Oklahoma Comprehensive Water Plan
2012 Update

OCWP Water Supply Hot Spot Report

November 2011

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, due for submittal to the State Legislature in 2012. Results from this and other studies have been incorporated where appropriate in the OCWP's technical and policy considerations. The general goal of the OCWP 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.

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Acronyms

°F	degrees Fahrenheit
μg/L	microgram per liter
AF/month	acre-feet per month
AFY	acre-feet per year
AFY/acre	acre-feet per year per acre
AG	Agriculture
BUMP	Beneficial Use Monitoring Program
gpm	gallons per minute
GW	Groundwater
M&I	Municipal and Industrial
mg/L	milligrams per liter
NRCS	National Resources Conservation Service
NRW	non-revenue water
OCWP	Oklahoma Comprehensive Water Plan
ODEQ	Oklahoma Department of Environmental Quality
OWRB	Oklahoma Water Resources Board
PPWS	public and private water supplies
PSNR	public-supplied non-residential
PSR	public-supplied residential
PWA	Public Works Authority
RO	reverse osmosis
SSR	Self-Supplied Residential
TDS	total dissolved solids
TSI	trophic state index
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
Waurika MCD	Waurika Lake Master Conservancy District

Section 1
Introduction

This report documents the methods and results of Oklahoma Comprehensive Water Plan (OCWP) analyses to determine the basins in Oklahoma with the most significant potential limitations for water supply, referred to herein as "hot spots." Each of 82 watersheds, referred to as the 82 OCWP basins, was analyzed for current and future supply and demand conditions. While significant supply issues are forecasted to occur between now and 2060 for many of the 82 OCWP basins, the 12 water supply hot spots identified in this report are those with the most significant potential challenges in terms of physical supply availability, permit availability, and water quality constraints.

Three source types are analyzed throughout all the OCWP technical studies, including surface water, alluvial groundwater, and bedrock groundwater. Each of those source types was evaluated in each of the 82 OCWP basins to determine where the most significant potential for supply limitations may exist in the future. The methods employed in characterizing the basins and identifying water supply hot spot basins are documented in this report, and build on the results of the technical analyses that are documented in the OCWP *Physical Water Supply Availability Report* and the 13 OCWP *Watershed Planning Region Reports*.

To address those limitations, the effectiveness of several alternative supply solutions was examined for each basin exhibiting the potential for physical water supply shortages – whether it is or is not designated as a hot spot basin – in the 13 OCWP *Watershed Planning Region Reports*. A more detailed assessment of the supply alternatives for the 12 hot spot basins is provided in this report. The findings of this report are summarized in the *2012 OCWP Executive Report*.

Section 2
Hot Spot Identification Methodology

Hot spots were identified based on the physical supply availability, permit availability, and water quality metrics for each of the 82 OCWP basins. These analyses were based on data presented in the 13 OCWP *Watershed Planning Region Reports*. The criteria used to identify hot spots were developed based on quantitative metrics to provide an objective methodology. For the initial identification, hot spots were evaluated independently for Oklahoma's three major categories of supply – surface water, alluvial groundwater, and bedrock groundwater. The methodology used to identify the hot spots for each category is presented below.

2.1 Surface Water

Surface water supplies from reservoirs and direct river diversions are major supply sources for many of the 82 OCWP basins. Physical supply availability, permit availability, and water quality criteria were used to account for current water uses and the projected change in demand from 2010 to 2060. Details on each of the criteria are presented below.

2.1.1 Physical Supply Availability Criteria

For all OCWP surface water supply analyses, a 58-year record of historical monthly streamflow at the basin outlet was used to represent the basin's surface water supplies. The measured streamflow implicitly reflects the operating conditions that impact the stream at the time the data were recorded (e.g., hydrology, permitted use, infrastructure, or water quality constraints). Historic reservoir operations are also reflected in the stream gage record downstream of a reservoir. The surface water supply availability for each basin was calculated based on the historic streamflow, unused storage in existing reservoirs, and future demand. The water supply availability results, shown in the 13 OCWP *Watershed Planning Region Reports*, quantify how large a surface water gap will be (magnitude) and how often a gap is expected to occur (probability). The hot spot analyses were based on 2060 demand, representing the most significant issues anticipated in the 50-year OCWP planning horizon.

The most significant physical supply issues are gaps that occur frequently and are large in magnitude. Thus, physical water supply criteria were developed to incorporate both the magnitude and probability of gaps for each basin, as shown in Equation 1. The magnitude of a gap is represented by the likely size of a gap (median gap of all months with gaps) based on monthly analyses of the 58-year streamflow period of record (Water Years 1950 to 2007). The first term in Equation 1 indicates the severity of the gap in the basin by dividing the size of the gap by the total demand in the basin. This approach provides a common basis of analysis for large and small basins alike. The probability of a gap occurring in at least one month of the year, expressed as a percent, is used to indicate the likelihood of gaps.

$$SW\ Physical_{Basin} = \left(\frac{Median\ Annual\ Surface\ Water\ Gap_{2060}}{Total\ Demand_{2060}}\right) \times Probability\ of\ Surface\ Water\ Gap_{2060}$$

Eqn. 1

The result (SW $Physical_{Basin}$) is an index that was calculated for each of the 82 OCWP basins. The 82 OCWP basins were ranked based on their SW $Physical_{Basin}$ index, then converted to a score from 0 to 100, with a score of 100 indicating the most severe physical supply availability issues. If a basin does not have a projected surface water gap in 2060, the score for that basin is 0.

2.1.2 Permitting Criteria

The availability of new permits is based on Oklahoma Water Resources Board (OWRB) analyses of annual streamflow data. Therefore, permit availability is generally correlated with the physical availability results, but some differences do occur. An analysis of permit availability for each basin was conducted in the OCWP *Water Supply Permit Availability Report*. The results of those analyses were used as the basis for ranking each of the 82 OCWP basins in the water supply hot spot analyses. The availability of permits for surface water was used to rank the 82 OCWP basins and develop a corresponding permit availability score (*SW Permitting*) from 0 to 100 for each basin. A value of 0 indicates more surface water is available for permitting while a score of 100 indicates the least amount of water available for new permits. Basins that are already over-appropriated received the highest rankings and highest permit availability scores.

2.1.3 Water Quality Criteria

The impact of water quality on the use of a supply source is driven by numerous factors, including the specific constituents of concern to a given demand sector and the economic viability of treating the water to meet the end users' water quality requirements. For the purpose of this analysis, OWRB staff developed a surface water quality condition index for streams and reservoirs to be used in assessing the relative level of water quality issues prevalent in each basin. This analysis was conducted to delineate basins as potential hot spots, but should not be considered an absolute characterization of specific waterbodies.

The method for determining a water quality condition score was similar for streams and lakes. For both waterbody types, both a trend and standards index score were calculated. These index scores were given equal weight and summed to create a condition score. To discriminate between "good," "fair," and "poor" condition, quartiles were calculated for both the streams and lake condition scores. Those scoring below the 25th percentile are designated as having "poor" condition, while those scoring above the 75th percentile are designated as having "good" condition. Sites/lakes in the middle (inter-quartile range) are designated as having "fair" condition. After the separate lakes and stream delineations, waterbodies were grouped by basin to determine that basin's water quality score. Parameters used in the analysis are listed below. The selected parameters were based on available data relevant to consumptive use of surface water supplies, much of which was collected through the OWRB's Beneficial Use Monitoring Program (BUMP).

Stream Index of Parameters:

- Trends in conductivity
- Impaired for turbidity
- Impaired for public and private water supplies (PPWS)
- Impaired for agriculture (AG)
- Threatened for total nitrogen and phosphorus

Reservoir Index of Parameters:

- Trends in conductivity
- Impaired for turbidity
- Impaired for PPWS
- Impaired for AG
- Chlorophyll-a, total nitrogen, and phosphorus used to calculate trophic state index

The trend index was calculated using a percentile approach. Based on recent OWRB water quality trend analyses, each metric was assigned a value based on whether it is trending upward or downward and at what confidence level (80, 90, or 95 percent). Percentile scores range from 0.1 to 1.0, with the two tails (0.1 and 1.0) characterized by upward or downward trend at the 95 percent confidence level, respectively. A "no trend" designation was scored at 0.5. All metric scores for a particular waterbody were averaged to produce a final "trend index score."

For streams, the standards index is calculated using a binary approach based on certain water quality criteria. Turbidity is considered along with three beneficial uses — PPWS, AG, and aesthetics. For each metric, a value of 0.5 or 1.0 was assigned depending on whether a site is considered impaired for turbidity, PPWS, or AG, or threatened for total nitrogen and/or total phosphorus. All metric scores for a particular waterbody are averaged to produce a final "standards index score."

For lakes, a similar approach was used based on water quality criteria for turbidity and the agriculture beneficial use. However, two nutrient-based metrics were calculated using the sensitive water supply criterion and the chlorophyll-a based trophic state index (TSI). All metric scores for a particular waterbody are averaged to produce a final "standards index score."

The trend and standards index scores were combined to determine a water quality condition score. The trend and standards index scores are weighted equally (50 percent/ 50 percent) to get a composite score that is ranked to determine the relative water quality condition score (*SW Quality*) ranging from 0 to 100. A water quality condition score of 0 indicates less water quality concerns in the basin and 100 indicating more significant water quality concerns in the basin.

2.2 Groundwater

Groundwater in Oklahoma plays a key role in meeting water demands in basins where surface water is not readily accessible or groundwater supplies are more economical to develop. The groundwater criteria focus on physical supply availability metrics.

The water quality of Oklahoma's aquifers can be highly variable. Unlike surface water, there is no statewide water quality data collection program or database of water quality for groundwater. Additionally, groundwater quality can vary greatly from well to well within the same aquifer. The *Water Quality in Oklahoma Report* lists aquifers with known water quality issues. There are known constraints for public water providers (i.e., Blaine aquifer and Arbuckle-Timbered Hills aquifer); however, these aquifers are still used for agricultural or industrial uses. Although groundwater quality can be a significant factor in water supply analyses, the lack of a robust groundwater quality database precluded the use of groundwater quality as a criterion for this statewide evaluation.

Permit availability for groundwater sources has been evaluated in the OCWP *Water Supply Permit Availability Report* but those analyses concluded that the use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits for any of the 82 OCWP basins through 2060. Therefore, basins cannot be distinguished on the basis of permit availability, and no permit availability criteria were included in this analysis.

In the 13 OCWP *Watershed Planning Region Reports*, groundwater supplies were evaluated separately for bedrock aquifers and alluvial aquifers, based on differences in how recharge was represented. Alluvial aquifer recharge was based the basin's streamflow (58-year period of record), while bedrock aquifer recharge was based on average annual recharge estimates. Storage depletions occur when demand exceeds recharge (supply); gaps are not reported for groundwater. Storage depletions indicate the sustainability of aquifer use in a basin and the potential for localized decreases in available groundwater supplies. Separate criteria were developed for alluvial and bedrock groundwater as described below.

2.2.1 Alluvial Groundwater

Physical alluvial groundwater availability was determined using two components representing the severity of groundwater depletions and the rate of depletions relative to the amount of water in storage in each basin. As with surface water gaps, frequently-occurring large alluvial groundwater depletions are more concerning than infrequent or smaller depletions. Alluvial groundwater supplies are subject to hydrologic cycles of wet and drought periods, and thus, the occurrence and size of depletions will vary from year to year.

Two components were analyzed to assess alluvial groundwater supply availability. The first component is the severity of alluvial groundwater depletions relative to the amount of water in storage (to assess the rate of depletion relative to available supplies) occurring in 2060 (**Equation 2**). The *Alluvial* GW_1 scores were ranked for the 82 OCWP basins and then converted to a 0 to 100 score, with 100 indicating the most significant and frequent depletions.

$$Alluvial\ GW_1 = \left(\frac{Median\ Annual\ Alluvial\ Storage\ Depletions_{2060} \times Probability\ of\ Alluvial\ Storage\ Depletions_{2060}}{Major\ Alluvial\ Aquifer\ Storage\ in\ Basin}\right)$$

Eqn. 2

In the case where no alluvial aquifer storage exists within a basin, the value for alluvial groundwater was set to 0. A score of 0 was assigned because either an alluvial groundwater source is absent or corresponding alluvial groundwater use is not substantial. As a result, this de-prioritizes basins with little or no alluvial groundwater use while focusing on basins with substantial alluvial aquifer depletions.

The second component of the physical alluvial groundwater availability score was derived from using only the size and probability of alluvial groundwater depletions, storage was not considered (**Equation 3**).

$$Alluvial\ GW_2 = Median\ Annual\ Alluvial\ Storage\ Depletions_{2060} \times Probability\ of\ Alluvial\ Storage\ Depletions_{2060}$$

Eqn. 3

The 82 OCWP basins were ranked based on severity of depletions of the alluvial groundwater aquifer. This component (Alluvial GW_2) symbolizes the magnitude of the alluvial storage depletion in the basin. Those rankings were converted to a 0-to-100 score as follows:

- Basin with least or no alluvial groundwater depletion severity (score 0)
- Basin with highest alluvial groundwater depletion severity (score 100)

These two components were combined to develop a physical alluvial groundwater availability score for each basin (**Equation 4**). These two components are combined with equal weighting (50 percent/50 percent) to provide a score for each basin from 0 to 100, where 0 is a basin with little or no physical alluvial groundwater availability issues and 100 indicates the basin with the most significant supply issues.

$$Alluvial\ GW\ Physical = Alluvial\ GW_1 \text{ x } 50\% + Alluvial\ GW_2 \text{ x } 50\%$$

Eqn. 4

2.2.2 Bedrock Groundwater

The physical availability of bedrock groundwater was scored using a method similar to that used for alluvial groundwater. However, since bedrock groundwater supplies recharged at more constant rates (much less hydrology-dependent from year to year), the probability of bedrock storage depletions is not applicable – in a given future year, bedrock groundwater depletions either will or will not occur, based on whether the demand exceeds the relatively-constant rate of recharge in that year. The two components of the physical availability score for bedrock groundwater are shown below.

The first component relates the median annual depletion to the amount of bedrock groundwater storage in a basin, excluding minor aquifers (**Equation 5**), again representing the severity of the rate of depletion relative to available supplies. The *Bedrock GW* scores were ranked for the 82 OCWP basins and then converted to a 0 to 100 score, with 100 indicating the most significant depletions relative to the amount of storage in the basin.

$$Bedrock\ GW_{(Major\ Aquifers\ Only)} = \frac{Average\ Annual\ Bedrock\ Storage\ Depletions}{Major\ Bedrock\ Aquifer\ Storage\ in\ Basin}$$

Eqn. 5

The second component (Average Annual Bedrock Storage Depletions) ranks each basin's median (or average) annual depletion of bedrock groundwater supplies to other basins' bedrock groundwater depletions. The basin with highest depletions is given a score of 100, and the basin with the lowest or no depletions is given a score of 0.

These two components were used to develop a physical bedrock groundwater availability score for each basin (**Equation 6**). The weighting for these two components was equal (50 percent/50 percent) to provide a score from 0 to 100, where 0 is a basin with little or no physical bedrock groundwater availability issues and 100 indicates the basin with the most significant supply issues. Basins without major bedrock aquifers were given a ranking of 0 for the *Bedrock GW Physical* criteria.

$$Bedrock\ GW\ Physical = Bedrock\ GW \text{ x } 50\% + Avg\ Annual\ Bedrock\ Storage\ Depletions \text{ x } 50\%$$

Eqn. 6

2.3 Statewide Hot Spots

An overall hot spot ranking was developed for surface water and groundwater availability of each basin. For surface water, the physical supply availability, permit availability, and water quality results were combined to determine an overall score and ranking for the basins. As discussed above, alluvial and bedrock groundwater hot spot rankings were based solely on physical supply availability analyses.

In order to determine the basins' overall scores and rankings, a weighting of each of the criteria was needed. The following weights were assigned for surface water.

- Surface Water - Physical Supply Availability = 50 percent
- Surface Water - Water Quality = 20 percent
- Surface Water - Permit Availability = 30 percent

The heavier weighting on physical supply availability reflects the critical nature of having a physical supply shortage. Permit availability, while critical for utilizing a surface water supply, was weighted slightly lower because permit availability is dependent on surface water availability. Water quality also is highly important in meeting various water users' needs, but was viewed as less critical than the physical and permitting criteria because treatment technologies can be applied in many situations to resolve differences between raw water quality and the users' water quality requirements.

Using the weighting noted above and the scores for criterion, a composite score for surface water was developed for each of the 82 OCWP basins as shown in **Equation 7.** The *SW Availability* scores for the basins were then sorted by highest to lowest scores, the basins with highest scores having the greatest surface water supply availability concerns.

$$SW\ Availability_{Basin} = (SW\ Physical \text{ x } 50\%) + (SW\ Quality \text{ x } 20\%) + (SW\ Permitting \text{ x } 30\%)$$

Eqn. 7

The same approach was taken to develop a composite score for alluvial and bedrock groundwater for each of the 82 OCWP basins, but solely based on physical supply availability as discussed above and shown in **Equation 8.** The *GW Availability* scores for the basins were then sorted by highest to lowest scores, the basins with highest scores having the greatest groundwater supply availability concerns.

$$GW\ Availability_{Basin} = (GW\ Physical \text{ x } 100\%)$$

Eqn. 8

These three lists (ranking of basins for surface water hot spots, alluvial groundwater hot spots, and bedrock groundwater hot spots) were reviewed with the OWRB staff to validate the results against historical insights and known areas of concern. Upon that validation, 12 basins were selected by OWRB for subsequent analysis regarding the cause of the supply issues and more detailed investigations regarding potential water supply solutions for those basins. The 12 basins include the top 7 ranked surface water supply hot spot basins, the top 4 ranked alluvial groundwater supply hot spot basins, and the top 6 ranked bedrock groundwater supply hot spots, listed in **Table 2-1** and shown on a map in **Figure 2-1.** Because some basins are among the top hot spots in more than one supply category, the combined total number of basins is 12 (rather than the total of the individuals, which equals 17).

Table 2-1. OCWP Basins with the Most Significant Water Supply Challenges (ordered by basin number)

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

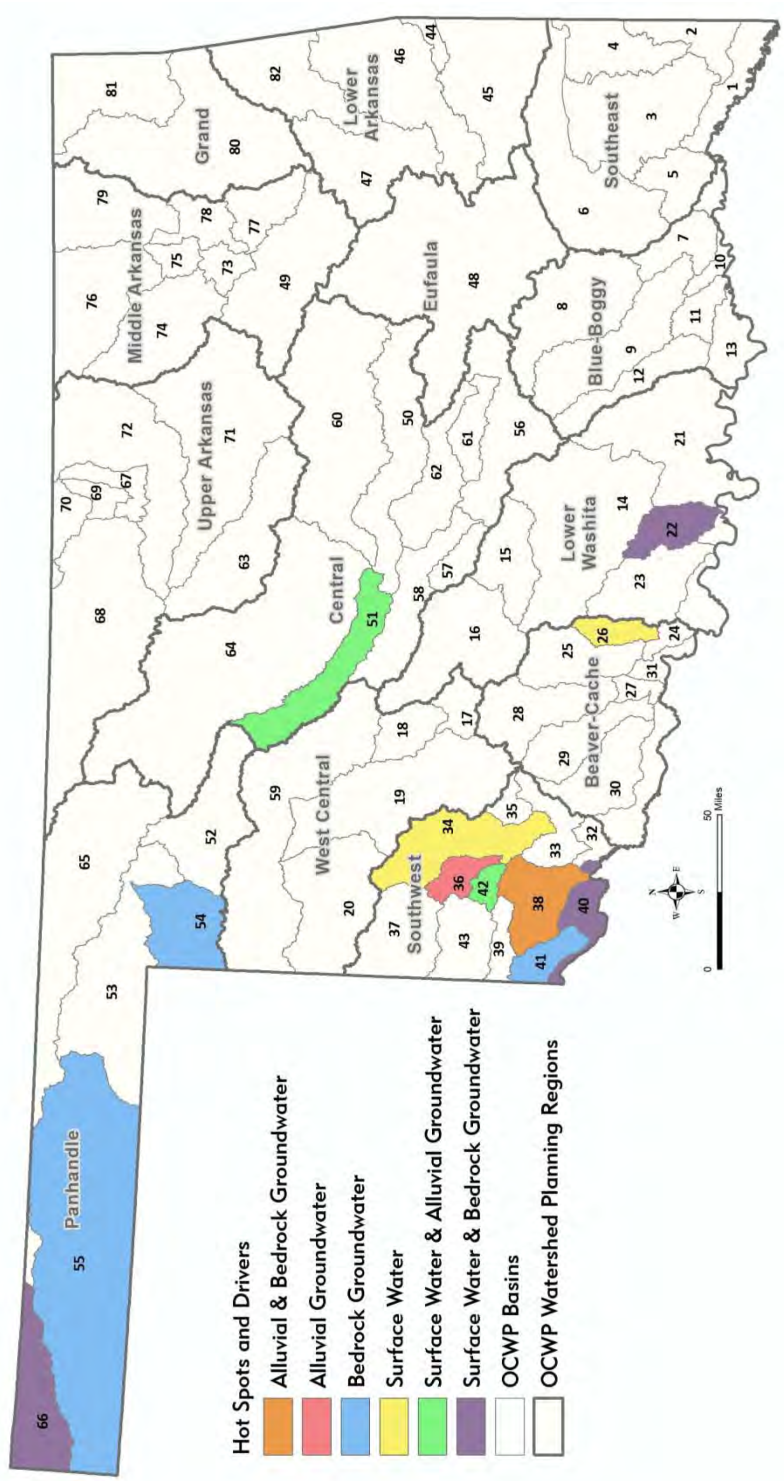

Figure 2-1. OCWP Basins with the most Significant Water Supply Challenges (OWRB 2011)

Section 3
Basin 22 (Walnut Bayou)

Basin 22, located in the Lower Washita Watershed Planning Region, is a surface water and bedrock groundwater hot spot. Surface water issues are mainly due to the basin's low physical availability of streamflow. Storage depletions are expected to provide water supply challenges based on the overall size of the depletions and for the rate of storage depletions relative to the amount of storage in the Antlers bedrock aquifer. More detailed information on this basin is available in the OCWP *Lower Washita Watershed Planning Region Report*. In addition to surface water gaps and bedrock groundwater storage depletions, alluvial groundwater storage depletions may occur by 2050. This section describes the driving factors for this basin being identified as a hot spot, provides an analysis of how to address supply availability issues, and evaluates identified alternatives.

3.1 Basin Description

Basin 22 encompasses portions of Carter and Love counties. The Lower Washita Watershed Planning Region consists of the Osage Plains of the Central Lowland. The region's terrain varies from lush pasture in the river bottoms to the rugged foothills of the Arbuckle Mountains. The region's climate is mild with annual mean temperatures varying from 61 degrees Fahrenheit (°F) to 64°F. Annual evaporation within the region ranges from 63 inches per year in the western areas to 55 inches per year in the eastern areas. Annual average precipitation ranges from 27 inches in the west to 43 inches in the east.

3.1.1 Surface Water Supplies

Surface water was used to meet 43 percent of the total demand in the basin in 2010 and is projected to increase by 31 percent (820 acre-feet per year [AFY]) by 2060. Walnut Bayou is the largest surface water supply source in the basin. The majority of surface water use and growth over this period will be in the Municipal and Industrial and Oil and Gas demand sectors. Historically, Walnut Bayou upstream of the Red River often flowed only in the spring and early summer, peaking in May (2,700 acre-feet per month [AF/month]). The median streamflow in Basin 22 is very low or zero from July to February, as shown in **Figure 3-1**. There are no major reservoirs in the basin. The availability of permits is not expected to limit the development of surface water supplies for in-basin use through 2060.

Relative to other basins in the state, the surface water quality in Basin 22 is considered fair. Surface waters of the Lower Washita Watershed Planning Region are impacted by excessive levels of turbidity. No streams within Basin 22 are impaired for agriculture or potable water use according to the 303d Impaired Stream List.

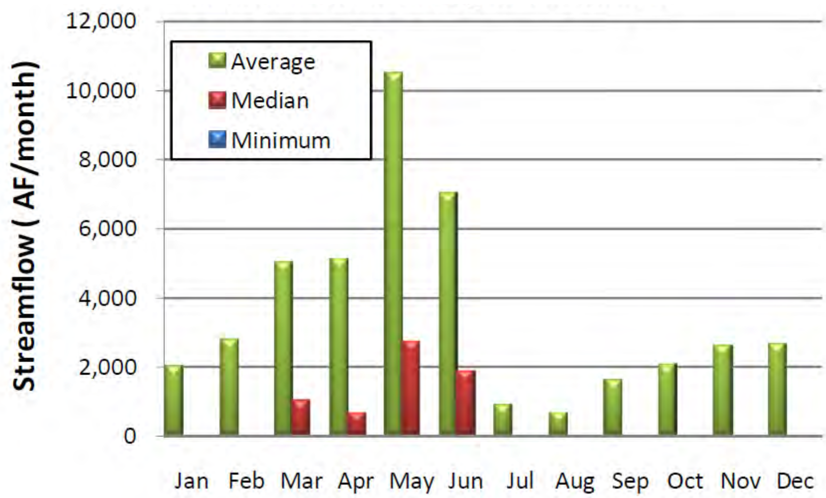

Figure 3-1. Monthly Streamflow Statistics over the Study Period of Record

3.1.2 Groundwater Supplies

Alluvial groundwater was used to meet 5 percent of the total demand in the basin in 2010 and is projected to increase by 22 percent (50 AFY) by 2060. The majority of alluvial groundwater use and growth in alluvial groundwater use over this period will occur in the Crop Irrigation and Livestock demand sectors. **Figure 3-2** illustrates the major aquifers and existing groundwater permits in Basin 22. About 3 percent (or 700 AFY) of total groundwater rights are provided by the Red River major alluvial aquifer. The majority of alluvial aquifer permits (1,600 AFY) are from minor non-delineated alluvial aquifers along Walnut Creek and its tributaries. These aquifers have not been studied; therefore, no information on storage, yield, or recharge is available. Site-specific information on the suitability of these minor aquifers for supply should be considered before large-scale use.

The Red River major alluvial aquifer is available to about 52 square miles (or 21 percent) in the southwest portion of the basin and has about 210,000 AF of groundwater stored in Basin 22. No Equal Proportionate Share (EPS) has been set for the Red River aquifer. Up to 2.0 acre-feet per year per acre (AFY/acre) of dedicated lands overlying the aquifer may be withdrawn through temporary permits. Note: temporary permitted withdrawals are subject to change when converted to regular permits. There are an estimated 253,000 AFY of remaining groundwater rights in this basin, which is not expected to be limited by the availability of new permits for local demand through 2060.

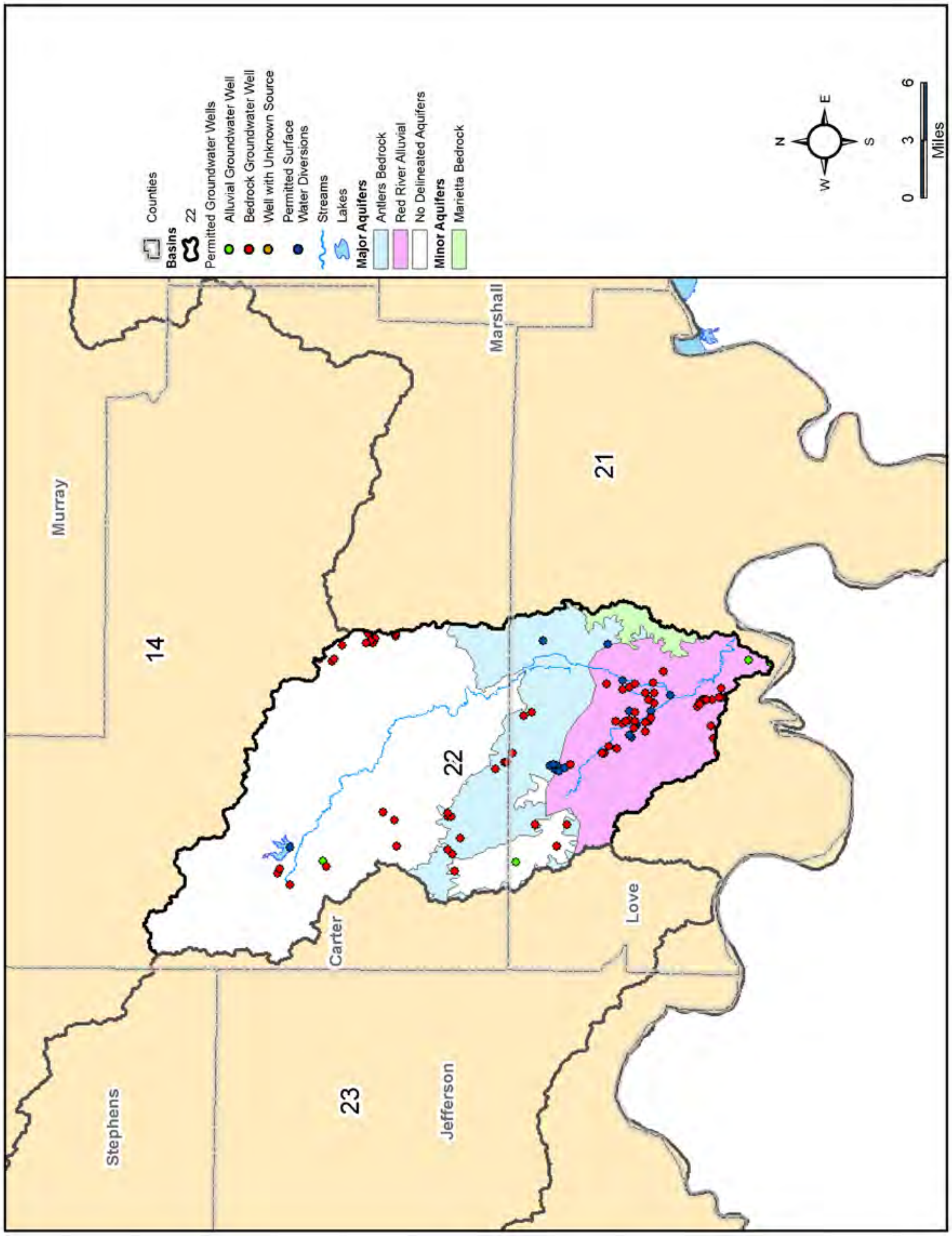

Figure 3-2. Groundwater Supplies in Basin 22

Bedrock groundwater was used to meet 11 percent of the total demand in the basin in 2010 and is projected to increase by 26 percent (600 AFY) by 2060. The majority of bedrock and groundwater use and growth in bedrock groundwater use over this period will be in the Crop Irrigation and Municipal and Industrial demand sectors. There are currently permits for the Antlers major bedrock aquifer and non-delineated minor bedrock aquifer. The non-delineated minor bedrock aquifers have not been studied; therefore, no information on storage, yield, or recharge is available. Site-specific information on the suitability of these minor aquifers for supply should be considered before large-scale use.

Approximately 80 percent (20,700 AFY) of the basin's groundwater rights are in the Antlers bedrock aquifer. This portion of the aquifer is available to a 130-square-mile area (or about 40 percent of the total area) in the southern part of the basin. Up to 2.1 AFY/acre of dedicated lands overlying the aquifer may be withdrawn through regular permits. There are an estimated 152,800 AFY of remaining groundwater rights in this basin, which is not expected to be limited by the availability of new permits for local demand through 2060. Wells in the Antlers aquifer can yield 20 gallons per minute (gpm) to 100 gpm. Water quality tends to degrade in the southern portion of the aquifer with higher levels of total dissolved solids making it unsuitable for some uses.

3.1.3 Water Demand

From the OCWP *Water Demand Forecast Report*, the total demand for this basin in 2060 is 8,750 AFY, an increase of 44 percent (or 2,680 AFY) from 2010 to 2060. Basin 22's water needs are about 8 percent of the total demand in the Lower Washita Watershed Planning Region. **Figure 3-3** illustrates the demand and growth in demand by source and sector for the basin. The majority of the demand over this period will be in the Municipal and Industrial and Crop Irrigation demand sectors. Crop Irrigation occurs throughout the basins over the Antlers and Red River aquifers, as shown in **Figure 3-4**. Peak in Oil and Gas demand is expected in 2020, however, by 2060, demand is expected to be at a level similar to 2010.

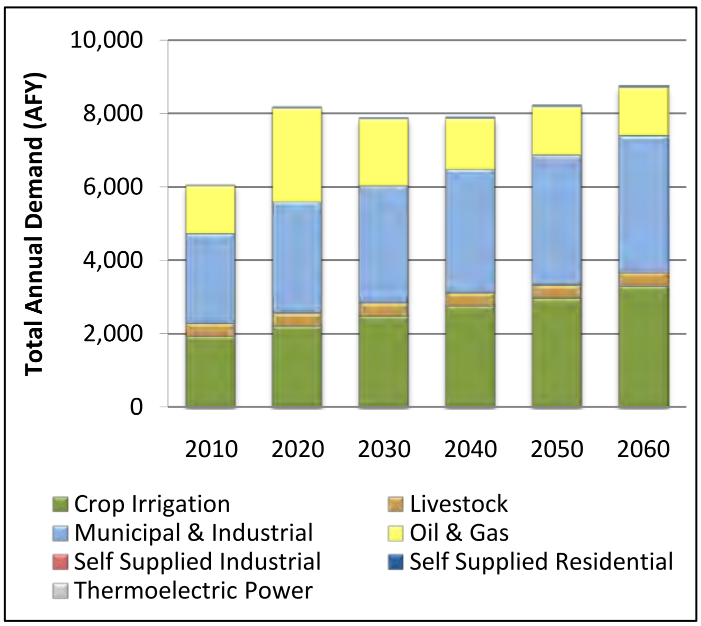

Figure 3-3. Total Demand by Sector in Basin 22

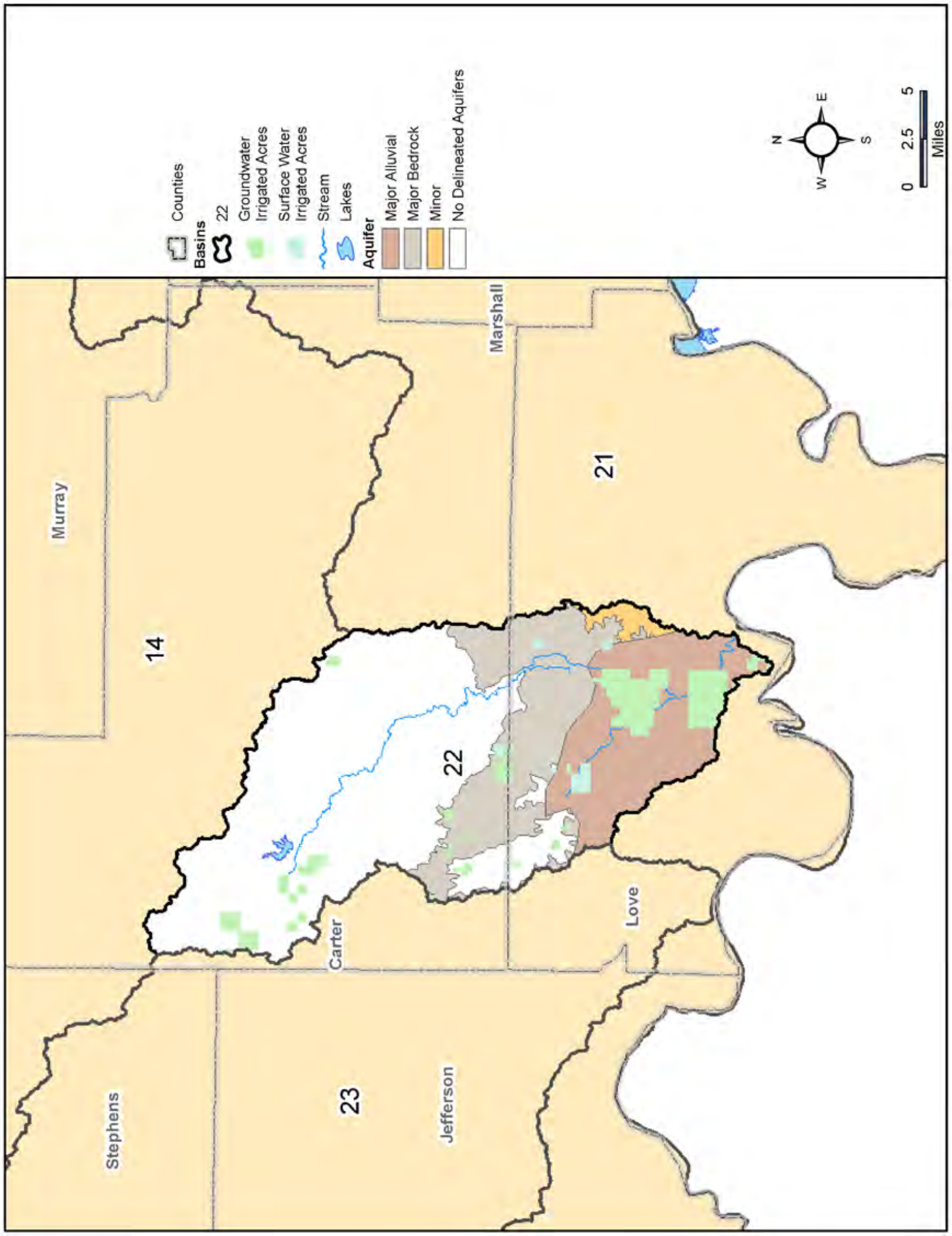

Figure 3-4. Distribution of Irrigated Land in Basin 22

Surface water was used to meet 43 percent of the total demand in the basin in 2010 and its use is projected to increase by 31 percent (820 AFY) by 2060. The majority of surface water use and growth in surface water use over this period will be in the Municipal and Industrial demand sector. There is expected to be significant water supply challenges for users of the Walnut Bayou.

Alluvial groundwater was used to meet 5 percent of the total demand in the basin in 2010 and its use is projected to increase by 62 percent (210 AFY) by 2060. The majority of alluvial groundwater use and growth in alluvial groundwater use over this period will be in the Crop Irrigation demand sector.

Bedrock groundwater was used to meet 52 percent of the total demand in the basin in 2010 and its use is projected to increase by 53 percent (1,650 AFY) by 2060. The majority of bedrock groundwater use and growth in bedrock groundwater use over this period will be in the Crop Irrigation demand sector. There is expected to be significant water supply challenges for users of the Antlers aquifer and non-delineated minor aquifers.

3.1.4 Gaps and Depletions

Based on projected demand and historical hydrology, surface water gaps and groundwater storage depletions may occur by 2020.

Surface water gaps in Basin 22 may occur throughout the year; peaking in size during the summer. There will be a 98 percent probability of gaps occurring in at least one month of the year by 2060. Surface water gaps in 2060 will be up to 30 percent (110 AF/month) of the surface water demand in the peak summer month, and as much as 21 percent (50 AF/month) of the winter months' surface water demand. Surface water gaps are most likely to occur during summer months.

Alluvial groundwater storage depletions in Basin 22 may occur throughout the year; peaking in size during the summer. There will be a 95 percent probability of alluvial groundwater storage depletions occurring in at least one month of the year by 2060. Alluvial groundwater storage depletions in 2060 will be up to 26 percent (50 AF/month) of the alluvial groundwater demand in the peak summer month, and as much as 14 percent (10 AF/month) of the fall months' alluvial groundwater demand. Alluvial groundwater storage depletions are most likely to occur during summer months. Projected annual alluvial groundwater storage depletions are minimal relative to the amount of water in storage in the Red River aquifer.

Bedrock groundwater storage depletions in Basin 22 will be 38 percent (510 AF/month) of the bedrock groundwater demand on average in the peak summer month. Projected annual bedrock groundwater storage depletions are small relative to the amount of water in storage in the Antlers aquifer. However, localized storage depletions may occur and adversely affect users' yields, water quality, and pumping costs.

3.2 Analysis of Supply Options

Six categories of supply options for mitigating the projected surface water gaps and groundwater storage depletions in Basin 22 are described in the text below. The six water supply options represent the basic ways to develop additional water supplies for all users in the basin. All options should be reviewed, as a combination of supply options will likely be needed to meet the basin's water supply challenges.

3.2.1 Demand Management

The demand management option considers permanent conservation measures and temporary drought restrictions. Moderately expanded and substantially expanded conservation measures were evaluated for both the Municipal and Industrial and Crop Irrigation demand sectors. The conservation scenarios are described briefly in Table 3-1, but the OCWP *Water Demand Forecast Report* provides full descriptions of the conservation measures considered. It is recommended that the basin consider additional permanent conservation activities, instead of temporary drought management activities. Due to the high probability of gaps and since aquifer storage could continue to provide supplies during droughts, the temporary drought management water supply option was not evaluated.

Table 3-1. Summary of OCWP Conservation Scenarios (Source: OCWP *Water Demand Forecast Report*)

Demand Sector	Conservation Scenario	Description
Municipal and Industrial	Scenario I Moderately Expanded Conservation	• Passive conservation achieved by 2060 for public-supplied residential (PSR) and 2030 for public-supplied non-residential (PSNR). Passive conservation is defined as conservation that can be achieved through government plumbing codes as part of the Energy Policy Act. • 90 percent of water providers in each county will meter their customers, unless current metered percentage is greater than 90 percent. • Non-revenue water (NRW) will be reduced to 12 percent, where applicable • Conservation pricing will be implemented by 20 percent of purveyors in rural counties, 40 percent in mostly urban counties, and 60 percent in counties with high metropolitan populations. • Water conservation educational programs will be implemented by all providers, which include billing inserts and conservation tip websites to reduce demands by 3 percent.
	Scenario II Substantially Expanded Conservation	• Passive conservation (as described in Scenario I). • All purveyors will meter their customers. • NRW will be reduced to 10 percent where applicable. • Conservation pricing will be implemented by 60 percent of purveyors in rural counties, 80 percent in mostly urban counties, and 100 percent in counties with high metro populations. • Water conservation education programs will be implemented to reduce demands by 5 percent including school education programs and media campaigns in addition to billing inserts and a conservation tip website. • High efficiency plumbing code ordinance will be implemented. This ordinance requires use of high efficiency fixtures with lower maximum flow rates than those required under the Energy Policy Act.

Table 3-1. Summary of OCWP Conservation Scenarios (Source: OCWP *Water Demand Forecast Report)*

Demand Sector	Conservation Scenario	Description
Agricultural Irrigation	Scenario I Moderately Expanded Conservation	• All sprinkler systems will have a field application efficiency of 90 percent beginning in 2015, representing implementation of LEPA nozzles on existing sprinkler systems. • Water saved through conservation activities is not applied to a water scheme elsewhere, such as expanding the number of irrigated acres, thus achieving true conservation.
	Scenario II Substantially Expanded Conservation	• All assumptions from Scenario I are applicable. • All acres of water intensive crops (corn for grain and forage crops, including alfalfa and pasture grass), shift to less water intensive crops (grain for sorghum) beginning in 2015. While is it highly unlikely that all water intensive crop production will stop, this assumption allows for analysis of full implementation of the "what-if" scenario.

Scenario I Conservation Measures

Implementing Scenario I Municipal and Industrial conservation measures decreases the projected 2060 demand in Basin 22 from 3,730 AFY to 3,090 AFY. Implementing Scenario I Crop Irrigation conservation measures decreases the projected 2060 demand in Basin 22 from 3,290 AFY to 3,110 AFY. Implementing conservation in both sectors could reduce the size of the annual surface water gaps in 2060 by about 44 percent, to a value of 460 AFY, alluvial groundwater storage depletions in 2060 by about 25 percent, to a value of 90 AFY, and bedrock groundwater depletions in 2060 by about 18 percent, to a value of 770. Under Scenario I conservation activities, the probability of be surface water gaps and storage depletions remains largely unchanged due to the high frequency of low to no-flow months. **Table 3-2** lists the irrigated acreage affected by Scenario I conservation measures. Conservation should be considered as a short- to long-term water supply option.

Table 3-2. Acreage of Sprinkler Irrigated Lands Converted to High Efficiency LEPA Nozzles

County	Irrigated Land (thousand acres) [1]
Carter	1
Love	2

[1] Acreage represents the irrigated land in the entire county for 2007, not just the portion in Basin 22.

Scenario II Conservation Measures

Substantially expanded conservation measures (Scenario II) for the Crop Irrigation demand sector would require crop shifts throughout the basin, switching from water intensive crops (e.g., corn for grain, pasture grasses, etc.) to sorghum for grain and wheat for grain, as well as the increase in irrigation efficiencies from Scenario I. The substantially expanded conservation measures include conversion of more than 1,433 acres from corn for grain and forage crops to sorghum in the counties encompassing Basin 22 as indicated in **Table 3-3**. The OCWP *Water Demand Forecast Report* recognizes that crop shifting is unlikely to occur unless crop managers are faced with severe water shortages, high pumping costs, or implementation of policies that provide incentives to do so.

Table 3-3. Acreage of Crops Converted to Sorghum for Substantially Expanded Conservation Activities

County	Corn for Grain (acres) [1]	Forage Crops including Alfalfa and Pasture Grass (acres) [1]
Carter	0	450
Love	387	596

[1] Acreage represents the entire county, not just the portion in Basin 22.

Scenario II conservation in the Municipal and Industrial demand sector would expand on the conservation measures implemented in Scenario I and require the implementation a high efficiency plumbing code ordinance. Table 3-1 provides additional information on Scenario II conservation measures.

Scenario II Municipal and Industrial conservation measures decrease the projected 2060 Municipal and Industrial demand from 3,730 AFY to 2,730 AFY and Crop Irrigation demand decreases from 3,730 AFY to 2,760 AFY. The combined demand reduction in both sectors may reduce the size of the annual surface water gaps in 2060 by an additional 28 percent (72 percent total), to a value of 230 AFY, alluvial groundwater storage depletions in 2060 by an additional 42 percent (67 percent total), to a value of 40 AFY, and bedrock groundwater depletions in 2060 by an additional 27 percent (45 percent total), to a value of 520 AFY. Reductions are not expected to substantially decrease the probability of surface water gaps or alluvial groundwater storage depletions, due to the high frequency of low to no flow months.

Scenario II conservation measures would require substantial changes in the agricultural economy throughout the basin. Therefore, this water conservation measure would likely take a relatively long period of time to implement. However, shifting crop types could aid individual irrigators in the short-term.

3.2.2 Out-of-Basin Supplies

Out-of-basin supplies would be among the most costly of options for Basin 22, but could eliminate the potential for surface water gaps and groundwater depletions. The development of out-of-basin supplies should be considered as a long-term water supply option for users throughout the basin. However, due to the scale and complexity of developing out-of-basin supplies, the cost-effectiveness of these supplies should be evaluated against other options on a local level.

Lake Texoma, which is approximately 40 miles from the center of Basin 22, has substantial unpermitted yield to meet the needs of new users. However, its use is severely restrained by water quality issues and would likely require advanced treatment for municipal and industrial use due to total dissolved solids (TDS) concentrations.

The OCWP *Reservoir Viability Study* identified 11 Category 4 and Category 3 potential out-of-basin reservoir sites in the Lower Washita Watershed Planning Region. Potential Category 4 out-of-basin supplies within a 35-mile radius of Basin 22 include Caddo Creek Reservoir (40,000 AFY yield), Courtney Reservoir (53,000 AFY yield) Durwood Reservoir

(232,000 AFY yield), and Ravia Reservoir (25,300 AFY yield). The Caddo Creek and Courtney Reservoir sites are approximately 14 miles from the center of Basin 22, and the Durwood and Ravia Reservoir sites are approximately 30 and 34 miles respectively from the center of Basin 22. With new terminal storage of about 1,200 acre-feet (AF), a 14-inch diameter pipe would be needed to bring out-of-basin supplies at a constant flow rate into Basin 22 for further distribution to users. With no terminal storage and variable flows in the pipeline, a 24-inch diameter pipeline would be needed. Each of these potential sites provide much more water than needed for Basin 22, thus might provide opportunities for regional water supply projects.

Regionalization of public water supply systems may provide an avenue for long-term implementation of major out-of-basin supplies. For purposes of this report, regionalization is defined as the shared development of and use of water supplies and the required diversion, conveyance, storage, and treatment infrastructure between two or more public water supply systems. Sharing of infrastructure, particularly for projects involving long transmission pipelines, can reduce the costs for each participant due to economies of scale. For example, conveyance of 50 million gallons per day of water could be accomplished through three individual pipelines: a 12-inch diameter pipeline, a 15-inch diameter pipeline, and a 42-inch diameter pipeline. That same flow could be conveyed through a single 48-inch diameter pipeline at roughly two-thirds the cost per mile of pipe. However, regionalization does not always reduce overall project costs and may not make economic sense depending on local and project-specific conditions. In particular, the closer two providers' distribution systems are, the more cost-effective a shared project will be.

Operational efficiencies are possible with regionalization in areas such as:

- Overnight and emergency plant staffing
- Maintenance equipment and staff
- Monitoring and reporting
- Water quality sampling and lab analyses/lab facilities
- Permitting and reporting
- Administration

At the same time, potential issues in sharing of supplies and infrastructure can bring challenges such as:

- Autonomy in decision-making and control:
  — Source of supply and capital cost decisions
  — Operational decisions (e.g., rates, drought restrictions)
- Institutional framework (new water supply district/authority vs. wholesale relationship)
- Differing needs (unequal rates of growth, condition of existing infrastructure, etc.)
- Water quality compatibility between sources
- Capital costs of interconnecting systems

Throughout the Lower Washita Watershed Planning Region, there are already numerous examples of inter-provider arrangements to share water supplies on a wholesale basis, as documented in the OCWP *Lower Washita Watershed Planning Region Report*. Often, regionalization projects are initiated by or involve larger providers in the area, for example Ardmore currently sells water to Lone Grove. Opportunities for regional supply between larger and smaller providers, particularly those whose service areas are adjacent and for major out-of-basin supply projects, could be considered as a means of addressing the significant supply challenges facing the water users in Basin 22.

The OCWP *Water Conveyance Study* updated information from the 1980 OCWP statewide water conveyance system and one southwest conveyance alternative which encompasses Basin 22. The conveyance systems require additional reservoirs, hundreds of miles of piping, canals, and inverted siphons, and many pumping plants. Study results determined that this option would not be feasible under current technology and economic constraints, but may be considered as a long-term opportunity for the future.

3.2.3 Reservoir Use

Additional reservoir storage in Basin 22 can effectively supplement supply during dry months. The entire increase in demand from 2010 to 2060 could be supplied by a new reservoir diversion and 5,800 AF of reservoir storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin's outlet may increase the amount of storage necessary to mitigate future gaps and storage depletions.

There are currently over 10 existing National Resources Conservation Service (NRCS) reservoirs in Basin 22, which are found on streams throughout the basin. These small reservoirs were typically built for flood control and to meet some agricultural demands, but could be evaluated to determine the potential for rehabilitation or reallocation of storage to meet the needs of any demand sector. The water supply yields, available storage, and water quality of these reservoirs are unknown. However, due to the potential volume of storage in the basin, shown in Table 3-4, further investigation of these water supplies may be merited.

Table 3-4. Summary of NRCS Reservoirs in Basin 22

Normal Pool Storage Category	Number of Reservoirs	Total Normal Pool Volume in Category (AF)
<50 AF	3	126
>50 AF	10	2,508
Largest Reservoir (AF)		999

The OCWP *Reservoir Viability Study* identified Burneyville Reservoir as a potential Category 3 reservoir site in Basin 22. This reservoir is expected to provide 25,000 AFY of dependable yield with a total conservation storage of 119,000 AF. This water supply yield is substantially greater than the amount required by Basin 22; therefore, the new reservoir may be able to provide out-of-basin supplies for nearby basins or serve as a regional supply. Additional analyses would be required to determine the feasibility of this project.

3.2.4 Increasing Reliance on Surface Water

Use of surface water to meet local demands in Basin 22 through 2060 is not expected to be limited by the availability of permits. However, there is a very high probability of surface water gaps starting in 2020 for the baseline demand projections. Increasing reliance on surface water use without reservoir storage would increase the size and probability of these gaps. Therefore, this water supply option is not recommended.

3.2.5 Increasing Reliance on Groundwater

Bedrock groundwater supplies, mainly from the Antlers bedrock aquifer, are used to meet 75 percent of the demand in Basin 22. The Antlers aquifer underlies most of the southern half of the basin and has substantial stored groundwater in the basin. The projected growth in surface water and alluvial groundwater use could instead be supplied by the Antlers bedrock aquifer, but would result in small (330 AFY) increases in projected bedrock groundwater storage depletions. While increasing use of bedrock water would not substantially increase depletions compared to the amount of water in storage, these localized storage depletions may adversely affect users' yields, water quality, and pumping costs. Therefore, the development of additional bedrock groundwater supplies to meet the growth in surface water and alluvial groundwater could be considered a long-term water supply option, but may require additional infrastructure and operation and maintenance costs for sustained reliability. Over a long-term period, demand management and other supply options may provide more consistent supplies and may be more cost-effective.

The majority of current alluvial groundwater rights are in non-delineated minor aquifers; therefore, the typical yields, volume of stored water, and water quality are unknown. Increased reliance on these supplies is not recommended without site-specific information.

3.2.6 Marginal Quality Water

The OCWP *Marginal Quality Water Issues and Recommendations* report identified areas where there is potential for use of marginal quality water to offset a significant amount of future demand. However, Basin 22 was not found to have significant marginal quality sources or significant potential to offset demand with marginal quality water. The Oil and Gas demand sector could potentially use marginal quality water from oil and gas flowback or produced water for drilling and operational activities. Opportunities to reuse flowback or produced water should be considered on an individual well field basis for cost-effectiveness relative to other available supplies.

3.3 Summary

Six categories of supply options for mitigating the projected surface water gaps and groundwater storage depletions in Basin 22 are summarized in Table 3-5. Four options were potential short or long-term options: demand management, out-of-basin supplies, increasing reliance on groundwater and reservoir use.

Table 3-5. Summary of Water Supply Options for Basin 22

Water Supply Option	Option	Feasibility
Demand Management	• Moderately expanded Municipal and Industrial conservation measures and increased sprinkler irrigation efficiency • Significantly expanded Municipal and Industrial conservation measures and shift to crops with lower water demand	• Short- to long-term solution that may reduce up to 70 percent of surface water gaps and alluvial groundwater storage depletions, and up to 45 percent of bedrock groundwater storage depletions
Out-of-Basin Supplies	• Potential Caddo Creek, Courtney, Durwood, and Ravia reservoirs • Supply from Lake Texoma • Statewide water conveyance	• Potential long-term solution
Reservoir Use	• Development of new reservoirs and/or reallocation of storage	• May provide long-term solution. Additional analysis required.
Increasing Reliance on Surface Water	• Increasing reliance on surface water, without reservoir storage	• Not feasible
Increasing Reliance on Groundwater	• Increasing reliance on the Antlers bedrock aquifer instead of increased surface water and alluvial groundwater use	• May provide long-term solution; localized adverse impacts may occur
Marginal Quality Water	• Use of marginal quality water sources	• No significant sources identified; site-specific potential for reuse of oil and gas flowback and produced water for oil and gas drilling and operations

Section 4
Basin 26 (Beaver Creek - 3)

Basin 26, located in the Beaver-Cache Watershed Planning Region, is a surface water hot spot, where surface water issues are mainly associated with the basin's low physical availability of streamflow and poor water quality. More detailed information on this basin is available in the OCWP *Beaver-Cache Watershed Planning Region Report*. In addition to surface water gaps, alluvial groundwater storage depletions may occur by 2060 and bedrock groundwater storage depletions may occur by 2020.This section describes the driving factors for this basin being identified as a hot spot, provides an analysis of how to address supply availability issues, and evaluates identified water supply options.

4.1 Basin Description

Basin 26 encompasses portions of Jefferson and Stephens counties. The Beaver-Cache Watershed Planning Region borders the eastern edge of the central Great Plains. The region's terrain varies from lush pasture in the river bottoms and gently rolling plains to the Wichita Mountains in the northwest, which rise 400 to 1,100 feet above surrounding red bed plains. Mixed eroded plains occur over the southwest portion of the region, much of which has been converted for wheat or cotton production, transitioning east to tall grass prairie and intergrading in the northeast to Post-Oak-Blackjack forest, known locally as the Cross Timbers. The region has a generally mild climate with average monthly temperatures varying from 40°F in January to 83°F in July. Annual average precipitation is 38 inches. Annual evaporation ranges from 27 inches in the west to 33 inches in the east.

4.1.1 Surface Water Supplies

Surface water supplies are the main sources of supply in Basin 26, meeting 77 percent of the total demand. Cow Creek and Dry Creek are the largest surface water supply sources in Basin 26. The majority of surface water use and growth in surface water use will be in the Municipal and Industrial demand sector. There are no major reservoirs in the basin.

The median flow of Cow Creek at Waurika has low to no flow from July through April, but over 4,700 AF/month in May and 2,600 AF/month in June, as shown in **Figure 4-1**, but other months. However, periods of low or no flow can occur in May and June as well. Basin 26 will have available surface water for new permitting to meet local demand through 2060, although the amount will be relatively low.

Relative to other basins in the state, the surface water quality in Basin 26 is considered poor. Natural elevated levels of salinity in the Beaver-Cache Watershed Planning Region produce agricultural use impacts and make several streams unsuitable for use as public water supply. Waurika and Lawtonka lakes, which are both designated as Sensitive Water Supply (SWS) sources, are impaired due to high levels of chlorophyll-*a*. Both Cow Creek and Dry Creek are impaired (303d list) for agricultural use along their entire length within Basin 26. However, individual lakes and streams may have acceptable water quality.

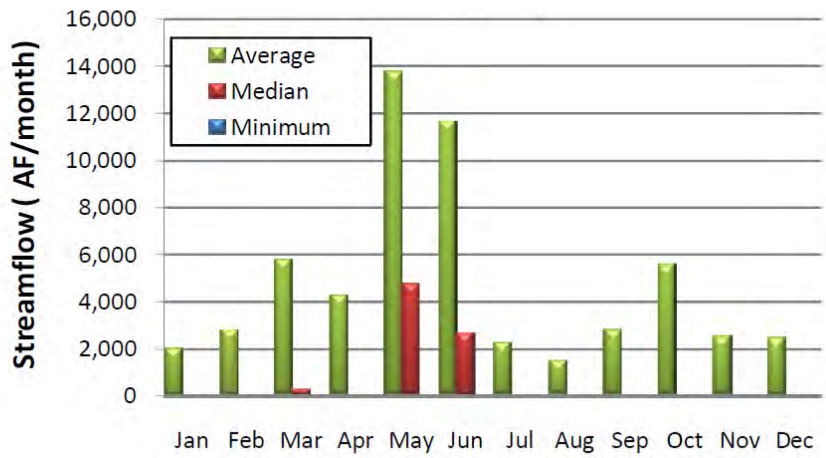

Figure 4-1. Monthly Streamflow Statistics over the Study Period of Record

4.1.2 Groundwater Supplies

Groundwater supplies are used to meet 23 percent of the total demand in Basin 26. **Figure 4-2** illustrates the aquifers and existing groundwater permits in Basin 26.

Alluvial groundwater is used to meet 4 percent of the total demand in the basin. The majority of alluvial groundwater used and growth in alluvial groundwater will be in the Crop Irrigation demand sector. The relatively few alluvial aquifer permits (300 AFY) are in minor non-delineated alluvial aquifers. These aquifers have not been studied; therefore, no information on storage, yield, or recharge is available. Site-specific information on the suitability of these minor aquifers for supply should be considered before large-scale use.

Bedrock groundwater is used to meet 19 percent of the total demand in the basin. The Crop Irrigation demand sector accounts for about 90 percent of the total bedrock groundwater demand growth from 2010 to 2060. There are currently permits for the El Reno minor bedrock aquifer and non-delineated minor bedrock aquifer; however less than 50 AFY of the basin's groundwater rights are supplied by the El Reno bedrock aquifer. The average yield of wells in the El Reno is 25 gpm with a minimum yield of only a few gpm to a maximum of 800 gpm. Locally, where fractures have formed or mineral dissolution has occurred, the storage and yield capacity of the shale units can be enhanced (Reed 1952).

The majority of bedrock groundwater permits are in non-delineated minor aquifers. These aquifers have not been studied; therefore, no information on storage, yield, or recharge is available. Site-specific information on the suitability of these minor aquifers for supply should be considered before large-scale use.

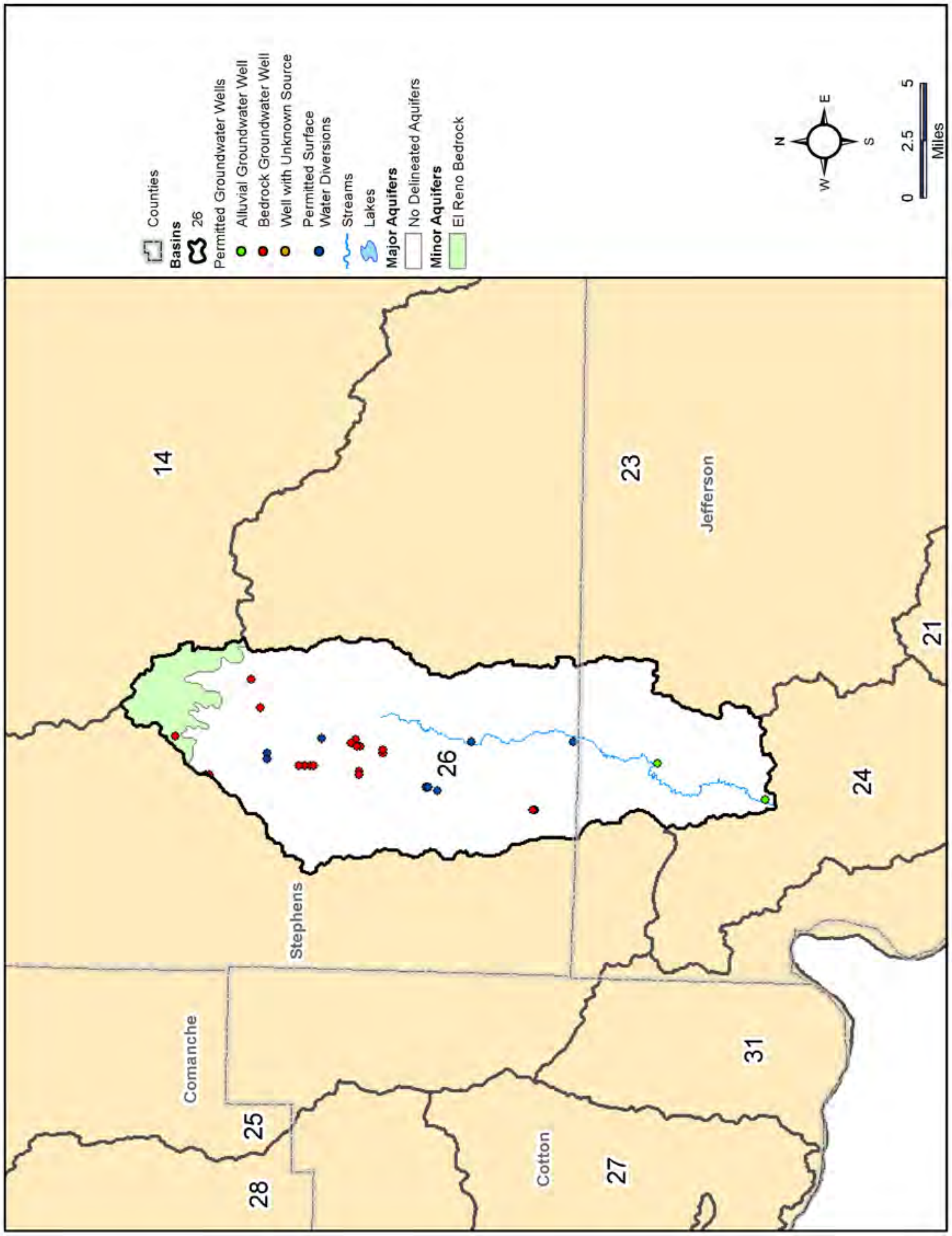

Figure 4-2. Groundwater Supplies in Basin 26

The use of groundwater to meet in-basin demand is not expected to be limited by the availability of permits through 2060. Up to 2.0 AFY/acre of dedicated lands overlying the aquifer may be withdrawn through temporary permits. Note: temporary permitted withdrawals are subject to change when converted to regular permits.

4.1.3 Water Demand

From the OCWP *Water Demand Forecast Report*, the total demand for this basin in 2060 is projected to be 3,340 AFY, which is about 6 percent of the total demand in the Beaver-Cache Region. The projected total demand in Basin 26 is presented in **Figure 4-3**. The projected increase in total demand in Basin 26 is 660 AFY, an increase of 24 percent. The majority of the demand is in the Municipal and Industrial demand sector. The Crop Irrigation demand sector accounts for two thirds (440 AFY) of the increase in demand from 2010 to 2060. Crop Irrigation occurs throughout the basins in non-delineated minor aquifers, as shown in **Figure 4-4**.

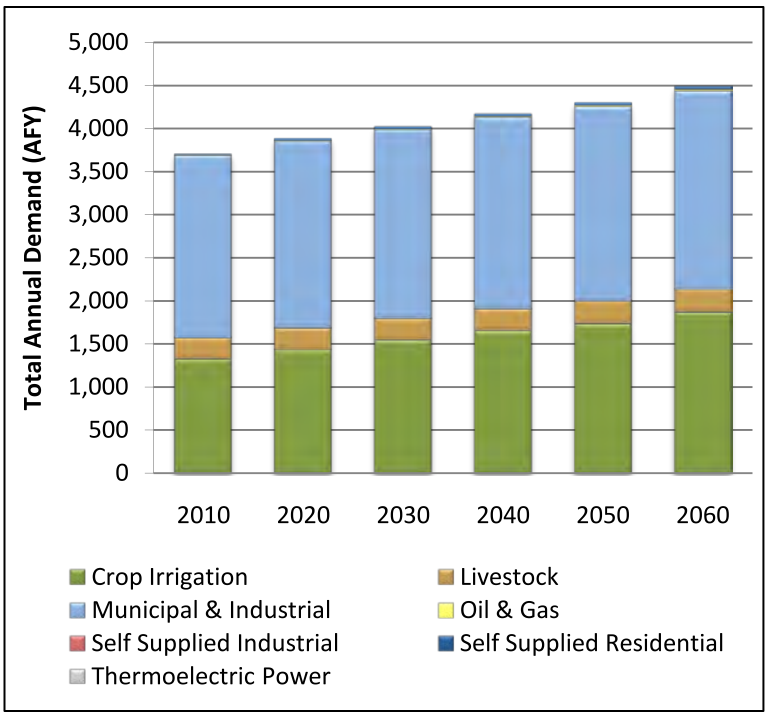

Figure 4-3. Total Demand by Sector in Basin 26

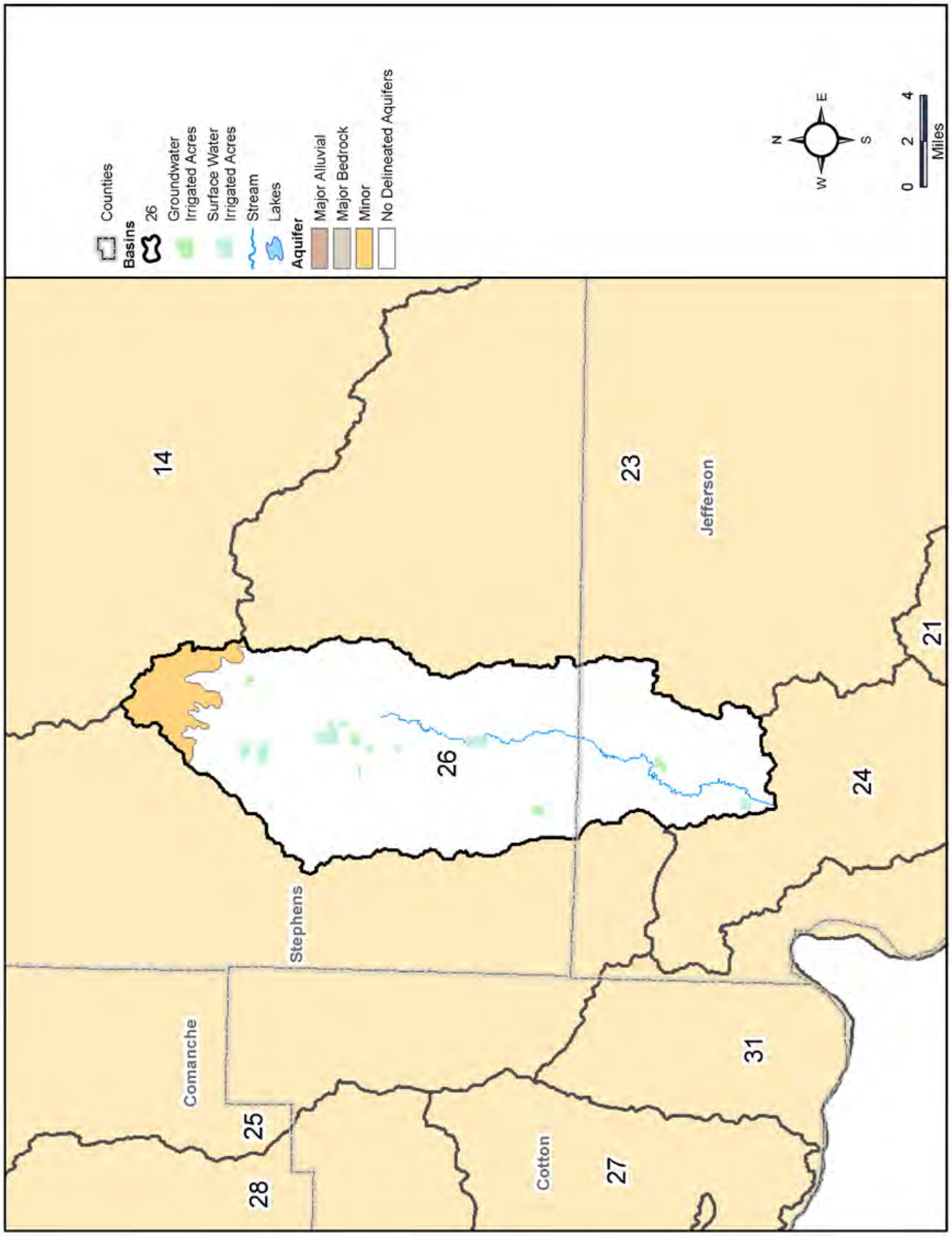

Figure 4-4. Distribution of Irrigated Land in Basin 26

Surface water was used to meet 77 percent of the total demand in the basin in 2010 and its use is projected to increase by 15 percent (310 AFY) by 2060. The majority of surface water use and growth in surface water use over this period will be in the Municipal and Industrial demand sector. Out-of-basin supplies from the Waurika Lake Master Conservancy District (WLMCD) is a major source of surface water supply for Basin 26, where the City of Duncan and City of Comanche received over 5,000 AFY of supply in 2007.

Alluvial groundwater was used to meet 4 percent of the total demand in the basin in 2010 and its use is projected to increase by 40 percent (40 AFY) by 2060. The majority of alluvial groundwater used and growth in alluvial groundwater will be in the Crop Irrigation demand sector.

Bedrock groundwater was used to meet 19 percent of the total demand in the basin in 2010 and its use is projected to increase by 60 percent (310 AFY) by 2060. The largest bedrock groundwater use and growth in bedrock groundwater use over this period will be in the Crop Irrigation demand sector.

4.1.4 Gaps and Depletions

Based on projected demand and historical hydrology, surface water gaps and bedrock groundwater depletions are projected to occur by 2020, while alluvial groundwater storage depletions are expected by 2060.

Surface water gaps in 2060 will be up to 17 percent (60 AF/month) of the surface water demand in the peak summer months. By 2060, there will be a 79 percent probability of gaps occurring during summer months. Gaps would likely have been larger; however, up to 300 AFY of out-of-basin supplies from the WLMCD were included in Basin 26 to represent potential future transfers.

Alluvial groundwater storage depletions in Basin 26 may occur during the summer and will be up to 33 percent (10 AF/month) of the 2060 alluvial groundwater demand in the peak summer month. There will be a 69 percent probability of alluvial groundwater storage depletions occurring in at least one month of the year by 2060.

Bedrock storage depletions from minor aquifers will be used to meet demand in the spring, summer and fall, peaking in size during the summer. Bedrock groundwater storage depletions will be up to 50 percent (130 AF/month) of the bedrock groundwater demand in the peak summer month, and as much as 25 percent (10 AF/month) of the spring months' bedrock groundwater demand. Future bedrock groundwater withdrawals are expected to occur from minor aquifers. Therefore, the severity of the storage depletions cannot be evaluated.

4.2 Analysis of Supply Options

Six categories of supply options for mitigating the projected surface water gaps and groundwater storage depletions in Basin 26 are described in the text below. The six water supply options represent the basic ways to develop additional water supplies for all users in the basin. All options should be reviewed, as a combination of supply options will likely be needed to meet the basin's water supply challenges.

4.2.1 Demand Management

The demand management option considers permanent conservation measures and temporary drought restrictions. Moderately expanded and substantially expanded conservation measures were evaluated for both the Municipal and Industrial and Crop Irrigation demand sectors. The conservation scenarios are described briefly in Table 4-1, but the OCWP *Water Demand Forecast Report* provides full descriptions of the conservation measures considered. It is recommended that the basin consider additional permanent conservation activities, instead of temporary drought management activities. Due to the high probability of gaps and since aquifer storage could continue to provide supplies during droughts, the temporary drought management water supply option was not evaluated.

Table 4-1. Summary of OCWP Conservation Scenarios(Source: OCWP *Water Demand Forecast Report*)

Demand Sector	Conservation Scenario	Description
Municipal and Industrial	Scenario I Moderately Expanded Conservation	• Passive conservation achieved by 2060 for PSR and 2030 for PSNR. Passive conservation is defined as conservation that can be achieved through government plumbing codes as part of the Energy Policy Act. • 90 percent of water providers in each county will meter their customers, unless current metered percentage is greater than 90 percent. • NRW will be reduced to 12 percent, where applicable • Conservation pricing will be implemented by 20 percent of purveyors in rural counties, 40 percent in mostly urban counties, and 60 percent in counties with high metropolitan populations. • Water conservation educational programs will be implemented by all providers, which include billing inserts and conservation tip websites to reduce demands by 3 percent.
	Scenario II Substantially Expanded Conservation	• Passive conservation (as described in Scenario I). • All purveyors will meter their customers. • NRW will be reduced to 10 percent where applicable. • Conservation pricing will be implemented by 60 percent of purveyors in rural counties, 80 percent in mostly urban counties, and 100 percent in counties with high metro populations. • Water conservation education programs will be implemented to reduce demands by 5 percent including school education programs and media campaigns in addition to billing inserts and a conservation tip website. • High efficiency plumbing code ordinance will be implemented. This ordinance requires use of high efficiency fixtures with lower maximum flow rates than those required under the Energy Policy Act.

Table 4-1. Summary of OCWP Conservation Scenarios(Source: OCWP *Water Demand Forecast Report*)

Demand Sector	Conservation Scenario	Description
Agricultural Irrigation	Scenario I Moderately Expanded Conservation	• All sprinkler systems will have a field application efficiency of 90 percent beginning in 2015, representing implementation of LEPA nozzles on existing sprinkler systems. • Water saved through conservation activities is not applied to a water scheme elsewhere, such as expanding the number of irrigated acres, thus achieving true conservation.
	Scenario II Substantially Expanded Conservation	• All assumptions from Scenario I are applicable. • All acres of water intensive crops (corn for grain and forage crops, including alfalfa and pasture grass), shift to less water intensive crops (grain for sorghum) beginning in 2015. While is it highly unlikely that all water intensive crop production will stop, this assumption allows for analysis of full implementation of the "what-if" scenario.

Scenario I Conservation Measures

Implementing Scenario I Municipal and Industrial conservation measures decreases the projected 2060 demand in Basin 26 from 730 AFY to 690 AFY. Implementing Scenario I Crop Irrigation conservation measures decreases the projected 2060 demand in Basin 26 from 2,300 AFY to 1,930 AFY. Implementing conservation in both sectors could reduce the size of the annual surface water gaps by up to 90 percent in 2060, to a value of 10 AFY, bedrock groundwater depletions in minor aquifers by about 17 percent in 2060, to a value of 250 AFY. Under Scenario I conservation activities, the probability of surface water gaps and storage depletions may be reduce by 10 percent from 79 percent to 69 percent. **Table 4-2** lists the irrigated acreage affected by Scenario I conservation measures. Moderately expanded conservation measures could benefit users throughout the basin and should be considered as a short- to long-term water supply option.

Table 4-2. Acreage of Sprinkler Irrigated Lands Converted to High Efficiency LEPA Nozzles

County	Irrigated Land (thousand acres) [1]
Jefferson	0
Stephens	1

[1] Acreage represents the irrigated land in the entire county for 2007, not just the portion in Basin 26.

Scenario II Conservation Measures

Substantially expanded conservation measures (Scenario II) for the Crop Irrigation demand sector would require crop shifts throughout the basin, switching from water intensive crops (e.g., corn for grain, pasture grasses, etc.) to sorghum for grain and wheat for grain, as well as the increase in irrigation efficiencies from Scenario I. The substantially expanded conservation measures include conversion of 590 acres from corn for grain and forage crops to sorghum in the counties located in and around the basin, as indicated in **Table 4-3**. The OCWP *Water Demand Forecast Report* recognizes that crop shifting is unlikely to occur unless crop managers are faced with severe water shortages, high pumping costs, or implementation of policies that provide incentives to do so.

Table 4-3. Acreage of Crops Converted to Sorghum for Substantially Expanded Conservation Activities

County	Corn for Grain (acres) [1]	Forage Crops including Alfalfa and Pasture Grass (acres) [1]
Jefferson	0	138
Stephens	0	452

[1] Acreage represents the entire county, not just the portion in Basin 26.

Scenario II conservation in the Municipal and Industrial demand sector would expand on the conservation measures implemented in Scenario I and require the implementation a high efficiency plumbing code ordinance. Table 4-1 provides additional information on Scenario II conservation measures.

Scenario II Municipal and Industrial conservation measures decrease the projected 2060 Municipal and Industrial demand from 730 AFY to 520 AFY and Crop Irrigation demand decreases from 2,300 AFY to 1,720 AFY. Surface water gaps could be eliminated with substantially expanded conservation measures and reduce bedrock groundwater depletions an additional 37 percent (total of 53 percent) - to a value of 140 AFY in 2060.

Scenario II conservation measures would require substantial changes in the agricultural economy throughout the basin. Therefore, this water conservation measure would likely take a relatively long period of time to implement. However, shifting crop types could aid individual irrigators in the short-term.

4.2.2 Out-of-Basin Supplies

Out-of-basin supplies from the Waurika Lake through the WLMCD are a major source of supply for Basin 26, where the cities of Duncan and Comanche received over 5,000 AFY of supply in 2007. Increased reliance on Waurika, assuming existing infrastructure is adequate or, if needed, construction of new infrastructure, could mitigate surface water gaps. However, Waurika Lake is fully allocated to the WLMCD, thus existing users and allocation of the lake's supplies would need to be considered. If suitable supplies could be allocated from the WLMCD, an additional 180 AFY of out-of-basin supplies from Waurika Lake, which is approximately 10 miles away from the center of the basin, could meet the Municipal and Industrial demand in Basin 26. A 6-inch diameter pipe would be needed to bring out-of-basin supplies into Basin 26 for further distribution to users.

The construction of new out-of-basin supplies would be among the most costly of options, but could eliminate the potential for surface water gaps and groundwater depletions. The development of out-of-basin supplies should be considered as a long-term water supply option for users throughout the basin. However, due to the scale and complexity of developing out-of-basin supplies, the cost-effectiveness of these supplies should be evaluated against other options on a local level.

The OCWP *Reservoir Viability Study* identified two potential reservoir sites within the Beaver-Cache Watershed Planning Region: Snyder Lake (Category 3) and Cookietown Reservoir (Category 4). The site in nearest proximity to Basin 26 is Cookietown Reservoir located in Basin 30. This reservoir is expected to provide 34,700 AFY of dependable yield with a total conservation storage of 208,000 AF. With new terminal storage of approximately 300 AF, an 8-inch diameter pipe would be needed to bring Cookietown Reservoir supplies at a constant flow rate into Basin 26 for further distribution to users. With no terminal storage and variable flows in the pipeline, a 14-inch diameter pipeline would also be recommended. Cookietown Reservoir could supply a much greater amount of dependable yield than required by Basin 22; therefore, the new reservoir may be able to provide a regional source of supply for nearby basins as well.

Regionalization of public water supply systems may provide an avenue for long-term implementation of major out-of-basin supplies. For purposes of this report, regionalization is defined as the shared development of and use of water supplies and the required diversion, conveyance, storage, and treatment infrastructure between two or more public water supply systems. Sharing of infrastructure, particularly for projects involving long transmission pipelines, can reduce the costs for each participant due to economies of scale. For example, conveyance of 50 million gallons per day of water could be accomplished through three individual pipelines: a 12-inch diameter pipeline, a 15-inch diameter pipeline, and a 42-inch diameter pipeline. That same flow could be conveyed through a single 48-inch diameter pipeline at roughly two-thirds the cost per mile of pipe. However, regionalization does not always reduce overall project costs and may not make economic sense depending on local and project-specific conditions. In particular, the closer two providers' distribution systems are, the more cost-effective a shared project will be.

Operational efficiencies are possible with regionalization in areas such as:

- Overnight and emergency plant staffing
- Maintenance equipment and staff
- Monitoring and reporting
- Water quality sampling and lab analyses/lab facilities
- Permitting and reporting
- Administration

At the same time, potential issues in sharing of supplies and infrastructure can bring challenges such as:

- Autonomy in decision-making and control:
  - Source of supply and capital cost decisions
  - Operational decisions (e.g., rates, drought restrictions)
- Institutional framework (new water supply district/authority vs. wholesale relationship)
- Differing needs (unequal rates of growth, condition of existing infrastructure, etc.)
- Water quality compatibility between sources
- Capital costs of interconnecting systems

Throughout the Beaver-Cache Watershed Planning Region, there are already numerous examples of inter-provider arrangements to share water supplies on a wholesale basis, as documented in the OCWP *Beaver-Cache Watershed Planning Region Report*. Often, regionalization projects are initiated by or involve larger providers in the area, for example WLMCD sells to Duncan and others. Opportunities for regional supply between larger and smaller providers, particularly those whose service areas are adjacent and for major out-of-basin supply projects, could be considered as a means of addressing the significant supply challenges facing the water users in Basin 26.

The OCWP *Water Conveyance Study* updated information from the 1980 OCWP statewide water conveyance system and one southwest conveyance alternative, which encompasses Basin 26. The conveyance systems require additional reservoirs; hundreds of miles of piping, canals, and inverted siphons; and many pumping plants. Study results determined that this option would not be feasible under current technology and economic constraints, but may be considered as a long-term opportunity for the future.

4.2.3 Reservoir Use

Additional reservoir storage in Basin 26 could effectively supplement supplies during dry months. The entire increase in demand from 2010 to 2060 could be supplied by a new river diversion and 900 AF of reservoir storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the size of storage necessary to mitigate future gaps and storage depletions.

There are currently over 20 existing NRCS reservoirs in Basin 26, which are found on streams throughout the basin. These small reservoirs were typically built for flood control and to serve relatively minor agricultural needs, but could be evaluated to determine the potential for rehabilitation and/or reallocation of storage to meet the needs of any demand sector. The water supply yields, available storage, and water quality of these reservoirs are unknown. However, due to the potential volume of storage in the basin, shown in Table 4-4, further investigation of these water supplies may be merited.

Table 4-4. Summary of NRCS Reservoirs in Basin 26

Normal Pool Storage Category	Number of Reservoirs	Total Normal Pool Volume in Category (AF)
<50 AF	11	323
>50 AF	12	1,423
Largest Reservoir (AF)		377

The OCWP *Reservoir Viability Study* did not identify any viable reservoir sites in Basin 26.

4.2.4 Increasing Reliance on Surface Water

There is a high probability of surface water gaps in supplies from Cow Creek starting in 2020 for the baseline demand projections. Increasing reliance on surface water, which has relatively poor water quality, would increase the size and probability of these gaps. Therefore, this water supply option is not recommended.

4.2.5 Increasing Reliance on Groundwater

There are no major aquifers in Basin 26. The majority of groundwater rights in Basin 26 are in non-delineated minor bedrock aquifers. Increasing reliance on these supplies is not recommended on a basin scale. Because of the low well yields associated with minor aquifers, these supplies may not meet the needs of large-scale users and the viability of these supplies is site-specific.

4.2.6 Marginal Quality Water

The OCWP *Marginal Quality Water Issues and Recommendations* report identified areas where there is potential for use of marginal quality water to offset a significant amount of future demand. However, Basin 26 was not found to have significant marginal quality sources or significant potential to offset demand with marginal quality water.

4.3 Summary

Six categories of supply options for mitigating the projected surface water gaps and groundwater storage depletions in Basin 26 are summarized in Table 4-5. Demand management and out-of-basin supplies were identified as potential short or long-term options.

Table 4-5. Summary of Water Supply Options for Basin 26

Water Supply Option	Option	Feasibility
Demand Management	• Moderately expanded conservation for Municipal and Industrial sector and increased Crop Irrigation efficiency • Substantially expanded Municipal and Industrial and irrigation conservation	• Short- to long-term solution that may eliminate surface water gaps and reduce groundwater storage depletions by 53%
Out-of-Basin Supplies	• Waurika Lake • Cookietown Reservoir • Statewide water conveyance	• Potential long-term solutions
Reservoir Use	• Development of new reservoirs and/or reallocation of storage	• Small impoundments may be feasible for long-term solutions
Increasing Reliance on Surface Water	• Increasing reliance on surface water supplies, without reservoir storage	• Not feasible
Increasing Reliance on Groundwater	• Increasing reliance on the non-delineated minor groundwater sources currently used	• Not feasible
Marginal Quality Water	• Use of marginal quality water sources	• No significant sources identified

Section 5
Basin 34 (Lower North Fork Red River - 3)

Basin 34, located in the Southwest Watershed Planning Region, is a surface water hot spot. Surface water issues are mainly due to the basin's low physical availability of streamflow, lack of available streamflow for new permits, and poor water quality. More detailed information on this basin is available in the OCWP *Southwest Watershed Planning Region Report*. In addition to surface water gaps, alluvial groundwater storage depletions may occur by 2020. This section describes the driving factors for this basin being identified as a hot spot, provides an analysis of how to address supply availability issues, and evaluates identified water supply options.

5.1 Basin Description

Basin 34 encompasses portions of Jackson, Kiowa, Washita, and Beckham counties. The Southwest Watershed Planning Region is in the Southern Great Plains and has mild winters and long, hot summers. The terrain includes large farming areas along with rolling river bottoms, and the Wichita Mountains near the outlet of the basin. The region's climate is mild with annual mean temperatures varying from 59°F to 64°F. Annual evaporation within the region ranges from 62 to 65 inches per year. Annual rainfall in the region averages 29 inches.

5.1.1 Surface Water Supplies

Surface water was used to meet 48 percent of the basin's total demand in 2010. The majority of the surface water use over this period will be in the Crop Irrigation and Oil and Gas demand sectors. The largest surface water supply sources in the basin are the North Fork of the Red River and Elk Creek. The median flow in the North Fork of the Red River near Headrick, Oklahoma is greater than 3,500 AF/month throughout the year and greater than 19,000 AF/month in May and June. Historically, periods of low to zero flow have occurred in the basin in each month of the year, as shown in Figure 5-1. Surface water in Basin 34 has been fully allocated, leaving no surface water available for new permits.

Basin 34 has two municipal reservoirs on tributaries of the North Fork of the Red River—Rocky Lake and Elk City Lake. Rocky Lake provides flood control and recreation for the City of Hobart. Elk City Lake provides water supply and recreation for Elk City. The ability of these reservoirs to provide future water supplies could not be evaluated because the water supply yields are unknown. Yield studies should be undertaken for both reservoirs.

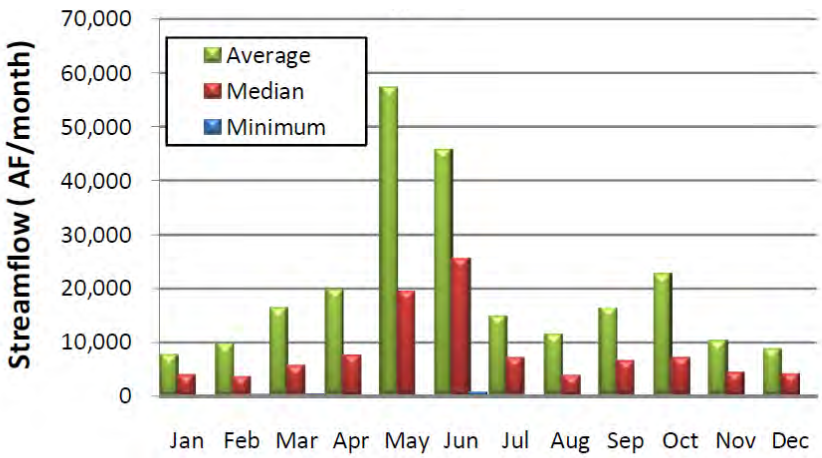

Figure 5-1. Monthly Streamflow Statistics over the Study Period of Record

Relative to other basins in the state, the surface water quality in Basin 34 is considered poor. Water quality of the Southwest Watershed Planning Region varies considerably. Natural elevated levels of salinity in this region produce agricultural and public private water supply impacts, particularly in the North Fork of the Red River and the Salt Fork of the Red River and their tributaries. The North Fork of the Red River and several of its tributaries in Basin 34 are impaired for Agricultural use due to high levels of total dissolved solids (TDS), chloride, and sulfate. Rocky Lake is impaired for Public and Private Water Supply due to high levels of chlorophyll-*a*. However, Elk Creek is not impaired for Agriculture or Public and Private Water Supplies.

5.1.2 Groundwater Supplies

Groundwater is the primary source of water and currently supplies about 52 percent of total demand in this basin. **Figure 5-2** illustrates the alluvial aquifers and existing groundwater permits in Basin 34. Current groundwater rights are mainly from the North Fork of the Red River major alluvial aquifer and the Elk City major bedrock aquifer. The small amount of remaining alluvial and bedrock aquifer rights are in the Western Oklahoma minor aquifer or non-delineated minor aquifers. These aquifers have not been studied; therefore, no information on storage, yield, or recharge is available. Site-specific information on the suitability of these minor aquifers for supply should be considered before large-scale use.

The North Fork of the Red River alluvial aquifer supplies about 30 percent (or 4,100 AFY) of the basin's current groundwater rights (13,700 AFY). This portion of the aquifer is available only to about 16 percent of the total area in the southern part of the basin. Up to 1.0 AFY/acre of dedicated lands overlying the aquifer may be withdrawn through regular permits. There are an estimated 76,900 AFY of remaining groundwater rights remaining in this basin, which is not expected to be limited by the availability of new permits for local demand through 2060. There are no significant groundwater quality issues in the basin.

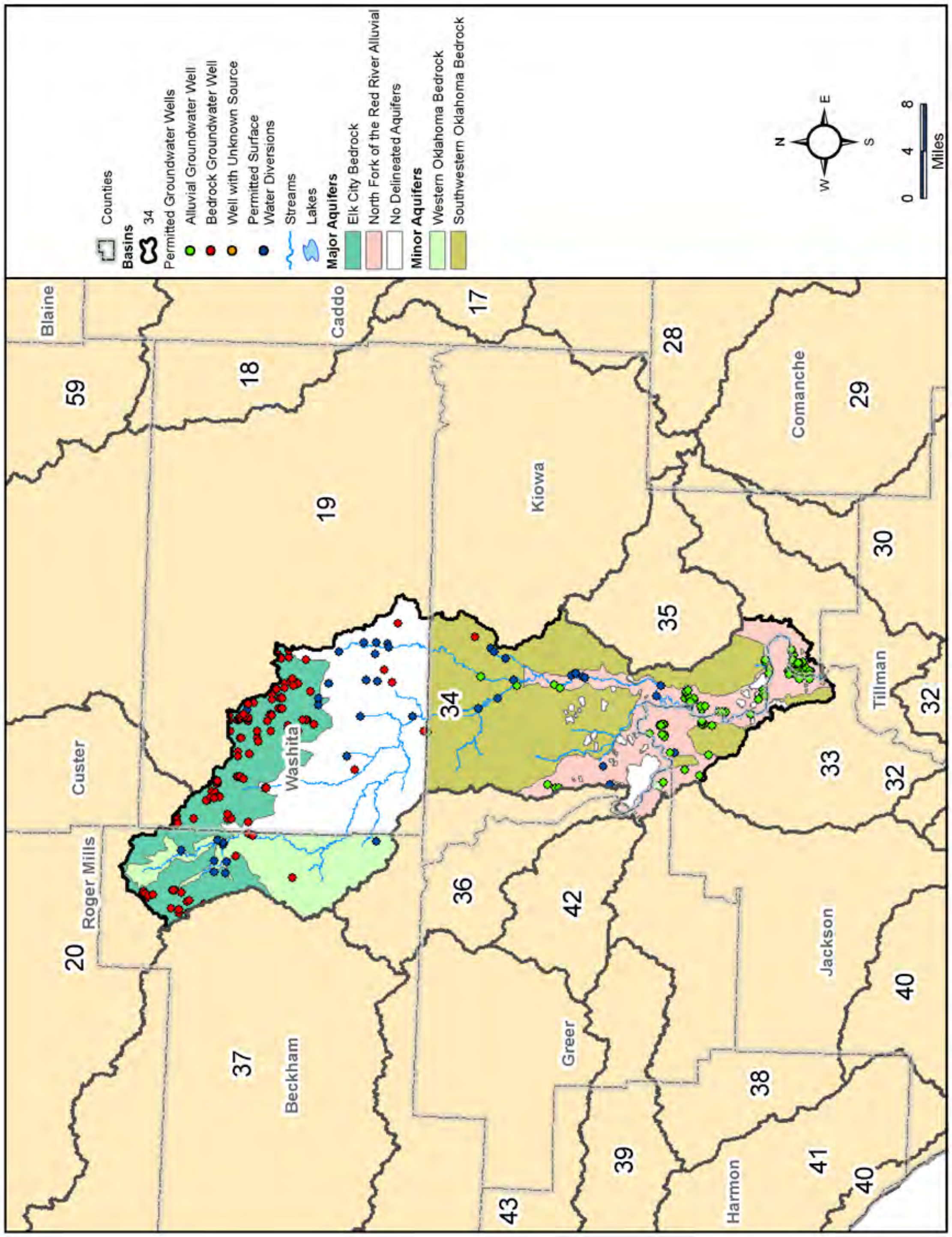

Figure 5-2. Groundwater Supplies in Basin 34

Elk City bedrock aquifer supplies about 55 percent (or 7,500 AFY) of the basin's groundwater rights (13,700 AFY). This portion of the aquifer is available only to about 17 percent of the total area in the northern part of the basin. Up to 1.0 AFY/acre of dedicated lands overlying the aquifer may be withdrawn through regular permits. There are an estimated 78,000 AFY of remaining groundwater rights in this basin, which is not expected to be limited by the availability of new permits for local demand through 2060.

Basin 34 has two minor bedrock aquifers—the Western Oklahoma aquifer and the Southwestern Oklahoma. There are no current groundwater rights in the Southwestern Oklahoma aquifer and 200 AFY (or 1 percent of the basin's groundwater rights) in the Western Oklahoma aquifer. No EPS has been set for the Western Oklahoma and Southwestern Oklahoma aquifers. Up to 2.0 AFY/acre of dedicated lands overlying these aquifers may be withdrawn through temporary permits. Note: temporary permitted withdrawals are subject to change when converted to regular permits. The site-specific information on these minor aquifers for long-term supply should be considered before large-scale use.

The non-delineated bedrock and alluvial minor aquifers in Basin 34 supplies about 14 percent (or 1,900 AFY) of the basin's groundwater rights. Up to 2.0 AFY/acre of dedicated lands overlying these aquifers may be withdrawn through temporary permits. Note: temporary permitted withdrawals are subject to change with converted to regular permits. The site-specific information on these minor aquifers for long-term supply should be considered before large-scale use.

5.1.3 Water Demand

From the OCWP *Water Demand Forecast Report*, the total demand for this basin in 2060 is 19,010 AFY, an increase of 50 percent from 2010 to 2060. The project total demand in Basin 34 is presented in **Figure 5-3**. The majority of the demand will be in the Crop Irrigation demand sector; however, the largest demand growth from 2010 to 2060 will occur in the Oil and Gas sector. Crop Irrigation occurs throughout the basins, as shown in **Figure 5-4**. However, the majority of irrigated acres are in the northern portion of the basin (Elk City aquifer), the southern portion of the basin along the North Fork of the Red River (both surface water and groundwater sources), and along Elk Creek in the center of the basin.

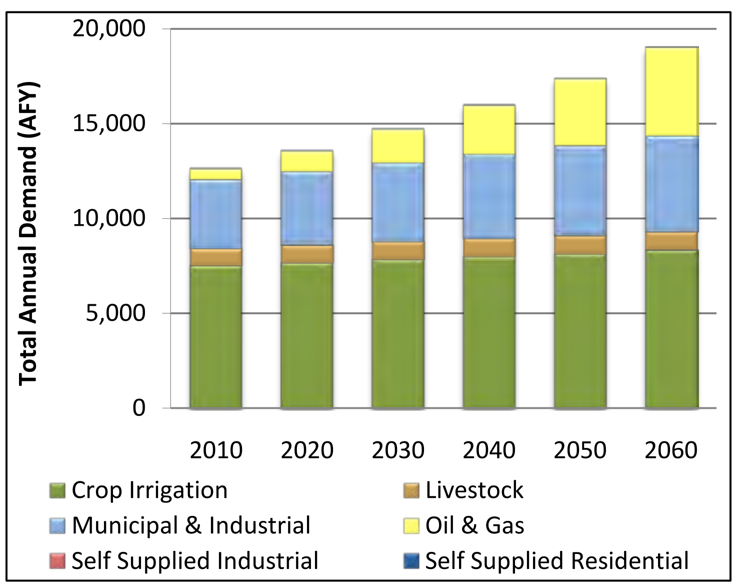

Figure 5-3. Total Demand by Sector in Basin 34

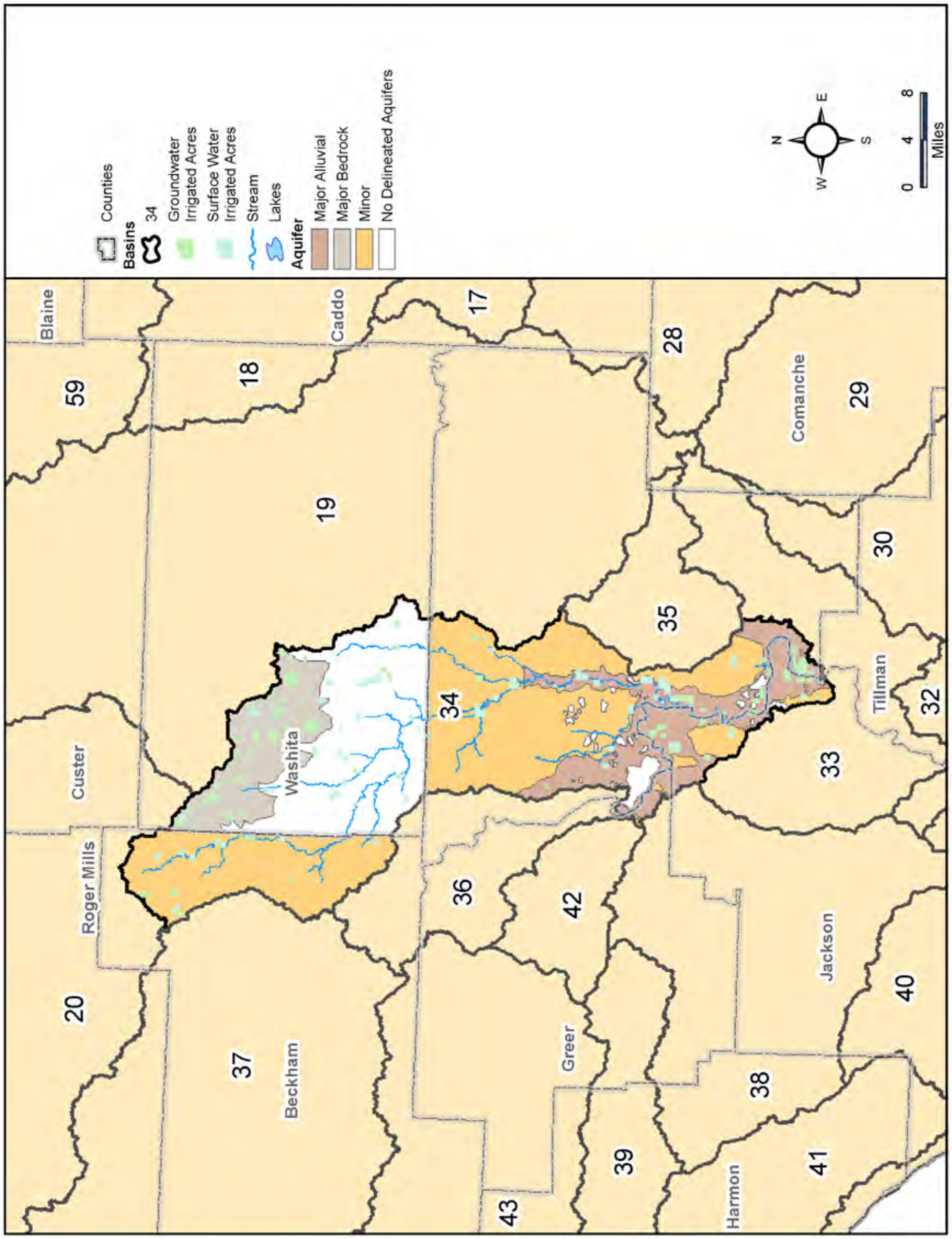

Figure 5-4. Distribution of Irrigated Land in Basin 34

5.1.4 Gaps and Depletions

Based on projected demand and historical hydrology, surface water gaps and alluvial groundwater storage depletions are projected to occur by 2020. The recharge to the Elk City aquifer is expected to be sufficient to meet future bedrock groundwater demands.

Surface water gaps in Basin 34 may occur throughout the year; peaking in size during the summer. Surface water gaps in 2060 will be up to 15 percent (290 AF/month) of the surface water demand in the peak summer month, and as high as 35 percent (220 AF/month) of the winter months' surface water demand. By 2060, there will be a 64 percent probability of gaps occurring in at least one month of the year. Surface water gaps are most likely to occur during winter months. Upstream surface water use, which includes out-of-state users, is expected to reduce available surface water supplies and contribute to the moderate probability of gaps.

Alluvial groundwater storage depletions in Basin 34 may occur throughout the year; peaking in size during the summer. Alluvial groundwater storage depletions in 2060 will be up to 15 percent (160 AF/month) of the alluvial groundwater demand in the peak summer month, and as high as 33 percent (10 AF/month) of the winter months' alluvial groundwater demand. By 2060, there will be a 64 percent probability of storage depletions occurring in at least one month of the year. Alluvial groundwater storage depletions are most likely to occur during winter months. Alluvial groundwater storage depletions are minimal compared to the groundwater storage in this basin. However, localized storage depletions may adversely impact users' yields, water quality, or pumping costs.

5.2 Analysis of Supply Options

Six categories of supply options for mitigating the projected surface water gaps and groundwater storage depletions in Basin 34 are summarized in the text below. The six water supply options represent the basic ways to develop additional water supplies for all users in the basin. All options should be reviewed, as a combination of supply options will likely be needed to meet the basin's water supply challenges.

5.2.1 Demand Management

The demand management option considers permanent conservation measures and temporary drought restrictions. Moderately expanded and substantially expanded conservation measures were evaluated for both the Municipal and Industrial and Crop Irrigation demand sectors. The conservation scenarios are described briefly in **Table 5-1**, but the OCWP *Water Demand Forecast Report* provides full descriptions of the conservation measures considered. For Basin 34, 60 percent of the demand growth between 2010 and 2060 comes from the Oil and Gas demand sector, which is not impacted by demand reduction measures studied in this project.

It is recommended that the basin consider additional permanent conservation activities, instead of temporary drought management activities, due to the moderate probability of gaps and since aquifer storage could continue to provide supplies during droughts. Therefore, temporary drought management was not evaluated.

Table 5-1. Summary of OCWP Conservation Scenarios (Source: OCWP *Water Demand Forecast Report*)

Demand Sector	Conservation Scenario	Description
Municipal and Industrial	Scenario I Moderately Expanded Conservation	• Passive conservation achieved by 2060 for PSR and 2030 for PSNR. Passive conservation is defined as conservation that can be achieved through government plumbing codes as part of the Energy Policy Act. • 90 percent of water providers in each county will meter their customers, unless current metered percentage is greater than 90 percent. • NRW will be reduced to 12 percent, where applicable • Conservation pricing will be implemented by 20 percent of purveyors in rural counties, 40 percent in mostly urban counties, and 60 percent in counties with high metropolitan populations. • Water conservation educational programs will be implemented by all providers, which includes billing inserts and conservation tip websites to reduce demands by 3 percent.
	Scenario II Substantially Expanded Conservation	• Passive conservation (as described in Scenario I) • All purveyors will meter their customers. • NRW will be reduced to 10 percent where applicable. • Conservation pricing will be implemented by 60 percent of purveyors in rural counties, 80 percent in mostly urban counties, and 100 percent in counties with high metro populations. • Water conservation education programs will be implemented to reduce demands by 5 percent including school education programs and media campaigns in addition to billing inserts and a conservation tip website. • High efficiency plumbing code ordinance will be implemented. This ordinance requires use of high efficiency fixtures with lower maximum flow rates than those required under the Energy Policy Act.
Agricultural Irrigation	Scenario I Moderately Expanded Conservation	• The field application efficiency of surface irrigation systems for Harmon, Jackson, Tillman, and Kiowa counties will increase to 80 percent beginning in 2015 (All of Basins 40 and 41, portions of Basins 34, 36, 38, and 42). • In Harmon, Jackson, Tillman, and Kiowa counties, 10 percent of the land irrigated by surface irrigation will shift to micro-irrigation beginning in 2015. (All of Basins 40 and 41, portions of Basins 34, 36, 38, and 42). • All sprinkler systems will have a field application efficiency of 90 percent beginning in 2015, representing implementation of LEPA nozzles on existing sprinkler systems. • Water saved through conservation activities is not applied to a water scheme elsewhere, such as expanding the number of irrigated acres, thus achieving true conservation.
	Scenario II Substantially Expanded Conservation	• All assumptions from Scenario I are applicable. • All acres of water intensive crops (corn for grain and forage crops, including alfalfa and pasture grass), shift to less water intensive crops (grain for sorghum) beginning in 2015. While is it highly unlikely that all water intensive crop production will stop, this assumption allows for analysis of full implementation of the "what-if" scenario.

Scenario I Conservation Measures

Demand management could reduce surface water gaps or groundwater storage depletions through expanded permanent conservation measures. Increasing the irrigation efficiency in the Crop Irrigation demand sector and implementing moderately expanded conservation measures for the demand sector (Scenario I conservation, as defined in the

OCWP *Water Demand Forecast Report*) could reduce the total demand by 1,970 AFY and reduce the size of the annual surface water gaps by up to 35 percent in 2060 to a value of 1,620 AFY, and alluvial groundwater storage depletions in 2060 by about 59 percent to a value of 190 AFY. Table 5-2 lists the irrigated acreage affected by Scenario I conservation measures. Under Scenario I conservation activities, the probability of surface water gaps and storage depletions remains nearly unchanged, due to the high frequency of low to no-flow months.

Table 5-2. Acreage of Irrigated Lands with Increased Irrigation Efficiency under Scenario I Conservation

County	Irrigated Land (thousand acres) [1]
Beckham	7
Kiowa	3
Jackson	55
Washita	7

[1] Acreage represents the irrigated land in the entire county for 2007, not just the portion in Basin 34.

Moderately expanded conservation measures could provide a water supply solution in a relatively short period of time and could be implemented throughout the basin. This conservation measure should be considered as a short- to long-term water supply option.

Scenario II Conservation Measures

Substantially expanded conservation measures (Scenario II) for the Crop Irrigation demand sector would require crop shifts throughout the basin, switching from water intensive crops (e.g., corn for grain, pasture grasses, etc.) to sorghum for grain and wheat for grain, as well as the increase in irrigation efficiencies from Scenario I. The substantially expanded conservation measures include conversion of 6,690 acres from corn for grain and forage crops to sorghum in the counties located in and around the basin, as indicated in Table 5-3. The OCWP *Water Demand Forecast Report* recognizes that crop shifting is unlikely to occur unless crop managers are faced with severe water shortages, high pumping costs, or implementation of policies that provide incentives to do so.

Table 5-3. Acreage of Crops Converted to Sorghum for Substantially Expanded Conservation Activities

County	Corn for Grain (acres) [1]	Forage Crops including Alfalfa and Pasture Grass (acres) [1]
Beckham	387	1,261
Kiowa	387	840
Jackson	387	2,101
Washita	472	855

[1] Acreage represents the entire county, not just the portion in Basin 34.

Scenario II conservation in the Municipal and Industrial demand sector would expand on the conservation measures implemented in Scenario I and would require the implementation of a high efficiency plumbing code ordinance.

Scenario II Municipal and Industrial conservation measures decrease the projected 2060 Municipal and Industrial demand from 5,040 AFY to 4,080 AFY and Crop Irrigation demand decreases from 8,330 AFY to 6,570 AFY. The combined demand reduction in both sectors may reduce the total associated 2060 demand by 2,720 AFY and reduce the size of the annual 2060 surface water gaps by 48 percent to a value of 1, 300 AFY and alluvial groundwater storage depletions by 72 percent to a value of 130 AFY. Reductions are expected to decrease the probability of gaps; however, the probability will remain moderately high due to the high frequency of low to no flow months.

Scenario II conservation measures would require substantial changes in the agricultural economy throughout the basins. Therefore, this water conservation measure would likely take a relatively long period of time to implement. However, shifting crop types could aid individual irrigators in the short term.

5.2.2 Out-of-Basin Supplies

The City of Elk City is the largest Municipal and Industrial demand in the basin and currently obtains out-of-basin water supplies from the North Fork of the Red River aquifer in Basin 37. Increased use of this supply could be a short- to long- term water supply option for the city in the future. However, storage depletions from local demand may occur in Basin 37 by 2020 and adversely affect well yields, water quality, and/or pumping costs.

Implementation of new out-of-basin supplies would be among the most costly of options, but could eliminate the potential for alluvial groundwater depletions and surface water gaps. The development of new out-of-basin supplies should be considered as a long-term water supply option for users throughout the basin. However, due to the scale and complexity of developing new out-of-basin supplies, the cost-effectiveness of these supplies should be evaluated against other options on a local level.

The OCWP *Reservoir Viability Study* identified one potential out-of-basin reservoir site in the Southwest Watershed Planning Region. The Mangum Reservoir (Lower Mangum Damsite) Category 4 site, located about 16 miles from the center of Basin 34 in Basin 39, would provide a dependable yield of 18,494 AFY from a 47,043 AF of storage. With new terminal storage of about 1,800 AF, a 14-inch diameter pipe would be needed to bring out-of-basin supplies at a constant flow rate into Basin 34 for further distribution to users. With no terminal storage and variable flows in the pipeline, a 30-inch diameter pipeline would be needed. The site would provide much more water than needed for Basin 34 alone, thus might be a possible consideration for a regional-type water supply source.

Regionalization of public water supply systems may provide an avenue for long-term implementation of major out-of-basin supplies. For purposes of this report, regionalization is defined as the shared development of and use of water supplies and the required diversion, conveyance, storage, and treatment infrastructure between two or more public water supply systems. Sharing of infrastructure, particularly for projects involving long transmission pipelines, can reduce the costs for each participant due to economies of scale. For example, conveyance of 50 million gallons per day of water could be accomplished through three individual pipelines: a 12-inch diameter pipeline, a 15-inch diameter pipeline, and a 42-inch diameter pipeline. That same flow could be conveyed through a single 48-inch diameter pipeline at roughly two-thirds the cost per mile of pipe. However, regionalization does not always reduce overall project costs and may not make economic sense depending on local and project-specific conditions. In particular, the closer two providers' distribution systems are, the more cost-effective a shared project will be.

Operational efficiencies are possible with regionalization in areas such as:

- Overnight and emergency plant staffing
- Maintenance equipment and staff
- Monitoring and reporting
- Water quality sampling and lab analyses/lab facilities
- Permitting and reporting
- Administration

At the same time, potential issues in sharing of supplies and infrastructure can bring challenges such as:

- Autonomy in decision-making and control:
  — Source of supply and capital cost decisions
  — Operational decisions (e.g., rates, drought restrictions)
- Institutional framework (new water supply district/authority vs. wholesale relationship)
- Differing needs (unequal rates of growth, condition of existing infrastructure, etc.)
- Water quality compatibility between sources
- Capital costs of interconnecting systems
- Funding/financing capabilities and methods

Throughout the Southwest Watershed Planning Region, there are already numerous examples of inter-provider arrangements to share water supplies on a wholesale basis, as documented in the OCWP *Southwest Watershed Planning Report*. Often, regionalization projects are initiated by or involve larger providers in the area, for example Quartz Mountain Rural Water District sells water to Lone Wolf and others. Opportunities for regional supply between larger and smaller providers, particularly those whose service areas are adjacent and for major out of basin supply projects, could be considered as a means of addressing the significant supply challenges facing the water users in Basin 34.

The OCWP *Water Conveyance Study* updated information from the 1980 OCWP statewide water conveyance system and one southwest conveyance alternative that encompasses Basin 34. The conveyance systems require additional reservoirs; hundreds of miles of piping, canals, and inverted siphons; and many pumping plants. Study results determined that this option would not be feasible under current technology and economic constraints, but may be considered as a long-term opportunity for the future.

5.2.3 Reservoir Use

If permittable, the basin's entire growth in demand from 2010 to 2060 could be supplied by a new river diversion and 4,100 AF of reservoir storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the amount of storage necessary to mitigate future gaps and storage depletions. Since surface water in the basin is fully permitted, the potential for existing water rights to supply additional storage would need to be analyzed.

There are currently 35 existing NRCS reservoirs in Basin 34, which are found on streams throughout the basin. These small reservoirs were typically built for flood control and to provide relatively minor agricultural supplies, but could be evaluated to determine the potential for rehabilitation and/or reallocation of storage to meet the needs of any demand sector. The water supply yields, available storage, and water quality of these reservoirs are unknown. However, due to the volume of storage in the basin, shown in Table 5-4, further investigation of these water supplies may be merited.

Table 5-4. Summary of NRCS Reservoirs in Basin 34

Normal Pool Storage Category	Number of Reservoirs	Total Normal Pool Volume in Category (AF)
<50 AF	14	530
>50 AF	21	3,408
Largest Reservoir (AF)		964

The OCWP *Reservoir Viability Study* identified Port Reservoir as a potential Category 3 reservoir site in Basin 34. This reservoir is expected to provide 9,000 AFY of dependable yield with a total conservation storage of 115,700 AF. This water supply yield is greater than the amount required by Basin 34; therefore, the new reservoir may be able to provide out-of-basin supplies for nearby basins or serve as a regional supply. However, since the basin has been fully allocated, substantial permit issues would have to be resolved to construct larger reservoirs.

5.2.4 Increasing Reliance on Surface Water

Surface water in the basin is fully allocated, limiting diversions to existing permitted amounts. There is a moderate probability of surface water gaps starting in 2020 for the baseline demand projections. Increasing reliance on surface water supplies, which have relatively poor water quality, would increase the size and probability of gaps. Therefore, increasing reliance on surface water without reservoir storage is not recommended.

5.2.5 Increasing Reliance on Groundwater

Alluvial groundwater supplies are used to meet about 20 percent of the total demand, and bedrock groundwater is used to meet about 30 percent of the total demand, largely for the Crop Irrigation and Oil and Gas demand sectors. The North Fork of the Red River alluvial aquifer underlies the basin in the south (about 16 percent of the overall basin area) and the Elk City bedrock aquifer underlies the basin in the north (about 17 percent of the overall basin area). Due to the hydraulic interconnectivity between alluvial groundwater and surface water, a shift from surface water to alluvial groundwater is not expected to substantially change the maximum storage depletions or surface water gaps in the basin. Increased reliance of the Elk City bedrock aquifer, with new infrastructure, could provide short- to long-term supplies instead of increasing surface water and alluvial groundwater use, but may cause storage depletions. The resulting storage depletions of up to 710 AFY are minimal relative to the amount of storage (over one million AF) in Basin 34's portion of the Elk City aquifer.

5.2.6 Marginal Quality Water

The OCWP *Marginal Quality Water Issues and Recommendations* report identified areas where there is potential for use of marginal quality water to offset a significant amount of future demand. However, Basin 34 was not found to have significant marginal quality sources or significant potential to offset demand with marginal quality water.

5.3 Summary

Six categories of supply options for mitigating the projected surface water gaps and groundwater storage depletions in Basin 34 are summarized in Table 5-5. Four options were potential short- or long-term options—demand management, out-of-basin supplies, increasing reliance on groundwater, and reservoir use.

Table 5-5 Summary of Water Supply Options for Basin 34

Water Supply Option	Option	Feasibility
Demand Management	• Moderately expanded Municipal and Industrial conservation and increase Crop Irrigation efficiency • Substantially expanded Municipal and Industrial and shift to crops with lower water demand	• Short- to long-term solution that may reduce about 50 percent of surface water gaps and 60 percent of alluvial groundwater storage depletions
Out-of-Basin Supplies	• Statewide water conveyance	• Potential long-term solution
Reservoir Use	• Development of new reservoirs and/or reallocation of storage	• Potentially long-term solution; additional analyses required
Increasing Reliance on Surface Water	• Increasing reliance on surface water supplies without reservoir storage	• Not feasible
Increasing Reliance on Groundwater	• Increasing reliance on Elk City bedrock aquifer instead of increased surface water or alluvial groundwater use • Increasing reliance on North Fork of the Red River alluvial aquifer instead of increased surface water use	• Elk City bedrock aquifer could be a short- to long-term solution
Marginal Quality Water	• Use marginal quality water	• No significant sources were identified

Section 6
Basin 36 (Upper North Fork Red River - 1)

Basin 36, located in the Southwest Watershed Planning Region, is an alluvial groundwater hot spot, where storage depletions are expected to provide water supply challenges based on the overall size of the depletions and for the rate of storage depletions relative to the amount of groundwater storage in the North Fork of the Red River aquifer. More detailed information on this basin is available in the OCWP *Southwest Watershed Planning Region Report*. In addition to alluvial groundwater storage depletions, surface water in Basin 36 is fully allocated and surface water surface water gaps may occur by 2050. This section describes the driving factors for this basin being identified as a hot spot, provides an analysis of how to address supply availability issues, and evaluates identified alternatives.

6.1 Basin Description

Basin 36 encompasses portions of Beckham, Washita, Greer, and Kiowa counties. The Southwest Watershed Planning Region is in the Southern Great Plains and has mild winters and long, hot summers. The terrain includes large farming areas along with rolling river bottoms, and the Wichita Mountains to near the outlet of the basin. The region's climate is mild with annual mean temperatures varying from 59°F to 64°F. Annual evaporation within the region ranges from 62 to 65 inches per year. Rainfall averages 29 inches per year.

6.1.1 Surface Water Supplies

Surface water was used to meet approximately 1 percent of the total demand in Basin 36 in 2010. There are no public water providers currently using surface water supplies in this basin. The North Fork of the Red River is the largest surface water supply source in Basin 36. Lugert-Altus Reservoir, which is located at the basin outlet, provides 47,100 AFY of dependable yield to the Lugert-Altus Irrigation District and public water providers. The median flow released from Lugert-Altus Reservoir to the river is less than 50 AF/month, as shown in Figure 6-1, except in May and June when the median flow is about 2,500 AF/ month. The Lugert-Altus Reservoir is not expected to provide additional supplies to new irrigators in the future. Surface water in Basin 36 is fully allocated, leaving no surface water available for new permits.

Relative to other basins in the state, the surface water quality in Basin 36 is considered fair. Water quality in the Southwest Watershed Planning Region varies considerably. Natural elevated levels of salinity in this region produce agricultural and public private water supply impacts, particularly in the North Fork of the Red River and its tributaries. The North Fork of the Red River and Otter Creek are impaired for Agricultural use by TDS and chlorides.

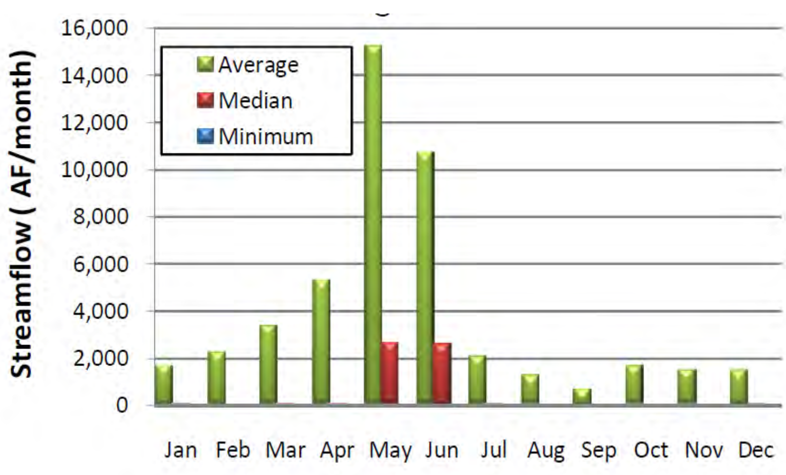

Figure 6-1. Monthly Streamflow Statistics over the Study Period of Record

6.1.2 Groundwater Supplies

Alluvial groundwater was used to supply about 99 percent of total demand in Basin 36 in 2010. **Figure 6-2** illustrates the aquifers and existing groundwater permits in Basin 36. All of the current groundwater rights in the basin are in the North Fork of the Red River major alluvial aquifer, which covers approximately 60 percent of the basin. There is approximately 675,000 AF of groundwater stored in Basin 36's portion of the aquifer. Up to 1.0 AFY/acre of dedicated lands overlying the aquifer may be withdrawn through regular permits. There are an estimated 53,700 AFY of remaining groundwater rights in this basin, which is not expected to be limited by the availability of new permits for local demand through 2060. There are no significant groundwater quality issues in the basin.

There is currently no bedrock groundwater use in Basin 36; therefore, no future demand is expected.

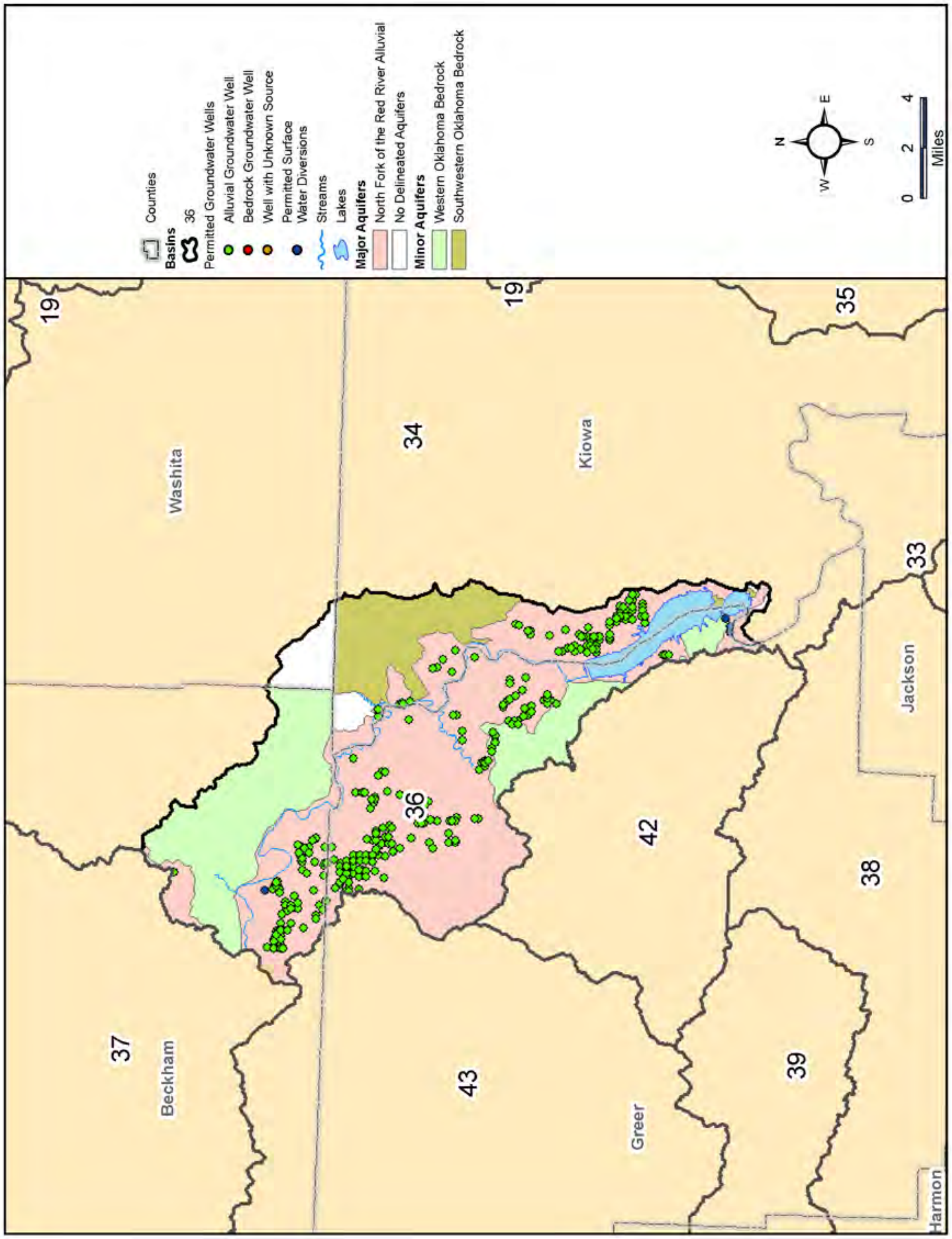

Figure 6-2. Groundwater Supplies in Basin 36

6.1.3 Water Demand

From the OCWP *Water Demand Forecast Report*, the total demand for this basin in 2060 is projected to be 6,600 AFY, which is about 2 percent of the Southwest Watershed Planning Region's water needs. The projected increase in total demand represents an increase of 75 percent from 2010 to 2060.The projected total demand in Basin 36 is presented in **Figure 6-3.** The majority of the demand and growth in demand over this period will be in the Crop Irrigation demand sector. Crop Irrigation occurs throughout the basins over the North Fork of the Red River aquifer, as shown in **Figure 6-4.** There is also locally significant Municipal and Industrial demand.

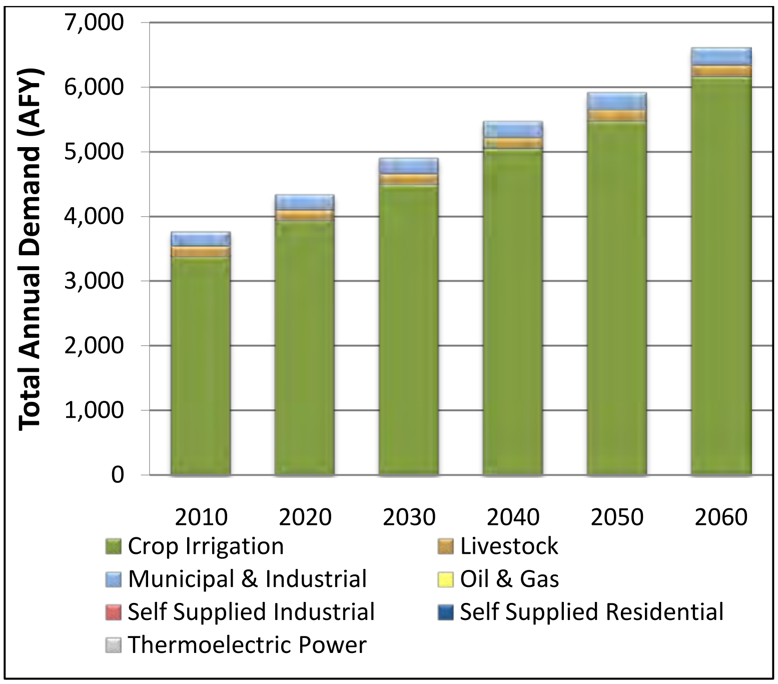

Figure 6-3. Total Demand by Sector in Basin 36

Alluvial groundwater was used to supply about 99 percent of total demand in Basin 36 in 2010. Alluvial groundwater use is projected to increase by 75 percent (2,810 AFY) from 2010 to 2060. The majority of water use and growth in alluvial groundwater use over this period will be in the Crop Irrigation demand sector. As a result, the peak summer month demand is about 32 times the winter demand. There is expected to be significant water supply challenges for users of the North Fork of the Red River aquifer.

Surface water was used to supply about 1 percent of total demand in Basin 36 in 2010. Surface water use is projected to increase by 72 percent (20 AFY) from 2010 to 2060. The majority of surface water use and growth in surface water use over this period will be in the Crop Irrigation demand sector.

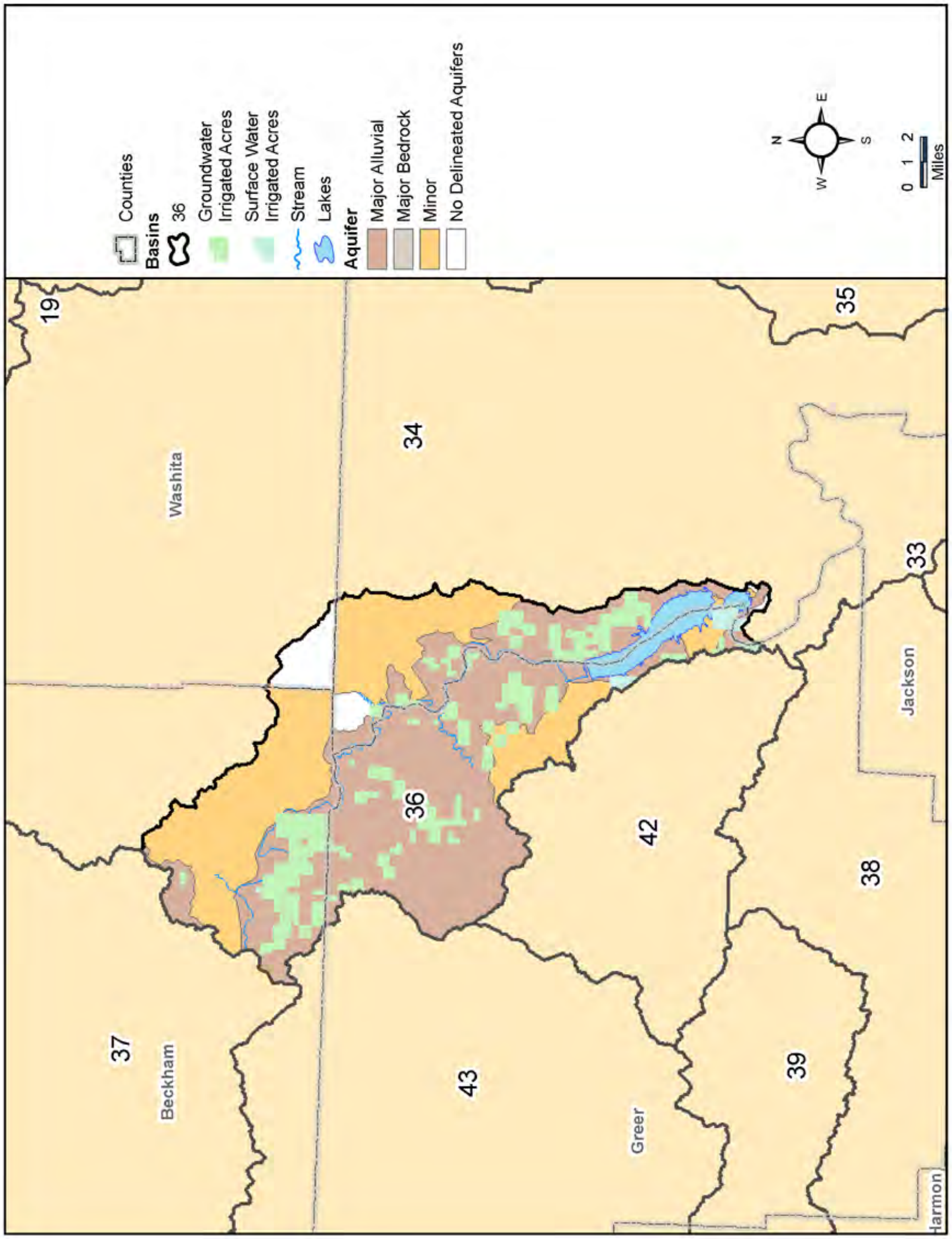

Figure 6-4. Distribution of Irrigated Land in Basin 36

6.1.4 Gaps and Depletions

Based on projected demand and historical hydrology, alluvial groundwater depletions may occur by 2020, while surface water gaps may occur by 2050. Bedrock groundwater storage depletions were not evaluated, since no demand is expected.

Alluvial groundwater storage depletions are expected to occur in at least one month of each year (100 percent probability). Alluvial groundwater storage depletions in Basin 36 may occur during the spring, summer, and fall; peaking in size during the summer. Alluvial groundwater storage depletions in 2060 will be up to 40 percent (1,000 AF/month) of the alluvial groundwater demand in the peak summer month, and as much as 38 percent (60 AF/month) of the spring months' alluvial groundwater demand.

Projected annual alluvial groundwater storage depletions are minimal relative to volume of water stored in the major aquifers underlying the basin. However, localized storage depletions may occur and adversely affect users' yields, water quality, and pumping costs. A detailed analysis of alluvial groundwater recharge may result in decreased storage depletions, due to the potential reduction of streamflow (used for estimating recharge) at the basin outlet from the yield of the Lugert-Altus Reservoir.

Surface water gaps will have a 97 percent probability of occurring in at least one month of each almost every summer and surface water gaps in 2060 will be up to 50 percent (10 AF/month) of the surface water demand in the peak summer month.

6.2 Analysis of Supply Options

Six categories of supply options for mitigating the projected surface water gaps and groundwater storage depletions in Basin 36 are described in the text below. The six water supply options represent the basic ways to develop additional water supplies for all users in the basin. All options should be reviewed, as a combination of supply options will likely be needed to meet the basin’s water supply challenges.

6.2.1 Demand Management

The demand management option considers permanent conservation measures and temporary drought restrictions. Moderately expanded and substantially expanded conservation measures were evaluated for both the Municipal and Industrial and Crop Irrigation demand sectors. The conservation scenarios are described briefly in Table 6-1, but the OCWP *Water Demand Forecast Report* provides full descriptions of the conservation measures considered. It is recommended that the basin consider additional permanent conservation activities, instead of temporary drought management activities. Due to the very high probability gaps and since aquifer storage could continue to provide supplies during droughts, the temporary drought management water supply option was not evaluated.

Table 6-1. Summary of OCWP Conservation Scenarios (Source: OCWP *Water Demand Forecast Report*)

Demand Sector	Conservation Scenario	Description
Municipal and Industrial	Scenario I Moderately Expanded Conservation	• Passive conservation achieved by 2060 for PSR and 2030 for PSNR. Passive conservation is defined as conservation that can be achieved through government plumbing codes as part of the Energy Policy Act. • 90 percent of water providers in each county will meter their customers, unless current metered percentage is greater than 90 percent. • NRW will be reduced to 12 percent, where applicable • Conservation pricing will be implemented by 20 percent of purveyors in rural counties, 40 percent in mostly urban counties, and 60 percent in counties with high metropolitan populations. • Water conservation educational programs will be implemented by all providers, which include billing inserts and conservation tip websites to reduce demands by 3 percent.
	Scenario II Substantially Expanded Conservation	• Passive conservation (as described in Scenario I). • All purveyors will meter their customers. • NRW will be reduced to 10 percent where applicable. • Conservation pricing will be implemented by 60 percent of purveyors in rural counties, 80 percent in mostly urban counties, and 100 percent in counties with high metro populations. • Water conservation education programs will be implemented to reduce demands by 5 percent including school education programs and media campaigns in addition to billing inserts and a conservation tip website. • High efficiency plumbing code ordinance will be implemented. This ordinance requires use of high efficiency fixtures with lower maximum flow rates than those required under the Energy Policy Act.
Agricultural Irrigation	Scenario I Moderately Expanded Conservation	• The field application efficiency of surface irrigation systems for Harmon, Jackson, Tillman, and Kiowa counties will increase to 80 percent beginning in 2015 (all of Basins 40 and 41, portions of Basins 34, 36, 38, and 42) . • In Harmon, Jackson, Tillman, and Kiowa counties, 10 percent of the land irrigated by surface irrigation will shift to micro-irrigation beginning in 2015. (All of Basins 40 and 41, portions of Basins 34, 36, 38, and 42) • All sprinkler systems will have a field application efficiency of 90 percent beginning in 2015, representing implementation of LEPA nozzles on existing sprinkler systems. • Water saved through conservation activities is not applied to a water scheme elsewhere, such as expanding the number of irrigated acres, thus achieving true conservation.
	Scenario II Substantially Expanded Conservation	• All assumptions from Scenario I are applicable. • All acres of water intensive crops (corn for grain and forage crops, including alfalfa and pasture grass), shift to less water intensive crops (grain for sorghum) beginning in 2015. While is it highly unlikely that all water intensive crop production will stop, this assumption allows for analysis of full implementation of the "what-if" scenario.

Scenario I Conservation Measures

Implementing Scenario I Municipal and Industrial conservation measures decreases the projected 2060 demand in Basin 36 from 270 AFY to 230 AFY. Implementing Scenario I Crop Irrigation conservation measures decreases the projected 2060 demand in Basin 36 from 6,160 AFY to 5,760 AFY. Implementing conservation in both sectors is not expected to reduce the 2060 surface water gap. Implementing conservation in both sectors could reduce the 2060 alluvial groundwater storage depletions by 380 AFY, reducing the size of the 2060 alluvial groundwater storage depletions 15 percent to a value of 2,180 AFY. Under Scenario I conservation activities, the probability of surface water gaps and storage depletions remains unchanged due to high frequency of low to no-flow months. **Table 6-2** lists the irrigated acreage affected by Scenario I conservation measures in counties encompassing Basin 36. In Kiowa County, Scenario I conservation measures would also include increasing the efficiency of surface irrigation systems to 80 percent and shifting 10 percent of the land irrigated by surface irrigation to micro-irrigation.

Table 6-2. Acreage of Irrigated Lands with Increased Irrigation Efficiency under Scenario I Conservation

County	Irrigated Land (thousand acres) [1]
Beckham	7
Greer	3
Kiowa	3
Washita	7

[1] Acreage represents the irrigated land in the entire county for 2007, not just the portion in Basin 36.

Scenario II Conservation Measures

Substantially expanded conservation measures (Scenario II) for the Crop Irrigation demand sector would require crop shifts throughout the basin, switching from water intensive crops (e.g., corn for grain, pasture grasses, etc.) to sorghum for grain and wheat for grain, as well as the increase in irrigation efficiencies from Scenario I. The substantially expanded conservation measures include conversion of 5,442 acres from corn for grain and forage crops to sorghum in the counties located in and around the basin, as indicated in **Table 6-3**. The OCWP *Water Demand Forecast Report* recognizes that crop shifting is unlikely to occur unless crop managers are faced with severe water shortages, high pumping costs, or implementation of policies that provide incentives to do so.

Table 6-3. Acreage of Crops Converted to Sorghum for Substantially Expanded Conservation Activities

County	Corn for Grain (acres) [1]	Forage Crops including Alfalfa and Pasture Grass (acres) [1]
Beckham	387	1,261
Greer	387	853
Kiowa	387	840
Washita	472	855

[1] Acreage represents the entire county, not just the portion in Basin 36.

Scenario II conservation in the Municipal and Industrial demand sector would expand on the conservation measures implemented in Scenario I and require the implementation of a high efficiency plumbing code ordinance. Table 6-1 provides additional information on Scenario II conservation measures.

Scenario II Municipal and Industrial conservation measures decrease the projected 2060 Municipal and Industrial demand from 6,160 AFY to 4,900 AFY and Crop Irrigation demand decreases from 270 AFY to 210 AFY. Scenario II substantially expanded irrigation and Municipal and Industrial conservation measures could reduce the total 2060 demand by 1,320 AFY. The combined demand reduction in both sectors may eliminate 2060 surface water gaps and decrease 2060 alluvial groundwater storage depletions by about 47 percent to a value of 1,360 AFY. Reductions are not expected to decrease the probability of alluvial groundwater storage depletions.

Scenario II conservation measures would require substantial changes in the agricultural economy throughout the basin. Therefore, this water conservation measure would likely take a relatively long period of time to implement. However, shifting crop types could aid individual irrigators in the short-term.

6.2.2 Out-of-Basin Supplies

Out-of-basin supplies would be among the most costly of options, but could eliminate the potential for alluvial groundwater depletions and surface water gaps. The development of out-of-basin supplies should be considered as a long-term water supply option for users throughout the basin. However, due to the scale and complexity of developing out-of-basin supplies, the cost-effectiveness of these supplies should be evaluated against other options on a local level.

The OCWP *Reservoir Viability Study* identified two potential Category 3 or 4 sites in the OCWP Southwest Watershed Planning Region: Port Reservoir (Category 3) in Basin 34 and the Lower Mangum site (Category 4) in Basin 39. The Mangum Reservoir site was recognized as the nearest most viable site, located about 16 miles from the center of Basin 36. The potential site could provide a dependable yield of about 18,494 AFY from 47,043 AF of total storage. With new terminal storage of about 1,800 AF, a 14-inch diameter pipe would be needed to bring out-of-basin supplies at a constant flow rate into Basin 36 for further distribution to users. With no terminal storage and variable flows in the pipeline, a 30-inch diameter pipeline would be needed. The estimated reservoir yield in Mangum is much greater than what is needed to supply Basin 36, thus the site might be considered for a regional water supply project.

Regionalization of public water supply systems may provide an avenue for long-term implementation of major out-of-basin supplies. For purposes of this report, regionalization is defined as the shared development of and use of water supplies and the required diversion, conveyance, storage, and treatment infrastructure between two or more public water supply systems. Sharing of infrastructure, particularly for projects involving long transmission pipelines, can reduce the costs for each participant due to economies of scale. For example, conveyance of 50 million gallons per day of water could be accomplished through three individual pipelines: a 12-inch diameter pipeline, a 15-inch diameter pipeline, and a 42-inch diameter pipeline. That same flow could be conveyed through a single 48-inch diameter pipeline at roughly two-thirds the cost per mile of pipe. However, regionalization does not always reduce overall project costs and may not make economic sense depending on local and project-specific conditions. In particular, the closer two providers' distribution systems are, the more cost-effective a shared project will be.

Operational efficiencies are possible with regionalization in areas such as:

- Overnight and emergency plant staffing
- Maintenance equipment and staff
- Monitoring and reporting
- Water quality sampling and lab analyses/lab facilities
- Permitting and reporting
- Administration

At the same time, potential issues in sharing of supplies and infrastructure can bring challenges such as:

- Autonomy in decision-making and control:
  — Source of supply and capital cost decisions
  — Operational decisions (e.g., rates, drought restrictions)
- Institutional framework (new water supply district/authority vs. wholesale relationship)
- Differing needs (unequal rates of growth, condition of existing infrastructure, etc.)
- Water quality compatibility between sources
- Capital costs of interconnecting systems
- Funding/financing capabilities and methods

Throughout the Southwest Watershed Planning Region, there are already numerous examples of inter-provider arrangements to share water supplies on a wholesale basis, as documented in the OCWP *Southwest Watershed Planning Report*. Often, regionalization projects are initiated by or involve larger providers in the area, for example, Quartz Mountain Regional Water Authority. Opportunities for regional supply between larger and smaller providers, particularly those whose service areas are adjacent to another and for major out of basin supply projects, could be considered as a means of addressing the significant supply challenges facing the water users in Basin 36.

The OCWP *Water Conveyance Study* updated information from the 1980 OCWP statewide water conveyance system and one southwest conveyance alternative that encompasses Basin 36. The conveyance systems require additional reservoirs, hundreds of miles of piping, canals, and inverted siphons, and many pumping plants. Study results determined that this option would not be feasible under current technology and economic constraints, but may be considered as a long-term opportunity for the future.

6.2.3 Reservoir Use

Surface water in the basin is fully allocated, limiting diversions to existing permitted amounts. The Lugert-Altus Reservoir currently uses the majority of flow to supply dependable yield to its users and is not expected to provide additional supplies in the future unless supplemental water resources are found. New small reservoirs (less than 50 AF) could be developed under existing permits to mitigate surface water gaps and reduce the adverse effects of localized storage depletions. There are insufficient surface water supplies to meet the entire increase in demand from 2010 to 2060, and the construction of larger reservoirs would require that substantial permit issues be resolved. If permittable, a new river diversion and 200 AF of reservoir storage at the basin outlet could meet the increase in surface water demand; however, any new reservoirs could not impact the yield of Luger-Altus Reservoir. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the size of storage necessary to mitigate future gaps and storage depletions.

6.2.4 Increasing Reliance on Surface Water

Surface water in the basin is fully allocated, limiting diversions to existing permitted amounts. There is a very high probability of surface water gaps starting in 2050 for the baseline demand projections. Increasing reliance on surface water use, if permits could be issued, would increase the size and probability of these gaps. Therefore, this water supply option is not recommended.

6.2.5 Increasing Reliance on Groundwater

Alluvial groundwater storage depletions of up to 1,000 AF/month are expected to occur in the months of July and August of almost every summer by 2060. These storage depletions are small in size relative to the basin storage in the North Fork of the Red River alluvial aquifer, which underlies about 60 percent of the basin. Due to the relatively small projected growth in surface water use, new surface water users could instead be supplied by the North Fork of the Red River aquifer with minimal (10 AFY) increases in projected storage depletions. Due to the alluvial aquifer's connection to river flows and precipitation, aquifer levels may fluctuate naturally due to prolonged periods of drought or above-average precipitation. While increasing use of alluvial water would not substantially increase depletions water in storage, the effect of these storage depletions may be intensified during periods of drought and localized storage depletions may adversely affect users' yields, water quality, and pumping costs. Therefore, the development of additional alluvial groundwater supplies to meet the growth in surface water could be considered a long-term water supply option, but may require additional infrastructure and increased operation and maintenance costs for sustained reliability. Over a long-term period, demand management and other supply options may provide more consistent supplies and may be more cost-effective.

6.2.6 Marginal Quality Water

The OCWP *Marginal Quality Water Issues and Recommendations* report identified areas where there is potential for use of marginal quality water to offset a significant amount of future demand. Basin 36 was found to have significant brackish marginal quality groundwater sources that could be used to meet Crop Irrigation demand. These groundwater sources are typically deeper than fresh water aquifers and not associated with delineated aquifers. Crops that are among the most salinity-tolerant include barley and wheat. Brackish water supplies are those that have between 1,000 mg/L and 35,000 mg/L TDS. OWRB does not have regulatory authority to permit withdrawals of groundwater with TDS concentrations greater than 5,000 mg/L. The U.S. Geological Survey (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. Brackish groundwater underlies the entire basin and should be evaluated as a potential short- to long-term water supply option. However, these supplies will likely be less preferable than supplies from the lower-salinity North Fork of the Red River aquifer. Site-specific information on the suitability of the brackish groundwater sources for supply should be considered before large scale use.

6.3 Summary

Six categories of supply options for mitigating the projected surface water gaps and groundwater storage depletions in Basin 36 are summarized in **Table 6-4**. Five options were potential short or long-term options: demand management, marginal quality water sources, out-of-basin supplies, increasing reliance on groundwater and reservoir use.

Table 6-4. Summary of Water Supply Options for Basin 36

Water Supply Option	Option	Feasibility
Demand Management	• Moderately expanded Municipal and Industrial conservation measures and increased sprinkler irrigation efficiency • Significantly expanded Municipal and Industrial conservation measures and shift to crops with lower water demand	• Short- to long-term solution that could eliminate surface water gaps and reduce 2060 groundwater depletions by 15 percent to almost 50 percent
Out-of-Basin Supplies	• Mangum Reservoir or Statewide Water Conveyance	• Potential long-term solution
Reservoir Use	• Development of new reservoirs	• Potential long-term solution, but limited in reservoir size; additional analysis required
Increasing Reliance on Surface Water	• Increasing reliance on surface water supplies without reservoir storage	• Not feasible
Increasing Reliance on Groundwater	• Increasing reliance on North Fork of Red River aquifer	• Long-term solution with possible localized adverse impacts
Marginal Quality Water	• Use brackish groundwater sources for Crop Irrigation	• Potential long-term applicability for irrigation of certain crops

Section 7
Basin 38 (Salt Fork Red River - 1)

Basin 38, located in the Southwest Watershed Planning Region, is an alluvial groundwater and bedrock groundwater hot spot. The basin is mainly challenged by the rate of storage depletions in the Blaine and North Fork of the Red River aquifers. However, the overall size of storage depletions to these aquifers may also create significant water supply challenges. More detailed information on this basin is available in the OCWP *Southwest Watershed Planning Region Report*. In addition to alluvial groundwater storage depletions, surface water gaps and bedrock groundwater storage depletions may occur by 2060; however, surface water permit availability is not projected to limit surface water use through 2060. This section describes the driving factors for this basin being identified as a hot spot, provides an analysis of how to address supply availability issues, and evaluates identified alternatives.

7.1 Basin Description

Basin 38 encompasses portions of Harmon, Greer, and Jackson counties. The Southwest Watershed Planning Region is primarily located in the Osage Plains of the Great Lowlands, with the High Plains bordering to the west. The region's terrain includes vast farming areas along with rolling river bottoms. The region has a generally mild climate with mild winters and long, hot summers. Average monthly temperatures vary from 59°F to 64°F. Annual average precipitation is 29 inches. Annual evaporation ranges from 62 to 65 inches per year.

7.1.1 Surface Water Supplies

Surface water and out-of-basin supplies were used to meet 62 percent of the total demand in 2010. The largest surface water supply sources in the basin are the Salt Fork of the Red River and Turkey Creek. There are no major reservoirs in the basin. The median flow in the Salt Fork of the Red River near Elmer, Oklahoma is greater than 2,500 AF/month throughout the year and greater than 13,000 AF/month in May and June. Historically, periods of low to zero flow have occurred in the basin in each month of the year, as shown in Figure 7-1. Basin 38 will have available surface water for new permitting to meet local demand through 2060. In 2060, there is expected to be about 9,000 AFY of unpermitted streamflow. The estimated annual flow in 2060 is expected to be at least 14,800 and about 99,100 AFY on average. However, surface water gaps may occur during spring, summer, and fall; peaking in size in the summer.

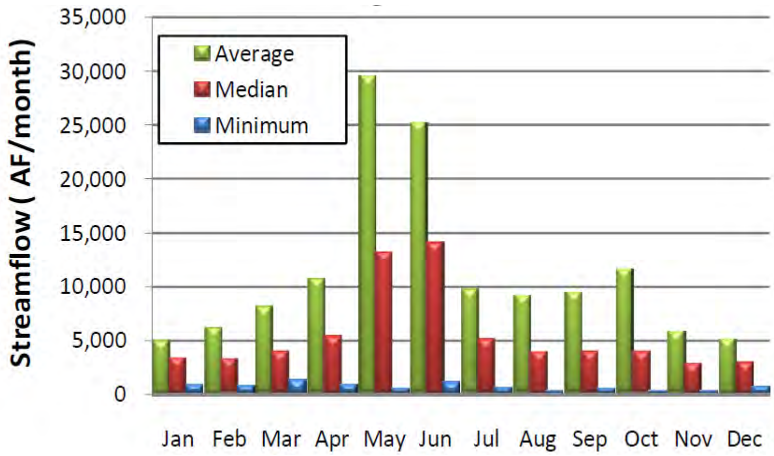

Figure 7-1. Monthly Streamflow Statistics over the Study Period of Record

Relative to other basins in the state, the surface water quality in Basin 38 is considered poor. Water quality of the Southwest Watershed Planning Region varies considerably. Natural elevated levels of salinity in this region produce agricultural and public private water supply impacts, particularly in the North Fork of the Red River and the Salt Fork of the Red River and their tributaries. The Salt Fork of the Red River is impaired for Public and Private Water Supply due to high levels of selenium. Turkey Creek and Bitter Creek are impaired for Agricultural use due to high levels of TDS, chloride, and sulfate. However, individual lakes and streams may have acceptable water quality.

7.1.2 Groundwater Supplies

Groundwater satisfies about 38 percent of the total demand in 2010. Figure 7-2 illustrates the aquifers and existing groundwater permits in Basin 38. The majority of groundwater rights in the basin are from the major Blaine bedrock aquifer. There are substantial water rights in non-delineated minor aquifers along the Salt Fork of the Red River and Turkey Creek. There are also water rights in the major North Fork of the Red River alluvial aquifer and non-delineated minor bedrock aquifers as well.

The Blaine bedrock aquifer underlies the western portion of Basin 38, or underlies 48 percent of the basin. Irrigation wells typically average 140 AFY/well; however, maximum well yields are 50 gpm or higher. Up to 2.0 AFY/acre of dedicated lands overlying the aquifer may be withdrawn through temporary permits. Note: temporary permitted withdrawals are subject to change when converted to regular permits. There are an estimated 279,200 AFY of remaining groundwater rights from this aquifer in this basin, which is not expected to be limited by the availability of new permits for local demand through 2060. The water quality is generally poor with high concentrations of TDS (generally between 2,000 – 6,000 mg/L), sulfate (1,000 – 2,000 mg/L) and other ions. Chloride content can be greater than 1,000 mg/L and is considered brackish.

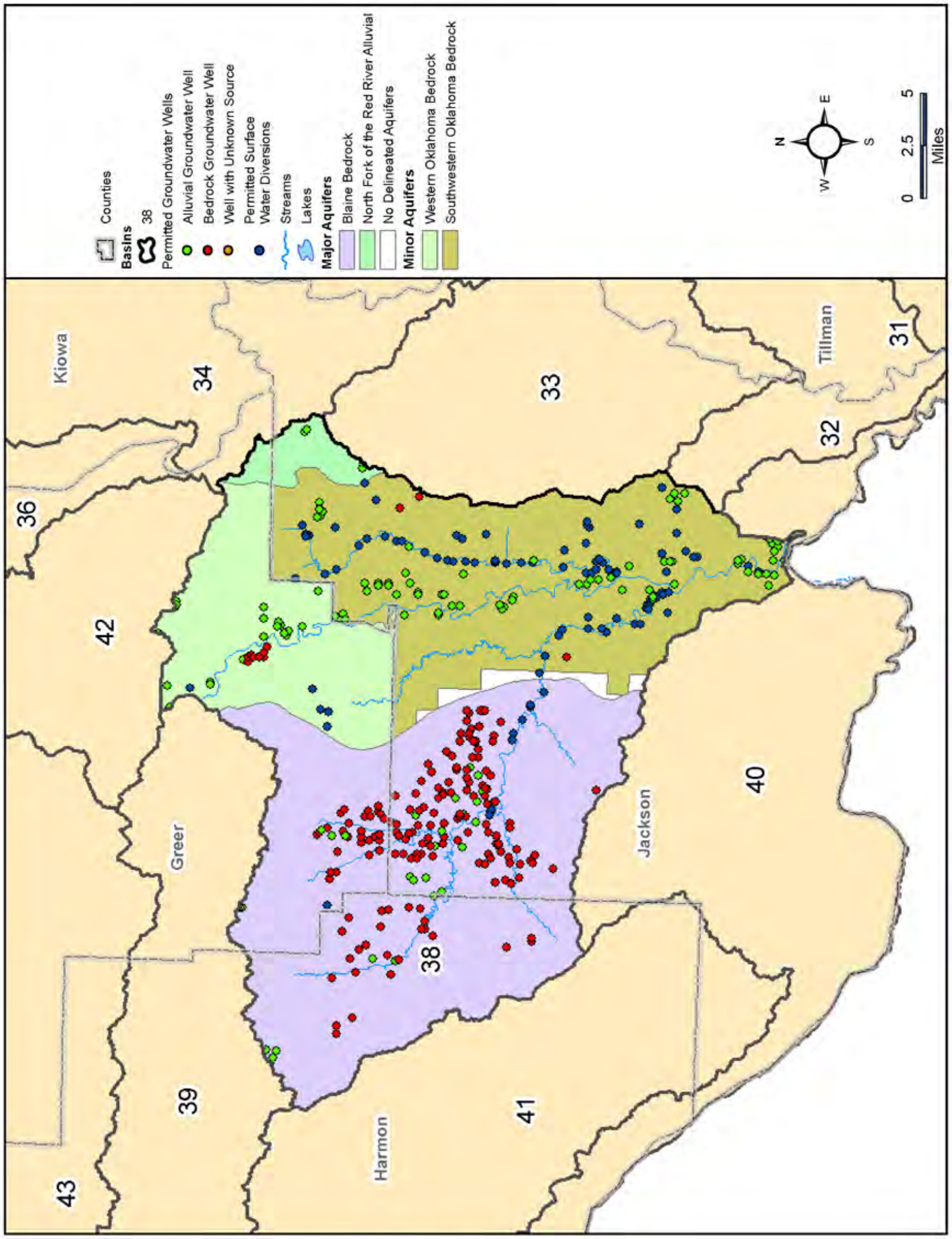

Figure 7-2. Groundwater Supplies in Basin 38

The North Fork of the Red River alluvial aquifer underlies about two percent of the northeastern portion of the basin. As only a small portion of the basin has access to the aquifer, there are only 300 AFY of groundwater rights. There are an estimated 6,000 AFY of remaining groundwater rights from this aquifer in this basin, which is not expected to be limited by the availability of new permits for local demand through 2060. Non-delineated minor aquifers along Turkey Creek have not been studied; therefore, no information on storage, yield, or recharge is available. Site-specific information on the suitability of these minor aquifers for supply should be considered before large-scale use.

There are no significant basin-wide groundwater quality issues in the basin. Water quality issues from high TDS concentrations are expected to limit the use of the Blaine aquifer to agriculture (Crop Irrigation and Livestock demand sectors).

7.1.3 Water Demand

From the OCWP *Water Demand Forecast Report*, the total demand for this basin in 2060 is 83,580 AFY or about 42 percent of the Southwest Watershed Planning Region's water needs. The total demand is expected to increase by 13 percent (9,930 AFY) from 2010 to 2060. The project total demand by sector in Basin 38 is presented in **Figure 7-3**.The majority of the demand and growth in demand over this period will be in the Crop Irrigation demand sector. As a result of the crop irrigation demand, the peak summer month demand in Basin 38 is about 146 times the winter demand, which is much more pronounced than the overall statewide pattern. Crop Irrigation occurs throughout the basin, as shown in **Figure 7-4**.

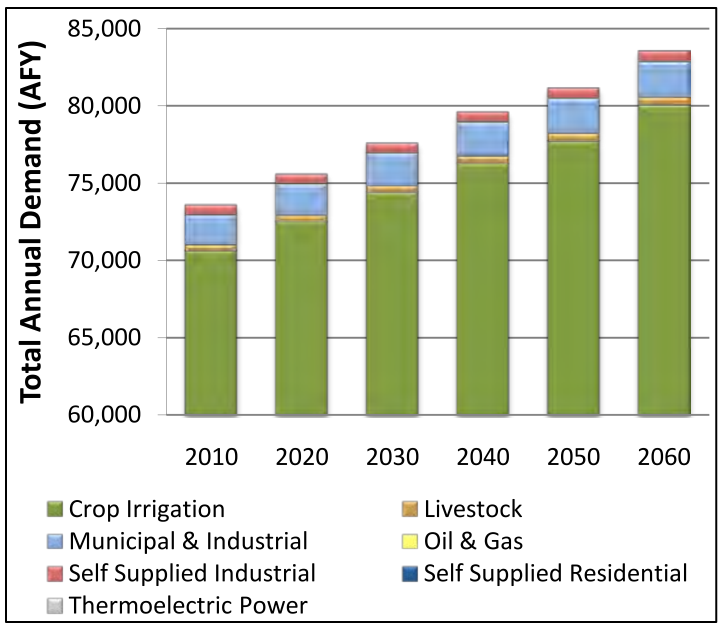

Figure 7-3. Total Demand by Sector in Basin 38

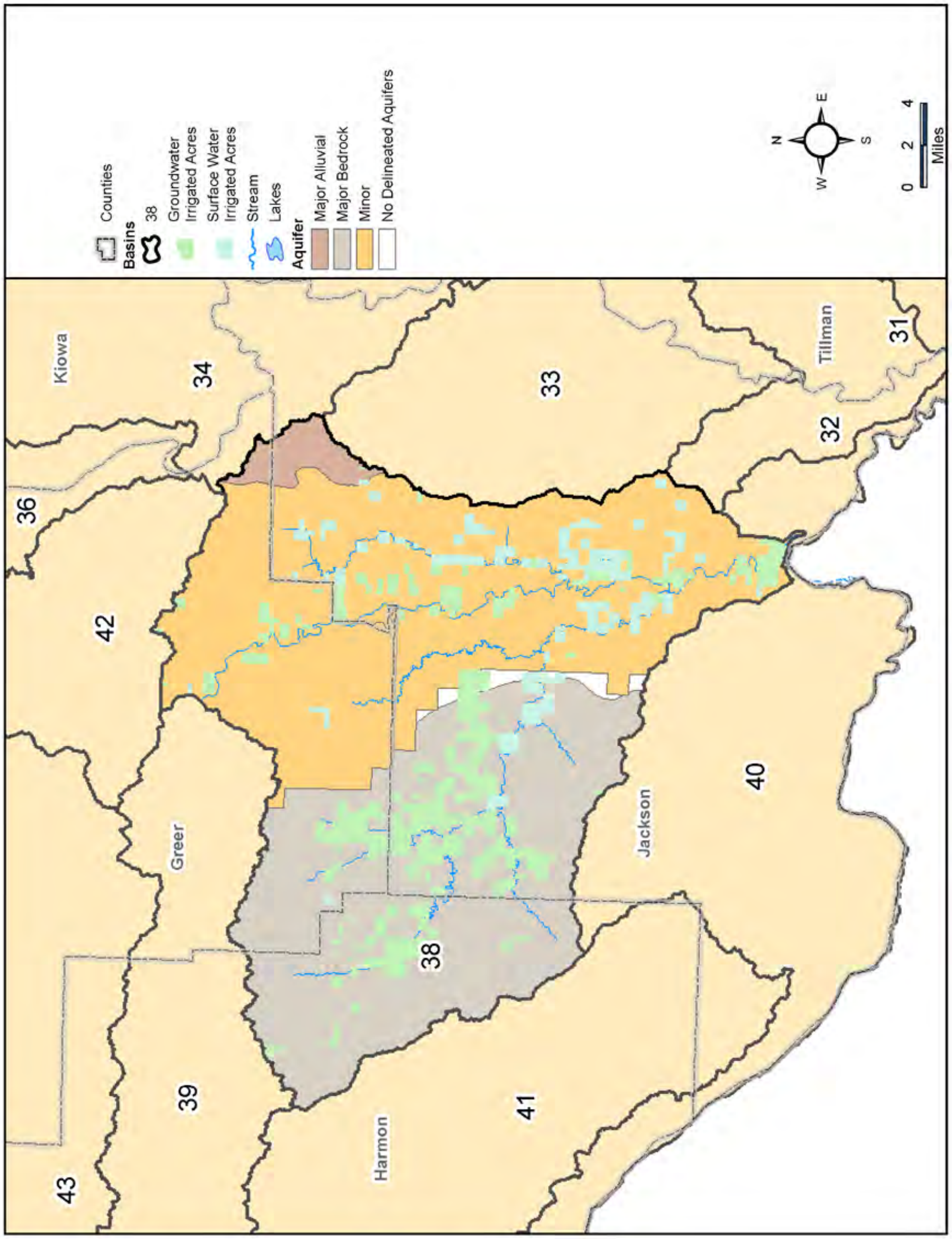

Figure 7-4. Distribution of Irrigated Land in Basin 38

Surface water and out-of-basin supplies are used to meet 62 percent of the current total demand and its use will increase by 14 percent (6,190 AF/month) from 2010 to 2060. The majority of surface water use represents out-of-basin supplies from the Lugert-Altus Irrigation District. However, the Lugert-Altus Irrigation District is not expected to provide supplies to new irrigators in the future. Therefore, new irrigators were assumed to obtain supplies from in-basin surface water sources.

Alluvial groundwater is used to meet 13 percent of current total demand and its use will increase by 13 percent (1,290 AF/month) between 2010 and 2060. The majority of alluvial groundwater use and growth in alluvial groundwater use over this period will be in the Crop Irrigation demand sector. There is expected to be significant water supply challenges for users of the North Fork of the Red River aquifer and non-delineated aquifers along Salt Fork of the Red River and Turkey Creek.

Bedrock groundwater is used to meet 25 percent of current total demand and its use will increase by 13 percent (2,450 AF/month) between 2010 and 2060. The majority of bedrock groundwater use and growth in bedrock groundwater use over this period will be in the Crop Irrigation demand sector. There is expected to be significant water supply challenges for users of the Blaine aquifer.

7.1.4 Gaps and Depletions

Based on projected demand and historical hydrology, surface water gaps and groundwater storage depletions may occur by 2020. Surface water gaps in Basin 38 may occur during spring, summer, and fall; peaking in size in the summer. Surface water gaps in 2060 will be up to 11 percent (2,450 AF/month) of the surface water demand in the peak summer month, and as much as 7 percent (50 AF/month) of the spring months' surface water demand. There will be a 53 percent probability of gaps occurring in at least one month of the year by 2060. Surface water gaps are most likely to occur during summer months.

Alluvial groundwater storage depletions in Basin 38 may occur during spring, summer, and fall; peaking in size in the summer. Alluvial groundwater storage depletions in 2060 will be up to about 10 percent (520 AF/month) of the alluvial groundwater demand in the peak summer month, and as much as 8 percent (10 AF/month) of the spring months' alluvial groundwater demand. There will be a 53 percent probability of storage depletions occurring in at least one month of the year by 2060. Alluvial groundwater storage depletions are most likely to occur during summer months. Current alluvial withdrawals are largely from non-delineated minor aquifers. Therefore, the severity of the storage depletions cannot be evaluated. However, localized groundwater storage depletions may occur and have adverse effects on water yield, water level, and water quality.

Bedrock groundwater storage depletions in Basin 38 may occur in the summer and fall; peaking in size in the summer. Bedrock groundwater storage depletions in 2060 will be up to 12 percent of the monthly bedrock groundwater demand and will be up to 1,100 AF/month on average in summer months and up to 500 AF/month on average in fall months. Projected annual bedrock storage depletions are minimal relative to the volume of water stored in Basin 38's portion of the Blaine aquifer. However, localized storage depletions may adversely impact users' yields, water quality, or pumping costs.

7.2 Analysis of Supply Options

Six categories of supply options for mitigating the projected surface water gaps and groundwater storage depletions in Basin 38 are described in the text below.

7.2.1 Demand Management

The demand management option considers permanent conservation measures and temporary drought restrictions. Moderately expanded and substantially expanded conservation measures were evaluated for both the Municipal and Industrial and Crop Irrigation demand sectors. The conservation scenarios are described briefly in **Table 7-1**, but the OCWP *Water Demand Forecast Report* provides full descriptions of the conservation measures considered. It is recommended that the basin consider additional permanent conservation activities, instead of temporary drought management activities. Due to the high probability of gaps and since aquifer storage could continue to provide supplies during droughts, the temporary drought management water supply option was not evaluated.

Table 7-1. Summary of OCWP Conservation Scenarios (Source: OCWP *Water Demand Forecast Report*)

Demand Sector	Conservation Scenario	Description
Municipal & Industrial	Scenario I Moderately Expanded Conservation	• Passive conservation achieved by 2060 for PSR and 2030 for PSNR. Passive conservation is defined as conservation that can be achieved through government plumbing codes as part of the Energy Policy Act. • 90 percent of water providers in each county will meter their customers, unless current metered percentage is greater than 90 percent. • NRW will be reduced to 12 percent, where applicable • Conservation pricing will be implemented by 20 percent of purveyors in rural counties, 40 percent in mostly urban counties, and 60 percent in counties with high metropolitan populations. • Water conservation educational programs will be implemented by all providers, which include billing inserts and conservation tip websites to reduce demands by 3 percent.
	Scenario II Substantially Expanded Conservation	• Passive conservation (as described in Scenario I) • All purveyors will meter their customers. • NRW will be reduced to 10 percent where applicable. • Conservation pricing will be implemented by 60 percent of purveyors in rural counties, 80 percent in mostly urban counties, and 100 percent in counties with high metro populations. • Water conservation education programs will be implemented to reduce demands by 5 percent including school education programs and media campaigns in addition to billing inserts and a conservation tip website. • High efficiency plumbing code ordinance will be implemented. This ordinance requires use of high efficiency fixtures with lower maximum flow rates than those required under the Energy Policy Act.

Table 7-1. Summary of OCWP Conservation Scenarios (Source: OCWP *Water Demand Forecast Report*) (cont.)

Demand Sector	Conservation Scenario	Description
Agricultural Irrigation	Scenario I Moderately Expanded Conservation	• The field application efficiency of surface irrigation systems for Harmon, Jackson, Tillman, and Kiowa counties will increase to 80 percent beginning in 2015 (All of Basins 40 and 41, portions of Basins 34, 36, 38, and 42) . • In Harmon, Jackson, Tillman, and Kiowa counties, 10 percent of the land irrigated by surface irrigation will shift to micro-irrigation beginning in 2015. (All of Basins 40 and 41, portions of Basins 34, 36, 38, and 42) • All sprinkler systems will have a field application efficiency of 90 percent beginning in 2015, representing implementation of LEPA nozzles on existing sprinkler systems. • Water saved through conservation activities is not applied to a water scheme elsewhere, such as expanding the number of irrigated acres, thus achieving true conservation.
	Scenario II Substantially Expanded Conservation	• All assumptions from Scenario I are applicable. • All acres of water intensive crops (corn for grain and forage crops, including alfalfa and pasture grass), shift to less water intensive crops (grain for sorghum) beginning in 2015. While is it highly unlikely that all water intensive crop production will stop, this assumption allows for analysis of full implementation of the "what-if" scenario.

Scenario I Conservation Measures

Moderately expanded permanent conservation activities (Scenario I) in the Crop Irrigation demand sector could eliminate surface water, alluvial groundwater storage depletions, and bedrock groundwater storage depletions. These additional conservation activities would require increasing the sprinkler irrigation efficiency, increasing the efficiency of surface irrigation systems to 80 percent, and shifting 10 percent of the land irrigated by surface irrigation to micro-irrigation (Scenario I conservation, as defined in the OCWP *Water Demand Forecast Report*). These reductions would decrease the basin's crop irrigation demand by 15,210 AFY. Table 7-2 lists the irrigated acreage affected by Scenario I conservation measures in the counties encompassing Basin 38. Irrigation conservation measures could benefit users throughout the basin and should be considered as a short to long-term water supply option.

Table 7-2. Acreage of Irrigated Lands with Increased Irrigation Efficiency under Scenario I Conservation

County	Irrigated Land (thousand acres) [1]
Greer	1
Harmon	18
Jackson	55

[1] Acreage represents the irrigated land in the entire county for 2007, not just the portion in Basin 38.

Implementing Municipal and Industrial conservation measures could help reduce gaps and storage depletions for public water providers and may delay the need to build new infrastructure.

Scenario II Conservation Measures

Substantially expanded conservation measure (Scenario II) through shifting from water intensive crops to lower water use crops is not necessary to eliminate gaps and storage depletions. The OCWP *Water Demand Forecast Report* recognizes that crop shifting is unlikely to occur unless crop managers are faced with severe water shortages, high pumping costs, or implementation of policies that provide incentives to do so. Therefore, Scenario II conservation measures are unlikely to be implemented for Basin 38.

7.2.2 Out-of-Basin Supplies

There are substantial existing out-of-basin supplies from the Lugert-Altus Irrigation District; however, the Irrigation District is not expected to provide supplies for new irrigators in the future unless additional sources of supply are secured. The City of Altus also receives an out-of-basin supply from the Mountain Park Master Conservancy District in Basin 35, and the City of Mangum obtains out-of-basin supplies from the North Fork of the Red River aquifer in Basin 36.

New out-of-basin supplies would be among the most costly of options, but could eliminate the potential for surface water gaps and groundwater depletions. The construction of new out-of-basin reservoir supplies should be considered as a long-term water supply option for users throughout the basin. However, due to the scale and complexity of developing out-of-basin supplies, the cost-effectiveness of these supplies should be evaluated against other options on a local level.

The OCWP *Reservoir Viability Study* identified two potentially viable sites in the Southwest Watershed Planning Region: Mangum Lower Dam Site (Category 4) in Basin 39 and Port Reservoir (Category 3) located in Basin 34. Mangum Reservoir was recognized as the nearest most viable site, located about 11 miles from the center of Basin 38. The potential site could provide a dependable yield of about 18,494 AFY from 47,043 AF of total storage. With new terminal storage of about 7,000 AF, a 30-inch diameter pipe would be needed to bring out-of-basin supplies at a constant flow rate into Basin 38 for further distribution to users and eliminate gaps and storage depletions. With no terminal storage and variable flows in the pipeline, a 54-inch diameter pipeline would be needed. The estimated yield of the Mangum Reservoir site is much higher than needed to meet Basin 38's long-term needs, thus this site might be considered for a regional water supply project.

Regionalization of public water supply systems may provide an avenue for long-term implementation of major out-of-basin supplies. For purposes of this report, regionalization is defined as the shared development of and use of water supplies and the required diversion, conveyance, storage, and treatment infrastructure between two or more public water supply systems. Sharing of infrastructure, particularly for projects involving long transmission pipelines, can reduce the costs for each participant due to economies of scale. For example, conveyance of 50 million gallons per day of water could be accomplished through three individual pipelines: a 12-inch diameter pipeline, a 15-inch diameter pipeline, and a 42-inch diameter pipeline. That same flow could be conveyed through a single 48-inch diameter pipeline at roughly two-thirds the cost per mile of pipe. However, regionalization does not always reduce overall project costs and may not make economic sense depending on local and project-specific conditions. In particular, the closer two providers' distribution systems are, the more cost-effective a shared project will be.

Operational efficiencies are possible with regionalization in areas such as:

- Overnight and emergency plant staffing
- Maintenance equipment and staff
- Monitoring and reporting
- Water quality sampling and lab analyses/lab facilities
- Permitting and reporting
- Administration

At the same time, potential issues in sharing of supplies and infrastructure can bring challenges such as:

- Autonomy in decision-making and control:
  — Source of supply and capital cost decisions
  — Operational decisions (e.g., rates, drought restrictions)
- Institutional framework (new water supply district/authority vs. wholesale relationship)
- Differing needs (unequal rates of growth, condition of existing infrastructure, etc.)
- Water quality compatibility between sources
- Capital costs of interconnecting systems
- Funding/financing capabilities and methods

Throughout the Southwest Watershed Planning Region, there are already numerous examples of inter-provider arrangements to share water supplies on a wholesale basis, as documented in the OCWP *Southwest Watershed Planning Region Report*. Often, regionalization projects are initiated by or involve larger providers in the area, for example, Altus currently sells water to Jackson County Water Corporation and others. Opportunities for regional supply between larger and smaller providers, particularly those whose service areas are adjacent and for major out-of-basin supply projects, could be considered as a means of addressing the significant supply challenges facing the water users in Basin 38.

The OCWP *Water Conveyance Study* updated information from the 1980 OCWP statewide water conveyance system and one southwest conveyance alternative that encompasses Basin 38. The conveyance systems require additional reservoirs, hundreds of miles of piping, canals, and inverted siphons, and many pumping plants. Study results determined that this option would not be feasible under current technology and economic constraints, but may be considered as a long-term opportunity for the future.

7.2.3 Reservoir Use

Reservoir storage could provide dependable supplies to mitigate surface water gaps and adverse effects of localized storage depletions. The entire increase in demand from 2010 to 2060 could be met by a new river diversion and 8,900 AF of storage at the basin outlet. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the size of storage necessary to mitigate future gaps and storage depletions. However, a detailed evaluation of the feasibility of any reservoir would be needed and should include consideration of existing land ownership, costs, geology, water quality, and permitting compact obligations. The OCWP *Reservoir Viability Study* did not identify any large viable sites in Basin 38.

There are currently over 25 NRCS reservoirs in Basin 38, which are found on streams throughout the basin. These small reservoirs were typically built for flood control and to provide water for relatively small agricultural uses, but could be evaluated to determine the potential for rehabilitation and/or reallocation of storage to meet the needs of any demand sector. The water supply yields, available storage, and water quality of these reservoirs are unknown. However, due to the potential volume of storage in the basin, shown in Table 7-3, further investigation of these water supplies may be merited.

Table 7-3. Summary of NRCS Reservoirs in Basin 38

Normal Pool Storage Category	Number of Reservoirs	Total Normal Pool Volume in Category (AF)
<50 AF	5	226
>50 AF	23	2,846
Largest Reservoir (AF)		640

7.2.4 Increasing Reliance on Surface Water

The primary sources of water (62 percent of the total demand) in this basin are surface water and out-of-basin supplies from the Lugert-Altus Irrigation District, which is not expected to provide supplies for new irrigators in the future without additional water supply sources. Therefore, additional water supplies will be needed from the Salt Fork of the Red River or from alluvial or bedrock aquifers. Unlike many basins in the Southwest Watershed Planning Region, use of surface water to meet local demand in Basin 38 through 2060 is not expected to be limited by the availability of permits. However, there is a low to moderate probability of surface water gaps starting in 2020 for new river diversions. Increasing reliance on surface water use, without reservoir storage, would increase the size and probability of these gaps. Therefore, this water supply option is not recommended.

7.2.5 Increasing Reliance on Groundwater

Currently, about 25 percent of the total demand in Basin 38 is met from the Blaine aquifer, primarily for Crop Irrigation due to water quality constraints, and about 13 percent is met from non-delineated minor aquifers along the Salt Fork of the Red River and Turkey Creek. Under baseline demand conditions, storage depletions in alluvial and bedrock aquifers are expected to increase due largely to the growth in Crop Irrigation demand, which may cause adverse effects in localized areas. The projected growth in surface water and alluvial groundwater use for irrigation purposes could alternatively be supplied by the Blaine bedrock aquifer in the western half of the basin, but would result in large (9,240 AFY) increases in projected bedrock groundwater storage depletions. While the storage depletion is minimal compared to the amount of water in storage, these localized storage depletions may adversely affect users' yields, water quality, and pumping costs. The impacts may be intensified by the geology of the aquifer; water may be obtained from cavities, solution channels, and fractures in the rock, where depletions could create changes in these features that may intensify the effect of storage depletions on a local level.

Therefore, the development of additional bedrock groundwater supplies to meet the growth in surface water could be considered a long-term water supply option, but may require additional infrastructure and increased operation and maintenance costs for sustained reliability. Over a long-term period, demand management and other supply options may provide more consistent supplies and may be more cost-effective.

Artificial recharge has been conducted in the Blaine aquifer since the late 1960s. In 1997, a groundwater recharge study was performed by the OWRB to determine the effectiveness of artificial recharge wells in Basins 40 and 41. The study found that on average, one recharge well could recharge the aquifer at a rate of about half that of the water withdrawal from an irrigation well (recharge of 70 AFY compared to average annual pumping of 142 AFY per irrigation well). Increased use of this practice could be effective at reducing the effects of localized storage depletions in Basin 38.

The majority of current alluvial groundwater rights are in non-delineated minor aquifers; therefore, the typical yields, volume of stored water, and water quality are unknown. Increased reliance on these supplies is not recommended without site-specific information.

7.2.6 Marginal Quality Water

The OCWP *Marginal Quality Water Issues and Recommendations* report identified areas where there is potential for use of marginal quality water to offset a significant amount of future demand. Basin 38 was found to have significant brackish marginal quality groundwater sources that could be used to meet Crop Irrigation demand. These groundwater sources are typically deeper than fresh water aquifers and not associated with delineated aquifers, such as the Blaine aquifer. Crops that are among the most salinity-tolerant include barley and wheat. Brackish water supplies are those that have between 1,000 mg/L and 35,000 mg/L TDS. OWRB does not have regulatory authority to permit withdrawals of groundwater with TDS concentrations greater than 5,000 mg/L. 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. Brackish groundwater underlies the entire Basin and should be evaluated as a potential short- to long-term water supply option. However, these supplies will likely be less preferable than supplies from the lower-salinity North Fork of the Red

River aquifer. Site-specific information on the suitability of the brackish groundwater sources for supply should be considered before large scale use.

7.3 Summary

Six categories of supply options for mitigating the projected surface water gaps and groundwater storage depletions in Basin 38 are summarized in Table 7-4. Five options were potential short or long-term options: demand management, marginal quality water sources, out-of-basin supplies, increasing reliance on groundwater and reservoir use.

Table 7-4. Summary of Water Supply Options for Basin 38

Water Supply Option	Option	Feasibility
Demand Management	• Increased Crop Irrigation efficiency	• Short- to long-term solution that may eliminate surface water gaps and groundwater depletions
Out-of-Basin Supplies	• Mangum Reservoir or Statewide Water Conveyance	• Potential long-term solution
Reservoir Use	• Development of new reservoirs and reallocation of storage	• Potentially feasible
Increasing Reliance on Surface Water	• Increasing reliance on surface water supplies, without reservoir storage	• Not feasible
Increasing Reliance on Groundwater	• Increasing reliance on the Blaine aquifer instead of increased surface water and alluvial groundwater use	• Long-term solution; potential localized adverse impacts
Marginal Quality Water	• Use brackish groundwater sources for Crop Irrigation	• Potential long-term applicability for irrigation of certain crops

Section 8
Basin 40 (Prairie Dog Town Fork Red River - 1) and Basin 41 (Prairie Dog Town Fork Red River - 2)

Basins 40 and 41, located in the Southwest Watershed Planning Region, represent the entire watershed of Sand Creek in Oklahoma and have very similar water supply needs and resources; therefore, they were evaluated as a single hot spot. Basin 40 is a surface water and bedrock groundwater hot spot, and Basin 41 is a bedrock groundwater hot spot. Surface water issues are mainly due to low physical availability of streamflow, lack of available streamflow for new permits, and relatively poor water quality. Both basins are challenged by the overall size of storage depletions and for the rate of storage depletions relative to the amount of groundwater storage in the Blaine aquifer. Shortages in these basins are in large part driven by the significant seasonal demand of the area's Crop Irrigation demand sector. More detailed information on these basins are available in the OCWP *Southwest Watershed Planning Region Report*. In addition to the challenges noted, surface water gaps may occur in Basin 41 by 2030 and alluvial groundwater storage depletions may occur by 2020 in both Basin 40 and Basin 41. This section describes the driving factors for these basins being identified as a hot spot, provides an analysis of how to address supply availability issues, and evaluates identified alternatives.

8.1 Basin Description

Basins 40 and 41 encompass portions of Harmon and Jackson counties. The Southwest Watershed Planning Region is primarily located in the Osage Plains of the Great Lowlands, with the High Plains bordering to the west. The region's terrain includes vast farming areas along with rolling river bottoms. The region has a generally mild climate with mild winters and long, hot summers. Average monthly temperatures vary from 59°F to 64°F. Annual average precipitation is 29 inches. Annual evaporation ranges from 62 to 65 inches per year.

8.1.1 Surface Water Supplies

Surface water supplies were used to meet approximately 4 percent of total demand in Basins 40 and 41 in 2010. Sand Creek is the largest surface water supply source in Basins 40 and 41. There are no major reservoirs in these basins. The median flow in Sandy Creek near Eldorado, Oklahoma (Basin 41 outlet) has been less than about 200 AF/month, except in May and June when it is greater than 1,500 AF/month. The median flow in Sand Creek and the creeks of Basin 40 are less than 200 AF/month except in May and June when the median flow is about 1,400 AF/month. **Figures 8-1 (a) and (b)** illustrate the monthly streamflow statistics. Surface water in Basins 40 and 41 are fully allocated, leaving no surface water available for new permits.

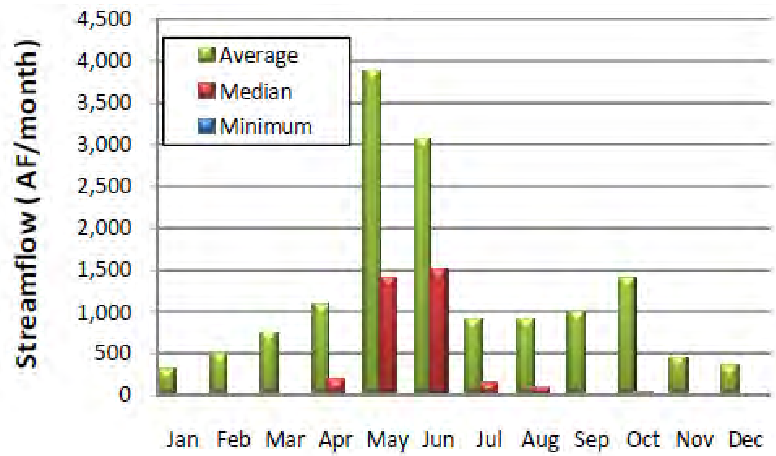

Figure 8-1a. Monthly Streamflow Statistics over the Period of Record in Basin 40

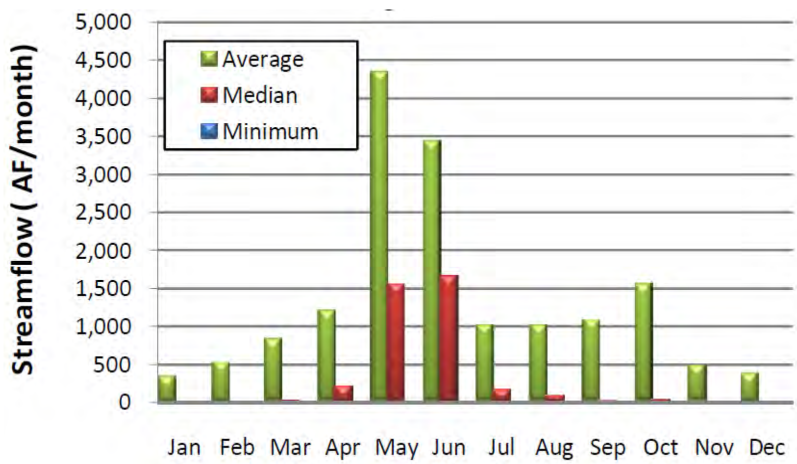

Figure 8-1b. Monthly Streamflow Statistics over the Period of Record in Basin 41

Relative to other basins in the state, the surface water quality in Basins 40 and 41 is considered poor. Water quality of the Southwest Watershed Planning Region varies considerably. Natural elevated levels of salinity in this region produce agricultural and public private water supply impacts, particularly in the North Fork of the Red River and the Salt Fork of the Red River and their tributaries. Sandy Creek and Gypsum Creek are impaired for Agricultural use due to high levels of TDS, chlorides, and sulfates. However, individual lakes and streams may have acceptable water quality.

8.1.2 Groundwater Supplies

Bedrock groundwater is the primary source of water and currently supplies about 65 percent of total demand in these basins while alluvial groundwater is used to meet 31 percent of the total demand. **Figure 8-2** illustrates the aquifers and existing groundwater permits in Basins 40 and 41. Nearly all of the current bedrock groundwater rights are from the Blaine Aquifer. The small amount of remaining bedrock aquifer rights are in minor non-delineated bedrock aquifers.

The Blaine Aquifer underlies most of Basins 40 and 41. Irrigation wells typically average 140 AFY/well; however, maximum well yields are 50 gpm or higher. An EPS for the Blaine aquifer has not been established. Up to 2.0 AFY/acre of dedicated lands overlying the aquifer may be withdrawn through the temporary permits. Note: temporary permits are subject to change when converted to regular permits. There are an estimated 4,219,000 AFY of remaining groundwater rights from the Blaine aquifer in these basins, which is not expected to be limited by the availability of new permits for local demand through 2060. The water quality is generally poor with high concentrations of TDS (generally between 2,000 – 6,000 mg/L), sulfate (1,000 – 2,000 mg/L) and other ions. Chloride content can be greater than 1,000 mg/L and is considered brackish.

The majority of alluvial groundwater rights are from non-delineated alluvial and terrace aquifers along the Red River or Sandy Creek. There are also water rights from non-delineated minor bedrock aquifers. These aquifers have not been studied; therefore, no information on storage, yield, or recharge is available. Site-specific information on the suitability of these minor aquifers for supply should be considered before large-scale use.

8.1.3 Water Demand

From the OCWP *Water Demand Forecast Report*, the total demand for both basins in 2060 is 52,240 AFY or about 30 percent of the total demand in the Southwest Watershed Planning Region's water needs. The total demand is expected to increase 13 percent (5,950 AFY) from 2010 to 2060. The projected total demand by sector in Basins 40 and 41 is presented in **Figures 8-3 (a) and (b)**. The majority of demand and growth in demand over this period will be in the Crop Irrigation demand sector. As a result, the peak summer month demand over 150 times the winter demand in both Basins 40 and 41, which is much more pronounced than the overall statewide pattern. Crop Irrigation occurs throughout Basin 41, but is dispersed in Basin 40, as shown in **Figure 8-4**.

Bedrock groundwater demand in Basins 40 and 41 was 30,130 AFY in 2010 and is projected to increase by 13 percent (3,820 AFY) by 2060. About 70 percent of the bedrock groundwater demand is expected in Basin 41. The majority of bedrock groundwater use and growth in bedrock groundwater use over this period will be in the Crop Irrigation demand sector. There is expected to be significant water supply challenges for users of the Blaine aquifer.

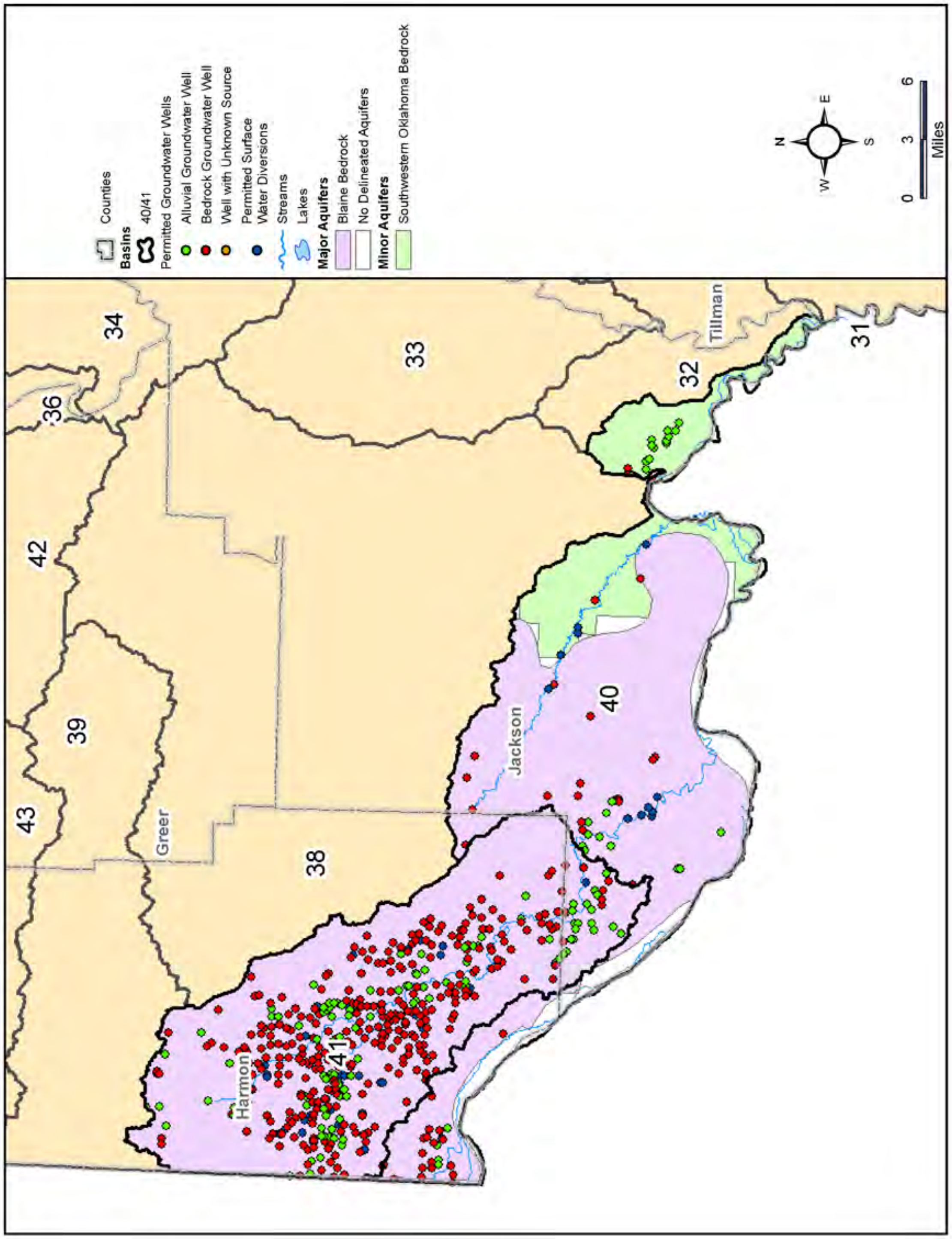

Figure 8-2. Groundwater Supplies in Basins 40 and 41

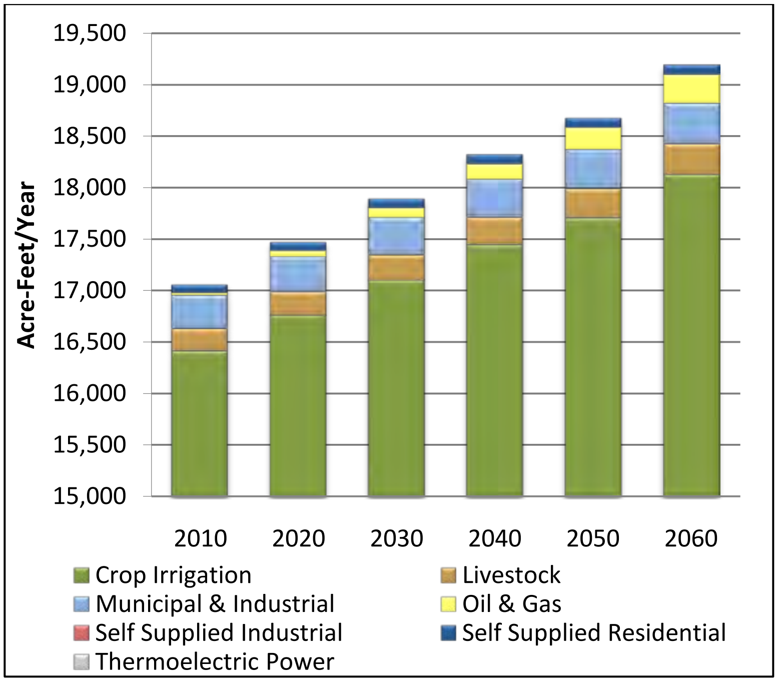

Figure 8-3a. Total Demand by Sector in Basin 40

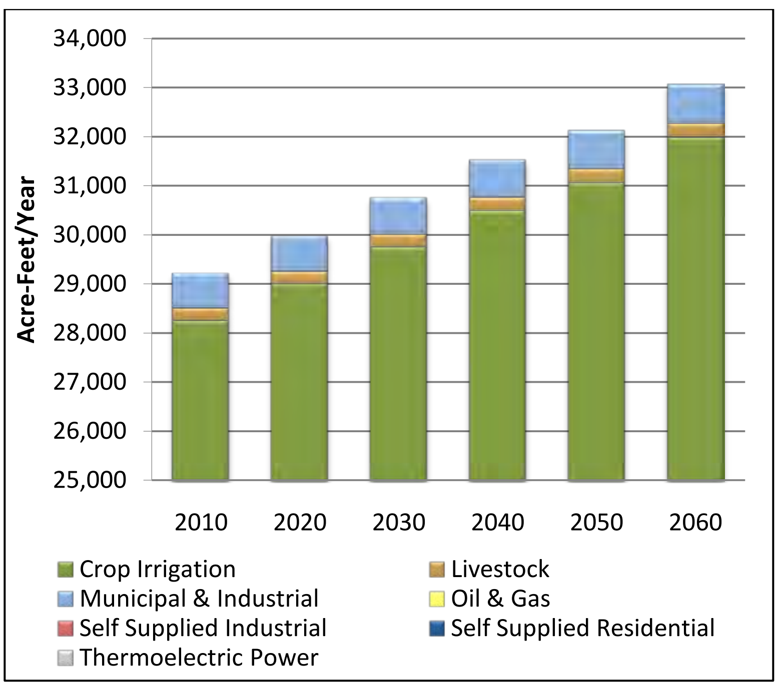

Figure 8-3b. Total Demand by Sector in Basin 41

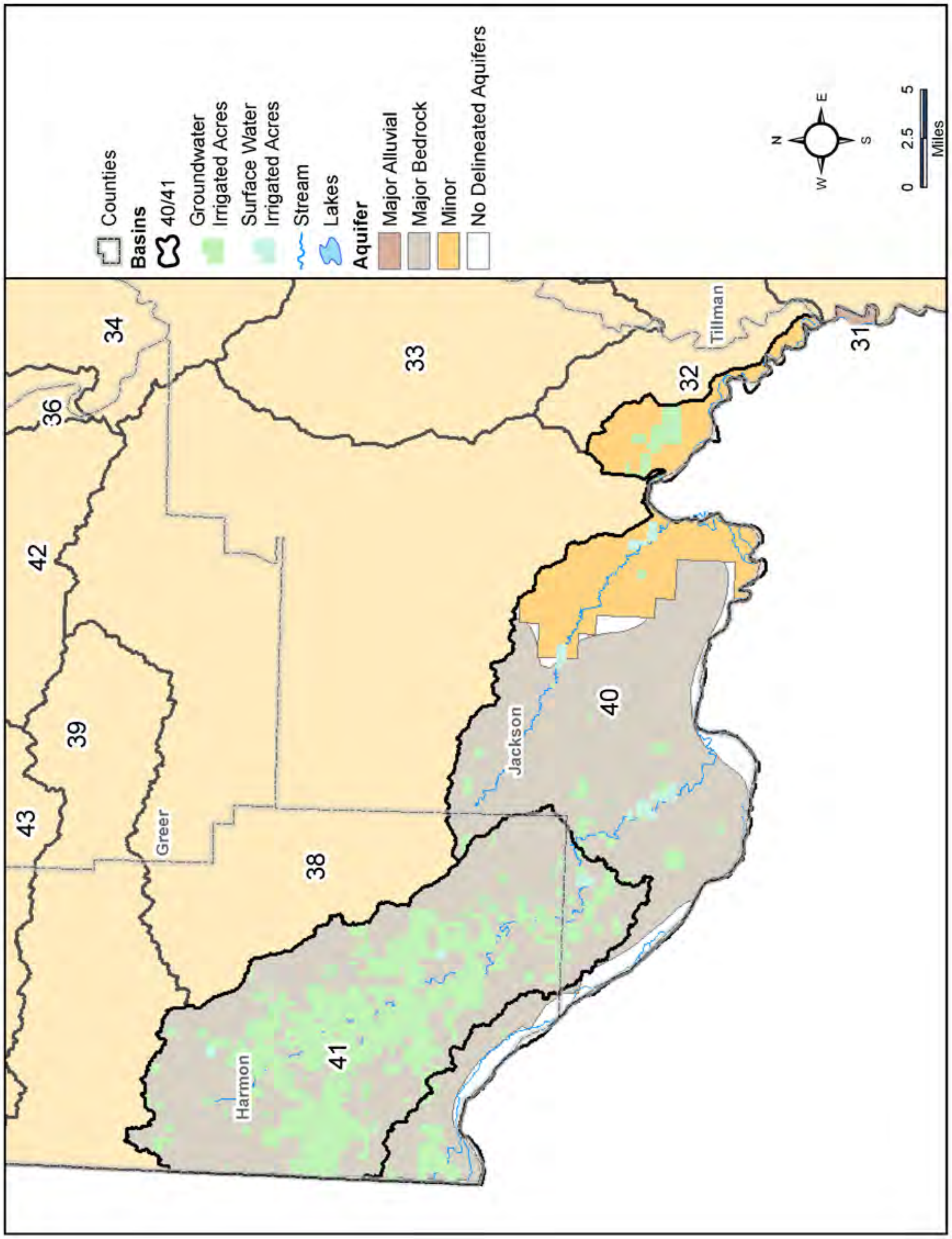

Figure 8-4. Distribution of Irrigated Land in Basins 40 and 41

Alluvial groundwater demand in Basins 40 and 41 was 16,340 AFY in 2010 and is projected to increase by 11 percent (1,750 AFY) by 2060. About 21 percent of the alluvial groundwater demand is expected in Basin 41. The majority of alluvial groundwater use and growth in alluvial groundwater use over this period will be in the Crop Irrigation demand sector.

Surface water demand in Basins 40 and 41 was 2,100 AFY in 2010 and is projected to increase by 20 percent (1,960 AFY) by 2060. About 90 percent of the surface water demand is expected in Basin 40. The majority of surface water use and growth in surface water use over this period will be in the Crop Irrigation demand sector.

8.1.4 Gaps and Depletions

Based on projected demand and historical hydrology, surface water gaps and groundwater storage depletions may occur in Basin 40 by 2020. Alluvial and bedrock groundwater depletions may occur in Basin 41 by 2020, while surface water gaps are expected by 2030.

Surface water gaps in Basin 40 are expected to occur in at least one month of almost every year by 2060. Surface water gaps may occur throughout the year; peaking in size in the summer. Basin 40's surface water gaps in 2060 will be up to 9 percent (60 AF/month) of the surface water demand in the peak summer month, and as high as 67 percent (20 AF/month) of the winter months' surface water demand.

Alluvial groundwater storage depletions in Basin 40 are expected to occur in at least one month of almost every year by 2060. Alluvial groundwater storage depletions may occur throughout the year; peaking in size during the summer. Basin 40's alluvial groundwater storage depletions in 2060 will be up to 9 percent (320 AF/month) of the alluvial groundwater demand in the peak summer month, and while much smaller in size (10 AF/month), storage depletions during winter months may equal the entire alluvial groundwater demand. Current alluvial withdrawals are largely from non-delineated minor aquifers. Therefore, the severity of the storage depletions cannot be evaluated.

Bedrock groundwater storage depletions in Basin 40 may occur during the summer and fall, peaking in size in the summer. Bedrock groundwater storage depletions in 2060 will be 10 percent (410 AF/month) of the bedrock groundwater demand on average in the peak summer month, and 10 percent (190 AF/month) on average of the fall months' bedrock groundwater demand. Projected annual bedrock groundwater storage depletions are small relative to the amount of water stored in Basin 40's portion of the Blaine aquifer. However, localized storage depletions may occur and adversely affect users' yields, water quality, and pumping costs.

There will be a 95 percent probability of surface water gaps in Basin 41 occurring in at least one month of the year by 2060. Surface water gaps in Basin 41 by 2060 will be up to 14 percent (20 AF/month) of the surface water demand in the peak summer month, and as much as 17 percent (10 AF/month) of the winter months' surface water demand.

There will be an 88 percent probability of alluvial groundwater storage depletions in Basin 41 occurring in at least one month of the year by 2060. Alluvial groundwater storage depletions are most likely to occur during summer months. Alluvial groundwater storage depletions may occur during the spring, summer, and fall. Basin 41's surface water gaps in 2060 will be up to 11 percent (370 AF/month) of the alluvial groundwater demand in the peak summer month, and as much as 20 percent (10 AF/month) of the winter months' alluvial groundwater demand. Current alluvial withdrawals are largely from a non-delineated groundwater source. Therefore, the severity of the storage depletions could not be evaluated.

Bedrock groundwater storage depletions in Basin 41 may occur during the summer and fall. Bedrock groundwater storage depletions in 2060 will be 12 percent (1,190 AF/month) of the bedrock groundwater demand on average in the peak summer month, and 12 percent (510 AF/month) on average of the winter months' bedrock groundwater demand. Projected annual bedrock storage depletions are small in size relative to the amount of water in storage in the aquifer. However, localized storage depletions may occur and adversely affect users' yields, water quality, and pumping costs.

8.2 Analysis of Supply Options

Six categories of supply options for mitigating the projected surface water gaps and groundwater storage depletions in Basins 40 and 41 are described in the text below. The six water supply options represent the basic ways to develop additional water supplies for all users in these basins. All options should be reviewed, as a combination of supply options will likely be needed to meet the basins' water supply challenges.

8.2.1 Demand Management

The demand management option considers permanent conservation measures and temporary drought restrictions. Moderately expanded and substantially expanded conservation measures were evaluated for both the Municipal and Industrial and Crop Irrigation demand sectors. The conservation scenarios are described briefly in Table 8-1, but the OCWP *Water Demand Forecast Report* provides full descriptions of the conservation measures considered. It is recommended that these basins consider additional permanent conservation activities, instead of temporary drought management activities. Due to the high probability of gaps and since aquifer storage could continue to provide supplies during droughts, the temporary drought management water supply option was not evaluated.

Table 8-1. Summary of OCWP Conservation Scenarios (Source: OCWP *Water Demand Forecast Report*)

Demand Sector	Conservation Scenario	Description
Municipal and Industrial	Scenario I Moderately Expanded Conservation	• Passive conservation achieved by 2060 for PSR and 2030 for PSNR. Passive conservation is defined as conservation that can be achieved through government plumbing codes as part of the Energy Policy Act. • 90 percent of water providers in each county will meter their customers, unless current metered percentage is greater than 90 percent. • NRW will be reduced to 12 percent, where applicable • Conservation pricing will be implemented by 20 percent of purveyors in rural counties, 40 percent in mostly urban counties, and 60 percent in counties with high metropolitan populations. • Water conservation educational programs will be implemented by all providers, which include billing inserts and conservation tip websites to reduce demands by 3 percent.
	Scenario II Substantially Expanded Conservation	• Passive conservation (as described in Scenario I) • All purveyors will meter their customers. • NRW will be reduced to 10 percent where applicable. • Conservation pricing will be implemented by 60 percent of purveyors in rural counties, 80 percent in mostly urban counties, and 100 percent in counties with high metro populations. • Water conservation education programs will be implemented to reduce demands by 5 percent including school education programs and media campaigns in addition to billing inserts and a conservation tip website. • High efficiency plumbing code ordinance will be implemented. This ordinance requires use of high efficiency fixtures with lower maximum flow rates than those required under the Energy Policy Act.
Agricultural Irrigation	Scenario I Moderately Expanded Conservation	• The field application efficiency of surface irrigation systems for Harmon, Jackson, Tillman, and Kiowa counties will increase to 80 percent beginning in 2015 (all of Basins 40 and 41, portions of Basins 34, 36, 38, and 42) . • In Harmon, Jackson, Tillman, and Kiowa counties, 10 percent of the land irrigated by surface irrigation will shift to micro-irrigation beginning in 2015. (All of Basins 40 and 41, portions of Basins 34, 36, 38, and 42) • All sprinkler systems will have a field application efficiency of 90 percent beginning in 2015, representing implementation of LEPA nozzles on existing sprinkler systems. • Water saved through conservation activities is not applied to a water scheme elsewhere, such as expanding the number of irrigated acres, thus achieving true conservation.
	Scenario II Substantially Expanded Conservation	• All assumptions from Scenario I are applicable. • All acres of water intensive crops (corn for grain and forage crops, including alfalfa and pasture grass), shift to less water intensive crops (grain for sorghum) beginning in 2015. While is it highly unlikely that all water intensive crop production will stop, this assumption allows for analysis of full implementation of the "what-if" scenario.

Scenario I Conservation Measures

Moderately expanded permanent conservation activities (Scenario I) in the Crop Irrigation demand sector could eliminate surface water, alluvial groundwater storage depletions, and bedrock groundwater storage depletions. These additional conservation activities would require increasing the sprinkler irrigation efficiency, increasing the efficiency of surface irrigation systems to 80 percent, and shifting 10 percent of the land irrigated by surface irrigation to micro-irrigation (Scenario I conservation, as defined in the OCWP *Water Demand Forecast Report*).These reductions could decrease the two basins' combined demand by 8,630 AFY. **Table 8-2** lists the irrigated acreage affected by Scenario I conservation measures.

Table 8-2. Acreage of Irrigated Lands with Increased Irrigation Efficiency under Scenario I Conservation

County	Irrigated Land (thousand acres) [1]
Harmon	18
Jackson	55

[1] Acreage represents the irrigated land in the entire county for 2007, not just the portion in Basins 40 and 41.

Implementing Scenario I Municipal and Industrial conservation measures decreases the projected 2060 demand in Basin 40 from 480 AFY to 400 AFY. Implementing Scenario I Crop Irrigation conservation measures decreases the projected 2060 demand in Basin 40 from 18,120 AFY to 14,600 AFY. Implementing conservation in both sectors is expected to reduce the 2060 surface water gap by 73 percent to a value of 70 AFY. Implementing conservation in both sectors could eliminate bedrock groundwater storage depletions in Basin 40 and reduce the 2060 alluvial groundwater storage depletions by 90 percent to a value of 80 AFY. Under Scenario I conservation activities, the probability of surface water gaps and storage depletions remains high due to the high frequency of low to no-flow months.

Implementing Scenario I Municipal and Industrial conservation measures decreases the projected 2060 demand in Basin 41 from 800 AFY to 690 AFY. Implementing Scenario I Crop Irrigation conservation measures decreases the projected 2060 demand in Basin 41 from 31,980 AFY to 26,870 AFY. Implementing conservation in both sectors is expected to eliminate surface water gaps, alluvial groundwater storage depletions, and bedrock groundwater storage depletions.

Scenario II Conservation Measures

Substantially expanded conservation measure (Scenario II) through shifting from water intensive crops to lower water use crops is not necessary to eliminate gaps and storage depletions in Basin 41 and is not expected to provide substantial additional reductions in gaps and storage depletions in Basin 40. The OCWP *Water Demand Forecast Report* recognizes that crop shifting is unlikely to occur unless crop managers are faced with severe water shortages, high pumping costs, or implementation of policies that provide incentives to do so. Therefore, Scenario II conservation measures are unlikely to be implemented for Basins 40 and 41.

8.2.2 Out-of-Basin Supplies

Gould Public Works Authority (PWA), which is located in Basin 41, currently has an existing permit to transfer water from out-of-basin sources in Basin 39. Substantial increases in out-of-basin supplies from this basin are not expected, since all surface water in Basin 39 is fully allocated and the basin has a moderate annual probability of surface water gaps.

Construction of new out-of-basin supplies would be among the most costly of options, but could eliminate the potential for surface water gaps and groundwater depletions. The construction of new out-of-basin reservoir supplies should be considered as a long-term water supply option for users throughout the basin. However, due to the scale and complexity of developing out-of-basin supplies, the cost-effectiveness of these supplies should be evaluated against other options on a local level.

The OCWP *Reservoir Viability Study* identified two potentially viable sites in the Southwest Watershed Planning Region: Mangum Lower Dam Site (Category 4) in Basin 39 and Port Reservoir (Category 3) located in Basin 34. Mangum Reservoir, the nearest most viable site, is located about 25 miles from the center of Basins 40 and 41 and could provide a dependable yield of about 18,494 AFY from 47,043 AF of total storage. With new terminal storage of about 4,000 AF, a 20-inch diameter pipe would be needed to bring out-of-basin supplies at a constant rate into Basins 40 and 41 for further distribution to users and eliminate gaps and storage depletions. With no terminal storage and variable flows in the pipeline, a 40-inch diameter pipeline would be needed. Since the estimated yield of Mangum Reservoir is greater than needed to supply both basins' demand, this site could be considered for a regional water supply project.

Regionalization of public water supply systems may provide an avenue for long-term implementation of major out-of-basin supplies. For purposes of this report, regionalization is defined as the shared development of and use of water supplies and the required diversion, conveyance, storage, and treatment infrastructure between two or more public water supply systems.

Sharing of infrastructure, particularly for projects involving long transmission pipelines, can reduce the costs for each participant due to economies of scale. For example, conveyance of 50 million gallons per day of water could be accomplished through three individual pipelines: a 12-inch diameter pipeline, a 15-inch diameter pipeline, and a 42-inch diameter pipeline. That same flow could be conveyed through a single 48-inch diameter pipeline at roughly two-thirds the cost per mile of pipe. However, regionalization does not always reduce overall project costs and may not make economic sense depending on local and project-specific conditions. In particular, the closer two providers' distribution systems are, the more cost-effective a shared project will be.

Operational efficiencies are possible with regionalization in areas such as:

- Overnight and emergency plant staffing
- Maintenance equipment and staff

- Monitoring and reporting
- Water quality sampling and lab analyses/lab facilities
- Permitting and reporting
- Administration

At the same time, potential issues in sharing of supplies and infrastructure can bring challenges such as:

- Autonomy in decision-making and control:
  - — Source of supply and capital cost decisions
  - — Operational decisions (e.g., rates, drought restrictions)
- Institutional framework (new water supply district/authority vs. wholesale relationship)
- Differing needs (unequal rates of growth, condition of existing infrastructure, etc.)
- Water quality compatibility between sources
- Capital costs of interconnecting systems
- Funding/financing capabilities and methods

Throughout the Southwest Watershed Planning Region, there are already numerous examples of inter-provider arrangements to share water supplies on a wholesale basis, as documented in the OCWP *Southwest Watershed Planning Region Report*. Often, regionalization projects are initiated by or involve larger providers in the area, for example, Harmon County Water Corporation currently sells water to Eldorado. Opportunities for regional supply between larger and smaller providers, particularly those whose service areas are adjacent and for major out of basin supply projects, could be considered as a means of addressing the significant supply challenges facing the water users in Basins 40 and 41.

The OCWP *Water Conveyance Study* updated information from the 1980 OCWP statewide water conveyance system and one southwest conveyance alternative that encompasses Basins 40 and 41. The conveyance systems require additional reservoirs, hundreds of miles of piping, canals, and inverted siphons, and many pumping plants. Study results determined that this option would not be feasible under current technology and economic constraints, but may be considered as a long-term opportunity for the future.

8.2.3 Reservoir Use

New small reservoirs (less than 50 AF) could be potentially effective to reduce surface water gaps or adverse effects of localized storage depletions. Substantial permit issues must be resolved in order to construct larger reservoirs. If permittable, Basin 40's entire growth in demand from 2010 to 2060 could be supplied by a new river diversion and 5,600 AF of reservoir storage at the basin outlet and Basin 41's by a new river diversion and a 12,600 AF of reservoir storage at the basin outlet. The use of multiple reservoirs in the basins or reservoirs upstream of the basins' outlets may increase the amount of storage necessary to mitigate future gaps and storage depletions.

8.2.4 Increasing Reliance on Surface Water

Surface water in these basins is fully allocated, limiting diversions to existing permitted amounts. There is a moderate to high probability of surface water gaps starting in 2020 for Basin 40 and 2030 for Basin 41 for the baseline demand projections. If permits could be issued, increasing reliance on surface water use without reservoir storage would increase the size and probability of these gaps. Therefore, this water supply option is not recommended.

8.2.5 Increasing Reliance on Groundwater

Currently, about 65 percent of the total demand is met from the Blaine aquifer and about 30 percent is met from non-delineated minor aquifers along the Red River and Sandy Creek. Under baseline demand conditions, storage depletions in alluvial and bedrock aquifers are expected to increase due largely to the growth in Crop Irrigation demand, which may cause adverse effects in localized areas.

The projected growth in surface water and alluvial groundwater use for irrigation could be supplied by the Blaine aquifer, which would result in about 1.5 times the projected bedrock groundwater storage depletions under the baseline scenario. While the storage depletion is minimal compared to the amount of water in storage, these localized storage depletions may adversely affect users' yields, water quality, and pumping costs. The impacts may be intensified by the geology of the aquifer; water may be obtained from cavities, solution channels, and fractures in the rock, where depletions could create changes in these features that may intensify the effect of storage depletions on a local level. Therefore, the development of additional bedrock groundwater supplies to meet the growth in surface water could be considered a long-term water supply option, but may require additional infrastructure and increased operation and maintenance costs for sustained reliability. Over a long-term period, demand management and other supply options may provide more consistent supplies and may be more cost-effective.

The majority of current alluvial groundwater rights are in non-delineated minor aquifers; therefore, the typical yields, volume of stored water, and water quality are unknown due to lack of sufficient data. Increased reliance on these supplies is not recommended without site-specific information.

Artificial recharge has been conducted in the Blaine aquifer since the late 1960s. In 1997, a groundwater recharge study was performed to determine the effectiveness of artificial recharge wells in these basins. The study found that on average, one recharge well could recharge the aquifer at a rate of about half that of the water withdrawal from an irrigation well (recharge of 70 AFY compared to average annual pumping of 142 AFY per irrigation well). Increased use of this practice could be effective at reducing the effects of localized storage depletions in Basins 40 and 41.

8.2.6 Marginal Quality Water

The OCWP *Marginal Quality Water Issues and Recommendations* report identified areas where there is potential for use of marginal quality water to offset a significant amount of future demand. Basins 40 and 41 were found to have significant brackish marginal quality groundwater sources that could be used to meet Crop Irrigation demand. These groundwater sources are typically deeper than fresh water aquifers and not associated with delineated aquifers, such as the Blaine aquifer. Crops that are among the most salinity-tolerant include barley and wheat. Brackish water supplies are those that have between 1,000 mg/L and 35,000 mg/L TDS. OWRB does not have regulatory authority to permit withdrawals of groundwater with TDS concentrations greater than 5,000 mg/L. 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. Brackish groundwater underlies the entire basin and should be evaluated as a potential short- to long-term water supply option. However, these supplies will likely be less preferable than supplies from the shallower Blaine aquifer. Site-specific information on the suitability of brackish groundwater sources for supply should be considered before large scale use.

8.3 Summary

Six categories of supply options for mitigating the projected surface water gaps and groundwater storage depletions in Basins 40 and 41 are summarized in Table 8-3. Five options were potential short or long-term options: demand management, marginal quality water sources, out-of-basin supplies, increasing reliance on groundwater and reservoir use.

Table 8-3. Summary of Water Supply Options for Basins 40 and 41

Water Supply Option	Option	Feasibility
Demand Management	• Moderately expanded Municipal and Industrial conservation measures and increased sprinkler irrigation efficiency	• Short- to long-term solution that may reduce surface water gaps in Basin 40 by 73 percent, alluvial groundwater storage depletions by about 90 percent, and eliminate bedrock storage depletions • All gaps and storage depletions could be eliminated in Basin 41
Out-of-Basin Supplies	• Mangum Reservoir or Statewide Water Conveyance	• Potential long-term solution
Reservoir Use	• Development of new reservoirs	• Potentially long-term solution; additional analyses required
Increasing Reliance on Surface Water	• Increasing reliance on surface water supplies, without reservoir storage	• Not feasible
Increasing Reliance on Groundwater	• Increasing reliance on the Blaine bedrock aquifer	• Long-term solution; may cause adverse localized impacts
Marginal Quality Water	• Use brackish groundwater sources for Crop Irrigation	• Potential long-term applicability for irrigation of certain crops

Section 9
Basin 42 (Elm Fork Red River - 1)

Basin 42, located in the Southwest Watershed Planning Region, is a hot spot for surface water and alluvial groundwater supplies. Surface water issues are mainly associated with the basin's low physical availability of streamflow, rather than permit availability, and relatively poor water quality. The basin also is challenged by the overall size of storage depletions and for the rate of storage depletions relative to the amount of groundwater storage in the North Fork of the Red River aquifer. Shortages in the basin are in large part driven by the significant seasonal demand of the area's Crop Irrigation practices. More detailed information on this basin is available in the OCWP *Southwest Watershed Planning Region Report*. In addition to the challenges noted, bedrock groundwater storage depletions are projected to occur by 2020. This section describes the basin's supplies, demands, water supply issues, and water supply options to mitigate the basin's issues.

9.1 Basin Description

Basin 42 is located primarily in Greer County with a small portion in Kiowa County. The Southwest Watershed Planning Region is in the Southern Great Plains and has mild winters and long, hot summers. The terrain includes large farming areas along with rolling river bottoms, and the Wichita Mountains near the outlet of the basin. The region's climate is mild with annual mean temperatures varying from 59°F to 64°F. Annual evaporation within the region ranges from 62 to 65 inches per year. Rainfall averages 29 inches per year.

9.1.1 Surface Water Supplies

Surface water supplied about 19 percent of the total 2010 demand in Basin 42. The Elm Fork of the Red River is the largest supply source in the basin. There are no major reservoirs in the basin. The flow in the Elm Fork of the Red River upstream of North Fork of the Red River varies seasonally, as shown in Figure 9-1, where the flow is typically less than 1,000 AF/month from July through November and greater than 9,000 AF/month in April and May. However, the river can have periods of low flow in any month of the year.

Basin 42 is expected to have available water for new permitting to meet local demand through 2060. The basin currently has an estimated 12,900 AFY of unpermitted streamflow on the mainstem of the Elm Fork of the Red River; however, the permit availability may vary on individual tributaries and all new water supplies are subject to the OWRB permitting process.

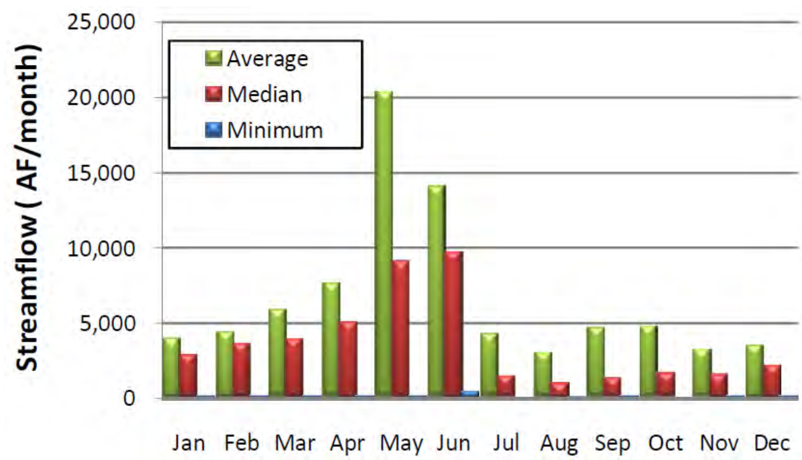

Figure 9-1. Monthly Streamflow Statistics over the Study Period of Record

Relative to other basins in the state, the surface water quality in Basin 42 is considered poor. Water quality of the Southwest Watershed Planning Region varies considerably. Natural elevated levels of salinity in this region produce agricultural and public private water supply impacts, particularly in the North Fork of the Red River and the Salt Fork of the Red River and their tributaries. The Elm Fork of the Red River is impaired for Agricultural use due to high levels of chloride. However, individual lakes and streams may have acceptable water quality.

9.1.2 Groundwater Supplies

Alluvial groundwater supplied about 71 percent of the total 2010 demand in Basin 42. **Figure 9-2** illustrates the Aquifers and existing groundwater permits in Basin 42. About 60 percent (4,300 AFY) of the groundwater rights in the basin are in the North Fork of the Red River alluvial aquifer. The remainder of the alluvial groundwater rights (2,800 AFY) is in non-delineated minor terrace aquifers of the Salt Fork of the Red River. These aquifers have not been studied; therefore, no information on storage, yield, or recharge is available. Site-specific information on the suitability of this minor aquifer for supply should be considered before large scale use.

The North Fork of the Red River aquifer underlies the Elm Fork of the Red River and surrounding area, which covers about 21 percent of the total area in the Basin. Up to 1.0 AFY/acre of dedicated lands overlying the aquifer may be withdrawn through regular permits. There are an estimated 8,400 AFY of remaining groundwater rights in the North Fork of the Red River aquifer, which is not expected to be limited by the availability of new permits for local demand through 2060.

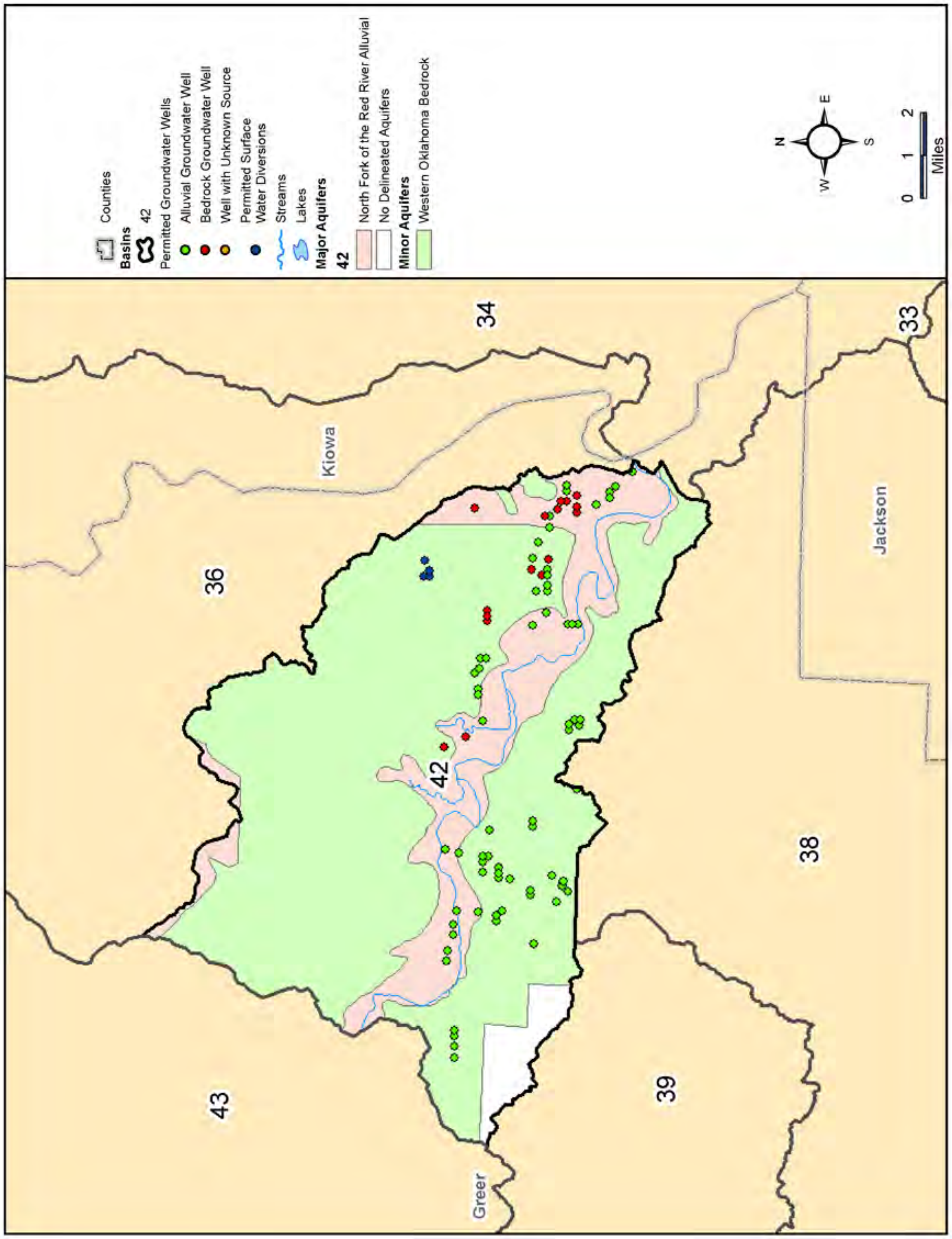

Figure 9-2. Groundwater Supplies in Basin 42

The Western Oklahoma alluvial aquifer supplies about two percent (or 200 AFY) of the basin's current ground water rights. This portion of the aquifer is available to 97 percent of the basin. No EPS has been set for the Western Oklahoma aquifer. Up to 2.0 AFY/acre of dedicated lands overlying the aquifer may be withdrawn through temporary permits. Note: temporary permitted withdrawals are subject to change when converted to regular permits. The remaining bedrock groundwater rights (800 AFY) in the basin are in non-delineated minor bedrock aquifers. These aquifers have not been studied; therefore, no information on storage, yield, or recharge is available. Site-specific information on the suitability of these minor aquifers for supply should be considered before large scale use.

9.1.3 Water Demand

From the OCWP *Water Demand Forecast Report*, the total demand for this Basin in 2060 is projected to be 7,070 AFY, which is about 2 percent of the water needs in the Southwest Watershed Planning Region. The total demand is projected to increase by 148 percent (4,220 AFY) from 2010 to 2060. The total demand in Basin 42 is presented in **Figure 9-3**. The majority of demand and growth in demand over this period will be in the Crop Irrigation demand sector. As a result of the crop irrigation demand, the peak summer month demand in Basin 42 is about 23 times the winter demand, which is much more pronounced than the overall statewide pattern. Crop Irrigation occurs largely in the southern portion of the basin, as shown in **Figure 9-4**. There is also locally significant Municipal and Industrial demand.

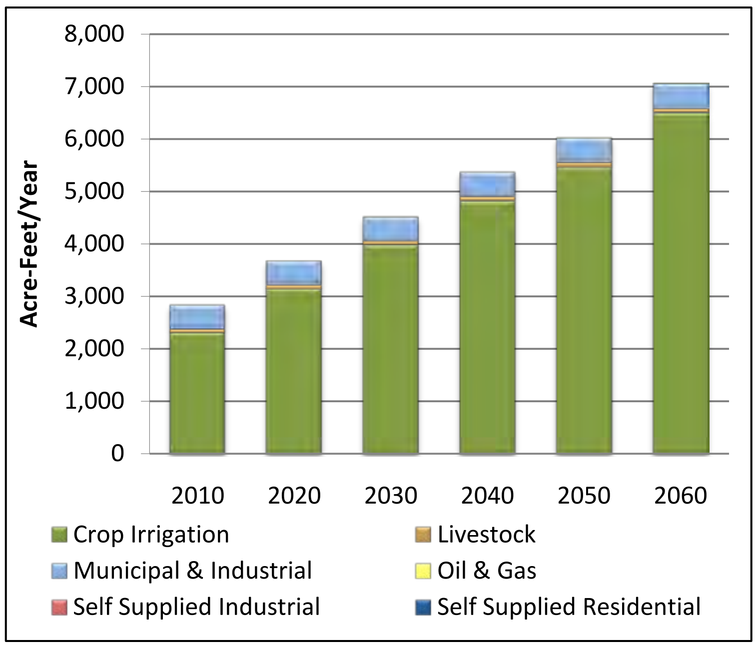

Figure 9-3. Total Demand by Sector in Basin 42

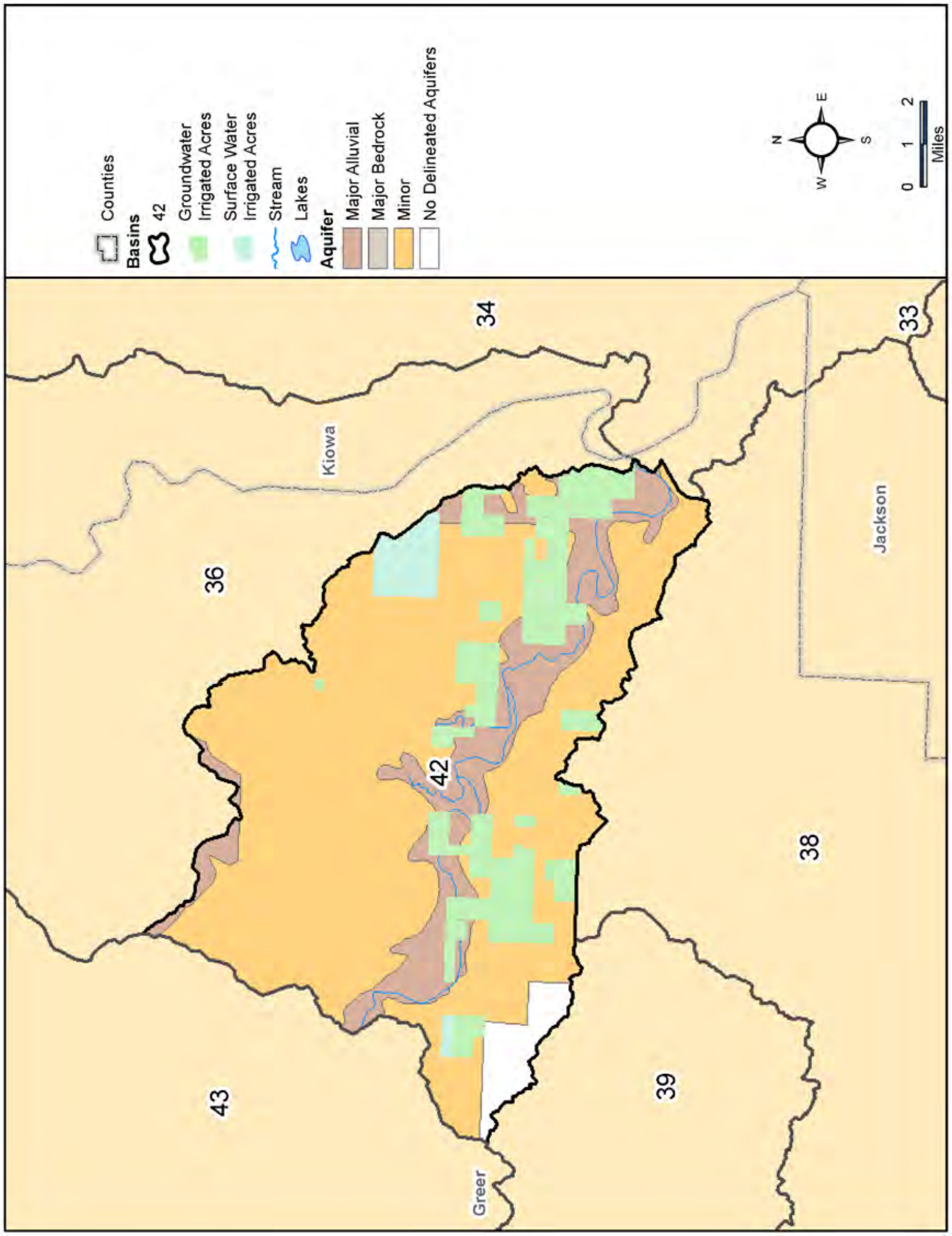

Figure 9-4. Distribution of Irrigated Land in Basin 42

Surface water was used to meet 19 percent of the total demand in 2010 and its use is projected to increase by 48 percent (260 AFY) from 2010 to 2060. The majority of surface water use over this period will be in the Municipal and Industrial demand sector. However, the majority of growth in surface water use from 2010 to 2060 will be in the Crop Irrigation demand sector. There is expected to be significant water supply challenges for surface water users in the basin.

Alluvial groundwater was used to meet 71 percent of the total demand in 2010 and its use is projected to increase by 175 percent (3,510 AFY) from 2010 to 2060. The majority of alluvial groundwater use and growth in alluvial groundwater use over this period will be in the Crop Irrigation demand sector. There is expected to be significant water supply challenges for surface water users of the North Fork of the Red River aquifer and other minor alluvial aquifers.

Bedrock groundwater was used to meet 10 percent of the total demand in 2010 and its use is projected to increase by 153 percent (450 AFY) from 2010 to 2060. The majority of bedrock groundwater use and growth in bedrock groundwater use over this period will be in the Crop Irrigation demand sector.

9.1.4 Gaps and Depletions

Based on projected demand and historical hydrology, surface water gaps and alluvial and bedrock groundwater storage depletions are projected to occur by 2020. Surface water gaps in Basin 42 may occur during spring, summer and fall; peaking in size during the summer. Surface water gaps in 2060 will be up to 56 percent (100 AF/month) of the surface water demand in the peak summer month, and as little as 10 AF/month in the spring months. There will be a 78 percent probability of gaps occurring in at least one month of the year by 2060. Surface water gaps are most likely to occur during the summer months.

Alluvial groundwater storage depletions in Basin 42 may occur during spring, summer and fall; peaking in size during the summer. Alluvial groundwater storage depletions in 2060 will be up to 57 percent (1,120 AF/month) of the alluvial groundwater demand in the peak summer month, and as little as 20 AF/month in spring months. There will be a 78 percent probability of storage depletions occurring in at least one month of the year by 2060. Alluvial groundwater storage depletions are most likely to occur during summer months. Projected annual alluvial groundwater storage depletions are moderate in size relative to the volume of water in Basin 42's portion of the amount of water stored in the North Fork of the Red River aquifer. Localized storage depletions may occur and adversely affect users.

Bedrock groundwater storage depletions in Basin 42 may occur during spring, summer, and fall; peaking in size during the summer. Bedrock groundwater storage depletions in 2060 will be 64 percent (160 AF/month) of the bedrock groundwater demand on average in the peak summer month, and while much smaller in size (10 AF/month), storage depletions during spring months may equal the entire bedrock groundwater demand. Bedrock groundwater rights are from non-delineated groundwater source minor aquifers. Therefore, the severity of the storage depletions cannot be evaluated.

9.2 Analysis of Supply Options

Six categories of supply options for mitigating the projected surface water gaps and groundwater storage depletions in Basin 42 are described in the text below. The six water supply options represent the basic ways to develop additional water supplies for all users in the basin. All options should be reviewed, as a combination of supply options will likely be needed to meet the basin's water supply challenges.

9.2.1 Demand Management

The demand management option considers permanent conservation measures and temporary drought restrictions. Moderately expanded and substantially expanded conservation measures were evaluated for both the Municipal and Industrial and Crop Irrigation demand sectors. The conservation scenarios are described briefly in Table 9-1, but the OCWP *Water Demand Forecast Report* provides full descriptions of the conservation measures considered. It is recommended that the basin consider additional permanent conservation activities, instead of temporary drought management activities. Due to the very high probability gaps and since aquifer storage could continue to provide supplies during droughts, the temporary drought management water supply option was not evaluated.

Table 9-1. Summary of OCWP Conservation Scenarios (Source: OCWP *Water Demand Forecast Report*)

Demand Sector	Conservation Scenario	Description
Municipal and Industrial	Scenario I Moderately Expanded Conservation	• Passive conservation achieved by 2060 for PSR and 2030 for PSNR. Passive conservation is defined as conservation that can be achieved through government plumbing codes as part of the Energy Policy Act. • 90 percent of water providers in each county will meter their customers, unless current metered percentage is greater than 90 percent. • NRW will be reduced to 12 percent, where applicable • Conservation pricing will be implemented by 20 percent of purveyors in rural counties, 40 percent in mostly urban counties, and 60 percent in counties with high metropolitan populations. • Water conservation educational programs will be implemented by all providers, which include billing inserts and conservation tip websites to reduce demands by 3 percent.

Table 9-1. Summary of OCWP Conservation Scenarios (Source: OCWP *Water Demand Forecast Report*) (cont.)

Demand Sector	Conservation Scenario	Description
Municipal and Industrial (cont.)	Scenario II Substantially Expanded Conservation	• Passive conservation (as described in Scenario I). • All purveyors will meter their customers. • NRW will be reduced to 10 percent where applicable. • Conservation pricing will be implemented by 60 percent of purveyors in rural counties, 80 percent in mostly urban counties, and 100 percent in counties with high metro populations. • Water conservation education programs will be implemented to reduce demands by 5 percent including school education programs and media campaigns in addition to billing inserts and a conservation tip website. • High efficiency plumbing code ordinance will be implemented. This ordinance requires use of high efficiency fixtures with lower maximum flow rates than those required under the Energy Policy Act.
Agricultural Irrigation	Scenario I Moderately Expanded Conservation	• The field application efficiency of surface irrigation systems for Harmon, Jackson, Tillman, and Kiowa counties will increase to 80 percent beginning in 2015 (all of Basins 40 and 41, portions of Basins 34, 36, 38, and 42) . • In Harmon, Jackson, Tillman, and Kiowa counties, 10 percent of the land irrigated by surface irrigation will shift to micro-irrigation beginning in 2015. (All of Basins 40 and 41, portions of Basins 34, 36, 38, and 42) • All sprinkler systems will have a field application efficiency of 90 percent beginning in 2015, representing implementation of LEPA nozzles on existing sprinkler systems. • Water saved through conservation activities is not applied to a water scheme elsewhere, such as expanding the number of irrigated acres, thus achieving true conservation.
	Scenario II Substantially Expanded Conservation	• All assumptions from Scenario I are applicable. • All acres of water intensive crops (corn for grain and forage crops, including alfalfa and pasture grass), shift to less water intensive crops (grain for sorghum) beginning in 2015. While is it highly unlikely that all water intensive crop production will stop, this assumption allows for analysis of full implementation of the "what-if" scenario.

Scenario I Conservation Measures

Implementing Scenario I Municipal and Industrial conservation measures decreases the projected demand in Basin 42 from 480 AFY to 400 AFY. Implementing Scenario I Crop Irrigation conservation measures decreases the projected demand in Basin 42 from 6,500 AFY to 6,160 AFY. Implementing Scenario I conservation measures for both sectors could reduce the surface water gaps by 40 AFY (15 percent) to a value of 230 AFY; reduce alluvial groundwater storage depletions by about 280 AFY (10 percent) to a value of 2,400 AFY; and reduce bedrock groundwater storage depletions by 40 AFY (9 percent) to a value of 410 AFY. In all of the moderately expanded conservation scenarios, the probability of surface water gaps and storage depletions remains unchanged due to frequency of low to no-flow months. Table 9-2 lists the irrigated acreage affected by Scenario I conservation measures in the counties encompassing Basin 42.

Table 9-2. Acreage of Irrigated Lands with Increased Irrigation Efficiency under Scenario I Conservation

County	Irrigated Land (thousand acres) [1]
Greer	3
Kiowa	3

[1] Acreage represents the irrigated land in the entire county for 2007, not just the portion in Basin 42.

Moderately expanded conservation measures could provide a water supply solution in a relatively short period of time and could be implemented throughout the basin. Additional Municipal and Industrial use conservation measures, if implemented, will have little overall effect on gaps and storage depletions. However, these measures may help reduce gaps and adverse effects of localized storage depletions for public water providers and individual irrigators throughout the basins.

Scenario II Conservation Measures

Substantially expanded conservation measures (Scenario II) for the Crop Irrigation demand sector would require crop shifts throughout the basin, switching from water intensive crops (e.g., corn for grain, pasture greases, etc.) to sorghum for grain and wheat for grain, as well as the increase in irrigation efficiencies from Scenario I. The substantially expanded conservation measures include conversion of 2,467acres from corn for grain and forage crops to sorghum in the counties located in and around the basin, as indicated in Table 9-3. The OCWP *Water Demand Forecast Report* recognizes that crop shifting is unlikely to occur unless crop managers are faced with severe water shortages, high pumping costs, or implementation of policies that provide incentives to do so.

Table 9-3. Acreage of Crops Converted to Sorghum for Substantially Expanded Conservation Activities

County	Corn for Grain (acres) [1]	Forage Crops including Alfalfa and Pasture Grass (acres) [1]
Greer	387	853
Kiowa	387	840

[1] Acreage represents the entire county, not just the portion in Basin 42.

Scenario II conservation in the Municipal and Industrial demand sector would expand on the conservation measures implemented in Scenario I and require the implementation of a high efficiency plumbing code ordinance. Table 9-1 provides additional information on Scenario II conservation measures.

Substantially expanded conservation measures (Scenario II) could decrease the Crop Irrigation demand from 6,500 AFY to 5,140 AFY and the Municipal and Industrial demand from 480 AFY to 360 AFY. The combined demand reduction in both sectors could reduce 2060 surface water gaps by 37 percent to a value of 170; decrease alluvial groundwater storage depletions by 37 percent to a value of 1,680 AFY; and decrease bedrock groundwater storage depletions by 33 percent to a value of 300 AFY. Reductions are not expected to substantially decrease the probability of surface water gaps and alluvial groundwater storage depletions, due to the high frequency of low to no flow months.

Scenario II conservation measures would require substantial changes in the agricultural economy throughout the basin. Therefore, this water conservation measure would likely take a relatively long period of time to implement. However, shifting crop types could aid individual irrigators in the short-term.

9.2.2 Out-of-Basin Supplies

The Towns of Mangum and Granite currently obtain supplies from the North Fork of the Red River aquifer in Basin 36, where the aquifer is much larger. Continued use of these out-of-basin supplies could reduce projected surface water gaps; however, this portion of the aquifer is also expected to have significant water supply challenges statewide. Therefore, these out-of-basin supplies should are not expected to be able to help meet the Crop Irrigation demand in Basin 42.

New out-of-basin supplies would be among the most costly of options, but could eliminate the potential for surface water gaps and groundwater depletions. The development of out-of-basin supplies should be considered as a long-term water supply option for users throughout the basin. However, due to the scale and complexity of developing out-of-basin supplies, the cost-effectiveness of these supplies needs to be evaluated against other options on a local level

The OCWP *Reservoir Viability Study* identified one Category 3 and one Category 4 potential reservoir sites in the Southwest Watershed Planning Region: Port Reservoir located in Basin 34 and the Mangum Lower Dam Site in Basin 39. Mangum Reservoir (Category 4) is the closest viable site, located only approximately six miles from the center of Basin 42, and could provide a dependable yield of about 18,494 AFY from 47,043 AF of total storage. With new terminal storage of about 3,000 AF, an 18-inch diameter pipe would be needed to bring out-of-basin supplies at a constant flow rate into Basin 42 for further distribution to users. With no terminal storage and variable flows in the pipeline, a 36-inch diameter pipeline would be needed. Mangum is the only Category 4 reservoir site identified in the Southwest Watershed Planning Region; therefore, it may be considered as a regional supply to meet demands from other basins in the region.

Regionalization of public water supply systems may provide an avenue for long-term implementation of major out-of-basin supplies. For purposes of this report, regionalization is defined as the shared development of and use of water supplies and the required diversion, conveyance, storage, and treatment infrastructure between two or more public water supply systems. Sharing of infrastructure, particularly for projects involving long transmission pipelines, can reduce the costs for each participant due to economies of scale. For example, conveyance of 50 million gallons per day of water could be accomplished through three individual pipelines: a 12-inch diameter pipeline, a 15-inch diameter pipeline, and a 42-inch diameter pipeline. That same flow could be conveyed through a single 48-inch diameter pipeline at roughly two-thirds the cost per mile of pipe.

However, regionalization does not always reduce overall project costs and may not make economic sense depending on local and project-specific conditions. In particular, the closer two providers' distribution systems are, the more cost-effective a shared project will be.

Operational efficiencies are possible with regionalization in areas such as:

- Overnight and emergency plant staffing
- Maintenance equipment and staff
- Monitoring and reporting
- Water quality sampling and lab analyses/lab facilities
- Permitting and reporting
- Administration

At the same time, potential issues in sharing of supplies and infrastructure can bring challenges such as:

- Autonomy in decision-making and control:
  - Source of supply and capital cost decisions
  - Operational decisions (e.g., rates, drought restrictions)
- Institutional framework (new water supply district/authority vs. wholesale relationship)
- Differing needs (unequal rates of growth, condition of existing infrastructure, etc.)
- Water quality compatibility between sources
- Capital costs of interconnecting systems
- Funding/financing capabilities and methods

Throughout the Southwest Watershed Planning Region, there are already numerous examples of inter-provider arrangements to share water supplies on a wholesale basis, as documented in the OCWP *Southwest Watershed Planning Region Report*. Often, regionalization projects are initiated by or involve larger providers in the area, for example, Quartz Mountain Regional Water Authority currently sells water to Granite and others. Opportunities for regional supply between larger and smaller providers, particularly those whose service areas are adjacent and for major out of basin supply projects, could be considered as a means of addressing the significant supply challenges facing the water users in Basin 42.

The OCWP *Water Conveyance Study* updated information from the 1980 OCWP statewide water conveyance system and one southwest conveyance alternative that encompasses Basin 42. The conveyance systems require additional reservoirs, hundreds of miles of piping, canals, and inverted siphons, and many pumping plants. Study results determined that this option would not be feasible under current technology and economic constraints, but may be considered as a long-term opportunity for the future.

9.2.3 Reservoir Use

Development of reservoir storage in Basin 42 may be an effective long-term solution to mitigate surface water gaps and the adverse effects of localized storage depletions. A new river diversion and 3,900 AF of reservoir storage at the basin outlet could meet the entire growth in demand from 2010 to 2060. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the size of storage necessary to mitigate future gaps and storage depletions. A detailed evaluation of the feasibility of any reservoir would be needed and should include consideration of existing land ownership, costs, geology, water quality, and permitting/compact obligations.

9.2.4 Increasing Reliance on Surface Water

Unlike many basins in the Southwest Watershed Planning Region, use of surface water to meet local demand in Basin 42 through 2060 is not expected to be limited by the availability of permits. However, there is a moderate to high probability of surface water gaps starting in 2040 for the baseline demand projections. Increasing reliance on surface water use without reservoir storage would increase the size and probability of these gaps. Therefore, this water supply option is not recommended.

9.2.5 Increasing Reliance on Groundwater

The North Canadian River alluvial aquifer is the primary source of water in Basin 42, supplying 71 percent of the total demand. Under baseline demand, storage depletions are expected to occur in the North Canadian River and in non-delineated minor aquifers in terrace deposits of the Salt Fork of the Red River, due largely to the growth in Crop Irrigation demand. Due to the alluvial aquifer's connection to river flows and precipitation, aquifer levels may also fluctuate naturally in response to prolonged periods of drought or above-average precipitation. The projected growth in surface water and bedrock groundwater use could instead be supplied by the North Canadian River aquifer, which would result in moderate increases of about 510 AFY in projected alluvial groundwater storage depletions. While the storage depletion is minimal compared to the amount of water in storage, these localized storage depletions may adversely affect users' yields, water quality, and pumping costs. Therefore, the development of additional alluvial groundwater supplies to meet the growth in surface water and bedrock could be considered a long-term water supply option, but may require additional infrastructure and operation and maintenance costs for sustained reliability. Over a long-term period, demand management and other supply options may provide more consistent supplies and may be more cost-effective.

Bedrock groundwater supplies are from non-delineated minor aquifers; therefore, increased reliance on these supplies is not recommended without site-specific information.

9.2.6 Marginal Quality Water

The OCWP *Marginal Quality Water Issues and Recommendations* report identified areas where there is potential for use of marginal quality water to offset a significant amount of future demand. Basin 42 was found to have significant brackish marginal quality groundwater sources that could be used to meet Crop Irrigation demand. These groundwater sources are typically deeper than fresh water aquifers and not associated with delineated aquifers. Crops that are among the most salinity-tolerant include barley and wheat. Brackish water supplies are those that have between 1,000 mg/L and 35,000 mg/L TDS. OWRB does not have regulatory authority to permit withdrawals of groundwater with TDS concentrations greater than 5,000 mg/L. 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. Brackish groundwater underlies the entire basin and should be evaluated as a potential short- to long-term water supply option. However, these supplies will likely be less preferable than supplies from the lower-salinity North Fork of the Red River aquifer. Site-specific information on the suitability of the brackish groundwater sources for supply should be considered before large scale use.

9.3 Summary

Six categories of supply options for mitigating the projected surface water gaps and groundwater storage depletions in Basin 42 is summarized in Table 9-4. Five options were potential short or long-term options: demand management, marginal quality water sources, out-of-basin supplies, increasing reliance on groundwater and reservoir use.

Table 9-4. Summary of Water Supply Options for Basin 42

Water Supply Option	Option	Feasibility
Demand Management	• Moderately expanded Municipal and Industrial conservation measures and increased sprinkler irrigation efficiency • Significantly expanded Municipal and Industrial conservation measures and shift to crops with lower water demand	• Short- to long-term solution that could reduce 2060 surface water and groundwater depletions by 9 percent to 37 percent
Out-of-Basin Supplies	• Mangum Reservoir or Statewide Water Conveyance	• Potential long-term solution
Reservoir Use	• Development of new reservoirs	• Potential long-term solution; additional analyses required
Increasing Reliance on Surface Water	• Increasing reliance on surface water supplies, without reservoir storage	• Not feasible
Increasing Reliance on Groundwater	• Increasing reliance on the North Canadian River alluvial aquifer instead of increased surface water and bedrock groundwater use	• Long-term solution; may cause adverse localized impacts
Marginal Quality Water	• Use brackish groundwater sources for Crop Irrigation	• Potential long-term applicability for irrigation of certain crops

Section 10
Basin 51 (Middle North Canadian River)

Basin 51, located in the Central Watershed Planning Region, is a surface water and alluvial groundwater hot spot. Surface water issues are mainly associated with the basin's low physical availability of streamflow, lack of available streamflow for new permits, and to a lesser extent its poor water quality. Storage depletions are expected to present water supply challenges based on the overall size of the depletions and for the rate of those depletions relative to the amount of groundwater storage in the North Canadian River and Canadian River alluvial aquifers. More detailed information on this basin is available in the OCWP *Central Watershed Planning Region Report*. In addition to surface water gaps and alluvial groundwater storage depletions, bedrock groundwater storage depletions may occur by 2020. This section describes the driving factors for this basin being identified as a hot spot, provides an analysis of how to address supply availability issues, and evaluates identified alternatives.

10.1 Basin Description

Basin 51 encompasses portions of Blaine, Canadian, Dewey, and Oklahoma counties. The western portion of the Central Watershed Planning Region, including Basin 51, is characterized by the Prairie Tablelands. They are dominated by cropland with dense mixed grass prairies. The mean annual temperatures in the region range from varying from 59°F to 62°F. Annual evaporation within the region ranges from 52 to 62 inches per year. Annual rainfall in the region averages about 35 inches.

10.1.1 Surface Water Supplies

Surface water was used to meet 32 percent of the total 2010 demand in the basin. The North Canadian River is the largest surface water supply source in Basin 51. Its use will increase by 28 percent (1,960 AFY) from 2010 to 2060. The majority of surface water use and growth in surface water use over this period will be in the Municipal and Industrial demand sector. The median streamflow in the North Canadian River below Lake Overholser near Oklahoma City is greater than about 2,000 AF/month in each month of the year, except August, and greater than 5,000 AF/month in the spring and early summer. Historically, Basin 51, has undergone periods of very low or no flow in any month of the year, as shown in Figure 10-1. Surface water in the basin is fully allocated, limiting diversions to existing permitted amounts.

Lake Overholser is located at the basin outlet and provides 5,000 AFY of dependable water supply yield to Oklahoma City. The lake is not expected to provide additional future water supplies. Lake El Reno is located in the basin, but not used for water supply.

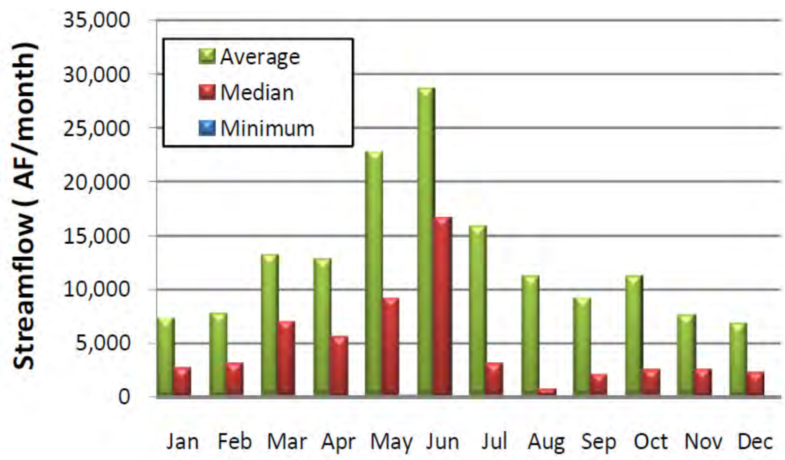

Figure 10-1. Monthly Streamflow Statistics over the Study Period of Record

Relative to other basins in the state, the surface water quality in Basin 51 is considered poor. Many surface waters in the Central Watershed Planning Region are impacted by urbanization, including increased nutrients and sediment as well as stream habitat alterations due to increases in impervious surfaces. Water from the Garber-Wellington (Central Oklahoma) aquifer is typically suited for public water supply but, in some areas, concentrations of nitrate, arsenic, chromium, and selenium exceed drinking water standards. Elevated concentrations of nitrate can occur in shallow water, which can be a concern for domestic well users. Elevated concentrations of arsenic, chromium, and selenium occur in deep parts of the aquifer, mostly affecting public water supply wells. The highest concentrations of arsenic tend to occur in the western portion of the aquifer where it is overlain by younger rocks. However, individual streams, rivers, and lakes may be of acceptable quality.

10.1.2 Groundwater Supplies

Groundwater supplies were used to meet 68 percent of the total 2010 demand in Basin 51. **Figure 10-2** illustrates the aquifers and existing groundwater permits in Basin 51.

Alluvial groundwater was used to meet 59 percent of the total demand in 2010 in the basin. Its use is projected to increase by 27 percent (3,570 AFY) from 2010 to 2060. The largest alluvial groundwater use over this period will be in the Crop Irrigation demand sector. However, the greatest growth in alluvial groundwater use from 2010 to 2060 will be in the Municipal and Industrial demand sector. About 80 percent (or 58,100 AFY) of total groundwater rights are provided by the North Canadian River major alluvial aquifer. The remainder of alluvial aquifer permits (12,100 AFY) is provided by the Canadian River major alluvial aquifer. The alluvial aquifers cover the northern portion of the Basin.

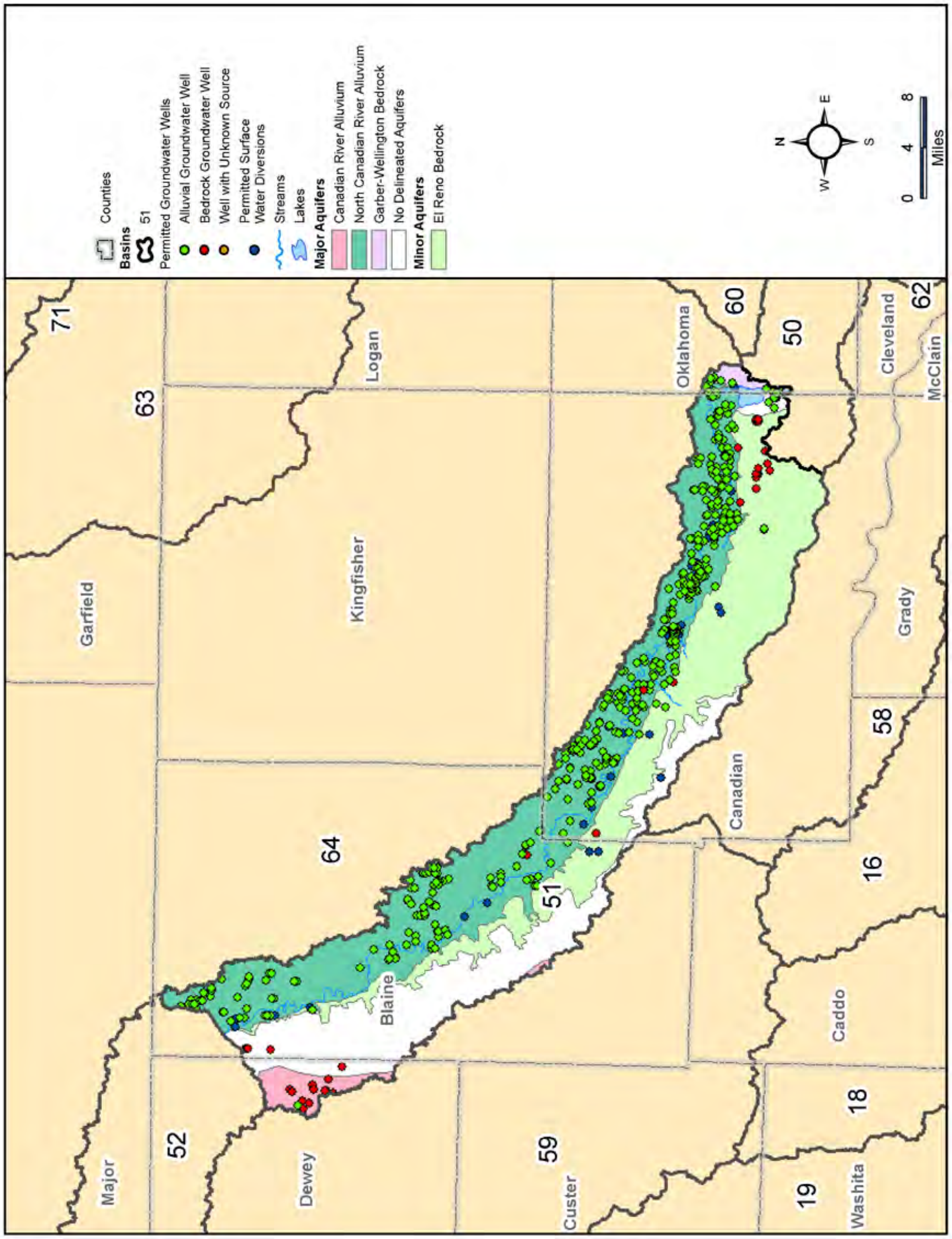

Figure 10-2. Groundwater Supplies in Basin 51

The North Canadian River major alluvial aquifer is available to about 320 square miles (or 45 percent). Up to 1.0 AFY/acre of dedicated lands overlying the aquifer may be withdrawn through regular permits. There are an estimated 148,600 AFY of remaining groundwater rights for the aquifer in this basin, which is not expected to be limited by the availability of new permits for local demand through 2060.

The Canadian River major alluvial aquifer is available to about 20 square miles (or 3 percent) in the northwestern portion of the basin. Up to 1.0 AFY/acre of dedicated lands overlying the aquifer may be withdrawn through regular permits. The aquifer could supply an estimated 24,800 AFY of remaining groundwater rights in this basin, which is not expected to limit the availability of new permits for local demand through 2060.

Bedrock groundwater was used to meet 9 percent of the total 2010 demand in the basin. Its use is projected to increase by 6 percent (120 AFY) from 2010 to 2060. The majority of bedrock groundwater use and growth in bedrock groundwater use over this period will be in the Crop Irrigation and Oil and Gas demand sectors. About 3 percent (or 2,400 AFY) of total groundwater rights are provided by the El Reno minor bedrock aquifer. There are currently no water rights in the Garber-Wellington major bedrock aquifer. Site-specific information on the suitability of the El Reno aquifer for supply should be considered before large-scale use.

10.1.3 Water Demand

From the OCWP *Water Demand Forecast Report*, the total demand for this basin in 2060 is 27,750 AFY an increase of 26 percent (or 5,650 AFY) from 2010 to 2060. **Figure 10-3** illustrates the demand and growth in demand by source and sector for the basin. The majority of demand and growth in demand will occur in the Municipal and Industrial and Crop Irrigation demand sectors. Crop Irrigation occurs throughout the basins over the North Canadian River aquifer and Canadian River aquifer, as shown in **Figure 10-4**. However, the highest concentration of irrigated acres is in the southern portion of the basin.

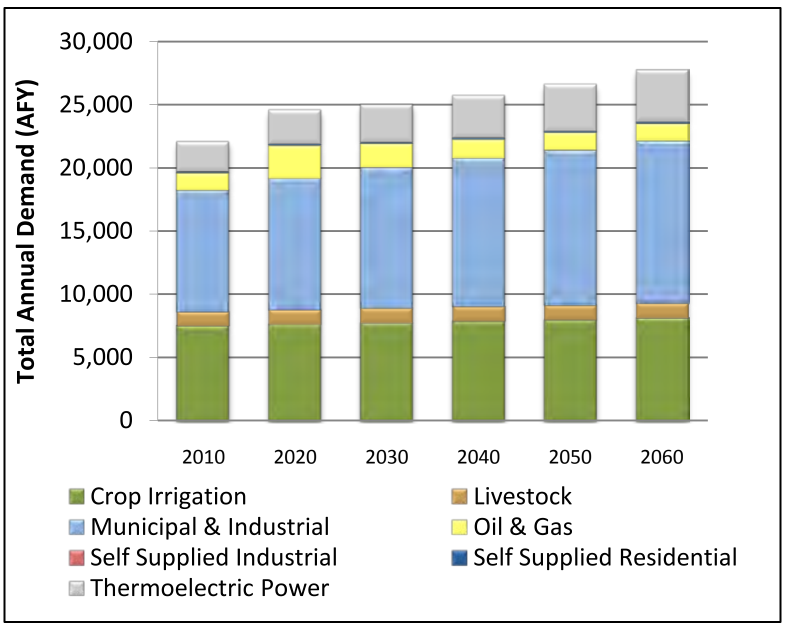

Figure 10-3. Total Demand by Sector in Basin 51

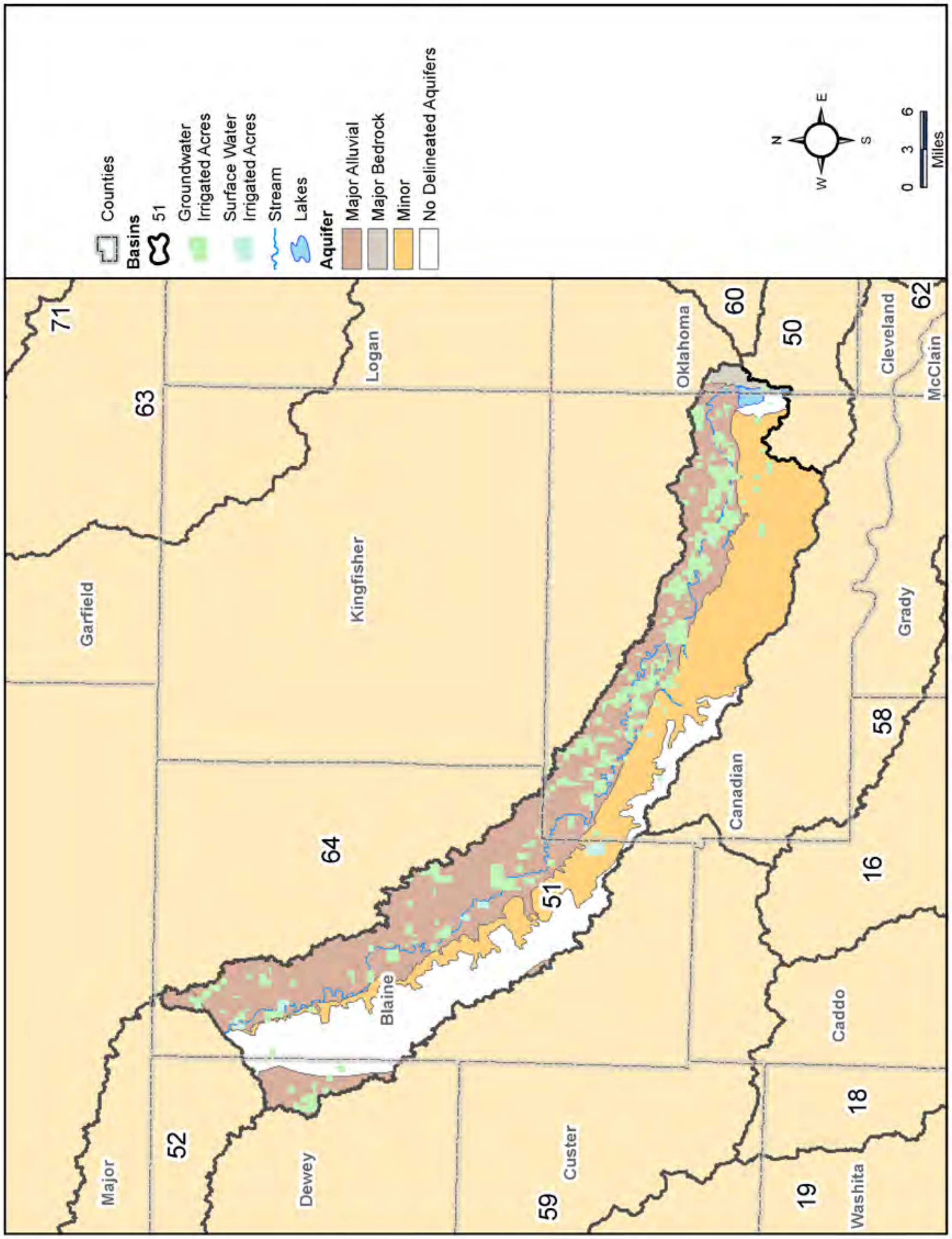

Figure 10-4. Distribution of Irrigated Land in Basin 51

Surface water was used to meet 32 percent of the total 2010 demand in the basin and its use is projected to increase by 28 percent (1,940 AFY) from 2010 to 2060. The largest demand and greatest growth in demand over this period will be in the Municipal and Industrial demand sector. Substantial growth in Thermoelectric Power demand is also projected. There is expected to be significant water supply challenges for users of the North Canadian River.

Alluvial groundwater was used to meet 59 percent of the total demand in the basin in 2010 and its use is projected to increase by 27 percent (3,600 AFY) from 2010 to 2060. The largest alluvial groundwater use over this period will be in the Crop Irrigation demand sector. However, the greatest growth in alluvial groundwater use from 2010 to 2060 will be in the Municipal and Industrial demand sector. There is expected to be significant water supply challenges for users of the North Canadian River aquifer and Canadian River aquifer.

Bedrock groundwater is used to meet 9 percent of the total demand in the basin. Its use will increase by 6 percent (110 AFY) from 2010 to 2060. The majority of the bedrock groundwater use over this period will be in the Crop Irrigation demand sector. Oil and Gas demand and bedrock groundwater use will peak around 2020 because of anticipated Woodford Shale drilling activities.

10.1.4 Gaps and Depletions

Based on projected demand and historical hydrology, surface water gaps and groundwater storage depletions are expected to occur by 2020. Surface water gaps in Basin 51 may occur throughout the year; peaking in size during the summer. Surface water gaps in 2060 will be up to 16 percent (190 AF/month) of the surface water demand in the peak summer month, and as much as 24 percent (130 AF/month) of the winter months' surface water demand. There will be an 81 percent probability of gaps occurring in at least one month of the year by 2060. Surface water gaps are likely to occur during all seasons.

Alluvial groundwater storage depletions in Basin 51 may occur throughout the year; peaking in size during the summer. Alluvial groundwater storage depletions in 2060 will be up to 15 percent (570 AF/month) of the alluvial groundwater demand in the peak summer month, and as much as 22 percent (210 AF/month) of the winter months' alluvial groundwater demand. There will be an 81 percent probability of alluvial groundwater storage depletions occurring in at least one month of the year by 2060. Alluvial groundwater storage depletions are likely to occur during all seasons.

Bedrock groundwater storage depletions in Basin 51 may occur during the summer and fall; peaking in size during the summer. Bedrock groundwater storage depletions in 2060 will be 8 percent (40 AF/month) of the bedrock groundwater demand on average in the peak summer month, and 5 percent (10 AF/month) on average of the fall months' bedrock groundwater demand.

Alluvial storage groundwater depletions are minimal compared to the groundwater storage in the basin. Future bedrock groundwater withdraws are expected to occur from minor aquifers. Therefore, the severity of the storage depletions cannot be evaluated.

10.2 Analysis of Supply Options

Six categories of supply options for mitigating the projected surface water gaps and groundwater storage depletions in Basin 51 are described in the text below. The six water supply options represent the basic ways to develop additional water supplies for all users in the basin. All options should be reviewed, as a combination of supply options will likely be needed to meet the basin's water supply challenges.

10.2.1 Demand Management

The demand management option considers permanent conservation measures and temporary drought restrictions. Moderately expanded and substantially expanded conservation measures were evaluated for both the Municipal and Industrial and Crop Irrigation demand sectors. The conservation scenarios are described briefly in **Table 10-1**, but the OCWP *Water Demand Forecast Report* provides full descriptions of the conservation measures considered. It is recommended that the basin consider additional permanent conservation activities, instead of temporary drought management activities. Due to the high probability of gaps and since aquifer storage could continue to provide supplies during droughts, the temporary drought management water supply option was not evaluated.

Table 10-1. Summary of OCWP Conservation Scenarios (Source: OCWP *Water Demand Forecast Report*)

Demand Sector	Conservation Scenario	Description
Municipal and Industrial	Scenario I Moderately Expanded Conservation	• Passive conservation achieved by 2060 for PSR and 2030 for PSNR. Passive conservation is defined as conservation that can be achieved through government plumbing codes as part of the Energy Policy Act. • 90 percent of water providers in each county will meter their customers, unless current metered percentage is greater than 90 percent. • NRW will be reduced to 12 percent, where applicable • Conservation pricing will be implemented by 20 percent of purveyors in rural counties, 40 percent in mostly urban counties, and 60 percent in counties with high metropolitan populations. • Water conservation educational programs will be implemented by all providers, which include billing inserts and conservation tip websites to reduce demands by 3 percent.

Table 10-1. Summary of OCWP Conservation Scenarios (Source: OCWP *Water Demand Forecast Report*)(cont.)

Demand Sector	Conservation Scenario	Description
Municipal and Industrial (cont.)	Scenario II Substantially Expanded Conservation	• Passive conservation (as described in Scenario I). • All purveyors will meter their customers. • NRW will be reduced to 10 percent where applicable. • Conservation pricing will be implemented by 60 percent of purveyors in rural counties, 80 percent in mostly urban counties, and 100 percent in counties with high metro populations. • Water conservation education programs will be implemented to reduce demands by 5 percent including school education programs and media campaigns in addition to billing inserts and a conservation tip website. • High efficiency plumbing code ordinance will be implemented. This ordinance requires use of high efficiency fixtures with lower maximum flow rates than those required under the Energy Policy Act.
Agricultural Irrigation	Scenario I Moderately Expanded Conservation	• All sprinkler systems will have a field application efficiency of 90 percent beginning in 2015, representing implementation of LEPA nozzles on existing sprinkler systems. • Water saved through conservation activities is not applied to a water scheme elsewhere, such as expanding the number of irrigated acres, thus achieving true conservation.
	Scenario II Substantially Expanded Conservation	• All assumptions from Scenario I are applicable. • All acres of water intensive crops (corn for grain and forage crops, including alfalfa and pasture grass), shift to less water intensive crops (grain for sorghum) beginning in 2015. While is it highly unlikely that all water intensive crop production will stop, this assumption allows for analysis of full implementation of the "what-if" scenario.

Scenario I Conservation Measures

Implementing Scenario I Municipal and Industrial conservation measures decreases the projected 2060 demand in Basin 51 from 12,840 AFY to 9,730 AFY. Implementing Scenario I Crop Irrigation conservation measures decreases the projected 2060 demand in Basin 51 from 8,100 AFY to 7,650 AFY. Implementing conservation in both sectors could reduce the size of the annual surface water gaps by up to about79 percent in 2060 to a value of 340 AFY, alluvial groundwater storage depletions by about 73 percent, to a value of 770 AFY, and bedrock groundwater storage depletions by about 80 percent, to a value of 20 AFY. Under Scenario I conservation activities, the probability of surface water gaps and storage depletions remains unchanged due to high frequency of low to no-flow months. **Table 10-2** lists the irrigated acreage affected by Scenario I conservation measures. Moderately expanded conservation should be considered as a short- to long-term water supply option.

Table 10-2. Acreage of Sprinkler Irrigated Lands Converted to High-Efficiency LEPA Nozzles

County	Irrigated Land (thousand acres) [1]
Blaine	6
Canadian	4
Dewey	3
Oklahoma	3

[1] Acreage represents the irrigated land in the entire county for 2007, not just the portion in Basin 51.

Scenario II Conservation Measures

Substantially expanded conservation measures (Scenario II) for the Crop Irrigation demand sector would require crop shifts throughout the basin, switching from water intensive crops (e.g., corn for grain, pasture greases, etc.) to sorghum for grain and wheat for grain, as well as the increase in irrigation efficiencies from Scenario I. The substantially expanded conservation measures include conversion of more than 4,963 acres from corn for grain and forage crops to sorghum in the counties encompassing Basin 51 as indicated in **Table 10-3**. The OCWP *Water Demand Forecast Report* recognizes that crop shifting is unlikely to occur unless crop managers are faced with severe water shortages, high pumping costs, or implementation of policies that provide incentives to do so.

Table 10-3. Acreage of Crops Converted to Sorghum for Substantially Expanded Conservation Activities

County	Corn for Grain (acres) [1]	Forage Crops including Alfalfa and Pasture Grass (acres) [1]
Blaine	1,106	138
Canadian	678	1,243
Dewey	387	899
Oklahoma	0	512

[1] Acreage represents the entire county, not just the portion in Basin 51.

Scenario II conservation in the Municipal and Industrial demand sector would expand on the conservation measures implemented in Scenario I and require the implementation of a high efficiency plumbing code ordinance. Table 10-1 provides additional information on Scenario II conservation measures.

Scenario II Municipal and Industrial conservation measures decrease the projected 2060 Municipal and Industrial demand from 12,840 AFY to 8,580 AFY and Crop Irrigation demand decreases from 8,100 AFY to 6,920 AFY. The combined demand reduction in both sectors may reduce the size of the annual surface water gaps in 2060 by 97 percent to a value of 50 AFY, alluvial groundwater storage depletions in 2060 by 96 percent to a value of 110 AFY, and could eliminate bedrock groundwater depletions. The probability of surface water gaps or alluvial groundwater storage depletions may be reduced from 81 percent to 45 percent.

Scenario II conservation measures would require substantial changes in the agricultural economy throughout the basins. Therefore, this water conservation measure would likely take a relatively long period of time to implement. However, shifting crop types could aid individual irrigators in the short-term.

10.2.2 Out-of-Basin Supplies

Oklahoma City's Lake Overholser in Basin 51 and Hefner Lake in Basin 64 receive substantial supplies out-of-basin from Canton Reservoir in Basin 52 through releases to the North Canadian River. It is anticipated that Basin 51 will continue to receive supplies from these resources as allocated by existing permits. Oklahoma City currently provides supply to several users in the basin, including El Reno, Yukon and the Canadian County Water Authority. Increased regionalization of supplies could reduce future gaps and depletions.

Development of new out-of-basin supplies would be among the most costly of options, but could eliminate the potential for surface water gaps and groundwater depletions. The development of new out-of-basin supplies should be considered as a long-term water supply option for users throughout the basin. However, due to the scale and complexity of developing out-of-basin supplies, the cost-effectiveness of these supplies should be evaluated against other options on a local level. With new terminal storage of 900 AF, a 20-inch diameter pipe would be needed to bring out-of-basin supplies at a constant flow rate into Basin 51 for further distribution to users. With no terminal storage and variable flows in the pipeline, a 30-inch diameter pipeline would also be recommended.

The OCWP *Reservoir Viability Study* identified five Category 4 sites that are within a 50-mile radius of Basin 51. Hennessey (estimated yield of 18,819 AFY) and Navinia (34,615 AFY estimated yield) in Basin 64 of the Central Watershed Planning Region; Hydro (114,934 AFY yield) in Basin 59 in the West Central Watershed Planning Region; and Sheridan (23,525 AFY yield) and Skeleton (41,448 AFY yield) in Basin 63 of the Upper Arkansas Watershed Planning Region. The Hydro Reservoir site is approximately 20 miles from the center of Basin 51; the Hennessey, Navina, Sheridan, and Skeleton Reservoir sites are approximately 35-45 miles from the center of Basin 51. These sites also might be considered for potential regional water supply projects.

Regionalization of public water supply systems may provide an avenue for long-term implementation of major out-of-basin supplies. For purposes of this report, regionalization is defined as the shared development of and use of water supplies and the required diversion, conveyance, storage, and treatment infrastructure between two or more public water supply systems. Sharing of infrastructure, particularly for projects involving long transmission pipelines, can reduce the costs for each participant due to economies of scale. For example, conveyance of 50 million gallons per day of water could be accomplished through three individual pipelines: a 12-inch diameter pipeline, a 15-inch diameter pipeline, and a 42-inch diameter pipeline. That same flow could be conveyed through a single 48-inch diameter pipeline at roughly two-thirds the cost per mile of pipe. However, regionalization does not always reduce overall project costs and may not make economic sense depending on local and project-specific conditions. In particular, the closer two providers' distribution systems are, the more cost-effective a shared project will be.

Operational efficiencies are possible with regionalization in areas such as:

- Overnight and emergency plant staffing
- Maintenance equipment and staff
- Monitoring and reporting
- Water quality sampling and lab analyses/lab facilities
- Permitting and reporting
- Administration

At the same time, potential issues in sharing of supplies and infrastructure can bring challenges such as:

- Autonomy in decision-making and control:
  - Source of supply and capital cost decisions
  - Operational decisions (e.g., rates, drought restrictions)
- Institutional framework (new water supply district/authority vs. wholesale relationship)
- Differing needs (unequal rates of growth, condition of existing infrastructure, etc.)
- Water quality compatibility between sources
- Capital costs of interconnecting systems
- Funding/financing capabilities and methods

Throughout the Central Watershed Planning Region, there are already numerous examples of inter-provider arrangements to share water supplies on a wholesale basis, as documented in the *Central Watershed Planning Region Report*. Often, regionalization projects are initiated by or involve larger providers in the area, for example Oklahoma City sells water to El Reno and others. Opportunities for regional supply between these providers and smaller providers, particularly those whose service areas are adjacent and for major out of basin supply projects, could be considered as a means of addressing the significant supply challenges facing the water users in Basin 51.

The OCWP *Water Conveyance Study* updated information from the 1980 OCWP statewide water conveyance system that encompasses Basin 51. The conveyance systems require additional reservoirs, hundreds of miles of piping, canals, and inverted siphons, and many pumping plants. Study results determined that construction of the entire system would not be feasible under current technology and economic constraints. However, certain segments, such as additional conveyance of water from southeast to central Oklahoma, are currently under consideration.

10.2.3 Reservoir Use

Additional reservoir storage in Basin 51 could supplement supplies during dry months. However, surface water in the basin is fully allocated, limiting diversions to existing permitted amounts. If permittable, the entire increase in demand from 2010 to 2060 could be supplied by a new river diversion and 19,500 AF of reservoir storage at the basin outlet. The use of multiple reservoirs in the basin or upstream of the basin's outlet may increase the amount of storage necessary to mitigate future gaps and storage depletions.

The OCWP *Reservoir Viability Study* evaluated the potential for reservoirs throughout the state; no viable sites were identified in Basin 51.

10.2.4 Increasing Reliance on Surface Water

Surface water in the basin is fully allocated, limiting diversions to existing permitted amounts. There is a high probability of surface water gaps in Basin 51 starting in 2020 for the baseline demand projections. If permits could be issued, increasing reliance on surface water use without reservoir storage would increase these gaps. Therefore, this water supply option is not recommended.

10.2.5 Increasing Reliance on Groundwater

The North Canadian River and Canadian River alluvial aquifers are the primary source of water supply in Basin 51, comprising 59 percent of the total demand. Under baseline demand, storage depletions are expected to occur in these aquifers due largely to the growth in the Municipal and Industrial and Thermoelectric Power demand sectors. The projected growth in surface water use could instead be supplied by the North Canadian River or Canadian River alluvial aquifers, which would result in moderate (520 AFY) increases in projected alluvial groundwater storage depletions. Due to the alluvial aquifers' connection to river flows and precipitation, aquifer levels may also fluctuate naturally due to prolonged periods of drought or above-average precipitation. While increased use of alluvial water would increase the amount of alluvial groundwater storage depletions, the depletions would be minimal compared to the total amount of water in storage. Therefore, the development of additional alluvial groundwater supplies to meet the growth in surface water demand could be considered a long-term water supply option, but may require additional infrastructure and increased operation and maintenance costs for sustained reliability. Over a long-term period, demand management and other supply options may provide more consistent supplies and may be more cost-effective.

Bedrock groundwater supplies are from the El Reno minor aquifer; therefore, increased reliance on these supplies is not recommended without site-specific information.

The Aquifer Recharge Workgroup identified a site near El Reno (site # 27) as potentially feasible for aquifer recharge and recovery. Water could potentially be withdrawn from the North Canadian River to recharge the North Canadian alluvial terrace aquifer. However, there was not sufficient water available for new permits so a detailed analysis was not completed for this site.

10.2.6 Marginal Quality Water

The OCWP *Marginal Quality Water Issues and Recommendations* report identified areas where there is potential for use of marginal quality water to offset a significant amount of future demand. Basin 51 was found to have significant brackish marginal quality groundwater sources that could be used to meet a portion of the basin's Municipal and Industrial and Livestock demand. These groundwater sources are typically deeper than fresh water aquifers and not associated with delineated aquifers. The use of these supplies for Municipal and Industrial demand may require advanced treatment processes, such as reverse osmosis (RO) or ion exchange. OWRB does not have regulatory authority to permit withdrawals of groundwater with TDS concentrations greater than 5,000 mg/L. 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. Brackish groundwater underlies the entire basin and should be evaluated as a potential short- to long-term water supply option. However, these supplies will likely be less preferable than supplies from the lower-salinity North Canadian River aquifer.

10.3 Summary

Six categories of supply options for mitigating the projected surface water gaps and groundwater storage depletions in Basin 51 is summarized in Table 10-4. Five options were potential short or long-term options: demand management, marginal quality water sources, out-of-basin supplies, increasing reliance on groundwater, and reservoir use.

Table 10-4. Summary of Water Supply Options for Basin 51

Water Supply Option	Option	Feasibility
Demand Management	• Moderately expanded conservation for Municipal and Industrial sector and increased Crop Irrigation efficiency • Substantially expanded Municipal and Industrial conservation measures and shift to crops with lower water demand	• Short- to long-term solution that may significantly reduce or eliminate surface water gaps and groundwater storage depletions
Out-of-Basin Supplies	• Potential reservoir sites in other basins may provide supplies. Terminal storage in-basin could reduce the size of the pipe needed to convey supplies in basin.	• Potential long-term solution
Reservoir Use	• Development of new reservoirs	• Potential long-term solution; surface water is fully allocated and additional analyses would be required
Increasing Reliance on Surface Water	• Increasing reliance on surface water supplies, without reservoir storage	• Not feasible
Increasing Reliance on Groundwater	• Increasing reliance on North Canadian River and Canadian River alluvial aquifers	• Long-term solution; may have localized adverse impacts
Marginal Quality Water	• Use brackish groundwater sources for Crop Irrigation	• Use brackish groundwater sources for Livestock or, with treatment, for Municipal and Industrial demand

Section 11
Basin 54 (Upper North Canadian River - 3)

Basin 54, located in the Panhandle Watershed Planning Region, is a bedrock groundwater hot spot, where storage depletions are expected to present water supply challenges based on the overall size of the depletions and for the rate of those depletions relative to the amount of groundwater storage in the Ogallala aquifer. Shortages in the basin are in large part driven by the significant seasonal demand of the area's Crop Irrigation practices. More detailed information on this basin is available in the OCWP *Panhandle Watershed Planning Region Report*. In addition to bedrock groundwater storage depletions, alluvial groundwater storage depletions may occur in Basin 54 by 2020 and surface water gaps may occur by 2030. Surface water is also fully allocated. This section describes the driving factors for this basin being identified as a hot spot, provides an analysis of how to address supply availability issues, and evaluates identified water supply options.

11.1 Basin Description

Basin 54 is primarily located in Ellis County with a small portion in Woodward County. The Panhandle Watershed Planning Region borders the western edge of the central Great Plains and has a generally mild climate. The terrain is flat, with wide sandy river bottoms. The region's average monthly temperatures vary from 33°F in January to 79°F in July. Annual evaporation ranges in the region range from 56 to 64 inches. Rainfall averages about 20 inches per year.

11.1.1 Surface Water Supplies

Surface water supplies were used to meet less than 1 percent of the total demand in Basin 54 in 2010. Wolf Creek is the largest surface water supply source in the basin. No public water providers currently have permitted surface water supplies in this basin or the Panhandle Region. The flow in Wolf Creek upstream of the North Canadian River varies seasonally, as shown in Figure 11-1, where flow is typically less than 500 AF/month in the late summer and fall and greater than 1,500 AF/month in winter, spring, and early summer. However, the river can have periods of low flow in any month of the year.

Wolf Creek is regulated by Fort Supply Lake, which is located at the basin outlet. The reservoir was built in 1942 and is operated by USACE. The 13,900 AF lake is used for flood control and conservation storage. The reservoir does have 400 AF of storage dedicated to water supply yield (224 AFY) that is currently available for new users.

Relative to other basins in the state, the surface water quality in Basin 54 is considered fair. Surface water impairments in the Panhandle Watershed Planning Region have occurred due to alterations of streamflow. No streams within Basin 54 are impaired for agriculture or potable water use according to the 303d Impaired Stream List.

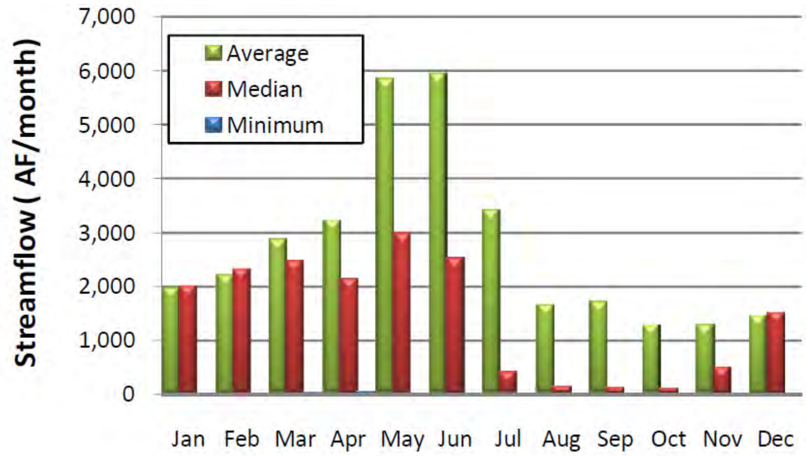

Figure 11-1. Monthly Streamflow Statistics over the Period of Record

11.1.2 Groundwater Supplies

Groundwater supplies were used to meet 99 percent of the total demand in this basin in 2010. Figure 11-2 illustrates the aquifers and existing groundwater permits in Basin 54.

Bedrock groundwater is the primary source of water and supplied about 95 percent of the 2010 total demand in Basin 54. About 96 percent of the groundwater rights in the basin are in the Ogallala bedrock aquifer. The majority of the remaining water rights are in minor, non-delineated groundwater aquifers. These aquifers have not been studied; therefore, no information on storage, yield, or recharge is available. Site-specific information on the suitability of these minor aquifers for supply should be considered before large-scale use.

The Ogallala aquifer, or High Plains aquifer, is a very large aquifer extending north through Kansas and Nebraska and south into Texas. Oklahoma's portion of the aquifer is a small portion of the overall aquifer, but is a very important supply source. The Ogallala commonly yields 500 to 1,000 gpm. Water quality of the aquifer is generally very good. In local areas, water quality has been impaired by high concentrations of nitrate. Up to 1.4 AFY/acre of dedicated lands overlying the aquifer may be withdrawn through regular permits. There are an estimated 663,700 AFY of remaining groundwater rights, which is not expected to be limited by the availability of new permits for local demand through 2060.

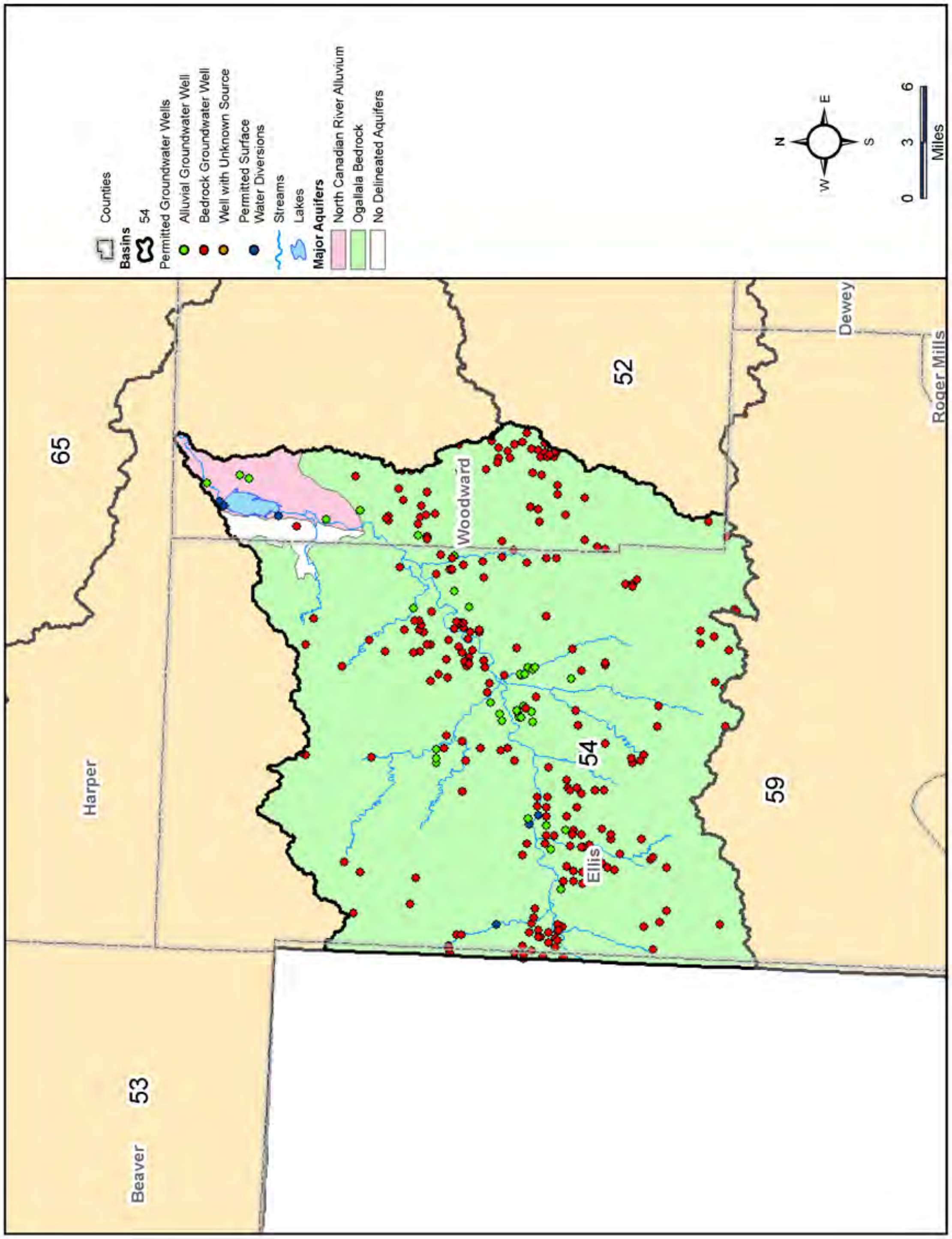

Figure 11-2. Groundwater Supplies in Basin 54

Alluvial groundwater rights are supplied by the North Canadian River Aquifer (major alluvial) and non-delineated minor aquifers. The North Canadian River Aquifer underlies Wolf Creek about 15 miles upstream of the outlet of the basin (as shown in Figure 11-2). There are currently 800 AFY of groundwater rights in the North Canadian River Aquifer. Up to 1.0 AFY/acre of dedicated lands overlying the aquifer may be withdrawn through regular permits. There are an estimated 17,400 AFY of remaining groundwater rights, which is not expected to be limited by the availability of new permits for local demand through 2060. The non-delineated groundwater sources have not been studied; therefore, no information on storage, yield, or recharge is available. Site-specific information on the suitability of these minor aquifers for supply should be considered before large-scale use.

11.1.3 Water Demand

From the OCWP *Water Demand Forecast Report*, the total demand for this basin in 2060 is projected to be 30,400 AFY, an increase of 60 percent from 2010 to 2060. The projected total demand in Basin 54 is presented in **Figure 11-3**. The majority of demand and growth in demand over this period is projected to be in the Crop Irrigation demand sector. Crop Irrigation occurs throughout the basins, as shown in **Figure 11-4**. There is also substantial growth in demand projected for the Oil and Gas demand sector.

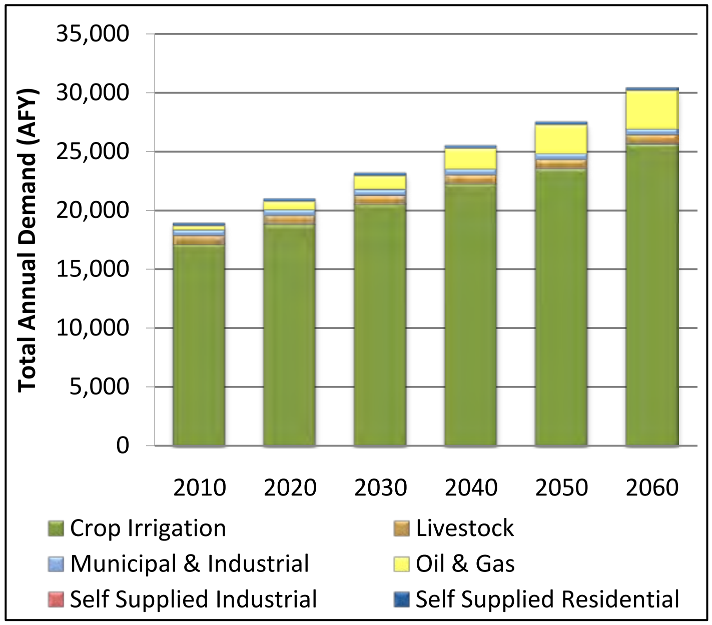

Figure 11-3. Total Demand by Sector in Basin 54

Bedrock groundwater is the primary source of water (about 95 percent of total demand). Bedrock groundwater use in Basin 54 was 18,000 AFY in 2010 and is projected to increase by 59 percent (10,690 AFY) by 2060. Crop Irrigation is the dominant water use, which is consistent with the total demand. Crop Irrigation has a high demand in summer months and little or no demand in winter months. As a result, the peak summer month demand in Basin 54 is about 40 times the winter demand, which is much more pronounced than the overall statewide pattern. There is expected to be significant water supply challenges for users of the Ogallala aquifer.

Alluvial groundwater supplies were used to meet about 5 percent of the total demand in 2010, while surface water supplied less than 1 percent of the total demand. The majority of water use from alluvial groundwater is from the Crop Irrigation demand sector, while the majority of surface water use is projected to be from the Oil and Gas demand sector.

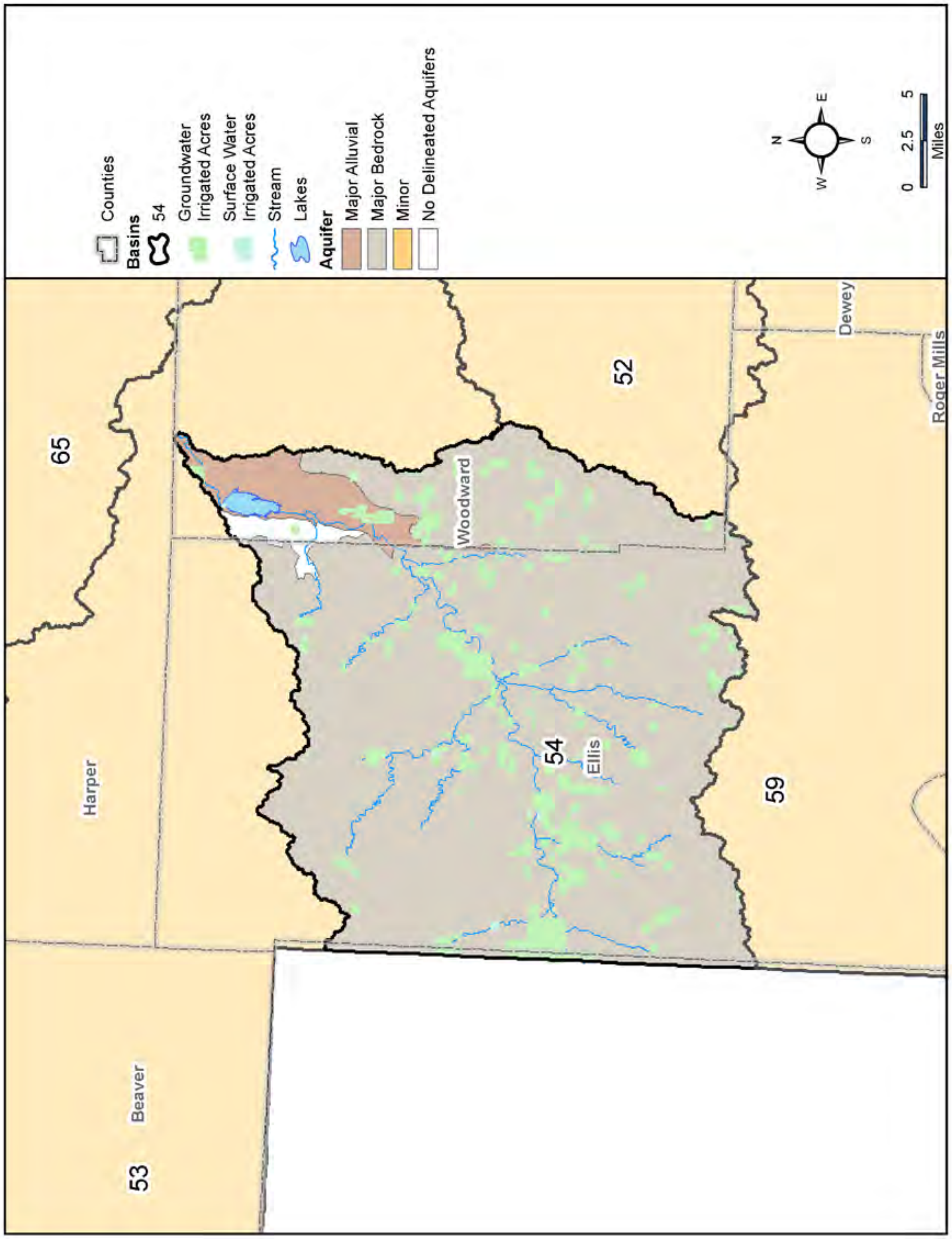

Figure 11-4. Distribution of Irrigated Land in Basin 54

11.1.4 Gaps and Depletions

Based on projected demand and historical hydrology, groundwater storage depletions are projected to occur by 2020, while surface water gaps are expected by 2030. Surface water gaps in Basin 54 may occur throughout the year. Surface water gaps in 2060 will be up to 20 AF/month, which is 50 percent of the surface water demand in the peak summer month and 67 percent of the winter months' surface water demand. By 2060, there will be a 71 percent probability of gaps occurring in at least one month of the year and are most likely to occur during summer and fall months.

Alluvial groundwater storage depletions in Basin 54 may occur throughout the year, peaking in size during the summer. Alluvial groundwater storage depletions in 2060 will be up to 33 percent (120 AF/month) of the alluvial groundwater demand in the peak summer month. Alluvial groundwater storage depletions during winter months, while much smaller in size (10 AF/month), may represent the entire alluvial groundwater demand. By 2060, there will be a 74 percent probability of storage depletions occurring in at least one month of the year and are most likely to occur during the summer and fall months.

Bedrock groundwater storage depletions in Basin 54 may occur in spring, summer, and fall, peaking in size during the summer. Bedrock groundwater storage depletions in 2060 will be 35 percent (2,740 AF/month) of the bedrock groundwater demand on average in the peak summer month, and 35 percent (950 AF/month) on average of the spring months' bedrock groundwater demand.

11.2 Analysis of Supply Options

Six categories of supply options for mitigating the projected surface water gaps and groundwater storage depletions in Basin 54 are described in the text below. The six water supply options represent the basic ways to develop additional water supplies for all users in the basin. All options should be reviewed, as a combination of supply options will likely be needed to meet the basin's water supply challenges.

11.2.1 Demand Management

The demand management option considers permanent conservation measures and temporary drought restrictions. Moderately expanded and substantially expanded conservation measures were evaluated for both the Municipal and Industrial and Crop Irrigation demand sectors. The conservation scenarios are described briefly in Table 11-1, but the OCWP *Water Demand Forecast Report* provides full descriptions of the conservation measures considered. It is recommended that the basin consider additional permanent conservation activities, instead of temporary drought management activities, due to the high probability of gaps and since aquifer storage could continue to provide supplies during droughts. Therefore, temporary drought management was not evaluated.

Table11-1. Summary of OCWP Conservation Scenarios (Source: OCWP *Water Demand Forecast Report*)

Demand Sector	Conservation Scenario	Description
Municipal and Industrial	Scenario I Moderately Expanded Conservation	• Passive conservation achieved by 2060 for PSR and 2030 for PSNR. Passive conservation is defined as conservation that can be achieved through government plumbing codes as part of the Energy Policy Act. • 90 percent of water providers in each county will meter their customers, unless current metered percentage is greater than 90 percent. • NRW will be reduced to 12 percent, where applicable • Conservation pricing will be implemented by 20 percent of purveyors in rural counties, 40 percent in mostly urban counties, and 60 percent in counties with high metropolitan populations. • Water conservation educational programs will be implemented by all providers, which include billing inserts and conservation tip websites to reduce demands by 3 percent.
	Scenario II Substantially Expanded Conservation	• Passive conservation (as described in Scenario I) • All purveyors will meter their customers. • NRW will be reduced to 10 percent where applicable. • Conservation pricing will be implemented by 60 percent of purveyors in rural counties, 80 percent in mostly urban counties, and 100 percent in counties with high metro populations. • Water conservation education programs will be implemented to reduce demands by 5 percent including school education programs and media campaigns in addition to billing inserts and a conservation tip website. • High efficiency plumbing code ordinance will be implemented. This ordinance requires use of high efficiency fixtures with lower maximum flow rates than those required under the Energy Policy Act.
Agricultural Irrigation	Scenario I Moderately Expanded Conservation	• All sprinkler systems will have a field application efficiency of 90 percent beginning in 2015, representing implementation of LEPA nozzles on existing sprinkler systems. • Water saved through conservation activities is not applied to a water scheme elsewhere, such as expanding the number of irrigated acres, thus achieving true conservation.
	Scenario II Substantially Expanded Conservation	• All assumptions from Scenario I are applicable. • All acres of water intensive crops (corn for grain and forage crops, including alfalfa and pasture grass), shift to less water intensive crops (grain for sorghum) beginning in 2015. While is it highly unlikely that all water intensive crop production will stop, this assumption allows for analysis of full implementation of the "what-if" scenario.

Scenario I Conservation Measures

Moderately expanded permanent conservation activities (Scenario I) in the Municipal and Industrial and Crop Irrigation demand sectors could reduce surface water gaps by about 6 percent and groundwater storage depletions by about 15 percent. Implementing Scenario I Municipal and Industrial conservation measures decreases the projected demand in Basin 54 from 500 AFY to 460 AFY. Implementing Scenario I Crop Irrigation conservation measures decreases the projected demand in Basin 54 from 25,600 AFY to 24,200 AFY. Implementing additional conservation in both sectors is only expected to reduce the surface water gap by 10 AFY (6 percent) to 150 AFY. Implementing additional conservation in both sectors could reduce the alluvial groundwater storage depletions by 50 AFY (13 percent) to 340 AFY. Implementing additional conservation in both sectors could reduce the bedrock groundwater storage depletions by 1,390 AFY (15 percent) to 7,720 AFY.

Table 11-2 lists the irrigated acreage affected by Scenario I conservation measures. Under Scenario I conservation activities, the probability of surface water gaps and storage depletions remains nearly unchanged, due to the high frequency of low to no-flow months.

Table 11-2. Acreage of Sprinkler Irrigated Lands Converted to High Efficiency LEPA Nozzles

County	Irrigated Land (thousand acres) [1]
Ellis	13
Woodward	8

1 Acreage represents the irrigated land in the entire county for 2007, not just the portion in Basin 54.

Moderately expanded conservation measures could provide a water supply solution in a relatively short period of time and could be implemented throughout the basin. Additional Municipal and Industrial use conservation measures, if implemented, will have little overall effect on gaps and storage depletions. However, these measures may help reduce gaps and adverse effects of localized storage depletions for public water providers and individual irrigators throughout the basin.

Scenario II Conservation Measures

Scenario II conservation measures would require crop shifts throughout the basin, typically switching from water intensive crops (e.g., corn for grain, pasture greases, etc.) to grain sorghum and wheat, as well as the increase in irrigation efficiencies from Scenario I. The substantially expanded conservation measures include conversion of approximately 10,359 acres from corn for grain and forage crops to sorghum in the counties encompassing Basin 54 as indicated in **Table 11-3**. The OCWP *Water Demand Forecast Report* recognizes that crop shifting is unlikely to occur unless crop managers are faced with severe water shortages, high pumping costs, or implementation of policies that provide incentives to do so.

Table 11-3. Acreage of Crops Converted to Sorghum for Substantially Expanded Conservation Activities

County	Corn for Grain (acres) [1]	Forage Crops including Alfalfa and Pasture Grass (acres) [1]
Ellis	387	7,960
Woodward	310	1,702

1 Acreage represents the entire county, not just the portion in Basin 54.

Scenario II conservation in the Municipal and Industrial demand sector would expand on the conservation measures implemented in Scenario I and require the implementation of a high efficiency plumbing code ordinance. Table 11-1 provides additional information on Scenario II conservation measures.

Scenario II Municipal and Industrial conservation measures decrease the projected 2060 Municipal and Industrial demand from 500 AFY to 400 AFY and Crop Irrigation demand decreases from 25,610 AFY to 15,440 AFY. The combined demand reduction in both sectors may decrease 2060 surface water gaps by 60 AFY to 100 AFY, a 38 percent reduction from the maximum 2060 value. Alluvial groundwater storage depletions may be decreased by 330 AFY in Basin 54 to 60 AFY, an 85 percent reduction from the maximum 2060 value. Bedrock groundwater storage depletions in 2060 may be reduced by 9,040 AFY to 70 AFY, a 99 percent reduction from the maximum 2060 value. Reductions are expected to decrease the probability of gaps and alluvial groundwater storage depletions to approximately 20 percent.

Scenario II conservation measures would require substantial changes in the agricultural economy throughout the basins. Therefore, this water conservation measure would likely take a relatively long period of time to implement. However, shifting crop types could aid individual irrigators in the short-term.

11.2.2 Out-of-Basin Supplies

The City of Woodward, which is located partially within Basin 54, has existing permitted withdrawals from the North Canadian River alluvial aquifer in Basin 52 that is transferred through its distribution system. Increased reliance on this source could be used to meet Woodward's portion of the future Municipal and Industrial demand. Woodward and other public water providers in the basin could consider the transfer of supplies through wholesale water sales/purchases, which could help distribute the cost of new supplies and infrastructure. However, substantial infrastructure may be needed to connect the public water providers in Basin 54 which are currently not inter-connected.

Development of new out-of-basin supplies would be among the most costly of options, but could eliminate the potential for surface water gaps and groundwater depletions. The development of out-of-basin supplies should be considered as a long-term water supply option for users throughout the basin. However, due to the scale and complexity of developing out-of-basin supplies, the cost-effectiveness of these supplies needs to be evaluated against other options on a local level.

The OCWP *Reservoir Viability Study* identified two potential reservoir sites in the Panhandle Watershed Planning Region: Forgan (Category 3) and Englewood (Category 4) Reservoirs, both located on the Cimarron River in Basin 65. Englewood Reservoir would be 45 miles or more away from the majority of users in Basin 54, but could provide an estimated dependable yield of 36,967 AFY from 424,400 AF of total storage. This reservoir also would require approval of the Kansas-Oklahoma Arkansas River Compact Commission. With new terminal storage of about 5,000 AF, a 30-inch diameter pipe would be needed to bring out-of-basin supplies at a constant flow rate into Basin 54 for further distribution to users. With no terminal storage and variable flows in the pipeline, a 48-inch diameter pipeline would be needed. The reservoir would yield more water than needed to meet Basin 54's demands, thus the site could be considered as a potential regional project.

The beneficial use of Englewood Reservoir, without treatment, would likely be limited to crop irrigation due to high concentrations of chlorides and sulfates. Construction of the reservoir as well as complications with distributing water to individual irrigators hinders its feasibility. However, its relative proximity to the basin and generally centralized demand locations make this alternative worth considering.

Regionalization of public water supply systems may provide an avenue for long-term implementation of major out-of-basin supplies. For purposes of this report, regionalization is defined as the shared development of and use of water supplies and the required diversion, conveyance, storage, and treatment infrastructure between two or more public water supply systems. Sharing of infrastructure, particularly for projects involving long transmission pipelines, can reduce the costs for each participant due to economies of scale. For example, conveyance of 50 million gallons per day of water could be accomplished through three individual pipelines: a 12-inch diameter pipeline, a 15-inch diameter pipeline, and a 42-inch diameter pipeline. That same flow could be conveyed through a single 48-inch diameter pipeline at roughly two-thirds the cost per mile of pipe. However, regionalization does not always reduce overall project costs and may not make economic sense depending on local and project-specific conditions. In particular, the closer two providers' distribution systems are, the more cost-effective a shared project will be.

Operational efficiencies are possible with regionalization in areas such as:

- Overnight and emergency plant staffing
- Maintenance equipment and staff
- Monitoring and reporting
- Water quality sampling and lab analyses/lab facilities
- Permitting and reporting
- Administration

At the same time, potential issues in sharing of supplies and infrastructure can bring challenges such as:

- Autonomy in decision-making and control:
  — Source of supply and capital cost decisions
  — Operational decisions (e.g., rates, drought restrictions)
- Institutional framework (new water supply district/authority vs. wholesale relationship)
- Differing needs (unequal rates of growth, condition of existing infrastructure, etc.)
- Water quality compatibility between sources
- Capital costs of interconnecting systems
- Funding/financing capabilities and methods

Throughout the Panhandle Watershed Planning Region, there are already numerous examples of inter-provider arrangements to share water supplies on a wholesale basis, as documented in the OCWP *Panhandle Watershed Planning Region Report*. Often, regionalization projects are initiated by or involve larger providers in the area, for example Woodward County Rural Water District #1 sells to Freedom. Opportunities for regional supply between larger and smaller providers, particularly those whose service areas are adjacent and for major out of basin supply projects, could be considered as a means of addressing the significant supply challenges facing the water users in Basin 54.

The OCWP *Water Conveyance Study* updated information from the 1980 OCWP statewide water conveyance system that encompasses Basin 54. The conveyance systems require additional reservoirs, hundreds of miles of piping, canals, and inverted siphons, and many pumping plants. Study results determined that this option would not be feasible under current technology and economic constraints, but may be considered as a long-term opportunity for the future.

11.2.3 Reservoir Use

Fort Supply Lake is located at the basin outlet and was built for flood control and conservation storage. The reservoir has a normal pool storage capacity of 13,900 AF, which includes 400 AF of water supply storage yielding 224 AFY. Fort Supply Lake is operated by the U.S. Corps of Engineers and may provide additional supplies in the future.

Additional reservoir storage could mitigate surface water gaps. The flow in Basin 54 has been fully permitted and is expected to severely limit the size and location of new reservoirs. However, if permittable, a river diversion and 200 AF of reservoir storage at the basin outlet could supply the entire increase in surface water use through 2060. The use of multiple reservoirs in the basin or reservoirs upstream of the basin outlet may increase the amount of storage necessary to mitigate future gaps. A detailed analysis is needed to determine the feasibility of using reservoir storage to meet future groundwater demands.

The OCWP *Reservoir Viability Study* evaluated the potential for new reservoirs throughout the state; no viable new sites were identified for construction in Basin 54.

11.2.4 Increasing Reliance on Surface Water

Surface water in the basin is fully allocated, limiting diversions to existing permitted amounts. There is a moderate to high probability of surface water gaps starting in 2030 for the baseline demand projections. Increasing reliance on surface water use, if permits could be issued, would increase the size and probability of these gaps. Therefore, this water supply option is not recommended.

11.2.5 Increasing Reliance on Groundwater

The Ogallala bedrock aquifer is the primary source of water in Basin 54, supplying up to 95 percent of the total water demand. Water levels in Basin 54's portion of the Ogallala aquifer have remained relatively constant or have been increasing in recent years (OWRB Mass Well Measurement 2011). Under baseline demand, storage depletions are expected to increase due largely to the growth in Crop Irrigation demand. The projected growth in surface water and alluvial groundwater use could instead be supplied by the Ogallala aquifer, which would result in small (550 AFY) increases in projected storage depletions. Additionally, some Municipal and Industrial water users could consider obtaining wholesale water supplies from water providers with wells in more dependable portions of the Ogallala aquifer. While the storage depletion is minimal compared to the amount of water in storage, these localized storage depletions may adversely affect users' yields, water quality, and pumping costs. Therefore, the development of additional bedrock groundwater supplies to meet the growth in surface water and bedrock groundwater could be considered a long-term water supply option, but may require additional infrastructure and operation and maintenance costs for sustained reliability. Over a long-term period, demand management and other supply options may provide more consistent supplies and may be more cost-effective.

Use of alluvial groundwater instead of increasing surface water use would increase alluvial groundwater storage depletions by 100 AFY by 2060. However, the majority of alluvial groundwater use is from non-delineated minor aquifers on Wolf Creek. Therefore, increased reliance on these supplies is not recommended without site-specific information.

The OCWP *Artificial Aquifer Recharge Issues and Recommendations* report identified a site near the City of Woodward (site #2) as potentially feasible for aquifer recharge and recovery. Water could be withdrawn from the Upper North Canadian River to recharge the Ogallala aquifer. Further study of ASR feasibility and pilot testing may be warranted for this location.

11.2.6 Marginal Quality Water

The OCWP *Marginal Quality Water Issues and Recommendations* report identified areas where there is potential for use of marginal quality water to offset a significant amount of future demand. However, Basin 54 was not found to have significant marginal quality water sources or significant potential to offset demand with marginal quality water. The Oil and Gas demand sector could potentially use marginal quality water from oil and gas flowback or produced water for drilling and operational activities. Opportunities to reuse flowback or produced water should be considered on an individual well field basis for cost-effectiveness relative to other available supplies.

11.3 Summary

Six categories of supply options for mitigating the projected surface water gaps and groundwater storage depletions in Basin 54 is summarized in **Table 11-4**. Four options were potential short or long-term options: demand management, out-of-basin supplies, increasing reliance on groundwater, and reservoir use.

Table 11-4 Summary of Water Supply Options for Basin 54

Water Supply Option	Option	Feasibility
Demand Management	• Moderately expanded Municipal and Industrial conservation measures and increased sprinkler irrigation efficiency • Significantly expanded Municipal and Industrial conservation measures and shift to crops with lower water demand	• Short- to long-term solution that could reduce 2060 bedrock groundwater depletions up to 99 percent
Out-of-Basin Supplies	• Englewood Reservoir or Statewide Water Conveyance	• Potential long-term solution
Reservoir Use	• Development of new reservoirs	• Potential long-term solution; additional analyses needed
Increasing Reliance on Surface Water	• Increasing reliance on surface water supplies, without reservoir storage	• Not feasible
Increasing Reliance on Groundwater	• Increasing reliance on the Ogallala aquifer	• Long-term solution; will have adverse localized impacts
Marginal Quality Water	• Use of marginal quality water sources	• No significant sources identified; site-specific potential for reuse of oil and gas flowback and produced water for oil and gas drilling and operations

Section 12
Basin 55 (North Canadian Headwaters) and Basin 66 (Cimarron Headwaters) Hot Spot Analysis

Basins 55 and 66 (Cimarron Headwaters), located in the Panhandle Watershed Planning Region, are adjacent basins with very similar water supply needs and resources; therefore, they were evaluated as a single hot spot. Basins 55 and 66 are bedrock groundwater hot spots and Basin 66 is also a surface water hot spot. Storage depletions in both basins are expected to present water supply challenges based on the overall size of the depletions and for the rate of those depletions relative to the amount of groundwater storage in the Ogallala aquifer. Surface water issues in Basin 66 are mainly due to the basin's low physical availability of streamflow and lack of available streamflow for new permits. Shortages in the basins are in large part driven by the significant seasonal demand of the area's Crop Irrigation practices. More detailed information on these basins is available in the OCWP *Panhandle Watershed Planning Region Report*. In addition to challenges noted, surface water gaps and alluvial groundwater storage depletions may occur in Basin 55 by 2020 and alluvial groundwater storage depletions may occur in Basin 66 by 2050. This section describes the driving factors for these basins being identified as a hot spot, provides an analysis of how to address supply availability issues, and evaluates identified alternatives.

12.1 Basin Description

Basins 55 and 66 encompass all of Cimarron and Texas counties and the western portion of Beaver County. The Panhandle Watershed Planning Region's terrain is that of the High Plains, which is generally flat. The climate is semi-arid with average annual precipitation of about 20 inches. Annual evaporation is significant, ranging from 56 to 64 inches. The region's average monthly temperatures vary from 33°F in January to 79°F in July.

12.1.1 Surface Water Supplies

Surface water supplies were used to meet less than 1 percent of the total demand in Basins 55 and 66 in 2010. No public water providers currently have permitted surface water supplies in these basins or the Panhandle Region. The Beaver River is the largest surface water supply source in Basin 55. Irrigation has had a significant effect on streamflow in the Beaver River since 1978 (USGS 2009), where streamflow has decreased substantially since the 1970s. The median flow over the period of record in the Beaver River at Beaver, Oklahoma, is about 1,400 AF/month in summer, but only 10 AF/month in fall, as shown in **Figure 12-1**. Irrigation has had a significant effect on streamflow in the Cimarron River since about 1965 (USGS 2009), which is the largest surface water supply source in Basin 66. The median flow in the Cimarron River near Elkhart, Kansas is less than 30 AF/month throughout the year, except in August when it is about 250 AF/month. Surface water in the basin is fully allocated, limiting diversions to existing permitted amounts.

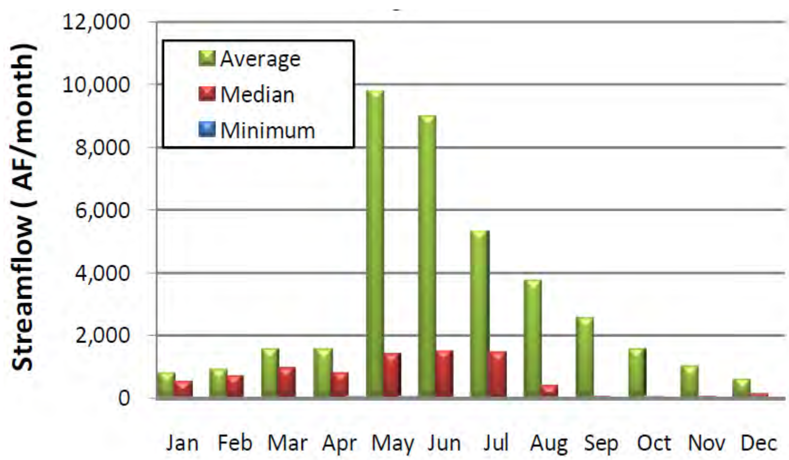

Figure 12-1. Monthly Streamflow Statistics over the Period of Record for Basin 55

Optima Lake regulates flow in the Beaver River at Beaver, Oklahoma (Basin 55). However, this reservoir does not sustain a water supply yield. Construction of the Optima Reservoir was completed in 1978, coinciding with the decreasing aquifer and streamflow levels. According to the USACE website (USACE 2011), the water in the lake has never reached normal pool and at times the lake's level can be very low.

Relative to other basins in the state, the surface water quality in Basins 55 and 66 is considered fair. Surface water impairments in the Panhandle Watershed Planning Region have occurred due to alterations of streamflow. Palo Duro Creek is impaired (303d list) for agricultural use along its entire length in Basin 55. However, individual lakes and streams may have acceptable water quality.

12.1.2 Groundwater Supplies

Groundwater supplies were used to meet 99 percent of the total demand in these basins in 2010. **Figure 12-2** illustrates the aquifers and existing groundwater permits in Basins 55 and 66.

Bedrock groundwater is the primary source of water and supplied about 98 percent of total demand in these basins in 2010. Nearly all of the current groundwater rights are from the Ogallala Aquifer. There is also a small amount of bedrock aquifer rights in non-delineated minor aquifers. These aquifers have not been studied; therefore, no information on storage, yield, or recharge is available. Site-specific information on the suitability of these minor aquifers for supply should be considered before large-scale use.

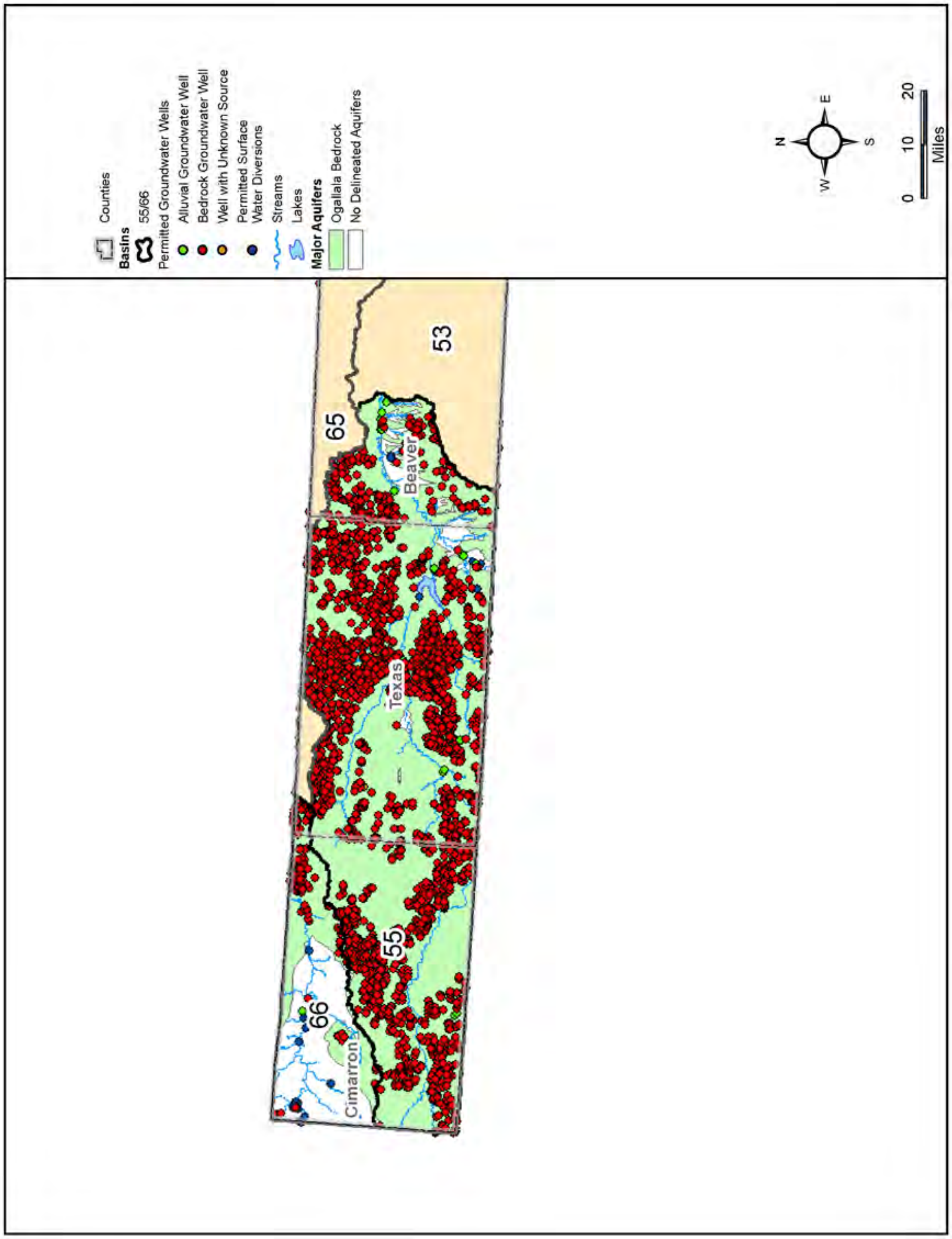

Figure 12-2. Groundwater Supplies in Basins 55 and 66

The Ogallala aquifer, or High Plains aquifer, is a very large aquifer extending north through Kansas and Nebraska and south into Texas. Oklahoma's portion of the aquifer is a small portion of the overall aquifer, but is a very important supply source. The Ogallala aquifer underlies the vast majority of Basins 55 and 66. The Ogallala commonly yields 500 to 1,000 gpm and can yield up to 2,000 gpm in thick, highly permeable areas. Water quality of the aquifer is generally very good (USGS 2000). In local areas, water quality has been impaired by high concentrations of nitrate. In Basins 55 and 66, up to 2.0 AFY/acre of dedicated lands overlying the aquifer may be withdrawn through regular permits. There are an estimated 3,557,300 AFY of remaining groundwater rights in these basins, which is not expected to be limited by the availability of new permits for local demand through 2060.

Alluvial aquifer use is from non-delineated minor aquifers along the Beaver River, Cimarron River, and other tributaries to these major rivers. These aquifers have not been studied; therefore, no information on storage, yield, or recharge is available. Site-specific information on the suitability of these minor aquifers for supply should be considered before large scale use.

12.1.3 Water Demand

From the OCWP *Water Demand Forecast Report*, the total demand for these basins in 2060 is projected to be 335,420 AFY with 312,940 AFY occurring in Basin 55 and 22,480 AFY from Basin 66. The projected total demand in Basin 55 and Basin 66 are presented in Figure 12-3(a) and (b). The majority of demand and growth in demand over this period in Basin 55 and Basin 66 is projected to be in the Crop Irrigation demand sector. Crop Irrigation occurs throughout the basins, as shown in Figure 12-4. Areas of sparser irrigation typically coincide to portions of the Ogallala aquifer with less storage. There is also significant growth in the Self Supplied Residential and Municipal and Industrial demand sectors in Basin 55. There is no Municipal and Industrial use in Basin 66, which is not typical statewide.

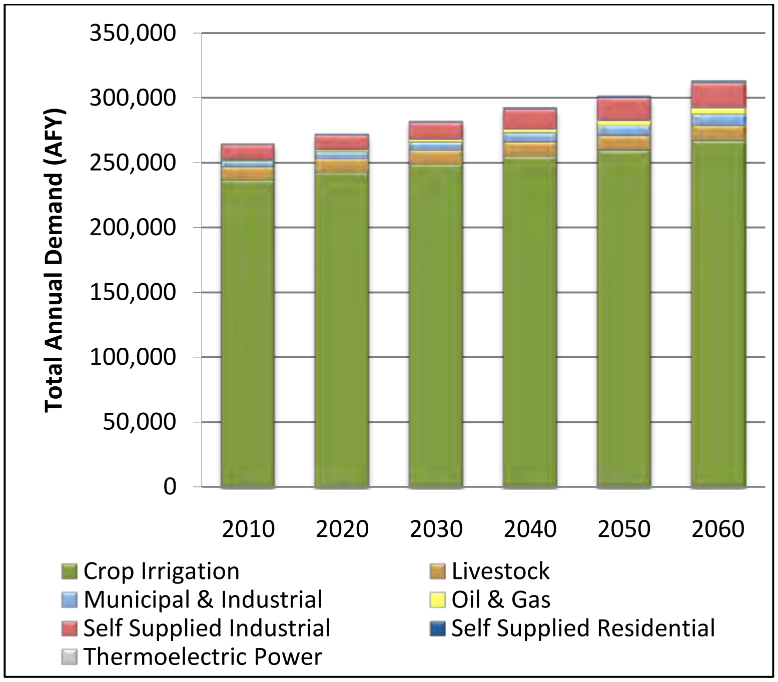

Figure 12-3a. Total Demand by Sector in Basin 55

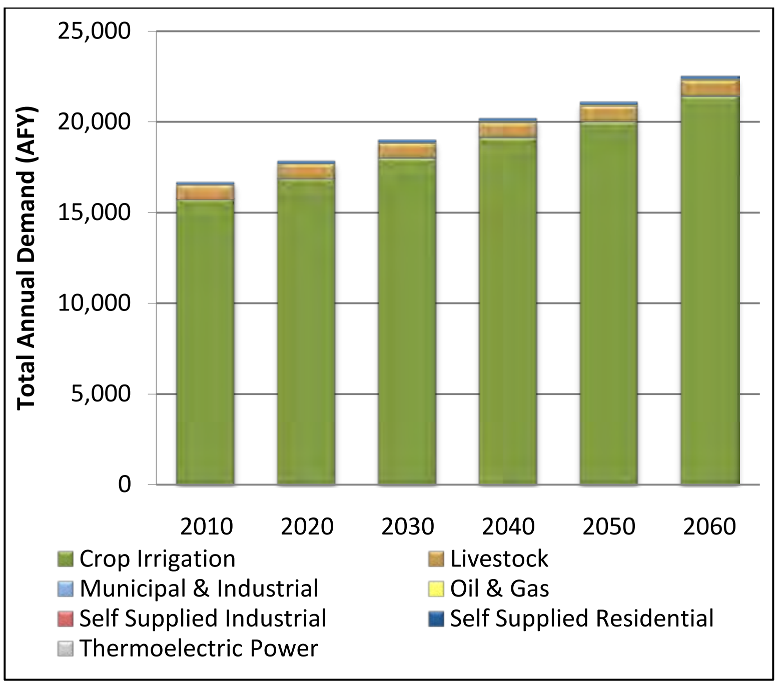

Figure 12-3b. Total Demand by Sector in Basin 66

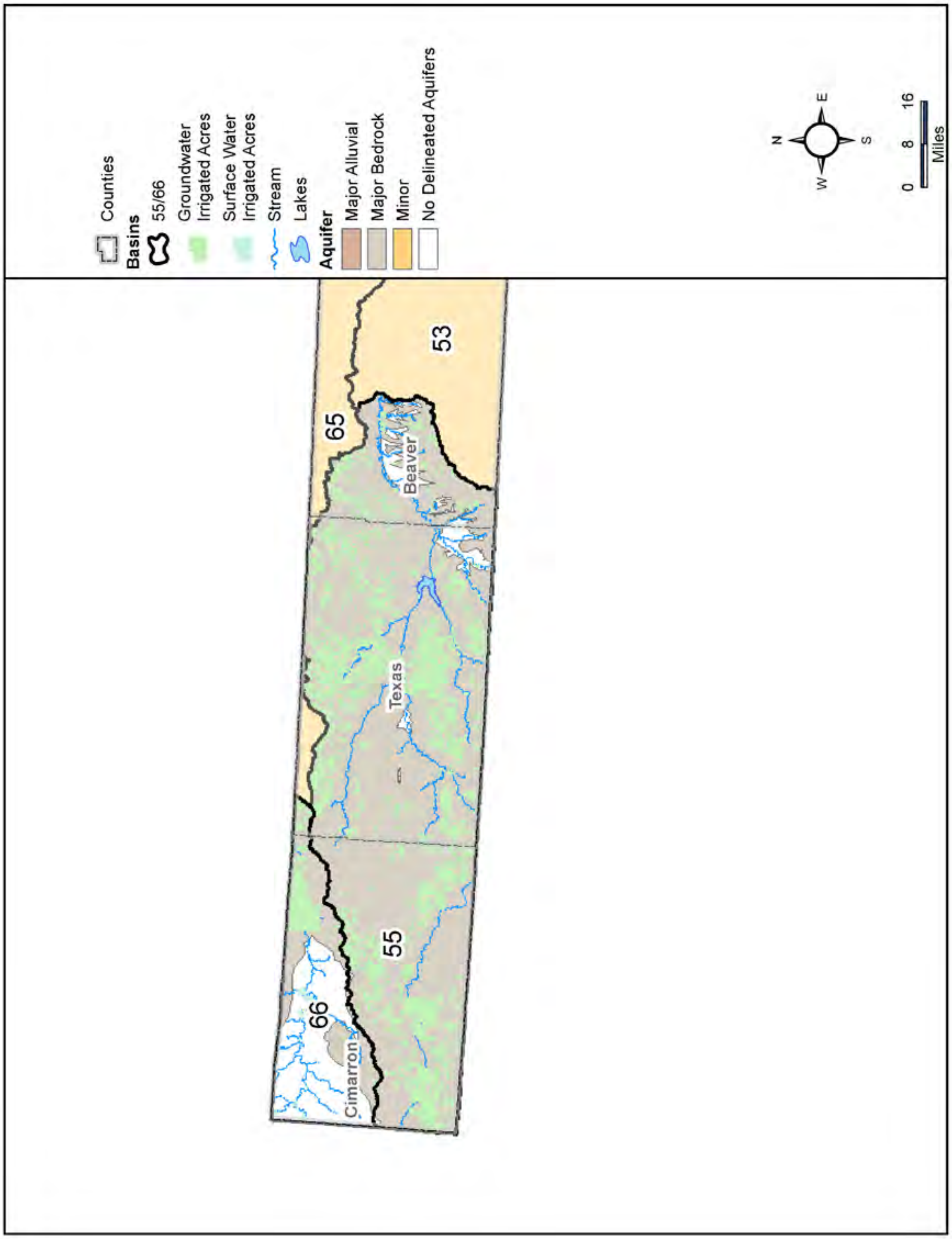

Figure 12-4. Distribution of Irrigated Land in Basins 55 and 66

Bedrock groundwater is the primary source of water (about 98 percent of total demand). Bedrock groundwater use in Basins 55 and 66 was 276,900 AFY in 2010 and s projected to increase by 19 percent (52,410 AFY) by 2060. Crop Irrigation is the dominant water use, which is consistent with the total demand. Crop Irrigation has a high demand in summer months and little or no demand in winter months. As a result, the peak summer month demand in Basin 66 is about 72 times the winter demand and about 35 times the winter demand in Basin 55, which are much more pronounced than the overall statewide pattern.

Surface water and alluvial groundwater supplies were used to meet about 2 percent of the total demand in 2010. The majority of water use from these sources is from the Crop Irrigation demand sector. There is expected to be significant water supply challenges for users of the Cimarron River and its tributaries. Surface water in Basin 66 was used to meet 8 percent of the demand in Basin 66 in 2010 and projected to increase by 34 percent (450 AFY) from 2010 to 2060.

12.1.4 Gaps and Depletions

Based on projected demand and historical hydrology, gaps and storage depletions are projected to occur by 2020. Surface water gaps in Basin 55 may occur throughout the year. Surface water gaps in 2060 will be up to 11 percent (50 AF/month) of the surface water demand in the peak summer month, and as much as 67 percent (20 AF/month) of the winter months' surface water demand. By 2060, there will be a 95 percent probability of gaps occurring in at least one month of the year. Surface water gaps are most likely to occur during winter and summer months.

Alluvial groundwater storage depletions on minor aquifers in Basin 55 may occur throughout the year; peaking in size during the summer. Alluvial groundwater storage depletions in 2060 will be up to 12 percent (80 AF/month) of the alluvial groundwater demand in the peak summer month, and while small in size (10 AF/month), storage depletions will be as much as 50 percent of the winter months' alluvial groundwater demand. By 2060, there will be a 95 percent probability of storage depletions occurring in at least one month of the year. Alluvial groundwater storage depletions are most likely to occur during winter and summer months. Bedrock groundwater storage depletions in Basin 55 may occur throughout the year; peaking in size during the summer.

Bedrock groundwater storage depletions in 2060 will be 13 percent (10,790 AF/month) of the bedrock groundwater demand on average in the peak summer month, and 37 percent (1,250 AF/month) on average of the winter months' bedrock groundwater demand. These storage depletions are in addition to any current storage depletions. Projected annual storage depletions are minimal relative to the storage depletions are minimal relative to the amount of water stored in major aquifers in the basin. However, localized storage depletions may adversely impact users' yields, water quality, or pumping costs.

Based on projected demand and historical hydrology in Basin 66, surface water gaps and bedrock groundwater storage depletions are projected to occur by 2020, while alluvial groundwater storage depletions are expected by 2050. Surface water gaps in Basin 66 may occur during the spring, summer, and fall, peaking in size during the summer. Surface water gaps in 2060 will be up to about 20 percent (120 AF/month) of the surface water demand in the peak summer month, and up to 20 percent (20 AF/month) of the peak spring months' surface water demand. By 2060, surface water gaps will occur in at least one month of every year.

Alluvial groundwater storage depletions in Basin 66 may occur in the summer. Alluvial groundwater storage depletions in 2060 will be up to 33 percent (10 AF/month) of the alluvial groundwater demand in the peak summer month. By 2060, there will be a 66 percent probability of storage depletions occurring in at least one month of the summer. Bedrock groundwater storage depletions in Basin 66 may occur in the spring, summer, and fall.

Bedrock groundwater storage depletions in 2060 will be up to about 25 percent (300 AF/month) of the bedrock groundwater demand on average in the peak spring month, and 25 percent (1,590 AF/month) on average of the peak summer months demand. Projected bedrock groundwater storage depletions are minimal relative to the amount of water stored in major aquifers in the basin. However, localized storage depletions may adversely impact yields, water quality, and/or pumping costs.

12.2 Analysis of Supply Options

Six categories of supply options for mitigating the projected surface water gaps and groundwater storage depletions in Basins 55 and 66 are described in the text below. The six water supply options represent the basic ways to develop additional water supplies for all users in the basin. All options should be reviewed, as a combination of supply options will likely be needed to meet the basins' water supply challenges.

12.2.1 Demand Management

The demand management option considers permanent conservation measures and temporary drought restrictions. Moderately expanded and substantially expanded conservation measures were evaluated for both the Municipal and Industrial and Crop Irrigation demand sectors. The conservation scenarios are described briefly in Table 12-1, but the OCWP *Water Demand Forecast Report* provides full descriptions of the conservation measures considered. It is recommended that the basin consider additional permanent conservation activities, instead of temporary drought management activities, due to the high probability of gaps and since aquifer storage could continue to provide supplies during droughts. Therefore, temporary drought management was not evaluated.

Table 12-1. Summary of OCWP Conservation Scenarios (Source: OCWP *Water Demand Forecast Report*)

Demand Sector	Conservation Scenario	Description
Municipal and Industrial	Scenario I Moderately Expanded Conservation	• Passive conservation achieved by 2060 for PSR and 2030 for PSNR. Passive conservation is defined as conservation that can be achieved through government plumbing codes as part of the Energy Policy Act. • 90 percent of water providers in each county will meter their customers, unless current metered percentage is greater than 90 percent. • NRW will be reduced to 12 percent, where applicable. • Conservation pricing will be implemented by 20 percent of purveyors in rural counties, 40 percent in mostly urban counties, and 60 percent in counties with high metropolitan populations. • Water conservation educational programs will be implemented by all providers, which include billing inserts and conservation tip websites to reduce demands by 3 percent.
	Scenario II Substantially Expanded Conservation	• Passive conservation (as described in Scenario I) • All purveyors will meter their customers. • NRW will be reduced to 10 percent where applicable. • Conservation pricing will be implemented by 60 percent of purveyors in rural counties, 80 percent in mostly urban counties, and 100 percent in counties with high metro populations. • Water conservation education programs will be implemented to reduce demands by 5 percent including school education programs and media campaigns in addition to billing inserts and a conservation tip website. • High efficiency plumbing code ordinance will be implemented. This ordinance requires use of high efficiency fixtures with lower maximum flow rates than those required under the Energy Policy Act.
Agricultural Irrigation	Scenario I Moderately Expanded Conservation	• All sprinkler systems will have a field application efficiency of 90 percent beginning in 2015, representing implementation of LEPA nozzles on existing sprinkler systems. • Water saved through conservation activities is not applied to a water scheme elsewhere, such as expanding the number of irrigated acres, thus achieving true conservation.
	Scenario II Substantially Expanded Conservation	• All assumptions from Scenario I are applicable. • All acres of water intensive crops (corn for grain and forage crops, including alfalfa and pasture grass), shift to less water intensive crops (grain for sorghum) beginning in 2015. While is it highly unlikely that all water intensive crop production will stop, this assumption allows for analysis of full implementation of the "what-if" scenario.

Scenario I Conservation Measures

Moderately expanded permanent conservation activities (Scenario I) in the Municipal and Industrial and Crop Irrigation demand sectors could reduce surface water gaps and groundwater storage depletions by about 30 percent. More specifically, Scenario I moderately expanded irrigation measures in Basins 55 and 66 and municipal and industrial conservation measures in Basin 55 (Basin 66 does not have any Municipal and Industrial demand) could reduce the total associated 2060 demand in both basins by 16,900 AFY. From an individual basin perspective, implementing Scenario I Municipal and Industrial conservation measures decreases the projected 2060 demand in Basin 55 from 9,120 AFY to 7,840 AFY (there is no Municipal and Industrial demand in Basin 66).

Implementing Scenario I Crop Irrigation conservation measures decreases the projected 2060 demand in Basins 55 and 66 from 288,430 AFY to 272,930 AFY. Implementing conservation in both sectors is only expected to reduce the combined 2060 surface water gap by about 29 percent to a value of 510 AFY. Implementing conservation in both sectors could reduce the combined 2060 alluvial groundwater storage depletions by about 28 percent to a value of 280 AFY. Implementing conservation in both sectors could reduce the combined 2060 bedrock groundwater storage depletions by up to 32 percent or a value of 35,750 AFY. Table 12-2 lists the irrigated acreage affected by Scenario I conservation measures. Under Scenario I conservation activities, the probability of surface water gaps and storage depletions remains nearly unchanged, due to high frequency of low to no-flow months.

Table 12-2. Acreage of Sprinkler Irrigated Lands Converted to High Efficiency LEPA Nozzles

County	Irrigated Land (thousand acres) [1]
Beaver	29
Cimarron	46
Texas	156

[1] Acreage represents the irrigated land in the entire county for 2007, not just the portion in Basins 55 and 66.

Moderately expanded conservation measures could provide a water supply solution in a relatively short period of time and could be implemented throughout the basin. However, while additional conservation measures in the Municipal and Industrial demand sector in Basin 55 (Basin 66 does not have any Municipal and Industrial demand) may help reduce the adverse effects of localized storage depletions, this measure will not have a significant impact basin wide because the basin's Municipal and Industrial demand is significantly less than that of the Crop Irrigation demand sector.

Scenario II Conservation Measures

Substantially expanded conservation measures (Scenario II) for the Crop Irrigation demand sector would require crop shifts throughout the basins, switching from water intensive crops (e.g., corn for grain, pasture greases, etc.) to sorghum for grain and wheat for grain, as well as the increase in irrigation efficiencies from Scenario I. The substantially expanded conservation measures include conversion of more than 106,123 acres from corn for grain and forage crops to sorghum as indicated in Table 12-3. The OCWP *Water Demand Forecast Report* recognizes that crop shifting is unlikely to occur unless crop managers are faced with severe water shortages, high pumping costs, or implementation of policies that provide incentives to do so. However, Almas et al. (1998) has shown through an economic optimization model that irrigated acres will significantly decrease in Cimarron, Texas, and Beaver Counties by 2060 due to groundwater declines. Thus, in Panhandle counties, transition from irrigation to dry land farming may be a viable (and likely) future outcome.

Table 12-3. Acreage of Crops Converted to Sorghum for Substantially Expanded Conservation Activities

County	Corn for Grain (acres) [1]	Forage Crops including Alfalfa and Pasture Grass (acres) [1]
Beaver	4,390	5,814
Cimarron	13,018	8,475
Texas	66,291	8,135

[1] Acreage represents the entire county, not just the portion in Basins 55 and 66.

Scenario II conservation in the Municipal and Industrial demand sector would expand on the conservation measures implemented in Scenario I and require the implementation of a high efficiency plumbing code ordinance. Table 12-1 provides additional information on Scenario II conservation measures.

Scenario II municipal and industrial conservation measures decrease the projected 2060 Municipal and Industrial demand from 9,120 AFY to 7,210 AFY (Basin 55) and Crop Irrigation demand decreases from 288,430 AFY to 222,900 AFY (Basins 55 and 66). Scenario II substantially expanded irrigation measures in Basins 55 and 66 and Municipal and Industrial conservation measures in Basin 55 could reduce the total associated 2060 demand in both basins by 67,620 AFY and reduce the size of the combined annual 2060 surface water gaps by about 86 percent or a value of 100 AFY, alluvial groundwater depletions by 85 percent or a value of 60 AFY, and bedrock groundwater depletions by up to 87 percent or a value of 6,650 AFY.

Based on an individual basin perspective, the combined Scenario II demand reduction in both sectors may decrease 2060 surface water gaps by 260 AFY in Basin 55 and 360 AFY in Basin 66. Alluvial groundwater storage depletions may be decreased by 310 AFY in Basin 55 and may be eliminated in Basin 66. Bedrock groundwater storage depletions in 2060 may be reduced by 41,040 AFY in Basin 55 and by 4,660 AFY in Basin 66. These decreases in gaps and storage depletions are between 80 percent and 100 percent of the demand from the supply sources. While these reductions are expected to decrease the probability of gaps, the probability will remain high due to the high frequency of low to no flow months.

Scenario II conservation measures would require substantial changes in the agricultural economy throughout the basins. Therefore, this water conservation measure would likely take a relatively long period of time to implement. However, shifting crop types could aid individual irrigators in the short term.

12.2.2 Out-of-Basin Supplies

Out-of-basin supplies would be among the most costly of options, but could eliminate the potential for surface water gaps and groundwater depletions. The development of out-of-basin supplies should be considered as a long-term water supply option for users throughout the basin. However, due to the scale and complexity of developing out-of-basin supplies, the cost-effectiveness of these supplies needs to be evaluated against other options on a local level.

The OCWP *Reservoir Viability Study* identified two potentially viable reservoir sites in the Panhandle Watershed Planning Region: Forgan (Category 3) and Englewood (Category 4) Reservoirs, both located on the Cimarron River in Basin 65. Englewood Reservoir would be 90 miles or more away from the majority of users in Basins 55 and 66, but could provide an estimated dependable yield of 36,967 AFY from 424,400 AF of total storage. However, the potential dependable yield of the reservoir should be updated to account for decreases in streamflow observed in the Cimarron River since the 1970s. This reservoir also would require approval of the Kansas-Oklahoma-Arkansas River Compact Commission.

Basins 55 and 66 could use the entire potential yield of the Englewood site as a source of out-of-basin supply, without meeting the full growth in demand from 2010 to 2060. With new terminal storage of about 13,000 AF, a 48-inch diameter pipe would be needed to bring out-of-basin supplies equal to the potential yield into Basins 55 and 66 for further distribution to users and to reduce gaps and storage depletions. With no terminal storage, a 72-inch diameter pipeline would be needed. The beneficial use of the reservoir would likely be limited to crop irrigation due to high concentrations of chlorides and sulfates. Construction of the reservoir as well as complications with distributing water to individual irrigators hinders its feasibility. However, its relative proximity to the basin and generally centralized demand locations make this alternative worth considering.

Regionalization of public water supply systems may provide an avenue for long-term implementation of major out-of-basin supplies. For purposes of this report, regionalization is defined as the shared development of and use of water supplies and the required diversion, conveyance, storage, and treatment infrastructure between two or more public water supply systems. Sharing of infrastructure, particularly for projects involving long transmission pipelines, can reduce the costs for each participant due to economies of scale. For example, conveyance of 50 million gallons per day of water could be accomplished through three individual pipelines: a 12-inch diameter pipeline, a 15-inch diameter pipeline, and a 42-inch diameter pipeline. That same flow could be conveyed through a single 48-inch diameter pipeline at roughly two-thirds the cost per mile of pipe. However, regionalization does not always reduce overall project costs and may not make economic sense depending on local and project-specific conditions. In particular, the closer two providers' distribution systems are the more cost-effective a shared project will be.

Operational efficiencies are possible with regionalization in areas such as:

- Overnight and emergency plant staffing
- Maintenance equipment and staff
- Monitoring and reporting
- Water quality sampling and lab analyses/lab facilities

- Permitting and reporting
- Administration

At the same time, potential issues in sharing of supplies and infrastructure can bring challenges such as:

- Autonomy in decision-making and control:
  — Source of supply and capital cost decisions
  — Operational decisions (e.g., rates, drought restrictions)
- Institutional framework (new water supply district/authority vs. wholesale relationship)
- Differing needs (unequal rates of growth, condition of existing infrastructure, etc.)
- Water quality compatibility between sources
- Capital costs of interconnecting systems
- Funding/financing capabilities and methods

Throughout the Panhandle Watershed Planning Region, there are already numerous examples of inter-provider arrangements to share water supplies on a wholesale basis, as documented in the OCWP *Panhandle Region Watershed Planning Report*. Often, regionalization projects are initiated by or involve larger providers in the area. Opportunities for regional supply between larger and smaller providers, particularly those whose service areas are adjacent and for major out of basin supply projects, should be considered as a means of addressing the significant supply challenges facing the water users in Basins 55 and 66.

The OCWP *Water Conveyance Study* updated information from the 1980 OCWP statewide water conveyance system that encompasses Basins 55 and 66. The conveyance systems require additional reservoirs, hundreds of miles of piping, canals, and inverted siphons, and many pumping plants. Study results determined that this option would not be feasible under current technology and economic constraints, but may be considered as a long-term opportunity for the future.

12.2.3 Reservoir Storage

The development of reservoir storage in Basins 55 and 66 is not recommended. The OCWP *Reservoir Viability Study Report* evaluated the potential for reservoirs throughout the state; no viable sites were identified in Basins 55 and 66. Additionally, basin-level evaluations in the OCWP *Panhandle Watershed Planning Region Report* indicate that the streamflow in these basins could supply little dependable yield, which is consistent with the conditions seen in Lake Optima. Furthermore, surface water has been fully permitted in both basins, which is expected to severely limit the size and location of new reservoirs.

12.2.4 Increasing Surface Water Use

Surface water in the basins is fully allocated, limiting diversions to existing permitted amounts. There is a moderate to high probability of surface water gaps in both basins starting in 2020 for the baseline demand projections. Increasing reliance on surface water use through direct diversions, if permits could be issued, would increase these gaps. Therefore, this water supply option is not recommended.

12.2.5 Increasing Groundwater Use

The primary source of water in these basins is bedrock groundwater from the Ogallala aquifer, which provides 98 percent of the total demand. Water levels in the Ogallala aquifer have declined substantially in many areas (OWRB 2006); however, the rate of water level declines has slowed due to the efforts of the Panhandle community (OWRB Mass Well Measurement 2011). Under baseline demand, storage depletions are expected to increase due largely to the growth in Crop Irrigation in the basins. These declining water levels could result in higher pumping costs, the need for deeper wells, and potentially changes to well yields or water quality.

The projected growth in surface water and alluvial groundwater use could instead be supplied by the Ogallala aquifer, which would result in minimal (1,200 AFY) increases in projected storage depletions. Additionally, some Municipal and Industrial water users could consider obtaining wholesale water supplies from water providers with wells in more dependable portions of the Ogallala aquifer. While the storage depletion is minimal compared to the amount of water in storage, these localized storage depletions may adversely affect users' yields, water quality, and pumping costs. Therefore, the development of additional bedrock groundwater supplies to meet the growth in surface water and alluvial groundwater demand could be considered a long-term water supply option, but may require additional infrastructure and operation and maintenance costs for sustained reliability. Over a long-term period, demand management and other supply options may provide more consistent supplies and may be more cost-effective.

Use of additional alluvial groundwater instead of increasing surface water use would increase alluvial groundwater storage depletions by 190 AFY by 2060. However, the majority of alluvial groundwater use is from non-delineated minor aquifers. Therefore, increasing reliance on these supplies is not recommended without site-specific information.

12.2.6 Marginal Quality Water

The OCWP *Marginal Quality Water Issues and Recommendations* report identified areas where there is potential for use of marginal quality water to meet future demand. However, Basins 55 and 66 were not found to have significant marginal quality water sources or significant potential to offset demand with marginal quality water. The Oil and Gas demand sector could potentially use marginal quality water for drilling and operational activities, but the use of this marginal quality water source could not be estimated, since any use would be on a well by well basis.

12.3 Summary

Six categories of supply options for mitigating the projected surface water gaps and groundwater storage depletions in Basins 55 and 66 are summarized in Table 12-4. Four options were potential short or long-term options: demand management, out-of-basin supplies, increasing reliance on groundwater and reservoir use.

Table 12-4 Summary of Water Supply Options for Basins 55 and 66

Water Supply Option	Option	Feasibility
Demand Management	• Increasing irrigation efficiency • Shift to crops with lower water demand	• Short- to long-term solution that may reduce groundwater storage depletions by 30 percent to about 90 percent and surface water gaps by up to 75 percent.
Out-of-Basin Supplies	• Englewood Reservoir and Statewide Water Conveyance	• Potential long-term solution
Reservoir Storage	• Development of new reservoirs	• Not feasible
Increasing Reliance on Surface Water	• Increasing reliance on surface water supplies, without reservoir storage	• Not feasible
Increasing Reliance on Groundwater	• Increasing reliance on the Ogallala aquifer instead of increased surface water and alluvial groundwater use	• Long-term solution; additional infrastructure and increased operation and maintenance cost may be required for sustained reliability.
Marginal Quality Water	• Use of marginal quality water sources	• No significant sources identified

Section 13
Recommendations

Based on the results of the Oklahoma H_2O tool, many of the 82 OCWP basins are projected to experience surface water gaps and/or groundwater depletions by 2060. Methods were further developed to assess basin characteristics and assign appropriate rankings to each basin to determine the 12 basins with the most significant water supply challenges, referred to as "hot spots." While the OCWP *Watershed Planning Region Reports* contain a description and analyses of all 82 OCWP basins based primarily on the results of the Oklahoma H_2O tool, the *OCWP Water Supply Hot Spot Report* revisits the 12 hot spot basins with more in-depth observations as summarized in the previous sections. Six potential water supply options--demand management, out-of-basin supplies, reservoir use, increasing reliance on surface water, increasing reliance on groundwater, and marginal quality water--were evaluated for their potential to mitigate supply issues in each hot spot basin. As shown in **Table 13-1**, at least three options and as many as five options were recognized for each basin as having the potential to provide a short-term or long-term solution in mitigating water supply challenges.

Table 13-1. Option Effectiveness for Hot Spot Basins

Hot Spot Basin	Demand Management	Out-of-Basin Supplies	Reservoir Use	Increasing Reliance on Surface Water	Increasing Reliance on Groundwater	Marginal Quality Water Use
22	Partial	Potential	Potential	No	Potential	No
26	Partial	Potential	Potential	No	No	No
34	Partial	Potential	Potential	No	Potential	No
36	Partial	Potential	Potential	No	Potential	Some Uses
38	Potential	Potential	Potential	No	Potential	Some Uses
40	Partial	Potential	Potential	No	Potential	Some Uses
41	Potential	Potential	Potential	No	Potential	Some Uses
42	Partial	Potential	Potential	No	Potential	Some Uses
51	Potential	Potential	Potential	No	Potential	Some uses
54	Partial	Potential	Potential	No	Potential	No
55	Partial	Potential	No	No	Potential	No
66	Partial	Potential	No	No	Potential	No

While several options were determined to be effective in eliminating gaps and/or depletions in many of the basins, the "out-of-basin supplies" is the only option that was determined to be a potential long-term solution capable of eliminating shortages for all hot spot basins. Due primarily to the costs and complexity of out-of-basin supplies, this report discusses the benefits of regionalization of public water supply systems as an opportunity for long-term implementation of major out-of-basin conveyances. However, regionalization can take many forms and does not necessitate use of out-of-basin supplies. The scale of a project can encompass two neighboring water providers using water within a single basin such as those sources identified under the "reservoir use" option, as well as several providers sharing water conveyed across a region or across several regions.

The main driver for regionalization is usually the potential to realize economies of scale by providing services to a larger customer base, thereby providing services more efficiently and at a lower cost. Despite the case for regionalization being a logical solution that could be relatively easy to construct, regional projects have historically been unsuccessful because political will is lacking , the perceived loss of autonomy, the potential benefits are not clearly understood, or the process is perceived as too complex.

Generally, success in implementing a regional project requires a leader or "champion" to drive the process and to steer the initial development of the idea. A number of levels of governments—such as state, regional, and/or local—can initiate the process (Kingdom 2005.) Regional planning groups, such as those supported throughout the public input process of the *2012 OCWP Update* and as identified as a "Priority Recommendation" in the *2012 OCWP Executive Report*, could provide the mechanism for promoting and funding the evaluation of regional projects. Representatives of the entities that are candidates for participating in the project and other stakeholders could also set up a group to help drive the process.

As explained in Section 2 of this report, the selected hot spot basins and potential water supply options were based on basin-wide water availability and, where identifiable, water quality characteristics. This methodology was considered to be an unbiased approach and an appropriate scale of analyses for a statewide planning document. If there is an established interest in pursuing a regional or local project—whether it involves in-basin sources, out-of-basin supplies, or a combination thereof—more detailed evaluations should be conducted on a local level to better understand the issues and to develop locally effective solutions. Localized studies can be conducted for individual water users or for a group of water users. As discussed above, the sharing of regional infrastructure and related planning can reduce the costs for each participant due to greater efficiencies and economies of scale. The *2012 OCWP Update* and other technical reports provide extensive data and analyses to serve as the foundation for local evaluations.

Section 14
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