Water Quality
Planning to Transition from Groundwater to Lake Michigan Water

Tony Myers – Jacobs
Kelly Zylstra– Waukesha Water Utility
Presentation Outline

- Background – Transition from groundwater to Lake Michigan water
- Pre-Transition Water Quality Planning Studies
- Post-Transition Results
Background
Background – Current Water System

- Waukesha serves about 70,000 people in southeast Wisconsin.
- Waukesha water supply was from deep and shallow wells.
- The deep wells contain radium above the EPA limit.
- The aquifer is not sustainable.
- Waukesha has been studying water supply alternatives for over three decades.
### Waukesha Water System - Then and Now

<table>
<thead>
<tr>
<th>Facility</th>
<th>Groundwater System</th>
<th>Lake Michigan System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wells</td>
<td>12</td>
<td>4 (Emergency)</td>
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<tr>
<td>Booster Pump Stations</td>
<td>11</td>
<td>12</td>
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<tr>
<td>Ground Storage Reservoirs</td>
<td>6 (12.8 MG)</td>
<td>4 (20.7 MG)</td>
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<tr>
<td>Elevated Towers</td>
<td>5 (2 MG)</td>
<td>6 (3 MG)</td>
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<tr>
<td>Pressure Zones</td>
<td>10</td>
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</table>
Booster Pump Station and Reservoirs
Purpose of Water Quality Planning

- Continue providing high quality drinking water as Waukesha transitions from groundwater to treated Lake Michigan water.
Water Quality Planning Studies
Groundwater Differences **Waukesha WI** and **North and East Metro Area**

<table>
<thead>
<tr>
<th>Community</th>
<th>City Of North St Paul</th>
<th>City of Oakdale</th>
<th>Mahtomedi</th>
<th>Vadnais Heights</th>
<th>City of Lake Elmo</th>
<th>City of Hugo</th>
<th>City of New Brighton</th>
<th>White Bear Township</th>
<th>City of Shoreview</th>
<th>White Bear Lake</th>
<th>City of Lino Lakes</th>
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</thead>
<tbody>
<tr>
<td>Hardness, Alkalinity (mg/L)</td>
<td>350</td>
<td>290</td>
<td>226</td>
<td>350</td>
<td>7.4</td>
<td>7.8</td>
<td>0.1</td>
<td>0.5</td>
<td>0.02</td>
<td>0.2</td>
<td>0.5</td>
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</tbody>
</table>
Differences between treated Lake Michigan and SPRWS water
Differences in WI Groundwater vs Lake Michigan – Corrosion Inhibitor

**Silica**

- Waukesha: 17 mg/L
- Milwaukee: 2 mg/L

**Orthophosphate**

- Waukesha: 0.0 mg/L as PO₄
- Milwaukee: 1.5 mg/L as PO₄
Differences in WI Groundwater vs Lake Michigan – Disinfectant

- Chlorine ($Cl_2$)
- Chloramine ($NH_2Cl$)
Chloramines 101

Tony Myers, P.E.

Jacobs
What are Chloramines?

Chlorine + Ammonia = Chloramines

- Monochloramine (NH₂Cl)
- Dichloramine (NHCl₂)
- Trichloramine (NCl₃)
What is the Proper Chlorine to Ammonia Ratio to form Monochloramine?

- About 4.5 parts chlorine (Cl$_2$) to 1 part ammonia (NH$_3$-N), by weight

*Waukesha uses liquid sodium hypochlorite and liquid ammonium sulfate to “boost” chloramine*
Typical breakpoint curve for pH 7.5-8.5

Section 1
Formation of monochloramine & organochloramines

Section 2
Monochloramine destroyed forming dichloramine.
(These can create taste and odor issues at low levels down to 0.8 mg/l)

Section 3
Free Available Chlorine Residual (HOCI ↔ H⁺ + OCl⁻)
(50% of each specie @ pH 7.5)

Section 4
Breakpoint
All ammonia is oxidized to nitrogen gas, nitrate, or nitrogen trichloride (trichloramine).

(Numbers on this scale indicate the ratio of chlorine to ammonia N, not total chlorine)

More Chlorine Added

www.solarbee.com
## Chlorine vs Monochloramine

<table>
<thead>
<tr>
<th>Chlorine</th>
<th>Chloramine</th>
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</thead>
<tbody>
<tr>
<td>Stronger disinfectant, but decays faster in distribution system</td>
<td>Weaker disinfectant but longer lasting residual and good for biofilms in pipes</td>
</tr>
<tr>
<td>Easier to use (1 chemical)</td>
<td>More complex (2 chemicals)</td>
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<tr>
<td>Forms regulated chlorinated DBPs</td>
<td>Does not form regulated chlorinated DBPs. Forms some unregulated DBPs.</td>
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<tr>
<td></td>
<td>Potential for nitrification</td>
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</table>
What should I measure in my water?

✓ Total Chlorine
✓ Monochloramine
✓ Free Ammonia
✓ Nitrite
6 Elements of Water Quality Transition Planning
Planning for the new water supply (1)

1. A corrosion control treatment study using Waukesha pipes and Milwaukee water to determine impacts on water quality. 2018 - 2019
1. Corrosion Control Treatment Study

Major Findings

- Lead was lower with Milwaukee water in Waukesha pipes, versus Waukesha groundwater.
- Release of iron and manganese was low
- Radium was not released from the pipe scale.
Planning for the new water supply (2)

1. A pipe loop corrosion control study using Waukesha pipes and Milwaukee water to determine impacts on water quality. 2018 - 2019

2. A unidirectional flushing (UDF) program to flush sediment from the distribution system pipes before and after the water transition. 2020 – 2021, 2023
2. Unidirectional Flushing (UDF) Program

Highlights

- Completed in 2021 by Waukesha Water Utility.
- 115 flushing zones and 1,500 flush sequences throughout the distribution system.
- Over 1 million feet of water main flushed.
- 4 to 5 person crew, took 4 to 5 months.
2. Unidirectional Flushing (UDF)

- Gathered good information on areas with high color
- Useful for determining area for follow up flushing
Planning for the new water supply (3)

1. A pipe loop corrosion control study using Waukesha pipes and Milwaukee water to determine impacts on water quality. 2018 - 2019

2. A unidirectional flushing (UDF) program to flush sediment from the distribution system pipes before and after the water transition. 2020 – 2021, 2023

3. An Initial Distribution System Evaluation (IDSE) to determine water sampling locations to meet regulations. 2021.
Planning for the new water supply (4)

1. A pipe loop corrosion control study using Waukesha pipes and Milwaukee water to determine impacts on water quality. 2018 - 2019

2. A unidirectional flushing (UDF) program to flush sediment from the distribution system pipes before and after the water transition. 2020 - 2021, 2023

3. An Initial Distribution System Evaluation (IDSE) to determine water sampling locations to meet regulations. 2021.

4. A distribution system water quality monitoring plan recommending monitoring to maintain water quality. 2021 - 2023
4. Distribution System Water Quality Monitoring Plan (1 of 2)

Highlights

- Not a regulatory requirement
- Better manage water quality at areas with longer water age.
- Measures indicators of nitrification (nitrite, free ammonia) plus monochloramine and others.
4. Distribution System Water Quality Monitoring Plan (2 of 2)

Four locations initially, plus entry point.

**Parameters Measured**

**On-line**
- Monochloramine
- Total ammonia
- Free ammonia
- Nitrite
- Nitrate
- Color
- UV 254
- pH/temp

**Grab**
- Iron
- Orthophosphate
- Fluoride
- HPC
Planning for the new water supply (5)

1. A pipe loop corrosion control study using Waukesha pipes and Milwaukee water to determine impacts on water quality. 2018 - 2019

2. A unidirectional flushing (UDF) program to flush sediment from the distribution system pipes before and after the water transition. 2020 – 2021, 2023

3. An Initial Distribution System Evaluation (IDSE) to determine water sampling locations to meet regulations. 2021.

4. A distribution system water quality monitoring plan recommending monitoring to maintain water quality. 2021 - 2023

5. A transition flushing plan to move the groundwater out and the Lake Michigan water while maintaining water quality 2022 - 2023
5. Transition Flushing Plan (1 of 1)

**Highlights**

- Minimize mixing chlorinated groundwater and chloraminated Lake Michigan water
- May not be necessary for a chlorine-to-chlorine or chloramine-to-chloramine water transition.
- *Need to incorporate Utility operational expertise with hydraulic modeling.*
5. Transition Flushing Plan (2 of 2)

Three alternatives evaluated.

- **No hydrant Flushing** – Normal tower operations. Water moves based on demand.

- **Active Flushing** – 70 hydrants flushed. All towers offline. 24-hr crew.

- **Staggered Tank** – 12 hydrants flushed. Tower on and off based on water movement.
5. Transition Flushing Plan – No Flushing (1 of 2)

Method
- Normal operations

Results
- Greater than 20 days transition
- Significant mixing of water sources
5. Transition Flushing Plan – No Flushing (2 of 2)

Source Water Turnover

% Lake Michigan Water

Time (hour)

Chloramine Residual → Breakpoint! → Free Chlorine Residual
5. Transition Flushing Plan – Active Flushing

Method
- 70 flushing hydrants
- Valved off storage tanks

Results
- About 4 days transition
- Minimal mixing of water sources
5. Transition Flushing Plan – Staggered Tank

Method
- 12 flushing hydrants
- Tanks **offline** when Lake Michigan water enters
- Tanks **online** when Lake Michigan water arrives

Results
- About 5 days transition
- Minimal mixing of water sources
- Better fire protection
Planning for the new water supply (6)

1. A pipe loop corrosion control study using Waukesha pipes and Milwaukee water to determine impacts on water quality. 2018 - 2019

2. A unidirectional flushing (UDF) program to flush sediment from the distribution system pipes before and after the water transition. 2020 – 2021, 2023

3. An Initial Distribution System Evaluation (IDSE) to determine water sampling locations to meet regulations. 2021.

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5. A transition flushing plan to move the groundwater out and the Lake Michigan water while maintaining water quality 2022 – 2023

6. An overall Transition Plan Summarized 5 reports, nitrification control, re-chloramination, distribution system water quality, customer information.
6. Overall Water Transition Plan

- Summarized 5 previous studies
- Addressed nitrification, re-chloramination
- Best practices for distribution system water quality.
- Information for Water Customers (Dialysis, Fish, Home Softening, etc.)
Water Quality at the Start of the Transition

- Boosted monochloramine residual from about 1.5 mg/L to 2.5 mg/L
- Used lower chlorine: ammonia ratio (3.5 to 1)

Water Quality after the Transition

- Reduce monochloramine residual slowly.
- Increase chlorine: ammonia ratio (4.5 or 5 to1)
- Monitored free ammonia.
### Excel Spreadsheet for determining chlorine and ammonia doses

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monochloramine, Upstream of chemical addition</td>
<td>1.36</td>
<td>mg/l</td>
</tr>
<tr>
<td>Free Ammonia, Upstream of chemical addition</td>
<td>0.08</td>
<td>mg/l as N</td>
</tr>
<tr>
<td>Flowrate in chemical addition pipe</td>
<td>1,950</td>
<td>gpm</td>
</tr>
<tr>
<td>Flowrate in chemical addition pipe</td>
<td>2.81</td>
<td>mgd</td>
</tr>
<tr>
<td>Desired Monochloramine Residual after chemical addition</td>
<td>2.50</td>
<td>mg/l</td>
</tr>
<tr>
<td>Cl(_2):N weight ratio</td>
<td>5.0</td>
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<tr>
<td>Chlorine dose added</td>
<td>1.14</td>
<td>mg/l as Cl(_2)</td>
</tr>
<tr>
<td>Ammonia dose added</td>
<td>0.148</td>
<td>mg/l as N</td>
</tr>
<tr>
<td>Chlorine pump setting</td>
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<tr>
<td>Gal/hr</td>
<td>0.88</td>
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<td>ml/min</td>
<td>56</td>
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<tr>
<td>RPM</td>
<td>32</td>
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<tr>
<td>% speed</td>
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<tr>
<td>Ammonia pump setting</td>
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<tr>
<td>Gal/hr</td>
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<td>ml/min</td>
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<tr>
<td>RPM</td>
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<tr>
<td>% speed</td>
<td>3%</td>
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</table>
Getting Ready

✓ Started filling reservoirs October 6, 2023 (Friday).
✓ Started delivering water October 9 (Monday).

Target Monochloramine 2.5 mg/l
Target Free Ammonia 0.10 mg/l
Transition Results
Public Information Early and Often

- Kidney Dialysis centers
- Hospitals and long-term care facilities
- Pet stores
- Major Industry
- Correctional Institutes
- Social media, websites, news outlets

Frequently Answered Questions

- 2023 Water Transition
- Causes
- Construction
- Impact
- Implementation
- Root River
- Waukesha Rates
Operational Steps Needed Before Transition, Day - 3

- Begin filling reservoir #1 with MWW water and adjusting chemistry for higher disinfectant for Day 0 (start up)
Operational Steps Needed Before Transition, Day - 2

• Begin filling reservoir #2 with MWW water and adjusting chemistry for higher disinfectant for Day 0
Operational Steps Needed Before Transition, Day -1 (1 of 2)

• Using reservoir mixing pumps, continuously mix water and verify chemistry prior to Day 0
• Mixing lines in reservoirs
Operational Steps Needed Before Transition, Day -1 (2 of 2)

- Move in ‘hotel’ at the BPS for overnight operations.
Operational Steps Transition, Day 0, Monday 10/9/2023 (1 of 2)
Operational Steps Transition, Day 0, Monday 10/9/2023 (2 of 2)

- The Mayor, Commission President and Dan started the pumps.
- Operation staff turned off the wells and started the field work.
**Water Transition at Hour 0**

<table>
<thead>
<tr>
<th>Tower Fill</th>
<th>Tower Empty</th>
<th>Valve Opened/Closed</th>
<th>Transition Hydrant Flushing</th>
<th>Optional Dead-end Hydrant Flushing</th>
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<th>Day</th>
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<td><strong>Ramp Nike water quality confirmed, start of transition</strong></td>
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<td><strong>Close valve at Hilcrest, reservoir is now permanently offline</strong></td>
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<td><strong>Close valve at Hunter</strong></td>
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<td><strong>Close valve at Sayesville</strong></td>
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<td>Open Hydrant ID: 10715</td>
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<td>Hydrant ID: 10716 Flow at 150 gpm</td>
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<td>Hydrant ID: 12086 Flow at 200 gpm</td>
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<td>Close valve at Crestwood</td>
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<td>Hydrant ID: 13726 Flow at 300 gpm</td>
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<tr>
<td>Close valve at UAW, turn on 1 pump at Airport and Madison</td>
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</tr>
</tbody>
</table>

**LEGEND**
- Ground Storage
- Elevated Storage: less than 20
- Offline Storage: 20 ~ 40
- Flushing Hydrant: 40 ~ 60
- 60 ~ 80
- 80 ~ 100
Operational Steps Transition, Day 0, Monday 10/9/2023

- Consultants field testing water quality entering and leaving BPS.
- BPS required on site monitoring 24/7 by WWU staff.
- Field testing of water quality done by WWU staff in the system; 3 shifts
Transition, Day 0, plus 12 hours

- On-line map was designed so customers would know where the Lake Michigan water was.
Day 0, plus 12 hours
Day 0, plus 16 hours
Day 1 – model v map
Day One (Tuesday) –
Some time during the day
Day 3 – model v map
Day 4 – model v map
Day 5 – model v map
Day – No clue, time not sure, too tired to know.
Water Quality

- Lead and copper levels very low
- Radium at detection level
- Chloramine residual throughout system
- No signs of nitrification
- Iron and Manganese levels low
- Customers are pleased with the new water!
Lucky Mascot
What did Customers Say?

- Mostly positive comments
  - Love the softer water
  - Initial chlorine smell but went away
  - Some localized red water, but nothing out of the ordinary

Water Utility reports transition to Lake Michigan water going smoothly, Waukesha Freeman, October 11, 2023

“It’s better than expected,” “We were very, very pleasantly surprised with the limited number of complaints that we had.”

"Looks pretty good," southeast Waukesha neighbor Andrea Matthis

“Community members didn’t receive any major complaints about the quality of the H2O.”
Acknowledgements

Waukesha Water Utility
Operations
Customer Service
Engineering
Management

Wisconsin DNR

Jacobs

Great Water Alliance
Greeley and Hansen
Black & Veatch
RA Smith
Schreiber GR Group
MKR Agency
Katz and Assoc.
Questions?

Water Quality Planning to Transition from Groundwater to Lake Michigan Water

The important thing is to Not stop questioning. Curiosity has its own reasons for existing.

~Albert Einstein
Water Temperature Entering the Distribution System

Water Temperature (F)


Groundwater
# Water Quality Summary

<table>
<thead>
<tr>
<th>Community</th>
<th>Total hardness (mg/L as CaCO₃)</th>
<th>Alkalinity (mg/L as CaCO₃)</th>
<th>pH</th>
<th>Fe (mg/L)</th>
<th>Mn (mg/L)</th>
<th>Free chlorine (mg/L)</th>
<th>Corrosion Inhibitor</th>
</tr>
</thead>
<tbody>
<tr>
<td>City Of North St Paul</td>
<td>255</td>
<td>210</td>
<td>7.5</td>
<td>0.0</td>
<td>0.02</td>
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<td></td>
</tr>
<tr>
<td>City of Oakdale</td>
<td>250</td>
<td>200</td>
<td>7.7</td>
<td>0.0</td>
<td>0.01</td>
<td>0.4</td>
<td>Polyphosphate</td>
</tr>
<tr>
<td>Mahtomedi</td>
<td>200</td>
<td>180</td>
<td>7.8</td>
<td>1.0</td>
<td>0.30</td>
<td>0.2</td>
<td>Polyphosphate</td>
</tr>
<tr>
<td>Vadnais Heights</td>
<td>210</td>
<td>210</td>
<td>8.2</td>
<td>0.4</td>
<td>0.05</td>
<td>1.0</td>
<td>Polyphosphate</td>
</tr>
<tr>
<td>City of Lake Elmo</td>
<td>210</td>
<td>210</td>
<td>7.5</td>
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<td>0.0</td>
<td>0.7</td>
<td></td>
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<tr>
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<td>207</td>
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<tr>
<td>City of New Brighton</td>
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<td>360</td>
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<td>0.8</td>
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<tr>
<td>White Bear Township</td>
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<td>210</td>
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<td>0.3</td>
<td>0.15</td>
<td>0.7</td>
<td>Polyphosphate</td>
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<tr>
<td>City of Shoreview</td>
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<td>0.2</td>
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<td>0.4</td>
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<tr>
<td>White Bear Lake</td>
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<td>210</td>
<td>7.7</td>
<td>0.4</td>
<td>0.06</td>
<td>0.3</td>
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<tr>
<td>City of Lino Lakes</td>
<td>234</td>
<td>245</td>
<td>7.7</td>
<td>2.7</td>
<td>0.27</td>
<td>0.6</td>
<td>Polyphosphate</td>
</tr>
</tbody>
</table>

| Average | 245 | 226 | 7.8 | 0.5 | 0.2 | 0.5 |
| Minimum | 200 | 180 | 7.5 | 0  | 0.01 | 0.2 |
| Maximum | 359 | 360 | 8.2 | 2.7 | 0.32 | 1   |