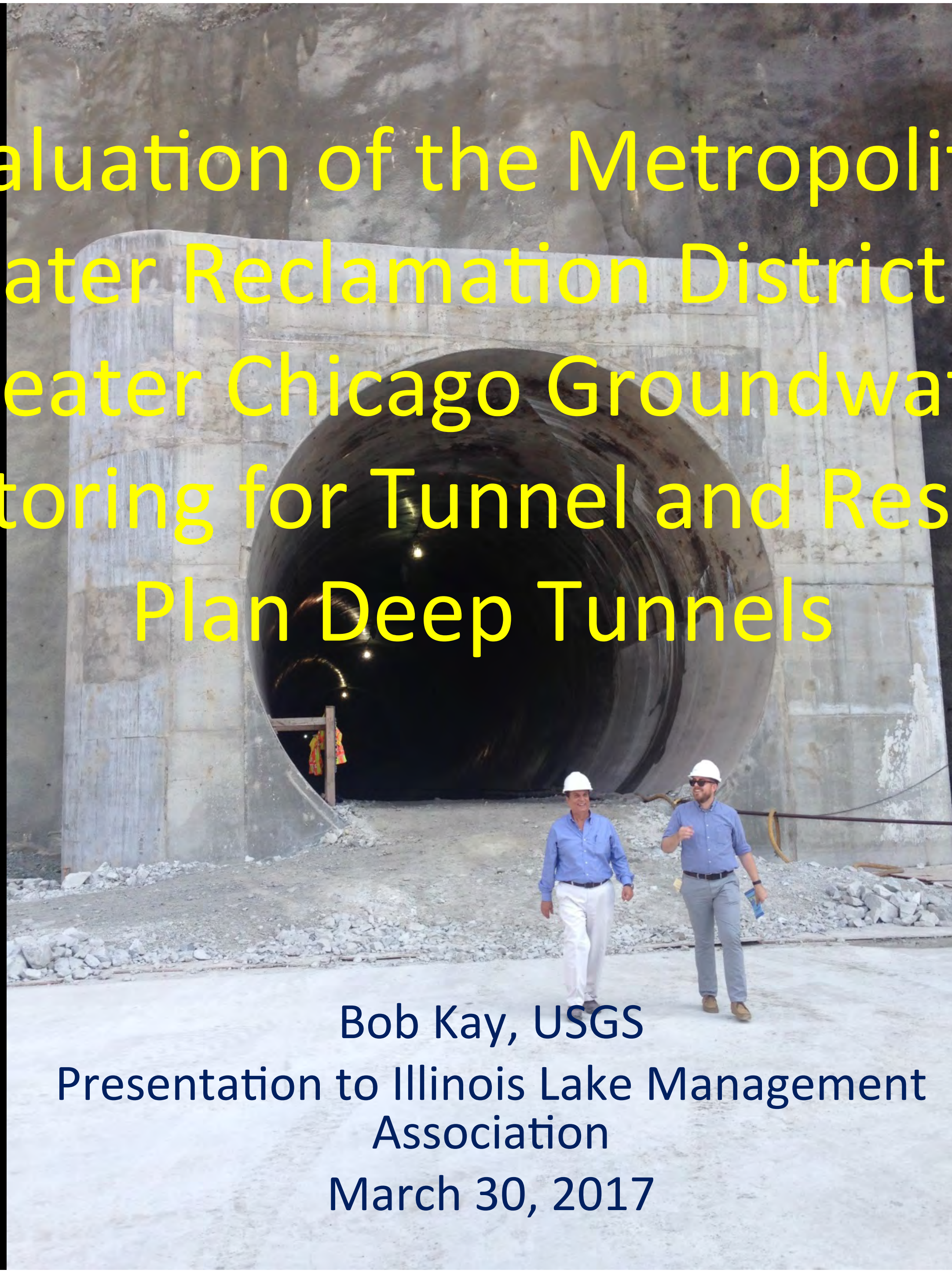
Evaluation of the Metropolitan Water Reclamation District of Greater Chicago Groundwater Monitoring for Tunnel and Reservoir Plan Deep Tunnels



Bob Kay, USGS

Presentation to Illinois Lake Management Association

March 30, 2017

Problem

- Most of Chicago area has combined sewers—stormwater, industrial wastewater, and domestic sewage transmitted through same pipes
- As urbanization increased sewers were unable to handle flow from storm events
- Resulting in Combined Sewer Overflow (CSO) to local waterways, roads, basements, occasionally Lake Michigan
- Health issues, damage to ecosystems

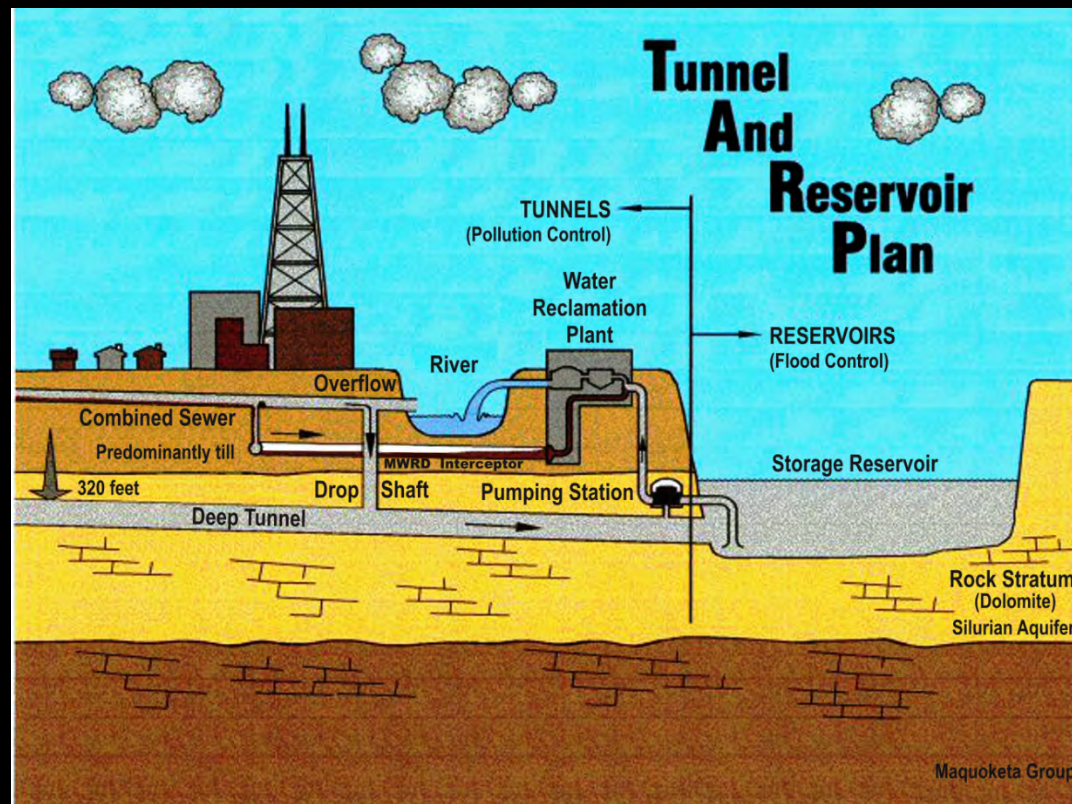
Solution: Tunnel and Reservoir Plan (TARP)

*Divert CSO to deep tunnels in Silurian dolomite bedrock

*Store water in tunnels and reservoirs

*Treat water at Water Reclamation Plants as capacity becomes available

*Safely discharge treated wastewater



Modified from Metropolitan Water Reclamation District of Greater Chicago, 2013

TARP System

Upper Des Plaines drains to Majewski Reservoir

*Tunnels on line in 1981

*Reservoir on line in 1998

Des Plaines and Mainstream Systems drain toward McCook Reservoir

*Tunnels constructed by 1999

*Reservoir on line in 2017

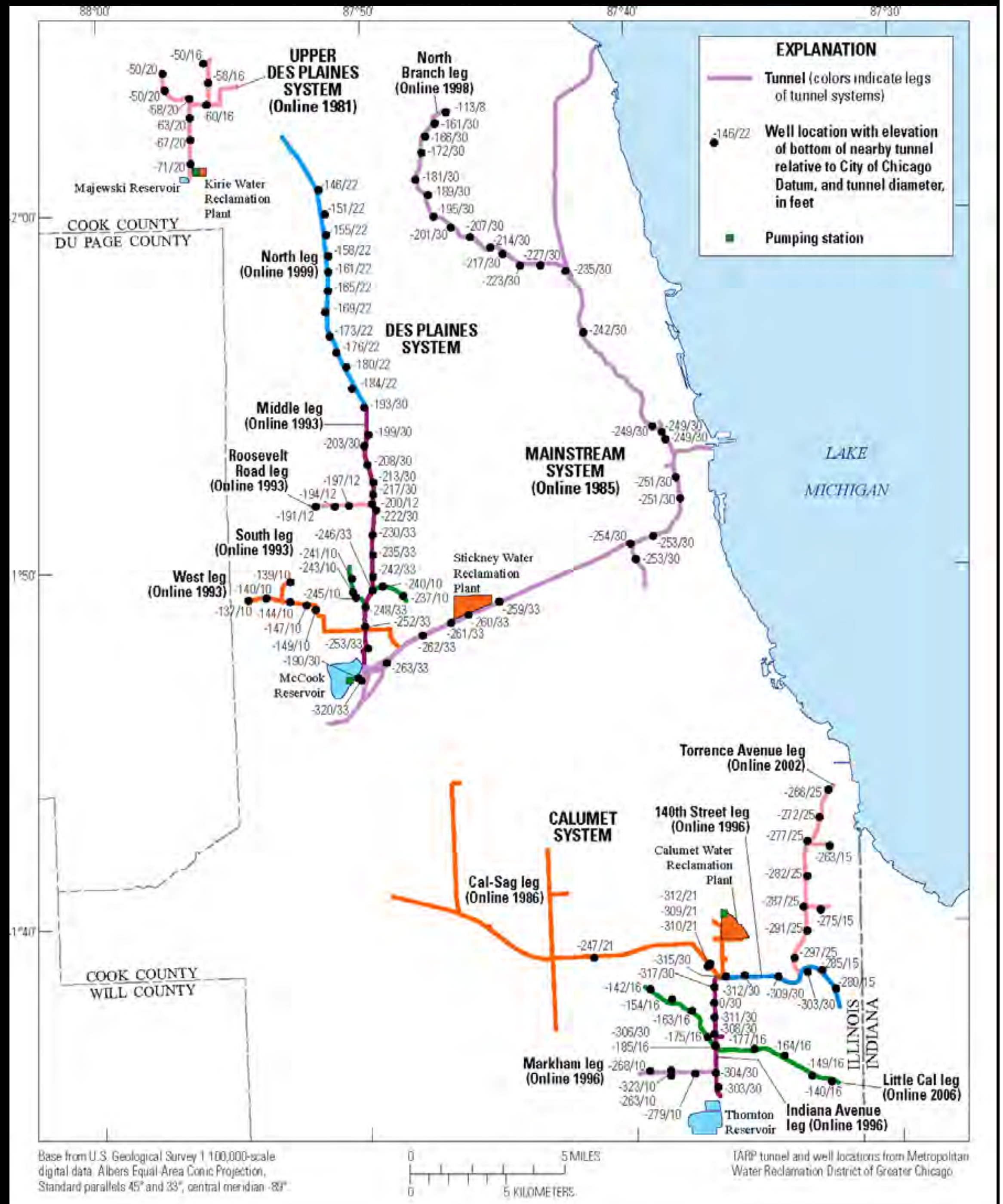
Calumet System drains to Thornton Reservoir

*Tunnels constructed by 2002

*Reservoir on line in 2015

Tunnels concrete lined and grouted, up to 30 ft in diameter

Reservoirs are low points in system



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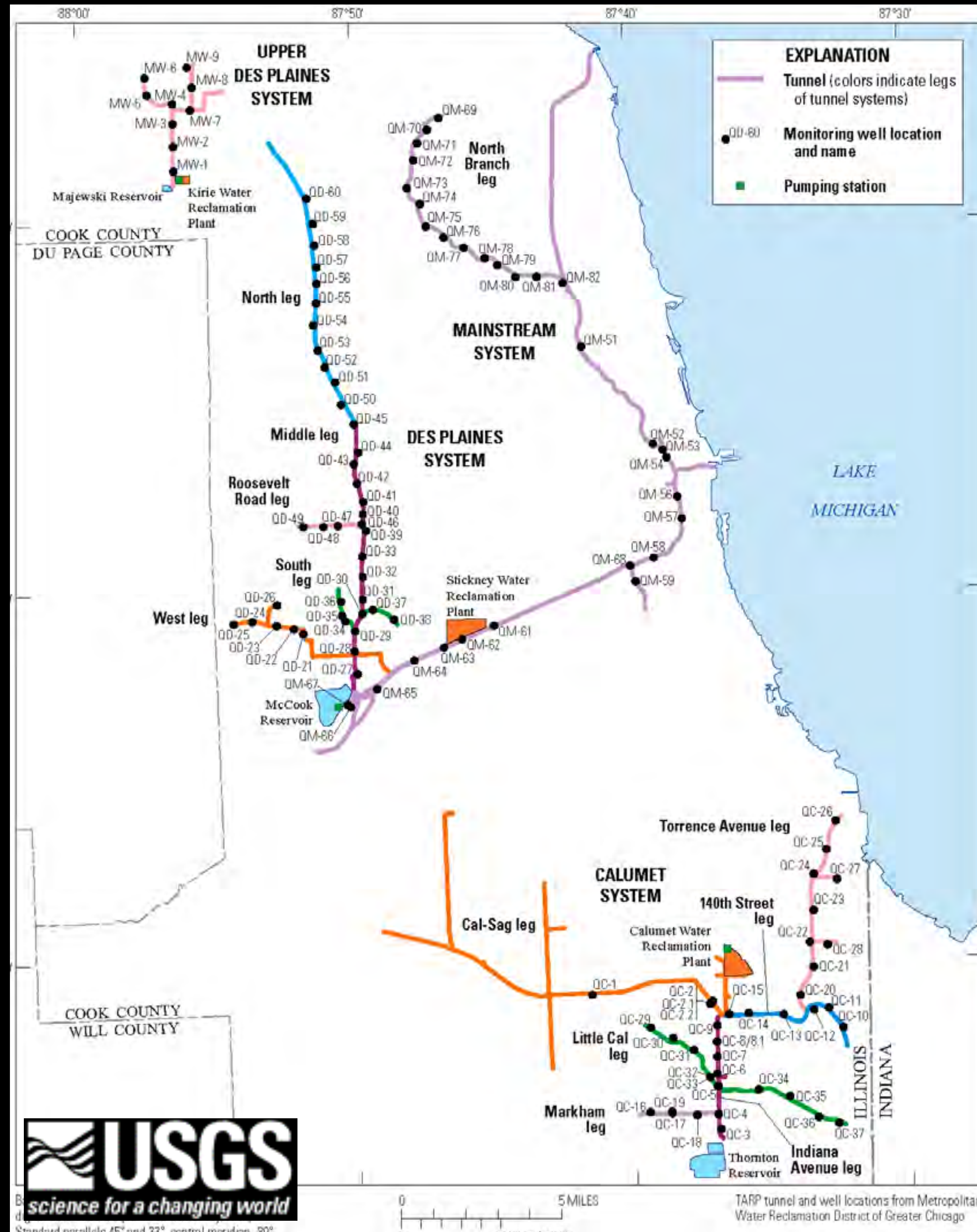
IEPA Requires Groundwater Monitoring to Assess TARP Impacts to Aquifer

- 106 functional wells
- 200 ft from center line of tunnels
- Sampled to assess impacts of combined sewer flow (CSF) on surrounding aquifer
- Approximately even distance between wells for the most part
- Well open to elevation of nearby tunnel
- Monitored for water level, temperature, total dissolved solids (TDS), chloride, hardness, electrical conductance, pH, sulfate, ammonia, fecal coliform, dissolved organic carbon (DOC)
- Sampling began in 1970s
- Sampling occurs on a more or less fixed schedule
  - Typically every 2-3 months



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 don't provide insight into CSF presence
  - ID correlations of analytes or well groupings that can be used to streamline data collection and analysis
  - ID optimal periods for data collection
  - ID analyses that provide insight into CSF effects

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USGS Analysis of TARP Well Data

- Time period selected because data electronically accessible
  - Data available before 1995 but too difficult to compile
  - Many of the tunnels already operational for several years by this point confounding some of the trend analysis
  - CSF storage mainly in the tunnels during this time period
  - Reservoirs typically not receiving CSF
  - Less pressure on the tunnels moving forward

- 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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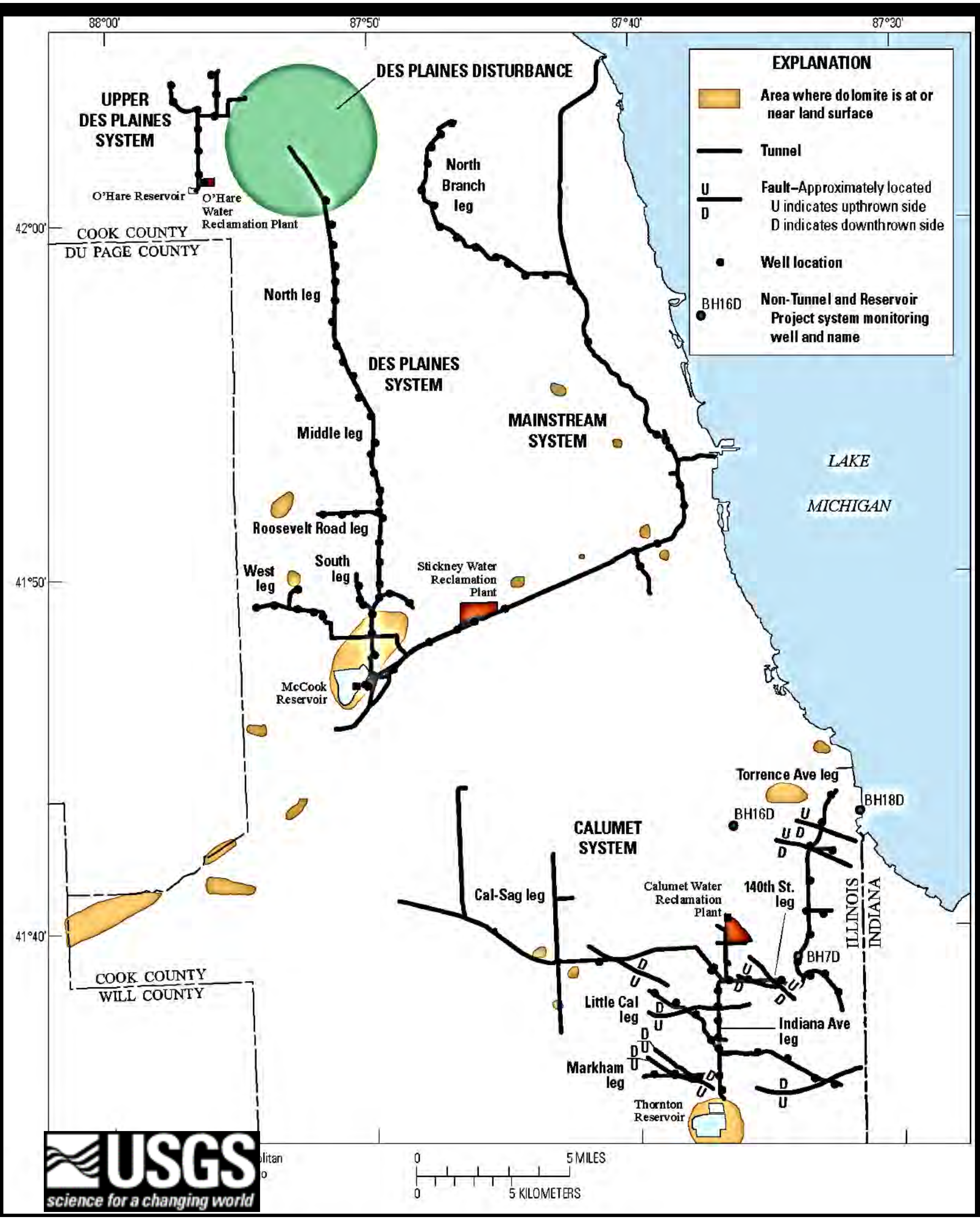
Geology

In most of area surficial geologic material is silt and clay till—poorly permeable—<25 to >200 feet thick

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

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



Water-Level Data

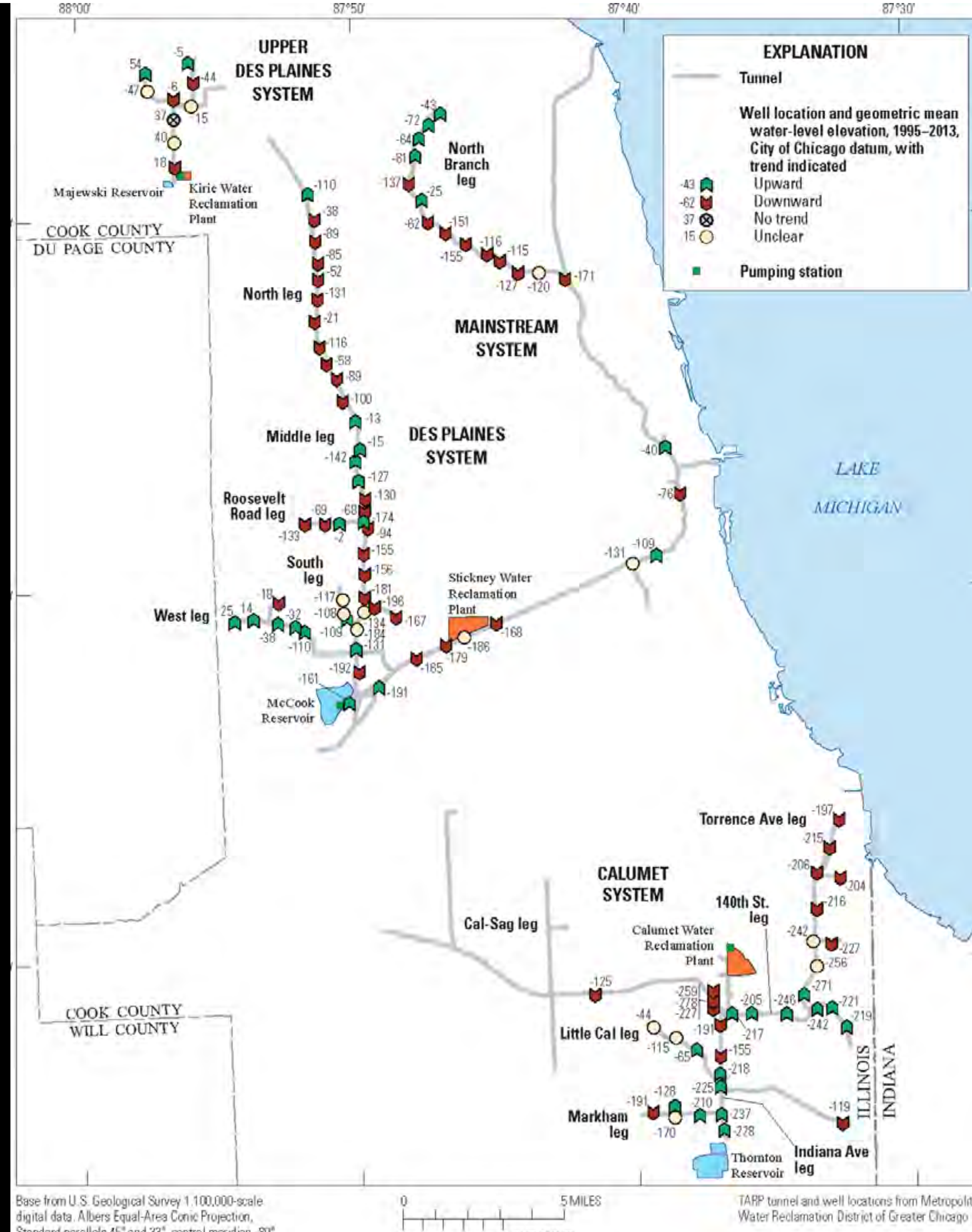
Geometric mean water level in a well is spatially variable

Generally decrease with decreasing elevation of the nearby tunnel

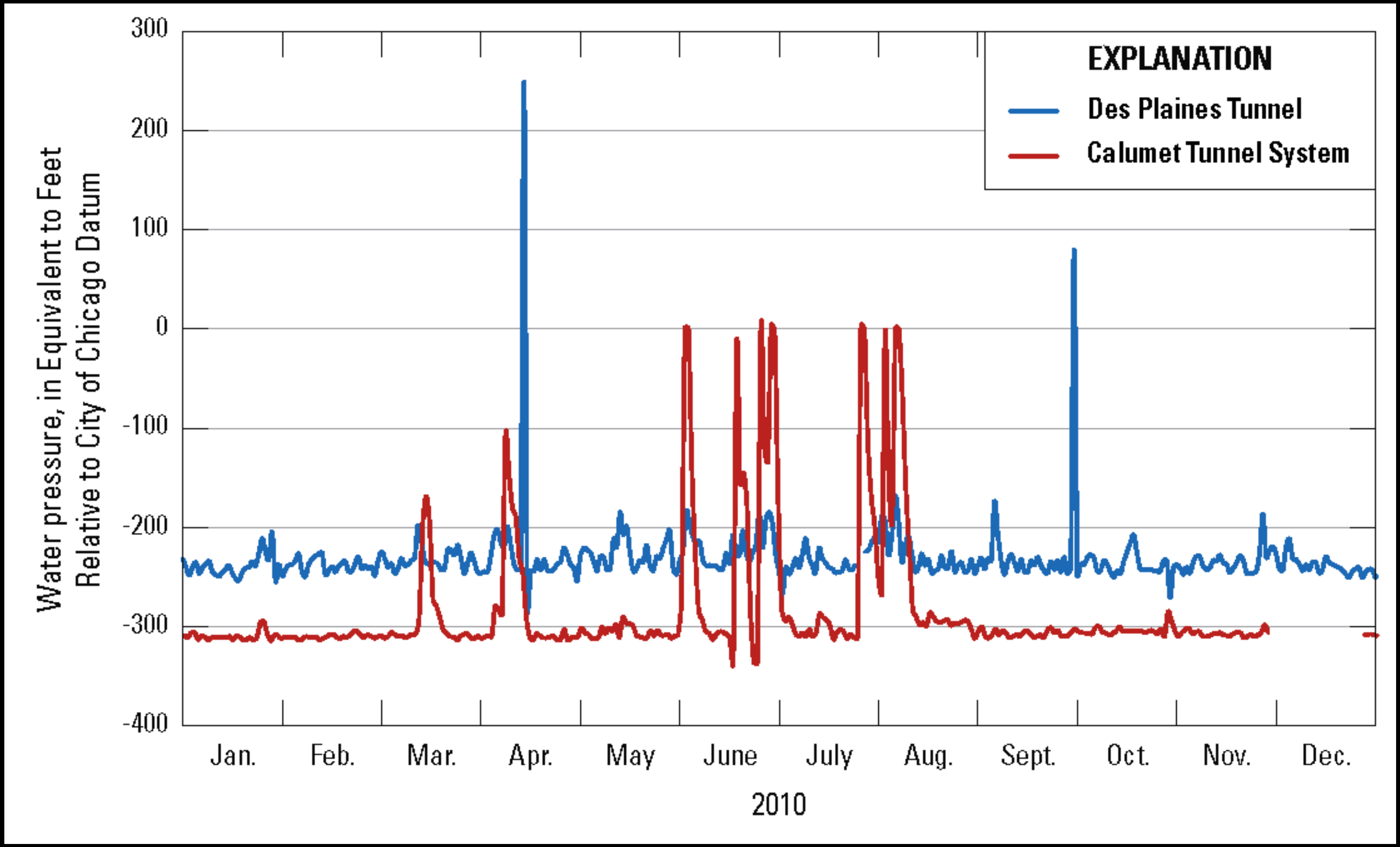
Data indicate water levels affected by drainage from aquifer to tunnel

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



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



Hydrology of TARP System

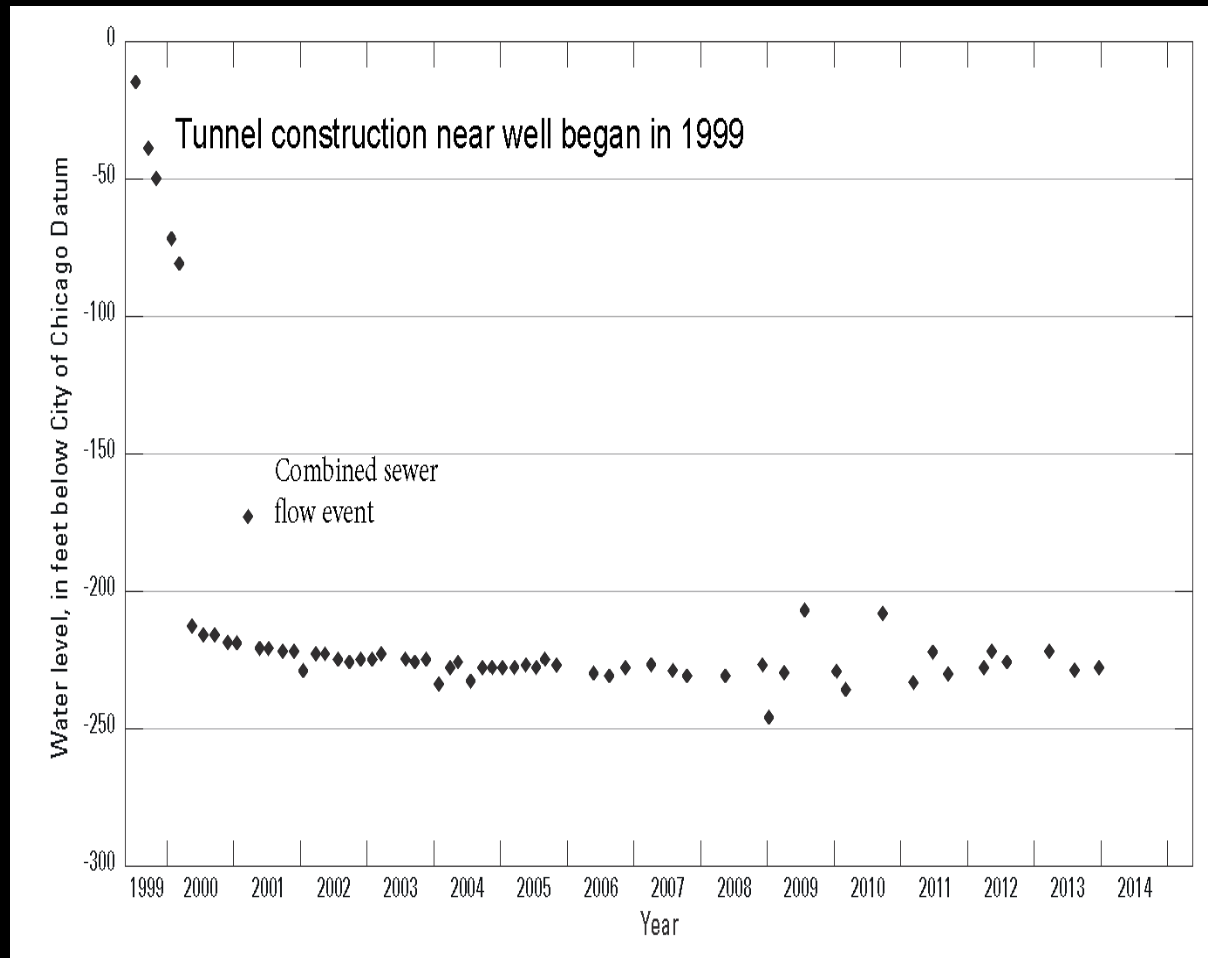
There is water exchange between the aquifer and the tunnels

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



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

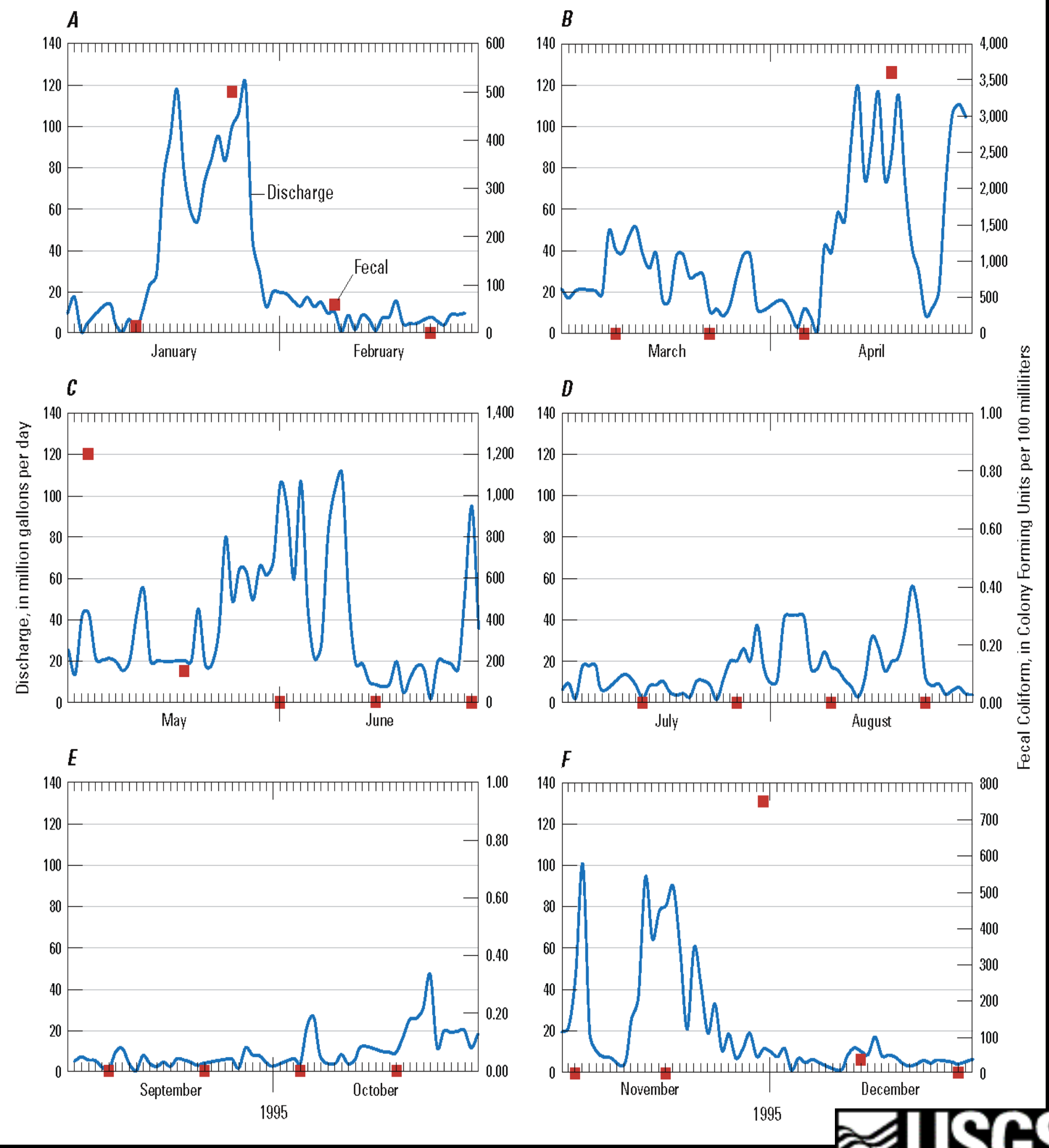
* Discharge >75 Mgal/d on June 22, 23, 24, 1996

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

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

Bi-weekly (every 2 weeks) sampling in one of the monitoring wells indicates fecal coliform concentrations 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

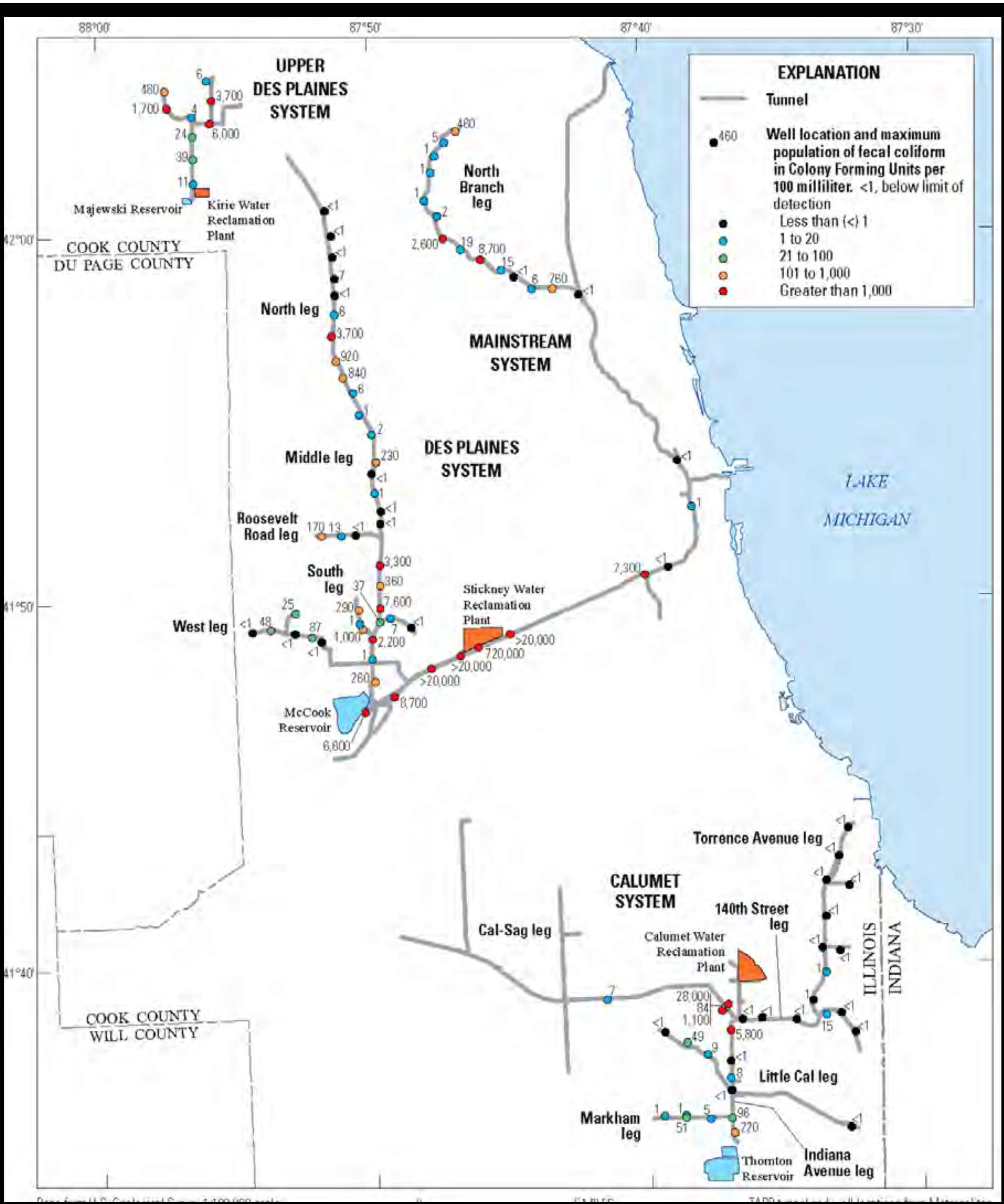


Fecal Coliform Concentrations

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

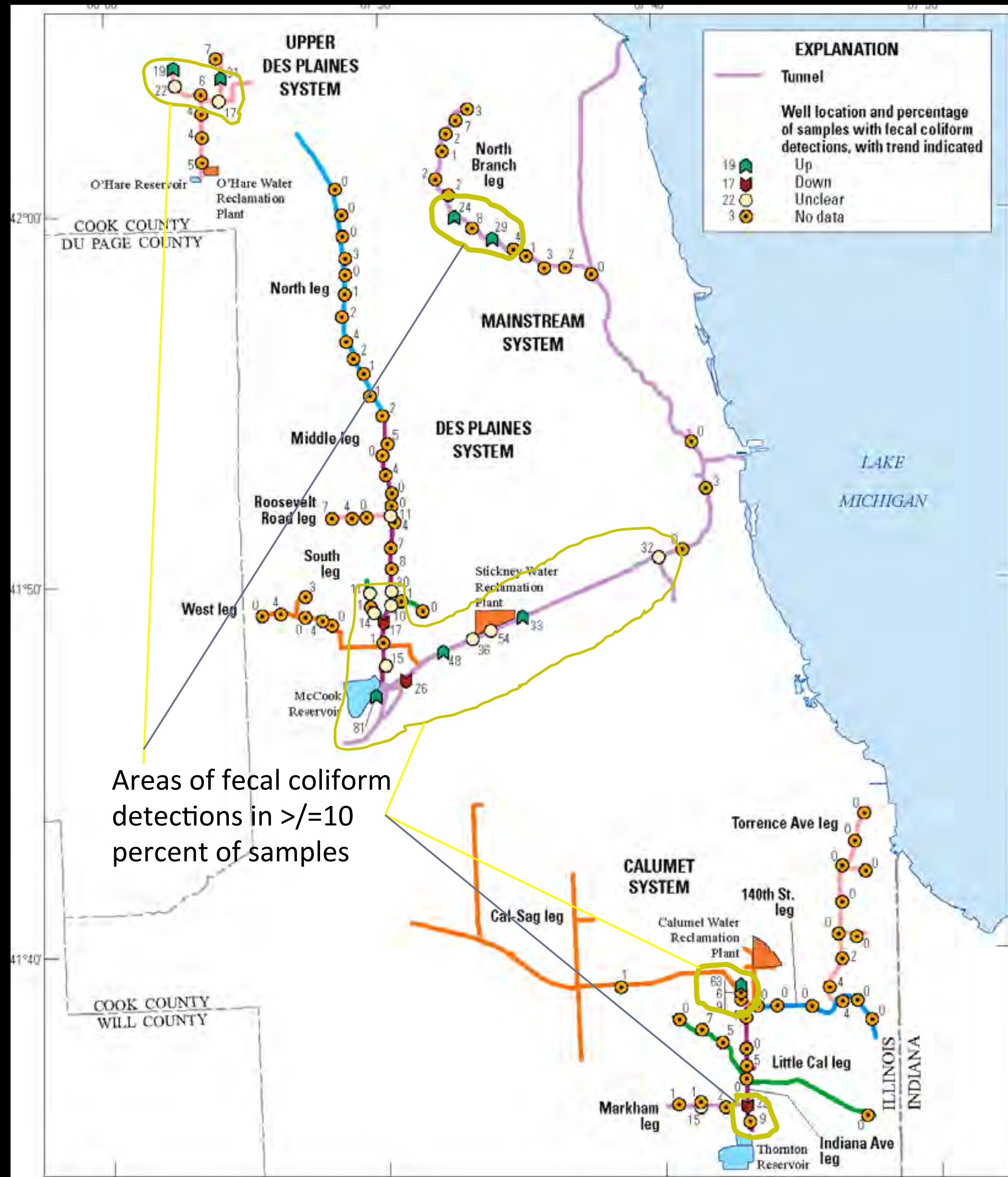
Detected most often in downstream parts of Calumet, Des Plaines, and Mainstream tunnels.

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

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



Hardness Values in TARP Wells

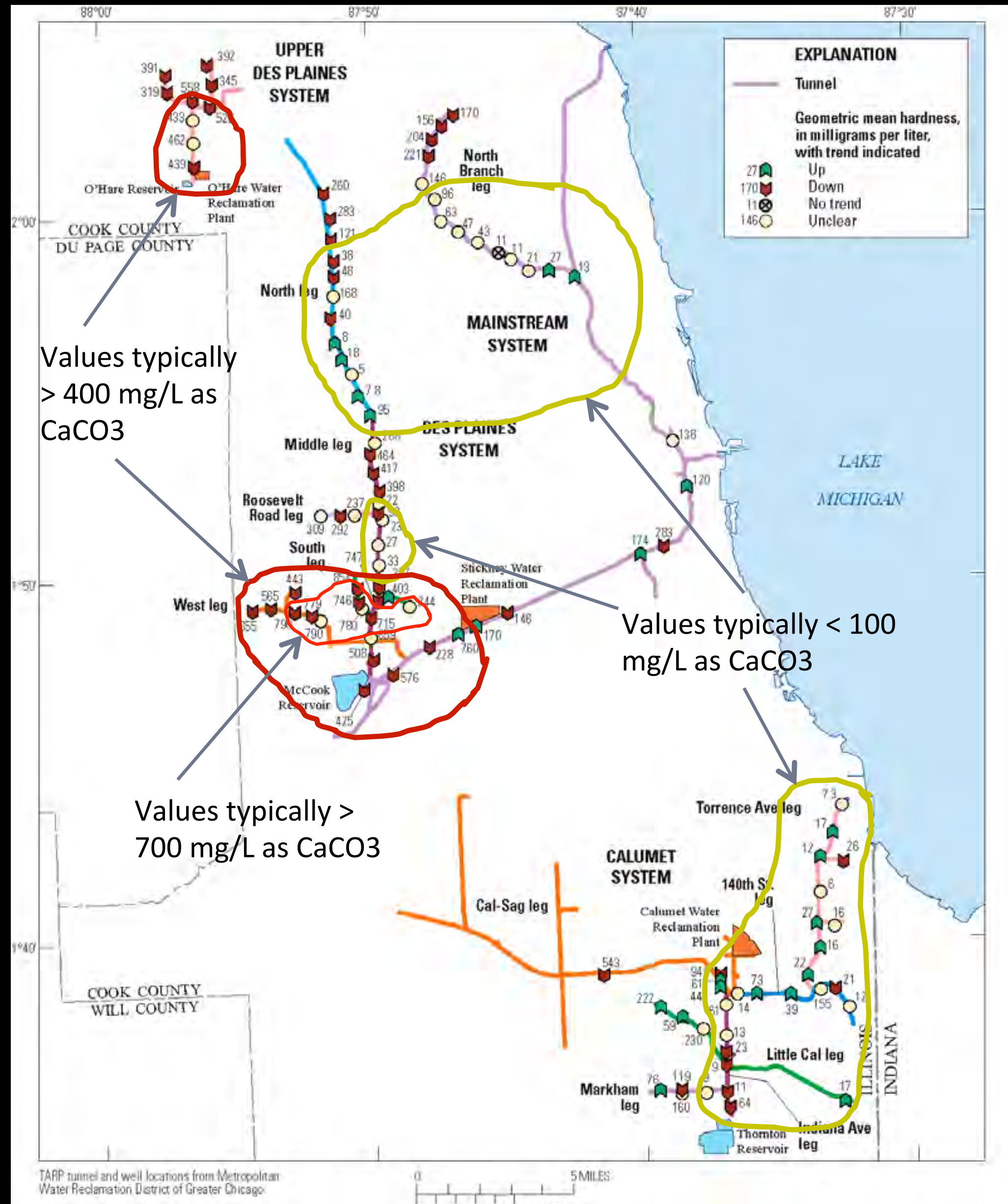
Above 400 mg/L as CaCO3 in much of Upper Des Plaines System and Des Plaines and Mainstream Systems near future McCook Reservoir

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



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“Background” Hardness in the Silurian Aquifer

Sampling before TARP

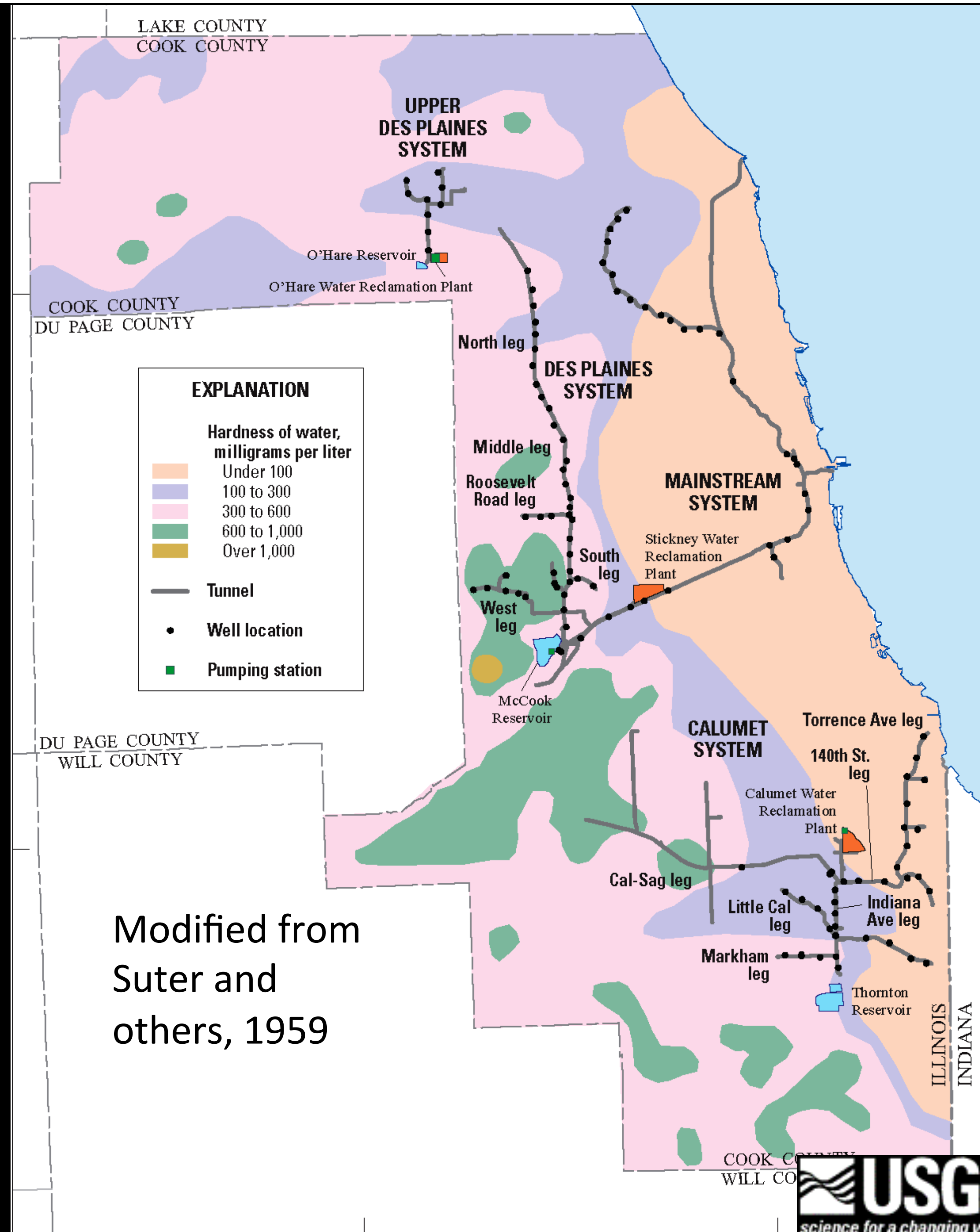
Less than 100 mg/L as CaCO3 near Lake Michigan

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 spatial patterns indicate hardness values in TARP wells primarily reflects chemistry of Silurian aquifer—consistent with fixed schedule sampling

Background WQ important



Modified from Suter and others, 1959

Chloride Concentrations in TARP wells

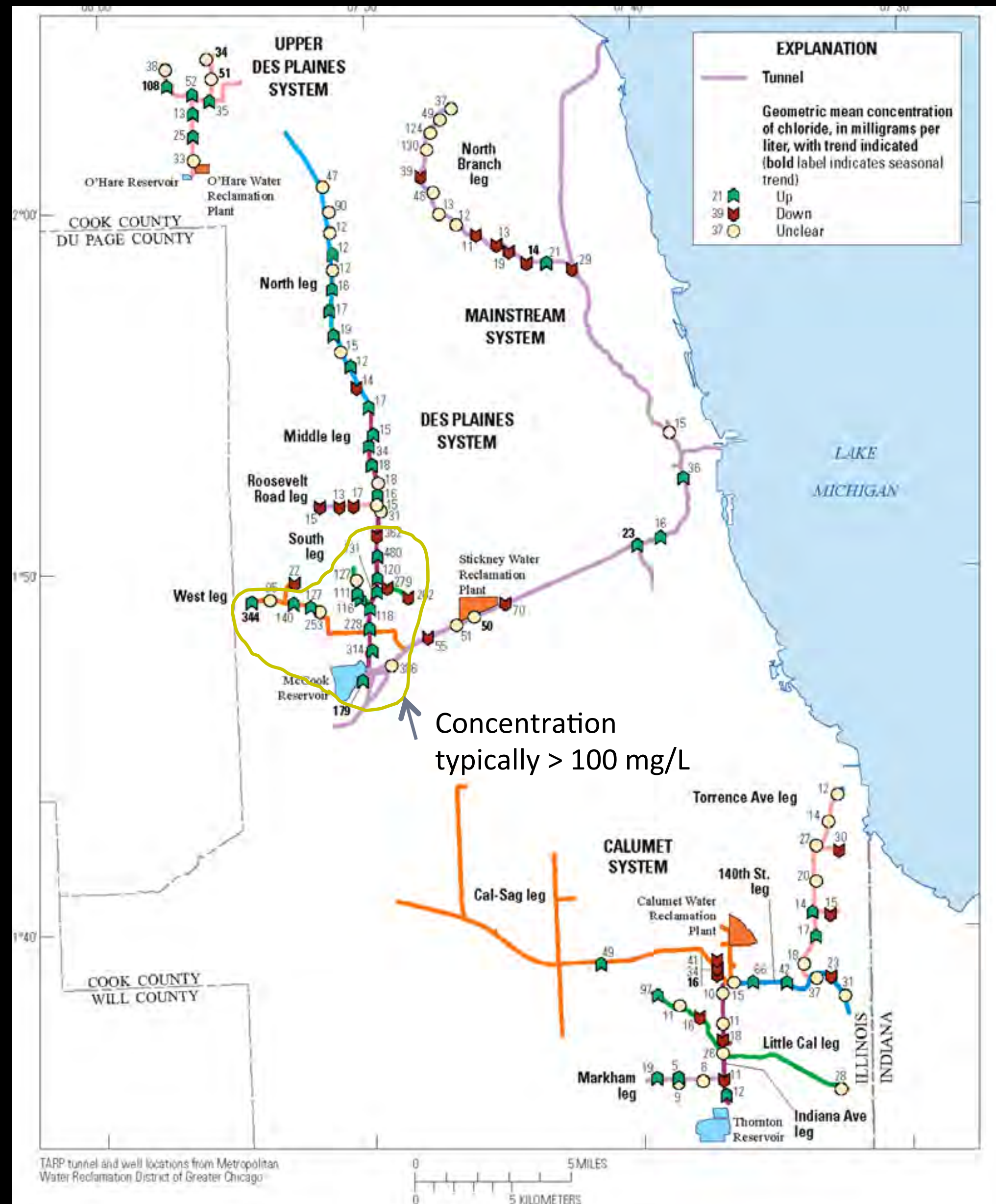
Highest geometric mean chloride concentrations in vicinity of future McCook Reservoir.

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



"Background" Chloride Concentrations in Silurian Aquifer

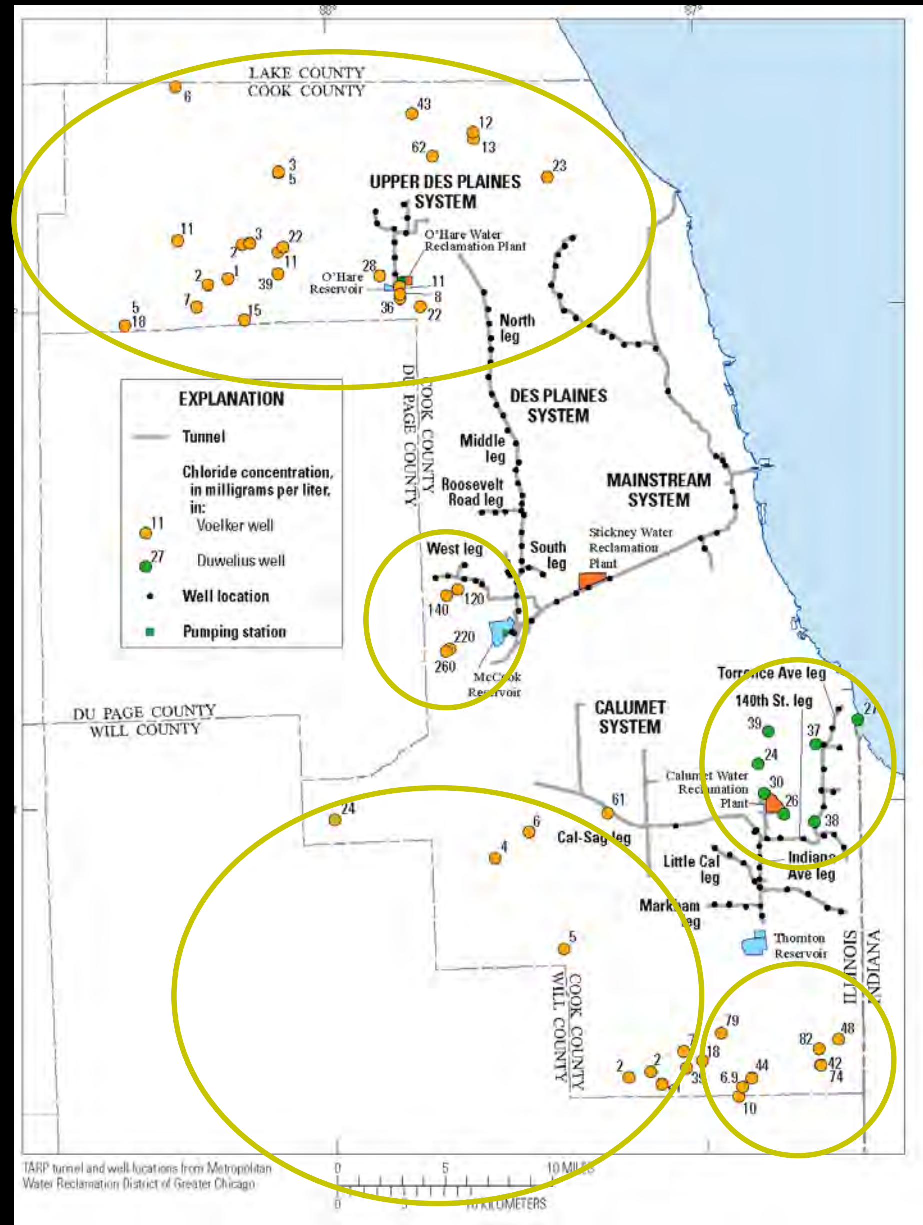
*Typically less than 25 mg/L in northern and southwestern parts of County

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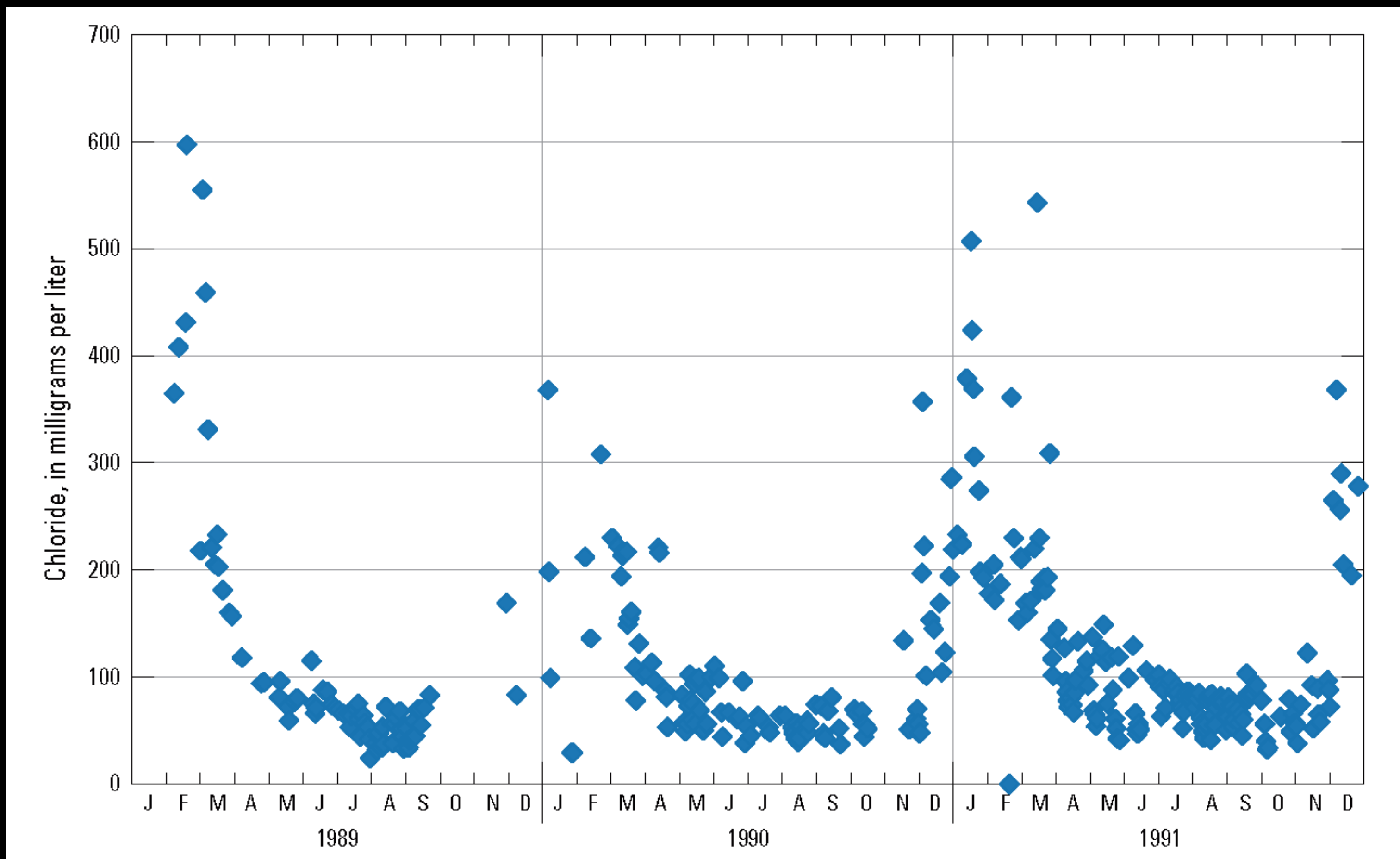
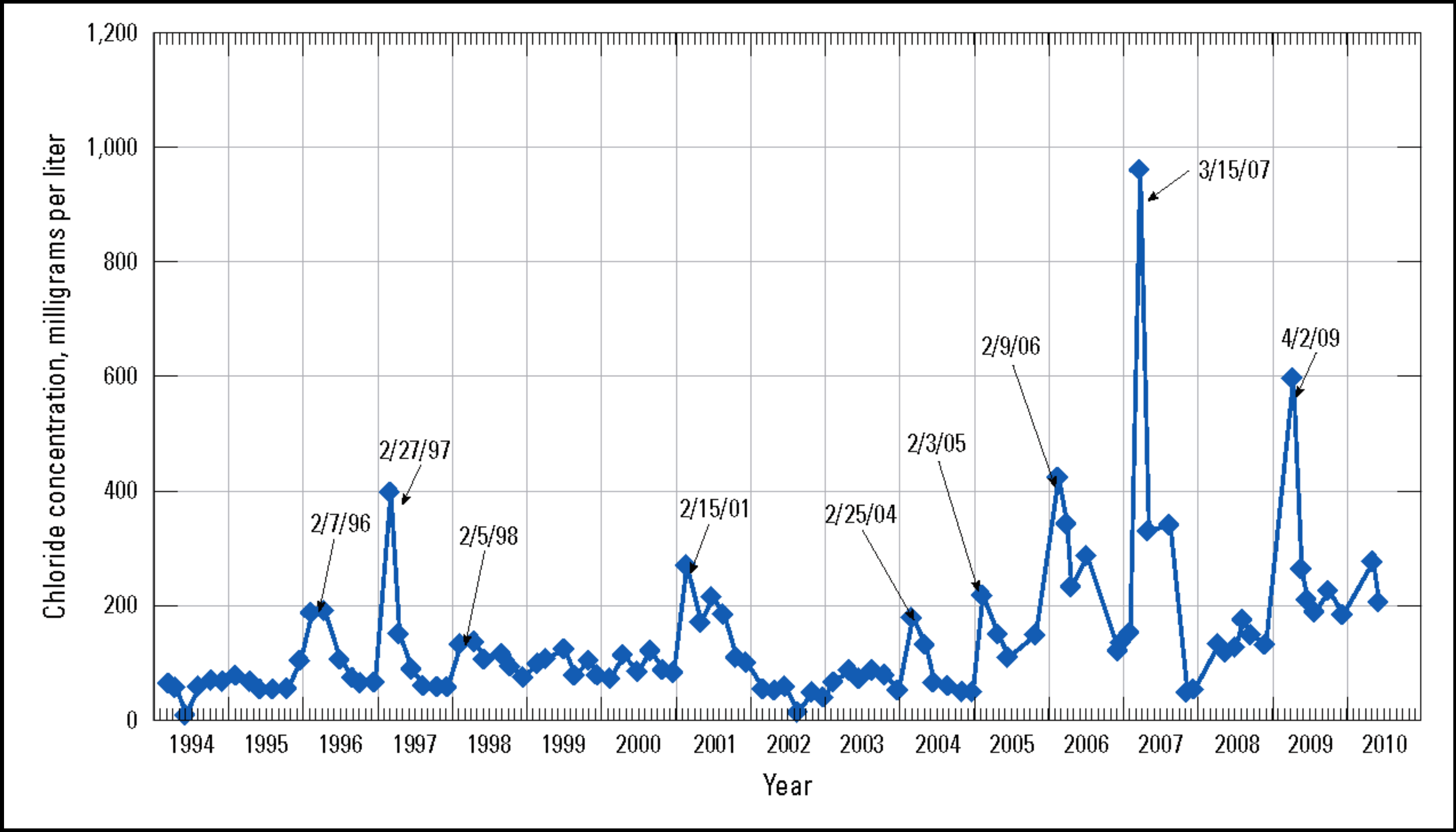
Seasonal variation in chloride concentration in TARP discharge due to road salt application



Chloride in TARP monitoring well MW5—elevated Cl always preceded by >80 Mgal/d discharge from TARP system



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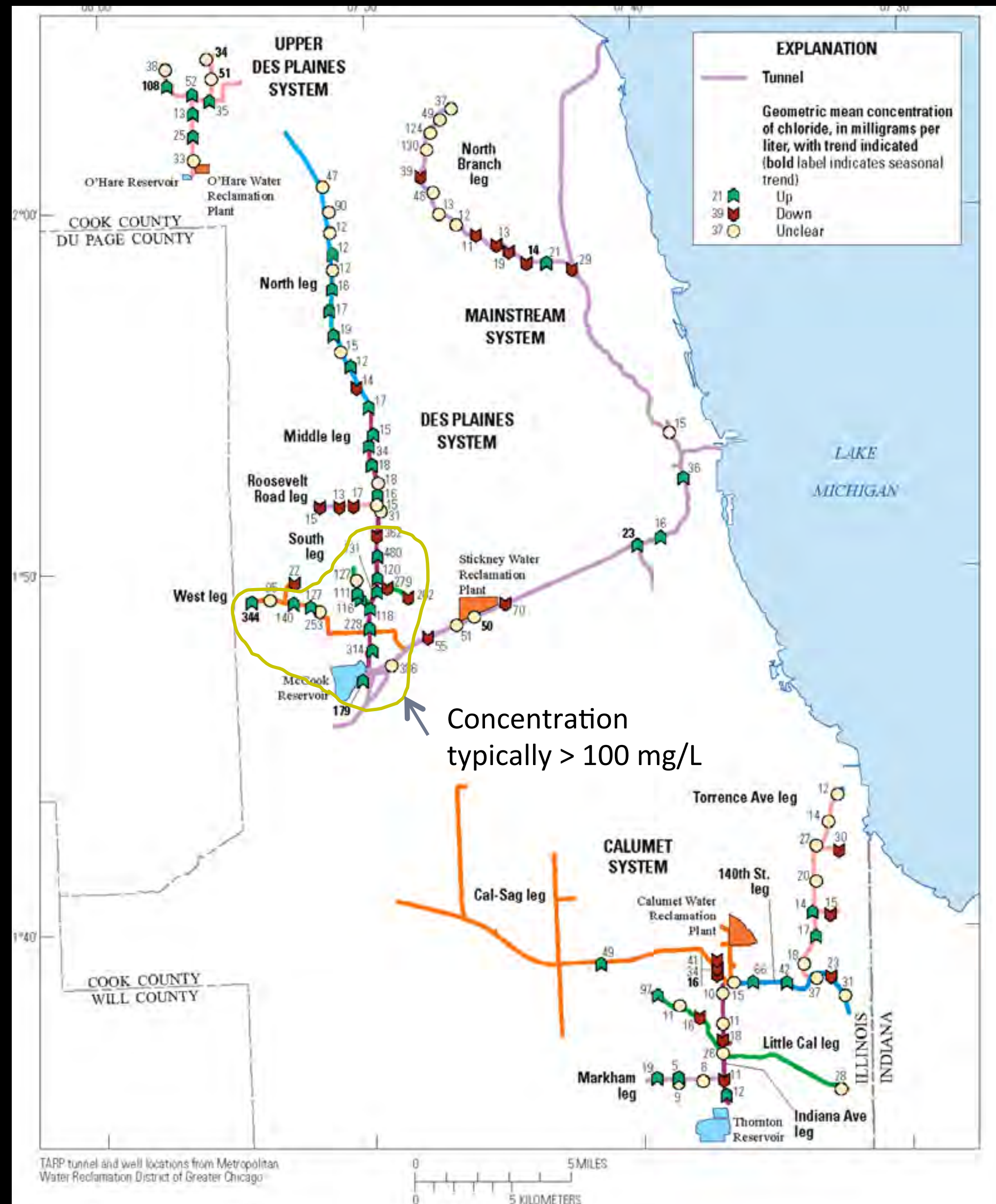
Chloride Concentrations in TARP wells

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.



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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 in some wells
- 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

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Thanks

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