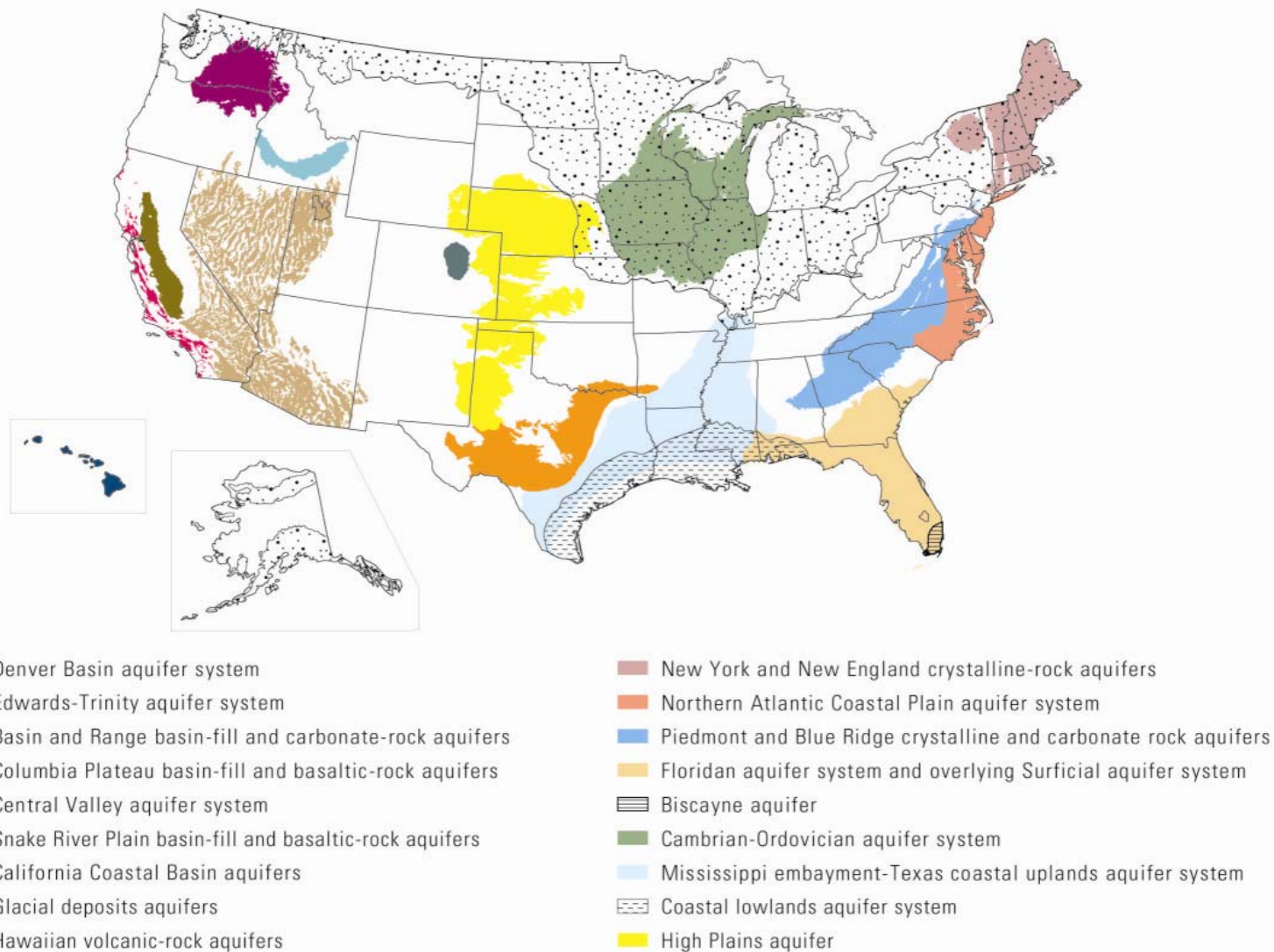




Ground-Water Quality of the Cambrian-Ordovician Aquifer System in the Northern Midwest

National Water-Quality Assessment Program:
Principal Aquifer Synthesis

Principal Aquifers



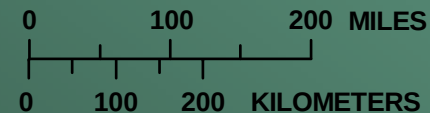
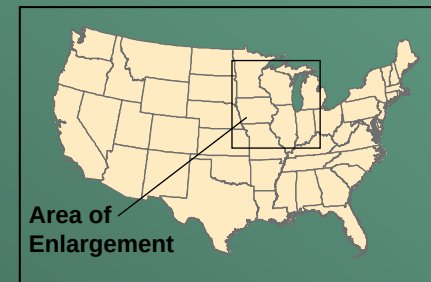
Source: USGS, 2003, Principal Aquifers of the United States.

Extent of Cambrian-Ordovician Aquifer



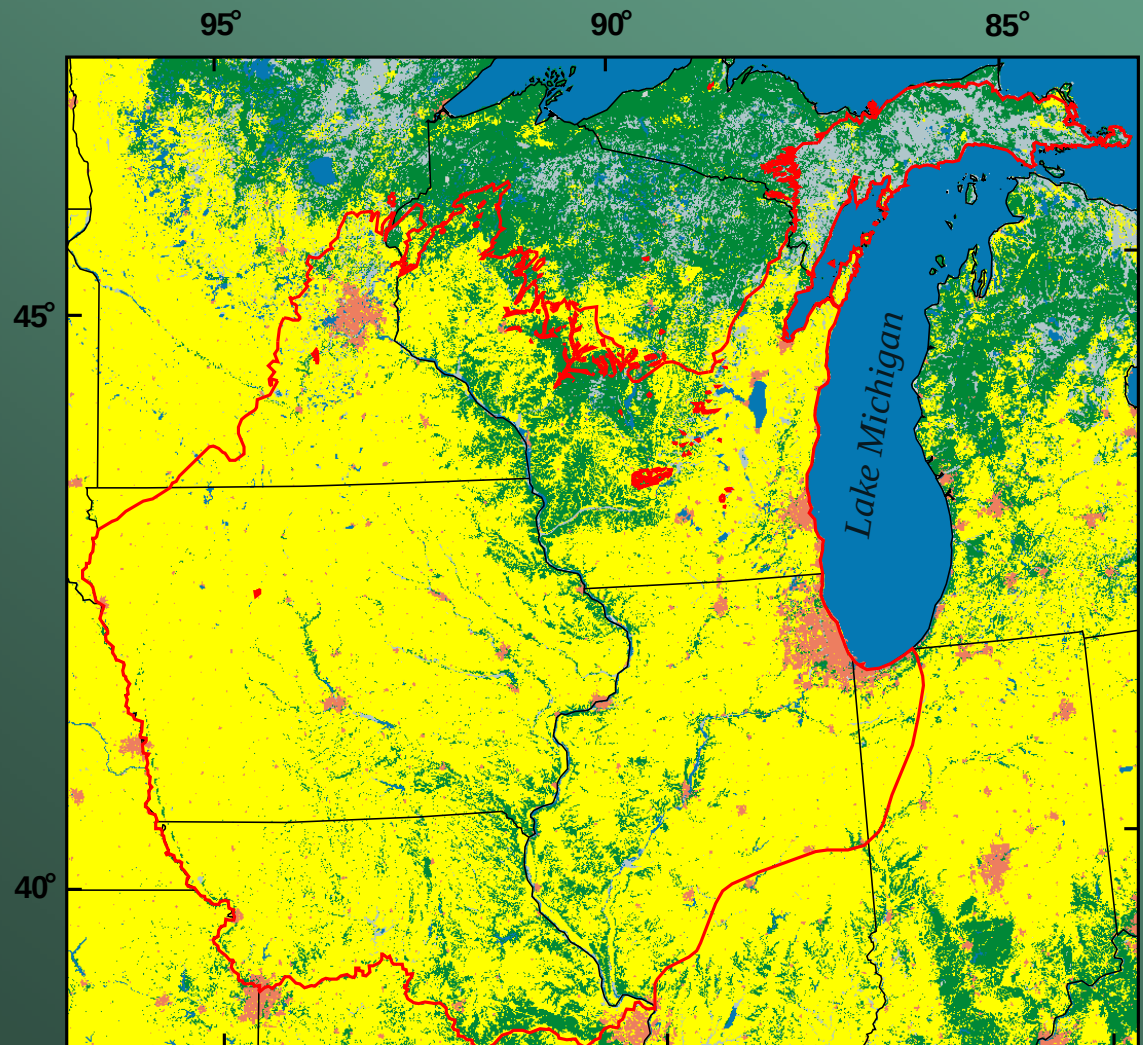
EXPLANATION

-  CAMBRIAN-ORDOVICIAN AQUIFER
-  PRECAMBRIAN SANDSTONES





LAND USE (1993 data)

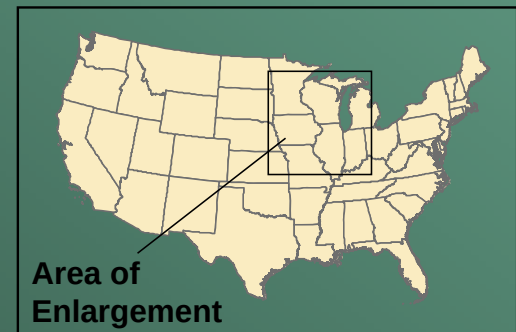


EXPLANATION

- Open water
- Residential & urban
- Barren, mined
- Forest
- Agricultural
- Wetland
- Cambrian-Ordovician Aquifer System boundary



0 100 MILES
0 100 KILOMETERS

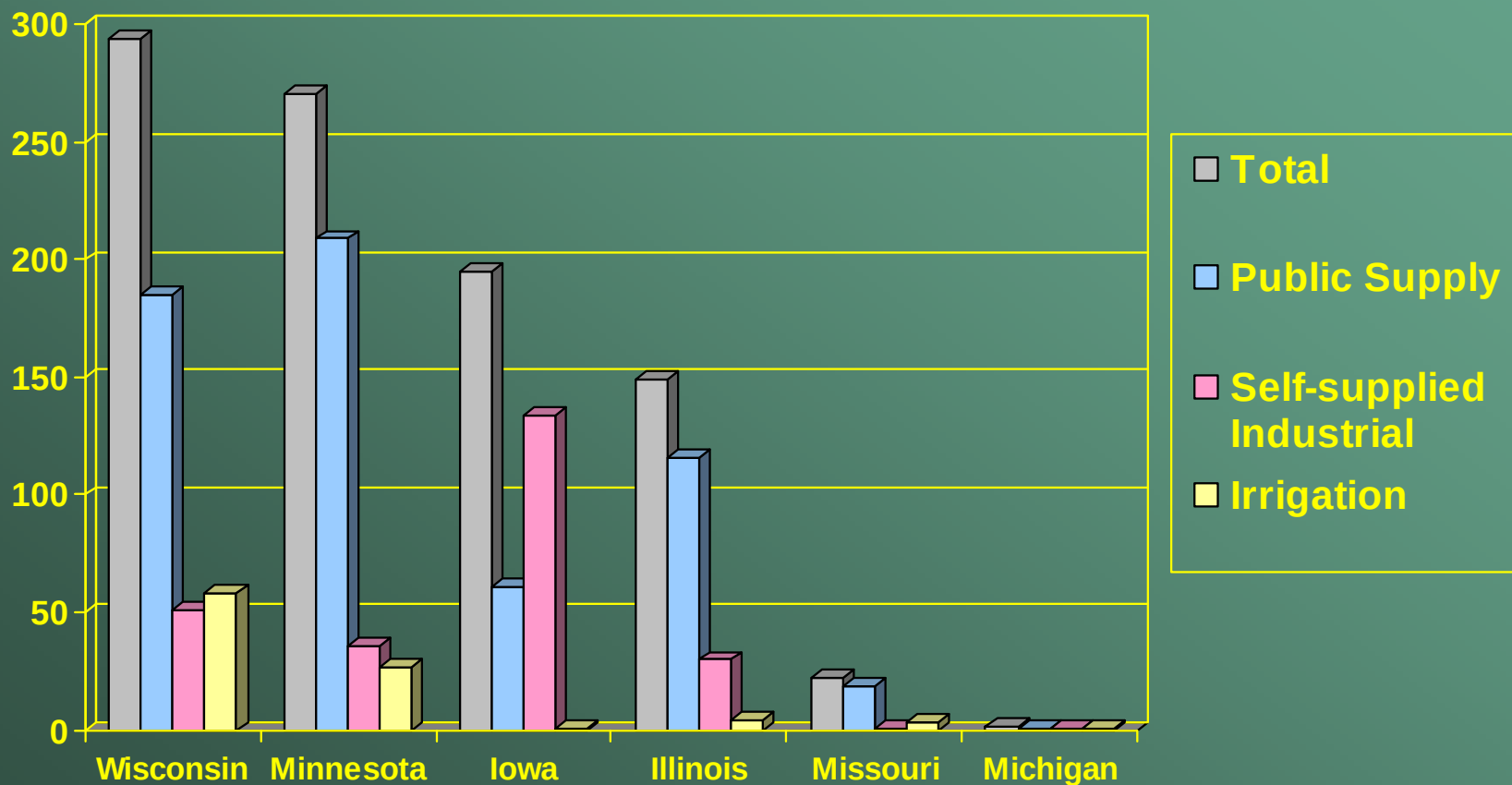




Cambrian-Ordovician Aquifer System

Water Use by Category

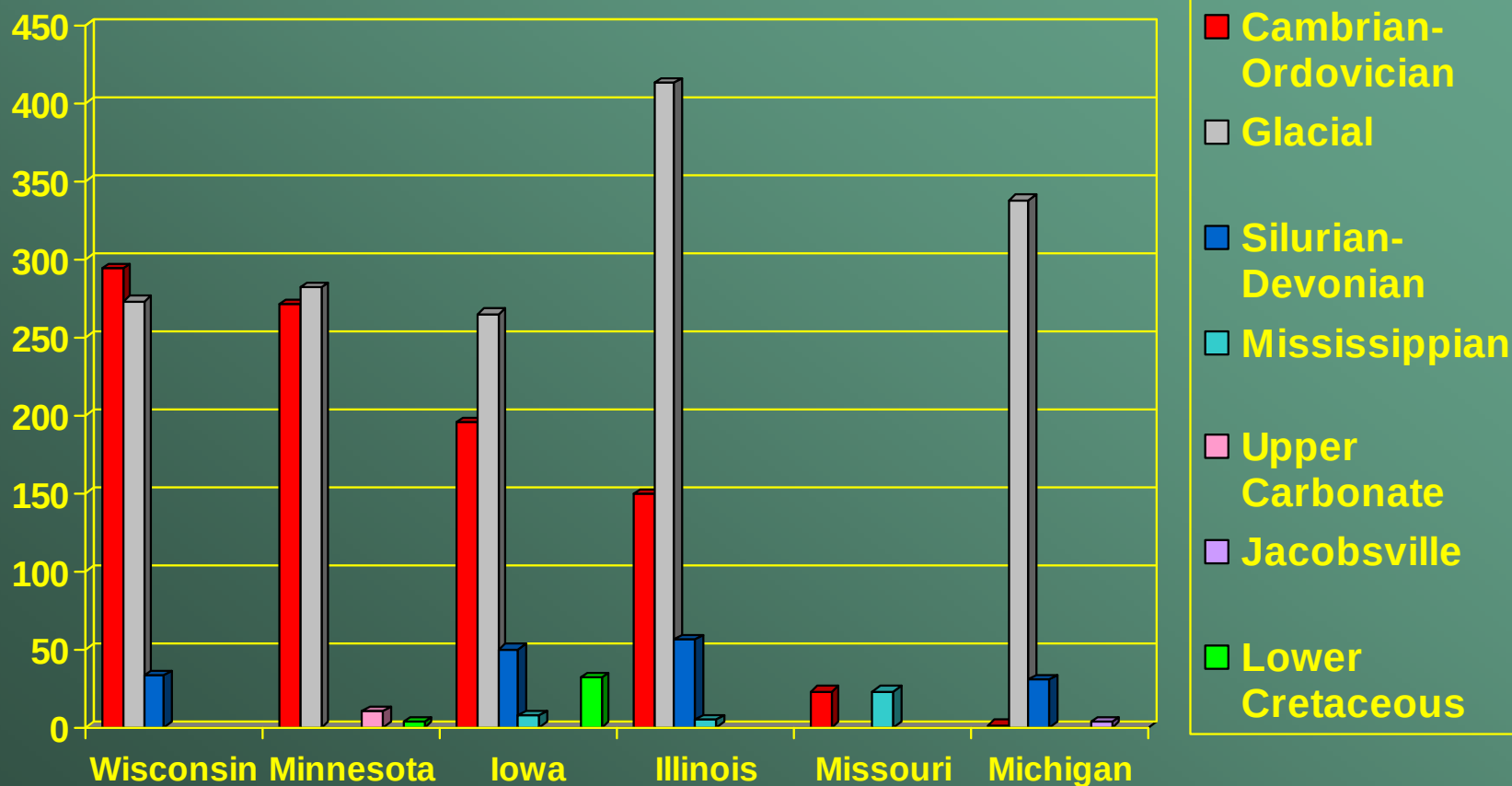
in million gallons per day (933 total)



Source: Maupin and Barber, 2005: USGS Circular 1279, Estimated Withdrawals from Principal Aquifers in the United States, 2000

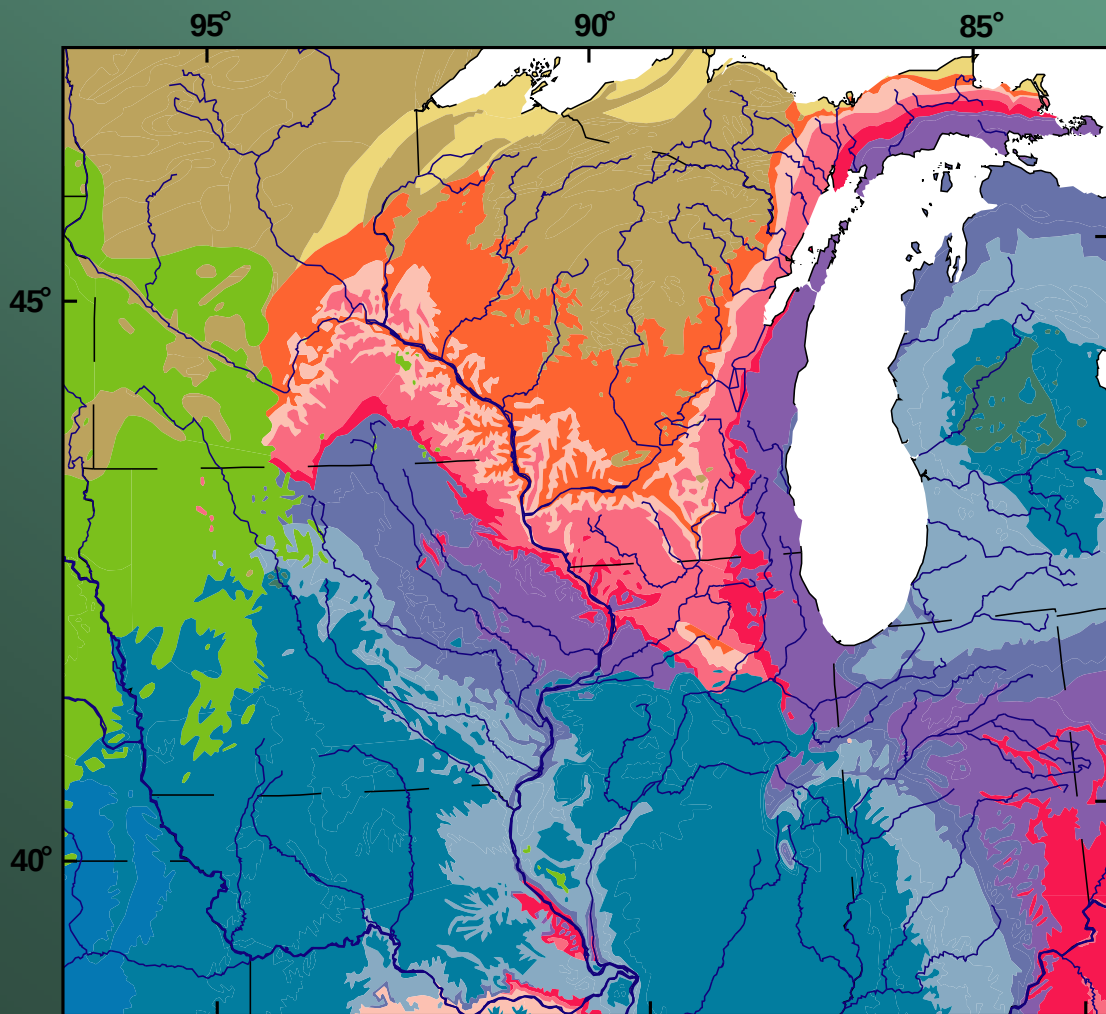


Water Use from Selected Principal Aquifers of the Northern Midwest



Source: Maupin and Barber, 2005: USGS Circular 1279, Estimated Withdrawals from Principal Aquifers in the United States, 2000

BEDROCK GEOLOGY



EXPLANATION

	Cretaceous		Upper Ordovician
	Jurassic		Middle Ordovician
	Permian		Lower Ordovician
	Pennsylvanian		Cambrian
	Mississippian		Precambrian Sandstones
	Devonian		Precambrian undivided
	Silurian		

Geology from Digital Data Series 11,
Release 2, King and Beikman, 1974

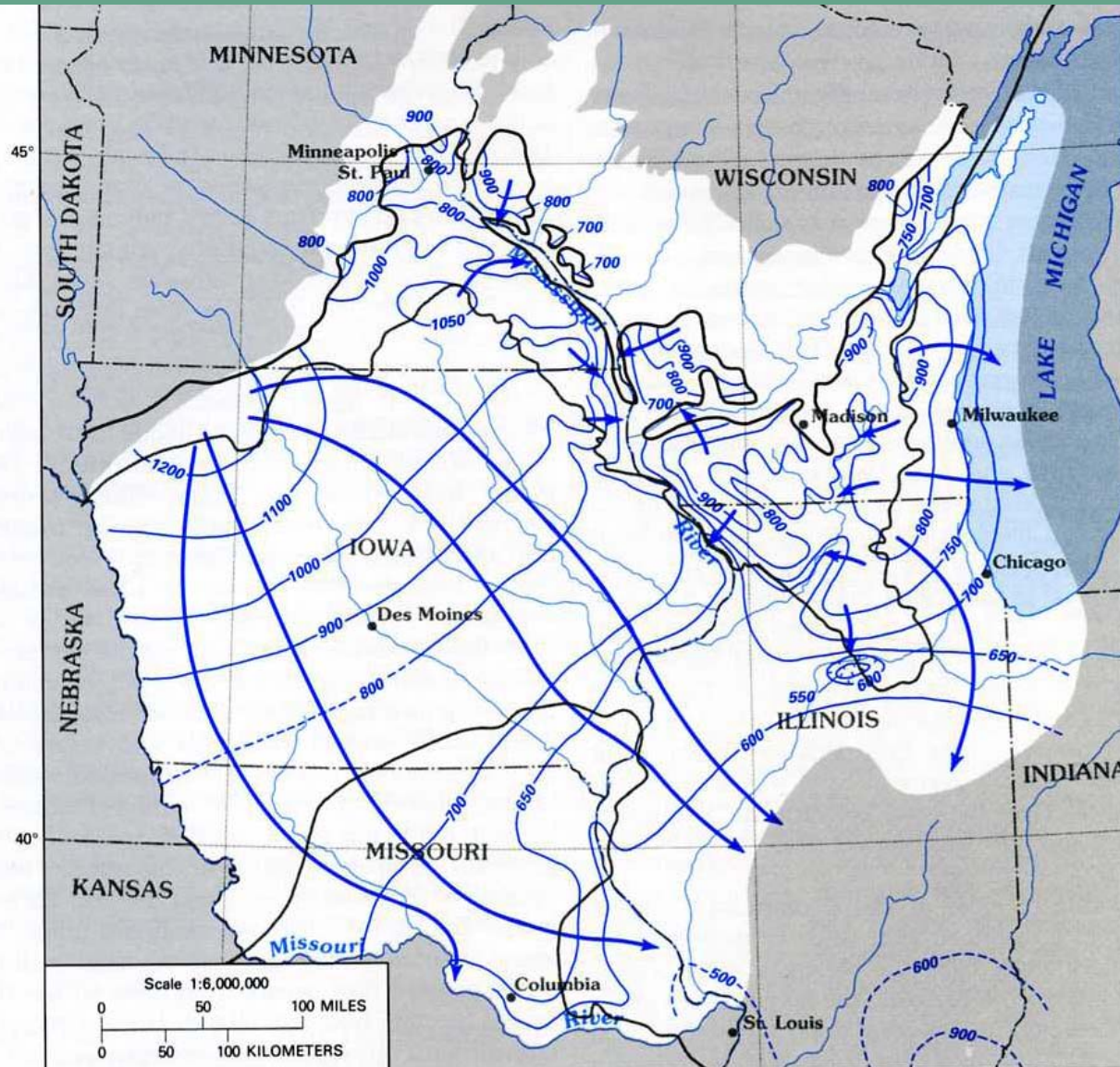


0 100 MILES
0 100 KILOMETERS

Stratigraphy

			HYDROGEOLOGIC UNIT	HYDROGEOLOGIC UNIT
SYSTEM	GROUP	FORMATION OR GROUP	MINNESOTA	WISCONSIN
UPPER ORDOVICIAN	Maquoketa	Maquoketa Shale	Maquoketa Shale confining unit	Maquoketa Shale confining unit
MIDDLE ORDOVICIAN	Sinnipee	Galena Dolomite		
		Decorah Shale	Decorah-Platteville-Glenwood confining unit	Galena-Platteville aquifer
		Platteville Fm		
	Ansell	Glenwood Shale		Glenwood confining unit
		St. Peter Sandstone	St. Peter aquifer	St. Peter aquifer
LOWER ORDOVICIAN	Prairie du Chien	Prairie du Chien Group		Prairie du Chien aquifer
CAMBRIAN	Trempealeau	Jordan Sandstone	Prairie du Chien-Jordan aquifer	
		St. Lawrence Fm	St. Lawrence confining unit	St. Lawrence confining unit
	Tunnel City	Franconia Fm	Franconia-Ironton-Galesville aquifer	Tunnel City-Wonewoc-Eau Claire aquifer
	Elk Mound	Ironton Sandstone		
		Galesville Sandstone		
		Eau Claire Fm	Eau Claire confining unit	
		Mt. Simon Sandstone		
PRECAMBRIAN		Hinckley Sandstone	Mt. Simon-Hinckley-Fond du Lac aquifer	Mt. Simon-Hinckley-Fond du Lac aquifer
		Fond du Lac Sandstone		
		Solor Church Fm	Undifferentiated sandstone	Undifferentiated sandstone
		Igneous/metamorphic rocks	Igneous/metamorphic rocks	Igneous/metamorphic rocks

Predevelopment Generalized Flow Directions



Base enlarged from
U.S. Geological Survey
1:7,500,000, 1970

From Mandle and Kontis, 1992, USGS PP 1405-C

NAWQA Wells

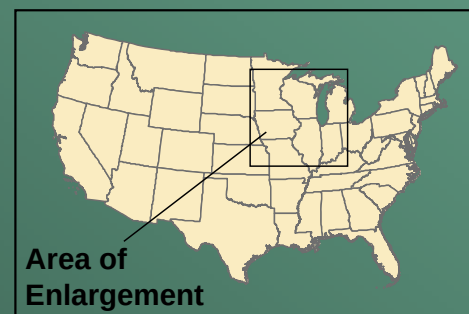


EXPLANATION

 Cambrian-Ordovician Aquifers

 Precambrian sandstones

● NAWQA well
N = 156
Sampled 1994-2007



Other Data Sources

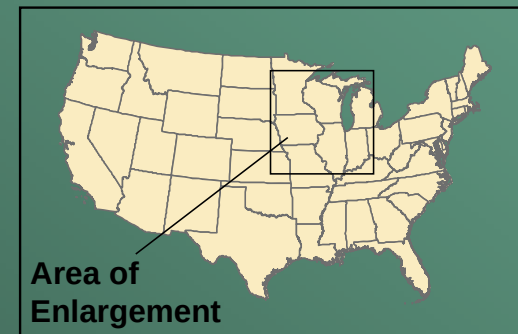
- USGS Regional Aquifer-System Analysis (RASA Study) (D.I. Siegel, 1989)
- USGS National Water Information System Data Base
- Illinois EPA
- Michigan DEQ
- Minnesota DOH
- Minnesota PCA
- Missouri DNR
- Wisconsin DNR

Buried and Exposed Bedrock Areas



EXPLANATION

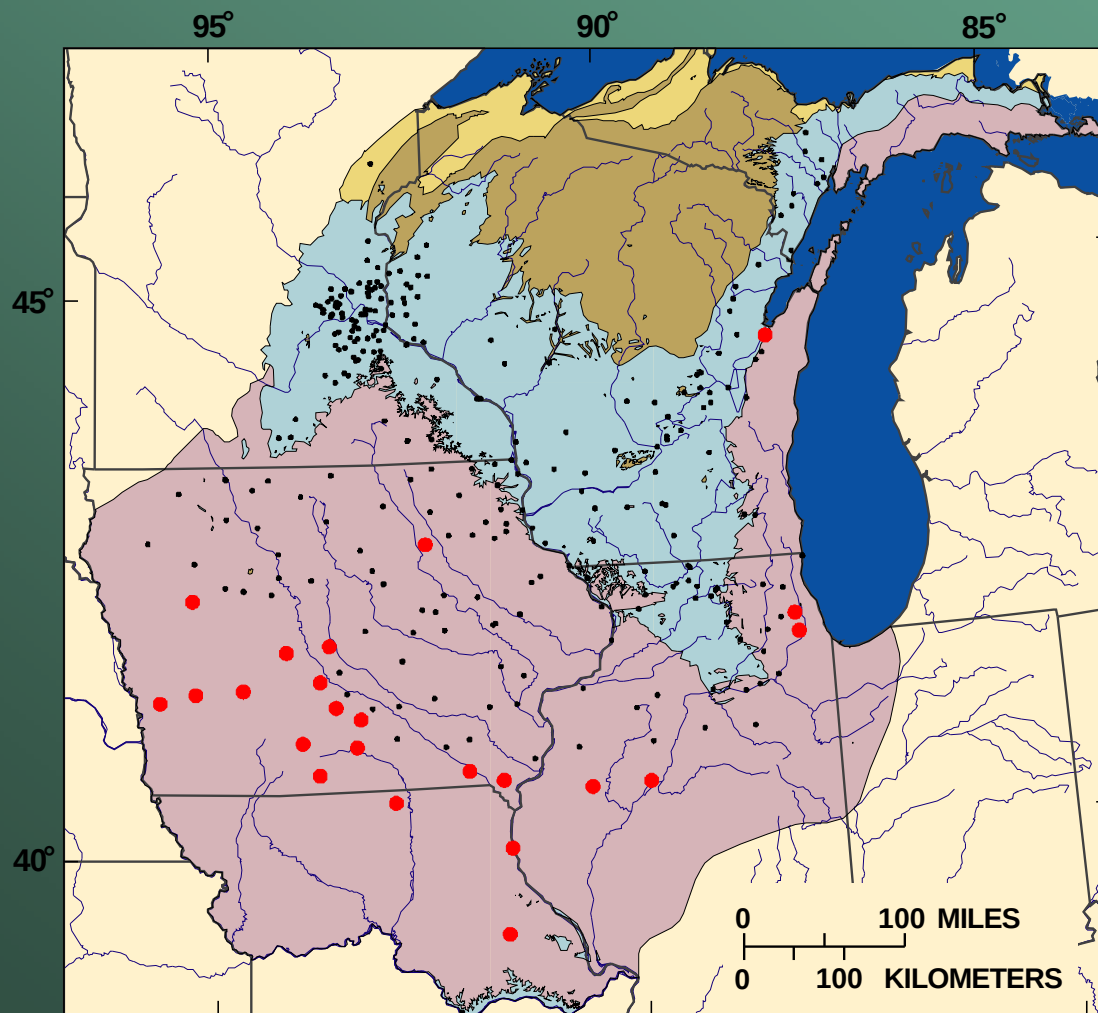
-  Cambrian-Ordovician Aquifers exposed at bedrock surface
-  Cambrian-Ordovician Aquifers covered by Maquoketa Shale or younger rocks
-  Precambrian sandstones
-  Precambrian undivided



Maps Showing Distribution of:

- Fluoride
- Selected Trace Elements
- Radon and Radium

Fluoride Concentrations



EXPLANATION

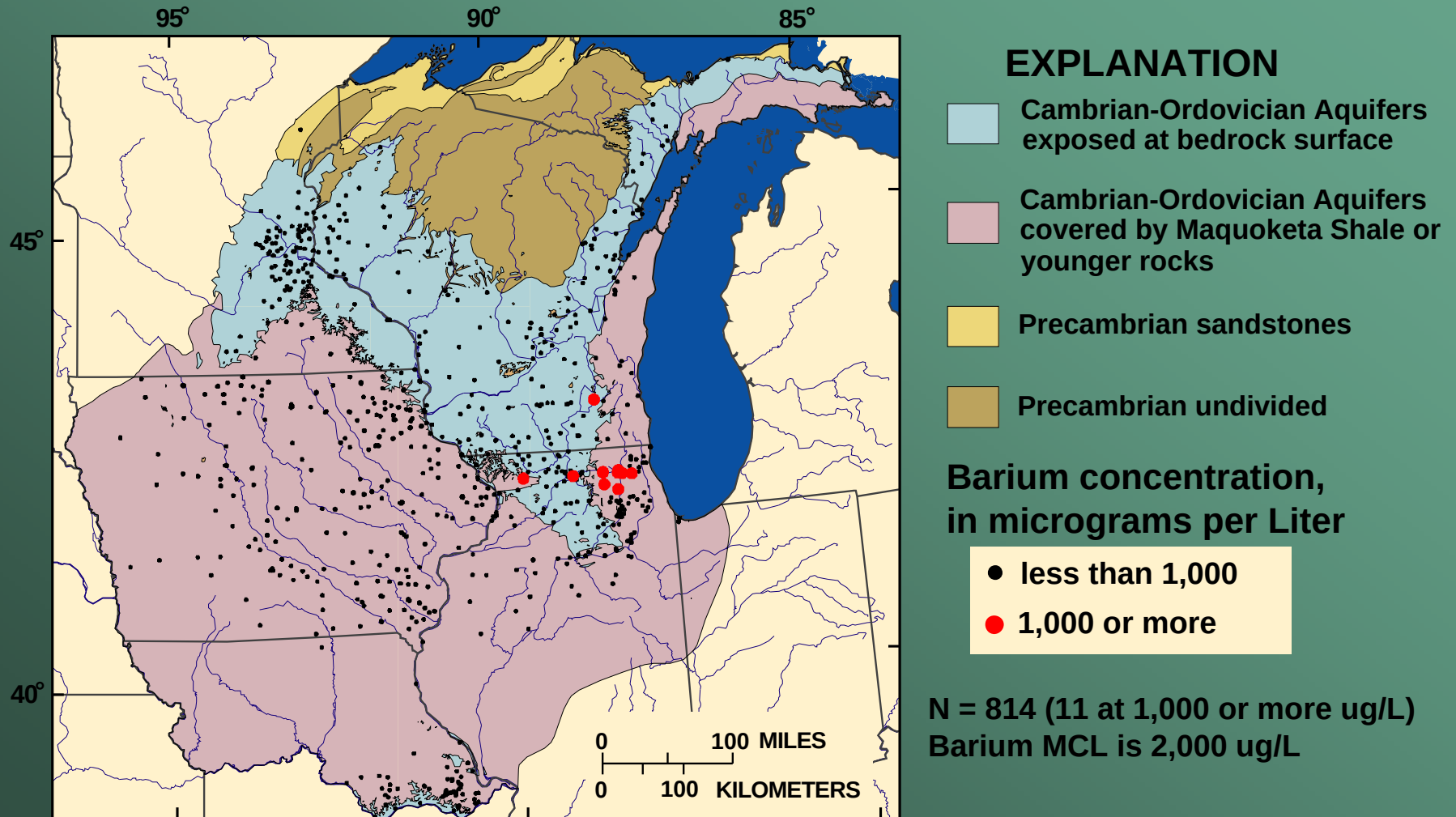
-  Cambrian-Ordovician Aquifers exposed at bedrock surface
-  Cambrian-Ordovician Aquifers covered by Maquoketa Shale or younger rocks
-  Precambrian sandstones
-  Precambrian undivided

Fluoride concentration,
in milligrams per Liter

-  less than 2
-  2 or more

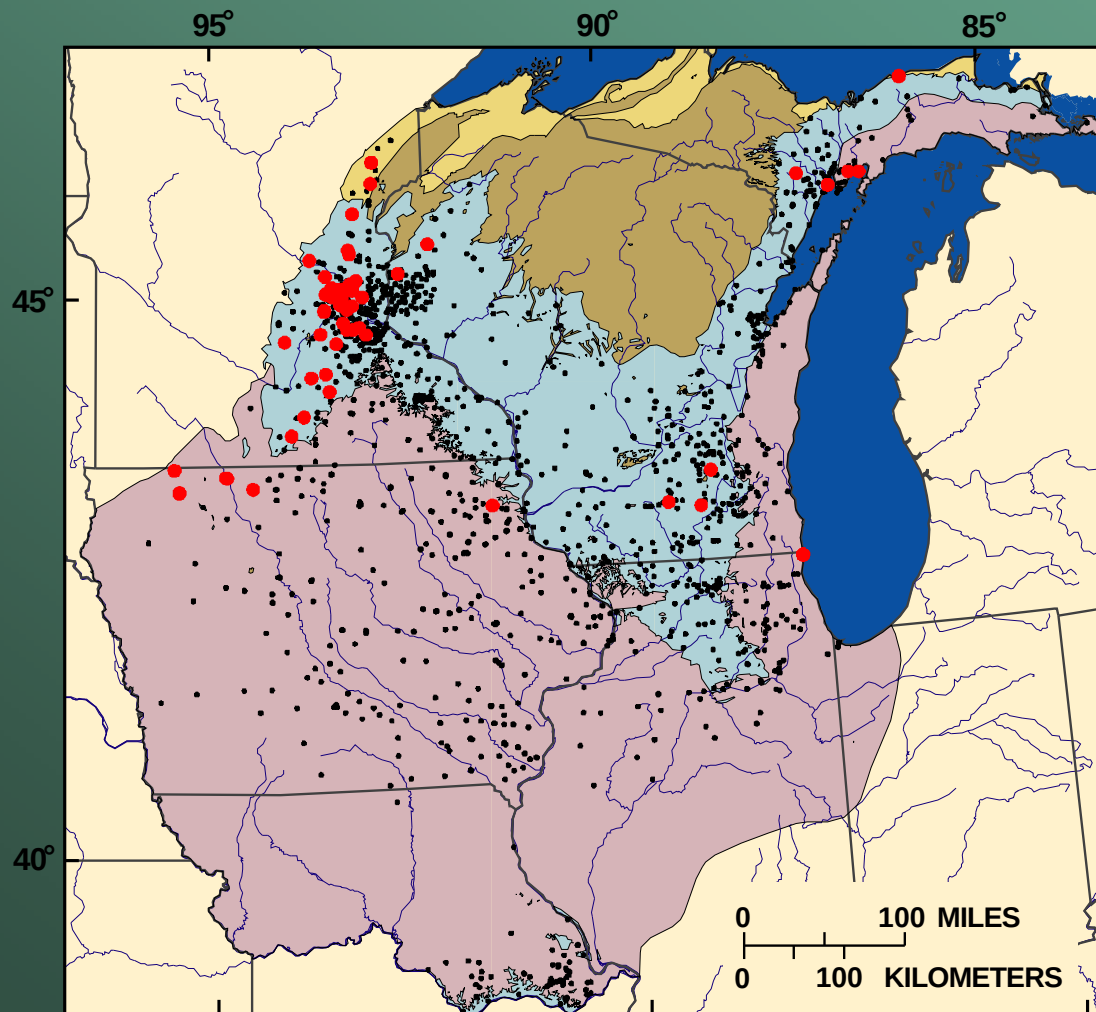
N = 300 (23 at 2 or more mg/L)
Fluoride MCL is 4 mg/L

Barium Concentrations





Manganese Concentrations



EXPLANATION

-  Cambrian-Ordovician Aquifers exposed at bedrock surface
-  Cambrian-Ordovician Aquifers covered by Maquoketa Shale or younger rocks

 Precambrian sandstones

 Precambrian undivided

Manganese concentration,
in micrograms per Liter

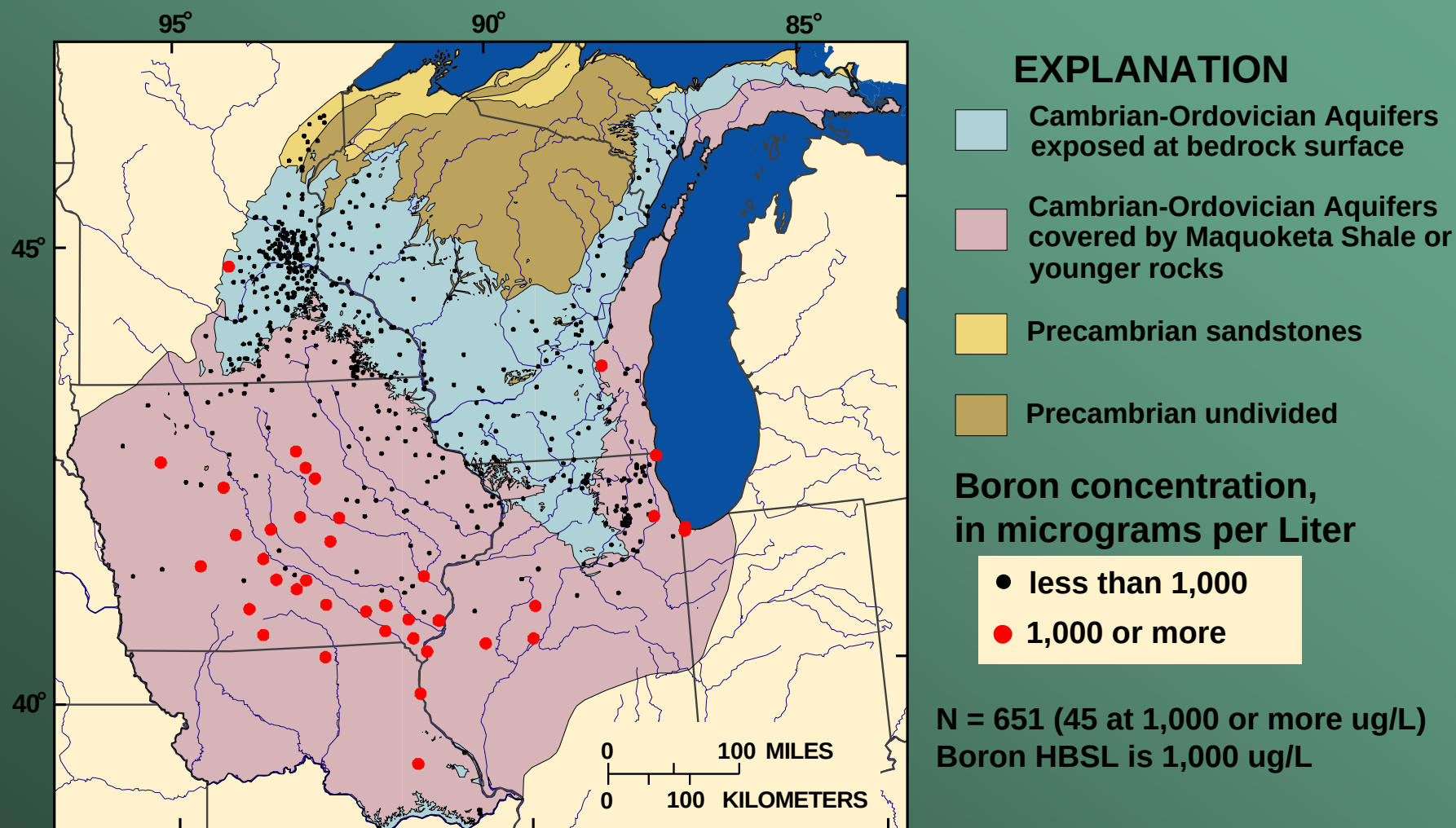
● less than 300

● 300 or more

N = 1,527 (86 at 300 or more ug/L)

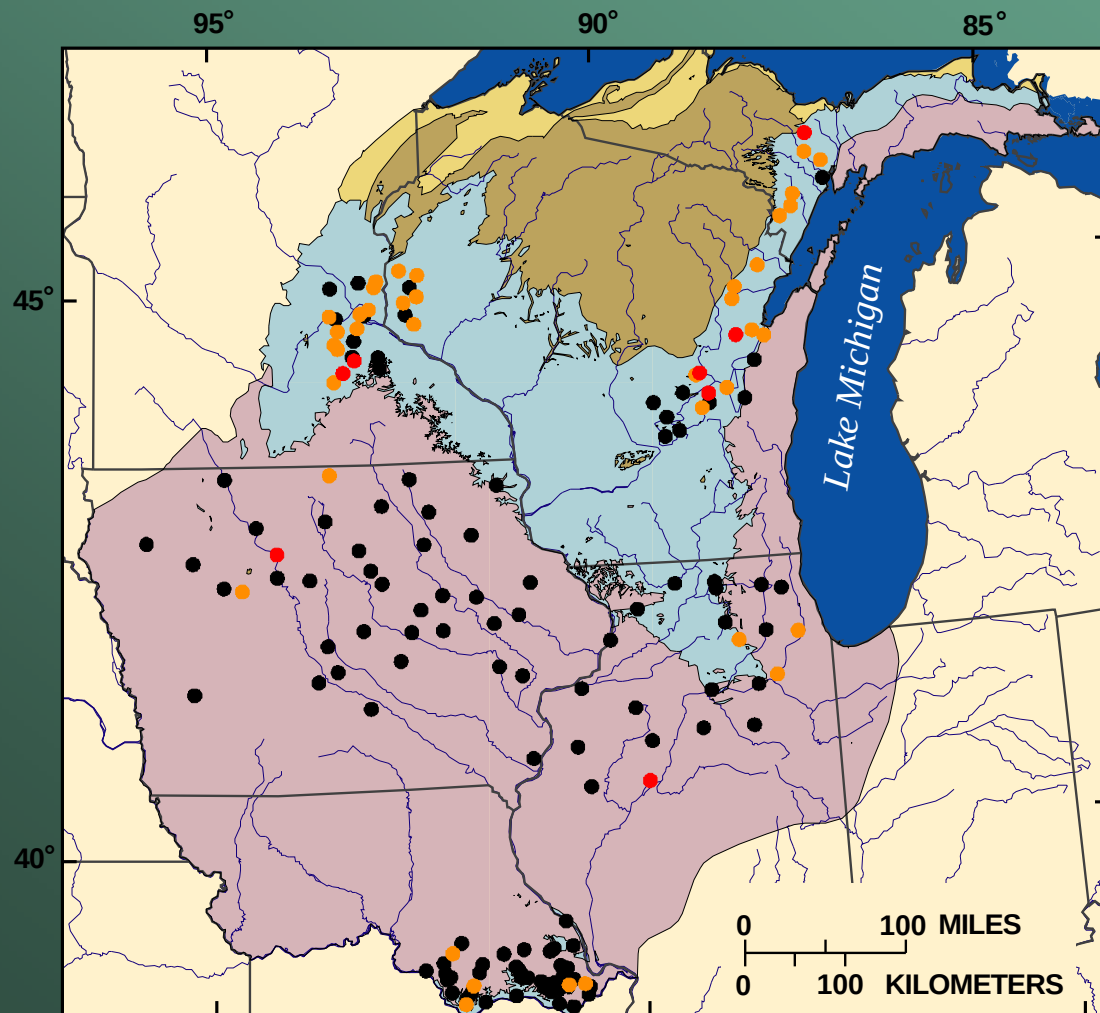
Manganese HBSL is 300 ug/L

Boron Concentrations





Radon-222 Concentrations



EXPLANATION

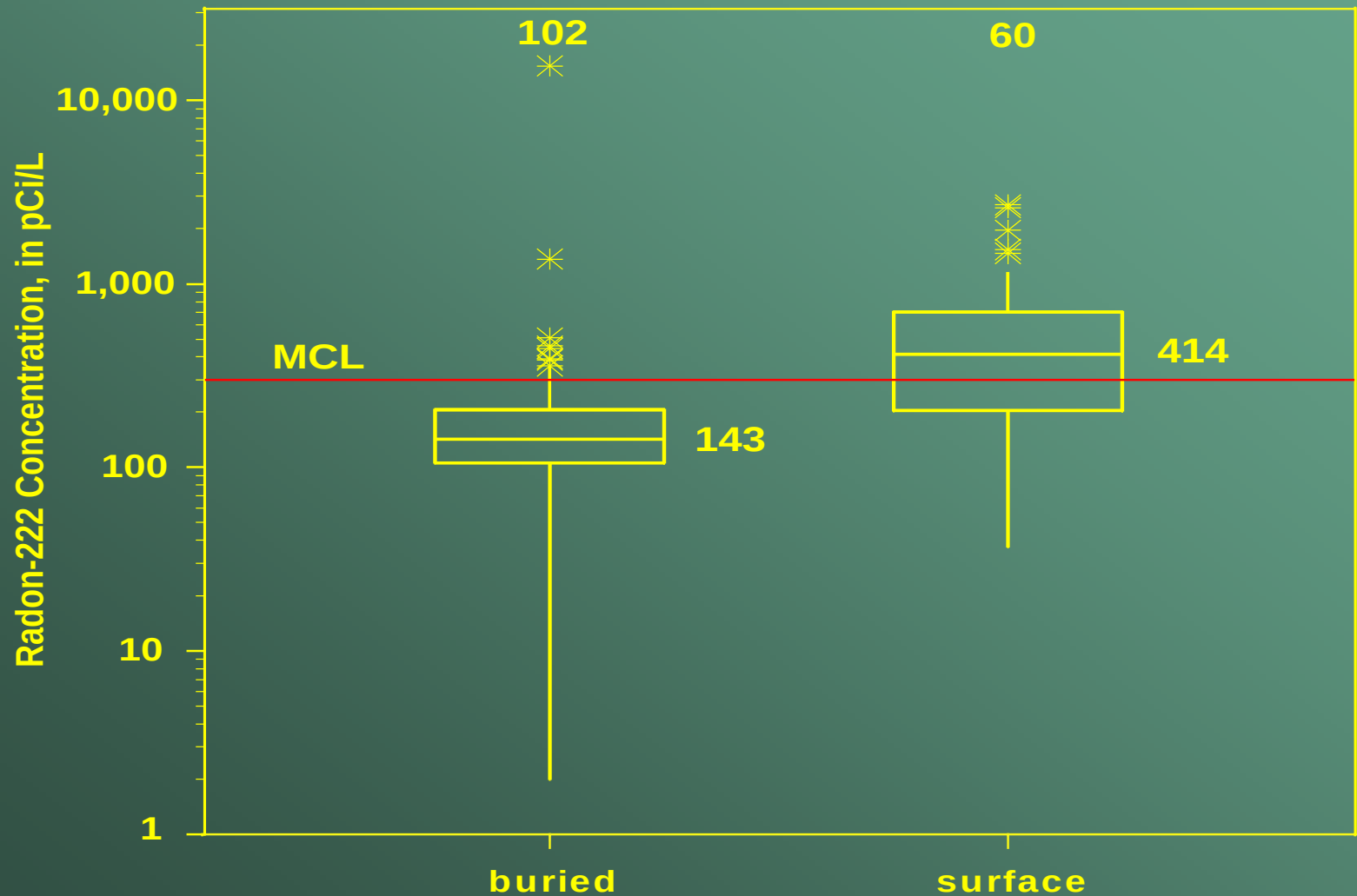
- Cambrian-Ordovician Aquifers exposed at bedrock surface
- Cambrian-Ordovician Aquifers covered by Maquoketa Shale or younger rocks
- Precambrian sandstones
- Precambrian undivided

Radon concentration,
in picocuries per Liter

- Less than 300
- 300 to less than 1,000
- 1,000 and above

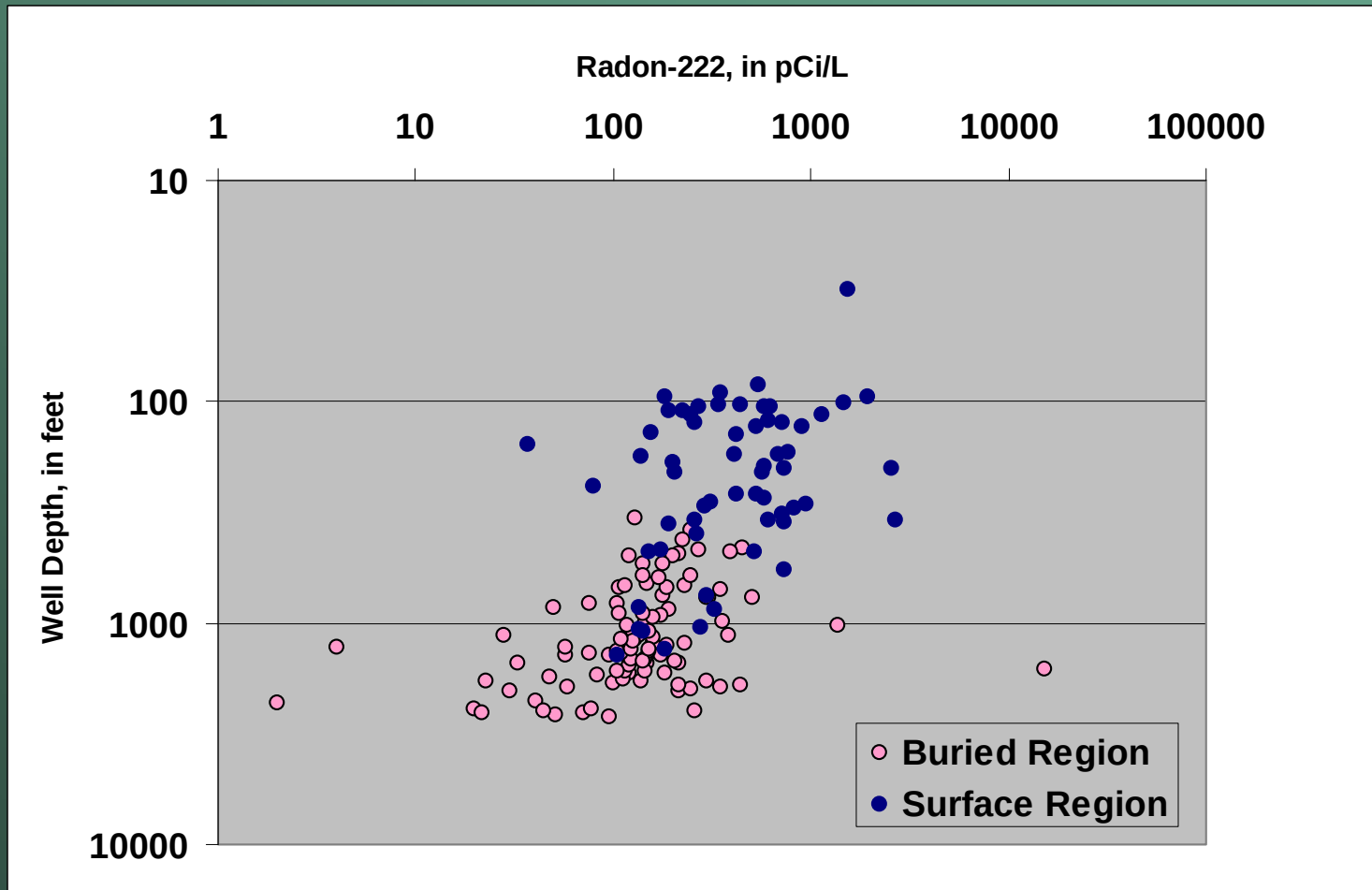
N = 162, 46 at 300 or more pCi/L
Sample Dates 1993-2007

Radon-222 Concentrations by Bedrock Region

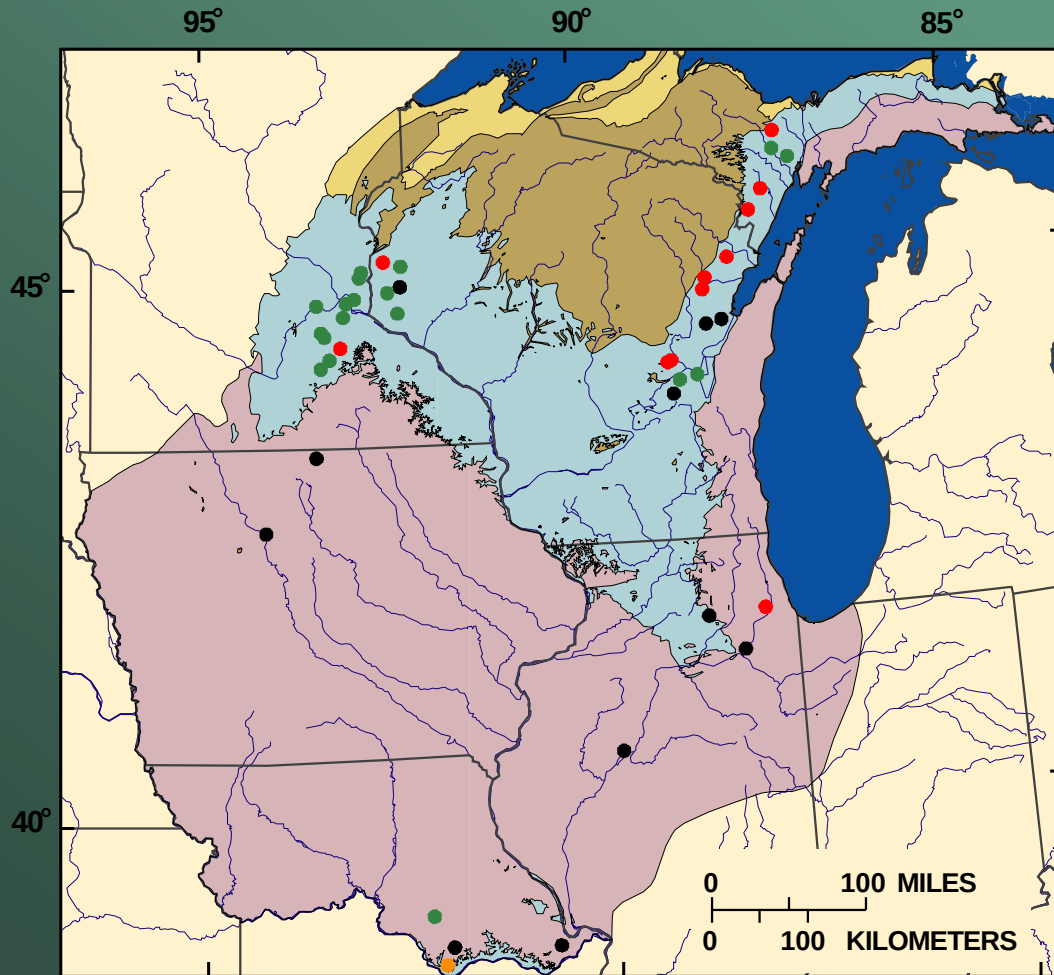




Radon-222 vs. Well Depth



Radon-222 by Aquifer Group (Concentrations of 300 or more pCi/L)



EXPLANATION

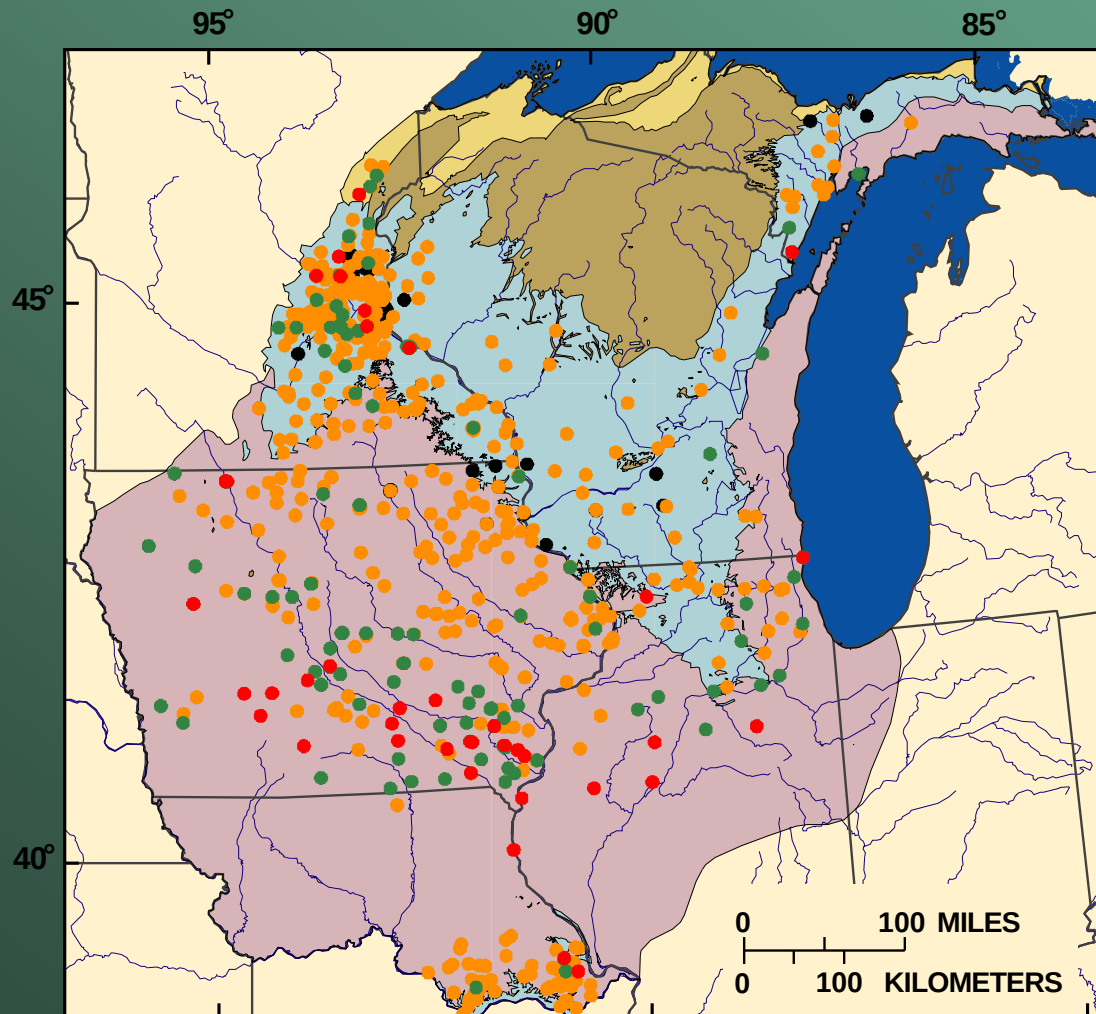
- Cambrian-Ordovician Aquifers exposed at bedrock surface
- Cambrian-Ordovician Aquifers covered by Maquoketa Shale or younger rocks
- Precambrian sandstones
- Precambrian undivided

Aquifer Group

- Upper-Middle Ordovician
- Prairie du Chien
- Prairie du Chien-Trempealeau
- Cambrian

N = 41 of 46 wells at 300 or more pCi/L

Radium-226 Concentrations



EXPLANATION

-  Cambrian-Ordovician Aquifers exposed at bedrock surface
-  Cambrian-Ordovician Aquifers covered by Maquoketa Shale or younger rocks
-  Precambrian sandstones
-  Precambrian undivided

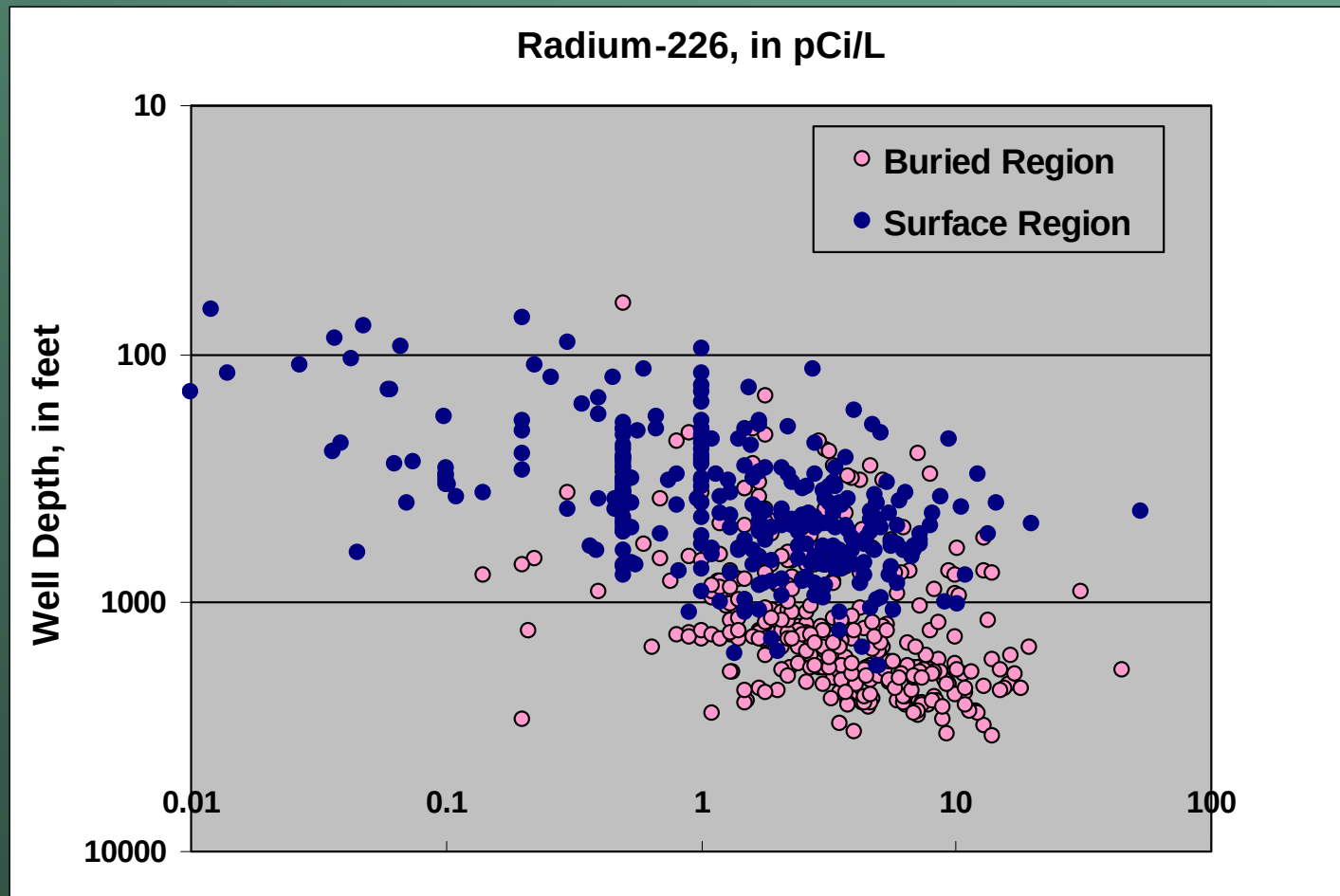
Radium-226 concentration,
in picocuries per Liter

-  non detection
-  less than 5
-  5 to less than 10
-  10 or more

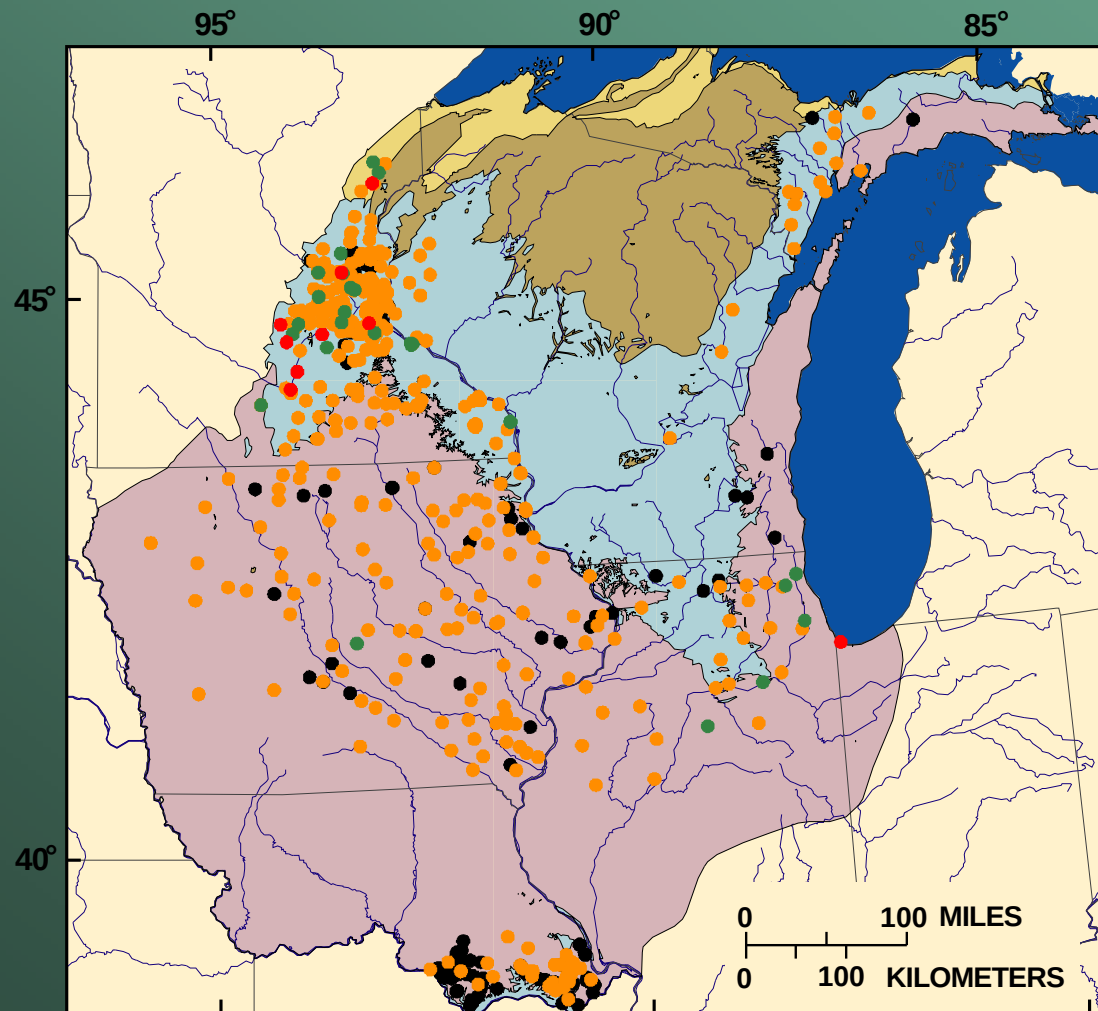
N = 689, 149 at 5 or more pCi/L
Sample Dates 1969-2007



Radium-226 vs. Well Depth



Radium-228 Concentrations



EXPLANATION

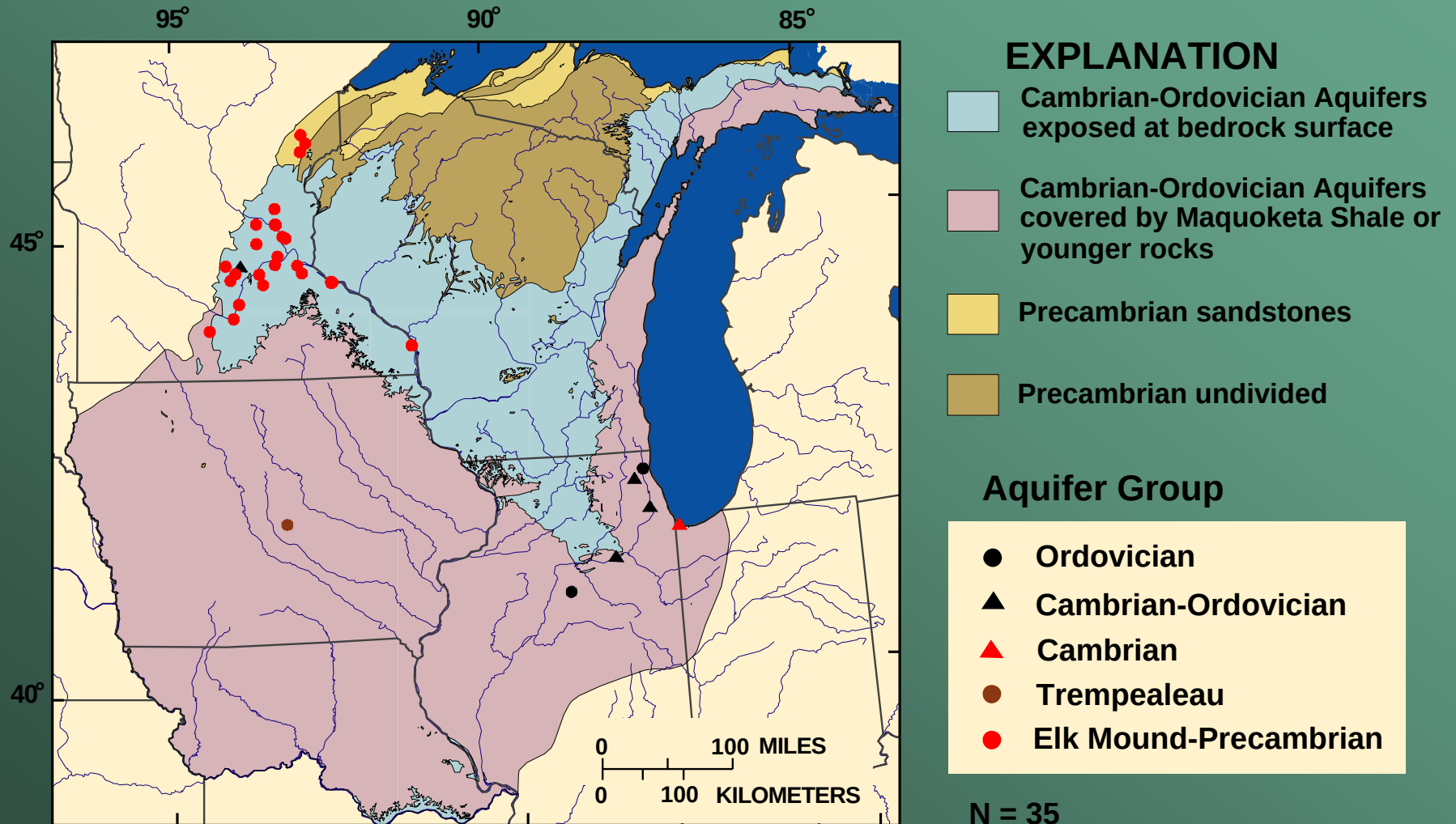
-  Cambrian-Ordovician Aquifers exposed at bedrock surface
-  Cambrian-Ordovician Aquifers covered by Maquoketa Shale or younger rocks
-  Precambrian sandstones
-  Precambrian undivided

Radium228 concentration,
in picocuries per Liter

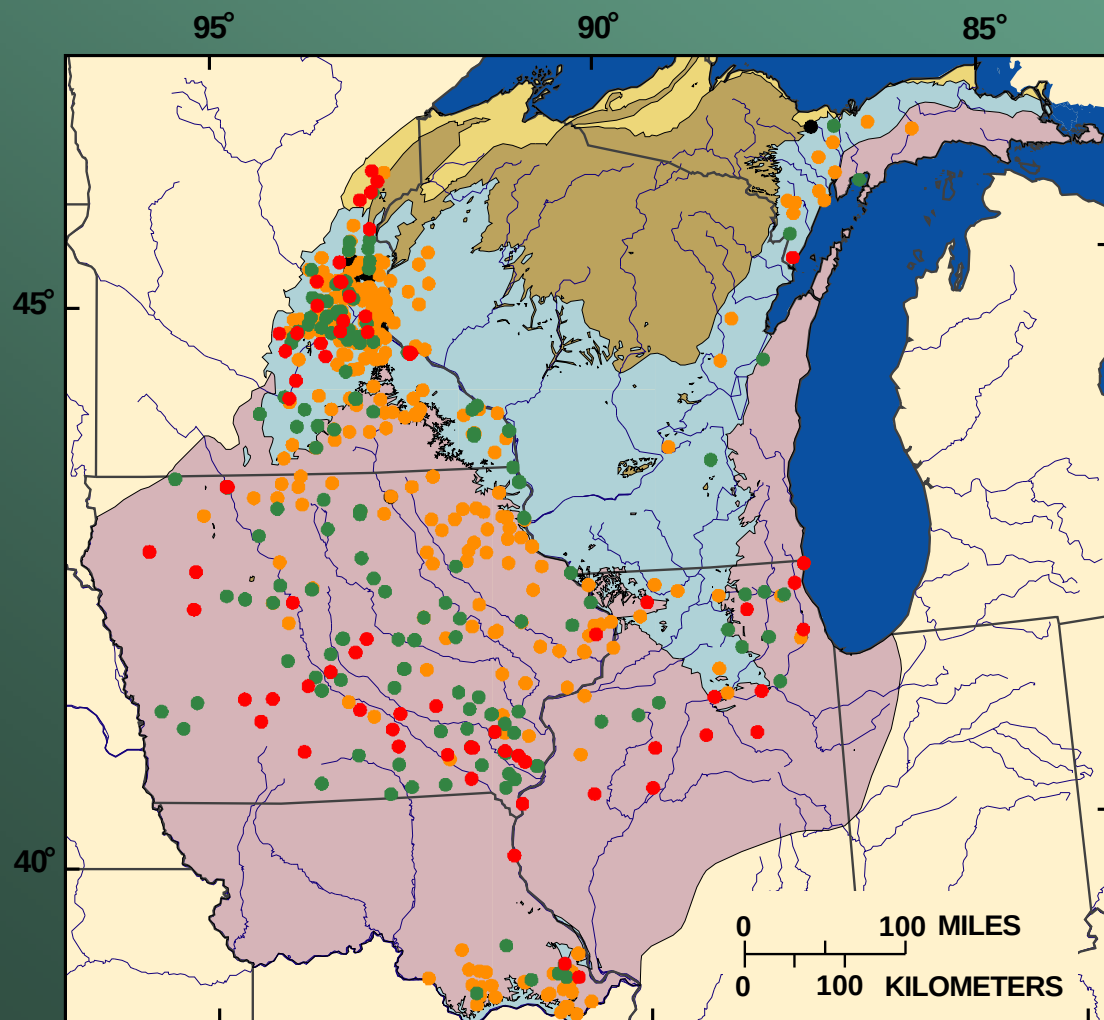
-  non detection
-  less than 5
-  5 to less than 10
-  10 or more

N = 547, 35 at 5 or more pCi/L
Sample Dates 1982-2007

Radium-228 by Aquifer Group (Concentrations of 5 or more pCi/L)



Combined Radium Concentrations



EXPLANATION

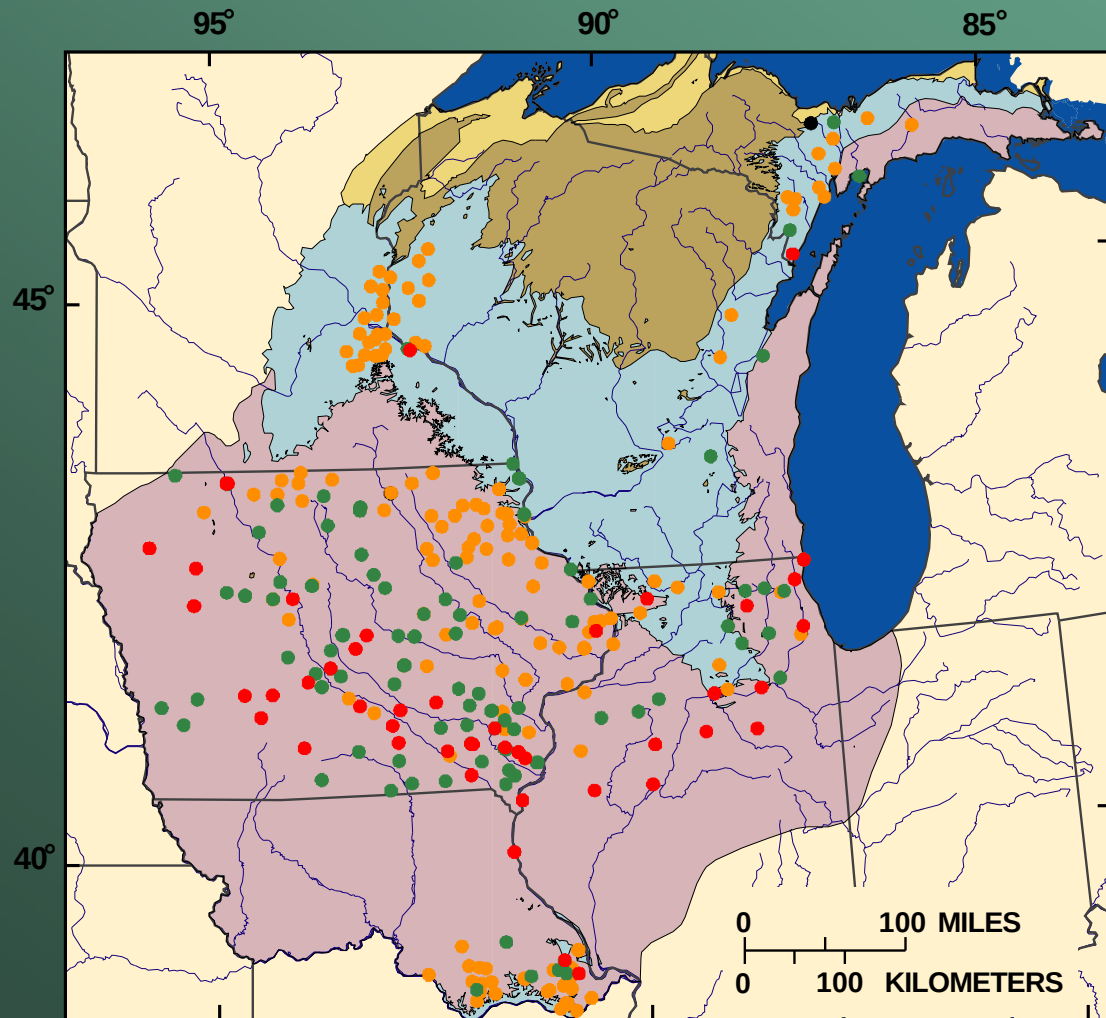
- Cambrian-Ordovician Aquifers exposed at bedrock surface
- Cambrian-Ordovician Aquifers covered by Maquoketa Shale or younger rocks
- Precambrian sandstones
- Precambrian undivided

Radium²²⁶+²²⁸ concentration,
in picocuries per Liter

- non detection
- less than 5
- 5 to less than 10
- 10 or more

N = 543, 237 at 5 or more pCi/L
Sample Dates 1969-2007

Combined Radium Concentrations



EXPLANATION

- Cambrian-Ordovician Aquifers exposed at bedrock surface
- Cambrian-Ordovician Aquifers covered by Maquoketa Shale or younger rocks
- Precambrian sandstones
- Precambrian undivided

Radium²²⁶+²²⁸ concentration,
in picocuries per Liter

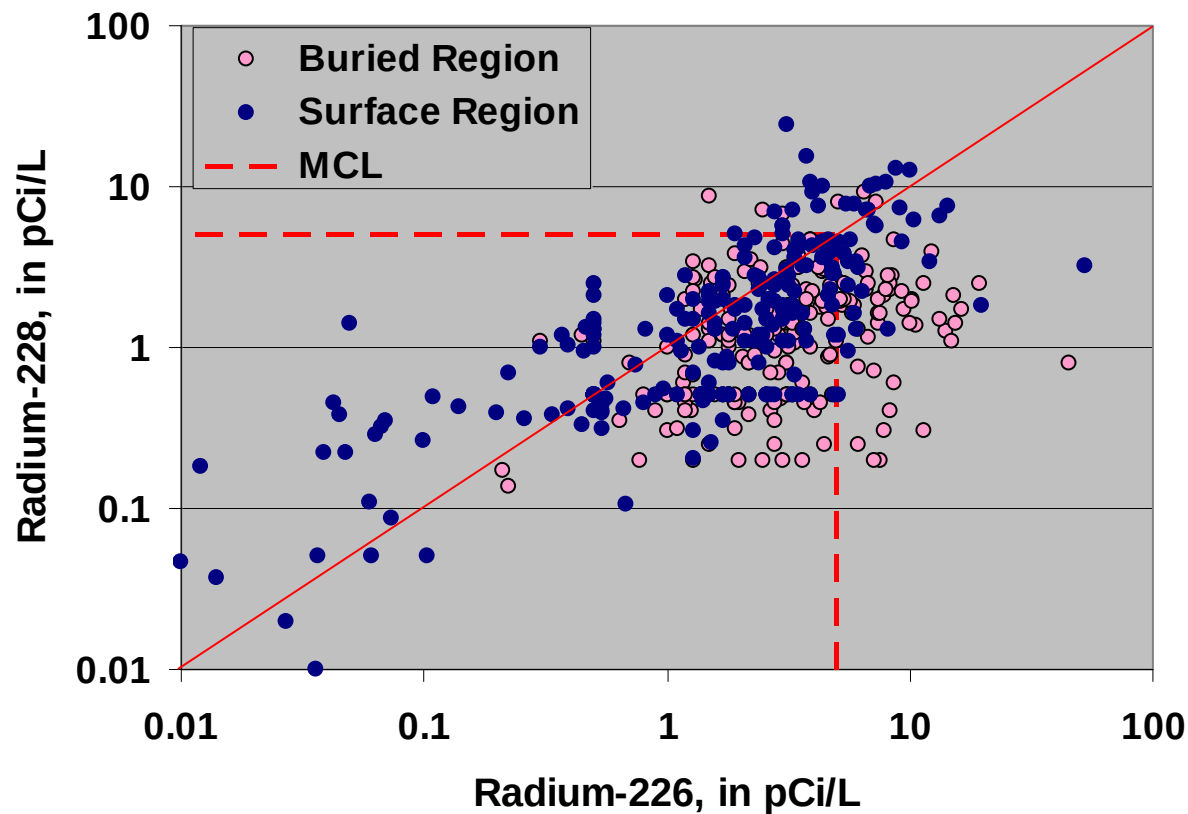
- non detection
- less than 5
- 5 to less than 10
- 10 or more

N = 319, 156 at 5 or more pCi/L
Sample Dates 1969-2007

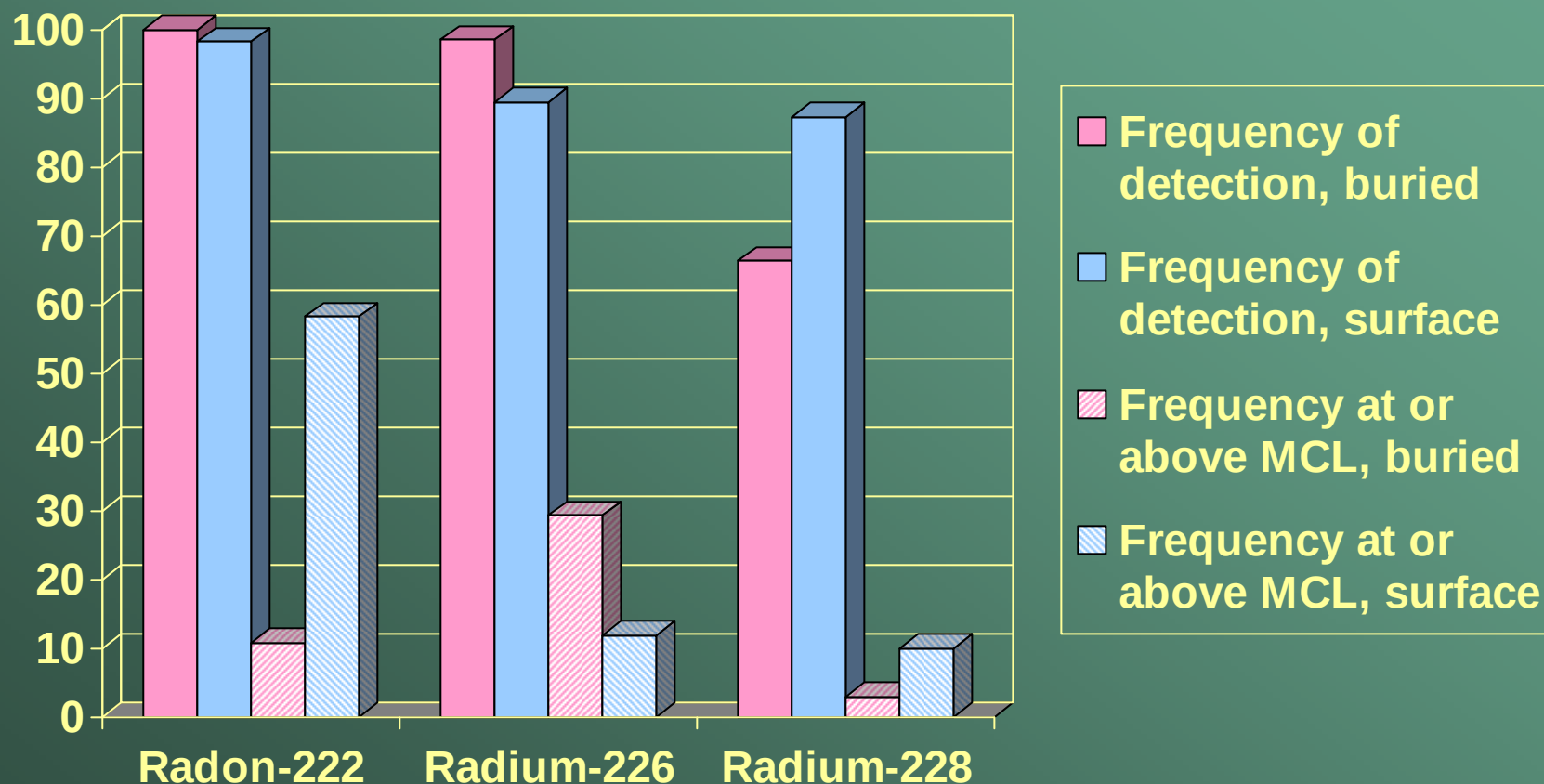
MN DOH wells not shown



Radium-226 vs. Radium-228



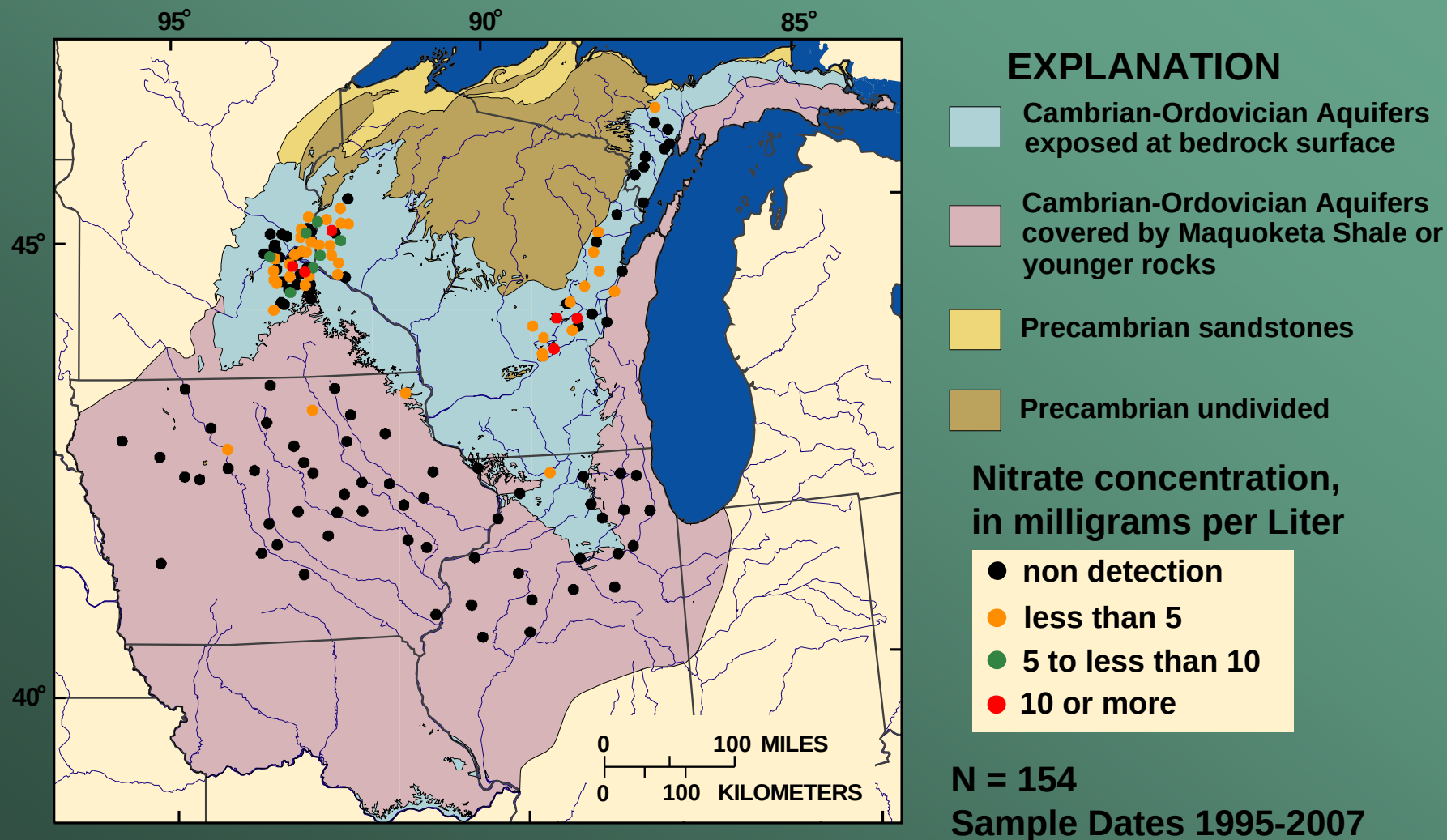
Radon-222, Radium-226, Radium-228



Maps Showing Distribution of:

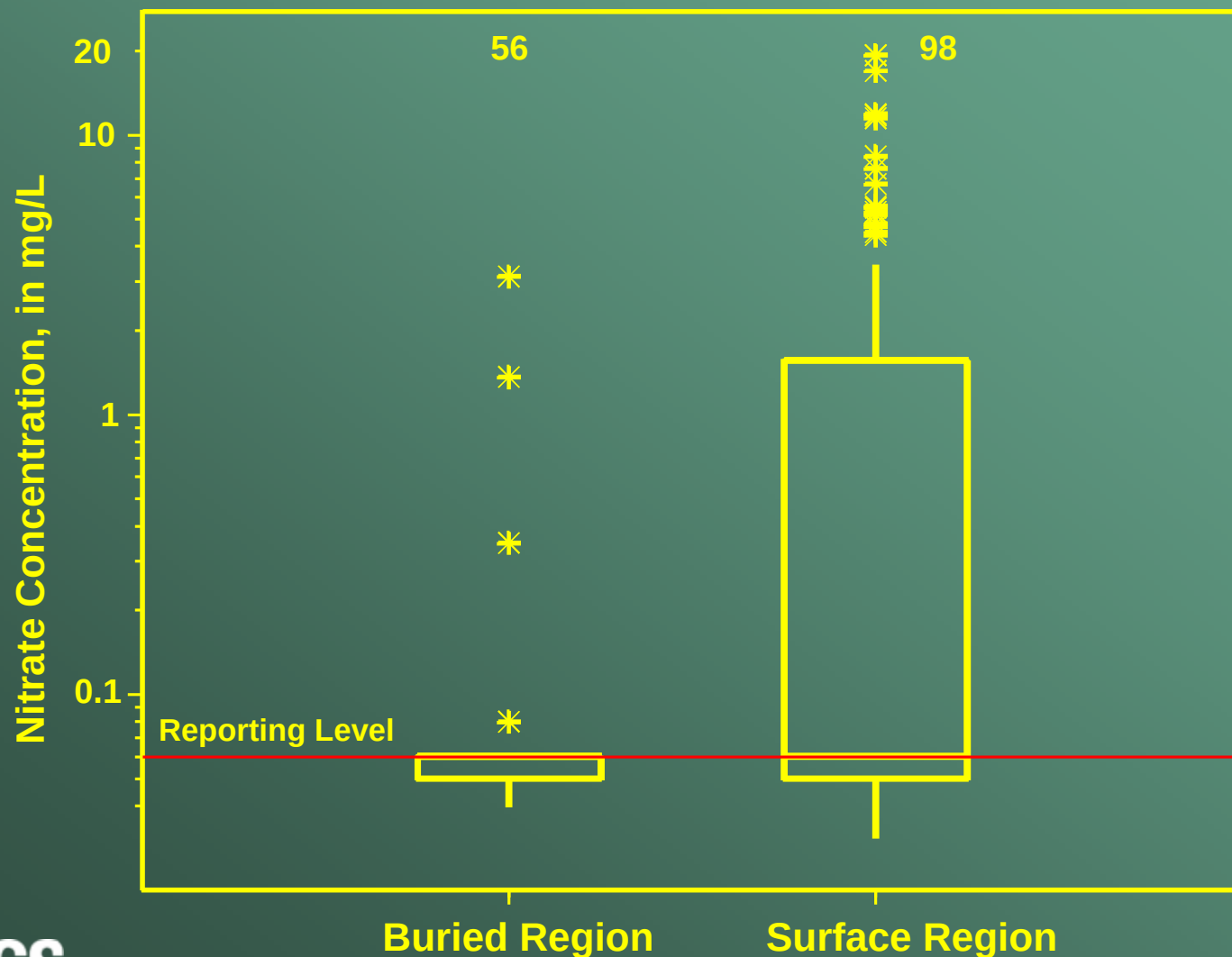
- Nitrate and Ammonia
- Pesticide Detections
- VOC Detections

Nitrate Concentrations in NAWQA Wells

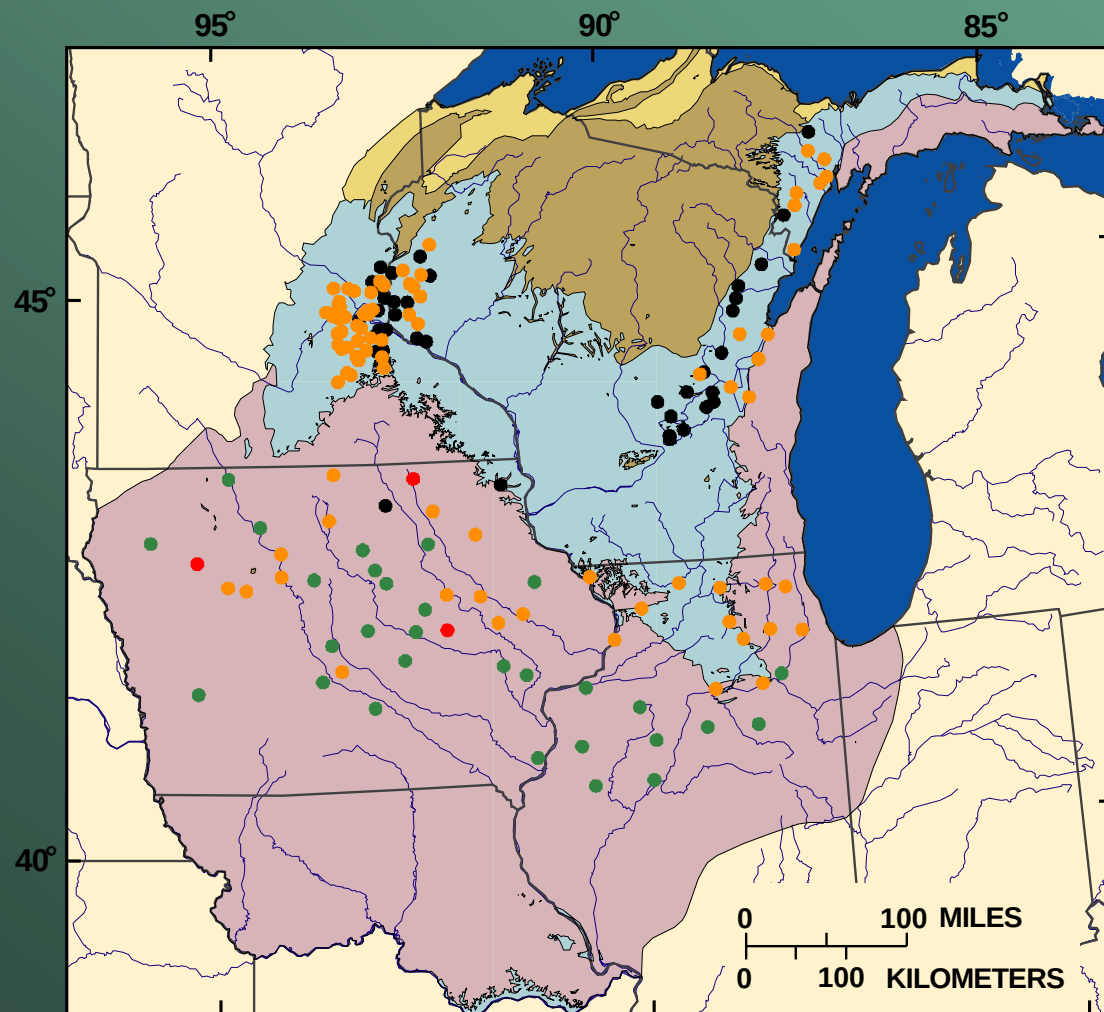




Nitrate Concentrations by Bedrock Region



Ammonia Concentrations in NAWQA Wells



EXPLANATION

- Cambrian-Ordovician Aquifers exposed at bedrock surface
- Cambrian-Ordovician Aquifers covered by Maquoketa Shale or younger rocks
- Precambrian sandstones
- Precambrian undivided

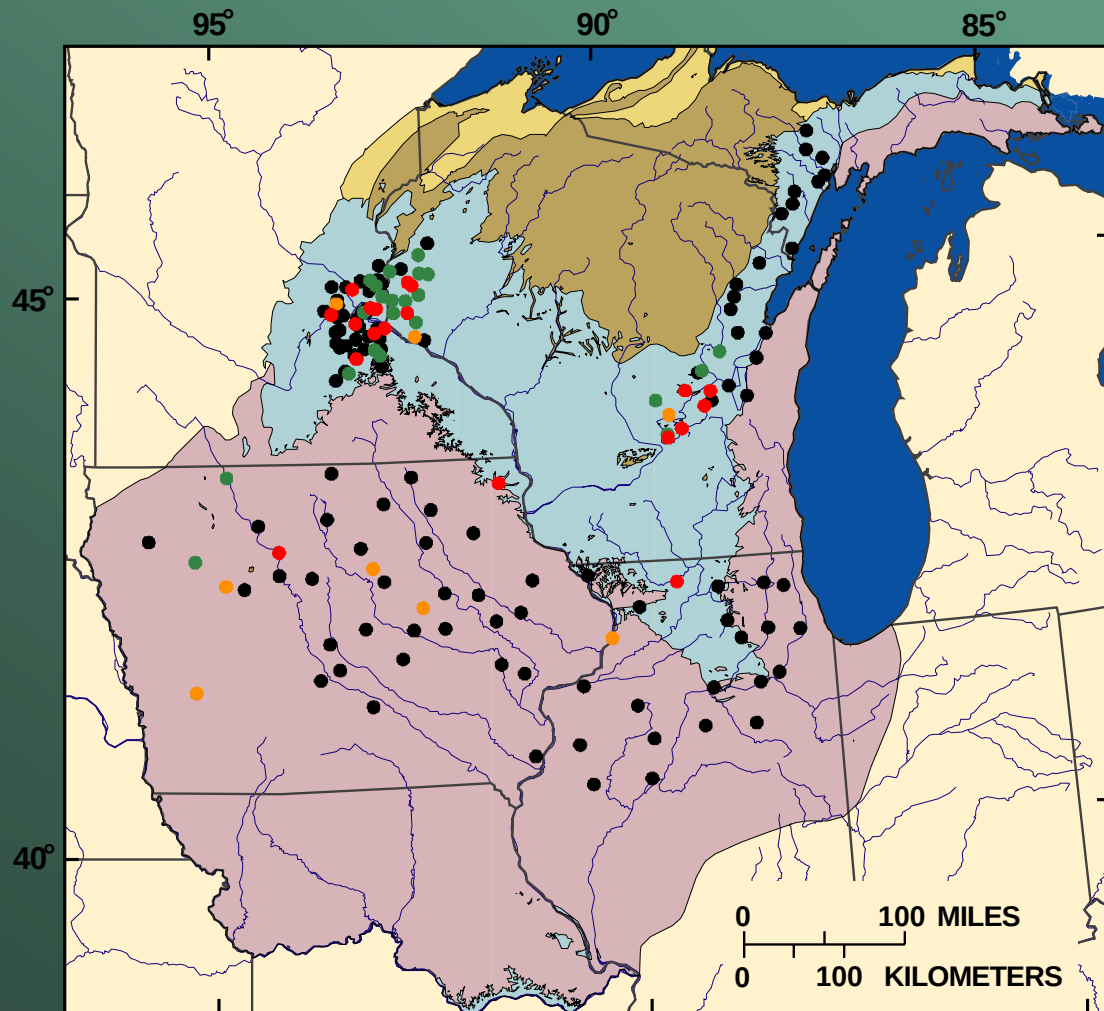
Ammonia concentration,
in milligrams per Liter

- non detection
- less than 1
- 1 to less than 2
- 2 to 4.3

N = 154

Sample Dates 1995-2007

Pesticide Detections in NAWQA Wells



EXPLANATION

-  Cambrian-Ordovician Aquifers exposed at bedrock surface
-  Cambrian-Ordovician Aquifers covered by Maquoketa Shale or younger rocks
-  Precambrian sandstones
-  Precambrian undivided

Pesticide detections

-  none
-  1
-  2
-  3 or more

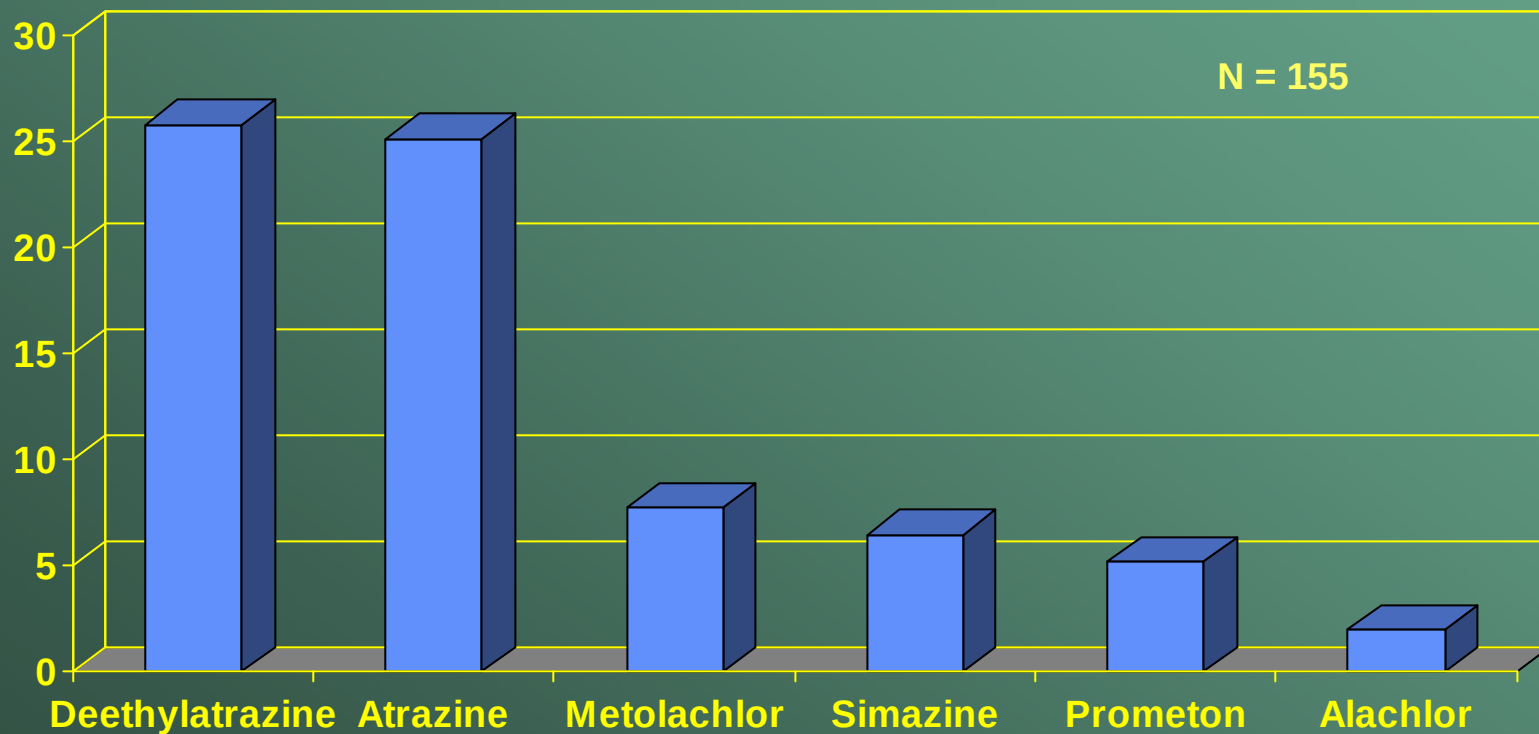
N = 155

Sample Dates 1995-2007

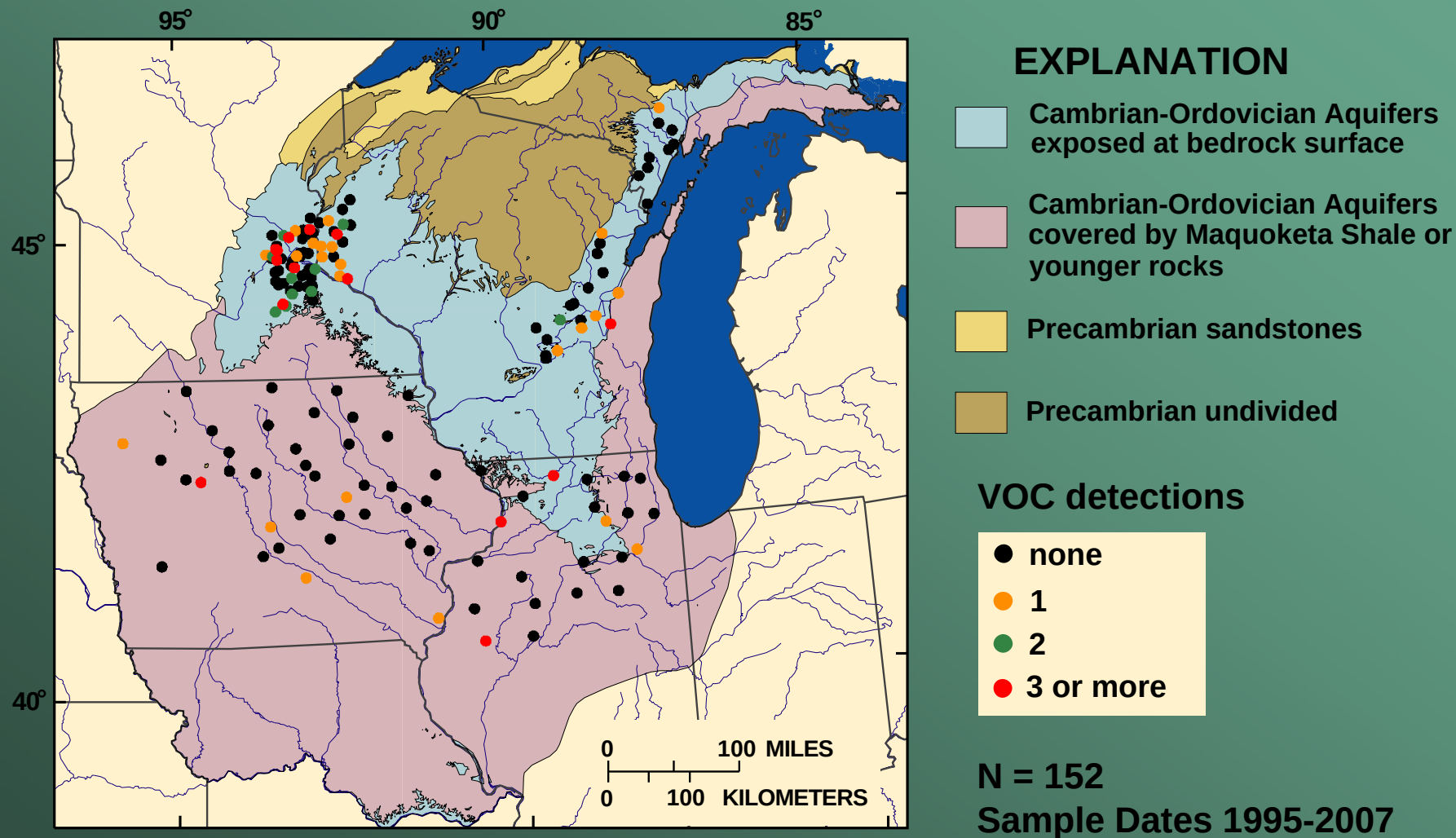


Most Commonly Detected Pesticides

Occurrence Frequency, in percent



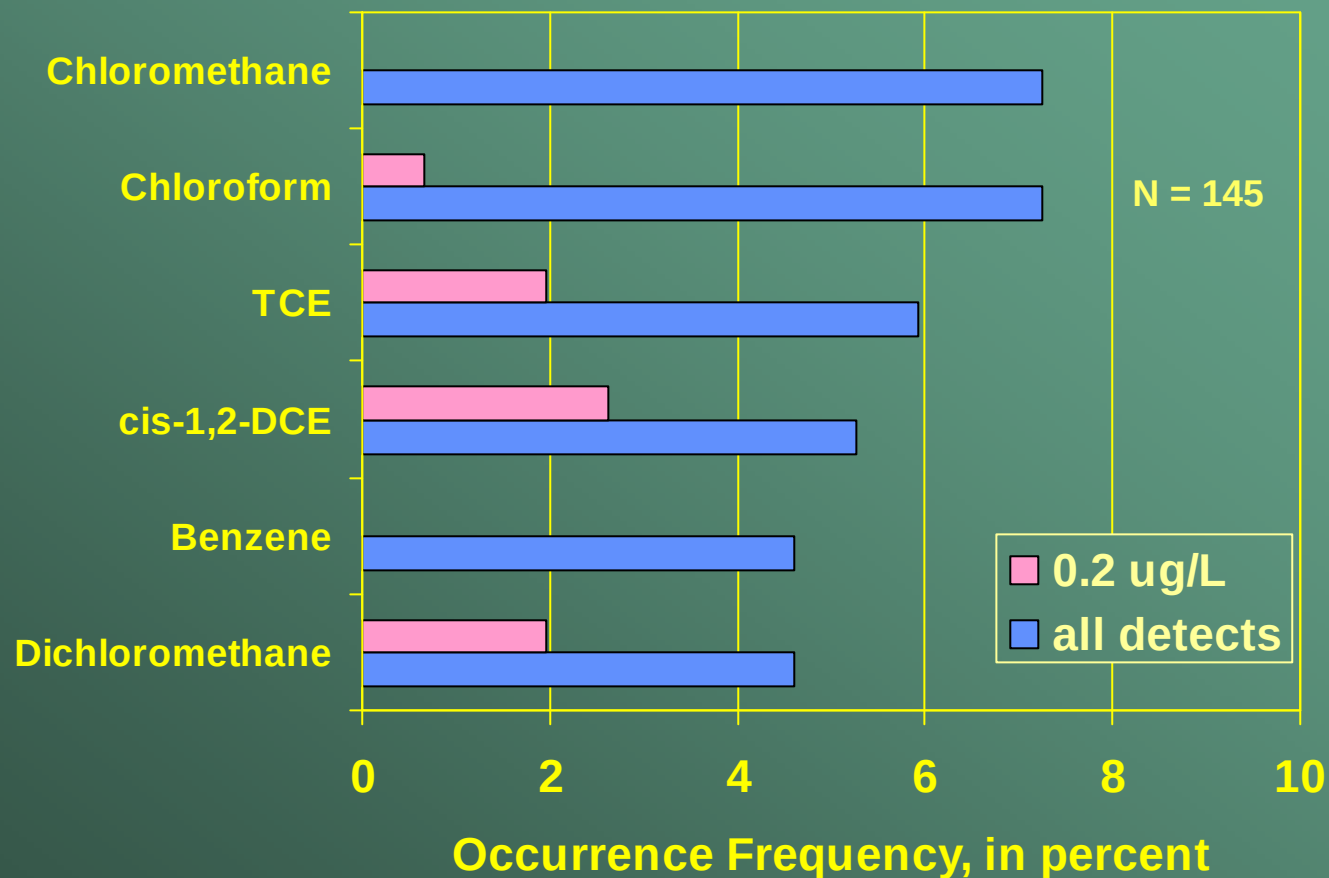
VOC Detections in NAWQA Wells



Includes 55 VOCs from Zogorski and others, 2006: USGS Circular 1992, Volatile Organic Compounds in the Nation's Ground Water and Drinking-Water Supply Wells

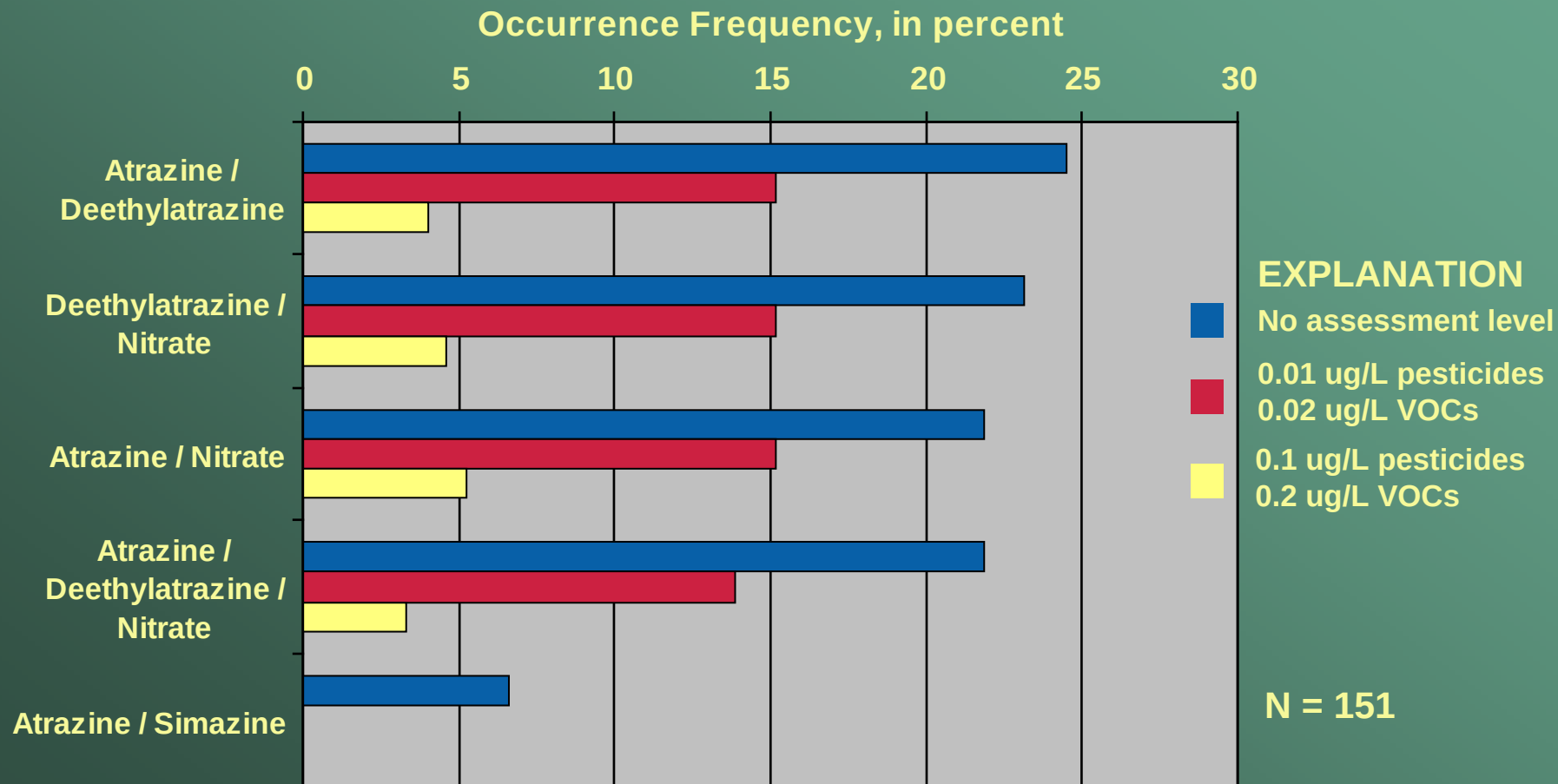


Most Commonly Detected VOCs





Pesticides, Nitrate, and VOCs Mixtures in NAWQA Samples



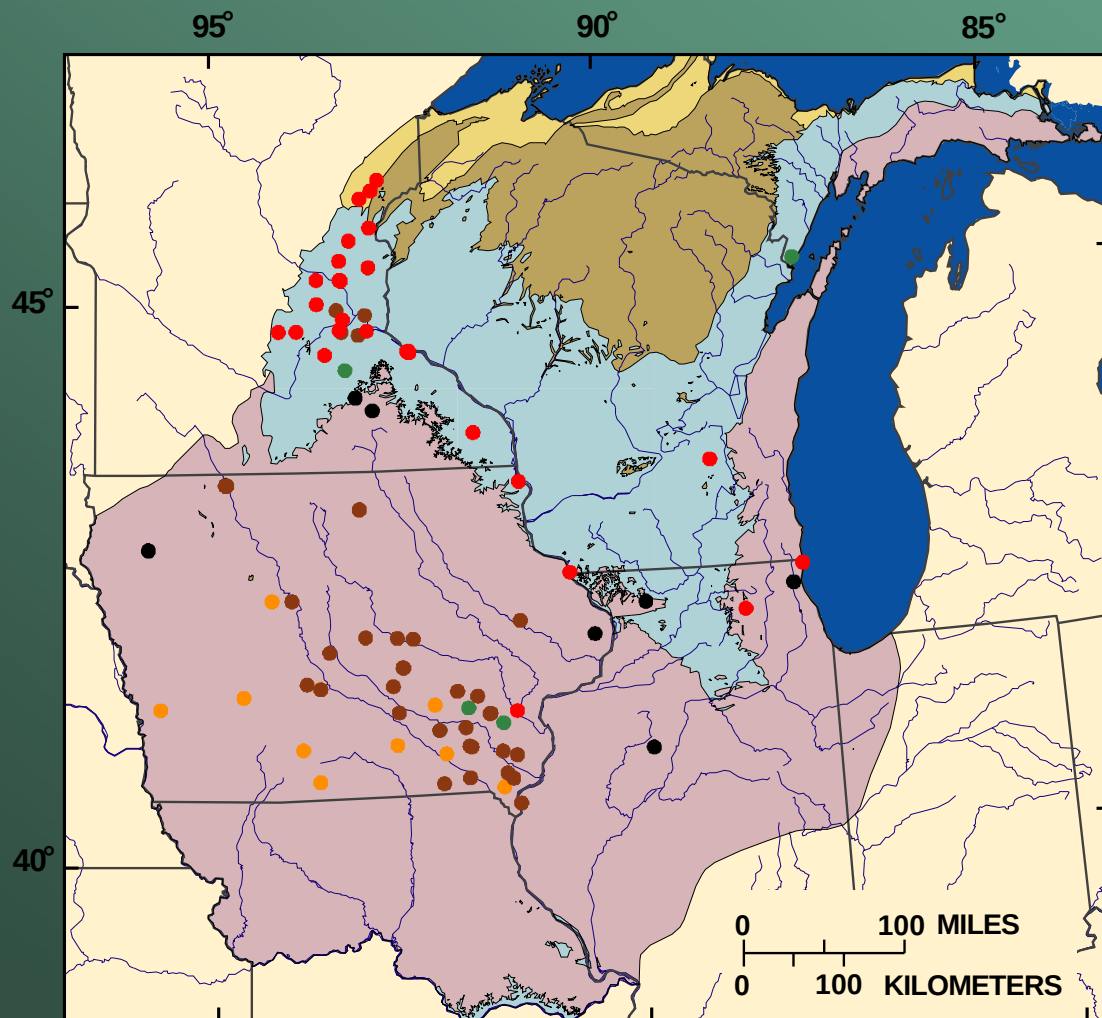
Acknowledgments

- Illinois EPA: Rick Cobb, Joe Konczyk
- Michigan DEQ: Chuck Thomas
- Minnesota DOH: Jim Lundy
- Minnesota PCA: Mindy Erickson
- Missouri DNR: Thomas Adams
- Wisconsin DNR: Dave Johnson



Radium-226 by Aquifer Group

(Concentrations of 5 or more pCi/L)



EXPLANATION

- Cambrian-Ordovician Aquifers exposed at bedrock surface
- Cambrian-Ordovician Aquifers covered by Maquoketa Shale or younger rocks
- Precambrian sandstones
- Precambrian undivided

Aquifer Group

- Upper-Middle Ordovician
- Prairie du Chien
- Prairie du Chien-Trempealeau
- Trempealeau
- Elk Mound-Precambrian

N = 89 of 149 wells at 5 or more pCi/L