Arkansas Rice Federation
1020 West Third Street
Little Rock, AR 72201
(501) 375-1100

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To: Arkansas Natural Resources Commission
From: Arkansas Rice Farmers
Re: ANRC Water Plan
Date: 10/24/2014

Contents:

Arkansas Rice Federation
1020 West Third Street
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October 24, 2014

Arkansas Natural Resources Commission
101 East Capitol
Suite 350
Little Rock, AR 72201

RE: State Water Plan Comments

As you know, the rice industry is an important economic engine of the state. Arkansas grows rice on approximately 1.3 million acres each year. Rice is the state's second highest value commodity and the top agricultural export. Arkansas rice farmers and millers contribute more than $6 billion to the state's economy annually and account for over 25,000 jobs, which are crucial to rural communities. Our membership is composed of Arkansas rice farmers, producers, millers and merchants. The comments and proposals submitted by the Arkansas Rice Farmers, which support the continued availability of water through water development projects in order to support the rice industry in Arkansas, benefit the public interest of the entire state.

We express our appreciation for the efforts undertaken by the ANRC to provide a new water plan reflecting the many changes that have taken place since the 1990 water plan. Arkansas Rice Farmers understand the importance of efficient irrigation management practices for future generations. Developing a plan that takes into consideration all stakeholders is important in keeping Arkansas as a leader in rice production and conservation. We provide the following comments to encourage the ANRC to produce a plan that keeps Arkansas Rice as an integral component of Arkansas' economy while preparing for a future that demands responsible and practical use of water.

Thank you for the opportunity to provide feedback and comments throughout the development of the water plan. Please contact us if you have additional questions or if we can be of further assistance.

Sincerely,

Dow Brantley
Chairman
Arkansas Rice Farmers

Comments of the Arkansas Rice Federation
On the Arkansas Water Plan Update
June 30, 2014 Draft Executive Summary

October 24, 2014

ANRC Water Plan Background

Under Arkansas state law, the Arkansas Natural Resources Commission (ANRC) is responsible for preparing and periodically updating a statewide water resource-planning document commonly referred to as the Arkansas Water Plan (Water Plan). Under the Water Plan, the ANRC is charged with creating and updating a comprehensive master program to serve as the primary water policy document for the development and management of the state's water resources through water development projects. The ANRC's preparation of the Water Plan must be done with regard to the public interest of the entire state, and the Water Plan must be directed at protecting the water resources of the state from unwarranted encroachment by other states and the United States. State sponsored water development projects must be approved by the ANRC in compliance with the Water Plan. Within the limits of this grant of authority from the Legislature, all state agencies, commissions and political subdivisions must take the Water Plan into consideration to the extent that the discharge of their duties may affect the Water Plan. Ark. Code Ann. §15-22-503.

The first Arkansas Water Plan was published in 1975. The previous update of the Water Plan was completed in 1990. In 2012, ANRC initiated an update of the 1990 Water Plan to be completed in 2014. The process for updating the Water Plan has involved several major steps including the quantification of current and future water demand, assessment of surface and groundwater availability, gap analysis of demand and availability, and development of recommendations to address current and future water resource shortfalls. During the water plan update process, projected water needs were evaluated from 2010 through the year 2050 for all of our state's major water demand sectors. Estimates of available water supplies were also compiled incorporating needs to protect fish and wildlife.

Five water resources planning regions were identified as a framework to quantify and compare demands to available water supply; North, West Central, East, South Central, and Southwest. The overall purpose of the Planning Regions is to group areas of the state with shared resources and similar economic, social, and institutional characteristics. Each planning region represents multiple water demand sectors which include agriculture irrigation, agriculture livestock/poultry/aquaculture, conservation districts, county governments, fish and wildlife, industry, municipal governments, navigation, public water/wastewater providers, recreation, and thermoelectric utilities.

Water Plan Overview Statement: Arkansas Rice Comments to Executive Summary

The Data

The data gathered and used to support the development of the current draft Water Plan should include caveat language as to the data's accuracy and the purposes for which the data should be utilized. The caveat language should point out that this data was used in producing the supply and demand forecasting contained in the Water Plan and should explain the limitations of the methodology and data used and specify the degree of uncertainty attributable both to the data used and to the conclusions reached. The caveat language should point out all assumptions taken into account when formulating the forecast. If the caveat language is not included, and there is not specific language stating that the data contains flaws or explaining the limitations of the methodology, then the data and conclusions in the Water Plan could be misunderstood and could lead to harmful or unnecessary laws and regulations. These unwarranted or unnecessary laws could lead to a number of unintended consequences. We share the concerns expressed over the data collection and forecasting methods in the University of Arkansas' Report (An Evaluation of the Water Demand Forecast Report for the Arkansas Water Plan) which is attached hereto and incorporated into these comments by reference.

Executive Summary Development

Please confirm whether and how the Executive Summary dated June 30, 2014, becomes the final Arkansas Water Plan adopted by ANRC. The title of the report is Executive Summary. A summary of what? Will ANRC develop additional reports for each of the five regions? If so, will these region reports become part of the water plan? The stakeholder process for the Water Plan update has generated many supporting documents and proposed recommendations. The ANRC should clearly delineate which of those recommendations become part of the Water Plan.

The recommendations that ultimately become the Water Plan, whether contained in the Executive Summary or elsewhere, must demonstrate due regard for the public interest of the entire state; consequently, to the extent that any of the proposed recommendations developed during the stakeholder process do not satisfy this requirement, or if the record does not adequately demonstrate this requirement, such recommendations should not be adopted into the Water Plan itself.

Finally, the final Water Plan and its supporting record should demonstrate reasoned consideration of each element of the Plan or recommendation adopted by the ANRC, and not be merely a compilation of proposed recommendations by workgroup members or other interested persons. Under the process followed by the ANRC and its consultants, the Water Plan meetings have identified hundreds of issues and recommendations related to the five water demand sectors in the state. Consideration, prioritization and adoption of these issues and recommendations to date has been through a stakeholder voting process that allocates a limited number of votes to parties, organizations and interests that have been granted formal status as "stakeholders." While this process may serve to inform the ANRC in updating the Water Plan, this process should not take the place of reasoned consideration and judgment by the ANRC as to which recommendations are to be formally adopted as the updated

Water Plan, consistent with the Water Plan's purpose as a comprehensive plan for water development projects in the state. Because the Water Plan must be taken into account by all state agencies, a proliferation of issues and recommendations in the Water Plan would make the end product unwieldy and unusable, especially as to recommendations that do not clearly and directly relate to a comprehensive plan for water development projects.

A more practical approach would be to clearly separate the final Water Plan findings and recommendations from the efforts of the stakeholder process. The final Water Plan would serve as the official and final plan containing those limited findings and recommendations that ANRC has actually and affirmatively determined relate to a comprehensive plan for water development projects and to be in the "public interest of the entire state," based on record evidence of scientific, economic, cultural, historical, legal and other proper factors supporting ANRC's decision. A separate document, e.g., a water plan stakeholder process report, could serve as a repository and future resource for all issues and recommendations identified by stakeholders or the public, consistent with the ANRC's authority under Ark. Code Ann. §15-22-220.

Property Rights

In the issue described as "water levels in aquifers are declining", it says ANRC will seek authority to **condemn** sites for meter installation. The use of condemnation authority for water meters is way out of line. It is contrary to the cooperative approach and the recommendations farmers have brought to this process. We strongly oppose any use of condemnation authority for water meters, and encourage a voluntary approach.

Conjunctive Water Management

The Water Plan should support water development projects that encourage surface water usage from:

1) large irrigation projects from existing waterways (Ex: Bayou Meto Irrigation District)

2) on-farm collection systems

3) existing water reservoirs

4) storage and distribution systems.

Excess Surface Water

We believe that because of the water development projects mentioned above, and in order to fulfill the purpose of such projects as well as other similar water development projects, the Water Plan should recommend that additional surface water be used for agriculture-related purposes by increasing the level of surface water available to non-riparian users. The Water Plan should not attempt to impose new or modified measurement methods for stream flows and water allotments without strong scientific and other technical facts, data, information and input from lawmakers and the public, adequate and appropriate consideration of the real and quantifiable costs and benefits associated with implementation of any such methodology, and a

demonstration that any such new or modified methodology would result in significant, quantifiable net economic benefits.

Regarding the definition of excess water, the farm industry has been consistent in this process in recommending that the definition of excess water be raised from its current 25% limit. ANRC's 1990 Water Plan recommends that the limit be raised to 75%; however, the June 2014 Draft Executive Summary seems to remove the current 25% limit in favor of an undefined "study period." This potentially puts the definition and use of excess water on hold—no one will know what threshold will apply. Such uncertainty could effectively block development of any regional surface water project. The Rice Federation affirmatively and strongly supports a recommendation to increase the definition of excess water to at least 75% in order to effectuate the purpose and implementation of water development projects under the Water Plan.

In order to clarify the ambiguous language found in the 2014 Draft Executive Summary regarding the definition of excess surface water, the Rice Federation offers the following edit.

Remove the following language found in page 13:

> *"Remove the 25 percent limitation for estimating excess water available for nonriparian transfer and conduct scientific studies …"*

Replace with the following language:

> *"Increase the limitation from 25 percent to 75 percent for estimating excess water available for nonriparian transfer. Conduct scientific studies …"*

Incentivizing Water Conservation/Tax Credits

The Water Plan should highlight the positive outcomes of existing incentives for new technologies, land improvements, irrigation systems, and related best management practices as water development projects that promote water conservation. Given the success of the incentive programs already in place, we think it is appropriate that the Water Plan should recommend expanding them to further enhance conservation efforts by farmers.

Regarding tax credits, the Draft Executive Summary says "evaluate the effectiveness of existing tax credits". We already know the existing tax credits are grossly inadequate. Please do not waste time studying what we all know is inadequate. It is the entire state's best interest to get a fast broad start on conservation measures and best practices being identified. The tax credits on conservation measures need to i) be a bigger percentage of the cost, ii) have higher annual limits, and iii) allow a longer period over which to claim the credit. Add a sunset to these aggressive tax credits to encourage people to get on board quickly.

Water Infrastructure

The Water Plan should recommend additional funding for regional surface water systems that will divert surface water for irrigation use to farmers. Examples include the previously mentioned Bayou Meto Irrigation Project and the Grand Prairie Project. The Water Plan should also voice its support of water infrastructure projects that will aid agricultural water management.

Additionally, the Draft Executive Summary recognizes one funding source through ANRC's bonding program. Other sources of funding may be available, so a recommendation should encourage seeking out other funding options including state, federal and local funding and financing options.

Education

The Water Plan should recommend funding for education programs that will demonstrate the benefits of water conservation systems and technologies for agriculture to farmers.

*All comments herein are directed at the Water Plan Update Draft Executive Summary dated June 30, 2014, and were raised during the public meetings held during September 2014.

An Evaluation of the Water Demand Forecast Report for the Arkansas Water Plan

Prepared for the Arkansas Natural Resources Commission

May 22th, 2014

C. G. Henry and K. B. Watkins

Rice Research and Extension Center, University of Arkansas, Division of Agriculture

Collaborators: Jarrod Hardke, Jason Kelley, Mike Daniels, David Carwell, Stan Baker, Ron Baker, Mike Andrews, Ray Benson, Jason Osborn, Herb Ginn, Allen Davis, Branon Thiesse and Eric Grant, Michael Paskewitz, Brent Griffin, Van Banks, Anthony Whittington, Wes Kirkpatrick, and Randy Chlapecka.

Preface

As requested, the University of Arkansas, Division of Agriculture has reviewed the Water Demand Forecast Report (referred to as the "demand report" in this document) developed by CDM Smith, the consultants for the Arkansas water planning process. We have specifically reviewed the technical analysis used to predict future irrigated acres in Arkansas counties and also irrigation water use by crop derived from the Arkansas Water User Data Base (WUDB). We offer some suggestions to improve the current or future planning efforts. In the big picture, the issues we investigated regarding the demand report with water use estimates greatly impacts the overall projected water demand for irrigated agriculture. While there may be concerns over commodity acreage and irrigated development in certain counties, we encourage future efforts to be focused on obtaining better water use estimates as this has the most influence on the total projected future water demand.

It is critical to get a good estimate of water use, since should a sustainable yield be developed for the aquifers, a gross overestimate of water use will result in conservation targets and water development needs that are much more than necessary for agricultural users. Additionally it could create frustration with farmers as reductions to become sustainable will be higher than really necessary to reduce aquifer overdrafts. As such, we recommend a review of the WUDB system and the data that are collected so that it could better serve the citizens of Arkansas.

We also investigated projections of irrigation development in three counties with large projected increases. We found that the large increase in the projections may be attributable to crop mix

changes rather than across the board increases as projected in the demand report. It appears that the driver for irrigation development is coming from the conversion of other land uses to irrigated soybeans, as opposed to each crop increasing at respective rates. This has resulted in a large projected increase in soybean irrigation development that may not be appropriately applied to all crops equally.

We have organized this report into two primary sections, the first an analysis of the water use data used in the demand report and the second section on the crop acre estimates used to project future irrigable land development in Arkansas. We contacted and collaborated with CDM Smith, specifically Kelly Collins and other staff, Jaysson Funkhouser and other professionals at the Arkansas United States Geological Survey (USGS), and Edward Swain, at the Arkansas Natural Resource Commission to gather necessary information for this report.

Analysis of Water Use Data

We investigated water use in the report by querying the online water use database, reviewing the demand report and the accompanying appendix, and by interviewing USGS scientists in charge of administering the WUDB. We accessed many online reports at the USGS website. We accessed United States Department of Agriculture National Agricultural Statistics Service (USDA NASS) online resources for County crop acreage data. Also, we requested additional information from CDM Smith, primarily GIS maps and tabular water use data.

The Arkansas Water User DataBase (WUDB)

In our review of the water use data, we have focused our analysis on rice, where we have some other data aside from the WUDB to review the demand report results. We interviewed scientists from the USGS who had intimate knowledge of the WUDB. The water use is reported in publications and is available online. We made use of the online system. We felt that the USGS have done an excellent job administering the WUDB system, and they have done a good job given the limited resources available.

It is our understanding of the WUDB system that for agriculture, users voluntarily report their water use, either by some measurement method or just an estimate they provide themselves. We suspect that in some counties the people who administer the entry of data into the database may provide some assistance to the user when they are uncertain of their water use. We have not substantiated this. We could not find any **current** publicly available information on how the WUDB is administered, and it is unknown if there are differences among counties on what assumptions or assistance is provided.

The only information we located about the WUDB is a 1990 report written by USGS (Baker, 1990). In this report it describes the history of the reporting legislation and the history of water use estimates dating back to 1960. It describes the forms and procedures used to conduct the WUDB. It compared the previous to legislation estimating procedures (aggregating estimates)

with the reported water use between 1985-1988. We found several parallels and recommendations in this report that would still be applicable in the present-day WUDB data we have evaluated.

- Baker (1990) found discrepancies between Ag Statistic Service data (today National Ag Statistics Service) and reported water use acreage data. She noted that differences in acreage reported to the Arkansas Soil and Water Conservation Commission (ASWCC aka WUDB) and from the Arkansas Statistics Service, (ASS, aka NASS) as accounting for most of the difference between reported water-use amounts and the USGS aggregated estimates.
- Variation in water application rates for major crops was found in the reported data, some counties reported a wide range of application rates, while some counties reported nearly the same application rate -noting that in some cases almost everyone in the County reported the same application rate for some crops.
- In 1985, Arkansas CountyCounty reported about 50% more water use than the aggregate estimate, while Craighead, Cross, Lonoke, Mississippi and Monroe Counties reported good agreement with the aggregate estimate.
- Several recommendations were made in the report including better training of personnel, improved quality assurance, and different reporting methods and procedures.

Reviewing this publication would be a worthwhile refresher for anyone making recommendations for agriculture in the 2014 Arkansas Water Plan. It can be found at this URL, http://pubs.er.usgs.gov/publication/wri904177 .

It is understood that USGS does quality control checking of water use with what is reported. It is unknown for how long this has taken place, to what degree this has been done, and how many changes have been made to the WUDB since this report was published. We are confident that this information exists; we just did not research this any further.

Recommendation: A more involved review of how the WUDB is administered and documented is warranted in our opinion. It would be useful to have this information available on the website.

Recommendation: Those involved in suggesting changes to the WUDB should review the Baker (1990) report. We also recommend commissioning a more current report and analysis of the WUDB data for agriculture.

Water Use Data Currently Available

There is very little irrigation water use data available for the southern region. We summarized water use data from the water plan, the YMD (Yazoo Mississippi Delta – Joint Water Management District) in Mississippi, and data from the University of Arkansas, Division of Agriculture and the results are summarized in Table 1.

The demand report estimated water use from the users and summarized it in the report. The YMD district in the Mississippi Delta has measured water use annually since 2002. The district measures about 140 sites per year, by tracking electric meter usage and spot measurements of flow rate. They report the data based on crop type and irrigation system. It should be noted that the flow data is a one-time spot measurement (although some years they measure monthly).

The UADA Rice Research Verification Program (RRVP) has tracked water use in rice intermittently since 1985, and recent historical data exists. Also we found expert estimated water use reported in a publication from 1998. Data in Table 1 are presented as a frame of reference, to compare and contrast what little data exists on the subject that we could find for Arkansas.

Table 1. Water Use in Crop as reported by AR Water Plan, MS YMD, and UADA.

Ac-in/ac	Rice	Soybeans	Cotton	Corn
Arkansas Water Plan Demand Report (2000-2010)	37.0 (Range13.5-47.6)	16.3 (Range 1.0-32.2)	15.3 (Range 9.8-30.2)	18.1 (Range 2.6-30.6)
YMD Irrigation District, Mississippi, (2002-2012)	36.0 (Range 9.6-72, n=284)	9.6 (Range 1.2-27.1, n=388)	6.0 (Range 1.2-20.4, n=170)	10.8 (Range 1.2-27.6, n=213)
UADA Rice Research Verification Program (2003-2012)	30 (Range 10-74, n=105)			
Agriculture Water Management in the Mississippi Delta Region of Arkansas (1998)*	30	9	9	10
Eastern Arkansas Water Conservation Project (1984-1987)	42.1 (Range 26.3-82.0, n=20)			

*Irrigation depth estimates obtained from a panel of experts, no data

Geographic Water Use Appears Unreasonable in Some Counties

To better understand the increase in crop acreage we asked CDM Smith to develop GIS maps of "Irrigation Application Rate by County" for rice, soybeans, corn, and cotton. They were very helpful in developing these resources and responded timely. These maps are included in the appendix of this document. We used these maps to help us better understand the geographic distribution of the irrigation water use presented in the demand report. What is evident in the maps are clear geographic differences in water use reported by counties. We used these maps to evaluate if reported water use was reasonable compared to neighboring counties.

From the maps (see appendix) it is clear that there are some geographical differences in water use reported by users. For example, Arkansas County is reported to use 47.6 ac-in/ac of water while the neighboring counties of Prairie (29.7), Monroe (36.3), Phillips (35.7), Desha (37.2), Jefferson (31.2) and Lonoke (36.8) report lower water use. The same is true of St. Francis

County. Greene County reports 28.8 ac-in/ac, much lower than any neighboring counties. Pope, Conway, and Faulkner counties all report usage rates in the high 20's while neighboring counties of Yell, Perry and Pulaski report usage in the low 30's for rice.

For soybeans, Cross County reports 25.1 inches while the neighboring County of Woodruff County reports 11 inches. Mississippi County reports 10.2 inches while neighboring Poinsett County reports more than double that usage at 22.3 inches.

For cotton, Arkansas, Jefferson, and Lincoln counties report using 20 inches of water, and Clay County about 30 inches. These are just a few examples, there will be soil type differences and climatic differences for counties, and we recognize this. However, there appears to be a *considerable* amount of variation in water use between counties for the same crops, more than one would consider to be reasonable.

Water use by year does not seem reasonable in some counties.

We also looked at the historical reported water use data for a few select counties. Specifically we looked at St. Francis, Desha, Mississippi, Prairie, Poinsett, Clay and Arkansas counties, for cotton, rice, soybeans and corn water use. We used water use data reported from the WUDB website.

For example in Clay County Table 2 for soybeans, the water use in 2000 through 2005 was between 12 and 15 ac-in/ac. Then in 2006 though 2010 the water use increases to between 33 and 59 inches of water. It is highly unlikely that the use reported between 2006 and 2010 is this high, and it is difficult to fathom this much water being applied to soybeans. Additionally the average for the period 2000 to 2010 is 32 ac-in/ac of water, this value itself is suspect and unreasonable and without using the 2000-2006 water use the average would be appreciably higher. A similar trend exists for cotton and corn in this County. It is difficult to imagine increasing water use from 12 ac-in/ac in 2000 for a drought tolerant crop such as cotton to 47 ac-in/ac by 2010. Rice is less dynamic, usage is relatively flat between 2000 and 2006 and then seems to arbitrarily increase in 2007 to between 47 and 49 ac-in/ac and then in 2010, rice water use is 29.7 ac-in/ac. The reported water use of 47 to 49 ac-in/ac seems unreasonable to us, even for rice. From our memory, 2010 was a dry year, where water use was reported to be 29.69 ac-in/ac yet in 2009 a high rainfall year, the water use was reported water to be 47.88 ac-in/ac. Most who are familiar with growing crops those years, would recognize this inconsistency. Finally, Clay County reports using 30 ac-in/ac of water on wheat in July and August, again which does not seem reasonable (this can be found in Appendix I of the demand report, in table labeled "Crop Application Rates by Crop, County, and Month").

Table 2. Water Use and Acres for Clay County from WUDB

Year	Rice Acres	Rice Water Use (Acre-Feet)	Rice Water Use Per Acre (Acre-Inches/Ac)
2010	71,293	176,414	29.69
2009	68,211	272,135	47.88
2008	60,116	239,418	47.79
2007	61,989	258,179	49.98
2006	71,334	213,736	35.96
2005	76,090	226,279	35.69
2004	69,124	203,885	35.39
2003	65,230	195,068	35.89
2002	65,610	196,608	35.96
2001	77,138	230,796	35.90
2000	130,733	398,878	36.61
Average	74,261	237,399	***38.79***
Year	**Soybean Acres**	**Soybean Water Use (Acre-Feet)**	**Soybean Water Use Per Acre (Acre-Inches)**
2010	63,083	178,973	34.05
2009	75,493	372,533	59.22
2008	74,379	368,850	59.51
2007	70,996	351,794	59.46
2006	73,307	219,381	35.91
2005	78,347	215,496	33.01
2004	72,743	90,338	14.90
2003	72,064	89,582	14.92
2002	76,925	96,681	15.08
2001	74,244	97,143	15.70
2000	149,446	151,115	12.13
Average	80,093	202,899	***32.17***
Year	Corn Acres	Corn Water Use (Acre-Feet)	***Corn Water Use Per Acre (Acre-Inches)***
2010	17,628	44,798	***30.50***
2009	24,907	99,408	***47.89***
2008	27,063	108,121	***47.94***
2007	32,327	128,516	***47.71***
2006	19,070	38,017	***23.92***
2005	18,773	37,572	***24.02***
2004	19,026	37,452	***23.62***

2003	17,488	34,774	***23.86***
2002	12,588	25,256	***24.08***
2001	12,880	25,510	***23.77***
2000	27,349	42,669	***18.72***
Average	20,827	56,554	***30.55***
Year	Cotton Acres	Cotton Water Use (Acre-Feet)	***Cotton Water Use Per Acre (Acre-Inches)***
2010	22,887	60,748	***31.85***
2009	23,648	93,796	***47.60***
2008	22,800	90,386	***47.57***
2007	26,768	105,926	***47.49***
2006	31,372	64,833	***24.80***
2005	24,581	49,374	***24.10***
2004	18,657	36,014	***23.16***
2003	20,507	40,776	***23.86***
2002	20,105	40,120	***23.95***
2001	22,546	44,611	***23.74***
2000	30,545	31,231	***12.27***
Average	24,038	59,801	***30.04***

Desha County reports using 86.8 ac-in/ac of irrigation on sorghum, another drought tolerant crop, this is also unreasonable. We did not look at all of the data, but some adjustment or data checking should be done to ensure that what is reported is reasonable for the crop and County. While a small amount of acreage in the situation for sorghum in Desha County, it does impact the County water demand because the value is so extreme. In the Desha County situation, if we blindly accepted the reported water use as a baseline, the water demand for grain sorghum would be 1,322 acres times 86 ac-in/ac =113,692 ac-in. If true water demand was closer to 10-20 ac-in/ac (Cooperative Extension Service, 1997) for grain sorghum, there is enough excess water demand to irrigate 5,352 acres of soybeans (using the demand reports reported demand estimate of 16.3 ac-in/ac for soybeans) The total expected increase in irrigable land in Desha County is 8,668 acres (258,476-249,808). Just this one error in water demand for a minor crop is almost as much as the anticipated 40 year future water demand for Desha County.

Water User Reported by Grain Sorghum for Desha County

$$86.9\ {}^{acin}/_{ac}\ x\ 1322\ acres = 113{,}692\ acin\ irrigation\ water$$

Probable Water use by Grain Sorghum in Desha County in 2010

$$1322\ acres\ x\ 20ac\ {}^{in}/_{ac} = 26{,}440\ acin$$

Amount of Overestimated Water Use

$$113{,}692\ acin - 26{,}440\ acin = 87{,}252\ acin$$

Acres of Soybeans that could be irrigated with Overestimated Water Use

$$\frac{87{,}252 acin}{16.3 acin\ water\ demand\ for\ soybeans} = 5{,}352\ acres$$

Water use by year does not seem to change with seasonally expected variation.

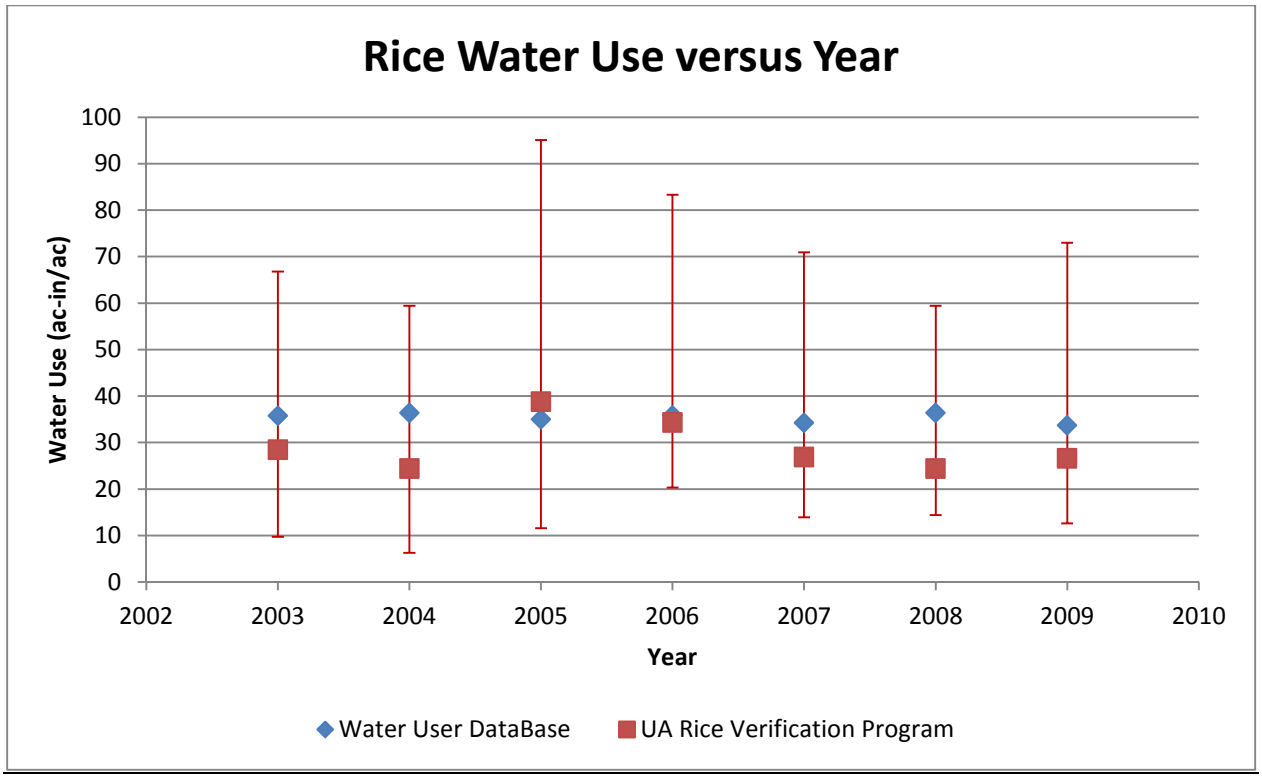
We compared the water use from the University of Arkansas Rice Research Verification Program (RRVP) to the estimates of water use from the demand report for the common years of 2003 through 2009 Figure 1. In the RRVP water use on fields is measured with portable totalizing flow meters on about half of the producer fields enrolled in the program each year. While the program measures total seasonal water use for participating rice fields the data is still a very limited dataset due to the small sample size. We plotted the water use measured from the program and compared it to the reported annual values in the WUDB. There is little variation in the WUDB water use data as can be seen in Figure 1. The range of measured water use is varies every year between farms and it varies year to year based on weather conditions, as one would expect.

When reviewing the water use data from the WUDB shown in Table 3, there is little variation from year to year in this time period, in fact for Arkansas County, the water use is about 46 inches for 2000-2002 and then right around 36 inches for 2004 to 2010 reported by the WUDB. Why the water use changes so abruptly and is so flat between years may suggest that users are reporting the same water use irrespective of the climatic conditions. Perhaps some clerical change was made in how water use was reported in 2004 or all or many users changed the value they reported based on some information. Either way, the trend in Table 3 does not appear to reflect any climatic variation in rice water use in Arkansas County.

Table 3. Water use in Arkansas County from WUDB

Arkansas County Rice Water Use Data			
Year	TOTAL ACRE FEET	**WUDB ACRES**	ACIN
2010	433,427	**149,301**	34.8
2009	392,158	**132,018**	35.6
2008	375,671	**125,998**	35.8
2007	385,729	**129,914**	35.6
2006	403,372	**136,110**	35.6
2005	444,608	**150,984**	35.3
2004	425,355	**143,549**	35.6
2003	427,740	**144,264**	35.6
2002	542,298	**139,149**	46.8
2001	581,533	**148,070**	47.1

2000	595,134	**156,328**	45.7
Average	455,184	141,426	38.50



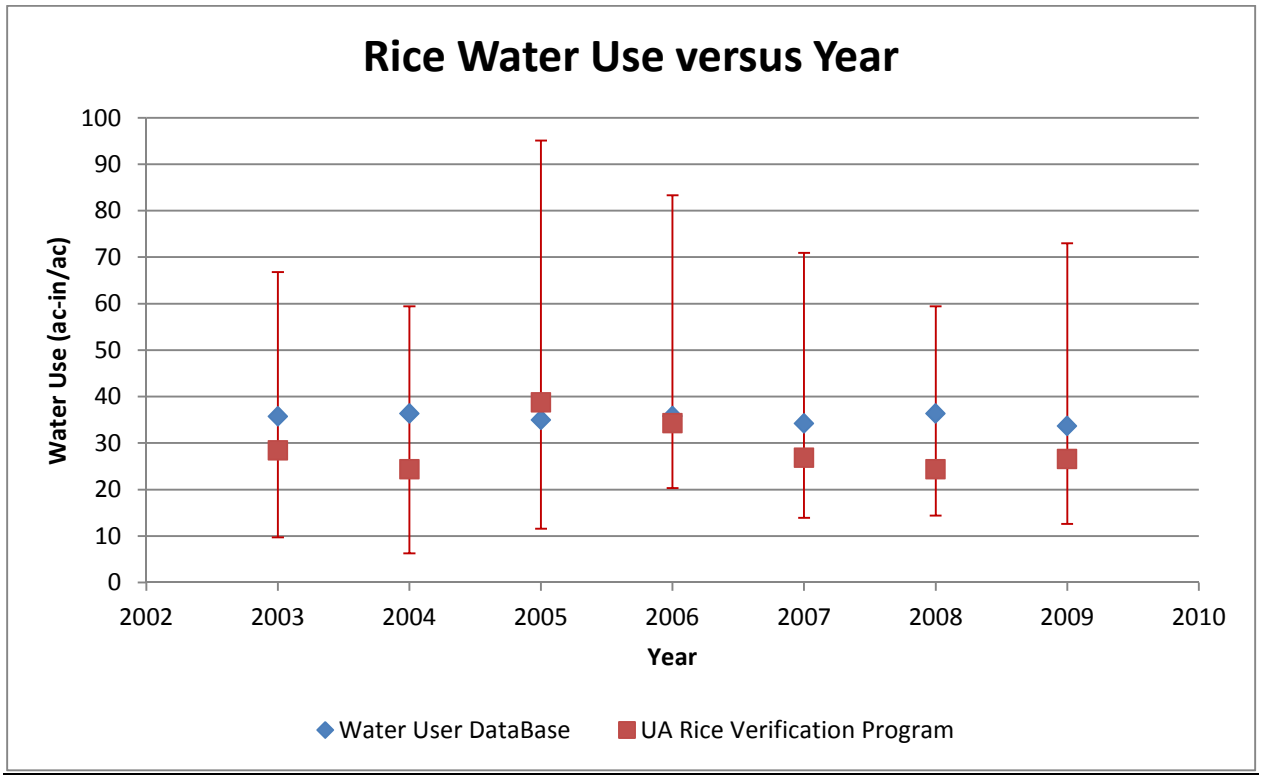


Figure 1. Comparison of Rice Water use between WUDB and RRVP. RRVP water use data varies more than WUDB.

Table 4. Irrigation water use and precipitation for rice in Arkansas by year (2003 – 2012) from RRVP.

Year	n	Annual Average Irrigation Water Use in mm (inches)	Annual Irrigation Water Use Range in mm (inches)	Growing Season Average Precipitation in mm (inches)	Growing Season Average Precipitation Range in mm (inches)	Total Water - Irrigation plus Precipitation in mm (inches)
2003	10	724 (28.5)	478-973 (18.8-38.3)	333 (13.1)	173-569 (6.8-22.4)	1057 (41.6)
2004	10	621 (24.4)	460-889 (18.1-35.0)	424 (16.7)	297-622 (11.7-24.5)	1045 (41.1)
2005	15	985 (38.8)	690-1431 (27.2-56.3)	250 (9.8)	79-335 (3.1-13.2)	1235 (48.6)
2006	11	871 (34.3)	356-1245 (14.0-49.0)	296 (11.6)	152-457 (6.0-18.0)	1842 (45.9)
2007	9	683 (26.9)	330-1118 (13.0-44.0)	294 (11.6)	203-356 (8.0-14.0)	1366 (38.5)
2008	12	620 (24.4)	254-889 (10.0-35.0)	343 (13.5)	102-711 (4.0-28.0)	1240 (37.9)
2009	13	677 (26.6)	356-1179 (14.0-46.4)	666 (26.2)	356-991 (14.0-39.0)	1354 (52.8)
2010	9	955 (37.6)	500-1880 (19.7-74.0)	307 (12.1)	107-423 (4.2-16.7)	1910 (49.7)
2011	12	687 (27.1)	508-965 (20.0-38.0)	464 (18.3)	234-655 (9.2-25.8)	1374 (45.4)
2012	8	764 (30.1)	445-1151 (17.5-45.3)	289 (11.4)	168-465 (6.6-18.3)	1528 (41.5)
Average Standard deviation		763 (30.0) 280 (11.0)		373 (14.7) 175 (6.9)		

*Average and standard deviation values are for the entire dataset

Irrigated acres are different in some counties between data sources

The demand report calculated water use per crop as the 10-year average ratio of total water use by crop in acre feet divided by total crop acres, with both numbers obtained from the WUDB. For two counties we reviewed, Arkansas and St. Francis counties, water use for rice reported in the demand report does not match that calculated from the WUDB. For Arkansas County, the water use for rice is reported to be 47.6 inches in the demand report. However, water use for rice in Arkansas County based on the WUDB is 38.5 acre inches. It appears that the demand report divided total water use by NASS acres instead of WUDB acres to calculate rice water use in Arkansas County. Ten-year average WUDB acres for rice were 141,426 acres, while 10-year average NASS acres for rice were 114,373 acres in Arkansas County.

Table 5. Water Use in Arkansas County from WUDB and Demand Report

Arkansas County Rice Water Use Data					
Year	TOTAL ACRE FEET	**WUDB ACRES**	ACIN	**NASS ACRES**	ACIN
2010	433,427	**149,301**	34.8	**128,000**	40.6
2009	392,158	**132,018**	35.6	**116,500**	40.4
2008	375,671	**125,998**	35.8	**103,000**	43.8
2007	385,729	**129,914**	35.6	**106,000**	43.7
2006	403,372	**136,110**	35.6	**111,000**	43.6
2005	444,608	**150,984**	35.3	**121,700**	43.8
2004	425,355	**143,549**	35.6	**118,000**	43.3
2003	427,740	**144,264**	35.6	**111,800**	45.9
2002	542,298	**139,149**	46.8	**114,100**	57.0
2001	581,533	**148,070**	47.1	**117,000**	59.6
2000	595,134	**156,328**	45.7	**111,000**	64.3
Average	455,184	141,426	38.50	**114,373**	**47.83**

Since NASS rice acres were smaller than WUDB acres for Arkansas County, the resulting amount of water use on rice was larger for Arkansas County than it was reported by users (47.6 ac-in/ac in the demand report versus 38.5 ac-in/ac using WUDB data). This makes the application rate used for Arkansas County rice by the demand report unreasonably high. The same was done for rice water use in St. Francis County. We think this may simply have been a calculation or procedural error in which NASS acres were used in place of WUDB acres by accident. The discrepancy of using NASS rather than WUDB acres in the crop water use calculations appears to be solely due to rice and soybeans, as only these two crops use NASS acres (called County Agricultural Production Survey data in the demand report) in place of WUDB acres in the acreage projections for over time. Furthermore, we found the discrepancy only Arkansas and St. Francis Counties. All other counties we looked at used WUDB acres regardless of crop in the crop water use calculations.

One author recalls lengthy discussions concerning the acre estimates procedure used in the analysis by the technical working group. The author recalled the group felt that the WUDB acre estimates to be less reliable and accurate than the USDA or NASS crop acre estimates. It is our understanding that it was agreed by the technical working group that for projections NASS acres should be used and we concur with this decision.

Recommendation: The crop water use estimate will be considerably different depending on the total acre estimates used (WUDB or NASS). Most of the counties we looked at used WUDB acres in the crop water use estimates. We only noted the use of NASS acres in Arkansas and St. Francis counties. However, there may be more instances where NASS acres may have inadvertently been used in place of WUDB acres in the crop water use calculations or it was

simply the procedure that was used. We recommend that the number of acres used as the denominator in the rice and soybean crop water use calculations be checked for all counties for consistency. WUDB acres should be used as the denominator rather than NASS acres when calculating water use by crop for all crops within a particular county. Making this change should make the water use for these two counties more reasonable (although for St. Francis County the value still seems too high for rice). This should result in the total water demand for each county using the application rate times NASS acres (rice and soybeans). We don't think anyone from the technical working group considered the different calculations methods as being an issue. The point of this recommendation is that this discrepancy in acre estimates can create some real uncertainty as to total water demand for a county.

Estimating Water Use for Rice

The RRVP data can be used to generate a measured water use estimate for rice for the purpose of comparing the user reported estimate from the demand report (37 ac-in/ac). We can derive a value based on the measured values of 32 ac-in/ac for contour and precision graded fields and 19 ac-in/ac for zero grade fields(Table 2). Additionally in 2009 about 7% of the rice acreage in Arkansas was zero grade and the remaining was in precision and contour levee systems, according to a survey of county agents (Wilson et al., 2010). Using these estimates of water use and acreage we can calculate a weighted average water use estimate for rice, for Arkansas (32 ac-in/ac*0.93+19 ac-in/ac*0.07=31 ac-in/ac) of 31 ac-in/ac**.** This estimate is less than the average value derived from the WUDB of 37 ac-in/ac, from the demand report. We believe that a more likely average statewide value for water use in rice is around **31 ac-in/ac, based on the data from the RRVP**.

However, the demand report estimate of 37 ac-in/ac for rice is nearly identical to the estimate of 36 ac-in/ac from the YMD for rice in Mississippi. Using these two sources of limited information where water use was measured, one can conclude that water use in rice is probably within the 31 ac-in/ac to 36 ac-in/ac range, with the caveat that in some counties the water use will be higher and some lower, due to soil type, water availability, irrigation system types, seasonal variation due to climatic conditions, etc. However, it is difficult to be confident about a good estimate for rice water use in Arkansas using these limited data sets.

Table 6. Irrigation Water Use for Rice in Arkansas by Irrigation System Type (2005 – 2012)

Irrigation System Type	n	Average Irrigation Water Use	Range	Standard Error
Contour	33	814 mm (32.1 in) [a]	406 – 1430 mm (16.0 – 56.3 in)	49.8 mm (2.0 in)
Straight Levee	39	822 mm (32.4 in) [a]	356 – 1880 mm (14.0 – 74.0 in)	44.1 mm (1.7 in)
Zero Grade	12	486 mm (19.1 in)	254 – 864 mm (10.0 – 34.0 in)	84.3 mm (3.3 in)

[a] Means within a column followed by the same letter are not significantly different at α=0.05

Recommendation: We suggest a more thorough evaluation of counties with reported water use outside of this range for an explanation and possible adjustment to improve the water demand estimate for the water plan. Expert estimates, GIS maps and other county specific information could be used to ensure estimates are reasonable.

How much does a difference of 5 ac-in/ac for rice water use really make?

The difference between 31 ac-in/ac and 36 ac-in/ac may seem trivial on the surface, but if we take the difference between these two water use estimates for rice times the total rice acres in Arkansas for 2010 of 1.78 million acres (1,780,000 ac/yr * 5 ac-in/ac / 12 in/ ft = 741,666 ac-ft or 0.742 MAF/yr) this results in a difference of about 0.742 MAF of water for 2010. The projected increase in demand for all crop irrigation from the demand report to 2050 is estimated to be 1.32 MAF/yr. A difference of 5 ac-in/ac in the water use estimate for rice represents about half of the total projected water demand increase for all irrigated crops in Arkansas. A similar scenario is true for soybeans.

Conclusion:

We believe in our research into the WUDB and other interviews, that users may not really know their actual water use. In our mind the value and quality of the data in the WUDB is very suspect and appears unreasonable in some counties and crops and we question the value and usefulness of the WUDB to make a projection on the future water demand for the state. The WUDB data does not appear to reflect climatic or seasonal expected variations, there are geographical differences that are difficult to explain, annual trends do not always seem reasonable, and some water use estimates for different crops by county appear unreasonable.

Recommendation: We recommend a more thorough examination of water use by county. In some counties the water use appears unreasonable. However we do not have hard data to really say one way or the other with a large degree of confidence what a good estimate of rice water use really is for Arkansas. We have much less data on the other commodity crops.

We do believe that a review of water use amounts is warranted. Two approaches could be considered in the short term, to make adjustments to water use estimates that appear unreasonable. In counties that appear reasonable, the water use could be left as is. However, in counties where water use for a crop seems unreasonable, a subjective adjustment could be made based on an expert estimation or one could use bordering counties average usage data.

A second and less subjective approach would be to do a crop water estimate using crop water modeling data, such as a Blaney-Criddle method, FAO methodology, or other crop water usage modeling estimation methodology and assigning an estimate of irrigation efficiency. There are also problems with this method, as there is little to no published work on irrigation efficiencies in Arkansas, so these estimates would require expert estimates. Even with conservative assumptions, this may provide more reasonable water use estimates than are currently reported. With both methods, they are just estimates and will never provide a better estimate than ones that would include more measured values.

Recommendation: In the Agricultural and Irrigation water-user registration form, water use is reported as being estimated, calculated or measured. We assumed that measured is taken to mean water use is measured with a flow meter or other device. Another approach to estimate water use, that may or may not be more useful, would be to use only measured water use reports by crop type to estimate use for each county. This water use estimate could be compared to the reported water use for each county to judge if water use for a county is reasonable or if an alternative method should be used.

One caveat to this method is that if most of the measured reported values are confining aquifers, users with these wells are not as likely to apply as much water as an alluvial user. Pumping costs are significantly higher between these aquifers, so we assume that there would be less pumped from a confining aquifer than an alluvial. Additionally the yields from confining aquifers may not be as productive as alluvial aquifers. So some professional judgment will likely be needed to interpret the results.

Another important caveat with this method is that we do not know if users are actually using meter readings to estimate water use even if they indicate this on the report. We would recommend interviewing the personnel that enter the water use data to better understand if meters are actually used for these estimates. We would also suggest interviewing entry personnel to determine what assistance is provided, and how estimated values are derived. It could be that some individuals reporting water use with meters in counties are used to derive water use estimates for others.

There may be a strong relationship between the assistance provided in the county office and what the water use estimate is for the county. We expect if one were to compare the county supplied estimate of water use for each crop, that they would be very similar to the all users reported water use estimate. For example, farmers have reported to us, that for Prairie County for rice,

that 30 ac-in/ac is used and for Arkansas County 36 ac-in/ac is used for producers that do not know what their water use is. These values are very similar to the values reported in the water plan (adjusting for the error in Arkansas county) of 29.7 ac-in/ac for Prairie County and 38.5 ac-in/ac for Arkansas County. These questions should be answered for the WUDB to be useful for future water planning purposes.

There should be a review of the purpose of the WUDB. If it is truly going to be used to understand the water needs of the state then adjustments to the current program should be made to ensure that the data being reported is reasonable and as accurate as possible so that it is useful. Such changes would be the foundation of a quality control program for the WUDB. It would be useful to have the data published in a format that can be analyzed by others more readily. Agriculture water use should be reported as ac-in/ac or ac-ft/ac rather than as Million Gallons per Day (MGD) on the website so that it can be better understood by irrigators, those that advise irrigators, and water resource professionals.

Analysis of Crop Acreage Estimates

We evaluated the acre estimates for the different crops and the analysis done in the demand report for reasonableness. We noticed that there are several counties that appear to have large increases in irrigated acres. We investigated if these crop acre increases were reasonable.

We evaluated the projected increase in irrigation development in the state from the demand report. The projected potential for increased irrigation development is the difference between the current irrigated acres as defined by the USDA 2010 Cropland Data Layer Database (CDL) and other sources and the total tillable acres reported in each county. The analysis for the demand report uses regression analysis to project a rate of increase for irrigable land development by county and per crop type. The R^2 was used to determine if there was a trend for each commodity (increase or decrease) or if it was static (no development). Acre estimation for corn was different from the other crops in that it included crop price in the regression analysis, whereas price was not used in the analysis for any of the other commodities.

To better understand the increase in crop acreage we asked CDM Smith to develop GIS maps of "Percent Change from 2010 to 2050 Irrigated Acres by County" for rice, soybeans, corn, and cotton. We used this to help better understand the geographic distribution of the projected increases outlined in the demand report. The maps made it easier to compare crops and county projected increases.

The procedure used in the demand report does not account for crop mix, so recent increases in soybean and corn acres at the expense of cotton acres could bias the trend of these crops in some counties. Not all of the estimated trend for a particular crop is attributable to increased irrigation development. Some of the trend may be attributed to acreage shifts from one crop to another, and it is likely that the technique used in the demand report shows a higher increase in irrigation

development than realistically could occur. We address this in more detail below looking at three particular counties in a section entitled "A Closer Look at the Methodology Used for Future Acreage Projections."

We had some concern that in some counties there may be physical, topographical, or water availability constraints that would preclude the ability to convert all of the tillable acres to irrigable acres. To address this concern, we conducted a survey of county Extension agents in the Delta, of counties that had a large increase in irrigated acres and ones we identified as being questionable. We only asked the agents about increased acre development in rice and soybeans, and asked the agents to consider soybeans rotated with cotton and corn. This was done to reduce the amount of information they would have to respond to and interpret. The survey and results are shown in the Appendix.

In general, the county agents did not identify any barrier to developing remaining tillable acres to irrigated acres. They generally agreed that it could be possible to expand the acreage in their counties to the amount projected in the demand report, and several indicated some resistance at the very end which would be expected. Desha County indicated some barrier to irrigation based on topography (flood and low lying areas). There are likely acres in some counties that are prone to flooding and it may not be feasible to develop these areas for irrigation.

Using the 2010 CDL data to obtain the maximum number of irrigated acres for each county we felt was sound. However, not all tillable acres can be converted to irrigation in every county. For example, several northeastern counties have Crowley's Ridge (Clay, Greene, Craighead, Poinsett, Cross, St. Francis, and Lee) running through them. Many non-irrigated acres west of Crowley's ridge have limited availability or no exploitable water resource and cannot be developed for irrigation. Also on the CDL there are some tillable crop acres listed on the ridge. These tillable acres on the ridge and very near the ridge are likely not irrigable. The county agents confirmed this through the survey (Clay, Greene and Lee). Other limitations to expansion in irrigated acres are soil type, topography, ability to landform, cropland rental arrangements (most cropland is rented in Arkansas and landowners rather than tenants are responsible for the cost of irrigation land improvements), and higher crop production expenses resulting from increased energy and input costs.

One clear barrier to irrigation development appears to be the cost for irrigation development. This is a short term barrier and if economics are favorable enough, for planning purposes we believe these acres could eventually be developed for irrigation, as the demand report assumes.

Finally, we interviewed Phil Tacker, the previous University of Arkansas irrigation specialist, who has extensive experience in the state and assisted many growers in Arkansas to develop irrigation. He felt that in his expert opinion, that only about 80% of total tillable acres in any given county could potentially be developed for irrigation (Tacker, 2014). He felt that there are many small areas in many counties that are not feasible for irrigation, water is not available, cost

may be prohibitive for such small areas, topography does not lend to irrigation, and future urbanization limits irrigation development to all tillable acres. If some limit was warranted, for this analysis or future analysis, this may be a good expert estimate.

Recommendation: In Clay, Greene, Craighead, Poinsett, Cross, St. Francis, and Lee counties it may be warranted to reduce their potential for irrigable acres due to water availability. Exclude Crowley's ridge if acres along the ridge are included in the tillable acreage estimate as these acres will likely not be irrigable. A more in-depth investigation of Greene county and other counties that were not reported on, may be warranted. There is some resistance to complete conversion of tillable acres to irrigation. An expert estimate for this may be about 80% of tillable can be converted, however many agents felt that it would not be unreasonable to assume most of the tillable acres could eventually be converted to irrigation. Clearly some resistance or barrier exists at the very end, and it would likely be inappropriate to assume all tillable acres in a county would be converted to irrigation. Likely, anywhere between 5% to 20% of total tillable acres will not ever be developed for irrigation, but we don't have a recommendation for an exact value.

Recommendation: Little is known about irrigation system types, barriers to irrigation, conservation practices, and other key data about irrigation in Arkansas. Many conservation practices such as multiple inlet, computerized hole selection, reservoir construction, scheduling methods, initiation and termination practices, surge irrigation are specific to the southern region and are not reported in USDA publications or surveys. Also barriers to irrigation development are not well known. It would be valuable to conduct an irrigation survey of Arkansas row crop production practices to better understand trends, adoption and use of conservation measures, development practices for planning and policy purposes.

A Closer Look at the Methodology Used for Future Acreage Projections

The demand report ignores the interaction between crops in the regression analysis. In recent years there have been crop mix shifts, mainly away from cotton and rice in favor of corn and soybeans due to favorable market prices. The regression analysis does not incorporate acreage shifts from one crop to the next. Therefore, in some counties there will be a stronger rate of increase projected, for soybeans and corn, than for the other two crops. In some counties, irrigated acres are increased for all crops regardless of a trend being statistically evident for all crops. The regression procedure used in the demand report is as follows:

"If the R^2 of an individual crop was 0.65 or more, and greater than the R^2 for the total irrigated acreage trend of the county, then the individual crop trend line was used to project the growth in future irrigated acres for that crop. If the R^2 for total acres was 0.65 or more, and greater than any individual crop R^2 in the county, then the future irrigated acres of all crops in the county increased at the same trend using the total acres trend. If neither the total acres nor individual crop R^2 indicated a good fit (i.e., was 0.65 or more) then the irrigated acres of all crops in the county remained constant at the current level. In a few instances, rice and cotton irrigated acres

had significant R^2 values but negative trends, which resulted in a declining projection in future irrigated acres for these crop types."

The determination of R^2 of *"0.65 or more"* appears to be arbitrary, and no explanation is given for the R^2 rule used in the demand report, although one might assume the authors wanted trend equations that captured over two-thirds of the explainable variation.

We have evaluated the methods used in the demand report to project irrigated acres into the future. In doing so, we have focused on three counties: Mississippi, St. Francis, and Lee. In each of these counties, irrigated acres were projected to increase for all crops irrespective of trends being evident based on the following rule stated above: "*If the R^2 for total acres was 0.65 or more, and greater than any individual crop R^2 in the county, then the future irrigated acres of all crops in the county increased at the same trend using the total acres trend.*" We looked into the soundness of this rule with additional data from the USDA CDL database and additional NASS data on non-irrigated soybean and cotton acres.

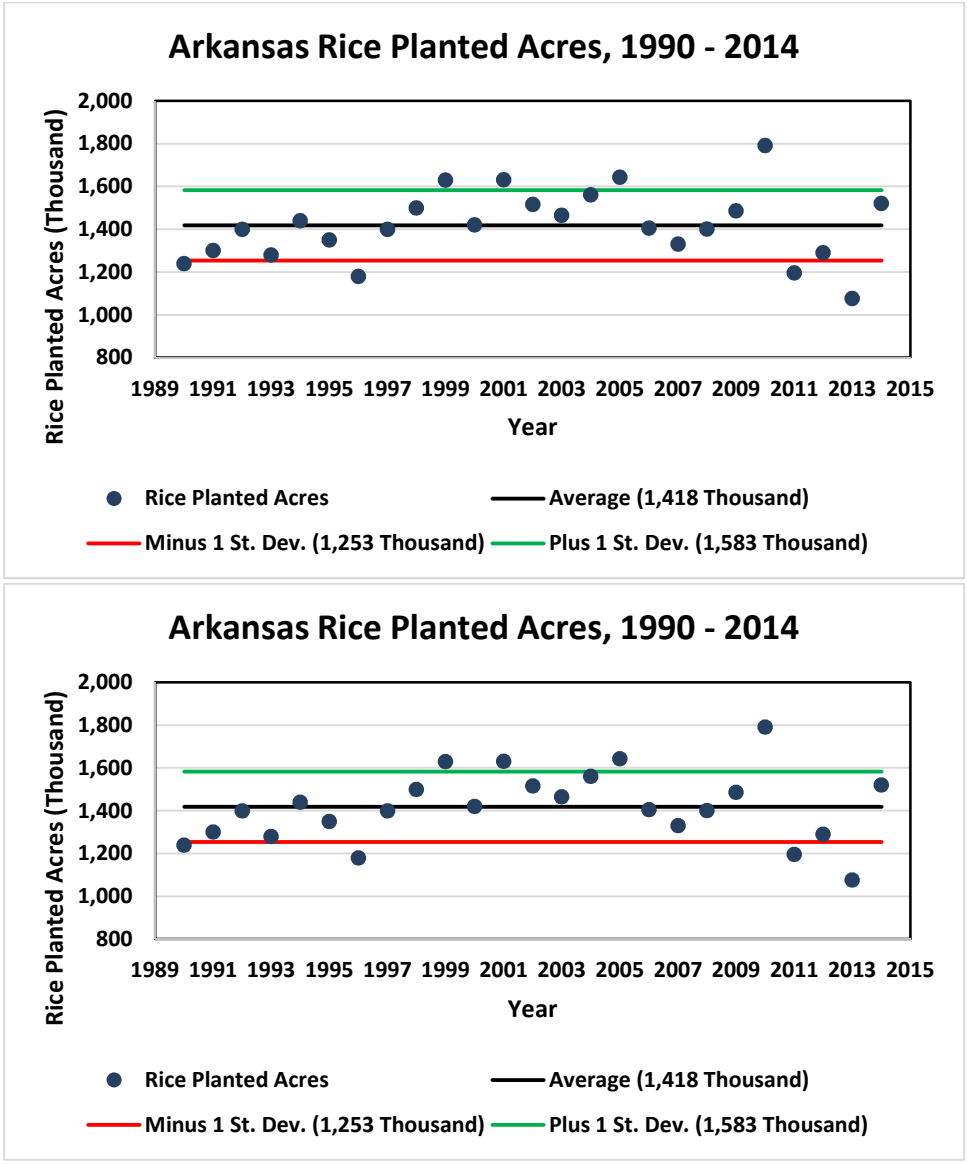


Figure 2. Arkansas Rice Planted Acres, 1990-2014 (Source: USDA NASS, 2014)

Statewide rice acres have not experienced a significant increasing or decreasing trend (Figure 2) in the last 25 years. The slope for this trend is 2.76, with an R^2 of 0.02 and the Prob(T) statistic is 0.558 (non-significant). As a result it may be most appropriate, to hold rice acreage constant in most counties based on the statewide trend. We believe that there is still opportunity for increasing rice acreage in Arkansas, but it is unlikely it will be at the same rate that the other row crops, mainly soybeans could increase. In counties where there is potential for rice acreage to increase, we suggest a smaller increase relative to the other crops. Whether or not to hold constant or increase rice acreage may be a county by county decision, based on trend data. We did not evaluate all of the counties.

Trends in Irrigated Acres: The Case of Mississippi County

Mississippi County was one of the counties for which irrigated acres for all crops were increased over time based on the total irrigated acres R^2 rule. Based on the demand report, Mississippi county has a projected increase of 56% for all crops and levels off in about 2010 when all of the tillable acres are converted to irrigated acres. This equates to an increase of 83,832 acres of soybeans and for rice, it is projected that an additional 30,180 acres will come into production. For cotton this equated to 48,689 acres and for corn 6,951 acres. The analysis for Mississippi County had all crops increasing at the total trend slope which had the best R^2.

However, when looking at the irrigated acreage trends for individual crops over the 2000 – 2010 period using demand report data, only irrigated soybeans and corn acres had significant upward trends (the soybean acreage trend was significant at the 0.05 level, while the corn acreage trend was significant at the 0.10 level). "Other" acres had a downward trend significant at the 0.10 level. These results are shown in Table 7.

Table 7. Linear Trend Analysis of Total Irrigated Acres and Irrigated Acres by Crop for Mississippi County, 2000 – 2010.

Statistic	Total Acres	Soybeans	Cotton	Rice	Corn	Other
Slope	8.731	9.500	-2.253	0.938	0.713	-0.168
Prob(T)	0.000	0.001	0.114	0.138	0.052	0.052
R^2	0.945	0.731	0.250	0.224	0.352	0.350

We assembled and evaluated the USDA crop layer data maps for Mississippi County for 2000 through 2010. We compared the crop mix in 2000 and 2010 and found that nearly all of the increase in soybean acres (as well as most corn acres) came at the expense of cotton acres. In 2000, cotton had the largest number of acres, followed by soybeans (See "2000 CDL, Mississippi County, Arkansas" in appendix). However, soybeans had the largest number of acres in 2010 (See "2010 CDL, Mississippi County, Arkansas" in appendix), and it is evident from the two CDL maps that the "red' areas comprising cotton acres decreased over time in favor of the "green" areas delineating soybean acres and a few "yellow" areas delineating corn acres.

The correlation coefficient for cotton and soybean planted acres is -0.98, based on NASS total acreage data for both cotton and soybeans (total acreage in this case being irrigated plus non-irrigated acres for both crops) for the period 2000 – 2010. (Note: all correlations reported unless expressed otherwise are significant at the 0.05 level). This would imply that soybeans replaced cotton on nearly a one-to-one basis during the 2000 – 2010 period. Splitting NASS soybean and cotton acres into irrigated and non-irrigated acres and looking at the linear trend in these data over the 2000 – 2010 period provides more insight into which cotton acres were being converted to irrigated soybean acres. The slopes of the resulting trend equations were estimated using NASS data and are presented below in Table 8.

Table 8. Linear Trend Analysis of Irrigated and Non-Irrigated Cotton and Soybean Acres, Mississippi County, 2000 – 2010.

Irrigated Soybean Acres	Non-Irrigated Soybean Acres	Irrigated Cotton Acres	Non-Irrigated Cotton Acres
Slope = 9.50	Slope = -0.20	Slope = -1.80	Slope = -8.59
Prob(T) = 0.00	Prob(T) = 0.87	Prob(T) = 0.22	Prob(T) = 0.000
R2 = .73	R2 = .00	R2 = .16	R2 = .84

These data tell us several things. One observation is that irrigated soybean acres trended upwards at around 9,500 acres per year during the 2000 – 2010 period. There is no significant trend in non-irrigated soybean acres, meaning that little if any of the increase in irrigated soybeans came from non-irrigated soybeans, and non-irrigated soybean acreage remained fairly unchanged over time. Irrigated cotton acres had a negative but not significant downward trend of -1,800 acres per year during the 2000 – 2010 period. Thus for the most part, irrigated cotton acres did not change much during this period. However, non-irrigated cotton acres had a significant downward trend of -8,590 acres per year over the 2000 – 2010 period. This would imply that most of the increase in irrigated soybean acres came from non-irrigated cotton acres. We came to this conclusion by evaluating the correlations between irrigated soybean acres and both irrigated and non-irrigated cotton acres using the NASS data. The correlation between irrigated soybean acres and irrigated cotton acres is -0.76, implying that some irrigated cotton acres shifted to irrigated soybean acres. However the correlation between irrigated soybean acres and non-irrigated cotton acres is much stronger (-0.97), **suggesting most of the acreage shift occurred between non-irrigated cotton and irrigated soybeans**.

The results above are likely due to the relative profitability of irrigated soybeans and non-irrigated cotton. Cotton is a very expensive crop to grow, non-irrigated or otherwise. Variable production expenses for non-irrigated cotton range from $389 to $422 per acre, based on 2014 Arkansas crop production budgets. Alternatively, variable production expenses for irrigated soybeans range from $271 to $335 per acre. Crop prices have been more favorable for soybeans than for cotton during much of the 2000 – 2010 period. Thus, relative profitability has favored irrigated soybeans over non-irrigated cotton.

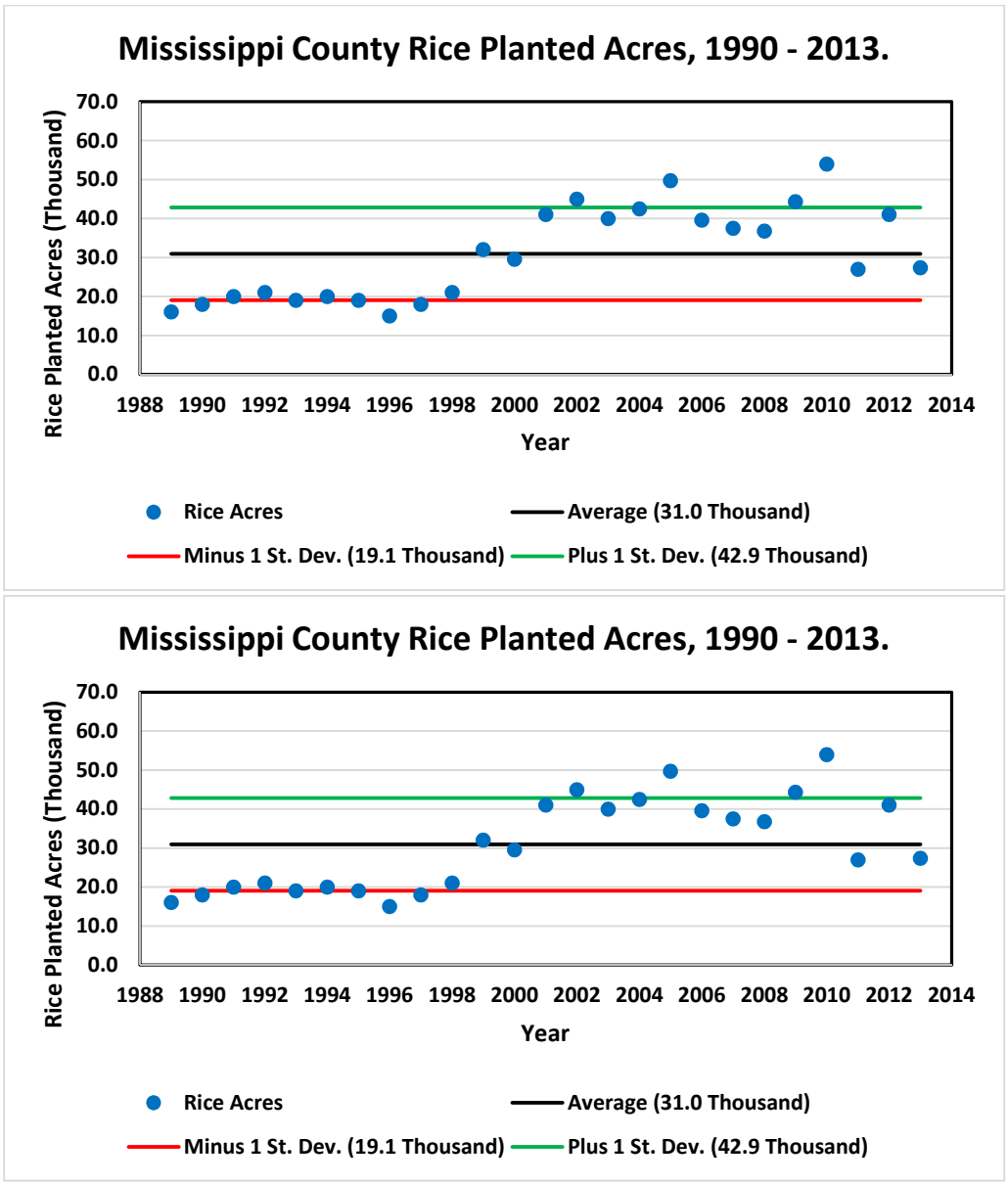
Irrigated cotton remained unchanged over the 2000 – 2010 period due to a couple of possible factors. Machinery requirements for cotton are very different than for soybeans. Cotton pickers in particular have increased in cost substantially, and can only be used to harvest cotton. Additionally many growers have shifted from traditional module pickers to bale pickers to reduce support equipment requirements, reduce labor and improve quality as the bales are covered with plastic.

Soybeans can be grown and harvested with the same combine as wheat, corn, rice, and grain sorghum. Generally the other support equipment for soybean production is all common to the

other crops. Thus we speculate that a grower producing these other crops would easily be able to grow soybeans with less equipment needs and a much less fixed cost per acre over cotton and possible higher revenue potential. In essence, it is likely that growers have chosen to sell their cotton equipment to develop irrigation and use existing equipment for soybeans. Thus, cotton producers need to raise enough irrigated cotton to spread their fixed costs across the acres they farm. Another factor affecting the number of irrigated cotton acres produced in Mississippi County is the existence of cotton gins in the county. Owners of these gins own large tracts of cotton land and require their tenants to produce enough cotton to fulfill their supply needs.

As mentioned above, there was no trend in rice acres in Mississippi County during the 2000 – 2010 period. Looking again at the CDL maps, one can see where cotton acres are located relative to rice acres in the county. The two crops are produced on different soil types, largely precluding any transfer of acres from one crop to another. Cotton is grown primarily on light, sandy soils. Corn and soybeans can also be grown on these types of soils, which explains why many cotton acres shifted to either corn or soybeans. Rice on the other hand is grown on heavier, clay or silt loam soil types, most of which have a hard pan layer beneath them that limits water percolation and allows for efficient flood irrigation. Rice also has certain topographical constraints, since maintaining a good flood for rice requires the ability to cascade water across the field. As slope increases, more levees are needed which reduces the productive area, lessening the suitability of the land for rice production. Rice is typically grown in rotation with soybeans due to the synergistic effects each crop has on the other.

Rice acres in Mississippi County were at their highest in 2010 (54,000), which was coincidently the year rice acres were highest for the entire state of Arkansas (Figure 3). Additional land may be developed for rice in the future via land leveling, and future rice acres might increase higher than the 54,000 acre level observed in 2010. During the period of 1990 though 2013, there is a increasing trend in rice acres. However, the 2000 – 2010 data doesn't support applying an upward trend to rice acres based on a trend in total acres.



Mississippi County Rice Planted Acres, 1990 - 2013.
Rice Planted Acres (Thousand)
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014
Year
Rice Acres
Average (31.0 Thousand)
Minus 1 St. Dev. (19.1 Thousand)
Plus 1 St. Dev. (42.9 Thousand)

Figure 3. Mississippi County Rice Planted Acres, 1990-2013 (Source USDA NASS, 2014)

Corn acres may also increase in the future, but these will likely come from cotton acres. Like irrigated soybean acres, corn acres had a significant upward trend over the 2000 – 2010 period, although the level of significance was statistically lower for corn than for soybeans. Corn had negative correlations with both irrigated cotton (-0.38) and non-irrigated cotton (-0.58), although neither of these correlation coefficients were significant at the 0.05 level.

Conclusions for Mississippi County:

It would appear based on the data that only irrigated soybean and corn acres are trending upward in Mississippi County at around 9,500 and 713 acres and per year, respectively, based on the 2000 – 2010 data. **The majority of the acreage increase in irrigated soybean and corn appear to be at the expense of non-irrigated cotton acres.** There were 44,200 acres of non-irrigated cotton in Mississippi County in 2010 based on NASS data. These acres may continue to be converted into irrigated soybean and corn acres in the future. There was no downward trend in non-irrigated soybean acres, and it is unclear if these acres will eventually be developed into irrigated acres in the future. Non-irrigated soybean acres numbered 105,500 acres in Mississippi County during 2010 based on NASS data. They were as low as 78,000 acres in 2007 and as high as 114,000 acres both in 2000 and 2009. The fact that non-irrigated soybean acres had no downward trend during the 2000 – 2010 period may mean that these acres are largely located in areas where irrigation water is not readily available or is too cost-prohibitive to develop.

We also don't know if the upward trend of 9,500 acres per year for irrigated soybeans will continue to be as strong through the projected 40-year future. The trend appears to be based on the more favorable profitability of irrigated soybeans relative to non-irrigated cotton that prevailed during the 2000 – 2010 period. One caveat is that future acres may shift away from irrigated soybeans to irrigated (rather than non-irrigated) cotton should cotton prices strengthen sufficiently relative to soybean prices in the future. These acres would likely shift to irrigated cotton in this instance, since the land has already been developed for irrigation. This upward trend may need to be tempered somewhat, so as not to project irrigated soybean acres beyond what is believable in the future.

In our opinion, we do not think it likely that rice acres would increase in Mississippi County, based on historical trends. Irrigation development appears to be occurring only in the other row crops. Additionally, because the trend in irrigation development appears to be due to a crop mix shift, it may only be reasonable to increase irrigated acres in Mississippi County by the amount of dry land cotton acres available (44,200 acres) or about half of the current soybean increase projected in the demand report. It is likely, that some development would occur in dry land soybeans and not all of the dry land cotton acres would be developed. So 44,200 acres may be a good estimate or upper limit for irrigation in Mississippi County. This is about 26% of what was projected in the demand report.

The Mississippi County Extension agent, Jason Osborn provides additional insight as to barriers to irrigation development in Mississippi County.

"Mississippi County has a vast amount of acreage that lies inside the Mississippi River levee that is prone to flooding. Most of this land will not be improved due to the fact that as flood waters rise existing center pivots must be dismantled and removed to the other side of the levee to prevent damage to the equipment. Also this land most likely will not be improved due to the

expense of having to re-grade the fields after each flood cycle because of soil movement. Wheat is not grown inside the levee due to floods and in many years cotton is not grown on the sandy soil because it is too late in the year due to late spring floods. Short season dry-land soybeans are the crop of choice because they can be planted after late spring foods and harvested before fall floods inside the levee.

There are numerous sloughs in the southern part of the county with elevation changes that may not be economically feasible to irrigate and land owners are unwilling to invest to improve the land for irrigation."

Trend in Irrigated Acres: The Case of St. Francis County

St. Francis County was another county for which irrigated acres for all crops were increased over time based on the total irrigated acres R^2 rule. Significant crop acreage shifts have occurred for St. Francis County since 2000. This can be seen by looking at the USDA Crop Data Layer (CDL) maps for St. Francis County for 2000 and 2010. Looking at these maps, one can see a clear indication that cotton, corn, and grain sorghum acres are greater in 2010 than in 2000 as their colors show up more prominently in the 2010 map.

We estimated trend equations for total irrigated acres in St. Francis County as well as acreage trend equations for soybeans, cotton, rice, corn, and "other." This was done using the specified 2000 to 2010 acreage data in the demand report. The results of our trend analysis are shown in Table 9.

Table 9. Linear Trend Analysis of Total Irrigated Acres and Irrigated Acres by Crop for St. Francis County, 2000 – 2010.

Statistic	Total Acres	Soybeans	Cotton	Rice	Corn	Other
Slope	3.727	2.900	1.054	-0.645	0.321	0.097
Prob(T)	0.000	0.003	0.002	0.386	0.090	0.543
R^2	0.785	0.617	0.663	0.084	0.282	0.042

The trend equation for total acres had a higher R^2 (0.785) than the trend equations for each of the individual crops. However, not all crops had statistically significant acreage trends. Only irrigated soybean and cotton acres exhibited a statistically significant upward trend of 2,900 and 1,054 acres per year at the 0.05 level. Corn exhibited a statistically significant upward trend of 321 acres per year at the 0.10 level during the 2000 – 2010 period. Trends for rice and "Other" were not significant during the 2000 through 2010 period. Thus cotton, soybeans, and corn trended upward in irrigated acres, but rice and "Other" acres did not.

Where did the increased irrigated acres come from for the former three crops? Again, one can get some insight about this expansion by looking at the USDA CDL data maps for 2000 and 2010. Soybeans had the largest number of acres during 2000. However, grass/pasture was second in terms of land area in 2000. By 2010, grass/pasture land area had shrunk relative to soybeans, rice

and cotton, coming in as 6th overall in land area (Table 10). Grass/pasture area decreased by 71,345 acres, and it is likely that about some of these acres were converted to irrigation.

Table 10. 2000 and 2010 CDL Land Cover Categories and Amounts in Acres by Rank (Source USDA NASS, Cropscape, 2014)

2000		2010	
Soybeans	183,139	Soybeans	154,084
Grass/Pasture	78,380	Rice	56,133
Rice	53,864	Cotton	24,540
Fallow	17,889	Fallow	18,413
Cotton	12,501	Grain Sorghum	7,485
Sod/Grass Seed	10,154	Grass/Pasture	7,431

However, we believe some of this trend may be due to reclassification of land uses by the CDL, a change that appears to occur in 2005. That is in 2000, non-agricultural uses were classified in broader terms than in 2010. In 2000 there is a large area of grass/pasture west of Crowley's ridge that was classified as grass/pasture and forest, where in 2010 it was defined as woody wetlands. So clearly this explains some of the large decrease in grass/pasture area between 2000 and 2010. However, we do observe a general downward trend in grass/pasture area in each year between 2000 and 2010, even after the reclassification in 2005 as shown in Table 11. So we believe this is one of the drivers behind the increased irrigation development in St. Francis County. The remainder is explained by land use reclassification.

Table 11. Grass/Pasture Acres for St. Francis County, 2000-2010, CDL data

Year	Grass/Pasture Acres
2010	7,431
2009	7,256
2008	11,661
2007	22,360
2006	17,701
2005	4,116
2004	54,890
2003	51,316
2002	81,164
2001	86,213
2000	78,380

We asked the St. Francis County Extension Agent, David Carwell, about his experience about how irrigation was developed between 2000 and 2010. He felt that the primary driver was commodity shifts and that pasture conversions were a smaller factor in new irrigation development.

We looked at the correlation across crops (irrigated and non-irrigated soybeans, irrigated and non-irrigated cotton, corn, and rice) and grass/pasture land during the 2000 – 2010 period using NASS data for row crops and USDA CDL data for grass/pasture land. We found significant negative correlations between irrigated soybeans and grass/pasture land (correlation = -0.73) and between irrigated cotton and grass/pasture land (correlation = -0.81). Corn also had a negative though not statistically significant correlation with grass/pasture land (correlation = -0.31). Looking at the cumulative irrigated soybean, irrigated cotton, and corn acres and their correlation with grass/pasture land revealed a significant negative correlation of -0.89. Thus, some of the irrigated acreage expansion during 2000 – 2010 came from grass/pasture land shifting to irrigated soybeans, irrigated cotton, and corn.

Another source of the increase in irrigation development is believed to come from non-irrigated soybeans. Non-irrigated soybeans had a significant negative trend at the 0.10 level during the 2000 – 2010 period, based on NASS data (slope = -1.625; Prob(T) = 0.062; R^2 = 0.363). Non-irrigated soybeans had a significant negative correlation with corn (-0.69), and a negative though not significant correlation with cumulative irrigated soybeans, irrigated cotton, and corn acres (-0.53).

Thus it appears that some expansion in irrigated cropland in St. Francis County came from grass/pasture land with most of the expansion coming from non-irrigated soybeans, with the latter acres shifting primarily to corn. Will there be future expansion in irrigated cropland St. Francis County? If there is, it will have to come from another source other than grass/pasture land. There were only 7,431 or so acres of grass/pasture land for St. Francis County in 2010. If there is future expansion, it will likely come from non-irrigated soybeans. Non-irrigated soybeans accounted for 43,100 acres in St. Francis County during 2010, based on NASS data. Regardless of whether or not expansion continues, it would be inappropriate to increase rice acres the same as cotton, soybeans, and corn, as rice acres have for the most part remained unchanged and will likely remain unchanged in the future in St. Francis county.

The demand report predicts an increase of 68,288 irrigated acres by 2050. If St. Francis County sod busts the remaining grass/pasture land (7,431 acres) and converts all non-irrigated soybeans to irrigated (43,100), this would be an increase of 50,531 acres. There will be some resistance to developing the remaining grass and non-irrigated soybeans but some additional acreage development may come from other crops such as wheat, millet, etc, so this may be a reasonable estimate for the county. Using 50,531 acres may be a better estimate in St. Francis County than 68,288 acres. There does not appear to be an increasing trend in rice or other crops. We felt it only appropriate to apply future increasing trends to corn, soybeans and cotton.

Trend in Irrigated Acres: The Case of Lee County

Lee County is an enigma compared with Mississippi and St. Francis Counties. As with both Mississippi and St. Francis Counties, irrigated acres for Lee County were increased over time based on the total irrigated acres R^2 rule. However, none of the individual crops had a statistically significant trend in irrigated acres during the 2000 – 2010 period. Below in Table 12 are slopes of estimated linear trends for total irrigated acres as well as for soybeans, cotton, rice, corn, and "other" acres for Lee County using demand report data.

Table 12. Linear Trend Analysis of Total Irrigated Acres and Irrigated Acres by Crop for Lee County, 2000 – 2010.

Statistic	Total Acres	Soybeans	Cotton	Rice	Corn	Other
Slope	2.693	0.650	2.048	-1.080	0.988	0.088
Prob(T)	0.000	0.604	0.162	0.160	0.160	0.724
R^2	0. 848	0.031	0.202	0.204	0.204	0.014

As can be seen above, only total irrigated acres had a statistically significant trend during the 2000 – 2010 period. However, none of the individual crop trends were statistically significant during the period. Why would total irrigated acres have an upward trend when none of the individual crops exhibited an upward trend in irrigated acres? We can gain some insight into why this takes place by looking at CDL maps and data for Lee County (these maps can be found in the appendix).

The 2000 USDA CDL map for Lee County revealed that grass/pasture acres accounted for the second largest number of acres. The 2010 USDA CDL map shows that grass/pasture acres decreased in size and ranked 9th in total land cover area. We found a similar scenario as discussed earlier in St. Francis County. In 2000 grass/pasture accounted for 68,827 total acres in Lee County, but accounted for only 3,096 acres in 2010. Sometime around 2005, USDA must have reclassified land use categories, as discussed previously. Graphically comparing the 2000 and 2010 CDL maps USDA appears to have reclassified large amounts of grass/pasture from 2000 to woody wetlands and fallow/idle cropland by 2010. This accounts for the majority of the change from 2000 to 2010 in the grass/pasture acreage as can be seen in Table 13. Like St. Francis County, there does appear to be a downward trend in grass/pasture acres, even in spite of the reclassification. We believe there was some conversion of grass/pasture to tillable acres developed for irrigation, but the exact amount is hard to estimate.

It would appear over time that many of these acres were converted into irrigated crop production of cotton, soybeans, and corn or reclassified by the CDL. Correlations between individual acres of these crops and grass/pasture acres are not significant, but summing NASS cotton, corn, and soybean irrigated acres and comparing their collective correlation with USDA CDL grass/pasture acres over the 2000 – 2010 period reveals a significant negative correlation of -0.95. Thus although the trends for individual cotton, corn and soybean acres were not significant during the

2000 – 2010 period, the resulting trend of their collective acres summed together was significant, and it seems likely that some new irrigation development came from grass/pasture acres.

Table 13. Grass/Pasture Acres for Lee County, 2000-2010, CDL data

Year	Grass/Pasture Acres
2010	3,096
2009	2,260
2008	3,290
2007	16,396
2006	10,381
2005	1,822
2004	45,558
2003	44,742
2002	76,007
2001	72,300
2000	68,827

Land use changes favoring irrigated cropland development in Lee County during the 2000 – 2010 period also appear to be due to non-irrigated soybeans and non-irrigated cotton. Both non-irrigated crops experienced significant downward trends during the 2000 – 2010 period based on NASS data (Non-Irrigated Soybeans: slope = -2.56; Prob(T) = 0.011; R^2 = 0.517, Non-Irrigated Cotton: slope = -2.164; Prob(T) = 0.006; R^2 = 0.572). Both non-irrigated crops had significant negative correlations with cumulated irrigated acres of cotton, soybeans, and corn. Non-irrigated soybeans had a negative correlation of -0.69 with cumulated irrigated cotton and corn acres. Non-irrigated cotton had a negative correlation of -0.75 with cumulative irrigated cotton, irrigated soybeans, and corn acres. Interestingly, rice acres had a significant negative correlation with cumulated irrigated cotton and corn acres (-0.72), implying some rice acres in Lee county were on marginal rice ground and shifted to irrigated cotton and corn acres during the 2000-2010 period. Rice acres had a downward though not significant trend during the 2000- 2010 period (see Table 12 above).

Based on the information reported above, it appears that irrigated development in Lee County came primarily from non-irrigated soybean and cotton acres with some irrigation development also attributed to grass/pasture land. It appears based on the acre correlations that irrigation development favored irrigated soybeans, corn, and cotton. Will there be future expansion of irrigated cropland in Lee County? If irrigated acreage expansion does occur for Lee County in the future, it will likely come from non-irrigated soybeans. Grass/pasture acres remaining in the County were 3,094 acres in 2010, so there is limited capacity to develop additional irrigated acres from this land use in the future.

Non-irrigated cotton acres were zero in 2007, 2008, and 2010 and totaled only 5,200 acres in 2009 based on NASS data, implying that few if any non-irrigated cotton acres are available for future irrigation development. Non-irrigated soybeans accounted for 57,500 acres in Lee County during 2010, based on NASS data. Regardless of whether or not expansion continues, it would be inappropriate to increase rice acres the same as cotton, soybeans, and corn and we suggest holding rice acres at 2010 estimates for future projections. The demand report projected total irrigation development to be 86,850 acres by 2050 for Lee County. A more likely estimate is 57,500 acres from non-irrigated soybeans and 3,309 acres from grass/pasture may be a more likely upper limit for irrigation development in Lee County.

We asked the Lee County Extension Agent, Stanley Baker, about his experience about how irrigation was developed between 2000 and 2010. He commented that the estimated 57,500 acres remaining would likely be located in river bottoms. He argued some of these acres may be irrigated by center pivots, but most of these acres would require large expenditures in land forming to make them suitable for irrigation. Based on his comments, even 57,500 acres for additional irrigation development may be too high, because such areas are prone to flooding, which is a significant barrier to irrigation development.

Recommendations for Estimating County Irrigated Acres

- Each individual county should be evaluated based on its own irrigation development trends. There appears to be data available to understand past trends and make reasonable future projections. There has been irrigation development in the last 10 years, but it would appear that future development trends could be very different.

- It does not appear appropriate to project future irrigated acres of individual crops based on an overall trend in total irrigated acres unless you have good data to support this. Rather, individual crop acreage trends may be most appropriate to increase or decrease future projected irrigation acres over time. If there is no upward trend in the individual crop acreage data, it would be inappropriate to impose one simply because total irrigated acres have a significant upward trend. Lee County would appear to be an exception to this rule. It would appear at least for Lee County that irrigated cotton, soybeans, and corn acres could be increased by and overall irrigated acreage trend. However, even in the case of Lee County, there is no good evidence for increasing rice acres by an overall irrigated acreage trend.

- We found that using statistically significant trends provided a better explanation of irrigation development and land use changes. The level of significance should be considered when assigning a slope for a projected trend (less than or equal to 0.05 or 0.10, for example). This would be more justifiable than basing the level of significance on some arbitrary R^2 value.

- Historical USDA CDL maps provide clues regarding the location and movement of acres from one crop to another over time within a County. The demand report used the 2010 CDL exclusively to define irrigable acre limits. The USDA CDL data are available for all the

historical years used in the analysis (2000 – 2010) and provide a valuable source of information from which to draw inferences and explain irrigation development trends.

- Developing correlations between irrigated and non-irrigated NASS data may provide insight as to where irrigated crop acres are shifting (e.g., development of non-irrigated land into irrigated land or acreage shifts from one irrigated crop to another). The demand report did not consider non-irrigated acre land use changes to explain trends.

- It would be useful to use a Geographic Information System to derive crop use changes through a series of queries to better ascertain crop mix changes. We did not use this technique. This information could help understand the crop mix influence and how it impacts irrigation development in a County. It may be more appropriate to look at each County's CDL before applying regression analysis, so that projected irrigation development can be better estimated. It seems that irrigation development potential in Arkansas is not as substantial as originally projected, and this is an important finding for projecting future demand. There do seem to be some inconsistent trends in the CDL data layers, likely from improvements made in the system over time, so multiple years should be used to draw conclusions.

Overall Conclusions and Recommendations

In our analysis of the demand report for the Arkansas Water Plan, we found many improvements and alternate methodologies that may improve the current report or future work. We specifically evaluated the water use estimates for rice, cotton, soybeans and corn. Also we investigated future irrigated acres projections for three counties in Arkansas. Specific recommendations are provided in the body of this report.

We evaluated water use for the major crops and found that the data from the water user database is likely overestimating actual water use. In looking at trends and other sources of data we believe there are major systemic issues in the water use reporting system, that warrant a review of the entire water use database system. We question the value and quality of this information from the water user database for water planning purposes.

We also investigated crop acre increase projections from the demand report for reasonableness and we attempted to explain the results. We believe that a closer look at each County with large irrigable projected acre changes is warranted. We question whether irrigation development potential in Arkansas is as substantial as originally projected, and this is an important finding for projecting future water demand. We provide explanations for large increase in irrigation development and how to adjust the analysis to provide more reasonable estimates. We could not justify much, if any, of an increase in rice acres in the counties we investigated, and it may be more reasonable to apply only small increases or keep them constant for future projections. The primarily development in irrigated acres appears to come from soybeans, and from our analysis it

appears at the expense of other crops and land uses such as non-irrigated soybeans, non-irrigated cotton and grass/pasture. It seems that projecting increases in all crops equally in a County may overestimate actual future irrigation development.

Condensed recommendations from this report are as follows:

- **Water use data is largely impactful to the overall demand projection for agriculture and for the total water demand in Arkansas. The usefulness of the WUDB is suspect and many inconsistencies and irrational water use values were found in the WUDB. A thorough review of the WUDB is warranted for reasonableness, usefulness, and accuracy for water planning in Arkansas. Specifically how water use is collected and reported by agricultural users needs examination. Improvements in water use accounting for rice, soybean, corn, and cotton are needed for reasonable estimates of water demands for irrigated agriculture, sustainable aquifer yields, the impact of conservation measures, and water infrastructure needs. Barring changes to the WUDB, it may be warranted to use other estimation methodologies for irrigated agriculture.**

- **A more thorough investigation into future irrigation development is warranted. The future potential for developing irrigation in Arkansas does not appear to be as substantial as projected in the demand report. To better estimate irrigation development in Arkansas, we recommend a closer investigation of crop and land use changes in counties with significant trends in crop changes and irrigation development. A closer evaluation of County historical trends in land use, using the USDA CDL data and NASS data on non-irrigated acres will likely explain questionably high projected irrigation development trends. These data could be used to better estimate and quantify future irrigation development.**

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