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OF THE 2017
M&R SEMINAR SERIES

BEFORE WE BEGIN

- SAFETY PRECAUTIONS
  - PLEASE FOLLOW EXIT SIGN IN CASE OF EMERGENCY EVALUATION
  - AUTOMATED EXTERNAL DEFIBRILLATOR (AED) LOCATED OUTSIDE
- PLEASE SILENCE CELL PHONES OR SMART PHONES
- QUESTION AND ANSWER SESSION WILL FOLLOW PRESENTATION
- PLEASE FILL EVALUATION FORM
- SEMINAR SLIDES WILL BE POSTED ON MWRD WEBSITE (www. MWRD.org: Home Page ⇒ Reports ⇒ M&R Data and Reports ⇒ M&R Seminar Series ⇒ 2017 Seminar Series)
- STREAM VIDEO WILL BE AVAILABLE ON MWRD WEBSITE (www.MWRD.org: Home Page ⇒ MWRDGC RSS Feeds)

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Current: Hydrologist, U.S. Geological Survey (Since 1986)

Experience:
- Regional and site-specific investigations of hydrogeology and water quality at hazardous-waste disposal sites
- Plan and conduct investigations of geology, hydrology, and water quality of lakes and wetlands
- Plan and conduct investigations evaluating water resources in residential-supply aquifers
- Manage projects including program development & cooperator relations

Education:
- B.S. Geology (1984), Univ. Iowa, Iowa City, IA
- M.S. Geology (1987), Northern IL Univ., Dekalb, IL

Professional:
- Wrote and published results of investigations in USGS outlets and scientific journals
- Primary person performing data interpretation and analysis for most projects

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Experience:	**Program Officer, National Academy of Sciences, Washington, DC** **(2009 to 2013)** **Environmental Scientist, ToxServices, LLC, Washington, DC**
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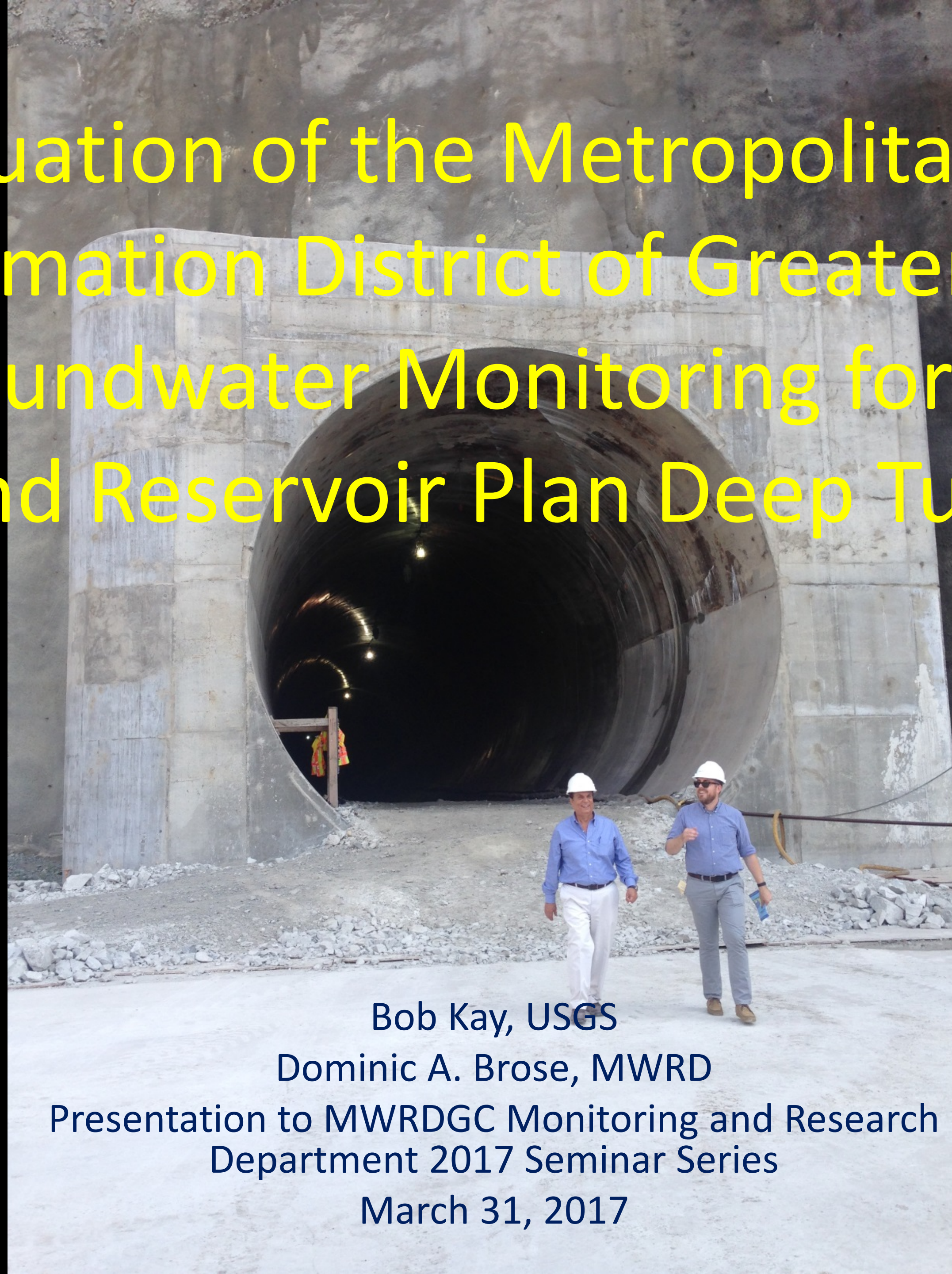


Evaluation of the Metropolitan Water Reclamation District of Greater Chicago Groundwater Monitoring for Tunnel and Reservoir Plan Deep Tunnels

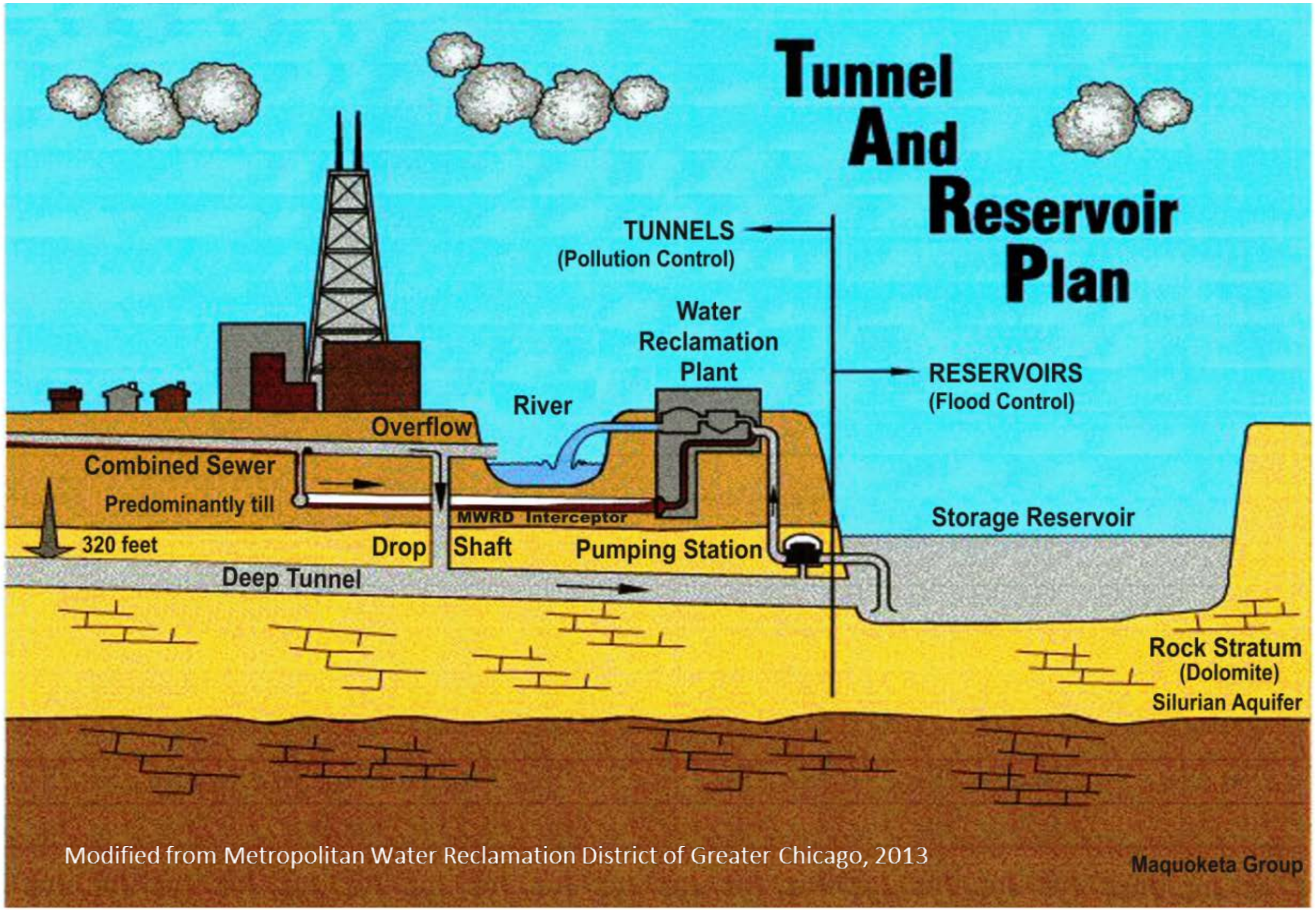
Bob Kay, USGS
Dominic A. Brose, MWRD

Presentation to MWRDGC Monitoring and Research Department 2017 Seminar Series

March 31, 2017

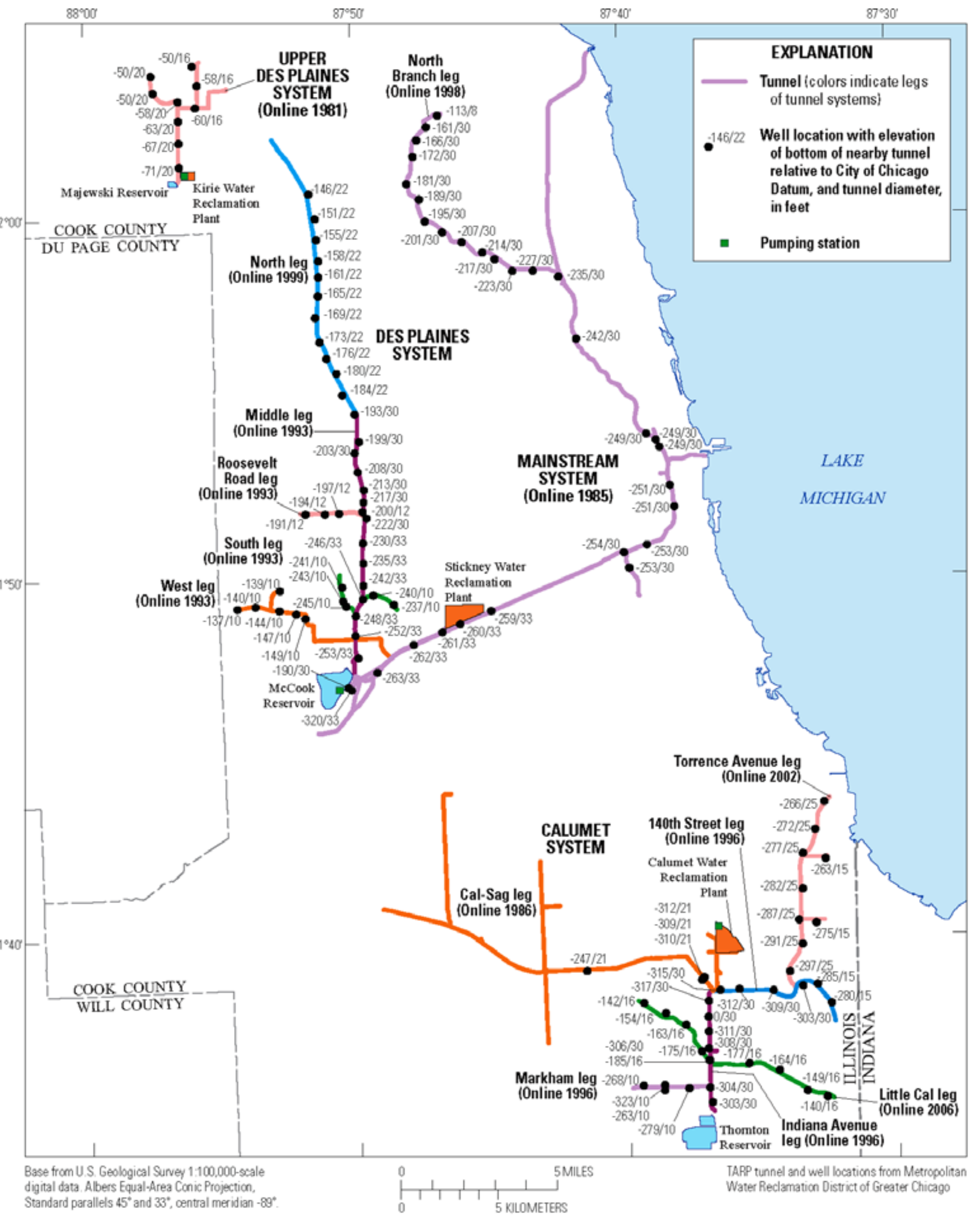
Flooding and TARP

- **TARP diverts CSO to deep tunnels in Silurian dolomite bedrock**



TARP Monitoring Program

- **M&R established robust monitoring program with 120 wells as tunnel systems came online**
- **Sampling occurs on a fixed schedule of either three or six times annually**



TARP Monitoring Program

- Wells monitored for water level, temperature, total dissolved solids (TDS), chloride, hardness, electrical conductance, pH, sulfate, ammonia, fecal coliform, dissolved organic carbon (DOC)
- Many analytes are poor indicators of CSO
  - Naturally occurring
  - Concentrations in aquifer prior to TARP not well known
- Sampling schedule does not necessarily coincide with storm events

Partnering with USGS

- **No evaluation of the groundwater sampling program has been completed in the more than 20 years of data collection**
- **An evaluation of all aspects of the monitoring network was needed (e.g., frequency of data collection, number of monitoring wells, analytes)**
- **The insights gained from the evaluation would help the District to develop, with IEPA approval, a more cost-effective and meaningful monitoring program**

USGS Analysis of TARP Well Data

– Analysis of data collected during 1995-2013 done to find ways to improve efficacy of data collection
    - ID wells not giving useful data
    - ID analytes that provide insight into CSF presence
    - ID conditions affecting data
– Time period selected because data electronically accessible
– Typically more than 50 samples for each well during 1995-2013
– Full analysis presented in

https://pubs.er.usgs.gov/publication/sir20155186

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USGS Analysis

- Compile all data from every TARP well for 1995-2013 period
- MWRDGC compiled data on water discharged from TARP system
  - Flow (daily)
  - Quality (variable, often daily)
- Plot every analyte in every well
  - Anomalies (fix if appropriate)
  - Identify CSF events(?)
  - Identify preliminary trends in concentration
- Summary Statistics (max, min, geo mean, SD, COV)
- Plot geometric mean values for each analyte in each well
- Test for correlations between analytes
- Test for 1995-2013 temporal trends for every analyte in every well
- Test for seasonal trends for every analyte in every well

Geologic Factors Affecting Analyte Concentrations in TARP Monitoring Wells

Mostly till at land surface

Dolomite at the land surface allows for comparatively easy migration of surface constituents into the aquifer

Des Plaines Disturbance is a highly fractured area that may allow enhanced movement of constituents within the upper bedrock

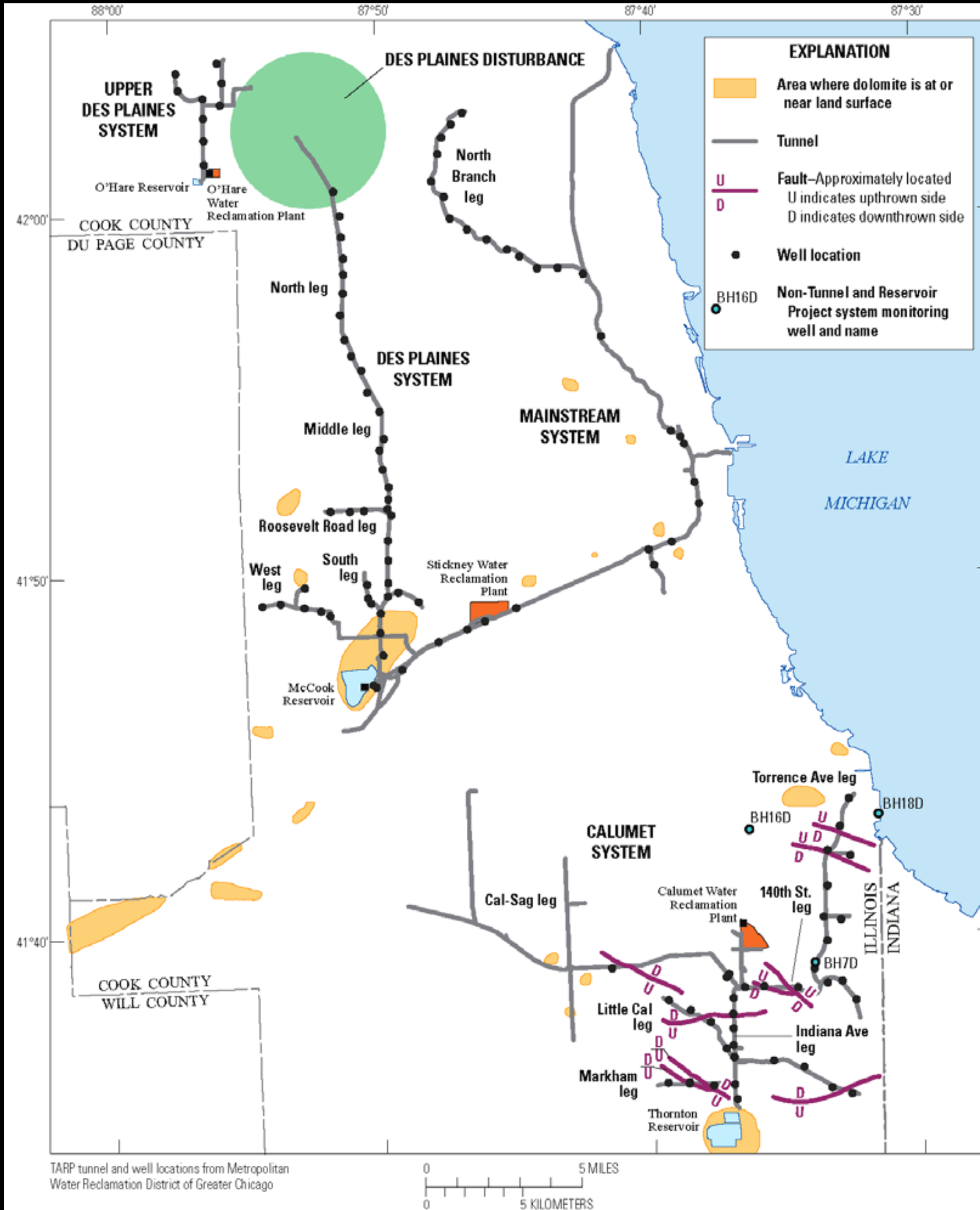


Figure 5. Selected geologic features in the vicinity of the Tunnel and Reservoir Plan system, Cook County, Illinois.

Water-Level Data

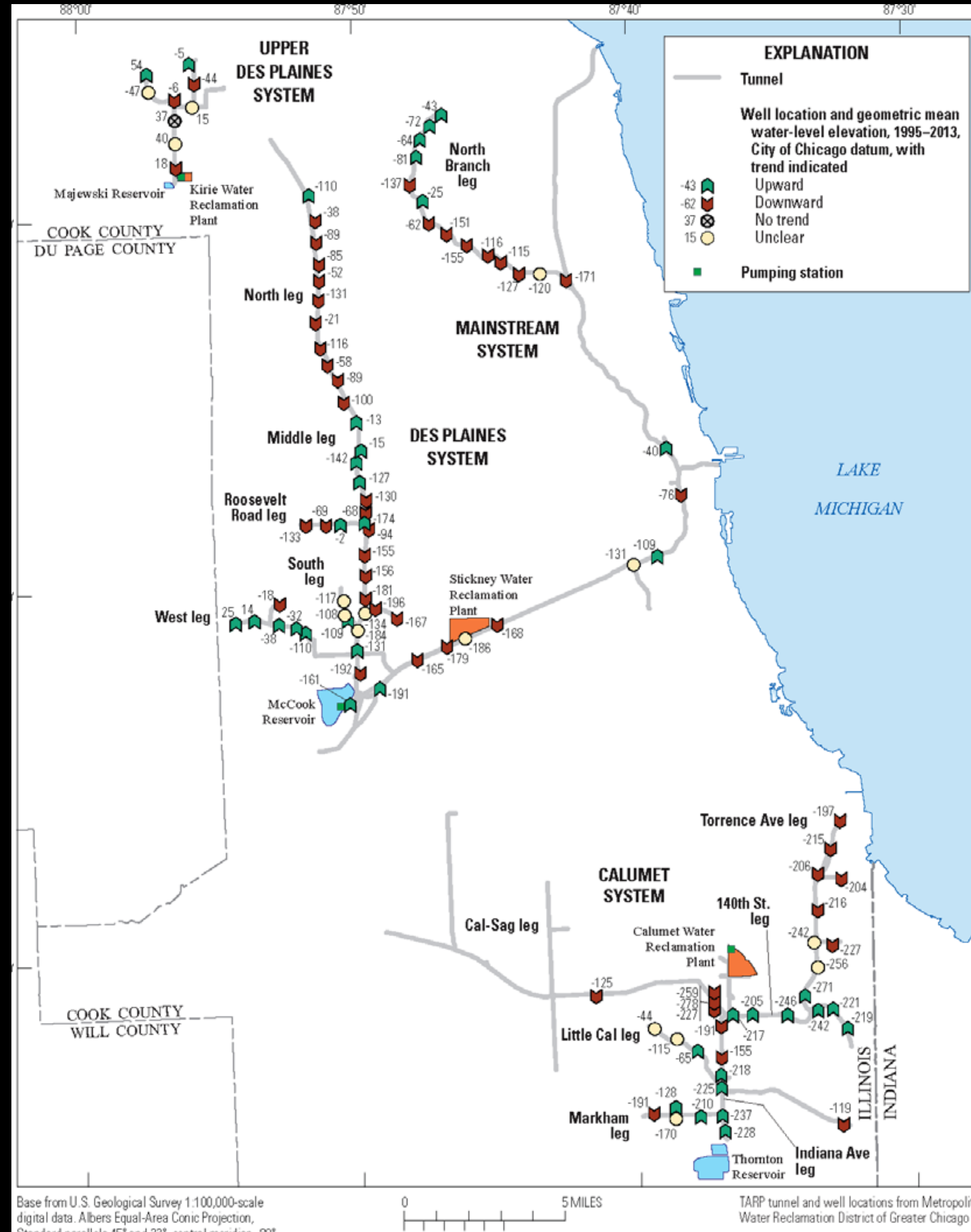
Geometric mean water level in a well is spatially variable

Generally decrease with decreasing elevation of the nearby tunnel

Data indicate water levels affected by drainage from aquifer to tunnel

Some of the wells with locally high water levels are associated with high angle faults (Des Plaines System)

*Aquifer less stressed due to elevated permeability or less flow to tunnel



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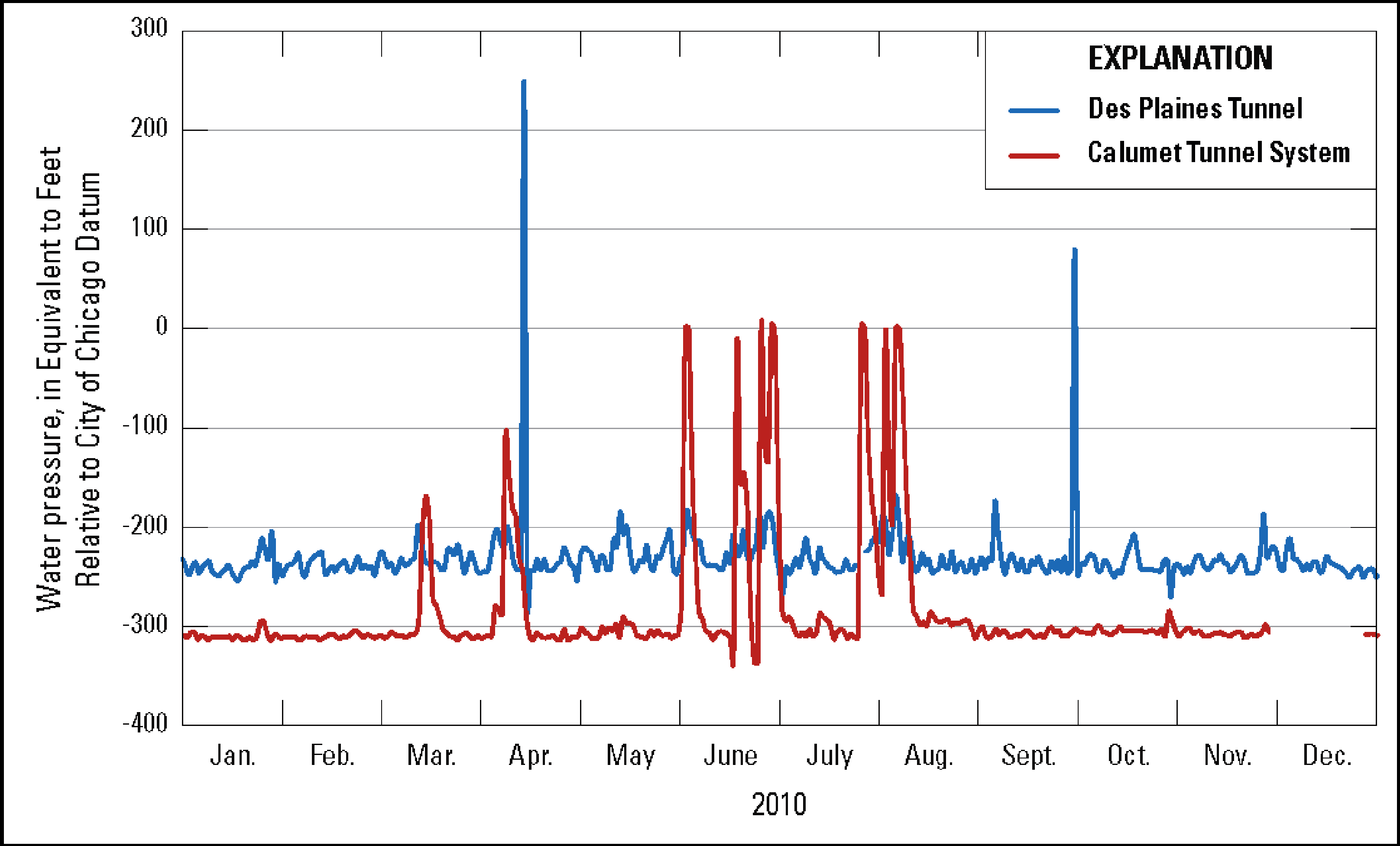
Head is elevated in TARP Tunnels during Combined Sewer Flow (CSF) Events



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Hydrology of TARP System

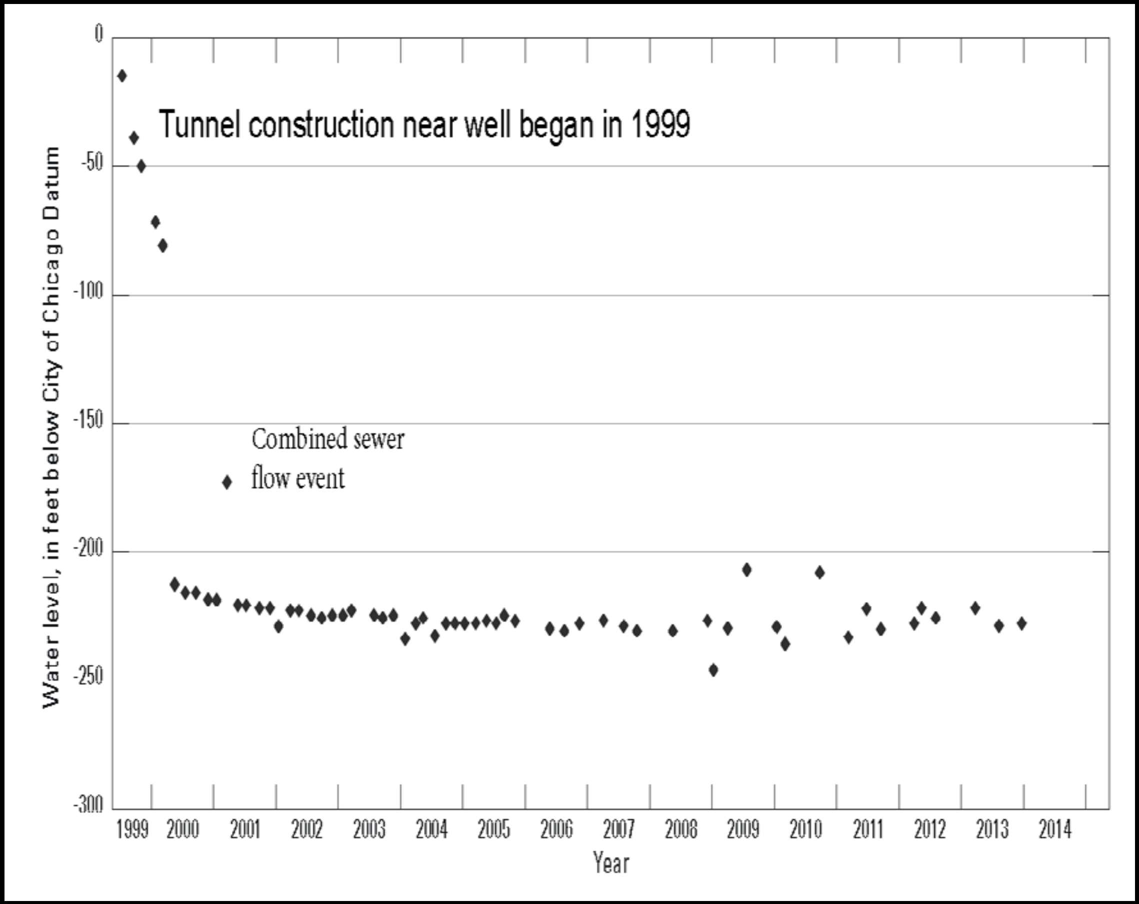
There is water exchange between the aquifer and the tunnels

Typically flow is from Silurian aquifer into the TARP tunnels, creates as much as 200 ft of water-level drop after tunnel construction that can extend more than 4,700 ft from the TARP tunnels

Once aquifer responds to drainage to tunnels, water levels are fairly constant

During intermittent CSF events water pressure inside the tunnels increases substantially, reversing typical gradient so that flow is temporarily from tunnel to aquifer

After CSF event, typical flow condition returns



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This hydraulic "push-pull" results in fluctuating concentrations of CSF components in the aquifer

Well	QC–2	QC–2	QC–2.2	QC–2.2	
Sampling date (month/day/year)	Groundwater level (feet from city of Chicago datum)	Fecal coliform (colony forming units per 100 milliliter)	Groundwater level (feet from city of Chicago datum)	Fecal coliform (colony forming units per 100 milliliter)	Discharge from Tunnel and Reservoir Plan system to Calumet Water Reclamation Plant (million gallons per day)
2/7/1996	−271	<1	ns	ns	26
2/22/1996	−269	<1	−240	<1	2
3/7/1996	−272	<1	−244	<1	18
3/21/1996	−271	<1	−247	<1	11
4/4/1996	−275	<1	−240	<1	6
4/18/1996	−273	<1	−248	<1	15
5/2/1996	−273	<1	−248	<1	64
5/16/1996	**−108**	**4,000**	−248	<1	**94**
5/30/1996	−254	**8,500**	−240	<1	3
6/13/1996	**−234**	<1	**−225**	**1,100**	**111**
6/27/1996	**−229**	**2,000**	−247	<1	20*
7/11/1996	−255	**260**	−238	<1	18
7/25/1996	**−102**	**3,600**	ns	ns	80
8/8/1996	**−230**	**3,100**	**−204**	<1	65
8/22/1996	−258	**210**	−249	<1	12
9/5/1996	−260	**19**	−246	<1	43
9/19/1996	−266	**2**	−235	<1	9
10/3/1996	**−235**	**2,600**	ns	ns	21**
10/17/1996	−262	**300**	ns	ns	31
10/31/1996	−266	**68**	ns	ns	13
11/14/1996	−268	**4**	ns	ns	20
11/27/1996	−272	<1	ns	ns	7
12/12/1996	−272	<1	ns	ns	43
12/26/1996	−277	<1	ns	ns	41

* Discharge >75 Mgal/d on June 22, 23, 24, 1996

**Discharge 77 Mgal/d on Sept 29, 1996

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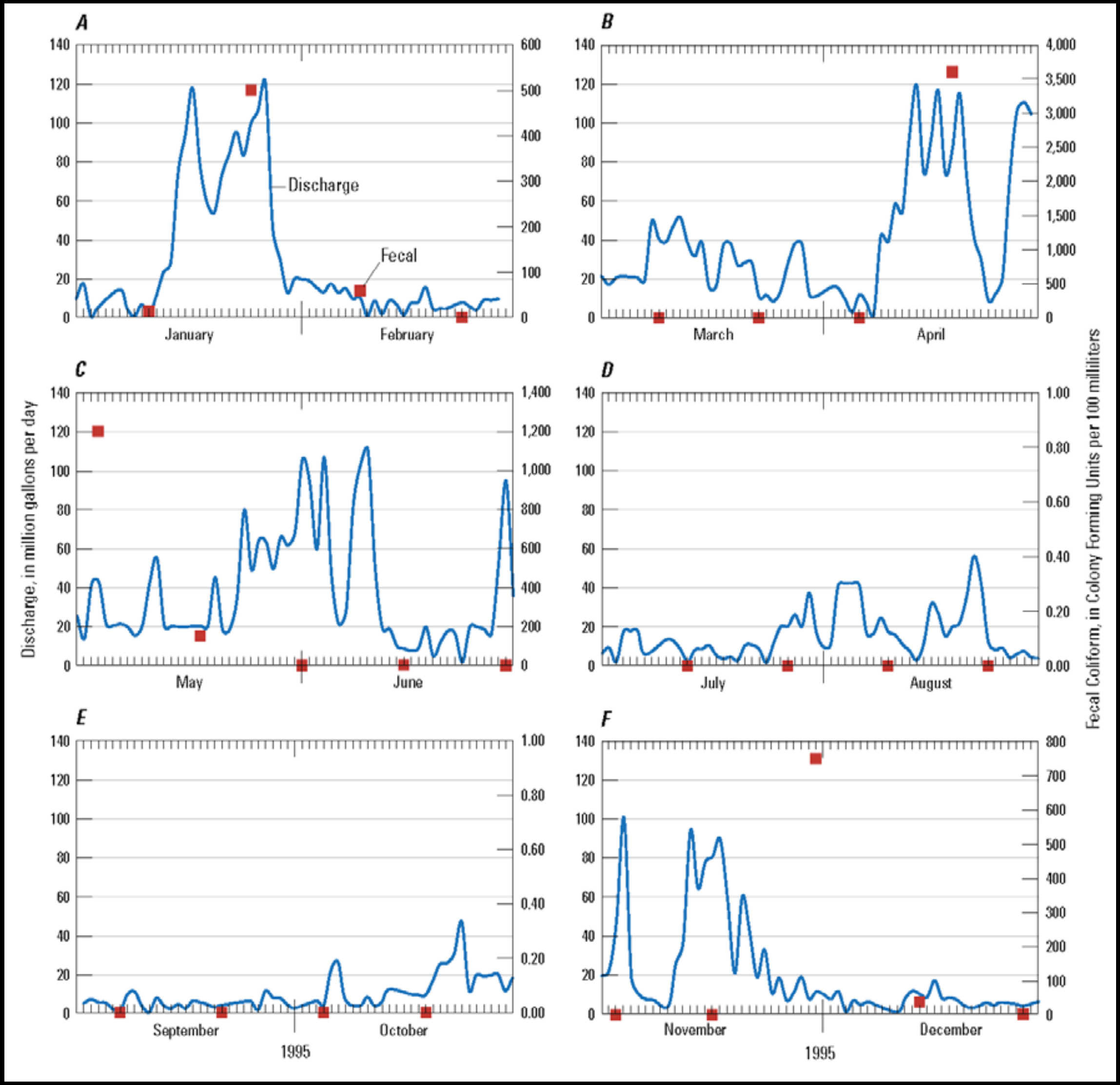
This hydraulic "push-pull" results in fluctuating concentrations of CSF components in the aquifer

Fecal coliform concentrations in QC-2 increase following CSF events producing TARP discharge in excess of 80 Mgd—roughly the minimum discharge sufficient to move water from the tunnels into the surrounding Silurian aquifer

Concentrations increase substantially within 2 weeks of the CSO event, then decrease to near non-detect within about 1 month as ambient flow toward the tunnels flushes the fecal coliform from the aquifer



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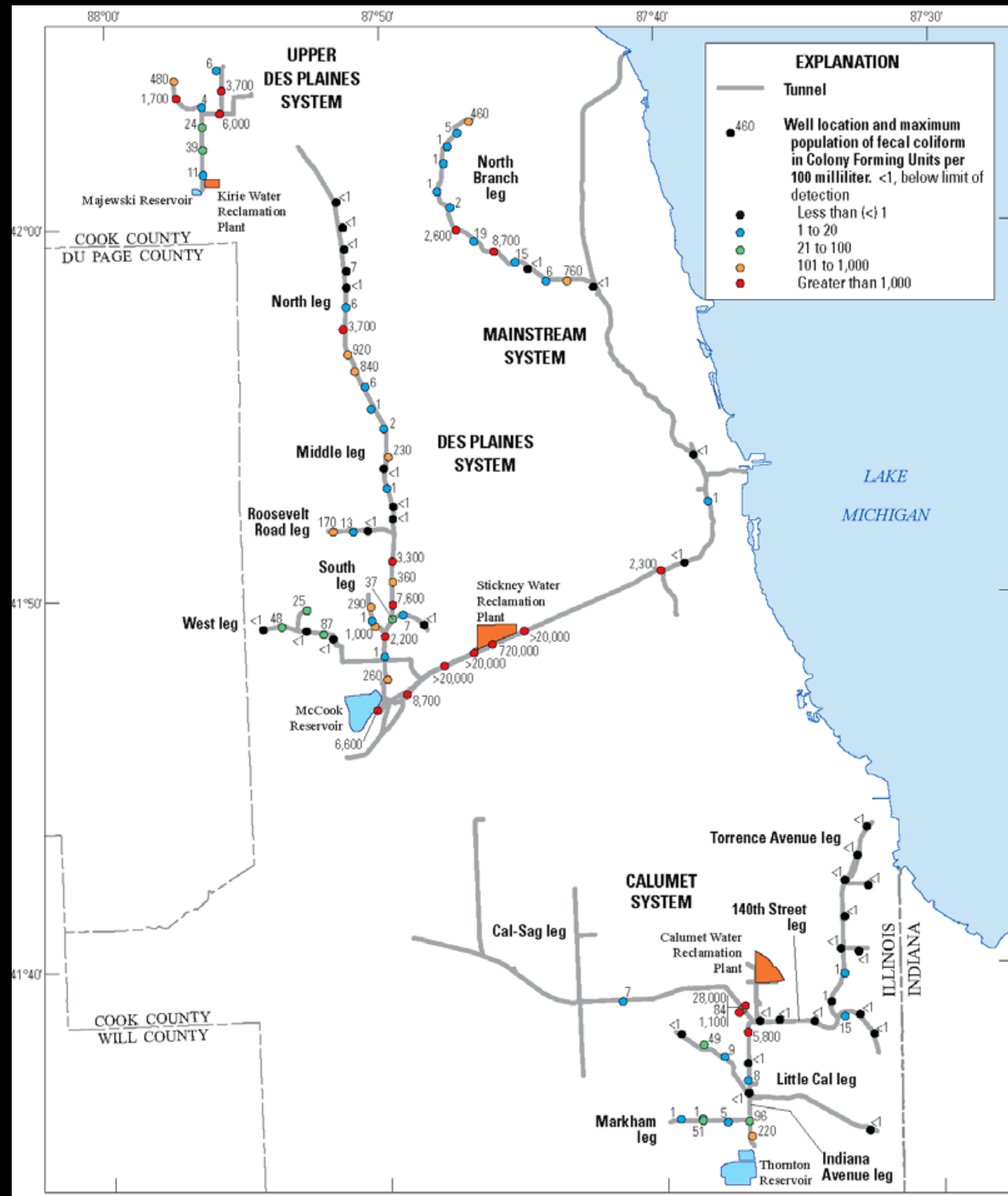
Fecal Coliform Concentrations

Not naturally present in the Silurian aquifer so detections indicate CSF impacts

Best indicator of TARP impacts

Consistently very high concentrations near downstream end of Mainstream and Des Plaines Tunnels.



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Fecal Coliform Frequency of Detection

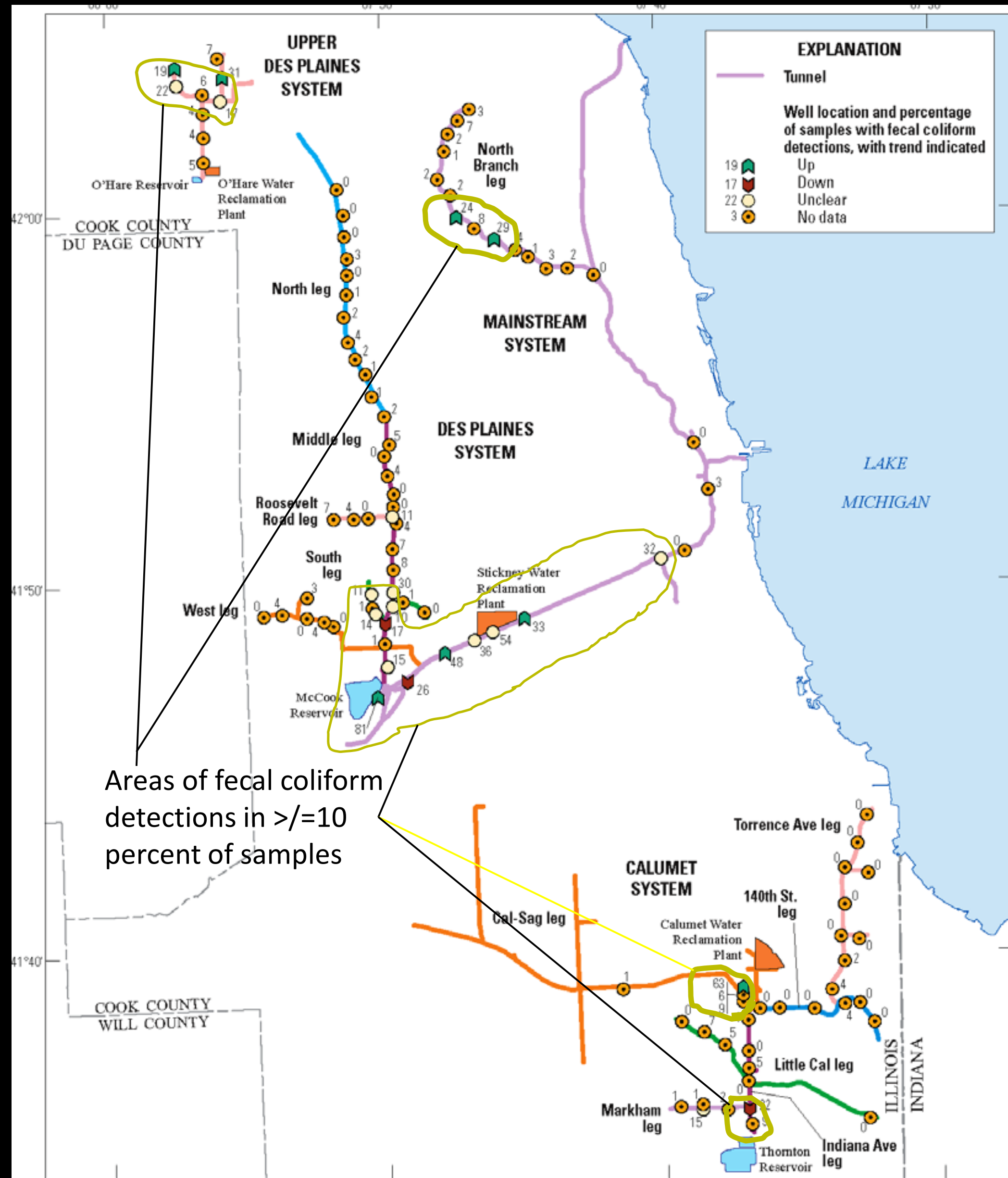
Detected in less than 10 percent of samples in 83 of 106 wells

Detected in >50 percent of samples in two wells

Detected most often in downstream parts of Calumet, Des Plaines, and Mainstream tunnels. Where water is present in tunnels longest and under highest hydraulic pressures

Promotes CSF migration to aquifer

Hydraulics and water quality likely to change once McCook Reservoir is connected to tunnels



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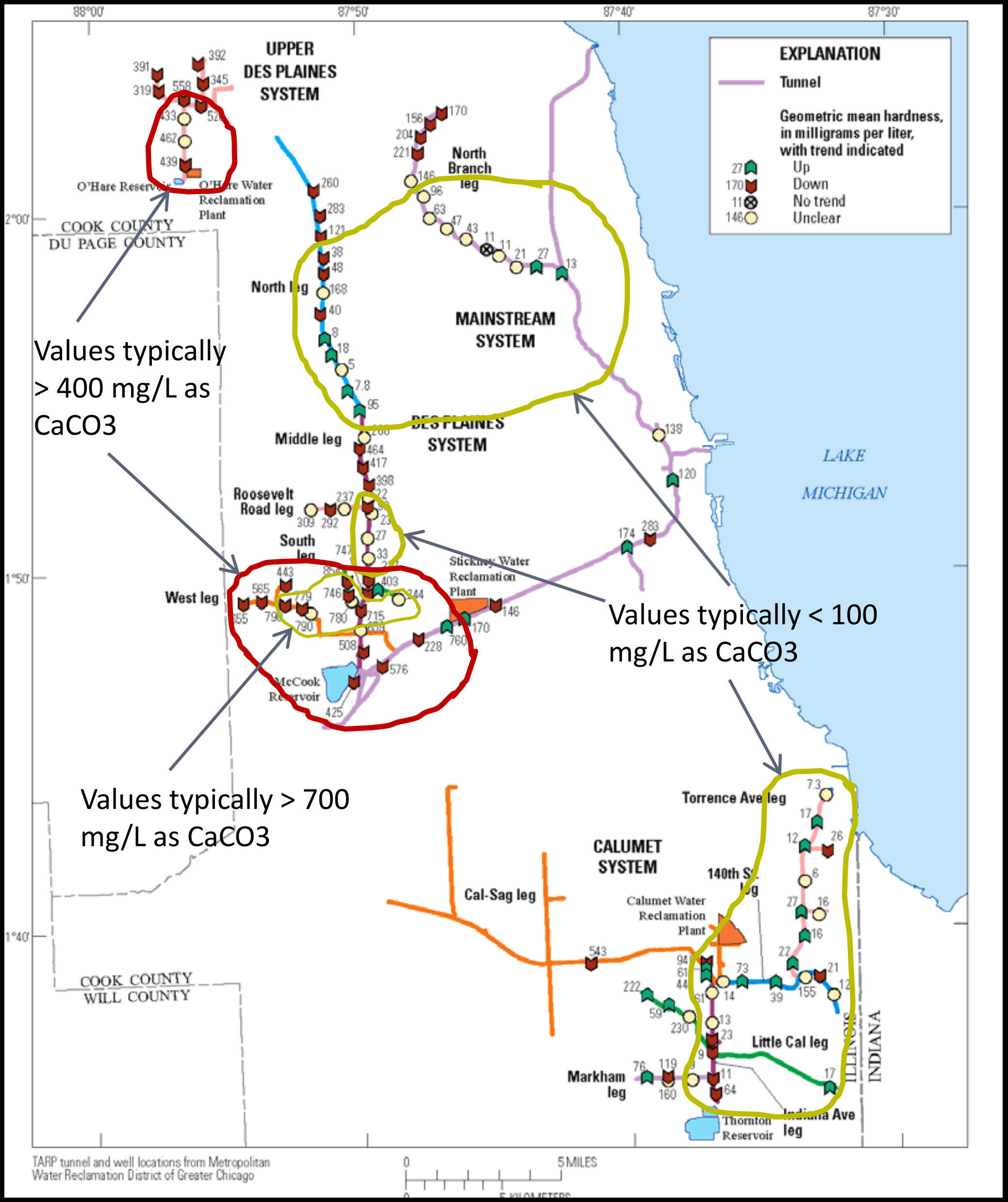
Hardness Values in TARP wells

*Above 400 mg/L as CaCO3 in much of Upper Des Plaines System and Des Plaines and Mainstream Systems near future McCook Reservoir

*Values more than 700 mg/L as CaCO3 along Des Plaines System north of future McCook Reservoir

*Values less than 100 mg/L as CaCO3 in northern parts of Mainstream and Des Plaines Systems and much of Calumet System



Generally consistent with increased CSF drainage to aquifer in lower parts of non-Calumet tunnel systems.

BUT

"Background" Hardness in the Silurian Aquifer

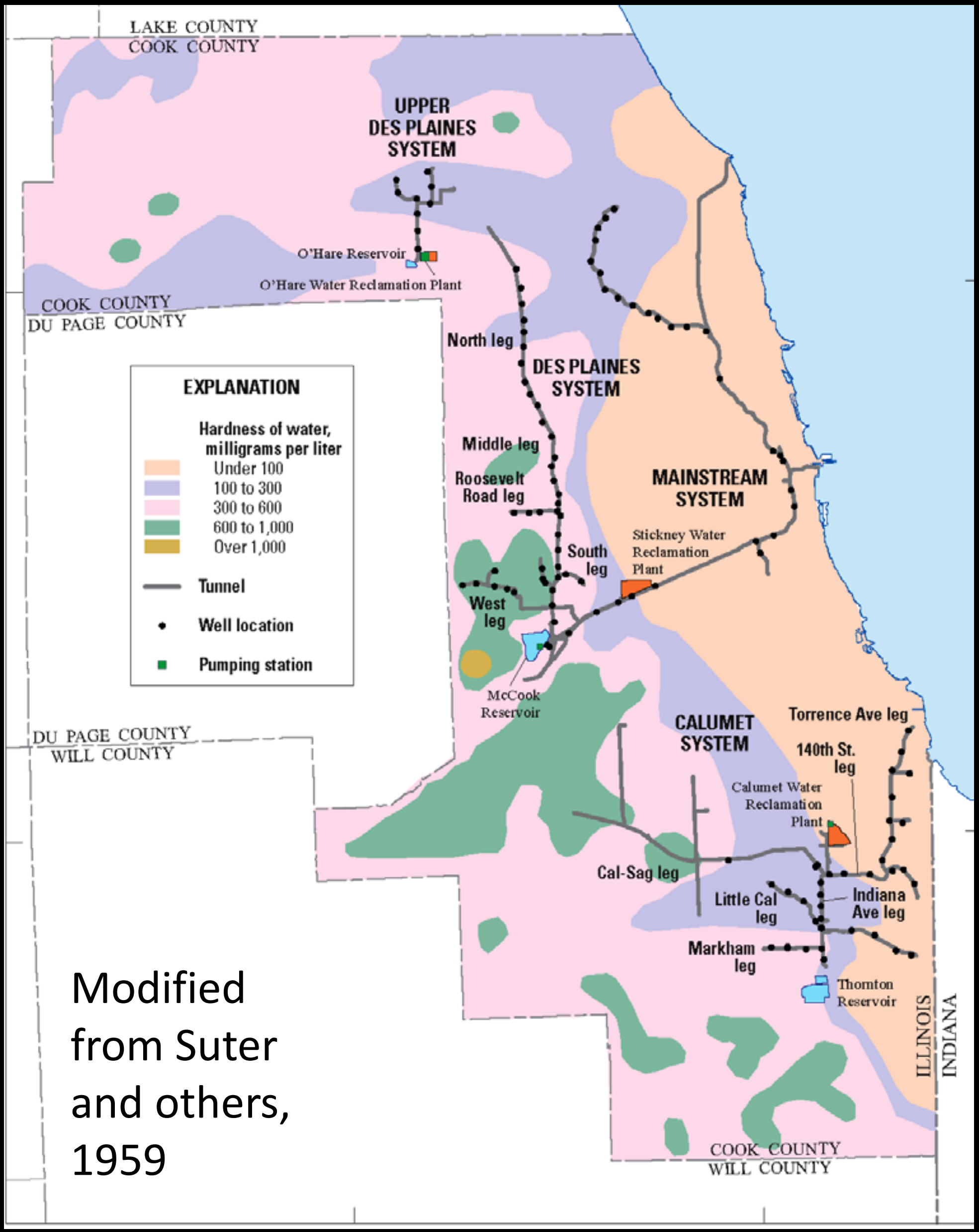
Sampling prior to 1959, before TARP went on line

Less than 100 mg/L as CaCO3 near Lake Michigan

More than 600 mg/L as CaCO3 near lower part of Des Plaines tunnel

More than 1,000 mg/L as CaCO3 near LaGrange, where dolomite is near land surface

No hardness data from TARP discharge, but concentrations and spatial patterns indicate hardness values in TARP wells primarily reflects chemistry of Silurian aquifer—consistent with fixed schedule sampling



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Chloride Concentrations in TARP wells

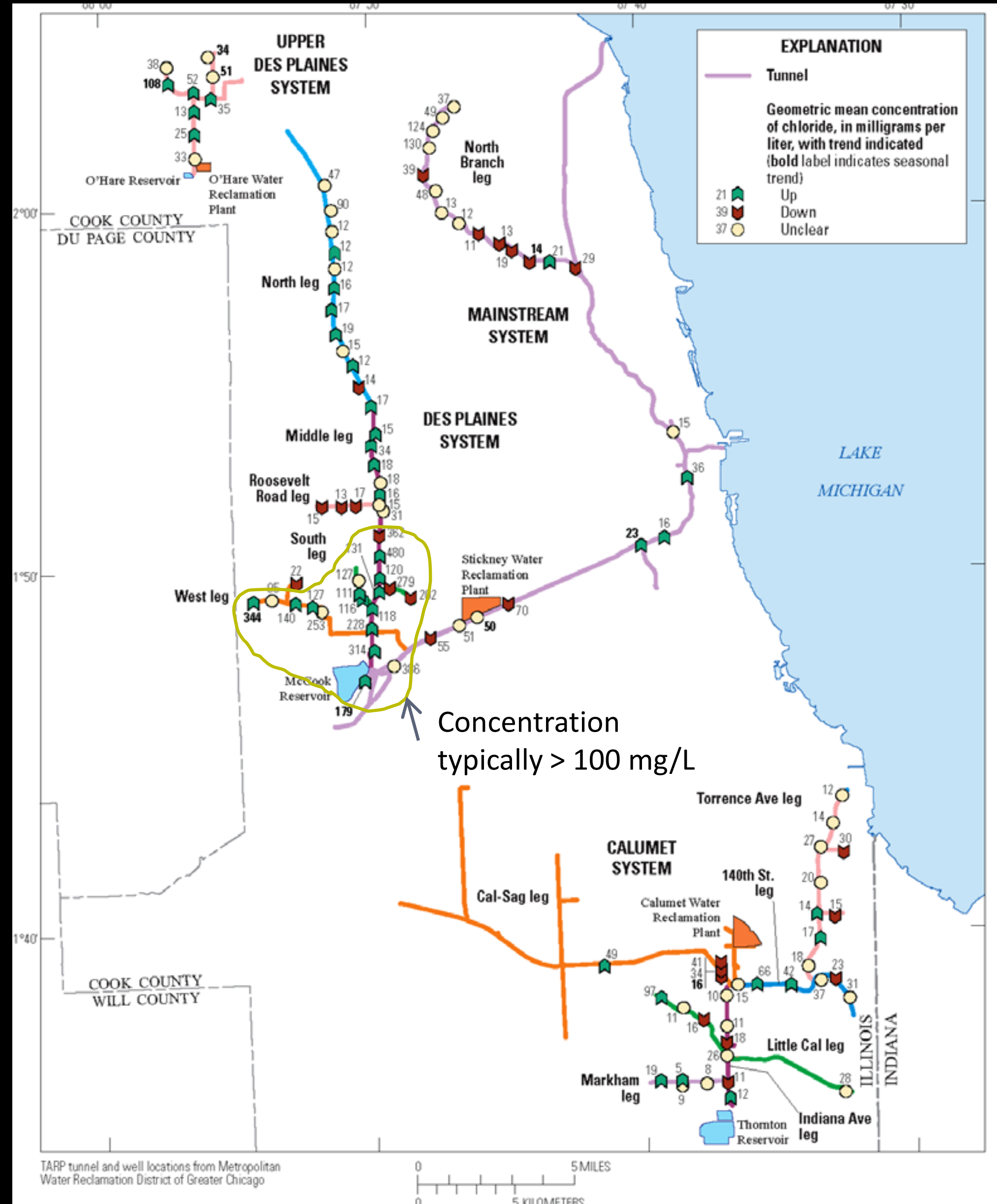
Highest geometric mean chloride concentrations in vicinity of future McCook Reservoir.

Roughly similar to pattern in fecal coliform

Data consistent with increased TARP discharge in southern part of Des Plaines and Mainstream Systems

Also where hardness is highest

Also where bedrock is near land surface and non-TARP chloride concentrations are increasing through time



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"Background" Chloride Concentrations in Silurian Aquifer

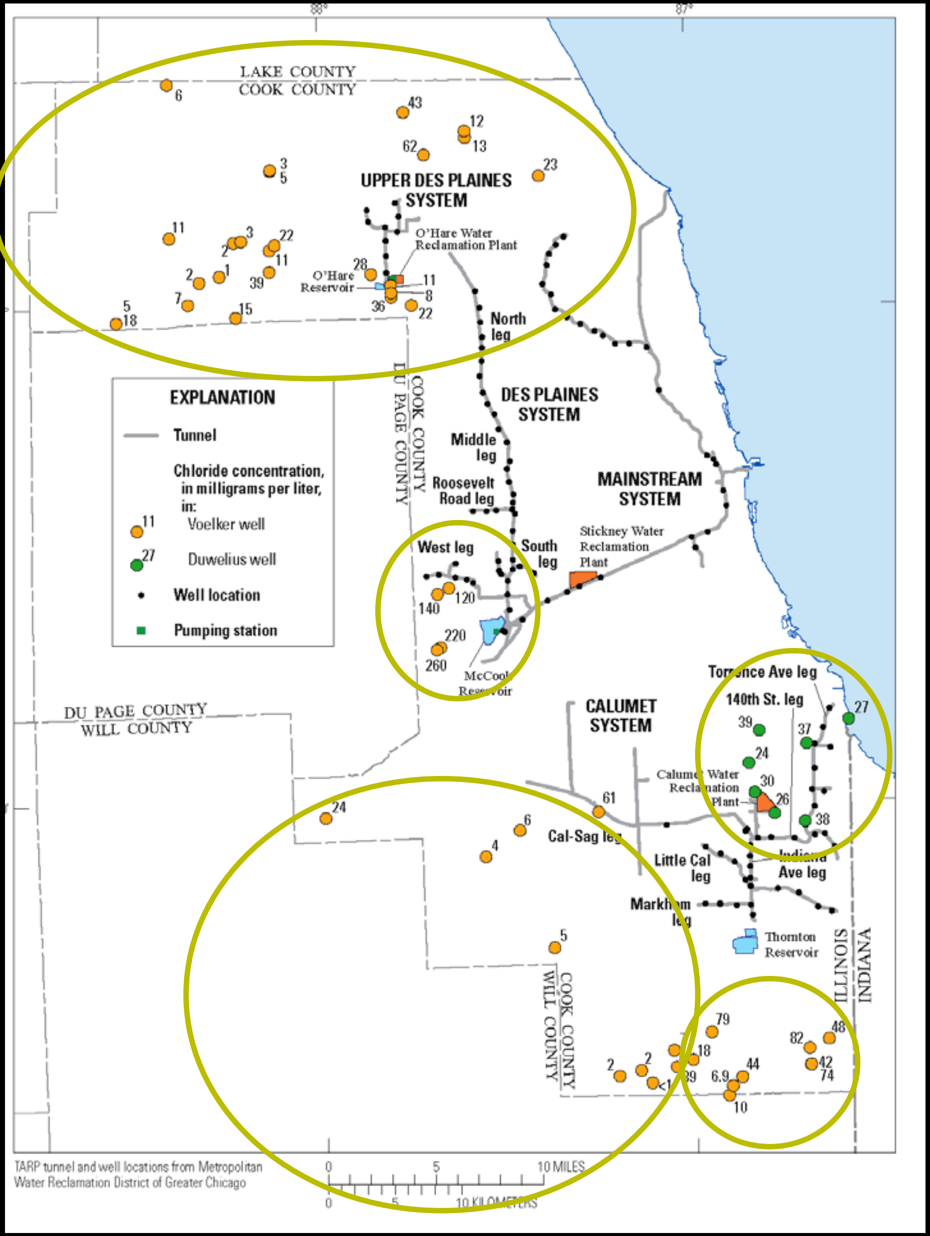
*Typically less than 25 mg/L in northern and southwestern parts of County

*More than 100 mg/L near LaGrange and future McCook reservoir

*About 30 mg/L near Calumet area

*Often greater than 40 mg/L in far southeastern part of County

Mean concentrations in TARP wells likely affected primarily by chloride concentrations in the Silurian aquifer near the well



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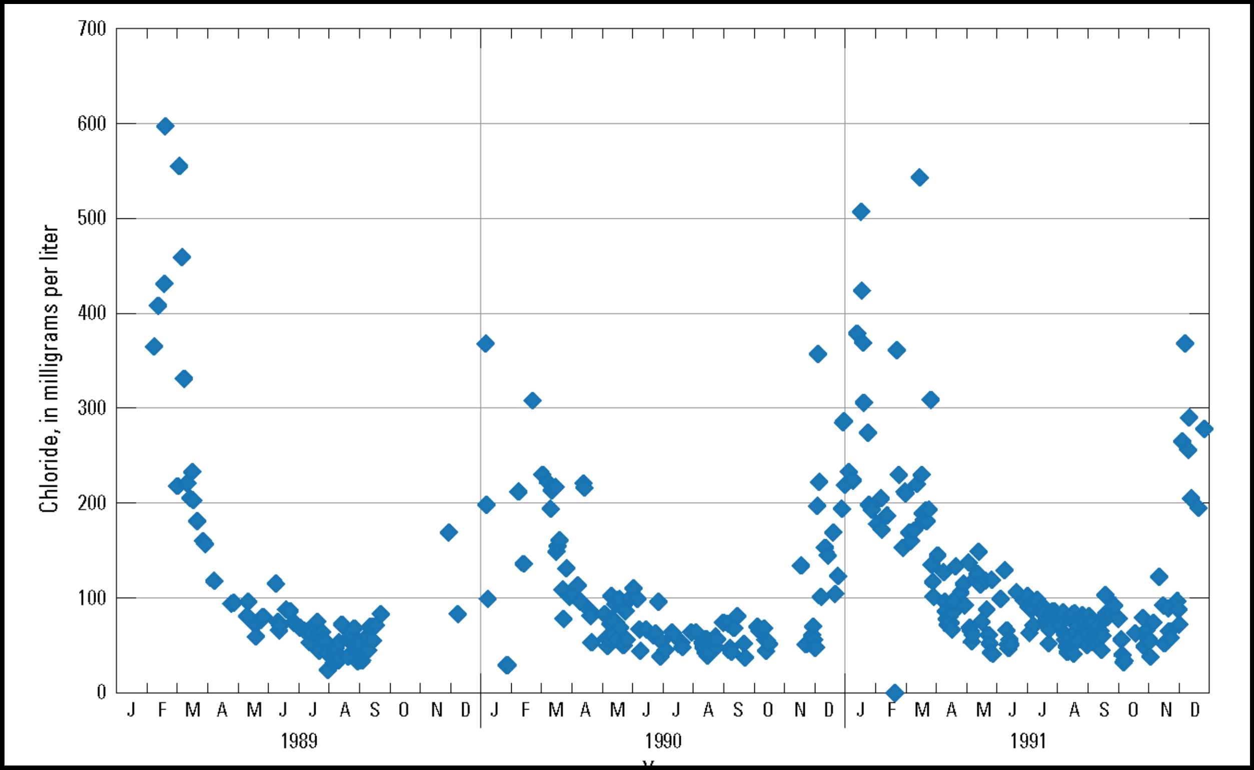
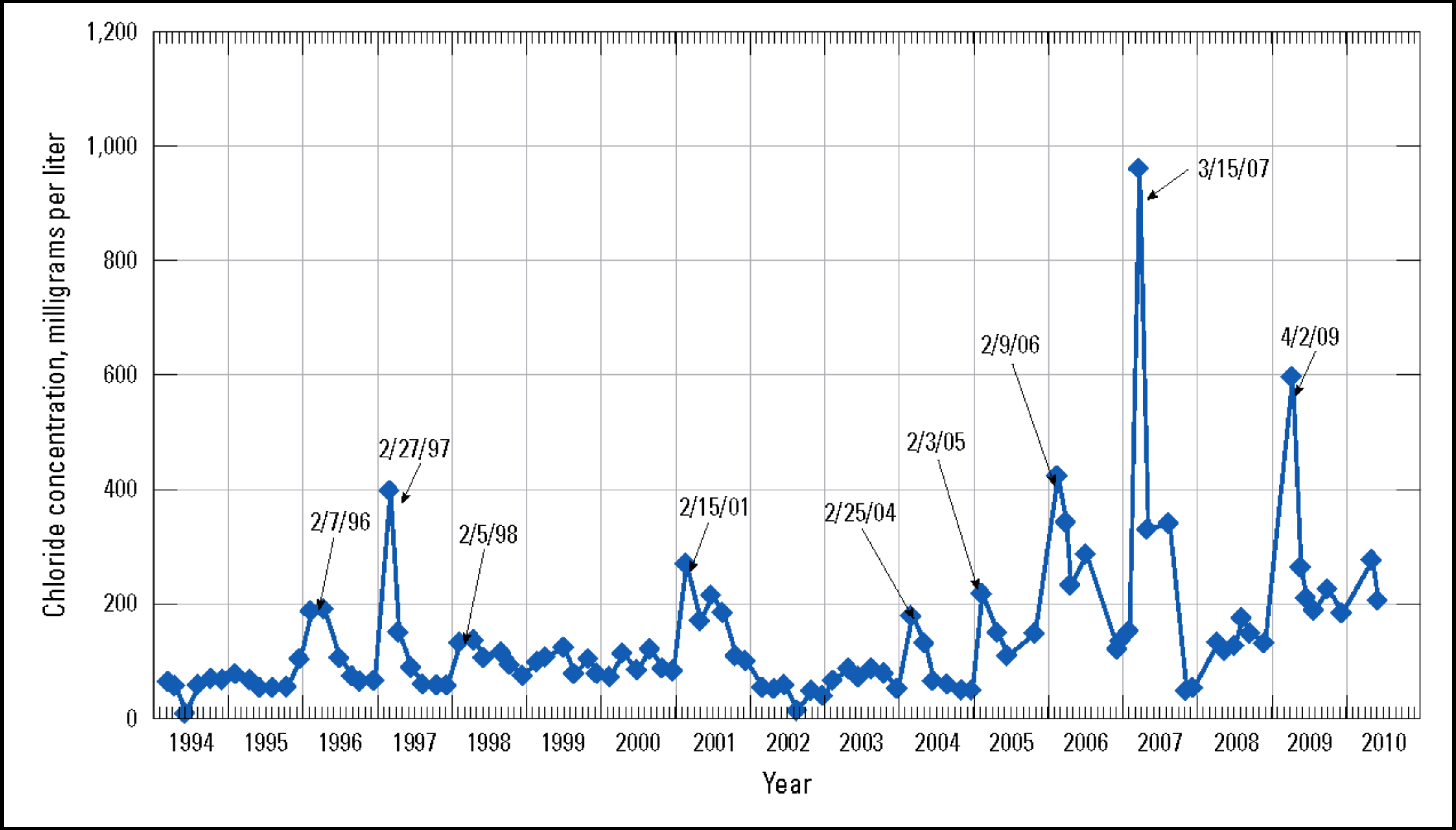
Seasonal variation in chloride concentration in TARP discharge due to road salt application



Chloride in TARP monitoring well MW5—elevated Cl always preceded by high discharge through TARP system



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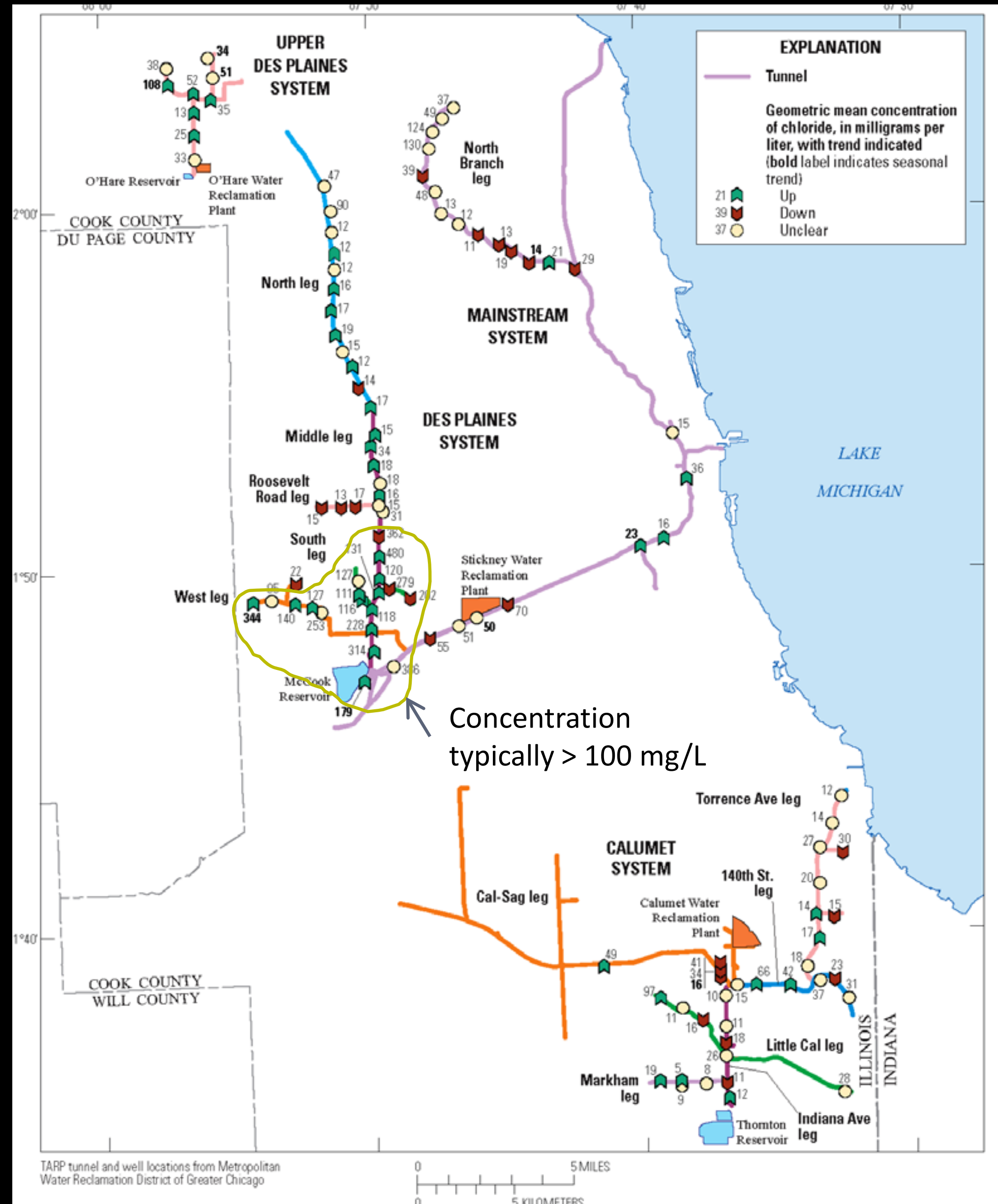
Chloride Concentrations in TARP wells

Seasonal trend in chloride concentrations identified in a few wells.

Highest in winter and spring, return to "base line" over a period of months.

Some TARP discharge at these wells.



Electrical Conductance

Geometric mean values in CSF ~1,100 umho/cm

In TARP wells, generally lower near Lake Michigan and highest near the future McCook Reservoir

Consistent with increased TARP discharge in lower part of Des Plaines and Mainstream systems but also consistent with natural variation within the Silurian aquifer

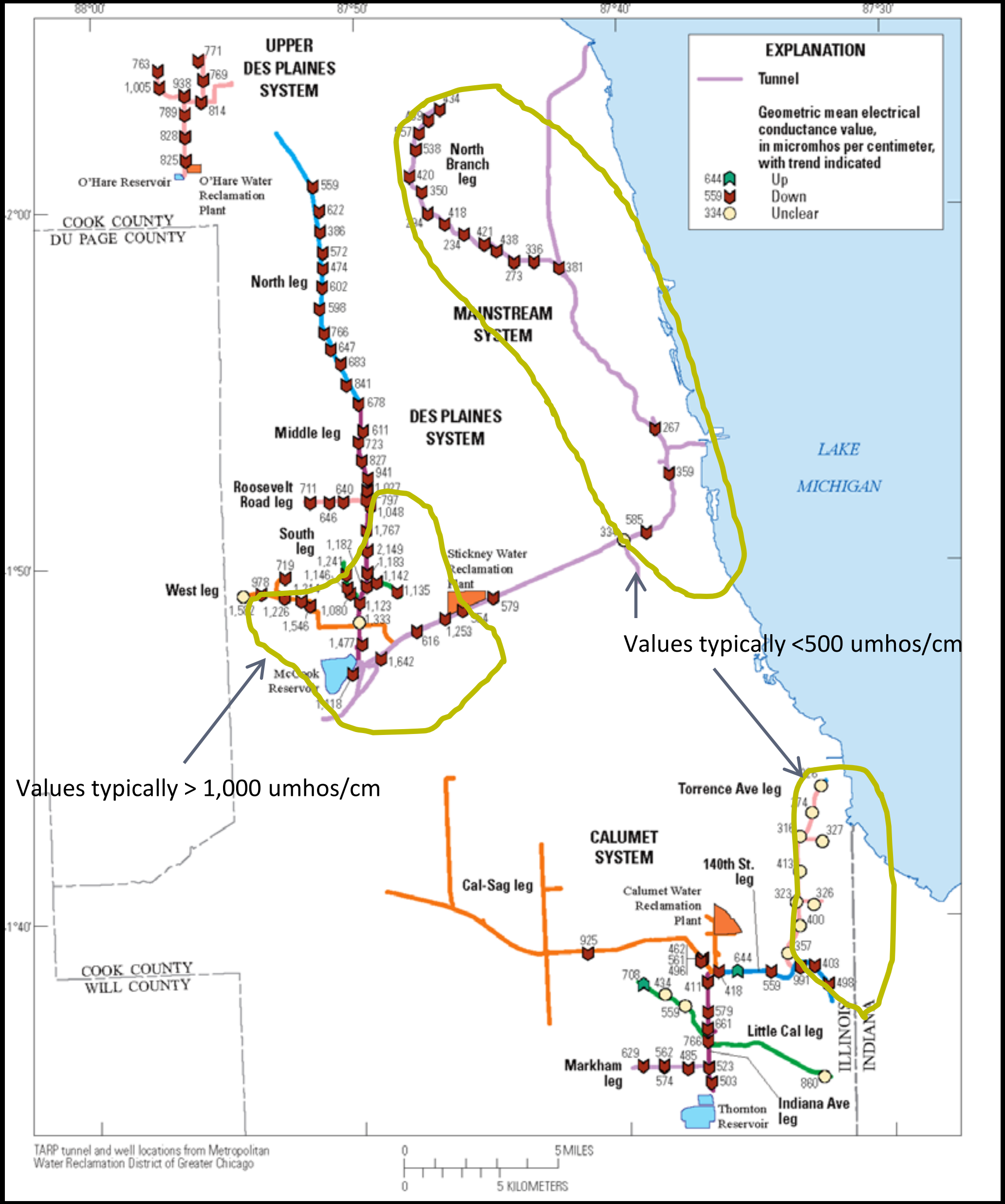
From 1995 to 2013 EC values showed a statistically significant decrease in 91 of 106 wells.

Except comparatively new wells on Torrence Avenue leg of Calumet System

Would likely increase through time if CSF impacts

Indication most samples are of aquifer water due to fixed schedule sampling

Indicates migration of lower conductivity water in the (shallower?) Silurian aquifer to the wells over time?



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Sulfate

Concentrations in TARP wells vary spatially

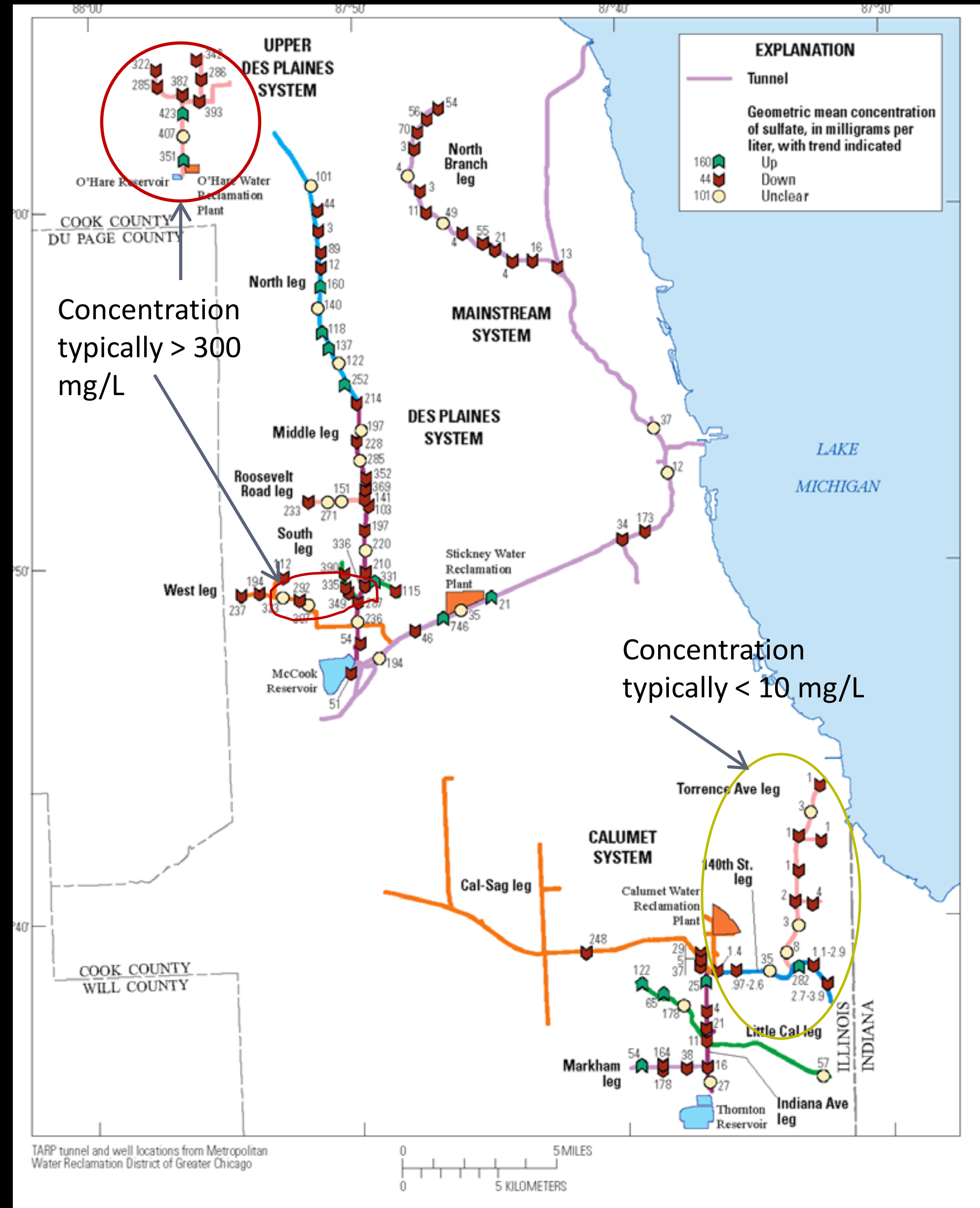
Tend to be lowest near Lake Michigan

Concentrations in aquifer not well characterized

Concentrations in CSF 80-210 mg/L

Sulfate concentrations likely reflect primarily aquifer water in the TARP well samples

Not useful for identifying CSF



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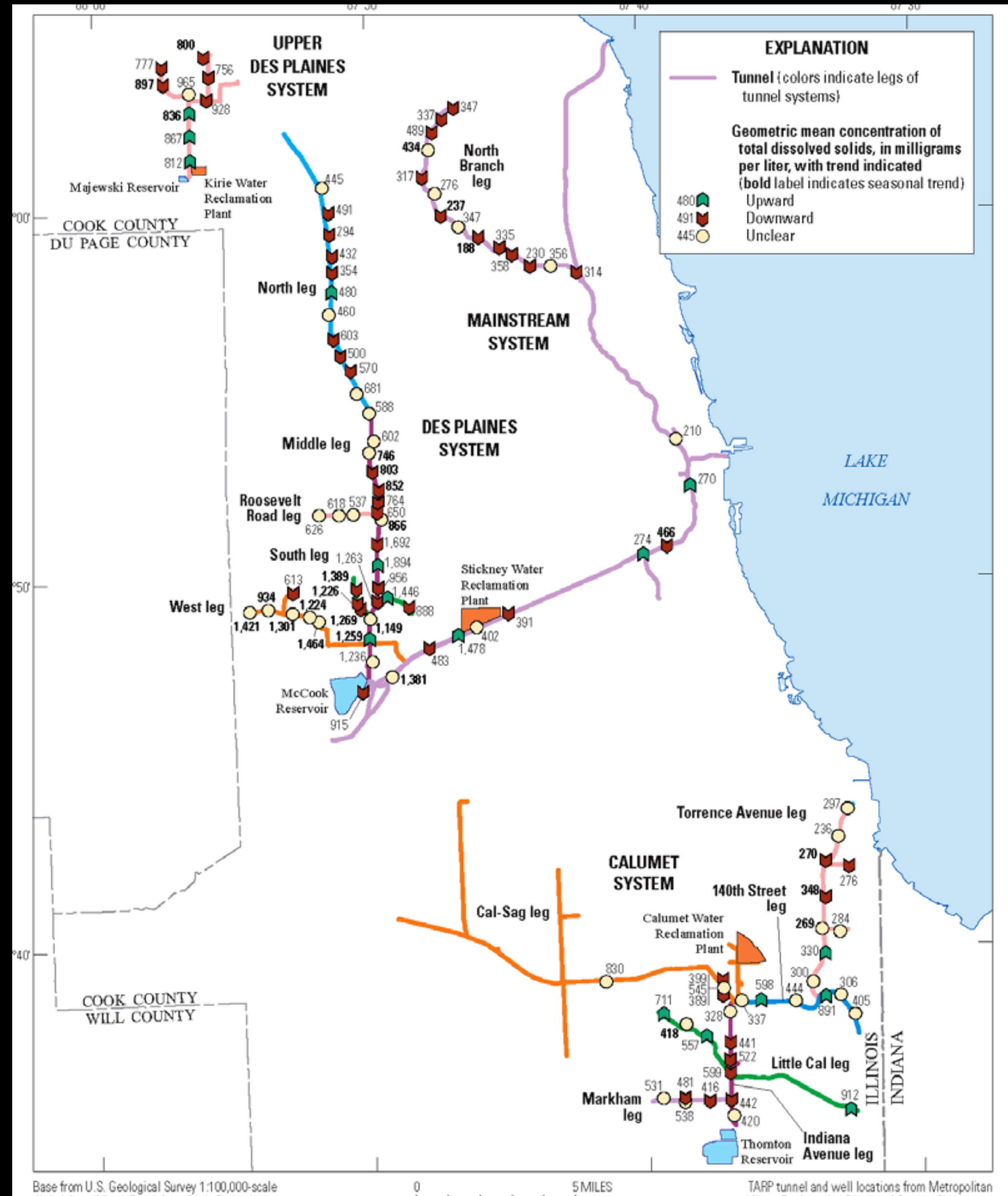
Total Dissolved Solids

Not characterized in aquifer or in CSF but generally related to concentration of major ions

Typically above 1,000 mg/L near McCook Quarry

Seasonal variation in 20 wells

- Mostly high in Summer low in Winter
- Unclear why but could be related to seasonal variation in amount of CSF discharge



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Ammonia as N

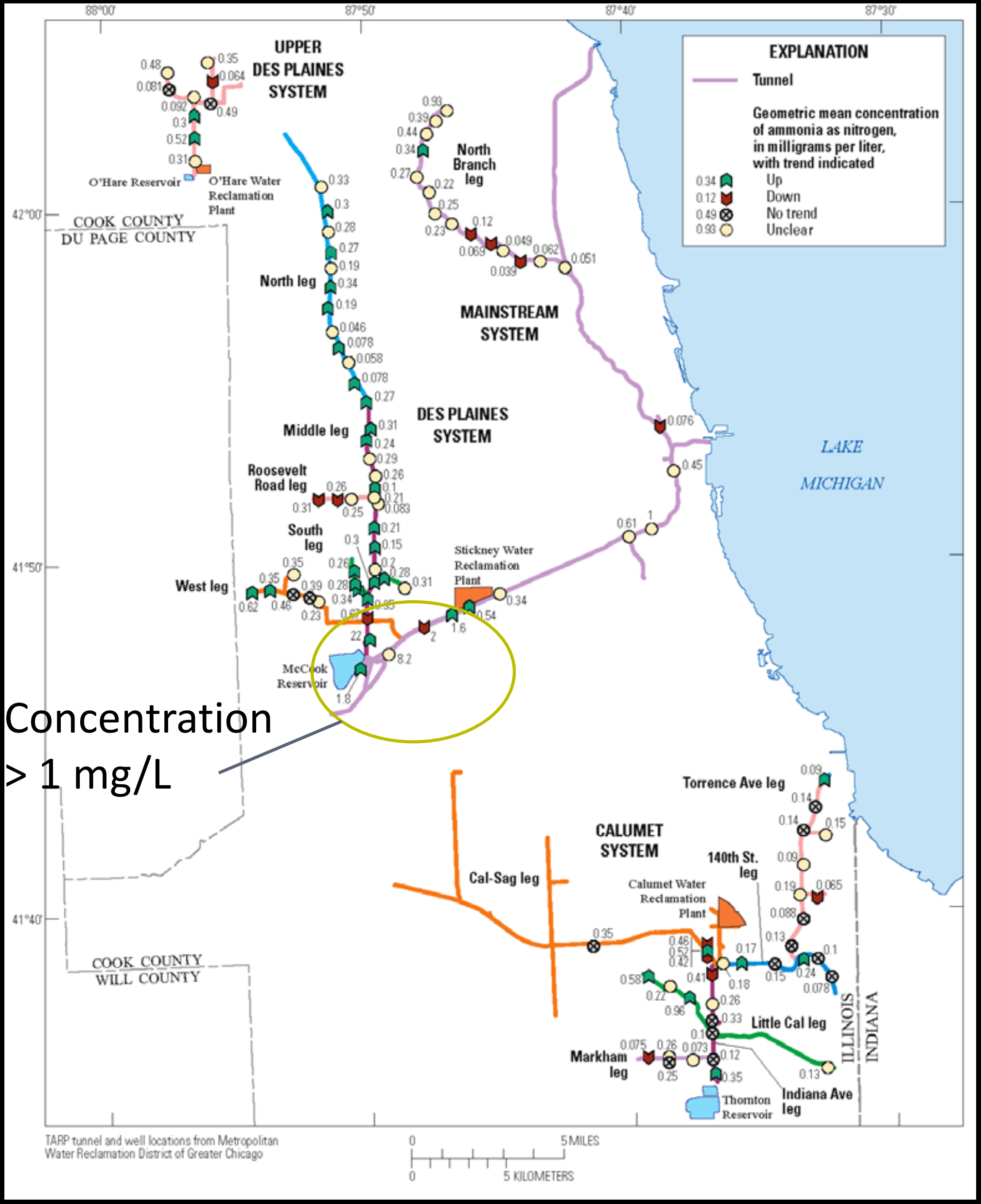
Ammonia concentrations in the ambient Silurian aquifer <1 mg/L from regional studies, but not well characterized

Ammonia concentration in CSF 9-30 mg/L

TARP-affected water will have a higher ammonia concentration

Geometric mean concentration of ammonia in the TARP monitoring wells >1 mg/L near future McCook reservoir, as high as 22 mg/L

Ammonia concentrations in TARP wells likely affected by TARP discharge to Silurian aquifer near McCook



Concentration > 1 mg/L

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Dissolved Organic Carbon

Concentrations in ambient Silurian aquifer <2-83 mg/L, median of 7.1 mg/L, not well characterized

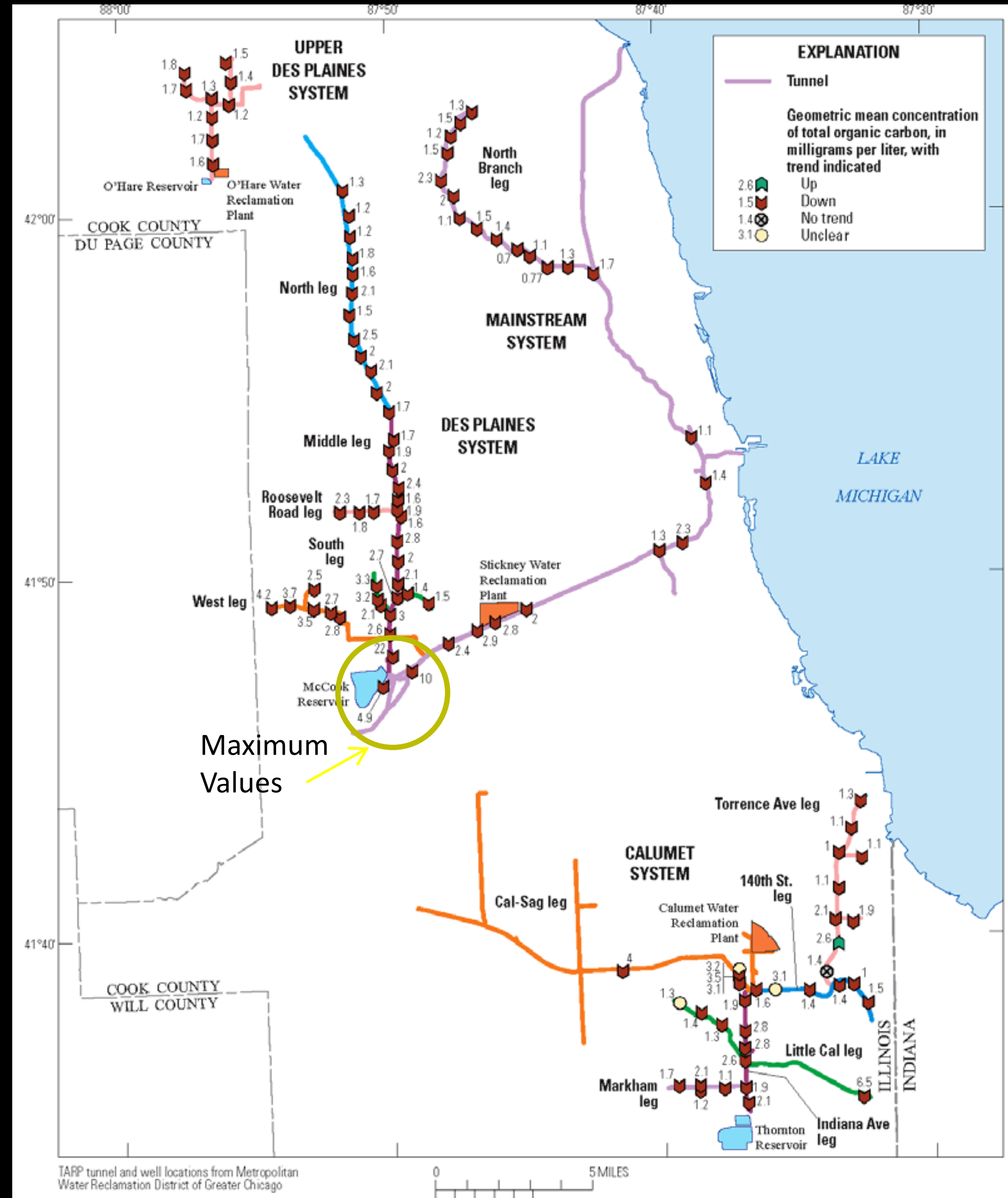
Geometric mean concentration in CSF ranged from 21 to 51 mg/L

TARP-influenced water likely to be high in DOC

Geometric mean DOC concentrations in TARP wells >4.5 mg/L near McCook reservoir

DOC concentrations likely affected by some TARP discharge near McCook Reservoir

Downward trend in concentration in essentially every well—indicates aquifer flow?



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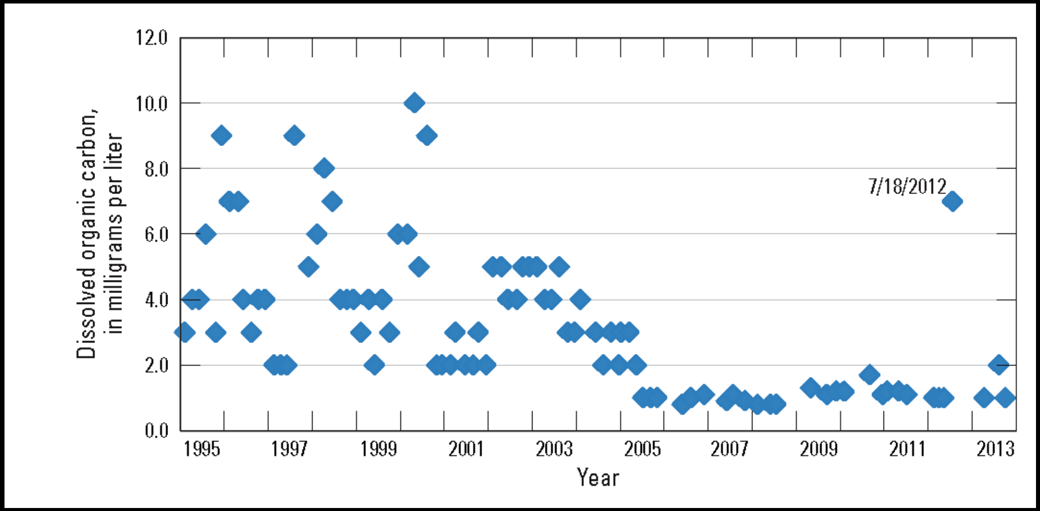
Dissolved Organic Carbon

Concentrations drop in 2005 associated with a shift in analytical instrumentation

May or may not be real decrease through time



Summary

- Flow typically from Silurian aquifer to TARP system, but can be reversed for periods of time due to >80 Mgal/d combined sewer flow events
- Water-quality in the monitoring wells is primarily a reflection of the water quality in that part of the Silurian aquifer draining to the part of the TARP System being monitored by a given well.
- Constituents dissolved in combined sewer flow are periodically detected in the monitoring wells
  - Typically for a period of 2-4 weeks
  - Seasonally for chloride and TDS in some wells
  - An event-based sampling regimen would better allow for the detection of these constituents
- Impacts of combined sewer flow are greatest in the downstream parts of the Calumet, Mainstream, and Des Plaines Tunnel Systems
- Understanding groundwater quality in the Silurian aquifer and in CSF in space and time is crucial to assessing the impacts of combined sewer flow on the aquifer
  - Multiple analytical methods needed

Thanks

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