Memorandum

To: *Water Demand and Forecasting Working Group*

From: *Rick Brown and Mitch Horrie, CDM Smith*

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Subject: *Draft: Arkansas Water Plan Update Water Demand Forecast Methodology*

1.0 Introduction

The update to the Arkansas Water Plan (AWP) will involve several major steps including:

1. A description of regional water resources and the socioeconomic characteristics of the different areas of the state.

2. A quantification of current and future water needs (also referred to as water demand or demand), including consideration of water and wastewater infrastructure (this will provide an answer to the question – *How much water do we need?*).

3. An assessment of surface and groundwater supply availability, including water quality considerations (this will provide an answer to the question – *How much water do we have?*).

4. Once information on water demand and supply is obtained, an assessment will be completed to determine if there are any shortfalls or gaps between demand and supply.

5. Finally, a set of recommendations will be developed to address the state's current and future water resource shortfalls. These recommendations may include recommended projects or other non-structural and policy actions.

The remainder of this document will focus on the proposed process or methods to quantify current and future water demands (item 2 above). The update of the AWP requires assessment quantification of current and future water needs in order to achieve a future that sustainably meets those needs while ensuring the health, safety, and prosperity of the citizens of Arkansas and the protection of fish and wildlife.

The methodologies described in this document will provide a means of maintaining consistency in the forecasting effort while still allowing for regional variation to be captured. This information will be used to develop a completed statewide and regional quantification of current and future water needs by source of supply (groundwater and surface water) and by various demand sectors (see below for more information). Forecasts will be developed at the county level and aggregated to Planning Region. Planning Region water demand forecasts will be used to:

- Understand the changes the Planning Region may experience over the planning horizon due to factors such as demographic shifts and local and regional economic influences; and

- Identify "gaps" in supply that may exist, either currently or in the future, so as to understand the capability of available supplies to meet future water needs and to develop management practices to address those issues.

This paper begins with a presentation of the sectors for which water use will be forecast.

1.1 Sectors of Use

Demands will be forecast separately for nine sectors of use. Sector forecasts are necessary because each sector has unique factors that influence its water demand. This document describes the process and methods to be used to forecast future water needs in the State of Arkansas through 2050 for the following sectors.[1,2]

- Municipal domestic (i.e., residential)
- Municipal non-domestic (i.e., municipally-supplied non-residential (major uses in this sector include industrial, commercial, and mining))[3]
- Self-supplied domestic
- Self-supplied commercial and industrial
- Agriculture including crop irrigation, livestock, and aquaculture
- Thermoelectric power
- Hydropower
- Mining (includes hydraulic fracturing water use in the Fayetteville Shale)
- Navigational considerations
- Recreational considerations (including but not limited to hunting clubs (duck) and fish and game management areas)

1.2 Water Use Data

Historical water withdrawal data are used to establish baseline levels of demand by water use sector for developing demand forecasts. In Arkansas, water withdrawal permits are required for

[1] The instream flow evaluation process for fish and wildlife will be evaluated as part of the supply quantification process.
[2] A preliminary review of hydropower and recreational data will be completed to determine if the quantification of the needs should be completed under demand versus supply quantification.
[3] To the extent that hydraulic fracturing water withdrawals supplied by municipal systems can be identified in the water use registration database, they will be combined with self-supplied withdrawals for hydraulic fracturing and accounted for in the Mining sector forecast.

all surface water users withdrawing 1 acre-foot (AF) or more per year and all groundwater users with the potential to pump 50,000 gallons per day (gpd) under the Water-Use Registration Program. This program is under the purview of the Arkansas Natural Resources Commission (ANRC). Withdrawal data are reported by registered users annually for the approximately 6,100 surface water withdrawal sites and 49,000 groundwater withdrawal sites. Reported withdrawals are stored in the Water-Use Database (WUDBS), which is managed by the U.S. Geological Survey (USGS) through a cooperative agreement with ANRC. This database contains monthly water withdrawal volumes by registered user. Key data fields include the diverter name, location of withdrawal, and industry type.

1.3 Geographic Considerations

1.3.1 Planning Regions

Sector water demand forecasts will be developed at the county level for each of Arkansas' 75 counties. The county is a necessary geographic unit for forecasting demand because much of the data required to forecast future demand (e.g., demographic) is aggregated at the county level.

Each county is then assigned to a Planning Region. The total number of Planning Regions is under development and will take into consideration both watersheds and groundwater resources. This process provides a framework to quantify and compare demands to available water supply. The aggregation of counties to Planning Regions will also consider the structure of the 1990 State Water Plan; however, this Update may revise the eight basins used in 1990 Plan. The overall purpose of the Planning Regions is to group counties with shared resources and similar economic, social, and institutional characteristics in order to facilitate the planning process and to devise basin-and-resource focused planning needs, goals, and management practices/solutions to address local and regional needs.

1.3.2 Geographic Distribution of Forecast Demands

The geographic distribution of existing (i.e., baseline) water withdrawals, including the county where demands occur as well as the groundwater or surface water source, will be identified based on the information available in the Arkansas WUDBS. This database identifies water withdrawals by source from permitted users as identified by the ANRC Water-Use Registration Program. As water withdrawal information is extracted from the database for use in developing the water demand models, the corresponding water source will be maintained. For the Water Plan Update, it is recommended to assume that the water supply source for future water demands will reflect existing sources of supply; unless there are identified reasons to change this assumption based on location or sector-specific information. For instance, if a provider currently supplies its customers with groundwater from the alluvial aquifer, it will be assumed that the alluvial aquifer is the source of supply for future demands as well. Alternatives to this assumption may be considered and developed through the stakeholder process given sufficiently supported evidence and as part of the analysis of demand versus supply availability.

Existing and future water demands will be summarized by source of supply. Thus, for each county, surface water and groundwater demands will be identified by aquifer unit or surface water source for each forecast year and for each sector of use. By developing information at the county level we will be able to aggregate the information up to a higher level (e.g., Planning Region and statewide).

1.4 Planning Horizon

Demands will be forecast for all sectors of use through 2050. Demand forecast models will generate demands at 10-year intervals from a baseline year of 2010 through 2050.

The following sections provide a brief overview of each sector of water use and describe the recommended water demand forecast methodology for the sector.

2.0 Municipally-Supplied Domestic Sector Demand Forecast

Municipally-supplied water is water that is supplied to customers through a public utility providing treated water. Users of municipally-supplied water can include households, commercial businesses, and industrial facilities, among others. USGS defines public suppliers as public and private systems providing water to at least 25 people or have a minimum of 15 service connections (Holland 2007). In Arkansas, about 93 percent of the state's population is served water by public supply systems.

Data on municipally-supplied water use will be obtained from the Arkansas WUDBS. This database contains monthly withdrawal totals by supplier; the domestic population served; estimates of municipally-supplied deliveries to commercial, industrial, and mining customers; and loss amounts (i.e., non-revenue water [NRW]). In addition, the Arkansas Department of Health develops data for public water suppliers. These data will be used to supplement and/or verify WUDBS data.

Municipally-supplied domestic and non-domestic demands will be identified for the base year and forecast separately in the future. Municipally-supplied domestic water demand will be forecast using the "driver times rate of use" approach whereby each county's baseline domestic per capita rate of use (i.e., gallons per capita per day [gpcd]) is multiplied by county population projections to derive estimates of future demands. Several years of municipally-supplied domestic water use data will be analyzed to determine the appropriate baseline per capita rate of use for each county in the state.

2.1 Municipally-Supplied Domestic Baseline per Capita Water Use

A baseline domestic per capita water use rate will be estimated and applied to projected municipally-supplied population for each county in Arkansas to derive estimates of future domestic municipally-supplied demands. Determining a baseline county per capita rate of use will involve five steps in order to refine the final water use value. The steps required to arrive at a baseline county gpcd are as follows.

Step 1: Estimate the "Raw" Per Capita Water Use Rate

Using available water withdrawal information from the WUDBS and USGS, a preliminary gpcd will be calculated for each supplier in each county for which data are available. Several years of data will be analyzed to identify trends and factors influencing the rate of use to ensure both dry and wet year climate effects are taken into consideration.

The WUDBS identifies the portion of public utility withdrawals **delivered** to non-domestic customers as well as the portion **delivered** to domestic customers. Thus, a supplier volume of municipally-supplied **domestic** demands will be derived based on these utility-reported volumes. For each year analyzed, these demands will be used to derive a domestic per capita rate of use for each supplier. Thus, the supplier per capita rate of use will be calculated as follows:

Equation 1:

$$\boldsymbol{GPCD_s^{MSD} = \frac{Q_s^{MSD}}{P_s^{MS}}}$$

Where:

$\boldsymbol{GPCD_s^{MSD}}$= Baseline municipally-supplied domestic gpcd for supplier (s)

$\boldsymbol{Q_s^{MSD}}$ = Total municipal supply demand quantity for supplier (s)

$\boldsymbol{P_s^{MS}}$ = Population served by municipal supply for supplier (s)

Step 2: Determine the Need for Additional Information

Following the calculation of supplier municipally-supplied domestic per capita use rates as outlined in Step 1, the results will be analyzed and compared to typical rates of use range as seen in other parts of the state and country. A typical range has been shown to be significantly influenced by the size of the domestic population served; however, for planning purposes, a typical range has been determined to be between 75 and 200 gallons per person per day (independent analysis of per capita use by W.Y. Davis, unpublished). This range may be modified to a more suitable range based upon information and input from water suppliers in the state if necessary. Supplier domestic per capita values outside of the aforementioned range will be further investigated for information to identify the cause of any anomaly. Investigations may involve discussions with ANRC staff, interviews of pertinent water providers, or other appropriate means.

Step 3: Adjust Raw Municipally-Supplied Domestic Per Capita Rate of Use Based on Available Information

For those suppliers determined to be outside of a typical per capita rate of use range, the information gathered in Step 2 will be used to adjust the municipally-supplied domestic gpcd. The adjusted gpcd will serve as the supplier baseline municipally-supplied domestic gpcd. All adjustments to raw county per capita rates will be documented and tracked in a Microsoft Excel spreadsheet.

Step 4: Calculate the Weighted County Domestic Per Capita Rate of Use

Using the adjusted supplier domestic per capita rates of use developed in step 3, the next step is to derive a weighted county domestic per capita rate of use. For each supplier in a given county, its adjusted domestic per capita rate of use will be weighted by its population served to calculate a weighted domestic per capita rate of use for each county.

Step 5: Passive Conservation Adjustment

The baseline weighted county domestic per capita rates of use will be adjusted in future forecast years to account for efficiency gains associated with the replacement of water-using fixtures with more efficient models. The 1992 Energy Policy Act requires that all homes built or remodeled after January 1, 1994 install 1.6 gallons per flush (gpf) toilets, 2.2 gallon per minute (gpm) faucets, and 2.5 gpm showerheads. Thus, average domestic per capita rates of use are expected to decrease in the future due to the increased prevalence of these more efficient fixtures if all else remains the same.(Note: in some areas of the country, increased use of automatic sprinkler systems have offset the water savings of indoor fixtures.)

U.S. Census Bureau housing stock data identifying the year built and number of bathrooms of each county's housing stock will be used in conjunction with standard assumptions for the rate of replacement of existing fixtures; number of toilets, showers, faucets, and persons per household; and the number of flushes and showers per person per day to derive an estimate of the future decrease in demand attributable to the increased number of more efficient fixtures in each county.

2.2 Non-Revenue Water

Public supply utilities report annual water losses to the WUDBS. These losses are also referred to as NRW. NRW includes water losses during the treatment and distribution of water. Thus for each utility and each county, the average percent of total withdrawals that are lost through water treatment and distribution will be calculated. An average non-revenue percent will be derived for each county and used in conjunction with future municipally-supplied domestic demand estimates to derive the total municipally-supplied domestic water demand. The assumed future county municipally-supplied percent non-revenue may be adjusted to account for planned or expected system improvements as identified by stakeholders.

2.3 Municipally-Supplied Domestic Demand Calculation

Future municipal-domestic water demands will be calculated as follows:

Equation 2:

$$Q_{c,y}^{MSD} = [\mathbf{rgpcd}_{c,y} \times P_{c,y}^{MSD}] \times [1 + (\mathbf{NRW}_c/(1 - \mathbf{NRW}_c))]$$

Where:

$\mathbf{Q_{c,y}^{MSD}}$ = Municipal-domestic water demand including system losses in county (c) in year (y)

$\mathbf{rgpcd_{c,y}}$ = Weighted average domestic per capita rate of use in county (c) and in year (y)

$P_{c,y}^{MSD}$ = Population supplied by public systems in county (c) in year (y)

$\mathbf{NRW_c}$ = Percent system losses in county (c)

In the equation above, each county's baseline per capita rate of water use is derived from the WUDBS. Each public supplier's municipal-domestic gpcd is calculated using these withdrawal data. The county per capita rate of municipal-domestic demand is the weighted average of all suppliers' gpcds in the county. To derive the county gpcd, each supplier's gpcd is weighted by its population served. The baseline weighted county gpcd will be multiplied by county population served to compare the baseline annual withdrawal amount to the total WUDBS withdrawal amount.

2.4 Municipally-Supplied Domestic Forecast Scenarios

As mentioned above, county population projections will drive the county municipally-supplied domestic water demand forecast. Three sources of county population projections have been identified heretofore. Each set of projections provides a different projection of future county population growth in Arkansas. The three sources are:

- University of Arkansas Institute for Economic Advancement (AIEA) (through 2030)
- Woods & Poole Economics, Inc. (through 2040)
- ANRC Water Resources Development Division (through 2050)

Figure 1 shows the statewide population projections by source from 2010 through 2050. Dashed lines in the chart represent a linear extrapolation from the end year of the published projections to 2050.

Of the three population projections shown in Figure 1, the Woods & Poole projections show the largest statewide 2050 population and the ANRC Water Resources Development Division shows the lowest statewide 2050 population. The resulting range of 2050 statewide population projections is 768,573.

For planning purposes, the county population projections comprising the statewide projections presented in Figure 1 will be used to develop three municipally-supplied water demand forecast scenarios. These scenarios will be characterized as "High Growth" (Woods & Poole), "Medium Growth" (AIEA), and "Low Growth" (ANRC). It should be noted that while the terms “High Growth”, “Medium Growth” and “Low Growth” are used to describe the three statewide population projection scenarios, that not all counties within the state will experience population increases under these scenarios. Some counties may experience declines in population under particular scenarios. If county population decreases into the future, municipal-domestic water demand will decrease accordingly. Final demand forecast documentation will provide county-level population projection tables to illustrate population projections for each county under each scenario. Forecasted municipally-supplied domestic water demands derived using these three population projections will allow for a range of potential municipally-supplied water demand to be analyzed for water resources decision-making.

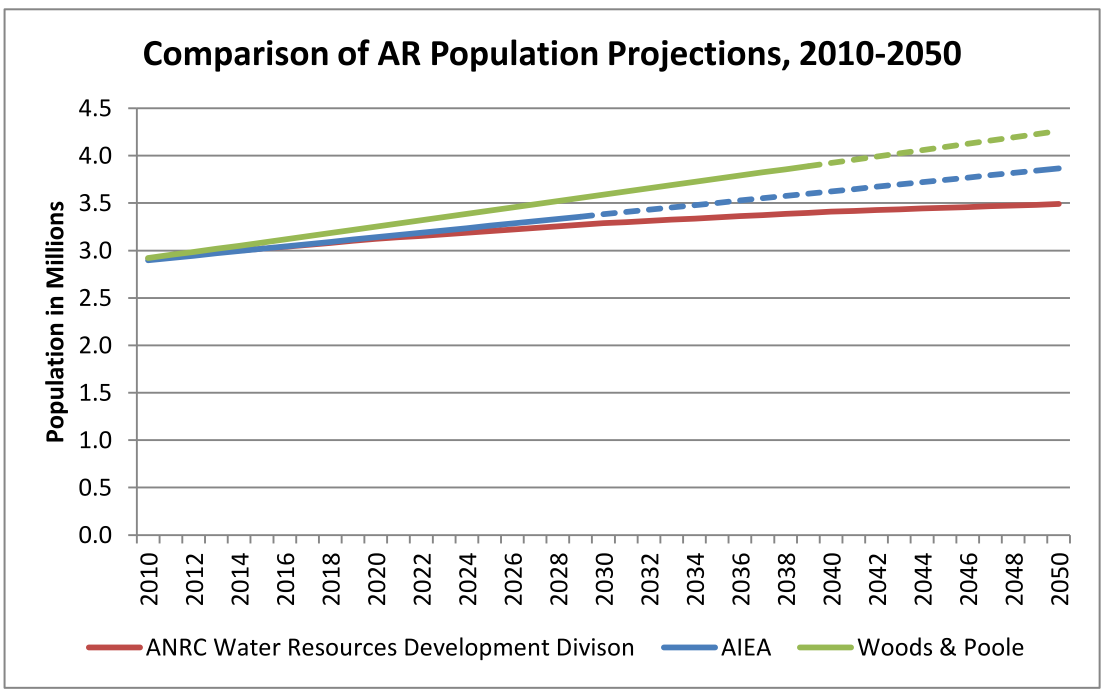

Figure 1. Statewide Population Projections

3.0 Municipally-Supplied Non-Domestic Sector Demand Forecast

Municipally-supplied non-domestic water use refers to water use by all municipally-supplied customers other than residential housing such as office buildings, retail centers, schools, churches, hotels, industry, etc. The municipally-supplied non-domestic water demand forecast captures the water use from all municipally-supplied non-domestic establishments. Self-supplied non-domestic water use will be forecast separately.

The data and methodology for the municipally-supplied non-domestic demand forecast is discussed in the following sections.

3.1 Municipally-Supplied Non-Domestic Water Use

As part of the Water-Use Registration Program, public supply utilities are asked to report the number of accounts and the volume of water delivered to industrial, commercial, and mining customers. These data are entered into the WUDBS. Therefore, for each utility, the available data will allow for the disaggregation of not only domestic and non-domestic municipally-supplied water use but also further disaggregation of non-domestic water use by customer type. Incomplete data from the WUDBS regarding the percent of municipally-supplied water delivered to non-domestic users will be substituted using average ratios of non-domestic deliveries to total deliveries for other suppliers in the county.

Using the available data in the WUDBS, the non-domestic water use by customer type for each utility will be summed by county to derive the base year county municipally-supplied non-domestic water use for commercial, industrial, and mining customers. Multiple years of data will be analyzed to ensure that both dry year and wet year effects are taken into consideration.

3.2 Employment Data

Total county employment data will be used to estimate the employment associated with the baseline municipally-supplied non-domestic water use. U.S. Census Bureau County Business Pattern (CBP) data will be used to identify the number of establishments and employment by employment group (North American Industrial Classification System [NAICS] groups) for each county. The total employment by NAICS in the county will be divided by the number of establishments by NAICS in the county to derive the average employees per establishment for each NAICS group in each county. The number of employees by NAICS for each county will then be estimated for those establishments that are municipally-supplied and those establishments that are self-supplied.

The WUDBS maintains records for self-supplied industrial and commercial water users in the state and these records include an employment group (Standard Industrial Classification (SIC)) code.[4] An SIC code can be easily translated into a NAICS code. Therefore, the number of permits by employment group in each county will be subtracted from the total number of employment group establishments in that county as derived from the CBP. The difference is the assumed number of employment group establishments in the county that are municipally-supplied. Using the average number of employees by establishment for each NAICS group in each county, the number of municipally-supplied and self-supplied employees will be estimated.

The estimate of current municipally-supplied employment by NAICS group for each county is as follows:

Equation 3:

$$E_{NAICS,c}^{MSND} = \left(\frac{Emp_{NAICS,c}}{Est_{NAICS,c}}\right) x \left(Est_{NAICS,c} - WUDBS_{NAICS,c}\right)$$

Where:

$E_{NAICS,c}^{MSND}$ = Municipally-supplied non-domestic employment for NAICS group in county (c)

$Emp_{NAICS,c}$ = Total employment for NAICS group in county (c)

$Est_{NAICS,c}$ = Total number of establishments for NAICS group in county (c)

$WUDBS_{NAICS,c}$ = Total WUDBS permits for NAICS group in county (c)

It should be noted that for some counties, the number of employees and/or number of establishments by NAICS may not be available to avoid disclosing data for individual companies. In these cases, the U.S. Census Bureau provides a range of employees and establishments. When data for a particular county are undisclosed, the midpoint of the given range will be used to estimate number of establishments and/or number of employees by NAICS group.

3.3 Employment Projections

The municipally-supplied non-domestic water demand forecast is driven by economic activity. A common metric used to represent economic activity and drive future non-domestic water demand is employment. Employment projections through 2018 developed by the Arkansas Department of Workforce Services for 10 Local Workforce Investment Areas (WIAs) will drive future municipally-supplied non-domestic water demands.[5] Each WIA consists of between 5 and 12 counties, with the exception of the City of Little Rock, which is its own WIA. These projections are developed for 6-digit NAICS groups.

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[4] Note that the SIC was replaced by the NAICS in 1997.

[5] The Arkansas Department of Workforce Services released statewide employment projections through 2020 in October 2012. County-level projections by industry type will be incorporated into the AWP Update water demand forecast once they are made available online.

For each WIA, employment projections will be disaggregated to the county level and for each industry group. First, current employment by NAICS group will be estimated for each county in each WIA using U.S. Census Bureau CBP data. Next, the ratio of current employment by county for each NAICS group to total employment by NAICS group of all counties within its respective WIA will be calculated. This ratio is assumed to remain constant through 2018 and will be applied to the WIA employment projections by NAICS to derive the projected county employment by NAICS group. That is to say the 2018 WIA employment projections by industry type will be allocated to each county within that WIA based upon each county's baseline (i.e., 2010) ratio of NAICS group employment to total 2010WIA NAICS group employment.

Beyond 2018 (to 2050), employment for each NAICS group will be assumed to grow in direct proportion to county population projections. That is, the ratio of county employment by NAICS group to county population as projected for 2018 will remain constant after 2018 through the 2050 planning horizon. If better information concerning employment growth (i.e., known major industry locating to the county, etc.) by NAICS category is available for a particular county, that data will be incorporated into the employment projections.

The county-level employment projections by NAICS through 2050 derived using the process outlined above will be used to drive both the municipally-supplied non-domestic and self-supplied industrial and commercial water demand forecasts. For each forecast sector, baseline demands will increase or decrease based upon the projected rates of growth or decline in employment within each county. The following section describes the demand calculation for the municipally-supplied non-domestic demand sector.

3.4 Municipally-Supplied Non-Domestic Demand Calculation

The WUDBS database does not allow for further disaggregation of municipally-supplied water deliveries beyond the customer type. Thus, municipally-supplied water use by NAICS for each county cannot be accurately estimated using this data set. Baseline demands will be estimated for municipally-supplied industrial and commercial water uses. These baseline demands will be forecast to increase or decrease using employment projections for broad categories rather than for individual NAICS groups. For the baseline municipally-supplied industrial water demands, forecast withdrawals will increase or decrease according to the rate of growth in each county's overall manufacturing employment (NAICS 311 through 339). For the baseline municipally-supplied commercial water demands, forecast withdrawals will increase or decrease according to the rate of growth in each county's non-manufacturing employment (all NAICS except manufacturing).

Based upon the data and methodology presented above and the discussion of NRW in Section 2.2, the municipally-supplied industrial demand will be calculated as follows:

Equation 4:

$$Q^{MSI}_{c,y} = [\ (Baseline^{Industrial}_{c,y} \text{ x } E^{Mfg}_{c,y})] \text{ x } [1 + (NRW_c/(1\text{-}\ NRW_c))]$$

Where:

$Q^{MSI}_{c,y}$ = Municipally-supplied industrial water demand including system losses in county (c) in year (y)

$Baseline^{Industrial}_{c,y}$ = Baseline municipally-supplied industrial water demand in county (c) and year (y)

$E^{Mfg}_{c,y}$ = Manufacturing employment rate of growth in county (c) and year (y)

NRW_c = Percent system losses in county (c)

Municipally-supplied commercial demand will be calculated as follows:

Equation 5:

$$Q^{MSC}_{c,y} = [(Baseline^{Commercial}_{c,y} \text{ x } E^{Non-Mfg}_{c,y})] \text{ x } [1 + (NRW_c/(1\text{-}\ NRW_c))]$$

Where:

$Q^{MSNR}_{c,y}$ = Municipally-supplied commercial water demand including system losses in county (c) in year (y)

$Baseline^{Commercial}_{c,y}$ = Baseline municipally-supplied non-domestic water demand by customer type in county (c) and year (y)

$E^{Non-Mfg}_{c,y}$ = Non-manufacturing employment rate of growth in county (c) and year (y)

NRW_c = Percent system losses in county (c)

Municipally-supplied mining demand will be calculated as follows:

Equation 6:

$$Q^{MSM}_{c,y} = [(Baseline^{Mining}_{c,y} \text{ x } E^{Mining}_{c,y})] \text{ x } [1 + (NRW_c/(1\text{-}\ NRW_c))]$$

Where:

$Q^{MSM}_{c,y}$ = Municipally-supplied mining water demand including system losses in county (c) in year (y)

$\boldsymbol{Baseline_{c,y}^{Mining}}$ = Baseline municipally-supplied mining water demand by customer type in county (c) and year (y)

$\boldsymbol{E_{c,y}^{Mining}}$ = Mining employment rate of growth in county (c) and year (y)

$\mathbf{NRW_c}$ = Percent system losses in county (c)

3.5 Municipally-Supplied Non-Domestic Forecast Scenarios

Since the future employment of each county after 2018 is assumed to grow in direct proportion to county population projections, the municipally-supplied non-domestic forecast will also be developed for three scenarios based upon the population projections available. Thus three employment projection scenarios will be generated. These scenarios will exhibit growth or decline by county at the same rates as the population projections.

It should be noted that employment projections account for the number of employees by place of employment, not by place of residence. Thus, county-level employment estimates are assumed encompass workers living in another county or another state. Applying the county-level population projection growth trends to the county-level employment simply uses the most appropriate available metric for extrapolating county employment through the planning horizon. The method of extrapolating future employment estimates may be revised based upon stakeholder and Work Group input.

4.0 Self-Supply Domestic Sector Demand Forecast

The self-supplied domestic sector is comprised of those residential water users not connected to a municipal supply system and who obtain water from individual wells. In Arkansas, these users are exempt from the Water-Use Registration Program because they do not have the capability to pump 50,000 gpd of groundwater. Consequently, water use data for these users are not available from this program. In 2005, USGS estimated that about 199,000 people (about 7 percent of the state's total current population) were categorized as self-supplied domestic water users.

4.1 Baseline per Capita Water Use

For planning purposes, it is assumed that self-supplied domestic water users use water at the same rate as municipally-supplied domestic water users within their respective county. Thus the county domestic per capita rates of use developed for the municipally-supplied domestic forecast discussed in Section 2 above will be applied to the self-supplied domestic population to estimate a baseline self-supplied domestic water demand and to forecast future self-supplied domestic water demand. *The baseline self-supplied county population is calculated as the difference between the U.S. Census Bureau 2010 county population estimate and the Arkansas Department of Health 2010 county population served by public suppliers estimate.*

4.2 Population Projections

The population projection scenarios presented in Section 2.4 will also be applied to the self-supplied domestic water demand forecast. *Self-supplied population for each county is calculated as the difference between total county population and population served by public suppliers in the county.* An analysis of the percent of total population that is self-supplied by county from 1990 to 2010 will be performed to understand trends in the portion of county population that is self-supplied. USGS data will inform this analysis. The trend observed over this period will be applied to county population projections to account for a growing or declining self-supplied population in the future. The average annual rate of growth or decline in county self-supplied population will be applied to the county population projections for each forecast year moving forward from the base year.

4.3 Self-Supply Domestic Water Demand Calculation

As with the municipally-supplied domestic water demand forecast, population projections will drive future self-supplied domestic water demands. The baseline per capita rates of use by county will be multiplied by projections of self-supplied population by county as described in the section above to derive forecast self-supplied domestic water demands for each county. The future self-supplied domestic water demand will be calculated using the following formula:

Equation 7:

$$\boldsymbol{Q_{c,y}^{SSD}} = [\mathbf{rgpcd_c} \text{ x } (\boldsymbol{P_{c,y}} - \boldsymbol{P_{c,y}^{MS}})]$$

Where:

$\boldsymbol{Q_{c,y}^{SSR}}$ = Self-supplied domestic water demand in county (c) in year (y)

$\mathbf{rgpcd_c}$ = Weighted average domestic per capita daily water use in county (c) and year (y) from municipally-supplied domestic analysis

$\boldsymbol{P_{c,y}}$ **=** Population in county (c) in year (y)

$\boldsymbol{P_{c,y}^{MS}}$ = Population municipally-supplied in county (c) in year (y)

4.4 Forecast Scenarios

Three self-supplied domestic water demand forecast scenarios will be developed based upon the "High Growth," "Medium Growth," and "Low Growth" population projections presented in Section 2.4.

4.5 Passive Conservation Adjustment

The baseline county self-supplied domestic per capita rates of use will be adjusted in future forecast years to account for efficiency gains associated with the replacement of water-using fixtures with more efficient models. The 1992 Energy Policy Act requires that all homes built or remodeled after January 1, 1994 install 1.6 gpf toilets, 2.2 gpm faucets, and 2.5 gpm showerheads. Similar more recent standards have been established for clothes washers. Thus, average domestic per capita rates of use are assumed to decrease in the future due to the increased prevalence of these more efficient fixtures.

U.S. Census Bureau housing stock data identifying the year built and number of bathrooms of each county's housing stock will be used in conjunction with assumptions for the rate of replacement of existing fixtures; number of toilets, showers, faucets, and persons per household; and the number of flushes and showers per person per day to derive an estimate of the future decrease in demand attributable to the increased number of more efficient fixtures in each county.

5.0 Self-Supplied Commercial and Industrial Sector Water Demand Forecast

Self-supplied commercial and industrial water users with the capability to withdraw 50,000 gpd of groundwater or 1 acre-foot per year (AFY) of surface water are required to report monthly water use to the ANRC under the Water Use Registration Program. Withdrawals reported by those users captured under the Water Use Registration will be used in deriving the baseline self-supplied commercial and industrial sector water demand for each county. The surface and groundwater sources of these baseline withdrawals will be identified and carried forward in the demand forecast. The source and/or location of future self-supplied commercial and industrial withdrawals are assumed to remain unchanged into the future. This assumption may be adjusted based upon input from stakeholders and Work Groups.

5.1 Self-Supplied Commercial and Industrial Employment by NAICS

As described in Section 3.2 above, the baseline number of employees by NAICS group for each county will be derived using CBP data. Often times, CBP data provides a range of county employment by NAICS to avoid disclosure of site-specific information in its published data. For instance, rather than providing the number of employees by NAICS in a particular county, the U.S. Census Bureau will use a letter coding system with each letter representing a range of employees. Thus, when these codes are the only data provided, actual employment is unknown and an assumption must be applied. For the purposes of estimating a baseline inventory of employees by NAICS for each county, the midpoint of the range provided is the assumed number of employees. For instance, if the range of employment for a NAICS code in a particular county is 50 to 100, then the assumed employment is 75. This baseline count of employment by NAICS for each county is important insofar as it is used to generate an average annual growth rate between a baseline estimate and a 2018 project produced by the Arkansas Department of Workforce Services.

5.2 Self-Supplied Commercial and Industrial Baseline Water Demand

The WUDBS will be used to establish a baseline water demand by NAICS and by source for each county. WUDBS water withdrawal data for self-supplied industrial and commercial permit holders from 2000 to 2009 has been made available to CDM Smith for this analysis. These data allow for an analysis of trends in withdrawals over a 10-year period and provide information as to which industry types are withdrawing water in which counties. Using these data, a baseline level of water demand by NAICS for each county will be derived. This demand will be determined using a 3-year average of withdrawals. Using a multi-year average will serve to account for the annual variation in withdrawals that may exist due to a variety of external factors including climate and market fluctuations. Thus a 3-year average withdrawal is less likely to be influenced by anomalous conditions that may lead to higher or lower than normal withdrawal rates.

5.3 Self-Supplied Commercial and Industrial Water Demand Calculation

The baseline withdrawals by NAICS for each county derived using the data and processes described above along with the available employment and population projections will be used to derive the total self-supplied commercial and industrial water demand for each county. These demands will be summarized by county and by source of water within each county. The baseline NAICS group withdrawals by county will be multiplied by the corresponding county NAICS employment rate of growth projections to derive a county-level forecast demand by NAICS. The Arkansas Department of Workforce Service's employment projections by county and by NAICS, as derived from WIA projections, will drive demand through 2018. Following 2018 the ratio of employment to population will be assumed to remain constant and total county employment will grow or decline at the same rate of projected population. It is also assumed that the proportion of employment by NAICS for each county to total county employment will remain constant as county employment grows or declines in the future.

The future self-supplied commercial and industrial water demand will be calculated as follows:

Equation 8:

$$\boldsymbol{Q_{c,y}^{SSC\&I}} = [\Sigma(\boldsymbol{Baseline_{c}^{NAICS}\,x\;E_{c,y}^{NAICS}})]$$

Where:

$\boldsymbol{Q_{c,y}^{SSC\&I}}$ = Self-supplied commercial and industrial water in county (c) and year (y)

$\boldsymbol{Baseline_{c}^{NAICS}}$ = Baseline withdrawal by NAICS group in county (c)

$\boldsymbol{E_{c,y}^{NAICS}}$ = Self-supplied commercial and industrial employment rate of growth by NAICS group in county (c) and year (y)

5.4 Disaggregation and Summarization of Self-Supplied Commercial and Industrial Water Demands

The county self-supplied commercial and industrial water demands calculated using the formula above may be summarized in a variety of ways. The portion of demands by NAICS group by water source (surface water or aquifer unit) will be maintained so that forecast water demands by industry type can be summarized by surface water source or aquifer unit at the county level, the Planning Region, or statewide. Furthermore, total self-supplied commercial and industrial forecast water demands by source can also be summarized by surface water source or aquifer unit at the county level or statewide.

5.5 Self-Supplied Commercial and Industrial Water Demand Scenarios

Similar to the municipally-supplied non-domestic forecast described in Section 3 above, the self-supplied commercial and industrial forecast will be presented under three growth scenarios. These rates of growth correspond to the three population projection scenarios presented in Section 2 above: "Low Growth," "Medium Growth," and "High Growth." Thus three employment projection scenarios will be generated to drive future self-supplied commercial and industrial demand. After 2020, these employment projection scenarios will exhibit growth or decline by county at the same rates as the corresponding population projections for each county.

6.0 Agricultural Sector Water Demand Forecast

Agricultural water demands represent a significant percent of statewide water withdrawals; irrigation alone accounted for 92 percent of groundwater withdrawals in 2005 (Holland 2007). Agriculture irrigation and livestock production support an important economic sector in the state, accounting for 10 percent of the gross domestic product (GDP), adding $17 billion in value in 2009 (UA 2011). Nationwide, Arkansas is the #2 producer of meat-type chickens, with a 2011 inventory of over 200 million birds, and the #1 producer of rice, with acres totaling 1.33 million in 2011 (USDA 2011). Agriculture is a key economic sector that relies on a stable water supply for its success.

Current and future agriculture demands will be estimated for the planning horizon by county for two major sub-sectors—livestock and crop irrigation—which will be further quantified based on available data and level of demand. A description of the proposed methodology for these sub-sectors is provided below including a description of the data sources, assumptions, and proposed draft scenarios. Estimating water demand for agriculture users, both currently and in the future, will require close coordination with ANRC, stakeholders, and Work Groups.

6.1 Livestock

Livestock require water for animal nutrition, animal cooling, sanitation, and waste removal. Current estimates of livestock demands will be based on the major livestock groups in Arkansas and their respective daily water requirements. Major livestock groups to be evaluated include cattle, dairy cows, sheep, hogs, horses, poultry, and aquatic species.

As many livestock water withdrawals fall below the ANRC threshold for reporting, alternate data sources and a theoretical model will be utilized to estimate livestock water use by county. The annual livestock water demand for a given forecast year will be calculated by multiplying the daily water requirement for each group by the count of livestock in the county and then the number of days in a year. The annual demand in gallons is then converted to AFY. This computation is as follows:

Equation 9:

$$QLS_{c,y}^{AFY} = \frac{LSC_{c,y}^{n} \ x \ DWR^{n} \ x \ 365}{321{,}851}$$

Where:

$\mathbf{QLS_{c,y}^{AFY}}$ = Livestock water demand in AFY in county (c) in year (y)

$\mathbf{LSC_{c,y}^{n}}$ = Livestock count for animal group (n) in county (c) and year (y)

$\mathbf{DWR^{n}}$ = Daily water requirement per animal (n)

To verify the base year of the model, data on livestock water withdrawals available from the most recent USGS water use report will be compared against the livestock water projections developed using the above formula.

A number of data sources will be utilized to collect the information needed to forecast livestock demand. An accurate estimate of livestock counts by county is needed for the projections, including historical counts, current counts, and future counts. Water withdrawal requirements are needed for each of the livestock groups.

6.1.1 Livestock Inventory

The Census of Agriculture (Ag Census), taken every 5 years by the U.S. Department of Agriculture (USDA), is a complete count of U.S. farms and ranches and the people who operate them. The most recent Ag Census was completed in 2007 and an updated count will be conducted at the close of 2012. The Ag Census reports on livestock counts by county, as well as many other areas. This source will be examined for appropriateness of use for assessing the current levels of livestock by county in Arkansas as well as for reviewing historical trends. Additional sources of livestock data will be sought if needed, such as the University of Arkansas, Division of Agriculture, Conservation District offices, and the USDA National Agricultural Statistics Service (NASS) program.

Once an accurate estimate of livestock counts by county are obtained for the historical and current period, trends in the data will be assessed. This information, along with input from the stakeholder and Work Groups, will be used to determine a reasonable estimate of livestock counts through the planning horizon. It may be necessary to conduct academic research into the future trends in the dairy, cattle, hog, and chicken farming industries and its implications for Arkansas producers.

6.1.2 Daily Animal Water Requirement

To complete the livestock water demand projections, data on daily animal water requirements will be obtained from the USGS Method for Estimating Water Withdrawals for Livestock in the U.S. (USGS 2005). Daily water requirements for each livestock group include that used for drinking water, cooling, and sanitation and waste removal requirements. In order to verify that the USGS per animal estimates are reasonable for the Arkansas State Water Plan, input will be sought from the stakeholder and Work Groups. The daily animal water requirement by livestock group will be assumed constant throughout the planning horizon.

6.1.3 Livestock Use by Water Source

The 2005 USGS reported livestock use by county by source will be used to aggregate total county livestock withdrawals by water source (groundwater or surface water). The percentage of groundwater/surface water to total use will be assumed constant for the planning horizon unless evidence exists that these patterns may change in the future.

6.1.4 Future Scenarios

The livestock water demand forecast through 2050 will be produced for two scenarios, as informed through a literature search and finalized by the stakeholder and Work Groups. One scenario will assume that current trends in meat and dairy consumption will persist both globally and within the U.S. This scenario will assume increases in Arkansas livestock production. A second scenario will assume meat and dairy consumption begins to decline per capita and thus production does not increase but will remain constant as more population grows. Thus, with levels of livestock production assumed to remain constant, it is assumed that livestock water demands will also remain constant through the planning horizon under this scenario.

6.2 Crop Irrigation

Approximately 4.5 million acres of crop land are irrigated in Arkansas. As of the 2007 Census of Agriculture, 42 percent of those acres were planted in soybeans, 30 percent in rice, 16 percent in cotton, and 11 percent in corn (for grain). These crops have differing water requirements, with rice being the most water intensive, followed by cotton and corn, and then soybeans. Many factors drive the amount of water applied to crops in a given year to support crop production: the crop type, the on-farm irrigation system used, temperature, the amount of rainfall received, water availability, and producer financial resources.

A basic methodology will be employed to estimate irrigation water demands now and in the future by county that captures the driving forces. The basic methodology is total irrigated acres times the weighted average crop irrigation water requirement (WCIR) per irrigated acre by county, as shown in the equation below and further discussed below.

Equation 10:

$$\boldsymbol{Q_{c,y} = IA_{c,y} \times WCIR_{c,b}}$$

Equation 11:

$$\boldsymbol{WCIR_{c,b} = \left(\sum_{n}^{i}\left(IA_{c,b}^{Crop_i} \times CIR_{c}^{Crop_i}\right)\right) \Big/ IA_{c,b}}$$

Where:

$\mathbf{Q_{c,y}}$ = Total crop irrigation requirements in AFY in county (c) in year (y)

$\mathbf{IA_{c,y}}$ = Total irrigated acres in county (c) in year (y)

$\mathbf{WCIR_{c,b}}$ = Weighted crop irrigation requirement in county (c) in base year (b) (2010)

$\mathbf{IA_{c,b}^{Crop_i}}$ = Irrigated acres in crop (i) in county (c) in base year (b) (2010)

$\mathbf{CIR_{c}^{Crop_i}}$ = Irrigation water required per acre in AFY for crop (i) in county (c)

$\boldsymbol{IA_{c,b}}$ = Total irrigated acres in county (c) in the base year (b) (2010)

The WCIR captures annual water demands for irrigation considering the unique mix of crop type, crop irrigation requirements, and precipitation for each county.

A final step is taken to adjust the irrigation water demands to capture on-farm losses from irrigation distribution systems, over watering behaviors, and other inefficiencies. These losses need to be considered when estimating total irrigation water withdrawals. Estimating losses separately allows for adjustments in the calculations as irrigation efficiencies assumptions change in future years. The formula for adjusting total crop irrigation requirements to account for field application efficiencies is as follows:

Equation 12:

$$\mathbf{GrossQ_{c,y} = Q_{c,y}/WFAE_{c,b}}$$

Where:

$\mathbf{GrossQ_{c,y}}$ = Gross water requirement for irrigation in AF in county (c) in year (y)

$\mathbf{Q_{c,y}}$ = Total crop irrigation requirements in AF in county (c) in year (y)

$\mathbf{WFAE_{c,b}}$= Weighted field application efficiency in county (c) in base year (b)

The gross irrigation water requirement thus includes the estimated crop irrigation water requirement plus water losses.

Determining the gross water requirement for irrigation now and in the future requires a number of data elements, as described below. A central data source will be the WUDBS. The ANRC collects and stores detailed information on water withdrawals for irrigation purposes in the WUDBS, including the crop type, number of irrigated acres, the irrigation method, total amount withdrawn, geographic location of the withdrawal, and source information. A time-series database of WUDBS data will be created to determine how irrigated acres by crop type and total acres have changed historically. WUDBS withdrawals for irrigation purposes will be grouped by county and summarized by crop type by month and a summary of the number of acres irrigated.

6.2.1 Irrigated Acres, Total and by Crop Type

Many factors drive a producer's decision as to which crop to plant under an irrigation system and how many acres to have under irrigation in total. These deciding factors must be carefully considered when forecasting irrigated acres by crop type in the future. The WUDBS data will be analyzed by county to assess any historical trends in total irrigated acres by county and the unique mix of crops and acreage under irrigation. The factors driving any noted trends will be carefully investigated and considered. A reasonable estimate of future irrigated acres will be determined by working closely with the stakeholder and Work Groups to estimate which trends may hold true in the future or what new trends may be experienced. As needed, a number of scenarios may be developed to explore an uncertain future condition.

As an example, consideration will be given to acres taken out of production and put into the USDA's Conservation Reserve Program (CRP) or the Wetland Reserve Program (WRP) and how changes in these programs have impacted irrigated acres historically and may impact it in the future. Also, increasing producer wealth and profitability in irrigated agriculture may drive additional irrigation in the future. Declines in groundwater levels may change irrigated acres in some areas or may change the type of crop planted in an irrigation scheme. Corn for grain has a higher water requirement when compared to other row crops such as soybeans. From 2011 to

2012, the number of acres planted in corn increased by 34 percent statewide, likely in response to high commodity prices for corn. These factors, along with others as identified by the stakeholders or Work Groups, will be considered in determining a reasonable estimate of irrigated acres, both total and by crop type, in the future.

The Agricultural Census and/or NASS statistical data for irrigated acres by commodity type and county will be compared against the WUDBS summary data to verify accuracy of the reported data. Data will be supplemented as needed.

6.2.2 Irrigation Requirement by Crop Type

Monthly crop irrigation water requirements (variable $CIR_c^{Crop_i}$ in Equation 9) for average weather years will be obtained for the crop types that are irrigated in Arkansas. The variable "crop irrigation requirement" represents what is needed by the crop minus effective rainfall. According to the 2007 USDA Agricultural Census, the following crop types were irrigated in Arkansas in 2007: corn for grain, cotton, rice, sorghum for grain, and wheat for grain[6]. A complete list of irrigated crops will be extracted from the WUDBS and checked against the Ag Census results. The WUDBS does provide the number of acres, water applied, and crop type, which may be used to derive an irrigation application by crop type. However, these values represent what the producer is applying to the scheme in a given month, under the particular weather conditions, with the irrigation system at hand and not what is required by the crop under average conditions as is needed for planning.

Crop irrigation requirements are available for rice and soybeans from the University of Arkansas Division of Agriculture, Research and Extension center (http://www.aragriculture.org/soil_water/irrigation/crop/default.htm). The website notes that irrigation requirements will be available for corn, cotton, and grain sorghum in the future. Additionally, the University of Arkansas Division of Agriculture Cooperative Extension Service has published crop production handbooks for corn and grain sorghum that provide guidelines for growing season water needs in Arkansas. Additional sources of crop irrigation requirements will be sought as needed. The values may be developed regionally if significant rainfall variations exist across the state.

Irrigation requirements by crop type will be assumed constant throughout the planning horizon unless significant evidence exists that crop requirements for water will change in the future. A scenario where crops require less water to produce profitable yields is conceivable given the strides in genetically modified crops in the recent past, although current research focuses on drought tolerant varieties. Discussions with the Work Groups and stakeholders will finalize the assumption regarding crop irrigation requirements in the future.

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[6] Crop types with irrigated acres greater than zero.

6.2.3 System Efficiencies

Total water applied to an irrigation scheme is a summation of:

1. Water required by the crop minus seasonal local rainfall[7]
2. Water lost through evaporation
3. Water lost through the application process, such as runoff
4. Plus/minus the water that is actually applied in excess/shortage of what was required

Irrigation requirement (variable $CIR_c^{Crop_i}$ in Equation 11) covers item #1 above. The remaining items #2 through #4 constitute the system efficiency. Depending on the type of irrigation system in place, irrigation efficiencies range from 35 percent to 98 percent. Flood/surface irrigation efficiency is reported as high as 95 percent and as low as 35 percent, often depending on the grade of the field and the existence of canal lining materials. Sprinkler irrigation efficiency values are as high as 98 percent and as low as 60 percent, depending on the type of system used. Drip or micro-irrigation efficiencies range from 70 percent to 95 percent (Vickers 2001; Washington State Department of Ecology 2005). Given the range of efficiencies feasible throughout the state, data will be collected to determine more precise values for each county and the factors driving those values.

The WUDBS collects information on the irrigation method, although the level of detail is unknown at the time of this writing. Assuming that, at a minimum, the WUDBS distinguishes by flood/surface, sprinkler, and micro-irrigation, the WUDBS information will be used to determine the weighted field application efficiency by county. To achieve this calculation, the applied irrigation expressed in inches per acre (derived from the WUDBS annual crop reports) will be paired with annual total rainfall and the total seasonal crop water requirement. The efficiency will be calculated by first subtracting the effective rainfall from the seasonal water requirement. The remaining amount, representing water required by the crop to be supplemented by irrigation, will be expressed as a percent of actual applied. Percentages will be weighted by county based on total irrigated acres.

There is a great amount of uncertainty in future water withdrawals for agriculture based on irrigation system efficiencies and how it may change over time. Consider that on-farm water management decision tools, such as soil or plant moisture sensing devices, have been available for many years yet less than 10 percent of irrigated farms in the U.S. use them (USDA 2012). Substantial technological innovations have increased irrigation efficiencies over the past decades yet there is significant potential for continued improvement (USDA 2012). Research led by the USDA's Agriculture Research Service (ARS) showed that multiple-inlet rice irrigation (MIRI) systems required an average of 24 percent less irrigation water than conventional paddy flooding (http://www.ars.usda.gov/is/AR/archive/jan09/rice0109.htm). Given the likely strides in

[7] This component assumes that irrigators irrigate optimally. That is to say it assumes that irrigators will only irrigate to meet the crop water requirement and will curb irrigation withdrawals when precipitation is adequate.

irrigation efficiencies in the future and the adoption of new technologies and practices, two scenarios will be explored for weighted irrigation efficiencies by county. The first will characterize the most likely scenario for application efficiencies, assuming average producer technology adoption rates paired with technology already available on the market. The second will capture a scenario that assumes more aggressive adoption rates and ever improving technology.

6.2.4 Irrigation Use by Water Source

The WUDBS collects information on the irrigation withdrawal by source, which will be used to determine the surface water and groundwater percent of withdrawals by county. The ratio of groundwater/surface water to total use will be assumed constant for the planning horizon unless evidence exists that these patterns may change in the future.

6.2.5 Future Scenarios

The crop irrigation water demand forecast through 2050 will be produced for multiple scenarios, as informed and finalized by the stakeholder and Work Groups. These scenarios will explore the potential impacts of a range of future crop irrigation patterns in the state. Several key questions must be asked and discussed in order to arrive at the scenarios that will be developed for crop irrigation water demand forecasting:

1. What will influence future crop irrigation patterns in Arkansas?
2. What trends in crop irrigation are already being observed?
3. What will future crop irrigation patterns in Arkansas look like?
    a. More or less irrigated acres?
    b. More or less water-intensive crops?
    c. Regional considerations?
    d. Timing of transition(s)?
4. Beyond the major crop types listed above, what other specialty or small-acre crops need to be considered?

One likely scenario will assume baseline or expected growth coupled with a transition to less water intensive crops and aggressive improved efficiencies. The most water-intensive crop grown in Arkansas is rice. Under this scenario, it will be assumed that fewer irrigated acres (compared to current irrigated acres) are devoted to rice production in the future. As fewer irrigated acres are involved in rice production, those acres are replaced by less water-intensive crops, thus ultimately reducing crop irrigation water demands in those areas experiencing the transition. Which crops comprise this replacement, the number irrigated acres to experience transition, where this transition is most likely to take place, and the timing of the transition are all issues to be discussed as part of the stakeholder and Work Group process.

Another likely scenario will assume higher growth in irrigated crop production including water intensive crops such as rice and corn. Under this scenario it will be assumed that irrigated acres for rice and corn increase in the future. This scenario will illustrate the impact of higher rice and corn production, and thus higher irrigation withdrawals on statewide water resources.

The crop irrigation scenarios presented heretofore represent possible approaches and are not intended to reflect finalized scenarios for water demand forecasting. It is expected that the stakeholder and Work Group collaboration process will provide an opportunity for obtaining data and information as well as provide a forum for discussion to develop consensus-based crop irrigation water demand forecast scenarios.

7.0 Power Sector Water Demand Forecast

The thermoelectric water demand forecast will estimate future water withdrawal and consumption demands for thermoelectric power generation in Arkansas. Thermoelectric power production generally requires the burning of fossil fuels to produce heat and cooling water to produce steam to drive a turbine that generates electric power. Biomass can also be used to generate thermoelectric power. The thermoelectric power generation process, including the fuel type, prime mover (engine or turbine), and cooling type, influences the volume of water required to produce a unit of energy. Therefore, for each power generation combination (i.e., combination of fuel type, prime mover, and cooling type) in the state, future demands will be forecast separately to capture the unique water requirements of each.

Within the State of Arkansas there are 50 thermoelectric and hydroelectric facilities (NAICS 22 – Utilities). Total statewide generating capacity is about 2,400 megawatts (MW). In 2010 these facilities generated nearly 60,000,000 megawatt hours (MWh) of electricity (enough electricity to supply approximately 2.8 million homes). Table 1 below provides an inventory of the power generating facilities in the state.

7.1 Power Generation Projections

For the purposes of developing a power generation water demand forecast, future power generation in the state is assumed to grow based on regional electricity generation projections through 2035 as published in the 2012 Annual Energy Outlook (U.S. Energy Information Administration [EIA] 2012a). The EIA's power generation projections are developed by fuel type. Therefore, for each Electricity Market Module Region, the EIA develops power generation projections for the following fuel types:

- Coal
- Petroleum
- Natural Gas
- Pumped Storage/Other[8]
- Renewables[9]

[8] Other includes non-biogenic municipal waste.

The EIA develops power generation projections for 22 Electricity Market Module Regions in the United States (see **Figure 2** below). There are two Electricity Market Module Regions in Arkansas. Eastern Arkansas is in the Southwest Power Pool – South Region. The remainder of the state is located in the SERC Reliability Corporation – Delta Region. It is assumed that baseline power generation by fuel type of existing generating capacity in the state will increase according to the rate of growth in the corresponding Electricity Market Module Region Annual Energy Outlook projections. A base level of power generation will be derived through an analysis of EIA data for power generation by facility. It should be noted that not all power generated in Arkansas is consumed in Arkansas, making it a regional commodity influenced by regional demand and consumption projections and patterns. However, all power generated in Arkansas requires water from sources within the state's boundaries. Thus projecting future power generation needs for facilities within Arkansas based upon regional projections is an appropriate approach.

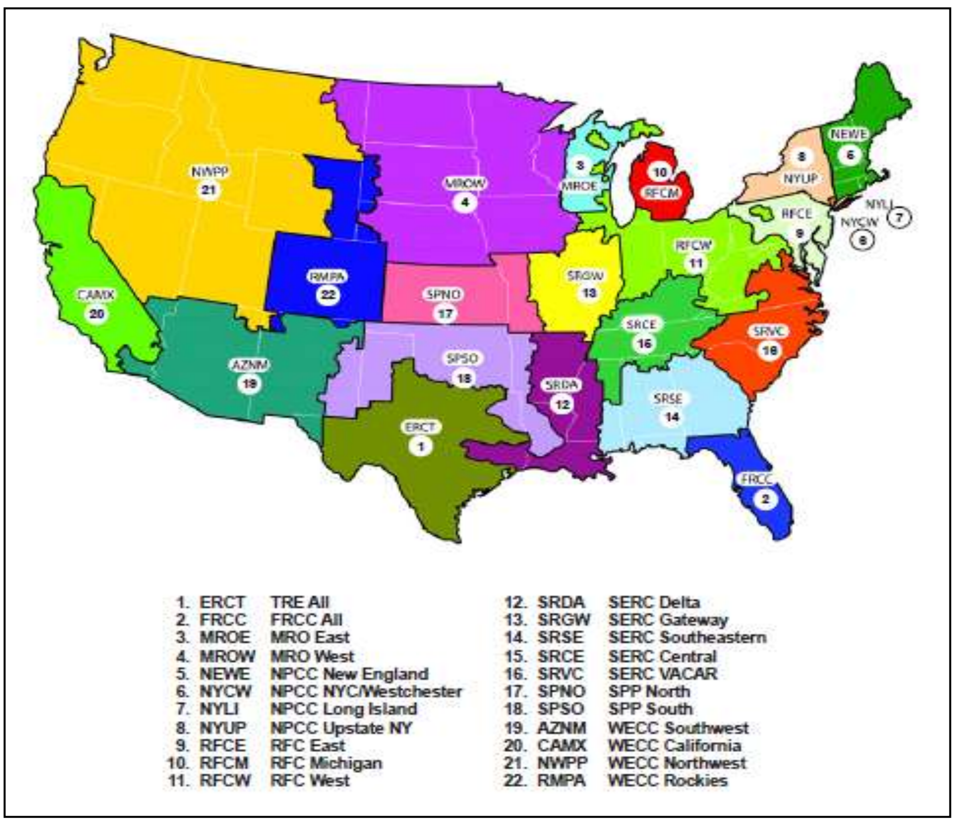

Figure 2. EIA Electricity Market Module Regions

[9] Renewables include conventional hydroelectric, geothermal, wood, wood waste, biogenic municipal waste, other biomass, solar thermal, photovoltaics, and wind power.

For existing (i.e., base year) power generation located within the Southwest Power Pool – South Region, future generation is assumed to increase or decrease based upon the rate of growth or decline for that Market Module Region. For existing power generation located within the SERC Reliability Corporation – Delta Region, future generation is assumed to increase or decrease based upon the rate of growth or decline for that Market Module Region. Applying these growth rate projections to existing generation by source results in a total statewide power generation need in the state in the future through 2035. For planning purposes, it is assumed that the average annual rates of growth for power generation as projected from the base year of 2010 through 2035 will continue through 2050.

7.2 Modeling Future Power Needs

Using EIA projections for power generation and data for existing statewide generating capacity, it will be determined if existing capacity will be sufficient to meet future generation needs. For water demand forecasting purposes, it is assumed that existing capacity will satisfy future statewide generation needs until the point of surpassing realistic sustainable capacity factors (i.e., the ratio of actual output over a period of time to potential output at full nameplate capacity) for the type of power generation (i.e., fuel type and cooling type mix). Realistic sustainable capacity factors depend on whether a facility is a base load facility, a load following plant, or a peaking plant. Maximum sustainable capacity factors by plant type will be determined based upon stakeholder and Work Group collaboration. The plant types for which these capacity factors will be developed are shown in **Table 1**.

Table 1. Power Generation Facility Types

Fuel Type	Prime Mover	Cooling Type
Fossil Fuel[1]	Steam Turbine	Once-Through
Fossil Fuel[1]	Steam Turbine	Closed-Loop
Natural Gas	Combined-Cycle	Closed-Loop
Nuclear[2]	Steam Turbine	Once-Through
Nuclear[2]	Steam Turbine	Closed-Loop
Water	Hydroelectric Turbine	N/A
Biomass	Steam Turbine	Closed-Loop

[1]Fossil fuels include coal, natural gas, and fuel oil.

[2] Arkansas Nuclear One plant has two generators. Generator 1, built in 1974, utilizes once-through cooling. Generator 2, built in 1980 utilizes recirculating cooling with natural draft cooling towers.

If existing capacity is not sufficient to satisfy projected generation needs, additional generating capacity will be assumed to become available in the demand forecast model when needed (i.e., when generation needs exceed available capacity at maximum sustainable capacity factors). Available credible information with respect to planned generating capacity in the state, its location, and likely source of water will be incorporated into the model if available. If projected generation needs are greater than currently available and planned capacity, assumptions of additional capacity, location, and source of water will be made based upon stakeholder input and best available data. In the absence of stakeholder input or credible data, water demands required to meet future power generation needs will be assumed to remain proportional to current distribution (by location and source).

Additionally, facility retirements will be considered when developing the water demand forecast model. EIA-860 data files include fields for the planned effective month and year of scheduled retirement for each generator. An initial review of the EIA-860 data did not show any scheduled generator retirements for generators in Arkansas, although it appears that these data fields are rarely populated. The stakeholder and Work Group process will seek to identify information related to generator retirements within the planning horizon.

7.3 Rates of Water Demand

Each thermoelectric facility requires water for cooling processes. The fuel type and method of cooling determines the volume of water required for these processes. Once-through cooling requires large water withdrawals with little consumption (i.e., water lost to the environment through evaporation). On the other hand, plants with closed loop or re-circulated cooling require relatively small withdrawals but consume a larger portion of those withdrawals due to evaporation. Thus, water withdrawals and consumption vary by power generation fuel type and cooling type combination.

For each fuel type and cooling type combination for thermoelectric facilities in Arkansas, an average rate of withdrawal and consumption will be calculated. These rates will be derived using reported water withdrawal data from the WUDBS and reported power generation data from the EIA. These statewide average rates will be compared to rates identified in the literature. Rates of withdrawal and consumption have been produced in recent research by the Energy Power Research Institute (EPRI) and the U.S. Department of Energy National Renewable Energy Laboratory (NREL). If rates of withdrawal and/or consumption deviate significantly from these industry rates, a suitable rate of withdrawal and/or consumption from the literature will be assumed.

7.4 Thermoelectric Power Water Demand Calculation

Projected power generation needs by fuel type and cooling type combination will be multiplied by the selected statewide metrics for withdrawal and consumption per unit of power generated to derive the water demand associated with those future power generation needs. The thermoelectric water demand will be calculated as follows:

Equation 13:

Withdrawals:

$$\boldsymbol{QW^{T}_{f,c,y}} = \Sigma\ [(\boldsymbol{G^{f}_{c,y}} \text{ x } \frac{\boldsymbol{W_f}}{\boldsymbol{Mwh}})]$$

Where:

$\boldsymbol{QW^{T}_{f,c,y}}$ = Withdrawals for facility combination (f) in county (c) in year (y)

$\boldsymbol{G^{f}_{c,y}}$ = Power generation needs for facility combination (f) in county (c) in year (y)

$\frac{\boldsymbol{W_f}}{\boldsymbol{Mwh}}$ = Withdrawal requirement per megawatt hour for facility combination (f)

The forecasted *withdrawals* for each combination will be summed to derive total thermoelectric water withdrawal demand at the county, planning region, and state levels.

Equation 14:

Consumption:

$$\boldsymbol{QC^{T}_{f,c,y}} = \Sigma\ [(\boldsymbol{G^{f}_{c,y}} \text{ x } \frac{\boldsymbol{C_f}}{\boldsymbol{Mwh}})]$$

Where:

$\boldsymbol{QC^{T}_{f,c,y}}$ = Consumption for facility combination (f) in county (c) in year (y)

$\boldsymbol{G^{f}_{c,y}}$ = Power generation needs for facility combination (f) in county (c) in year (y)

$\frac{\boldsymbol{C_f}}{\boldsymbol{Mwh}}$ = Consumption requirement per megawatt hour for facility combination (f)

The forecasted *consumption* for each combination will be summed to derive total thermoelectric water consumption demand at the county, planning region, and state levels.

7.5 Geographic Distribution of Thermoelectric Water Demand

The thermoelectric water demand forecast model will maintain the location and source of withdrawals and consumption associated with existing generating capacity facilities. Future water demands associated with the power generation at these existing facilities will be assumed to come from their identified sources (e.g., groundwater or surface water).

Water demands associated with power generation from *planned* facilities may be assumed to come from a source and location to be identified by industry stakeholders. An alternative to this assumption is the assumption that water demands required to meet projected generation needs beyond the capacity of existing and planned facilities will come from counties, Planning Regions, and sources proportional to the demands of existing and planned facilities in the forecast year prior to the need for this additional capacity. That is to say the total water demands associated with unplanned facilities will be calculated and then allocated to counties, Planning Regions, and sources based upon the proportional distribution of demands as estimated in the forecast year prior to the need for additional unplanned capacity. For instance, if additional unplanned capacity is not required in the forecast model to meet projected power generation needs until 2040, the water demands associated with the additional capacity added to the forecast model for 2040 will be allocated to counties, Planning Regions, and sources at the same proportion of the distribution of demands as evident in the 2030 forecast year. This assumption may be adjusted based upon credible stakeholder input.

7.6 Thermoelectric Water Demand Forecast Scenarios

Electricity Market Module Region generation projections as published in the 2012 Annual Energy Outlook are presented under three economic growth scenarios—Low Economic Growth, Reference Case, and High Economic Growth. These scenarios are defined as:

- Reference Case – "Business as usual" given known technology and technological and demographic trends; current laws and regulations are maintained.
- Low Economic Growth – Assumes lower growth rates for population and labor productivity, higher interest rates, and lower growth in industrial output, ultimately reducing demand for electricity.
- High Economic Growth – Assumes high growth rates for population and labor productivity, and lower inflation and interest rates, ultimately increasing demand for electricity.

As described above, projections are developed separately for six fuel types. The rates of growth/decline for each of these scenarios will be applied to baseline power generation by fuel type to develop three power generation scenarios—Low, Medium, and High. The water demands required to meet the power generation needs by fuel type for each of these power generation projection scenarios will be estimated and reported for the AWP Update.

7.7 Hydroelectric and Renewable Energy

In Arkansas, approximately 8 percent of the overall generating capacity and 6 percent of the power generated is produced by hydroelectric facilities.[10] The issue of water requirements for

[10] Based upon an analysis of 2005 - 2010 power generation data published in EIA Form 860.

hydroelectric power generation must consider the multiple uses for water stored in a reservoir such as flood control, recreation, thermoelectric power generation, and municipal water supply. Disaggregating the end use of hydroelectric dam water for these other purposes is not simple. Furthermore, the water requirements for generating a unit of electricity differs from site to site with the correlation of power generation to the volume water passing through the turbines dependent upon the height difference between the upstream and downstream water levels. As such, there is no standard range or rule of thumb to estimate a flow volume (e.g., gallons) per unit of hydroelectric power generated.

The rate of water consumption due to evaporation in storage reservoirs per unit of hydroelectric power generated has been analyzed by Torcellini (2003). This report found that the weighted average U.S. rate of water consumption per kilowatt-hour (kWh) of energy *consumed* is 18.27 gallons per kWh (0.01827 gallons per megawatt-hour [MWh]). An estimate specific to Arkansas was not developed for this report. Since reservoirs are often used for multiple purposes, not all of this evaporation can be associated with hydroelectric power generation. Thus, for planning purposes, this rate of evaporation will not be considered in estimating future hydropower water demands. Instead, water stored in reservoirs that is lost to evaporation will be considered as part of the water supply component of the AWP Update.

The EIA reports that in 2010, biomass supplied all of Arkansas' non-hydroelectric renewable energy electricity generation (EIA 2012b). EIA power generation projections indicate that renewable energy production will increase in most areas of the country over the next 20 years. However, which technologies will be adopted first and where they will be adopted is not well known. Thus, assumptions of most likely renewable energy sources in Arkansas will be developed with the assistance of Work Group and stakeholder input. Based on these assumptions and the rates of water withdrawal and consumption by renewable energy technology from the literature, water demands for renewable power generation will be estimated.

8.0 Mining Sector Water Demand Forecast

Water is used in many mining and oil and gas extraction activities including as a supplemental fluid in enhanced recovery of petroleum resources and during drilling and completion of an oil or gas well. In its pentennial water use reporting for Arkansas, USGS reports mining water use. This reported category of use includes water used for coal mining, sand and gravel washing operations, and saline withdrawals from oil and natural gas production wells.

The WUDBS will serve as an inventory of current demands by mining NAICS sub-group (NAICS category 21 is the Mining, Quarrying, and Oil and Gas Extraction group). The WUDBS contains data for mining water use as reported by water use permit holders in the mining sector. These reported withdrawals also include the SIC code of the permit holder. Therefore, historical WUDBS data will be used to determine the baseline portion of mining withdrawals by type of operation. These types of operations may include coal mining, sand and gravel mining, or natural gas production. It should be noted that mining water demand that is supplied by municipal suppliers is also tracked within the WUDBS. However, these demands are identified as a portion of supplier deliveries and detail with respect to the type of mining operation being served are not provided in the database. Therefore, municipally-supplied water deliveries for mining activities will be subtracted from the municipal-domestic sector and accounted for in the mining sector water demand forecast. However, the specific activities associated with these deliveries cannot be known with certainty.

8.1 Shale Gas Production

There has been rapid growth in natural gas exploration and related activities in the state in recent years. Technological advances in natural gas extraction using the hydraulic fracturing (fracking) process have led to significant drilling activity in the Fayetteville Shale play[11]. From 2008 to 2011, Fayetteville Shale natural gas production occurred in the following nine counties—Cleburne, Conway, Faulkner, Franklin, Independence, Jackson, Pope, Van Buren, and White (University of Arkansas 2012).

A recent report developed by the State Review of Oil & Natural Gas Environmental Regulations (STRONGER) reviewing the Arkansas Oil and Gas Commission's (AOGC) hydraulic fracturing program states that from 2008 to 2011 the ANRC has received about 1,500 permit applications for non-riparian water withdrawals to be used in hydraulic fracturing operations (STRONGER 2012). The state has issued around 900 active permits. The STRONGER (2012) report also states that ANRC and AOCG have indicated that no groundwater is used for make-up water for hydraulic fracturing operations in the Fayetteville Shale development area.

There are challenges in estimating both current and future water demands from the mining and oil and gas industry. Due to the rapid expansion and dynamic nature of certain mining and exploration activities, actual water use may not be fully reported. Furthermore, future levels of activity and location of activities are dependent on many factors including the national and regional economy, commodity prices, technological developments, and state, local, and national policies.

The EIA reports that production levels in major U.S. shale plays, including the Fayetteville, decline significantly after the first year of operation with about 65 percent of the estimated ultimate recovery (EUR) produced within the first 4 years and 100 percent of total EUR produced within

[11] The U.S. EPA defines hydraulic fracturing as a well stimulation process used to maximize the extraction of underground resources; including oil, natural gas, geothermal energy, and even water. The oil and gas industry uses hydraulic fracturing to enhance subsurface fracture systems to allow oil or natural gas to move more freely from the rock pores to production wells that bring the oil or gas to the surface. See the following website for additional information from the U.S. EPA:
http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/wells_hydrowhat.cfm.

20 years. Additionally, the EIA reports that as of January 1, 2010 the number of potential new wells in the entire Fayetteville shale gas play was 10,181.

Projecting future levels of activity in the Fayetteville Shale play presents its own challenges due to the uncertainty of factors that influence production. For instance, Fayetteville shale gas production levels are highly susceptible to natural gas prices. Natural gas prices have experienced decline since 2008 and these trends have resulted in a decline in the number of drilling permits in Fayetteville Shale counties (University of Arkansas, 2011). The volatile natural gas prices make projecting future trends in production highly uncertain.

8.2 Mining Sector Methodology

Due the uncertainties regarding future trends in the mining and oil and gas sectors, the type of mining/exploration activity will be forecast separately to account for projections of market trends specific to those activities. The EIA has projected natural gas production levels through 2035 by shale play. These projections have been developed for four growth scenarios—reference case (i.e., business as usual), low EUR, high EUR, and high technically recoverable resources (TRR). **Figure 3** provides an illustration of these four projection scenarios. For planning purposes, water demand for natural gas production in Arkansas may be forecast using the projected nationwide rates of growth for shale gas production for each of these four scenarios.[12] Other scenarios or selection among the four projections shown in Figure 2 may also be explored as options for forecasting natural gas industry water demands. Options to extend the EIA projections through the 2050 planning horizon will also be discussed as part of the stakeholder and Work Group collaboration process.

[12] Sand and gravel mining in Arkansas is closely tied to the level of production of Fayetteville shale natural gas because sand is used in the extraction process. Thus, water use for sand and gravel mining may be assumed to grow at the same rate of natural gas extraction demands using the scenarios presented in Section 8.1.

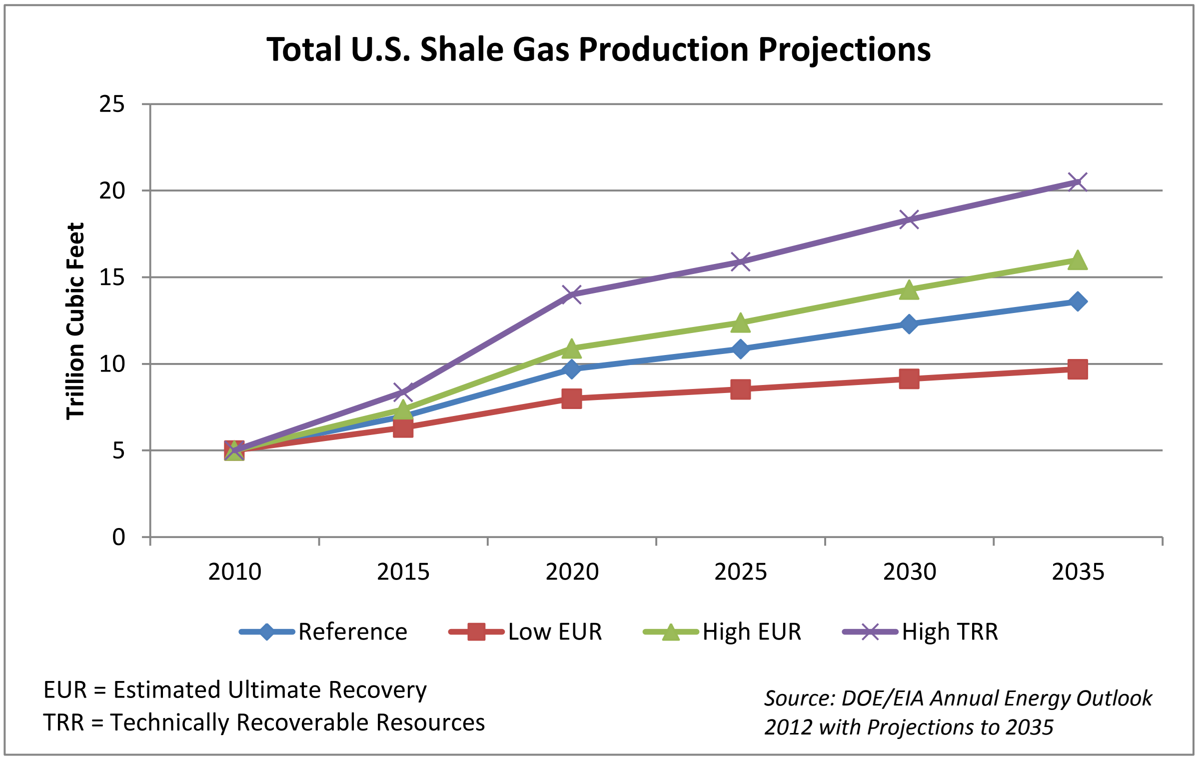

Figure 3. EIA Gas Shale Production Projections, 2010-2035

For other mining sector water demands less is known with respect to future levels of production. Growth scenarios will be explored as part of the stakeholder and Work Group collaboration process. One option is to assume that all non-natural gas extraction water demand will remain constant through the planning horizon. Another option is to use mining sector employment as a driver of future mining water demand.

8.2 Mining Sector Water Demand Calculation

The mining and oil and gas water demand calculation is proposed as follows:

Equation 15:

$$Q_{s,c,y}^{SSM} = [\Sigma(Q_{c,y}^{NG} \text{ x } EIA_{s,y}^{NG})] + \Sigma(Q_{c,by}^{M})$$

Where:

$Q_{s,c,y}^{SSM}$ = Self-supplied mining and oil and gas water for scenario (s) in county (c) and year (y)

$Q_{c,y}^{NG}$ = Self-supplied natural gas extraction base year water demand by NAICS group in county (c) and year (y)

$\boldsymbol{EIA^{NG}_{s,y}}$ = EIA projected rate of growth for natural gas for scenario (s) and year (y)

$\boldsymbol{\Sigma(Q^{M}_{c,by})}$ = The quantity of base year water demand for all non-natural gas extraction mining and oil and gas activities in county (c) in the base year (by)

9.0 Recreation and Navigation Considerations

Water-based recreation and navigation have instream requirements for water availability. Recreation and navigation on rivers and streams requires minimum flows to be satisfied in order for these activities to take place unimpeded. Similarly, recreation and navigation on lakes and reservoirs require minimum depths in order for these activities to take place without constraint. Stream, river, lake, and reservoir water availability is influenced by a host of factors including precipitation, groundwater inflows, and withdrawals from the source. Changes in any or all of these factors affect availability.

It is not anticipated that recreation and navigation flow and depth requirements will change over the planning horizon. That is to say, regardless of the future demand for recreation and navigation in Arkansas, the minimum flows for rivers and streams and depth of lakes and reservoirs needed to satisfy these demands will not be any more or less than they are today. Therefore, for planning purposes, it is assumed that the instream water demand for recreation and navigation in Arkansas will not grow or decline in the future. Water demand for recreation and navigation is determined based upon the range of preferred flows and/or depths. As part of the supply analysis component of the AWP Update, the impact of demands on these flow and depth availabilities will be analyzed.

9.1 Duck (Hunting) Clubs and Wildlife Management Water Demand Forecast

Offstream water withdrawals are needed to support various recreation activities throughout the state. One such activity is duck (hunting) clubs. According to Holland (2007), up until 2003, duck (hunting) club water use had been reported in the irrigation category for USGS reporting of water use in the state. In 2005, duck (hunting) clubs in Arkansas used a total of 269 million gallons per day (mgd), with about 30 percent from groundwater and 70 percent from surface water sources. Duck (hunting) club water use follows a seasonal pattern corresponding to duck hunting season. Thus for planning purposes it is assumed that duck (hunting) club demand only occurs between October and January each year.

Very little is known with regards to historical demands for duck (hunting) clubs and the number of acres receiving water applications. Therefore, additional information regarding what influences these withdrawals and how demand may change over time is needed.

Additionally, some wildlife management activities require offstream water withdrawals. For instance the WUDBS shows that the Arkansas Game and Fish Commission (AGFC) has registered to withdrawal both surface water and groundwater for wildlife management (these withdrawals are listed under NAICS 114210, Hunting and Trapping). In 2009, the most recent year of available WUDBS data, AGFC surface water withdrawals were about 5.5 mgd and groundwater withdrawals were just over 2,000 gallons per day. More information regarding these withdrawals is required in order to develop water demand forecast scenarios.

For planning purposes, it may be assumed that the reported level of duck (hunting) club water use in 2005 and an average (i.e., baseline) rate of withdrawal for wildlife management will remain constant by location and source over the planning horizon. It is expected that this assumption may be adjusted based upon stakeholder and Work Group input.

10.0 Recommended Steps Forward

The water demand forecast methodology described in this memorandum frequently references the need for input from stakeholders and Work Groups. These groups will be instrumental in finalizing the approach to forecasting water demands for the AWP Update. Therefore, it is recommended that, beginning with this draft methodology, stakeholder and Work Group input is obtained through a series of informational meetings.

An initial step in this process is the review of the demographic data that will drive future estimates of domestic and commercial and industrial water demands. First, the population projections presented in Figure 1 of this memorandum will be presented by county. Additionally, the disaggregation of these projections by county to show population served by public suppliers and self-supplied population will be presented for stakeholder and Work Group review. County-level employment projections will also be derived from the WIA projections. These projections will be compiled for stakeholder review.

Next, an analysis of the WUDBS public supplier data will be performed to derive supplier domestic gpcds. These supplier domestic gpcds will be used to derive a weighted county domestic gpcd. It is recommended that these rates of use be reviewed by appropriate stakeholders and Work Groups.

In addition to a review of demographic projections and baseline rates of water use, it is recommended that the forecast scenarios developed for the agriculture, thermoelectric, hydroelectric, oil and gas and mining, and duck (hunting) clubs be presented and discussed. The purpose of these discussions is to present the scenarios identified through a review of the literature or through professional judgment and illustrate the ranges these scenarios represent. This review exercise will be used to consider scenarios, develop alternative approaches, and to arrive at acceptable scenarios for forecasting.

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