Equus Beds Water Quality and Quantity Studies

Equus Team: Andy Ziegler, Brian Kelly, Cristi Hansen, Mandy Stone, Brian Klager, Josh Whisnant, Jenny Lanning-Rush, and Danny Tappa

Wichita Field Office: Trudy Bennett, Barb Dague, Carl Collins, John Rosendale, Courtney Huston, Tim Nicholson, Mike Holt, Chris Moehring, Travis See, Slade Hackney

Participation from GMD2, city of Wichita, DWR, KDHE, KGS, KCC, BoR, Burns and McDonnell,…..and many others

U.S. Department of the Interior
U.S. Geological Survey

GMD2 Presentation
December 9, 2014

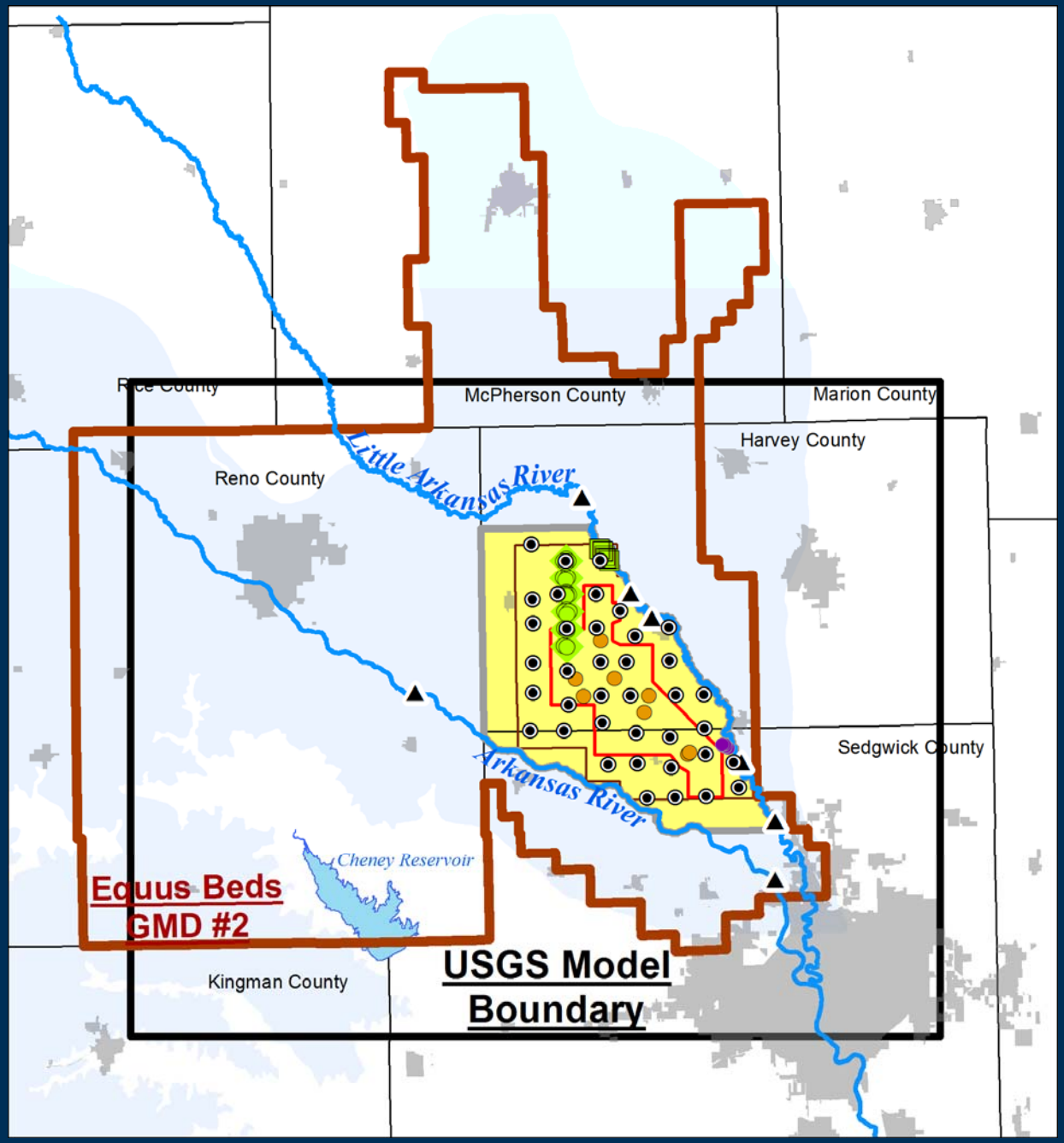
Agenda

1) Water-levels and storage

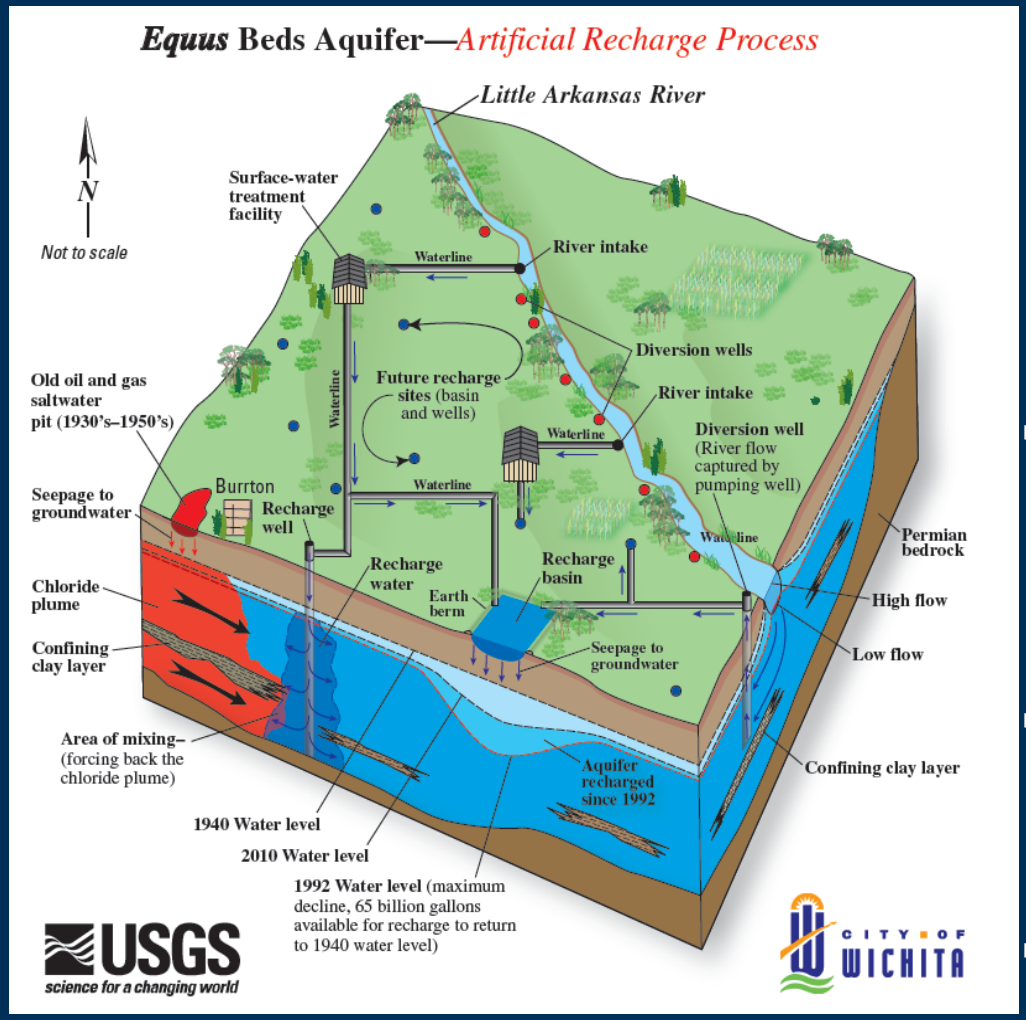
2) Water quality

3) Chloride modeling & network analysis

4) HBMP & Little Ark. River flow analysis


Rice County
McPherson County
Marion County
Harvey County
Reno County
Little Arkansas River
Sedgwick County
Arkansas River
Cheney Reservoir
Equus Beds
GMD #2
Kingman County
USGS Model
Boundary

Water issues



http://ks.water.usgs.gov/equus-beds-recharge

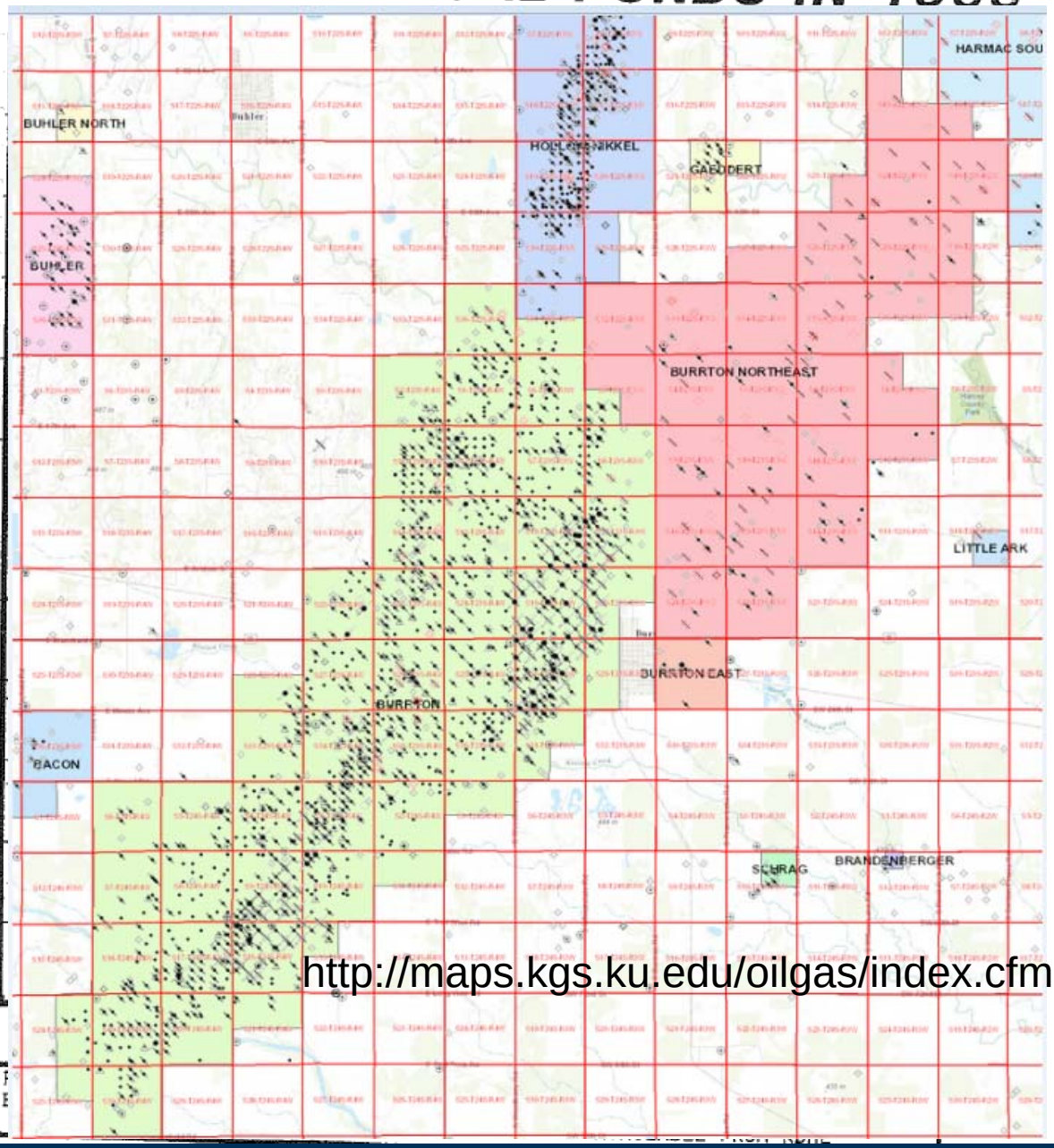
- Saltwater migration from Burrton and along the Arkansas River accelerated because of large water level declines from agricultural and city pumping. Current rate is about 0.8 ft per day (~0.5 miles per decade)
- Declines in water levels caused by agricultural and city pumping increase velocity of chloride movement
- Artificial Recharge and Aquifer Storage and Recovery Program began in 1995
- ASR will help preserve Wichita water supply through 2060+ and agricultural supply

USGS

CITY OF WICHITA www.wichita.gov

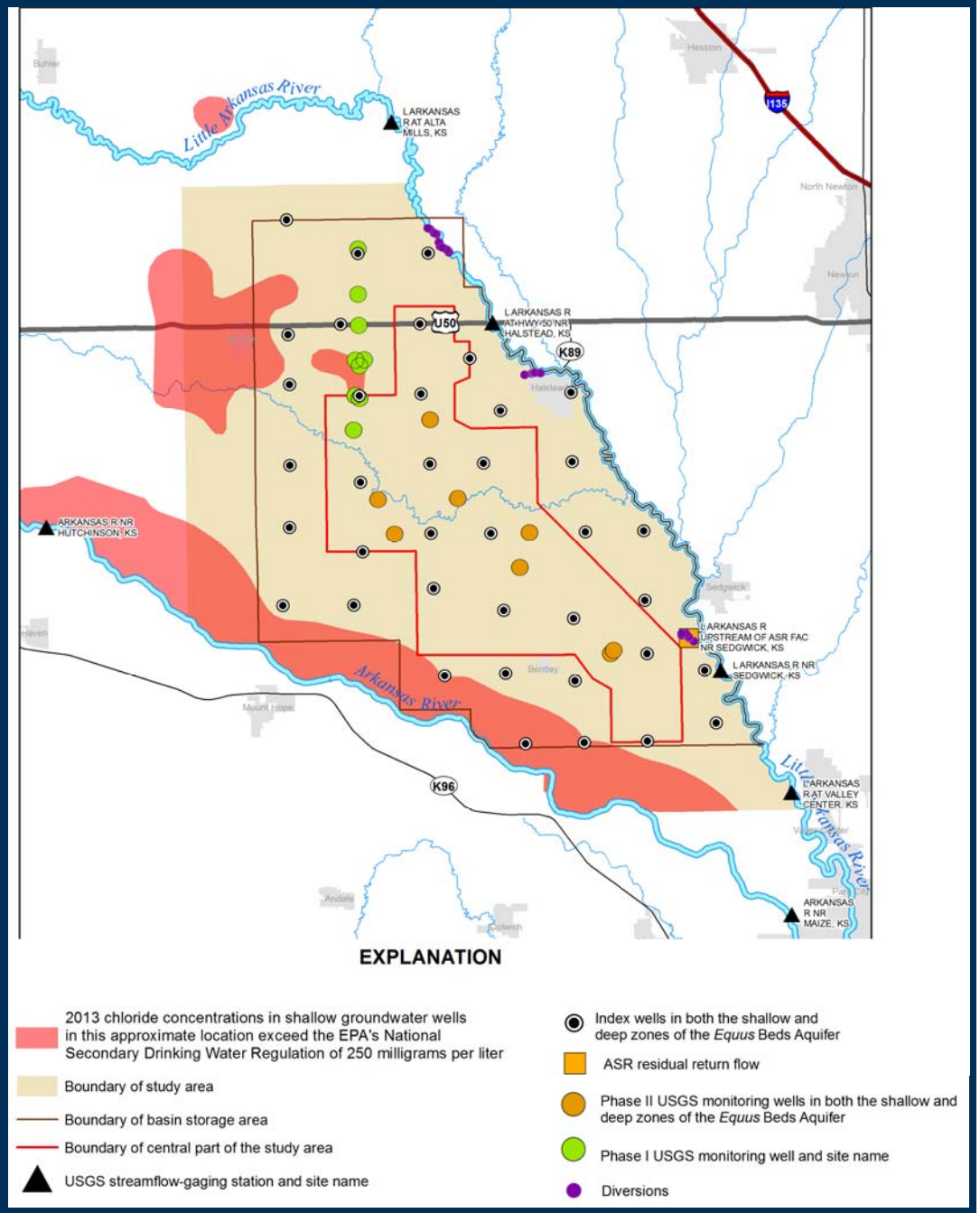
LOCATION OF BRINE DISPOSAL PONDS IN 1938

Figure 15



http://maps.kgs.ku.edu/oilgas/index.cfm

- Burrton plume caused by disposal of salt water from oil/gas production into pits in 1920s-1940s
- Brine disposal about 1.9 million tons of salt (~1 million tons of chloride)
- Burrton contamination area about 30 mi^2 (>250 mg/L Cl) and about 200 ft thick
- Current movement is about 0.8 ft/day



Lack of precipitation *generally* leads to increased pumping and water-level declines

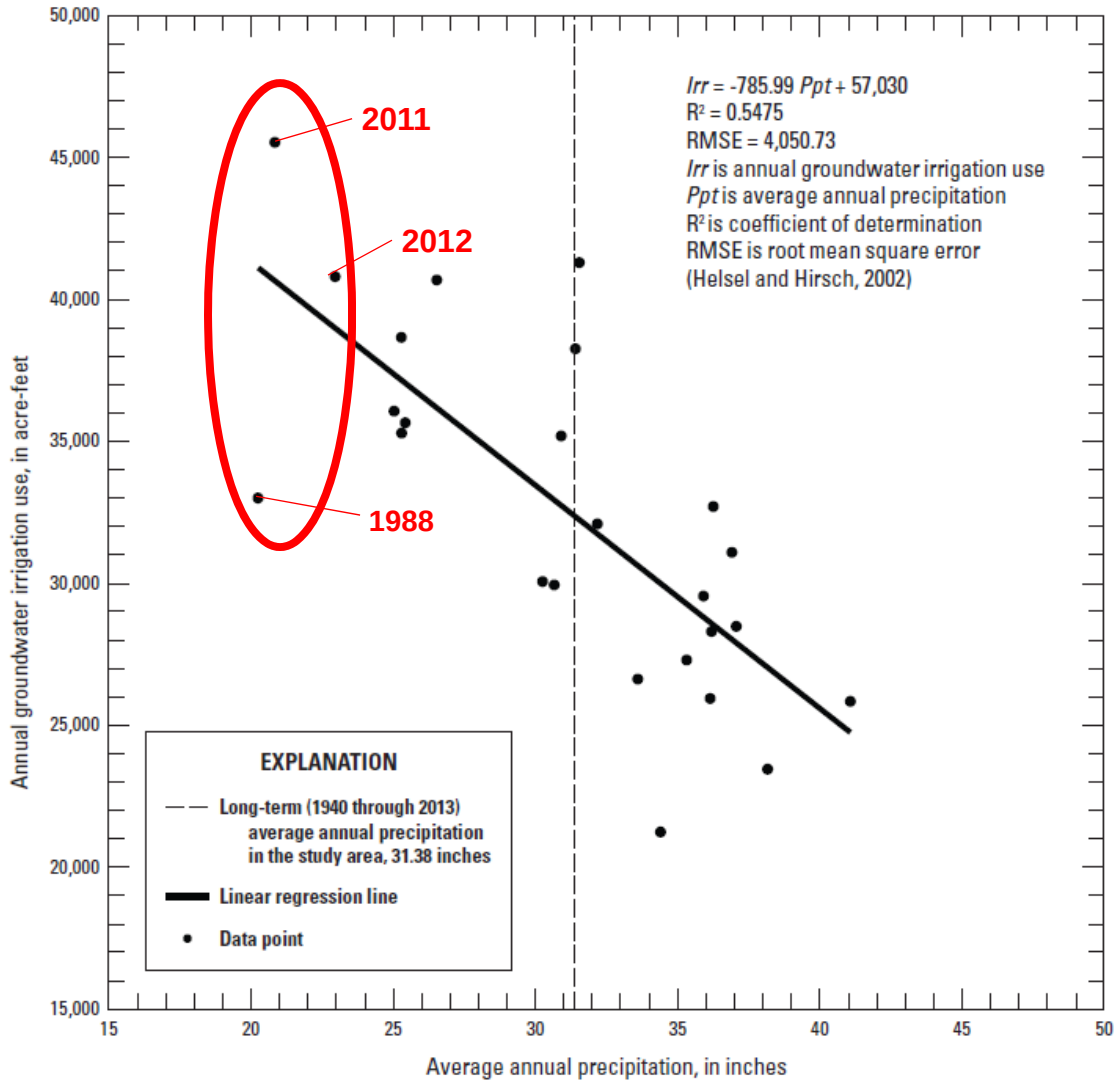


Figure 3. Statistical relation between annual groundwater irrigation use and average annual precipitation in the study area, 1988 through 2012. [Precipitation data are from National Oceanic and Atmospheric Administration (2014a); water-use data are from Kansas Department of Agriculture and Kansas Geological Survey (2014).]

USGS

CITY OF WICHITA www.wichita.gov

Hansen and others, 2014 (http://pubs.usgs.gov/sir/2014/5185/)

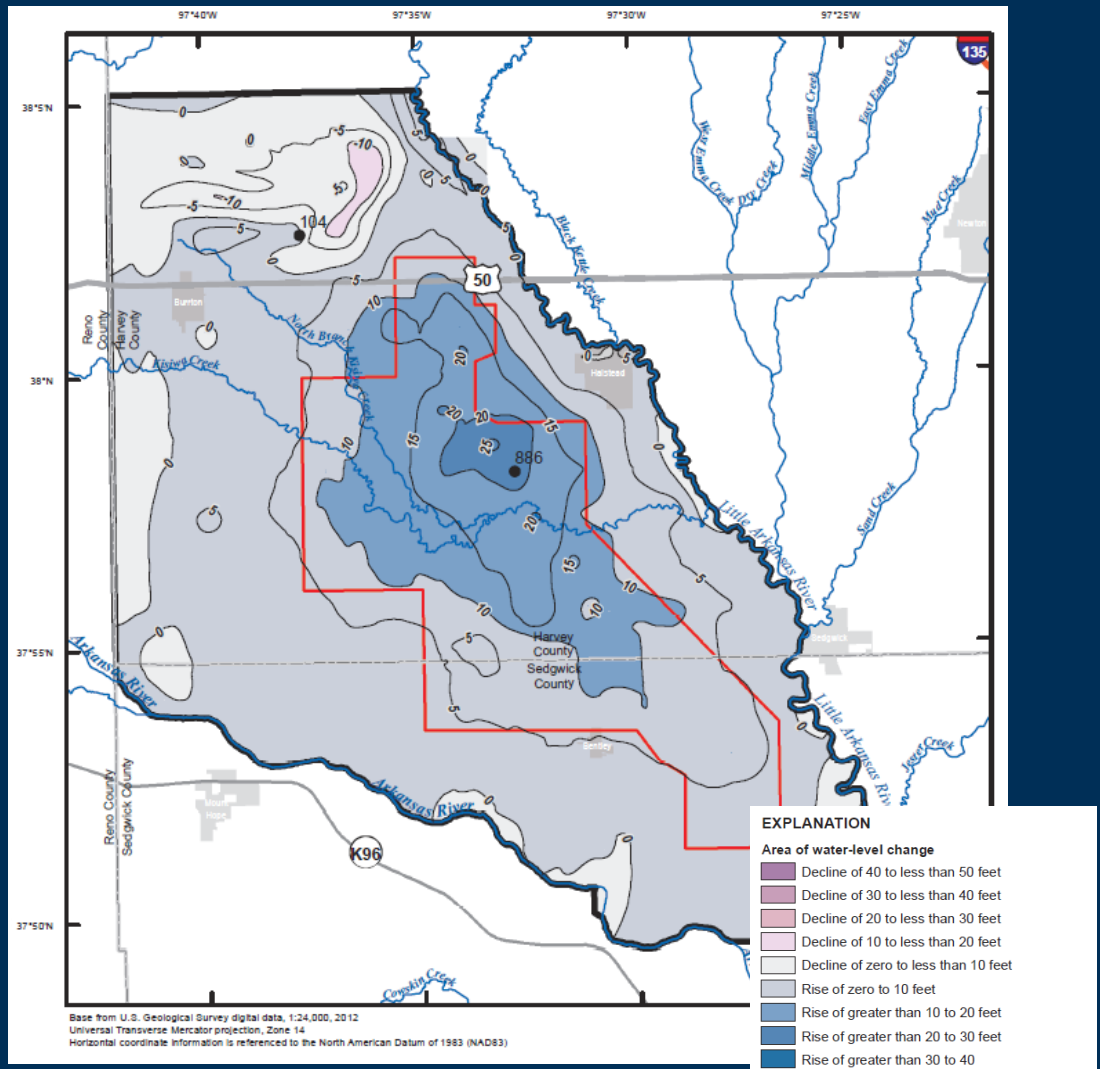
1) Water-level declines led to concerns of increased chloride movement

1 → In 1993, water levels in the Wichita well field area were as much as 40 ft lower than predevelopment levels. Gradient 12 ft per mile.

2 → Wichita increased use from Cheney Reservoir and decreased withdrawals from well-field starting in 1993, city well field use was eventually decreased by about 40%.

3 → In winter 2014, water levels in the Wichita well field area recovered 20 ft, but remain 20 ft lower than predevelopment levels. Gradient about 8 ft per mile.

1993 to winter 2014



Hansen and others, 2014
(http://pubs.usgs.gov/sir/2014/5185/)

USGS

Water-level data: GMD2, city of Wichita, and USGS

In 1993, city increased Cheney use and decreased use in well field 50%

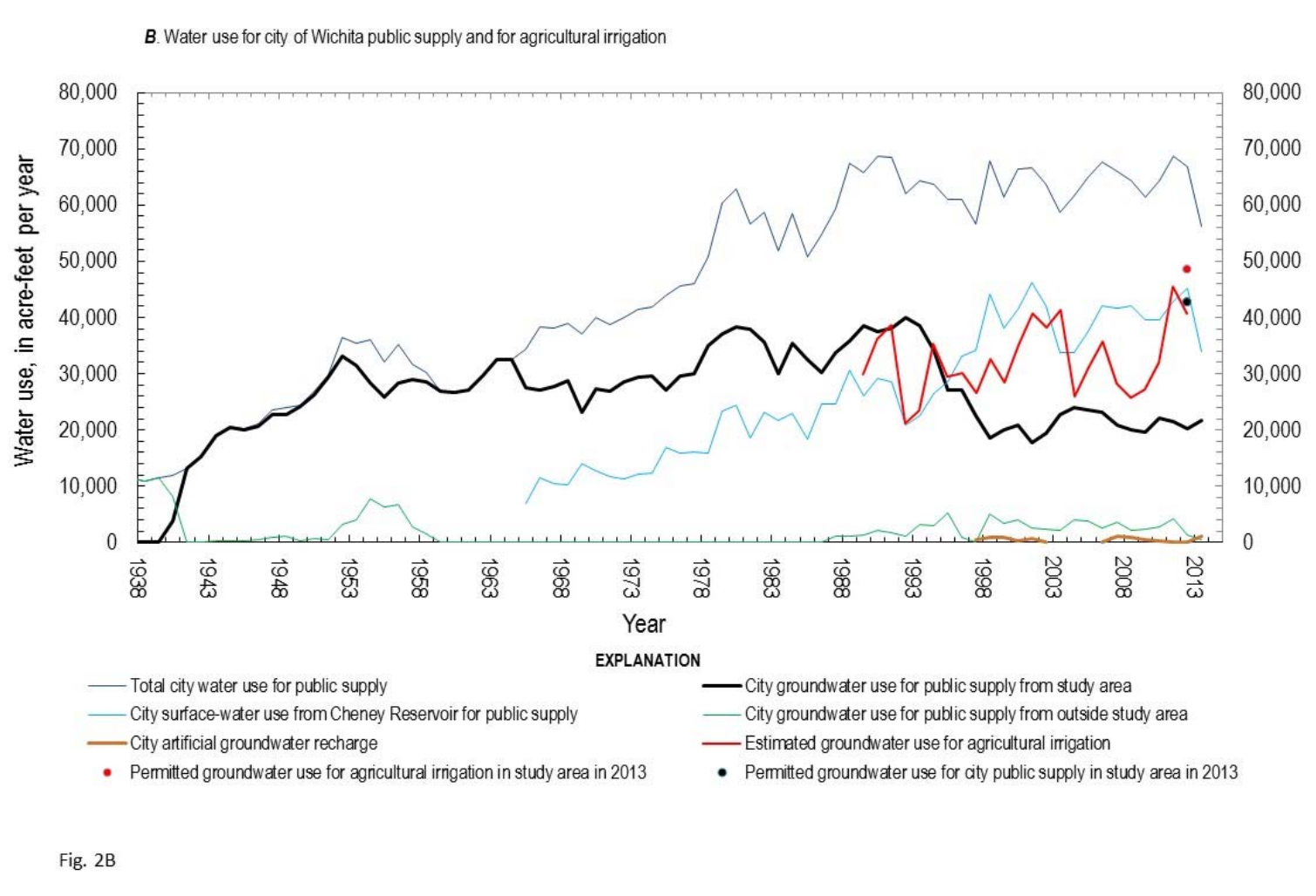
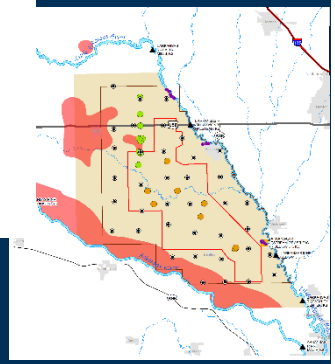


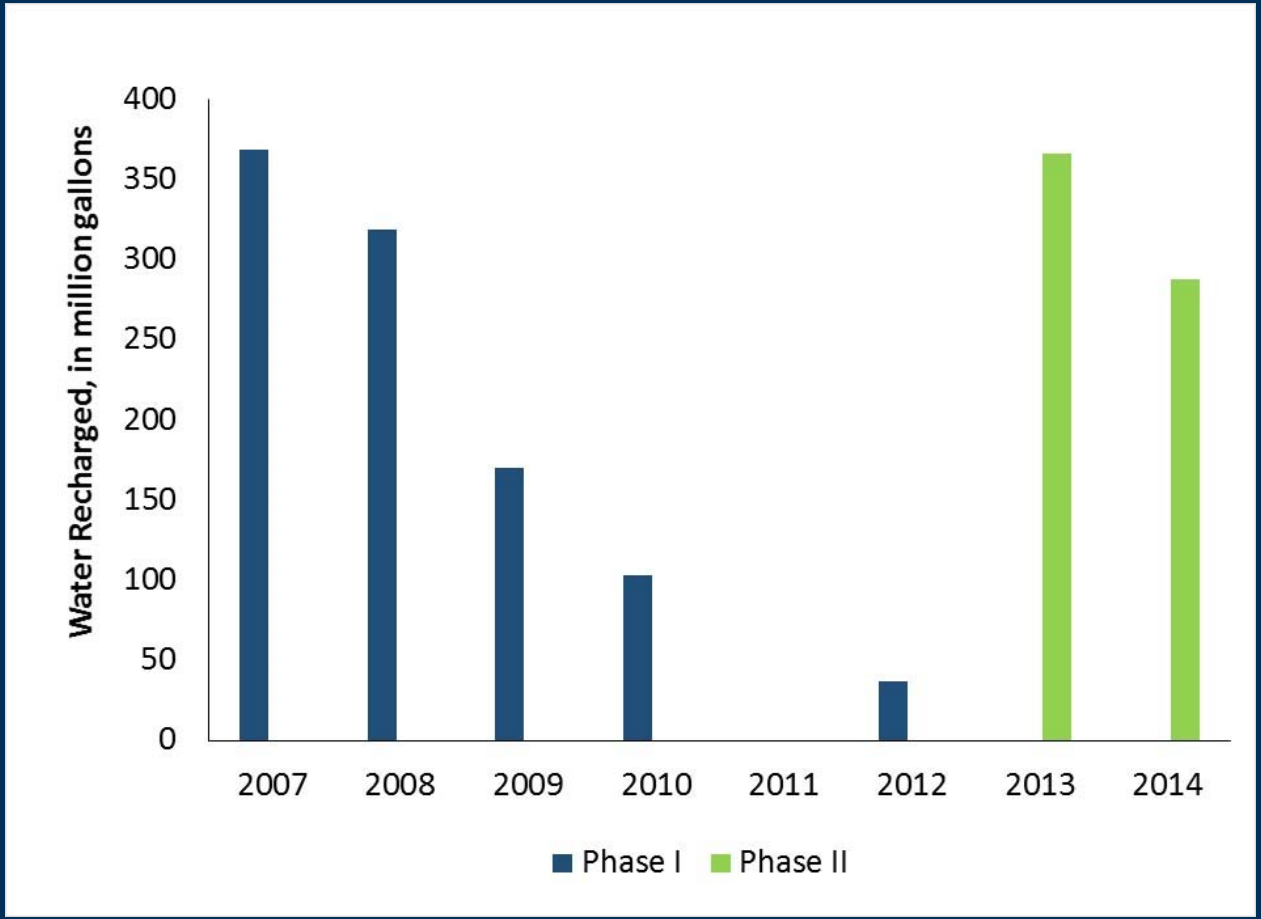
Fig. 2B



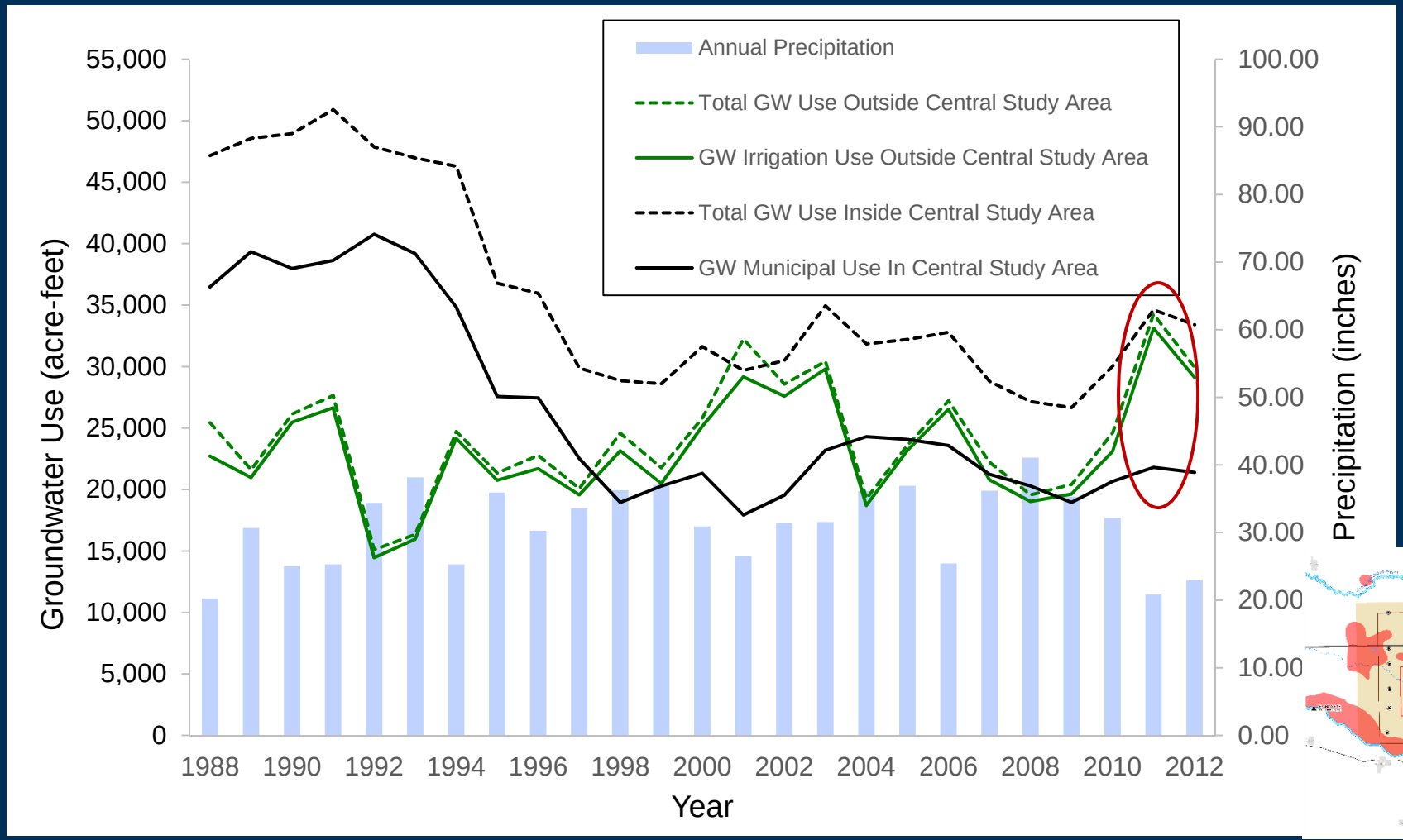
USGS

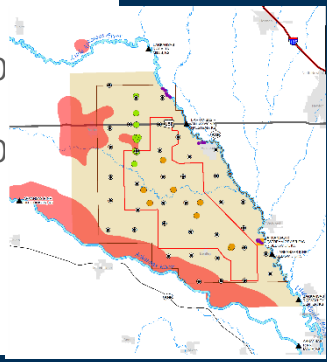
Hansen and others, 2014 (http://pubs.usgs.gov/sir/2014/5185/)

1.6 billion gallons (~4,900 acre-feet) recharged since 2007 (Total including demo project is about 2.6 BG or 8,000 acre feet)



1) During 2011–2012 drought, Irrigation GW use highest on record while city use didn't change





USGS

Hansen and others, 2014 (http://pubs.usgs.gov/sir/2014/5185/)

CITY OF WICHITA www.wichita.gov

1) Storage recovery since 1993 largest in central part of study area during 2012 drought

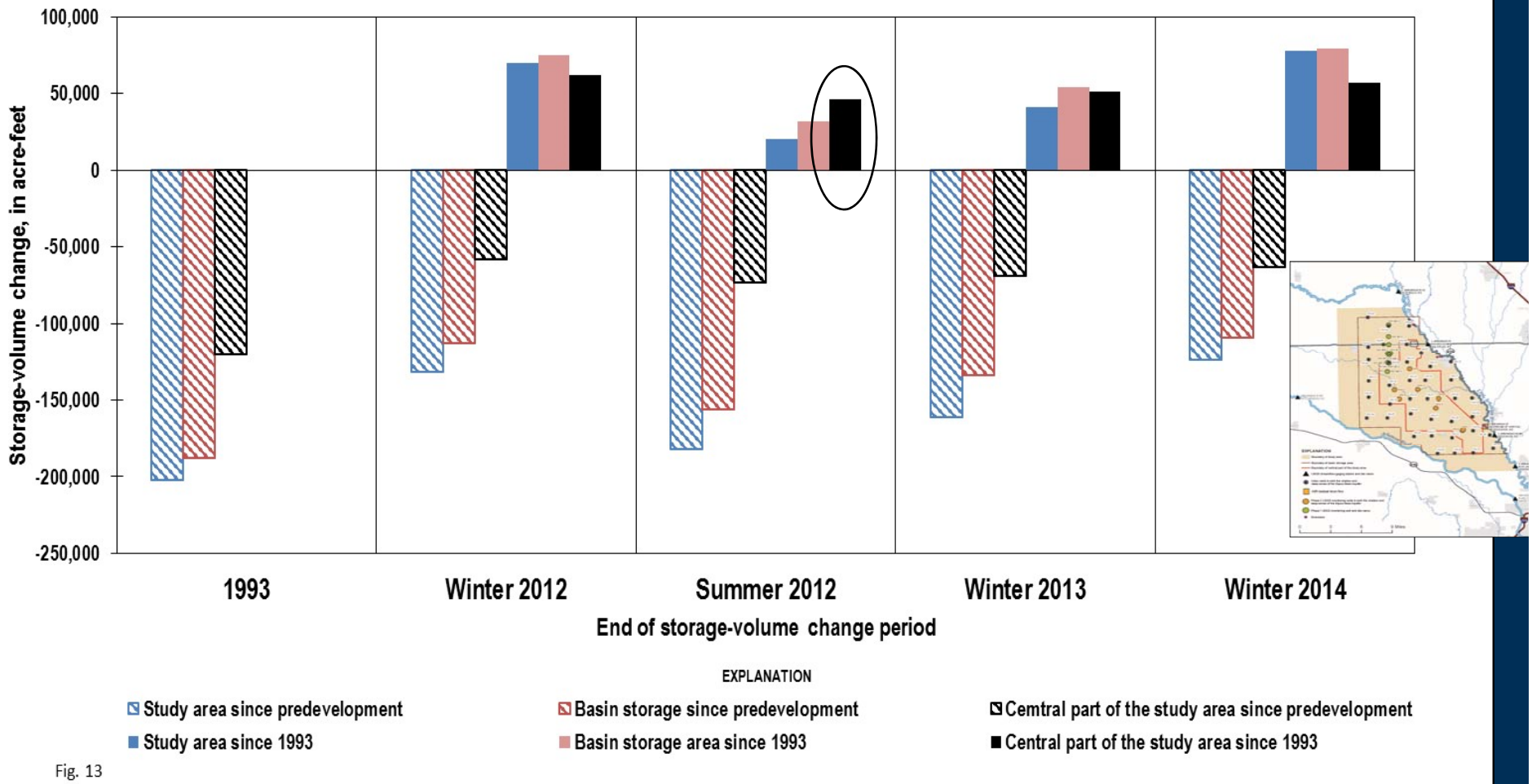


Fig. 13

Hansen and others, 2014 (http://pubs.usgs.gov/sir/2014/5185/)

2)

Water-Quality Highlights 1995–2012

Chloride Federal SDWR: 250mg/L

- **Little Arkansas River near Halstead: 22% of computed samples exceeded SDWR (primarily during low-flow)**
- **Groundwater exceeded SDWR primarily near Burrton and along Arkansas River (about 10 percent of study area)**

Atrazine Federal MCL: 3 µg/L

- **50% of Little Ark. River computed samples exceeded (primarily late spring-early fall)**
- **Detected in 57% of shallow wells, 1% deep (none exceed MCL)**

USGS

Tappa and others, in-review

CITY OF WICHITA www.wichita.gov

2)

Water-Quality Highlights 1995–2012

Arsenic Federal MCL: 10 µg/L

- **Little Arkansas River: exceeded 12% of time (computed)**
- **12% of shallow wells exceeded**
- **34% of deep wells exceeded**

Total Coliform Federal MCLG: 0 colonies

- **93% of Little Ark. samples exceeded**
  → median density: 1700 col/100 mL
- **25% of shallow well samples exceeded, 12% deep**

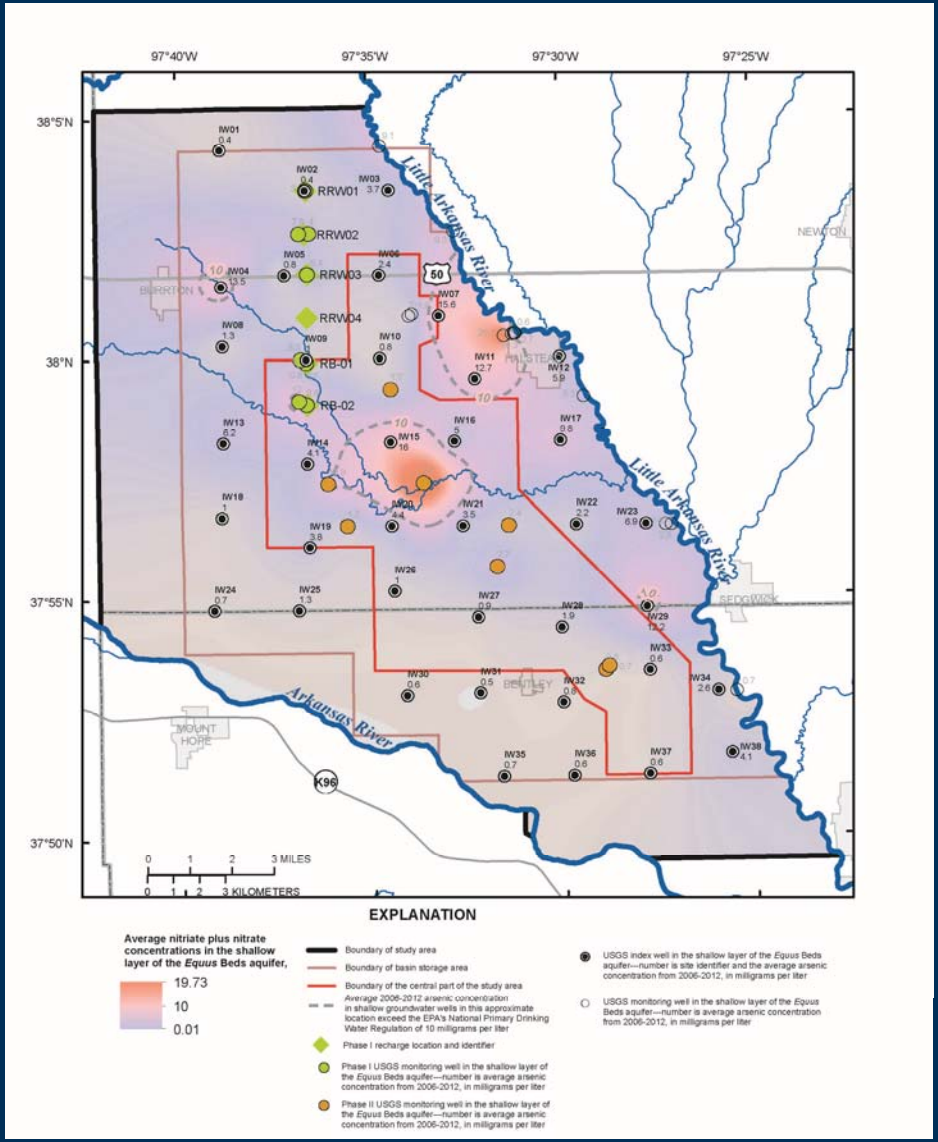
USGS

Tappa and others, in-review

CITY OF WICHITA www.wichita.gov

Arsenic Concentrations 2006–2012

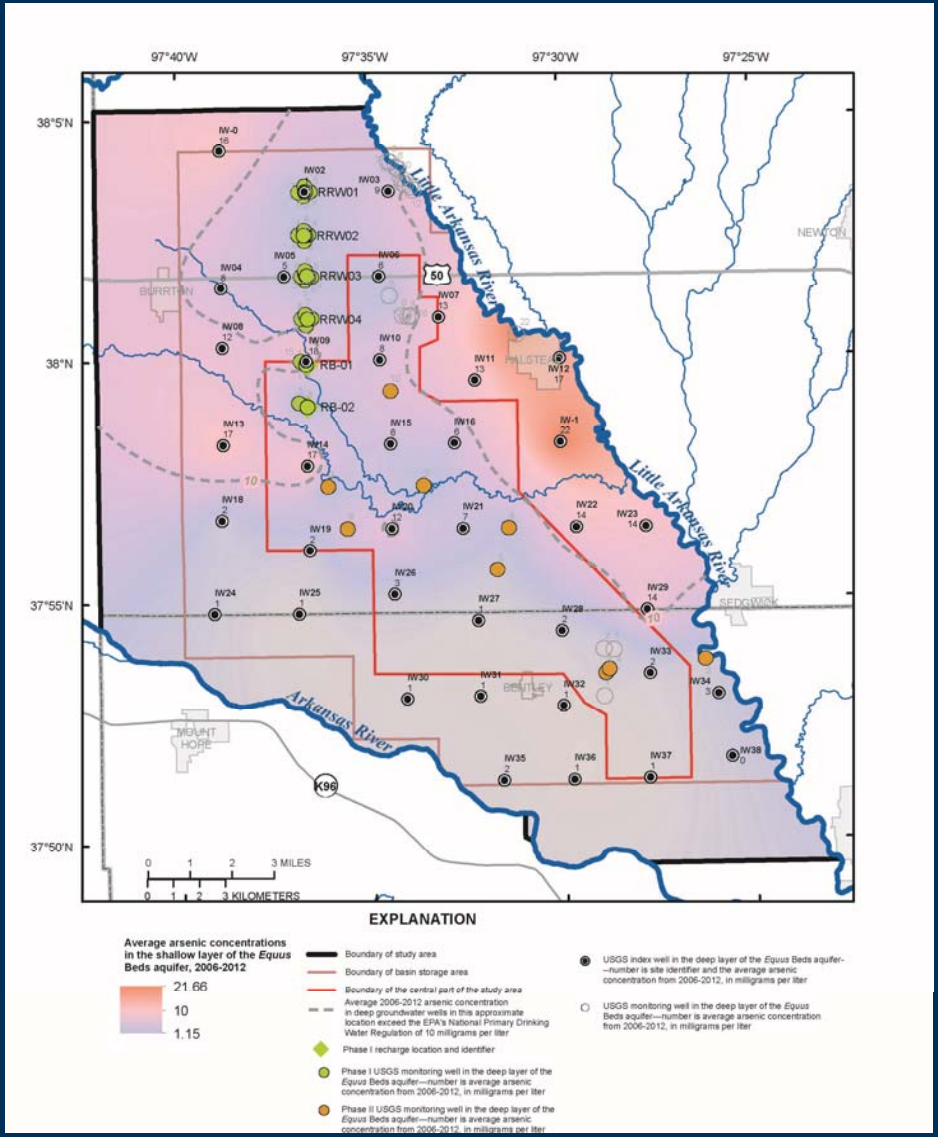
Shallow



Tappa and others, in-review

Arsenic Concentrations 2006–2012

Deep



Tappa and others, in-review

2) Increasing concentrations of most constituents of concern in study area during 2007–2012 compared to 2001–2006

2007-2012 Index Well Avg. Increases

- Arsenic (1%)
- Iron (8%)
- Manganese (3%)
- Nitrate (7%)
- Sulfate (9%)
- Spec. Conductance (3%)

2007-2012 Index Well Avg. Decreases

- Oxidation-Reduction Potential (18%, bad– means more metals are mobilizing)
- Chloride (3%)

Largest increases (Fe & SO_4^{2-}) likely a result of the oxidation of aquifer material during drawdown, specifically pyrite (FeS_2), before recovery. Decreased ORP caused partially by 2010–2012 drought conditions and lack of oxygenated water infiltrating to the water table.

USGS

Tappa and others, in-review

CITY OF WICHITA www.wichita.gov

2)

Phase I recharge slowed (or diluted) chloride at IW-05?

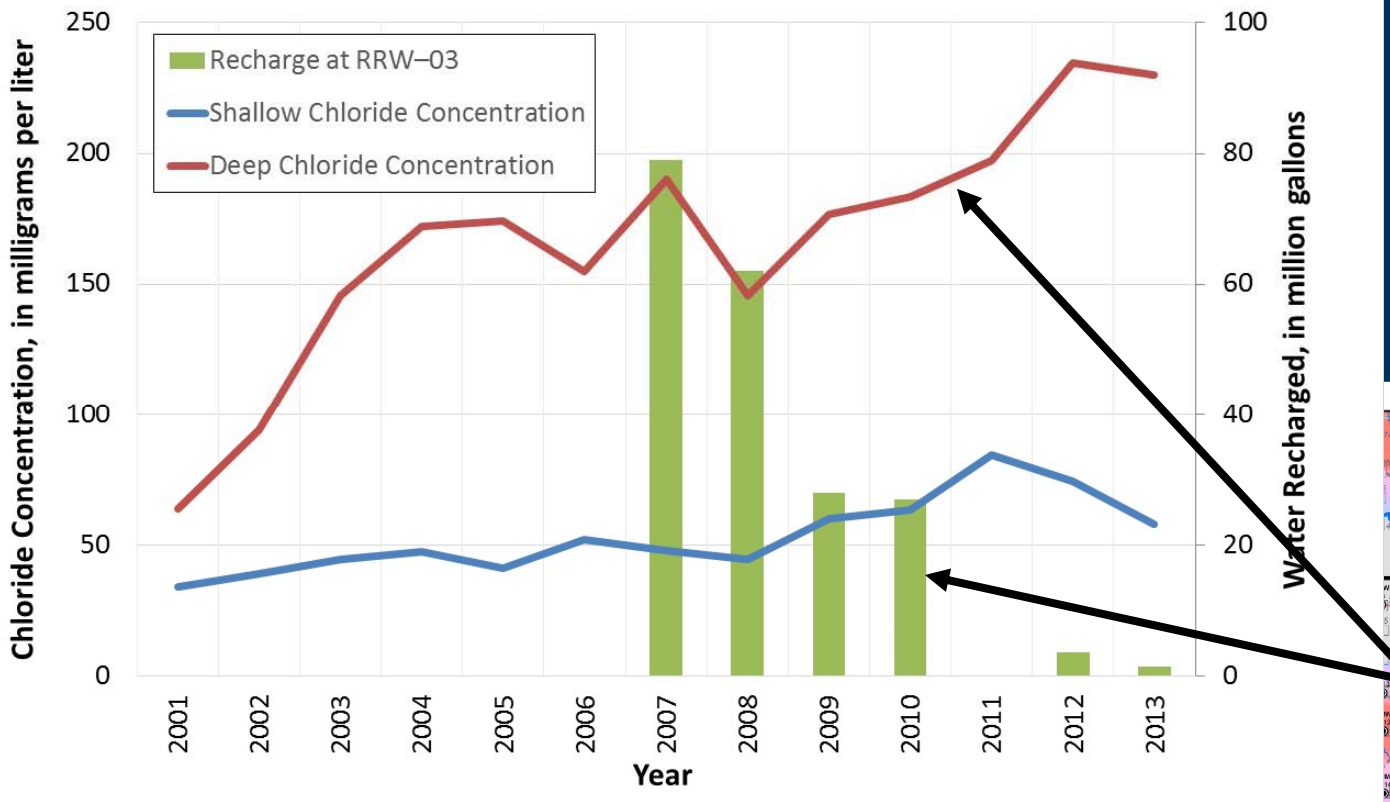
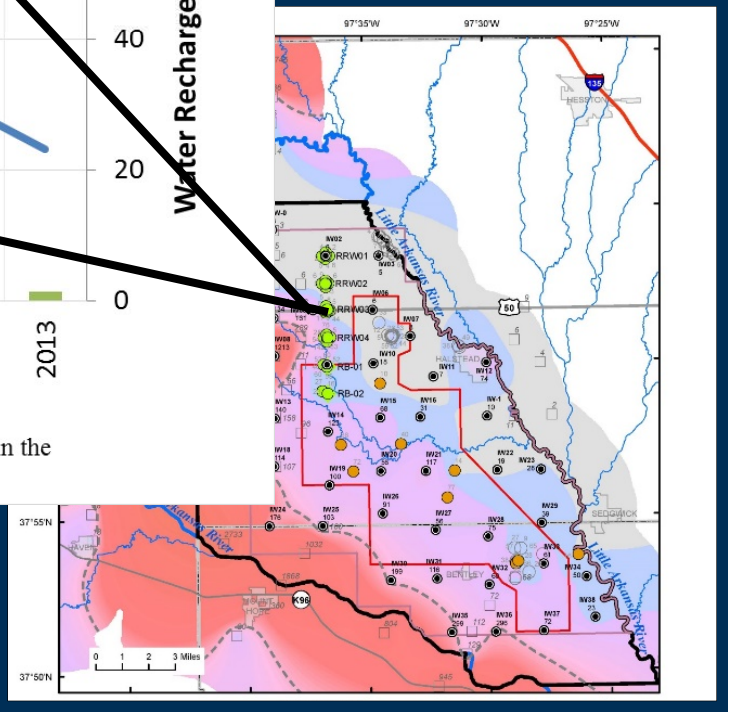


Figure 16. Chloride concentrations in IW–05 (shallow and deep) and Phase I Recharge at RRW–03 in the Equus Beds aquifer near Burrton, Kansas, 2001–2012.



USGS

CITY OF WICHITA www.wichita.gov

3)

Chloride-transport simulations

- **Primary goals of Wichita's ASR program are to slow the movement of chloride into the well field and store artificially recharged water for future withdrawal.**

- **A groundwater model can be used to estimate the effect of hypothetical scenarios on water levels and chloride movement.**

- **Scenarios tested include removing all pumping, doubling Wichita pumping from the well field, decreased agricultural pumping, and increased artificial recharge.**

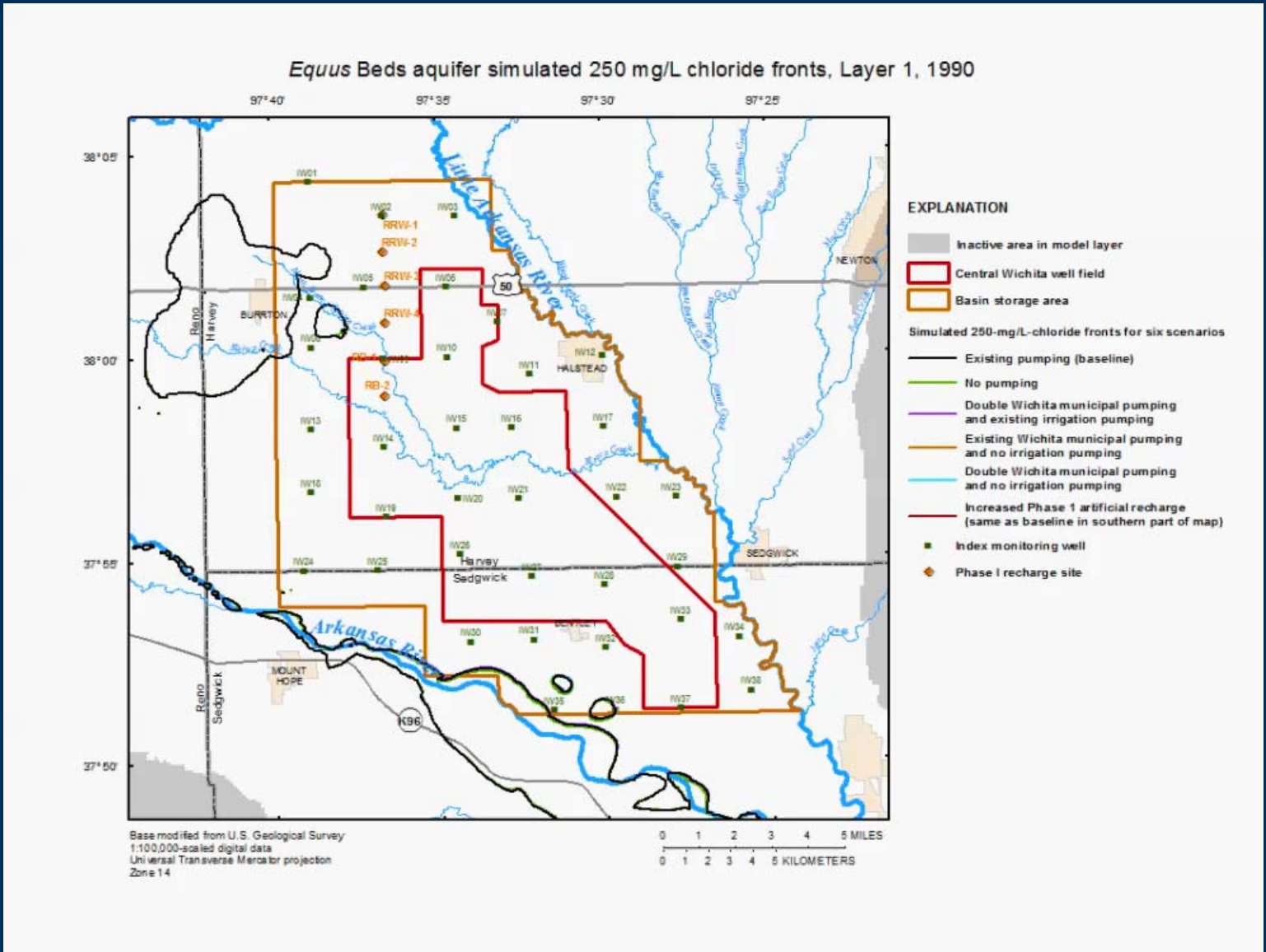
USGS

Klager and others, 2014 (http://pubs.usgs.gov/of/2014/1162/)

CITY OF WICHITA www.wichita.gov

3)

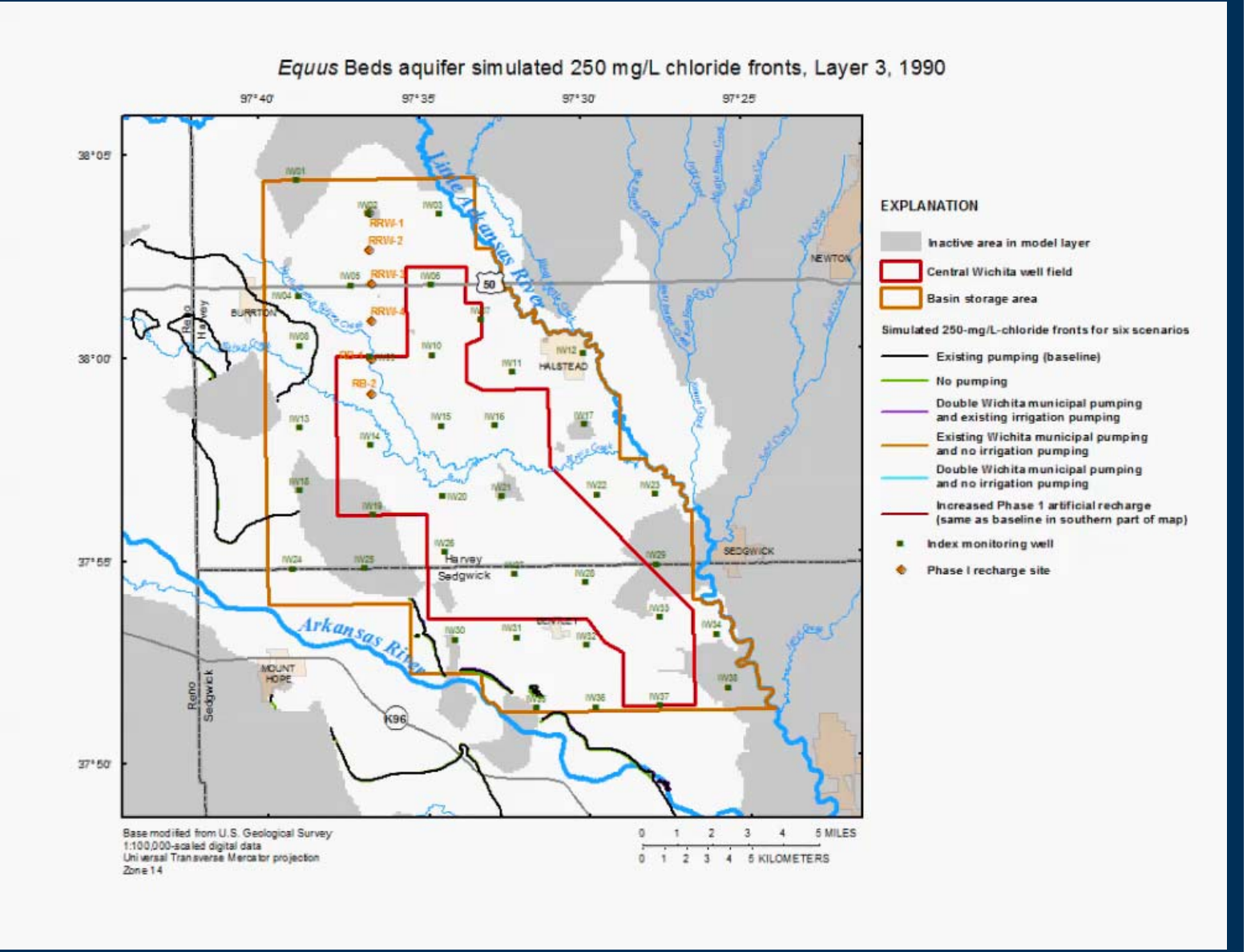
Layer 1: 1990-2008



Klager and others, 2014 (http://pubs.usgs.gov/of/2014/1162/)

3)

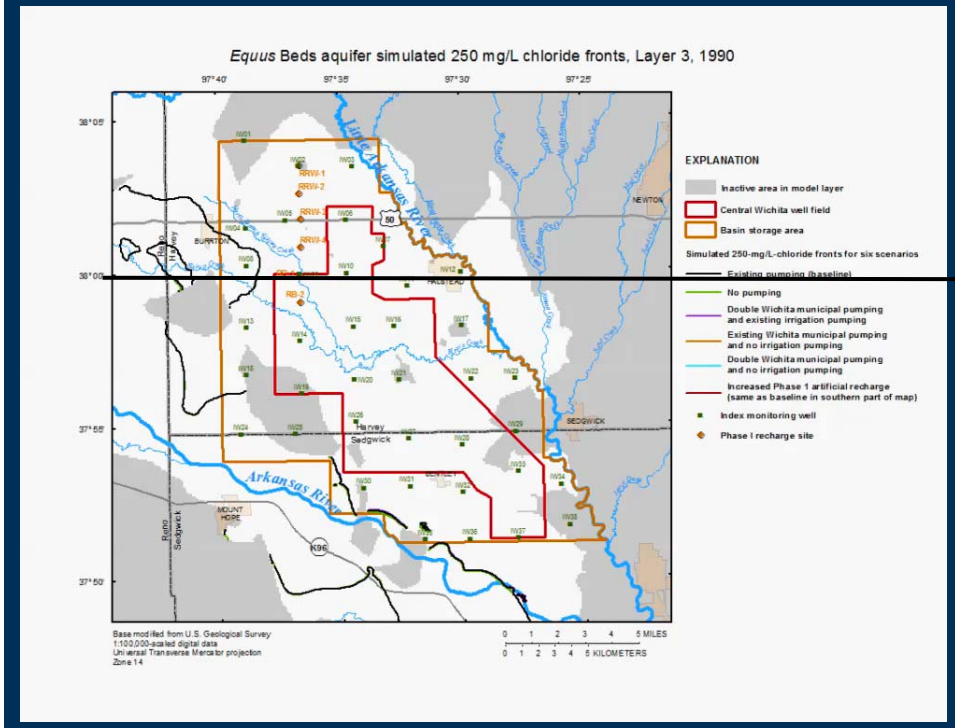
Layer 3: 1990-2008

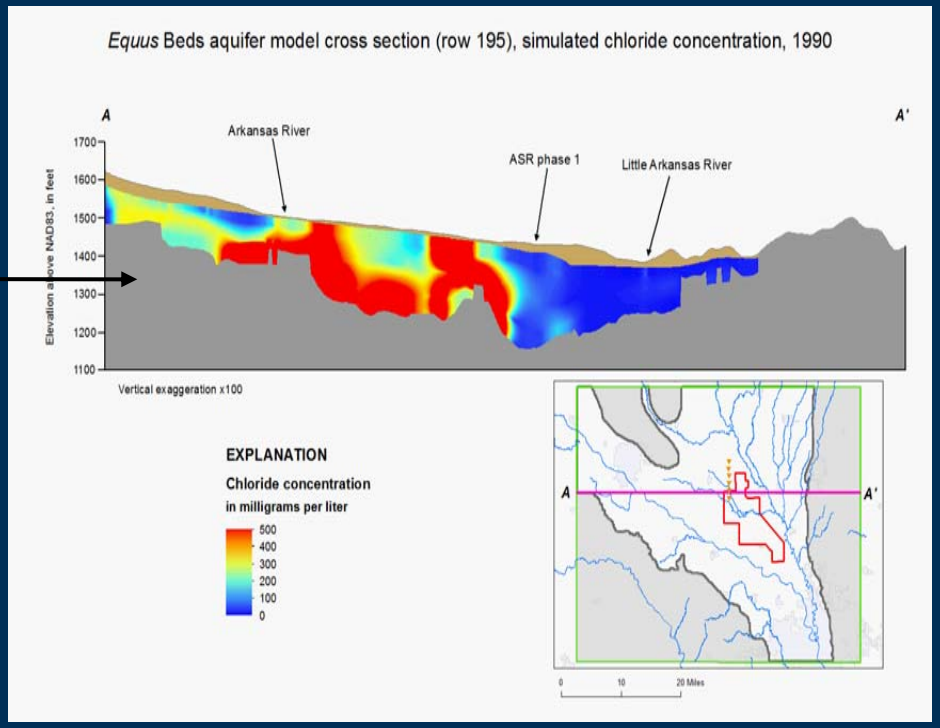


Klager and others, 2014 (http://pubs.usgs.gov/of/2014/1162/)

3)

Simulated Chloride Migration (1990–2008)





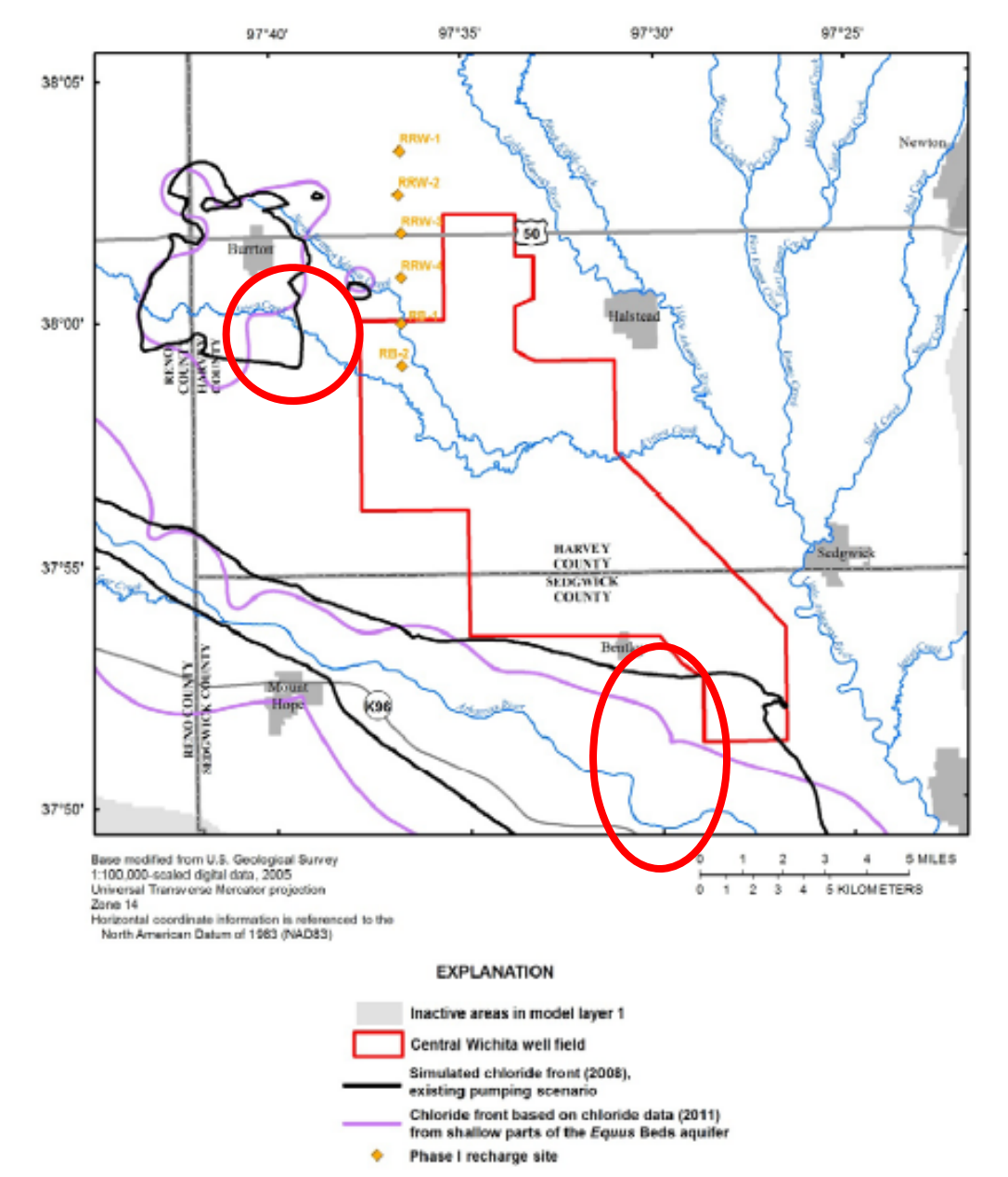
Klager and others, 2014 (http://pubs.usgs.gov/of/2014/1162/)

USGS

CITY OF WICHITA www.wichita.gov

Shallow measured 2011 chloride compared to 2008 model

- Demonstrates:
  - Data needs/gaps
  - Recalibration
  - Pumping effects

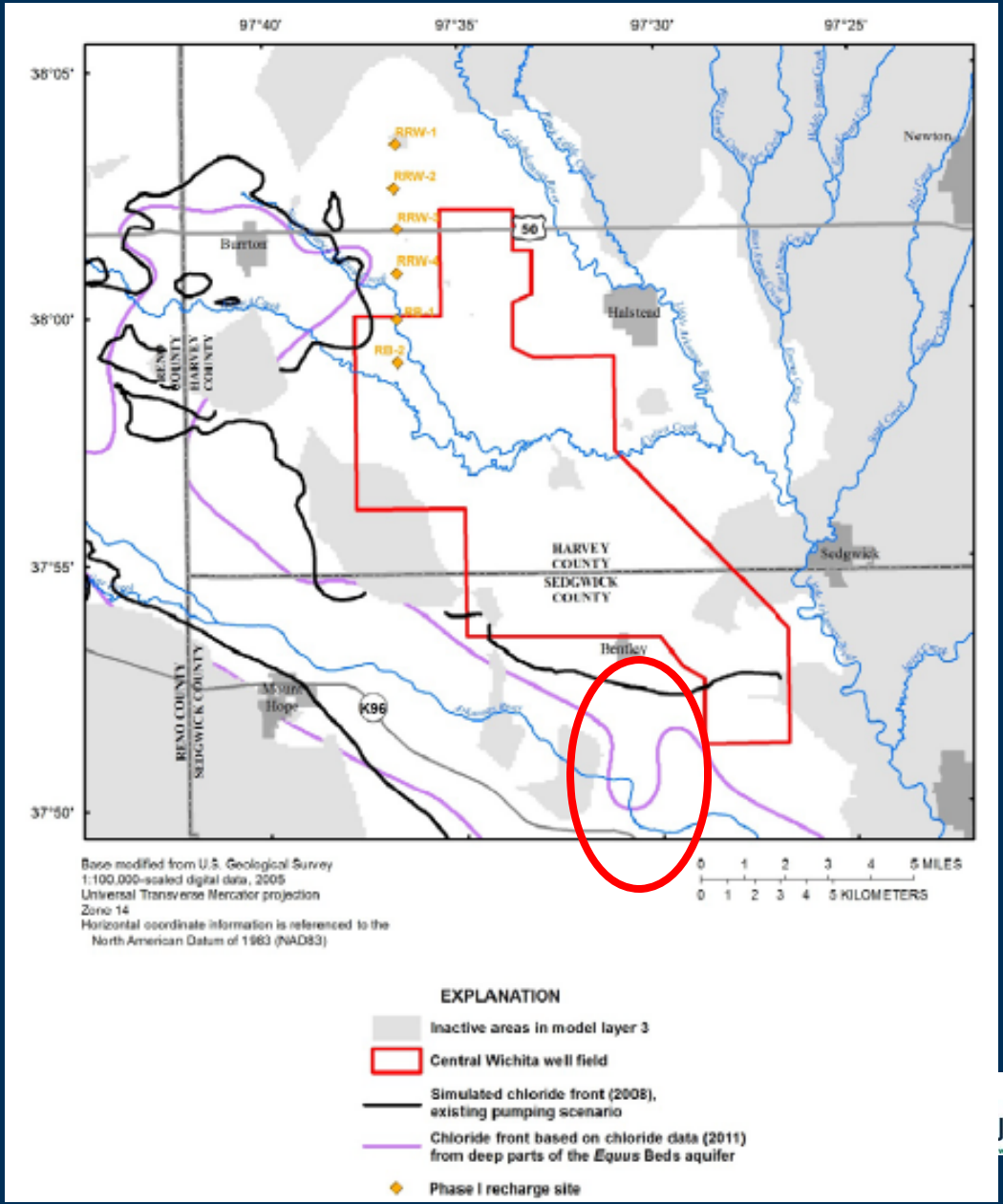


USGS

CITY OF WICHITA
www.wichita.gov

Deep measured 2011 chloride compared to 2008 model

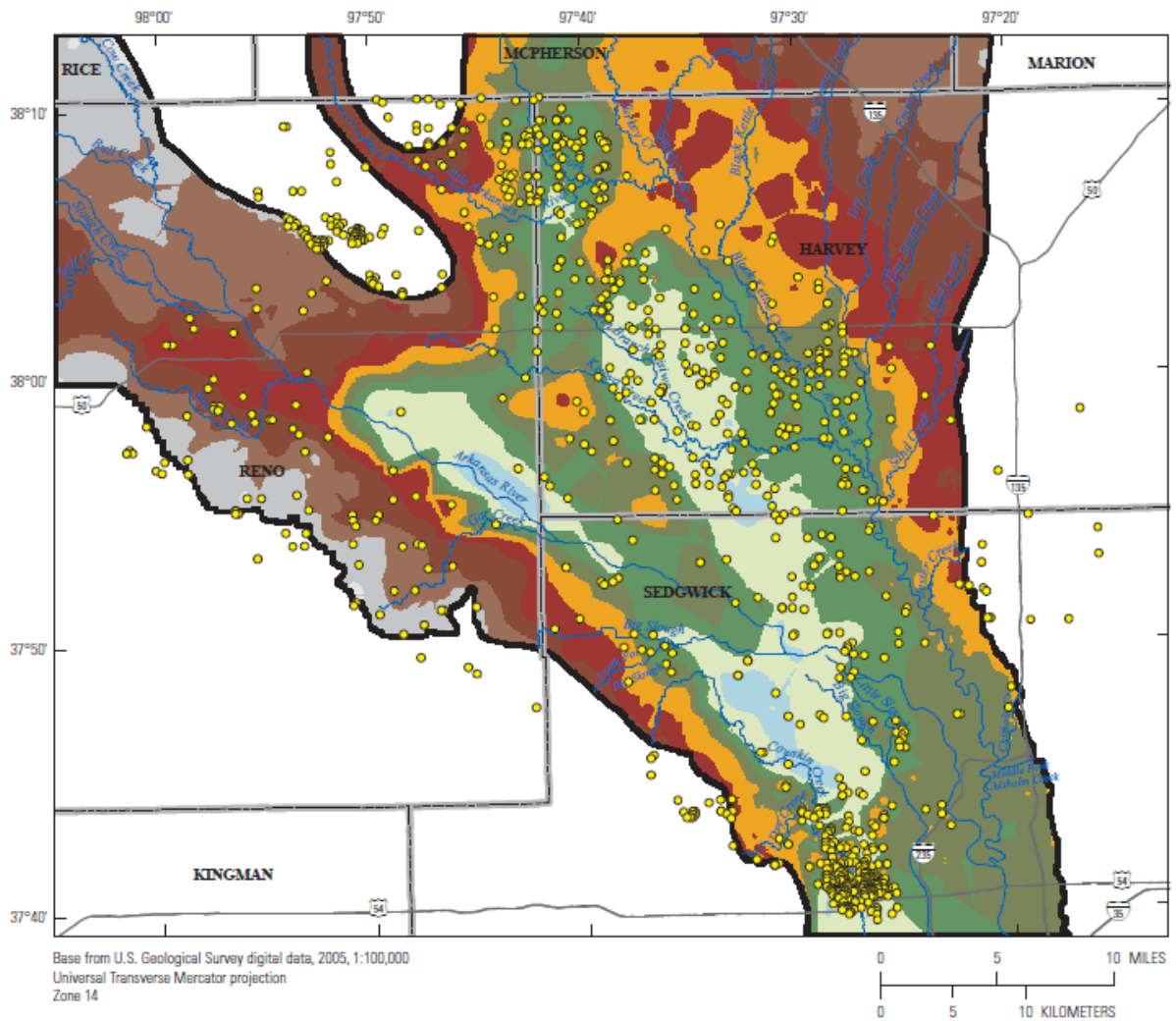
- Demonstrates:
  - Data needs/gaps
  - Recalibration
  - Pumping effects
  - Bedrock controls



USGS

CITY OF WICHITA
www.wichita.gov

Bedrock altitude



EXPLANATION

Bedrock altitude—In feet above North American Vertical Datum of 1988

1,551 to 1,600	1,301 to 1,350
1,501 to 1,550	1,251 to 1,300
1,451 to 1,500	1,201 to 1,250
1,401 to 1,450	1,151 to 1,200
1,351 to 1,400	1,100 to 1,150

Active model boundary

Depth to bedrock data

Figure 7. Bedrock altitude and locations of wells with depth to bedrock data.

USGS

CITY OF WICHITA www.wichita.gov

3)

Summary of hypothetical scenarios

- Average simulated speed from 1990-2008 of the Burrton plume under actual pumping and artificial recharge conditions was about 0.8 feet/day.
- Doubling Wichita pumping from well field increased rate of Burrton plume migration to about 1.2 feet/day.
- Increasing phase 1 artificial recharge by 2,300 acre-feet/year slowed the plume to about 0.7 feet/day.
- If all pumping is removed, the Burrton chloride plume continues to move about 0.7 feet/day

USGS

Klager and others, 2014 (http://pubs.usgs.gov/of/2014/1162/)

CITY OF WICHITA www.wichita.gov

3)

Next steps and potential model applications:

- Update all data through 2013+
- Recalibrate model
- Identify (and fill) data-collection needs
- Test additional scenarios
- Artificial recharge accounting
- Optimization of artificial recharge and pumping sites and rates
- Testing strategies for dealing with the plume, such as pumping from the plume

USGS

CITY OF WICHITA www.wichita.gov

3)

Well network in Equus study area

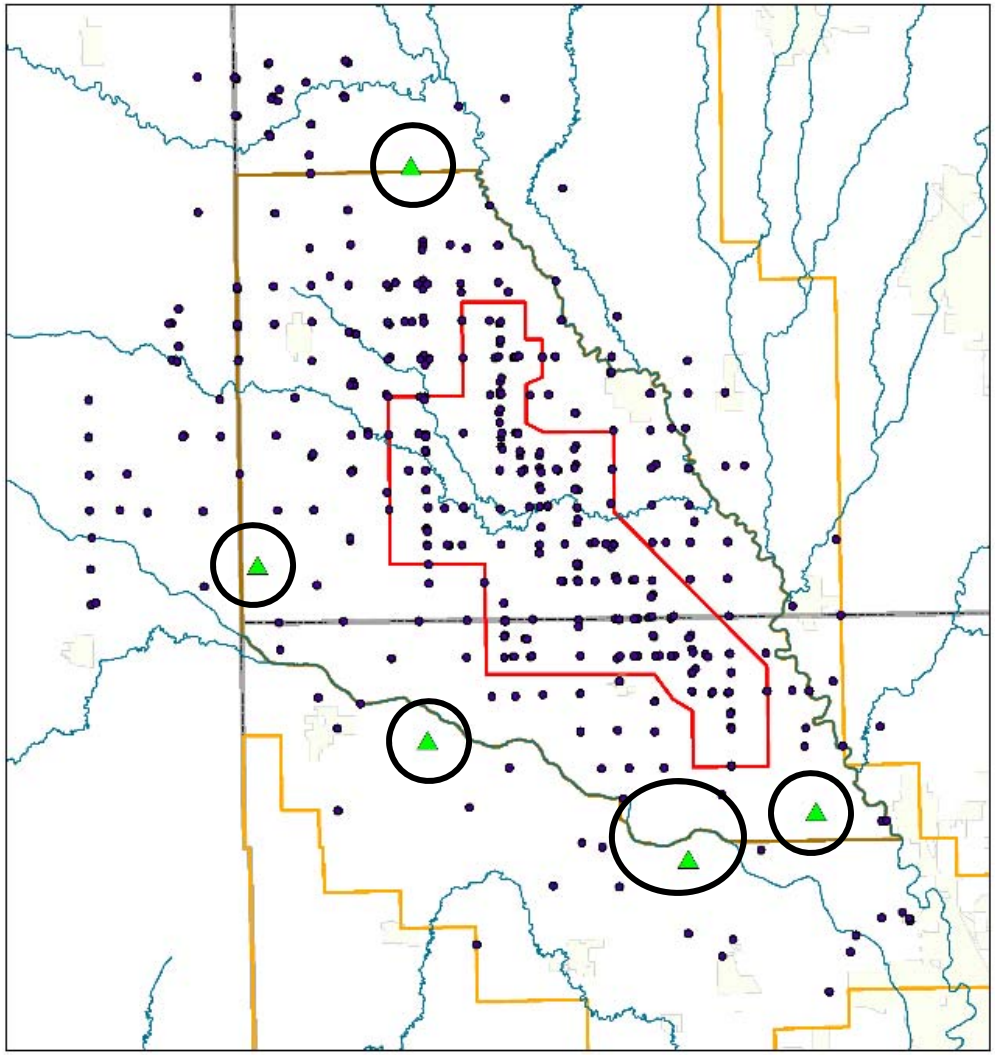
- **100 wells identified that are close to (within 300 meters) other wells of similar depth – mostly redundant monitoring wells**

- **Some GMD2 sites that are close to IWs:**

Well:	Close to:
EB8A/C	IW8A/C
EB9A/C	IW4A/C
EB12A/C	IW13A/C
EB18A/C	IW18A/C
EB22A/B	IW1A/C
EB208A/C	IW25A/C
AN133A	IW17C

3)

Potential sites for new monitoring wells



USGS

CITY OF WICHITA www.wichita.gov

4)

HBMP Preliminary Conclusions

Continuous Monitoring

*Continuous monitoring

-Newly installed continuous nitrate and CDOM monitors performed well and demonstrated value for the city of Wichita for continuous monitoring applications

-Model for continuous bromide allows for continuous estimates of bromide concentrations and illustrates utility of continuous data collection

-Continuous groundwater well data allows for effective recharge monitoring

Discrete Sampling

*Continued sampling

-Higher streamflows during the post operational period likely related to higher water-quality constituent concentrations

-Post operational discrete data collected during 2014-14 will be used to quantify ASR Facility discharge effects, if any.

USGS

CITY OF WICHITA www.wichita.gov

4)

Little Ark. Flow Analysis Preliminary Conclusions

-Historically, Little Ark R. nr Sedgwick streamflow is ~8% less than Valley Center

-During 1999-2013, a yield of 11,000 ac-ft attainable for 3 years during April 15-Oct 15 and 10 years during entire calendar year, and bromide limits withdrawal ~8% of days.

-Runoff water available most years within April 15-Oct 15

-Bromide limits withdrawal ~8% of available days

-Turbidity analysis is complex. During 2013, little measured difference between upstream & downstream turbidity.

Overall Conclusions

- Decreased reliance on aquifer by Wichita helped to maintain aquifer water storage in central part of study area during 2012 drought.
- Concentrations of water-quality constituents of concern haven't increased substantially during ASR Phase I & II, likely more influenced by climate and drawdown and recovery.
- Chloride plume is moving toward Wichita well-field regardless of pumping rates, but plume moves slower with lower pumping rates and increased artificial recharge.
- Minimal water quality and macroinvertebrate (indicators of water quality) differences between upstream and downstream of Sedgwick Little Arkansas diversion site.

Next steps

- Publish water quality report and update results on web page through 2014
- Complete HBMP and Little Arkansas River flow analysis studies.
- Continue mapping annual water-levels (winter), annual report
  - January 5th, 2015 water-level survey
  - We will provide list of priority wells to GMD2 and city of Wichita.
- Complete network analysis
- Continue monitoring water quality and potential effects related to ASR.
- Recalibrate flow model and potentially expand model area?

Selected publications:

- Burrton Task force report and DWR Chief Engineer order issued on June 1, 1984. https://agriculture.ks.gov/docs/default-source/igucas/burrton198406.pdf?sfvrsn=2 and correctional order issued on July 24, 1984 https://agriculture.ks.gov/docs/default-source/igucas/burrtoncorrection198407.pdf?sfvrsn=2

- Klager, B.J., Kelly, B.P., and Ziegler, A.C., 2014, Preliminary simulation of chloride transport in the Equus Beds aquifer and simulated effects of well pumping and artificial recharge on groundwater flow and chloride transport near the city of Wichita, Kansas, 1990 through 2008: U.S. Geological Survey Open-File Report 2014–1162, 76 p., http://dx.doi.org/10.3133/ofr20141162

- Kelly, B.P., Pickett, L.L., Hansen, C.V., Ziegler, A.C., 2013, 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: U.S. Geological Survey Scientific Investigations Report 2013–5042, 90 p.

- Hansen, C.V., Whisnant, J.A., and Lanning-Rush, J.L., 2014, Status of groundwater levels and storage volume in the *Equus* Beds aquifer near Wichita, Kansas, 2012 to 2014: U.S. Geological Survey Scientific Investigations Report 2014-5185, 39 p.

- Hansen, C.V., Lanning-Rush, J.L., Ziegler, A.C., 2013, Revised shallow and deep water-level and storage-volume changes in the Equus Beds Aquifer near Wichita, Kansas, predevelopment to 1993: U.S. Geological Survey Scientific Investigations Report 2013-5170, 18 p.

- Heidari, M., Sadeghipour, J. and Drict, O., 1987, Velocity Control as a tool for optimal plume containment in the Equus Beds Aquifer, Kansas, Water Resources Bulletin, Journal of American Water Resources Association, volume 23, no.2, 11 pp.

- Whittemore, D.O., 2007, Fate and identification of oil-brine contamination in different hydrogeologic settings: Applied Geochemistry, v. 22, no. 10, p. 2,099–2,114.

- Whittemore, 2012, Distribution and Change in Salinity in the Equus Beds Aquifer in the Burrton Intensive Groundwater Use Control Area, Kansas Geological Survey Open-file Report 2012-1, 35 pp.

- Williams, C.C., Lohman, S.W., 1949. Geology and ground-water resources of a part of south-central Kansas. Kansas Geol. Surv. Bull. 79.

- Ziegler, A.C., Hansen, C.V., Finn, D.A., 2010, Water quality in the Equus Beds aquifer and the Little Arkansas River before implementation of large-scale artificial recharge, south-central Kansas, 1995-2005: U.S. Geological Survey Scientific Investigations Report 2010-5023, 143 p.

USGS

CITY OF WICHITA www.wichita.gov

Questions?

Andy Ziegler

aziegler@usgs.gov

785-832-3539

For more information

http://ks.water.usgs.gov/equus-beds-recharge