Oklahoma Comprehensive Water Plan
Supplemental Report

Marginal Quality Water
Issues & Recommendations

September 2010

This study was funded through an agreement with the Oklahoma Water Resources Board under its authority to update the Oklahoma Comprehensive Water Plan, the state's long-range water planning strategy. Results from this and other studies have been incorporated where appropriate in the OCWP's technical and policy considerations. The general goal of the 2012 OCWP Update is to ensure reliable water supplies for all Oklahomans through integrated and coordinated water resources planning and to 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.

Marginal Quality Water Issues and Recommendations

The following report was commissioned by the Oklahoma State Legislature in 2008 as a component of technical work performed under the 2012 Update of the Oklahoma Comprehensive Water Plan. This report presents the results of a technical workgroup study, supported by the Oklahoma Water Resources Board and CDM, directed to evaluate the use of marginal quality water sources to augment water supplies throughout the state. More specifically, this report evaluates potential sources in Oklahoma and examines how to economically increase the available and beneficially usable supply of such water.

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Acronyms

AF	acre-feet
AFY	acre-feet per year
BMPs	best management practices
BOD	biochemical oxygen demand
BOR	U.S. Bureau of Reclamation
BTW	base of treatable water
BUMP	Beneficial Use Monitoring Program
Corp Comm	Oklahoma Corporation Commission
DBP	disinfection byproduct
EDR	electro-dialysis reversal
EM	Electro-Mag
EMC	event mean concentration
EPA	U.S. Environmental Protection Agency
GAC	granular activated carbon
GFH	granular ferric hydroxide
GIS	geographic information system
GWUI	groundwater under the influence
HUC	Hydrologic Units
LPRO	low pressure reverse osmosis
M&I	municipal and industrial
MCL	maximum contaminant level
MF	microfiltration
mg/L	milligrams per liter
MQW	Marginal Quality Water
MS4s	municipal separate storm sewer systems
NGWA	National Groundwater Association
NPDES	National Pollutant Discharge Elimination System
OCWP	Oklahoma Comprehensive Water Plan
ODEQ	Oklahoma Department of Environmental Quality
OPDES	Oklahoma Pollutant Discharge Elimination System
OWRB	Oklahoma Water Resources Board
PPCPs	pharmaceuticals and personal care products
ppm	parts per million
PPWS	public and private water supply
RO	reverse osmosis
SB	Senate Bill
SOC	synthetic organic carbons
TDS	total dissolved solids
TM	technical memorandum
TOC	total organic carbon

TSS	total suspended solids
UF	ultrafiltration
USGS	U.S. Geological Survey
UV	ultraviolet
VOC	volatile organic compound
WTP	water treatment plant
WWTP	wastewater treatment plant

Section 1
Introduction

The Oklahoma Water Resources Board (OWRB) is developing a major update to the Oklahoma Comprehensive Water Plan (OCWP). The Oklahoma Legislature passed Senate Bill (SB) 1627 in 2008 requiring OWRB to establish a technical work group to analyze the potential for expanded use of "Marginal Quality Water" (MQW) from various sources throughout Oklahoma. SB1627 states that MQWs "include brackish or saline contaminated waters, which result from natural or man-made contamination that may be used or reused for many industrial purposes." The full text of the bill is available in Appendix A.

Through technical work group input, MQW has been further defined for this analysis to include all waters that may be of lower quality and have historically not been widely used for supplying Oklahoma's water needs. This can include constraints on the use of various MQW sources because of technological and/or economical issues with treating the water, or social perception issues faced when considering its use. It can include waters that would not typically be considered for beneficial uses, such as municipal, industrial, or agricultural supplies. As the OWRB examines future supplies of water, MQW supplies are being characterized to identify potential uses to benefit Oklahoma's citizens, economy, and environment.

1.1 Marginal Quality Water Technical Work Group

SB1627 directed OWRB to establish a technical work group for purposes of analyzing MQW in Oklahoma. SB1627 required that the group consist of representatives from the Department of Environmental Quality (DEQ); the Oklahoma Department of Agriculture, Food, and Forestry; the Oklahoma Conservation Commission; the Department of Mines; the Corporation Commission (Corp Comm); the Oklahoma Energy Board; the Commission on Marginally Producing Oil and Gas Wells; and any other state entity that OWRB deemed appropriate. The Bill also required that the executive director of the OWRB designate a chair and that a vice-chair be appointed. Kyle Arthur of OWRB was designated as the chair of the work group and Kelly Hurt with the Chickasaw Nation, at the time of his appointment, was designated as the vice-chair.

Appendix B contains a detailed summary of the six MQW group meetings. The initial meeting of the MQW Technical Work Group took place in December 2008 and included representatives from the above mentioned agencies and other stakeholders. Complete lists of the stakeholders present at each meeting are included in the meeting summaries in Appendix B. The group collaborated on outlining potential sources and uses of MQW and developed a flow chart for the analysis of MQW in Oklahoma (Figure 1-1) and eventual integration of the analysis into the OCWP.

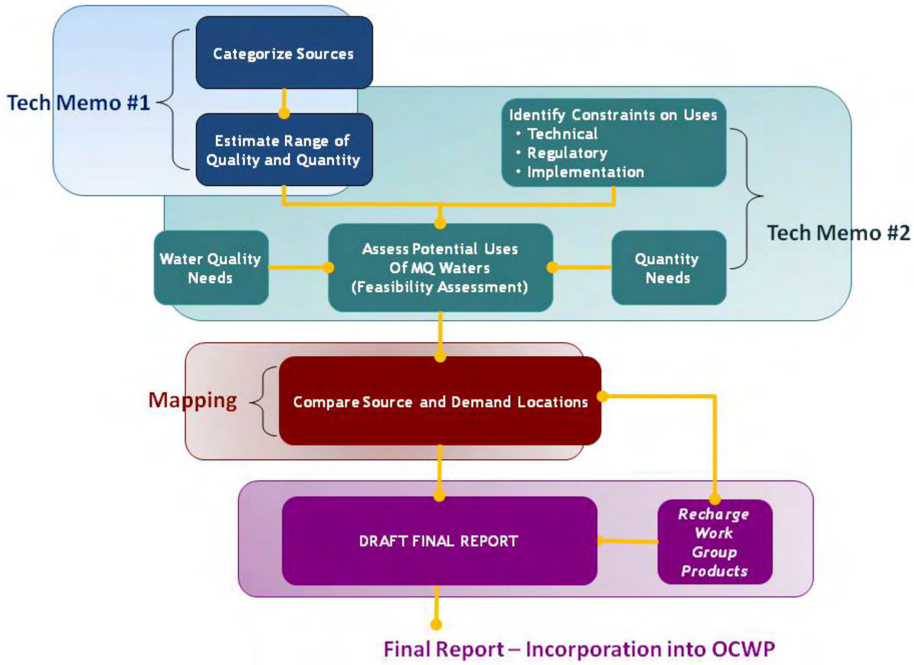


Figure 1-1
Analysis Plan for Marginal Quality Water Technical Work Group

The second meeting of the MQW Technical Work Group took place in February 2009, when work group participants further discussed potential sources and constraints on using MQW. The meeting included a presentation (see meeting summary and presentation in Appendix B) and discussion of MQW sources, and it was stressed that the goal of the OCWP and this technical work group was to identify reliable sources of water for Oklahoma. The third meeting of the MQW Technical Work Group took place in December 2009. The draft technical memorandum (TM1), which characterized sources of MQW and estimated ranges of quality and quantity, was presented and discussed.

The second draft technical memorandum (TM2) was presented at a fourth work group meeting in March 2010. TM2 expanded on the analysis completed for TM1 to identify the constraints on using MQW and assessed the possible treatment options available to overcome the identified constraints to increasing the beneficial use of MQW.

A series of maps were subsequently developed to compare locations of MQW sources to locations of water sector demands. A fifth work group meeting took place in April 2010 to present the graphical overlay of source and demand locations and further discuss the areas with the highest potential for matches between MQW supply and demands in each of the seven OCWP water use sectors.

A final meeting is planned for June 2010. Throughout the work group process, participants have been encouraged to provide feedback and submit comments. Appendix C contains a summary that catalogs, and provides responses to, work group members' comments received throughout the course of this effort.

1.2 MQW Sources and Uses

For purposes of the SB1627 analyses, the following MQW source categories were defined by the work group participants:

- Treated wastewater effluent
- Stormwater runoff
- Oil and gas flowback and produced water
- Brackish surface and groundwater
- Water with elevated levels of other key constituents

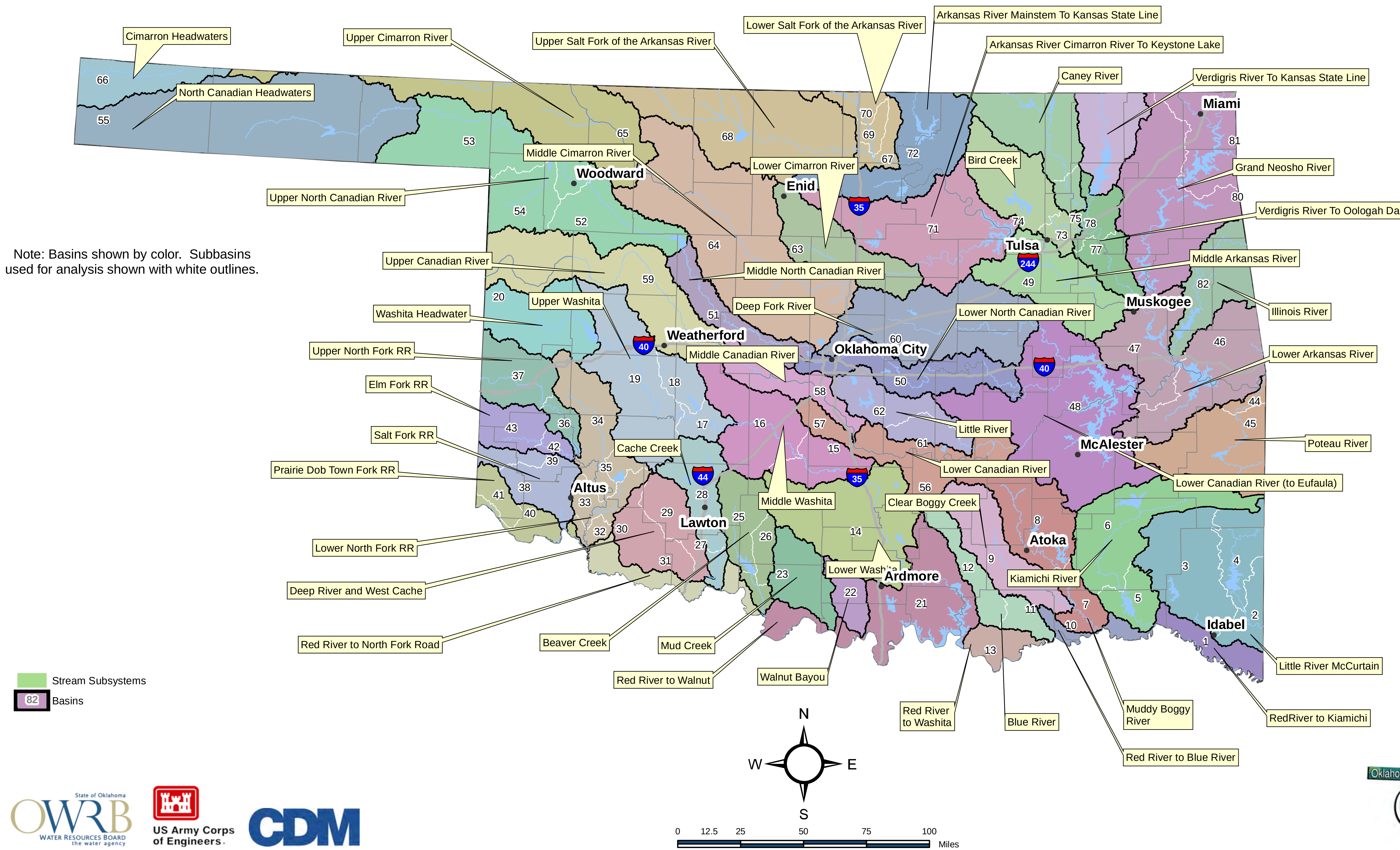
Sources of MQW that could be used to meet a portion of the water needs of specific water use sectors were identified through a process that first identified and characterized potential supplies and uses of MQW, then examined the constraints of use for each of the above MQW categories on a qualitative, non-geographic basis. The water quantity and quality needs of each OWCP water use sector were also considered. This information was synthesized into a qualitative assessment of potential uses of MQW, by source category, to meet the demands of the various water use sectors. A final screening was performed by mapping the MQW source locations with areas of high water demand (by sector) to identify geographic areas that may have a broader opportunity to further investigate MQW supplies to meet some water demands.

1.3 OCWP Planning and Analysis Basins

Water demands and supplies, including MQW supplies, can be evaluated using a myriad of different boundaries and geographic extents. For example, one could analyze the sum total of all demands and supplies for the entire state, without further subdivision. That level of analysis would not allow an investigation of localized supply and demand issues. In contrast, the analyses could be performed at such a micro-level (e.g., a single residence) as to not provide practical results. Thus, balancing the spatial extent, or resolution, of the analyses was considered in developing the approach for the OCWP technical analyses.

To allow direct use of OCWP supply and demand data, as well as integration of MQW analyses into the overall OCWP, the MQW analysis used the same set of basins as other ongoing OCWP technical studies. The statewide water supply availability analysis was performed on a geographic basis by subdividing the state into 82 surface water basins using existing OWRB stream system analysis boundaries and United States Geologic Survey (USGS) Hydrologic Units 12 (HUC12) boundaries. OWRB stream system boundaries were revised to include a USGS streamgage at or near the basin outlet (downstream end), where practical. Each of the 82 basins has been assigned a name, a unique five digit basin identification (basin ID), and a unique two-digit numerical identification for graphical representation (basin number). Figure 1-2 shows the basins used in the supply availability analysis, including basin names and numbers.

Figure 1-2 - Oklahoma Comprehensive Water Plan Basins



State of Oklahoma OWRB Water Resources Board the water agency

US Army Corps of Engineers

CDM

Oklahoma Comprehensive Water Plan OCWP

1.4 Report Organization

The purpose of this document is to compile the work completed through the work group process to satisfy the requirements of SB1627. The remaining sections of this report include:

- **Section 2 Quality and Quantity of Marginal Quality Water Sources** identifies and categorizes MQW sources with regard to quality and available quantity.
- **Section 3 Constraints on Use of Marginal Quality Water** presents a matrix of identified constraints on the uses of MQW by source category
- **Section 4 Water Quantity and Quality Needs by Water Use Sector** discusses the quality and quantity needs of each water use sector identified in the OCWP
- **Section 5 Potential Uses by of Marginal Quality Water** matches MQW categories to water use sectors with consideration to identified constraints
- **Section 6 Potential Treatment Solutions** describes treatment processes available for MQW and provides relative costing information
- **Section 7 Conclusions and Recommendations**
- **Section 8 References**

Section 2
Quantity and Quality of Marginal Quality Water Sources

The MQW technical work group identified treated wastewater, stormwater runoff, oil and gas flowback/produced water, brackish water, and water with elevated levels of other key constituents as potential MQW sources. The following presents estimates on the available quantities and a summary of typical water quality for each of the identified MQW categories.

2.1 Source Categories

The work group defined MQW sources as follows:

- **Treated wastewater effluent:** Treated wastewater effluent is wastewater that has gone through primary, secondary, and/or tertiary treatment processes to meet regulated discharge limits for a variety of water quality parameters. For purposes of this document, municipal discharges to surface waters were considered for analysis.

- **Stormwater runoff:** Impervious surfaces like driveways, sidewalks, and streets prevent stormwater runoff from naturally entering the hydrologic cycle. Stormwater oftentimes convey debris, chemicals, sediment, and other pollutants to storm sewer systems or directly into a receiving waterbody. Stormwater may or may not be treated through best management practices (BMPs) prior to entering waterbodies.

- **Oil and gas flowback and produced water:** Flowback water is the water that returns to the surface during initial oil and gas well completion activities, while produced water is a byproduct of well production.

- **Brackish surface and groundwater:** Surface and groundwater sources that have higher salinity than freshwater, but less than seawater, are considered brackish. Through the work group process, it was determined that waters with total dissolved solids (TDS) concentrations between 1,000 milligrams per liter (mg/L) and less than 35,000 mg/L (the point at which water is deemed “brine”) would be considered brackish for these efforts.

- **Water with elevated levels of key constituents:** Sources of water that have concentrations of key constituents that would require advanced treatment before beneficial use, such as nitrate reduction/removal prior to public water supply (potable) use.

2.1.1 Treated Wastewater

Consistent with direction from the MQW technical work group, treated effluent discharges from public wastewater treatment facilities were considered the primary source for this category of MQW. A significant portion of water withdrawn for public water supply is not consumed and is ultimately returned to a stream as treated wastewater effluent, referred to here as "return flows." Return flows can be captured and reused through a variety of approaches, referred to here as "reuse." Because effluent from municipal treatment facilities are the focus of this effort, only return flows from the Municipal and Industrial (M&I) demand sector were considered.

Across the United States, the most common applications of reuse water for public water providers are non-potable irrigation (e.g., lawn watering, golf course irrigation, pasture/agriculture) and industrial applications (U.S. Environmental Protection Agency [EPA] 2004). Reuse of municipal return flows must consider both the quantity (magnitude and timing) and water quality of supplies relative to the needs of the end users of the reuse water.

As part of the ongoing OCWP technical work, a Microsoft *Access* and geographical information system (GIS) based analysis tool was created to compare projected demands with physical supplies for each of the 82 OCWP basins. The "Oklahoma H_2O Tool" was used in the planning process to identify areas of potential "wet water" shortages (physical supply availability constraints), to more closely examine demands and supplies, and to evaluate potential water supply solutions. Adequately characterizing the physical water supply availability required an analysis of the available water resources, the current and future demands that will be placed on those supplies, and the quantity of return flows associated with water use for each demand sector. The Oklahoma H_2O Tool was therefore developed to include a simulation of return flows from surface water and groundwater use in each demand sector. Return flows are quantified in the tool based on a percentage of the demand, which varies by sector and by basin.

To calculate the quantity of treated wastewater generated from M&I uses, the return flow percentage was applied to the minimum monthly M&I demand in each basin (i.e., accounting for indoor use only since outdoor uses are primarily consumptive in nature). The return flow percentages for M&I demands were estimated based on the type of wastewater treatment facilities prevalent in each basin (e.g., surface water discharge, lagoon, land application, or septic system). For this analysis, only surface water discharges were considered and it was estimated that surface water discharge facilities generate surface water return flows equal to 95 percent of the lowest month's demand. Other types of treatment systems, such as septic systems or lagoon facilities, are not as conducive to capturing and beneficially revising their treated effluent.

Because information on the size of each individual treatment facility was not directly available, return flows from basins with multiple treatment facilities were estimated based on the number of facilities for each discharge type. The resulting return flow percentage is used in the Oklahoma H_2O Tool to calculate M&I return flow volumes by basin. Estimates of the potential annual M&I return flows to surface waters from surface water treatment facilities are presented in Table 2-1 and shaded by basin in Figure 2-1. Existing reuse of municipal return flows is very limited in Oklahoma, based on results of the 2008 OCWP Water Provider survey and dialogue with the Oklahoma DEQ, and was therefore not accounted for in this analysis.

Table 2-1 Estimated Return Flows from M&I Surface Water Discharges by Basin

Basin Number	Basin ID	Basin Name	Return Flow Generated (AFY) [1, 2]		
			2007	2030	2060
1	10100	Red River Mainstem (To Kiamichi River)	924	1,025	1,115
2	10201	Little River (McCurtain County) - 1	588	652	709
3	10202	Little River (McCurtain County) - 2	1,018	1,142	1,267
4	10203	Little River (McCurtain County) - 3	173	193	212
5	10301	Kiamichi River - 1	921	1,054	1,209
6	10302	Kiamichi River - 2	1,572	1,909	2,409
7	10411	Muddy Boggy River - 1	492	575	678
8	10412	Muddy Boggy River - 2	2,697	3,316	4,208
9	10420	Clear Boggy Creek	2,178	2,582	3,103
10	10500	Red River Mainstem (To Blue River)	313	346	373
11	10601	Blue River - 1	313	392	495
12	10602	Blue River - 2	2,217	2,726	3,395
13	10700	Red River Mainstem (To Washita)	2,935	3,666	4,635
14	10810	Lower Washita	5,372	6,004	6,802
15	10821	Middle Washita - 1	1,784	2,114	2,536
16	10822	Middle Washita - 2	2,917	3,331	3,766
17	10831	Upper Washita - 1	742	819	891
18	10832	Upper Washita - 2	0	0	0
19	10833	Upper Washita - 3	2,140	2,370	2,570
20	10840	Washita Headwaters	493	523	551
21	10900	Red River Mainstem (To Walnut Bayou)	4,421	7,831	10,221
22	11000	Walnut Bayou	2,120	2,847	3,319
23	11100	Mud Creek	705	910	1,001
24	11201	Beaver Creek - 1	71	75	80
25	11202	Beaver Creek - 2	165	179	189
26	11203	Beaver Creek - 3	1,860	1,947	2,042
27	11311	Cache Creek - 1	0	0	0
28	11312	Cache Creek - 2	4,594	5,628	6,124
29	11321	Deep Red River And West Cache Creek - 1	748	911	990
30	11322	Deep Red River And West Cache Creek - 2	217	233	250
31	11400	Red River Mainstem (To North Fork of Red)	405	432	462
32	11511	Lower North Fork Red River - 1	0	0	0
33	11512	Lower North Fork Red River - 2	1,275	1,441	1,567
34	11513	Lower North Fork Red River - 3	710	835	1,008
35	11514	Lower North Fork Red River - 4	0	0	0
36	11521	Upper North Fork Red River - 1	160	176	200
37	11522	Upper North Fork Red River - 2	453	546	678
38	11601	Salt Fork Red River - 1	942	1,052	1,140
39	11602	Salt Fork Red River - 2	0	0	0
40	11701	Prairie Dog Town Fork Red River - 1	0	0	0
41	11702	Prairie Dog Town Fork Red River - 2	460	490	533
42	11801	Elm Fork Red River - 1	444	453	476
43	11802	Elm Fork Red River - 2	0	0	0
44	20101	Poteau River - 1	1,245	1,452	1,723
45	20102	Poteau River - 2	5,634	6,523	7,733
46	20201	Lower Arkansas River - 1	7,244	9,037	11,406
47	20202	Lower Arkansas River - 1	5,872	6,736	7,762

Table 2-1 Estimated Return Flows from M&I Surface Water Discharges by Basin

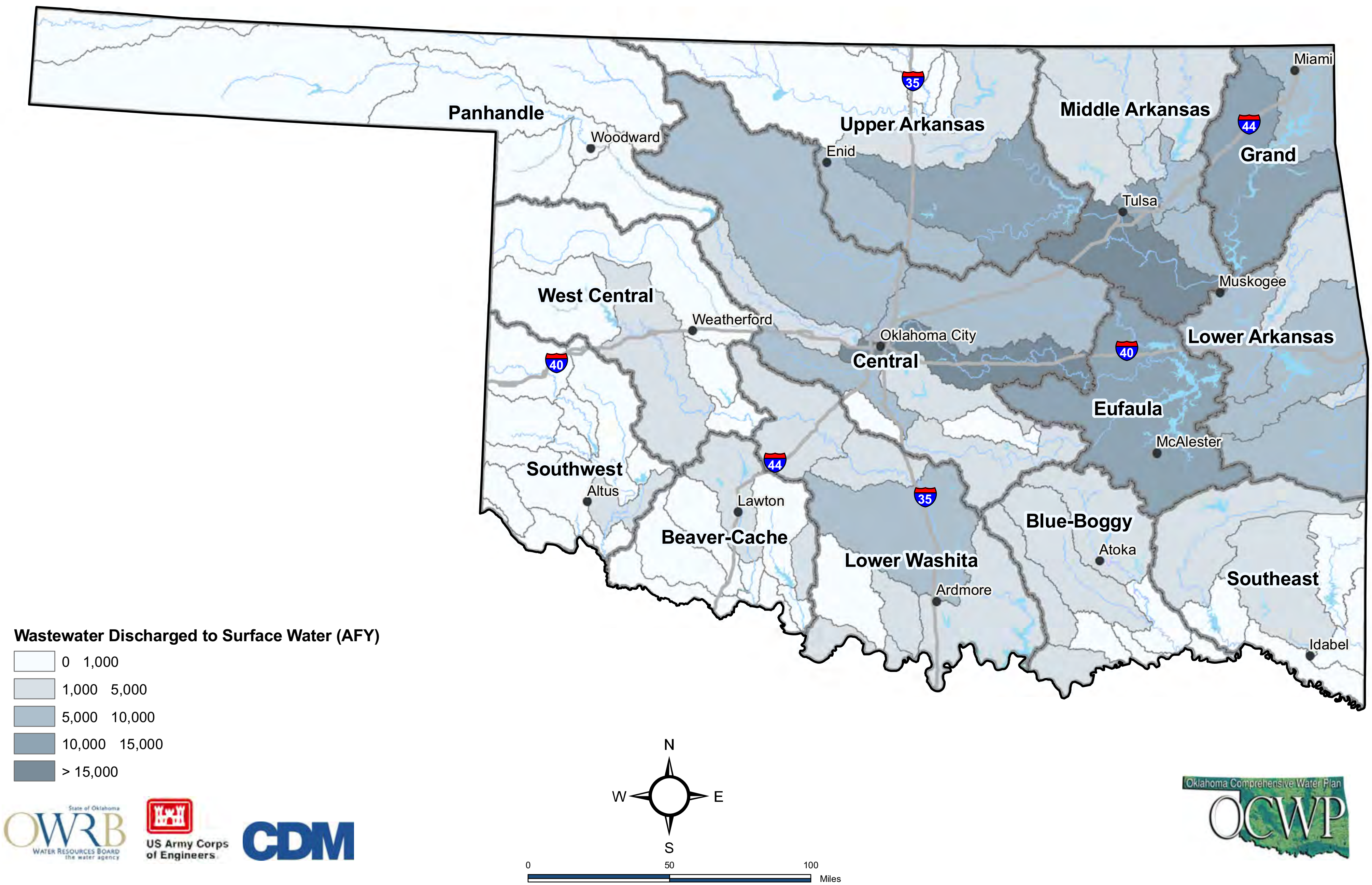
Basin Number	Basin ID	Basin Name	Return Flow Generated (AFY) [1, 2]		
			2007	2030	2060
48	20300	Canadian River (To North Canadian River)	13,585	15,556	18,373
49	20400	Middle Arkansas River	33,140	37,720	41,007
50	20510	Lower North Canadian River	21,815	24,848	26,861
51	20520	Middle North Canadian River	2,152	2,567	2,964
52	20531	Upper North Canadian River - 1	73	79	83
53	20532	Upper North Canadian River - 2	779	850	901
54	20533	Upper North Canadian River - 3	0	0	0
55	20540	North Canadian Headwaters	127	187	268
56	20611	Lower Canadian River - 1	1,710	1,985	2,245
57	20612	Lower Canadian River - 2	294	390	520
58	20620	Middle Canadian River	5,644	6,727	7,658
59	20630	Upper Canadian River	588	639	692
60	20700	Deep Fork River	6,707	7,638	8,259
61	20801	Little River - 1	591	683	789
62	20802	Little River - 2	1,722	2,009	2,208
63	20910	Lower Cimarron River	6,943	7,968	9,040
64	20920	Middle Cimarron River	9,988	11,517	12,890
65	20930	Upper Cimarron River	619	647	676
66	20940	Cimarron Headwaters	0	0	0
67	21011	Lower Salt Fork of the Arkansas River - 2	735	806	863
68	21020	Upper Salt Fork of the Arkansas River	658	688	722
69	21012	Lower Salt Fork of the Arkansas River - 2	265	290	311
70	21013	Lower Salt Fork of the Arkansas River - 3	0	0	0
71	21100	Arkansas River - Cimarron Rivers to Keystone Lake	11,867	14,029	16,184
72	21200	Arkansas River Mainstem (To Kansas State Line)	3,856	4,285	4,666
73	21301	Bird Creek - 1	11,050	12,568	13,542
74	21302	Bird Creek - 2	2,972	3,388	3,706
75	21401	Caney River - 1	1,591	1,822	1,991
76	21402	Caney River - 2	2,582	2,761	2,899
77	21511	Verdigris River (To Oologah Dam) - 1	5,776	7,123	8,586
78	21512	Verdigris River (To Oologah Dam) - 2	5,108	6,286	7,608
79	21520	Verdigris River (To Kansas State Line)	3,252	4,138	5,298
80	21601	Grand (Neosho) River - 1	10,571	13,284	17,062
81	21602	Grand (Neosho) River - 2	7,534	9,306	11,745
82	21700	Illinois River	3,449	4,561	6,112

Notes:

[1] Percentage of treatment type was basin on the number of wastewater treatment facilities in a basin. The size of the treatment facility was not considered in this analysis.

[2] Return flows generated based on M&I Demands for the Oklahoma Comprehensive Water Plan Update - Water Supply and Availability Report (October 2009)

Figure 2-1 - Treated Wastewater Discharged to Surface Water by Basin (2007)



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ODEQ regulates the water quality of treated wastewater discharges through the Oklahoma Pollutant Discharge Elimination System (OPDES). Most municipal wastewater discharges are regulated by permit for pathogenic bacteria, biochemical oxygen demand (BOD), total suspended solids (TSS), and pH under Title 252: Chapter 606 of the Oklahoma Rules. Limits for other parameters may be included, and permit-specific limits are often developed, based on site-specific conditions associated with the discharge. Wasteload allocations may also be written into a permit for other parameters where deemed necessary to protect the beneficial uses of the receiving water.

Many states have developed guidelines or regulations for treatment and water quality for water reuse. To date, Oklahoma has not developed detailed reuse regulations or guidelines. Chapter 656 of the ODEQ regulations “Water Pollution Control Facility Construction Standards” contains limited reference to reuse. There are no national regulations for reuse, but EPA's 2004 Guidelines for Water Reuse (EPA 2004) provide generally-accepted guidance for treatment technologies, water quality requirements, and implementation for a range of reuse applications. Non-potable uses with minimal potential for human contact or ingestion generally require less treatment and lower water quality than those with higher potentials for contact or cross-connection with potable systems.

Depending on the specific intended use(s) of reuse water, additional treatment (above and beyond that required for discharge to a surface water) may or may not be required. For example, uses with a high potential for human contact (e.g., daytime irrigation of parks) may require filtration, a process not often employed at treatment facilities that only discharge to surface waters. Conversely, some treatment facilities are required to remove nutrients (nitrogen and phosphorus) for discharge to surface waters, but such advanced treatment may not be required for landscape irrigation reuse where nutrients are desirable for plant uptake and growth. Thus, assessing the potential "match" between sources of treated wastewater for reuse and suitable uses of that supply depends on conditions that are site-specific in nature.

2.1.2 Stormwater Runoff

Stormwater runoff occurs when precipitation from a weather event flows over natural and man-made surfaces. Impervious surfaces like driveways, sidewalks, and streets prevent stormwater runoff from naturally soaking into the ground. Stormwater can pick up debris, chemicals, sediment, and other pollutants and flow into a storm sewer system or directly to a waterbody. Stormwater is typically untreated prior to entering waterbodies, although stormwater "best management practices" (BMPs) are typically used in urbanized settings to reduce the water quality impacts of stormwater discharges on receiving waters.

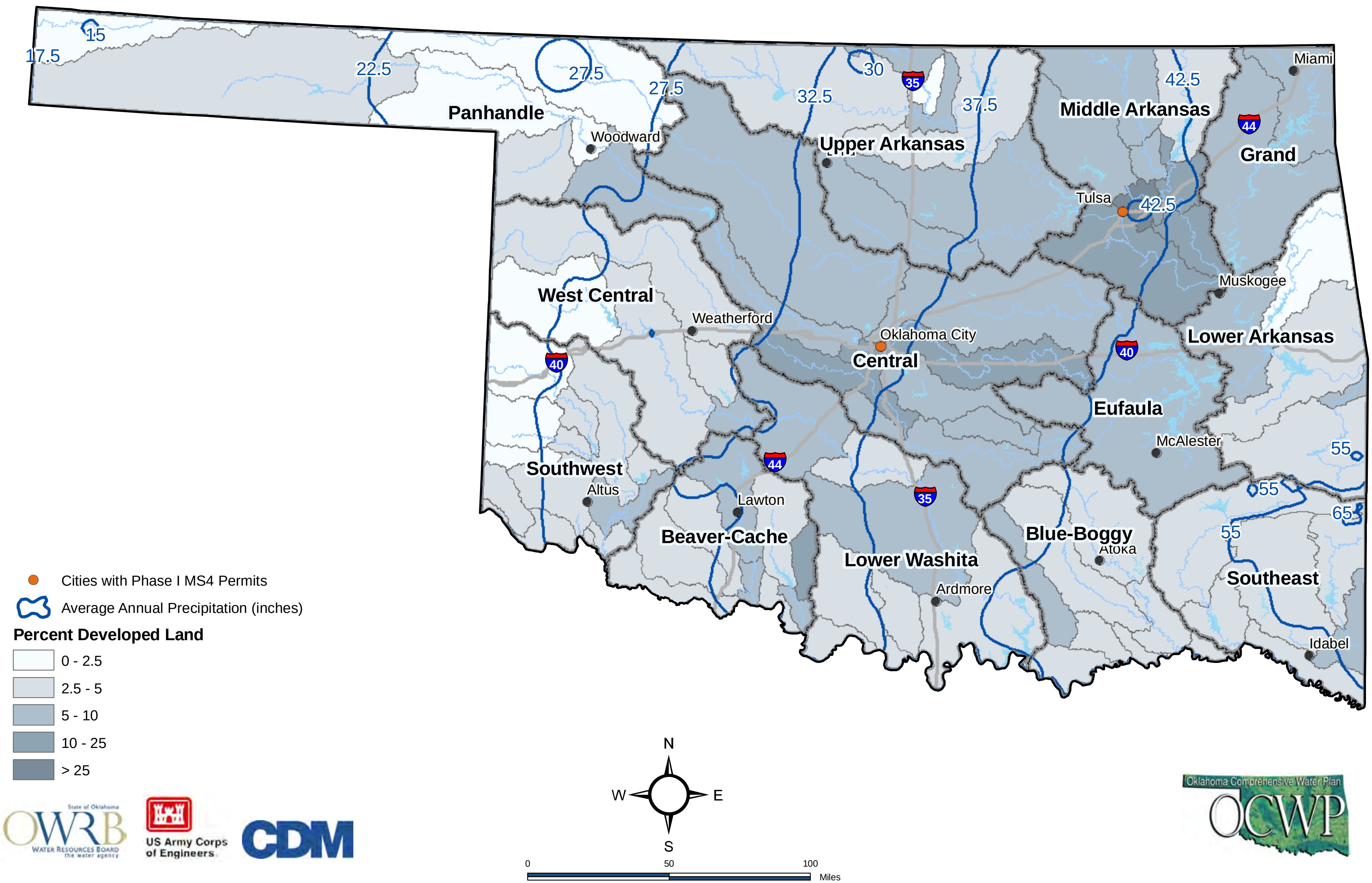
Precipitation has a greater potential to runoff into waterbodies in areas with greater amounts of impervious surface. Therefore, areas of greater development generally have higher rates of stormwater runoff. Additionally, the volume of runoff is driven by the amount of precipitation (rainfall and snow melt) that occurs on the area. Geospatial land use data representing land cover in 2001 were downloaded from National Land Cover Database and intersected with the OCWP basins in GIS. Figure 2-2 presents the average annual precipitation over the entire state (Oklahoma Climate Survey, 1961-1990) and the percent of each basin that is developed. This overview can be used to determine basins with greater potential for stormwater runoff. For example, the Tulsa area receives approximately 39 inches of precipitation per year and is developed. In contrast, the Woodward area receives 25 inches of precipitation each year and has much less developed land. It is likely that the Tulsa area would generate a greater volume of stormwater runoff in any given year.

Statewide estimates of stormwater runoff were not prepared for this analysis, given the site-specific nature of land development, stormwater collection and storage infrastructure, and hydrologic variability (temporal and spatial). However, to demonstrate the amount of runoff that might be anticipated in an urban area, the "rational" method was used to provide an estimate of potential stormwater quantity in the Oklahoma City area. Oklahoma City receives approximately 3 feet (36 inches) of precipitation per year on average, and is largely developed relative to many parts of the state. A study of three watersheds in Oklahoma City showed that runoff volumes equaled between 22 percent and 38 percent of precipitation in those areas (Williams 1980). For 100 acres of similar land in Oklahoma City, approximately 66 to 114 acre-feet of stormwater runoff would be generated (100 acres * 3 feet of precipitation * 0.38 = 114 acre-feet per year [AFY]).

Because the majority of stormwater runoff occurs during and directly after a storm event, collection systems and storage would be required to make full use of this water supply. In areas of greater urban development, stormwater runoff is commonly transported through municipal separate storm sewer systems (MS4s). Stormwater is collected in a storm sewer system and discharged untreated into local waterbodies.

Retention or detention storage is typically required to reduce the impact of peak stormwater flows on downstream waterbodies and associated flooding potential. This storage essentially "slows down" the transport of stormwater runoff to receiving waters, and is sized specifically for that purpose. Therefore, additional storage would likely be needed if a community were to store runoff and "firm up" that supply for beneficial use (e.g., irrigation), before it discharged to a receiving water. However, an MS4 would provide collection system infrastructure (inlets and pipelines) that would be a key component of capturing the stormwater for beneficial use.

Figure 2-2 - Annual Precipitation and Developed Areas



On a much smaller scale, some communities around the United States have promoted the use of rain barrels or cisterns to capture runoff from residential properties. These individual-sized systems can help conserve water supplies when used, for example, to irrigate landscaping onsite at the residence where the runoff was collected. Rain barrel programs could be used to offset a portion of water demands, but practically are limited in their ability to capture and use significant amounts of the total urban runoff.

Moreover, capture and use of stormwater runoff is controversial in many areas, whether on an individual homeowner scale or a broader community scale, because of potential water rights issues. In states like Oklahoma that use a prior appropriation system for surface water rights administration, issues can arise with the capture and use of water that would otherwise be discharged to waterbodies and subsequently diverted by downstream permit holders. An assessment of the legal implications of stormwater capture and use in Oklahoma may be warranted if this concept is to be further developed.

If implemented, nonpotable uses would likely be more appropriate than potable uses of stormwater runoff, in that treatment to potable standards would be very costly. Stormwater treatment facilities have been constructed in some coastal areas of California, either for water quality improvement (e.g., bacteria) before discharging to ocean beach areas, or less commonly for beneficial reuse. Factors driving the capture and treatment of stormwater in California may include a lack of water rights constraints (for ocean discharges), extreme water shortages relative to population growth and demand, and ocean/beach water quality issues associated with urban runoff. These factors may not directly apply to stormwater management in Oklahoma, so there may be less of a driver to implement similar systems in Oklahoma.

Water quality regulations for MS4 systems have developed over the past several decades. To prevent harmful pollutants from being washed or dumped into an MS4, owners of MS4 must obtain a stormwater discharge permit and develop a stormwater management plan. The MS4 regulatory program has two phases:

- Phase I requires medium and large cities or certain counties with populations of 100,000 or more to obtain permit coverage for their stormwater discharges. Tulsa and Oklahoma City are the only Phase I permitted cities in Oklahoma.

- Phase II requires regulated small MS4s in urbanized areas, as well as small MS4s outside the urbanized areas that are designated by the permitting authority, to obtain permit coverage for their stormwater discharges. There are 48 Phase II regulated communities in Oklahoma (Appendix D contains the full list of MS4 permitted entities).

The water quality of stormwater runoff is typically summarized by the predominant land use type. Concentrations of pollutants are commonly represented by an event mean concentration (EMC). An EMC is the average concentration of pollutant that is generated by a runoff event (rainfall or snow melt). In 2001, an EPA water grant was awarded to the University of Alabama to collect and evaluate stormwater data from a representative number of MS4 municipal stormwater permit holders. Data from 200 municipalities collected over 10 years were statistically analyzed to characterize stormwater quality from developed areas. Table 2-2 contains median values for a number of parameters. Site specific practices and local soil types will result in varied EMC values.

Table 2-2 Median of Detected Values in Urban Stormwater (Pitt et. al, 2003)

Land Use	Hardness (mg/L $CaCO_3$)	BOD_5 (mg/L)	TSS (mg/L)	TDS (mg/L)	$N0_2$+NO_3 (mg/L)	Ammonia (mg/L)	Total Phosphorus (mg/L)	pH
Commercial	36	12	48	74	0.62	0.6	0.23	7.1
Freeways	34	8	99	78	0.28	1.1	0.25	7.1
Industrial	37	9	90	84	0.75	0.5	0.27	7.2
Institutional	–	9	17	53	0.6	0.3	0.17	–
Mixed Residential	43	7	75	85	0.56	0.4	0.27	7.3
Residential	31	9	50	69	0.58	0.3	0.31	7.13
All Land Use Types	39	8	63	78	0.6	0.4	0.27	7.4

2.1.3 Oil and Gas Flowback and Produced Water

The oil and gas industry comprises a significant portion of Oklahoma's economy. While oil and gas activities require water for drilling, completion, and production operations (e.g. Corp Comm indicated that 93 billion gallons of water were produced and reinjected in Oklahoma during 2008), many completed wells generate produced water at rates that vary from well to well and area to area.

Another indicator of the potential supply for oil and gas flowback and produced water is the number of drilling activities projected for Oklahoma. As part of projecting future water demands (in separate OCWP water demand analyses), the number of drilling activities (well completions) in Oklahoma has been estimated or projected as follows:

- Conventional drilling activities: 2,459 (2008); 4,349 (2030); 5,892 (2060)
- Horizontal drilling activities: 274 (2008); 1,081 (2030); 2,090 (2060)
- Woodford Shale drilling activities: 706 (2008); 987 (2030); 10 (2060)

County-by-county estimates of drilling activities, and estimates in other decade intervals through 2060, are also available.

Table 2-3 shows expected water quality ranges for produced water in Oklahoma. The data for Table 2-3 were obtained from the USGS Produced Waters database (provisional release, May 2002). The database contains records from 8,200 water samples from oil and gas wells throughout Oklahoma, taken between 1921 and 1980. Samples with pH values less than 4 or greater than 9 were excluded from the database as these values would not be typical for produced/flowback water. Values provided in parts per million (ppm) were converted to mg/L assuming a density equal to that of water.

Table 2-3 Water Quality of Produced Water in Oklahoma (USGS Produced Waters database: provisional release, May 2002)

Parameter	Minimum (mg/L)	Median (mg/L)	Maximum (mg/L)
pH	5.0	6.4	8.9
Bicarbonates	—	80	12,000
Calcium	—	9,300	74,000
Chloride	11	100,000	240,000
Magnesium	—	1,900	11,000
Potassium	—	86	2,100
Sodium	13	51,000	130,000
Sulfate	—	210	14,000
TDS	1,100	160,000	390,000

Management or reuse of flowback water and produced water is often a function of the economics, quality, and quantity of available water supply and water quality. Flowback water is often, but not always, better water quality than produced water, but is also produced in significantly lower quantities than produced water. Deep-well injection of these potential MQW sources rather than reuse is commonplace, driven in part by the following factors:

- Ready availability of fresh water supplies (surface water or groundwater) for demands associated with drilling completion and production operations
- Water quality of produced water, often with TDS concentrations exceeding 100,000 mg/L, that would require significant treatment before surface discharge or beneficial reuse
- Mobile and temporary nature of drilling and completion operations and well production operations that would create challenges related to mobilization and use of storage and use treatment equipment
- Distances between sources of flowback and produced water (i.e., an operating well) and potential uses of flowback and produced water (e.g., drilling of new well or other beneficial uses)

A recent study of water supplies and reuse for Woodford Shale drilling in Southeast Oklahoma (Pittsburg, Hughes, Coal, and Atoka Counties) evaluated several strategies and options for disposal or reuse of produced water. This report, titled "Water Availability and Use in the Woodford Shale Play (Arkoma Basin)" (Environmental Resources Management Southwest, Inc., June 2009), assesses the following options:

- Disposal via underground injection
- Disposal via surface discharge
- Minimization (e.g., downhole gas/water separator)
- Reuse/recycle (e.g., use for a subsequent onsite frac, trucking to offsite storage and reuse facilities, onsite treatment for potable water or a subsequent frac)
- Treatment (often in conjunction with one of the above strategies)

The report concludes that "various reuse/recycling options can be considered, though some are not feasible for the study area." Several examples of reuse and treatment activities now underway in Southeast Oklahoma are cited in the report.

Quantifying the amount of flowback and produced water on a statewide basis is challenging, given that per-well production rates of flowback water and produced water vary significantly from one region of the state to another, and even from one well to another in the same vicinity. Moreover, the water quality variability from one area or well to another makes an assessment of the potential use of these supplies challenging.

Subsequent technical analyses could focus on specific areas of the state where per-well production rates are generally high, water quality has generally lower concentrations of key constituents and may be more amenable to treatment or reuse, and oil and gas operations are expected to continue to be significant.

2.1.4 Brackish Water

Brackish water is water with elevated salinity, but less salt than seawater. Brackish water is defined by the concentration of salts (primarily chloride or sodium) in the water or by the amount of TDS. According to Alley (2003), water with a TDS concentration greater than 1,000 mg/L is commonly considered saline. The National Groundwater Association (NGWA) (2005) considers brackish groundwater as water with a TDS concentration between 1,000 and 10,000 mg/L. Brine is usually considered very salty water with TDS greater than 35,000 mg/L. The U.S. Bureau of Reclamation (BOR) (2003) classifies saline waters by TDS concentration as:

Mildly brackish	1,000-5,000 mg/L
Moderately brackish	5,000-15,000 mg/L
Heavily brackish	15,000-35,000 mg/L
Seawater and brine	>35,000 mg/L

The sources of brackish water groundwater in Oklahoma are presented in this section. Brackish surface water is discussed in Section 2.1.5.

2.1.4.1 Brackish Groundwater

OWRB regulates permitted withdrawals of "fresh" groundwater, which is defined as groundwater with TDS concentrations less than 5,000 ppm. Groundwater with TDS concentrations less than 5,000 mg/L is characterized in groundwater basin studies and are accounted for in the allocation of water rights. Mildly brackish waters, with TDS concentrations of 1,000 to 5,000 mg/L, occur in several aquifers in the western portion of the state from contact with rock formations containing gypsum ($CaSO_4*2H_2O$) and halite (NaCl), and are currently used for some stock and irrigation purposes. For example, the Blaine aquifer in southwest Oklahoma has a median TDS concentration of approximately 3,500 mg/L and median sulfate concentration of approximately 2,000 mg/L. Local farmers rely on the aquifer for irrigation of cotton and other crops (Osborn and others, 1997).

Naturally occurring brackish groundwater underlies most of Oklahoma. The depth to brackish and saline waters varies across the state, from less than 500 feet to more than 1,000 feet. Hart (1966) mapped the base of fresh groundwater (TDS < 5,000 mg/L) in southern Oklahoma. Corp Comm, in cooperation with the oil and gas industry, has developed base of treatable water maps for the state, with treatable water defined as water with TDS concentrations greater than 10,000 mg/L (Figure 2-3). Little information exists on the extent (geographic area and volume) of moderately brackish groundwater in Oklahoma. The USGS is currently conducting a 3-year study (to be completed in 2012) to delineate and assess saline groundwater supplies (including brackish groundwater) in Oklahoma and surrounding states.

In addition since 1996, Corp Comm has collected groundwater samples near known and suspected oil and gas spill sites and/or in response to complaints from citizens in these areas. Samples are analyzed for a suite of parameters including TDS, chlorides, and sulfates. Corp Comm has begun to list significantly impacted groundwater pollution sites in Appendix H of OWRB Chapter 45 so that the public and water well drillers can be knowledgeable about conditions for well installation.

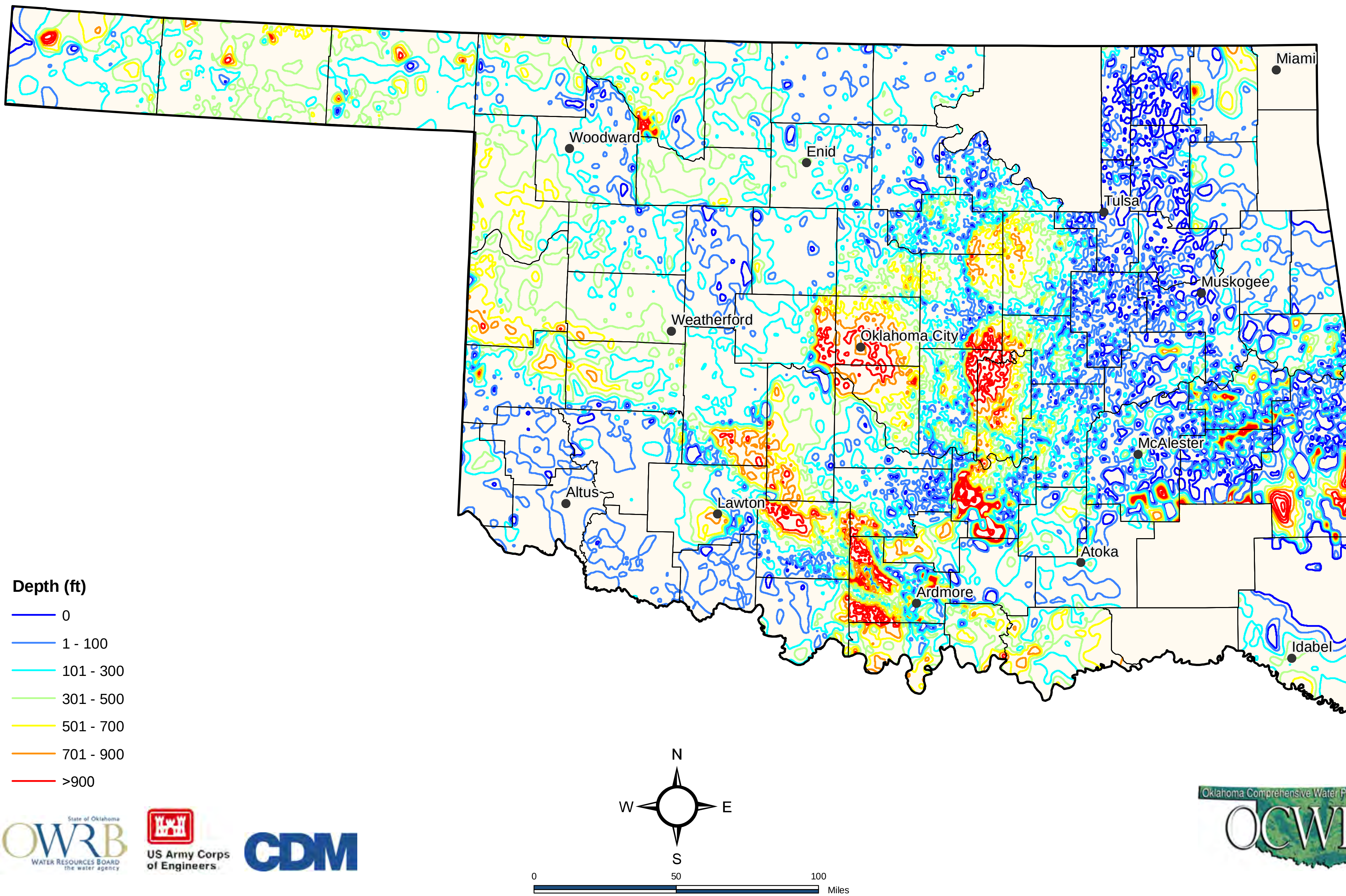
Based on the previous discussion of OWRB's regulatory authority, water use, and hydrogeologic factors, two categories of brackish groundwater were considered as sources of MQW:

- Mildly brackish groundwater with TDS concentrations of 1,000-5,000 mg/L, which is regulated by OWRB for permitted withdrawals but are limited in use; and
- Moderately brackish groundwater with TDS concentrations of 5,000-10,000 mg/L, which is not regulated by OWRB and is much more limited in use than mildly brackish groundwater.

There are a number of factors to evaluate when considering brackish groundwater for beneficial water use:

- Most moderately brackish groundwater supplies cannot be used sustainably. These formations contain water that was recharged tens of thousands to millions of years ago. They receive little or no recharge from surface source, such as infiltration from rainfall or percolation from streams. These waters could be used in times of water shortages, but may not be viable as a long-term sole source of supply.

Figure HπOʸ Depth to Base of Treatable Waterπ10,000 mg/L TDS



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- Freshwater portions of aquifers could be impacted negatively by removing large amounts of water from the brackish zone. Groundwater formations containing saline water may or in some instances be connected hydraulically to aquifers that contain freshwater. Thus, development of one resource affects the other, as well as potentially affecting the flow and quality of surface-water bodies connected to the groundwater system (Alley, 2003).

- Little is known about the hydrogeology of the parts of the formations that contain marginally brackish waters. Groundwater investigations in Oklahoma have been largely focused on characterizing "fresh" groundwater (TDS < 5,000 mg/L) regulated by OWRB. Additionally, there is little information about the factors required to understand the development potential of moderately brackish aquifers or to predict potential environmental impacts of withdrawing moderately brackish groundwater. These factors include hydraulic conductivity, transmissivity, storage coefficients, and the three-dimensional extent of the aquifer.

- OWRB does not have regulatory authority to permit withdrawals of groundwater with TDS concentrations greater than 5,000 mg/L. As such, OWRB cannot plan for or administer the use of marginally brackish water supplies, and it cannot protect against potential effects of moderately brackish groundwater withdrawals on freshwater aquifers.

2.1.5 Water with Elevated Levels of Key Constituents

Water quality data are compiled by OWRB and other agencies in statewide databases. Data from those sources were reviewed in a coordinated effort with the ongoing OCWP supply and demands analyses to perform a screening of available water supplies. The purpose of this analysis was to identify areas of water quality impairment that may restrict water supply development. The data and information generated during this evaluation is intended to serve as additional information in the development and evaluation of water supply alternatives in subsequent phases of the OCWP and has been incorporated into this MQW discussion.

2.1.5.1 Groundwater with Elevated Levels of Key Constituents

Water quality data are generally much more available on a statewide basis for surface water supplies. Groundwater quality data tend to be collected on a much more site-specific or project-specific basis, and as such, are not generally available in statewide databases. There is some discussion of statewide groundwater quality in the 2008 Oklahoma Integrated Report. There are twenty-one major groundwater basins in the state and approximately 150 minor basins (ODEQ 2008). Oklahoma has groundwater standards located in OAC 785:45-7. Statewide statistically summarized data from public drinking wells are available in chart form by the ODEQ Groundwater Monitoring section at *http://www.deq.state.ok.us/wqdnew/*. In addition, in 1990 OWRB produced a document entitled "Statistical Summary of Groundwater Quality Data: 1986-1988". This was the only document found to contain groundwater quality information summarized by aquifer. This document is available at h*ttp://www.owrb.ok.gov/studies/reports/reports_pdf/tr90_1_gwquality.pdf.*

2.1.5.2 Surface Water with Elevated Levels of Key Constituents

The state's surface water quality assessment program was reviewed for surface water quality impairment information. Surface water quality data collected in the last 10 years were statistically analyzed by basin. The results of these analyses are presented below.

Water quality standards are used to enhance water quality and protect public health and welfare. Water quality standards provide the foundation for accomplishing two of the principal goals of the Clean Water Act (Section 101):

- Restore and maintain the chemical, physical, and biological integrity of the nation's waters
- Where attainable, to achieve water quality that promotes protection and propagation of fish, shellfish, and wildlife, and provides for recreation in and on the water

Water quality standards consist of three elements:

- The designated beneficial use or uses of a waterbody or segment of a waterbody
- The water quality criteria (numeric or narrative) necessary to protect the designated use or uses of that particular waterbody
- An antidegradation policy

Oklahoma's water quality standards are found in Chapter 45 of the OWRB's Rules. Designated uses that were reviewed for this exercise include public and private water supply (PPWS) and agriculture. Waters designated for PPWS include a raw water intake and are used for drinking water. Waters designated for agricultural use must be suitable for livestock watering and crop irrigation.

Section 303(d) of the Clean Water Act requires states to assess water quality every 2 years. Water bodies that do not meet the state's water quality standards are put on the "303(d) list" of impaired waters. An initial water quality screening was performed to identify waters that are currently on the 2008 303(d) list for PPWS and agricultural use impairments (Figure 2-4). Waters not highlighted in Figure 2-4 are either unimpaired or were not assessed. The highlighted waters do not meet at least one water quality standard developed to protect the PPWS and/or agricultural use and may be less desirable to use as a water supply. Table 2-4 provides information on the number of waterbodies listed for impairment of PPWS and agricultural uses. Agricultural use impairment means that the waterbody exceeded one or more of the following criterion: TDS concentration of 700 mg/L; chloride concentration of 250 mg/L; and/or sulfate concentration of 250 mg/L.

Figure 2-4 - Waterbodies Impaired for Agriculture and/or Public Water Supply Uses Based on the 2008 303(d) List

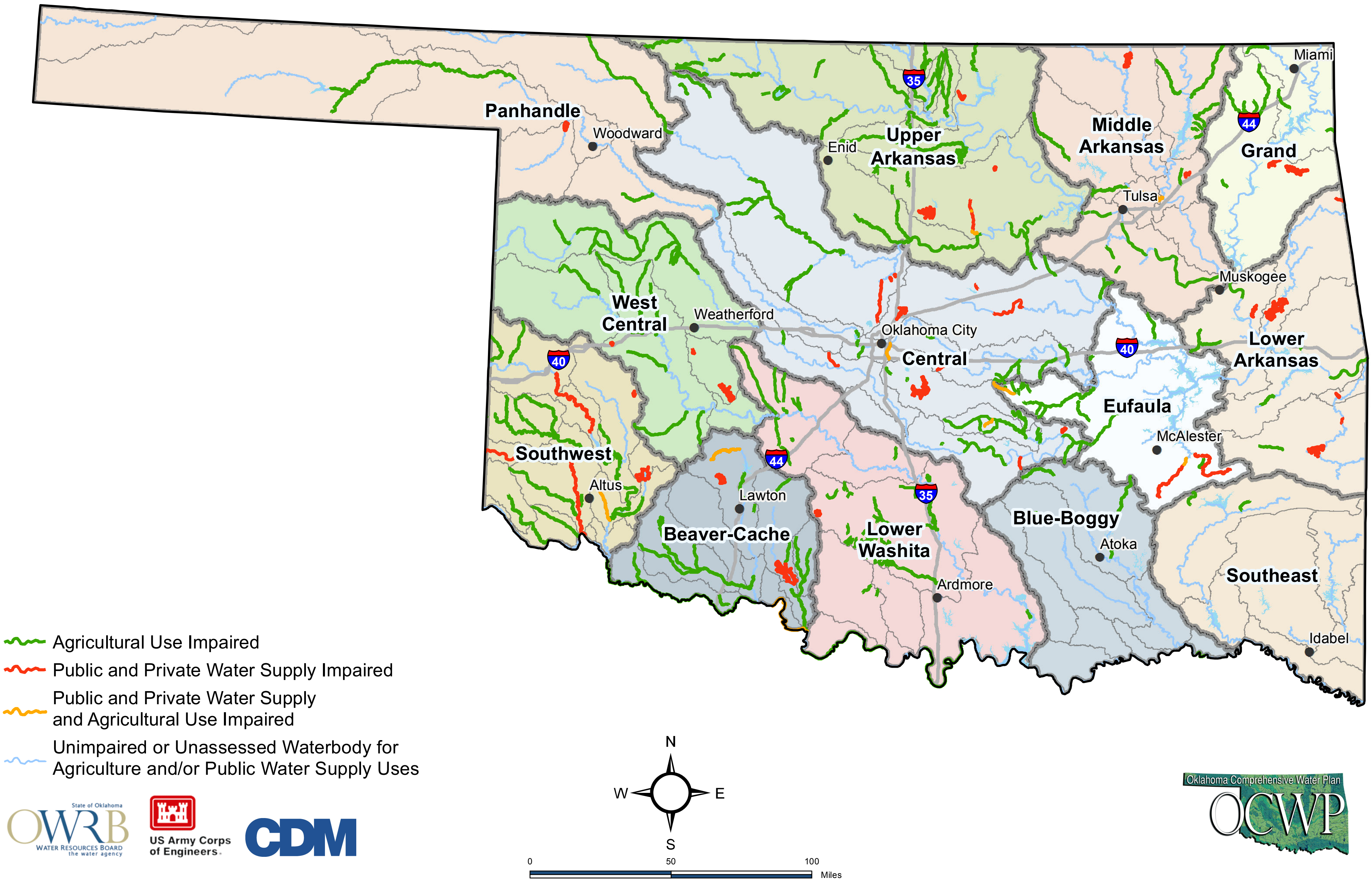

Table 2-4 Summary of 2008 Impaired Waters (PPWS and Ag) (ODEQ, 2008)

Waterbody Type	Use	Total Size	Size Fully Supporting	Size Not Supporting
Lakes and Reservoirs (acres)	Agriculture	637,326	464,606	15,955
	PPWS	593,714	165	66,222
Streams and Rivers (miles)	Agriculture	32,269	7,258	501
	PPWS	14,788	1,068	395

The most common cause of PPWS use impairment is chlorophyll-a, which is an indicator of high nutrients. Other causes of PPWS impairment include metals, total coliform, oil and grease, and nitrates. The entire 2008 303(d) list for Oklahoma is available at: http://www.deq.state.ok.us/WQDnew/305b_303d/2008_integrated_report_app_c_303d_list.pdf.

Many water quality parameters are considered while determining source suitability and treatment options from a user's standpoint. A list of basic water quality considerations in terms of water treatment for public water supply was developed for this evaluation, including: nitrates; TDS; total suspended solids (TSS); hardness; total organic carbon (TOC); nutrients; radionuclides; bacteria; heavy metals; organics; hydrocarbons; and chlorides; and sulfates. Although treatment can be used to address the majority of source water quality issues, high levels of these parameters may cause a public water supply provider to look elsewhere for a water source due to the capital and operating costs of such treatment.

Water quality parameters of interest for crop irrigation are most commonly associated with TDS and salinity. Because the tolerance of crops to salinity is a function of the type of crop, irrigation patterns, and soil conditions, it is difficult to set specific statewide water quality thresholds for crop irrigation use. However, generally speaking, waters meeting public water suppliers' needs will often meet crop irrigation water quality requirements. It is very uncommon for irrigators to treat water before using it for crop irrigation.

A number of these parameters have already been assessed through the 303(d) listing process (nutrients via chlorophyll-a and dissolved oxygen, heavy metals, and bacteria). Other parameters have very limited data (TOC, organics, hydrocarbons) and may be identified through basin-specific knowledge. Again, there are certainly more parameters that may cause concern, but for purposes of this analysis, the list has been refined to basic parameters that have broadly available data for assessment. These include:

- TDS
- TSS
- Nitrates
- Hardness

The refined list was then considered for "threshold concentrations," or levels at which a public water supply provider may avoid the water source or levels that may drive substantial capital and operating costs for water treatment. Table 2-5 contains the "threshold concentrations" used for this analysis.

Table 2-5: Threshold Concentrations for Parameters of Concern

Parameter	Threshold Concentration (mg/L)	Treatment Concern
TDS	1,000	Secondary drinking water standard for TDS is 500 mg/L and water is considered brackish at 1,000 mg/L. TDS reduction often requires advanced treatment technologies.
TSS	50	Increases solids handling at the treatment plant
Nitrates	10 (as nitrogen)	Maximum contaminant level (MCL) for potable water is 10 mg/L. High nitrate level may indicate influence from wastewater treatment discharges or agricultural activities. Reducing nitrate requires advanced treatment technologies.
Hardness	125	Aesthetics associated with increased soap consumption, spots on dishes, cars, windows

Surface water quality data for the identified parameters of concern collected since 1998 were provided by OWRB. Data were listed by sampling locations that were then grouped by basin for analysis. Not every sampling location had available data for each of the parameters of concern. It should be noted that a lack of data does not necessarily mean a lack of presence. Data were statistically analyzed for minimum, maximum, average, and median values by basin. Table 2-6 contains median values along with data counts (number of samples) for reference. Median values that exceed the threshold concentrations are indicated with bold red text. Figures 2-5 through 2-7 geographically show sampling locations where median surface water concentrations exceed the threshold values for TDS, TSS, and hardness, respectively (as defined in Table 2-5). There were no sampling locations where median concentrations of nitrates exceeded 10 mg/L. No apparent geographic trends were evident for nitrates and TSS while hardness and TDS were generally higher in the western basins of the state. Hardness and TDS in sampled waterbodies were also more likely to exceed the threshold concentrations.

Table 2-6: Median Surface Water Concentrations (mg/L) and Data Count by OCWP Basin

Basin	TDS		Hardness, Total (as $CaCO_3$)		TSS		Nitrogen, Nitrate as N	
	Median	Count	Median	Count	Median	Count	Median	Count
1	**596**	39	**285**	75	**58**	28	0.05	77
2	no data	0	no data	0	no data	0	no data	0
3	44	107	13	300	6	158	0.06	370
4	30	81	8	280	4	61	0.11	252
5	74	45	31	65	18	69	0.05	211
6	44	131	12	270	6	149	0.05	443
7	218	29	125	88	**62**	17	0.06	60
8	136	53	50	222	12	98	0.05	384
9	235	50	**208**	151	46	33	0.05	110
10	**662**	57	**280**	125	36	37	0.06	109

Table 2-6: Median Surface Water Concentrations (mg/L) and Data Count by OCWP Basin

Basin	TDS		Hardness, Total (as $CaCO_3$)		TSS		Nitrogen, Nitrate as N	
	Median	Count	Median	Count	Median	Count	Median	Count
11	232	41	**229**	75	30	34	0.09	71
12	187	4	no data	0	8	4	0.05	4
13	no data	0	no data	0	no data	0	no data	0
14	**798**	136	**290**	276	12	109	0.05	785
15	456	1	**364**	10	no data	0	0.07	34
16	**1354**	35	**940**	103	12	22	0.05	134
17	**1190**	39	**862**	120	**123**	18	0.05	100
18	no data	0	**211**	11	9	91	0.08	209
19	**1520**	202	**1180**	247	32	186	0.09	443
20	**1804**	198	**1080**	164	25	160	0.10	288
21	**910**	118	**463**	204	44	100	0.05	360
22	392	9	83	7	27	10	0.05	56
23	484	44	**223**	77	47	34	0.05	129
24	no data	0	no data	0	no data	0	no data	0
25	356	19	no data	0	12	23	0.06	68
26	442	19	**324**	21	**78**	21	0.48	40
27	401	54	**196**	146	**77**	23	2.02	106
28	52	13	**150**	64	8	96	0.05	290
29	499	47	**233**	82	**64**	21	0.19	56
30	no data	0	**128**	16	no data	0	0.07	49
31	**4250**	105	**1234**	178	**146**	49	0.14	145
32	no data	0	no data	0	no data	0	no data	0
33	no data	0	no data	0	no data	0	no data	0
34	**2810**	261	**895**	311	29	99	0.05	261
35	444	12	**246**	22	12	23	0.05	63
36	**1695**	66	**890**	87	16	43	0.07	127
37	**1575**	84	**766**	86	**59**	2	0.40	2
38	**2895**	88	**1545**	166	**63**	26	0.57	95
39	no data	0	no data	0	no data	0	no data	0
40	**6183**	43	**2416**	82	**70**	23	2.29	62
41	no data	0	no data	0	no data	0	no data	0
42	11	392	**1660**	369	25	35	0.18	119
43	**21600**	73	**2990**	67	**216**	1	0.05	1
44	102	20	48	89	45	27	0.07	107
45	71	76	43	211	16	85	0.08	354
46	243	49	68	180	12	95	0.11	351
47	300	62	**150**	191	26	39	0.15	269
48	269	163	99	341	17	254	0.08	864
49	**548**	162	**216**	333	17	142	0.14	490
50	**551**	88	**217**	418	15	205	0.07	721
51	**852**	55	**428**	147	25	40	0.05	183
52	**1030**	37	**455**	92	**54**	24	0.05	118
53	**912**	169	**504**	325	20	96	0.05	233

Table 2-6: Median Surface Water Concentrations (mg/L) and Data Count by OCWP Basin

Basin	TDS		Hardness, Total (as $CaCO_3$)		TSS		Nitrogen, Nitrate as N	
	Median	Count	Median	Count	Median	Count	Median	Count
54	**583**	51	**301**	82	34	66	0.21	149
55	307	62	**280**	155	26	31	0.05	114
56	**647**	149	**295**	302	**74**	84	0.05	303
57	357	1	**329**	1	**60**	1	0.05	37
58	**756**	63	**406**	139	16	46	0.32	138
59	**1215**	126	**616**	220	8	119	0.05	325
60	310	147	**204**	234	19	154	0.05	577
61	**2227**	24	no data	0	**86**	1	0.07	1
62	171	18	**177**	30	10	506	0.05	612
63	**999**	53	**464**	209	**101**	28	0.20	177
64	**4838**	127	**815**	405	20	143	0.09	513
65	**2600**	100	**504**	229	40	48	0.06	166
66	**1610**	1	**559**	1	**50**	1	0.05	33
67	**1349**	36	**444**	140	**101**	24	0.05	91
69	484	55	**310**	81	41	47	0.78	86
70	**2620**	3	**1568**	3	29	3	0.13	3
68	**1560**	33	**870**	171	**81**	43	0.20	225
71	**524**	172	**211**	433	26	310	0.14	970
72	**561**	59	**219**	87	12	117	0.07	341
73	169	50	125	142	18	41	0.69	115
74	128	47	94	87	10	192	0.07	457
75	210	45	**146**	76	**62**	37	0.24	75
76	206	30	**194**	3	20	85	0.06	203
77	194	18	**140**	98	22	14	0.40	83
78	197	49	**141**	148	31	28	0.10	162
79	184	61	**142**	101	16	53	0.16	154
80	160	169	123	574	7	198	0.23	717
81	214	101	**156**	384	13	102	0.90	428
82	142	157	110	543	3	170	1.61	580

Figure 2-5 - Surface Water Sampling Locations with TDS Concentrations Greater than or Equal to 1,000 mg/L

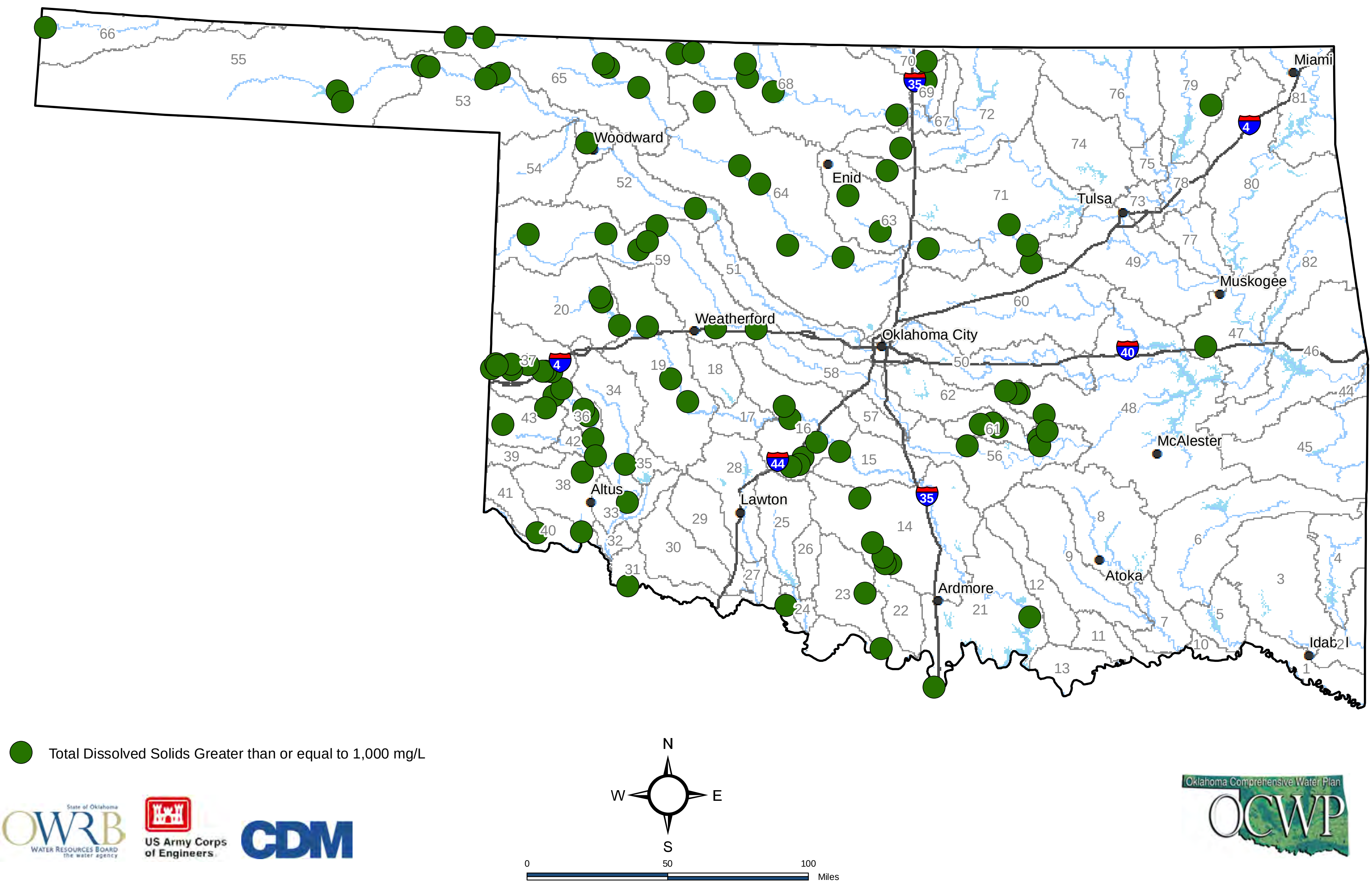

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Figure 2-6 - Surface Water Sampling Locations with Total Suspended Solids Concentrations Greater than or Equal to 50 mg/L

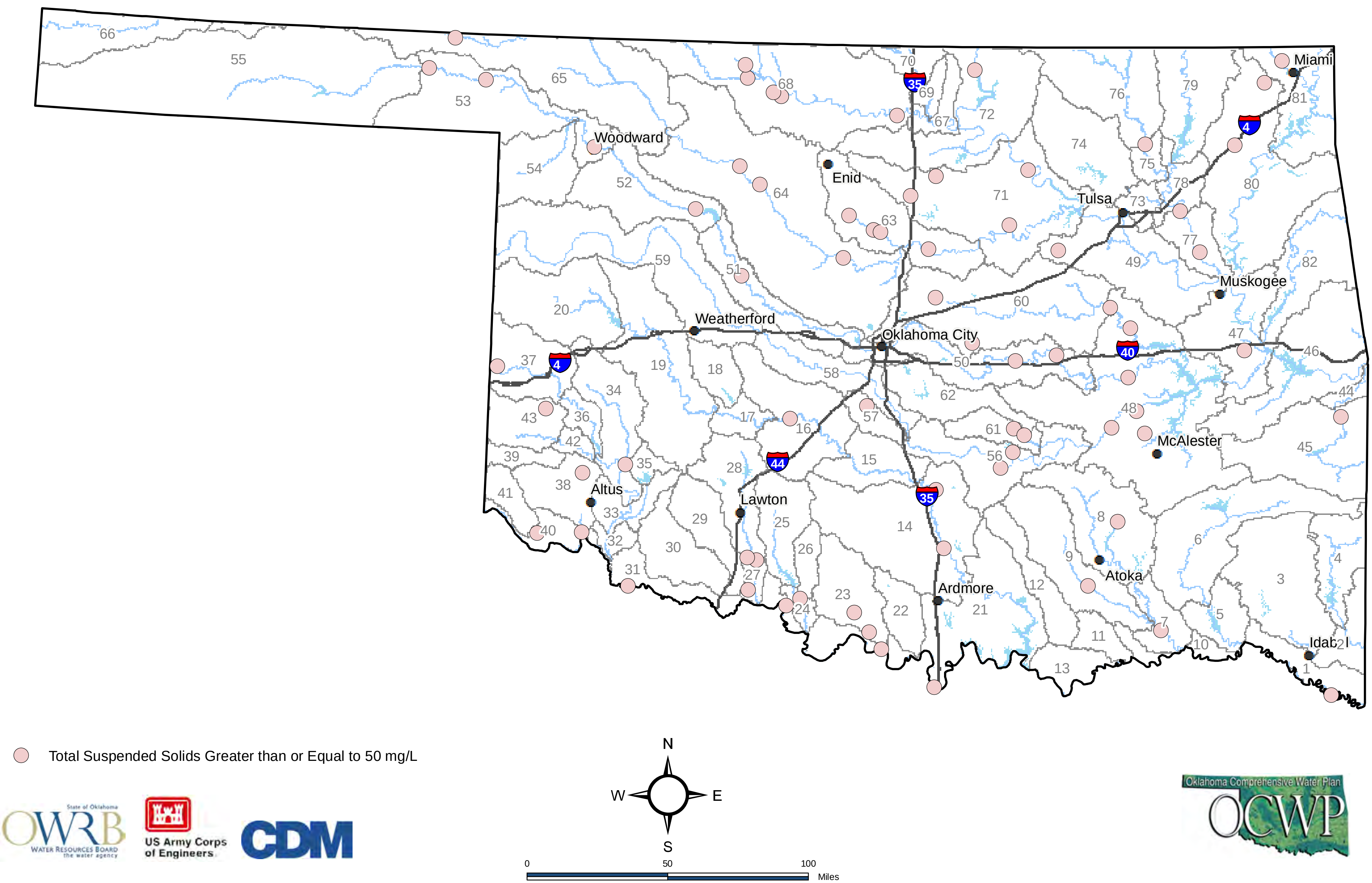
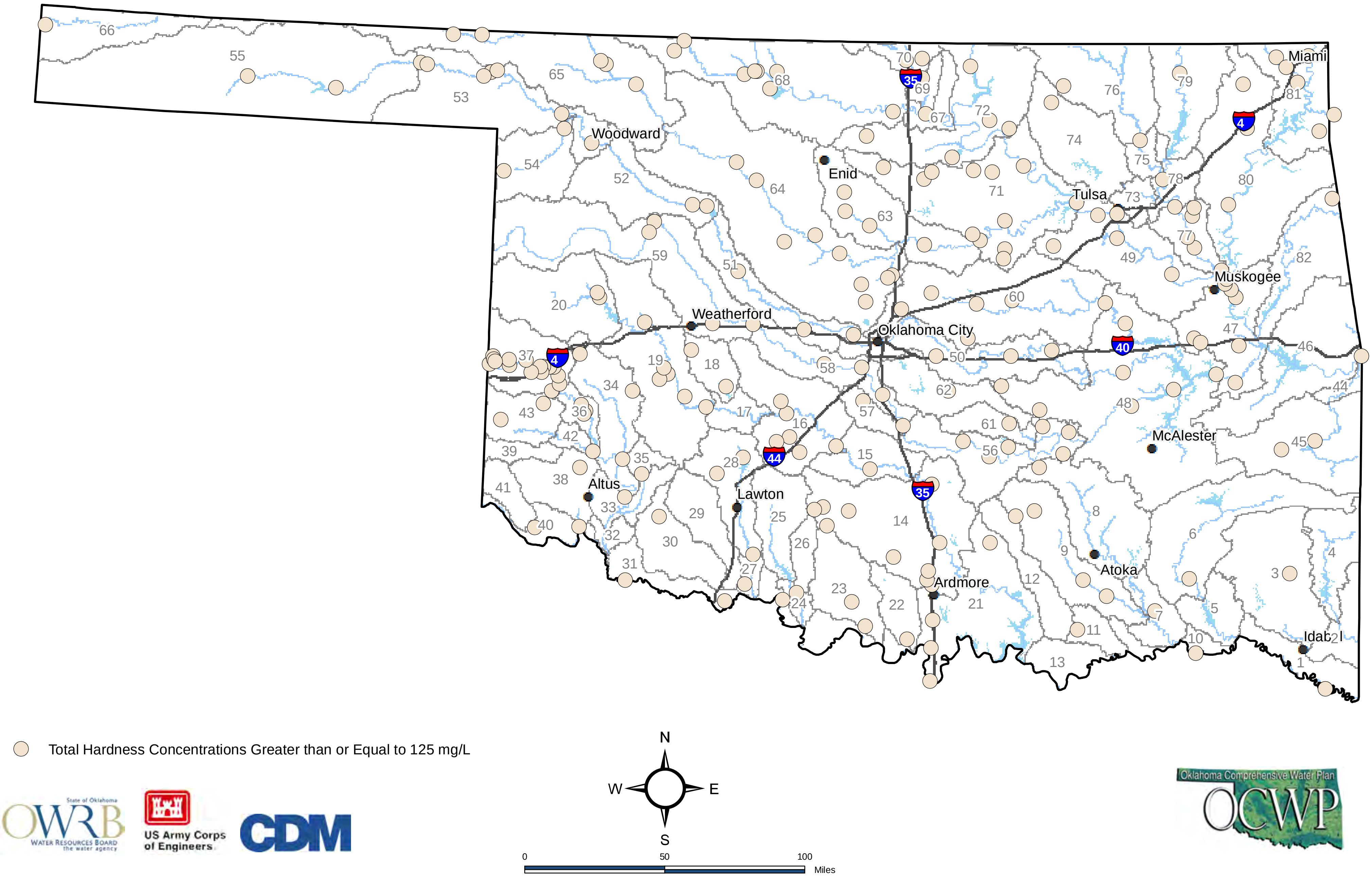


Figure 2-7 - Surface Water Sampling Locations with Total Hardness Concentrations Greater than or Equal to 125 mg/L as Calcium Carbonate



Section 3
Constraints on Uses of Marginal Quality Water

The sources of MQW identified and described in Section 2 were analyzed qualitatively for their potential ability to meet the water supply needs of Oklahoma water users. The evaluation first focused on potential constraints on the use of MQW by source, as described in this section. The water quality needs of Oklahoma's various water use sectors are described in Section 4.

3.1 Potential Constraints

Each source category of MQW was considered in terms of constraints on its use. The following technical, regulatory, environmental and implementation constraints were identified as they pertain to each category:

- **Technical Constraints:** The technical constraints on uses of MQW could include infrastructure needs (e.g., enhanced treatment for reuse of effluent, collection and distribution systems needed for stormwater, mobile/temporary treatment facilities for oil and gas operations, etc.), treatment requirements, variable or finite supplies (e.g., precipitation-related supplies for stormwater, non-renewable aquifers for brackish groundwater, etc.), and supply location relative to demands.

- **Regulatory Constraints:** Regulatory requirements for MQW are dependent on the intended use. Currently, there are no detailed reuse standards in Oklahoma, with limited guidance for treatment requirements needed for MQW sources. Any water intended for potable use must meet drinking water standards. Similarly, any water that would eventually be discharged would be required to meet permit requirements (National Pollutant Discharge Elimination System [NPDES], MS4, etc.). Regulatory constraints may be placed on the use of water based on existing water rights, domestic uses, and other similar situations. Additional regulatory constraints may be placed on the storage and transportation of MQW in the future.

- **Environmental Constraints:** Environmental constraints could include the disposal of treatment residuals, impacts of decreases in instream and downstream flows (water quality and habitat effects), and subsidence impact on fresh water from pumping deep aquifers' brackish water supplies.

- **Implementation Constraints:** The major, overarching constraints for the use of MQW sources are public perception and costs. Public perception refers to a negative perception of using the water source, which may be contrary to the available technical information. Although driven in large part by site-specific conditions, the historic use of non-MQW sources (i.e., raw water, fresh water supplies, and/or potable options) over MQW sources is likely due to the cost of MQW use relative to the traditional non-MQW source options. Costs can include storing, treating, or transporting MQW, including the associated liability costs. Availability of land may be a constraint to implementation as well.

3.2 Overview of Possible Constraints on Using Each MQW Source

Table 3-1 summarizes the discussion presented above. The matrix contains an overview of potential technical, regulatory, environmental, and/or implementation constraints associated with each MQW source category.

Table 3-1 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 • Water quality/treatment needs	• Discharge regulations • Storage and transportation • Permitting	• Treatment 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	• Treatment residuals disposal	• Cost relative to raw, fresh, potable water options • Public perception • Availability of land • Liability of storing, treating, or transporting

Table 3-1 Constraints on Using MQW Sources

Category	Possible Constraints			
	Technical	**Regulatory**	**Environmental**	**Implementation**
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	• Treatment residuals disposal	• Cost relative to raw, fresh, potable water options • Public perception • Availability of land
Waters with Elevated Levels of Key Constituents	• Treatment	• Potable quality standards and treatment requirements	• Treatment residuals disposal	• Cost relative to raw, fresh, potable water options • Public perception

MS4s – Municipal separate storm sewer systems
PPCPs – Pharmaceuticals and personal care products

Section 4
Quality and Quantity Needs by Water Use Sector

Water needs were qualitatively characterized for each water use sector. The seven OCWP water use sectors include:

- Municipal and industrial (M&I)
- Self-supplied residential
- Self-supplied industrial
- Thermoelectric Power
- Oil and gas
- Crop irrigation
- Livestock

Water quantity needs presented below were summarized based on the water demand projections developed for the OCWP Update. Water quality needs for each sector were characterized based on available literature and industry-specific knowledge. The OCWP Water Demand Forecast Report was previously developed as a component of the OCWP technical work effort.

The projected statewide total demands by sector through 2060 are presented in Figure 4-1. Crop Irrigation, M & I, and Thermoelectric Power are the three largest use sectors. The demands presented are total demands, which include both the consumptive and non-consumptive (potential return flow) portion of the demand. For example, a thermoelectric power plant using surface water typically consumes 60 percent of the water diverted and returns 40 percent of the demand to the stream.

4.1 Municipal and Industrial Demands

M&I demands represent water that is provided by public water systems to homes, businesses, and industries throughout Oklahoma, excluding water supplied to thermoelectric power plants and agricultural water users. Water uses include water for bathing, flushing, washing, drinking, landscape irrigation, car washing, recreation, domestic animal care, etc.

4.1.1 Water Quantity

The projected M&I demand density by basin for 2060 is shown in Figure 4-2. The greatest M&I demands are located in and around the larger population centers of the state (e.g., Oklahoma City, Tulsa, and Lawton).

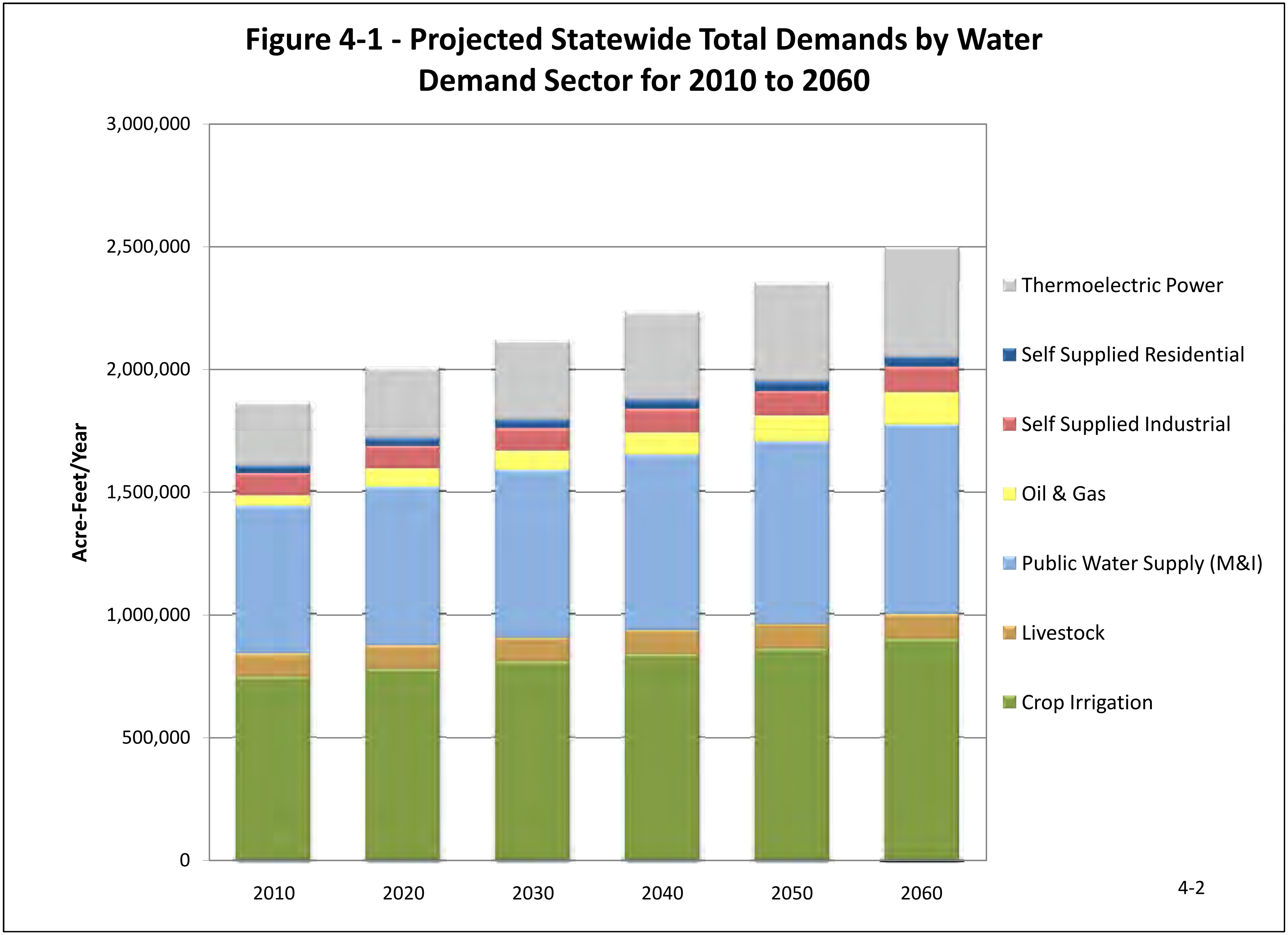
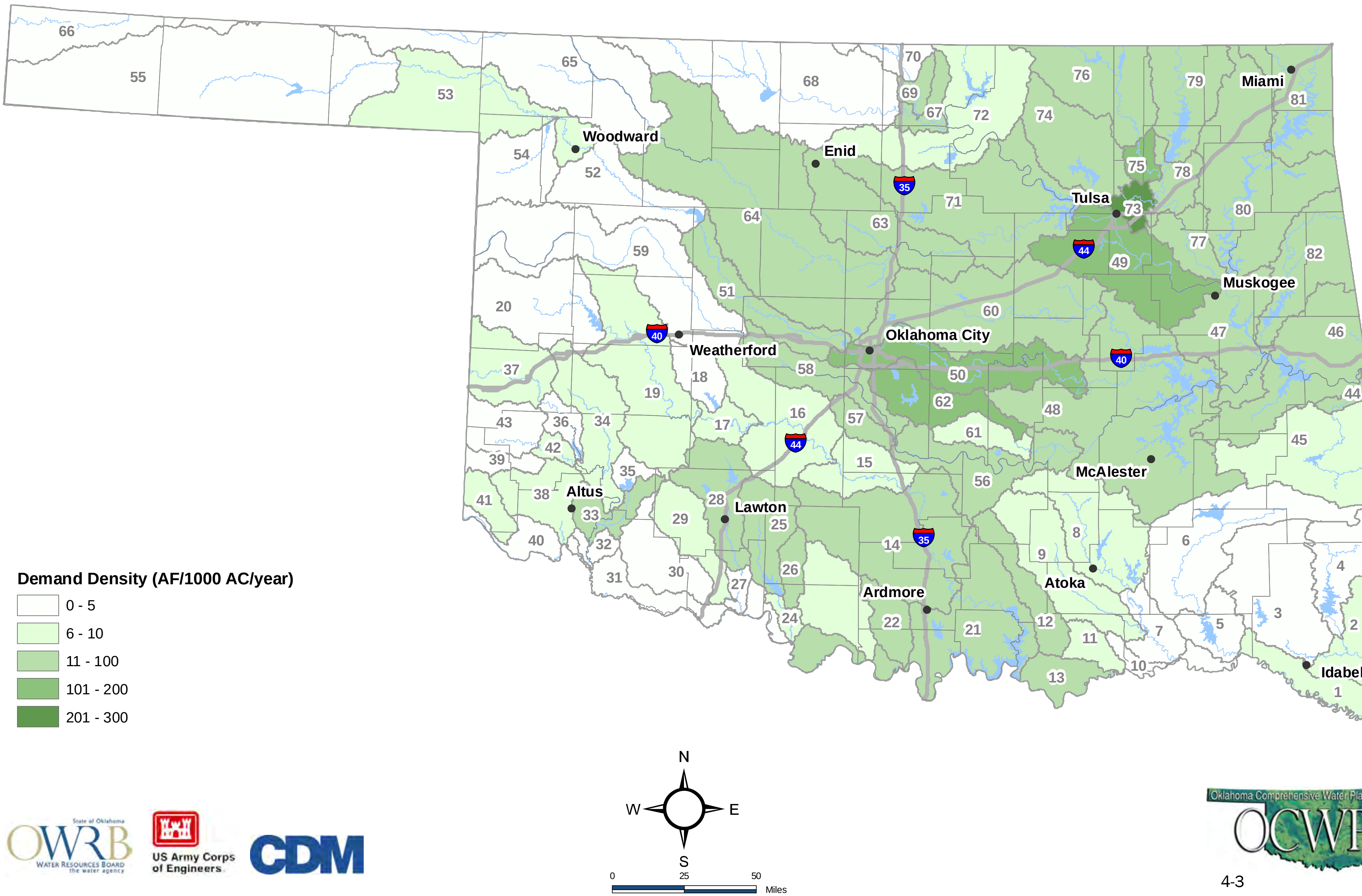


Figure 4-1 - Projected Statewide Total Demands by Water Demand Sector for 2010 to 2060
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
Acre-Feet/Year
2010
2020
2030
2040
2050
2060
Thermoelectric Power
Self Supplied Residential
Self Supplied Industrial
Oil & Gas
Public Water Supply (M&I)
Livestock
Crop Irrigation

Figure 4-2 - 2060 Municipal and Industrial Demand Density



4.1.2 Water Quality

M&I demand sector source water can vary with regard to quality. Water quality standards have been promulgated for surface water and groundwater that are used for public drinking water supplies. Oklahoma's surface water quality standards can be found in Chapter 45 of the OWRB's Rules. In addition to federal and state laws, Section 2.1.5 presented "threshold concentrations," or levels at in many cases, the potential costs associated with such treatment may cause providers to consider or implement other sources of supply, that may drive substantial capital and operating costs for water treatment for TSS, TDS, nitrates, and hardness.

Wastewater reuse is often accomplished via a dedicated conveyance system after the wastewater is treated based on the intended use for the water. There are no national regulations for reuse; however, EPA's 2004 Guidelines for Water Reuse (EPA 2004) provide guidance for treatment technologies, water quality requirements, and implementation for a range of reuse applications. Non-potable uses with minimal potential for human contact or ingestion generally require less treatment and lower water quality than those with higher potentials for contact or cross-connection with potable systems.

4.2 Self-Supplied Residential

The self-supplied residential sector includes demands for households on private wells that are not connected to a public water supply system. These households are located primarily in rural areas of the state but may also be located in suburbs of municipal areas. While some self-supplied residential homes use well water for livestock care, demands for the self-supplied residential sector only represent water use inside the home, as well as non-agricultural related outdoor use.

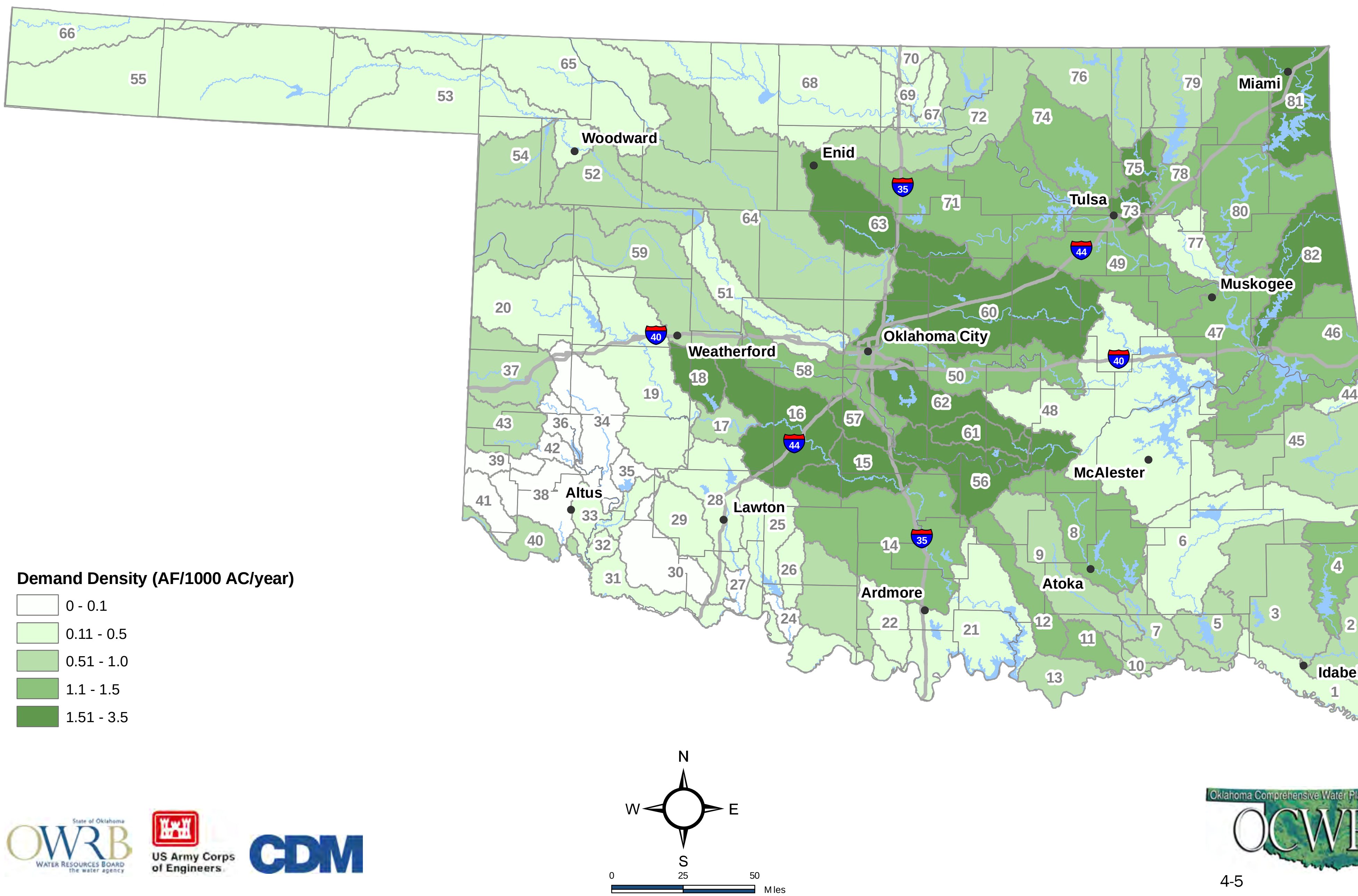
4.2.1 Water Quantity

The self-supplied residential demand density by basin for 2060 is shown in Figure 4-3. The self-supplied residential sector represents small quantities of water for individual households that are located across broad geographic areas.

4.2.2 Water Quality

The self-supplied residential sector typically requires high quality source water, because the water is used for potable supply. Typically no advanced treatment occurs prior to self-supplied residential use. Rather, individual wells are typically used, with minimal or no treatment. Therefore, self-supplied residential users usually require source water at or near potable quality.

Figure 4-3 - 2060 Self Supplied Residential Demand Density



4.3 Self-Supplied Industrial

Large industries that are identified as self-supplied users with available water use data and employment counts are included in this group. Data were provided by the OWRB and industries without data were included in the M&I demand sector. Example industries include sand companies, gypsum production plants, quarry mines, concrete plants, petroleum refineries, paper mills, sawmills, bottling and distribution plants, chemical plants, tire manufacturing plants, lime production, natural gas plants, and meat packing plants.

4.3.1 Water Quantity

The self-supplied industrial demand density by basin for 2060 is shown in Figure 4-4. The self-supplied industrial sector demands are distributed throughout the state; however, many basins do not have a demand from this sector.

4.3.2 Water Quality

Many self-supplied industries construct and operate onsite treatment facilities to treat available supplies to the individual facility's specific water quality standards. The water quality required can vary significantly from one industry to another and from one facility to another. Thus, it is difficult to broadly characterize the water quality needs of self-supplied industries for this statewide assessment of MQW use.

4.4 Thermoelectric Power

Self-supplied water and municipal-supplied water associated with thermoelectric power producing plants are included in the Thermoelectric Power sector.

4.4.1 Water Quantity

The Thermoelectric Power demand density by basin for 2060 is shown in Figure 4-5. Specific sites for future power plants have not been determined. In lieu of such information, future power water use was assumed to occur in the same basin as existing permitted power facilities. Thermoelectric Power often represents a significant portion of the demand in the basins where it occurs. However, Thermoelectric Power uses only consume an estimated 60 percent of the diverted amount, returning 40 percent to the stream for other users.

Figure 4-4 - 2060 Self Supplied Industrial Demand Density

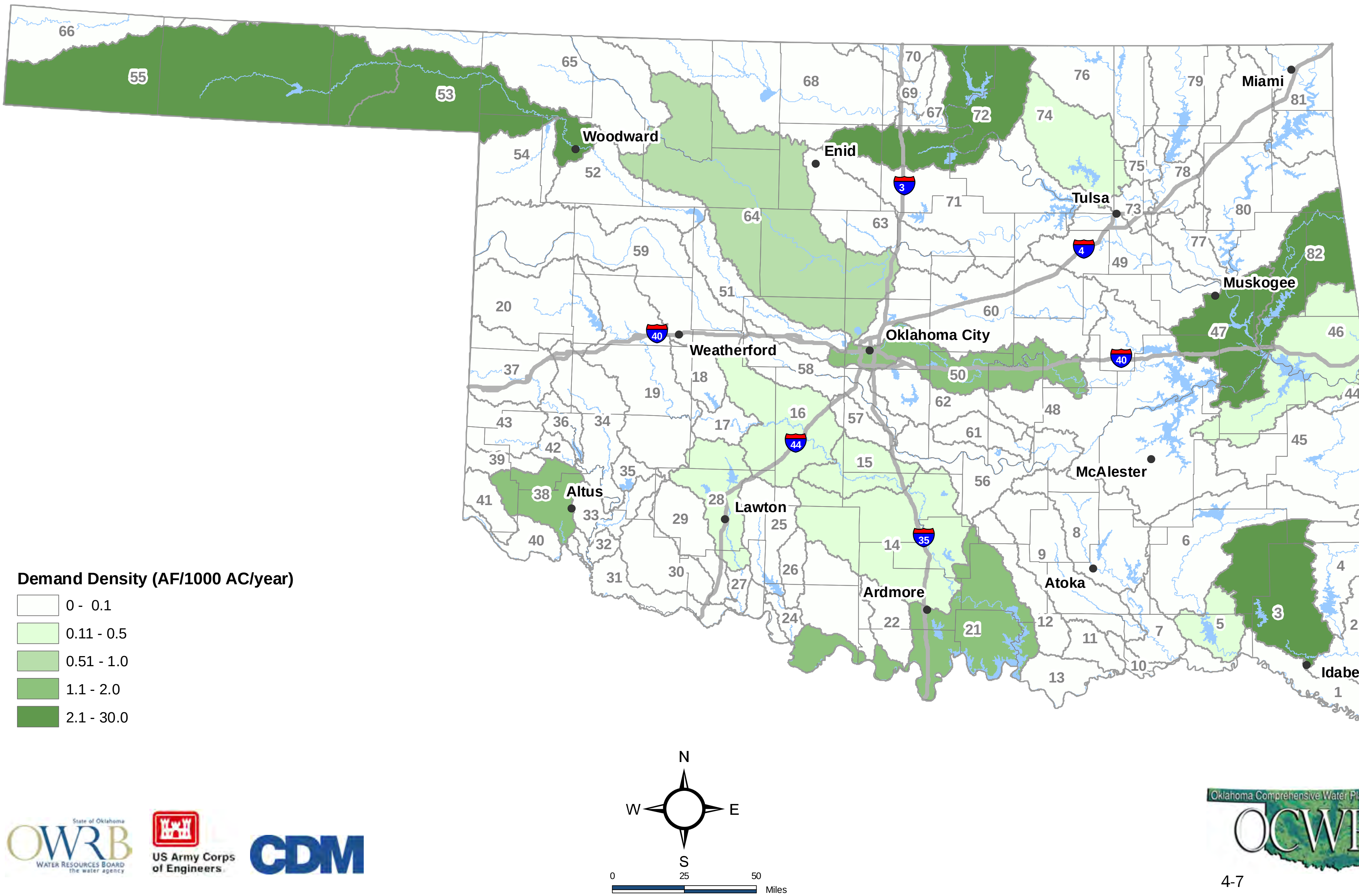
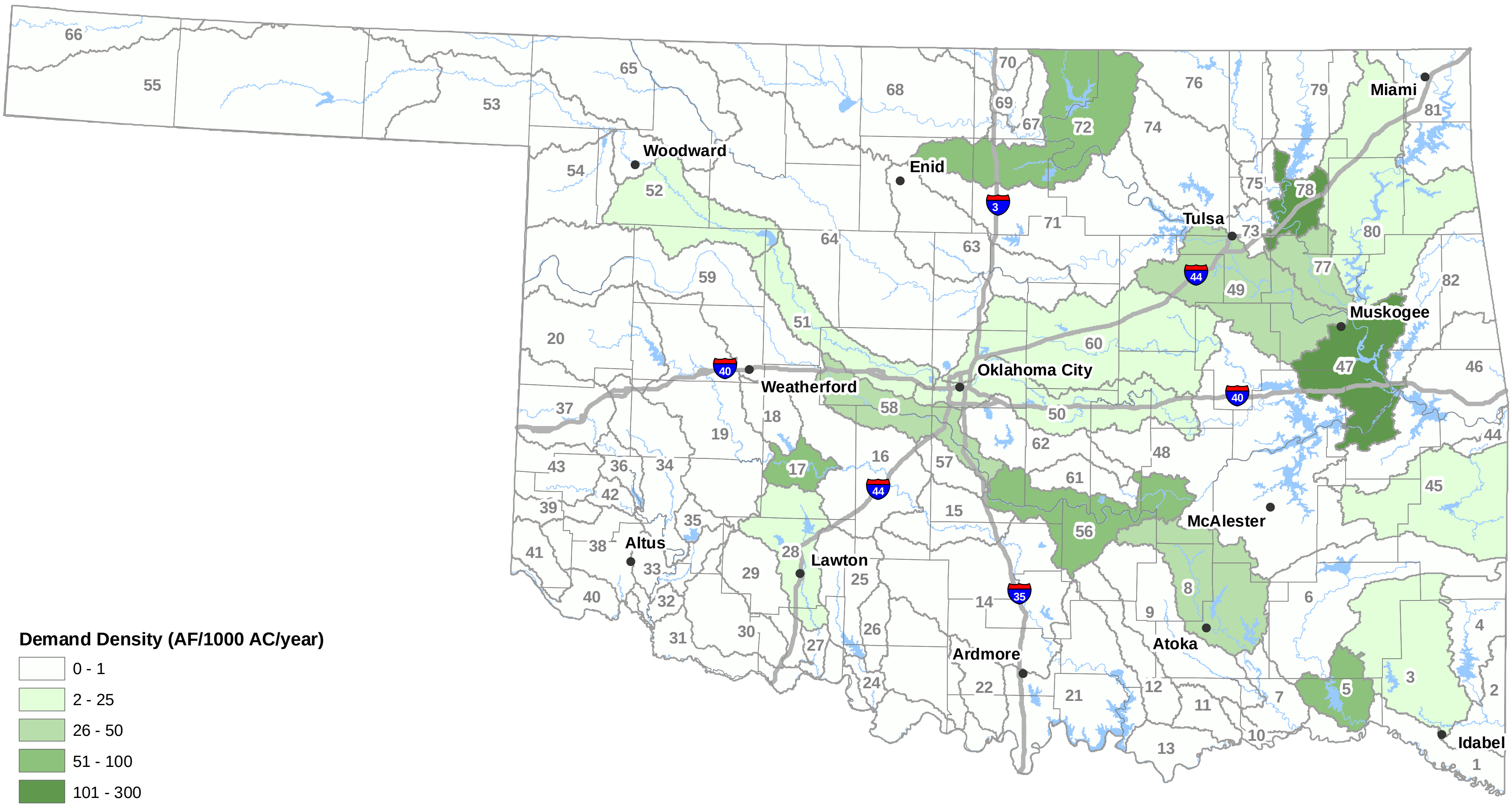


Figure 4-5 - 2060 Thermoelectric Power Demand Density



Demand Density (AF/1000 AC/year)

- 0 - 1
- 2 - 25
- 26 - 50
- 51 - 100
- 101 - 300

N W E S

0 25 50 Miles

4.4.2 Water Quality

Thermoelectric power plants use water primarily for cooling. The majority of plants in Oklahoma use cooling towers (National Energy Technology Laboratory 2009), which dissipate heat by evaporating water. The process of evaporating water can lead to fouling that can reduce the efficiency of power generation or lead to equipment failure. Particulates or dissolved minerals can lead to corrosion and scaling, which can clog air vents or coat heat exchangers. Nutrients can lead to biological growth that can cause similar issues. Power generators use a variety of chemicals or physical management practices (e.g., maintenance cleaning or expelling "blowdown" water), to reduce or eliminate fouling. Water sources with lower TDS and nutrients can reduce the extent of fouling, which is preferable from an operational and economic perspective.

4.5 Oil and Gas

This sector represents water used in oil and gas drilling and exploration activities but does not include water used at oil and gas refineries (which are typically categorized as self-supplied industrial users). Drilling and exploration activities use water for supplemental fluid during well drilling and completion (up to 6,000,000 gallons during fracing of gas shale wells) (Corp Comm), during workover of an oil or gas well, as rig wash water, as coolant for equipment, and for sanitary purposes. Water use from both conventional and unconventional drilling techniques was considered.

4.5.1 Water Quantity

The oil and gas demand density by basin for 2060 is shown in Figure 4-6. Peak development of the Woodford Shale deposits is expected to occur in about 2030 and decline thereafter. The majority of water need for oil and gas is used during well development, where typically only a short-term permit, 90 days, is required. The demands represent the drilling and development of many wells that may not occur in a central location. Due to the short-term and potentially decentralized nature of these demands, the development of permanent infrastructure may not be economically feasible.

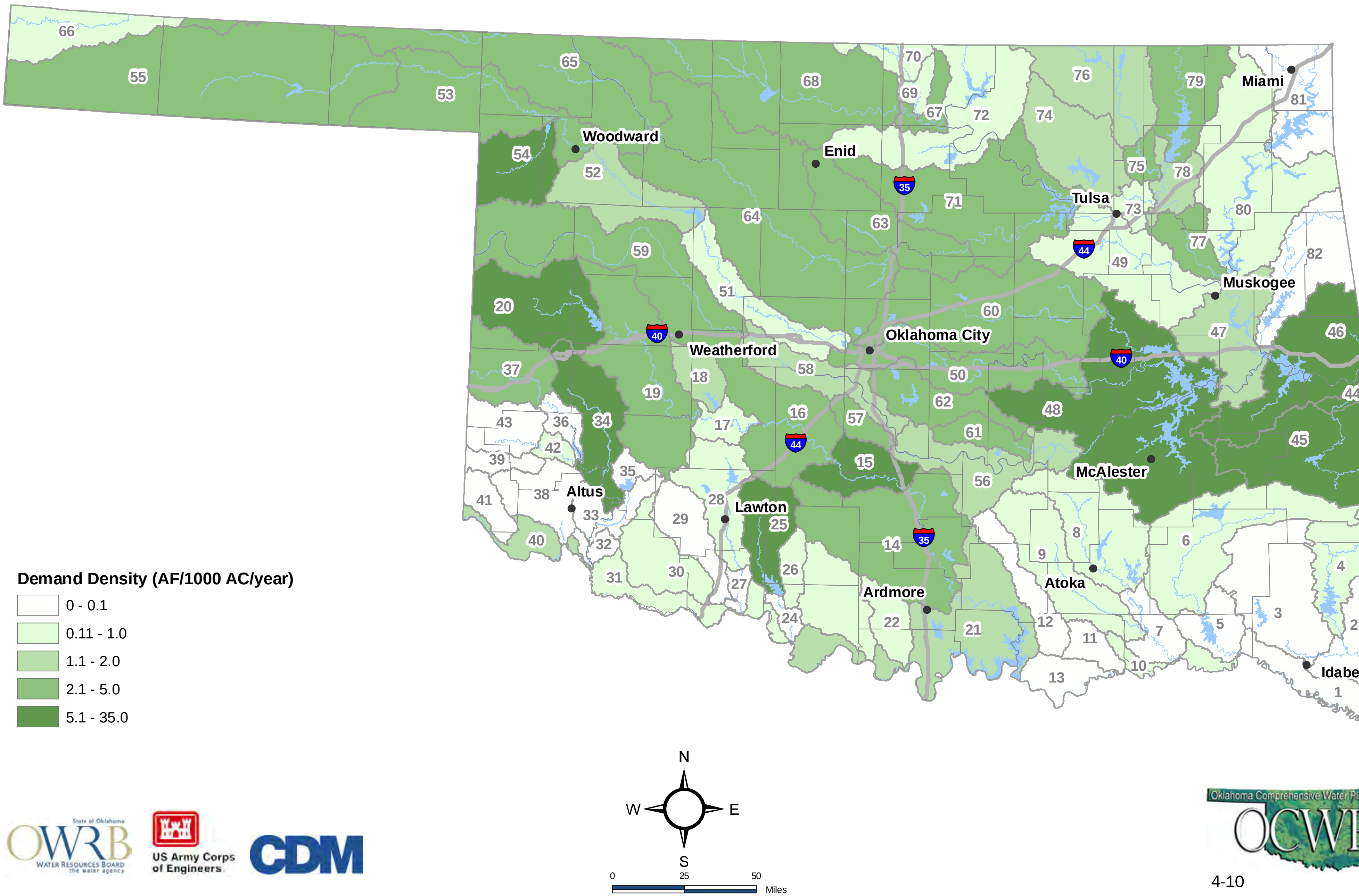
4.5.2 Water Quality

Water quality requirements for oil and gas drilling activities are reported to vary significantly, depending on the type of drilling and the specific operations and standards of the energy company. Some general requirements for the base fluid in completion operations (as provided by Chesapeake Energy) are:

- Chloride <10,000 mg/L
- Total Hardness <1,000 mg/L
- Iron <5 mg/L

An additional requirement for cross-linked gel make-up is that Boron be less than 2 mg/L. These values are for overall fluid. If the fluid included fresh blend water, the values could be much higher.

Figure 4-6 - 2060 Oil and Gas Demand Density



4.6 Crop Irrigation

Water demands from crop irrigation were estimated based on the 2007 Agriculture Census on irrigated acres by crop type density by basin. Crops included alfalfa, corn (silage and grain), cotton, sorghum, peanuts, pasture grasses, potatoes (not commercially grown), soybeans, sunflowers, watermelons, and wheat.

4.6.1 Water Quantity

The crop irrigation demand density by basin for 2060 is shown in Figure 4-7. Areas in the western and Panhandle areas of Oklahoma typically use greater amounts of irrigation water than eastern areas, due primarily to Oklahoma's substantial west-to-east increasing precipitation gradient. The role and importance of agriculture in Oklahoma's economy is significant, and heavily reliant on reliable water supplies, as described in a recent article in the Oklahoma Academy's May 2010 Town Hall background report on water issues (Oklahoma Academy 2010).

4.6.2 Water Quality

Salts – indicated by concentrations of chlorides, TDS, and sulfates – are the major impairments for crop irrigation in Oklahoma (2008 303(d) list). The effects and management of saline irrigation water has been well studied in Oklahoma and throughout the West. The effect of saline irrigation water varies by the specific salts in the water, the soil type, crop type, weather, and other factors. Table 4-1 shows percent yield reductions for a variety of crops based on TDS levels. Soybeans and hay are also commercially grown in Oklahoma, however, data for yield reduction due to TDS levels was not readily available for these crops.

Table 4-1 Potential Yield Reduction from Saline Water for Selected Irrigated Crops[1]

Crop	Percent Yield Reduction			
	0%	10%	25%	50%
	Total Dissolved Solids (mg/L)			
Barley	2,752	5,360	6,960	9,600
Wheat	2,560	3,136	5,120	6,960
Alfalfa	832	1,408	2,304	4,720
Corn (grain)	704	1,088	1,600	2,496
Corn (silage)	768	1,344	2,240	4,560

[1] Adapted from "Quality of Water for Irrigation." R.S. Ayers. Jour. of the Irrig. and Drain. Div., ASCE. Vol 103, No. IR2, June 1977, p. 140.

Elevated concentrations of additional parameters in soil or ground/irrigation water can also affect crops. Table 4-2 presents the maximum concentrations of additional parameters that selected plant groups can tolerate.

Figure 4-7 - 2060 Crop Irrigation Demand Density

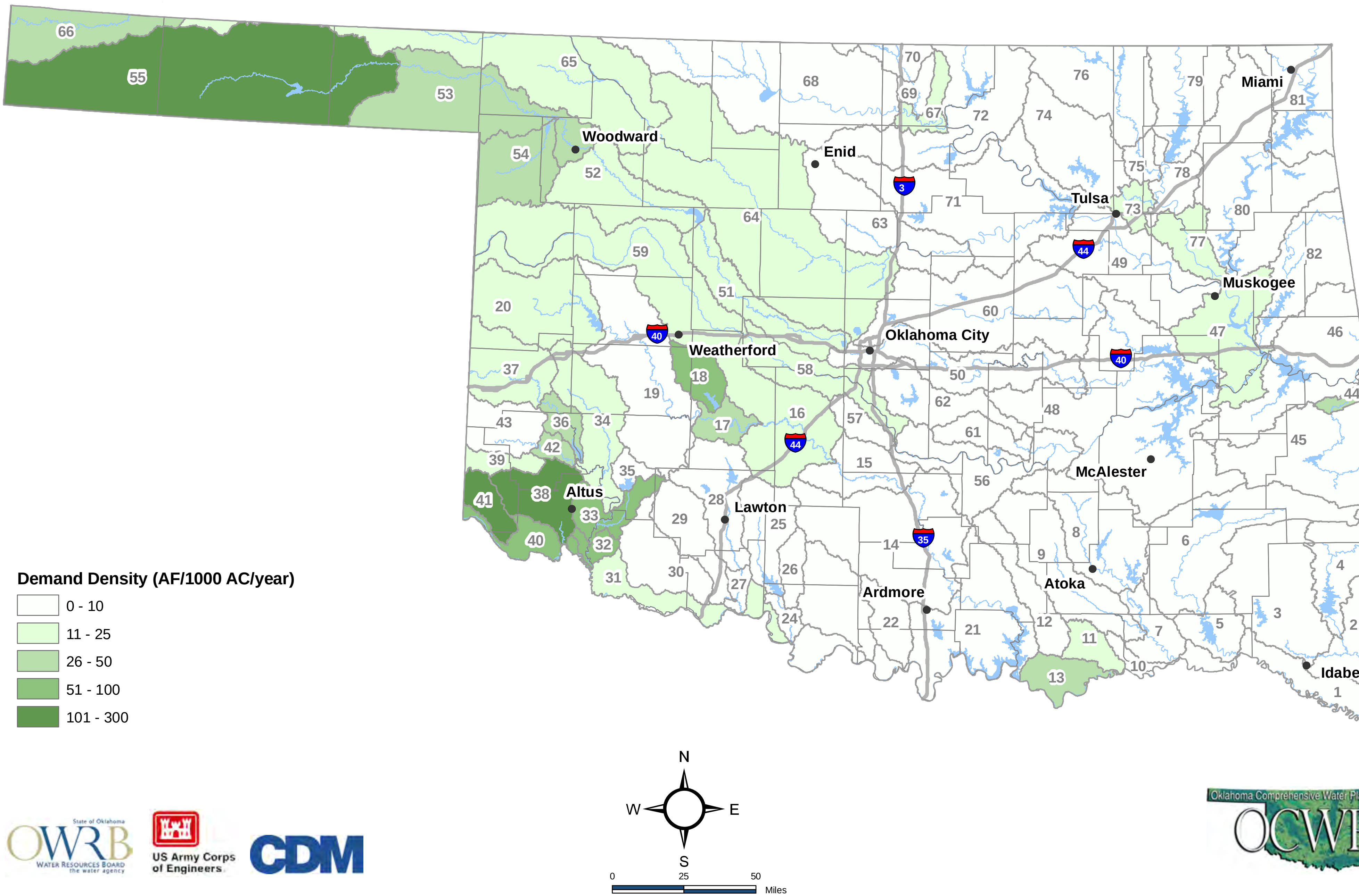


Table 4-2 Recommendations for Levels of Toxic Substances in Drinking Water for Livestock (Soltanpour and Raley 1999)

Water Quality Parameter	Upper Limit	Water Quality Parameter	Upper Limit
Aluminum (Al)	5.0 mg/L	Lead (Pb)	0.1 mg/L[1]
Arsenic (As)	0.2 mg/L	Manganese (Mn)	no data
Beryllium (Be)	no data	Mercury (Hg)	0.01 mg/L
Boron (B)	5.0 mg/L	Molybdenum (Mo)	no data
Cadmium (Cd)	0.05 mg/L	Nitrate + nitrite (NO_3-N + NO_2-N)	100 mg/L
Chromium (Cr)	1.0 mg/L	Nitrite (NO_2-N)	10 mg/L
Cobalt (Co)	1.0 mg/L	Selenium (Se)	0.05 mg/L
Copper (Cu)	0.5 mg/L	Vanadium (V)	0.10 mg/L
Fluorine (F)	2.0 mg/L	Zinc (Zn)	24 mg/L
Iron (Fe)	no data	Total dissolved solids (TDS)	10,000 mg/L[2]

Notes:
[1] Lead is accumulative and problems may begin at threshold value = 0.05 mg/L
[2] See Table 4-3.

4.7 Livestock

Livestock demands are evaluated by livestock group (beef, poultry, etc.) and are based on the 2007 Agriculture Census.

4.7.1 Water Quantity

The livestock demand density by basin for 2060 is shown in Figure 4-8. Livestock demands are widely distributed across the state.

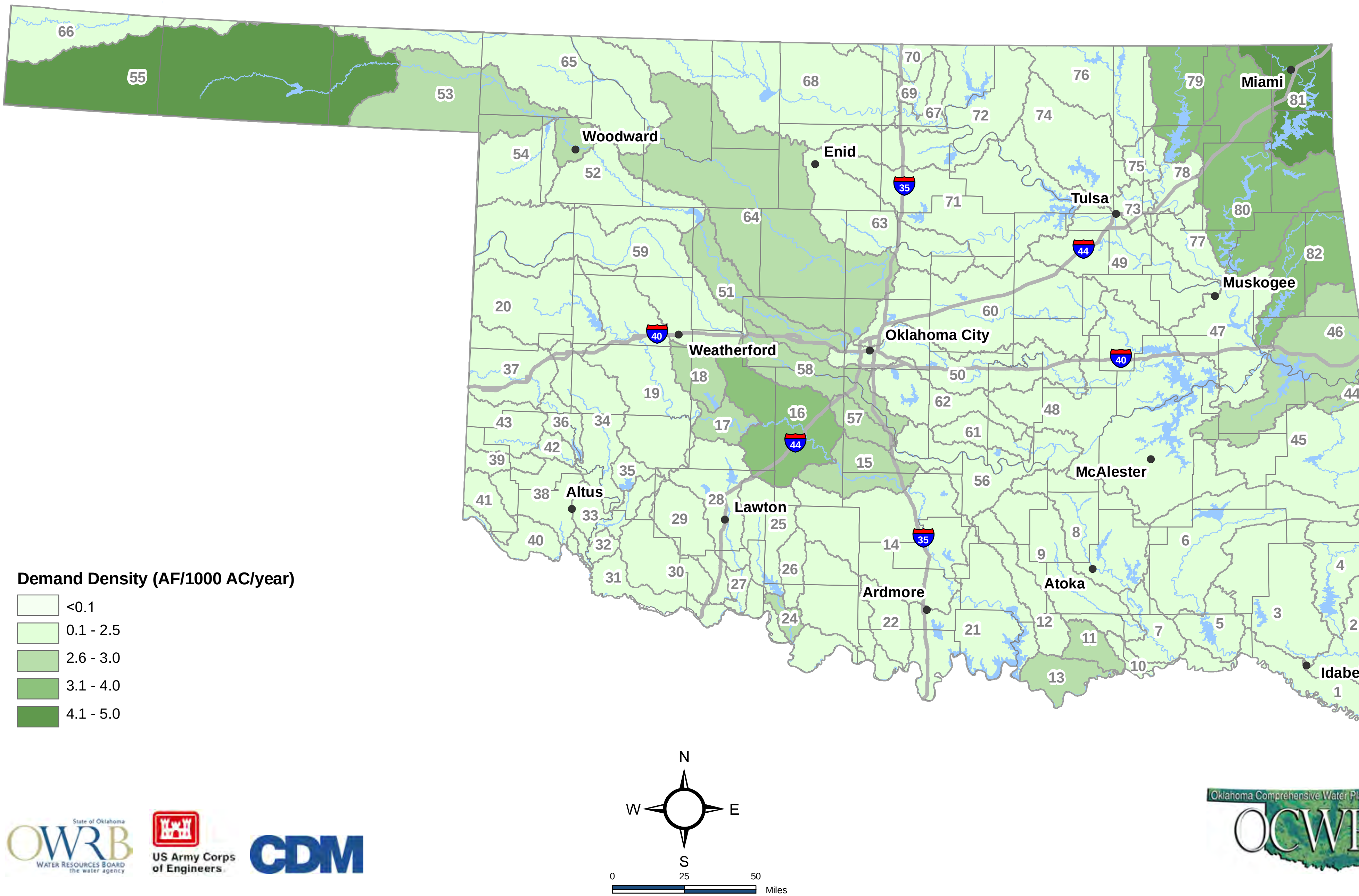
4.7.2 Water Quality

Livestock can be adversely affected by a range of water quality parameters. The level that some common water quality parameters become toxic are presented in Table 4-2. At non-toxic levels, saline water can adversely affect livestock, which is described in Table 4-3.

Table 4-3 Guide to the Use of Saline Waters for Livestock and Poultry (Soltanpour and Raley 1999)

Total Dissolved Solids Content of Waters	Uses
Less than 960 mg/L	Relatively low level of salinity. Excellent for all classes of livestock and poultry.
961 - 3,200 mg/L	Very satisfactory for all classes of livestock and poultry. May cause temporary and mild diarrhea in livestock not accustomed to them; may cause watery droppings in poultry.
3,200-6,400 mg/L	Satisfactory for livestock, but may cause temporary diarrhea or be refused at first by animals not accustomed to them. Poor waters for poultry, often causing watery feces, increased mortality, and decreased growth, especially in turkeys.
6,400-8,800 mg/L	Can be used with reasonable safety for dairy and beef cattle, sheep, swine, and horses. Avoid use for pregnant or lactating animals. Not acceptable for poultry.
8,800-12,800 mg/L	Unfit for poultry and probably for swine. Considerable risk in using for pregnant or lactating cows, horses, or sheep, or for the young of these species. In general, use should be avoided although older ruminants, horses, poultry, and swine may subsist on them under certain conditions.
Over 12,800 mg/L	Risks with these highly saline waters are so great that they cannot be recommended for use under any condition.

Figure 4-8 - 2060 Livestock Demand Density



US Army Corps of Engineers

OWRB State of Oklahoma Water Resources Board the water agency

CDM

Oklahoma Comprehensive Water Plan OCWP

Section 5
Potential Uses of Marginal Quality Water Sources

Sections 3 and 4 of this document presented the potential constraints on the use of MQW sources and the quantity and quality needs of Oklahoma's seven water demand sectors. These discussions have been synthesized into a matrix and associated mapping that present an evaluation of opportunities to use MQW to meet the demands of water users. The matrix provides information on the feasibility of applying MQW to meet demands and the level of treatment that may be needed to put the MQW source to beneficial use by water use sector. The matrix evaluation was conducted on a qualitative, non-geographical basis as an initial screening of the relative feasibility of each supply/demand permutation. The matrix is presented and discussed in Section 5.1.

The mapping that was performed for this evaluation used Geographic Information System (GIS) software to overlay basins with higher demand densities with basins that have relatively higher supplies of MQW. The comparisons were made for each potentially feasible permutation of water demand sector and MQW source categories. Basins where these two geographic coverages converge are areas where there may be the greatest potential to meet a significant portion of future demands with MQW sources, and where further investigation into the use of MQWs may be warranted. These maps are referenced throughout this section.

5.1 Screening Assessment

A screening matrix of the potential feasibility for using MQW supplies to meet some or all of the water needs of each of Oklahoma's major water use sectors is presented in Table 5-1. The legend that accompanies Table 5-1 provides further information on the potential feasibility of each combination. Drawing conclusions regarding the feasibility of supply/demand combinations on a broad, statewide basis is challenging. Localized conditions and site-specific issues could cause the feasibility of using a given specific supply to be directly opposite what is described herein. Rather, this assessment is intended to serve as a guide for the *relative* feasibility of each MQW supply/demand combination on a categorical basis. That in turn helped facilitate our evaluation of more geography-specific opportunities to use MQW, shown through mapping and described throughout this section. That evaluation identified the uses of MQW that have the greatest potential to address Oklahoma's current and future water needs.

Table 5-1 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	Waters with Elevated Levels of Key Constituents
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
Thermoelectric 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

<u>**Legend**</u>

✓ **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 may not be near location of significant demand
REL Reliability of supply inadequate to meet demand without significant storage infrastructure
PUB Public Perception

A brief description of the issues and opportunities associated with using each MQW source type for the various demand sectors is provided in the following subsections.

5.1.1 Treated Wastewater

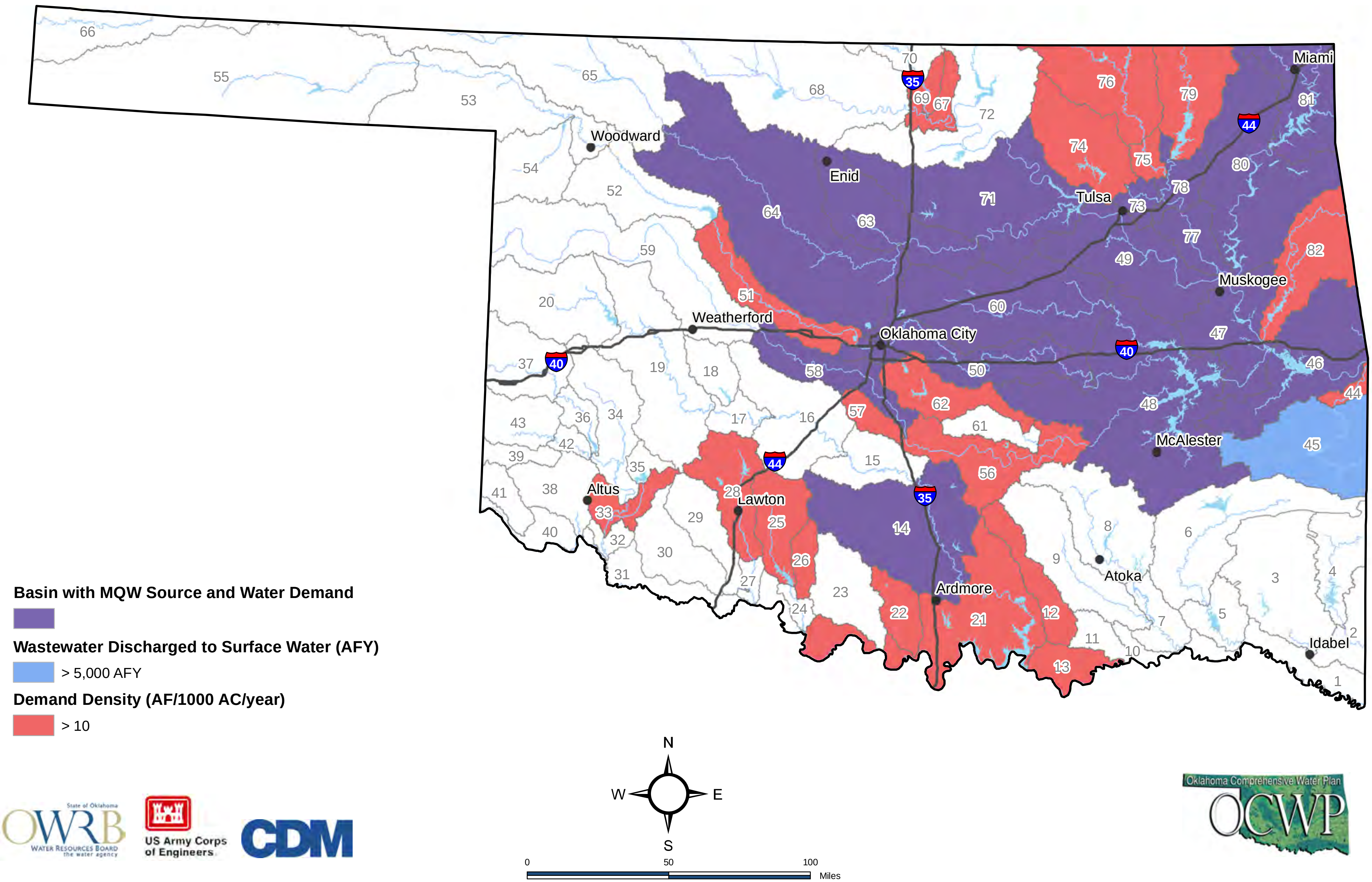
Reuse of treated wastewater is practiced in some areas of Oklahoma, primarily in and near the state's more urbanized areas. Nationally, reuse is generally more widespread in areas where water shortages are prevalent. Reuse is often characterized by "direct" and "indirect" reuse. Direct reuse includes applications where treated effluent is taken directly from the wastewater treatment facility and piped or otherwise conveyed to additional treatment (if needed) and delivery points for use. Indirect reuse includes applications where treated effluent is used to augment raw water supplies, such as rivers, lakes, and groundwater resources. Indirect uses were not explicitly considered in this evaluation.

Direct potable reuse – directly plumbing treated effluent from a wastewater treatment plant (WWTP) to a water treatment plant (WTP) and then into distribution for potable use – is not currently practiced anywhere in the U.S. It was implemented on an emergency basis in Chanute, Kansas, for a five-month period in 1956 during an extreme drought and was evaluated in Denver, Colorado, during a demonstration project from 1985 to 1992. The only known existing direct potable reuse facility in the world is located in Windhoek, Namibia (NWRI, 2010). Water quality and treatment reliability requirements, coupled with public perception issues, have limited the attractiveness of direct potable reuse. However, direct non-potable uses such as irrigation are commonplace in many areas of the country. For these reasons, M&I use of MQW was separated into potable and non-potable subcategories. Treated wastewater can be utilized for non-potable M&I demands, but may require advanced wastewater treatment such as enhanced disinfection or filtration to protect public health and the environment, depending on the water quality requirements of the end use.

Figure 5-1 shows that the highest M&I demand densities and larger volumes of treated wastewater are found along the eastern corridors of Interstate 44 and Interstate 40. The larger metropolitan areas of the state may have the most significant opportunities to offset major water demands with a treated wastewater reuse program, as they have the highest M&I demands, including municipal irrigation needs, and largest volumes of treated wastewater.

Self-supplied Residential water users are not good candidates for using treated municipal wastewater as a direct source of supply, as they are not using public water supplies and likely regional wastewater treatment due to location, economics, or other reasons. Moreover, these users' needs include potable uses, which is not practiced in Oklahoma. There may be some opportunities to utilize treated wastewater from local and/or individual aerobic wastewater treatment units for Self-supplied Residential water use, but these opportunities would be very site-specific and difficult to determine on a basin or statewide scale.

Figure 5-1 - Treated Wastewater for Municipal and Industrial Use (2060)



Self-supplied Industrial and Thermoelectric Power users have the potential to utilize treated wastewater as a source of supply, provided that the wastewater is treated to the required water quality for each specific user, and that the industrial facility is within reasonable proximity to the WWTP source. Industrial and power-generation facilities' use of treated municipal wastewater is commonplace in many parts of the country, and is already in limited practice in Oklahoma. Figures 5-2 and 5-3 show basins where higher Self-supplied Industrial and Thermoelectric demands and higher volumes of treated wastewater co-exist, respectively. Three basins (two near Oklahoma City and one near Muskogee) may have opportunities to reuse significant quantities of treated wastewater for Self-supplied Industrial facilities while areas near Tulsa, Muskogee and south of Oklahoma City were identified through mapping as potential areas of significant opportunity for treated wastewater reuse by Thermoelectric users. For the most part, Oil and Gas uses are located in rural or remote areas. While local development conditions and other site-specific factors will affect the feasibility of such use, there are likely fewer opportunities to cost-effectively and practically implement and operate systems to utilize treated wastewater for these uses relative to other available water supply options.

Similarly, agricultural uses of water (Crop Irrigation and Livestock Watering) tend to be located in rural areas away from large sources of treated wastewater (usually associated with urban areas). There are some instances where treated wastewater is currently being used for crop irrigation. Figures 5-4 and 5-5 show that limited opportunities for agricultural use were identified on a basin-wide scale. Only one basin, OCWP basin 73 near Tulsa, had both high crop irrigation demands and large volumes of treated wastewater (Figure 5-4). Areas near Oklahoma City and in the far east and northeast portions of the state were identified as potential basins with significant opportunities for using treated wastewater for livestock watering needs (Figure 5-5).

5.1.2 Stormwater

For this analysis, Stormwater MQW is considered to be storm runoff that is captured in a stormwater collection system such as a storm sewer system or open channel conveyance structures. Stormwater runoff that has been discharged to receiving waters or infiltrates to groundwater was considered to be part of the state's overall non-MQW sources of raw water supply. Potential implications of capturing and using storm runoff that would otherwise augment downstream users' supplies are not clearly established in Oklahoma water law, but would need to be investigated as part of any implementation activities.

Figure 5-2 - Treated Wastewater - Self-Supplied Industrial Use (2060)

Water Demand Use Sector	MQW Source Category				
	Treated Wastewater	Stormwater	Oil and Gas Flowback / Produced Water	Brackish Water	Waters with Elevated Levels of Key Constituents
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
Thermoelectric 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

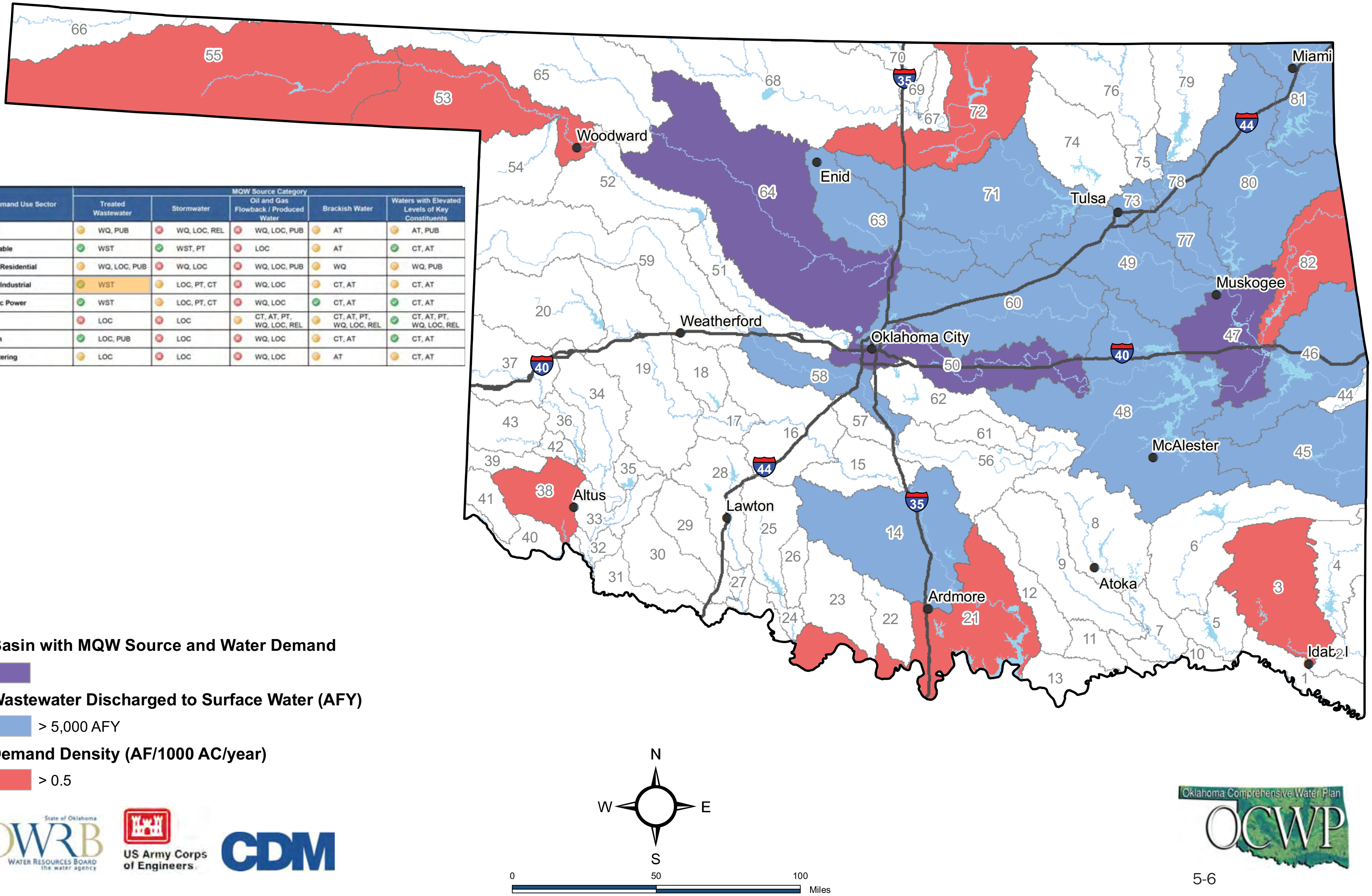
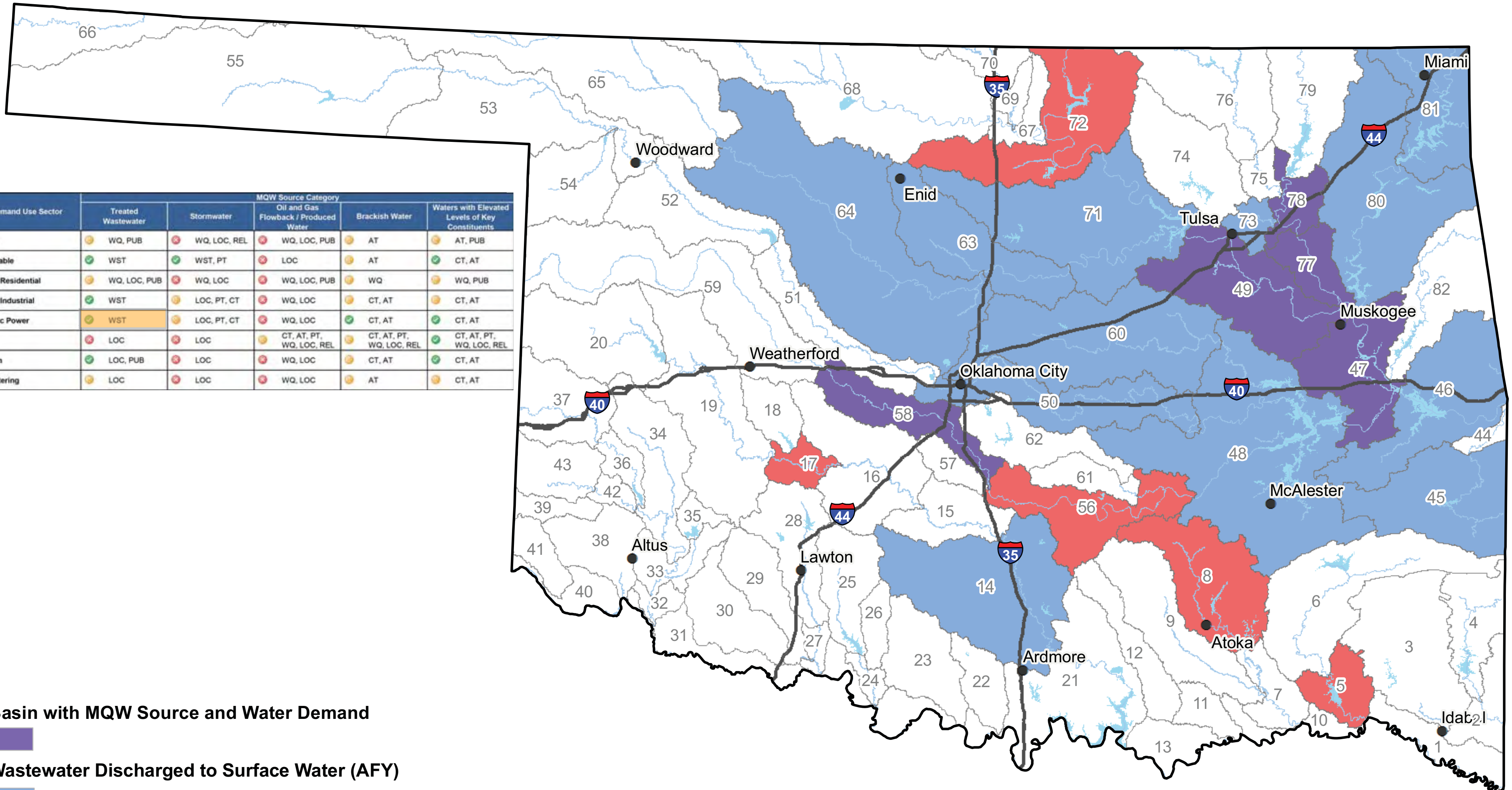


Figure 5-3 - Treated Wastewater - Thermoelectric Power Use (2060)



Water Demand Use Sector	MQW Source Category				
	Treated Wastewater	Stormwater	Oil and Gas Flowback / Produced Water	Brackish Water	Waters with Elevated Levels of Key Constituents
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
Thermoelectric 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

Basin with MQW Source and Water Demand

Wastewater Discharged to Surface Water (AFY)

> 5,000 AFY

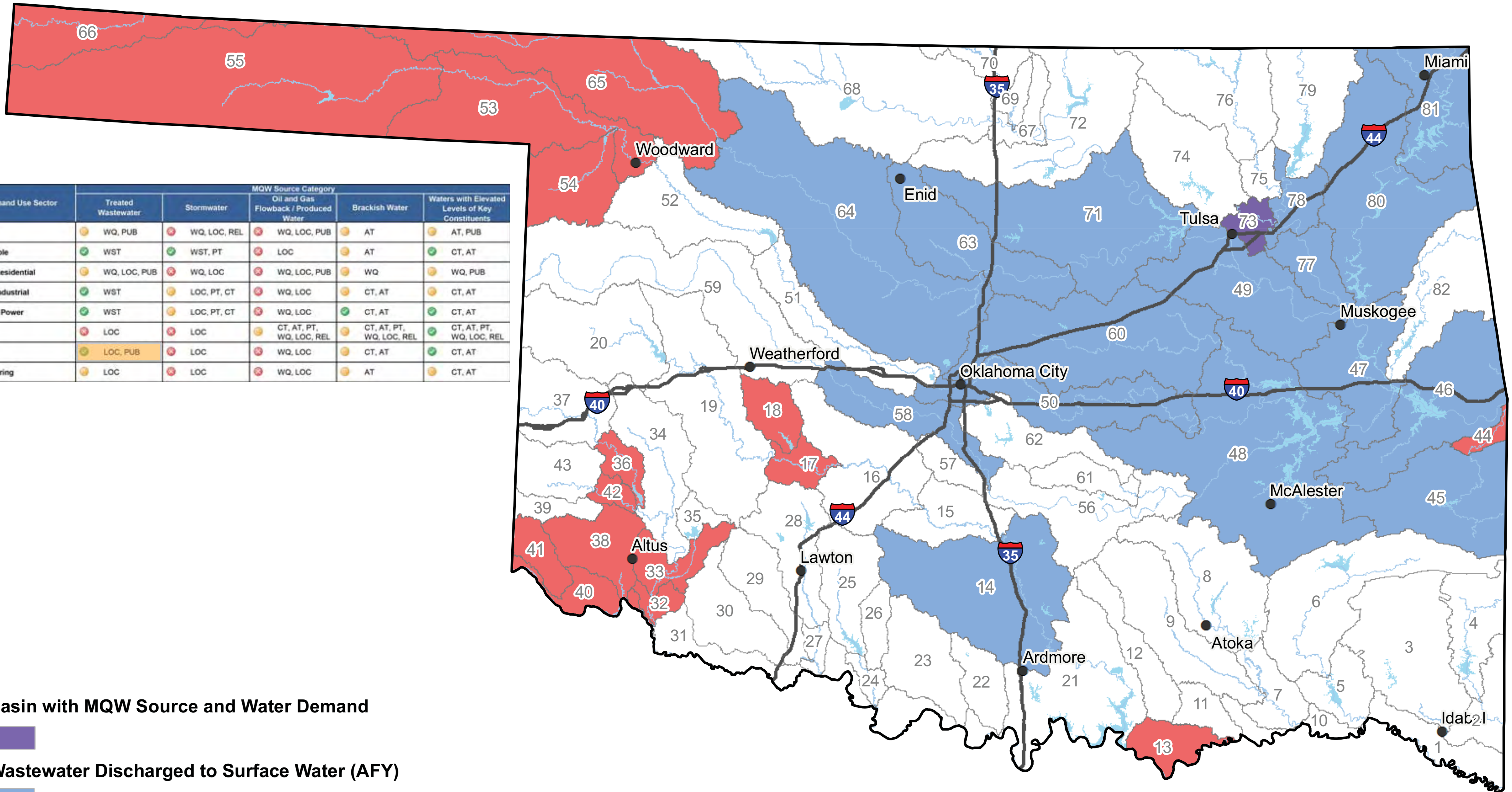
Demand Density (AF/1000 AC/year)

> 25

N
W E
S

0 50 100 Miles

Figure 5-4 - Treated Wastewater - Crop Irrigation Use (2060)



Water Demand Use Sector	MQW Source Category				
	Treated Wastewater	Stormwater	Oil and Gas Flowback / Produced Water	Brackish Water	Waters with Elevated Levels of Key Constituents
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
Thermoelectric 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

Basin with MQW Source and Water Demand

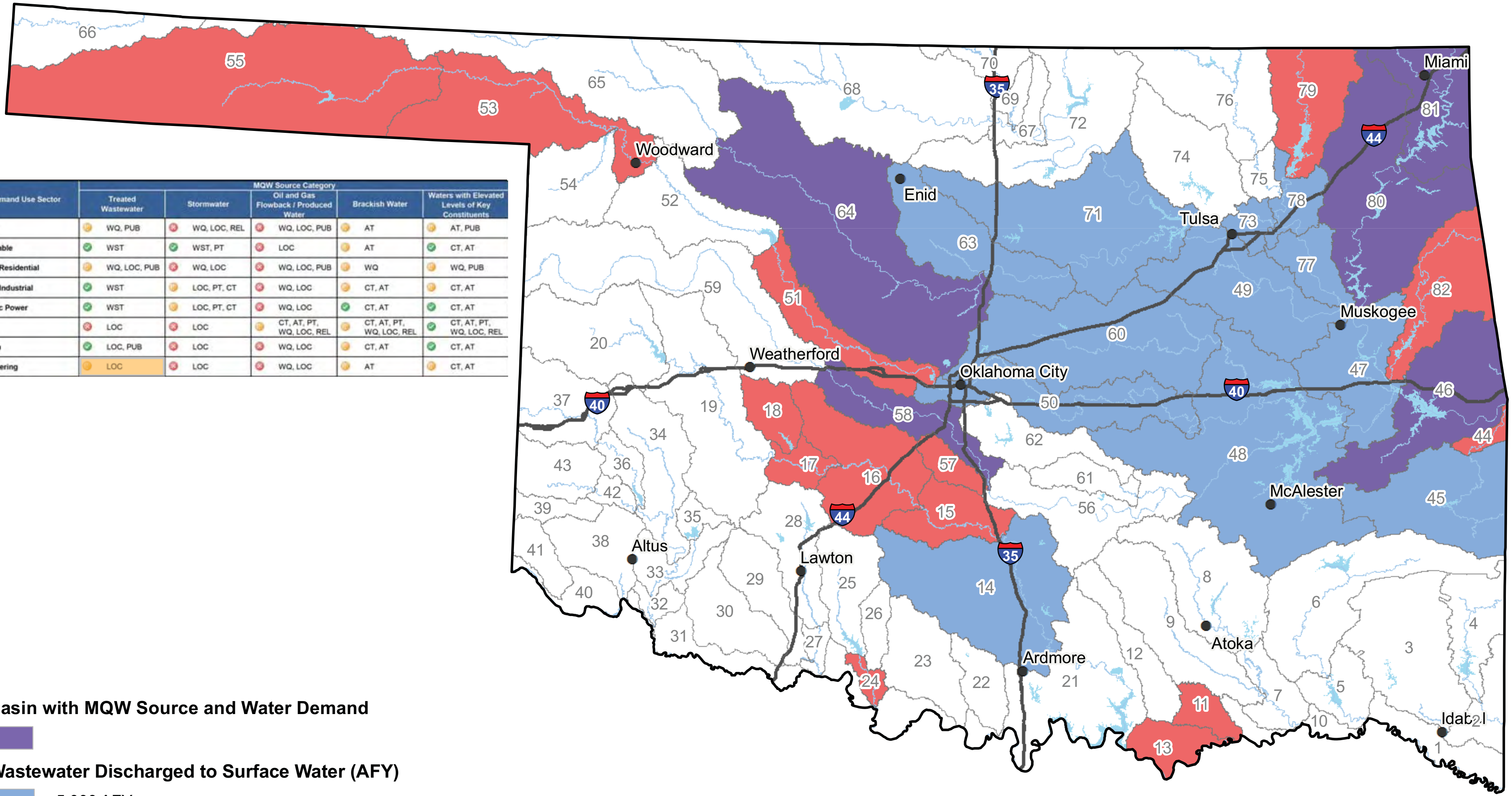
Wastewater Discharged to Surface Water (AFY)

> 5,000 AFY

Demand Density (AF/1000 AC/year)

> 25

Figure 5-5 - Treated Wastewater - Livestock Watering Use (2060)



Water Demand Use Sector	MQW Source Category				
	Treated Wastewater	Stormwater	Oil and Gas Flowback / Produced Water	Brackish Water	Waters with Elevated Levels of Key Constituents
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
Thermoelectric 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

Basin with MQW Source and Water Demand

Wastewater Discharged to Surface Water (AFY)

> 5,000 AFY

Demand Density (AF/1000 AC/year)

> 2.5

N
W E
S

0 50 100 Miles

Storm runoff is inherently variable in its availability, which in turn may require significant storage facilities to buffer its availability relative to demand patterns. For this reason, and for water quality and treatment feasibility reasons, Stormwater is likely not a strong candidate for meeting M&I potable water supply needs – except through indirect augmentation of rivers, streams, and groundwater resources. However, stormwater that is captured can serve as a source of supply for non-potable demands such as irrigation. This application is practiced in many areas of the country. Depending on the specific non-potable use, passive treatment (e.g., stormwater BMPs such as trash racks and sedimentation ponds) may be needed. For applications with more demanding water quality requirements, additional treatment may be required – with the practicality and feasibility of using stormwater decreasing as treatment needs increase.

As defined, Stormwater captured in an urban collection system is generally less conducive to use in meeting demands outside urbanized areas. This may include Self-Supplied Industrial users and Thermoelectric Power generation facilities, and is likely true for the majority of Self-Supplied Residential users. Stormwater use is not likely feasible on a wide-scale basis for Oil and Gas drilling activities, Crop Irrigation, and Livestock Watering applications. Water quality needs of each of these uses could also constrain the use of Stormwater to meet their demands.

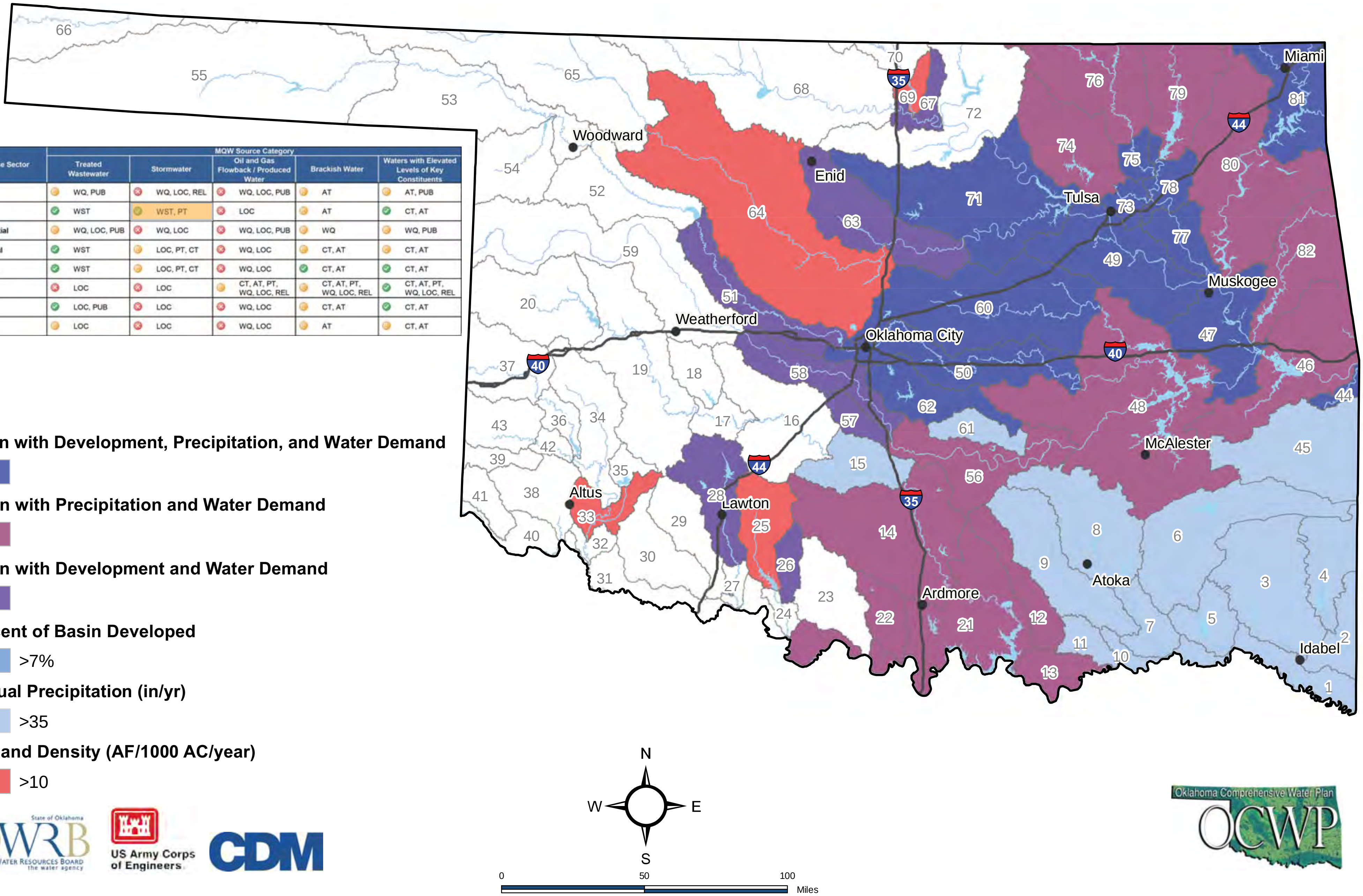
Figures 5-6 through 5-8 identify areas with the greatest potential for stormwater by showing basins with greater than 35 inches of precipitation per year and more than 7 percent of their area developed in shades of blue. Relatively high demand densities for the M&I, Self-Supplied Industrial, and Thermoelectric sectors are shown in red on Figures 5-6 through 5-8, respectively. Basins where all three categories match up are shown in a deep purple shade.

5.1.3 Oil and Gas Flowback and Produced Water

Oil and Gas Flowback and Produced Water is water that is characterized by temporary availability, as drilling and operational activities move from one site and area to another over time. Utilization of this water resource as a supply is therefore inherently challenging, as most users in the various demand sectors seek a permanent and reliable source of supply. Further complicating the use of this source is the wide range of water quality that is observed within a given drilling operation and from one area of the state to another. Due to the many variables, wells may need case by case evaluations to determine if the produced water may potentially be reused.

Thus, it is difficult to broadly characterize the feasibility of using flowback and produced water supplies to meet the various users' needs. Localized conditions such as water quality and the proximity of drilling operations to meet significant water demands will govern the feasibility of any individual situation. However, relative to other available supplies, in many cases the location and water quality of flowback and produced water may suggest that its potential for beneficial use is limited and may be most feasible for use by the oil and gas industry. The cost to treat, store, and transport flowback and/or produced water may also be cost prohibitive.

Figure 5-6 - Estimated Potential Runoff for Municipal and Industrial Use (2060)



Water Demand Use Sector	MQW Source Category				
	Treated Wastewater	Stormwater	Oil and Gas Flowback / Produced Water	Brackish Water	Waters with Elevated Levels of Key Constituents
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
Thermoelectric 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

Basin with Development, Precipitation, and Water Demand

Basin with Precipitation and Water Demand

Basin with Development and Water Demand

Percent of Basin Developed

>7%

Annual Precipitation (in/yr)

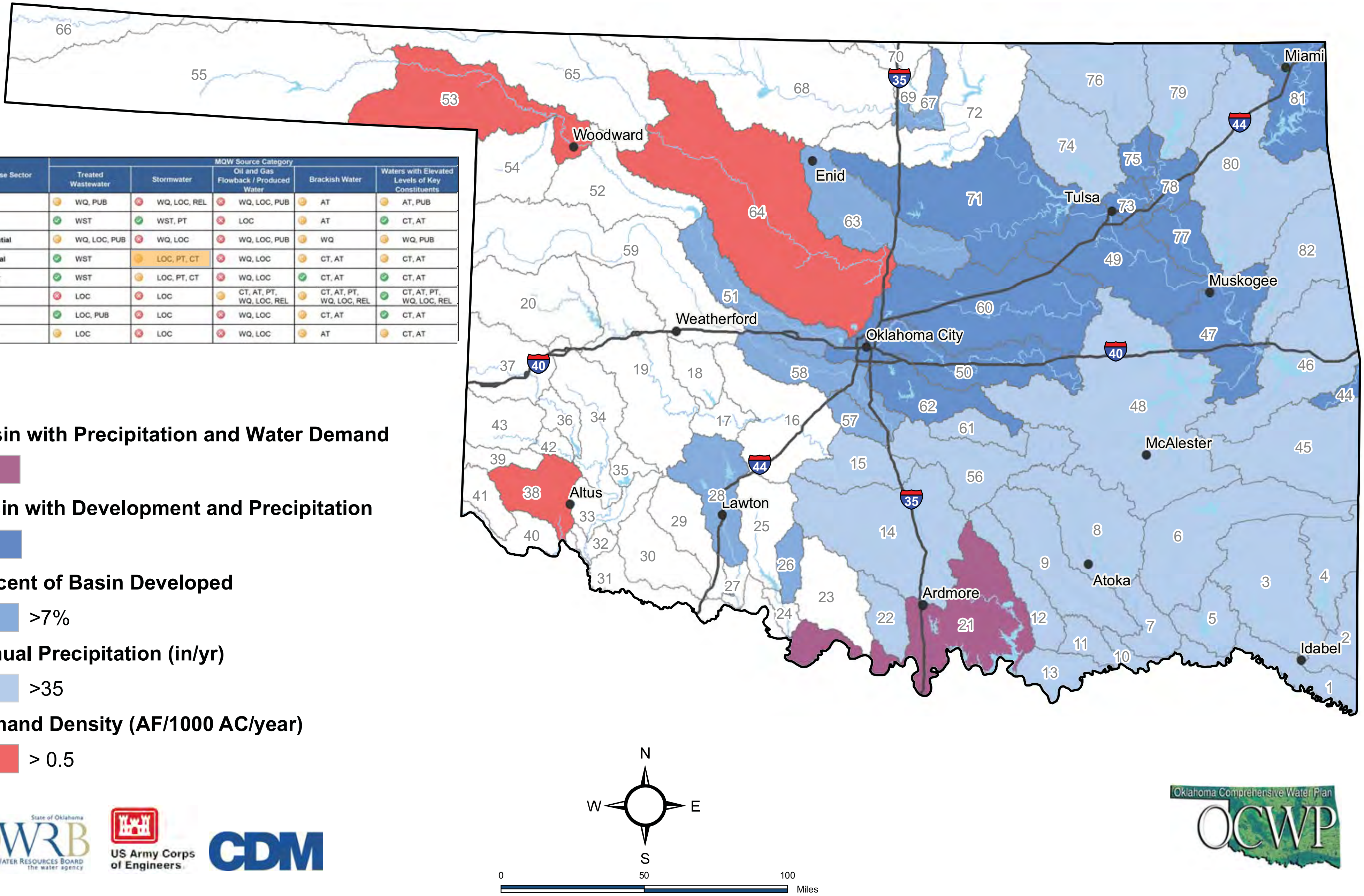
>35

Demand Density (AF/1000 AC/year)

>10

Figure 5-7 - Estimated Potential Runoff for Self-Supplied Industrial Use (2060)

Water Demand Use Sector	MQW Source Category				
	Treated Wastewater	Stormwater	Oil and Gas Flowback / Produced Water	Brackish Water	Waters with Elevated Levels of Key Constituents
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
Thermoelectric 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



Basin with Precipitation and Water Demand

Basin with Development and Precipitation

Percent of Basin Developed

>7%

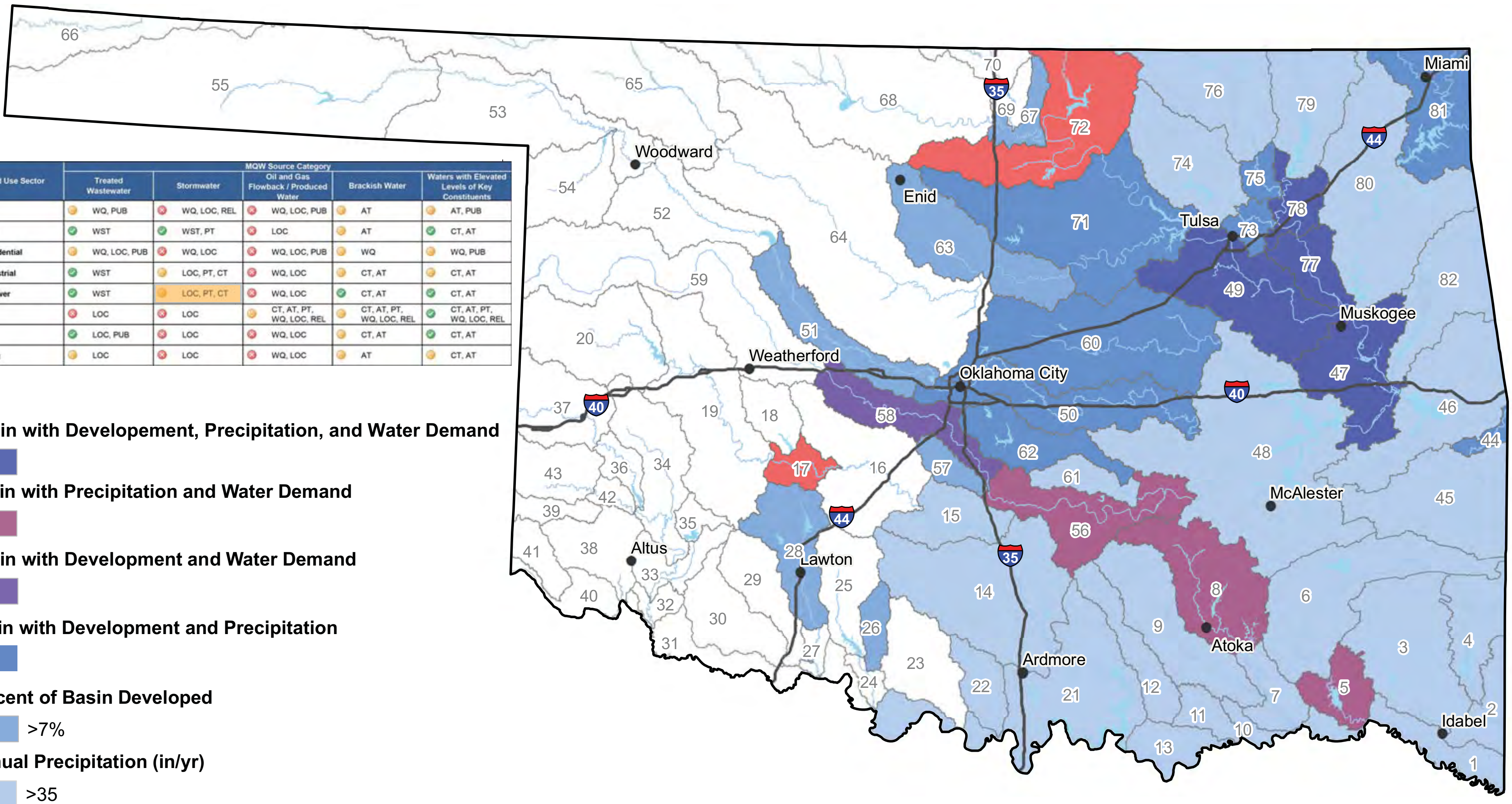
Annual Precipitation (in/yr)

>35

Demand Density (AF/1000 AC/year)

> 0.5

Figure 5-8 - Estimated Potential Runoff for Thermo-Electric Power Use (2060)



Water Demand Use Sector	MQW Source Category				
	Treated Wastewater	Stormwater	Oil and Gas Flowback / Produced Water	Brackish Water	Waters with Elevated Levels of Key Constituents
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
Thermoelectric 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

Basin with Developement, Precipitation, and Water Demand

Basin with Precipitation and Water Demand

Basin with Development and Water Demand

Basin with Development and Precipitation

Percent of Basin Developed

>7%

Annual Precipitation (in/yr)

>35

Demand Density (AF/1000 AC/year)

>25

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Perhaps the most promising potential use of this MQW resource is reuse of water produced from operating wells at nearby drilling and development activities for new wells. Some onsite treatment may be needed to achieve the required water quality for drilling or fracing, recognizing again that site-specific factors will govern any individual situation. Opportunities for reusing Flowback and Produced Water for drilling water supply was thoroughly compared to discharge and disposal options for one of Oklahoma's most active drilling areas in an industry report titled Water Availability and Use in the Woodford Shale Play (Arkoma Basin) (Environmental Resources Management Southwest, Inc. 2009). As discussed in Section 2.1.3, the report assesses the following options:

- Disposal via underground injection
- Disposal via surface discharge
- Minimization (e.g., downhole gas/water separator)
- Reuse/recycle (e.g., use for a subsequent onsite frac, trucking to offsite storage and reuse facilities, onsite treatment for potable water or a subsequent frac)
- Treatment (often in conjunction with one of the above strategies)

The report concludes that "various reuse/recycling options can be considered, though some are not feasible for the study area." Some examples of reuse and treatment activities now underway in Southeast Oklahoma are cited in the report. Figures were not developed for this MQW source because Oil and Gas Flowback and Produced Water may best be suited for internal industry use only and any opportunities are site-specific in nature.

5.1.4 Brackish Water

Brackish water supplies, whether surface water or groundwater, could be a significant source of supply to many of Oklahoma's water users in the future. As desalination treatment technologies evolve, removal of TDS and individual salt compounds are becoming more cost-effective and operationally feasible. Communities such as El Paso, Texas are turning more and more to the use of inland brackish water resources to meet potable and non-potable water demands.

Some uses are more tolerant to levels of salinity than others. Virtually any water use sector could utilize brackish water resources as a source of supply, provided that some level of salinity-reducing treatment is in place. Reducing salinity levels requires advanced treatment processes, such as reverse osmosis (RO) or ion exchange, as described further in Section 6. Some industrial users and some of the more salt-tolerant crops described in Section 4.6.2, may be able to use brackish supplies without treatment.

Also, some livestock groups are more tolerant of salinity than others. For example, poultry are reported to be generally less tolerant of saline water, whereas dairy and beef cattle can tolerate salinity concentrations as high as 8,800 mg/L TDS. This may present opportunities to utilize brackish water resources in areas where brackish supplies are available and salinity-tolerant livestock are raised. For reference, the top five counties in

Oklahoma for cattle from 2009 to 2010 according to the National Agricultural statistics were

- Texas (370,000 head),
- Osage (240,000 head),
- Caddo (160,000 head),
- Cimarron (150,000 head), and
- Grady (140,000 head).

Self-supplied Residential users are less likely to utilize Brackish Water resources because of the need to reduce TDS for aesthetic acceptability for potable use, and the practical limitations of employing onsite advanced treatment processes at an individual residence.

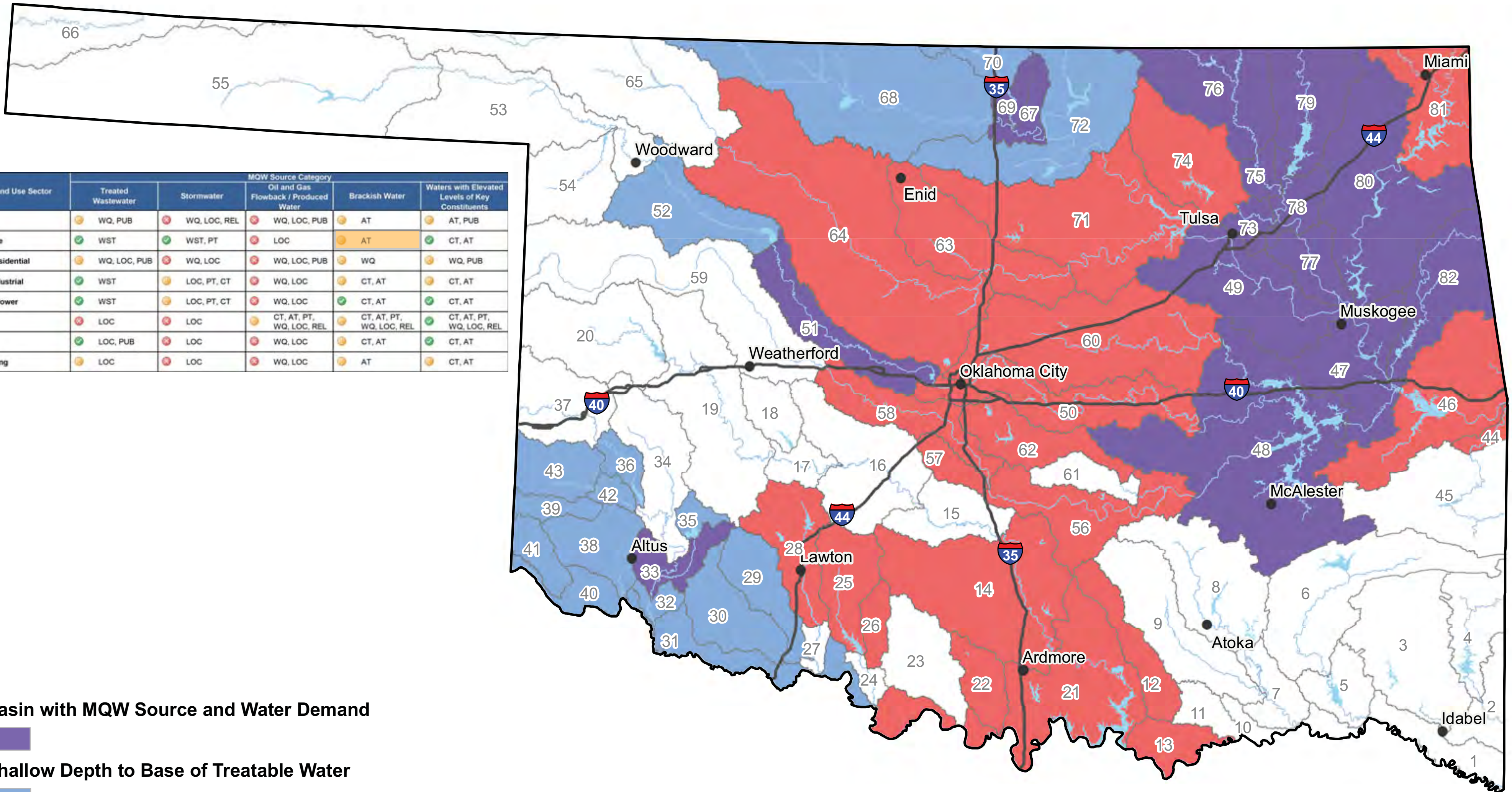
The base to treatable water map (see Figure 2-3) was used to determine where brackish groundwater may be more easily accessible for future uses. Figures 5-9 through 5-14 highlight (in blue) basins where the depth to 10,000 mg/L TDS was relatively shallow (majority of depth contours were approximately 100 ft). A relatively shallow depth indicates that the source of brackish water may be relatively accessible if needed. Basins highlighted in blue were located in the north-central portion, northeast and southwest corners of the state. Note, much of this area has minor aquifers or do not have a delineated aquifer, which indicates relatively low availability of fresh groundwater supplies. Relatively high demand densities for the following sectors: M&I, Self-supplied Residential, Self-Supplied Industrial, Thermoelectric Power, Crop Irrigation, and Livestock Watering are shown in red on figures 5-9 through 5-14, respectively. Basins with coinciding higher demand densities and relatively shallow depths to brackish groundwater vary by demand sector.

5.1.5 Waters with Elevated Levels of Key Constituents

Waters with elevated levels of key constituents such as nitrates were primarily defined around potable use of available water resources. Therefore, utilization of MQWs with elevated levels of these constituents is better-suited for non-potable applications such as M&I non-potable demands, oil and gas drilling, thermoelectric water needs and crop irrigation. M&I potable use would require advanced treatment for most waters fitting this category, and conventional or advanced treatment may be required for use in Self-Supplied Industrial, Thermo-electric Power, and Livestock Watering categories – depending on the specifics of the available water quality and the water quality requirements of each user. For reasons similar to those described in Section 5.1.4, waters with elevated levels of key constituents are likely not good candidates for meeting the needs of Self-supplied Residential users.

The spatial assessment for MQW sources with elevated levels of key parameters and each demand sector was completed by highlighting all sampling locations with mean concentrations above the thresholds presented in Table 2-5 and shading basins with relatively high demand densities in red.

Figure 5-9 - Brackish Groundwater for Municipal and Industrial Use (2060)



Water Demand Use Sector	MQW Source Category				
	Treated Wastewater	Stormwater	Oil and Gas Flowback / Produced Water	Brackish Water	Waters with Elevated Levels of Key Constituents
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
Thermoelectric 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

Basin with MQW Source and Water Demand

Shallow Depth to Base of Treatable Water

Demand Density (AF/1000 AC/year)

> 10

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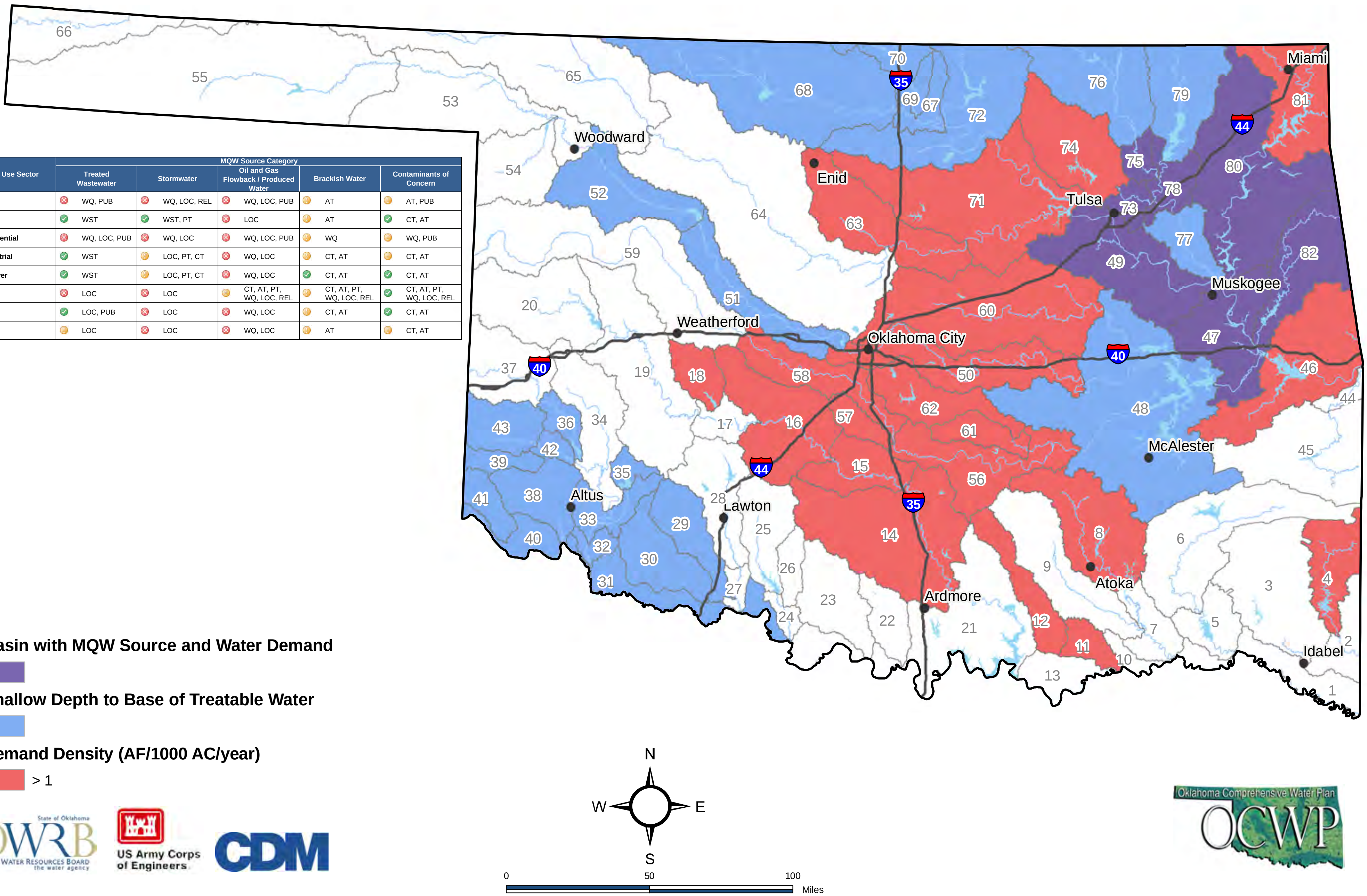
Figure 5-10 - Brackish Groundwater for Self-Supplied Residential Use (2060)



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
Thermoelectric 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

Basin with MQW Source and Water Demand

Shallow Depth to Base of Treatable Water

Demand Density (AF/1000 AC/year)

> 1

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Figure 5-11 - Brackish Groundwater - Self-Supplied Industrial Use (2060)

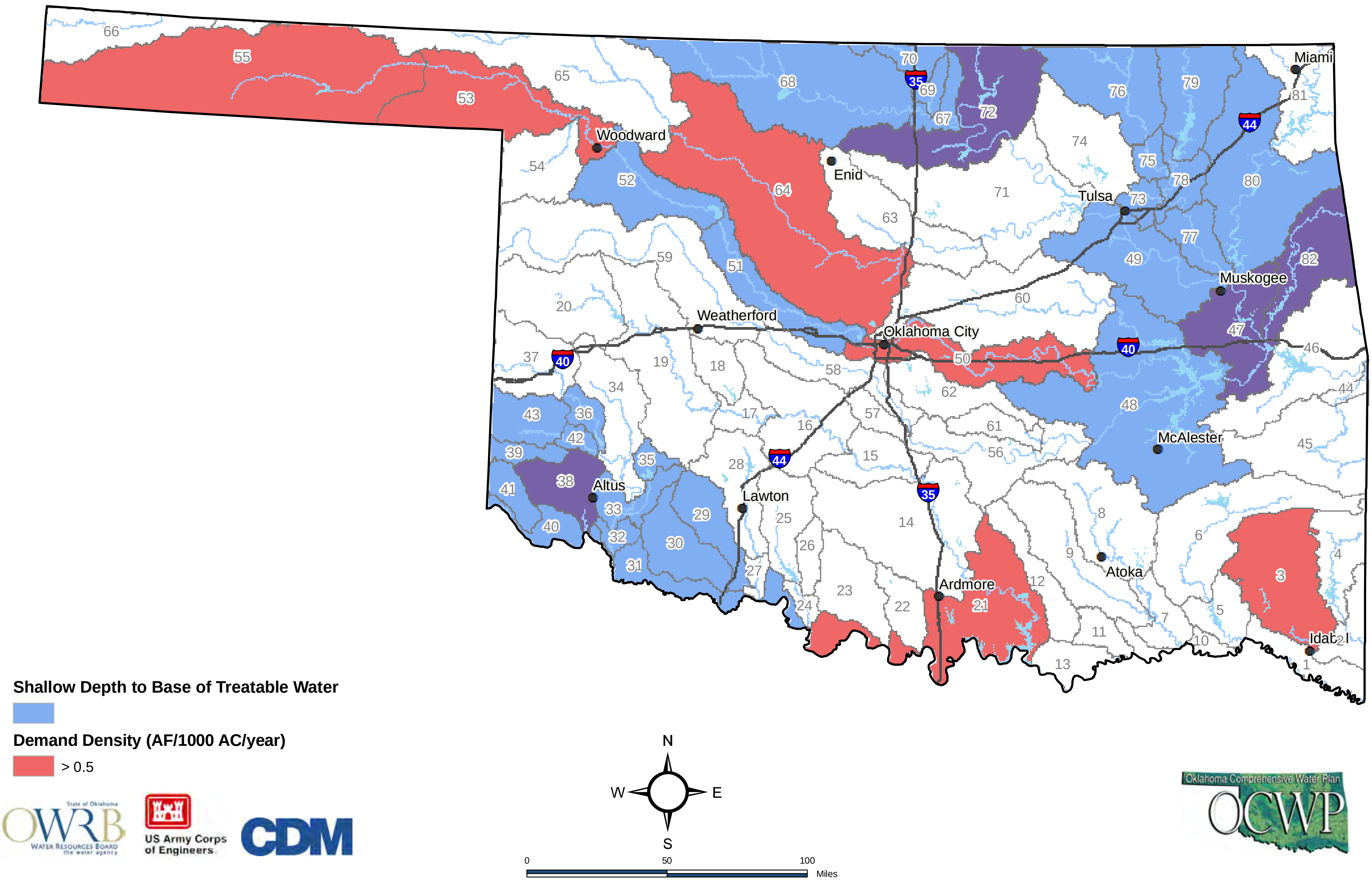
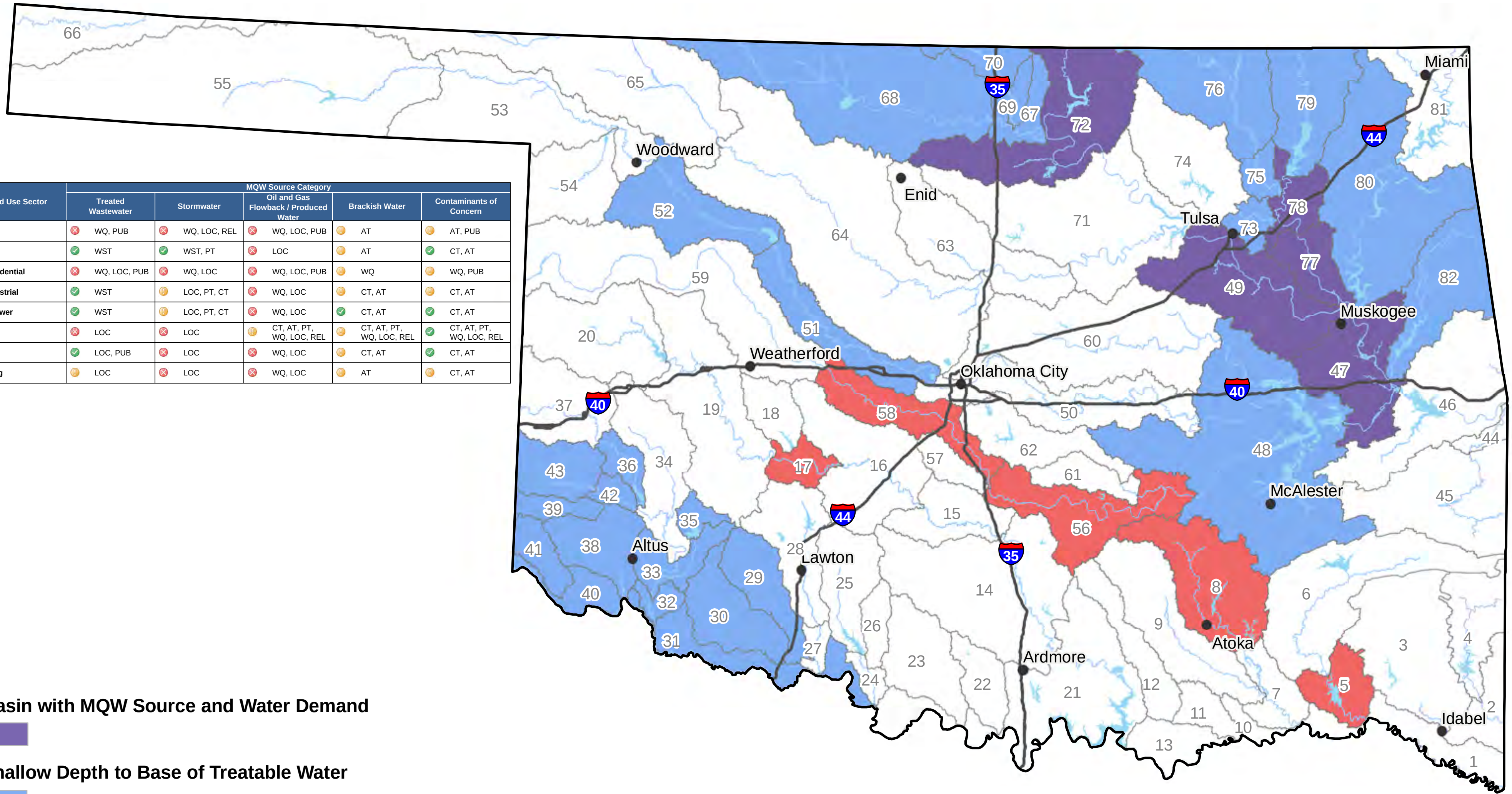


Figure 5-12 - Brackish Groundwater for Thermoelectric Power Use (2060)



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
Thermoelectric 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

Basin with MQW Source and Water Demand

Shallow Depth to Base of Treatable Water

Demand Density (AF/1000 AC/year)

> 25

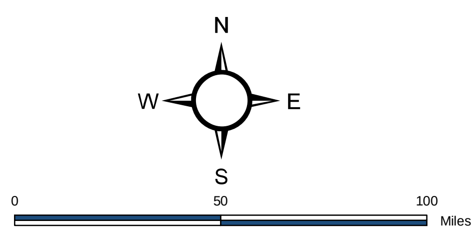


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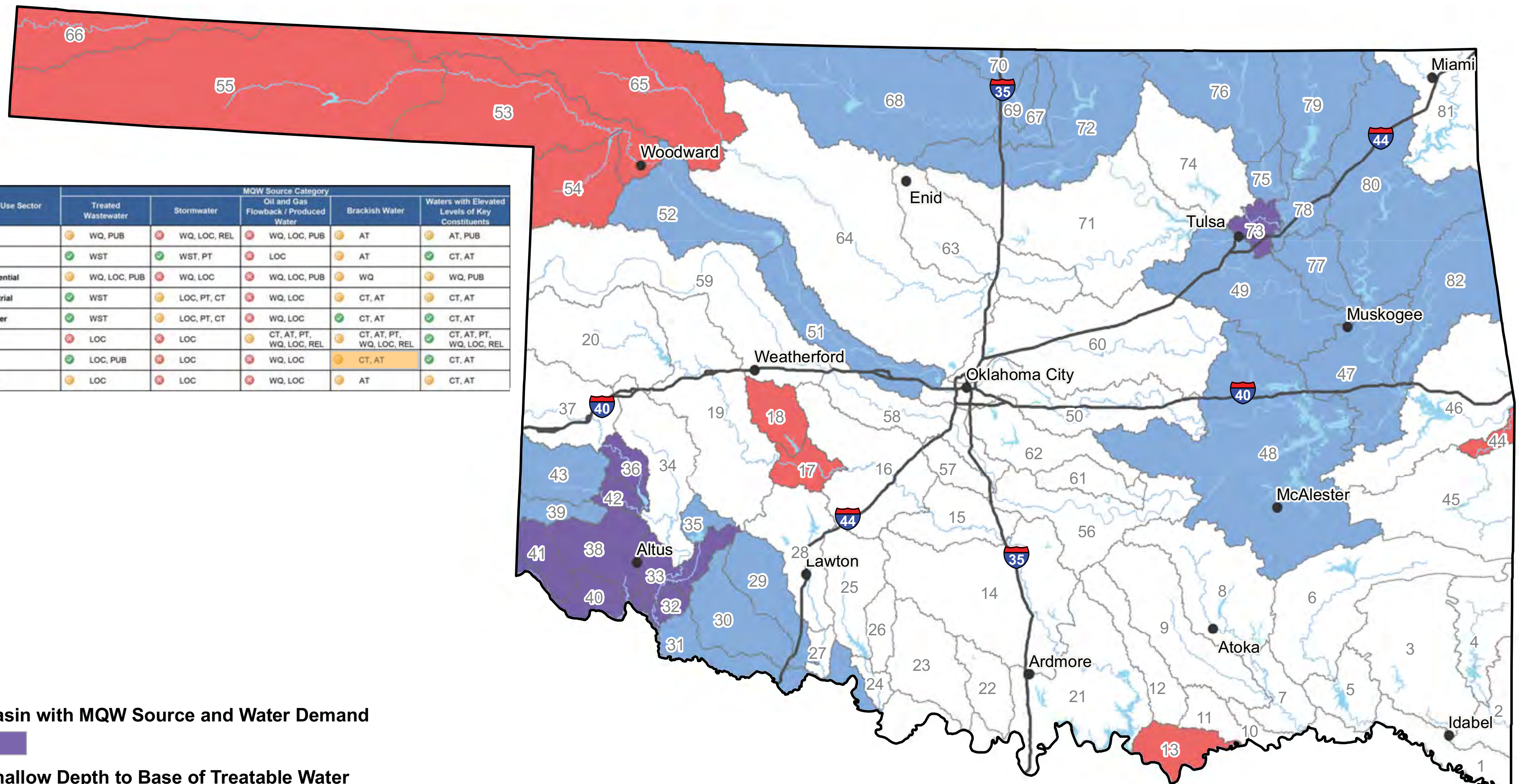
Figure 5-13 - Brackish Groundwater for Crop Irrigation Use (2060)



Water Demand Use Sector	MQW Source Category				
	Treated Wastewater	Stormwater	Oil and Gas Flowback / Produced Water	Brackish Water	Waters with Elevated Levels of Key Constituents
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
Thermoelectric 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

Basin with MQW Source and Water Demand

Shallow Depth to Base of Treatable Water

Demand Density (AF/1000 AC/year)

> 25

N
W E
S

0 50 100 Miles

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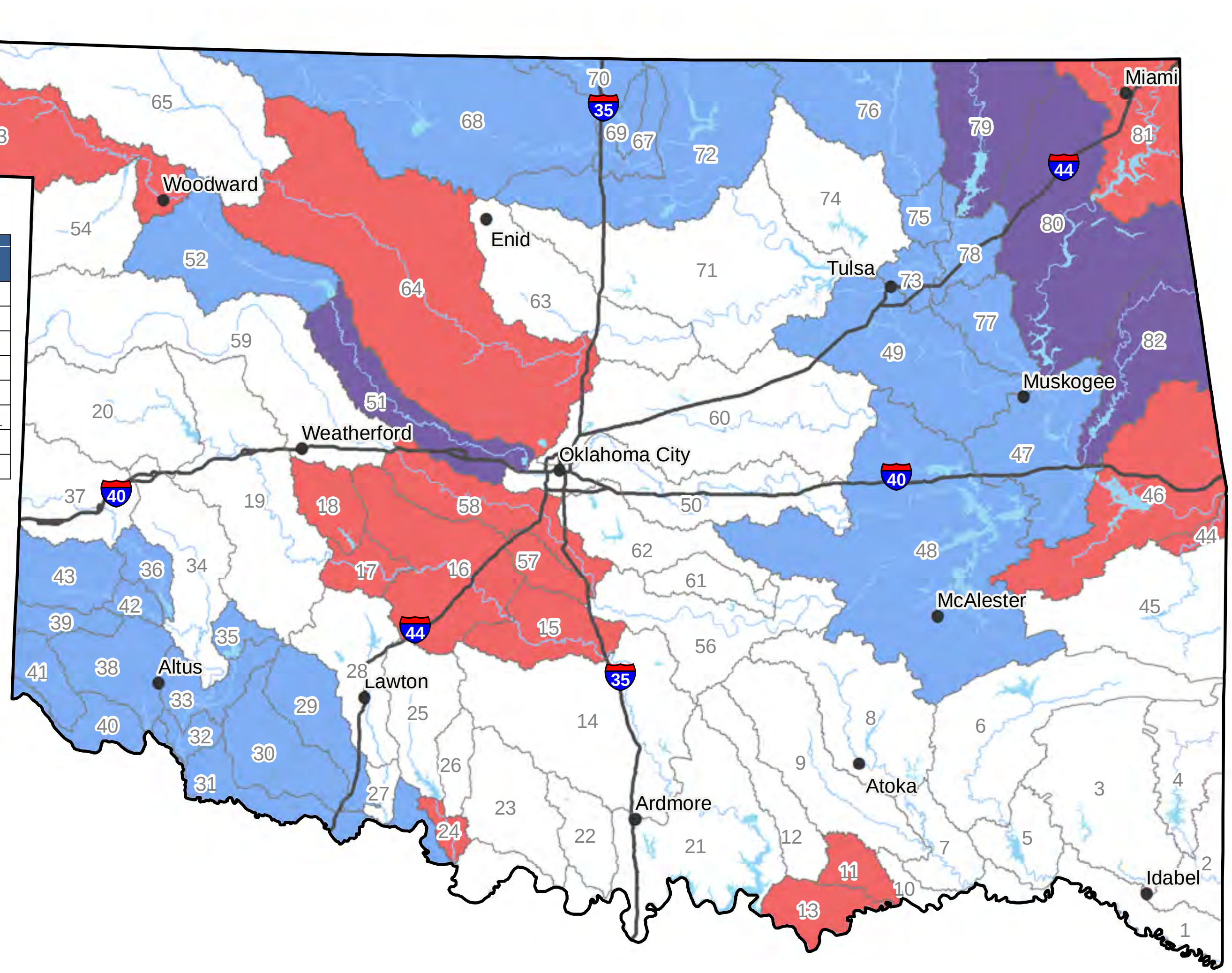
Figure 5-14 - Brackish Groundwater for Livestock Watering Use (2060)



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
Thermoelectric 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

Basin with MQW Source and Water Demand

Shallow Depth to Base of Treatable Water

Demand Density (AF/1000 AC/year)

> 2.5

N
W E
S

0 50 100
Miles

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Figure 5-15 - Surface Waters with Elevated Levels of Key Constituents - Municipal and Industrial Demands (2060)

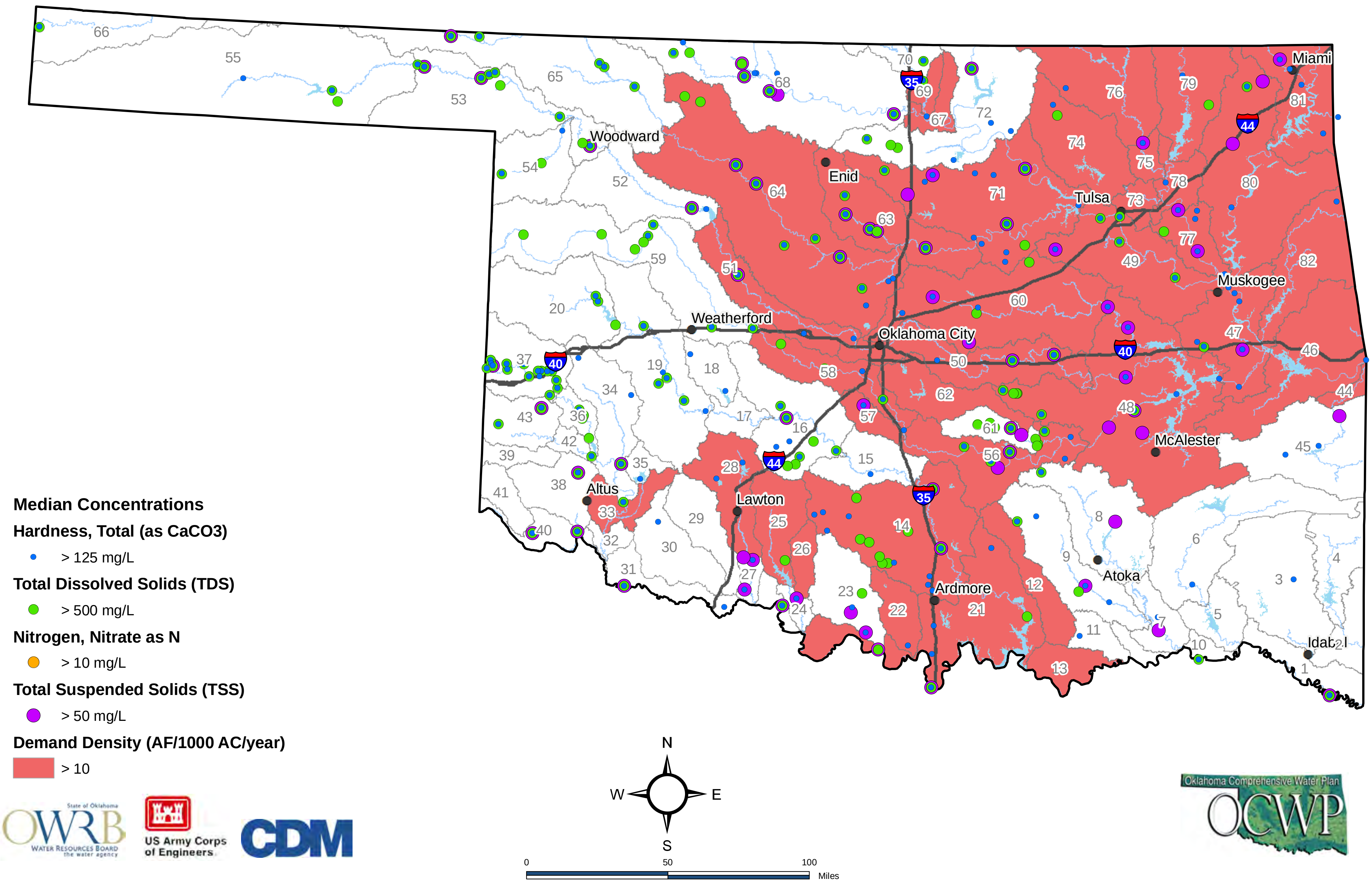
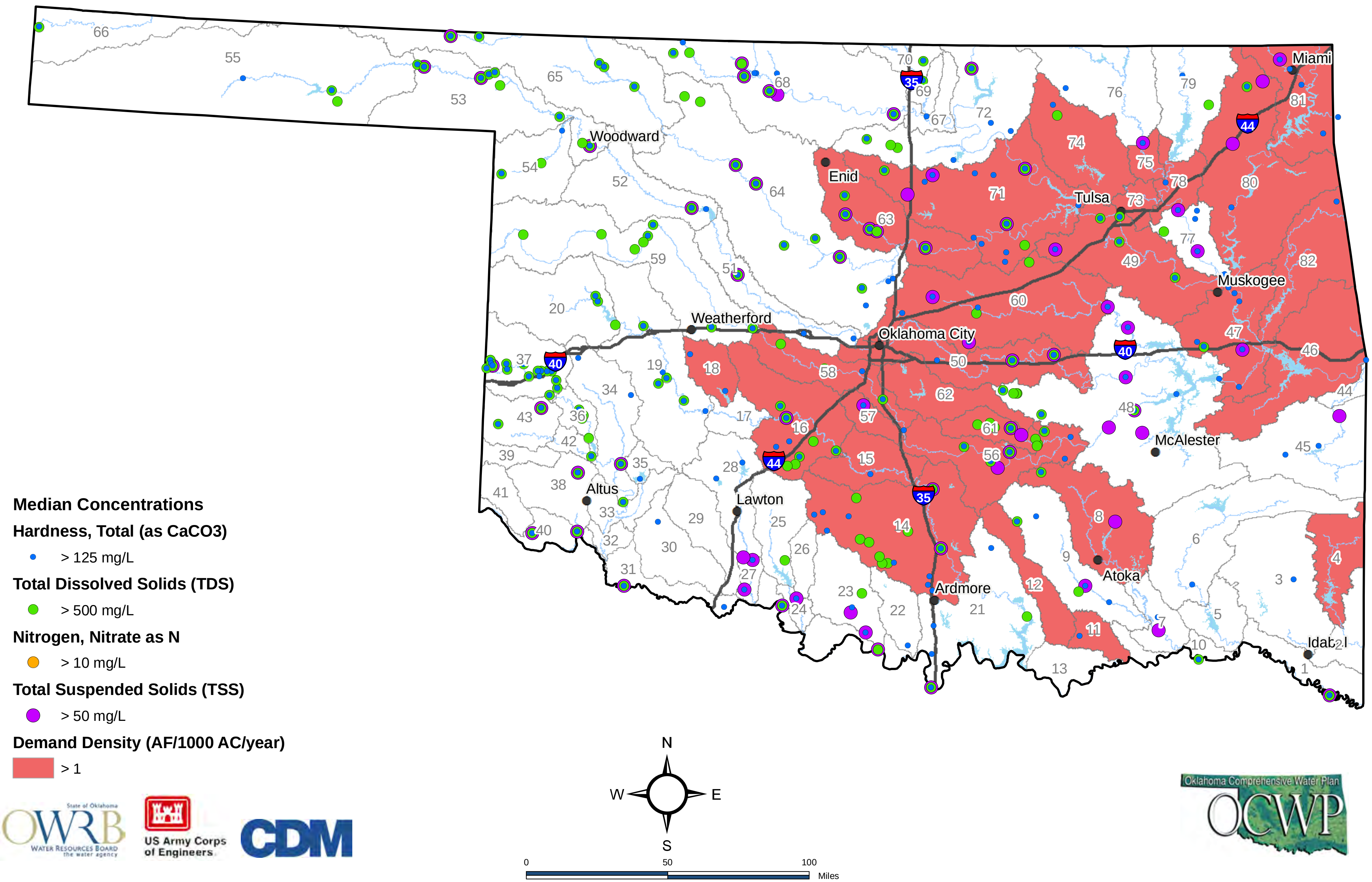


Figure 5-16 - Surface Waters with Elevated Levels of Key Constituents - Self-Supplied Residential Demands (2060)



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Oklahoma Comprehensive Water Plan OCWP

Figure 5-17 - Surface Waters with Elevated Levels of Key Constituents - Self-Supplied Industrial Demands (2060)

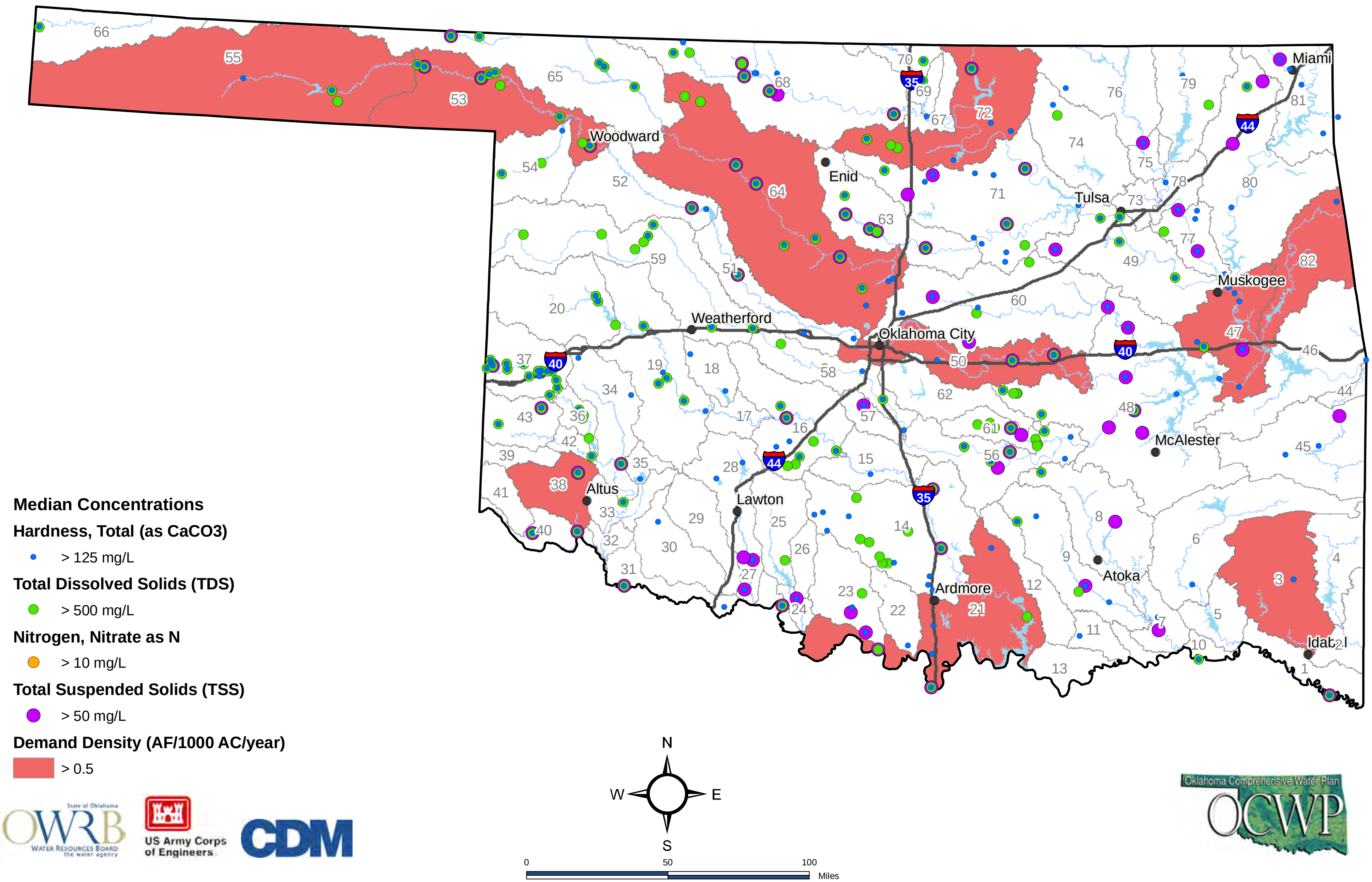


Figure 5-18 - Surface Waters with Elevated Levels of Key Constituents - Thermoelectric Power Demands (2060)

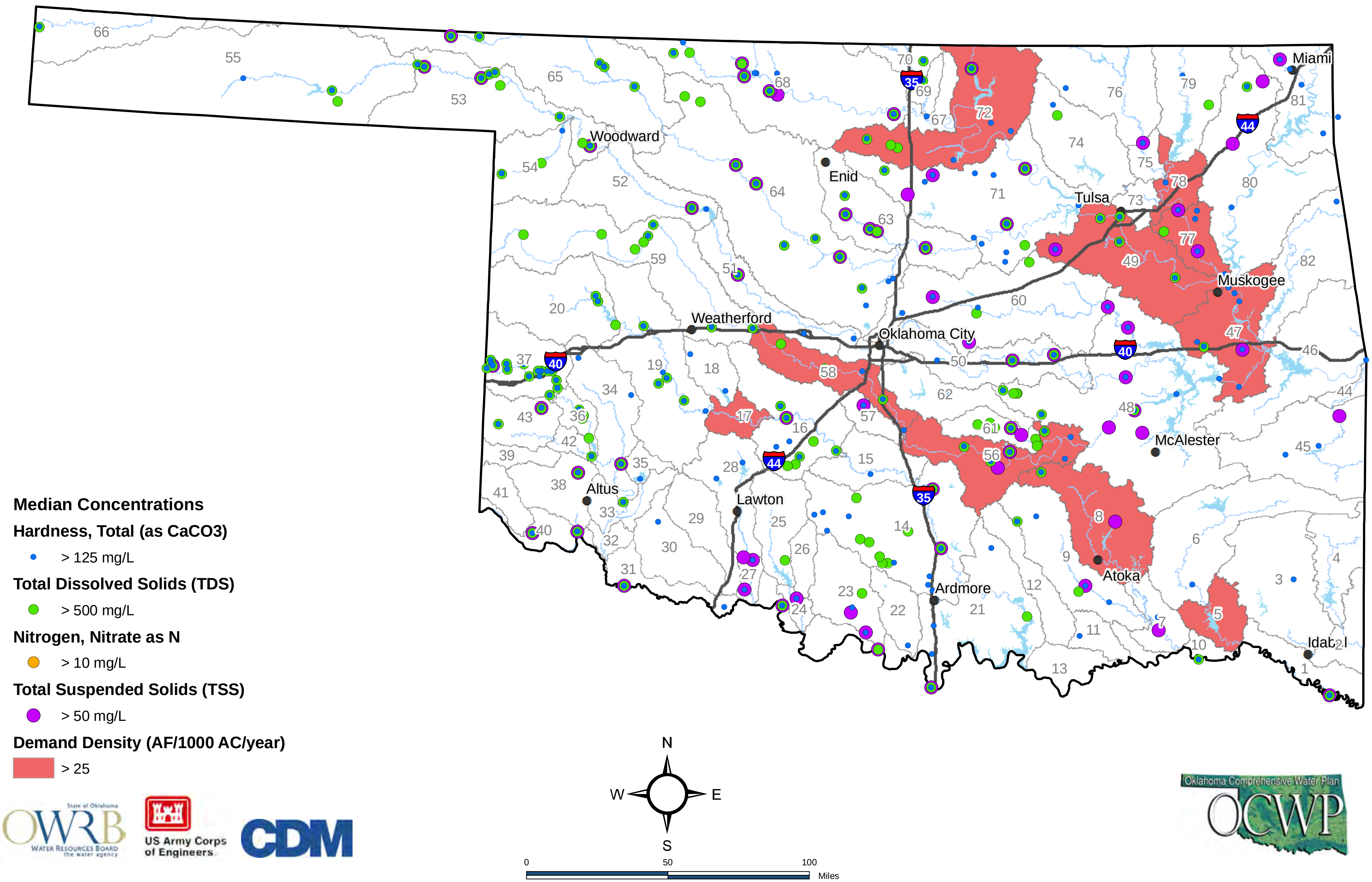


Figure 5-19 - Surface Waters with Elevated Levels of Key Constituents - Crop Irrigation Demands (2060)

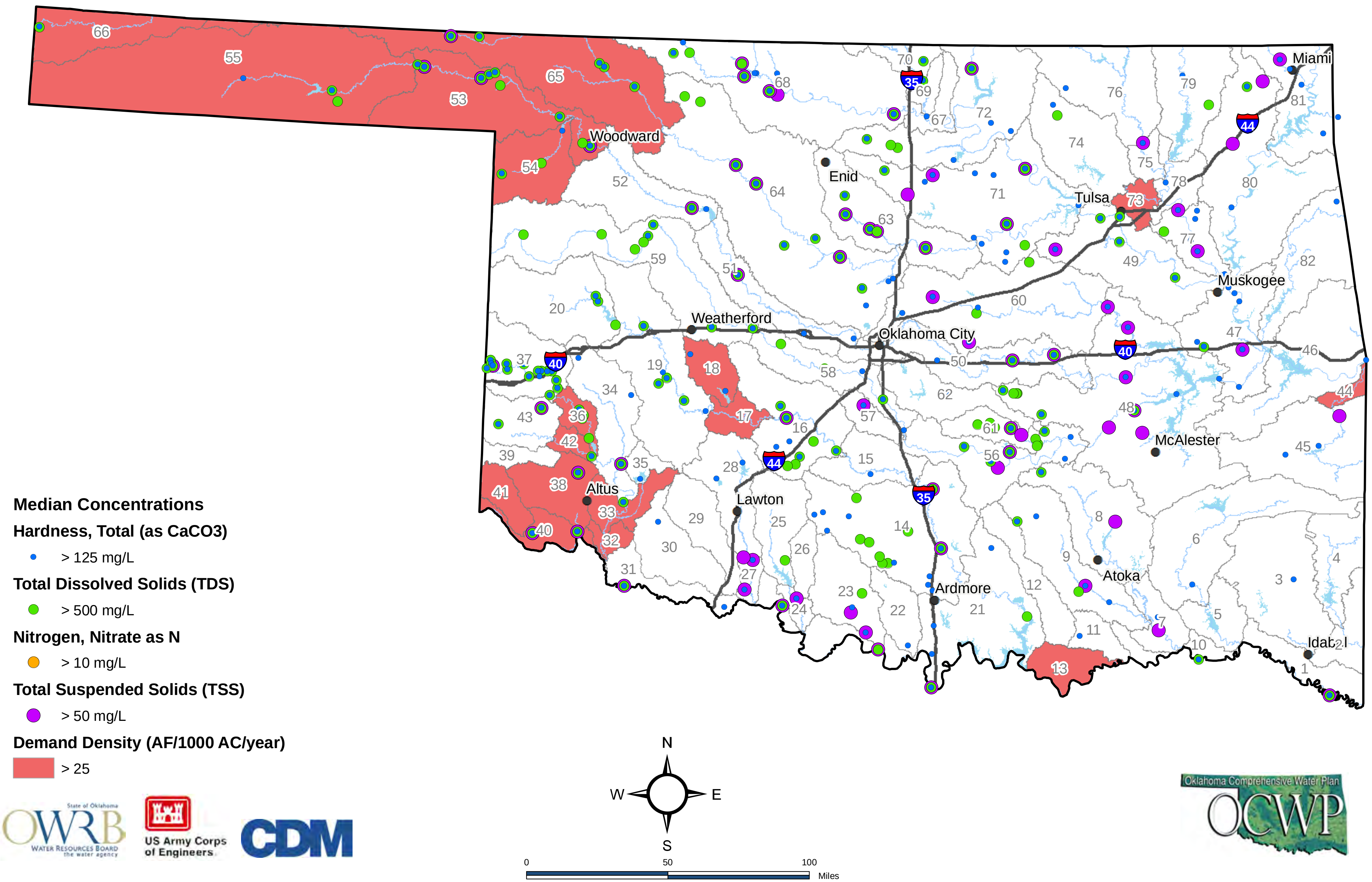
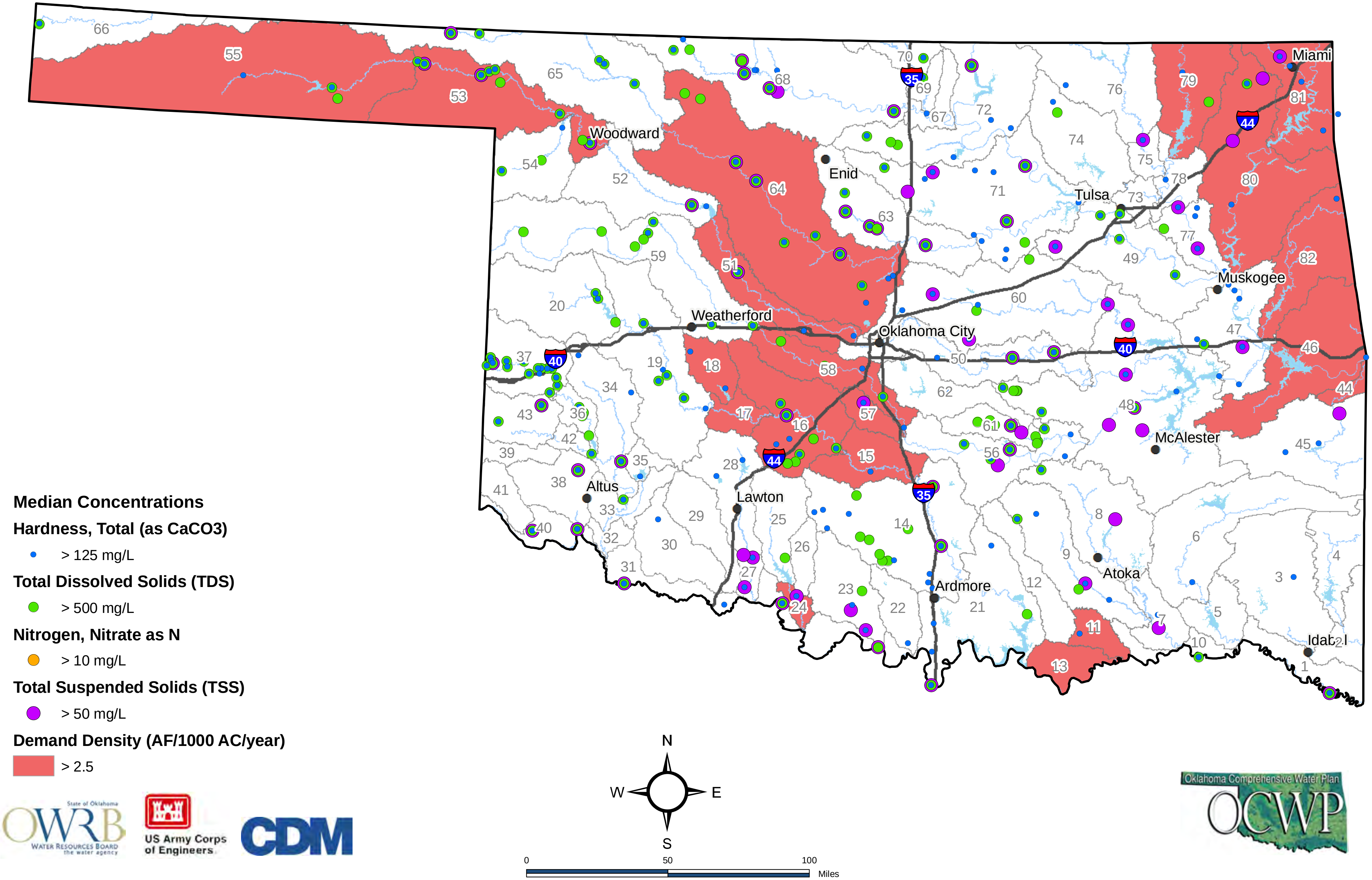


Figure 5-20 - Surface Waters with Elevated Levels of Key Constituents - Livestock Watering Demands (2060)



US Army Corps of Engineers

CDM

Oklahoma Comprehensive Water Plan

Section 6
Potential Treatment Solutions

Some MQW supplies might only meet a given demand sector's needs with adequate treatment. This section describes the treatment processes and planning-level costs that may be required to meet the users' water quality needs. This discussion focuses on treatment for the M&I water use sector, recognizing that treatment plant infrastructure is most commonly and feasibly used to address water quality gaps between untreated supplies and end users' needs. In contrast, many other users' demands and systems are small, self-supplied, and/or remote. In many of those situations, the economics and operational requirements of localized or onsite treatment can have significant challenges.

Table 5-1 identified potential opportunities to use MQW for various water demand sectors. It may not be feasible at this time to address all of the constraints on the use of MQW sources (e.g., location of supplies relative to demands, water quality requirements, and/or non-reliable supplies). However, with various degrees of treatment, some constraints may be eased or overcome so that MQWs can help meet the needs of water users across the state.

6.1 Passive Treatment

Passive treatment was identified in Table 5-1 for some applications of stormwater. This may be feasible for use of stormwater for irrigation purposes where the irrigation demands are located in an area that can easily capture storm events and readily distribute the water within a reasonable distance. The term passive treatment refers to treatment technologies that can function with little or no operation or maintenance over long periods of time. For stormwater, this could include catchment basins or cisterns to store runoff for future use and/or the application of minimal BMPs such as trash screens or sedimentation basins to improve water quality.

6.2 Conventional Treatment

EPA and the State of Oklahoma require all surface water and groundwater under the influence (GWUI) of surface water to be filtered and receive 3 logs (99.9 percent) of *giardia* and 4 logs (99.99 percent) of virus removal or inactivation before distributing it as potable water for M&I use. This requires either a conventional treatment process (coagulation, flocculation, sedimentation, filtration, and disinfection) or a conventional membrane filtration and disinfection process. Therefore, even very high quality, low turbidity water requires the base treatment process, and this addresses the turbidity, color, microbial quality, organics, metals, and disinfection byproducts issues for most water sources. Many MQW sources would require supplemental treatment processes to address specific contaminants not removed by a conventional treatment process or otherwise reduce WTP reliability, or significantly increase capital and operating costs.

The type of water treatment processes used can be dependent on the level of the contaminants, but is also dependent on the final water quality goals selected by the end user. Therefore, some water sources may be considered marginal because they result in unsatisfactory aesthetic quality such as hardness, taste, odor, or color. A high cost for conventional treatment due to high turbidity, dissolved organics, or objectionable taste may also result in designation of a water source as marginal. Softening, aeration, and even granular activated carbon (GAC) are examples of current treatment processes added to conventional WTPs to address typical aesthetic water quality problems associated with some MQW sources.

6.3 Advanced Treatment

Deep alluvial groundwater not under the influence of surface water and deep bedrock groundwater does not require conventional coagulation and filtration treatment. In these cases, the source may be considered marginal only if there are specific contaminants that require treatment processes in addition to chlorination disinfection. Examples of marginal groundwater quality include contamination with pesticides, volatile organic compounds (VOC), synthetic organic compounds (SOC), hydrocarbons, inorganic metals or salts, and radionuclides. GAC for VOCs and pesticides, granular ferric hydroxide (GFH) for arsenic, strong base anion exchangers for perchlorate and uranium, manganese greensand for iron and manganese removal are commonly used treatment processes to remove these contaminants, but the cost to treat the water increases significantly. Low pressure reverse osmosis (LPRO) can be used to treat MQW sources with high TDS and hardness that cannot be blended with other sources to achieve the water quality goals established by the utility.

Lower stream flows in certain parts of the state could result in a high percentage of wastewater effluent or runoff from animal waste, including wildlife and domestic pets, that could result in water sources being classified as MQW for M&I supply due to the high risk for pathogen contamination and designation of the water source as Bins 2, 3, or 4 under EPA's Long Term 2 Enhanced Surface Water Treatment Rule. This results in the need for additional inactivation/removal credit for *giardia*, *cryptosporidium*, and viruses, and could result in the installation of ozone, ultraviolet (UV), or membrane filtration systems.

MQW can also be associated with shallow reservoirs with lots of vegetation or sediments that result in high dissolved organics, algae, iron manganese, and oxygen depleted environments that results in significant taste, odor, and disinfection byproduct (DBP) issues. In this case it is not nitrate and phosphorus leading to algae blooms, but the inherent nature of the shallow impoundments. There are also examples of water sources with a specific parameter or two that exceed the maximum contaminant level (MCL), and the parameters are not generally removed by a conventional WTP such as fluoride, arsenic, radionuclides, cyanide, cadmium, lead, hydrocarbons, etc. These could be associated with historical mining activities, oil drilling, or natural formations (salt plains and gypsum hills). The type of treatment required for these MQW supplies is difficult to generalize.

A typical progression in selecting a water treatment process involves balancing the reliability of the supply, distance to the users, raw water quality, final water quality goals, cost of water treatment, complexity of operation, residuals disposal, and existing operations. A general summary of the common water treatment processes from the simplest to the most complex is shown in Table 6-1.

Table 6-1 Summary of Common Water Treatment Processes

Water Quality Issue	Treatment Process
Base requirement for groundwater not under the influence of surface water	Disinfection with gas chlorine or sodium hypochlorite
Groundwater under the influence	Pressure filters or microfiltration (MF) + chlorine disinfection ***or*** UV disinfection
Base requirement to treat surface water for turbidity, organics, *giardia*, bacteria, and viruses	Conventional treatment = coagulation + flocculation + dual media filtration + disinfection ***or*** Conventional treatment = coagulation + membrane filtration + disinfection
Surface water with high turbidity results in high solids loadings	Conventional treatment = coagulation + flocculation + clarification + filtration + disinfection
Surface water with high organics or dissolved iron or manganese resulting in high chemical dosages and raw water and finished water pH adjustments	Enhanced coagulation pH reduction + coagulation + flocculation + sedimentation + filtration + disinfection + pH adjustment • Flocculation/clarification options (Actiflo, Super Pulsators, Contact Clarifiers, inclined plates, roughing filters, MIEX) • Filtration options (microfiltration, ultrafiltration, dual sand/anthracite filters, sand/GAC filters, greensand filters, monomedia)
Surface water with significant taste and odor issues, high organics contributing to high levels of disinfection byproducts, high concentrations of *giardia* or *cryptosporidium*, algal toxins	Conventional treatment with advanced oxidation (ozone, UV/peroxide)- coagulation + flocculation + filtration + ozone + disinfection
Surface water with high hardness	Conventional treatment with lime softening
Groundwater with organic or inorganic contaminants	VOCs – GAC, air stripping, advanced oxidation SOCs – GAC, air stripping, advanced oxidation Arsenic – granular ferric hydroxide or iron precipitation Nitrate – Ion Exchange Perchlorate – Ion Exchange Selenium – Ion exchange Radionuclides – ion exchange or precipitation
Groundwater with high hardness	Ion exchange or Lime Softening
Groundwater with high organics and color	Nanofiltration or ion exchange
Groundwater well with TDS and/or nitrates	LPRO or electro-dialysis reversal (EDR) or blending
Highly impaired surface water or reclaimed wastewater	Conventional treatment + LPRO + UV + corrosion control + disinfection

6.4 Relative Water Treatment Cost Information

As the quality of the raw water diminishes, more extensive treatment processes are required, and the capital and operating cost of the treatment system increases. Generally there is a gradual increase in the present worth cost of the construction and ongoing operating costs. The optimum balance between the initial capital cost and the operating cost will vary between utilities, depending on the financing for the project and the capabilities of the operations staff. Table 6-2 compares the costs for a range of treatment alternatives, from simple well systems to complex surface water treatment processes treating highly impaired waters.

Table 6-2 Planning Level Construction Costs for Various Water Treatment Processes

Treatment Process	Planning Level Construction Costs[1] $/gal/day of capacity	Operating Costs[2] $/MG treated
Groundwater Wells + disinfection (GW base process)	$0.20 to 0.30	$60
GW Base Process + GAC	$0.40 to 0.50	$170
GW Base Process + Ion Exchange	$0.40 to 0.80	$100 - $600
GW Base + RO	$1.40 to $3.00	$500 - $1000
SW Coagulation + Filtration + disinfection (SW base process)	$1.50 to $3.00	$100 - $400
SW base process + sedimentation	$2.00 to $4.00	$200 - $500
SW base process using MF or ultrafiltration (UF)	$1.50 to $3.00	$300 - $700
SW base process + enhanced coagulation	$2.00 to $4.00	$400 - $700
SW base process + lime softening	$2.00 to $4.00	$400 - $700
SW base process + enhanced coagulation + advanced oxidation	$3.00 to $5.00	$600 - $900
SW base process using MF or UF + RO + pH adjustment + UV	$5.00 to $7.00	$1500 - $3000

(1) Furnish and install equipment and ancillary facilities including buildings, residuals handling, controls, electrical and piping to transfer the raw water to the treatment plant and delivery it to a distribution system pump station. The cost does not include treated water storage or pump station.

(2) Operating costs include power, chemicals, laboratory, and operating labor to transfer raw water to the treatment facility and delivery it to the distribution system pump station. The costs do not include any water rights costs, utility management overhead, insurance, or pumping costs into the distribution system. Electrical costs were assumed to be $0.10 / kW-hr.

Section 7
Conclusions and Recommendations

Opportunities for increased utilization of MQW supplies may exist at local and statewide levels for several combinations of MQW supply and Oklahoma's seven water demand sectors. Site- and project-specific conditions will affect the economics, technical viability, and user acceptance of every project. Historical limitations on the use of MQW to meet various water needs have likely been based on the economics of its use relative to other source-of-supply options. However, this statewide screening analysis provides insights into the relative viability of using MQW supplies to meet Oklahoma's future water needs.

Specifically, the following trends were identified through this analysis:

- **Treated Wastewater** from municipal treatment facilities, often referred to as "water reuse," is a potentially viable source of supply for non-potable uses, rather than discharging the water into area streams. Because supplies are greater in and near the state's cities and towns, M&I non-potable demands (e.g., landscape irrigation) and some industrial or power-generating facilities are likely to be the most cost-effective application for this source of MQW supply. Mapping (Figures 5-1 through 5-5) showed that opportunities to use Treated Wastewater to meet the water needs of the M&I include the Oklahoma City metro area and areas to the east, and opportunities to meet other Industrial (Self-supplied and Thermoelectric) use sectors' needs are located in the areas around Oklahoma City, Tulsa and Muskogee. Any future uses of treated wastewater must consider the impacts to downstream water availability, needs, and water rights.

- **Stormwater** collected in municipal storm sewer systems could be utilized – primarily for non-potable uses – where suitable storage could be provided to buffer the intermittent supply against the demands placed upon this source. Again, the more urban nature of this source of MQW supply suggests that its most cost-effective use will be in and around the state's communities and more highly-developed areas. Stormwater released to receiving waters (surface water or groundwater) was not considered in this evaluation. Areas of most opportunity for stormwater to be used for M&I, Self-supplied Industrial and Thermoelectric needs are located along a corridor between Oklahoma City, Tulsa and Muskogee (see Figures 5-6 through 5-8). Any future uses of treated wastewater must consider the impacts to downstream water availability, needs, and water rights.

- **Oil and Gas Flowback Water** is relatively low volume while **Produced Water** can be a locally significant source of MQW, but utilization of this resource is likely to be limited by temporal, location, and water quality issues. In addition, treatment requirements, storage needs, and the location of significant water users' demands relative to oil and gas production activities may negatively impact the cost-effectiveness of using the water resource. Of Oklahoma's seven demand sectors, reuse of flowback and produced water to support the water needs of nearby oil and gas drilling, fracing, and secondary/tertiary recovery may potentially be the most viable opportunities from a technical and economic perspective. Oil and gas production activities are major economic driver for the state and are expected to continue to occur across a wide geographic range in Oklahoma.

- **Brackish Water** would in most cases need advanced treatment to meet potable water quality standards. Advanced treatment incurs capital and operational costs that are significantly higher than traditional treatment technologies. The most viable users of Brackish Water supplies are likely public water suppliers (M&I demand) and industrial users who have the financial resources and technical capability to operate advanced treatment facilities, and who have limited alternatives for supply. Some of the more salinity-tolerant crops such as barley and wheat, and some livestock groups such as dairy and beef cattle, could potentially use Brackish Water supplies to meet their needs without treatment.

  Mapping (Figures 5-9 through 5-14) showed where higher demands for each sector are located relative to shallower brackish groundwater depths. The northeastern quadrant of the state shows that opportunities may exist to use brackish groundwater for M&I demands. A smaller portion of the northeast quadrant shows some basins where brackish groundwater may be easier to access to meet the needs of Self-supplied residential users with point-of-use water treatment systems. Self-supplied Industrial opportunities may exist northeast of Enid, near Muskogee and near Altus, while Thermoelectric power opportunities may exist between Tulsa and Muskogee and northeast of Enid. There may be opportunity to offset crop irrigation demands with brackish groundwater sources in the southwest portion of the state. Livestock watering demands best match up to brackish groundwater depths in northeast and western portions of Oklahoma. Again, the ability of brackish groundwater sources to meet livestock water demands is dependent predominantly on animal type.

- Waters containing **elevated levels of key constituents** (as defined for this work group effort) are potential candidates for non-potable uses. Industry use of these MQW sources will be heavily contingent on the specific water quality needs of each industrial user. Potable use of waters with elevated levels of key constituents would require advanced treatment, which would likely only be cost-effective in situations where alternative supplies are not readily available. Figures 5-15 through 5-20 show sampling locations with median concentrations of key constituents that exceed the thresholds discussed in Section 2.

Any application of a MWQ source to meet demands should consider the impacts to downstream water availability, needs, and water rights. In addition to the trends identified above, the following recommendations were developed and discussed with the technical work group for future development of MQW use:

- Treated Wastewater: The greatest near-term opportunity to increase the beneficial use of MQW is the use of treated effluent in urban settings for certain non-potable applications. Public water suppliers and users should consider treated effluent reuse where it can be cost-effectively implemented and socially acceptable. The state should continue to support the development of more detailed reuse regulations to provide a framework for utilizing this MQW source while recognizing downstream uses of that water. Aquifer recharge is another potential use of this MQW that may warrant further investigation.

- Stormwater Runoff: The potential for storage and use of stormwater runoff to meet non-potable demands should be further examined in urbanized areas in central and eastern Oklahoma, in light of site-specific issues and considering potential water rights issues related to downstream diversions. Focus areas should include locations where precipitation is relatively high and infrastructure exists to accommodate stormwater reuse applications.

- Brackish Water: The state should continue to follow developments in the ongoing USGS study to characterize areas where brackish groundwater is most readily accessible. Particular attention should be given to areas with projected water shortages and areas where predominant water uses may require less treatment (e.g., areas with salt-tolerant crops and livestock). Advances in treatment technologies such as desalination should be followed for potential application in the future and the deep well injection permitting process could be streamlined to facilitate the disposal of treatment residuals.

- Oil and Gas Flowback and Produced Water: Oil and gas producers in Oklahoma should be encouraged to continue to seek cost-effective opportunities to reuse flowback and produced water to help meet oil and gas drilling and fracing water needs.

- Waters with Elevated Levels of Key Constituents: The state and water users should continue to support research and development of advanced treatment technologies to facilitate the cost-effective use of this MQW source.

Section 8
References

Ayers, R.S. and D.W. Westcot. 1976. Water Quality for Agriculture. Food and Agriculture Organization of the United Nations, Rome.

CDM. 2009. Oklahoma Comprehensive Water Plan 2011 Update Water Demand Forecast Report.

Environmental Resources Management Southwest Inc. 2009. Water Availability and Use in the Woodford Shale Play (Arkoma Basin), June 10.

Environmental Studies Board. 1972. Nat. Acad. of Sci., Nat. Acad. of Eng., Water Quality Criteria.

EPA (U.S. Environmental Protection Agency). 2004. Guidelines for Water Reuse, EPA/625/R-04/108 August.

EPA Region 6. 2009. State of Groundwater Report. http://www.epa.gov/region6/water/swp/groundwater/2008-report.pdf

Hart, D.L.. 1966. Base of fresh ground water in southern Oklahoma: U.S. Geological Survey Hydrologic Investigations Atlas HA-223, 2 sheets.

Multi-Resolution Land Characteristics (MRLC) Consortium. 2001. The National Land Cover Database Land Cover Layer for Mapping

National Energy Technology Laboratory. 2009. Estimating Freshwater Needs to Meet Future Thermoelectric Generation Requirements 2009 Update, US Department of Energy, http://www.netl.doe.gov/energy-analyses/refshelf/detail.asp?pubID=278.

Nation Ground Water Association. 2005. Ground water quality and desalination questions: NGWA report, http://www.ngwa.org/govaffairs/environmental.aspx.

ODEQ (Oklahoma Department of Environmental Quality). 2009. Fact Sheet for OPDES Permit OKR04, Small MS4s.
http://www.deq.state.ok.us/WQDNew/stormwater/ms4/phase_ii_small_ms4_fact_sheet_8_feb_2005.pdf

________. 2008. 303(d) List. http://www.deq.state.ok.us/WQDnew/305b_303d/2008_integrated_report_app_c_303d_list.pdf.

Oklahoma Academy. 2010. Role of Agriculture in Oklahoma's Water Plan.

P.N. Soltanpour and W.L. Raley, 1999. Livestock Drinking Water Quality no. 4.908, Colorado State University Cooperative Extension Service.

http://www.extsoilcrop.colostate.edu/SoilLab/documents/04908LivestockDrinkingwaterquality.PDF

Robert Pitt, Alex Maestre, and Renee Morquecho of Dept. of Civil and Environmental Engineering, University of Alabama, Ted Brown, Chris Swann, Karen Cappiella, and Tom Schueler of Center for Watershed Protection. 2003. Evaluation of NPDES Phase I Municipal Stormwater Monitoring Data.
http://www.epa.gov/nps/natlstormwater03/28Pitt.pdf 2003

U.S. Bureau of Reclamation (BOR). 2003. Desalting handbook for planners-3rd Edition: U.S. Bureau of Reclamation Desalination Research and Development Program Report No. 72, July 2003.

U.S. Geological Survey (USGS). 2002. Produced Waters database: provisional release, May.

Appendix A
Senate Bill 1627

THE STATE SENATE

Monday, February 25, 2008

Committee Substitute for

Senate Bill No. 1627

COMMITTEE SUBSTITUTE FOR SENATE BILL NO. 1627 - By: PADDACK of the Senate and BILLY of the House.

[water supplies - marginal-quality water technical review group - emergency]

BE IT ENACTED BY THE PEOPLE OF THE STATE OF OKLAHOMA:

SECTION 1. NEW LAW A new section of law not to be codified in the Oklahoma Statutes reads as follows:

A. The Oklahoma Legislature hereby finds that:

1. Our state contains a relative wealth of both high- and marginal-quality waters, both surface and ground;

2. Marginal-quality waters include brackish or saline contaminated waters which result from natural or man-made contamination which may be used or reused for many industrial purposes;

3. Demands on and threats to high-quality water supplies pose an increasingly pressing resource management challenge, a challenge that will most prudently be addressed through a multi-stakeholder approach that is based on current science-based assessments of available technologies and regulatory systems; and

4. The Legislature would benefit from a study and evaluation of those technologies and regulatory or management systems in place elsewhere or otherwise being developed to maximize beneficially useable supplies of marginal-quality water.

B. The Legislature hereby directs the Oklahoma Water Resources Board, in the development of the update to the Oklahoma Comprehensive Water Plan, to establish before September 1, 2008, a marginal-quality water technical work group consisting of representatives from the Department of Environmental Quality, the Oklahoma Department of Agriculture, Food, and Forestry, the Oklahoma Conservation Commission, the Department of Mines, the Corporation Commission, the Oklahoma Energy Resources Board, the Commission on Marginally Producing Oil and Gas Wells and any other state entity it deems appropriate, and from the following stakeholder groups: municipal governments, American Indian tribal governments, agriculture industry, oil and gas industry, mining industry, electrical power industry, rural water associations, hunting and/or fishing groups and a statewide nonprofit environmental organization, and in addition each member shall have demonstrated experience or interest in one or more issues affecting water management, supply, delivery, treatment, or rights.

C. The Executive Director of the Oklahoma Water Resources Board or a designee shall chair the technical review group, and the technical review group shall select from its membership a vice-chair. Members shall serve without compensation but shall be eligible for actual and necessary travel reimbursement in accordance with the provisions of the State Travel Reimbursement Act.

D. The technical review group shall:

1. Identify those municipal, industrial, business, or environmental flow water needs that do not require the allocation or consumption of high-quality water supplies;

2. Identify those marginal-quality water supplies that may be available for potential development for such uses;

3. Study and examine how this state could effectively and economically increase the available and beneficially useable supply of marginal-quality water; and

4. Make recommendations on how best to utilize marginal-quality water supplies which will improve the long-term and sustainable management of our state’s high-quality surface and ground water supplies for the benefit of our citizens, economy, and environment.

E. To the greatest extent possible, the technical review group shall provide information for use in the Oklahoma Comprehensive State Water Plan update process.

F. The technical review group shall summarize its study, examination, majority recommendations based thereon, and any dissenting viewpoints in a report to be made part of the update to the Oklahoma Comprehensive Water Plan that shall be distributed to the Governor, the Speaker of the House of Representatives, and the President Pro Tempore of the Senate.

G. Staff assistance for the technical review group shall be provided by the Oklahoma Water Resources Board.

SECTION 2. This act shall become effective July 1, 2008.

SECTION 3. It being immediately necessary for the preservation of the public peace, health and safety, an emergency is hereby declared to exist, by reason whereof this act shall take effect and be in full force from and after its passage and approval.

COMMITTEE REPORT BY: COMMITTEE ON ENERGY & ENVIRONMENT, dated 2-21-08 - DO PASS, As Amended and Coauthored.

Appendix B
Marginal Quality Water Work Group Meeting Summaries

MARGINAL-QUALITY WATER TECHNICAL WORKGROUP
MEETING #2
February 9, 2009
Meeting Summary

The second group meeting occurred in the Offices of the Oklahoma Water Resources Board, 3800 N. Classen Blvd., Oklahoma City, Oklahoma, and began at 1:00 pm. Workgroup members were also provided the opportunity to participant via telephone conference set-up. Attendees participating in person were: Pat Billingsly, Corp. Comm.; Tom Buchanan, Lugert-Altus Irrigation District; Bryan Mitchell, CDM; Angie Burckhalter, OIPA; Mike Mathis, Chesapeake; Kyle Arthur, OWRB; Duane Smith, OWRB; John Rehring, CDM; Derek Smithee, OWRB; Terri Sparks, OWRB; Noel Osborn, OWRB; Steve Sowers, OERB; Julie Cunningham, OWRB. Those members joining by telephone conference were: Kim Winton, USGS; BJ Frasier, Devon; Michael Overbay, EPA Region 6; Jon L. Craig, DEQ; Kelly Hurt, Chickasaw Nation; Saba Tahmassebi, ODEQ; Todd Thompson, Williams; Casey Day, Oklahoma Conservation Commission; Marla Peek, OFB; Marvin Abbott, USGS; and Sarah Lingenfelter, OML. (Agenda attached.)

Mr. Kyle Arthur, OWRB, began the meeting by asking participants to introduce themselves. Duane Smith, OWRB Executive Director, thanked everyone for attending. In accordance with the provisions of SB1627, he then officially appointed Kyle Arthur, OWRB Director of Water Planning, as his designee to chair the workgroup. Marla Peek nominated Kelly Hurt, Chickasaw Nation, as vice-chair, which was approved by vote of the workgroup membership pending his acceptance. (Mr. Hurt joined the telephone conference soon after and accepted the position of vice-chair.)

Kyle continued with an overview of Group Meeting 1, as shown in the attached handout. Definitions of Marginal-Quality Water (MQW) were reviewed, including a discussion on perhaps defining waters with key parameters over identified thresholds or perhaps lower and upper threshold limits.

John Rehring talked about CDM's current investigations of water quality issues in connection with the state water plan. For example, he noted that water sources included on the 303(d) list were typically high in TDS. Derek Smithee characterized the quality of water sources into four basic categories:

1. Very Good
2. Fair
3. Bad
4. Not Usable

He concluded that we should probably be looking at Categories 2 and 3 (Fair and Bad) for purposes of assessing potential uses of MQW. Mike Mathis suggested looking at the state groundwater law in terms of a "regulatory" threshold, where waters with total dissolved solids (TDS) over 5,000 mg/l are defined by regulation as no longer being considered "fresh water." He said that water with TDS in the 5,000 – 10,000 mg/l range may be used for fracking.

Kelly Hurt then questioned whether Mr. Mathis meant flowback or produced water, noting that flowback water is better quality as it was the first to be recycled back. Angie agreed that the terms mean two different things – and that produced water can have a wide range of quality. The group agreed to refer to this water as"flowback/produced water." The group also discussed the need to avoid making broad statements about the usability of flowback/produced water, without referencing site-specific conditions and water quality.

John Rehring then talked about the work plan for MQW analyses, and the group agreed upon the following work plan goals:

- Identify and characterize potential supplies and uses of MQW; and
- Make recommendations on how best to utilize MQW supplies to benefit Oklahoma's citizens, economy and environment.

John then went over the draft work plan diagram shown in frame 9 of the handout. He specifically noted that we:

- Need to look at how to marry the goals of the MQW evaluations with OCWP technical analyses
- Need to prioritize the assessment of MQW in areas where water shortages are anticipated
- Should look at future opportunities to integrate this work into the OCWP
- Should consider constraints on MQW use and how to overcome them.

Kelly said we needed to compare MQW source locations and questioned the possibility of using MQW to help address Texas' needs. Kyle said the information from these analyses will be made publicly available, but from his perspective, the OCWP and legislative workgroups are looking at Oklahoma water to meet its citizens' needs.

Kim Winton questioned the need to look at economic and social engineering aspects. John said that those aspects would come between Steps 2 and 3 of the work plan. Kelly thinks the expense of membrane treatment may be offset by infrastructure costs that would be required to develop alternative sources of supply. That is, new lakes, pipelines, etc. may be more expensive than using membranes to treat local supplies. He suggested that Kim's comments regarding social engineering could be investigated by Oklahoma State University, and that we need to add "social acceptance" to the evaluation criteria (see handout, Box 2 of the diagram in frame 19). It was also noted that the USGS's Fort Collins office has developed models to assess these aspects.

Noel Osborn stressed the need to look at environmental impacts. She indicated that there are no existing regulatory requirements on the use of MQW. Large withdrawals of MQW, which are unregulated, could adversely impact fresh water. Angie agreed that we needed to look at both social and environmental aspects, as these impacts might become constraints on MQW use. Noel stressed that another issue would be disposal of reject water. Kelly noted that we need to look at water as both a supply and demand; use and discharge.

John mentioned ongoing OCWP efforts that could leverage work on MQW. Referring to frame 12 of the handout, he noted that where good gaging data is available, it would be easier to evaluate MQW use. Also, supplies such as municipal effluent could be estimated quantitatively and geographically using the OCWP "gap tool." Frame 13 gives some examples of constraints.

Derek said that a lot of information assumes static water quality concentrations, such as nitrates. He questioned how you would deal with changes that will occur in the future, since water quality may change by the time you need to use the water. He questioned how you maintain feedback to the process as issues and changes evolve. He also challenged the group to consider the potential to take proactive prevention steps on water quality, rather than simply reacting to observed conditions. Finally, he noted that many water quality programs do not apply to groundwater, such as the 303(d) impaired waters list, and the state's antidegradation policy.

Kelly asked if he meant we need to initiate an education effort. He questioned whether water quality and water quantity would ever be integrated on a federal perspective. Jon Craig stressed that water quantity was viewed as a state effort – that states would have a big problem with federal government getting into quantity issues.

Regarding frame 12, Mike Mathis questioned how use of effluent would impact downstream users and/or dependable yields. John said we are not getting to the permit level, just the screening level at this time.

Angie asked whether the report would give options or actual recommendations. John said that the legislation was not specific. Kyle continued by saying that the report would probably give general recommendations; maybe recommendations for further studies. John Rehring said that recommendations would probably be screening of opportunities and constraints.

Angie asked if there were any statewide assessments of what has been done with MQW. Kim Winton recommended viewing Mark Overbay's PowerPoint on MQW. Mike Overbay noted that the presentation was prepared by Dr. Dale Hutchison. Mr. Overbay noted that stakeholders and legislative process (see frame 16) was shown as being the very last action. He asked if there would be public meetings. John and Kyle indicated that they do not envision additional public meetings – they perceived the current advisory groups as adequately representing stakeholders.

Sources Discussed:

- Southwest Oklahoma Chloride Control
- Treated Wastewater
- Produced/Flowback Water

Constraints Discussed:

- Lack of demand (historically)
- Financial
- Social acceptance of reuse
- Regulatory/water rights
- Availability of alternative supplies

Treatment and/or distribution
Capital costs
Economics vs. alternate supplies
Water quality beyond treatability
Formation/location specific
Regulatory liabilities

Derek mentioned that there were no real incentives to reuse water, other than the potential need for the physical supply. Kelly noted that an incentive for making water reusable could be the price you could get for selling the water. The group discussed the fact that the cost-effectiveness of using MQW supplies usually is relative to the cost to convey and treat other available sources of water.

To demonstrate one way of identifying potential constraints on MQW use, John asked oil and gas representatives why, hypothetically, they were not more engaged in reuse. Angie answered that the quality required is relative to use; type of formation limits quality. Others agreed the formations and type of water you needed to use could be constraints; you could treat the water, but cost might make it unfeasible. Pat Billingsly noted that produced water was being used in water flooding, so it was happening in some cases.

John Rehring asked the group to be giving more thought as to why more quantities of MQW are not being used. What are the constraints and what could be done to encourage more use of MQW? He asked that suggestions and comments be e-mailed to Kyle Arthur. John also mentioned that the Recharge workgroup was getting back together on March 9 to talk about a potential presentation to the Legislature on Water Day, which is March 10 at the Capitol. Kelly questioned what CDM planned to do between now and the next meeting. John said that they do not have authority from the OWRB for specific work, but will draft an inventory process to use in quantifying and characterizing sources of water quality.

Kyle, in closing, stressed very strongly that the goal of the OCWP and these groups is solely to identify dependable sources of water for Oklahoma. Data may or may not be used later for Texas issues; we have no control over that. He noted that a contract for CDM to work with the work groups was on tomorrow's OWRB Board agenda for consideration. Kelly said that the Chickasaw Nation may also have some funds from Tribal grants and other sources to dedicate to the project.

John Rehring asked that the Workgroup members get all relevant information to Kyle by e-mail by February 23. The next meeting was set for 3:00 pm, March 9, in order to talk about what to include in a presentation to the Legislature on March 10, during Water Day at the State Capitol. *[That meeting was later postponed, since updated plans for Water Day did not include a detailed presentation on OCWP or MQW activities.]*

Oklahoma Comprehensive Water Plan
Marginal-Quality Water Technical Work Group Meeting #2

PRELIMINARY AGENDA
RESCHEDULED – February 9, 2009
Oklahoma Water Resources Board Offices – 3800 N. Classen, Oklahoma City
(Teleconference also available – 888-596-9024 / Passcode 778668#)

1:00 p.m. Welcome and Introductions

1:10 p.m. Recap of Senate Bill 1627 Work Group Background and Logistics
- Recap of Work Group Meeting 1 (December 8, 2008)
- Review definitions of Marginal-Quality Water
- Selection of Marginal-Quality Water Technical Work Group Vice-Chair

1:20 p.m. Review and Discussion of Draft Work Plan Outline
- Goals, objectives, and end products for this Work Group
- Work Plan components
- Schedule

2:10 p.m. Identification of Marginal-Quality Supplies for Potential Development
- Inventory of potential supplies
- Discussion of constraints on use (by category of marginal-quality supply)
- Anticipated data needs and potential resources

2:40 p.m. Set Meeting Schedule and Path Forward
- Schedule and topics for next Work Group Meetings
  - Meeting #3 (February 2009)
    - i. Examine How Oklahoma May Beneficially Use Marginal-Quality Water
    - ii. Examine How to Address Marginal-Quality Water Treatment Needs
    - iii. Water Day at the Capitol
  - Meeting #4 (April 2009)
    - i. Recommend Potential Uses of Marginal-Quality Water
  - Meeting #5 (May 2009)
    - i. Conclusion and Integration into the Oklahoma Comprehensive Water Plan

3:00 p.m. Adjourn

CDM

OKLAHOMA COMPREHENSIVE WATER PLAN

Marginal Quality Water Technical Work Group Meeting #2

OWRB Offices, Oklahoma City

Rescheduled – February 9, 2009

Water Plan · OWRB · CDM

Recap of SB 1627 & Work Group Meeting #1

Recap of Work Group Meeting #1

- Background & goals of SB 1627
- Presentations
  - *Dr. Kelly Hurt: Chickasaw Nation brackish water*
  - *Aaron Horn: Produced water and flowback fluids*
- Discussed definition of Marginal-Quality Water
- Developed MQW analysis flowchart and approach for integration into Oklahoma Comprehensive Water Plan

Definitions of Marginal Quality Water

- Surface or groundwater
- Water not typically used for public supply
- Treated wastewater effluent
- Stormwater runoff
- Brackish groundwater or surface water
- Produced water
- Nitrates and other contaminants

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Definitions of Marginal Quality Water

- Surface or groundwater
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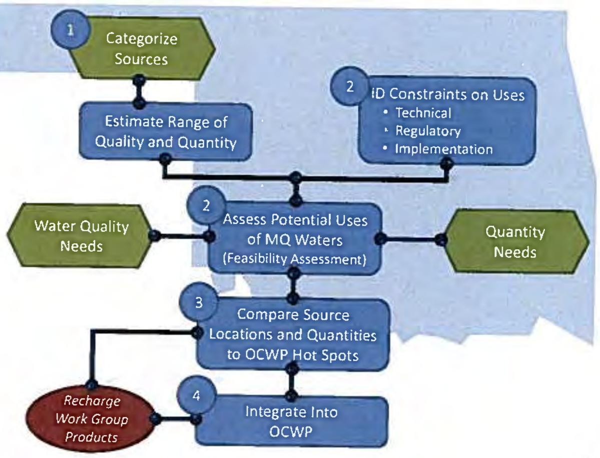
- Treated wastewater effluent
- Stormwater runoff
- Brackish groundwater or surface water
- Produced water (or broader definition?)
- Waters with key parameters over identified thresholds

Draft Work Plan Outline

Goals and Overview of Process

Study Goal:

- Identify and characterize potential supplies and uses of marginal-quality waters, and make recommendations on how best to utilize marginal-quality water supplies to benefit Oklahoma's citizens, economy, and environment.



Step 1

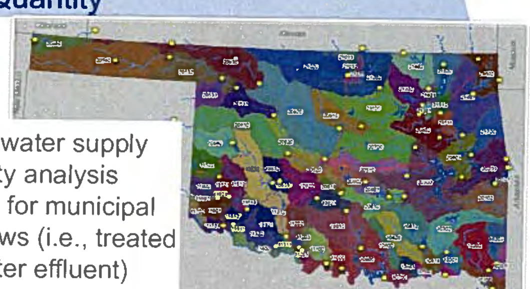
Categorize and Characterize Potential Sources

- 1.1 – Identify and Categorize MQW Sources
- 1.2 – Define Water Quality Parameters of Significance
- 1.3 – Estimate Range of Quality and Quantity by MQW Source Category
- 1.4 – Advisory Group and Stakeholder Input

Leveraging Ongoing OCWP Analyses: Water Quality

- OCWP efforts are underway to broadly assess potential water quality constraints for water use
- Characterizing water quality based on:
  - *Comparison of BUMP and other data to identified constituent threshold concentrations*
  - *303(d) listings for designated uses (non-instream)*
  - *Streamflow depletions as a "flag" for potential WQ issues*
  - *Anecdotal info on water quality constraints not identified above*
  - *OWRB WQ trending results for key parameters*

Leveraging Ongoing OCWP Analyses: Water Quantity



- Physical water supply availability analysis accounts for municipal return flows (i.e., treated wastewater effluent)
- Consumptive and non-consumptive water use being projected on watershed (basin) basis

Example Constituents

- Parameters and levels that would drive significant infrastructure costs
  - *Treatment to reduce to primary or secondary standards*
  - *Pipeline & pumping infrastructure to import water from more distant, higher-quality sources*
- Examples (public water supply):
  - *Arsenic*
  - *Nitrate*
  - *Dissolved oxygen, Nitrogen, Phosphorus (algae)*
  - *Total organic carbon*
  - *Total dissolved solids*

Step 2



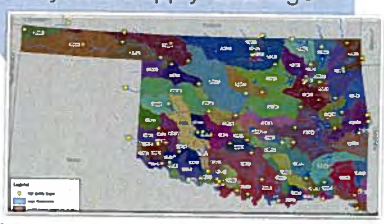
Identify Constraints and Potential Uses of MQW

- 2.1 – Inventory Potential Technical, Regulatory, and Implementation Constraints by MQW Category
- 2.2 – Broadly Characterize Water Quality and Quantity Needs by OCWP Water Use Sector
- 2.3 – Summarize Potential Technology Solutions
- 2.4 – Qualitative Assessment of Potential Uses by Source Category
- 2.5 – Advisory Group Review

Step 3

Identify Potential Matches Between MQW Supply and Demand

- 3.1 – Compare MQW Source Locations and Quantities to OCWP Physical Supply Shortage ("Gap") Areas
- 3.2 – Summarize Data Gaps
- 3.3 – Prepare Recommendations for Priority Areas to Investigate Further



Step 4

Reporting and Coordination

- 4.1 – Draft Report
- 4.2 – Advisory Group Review
- 4.3 – Finalize Report
- 4.4 – Stakeholder and Legislative Meetings/ Presentations

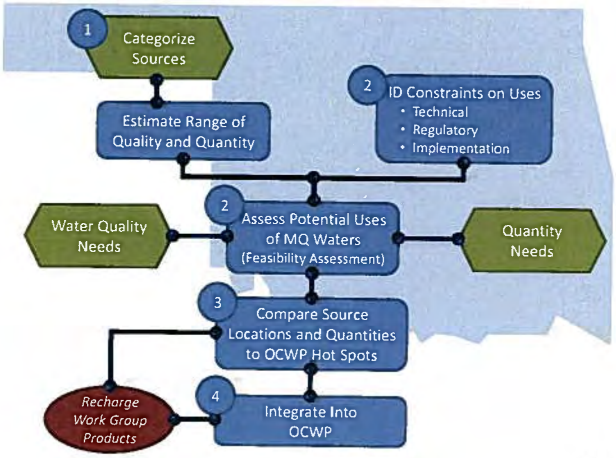
Oklahoma COMPREHENSIVE Water PLAN

MQW Supplies for Potential Development

- ***Inventory of Potential Supplies***
- ***Discussion of Constraints on Use***
- ***Anticipated Data Needs and Potential Resources***

Oklahoma COMPREHENSIVE Water PLAN

Work Group Meeting Topics and Schedule



OKLAHOMA COMPREHENSIVE WATER PLAN

Marginal Quality Water Technical Work Group Meeting #2

OWRB Offices, Oklahoma City

Rescheduled – February 9, 2009

OWRB CDM

MARGINAL-QUALITY WATER TECHNICAL WORKGROUP MEETING DECEMBER 8, 2008

The first group meeting occurred in the Offices of the Oklahoma Water Resources Board, 3800 N. Classen Blvd., Oklahoma City, Oklahoma and began at 2:30 pm. Attendees included: Aaron Horn, Newfield Exploration; Buck Ray, ODWC; Greg Klozin, Oklahoma Conservation Commisssion; B.J. Frazier, Devon Energy; Pat Billingsley, Oklahoma Conservation Commission; Noel Osborn, OWRB; Terri Sparks, OWRB; Mike Melton, OWRB; Dave Dillon, OWRB; Scott Thompson, ODEQ; Derek Smithee, OWRB; Robert Fabian, OWRB; Gordon McCurry, CDM; John Rehring, CDM; Bryan Mitchell, CDM; Senator Susan Paddack, Oklahoma State Senate; Cheryl Dorrance, OML; Todd Thompson, Williams E&P; Mike Mathis, Chesapeake; Angie Burckhalter, OIPA; Kyle Arthur, OWRB; Tek Tsegay, ODM; Marla Peek, Oklahoma. Farm Bureau; Steve Sowers, OERB; Dr. Kelly Hurt, Chickasaw Nation; Jim Rodriguez, OKAA; Saba Tahmassebi, ODEQ; Jon L. Craig, ODEQ; Gene Whatley, ORWA; Bud Ground, PSO; and Duane Smith, OWRB.

Senator Paddack started the meeting by providing an overview of SB 1627 (attached). Dr. Kelly Hurt briefly discussed the definition of "marginal-quality" as water that is unusable without treatment or water that is uneconomical to use. It could include waters that one would not typically think of for municipal and industrial supply. These waters would include brackish water (groundwater and stream water), wastewater reuse, storm water runoff, produced water (from oil and gas and other activities), and water with elevated levels of other contaminants such as arsenic or nitrates. Reuse of agricultural tail water could also be considered to be use of marginal quality water.

Dr. Hurt presented a summary of the Chickasaw Nation's developments in southern Oklahoma, noting they are looking at treating brackish water and also looking at the benefits of drilling beneath the river (e.g., horizontal collector wells), where they could potentially encounter up even if the river went dry, and would not have all the problems related to surface water turbidity.

Aaron Horn gave a presentation on oil and gas produced water and flowback fluids, which included information on:

- definition of terms in the oil and gas industry in hydraulic fracturing,
    - Each well requires between 1 and 4 million gallons of water during completion
    - Blending of surface water with recycled flow back water occurs when feasible;
- impediments to reuse of flowback fluid (scale, hydrogen sulfide gas, corrosion);
- methods to treat marginal-quality water (chlorine dioxide, biocides, scale inhibitors, pH altering chemicals; and
- disposal of marginal-quality water (evaporation pits, soil farming, distillation, underground injection, reuse in flooding/fracturing)

Mr. Horn also talked about the Newfield Ecosphere Water Treatment Project, a pilot project that was completed in 2008. This advanced oxidation process, combined with reverse osmosis, allowed up to 99% of all water to be recycled or reused. Mr. Horn, as an example of their potential water use, noted that Newfield's estimated water needs for drilling 90 wells in 2009 is 378 million gallons or about 1160 acre-feet of water.

The group also discussed power plant cooling water, which typically gets re-circulated multiple times. About 5 plants currently use wastewater effluent, but it was noted that industrial water use is regulated differently than public utilities. Industrial discharges may have total dissolved solids limits, whereas municipal wastewater treatment plants typically do not. Industrial plants can in many cases be designed to use water of a wide range of quality. Representatives from the aggregates production industry noted that large volumes of water area used, mostly for dust suppression. They are interested in using marginal quality water but this would depend on what is in the water, since most quarried sand is used for ready-mix concrete and which requires a non-reactive aggregate. OML representatives noted that there are opportunities for reuse with plant washdown water, and that DEQ has about 200 permits for reuse in place now.

Duane Smith asked participants for their general perspectives on benefits, potential, and impediments concerning reuse of marginal-quality water. The majority expressed support in looking at options for using marginal-quality water where feasible and cost effective.

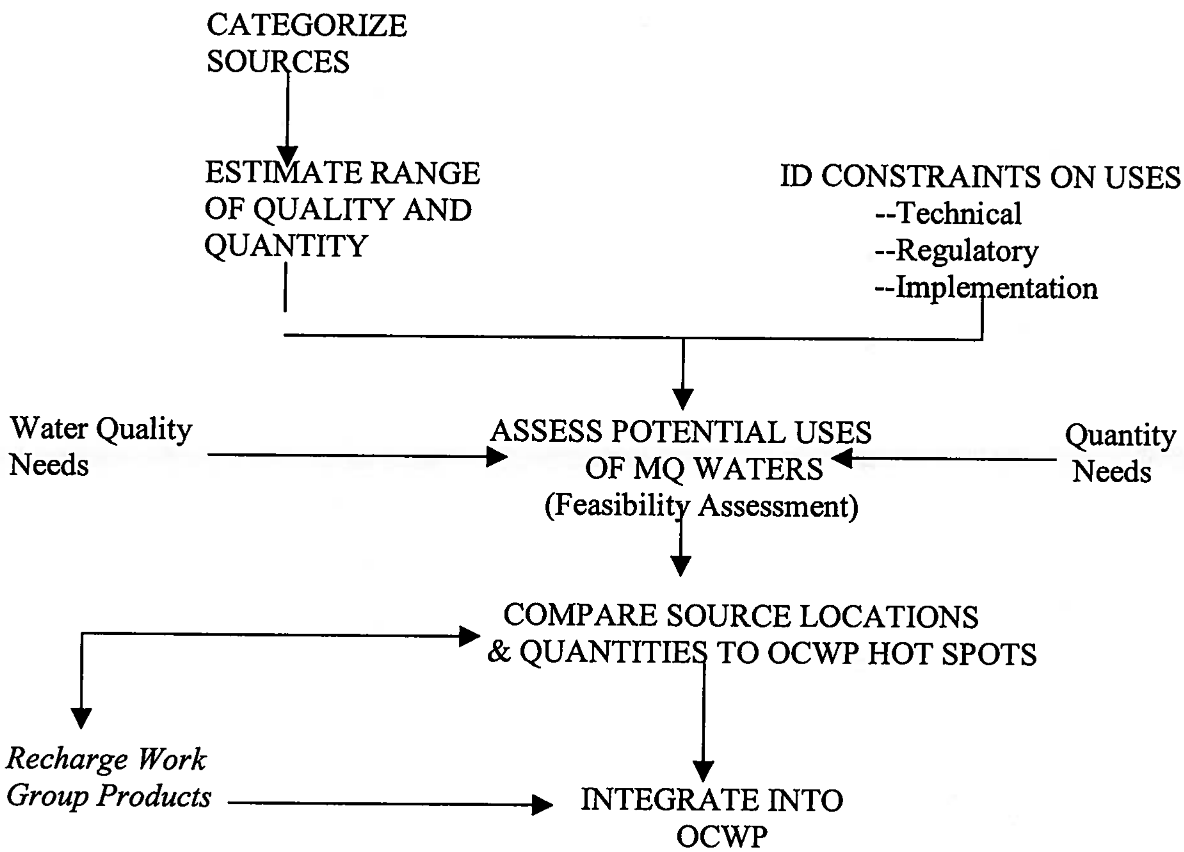
The group collaborated in outlining the following characteristics for marginal-quality water use and a work plan for future action:

SOURCES:

Surface or groundwater
Water not typically used for public supply
Treated wastewater effluent
Stormwater runoff
Brackish groundwater or surface water
Produced water
Nitrates and other contaminants

USES:

Potable or nonpotable
Municipal/rural, industrial, other demands and uses



The next meeting of the Marginal-Quality Water Technical Workgroup was tentatively scheduled for January 21, 2009, at 3:00 p.m. Duane Smith asked CDM staff to flesh out a more detailed work plan based on the above guidance for consideration at the next meeting.

MARGINAL QUALITY WATER TECHNICAL WORK GROUP MEETING #4
March 3, 2010
Draft Meeting Summary

The fourth group meeting of the Marginal Quality Water (MQW) Technical Work Group occurred in the offices of the Oklahoma Water Resources Board, 3800 N. Classen Blvd., Oklahoma City, Oklahoma, and began at 9:30 a.m. Meeting attendees included:

Bud Ground, PSO	Tek Tsegan, ODM
Saba Tahmassebi, ODEQ	Todd Thompson, Williams
Mike Mathis, Chesapeake	Jona Tucker, TNC
Stacey Day, OK Cons. Comm.	Tim Ward, ODEQ
Becky Dunavant, CDM	Bryan Mitchell, CDM
Terri Sparks, OWRB	Bob Fabian, OWRB
Gene Whatley, ORWA	Mark Becker, USGS
Marla Peek, OFB	Buck Ray, ODWC
Noel Osborn, OWRB	Derek Smithee, OWRB
Tom Buchanan, LAID	John Rehring, CDM
Kyle Arthur, OWRB	Dan Reisinger, CDM

Mr. Kyle Arthur, OWRB, began the meeting by asking participants to introduce themselves. Becky Dunavant, CDM, then gave a PowerPoint presentation (attached) recapping the work completed to date. She noted that we are moving along with the MQW analysis flowchart and approach for integration into the Oklahoma Comprehensive Water Plan. CDM anticipates presenting a draft final report to the work group in May 2010 in order to integrate the results into the Oklahoma Comprehensive Water Plan (OCWP).

It was noted that CDM's Draft Technical Memorandum 1 (TM1), *Categories and Characteristics of Marginal Quality Water Sources*, was discussed at the last meeting. The purpose of TM 1 was to lay the groundwork for further engineering analysis of MQW by identifying and characterizing potential supplies and uses of MQW. The following sources of MQW were defined, characterized, and analyzed for potentially available quantity and quality:

1. Treated wastewater effluent;
2. Stormwater runoff;
3. Oil and gas flowback and produced water;
4. Brackish surface and groundwater; and
5. Water with elevated levels of other key constituents.

Ms. Dunavant mentioned that there had been some feedback received since the last meeting, indicating that the work group should only look at brackish water since that was specifically mentioned in SB1627, the authorizing legislation. After some discussion, the group agreed that the broadened five categories, as listed above, were appropriate.

Ms. Dunavant also noted that, as agreed to at the previous meeting, a conference call was held between several members to discuss and identify additional sources of groundwater information.

The discussion then turned to the Draft TM2, *Potential Uses of MQW*, which was sent out prior to this meeting. The purpose of TM2 was to build on the analysis completed for TM1 and to:

- ▪Identify the constraints on use of MQW,
- ▪Investigate match between water demand and sources; and
- ▪Assess possible treatment options.

Ms. Dunavant then began discussing constraints and proposed the following three categories of constraints on using MQW sources:

- ▪Technical Constraints—Infrastructure needs, treatment requirements, variable supplies, supply location relative to demands
- ▪Regulatory Constraints—Dependent on the intended use
- ▪Implementation Constraints—Public perception and costs relative other options.

A matrix was presented for each of the five sources of MQW, cross-referencing specific constraints falling into each of the above three categories (see slides). There was some discussion on the potential constraints to wastewater reuse because of impacts on instream flows and downstream water rights holders. Another suggested category of constraints was Environmental Constraints which could include issues like disposal of treatment residuals, impacts of decreases in instream and downstream flows, and subsidence impact on fresh water from pumping deep aquifers' brackish water supplies.

Dan Reisinger, CDM, then discussed the seven water demand sectors (Municipal and Industrial/Public Water Supply; Self-Supplied Rural Residential; Crop Irrigation; Livestock; Thermoelectric Power; Self-supplied Industry; and Oil and Gas) and the water quality requirements for each. He also displayed state maps showing 2060 county water demands for each sector. Some discussion ensued on the appropriateness of the term Self-supplied Rural Residential vs. Domestic. The group agreed to drop "rural" from the demand sector name.

Bud Ground, PSO, questioned whether CDM's model took return flows into account, which was affirmed. He showed some concern that the text in TM2 suggested that the water quality needs for thermoelectric power generation were more sensitive than reality. Mr. Ground indicated that low quality waters could/are being used; for example, Arkansas River water is used for power generation. Mr. Reisinger indicated they will take this information into account.

Marla Peek, OFB, said she would provide more numbers on water quality constituents as pertains to crop irrigation. Derek Smithee, OWRB, also noted that Appendix C of the Water Quality Standards has water quality classifications for crops.

John Rehring , CDM, then introduced a draft screening matrix of the "Potential Uses of MQW to Meet Water Demands." (See slides.) The matrix provided information on the feasibility of applying MQW by source category to meet demands by sector, as well as the type of treatment that may be required. Mr. Rehring went through the matrix to receive feedback from the group. Some of the comments and recommended changes to the matrix included:

- ▪Irrigation and Livestock Watering—change Treated Wastewater from red (not feasible) to yellow (less feasible).
- ▪Should public perception be included in the matrix?

▪Do not be too negative as far as feasibility—do not want residents to rely totally on this document when looking at MQW suitability—may be other localized factors that make it work.
▪ODEQ is incorporating better technology for allowing reuse, such as at the Gaillardia development in Oklahoma City.
▪Thermo-Electric Power—change Brackish Water to green instead of yellow-level feasibility.
▪Self-Supplied—Change to yellow.
▪Need to note that water <5,000ppm total dissolved solids is within OWRB's permitting jurisdiction; anything greater is not.
▪Brackish water for irrigation—add conventional and unconventional treatment.

After the matrix discussion, Mr. Rehring quickly discussed treatment solutions. He requested that any additional comments on TM 2 be provided by March 17, 2010. A suggestion was made to include the water demand chart shown in the presentation in the report. The next meeting will include mapping to identify areas where MQW sources may be able to meet identified demands. The meeting ended at around 11:20 a.m.

Oklahoma Comprehensive Water Plan
Marginal-Quality Water Technical Work Group Meeting #4

AGENDA
March 3, 2010
Oklahoma Water Resources Board Offices – 3800 N. Classen, Oklahoma City

9:30 a.m.	Welcome and Introductions
9:40 a.m.	Recap of Senate Bill 1627 Work Group Background and Logistics - Recap of Work Group Meetings 1, 2 and 3 - Review definitions and categories of Marginal Quality Water
9:50 a.m.	Review and Discussion of Draft Technical Memorandum on MQW Constraints and Uses - Overview - Constraints on Use of MQW - Water Quality and Quantity Needs by Water Demand Use Sector
10:20 a.m.	Discussion on MQW Source/Water Demand Use Sector Matrix - Treatment Options
11:20 a.m.	Action Items and Next Steps - Follow-up actions from this meeting - Comments on Technical Memorandum 2 and next steps in technical analysis - Schedule and content for Work Group Meeting #5
11:30 a.m.	Adjourn

OKLAHOMA COMPREHENSIVE WATER PLAN

Marginal Quality Water
Technical Work Group Meeting #4

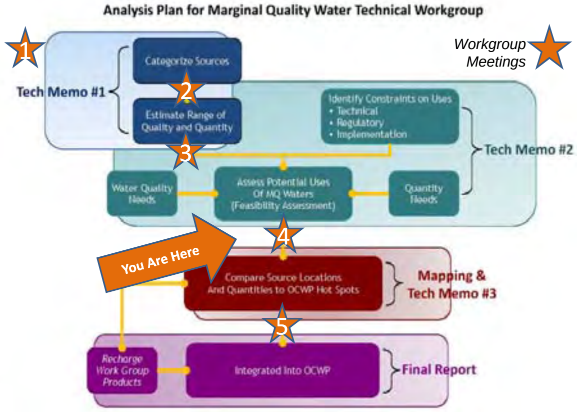
OWRB Offices, Oklahoma City
March 3, 2010

Oklahoma Comprehensive Water Plan
OCWP

Recap of Previous Work Group Meetings

2

Analysis Plan for Marginal Quality Water Technical Workgroup



Recap of Work Group Meeting #1

- Background & goals of SB 1627
- Presentations
  - *Dr. Kelly Hurt: Chickasaw Nation brackish water*
  - *Aaron Horn: Produced water and flowback fluids*
- Discussed definition of Marginal-Quality Water
- Developed MQW analysis flowchart and approach for integration into Oklahoma Comprehensive Water Plan

4

Recap of Work Group Meeting #2

- Presentation
  - *Draft Work Plan for MQW Analysis*
- Refinements to Work Plan
- Further discussion on sources and constraints
- Kyle Arthur appointed chair and Kelly Hurt nominated for vice-chair

5

Recap of Work Group Meeting #3

- Presentation
  - *Categorize and Characterize Potential Sources of MQW*
- Further discussion on sources availability, water quality, and constraints
- Identified data sources and needs

6

Definitions 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 thresholds

7

Oklahoma Comprehensive Water Plan

OCWP

Draft Technical Memorandum #2

8

Draft Tech Memo #2

Purpose:

Build on the analysis completed for TM1 to identify the constraints on using MQW and assess the possible treatment options available to overcome these constraints and increase the beneficial use of MQW.

- *Sec. 1 – Introduction*
- *Sec. 2* – Constraints on Uses of Marginal Quality Water
- *Sec. 3* – Quality and Quantity Needs by Water Use Sector
- *Sec. 4* – Potential Uses of Marginal Quality Water Sources
- *Sec. 5 – References*

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Constraints on Using MQW Sources

- **Technical Constraints**
  - *Infrastructure needs*
  - *Treatment requirements*
  - *Variable or finite supplies*
  - *Supply location relative to demands*
- **Regulatory Constraints**
  - *Dependent on the intended use*
- **Implementation Constraints**
  - *Public perception*
  - *Costs relative to other supply options*

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Constraints on Using MQW Sources – Treated Wastewater

Category	Possible Constraints		
	Technical	Regulatory	Implementation
Treated Wastewater	• Treatment to required quality • Higher dissolved solids • Emerging contaminants (e.g., PPCPs) • Infrastructure needs	• No Oklahoma standards for reuse • Dependent on use • Water rights issues	• Cost relative to raw/fresh/ potable water options • Public perception

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Constraints on Using MQW Sources – Stormwater Runoff

Category	Possible Constraints		
	Technical	Regulatory	Implementation
Stormwater Runoff	• Collection/ distribution system • Intermittent supply and associated storage needs • Variable and extreme water quality	• Downstream water rights • MS4s	• Cost relative to raw/ fresh/ potable water options

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Constraints on Using MQW Sources – Oil and Gas Produced/Flowback Water

Category	Possible Constraints: Technical	Regulatory	Implementation
Oil and Gas Produced/ Flowback Water	• Location relative to demand • Mobile operations/ mobile treatment • Small volume • Temporary supply • Water quality/ treatment needs	• Discharge regulations • Treatment residuals disposal	• Cost relative to raw/ fresh/ potable water options • Public perception

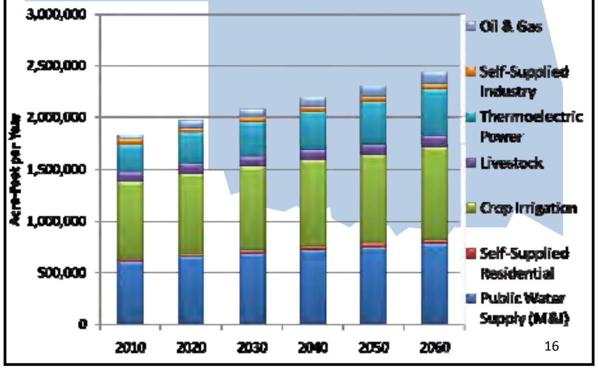
Constraints on Using MQW Sources – Brackish Water

Category	Possible Constraints: Technical	Regulatory	Implementation
Brackish Water	• Treatment - residuals disposal • Depth of wells • Location relative to demands • Sustainability (groundwater sources) • Reliability (surface water sources)	• Discharge regulations • Treatment residuals disposal	• Cost relative to raw/ fresh/ potable water options • Public perception

Constraints on Using MQW Sources – Contaminants of Concern

Category	Possible Constraints: Technical	Regulatory	Implementation
Contaminants of Concern	• Treatment	• Potable quality standards and treatment requirements	• Cost relative to raw/ fresh/ potable water options • Public perception

Quantity and Quality Needs by Water Use Sector



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Municipal and Industrial

- Public water systems to homes, businesses and industries
- Uses include bathing, flushing, washing, drinking, etc…
- Water quality standards exist for drinking water supplies
- Threshold concentrations were developed for TM1 for "Contaminants of Concern"
  - *TSS*
  - *TDS*
  - *Nitrates*
  - *Hardness*

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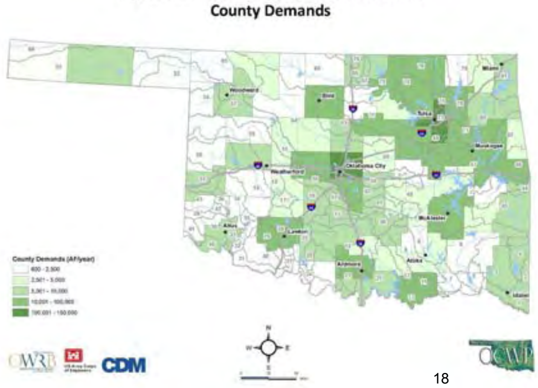
Figure 3-1 - 2060 Municipal and Industrial County Demands



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Self-supplied Rural Residential

- Households on private wells that are not connected to public water supply systems
- Used for potable water with little to no advanced treatment
- Requires high quality source water

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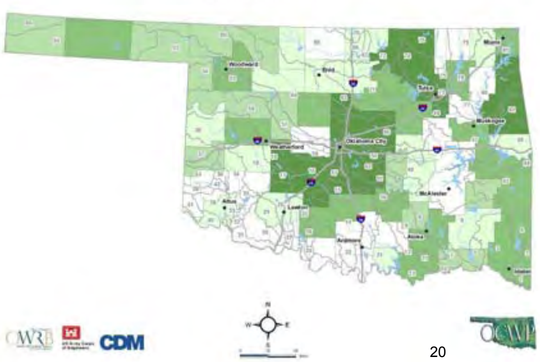
Figure 3-2 - 2060 Self Supplied Rural Residential County Demands



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Self-supplied Industrial

- Large industries that are self-supplied users
- Can include sand companies, paper mills, quarry mines, petroleum refineries, etc.
- Many operate on-site treatment facilities that treat to the industry's specific needs
- Water quality requirements vary greatly by industry

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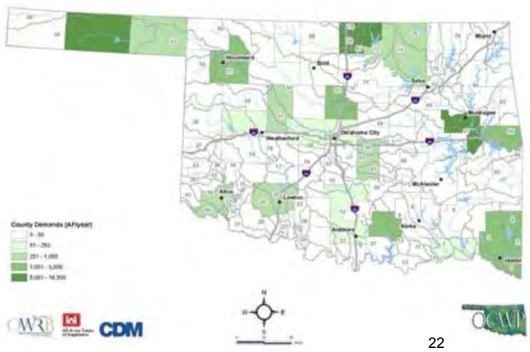
Figure 3-3 - 2060 Self Supplied Industrial County Demands



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Thermo-Electric Power

- Includes Thermoelectric power producing plants
- Can be self- or municipal-supplied
- Water is used for cooling
- Water quality needs are based on fouling and scaling
- Preferable to have source water with lower TDS and nutrients

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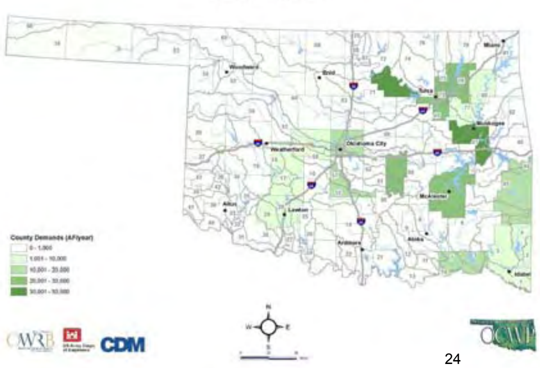
Figure 3-4 - 2060 Thermoelectric Power County Demands



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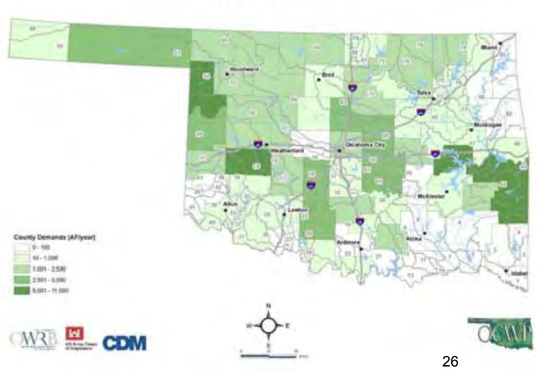
Oil and Gas

- Represents water used in oil and gas drilling and exploration activities
- Water quality requirements for drilling activities vary by drilling type and specific operations and standards
- *Seeking additional input from workgroup on water quality requirements*

25

Figure 3-5 - 2060 Oil and Gas County Demands



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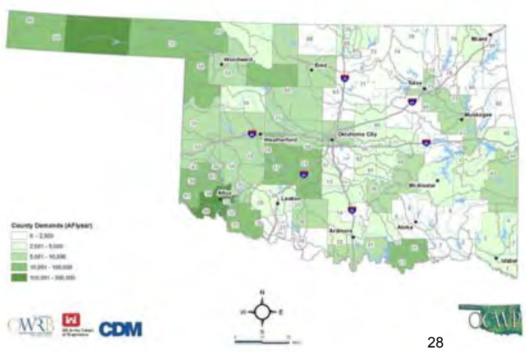
Crop Irrigation

- Demands developed using information from the 2007 Agricultural Census
- Salts (chlorides, TDS, and sulfates; SAR) are the most prevalent water quality issue for crop irrigation
- Effects vary by specific salts, soil type, crop type, weather, and other factors

Potential Yield Reduction from Saline Water for Selected Irrigated Crops

Crop	Percent Yield Reduction			
	0%	10%	25%	50%
	Total Dissolved Solids (mg/L)			
Barley	4,240	5,360	6,960	9,600
Wheat	2,560	3,136	5,120	6,960
Alfalfa	832	1,408	2,304	4,720
Potato	704	1,088	1,600	2,496
Corn (grain)	704	1,088	1,600	2,496
Corn (silage)	768	1,344	2,240	4,560

Figure 3-6 - 2060 Crop Irrigation County Demands



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Livestock

- Parameters can become toxic to livestock at varying levels

Recommendations for Levels of Toxic Substances in Drinking Water for Livestock (Soltanpour and Raley 1999)

Water Quality Parameter	Upper Limit	Water Quality Parameter	Upper Limit
Aluminum (Al)	5.0 mg/L	Lead (Pb)	0.1 mg/L[1]
Arsenic (As)	0.2 mg/L	Manganese (Mn)	no data
Beryllium (Be)	no data	Mercury (Hg)	0.01 mg/L
Boron (B)	5.0 mg/L	Molybdenum (Mo)	no data
Cadmium (Cd)	0.05 mg/L	Nitrate + nitrite (NO_3-N + NO_2-N)	100 mg/L
Chromium (Cr)	1.0 mg/L	Nitrite (NO_2-N)	10 mg/L
Cobalt (Co)	1.0 mg/L	Selenium (Se)	0.05 mg/L
Copper (Cu)	0.5 mg/L	Vanadium (V)	0.10 mg/L
Fluorine (F)	2.0 mg/L	Zinc (Zn)	24 mg/L
Iron (Fe)	no data	Total dissolved solids (TDS)	10,000 mg/L[2]

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Livestock

- Saline water can also adversely affect livestock

Guide to the Use of Saline Waters for Livestock and Poultry (Soltanpour and Raley 1999)

Total Dissolved Solids Content of Waters	Uses
Less than 960 mg/L	Relatively low level of salinity. Excellent for all classes of livestock and poultry.
961 - 3,200 mg/L	Very satisfactory for all classes of livestock and poultry. May cause temporary and mild diarrhea in livestock not accustomed to them; may cause watery droppings in poultry.
3,200-6,400 mg/L	Satisfactory for livestock, but may cause temporary diarrhea or be refused at first by animals not accustomed to them. Poor waters for poultry, often causing watery feces, increased mortality, and decreased growth, especially in turkeys.
6,400-8,800 mg/L	Can be used with reasonable safety for dairy and beef cattle, sheep, swine, and horses. Avoid use for pregnant or lactating animals. Not acceptable for poultry.
8,800-12,800 mg/L	Unfit for poultry and probably for swine. Considerable risk in using for pregnant or lactating cows, horses, or sheep, or for the young of these species. In general, use should be avoided although older ruminants, horses, poultry, and swine may subsist on them under certain conditions.
Over 12,800 mg/L	Risks with these highly saline waters are so great that they cannot be recommended for use under any condition.

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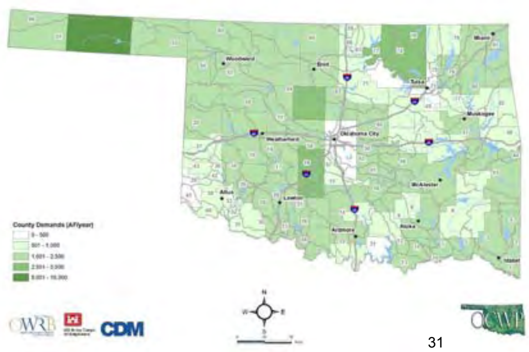
Figure 3-7 - 2060 Livestock County Demands



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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	WQ, LOC, REL	WQ, LOC	AT	AT
M&I - non-potable	WST	WST, PT	LOC	AT	CT, AT
Self-Supplied Rural Residential	WQ, LOC	WQ, LOC	WQ, LOC	WQ	WQ
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	CT, AT	CT, AT
Crop Irrigation	LOC	LOC	WQ, LOC	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
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

Not feasible on a widescale basis for indicated reason(s)
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

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Potential Treatment Solutions

- Dependent on source quality and user's needs
- Generalized categories
  - *No additional treatment*
  - *Passive treatment (e.g., stormwater BMPs)*
  - *Conventional treatment*
  - *Advanced treatment*
- Planning level costs expressed as $/gal/day of capacity
- Operating costs expressed as $/million gallons of treated water

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Oklahoma Comprehensive Water Plan

OCWP

Action Items & Next Steps

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MARGINAL QUALITY WATER TECHNICAL WORK GROUP MEETING #3
December 15, 2009
Draft Meeting Summary

The third group meeting occurred in the Offices of the Oklahoma Water Resources Board, 3800 N. Classen Blvd., Oklahoma City, Oklahoma, and began at 9:30 a.m. Meeting attendees included:

Susan Paddack, OK State Senate	Tek Tsegan, ODM
Saba Tahmassebi, ODEQ	Pat Billingsly, Corp. Comm.
Mike Mathis, Chesapeake	B.J. Frazier, Devon
Angie Burckhalter, OIPA	Michael Overbay, US EPA
Stacey Day, OK Cons. Comm.	Kelly Hurt, Chickasaw Nation
Becky Dunavant, CDM	Bryan Mitchell, CDM
Terri Sparks, OWRB	Bob Fabian, OWRB
Gene Whatley, ORWA	Mark Becker, USGS
Matt VonTurgeln, OFB	Wayne Kellogg, Chickasaw Nation
Noel Osborn, OWRB	Derek Smithee, OWRB
Kim Winton, USGS	Larry Harden, ODAFF
John Rehring, CDM	Cheryl Dorrance, OML
Kyle Arthur, OWRB	Dan Reisinger, CDM

Tom Buchanan, Lugert-Altus Irrigation District

Mr. Kyle Arthur, OWRB, began the meeting by asking participants to introduce themselves. Mr. John Rehring, CDM, then gave a PowerPoint presentation (attached) reviewing Group Meetings 1 and 2 and recapping the work completed to date. Major accomplishments include:

- Discussions on Definitions of Marginal Quality Water (MQW)
- Development of a MQW analysis flowchart and approach for integration into the Oklahoma Comprehensive Water Plan (OCWP)
- Development of a Work Plan Outline
- Discussions on sources of MQW and constraints
- Approval of a contract for CDM to provide support for group activities

CDM anticipates having a final report available in May 2010 in order to integrate the results into the Oklahoma Comprehensive Water Plan (OCWP).

In reviewing previous discussed definitions of MQW, John outlined two general categories:

1) Surface water or groundwater, and
2) Water not typically used for public supply

He also outlined five more specific sources:

1) Treated wastewater effluent
2) Stormwater runoff
3) Brackish groundwater or surface water
4) Flowback/Produced water
5) Nitrates and other contaminants, redefined as waters with key parameters over identified thresholds.

Discussion then turned to CDM's attached Draft Technical Memorandum1, *Categories and Characteristics of Marginal Quality Water Sources,* which was sent out to the technical work group the week before the meeting. Mr. Rehring noted that the purpose of the memorandum is to lay the groundwork for further engineering analysis of MQW by identifying and characterizing potential supplies and uses of MQW. The following sources of MQW were defined, characterized, and analyzed for potentially available quantity and quality:

▪Treated wastewater effluent;
▪Stormwater runoff;
▪Oil and gas flowback and produced water;
▪Brackish surface and groundwater; and
▪Water with elevated levels of other key constituents.

In reviewing sources of water quality data, it was noted that surface water quality data were much more accessible on a state-wide basis than groundwater quality data, thus the analysis in the memorandum was restricted primarily to surface water. Water quality and related data evaluations included:

▪Impaired waters--first evaluated the 2008 303(d) listing for public water supply and agriculture use

▪Streamflow reductions—used the Oklahoma H2O gap tool to estimate streamflow reduction as an indirect indicator of potential future water quality degradation

▪Key threshold concentrations for parameters of concern—TDS, TSS, Nitrates and Hardness

Mike Overbay, EPA, questioned the streamflow reduction analysis and wondered if Oklahoma water laws allowed withdrawals from streams that would result in zero flows (as shown in the corresponding report table). Kyle Arthur, OWRB, responded that such was allowed. Mr. Overbay and others questioned the impact on downstream water rights—John Rehring indicated that would be addressed as they looked at legal availability.

There were several questions concerning projections of MQW resulting from the decrease in streamflows associated with future growth. John Rehring explained that this does not constitute a MQW "source," but may be indicative of a potential for water quality degradation in sources that could be considered for future use.

In response to a question concerning basins showing zero flows, Dan Reisinger responded that all flow measurements and projections were based on monthly flows.

Becky Dunavant then went over the threshold concentrations for parameters of concern and displayed median concentrations by basins for each (see PowerPoint Presentation Slides #s 16-20.) When asked if this evaluation would be also conducted for groundwater, Becky explained that this might be more difficult due to lack of information. Several participants expressed that they thought the information was available, just not in a localized area for easy access. Noel Osborn, Mark Becker, Kelly Hurt and Mike Overbay agreed to have an off-line discussion to look at sources of groundwater quality data that might be useful for this analysis.

Further discussion centered on the identified sources of MQW: treated wastewater, stormwater, oil and gas flowback/produced water and brackish water. Dan Reisinger gave more detail on how discharges were determined using the Oklahoma H20 tool. Dan noted that it was assumed that 50% of effluent from land application facilities is returned to streams, while several participants noted that such discharges would not be authorized. John Rehring explained that they were primarily looking at direct surface discharging facilities, since those would be most conducive to recapture and reuse of the treated effluent. When asked if potential impacts to downstream users' supplies was being assessed, John explained it was not assessed as part of the characterization of physical supply availability, but could certainly be considered as one of the constraints as the MQW process moves forward toward identifying the feasibility of using the various MQW sources.

Derek Smithee, OWRB, pointed out that there is now a prohibition in Oklahoma on new discharges into some state lakes. John Rehring noted that this has been a driver for reuse in other states: need for more water vs. no discharge to streams.

Stormwater runoff was noted as being difficult to quantify and reuse options will likely be restricted to cities that had storm sewers and storage and conveyance capabilities. Also, areas with greater development would constitute larger amounts of impervious surface, therefore resulting in higher rates of stormwater runoff—primarily a function of precipitation and developed area. Phase I and Phase II water quality requirements requiring owners of municipal separate storm sewer systems (MS4s) to obtain permit coverage for their stormwater discharges were discussed. Tulsa and Oklahoma City are the only Phase I permitted cities, with 48 Oklahoma communities designated as Phase II. Kelly Hurt noted several projects where use of stormwater runoff was being implemented.

John Rehring noted that oil and gas flowback and produced water was also hard to quantify. A table showing water quality of produced water in Oklahoma was displayed (Slide #27). Pat Billingsly, OK Corp. Comm., suggested putting locations on a map to show areas where reuse might be feasible. The use of recycled brine water for drilling activities was discussed as having possibilities, but adverse implications as well.

Sources of brackish water, defined as water having total dissolved solids concentrations in excess of 1,500 mg/L, were characterized as not being well quantified or delineated. Kim Winton, USGS, provided more information on USGS's study to assess brackish water in the South Central area of the United States, including portions of Oklahoma. The project, which is in the proposal stage right now, would piece together existing data on saline/brackish waters in the area. Kelly Hurt suggested editing the depth increments shown (particularly the 901-8900 feet bin) on the depth-to-base of fresh water map (Slide #30). Tom Buchanan, Lugert-Altus Irrigation District, suggested contacting the Corps of Engineers as they had substantial information in connection with their Red River Chloride Control Project.

In closing, John Rehring asked that any comments on the draft "*Technical Memorandum 1: Categories and Characteristics of Marginal Quality Water Sources*," December 2009, be transmitted to Kyle Arthur, OWRB, by January 8, 2010. John also noted that the next step would be to start looking at constraints on the use of MQW. The next meeting will likely be in February, where a presentation on treatment technologies is planned, as well as discussions on Phase 2 documentation. In the meantime, a conference call will be initiated, as discussed previously, to investigate additional sources of groundwater quality data. *The meeting was adjourned at approximately 11:00 a.m.*

Oklahoma Comprehensive Water Plan
Marginal-Quality Water Technical Work Group Meeting #3

AGENDA
December 15, 2009
Oklahoma Water Resources Board Offices – 3800 N. Classen, Oklahoma City

9:30 a.m. Welcome and Introductions

9:40 a.m. Recap of Senate Bill 1627 Work Group Background and Logistics

- Recap of Work Group Meetings 1 and 2
- Review definitions and categories of Marginal Quality Water

9:50 a.m. Review and Discussion of Draft Technical Memorandum on MQ Supplies

- Overview
- Discussion of MQ Sources, Additional Information Needs, and Constraints to Increased Utilization of MQ Supplies
  - Treated municipal wastewater effluent
  - Stormwater runoff
  - Oil & gas flowback and produced water
  - Brackish surface water and groundwater
  - Other constituents

11:05 a.m. Presentation on Treatment Technologies

11:20 a.m. Action Items and Next Steps

- Follow-up actions from this meeting
- Next steps for finalizing Technical Memorandum and next steps in technical analyses
- Schedule and content for Work Group Meeting #4

11:30 a.m. Adjourn

CDM

OKLAHOMA COMPREHENSIVE WATER PLAN

Marginal Quality Water
Technical Work Group Meeting #3

OWRB Offices, Oklahoma City
December 15, 2009

Recap of Work Group Meetings 1 & 2

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Recap of Work Group Meeting #1

- Background & goals of SB 1627
- Presentations
  - *Dr. Kelly Hurt: Chickasaw Nation brackish water*
  - *Aaron Horn: Produced water and flowback fluids*
- Discussed definition of Marginal-Quality Water
- Developed MQW analysis flowchart and approach for integration into Oklahoma Comprehensive Water Plan

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Recap of Work Group Meeting #2

- Presentation
  - *John Rehring: Draft Work Plan for MQW Analysis*
- Refinements to Work Plan
- Further discussion on sources and constraints
- Kyle Arthur appointed chair and Kelly Hurt nominated for vice-chair

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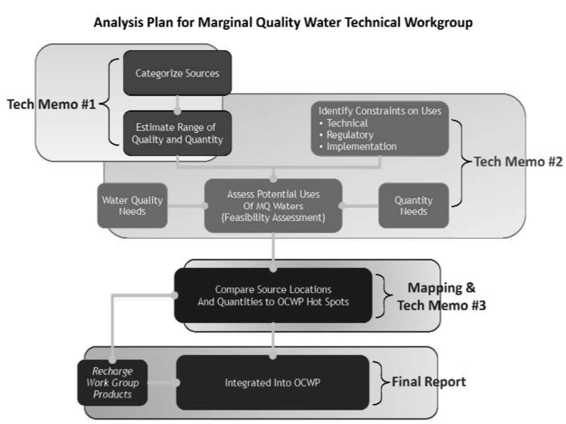

Definitions of Marginal Quality Water

- Surface water or groundwater
- Water not typically used for public supply
- Treated wastewater effluent
- Stormwater runoff
- Brackish groundwater or surface water
- Flowback/Produced water
- Nitrates and other contaminants

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Definitions of Marginal Quality Water

- Surface water or groundwater
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- Treated wastewater effluent
- Stormwater runoff
- Brackish groundwater or surface water
- Flowback/Produced water
- Nitrates and other contaminants

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Definitions 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 thresholds

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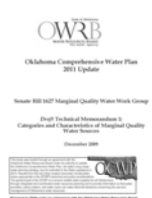
Oklahoma Comprehensive Water Plan

OCWP



Draft Technical Memorandum #1

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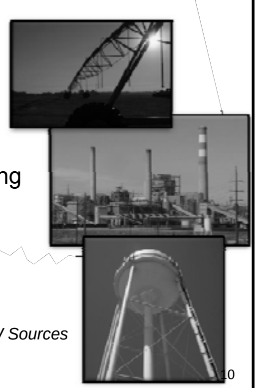
Draft Tech Memo #1

Purpose:

Lay the groundwork for further engineering analysis of MQW by identifying and characterizing potential supplies of MQW.



- *Sec. 1 – Introduction*
- *Sec. 2 – MQ Water background*
- *Sec. 3 – Statewide WQ Data*
- *Sec. 4 – Quantity & Quality of MQW Sources*
- *Sec. 5 – References*

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Statewide Water Quality Data (TM1 Section 3)

- Impaired Waters
- Streamflow Reductions
- Parameters of Concern

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Statewide Water Quality Data: Impaired Waters

- 2008 303(d) List for PPWS & Ag use Impairments
  - *Ag Listings: TDS, Chloride, Sulfates*
  - *PPWS Listings: chlorophyll-a, metals, total coliform, oil and grease, and nitrates*

Summary of 2008 Impaired Water (PPWS and Ag)			
Use	**Number of Waterbodies**	**Number Assessed**	**Number Impaired**
PPWS	1,194	104	49
Agriculture	4,052	779	256

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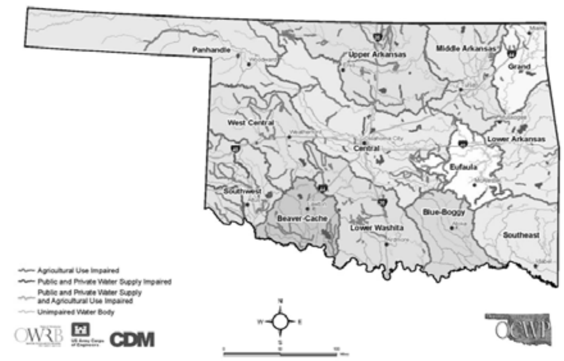
Figure 3-1 - Impaired Waterbodies Based on 2008 303(d) List



Estimating Streamflow Reductions

- Future reductions in streamflow:
  potential “red flag” for water quality degradation
- 2060 demand projections per OCWP technical work
  - *82 basins*
  - *Baseline = demands subtracted from supply sources current surface water / groundwater proportions*
  - *Baseline = local sources & existing interbasin transfers; other scenarios evaluated in OCWP technical analyses*
- Reduction calculation based on historic median flow (1949-2007) vs. 2060 median flow

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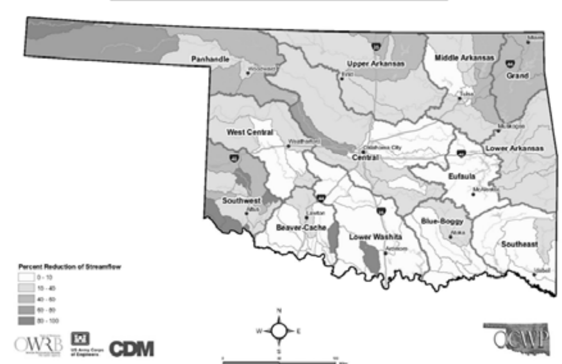
Figure 3-2 - Percent Reduction of Streamflow (Historic Median to 2060 Median)



Statewide Water Quality Data: Key Parameters of Concern

Threshold Concentrations for Parameters of Concern

Parameter	Threshold Concentration (mg/L)	Treatment Concern
TDS	500	Secondary drinking water standard. TDS reduction often requires advanced treatment technologies.
TSS	50	Increases solids handling at the treatment plant.
Nitrates	10 (as nitrogen)	Maximum contaminant level (MCL) for potable water is 10 mg/L. High nitrate level may indicate influence from wastewater treatment or agricultural activities. Reducing nitrate requires advanced treatment technologies.
Hardness	125	Aesthetics associated with increased soap consumption, spots on dishes, cars, windows.

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Figure 3-3 - Median Surface Water Concentrations for Total Dissolved Solids by Basin

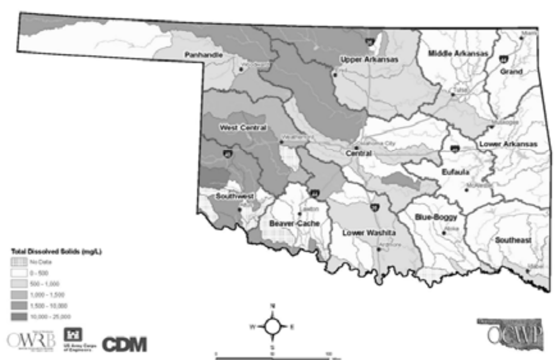


Figure 3-4 - Median Surface Water Concentrations for Total Suspended Solids by Basin

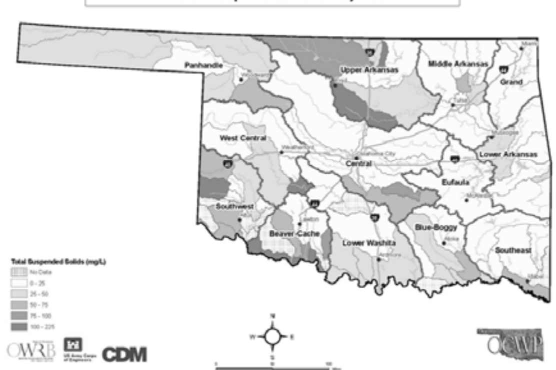
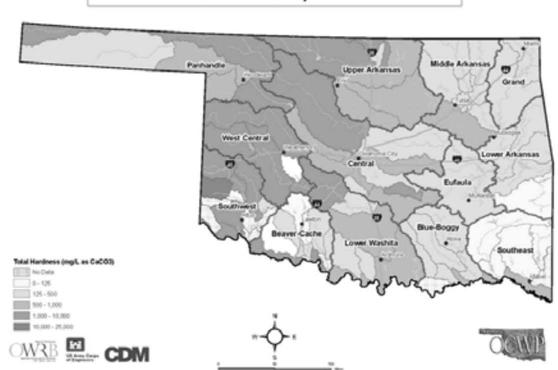


Figure 3-5 - Median Surface Water Concentrations for Nitrates by Basin

Figure 3-6 - Median Surface Water Concentrations for Hardness by Basin



Quality and Quantity of MQW Sources (TM1 Section 4)

Ultimate Goal: Identify Potential Matches Between MQW Supply and Demand

- Treated Wastewater
- Stormwater
- Oil and Gas Flowback/Produced Water
- Brackish Water

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Treated Wastewater ("Reuse")

- Considering return flows from public water supply
- Municipal wastewater treatment varies by basin
  - *Direct surface discharge*
  - *Lagoons*
  - *Retention / septic systems*
- Oklahoma H_2O Tool quantifies discharges to surface waters for each of 82 basins
- Quality regulated via discharge permits (BOD, TSS, bacteria, pH, et al)
- EPA's *2004 Guidelines for Water Reuse* provides guidance for treatment & water quality

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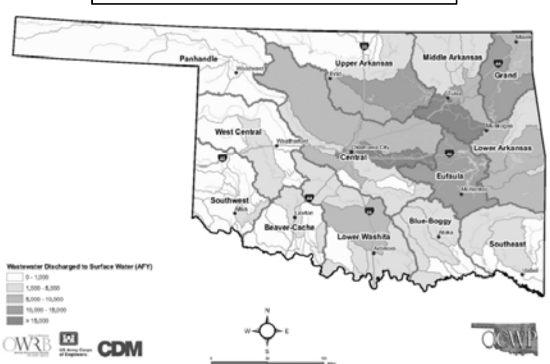
Figure 4-1 Treated Wastewater Discharged to Surface Water by Basin (2007)



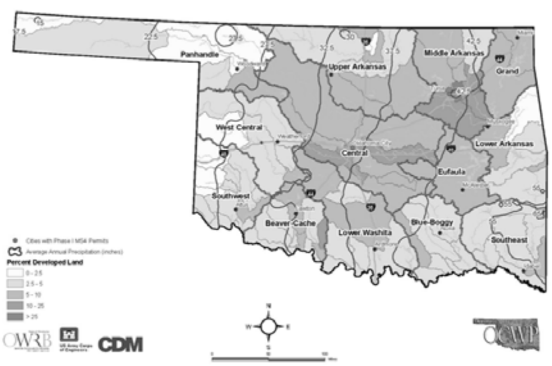
Stormwater Runoff

- Function of precipitation and developed area
- MS4 Cities (2 Phase I and 48 Phase II in OK)
- Typical water quality tabulated
- Estimated runoff quantity for example area

Median of Detected Values in Urban Stormwater (Pitt et. al, 2003)

Land Use	Hardness (mg/L $CaCO_3$)	BOD_5 (mg/L)	TSS (mg/L)	TDS (mg/L)	NO_2+NO_3 (mg/L)	Ammonia (mg/L)	TP (mg/L)	pH
Commercial	36	12	48	74	0.62	0.6	0.23	7.1
Freeways	34	8	99	78	0.28	1.1	0.25	7.1
Industrial	37	9	90	84	0.75	0.5	0.27	7.2
Institutional	–	9	17	53	0.6	0.3	0.17	–
Mixed Residential	43	7	75	85	0.56	0.4	0.27	7.3
Residential	31	9	50	69	0.58	0.3	0.31	7.13
All Land Use Types	39	8	63	78	0.6	0.4	0.27	7.4

Figure 4-2 - Annual Precipitation and Developed Areas



Oil and Gas Flowback/Produced Water

- Difficult to Quantify on a Statewide Basis
  - *Regional and site-specific conditions*
  - *Quantity and quality highly variable*
- Projected Drilling Activity as one indicator of potential quantity:
  - *Conventional drilling activities:*
    2,459 (2008); 4,349 (2030); 5,892 (2060)
  - *Horizontal drilling activities:*
    274 (2008); 1,081 (2030); 2,090 (2060)
  - *Woodford Shale drilling activities:*
    706 (2008); 987 (2030); 10 (2060)

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Oil and Gas Flowback/Produced Water

Water Quality of Produced Water in Oklahoma (USGS Produced Waters database: provisional release, May 2002)

Parameter	Min (mg/L)	Median (mg/L)	Max (mg/L)
pH	5.0	6.4	8.9
Bicarbonates	—	80	12,000
Calcium	—	9,300	74,000
Chloride	11	100,000	240,000
Magnesium	—	1,900	1 1,000
Potassium	—	86	2,100
Sodium	13	51,000	130,000
Sulfate	—	210	14,000
TDS	1,100	160,000	390,000

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Oil and Gas Flowback/Produced Water

- Challenges in utilizing flowback/produced water
- Availability of fresh water sources for drilling and fracking
- Water quality of flowback/produced water
  - Treatment cost and logistics
  - Discharge/disposal options
- Recent Woodford Shale report assesses discharge, disposal, and reuse options in southeast Oklahoma

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Brackish Water

- Surface waters with elevated chloride and TDS
  - *15 of 82 basins have median TDS above 1,500 mg/L*
- Sources not well quantified or delineated
- USGS conducting a 3-year study to delineate and assess saline groundwater supplies in Oklahoma and surrounding states
- Depth to base of treatable water (BTW) contours available to show depth at which 10,000 mg/L TDS occurs

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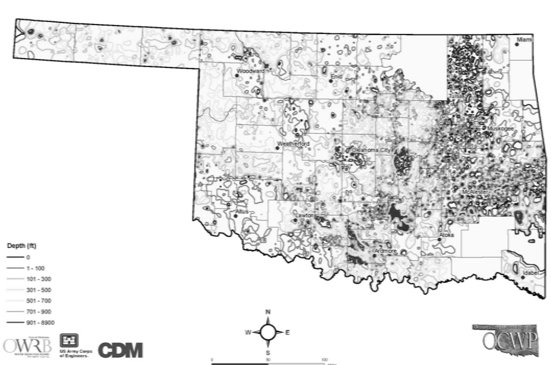
Figure 4-3 - Depth to Base of Treatable Water (10,000 mg/L TDS)



Treatment Technologies

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Action Items & Next Steps

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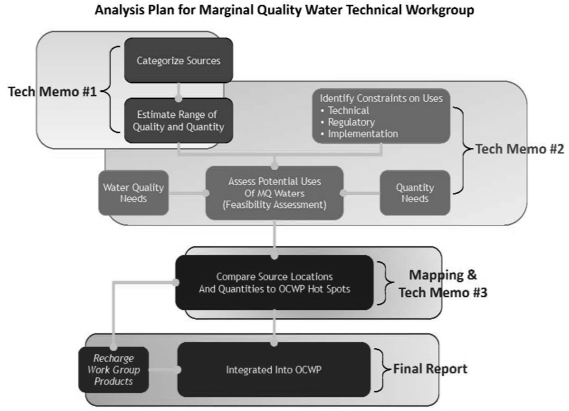
Analysis Plan for Marginal Quality Water Technical Workgroup



Appendix C
Marginal Quality Water Technical Work Group Comments

Appendix C
Marginal Quality Water Technical Work Group Comments

This appendix provides a listing of MQW work group comments on interim written deliverables and a brief summary of how each comment was addressed. Interim deliverables were revised and incorporated into this final report.

TECHNICAL MEMORANDUM #1

Angie Burckhalter
Oklahoma Independent Petroleum Association
Comments on Marginal Quality Water – Draft Technical Memorandum 1
January 7, 2010

Section 1:
In the "introduction", MQWs should be defined as provided by the legislature

Language from SB1627 has been incorporated into the Introduction

Section 2:
The legislation (Section 1, part D) is very clear as to the focus of the technical work group. The flow chart provided in Section 2.1 needs to be reviewd to ensure it coincides with the legislation.

In Section 2.2, the categories of treated wastewater effluent, stormwater runoff and water with elevated levels of key constituents seems inconsistent with the legislation.

The flowchart has been moved to Section 1.1 and reflects the goals and objectives developed by the work group participants. OIPA and the sponsoring Senator for SB1627 attended the first two MQW Work Group meetings, which included the flow chart development and substantial discussions to further define and clarify the types of water that are considered to be sources of MQW. Because these categories were agreed upon and confirmed at more than one meeting by the work group, these categories were used for this document.

Section 3:
In the preamble of this section, there is a statement on groundwater quality information being unavailable. Noel Osborne with OWRB stated in the last meeting that there is at least some basic water quality information available on groundwater at the OWRB. The text should be rewritten to reflect what is available.

A conference call was conducted with Noel Osborne, Mike Overbay, Nancy Dorsey and Kelly Hurt to further discuss groundwater information. Section 2.1.4 has been updated with information that Noel Osborne provided.

In reference to Section 3.1 (Impaired Waters) and 3.2 (Streamflow Reductions), including these types of waters will essentially include most, if not all waters of the

state. We think this is outside the scope of the legislation and should be removed from the report.
It is not clear why Section 3.3 (Parameters of Concern) and 3.3.1 (Water Quality Evaluation) are included in this document and not in future documents where potential users' water quality requirements will be evaluated. Clarification is needed.

This discussion has been moved to Section 2.1.5. Impaired waters are by definition an indication of waters not meeting their designated uses' water quality standards. As discussed in the Work Group meeting, there may be opportunities to utilize impaired waters for certain beneficial uses and are included in this report. The projection of potential future streamflow reductions was not defined by the group, or in TM1, as a category of MQW. It has been removed from the document, as it does not directly characterize any specific MQW source waters.

The water quality needs of various uses and users, along with an assessment of various constraints in using MQW, were detailed in TM2 (now Sections 3-6). The discussion of water quality is relevant to Section 2 because it is focused on characterizing potential sources of MQW supply.

Section 4:
In reference to Section 4.1 (Treated Wastewater) and 4.2 (Stormwater Runoff), we question whether treated wastewater and storm water runoff is within the scope of SB 1627. In addition, by potentially using these waters elsewhere and not allowing them to flow into existing streams, does this not create downstream quantity and quality issues, including potential impairments to existing appropriative rights and reservoir dependable yields?

Please refer to previous explanations on the inclusion of Treated Wastewater and Stormwater Runoff. Downstream water rights are included in the table of potential constraints on the use of MQW sources that is presented in Section 3.

The statement of Page 4-2 regarding "... land application facilities generate retun flows of 50 percent of the ..." seems to imply ODEQ violations as there should not be runoof/return flows from land application facilities. Clarification is needed.

This language was removed from the document. For purposes of this document, treated wastewater was only considered from surface discharging facilities.

In Section 4.3 (Oil and Gas Flowback/Produced Water), page 4-12, we recommend the following language changes to the second sentence in the first paragraph. "While oil and gas activities require water for drilling, completion, and production operations, many completed wells generate produced water at rates that vary from well to well and area to area."

This sentence was changed to reflect this edit and can now be found in Section 2.1.3.

In reference to the bullets on page 4-12, the legislation appears to be focused on the current use of MQWs. How does OWRB plan to use future estimated demand information in this process? Clarification is needed.

Consistent with the overall OCWP technical studies, demands and supplies were evaluated on a 50-year planning period (through 2060).

In the last paragraph on page 4-12, we recommend the following language: "Samples with pH values less than 4 or greater than 9 were exceeded from the database as those values would not be typical for produced/flowback water."

This sentence is now in Section 2.1.3 and has been revised to reflect this suggested edit.

On page 4-13, what is OWRB trying to convey by the first sentence? Do you mean the "reuse" of produced/flowback water is a function of a number of things including economics, quantity and quality? Clarification is needed.

The sentence, now in Section 2.1.3, states: Management or reuse of flowback water and produced water is often a function of the economics, quality and quantity of available water supply and water quality.

In reference to the second sentence on page 4-13, this is "generally, but not always true". We suggest language be added to clarify this sentence.

In reference to the first bullet on page 4-13, we recommend the following language changes. "Ready availability of fresh water supplies (surface or groundwater) for demands associated with drilling completion and production operations"

In reference to the third bullet on page 4-13, we suggest the following language changes, "Mobile and temporary nature of drilling and completion operations that would create challenges related to storage and use of treatment equipment".

In reference the first sentence in Section 4.4 on page 4-13, we suggest the following change: "Brackish water is water with elevated salinity, but…".

In reference to the last sentence in Section 4.4 on page 4-16, the OCC, in cooperation with the oil and gas industry, has defined and developed a map of the base of treatable water"

The above suggestions have all been incorporated into Section 2 of the final report.

Michael Overbay
Environmental Protection Agency – Region 6
Email to Kyle Arthur of OWRB
1/15/2010

On the tables that show available water flows, I was troubled by some of the numbers which indicate up to 100% of the flow could be diverted for use, implying it would be acceptable to essentially dry up the stream. When I raised this as a concern in the discussion, a comment was made that no Oklahoma laws would prevent it. After consulting with our water quality standards folks, our thoughts are that we think there is a Supreme Court ruling on this topic that required maintenance of flows necessary to support designated beneficial uses (although we did not consult with our attorneys). Also, we believe it is likely that downstream water rights owners, environmentalists, and natural resource trustees may litigate such a wholesale appropriation of water. Based on these thoughts, I would like to suggest adding a footnote to these tables that would indicate something along the lines of an acknowledgment these are only estimates, and that other pre-existing uses of the water may restrict the availability to less than the numbers contained in the table.

The discussion of streamflow reductions and associated table/figure have been removed from the document.

Kelly Hurt
Chickasaw Nation
Email to Kyle Arthur of OWRB
Subject: Marginal Quality Water Draft
1/7/2010

All in all, it looks good to me except for the fact that very little was written on brackish groundwater, which is probably the largest source of marginal water in the state. Think they could add more on brackish groundwater resources?

Additional information has been added on brackish groundwater resources throughout the document, particularly in Sections 2 and 5.

Marla Peek
Farm Bureau
Email to Kyle Arthur of OWRB
Subject: comments on draft technical memorandum 1, marginal quality water
1/7/2010

Page 1-1. "MQW is water that may be unusable because of technological or economical issues with treating the water." Comment: Suggest you use the definition of MQW from SB 1627, and the above sentence as an explanation.

The Legislative language has been incorporated into the introduction.

Page 1-1. Introduction. Comment: Suggest somewhere in the beginning of the document explain why the 82 basins are used and how.

Further explanation on the 82 Basins has been included in Section 1.

Page 3-1. Section 3, Statewide Water Quality Data. "The purpose of this analysis was to identify areas of water quality impairment that may restrict water supply development." Comment: I don't understand this section. I thought the purpose of the work group was to identify sources of marginal quality water and how they might be used. If a waterbody is used as a PPWS, it will be used in that manner regardless of impairments. The water will be treated. Practically every stream and river in the state is listed for pathogens/bacteria. I don't understand the utility of this section.

Our intent was to review state waters that are currently not meeting their intended use due to water quality issues. This analysis was a broad first step at narrowing the focus to the "parameters of concern" list – surface waters where we know there is a current issue and monitoring data has shown higher than desirable levels of these parameters in terms of treatment requirements.

"The most common cause of PPWS use impairment is chlorophyll-a."Comment: Chlorophyll-a is an indicator of use impairment.

Chlorophyll-a is categorized as a "cause of impairment" on the state's 303(d) list. Information was added that states that chlorophyll-a is used as surrogate parameter/indicator for nutrients.

Page 3-2. 3.2 Streamflow Reductions Comment: Did these streamflow reduction projects take into account that state law requires domestic use be protected for riparian landowners (82 O.S. Section 105.2)? This projection seems to infer that there are no restrictions on how much water can be taken from a stream or river. Am I inferring that correctly? I don't understand how reservoirs fit in with this basin approach? The reservoirs reside within the basins. Are they considered to have a flow? This section is confusing. It is unclear how this section relates to the purpose of the workgroup.

The projection of potential future streamflow reductions was not defined by the group, or in TM1, as a category of MQW. It was provided as a qualitative indicator of potential water quality trends, as described in TM1, however, it has been removed from this document.

Page 3-7. "Water quality parameters of interest for crop irrigation are primarily associated with TDS and salinity. Because the tolerance of crops to salinity is function of the type of crop, irrigation patterns, and soil conditions, it is difficult to set specific statewide water quality thresholds for crop irrigation use." Comment: We would like to provide you with some information on this issue. These thresholds are knowable. We will put together a bibliography of documents regarding what kind of water quality agriculture requires.

Tolerance information for a variety of plants/crops have been included in the document.

Patricia Billingsley
Oklahoma Corporation Commission
Emails to Becky Dunavant and John Rehring CDM
Subject: Waterplan - Ground Water Data OK Corporation Commission
1/8/2010

P. Billingsley submitted surface water and groundwater quality databases.

Text has been added to Section 2.1.4 and 2.1.5 to discuss OCC's monitoring programs.

P. Billingsley submitted the following information:

Salinity Cleanup Standards For Surface Water and Groundwater (GW) – most uses		
Surface Water	OWRB standards	Appendix F http://www.owrb.state.ok.us/util/rules/pdf_rul/Chap45.pdf
Surface and ground water for irrigation	OSU guidelines	OSU F-2401 Classification of Irrigation Water Quality http://pods.dasnr.okstate.edu/docushare/dsweb/Get/Document-2223/F-2401web.pdf. SAR £4; EC £4 mmhos/cm, varies with Na percent.
Ground water @ water well	EPA standards	EPA secondary drinking water standards include 250 ppm chlorides. http://www.epa.gov/safewater/consumer/2ndstandards.html
Groundwater	Other uses	Make sure GW will meet standards when it gets to the well or stream

Recommended Maximum Salt (as TSS/TDS) in Animal Drinking Water; young need lower limits			
Poultry	Dairy cows, horses, swine	Beef Cattle	Sheep, goats
3,000 ppm, mg/l	7,000 (Cl or sodium–300 mg/l cows; 500 horses)	10,000 ppm, mg/l	12,000 ppm

Maximum *Boron Limits Table[1] for High-Boron Brine Spills to Soil or Ground/Irrigation water					
Boron concentrations in soil and water indicate the maximum range each plant/group will tolerate					
<1.1 soil <0.75 water	<1.5 soil <1 water	<3 soil <2 water	<6 soil <4 water	<9 soil <6 water	<15 soil <10 water
Blackberry (best <0.5ppm);	Grain crops (e.g. wheat, milo) corn,	Vegetables like pepper,	Clover, oats, bluegrass, lettuce,	Sorghum, alfalfa, tomato,	Cotton, asparagus

grape, most other fruits, nut trees, onion	pumpkin, beans, sun-flower, oats, peanut, strawberry	peas, carrot, potato, cucumber	cabbage, melon, squash	vetch, beet, most grasses	

This information was appreciated and incorporated throughout the report where appropriate.

TECHNICAL MEMORANDUM #2

Michael Overbay
Environmental Protection Agency – Region 6
Email to Terri Sparks of OWRB
4/1/2010

On page 2-2, at the bottom, regarding the technical constraints on flowback/produced waters: I think we need to consider breaking these into flowback waters and produced waters here. The reason is that while flowback waters may be temporary and by some measures small volumes, produced waters are for a comparatively longer term and of larger volumes, as demonstrated by our UIC class II permitting programs. This is discussed later in the text.

This is now Table 3-1 and this edit has been made.

Figure 3-2, on page 3-4, needs a legend or key to explain the "demand" color assignments.

A legend has been added.

Section 3.5 at the bottom of page 3-5 indicates water is used for enhanced oil recovery operations. To my knowledge, this is always a re-injection of produced waters, and does not include fresh waters. Should this activity be deleted, as it does not impact any fresh water supplies?

The reference to enhanced oil recovery has been removed from this discussion.

Table 3-1, page 3-11. Footnotes 2 & 3 are not used in this table, and are likely carryovers from the original source. Since they are not used, I would recommend removing them.

These footnotes have been removed.

In the 7th line from the bottom of page 4-6, VOC's should be volatile organic compounds, not carbon. Same on next line for synthetic organic compounds.

This edit has been made.

I recommend adding to the end of the paragraph in 4.3, on page 4-8, the following sentence: "Generally, costs can also expect to benefit from the economies of scale realized with larger projects."

This sentence has been added.

Noel Osborne
OWRB
Memo Attachment to an Email to Terri Sparks of OWRB
Subject: Comments regarding the Draft Technical Memorandum 2: Potential Uses of Marginal Quality Water, February 2010
3/25/2010

I found the Draft report Technical Memorandum 2: Potential Uses of Marginal Quality Water, February 2010 to be a well-written report that reflects the consensus of the technical committee. The decision matrix of potential uses appears reasonable and is helpful for prioritizing future efforts. I do, however, have some concerns regarding the description and use of brackish groundwater, and hope that these can be discussed in future meetings and addressed in the final report.

Regarding the definition of brackish water, I suggest a more precise definition than the one listed on page 2-1 ("Surface and groundwater sources that have higher salinity than freshwater, but less than seawater"). The discussion of brackish waters in Technical Memorandum 1 (Section 4.4) indicates that brackish water is considered to be waters with TDS concentrations more than about 1,500 mg/L and less than 10,000 mg/L. This is a reasonable definition, as the definition of brackish and saline groundwater is somewhat arbitrary. According to Alley (2003), water with a TDS concentration greater than 1,000 mg/L commonly is considered saline. NGWA (2005) considers brackish groundwater as water with a TDS concentration between 1,000 and 10,000 mg/L. Brine is usually considered very salty water with TDS greater than 35,000 mg/L. The U.S. Bureau of Reclamation (2003) classifies saline waters by TDS concentration as:

Mildly brackish	***1,000-5,000 mg/L***
Moderately brackish	***5,000-15,000 mg/L***
Heavily brackish	***15,000-35,000 mg/L***
Seawater and brine	***>35,000 mg/L***

OWRB has regulatory authority of "fresh" groundwater, which is defined as groundwater with dissolved solids (TDS) concentrations less than 5,000 ppm. Groundwater with TDS concentrations less than 5,000 mg/L are characterized in groundwater basin studies and are accounted for in the allocation of water rights. These waters occur in several aquifers in the western portion of the state from contact with rock formations containing gypsum ($CaSO_4 \cdot 2H_2O$) and halite (NaCl), and are currently used for stock and irrigation purposes. For example, the Blaine aquifer is southwest Oklahoma has a median TDS concentration of about 3,500 mg/L and

sulfate concentration of about 2,000 mg/L. Local farmers rely on the aquifer for irrigation of cotton and other crops (Osborn and others, 1997).

Brackish and saline waters underlie most of Oklahoma. (For this discussion I consider saline water to have a TDS concentration greater than 10,000 mg/L). Under most aquifers there is a transition from fresh to brackish to saline water. The depth to brackish and saline waters varies across the state, from less than 500 feet to more than 1,000 feet. Hart (1966) mapped the base of fresh groundwater (TDS < 5,000 mg/L) in southern Oklahoma. The Oklahoma Corporation Commission has developed base of treatable water maps for the state, with treatable water defined as water with TDS concentrations greater than 10,000 mg/L.

Based on the previous discussion of OWRB's regulatory authority, water use, and hydrogeologic factors, I propose two categories of brackish groundwater to be considered as sources of marginal quality water:

1. *Mildly brackish groundwater with TDS concentrations of 1,000-5,000 mg/L, which are regulated by OWRB but are limited in use.*
2. *Moderately brackish groundwater with TDS concentrations of 5,000-10,000 mg/L, which are unregulated and much more limited in use than mildly brackish groundwater.*

I have some concerns regarding the use of moderately brackish groundwater (TDS 5,000-10,000 mg/L) in Oklahoma, which are listed below. Similar concerns are discussed in the literature (for example, Alley, 2003).

1. *Most moderately brackish groundwater supplies are not sustainable. These waters contain water that was recharged tens of thousands to millions of years ago. They receive little or no recharge from surface source, such as infiltration from rainfall or percolation from streams. Thus, these waters should not be relied upon for a sole source of supply. (However, they could be used in times of water shortages.)*
2. *Freshwater portions of aquifers could be impacted negatively by removing large amounts of water from the brackish zone. The parts of aquifers containing saline water commonly are connected hydraulically to parts of the same aquifer or aquifer system that contain freshwater. Thus, development of one resource affects the other, as well as potentially affecting the flow and quality of surface-water bodies connected to the groundwater system (Alley, 2003).*
3. *Little is known about the hydrogeology of the parts of the aquifers that contain marginally brackish waters. Groundwater investigations in Oklahoma have been limited to characterizing fresh groundwater (TDS < 5,000 mg/L). However, there is little information about the factors required to understand the development potential of moderately brackish aquifers or to predict potential environmental impacts of withdrawing moderately brackish groundwater. These factors include hydraulic conductivity, transmissivity, storage coefficient, and the three-dimensional extent of the aquifer.*
4. *OWRB does not have jurisdiction over groundwater with TDS concentrations greater than 5,000 mg/L. Oklahoma cannot plan and manage marginally brackish water supplies, and it cannot protect freshwater supplies until these legal issues are resolved.*

The majority of this information has been included in Section 2.1.4

Patricia Billingsley
Oklahoma Corporation Commission
Email to Becky Dunavant CDM and Kyle Arthur OWRB
3/12/2010

1. ***Flowback water is low volume, but produced water is NOT low volume.***
   - ***Total fluid injection in 2008= 2,218,391,290 BBLs, or***
   - ***Total fluid injection in 2008= 93,172,434,180 gallons of water (yes, 93 billion)***
   - ***Much of the water is highly saline, but some is low in salinity. We would have to check the original order on each field to differentiate.***

2. ***Fracturing wells is shortened as fracing or doing a frac – NOT fracking or frack. There is no K – only EPA and the press have started to put in a K.***

Text has been added to distinguish flowback and produced water volumes. Frac has been corrected throughout the document.

Howard L. (Bud) Ground
Public Service Company of Oklahoma
Email to John Rehring CDM
3/5/2010

I am not sure exactly where or how but please describe that thermo electrics are not large consumers of water. We "use" alot of water but most (approx 85%) returns to the receiving stream.

Text has been added to the Section 4 Introduction and Section 4.4 to further describe the consumptive vs. nonconsumptive uses of water by thermo electrics.

In the graph on 4-2 please change the brackish water category for thermo electric to "potentially feasible".

This edit has been made.

Include the graph in the report of water users that was shown on the power point. This is a good place to differentiate between consumptive users and non-consumptive users.

This graph is now included as Figure 4-1.

Mike Mathis
Chesapeake Energy
Email to Dan Reisinger CDM
2/25/2010

Following is some draft guidance for you.
For a base slickwater fluid, general requirements would be:

Chloride	***<10,000 mg/L***
Total Hardness	***<1,000 mg/L***
Iron	***<5 mg/L***

For cross-linked gel make-up, there is an additional requirement that Boron be less than 2 mg/L.

Keep in mind, these are for the overall fluid. If we were looking to blend in a water, it could have numbers much higher as long as the end blend met the specs above.

This information has been added to the document.

Marla Peek
Farm Bureau
Email to Kyle Arthur OWRB, Terri Sparks OWRB, and Becky Dunavant CDM
Subject: Oklahoma Farm Bureau Comments on Draft Technical Memorandum 2: Potential Uses of Marginal Quality Water
3/17/2010

Page 3-1: Water quantity needs presented below were summarized based on the water demand projections developed for the OCWP updates. OFB comment: The OWRB has contracted with the Oklahoma Department of Ag Food and Forestry to develop an agricultural water needs document for the statewide water plan, so a water demand for agricultural needs document is not complete at this time. We urge you to update TM2 after that document is finalized.

Reference has been made to the recent article published in the Oklahoma Academy's May 2010 Town Hall background report on water issues (Oklahoma Academy 2010)."

Page 3-4. OFB comment: The legend for Figure 3-2 is omitted.

A legend has been added to this figure.

Page 3-11. Table 3-1. OFB comment: We submitted some questions and comments via phone and email to Becky Dunavant that may change the content in the table to better reflect major OK crops.

Potatoes have been removed from the table as they are not commercially grown in OK. Information on the wheat variety, or yield reduction/TDS levels for hay and soybean were not readily available. The footnotes to the table have been corrected.

Page 4-3. Direct potable reuse – directly plumbing treated effluent from a wastewater treatment plant to a water treatment plant and then into distribution for potable use – is not practiced in the US and is in limited practice globally. OFB comment: It is our understanding this practice is currently being used in one community in California.

Further investigation of this topic was performed. A study completed by the National Water Research Institute in 2010 titled "Regulatory Aspects of Direct Potable Reuse in California" states that "Direct potable reuse currently is not practiced anywhere in the U.S. It was implemented on an emergency basis in Chanute, Kansas, for a five-month period in 1956 during an extreme drought circumstance and was evaluated in Denver, Colorado, during a demonstration project from 1985 to 1992. The only known existing direct potable reuse facility in the world is located in Windhoek, Namibia." The paper is available at http://www.nwri-usa.org/pdfs/NWRIPaperDirectPotableReuse2010.pdf

Page 4-7. OFB comment: Please edit this sentence as follows: Lower stream flows in certain parts of the state could result in a high percentage of wastewater effluent or runoff from animal waste, including wildlife and domestic pets, that could result in water sources being classified as MQW for M&I supply due to the high risk for pathogen contamination and designation of the water source as Bins 2, 3, or 4 under EPA's Long Term 2 Enhanced Surface Water Treatment Rule.

This edit has been incorporated.

Angie Burckhalter
Oklahoma Independent Petroleum Association
Comments on Marginal Quality Water – Draft Technical Memorandum 2
3/17/2010

Section 2.1:

a. ***We would like to reiterate our preciously submitted comments on the scope of the MQWs being considered in this study. We understand the work group has collectively decided on a broader definition; however, we have concerns that some of the waters being considered in this study may already be appropriated, set aside for domestic use, or other similar situations. There may be negative impacts if these waters are used elsewhere.***
b. ***We recommend that brackish water be clarified in this document i.e. what is the threshold to be considered "brackish"? Is it the regulatory threshold or has the group established a different threshold? Likewise, it would be helpful to define "fresh water". In additiona, should brackish water be further segregated into categories where a certain range would be more feasibile to economically treat?***

Part a: please see our response to the TM1 comment. Part b: additional information has been added to categorize brackish water.

Section 2.2:

a. ***Regulatory constraints should consider the impacts to existing water rights, domestic uses, and other similar situations. In addition, regulatory requirements regarding the storage and transportation of MQWs should be included.***
b. ***An implementation constraint should include the liability aspect associated with storing, treating, or transporting of a MQW, especially produced or brackish waters.***

These constraints have been added to the discussion and to the table – which is now Table 3-1.

Section 2.3, Table 2-1:

a. ***As previously stated, the impacts of using treated wastewater, stormwater runoff, and contaminants of concern may have negative impacts that need to be considered under "Implementation" if these water are used elsewhere.***

A category has been added for "environmental" constraints and reduced receiving water flow has been added to the wastewater and stormwater categories.

b. ***In the oil and gas produced water/flowback water category, what is meant by "small volume" and "temporary supply" in the second column? In the third column, disposal of produced water is the most common method used whereas discharge is not typically used. In addition, we suggest liability issues and availability of land be included. Also, what is meant by "public perception" in this column?***

These categories have been separated. The small volume bullet is now found within the flowback water category. Temporary supply means this would not necessarily be a continuously discharging supply.

c. ***Under the Brackish Water category, suggest storage and transportation issues be included under regulatory constraints. Again, it would be helpful to define brackish water versus fresh water. Also, we recommend liability and availability of land issues be included under the implementation constraints.***

These suggestions have been added to the table.

d. ***Under the "Contaminants of Concern" category, what waters (surface and/or groundwater" does this include.***

This category was further defined in Section 2.1.5.

Section 4: In table 4-1, we recommend that "PT", "WQ", "LOC" and "REL" be added to the oil and gas sector under oil and gas flowback/produced water, brackish water, and contaminants for concern columns to cover a variety of scenarios that are most likely to be encountered.

These suggestions have been incorporated into the matrix – Now Figure 5-1.

Section 4.1.3: At the bottom of page 4-4, a reference to a report has been added. Can a few sentences be added to summarize the results of that report?

Additional information has been added from this report.

MISC WORK GROUP COMMENTS FROM MEETING #4 (3/3/2010)

Another suggested category of constraints was Environmental Constraints which could include issues like disposal of treatment residuals, impacts of decreases in instream and downstream flows, and subsidence impact on fresh water from pumping deep aquifers' brackish water supplies.

This edit has been incorporated.

Self-Supplied Rural Residential should be renamed Self-Supplied Residential with no reference to "rural"

Rural has been removed from the self-supplied residential category.

Appendix C of the Water Quality Standards has water quality classifications for crops.

Appendix C from Chapter 45: Water Quality Standards has been "REVOKED" and was not available for integration into the report.

Comments on Matrix:
Irrigation and Livestock Watering—change Treated Wastewater from red (not feasible) to yellow (less feasible). This comment has been incorporated. And crop irrigation has been changed to green per a comment below.

▪***Should public perception be included in the matrix?*** Public Perception has been added to the matrix

▪***Do not be too negative as far as feasibility—do not want residents to rely totally on this document when looking at MQW suitability—may be other localized factors that make it work.***

▪***ODEQ is incorporating better technology for allowing reuse, such as at the Gaillardia development in Oklahoma City.***

▪***Thermo-Electric Power—change Brackish Water to green instead of yellow-level feasibility.*** This comment has been incorporated.

▪***Self-Supplied—Change to yellow.*** This comment has been incorporated.

▪***Need to note that water <5,000ppm total dissolved solids is within OWRB's permitting jurisdiction; anything greater is not.*** See earlier response to similar comments.

▪***Brackish water for irrigation—add conventional and unconventional treatment.*** This comment has been incorporated.

MISC WORK GROUP COMMENTS FROM MEETING #4 (4/25/2010)

Matrix: Change Treated WW on Ag to green

This edit has been made.

Matrix: Change Brackish Water for Crop Irrigation to Yellow

This edit has been made.

Note in Treated WW that there are some opportunities to utilize treated WW from local/individual aerobic treatment units to use that water for self-supplied residential.

Text has been added to reflect this comment.

Figure 2 (Treated WW for Self-Supplied Residential) : Why is panhandle red (high demand)? Why isn't anything around Tulsa purple?

Self supplied industrial demands consist of demands associated with large industries identified as self-supplied users with available water use data and employment counts. There is a relatively small industrial user (~150 AFY) in 2060 in eastern Osage county and large users in western Osage County and eastern Muskogee County. The industries near Tulsa are likely included in the M&I demand sector. The Panhandle has several small and medium size industries.

Figure 4 (Treated WW for Crop Irrigation): Should more of SE be shaded red?

Crop irrigation demands are estimated using the total irrigated land in the 2007 United States Department of Agriculture (USDA) Census of Agriculture data and water use data from the Natural Resource Conservation Service (NRCS) Irrigation Guide Report, Oklahoma Supplement (USDA NRCS 1997). The southeastern portion of the state has relatively low crop irrigation demand densities due to relatively few irrigated lands and relatively large basin sizes.

Need to note that brackish GW feasibility depends on specifics of 1. Whether it is 1,000, 3,000, 10,000 mg/L TDS, etc; 2. Which crops; 3. What comprises the brackish TDS (SO4, Na)?

This information has been added to Sections 2.1.4.1 and 5.1.4.

Verify that livestock watering includes washdown, etc. Are CAFOs included in Livestock?

Daily water requirements for each livestock group include that used for drinking water, cooling, and sanitation and waste removal requirements. Water use by livestock were estimated using the USGS Method for Estimating Water Withdrawals for Livestock in the U.S. (USGS 2005).

Think about whether/how to subdivided brackish water for livestock watering since different animals tolerate different levels.

These maps have changed since the last meeting. Table 5-2 has been added to provide information on counties with the highest numbers of cattle.

DRAFT FINAL REPORT

Marla Peek
Farm Bureau
Email to Terri Sparks OWRB and Becky Dunavant CDM
Subject: OFB Comments on the Senate Bill 1627 Marginal Quality Water Work Group Draft Report
6/23/2010

1. Page 2-10 2.1.3 Oil and Gas Flowback/Produced Water

OFB Comment: It would be helpful to include a glossary in the document or please define "produced" and "flowback" water.

We believe that words are adequately defined in the text of the document and a glossary has not been added as it is difficult to determine the extent of words that should be included in a glossary. Produced and flowback waters are both defined in Section 2 on page 2-1. Further details on characteristics of produced and flowback water and provided throughout the text.

2. Page 2-12
"OWRB has regulatory authority over the use of "fresh" groundwater, which is defined as groundwater with TDS concentrations less than 5,000 ppm."

OFB Comment: This statement could be misconstrued by a lay person reading this report. We would appreciate the OWRB providing language to reflect their authority more appropriately. OWRB sets standards for water well drilling and classifications for groundwater. We suggest the statement of OWRB's authority could be derived from the information in some of the following statutes and rules: 27A: 1-3-101; 82:1020.1(7); 82:1020.1(1); 785:30-1-2; 785:45-1-2; and 785:45-7-3.

***OFB Comment:** Jurisdiction over groundwater pollution lies with the various agencies with statutory authority for the industries they regulate. For instance, the Oklahoma Department of Agriculture Food and Forestry has oversight over groundwater pollution from agriculture. The Oklahoma Corporation Commission has oversight over groundwater pollution from oil and gas activities. The Oklahoma Department of Environmental Quality has oversight over groundwater pollution from septic tanks and wastewater lagoons, etc. Some of the information on the various agencies responsibility for groundwater protection can be found at 27A:1-1-202 and 27A: 1-3-101, and could be used to explain the authority over "fresh" groundwater.*

Noel Osborn of OWRB provided comments on this text following discussion on the subject at workgroup meeting #6. Here comments are detailed below and the text has been revised accordingly.

***3. Page 2-13** "Based upon the previous discussion of OWRB's regulatory authority, water use, and hydrogeologic factors, two categories of brackish groundwater were considered as sources of MQW: ■ Mildly brackish groundwater with TDS concentrations of 1,000-5,000 mg/L, which are regulated by OWRB but are limited in use; and ■ Moderately brackish groundwater with TDS concentrations of 5,000-10,000 mg/L, which are not regulated by OWRB and much more limited in use than mildly brackish groundwater."*

***OFB Comment:** See comments for #2.*

Please refer to above response.

4. Page 2-15 "Groundwater investigations in Oklahoma have been largely focused on characterizing groundwater regulated by OWRB (TDS<5,000 mg/L)…OWRB does not have jurisdiction over groundwater with TDS concentrations greater than 5,000 mg/L. As such OWRB cannot plan for or administer the use of marginally brackish water supplies, and it cannot protect against potential effects on freshwater aquifers related to brackish groundwater withdraws."

***OFB Comment:** For the first two sentences, please see comments for #2. The last sentence makes it sound like the OWRB should have the right to regulate something the law hasn't addressed yet. We suggest you might reword the last sentence to something like, "the law is silent on how marginally brackish water supplies may be regulated, including potential effects on freshwater aquifers related to brackish groundwater withdrawals."*

Please refer to above responses.

***5. Page 4-11** "The role of importance in Oklahoma's economy is significant, and heavily reliant on reliable water supplies, as described in a recent article in the*

Oklahoma Academy's May 2010 Town Hall background report on water issues (Oklahoma Academy 2010)."

OFB Comment: If this is the article referred to, please use the title, "Role of Agriculture in Oklahoma's Water Plan."

The full title is included in the reference section of the document (Section 8).

6. Page 4-11 Table 4.1 Potential Yield Reduction from Saline Water for Selected Irrigated Crops

OFB Comment: Please refer to comments in Email #1 from Oklahoma State University assistant professor in Plant and Soil Sciences Tyson Ochsner and professor in Plant and Soil Sciences Hailin Zhang, including the August 2007 document, "Managing Irrigation Water Quality for Crop Protection in the Pacific Northwest".

Suggested edits were made to Table 4-1.

7. Pages 5-14-15 "For reference, the top five counties in Oklahoma for cattle for 2009 to 2010 according to the National Agricultural Statistics were: Blaine (135,000 head); Caddo (135,000 head); Cimarron (135,000 head); Grady (135,000 head); and Osage (135,000 head)."

OFB Comment: Please use the cattle numbers provided by Oklahoma State University professor and extension economist Darrell Peel. Email #2 is attached, for your information.

The information on the top five counties and livestock numbers have been corrected.

Angie Burckhalter
Oklahoma Independent Petroleum Association
Comments on Marginal Quality Water – Draft Final Report
January 7, 2010

TOC - Recommend the use of "Elevated Levels of Key Constituents" instead of "Contaminants of Concern" in the TOC and throughout the document.

This change has been made.

Page 2-1 (below text represents edits and comments):

- *Oil and gas flowback and produced water: Flowback water is the water that returns to the surface during initial oil and gas well completion activities, while produced water is a byproduct of well production.*

- *Brackish surface and groundwater: Surface and groundwater sources that have higher salinity than freshwater, but less than seawater, are considered brackish. Through the work group process, it was determined that waters with total dissolved solids (TDS) concentrations between 1,000 milligrams per liter (mg/L) and 35,000 mg/l (comment- Should a "brackish" range be included? At around 35,000 mg/l, water is deemed "brine".)would be considered brackish for these efforts.*

Text has been edited to reflect these comments. Please refer to Section 2.

2.1.3 Oil and Gas Flowback <u>and</u> Produced Water

Flowback/Produced has been changed to Flowback and Produced Waters.

Section 2.1.4 Comment – Should EPA's definition of USDW (i.e. TDS concentration less than 10,000 mg/l) be included as well?)

Thank you for the suggestion. This definition was not included as the paragraph did not include discussion of drinking water.

Page 2-14: Freshwater portions of aquifers could be impacted negatively by removing large amounts of water from the brackish zone. (comment - In the next sentence, clarification is needed.)Groundwater formations containing saline water may or in some instances be connected hydraulically to aquifers that contain freshwater. Thus, development of one resource affects the other, as well as potentially affecting the flow and quality of surface-water bodies connected to the groundwater system (Alley, 2003).

The suggested edits were incorporated.

Section 2.1.5 (Recommend this section be broken out into subsections i.e. surface water and groundwater.)

This section has been subdivided into a groundwater and surface water discussion.

Third Paragraph Section 2.1.5 (comment – The following text on oil and gas seems out of place. To improve the flow of the document, move the oil and gas discussion to the end of the section.)

This edit has been made. This text was moved to the end of the oil and gas discussion.

Section 3 – Table 3-1. Under Environmental Constraints, change Residuals disposal to Treatment residuals disposal.

This edit has been made.

4.5.2 Water Quality: Water quality requirements for oil and gas drilling activities are reported to vary significantly, depending on the type of drilling and the specific operations and standards of the energy company. Some general requirements for the base fluid in completion operations (as provided by Chesapeake Energy) are:

These edits have been made.

Comment – On table 5-1, in the box where "Oil and Gas" and Stormwater intersect, it is marked as "less feasible, depending on site-specific conditions". We recommend it be changed to "not feasible on a wide scale basis for indicated reasons". A similar rationale provided for treated wastewater (on page 5-5) would apply in this situation. Also, this conflicts with the text provided on page 5-10.

The matrix has been edited accordingly and no longer conflicts with text in later sections.

5.1.3: Add Also, the cost to treat, store, transport, etc. can be cost prohibitive as well.

The following sentence was added: The cost to treat, store, and transport flowback and/or produced water may also be cost prohibitive.

Section 5 figures: is a figure for O&G missing?

Using the matrix (table 5-1), figures were developed for any combination that was designated as potentially feasible or less feasible (green or yellow). Flowback and produced waters were only designated as less feasible for potential use by the oil and gas industry. Because sufficient geographic data are not readily available for this demand sector, a map was not developed.

Section 7:

- ***Oil and Gas Flowback Water is relatively low volume while Produced Water can be a locally significant source of MQW, but utilization of this resource is likely to be limited by temporal, location, and water quality issues. In addition, the location of significant water users' demands relative to oil and gas production activities may negatively impact the cost-effectiveness of using the water resource. The cost to treat, store, transport, etc. can be prohibitive and must be considered. Of Oklahoma's seven demand sectors, reuse of flowback and produced water to support the water needs of nearby oil and gas drilling may be the most viable from a technical and economic perspective. Oil and gas production activities are expected to continue to occur across a wide geographic range in Oklahoma.***

Similar edits were made to the conclusion.

Recommendations:

The text in the stormwater runoff recommendations (i.e. "and considering potential water rights issues related to downstream diversion" should be included for treated wastewater, and "elevated levels of key constituents."

This language has been added to both the conclusions and recommendations.

Noel Osborne
OWRB
Memo Attachment to an Email to Terri Sparks of OWRB
Subject: suggested edits for Marginal Quality Water report, July 8, 2010

Below text includes edits to text in Section 2.1.4
2.1.4.1 Brackish Groundwater
OWRB regulates permitted withdrawals of "fresh" groundwater, which is defined as groundwater with TDS concentrations less than 5,000 ppm. Groundwaters with TDS concentrations less than 5,000 mg/L are characterized in groundwater basin studies and are accounted for in the allocation of water rights. Mildly brackish waters, with TDS concentrations of 1,000-5,000 mg/L, occur in several aquifers in the western portion of the state from contact with rock formations containing gypsum (CaSO4*2H2O) and halite (NaCl), and are currently used for some stock and irrigation purposes. For example, the Blaine aquifer in southwest Oklahoma has a median TDS concentration of approximately 3,500 mg/L and median sulfate concentration of approximately 2,000 mg/L. Local farmers rely on the aquifer for irrigation of cotton and other crops (Osborn and others, 1997).

Naturally occurring brackish groundwater underlies most of Oklahoma. The depth to brackish water varies across the state, from less than 500 feet to more than 1,000 feet. Hart (1966) mapped the base of fresh groundwater (TDS < 5,000 mg/L) in southern Oklahoma. The Oklahoma Corporation Commission (OCC), in cooperation with the oil and gas industry, has developed base of treatable water maps for the state, with treatable water defined as water with TDS concentrations greater than 10,000 mg/L (Figure 2-3). Little information exists on the extent (geographic area and volume) of moderately brackish groundwater in Oklahoma. The USGS is currently conducting a 3-year study (to be completed in 2012) to delineate and assess saline groundwater supplies (including brackish groundwater) in Oklahoma and surrounding states.

In addition to naturally occurring brackish groundwater, some areas in Oklahoma have brackish and saline groundwater resulting from oil-field activities.Since 1996, the OCC has collected groundwater samples near known and suspected oil and gas spill sites and/or in response to complaints from citizens in these areas. Samples are analyzed for a suite of parameters including TDS, chlorides, and sulfates. OCC has begun to list significantly impacted groundwater pollution sites in OWRB Chapter 45, Appendix H so that the public and water well drillers can be knowledgeable about conditions for well installation.

Based on the previous discussion of OWRB's regulatory authority, water use, and hydrogeologic factors, two categories of brackish groundwater were considered as sources of MQW:

- ***Mildly brackish groundwaters with TDS concentrations of 1,000-5,000 mg/L, which are regulated by OWRB for permitted withdrawals but are limited in use; and***
- ***Moderately brackish groundwaters with TDS concentrations of 5,000-10,000 mg/L, which are not regulated by OWRB and are much more limited in use than mildly brackish groundwaters.***

There are a number of factors to evaluate when considering brackish groundwater for beneficial water use:

- ***Most moderately brackish groundwater supplies cannot be used sustainably. These formations contain water that was recharged tens of thousands to millions of years ago. They receive little or no recharge from surface source, such as infiltration from rainfall or percolation from streams. These waters could be used in times of water shortages, but may not be viable as a long-term sole source of supply. Freshwater portions of aquifers could be impacted negatively by removing large amounts of water from the brackish zone. Groundwater formations containing saline water commonly are connected hydraulically to aquifers that contain freshwater. Thus, development of one resource affects the other, as well as potentially affecting the flow and quality of surface-water bodies connected to the groundwater system (Alley, 2003).***

- ***Freshwater portions of aquifers could be impacted negatively by removing large amounts of water from the brackish zone. Groundwater formations containing saline water commonly are connected hydraulically to aquifers that contain freshwater. Thus, development of one resource affects the other, as well as potentially affecting the flow and quality of surface-water bodies connected to the groundwater system (Alley, 2003).***

- ***Little is known about the hydrogeology of the parts of the formations that contain marginally brackish waters. Groundwater investigations in Oklahoma have been largely focused on characterizing "fresh" groundwater (TDS < 5,000 mg/L) regulated by OWRB. Additionally, there is little information about the factors required to understand the development potential of moderately brackish aquifers or to predict potential environmental impacts of withdrawing moderately brackish groundwater. These factors include hydraulic conductivity, transmissivity, storage coefficients, and the three-dimensional extent of the aquifer.***

- ***OWRB does not have regulatory authority to permit withdrawals of groundwater with TDS concentrations greater than 5,000 mg/L. As such, OWRB cannot plan for or administer the use of marginally brackish water supplies, and it cannot protect against potential effects of moderately brackish groundwater withdrawals on freshwater aquifers.***

These edits were incorporated into the text.

Patricia Billingsley
Oklahoma Corporation Commission
Email to OWRB and CDM
Subject: Marginal-Quality Water Report Initial Comments June 30, 2010

These comments are mainly on the O&G issues; I will comment on the conclusions/recommendations and some other small things later. Great maps – they help the presentation a lot. Suggested edits, and questions:

Page v
OCC Oklahoma Corporation Commission

What is the acronym for the Oklahoma Conservation Commission? I have no objection to OCC being used for the Corporation Commission, but I know that In other interagency workgroups and documents, the agencies are often referred to as OCC for the Conservation Commission and Corp Comm for the Corporation Commission. I don't want any confusion later.

The Oklahoma Corporation Commission is now referred to as Corp Comm throughout the document.

Page 2-10
The oil and gas industry comprises a significant portion of Oklahoma's economy. While oil and gas activities require water for drilling, completion, and production operations, many completed wells generate produced water at rates that vary from well to well and area to area. The potential volume of produced water is large; 93 billion gallons was produced and reinjected in Oklahoma during 2008. If even a portion of this could be re-used, it could add significantly to water supplies in certain areas. (exact figures are 2,218,391,290 BBLs, or 93,172,434,180 gallons, if you want to use those)

A sentence has been added to this section to indicate the volume of produced and reinjected water.

Page 2-11
Water quality of produced water, often with TDS concentrations exceeding 100,000 mg/L, much of which ~~that~~ would require significant treatment before surface discharge or beneficial reuse; only the produced waters <10,000 TDS are readily reusable for most purposes, although higher TDS water may be treatable/reusable for some oilfield and industrial purposes.

This edit was not made as the discussion was focused on the current drivers for reinjection rather than beneficial use.

(question – can CDM estimate % for this based on the number of wells in the database with TDS <10,000 and <50,000 TDS?)

This analysis was not performed due to time constraints and the focus of the of the bullet list in question.

Mobile and temporary nature of drilling and completion operations ~~and well production operations~~ makes flowback waters a hard to plan for temporary source that would create challenges related to mobilization and use of storage and use treatment equipment. Water produced once a well is proven for production is a much longer term potential source that is easier to include in planning.

See above response.

Pages 2-15 and 2-16 – one long paragraph needs to be broken into several Water quality data are generally much more available on a statewide basis for surface water supplies. Groundwater quality data tend to be collected on a much more ~~sitespecific~~ site specific or project-specific basis, and as such, are not generally available in statewide databases. There is some discussion of statewide groundwater quality in the 2008 Oklahoma Integrated Report. There are twenty-one major groundwater basins in the state and approximately 150 minor basins (ODEQ 2008). Oklahoma has groundwater standards located in OAC 785:45-7. Statewide statistically summarized data from public drinking wells are available in chart form by the ODEQ Groundwater Monitoring section at http://www.deq.state.ok.us/wqdnew/.

(New paragraph)
As discussed in Section 2.1.4, the OCC also collects groundwater samples near known and suspected oil and gas spill sites and/or in response to complaints from citizens in these spill areas. OCC is also attempting to utilize this data in conjunction with surface water data to determine potential sources of watershed impairments and/or areas in which saline groundwater is the cause of a stream's excess salinity. For example, only a few years ago the OCC discovered that some produced waters contain boron, which inhibits plant growth; OCC added boron to the parameters being tracked, and in 2007 added numerical boron limits to its cleanup guidance. OCC has several project areas where they have sampled streams for salinity impacts from a century of producing saline water with oil. The focus has been in Kay County; Custer-Dewey Counties; Seminole, Pottawatomie and Hughes Counties; and a 1,000 square miles in South-Central Oklahoma where Carter, Grady, and Stephens Counties come together. In the South-Central Oklahoma area, OCC and USGS have also run helicopter Electro-Mag (EM) surveys to map the saline plumes in the groundwater, some of which exceed a square mile in size.

Page 2-16
I suggest that you have a Surface Water sub heading above the following paragraph, to make the switch from groundwater easier to follow:

This paragraph has been moved to the end of the oil and gas discussion. The text edits have been incorporated.

Page 2-17 – oil & grease is minor compared to salinity; I suggest that the more common oilfield problem be used, especially since it caused much of the agriculturally impaired streams listed in table 2-4
The most common cause of PPWS use impairment is chlorophyll-a, which is an indicator of high nutrients. Other causes of PPWS impairment include metals, total coliform, ~~oil and grease~~ salinity (chlorides and sulfate), and nitrates. The entire 2008 303(d) list for Oklahoma is available at: http://www.deq.state.ok.us/WQDnew/305b_303d/2008_integrated_report_app_c_303d_list.pdf.

This edit was not made as the discussion is focused on other causes of impairment to Public and Private Drinking Water Supplies as listed on the state's 303(d) list. The 303(d) list does not list salinity as a cause of impairment for the PPWS use. Chloride and sulfate listings are discussed in the preceding paragraph that is focused on agricultural uses.

Page 2-17
TSS should be explained because Corp Comm regs use TSS for Total Soluable Salts – not the same thing! Many water quality parameters are considered while determining source suitability and treatment options from a user's standpoint. A list of basic water quality considerations in terms of water treatment for public water supply was developed for this evaluation, including: nitrates; TDS; TSS (total suspended solids); hardness; total organic carbon (TOC); nutrients;

TSS is now defined as Total Suspended Solids in the text. It is also listed in the List of Acronyms in the table of contents.

Page 2-20
Surface water quality data for the identified parameters of concern collected since 1998 in lakes and rivers/major streams were provided by OWRB.

This edit was not made as it states that the water quality data is surface water.

Table 2-6
CDM should also include TDS/Total soluble salt numbers for streams in the Surface Water Data Table I sent them. OWRB data is for rivers and lakes; mine covered a few rivers and streams. The Conservation Commission samples many more streams – their data would be valuble.

Thank you for the suggestion. These data have not been incorporated as it was the intent of this effort to show general surface water quality information based on the state BUMP program which stores data in a ready-to-use database format. If site-specific opportunities arise to use water with elevated levels of key constituents, further data evaluation could be warranted and additional data sources should be reviewed.

Page 2-23 Map
Figure 2-5 - ~~Surface Water~~ Lake and River Sampling Locations with TDS Concentrations Greater than or Equal to 1,000 mg/L

This edit was not made. The term surface water is used throughout the document and it was left on the map to be consistent.

There should also be a map. Based on Conservation Commission and corp Comm data, for Stream Sampling Locations with TDS Concentrations Greater than or Equal to 1,000 mg/L

Please see response to the similar suggestion above.

Page 3-2
Table 3-1 Constraints on Using MQW Sources Oil and Gas Produced Water – Remove • ~~Mobile operations/ mobile treatment~~

This edit has been made.

Page 4-9
4.5 Oil and Gas This sector represents water used in oil and gas drilling and exploration activities but does not include water used at oil and gas refineries (which are typically categorized as selfsupplied industrial users). Drilling and exploration activities use water for supplemental fluid during well drilling and completion, especially when fracing a shale gas well (up to 6,000,000 gallons); during workover of an oil or gas well~~,~~; as rig wash water~~,~~; as coolant for equipment~~,~~; and for sanitary purposes. Water use from both conventional and unconventional drilling techniques was considered.

This text has been edited.

Page 4-11
Boron concentrations Table 4-2 is missing; they jump instead to Table 4-2 Recommendations for Levels of Toxic Substances in Drinking Water for Livestock

This text has been edited.

Maps Section 5 – need Purple on the legends.

Legend items have been added for purple areas.

Page 5-10
5.1.3 Oil and Gas Flowback and Produced Water

Oil and Gas Flowback ~~and Produced~~ Water is water that is characterized by temporary availability, as drilling and operational activities move from one site and area to another over time. Utilization of this water resource as a supply is therefore inherently challenging, as most users in the various demand sectors seek a permanent and reliable source of supply. Further complicating this is the wide range of water quality that is observed within a given drilling operation and from one area of the state to another. Thus, it is difficult to broadly characterize the feasibility of using Flowback ~~and Produced~~ Water supplies to meet the various users' needs.

Produced Water would be a much more stable source, since wells once completed produce water, often in increasing amounts over the life of a well, from 5 to 50+ years.

Produced waters have been removed where suggested and this paragraph has been edited to include the following sentence: Produced Water would be a more stable source as Corp Comm has indicated that once wells are completed, they produce water for anywhere from 5 to 50 or more years.

Localized conditions such as water quality and the proximity of drilling operations to meet significant water demands will govern the feasibility of any individual situation. However, relative to other available supplies, in many cases the location and water quality of Flowback and Produced Water may suggest that its potential for beneficial use is limited. <u>These waters should be considered on an area-specific basis. One of the largest users is likely to be the oil and gas industry itself, which could reduce industry demand for fresh water.</u>

The final sentence of this paragraph was edited to say: However, relative to other available supplies, in many cases the location and water quality of Flowback and Produced Water may suggest that its potential for beneficial use is limited and may be most feasible for use by the oil and gas industry.

A map of oilfields in Oklahoma would be useful here.

Thank you for the suggestion. This map was not included as the spatial data were not available during document development.

Page 5-15
The base to treatable water map (see Figure 2-3) was used to determine where brackish groundwater may be more easily accessible for future uses. Figures 5-9 through 5-14 highlight (in blue) basins where the depth to 10,000 mg/L TDS was relatively shallow (majority of depth contours were approximately 100 ft). A relatively shallow depth indicates that the source of brackish water may be relatively accessible if needed. Basins highlighted in blue were located in the north-central portion, northeast and southwest corners of the state. Note, much of this area has minor aquifers or do not have a delineated aquifer, which indicates relatively low availability of fresh groundwater supplies.

Relatively high demand densities for the following sectors: M&I, Self-supplied Residential, Self-Supplied Industrial, Thermoelectric Power, Crop Irrigation, and Livestock Watering are shown in red on figures 5-9 through 5-14, respectively. Basins with coinciding higher demand densities and relatively shallow depths to brackish groundwater vary by demand sector. In addition, low TDS oilfield produced water could be considered in the brackish water category.

All produced waters were considered in the "Produced and Flowback Waters" category. TDS information was provided in discussions of water quality associated with this MQW source.

Page 6-3
Saline water treatments such as reverse osmosis and distillation were not mentioned in text or in Table 6-1 Summary of Common Water Treatment Processes

Section 6 includes discussion on Low Pressure Reverse Osmosis (LPRO) in both the Advanced Treatment section and the table.

Page 7-1
*** Oil and Gas Flowback Water is relatively low volume and quite time limited; ~~while~~ Produced Water can be a locally significant source of MQW for 5 to 50+ years, but utilization of this resource is likely to be limited by ~~temporal,~~ location, and water quality issues. ~~Because oil and gas production activities at a given site are not permanent, the water co-production at each site will eventually cease.~~ In addition, the location of significant water users' demands relative to oil and gas production activities may negatively impact the cost-effectiveness of using the water resource. Of Oklahoma's seven demand sectors, reuse of flowback and produced water to support the water needs of nearby oil and gas drilling, fracing, and secondary/tertiary recovery may be the most viable from a technical and economic perspective. Oil and gas production activities are a major economic driver for the state, and are expected to continue to occur across a wide geographic range in Oklahoma.***

The conclusions for oil and gas flowback and produced waters were edited to reflect these suggestions.

Patricia Billingsley
Oklahoma Corporation Commission
Email to OWRB and CDM
Subject: Marg Waters - Edits to Conclusions and Recommendations July 7, 2010

- ***Treated Wastewater from municipal treatment facilities, often referred to as "water reuse," is a potentially viable source of supply for non-potable uses, rather than just discarding the water into area streams. Because supplies are greater in and near the state's cities and towns, M&I non-potable demands (e.g., landscape irrigation) and some industrial or power-generating facilities***

are likely to be the most cost-effective application for this source of MQW supply. Mapping (Figures 5-1 through 5-5) showed that opportunities to use Treated Wastewater to meet the water needs of the M&I include the Oklahoma City metro area and areas to the east, and opportunities to meet other Industrial (Self-supplied and Thermoelectric) use sectors' needs are located in the areas around Oklahoma City, Tulsa and Muskogee.

Text has been added that says "rather than discharging the water into area streams".

- ***Stormwater collected in municipal storm sewer systems could be utilized – primarily for non-potable uses – where suitable storage could be provided to buffer the intermittent supply against the demands placed upon this source. Again, the more urban nature of this source of MQW supply suggests that it's most cost-effective use will be in and around the state's communities and more highly-developed areas. Stormwater released to receiving waters (surface water or groundwater) was not considered in this evaluation. Areas of most opportunity for stormwater to be used for M&I, Self-supplied Industrial and Thermoelectric needs are located along a corridor between Oklahoma City, Tulsa and Muskogee (see Figures 5-6 through 5-8). Another possible use is infiltration to shallow aquifers via infiltration basins, which can also serve as temporary catchment basins that reduce the chances of street and stream overflow flooding due to sudden high volume rainstorms.***

The grammatical edit was not made as it was correct as originally typed. The additional suggested edit was not incorporated as it describes a stormwater BMP rather than the use of stormwater to meet the demands of a water use sector.

- ***Oil and Gas Flowback Water is relatively low volume while Produced Water that comes up with oil and gas as it is produced can be a locally significant source of MQW, but utilization of this resource is likely to be limited by temporal, location, and water quality issues. While flowback water is short term, produced water production can last a few to 50+ years; the amount of water produced tends to increase over time as oil production per well decreases. While some of the 93 billion gallons of this water produced annually in Oklahoma is low enough in salinity (TDS <10,000 ppm) to be used either as is or treated, most is quite saline. In addition, the location of significant water users' demands relative to oil and gas production activities may negatively impact the cost-effectiveness of using the water resource. Of Oklahoma's seven demand sectors, reuse of flowback and produced water to support the water needs of nearby oil and gas drilling, plus the occasional use for agriculture (e.g. animal watering, similar to brackish water use) or industrial purposes, will likely be the most viable from a technical and economic perspective. Oil and gas production activities are expected to continue to occur across a wide geographic range in Oklahoma.***

The suggested edits were not added to the conclusions as it was felt that the additional information was already presented throughout the body of the document and that the bullets presented in this section were meant to succinctly summarize the overall findings.

- *Brackish Water aquifers underlie fresh water aquifers in much of the state, and are also in surface water from saline rivers such as the Cimarron, the Salt Fork of the Arkansas, and the upper Red River. This water would in most cases need advanced treatment to meet potable water quality standards, but can be used as in for some industrial purposes including cooling. Advanced treatment incurs capital and operational costs that are significantly higher than traditional treatment technologies. The most viable users of Brackish Water supplies are likely public water suppliers (M&I demand) and industrial users who have the financial resources and technical capability to operate advanced treatment facilities, and who have limited alternatives for supply. Some of the more salinity-tolerant crops such as barley and wheat, and some livestock groups such as dairy and beef cattle, could potentially use Brackish Water supplies to meet their irrigation and/or ingestion needs without treatment; for example, goats and sheep can drink saline water up to at least 10,000 TDS.*

These edits were not incorporated. Please see the response above.

Mapping (Figures 5-9 through 5-14) showed where higher demands for each sector are located relative to shallower brackish groundwater depths. The northeastern quadrant of the state shows that opportunities may exist to use brackish groundwater for M&I demands. A smaller portion of the northeast quadrant shows some basins where brackish groundwater may be easier to access to meet the needs of Self-supplied residential users with small, fairly inexpensive, in-home water treatment systems. Self-supplied Industrial opportunities may exist northeast of Enid, near Muskogee and near Altus, while Thermoelectric power opportunities may exist between Tulsa and Muskogee and northeast of Enid. There may be opportunity to offset crop irrigation demands with brackish groundwater sources in the southwest portion of the state. Livestock watering demands best match up to brackish groundwater depths in northeast and western portions of Oklahoma. Again, the ability of brackish groundwater sources to meet livestock water demands is dependent predominantly on animal type.

This suggestion was incorporated with the following edit: A smaller portion of the northeast quadrant shows some basins where brackish groundwater may be easier to access to meet the needs of Self-supplied residential users with point-of-use water treatment systems.

MISC WORK GROUP COMMENTS FROM MEETING #6 (6/30/2010)

A legend item should be added to all maps that defines the purple areas (areas where significant source locations match up with significant demands)

A legend item defining the purple "overlap" areas has been added to each map where applicable.

Water rights and instream biological needs should be emphasized in any conclusions for wastewater and stormwater uses

Text has been added to emphasize the need to consider downstream uses.

Some of the maps could be applicable for the ongoing instream flow work

The instream flow group is welcome to use any information or maps developed for this effort.

Add a descriptive phrase which indicates that we are looking at produced and flowback water for oil and gas.

Further descriptions of produced and flowback waters have been added throughout the document.

Contaminants of Concern category should be changed to Constituents of Concern throughout the document.

Contaminants of Concern has been changed to "Waters with Elevated Levels of Key Constituents" throughout the document.

The matrix should be added to the maps as shown in the presentation slides.

The matrix has been added to each of the maps that were shown in the presentation given at meeting #6 on June 30, 2010.

Include recommendations for aquifer recharge as a use of treated wastewater and reword the recommendation so that emphasis is not solely on public water suppliers

Language has been added to the treated wastewater recommendations to reflect these suggestions.

Expand the recommendation on Brackish Water to include desalination. El Paso provides a good example of how improved technology, coupled with a lack of other alternatives, is making desalinization a more attractive alternative; should recommend tracking the technology for future use.

Language has been added to the Brackish Water recommendations to include desalination.

Recommend streamline permitting and help eliminate barriers to deep well injection process for disposal of reverse osmosis water.

Text has been added to the brackish water recommendations section to reflect this suggestion.

Results of this study should be used to enhance other water plan studies/activities.

COMMENTS RECEIVED ON DRAFT FINAL REPORT

Angie Burckhalter
Oklahoma Independent Petroleum Association
Comments on Marginal Quality Water – Draft Final Report
9/16/2010

Page 2-10: Second paragraph of Section 2.1.3. Delete first sentence and move to the bottom of page with clarifying language – End of page, last sentence, add the following – "Although Corp Comm indicated that 93 billion gallons of water were produced and reinjected in Oklahoma during 2008, Table 2-3 clearly indicates that a majority of the produced water has high chlorides and TDS rendering them infeasible for treatment.

Text was edited as follows: The oil and gas industry comprises a significant portion of Oklahoma's economy. While oil and gas activities require water for drilling, completion, and production operations (for example, Corp Comm indicated that 93 billion gallons of water were produced and reinjected in Oklahoma During 2008), many completed wells generate produced water at rates that vary from well to well and area to area and the majority of the water produced tends to have high chlorides and TDS.

Page 2-12: Second paragraph. Delete text referring to Corp Comm groundwater samples. OIPA recommends that these comments be removed since no other industry/site-specific historical contamination scenarios are included in this document.

This edit has been made.

Page 2-14: Second paragraph. Delete paragraph referring to Corp Comm groundwater samples. OIPA recommends that these comments be removed since no other industry/site-specific historical contamination scenarios are included in this document.

Text was edited as follows (text below was from a previously reviewed and agreed upon draft): …. the oil and gas industry, has developed base of treatable water maps for the state, with treatable water defined as water with TDS concentrations greater than 10,000 mg/L (Figure 2-3). Little information exists on the extent (geographic area and volume) of moderately brackish groundwater in Oklahoma. The USGS is currently conducting a 3-year study (to be completed in 2012) to delineate and assess saline groundwater supplies (including brackish groundwater) in Oklahoma and surrounding states. In addition, since 1996, the OCC has collected groundwater samples near known and suspected oil and gas spill sites and/or in response to complaints from citizens in these areas. Samples are analyzed for a suite of parameters including TDS, chlorides, and sulfates. OCC has begun to list significantly impacted groundwater pollution sites in OWRB Chapter 45, Appendix H so that the public and water well drillers can be knowledgeable about conditions for well installation.

Page 3-1: First bullet, OIPA recommends that "treatment technology constraints" be added between e.g. and enhanced

This edit was not made as a number of treatment-related constraints are listed.

Table 3-1: Under the Technical column, add a bullet for "treatment technology constraints" to each row

This edit was not made, see above response.

Page 4-9: Section 4.5, middle of paragraph. OIPA recommends removing the Corp Comm provided reference of "up to 6,000,000 gallons during fracing of gas shale wells) and for consistency, recommends a reference to CDM's Water Demand Forecast Report that includes a section on projected oil and gas water use.

This edit was not made. The information provided by Corp Comm does not refer to projections.

Page 5-10: Section 5.1.3 First Paragraph. OIPA recommends that the language that was deleted from the first sentence ("and Produced") be left in the document and that the proposed language that was supplied by Corp Comm (" Produced Water would be a more stable source as Corp Comm has indicated that once wells are completed the produce water for anywhere from 5 to 50 or more years") be removed as there are many variables and scenarios that a case by case analysis needs to be conducted on a well to determine if the produced water has any potential reuse.

The paragraph was edited as follows: Oil and Gas Flowback and Produced Water is water that is characterized by temporary availability, as drilling and operational activities move from one site and area to another over time. Utilization of this water resource as a supply is therefore inherently challenging, as most users in the various demand sectors seek a permanent and reliable source of supply. Further complicating the use of this source is the wide range of water quality that is observed within a given drilling operation and from one area of the state to another. Due to the many variables, wells may need case by case evaluations to determine if the produced water may potentially be reused.

Section 7: First three bullets – edit last sentence of each bullet to say "Any future uses of… must consider the impacts to downstream water availability, needs, and water rights"

This edit has been made.

Section 7: Oil and Gas Flowback and Produced Water bullet. OIPA recommends deleting the first two sentences as replacing them with "Oil and Gas Flowback Water and Produced Water is likely to be limited by temporal, location, and water quality issues" and recommends inserting the word"potentially" between "may" and "be" and the word "opportunities" between "viable" and "from" in the second to last sentence.

The bullet has been edited as follows: Oil and Gas Flowback Water is relatively low volume while Produced Water can be a locally significant source of MQW, but utilization of this resource is likely to be limited by temporal, location, and water quality issues. In addition, treatment requirements, storage needs, and the location of significant water users' demands relative to oil and gas production activities may negatively impact the cost-effectiveness of using the water resource. Of Oklahoma's seven demand sectors, reuse of flowback and produced water to support the water needs of nearby oil and gas drilling, fracing, and secondary/tertiary recovery may potentially be the most viable opportunities from a technical and economic perspective. Oil and gas production activities are major economic driver for the state and are expected to continue to occur across a wide geographic range in Oklahoma.

Page 7-2: First paragraph after bullet list. OIPA recommends replacing the first sentence with the following – "Any application of a MQW source to meet demands should consider the impacts to downstream water availability, needs, and water rights".

This edit has been made.

Page 7-3: Oil and Gas bullet. OIPA recommends inserting "technologically viable and" between "seek" and "cost-effective".

This edit was not made.

Cheryl Dorrance
Oklahoma Municipal League
Comments on the Margnal Quality Water Study
9/6/2010

Overall I thought that the report fundamentally addresses some of the issues that may guide future decision-making.

Table 2-4 Do we need an explanation of Size Fully Supported and Size Not Supported?

The first column of the table displays the units for each category. Supporting/Not supporting refers to the designated uses as described in the text preceding the table.

Table 5-1
- M&I potable – treated wastewater change WQ to WST - basically from prohibited to difficult
- the same on Self –supplied residential, WQ to WST – prohibited to difficult
- LOC definition, strike "likely not" and insert "may not be"

Edits were made to the colors in these categories. WQ was not changed to WST as WQ requirements would be difficult to meet. LOC was edited as suggested.

Terri Sparks
OWRB
Comments on Marginal Quality Water – Draft Final Report
6/21/2010

Page 1-1: Punctuation edits suggested in the first paragraph of Section 1.1.

The punctuation has been corrected.

Page 1-1: suggest listing all stakeholder groups in the first paragraph of Section 1.1.

The second paragraph of Section 1.1 has been edited to say the following: Appendix B contains a detailed summary of the six MQW group meetings. The initial meeting of the MQW Technical Work Group took place in December 2008 and included representatives from the above mentioned agencies and other stakeholders. Complete lists of the stakeholders present at each meeting are included in the meeting summaries in Appendix B.

Page 1-2: Minor punctuation and sentence structure edits suggested.

All edits were made

Figure 1-2: Suggest resizing so it prints 8.5X11.

Figure was setup to print 11X17 so was cut off when printing double-sided to 8.5X11. All attempts to resize this figure cause the labels to be illegible.

Page 1-5: ***Punctuation edits suggested throughout bullet list***

All edits were made

Page 2-2: Top sentence – why were flows from the N&I sector only considered?
Top sentence has been edited to say: Because effluent from municipal treatment facilities are the focus of this effort, only return flows from the Municipal and Industrial (M&I) demand sector were considered.

Figure 2-2: Add dates for precipitation data.

Section 2 was edited to include a reference for the data within the text. The following reference was added (Oklahoma Climate Survey, 1961-1990).

Figure 2-3: Should last bin should be >900?

This edit has been made.

Figures 4-7 and 4-8: Adjust the bins in the legend to match the cutoffs for the associated source and demand maps in Section 5. And explain why the basin around Altus is not highlighted on Figure 4-7.

The bins have been edited so that they can be easily compared to the associated section 5 maps. Figure 4-7 has been corrected to show the Altus basin shaded green (high demand density).

Page 4-4: Section 4-2 Second sentence. Should suburbs of major cities be included?

The sentence was edited as follows: These households are located primarily in rural areas of the state but may also be located in suburbs of municipal areas.

Page 4-4: Section 4.2.1. Delete last sentence of the paragraph.

This edit has been made.

Section 5: First sentence. Move "of" before "Oklahoma's" rather than between "seven" and "water".

This edit has been made.

Appendix D
Phase II MS4s

Source: Page 19 of Fact Sheet for OPDES Permit OKR04, Small MS4s

Small MS4 Designations: Town, Cities, State Agencies, Federal Agencies, and Counties that are partially or wholly located in an urban area are:

- Arkoma
- Bethany
- Bixby
- Broken Arrow
- Catoosa
- Choctaw
- Cleveland County
- Comanche County
- Coweta
- Creek County
- Del City
- Edmond
- Forest Park
- Fort Sill AB
- Guthrie
- Hall Park
- Jenks
- Lawton
- Logan County
- Midwest City
- Moffett
- Moore
- Mustang
- Nichols Hills
- Nicoma Park
- Noble
- Norman
- Oakhurst
- Oklahoma County
- ODOT
- OTA
- Pocola
- Rogers County
- Sand Springs
- Sapulpa
- Sequoyah County
- Smith Village
- Spencer
- Sperry
- The Village
- Tinker AFB
- Turley
- Tulsa County
- Valley Brook
- Wagoner County
- Warr Acres
- Woodlawn Park
- Yukon