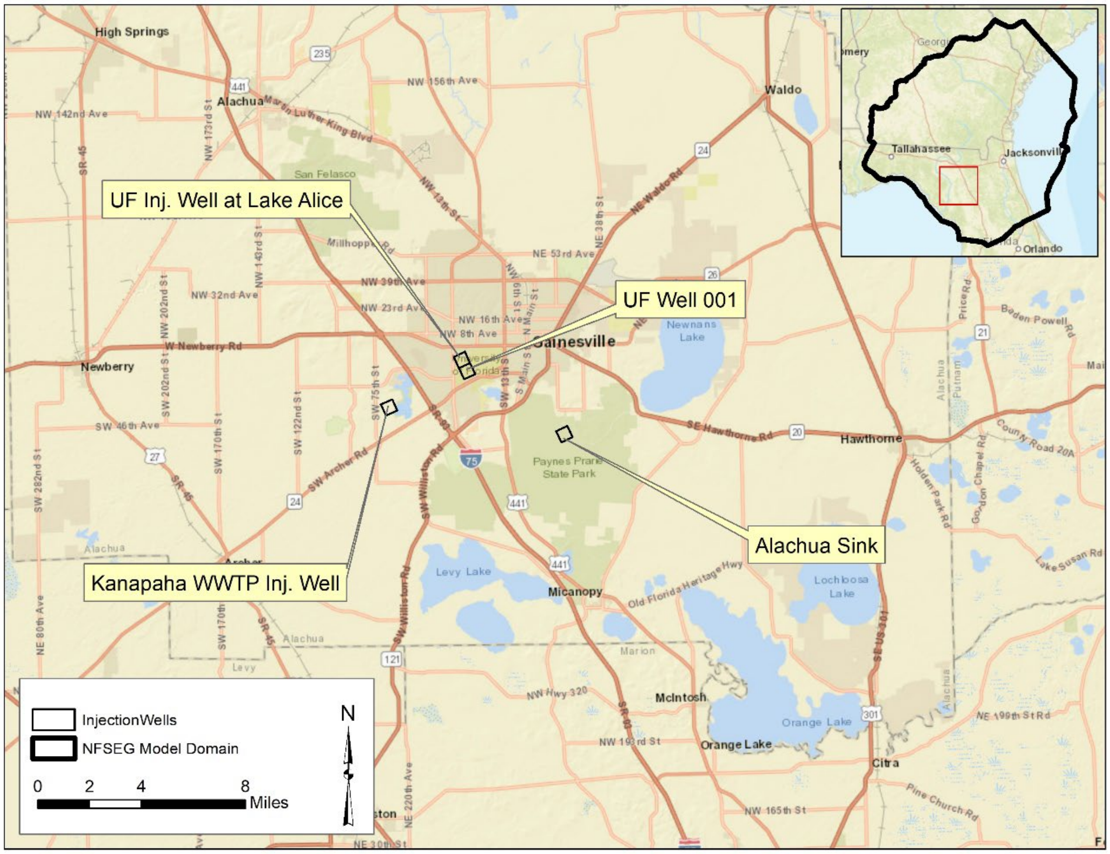

Figure 1. Map of injection wells located in the NFSEG

2.0 INJECTION WELLS

2.1 Kanapaha

The average estimated flow into the well at Kanapaha from January 1982 through February 1984 was 6.1 mgd (Phelps 1987). This value was used to estimate flow from 1978-1981. The Kanapaha wastewater treatment facility came online in 1977 but no month is stated, therefore it is assumed that it came online halfway through the year and half of the 6.1 mgd was assigned to 1977 (Gainesville Regional Utility Accessed 2019). Prior to 1977, the injection rate was set to zero because the wastewater treatment plant did not exist, therefore no water was being injected into the Floridan Aquifer.

Jones Edmunds has a time series of injection flows by month for Kanapaha from 1982 through 2012. Injection flows from each month were averaged to get an estimate for the flow in each given year. These numbers are also reported from Gainesville Regional Utilities Historical Wastewater Flow Rates.

Estimates for 2014-2015 were obtained from a SJRWMD file of wastewater treatment and reuse. This included data from 1995-2017.

From the reported data gathered, the average estimate of water injected for the Kanapaha well was 8.41794 MGD. Figure 2 shows the estimated flow of reclaimed water into the Kanapaha well.

2.2 Murphree Well Field Withdrawal data [Required for Alachua Sink Injection Estimates]

The Murphree well field is located in SJRWMD. Withdrawal data was obtained from SJRWMD and includes pumping estimates from 1986-2010. The Murphree withdrawal data was divided by Alachua County Public Supply data for corresponding years to get a ratio of withdrawal to public supply for each year. The ratios of reported years (1986-2010) were averaged together to get an average ratio of 0.901955. This ratio was used to hindcast and estimate Murphree withdrawal data going back to 1900 and for 2011-2015.

The Murphree well field withdrawal dataset is used for the estimation of the expected injection flow at the Alachua Sink.

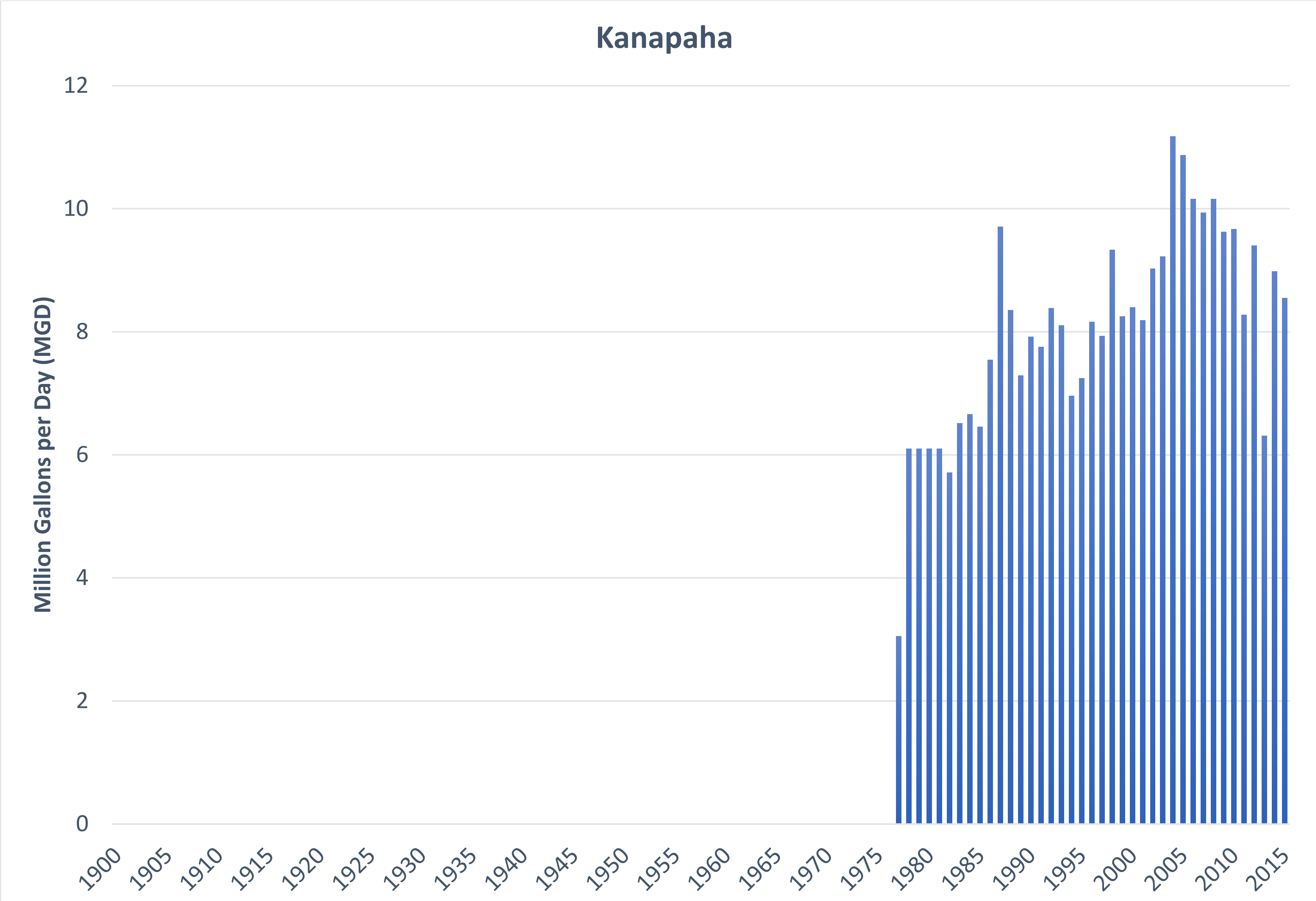

Figure 2. Estimated Kanapaha injection well flows

2.3 Alachua Sink

The main assumption regarding Alachua Sink is that all of the wastewater discharging from the Main Street WWTP is making its way to Alachua Sink. Another assumption made is that before the Kanapaha WWTP came online, the volume of treated wastewater being discharged to Alachua Sink included a proportional amount of the Kanapaha flow. The flow from the Main Street WWTP was hindcast back to 1930, when the plant came online (Gainesville Regional Utility Accessed 2019).

From 1982-2012, estimates were obtained from Gainesville Regional Utilities Historical Wastewater Flow Rates as well as the time series from Jones Edmunds. Estimates for 2014-2015 were obtained from SJRWMD file of wastewater treatment and reuse. This included data from 1995-2017. From the reported data gathered, the average of treated wastewater calculated for the Main Street WWTP was 5.8195 MGD.

For the years before the Kanapaha WWTP came online, the sum of the average injection of the treated Kanapaha wastewater ($\overline{Q}injection, Kanapaha$) and the Main Street treated wastewater (*Main Street*) was divided by the average withdrawal from the Murphree well field $\overline{(W Murphree)}$ to find ratio *c1*. The value of *c1* is 0.59888.

$$c1=\frac{\overline{Q}\text{injection, Kanapaha+Main Street}}{\overline{W}\text{Murphree}}$$

Then, the product of ratio *c1* and the average Murphree well field withdrawal ($\overline{W}Murphree$) was subtracted from the average of Alachua County Public Supply (Q_*Alachua*) to obtain an estimate of injection flow for each year of missing data (1900-1977) (*Pre-Kanapaha*).

$$\text{Pre Kanapaha}=(\text{Q\_}\textit{Alachua})\text{-}(\text{c1}\times\ \overline{\text{W}}\text{Murphree})$$

After Kanapaha came online, the same methodology was applied to calculate ratio *c2*, however, the injection flow from Main Street $\overline{(Q}injection, Main\ Street)$ was used, instead of adding in the Kanapaha flow. This value of *c2* is 0.24479.

$$c2=\frac{\overline{Q}\text{injection, Main Street}}{\overline{W}\text{Murphree}}$$

Thus, the estimated injection (*Post-Kanapaha*) is the ratio *c2* multiplied by the average Murphree well field withdrawal. This was applied for years 1977-1981. The value in 1977 was divided by two, because of the assumption of the Kanapaha WWTP coming online halfway through the year. Injection estimates are available starting in 1982.

$$\text{Post Kanapaha}=\text{c2}\times\ \overline{\text{W}}\text{Murphree}$$

Figure 3 shows the estimated flow into Alachua Sink.

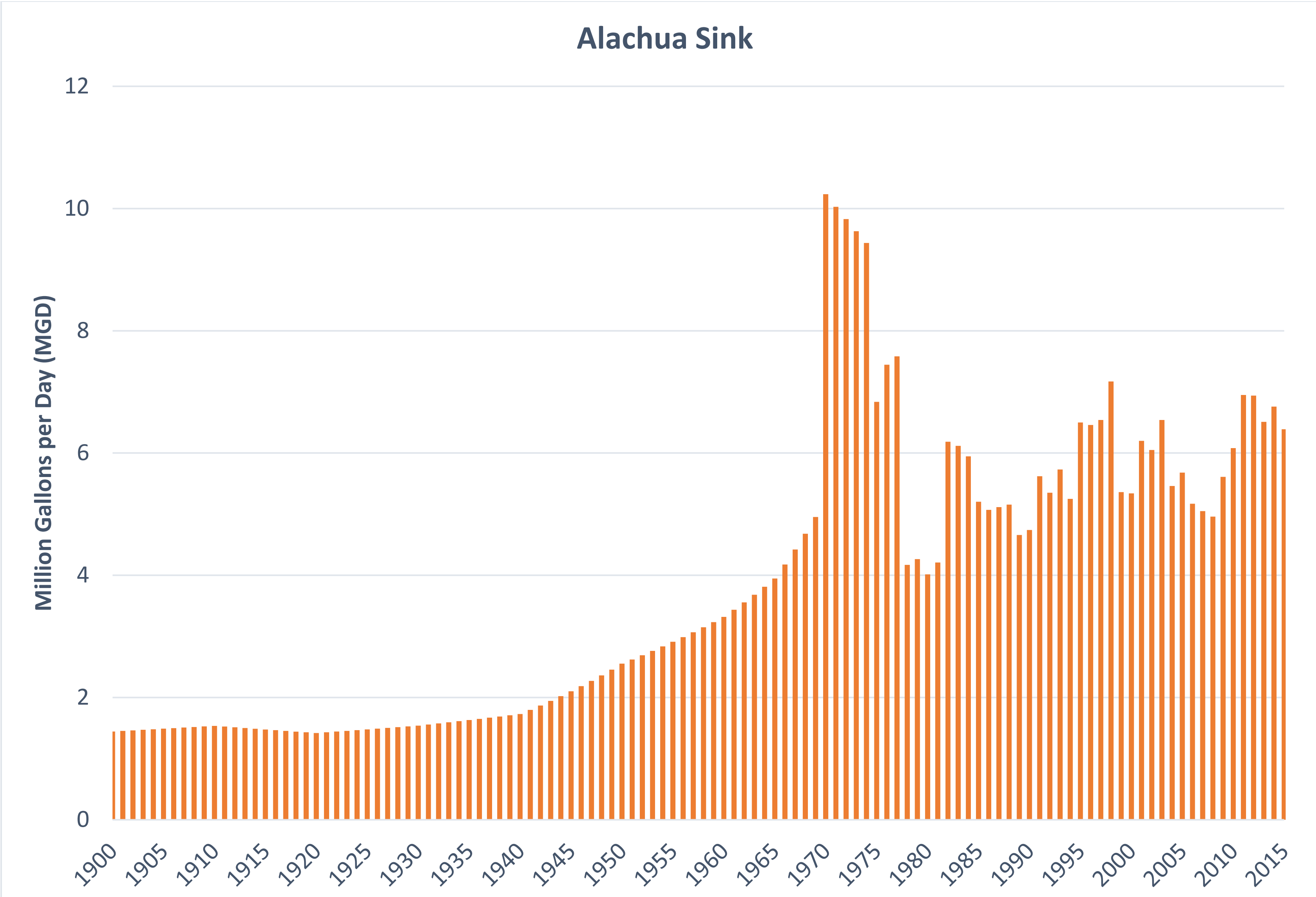

Figure 3. Estimated flows for Alachua Sink

2.4 University of Florida

The University of Florida wastewater treatment plant was constructed in 1926. In 1959, two injection wells were installed for lake level control. In 1994, the water reclamation plant (WRP) began operation and in 1995 the effluent from the plant was discharged directly to the R2 (Lake Alice - FLA011322_8285) injection well, leaving the other well, R1 (UF well number 001) to be used only for lake level control.

Starting in 1995, injection flow rates from the WRP and total flow rates were reported to FDEP. SJRWMD provided a spreadsheet with these numbers (file name "1995 - PRESENT WW TREATMENT AND REUSE MASTER FILE 051518"). The injection flow rates reported from 1995-2015 were assigned to only well R2 because the reclaimed water is injected directly into that well. Well R1 was set to zero for these years.

To estimate the flow through the wells prior to 1995, the average of the total flow reported from FDEP from 1995-2015 was calculated. This average of 1.890762 MGD was then divided by the average Murphree Well Field withdrawal for reported years (23.7734448 MGD) to get a ratio of 0.079532517. This ratio was then multiplied by the Murphree Well Field withdrawal data back to 1926 and divided equally amongst the R1 and R2 wells. Figure 4 shows the estimated flow into both University of Florida injection wells.

Figure 5 displays the time series for all injection wells where flows were estimated.

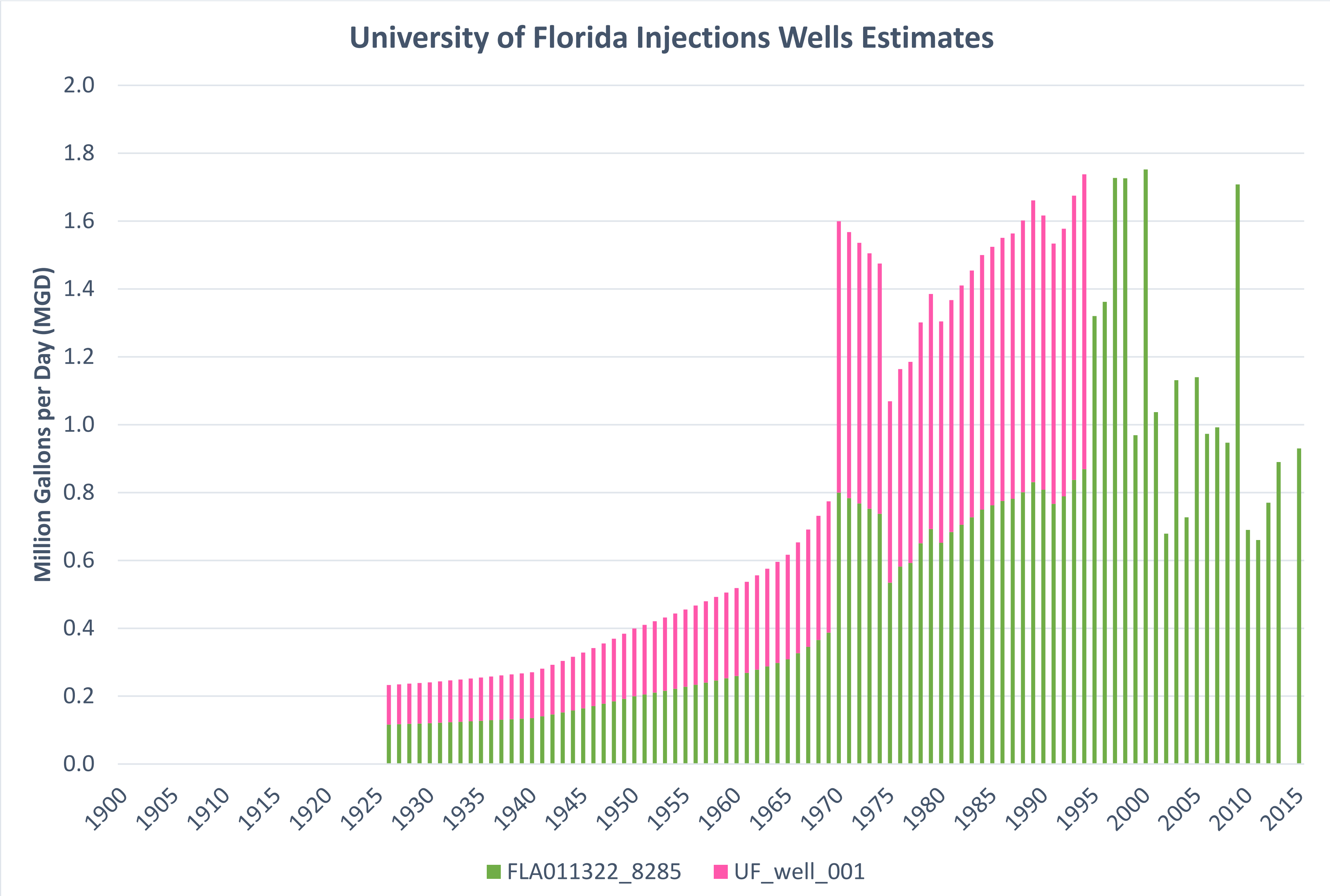

Figure 4. Estimated flows for University of Florida injection wells

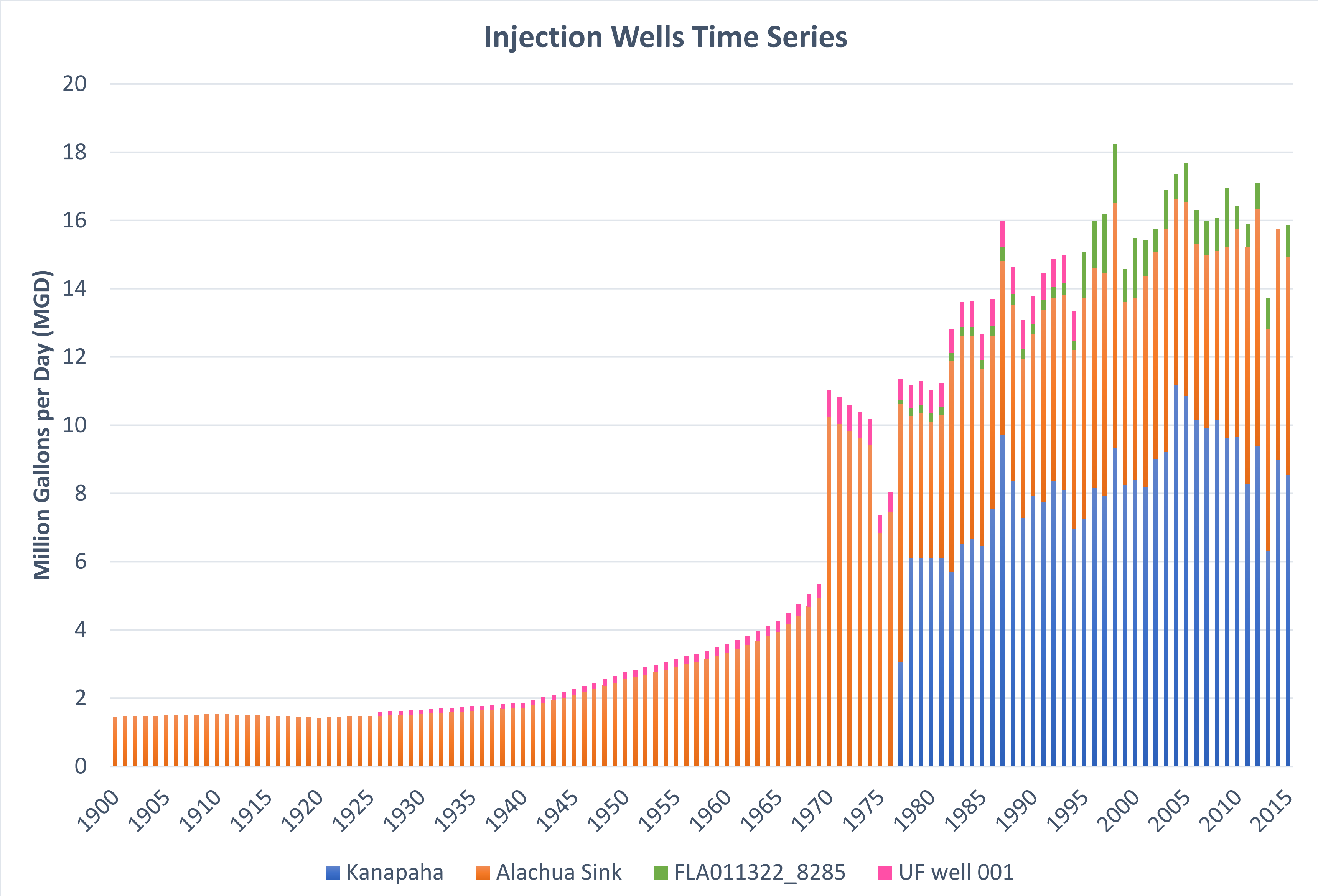

Figure 5. Estimated injection well flows time series for all wells

3.0 MOVING AVERAGE

Lastly, a five-year moving average was calculated from the injection rates for each station. This moving average used the current year, and four years prior to calculate an average that was then applied for the given year. For example, the years used to calculate a five-year moving average for 2015 would include 2011, 2012, 2013, 2014, and 2015. Figure 6, Figure 7, and Figure 8 show the moving average estimates of injection for the Kanapaha well, Alachua Sink, and University of Florida wells. Figure 9 shows the moving average injection flows for all wells. The results of this injection well flow estimation process relative to the single-year estimates for the NFSEG are summarized in Table 2 (Durden, et al. 2019).

Year	Injection wells reclaimed water flows in NFSEG Domain (MGD)	Hindcasting Output (MGD)	Hindcasting Five-Year Moving Average Output (MGD)
2001	16.40	15.42	15.98
2009	15.34	16.94	16.60
2010	14.18	16.44	16.35

Table 2. Comparison between estimated injection well flows in the NFSEG model, hindcasting, and five-year moving average

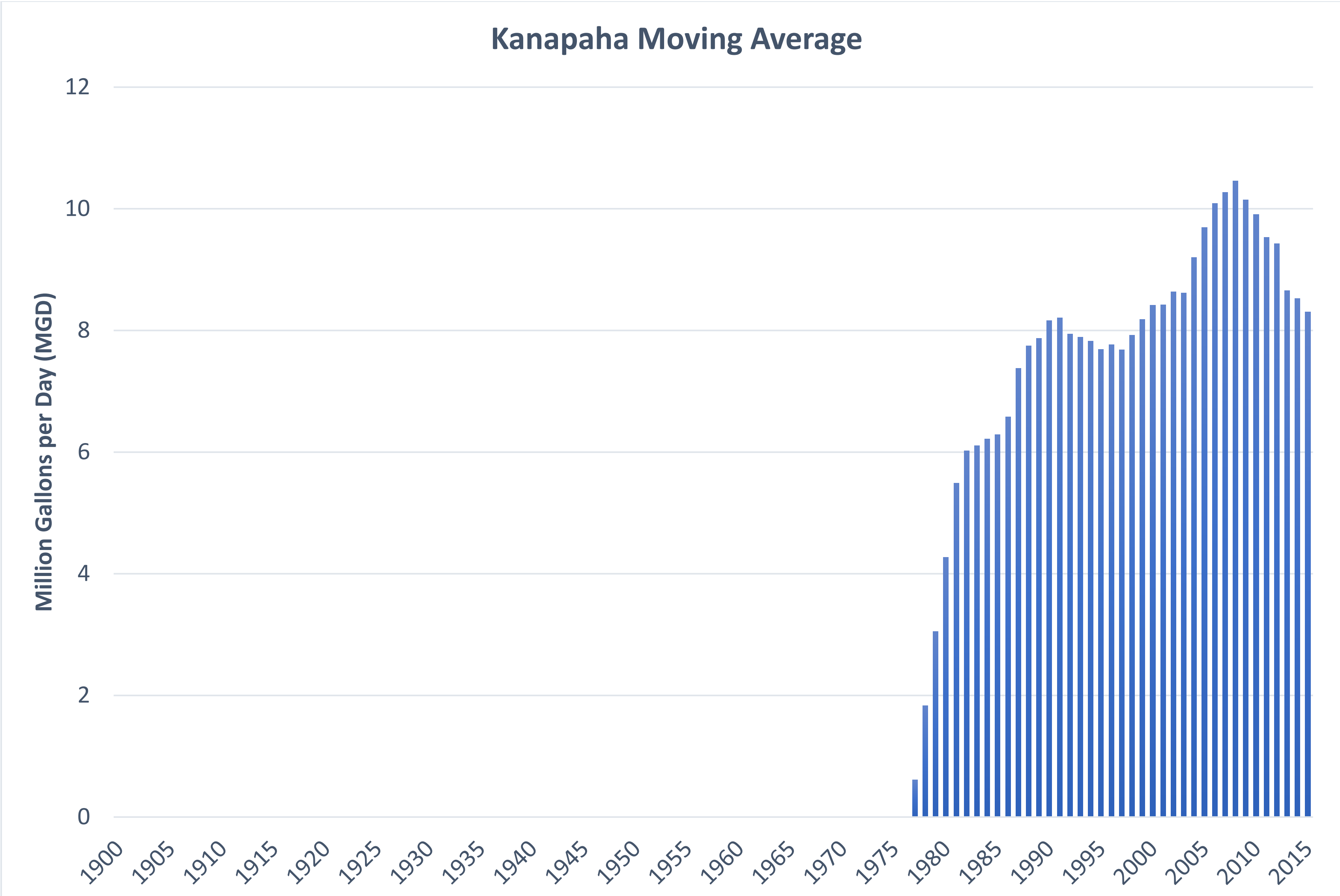

Figure 6. Moving average time series for Kanapaha injection well

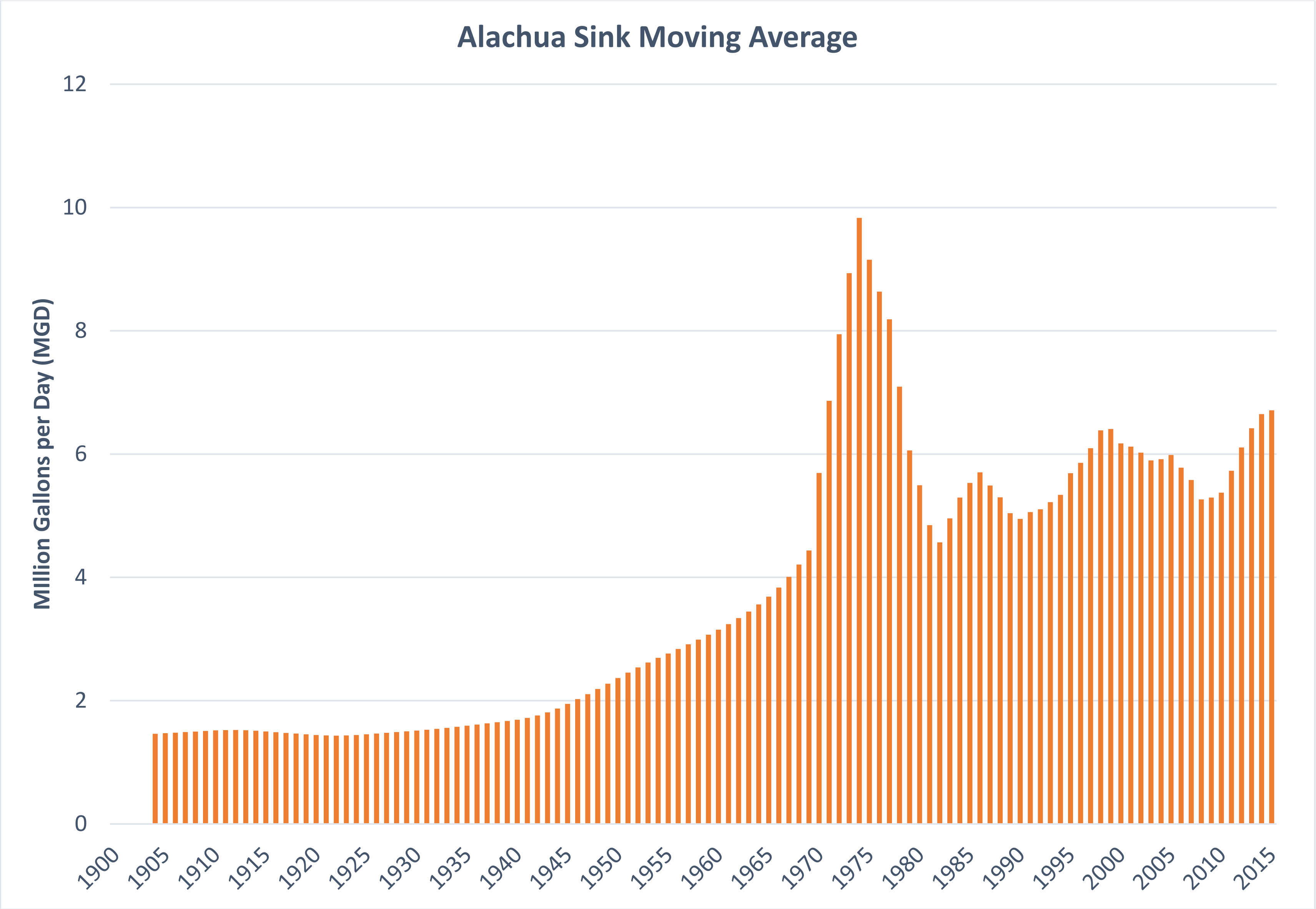

Figure 7. Moving average time series for Alachua Sink

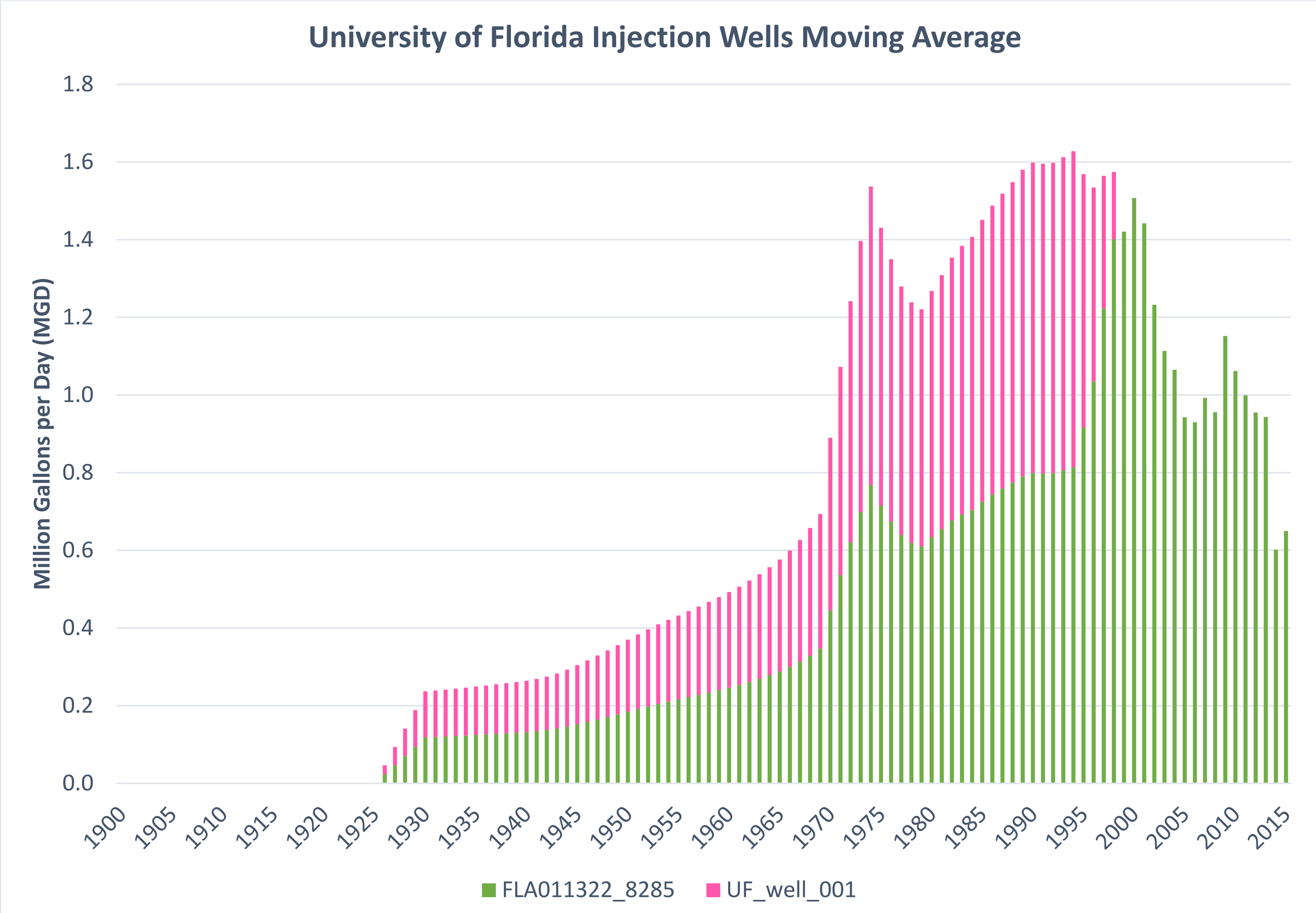

Figure 8. Moving average time series for University of Florida injection wells

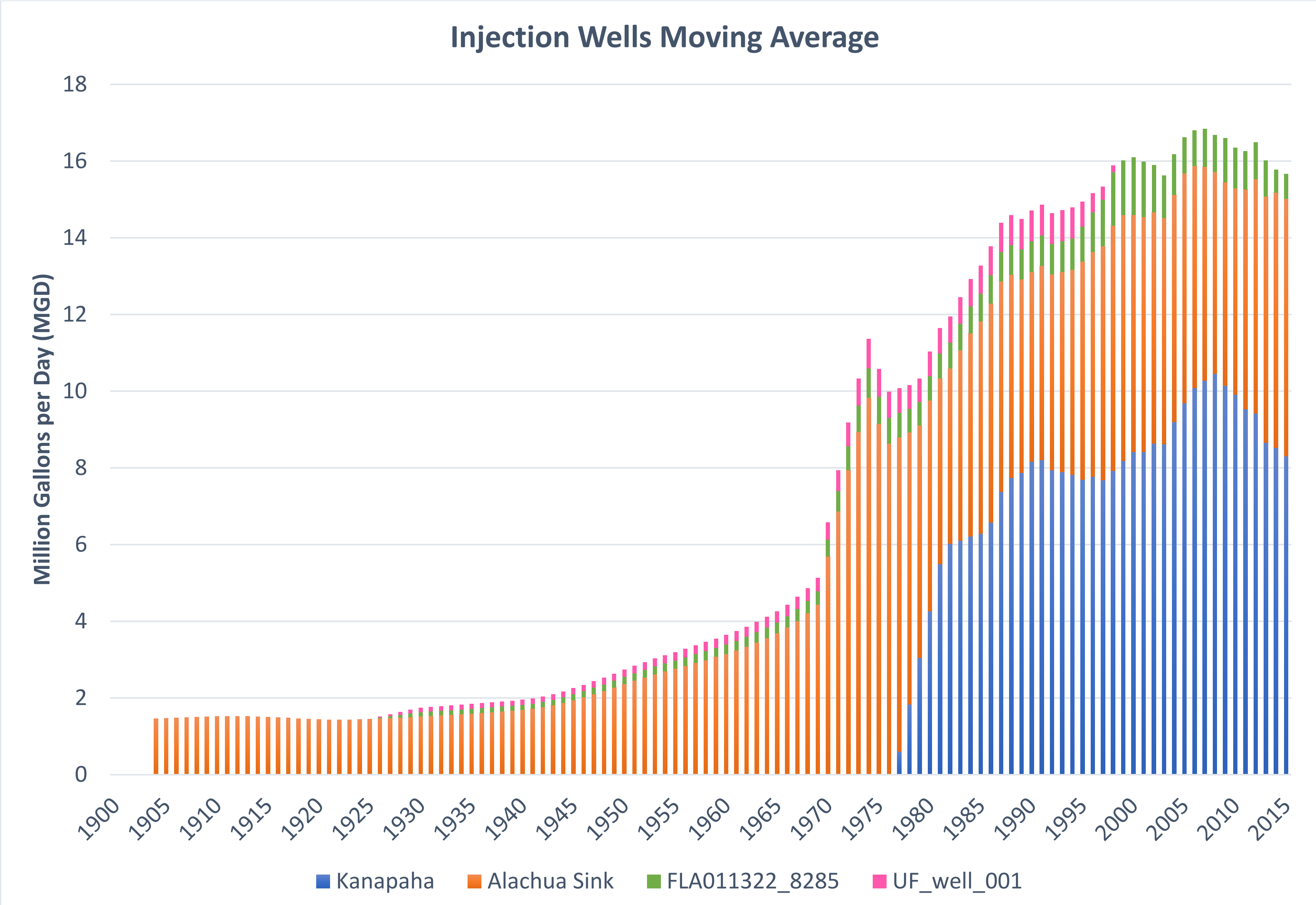

Figure 9. Moving average time series for all injection wells

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