The Garber-Wellington (Central Oklahoma) Aquifer

- *A brief history of the aquifer and human exploitation*
- *Studies of the aquifer: Past, present, and future*

National Water-Quality Assessment Program

USGS
science for a changing world

The Garber-Wellington (Central Oklahoma) Aquifer

Issues and Investigations

- *Late 1800s – mid 1980s: Water Quantity*
- *Mid 1980s – present: Water Quality*
- *Future: Water Quantity*

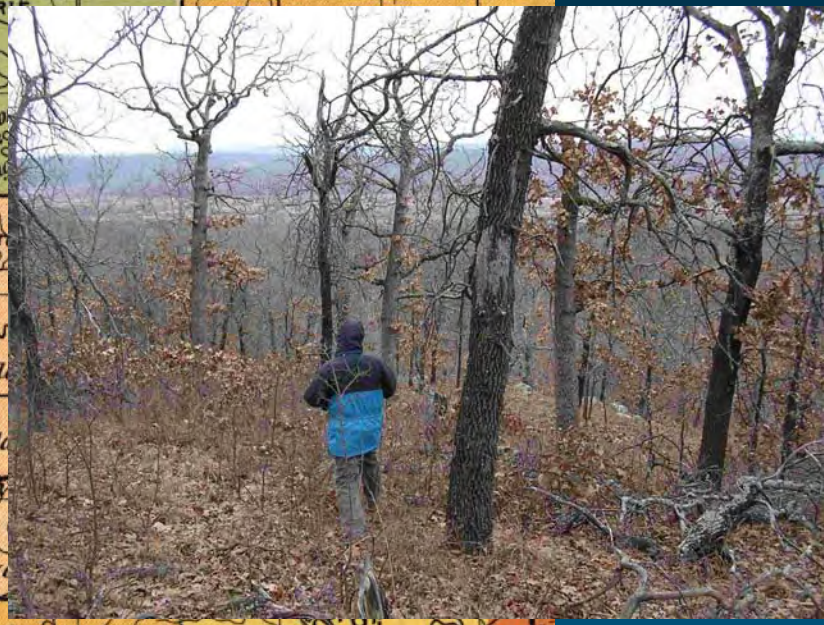
USGS
science for a changing world

Garber Sandstone

Wellington Formation

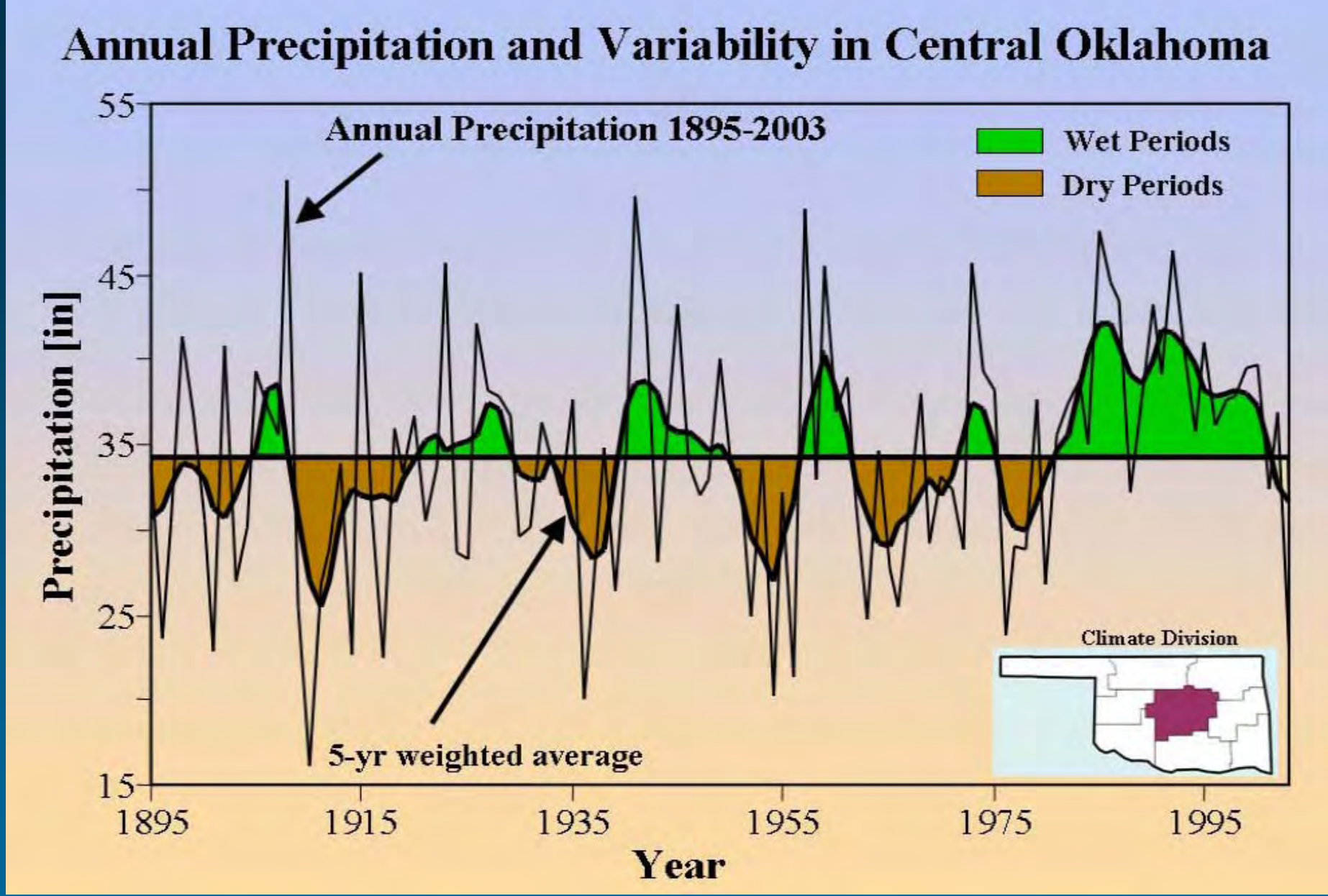
Garber Sandstone and Wellington Formation were deposited by streams about 300 million years ago in an arid environment

USGS
science for a changing world



Map of Oklahoma Territory in 1892

USGS
science for a changing world



Graphic from USDA ARS El Reno, Oklahoma

USGS
science for a changing world

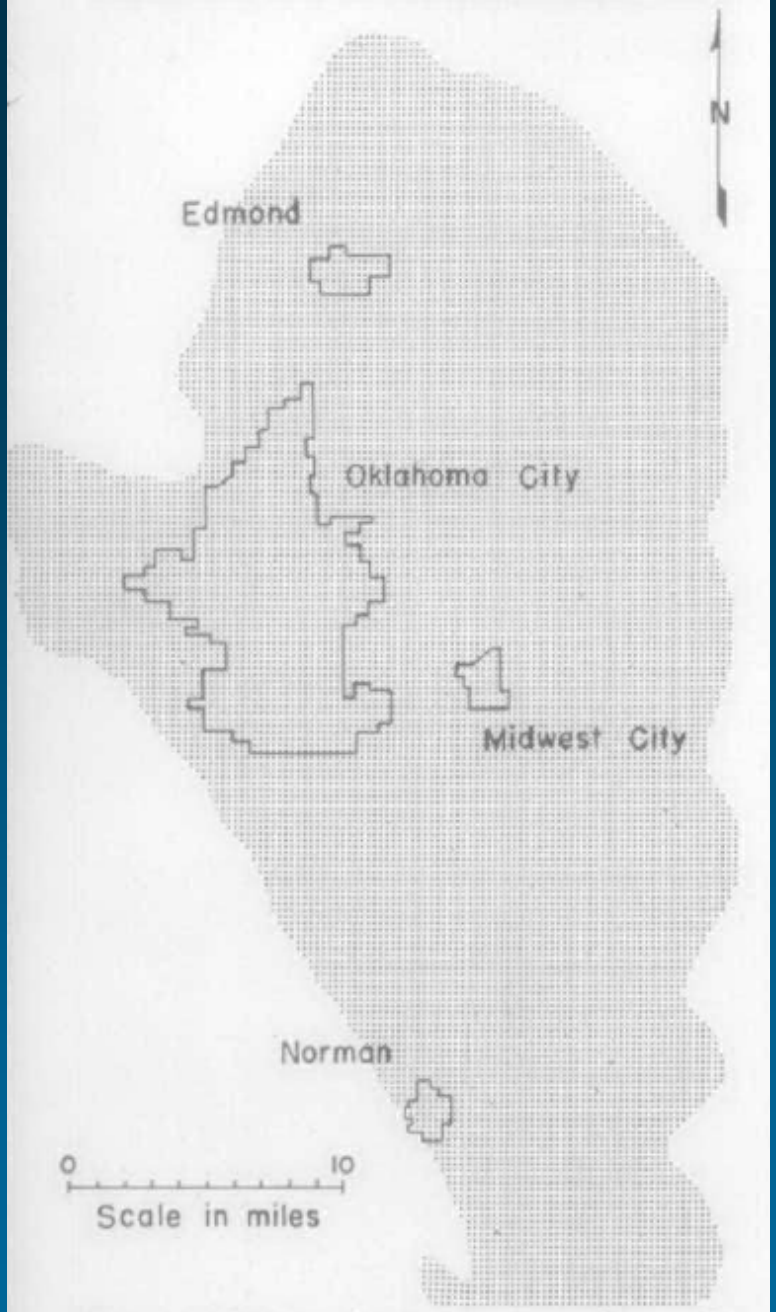
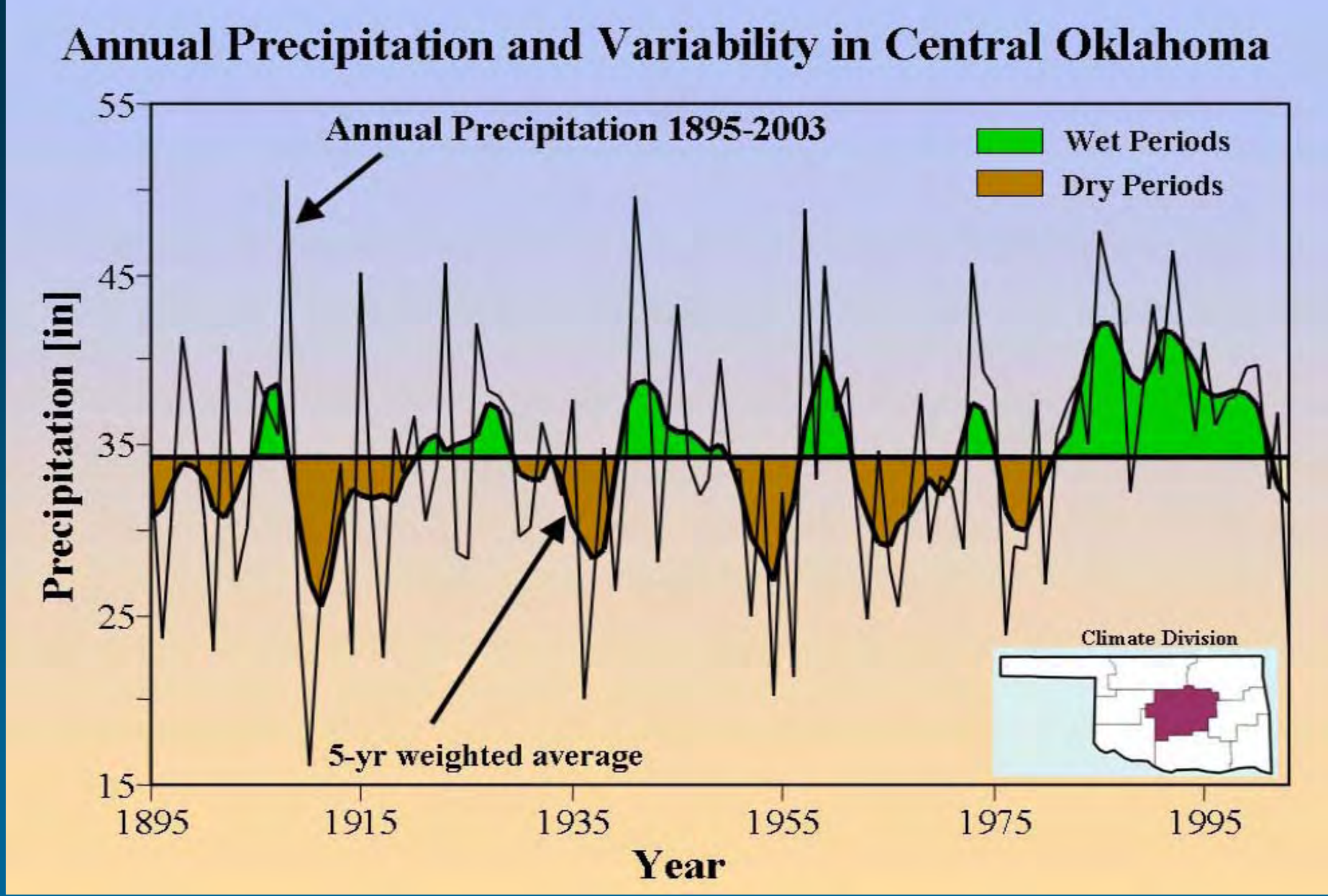


Fig. 2. Garber formation supplies soft, fresh water to municipal and private wells located within the shaded area.

Johnson National Drillers Journal March-April, 1960

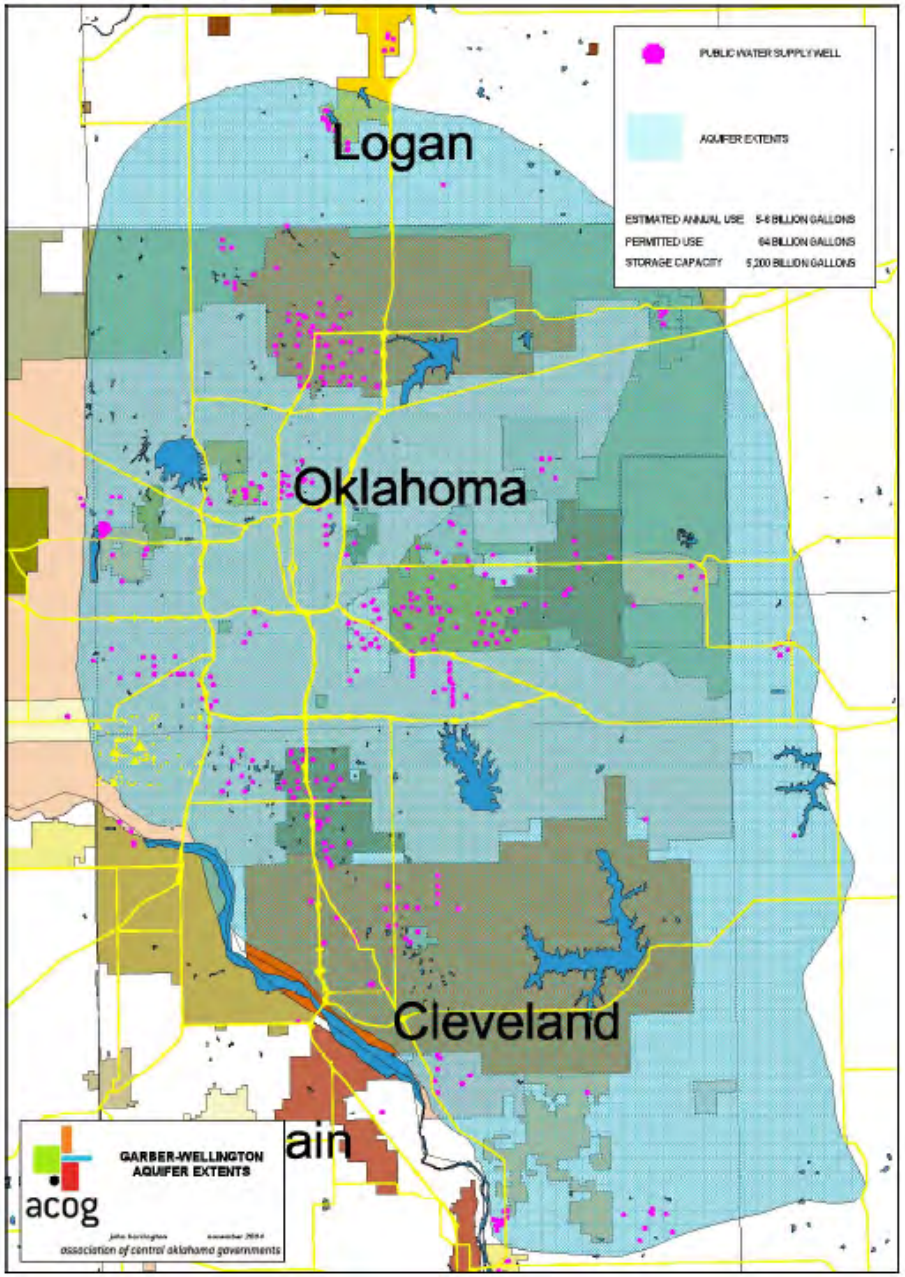
USGS science for a changing world



Graphic from USDA ARS El Reno, Oklahoma

USGS
science for a changing world

Figure 3-2 Garber-Wellington Aquifer Limits (ACOG, 2004)



Garber-Wellington Association founded in 1979

- *Response to drought in 1960s and 1970s*
- *Realization that geologic, hydrologic, and water-quality data were not archived*

Graphic from Association of Central Oklahoma Governments

USGS science for a changing world

U.S. Geological Survey
National Water Quality Assessment Program

Pilot program started in 1986:

1. Provide a nationally consistent description of the current status of water quality for a major part of the Nation's water resources;
2. Define trends in water quality that have occurred in recent decades,
3. Identify and describe current water quality in relation to natural factors and human activities

USGS
science for a changing world

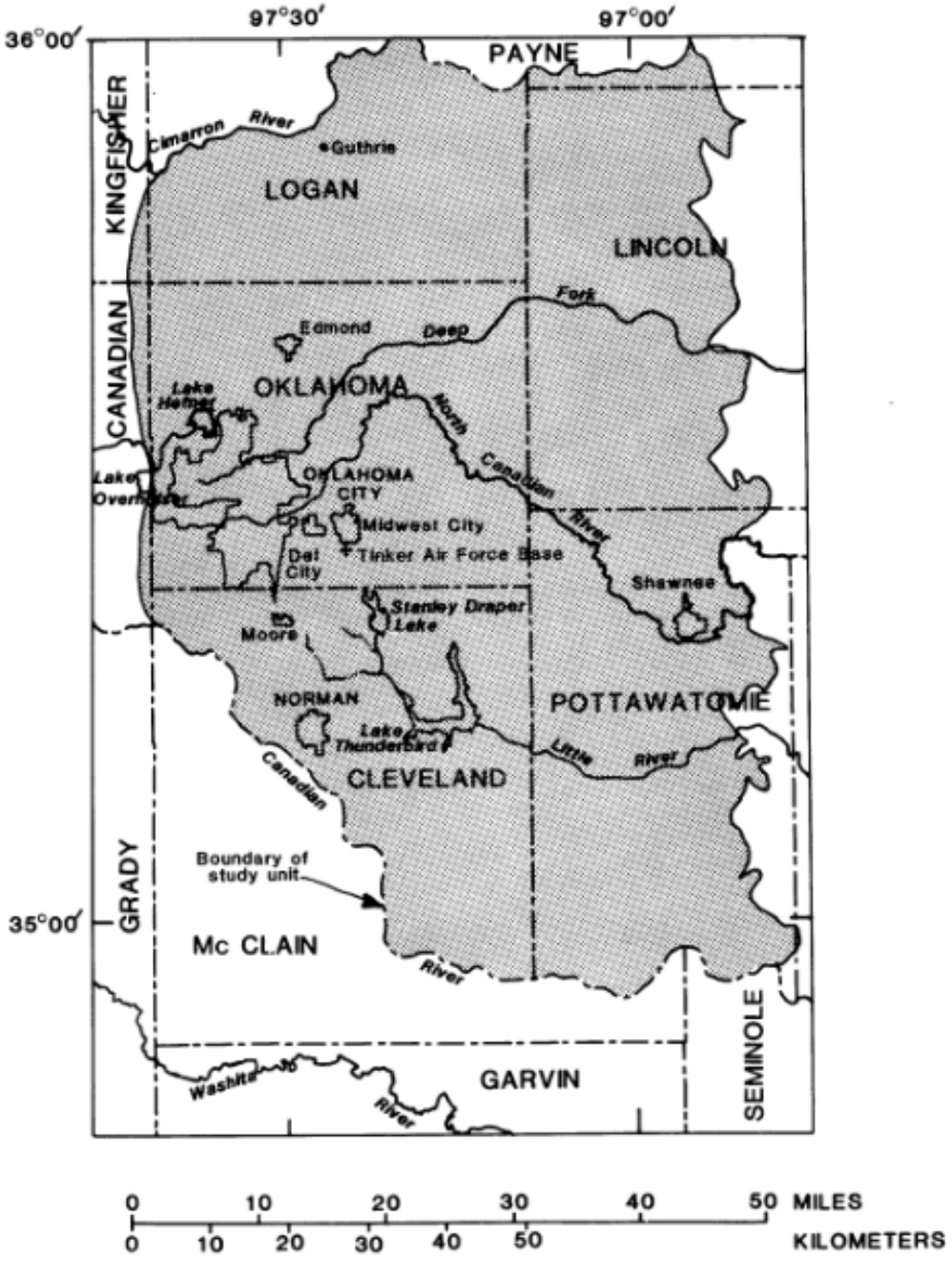


Figure 2.—Geographic features of study unit

Water-Quality Problems:

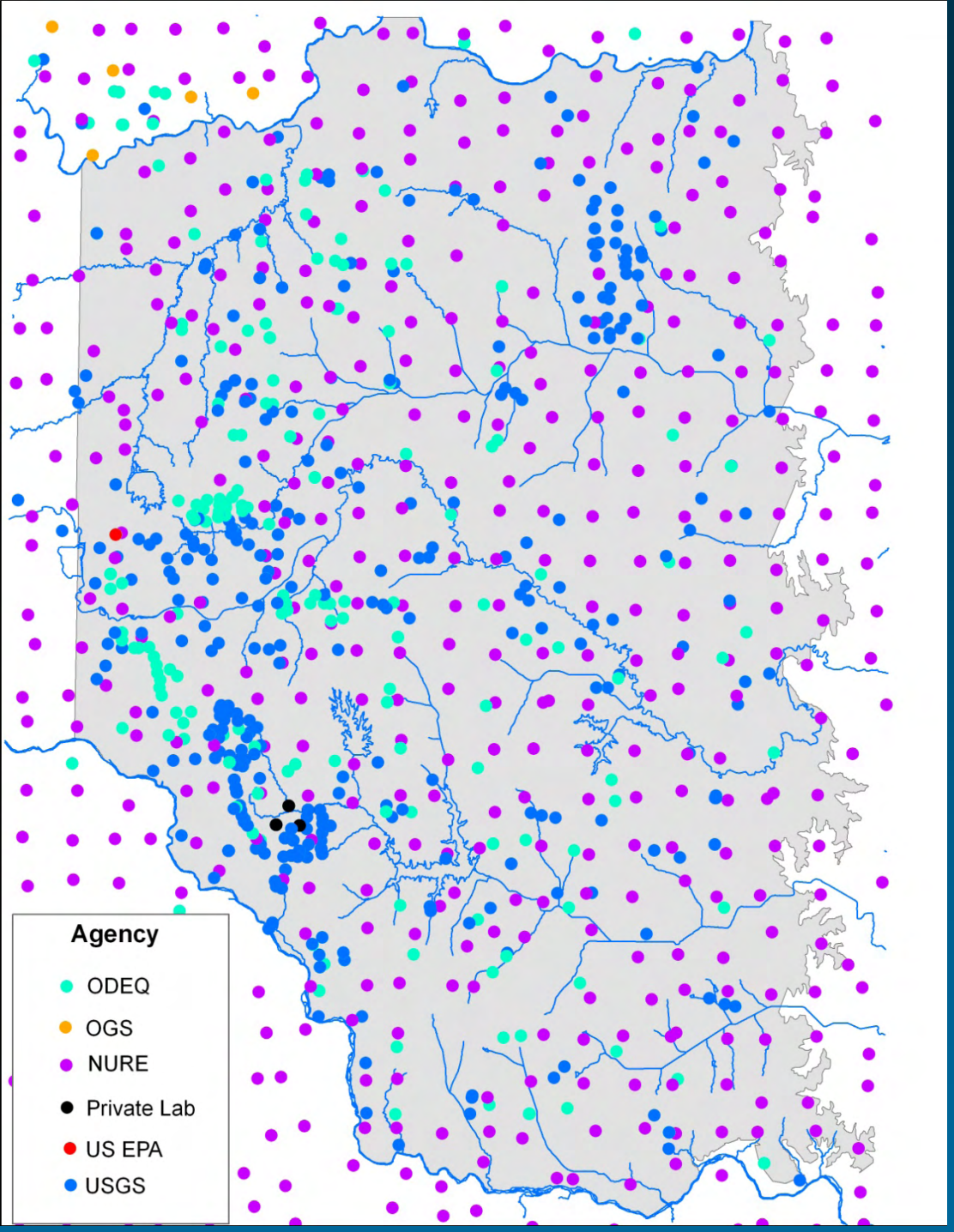
1. Arsenic, chromium, and selenium
2. Potential effects of urbanization
3. Naturally occurring radioactive constituents (radium, thorium, uranium, gross alpha)
4. Potential contamination from oil and gas activities
5. Potential nitrate contamination
6. Potential industrial contamination
7. Sulfate and dissolved solids

Christenson, S. C., and Parkhurst, D. L., 1987, Ground-Water Quality Assessment of the Central Oklahoma Aquifer, Oklahoma; Project Description: U.S. Geological Survey Open-File Report 87-235

National Water-Quality Assessment Program
Central Oklahoma Aquifer

1. Retrospective analysis
2. Solid-phase sampling and sequential extractions and analysis
3. Stratified random sampling of existing supply (domestic and municipal) wells
4. Geochemical (flowpath) sampling
5. Groundwater-flow model

USGS
science for a changing world



Retrospective Analysis:

Locations of wells and distribution systems with chemical analyses of groundwater

Source: U.S. Geological Survey National Water Information system

USGS
science for a changing world

Soils

Solid Phase Sampling and Analysis

Cores

Outcrop

USGS
science for a changing world

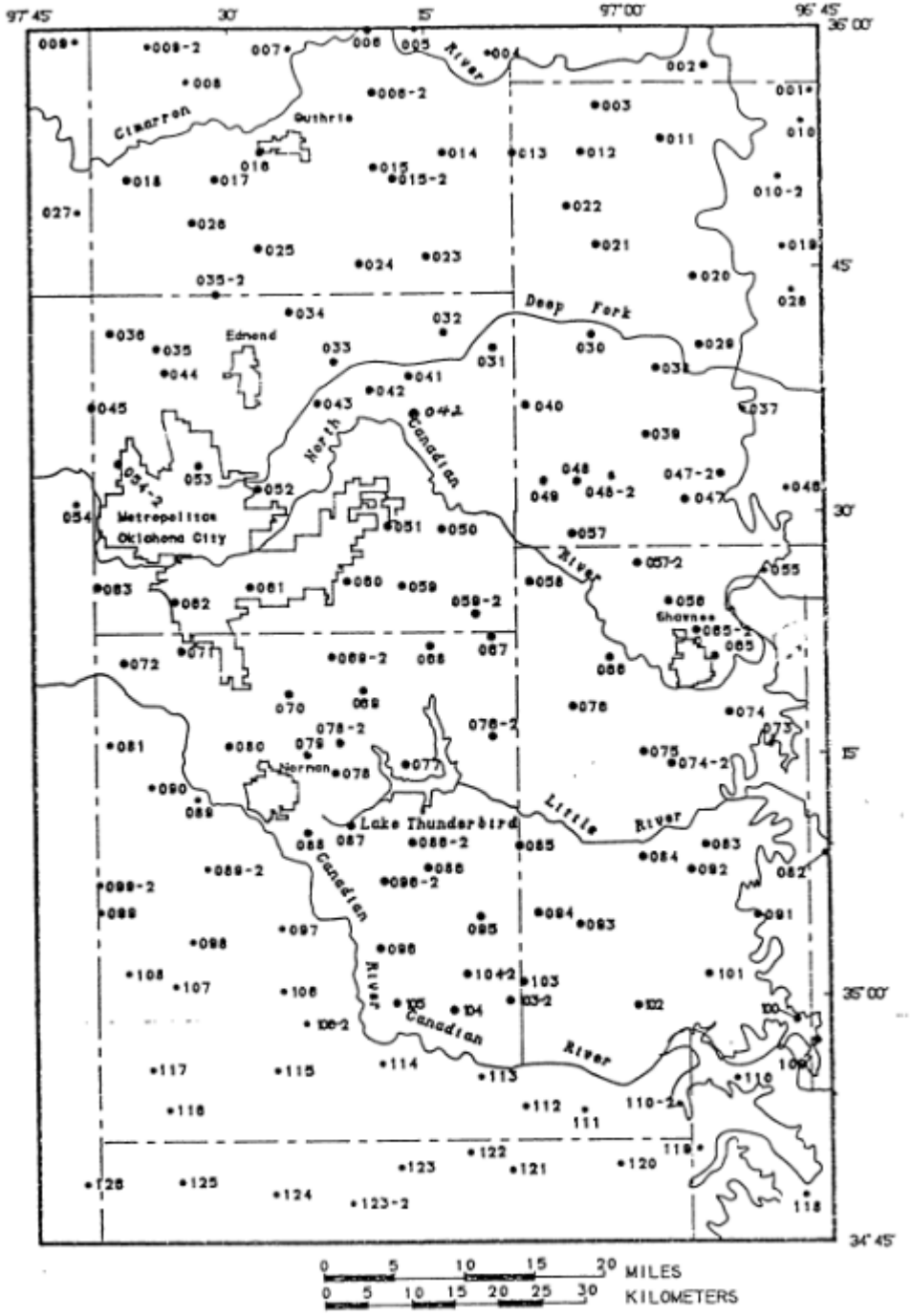


Figure 4. Map showing location sites for phase 1 B-horizon soil samples.

293 Soil Samples

Mosier, E.L., Bullock, J.H., Jr., Fey, D.L., Kennedy, K.R., McKown, D.M., Vaughn, R.B., and Welsch, E.P., 1991, Elemental composition of surficial materials from central Oklahoma: U.S. Geological Survey Open-File Report 91-442

USGS
science for a changing world

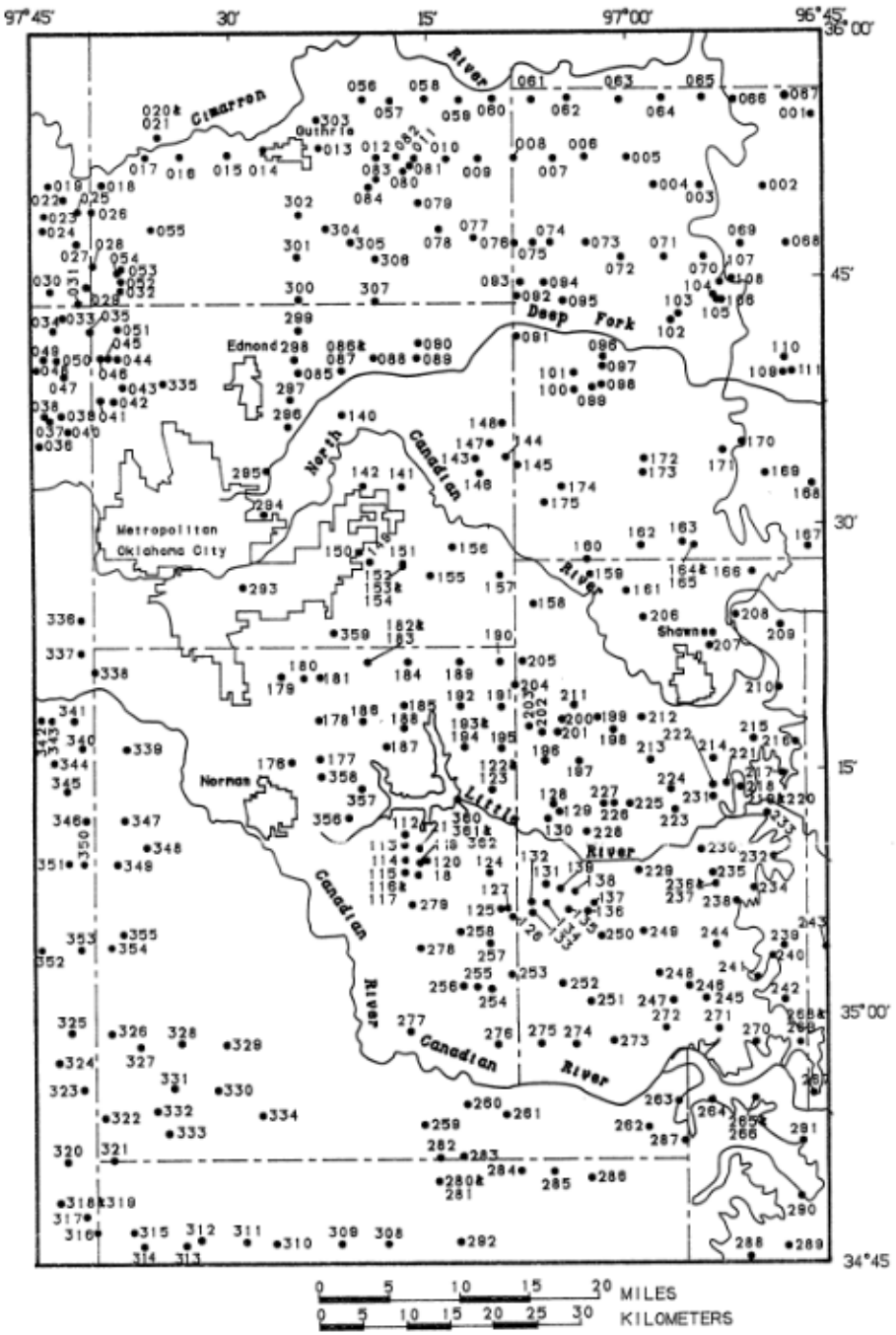


Figure 6. Map showing location sites for outcrop rock samples.

362 Outcrop Samples

Mosier, E.L., Bullock, J.H., Jr., Fey, D.L., Kennedy, K.R., McKown, D.M., Vaughn, R.B., and Welsch, E.P., 1991, Elemental composition of surficial materials from central Oklahoma: U.S. Geological Survey Open-File Report 91-442

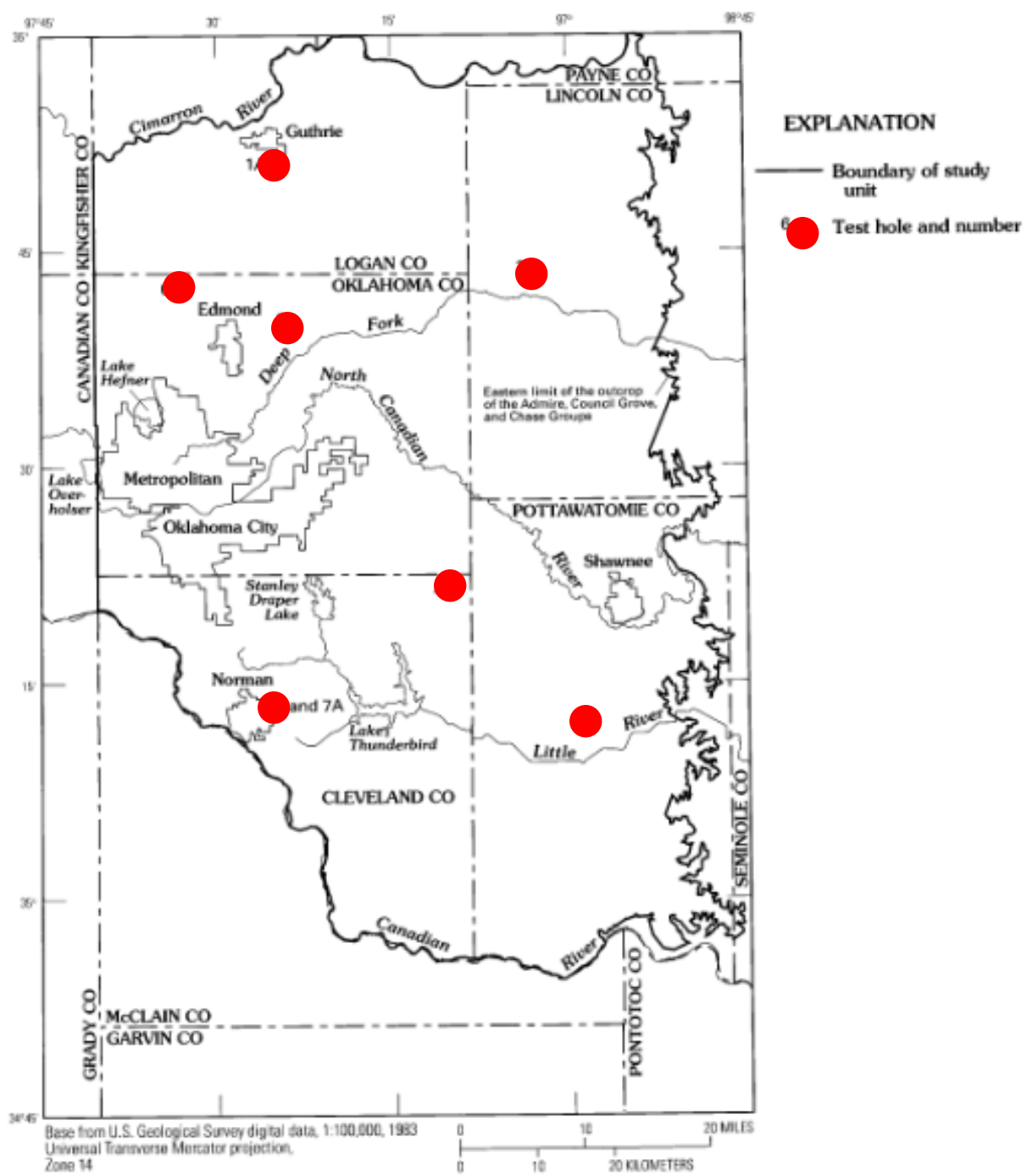
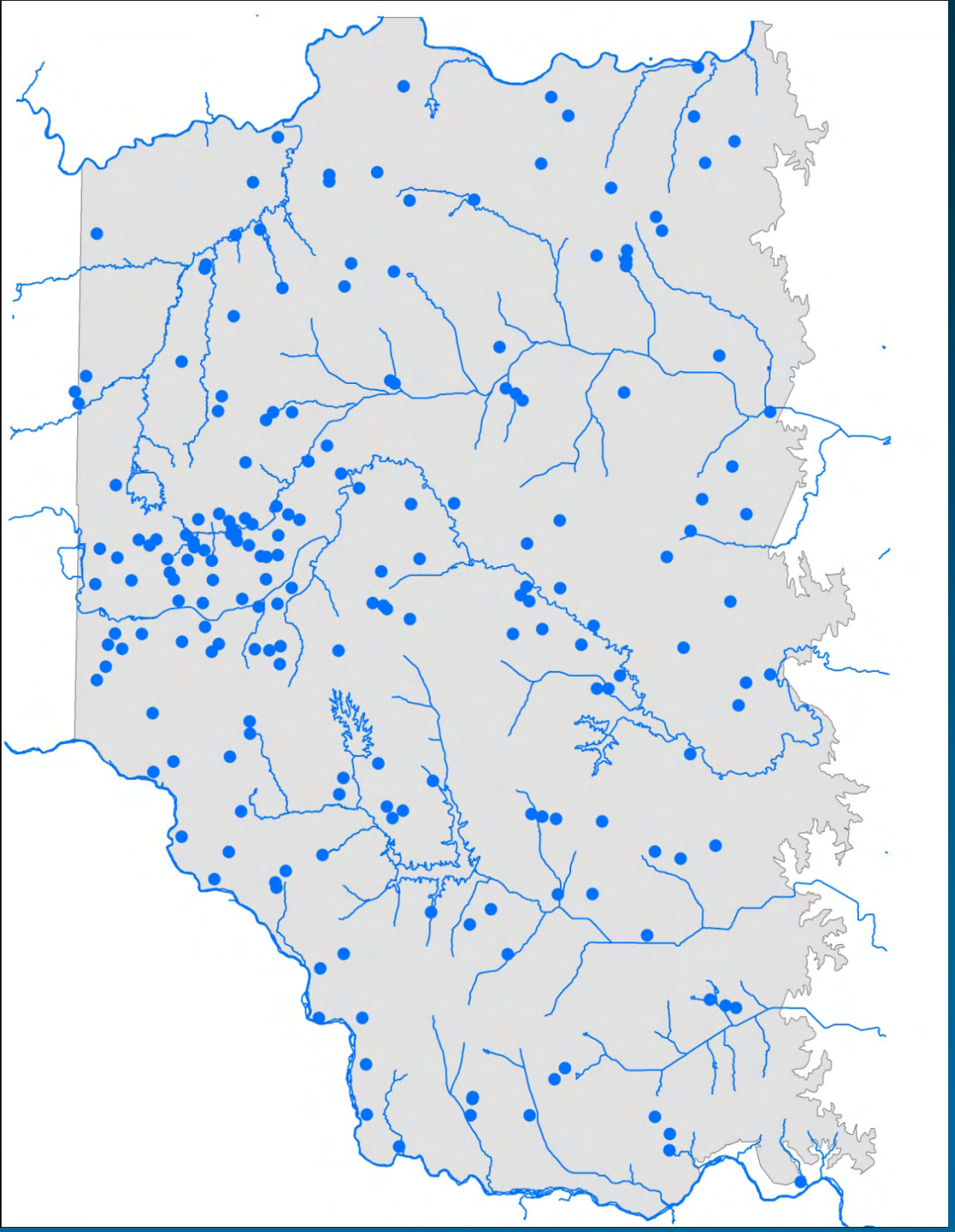


Figure 1. Location of test holes.

Drilled and Cored 7 Test Holes 549 Core Samples Analyzed

Schlottman, J.L., Mosier, E.L., and Breit, G.N., 1998, Arsenic, Chromium, Selenium, and Uranium in the Central Oklahoma Aquifer, *in* Christenson, Scott, and Havens, J.S., 1998, Ground-Water-Quality Assessment of the Central Oklahoma Aquifer, Oklahoma : Results of Investigations: U.S. Geological Survey Water-Supply Paper 2357A.



Water-Quality and Geochemistry Samples from 207 Wells

USGS
science for a changing world

David Parkhurst determining alkalinity in the field, 1988

USGS
science for a changing world

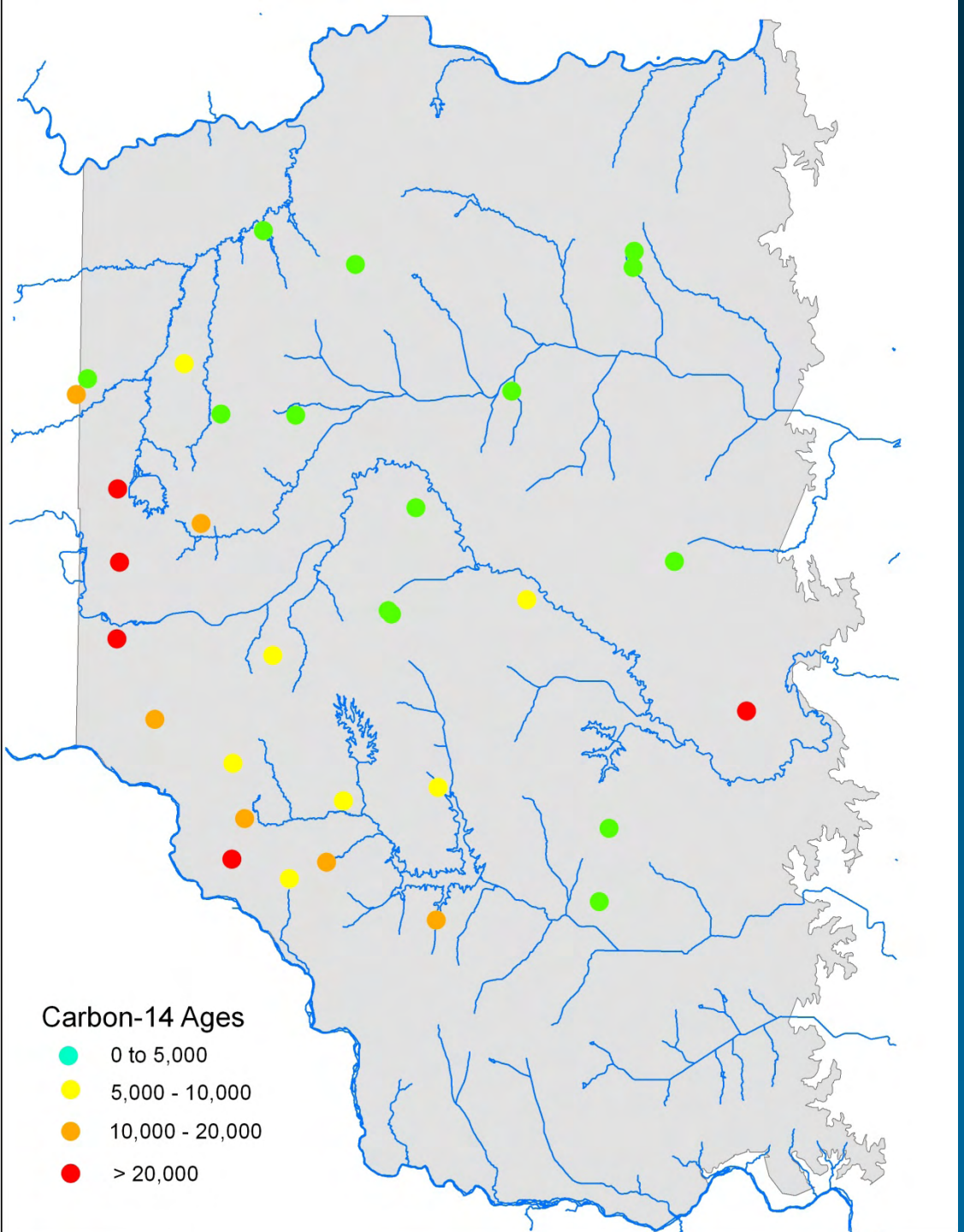
L. Niel Plummer Sampling a Bethany municipal supply well for chlorofluorocarbons 1990

Busenberg, Eurybiades, and Plummer, L.N., 1992, Use of chlorofluorocarbons (CCl_3F and CCl_2F_2) as hydrologic tracers and age—dating tools: Example–The alluvium and terrace system of central Oklahoma: Water Resources Research, v. 28, 2257–2284.

USGS
science for a changing world

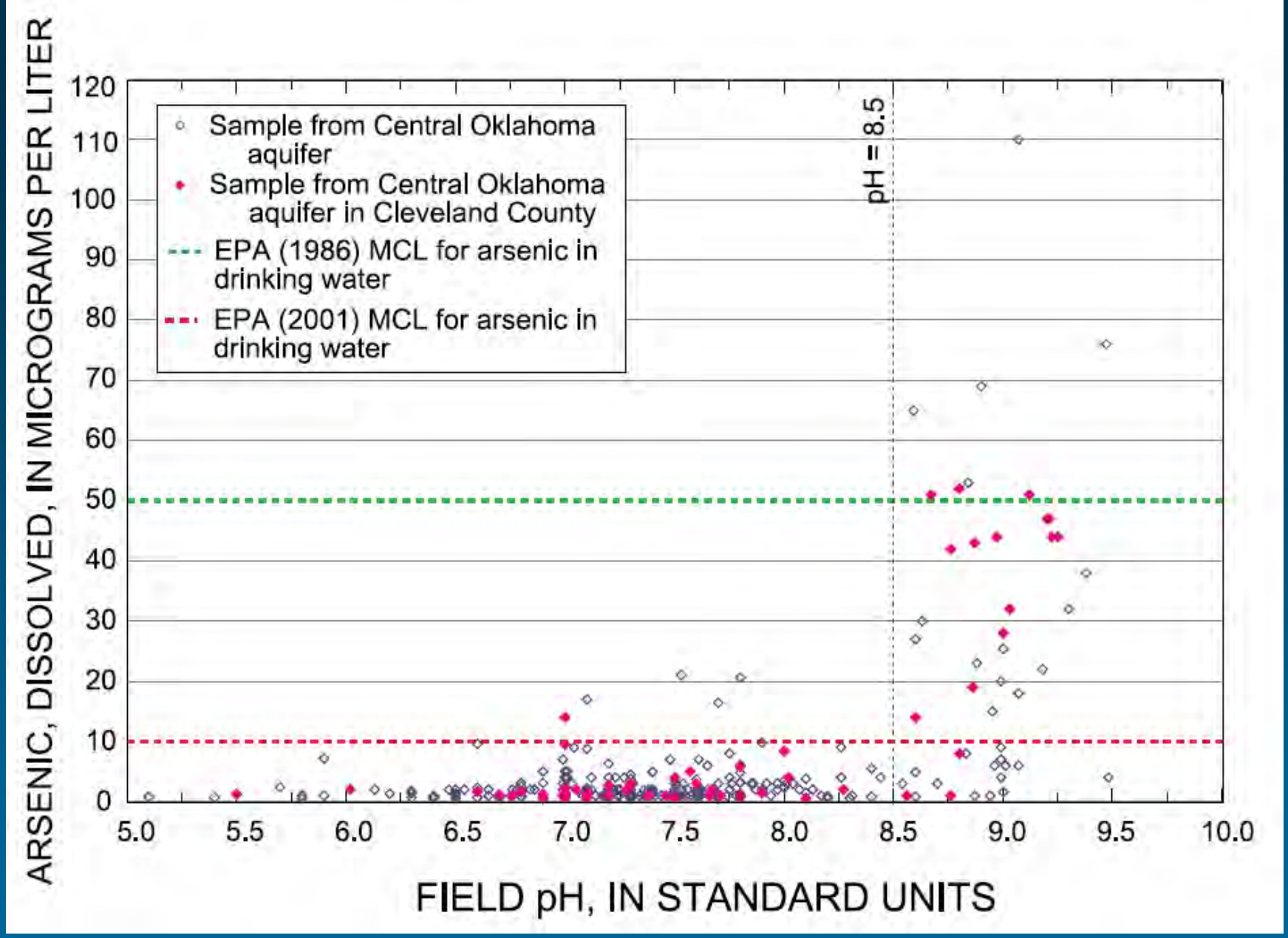
Dale Ferree collecting a sample for carbon-14 analysis, 1988

USGS
science for a changing world



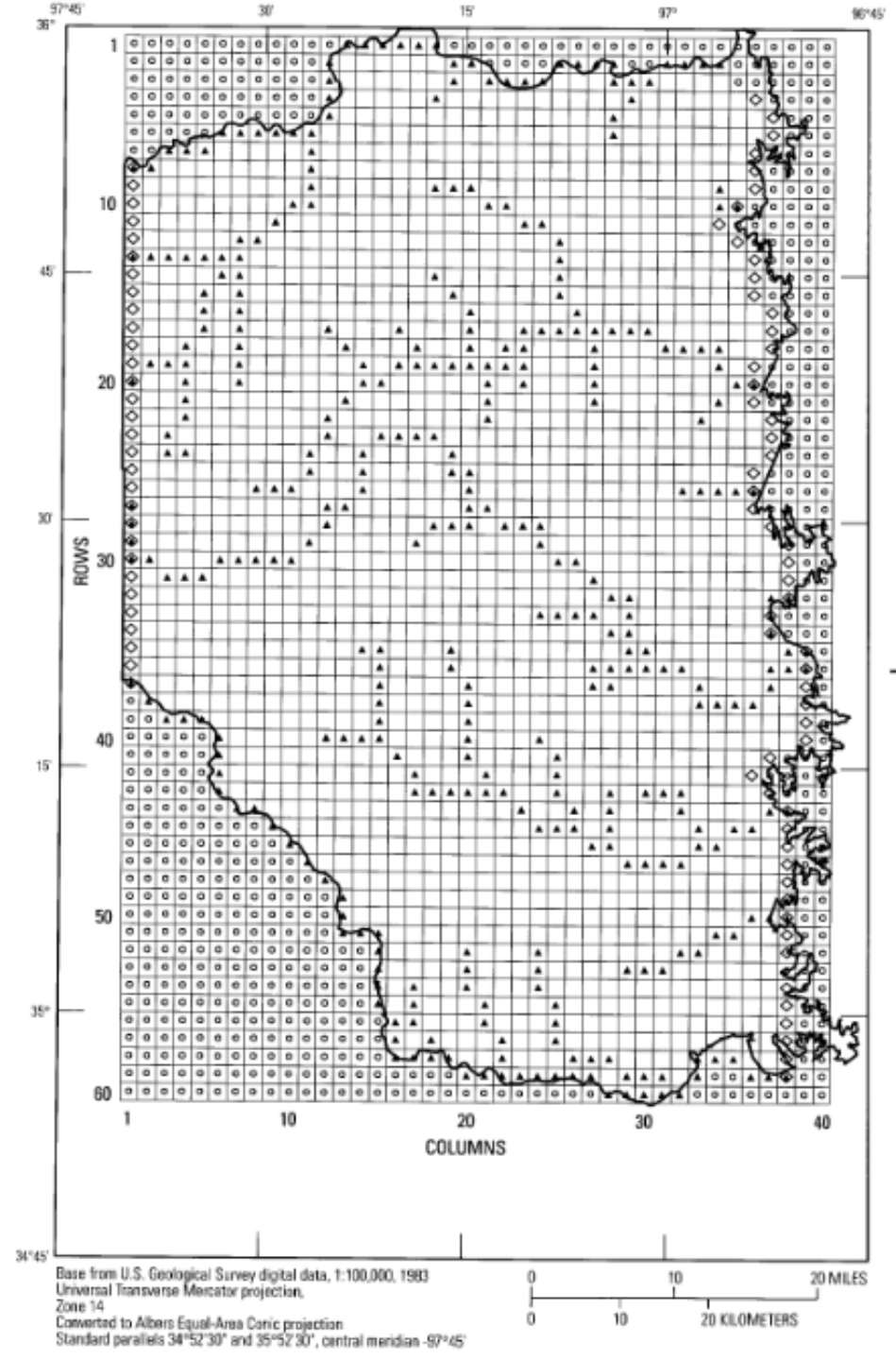
Carbon-14 Ages from Groundwater Samples

USGS
science for a changing world



Smith, S.J., Paxton, S.T., Christenson, Scott, Puls, R.W., and Greer, J.R., 2009, Flow contribution and water quality with depth in a test hole and public-supply wells: Implication for arsenic remediation through well modification, Norman, Oklahoma, 2003-2006: U.S. Environmental Protection Agency 600/R-09/36, April 2009

USGS
science for a changing world



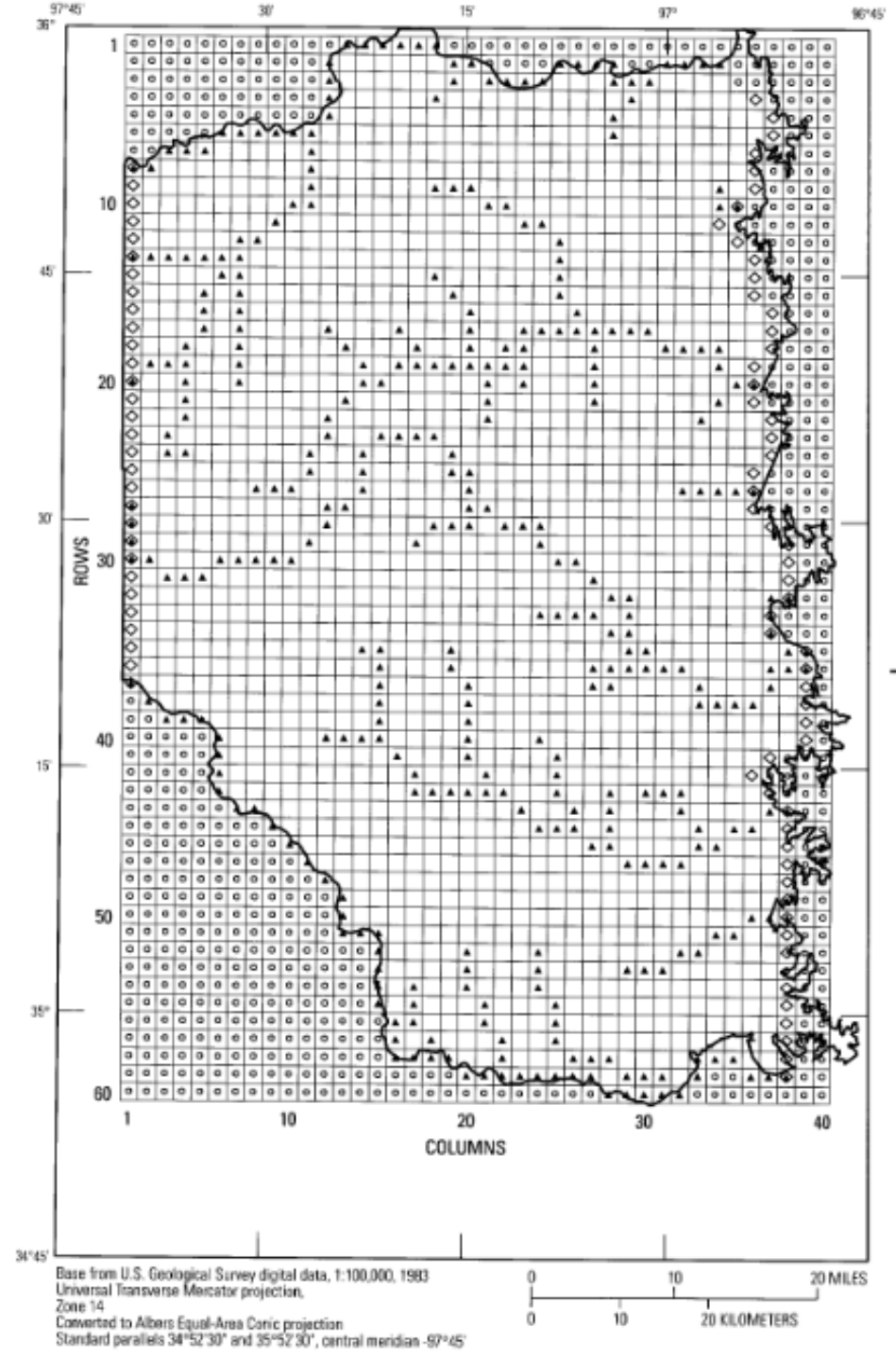
EXPLANATION

- **Active cell**—An active cell occurs in at least one layer at this column and row
- **Constant-head cell**—The uppermost active cell at this column and row is a constant-head cell
- **Stream cell**—The uppermost active cell at this column and row is a stream cell
- **Inactive cell**—No active cells occur in any layer at this column and row
- **Boundary of study unit**

Central Oklahoma Aquifer Groundwater-Flow Model MODFLOW-88

Parkhurst, D. L.; Christenson, S. C.; and Breit, G. N., 1993, Ground-Water-Quality Assessment of the Central Oklahoma Aquifer, Oklahoma; Geochemical and Geohydrologic investigations: U.S. Geological Survey Open-File Report 92-642.

USGS
science for a changing world



"All models are wrong, but some are useful"

George E.P. Box

Professor Emeritus of Statistics at the University of Wisconsin

Parkhurst, D. L.; Christenson, S. C.; and Breit, G. N., 1993, Ground-Water-Quality Assessment of the Central Oklahoma Aquifer, Oklahoma; Geochemical and Geohydrologic investigations: U.S. Geological Survey Open-File Report 92-642.

USGS
science for a changing world

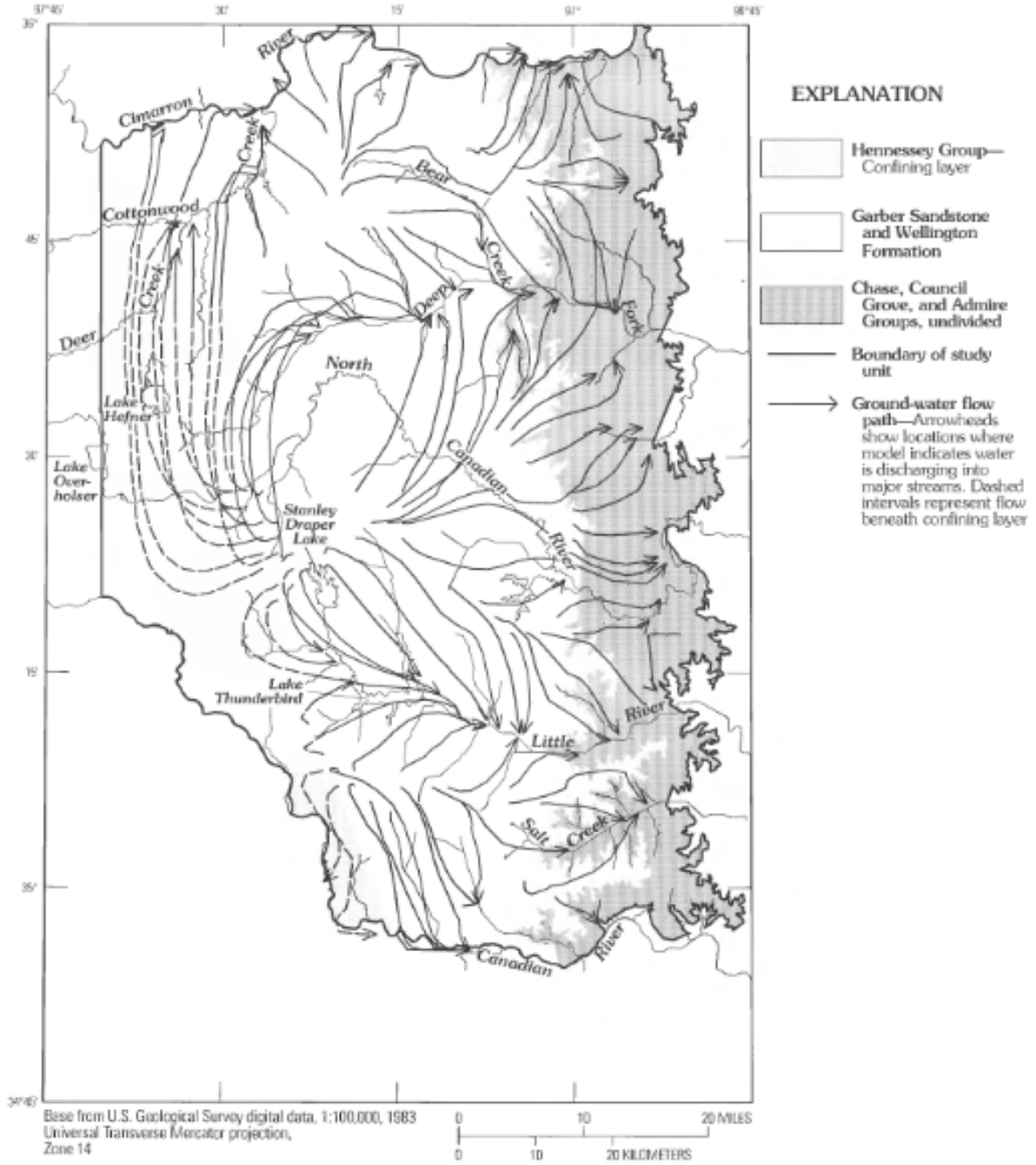
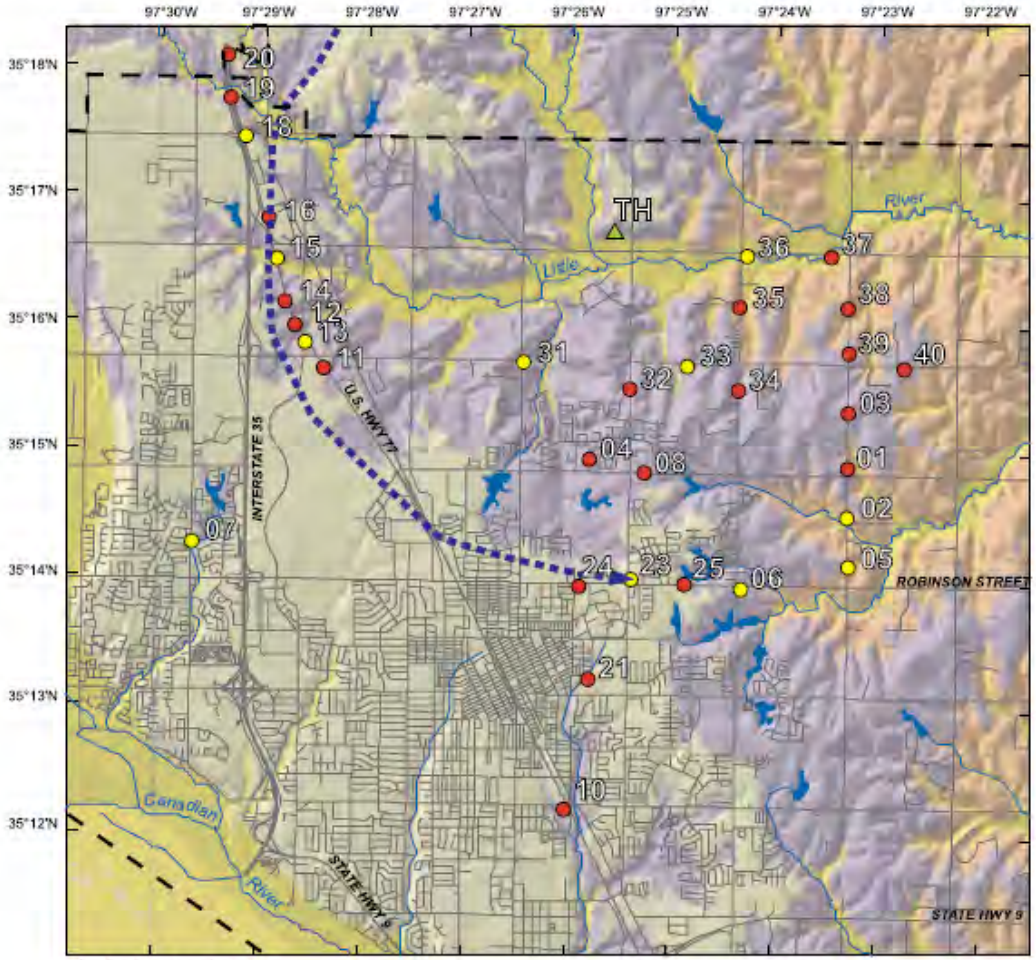
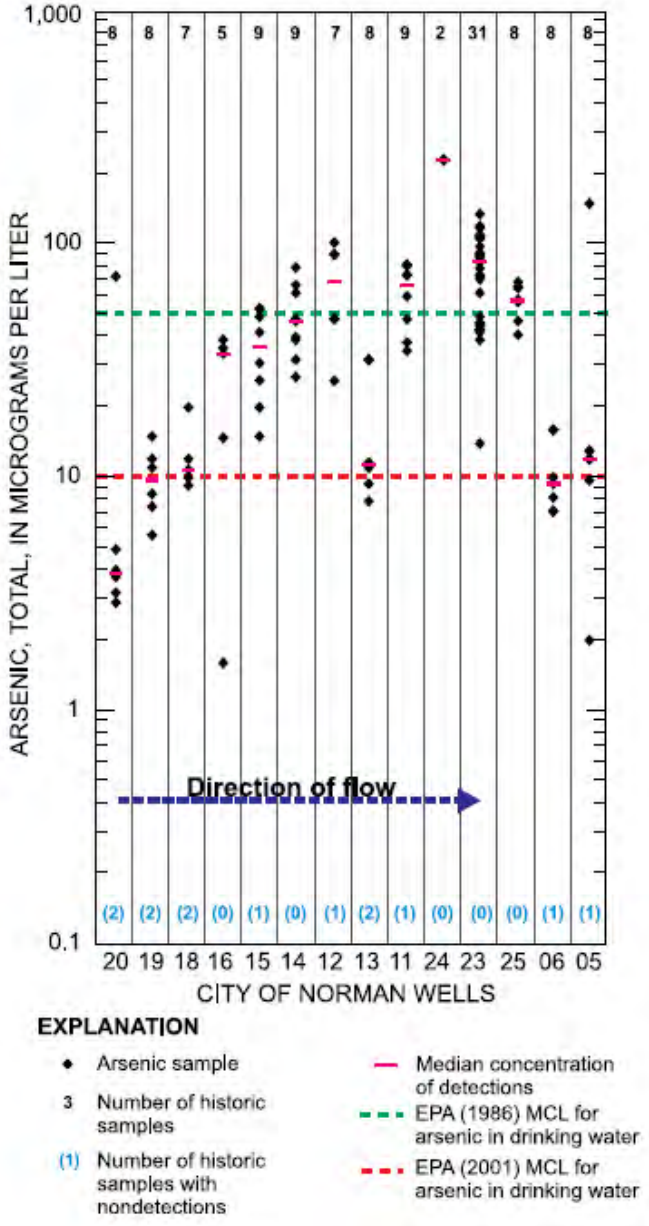


Figure 5. Selected pathlines of flow in the Central Oklahoma aquifer generated by the particle-tracking model by placing a particle at the center of selected cells in the unconfined part of the Central Oklahoma aquifer (from Parkhurst, Christenson, and Breit, 1993).

Schlottman, J.L., Mosier, E.L., and Breit, G.N., 1998, Arsenic, Chromium, Selenium, and Uranium in the Central Oklahoma Aquifer, *in* Christenson, Scott, and Havens, J.S., 1998, Ground-Water-Quality Assessment of the Central Oklahoma Aquifer, Oklahoma : Results of Investigations: U.S. Geological Survey Water-Supply Paper 2357A.

USGS
science for a changing world



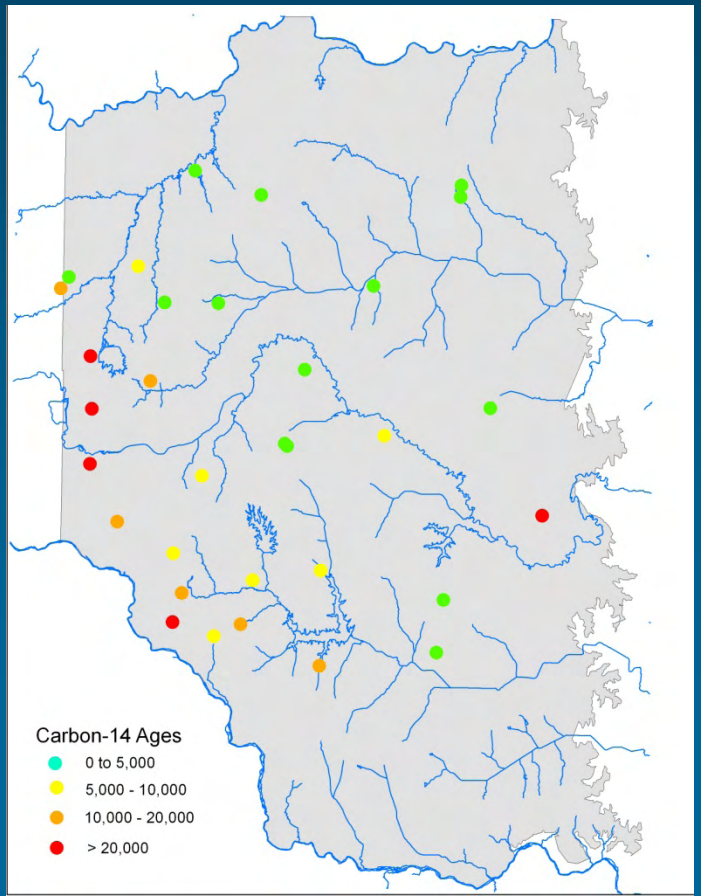


Smith, S.J., Paxton, S.T., Christenson, Scott, Puls, R.W., and Greer, J.R., 2009, Flow contribution and water quality with depth in a test hole and public-supply wells: Implication for arsenic remediation through well modification, Norman, Oklahoma, 2003-2006: U.S. Environmental Protection Agency 600/R-09/36, April 2009, 57 p.

USGS science for a changing world

Current Garber-Wellington issues related to water quantity

- Maximum annual yield has not been set for the Garber Wellington aquifer
- Desalination?



Summary

- Garber-Wellington issues have changed over time
- Quantity to quality to quantity
- Issues drive the scientific investigations
- Multi-disciplinary scientific investigations can solve problems
- Multi-disciplinary science can have substantial costs $750,000 in 1987 - 1990 ≈ $1,400,000 in 2009

Acknowledgements

- George Breit, Elwin “Mose” Mosier, David Parkhurst, L. Niel Plummer, Jamie Schlottmann
- S. Jerrod Smith
- Oklahoma Water Resources Board

Scott Christenson
U.S. Geological Survey
Email: schris@usgs.gov