ASR Permit Modification Proposal Revised Minimum Index Levels & Aquifer Maintenance Credits

City of Wichita, Kansas

Project No. 71395

3/12/2018

ASR Permit Modification Proposal Revised Minimum Index Levels & Aquifer Maintenance Credits

prepared for

City of Wichita, Kansas

Wichita, Kansas

Project No. 71395

3/12/2018

prepared by

Burns & McDonnell Engineering Company, Inc.

INDEX AND CERTIFICATION

City of Wichita, Kansas
ASR Permit Modification Proposal
Revised Minimum Index Levels & Aquifer Maintenance Credits
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Report Index

Certification

I hereby certify, as a Professional Engineer in the state of Kansas, that the information in this document was assembled under my direct personal charge. This report is not intended or represented to be suitable for reuse by the City of Wichita, Kansas or others without specific verification or adaptation by the Engineer.

Paul A. McCormick, P.E.

Date: March 12, 2018

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LIST OF ABBREVIATIONS

Abbreviation	**Term/Phrase/Name**
AF	acre-feet
AMC	Aquifer Maintenance Credit
ASR	Aquifer Storage and Recovery
ASR WTP	ASR Water Treatment Plant
BMcD	Burns & McDonnell Engineering Company, Inc.
BSA	Basin Storage Area
City	City of Wichita, Kansas
CWSA	USGS Central Wellfield Study Area
DRP	Drought Response Plan
DWR	State of Kansas Division of Water Resources
EBGWM	USGS Equus Beds Groundwater Flow Model
EBWF	Equus Beds Well Field
GIS	Geographic Information System
GMD2	Groundwater Management District No. 2
HCH	High Country Hydrology, Inc.
HSU	Hydro-Stratigraphic Unit
ILWSP	Integrated Local Water Supply Plan
IW	Index Well
MGD	million gallons per day
NOAA	National Oceanic and Atmospheric Administration
PDSI	Palmer Drought Severity Index
PEC	Professional Engineering Consultants
RB	Recharge Basin
RRW	Recharge and Recovery Well
SAIC	Science Applications International
SP	Stress Period
USDA	United States Department of Agriculture
USDM	United States Drought Monitor
USGS	United States Geological Survey

1.0 INTRODUCTION

Since the implementation of the Integrated Local Water Supply Plan (ILWSP) in 1993 the City of Wichita (City) has been continuously reviewing ways to improve existing water supplies through infrastructure upgrades and integrated water resources management. In the spring of 2014 a comprehensive water supply planning evaluation was presented to the Wichita City Council. This planning included consideration of future projected demand, drought, current water resources, and enhancements to existing water supply. Based on that review, the City Council decided in April of 2014 to utilize a 1% exceedance probability drought for water resource planning for future water supplies. As a result of this decision, City staff initiated a series of studies, professional engineering evaluations, and permit reviews, to ensure that existing and planned water resources are adequate to meet the demands of a 1% drought.

As part of these studies, the City has been reviewing the permit conditions that regulate the operation of the City's Aquifer Storage and Recovery (ASR) project. One of these permit conditions restricts the recovery of recharge credits to periods when water levels are above an established minimum index water level. This restriction means that the City can only pump recharge credits out of the ASR wells when the groundwater elevation is *above* the minimum index water level. The minimum index water level elevations for the City's ASR project and the Basin Storage Area (BSA) are based on the historic water levels recorded in January of 1993 from wells screened within the lower production zone of the Equus Beds Aquifer. The index monitoring wells associated with the ASR project did not exist in 1993. Therefore, elevations for the index well sites were developed based on interpolations of the best available water level information during a joint review process that included the City, the Division of Water Resources (DWR), Groundwater Management District No. 2 (GMD2), and the United States Geological Survey (USGS) completed in early 2015. At the time that ASR Phase I regulations were developed, the 1993 levels were the lowest water levels recorded in the aquifer. The evaluation of current ASR permit conditions relative to drought has identified the 1993 levels as a limitation that will restrict the City's access to ASR recharge credits during prolonged drought. Extensive data analysis and predictive modeling suggests that during prolonged drought, groundwater level elevations will drop below the current minimum index water level restrictions throughout the majority of the City's well field, preventing the withdrawal of ASR credits when they are needed most (see Attachment I). This finding requires the City to seek a reasonable alternative minimum index level for the existing ASR project so that recharge credits are available throughout periods of long-term drought.

The State of Kansas Division of Water Resources (DWR) recently modified K.A.R. 5-12-1 in acknowledgement that additional flexibility was needed statewide for ASR projects with respect to the defined bottom of a basin storage area. To calculate a more appropriate minimum index level elevation for the City's ASR project, the City and Burns & McDonnell (BMcD) began by engaging GMD2 and DWR technical staff. Through this collaborative process several methods for projecting drought impact on groundwater levels within the ASR BSA were evaluated ranging from simple analytical methods to a more detailed analysis utilizing groundwater modeling. The same groundwater model utilized for the current ASR credit annual tracking and accounting process has been adapted to facilitate the input of 1% drought hydrologic variables, future City demand, the City's drought response plan, and long-term water resource management goals. The groundwater modeling inputs, results, and figures within this report are reflective the feedback and comments received during an extensive model development and review process between the City, BMcD, GMD Staff, and DWR Staff and technical resources.

In addition, the City has been reviewing how recent groundwater level recoveries limit the physical recharge capacity of the ASR system. The City's approach to outcome based management of water resources has resulted in unprecedented groundwater level recoveries within the City of Wichita's Equus Beds Well Field (EBWF). These groundwater level recoveries are a direct result of the City's utilization of alternate surface water resources, such that the aquifer within the EBWF has recovered to nearly 100% full pre-development conditions. It is clear that higher groundwater levels directly limit the physical recharge capacity of the City's Aquifer Storage and Recovery (ASR) program. The ability to establish and recover ASR credits remains a critical component of the City's plan to meet the enhanced demand for raw water during an extended drought. Under existing ASR permit conditions, the City can enhance the physical recharge capacity of the ASR program by making a shift to utilization of more groundwater from the EBWF. Rather than lowering groundwater levels in the EBWF to create physical recharge capacity and storage for the ASR system, an alternative recharge credit development strategy during full aquifer conditions is being proposed for consideration. The City proposes that the quantity of water diverted from the Little Arkansas River that cannot be physically recharged through the ASR system could be sent to the City's main water treatment plant to directly meet City water demands. The water left in storage as a result of utilizing Little Arkansas River flows rather than groundwater from the EBWF would be considered as an ASR Aquifer Maintenance Credit (AMC) with similar characteristics to the current ASR recharge credits. To facilitate consideration of this proposal the City has assembled documentation on: historic water resources management, a brief history on the development and vision for the City's ASR program, a physical ASR recharge operations plan for determining the annual capacity to develop AMCs, an AMC accounting system, and several additional anticipated permit conditions.

2.0 PROPOSED ASR MINIMUM INDEX LEVELS

The City relies on Cheney Reservoir and the Equus Beds Well Field (EBWF) as its two main sources of raw water supply. To extend the viability of these resources during prolonged drought the City developed and adopted a formal Drought Response Plan (DRP) on October 8th, 2013. This plan formalized various levels of water conservation measures throughout the City based on the condition of raw water resources (Attachment A). The EBWF, ASR Recharge Credits, and Cheney Reservoir must all be simultaneously available to meet normal day and peak day demands during future droughts. The City's DRP is based on a 12-month average percentage of the conservation pool at Cheney Reservoir. The DRP limits demand at the customer level and has the effect of extending the viability of both Cheney Reservoir and the EBWF throughout prolonged drought (see Table 2-1 below).

Table 2-1: *City of Wichita Drought Response Plan (DRP) Stages*

Drought Response Stage	Drought Response & Customer Conservation Steps	Condition of Cheney Reservoir (% of Conservation Pool)
Normal	Continued Water Saving Initiatives	100% - 90%
Stage No. 1	Voluntary Conservation	89% - 70%
Stage No. 2	Irrigation 1-Day/Week Rotating Irrigation Quadrants	69% - 50%
Stage No. 3	All Outdoor Watering Banned	49% - 35%
Stage No. 4	Outdoor Watering Ban Mandatory 15% reduction to AWC	34% - 0%

Source: Attachment A, City of Wichita Drought Response Plan

2.1 1% Drought Reconstruction – Palmer Drought Severity Index (PDSI)

The classification of prolonged drought must be considered in the context of both magnitude (severity) and duration. To develop the statistical magnitude and duration of a 1% drought the City utilized the Palmer Drought Severity Index (PDSI). The PDSI was developed in 1965, and is used today as scale to reflect the relative wetness or dryness of a given period. The original paper developed by Wayne C. Palmer "*Meteorological Drought – Research Paper No. 45. Office of Climatology, Washington DC. 1965*" has been included for review as Attachment B. The PDSI is utilized by the National Oceanic and Atmospheric Administration (NOAA), the United States Department of Agriculture (USDA), the United States Drought Monitor (USDM), and other agencies to classify relative drought conditions. PDSI values are generally bounded by a range of -6 to +6 with a value of zero representing normal hydrologic conditions for a given area. Negative PDSI values represent time periods drier than normal, while positive PDSI values represent periods wetter than normal. The lower PDSI value the drier the period of consideration. For example, a drought year of with a PDSI value of -4.0 would be drier and considered more extreme than a drought year with a value of -3.0.

The City contracted High Country Hydrology, Inc. (HCH) to examine hydrologic data to quantify the duration and intensity of a drought with a 1% exceedance probability. During their review of hydrologic data, HCH found that estimates of the Palmer Drought Severity Index (PDSI) generated from tree ring chronology could be used to review historic droughts of record for their intensity and duration (Attachment C). HCH calculated that a 1% drought can be approximated by the drought of 1933 through 1940, as illustrated in Table 2 below.

Table 2-2: *1% Drought Reconstruction from PDSI*

Suggested Drought Intervals based on Reconstructed PDSI (1640-2003)				Representative Historical Years	
Exceedance Probability %	Duration (Years)	Cumulative PDSI	Mean PDSI	Years	Actual Cumulative PDSI
10%	2	-4.4	-2.20	1925-1926	-4.9
4%	4	-8.8	-2.21	1925-1926, 1981 x 2	-8.8
2.0%	6	-15.6	-2.60	1952-1956, 1959	-16.1
1.3%	7	-19.6	-2.80	1946, 1952-1956, 1981	-19.6
1.0%	8	-22.4	-2.80	1933-1940	-24.4
0.40%	10	-31.4	-3.14	1952-1956 x 2	-31.1
0.20%	12	-38.2	-3.18	1952-1956 x 2, 1963-1964	-38.4
0.10%	14	-45.0	-3.21	1925, 1933-1940, 1936-1937, 1937, 1940, 1976	-45.0

Source: Attachment C, HCH Technical Memorandum 4, March 14, 2013, Table 1

2.2 City of Wichita - Future Raw Water Demand Assessment

The City's projected water demands were recently examined in a study completed by Science Applications International (SAIC) and Professional Engineering Consultants (PEC) in August of 2013 (Attachment D). This study indicates that by the year 2060 the City's normal annual water demands will be in the range of 71,370 acre-feet (AF) to 105,858 AF. Three growth scenarios were included within the study (low, medium, and high growth) to generate a band of likely forecasted populations. The medium growth forecast with a projected demand of 87,597 AF by the year 2060 was selected for modeling future demands to simulate future demands between the confines of the low and high bands of forecasted growth. The City believes that the medium growth forecast raw water demands for 2060 may be further reduced to 81,690 AF by implementing planned water use conservation measures, and has utilized this demand forecast to evaluate how water resources will perform under various hydrologic conditions.

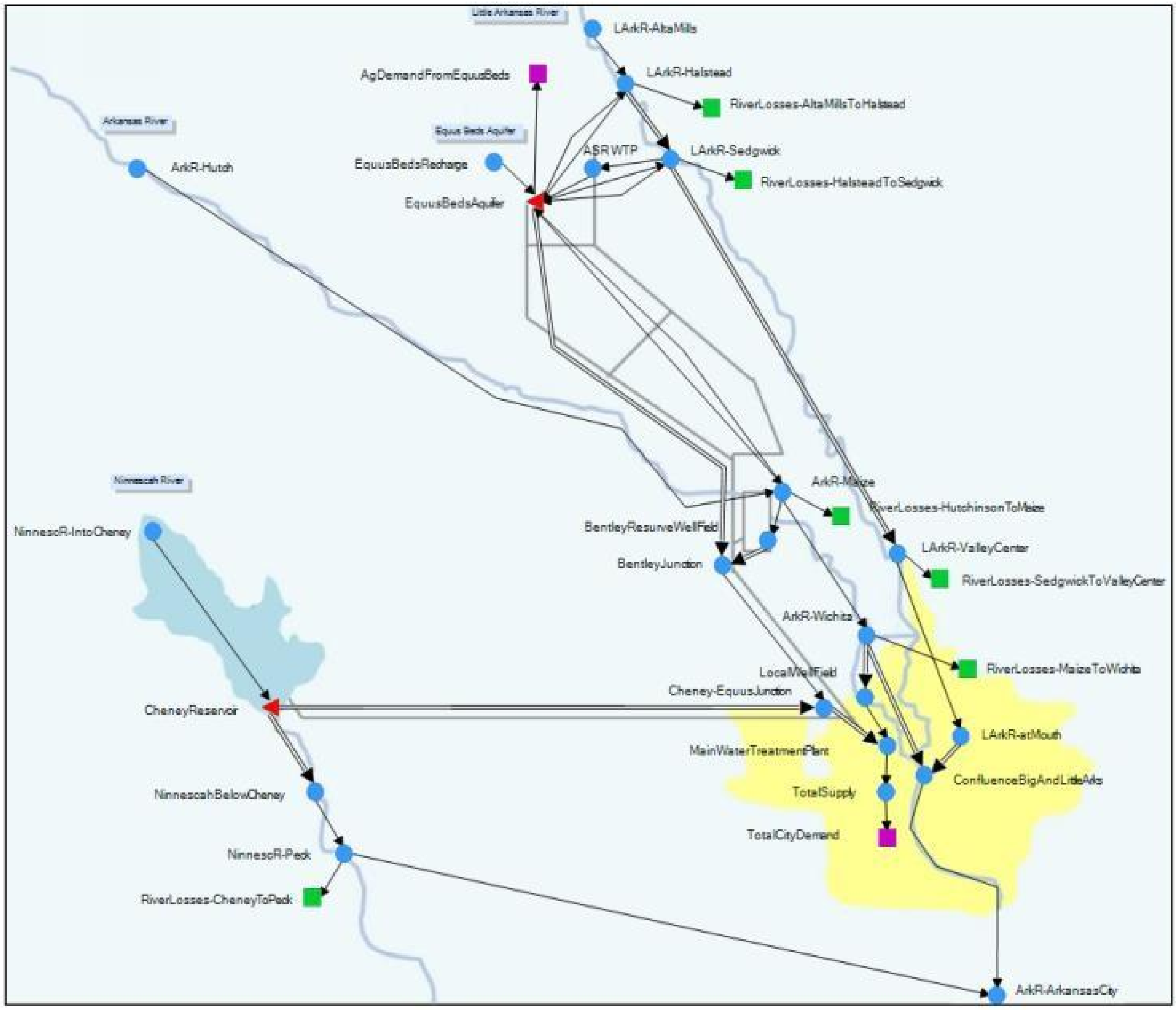
2.3 Integrated Water Resources Management During a 1% Drought Using MODSIM-DSS

To evaluate the viability of existing and planned raw water resources versus the projected demands of 81,690 AF by the year 2060, the City developed a dynamic raw water resources model based on MODSIM-DSS (Figure 1). MODSIM-DSS is a water rights planning, water resources management, and river operations decision support system software that can simulate the effects that complex water resource management rules and strategies have on a set of networked raw water resources such as reservoirs, streams, or aquifers. MODSIM-DSS provides for input of variables such as integrated water resources management policy, water rights quantity limitations, water right rate limitations, raw water pipeline capacities, seasonal raw water resource preferences, reservoir conditions, streamflow levels, etc. Using MODSIM-DSS the City can optimize how raw water resources are utilized to meet demand based on any number of management criteria or outcome based goals. To simulate how the raw water demands during a 1% drought should be distributed between Cheney Reservoir, the EBWF, and ASR system, the City utilized the MODSIM-DSS model with the addition of updated drought variables:

1% Drought Simulation MODSIM-DSS Updates

- **Raw water resources include Cheney Reservoir, EBWF, ASR Credits**
    - Cheney Reservoir – existing water rights and a starting storage condition of 110% full based on the reservoir achieving this level during pre-drought conditions
    - EBWF – existing water rights of 40,000 AF
    - ASR Recharge Credits - 60,000 AF of credits available not limited by current minimum index water level restriction
    - E&S Wellfield is not considered a firm source during drought due to water quality and limited capacity during lowered Arkansas River flows
    - Bentley Reserve Wellfield is not considered a firm source during drought due to limiting streamflow triggers and poor water quality during lowered Arkansas River flows
- **Future projected 2060 demand of 81,690 AF**
    - Raw water savings available through DRP added
    - Base demand is reduced depending on Cheney Reservoir condition and associated DRP triggers
- **Simulated 8-Year Drought Hydrologic Components**
    - 1933-1940 stream flows for rivers and streams and Cheney Reservoir
    - 1933-1940 precipitation and evaporation for Cheney Reservoir

Figure 1 - *A computer screen capture of the graphical user interface of the City's MODSIM-DSS raw water resources model showing the network of simulated reservoirs, streams, aquifers, interconnections, and sources of demand.*



- **Updated Outcome-Based Goals**
  - Prevent economic distress of consumers due to occurrence of DRP Stages 3 and 4
  - Must maintain both Cheney Reservoir and EBWF as viable resources at all times
  - Utilize 40,000 AF per year from EBWF prior to use of ASR Recharge Credits

By running MODSIM-DSS with the updated 1% drought simulation variables, an optimized daily raw water demand is generated for each water resource. The results of the 1% drought MODSIM-DSS simulation indicate that both the EBWF and Cheney Reservoir can be kept viable through the drought by utilizing ASR recharge credits and the City's DRP (Table 2-3). Under these conditions the City must maintain the availability of all raw water resources (EBWF, ASR Recharge Credits, and Cheney Reservoir) to meet daily drought demands and prevent implementation of Stage 3 water restrictions. Further review of the reservoir accounting results indicates that Cheney Reservoir can be balanced such that the calculated minimum reservoir condition during the eight-year drought period is 42% of conservation pool, with an average of 62% (see Figure 2).

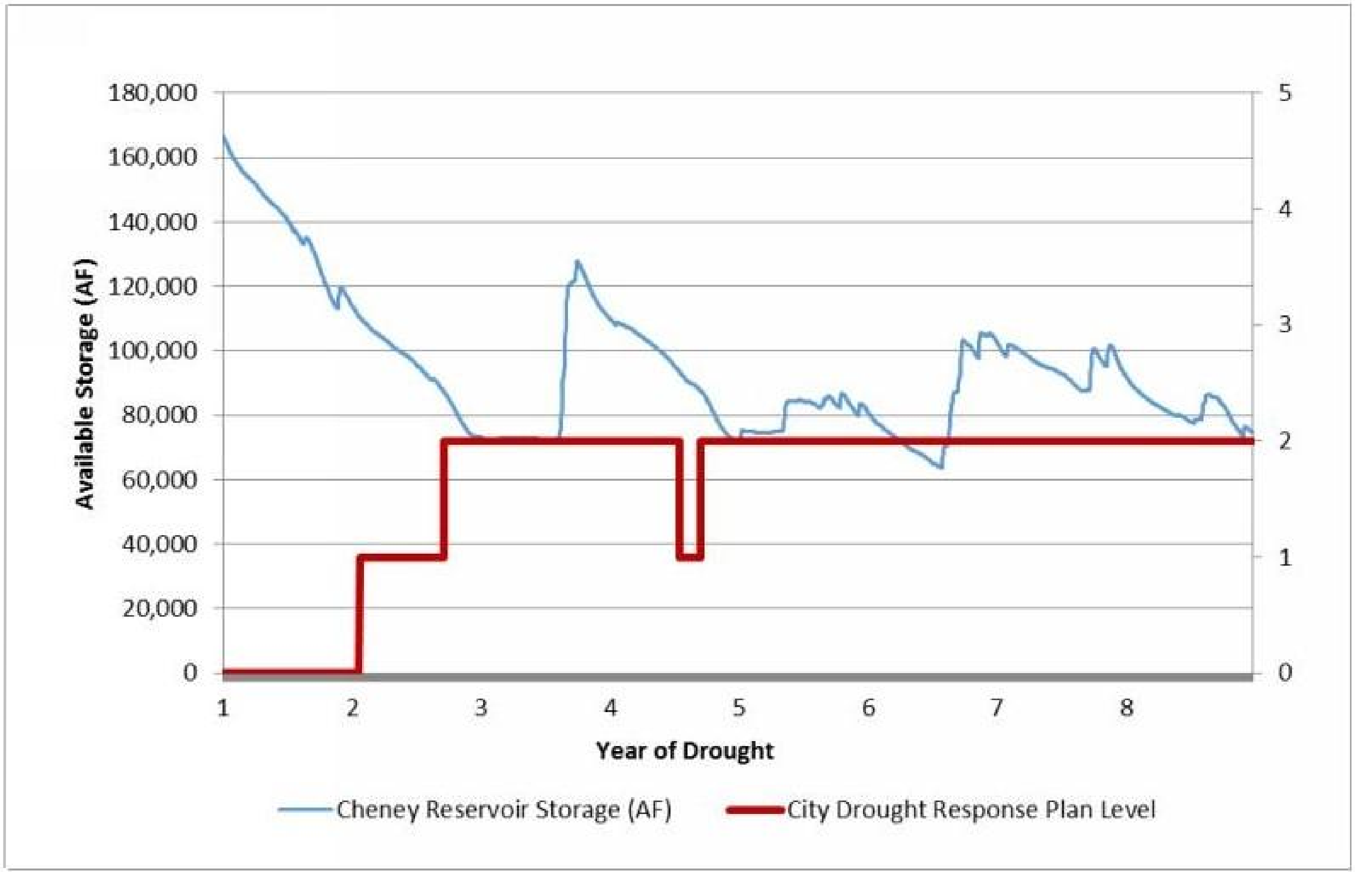
Table 2-3: *MODSIM-DSS simulation results for the 1% drought utilizing projected 2060 demands*

MODSIM-DSS Variable	Drought Year 1	Drought Year 2	Drought Year 3	Drought Year 4	Drought Year 5	Drought Year 6	Drought Year 7	Drought Year 8
Baseline City Demand (AF)	81,690	81,690	81,690	81,690	81,690	81,690	81,690	81,690
Simulated Calendar Year of Drought	1933	1934	1935	1936	1937	1938	1939	1940
Revised City Demand from Drought Response Plan (AF)	81,262	72,492	71,116	71,890	70,812	70,811	71,116	70,664
City Demand Assigned to EBWF & ASR	34,202	45,651	59,907	46,732	56,579	41,980	39,308	39,491
City Demand Assigned to Cheney Reservoir	47,060	26,841	11,209	25,158	14,233	28,831	31,808	31,173
Cheney % of Conservation Pool 12 Month Average	110%	92%	62%	59%	62%	53%	53%	63%

2.4 Groundwater Modeling Setup - 1% Drought Simulation

In 2009, to better understand the regional Equus Beds Aquifer and the effects on water levels due to current and planned ASR activities, the City contracted a study by the USGS. This study developed a three-dimensional finite-difference groundwater-flow model based on MODFLOW-2000. MODFLOW software is broadly recognized as the standard for simulation and prediction of groundwater conditions.

Figure 2 - *Results of 1% drought simulation using MODSIM-DSS, indicates Cheney Reservoir can be maintained viable through the drought utilizing by ASR credits and various levels of the City's adopted Drought Response Plan*

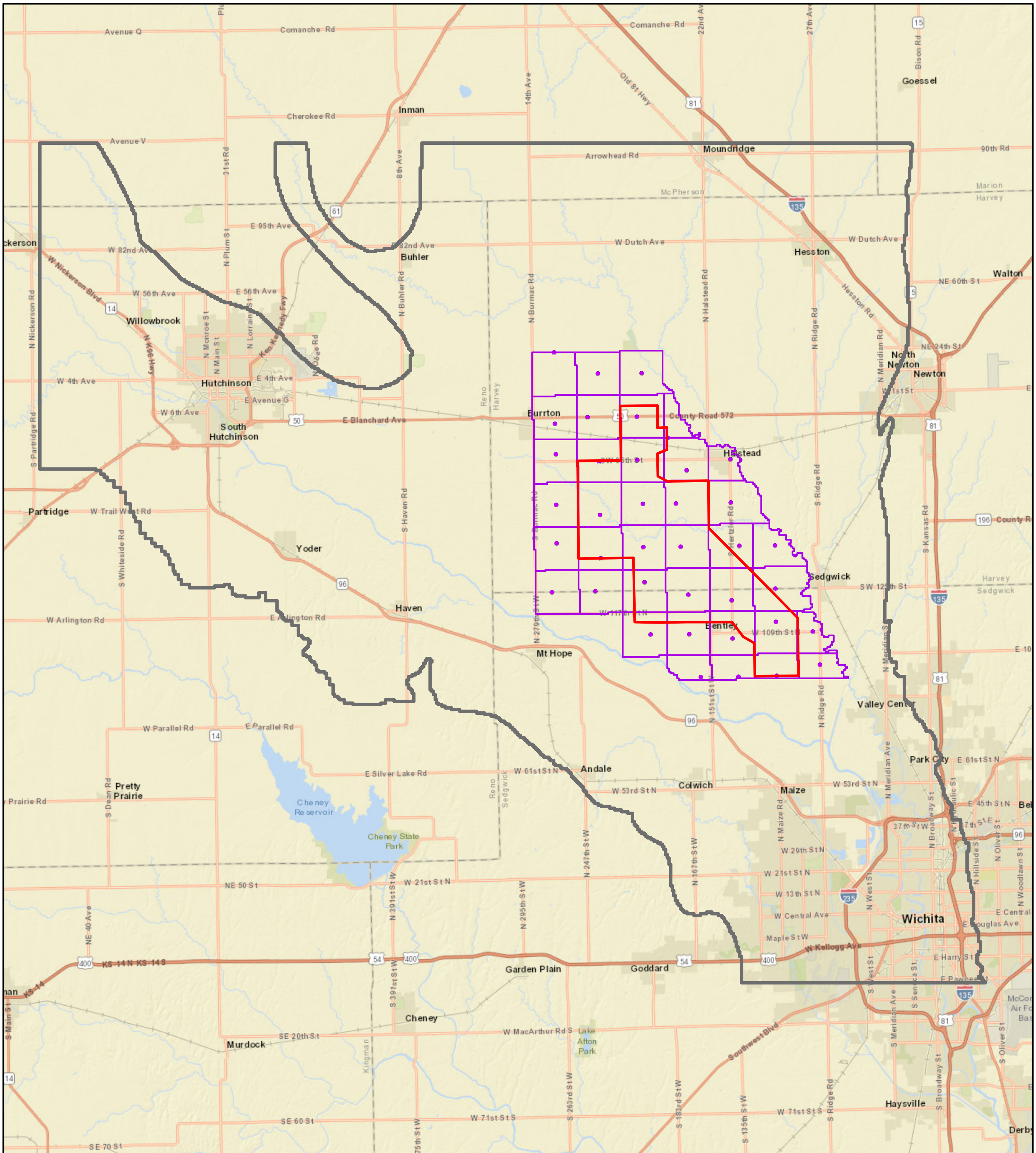


Details of the USGS Equus Beds Groundwater Flow Model (EBGWM), including information regarding the model setup, calibration, sensitivity analysis and results are contained in the public document "*Simulation of Groundwater Flow, Effects of Artificial Recharge, and Storage Volume Changes in the Equus Beds Aquifer near the City of Wichita, Kansas Well Field, 1935-2008,*" USGS Scientific Investigations Report 2013-5042 (Kelly, et al, 2013) which has been included as Attachment E. The model captures the areal extent of the City's ASR BSA, and is currently approved for use as the method for accounting and tracking of ASR credits (Figure 3).

The EBGWM is currently the best forward analysis and prediction tool available for simulating the total combined effects of a 1% drought on the local and regional water levels surrounding the City's ASR project. The EBGWM provides a method to simulate the effects of a 1% drought on the aquifer water levels by the input of simulated drought variables including increased agricultural irrigation pumping, additional City pumping, reduced aquifer recharge, reduced streamflow, and increased evapotranspiration. When developed by the USGS, the EBGWM was calibrated to groundwater flow and water level changes from 1935 through 2008. Since publication of the model, BMcD has updated the model inputs to include the years 2009 through 2015 to generate the ASR annual accounting report. BMcD used a pre- and post-processing software package (Groundwater Vistas) to facilitate import of modeling files and analysis of results. Groundwater Vistas utilizes the same calculation packages used by the original EBGWM (MODFLOW-2000), and no changes were made to the original construction or hydrogeologic properties of the model. The performance of the model remains identical to the original transient calibrations performed and published by the USGS. The EBGWM model was modified for the purposes of simulating the effects of a 1% drought adding stress periods to include the years 2009 through 2015 and the necessary data for those calendar years to be simulated in a forward analysis. Model parameters such as boundary conditions, surface elevation, bedrock elevation, aquifer hydraulic conductivity, storativity, and hydrologic unit groups are as originally established by the USGS.

2.4.1 Stress Period (SP) Development

The MODSIM-DSS model performs simple reservoir accounting based on the inputs of one inflow source and local hydrologic variables for the reservoir. The EBGWM is a complex regional scale tool that requires more detailed information from multiple stream gages and weather stations to create stress periods as prescribed by the original USGS EBGWM documentation. Hydrologic data was collected from the NOAA, USGS, and other sources and examined for the 1% drought occurrence years of 1933-1940. The availability of detailed hydrologic data for this period was found to be limited for the groundwater model area in both density and completeness for evapotranspiration, stream flows, and



Legend

- Boundary of Active Groundwater Model
- Central Wellfield Study Area
- ASR Index Cells & Basin Storage Area
- ASR Index Monitoring Wells

N

1:375,000

0 2 4 8
Miles

CITY OF WICHITA

BURNS McDONNELL

Figure 3
USGS Equus Beds
Groundwater Flow
Model Active Model
Boundary

precipitation. The sporadic hydrologic data for the groundwater model area during 1933-1940 would make generation of model inputs for annual stress periods using the methods prescribed by the original groundwater model documentation problematic. Data from the 1930's would also require additional consideration and potential adjustment for variables such as stream gage elevations, incising of stream beds, and stream base flow. Rather than attempt interpolation from incomplete hydrologic data, the PDSI values from 1933 to 1940 were compared to more recent years to find and develop a complete hydrologic data set for simulating the duration and intensity of the 1% drought. The data provided in Attachment C indicates that a 1% drought should extend for a total of approximately eight years and exhibit a cumulative PDSI of roughly -22.4 with a mean PDSI of -2.80. PDSI information for recent calendar years for South Central Kansas was obtained from NOAA for comparison to the PDSI from 1933 to 1940 (Attachment F). The annual (12 Month) and seasonal (6 Month) intensities from this data set were compared to the PDSI statistics of the target years of 1933 through 1940. The recent calendar years that best compare to the target years were 1991, 2002, 2006, 2011, and 2012. Based on this comparison, the years 2011 and 2012 were selected to repeat four times, for a total of eight years, to simulate a 1% drought. This approach results in a total seasonal cumulative PDSI of -23.45 with a mean PDSI of -2.93 (Table 2-4).

Table 2-4: *PDSI values for South-Central Kansas*

Drought Year	12 Month Annual PDSI Calculated NOAA South Central KS	6 Month Seasonal PDSI Calculated NOAA South Central KS
1934	-4.26	-4.78
1936	-2.71	-3.98
1933	-2.58	-3.96
2011	-1.99	-3.68
1937	-3.13	-2.90
1940	-3.10	-2.63
1939	-1.63	-2.55
2012	-1.92	-2.18
1935	-2.60	-1.48
1938	-1.08	0.69
1933-1940 AVG	-2.64	-2.70
2011-2012 AVG	-1.96	-2.93
1933-1940 Cumulative	-21.09	-21.58
2011-2012 Simulated 8 Year Cumulative	-15.64	-23.45

DWR and GMD2 also requested that in addition to simulating a 1% drought, two years of aquifer recovery conditions be included in the modeling scenario. After examining the recent historic record of PDSI information, the year 2010 was chosen as a wet calendar year to simulate aquifer recoveries based

Table 2-5: *Water Resource Variables and Inputs to the EBGWM by Stress Period*

Model Variable or Assumption	Model Stress Period									
	1	2	3	4	5	6	7	8	9	10
Future Demand Planning Year	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069
Simulated Hydrologic Year	2011	2012	2011	2012	2011	2012	2011	2012	2010	2010
Streamflows	2011	2012	2011	2012	2011	2012	2011	2012	2010	2010
Precipitation & Recharge	2011	2012	2011	2012	2011	2012	2011	2012	2010	2010
Evapotranspiration	2011	2012	2011	2012	2011	2012	2011	2012	2010	2010
Irrigation, Industrial, Other Well Pumping	2011 DWR Reported	2012 DWR Reported	2011 DWR Reported	2012 DWR Reported	2011 DWR Reported	2012 DWR Reported	2011 DWR Reported	2012 DWR Reported	2010 DWR Reported	2010 DWR Reported
Total EBWF & ASR (AF)	34,202	45,651	59,907	46,732	56,579	41,980	39,308	39,491	20,067	20,067
City of Wichita ASR Credit Pumping (AF)	0	5,651	19,907	6,732	15,552	1,980	0	0	0	0
Cheney Reservoir Pumping (AF)	47,060	26,841	11,209	25,158	14,233	28,831	31,808	31,173	Not Simulated	Not Simulated
City of Wichita Drought Conservation Stage	Normal	Stage 1	Stage 1	Stage 2	Stage 2	Stage 2	Stage 2	Stage 2	Not Simulated	Not Simulated
Cheney % of Conservation Pool 12 Month Simulated AVG at Beginning of Year	110%	92%	62%	59%	62%	53%	53%	63%	Not Simulated	Not Simulated
Total City of Wichita Demand EBWF + Cheney (AF)	81,262	72,492	71,116	71,890	70,812	70,811	71,116	70,664	Not Simulated	Not Simulated

on a NOAA reported annual PDSI of +2.5 and a six-month seasonal PDSI of +1.56. The groundwater modeling inputs utilized for each stress period of the simulated 1% drought are summarized in Table 2-5 and described below.

2.4.2 Starting Groundwater Model Elevations

To establish the starting groundwater elevations for the 1% drought simulation, BMcD and City staff reviewed historic, current, and future water resource management and ASR strategies. To select initial head conditions for the 1% drought scenario, the simulated transient water levels provided by USGS in the original model report for 1990-2008 were compared against the designed recharge capacity of existing ASR infrastructure. This comparison indicated that the simulated groundwater levels representing the end of the 1998 period were the best match for representing the minimum groundwater levels required to maintain 30 MGD of physical ASR recharge capacity. These initial water levels represent an average of 91% full conditions across model cells inside the USGS Central Wellfield Study Area (CWSA) and 94% full conditions for the BSA as a percentage of predevelopment saturated thickness (see Figure 3 for boundaries of the active groundwater model, CWSA and BSA). The starting groundwater elevations represent the lower anticipated groundwater elevation range considerate of ASR recharge capacity, re-occurrence of drought, and the aquifer management strategies currently available to the City.

2.4.3 Groundwater Pumping – Agricultural Irrigation, Industrial Use, Other Municipal Users

The withdrawal of groundwater is regulated and tracked through a statewide metering and reporting program managed by the DWR. For the drought and drought recovery simulation, the model utilizes the matching DWR reported pumping values from calendar years 2010, 2011, and 2012. The DWR metered pumping values for industrial and other non-Wichita municipal pumping were utilized to develop the pumping inputs for the model.

During agricultural irrigation, some portion of the applied water returns to the aquifer as infiltration. To account for this infiltration, the DWR reported quantity for the target model years of 2010, 2011, and 2012 were adjusted as documented in the original groundwater model documentation (Attachment E - *USGS Scientific Investigations Report 2013-5042*). Net irrigation use within the CWSA is shown in Table 2-6. The total calculated currently authorized quantity for irrigation use when considering all irrigation water rights within the CWSA is approximately 13,400 AF.

Table 2-6: *Net Irrigation Use in the 1% Drought Model*

Model Stress Period	Water Use Data Year	Net Irrigation Use CWSA (Acre Feet)	Net Irrigation Use BSA (Acre Feet)
1	2011	10,808	31,319
2	2012	10,190	22,706
3	2011	10,808	31,319
4	2012	10,190	22,706
5	2011	10,808	31,319
6	2012	10,190	22,706
7	2011	10,808	31,319
8	2012	10,190	22,706
9	2010	7,743	22,022
10	2010	7,743	22,022

2.4.4 Groundwater Pumping – City of Wichita

The total simulated City of Wichita groundwater pumping from the EBWF for drought years 1 through 8 is based on the MODSIM-DSS 1% drought modeling work completed by the City. The City examined projected demands through 2060, the magnitude and duration of 1% drought, and the effects of the City's DRP on available water resources. From this information MODSIM-DSS was utilized to optimize the City's integrated water resources strategy and to formally quantify the amount of water that should be utilized from each major water resource during a 1% drought. BMcD utilized the simulated demands directly from the City's MODSIM results as the City pumping inputs for the EBGWM during stress periods one through eight (see Table 2-7 below). City well pumping was distributed based on the actual water rights allocation for each well as a percentage of total authorized EBWF water rights. For the two requested recovery years, the actual City water use for the year 2010 was utilized (20,067 AF applied in model stress periods nine and ten).

Cheney Reservoir is not included within the bounds of the EBWGM and therefore has no direct simulated effect on groundwater elevations or the EBGWM results. The condition of Cheney Reservoir during 1% drought is only considered within the City's MODSIM-DSS model, which generated the distribution of projected raw water resource demands throughout the simulated drought.

Table 2-7: *Distributed City of Wichita Pumping by Stress Period*

	Drought Year								Recovery Year	
Raw Water Resource Name	1 (SP1)	2 (SP2)	3 (SP3)	4 (SP4)	5 (SP5)	6 (SP6)	7 (SP7)	8 (SP8)	1 (SP9)	2 (SP10)
Simulated Cheney Demand (AF)	47,060	26,841	11,209	25,158	14,233	28,831	31,808	31,173	Not Simulated	Not Simulated
Simulated EBWF + ASR Demand (AF)	34,202	45,651	59,907	46,732	56,579	41,980	39,308	39,491	20,067	20,067
Total Simulated City of Wichita Demand (AF)	81,262	72,492	71,116	71,890	70,812	70,811	71,116	70,664	Not Simulated	Not Simulated

2.4.5 Streamflow – Arkansas River, Little Arkansas River, Cow Creek

Streams, creeks, and rivers can contribute to aquifer recharge or discharge depending on river stage, river bed conductivity, and elevation of the underlying groundwater table. Variations in river stage and flow are considered in the groundwater model using the MODFLOW-2000 stream package, and smaller streams and tributaries were simulated using the drain package. The USGS maintains several gaging stations for each of the streams included in the groundwater flow model. Data from the USGS streamflow gages on the Arkansas River, Little Arkansas River, and Cow Creek were utilized to calculate an average annual stage for each river for the years 2010, 2011, and 2012. Stage elevation for the cells between gages were assigned by interpolation of the flow gradient consistent with the original groundwater model documentation (USGS Scientific Investigations Report 2013-5042). Figure 4 illustrates the location of USGS stream gages throughout the active groundwater model and BSA. Attachment G provides streamflow hydrographs and flow percentile classification for calendar years 2010 through 2012 at gaging stations located above and below the BSA.

2.4.6 Precipitation & Natural Aquifer Recharge

A percentage of annual precipitation contributes to natural recharge within the EBGWM. The amount of natural recharge entering an aquifer system can be based on many factors including the amount of precipitation, surface soil texture, slope, and type and amount of groundcover. The EBGWM uses average precipitation from area weather stations and then distributes the recharge across the model to recharge zones grouped and developed based on soil type, ground cover and model calibration (USGS Scientific Investigations Report 2013-5042). For the 1% drought model, BMcD gathered data on precipitation for calendar years 2010, 2011, and 2012 and distributed natural recharge consistent with the original model documentation. The average precipitation and the distribution of natural recharge by recharge zone for each simulated model year is summarized below in Table 2-8.

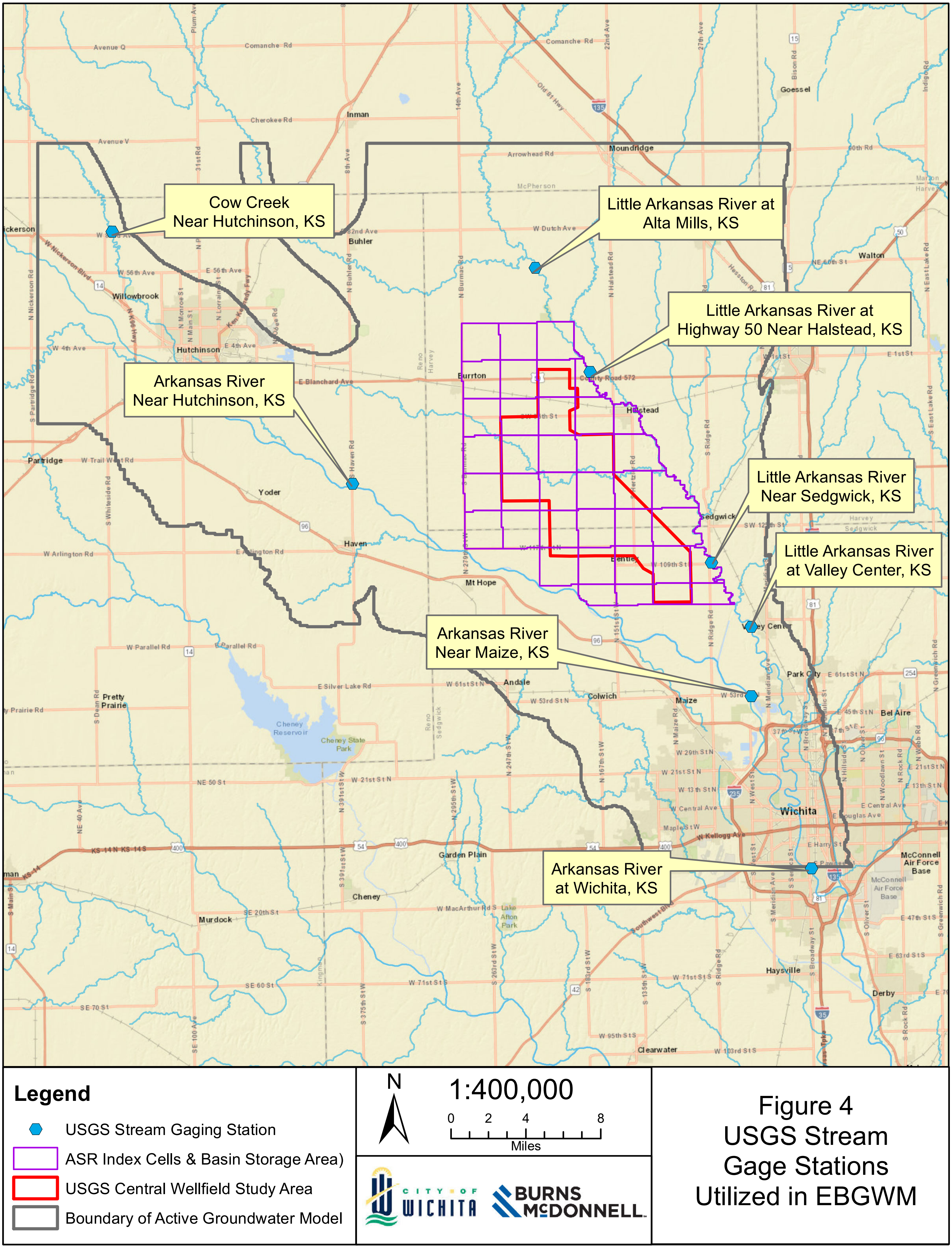


Figure 4
USGS Stream Gage Stations Utilized in EBGWM

Table 2-8: *Simulated Natural Aquifer Recharge Inputs for EBGWM*

Calendar Year	Total Annual Precipitation (Inches)	Simulated Recharge Rates as % of Precipitation	Simulated Recharge Rates (in/year)
2010	32.10	5-32%	1.60 to 10.27
2011	20.90	5-32%	1.04 to 6.68
2012	22.80	5-32%	1.14 to 7.29

2.4.7 Evaporation & Transpiration

Evapotranspiration in the model simulates the groundwater losses to evaporation and transpiration by plants. Evapotranspiration is maximized at the surface, and set to zero at a depth of 10 feet below ground surface. The rate of evapotranspiration was calculated using the process set up by the USGS during development of the EBGWM. This process utilizes the Hamon equation to take the saturated vapor pressure, mean daily air temperature, and average number of daylight hours to calculate the maximum evapotranspiration rate. The calculated evapotranspiration rate for calendar years 2010, 2011, 2012 utilized in the groundwater model is 35.1, 36.8, and 36.9 inches per year, respectively.

2.5 Groundwater Modeling Results – 1% Drought Simulation

The USGS established the current ASR minimum index level elevations and estimates of predevelopment groundwater levels (Attachment H – "*Revised Shallow and Deep Water-Level and Storage-Volume Changes in the Equus Beds Aquifer near Wichita, Kansas, Predevelopment to 1993*" USGS Scientific Investigations Report 2013-5170 (Hansen C.V., Lanning-Rush J.L., and Ziegler A.C., 2013). BMcD utilized Geographic Information System (GIS) software to geo-reference the groundwater elevation figures from this report for both predevelopment and January 1993. Using this approach, interpolated shallow aquifer groundwater elevation surfaces for predevelopment and January 1993 shallow aquifer conditions were generated and assigned to model cells to facilitate relative comparison of total saturated aquifer thickness during simulated drought conditions. To maintain consistency, the references to saturated thickness throughout this report refer to groundwater elevations sourced from Layer 1 of the model corresponding to the upper zone of the aquifer.

The EBGWM simulated groundwater levels from model Layer 1 (upper aquifer) for starting conditions, the end of the drought (SP8), and the end of each simulated recovery year have been exported and as Figures 5 through 8. The average simulated water level change from initial model conditions to the end of the 8-year drought was -11.59 feet for model cells in the CWSA and -8.19 feet for model cells within the BSA. The interpolated shallow water level elevations from January 1993 correlate to a calculated average of 88% full conditions for model cells within the CWSA and 92% full conditions for model cells within the BSA as a percentage of predevelopment saturated thickness (Figure 9). By contrast, at the end of the 8-year simulated drought, the average remaining saturated thickness as a percentage of predevelopment saturated thickness was 86% for model cells in the CWSA and 89% for model cells for the entire BSA (see Figure 10 and Table 2-9).

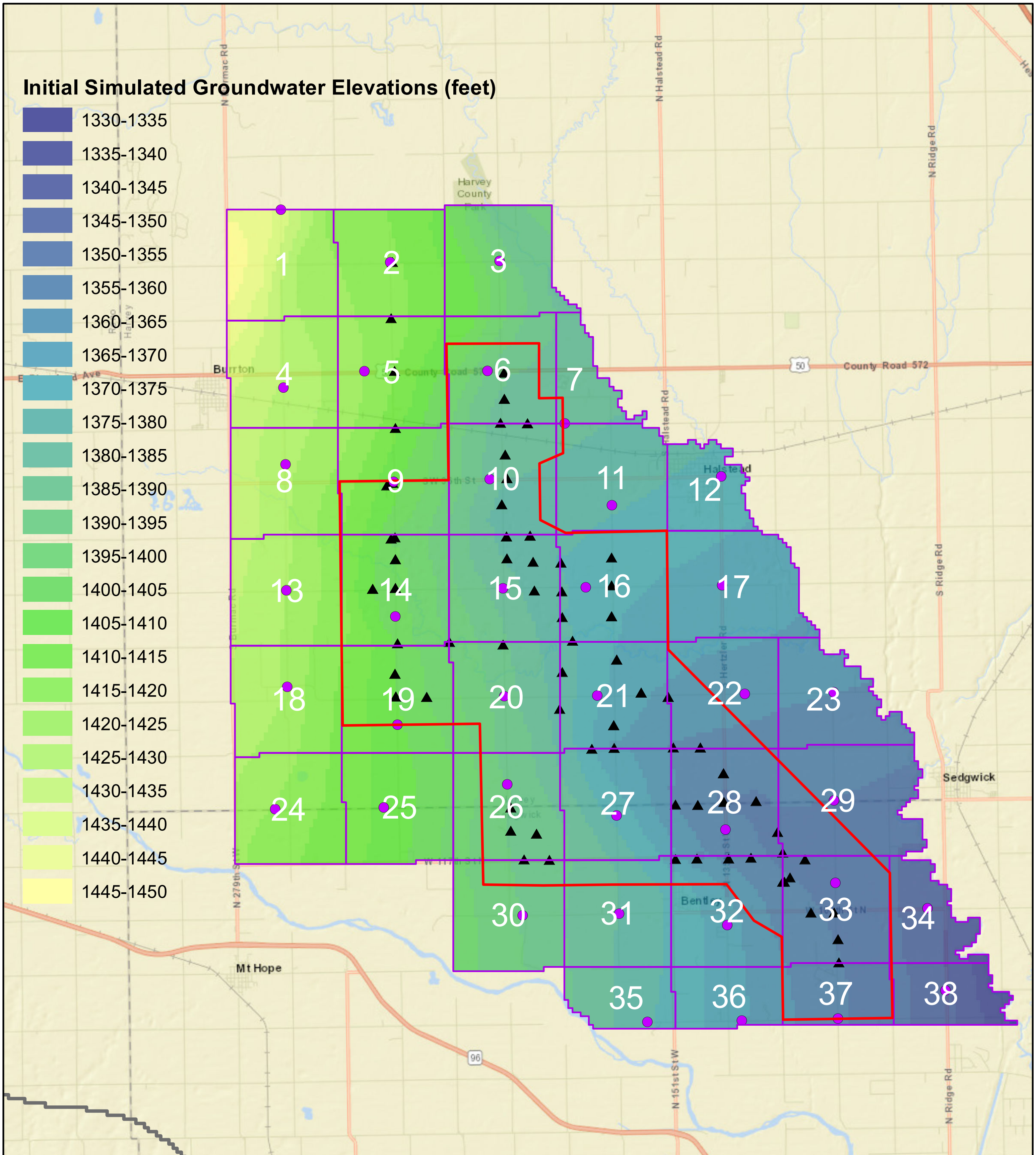
Table 2-9: *Groundwater Modeling Results for 1% Drought Simulation*

	Drought Years								Recovery Years	
EBGWM 1% Drought Simulation Statistics	SP1	SP2	SP3	SP4	SP5	SP6	SP7	SP8	SP9	SP10
ASR BSA avg Water Level Change from Starting Conditions (ft)	-1.8	-3.4	-5.2	-6.1	-7.3	-7.7	-7.9	-8.2	-6.1	-4.6
CWSA avg Water Level Change from Starting Conditions (ft)	-2.1	-4.4	-7.7	-8.9	-11.0	-11.2	-11.4	-11.6	-8.6	-6.3
ASR BSA Aquifer Condition (% Full)	93%	92%	91%	90%	90%	90%	90%	89%	91%	91%
CWSA Aquifer Condition (% Full)	90%	89%	87%	87%	86%	86%	86%	86%	87%	88%

Hydrographs have been generated for the model cells belonging to each of the existing ASR Index Well (IW) sites to record simulated water levels (Attachment I - Hydrographs 1 through 38). Further review of the hydrographs relative to January 1993 aquifer conditions indicates that groundwater levels within the EBWF are projected to fall below the current ASR minimum index levels during the simulated drought. Tables and maps illustrating when and where the January 1993 conditions are encountered have also been included within Attachment I.

2.6 Proposed Modifications to ASR Minimum Index Water Levels

The results of EBGWM 1% drought simulation confirm that after the drought, pumping demands will cause groundwater levels within the majority of the EBWF to drop below the currently permitted ASR minimum index level restrictions (Attachment I). This requires the City to seek reasonable alternative minimum index water levels for the existing ASR project that ensure recharge credits are available throughout periods of drought. The results of the EBGWM 1% drought simulation were utilized to calculate the lowest groundwater elevation for each IW site throughout the eight-year simulated drought.



Legend

- Boundary of Active Groundwater Model
- USGS Central Wellfield Study Area
- ASR Index Cells (Numbered)
- ASR Index Cell Monitoring Wells
- City of Wichita Groundwater Wells

N

1:150,000

0 0.5 1 2
Miles

CITY OF WICHITA

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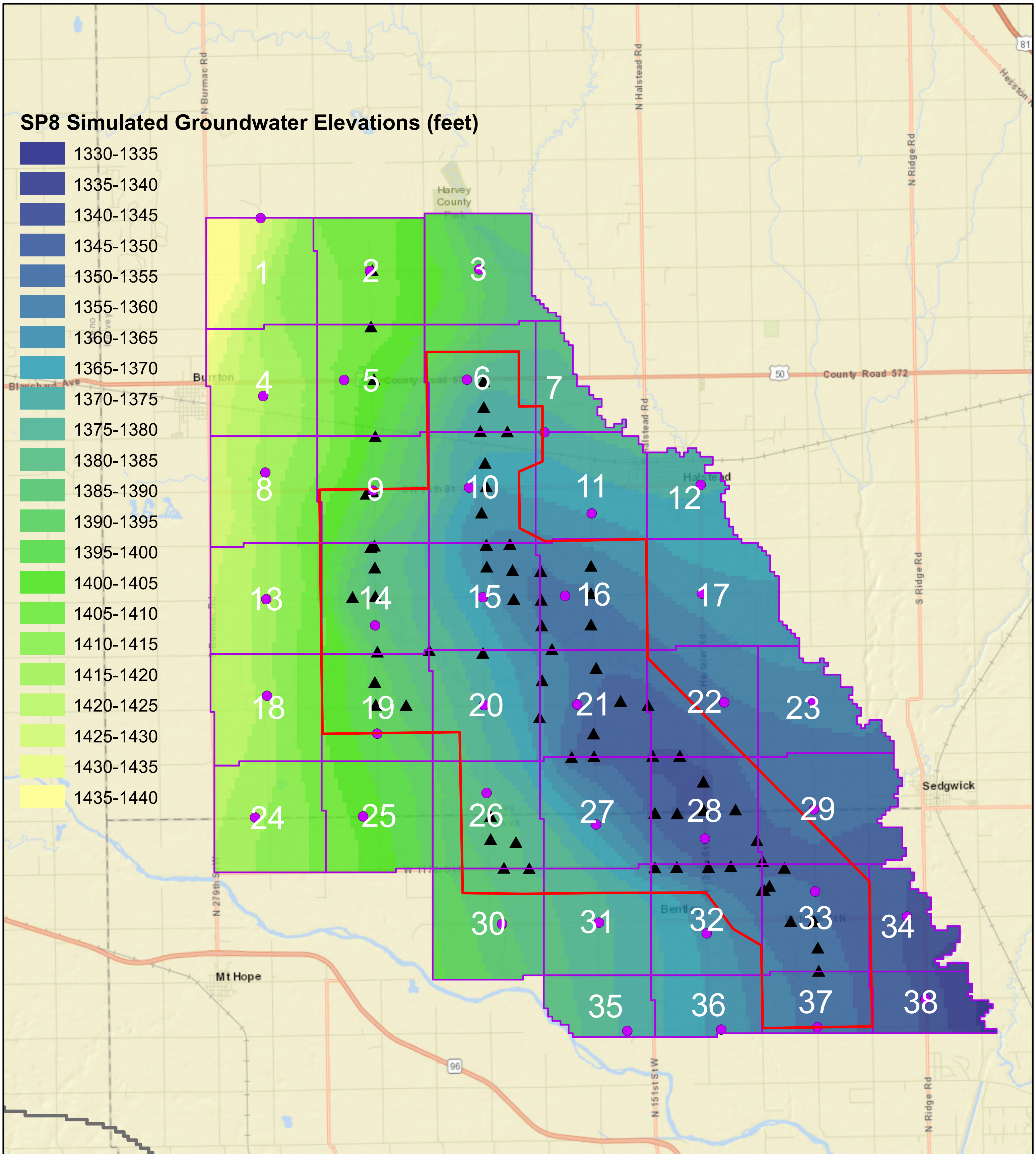
Figure 5
Simulated Drought
Starting Model Heads
(January of 1998)
Clipped to ASR BSA



Legend

Boundary of Active Groundwater Model

USGS Central Wellfield Study Area

ASR Index Cells (Numbered)

ASR Index Cell Monitoring Wells

City of Wichita Groundwater Wells

N

1:150,000

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Miles

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Figure 6
Simulated Groundwater Elevations
End of Drought Year 8 (SP8)
Results Clipped to ASR BSA

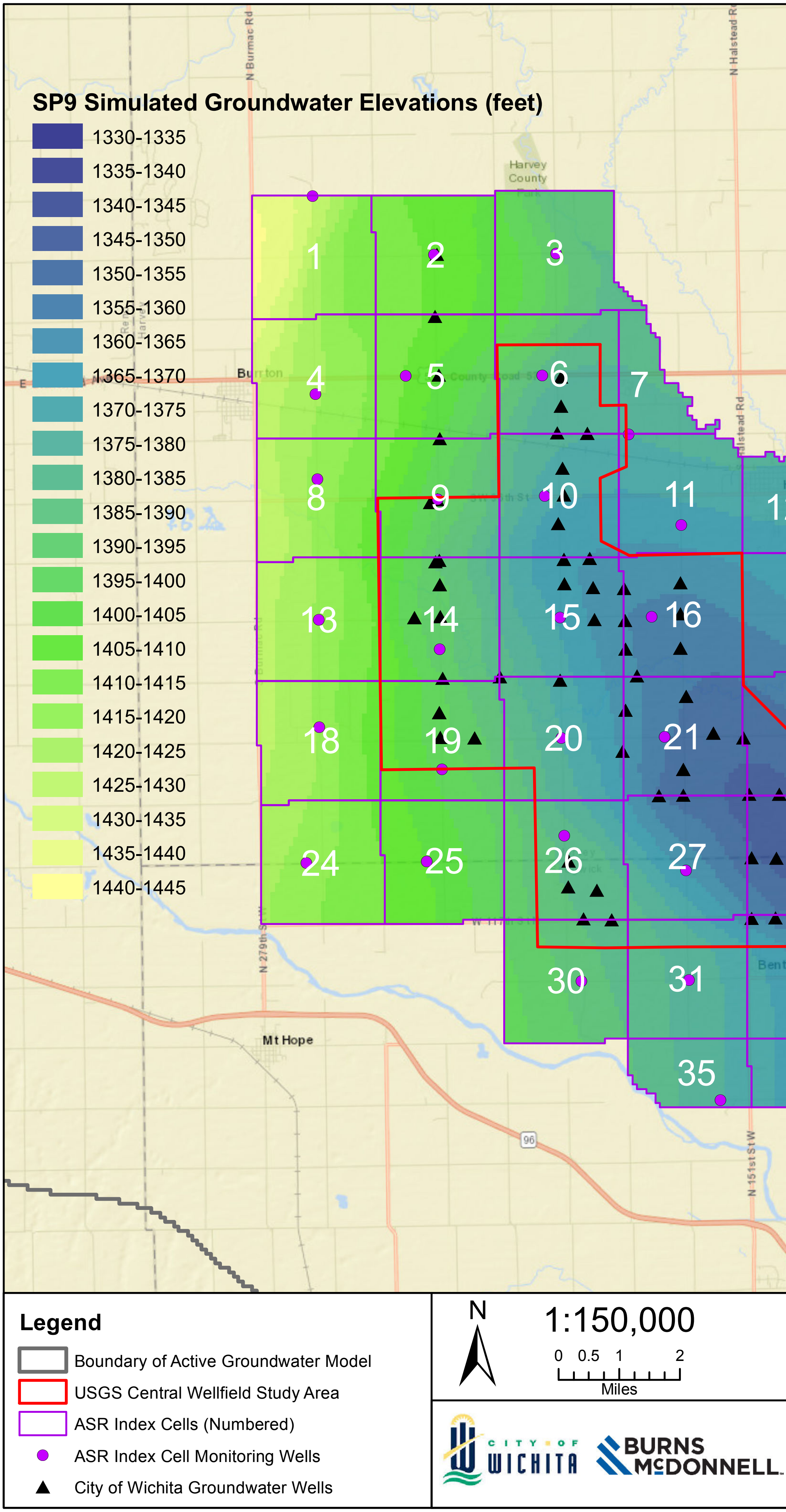


Figure 7
Simulated Groundwater Elevations
End of Recovery Year 1 (SP9)
Results Clipped to ASR BSA

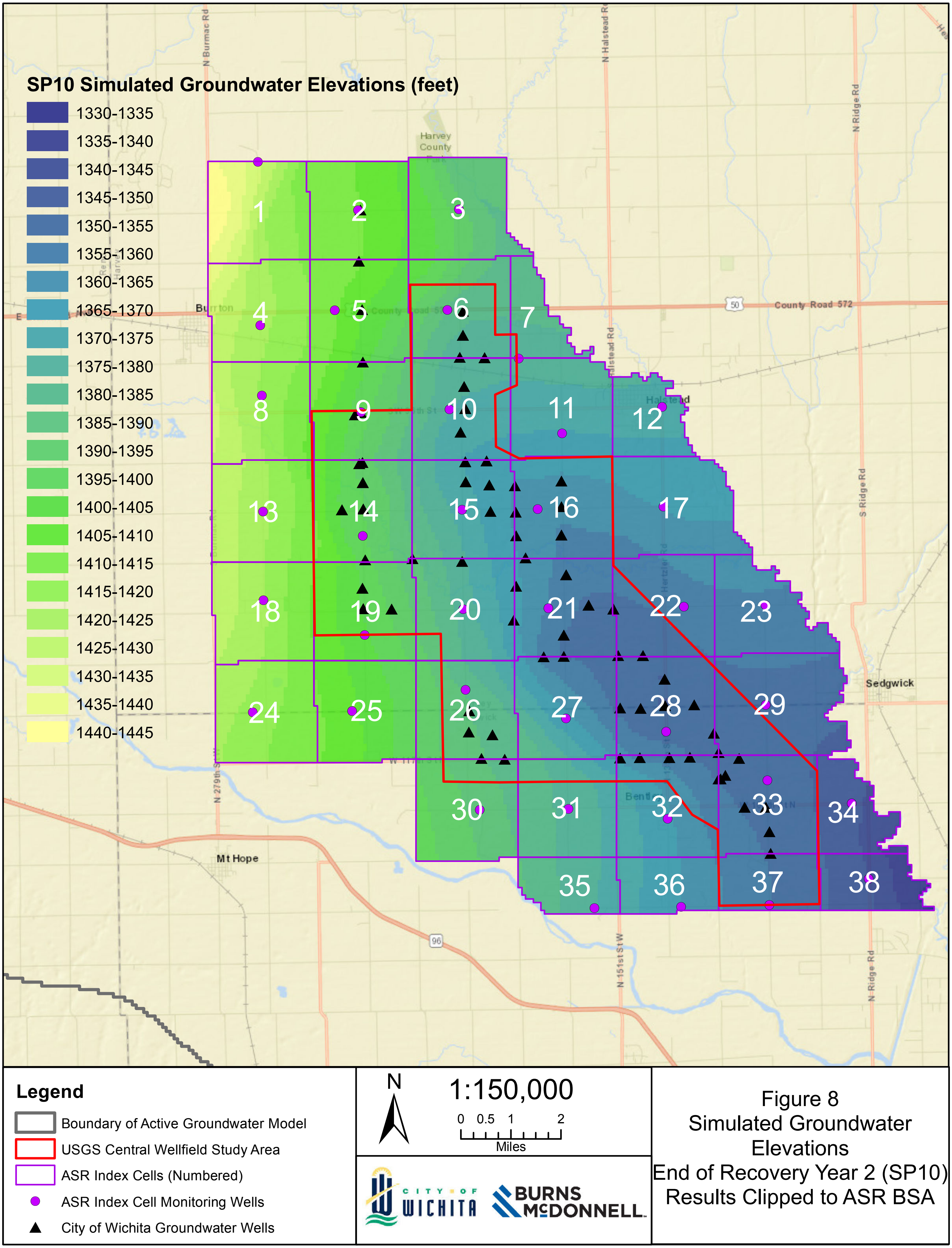


Figure 8
Simulated Groundwater Elevations
End of Recovery Year 2 (SP10)
Results Clipped to ASR BSA

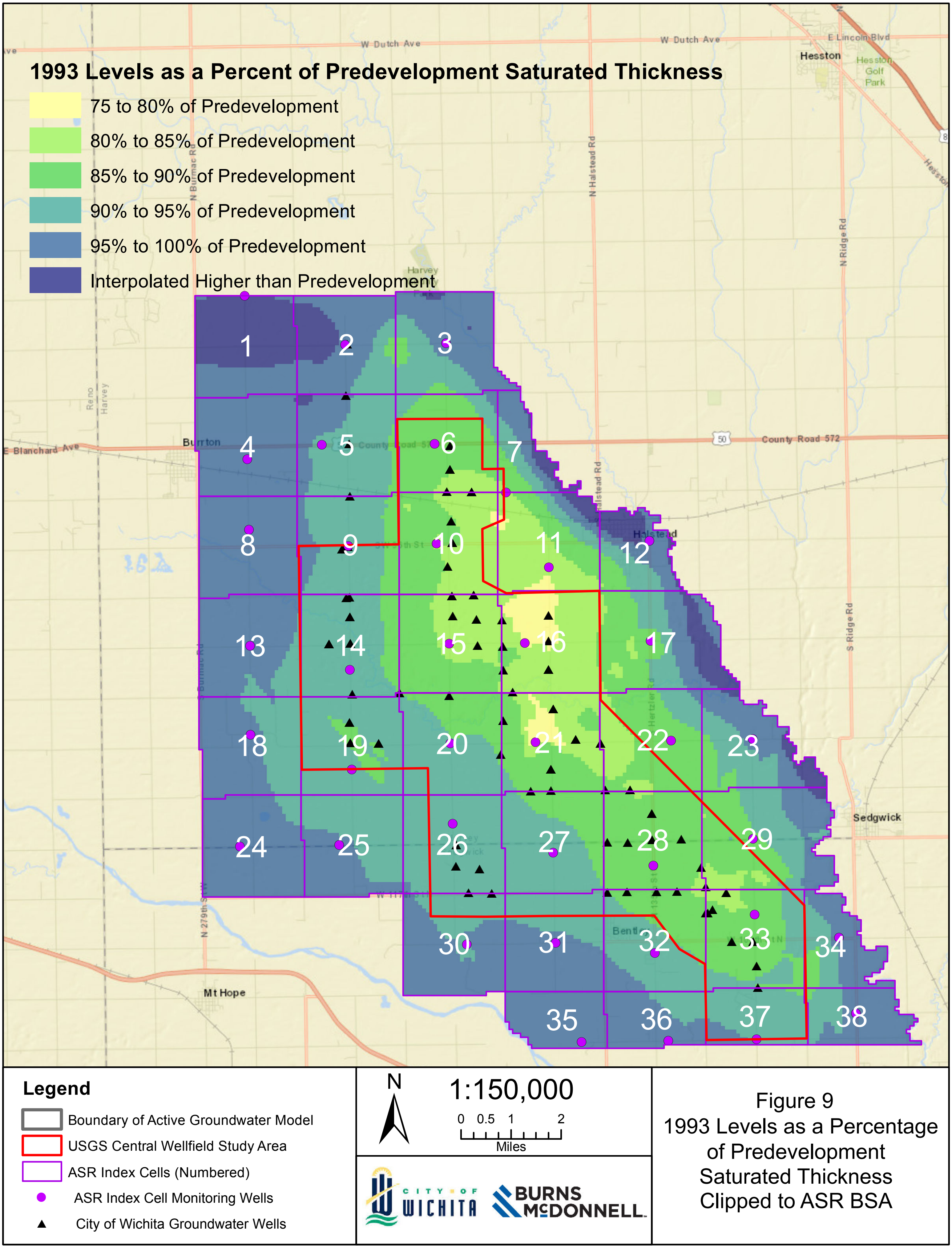
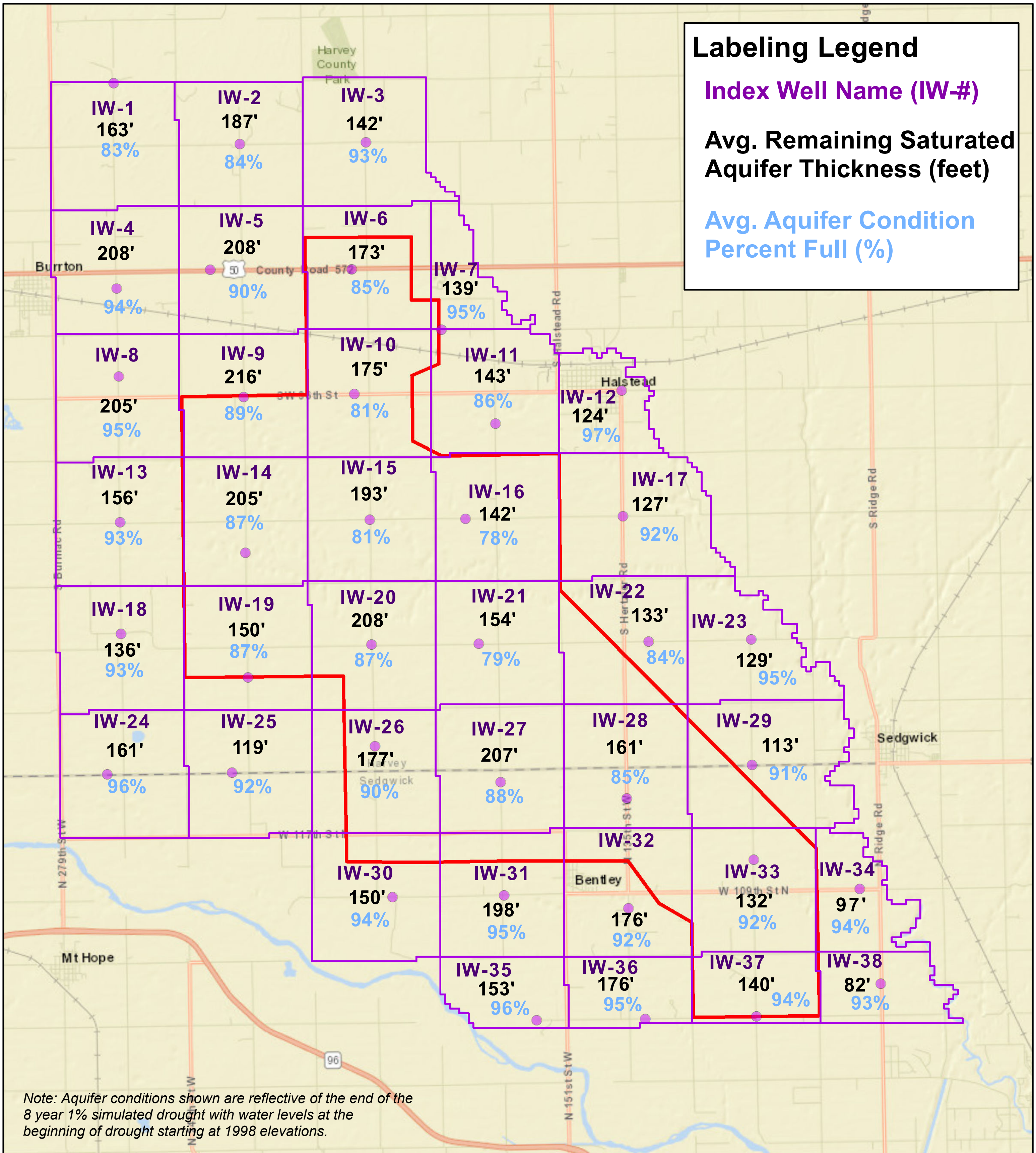


Figure 9
1993 Levels as a Percentage of Predevelopment Saturated Thickness Clipped to ASR BSA



Legend

- ASR Index Cells (Numbered)
- USGS Central Wellfield Study Area
- ASR Index Well Locations

N

1:130,000

0 0.5 1 2
Miles

CITY OF WICHITA

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Figure 10

Average Aquifer Conditions by Index Cell at the End of Simulated Drought Stress Period 8

To account for variability in actual drought conditions such as initial water resource conditions (both of Cheney reservoir and the EBWF), an additional contingency was subtracted from the calculated lowest groundwater elevations encountered during the groundwater modeling simulation for each IW site to develop the proposed ASR minimum index levels (see Table 2-10). Table 2-11 contains the proposed ASR minimum index elevations, and a comparison to the existing index levels. In addition, Figure 11 illustrates the average remaining aquifer saturated thickness for each Index Cell under the proposed levels as a percentage of predevelopment aquifer thickness. The City is requesting that the proposed minimum index levels be applied to all existing ASR Phase II infrastructure, currently pending ASR applications, and potentially future ASR infrastructure. Modifications to the minimum index level on permits covering ASR Phase I infrastructure are not being requested at this time.

2.7 Summary

The City of Wichita developed the ASR project with the goal of improving long-term aquifer sustainability and lowering drought vulnerability. Through extensive data analysis and groundwater modeling, the City has confirmed that groundwater levels will drop below the currently permitted ASR minimum index water levels during a prolonged drought, preventing the withdrawal of ASR credits when they are needed most. The groundwater modeling results indicate that at the end of a simulated 1% drought the aquifer will be approximately 86% full across the EBWF area and 89% full across the entire project basin storage area. To address the concern of recharge credits becoming unavailable during drought the proposed ASR minimum index water level elevations illustrated in Table 2-11 are being submitted for consideration.

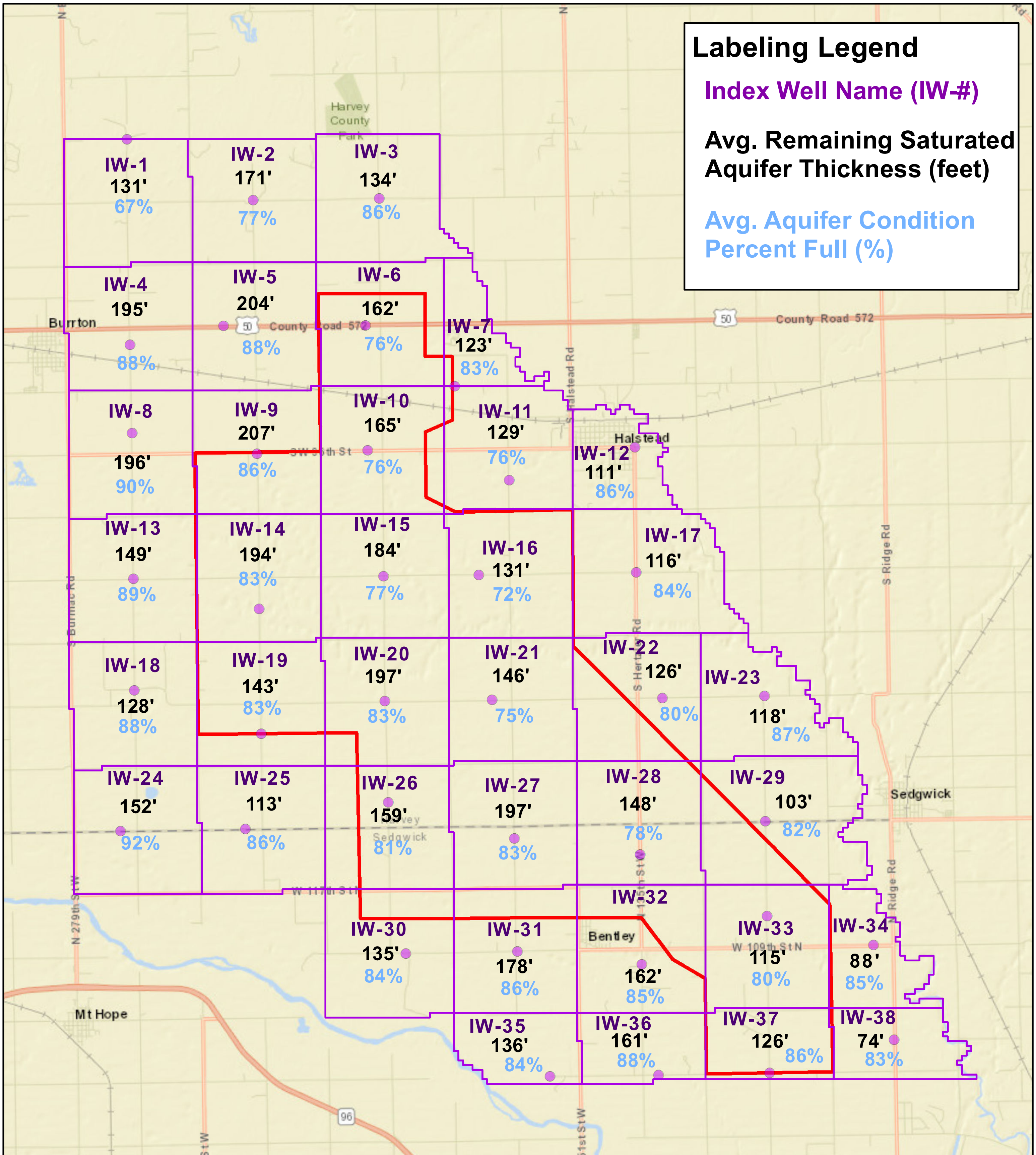
Table 2-10: *Development of Proposed ASR Minimum Index Levels*

		Minimum Index Level Elevations			
Index Well No.	Minimum Drought Model Elevation (feet)	Existing Level (1993 Level) (feet)	Basis for Proposed Level[1]	Contingency Added (feet)	Proposed Levels[2] (feet)
IW01C	1429.14	1413.42	Existing	20	1390
IW02C	1407.96	1410.52	Existing	10	1390
IW03C	1389.76	1396.93	Modeled	10	1380
IW04C	1420.35	1417.6	Existing	10	1407
IW05C	1408.21	1407.23	Modeled	10	1398
IW06C	1380.42	1388.74	Modeled	10	1370
IW07C	1372.79	1369.95	Existing	10	1360
IW08C	1418.06	1417.56	Modeled	10	1408
IW09C	1394.74	1394.1	Modeled	10	1385
IW10C	1368.08	1375.09	Modeled	10	1358
IW11C	1365.27	1363.75	Existing	10	1354
IW12C	1370.6	1365.78	Existing	10	1355
IW13C	1417.21	1418.27	Modeled	10	1407
IW14C	1386.6	1396.56	Modeled	10	1377
IW15C	1364.07	1369.75	Modeled	10	1354
IW16C	1354.11	1360.21	Modeled	10	1344
IW17C	1363.16	1360.59	Existing	10	1351
IW18C	1417.28	1421.4	Modeled	10	1407
IW19C	1396.07	1398.95	Modeled	10	1386
IW20C	1373.34	1376.05	Modeled	10	1363
IW21C	1352.12	1363.04	Modeled	10	1342
IW22C	1353.79	1354.92	Modeled	10	1344
IW23C	1356.94	1355.55	Existing	10	1345
IW24C	1416.31	1418.96	Modeled	10	1406
IW25C	1403	1407.27	Modeled	10	1393
IW26C	1380.64	1374.89	Existing	10	1364
IW27C	1363.16	1360.92	Existing	10	1350
IW28C	1343.8	1349.14	Modeled	10	1334
IW29C	1350.36	1349.51	Modeled	10	1340
IW30C	1386.13	1379.77	Existing	10	1370
IW31C	1376.18	1366.06	Existing	10	1356
IW32C	1362.86	1356.51	Existing	10	1346
IW33C	1348.93	1344.68	Existing	10	1334
IW34C	1344.62	1344.24	Modeled	10	1335
IW35C	1373.74	1366.76	Existing	10	1356
IW36C	1363.02	1360.13	Existing	10	1350
IW37C	1352.85	1350.51	Existing	10	1340
IW38C	1343.19	1344.65	Modeled	10	1333

[1] Existing refers to the Existing 1993 Level, Modeled refers to the Minimum Drought Model Elevation.
[2] Values were rounded to the nearest foot.

Table 2-11: *Proposed ASR Minimum Index Levels*

	Minimum Index Level Elevations				
Index Cell No.	Existing Level (1993 Level) (feet)	Proposed Level (feet)	Existing versus Proposed (feet)	Proposed Level - Remaining Aquifer Saturated Thickness (feet)	Proposed Level as a Percentage of Predevelopment Saturated Thickness (%)
1	1413.42	1390.00	-23.42	131	67%
2	1410.52	1390.00	-20.52	171	77%
3	1396.93	1380.00	-16.93	134	86%
4	1417.60	1407.00	-10.60	195	88%
5	1407.23	1398.00	-9.23	204	88%
6	1388.74	1370.00	-18.74	162	76%
7	1369.95	1360.00	-9.95	123	83%
8	1417.56	1408.00	-9.56	196	90%
9	1394.10	1385.00	-9.10	207	86%
10	1375.09	1358.00	-17.09	165	76%
11	1363.75	1354.00	-9.75	129	76%
12	1365.78	1355.00	-10.78	111	86%
13	1418.27	1407.00	-11.27	149	89%
14	1396.56	1377.00	-19.56	194	83%
15	1369.75	1354.00	-15.75	184	77%
16	1360.21	1344.00	-16.21	131	72%
17	1360.59	1351.00	-9.59	116	84%
18	1421.40	1407.00	-14.40	128	88%
19	1398.95	1386.00	-12.95	143	83%
20	1376.05	1363.00	-13.05	197	83%
21	1363.04	1342.00	-21.04	146	75%
22	1354.92	1344.00	-10.92	126	80%
23	1355.55	1345.00	-10.55	118	87%
24	1418.96	1406.00	-12.96	152	92%
25	1407.27	1393.00	-14.27	113	86%
26	1374.89	1364.00	-10.89	159	81%
27	1360.92	1350.00	-10.92	197	83%
28	1349.14	1334.00	-15.14	148	78%
29	1349.51	1340.00	-9.51	103	82%
30	1379.77	1370.00	-9.77	135	84%
31	1366.06	1356.00	-10.06	178	86%
32	1356.51	1346.00	-10.51	162	85%
33	1344.68	1334.00	-10.68	115	80%
34	1344.24	1335.00	-9.24	88	85%
35	1366.76	1356.00	-10.76	136	84%
36	1360.13	1350.00	-10.13	161	88%
37	1350.51	1340.00	-10.51	126	86%
38	1344.65	1333.00	-11.65	74	83%



Legend

- ASR Index Cells (Numbered)
- USGS Central Wellfield Study Area
- ASR Index Well Locations

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Figure 11

Average Aquifer Conditions by Index Cell at Modified ASR Minimum Index Level Elevations

3.0 AQUIFER MAINTENANCE CREDITS PROPOSAL

The City's continued approach to outcome based management of water resources has resulted in unprecedented groundwater level recoveries within the City of Wichita's EBWF. These groundwater level recoveries are a direct result of the City's utilization of alternate surface water resources, such that the aquifer within the EBWF has recovered to nearly 100% full pre-development conditions. The operational shift to the use of more surface water has resulted in a savings of over 400,000 AF of groundwater since 1993. Groundwater level recoveries have improved general groundwater availability, groundwater quality, and provide direct benefits to both the City and other groundwater users in the area.

The City has been reviewing how these groundwater level improvements impact long-term water resource operations and drought resiliency. It is clear that higher groundwater levels directly limit the physical recharge capacity of the City's Aquifer Storage and Recovery program. The ability to establish and recover ASR credits remains a critical component of the City's plan to meet the enhanced demand for raw water during an extended drought. Under existing ASR permit conditions, the City can enhance the physical recharge capacity of the ASR program by making a shift to utilization of more groundwater from the EBWF. Rather than lowering groundwater levels in the EBWF to create physical recharge capacity and storage for the ASR system, an alternative recharge credit development strategy during full aquifer conditions is being proposed for consideration. The City's long-standing history of responsible water resources management and the continued outcome based management of available water supplies merits an alternative procedure for establishing ASR recharge credits during periods of high groundwater levels.

The City proposes that the quantity of water diverted from the Little Arkansas River that cannot be physically recharged through the ASR system could be sent to the City's main water treatment plant to directly meet City water demands. The water left in storage because of utilizing Little Arkansas River flows rather than groundwater from the EBWF would be considered an ASR Aquifer Maintenance Credit (AMC) with similar characteristics to the current ASR recharge credits. To facilitate consideration of this proposal the City has assembled documentation on: historic water resources management, a brief history on the development and vision for the City's ASR program, a physical ASR recharge operations plan for determining the annual eligibility of AMCs, an AMC accounting system, and several additional anticipated permit conditions.

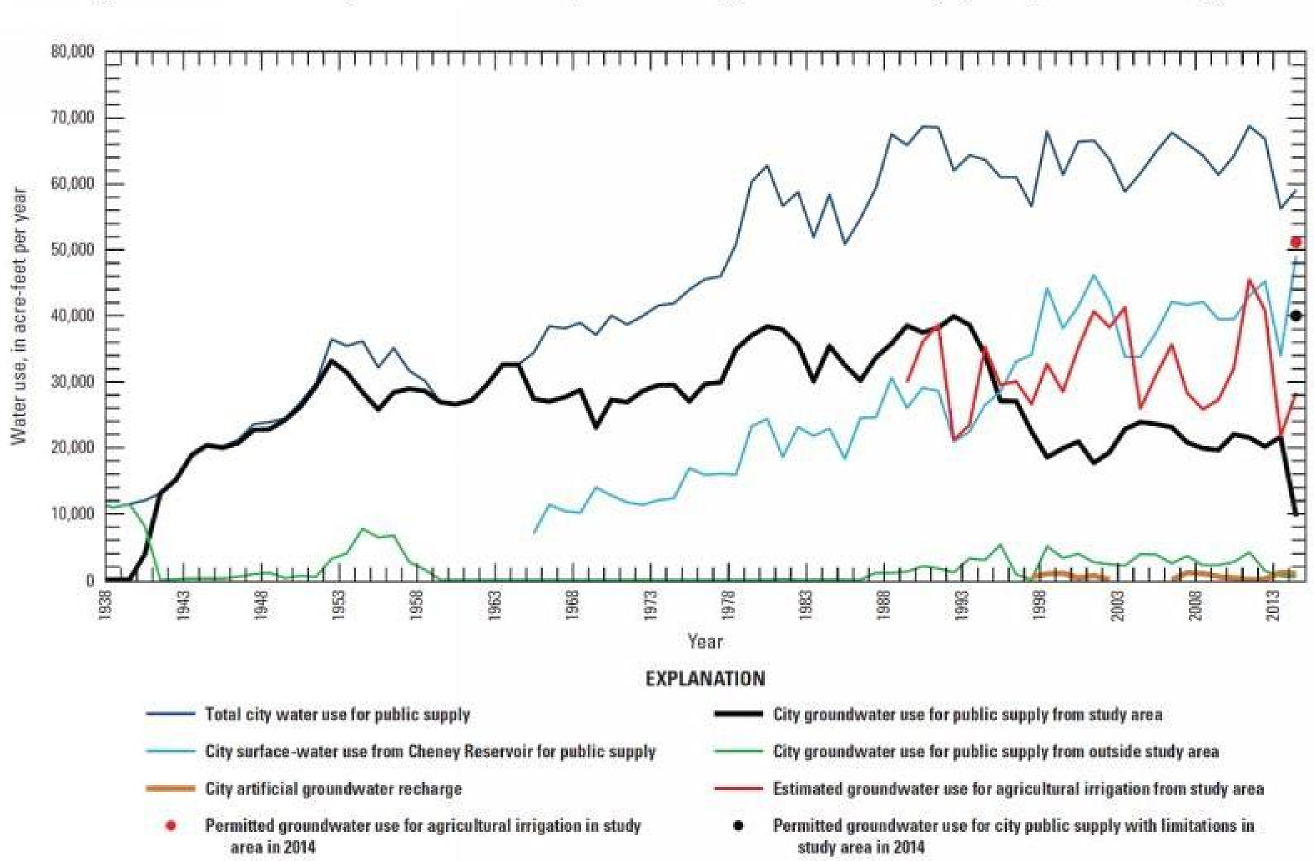
3.1 Integrated Local Water Supply Plan (ILWSP)

The City has adopted and implemented an Integrated Local Water Supply Plan (ILWSP) focused on strategic utilization of groundwater, surface water, and development of an Aquifer Storage and Recovery Program. Prior to implementation of the ILWSP, the EBWF supplied 60 to 70 percent of the City's annual municipal water supply. The over-appropriation and heavy utilization of groundwater with the EBWF began to cause groundwater level declines and concerns about the long-term yield and water quality of the aquifer. The ILWSP developed by the City created a proactive plan to address the declining groundwater levels and to ensure that the EBWF could sustain projected future demands. To manage the resource in a sustainable manner, the City shifted operations to utilize the EBWF to supply 30 to 40 percent of the City's municipal water supply, and constructed Phase 1 and Phase 2 of the ASR program infrastructure. The implementation of the ILWSP has resulted in a substantial increase in the percentage of surface water used by the City to meet demands, with recent surface water usage as high as 85 to 90 percent. The groundwater level recoveries within the EBWF area are a direct result of the implementation of the ILWSP and the City's ASR program. The results of responsible resource management and conservation by the City have promoted a historic period of groundwater level recoveries to the benefit of the City of Wichita and other groundwater users. Figures 11 and 12 illustrate historic trends in water use and the most recent survey of aquifer conditions as published by the USGS.

3.2 City of Wichita ASR Program Development

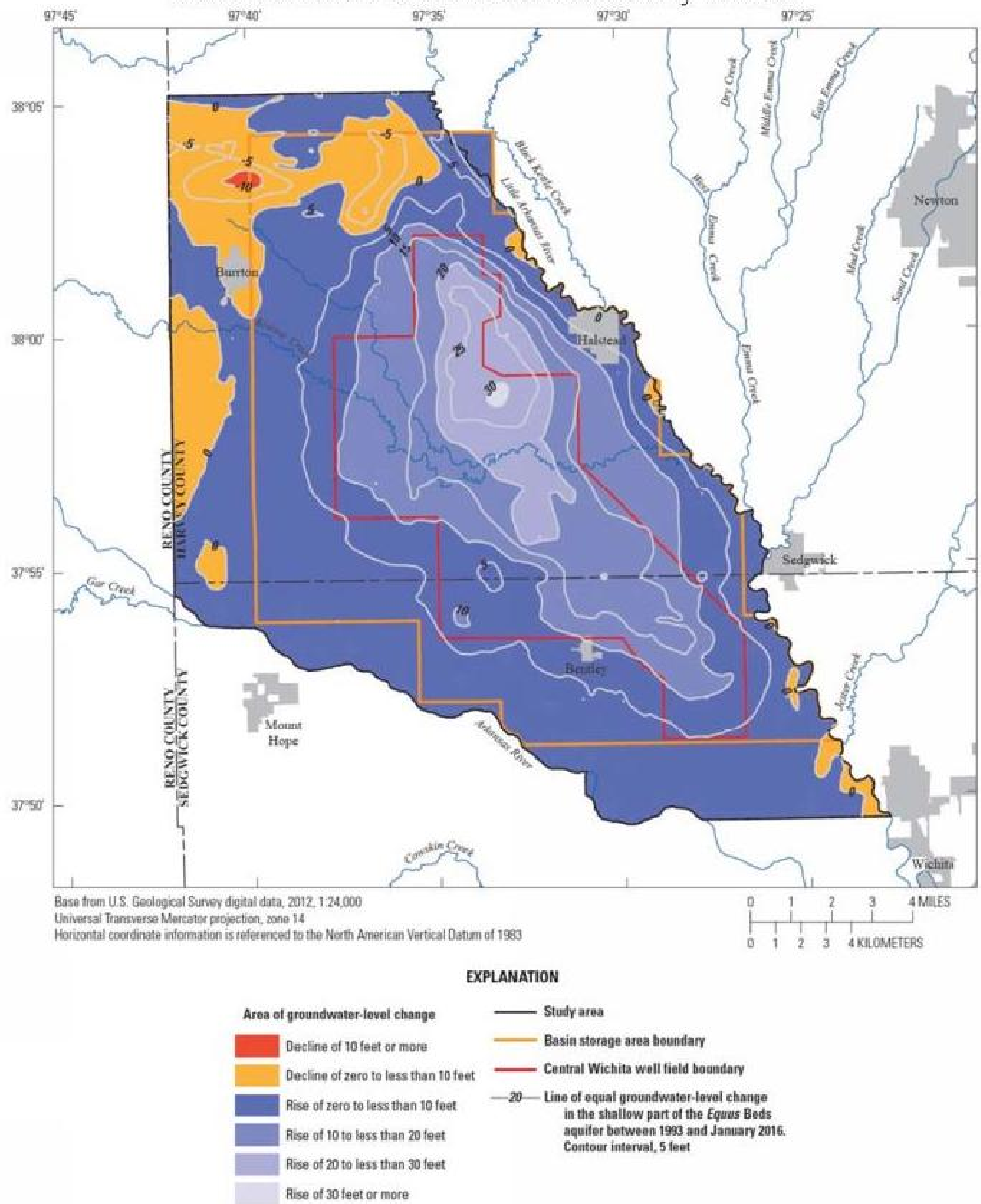
The City of Wichita's ASR system captures water from the Little Arkansas River during above-baseflow events via bank storage wells and surface water intakes. The surface water from the Little Arkansas River is then treated then distributed into groundwater storage throughout the EBWF utilizing a network of recharge wells and recharge basins. The implementation of ASR was envisioned and constructed to improve groundwater levels, sustain water quality, and to meet the future projected daily demands of the City. Over the last 20 years, daily demand growth from the City has flattened below the projections made during the early 1990's. The reduced rate of demand growth can be attributed to many factors including a modification to City's water rate structure, a shift to water conserving appliances and fixtures, and focused conservation programs established and financed by the City of Wichita. The reductions in water demand have shifted the need for ASR recharge credits from a normal daily source of supply to a long-term resource only required during extended drought. The focus of the ASR program on drought mitigation allows for the same water quantity and water quality benefits as originally envisioned and results in utilization of ASR recharge credits less frequently. The focus of the ASR program on drought mitigation also means that recharge credits must be maintained at quantities sufficient to meet the projected demands of an extended drought.

Figure 12 – Historic water use for the City of Wichita and surrounding Agricultural Irrigation near the City of Wichita's Aquifer Storage and Recovery (ASR) Basin Storage



Source: Whisnant, J.A., Hansen, C.V., and Eslick, P.J., 2015, Groundwater-level and storage-volume changes in the Equus Beds Aquifer near Wichita, Kansas, predevelopment through January 2015: U.S. Geological Survey Scientific Investigations Report 2015–5121, 27 p., http://dx.doi.org/10.3133/sir20155121.

Figure 13 – Groundwater level changes in the shallow part of the Equus Beds aquifer in and around the EBWF between 1993 and January of 2016.



Source: Klager, B.J., 2016, Status of groundwater levels and storage volume in the Equus Beds aquifer near Wichita, Kansas, January 2016: U.S. Geological Survey Scientific Investigations Report 2016–5165, 15 p., https://doi.org/10.3133/sir20165165.

3.3 Benefits of ASR Aquifer Maintenance Credits (AMCs)

To continue to incentivize groundwater conservation and to address the challenges of establishing physical recharge credits in an aquifer that has recovered to levels near pre-development, the City is proposing an alternative procedure for establishing recharge credits during periods of high groundwater levels. In-lieu of implementing a pumping strategy to increase the storage capacity within the EBWF, the quantity of water diverted from the Little Arkansas River that cannot be physically recharged through the ASR system could be sent to the City's main water treatment plant to directly meet City water demands. The capture and use of transient surface water in the Little Arkansas River directly offsets groundwater that would have been pumped to meet daily demand and to create physical ASR recharge capacity. The City is proposing that the water left in storage because of utilizing Little Arkansas River flows be considered a ASR Aquifer Maintenance Credit (AMC) with similar characteristics to the current ASR recharge credits.

The availability of water in the Little Ark River for diversion would remain identical to the base flow and seasonal limits developed as part of the ASR Phase 1 and Phase 2 permitting process. The Little Arkansas River water that cannot be physically recharged using the ASR system would be put to a beneficial use by transmission to the City for treatment and distribution. Use of this water directly replaces diversions that would otherwise be required from the EBWF resulting in an equal amount of groundwater effectively left in storage to the benefit of all aquifer users.

3.4 Proposed AMC Permit Conditions

The City's ASR system facilitates a unique physical link between surface water flows in the Little Arkansas River and groundwater storage in the EBWF. Direct diversions of above-baseflow water from the Little Arkansas River to the City to meet daily demands during periods of limited physical ASR recharge capacity directly offsets diversions from the EBWF. This effectively leaves groundwater in storage within the EBWF. Direct diversions to the City of above-baseflow water from the Little Arkansas River to meet daily demands during periods of limited physical ASR recharge capacity would result in the generation of an AMC in an amount established by the proposed accounting process discussed later within this proposal. The water diverted from the Little Arkansas River may be used for direct aquifer recharge, diverted to the City for treatment and distribution, or both depending on the condition of the aquifer. The City will continue to maintain an ASR operational priority focused on development of physical recharge credits when and where groundwater levels are at elevations that facilitate physical recharge capacity. The following list represents the key components and generally anticipated permit conditions that would guide the operations and accounting of AMCs:

1. Physical recharge activities will continue to occur during periods when aquifer conditions facilitate adequate physical recharge capacity defined by an annual ASR Operations Plan.
2. The rate of accrual of all recharge credits cannot exceed the constructed physical diversion capacity of the ASR system including direct surface water diversions and future bank storage wells, and will be limited to the rate and quantity authorized by Water Right No. 46627.
3. ASR Phase I RRW's are not eligible to receive AMCs, only physical recharge at Phase I RRW's or recharge basins will result in the development of an ASR recharge credit.
4. The estimated aquifer storage volume in the CWSA during initial implementation of the ILWSP by the City and during the conceptual development of the ASR program is estimated at 120,000 AF (see Attachment H, page 13) therefore the combined total quantity of AMCs and physical recharge credits cannot exceed 120,000 AF. The proposed 120,000 AF limit on the combined total quantity of AMCs and physical recharge credits represents an estimated 11.7% of total available aquifer storage within the CWSA
5. The fundamental differences between the processes used to generate physical recharge credits and AMCs will require an alternative or modified accounting process for AMCs.
6. AMCs would be accumulated based on the metered quantity of water diverted from the Little Arkansas River via direct surface water diversions or water captured via bank storage wells and sent directly to the City.
7. A straight-forward spreadsheet accounting process will be adopted similar to other existing water management conservation programs in the State.
    a. A uniform and equal annual distribution throughout the EBWF to all authorized City points of diversion within the EBWF based on the annual quantity of water diverted from the Little Arkansas River sent directly to the Wichita MWTP.
    b. Uniform distribution of AMCs to all authorized City points of diversion within the wellfield reasonably reflects historic wellfield operations at locations where groundwater has effectively been left in storage within the aquifer due to the development and utilization of Little Arkansas River flows.
    c. After distribution and assignment of AMC quantities by point of diversion, an acceptable AMC accounting process will track the quantity of AMCs stored within each Index Cell.

3.5 ASR Physical Recharge & ASR Operations Plan

To illustrate the City's commitment to conducting physical recharge activities during periods when the aquifer permits physical recharge capacity, the City is proposing the use of an annual ASR Operations

Plan. The operations plan will utilize groundwater level monitoring and the calculated recharge capacity of the ASR recharge well network to determine the quantity and eligibility to accumulate AMCs. The ASR Phase II Water Treatment Plant (ASR WTP) can operate at either 15 or 30 MGD. The City is proposing that if the available physical recharge capacity of the ASR recharge well network drops below a cumulative total of 5 MGD that all water from the ASR WTP sent to town would be considered eligible for conversion to an AMC. The 5 MGD minimum for physical recharge capacity is considerate of the operational limitations at lower flows (pipeline residence times, well redevelopment frequency, pipeline flushing requirements, and system startup and shutdown requirements). During periods where the calculated physical recharge capacity of the ASR recharge well network exceeds 5MGD, the physical recharge capacity of the recharge well network would be subtracted from total production of the ASR WTP to calculate the quantity of water eligible for conversion to an AMC (see examples below).

Example 1 – High Groundwater Levels Limited Recharge Capacity

ASR Physical Recharge Capacity – 4 MGD

ASR WTP Running at 15 MGD – 15 MGD being sent to City to meet demands

Amount of ASR WTP water eligible for AMC – **15 MGD**

Example 2 – Moderate Groundwater Levels with Moderate Recharge Capacity

ASR Physical Recharge Capacity – 10 MGD

ASR WTP Running at 15 MGD – 5 MGD being sent to City to meet demands

Max amount of ASR WTP water eligible for AMC – **5 MGD**

Example 3 – Lowered Groundwater Levels with Available Recharge Capacity

ASR Physical Recharge Capacity – 15 MGD

ASR WTP Running at 30 MGD – 15 MGD being sent to City to meet demands

Max amount of ASR WTP water eligible for AMC – **15 MGD**

To determine the physical recharge capacity of the ASR recharge well network, the City proposing the implementation of an annual water level monitoring program in conjunction with a recharge capacity calculation table. For each of the City's ASR recharge wells, the individual sustainable recharge capacity is a function of static groundwater elevation, the maximum feasible limiting groundwater elevation below land surface, constructed wellhead infrastructure, and specific injectivity. During January of each year, the City will measure and document static groundwater levels at each of the existing ASR Index Wells and at each of the City's ASR recharge wells. The static groundwater elevations obtained from the ASR recharge well network during January of each year will be used to generate an annual operations table that will calculate the available recharge capacity for each individual ASR recharge well and the cumulative capacity of the ASR recharge well network system. The annual operations table will utilize the following variables and terms:

i. *Static Groundwater Elevation* – Groundwater elevation will be gathered at each ASR recharge well location during January of each year when the well is off to eliminate or mitigate the effects of observing drawdown.

ii. *Maximum Groundwater Elevation* – The City's ASR operations protocols prevents recharge when groundwater levels reach ten feet below ground surface to protect wellhead equipment and surrounding infrastructure.

iii. *Sustainable Specific Injectivity* – During recharge operations, the long term sustainable recharge rate of a well can be divided by the rise in water level in the well column from static groundwater conditions to calculate a maximum sustained long term specific injectivity value in the units of gallons per minute per foot. This number is sourced from historic observations at each well during actual ASR recharge well operations.

iv. *Maximum Calculated Sustainable Recharge Rate* - The maximum sustainable recharge rate for each ASR well can be calculated as (Maximum Groundwater Elevation - Static Groundwater Elevation) x (Sustainable Specific Injectivity).

v. *Maximum Well Infrastructure Recharge Rate* – The City's recharge wells utilize recharge down tubes of various sizes to inject water below static groundwater level. The variety in sizes of the down tubes allows for recharge operations at various rates and pressures to best match the current recharge capacity of each well. The maximum recharge rate for each of the City's ASR wells is governed by the size and total number of recharge down tubes which have been designed and constructed to match the maximum anticipated recharge capacity of the well during depleted aquifer conditions.

vi. *Minimum Well Infrastructure Recharge Rate* – The City's recharge wells utilize recharge down tubes of various sizes to inject water below static groundwater level. The variety in sizes of the down tubes allows for recharge operations at various rates and pressures to best match the current recharge capacity of the well. The minimum recharge rate for each of the City's ASR wells is therefore limited by the rate available by using the smallest diameter recharge downtube available at each wellhead.

During periods where the maximum calculated sustainable recharge rate is less than the minimum well infrastructure recharge rate it is not practical to conduct physical recharge at the wellhead therefore the available physical recharge rate of the well is effectively zero. In addition, groundwater levels are above the maximum groundwater elevation (10 feet below land surface) the available physical recharge rate of the well is zero. Alternatively, if the maximum calculated sustainable recharge rate exceeds that of the minimum limits of the recharge well infrastructure, the available physical recharge capacity for each recharge well will be considered the maximum calculated sustainable recharge rate (see examples below).

Example 1 – High Groundwater Levels - No Available Physical Recharge Capacity

Well A – Land Surface Elevation – 1,420 feet

Well A – Static Groundwater Elevation – 1,395 feet (25 feet bls)

Well A – Maximum Groundwater Elevation - 1,410 feet (10 feet bls)

Well A – Sustainable Specific Injectivity – 6 gpm/foot

Well A – Maximum Calculated Sustainable Recharge Rate

(1410 – 1395) x (6 gpm/foot) = 90 gpm

Well A – Minimum Well Infrastructure Recharge Rate = 125 gpm

Well A – Available Physical Recharge Capacity = **0 gpm**

Since the Maximum Sustainable Injection of 90 gpm is less than the Minimum Infrastructure Injection Capacity of 125 gpm the Available Recharge Capacity is 0 gpm.

Example 2 – Lowered Groundwater Levels - Physical Recharge Capacity Available

Well B – Land Surface Elevation – 1,420 feet

Well B – Static Groundwater Elevation – 1,385 feet (35 feet bls)

Well B – Maximum Groundwater Elevation - 1,410 feet (10 feet bls)

Well B – Sustainable Specific Injectivity – 10 gpm/foot

Well B – Maximum Calculated Sustainable Recharge Rate

(1410 – 1385) x (10 gpm/foot) = 250 gpm

Well B – Minimum Well Infrastructure Recharge Rate = 125 gpm

Well B – Available Physical Recharge Capacity = **250 gpm**

Since the Maximum Sustainable Injection Rate of 250 gpm is greater than the Minimum Infrastructure Injection Capacity of 125 gpm the Available Recharge Capacity is 250 gpm.

The available physical recharge capacities for each of the recharge wells included in the ASR recharge well network will then be totaled to represent the physical recharge capacity of the ASR system. The City will assemble and submit an operations table as a part of the accounting process each year as the formal estimate of the total physical recharge capacity of the ASR system so that the quantity of water eligible for AMCs can be considered during the AMC accounting process. The operations table is intended as a guide to estimate the amount available physical recharge capacity available in the ASR recharge well network. Actual ASR recharge operations will need to remain flexible, and the operations table will be a living document that allows for improved representation of the ASR recharge well network (changes in the number of recharge wells, the availability of recharge well equipment, increases or decreases in specific injectivity, improvements to recharge well infrastructure, etc.). An example of a proposed operations table has been completed based on January 2016 groundwater levels (see Figure 13).

3.6 Outcome Based Management of Water Resources

The City's long-standing history of responsible water resources management and the continued outcome based management of available water supplies merits an alternative procedure for establishing ASR recharge credits during periods of high groundwater levels. This proposal for the consideration of AMCs presents a unique opportunity to achieve sustainable management of multiple high value regional water resources (Table 3-1).

The added flexibility granted by AMCs would City would reinforce the City's commitments outcome based management of water resources:

- The City of Wichita remains committed to optimizing the use of all available water supply resources both in times of abundance and times of drought.
- The City remains committed to making water resource management practices that are governed by outcome based results focused on the long-term sustainability of all available water supplies.
- The City will continue to maintain an ASR operational priority focused on generation of physical recharge credits where and when possible.
- The ability to develop and recover AMCs results in an aquifer management strategy focused on maintaining the maximum quantity of water possible in aquifer storage within the EBWF.

The capacity to maintain aquifer levels as full as possible during normal periods provides multiple local and regional water quality benefits by limiting migration of the Burrton chloride plume, limiting natural chloride intrusion from the Arkansas River, and through enhancement of base flow to creeks, streams, and rivers.

Table 3-1: *Benefits to Multiple Aquifer Users and Water Resources from AMCs*

Water Resource Parameter	Results Without Aquifer Maintenance Credits	Results With Aquifer Maintenance Credits
ASR Phase I	Regional groundwater levels including those at Phase I would be lowered from pumping in the core of the City's wellfield.	ASR Phase I permits would not be modified, regional groundwater levels can be managed to the benefit of water quality and all users.
ASR Phase II & Future	Regional groundwater levels would be lowered and managed at levels to facilitate physical recharge capacity for the ASR system.	Regional groundwater levels can be managed at near full conditions, improved groundwater quality and resource availability for all users.
Little Arkansas River Diversions	Water is lost downstream during periods when the ASR system lacks physical recharge capacity.	Additional river flow events can be put to beneficial use, river water directly replaces groundwater that would have been utilized from the City's Equus Beds Wellfield.
Cheney Reservoir	During full conditions water that could have been used by the City bypasses the reservoir as production remains focused on the Equus Beds Wellfield.	Increased use during full periods, optimized use of water resources matching the daily capacity and seasonal condition of all available resources.

Figure 14 - Example ASR Operations Plan
Based on 2016 City of Wichita Groundwater Level Measurements

Recharge Well Name	Static Groundwater Level Measured Below Top of Well Casing January 2016	Static Groundwater Elevation Measured January 2016	Maximum Groundwater Elevation at 10' Below Ground Surface	Water Column Available for Recharge	Sustainable Specific Injectivity	Maximum Calculated Sustainable Recharge Rate	Maximum Well Infrastructure Recharge Rate	Minimum Well Infrastructure Recharge Rate	Available Physical Recharge Capacity
	(feet)	(feet)	(feet)	(feet)	gpm/ft	gpm	gpm	gpm	gpm
MR02 (MK61)	37.60	1396.90	1420.3	23.40	5	117	1,000	125	0
MR04 (MK80)	37.69	1393.97	1418.42	24.45	8	196	1,000	125	196
MR06 (MK62)	34.45	1401.45	1421.7	20.25	8	162	1,200	150	162
MR08 (MK63)	28.61	1397.19	1411.6	14.41	12	173	1,100	150	173
MR10 (MK56)	29.96	1395.94	1411.7	15.76	8	126	1,000	125	126
MR11 (MK11)	28.96	1393.84	1409.65	15.81	8	126	700	150	0
MR13 (MK57)	23.30	1395.9	1405.1	9.20	15	138	1,200	250	0
MR14 (MK14)	29.00	1390.2	1405.51	15.31	11	168	800	225	0
MR18 (MK64)	23.04	1384.99	1390.7	5.71	10	57	1,000	150	0
MR19 (MK19)	25.16	1378.72	1391.68	12.96	7	91	350	150	0
MR20 (MK65)	25.00	1376.2	1384.4	8.20	7	57	1,200	150	0
MR22 (MK66)	25.41	1371.79	1381.1	9.31	6	56	700	150	0
MR23 (MK67)	27.60	1368.6	1377	8.40	7	59	700	100	0
MR26 (MK58)	23.89	1382.57	1391.3	8.73	13	113	1,200	150	0
MR42 (MK68)	26.54	1404.72	1416.4	11.68	6	70	700	100	0
MR43 (MK69)	18.67	1412.59	1414.1	1.51	8	12	700	100	0
MR44 (MK70)	16.20	1415.06	1415	0.00	7	0	625	50	0
MR45 (MK71)	17.34	1409.46	1412.6	3.14	14	44	400	125	0
MR47 (MK60)	17.88	1405.82	1409.5	3.68	5	18	500	50	0
MR48 (MK59)	25.94	1383.76	1395.5	11.74	10	117	1,100	175	0
MR50 (MK50)	24.94	1385.24	1398.25	13.01	4	52	325	250	0
MR51 (MK51)	20.37	1391.13	1399.34	8.21	4	33	200	100	0
MR55 (MK73)	15.31	1391.89	1393	1.11	30	33	1,200	225	0
MR56 (MK74)	15.96	1410.24	1412	1.76	13	23	525	75	0
MR57 (MK75)	25.62	1398.08	1409.5	11.42	4	46	500	50	0
MR58 (MK76)	23.98	1394.65	1402.6	7.95	12	95	1,200	125	0
MR59 (MK77)	24.74	1388.97	1396.6	7.63	7	53	650	100	0
MR60 (MK78)	32.27	1389.93	1408	18.07	9	163	1,200	150	163
MR61 (MK79)	25.02	1389.62	1399.9	10.28	11	113	1,000	150	0
					Total (GPM)	**2,513**	**23,975**	**3,975**	**819**
					Total (MGD)	**3.62**	**34.52**	**5.72**	**1.18**

4.0 PROPOSED ASR ACCOUNTING METHODOLOGY

ASR accounting is the process used to track the accumulation, migration, and recovery of recharge credits throughout the BSA. The current physical recharge accounting system uses the EBGWM to track and model water physically injected through recharge recovery wells (RRWs) or recharge basins (RBs). This process is accomplished by completing two runs of the EBGWM, one that incorporates ASR activities, and one that does not. The groundwater model does not track individual particles of water, rather recharge credits are tracked on a mass-balance basis such that overall influences on the system are evaluated. Since the only difference between the model input parameters in these two runs is the ASR activities, any variations in the model results are the result of ASR activities.

The calculation and tracking of recharge credits across the BSA is currently a very detailed procedure requiring a substantial amount of data preparation and processing. The results of the two EBGWM runs are compared to identify the changes in the flow distribution in the model caused by the ASR activities. Net flows caused by ASR activities are calculated for constant head boundaries, rivers, drains, general head boundaries, wells, streams, natural recharge, evapotranspiration, storage, and flows between index cells defined by Hydro-stratigraphic units. These net flows are then summed to evaluate the changes in flow into and out of the BSA and between each of the index cells.

Flow changes from each index cell are assessed individually to determine if they can be applied as recharge credits. This requires reviewing each index cell flow calculation specifically, and verifying that all the contributing terms the terms adding up the recharge credits are applicable and correlate to the observed water levels. Individual assessments must be made to determine if the changes and flow should be discounted or can be counted toward the recharge credit total. Recharge accounting using the EBGWM modeling process described above has been conducted for the City's ASR program for every year since 2006.

DWR, GMD2 staff, and the City have each conveyed interest in developing a simplified accounting method for AMCs. In addition, using the current accounting process for AMCs would be impractical as the physical ASR recharge accounting relies on a comparison of groundwater modeling results that utilize actual metered physical recharge values compared to actual water levels. There would be no observed water levels to compare the AMC results against, since the location of the AMC recharge would be theoretical. Based on the complexity of the current physical ASR recharge accounting process and the poor fit of the current accounting process to AMCs, an alternate accounting methodology for AMCs has been developed for consideration. The City is not proposing any modifications to the current physical recharge accounting process.

The current physical ASR recharge accounting process has been completed for 10 years, modeling physical recharge activities from 2006 through 2015. Groundwater flow and recharge credit migration is generally from west to east. Recharge credit migration losses are minimal on the west side of the BSA as credits generally migrate to adjacent index cells to the east. The majority of recharge credit losses occur on the east side of the BSA and along the southeastern boundary of the BSA, where groundwater flows out to the Little Arkansas River.

During the 2006 to 2015 period, 85% of water recharged to the aquifer has been retained as a recharge credit, despite rising water levels. As water levels rise and aquifer storage is filled, recharge credit loss increases. The greatest loss of credits occurred in the east and southeast portion of the BSA. Water levels in the southeastern portion of the BSA have historically been high, even during the 1993 period, due to less pumping density and the proximity to the Little Arkansas River.

Recharge Basin RB-36 is located in Index Cell 33 in the southeastern portion of the BSA. As water levels have risen, recharge wells have not been able to accept as much water, and ASR operations have required that more water to be diverted to RB-36 (currently more than 40% of total recharge is to RB-36). Due to the high water levels and the close proximity to the river and the southeastern boundary of the BSA only 53% of water diverted to RB-36 has been retained historically as a recharge credit. This high loss percentage coupled with the high volume of water sent to RB-36 significantly reduces the overall percentage of physical recharge credits retained. During future periods of low water levels ASR recharge operations will be focused on the core of the wellfield and recharge to RB36 will be minimized, and water will be recharged where credit retention rates are higher.

As discussed in detail in Section 1.0 of this report, the drought modeling activities that have been completed to date indicate that 30 MGD of physical recharge can be accomplished utilizing existing recharge well infrastructure when water levels are at or below levels observed in 1998. Under these conditions, 95% of the water recharged is retained as a recharge credit (Attachment J).

The objective of AMCs is to maintain overall aquifer health by sustaining water levels as high as possible. The City, GMD2 staff and the DWR have indicated that a simplified accounting method is desirable and will benefit all parties by allowing for easier understanding of how recharge credits accrue.

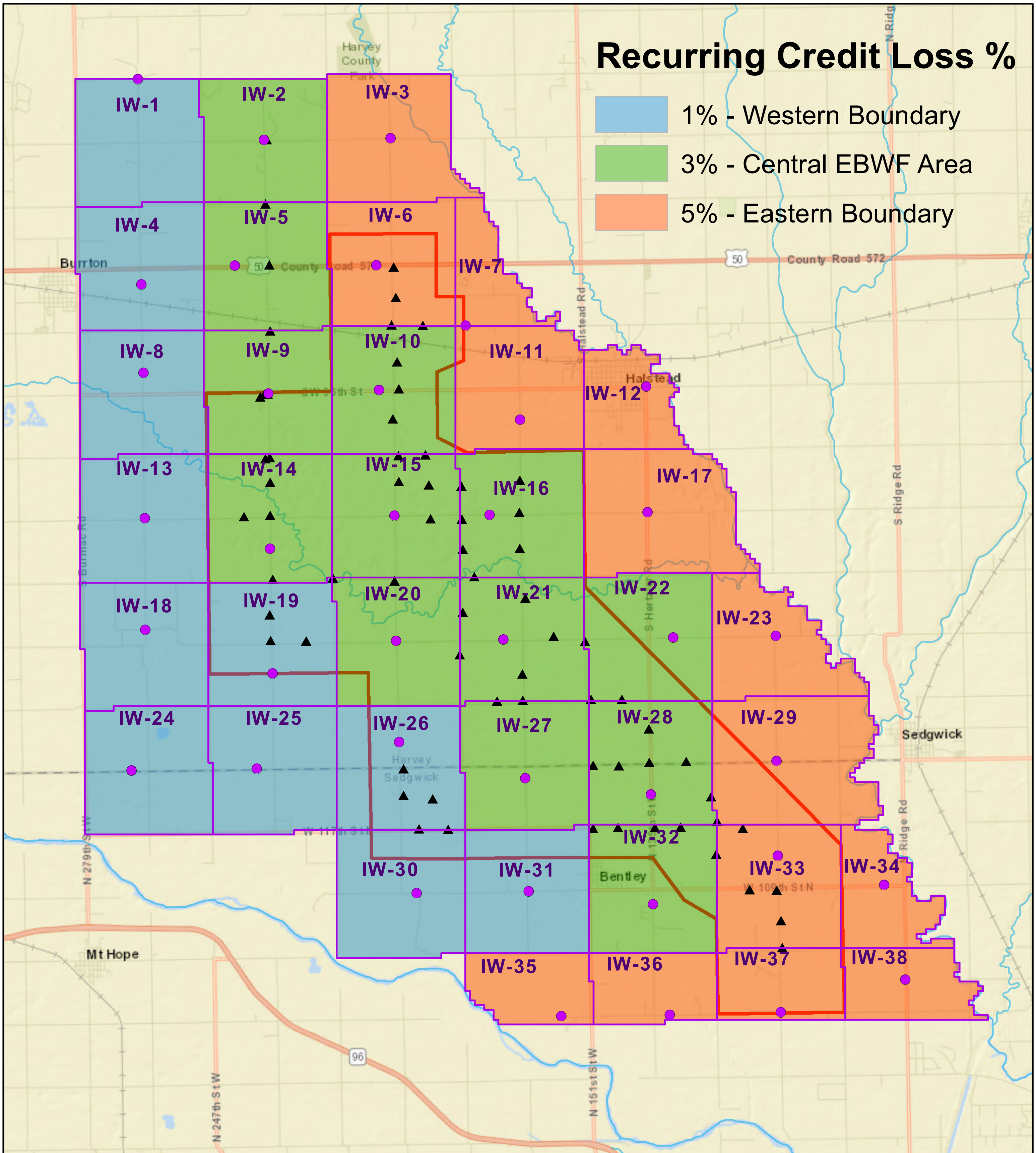
To achieve both of these objectives, the City is proposing the use of a simplified accounting process for AMCs. This process is supported by the historic physical ASR recharge accounting results, supplemental groundwater modeling, and the hydrogeologic characteristics of groundwater throughout the BSA.

The City proposes that AMCs will be assigned to Index Cells annually by the following methods:

- AMCs will be assigned by dividing the total volume of water diverted from the Little Arkansas River to the City's Main Water Treatment Plant by the total number of points of diversion within the EBWF in service that year (excluding Phase I recharge and recovery infrastructure). This distributes the AMCs equally across the production wells that could have pumped the water from the aquifer.
- A one-time, five percent (5%) initial loss will be deducted from the total number of AMCs applied in each index cell. This initial loss accounts for losses to the aquifer inherent in the injection and recovery process.
- An average annual recurring loss of three percent (3%) will be applied annually to recharge credits to account for recharge credit migration from the BSA. This recurring loss will be gradational geographically across the BSA, as described below.

The gradational recurring loss would be applied across the BSA to account for the migration of recharge credits and losses from the BSA illustrated by the model and historic data. Generally, index cells on the west side would have a one percent (1%) loss, index cells in the central area a three percent (3%) loss, and index cells on the east side a five percent (5%) loss. These losses would be taken from the cumulative total beginning the year after the water is recharged, as they represent losses to migration that occur during the year. Table 4-1 summarizes, and Figure 14 illustrates the loss percentage by index cell, as well as the existing infrastructure in each index cell.

Loss rates of five percent (5%) initially and three percent (3%) annually are supported by the historic accounting process modeling, the drought modeling efforts, and the hydrogeological characteristics of the aquifer. Based on the water level changes that have occurred from 2006 to 2015, these percentages are conservative. If water levels had remained at the 2006 levels or lowered, recharge credit retention percentages would have been greater. In addition, as water levels increased a greater portion of recharge was directed to RB-36, an area which has a substantially higher rate of loss than wells in the CWSA. As illustrated in Figure 15, recharge accounting with the proposed method mirrors the current accounting system results. The slightly higher total is reflective of the reduced reliance on RB-36, and the higher recharge credit retention rates provided within the CWSA.



Legend

- ASR Index Cell Monitoring Wells
- City of Wichita Groundwater Wells
- ASR Index Cells & Basin Storage Area)
- USGS Central Wellfield Study Area

N

1:130,000

0 0.5 1 2

Miles

CITY OF WICHITA

BURNS McDONNELL

Figure 15

AMC Recurring Annual Credit Loss Percentage by Index Cell

Table 4-1: *Index Cell Infrastructure and Loss Percentage*

Index Cell	ASR Phase I Well Names	ASR Phase II & City of Wichita Well Names	Recharge Basin	Recurring Loss Percentage
1				1
2	RRW-1	RRW-1		3
3				5
4				1
5	RRW-2, RRW-3			3
6		M-01, MR-02, M-03, MR-04		5
7				5
8				1
9	RRW-4, RR-05		RB-1	3
10		M-05, MR-06, M-07		3
11				5
12				5
13				1
14		M-41, MR-42, MR-43, MR-44, RR-56, RR-57	RB-2	3
15		MR-08, MR-10, M-09, MR-11, MR-13		3
16		M-12, MR-14, M-15, M-16, M-17, MR-18, RR-59		3
17				5
18				1
19		MR-45, MR-46, MR-47		1
20		RR-58, RR61		3
21		MR-26, MR-19, MR-20, MR-48, M-49, MR-50, RR-60		3
22		M-21, MR-22		3
23				5
24				1
25				1
26		MR-51, M-52, M-53, M-54, MR-55		1
27		None		3
28		MR-23, M-24, M-35, M-27, M-28, M-33		3
29		M-34		5
30		None		1
31		None		1
32		M-29, M-30, M-32, M-32		3
33		M-35, M-36, M-37, M-38, M-39, M-40	RB-36	5
34				5
35				5
36				5
37				5
38				5

Figure 16 - Current and Proposed Accounting Method Results Comparison

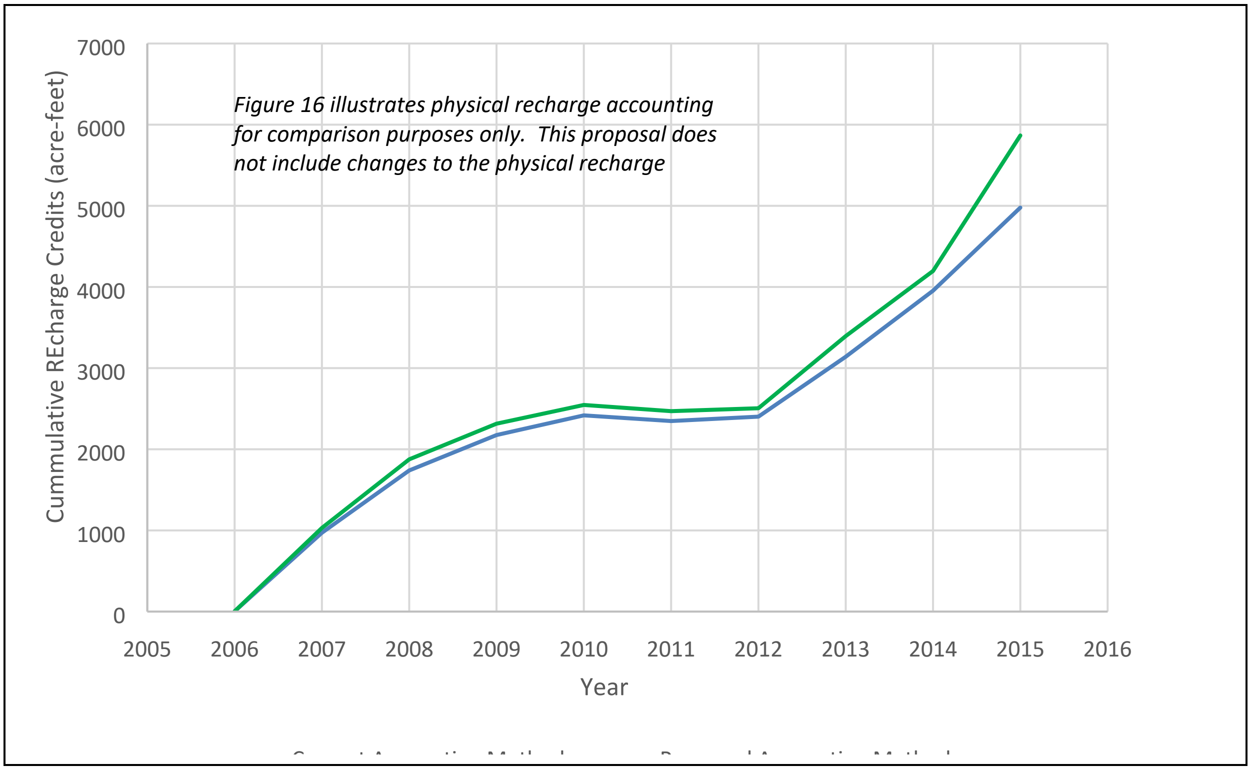


Table 4-2: *Current and Proposed Accounting Method Results Comparison*

	Current Accounting Process		Proposed Accounting Process	
Year	Actual Physical Recharge (acre-feet)	Actual Cummulative Physical Recharge Credits Earned (acre-feet)	Annual Physical Recharge Credit - 5% Initial Loss (acre-feet)	Cummulative Recharge Credit - 3% Recurring Loss (acre-feet)
2006	3.44	3.39	3.27	3.27
2007	1,081.64	971.50	1,027.56	1,030.73
2008	922.23	1,739.05	876.12	1,875.93
2009	521.78	2,175.36	495.70	2,315.34
2010	316.03	2,417.87	300.23	2,546.12
2011	0.00	2,347.98	0.00	2,469.73
2012	115.79	2,402.11	110.00	2,505.64
2013	1,014.97	3,140.31	964.22	3,394.70
2014	951.67	3,954.10	904.08	4,196.94
2015	1,890.40	4,978.20	1,795.88	5,866.92

Table 4.2 illustrates physical recharge accounting for comparison purposes only. This proposal does not include changes to the physical recharge accounting methodology.

Table 4-3 provides a theoretical example of AMCs applied to Index Cell 15 for three years. In this example, each year a total of 1,000 AF of Little Arkansas River water was diverted to the City and could be claimed as an AMC. During this example period the City had 50 points of diversion in operation in the EBGWF. Dividing the 1,000 AF of water evenly among these wells results in an AMC of 20 AF of water per well.

Table 4-3: *Theoretical Recharge Accounting Example for Index Cell 15*

		Index Cell 15			
Year	Well No.	AMC (acre-ft)	Credit After 5% Initial Loss (acre-ft)	Cumulative Credit After 3% Recurring Loss (acre-ft)	Total Cumulative Recharge Credit (acre-ft)
1	MR-08	20.0	19.0	0.0	19.0
	M-09	20.0	19.0	0.0	19.0
	MR-10	20.0	19.0	0.0	19.0
	MR-11	20.0	19.0	0.0	19.0
	MR-13	20.0	19.0	0.0	19.0
		100.0	95.0	0.0	95.0
2	MR-08	20.0	19.0	18.4	37.4
	M-09	20.0	19.0	18.4	37.4
	MR-10	20.0	19.0	18.4	37.4
	MR-11	20.0	19.0	18.4	37.4
	MR-13	20.0	19.0	18.4	37.4
		100.0	95.0	92.2	187.2
3	MR-08	20.0	19.0	36.3	55.3
	M-09	20.0	19.0	36.3	55.3
	MR-10	20.0	19.0	36.3	55.3
	MR-11	20.0	19.0	36.3	55.3
	MR-13	20.0	19.0	36.3	55.3
		100.0	95.0	181.5	276.5
	Totals	300.0			276.5

Each of the City's wells with an ASR recovery water right would have access to the quantity of recharge credits available in the index cell for which the water right and point of diversion resides. The total available quantity of recharge credits in each index cell would be the sum of physical recharge credits and

AMCs. Prior to the recovery and use of recharge credits, the City anticipates utilizing the full available native water rights at each point of diversion.

Recharge credits would be accrued annually and cumulative up to a maximum total for the BSA of 120,000 AF. A recharge credit storage cap of 120,000 AF is approximately equal to the volume of groundwater required to fill the aquifer between the 1993 water levels (when the ILWSP was implemented and development of the City's ASR program began) and pre-development aquifer conditions (Attachment H). An annual accounting report will continue to be generated and submitted to DWR for review and approval, with a corresponding review and commentary from GMD2, as required by K.A.R. 5-12-2 and 5-22-10.