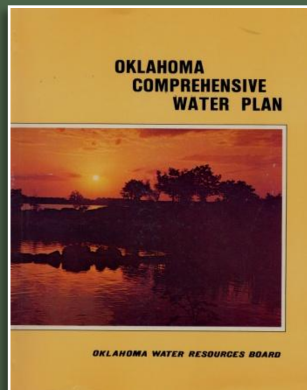
Oklahoma Comprehensive Water Plan

OCWP

Towards Implementation – The Technical Studies

State of Oklahoma
OWRB
WATER RESOURCES BOARD
the water agency

The OCWP: A Brief History



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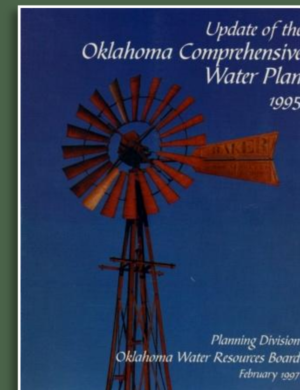


1980:

- First official statewide water plan
- Project-oriented
- Proposed statewide east/west water transfer

1995:

- First Water Plan update
- Policy-oriented
- Great success in achieving OCWP water policy recommendations at the state level

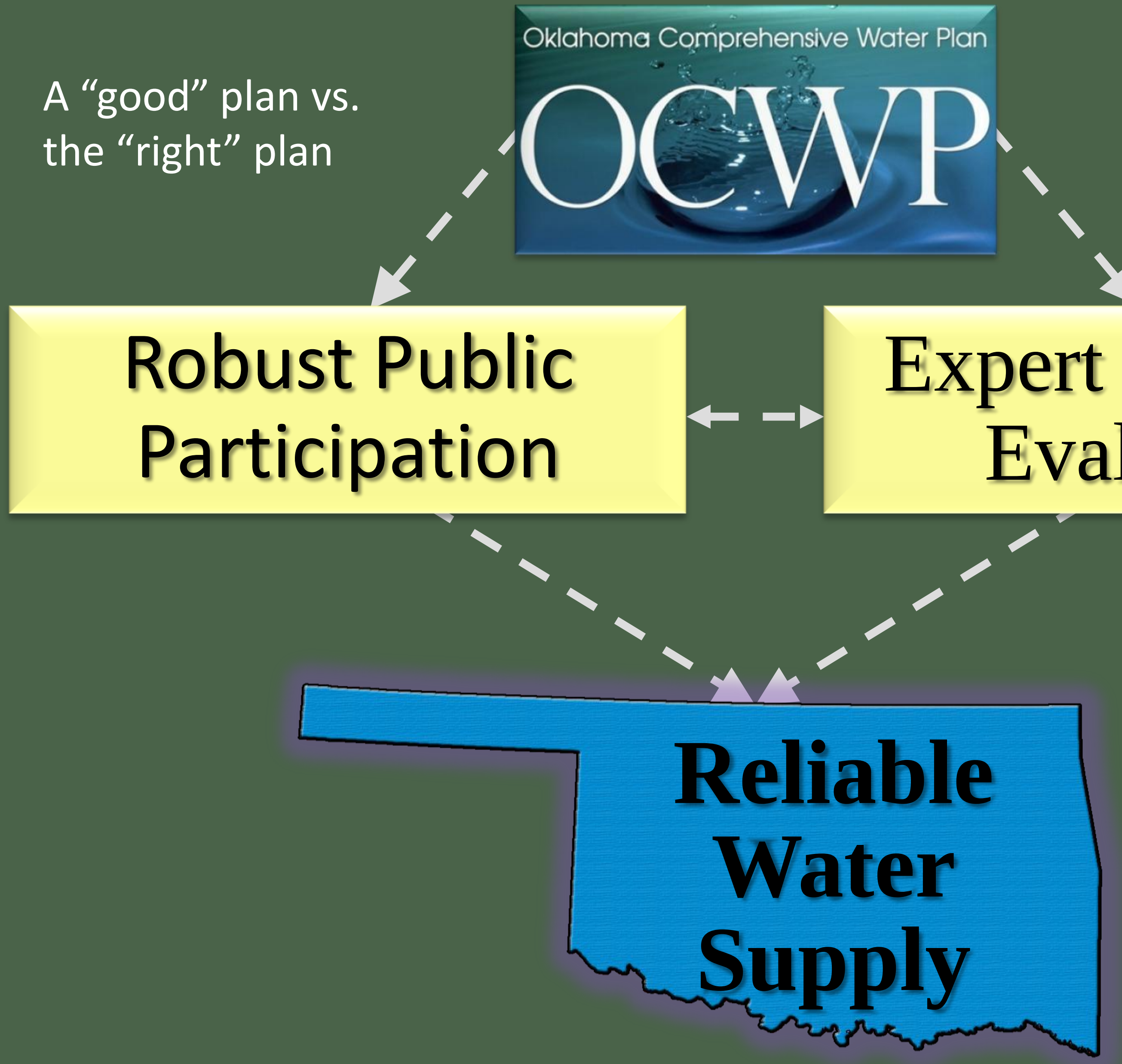
Goals of the 2012 OCWP Update

1. Characterize **demands** by water use sector.
2. Identify reliable **supplies** to meet forecasted demands.
3. Perform **technical studies** in support of the evaluation of emerging water management issues.
4. Comprehensive **stakeholder engagement** to make recommendations regarding the management of Oklahoma's water resources.
5. Ensure water resources management programs that **create reliability**.
6. Make **"implementable" recommendations** regarding the future of water management in Oklahoma based upon technical evaluations and stakeholder input.

Oklahoma Comprehensive Water Plan
OCWP

Two Major Components

A “good” plan vs.
the “right” plan

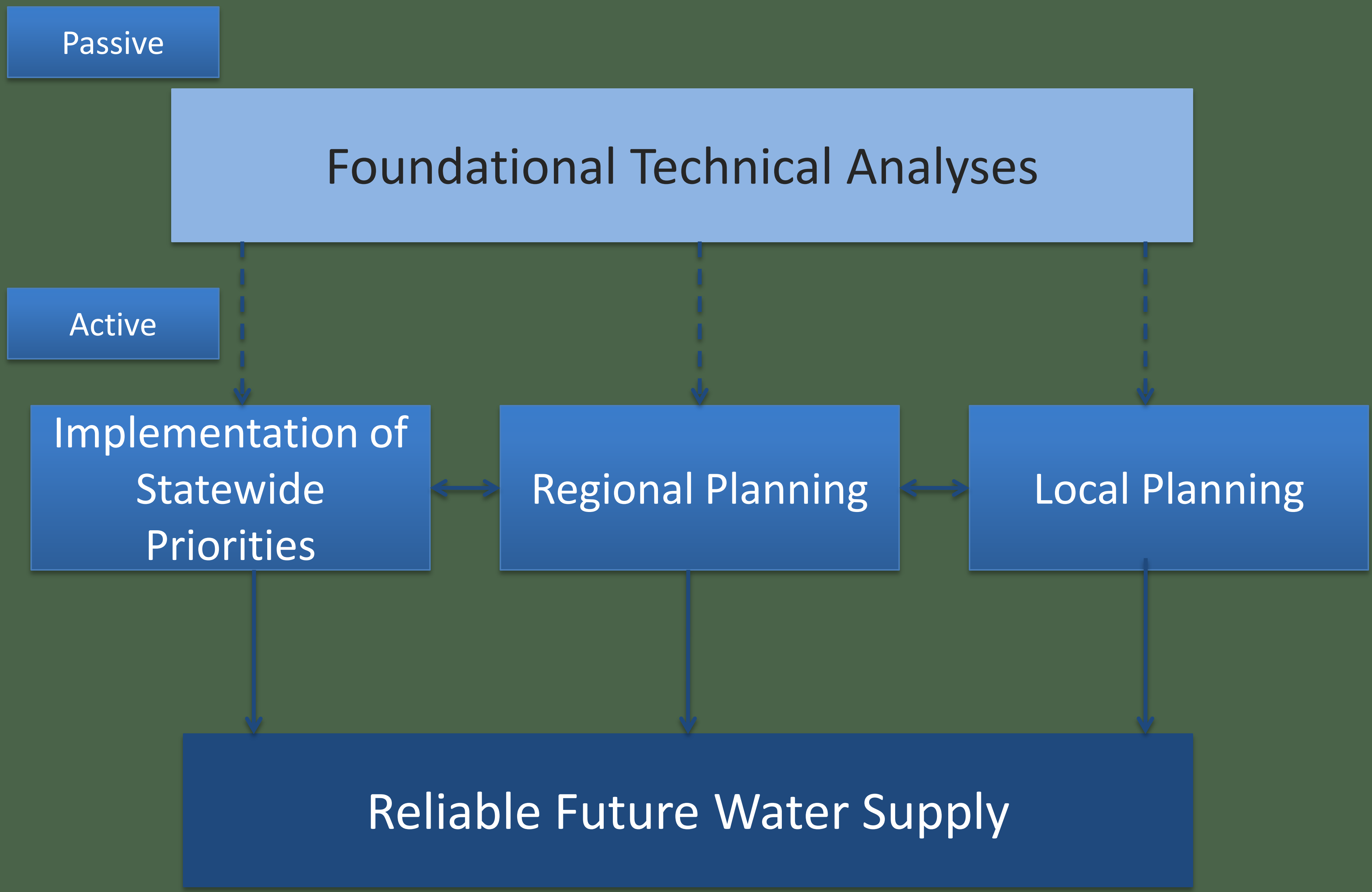


What is a Water Plan?

- It has both passive and active characteristics and functions
- Passive
  - A resource to inform future decisions
  - Foundational analysis decisions
  - Supply/demand, extent of limitations, effectiveness of options
  - Short-term and long-term
  - Statewide, regional and local planning
  - A firm foundation for implementation
- Active
  - An identification of the most pressing issues
  - A Plan for moving those issues forward
  - Informed by technical analyses (and stakeholder input)
  - Implementation of priority investigations, policies and programs to ensure a reliable future water supply

Water Planning Philosophy

- Always looking to the future
- Worst case scenario planning
- Solutions oriented
- Informing and empowering local decision-making
- Enabling and facilitating implementation


Passive
Foundational Technical Analyses
Active
Implementation of Statewide Priorities
Regional Planning
Local Planning
Reliable Future Water Supply

What is this Plan?
"A Foundation"

- An answer to a statutory mandate.
- A driver for economic development.
- Well-vetted and scientifically sound.
- A living document.
- A picture of where we are and what we have:
  - An impressive compendium of water related information on 82 basins and 13 regions across the state.
  - A thorough and frank evaluation of Oklahoma's current and future water policies and programs.
- What the future will look like:
  - Technical information on water supplies, demands, limitations and options to prepare for the future.
  - An evaluation of both emerging issues and future opportunities.
  - A deliberation of public and stakeholder input on innovative technical analyses and diverse policy evaluations.
- A strategy on how to get us there:
  - A tool to inform decision-making and stimulate intensive local planning.
  - Synthesized information resulting in priority water policy recommendations and other initiatives that will ensure a reliable water future for Oklahoma.

Components of the OCWP Update

I. Executive Report:
   - Synthesis of OCWP Technical Studies and Results
   - Water Policy Recommendations

II. Watershed Planning Region Reports (13):
   - Presents results of OCWP technical analyses, including options to address identified water shortages

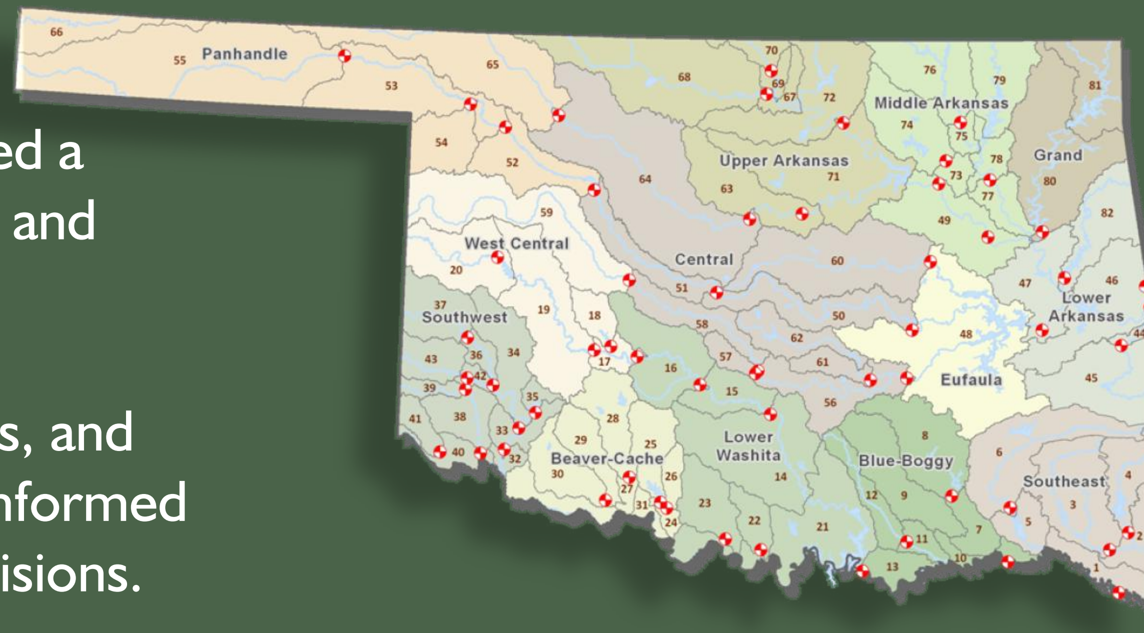
Planning for What, Exactly?

A Plan for Reliability Means Having a Reliable Plan

- Expert Technical Evaluation
- Consistent, Defensible Methodologies
- Robust Public Participation
- Innovative and Forward-thinking
- Integrated and Coordinated
- Consistent with Emerging Federal Priorities and Initiatives

Technical Studies

- The OCWP has collected a wealth of technical data and information that will be indispensable to water providers, policy makers, and water users in making informed water management decisions.
- Ten separate technical workgroups, including more than 100 experts, have provided invaluable input into OCWP technical methodologies and decisions.



13 Watershed Planning Regions:

- Aggregated from 82 basins delineated by hydrology and stream gage locations

Sources of Data

- Best Available
- USGS – streamflow, groundwater models, brackish water characterization, water use data
- Corps of Engineers – Reservoir yields,
- USDA – Livestock data, irrigated acres by crop
- NRCS – reservoir yields, crop irrigation requirements
- Bureau of Reclamation – reservoir yields, climate change datasets,
- OWRB – water rights data; water quality; groundwater basin data
- DEQ – public water supply providers data, water quality data
- OESC – employment projections
- ODOC – Population projections
- OK Corp Comm – Oil and Gas drilling data

Expert Technical Evaluation

Oklahoma Water Resources owrri Research Institute

Oklahoma State University

State of Oklahoma OWRB Water Resources Board the water agency

OU

CDM

Oklahoma Comprehensive Water Plan

OCWP

amec

National Oceanic and Atmospheric Administration NOAA U.S. Department of Commerce

U.S. Department of the Interior Bureau of Reclamation

DEQ Oklahoma Department of Environmental Quality

Guernsey

USGS science for a changing world

Oklahoma Climatological Survey

Oklahoma Conservation Commission

Oklahoma Department of Mines

Oklahoma Corporation Commission

The University of Tulsa

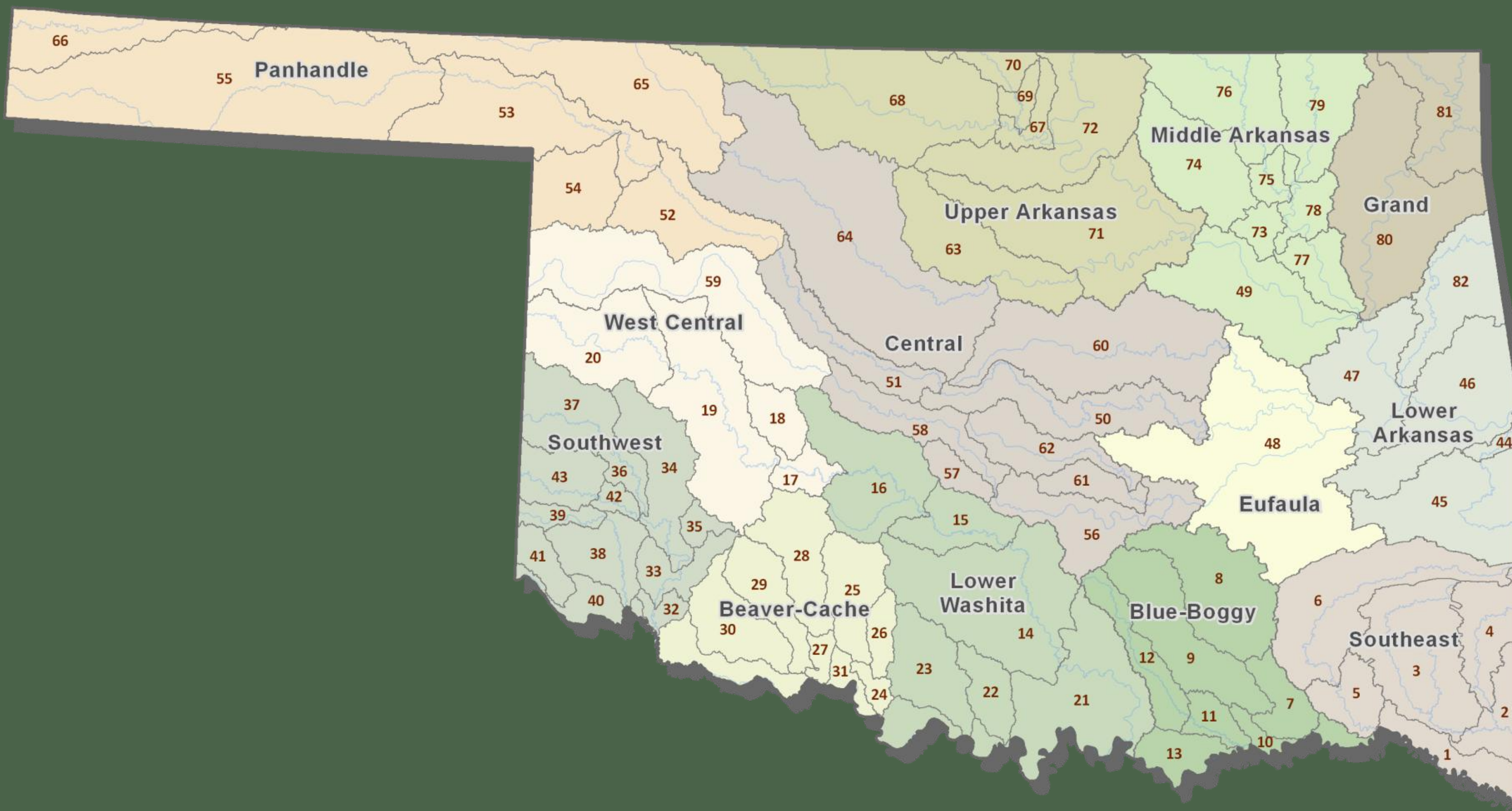
U.S. Fish & Wildlife Service Department of the Interior

United States Environmental Protection Agency

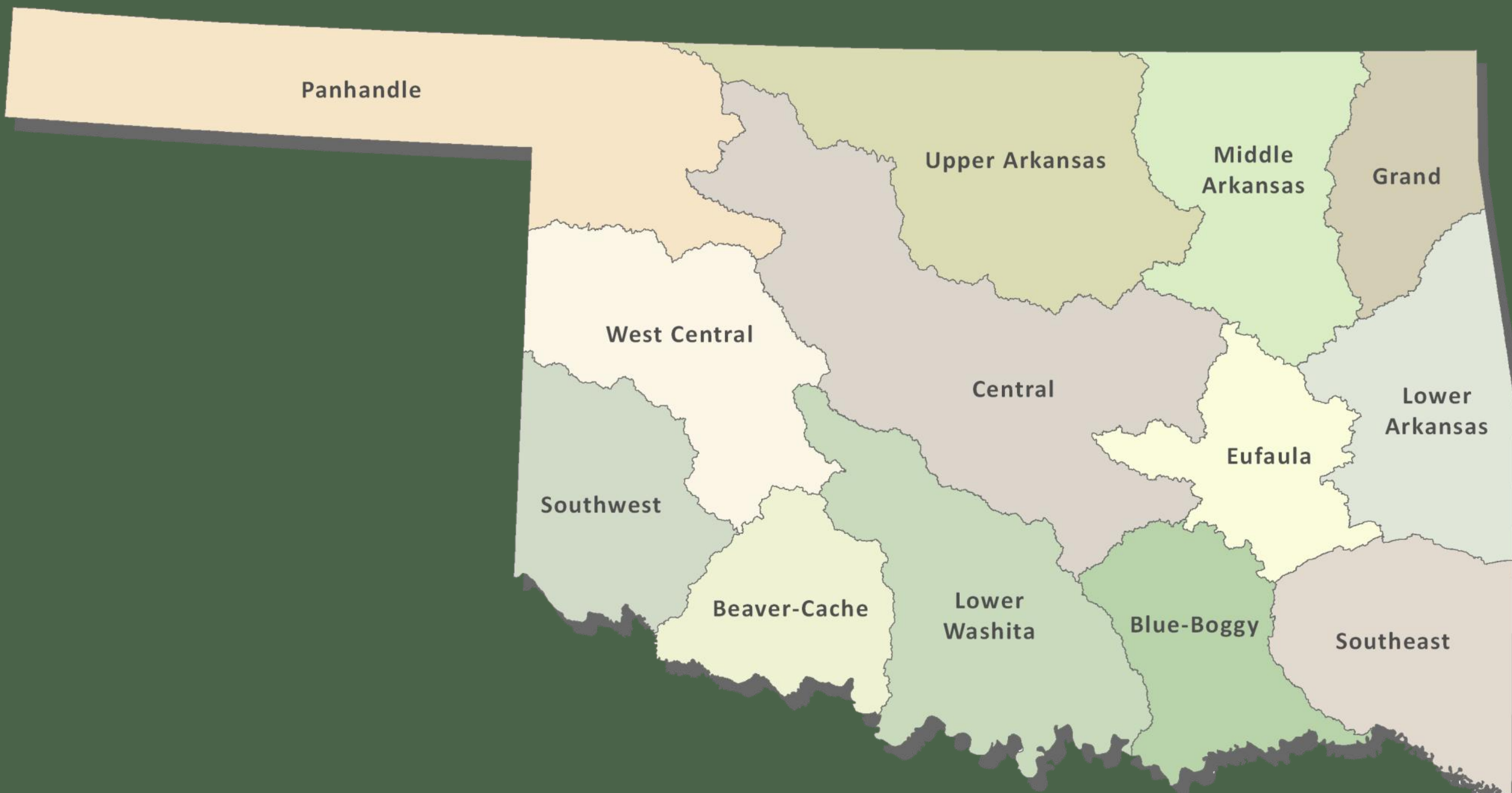
Oklahoma Department of Wildlife Conservation

Oklahoma Agriculture • Food • Forestry

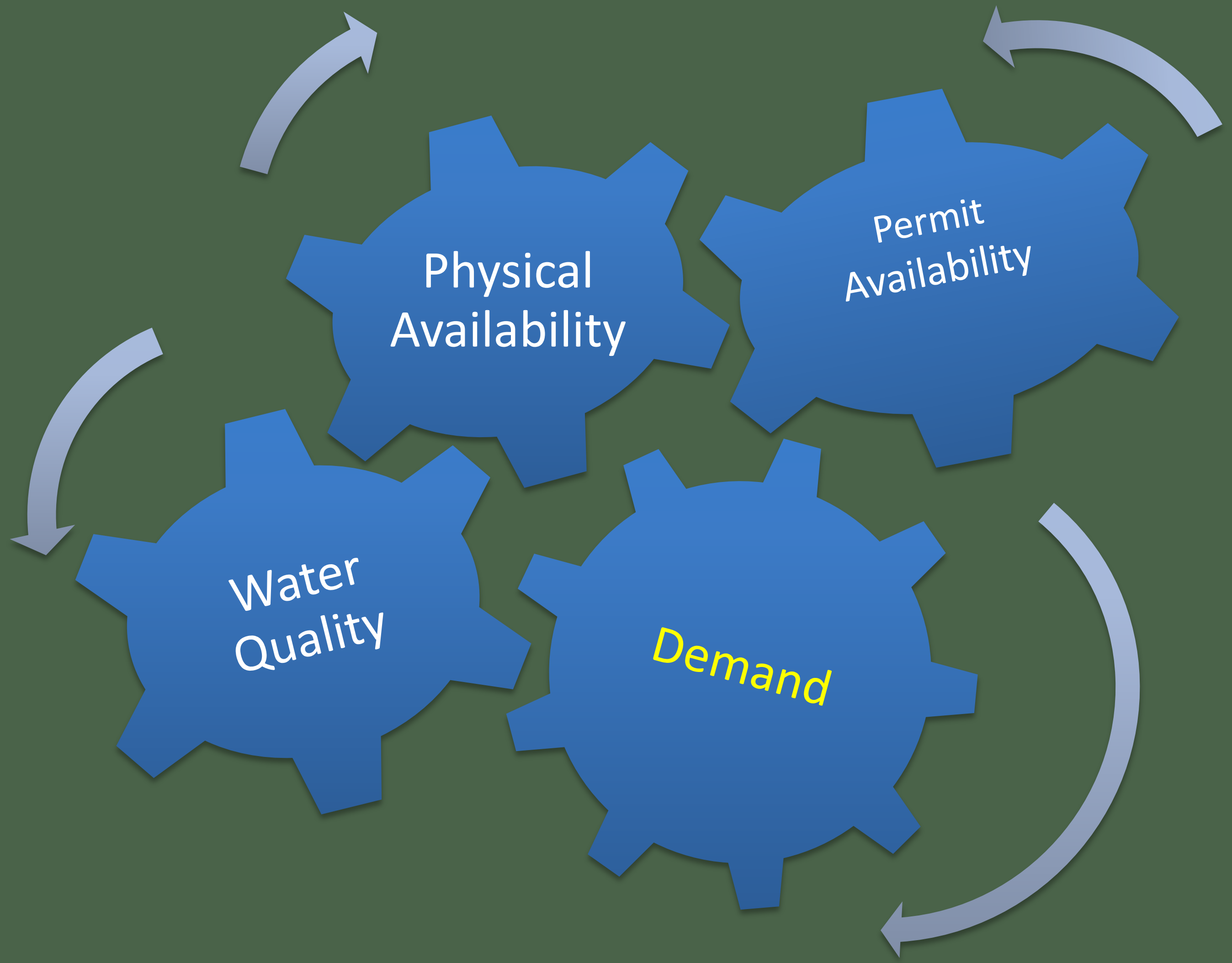
82 Basins for Detailed OCWP Analyses



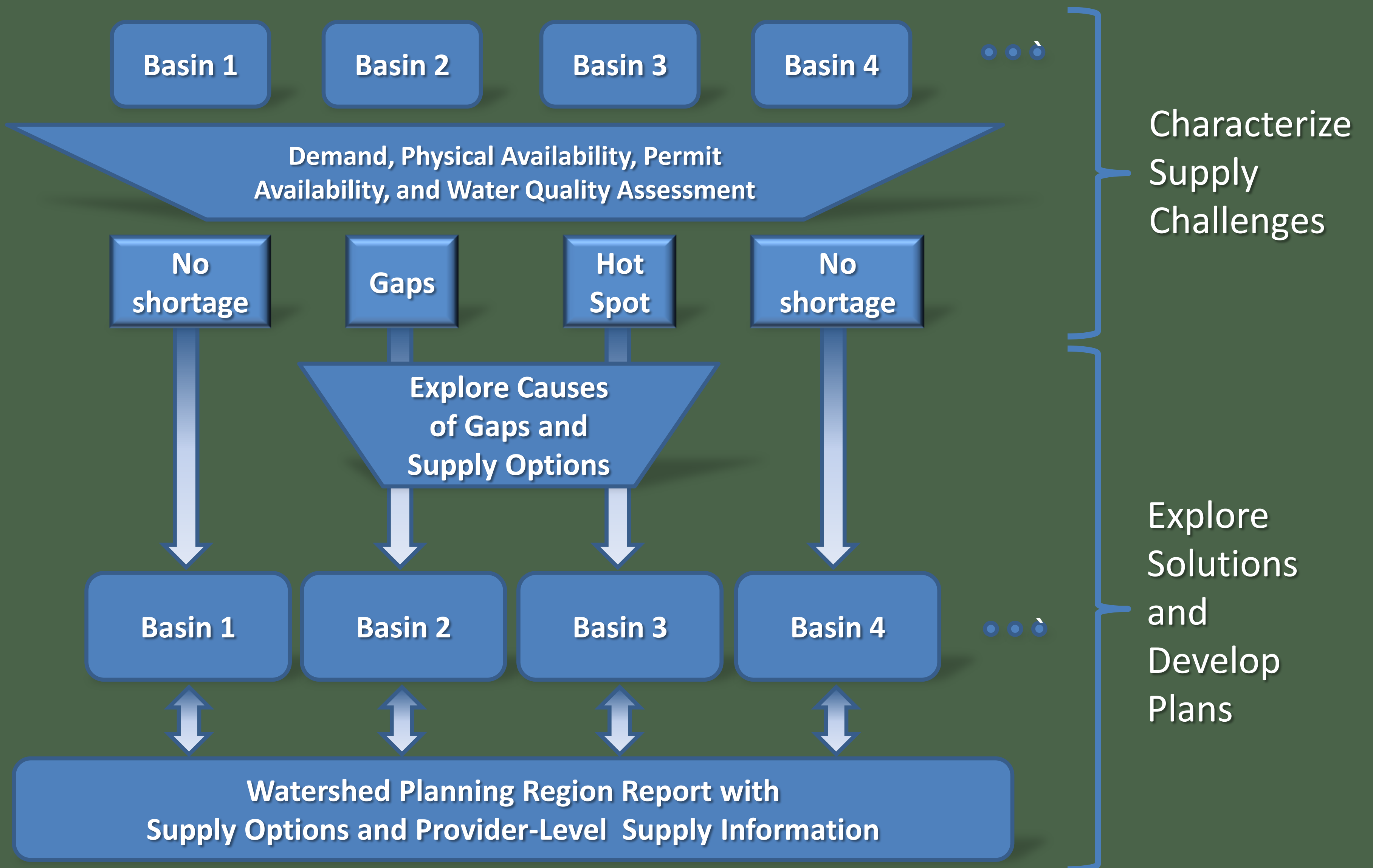
Aggregated into 13 Watersheds for Regional Supply Planning



Four Interrelated Components



Focused Planning Process for OCWP



Water Demand Forecasting

Demand Forecasting

- The following sectors were forecasted
  - Municipal and Industrial (PWS systems)
  - Self-Supplied Residential
  - Self-Supplied Industrial
  - Thermoelectric Power
  - Agriculture (Irrigation and Livestock)
  - Oil and Gas
  - Demands forecasted at the Region and Basin level

Municipal and Industrial Demands

County-Level Public-Supplied Residential

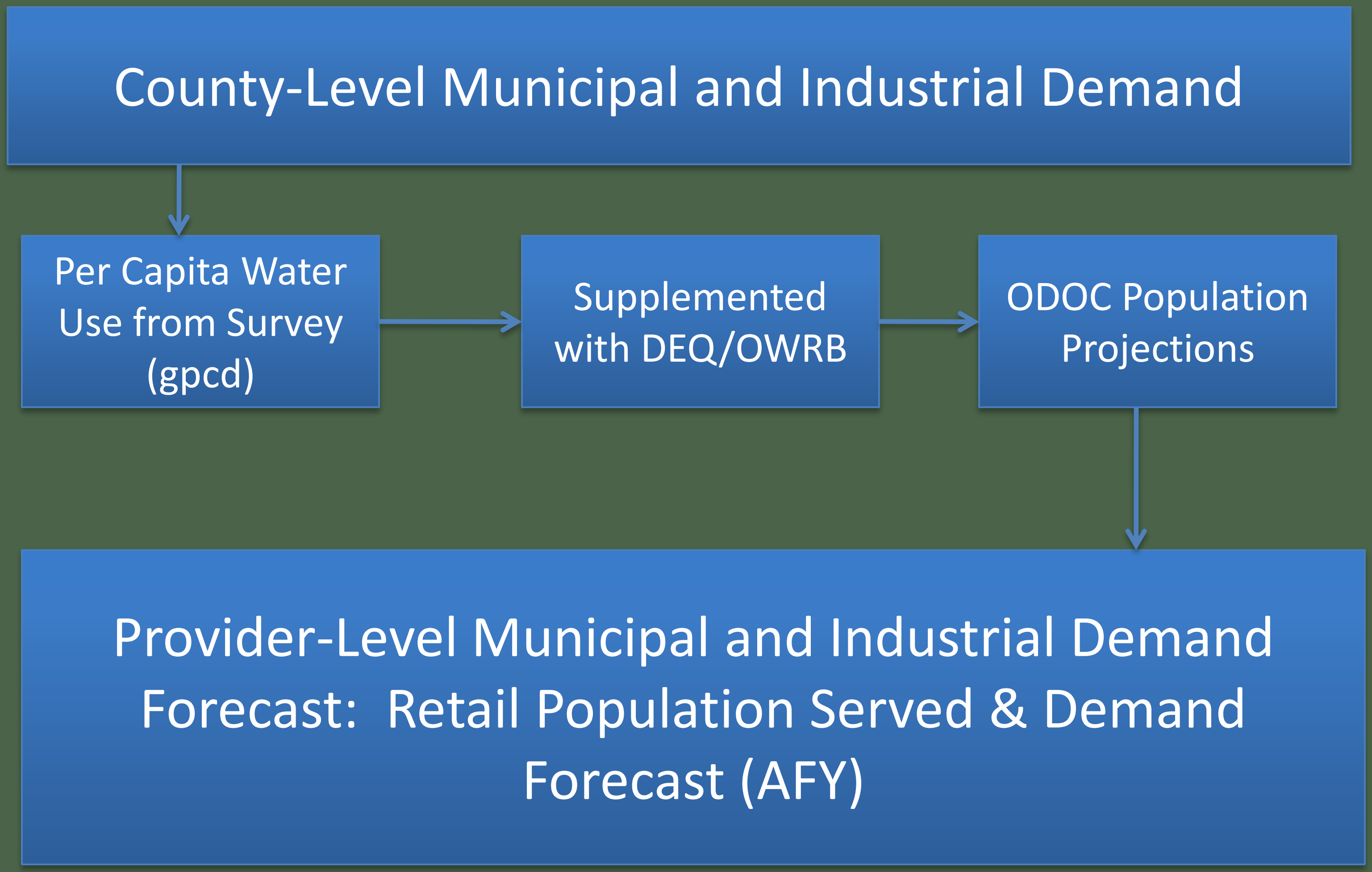
- ODOC Population Projections
- USGS Data on Self-Supplied
- Per capita Water Use from Survey
- System Water Loss from Survey

County-Level Public Supplied Nonresidential Demand

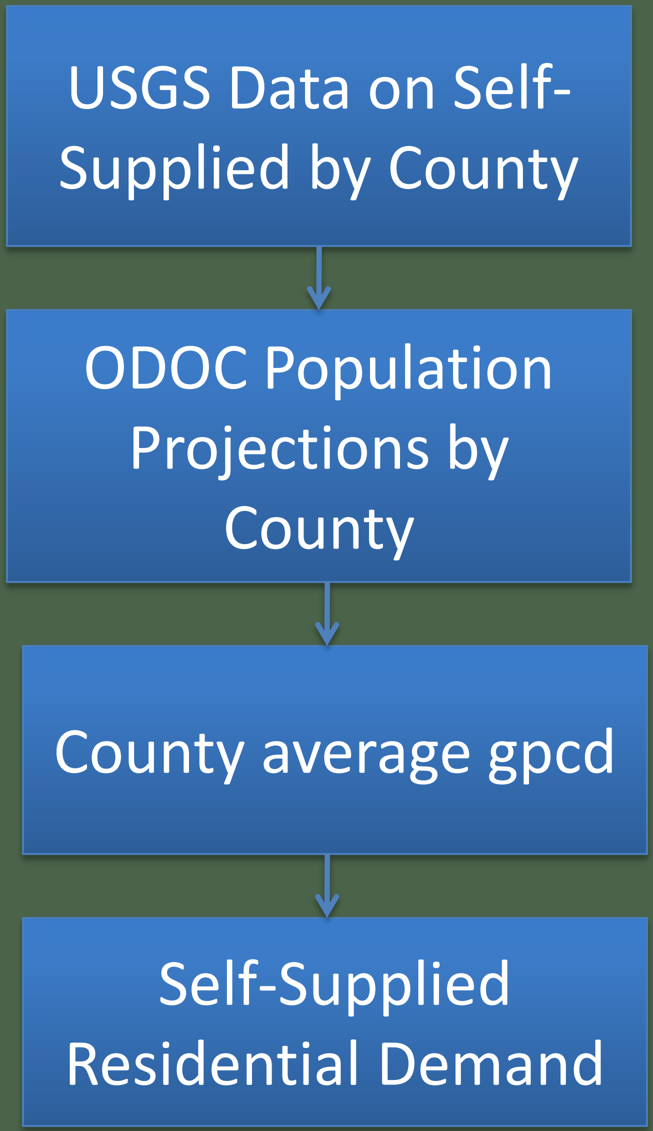
- Employment Data from NAICS
- OESC Data for Projections
- IWR Water Use Factors by NAICS

County Level Municipal and Industrial Demand

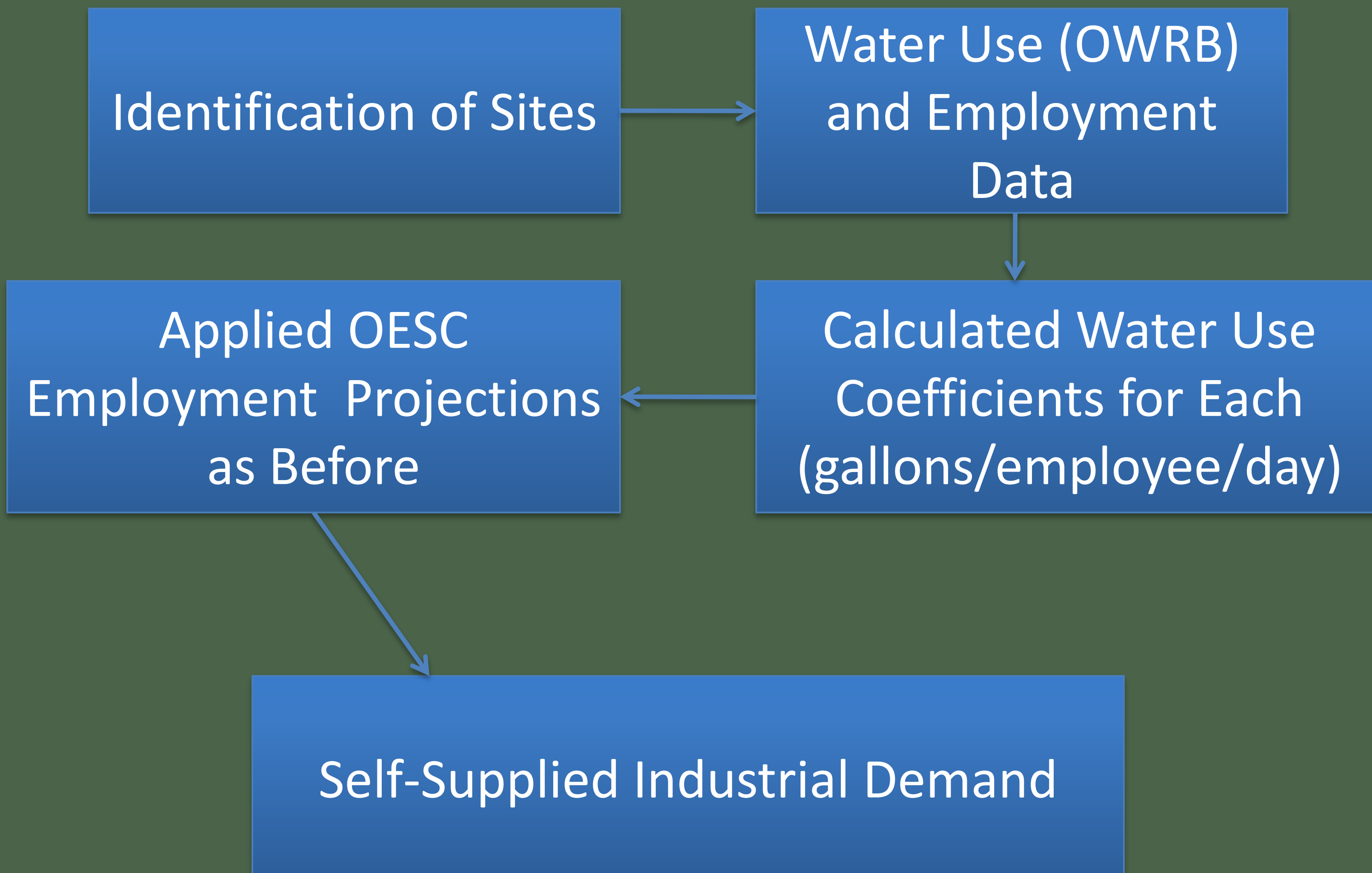
Provider Level Demand



Self Supplied Residential Demand



Self-Supplied Industrial Demand



Thermoelectric Power Demand

Existing and Proposed Sites Identified

↓

USGS and CDM Analysis = 775 gal/MWh

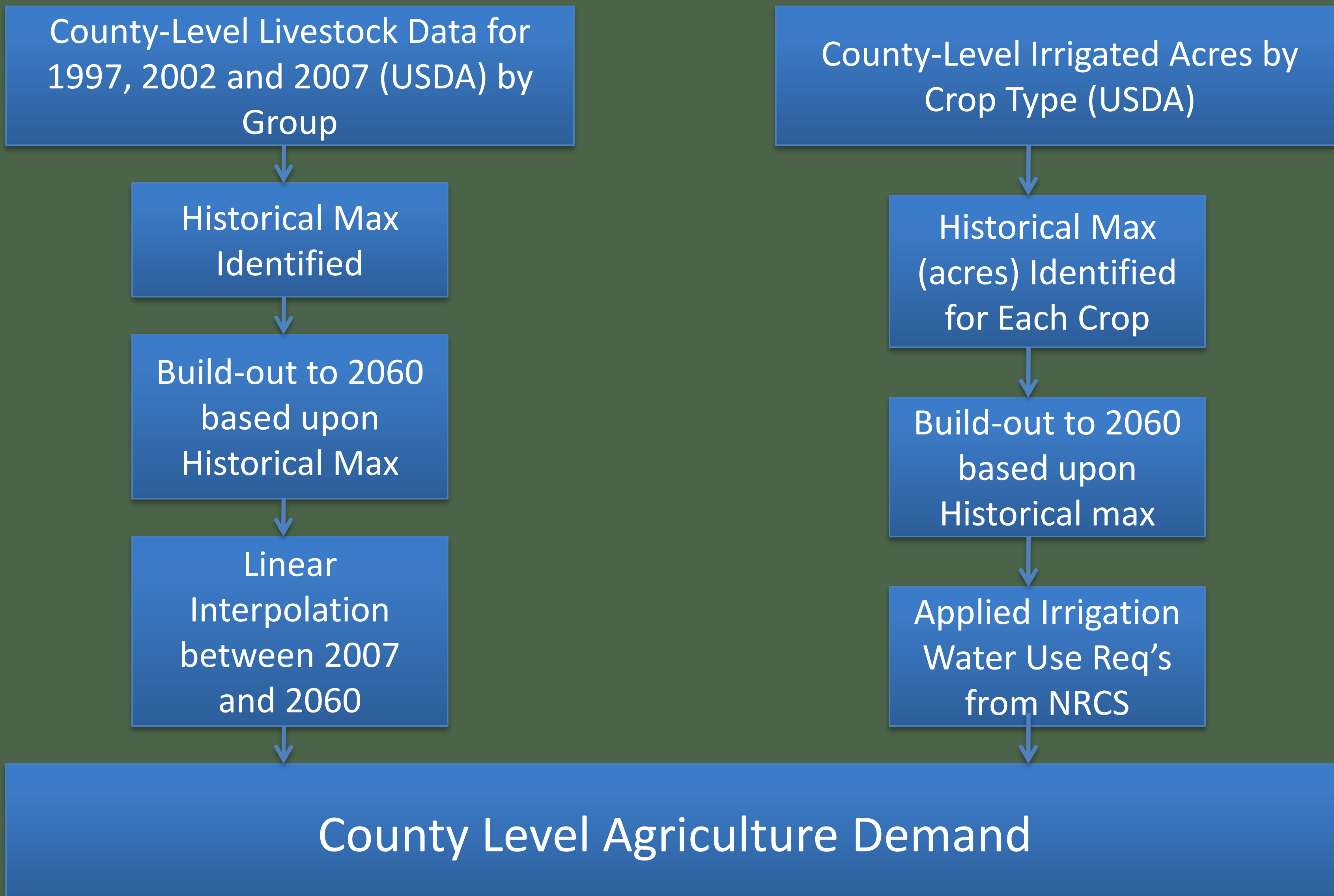
↓

US DOE forecasts 1.1% annual growth rate to 2060

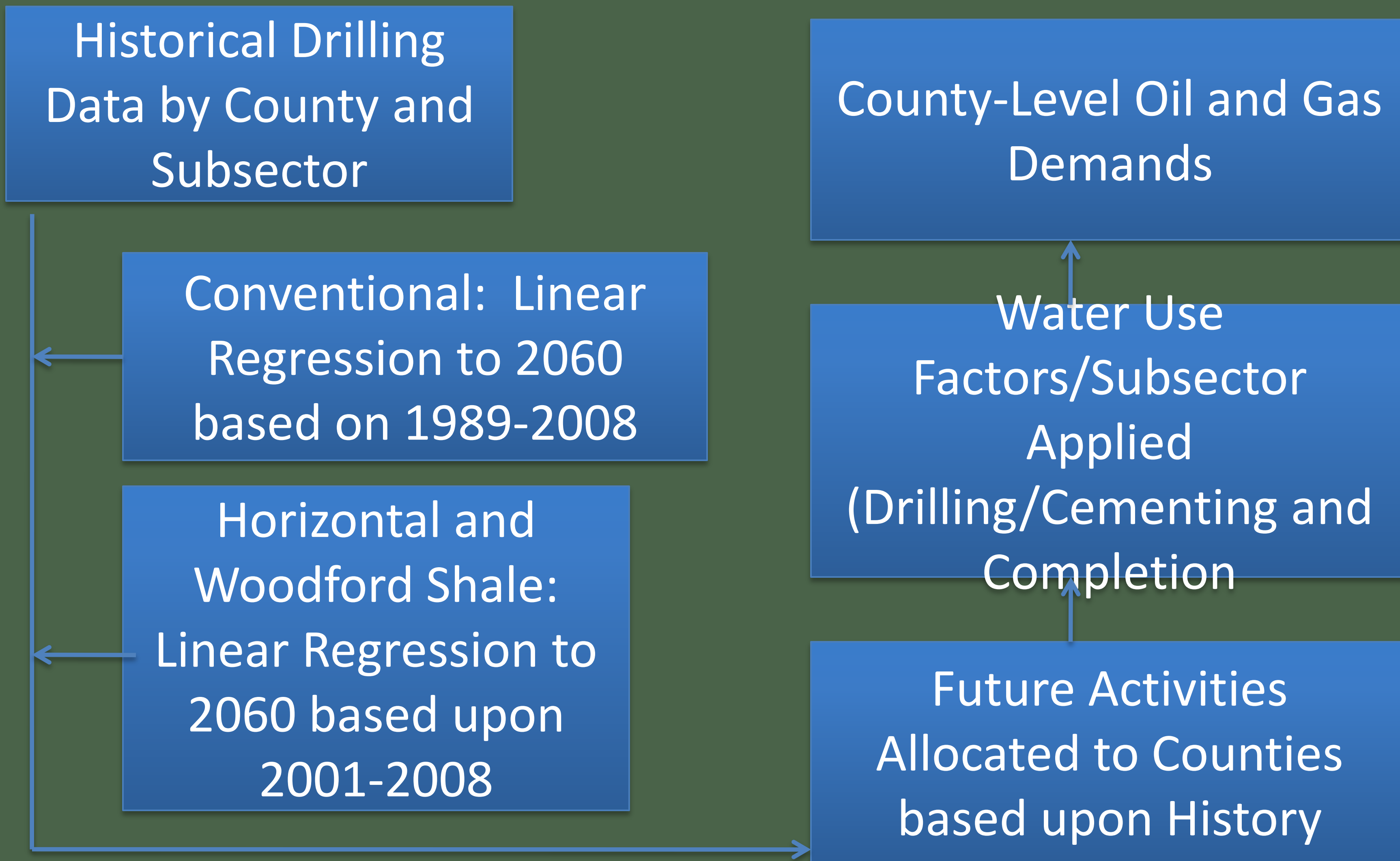
↓

Thermoelectric Power Demand

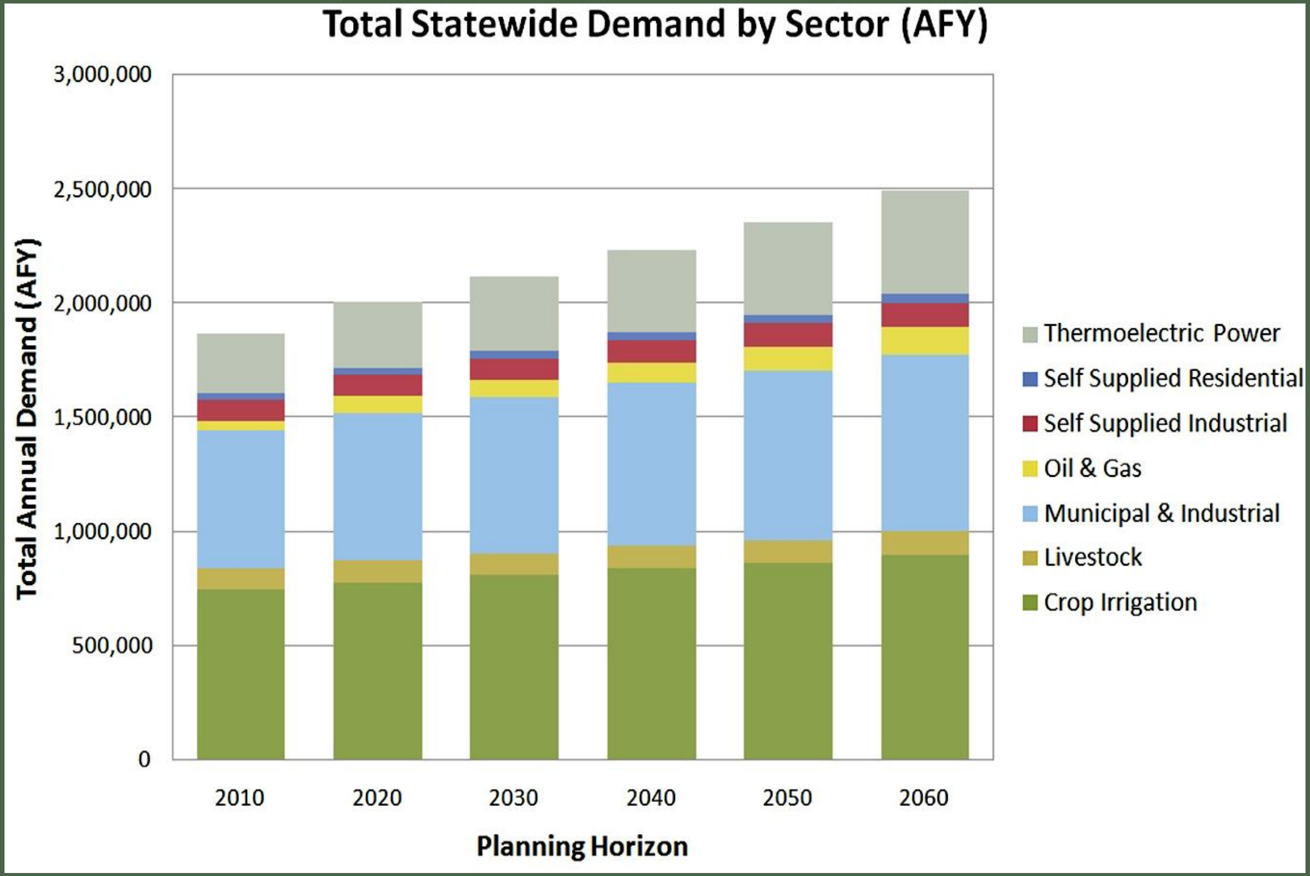
Agriculture Demand



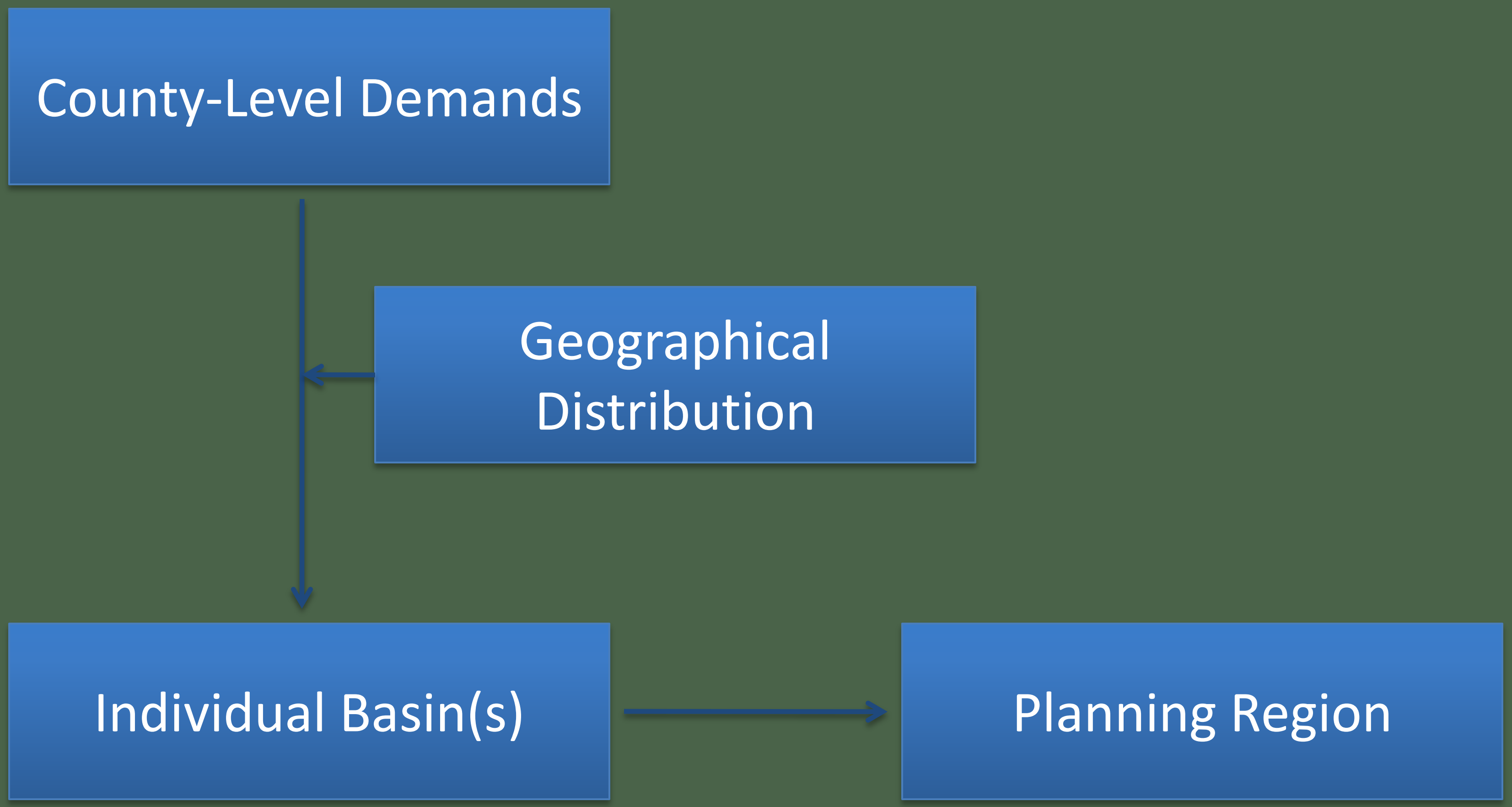
Oil and Gas


Historical Drilling Data by County and Subsector
Conventional: Linear Regression to 2060 based on 1989-2008
Horizontal and Woodford Shale: Linear Regression to 2060 based upon 2001-2008
Future Activities Allocated to Counties based upon History
Water Use Factors/Subsector Applied (Drilling/Cementing and Completion
County-Level Oil and Gas Demands

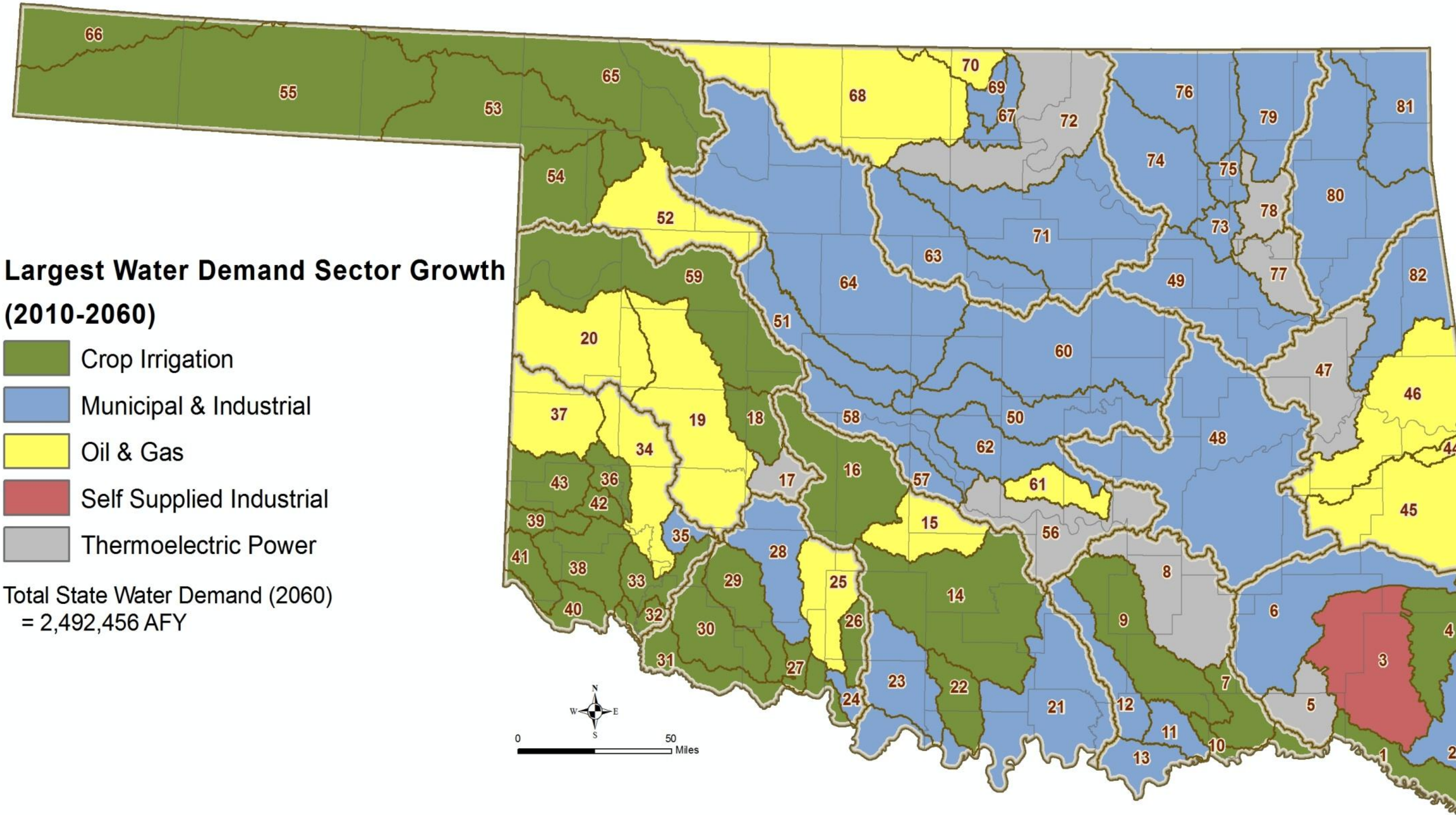
Statewide Water Demand by Sector



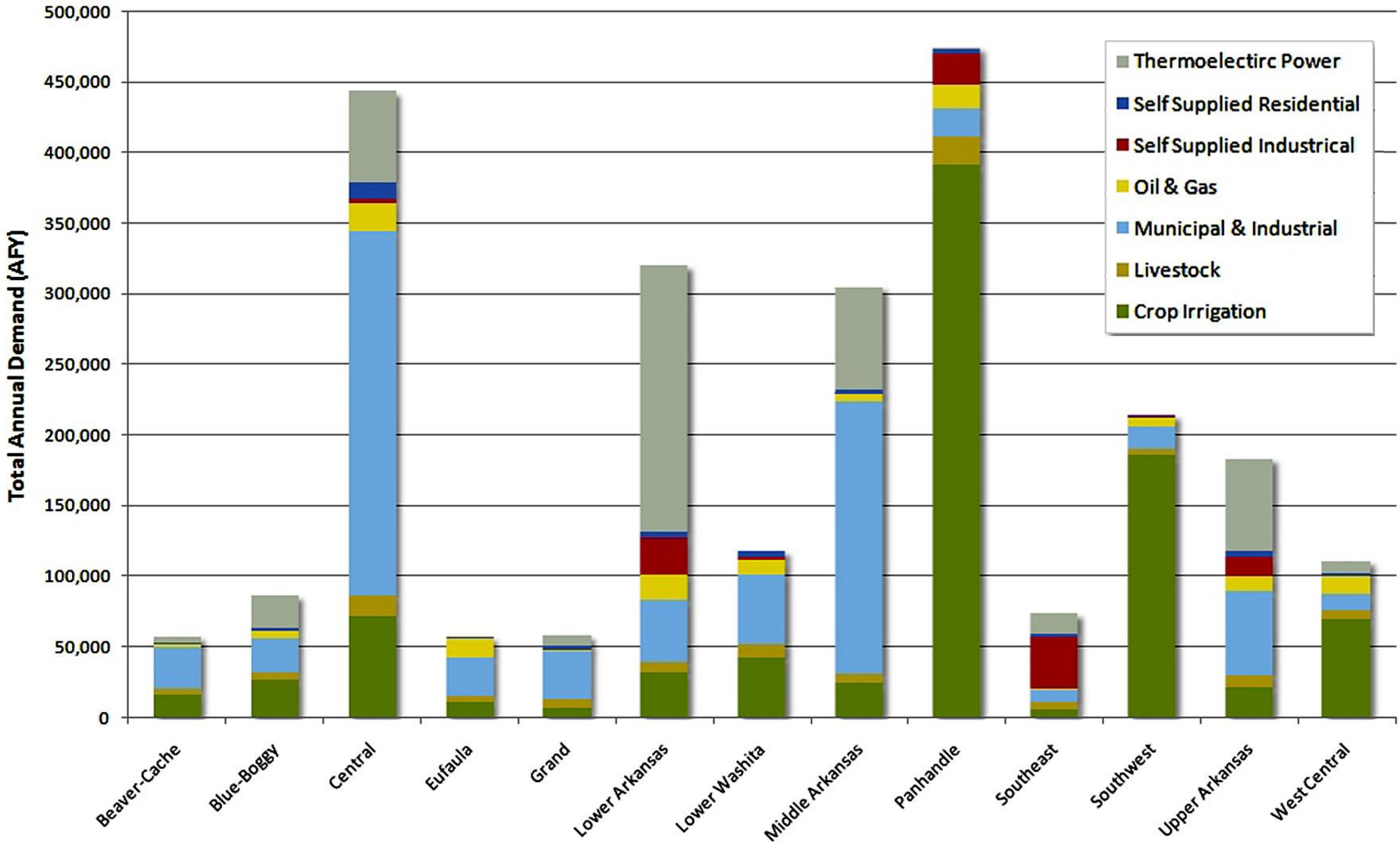
Allocation to Basins



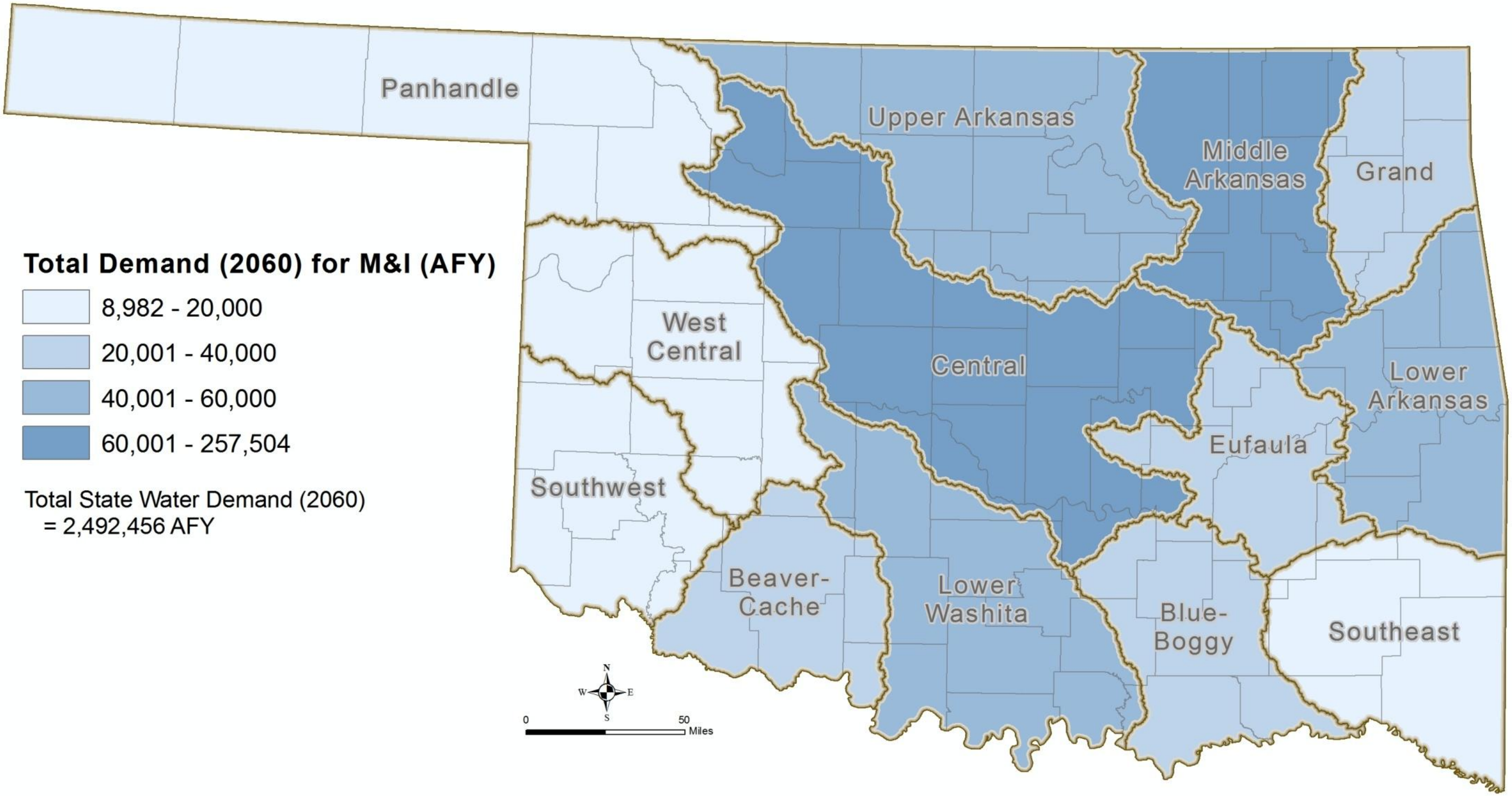
Largest Water Demand Sector Growth (2010-2060)

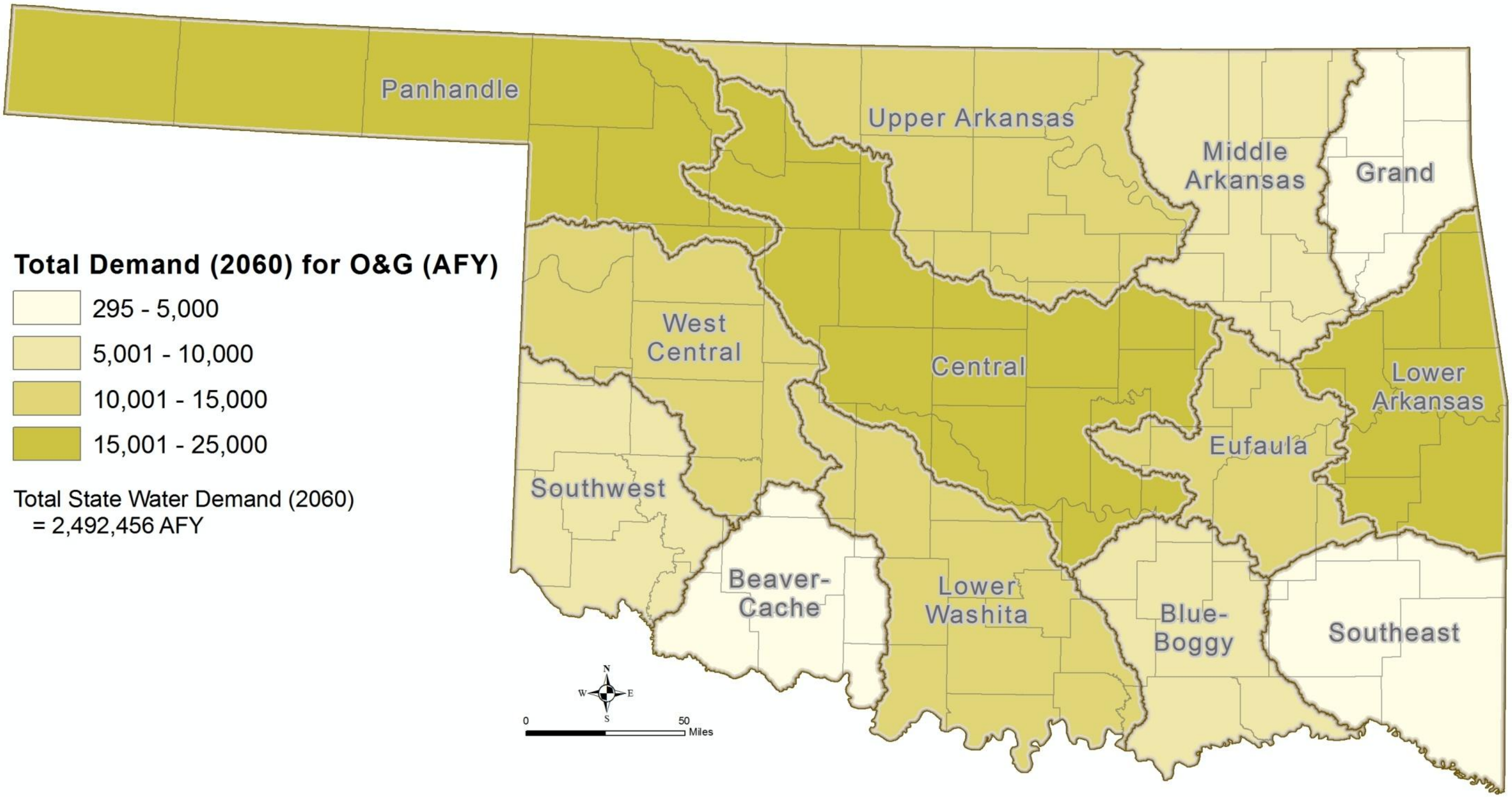


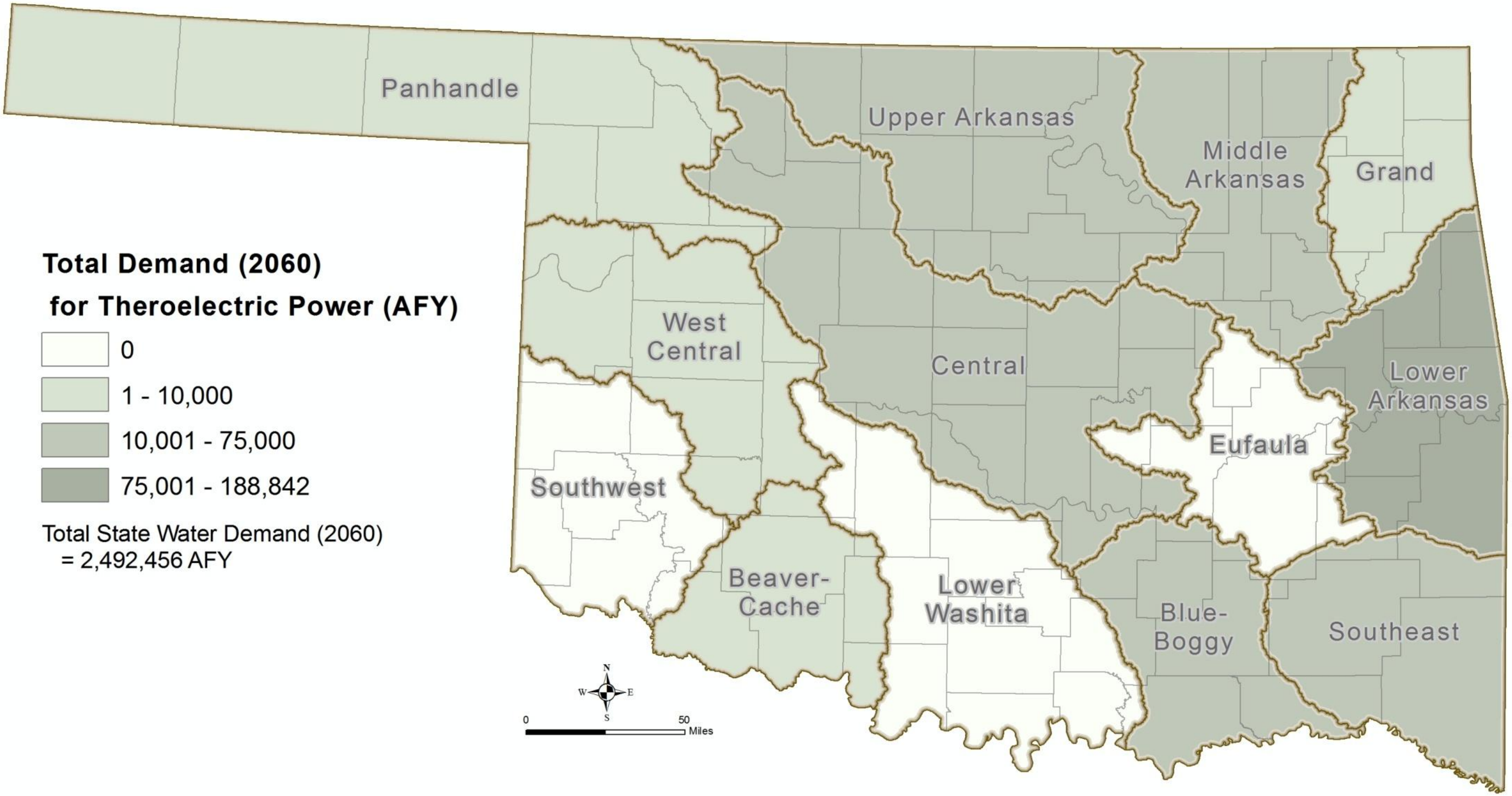
Total State Water Demand (2060)
= 2,492,456 AFY

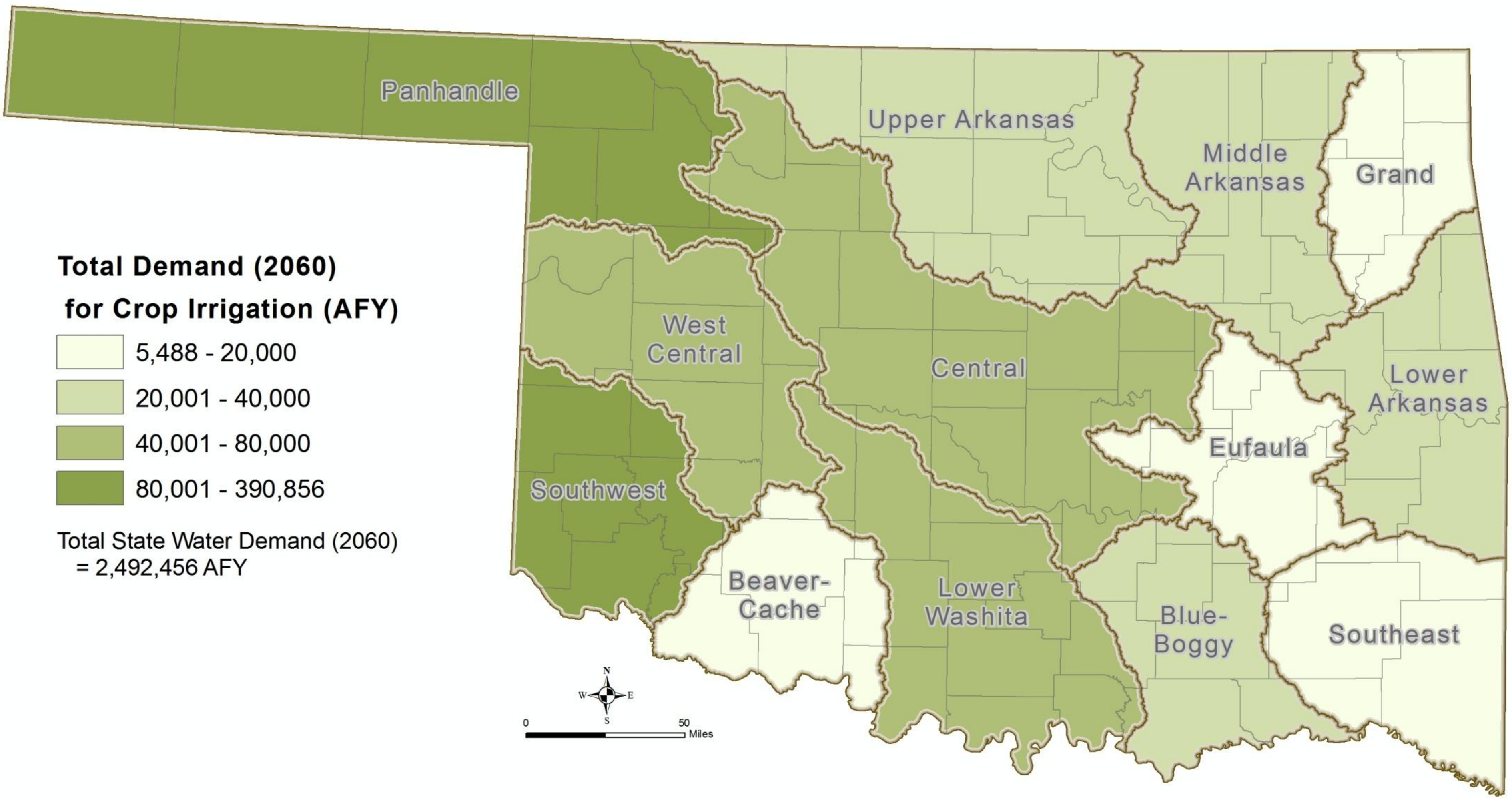


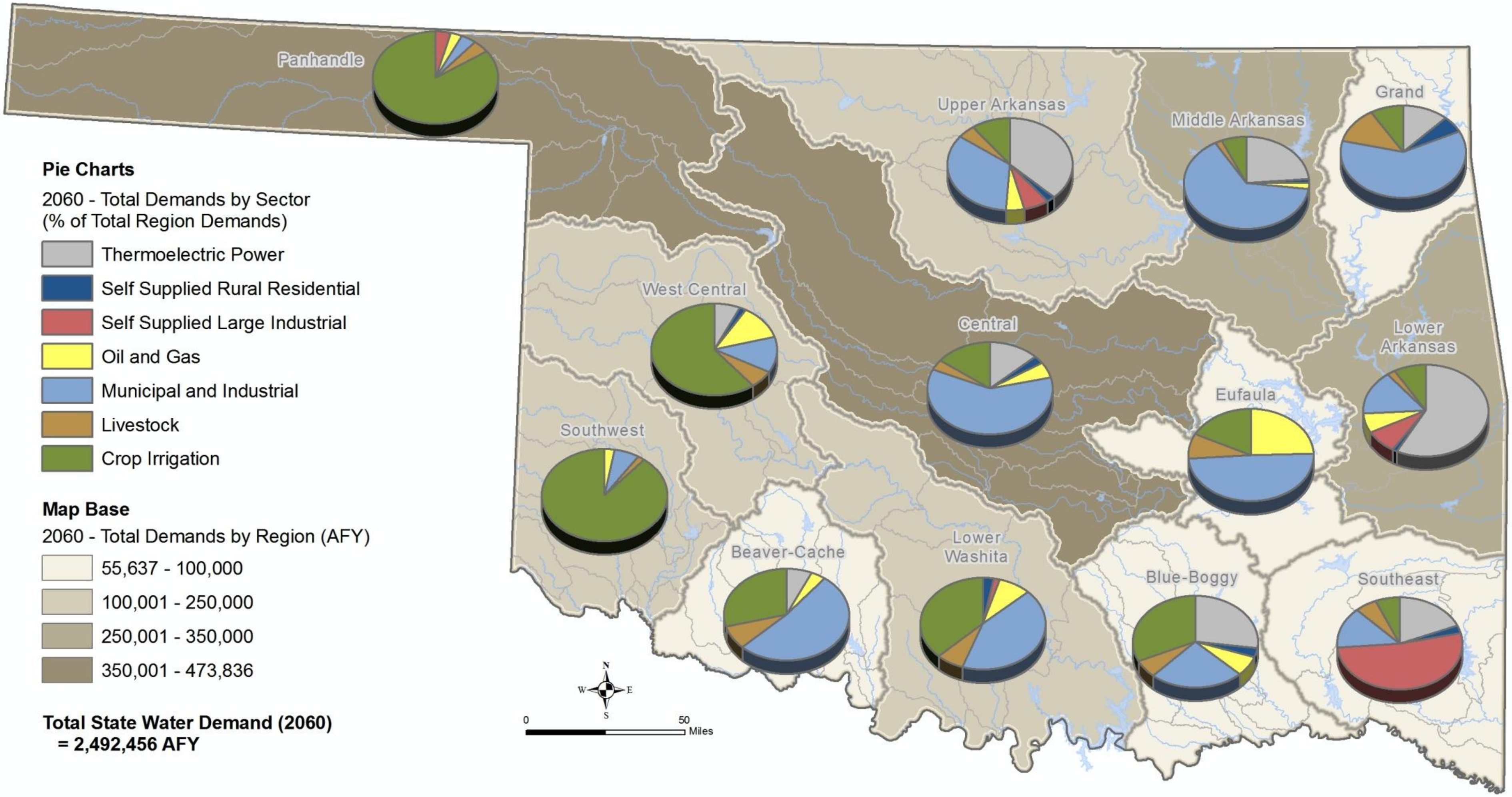
Total Annual Demand (AFY)
500,000
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Thermoelectirc Power
Self Supplied Residential
Self Supplied Industrical
Oil & Gas
Municipal & Industrial
Livestock
Crop Irrigation
Beaver-Cache
Blue-Boggy
Central
Eufaula
Grand
Lower Arkansas
Lower Washita
Middle Arkansas
Panhandle
Southeast
Southwest
Upper Arkansas
West Central

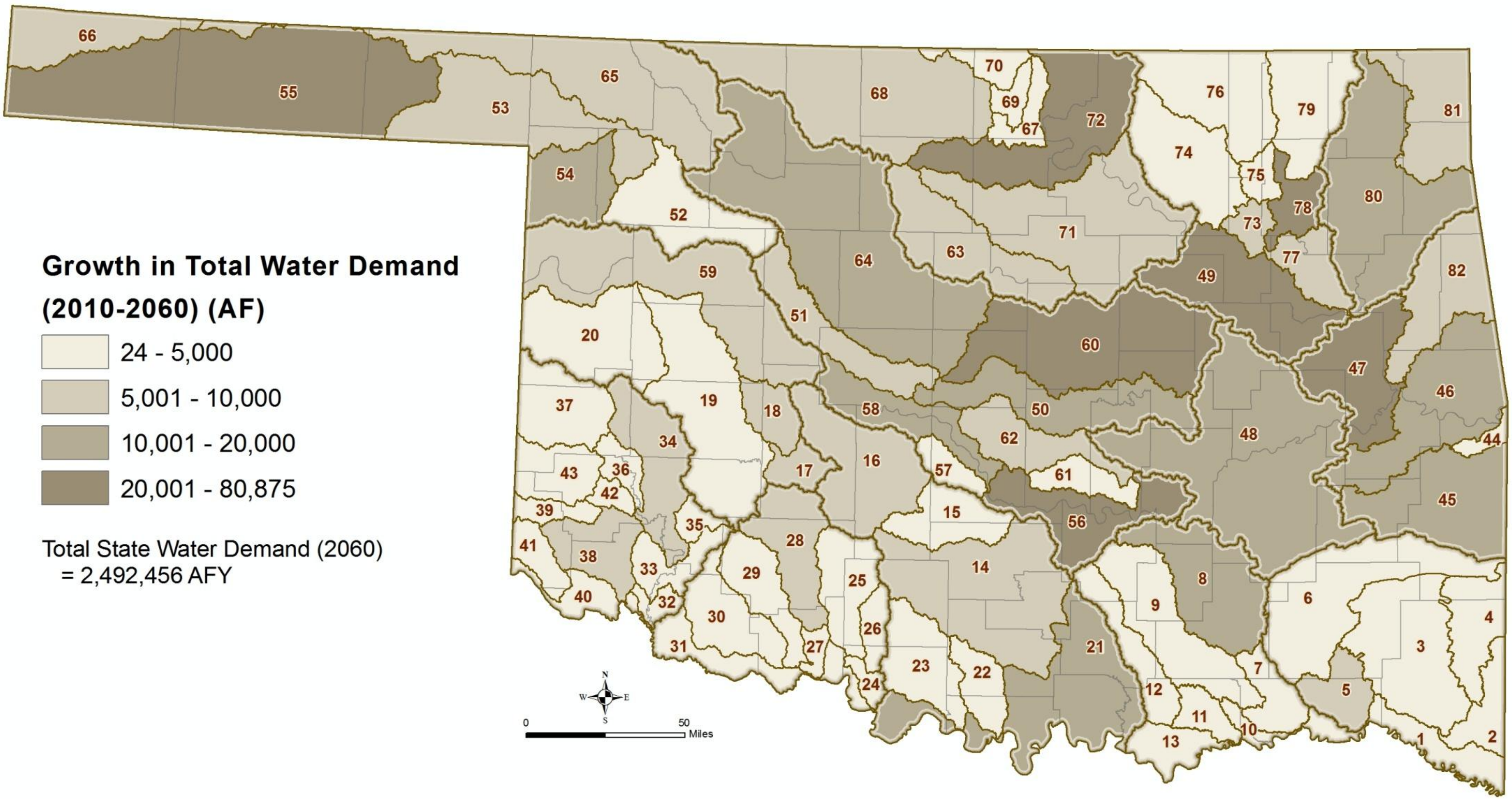

Total Demand (2060) for M&I (AFY)
8,982 - 20,000
20,001 - 40,000
40,001 - 60,000
60,001 - 257,504
Total State Water Demand (2060)
= 2,492,456 AFY
Panhandle
Upper Arkansas
Middle Arkansas
Grand
West Central
Central
Lower Arkansas
Eufaula
Southwest
Beaver-Cache
Lower Washita
Blue-Boggy
Southeast
N
W
E
S
0
50
Miles


Total Demand (2060) for O&G (AFY)
295 - 5,000
5,001 - 10,000
10,001 - 15,000
15,001 - 25,000
Total State Water Demand (2060)
= 2,492,456 AFY
Panhandle
Upper Arkansas
Middle Arkansas
Grand
West Central
Central
Lower Arkansas
Eufaula
Southwest
Beaver-Cache
Lower Washita
Blue-Boggy
Southeast
N
W
E
S
0
50
Miles


Total Demand (2060)
for Theroelectric Power (AFY)
0
1 - 10,000
10,001 - 75,000
75,001 - 188,842
Total State Water Demand (2060)
= 2,492,456 AFY
Panhandle
Upper Arkansas
Middle Arkansas
Grand
West Central
Central
Lower Arkansas
Eufaula
Southwest
Beaver-Cache
Lower Washita
Blue-Boggy
Southeast
N
W
E
S
0
50
Miles


Total Demand (2060)
for Crop Irrigation (AFY)
5,488 - 20,000
20,001 - 40,000
40,001 - 80,000
80,001 - 390,856
Total State Water Demand (2060)
= 2,492,456 AFY
Panhandle
Upper Arkansas
Middle Arkansas
Grand
West Central
Central
Lower Arkansas
Eufaula
Southwest
Beaver-Cache
Lower Washita
Blue-Boggy
Southeast
N
W
E
S
0
50
Miles


Pie Charts
2060 - Total Demands by Sector
(% of Total Region Demands)
Thermoelectric Power
Self Supplied Rural Residential
Self Supplied Large Industrial
Oil and Gas
Municipal and Industrial
Livestock
Crop Irrigation
Map Base
2060 - Total Demands by Region (AFY)
55,637 - 100,000
100,001 - 250,000
250,001 - 350,000
350,001 - 473,836
Total State Water Demand (2060)
= 2,492,456 AFY
Panhandle
Upper Arkansas
Middle Arkansas
Grand
West Central
Central
Lower Arkansas
Eufaula
Southwest
Beaver-Cache
Lower Washita
Blue-Boggy
Southeast
N
W
E
S
0
50
Miles

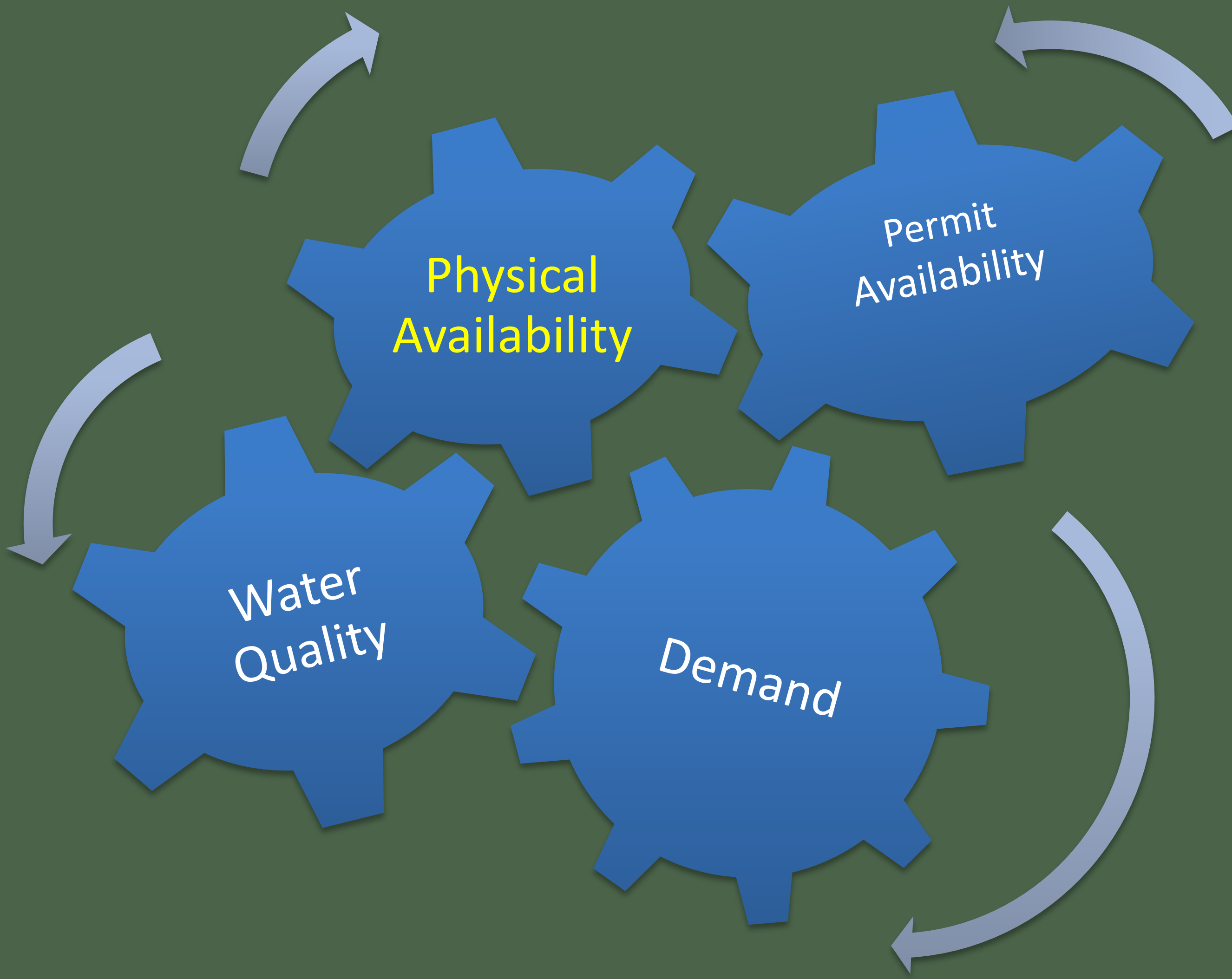


Growth in Total Water Demand
(2010-2060) (AF)
24 - 5,000
5,001 - 10,000
10,001 - 20,000
20,001 - 80,875
Total State Water Demand (2060)
= 2,492,456 AFY
N
W
E
S
0
50
Miles

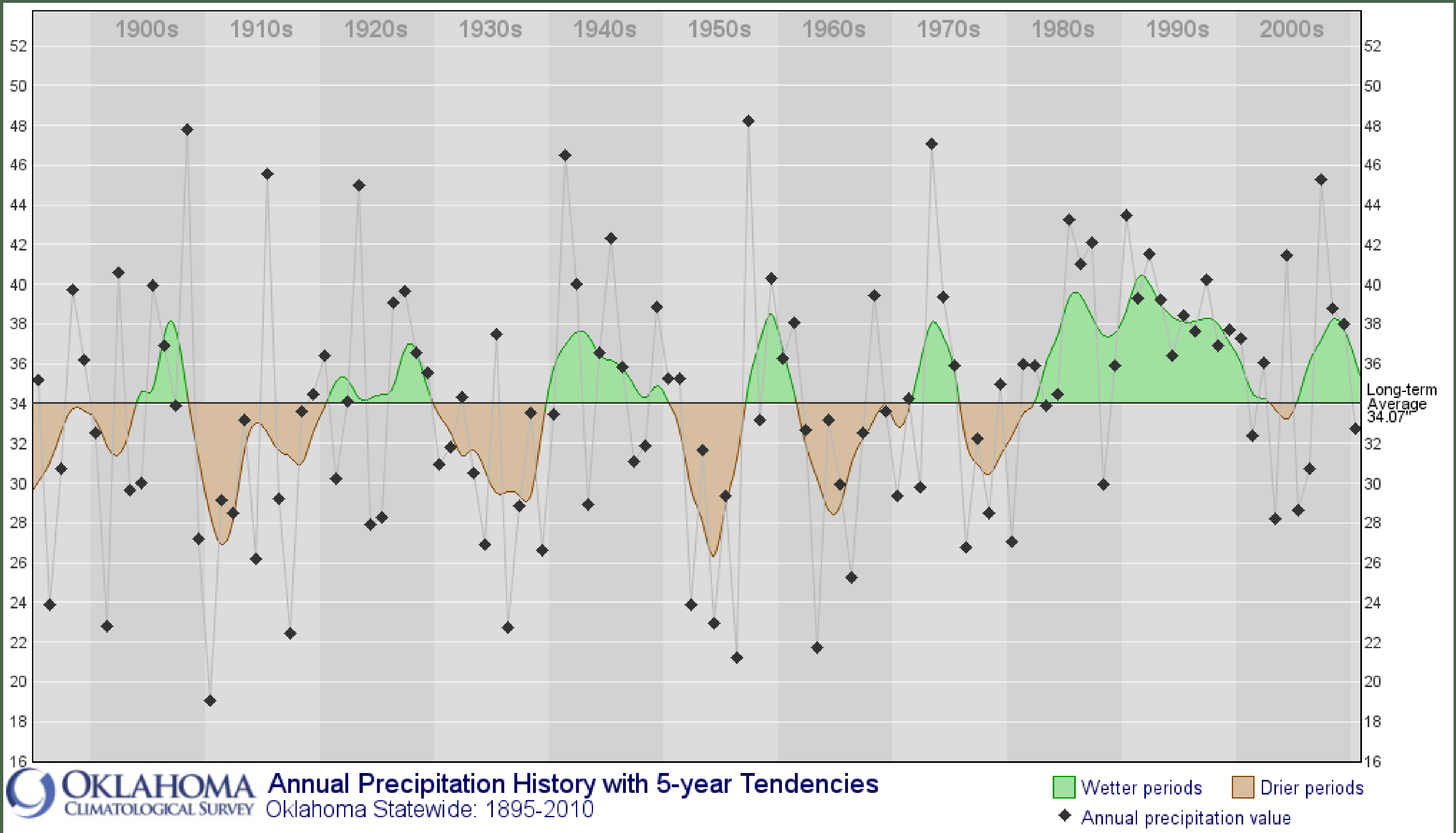
Water Demand Findings

- Statewide consumptive demand increase by 33% to 2060
- Crop Irrigation largest sector in 2060 at 897, 464 acre-feet/year (36% of total demand)
- Oil and Gas largest growth sector at 300%
- Panhandle Region the largest 2060 demand at 473,840 acre-feet/year; Eufaula the lowest at 55,640

Four Interrelated Components



Historical Precipitation



Oklahoma has 3 Types of Water Supply

SURFACE WATER

- *Creeks, streams, rivers*
- *Lakes and reservoirs*
- *Flow varies significantly over time*

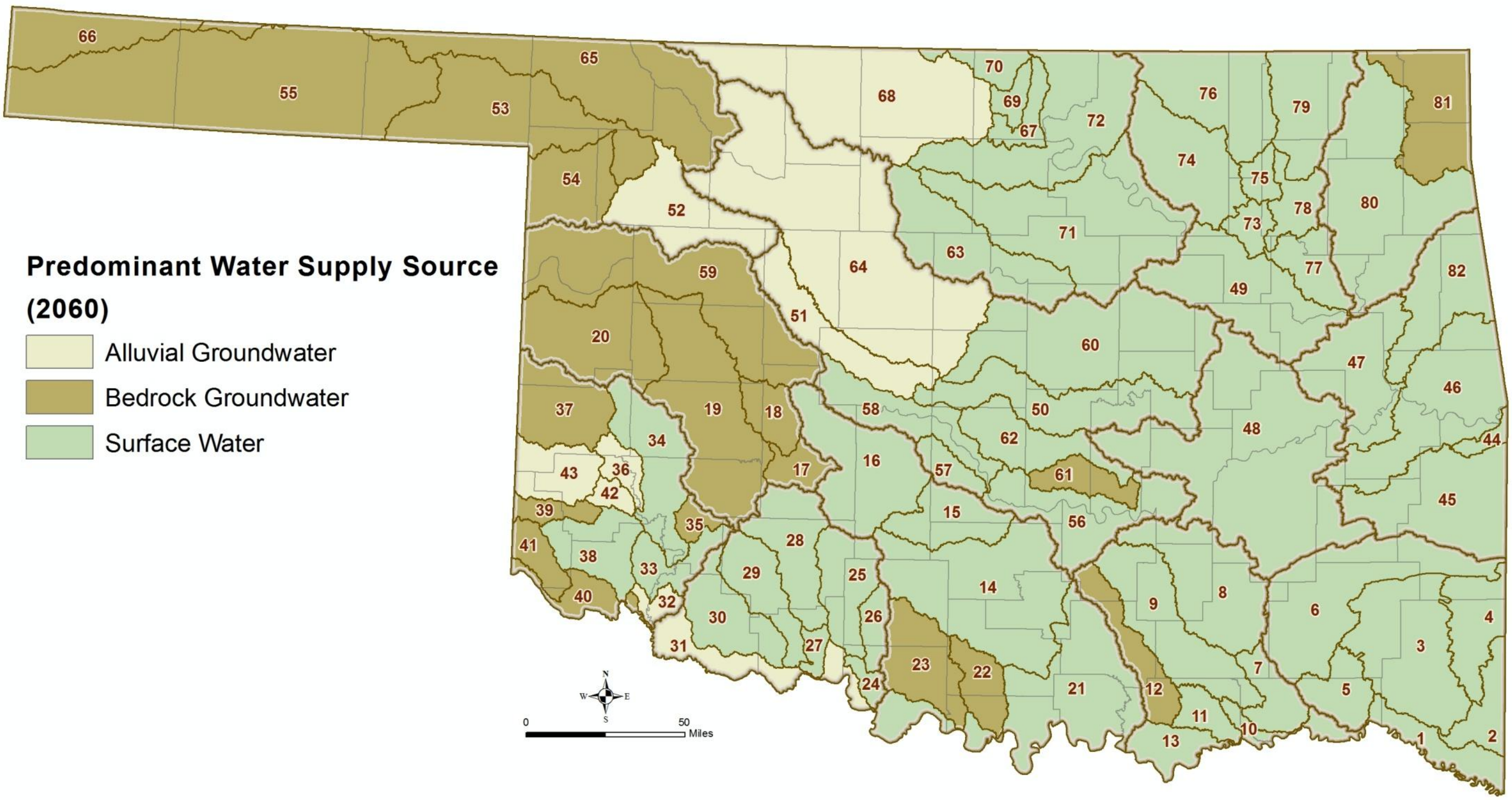
ALLUVIAL GROUNDWATER

- *Aquifer made up of sediment deposited by rivers*
- *Recharged by infiltration of surface water or precipitation*
- *Recharge rate varies over time*

BEDROCK GROUNDWATER

- *Not associated with rivers*
- *Recharged with water percolating from the surface or other overlying aquifers*
- *Recharge is fairly constant over time*

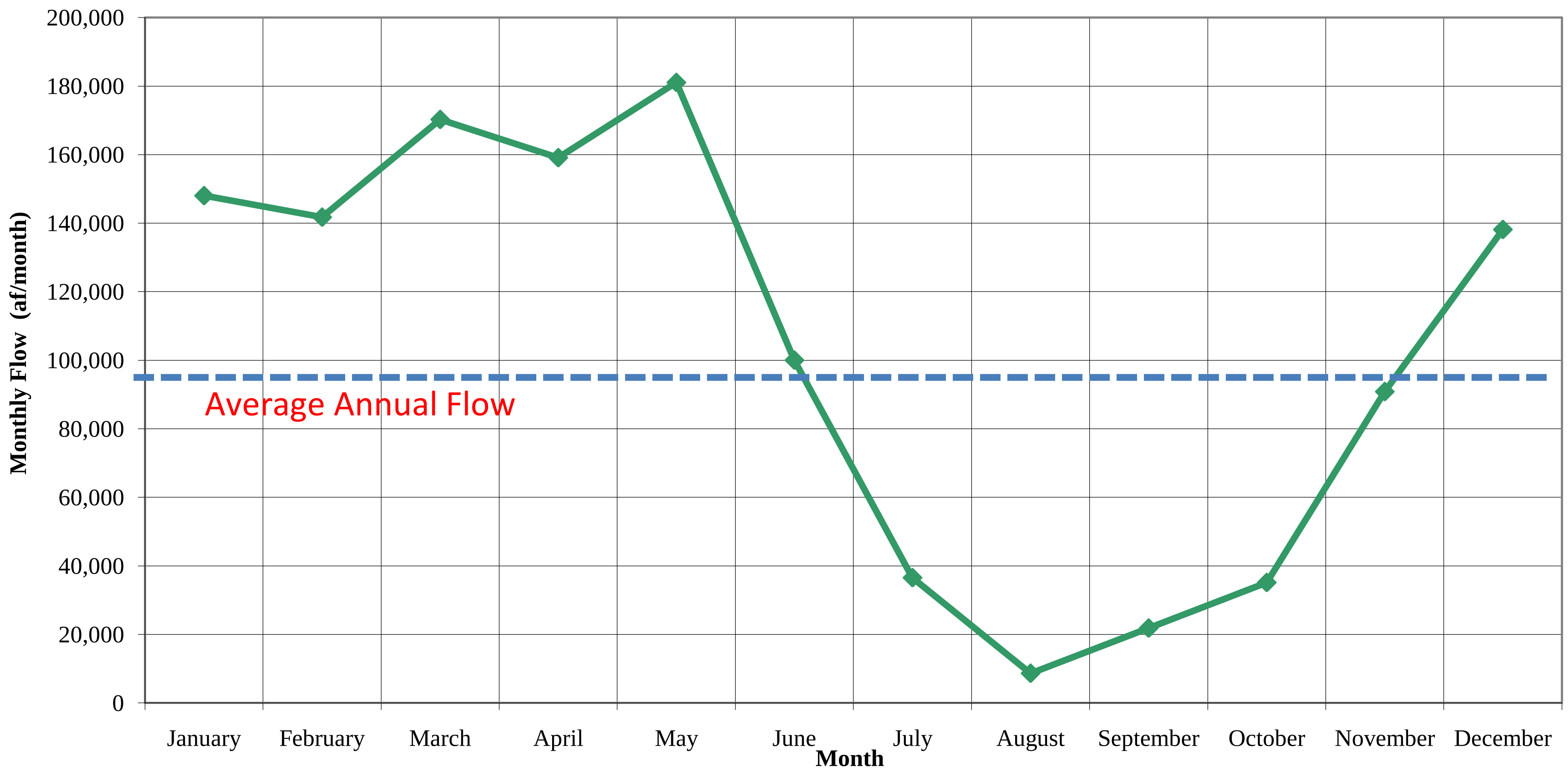
Water Supply Sources



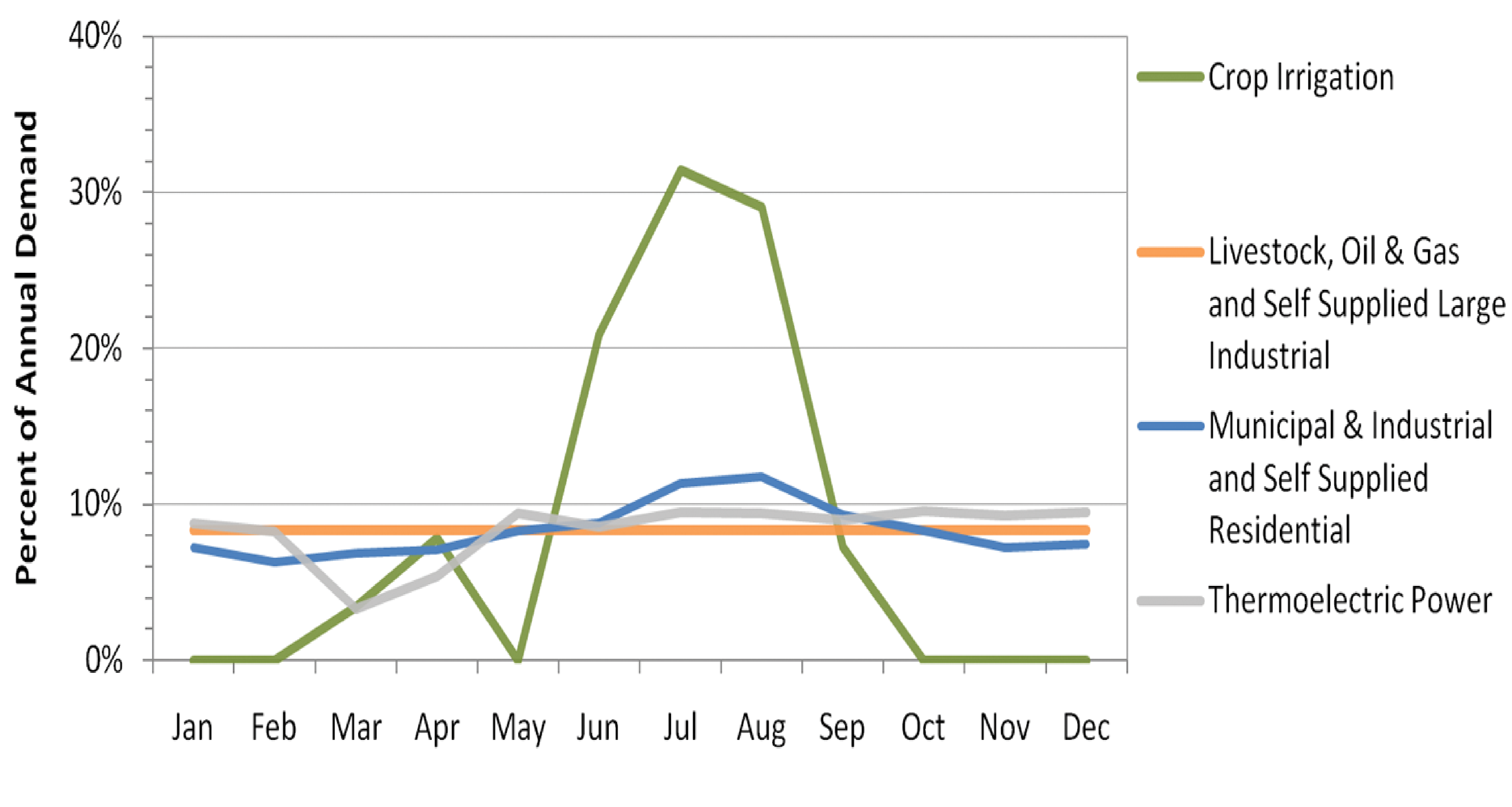
Characterizing Supply Shortages

Surface Water "Gap"	Alluvial GW "Storage Depletion"	Bedrock GW "Storage Depletion"
▪ *Occurs when surface water use exceeds surface water flow* ▪ *Demand is not met* ▪ *Evaluated using 58 years of monthly flow data in each basin*	▪ *Occurs when alluvial groundwater use exceeds rate of recharge to the alluvial aquifer* ▪ *Net reduction in water in aquifer storage but demand may be met* ▪ *Varies with hydrology*	▪ *Occurs when bedrock groundwater use exceeds rate of recharge to the bedrock aquifer* ▪ *Net reduction in water in aquifer storage but demand may be met* ▪ *Does not vary with hydrology*

Mean Monthly Streamflow (Period of Record)



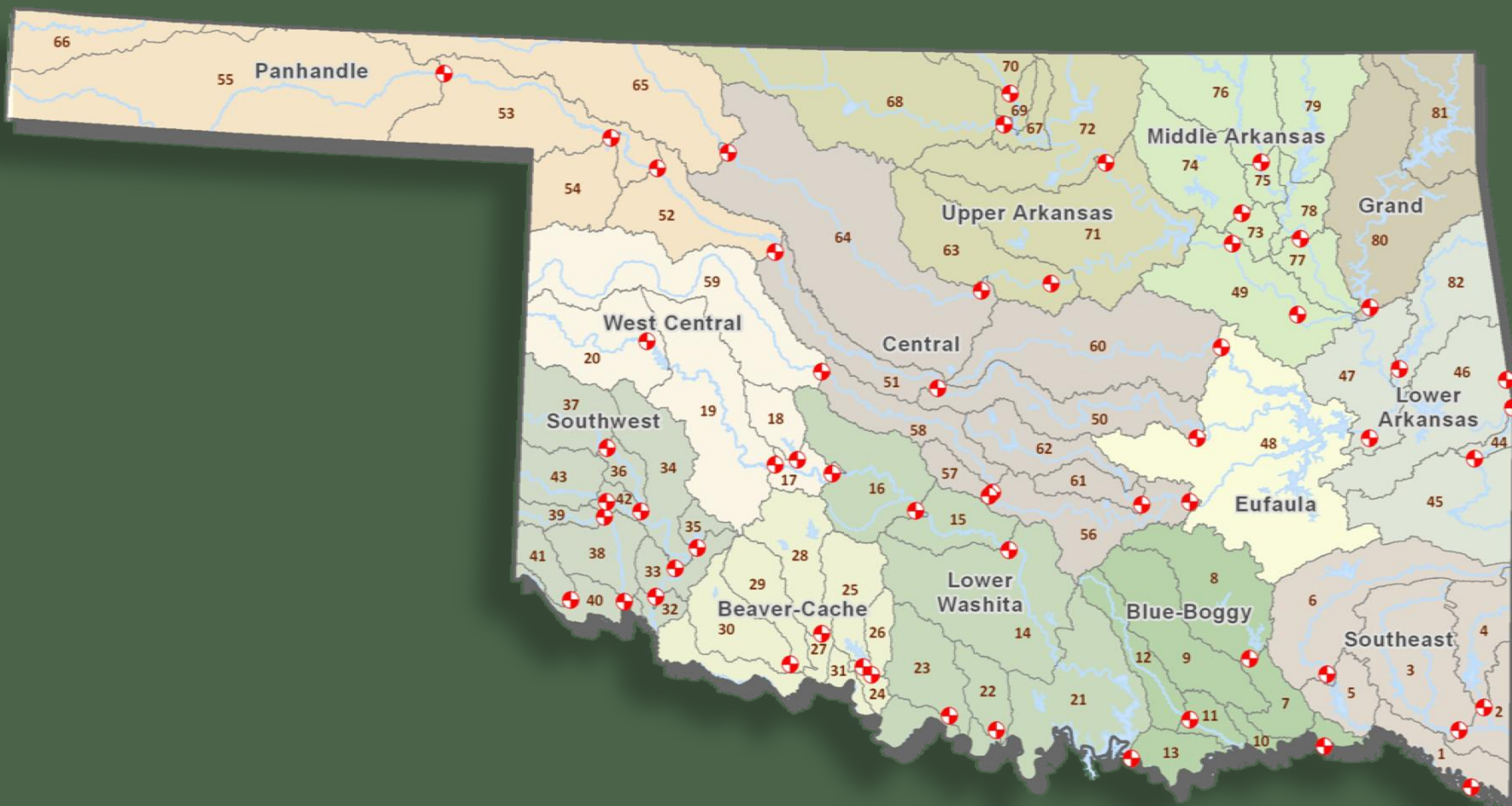
Variable Demand Patterns



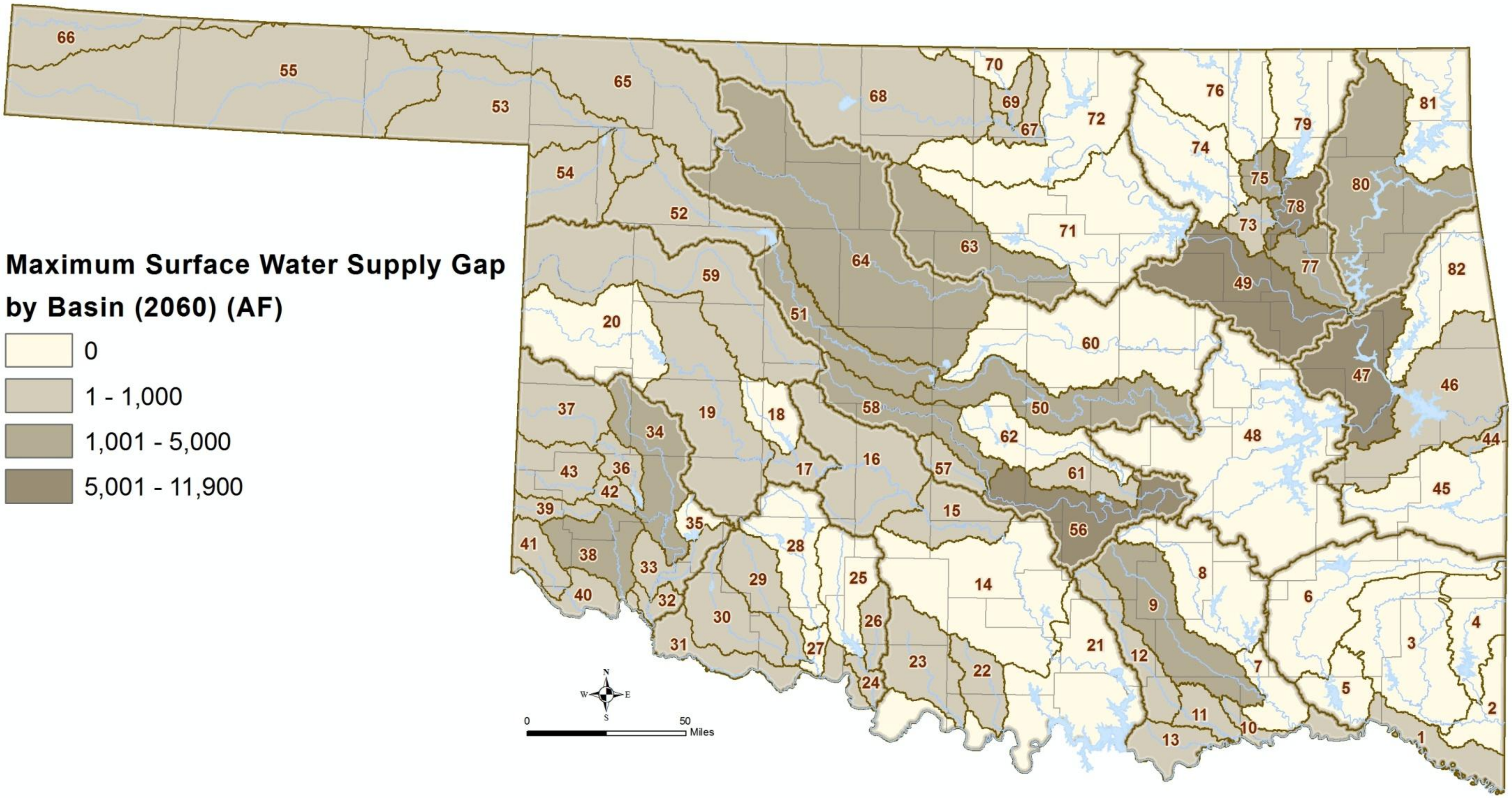
Data Considered and Methodology

- Surface Water:
  - Considered 58 years of streamflow based upon USGS gage data in all 82 basins
  - Looked at annual average and minimum (drought of record) streamflow
  - Considered storage in reservoirs
  - Baseline scenario: current supply proportions held constant in the future
  - Evaluated impacts of future surface water demands on a monthly time step

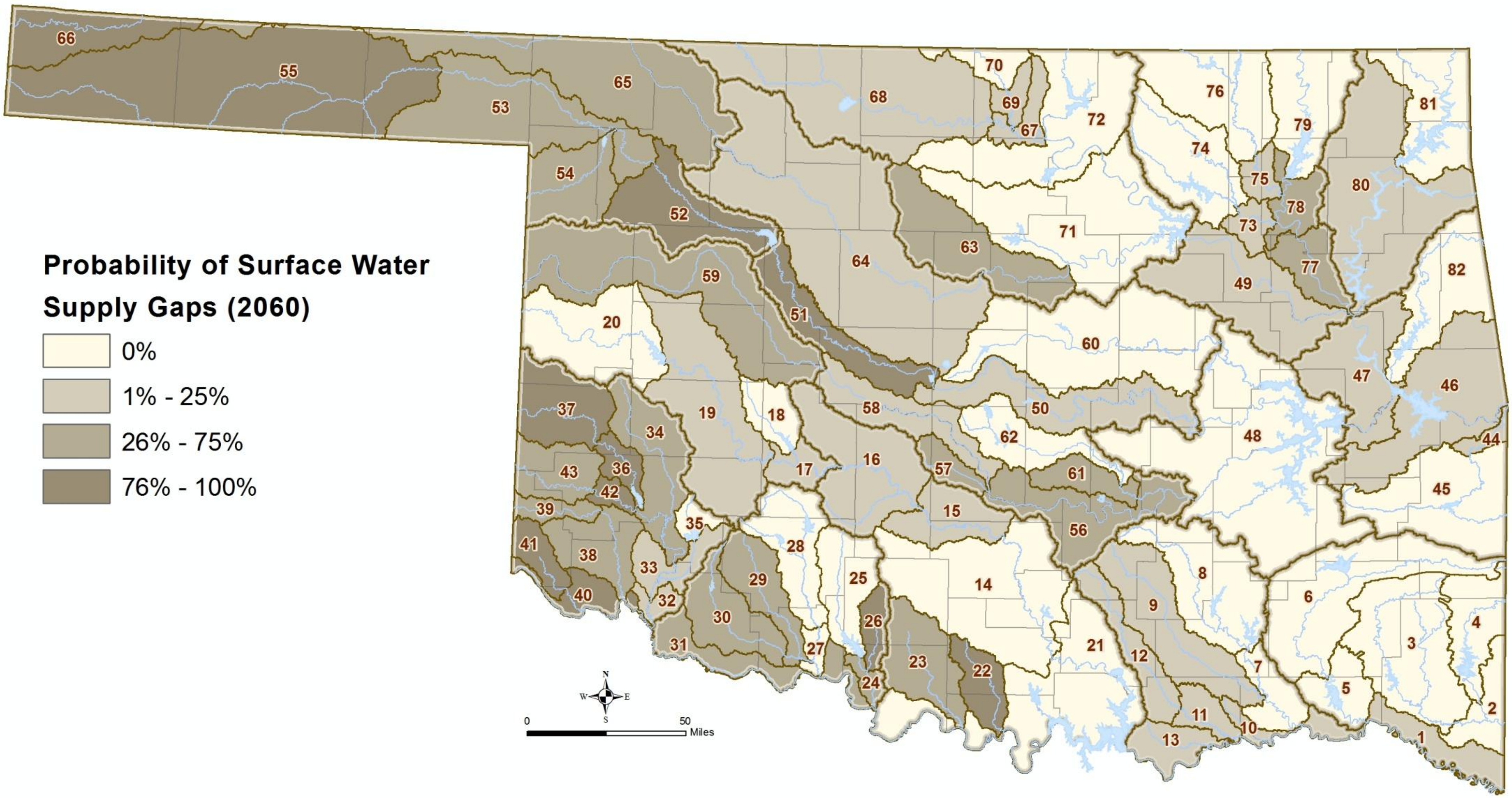
Gage Locations



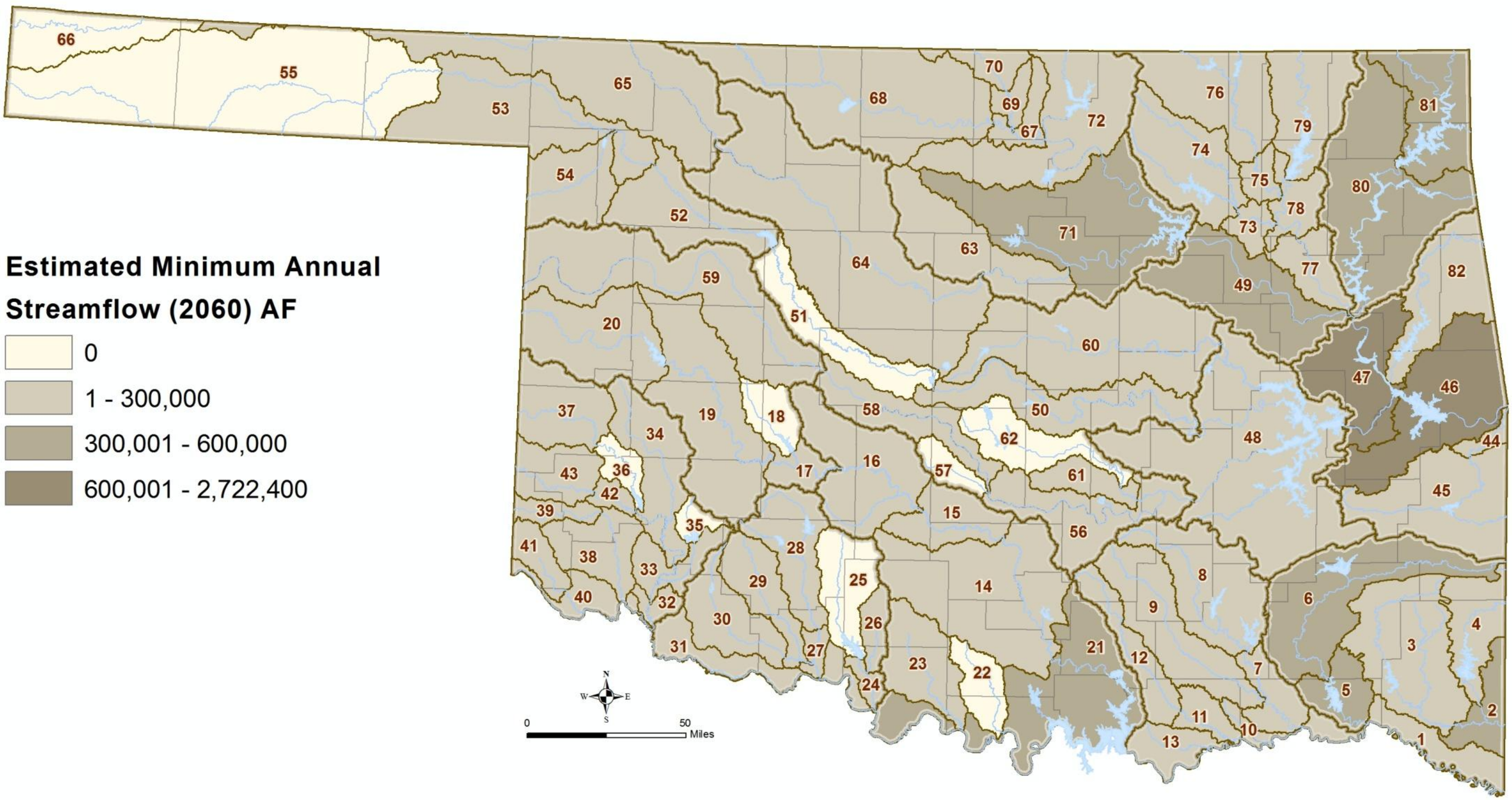
Surface Water Gaps



Probability of Gaps

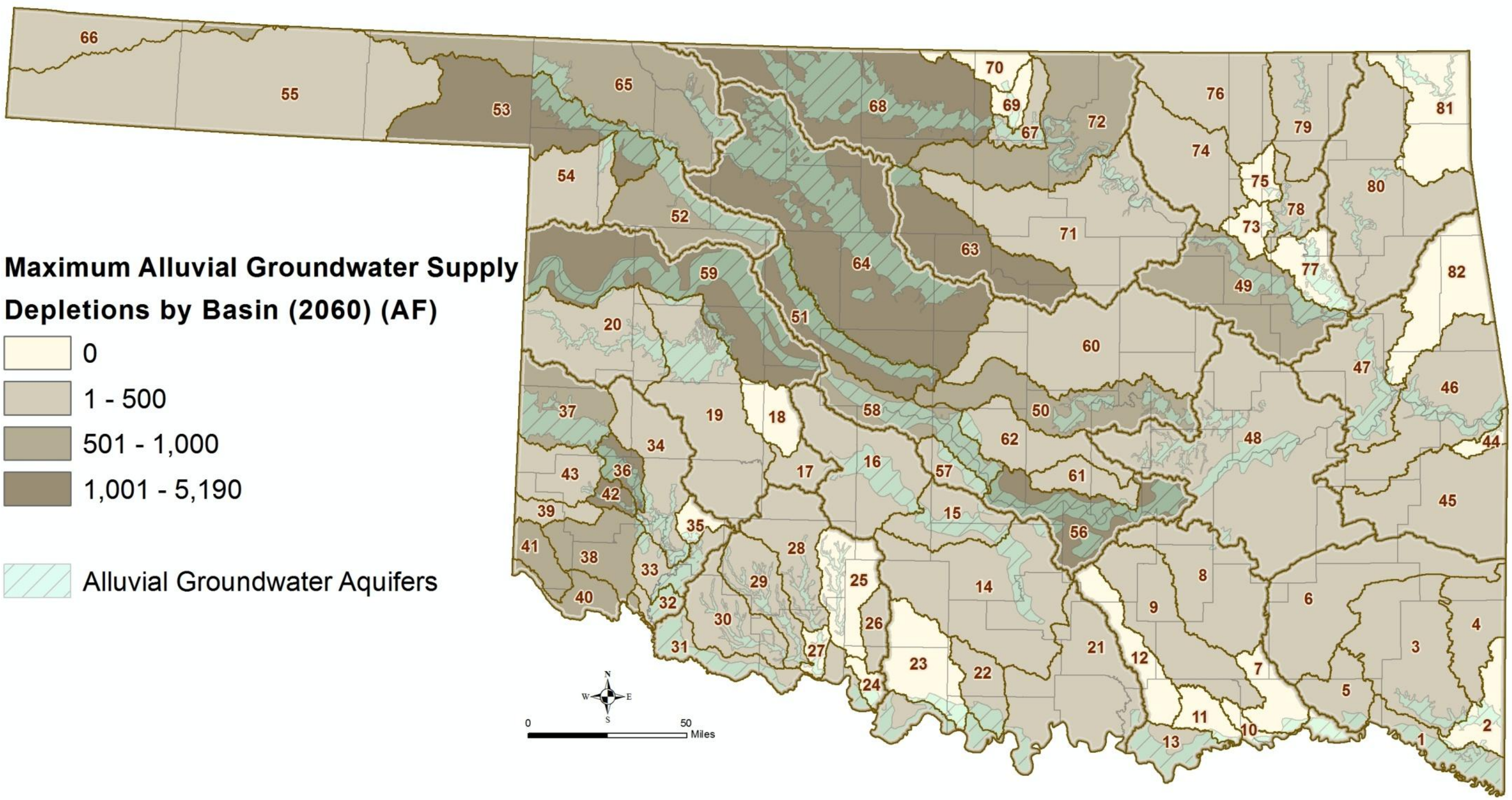


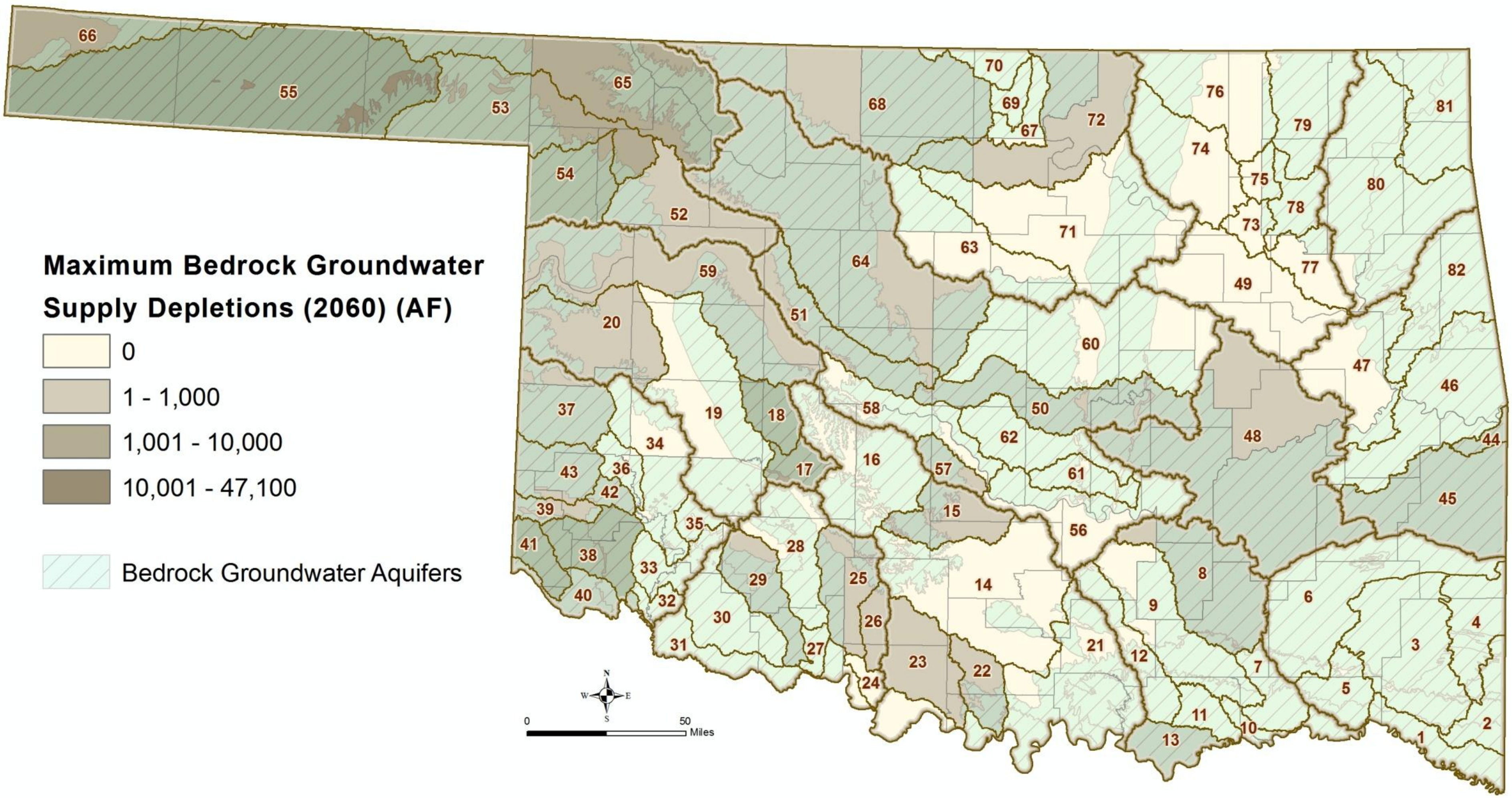
Minimum Annual Streamflow



Groundwater

- Evaluated alluvial and bedrock sources
- Data from previously developed assessments of aquifer storage and recharge rates
- Groundwater resources distributed to the 82 basin level
- Impacts of future demands on groundwater evaluated at the basin level
- Baseline scenario: current supply proportions held constant in the future
- Depletion rates typically minimal statewide, but localized impacts could occur—important for planning


Maximum Alluvial Groundwater Supply
Depletions by Basin (2060) (AF)
0
1 - 500
501 - 1,000
1,001 - 5,190
Alluvial Groundwater Aquifers
N
W
E
S
0
50
Miles



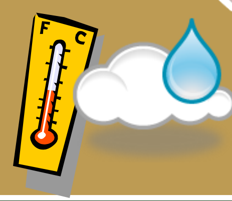
Maximum Bedrock Groundwater Supply Depletions (2060) (AF)
0
1 - 1,000
1,001 - 10,000
10,001 - 47,100
Bedrock Groundwater Aquifers
0
50
Miles

OCWP Climate Change Analyses

Potential Changes in Water Supply

- GCM climate projections
- Quantity, intensity, and seasonality of runoff in 82 basins

Potential Changes in Water Demand



- GCM climate projections
- Focus on M&I and Ag
- Climate Demand Model

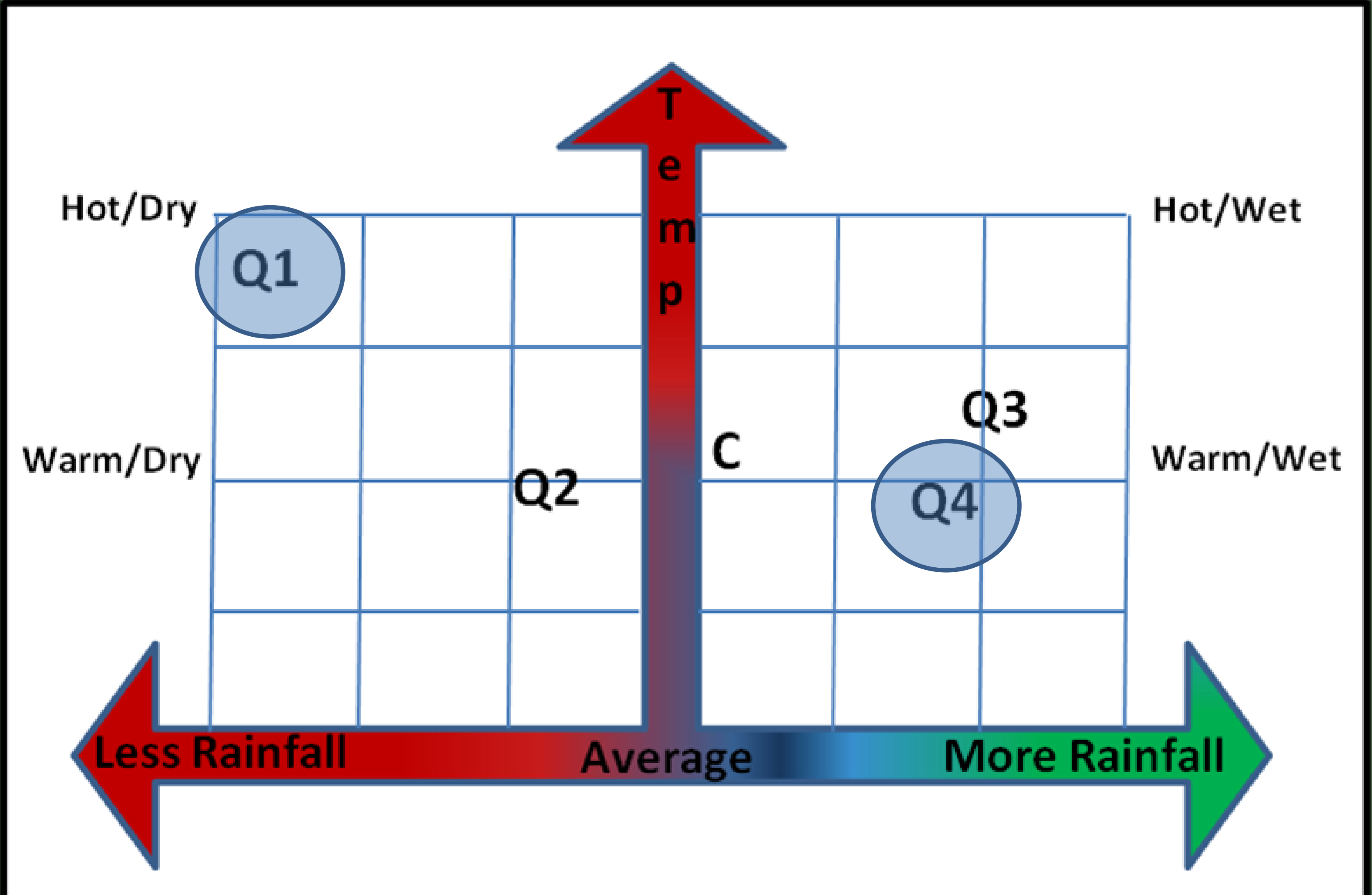
Use Oklahoma H_2O to Assess Impacts on Shortages & Solutions

- Oklahoma H2O Gap Tool
- Reservoir Yield Model
- Supply Solutions

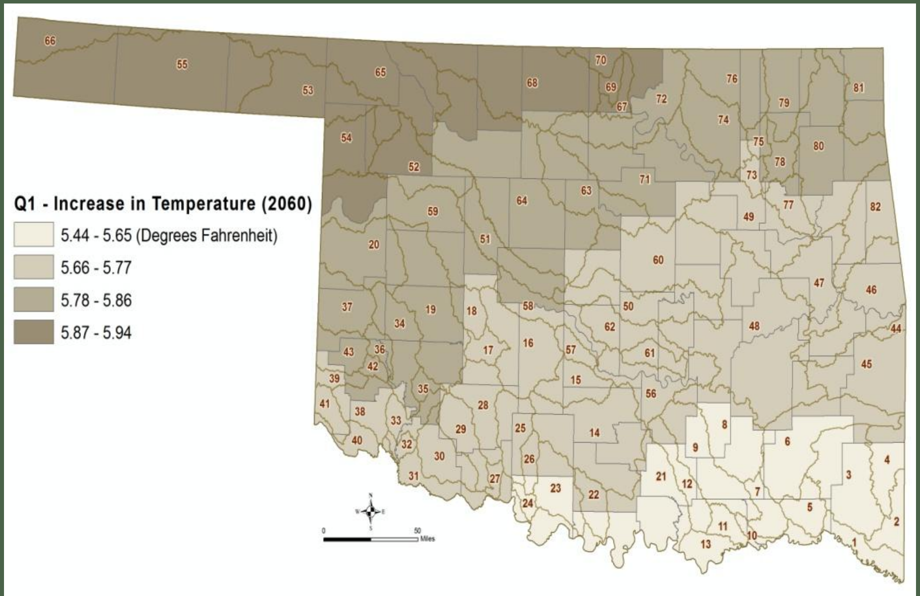
Climate Projections

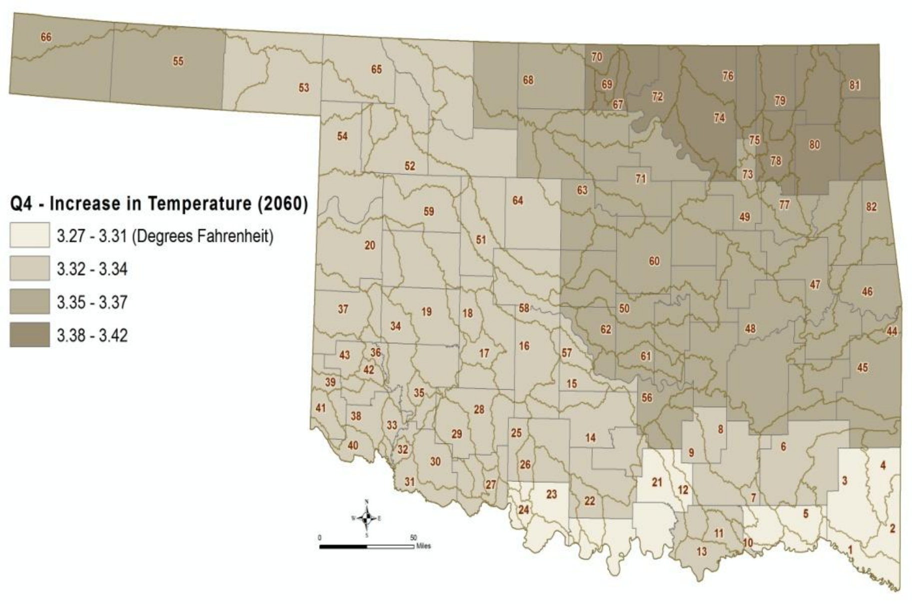
- Based upon increased emissions of CO_2, globally temperature will increase
- As a result, evaporation will increase which will result in increased precipitation
- Precipitation increases not predicted everywhere, not evenly distributed
- Increased temp with increase precip means higher evap and evapotranspiration, less water available
- Impacts supply and demand

Two Ensemble Hybrid-Delta Projections Demonstrate Range of Climate Change

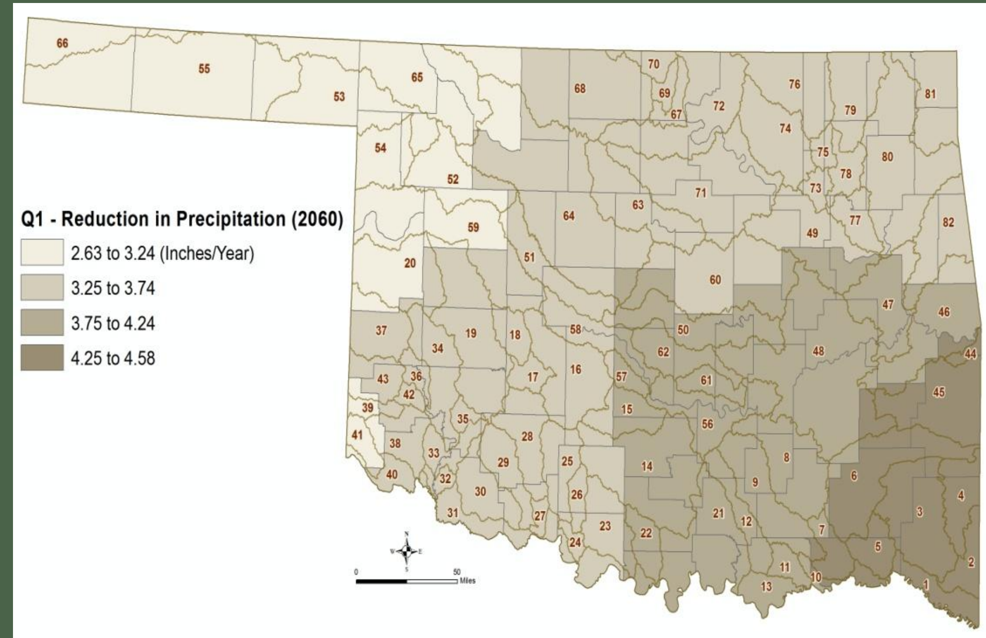


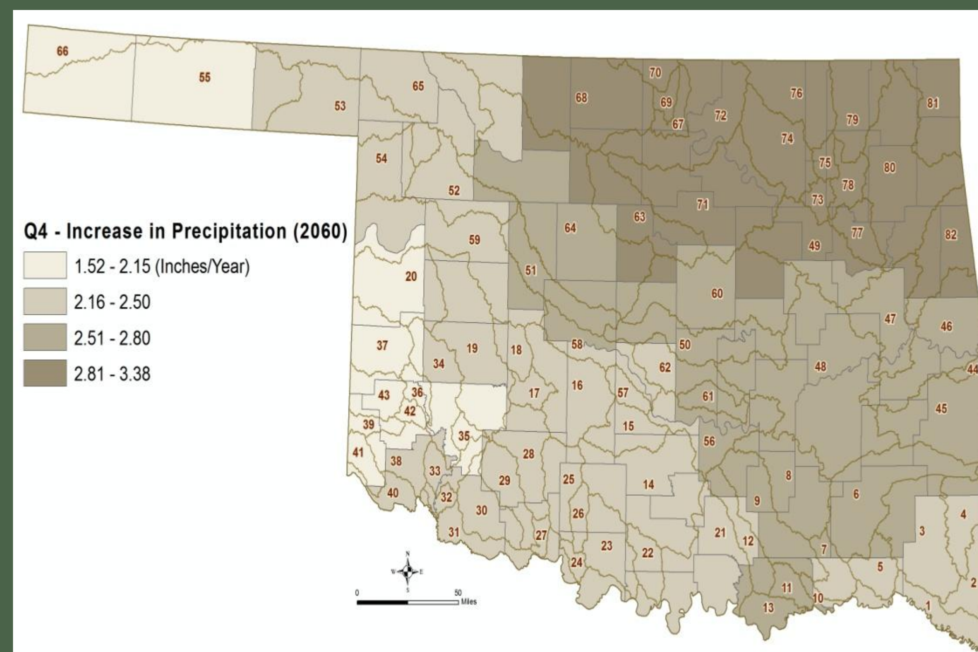
Change in August Historical Average Temperature in 2060



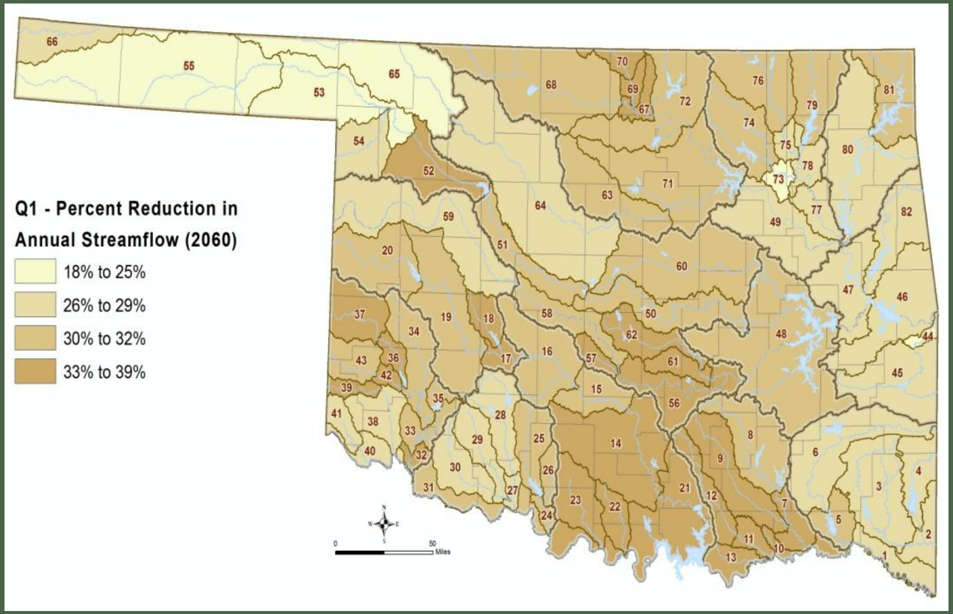


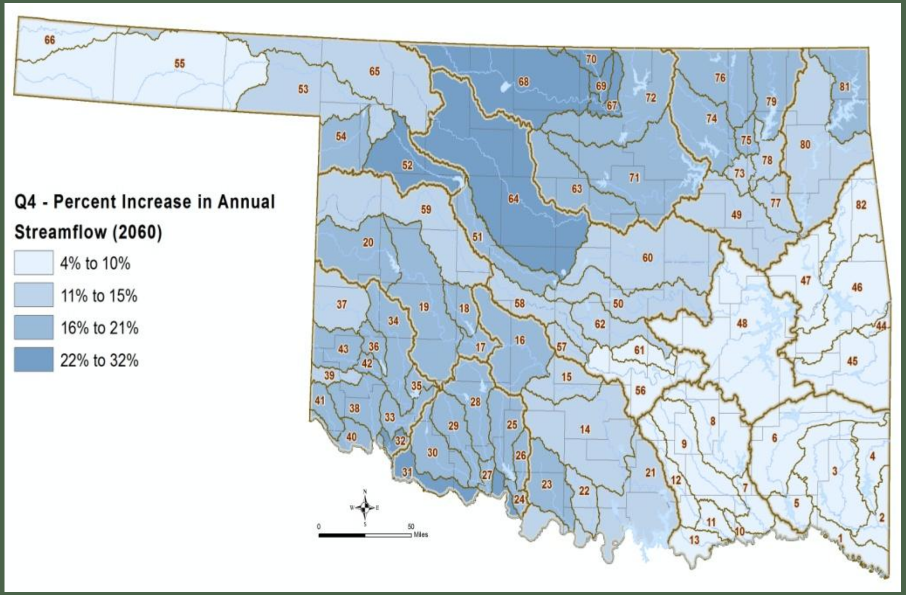
Increase in Historical Average Annual Precipitation



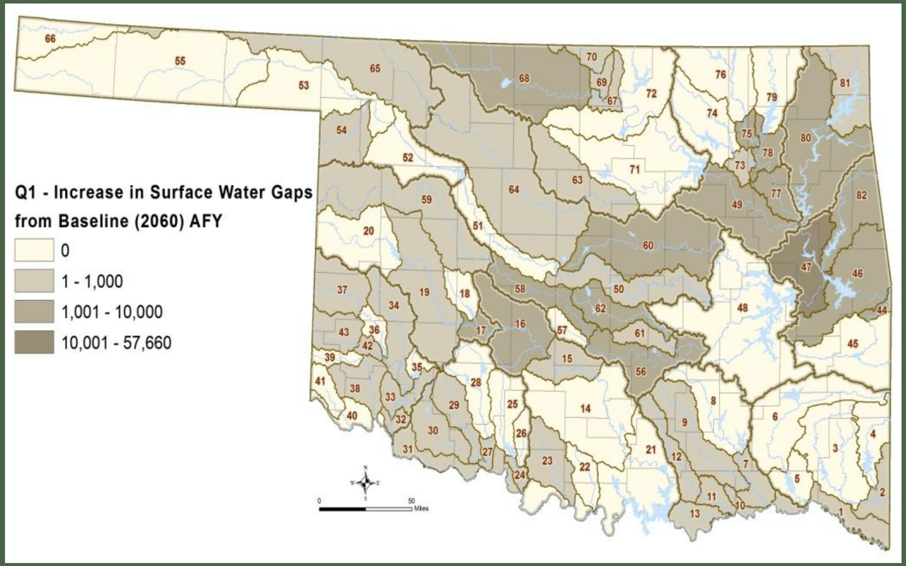


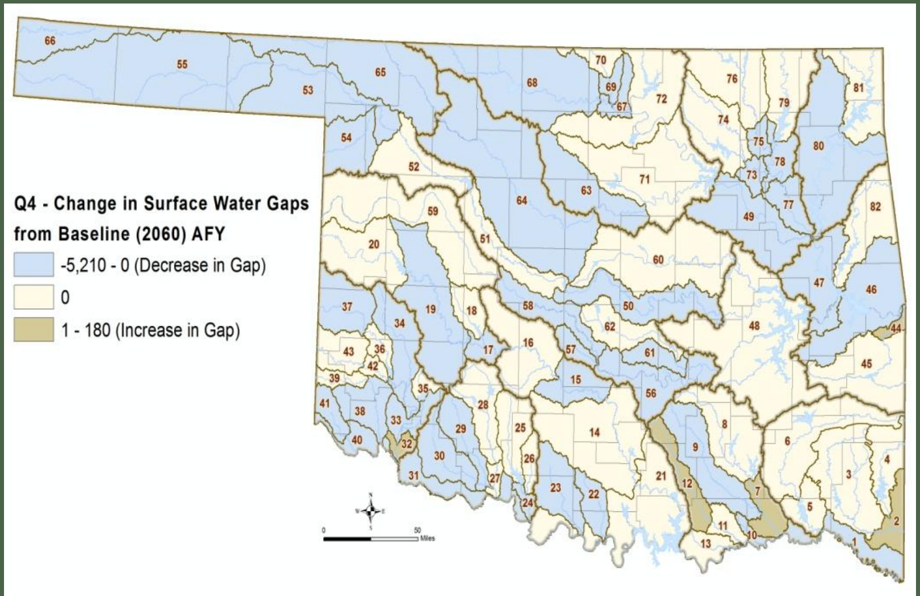
Impacts to Streamflow





Impacts to Surface Water Gaps





Changes to Demand

Statewide M&I Demand Forecast Under Climate Change Scenarios

Year	Baseline (AFY or %)	Hot/Dry (AFY or %)	Warm/Wet (AFY or %)
2030	682,391	718,747	699,119
2060	772,773	846,029	805,398
Change from Baseline			
2030	N/A	36,356	16,727
2060	N/A	73,256	32,625
Percent Increase from Baseline			
2030	N/A	5.3%	2.5%
2060	N/A	9.5%	4.2%

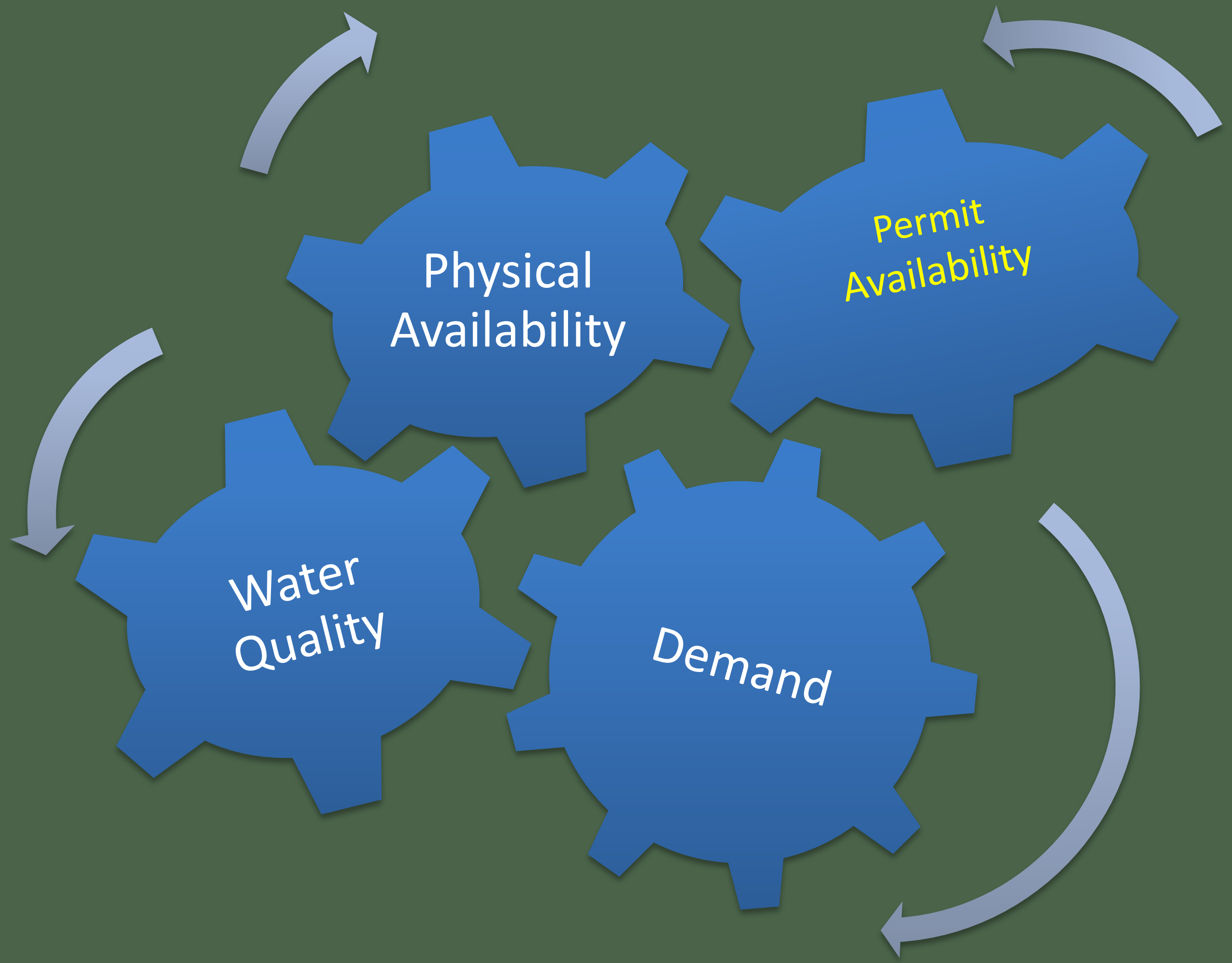
Statistical relationship established between temperature and precipitation and demand (monthly time step)

Statewide Crop Irrigation Demand Forecast Under Climate Change Scenarios

Year	Baseline (AFY or %)	Hot/Dry (AFY or %)	Warm/Wet (AFY or %)
2030	806,112	892,221	823,622
2060	897,464	1,041,032	926,557
Change from Baseline			
2030	N/A	86,109	17,511
2060	N/A	143,567	29,093
Percent Increase from Baseline			
2030	N/A	10.7%	2.2%
2060	N/A	16.0%	3.2%

Relationships established between temperature, precipitation and evapotranspiration and thus irrigation needs

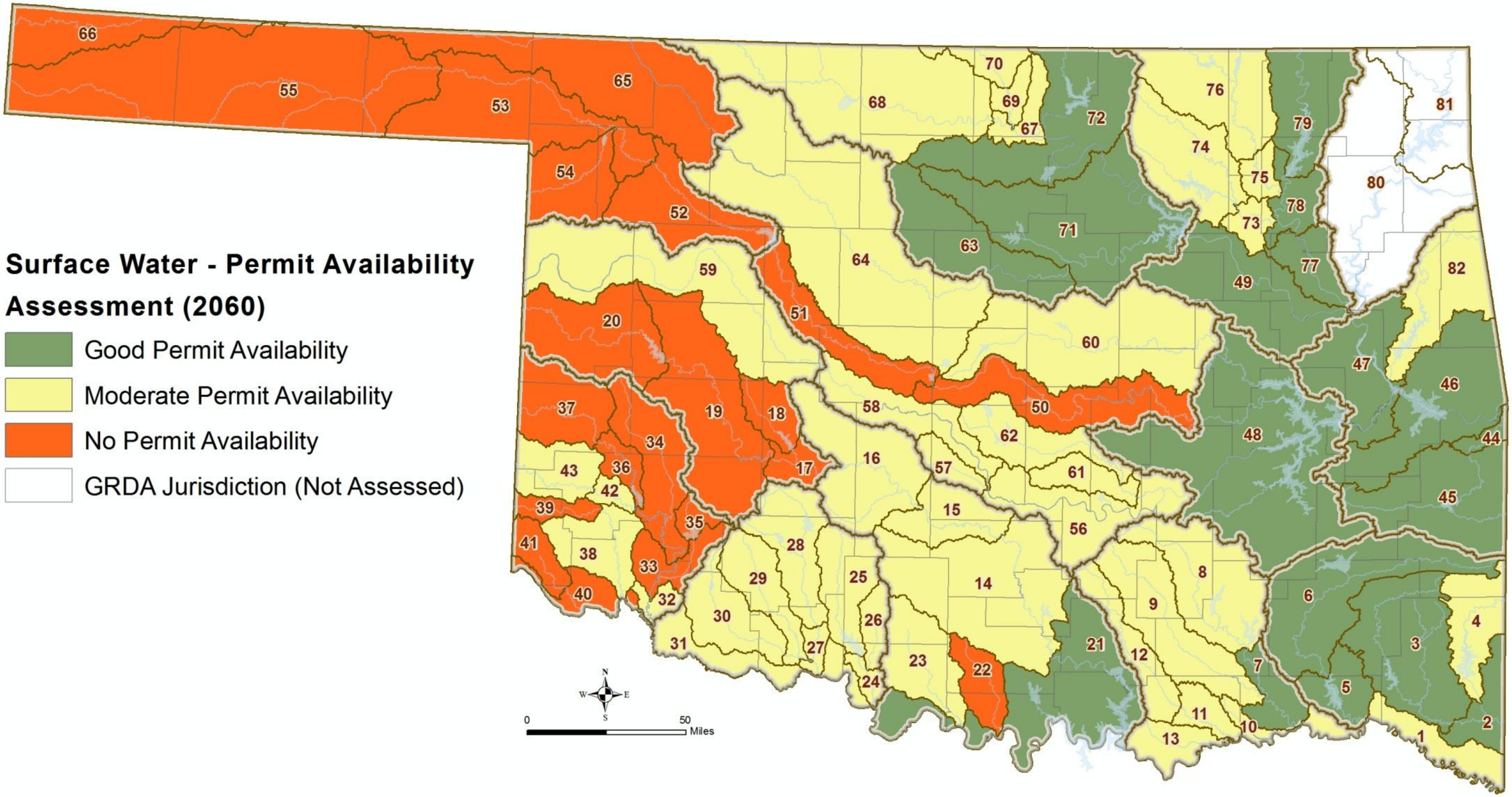
Four Interrelated Components



Data and Methodology

- Predicting future permit availability
- Utilized existing permit data from OWRB
- Followed current OWRB permitting protocol
- Surface Water
  - Prior Appropriation Doctrine
  - Average Annual Flow
  - Beneficial Use
  - Availability to 2060 considered: existing rights, future rights (based upon demand forecasts), reservoir yields, domestic use, compact obligations and downstream basin's permit need to 2060

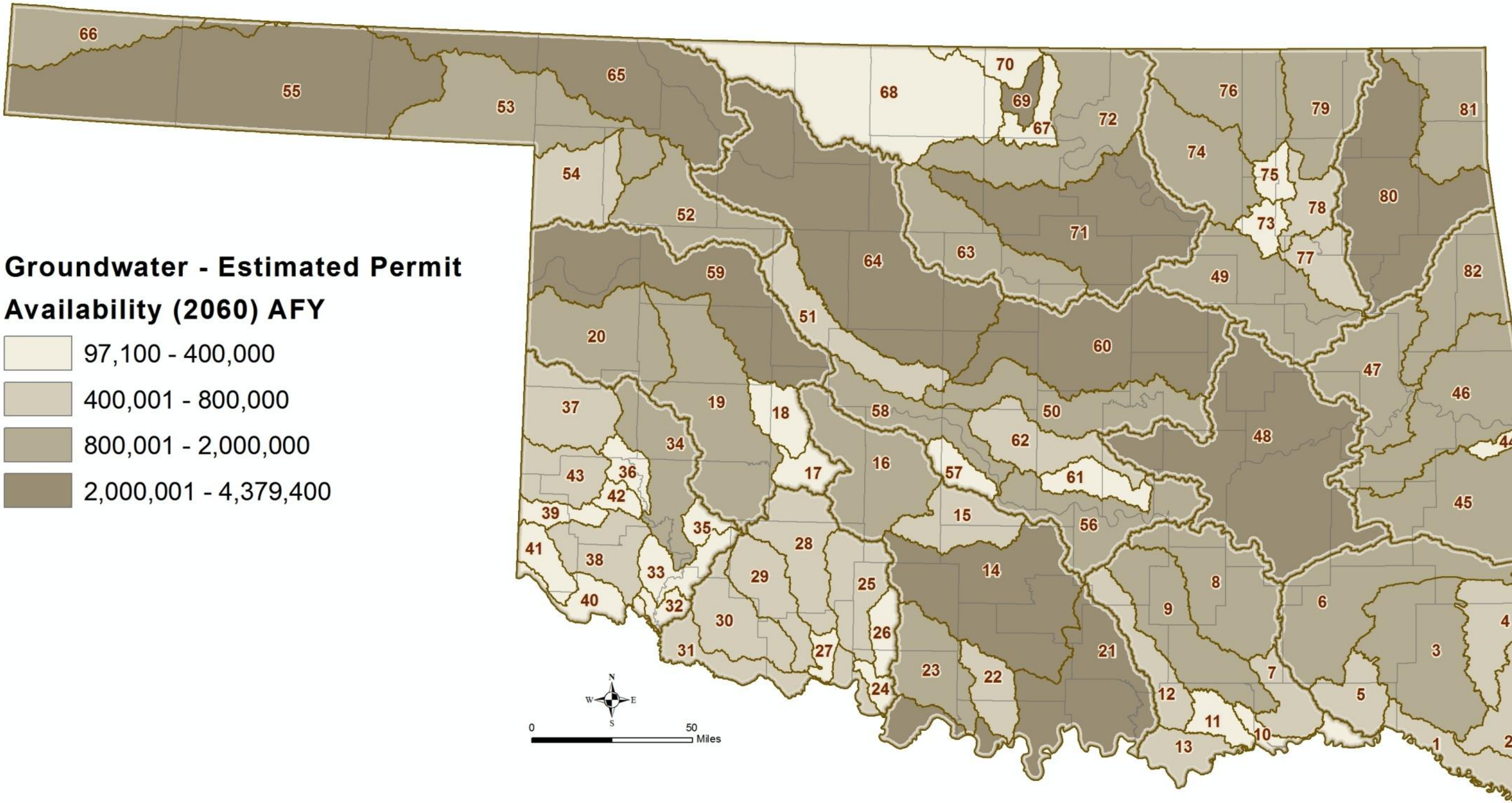
Surface Water Permit Availability at 2060



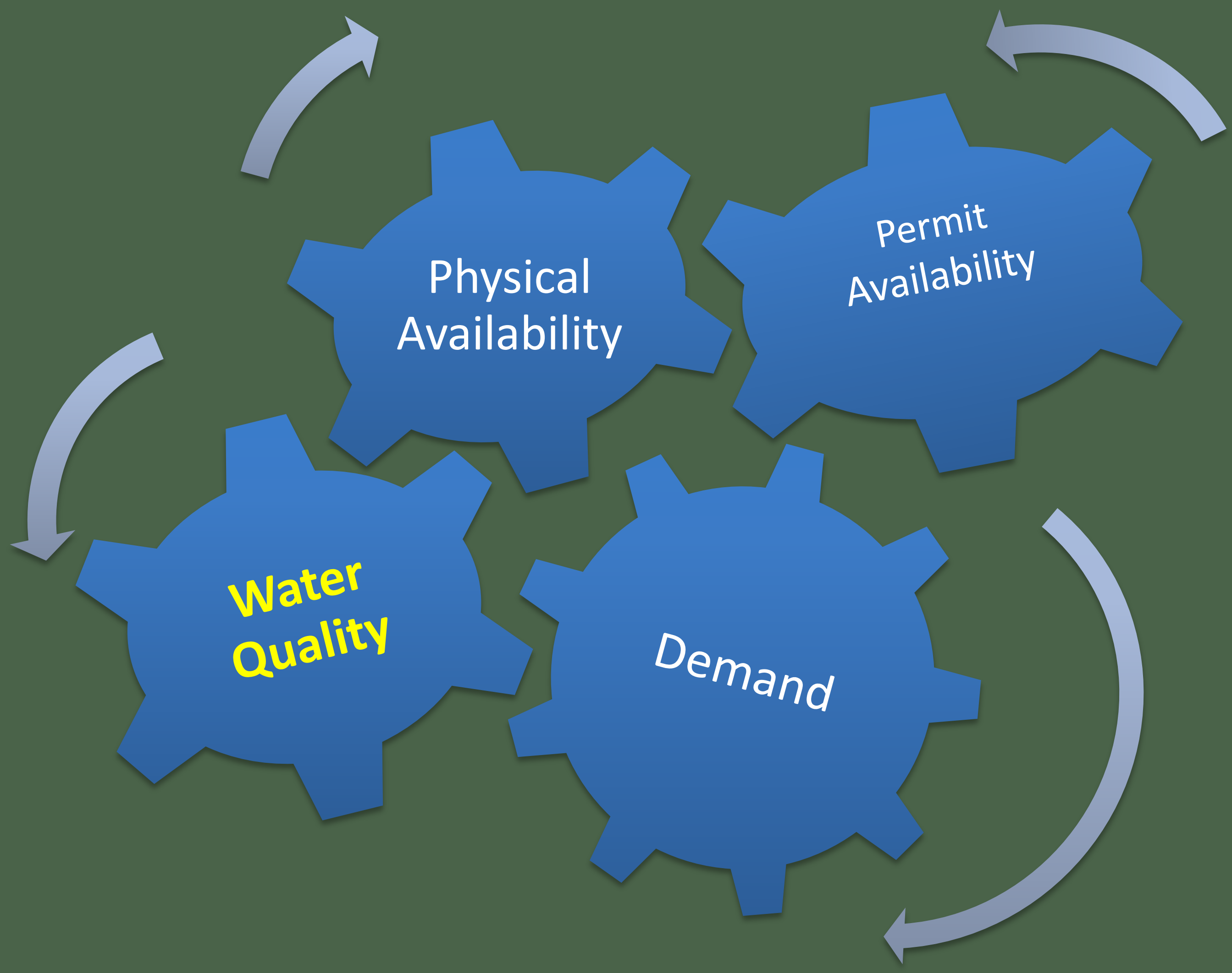
Data and Methodology

- Groundwater (alluvial and bedrock)
  - Private Property Right
  - Followed current OWRB permitting protocol
  - Considered temporary allocations of 2.0 acre-feet/surface acre/year for unstudied basins
  - Considered Equal Proportionate Share (regular permits) as appropriate in studied basins
  - Distributed availability to 82 basin level

Groundwater Permit Availability at 2060



Four Interrelated Components



Data and Methods

- Surface Water only; lack of holistic data for GW
- Water quality condition score determined for all basins
- Evaluated separately for streams and lakes
- Assessed characteristic that could impair future beneficial use:
  - Trends in key parameters based largely on OWRB's Beneficial Use Monitoring Program data
  - Impairments for AG and PPWS beneficial uses
  - Impairment for turbidity
  - Threatened for total nitrogen, phosphorus and chlorophyll-a (lakes only)

Example of Trends Work

Lake Water Quality Trends
Middle Arkansas Region

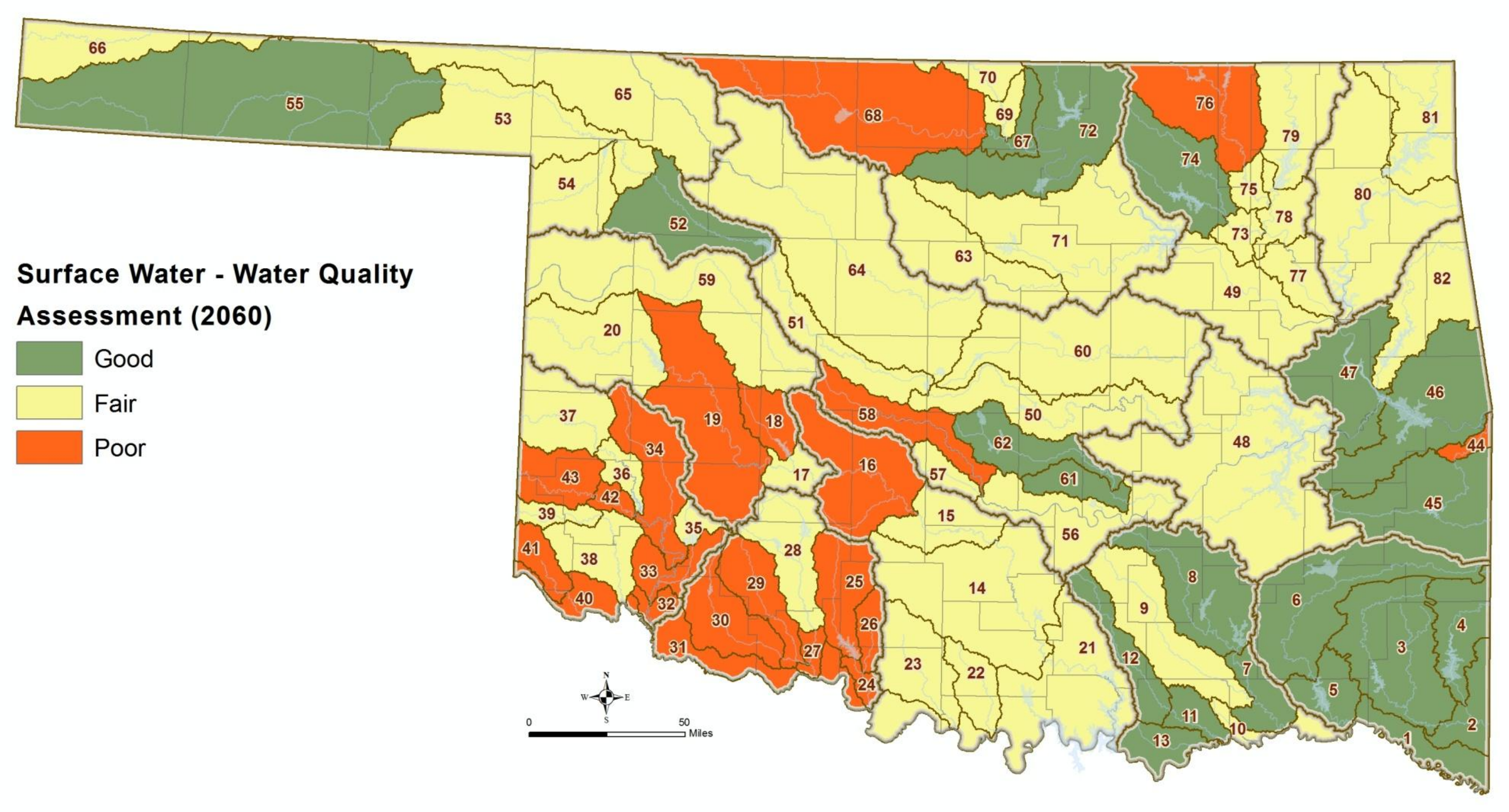
Parameter	Birch Lake (1980-2009)	Bluestem Lake (1995-2009)	Claremore Lake (1994-2006)	Copan Lake (1994-2008)	Heyburn Lake (1996-2008)	Hulah Lake (1994-2008)	Oologah Lake (1996-2008)	Skiatook Lake (1991-2007)
Chlorophyll-a (mg/m3)	NT	↓	NT	↑	NT	NT	NT	NT
Conductivity (us/cm)	NT	↑	NT	↓	↑	↓	↓	↓
Total Nitrogen (mg/L)	NT	↓	↑	NT	↑	↑	↓	NT
Total Phosphorus (mg/L)	↓	↓	↓	↑	↑	NT	NT	NT
Turbidity (NTU)	↓	↓	↑	↑	↓	↑	↓	NT

Increasing Trend[1] ↑ **Decreasing Trend**[1] ↓ NT = No significant trend detected

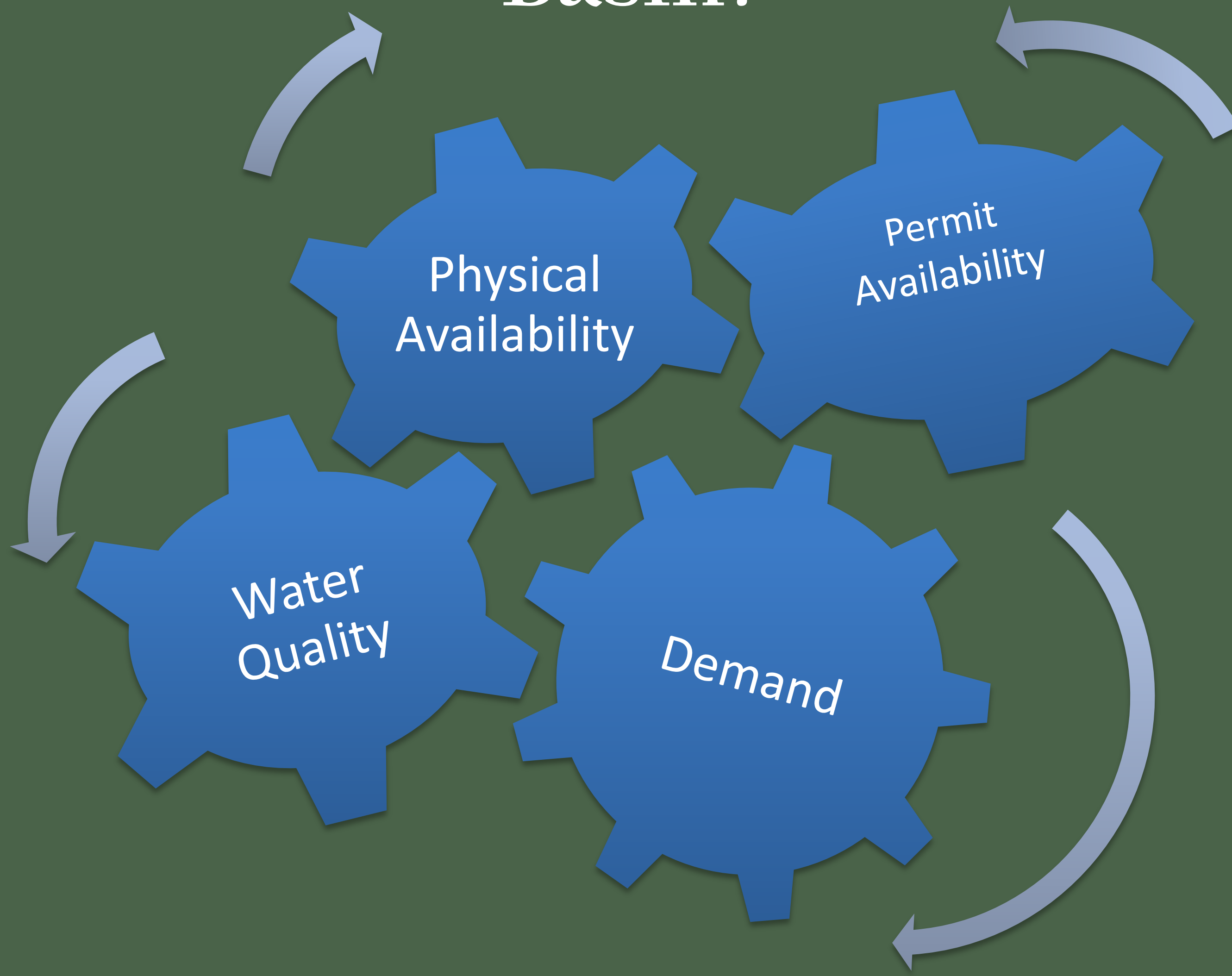
1 *Trend magnitude and statistical confidence levels vary for each site. Site-specific information can be obtained from the OWRB Water Quality Division.*

- Chlorophyll-a demonstrates a slightly significant downward trend at Bluestem Lake and moderately significant upward trend at Copan Lake. All other lakes have no significant trend.
- Conductivity has a moderately/highly significant downward trend at Copan, Hulah, Oologah, and Skiatook Lakes. Bluestem and Heyburn demonstrate a highly significant upward trend. Birch and Claremore Lakes have no significant trend.

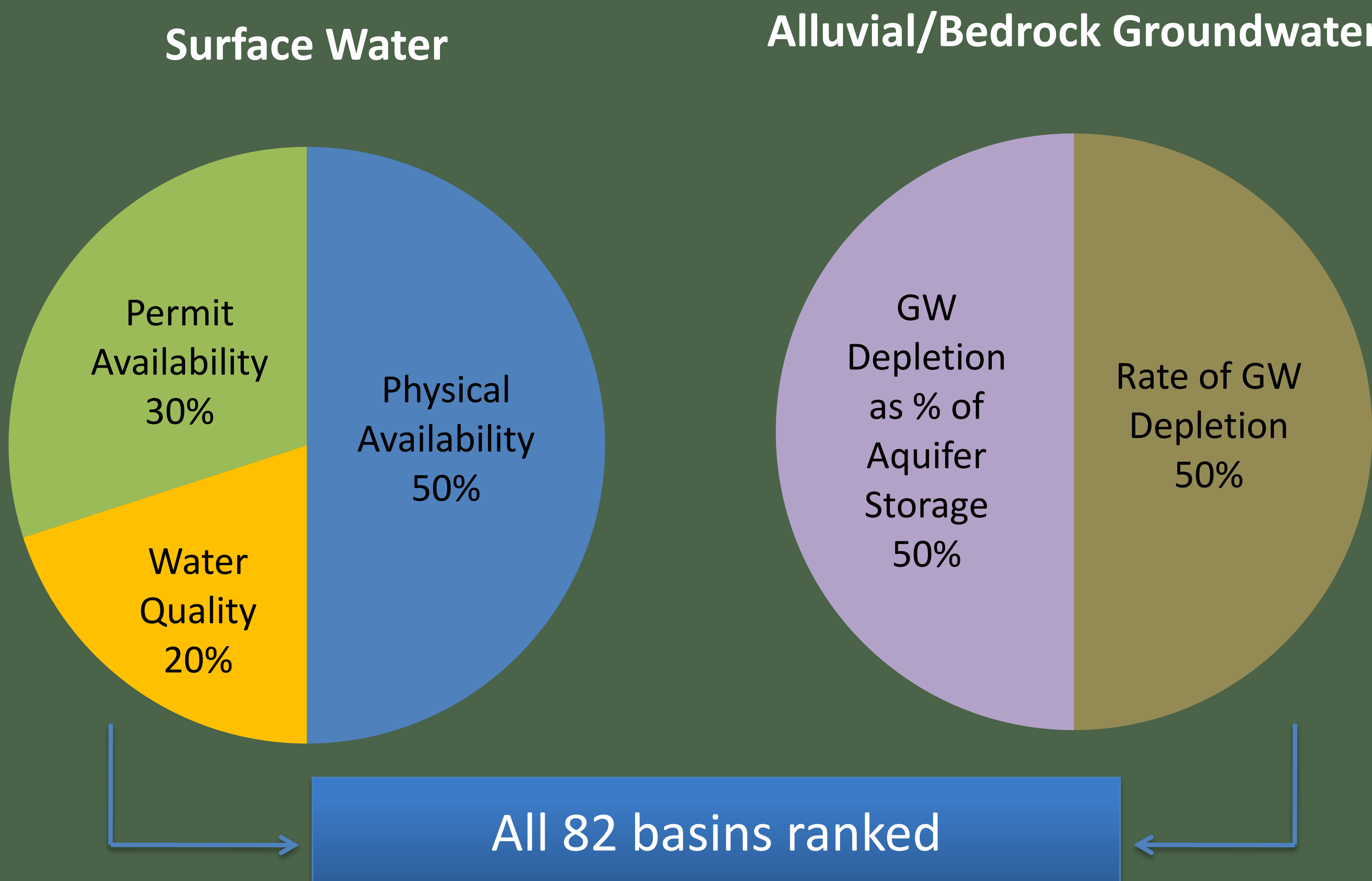
Water Quality Assessment



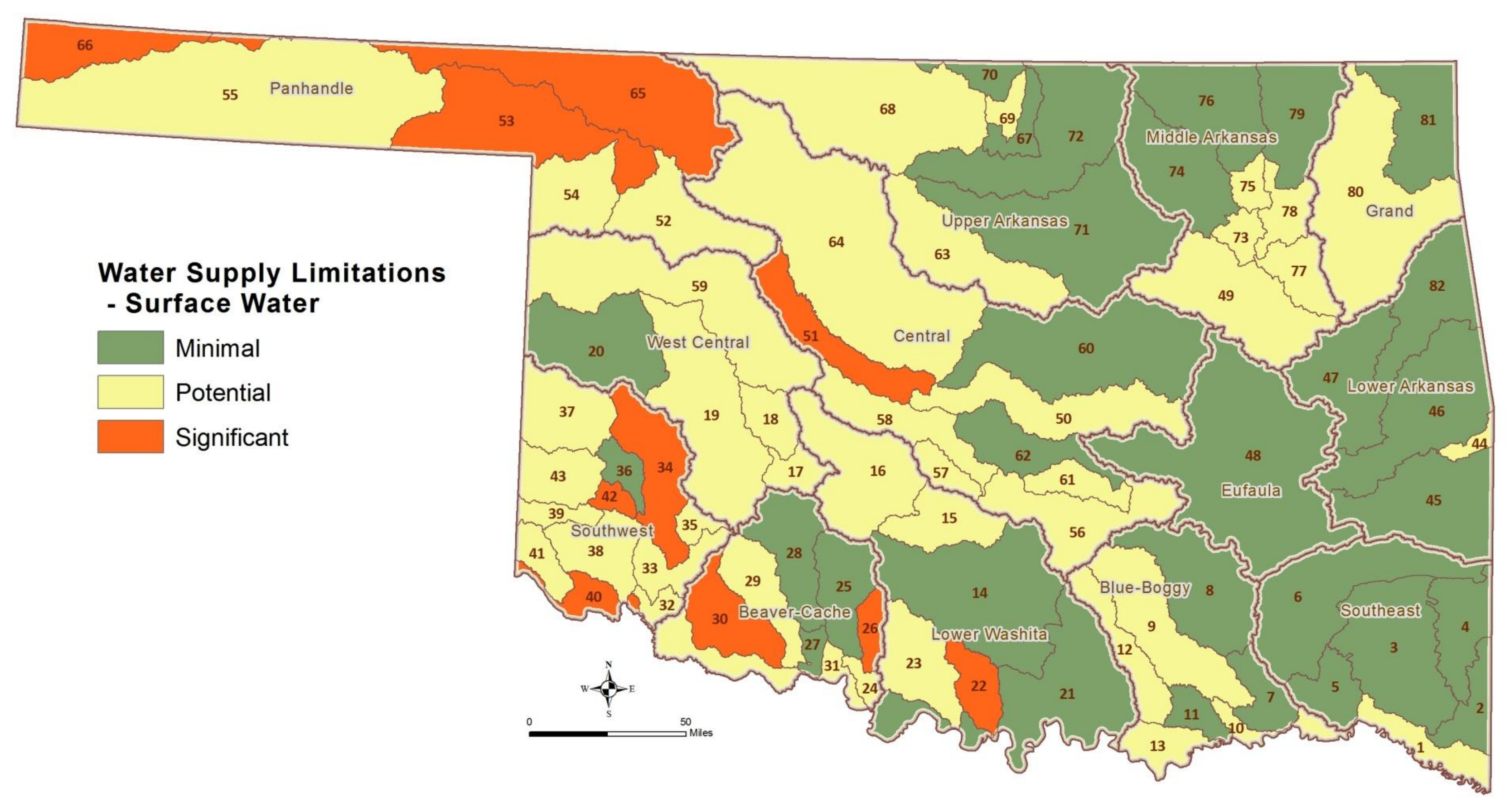
How Do These Gears Turn in Each Basin?



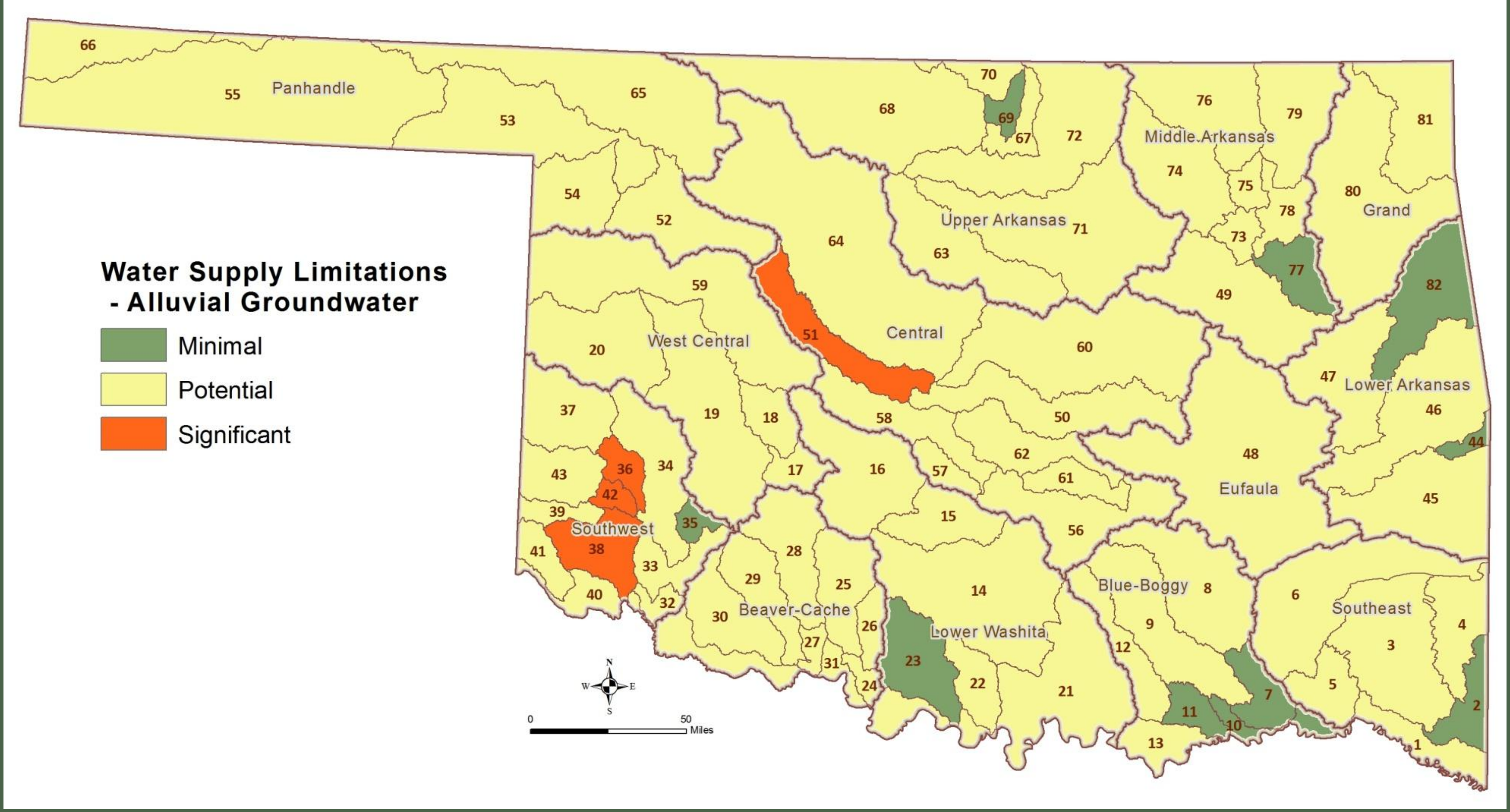
Potential limitations of each supply source to meet 2060 demands



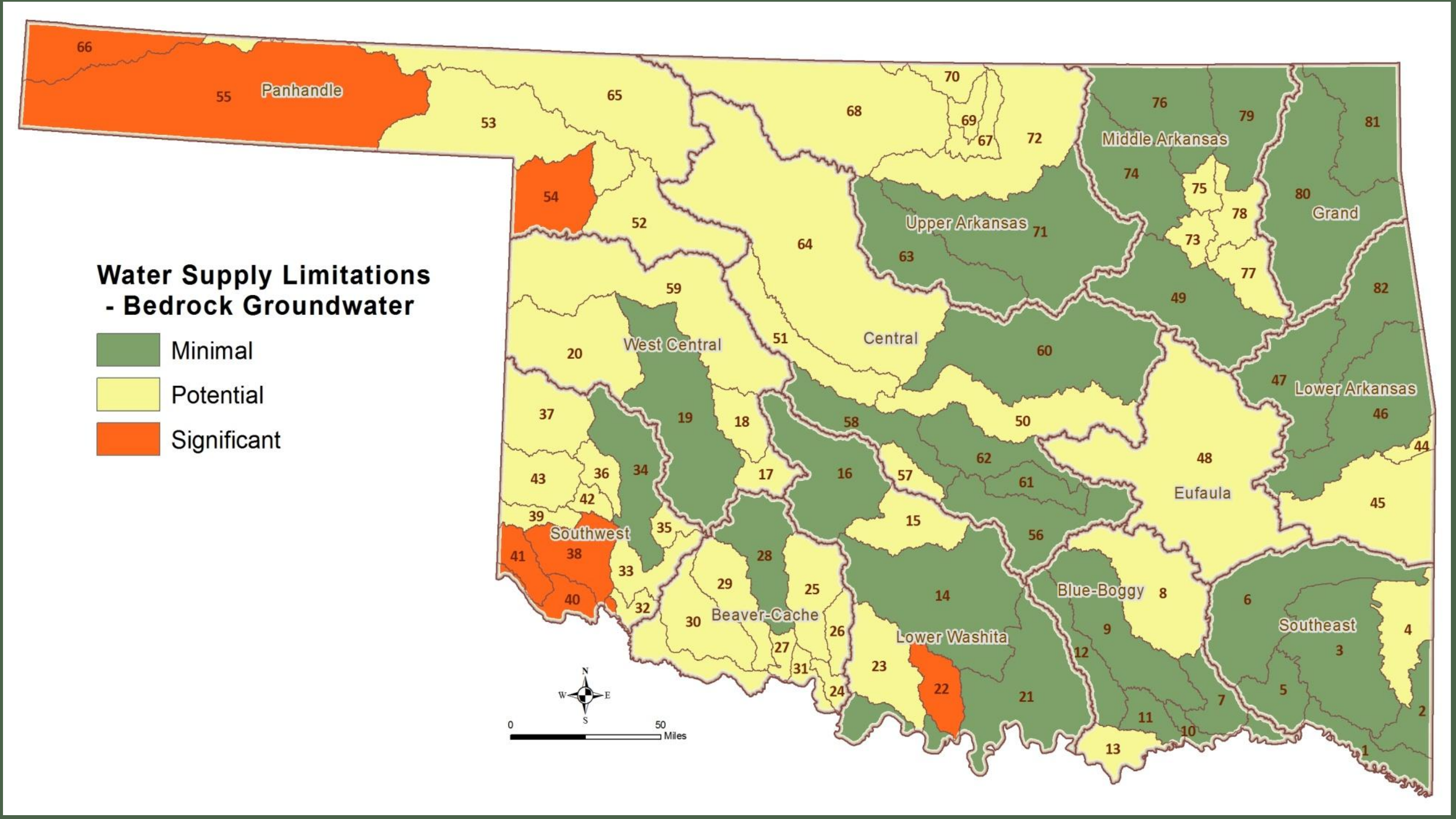
Surface Water Limitations



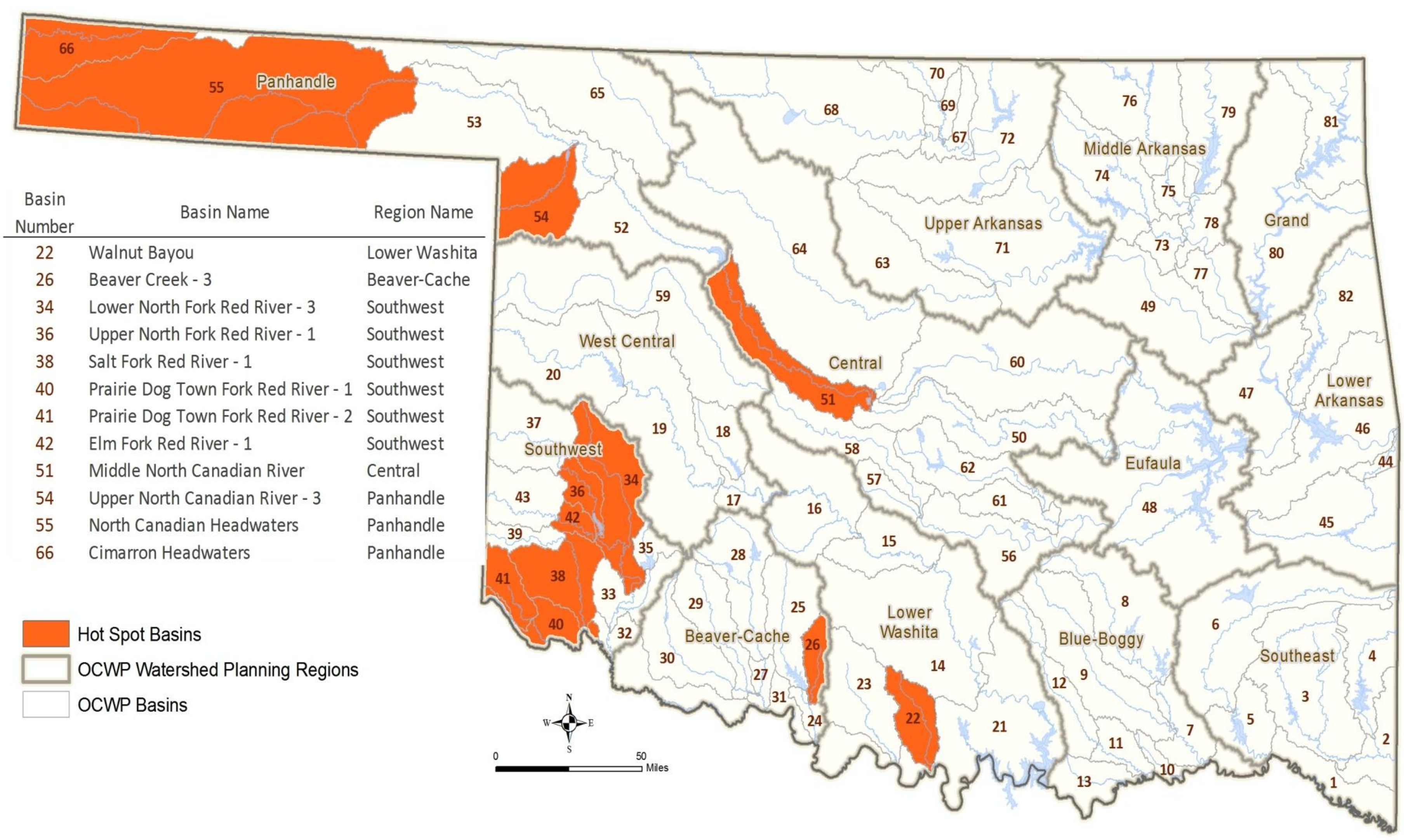
Alluvial Groundwater Limitations



Bedrock Groundwater Limitations



Hot-Spot Basins



Basin Number	Basin Name	Region Name
22	Walnut Bayou	Lower Washita
26	Beaver Creek - 3	Beaver-Cache
34	Lower North Fork Red River - 3	Southwest
36	Upper North Fork Red River - 1	Southwest
38	Salt Fork Red River - 1	Southwest
40	Prairie Dog Town Fork Red River - 1	Southwest
41	Prairie Dog Town Fork Red River - 2	Southwest
42	Elm Fork Red River - 1	Southwest
51	Middle North Canadian River	Central
54	Upper North Canadian River - 3	Panhandle
55	North Canadian Headwaters	Panhandle
66	Cimarron Headwaters	Panhandle

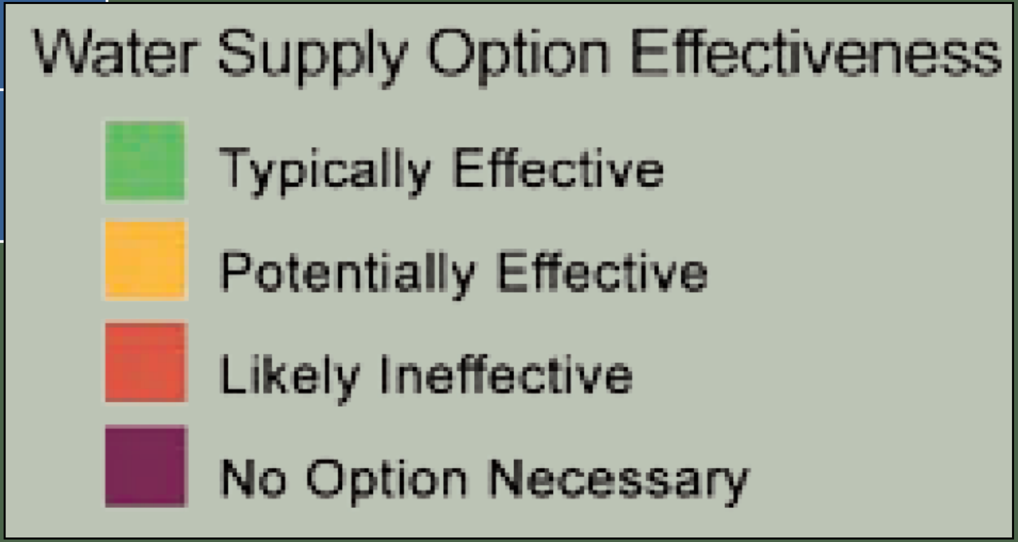
Water Supply Findings

- Surface water gaps projected in 55 of the 82 basins by 2060
- 21 basins forecasted to have surface water permit availability gaps by 2060
- No permitting constraints for groundwater
- 27 basins are considered to have poor water quality as it relates to uses for PWS and Ag
- Alluvial groundwater depletions (minor) are forecasted in 64 basins
- Bedrock groundwater depletions (minor) are forecasted in 34 basins
- Seven basins are forecasted to have no water supply shortages: 2 (SE), 7 (Blue-Boggy), 27, (Beaver-Cache), 35 (SW), 70 (Upper Ark), 81 (Grand) and 82 (Lower Arkansas)

Water Supply Options

SUPPLY OPTION CATEGORIES
DEMAND MANAGEMENT
OUT OF BASIN SUPPLIES
ADDITIONAL RESERVOIR STORAGE
INCREASE SUPPLY FROM SURFACE WATER
INCREASE SUPPLY FROM GROUNDWATER

Based upon results discussed so far, a mid-level analysis of potential options and their associated effectiveness was performed in all 82 basins



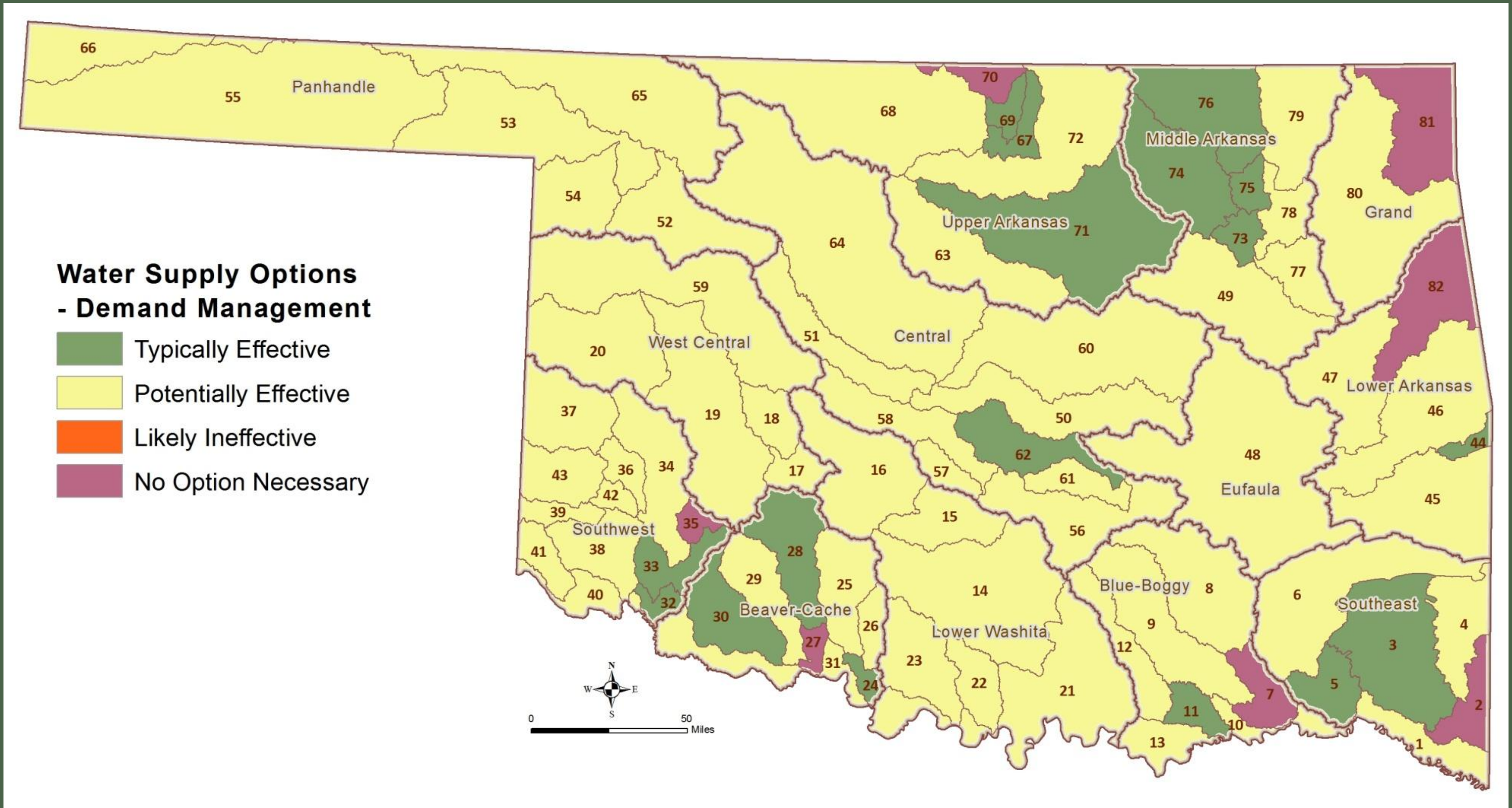
Definitions of Options

- Demand Management: considered conservation (moderate/long term) and drought management measures (short term)
- Out-of-basin supplies: importing water from another basin; evaluated potential, previously studied reservoir sites in the Region for storage
- Reservoir Use: development of in-basin reservoirs; evaluated if streamflow available to provide adequate storage to meet future demands; also evaluated previously studied sites and their viability (if any)

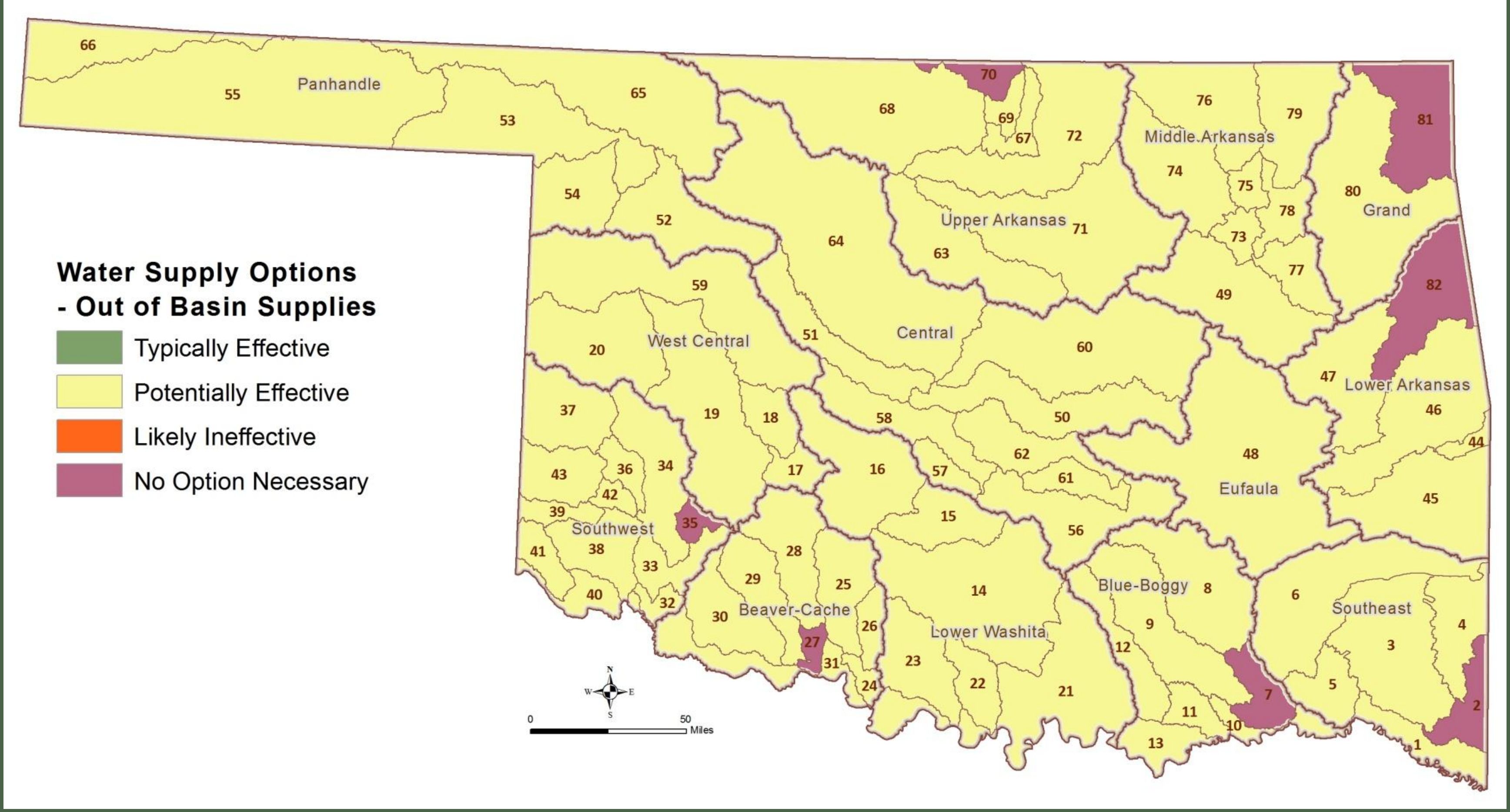
Definitions of Options

- Increased Use of Surface Water: considers the effectiveness of increasing the use of surface water through direct diversions (run-of-the-river, no storage), rather than through increased groundwater use
- Increased Use of Groundwater: considers the effectiveness of increasing the use of groundwater rather than increased surface water use

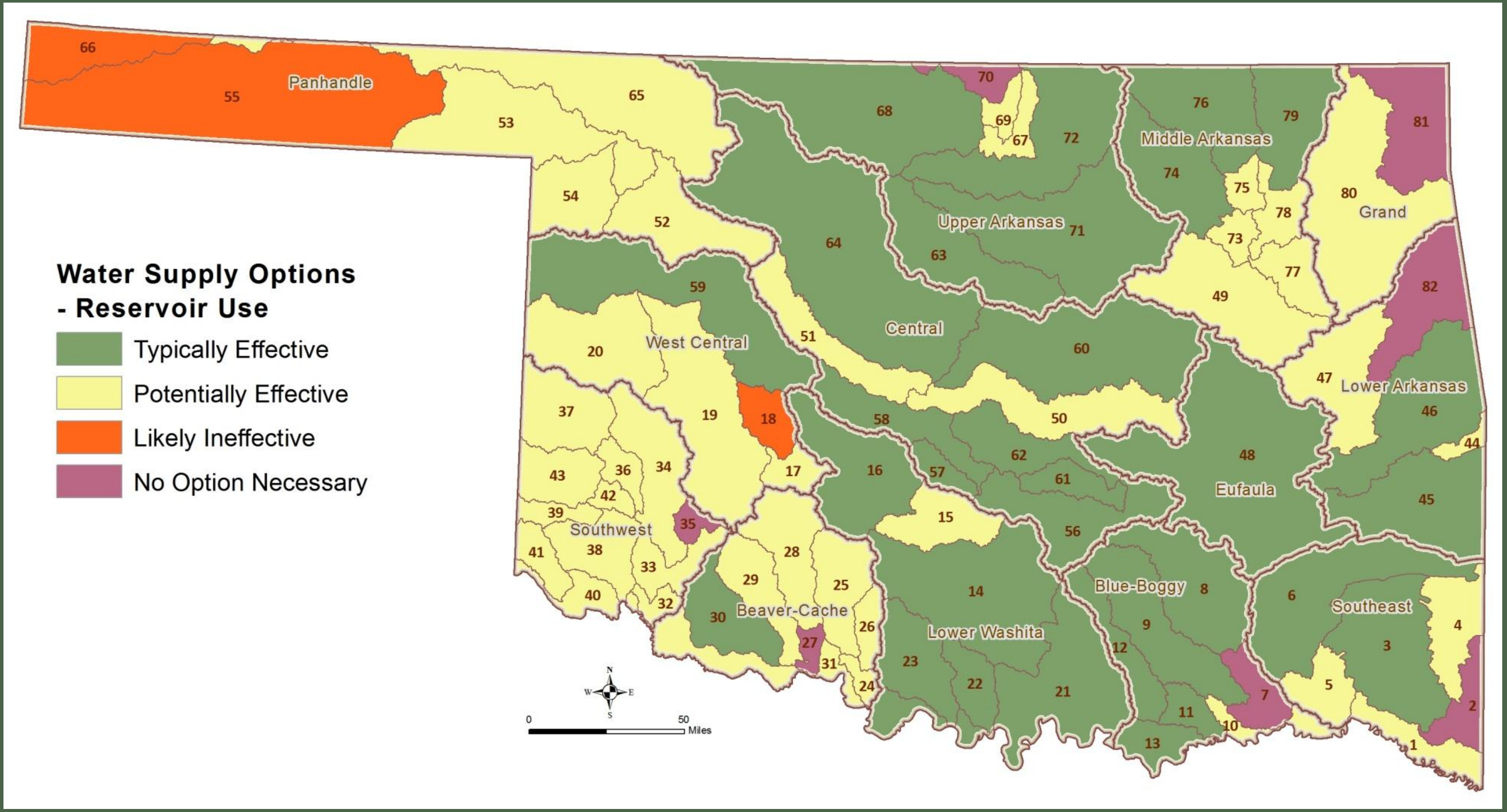
Demand Management



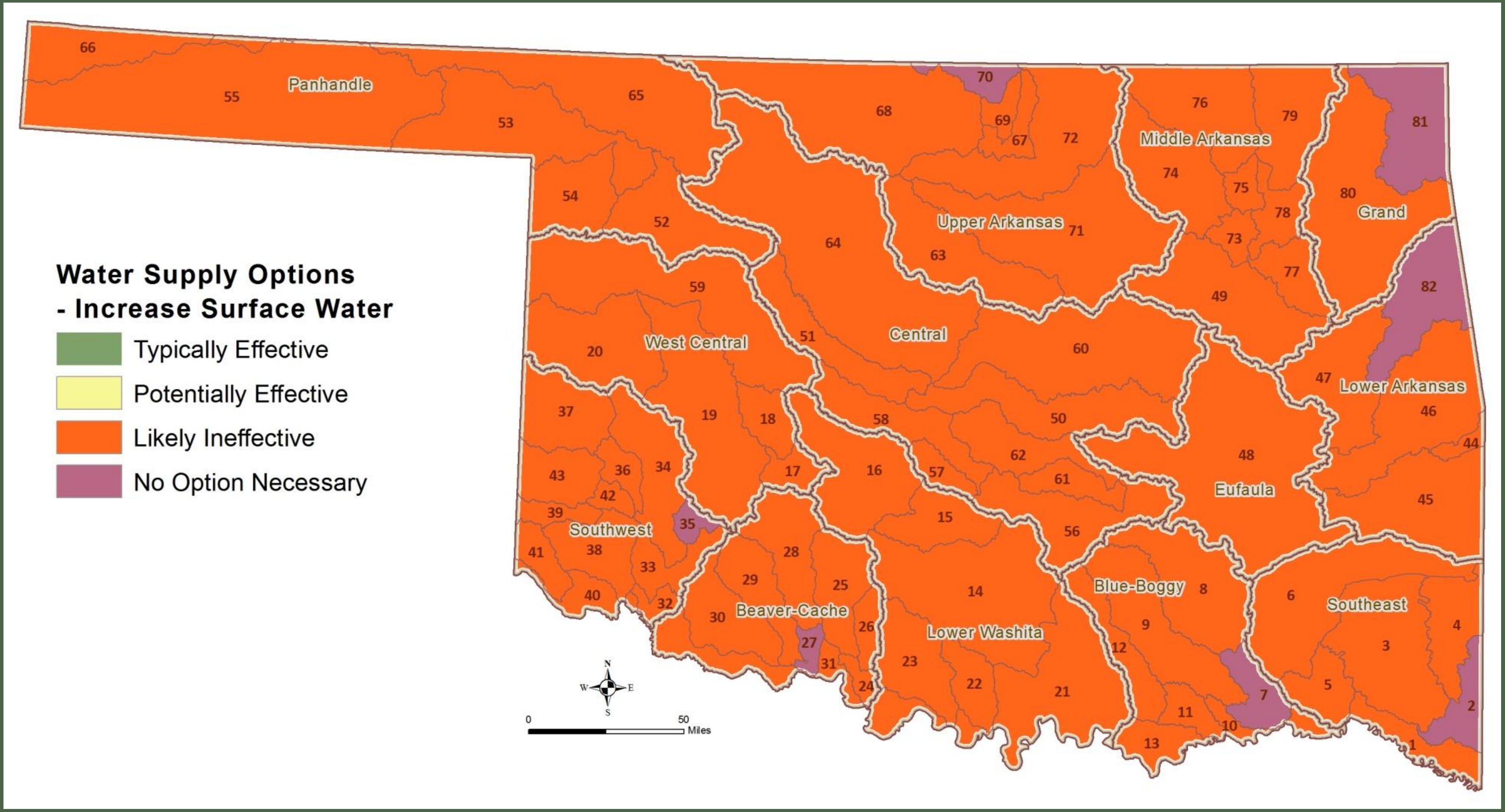
Out-of-Basin Supplies



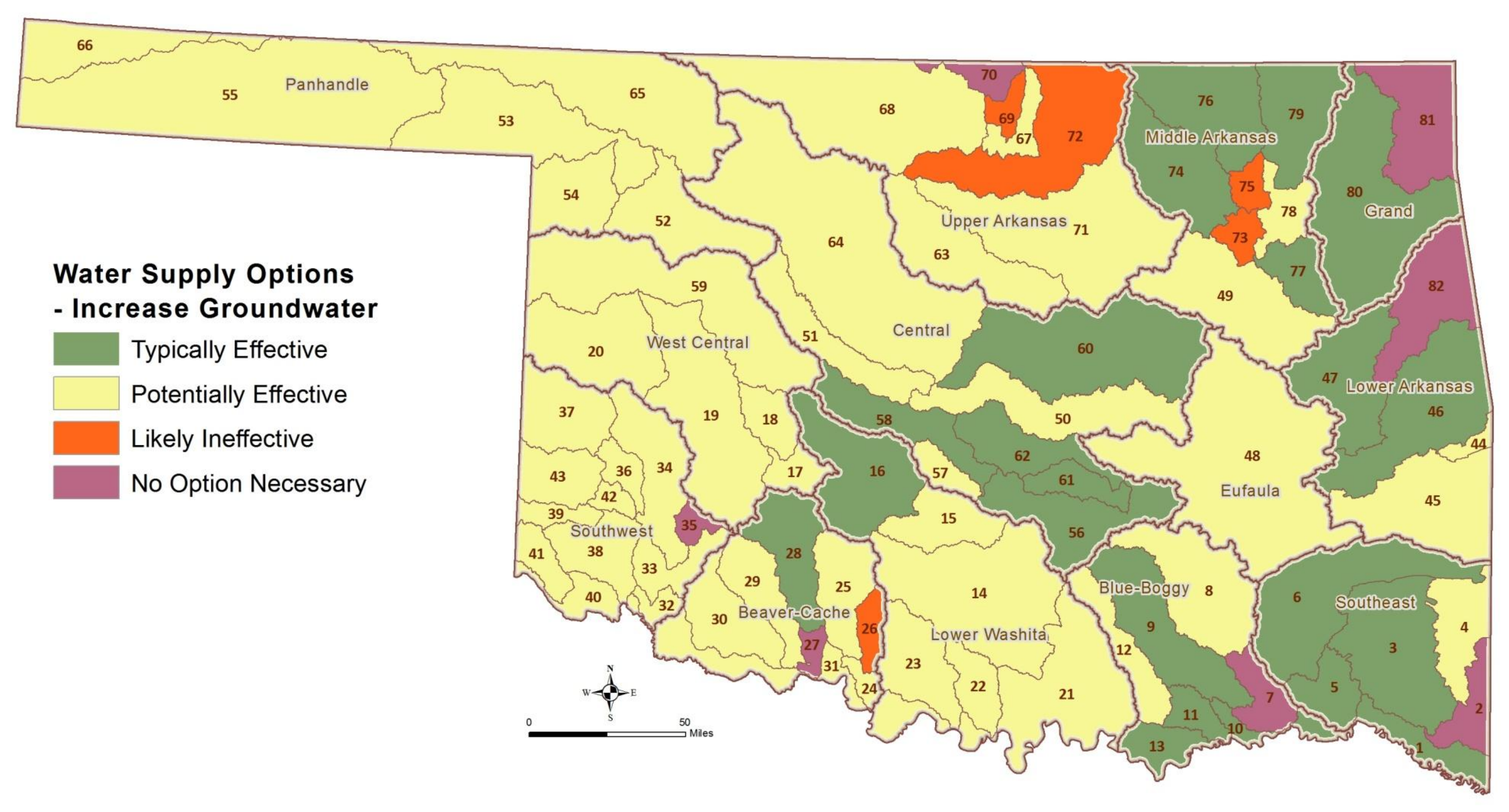
Reservoir Use



Increased Use of Surface Water



Increased Use of Groundwater



Expanded Options

- Options explored beyond the Primary Options
- Generally more statewide in perspective
- However, several as a part of the Primary Options
- Conservation
- Marginal Quality Water
- Artificial Recharge
- Reservoir Viability

Conservation

- Evaluated two scenarios (I and II): Moderate and Substantial
- Analyzed for the Municipal/Industrial and Irrigation sectors
- Assessed statewide and in all 82 basins
- Used the information to evaluate effectiveness as an option to reduce shortages (Demand Management)

OCWP Municipal/Industrial Conservation Analysis

Scenario I (Moderate Level) Considerations:

- Passive Conservation: water savings that are the direct result of plumbing codes of the federal Energy Policy Act of 1992 requiring water efficient plumbing fixtures
- Metering: installing meters to monitor water loss
- Tiered Rate Structure: increasing tiers of cost with increased water use
- Community Education and Information: changing fundamental habits

OCWP Municipal/Industrial Conservation Analysis

Scenario II (Substantial Level) Considerations:

- More aggressive implementation of various components of Scenario I
- Analyzed the impact of high efficiency indoor water use regulations beyond that of passive conservation

Fixture	Passive Mandates	High Efficiency Examples
Toilet	1.6 gpf	1.0 gpf
Urinal	1.0 gpf	0.5 gpf
Faucet	2.5 gpm	1.0 gpm
Showerhead	2.5 gpm	2.0 gpm

OCWP Irrigation Conservation Analysis

- Scenario I (Moderate Level)
  - Considered trends in the conversion to higher efficiency irrigation methods in the following categories:
    - Sprinkler (low pressure systems)
    - Surface/Flood (improvements in the infrastructure of the conveyance system)
    - Micro (at or near the surface or root zone)
- Scenario II (Substantial Level)
  - Considered the above plus an analysis of the impact of shifting to less water-intensive crops (e.g., grain sorghum instead of corn, forage crops like alfalfa and pasture grass instead of grain, etc.) beginning in 2015.

OCWP Conservation Analysis
Other Savings

- OCWP Analysis Also Considered Other Savings Associated with Conservation
- Energy:
  - Less energy required to produce water (treatment and delivery)
  - Less energy required to convey and treat wastewater (since less water in system)
  - *Therefore, less water requires less energy*
- Cost/Benefit :
  - Monetary savings associated with having to treat and convey less water and wastewater

OCWP Conservation Analysis
Conservation-Associated Cost Savings

- Considered direct operational costs for water (by source) and wastewater treatment and delivery saved due to conservation.
- Took into account electricity, labor, chemical costs, water analysis, regulatory compliance.

	Surface Water	Groundwater	Wastewater	Total
Scenario I	$26,036,731	$2,903,100	$18,510,151	$47,449,981
Scenario II	$38,961,078	$4,344,167	$23,880,443	$67,185,689

Energy/Water Nexus Savings

- It takes water to produce thermoelectric power; energy is used in the distribution and treatment of water and wastewater.
- Therefore, energy savings associated with reduced water production and wastewater treatment are important.

	Energy Saved	Water Saved
	GW hours	Acre-Feet/Year
Scenario I	102	221
Scenario II	146	316

OCWP Conservation Analysis
Total Water Savings

	M&I and Agriculture Statewide Demand Projections & Water Savings for Conservation Scenarios (AFY)						
	2010	2020	2030	2040	2050	2060	2060 with Energy Savings
Baseline	1,377,318	1,455,309	1,523,273	1,587,406	1,642,069	1,711,392	
Scenario I	N/A	1,301,816	1,332,781	1,388,603	1,435,807	1,496,643	1,496,422
Scenario II	N/A	1,155,397	1,170,248	1,209,372	1,244,123	1,295,569	1,295,252

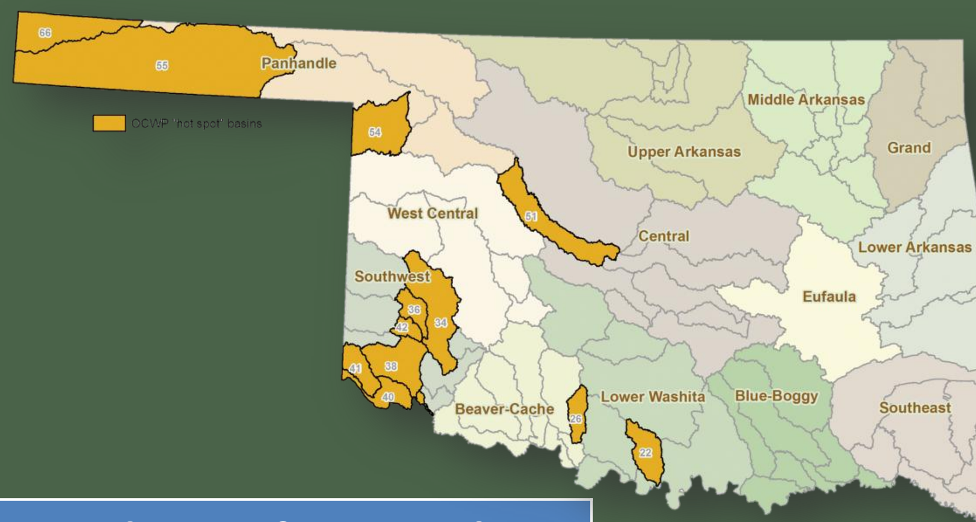
OCWP Conservation Analysis
What is the Impact?

Gaps/Depletions Mitigation Statewide (2060)

Source	Baseline Shortage Amount	Total & Percent Reduction from Baseline Shortage Amount			
		Moderate Conservation		Substantial Conservation	
SW	75,240 AFY	18,810 AFY	25%	23,980 AFY	32%
AGW	38,980 AFY	12,474 AFY	32%	22,554 AFY	59%
BGW	92,710 AFY	13,906 AFY	15%	73,784 AFY	78%

OCWP Conservation Analysis
What is the Impact?

Gaps/Depletions Mitigation for Hot Spots (2060)



Source	Baseline Shortage Amount	Total & Percent Reduction from Baseline Shortage Amount			
		Moderate Level		Substantial Level	
SW	14,590 AFY	7,440 AFY	51%	8676 AFY	60%
AGW	12,070 AFY	6,036 AFY	50%	9036 AFY	75%
BGW	69,000 AFY	24,080 AFY	35%	61,320 AFY	89%

OCWP Conservation Analysis
Improving the Water Future of Basins

	Reduction in the Number of Basins with Gaps and/or Storage Depletions		
	Surface Water	Alluvial Groundwater	Bedrock Groundwater
Baseline	55	63	34
Scenario I	42	51	26
Scenario II	33	41	23

OCWP Conservation Analysis
Further Benefits of Conservation

- Reduce Capital for Forecasted Infrastructure Needs:
  - Can stretch supplies and thereby reduce *$166 billion* need
- Drought Mitigation:
  - Reduces demand
  - Stretches supplies
  - Delays or avoids acute drought restrictions
- More Water for Non-consumptive Uses:
  - Protect Oklahoma's 3rd largest industry – tourism & recreation
  - Equally important to fish & wildlife, both sport industry and ecological protections (e.g., endangered species protection)
  - Can reduce impacts of drought on non-consumptive needs

- How can we use marginal quality supplies to meet Oklahoma’s future water needs?
- How can we increase the reliability of Oklahoma’s groundwater resources?

Two Legislative Workgroups

SB1627 Marginal Quality Water

- Characterizing quantity and quality
  - Defining MQ Water
  - Source quality
  - Source quantity
  - Constraints on use
- Assessing potential "good fits" for MQ supply vs. projected demand / gap

SB1410 Aquifer Recharge

- Screening sites for demonstration recharge project
- Statewide assessment
- Considering supply and demand
- Recommendations for demonstration phase

Integration into OCWP

Workgroup Members

SB1627 Marginal Quality Water

- Senator Paddack
- USGS
- US EPA
- OWRB
- ODEQ
- Okla. Conservation Commission
- Okla. Corporation Commission
- Okla. Farm Bureau
- Okla. Municipal League
- Okla. Rural Water Assoc.
- Chickasaw Nation
- Public Service of Oklahoma
- OIPA & Producers
- Nature Conservancy
- Lugert-Altus Irrigation Dist.

SB1410 Aquifer Recharge

- Senator Paddack
- USGS
- Bureau of Reclamation
- US EPA / EPA Kerr Lab
- NOAA / NSSL
- OWRB
- ODEQ
- University of Oklahoma
- Okla. Conservation Commission
- Okla. Corporation Commission
- Okla. Climatological Survey
- Okla. Geological Survey
- Chickasaw Nation
- OIPA & Producers

Oklahoma Comprehensive Water Plan

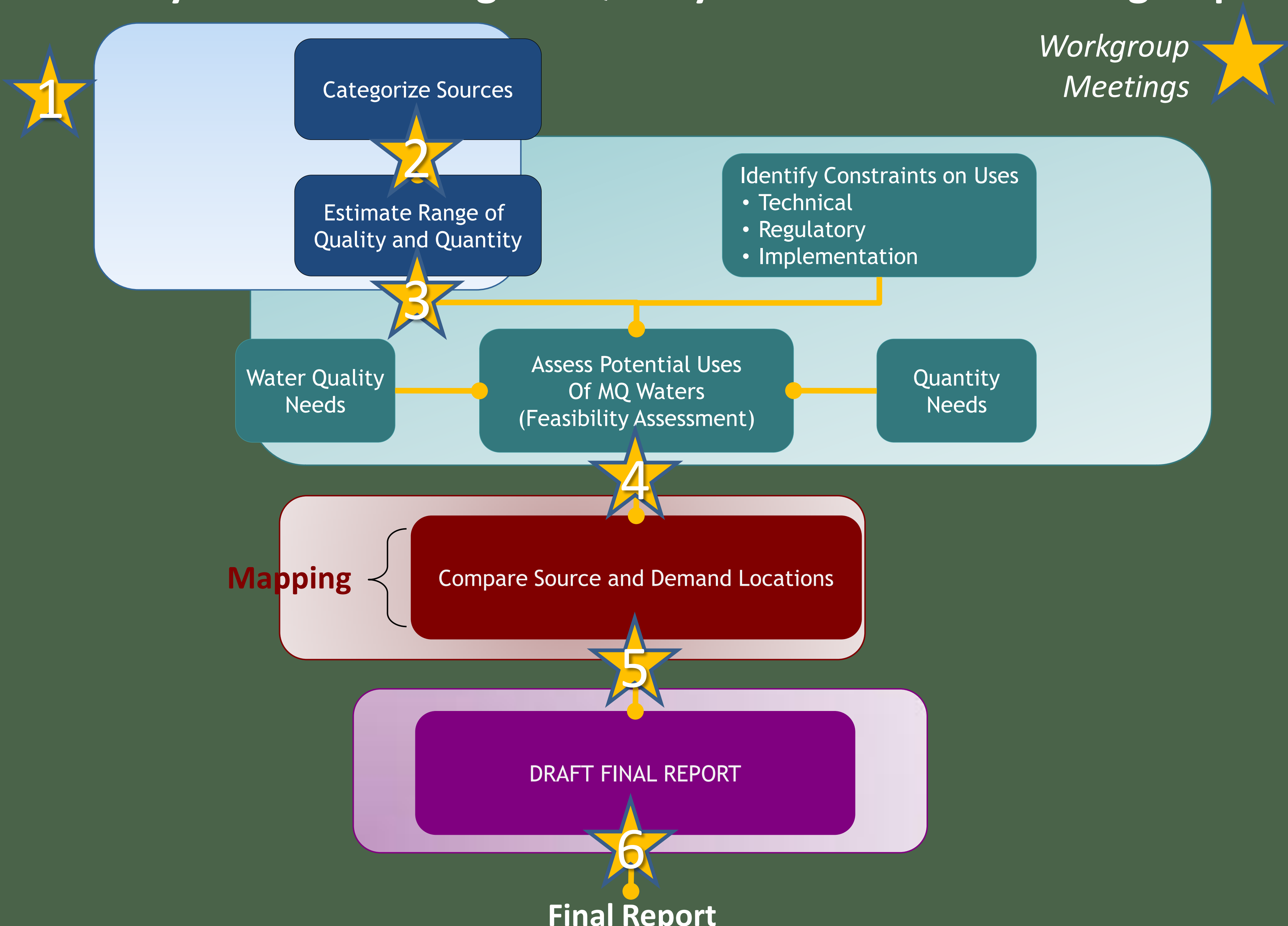
OCWP

MQW Workgroup

Senate Bill 1627

- MQWs "include brackish or saline contaminated waters, which result from natural or man-made contamination"
- Directed OWRB to establish a technical work group to identify potential MQW sources and users in Oklahoma
- Sought recommendations on how to best utilize MQW supplies for the benefit of our citizens, economy, and environment

Analysis Plan for Marginal Quality Water Technical Workgroup



Defined Categories of Marginal Quality Water

- Surface water or groundwater
- Water not typically used for public supply
- Treated wastewater effluent
- Stormwater runoff
- Brackish groundwater or surface water
- Flowback/Produced water
- Waters with key parameters over identified M&I thresholds ("Constituents of Concern")

Characterized MQW Sources by Quantity and Quality

- Goal: Assess sources, "best fit" areas and inform users about potential constraints
- Characterization of quantity
  - Leveraged OCWP analyses for quantity (sources) estimates and concentrated demand/shortages (uses)
  - Matched basins across the state with best sources and highest demand (need)
- Characterization of quality
  - Used statewide databases and literature values for quality estimates
  - Helped frame discussion on potential usability and potential concerns/issues
  - OWRB, DEQ, Corp. Commission, USGS, etc
- This is one method for determining "best fit", not the only method—Many could very well be possible in many places

Identified Potential Uses of MQW to Meet Water Demands

Table 4-1 Potential Uses of MQW to Meet Water Demands

Water Demand Use Sector	MQW Source Category				
	Treated Wastewater	Stormwater	Oil and Gas Flowback / Produced Water	Brackish Water	Contaminants of Concern
M&I - potable	WQ, PUB	WQ, LOC, REL	WQ, LOC, PUB	AT	AT, PUB
M&I - non-potable	WST	WST, PT	LOC	AT	CT, AT
Self-Supplied Residential	WQ, LOC, PUB	WQ, LOC	WQ, LOC, PUB	WQ	WQ, PUB
Self-Supplied Industrial	WST	LOC, PT, CT	WQ, LOC	CT, AT	CT, AT
Thermo-Electric Power	WST	LOC, PT, CT	WQ, LOC	CT, AT	CT, AT
Oil and Gas	LOC	LOC	CT, AT, PT WQ, LOC, REL	CT, AT, PT WQ, LOC, REL	CT, AT, PT WQ, LOC, REL
Crop Irrigation	LOC, PUB	LOC	WQ, LOC	CT, AT	CT, AT
Livestock Watering	LOC	LOC	WQ, LOC	AT	CT, AT

Legend

Potentially feasible, depending on site-specific conditions
Less feasible, depending on site-specific conditions
Not feasible on a widescale basis for indicated reason(s)

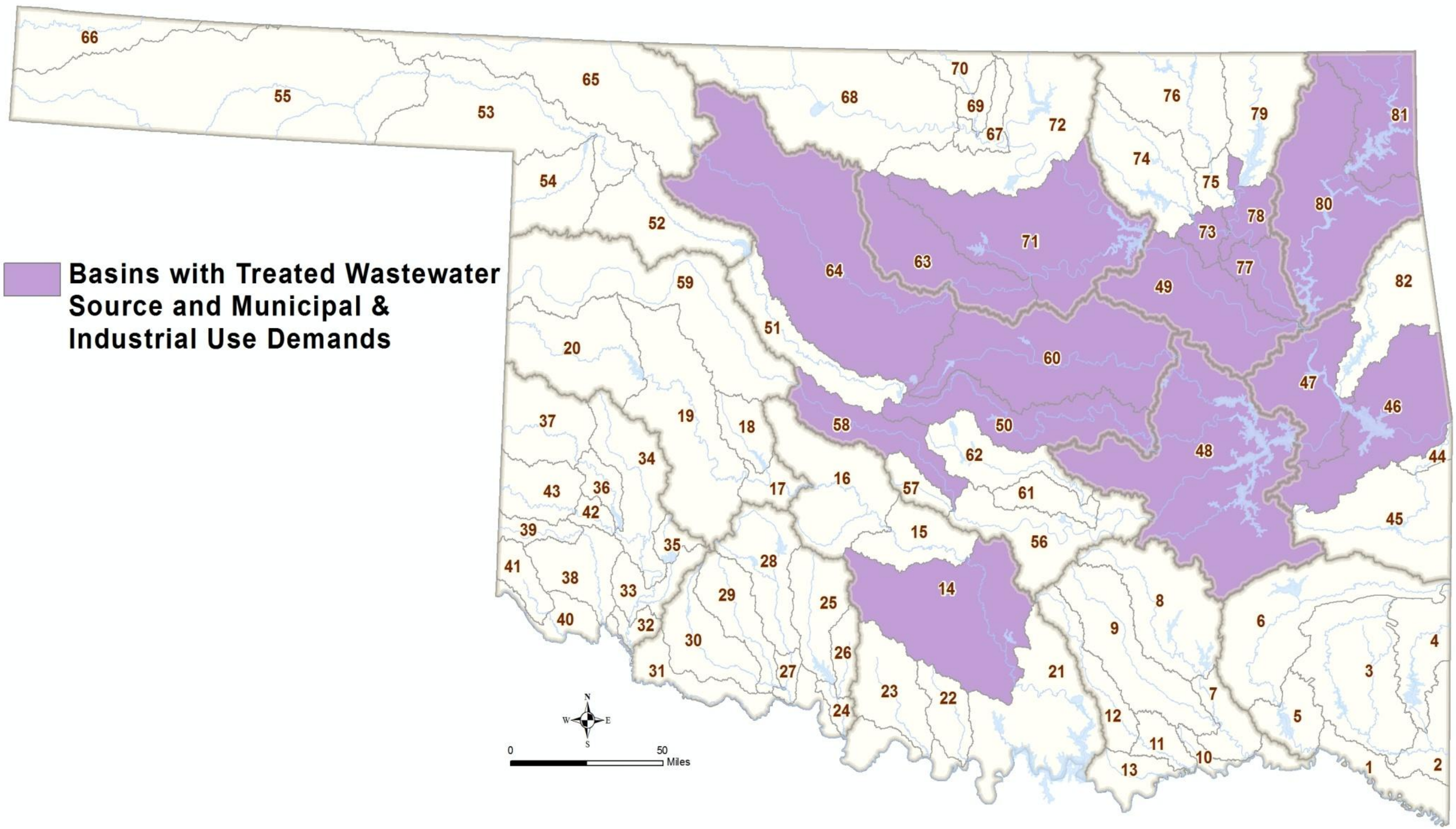
WST May require additional Wastewater or Stormwater Treatment beyond that required for discharges, depending on specific use
PT Passive treatment may be required
CT Conventional treatment may be required
AT Advanced treatment may be required
WQ Treated water quality requirements would prohibit use or make treatment economically infeasible for indicated user
LOC Location of supply likely not near location of significant demand
REL Reliability of supply inadequate to meet demand without significant storage infrastructure
PUB Public Perception

Potential Constraints to Consider

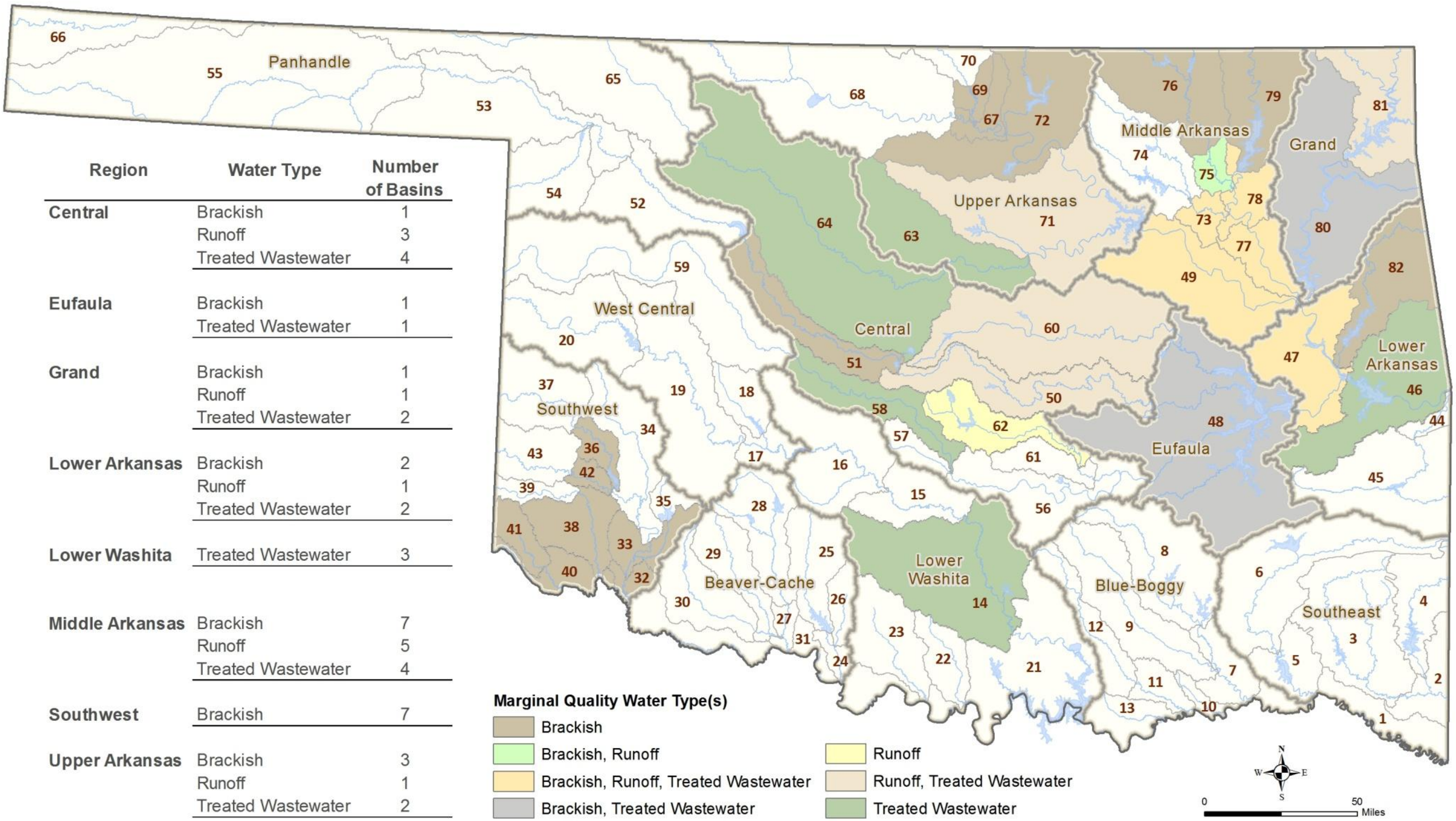
Constraints on Using MQW Sources

Category	Possible Constraints			
	Technical	Regulatory	Environmental	Implementation
Treated Wastewater	• Treatment to required quality • Higher dissolved solids • Emerging contaminants (e.g., PPCPs) • Infrastructure needs	• No detailed Oklahoma standards for reuse • Dependent on use • Downstream water rights and domestic use	• Reduced receiving water flow	• Cost relative to raw, fresh, potable water options • Public perception
Stormwater Runoff	• Collection/distribution system • Intermittent supply and associated storage needs • Variable and extreme water quality	• Downstream water rights and domestic use • MS4s	• Reduced receiving water flow	• Cost relative to raw, fresh, potable water options
Oil and Gas Produced Water	• Location relative to demand • Mobile operations/ mobile treatment • Water quality/treatment needs	• Discharge regulations • Storage and transportation • Permitting	• Residuals Disposal	• Cost relative to raw, fresh, potable water options • Public perception • Availability of land • Liability of storing, treating, or transporting
Oil and Gas Flowback Water	• Location relative to demand • Mobile operations/ mobile treatment • Temporary supply • Relatively small volume • Water quality/treatment needs	• Discharge regulations • Storage and transportation • Permitting	• Residuals Disposal	• Cost relative to raw, fresh, potable water options • Public perception • Availability of land • Liability of storing, treating, or transporting
Brackish Water	• Treatment/residuals disposal • Depth of wells • Location relative to demands • Sustainability (groundwater sources) • Reliability (surface water sources)	• Discharge regulations • Storage and transportation • Permitting	• Residuals Disposal	• Cost relative to raw, fresh, potable water options • Public perception • Availability of land
Contaminants of Concern	• Treatment	• Potable quality standards and treatment requirements	• Residuals Disposal	• Cost relative to raw, fresh, potable water options • Public perception

Treated Wastewater



Marginal Quality Water All Sources



Region	Water Type	Number of Basins
Central	Brackish	1
	Runoff	3
	Treated Wastewater	4
Eufaula	Brackish	1
	Treated Wastewater	1
Grand	Brackish	1
	Runoff	1
	Treated Wastewater	2
Lower Arkansas	Brackish	2
	Runoff	1
	Treated Wastewater	2
Lower Washita	Treated Wastewater	3
Middle Arkansas	Brackish	7
	Runoff	5
	Treated Wastewater	4
Southwest	Brackish	7
Upper Arkansas	Brackish	3
	Runoff	1
	Treated Wastewater	2

Oklahoma Comprehensive Water Plan

OCWP

Aquifer Recharge Workgroup

SB 1410 Goals and Overall Process

- Develop and apply criteria to prioritize potential locations throughout Oklahoma where aquifer recharge demonstration projects may be most feasible.
- Phase 1: Identification of most suitable area(s):
  - Screening
  - Detailed analysis / site recommendations
- Phase 2: Demonstration project(s) at one or more areas from Phase 1

Data Sources

- OCWP Gap Tool (CDM)
- American Water Institute
- Bureau of Reclamation
- US Geological Survey
- US Environmental Protection Agency

Fatal Flaw Criteria

57 Identified Sites → Fatal Flaw Criteria → 30 Sites for Threshold Analysis

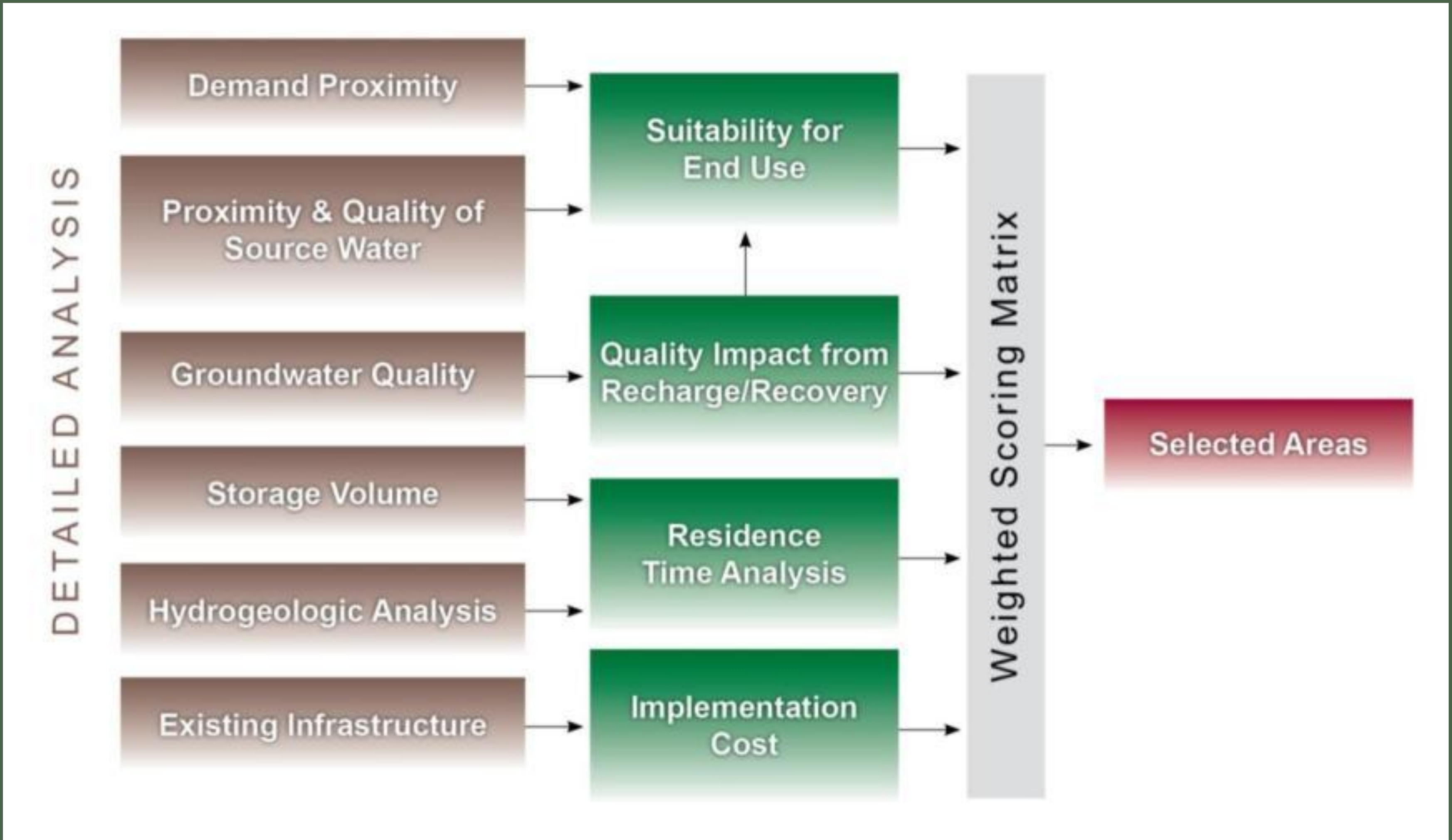
- Heavily developed aquifer
- Proximity of recharge location to demand & source water
- Quality of ground water (TDS < 2,000 mg/l)

Threshold Criteria

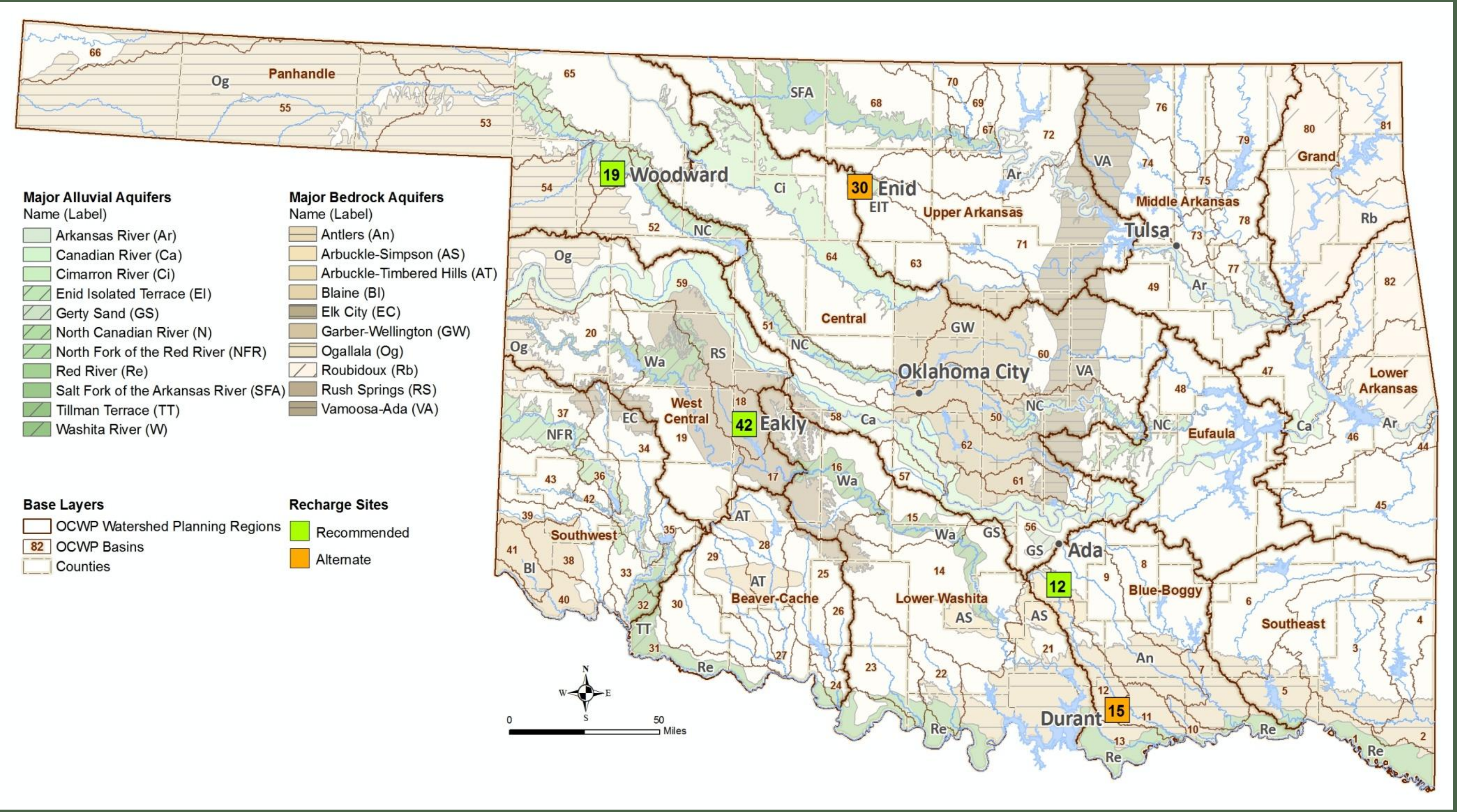
30 Sites Passing Fatal Flaw Criteria → **Threshold Criteria** → 15 Sites for Detailed Analysis

- Water quality of source water
- Source water availability
- Groundwater quality (e.g., nitrate, TDS)
- Hydrogeologic suitability – aquifer physical properties
  - Aquifer storage
  - Transmissivity
  - Residence time

Detailed Analysis



Recommended Sites for Pilot Project



Recommended Pilot Project Sites

- Site 12 – Near Ada, Arbuckle-Simpson Aquifer
  - Good water quality and chemistry
  - Public Water Supply wells nearby, source within 1 mile
  - Favorable hydrogeology
  - Pre-treatment likely not required
- Site 42 – Near Eakly, Rush-Springs Aquifer
  - Favorable hydrogeology
  - Lower demand could be entirely met by a pilot project
  - Water quality appears good, but further characterization recommended due to sparse data
  - Pre-treatment may be required pending additional water quality results
  - Source water availability somewhat of a concern due to nearby Fort Cobb reservoir. Operations should be coordinated with appropriate entities
- Site 19 – Near Woodward, N. Canadian alluvium
  - Favorable hydrogeology
  - Sufficient source availability but should be coordinated with Canton Reservoir operations
  - Good groundwater quality
  - Poor source water quality would require pre-treatment

Alternative Pilot Project Sites

- Site 15 – Near Durant, Antlers Aquifer
  - Good water quality, but lacks geochemistry data
  - Adequate water source
  - No existing infrastructure
- Site 30 – Near Enid, Enid Isolated Terrace Aquifer
  - Favorable hydrogeology
  - Good access to infrastructure and potential use of gravity feed ditch delivery/spreading basins (low infrastructure cost)
  - No surface water quality data
  - Potentially limited source

Reservoir Viability

- extensive literature search—data collection was the foundation for this work
- identification of criteria to determine a reservoir's viability
- creation of a database to store essential site information
- evaluation of every identified site
- Geographic Information System (GIS) mapping of the most viable sites
- aerial photograph and map reconnaissance of lake sites to identify cost drivers
- screening of environmental, cultural, and endangered species issues
- estimates of updated construction costs on a consistent cost basis, and
- assessment of viability according to five distinct categories

Potential Reservoir Site Categories

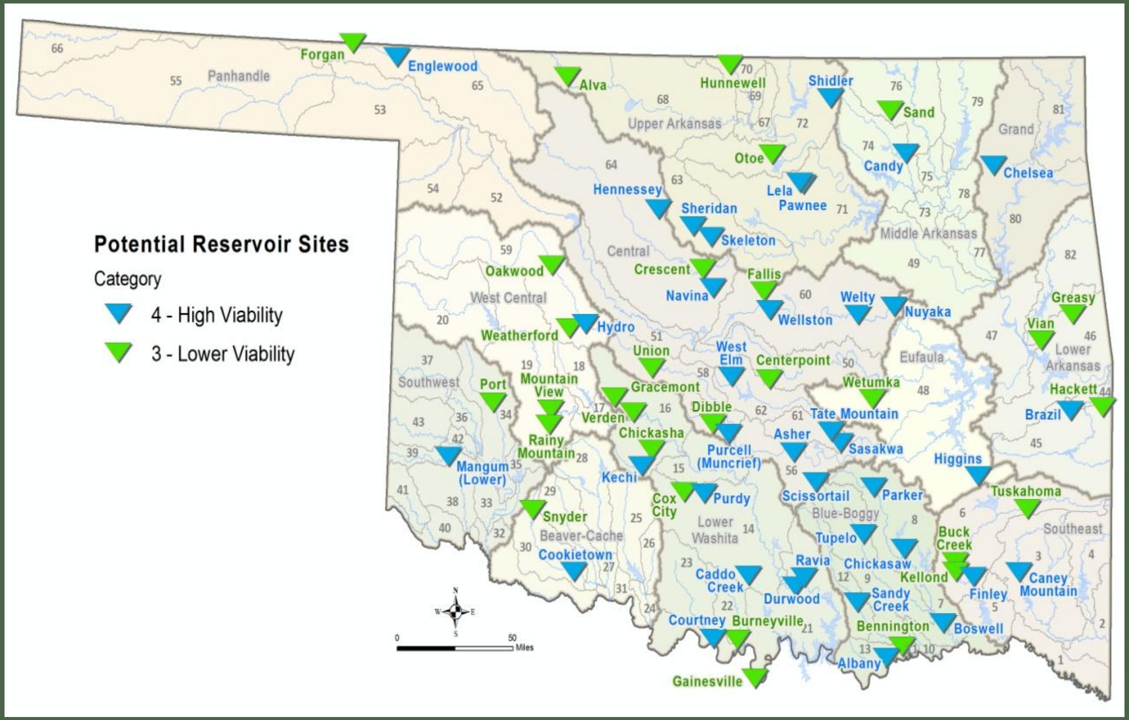
- Category 0—Some reservoir sites were identified by location on the 1966 OWRB map; however, no background or study data could be located for these sites
- Category 1—A number of reservoir sites was briefly described in regional master plans. Some data was reported but essential elements of information (location, dam configuration, drainage area, etc.) were not available.
- Category 2—Includes sites which may have significant data available for analysis, but have substantial obstacles which might prevent construction, such as endangered species.

Potential Reservoir Site Categories

- Category 3—These reservoirs have sufficient data for an analysis, but one or more factors, such as poor water quality, low dependable yield, high cost per unit, etc., indicate reservoir sites that are slightly less desirable than those in Category 4 below.
- Category 4—These reservoirs sites have undergone extensive evaluation and been determined to be the most viable candidates for future development.

Category 3 and 4 Sites

- 68 sites identified statewide that have at least sufficient data for additional analysis or are considered viable candidates for development



Water Supply Options Findings

- Moderate levels of conservation were shown to be very effective at addressing water supply shortages
- Out-of-basin supplies and constructing new reservoir sites potentially effective in all 82 basins. Level of effectiveness dependent upon local factors
- Reservoirs have significant potential to provide a reliable supply for the future. In only 3 basins was a new reservoir considered ineffective
- Increasing supply from direct diversions of stream water was considered likely ineffective in all basins. Due to OK's precipitation patterns and associated streamflow patterns, reservoir or off-stream storage is likely necessary

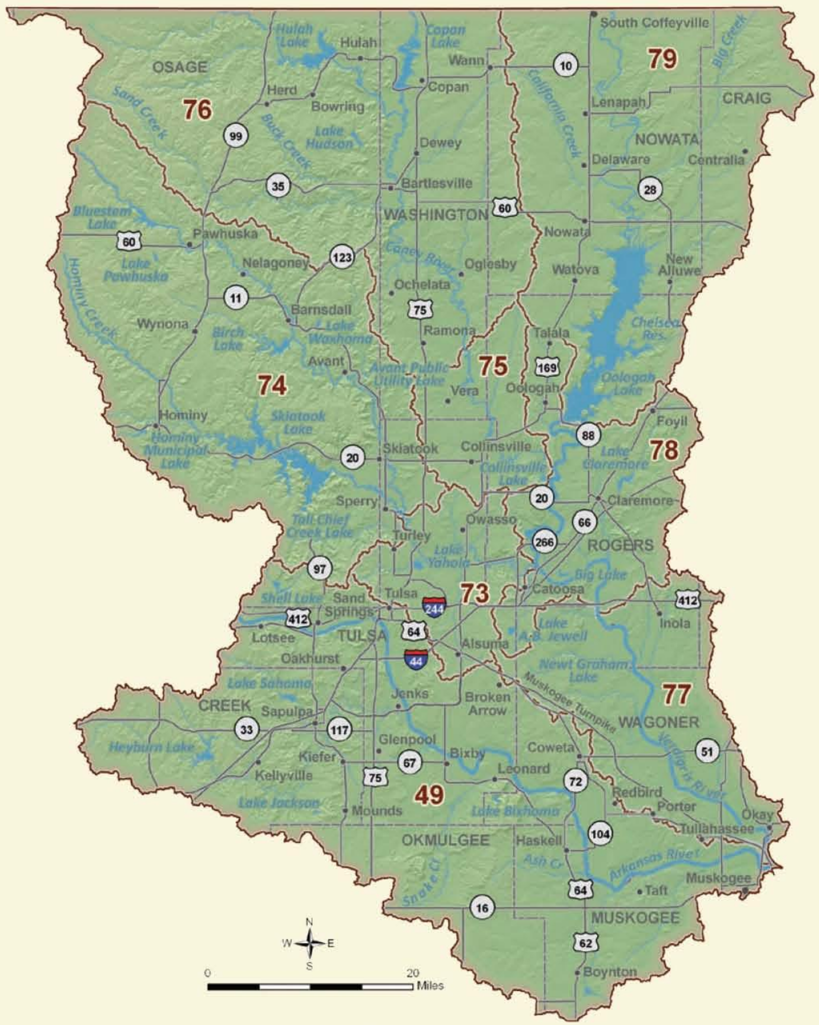
Water Supply Options Findings

- Groundwater was considered and excellent future supply source and a typically effective option in all but five basins, where there are only minor aquifers.
- Artificial Recharge would be an likely effective supply option at 5 locations across the state and many other depending local factors
- Marginal quality waters, particularly treated effluent, shows particular promise in stretching current supplies to meet future demands. Additionally, brackish groundwater shows viability in certain parts of the state, pending characterization by the USGS
- 68 viable reservoir sites exist across Oklahoma. Reservoirs should be considered a very viable option for meeting future demands and providing reliability

Oklahoma Comprehensive Water Plan

Report on the

Middle Arkansas Watershed Planning Region



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Introduction

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Introduction

The Oklahoma Comprehensive Water Plan (OCWP) was originally developed in 1980 and last updated in 1995. With the specific objective of establishing a reliable supply of water for state users throughout at least the next 50 years, the current update represents the most ambitious and intensive water planning effort ever undertaken by the state. The 2012 OCWP Update is guided by two ultimate goals:

1. Provide safe and dependable water supply for all Oklahomans while improving the economy and protecting the environment.
2. Provide information so that water providers, policy makers, and water users can make informed decisions concerning the use and management of Oklahoma's water resources.

In accordance with the goals, the 2012 OCWP Update has been developed under an innovative parallel-path approach: inclusive and dynamic public participation to build sound water policy complemented by detailed technical evaluations.

The primary factors in the determination of reliable future water supplies are physical supplies, water rights, water quality, and infrastructure. Gaps and depletions occur when demand exceeds supply, and can be attributed to physical supply, water rights, infrastructure, or water quality constraints.

Also unique to this update are studies conducted according to specific geographic boundaries (watersheds) rather than political boundaries (counties). This new strategy involved subdividing the state into 82 surface water basins for water supply availability analysis (see the OCWP Physical Water Supply Availability Report). Existing watershed boundaries were revised to include a United States Geological Survey (USGS) stream gage at or near the basin outlet (downstream boundary), where practical. To facilitate consideration of regional supply challenges and potential solutions, basins were aggregated into 13 distinct Watershed Planning Regions.

This Watershed Planning Region Report, one of 13 such documents prepared for the 2012 OCWP Update, presents elements of technical studies pertinent to the Central Region. Each regional report presents information from both a regional and multiple basin perspective, including water supply/demand analysis results, forecasted water supply shortages, potential supply solutions and alternatives, and supporting technical information.

As a key foundation of OCWP technical work, a computer-based analysis tool, "Oklahoma H2O," was created to compare projected demands with physical supplies for each basin to identify areas of potential water shortages.

Integral to the development of these reports was the Oklahoma H2O model, a sophisticated database and geographic information system (GIS) based analysis tool created to compare projected water demand to physical supplies in each of the 82 OCWP basins statewide. Recognizing that water planning is not a static process but rather a dynamic one, this versatile tool can be updated over time as new supply and demand data become available, and can be used to evaluate a variety of "what-if" scenarios at the basin level, such as a change in supply sources, demand, new reservoirs, and various other policy management scenarios.

Primary inputs to the model include demand projections for each decade through 2060, founded on widely-accepted methods and peer review of inputs and results by state and federal agency staff, industry representatives, and stakeholder groups for each demand sector. Surface water supply data for each of the 82 basins used 58 years of publicly-available daily streamflow gage data collected by the USGS. Groundwater resources were characterized using previously-developed assessments of groundwater aquifer storage and recharge rates.

Additional information gained during the development of the 2012 Update is provided in various OCWP supplemental reports. Assessments of statewide physical water availability and potential shortages are documented in the OCWP Physical Water Supply Availability Report. Statewide water demand projection methods and results are presented in the Water Demand Forecast Report. Permitting availability was evaluated based on the OWRB's administrative protocol and documented in the Water Supply Permit Availability Report. All supporting documentation can be found on the OWRB's website.

Regional Overview

The Central Watershed Planning Region includes nine basins (for reference, numbered 50, 51, 56-58, 60-62, and 64). The region is located in the Central Lowland physiography province, encompassing 10,142 square miles in central Oklahoma, spanning from southern Woods County to Hughes and Pontotoc Counties in the southeastern portion of the region and including all or portions of Alfalfa, Woodward, Garfield, Major, Kingfisher, Logan, Blaine, Dewey, Creek, Lincoln, Okmulgee, Canadian, Oklahoma, Okfuskee, Caddo, Seminole, Pottawatomie, Grady, Cleveland, McClain, and Garvin Counties.

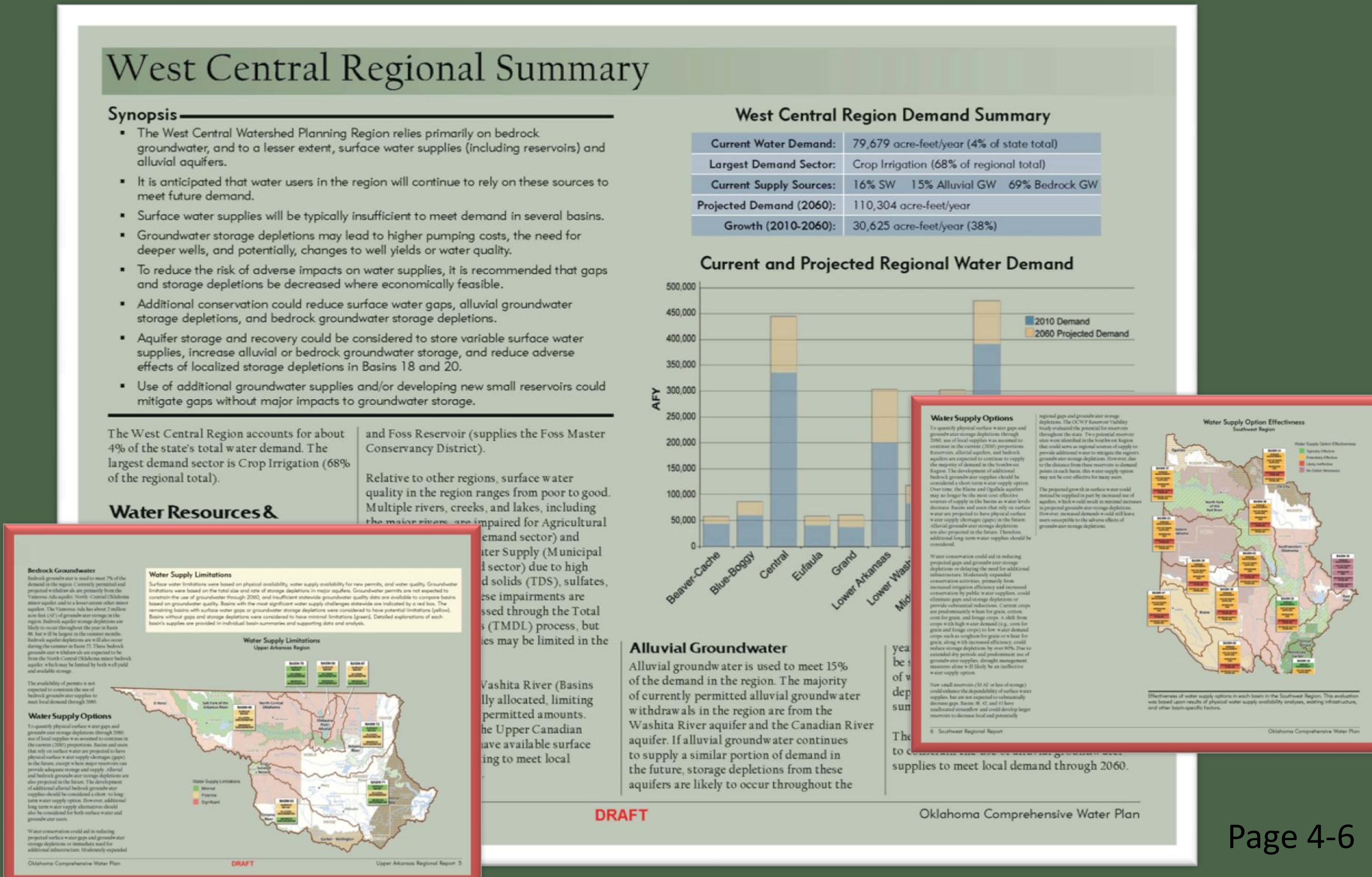
The region displays many of the physical diversities of the state. The extremes range from the metropolitan areas of Oklahoma City in Oklahoma County to the more forested areas of the southeast, the open farmland in the central and western areas, and the sand hills in the western portion of the region.

The region's climate is moist and sub-humid with the mean annual temperature ranging from 59°F to 62°F. Annual average precipitation ranges from 26 inches in the northwest to 46 inches in the southeastern corner. Annual lake evaporation ranges from 50 to 62 inches and exceeds precipitation. Frequent droughts cause severe crop damage while severe flooding also occurs as the result of concentrated areas of heavy precipitation. Thunderstorms accompanied by high winds, hail, and heavy rain increase the likelihood of flash flooding, emphasizing the necessity of watershed protection and flood prevention projects.

The largest cities in the region include Oklahoma City (2010 population of 501,450), Norman (109,865), Edmond (79,562), Midwest City (56,886), and Moore (52,621). The greatest demand is from Municipal and Industrial water use.

By 2060, this region is projected to have a total demand of 442,890 acre-feet per year (AFY), an increase of approximately 107,250 AFY (32%) from 2010.

Regional Summary



West Central Regional Summary

Synopsis

- The West Central Watershed Planning Region relies primarily on bedrock groundwater, and to a lesser extent, surface water supplies (including reservoirs) and alluvial aquifers.
- It is anticipated that water users in the region will continue to rely on these sources to meet future demand.
- Surface water supplies will be typically insufficient to meet demand in several basins.
- Groundwater storage depletions may lead to higher pumping costs, the need for deeper wells, and potentially, changes to well yields or water quality.
- To reduce the risk of adverse impacts on water supplies, it is recommended that gaps and storage depletions be decreased where economically feasible.
- Additional conservation could reduce surface water gaps, alluvial groundwater storage depletions, and bedrock groundwater storage depletions.
- Aquifer storage and recovery could be considered to store variable surface water supplies, increase alluvial or bedrock groundwater storage, and reduce adverse effects of localized storage depletions in Basins 18 and 20.
- Use of additional groundwater supplies and/or developing new small reservoirs could mitigate gaps without major impacts to groundwater storage.

The West Central Region accounts for about 4% of the state's total water demand. The largest demand sector is Crop Irrigation (68% of the regional total).

Water Resources &

and Foss Reservoir (supplies the Foss Master Conservancy District).

Relative to other regions, surface water quality in the region ranges from poor to good. Multiple rivers, creeks, and lakes, including the major rivers, are impaired for Agricultural ... emand sector) and ... ter Supply (Municipal ... l sector) due to high ... d solids (TDS), sulfates, ... se impairments are ... ssed through the Total ... (TMDL) process, but ... ies may be limited in the ...

... Vashita River (Basins ... lly allocated, limiting ... permitted amounts. ... he Upper Canadian ... ave available surface ... ing to meet local ...

West Central Region Demand Summary

Current Water Demand:	79,679 acre-feet/year (4% of state total)
Largest Demand Sector:	Crop Irrigation (68% of regional total)
Current Supply Sources:	16% SW 15% Alluvial GW 69% Bedrock GW
Projected Demand (2060):	110,304 acre-feet/year
Growth (2010-2060):	30,625 acre-feet/year (38%)

Current and Projected Regional Water Demand

Alluvial Groundwater

Alluvial groundwater is used to meet 15% of the demand in the region. The majority of currently permitted alluvial groundwater withdrawals in the region are from the Washita River aquifer and the Canadian River aquifer. If alluvial groundwater continues to supply a similar portion of demand in the future, storage depletions from these aquifers are likely to occur throughout the ...

... supplies to meet local demand through 2060.

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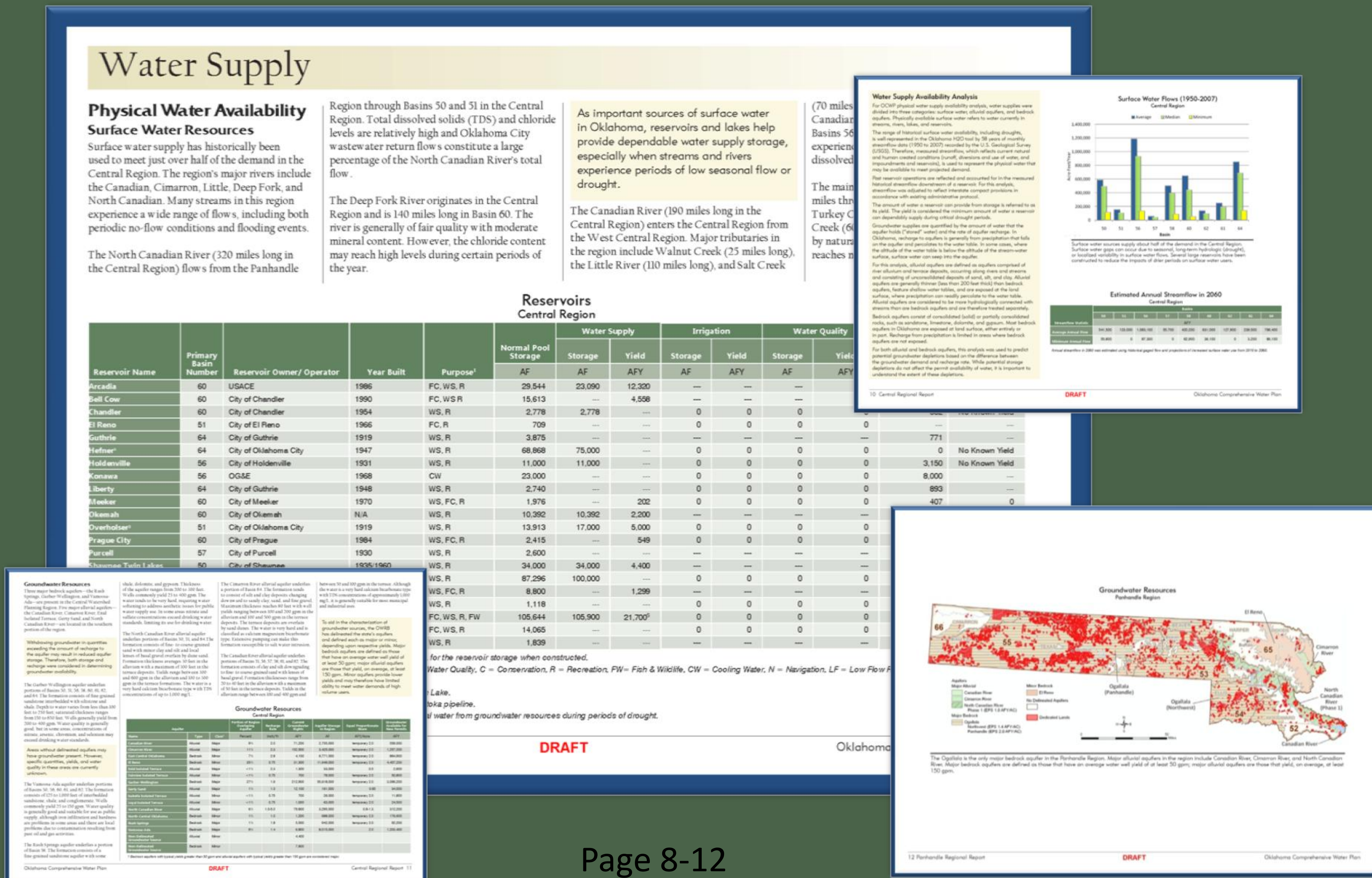
Oklahoma Comprehensive Water Plan

Physical Water Availability



Permitting (Legal) Availability

Permit Availability

For the OCWP water availability analysis, "permit availability" pertains to the amount of water that could be made available for withdrawals under permits issued in accordance with Oklahoma water law.

> If water authorized by a stream water right is not put to beneficial use within the specified time, the OWRB may reduce or cancel the unused amount and return the water to the public domain for appropriation to others.

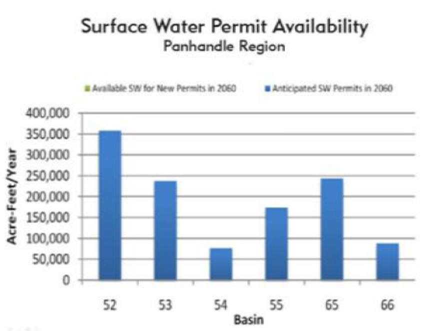
There is no surface water available for new permits in any basin in the Panhandle Region, limiting diversions to existing permitted amounts. For groundwater, the EPS has been set for all of the Ogallala aquifer with the exception of that underlying Roger Mills County, which is located in the West Central Watershed Planning Region. In the Panhandle Region, the Ogallala aquifer's EPS is set at two acre-feet per year (AFY) per acre in the three Panhandle counties and 1.4 AFY per acre for other basins in the Planning Region overlying the Ogallala. The EPS for the North Canadian River and the Canadian River aquifers is set at one AFY per acre. For the Cimarron River and El Reno aquifers, temporary permits are issued, granting users two AFY of water per acre of land until the OWRB conducts hydrologic investigations and establishes the maximum annual yield of the basins. Projections indicate that there will be groundwater available for new permits in all aquifers in the Panhandle Region through 2060.

Water Use Permitting in Oklahoma

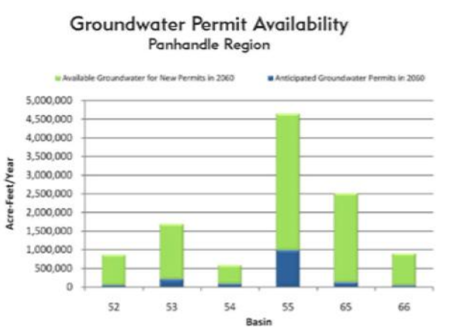
Oklahoma stream water laws are based on riparian and prior appropriation doctrines. Riparian rights to a reasonable use of water, in addition to domestic use, are not subject to permitting or oversight by the OWRB. An appropriative right to stream water is based on the prior appropriation doctrine, which is often described as "first in time, first in right." If a water shortage occurs, the diverter with the older appropriative water right will have first right among other appropriative right holders to divert the available water up to the authorized amount.

The permit availability of surface water is based on the average annual flow in the basin, the amount of water that flows past the proposed diversion point, and existing water uses upstream and downstream in the basin. The permit availability of surface water at the outlet of each basin in the region was estimated through OCWP technical analyses. The current allocated use for each basin is also noted to give an indication of the portion of the average annual streamflow used by existing water right holders. A site-specific analysis is conducted before issuing a permit.

Groundwater permit availability is generally based on the amount of land owned or leased that overlies a specific aquifer (groundwater basin). State law provides for the OWRB to conduct hydrologic investigations of groundwater basins and to determine amounts of water that may be withdrawn. After a hydrologic investigation has been conducted on a groundwater basin, the OWRB determines the maximum annual yield of the basin. Based on the "equal proportionate share"—defined as the maximum annual yield of water from a groundwater basin that is allocated to each acre of land overlying the basin—regular permits are issued to holders of existing temporary permits and to new permit applicants. Equal proportionate shares have yet to be determined on many aquifers in the state. For those aquifers, "temporary" permits are granted to users allocating two acre-feet of water per acre of land per year. Temporary permits are for one-year terms, which can be revalidated by the permittee each year, subject to conditions prescribed in OWRB rules or in an individual case by the OWRB. When the equal proportionate share and maximum annual yield are approved by the OWRB, all temporary permits overlying the studied basin are converted to regular permits at the new approved allocation rate. As with stream water, a groundwater permit grants only the right to withdraw water; it does not ensure yield.



Projections indicate that there will be no surface water available for new permits through 2060 in all basins in the Panhandle Region.



Projections indicate that there will be groundwater available for new permits through 2060 in all basins in the Panhandle Region.

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Characterization of Water Quality

Water Quality

Water quality of the Southeast Watershed Planning Region is defined by the lower Red River watershed and several minor and major water supply reservoirs. The region is primarily within the Ouachita Mountains (OM) and South Central Plains (SCP) ecoregions.

The OM Ecoregion covers the northern two-thirds to three-quarters of the region. The ecoregion is represented by several sub-ecoregions. Generally, the area is underlain by sedimentary rock, including shale/chert. Uplands are covered by oak-hickory-shortleaf pine forests; many intervening valleys are forested but may have intervening grasslands, hayfields and pasture. Major land uses are logging and recreation with some agriculture, especially confined feeding operations in the east. The majority of streams have moderate/high gradients with gravel/cobble/boulder/bedrock bottoms, although some sandy bottom streams do exist. Ecological diversity is high, but can be impacted by poor habitat/sedimentation.

The Athens Plateau and Central Mountain Ranges (CMR) lie along the eastern edge of the region. While the Athens Plateau is shaped by hills and low ridges underlain by shale, the CMR is more mountainous with sharp ridges and shallow, stony soils underlain mostly by sandstone, chert, and shale. Commercial logging is limited in CMR but widespread along the Plateau. The upper Mountain Fork River is the dominant watershed through both ecoregions while Broken Bow Lake and the lower Mountain Fork represent a large portion of the lower end of the area. Portions of the Glover River also flow through the CMR but it is more representative of the Western Ouachita Range. Salinity is extremely low throughout both areas. Stream mean conductivity is 30 µS/cm, while lake conductivity is slightly higher. Streams are typically oligotrophic with extremely low means of total phosphorus (TP, 0.01-0.03 ppm) and total nitrogen (TN, 0.45-0.05 ppm). Broken Bow Lake is phosphorus limited and mesotrophic with extremely low nutrient values. Clarity is excellent throughout. Stream mean turbidity values range from 3 to 6 NTU while lake Secchi depth average is 224 cm.

The Western Ouachita Mountains dominate the western 75-80% of the region. Underlain by sandstone and shale, it has lower elevations than the CMR and is less rugged than both the CMR and Fourche Mountains to the north. Logging and recreation are the major land uses. The upper Little River (including Pine Creek Lake) and Glover River mainstems and watersheds dominate the majority of the area but feeder creeks of the Kiamichi River become more dominant to the west and north. Salinity is extremely low with mean conductivity ranging from 20 µS/cm (Little) to 45 µS/cm (Glover). Pine Creek conductivity is slightly higher but generally remains below 80 µS/cm. Streams are mesotrophic with low nutrient values and excellent clarity. Mean TP, TN, and turbidity values are analogous to the Mountain Fork. Pine Creek Lake is phosphorus limited and eutrophic with slightly higher nutrient concentrations than Broken Bow. Clarity is good with a mean Secchi depth of 83 cm.

Lake Trophic Status

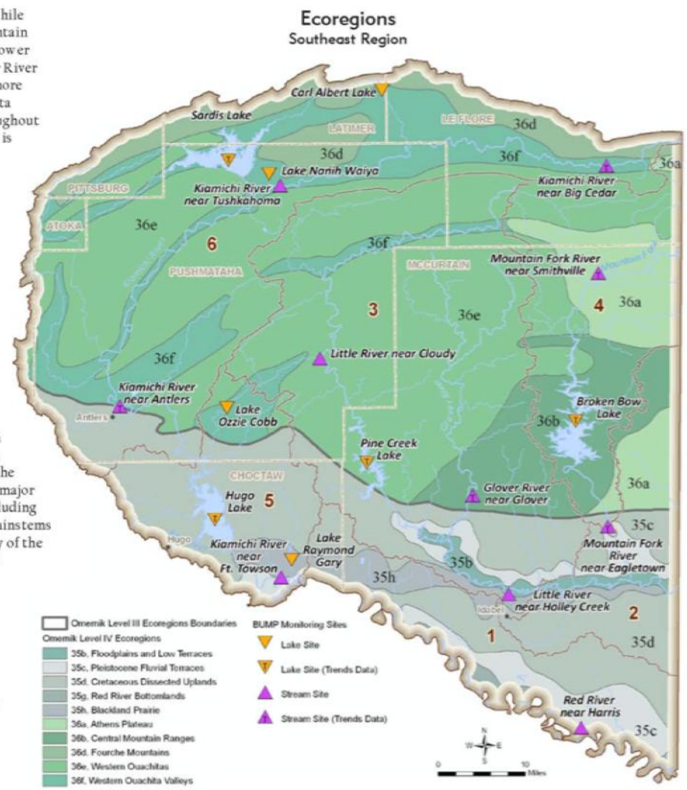
A lake's trophic state, essentially a measure of its biological productivity, is a major determinant of water quality.

Oligotrophic: Low primary productivity and/or low nutrient levels.

Mesotrophic: Moderate primary productivity with moderate nutrient levels.

Eutrophic: High primary productivity and nutrient rich.

Hypereutrophic: Excessive primary productivity and excessive nutrients.



The Southeast Planning Region is dominated by the Ouachita Mountains with significant influence from South Central Plains along the southern one-third of the region. Water quality is highly influenced by both geology and to some extent land use practices. It is generally excellent throughout the Ouachitas, and is good to excellent through most of the South Central Plains, but becomes only average along the Red River Bottomlands.

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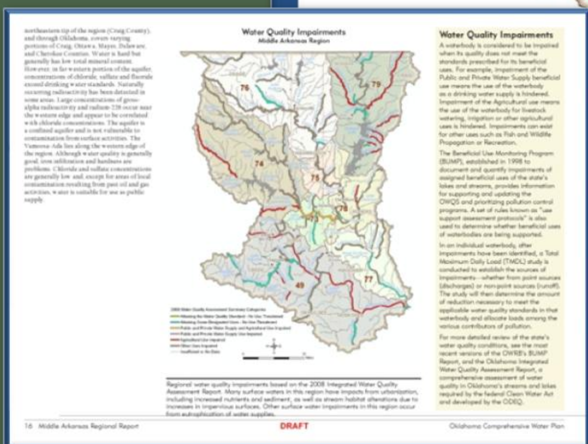
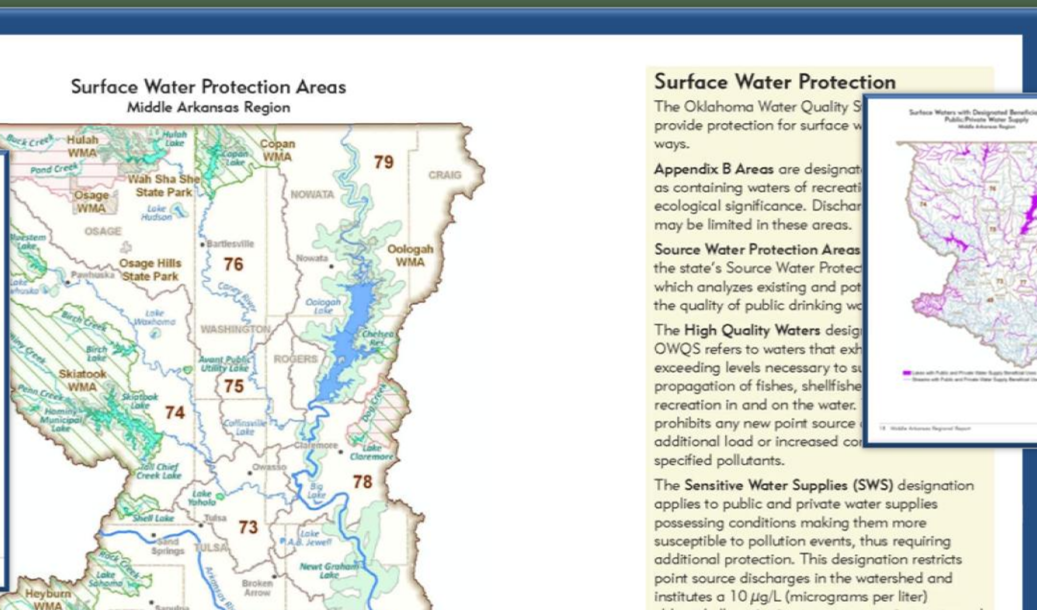
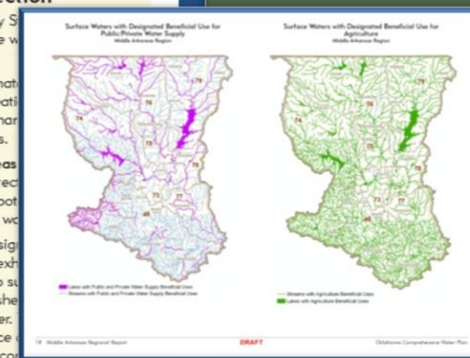
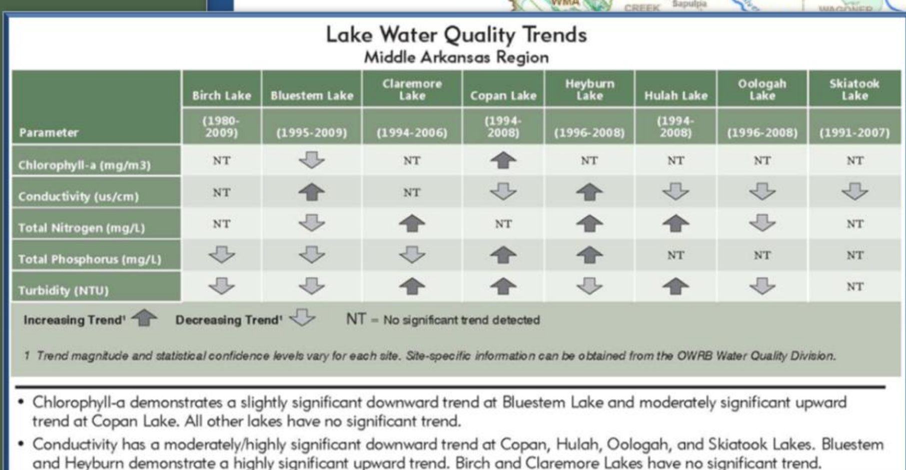
Water Quality
Protections-Standards-Trends









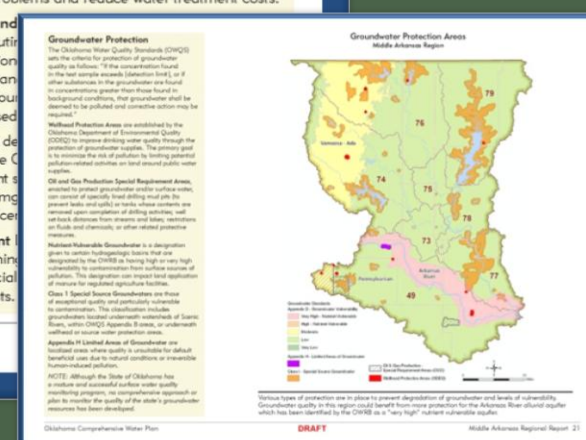
Lake Water Quality Trends
Middle Arkansas Region

Parameter	Birch Lake (1980-2009)	Bluestem Lake (1995-2009)	Claremore Lake (1994-2006)	Copan Lake (1994-2008)	Heyburn Lake (1996-2008)	Hulah Lake (1994-2008)	Oologah Lake (1996-2008)	Skiatook Lake (1991-2007)
Chlorophyll-a (mg/m3)	NT	↓	NT	↑	NT	NT	NT	NT
Conductivity (us/cm)	NT	↑	NT	↓	↑	↓	↓	↓
Total Nitrogen (mg/L)	NT	↓	↑	NT	↑	↑	↓	NT
Total Phosphorus (mg/L)	↓	↓	↓	↑	↑	NT	NT	NT
Turbidity (NTU)	↓	↓	↑	↑	↓	↑	↓	NT

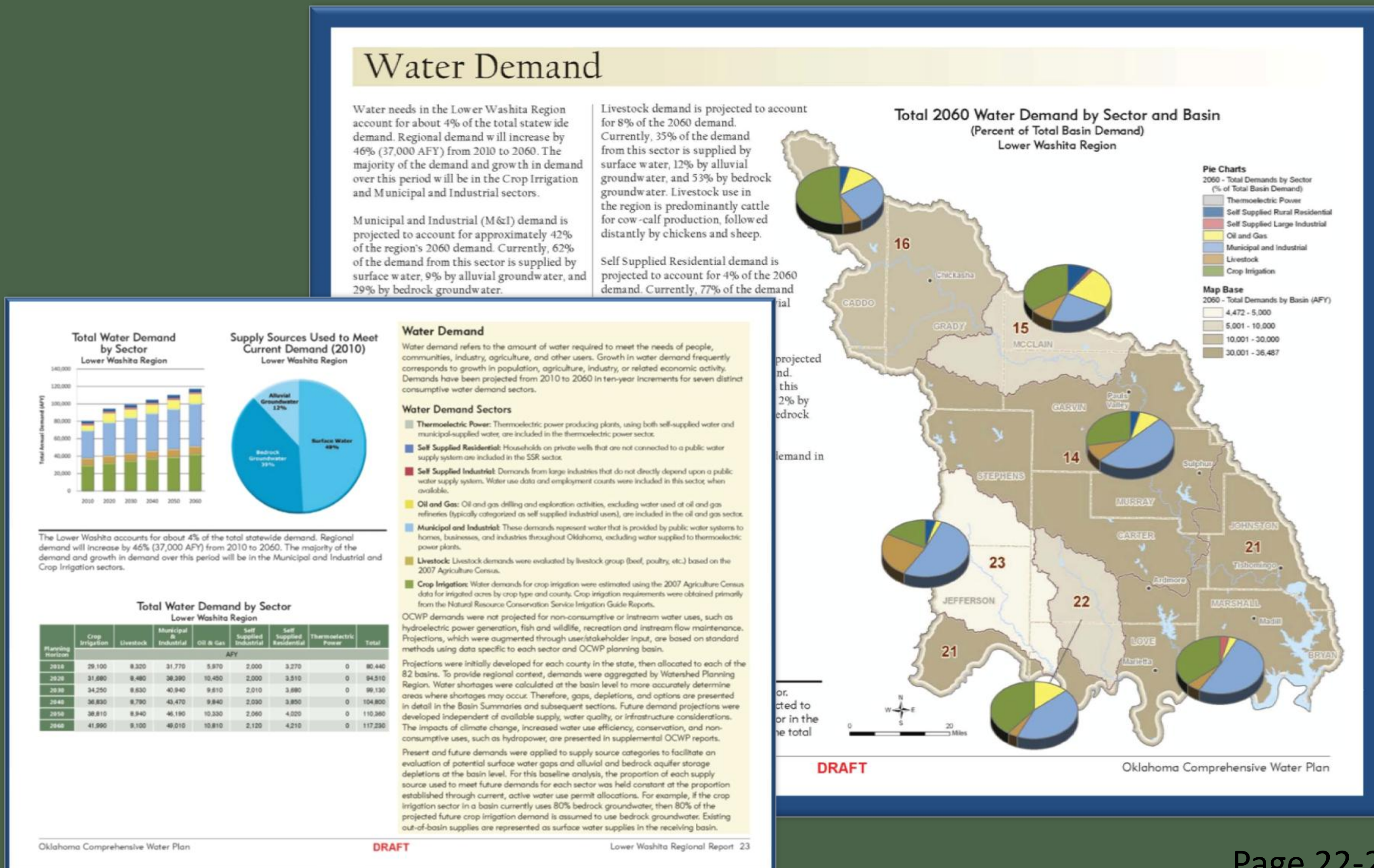
Increasing Trend[1] ↑ Decreasing Trend[1] ↓ NT = No significant trend detected

1 *Trend magnitude and statistical confidence levels vary for each site. Site-specific information can be obtained from the OWRB Water Quality Division.*

- Chlorophyll-a demonstrates a slightly significant downward trend at Bluestem Lake and moderately significant upward trend at Copan Lake. All other lakes have no significant trend.
- Conductivity has a moderately/highly significant downward trend at Copan, Hulah, Oologah, and Skiatook Lakes. Bluestem and Heyburn demonstrate a highly significant upward trend. Birch and Claremore Lakes have no significant trend.



Water Demand
Source-Sector thru 2060



Water Demand

Water needs in the Lower Washita Region account for about 4% of the total statewide demand. Regional demand will increase by 46% (37,000 AFY) from 2010 to 2060. The majority of the demand and growth in demand over this period will be in the Crop Irrigation and Municipal and Industrial sectors.

Municipal and Industrial (M&I) demand is projected to account for approximately 42% of the region's 2060 demand. Currently, 62% of the demand from this sector is supplied by surface water, 9% by alluvial groundwater, and 29% by bedrock groundwater.

Livestock demand is projected to account for 8% of the 2060 demand. Currently, 35% of the demand from this sector is supplied by surface water, 12% by alluvial groundwater, and 53% by bedrock groundwater. Livestock use in the region is predominantly cattle for cow-calf production, followed distantly by chickens and sheep.

Self Supplied Residential demand is projected to account for 4% of the 2060 demand. Currently, 77% of the demand

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Oklahoma Comprehensive Water Plan

The Lower Washita accounts for about 4% of the total statewide demand. Regional demand will increase by 46% (37,000 AFY) from 2010 to 2060. The majority of the demand and growth in demand over this period will be in the Municipal and Industrial and Crop Irrigation sectors.

Total Water Demand by Sector
Lower Washita Region

Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self Supplied Industrial	Self Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	29,100	8,320	31,770	5,970	2,000	3,270	0	80,440
2020	31,680	8,480	38,390	10,450	2,000	3,510	0	94,510
2030	34,250	8,630	40,940	9,610	2,010	3,680	0	99,130
2040	36,830	8,790	43,470	9,840	2,030	3,850	0	104,800
2050	38,810	8,940	46,190	10,330	2,060	4,020	0	110,360
2060	41,990	9,100	49,010	10,810	2,120	4,210	0	117,230

Water Demand

Water demand refers to the amount of water required to meet the needs of people, communities, industry, agriculture, and other users. Growth in water demand frequently corresponds to growth in population, agriculture, industry, or related economic activity. Demands have been projected from 2010 to 2060 in ten-year increments for seven distinct consumptive water demand sectors.

Water Demand Sectors

- **Thermoelectric Power:** Thermoelectric power producing plants, using both self-supplied water and municipal-supplied water, are included in the thermoelectric power sector.
- **Self Supplied Residential:** Households on private wells that are not connected to a public water supply system are included in the SSR sector.
- **Self Supplied Industrial:** Demands from large industries that do not directly depend upon a public water supply system. Water use data and employment counts were included in this sector, when available.
- **Oil and Gas:** Oil and gas drilling and exploration activities, excluding water used at oil and gas refineries (typically categorized as self supplied industrial users), are included in the oil and gas sector.
- **Municipal and Industrial:** These demands represent water that is provided by public water systems to homes, businesses, and industries throughout Oklahoma, excluding water supplied to thermoelectric power plants.
- **Livestock:** Livestock demands were evaluated by livestock group (beef, poultry, etc.) based on the 2007 Agriculture Census.
- **Crop Irrigation:** Water demands for crop irrigation were estimated using the 2007 Agriculture Census data for irrigated acres by crop type and county. Crop irrigation requirements were obtained primarily from the Natural Resource Conservation Service Irrigation Guide Reports.

OCWP demands were not projected for non-consumptive or instream water uses, such as hydroelectric power generation, fish and wildlife, recreation and instream flow maintenance. Projections, which were augmented through user/stakeholder input, are based on standard methods using data specific to each sector and OCWP planning basin.

Projections were initially developed for each county in the state, then allocated to each of the 82 basins. To provide regional context, demands were aggregated by Watershed Planning Region. Water shortages were calculated at the basin level to more accurately determine areas where shortages may occur. Therefore, gaps, depletions, and options are presented in detail in the Basin Summaries and subsequent sections. Future demand projections were developed independent of available supply, water quality, or infrastructure considerations. The impacts of climate change, increased water use efficiency, conservation, and non-consumptive uses, such as hydropower, are presented in supplemental OCWP reports.

Present and future demands were applied to supply source categories to facilitate an evaluation of potential surface water gaps and alluvial and bedrock aquifer storage depletions at the basin level. For this baseline analysis, the proportion of each supply source used to meet future demands for each sector was held constant at the proportion established through current, active water use permit allocations. For example, if the crop irrigation sector in a basin currently uses 80% bedrock groundwater, then 80% of the projected future crop irrigation demand is assumed to use bedrock groundwater. Existing out-of-basin supplies are represented as surface water supplies in the receiving basin.

Oklahoma Comprehensive Water Plan DRAFT Lower Washita Regional Report 23

Public Water Providers

Customers-Demand Forecasts-Infrastructure Needs

Public Water Providers

There are more than 1,600 Oklahoma water systems permitted or regulated by the Oklahoma Department of Environmental Quality (ODEQ); 785 systems were analyzed in detail for the 2012 OCWP Update. The public systems selected for inclusion, which collectively supply approximately 94 percent of the state's current population, consist of municipal or community water systems and rural water districts that were readily identifiable as non-profit, local governmental entities. This and other information provided in the OCWP will support provider-level planning by providing insight into future supply and infrastructure needs.

The Lower Arkansas Region includes 79 of the 785 public supply systems analyzed for the 2012 OCWP Update. The Public Water Providers map indicates the approximate service areas of these systems. (The map may not accurately represent existing service areas or legal boundaries. In addition, water systems often serve multiple counties and can extend into multiple planning basins and regions.)

In terms of 2010 population served (excluding provider-to-provider sales), the five largest systems in the region, in decreasing order, are Muskogee, Tahlequah PWA, Sequoyah County Water Association, Sallisaw, and Poteau PWA. These five systems provide service for approximately 40 percent of the population served by public water providers in the region.

Demands upon public water systems, which comprise the majority of the OCWP's Municipal and Industrial (M&I) water demand sector, were analyzed at both the basin and provider level. Retail demand projections detailed in the Public Water Provider Demand Forecast table were developed for each of the OCWP providers in the region. These projections include estimated system losses, defined as water lost either during water production or distribution to residential homes and businesses. Retail demands do not include wholesaled water.

OCWP provider demand forecasts are not intended to supersede water demand forecasts developed by individual providers. OCWP analyses were made using a consistent methodology based on accepted data available on a statewide basis. Where available, provider-generated forecasts were also reviewed as part of this effort.

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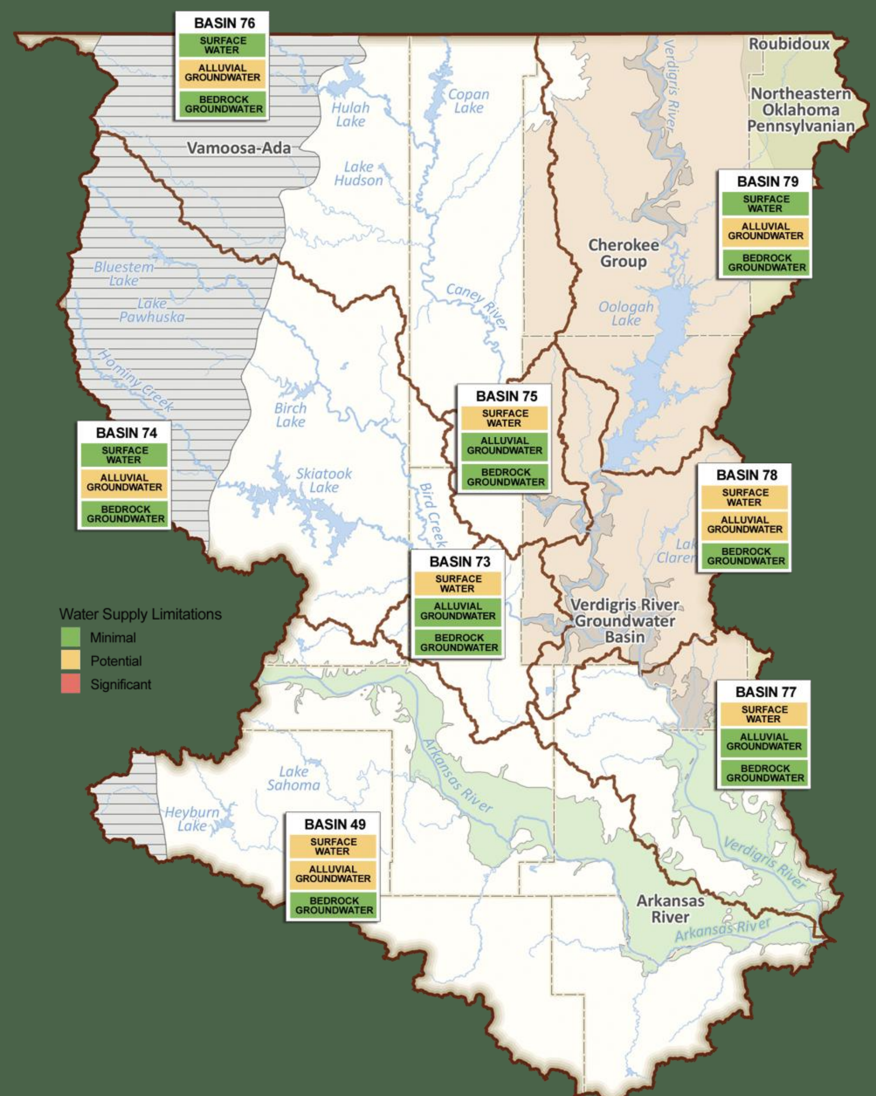
Water Supply Limitations & Options

Limitations Analysis:

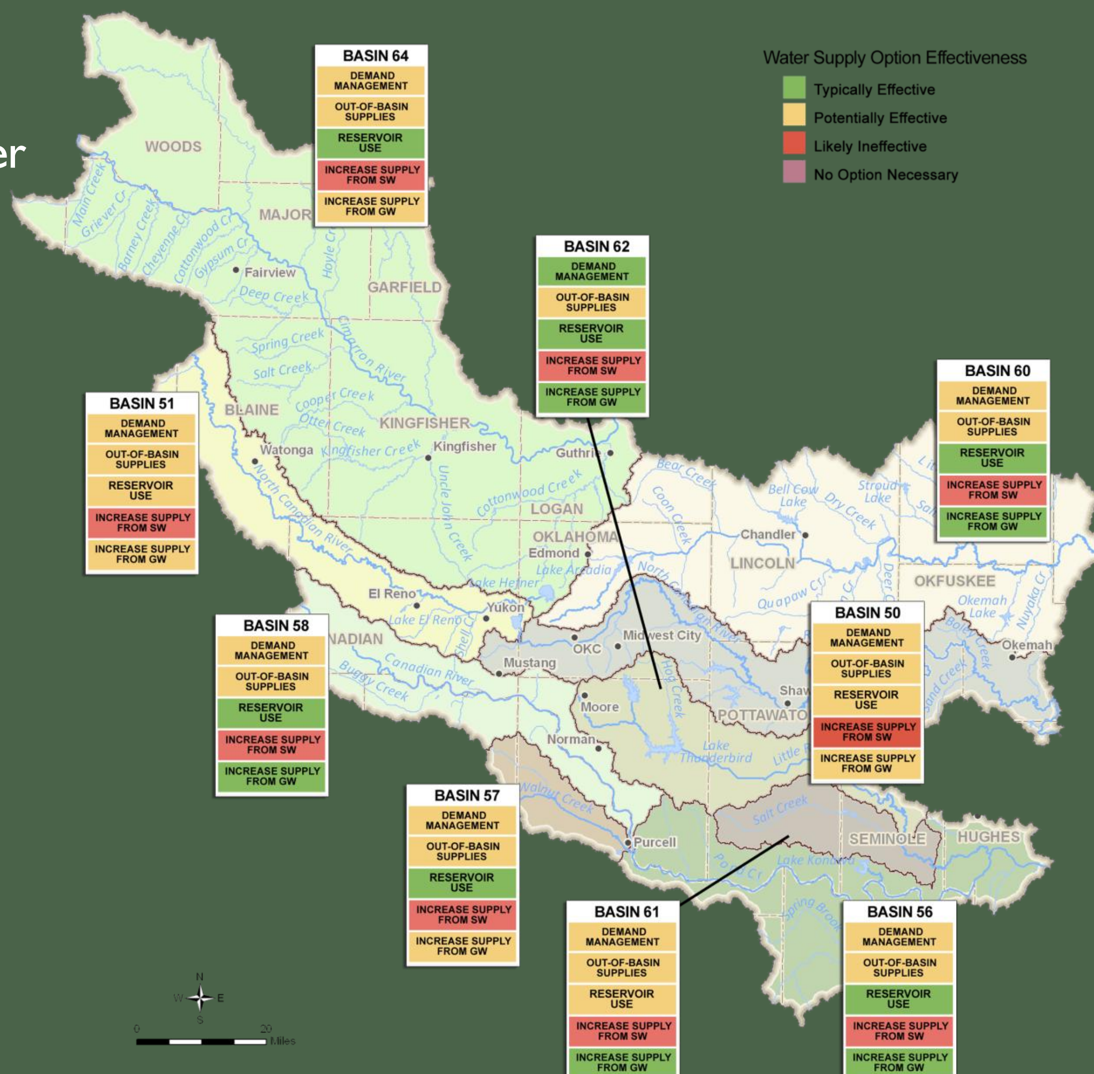
- Assessed factors limiting the use of the three major supply categories:
  - surface water
  - alluvial groundwater
  - bedrock groundwater



Water Supply Limitations & Options

Options Analysis:

- Assessed the ability of options to potentially mitigate identified water supply shortages
- Primary Options:
  - Demand Management
  - Out-of-Basin Supplies
  - Reservoir Use
  - Increasing Reliance on Surface Water
  - Increasing Reliance on Groundwater
- Additional Options:
  - Potential Reservoir Development
  - Water Conveyance System
  - Artificial Groundwater Recharge
  - Marginal Quality Water Sources

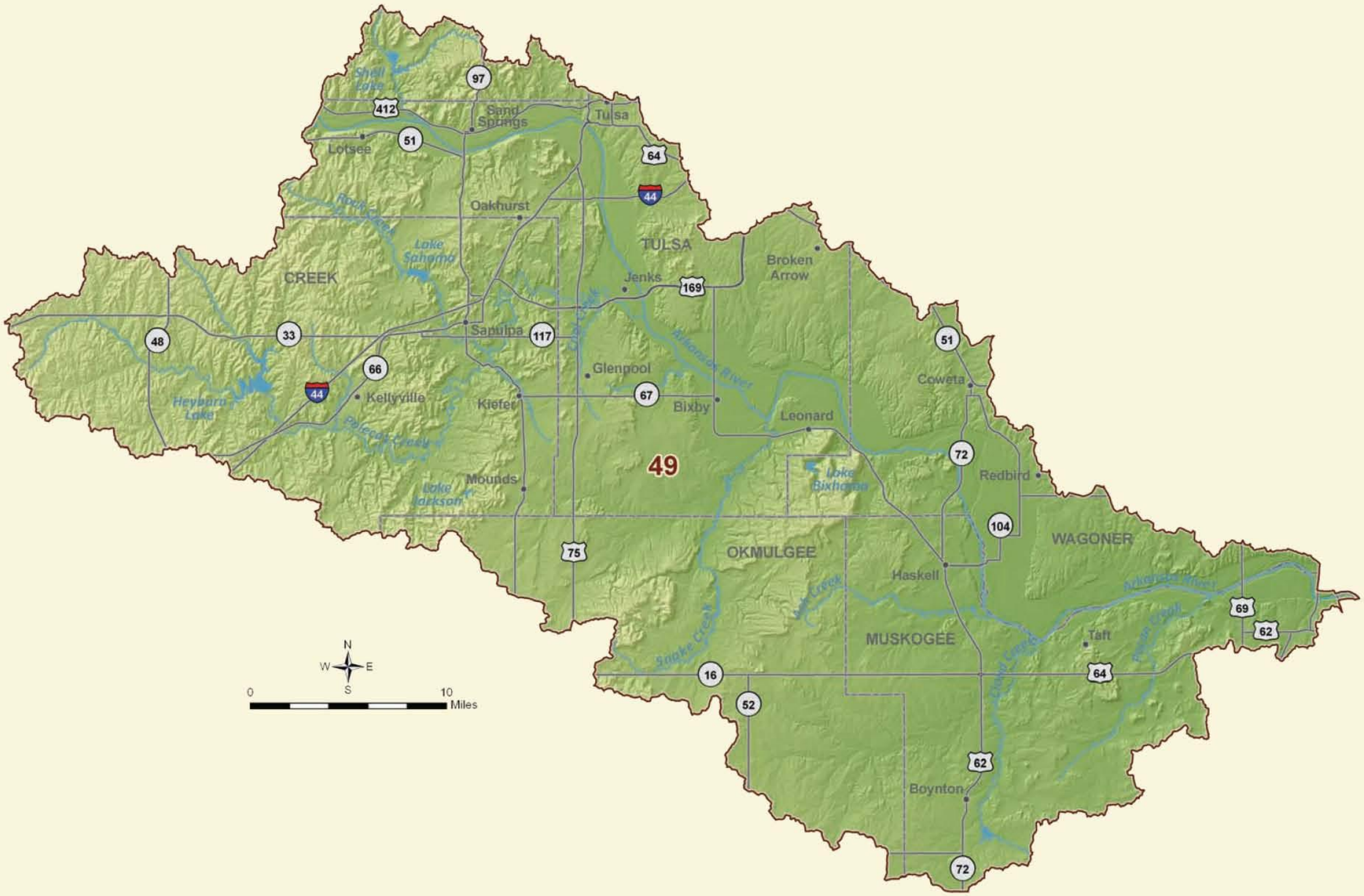


Oklahoma Comprehensive Water Plan

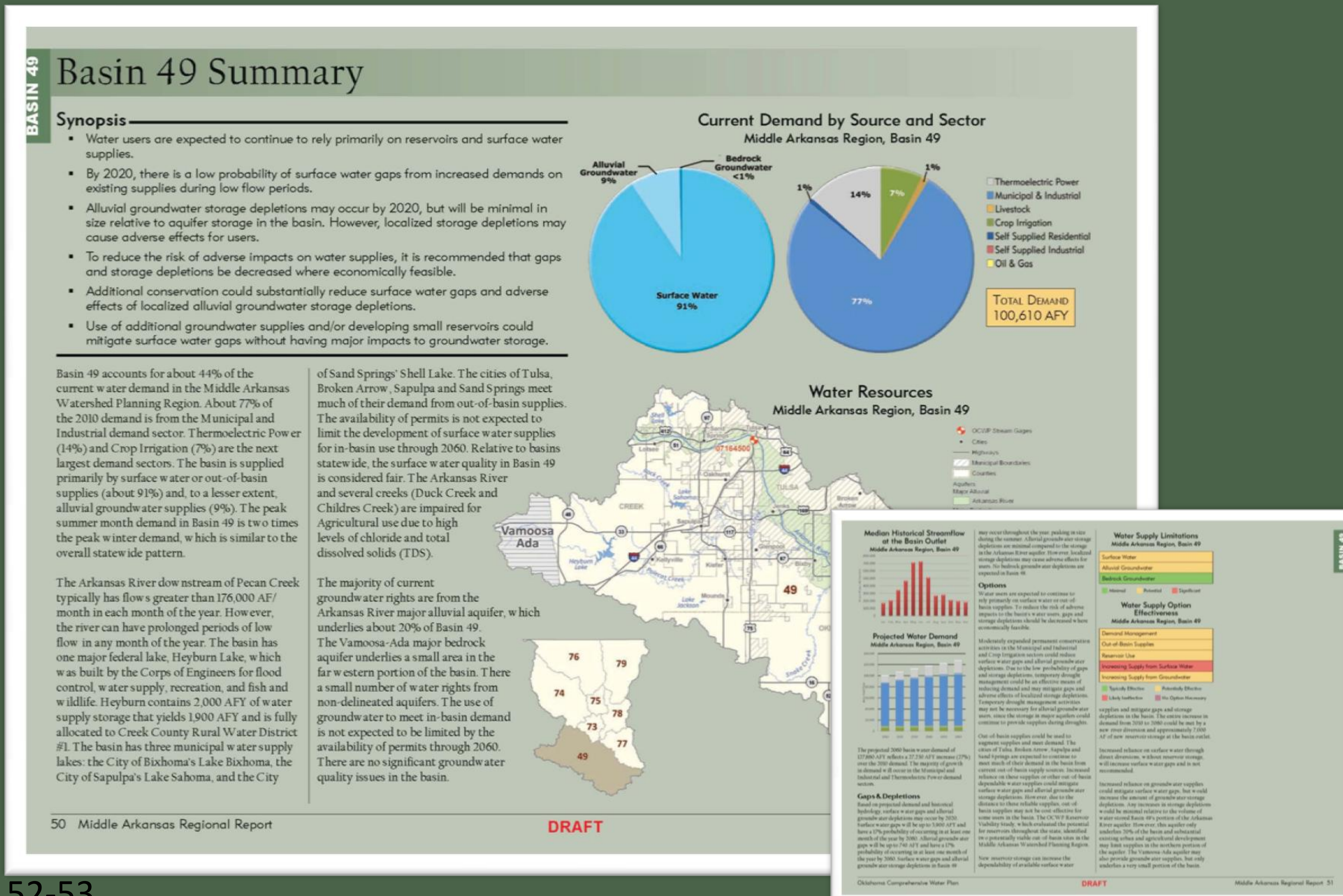
Data & Analysis

Middle Arkansas Watershed Planning Region

Basin 49



Basin Summary



BASIN 49

Basin 49 Summary

Synopsis

- Water users are expected to continue to rely primarily on reservoirs and surface water supplies.
- By 2020, there is a low probability of surface water gaps from increased demands on existing supplies during low flow periods.
- Alluvial groundwater storage depletions may occur by 2020, but will be minimal in size relative to aquifer storage in the basin. However, localized storage depletions may cause adverse effects for users.
- To reduce the risk of adverse impacts on water supplies, it is recommended that gaps and storage depletions be decreased where economically feasible.
- Additional conservation could substantially reduce surface water gaps and adverse effects of localized alluvial groundwater storage depletions.
- Use of additional groundwater supplies and/or developing small reservoirs could mitigate surface water gaps without having major impacts to groundwater storage.

Basin 49 accounts for about 44% of the current water demand in the Middle Arkansas Watershed Planning Region. About 77% of the 2010 demand is from the Municipal and Industrial demand sector. Thermoelectric Power (14%) and Crop Irrigation (7%) are the next largest demand sectors. The basin is supplied primarily by surface water or out-of-basin supplies (about 91%) and, to a lesser extent, alluvial groundwater supplies (9%). The peak summer month demand in Basin 49 is two times the peak winter demand, which is similar to the overall statewide pattern.

The Arkansas River downstream of Pecan Creek typically has flows greater than 176,000 AF/month in each month of the year. However, the river can have prolonged periods of low flow in any month of the year. The basin has one major federal lake, Heyburn Lake, which was built by the Corps of Engineers for flood control, water supply, recreation, and fish and wildlife. Heyburn contains 2,000 AFY of water supply storage that yields 1,900 AFY and is fully allocated to Creek County Rural Water District #1. The basin has three municipal water supply lakes: the City of Bixhoma's Lake Bixhoma, the City of Sapulpa's Lake Sahoma, and the City of Sand Springs' Shell Lake. The cities of Tulsa, Broken Arrow, Sapulpa and Sand Springs meet much of their demand from out-of-basin supplies. The availability of permits is not expected to limit the development of surface water supplies for in-basin use through 2060. Relative to basins statewide, the surface water quality in Basin 49 is considered fair. The Arkansas River and several creeks (Duck Creek and Childres Creek) are impaired for Agricultural use due to high levels of chloride and total dissolved solids (TDS).

The majority of current groundwater rights are from the Arkansas River major alluvial aquifer, which underlies about 20% of Basin 49. The Vamoosa-Ada major bedrock aquifer underlies a small area in the far western portion of the basin. There a small number of water rights from non-delineated aquifers. The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060. There are no significant groundwater quality issues in the basin.

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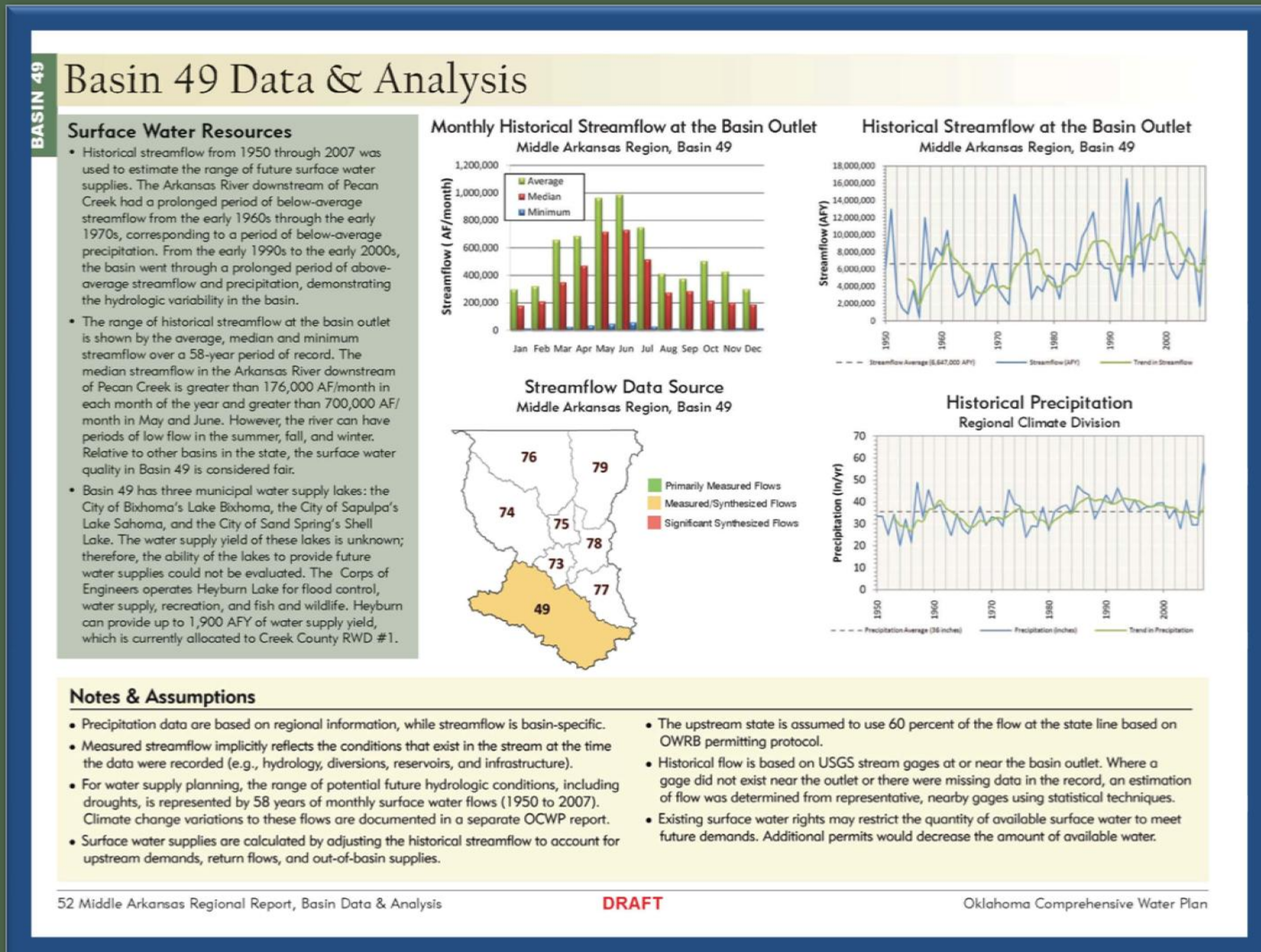
Historical/Monthly Precipitation & Streamflow



BASIN 49

Basin 49 Data & Analysis

Surface Water Resources

- Historical streamflow from 1950 through 2007 was used to estimate the range of future surface water supplies. The Arkansas River downstream of Pecan Creek had a prolonged period of below-average streamflow from the early 1960s through the early 1970s, corresponding to a period of below-average precipitation. From the early 1990s to the early 2000s, the basin went through a prolonged period of above-average streamflow and precipitation, demonstrating the hydrologic variability in the basin.
- The range of historical streamflow at the basin outlet is shown by the average, median and minimum streamflow over a 58-year period of record. The median streamflow in the Arkansas River downstream of Pecan Creek is greater than 176,000 AF/month in each month of the year and greater than 700,000 AF/month in May and June. However, the river can have periods of low flow in the summer, fall, and winter. Relative to other basins in the state, the surface water quality in Basin 49 is considered fair.
- Basin 49 has three municipal water supply lakes: the City of Bixhoma's Lake Bixhoma, the City of Sapulpa's Lake Sahoma, and the City of Sand Spring's Shell Lake. The water supply yield of these lakes is unknown; therefore, the ability of the lakes to provide future water supplies could not be evaluated. The Corps of Engineers operates Heyburn Lake for flood control, water supply, recreation, and fish and wildlife. Heyburn can provide up to 1,900 AFY of water supply yield, which is currently allocated to Creek County RWD #1.

Notes & Assumptions

- Precipitation data are based on regional information, while streamflow is basin-specific.
- Measured streamflow implicitly reflects the conditions that exist in the stream at the time the data were recorded (e.g., hydrology, diversions, reservoirs, and infrastructure).
- For water supply planning, the range of potential future hydrologic conditions, including droughts, is represented by 58 years of monthly surface water flows (1950 to 2007). Climate change variations to these flows are documented in a separate OCWP report.
- Surface water supplies are calculated by adjusting the historical streamflow to account for upstream demands, return flows, and out-of-basin supplies.
- The upstream state is assumed to use 60 percent of the flow at the state line based on OWRB permitting protocol.
- Historical flow is based on USGS stream gages at or near the basin outlet. Where a gage did not exist near the outlet or there were missing data in the record, an estimation of flow was determined from representative, nearby gages using statistical techniques.
- Existing surface water rights may restrict the quantity of available surface water to meet future demands. Additional permits would decrease the amount of available water.

Groundwater Supply Sources

Groundwater Resources - Aquifer Summary (2010)

Middle Arkansas Region, Basin 49

Aquifer			Portion of Basin Overlaying Aquifer	Current Groundwater Rights	Aquifer Storage in Basin	Equal Proportionate Share	Groundwater Available for New Permits
Name	Type	Class[1]	Percent	AFY	AF	AFY/Acre	AFY
Arkansas River	Alluvial	Major	19%	15,400	344,000	temporary 2.0	286,100
Vamoosa-Ada	Bedrock	Major	4%	200	264,000	2.0	63,000
Non-Delineated Groundwater Source	Bedrock	Minor	N/A	300	N/A	temporary 2.0	N/A
Non-Delineated Groundwater Source	Alluvial	Minor	N/A	0	N/A	temporary 2.0	N/A

1 Bedrock aquifers with typical yields greater than 50 gpm and alluvial aquifers with typical yields greater than 150 gpm are considered major.

BASIN 49

Groundwater Resources

- The majority of current groundwater rights are from the Arkansas River alluvial aquifer, which underlies about 19% of Basin 49. There is about 344,000 AF of storage in Basin 49's portion of the Arkansas River aquifer. The Vamoosa-Ada bedrock aquifer underlies a small portion of the far western part of the basin, but receives an estimated 3,000 AFY of recharge from the basin. There are also 300 AFY of groundwater rights in non-delineated minor bedrock aquifers.
- There are no significant groundwater quality issues in Basin 49.

Notes & Assumptions

- Alluvial groundwater recharge is not considered separately from streamflow in physical supply availability analyses because any increases or decreases in alluvial groundwater recharge or storage would affect streamflow. Therefore, surface water flows are used to represent available alluvial groundwater recharge.
- Site-specific information on minor aquifers should be considered before large scale use. Suitability for long term supply is typically based on recharge, storage yield, capital and operational costs, and water quality.
- Groundwater permit availability is generally based on the amount of land owned or leased that overlies a specific aquifer.
- Temporary permit amounts are subject to change when the aquifer's equal proportionate share is set by the OWRB.
- Current groundwater rights represent the maximum allowable use. Actual use may be lower than the permitted amount.
- Bedrock groundwater recharge is the long-term annual average recharge to aquifers in the basin. Recharge rates on a county- or aquifer-wide level of detail were established from literature (published reports) of each aquifer. Seasonal or annual variability is not considered; therefore the modeled bedrock groundwater supply is independent of changing hydrologic conditions.

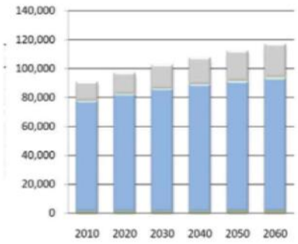
Water Demand thru 2060
Source & Water Use Sector

BASIN 49

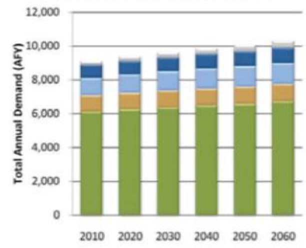
Water Demand

- The water needs of Basin 49 are about 44% of the total demand in the Middle Arkansas Watershed Planning Region and will increase by 27% (27,250 AFY) from 2010 to 2060. The majority of the demand and growth in demand from 2010 to 2060 will be in the Municipal and Industrial demand sector.
- Surface water is used to meet 91% of the total demand in the basin and its use will increase by 29% (26,040 AFY) from 2010 to 2060. The majority of surface water use and growth in that use over this period will be in the Municipal and Industrial demand sector, which will be met in part by existing out-of-basin supplies.
- Alluvial groundwater is used to meet 9% of the total demand in the basin and its use will increase by 13% (1,170 AFY) from 2010 to 2060. The majority of alluvial groundwater use and growth in the use will be in the Crop Irrigation demand sector.
- Bedrock groundwater is used to meet less than 1% of the total demand in the basin and its use will increase by 11% (40 AFY) from 2010 to 2060. The increase in bedrock groundwater use is minimal on a basin scale.

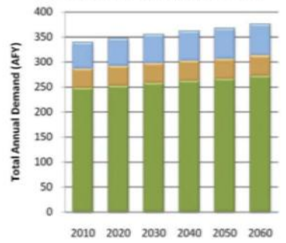
Surface Water Demand by Sector
Middle Arkansas Region, Basin 49



Alluvial Groundwater Demand by Sector
Middle Arkansas Region, Basin 49



Bedrock Groundwater Demand by Sector
Middle Arkansas Region, Basin 49



Thermoelectric Power · Self Supplied Residential · Self Supplied Industrial · Oil & Gas · Municipal & Industrial · Livestock · Crop Irrigation

Total Demand by Sector
Middle Arkansas Region, Basin 49

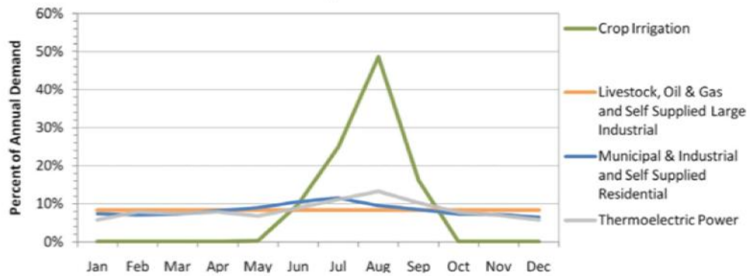
Planning Horizon	Crop Irrigation	Livestock	Municipal & Industrial	Oil & Gas	Self Supplied Industrial	Self Supplied Residential	Thermoelectric Power	Total
	AFY							
2010	7,470	1,180	77,580	110	0	760	13,510	100,610
2020	7,620	1,190	82,300	180	0	800	15,070	107,160
2030	7,760	1,200	86,000	280	0	830	16,810	112,880
2040	7,910	1,210	88,820	390	0	860	18,750	117,940
2050	8,020	1,230	91,160	520	0	880	20,920	122,730
2060	8,200	1,240	93,500	680	0	900	23,340	127,860

Notes & Assumptions

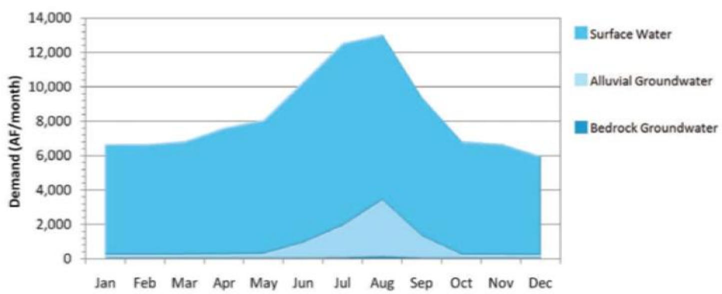
- Demand values represent total demand (the amount of water pumped or diverted to meet the needs of the user).
- Values are based on the baseline demand forecast from the March 2011 OCWP Water Demand Forecast Report.
- The effect of climate change, conservation, and non-consumptive uses, such as hydropower, are not represented in this baseline demand analysis but are documented in separate OCWP reports.
- The proportion of each supply source used to meet each water use sector's demand was assumed to be equal to the existing proportion, as represented in water rights.
- The proportions of future demands between water use sectors will vary due to differing growth rates.
- The overall proportion of supplies used to meet demand will change due to differing growth rates among the water use sectors.

Distribution Among Uses/Sources of Current & Projected Supply

Monthly Demand Distribution by Sector (2010)
Middle Arkansas Region, Basin 49



Monthly Demand Distribution by Source (2010)
Middle Arkansas Region, Basin 49



BASIN 49

Current Monthly Demand Distribution by Sector

- The Municipal and Industrial and Self Supplied Residential demand sectors use 52% more water in summer months than in winter months. Crop Irrigation has a high demand in summer months and little or no demand in winter months. Thermoelectric Power demand peaks in summer. Other basin demand sectors have a more consistent demand throughout the year.

Current Monthly Demand Distribution by Source

- The peak summer month total water demand in Basin 49 is two times the monthly winter demand, which is similar to the overall statewide pattern. Surface water use in the peak summer month is about twice the monthly winter use. Alluvial and bedrock groundwater use in the peak summer month is greater than 14 times the monthly winter use.

Notes & Assumptions

- The proportions of future demands between demand sectors will vary due to differing growth rates between those sectors.
- The overall proportion of supplies used to meet demand will change due to differing growth rates among the demand sectors.

Likelihood & Severity of Shortages

Surface Water Gaps-Groundwater Depletions

BASIN 49

Gaps and Storage Depletions

- Based on projected demand and historical hydrology, surface water gaps and alluvial groundwater depletions may occur by 2020. No bedrock groundwater depletions are expected in this basin due to the minimal growth in demand from 2010 through 2060.
- Surface water gaps in Basin 49 may occur throughout the year, peaking in size during the summer. Surface water gaps in 2060 will be up to 14% (1,800 AF/month) of the surface water demand in the peak summer month, and as much as 12% (990AF/month) of the monthly winter surface water demand. There will be a 17% probability of gaps occurring in at least one month of the year by 2060. Gaps are most likely to occur during fall months. Upstream demand will reduce streamflow and recharge to alluvial groundwater aquifers, resulting in increased probability of gaps and storage depletions in the future.
- Alluvial groundwater storage depletions in Basin 49 may occur throughout the year, peaking in size during the summer. Alluvial groundwater storage depletions in 2060 will be up to 13% (480 AF/month) of the alluvial groundwater demand in the peak summer month, and as much as 14% (30 AF/month) of the monthly winter alluvial groundwater demand. There will be a 17% probability of alluvial groundwater storage depletions occurring in at least one month of the year by 2060. Alluvial groundwater storage depletions are most likely to occur during fall months.
- Projected annual alluvial groundwater storage depletions are minimal relative to the amount of water stored in the basin's portion of the Arkansas River alluvial aquifer. However, localized storage depletions may occur and adversely affect yields, water quality, and/or pumping costs.

Surface Water Gaps by Season (2060 Demands)
Middle Arkansas Region, Basin 49

Months (Season)	Maximum Gap[1] AF/month	Median Gap AF/month	Probability Percent
Dec-Feb (Winter)	990	850	3%
Mar-May (Spring)	1,190	830	3%
Jun-Aug (Summer)	1,800	1,800	3%
Sep - Nov (Fall)	1,430	1,020	14%

1 Amount shown represents the largest amount for any one month in the season indicated.

Alluvial Groundwater Storage Depletions by Season (2060 Demands)
Middle Arkansas Region, Basin 49

Months (Season)	Maximum Storage Depletion[1] AF/month	Median Storage Depletion AF/month	Probability Percent
Dec-Feb (Winter)	30	25	3%
Mar-May (Spring)	40	25	3%
Jun-Aug (Summer)	480	480	3%
Sep - Nov (Fall)	180	30	14%

1 Amount shown represents the largest amount for any one month in the season indicated.

Magnitude and Probability of Annual Gaps and Storage Depletions
Middle Arkansas Region, Basin 49

Planning Horizon	Maximum Gaps/Storage Depletions			Probability of Gaps/ Storage Depletions	
	Surface Water	Alluvial GW	Bedrock GW	Surface Water	Alluvial GW
	AFY			Percent	
2020	400	90	0	16%	9%
2030	1,150	260	0	16%	16%
2040	2,350	410	0	16%	16%
2050	3,940	570	0	16%	16%
2060	5,900	740	0	17%	17%

Bedrock Groundwater Storage Depletions by Season (2060 Demands)
Middle Arkansas Region, Basin 49

Months (Season)	Maximum Storage Depletion[1] AF/month
Dec-Feb (Winter)	0
Mar-May (Spring)	0
Jun-Aug (Summer)	0
Sep-Nov (Fall)	0

1 Amount shown represents the largest amount for any one month in the season indicated.

Notes & Assumptions

- Gaps and Storage Depletions reflect deficiencies in physically available water (or "wet water"). Permitting, water quality, infrastructure, and nonconsumptive demand constraints are considered in separate OCWP analyses.
- Local gaps and storage depletions may vary from basin-level values due to local variations in demands and local availability of supply sources.
- For this baseline analysis, each basin's future demand is met by the basin's available supplies.
- For this baseline analysis, the proportion of future demand supplied by surface water and groundwater for each sector is assumed equal to current proportions.
- The available surface water supplies used in the OCWP water supply availability analysis include changes in historical streamflow due to increased upstream demand, return flows, and increases in out-of-basin supplies from existing infrastructure.
- Analysis of bedrock groundwater supplies is based upon recharge from major aquifers.
- Groundwater storage depletions are defined as the amount that future demands exceed available recharge.
- Median gaps and storage depletions are based only on months with gaps or storage depletions.
- Annual probability is based upon the number of years that a gap or depletion occurs in at least one month of that year.

Options & Alternatives to Forecasted Shortages

Reducing Water Needs Through Conservation

Middle Arkansas Region, Basin 49

Conservation Activities[1]	2060 Gap/Storage Depletion			2060 Gap/Storage Depletion Probability	
	Surface Water	Alluvial GW	Bedrock GW	Surface Water	Alluvial GW
	AFY			Percent	
Existing Conditions	5,900	740	0	17%	17%
Moderately Expanded Conservation in Crop Irrigation Water Use	5,720	680	0	17%	17%
Moderately Expanded Conservation in M&I Water Use	1,200	290	0	16%	7%
Moderately Expanded Conservation in Crop Irrigation and M&I Water Use	1,000	230	0	16%	7%
Substantially Expanded Conservation in Crop Irrigation and M&I Water Use	10	0	0	2%	0%

1 Conservation Activities are documented in the OCWP Demand Forecast Report

Reliable Diversions Based on Available Streamflow and New Reservoir Storage

Middle Arkansas Region, Basin 49

Reservoir Storage	Diversion
AF	AFY
100	8,600
500	11,000
1,000	13,100
2,500	16,900
5,000	22,700
Required Storage to Meet Growth in Demand (AF)	7,000
Required Storage to Meet Growth in Surface Water Demand (AF)	6,300

Water Supply Options & Effectiveness

BASIN 49

Typically Effective
Potentially Effective
Likely Ineffective
No Option Necessary

Demand Management

Moderately expanded permanent conservation activities in the Municipal and Industrial and Crop Irrigation sectors could reduce surface water gaps by about 80% and alluvial groundwater depletions by about 70%. Due to the low probability of gaps and storage depletions, temporary drought management could be an effective means of reducing demand, largely from irrigation, and may mitigate gaps and adverse effects of localized depletions. Temporary drought management activities may not be necessary for alluvial groundwater users since the storage in major aquifers could continue to provide supplies during droughts.

Out-of-Basin Supplies

Out-of-basin supplies could be used to augment supplies and meet demand. Currently, the Cities of Tulsa, Broken Arrow, Sapulpa and Sand Springs are expected to continue to meet much of their demand from out-of-basin sources. Out-of-basin supplies are primarily from Lake Skiatook in Basin 74, Lake Oolagah in Basin 79, and Lakes Eucha, Spavinaw, and Hudson (Markham Ferry) in Basin 80. The OCWP Reservoir Viability Study, which evaluated the potential for reservoirs throughout the state, identified two potentially viable out-of-basin sites in the Middle Arkansas Watershed Planning Region: Candy in Basin 74 and Sand in Basin 76. Increased reliance on existing or new out-of-basin supplies could mitigate surface water gaps and alluvial groundwater storage depletions. However, due to the distance to these reliable sources, out-of-basin supplies may not be cost-effective for some users in the basin.

Reservoir Use

New reservoir storage could increase the dependability of available surface water supplies and mitigate gaps and storage depletions. The entire increase in demand through 2060 could be met by a new river diversion and approximately 7,000 AF of new reservoir storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the amount of storage necessary to mitigate future gaps and storage depletions. Reallocation of existing storage at Lake Heyburn for additional water supply is another option currently being pursued through the Corps of Engineers.

Increasing Reliance on Surface Water

Increased reliance on surface water through direct diversions, without reservoir storage, will increase surface water gaps and is not recommended.

Increasing Reliance on Groundwater

Increased reliance on groundwater supplies could mitigate surface water gaps but would increase groundwater depletions. Any increases in groundwater storage depletions would be minimal relative to the volume of water stored in Basin 49's portion of the Arkansas River aquifer. However, this aquifer underlies only 20% of the basin and substantial existing urban and agricultural development may limit supplies in the northern portion of the aquifer. The Vamoosa-Ada aquifer may also provide groundwater supplies, but it underlies only a very small portion of the basin.

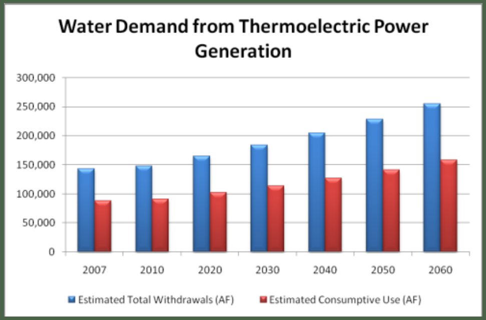
Notes & Assumptions

- Water quality considerations may limit the use of supply sources, which may require new or additional treatment before use.
- Infrastructure related to the diversion, conveyance, treatment, and distribution of water will affect the cost-effectiveness of using any new source of supply.
- The ability to reduce demands will vary based on local acceptance of additional conservation and temporary drought management activities.
- Gaps and depletions may be mitigated in individual calendar months without reductions in the annual probability (chance of having shortage during another month).
- River diversions for new or additional reservoir storage is based on a hypothetical on-channel reservoir at the basin outlet. Reported yields will vary depending upon the reservoir location; placement at the basin outlet would likely result in a higher yield.
- Surface water diversions may provide substantial annual dependable yield with little or no reservoir storage if surface supplies are frequently equal to or greater than the annual total and monthly pattern of demand.
- Aquifer storage and recovery may provide additional storage or an alternative to surface storage and should be evaluated on a case by case basis.

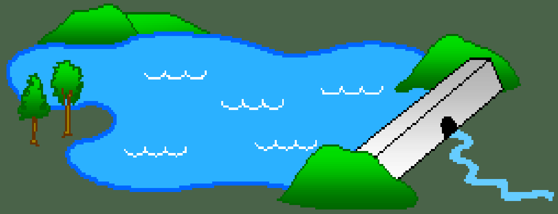
Tools Developed for the OCWP Update

under USACE / OWRB authorities

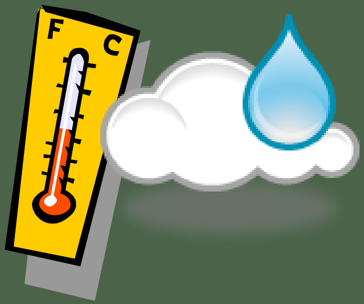
Supply/Demand/Options Tools



Demand Projection Model



Reservoir Yield Model

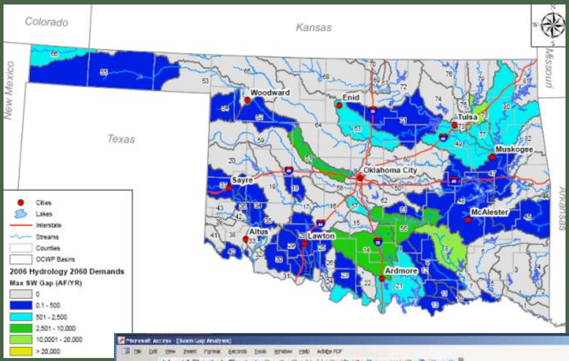


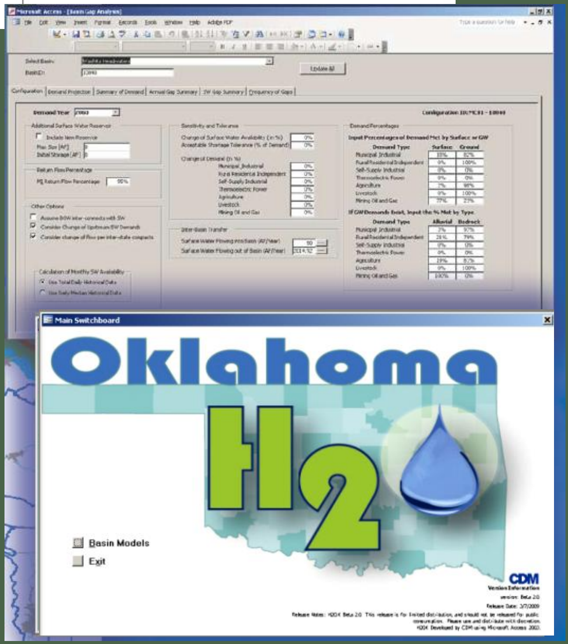
Climate Demand Model

Planning Guide

Water Allocation Models

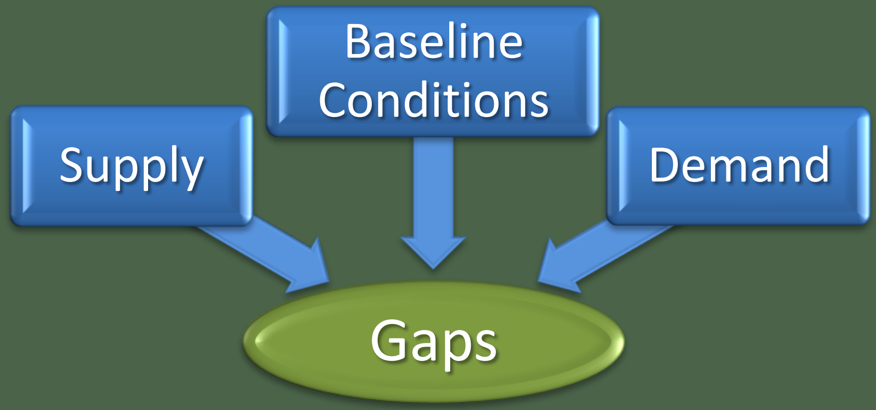
Oklahoma H_2O Tool





- Physical supply availability for each basin
- Supply shortages by year
  - 2010/2020/2030/2040/2050/2060
- Supply shortages by source
  - Surface water, Alluvial groundwater, Bedrock groundwater
- Magnitude & Frequency of Gaps Under Historical Range of Hydrologies
- Sensitivity analyses: water quality, new reservoirs, environmental flows, changing demand patterns, etc.

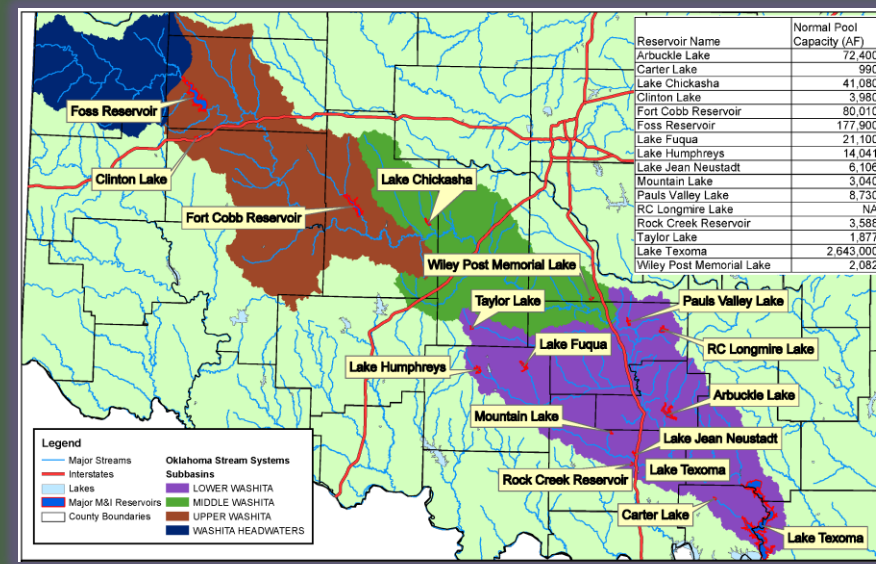
Built-in Flexibility for What-If Analyses



- Demand and/or supply adjustments
  - By basin, sector, & decade
  - Or statewide
- What-if scenarios and sensitivity testing
  - Surface water / groundwater supply proportions
  - Additional surface water storage
  - Climate change / climate variability
  - Conservation measures
  - Variation from demand projections
  - Upstream demand variability
  - Alternative sources of supply

Reservoir Yield Model

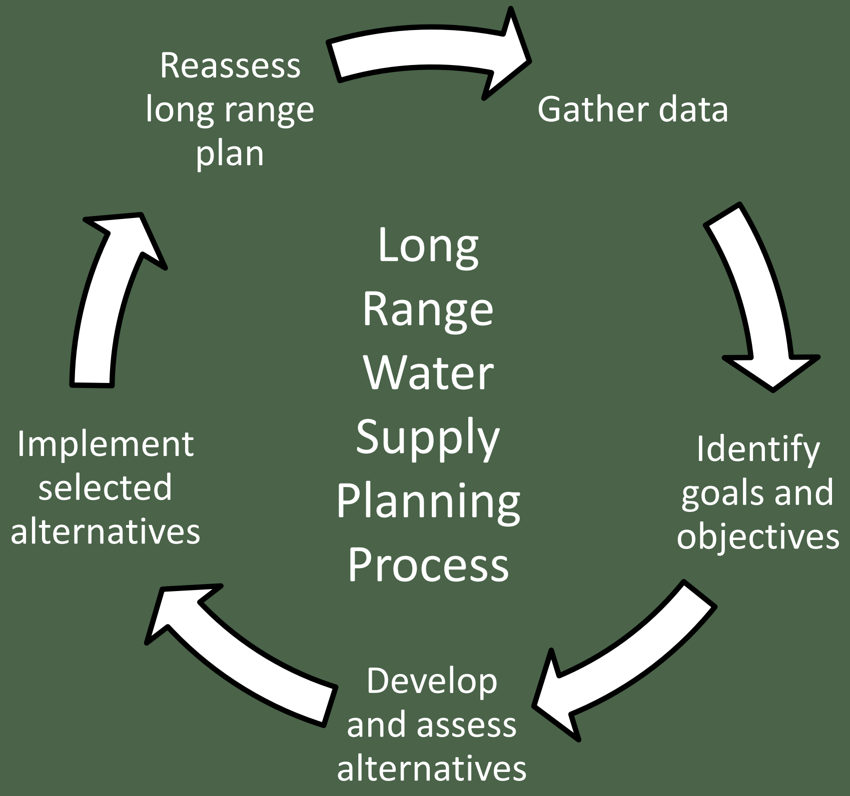
- 82% of PWS systems obtain their supply from reservoirs
- Firm Yield: Maximum amount of water that can be withdrawn through a drought of record



- Goal: Identify and test a , simplified and standardized method for estimating reservoir yields
- Easy to use, desktop model

Public Water Supply Planning Guide

- Assist small water supply providers
- Provides framework for long range planning activities, including tables, checklist and open-ended questions
- Builds on data developed as part of the OCWP
- Provides an example using the process for Any City, Oklahoma



2012

Oklahoma Comprehensive Water Plan

OCWP

www.owrb.ok.gov/ocwp