

Distribution of Arsenic in the Mahomet Aquifer of Central Illinois, USA

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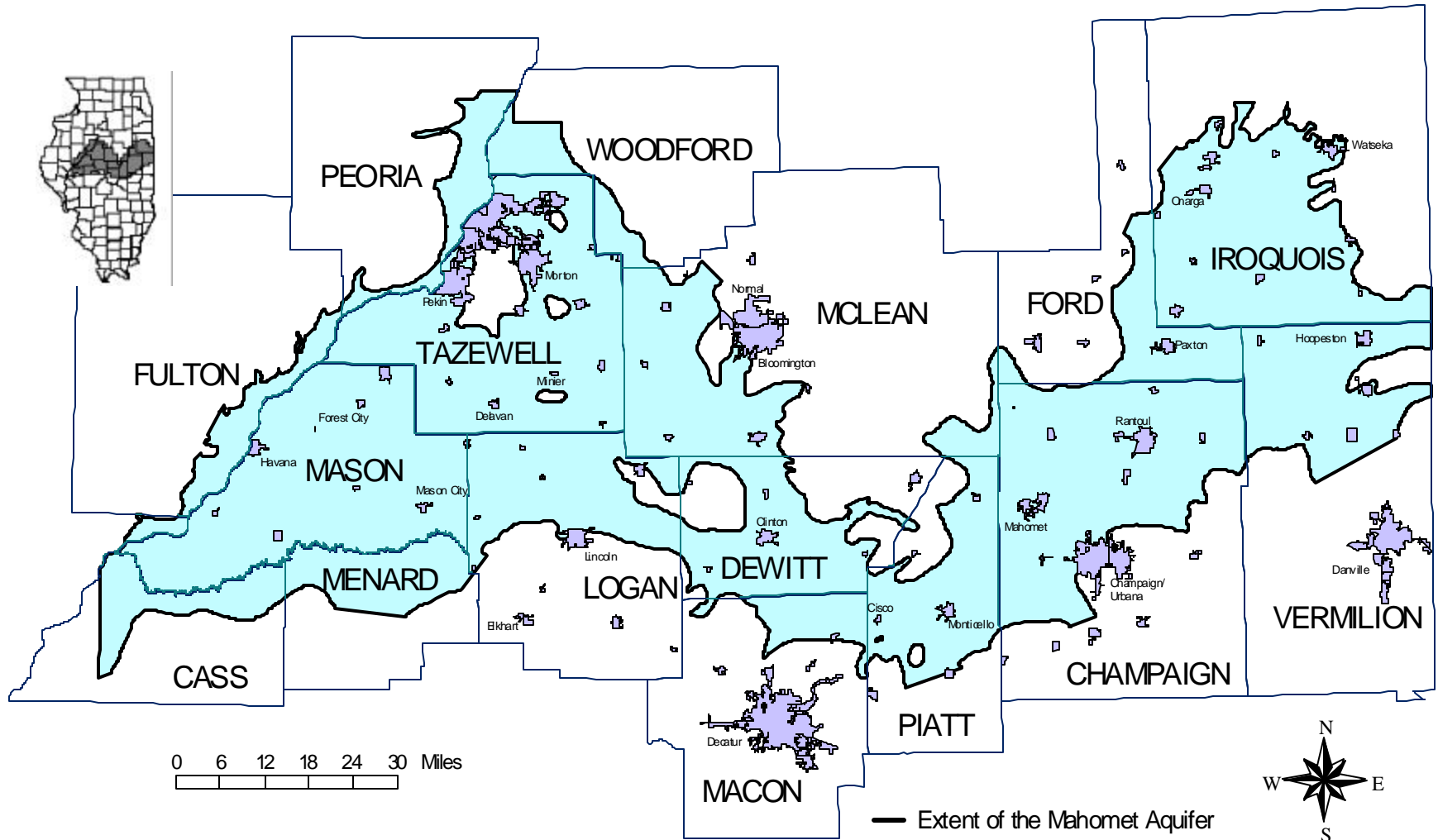
BACKGROUND

- Arsenic (As) is a highly toxic element, and As in drinking water is linked to cancer of the skin, bladder, lung, liver, and kidney and other ailments.
- The maximum contaminant level (MCL) for As in drinking water is 50 $\mu\text{g/L}$, but is in the process of being lowered to 10 $\mu\text{g/L}$, the same as the World Health Organization's standard.
- Arsenic is a minor constituent of some common minerals, and dissolved As concentrations greater than 1 $\mu\text{g/L}$ are common in ground water.
- In some aquifers and under certain conditions, much greater As concentrations can be found, and concentrations above 10 $\mu\text{g/L}$ are not uncommon.

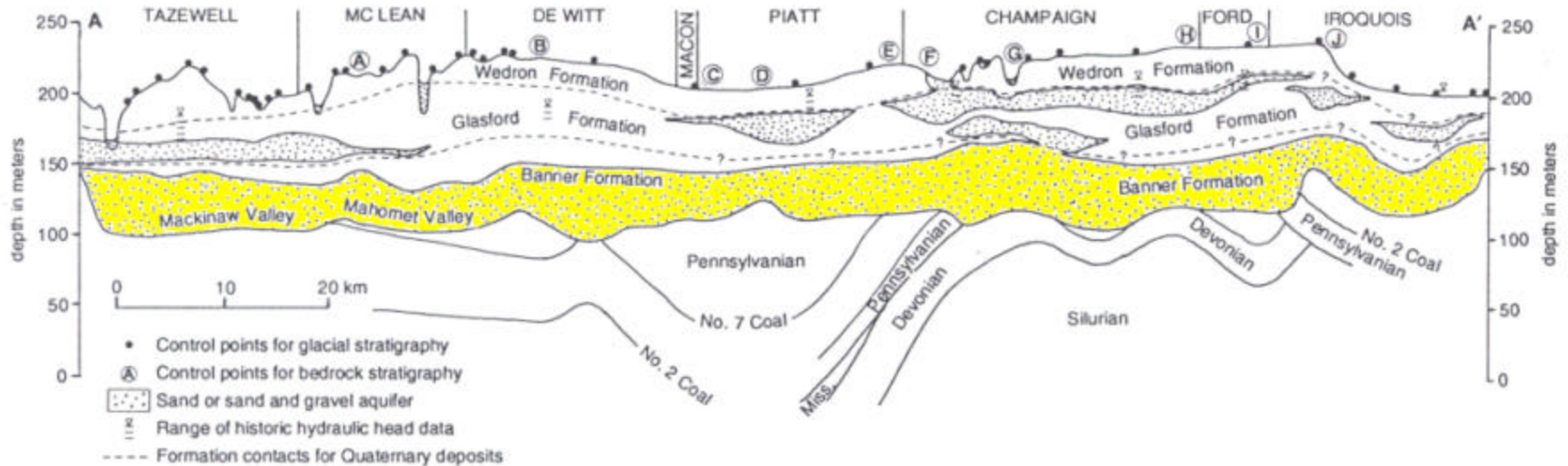
PURPOSE

Aqueous As concentration data have been collected in several unrelated studies in the Mahomet Aquifer in central Illinois. The purpose of this study was to assimilate data from these studies and databases to make a preliminary assessment of the extent of As contamination in the Mahomet Aquifer and determine how the new MCL would affect water supplies.

The Mahomet Aquifer is one of the largest and most important aquifers in Illinois, covering an area of 3700 square miles and providing approximately 670,000 people in central Illinois with drinking water. The producing sand and gravel unit is 200 feet thick in places and averages 100 ft, and the aquifer is estimated to have a yield of approximately 450 million gallons per day.



The Mahomet Aquifer. Longitudinal cross section showing the stratigraphy of the study area along the thalweg of the Mahomet Valley Aquifer (from Panno et al., 1994).



Sources of Arsenic Data in the Mahomet Aquifer

- Illinois Environmental Protection Agency (IEPA) Municipal Ambient Water Quality Database (1980 - present)
- Illinois State Water Survey (ISWS) Water Quality Database with both public and private wells (1900 - present)
- Tazewell County Health Department (late 1980's)
- Published and unpublished investigations

Study or Database	Location in Aquifer	# Wells	Well type
IEPA/ISWS Databases	Entire aquifer	460	Municipal
Tazewell Co. Health Dept.	SE Tazewell Co. (western)	494	Domestic
Holm and Curtiss (1988)	Entire aquifer	19*	Municipal
Holm and Curtiss (1988)	SE Tazewell Co. (western)	20	Domestic
Holm (1995)	Western	33	Monitoring
Warner (2001)	Eastern and central	30	Domestic
Kelly and Wilson (2000)	Central	21	Domestic

* Wells selected due to elevated As levels.

SUMMARY STATISTICS OF DATA

A broad range of concentrations was found in the studies. Highest concentrations tended to be in domestic wells in Tazewell County sampled by the Tazewell Co. Health Dept. and Holm and Curtiss (1988).

Study or Database	N	Minimum	Maximum	Median
IEPA/ISWS Databases	460	< 1	135	2
Tazewell Co. Health Dept.	494	< 1	259	26
Holm and Curtiss (public)	19	< 1	80	46
Holm and Curtiss (private)	20	9	226	42
Holm (1995)	33	< 3	99	9
Warner (2001)	30	< 1	84	17
Kelly and Wilson (2000)	21	1	46	13

N = number of samples

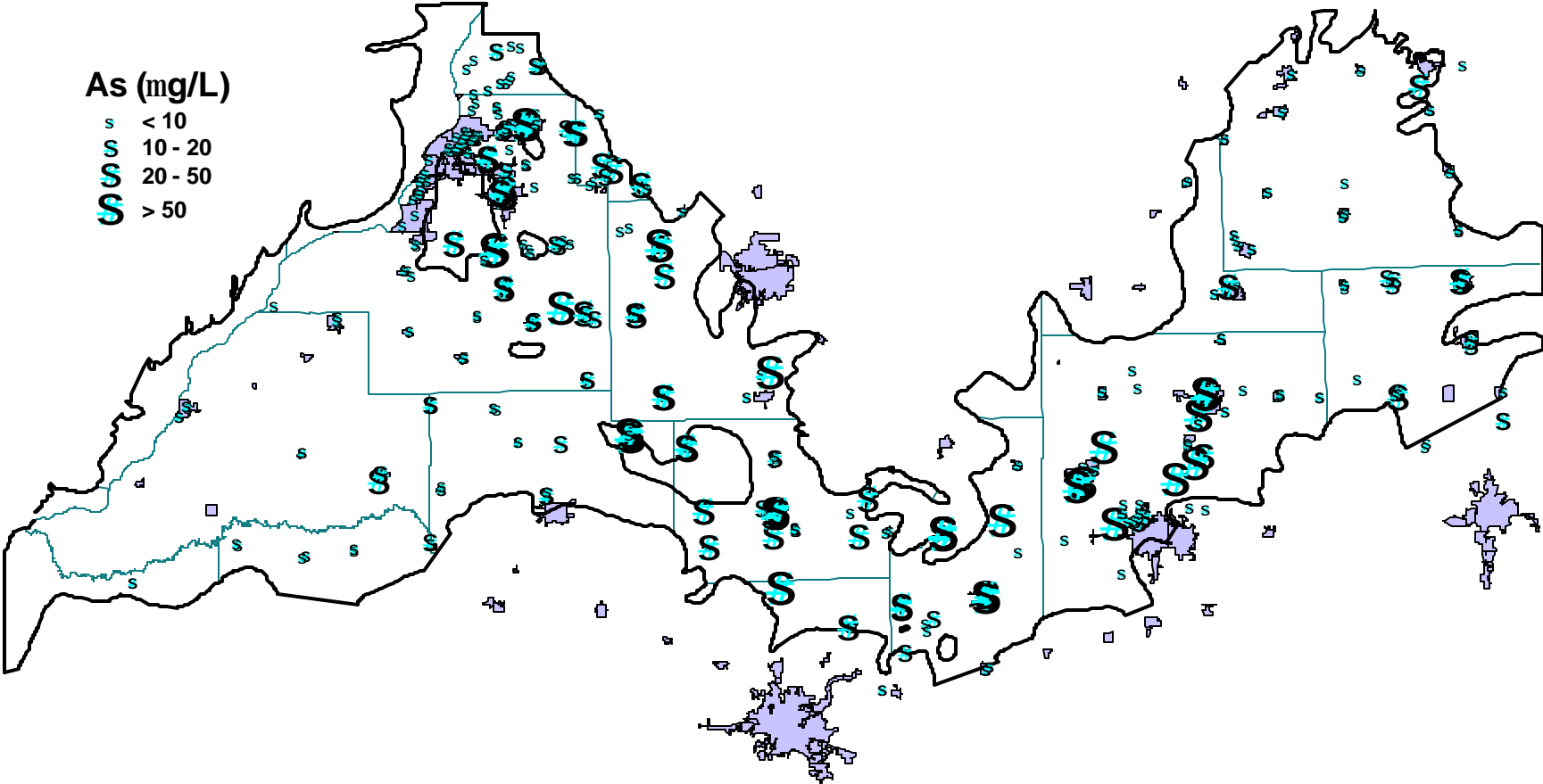
Values in $\mu\text{g/L}$

Summary Statistics of Data

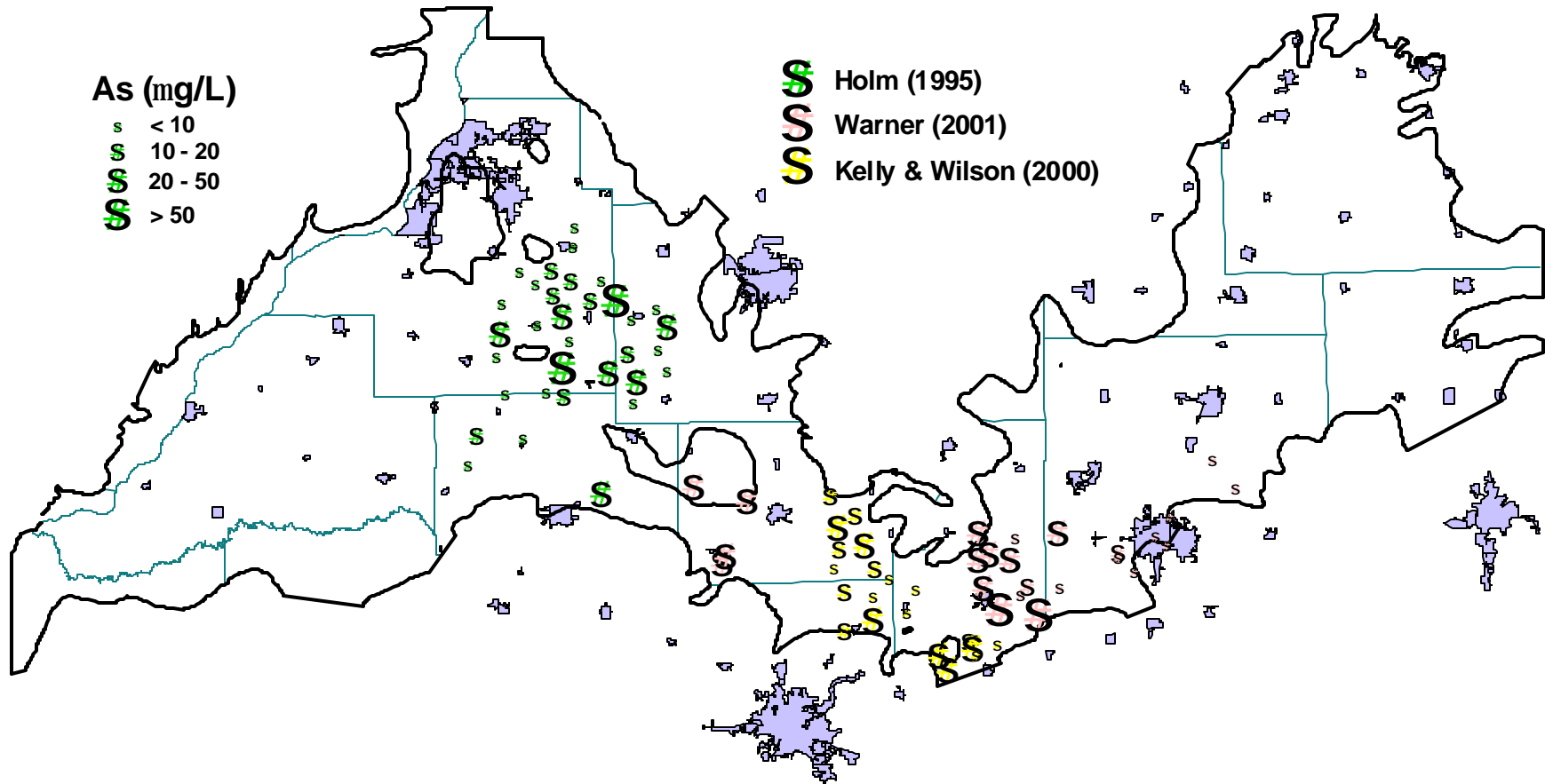
Percentage of samples with As concentrations in selected ranges ($\mu\text{g/L}$).

Study or Database	≤ 10	10-20	20-50	>50
IEPA/ISWS Databases	68.8	11.9	13.7	5.6
Tazewell Co. Health Dept.	39.3	6.9	18.6	35.2
Holm and Curtiss (public)	42.1	5.3	21.1	31.6
Holm and Curtiss (private)	10.0	5.0	45.0	40.0
Holm (1995)	54.6	21.2	18.2	6.1
Warner (2001)	56.7	3.3	33.3	6.7
Kelly and Wilson (2000)	38.1	38.1	23.8	0.0

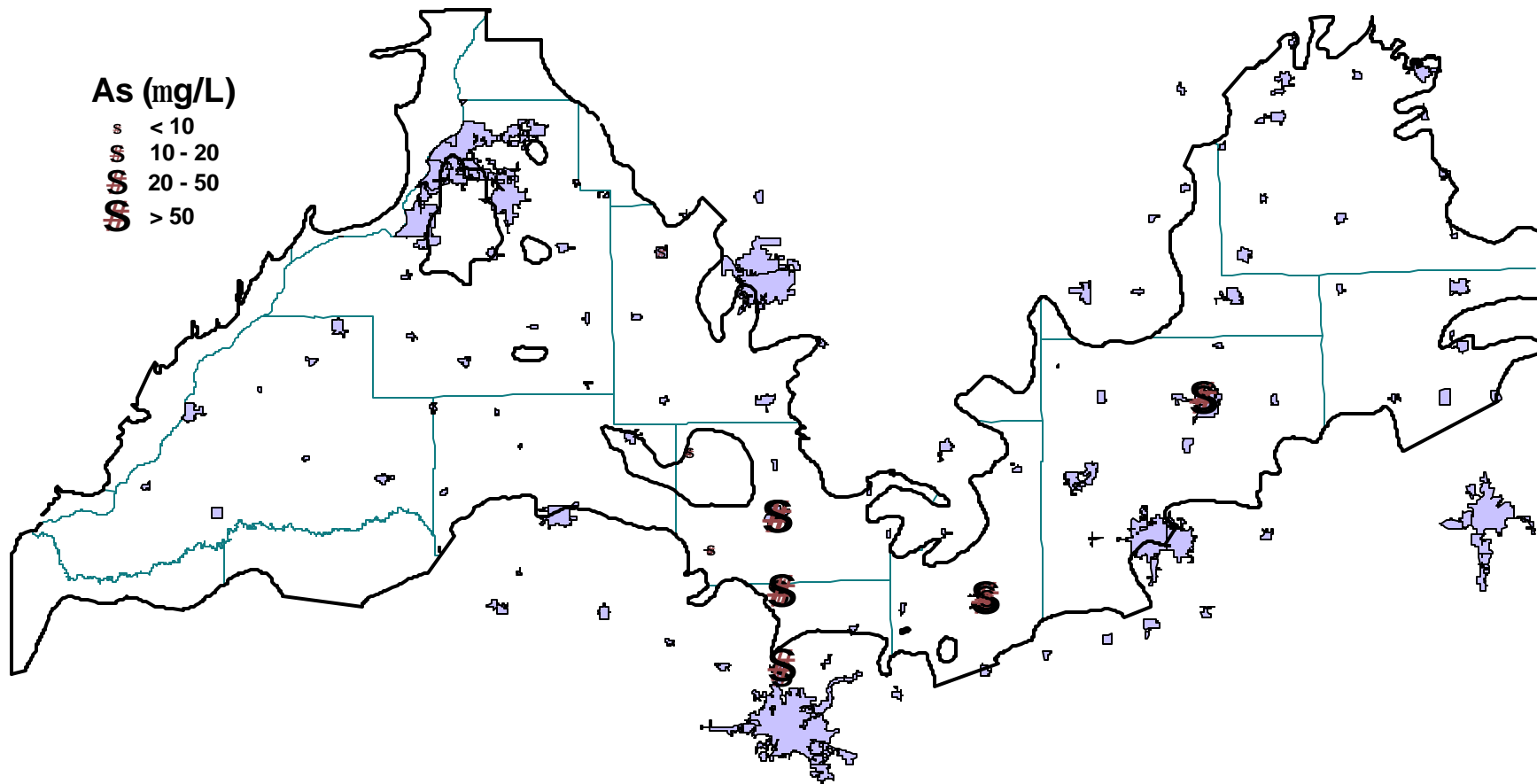
IEPA/ISWS Database: Municipal Wells



Domestic and Monitoring Wells










Holm and Curtiss (1988): Municipal Wells

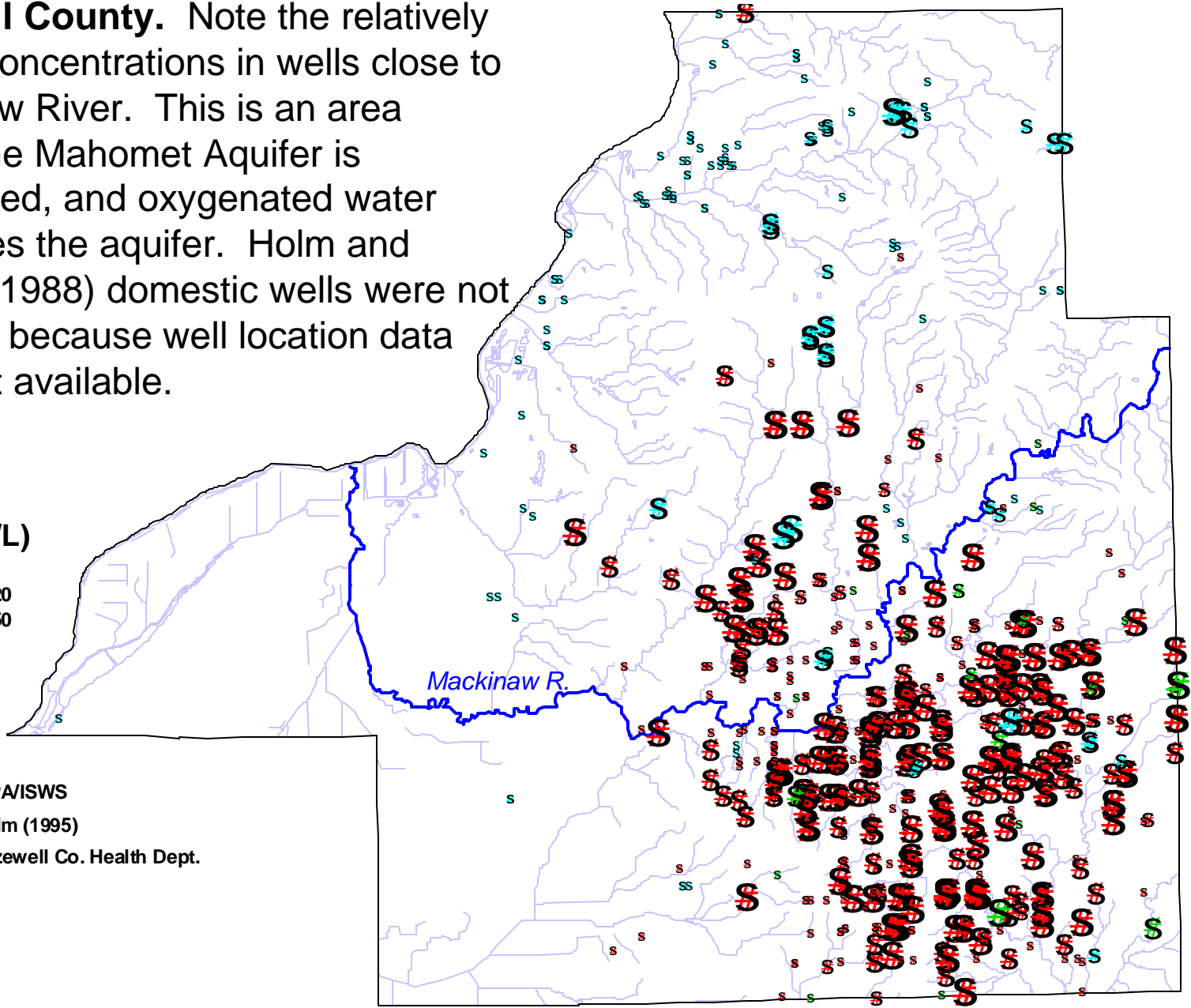


Tazewell County. Note the relatively low As concentrations in wells close to Mackinaw River. This is an area where the Mahomet Aquifer is unconfined, and oxygenated water recharges the aquifer. Holm and Curtiss (1988) domestic wells were not included because well location data were not available.

As (mg/L)

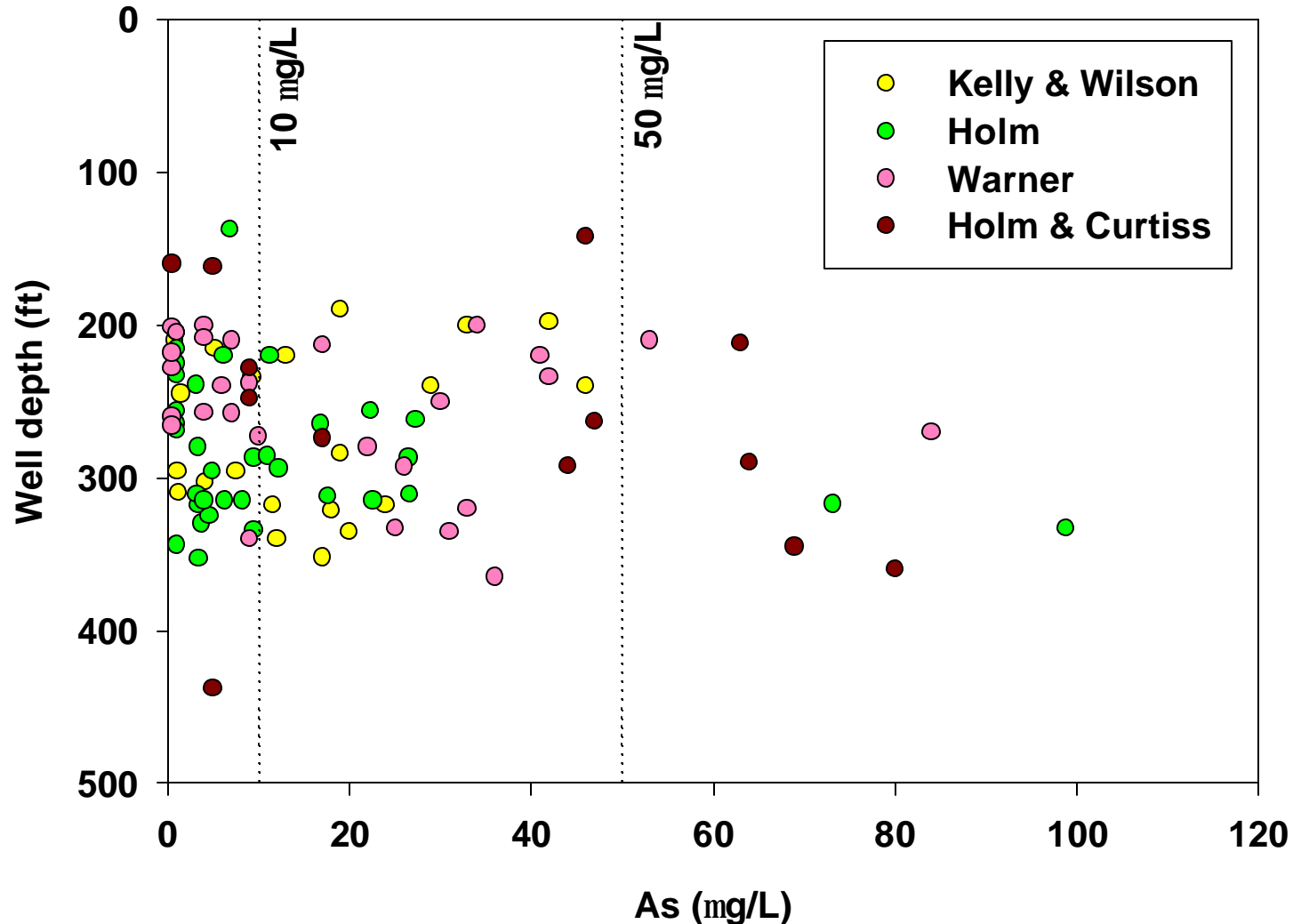
-  < 10
-  10 - 20
-  20 - 50
-  > 50

-  IEPA/ISWS
-  Holm (1995)
-  Tazewell Co. Health Dept.



ARSENIC CONCENTRATIONS AS A FUNCTION OF WELL DEPTH

- It is difficult to see any correlation between As and depth in the Mahomet Aquifer.
- Warner (2001) suggested there was a weak correlation between As and depth (As increases with depth), but this trend is not seen in the data from the other sources.

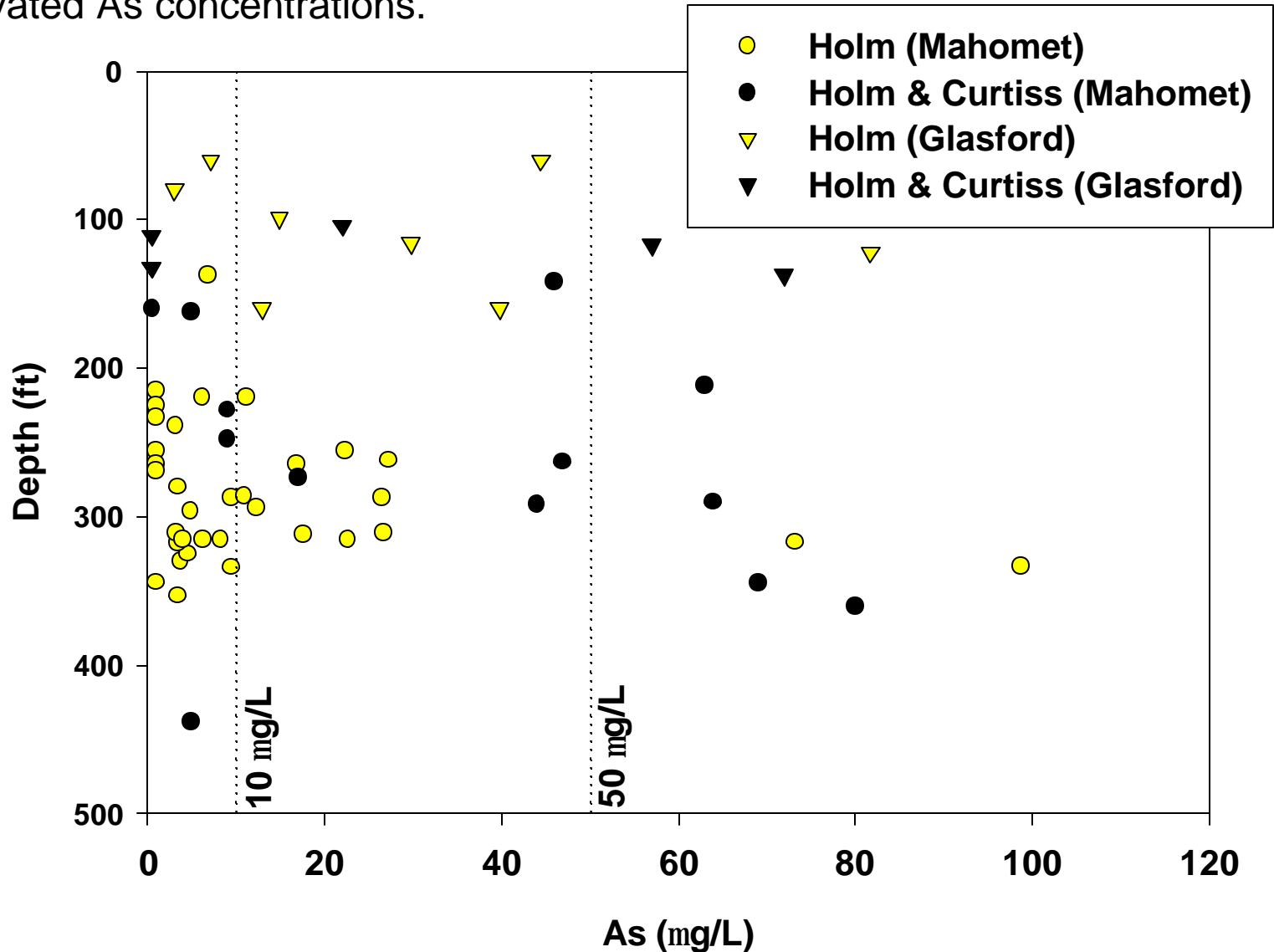


ARSENIC CONCENTRATIONS AS A FUNCTION OF WELL DEPTH

There is no well depth data for the Tazewell Co. Health Department study. However, the wells sampled were all domestic, and these wells tend to be shallow compared to municipal wells, and many, and perhaps most, of these wells probably are screened in the top of the Mahomet Aquifer or in overlying sand units. The elevated concentrations of As found in the Tazewell Co. Health Department study suggest that shallow wells may be more vulnerable to As contamination.

ARSENIC CONCENTRATIONS AS A FUNCTION OF WELL DEPTH

Holm and Curtiss (1988) and Holm (1995) sampled wells screened in the Mahomet and overlying Glasford Aquifers. A greater percentage of Glasford wells had elevated As concentrations.

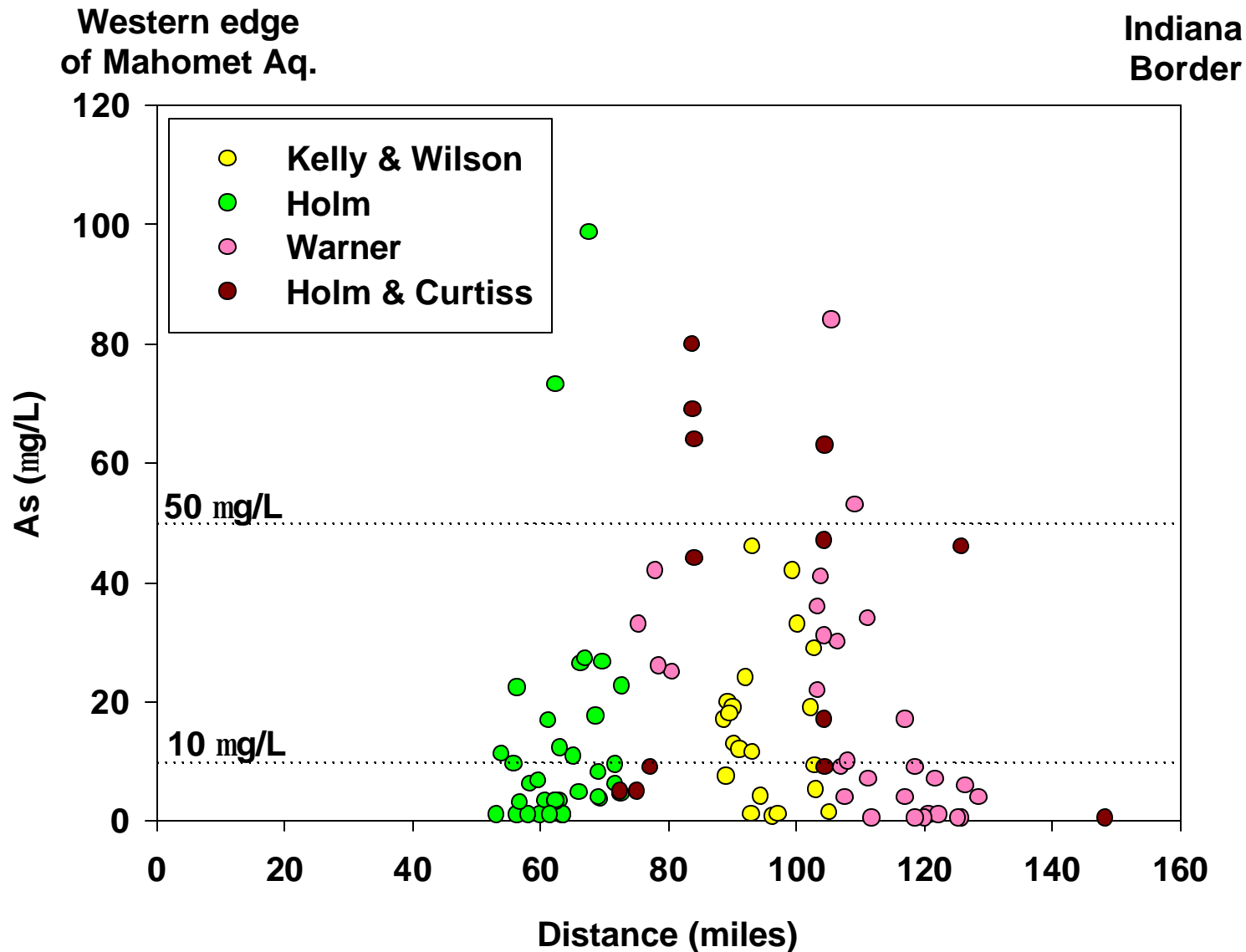


ARSENIC CONCENTRATIONS AS A FUNCTION OF LOCATION

- Warner (2001) observed an increase in As concentrations from east to west (direction of regional groundwater flow).
- There is no obvious correlation between As and geographic location in the Mahomet Aquifer for other data sources.
- A large number of wells in Tazewell County (western part of the aquifer) have elevated As concentrations, but this may be a function of the frequency of sampling in that area.
- Investigations in which samples were collected over relatively large spatial areas do not show obvious patterns in As concentrations.

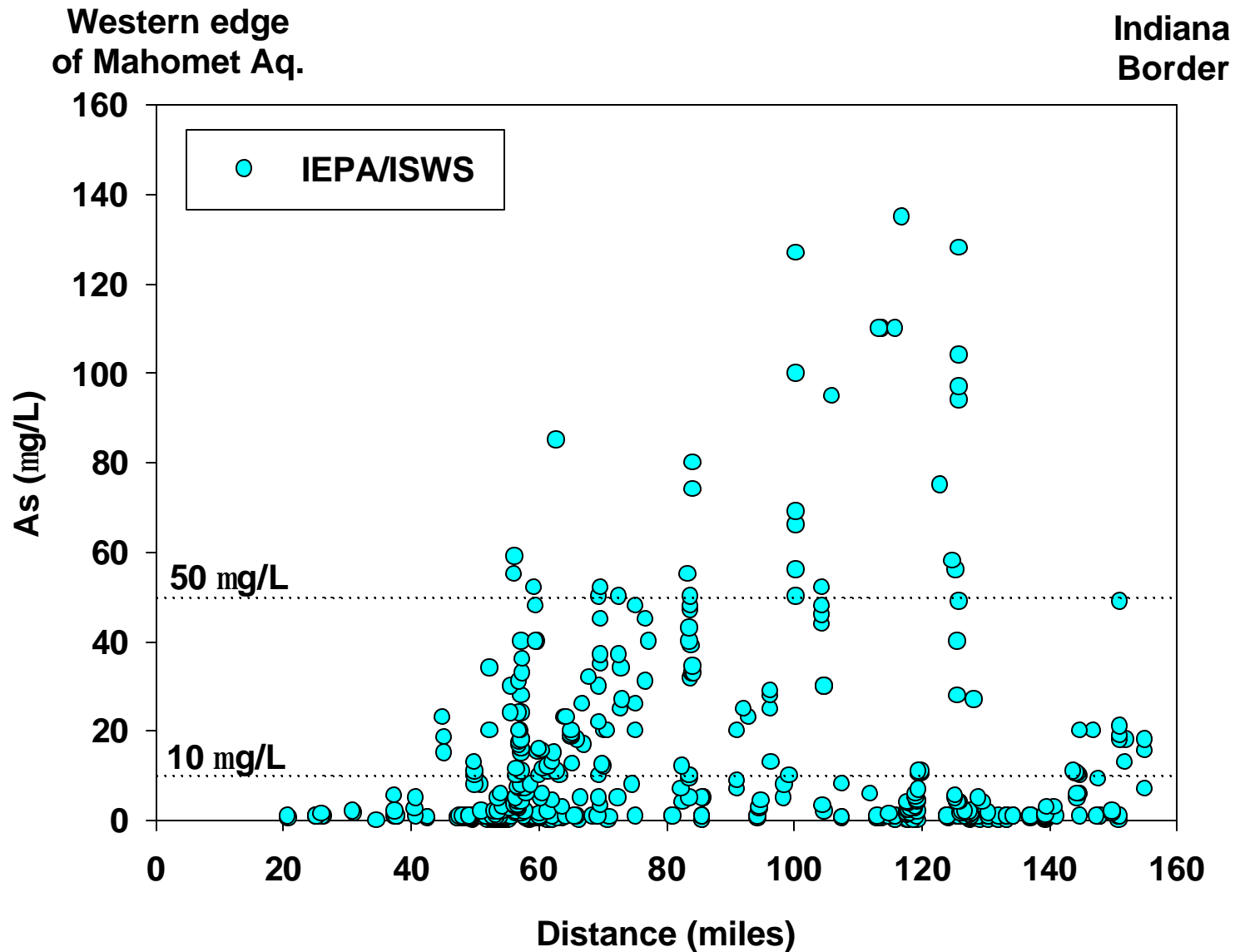
ARSENIC CONCENTRATIONS AS A FUNCTION OF LOCATION

The x axis represents the east-west location (lambert x) of each well.



ARSENIC CONCENTRATIONS AS A FUNCTION OF LOCATION

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ADDITIONAL CONSIDERATIONS

Arsenic Speciation

- In 43 municipal well samples, Holm and Curtiss (1988) found that the number of samples containing mostly As(III), mostly As(V), and approximately equal concentrations of As(III) and As(V), were roughly the same.
- In 20 domestic well samples, Holm and Curtiss (1988) found that As(V) was the dominant form of As.
- In 10 domestic well samples, Warner (2001) found that As(V) was the dominant form of As.

Solid-Phase Geochemistry

- Solid-phase data on As in the Mahomet Aquifer is rare.
- Warner (2001) characterized 6 complete cores (overlying till, sand and gravel, underlying bedrock). Median concentrations in the till and sand and gravel were 7.9 and 4 $\mu\text{g/g}$, respectively. Pennsylvanian shale and limestone had median concentrations of 21 and $<10 \mu\text{g/g}$, respectively.

Correlations Between As and Other Parameters

- Warner (2001) reported that As concentrations were significantly correlated with Cl⁻ and Ba, but not with Fe. As had a negative correlation with SO₄²⁻.
- Holm (1995) did not observe a correlation between As and Cl⁻ or Ba in either the Mahomet or the Glasford or between As and Fe in the Mahomet. They did observe a correlation between As and Fe in the Glasford and a negative correlation between As and SO₄²⁻ in both aquifers.

ONGOING WORK

- The Illinois State Water Survey recently began a project to sample 100 wells screened in the Mahomet Aquifer in Tazewell and Champaign Counties to investigate As concentrations as a function of well depth and to compare municipal and domestic wells. This study will also investigate As removal processes at treatment plants.
- Sampling of wells in the central part of the aquifer is also being done.

SUMMARY

- Arsenic is found in concentrations $>10 \mu\text{g/L}$ throughout most of the Mahomet Aquifer. The decrease in the MCL will affect a large number of municipalities in central Illinois.
- There is considerable spatial variability in As concentrations.
- There does not appear, in general, to be a correlation between As and well depth. However, shallow wells in the western part of the aquifer appear to have relatively elevated concentrations of As. Many of these wells may be screened in shallow sands above the Mahomet. It appears that domestic wells, which are not regulated for drinking water, may be especially vulnerable to As contamination.
- As(V) appears to be the predominant form of As in domestic wells, but significant amounts of As(III) are commonly found in municipal wells.

REFERENCES

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