No. 142, Original

In The
Supreme Court of the United States

STATE OF FLORIDA,

Plaintiff,

v.

STATE OF GEORGIA,

Defendant.

DIRECT TESTIMONY OF MARK H. MASTERS

October 26, 2016

TABLE OF CONTENTS

I, Mark H. Masters, offer the following as my Direct Testimony.

I. INTRODUCTION AND OVERVIEW

1. I currently live in Dawson, Georgia. I have lived in Georgia for 39 years.

2. I am the Director of the Georgia Water Planning & Policy Center at Albany State University ("Water Policy Center" or "Center"). The Water Policy Center is a research and policy institution that educates and advises policymakers, farmers, and other stakeholders on agricultural water resource issues in Georgia.

3. My testimony focuses on the State of Georgia's efforts to collect data on agricultural water use, its investments in agricultural water conservation, and its management of agricultural water resources. I will specifically discuss the State's multiple contracts with the Water Policy Center since 2005 to map irrigated acreage in the ACF Basin. Those efforts have yielded detailed information on agricultural water use in the Flint River Basin, including the number of acres potentially under irrigation and the types of irrigation systems generally used by farmers. The Center has also provided additional contractual support to the State in support of regional water planning efforts, including water planning in the Georgia portion of the ACF Basin ("ACF Georgia"). I will also discuss several of the State's agricultural water conservation programs, including center-pivot sprinkler retrofits, irrigation scheduling, and other measures. The Water Policy Center has gathered data on the use of different center pivot sprinkler types in the Lower Flint River Basin and has found that farmers use highly efficient, low pressure sprinklers on over 90% of the irrigated acreage in this region. Finally, I will review the on-the-ground agricultural management challenges faced by Georgia farmers and the necessity of irrigation to agriculture in ACF Georgia.

II. PERSONAL & PROFESSIONAL BACKGROUND

A. Educational Background

4. My educational background is in business and economics with a concentration in agricultural and resource economics. In 1999, I earned a bachelor's degree in Business Administration from Georgia Southwestern State University. In 2005, I earned a master's degree

in Economics from Auburn University, with a research focus on agricultural economics. I have completed necessary coursework toward a Ph.D. in Applied Economics from Auburn University.

B. Professional Experience

5. I began working as a research associate at the United States Department of Agriculture ("USDA") National Peanut Research Laboratory in 1999. In 2000, the USDA sponsored me to earn my master's degree from Auburn University, and while I was earning my master's degree, I continued my research and work at the USDA Peanut Laboratory.

6. My research at the USDA focused primarily on agricultural practices and irrigation management. My office was located at the USDA Peanut Laboratory in Dawson, Georgia, but I spent much of my time at various research sites operated by the Peanut Laboratory including the Multi-Crop Irrigation Research Farm in Shellman, Georgia.

7. I was part of the team from USDA that established the Shellman Farm, which conducts research and experiments on the impacts of different irrigation and agricultural management practices on crop yields and water use for different crops under various environmental conditions. My research involved: different crops, including various rotations of peanuts, corn, cotton, wheat, and soybeans; different irrigation practices, including limited irrigation, irrigation scheduling, and crop rotation; and different irrigation system types, including center pivots, sub-surface drip, and surface drip irrigation systems.

8. In addition to my work at the Shellman Farm, I also helped develop and open a "sister" research farm at the Hooks-Hanner Environmental Resource Center near Dawson. This research facility, owned by the State of Georgia, was made possible through a cooperative agreement between the USDA Peanut Laboratory and the Georgia Soil and Water Conservation Commission ("Georgia Soil & Water"). Similar to the Shellman Farm, the Hooks-Hanner Center also conducts research on the effects of various irrigation types and practices on a variety of crops but with the addition of various tillage practices (conventional tillage, minimum tillage, and full conservation tillage).

9. Since 2003, I have worked at Albany State University, first as a research associate and then as an assistant professor. From 2004-2012, I taught several courses at Albany State,

including courses in economics, water planning and policy, and resource economics. I have also served as an advisor to numerous graduate students completing degrees with a concentration in water policy and management.

10. Since 2004, I have been the director of the Water Policy Center at Albany State.

11. The Water Policy Center is located in Albany, Georgia, in the heart of the Lower Flint River Basin. The Center conducts research and analysis to educate and assist stakeholders and policymakers through data collection and analysis, technical assistance, and support for development of water policy in Georgia. Over the last 15 years, we have produced policy papers and research articles on agricultural water use and have conducted numerous outreach efforts with farmers in Georgia to help them improve their water management practices and promote water conservation measures. Partnerships are an integral part of the Center mission, and the Center has collaborated on programs for research and education with other universities, including the University of Georgia, Auburn University, University of Florida, University of Delaware, and Johns Hopkins University as well as numerous federal and state agencies.

12. In addition to research and analysis, the Water Policy Center is a primary contractor for the State of Georgia on various water management projects, including for state water planning. The Center's contractual relationship with the State of Georgia is primarily through the Georgia Environmental Protection Division ("Georgia EPD") and Georgia Soil & Water. The Center works directly with state agencies to support data collection and water policy and planning efforts. As Director, I manage all of the Center's activities, outreach, and policy efforts, including all contracts with and deliverables to the State of Georgia.

13. The Center's work under contract with Georgia EPD and Georgia Soil and Water has primarily involved mapping of irrigated acreage and collecting information regarding irrigation operations on individual farms throughout the entire state, including the ACF Basin. The Center's mapping work involves both field mapping and remote imagery mapping. Field mapping refers to visiting irrigation withdrawal sites to record information about the acreage of a field under irrigation, as well as information about the type of irrigation system used, type of water source, and type of conservation practices. Remote imagery mapping refers to the review of aerial and satellite imagery in Georgia to locate and create a map of total wetted acreage of

individual fields, sub-basins, and entire watersheds. The State of Georgia has also contracted with the Center to support multiple regional water councils in the ACF Basin in the development of their regional water plans and to develop statewide forecasts of agricultural water demand.

14. The Water Policy Center also engages in direct outreach and works with farmers in Georgia to promote agricultural water conservation and improve agricultural irrigation practices. The Center has secured funding for programs to expand the use of improved irrigation technology, such as remote soil moisture monitoring and irrigation scheduling tools as well as technical support to farmers in developing comprehensive farm conservation plans.

15. As director of the Water Policy Center, I work with federal and state officials and other institutions on the Center's grants, contracts, and cooperative projects. I review work products and contract deliverables before they are finalized. I have also presented the results of the Center's work to legislators, state agencies, local government officials, and other policymakers and stakeholders, including to all of the regional water councils in the State. In these presentations, I often review various issues that affect water management in Georgia, including which crops are produced in Georgia, irrigated acreage in Georgia, and provide an overview of significant legislation and water conservation efforts by the State of Georgia.

16. As director of the Water Policy Center, I oversee its finances. As part of Albany State University, and therefore the state University System of Georgia, the Center has received funding directly from the State of Georgia. It has also won competitive federal grants for various research and outreach work related to agricultural water use in Georgia. In addition, the Center receives funding from the State of Georgia through direct contracts to perform technical services in support of state and regional water planning efforts. In the past year, the Water Policy Center received the majority of its funding from the State of Georgia through contracts and direct funding. The State currently has engaged the Center for approximately $700,000 to support ongoing state and regional water planning. In addition, the Board of Regents of the University System of Georgia provided approximately $100,000 in direct funding. Within the last year, the Center has also secured federal grants of over $550,000 with other federal research projects pending.

C. Personal Farming Experience

17. Beyond my professional training and experience, I have personal knowledge of agricultural production and the use of water for agriculture from my own farming activities. I was raised on a farm in southwest Georgia, and my family has been involved in farming for generations. My family and I hold multiple agricultural withdrawal permits and I have first-hand experience in operating center pivot, traveler, and drip irrigation systems in southwest Georgia.

18. The combination of my personal and professional experience has led to my appointment to various local, state, and national boards and councils. I am a member of the Agricultural Water Advisory Committee for American Farm Bureau and am the Associate Director of the newly formed Center for Behavioral Agri-Environmental Research established by USDA. Closer to home, I serve as a supervisor for the Lower Chattahoochee Soil and Water Conservation District.

19. Agriculture is an important way of life throughout ACF Georgia. Similar to my own family, most farmers in the region have been involved in farming for many generations. While farming undoubtedly has a business component, many farmers go to great lengths to preserve and improve upon the farming operations that have been passed down to them. Local communities are structured around features of the agricultural industry, and these communities and the people who live in the region depend upon agriculture for their livelihoods and way of life.

20. The development of supplemental irrigation has been critical to the continued survival and productivity of agriculture in southwest Georgia. Precipitation in ACF Georgia can vary greatly from year to year, and even vary significantly on the same farm within a single season. Irrigation helps provide farmers stability in yield and crop quality, even with the variability of precipitation and potential for periods of drought during the growing season. Without irrigation, farmers are exposed to high risk of financial loss given the large capital outlays involved in planting a crop.

III. GEORGIA'S INVESTMENTS IN IMPROVED DATA REGARDING AGRICULTURAL WATER USE IN THE ACF BASIN

A. Georgia's Mapping and Data Collection Contracts with the Water Policy Center

21. Through a series of contracts in 2005-2006, 2006-2008, 2012-2014, and 2015-2016, the State of Georgia engaged the Water Policy Center to conduct extensive field and remote imagery mapping of irrigated acreage. At times these mapping efforts have focused specifically on the Georgia portion of the ACF Basin, and at other times they have included the entirety of the State of Georgia. These contracts are with Georgia EPD and Georgia Soil and Water. GX-84, GX-441, GX-807, GX-1241, GX-1242 (Water Policy Center mapping contracts and amendments).

- GX-84 is a true and accurate copy of the 2005 contract between the Water Policy Center and Georgia Soil and Water. The Center kept a copy of the contract in the course of its regularly conducted business activities and it was the Center's regular practice to enter into and maintain such contracts.

- GX-1241 is a true and accurate copy of the 2006 contract between the Water Policy Center and the Georgia Soil and Water. The Center kept a copy of the contract in the course of its regularly conducted business activities and it was the Center's regular practice to enter into and maintain such contracts.

- GX-1242 is a true and accurate copy of the 2008 renewal and amendment of the 2006 contract between the Water Policy Center and Georgia Soil and Water. The Center kept a copy of the contract in the course of its regularly conducted business activities and it was the Center's regular practice to enter into and maintain such contracts.

- GX-441 is a true and accurate copy of the 2012 contract between the Water Policy Center and Georgia Soil and Water. The Center kept a copy of the contract in the course of its regularly conducted business activities and it was the Center's regular practice to enter into and maintain such contracts.

- GX-807 is a true and accurate copy of the 2015 contract between the Water Policy Center and Georgia EPD. The Center kept a copy of the contract in the course of its regularly conducted business activities and it was the Center's regular practice to enter into and maintain such contracts.

22. The 2005-2006 and 2006-2008 contracts were between the Water Policy Center and Georgia Soil and Water. The mapping effort governed by these contracts was designed to

update the acreage and field information in the Agricultural Metering Database, which is maintained by the State.

23. The mapping data from the 2005-2006 and 2006-2008 contracts was also used from 2007-2009 by personnel from the National Environmentally Sound Production Agriculture Laboratory ("NESPAL")—an agriculture research center associated with the University of Georgia—to develop a statewide database of irrigated acreage. This database is known as as the "2010 NESPAL Database." The 2010 NESPAL Database was created to support the first round of statewide water planning. I worked closely with personnel from NESPAL to integrate the data collected by the Water Policy Center from 2005-2008 and other data maintained by the State into the 2010 NESPAL Database.

24. In 2012, Georgia Soil and Water awarded the Water Policy Center a contract for additional detailed field mapping of irrigated acreage in the ACF Basin. Among other things, the contract tasked the Center to collect detailed information about irrigation equipment used in the Lower Flint River Basin. The State specifically instructed the Center to evaluate "existing conservation measures in place such as low pressure drops and other relevant information, as available, that may be used by the Commission . . . in prioritizing future conservation programs." GX-441 at GA00803058.

25. Beginning in 2012, the Water Policy Center also completed field mapping of all surface water irrigated fields in the Ichawaynochaway, Spring Creek, and Lower Flint sub-basins (located in the southwest corner of Georgia, fairly close to the Florida border) and all groundwater withdrawals from the Capacity Use and Restricted Use areas in the Flint River Basin (geographic zones defined by the State in the 2006 Flint River Basin Plan). It is my understanding that Capacity Use areas are those having the highest degree of connectivity between groundwater and surface water flows, and that Restricted Use areas have a somewhat lower degree of connectivity between groundwater and surface water.

26. In 2015, EPD hired the Water Policy Center to update the 2010 NESPAL Database to support the second round of statewide water planning. Under the 2015 contract, the State directed the Center to combine existing wetted acreage information with new mapping performed by the Center in various regions in the state, including sub-basins in the ACF Basin.

The Center incorporated the field mapping ongoing from 2012 into this effort. In addition, the Center conducted two rounds of imagery analysis, one in 2013 and another in 2015 to supplement its field mapping. This work culminated in an updated statewide inventory of wetted acreage that is commonly referred to as the "2016 Wetted Acreage Database." JX-129.

27. Masters Demo. 1 shows some of the data compiled and delivered by the Water Policy Center as part of the 2016 Wetted Acreage Database. The Database contains over 33,000 entries and provides extensive information about the mapped irrigated fields in the State. Among other things the Database lists (1) a permit number(s) for each field; (2) the type of water source from which the farmer irrigates (surface, ground, or well-to-pond); (3) the type of irrigation system in use (in the column labeled "HdwType"); (4) the number of acres under irrigation; (5) the exact location of each field, categorized in multiple ways, including by county, watershed, basin, sub-basin, and planning-council region; and (6) the aquifer source for groundwater withdrawals.

Masters Demo. 1. Data in 2016 Wetted Acreage Database

AreaID	Permit_1	SrsType	HdwType	Acres	GW Pct	SW_ Pct	GW_ Acres	SW_ Acres	Throw_ Ac	ThrowGW _Ac	ThrowSW _Ac	County	HUC08	HUC12	Aquifer	SubArea4
WC-1	A00-086-0055	G	DR	98.0	100	0	98.0	0.0	98.0	98.0	0.0	Lanier	03110202	031102020901	Floridan	n
WC-10	A14-050-0083	G	CP	20.1	100	0	20.1	0.0	27.7	27.7	0.0	Lowndes	03110202	031102021103	Floridan	n
WC-100	A00-037-0353	S	CP	8.9	0	100	0.0	8.9	14.7	0.0	14.7	Cook	03110203	031102030403		n
WC-1000	A91-035-0236	W	CP	31.8	70	30	22.3	9.5	42.1	29.5	12.6	Colquitt	03110204	031102040404	Floridan	n

Source: JX-129 (2016 Wetted Acreage Database)

28. The 2016 Wetted Acreage Database reflects the acreage that can potentially be irrigated by existing irrigation systems. It was compiled for state water planning purposes. The total amount of acreage actually being irrigated by farmers changes from day to day, month to month, and growing season to growing season and is affected by a variety of factors.

29. In his pre-filed written testimony, Dr. David Sunding relies on acreage from the 2010 NESPAL Database because, in his view, "a number of irrigated areas included in NESPAL were omitted from the Wetted Acreage Database." Sunding Testimony ¶ 29. Dr. Sunding's implication is that the 2010 NESPAL Database is a more accurate reflection of irrigated acreage in the ACF Basin than is the 2016 Wetted Acreage Database. That is incorrect. The 2016 Wetted Acreage Database used the 2010 NESPAL Database as a starting point but contains *updated* information that is the product of extensive mapping efforts (both on the ground and using geospatial software) and thousands of hours of work by Water Policy Center personnel.

During this process, Center personnel did remove some fields that were included in the 2010 NESPAL Database for the 2016 Wetted Acreage Database. They did so for good reason. The detailed mapping work undertaken by the Center demonstrated that those fields were no longer (or never were) being irrigated. Conversely, the 2016 Database contains irrigated fields that were not included in the 2010 NESPAL database, but which mapping work now shows are being irrigated. The 2016 Wetted Acreage Database thus more accurately captures the true number of irrigated acres in the ACF Basin than does the 2010 NESPAL Database.

30. The 2016 Wetted Acreage Database also reflects more accurate source information than the 2010 NESPAL Database. For example, the extensive field mapping conducted by the Center demonstrated that tens of thousands of acres that were recorded as being irrigated by a surface water source in the 2010 NESPAL Database are either no longer being irrigated or are being irrigated by groundwater sources.

B. The Water Policy Center's Mapping Methodology

31. The mapping efforts undertaken by the Water Policy Center per its contracts with the State of Georgia are multi-step processes to ensure that the Center collects accurate data for the mapping of irrigated fields through both field mapping and remote imagery mapping.

32. For field mapping, the Center's staff physically visits a particular meter site or irrigated field to record data. At the site, the field mapper locates and records, via portable GPS device, the precise location of the water source, the location of the meter, and the location and extent of the irrigation system coverage. For a field irrigated by a center pivot, the field mapper maps the center of the pivot and also captures a point at the end of the pivot. If the pivot does not operate in a full circle, the field mapper also maps additional points where the pivot stops its rotation. For an irregularly shaped field, the field mapper maps various points along the boundary.

33. This data is then delivered to the Water Policy Center's offices and processed into map files using ArcGIS software. The program uses recorded GPS points to create polygons in the map file to represent the irrigated fields. Each polygon is then verified for accuracy by the same individual who performed the field mapping. This process ensures the accuracy of the field mapped data incorporated into the state's Wetted Acreage Database.

34. In addition to GPS location data, field mappers also record other information about the field for use by the State of Georgia. This information includes the type of water source, such as surface water, groundwater, or well-to-pond systems; the type of irrigation system, such as center pivot, traveler, or drip; and additional information, such as the serial number(s) for any meters associated with the irrigation system. Beginning in 2013, field mappers also recorded the type of sprinkler or nozzle used by the irrigation system and the type of power system used to operate the irrigation system.

35. For those areas not mapped by field personnel, Center personnel perform a remote imagery analysis by reviewing high-resolution aerial or satellite images to identify irrigated fields. These aerial images are obtained from a variety of sources, including the USDA National Aerial Imagery Program and Google Earth. Imagery for the area under review is divided into grids and staff members review an entire image, grid by grid, and identify all areas in each grid that appear to be irrigated. This level of analysis captures not only irrigated acreage added in recent years, but also acreage that may have been removed from production or modified in some way from earlier acreage compilations. In developing the 2016 Wetted Acreage Database, estimates of new, removed or modified irrigated acreage were made against the 2010 NESPAL Database.

36. After collecting and processing the data, the Water Policy Center produces map files which show the shape and size of the irrigated fields and associated data. For fields with a center pivot irrigation system, the Center also estimated additional acreage that could potentially be irrigated by end guns by adding 100 feet to the radius of the center pivot hardware. Center pivots irrigate fields via sprinklers and nozzles directly on, or under, the spans of the pivot. This acreage is often referred to as the "hardware acres." Most center pivots also have a sprinkler located at the end of the final span, called an end gun, which irrigates a portion of the field beyond the end of the actual center pivot hardware. This acreage is called "end gun acres."

37. Masters Demo. 2 shows a center pivot with drop nozzles and an end gun. GX-899 at GA02474121. Masters Demo. 2 shows that a portion of the irrigated acres ("hardware acres") are directly under the hardware of the center pivot and are irrigated by the drop nozzles. It also shows that a portion of the irrigated acres ("end gun acres") are irrigated by the sprinkler

at the end of the center pivot, which throws water several feet beyond the hardware of the center pivot.

- GX-899 at GA02474121 is a true and accurate copy of a photograph taken by William Laing Sr., an agent of the State of Georgia. Mr. Laing signed an affidavit stating that he took this picture on August 31, 2016 in Terrell County, Georgia. GX-897 (Affidavit of William D. Laing, Sr.). is a true and accurate copy of a picture taken by William Laing Sr., an agent of the State of Georgia. Based on my experience, I can see that this photograph depicts a center pivot with an end gun.

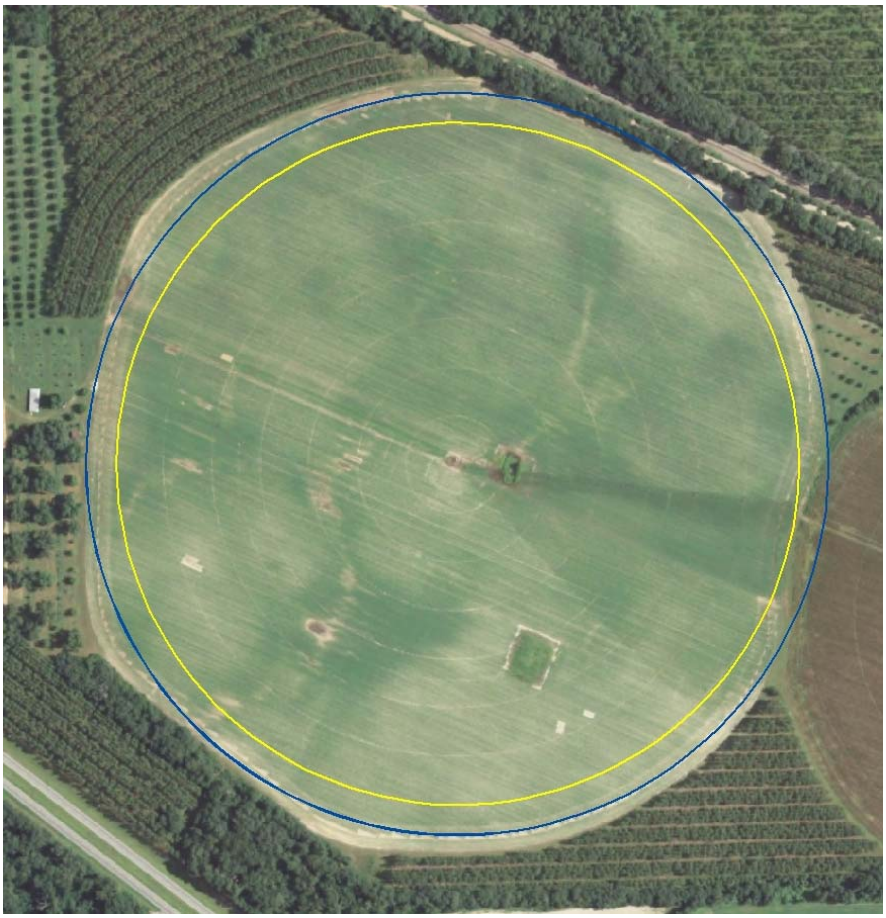
Masters Demo. 2. Center Pivot with End Gun

Source: GX-899 at GA02474121

38. As discussed above, to account for the additional end gun acres irrigated by a center pivot, the Water Policy Center added 100 feet to the measured radius of the center pivot. The 100-foot range is an assumption adopted by the Center to ensure that all center pivots in the 2016 Wetted Acreage Database used by EPD for water planning purposes were treated uniformly. Based on our direct observations of actual end gun throws during our initial field mapping efforts, the Center concluded that 100 feet was a reasonable estimate to use for end gun throw in the ACF Basin for water planning purposes.

39. Masters Demo. 3 is an image of a mapped field in Georgia that I captured using ArcGIS software. The yellow circle shows the extent of the irrigation by the center pivot hardware. The blue circle shows the additional acreage that can be irrigated by the estimated 100 foot throw from the end gun.

Masters Demo. 3. Sample Image of a Mapped Polygon



Source: ArcGIS

C. State of Georgia's Agricultural Metering Program

40. Through the Water Policy Center's contracts with Georgia Soil and Water and our work supporting the state and regional water councils by calculating future agricultural water demand, I am familiar with the State of Georgia's Agricultural Water Use Measurement Program ("Agricultural Metering Program"). I also have experience with the Agricultural Metering Program and with how flow meters work from my personal farm work.

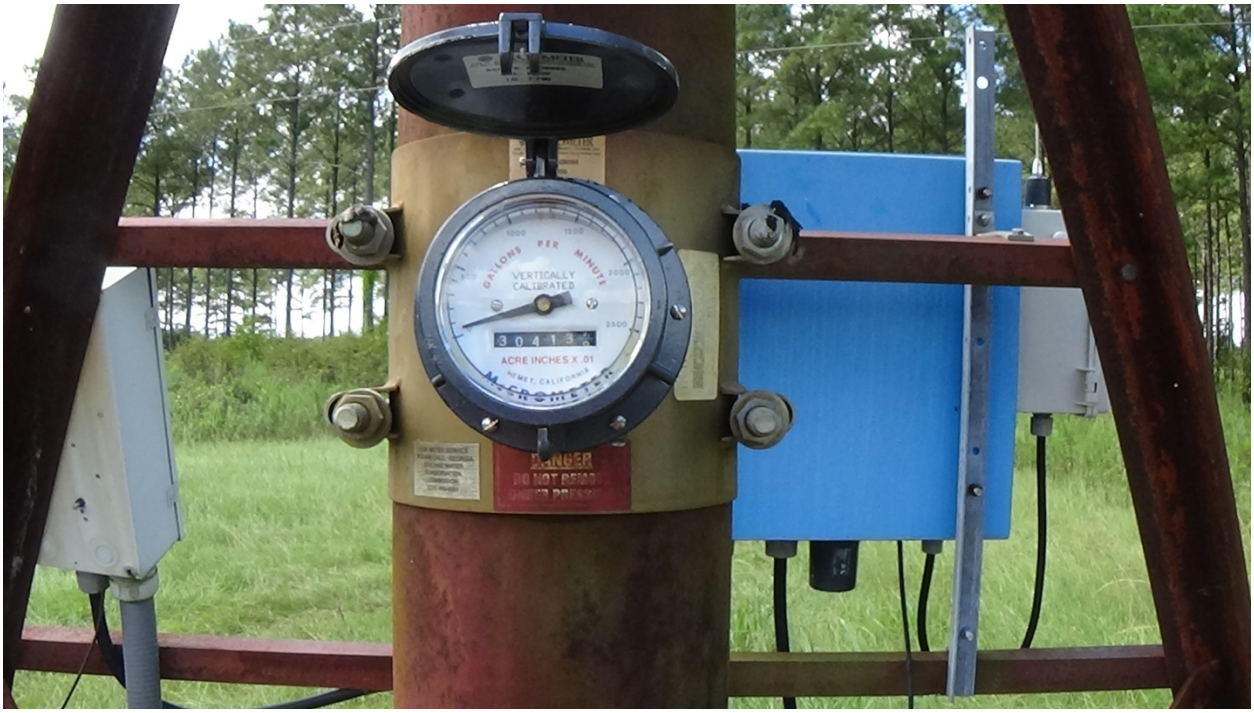
41. In 2003, the Georgia General Assembly passed legislation to establish the Agricultural Metering Program, an effort designed to measure agricultural water withdrawals statewide. As part of the program, the State installs mechanical flow meters on irrigation systems to measure the amount of water being used for irrigation. The direct measure of agricultural water use provided by the Agricultural Metering Program allows the state to calculate average irrigation depths and estimate the monthly irrigation distribution for metered fields. These depths are used by the State to estimate total agricultural water use for water planning purposes. For permits issued prior to 2003, the State installs, maintains, and reads these meters at no cost to farmers. For permits issued after 2003, farmers are responsible for purchasing and installing the flow meter while the state maintains the meters and reads them annually. Based on the Center's field mapping in the Lower Flint River Basin, I know that approximately 80% of irrigation systems are metered. GX-1133 (LF Mapping).

- GX-1133 is a true and accurate copy of a presentation on irrigation system characteristics recorded by the Water Policy Center during mapping work performed under contract with the State of Georgia. The Center kept a copy of the presentation in the course of its regularly conducted business activities and it was the Center's regular practice to create and maintain such presentations.

42. Masters Demo. 4 is an image of a flow meter that is installed on the pivot tower of an irrigation system. GX-899 at GA02474142.

- GX-899 at GA02474142 is a true and accurate copy of a picture taken by William Laing Sr., an agent of the State of Georgia. Mr. Laing has signed an affidavit stating that he took this picture on August 31, 2016 in Terrell County, Georgia. Based on my experience, I can see that this photograph depicts the kind of flow meters that can be installed in ACF Georgia.

Masters Demo. 4. Flow Meter on Pivot Tower



Source: GX-899 at GA02472142

43. Masters Demo. 5 is an image of a flow meter installed at the location of the groundwater source of the irrigation system. GX-899 at GA02474130.

- GX-899 at GA02474130 is a true and accurate copy of a picture taken by William Laing Sr., an agent of the State of Georgia. Mr. Laing has signed an affidavit stating that he took this picture on August 31, 2016 in Terrell County, Georgia. Based on my experience, I can see that this photograph depicts the kind of flow meter that can be installed in ACF Georgia.

Masters Demo. 5. Flow Meter at Groundwater Source

Source: GX-899 at GA02474130

44. Flow meters are typically installed near the water source, as shown in Masters Demo. 5, or on the irrigation system itself, such as on the pivot tower, as shown in Masters Demo. 4. They measure all the water that passes through the flow meter as water is delivered to the irrigation system. Because the flow meter is positioned to record water use before the water reaches the irrigation nozzles, emitters, or the end gun, it consequently records all the water used by that particular irrigation system.

45. On an annual basis, Georgia Soil and Water records the water use measured by flow meters. These annual meter readings are recorded in Georgia's Agricultural Metering Database. JX-138. Georgia Soil and Water also monitors and records water use from a subset of flow meters on a monthly basis. This monthly metering data is used to estimate the distributions of irrigation throughout the growing season.

46. In his written testimony, Dr. Sunding relies on the Agricultural Metering Database, JX-138, to identify a number of farmers who appear, at first glance, to be applying an excessive amount of water to their crops. Sunding Direct Testimony ¶ 31. In some cases, Dr. Sunding purports to identify farmers applying over 40 inches of water per acre. During Dr.

Stavins' deposition, Florida attempted to make a similar point when it presented Dr. Stavins with a set of examples that it claimed showed overwatering by Georgia farmers, including some cases in which farmers were purportedly applying more than 50 inches of water per acre.

47. Based on my experience, including years of working with the Agricultural Metering Database, I believe these high readings are likely due to mistaken linkages between the volume of water used and the acreage under irrigation per meter. As discussed above, flow meters measure the total volume of water that is used by the system(s) or drawn from the source to which it is attached. From my mapping efforts to support the Agricultural Metering Program, I know that some farmers use a *single* water source (with a single meter) to irrigate *multiple* fields using *multiple* irrigation systems. Because the meter is often placed at the water source, it records the total volume of water withdrawn for all the fields irrigated by that source, even if the farmer is irrigating two or more fields. If this total volume of water is assigned to only one field, rather than distributed over all of the fields, this can create the misleading impression that farmers are applying too much water to a single field. This can lead to erroneous conclusions concerning the water stewardship of that farmer.

48. For example, I reviewed data that Florida presented to Dr. Stavins during his deposition purporting to show that three farmers were applying more than 50 inches per acre. I compared those three entries to detailed mapping data the Center collected under contract with Georgia Soil & Water. In those three cases, I found the circumstances described above. Namely, the meter was measuring the amount of water going to *multiple* fields, but the irrigation depth that Florida calculated was erroneously associated with a *single field*. If *all* the fields irrigated by the relevant metered sources are taken into account, the irrigation depths would be much lower.

49. Another factor that can influence metered water use is the practice of double-cropping. I know many farmers that grow two different crops on their fields in certain years such as wheat/soybeans or multiple vegetable crops. The flow meter will measure the total volume of water that is used to irrigate both crops over the entirety of the growing season. However, because most meters are read only once a year, the person reading the meter might record only one of the crops in the rotation (the crop being grown at the time of the meter

reading). This can also give the mistaken impression that the farmer uses more water than would otherwise be expected when compared to crop model simulations or other producers irrigating a single crop.

IV. STATE OF GEORGIA'S INVESTMENTS IN AGRICULTURAL WATER CONSERVATION AND PLANNING

A. State of Georgia's Water Regulations and Planning

50. I have been involved and closely followed Georgia's water management policies throughout my professional career, including as a USDA researcher in Georgia and later as the Director of the Water Policy Center. In these capacities, I tracked proposed legislation and regulatory action pertaining to agricultural water use. From 2004-2006, I participated in the State's Sound Science Study and helped policymakers draft the 2006 Flint River Basin Regional Water Development and Conservation Plan ("2006 Plan"). Since then, the State of Georgia has hired the Water Policy Center to help with both the first and second rounds of state and regional water planning. I was also part of the working group that drafted the rules implementing the 2014 Flint River Drought Protection Act Amendments. I currently serve as a District Supervisor for the Lower Chattahoochee Soil & Water Conservation District. As a farmer in the State of Georgia, I am also a subject of Georgia's regulation of agricultural water use. I am very familiar with the State's regulatory system for agricultural water use and the changes it has undergone over the past 20 years.

51. Through my efforts in these activities and others, I know that the State of Georgia has invested substantial resources in, and has a strong commitment to, agricultural water conservation. I have seen those efforts first hand over the past two decades.

B. 2006 Flint River Basin Water Development and Conservation Plan

52. In 1999, Georgia issued a moratorium on new permit applications for all surface water withdrawals from the Flint River Basin and all groundwater withdrawals from the Floridan aquifer in Subarea 4. Shortly before the moratorium, Georgia initiated the Sound Science Study to better understand the effects of agricultural water use in the ACF Basin. The Sound Science Study was a broad initiative that entailed multiple studies to improve data collection, modeling, and stakeholder engagement in the Flint River Basin. The result of the Sound Science Study was

the 2006 Plan, which created new restrictions on agricultural water use in the Flint River Basin and lifted, in part, the permit moratorium. I worked closely with Georgia policymakers to draft the 2006 Plan. I served on the Technical Advisory Committee ("TAC") for the 2006 Plan, and I conducted analyses of the effects of various irrigation reduction scenarios in the 2006 Plan.

53. The role of the TAC was to review and analyze the technical materials that supported the State's policymaking efforts. These technical materials included the irrigated acreage estimations, modeling results, and water use estimates and projections. The TAC would support review of the technical material by the Stakeholder Advisory Committee ("SAC") and assisted the SAC with evaluating water management policies. As a member of the TAC, I went to stakeholder meetings, reviewed materials to be presented to SAC, and performed an analysis of EPD's acreage assumptions for reducing irrigation.

54. In the Flint River Basin Plan, the State of Georgia imposed conservation requirements for new permits, including end gun shutoff switches for center pivots, regular maintenance to prevent and repair leaks, pump-safety shutdown systems to stop water use in case of an irrigation system malfunction, and rain gage shutoff switches for traveler, solid set, and drip irrigation systems. Through my professional and personal experiences, I know that many farmers use a device called an end gun shutoff in the ACF Basin in Georgia. This allows a farmer to avoid applying water to areas that are non-cropped, where the farmer has not planted any crops. The State of Georgia also required new surface water withdrawal permits in the Spring Creek and Ichawaynochaway sub-basins to halt all irrigation if stream discharge at the withdrawal point was less than 25% of the average annual discharge. The State of Georgia also imposed restrictions on granting new groundwater permits based on their distance from existing groundwater withdrawals or from streams with a demonstrable connection to the aquifer.

55. Data collected since 2006 generally reflects the impact of permitting policies established in the 2006 Plan and subsequent action by Georgia EPD. Permits issued for new irrigation withdrawals in ACF Georgia have been almost entirely for groundwater withdrawals from aquifers other than the Floridan aquifer or in areas where the Sound Science Study showed that groundwater withdrawals had little to no impact on streamflow.

C. State and Regional Water Plans

56. In 2004, Georgia began working on a Statewide Water Plan, which was passed in 2008. The State Water Plan divided the state into water planning regions, and a regional council for each water planning region was directed to develop a regional water plan in conjunction with Georgia EPD. The regional water plans evaluated current and future water resources, water demand, and water management policies. The regional councils issued their water plans in 2011, except for the Metropolitan North Georgia Water Planning District, which issued water plans in 2003 and 2009. The water planning regions are currently engaged in the second round of water planning.

57. During the first round of regional water planning, the Water Policy Center worked as a subcontractor for Black & Veatch, which was under contract with the State of Georgia to support the regional planning. During that water planning process, I attended multiple meetings of each of the Lower Flint-Ochlockonee, Upper Flint, and Middle Chattahoochee Regional Water Councils. The Center provided both administrative and technical support to the Regional Water Councils in the first round of planning.

58. In 2013, Georgia EPD contracted directly with the Center to provide support to the Lower Flint-Ochlockonee, Middle Chattahoochee, and Upper Flint Regional Water Councils. GX-684 (2013 Water Policy Center contract). To support the Regional Water Councils, the State directed the Water Policy Center to complete several tasks. These included administrative and meeting facilitation support, including drafting agendas, organizing meetings, and coordinating all materials used by the Councils. The State also directed the Center to assist the Councils in compiling the materials for and drafting the Regional Assessment of Implementation Status.

- GX-684 is a true and accurate copy of the 2013 contract between the Water Policy Center and Georgia EPD. The Center kept a copy of the contract in the course of its regularly conducted business activities and it was the Center's regular practice to enter into and maintain such contracts.

59. The Water Policy Center also helped the policymakers and stakeholders on the regional water councils understand the technical work being done to support the water planning effort. Because several members of the regional water councils did not have a technical background, I often helped to translate the technical work into a format that could be understood

and used by the members. I also helped to organize the council meetings, set agendas for the meeting, and coordinate presentations on technical matters with Georgia EPD.

60. In the currently ongoing second round of regional water planning, the Water Policy Center is supporting review and revision of the regional water plans. The Center is also developing estimates of current and future agricultural water demand statewide. We are also helping the councils to revise and develop management priorities based on developments since the first round of planning.

V. STATE OF GEORGIA'S INVESTMENTS AND EFFORTS SUPPORTING EFFICIENT IRRIGATION TECHNOLOGY AND PRACTICES

A. Adoption of Efficient Irrigation Technologies in Georgia

61. From 2013 through 2015, the Water Policy Center conducted detailed field mapping in large portions of the Lower Flint River Basin, including field mapping covering 100% of the Capacity Use and Restricted Use areas identified by the 2006 Plan. At the direction of the State of Georgia, the Center collected detailed data on the different irrigation systems used by farmers, including information on irrigation efficiency and conservation measures. At the direction of the State of Georgia, I organized the data recorded by the Center and determined the percentage of systems and the percentage of irrigated acreage that used different types of irrigation systems and different types of sprinklers. JX-141 (GWPPC Mapped Pivots_Flint Basin.xlsx), GX-1133 (LF Mapping). This collected data shows that Georgia farmers have progressively moved to more efficient irrigation systems, which allow farmers to reduce the amount of water loss from irrigation. There are two primary ways in which the data shows that farmers have improved the efficiency of their irrigation systems.

62. *First*, we compared the types of irrigation systems that were being used in the Lower Flint-Ochlockonee Water Planning Region[1] in 2015 against the types of irrigation systems that were being used in 2009. Based on my long experience in agricultural irrigation, I know that center pivot and drip irrigation systems are more efficient than traveler irrigation systems. The data shows that the number of center-pivot and drip irrigation systems in the Lower Flint-

[1] The Lower Flint-Ochlockonee Water Planning Region includes all of the Lower Flint River Basin.

Ochlockonee Water Planning Region has increased by roughly 30% and 29% respectively since 2009. At the same time, the number of less efficient traveler irrigation systems has declined 37% in that area, and travelers systems today cover 46% less acreage than they did in 2009. JX-141 (GWPPC Mapped Pivots_Flint Basin.xlsx).

63. Masters Demo. 6 below summarizes the Center's findings as to how the prevalence of center pivot, traveler, and drip irrigation systems has changed since 2009 in the Lower Flint-Ochlockonee Water Planning Region. This table shows that the most common type of irrigation systems used are center pivot systems. Moreover, the number of center pivot systems and drip irrigation systems has increased since 2009, whereas the number of less efficient traveler systems has decreased since 2009. JX-141 (GWPPC Mapped Pivots_Flint Basin.xlsx).

Masters Demo. 6. Breakdown of Irrigation Systems by Type and Acreage

	2009		2015		Percentage Change from 2009 to 2015	
System	**Number**	**Acres**	**Number**	**Acres**	**Number**	**Acres**
Center Pivots	6,783	464,524	8,825	539,173	+30%	+16%
Traveler Systems	2,972	97,022	1,885	52,333	-37%	-46%
Drip Systems	511	23,958	660	31,815	+29%	+33%

Source: JX-141 (GWPPC Mapped Pivots_Flint Basin.xlsx)

64. *Second*, with respect to center pivot systems specifically, we collected data on the efficiency of the systems currently being used in the Lower Flint River Basin.

65. From my academic background, my research at USDA, my outreach work with the Water Policy Center, and my personal experience as a farmer, I am aware that one of the most important factors in the application efficiency of a center pivot irrigation system is the type of nozzle used. Masters Demo. 7 is an image of a high pressure sprinkler system, in which the sprinkler sits on top of the center pivot and applies water at a high pressure of 60 psi or greater. Masters Demo. 8 shows a low pressure sprinkler, on which the sprinkler sits on top of the center pivot and applies water at a low pressure of less than 30 psi. GX-899 at GA02474125. Masters

Demo. 9 shows a low pressure drop nozzle, in which the sprinkler drops hangs below the center pivot arm and applies water at a low pressure. GX-899 at GA02474140.

- GX-899 at GA02474125 is a true and accurate copy of a picture taken by William Laing Sr., an agent of the State of Georgia. Mr. Laing has signed an affidavit stating that he took this picture on August 31, 2016 in Terrell County, Georgia. Based on my experience, I can see that this photograph depicts a center pivot with a low pressure sprinkler.

- GX-899 at GA02474140 is a true and accurate copy of a picture taken by William Laing Sr., an agent of the State of Georgia. Mr. Laing has signed an affidavit stating that he took this picture on August 31, 2016 in Terrell County, Georgia. Based on my experience, I can see that this photograph depicts a center pivot with a low pressure drop.

Masters Demo. 7. High Pressure Sprinkler

Source: USGS[2]

[2] This is not an image taken of an irrigation system in Georgia. Instead, this image was taken from USGS and shows a center pivot in Idaho. The picture is publicly available at http://water.usgs.gov/edu/irsprayhigh.html. Based on my experience, I can see that this photograph depicts a center pivot with a high pressure sprinkler.

Masters Demo. 8. Low Pressure Sprinkler

Source: GX-899 at GA02474125

Masters Demo. 9. Low Pressure Drop

Source: GX-899 at GA02474140

66. Many of the early center pivot systems in the Flint River Basin used high pressure impact sprinklers. These types of sprinklers were typically situated on top of the center pivot span and applied water at high pressure. However, most farmers in the Flint River Basin now use low pressure sprinklers. Many farmers also use low pressure drop nozzles, which drop below the span of the center pivot and are thus closer to the ground. Both of these low pressure nozzles lose less water to evaporation and have a higher application efficiency than the older high pressure impact sprinklers.

67. The Water Policy Center collected data on sprinkler types used by farmers during the Center's mapping efforts. I summarize that data below in three separate tables: Masters Demo. 10, Masters Demo. 11, and Masters Demo. 12. These tables distinguish between (i) high-pressure impact sprinklers; (ii) lower-pressure sprinklers; and (iii) lower-pressure drop nozzles. Masters Demo. 10 reports these different irrigation systems as a percentage of total center pivots in the Lower Flint River Basin. This data demonstrates that approximately 90% of the center pivots in Lower Flint River Basin employ low pressure sprinklers or low pressure drop nozzle technology. GX-1133 (LF Mapping).

Masters Demo. 10. Center Pivot Efficiency in the Lower Flint River Basin

Type of Center Pivot Sprinkler	High Pressure Impact Sprinklers	Low Pressure Sprinklers	Low Pressure Drop Nozzles
Percentage of Center Pivot Systems	10.5%	30.6%	58.9%

Source: GX-1133 (LF Mapping)

68. Masters Demo. 11 reports these different irrigation systems as a percentage of total acreage in the Lower Flint River Basin. It shows that, combined, low pressure systems irrigate approximately 93% of the acreage the Lower Flint River Basin. GX-1133 (LF Mapping).

Masters Demo. 11. Center Pivot Efficiency by Acreage in the Lower Flint River Basin

Type of Center Pivot Sprinkler	High Pressure Impact Sprinklers	Low Pressure Sprinklers	Low Pressure Drop Nozzles
Percentage of Center Pivot Acreage	7.2%	27.9%	64.9%

Source: GX-1133 (LF Mapping)

69. I also analyzed Capacity Use, Restricted Use, and Conservation Use zones separately. As Masters Demo. 12 below shows, in Capacity Use Areas, about 93% of irrigated acreage is irrigated by low pressure center pivot, and of that acreage, 59% is irrigated by low pressure drop nozzles. In Restricted Use areas, about 90% of irrigated acreage is irrigated by a low pressure center pivot, and of that, 56% is irrigated by low pressure drop nozzles. GX-1133 (LF Mapping). Therefore, in the areas of the Lower Flint River Basin where agricultural pumping from groundwater has the greatest effect on streamflow, the overwhelming majority of farmers use highly efficient irrigation systems.

Masters Demo. 12. Center Pivot Efficiency in the Lower Flint River Basin by Zone Type

Type of Center Pivot Sprinkler	High Pressure Impact Sprinklers	Low Pressure Sprinklers	Low Pressure Drop Nozzles
Percentage of Capacity Use Zone Coverage	6%	34%	59%
Percentage of Restricted Use Zone Coverage	10%	34%	56%
Percentage of Conservation Use Zone Coverage	12%	28%	60%

Source: GX-1133 (LF Mapping)

B. Pictures of Irrigation Systems in Georgia and Florida

70. In his written testimony, Florida witness Mr. Brett Cyphers refers to pictures taken by his staff of center-pivot operations in Georgia. Mr. Cyphers believes these pictures are evidence supporting his claim that "Georgia does not appear to engage in the same conservation efforts" as does Florida. Cyphers Written Direct Testimony at ¶ 60.

71. I have reviewed the pictures referred to in Mr. Cypher's direct testimony. Contrary to Mr. Cypher's testimony, some of those pictures actually highlight Georgia farmers conserving water using end-gun shutoffs. In FX-120 and FX-124, the end guns are not applying any water due to use of an end gun shutoff. Based on my extensive experience with irrigation in Georgia, I do not believe the other pictures show that Georgia farmers are inefficiently or inappropriately using water on a large scale basis. While center pivots do offer an efficient means of delivering water to crops, even the most conscientious farmer may apply some water to

a non-cropped area simply due to the mechanical and operational limits of irrigation systems. Similarly, when it rains, a farmer cannot necessarily turn an irrigation system off immediately, particularly if they are managing multiple systems over a large area. If the rain event is very brief, it may not provide enough water to satisfy the crop's water requirements. It would be entirely reasonable for a farmer to allow the irrigation system to continue to run, even after rain has started, until he or she is confident that enough rain will fall to justify turning the irrigation system off. A picture only captures a single moment in time and cannot account for all the real-world factors and operational considerations that farmers must deal with in managing their irrigation systems.

72. Even if the pictures referred to in Mr. Cypher's testimony did capture a handful of examples of inefficient irrigation practices, they do not support drawing a broader conclusion about farmers in the ACF Basin as a whole. ACF Georgia has thousands of farmers and fields; it would not be surprising that, out of those thousands, a few farmers might not follow best management practices. However, as the data collected by the Water Policy Center shows, farmers in Georgia have largely adopted highly efficient irrigation technologies, and in my experience, Georgia farmers do follow efficient irrigation practices. The great majority of Georgia farmers apply water in a reasonable and efficient manner.

73. To highlight that a handful of pictures cannot necessarily be used to draw larger conclusions about agricultural practices, William Laing, Sr. took several pictures of the irrigation practices of farmers in Jackson County, Florida from August 23-24, 2016. GX-897 (Affidavit of William Laing, Sr.). Masters Demo. 13, Masters Demo. 14, Masters Demo. 15, and Masters Demo. 16 are images of end guns applying water onto roads and passing cars in Florida. GX-898 at GA02474111, GA02474114, GA02474115, GA02474118. Masters Demo. 17 and Masters Demo. 18 are images of end guns applying water to wooded areas in Florida. GX-898 at GA02474113, GA02474116. Even though Florida has far fewer farmers in ACF Florida than Georgia has in ACF Georgia, there are several examples of Florida's own farmers applying water to roads and other areas that do not contain crops.

- GX-898 at GA0247411 is a true and accurate copy of a picture taken by William Laing Sr., an agent of the State of Georgia. Mr. Laing has signed an affidavit stating that he took this picture on August 23, 2016 in Jackson County, Florida. Based on

my experience, I can see that this photograph depicts an irrigation system irrigating a road.

- GX-898 at GA0247414 is a true and accurate copy of a picture taken by William Laing Sr., an agent of the State of Georgia. Mr. Laing has signed an affidavit stating that he took this picture on August 23, 2016 in Jackson County, Florida. Based on my experience, I can see that this photograph depicts an irrigation system irrigating a road and cars.

- GX-898 at GA0247415 is a true and accurate copy of a picture taken by William Laing Sr., an agent of the State of Georgia. Mr. Laing has signed an affidavit stating that he took this picture on August 23, 2016 in Jackson County, Florida. Based on my experience, I can see that this photograph depicts an irrigation system irrigating a road and cars.

- GX-898 at GA0247418 is a true and accurate copy of a picture taken by William Laing Sr., an agent of the State of Georgia. Mr. Laing has signed an affidavit stating that he took this picture on August 24, 2016 in Jackson County, Florida. Based on my experience, I can see that this photograph depicts an irrigation system irrigating a road.

- GX-898 at GA0247413 is a true and accurate copy of a picture taken by William Laing Sr., an agent of the State of Georgia. Mr. Laing has signed an affidavit stating that he took this picture on August 23, 2016 in Jackson County, Florida. Based on my experience, I can see that this photograph depicts an irrigation system irrigating a wooded area.

- GX-898 at GA0247416 is a true and accurate copy of a picture taken by William Laing Sr., an agent of the State of Georgia. Mr. Laing has signed an affidavit stating that he took this picture on August 23, 2016 in Jackson County, Florida. Based on my experience, I can see that this photograph depicts an irrigation system irrigating a wooded area.

Masters Demo. 13. End Gun Irrigating a Road in ACF Florida

Source: GX-898 at GA0247411

Masters Demo. 14. End Gun Irrigating a Road and Cars in ACF Florida

Source: GX-898 at GA024714

Masters Demo. 15. End Gun Irrigating a Road and Cars in ACF Florida

Source: GX-898 at GA024715

Masters Demo. 16. End Gun Irrigating a Road in ACF Florida

Source: GX-898 at GA024718

Masters Demo. 17. End Gun Irrigating a Wooded Area in ACF Florida

Source: GX-898 at GA024713

Masters Demo. 18. End Gun Irrigating a Wooded Area in ACF Florida

Source: GX-898 at GA024716

C. Georgia's Mobile Irrigation Lab Program Helped Farmers Improve Center Pivot Uniformity

74. As a district supervisor for the Lower Chattahoochee Soil & Water Conservation District, I work closely with the officials of the State of Georgia that manage the Mobile Irrigation Lab program.

75. Georgia has helped farmers improve their irrigation system efficiency through the Mobile Irrigation Lab, which is provided at no cost to farmers. As part of that program, Georgia Soil and Water visits farmers and evaluates the uniformity of their center pivot systems. Because center pivot systems irrigate in a circle, nozzles near the end of the pivot cover a larger area of the field and must apply more water than nozzles closer to the center of the pivot. The Mobile Irrigation Lab analysis helped farmers determine whether their center pivot was applying water uniformly over the field and showed farmers how much water they could save by improving the uniformity of their pivots. For the sprinklers, technicians work to improve uniformity of water distribution, which leads to higher efficiency. For the end-guns, technicians sometimes install end-gun shut-off devices that stop the gun from operating in certain portions of the field or over non-cropped areas.

D. Georgia Promotes Irrigation Scheduling

76. I am also aware that Georgia promotes irrigation scheduling as a management tool for agricultural water use. Irrigation scheduling entails farmers tailoring the amount of irrigation applied at any particular time to the specific needs of the crop based on recent and forecasted precipitation, the amount of soil moisture, and the stage of the plant's lifecycle. There are several irrigation scheduling tools, such as irrigation apps, available to help farmers. I am anecdotally aware of many more farmers using some type of irrigation scheduling tools in the past few years. One example of such a tool is the Irrigator Pro program, which helps farmers use irrigation scheduling for a variety of crops. The USDA Peanut Research Laboratory developed the Irrigator Pro program, and I became aware of it and supported its development during my tenure with USDA. On behalf of Georgia Soil and Water, I coauthored an application for and secured a USDA grant for $750,000 to encourage farmers to use Irrigator Pro.

E. Education, Outreach, & Technology Transfer to Farmers

77. Beginning in 2010, the Center secured competitive grants from the USDA, the bulk of which was used to promote on-farm water conservation through the use of new technologies. Some of these projects were specifically targeted to "historically underserved producers," which is a defined term by the USDA referring to socially disadvantaged or limited resource farmers. These farmers are often late adopters of new technologies. The Center used these funds from the USDA to promote (and educate farmers about) a number of agricultural management practices, including irrigation scheduling, remote soil monitoring, farm conservation planning, and the use of telemetry equipment for efficient irrigation management.

78. The Center installed over a dozen demonstration sites on farms around the state. At these sites, the Center held "field days" in which farmers could visit the site, observe the technologies, and discuss the irrigation conservation measures with experts and cooperating farmers who had already adopted these technologies. The Center also held multi-day workshops where experts taught farmers how to use these technologies on their own farms. Over the course of these projects, the Center directly reached hundreds of farmers who attended the field days and workshops. The Center also funded three full-time field personnel to assist in educating farmers on the adoption and implementation of water conservation technologies, including those farmers who may not have been able to attend the field days and workshops. These field personnel also helped farmers complete farm conservation plans, a large component of which included water management practices.